RICAP-24 Roma International Conference on AstroParticle Physics

Monday, 23 September 2024 - Friday, 27 September 2024

Hotel Villa Tuscolana

Book of Abstracts

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Multi-Messenger Astrophysics with THESEUS

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Recent breakthrough discoveries in multi-messenger astronomy (MMA) include the first identifications of gravitational wave and neutrino cosmological sources, such as active galactic nuclei and gamma-ray bursts. Despite the still limited number of identified sources so far, the relevance of gamma/X-ray observations in MMA is already evident. More identifications are expected over the next years, but it will only be during the second half of the 2030s that statistically significant samples of multi-messenger sources will become available, thanks to the anticipated one order of magnitude increase in sensitivity of next-generation neutrino and gravitational wave detectors. By that time, gamma/X-ray surveyors like THESEUS will play a crucial role in independently detecting and accurately localizing the high-energy counterparts, enabling multi-band follow-up campaigns and detailed source characterization of unprecedented large samples of multi-messenger sources.

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Modelling of GRB 221009A through analytical description of VHE afterglow light curves

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In date 9th of October 2022, several ground-based and space-based detectors observed a Gamma-Ray Burst (GRB) then called GRB 221009A, which is recorded as the most energetic ever detected (with E_{iso} ~ 10^{55} erg, for this reason also known as the B.O.A.T., brightest of all time) spanning its emission over the whole electromagnetic spectrum, up to the very high energy (VHE) gamma-ray band. In particular the LHAASO observatory, in China, has been able to detect photons up to energies never detected before from a GRB, reaching ~ 10 TeV and so opening a new era for the observation of this kind of phenomena.
In the work we present here we describe the method we developed to model its VHE afterglow through an analytical description of the light curve behaviour, depending on four parameters driving the emission, followed by a Markov-Chain Monte Carlo (MCMC). The dependence on the physical parameters (electron energy fraction, magnetic energy fraction, initial bulk Lorentz fraction and ISM density) is inferred from the simulations produced with a numerical model based on temporal step-by-step calculation of the evolution of the blast wave and consequent GRB emission through the interaction with the ISM: by varying the parameters we extracted the behaviour of the light curves, and assuming a "modified" smoothed power law shape for the afterglow light curves we inferred a direct dependence on the parameters later used for the MCMC.

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Multi-messenger studies with the Pierre Auger Observatory

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Photons, neutrinos, gravitational waves and cosmic rays may originate from the same source regions, so a multi-messenger approach is crucial for a better understanding of the physics behind the production and propagation of these messengers. In this context, the Pierre Auger Observatory plays a key role to investigate the highest-energy primary particles, given its ability to distinguish extensive air showers generated by ultra-high-energy photons and neutrinos from hadronic showers above 10^{17} eV. The latest results in the search for diffuse fluxes and point-like sources of neutrinos and photons will be discussed in this contribution together with follow-up analyses. Results on photon fluences from a selection of gravitational wave sources detected by LIGO/Virgo and results of the search for ultra-high-energy neutrinos from binary black hole mergers will also be presented.

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LHAASO observation of TeV afterglow from GRB221009A can be of Photohadronic origin

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Gamma-ray burst (GRB), GRB 221009A, a long-duration GRB, was observed simultaneously by the Water Cherenkov Detector Array (WCDA) and the Kilometer Squared Array (KM2A) of the Large High Altitude Air Shower Observatory (LHAASO) during the prompt emission and the afterglow periods. Characteristic multi-TeV photons up to 13 TeV were observed in the afterglow phase. The observed very high-energy (VHE) gamma-ray spectra by WCDA and KM2A during different time intervals and in different energy ranges can be explained very well in the context of the photohadronic model with the inclusion of extragalactic background light models. In the photohadronic scenario, interaction of high-energy protons with the synchrotron self-Compton (SSC) photons in the forward shock region of the jet is assumed to be the source of these VHE photons. The observed VHE spectra from the afterglow of GRB 221009A are similar to the VHE gamma-ray spectra observed from the temporary extreme high-energy peaked BL Lac (EHBL), 1ES 2344+514 only during the August 11 and the August 12 of 2016 and are new, first among their kinds in the GRB context.In future, from the observations of many more GRBs in VHE at low redshifts, we expect to identify some of them with a two-zone VHE emission, feature observed in the several nearby transient EHBL-like sources.

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Neutrino Follow-Up Analysis of GRB 221009A with KM3NeT

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Gamma-ray bursts (GRBs) are powerful explosions emitting high-energy photons, followed by a less energetic afterglow emission. They occur at a rate of a few per day in the observable Universe. After more than fifty years of detecting and characterising GRBs in the electromagnetic spectrum, they are considered potential sources of extragalactic cosmic rays. While no neutrinos have been detected so far in coincidence with these violent phenomena, numerous models predict neutrino emissions by different mechanisms.

On October 9th, 2022, multiple facilities, including the Swift and the Fermi satellites, detected an extraordinarily bright burst, referred to as GRB 221009A, for which the LHAASO observatory reported photons detection up to ~10 TeV energies. This energetic transient event presented an exceptional opportunity for the search for neutrinos in temporal and spatial coincidence.

The KM3NeT undersea neutrino telescope was operating with 21 lines of the ARCA detector and 10 lines of the ORCA detector at the time of this event, allowing for a real-time search for neutrinos from GRB 221009A. Later, a refined study including reprocessed data and systematics effects was conducted covering multiple time windows in a wide energy range, from MeV up to a few PeVs. In this talk, I will review the main results of the analyses, focusing on how KM3NeT performs the follow-up of GRB phenomena in a multi-messenger context.

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AGILE contribution to GW high-energy counterparts search

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The AGILE space mission, having capabilities well suited to transient source studies, participated to all the recent campaigns to search for electromagnetic (e.m.) counterparts to gravitational wave (GW) events detected by the LIGO-Virgo-KAGRA interferometers during the observing runs O2, O3, and the initial part of O4 (O4a), which ended on January 16th, 2024.
AGILE operations ended on January 18th, 2024.
We review here the AGILE contribution, focusing on the follow-up observations of significant GW events detected till now, along with preliminary results from the O4a run. AGILE executed dedicated real-time searches using MCAL (400 keV - 100 MeV), GRID (30 MeV - 30 GeV), and Anticoincidence ratemeters (50-200 keV), with specific Data Analysis pipelines used also for other astrophysical sources.
We published a first paper on 2016 regarding the AGILE data analysis for the first GW source detected, GW150914, and then two papers regarding two events of the O2 run, GW170104 and GW170817, the last being the only GW event till now for which an e.m. counterpart was found, i.e. GRB170817A.
A first thorough analysis of all GW events from O1, and O2 was published in 2022: we describe below this work and the following further analysis of O3/O4a events currently in progress.
No e.m. counterparts were detected, but 3sigma flux upper limits from MCAL and GRID data were extracted, among the lowest and fastest ULs at these energies, and allowing to constrain some emission models. We describe the AGILE role in newborn multi-messenger astronomy, particularly in recent activities, and its challenges in this new field.

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Chasing Gravitational Waves with the Cherenkov Telescope Array Observatory

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A complete view of gravitational wave (GW) events requires combining GW observations with broadband electromagnetic follow-up. In particular, TeV gamma rays, the most-energetic electromagnetic radiation currently associated with individual sources, will be crucial in understanding the acceleration processes and the environment near compact object mergers.

The current generation of Cherenkov telescopes, such as H.E.S.S., MAGIC, and VERITAS is actively searching for TeV emission associated with GW alerts through dedicated follow-up programs. Prospects for future observatories, such as the ASTRI mini-array and the Cherenkov Telescope Array Observatory (CTAO), are under evaluation.

We describe our approach for determining whether binary neutron star (BNS) mergers emit TeV radiation detectable with the CTAO. The current generation of GW detections is often affected by high uncertainty regarding the source position. CTAO is well-suited for the rapid coverage of large localization areas associated with GWs and possesses unparalleled sensitivity at very high energies (20 GeV - 300 TeV). We simulated CTAO's response on a set of phenomenological models describing the electromagnetic afterglow emission from short gamma-ray bursts (sGRBs) associated with GW events from BNS mergers. We optimized the follow-up strategies and estimated the number of joint sGRB-GW events stemming from BNS mergers detectable with CTAO in the future LIGO-Virgo-KAGRA (LVK) science run O5 (from 2027 onward).

Our study aims to maximize the physical interpretative value of CTAO observations by studying the connection to physical parameters driving simulated sGRBs, including the jet opening angle, luminosity, distance, and off-axis angle.

This work can be further extended to the next generation of GW detectors, like the Einstein Telescope and Cosmic Explorer.

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Neutrinos from Tidal Disruption Events

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Tidal Disruption Events (TDEs) are energetic optical transients that occur when stars are tidally disrupted upon approaching the tidal radius of a supermassive black hole. Three TDEs and candidates (AT2019dsg, AT2019fdr, and AT2019aalc) have been found to coincide in time and position with three IceCube astrophysical neutrino events. In this talk, I will review the multi-messenger (neutrino and multiwavelength) observations and the theoretical models, including relativistic jets,

hidden winds, dust tori, and accretion disks of these neutrino-emitting TDEs. In addition to the aforementioned three TDEs, I will cover the recently identified candidates with potential neutrino counterparts, including two dust-obscured candidates and AT2021lwx, which exhibit significant similarities with AT2019dsg/fdr/aalc. The multi-messenger implications, such as constraints derived from the non-detection of accompanying electromagnetic cascades and the potential of TDEs as the origin of ultra-high-energy cosmic rays, will also be covered.

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On the jet composition of low-luminosity AGN

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Gamma rays, high-energy neutrinos and cosmic rays (CRs) impinging on Earth signal the existence of environments in the Universe that allow acceleration of particle populations into the extremely energetic regime. The general consensus of a CR–gamma-ray–neutrino connection as a basis for the search of the long-sought ultra-high-energy (UHE) CR sources has recently been weakened by the results of AUGER dipole and UHECR composition and spectrum modellings, which suggest gamma-ray dim objects in the local Universe as substantial UHECR-flux contributors.

In this work we investigate jetted low-luminosity Active Galactic Nuclei (LLAGN), with focus on Fanaroff-Riley 0 (FR0) radio galaxies, that constitute the most abundant persistent jet source population in the local Universe, as particle multi-messenger sources. Performing a comparative leptonic versus hadronic jet emission modelling, with taking into account all available multi-messenger data, our presentation assesses the jet composition of LLAGN. For this purpose we use our time-dependent heavy nuclei CR particle and photon propagation framework which takes into account all relevant secondary particle production and energy loss processes, allows for an evolving source environment and efficient treatment of transport non-linearities due to the produced particles/photons being fed back into the simulation chain.

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MeV neutrinos from SuperNovae

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KM3NeT Online Multi-Messenger Astronomy Results

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KM3NeT is a Cherenkov-based neutrino telescope, sensitive to energies from MeV to PeV. It is formed by two detectors located in the depths of the Mediterranean sea, KM3NeT/ARCA (Astroparticle Research with Cosmics in the Abyss) in Italy, and KM3NeT/ORCA (Oscillation Research with Cosmics in the Abyss) in France. Currently, both detectors are taking data, with roughly 15% of the total number of planned detection units already installed. The full completion of the detector is expected in 2029.

The energy range covered by KM3NeT, as well as its high duty cycle and large field of view make it suitable for detecting neutrinos from astrophysical sources.
Multi-messenger astronomy requires the simultaneous observation of an astrophysical event by different types of detectors. To meet those needs, we should be able to quickly identify and reconstruct interesting neutrino candidates and broadcast the relevant information, allowing a prompt follow-up of our events by other observatories.
Reciprocally, KM3NeT can follow-up on alerts emitted by partner experiments, looking for coincidences in our data. In some instances, this follow-up could be used to refine the position of poorly localised triggers, like gravitational wave alerts.

This contribution reports on the status of the KM3NeT online analysis framework that has been running since October 2022. The current astrophysical performances for the ARCA and ORCA detectors, along with a summary of the most relevant results, will be presented.

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Constraining the contribution of Seyfert galaxies to the astrophysical diffuse neutrino flux using source population simulations

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Recently, the IceCube collaboration reported evidence for TeV neutrino emission from several nearby Seyfert galaxies that are intrinsically bright in X-rays, with the highest significance found for NGC 1068. The fact that no gamma rays in the TeV energy range are observed from NGC 1068 indicates that these neutrinos are likely to be produced in the AGN corona, which is opaque to high-energy gamma rays. Based on this assumption, we model the neutrino emission of Seyfert galaxies with different X-ray properties. We fit the resulting spectrum for NGC 1068 to public IceCube data and find that our model provides a good fit to the data. Using the result of this fit as a benchmark, we apply our model to a selection of nearby Seyfert galaxies and a simulated population of sources. Taking into account the uncertainties in the cosmological evolution of Seyfert galaxies, this allows us to derive constraints on both the contribution of these sources to the astrophysical diffuse neutrino flux and the underlying source modelling parameters. In particular, we explore a possible correlation between the intrinsic X-ray luminosity of a source and its neutrino emission. Connecting the knowledge of individual nearby Seyfert galaxies to the source population as a whole, this approach provides a realistic picture of the contribution of Seyfert galaxies to astrophysical neutrino observations.

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Investigating IceCube's highest-energy neutrinos

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IceCube's highest-energy neutrinos (alert events) are among the purest astrophysical neutrino selections. Some of these events are expected to point back to their cosmic counterparts. We search for patterns within these events to gain further insights into their cosmic origins. Here, we report searches for multiplets and correlations in arrival times that could help pinpoint astrophysical phenomena. Additionally, we search for gamma-ray-detected blazars as counterparts within the uncertainty regions of alert events.

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Evaluating the contribution of pulsar wind nebulae to the Galactic high-energy neutrinos

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With the continuous injection from the powerful pulsars, pulsar wind nebulae (PWNe), especially the young ones, are among the most energetic astrophysical sources in the Galaxy. The TeV-PeV gamma-ray emission is usually interpreted as originating from inverse Compton Scattering in a leptonic scenario, but the hadronic origin cannot be ruled out. Therefore, PWNe could be possible candidates that contribute to the high-energy neutrinos via hadronic process detected by IceCube. Assuming the existence of protons, several works before have estimated the neutrino emission from the PWNe using different TeV catalogues. However, such results rely on the TeV observations and may omit unresolved sources. Here, instead of repeating the regular procedure, we model the temporal evolution of the young PWNe from a synthetic population in the Galaxy and calculate the neutrino flux directly.

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Exploiting the standing accretion shock instability for multi-messenger analysis of core-collapse supernovae

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Core Collapse supernovae are among the most interesting source of possible multimessenger detections, given the joint production of electromagnetic, neutrino and gravitational waves (GW). In this work we investigate the correlation of SASI structure of neutrino and GW to enhance the GW detection. We compare different search analyses for the case of a benchmark three-dimensional CCSN simulation with zero-age main sequence mass of 24 solar masses. In particular, we build a matched filter analysis which increase detection efficiency of 30% with respect to a standard excess power algorithm for nearby CCSN (less than 1.5 kpc). At further distance we expect that additional work is needed to outline the best strategy for GW detection from CCSN.

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Status and prospects for probing astrophysical GeV neutrino emissions with IceCube and KM3NeT

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In the last decade, Cherenkov neutrino telescopes have provided valuable insights into the sources and acceleration mechanisms responsible for the high-energy neutrino flux observed at Earth. These instruments utilise large volumes of naturally occurring optically transparent materials, such as the Antarctic ice for IceCube and the Mediterranean Sea water for KM3NeT. Specifically, IceCube, encompassing a cubic kilometre of glacier, and KM3NeT, currently being deployed and soon reaching a similar size, offer complementary sky coverage, ushering in a new era of neutrino astronomy.Although optimised for detecting GeV to TeV neutrinos, recent advancements in analysis techniques have lowered the energy thresholds and increased sensitivity to astrophysical GeV neutrinos. Despite high background rates at low energies, the large instrumented volumes allow for stringent constraints on theoretical predictions for transient sources. We examine the case of GRB221009 and the follow-up analysis of the initial observing runs of Ligo-Virgo-Kagra. Furthermore, we discuss ongoing efforts to enhance these sensitivities through dedicated machine learning techniques aimed at improving signal-to-noise discrimination down to 100 MeV.

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The population of neutrino blazar candidates from real-time high-energy neutrino alerts

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Observations from the Large Area Telescope (LAT) on board the Fermi Gamma-ray Space Telescope enabled the identification of the flaring gamma-ray blazar TXS 0506+056 as a likely counterpart to

the neutrino event IC-170922A. By continuously monitoring the gamma-ray sky, Fermi-LAT plays a key role in the identification of candidate counterparts to realtime high-energy neutrino alerts released by IceCube.
In this contribution, I will present our recent studies of real time follow-up of high-energy neutrino alerts with Fermi-LAT focusing on the most compelling neutrino candidates observed in more than 8 years (since April 2016) in the gamma-ray sky. In particular, our investigation is focused on the population of blazars coincident with single high-energy neutrinos, and we evaluate the relationship between their neutrino and gamma-ray luminosities. I will also present the current Fermi-LAT strategy for following up high-energy neutrino alerts and the future prospects on these searches.

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Latest Results from the LZ Dark Matter Experiment

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LUX-ZEPLIN(LZ) is a direct detection dark matter experiment located nearly a mile underground at the Sanford Underground Research Facility (SURF) in Lead, South Dakota, USA. Employing a dual-phase Time Projection Chamber (TPC) containing 7 tonnes of active xenon surrounded by veto systems, LZ offers world-leading sensitivity in detecting Weakly Interacting Massive Particles (WIMPs), a highly motivated dark matter candidate. Beyond the quest for WIMPs, the LZ experiment explores diverse new physics phenomena. This presentation will provide an overview of the LZ experiment and report on the most recent status in its operation and searches.

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The SABRE experiment: status and prospects

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The SABRE experiment aims to find Dark Matter through the annual modulation in NaI(Tl) crystals' rate. The project is conceived as a double-site experiment, with two similar detectors located respectively in the North hemisphere (LNGS, Italy) and in the South hemisphere (SUPL, Australia), in order to disentangle seasonal or site-related effects and verify the cosmic nature of an eventual modulation signal.
The collaboration produced various test crystals in partnership with RMD Company (US) in the last ten years, which were measured and characterized underground at LNGS. In particular the NaI-33 crystal demonstrated a background rate of 1.20±0.05 counts/day/kg/keV, the lowest ever reached with NaI(Tl) after DAMA/LIBRA. A zone refining (ZR) processing of the NaI powder in collaboration with Mellen company showed the possibility to reduce further K-40, Rb-87 and other important contaminants and is foreseen for the next generation crystals. This could lead to an expected rate of 0.5 cpd/kg/keV in the ROI.
Considering the limitations to use liquid scintillators at LNGS, and the reduction of veto-able backgrounds after ZR, SABRE North is proceeding to a full scale design with purely passive shielding made of copper and polyethylene. Instead, in the SABRE South design, the crystal matrix is immersed in a linear alkyl benzene (LAB) based liquid scintillator veto, further surrounded by passive steel and polyethylene shielding and a plastic scintillator muon veto.
This talk will report the status and prospects of SABRE for North and South facilities.

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Into the Neutrino Fog with XENONnT

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Several astrophysical and cosmological observations on different length scales indicate the presence of a massive, non-luminous and non-baryonic matter component which is commonly referred to as dark matter. Weakly interacting massive particles (WIMPs) which arise from several beyond-Standard-model theories are among the candidates for dark matter. Over the last decade, the search for these particles has been led by the Xenon-based dual-phase time projection chamber detectors. Among them, the XENONnT is currently taking data at Gran Sasso underground laboratories, exploiting 5.9 tonnes of instrumented liquid xenon. The collaboration has made a huge effort to design and commission several upgrades to increase the performance of the detector: a new and larger TPC, new liquid purification system, an online radon distillation column and the world's first water Cherenkov neutron veto. WIMPs detection via nuclear recoils is threatened by the so-called "neutrino fog", an irreducible background produced by neutrinos which can mimic the same nuclear recoil events expected from Dark Matter particle interaction in such a detector. In this talk, it will be reported the first ever reach of the neutrino fog from a dark matter direct search experiment. Using data for the first two science runs with a total exposure of approximately 3.5 tonne-year, solar Boron 8 neutrinos have been detected via Coherent Elastic Neutrino Nucleus Scattering

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BULLKID-DM: searching for light WIMP with monolithic arrays of detectors

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BULLKID-DM is a new experiment to search for hypothetical WIMP-like Dark-Matter particles with mass around 1 GeV and cross-section with nucleons smaller than 10^-41 cm^2.
The target will amount to 600 g subdivided in 2500 silicon dice sensed by phonon-mediated kinetic inductance detectors. With respect to other solid-state experiments in the field the aim is to control the backgrounds by creating a fully active structure and by applying fiducialization techniques. The experiment is intended to be placed at the Gran Sasso laboratories. After the encouraging results of a 20 g prototype, here we present the first results from a demonstrator array of 60 g and 180 silicon dice, the simulations of the experiment and the projected Dark Matter sensitivity.

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Direct Dark Matter search with the CRESST-III experiment

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CRESST-III (Cryogenic Rare Event Search with Superconducting Thermometers) installed at Laboratori Nazionali del Gran Sasso, is looking to directly detect dark matter particles scattering off target nuclei in cryogenic detectors. Thanks to its energy thresholds lower than 100 eV, CRESST-III is among the leading experiments in probing sub-GeV DM masses. In this contribution, an overview of CRESST-III is presented, reporting the latest DM results and plans for the future. Recent achievements are discussed on the Low Energy Excess (LEE), an unexplained rise of events at low energies (<200 eV), currently limiting the sensitivity in the low mass region. The most recent experimental campaigns, to identify the origin of LEE and reject this background, are also discussed.

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The effect of the LMC on non standard interactions for future dark matter direct detection experiments

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Previous studies have shown the effect of the Large Magellanic Cloud (LMC) on the local speed distribution of the dark matter particles. Since it dominates the high speed tail of the distribution and the gravitational interaction also boosts the solar neighbourhood dark matter particles to higher velocities, such an effect has an impact on direct detection searches. In this talk, I will discuss the impact of the LMC on the expected signals in different future direct detection experiments taking into account not only the standard spin-independent (dependent) signal but different dark matter - nucleon interaction types following the Non-Relativistic Effective Field Theory approach. Furthermore, I will discuss how the LMC affects the results in the case of inelastic dark matter.

