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Book of Abstracts

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”A scuola di astroparticelle”

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Gamma-ray Astronomy / **137**

10 years of the Fermi Gamma-ray Space Telescope

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The Fermi Gamma-ray Space Telescope was launched 10 years ago and since then it has dramatically changed our knowledge of the gamma-ray sky.
The status of the observatory, and in particular of the Large Area Telescope, and the main results of these first ten years of data taking will be presented, with particular attention to the multi-messenger context.

Gamma-ray Astronomy / **80**

15 years of MAGIC observation of a crowded TeV sky.

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The first MAGIC telescope was built in 2003, and operated as a standalone instrument until 2009, when the addition of a second twin telescope allowed stereoscopic observations. Since then, we have acquired more than 40 extragalactic and more than 10 galactic sources of very high energy gamma rays. The portfolio of physics that can be done with such observations is wide: it includes accretion onto black holes, relativistic jets, shocks, and the interconnection of these phenomena to the riddle of how cosmic ray particles are accelerated to very and ultra high energies. Additionally, MAGIC devoted a significant fraction of the observation time to contributions to fundamental physics questions such as the existence of signatures from dark matter particles, or Lorentz invariance violations. Some selected MAGIC highlights will be discussed, providing an assessment of the success of this project.

Cosmic Rays Direct Measurements / **5**

A decade of Cosmic Rays Investigation with the PAMELA Experiment

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It was the 15th of June 2006 when the PAMELA satellite-borne experiment was launched from the Baikonur cosmodrome in Kazakhstan. Then, for nearly ten years, PAMELA has been making high-precision measurements of the charged component of the cosmic radiation opening a new era of precision studies in cosmic-ray physics.
The measured antiparticle component of the cosmic radiation shows
features that can be interpreted in terms of dark matter annihilation or pulsar contribution. The measurements of the energy spectra of protons, electrons, helium and light nuclei together with their isotopes challenges our basic vision of the mechanisms of production, acceleration and propagation of cosmic rays in the galaxy. The study of the time dependence of the various components of the cosmic radiations clearly shows solar
modulation effects as well as charge sign dependence.
PAMELA measurement of the energy spectra during solar energetic particle events fills the existing energy gap between the highest energy particles measured in space and the ground-based domain. Finally, by sampling the particle radiation in different regions of the magnetosphere, PAMELA data provide a detailed study of this structure surrounding the Earth. In this talk we will review the PAMELA experiment and its scientific results.

Cosmic Rays Direct Measurements / **116**

AMS-02, result and perspectives

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I will review the AMS-02 data and the measurements performed in the first 7-years of data taking. I will then discuss the perspectives of the AMS-02 cosmic ray data in the landscape of the current puzzling scenario of the astroparticle physics.

Neutrinos / **12**

ANTARES highlights and recent multi-messenger studies.

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The ANTARES deep sea neutrino telescope, anchored on the seabed of the Mediterranean Sea, has been continuously taking data for more than ten years. Thanks to its excellent angular resolution in both the muon channel induced by muon neutrinos and the cascade channel induced by interactions of neutrinos of all flavours ANTARES has very large sensitivity for neutrino source searches in the Southern sky. Mild excess related to the all-flavour cosmic diffuse flux was seen with the latest 9-years data analysis, consistent with the IceCube discovery. The origin of the cosmic neutrinos observed by IceCube still remains unknown.

ANTARES is actively developing a wide multi-messenger program: latest experimental results from searches for neutrinos correlated with the recently discovered gravitational wave signals (including recent neutron star – neutron star merger GW170817) and Fast Radio Bursts will be reported.

Other physics topics are addressed by the ANTARES experiment as well, including setting constraints on dark matter from a search of neutrinos from potential dark matter annihilation in massive

objects like the Sun, the Galactic Center, or the Earth core, and the search for magnetic monopoles.

Instrumentation for Astroparticle Experiments / **24**

Assembly and validation of SiPM optical modules for the Schwarzschild-Couder Medium Size Telescope proposed for the CTA observatory.

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Silicon Photomultipliers are particularly suitable as optical units of Imaging Air Cherenkov Telescopes to detect the fast and low-intensity Cherenkov signal emitted by high energy atmospheric showers. The third generation of high density NUV SiPMs (NUV-HD3) produced by Fondazione Bruno Kessler (FBK) in collaboration with INFN have been used to equip optical modules intended to be integrated on a possible upgrade of the focal plane camera of the Schwarzschild-Couder Telescope prototype (pSCT) in the framework of the Cherenkov Telescope Array (CTA) project.
NUV-HD3 SiPMs are 6x6mm^2 devices based on 40x40μm^2 microcells with excellent photo detection efficiency for the NUV wavelengths. More than 40 optical modules, each composed of a matrix of 4x4 SiPMs, have been assembled and tested in the laboratories of INFN to be integrated on the pSCT camera. In this contribution we report on the development and on the assembly of the optical modules, on their validation and on their integration of the pSCT camera.

Instrumentation for Astroparticle Experiments / **14**

Brand-new optical modules for the KM3NeT neutrino detector

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The discovery of cosmic neutrinos by IceCube in 2013 gave to the field of high-energy neutrino astronomy a new exciting momentum. IceCube and ANTARES detectors, respectively in the ice of the South Pole and in the French deep-water of the Mediterranean Sea, are providing high-quality data and have become an important component of multi-messenger astronomy. New cubic kilometer size detectors are already under construction: KM3NeT in two deep-sea sites of the Mediterranean Sea, in France and Italy, and Baikal-GVD in the Lake Baikal of Russia.
All the different detectors can be generically described as a grid of optical sensors, called optical

modules, which are sensitive to the Cherenkov radiation emitted by charged particles produced by neutrino interactions.
Despite the same scientific objects, all the projects adopted different layout and technical solutions for the optical module design. IceCube, ANTARES and Baikal used a single large area photomultiplier, typically with a photocathode diameter of 10 inch, housed into 13 inch or 17 inch diameter transparent glass vessels.
The KM3NeT project already started a mass production of optical modules with an innovative multi-PMT design with 31 3-inch photomultipliers integrated into a 17-inch glass sphere.
This novel solution has several advantages with respect to optical modules that comprise single large photomultipliers. Since each PMT works independently, the segmented photocathode layout offers photon counting with high efficiency and provides directional information and rejection of optical background just at the DOM detection level. Moreover, it reaches almost three times the photocathode area of a single glass sphere equipped with a 10 inch PMT and has an almost uniform angular coverage.
The proposed contribution aims to give a general overview about the different optical module designs, with a particular focus on the main characteristics of the multi-PMT novel solution of the KM3NeT project.

Gamma-ray Astronomy / 46

Cherenkov Telescope Array: overview and Galactic science program

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The Cherenkov Telescope Array is the next generation ground-based gamma-ray observatory designed to detect photons in the 0.02 to 300 TeV energy range. With a sensitivity improvement of one order of magnitude over currently operating facilities, coupled with significantly better angular resolution, the array will be used to address many open questions in gamma-ray and cosmic-ray astrophysics. In addition, CTA will explore the ultrahigh energy (E > 50 TeV) window with great sensitivity for the first time.
This talk will provide an overview of CTA and will review the scientific motivation for CTA, with a focus on the key science projects that relate to the study of Galactic sources of very high-energy emission and to the long-standing question on the origin of cosmic rays.

