# SCHOOL: Multi-Aspect Young-ORiented Advanced Neutrino Academy (MAYORANA) - International School II edition

# Report of Contributions

Contribution ID: **2** Type: **Poster & Mini-talk**

# Characterization and simulation of the low background GAGG neutron detector

A precise measurement of neutron flux is crucial for underground experiments, as neutrons may cause significant background for rare events searches. Due to the high neutron capture cross-section of the gadolinium isotopes present in cerium-doped $Gd_3Al_2Ga_3O_{12}$ (GAGG) crystal, combined with the high attenuation coefficient for efficient detection of neutron-induced γ rays, the GAGG scintillating crystal has the potential to show a clean signature for detecting neutrons. Furthermore, it features an excellent property of pulse shape discrimination that allows to distinguish signal-like events and backgrounds.
A prototype neutron detector has been assembled using a 100 $cm^3$ GAGG crystal coupled to a photomultiplier tube. It is operated in the Gran Sasso underground laboratory, aiming to detect high energy γ rays as the signal signature. This work presents the detector characterizations, regarding its performance and capabilities for particle identification, as well as intrinsic background. The neutron response measured underground will also be shown. In order to verify and optimize the setup, Monte Carlo simulations are performed, and the preliminary results will be discussed.

**Primary author:** CHU, Yingjie

**Presenter:** CHU, Yingjie

Contribution ID: **3** Type: **Poster & Mini-talk**

# γ decay of IAS in 71Ge: a new pathway to Gallium anomaly

Inverse beta decay (IBD) is a crucial process historically employed to study neutrinos.
For example, discrepancies between measured and expected IBD rates on (^{71}\text{Ga}), the so-called , suggest the possible existence of sterile neutrinos. A recent publication showed that the poorly known associated Nuclear Matrix Element (NME) can be extracted measuring the decay width from the Isobaric Analog State (IAS) in (^{71}\text{Ge}). In this talk, I will present the preliminary results from an experiment carried out in February 2025 at Laboratori Nazionali di Legnaro, aimed at studying the feasibility of this measurement.

**Primary author:** STRAMACCIONI, Damiano (Istituto Nazionale di Fisica Nucleare)

**Presenter:** STRAMACCIONI, Damiano (Istituto Nazionale di Fisica Nucleare)

Contribution ID: **4** Type: **Poster & Mini-talk**

# The first neutrino mass measurement of HOLMES experiment

The determination of the absolute neutrino mass scale remains a fundamental open question in particle physics, with profound implications for both the Standard Model and cosmology. The only model-independent method for measuring the neutrino mass relies on the kinematic analysis of beta decay or electron capture (EC) decay, assuming only momentum and energy conservation. Embedding the radioactive source inside the detector ensures that all the energy is measured except the fraction carried away by the neutrino, minimizing the systematic uncertanties. Such calorimetric approach is chosen by the HOLMES experiment.

The HOLMES experiment focuses on the electron capture decay of $^{163}$Ho, which has a low Q-value (2.863 keV) and a relatively short half-life ($T_{1/2} \sim$ 4570 years), making it ideal for high-resolution calorimetric measurements. HOLMES uses an array of ion-implanted transition-edge sensor (TES) microcalorimeters, achieving an average energy resolution of 6 eV FWHM and a time resolution of 1.5 $\mu$s. These superconducting devices operate in the transition between resistive and superconducting states at temperatures around 100 mK. Each TES is coupled to an implanted gold absorber containing $^{163}$Ho. When an interaction occurs, the resulting temperature rise is proportional to the deposited energy. The experiment utilizes a microwave SQUID Multiplexing ($\mu$ MUX) readout system, allowing multiple detectors to be monitored with minimal cabling.

Over two months, we collected $7 \times 10^7$ decay events, setting a Bayesian upper bound on the effective electron neutrino mass of $m_\beta < 27$ eV/c$^2$ at 90\% CI. These results validate the feasibility of $^{163}$Ho calorimetry for next-generation neutrino mass experiments and demonstrate the potential of a scalable TES-based microcalorimetric technique to push the sensitivity of direct neutrino mass measurements beyond the current state of the art. The scalability of this approach paves the way for larger arrays with higher single pixel activities thus increasing the recorded statistics and ultimately enabling sub-eV sensitivity in future experiments.