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Latest Results from the CUORE experiment

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The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for 0νββ decay that has successfully reached the one-tonne mass scale. The detector, located at the LNGS in Italy, consists of an array of 988 TeO2 crystals arranged in a compact cylindrical structure of 19 towers. CUORE began its first physics data run in 2017 at a base temperature of about 10 mK and has been collecting data continuously since 2019, reaching a TeO2 exposure of 2 tonne-year in spring 2023. This is the largest amount of data ever acquired with a solid state cryogenic detector, which allows for further improvement in the CUORE sensitivity to 0νββ decay in 130Te. In this talk, we will present the new CUORE data release, based on the full available statistics and on new, significant enhancements of the data processing chain and high-level analysis.

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The DarkSide-20k experiment at LNGS

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The DarkSide program at Laboratori Nazionali del Gran Sasso (LNGS) aims to detect dark matter WIMP particles in dual phase Liquid Argon (LAr) Time Projection Chambers (TPC). Since 2015, DarkSide has run since a 50-kg-active-mass dual phase LAr TPC filled with low radioactivity argon from an underground source and produced results for both the low mass and high mass direct detection search.
The next stage of the DarkSide program will be a new generation experiment involving a global collaboration from all the current Argon based experiments. DarkSide-20k is designed as a 20-tonne fiducial mass dual phase LAr TPC with SiPM based cryogenic photosensors. Like its predecessor, DarkSide-20k will be housed at the INFN LNGS underground laboratory, and it is expected to attain a WIMP-nucleon cross section exclusion sensitivity of $7.4 \times 10^{-48}\ cm^2$ for a WIMP mass of $1\ TeV/c^2$ in a 200 t yr run. DarkSide-20k will be installed inside a membrane cryostat containing more than 700 ton of liquid Argon and be surrounded by an active neutron veto. The talk will give the latest updates of the ongoing construction and prototype tests validating the initial design.

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Annual modulation results from DAMA/LIBRA

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The DAMA/LIBRA experiment (about 250 kg of highly radio-pure NaI(Tl)) at the Gran Sasso National Laboratory (LNGS) of the I.N.F.N. is presented. Its main aim is the investigation of Dark Matter (DM) particles in the Galactic halo by pursuing the model independent DM annual modulation signature. DAMA/LIBRA–phase2, with improved experimental configuration and lower software energy threshold with respect to the phase1, confirms a signal that meets all the requirements of the model independent DM annual modulation signature, at high C.L.. No systematic or side reaction able to mimic the exploited DM signature has been found. The obtained DAMA model independent result is compatible with a wide set of scenarios regarding the nature of the DM candidate and related astrophysical, nuclear and particle physics models. A new configuration of DAMA/LIBRA–phase2 (dubbed "empowered") is now running with a further lowered energy threshold. This last phase of measurement is ongoing. In the talk, a summary of the results obtained so far by DAMA/LIBRA will be released and the perspectives of the present new running configuration will be presented.

Direct Dark Matter detection / **213**

Recent results from the PandaX-4T experiment

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The PandaX-4T experiment, located at the China Jinping Underground Laboratory, is a dual-phase xenon direct dark matter detection experiment utilizing 4 tons of liquid xenon as the target material in its sensitive volume. As of now, the total data exposure in PandaX-4T is approximately 1.6 ton-years, starting from 2020. Using the data, we have searched for multiple dark matter candidates and studied neutrino physics. In this talk, I will provide an overview of the PandaX-4T detector and discuss the recent physics progress from the experiment.

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Directional Dark Matter searches and current status of experimental efforts

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The presence of Dark Matter (DM) in the Universe is nowadays an established, yet still mysterious, paradigm: deciphering its essence is one of the most compelling tasks for fundamental physics today. While the majority of direct DM search experiment look for very low energy deposits by nuclear recoils induced by scattering with potential DM candidates, a much more robust signature is represented by the possibility to measure the directional modulation of a DM signal. This originates from the orientation of solar system motion inside the DM halo that embeds our Galaxy and which happens to point towards the constellation Cygnus. This represent a directional correlation with an astrophysical source that no background whatsoever can mimic. A detector sensitive to direction and sense of the arrival of particles can therefore hold the key to an unambiguous, positive observation of a DM signal and at the same time be able to continue DM searches also inside the so-called "Neutrino Fog", which has today become a reality after the recent evidence of 8B solar neutrinos coherent scattering by the XenonNT experiment. In this talk, we will review the status and the latest progresses of the experimental efforts in directional DM searches, and how these are joining together in the CYGNUS project aiming at establishing a Galactic Directional Recoil Observatory at the ton-scale.

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Study of Dark Matter with directionality approach using $ZnWO_4$ crystal scintillators.

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The development and use of low-background anisotropic scintillators can offer a unique way to study the Dark Matter (DM) particle component in the galactic halo, which is able to induce nuclear recoils through the directionality technique. This approach is based on studying the correlation between the arrival direction of DM candidates able to induce a nuclear recoil and the Earth's motion in the galactic frame. In particular, the $ZnWO_4$ crystal scintillator has unique characteristics, which makes it an excellent candidate for this type of research. In fact, both the light output and the scintillation pulse shape depend on the impinging direction of heavy particles (such as α particles and nuclear recoils) with respect to the crystal axes and can supply two independent modes to study the directionality and discriminate the β/γ radiation. The response of the $ZnWO_4$ scintillators to nuclear recoils induced by neutron scattering was studied and the anisotropic response was measured at 5.4 σ C.L. The sensitivity of such an approach for DM directionality investigation will be outlined.

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Latest results of the Muon g-2 experiment at Fermilab

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The muon anomalous magnetic moment, $a_\mu = \frac{g-2}{2}$, is a low-energy observable which can be both measured and computed to high precision, making it a sensitive test of the Standard Model and a probe for new physics. The Muon g-2 experiment at Fermilab aims to measure a_μ with a final accuracy of 140 parts per billion (ppb). The experiment is based on the measurement of the muon spin anomalous precession frequency, ω_a, using the arrival time distribution of high-energy decay positrons observed by 24 electromagnetic calorimeters, placed around the inner circumference of a 14~m diameter storage ring. Precise knowledge of the storage ring magnetic field and of the beam time and space distribution is crucial to achieve this level of precision
The first result of the experiment, based on the 2018 data-taking campaign, was published in 2021 and it confirmed the previous result obtained at the Brookhaven National Laboratory with a similar sensitivity of 460 ppb . In this talk we present the result based on the 2019 and 2020 datasets, which contain a factor four more data, thus increasing the sensitivity to 200 ppb. We will discuss the improvement in the accuracy with respect to the 2021 result and the future prospects for the experiment.

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The SuperCDMS experiment at SNOLAB

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The Super Cryogenic Dark Matter Search (SuperCDMS) SNOLAB is a direct detection dark matter (DM) search experiment that is currently being constructed 2 kilometers underground at SNOLAB, Canada. The experiment will employ 24 cryogenic semiconductor detectors (18 germanium and 6 silicon) that are comprised of two different types. The first type is called a High Voltage (HV) detector operated at $\sim$100 V that measures only phonon signals. The second type is an interleaved Z-sensitive Ionization and Phonon (iZIP) detector operated at $\sim$6-8 V that measures both phonon and charge signals. The phonons generated by the drifting ionizing charges due to the Neganov-Trofimov-Luke effect add to the phonons produced from the initial particle interaction in the crystal. The phonons are subsequently measured by transition edge sensors and converted to electrical signals. The HV detectors will lower the energy threshold, whereas the iZIP detectors will facilitate a better understanding of the backgrounds. The silicon detectors, due to their lower atomic mass, are more sensitive to sub-GeV DM. On the other hand, the germanium detectors will be able to explore weaker DM-nucleon cross-sections due to lower intrinsic backgrounds. The experiment aims to achieve world-leading sensitivity for DM-nucleon interactions in the DM mass range of 0.5 GeV to 5 GeV. SuperCDMS recently tested a set of HV detectors at a low background low-temperature user facility at SNOLAB called the Cryogenic Underground TEst facility (CUTE). This talk will highlight the experiment design, the current status of its construction, and findings from the detector tests done at CUTE.

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Status and Perspectives of the Real-Time Control of VIRGO Gravitational Waves Detector

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The Advanced VIRGO detector is currently taking data during the second part of the fourth observation run called O4b, which began last April and is scheduled to finish in spring 2025. In order to detect gravitational waves, VIRGO uses a complex real-time control system consisting of 135 multicore DSP processors and more than 1,000 channels of high-resolution analog inputs and outputs. In this talk we summarize the main requirements with associated technical choices focusing mainly on electronic hardware, entirely designed and produced by INFN. We also presents our plans for upcoming upgrades targeting next VIRGO observation run O5 and that will also lead to the conceptual design of the control system for the third-generation ground based detector Einstein Telescope.

Gravitational Waves detection / 184

Detecting fundamental fields with LISA observations of extreme mass ratio inspirals

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In this talk I will discuss in which cases black holes carry a scalar charge, and the implications when the latter scales with the black hole mass. I will talk about the phenomenological consequences of these insights for the physics of compact binaries, and how asymmetric systems evolving in the LISA band are ideal sources for searches of new fundamental fields coupled to gravity. I will lay out the framework for modelling such binaries in an effective field theory approach, and present some first forecasts on LISA's ability to constrain the properties of scalar fields from future gravitational wave observations.

Gravitational Waves detection / 130

Ring Laser gyroscopes and Gravitational waves research

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The INFN research for the development of top sensitivity ring laser gyroscope began about 15 years ago. At that time the aim was to develop top sensitivity tiltmeter for the Virgo suspensions, and the CSN2 has financed a group to develop ring laser gyroscopes for fundamental physics investigation. At present the apparatus GINGER, based on an array of ring lasers, is under construction inside the underground laboratory of LNGS and a transportable ring laser, called TRIO, has been built in Pisa. The feasible sensitivity and the possible utilisation for third generation GW detection will be discussed.

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A new concept for compact seismic attenuation systems to improve low-frequency sensitivity of gravitational wave detectors

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Third generation gravitational wave detectors like the Einstein Telescope will broaden our view of the Universe, thanks to higher sensitivities and broader frequency ranges. Improving the sensitivity in the low-frequency regime will enable the detection of coalescences of higher mass black holes and boost early alert capabilities for binary neutron star mergers, thus increasing the number of expected multimessenger observations. To achieve this goal, designing new-generation seismic attenuation systems will be a crucial R&D activity. We will introduce the main science cases and challenges for low-frequency gravitational wave observations, and we will present a new concept for a compact seismic attenuation mechanical filter that has the potential to reduce the size of current super attenuator systems, a result that could bring a leap in the sensitivity at low frequencies of gravitational-wave detectors and significant reduction in the underground civil work for the future Einstein Telescope.

Gravitational Waves detection / 218

Probing the Universe using Pulsar Timing Arrays

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Millisecond pulsars are extremely stable in their rotation. This stability provides very precise astrophysical timing measurements in the Galaxy. The Pulsar Timing Array (PTA) collaborations use this property to search for Gravitational Waves (GW). Last year, they reported evidence for the presence of a GW signal in their dataset. The main candidate for such a signal is a population of Super Massive Black Hole Binaries (SMBHB). The sum of their individual GW emissions would produce a stochastic Gravitational Wave Background (GWB) that could explain what is observed in the real data. This presentation will give a basic understanding of how PTAs work. Then, we will discuss the latest results that were obtained by the international collaborations and explore alternative explanations to the signal that is currently observed.

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Exploring Vacuum-Gravity Interaction through the Archimedes Experiment: Recent Results and Future Prospects

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The goal of the Archimedes experiment is to investigate the role of the interaction between the vacuum fluctuations and gravitational field. This will be possible thanks to a high sensitivity and cryogenic balance installed in the SarGrav laboratory in the Sos Enattos mine (Sardinia), the Italian candidate site for the third generation gravitational wave observatory Einstein Telescope. Archimedes will measure the small weight variations induced in two high temperature superconductors that have the property of "trapping" or "expelling" vacuum energy when their temperatures are greater or lower than their critical temperatures. Only the radiative heat exchange mechanism must be used to remove or add thermal energy to the sample as it must be isolated from any external interaction that could add energy other than the vacuum one. The status of the experiment will be illustrated together with the most recent results.

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Testing fundamental physics with gravitational waves

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Impact of the Newtonian Noise on Einstein Telescope science

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Einstein Telescope will be the European third generation of gravitational wave detectors. It aims to increase the detectable capability of one order of magnitude in the frequency range of the interferometers of the second generation and enlarge the bandwidth down to a few Hertz. The main noise sources at low frequencies are seismic noise (important below a few Hz) and the Newtonian noise (NN) dominant below 10 Hz. In this work, we will present the contribution of the NN evaluated from the seismic noise of the two candidate sites (The Netherlands and Italy) and we will evaluate those impacts on the science for compact binary coalescence signals. We find that the effect of the signal to noise ratio of the main kind of gravitational waves is negligible for the Italian site while it is strongly affecting the Dutch site due to the different geology and anthropogenic noise present.

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The challenge of low frequency sensitivity in ground-based GW detectors

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Within the context of Gravitational Waves (GW) detection, interferometric GW detectors have revolutionized astrophysics over the past decade, allowing the detection of relevant cosmic events which

were previously unobservable. These instruments are based on the principle of the Michelson interferometer, using resonant Fabry-Perot cavities in which the main optical components (test masses, i.e. TM) are suspended as free-falling bodies in order to isolate them from the seismic disturbances. In order to be able to detect the weak signal of a gravitational wave, it is necessary that such optical components are positioned in the so-called working-point, in which the mirrors are kept steady with respect to each other with enough accuracy in terms of residual motion, e.g. deviation from the operating point along the optical axis. Such requirements are typically of the order of 1·10^(-12) m for the longitudinal degrees of freedom, and 1·10^(-9) rad for the angular ones. Since the free motion of the suspended elements is orders of magnitudes larger, specific feedback control systems are necessary to sense and keep the elements in the correct operating point. As a consequence of the implementation of such feedback systems, control noise becomes one of the main offenders spoiling the detector sensitivity at low-frequency, below 40 Hz.
By addressing control noise, we aim to significantly improve the sensitivity of gravitational wave detectors at low frequencies, thereby enhancing our capability to detect and analyze gravitational waves from a wider range of astrophysical sources, especially in view of third-generation detectors which aim to further improve these noise limits. This work will provide an overview of the current status of low frequency noise for the second-generation detectors, noise reduction techniques, and future perspectives in overcoming control noise challenges to improve gravitational wave astronomy.

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Advanced Optics Research in Gravitational Wave Detection

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The detection of gravitational waves has opened a new era in astrophysics, providing unique insights into some of the most energetic events in the universe. Central to the success of detectors such as Virgo and LIGO are advanced optical technologies that enable unprecedented sensitivity and precision.
As we push for higher laser power to reduce shot noise and improve detector sensitivity at high frequency, power-induced optical aberrations become a significant challenge. Adaptive optics systems are essential in compensating for these aberrations. The concepts behind the system that monitors and actively corrects aberrations in current and future detectors will be reported.
Furthermore, the development of materials for ultra-low-loss optical coatings and substrate that minimize thermal noise in the sensitivity curve bucket will be presented.
By advancing our understanding and application of these optical technologies, we can pave the way for next-generation observatories. These improvements not only will allow higher detection rate but also enable the observation of fainter and more distant sources, thereby expanding our understanding of the universe.

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Input Optics for Gravitational Wave Detectors

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Gravitational wave detectors like Virgo and LIGO help us learn more about the universe. A key part of these detectors is the input optics system, which takes care of the optics downstream of the high

power laser and delivers the beam into the interferometer. This presentation will explain how this system works and why it's important.
The input optics system does several important tasks: it makes sure the laser beam meets strict requirements, ensuring optimal spatial mode quality, and stabilizing both the frequency and power of the beam. Important parts of this system include modulators, mode-cleaning cavities, isolators, and optics that shape the beam. Each part is carefully designed to reduce noise and improve efficiency.
We will talk about recent improvements in the input optics for current detectors, especially during the Advanced Virgo and Advanced LIGO upgrades. These improvements have made the detectors more sensitive to low-frequency gravitational waves, allowing them to detect more cosmic events.
We will also discuss ongoing research and future developments to further improve the input optics system.

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Cosmology with gravitational waves

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I will discuss methods, current constraints and future perspectives on the measurement of cosmological paramaters (including the dark energy equation of state and propagation effects from modified gravity) with gravitational wave (GW) events, both in the case of bright and dark sirens. Bright sirens are low-redshift events (thus mostly sensitive to the Hubble constant) with an electromagnetic counterpart allowing for direct redshift determination; in the case of dark sirens other statistical methods are used to gain information on redshift leading to a potential improvement on our knowledge of other cosmological parameters, especially with the next generation of GW detectors.
Another interesting cosmological application of GW science is the possibility to detect a stochastic GW background of cosmological origin. I will discuss this subject focusing in particular on a novel and solid framework for assessing the impact of the astrophysical foreground on the detection of a cosmological background with third-generation GW detectors.

Hardware & Software Developments / 241

The prototype Schwarzschild Couder Telescope: a Medium-Sized Telescope for the Cherenkov Telescope Array.

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Authors: Francesca Romana Pantaleo for the CTA SCT Project
Abstract:
The Schwarzschild Couder Telescope (SCT) is a dual mirror medium-sized
telescope proposed for the Cherenkov Telescope Array Observatory (CTAO),
the next-generation very-high energy (from about 20 GeV to 300 TeV) gamma-ray observatory. The SCT design is composed by a dual-mirror optics anda high-resolution camera with a field of view (FoV) of 8 degrees squared, which will allow exceptional performance in terms of angular resolution and background rejection. A prototype telescope (pSCT) has been installed and is operating at the Fred Lawrence Whipple Observatory (FLWO) in Arizona, USA. Its camera is partially equipped with silicon photomultiplier (SiPM) matrices produced by Fondazione Bruno Kessler (FBK) and Hamamatsu. At the moment, the camera covers a FoV of 2.7°. The pSCT has detected the Crab Nebula with a statistical significance of 8.6 standard deviations. The upgrade of the pSCT focal plane is now

ongoing, aimed to equip the full camera with upgraded sensors and electronics, enhancing the telescope field of view from the current 2.7° to the final 8°. In this presentation, an overview of the pSCT project and obtained results will be given, together with the camera upgrade status and expected performance.

Hardware & Software Developments / 160

A RoCEv2 RDMA based readout prototype for the SWGO Observatory

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SWGO (Southern Wide-Field Gamma Observatory) is a new facility that will be installed in the southern hemisphere for the mapping of large scale emissions.
Its prototype readout system, utilizing high-channel count fast sampling hardware, directly transfers data to processing servers via RDMA RoCEv2 protocol, eliminating custom backend hardware. For this purpose, a Bluespec Systemverilog core runs on small FPGAs in front-end readout electronics. A hardware prototype with Fast ADCs board and tests will be presented. Developed firmware showcases feasibility and scalability for high-channel count physics experiments.

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The online data taking system of the Cherenkov Telescope Array Observatory

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The Cherenkov Telescope Array Observatory (CTAO is the next-generation ground-based observatory for gamma-ray astronomy. CTAO will be constructed on two sites, one array in the Northern and the other in the Southern hemisphere, containing more than 60 telescopes of three different sizes, for covering different energy domains. The Array Control and Data Acquisition (ACADA) system is the central software governing on-site Cherenkov Telescope Array Observatory (CTAO) operations. ACADA controls, supervises, and acquires the data generated by the telescopes and the auxiliary instruments. It will drive the efficient planning and execution of observations while handling the several Gb/s camera data generated by each CTAO telescope. The ACADA software is based on the Alma Common Software (ACS) framework, and written in C++, Java, Python, and JavaScript. The first release of the ACADA software, ACADA Release 1, was finalized in July 2023, and successfully tested with the first CTAO Large-sized Telescope in October 2023, and a program for the integration of ACADA and the CTAO telescopes will be carried out during the next couple of years. This contribution describes the design of the ACADA software.

Hardware & Software Developments / 339

The M2Tech project, new perspectives on Multi-Messenger technologies

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Real time analysis for multi-messenger astrophysics

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The detection of the first multimessenger event, GW170817, highlighted the impact multimessenger analysis can have on our understanding of extreme phenomena in the universe. Real-time analysis in multimessenger astrophysics represents a significant advancement, enabling prompt and coordinated observations across various observatories and instruments. This progress relies on integrating advanced computational techniques, real-time data processing algorithms, and efficient software architecture. Real-time analysis facilitates the rapid localization, characterization, and cross-validation of astrophysical sources, thereby accelerating scientific discoveries and enabling timely responses to transient events. We will present the project Wavefier, a prototype for real-time gravitational wave transient signal classification, which can serve as the infrastructure for the multimessenger data analysis.

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The Italian Program PNRR CTA+ for the Cherenkov Telescope Array Observatory South Site

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CTA+ is an Italian project of the National Recovery and Resilience Plan (PNRR in Italian), funded by the European Union –NextGenerationEU, to complement the largest research infrastructure dedicated to the study of the very-high-energy sky: the Cherenkov Telescope Array Observatory (CTAO), a ground-based gamma-ray observatory currently under construction. Specifically, CTA+ will build two Large-Sized Telescopes (LSTs) and five Small-Sized Telescopes (SSTs) to be located at the CTAO-South site.
CTA+ is coordinated by the INAF in collaboration with the INFN, the Universities of Bologna, Bari, Siena and Palermo and the Polytechnic University of Bari. The approved and fully funded program has formally started on January 1, 2023 and has a duration of 36 months.
The objectives of CTA+ include:
• the customization and construction of two LSTs (23 meters in diameter) and five SSTs (5 meters in diameter) to be placed at the CTAO-South site;
• the optimization of the electromagnetic follow-ups (optical/infrared/radio) of the sources observed by CTAO;
• strengthening the research and development of future detectors for the CTAO;
• enhancing training and scientific support for the CTA+ program;
• supporting specific outreach activities and the CTAO headquarters in Bologna.
This talk will present the current status and main objectives of CTA+, focusing on the most recent progresses.

Hardware & Software Developments / 146

Gammapy: the Python package for gamma-ray astronomy into the Open Science

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Gammapy is an open-source Python package for the analysis of astronomical gamma-ray data. Starting from event lists and instrument response functions, Gammapy provides functionalities to reduce these data and generate the astrophysical high-level products needed for the very-high-energy domain. Its capacity to fit multi-instrument data using disparate astrophysical models demonstrates its versatility and strength. Despite being recognized as an open research software, Gammapy is being used as a reference library by a number of gamma-ray experiments and, in 2021, the CTA observatory chose it to be the core library for its official Science Analysis Tool.
The Gammapy team started the library in 2013 and has recently worked to make it a multi-wavelength/multi-messenger analysis tool that is interoperable with Python astrophysical modeling libraries. In addition, being involved in the Open Science movement, the team has undertaken to fully follow the FAIR4RS principles and to implement, where possible, the IVOA recommendations.
This presentation will describe the Gammapy project, synthetize its design and features, and summarize its refinements within the Open Science panorama.