The first multi-messenger event : GW170817 / 10

Constraining the nuclear matter EoS from the GW170817 merger event

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The equation of state (EoS) of nuclear matter is one of the key issues in understanding the internal structure of neutron stars (NS), the remnants of massive stellar collapses. They populate the plane of our Galaxy, isolated or in binary systems, and play a crucial role in the indirect (Hulse & Taylor 1975) and direct (Abbott et al. 2017a) testing of the existence of gravitational waves (GWs). Their physical properties (essentially the EoS) are still poorly known, owing to the lack of accurate measurements of masses and radii.

The detection of the 17 August event, GW170817, and its electromagnetic counterp arts allows to constrain the dense matter EoS. The upper limit put on the tidal deformability by the merger event, and the lower limit from the kilonova AT2017gfo signal, rule out respectively very stiff and very soft EoS. This translates into an allowed window for the radius of the 1.4Mo stellar configuration between~11.5 and 13. 5km. This seems to contradict several analyses of X-ray NS spectra, which suggest radii significantly smaller than 11. 5 km (Oezel & Freire 2016). We show that it is possible to satisfy all the observational constraints on the radii if GW170817 is interpreted as the merger of a hadronic star and of a quark (or hybrid) star (Burgio et al.).

Abbott, B.P., et al. 2017a, PRL, 119, 161101
Burgio, G. F., Drago, A., Pagliara, G., Schulze, H.-J., and Wei, J., arXiv:1803.09696
Hulse, R.A. & Taylor, J.H. 1975, ApJ, 195, L51
Oezel, F., & Freire, P. 2016, ARA&A, 54, 401

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Cosmic Rays Measurements with LOFAR

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Cosmic Rays Direct Measurements / **40**

Cosmic rays: direct measurements

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In this talk I will review the field of cosmic ray measurements by direct observations.
A wealth of new results obtained by balloon-borne and space-based experiments have enriched the field, covering several observation targets from nuclei and isotopes, to electrons and positrons, to antiprotons, measured over six decades in energy from few MeV up to some TeV.
The measurements from the AMS-02 and PAMELA spectrometers are characterized by a precision never reached before in CR history; they allowed to discover features in the CR energy spectra that compel a revision of the simple idea that CR fluxes are described by smooth single power-laws in energy, and prompted an intense theoretical activity to interpret the results.
Among the most interesting outcomes of the last years, the first measurement of the CR spectra outside the heliosphere (Voyager 1), the high-statistics measurement of the abundances of nuclei heavier than iron (SuperTIGER), and the first detection of a primary CR clock (ACE-CRIS) are certainly worth considering.
Moreover, very recent calorimetric missions (CALET, DAMPE) are collecting unprecedented statistics of CRs even at higher energies, in the multi-TeV range and finally approaching the knee. The first results on the electron spectrum are already stimulating interesting discussions.
All these advances indicate that we have entered a new era of precision measurements of CRs, which can contribute to shed light on several fundamental questions in CR physics, still open a century after their discovery, like the mechanism of acceleration of galactic cosmic rays (GCRs), the nature and composition of their sources, the CR propagation in the interstellar medium (ISM).

Outreach / **15**

Dissemination about natural radioactivity through Work-Based Learning experiences

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This work investigates the importance of Work-Based Learning experiences of Italian high school students and how some extracurricular basic knowledge may influence the student's intrinsic motivation.
The Italian model, named Alternation School-Work, highlights the partnership between schools and workplaces or real life situations. So that, we consider the experience of about 120 students of 3 different schools located in Campania Region (South Italy).
Our goal has been to educate students on topics such as environmental radioactivity and in particular about the public exposure to radioactivity of natural origin (cosmic rays, radon...), in the framework of astroparticles' school of National Institute of Nuclear Physics, also introducing they in real measurement campaigns.
Having improved knowledge about their country's geophysical features, the students have drawn up informative material and a simple survey to propose to the local population in order to understand the level of knowledge on the issue of radioactivity and the consequent perception of risk.
The result has been that the students could know and deal with the problem, in a realistic way, from the point of view of scientific research, thanks also to the Radiolab project of Italian National Institute of nuclear Physics, through which measurements of the concentration of radon gas activity have been carried out in the buildings of their own school complexes.

Outreach / **42**

Education and public outreach of the Pierre Auger Observatory

Charles for the Pierre Auger Collaboration TIMMERMANS[1]

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The scale and scope of the physics studied at the Pierre Auger Observatory continue to offer significant opportunities for original outreach work. Education, outreach and public relations of the Auger Collaboration are coordinated in a separate task whose goals are to encourage and support a wide range of education and outreach efforts that link schools and the public with the Auger scientists and the science of cosmic rays, particle physics, and associated technologies. The presentation will focus on the impact of the collaboration in Mendoza Province, Argentina. The Auger Visitor Center in Malargüe has hosted over 105,000 visitors since 2001, and a sixth Collaboration-sponsored science fair was held on the Observatory campus in November 2016. The seventh will be hosted next November. Numerous online resources, video documentaries, and animations of extensive air showers have been created for wide public release. Increasingly, collaborators draw on these resources to develop Auger related displays and outreach events at their institutions and in public settings to disseminate the science and successes of the Observatory worldwide. The presentation will also highlight the impact of the recently renovated Visitor Center, configured now to allow self-guided tours, which has increased the visitor count over the last year and provided a boost to local outreach.

Indirect Measurements of High Energy Cosmic Rays / **114**

Energy spectrum estimation and mass composition inferences from Xmax measurements of cosmic rays detected at the Pierre Auger Observatory and at the Telescope Array: an inter-collaborative look at the differences at the highest energies

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Ultra-high energy cosmic rays are observed through the giant air showers they produce in the atmosphere. With the construction and operation of the new generation of cosmic-ray experiments—the Pierre Auger Observatory in the Southern hemisphere and the Telescope Array in the Northern one—the study of these particles, the most energetic ever detected, has experienced a jump in statistics as well as in the data quality over the last decade, allowing for a much better sensitivity in measuring their energy spectrum and the in inferring their mass composition. Still, some differences persist, in particular in the energy spectrum at the highest energies. These spectral differences can be best addressed by focusing on the common field of view of the experiments. The inter-collaborative efforts to characterize the differences and to highlight the convergences of the various observations will be reviewed in this contribution.

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Gamma-ray and the future

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Gamma-ray Astronomy / 146

Gamma-rays and their future

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I will illustrate current and future technologies and planned observatories and discuss some of the highlight results concerning source observations and multi-messenger programs.

Multi-messenger Astronomy & Gravitational Waves / 34

Gravitational wave transient sources and what we learn from them

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The advent of advanced detectors truly opened the era of GW astronomy with the first signals from transient sources detected by Advanced LIGO and Advanced Virgo during the O1 and O2 runs. These include binary black hole mergers and the spectacular GW170817, the first signal from a binary neutron star coalescence and its associated electromagnetic counterparts. The talk will review the wealth of results provided by the sources reported to date and the prospects for the next observing runs.

Gamma-ray Astronomy / **37**

Highlights from the HAWC Observatory

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The High Altitude Water Cherenkov (HAWC) observatory is a wide-field survey instrument sensitive to cosmic rays and gamma rays in the energy range from a few hundred GeV to >100 TeV. Located in the state of Puebla, Mexico at 4100 m above sea level, HAWC has been fully operational for over 3 years, since its inauguration in March 2015. In this talk, I will highlight recent results from HAWC, including both Galactic and extragalactic gamma-ray sources as well as cosmic-ray observations. I will also discuss HAWC's role in several multimessenger studies, focusing on what we can learn in conjunction with neutrinos observed by IceCube and HAWC observations of GRBs in the context of gravitational waves.