**Primary authors:** Dr GAMBA, Sara (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr CATTANEO, Alessandro (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr AHRENS, Felix (Fondazione Bruno Kessler (FBK), Povo (TN), Italy; Trento Institute for Fundamental Physics and Applications (TIFPA), INFN, Trento, Italy); Dr ALPERT, Bradley (National Institute of Standards and Technology (NIST), Boulder, Colorado, USA); Dr BALATA, Marco (Laboratori Nazionali del Gran Sasso (LNGS), INFN, Assergi (AQ), Italy); Dr BECKER, Daniel (University of Colorado, Boulder, Colorado, USA); Dr BENNETT, Douglas (National Institute of Standards and Technology (NIST), Boulder, Colorado, USA); Dr BEVILACQUA, Adriano (Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Genova, Genova, Italy); Dr BOGONI, Enrico (Fondazione Bruno Kessler (FBK), Povo (TN), Italy; Trento Institute for Fundamental Physics and Applications (TIFPA), INFN, Trento, Italy,); Dr BORGHESI, Matteo (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr CAMPANA, Pietro (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr CAROBENE, Rodolfo (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr CERUTI, Giancarlo (Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr CIAN, Alessandro (Fondazione Bruno Kessler (FBK), Povo (TN), Italy; Trento Institute for Fundamental Physics and Applications (TIFPA), INFN, Trento, Italy); Dr CRESCINI, Nicolò (Fondazione Bruno Kessler (FBK), Povo (TN), Italy; Trento Institute for Fundamental Physics and Applications (TIFPA), INFN, Trento, Italy); Dr DE GERONE, Matteo (Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Genova, Genova, Italy); Dr FAVERZANI, Marco (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr FERRARI BARUSSO, Lorenzo (Dipartimento di Fisica, Università di Genova, Genova, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Genova, Genova, Italy); Dr FERRI, Elena (Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr FOWLER, Joseph (National Institute of Standards and Technology (NIST), Boulder, Colorado, USA); Dr GALLUCCI, Giovanni (Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Genova, Genova, Italy); Dr GARD, John (University of Colorado, Boulder, Colorado, USA); Dr GARRONE, Hobey (Istituto Nazionale di Ricerca Metrologica (INRiM), Torino, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Torino, Torino, Italy); Dr GATTI, Flavio (Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Genova, Genova, Italy; Dipartimento di Fisica, Università di Genova, Genova, Italy); Dr GIACHERO, Andrea (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr GOBBO, Marco (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr HILTON, Gene (National Institute of Standards and Technology (NIST), Boulder, Colorado, USA); Dr IRACE, Alessandro (Fondazione Bruno Kessler (FBK), Povo (TN), Italy; Trento Institute for Fundamental Physics and Applications (TIFPA), INFN, Trento, Italy); Dr KÖSTER, Ulli (Institut Laue-Langevin (ILL), Grenoble, France); Dr LABRANCA, Danilo (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr LUSIGNOLI, Maurizio (Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Roma 1, Roma, Italy; Dipartimento di Fisica, Sapienza, Università di Roma, Roma, Italy); Dr MALNATI, Federico (Istituto Nazionale di Ricerca Metrologica (INRiM), Torino, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Torino, Torino, Italy); Dr MANFRINETTI, Pietro (Dipartimento di Chimica, Università di Genova, Genova, Italy); Dr MANTEGAZZINI, Federica (Fondazione Bruno Kessler (FBK), Povo (TN), Italy; Trento Institute for Fundamental Physics and Applications (TIFPA), INFN, Trento, Italy); Dr MARGESIN, Benno (Fondazione Bruno Kessler (FBK), Povo (TN), Italy; Trento Institute for Fundamental Physics and Applications (TIFPA), INFN, Trento, Italy); Dr MATES, John (National Institute of Standards and Technology (NIST), Boulder, Colorado, USA); Dr MAUGERI, Emilio (Paul Scherrer Institut (PSI), Villigen, Switzerland); Dr MONTICONE, Eugenio (Istituto Nazionale di Ricerca Metrologica (INRiM), Torino, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Torino, Torino, Italy); Dr MORETTI, Roberto (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr NISI, Stefano (Laboratori Nazionali del Gran Sasso (LNGS), INFN, Assergi (AQ), Italy); Dr NUCCIOTTI, Angelo (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr ORIGO, Luca (Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr PARODI, Luigi (Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Genova, Genova, Italy); Dr PESSINA, Gianluigi (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr RAGAZZI, Stefano (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy); Dr RAJTERI, Mauro (Istituto Nazionale di Ricerca Metrologica (INRiM), Torino, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Torino, Torino, Italy); Dr REINTSEMA, Carl (National Institute of Standards and Technology (NIST), Boulder, Colorado, USA); Dr SCHMIDT, Dan (National Institute of Standards and Technology (NIST), Boulder, Colorado, USA); Dr SICCARDI, Fabio (Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Genova, Genova, Italy); Dr SWETZ, Daniel (National Institute of Standards and Technology (NIST), Boulder, Colorado, USA); Dr

TALIP, Zeynep (Paul Scherrer Institut (PSI), Villigen, Switzerland); Dr ULLOM, Joel (National Institute of Standards and Technology (NIST), Boulder, Colorado, USA); Dr VALE, Leila (National Institute of Standards and Technology (NIST), Boulder, Colorado, USA)

**Presenter:** Dr GAMBA, Sara (Dipartimento di Fisica, Università di Milano-Bicocca, Milano, Italy; Istituto Nazionale di Fisica Nucleare (INFN), Sezione di Milano-Bicocca, Milano, Italy)