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The optical calibration system for the CTA-North Large Sized Telescope camera

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The first Large-Sized Telescope (LST-1) for the Northern Site of the Cherenkov Telescope Array Observatory (CTAO) was inaugurated in October 2018 at the Observatorio del Roque de Los Muchachos (ORM) on La Palma (Canary Island). LST-1 has been regularly taking scientific data since November 2019.

Currently, the CTAO-LST project is in the last steps to complete the construction of the three remaining LSTs at the ORM: LST 2-4.

The LST camera requires a precise and regular calibration. The camera calibration system (CaliBox) is equipped with a UV laser at 350 nm wavelength, where the camera PMTs have their peak quantum efficiency. The CaliBox is designed to fulfill the requirements for the camera calibration: monitoring the photon flux to guarantee the laser stability, uniform illumination, and intensity range.

At INFN Roma1 Laboratory, we are finalizing the calibration systems for the cameras including an upgrade to the prototype installed in LST-1, particularly the photon monitor system and software.

We present, in detail, the design and performance of the optical system, photon flux monitor, related electronics, and evaluations and tests of the photon flux at the camera plane carried out at the INFN Rome1 Laboratory.

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Enabling Industry 4.0 approach in Multi-Messenger Astronomy experiments.

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Industry 4.0, with its approach based on digitisation and its tight connection to the Internet of the Thing, represents a reference paradigm that can significantly improve the efficiency and productivity in the construction of experimental infrastructures for science. In this work we propose a methodology based on integrated hybrid systems which combine digital twins of physical phenomena and hardware components together with parts of real apparatuses made of sensors, actuators and software implementations. The peculiarity of the proposed methodology is the orchestration approach which leverages the concept of Virtual Commissioning which allows the design, test and realisation of an infrastructure by means of synergic advancements of virtual representation and the actual implementation. In other words, it will be possible to create a virtually replicated apparatus that can be used for early experimentation, testing and trialing while the actual one is still being assembled. This approach could be actually attractive to large and complex experimental infrastructures for the Multi-Messenger Astronomy which are currently under design or construction, such as new generation underwater and under-ice neutrino telescopes and interferometers for gravitational waves.

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FlashCam: a high-performance camera for IACTs

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FlashCam is a PMT-based camera designed for Cherenkov telescopes. It is based on a custom developed continuous digital readout and trigger system with a sampling rate of 250 million samples per second. FlashCam is built using a horizontal architecture with three distinct sections: photodetectors, readout system and data acquisition. One copy of the camera has successfully been verified at HESS for several years, since its installation in 2019.

The future Cherenkov Telescope Array Observatory (CTAO) will consist of a large number of telescopes with multiple different sizes spread over two arrays (La Palma and Paranal) and will be the most sensitive ground-based Cherenkov detector. The FlashCam collaboration is developing the camera for the medium-sized telescopes of the South Array of CTAO. Within the team, we are preparing the camera to build a first pathfinder at or near the CTAO South Station. This contribution presents the current status of the camera, as well as the preparations for its series production.

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Radiation Damage on SiPM for High Energy Physics Experiments in space missions

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Silicon Photomultipliers (SiPMs), an array of Single Photon Avalanche photodiodes (SPADs) connected in parallel, are a promising technology for space missions for their high gain, compactness, low bias operating range, insensitivity to magnetic fields and low cost. It is of general interest to study the effect of radiation damage on a SiPM. Here, we report the effect of the irradiation with protons with four fluence levels up to $1 \times 10^{11} p/cm^2$ on SPADs and SiPMs NUV-HD-lowCT with poly in trench technology, developed by Fondazione Bruno Kessler (FBK), with different cell pitch (40µm and 15µm). Protons induce mainly damage in the bulk of the detector through point or cluster defects, enhancing the primary dark count rate (DCR) and this can be observed in an increase of the dark current. Functional tests on the irradiated samples (SPADs and SiPM) confirmed primary DCR increment and excluded significant variation in breakdown voltage. These results are in agreement with the evaluation of the effects of Ionizing and Non-Ionizing Energy Loss (NIEL and IEL) damage on SiPMs reported in literature for space application. These results provide insights for the design of future solutions aimed at mitigating SiPMs and SPADs performance degradation.

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KM3NeT Acquisition Electronics: Status, Upgrades and current developments

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The KM3NeT Collaboration is currently building a neutrino observatory in the Mediterranean Sea, deploying thousands of Digital Optical Modules in glass spheres over several cubic kilometers. These modules host acquisition electronics responsible for reading out 31 Photomultiplier Tubes. This contribution offers an overview of KM3NeT's acquisition electronics, emphasizing recent upgrades, ongoing developments, and reliability enhancements. The presentation addresses reliability improvements through theoretical analyses (FIDES method) and practical evaluations (HALT method). Synchronization efforts are also detailed, including current implementation at the Digital Optical Modules and the Detection-Unit Bases to achieve 1 nanosecond precision between nodes.

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Read-out system for the JUNO experiment

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Update on the Offline Analysis Framework for AugerPrime and integration of the AugerPrime Radio Detector reconstruction

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The Offline Framework serves as a comprehensive tool for the reconstruction of measured data and simulated air showers for the Pierre Auger Observatory. Originally developed for the Surface and Fluorescence Detectors, new detectors such as the Auger Engineering Radio Array have been successfully integrated already. The development and installation of the AugerPrime upgrade required incorporating new detector types and updating existing detector descriptions. This integration was facilitated by the modular structure of Offline, which strictly separates detector descriptions, data structures, and processing modules. We will discuss the general structure of the Offline Framework and explain the design decisions that provided its flexibility. Specifically, we will describe the reconstruction of data from the AugerPrime Radio Detector within Offline. This includes the signal reconstruction for each station, the directional reconstruction based on a spherical model of the signal arrival time at all stations, and the energy and distance to Xmax reconstruction from a fit of the lateral signal distribution. Additionally, we will outline anticipated improvements in the reconstruction process, such as an absolute calibration based on the galactic radio emission and an advanced suppression technique for narrow-band RFI pulses.

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The KM3NeT online processing for multi-messenger alerts

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KM3NeT is a deep-sea research infrastructure under construction in the Mediterranean Sea. It consists of two water-Cherenkov neutrino telescopes: ARCA (Italy), designed to identify and study TeV-PeV astrophysical neutrino sources, and ORCA (France), aiming at studying the intrinsic properties of neutrinos in the few-GeV range. KM3NeT is sensitive also to neutrinos emitted in the MeV range by core-collapse supernovae. The complementary energy ranges of ARCA and ORCA allow them to be used for neutrino astronomy across an energy spectrum ranging from a few MeV to a few PeV, despite they have different primary goals. KM3NeT actively takes part to real-time multi-messenger searches, which aim at combining information from the simultaneous observation of complementary cosmic messengers with different observatories. These searches allow to increase the discovery potential of transient sources and refine the localization of poorly localized triggers, such as gravitational waves, by distributing alerts in real-time when pontially interesting events are detected. In this respect, the KM3NeT online analysis framework is continuously reconstructing all ARCA and ORCA events, performing core-collapse supernova analyses and searching for spatial and temporal coincidences with alerts received from other multi-messenger instruments. The selection

of a sample of interesting events to send alerts to the external multi-messenger community is still in progress. This contribution deals with the description of the KM3NeT online processing.

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APEIRON: a framework for the development of smart TDAQ systems

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APEIRON is a framework encompassing the general architecture of a distributed heterogeneous processing platform and the corresponding software stack, from the low level device drivers up to the high level programming model.
The framework is designed to be efficiently used for studying, prototyping and deploying smart trigger and data acquisition (TDAQ) systems for physics experiments.
The general architecture of such a distributed processing platform includes m data sources, corresponding to the detectors or sub-detectors, feeding a sequence of n stream processing layers, making up the whole data path from readout to trigger processor (or storage server).
The processing platform features a modular and scalable low-latency network infrastructure with configurable topology. This network system represents the key element of the architecture, enabling the low-latency recombination of the data streams arriving from the different input channels through the various processing layers.
Developers can define scalable applications using a dataflow programming model (inspired by Kahn Process Networks) that can be efficiently deployed on a multi-FPGAs system: the APEIRON communication IPs allow low-latency communication between processing tasks deployed on FPGAs, even if hosted on different computing nodes.
Thanks to the use of High Level Synthesis tools in the workflow, tasks are described in high level language (C/C++) while communication between tasks is expressed through a lightweight API based on non-blocking send() and blocking receive() operations.
The mapping between the computational data flow graph and the underlying network of FPGAs is defined by the designer with a configuration tool, by which the framework will produce all project files required for the FPGAs bitstream generation. The interconnection logic is therefore automatically built according to the application needs (in terms of input/output data channels), allowing the designer to focus on the processing tasks expressed in C/C++ .
The aim of the APEIRON project was to develop a flexible framework that could be adopted in the design and implementation of both "traditional" low level trigger systems and of data reduction stages in trigger-less or streaming readout experimental setups.
For this purpose we studied and implemented algorithms capable of boosting the efficiency of these classes of online systems based on Neural Networks (NN), trained offline and leveraging the HLS4ML software package for deployment on FPGA.
We have validated the framework on the physics use case represented by the partial particle identification system for the low-level trigger of the NA62 experiment at CERN, working on data from its Ring Imaging Cherenkov detector to pick out electrons and number of charged particles.

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The AugerPrime extension of the Pierre Auger Observatory

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Only the less deflected cosmic rays point back to their origin and allow astronomical observations. Therefore, the key to identifying the sources of the highest energetic cosmic rays is to measure their mass on an event-by-event basis. Equally, the shower development at the extreme energies is still puzzling, like the muon deficit in extensive air-shower simulations, pointing to a lack of understanding of the hadronic interactions. For these purposes, the Pierre Auger Observatory extended the measurement capabilities of the full duty cycle Surface Detector to improve the separation of the muonic and electromagnetic components of the shower. The different extensions, the status of the deployment, the first performance studies and calibrations, as well as the first examples of the upgraded detector measurements will be discussed.

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The Zirè experiment onboard the NUSES space mission

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NUSES is a new space mission aiming to test innovative observational and technological approaches related to the study of low energy cosmic and gamma rays, high energy astrophysical neutrinos, Sun-Earth environment, Space weather and magnetosphere-ionosphere-lithosphere coupling (MILC). The satellite will host two payloads: Terzina and Zirè.

Zirè will perform measurements of electrons, protons and light nuclei from a few up to hundreds MeV, also testing new tools for the detection of cosmic MeV photons (e.g. for GRBs). For these purposes the Zirè instrument will include a Fiber TracKer (FTK), a Plastic Scintillator Tower (PST), a calorimeter (CALOg) and an AntiCoincidence System (ACS). Particle energies will be measured by the range and/or the total deposit, while particle identification will be provided by the DeltaE-E technique. The CALOg will also be used to measure cosmic photons at MeV energies exploiting dedicated windows in the satellite platform. Sensitivity to lower energy electrons will be provided by a dedicated Low Energy Module (LEM).

Innovative technologies for space-based particle detectors will be adopted and tested thus increasing the corresponding Technology Readiness Levels (TRL) of the adopted solutions. The light readout system (from plastic scintillators and crystals) will be entirely provided by Silicon Photo Multipliers (SiPMs), thus ensuring a compact and light design. The satellite will operate on a low-Earth and sun-synchronous polar orbit. For this reason, particular attention has been paid to the evaluation of radiation doses that will be integrated by the sensors and their effects on detector efficiency, dark currents and power budget. In this work, a general overview of the Zirè payload will be given , together with a focus on detector figures and science goals.

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White Rabbit FMC mezzanine as an interface for the new 10G WR-NIC to remote WR DAQ nodes

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The White Rabbit protocol (WR), developed at CERN for the distribution of sub-nanosecond timing to thousands of nodes distributed over large geographic areas, is becoming increasingly reliable and is being utilized in various contexts, notably in modern multi-messenger astronomy experiments in progress such as KM3NeT, CTAO and ET.
Currently, WR supports connectivity with 1 Gb/s Ethernet, both point-to-point and through WR-compliant network switches. Electronics compatible for data acquisition are primarily proprietary development tailored to specific applications. The WR community is already planning new developments toward a full 10 GB/s infrastructure, with plans for a new PCIe NIC board to connect PCs to the WR network. INFN-Bologna and Perugia (University and INFN) are designing a set of low-cost electronic boards enabling versatile management and readout of common sensors or actuators using WR technology for time-synchronization. We propose a lightweight dedicated mezzanine board, named Air-Plane, to complement the upcoming new NIC board and facilitate interface between legacy WR Node as well as with non-WR remote cards. This modular and highly scalable design will streamline the implementation of data acquisition systems in testing scenarios, such as ET mirror suspensions developments.
In this contribution, we present the conceptual design of Air-Plane and its realization plan presented as parto of the M2TECH project, recently submitted to the HORIZON-INFRA-2024-TECH-01-01 call.

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The evolution of the Data Acquisition System of KM3NeT

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The KM3NeT experiment is composed of two underwater large-scale neutrino telescopes currently under construction and located in the Mediterranean Sea, namely ARCA and ORCA, mostly designed for studying cosmic neutrinos and neutrino properties respectively. The two KM3NeT detectors share a common modular Data Acquisition System, which is designed to be scalable with the size of the detectors. The detector design has changed from the previous network architecture, based on a customized version of the White Rabbit time synchronization protocol, to the current network which follows a standard White Rabbit use-case. This was necessary to expand the detectors to the foreseen cubic kilometer volume. In this presentation, the evolution of the Data Acquisition System according to the new detector architecture will be presented.

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The High Energy Particle Detector ready to fly onboard CSES-02

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The China Seismo-Electromagnetic Satellite (CSES) space mission foresees a constellation of satellites devoted to the study of plasma, electromagnetic fields and particles perturbations potentially correlated with the occurrence of seismic events.
Like the first satellite, launched in February 2018, CSES-02 hosts several payloads, among which the Italian High Energy Particle Detector (HEPD).

Besides the study of bursts of Van Allen belt electron fluxes (particle precipitation) generated by high magnitude earthquakes, HEPD-02 will contribute to the study of the solar terrestrial environment, Solar Energetic Particle (SEP) events and low-energy galactic cosmic rays.

For this purpose, the instrument comprises several subdetectors, with major improvements with respect to the first one: the Direction Detector, the first silicon-pixel tracker ever designed for space, an improved trigger system, providing trigger pre-scaling and concurrent trigger configurations, a calorimeter, composed of a tower of plastic scintillators followed by an array of LYSO crystal and surrounded by a Veto system, and the Housekeeping system, with increased detector configurability and active monitoring.
Thanks to the simultaneous trigger configurations and prescaling capability, HEPD-02 will be able to perform measurements of the different particles that populate distinct orbital zones and whose flux can vary by many orders of magnitude, as well as to detect impulsive events, making it a perfect instrument for Space Weather purposes. Furthermore, a dedicated trigger algorithm exploiting the LYSO crystals extends its detection capability to gamma rays in the 2-20 MeV range.

HEPD-02, after a large test campaign for the space qualification and calibration, has been installed on satellite with the other payloads and is currently undergoing the tests at satellite level before launch, scheduled for December 2024.

In this contribution I will describe the instrument, focusing on its improved design, and the test campaign for the instrument space qualification and calibration.

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UHECR : Lightest to heavy nuclei confined in a nearest Universe

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Ultra High Energy Cosmic Rays, UHECR, since last two decades offered new hopes for a new Astronomy. Cosmic Rays in TeV- PeV energy range, are mostly bent by galactic magnetic fields, feeding an homogeneous noisy sky. But the highest energy particle rigidity, above tens EeV, are expected to follow nearly rectilinear trajectories tracing their sources. The surprising evolution, with growing energies,of their nuclear composition from lightest nuclei to heavy ones, imply severe bounds on their source distances mostly due to the photo-nuclear-distruption. These narrow cosmic sizes explain the few nearest candidate as Cen A, NGC 253,M82. The AUGER dipole anisotropy find an explanation by mixed sources. Most energetic events as recent Amaterasu one, could be understood by a heavy nuclei random flight by a well known nearby source. In alternative, by an exotic model, based on ZeV neutrinos ejected by far cosmic AGN, scattering onto relic, sterile, ones with mass, in dark halos.

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The Pierre Auger Observatory and Super Heavy Dark Matter

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We discuss the connection of the Pierre Auger Observatory data with a large class of dark matter models based on the early-universe generation of super-heavy particles, their role in the solution of the dark matter problem, highlighting the remarkable constraining capabilities of the Auger observations.

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Energy evolution of cosmic-ray mass and intensity measured by the Pierre Auger Observatory

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The Pierre Auger Observatory has conducted measurements of the energy spectrum and mass composition of cosmic rays using different methods. Utilizing both surface and fluorescence detectors (FD and SD), the Observatory provides unprecedented precision in understanding these particles. While primarily designed to measure ultra-high-energy cosmic rays, the FD's high-elevation telescopes and the dense arrays of SD stations enable observations even down to 6 PeV and 60 PeV, respectively. To determine the depth of shower maximum, a critical parameter for identifying primary particle types, both direct longitudinal profile measurements from the FD and indirect signal analyses from the SD are employed. An energy evolution of the mass of primary particles, as well as of the spectral index of the flux intensity, are observed and characterized by features described in presented work. The measurements benefit from the joint operation of the FD and SD, delivering a systematic uncertainty of 14% in energy determination and an accumulated exposure reaching 80 000 km^2 sr yr at the highest energies.

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Anisotropy searches at the highest energy cosmic rays with the Pierre Auger Observatory Phase I

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Ultra-high-energy cosmic rays (UHECRs) provide a unique window into the most energetic processes in the universe, yet their origins remain unknown. The near-isotropic distribution of arrival directions observed by the Pierre Auger Observatory suggests that a dominant Galactic source is unlikely, prompting investigations into nearby galaxy groups and clusters as potential origins of UHECRs. However, the presence of intergalactic and Galactic magnetic fields complicates the identification of these sources. To address this challenge, various methodologies have been developed to search for sources on small and intermediate angular scales. These include blind, model-independent searches for overdensities, correlation analyses with astrophysical structures, and cross-correlation studies with catalogs of candidate sources.

In this contribution, we present the principal results from studies conducted at small and intermediate scales throughout the entire Phase I operation of the Pierre Auger Observatory, the largest detector of UHECRs in the world. Over the course of eighteen years, spanning from 2004 to the upgrade to AugerPrime, the Observatory accumulated a detection exposure of approximately 135,000 km^2 sr yr, yielding high-quality data that enabled significant results. These include the detection of the dipole anisotropy and investigations on angular scales of tens of degrees with the highest-energy event dataset.

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On the challenging problem to estimate the energy of the Ultra High Energy Cosmic Rays

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Ultra High Energy Cosmic Rays (UHECRs) are rare nuclei that collides in the atmosphere with energy larger than 10^{18} eV producing a shower cascade made by bilions of particles. An estimation of the shower energy with a good control of the systematic uncertainties is attained with the fluorescence detector technique. The two largest observatories built to date, the Pierre Auger observatory and the Telescope Array project, use an hybrid detection technique in which the integral of the longitudinal profile, measured using the fluorescence telescopes, is used to calibrate a shower-size estimate made with the surface detector. Another technique that can provide a good estimate of the primary energy is recently emerging and it is based on the detection of radio emission in air showers.

In this contribution we critically review the experimental techniques for estimating the shower energy, trying to address current limitations, the potential improvements that can be developed in the coming years and the implications in those physical observables that require a precise measurement of the shower energy.

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Large-scale anisotropies of ultra-high-energy cosmic rays measured at the Pierre Auger Observatory

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Measurements of anisotropies in the arrival directions of ultra-high-energy cosmic rays are crucial to pinpoint their sources, which are yet to be discovered. A dipolar anisotropy in right ascension above 8 EeV has been detected by the Pierre Auger Observatory with a significance of 6.9σ. The direction of the dipole suggests an extragalactic origin of ultra-high-energy cosmic rays above those energies. In this contribution, we provide an overview of the studies on large-scale anisotropies in the arrival directions of ultra-high-energy cosmic rays measured at the Pierre Auger Observatory with energy thresholds from ~ 0.03 EeV up to 32 EeV and we present and discuss the recent results achieved with the latest available dataset, which includes 19 years of operations - resulting in a total exposure of 123,000 km^2 sr yr.

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Echoes from the ”Council of Giants”

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Echoes from Cen A’s Active Past

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Motivated by both the apparent lack of local extragalactic UHECR source candidates, beyond Cen A, and the correlation of UHECR anisotropies with local extragalactic structure, we investigate a scenario in which these anisotropies are imprinted during propagation. Such a possibility builds on the idea that galaxies are enshrouded in an extended halo of hot gas, which we postulate is also magnetised, enabling these objects to scatter UHECR during their propagation. Telltale signatures of this scenario are considered.

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Influence of local insteller medium on cosmic ray properties

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In this talk, I will discuss how local insteller environment may affect the oberved properties of cosmic rays in general and small scale anisotropy in particular. It is shown that a generalization of the Compton Getting effect can give rise to small scale anisotropy with a turbulent spectrum of scattering centers.

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Selection of cosmic-ray electrons and positrons in Fermi-LAT data with Unsupervised Learning techniques

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Measuring the energy spectrum of cosmic electrons+positrons in the energy range 50 GeV - few TeV can provide evidence of the existence of local sources of either an astrophysical or exotic nature (such as dark matter). Several results have been reported in the last years and there are significant differences among some of them, particularly at higher energies where uncertainties are more considerable.
The latest Fermi-LAT measurement was based on an electron+positron selection involving supervised Machine Learning methods, that are model-dependent, being trained on Monte Carlo simulations, and may thus be sensitive to important systematic uncertainties or biases. Here, we present an alternative approach based on Unsupervised Learning techniques, exploiting their potential in detecting patterns without any guidance and enabling a completely model-independent approach.