Neutrinos / **143**

Highlights from the IceCube Neutrino Observatory

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The IceCube Neutrino Observatory has discovered and measured a diffuse astrophysical neutrino flux spanning energies from several TeV to several PeV. The origins of the neutrinos are still unknown despite intense investigation using a variety of multi-messenger approaches. Spectral, temporal, and spatial studies of the astrophysical neutrinos have disfavored individual source classes including gamma-ray bursts, star-forming galaxies, and Fermi-LAT-detected blazars as producing the majority of the flux. While most of the astrophysical neutrino signal is extragalactic, there may be a Galactic component. I will summarize our astrophysical flux measurements as well as the search for the origins of the signal.

Indirect Measurements of High Energy Cosmic Rays / **33**

Highlights from the Pierre Auger Experiment

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The Pierre Auger Observatory is the world's largest air-shower detec- tor for cosmic rays with energies above 10^17 eV. Located near the small town of Malargue in Argentina, it consists of an array of about 1660 water Cherenkov detectors in a triangular grid which covers an area of more than 3000 km^2. In total 27 fluorescence telescopes at four sites overlooking the detector array provide an independent and complementary method for air shower detection. In the last decades, measurements performed at the Pierre Auger Observatory have led to considerable progress in understanding the properties of ultra-high-energy cosmic rays. In this contribution, a review of recent results from the Pierre Auger Observatory will be given, focussing on the energy spectrum of cosmic rays at the highest energies and their compo- sition. In addition, the ongoing activities to upgrade the detector systems of the Observatory will be discussed. This upgrade, named AugerPrime, aims mainly at impr!
oving the sensitivity of the detector to the mass of the pri- mary cosmic rays through a better measurement of the electromagnetic and muonic components of air showers.

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Highlights on DUNE

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Highlights on LISA-Pathfinder and LISA

In 2016, the LISA Pathfinder satellite demonstrated an unprecedented level of residual acceleration between two freely falling test masses in space, at the level required for a space based gravitational wave detector. This achievement has been the basis for the selection in 2017 of LISA as the 3rd Large class mission in the ESA Cosmic Vision 2015-2025 program. The promised scientific outcomes of LISA are outstanding, having the potentiality to unveil the most powerful sources of gravitational waves in the Universe in the mHz frequency band, a region of frequencies not accessible from on-ground observatories.
In this talk, I will review the results of the LISA Pathfinder mission, which paved the way to the selection of LISA by ESA and represent a fundamental heritage upon which LISA will be built. Moreover, I will highlight the status of the LISA project, entering now the Industrial Phase A, and its potential for the future of gravitational wave astrophysics.

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Instrumentation in Astroparticle Physics

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Introduction to Gravitational Wave detection : GW170817

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Indirect Measurements of High Energy Cosmic Rays / 50

Knee, ankle and GZK cutoff in historical perspective

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In the field of cosmic ray physics the energy spectrum of the high-energy primary particles is the basic information. The discovery and further investigation of the main features of the spectrum - first and second knee, ankle and GZK cutoff are described following the historical development.

The first multi-messenger event : GW170817 / **44**

LIGO-Virgo's Discovery of a Binary Neutron Star Merger from a Multi-messenger Perspective

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The recent discoveries of gravitational waves by LIGO and Virgo unveiled numerous opportunities in astrophysics, as well as in the study of the cosmos and the laws of physics. In particular, the observation of a binary neutron star merger and the ensuing multi-messenger follow-up campaign already yielded a range of expected and unexpected findings, giving us a taste of what is yet to come. I will discuss the discovery of GW170817 from the perspective of what we learned from multi-messenger data. In particular I will focus on the high-energy neutrino follow-up effort by ANTARES, IceCube, and the Pierre Auger Observatory, what we learned from these searches, and what we can expect for the near future when the rate of gravitational-wave discoveries is set to rapidly increase.

Cosmic Rays Direct Measurements / **2**

Measurement of Deuteron over Proton flux ratio among CR with the AMS-02 experiment

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Deuterons are the most abundant secondary light isotopes among cosmic rays (CR) and thus are an extremely sensitive tool to test and constrain cosmic ray propagation models.
Another important feature of the deuteron component of CR is the particularly low threshold of the proton-proton fusion reaction, one of the most important contributors of the sub-GeV deuteron abundance, an energy range accessible by the AMS-02 thanks to its Time of flight detector.
For these reasons, tools like the d/p flux ratio are extremely important for the comprehension of the

propagation of CR, integrating the informations coming from measurements such as 3He/4He and B/C and testing the universality of propagation models.
Due to its importance, the deuteron component of CR has been measured by multiple experiments to the time being, but with typically large errors and inconsistency with each other. In this picture, the measurement of AMS02 is a game-changer, being able to access with higher precision to a wider energy range with respect to all the predecessors, going from 0.3 to 9 GeV/n, combining the isotopic separation power of its ToF and RICH sub-detectors.
We will present a preliminary measurement of d/p fluxes ratio coming from the detection of 15 million deuterons over a 6 yrs of continuous data-taking.

Summary:

Cosmic Deuteron abundance measurement are very important for the knowledge of cosmic ray propagation, and AMS-02 can measure it with unprecedented precision in a wide energy range

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Measurements of High Energy Cosmic Rays and Cloud presence: A method to estimate cloud coverage in infra-red images taken from space and the ground

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Several projects and already-operative observatories aimed at detecting High Energy Cosmic Rays (HECR) are/will be equipped with instruments to monitor the atmosphere. Since cloud presence can affect the night-time indirect measurements of the HECRs and Cherenkov radiation, it is crucial to know the meteorological conditions during the observation period of the HECR detectors. Several meteorological satellites already provide useful information, however to obtain accurate reconstructions of the detected events it is more suitable using devices that operate synchronously with the main detector. To this purpose, infra-red cameras that acquire images of the whole field of view are thought to support the atmosphere monitoring during observations from both space and the ground. Meaningful parameters, like cloud coverage and cloud top/bottom height, can be retrieved from the analysis of those data. Multispectral information are typically analysed and combined to obtain cloud masks for each image, where a cloudy/cloud-free probability flag is associated with each pixel. These algorithms normally use several spectral bands that are not always available in non-meteorological sensors. For this reason a different approach is presented in this paper. It only relies on the grey level values of the image pixel, and it can be applied on thermal infra-red as well as visible images acquired from both space and the ground. To test the method on real cloudy scenes, images from polar satellite and all-sky data archives are considered, and the results are compared to the corresponding cloudiness masks provided by the same data repositories.