Contribution ID: **5** Type: **Poster & Mini-talk**

# CUORE Low-Energy Spectrum Sensitivity to Cosmic Axions

**Primary author:** SHAIKINA, Anastasiia (Gran Sasso Science Institute, Istituto Nazionale di Fisica Nucleare)

**Presenter:** SHAIKINA, Anastasiia (Gran Sasso Science Institute, Istituto Nazionale di Fisica Nucleare)

Contribution ID: **6** Type: **Poster & Mini-talk**

# Toward Precision Physics Test with CEνNS Cryogenic COHERENT CsI detector

The coherent elastic neutrino-nucleus scattering (CEνNS) is a neutral-current weak interaction in which a low-energy neutrino (tens of MeV) scatters off a nucleus, producing a small nuclear recoil that is extremely challenging to detect. Due to the low energies involved, this process was experimentally observed only in 2017 by the COHERENT experiment. Its significance lies in the fact that its cross section is considerably larger than that of other neutrino interactions at similar energies, making it a valuable tool for testing Standard Model parameters and searching for new physics. Moreover, CEνNS is also an important background component in experiments aimed at detecting dark matter.

My poster will present the potential of future COHERENT collaboration detectors using cesium iodide at cryogenic temperatures to constrain key parameters in electroweak physics. We will discuss the level of precision that can be achieved in measuring Standard Model parameters such as the Weinberg angle, the neutron distribution radius of iodine and cesium, and the neutrino charge radius. Furthermore, the prospects of probing new physics scenarios involving exotic neutrino properties and the existence of new mediators predicted by extensions of the Standard Model will also be explored.

**Primary author:** PAVARANI, Riccardo (Istituto Nazionale di Fisica Nucleare)

**Presenter:** PAVARANI, Riccardo (Istituto Nazionale di Fisica Nucleare)

Contribution ID: **7** Type: **Poster & Mini-talk**

# Inelastic neutrino scattering on argon

Low-energy neutrino processes on nuclei are a fundamental tool for studying weak interactions and nuclear structure. The dominant process at these energies is Coherent and Elastic Neutrino-Nucleus Scattering (CE$\nu$NS), which was measured on argon in 2020 by the COHERENT collaboration. As well as this, inelastic neutrino interactions on nuclei can also occur, mediated by charged or neutral currents, leading to the excitation of low-energy nuclear states. The study of these processes in argon nuclei is particularly relevant, given the large number of neutrino and dark matter experiments using argon as a target material. However, there are currently no experimental measurements of inelastic neutrino processes on argon, which are difficult to describe even from a theoretical point of view, given the need for a deep understanding of the nuclear structure.

Therefore, I have revisited the calculation of inelastic cross sections for both neutral and charged current interactions, with a focus on estimating the nuclear matrix elements necessary to describe the transitions that occur within the nucleus following a neutrino interaction. To refine these estimates, I considered available measurements on argon mirror nuclei, which are expected to exhibit similar characteristics, and photon scattering measurements on argon.

Improvements in the calculation of cross sections for inelastic neutrino processes on argon are relevant in order to estimate the number of inelastic events expected in experiments such as the future 750 kg argon detector of the COHERENT collaboration and the DarkSide-20k dark matter experiment.

**Primary author:** SESTU, Michela (Istituto Nazionale di Fisica Nucleare)

**Presenter:** SESTU, Michela (Istituto Nazionale di Fisica Nucleare)

Contribution ID: **8** Type: **Poster & Mini-talk**

# Analysis Chain of MONUMENT

The MONUMENT experiment investigates ordinary muon capture on isotopes relevant for $0\nu\beta\beta$ decay. Data were collected using two parallel acquisition systems, with this contribution focusing on ALPACA—an in-house developed system with fully offline analysis. The analysis chain comprises energy and time reconstruction, detector calibration, quality cuts, efficiency determination, and time-correlated event reconstruction to extract capture-induced de-excitation signatures. High-purity germanium detectors and photon counters are employed to identify correlated prompt and delayed signals from nuclear de-excitation. Background suppression is achieved through timing cuts and coincidence conditions. This contribution outlines the complete analysis procedure and presents first analysis findings on selected targets.