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New model of the coherent magnetic halo of the Milky Way and cosmic ray propagation

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I will present a new model of the coherent Galactic magnetic field outside of the thin disk. The model was fitted to the most recent catalog of extragalactic Faraday rotation measures (RM) and synchrotron polarization data (Stokes Q and U). The model is based on several phenomenological components of the GMF – the spiral arms, the toroidal halo, the X-shaped field and the compressed field of the Local Bubble wall. Our model for the first time takes into account our location inside of the Local Bubble. We show that the Local Bubble wall might be responsible for about 50% of the polarized emission at high Galactic latitudes and so our model does not require introduction of striated fields invoked in previous models. Also we show that the Fan Region can be modeled as a Galactic-scale feature. The pitch angle of the magnetic field in our fit converged to the value around 20 degrees. Interestingly, with value is very close to the direction of arms inferred recently from Gaia data. At the end, I will discuss the implications of our new model for the propagation of cosmic rays.

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Properties of Cosmic Deuterons Measured by the Alpha Magnetic Spectrometer

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Precision measurements of the cosmic ray D flux are presented as function of rigidity from 1.9 to 21 GV, based on 21 million D nuclei. We observed that over the entire rigidity range D exhibit nearly identical time variations with p, 3He, and 4He fluxes. Above 4.5 GV, the $D/^4He$ flux ratio is time independent and its rigidity dependence is well described by a single power law $\propto R\Delta$ with $\Delta D/^4He = -0.108 \pm 0.005$. This is in contrast with the $^3He/^4He$ flux ratio for which we find $\Delta ^3He/^4He = -0.289 \pm 0.003$. The significance of $\Delta D/^4He > \Delta ^3He/^4He$ exceeds 10 σ. In addition, we found that above ~ 13 GV the rigidity dependence of D and p fluxes is identical with a D/p flux ratio of 0.027 ± 0.001. These unexpected observations show that contrary to expectations, cosmic deuterons have a sizeable primary-like component.

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Global fit of UHECR spectrum, composition, and anisotropies measured at the Pierre Auger Observatory

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To uncover the sources of ultra-high-energy cosmic rays, three main observables are measured at the Pierre Auger Observatory - the cosmic-ray energies, the depths of maximum air shower development, and the arrival directions. At energy E>8 EeV, the arrival directions exhibit a dipolar structure pointing away from the center of our Galaxy indicating an extragalactic origin of cosmic rays at that energy. At the highest energies E>40 EeV, anisotropies at intermediate scales arise which correlate with the directions of nearby source candidates like Centaurus A or a catalog of starburst galaxies. By combining these observations of anisotropies in the cosmic-ray arrival directions with the energy spectrum and shower depth distributions in a global fit, the results can be interpreted further. This allows for conclusions on the contributions of individual source candidates, the density of sources, or the influence of extragalactic and Galactic magnetic fields, all of which will be discussed in this contribution.

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Results from the space-borne High Energy Particle Detector (HEPD-01) after 6 years in orbit

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The High-Energy Particle Detector (HEPD-01) onboard the China Seismo-Electromagnetic Satellite (CSES-01) - launched in February 2018 - is a light and compact payload suitable for measuring electrons (3-100 MeV), protons (30-300 MeV), and light nuclei (up to a few hundreds MeV/n). The very good capabilities in particle detection and separation, the high energy resolution, a wide angular acceptance, together with the Sun-synchronous orbit, make HEPD-01 extremely well suited for the observation of the many particle populations at Low-Earth Orbit. During its first 6 years of data-taking, the detector –completely designed and built in Italy –gathered results on galactic, solar, trapped and re-entrant particles, contributing to better understand some aspects of particle transport inside the heliosphere, the mechanism of acceleration during Solar Particle Events, and the interactions with the magnetosphere of the Earth in both quiet and disturbed conditions. In addition, HEPD-01 detected signatures of numerous strong GRBs, contributing in forming a catalog that is continuously growing. Moreover, starting from late 2024, HEPD-01 will be accompanied by the newest HEPD-02 and both will serve as a very reliable and accurate tool for studying low-energy particles in the near-Earth space towards the maximum of solar cycle 25. In this contribution, we report the main results obtained by HEPD-01, together with some insights on future analyses and open topics.

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Heritage and challenges for next generation charged cosmic-ray space missions

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The current generation of Charged Cosmic Ray (CCR) experiments in operation in space (e.g. AMS-02, DAMPE, CALET) is providing novel information and is measuring unexpected features that are challenging the phenomenological community to revisit the paradigms behind the established theories of cosmic-ray origin, acceleration and propagation, and to formulate comprehensive models able to consistently explain all the observed structures. This achievement has been made possible thanks to the observation of features in cosmic-ray spectra unveiled by the high granularity (in energy and in time), high resolution and high statistics measurement of all the CCR components, in a wide range of energies (O(GeV) - O(100 TeV)). Leveraging on the experience and on the heritage of the current detector generation, several new ideas to further improve, and possibly lead to a breakthrough, the field are being studied, developed, and being applied. The first two experiments benefiting of these novel ideas are the AMS-02 experiment with its "Layer0 Upgrade" (2026) and the HERD experiment

to be installed on the Chinese Space Station (2026 - 2027). The same concepts, in addition to other technological steps forward, are also being applied to the design of a new generation of revolutionary CCR experiments (e.g. ALADInO and AMS-100).
The lessons learned from the operations of the current generation of CCR detectors and the perspectives for future CCR space missions will be reviewed and discussed.

High Energy Cosmic Rays - 1 / 201

Results and Prospects of LHAASO Cosmic Ray Composition and Energy Spectra Measurement

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The Large High-Altitude Air Shower Observatory (LHAASO) is a hybrid detector experiment that includes a one-square-kilometer array of scintillator detectors and muon detectors, a 78,000-square-meter water Cherenkov detector array, and 18 wide-field-of-view Cherenkov telescopes. The multi-parameter observation of showers allows LHAASO to measure the single-element energy spectrum with high resolution. The full LHAASO array has been operational since July 2021. We use the moon shadow displacement measured by LHAASO to establish an absolute energy calibration method for the ground-based detector array. Accurate measurements of the single-element energy spectrum near the knee region can be achieved by LHAASO, which are essential for revealing the acceleration and propagation mechanisms of high-energy cosmic rays. The results of the all-particle energy spectra and composition, precisely measured by LHAASO, will be introduced, along with the prospects for proton, helium, and iron energy spectra that will be presented in the talk.

I Plenary / 231

Selected Studies of Celestial Gamma-ray Sources with MAGIC

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MAGIC is a ground-based Imaging Atmospheric Cherenkov Telescope (IACT) for studying the sky in gamma rays in the very high energy gamma-ray domain. It pioneered measurements with IACTs down to ~20 GeV regime. MAGIC consists of double telescopes with a diameter of 17 m, separated by a distance of 85 m, operating in coincidence mode (stereo). The telescopes are located at an altitude of 2200 m above sea level in the European Northern Observatory El Roque de los Muchachos on the Canary Island of La Palma. In recent years, the MAGIC collaboration has developed innovative techniques that increased the dynamic range and sensitivity of the telescopes also at the higher energy range at about 100 TeV. In this report we want to focus on some selected observations of gamma ray sources of galactic and extragalactic origin.

I Plenary / 136

Status of Large Size Telescopes and Early Science

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The array of four 23-meter-diameter Cherenkov Telescopes, the array of CTA-LSTs, is under construction in La Palma, Canary Islands. We have entered the scientific observational phase with LST1 since 2020 after the commissioning, with which we have examined the performance reached the designed value with a similar sensitivity to the MAGIC. The array of four LSTs will be completed by the summer of 2026, surveying the northern hemisphere with unprecedented sensitivity above a few 10s of GeV and the southern hemisphere, especially a galactic center, with a large zenith angle above a few 100GeV. We will report the status of the array of four LSTs, as well as the recent results and near-future prospects in science.

I Plenary / 331

Welcome and opening remarks

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I Plenary / 239

The AGILE mission legacy

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AGILE has been a unique and successful space mission of the Italian Space Agency (ASI), with the programmatic and technical contribution of INAF and INFN. During almost 17 years of observations in low Earth equatorial orbit (April 23, 2007 - January 18, 2024), AGILE contributed to high-energy astrophysics and terrestrial physics with many discoveries and detections.
The AGILE payload comprises the Silicon Tracker, the SuperAGILE X-ray detector, the Mini-Calorimeter (MCAL), and an AntiCoincidence System (ACS). The ST, MCAL, and ACS combination compose the Gamma-Ray Imaging Detector (GRID).
I will give an overview of the main AGILE scientific results, including some recent updates on the science of Gamma-Ray Bursts (GRBs), Fast Radio Bursts (FRBs) and the hunt for electromagnetic counterparts to Gravitational Waves (GW) and cosmic neutrinos. With the satellite re-entry the in-orbit phase ends, but a new phase of scientific work on the AGILE legacy data archive opens: AGILE may still hold future surprises.

II Plenary / 320

CTAO status and perspective

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The Cherenkov Telescope Array Observatory (CTAO) is the upcoming next-generation ground-based gamma-ray observatory. CTAO will have two sites, one located in the northern hemisphere in the

Roque de los Muchachos Observatory, La Palma (Spain) and a sourthern site in Paranal (Chile). CTAO will count on improved sensitivity, angular and spectral resolution with respect to the current generation of imaging atmospheric Cherenkov telescopes (IACTs) and will cover a broader energy range. In this contribution, we review the current status of CTAO and address the scientific questions that CTAO aims to answer. We outline the science perspectives of CTAO and the timeline of the observatory.

II Plenary / 185

H.E.S.S. status and recent results

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The High Energy Stereoscopic System is currently the only facility available for studying the Very High Energy sky in the Southern Hemisphere. Its setup of four 12m and a central 28m telescope has proven to be sufficiently versatile to allow for outstanding research results after more than 20 years since inauguration. New sources and phenomena were discovered/studied as a result of dedicated in-depth observations, continuous surveys, and rapid responses to time-domain opportunities. Likewise, more advanced analysis frameworks were introduced and increasingly used. I'll present highlights from observations made and results obtained during the last two years and will give an outlook for the planned new extension phase to operate H.E.S.S. well beyond 2025.

II Plenary / 314

The ASTRI project

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The ASTRI program was initiated a decade ago with the objective of developing small-sized dual-mirror aplanatic wide-field IACT telescopes. These telescopes would serve as precursors to the array of small-sized telescopes (SSTs) for the Cherenkov Telescope Array (CTA) observatory's southern site. Initially, the program received support from INAF and MUR (the Italian Ministry for Universities and Research), and later gained support from international partners such as the University of Sao Paulo/FAPESP, North-West University/South Africa, IAC, FGG, and Université de Geneve at various stages of the project. The program's first significant achievement was the development of the end-to-end ASTRI-Horn prototype, which was installed at the INAF site of Serra La Nave. The prototype featured an innovative compact camera based on SiPM sensors and proved the dual-mirror Schwarzschild-Couder optical configuration as an aplanatic system while detecting the Crab Nebula in gamma rays. Now, the ASTRI mini-array is under implementation in Tenerife at the Observatorio del Teide to analyze the gamma-ray sky in the 1-100 TeV energy band with unprecedented angular resolution (3 arcmin), complementing LHAAZO perfectly. This presentation provides an overview of the project's status and scientific goals.

II Plenary / 187

STATUS AND RESULTS OF THE HIGH ALTITUDE WATER CHERENKOV (HAWC) OBSERVATORY

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The High Altitude Water Cherenkov (HAWC) Observatory, located in Mexico at 4100 m altitude and 19 degrees N latitude, is designed to observe astrophysical sources of cosmic and gamma rays with energies from several hundred GeV up to several hundred TeV. HAWC comprises a central array of 300 closely spaced water Cherenkov detector (WCD) tanks surrounded by a sparse array of 345 small WCD tanks. The central array covers approximately 22,000 m^2 with a high fill factor, providing excellent sampling of extensive air showers (EAS). The outer array extends the total coverage area by a factor of four, improving the measurement of extensive air showers by better constraining their core location. HAWC has extensively studied galactic sources of gamma rays, measuring their energy spectra and morphology. HAWC's wide field of view and continuous operation allow for observing and measuring variable and transient sources and serves as a survey instrument to map a significant fraction of the gamma-ray sky. HAWC has participated in several multi-messenger studies with other observatories, including the Ice Cube neutrino and LIGO/Virgo gravitational wave observatories. HAWC has performed many cosmic ray studies, such as measuring their energy spectrum and anisotropy of arrival directions. HAWC has also performed indirect dark matter searches and studies of beyond-standard model particle physics measurements. This talk will provide an overview of the status and highlight some results from HAWC's observation of the TeV sky.

III Plenary / 321

Status and recent results from the LHAASO experiment

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LHAASO is a large hybrid extensive air shower array being constructed at Haizi Mountain, 4410 m a.s.l., in China. It has an excellent sensitivity for gamma-rays with energies from sub-TeV 10 PeV and also has a large field of view that can continuously monitor a large fraction of sky with declination from -20 degree to 80 degree since 2020. In this talk, we will report the status and recent achieved highlight science results in gamma-ray and cosmic ray observations. A prospect for the future observations and detector updating is also presented.

III Plenary / 259

Latest Results from the Alpha Magnetic Spectrometer on the International Space Station

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The Alpha Magnetic Spectrometer (AMS) is a precision particle physics detector on the International Space Station. Over 12 years, AMS has collected more than 230 billion cosmic rays, from elementary particles to iron nuclei, at energies up to multi-TeV. The precision spectrometer measures elementary particles and nuclei with ~1% accuracy, yielding many surprising results. The high energy data on elementary particles (electrons, positrons, antiprotons, and protons) requires new sources of explanation. The data on nuclei and isotopes show characteristic energy dependence not predicted by any theory. The comprehensive AMS data requires a new model of the cosmos.

III Plenary / 159

The SWGO project: status and perspective

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The Southern Wide-field Gamma-ray Observatory (SWGO) is the project to plan and design the next ground-based observatory to detect gamma rays in the Southern Hemisphere. The experiment will be based on water Cherenkov detector units and placed at an altitude greater than 4,400 m in the Andes, to measure gamma rays from a few hundred GeV up to the PeV scale. SWGO will complement CTA and the existing ground-based particle detectors of the Northern Hemisphere, namely HAWC and LHAASO, delivering a rich science programme. The SWGO collaboration is approaching the conclusion of the project R&D, having crossed all major milestones towards the definition of the array design and location, with prototype detector units being currently delivered and tested at altitude sites in South America. In this talk I will present an overview of the project R&D activities and current status, looking forward to the preparatory steps for the start of SWGO construction in the coming years.

III Plenary / 322

Galactic cosmic ray spectral measurements with the DAMPE space mission

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The space-based DAMPE (DArk Matter Particle Explorer) detector has been taking data since its successful launch in December 2015. Its main scientific goals include the indirect search for dark matter signatures in the cosmic electron and gamma-ray spectra, the measurements of galactic cosmic ray fluxes from tens of GeV up to hundreds of TeV and high energy gamma ray astronomy above a few GeV.
In particular, results on proton and helium, which revealed new spectral features, will be described. Ongoing analyses on light, medium, and heavy mass nuclei will be outlined, together with results on secondary-to-primary flux ratios.

Indirect Dark Matter Detection / 227

Gamma rays from dark matter spikes in EAGLE simulations

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Intermediate Mass Black Holes (IMBHs) with a mass range between 100 $M_\odot$ and 10^6 $M_\odot$ are expected to be surrounded by high dark matter densities, so-called dark matter spikes. The high density of self-annihilating Weakly Interacting Massive Particles (WIMPs) in these spikes leads to copious gamma-ray production. Sufficiently nearby IMBHs could therefore appear as unidentified gamma-ray sources. However, the number of IMBHs and their distribution within our own Milky Way is currently unknown.
In this work, we provide a mock catalogue of IMBHs and their dark matter spikes obtained from the EAGLE simulations, in which black holes are seeded into the centre of halos to model black hole feedback influencing the formation of galaxies. The catalogue contains the coordinates and dark matter spike parameters for about 2500 IMBHs present in about 150 Milky Way-like galaxies. We expect about 15^{+9}_{-6} IMBHs within our own galaxy, mainly distributed in the Galactic Centre and the Galactic Plane. We find that current and future gamma-ray observatories, such as Fermi-LAT, H.E.S.S. and CTA, would be sensitive enough to probe the thermal relic cross section of dark matter self-annihilation around IMBHs for dark matter particles with masses from GeV to TeV.

Indirect Dark Matter Detection / 189

Understanding dark matter using GAMBIT

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This talk presents recent findings on dark matter derived from the Global and Modular Beyond the Standard Model Inference Tool (GAMBIT). After summarising the core functionalities of the GAMBIT code, I underscore its potential as a robust framework for identifying signals of physics beyond the Standard Model in particle physics and cosmology. The latest GAMBIT results for various dark matter candidate models are then discussed, demonstrating the tool's effectiveness and versatility in advancing our understanding of dark matter.

Indirect Dark Matter Detection / 161

Probes of primordial black holes as dark matter

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Primordial black holes represent a natural candidate for one of the components of the dark matter in the Universe. In this talk, some of their potential signals will be examined, such as the emission of particles due to Hawking evaporation and due to the accretion of the surrounding matter. The most relevant probes capable of constraining their masses and population will be discussed.

Indirect Dark Matter Detection / 145

Measuring the Dark Matter Content of Dwarf Spheroidal Galaxies and Globular Clusters

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Dark matter (DM), a large (~85%) non-baryonic and non-relativistic component of the matter density of the Universe, likely consists of one or several so-far undetected particles hypothesized in theories beyond the Standard Model (SM). One of the most promising approaches to shed light on the nature of DM particles is to search for signatures of their annihilation or decay into SM particles from regions of the sky believed to be highly DM dominated, such as the Galactic Center, the clusters of galaxies and local compact objects such as the dwarf spheroidal galaxies (dSphs) and some globular clusters around the Milky Way. In this context, the latter two are among the most promising observational targets due to their relative proximity and lack of astrophysical background sources. In this contribution, I will present new determinations of the DM amount (i.e. the astrophysical factors for DM annihilation and decay) in dSph and globular cluster halos obtained through the MCMC Jeans analysis of their brightness and kinematic data through the CLUMPY software. I will also discuss the systematic uncertainties affecting the calculation of such quantities.

Indirect Dark Matter Detection / 221

Dark Matter Gamma-ray searches in Galaxy Clusters: status and prospects

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Galaxy clusters are the largest gravitationally bound structures in the Universe, being completely dark matter (DM) dominated objects. For DM decay, local galaxy clusters yield the highest expected fluxes respect to other prime targets. For the DM annihilation scenario, clusters can provide fluxes comparable to the ones from dwarf spheroidal galaxies, as long as the DM interactions expected in their substructures are taken into account. In this talk, I will present the analysis of 12 years of Fermi-LAT data in the direction of 49 clusters. We modelled the expected substructure population in these objects, providing benchmark models to precisely quantify the uncertainty on their contribution to the annihilation flux. From the combined search, we found a signal of 2.5-3.0 sigma significance, potentially associated either with DM or hadronic induced emission produced in the intracluster region by cosmic rays colliding with gas and photon fields. Finally, looking into the future, I will also discuss the prospects of the coming Cherenkov Telescope Array Observatory (CTAO), to detect diffuse gamma-ray emission from the Perseus galaxy cluster. With its improvement in sensitivy of more than one order of magnitude with respect current IACTs, we derive the tightest constraints for DM decay scenarios in the TeV range reaching values of τDM ~1027 s, using a template fitting approach.

Indirect Dark Matter Detection / 214

ALPs searches with LST1

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Axions and axion-like particles (ALPs) are hypothetical particles predicted by several extensions of the Standard Model and are viable candidates for solving one of the ultimate mysteries of the Universe: dark matter. By exploring the spectra of astrophysical objects obtained from observations with the Large Size Telescope (LST1), we can search for signatures that such particles may leave. In particular, we look for oscillations in the spectra due to conversions between ALPs and very-high-energy (VHE) gamma rays. Our targets of interest include blazars Mrk 421, Mrk 501, BL Lac, and 1ES1959+650, extensively observed with LST1. In addition to the magnetic field in the relativistic jet, we also consider the impact of the Extragalactic Background Light in the intergalactic magnetic field and the magnetic field of the Milky Way for each source separately. For ALP masses in the neV range and magnetic field strengths of O(μG), these oscillations occur in the GeV energy range, making LST1 an optimal instrument for testing the ALP hypothesis in the VHE gamma-ray range. By exploring LST1 data of several blazars, our aim is to combine constraints from each source at the likelihood level, ultimately creating unique constraints on the ALP parameter space. These would be the first combined constraints obtained with a dataset from a group of blazar sources.

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Dark matter searches with the KM3NeT telescope

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KM3NeT is an underwater neutrino telescope located at two sites in the Mediterranean sea. Neutrinos are indirectly detected from the products of their interactions, which produce Cherenkov radiation. The ORCA detector, off the coast of Toulon, is designed to measure atmospheric neutrino oscillations, and the ARCA detector, off the coast of Sicily, is designed to search for neutrinos from astrophysical sources. In tandem with the primary scientific goals of both detectors, observations also allow to address other major questions, like the indirect search for dark matter.

Different cosmological observations require the introduction of dark matter as the dominant matter component of the Universe, while vaguely constraining its nature. Many models could explain its nature; from modified gravity theories, to different dark matter particle theories. WIMPs (Weakly Interacting Massive Particles) constitute one of the possible particle dark matter theories. They not only emerge naturally in many extensions of the Standard Model and have the correct cosmological properties, but they also have many and diverse implications for observable phenomena. The main observable for neutrino telescopes is the neutrino flux created either directly by the annihilation of dark matter particles, or by the decay or interaction of the products of their annihilation.

In this contribution, the capability of the KM3NeT neutrino telescope to contribute to the long-standing question of the nature of dark matter will be discussed. Limits and sensitivities to the WIMP dark matter thermally-averaged annihilation cross-section will be presented, searching for a neutrino signal created by dark matter annihilations. The search focuses on annihilation signals coming from the Galactic Centre and the Sun, where an over-density of dark matter is believed to be present, exploring dark matter masses in the range of 1 GeV to 100 TeV.

Indirect Dark Matter Detection / 238

Search of dark matter annihilation in stellar streams with the Fermi LAT

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Stellar streams whose progenitor is a dwarf galaxy (dG) are particularly interesting targets for dark matter (DM) searches, since dGs are thought to be highly DM-dominated systems. We expect these streams to have lost most of their DM content during the stretching process, yet a significant amount of DM should remain within their core. If the DM particles are Weakly Interacting Massive Particles (WIMPs), they could annihilate in the streams'core, producing a detectable gamma-ray signal. We analyze data from the Large Area Telescope on board the NASA Fermi satellite (Fermi LAT) to look for a potential WIMP annihilation signal from the direction of an optimized sample of streams. In the absence of a signal, we place the first constraints on the WIMP parameter space obtained from these objects for several annihilation channels.