The first multi-messenger event : GW170817 / **18**

Multi messenger astronomy with the γ-ray satellite AGILE: gravitational-wave events and ultra high energy astrophysicsal neutrinos

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The gamma-ray satellite AGILE, launched on 2007, has just completed its eleventh year of operations in orbit. The main on-board instrument is the gamma-ray imaging detector (GRID) sensitive to gamma-rays in the energy range 30 MeV–30 GeV. The GRID is composed by the
gamma-ray silicon tracker, the mini-calorimeter (MCAL) and the anti-coincidence (AC) system for particle background rejection.
Since Nov. 2009, AGILE is operated in the spinning observation mode, in which the satellite rotates around its Sun-satellite versor performing a complete rotation in approximately 7 minutes
(200 times per day). Thanks to the very large field of view (FoV) of 2.5 sr and the spinning mode, the GRID is capable to observes 80% of the whole sky every day, with a sensitivity (at 5 sigma detection level) to gamma-ray fluxes above 100 MeV better than 2. x 10-6 ph cm-2 s-1 over two-day integration time intervals.
AGILE in spinning mode is a very effective instrument in performing all-sky searches for gamma-ray counterparts to multimessenger transient events like the IceCube neutrino HESE/EHE events and the LIGO-VIRGO gravitational-wave events.
Despite the small size (approximately a cube of side ~60 cm), the AGILE–GRID achieves an effective area of the order of 500 cm2 between 200 MeV and 10 GeV for on-axis gamma-rays, and an angular resolution (FWHM) of the order of 4° at 100 MeV, decreasing below 1° above 1 GeV.
Besides the GRID, the AGILE–MCAL can be used independently to search for burst-like events (particularly adequate for detecting GRB-like phenomena in coincidence with gravitational-wave events) on timescales ranging from sub-milliseconds to tens of seconds in the energy range of 0.35–100 MeV.
Results on searches for precursor and delayed emissions for the gravitational-wave events GW150914, GW170104, and GW170817 as well as for the IceCube-160731 neutrino event are presented.
AGILE is sentinelling the sky continuosly watching for gamma-rays in coincidence with gravitational-wave and neutrino events.

Summary:

The potential of the gamma-ray satellite AGILE for multi-messenger astronomy is introduced. Its first results in conjunction with
the gravitational wave events as well as the high energy IceCube neutrino events are presented. Prospects for the future are sketched.

Multi-messenger Astronomy & Gravitational Waves / **38**

Multi-messenger astronomy driven by the High-energy cosmic neutrinos.

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The era of high energy neutirno astronomy has come. The IceCube Neutrino Observatory started to operate the two online neutrno event selection channels, HESE (High-Energy Starting Event) and EHE (Extremely-High Energy).
Informations on a cosmic neutrino event candidate identified by these selections are delivered in public to world-wide astronomical facilities, which realize prompt follow-up observations. Recently the EHE channel detected a high energy neutrino, IceCube-170922A, which was followed by an extensive multi-wavelength campaign. In this talk we present the details on the detection of this event and the follow-up observations. A suggested possibility of identifying a high energy cosmic ray source is highlighted. We also discuss what the existing data of ultra-high energy cosmic rays (UHECRs), and high energy neutrinos can tell about a possible unified scheme to account all the UHECR and neutrino emissions in general.

Instrumentation for Astroparticle Experiments / **118**

Novel type of compact satellite borne gamma-ray telescope based on oriented crystals

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It has been known since the ‘50s that the lattice structure may strongly influence the electromagnetic processes in oriented crystals. In particular, if a beam of electrons or photons is aligned with the crystalline axes or planes, the probability of bremsstrahlung or pair production, respectively, are strongly enhanced. This results in a shortening of the radiation length, X0, and thereby of the electromagnetic shower exten. In the ‘90s, the CERN NA43 and NA48 experiments measured the X0 reduction in high-Z crystals of single element, such as tungsten, with a reduction factor of 3-4 times in case of perfect crystal-to-beam alignment. This factor decreases gradually as the angle between the photon/electron and crystal axes increases. Despite this, a measurable effect is maintained up to about 1°. Recently, our group extended these studies to high-Z scintillators commonly used in electromagnetic calorimeter. In particular, we measured a huge X0 reduction for 120 GeV electrons interacting with a lead tungstate crystals (PWO), from 8.9 to 1.6 mm in the case of beam alignment w.r.t crystal axes.
With the birth of multimessenger astrophysics, one may think of pointing a telescope towards a source. In a satellite with a gamma module made of oriented crystals, the shower of gamma rays with energy larger than 100 GeV can be completely contained in a quite restrained volume, thus reducing the necessary weight (and therefore the cost) compared to those currently used.
If we take as an example the FERMI LAT, each of its “tower” is composed by a Tracker and a Calorimeter module. The first one consists of layers of silicon detectors interleaved with thin W converter foils, while the Calorimeter is made of CsI scintillator crystals. An incoming gamma ray interacts with the W foil, thus converting in pairs that deposit their energy into the Calorimeter.
In case of pointing, an oriented crystals based hodoscopic calorimeter would strongly enhance the sensitivity of the telescope above few GeV, thus containing the electron/positron showers at energies up to TeV and more in a smaller volume as compared to standard detectors. Furthermore, if the W conversion foil is substitute by a crystalline W or high-Z crystal scintillator, the tracker length can be reduced and consequently the multiple scattering, with an improvement of the resolution in the localization of the gamma-ray, thus helping its identification.
The required 1° alignment precision needed for X0 reduction can be easily satisfied with “usual” satellites. Moreover, such an apparatus would continue to operate in a standard way in the absence of pointing.
Several fields of the astrophysics could be explored using the pointing strategy, for example:
1) observation of unidentified Fermi gamma-ray sources;
2) follow-up of flaring/transient and multimessenger sources;
3) pointing of the galactic center for the dark matter decay lines detection.
The connection with the TeV astrophysics from the ground is also fundamental and a detector in space able to see photons with increased efficiency in the range 10-100 GeV or more is what is needed for joint science with IACT observatories as CTA.
The idea of an oriented crystals based satellite may be useful in future missions, e.g., GAMMA-400.

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Observations of the Sun with Fermi-LAT in the first 10 years on-orbit

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We present the results of the observations of the Sun in its quiescent state with Fermi-LAT in almost 10 years on orbit. The high energy gamma-ray emission from the Sun is due to the interactions of cosmic ray (CR) protons and electrons with matter and photons in the solar environment. Such interactions lead to two component gamma-ray emission: a disk-like emission due to the nuclear interactions of CR protons and nuclei in the solar atmosphere and a space extended emission due to

the inverse Compton (IC) scattering of CR electrons off solar photons in the whole heliosphere. The observation of these two solar emission components may give useful information about the evolution of the solar cycle by probing two different CR components (proton and electrons) in regions not directly accessible by direct observations. The long period of observations allows us to study the variations of the emission between the maximum and the minimum of the solar cycle.
Moreover we will present an overview of the observation of the active Sun with Fermi, that has provided the largest sample of detected solar flares with emission greater than 30 MeV to date. The LAT data provides a new observational channel that, when combined with observations from across the electromagnetic spectrum, provide a unique opportunity to diagnose the mechanisms of high-energy emission and particle acceleration in solar flares.

Outreach / **49**

PONYS outreach activities

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Physics and Optics Naples Young Students (PONYS) is a group of students and young researchers of the Department of Physics at the University of Naples "Federico II".
Their missions are: outreach, networking and professional development. The activities organized by the group are financially supported by three main associations: the European Physical Society (EPS), the Optical American Society (OSA) and a society of photonics (SPIE).
In the last year PONYS organized and joined more than five big outreach events (hundreds to thousands of persons per event). The aim of our outreach activities is to find always new formats, new way to communicate to the others not only physical concepts but mainly our passion for science with the hope to ignite the sparkle of scientific curiosity especially in young guys.