**Primary author:** Dr MONDRAGON, Elizabeth (Technical University of Munich)

**Presenter:** Dr MONDRAGON, Elizabeth (Technical University of Munich)

Contribution ID: **10** Type: **Poster & Mini-talk**

# PROBING SHORT RANGE CORRELATIONS IN HEAVY-ION DOUBLE CHARGE EXCHANGE REACTIONS

The high momentum transfer encountered in heavy ion Double Charge Exchange (DCE) reactions provides an ideal environment for studying correlation phenomena beyond mean-field in Nuclear Matrix Elements (NMEs). This investigation is of paramount interest for probing the nuclear counterpart of the elusive neutrinoless double beta ($0\nu\beta\beta$) decay. Currently, the NMEs for such a decay are embedded in a complex puzzle due to the large uncertainty in their determination [1]. Knowing with high precision the NMEs, the neutrino Majorana mass might be determined, provided the $0\nu\beta\beta$ lifetimes [2]. In this respect, the NUMEN [3] project aims to study a wide range of heavy-ion induced DCE reactions in order to provide constraints in the calculation of the NMEs [2].
The DCE reaction is mainly fed through three main competitive processes, namely multi-nucleon Transfer Double Charge Exchange (TDCE) [4], the Double Single Charge Exchange (DSCE) [5] and the Majorana Double Charge Exchange (MDCE) [6]. The latter is a meson exchange process mediated by an effective rank-2 isotensor interaction, coming from the off-shell pion-nucleon DCE scattering. It presents a pronounced short-range character, ranging from the dimension of about 1 fm. Microscopic calculations of MDCE-NMEs have been performed, where the pion potentials play the role of the strong interaction counterparts to the $0\nu\beta\beta$ neutrino potentials. The strong short-range correlations induced by the pion potentials leading to a new type of two-body transition form factors, which are of central importance and highest interest for nuclear spectroscopy.
The multipole structure of pion potentials and NMEs will be discussed, focusing on the importance and features of the pion potentials.

References

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**Primary authors:** GAROFALO, Caterina (Istituto Nazionale di Fisica Nucleare); CAPPUZZELLO, Francesco (Istituto Nazionale di Fisica Nucleare); LENSKE, Horst (Univ. Glessen); CAVALLARO, Manuela (INFN -LNS)

**Presenter:** GAROFALO, Caterina (Istituto Nazionale di Fisica Nucleare)

Contribution ID: **11** Type: **Poster & Mini-talk**

# A Novel Liquid Scintillator Setup for Beta-spectrum Measurements

The process of neutrinoless double beta decay (0νββ) plays a crucial role in nuclear and particle physics. While several feasible candidate isotopes are available and a multitude of experimental efforts are ongoing all over the world, the decay has eluded detection. The half life measured in 0νββ experiments is converted into effective neutrino mass, where one of the main sources of uncertainties is the understanding of nuclear matrix elements. The rate at which this rare decay occurs strongly correlates with the value of the effective weak axial vector coupling strength (gA).

We propose a new small-scale measurement setup using a well proven Liquid Scintillator (LS) technique and supplementing it with gamma-tagging. Such a detection technique has an advantage, measuring the $\beta^+$ decay energy deposition practically without a threshold and in coincidence with the two 511 keV gammas emitted from $e^+e^-$ annihilation. Precise coincidence gating by time and energy will allow for very efficient background suppression. The gamma-tagging can also be applied to gamma-cascades or singular gammas, extending the setup's reach to $\beta^-$ domain as well.

**Primary author:** AHOLA, Timo (University of Jyväskylä)

**Presenter:** AHOLA, Timo (University of Jyväskylä)

Contribution ID: **12** Type: **Poster & Mini-talk**

# Searching for 123-Te electron capture with CUORE

The electron capture decay of 123-Te to 123-Sb is a second-order unique forbidden decay with a Q-value of 51.9 keV. It provides an excellent means to explore the limits of current theoretical models of electron capture at high daughter nucleus angular momentum and low Q-value. The Cryogenic Underground Observatory for Rare Events (CUORE) is a cryogenic calorimeter experiment located at Gran Sasso National Laboratory which uses natural TeO2 crystals allowing for the investigation of this rare electron capture due to the presence of 123-Te in the crystals. New analysis techniques have enabled the use of approximately 2 years of data with thresholds down to 3 keV for a total TeO2 exposure of 11.4 kg-yr. In this work, I present the first study with CUORE data of both the K- and L-shell captures in 123-Te. I present observations of peaks at 4.69 ± 0.03 keV and 30.6 ± 0.1 keV corresponding to the L1- and K-shell lines of Antimony (Sb). These lines can be produced in Tellurium electron captures and they have been found to have constant signal rates of 19.2 ± 1.0 counts per kg-day and 1.2 ± 0.1 counts per kg-day, respectively, in CUORE data.

**Primary author:** MOORE, Maya

**Presenter:** MOORE, Maya

Contribution ID: **13** Type: **Poster & Mini-talk**

# Monitored neutrino beams: ENUBET design and prototype performance

Fundamental neutrino physics experiments at GeV scale struggle with large uncertainties in neutrino interaction cross sections, especially when statistical uncertainty for next generation experiments will no longer be the dominant uncertainty. The nuSCOPE collaboration (previously known with the working name of SBN@CERN), born from merger of ENUBET and NuTag collaborations, is trying to tackle this issue by desinging a beamline which leverages two novel technologies, those of monitored (ENUBET) and tagged (NuTag) neutrino beams. This beamline enables flux monitoring at the percent level and provides neutrino energy measurement independant of final state particle reconstruction at the detector. nuSCOPE collaboration is exploring the potential implementation of such a beamline at CERN. This poster focuses on the work of the ENUBET collaboration and the monitoring of the charged leptons produced in the decay tunnel with the goal of estimating the neutrino flux. An instrumented decay tunnel prototype of ENUBET design was built and its performance tested multiple times using a charged-particle beam at the CERN PS accelerator.