In this talk, we summarize our current research on stellar streams as a novelty and complementary target for DM searches with gamma rays. A combined likelihood analysis of individual streams in our sample allows us to set constraints that are highly competitive to those obtained via other experiments and targets, shown the potentiality of these sources as possible probes of indirect DM detection.

Indirect Dark Matter Detection 2 / **228**

Search for gamma-ray spectral lines from dark-matter annihilation with the DAMPE satellite

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The annihilation of dark-matter particles may lead to the production of monochromatic gamma-ray emission. In this contribution, the search for spectral lines in the gamma-ray spectrum using eight years of data collected with the space-borne Dark Matter Particle Explorer is presented. To improve the event selection, two machine-learning algorithms were developed and proved to outperform all the standard methods. No line signal is found between 5 GeV and 1 TeV in several regions of interest. The constraint on the velocity-averaged cross-section of the neutralino annihilation is estimated for different dark-matter density profiles and compared with those obtained with the Fermi-LAT data.

Indirect Dark Matter Detection 2 / **217**

Indirect DM searches with Gravitational Waves

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LISA, the space-based gravitational wave detector which was recently adopted, is due to fly in the mid 2030s. An entire new frequency range will be opened up for discovering gravitational wave sources, including intermediate and extreme mass ratio black hole binaries which will remain in band for up to weeks, months or even years. This offers an exciting new avenue for fundamental physics discoveries because the environment of the binaries will have an effect on the gravitational waveform over this long period of time, and we will be able to measure the properties of the environments from the gravitational wave observations alone.
I will show that we can hope to measure the parameters of not only baryonic environments such

as accretion disks, but also the properties of dark matter spikes or clouds of scalar fields if they are present around the binaries. I will demonstrate that we can distinguish between different environments with a Bayesian model comparison approach and argue the importance of including environmental effects in waveform modelling. I will also address the various modelling and data analysis challenges that require development before LISA flies, and present ideas towards a realistic data analysis solution that relies on simulation based inference.

Indirect Dark Matter Detection 2 / 220

Search for Dark Matter with the GAPS balloon-borne experiment

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The search for Dark Matter (DM) in cosmic rays focuses on the particles generated in potential DM annihilation or decay. GAPS (General Antiparticle Spectrometer) is a balloon-borne experiment whose goal is to detect low-energy (E < 0.25 GeV/n) cosmic anti-nuclei for a deeper understanding of the physics beyond the Standard Model (e.g., dark matter annihilation or decay). In particular, antideuteron production from standard astrophysical processes is significantly suppressed in the low-energy range, allowing for an essentially background-free DM search. Moreover, GAPS will provide new precise measurements of cosmic antiprotons and search for cosmic antihelium-3. GAPS consists of 1000 lithium-drifted silicon wafers, forming the tracker, surrounded by a plastic scintillator time-of-flight system and its detection approach of antinuclei is based on the annihilation products and the uniquely characterized atomic X-rays from the decay of exotic atoms. Currently, GAPS is being integrated and calibrated in preparation for its first flight from Antarctica in late 2024. This talk will provide an overview of the GAPS mission and its scientific goals and a report on the current activities and status of the experiment.

IV Plenary / 275

UHE neutrino radio detection, status and perspective

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Ultra-high energy (UHE) neutrinos are an important missing piece of the rapidly growing field of multi-messenger astrophysics. They carry information about the nature of the sources of the highest energy cosmic rays and may also provide hints of any new physics at O(100 TeV). There are many strategies being pursued to detect UHE neutrinos, and the most promising ones utilize signatures at radio frequencies. I will review the status and latest results from experiments using different strategies to search for UHE astrophysical neutrinos. I will also discuss what we can expect for the future of the field.

IV Plenary / 327

Highlights from the IceCube Neutrino Observatory

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Over the past decade, the IceCube Neutrino Observatory, situated at the geographical South Pole, has opened a new window to observe and study the high-energy Universe. In 2013, IceCube discovered the first high-energy neutrino events confirming the existence of a diffuse flux of astrophysical neutrinos. The level of this neutrino flux implies a much richer hadronic activity in the non-thermal Universe than previously expected. In the recent years, IceCube has continue to break ground by identifying the first steady source emission of neutrinos, the starburst galaxy NGC1068, as well as capturing the neutrino emission from our own Milky Way. These fluxes, on the other hand, amount to a small percentage of the total diffuse astrophysical neutrino leaving much of this diffuse flux yet to be understood. In this presentation I will provide an overview of the latest results from the IceCube collaboration highlighting the ongoing efforts to characterize the diffuse neutrino flux, as well as to search and identify the first neutrino sources.

IV Plenary / 316

KM3NeT status and recent results

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The KM3NeT collaboration is building two underwater neutrino detectors in the Mediterranean: the ARCA (Astroparticle Research with Cosmics in the Abyss) and ORCA (Oscillation Research with Cosmics in the Abyss) detectors.
ARCA is located off the Sicilian coast of Capo Passero and aims to detect and identify astrophysical neutrino sources. The ORCA detector, located off the French coast of Toulon, has been optimized for the detection of atmospheric neutrinos in the GeV range, with the main aim of studying the fundamental properties of neutrinos. The two detectors, ARCA and ORCA, will allow the study of neutrino astronomy from MeV to a few hundreds of PeV. In the near future the KM3NeT detectors will play also an essential role in the multi-messenger astronomy.

The first detection units, which are strings containing the optical sensors, have already been deployed by the KM3NeT collaboration at the French and Italian sites. The two detectors are currently taking data in partial configurations and are already producing physics results, demonstrating the great potential of the two detectors for the coming years.

New and exciting results in both astrophysics and neutrino oscillation will be presented, together with the status of detector construction and future perspectives.

IV Plenary / 175

ANTARES recent results

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The ANTARES telescope was the first operational Neutrino Telescope in the Mediterranean Sea built at a depth of 2500 m offshore of Toulon, France, searching for astrophysical neutrinos in the TeV- PeV energy range. Debuting in May 2008, the ANTARES neutrino observatory served a 15-year mission

until February 2022. Nestled deep in the Mediterranean Sea, its exceptional angular resolution made it ideal for peering into the southern skies and unraveling the mysteries of cosmic neutrinos, particularly those originating within the Milky Way galaxy. The 15-year dataset collected by ANTARES continues to hold the potential for groundbreaking discoveries in high-energy cosmic neutrino sources and it is exploited carrying out several cosmic neutrino searches. These searches involve different key approaches, spanning from the searches for point-like neutrino sources and diffuse neutrino fluxes related to electromagnetic emission, to the investigation of promising source candidates listed in catalogs compiled by other experiments. In addition to its own searches, ANTARES has produced a wealth of scientific results through fruitful collaborations with the most important Collaborations in the world operating in the field of Neutrino Astronomy and Multimessenger Astronomy, leading to the enhance of ANTARES'discovery potential.
In this contribution the ANTARES'accomplishments and recent results in cosmic neutrino research are summarized.

Poster Session / 240

He isotopes spectra: a GALPROP-HelMod perspective

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The Alpha Magnetic Spectrometer-02 (AMS-02) has provided high-quality measurements of cosmic-ray (CR) spectra both for nuclei and for isotopes. The interpretation of such high-quality data is challenging because of the temporal variations in solar activity, impacting CR intensity assessments. Using the GALPROP-HelMod joint effort we created a unique analysis framework combining physical interpretation in terms of CR galaxy source and propagation (performed by GALPROP), with a comprehensive description of solar modulation effect on CR intensities (addressed by HelMod-4). In this work, we present our latest results. Alongside the main improvements introduced by the last version of HelMod-4, we investigated the origin and features of He isotopes fluxes and the 3He/4He flux ratio measured by AMS-02. In fact, an observed excess of 3He at higher energies might suggest the existence of primary 3He or indicate alterations in propagation parameters across the vast Galactic volume measured by the 3He/4He ratio.

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Cosmic-Ray Propagation Scenarios in the era of AMS-02 and Voyager Data

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Cosmic-ray measurements inform on cosmic-ray origin and propagation in the Galaxy. Based on AMS-02 and Voyager cosmic-ray measurements, we have tested and revised scenarios of cosmic-ray propagation.

Some previously disfavored scenarios are now reconsidered.
Resulting spectra of the main species, diffusion coefficients, secondary antiprotons and positrons for each scenario are presented and discussed.
The talk is based on our recent work: Silver & Orlando (2024) ApJ 963, 111

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SMALL THINKS BIG: A JOURNEY WITH TRANSFORMERS. GENERALIZATION IN KM3NeT/ORCA FOR NEUTRINO EVENT RECONSTRUCTION

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KM3NeT is a new research infrastructure housing the next generation of neutrino telescopes in the Mediterranean deep sea. This facility comprises two detectors: KM3NeT/ARCA and KM3NeT/ORCA, consisting of vertical arranged detection units, 230 and 115, respectively, each equiped with 18 digital optical modules. The photomultipliers within each optical module detect Cherenkov light emitted by charged particles propagating in the seawater. KM3NeT/ARCA is optimized for the search of astrophysiscal neutrino sources in the range of TeV to PeV; whereas KM3NeT/ORCA is used to study the neutrino oscillation phenomena in the GeV energy range.

The current size of the detector limits the reconstruction of neutrino events in the telescope. This study demonstrates the efficacy of transformer models as large representation models and their ability to retain valuable information from the full detector when evaluating data from various smaller KM3NeT/ORCA configurations. Beginning with models trained on simulations of the complete KM3NeT/ORCA detector, composed by 115 detection units, fine-tuning on smaller configurations yields remarkable improvements over models trained from scratch on these configurations with very limited data. These comparisons across different setups, as well as the final configuration, also enable an estimation of the detector sensitivity as it grows in size.

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Stochasticity of Galactic cosmic rays

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Supernova remnants have long been considered as the most potential class of sources for Galactic cosmic rays. The point-like nature of these objects could potentially lead to strong variations in the distribution of cosmic rays, especially in the MeV and PeV energy range (the two energy frontiers of Galactic cosmic rays). Such variations mean that the local cosmic-ray spectra may only be predicted only in a stochastic sense. We will discuss how this stochastic effect might help to better explain certain features in the local spectra observed by Voyager (for MeV cosmic rays) and by ARGO, KASCADE, IceCube and IceTop (for PeV cosmic rays and beyond).

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The Effects of Atmospheric Parameters on Cosmic Muon Measurements Using the Novel Portable Detector DECOS2

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The European Partnership on Metrology (EPM) joint research project BIOSPHERE aims to develop the necessary instrumentation, methods, and measurement infrastructure to assess how the increasing ionization of the atmosphere, caused by extraterrestrial radiation fields (cosmic rays and solar UV radiation) and amplified by anthropogenic emissions, affects the human and ecological health of our planet. Both electron precipitations of extraterrestrial origin and energetic bursts of protons released from the sun during solar flares or coronal mass ejections have the potential to increase the stratosphere and mesosphere ionization. The variations in atmospheric ionization can significantly affect the biosphere by depleting the ozone layer. Here, cosmic rays trigger electron-induced reactions that lead to formation of free radicals in the atmosphere (NOx, HOx and halogen radicals) which, subsequently, act as catalysts that initiate the breakdown of ozone molecules.
To explore the effects of cosmic rays in the ionization of the atmosphere, the Secondary Cosmic Rays (SCRs) measured on the ground need to be correlated with the flux of incoming parent Primary Cosmic Rays (PCRs) and atmospheric parameters. Both secondary cosmic muon and neutron rates at the Earth's surface vary with atmospheric conditions, particularly ground-level pressure and the atmospheric temperature profile. The temperature effect on muons is complex, influenced by air distribution at different altitudes, and involves two contributions: the positive correlation due to secondary particle interactions and the negative correlation due to muon decay. Muons primarily result from the decay of charged pions and kaons. Increased temperatures reduce atmospheric density, decreasing interaction probability and leading to more decays of pions and kaons, thereby producing more muons. Due to their high penetration capability, muons are less affected by interaction probability changes, resulting in increased surface rates with higher temperatures (positive effect). Conversely, as the atmosphere expands with increased temperature, muons must travel further before decaying, contributing to the negative effect.
The link between SCR on the ground and PCR needs to be determined using high-quality SCR data, incoming PCR fluxes and atmospheric profile parameters. All this should be combined with thorough Monte Carlo simulations to disentangle the interaction between SCR and air masses. In the framework of BIOSPHERE project, a cutting-edge muon detector (DECOS2) was used in tandem with a Lidar for atmospheric profiling, providing a comprehensive set of measurements that allow to explore the effect of atmospheric parameters (pressure and temperature) on SCR propagation. This talk will present data gathered from the DECOS2 muon detector during BIOSPHERE campaigns, emphasizing the methodology and processing tools used to correct SCR flux for atmospheric factors. Integrating diverse datasets, including aerosol and temperature data, enhances our understanding of how atmospheric changes influence muons and other cosmic ray components.

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Simulation-Based Analysis of Cosmic Muon Flux in Tunnels at EJUST

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Cosmic Ray Muons are highly energetic and can be used in different applications such as muography to detect voids and cracks within underground structures. In this work, PHITS based Analytical Radiation Model in the Atmosphere (PARMA) is used to generate cosmic ray muons at Egypt-Japan University for Science and Technology (E-JUST) location. The tracks of these muons through the layers of concrete in the building are simulated with PHITS (Particle and Heavy Ion Transport code System) to calculate the energy of the muons that reach the tunnel in E-JUST, where we will place the scintillator detector.

The flux of cosmic ray Muons is approximately 160 muons s-1·m-2 at sea level., However, this flux decreases by decreasing the altitude. This factor should be considered when simulating the muons for experiments held underground.
The interaction of muons with building materials, materials'thickness, and the altitude with respect to the sea level are considered as well. The particles tracks, the flux and the energy spectrum of the attenuated muons are also presented.

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Enhancement of Beta Measurements Accuracy in AMS-02 for Isotopes Analysis

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The Alpha Magnetic Spectrometer (AMS-02) is a precision particle physics detector installed on the International Space Station (ISS). It provides independent rigidity and beta measurements of cosmic particles with exceptional accuracy. While the rigidity measurements from AMS have been extensively studied, understanding the accuracy of beta measurements is crucial for isotopes analysis. This work focuses on studying the beta measurement accuracy from the AMS Ring Imaging Cherenkov Detector (RICH). The study investigates the dependencies of beta accuracy on cosmic nuclei charge, the fraction of reflected Cherenkov photons, time, and spatial positions. Corrections are applied to RICH beta measurements based on these results, ensuring a reliable template of mass for determining isotopic fractions. These methodologies guarantee the precision of the measurements of isotopes fluxes. The details of the methods are illustrated in this work.

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QC and characterization of the SMART board for the ADAPT hodoscope

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The "Advanced Particle astrophysics Telescope" (APT) is a mission
concept for a future very large area space-based MeV-TeV gamma-ray
observatory. A small-scale prototype, the Antarctic Demonstrator for APT
(ADAPT), is currently being designed and built to fly on a balloon.
Among its subdetectors is a hodoscope that will allow tracking and localization of charged particle trajectories coming through the detector stack. The hodoscope consists of four layers of interleaved scintillating fibers coupled to Silicon Photomultipliers (SiPMs).
Our work is focused on the characterization and study of a multichannel electronics to readout the hodoscope SiPM signals. Specifically, the SMART (SiPM Multichannel ASIC for high Resolution Cherenkov Telescopes) ASIC will be employed. It is characterized by high compactness and low costs, side by side with a good level of integration of the electronics, and its main goal is the amplification of signals coming from SiPMs.
In this contribution we will present the quality control and characterization results of the performance of the SMART readout board for the Hodoscope subsystem of ADAPT, that will allow the proper localization of the trajectory of the particles coming through the hodoscopes of the ADAPT detector stack, by employing of the SMART ASIC.

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Dark boson search on accelerators and in astrophysics

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This presentation is dedicated to my most recent results in the dark sector phenomenology. The anomalous nuclear decays observed at ATOMKI, Hungary lead to the existence of a dark vector meson. It is shown that the mass of the dark meson should be around 17 MeV and the interaction constant ~ 10−4e. Those parameters cannot introduce the required correction to the muon magnetic moment. We present a model based on tensor interactions with vector mesons which has the capability of explaining both effects. We show that the suggested mesons are detectable on PADME at LNF. The Lagrangian is then extended to include also a pseudo-scalar particle (ALP) and effects on the equation of state of a neutron star are derived.

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On the origin of cosmic rays of extreme energy

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The origin of the highest-energy cosmic rays continues to puzzle scientists. The data collected over the past 20 years by the Pierre Auger Observatory and the Telescope Array indicate the presence of anisotropy in their arrival directions, suggesting extragalactic astrophysical sources. However, the nature of these sources remains unsolved. This study aims to assess two potential models of extragalactic candidate sources, namely starburst galaxies (SBGs) and active galactic nuclei (AGNs), by analyzing the propagation of ultra-high-energy cosmic rays in the Galactic and extragalactic media. The simulations are conducted with the CRPropa 3 software framework, considering all pertinent particle interactions and magnetic deviations. The results show that nearby SBGs, and to a lesser extent, nearby AGNs, may explain some of the observed medium-scale anisotropies. Nevertheless,

none of the scenarios can account for the large-scale anisotropy reported by the Pierre Auger Observatory.

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Ultra-high-energy cosmic rays: Current understanding and future prospects

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In point of fact, ultra-high-energy cosmic rays (UHECRs) represent the pinnacle of particle acceleration in the universe, with energies exceeding 1018 eV - over a million times higher than the most powerful human-made particle accelerators. However, their very existence defies our current understanding of cosmic particle accelerators and challenges the limits of nuclear and particle physics. On the other hand, this review explores the profound mysteries surrounding these incredibly rare yet immensely energetic particles bombarding Earth from all directions.
More to the point, despite decades of dedicated observations, the origins and acceleration mechanisms of UHECRs remain elusive. In virtue of which, we synthesize the latest findings from ground-based observatories like the Pierre Auger Observatory and Telescope Array, which have mapped the energy spectrum, mass composition, and anisotropic arrival directions of these cosmic messengers. In this respect, potential astrophysical source candidates, including active galactic nuclei, starburst galaxies, gamma-ray bursts, and more exotic scenarios like cosmic defects, are critically examined. Above and beyond, key challenges encompass the discrimination between galactic and extragalactic UHECR populations, the effects of interactions with cosmic backgrounds, and the quest to increase statistics at the highest energies. In addition, upcoming upgrades and next-generation detectors promise unprecedented insights into these astroparticle physics enigmas with far-reaching implications for fundamental physics and our comprehension of the high-energy universe, as well.

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Cosmic-Ray Propagation Models Elucidate the Prospects for Antinuclei Detection

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Tentative observations of cosmic-ray antihelium by the AMS-02 collaboration have re-energized the quest to use antinuclei to search for physics beyond the standard model. However, our transition to a data-driven era requires more accurate models of the expected astrophysical antinuclei fluxes. We use a state-of-the-art cosmic-ray propagation model, fit to high-precision antiproton and cosmic-ray nuclei (B, Be, Li) data, to constrain the antinuclei flux from both astrophysical and dark matter annihilation models. We show that astro-physical sources are capable of producing O(1) antideuteron events and O(0.1) antihelium-3 events over 15 years of AMS-02 observations. Standard dark matter models could potentially produce higher levels of these antinuclei, but showing a different energy-dependence. Given the uncertainties in these models, dark matter annihilation is still the most promising candidate to explain preliminary AMS-02 results. Meanwhile, any robust detection

of antihelium-4 events would require more novel dark matter model building or a new astrophisical production mechanism.

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Core collaApse Supernovae parameTers estimatOR: a novel software for data analysis

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Title:

Core collaApse Supernovae parameTers estimatOR: a novel software for data analysis

Abstract:

The future of time-domain optical astronomy relies on the development of techniques and software capable of handling a rising amount of data and gradually complementing, or replacing if necessary, real observations. Next generation's surveys, like the Large Synoptic Survey Telescope (LSST), will open the door to the new era of optical astrophysics, creating, at the same time, a deficiency in spectroscopic data necessary to confirm the nature of each event and to fully recover the parametric space. In this framework, we developed Core collApse Supernovae parameTers estimatOR (CASTOR), a novel software for data analysis. CASTOR combines Gaussian Process and other Machine Learning techniques to build time-series templates of synthetic spectra and to estimate parameters for core collapse supernovae for which only multi-band photometry is available. Techniques to build templates are fully data driven and non-parametric through empirical and robust models, and rely on the direct comparison with a training set of 111 core collapse supernovae from the literature. Furthermore, CASTOR employs the real photometric data and the reconstructed synthetic spectra of an event to estimate parameters that belong to the supernova ejecta, to the stellar progenitor and to the event itself, in a rapid and user-friendly flow. In this contribution we will present the development of CASTOR and a direct demonstration of its usage, as presented in Simongini et al. 2024 (submitted to MNRAS). We will also discuss the possible role of CASTOR in a multimessenger and multiwavelength context.

Contributors:

Andrea Simongini; Fabio Ragosta; Silvia Piranomonte; Irene Di Palma

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The AugerPrime Radio Detector: Enhancing the Sensitivity to UHE Cosmic Rays

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The ongoing AugerPrime upgrade at the Pierre Auger Observatory significantly enhances the sensitivity and precision for measuring ultra-high-energy (UHE) cosmic rays beyond the baseline design. A crucial element of this upgrade is the installation of the Radio Detector (RD), comprising loop antennas mounted on top of each of the 1660 water-Cherenkov detectors (WCD). These dual-polarized antennas are sensitive to inclined air showers and will enhance the Observatory's sky coverage and

exposure. Particularly notable is the RD's high sensitivity to the electromagnetic component of air showers, providing new data for reconstructing the primary mass, energy, and arrival direction of cosmic rays. It will complement the WCD's sensitivity to muons, helping to yield a measurement of the muon number and its fluctuations with high precision. The symbiosis of both systems opens new possibilities for detecting rare primary particles, such as UHE photons and neutrinos, with a high identification probability.
In this presentation, we discuss the design, current deployment status and measurements of the RD. With increasing number of equipped stations, we showcase statistics and reconstructions of detected events. We provide insights into calibration measures as well as cross-validations with the other detector components at the Pierre Auger Observatory. Finally, we highlight the potential of the Observatory with the inclusion of radio measurements and RD triggering, particularly for detecting air showers with weak particle footprints.