Gamma-ray Astronomy / **140**

Particle Accelerators in Space: Recent News from VERITAS

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Our universe carries a small but important population of highly energetic denizens: supernova remnants with fast shocks, pulsars with powerful winds, intensely-interacting binary systems built from a compact object and a massive star, relativistic jets launched by supermassive black holes. All of these environments conspire to generate populations of nonthermal particles, and observations of the very high energy (VHE; E > 100 GeV) gamma rays produced by these particles are gradually revealing the methods by which Nature accelerates cosmic rays, as well as the ways in which those cosmic rays escape and diffuse into the interstellar medium. These observations include studies of cosmic-ray acceleration in the supernova remnants Cassiopeia A and IC 443, follow-up of unidentified HAWC sources, and the remarkable Fall 2017 periastron passage of VER J2032+4127, the 50-year-period binary system containing PSR J2032+4127 and a Be star. Fast TeV gamma-ray flares coincidental with the emergence of superluminal radio knots from the blazar BL Lac can be interpreted in terms of a coherent scenario of jet particle flow and radiation. The recent TeV gamma-ray discovery of the radio galaxy 3C 264 adds a new member to the small population of off-axis jets available for study. Meanwhile, the direct detection for the first time of gravitational wave (GW) transients by Advanced LIGO has motivated searches for their electromagnetic counterparts at all wavelengths. Neutrino astronomy is an emerging area of study in high-energy astrophysics, and

astrophysical neutrinos are natural cousins of VHE gamma rays. The VERITAS gamma-ray observatory has an active program of follow-up observations in the directions of potentially astrophysical high-energy neutrinos detected by IceCube, as well as in the direction of GW transients. In this talk, we discuss recent results from the VERITAS Galactic, Extragalactic, and Multi-Messenger Follow-up programs.

Instrumentation for Astroparticle Experiments / **4**

Performance of the FBK NUV HD technology for the realization of a camera prototype based on Silicon Photomultipliers for the Cerenkov Telescope Array project

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The Cerenkov Telescope Array (CTA) is a new generation observatory of ground telescopes for high energy gamma ray astronomy. The Italian Institute of Nuclear Physics (INFN) together with the Fondazione Bruno Kessler (FBK) is carring out an intensive R&D program to develop possible solutions for the Cherenkov photon cameras based on Silicon Photomultiplier (SiPM) devices at the near ultraviolet frequencies. SiPM technology is becoming very attractive in the fields of high energy and astroparticle physics thanks to the high Photon Detection Efficiency (PDE) and the price per mm2 of detector area. The sensors produced by FBK are different generations of NUV High-Density (NUV-HD) SiPMs grown on different substrates, based on a microcell of 40 μm × 40 μm and an area of 6 mm × 6 mm. A full characterization of the single devices will be reported in terms of gain, dark rate, cross talk and PDE in order to determine the best choice to arrange the optical modules (each made of a matrix of 4x4 SiPMs) that integrated with the readout electronics will be installed in the focal plane camera of the prototype of the Schwarzschild-Couder Telescope (pSCT) . An update on the recent quality tests and performance of the detectors arranged in this matrix configuration will be also given.

Cosmic Rays Direct Measurements / **135**

Results form the DAMPE space mission

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The DAMPE (DArk Matter Particle Explorer) satellite was launched on December 17th, 2015
and is in smooth data taking since few days after. It was designed in order to properly work for at least
three years and, thanks to its deep calorimeter, the precise tracking, and a large geometric factor,
is providing high quality measurements of leptonic and hadronic spectra up to about 10 and 100 TeV, respectively.
First results concerning gamma-ray astronomy, the all-electron energy spectrum,
and galactic protons and nuclei will be provided.

Indirect Measurements of High Energy Cosmic Rays / **43**

Results from the Telescope Array Experiment

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The Telescope Array (TA) is a hybrid experiment observing ultrahigh energy cosmic rays in the northern sky. Three fluorescence stations each view 108 degrees in azimuth and up to 30 degrees in elevation. They are located at the periphery of a ground array consisting of 507 plastic scintillator counters, of 1.2km spacing, and covering over 700 square kilometers. A low energy extension (TALE) is also in operation consisting of 10 high-elevation telescopes and an in-fill array of 103 surface detector counters. We will present the cosmic ray spectra from both TA and its low energy extension (TALE), covering a range of energies from below 10 PeV to over 100 EeV. We will also discuss current results from the measurements of mass composition by the TA group. Finally, we will present latest results from the search for arrival direction anisotropy.

Outreach / **3**

Search for coincident air showers over large scale distances with the EEE network

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The existence of time correlations in detectors separated by distances much larger of the size of the highest energy extensive air showers (EAS) has been long discussed over the years. Several mechanisms have been proposed to justify the existence of such events and, in the last decade, some experiments have also tried to search for correlations on a large scale distance, beyond one hundred kilometers. The approaches were based on the construction of clusters of telescopes placed at large relative distances, with the capability of selecting extensive air showers.
Within this context, the Extreme Energy Events (EEE) experiment can provide new inputs in the research of long distance correlations, thanks to its sparse array of muon telescopes distributed in several sites and spanning all the Italian territory.
The EEE telescopes are taking data since more than 10 years and enough statistics has been already accumulated to be able to search for such events, whose observation is intrinsically difficult due to the very low rates involved, many order of magnitudes smaller than the overall cosmic ray flux. In order to reduce the accidental correlations, different analysis approaches have been investigated for the selection of EAS events with the EEE telescopes. In this contribution we will present some few interesting correlation events obtained by analyzing most of the statistics
currently available, corresponding to an overall period of about 4000 days time exposure.

Neutrinos / **26**

Status and development of the KM3NeT/ARCA detector

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The multimessenger astronomy era has begun: combined measurement of gravitational waves, gammas and high-energy cosmic rays and neutrinos provide unprecedented tools to understand the birth and evolution of

cosmic sources. Hundred kilometres South West off Capo Passero, Sicily the KM3NeT Collaboration is building the ARCA neutrino detector, formed by 230 vertical units equipped with 130 thousand of photomultiplier tubes. With ARCA, high-energy neutrino sources can be identified thus providing the answer to the question of the origin of cosmic rays. The first two detection units of ARCA were deployed in 2015 and 2016 and operated till April 2017, providing valuable information for the validation of the detector technology, calibration methods and the water column properties. In 2017 another milestone was reached with the deployment of the first vertical unit of the low energy neutrino detector KM3NeT/ORCA offshore Toulon, France. The KM3NeT Collaboration is now producing detection units and refurbishing the seabed infrastructures to complete the first phase of KM3NeT with 24 detection units in ARCA and 7 in ORCA and subsequently start the extension towards a block of 115 detection units at each site. The status of the ARCA detector, data analysis and envisaged performances will be discussed.

Instrumentation for Astroparticle Experiments / 134

Status and perspectives for small-size photomultipliers

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Depending on the application, there is a large variety of small PMTs available on the market. The photocathode sensitivity ranges from the UV to the NIR; the characteristics of the PMTs depend on the specific application: scintillation readout, scintillation counting, high speed, Cherenkov, High Magnetic Field, low radioactivity, cryogenic experiments and so on. Moreover, the characteristics of the PMTs also depends on the research field application: collider, satellite, underwater and so on.

A summary of the available products and a comparison of their performance will be one of the main focus of this talk.

Eventually, we will focus on the PMTs used by three of the largest astro-particle experiments: Auger, CTA and KM3NeT. In particular, we will focus on the tools developed to perform the test and calibration of large samples and on the measured performance of these PMTs.