**Primary author:** Mr HALIĆ, Leon

**Presenter:** Mr HALIĆ, Leon

Contribution ID: **14** Type: **Poster & Mini-talk**

# CRAB: high-precision calibration for neutrino and dark matter experiments

Over the last few decades, major developments in cryogenic detectors have enabled detection thresholds in the energy range of a few tens of eV and resolutions in the energy range of a few eV, opening up unprecedented prospects in the search for rare events, such as the direct detection of dark matter and coherent elastic neutrino scattering on nuclei. The signal expected from these experiments takes the form of very low-energy nuclear recoil (from hundred eV to a few keV). Several calibration techniques are used to characterize cryo-detectors, but none offers a calibration that mimics the expected signal (a nuclear recoil) in the right energy range. The idea behind CRAB, which stands for Calibrated Recoil for Accurate Bolometry, is to offer an absolute calibration by inducing thermal neutron captures on the detector nuclei. A compound nucleus is then formed, with a known excitation energy - the neutron separation energy Sn - of between 5 and 8 MeV, depending on the isotope. If it deexcites by emitting a single gamma photon, the nucleus recoils with an energy of the order of 100eV, which is also perfectly known. As the detector has a cm-scale size, gamma escape without depositing any energy, and the measured energy in the cryo-detector is then due to nuclear recoils, creating calibration features.

My arrival in the collaboration coincides with the start of phase 2 of CRAB, the high-precision phase (high statistics + low background). For this purpose, the cryostat containing the cryo-detector has been moved to Vienna in Austria to the TRIGA Mk II research reactor (250 kW) to operate a pure thermal neutron beam (25 meV). A crown of BaF2 gamma detectors was installed around the cryostat to detect the gamma in coincidence with the nuclear recoil, to significantly increasing the signal-to-noise ratio.

This poster will present the new setup of CRAB phase 2. We will discuss the first commissioning data leading to the first observation of gamma/nuclear recoil coincidences, the update of 187W nuclear decay scheme, and to an overall good understanding of the setup.

**Primary author:** DOUTRE, Corentin (CEA)

**Presenter:** DOUTRE, Corentin (CEA)

Contribution ID: **15** Type: **Poster & Mini-talk**

# PNS parameters estimation with neutrino emission from supernovae

A novel functional form for fitting neutrino luminosities from core-collapse supernovae was recently proposed by Lucente et al. (2024), capturing the effects of convection inside the proto-neutron star (PNS) through a power-law temporal decay. While this model accurately describes the cooling phase, it does not account for the neutrino flux during, approximately, the first second, which is primarily driven by accretion. To address this, we introduce an additional term that models the early post-bounce phase in a simple yet effective way. After validating this extended model against multiple simulation datasets, we explore its applicability to SN1987A data. This approach allows us to extract meaningful estimates of the PNS temperature and radius. The radius is of particular interest, as it is closely linked to gravitational wave (GW) emission. Improved radius estimates may therefore enable joint neutrino-GW detection strategies and enhanced multi-messenger parameter inference.

**Primary authors:** TERNES, Christoph Andreas (Istituto Nazionale di Fisica Nucleare); PAGLIAROLI, Giulia (Istituto Nazionale di Fisica Nucleare); DRAGO, Marco (Istituto Nazionale di Fisica Nucleare); BALLELLI, Matteo (Istituto Nazionale di Fisica Nucleare)

**Presenter:** BALLELLI, Matteo (Istituto Nazionale di Fisica Nucleare)

Contribution ID: **16** Type: **Poster & Mini-talk**

# Energy calibration of bulk events in the BULLKID detector

BULLKID is a cryogenic, solid-state detector designed for direct searches of particle Dark Matter candidates, with mass ≤ 1 GeV/$c^2$, and coherent neutrino-nucleus scattering. It is based on an array of dice carved in 5 mm thick crystals, sensed by phonon mediated Kinetic Inductance Detectors. In previous works, the array was calibrated with bursts of optical photons, which are absorbed in the first micrometer of the dice and behave as surface events. In this work, I present the reconstruction of bulk events through
the X-rays generated by a $^{241}$Am source and by the lead holder of the detector.
The peaks resolution is ~ 4.5% and their mean are shifted by −10 % with respect to the optical calibration. The resolution is further improved by a factor ~ 1.9 combining the signal from neighbors dice. These results confirm the performance of the detector in view of the physics goals of the BULLKID-DM experiment.

**Primary author:** FOLCARELLI, Matteo (Istituto Nazionale di Fisica Nucleare)

**Presenter:** FOLCARELLI, Matteo (Istituto Nazionale di Fisica Nucleare)

Contribution ID: **17** Type: **Poster & Mini-talk**

# Improved description of double beta decay

We present the Taylor expansion formalism for describing the two-neutrino double-beta ($2\nu\beta\beta$) decay. In predicting the $2\nu\beta\beta$ decay spectra, we include the radiative and atomic exchange correction. We also investigate the impact of the electron phase shift on the angular correlation between the emitted electrons. Additionally, we examine the contribution of all s-wave electrons available for capture in the two-neutrino double electron capture ($2\nu$ECEC) processes, going beyond the $K$ and $L_1$ orbitals considered in prior studies. Finally, we propose a semi-empirical formula (SEF) for calculating the nuclear matrix elements (NMEs) for both the $2\nu\beta\beta$ decay and $2\nu$ECEC process. Compared with the previous phenomenological and nuclear models, the SEF yields the best agreement with the experimental NMEs.