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CTAO sensitivity to axion-like particles

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Axion-like particles (ALPs) are a common feature in several extensions of the Standard Model, arising, for example, as a solution to the strong CP problem in quantum chromodynamics, or as a prediction of string theories. A significant property for the experimental detection of ALPs is their coupling to photons, which enables ALP-photon conversions in ambient magnetic fields.

In particular, gamma-ray photons could convert into ALPs in the magnetic fields of distant objects and then reconvert in the Milky Way's magnetic field. By eluding absorption by the extragalactic background light (EBL), such a mechanism could produce a hardening in the gamma-ray spectra of these sources. I investigate the capability of the Cherenkov Telescope Array Observatory (CTAO) to detect signals of ALP-photon conversions in the very-high-energy spectra of known blazars at energies above 10 TeV, comparing different magnetic field scenarios.

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SS 433 surprising PeV-atron traces in very recent gamma records

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The high energy cosmic rays HECR, at Pevatron energy are difficult to be correlated to their source, because of the galactic magnetic fields bending and the loss of their original directions. However there are several imprint in radio, X, gamma energies offering some probe of HECR ejections. The well known binary system, SS433, is ejecting a twin jet precessing in spiral shapes. Moreover recent and surprising TeV gamma signal arouse without a clear understanding. We describe it within a model based on the possible PeV ejection of the SS433 at its early explosive birth, thousands of years ago. The model is based on well known photo-nuclear interactions and on the observed data. Some consequences on PeV up to EeV CR energy, are discussed.

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Particle identification in high-granularity 3D calorimeters for space-borne applications

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CCSNe detection perspectives with Einstein Telescope

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Core collapse supernovae are the most energetic explosions in the modern
Universe and, because of their properties, they are considered a potential source of detectable gravitational waveforms for long time. The main obstacles to their detection are the weakness of the signal and its complexity, which cannot be modelled, making almost impossible applying matched filter techniques as the ones used for detecting compact binary coalescences. While the first obstacle will be probably overcame by next generation gravitational wave detectors, the second one can be faced by adopting machine learning techniques. In this contribution, a novel method based on a classification procedure of the time-frequency images using a convolutional neural network will be described, showing the CCSN detection capability of the next generation graitational wave detectors, with a focus on Einstein Telescope.

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Characterizatio of light signal in the Liquid Argon TPC of the ReD experiment

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The existence of Dark Matter as a thermal remnant of the Big Bang could be proven observing the interaction of weakly interacting massive particles (WIMPs) with matter. To search for dark matter, we use argon as a target in a two-phase Time Projection Chamber (TPC). This is a demonstrated technology and has generated impressive results with the DarkSide-50 detector. The primary advantages of a TPC are the reduction in background by the detection of primary scintillation light and a delayed ionization signal and the excellent sensitivity of liquid argon to WIMP signals. As part of the Global Argon Dark Matter Collaboration, we are continuing to develop liquid argon TPCs.
The Recoil Directionality (ReD) project has been designed to characterize the response of a liquid Argon (LAr) TPC to neutron-induced nuclear recoils and to measure the charge yield for low-energy recoils. In particular the ReD project aims to cover the low-energy range of 2-5 keV, which is of interest for low-mass WIMP searches, and where the only available detection channel is the ionization one.

In ReD experiment the TPC was irradiated with neutrons from a 252Cf fission source and Nuclear Recoils (NR) were produced in the TPC via elastic scattering, finally using the two body kinematics approach the desired energy range is selected. The data taking campaign was conducted in Catania in 2023, the analysis is ongoing to finalize the measures of the ionization yield improve the models to be employed by the next generation of experiments dedicated to the light dark matter search.
The new project ReD+ aims to improve the results obtained in the predecessor project ReD, infact will extend the coverage of the measurements down to 0.4 keV, by using a new optimized TPC and a deuterium-deuterium neutron generator.

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DarkSide-20k Veto photon-detector units: construction and characterization

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DarkSide-20k, a global direct dark matter search experiment, is located at the Gran Sasso National Laboratory (LNGS), Italy. It is designed to reach a total exposure of 200 tonne-years nearly free from instrumental backgrounds. The core of the detector is a dual-phase Time Projection Chamber (TPC) containing 50 tonnes of underground liquid argon (UAr) with low levels of cosmogenic ^{39}Ar isotope. Surrounding the TPC walls is a layer of polymethylmethacrylate (PMMA), acting as a neutron veto. The neutron veto is equipped with large-area cryogenic Silicon Photomultiplier (SiPM) array detectors, positioned along the walls of the TPC on the outer side. SiPMs are arranged in a compact layout to reduce the amount of material used for the Printed Circuit Board (PCB), cables and connectors which together form the Veto PhotoDetection Units (vPDUs). A vPDU consists of SiPMs, along with front-end electronics and a motherboard, which distributes voltage and control signals and electrical signal transmission.

This talk focuses on the production of the first vPDUs, emphasising the rigorous QA/QC procedures, and the final characterisation of the first completed prototypes. Extensive testing in liquid nitrogen baths has been conducted on the vPDUs, aiming to assign a "quality passport" to ensure optimal performance and reliability in the DarkSide-20k experiment."

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Latest results and prospect on searching for fractionally charged particles with the DAMPE experiment

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The existence of fractionally charged particles (FCP) is foreseen in extensions of or beyond the Standard Model of particle physics. The FCP is commonly assumed to be a kind of heavy lepton-like particle which is searched in cosmic-rays by underground and space experiments like DAMPE. The DArk Matter Particle Explorer (DAMPE) is a space telescope launched on December 17th, 2015 and taking data since then. One of the main goals of DAMPE is the measurement of galactic cosmic rays with energy up to several tens of TeV and beyond. In this work, we will introduce the results of searching for 2/3e lepton-like FCP in space obtained from the analysis of on-orbit data collected

by the DAMPE detector. No positive evidence for such particle is observed in five years of observation, thus, we drive an FCP flux upper limit of $6.2\times10^{-10}\mathrm{cm}^{-2}\mathrm{sr}^{-1}\mathrm{s}^{-1}$ with kinetic energy above ~GeV. Our result refreshes the record in sensitivity among similar-type experiments by three orders of magnitude, which also more stringently restricts the conditions for the existence of FCP in primary cosmic rays. We will also introduce the preliminary work on the searches of a light-mass FCP.

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Precise Solutions to Non-Linear Partial Differential Equations of Einstein Tensor and Ricci Flow with its geometrical applications to Neural Networks and Neural Computing

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We present an exact solution of General Theory of Relativity, wherein rotational tensor and strain-deformation tensor are found embedded in Einstein curvature tensor. It turns out that these tensors encapsulate Dirac matrices, as concealed modules within Christoffel symbols of second kind. Additionally, the partial differentiation of these Christoffel symbols discovers three major underlying components of Ricci curvature tensor: (a) Dirac equations employing Gamma matrices as their wave functions; (b) d'Alembert operators for elucidating quantum gravitational waves; and (c) Hessian matrix or Laplacian operators for evaluating concavity and its geometric applications to neural networks and neural computing. Integration of these components to geometric analysis of Ricci flow leads to a unified formulation of all the three geometrical flows (spherical scalar curvature, "R>0" , flat - zero scalar curvature, "R=0", and hyperbolic scalar curvature, "R<0"), offering exact solutions to mathematical physics problems such as: (i) Singularity and dark energy; (ii) Ricci flow; (iii) Einstein field equations - Ricci curvature scalar; (iv) Completeness of geodesic equations; (v) Coordinate transformation of quantum fields as tensor fields; (vi) Resolution of the flatness problem involving accelerating-expanding universe; and (vii) Reformulation of Christoffel symbols of first and second kinds, under the principles of Ricci theorem. Thus, this paper concludes the complete theoretical framework of Quantum Gravitation and its cutting-edge application to the optimisation of reinforcement learning for Artificial Neural Machines.

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X-ray Emission as a Probe of Cosmic Ray Diffusion near Galactic γ-ray Sources

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Galactic γ-ray extension sources exhibit complex emission patterns, potentially dominated by either leptonic or hadronic processes. Pulsar halos, known as TeV halos, are extended γ-ray emissions around middle-aged pulsars. While the TeV emission is attributed to inverse Compton scattering, the transport mechanism within the halo remains debated.

This study explores the multiwavelength emissions from pulsar halos under various diffusion models. We predict that synchrotron radiation from escaping electrons can form an X-ray halo around the pulsar, showing distinct surface brightness profiles across different models. We advocate for sensitive

X-ray detectors with wide fields of view (e.g., eROSITA/EP) to probe the particle transport mechanism, which is helpful in understanding interstellar turbulence and pulsar halo formation.

Additionally, we analyze the morphology of multiwavelength emissions from diffusive protons, highlighting how synchrotron radiation from secondary electrons could contribute to the X-ray background for γ-ray hadronic sources. Our findings suggest that spatial morphology in X-ray radiation could aid in distinguishing between leptonic and hadronic origins for sources with ambiguous energy spectra.

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A robust determination of satellite dwarf galaxy J-Factors from DESI observations

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ABSTRACT

Dwarf satellite galaxies orbiting the Milky Way are thought to have significantly larger amounts of mass than the ones derived from their observed light. This 'dark matter' (DM) is not only in these objects but it is present at all scales, accounting for more than 80% of the total mass in the Universe. In the case of dwarf satellite galaxies, current DM density profile models usually exhibit large uncertainties due to the limited availability and precision of kinematics data used to constrain them. This, in turn, implies large uncertainties in the prediction of potential DM-induced signals expected at Earth, according to the most accepted particle physics scenarios.
The main goal of this work is to calculate accurate DM density profiles for dwarf galaxies using the CLUMPY open-source package, which uses both MCMC and the standard Jeans equations to derive underlying DM distributions. In addition to previous data sets, we will use stellar spectroscopic data from DESI, an ongoing optical survey that is obtaining spectroscopic data with unprecedented precision. By improving our knowledge of the actual DM distribution in these objects, it will be also possible to obtain a more precise determination of their DM-induced gamma-ray fluxes. The latter will have important implications in the derivation of robust limits to the DM particle properties.

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Overview of Machine Learning Applications at the Pierre Auger Observatory

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Running since 2004, the Pierre Auger Observatory remains the largest detector for extensive air showers induced by ultra-high-energy cosmic rays. The complex spatio-temporal information from shower footprints, comprised of particle arrival times and traces measured by water-Cherenkov detectors, is challenging to analyse with traditional methods but well-suited for machine learning based analyses. In this contribution, we provide an overview of the ML applications developed to leverage the high event statistics acquired by the Observatory. The deep learning methods that complement traditional analyses and introduce novel techniques to determine high-level shower observables are presented here.

One notable application is the prediction of the depth of shower maximum, $X_{\rm max}$, allowing for high-statistics analysis of mass composition by studying the observable distribution as a function of energy. In the context of the energy spectrum, a neural network approach for energy reconstruction has demonstrated potential in reducing composition biases in the energy estimator. Aligned with AugerPrime, the ongoing upgrade of the Observatory, the impact of enhanced electronics and scintillation detectors was explored via simulations. Both transformers and convolutional networks are promising for the reconstruction of mass-composition sensitive observables like $X_{\rm max}$ and the muon number, demonstrating the benefits of the Observatory's upgrade.

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Navigating from raw data to high data quality in the KM3NeT experiment: advantages and challenges

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KM3NeT is a water Cherenkov neutrino telescope foreseeing two detection sites in the Mediterranean Sea: ORCA and ARCA, both sharing the same technology. ORCA, under construction offshore Toulon (France), aims at clarifying the neutrino mass ordering exploiting the oscillation of atmospheric neutrinos in the energy range of a few GeV to 100 GeV traversing the Earth. ARCA, under construction offshore CapoPassero (Sicily, Italy), is instead optimised for detecting neutrinos in the TeV to PeV scale and focuses on neutrino astronomy searches.

KM3NeT's advantage and challenge is its modular structure that allows for collecting physics data also during the construction phase. In this talk, a description of the data taking, processing, and quality will be given. The focus will be on the so-called *run-by-run* approach that was used to process data for several detector configurations, from 2020 onwards. This method guarantees the optimization of Monte Carlo simulations, the best control of data-taking conditions, and maximum efficiency in the data processing of high-quality data.

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An Effective and Predictive Model for the Long-Term Variations of Cosmic Rays in the Heliosphere

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Investigating the relationship between cosmic rays and solar activity is of paramount importance in astroparticle and space physics. On one hand, it brings a deeper understanding of the physical mechanisms governing the transport of cosmic rays inside the heliosphere. On the other hand, it plays a crucial role in evaluating radiation exposure and associated risks in space missions. Here, we present our endeavors to establish a new effective and predictive model of solar modulation. Our model incorporates fundamental physics processes of particle transport such as diffusion, drift, convection, and adiabatic cooling to compute the energy spectrum and temporal evolution of cosmic radiation in the inner heliosphere. Calibration and validation of our model are performed using the most recent cosmic-ray data from space-based detectors, such as AMS-02 on the International Space Station, along with multichannel observations of solar activity and interplanetary parameters. This comprehensive model not only demonstrates good results in reproducing observations but also showcases its potential in space radiation monitoring and forecasting. By providing valuable insights for evaluating exposure in future space missions across different regions in the heliosphere, our model is under continuous evolution as new data, such as from AMS-02, become available. By providing a robust framework for understanding cosmic ray variations and their implications for space travel, our research contributes to advancing the safety and effectiveness of space exploration endeavors.

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The lightcurves package for times series analysis

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The lightcurves package is a python module that is readily available via PyPi. It was developed to analyze variability in Fermi-LAT light curves of blazars but the tools can be applied to any time series. The functionalities include, for instance, the Bayesian block algorithm, the HOP algorithm, methods to study temporal correlation and analysis methods for the power density spectrum. Moreover, the package contains functions that interpret the time series to be a stochastic process (a Ornstein Uhlenbeck process) and determine the best parameters do describe it as such. In this poster I will present the light curves package and its application to Fermi-LAT light curves.

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Looking at the Central Molecular Zone and Cygnus region with the KM3NeT/ARCA telescope

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In this contribution, a search for neutrino emission from the Central
Molecular Zone (CMZ) and the Cygnus region is presented exploiting
KM3NeT/ARCA capabilities.
The CMZ extends for few hundred parsecs around the Galactic centre,
containing the massive molecular clouds Sgr A, Sgr B, and Sgr C.
On the other hand, the Cygnus region is a massive star-forming region
of few hundred parsecs in the constellation of Cygnus. It host a high gas density too and a rich

stellar population. The high energy emission from these regions is expected to be dominated by the interactions of cosmic-rays with the molecular gas, which translate into granted gamma-rays and neutrinos production.
Here we explored the sensitivity level of the actual KM3NeT/ARCA geom-
etry and we set upper limits for both regions. Moreover, we also explored the case of the full KM3NeT/ARCA detector geometry.

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"Search for Time-Dependent Cosmic Neutrino Emission with ANTARES and KM3NeT"

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Neutrino astronomy has achieved notable success in the last decade, thanks to the observation of the first
probable cosmic neutrino sources. However, a clear identification remains elusive. Active galactic nuclei have
been proposed as potential extra-galactic sources for neutrinos and high-energy cosmic rays. In this contribution, we present an analysis that focuses on the detection of cosmic neutrino sources correlated with
gamma-ray flares from extra-galactic sources, in particular blazars. Constraining the neutrino emission to a
given time period drastically reduces the expected background lowering the threshold for a significant
detection compared to time-integrated searches. We present a search based on the hypothesis that neutrino
emission happens simultaneously with gamma-ray emission in blazar flares. In particular, we target sources
detected by Fermi-LAT, and use 15 years of data from ANTARES and 2 years from the KM3NeT/ARCA neutrino telescopes on its partial configurations.

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The extragalactic sky seen by eROSITA

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GRBs in the Swift and Fermi era

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The era of the Swift and Fermi missions has marked a significant advance in the study of Gamma-Ray Bursts (GRBs). Swift's rapid detection and multi-wavelength observation capabilities have uncovered diverse GRB populations, including high-redshift bursts, and revealed extended emissions and X-ray flares, thus improving our knowledge of the environments surrounding GRBs.
Fermi's Large Area Telescope (LAT) and Gamma-ray Burst Monitor (GBM) have expanded this understanding by detecting high-energy gamma-ray emission, allowing for detailed spectral analysis and challenging existing theoretical models. Furthermore, with its nearly all-sky coverage capability and its broad range of gamma-ray energies, Fermi GBM proved to be the most prolific GRB detector ever.

In this contribution I will give a broad overview of GRB observations over the past 20 years, focusing on several joint GRB observations which have highlighted the key synergy between these missions, such as GRB 080916C, GRB 090510, GRB 130427A, and the landmark detection of GRB 170817A associated with gravitational waves, confirming neutron star mergers as short GRB sources. Also the detection and study of very high-energy (VHE) emission from bursts like GRB 180720B, GRB 190114C, and GRB 190829A have been significantly enhanced by the combined efforts of both observatories. Together, Swift and Fermi play a fundamental role in multi-messenger astronomy, enricheing our understanding of GRB science and continuosly driving new discoveries.

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AGILE observations of the ultra-luminous GRB 221009A

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The ultra-luminous, long-duration transient event GRB 221009A was detected by several observatories - as the most luminous gamma-ray burst ever observed - from radio to VHE gamma rays, up to tens of TeV.
AGILE detected an extraordinary incoming flux of hard X-ray and high-energy gamma-ray photons during this unprecedented event. The high-energy emission (from tens of keV up to GeV energies) has been recorded by the AGILE detectors with an almost-continuous time coverage, monitoring the transition between the prompt and the afterglow phase, up to ~20 ks after the onset of the GRB.
AGILE time-resolved spectra and light curves are presented in a multi-frequency context, focused on the observed high-energy component of this intense GRB. The AGILE simultaneous hard-X/gamma-ray observations during the key phases of the burst will be crucial to give robust constraints to the physical evolution of the GRB's high-energy emission.

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Multi-class classification of unassociated Fermi LAT sources with machine learning and dataset shifts

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About one third of Fermi-LAT sources are unassociated. In this talk, I will present recent developments in the multi-class classification of Fermi-LAT sources using machine learning with the goal of probabilistic classification of the unassociated sources. A particular attention will be paid to the fact that the distributions of associated and unassociated sources are different as a function of most source parameters, such as the spectral index, spectral curvature, galactic latitude, flux, or variability. On the one hand, such differences can be caused by association bias as it is typically easier to determine associations for bright high-latitude sources with hard spectra. Alternatively, these differences may hint at a possible existence of a new class of gamma-ray sources. We will discuss this problem in the framework of dataset shifts in machine learning.

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Open-Source Radiative Modeling Tools for Extragalactic VHE Gamma-ray Sources

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In the first part of this review, I will present the current state of open-source radiative modelling tools for the multiwavelength emission from extragalactic relativistic jets. I will highlight the features and the limitations of these tools related to the implementation of the different physical processes, and I will discuss the implications in terms of reproducibility, interoperability, maintainability, and overlapping, outlining the advisable routes for the near future. In the second part, I will focus on some of the most intriguing open questions in the understanding of the physics of extragalactic jets, in connection to their VHE spectral emission and optical/X-ray polarization, and I will discuss the requirements, for the development of the current tools, to advance our understanding.

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The roadmap to CTAO AGN Science: Early results on AGNs of LST-1

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After nearly two decades of operation, the current generation of Imaging Atmospheric Cherenkov Telescopes (IACTs) - consisting of MAGIC, VERITAS, and H.E.S.S. - has identified approximately 100 very-high-energy (VHE, E > 100GeV) gamma-ray sources beyond our Galaxy, most of which are Active Galactic Nuclei (AGNs), reaching up to a redshift of z=1. The forthcoming Cherenkov Telescope Array Observatory (CTAO), with its two locations in both the Northern and Southern Hemispheres, promises to revolutionise the field. CTAO will significantly expand the observable Universe at VHE, increasing the number of detectable sources, and enhancing the quality of data collected for population studies, highly detailed spectral and time-series analyses of specific targets.

In this talk, I will present the initial extragalactic science results from the Large-Sized Telescope prototype (LST-1) of the CTAO, a 23-meter diameter class telescope that has been observing regularly since November 2019 and is optimised to detect gamma rays with energies of 20-150 GeV. Additionally, I will provide a preview of the advancements expected with the completion of the remaining three LSTs at the CTAO-North site.

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Insights into the high-energy emission of blazars from the first combined VHE and X-ray polarization measurements

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Blazars have been studied for more than half a century, but they are still far from being understood. The advent of new instrumentation brings new perspectives that are starting to help out unravelling the insights of these powerful cosmic accelerators. One of the novel facilities is the IXPE satellite, that reported the first measurement of X-ray polarization in blazars in the year 2022, thus opening a new window for testing acceleration and radiation models. In the conference, I will present results from extensive multi-instrument observations of two bright and nearby blazars, Mrk421 and Mrk501, that include, for the first time, data from simultaneous observations performed IXPE and with MAGIC. The IXPE observations spanned over months, and were simultaneous to the observations performed with other instruments (including XMM, NuSTAR and MAGIC), which permitted variability and correlation studies on timescales ranging from weeks down to hours. Building on the IXPE results, that indicate an energy-stratified jet, we employ a multiple-zone model to describe the radio-to-VHE spectrum, and to explain the multi-wavelength polarization trends observed in the data.

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Multi-messenger signals from Seyfert galaxies

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Active galactic nuclei (AGN) can launch and sustain powerful wide-angle winds which can unbind the gas from the host galaxies, offering a plausible physical origin for the black hole-galaxy co-evolution.

Propagating through the galaxy, AGN-driven winds can interact with the interstellar medium creating strong shocks which are able to accelerate charged particles to high energies. Accelerated particles can interact with ambient matter and radiation fields producing gamma-rays and neutrinos.

I will present the multi-messenger potential of AGN-driven winds in terms of escaping cosmic rays, high-energy gamma rays, and neutrinos. The general predictions are then specialized to the case of the composite starburst/Seyfert galaxy NGC 1068. NGC 1068 is the brightest of the starburst galaxies detected in the gamma-ray band, and it is reported as a point-like neutrino source by the IceCube collaboration.

I will compare the gamma-ray and neutrino fluxes expected in the AGN wind model and those corresponding to other models, such as starburst and AGN corona models, with available observations in order to derive constraints on gamma-ray and neutrino production sites.