Multi-messenger Astronomy & Gravitational Waves / 6

Status of AdVirgo before the new Observation Run

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After the exciting results obtained by Advanced Virgo in the last joint run with LIGO, the observation of first GW source together with gamma and X satellites and astronomical observatories and the scientific outcomes of this revolutionary observation, we report on the status of Advanced Virgo before the next, new observation run and on the perspectives of the upgrades for the future

Multi-messenger Astronomy & Gravitational Waves / 11

Strategies for the Follow-up of Gravitational Wave Transients at Very High-Energy Gamma Rays with the Cherenkov Telescope Array

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With the observation of the first electromagnetic counterpart of Gravitational Wave (GW) transient GW170817, the potential of multi-messenger astronomy has been clearly demonstrated. In its full configuration, the Cherenkov Telescope Array (CTA) observatory will be capable of rapidly covering the regions localized by future GW observations with sufficient sensitivity at very high-energy gamma rays. In view of the forthcoming deployment of its first telescopes, we identify some general strategies for GW follow-up that will improve the CTA contribution to multi-messenger discoveries.

Indirect Measurements of High Energy Cosmic Rays / 8

Study of the origins of ultra-high energy cosmic rays with the Pierre Auger Observatory

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The persisting unknown origin of ultra-high energy cosmic rays is constantly investigated at the Pierre Auger Observatory on all angular scales.

Recent studies on the large angular scale have discovered the existence of anisotropy with a 5.2 \sigma level of significance in the arrival directions of events with energies higher than 8 EeV. This anisotropy can be described by a dipole with an amplitude of 6.5% toward right ascension of 100 degrees and declination of -24 degrees.

On an intermediate angular scale, sky models with extragalactic gamma-rays emitters such as Active Galactic Nuclei (AGN) and Starburst galaxies have been constructed using Fermi-LAT observations and compared with the highest energy events of the Pierre Auger Observatory. An excess in the arrival directions has been highlighted from the positions of strong and nearby sources with a significance of 4.0 \sigma for starburst galaxies and 2.7 \sigma for AGNs. All types of galaxies from the Swift-BAT and 2MASS surveys have been investigated for comparison.

This presentation aims to explain how these results have been obtained and the conclusions that can be drawn from them.

Neutrinos / 0

Tau Airshower Astronomy in space

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Highest energy neutrino in ICECUBE (hundred TeV or PeVs) suggested since five years the birth of a Neutrino Astronomy.
However the possible pollution by atmospheric neutrino signals, in particular prompt charmed ones, might offuscate the ability to discover the main astrophysical UHE neutrino sources. Indeed up to now no AGN or GRB or galactic sharp signal have detected.
A possible guaranteed, extraterrestrial, neutrino signals is made by the relativistic tau neutrino component. Above PeVs energies any astrophysical PeV tau neutrino (made by oscillation and mixing) may interact inside the terrestial crust, emerge from the Earth and decay upward in air. The consequent upward tau airshower may blaze into top mountain array (as Magic Telescopes) or satellites leading to a Tau Airshower Astronomy in space.
New satellite system and optical array detector for such tau airshowers will be shown: they might disentangle also high altitude hadronic UHE (PeV, EeV) Cosmic Rays.

Summary:

The new developed proposals of Tau Airshower (Also called Earth skimming) will be shown.

Instrumentation for Astroparticle Experiments / 13

The ASTRI Camera control software of the ASTRI SST-2M prototype for the Cherenkov Telescope Array

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Within the framework of the Cherenkov Telescope Array (CTA) observatory, the Italian National Institute for Astrophysics (INAF) is leading the “Astrofisica con Specchi a Tecnologia Replicante Italiana” (ASTRI) Project mainly devoted to the definition and development of a set of small-size class telescopes under dual-mirror optical design (SST-2M) for the CTA southern site. The prototype of such telescopes, named ASTRI SST-2M, is installed in Italy at the INAF “M.C. Fracastoro” observing station located in Serra La Nave, Mount Etna, Sicily. In addition to the dual-mirror optical design based on the Schwarzschild-Couder configuration, the ASTRI SST-2M telescope adopts a focal plane camera formed by an array of monolithic Silicon Photomultiplier (SiPM) sensors coupled with a specifically designed Front-End Electronics (FEE) and Back-End Electronics (BEE) that represent a further innovative solution for the detection of atmospheric Cherenkov light. The ASTRI SST-2M prototype is currently under completion of the overall commissioning phase: structure, mirrors, camera, control software, data archiving and analysis pipeline. This contribution focuses the attention to the software devoted to the control and monitoring operations of the ASTRI camera. We will provide a brief description of the electronic assemblies and of the software architecture designed, according to software engineering modularization, in terms of functional blocks and how they are deployed in the BEE. Then, we will show how all these functionalities are accessible by the user through the Graphical User Interface (GUI) developed and currently used for the engineering tests performed on site.

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The Astrophysical Multimessenger Observatory Network

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The Astrophysical Multimessenger Observatory Network (AMON) is the first continuous, real-time system designed to enable the discovery of the sources of transient multimessenger signals. By sifting through subthreshold event streams from several multimessenger facilities, and correlating them in real-time in search of coincident subthreshold events, AMON provides a significant enhancement in the effective aggregate sensitivity of the multimessenger facilities for a small fraction of the facilities' total cost. By distributing the positions of coincident events in real-time to follow-up facilities, AMON enables fast-response counterpart searches and studies across the electromagnetic spectrum. The existence and nature of such counterparts may prove decisive to establishing the existence of some of the first multimessenger sources. Finally, by spearheading the development of a community-based, shared infrastructure, AMON provides a unified, low-cost solution to coincident real-time analysis for all collaborations and their funding agencies.
In this talk, I will describe the AMON network, I will present the on-going subthreshold coincidence analyses to obtain new information about cosmic sources, and I will discuss the prospects of combining data from the electromagnetic, particle, and gravitational windows to advance high energy astrophysics into a new era.

Neutrinos / **132**

The Detection Unit of the KM3NeT: qualification, integration procedures and technical results

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KM3NeT is a multisite research infrastructure in the Mediterranean Sea hosting neutrino detectors. The basic element of the detectors is the detection unit. From a mechanical point of view, it is a flexible
structure anchored to the seabed that allows for a staged construction of the detectors. In this talk I will review the DU mechanical components and their features, the qualification and acceptance processes, the integration procedures. Moreover, the technical results obtained with the first detection units deployed over the last years at the Italian and French sites will be presented.

Outreach / **142**

The Distributed Electronic Cosmic-ray Observatory

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Camera image sensors in cell phones can be used as detectors not only of optical photons but also of high energy particles. The Distributed Electronic Cosmic-ray Observatory (DECO) is a citizen science project launched in 2014 to detect cosmic rays and other ionizing radiation using smart phones. It consists of a free app and associated public web-based data browser. Users in over 80 countries and all seven continents contribute to the data set. In addition to cosmic-ray muons, the data set includes particle events due to electrons and gamma rays from terrestrial radioactivity. We use computer vision for automatic particle identification. I will summarize the app and data set as well as the measurements we have made with DECO.