**Primary authors:** Dr NITESCU, Ovidiu ("Horia Hulubei"National Institute of Physics and Nuclear Engineering; International Centre for Advanced Training and Research in Physics (CIFRA);); SIMKOVIC, Fedor

**Presenter:** Dr NITESCU, Ovidiu ("Horia Hulubei"National Institute of Physics and Nuclear Engineering; International Centre for Advanced Training and Research in Physics (CIFRA);)

Contribution ID: **18** Type: **Poster & Mini-talk**

# Majorana neutrino masses and neutrino-antineutrino oscillations

**Primary author:** CHVOSTÁLOVÁ, Miriam (Fakulta matematiky, fyziky a informatiky, UK v Bratislave)

**Presenter:** CHVOSTÁLOVÁ, Miriam (Fakulta matematiky, fyziky a informatiky, UK v Bratislave)

Contribution ID: **19** Type: **Poster & Mini-talk**

# The new gas tracker of the MAGNEX spectrometer for high-rate ion detection: an experimental challenge for the NUMEN project

The NUMEN (NUclear Matrix Elements for Neutrinoless double beta decay) project, as well as the NURE (NUclear REactions for neutrinoless double beta decay) project, have recently been proposed at the INFN-LNS laboratory to study Heavy-Ion-induced Double Charge Exchange (HI-DCE) reactions to provide data-driven information on the neutrinoless double beta (0νββ)-decay nuclear matrix elements. Since HI-DCE reactions are characterized by small cross sections (tens of nb), the use of high-intensity beams is a key feature: in this scenario, the ongoing upgrade of the LNS facility will have a crucial role. The experimental challenge the NUMEN project wants to address lies precisely in a substantial upgrade of the MAGNEX facility (installed at INFN-LNS laboratory), requiring a new focal plane detector (a low-pressure gas tracker based on a micropattern gas detector and a telescope array of SiC –CsI(Tl) for particle identification) and a scintillator array of LaBr3(Ce). These new devices must cope with extremely high fluxes of reaction products (up to MHz of ions) and should be sufficiently radiation-hard (up to fluencies of 10^13 ions/cm^2) while guaranteeing the good performance of the previous detection systems (to resolve mass ΔA/A~1/300, angles Δθ/θ~0.2° and energy ΔE/E ~1/1000).
An important phase of stand-alone characterization of these devices is in progress at both INFN-LNS and different laboratories. At INFN-LNS the use of different radioactive sources emitting α particles has allowed the unveiling of important features of the detector response, partially discussed in the present contribution. According to the specifications, the results obtained are promising, but new tests are needed to better understand the behaviour of the devices at high rates and fully integrate them into the spectrometer. In this view, a new test has already been performed at the Tandem facility at the University of São Paulo (Brazil) using well collimated beams (300 µm beam spot size) of medium/heavy ions at different rate.

**Primary authors:** PITRONACI, Antonino (UniCT Department of Physics & Astronomy "E. Majorana" - INFN Laboratori Nazionali del Sud); Dr BOIANO, Alfonso (INFN - Sezione di Napoli); Dr BRISCHETTO, Giuseppe (INFN - Laboratori Nazionali del Sud); Dr CALVO, Daniela (INFN - Sezione di Torino); Prof. CAPPUZZELLO, Francesco (UniCT Department of Physics & Astronomy "E. Majorana" - INFN Laboratori Nazionali del Sus); Dr CAVALLARO, Manuela (INFN - Laboratori Nazionali del Sud); Dr CIRALDO, Irene (INFN - Laboratori Nazionali del Sud); Dr PALLI, Konstantina (eDepartment of Physics and HINP, The University of Ioannina - Department of Chemistry, National and Kapodistrian University of Athens and HINP); Dr PIERROUTSAKU, Dimitra (INFN - Sezione di Napoli); Dr SARTIRANA, Diego (INFN - Sezione di Torino); Dr SGOUROS, Onoufrios (INFN - Laboratori Nazionali del Sud); Dr SOUKERAS, Vasilis (INFN - Laboratori Nazionali del Sud); Dr TORRESI, Domenico (INFN - Laboratori Nazionali del Sud)

**Presenter:** PITRONACI, Antonino (UniCT Department of Physics & Astronomy "E. Majorana" - INFN Laboratori Nazionali del Sud)

Contribution ID: **20** Type: **Poster & Mini-talk**

# Novel analysis techniques for neutrino and dark-matter experiments with the DIANA framework

Elusive particles like low-energy neutrinos and dark matter candidates require extremely sensitive detectors to be revealed. In experiments probing nuclear recoils, induced by sub-GeV dark matter particles or CE$\nu$NS, a low energy threshold and minimal backgrounds are mandatory. For these purposes, an advanced offline analysis of triggered pulses from the detector stream can make a significant difference.

The DIANA analysis software offers a portable, fast and open-source toolkit for low-energy physics analysis, featuring sophisticated signal processing techniques and utilities for higher level data fitting and analysis.