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Probing the near and far environments of the brightest of all time GRB 221009A with gamma-rays

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GRB 221009A, a relatively nearby (redshift z= 0.1505) and exceptionally bright gamma-ray burst, has been detected with the LHAASO-WCDA instrument in the energy range of 0.2-7 TeV, as well as with the LHAASO-KM2A array up to the energy of ≈ 13 TeV. The unprecedentedly high fluence of TeV gamma-rays from GRB 221009A allows us, for the first time for GRBs, to set constraints on the strength B of the extragalactic magnetic field (EGMF), excluding the values of $B < 10^{-18}$ G [Dzhatdoev et al., MNRAS Lett., 527, L95 (2024)]. The observation of ~ 10 TeV gamma-rays and the subsequent search for $\sim 1 - 100$ GeV pair echo allows to probe the "far"(~ 100 Mpc) environment of GRB 221009A.

Gamma-ray bursts are typically situated in star-forming regions. Therefore, the "near"(<100 pc) environment of GRBs is, as a rule, occupied by a significant amount of gas (typical column density $\sim 10^{21} - 10^{23}$ 1/cm^2). Furthermore, GRBs are expected to be capable of accelerating protons/nuclei up to the energy of at least 1 PeV/nucleon in the fireball's rest frame. The protons/nuclei accelerated during the GRB prompt phase could interact with dense photon fields of the prompt emission producing neutrons. These neutrons escape from the magnetic fields of the fireball freely and interact with the interstellar matter of the star-forming region, eventually resulting in an observable flux of multi-TeV gamma-rays. We show that for certain values of relevant parameters the intensity of these gamma-rays could contribute significantly to the observable spectrum at $E > 10$ TeV. Thus, the "near"(<100 pc) environment of GRBs could be probed with TeV gamma-ray observations as well.

We show that, contrary to some previous studies, the intrinsic (intergalactic absorption-corrected) gamma-ray spectrum of GRB 221009A reveals a surprising cutoff or a break above the energy of several TeV. The nature of the multi-TeV gamma-rays is not clear due to a possible strong influence of the Klein-Nishina effect, severely limiting the observable gamma-ray intensity at the energy in excess of several TeV. A significant part of \approx 10 TeV gamma-rays from GRB 221009A could have been produced by an unconventional mechanism, for example, the one discussed above. Finally, we discuss the relevance of the presented findings to the models of intrinsic gamma-ray production in GRB fireballs and to intergalactic gamma-ray propagation models, as well as to the searches for axion-like particles and Lorentz invariance violation effects.

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Using artificial neural networks in searches for Lorentz invariance violation

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Lorentz invariance violation (LIV) in gamma rays can have multiple consequences, such as energy-dependent photon group velocity, photon instability, vacuum birefringence, and modified electromagnetic interaction. Depending on how LIV is introduced, several of these effects can occur simultaneously. Nevertheless, in experimental tests of LIV, each effect is tested separately and independently. For the first time, we are attempting to test for two effects in a single analysis: modified

gamma-ray absorption and energy-dependent photon group velocity. In doing so, we are using artificial neural networks. In this contribution, we will discuss our experiences with using machine learning for this purpose and present our very first results.

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AGILE activity on FRB high-energy counterparts search

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Since 2019, the AGILE satellite has been involved in searches for high-energy counterparts to Fast Radio Bursts (FRBs) following the discovery of Repeating-FRBs (R-FRBs) with low excess Dispersion Measure (DM_{EXC}) by the CHIME/FRB instrument. These R-FRBs are closer than the average sample of FRBs detected at higher DM values. A new pipeline was developed to perform archival searches in the MCAL and GRID detector data for triggered transient sources.

Firstly, we targeted possible emissions for two nearby FRBs, FRB20180916B and FRB20181030A. After discovering its periodic "activity" phases of ~16 days, a multi-wavelength (MW) campaign on FRB20180916B was set up, involving Italian radio telescopes (mainly the Northern Cross) and the Swift mission. Although no detections were made in AGILE or Swift data, constraints on potential gamma-ray emissions for a magnetar model were established, excluding giant flares like the 2005 event from SGR 1806-20.

The 2020 discovery of a millisecond radio burst from SGR 1935+2154, simultaneous with a weak X-ray burst also detected by AGILE, was interpreted as possible confirmation of the magnetar model for at least a sub-class of FRBs through a comparison with the X-ray campaign on FRB20180916B. AGILE results are discussed within the MW collaboration, both in the specific FRB20180916B source paper and in a general study of all known sources in 2021. We will describe current AGILE FRB post-operations activities and the most recent MW campaigns.

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Deep Learning Models for Detecting and Localizing Gamma-Ray Bursts in Sky Maps and Time Series: Applications to AGILE and COSI Missions

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AGILE is a high-energy astrophysics space mission launched in 2007 which terminated the operations in 2024. Its payload is comprised of the Gamma-Ray Imaging Detector (GRID), the SuperAGILE X-ray detector, the Mini-Calorimeter (MCAL), and an AntiCoincidence System (ACS).

Over the past few years, the AGILE Team has developed deep learning (DL) models to analyze sky maps and time series acquired by AGILE detectors.

The first method developed is designed to detect Gamma-Ray Bursts (GRBs) in the GRID sky maps above 100 MeV. The model detected 21 GRBs from an input list. We developed an additional DL model to localize GRBs in sky maps.

Then, we implemented a method to perform anomaly detection on time series data generated by the AGILE ACS to identify GRBs. The DL model detected 72 GRBs, 15 of which for the first time in the AGILE data.

We implemented a new deep neural network to predict the expected background count rates of the ACS based on the orbital and attitude parameters of the AGILE satellite. The difference between predicted and acquired count rates in the ACS data is used to detect GRBs. Using this method, we detected 39 GRBs, between them four GRBs are new detections in the AGILE data.

We determine the p-value distribution for all DL models to evaluate the statistical significance of the detected GRBs.

Moreover, we are developing Quantum Deep Learning (QDL) models to compare them with the classical ones. The goal is to figure out how to exploit the quantum computer features.

Finally, we are developing DL models for the COSI space mission starting from the know-how acquired with AGILE. The first model aims to localize the GRBs using the count rates of the anticoincidence BGO panels and another model aims to predict the BGO background rate expected as a function of the orbital and attitude parameters to detect GRBs when the acquired rate exceeds the predicted one.

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Firmamento: A Multimessenger Astronomy Tool for Citizen and Professional Scientists

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On the polarized light from active galactic nuclei observed by IXPE

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X-rays are produced in the immediate vicinity of supermassive black holes and their analysis provides a unique tool to study accretion in astrophysical sources. Several X-ray emission processes produce polarized radiation and, even intrinsically unpolarized photons can become polarized through scattering. With its unique ability to measure the linear polarization of X-rays, IXPE has opened a new window into the X-ray universe and allowed us to constrain the properties of the magnetic field and the geometry of the emitting regions of AGN. In this talk, I will summarize and report how

IXPE observations have improved our understanding of radio quiet and radio loud active galactic nuclei.

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High-energy variability of the gravitationally lensed blazar PKS 1830–211

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The production site and process responsible for the highly variable high-energy emission observed from blazar jets are still debated. Gravitational lenses can be used as microscopes to investigate the nature of such sources. We study the broad-band spectral properties and the high-energy variability of the gravitationally-lensed blazar PKS 1830-211, for which radio observations have revealed two images, to put constraints on the jet physics and the existence of a gravitationally-induced time delay and magnification ratio between the images. We utilize Swift/XRT, NuSTAR, and Fermi-LAT observations from 2016 and 2019 to compare periods of low activity and high activity in PKS 1830-211. Short-timescale variability is elucidated with an unbinned power spectrum analysis of time-tagged NuSTAR photon data. To study the gravitationally-induced time delay in the gamma-ray light curve observed with Fermi-LAT, we elaborate on existing methods and introduce new approaches. We develop a metric optimization method yielding a delay of 22.4 ± 5.7 days consistent with the value obtained by our auto-correlation approach, 21.96 ± 0.30 days, both of which being constant over time; the image magnification ratio is more difficult to estimate, and is subject to a two-fold ambiguity. When comparing the 2016 and 2019 datasets, the X-ray part of the SED, especially as seen by NuSTAR, is remarkably constant in comparison to the dramatic change in the gamma-rays. The X-ray and gamma-ray parts of the SED can be fitted with a single component resulting from Comptonisation of infrared emission from the dusty torus, with different gamma-ray states arising solely due to a shift of the break in the electron energy distribution. The detection of a consistent lag throughout the whole light curve suggests that the the gamma-rays originate from a persistent location in the jet.

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Particle acceleration and gamma-ray emission from starburst galaxies

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The intense star-forming activity typical of starburst galaxies results in unique conditions for high-energy particles. The enhanced supernova rate associated with such star formation can in fact transfer a large amount of power to non-

thermal particles which, in turn, can lose most of their energy in the dense and perturbed starburst environment before being able to escape it. I will discuss the transport conditions in starburst galaxies and their multimessenger implications in terms of gamma rays and high-energy neutrinos. The starburst activity can also launch and sustain powerful galactic wind bubbles extending for several kiloparsecs. I will illustrate how particles can be accelerated up to hundreds of PeV at shocks produced in such winds and I will highlight the associated high-energy radiation. Finally, by taking into account the star formation history of the Universe, I will assess the potential contribution of starburst galaxies to the observed diffuse flux of gamma rays, high-energy neutrinos and cosmic rays at energies beyond the Knee.

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Constraints on the diffuse flux of cosmic neutrinos with the ANTARES neutrino telescope

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The ANTARES neutrino telescope took data for 15 years in the Mediterranean Sea, from 2007 to 2022, and collected a high-purity all-flavour neutrino sample. The search for a diffuse cosmic neutrino signal using this dataset is presented in this contribution. The non-observation of a statistically significant excess of high-energy neutrinos is converted into limits on the properties of the cosmic neutrino spectrum. Given the optimal sensitivity of the ANTARES neutrino telescope between 1 and 50 TeV, constraints are put on the behaviour of the diffuse cosmic neutrino flux below 20 TeV.

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Fermi-LAT Discovery of a Gamma-ray Outburst from Comptact Steep Spectrum object 3C 216

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3C 216 is an extra-galactic radio source classified as a Compact-Steep Spectrum. The source is known to have extended radio structure on kpc scale and a blazar core on pc scale. In general high energy emission is more easily observed in blazars, whose jets are closely aligned with the line of sight. Starting from November 2022 Fermi-LAT observed an enhancement in the gamma-ray activity of 3C 216, which culminated in a strong outburst in May 2023. The event was followed up by the Swift telescope. We performed a careful analysis of the multifrequency data (optical, UV, X-ray, Gamma-ray) collected in the first week of May 2023. We observed that the spectral energy distribution of the flaring source evolves in a coherent way, suggesting that the multifrequency emission traces back to the same origin. This result supports the idea that the gamma-ray emission can be interpreted within a single zone Synchrotron Self-Compton model, with important implications on the mechanisms that power energetic radiation in AGN jets.

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Investigating the blazar-neutrino connection with public IceCube data

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The IceCube collaboration has recently found evidence for connecting the blazar TXS 0506+056 to high-energy neutrino events. Several other studies have independently investigated the hypothesis of blazars and specific subclasses thereof as neutrino emitters with mixed results, including constraints on the contribution of these sources to the observed astrophysical neutrino flux. As such, open questions remain regarding the proposed neutrino production mechanisms, connection to multi-messenger signals, and population properties. Motivated by these challenges, we present an open-source statistical analysis framework to investigate possible sources with publicly available IceCube data. Complementary to existing methods we employ a Bayesian hierarchical model, allowing for more complex modelling and a unique perspective on source discovery. We showcase results of fits to simulated neutrino data of generic source populations, highlighting the benefit of possible inputs from multi-messenger studies as priors. In light of recent developments in multi-messenger modelling of source candidates, we go beyond simple power-law models and analyse 10 years of public IceCube data for possible point source contributions.

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The physical properties of candidate neutrino-emitter blazars

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High-energy neutrinos detected by the IceCube Observatory provide a unique opportunity to study the origin of cosmic rays and the nature of the sources producing them. Among the putative birthplaces of astrophysical high-energy neutrinos, blazar jets stand out due to their capability of accelerating particles and providing intense external radiation fields. Blazars are Active Galactic Nuclei (AGN), a class of luminous extra-galactic objects powered by a central supermassive black hole, with the jets pointing in the observer's line of sight.

In this contribution, we focus on a selected sample of 52 blazars that have been put forward as candidate IceCube neutrino counterparts (post-trial statistical significance 5σ). We use multi-wavelength data, both archival and proprietary, in the radio, optical, and γ-ray bands and characterize the sources' nature and their central engine's peculiarities. Properties such as redshift, black hole mass, accretion regime, radiation field, and jet power are crucial to investigate the properties of these blazars and the potential link with the acceleration of cosmic rays. We will present our findings, providing new insights into the intrinsic properties of these neutrino-emitter candidates, and interpreting our results in the context of the properties displayed by the general blazar population.

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Perspectives on ASTRI observations of AGNs and connections with fundamental physics

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Very-high-energy (VHE) astrophysics represents a privileged environment for carrying out studies concerning fundamental physics. The high energies achievable in sources such as blazars allow us to access sectors of particle physics that are difficult to explore in laboratory experiments. The ASTRI Gamma Ray Telescope will produce exciting new observational data at VHE, which could provide us with information on several fundamental physics scenarios, such as: hadron beam, axion-like particles and Lorentz invariance violation. In this talk, we will discuss the effects on astrophysical spectra of the above-mentioned scenarios which, in some cases, can produce similar features, but we will also stress how to disentangle among the different scenarios thanks to their peculiarities. Oncoming data from ASTRI are expected to be able to test all the above-mentioned scenarios providing us hints at new physics or further constraining the parameter space of the different scenarios.

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The search for point-like neutrino sources with ANTARES and KM3NeT/ARCA telescopes

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The multi-messanger approach has recently paved the way for possible breakthroughs in our comprehension of high energy particle emission in the Universe. Neutrino telescopes are essential for highlighting the hadronic component of these phenomena, also testing possible correlation with known sources of gamma rays. Joint analyses of different telescopes results may provide enhanced sensitivity.

This contribution will present the combined analyses of the data collected by two neutrino telescopes located in the depths of the Mediterranean Sea: the ANTARES detector, operational for over 15 years off the coast of Toulon (France), and KM3NeT/ARCA, one of the two detectors constituting the next-generation neutrino telescope KM3NeT. ARCA is optimized for astrophysical neutrinos exceeding 1 TeV in energy and is currently collecting data while being under construction near Portopalo di Capo Passero (Italy). In this analysis, a catalog of approximately one hundred point-like and extended sources was carefully investigated for neutrino emissions: the list encompasses bright γ-ray emitters, galactic γ-ray sources displaying indications of a hadronic presence (TeVCat catalog), extragalactic sources as radio-loud AGNs and the most significant candidate sources studied by IceCube.

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Latest results from the searches for ultra-high-energy photons at the Pierre Auger Observatory

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The Pierre Auger Observatory is the most sensitive detector to primary photons with energies above 0.2 EeV providing unprecedented exposure to ultra-high-energy (UHE) cosmic rays and specifically to UHE photons. The Pierre Auger Observatory measures extensive air showers using a hybrid technique that combines a fluorescence detector (FD) with a ground array of particle detectors (SD). The signatures of a photon-induced air shower are a larger atmospheric depth of the shower maximum ($X_{\max}$) and a steeper lateral distribution function, along with a lower number of muons with respect to the bulk of hadron-induced background. Using observables measured by the FD and SD, various photon searches in different energy bands are performed. These efforts have produced some of the most stringent upper limits on the diffuse fluxes of UHE photons. These limits place significant constraints on current models for the origin of UHE cosmic rays, highlighting the leading role of the Observatory in multimessenger astronomy at the highest energies.
In this contribution, an overview of current activities related to the search for UHE photons is shown, using more than 15 years of data from the Pierre Auger Observatory. The latest results of the searches for diffuse fluxes of photons will be presented, as well as follow-up searches for UHE photons in association with transient events, such as gravitational wave events, will be summarized. Future perspectives, in light of the ongoing AugerPrime detector upgrade, will also be discussed, which aim to further enhance the Observatory's sensitivity to photons at the highest energies.

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KM3NeT: From the Cosmos to the Sea

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Neutrinos are interesting elusive particles that can tell us much about our Universe. Due to their neutral, stable, and weakly interacting nature, neutrinos are valuable for studying various astrophysical phenomena including supernovae, solar flares, neutrino oscillations, and dark matter. However, neutrino fluxes at high energies are very small making critical the possibility of having very large detectors. The KM3NeT collaboration will meet this requirement by building two neutrino telescopes to investigate phenomena from the GeV to the PeV energy ranges. These two experiments are called ARCA (Astroparticle Research with Cosmics in the Abyss) and ORCA (Oscillation Research with Cosmics in the Abyss), and they are located in Sicily (at a depth of 3500m) and Toulon (at a depth of 2500m), respectively. ARCA is designed to detect high-energy astrophysical neutrinos whilst ORCA is optimised for less energetic neutrinos, giving this way, a comprehensive understanding of cosmic energies.
ARCA and ORCA consist in multi-PMT modules carefully studied and assembled in several integration sites all over Europe and Morocco. The module design provides excellent resolution capabilities, position and time calibration.
This talk aims to give an overview of KM3NeT telescopes technology, construction processes and calibration.

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Discovery of a Tight Binary Black Hole System Revealed via Quasi-Periodic Outflows

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Binaries containing a compact object orbiting a supermassive black hole are thought to be the precursors of gravitational wave events, but their identification has been extremely challenging. Here, we report the X-ray detection of quasi-periodic outflows (QPOuts) from a previously low-luminosity active galactic nucleus after an optical outburst, likely caused by a tidal disruption of a star. Using general relativistic magnetohydrodynamic simulations we show that these QPOuts, separated by 8.3 days, can be explained with an intermediate-mass black hole secondary (100-10000 solar masses) on a mildly eccentric orbit at a mean distance of about 100 gravitational radii from the primary supermassive black hole (10^7 solar masses). This suggests a scenario in which possibly multiple compact objects (such as black holes and stars) may be zooming through a gaseous disk, in comparison to the classical assumed picture of a simple accretion and ejection flow. Powerful and massive outflows, accelerated up to a velocity of 30% of the speed of light, are naturally enhanced when the secondary crosses the primary inner accretion disk. This discovery has significant implications for several key areas: the growth and evolution of black holes, the potential identification of counterparts to intermediate and extreme-mass ratio inspirals anticipated to be detected via gravitational waves, and particle acceleration through jets/outflows and shocks.

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Do the LHAASO Galactic diffuse emission data require a contribution from unresolved sources?

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Recently, the LHAASO experiment has obtained a measurement of the gamma-ray diffuse emission in the energy range $10 - 10^3$ TeV by masking the contribution of known sources.
We calculate the contribution of unresolved sources to the LHAASO measurement using our population study based on the H.E.S.S. Galactic Plane Survey. Remarkably, our model is able to reproduce the number and the total flux produced by observed sources listed in the KM2A catalog within 2σ.
We apply the LHAASO masking procedure to both diffuse emission and unresolved sources and further test for possible signatures of a progressive hardening of the cosmic-ray spectrum toward the Galactic center.
We find that the hardening effect and the contribution due to unresolved sources are significantly reduced.
As a result, the LHAASO data above ~ 20 TeV are well described by the truly diffuse emission once all the uncertainties are considered.

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The Quiet Sun with Fermi LAT

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The gamma rays from the non-flaring Sun as daily observed by the Fermi Large Area Telescope (LAT) are supposed to originate by continuous bombardment and interactions of Galactic cosmic rays with the solar surface and its surroundings.
We present our latest studies and unexpected discoveries and we discuss challenges between observations and theoretical expectations.

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LHAASO Discovery of a Ultrahigh-energy gamma-ray bubble in Cygnus X

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The Large High Altitude Air Shower Observatory (LHAAS) discovered a gamma-ray bubble spanning at least 100 deg^2 in ultra-high energy (UHE, >100TeV) band up to a few PeV in the direction of the star-forming region Cygnus X, implying the presence super PeVatron(s). I will introduce this study including LHAASO's observation and its implication for the origin of PeV cosmic rays.

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Contribution of young massive star clusters to Galactic diffuse γ-ray emission

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Young massive stellar clusters (YMSCs) have emerged as potential γ-ray sources, after the recent association of a dozen YMSCs with extended γ-ray halos. The large size of these halos, comparable to the wind-blown bubble expected around these objects, makes the detection of individual YMSCs significantly challenging. As a result, the emission from most of the galactic YMSCs could be non-resolved. If this is the case, the non-resolved emission from YMSCs could significantly contribute to the diffuse γ-ray radiation observed along the Galactic Plane.

In this study, we estimate the possible contribution to the galactic diffuse γ-ray emission from a synthetic population of YMSCs, and we compare it with the observations made available by different experiments, from 1 GeV to hundreds of TeV, in two regions of the Galactic Plane. As the population of galactic YMSCs is only known locally, we evaluate the contribution of γ-ray emission relying on the simulation of a synthetic population of YMSCs based on the observed properties of local clusters. We compute the γ-ray emission from each cluster assuming that the radiation is

purely hadronic in nature and produced by cosmic rays accelerated at the collective cluster wind termination shock.

We found that the γ-ray emission from non-resolved YMSCs can significantly contribute to the observed Galactic diffuse flux. This is especially true if particle diffusion in the bubble is mediated by a Kraichnan diffusion coefficient. The predicted γ-ray spectrum should be considered as a lower limit, given that our calculation neglects the contribution by supernovae exploding in the YMSCs.

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Galactic Center Observations with CTAO LST-1

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Very-high-energy gamma-ray observations of the central part of the Milky Way Galaxy allow for morphological study of cosmic-ray propagation around the supermassive black hole Sgr A. *An interpretation of the diffuse gamma-ray component, which spans a few hundred parsecs in longitude, is the PeVatron scenario: the spectral energy distribution follows a power law up to a few tens of TeV, with a spatial distribution that aligns the central molecular zone and accelerated cosmic rays are propagated in the vicinity of Sgr A*. Nevertheless, differences in the findings of earlier studies persist among current-generation telescopes, each offering different interpretations based on different analytical approaches. The MAGIC telescopes for example presented a hint of a presence of a spectral turnover at around 20 TeV, possibly in tension with the PeVatron scenario.