Indirect Measurements of High Energy Cosmic Rays / 39

The Extreme Universe Space Observatory on a Super Pressure Balloon (EUSO-SPB) Missions

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The Extreme Universe Space Observatory on a Super Pressure Balloon (EUSO-SPB), launched from Wanaka NZ, completed a 12 day flight above the Pacific Ocean in May of 2017. The mission goals were to observe high energy extensive air showers with a fluorescence detector looking down on the atmosphere, search for other transient signatures, and characterize the UV emission from Earth. Although the payload was lost, most of the data was downloaded.Preparation for a follow up mission, EUSO-SPB2, is in progress. EUSO-SPB2 will fly three telescopes. One will measure fluorescence light from air showers above 1 EeV. The other two will look for Cherenkov light from air showers at the PeV scale from near the earth's limb as a precursor to a search for cosmogenic tau neutrinos. EUSO-SPB2 will test methods and techniques that will be used in the dual satellite POEMMA (Probe of Extreme Multi-Messenger Astrophysics) space mission that is currently under a NASA sponsored conceptual design study.

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The Fermi view of GW170817

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The detection of the gravitational wave event GW 170817 by LIGO and Virgo was accompanied by the independent detection of the short Gamma-Ray Burst GRB 170817A by the Fermi Gamma-Ray Burst Monitor (GBM) and a follow-up observation with the Anti-Coincidence Shield for the Spectrometer of Integral (SPI-ACS). Here we focus on the results by Fermi-GBM, discussing the characteristics of the GRB and the constraints we derived on fundamental physics. Later observations by the Fermi Large Area Telescope (LAT) are also briefly presented. Finally, we want to highlight Fermi's key role at the dawn of the Era of Multimessenger Astronomy and to discuss prospects for the upcoming O3 observation run of LIGO/Virgo.

Instrumentation for Astroparticle Experiments / 19

The HEPD detector on board CSES satellite: in-flight performance

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CSES (China Seismo-Electromagnetic Satellite) is a scientific mission dedicated to monitoring electromagnetic field, plasma and particles perturbations of atmosphere and inner Van Allen belts caused

by solar and terrestrial phenomena and to the study of the low energy component of the cosmic rays. The satellite hosts several instruments onboard: two magnetometers, an electrical field detector, a plasma analyser, a Langmuir probe and two particle detectors. It has been successfully launched from the Jiuquan Satellite Launch Center located in west of inner Mongolia on February 2 2018 and is now orbiting in nominal condition.
The high energy particle detector (HEPD), designed and built by the Italian "Limadou" collaboration, aims at investigating precipitation of trapped particles induced by atmospheric EM emissions, as well as by the seismo-electromagnetic disturbances.
HEPD provides good energy resolution and high angular resolution for electrons (3-100 MeV) and proton (30-200 MeV). The instrument consists of: 2 planes of double-side silicon microstrip sensors placed on the top of the instrument (direction of particle); 2 two layers of plastic scintillators (trigger) and a calorimeter (constituted by other 16 scintillators and a layer of LYSO sensors). A scintillator veto system completes the instrument.
The commissioning of the HEPD and the other instruments on board is in progress and will last several months. In this contribution we will describe the HEPD detector and the (preliminary) performance in flight.

Neutrinos / **32**

The ICARUS experiment

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The 760 ton ICARUS T600 detector performed a successful three-year physics run at the underground LNGS laboratories, studying neutrino oscillations with the CNGS neutrino beam from CERN, and searching for atmospheric neutrino interactions. ICARUS performed a sensitive search for LSND like anomalous nu_e appearance contributing to constrain the allowed parameters to a narrow region around Δm2~eV2, where all the experimental results can be coherently accommodated at 90% C.L. The T600 detector underwent a significant overhauling at CERN and has now been moved to Fermilab, to be soon exposed to the Booster Neutrino Beam to search for sterile neutrino within the SBN program, devoted to definitively clarify the open questions of the presently observed neutrino anomalies.
The proposed contribution will address ICARUS achievements, its status and plans for the new run and the ongoing analyses also finalized to the next physics run at Fermilab.

Neutrinos / **45**

The Jiangmen Underground Neutrino Observatory

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JUNO is a Liquid Scintillator Detector (LSD) currently under construction in the south of China (Jiangmen city, Guangdong province). JUNO aims to detect reactor antineutrinos at a baseline of 53 km, with the goal of determining the neutrino mass ordering and performing a sub-percent measurement of three of the neutrino oscillation parameters. Its physics programme also includes the detection of supernova neutrinos, geoneutrinos and possibly solar neutrinos, making it a real multipurpose neutrino experiment. Once completed, JUNO will be the largest LSD ever built, consisting in a 20 kt target mass made of Linear AlkylBenzene liquid scintillator, monitored by 17000 20" high quantum efficiency (QE) photomultipliers (PMTs) providing a ~75% photo-coverage. Large photocoverage and large QE are indeed pivotal to reach a light level of 1200photoelectrons/MeV meant to

yield an unprecedented 3% total energy resolution at 1 MeV. JUNO will also be the first LAND to exploit a double calorimetry system comprising an additional set of 25000 3" PMTs meant to address the non-stochastic component of the energy resolution. In this talk I will describe JUNO's detector design, I will review its physics capabilities and I will shortly describe the experimental site and the related civil engineering.

Multi-messenger Astronomy & Gravitational Waves / **48**

The Laser Interferometer Gravitational-wave Observatory LIGO: Principles and Upgrades

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The first detections of gravitational waves from colliding black holes and neutron stars in 2015 and 2017 have started the field of gravitational-wave astronomy.
In this talk I will introduce some principles of the instruments making
these detections possible, focusing on the US-based LIGO detectors.
These exquisitely sensitive laser interferometers combine elements
from different fields of physics and engineering, such as mechanics, optics, electronics, material science, feedback control, electronics, and simulations.
I will also report on current upgrades and some future plans for LIGO.

The first multi-messenger event : GW170817 / **47**

The electromagnetic counterpart of the gravitational wave event GW170817

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With the gravitational event GW170817 on August 17th 2017 the Multi-Messenger astronomy era is started showing the capability of the synergic searches to provide an incredible amount of physical informations.
A world-wide effort has been carried out in optimizing the use of several observing facilities operating at all the available electromagnetic wavelenghts. This led to the identification and characterization of the electromagnetic counterpat of GW170817.
In this talk I will review such effort and the results obtained so far on the interpretation of the wealth of collected electromagnetic data.

The first multi-messenger event : GW170817 / **115**

The evolution of the X-ray and radio emission of GW170817/GRB170817A

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The electromagnetic counterpart of the binary neutron star merger GW170817 has been monitored from early to very late times at all wavelengths. In this talk, we discuss the temporal evolution of the associated afterglow emission in the X-rays and radio bands. These observations seem finally to support a flattening/decaying behaviour, favouring the "structured jet" interpretation for the origin of the electromagnetic emission.

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The gamma-ray properties of a sample of low-redshift BL Lacs

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With its discovery and characterization of several hundred sources, Fermi-LAT has revolutionized our knowledge and understanding of the BL Lac population with respect to other AGNs. The multi-wavelength picture has however not kept up the pace of the γ-ray observations. We have selected an unbiased sample of 42 nearby BL Lacs, located at z<0.2 and within the SDSS footprint, independent of flux density.
We have analysed data collected by the Fermi Large Area Telescope (LAT) during its first 8.5 years of operation in the energy range 0.1 – 300 GeV. We investigate the high-energy properties of the BL Lacs, and in particular the distribution of their γ-ray flux and photon index, and the connection between the γ rays and VLBI properties. The LAT-detected BL Lacs seem composed primarily of "classical" sources dominated by Doppler boosting and characterized by compact and bright radio emission as well as hard γ-ray spectra. However, three LAT-detected sources show non-classical properties for a γ-ray emitting BL Lac.