The software has been recently upgraded with modified versions of the matched filter, a digital filter for the amplitude estimation of a single waveform. Combining signals from different sensors with a multidimensional matched filter, it is possible to lower the detector energy threshold, and an advanced analysis of the signal shape can aid in signal/background discrimination.

**Primary author:** CAPPELLI, Matteo (Istituto Nazionale di Fisica Nucleare)

**Presenter:** CAPPELLI, Matteo (Istituto Nazionale di Fisica Nucleare)

Contribution ID: **21** Type: **Poster & Mini-talk**

# Designing and testing a phonon-mediated Kinetic Inductance Detector with phonon-funneling volume

Experiments searching for light dark matter or coherent elastic neutrino-nucleus scattering need to adopt detectors achieving very low energy thresholds, such as cryogenic phonon detectors. The phonon-mediated detection of silicon particle absorbers has been already proved with Kinetic Inductance Detectors, acting as phonon collectors and sensors at the same time.
We developed a first prototype of KID coupled to a separate structure of phonon absorbers for improving the sensitivity of the detector. This consists of a thin KID trilayer of Aluminium/Titanium/Aluminium coupled to a large Aluminum phonon collecting volume. With this contribution, we would present the studies and simulations we carried out and preliminary results to test the performances of such a new device, compared with those of a standard KID.

**Primary author:** PESCE, Leonardo (Sapienza / Istituto Nazionale di Fisica Nucleare)

**Presenter:** PESCE, Leonardo (Sapienza / Istituto Nazionale di Fisica Nucleare)

Contribution ID: **22** Type: **Poster & Mini-talk**

# FACT - Multi-wavelength and Multi-messenger Studies with the FACT Telescope

The First G-APD Cherenkov Telescope (FACT) is located at an altitude of 2200 meters a.s.l. on the island of La Palma. It was built to monitor bright blazars in the TeV energy range. In addition, FACT carries out follow-up observations of multi-wavelength and multi-messenger alerts. Its camera, which is based on silicon-based photosensors, allows observations during strong moonlight. The operation is automatic and remote, enabling a response to alerts within seconds to minutes. Since observations began in October 2011, 15.000 hours worth of data have been collected, of which about 25 hours were taken during automatic follow-up observations of transient alerts since May 2019.
In total, FACT followed more than 65 multi-wavelength and multi-messenger alerts, mostly triggered by blazar flares, gamma ray bursts, and high-energy neutrino events. Based on these follow-up observations, multi-band spectral energy distributions, light curves and correlations with multi-wavelength and multi-messenger data are studied. The data provide constraints for emission models and for the attenuation of gamma rays by photon-photon pair production in the low-energy extragalactic background radiation. The poster summarises the multi-wavelength and multi-messenger program of FACT from more than ten years of observations.

**Primary author:** BRAND, Katharina (Universität Würzburg)

**Co-authors:** ABHIR, Jayant (ETH Zurich); BALBO, Matteo (ISDC, Observatoire de Genève, Université de Genève); BILAND, Adrian (ETH Zurich); BRETZ, Thomas (RWTH Aachen University); DORNER, Daniela (Universität Würzburg); ELSAESSER, Dominik (Universität Würzburg); GÜNTHER, Patrick (Universität Würzburg); HASAN, Syed (ETH Zurich); HILDEBRAND, Dorothee (ETH Zurich); MANNHEIM, Karl (Universität Würzburg); NOETHE, Maximilian (TU Dortmund); PARAVAC, Aleksander (Universität Würzburg); PFEIFLE, Felix (Universität Würzburg); RHODE, Wolfgang (TU Dortmund); SCHLEICHER, Bernd (Universität Würzburg); SLIUSAR, Vitalii (Université de Genève); VORBRUGG, Marcel (Universität Würzburg); WALTER, Roland (Université de Genève)

**Presenter:** BRAND, Katharina (Universität Würzburg)

Contribution ID: **23** Type: **Poster & Mini-talk**

# Towards uniform detector response in large-scale KID arrays for Dark Matter searches with BULLKID-DM

Over the last decade, searches for sub-GeV particle Dark Matter (DM) candidates have rapidly advanced. Light Dark Matter particles detection represents a challenge because it requires sensitivity to faint nuclear recoils and thus very low energy threshold ($\mathcal{O}(0.1)$ keV). At the same time, accessing lower cross-section ranges demands high-mass targets. The BULLKID-DM experiment aims to reconcile these requirements by employing a monolithic array consisting of a stack of silicon wafers, carved in dices of
$5.4 \times 5.4 \times 5$ mm$^3$, yielding a total mass of 800 g and over 2000 dice. Particle interactions within each die generate phonons, which are detected by Kinetic Inductance Detectors (KIDs). However, the calibration of such large amount of single detectors is technically complex since the phase responsivity of each KID depends on the resonators' properties and on the applied readout power. We describe a possible reconstruction algorithm to extract the resonant frequency shift signal $\delta f_0/f_0$ in a manner that it is independent of individual KID charachteristics - such as quality factor and resonant frequency - and has limited dependance on the resonator's bias power.