We analyzed Galactic Center data taken by the Large-Sized Telescope prototype (LST-1) for the Cherenkov Telescope Array Observatory (CTAO), the next-generation project of a ground-based gamma-ray observatory currently under our commissioning. Despite the limited sensitivity due to the current monoscopic observation, the relatively wide field of view and the large-zenith-angle observation technique allow LST-1 to study of the diffuse emission in the TeV range. In this talk, we will report the current status of studies of the Galactic Center diffuse emission by including our results from LST-1 observations.

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High-energy Neutrinos from the Galactic Plane and the galactic hadronic sources

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The high-energy (TeV-PeV) neutrino diffuse emission from our Galactic Plane has been recently measured. The observed signal can be due to diffuse emission produced by cosmic rays interacting with interstellar gas but can also arise from a population of sources. In this talk, we discuss expectations for both the diffuse and source contribution by taking advantage of gamma-ray observations and/or theoretical considerations. In particular, we constrain the fraction of Galactic TeV gamma-ray sources (resolved and unresolved) with hadronic nature.

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Measurement of Ultra-High-Energy Diffuse Gamma-Ray Emission of the Galactic Plane with LHAASO-KM2A

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The diffuse Galactic γ-ray emission, mainly produced via interactions between cosmic rays and the interstellar medium and/or radiation field, is a very important probe of the distribution, propagation, and interaction of cosmic rays in the Milky Way. In this talk, we will present the measurements of diffuse γ rays from the Galactic plane between 10 TeV and 1 PeV energies, with the square kilometer array of the Large High Altitude Air Shower Observatory (LHAASO). Additionally, we will compare a model prediction of diffuse γ-ray emission with our measurements, based on up-to-date measurements of local cosmic-ray spectra and a simplified propagation setup. Our work reveals clear excesses in diffuse emission between several GeV and approximately 60 TeV.

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The Hunt of PeVatrons

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Neutrino fluxes from different classes of galactic sources

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We estimate the neutrino flux from different kinds of galactic sources and compare it with the recently diffuse neutrino flux detected by IceCube. We find that the flux from these sources may contribute to ~ 20% of the IceCube neutrino flux. Most of the sources selected in this work populate the southern hemisphere, therefore a detector like KM3NeT could help in resolving the sources out of the observed diffused galactic neutrino flux.

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The Galactic diffuse gamma-ray and neutrino emission at the PeV frontier

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The Tibet ASγ and LHAASO collaborations recently provided the first evidence of a diffuse γ-ray emission from the Galactic plane up to the PeV. Due to the challenges this imposes to current theoretical models it is crucial to carefully study different scenarios of diffuse γ-ray production, specially towards the centre of the Galaxy. In particular, the current models of Galactic diffuse γ-ray emission struggle to reproduce ASγ and LHAASO measurements, while consistently reproducing the lower energy data.
In this contribution, we show that these measurements seem to favour an inhomogeneous transport of cosmic rays throughout the Galaxy, specially motivated by the Fermi-LAT detector. Moreover, we discuss the relevance of non-uniform cosmic-ray transport scenarios and the possible detectability of the associated diffuse Galactic neutrino emission by IceCube or Km3Net in the next years.

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Young pulsars powering ultra-high energy sources

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The recent discovery of a new population of ultra-high-energy gamma-ray sources with spectra extending beyond 100 TeV revealed the presence of Galactic PeVatrons - cosmic-ray factories accelerating particles to PeV energies. These sources, except for the one associated with the Crab Nebula, are not yet identified. With an extension of 1 degree or more, most of them contain several potential counterparts, including Supernova Remnants, young stellar clusters and Pulsar Wind Nebulae (PWNe), which can perform as PeVatrons and thus power the surrounding diffuse ultra-high energy gamma-ray structures. In the case of PWNe, gamma rays are produced by electrons, accelerated at the pulsar wind termination shock, through the inverse Compton scattering of 2.7 K CMB radiation. In this presentation, I will discuss the implications of the theoretical maximum gamma-ray energy that the central pulsars nearby LHAASO sources and will compare it with the highest energy photons reported by them from a dozen of ultra-high-energy sources.

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The impact of the Cosmic-Ray diffusion in the gamma-ray observations of the Galactic Centre region

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Our Galaxy is a reservoir of extremely energetic cosmic rays (CRs) launched in the interstellar environment by powerful particle accelerators. The galactic magnetic fields confine CRs which travel causes gamma rays to be produced by the interactions with the gaseous matter locked in the Milky Way. Indeed, the interplay between the interstellar medium and CRs is of crucial relevance, as it acts like a passive source of gamma rays. This diffuse emission has a critical role in the analysis of gamma-ray data since it represents the background emission above which we can solve and detect sources. A complete and deepen understanding of the spectral and morphological nature of the large-scale background diffuse emission is fundamental for providing to collaborations increasingly realistic models in order to perform consistent and coherent analysis.

In this contribution some phenomenological models computed to reproduce such diffuse gamma-ray emission are scrutinized against currently available measurements. The choice of a certain parametrization of CR transport equations affects the spectrum of the related diffuse gamma-ray emission, as it leads to a variety of potential estimations which play a key role in this context, along with a realistic description of the gas distribution in our Galaxy. In view of the Cherenkov Telescopes Array Observatory (CTAO) era, the analysis and comparisons reported in this contribution are of crucial relevance for the study of the galactic gamma-ray emitters, particularly in complex scenarios like the Galactic Centre.

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Non-thermal lobe of the Milky Way powered by the Galactic Center outflows

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The large-scale structures such as Fermi Bubbles and eROSITA Bubbles provide a unique opportunity to study our Milky Way. However, the nature and origin of these large structures are still under debate. In this talk, I will present the identification of several kpc-scale magnetised structures based on their polarized radio emission and their gamma-ray counterparts, which can be interpreted as the radiation of relativistic electrons in the Galactic magnetic halo. These non-thermal structures extend far above and below the Galactic plane and are spatially coincident with the thermal X-ray emission from the eROSITA Bubbles. The morphological consistency of these structures suggests a common origin, which can be sustained by Galactic outflows driven by the active star-forming regions located at 3 − 5 kpc from the Galactic Centre. These results reveal how X-ray-emitting and magnetised halos of spiral galaxies can be related to intense star formation activities and suggest that the X-shaped coherent magnetic structures observed in their halos can stem from galaxy outflows.

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Massive stars in binary systems and star clusters

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Massive stars are rarely born alone and are generally found in binary or triple systems as part of star clusters and associations. The stars emit copious thermal radiation from radio to X-rays, and wind-wind collisions enable particle acceleration with associated broadband non-thermal emission. In this talk I will review some of the astrophysics of binary star systems and young massive clusters, from the early embedded phase to the superbubble phase when the most massive cluster members are exploding as supernovae. I will focus on the Wolf-Rayet evolutionary phase, when the densest and fastest stellar winds are driven, and on collective winds from many stars contributing to superbubble formation. Recent insights into particle acceleration and high-energy processes in binaries and clusters will be discussed.

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Gamma-ray emission from Embedded Star clusters

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Massive Star Clusters (SCs) have been proposed as additional contributors to Galactic Cosmic rays (CRs), to overcome the limitations of supernova remnants (SNR) to reach the highest energy end of the CR spectrum. Thanks to fast mass losses due to the collective stellar winds, the environment around SCs is potentially suitable for particle acceleration up to PeV energies and the energetics is enough to account for a large fraction of the Galactic CRs, if the system is efficient enough. A handful of star clusters has been detected in gamma-rays confirming the idea that particle acceleration is taking place in this environment, however the contamination of other sources often makes it difficult to constrain the contribution arising from SCs only.
Here I present a new analysis of Fermi-LAT data collected towards a few massive young star clusters. The young age (< 3 Myr) of the clusters guarantees that no SN exploded in the region, allowing us to determine the power contributed by the star component alone, and to quantify the contribution of these types of sources to the bulk of CRs. Moreover I will present a recent statistical investigation that quantifies the degree of correlation between gamma-ray sources and these astrophysical objects and briefly discuss the observational prospect for ASTRI and CTAO.

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Galactic population of supernova remnants in the TeV range

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Supernova remnants (SNRs) are likely to be significant sources of cosmic rays (CRs) up to the knee of the CR spectrum. They produce gamma rays in the very-high-energy (VHE) range. About a dozen SNRs emitting VHE gamma rays have been detected by current instruments and it is expected that many more will be detected by future instruments.

However, the details of particle acceleration at SNRs, and the mechanisms producing VHE gamma rays remain poorly understood. We studied the population of SNRs in the TeV range and its properties by confronting simulated samples to the catalog of VHE gamma-ray sources from the H.E.S.S.

Galactic Plane Survey (HGPS) under consideration of the multi-dimensional detection threshold of the HGPS. This allows us to address fundamental questions concerning particle acceleration at SNR shocks. What is the efficiency of particle acceleration? What is the spectrum of accelerated particles? Is the VHE gamma-ray emission dominated by hadronic or leptonic interactions?

We present here the first systematic exploration of the SNR-population parameter space relevant to our model. We identify preferred parameter combinations for which $gtrsim 90\%$ of the Monte Carlo realisations are in agreement with VHE gamma-ray data and exclude parts of the parameter space in contradiction with the HGPS data. One finding is a preference for large hadron domination (lower electron-to-proton fractions of K_{ep} $lesssim 10^{-4.5}$) in the SNRs, accompanied with a significant fraction ($\sim 50\%$) of leptonic gamma-ray emission in the sub-sample of detectable SNRs.

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Transient gamma rays from the 2021 outburst of RS Ophiuchi

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RS Ophiuchi is a recurrent nova which explodes on average every 15 years. These explosions result in nova shocks from which non-thermal particles and radiation are produced. In fact, the most recent outburst of RS Ophiuchi in 2021 has been observed by a few different gamma-ray instruments including FERMI-LAT, HESS and MAGIC. Interestingly, the highest TeV gamma rays are only detected about two days after the detection of GeV gamma rays such that there is a delay of about two days between the peaks of GeV and TeV gamma-ray light curves. Different models have been proposed to explain this delay, e.g. by involving multiple nova shocks or different production mechanisms (leptonic versus hadronic) for GeV and TeV gamma rays. In this talk, we discuss a possibility to explain the delay between GeV and TeV emissions by taking into account the effect of gamma-ray absorption due to interactions between gamma rays and optical photons emitted also during the outburst.

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Exploring NGC 3603 non-thermal emission through a realistic modelling of its environment

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Many star-forming regions have been detected in the gamma-ray band in recent years and are gaining a lot of interest as possible contributors to the Galactic hadronic cosmic-ray sea. However, not much emphasis has been put so far in the contribution of cosmic-ray electrons to their gamma-ray emission.

In our presentation we develop a novel approach to investigate the origin of the gamma-ray emission in star-forming regions. We build realistic observationally based models of the gas and radiation distribution on cluster resolution that allow us to obtain accurate results on the morphology of the gamma-ray source. Focusing on the young and massive star cluster NGC 3603 in particular, we introduce these target materials and fields to the CR propagation code PICARD, perform transport simulations and calculate the non-thermal broadband emission. We compare to results from a dedicated Fermi-LAT reanalysis of the source and other available mutiwavelength data. We show that both a purely hadronic and a purely leptonic injection of cosmic rays are disfavoured. A mixture of injected CR electrons and protons is required to explain the origin of the observed non-thermal emission of this system.

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The environment of pulsar halo progenitors

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Since the discovery of TeV halos around the Geminga and B0656+14 pulsars by the HAWC experiment in 2017, many theoretical efforts have been dedicated to understanding this source class. Indeed, assuming that they are probing the environment outside their parent supernova remnant (SNR), the gamma-ray emission hints at a confinement of high energy particles that challenges our current understanding of the CR transport in the average ISM.
Recent hypotheses, including those proposed by Fang et al. 2020, suggest that such an assumption could be erroneous for middle-aged pulsars. Instead, these pulsars may be located in the downstream of the SNR, where turbulence freshly induced by shock activity significantly alters turbulence conditions.
To settle the issue of the position of the relative position of the pulsar, we propose an evolutionary model which coherently describes the evolution of the SNR as a function of the explosion energy and the ambient gas density and take into account the observed distribution of pulsar kick velocities. These quantities being subject to large variance over the Galaxy, we rely on a Montecarlo approach which gives as a result the probability of a pulsar of a given age to remain behind the SNR.
Using this statistical approach and the observed properties of these pulsars, we compute for the first time the likelihood of the claim that Geminga and B0656+14 are inside their SNR parent.

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Investigating Unassociated Fermi-LAT sources for the search of Gamma ray Pulsars and Millisecond Pulsars.

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The fourth catalag of Fermi Large Area Telescope (LAT) consists of
2157 unassociated gamma ray sources. These are gamma-ray sources whose
counterparts in other wavelengths (such as radio, X-ray, or optical) have not
been identified. Their nature remains a mystery making them fascinating

objects to study. The Direct Search Analysis (DSA) , a novel method also utilised to analyse continuous gravitational waves, plays a crucial role in studying the nature of these unassociated sources. In the presentation, I will discuss the application of DSA to investigate the characteristics of the unassociated gamma ray sources. My analysis focuses on a selected group of unassociated sources, employing DSA to study their patterns and signatures to determine if these unassociated sources are gamma-ray Pulsars.

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VillaFalconieri

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Indirect search for dark matter with neutrino telescopes

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Extraterrestrial messengers can probe the presence of dark matter in the Milky Way and beyond. Among others, sizable anomalous fluxes of high-energy neutrinos expected from pair annihilation and decay of dark matter particles, giving neutrino telescopes a role in indirect searches. The energy features and space distribution of dark matter overdensity regions are used to characterise a signal to be discriminated from an atmospheric neutrino background. Other than in the main gravitational reservoir at the Galactic Centre, dark matter can be trapped in the Sun by losing energy in interaction with baryons. Its annihilation into neutrinos offers a unique opportunity when searching for a signal from the Sun, for which neutrino telescopes have almost no competitors. This lecture gives a review of experimental methods and results on the cross section for dark matter pair annihilation and dark matter-nucleon scattering obtained with neutrino telescope data.

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Ultra-High-Energy Cosmic Rays at the Pierre Auger Observatory: Insights and Future Directions

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For about 20 years, ultra-high-energy cosmic rays (UHECRs) have been studied using data from the Pierre Auger Observatory, the world's largest cosmic ray detector. A key feature of the observatory is its hybrid set-up, which detects UHECRs by observing the associated extensive air showers (EAS) using various complementary techniques. Analyses of the multi-detector data have enabled high-statistics and high-precision investigations into the UHECR energy spectrum, mass composition, and arrival direction distribution. This presentation summarizes the resulting scientific findings on UHECRs. While no discrete source of UHECRs has been identified, the extragalactic origin of the particles has recently been confirmed based on arrival directions above 8 EeV, and the possible source regions at higher energies are gradually being narrowed down. The presentation also discusses

future prospects in light of the extensive upgrade program currently underway to further enhance the Observatory's capabilities.

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Indirect search for Dark Matter

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Towards multi-messenger observations of core-collapse supernovae harbouring choked jets

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Over the last decade, choked jets have attracted particular attention as potential sources of high-energy cosmic neutrinos. However, testing this hypothesis is challenging because of the missing gamma-ray counterpart, such that the identification of other electromagnetic signatures is of paramount importance. A choked-jet source is expected, for instance, because of core-collapse supernovae with extended hydrogen envelopes (Type II SNe), leading to the release of ultraviolet (UV) and optical (O) emission for a few days. The UV band will be visible with an unprecedentedly large field of view by the future mission satellite ULTRASAT, for which we investigate the detection prospects in relation to the chocked source visibility in the O band with the currently operating telescope ZTF. By considering fiducial parameters of the source population, we estimate the maximum redshift up to which ULTRASAT will be able to detect UV signals from these explosions, finding that it will be able to double the volume of sky currently visible by ZTF for the same emitting sources, and consequently enlarge the sample of observed Type II SNe by 60%. Furthermore, we discuss coordinated multi-messenger observations among those instruments and high-energy neutrino telescopes. To optimize combined detections, we suggest a delay of 4 days between neutrinos and ULTRASAT observations, with a subsequent follow-up by like-ZTF instruments about one week after.

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The Primordial Black Holes Variations

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In the era of gravitational wave astronomy and direct black hole imaging, the possibility that some of the black holes in the universe have a primordial, rather than stellar, origin, and that they might be a non-negligible fraction of the cosmological dark matter, is both timely and intriguing. I will review the status of the field, describe search strategies and future prospects for detection across many decades in black hole mass, discuss how light primordial black holes could seed both baryonic and particle dark matter in the very early universe, and comment on how the search for primordial black holes may lead to a deeper understanding of the elusive Galactic "rogue planets".

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Early clustering of dark matter particles around primordial black holes: density profiles and signatures

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Primordial black holes may have been produced in the early stages of the universe, after cosmic inflation. If so, dark matter in the form of elementary particles can be subsequently accreted around these objects, in particular when it gets non-relativistic and further streams freely in the primordial plasma. A dark matter mini-spike builds up gradually around each black hole, with density orders of magnitude larger than the cosmological one. The radial profile of this mini-spike depends sensitively on black hole mass, dark matter particle mass and temperature of kinetic decoupling. It exhibits a rich variety of behaviors which I will discuss. Dark matter spikes subsequently annihilate and leave potentially detectable signatures, such as anomalous anisotropies in the cosmic microwave background (CMB). I will discuss how CMB observations constrain the early dressing of primordial black holes by particle dark matter.

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Extra-galactic and galactic sources of H.E. neutrinos: Open questions

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The main goals of high-energy neutrino astronomy are to identify the sources of high-energy cosmic rays, particularly ultra-high-energy ones, and to provide information on the acceleration process and constraints on models of high-energy astronomical objects. The detection of high-energy astronomical neutrinos demonstrates the potential for achieving these goals. I will discuss what we have learned from current neutrino observations and the prospects for making progress on identifying the sources.

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Diffuse high energy astrophysical neutrino flux and galactic contributions

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The diffuse astrophysical neutrino flux measured in the very high energy range introduced unresolved issues about the origin of these events and underlined as a viable solution the multi-component scenario. Recent studies show that galaxies with high star formation rate (above teens Mo/year) can be responsible of a seizable fraction of the observed astrophysical flux.
Despite their low luminosity, they can be considered as guaranteed “factories”of high energy neutrinos, being “reservoirs”of accelerated cosmic rays and hosting a high density target gas in the central region. On the other hand, in the same range of energies, recent measurements of IceCube and Antares telescopes set the contribution correlated with the diffuse Galactic emission. The Milky Way is a prominent astrophysical lab to correlate the high-energy diffuse emission with the physics of cosmic-ray injection and propagation as well as with the measured molecular gas distribution.
In this contribution we describe in details these two diffuse astrophysical components, presenting recent phenomenological studies and reviewing current observations made by high-energy neutrino telescopes

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High Energy Neutrinos from Blazars

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Overview of the Baikal-GVD neutrino telescope status 2024

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Baikal-GVD is a water Cherenkov neutrino telescope under construction in Lake Baikal that annually increases its detection volume. The winter expedition 2024 concluded at 110 strings with 3 960 optical modules underwater. The number of operationally and functionally independent sub-arrays (clusters) increased to 14. The modular design of the detector allows for data collection while being in the construction phase. This contribution reviews the design and basic characteristics of Baikal-GVD, currently the largest operating neutrino telescope in the Northern Hemisphere. Results of high-energy cascade events analysis that confirms the astrophysical diffuse neutrino flux at the level above 3⊠ will be discussed. Selected set of first high-energy events registered in track channel by Baikal-GVD will be shown. Participation in high-energy alert follow-ups will be presented.

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Science perspectives with the Einstein Telescope

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Einstein Telescope (ET) is the next generation gravitational wave observatory. In this talk I will review the current status and plans related to its realization. I will also summarize the science potential and possible discoveries that the ET will enable.

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The Gravitational wave experiments and the multimessenger astronomy

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The gravitational wave network of interferometers on Earth has completed three successful observing runs, detecting nearly a hundred events. Almost all detected gravitational wave signals are from the coalescence of compact binaries composed of black holes (BH/BH). A few others have been associated with the coalescence of neutron star/neutron star or mixed black hole/neutron star pairs. The fourth observing run started in May 2023, and until January 2024, only the two LIGO detectors were in observing mode, yielding 81 new high-confidence gravitational wave candidates. The detection rate has steadily increased since the LIGO and Virgo interferometers resumed observations after March 2024. Currently, data collection is still ongoing, leading to new discoveries. This talk will summarize the main observational results and their potential impact on multimessenger astronomy.

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Telescope Array recent results

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Closing remarks

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Closing remarks

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The Fermi Large Area Telescope: status and recent results

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In this review talk, we will peer into the Universe through the eyes of NASA's Fermi Large Area Telescope (Fermi-LAT) to marvel at the main results that has been recently achieved in the GeV energy range. Particular attention will be given to the latest results in the search of dark matter.

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Ricap 2026 announcement

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Progressing our understanding of cosmic rays with the HERD space-borne experiment

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A new generation of space experiments is needed to enhance our understanding of cosmic rays. The challenge of the direct detection at ever higher energies with improved energy and angular resolutions is guiding us in designing the detectors of the future. The High Energy cosmic-Radiation Detection facility (HERD) onboard the China Space Station will be the next calorimetric experiment. Starting from 2027 and for more than 10 years, HERD will be measuring cosmic protons and heavier nuclei from 30 GeV/nucleon to a few PeV/nucleon. It will search for dark-matter signatures in the energy spectrum of cosmic electrons from 10 GeV to 100 TeV and photons from 100 MeV to 100 TeV. The HERD design, prospects and expected performance, as well as its contribution to the multimessenger astronomy will be presented in this talk.

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Radiative signals from GRBs and multi-messenger searches

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Gamma-ray bursts (GRBs) are short lasting flares of keV-MeV radiation. These extragalactic transients are produced in the ultra-relativistic jets produced after collapse of massive stars or merger of neutron stars. In the last decade we have witnessed extraordinary observations of GRBs, including joint GRB-gravitational wave (GW) detection and very-high energy (VHE) gamma-ray observations.

More recently, the brightest of all the time GRB has been detected and followed up from the radio to VHE gamma-rays. In this talk I will first present the most recent multi-messenger and multi-wavelength observations of GRBs. I will then discuss the potentials of these observations in contribution to our understanding of physics of compact objects, relativistic jets and particle acceleration. And finally, a future prospects will be drawn for the next decade of GRB observations with GWs, VHE gamma-rays and high-energy (GeV-TeV) neutrinos.

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Particle acceleration and radiation:theory vs observation.

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Particle identification in high-granularity 3D calorimeters for space-borne applications

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