Multi-messenger Astronomy & Gravitational Waves / 117

The multi-messenger astronomy era : status and potential

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Despite much effort in the past, only very recently the first true multi-messenger measurements have been made. Gamma ray emission has been seen from a gravitational wave merger event and a gamma transient has been seen in coincidence with a high-energy neutrino event. Thus, the excitement and expectations are high, even though the journal papers are just written. Both events are transients of rather short duration, and only one event has been observed so far in each category. Theorists already use the events to constrain emission models. In this presentation, the current situation and the potential for future developments is assessed.

Cosmic Rays Direct Measurements / **22**

The satellite-based detector HERD: precise high-energy cosmic rays' physics and multimessenger astronomy.

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A few years from now, the HERD (High Energy Cosmic Radiation Detection) detector will be installed on the China's Space Station.
The main science objectives of HERD are searching dark matter particle, study of cosmic ray chemical composition up to the knee and high energy gamma-ray observations.
The main constraints imposed on HERD are: total weight less than around 2 tons and total power consumption less than around 2 kW.

HERD consists at the core of a very thick (3 lambda, 55 X0) cubic calorimeter made of small LYSO cubic crystals allowing 3D reconstruction; before the calorimeter there is a tracker
consisting of silicon micro-strip detectors and thin converter foils for gamma conversion; the detector is surrounded by plastic
scintillator plates for veto, trigger track charge measurements.
HERS will extend high precision and high statistics measurement of cosmic ray spectra to higher energy up to 1 PeV.
Furthermore it will provide high statistics and high resolution measurements of gamma-rays up to 1 TeV with large FOV
contributing to multimessenger astronomy together with ground based
high energy gamma-ray telescope (CTA,HAWC) and neutrino and gravitation wave detectors.

Summary:

The satellite-based detector HERD will provide high quality data on charged cosmic rays extending the measured range.
It will also collect large statistics of gamma-rays up
to very high energy contributing to multimessenger astronomy.

Neutrinos / **21**

Ultra-high energy neutrino searches and GW follow-up with the Pierre Auger Observatory

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The surface detector (SD) of the Pierre Auger Observatory is
sensitive to neutrinos at energies in the 100 PeV to 100 EeV range.
This sensitivity, together with its large acceptance, makes it a complementary detector to other neutrino telescopes, which have their peak sensitivities at lower energies.
The neutrino-induced air showers that the SD of the Pierre Auger
Observatory is sensitive to can be divided into those induced by
interactions of neutrinos of any flavor deep in the atmosphere,
and those induced by charged-current interactions of tau neutrinos in the Earth's crust.
Both of these types can be efficiently distinguished from cosmic ray-induced air showers, provided that their zenith angles are larger than 60 deg.
As no neutrino candidates were found in the performed searches, we
present limits on the diffuse all-flavor neutrino flux.

Using these limits, we obtained constraints on cosmic-ray and neutrino production models.
In the light of the recent observations of gravitational waves (GW), we also present the follow-up of LIGO/Virgo GW events.
These include binary black hole merger events and also GW170817, the only binary neutron star merger ever observed directly.

Instrumentation for Astroparticle Experiments / **51**

Using reference stars to verify the end-to-end absolute calibration and for the long term monitoring of the Fluorescence Detector telescopes at the Pierre Auger Observatory

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The absolute calibration of the Fluorescence Detectors telescopes of the Pierre Auger Observatory is an important element for correctly determining the energy of primary cosmic rays producing Extensive Air Showers in the atmosphere.
In this contribute we show that signals generated by stars traversing the field of view of the Fluorescence Detectors can effectively be used as a tool to verify the absolute calibration of these telescopes without requiring any dedicated external hardware device.
After describing the details of the procedure we report on the preliminary results obtained by the analysis of signals from reference stars as observed by the FD telescopes.

Summary:

Observation of reference stars is a simple and accurate procedure commonly used for the absolute calibration of optical telescopes, however, Fluorescence telescopes, that are designed to detect very short burst of light, are not able to directly measure the slowly varying night sky background flux.
It is possible, however, to overcome this limitation by the analysis of the statistical fluctuation (variance) of the signal recorded by the telescope detectors that, beeing directly proportional to the photon flux, allows to indirectly measure the star light and use it for calibration purposes. Without requiring any dedicated hardware device, and without any interference with normal telescope operations, the method developed provides an economical and simple way to verify the absolute calibration and to monitor the long-term stability of Fluorescence Telescopes.
In this contribution we describe details of the procedure, in particular on the correction of the star signals from atmospheric attenuation, and then report on results obtained by analysis of several reference stars as seen in the Fluorescence Telescopes of the Pierre Auger Observatory.

Outreach / **145**

Virgo Outreach

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Multi-messenger Astronomy & Gravitational Waves / **126**

Where are we coming from and where are we going: Comprehensive Multisensory Multimodal Integration in Gravitationa-wave Astrophysics

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The discovery of gravitational waves and their multimessenger fingerprint has opened tremendous opportunities for astrophysics. Extraordinary instrumental breakthroughs in gravitational-wave detectors on Earth and in Space, in electromagnetic and in neutrino observatories shall lead to an information explosion during the coming years and decades, rapidly expanding humanity's cosmic and scientific horizon. Multisensory observations of gravitational-wave sources promises opportunities that are complementary to insights gained through traditional means. After decades of focused efforts, the observation of an electromagnetic counterpart to the gravitational-wave event GW170817 by a multitude of instruments highlighted the value of multimessenger astrophysics and indicated that short gamma-ray bursts (GRB) could arise from mergers of pairs of neutron stars, and, more generally, that binary mergers are capable of accelerating particles and producing high-energy emission. Comprehensive Multisensory Multimodal Integration in gravitationa-wave Astrophysics is happening at an accelerated scale promising a bright future and shall bring new opportunities for LIGO, Virgo, Kagra and LISA.

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Where are we coming from and where are we going: Comprehensive Multisensory Multimodal Integration in Gravitationa-wave Astrophysics

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"THE PIERRE AUGER OBSERVATORY" a peculiar didactical ex-

perience between school and work

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In this presentation it will be described a peculiar educational experience with a class of Italian students aged 17-18 during the competition "at the school of Astroparticles" organized by the National Institute for nuclear physics INFN. It will also be shown how the action-research in scientific methodology formed an alternative, effective, and motivating approach to the study of Physics. Students had significant advantages thanks to the information and the scientific data recorded by the Pierre Auger Observatory and transmitted to a computer in an accessible area to process by the web. The teachers, researchers, and technicians of INFN were very helpful for the students who were able to reconstruct extensive atmospheric showers with computer software: intensity of signals, areas, directions and arrival times with data available for outreach activities of the Pierre Auger observatory, located in the Pampa Argentina on 3000Kmq of surface and composed of 1600 particle detectors and 24 fluorescence telescopes. This experience showed them an alternative captivating educational approach, having experienced the excitement of research, and having produced a scientific article and final software. The success of the educational activity is reflected both in auto-cognitive books written by the students themselves and in skills achieved in checks during the experience.

Summary:

- introduction to the didactical activity
- a brief history of cosmic rays
- the Pierre Auger Observatory (PAO)
- Pierre Auger Observatory data analysis
- data use for the reconstruction of the event
- effects in education

Outreach / **144**

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