**Primary author:** QUARANTA, Davide (Istituto Nazionale di Fisica Nucleare)

**Presenter:** QUARANTA, Davide (Istituto Nazionale di Fisica Nucleare)

Contribution ID: **24** Type: **Poster & Mini-talk**

# Probing the unseen: Prospects for sterile neutrino searches using the NINJA detector

Although the standard three-flavor neutrino framework has been firmly established, several experimental anomalies remain that cannot be explained within this model. One possible explanation involves extending the paradigm by introducing a light sterile neutrino - an SU(2) singlet that does not interact via the weak force. While this extension is theoretically well motivated, experimental confirmation is still lacking. The NINJA experiment, designed to measure neutrino-nucleus cross-sections using nuclear emulsion films and a high-intensity neutrino beam from J-PARC, also offers an opportunity to explore new physics beyond the Standard Model. In particular, its short-baseline configuration makes it a promising candidate for investigating sterile neutrino oscillations at the eV-scale. In this poster, I present a sensitivity study of NINJA to sterile neutrino parameters. I examine the impact of different flux configurations, including on-axis and off-axis beams, as well as various exposure scenarios, such as the combination of data from two detector locations. The analysis includes expected event rates and demonstrates how NINJA could contribute to constraining sterile neutrino parameters in future runs.

**Primary author:** BARČOT, Doris (Ruđer Bošković Institute)

**Presenter:** BARČOT, Doris (Ruđer Bošković Institute)

Contribution ID: **25** Type: **Poster & Mini-talk**

# The Gallium Anomaly: An Unsolvable Puzzle?

The study of neutrino interactions with matter has provided significant insights into the properties of neutrinos and the dynamics of weak interactions. One particularly intriguing puzzle is the so-called "Gallium Anomaly", observed in the GALLEX, SAGE, and more recently the BEST experiments, which measure the neutrino capture process on gallium,
$\nu_e + {}^{71}Ga \rightarrow e^- + {}^{71}Ge$, historically used for the detection of solar neutrinos.
Surprisingly, the event rate induced by neutrinos on ${}^{71}Ga$ is systematically lower than theoretical predictions, reaching a discrepancy with a significance of $5\sigma$ following the results of the BEST experiment. This anomaly has raised questions about the validity of theoretical cross-section calculations and their implications for physics beyond the Standard Model.
One of the main challenges in calculating the cross section lies in estimating the nuclear matrix element that describes the transition between the initial gallium state and the final germanium state. To compute it, one uses the matrix element of the inverse process—namely, electron capture in germanium—whose rate is experimentally measured.
In my work, I used a numerical code to solve the Dirac equation in a central potential in order to obtain the bound-state electron wavefunctions in germanium. The same code consistently computes the Fermi function, which accounts for the distortion of the outgoing electron wavefunction due to the Coulomb field.
This approach allows testing the assumptions underlying the cross-section calculation—such as the shape of the nuclear charge distribution—leading to a more robust determination and thereby contributing to the theoretical description of the process at the heart of the Gallium Anomaly.

**Primary author:** FERRO, Luca (Istituto Nazionale di Fisica Nucleare)

**Co-authors:** DORDEI, Francesca (INFN CA); CADEDDU, Matteo (Istituto Nazionale di Fisica Nucleare)

**Presenter:** FERRO, Luca (Istituto Nazionale di Fisica Nucleare)

Contribution ID: **26** Type: **Poster & Mini-talk**

# In-situ Time Calibration of KM3NeT ARCA

KM3NeT (Kilometre Cube Neutrino Telescope) is the largest underwater observatory worldwide. It is composed of two detectors deployed in two sites of the Mediterranean Sea (ARCA in the Ionian Sea and ORCA in the Ligurian Sea), and it is designed to detect high-energy (> 100 GeV) neutrinos through the Cherenkov radiation. The reconstruction of the neutrino direction relies on the detection of Cherenkov photons emitted by secondary charged particles, and achieving high angular resolution requires nanosecond-level time synchronization between photomultipliers. To meet this goal, the KM3NeT ARCA detector has recently implemented a full White Rabbit (WR)-based system for time synchronization, reaching a ns accuracy in time distribution across the detector components. This work presents the description of implementation of this timing architecture, detailing the on-shore calibration procedures of the White Rabbit system. System performance is further evaluated through an in-situ validation using the laser beacon, a powerful light source deployed on the seafloor that enables independent checks of the timing calibration.. Additionally, the work discusses a new calibration system within the KM3NeT Collaboration to intercalibrate darkrooms, ensuring a common timing reference across all production sites, thus enhancing the consistency and reliability of the detector.

**Primary authors:** PAESANI, Daniele (Istituto Nazionale di Fisica Nucleare); RICCOBENE, Giorgio Maria (Istituto Nazionale di Fisica Nucleare); TORRISI, Maria Rita (Istituto Nazionale di Fisica Nucleare)

**Presenter:** TORRISI, Maria Rita (Istituto Nazionale di Fisica Nucleare)