6th Symposium on Neutrinos and Dark Matter in Nuclear Physics 2018

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Book of Abstracts

Contents

Parallel Session 2-8 / 6

Directional Search for Dark Matter Using Nuclear Emulsion

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A variety of experiments have been developed over the past decades, aiming at the detection of Weakly Interactive Massive Particles (WIMPs) via their scattering in an instrumented medium. The sensitivity of these experiments has improved with a tremendous speed, thanks to a constant development of detectors and analysis methods. Detectors capable of reconstructing the direction of the nuclear recoil induced by the WIMP scattering are opening a new frontier to possibly extend Dark Matter searches beyond the neutrino background. Exploiting directionality would also give a proof of the galactic origin of dark matter making it possible to have a clear and unambiguous signal to background separation. The NEWSdm experiment, based on nuclear emulsions, is a new experiment proposal intended to measure the direction of WIMP-induced nuclear recoils with a solid-state detector, thus with a high sensitivity. We discuss the discovery potential of a directional experiment based on the use of a solid target made of newly developed nuclear emulsions and novel read-out systems achieving nanometric resolution. We also report results of a technical test conducted in Gran Sasso.

Parallel Session 1-1 / 7

Results from the CUORE experiment

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The Cryogenic Underground Observatory for Rare Events (CUORE) is the first bolometric experiment searching for neutrinoless double beta decay that has been able to reach the 1-ton scale. The detector consists of an array of 988 TeO2 crystals arranged in a cylindrical compact structure of 19 towers. The construction of the experiment and, in particular, the installation of all towers in the cryostat was completed in August 2016 and data taking started in spring 2017. In this talk we present the neutrinoless double beta decay results of CUORE from examining a total TeO2 exposure of 86.3 kg yr, characterized by an effective energy resolution of 7.7 keV FWHM and a background in the region of interest of 0.014 counts/(keV kg yr). In this physics run, CUORE placed a lower limit on the decay half-life of 130Te > 1.3E25 yr (90% C.L.). We then discuss the improvements in the detector performance achieved in 2018, the new results on the background model and the latest update on the study of rare processes in Tellurium.

Parallel Session 1-2 / 8

Interesting Models unifying Neutrino Mass, Dark Matter, Origin of PMNS and CKM, and GUT

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The Standard Model of particle physics have been extremely successful so far, but there are still many unanswered questions like the origin of neutrino mass, nature of dark matter, the source of quark and lepton flavor mixing and their possible correlation, the theory of grand unification of all SM interactions. In this talk I will focus on some interesting models that attempt to answer these questions and possible correlation between them. Embedding a Pati-Salam quark-lepton unification symmetry, $SU(4)_c \otimes SU(2)_L \otimes U(1)_R$, into SU(7) GUT with a Scotogenic radiate neutrino mass and LHC phenomenology will be discussed. I will also touch on $G_{SM} \otimes U(1)_{B-L}$ with residual Z_4 symmetry leading to Scotogenic radiative Dirac neutrino masses with dark matter, $0\nu4\beta$ and absence of $0\nu2\beta$ signal and phenomenology of related rare processes. Possible common origin of CKM and PMNS mixings in a complete model. Other possible topics will include chiral dark sector with composite dark matter leading to Scotogenic two loop neutrino mass and neutrino portal to SM.

Plenary Session 4 / 9

Review of underground laboratories: science and technology.

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Underground laboratories are multidisciplinary research infrastructures with a rock overburden of the order of 1000 meter-water-equivalent.
A number of these infrastructures (15) are at work in the north hemisphere and three new ones are underway, two in the south hemisphere.
A description of the main characteristics of the existing facilities is given.
Due to the significant cosmic ray flux reduction a number of rare events processes can be searched for in underground laboratories, in particular neutrino interactions, neutrinoless double beta decay, and dark matter. Yet, these infrastructures offer a unique opportunity to search also for rare geophysics phenomena, such as weak oscillations from the Earth's core, and in the next future for gravitational waves. A summary of the main physics case in underground laboratories is reported.
Underground laboratories can play a crucial role to drive new technologies. A few selected examples of technologies developed in the framework of underground laboratories are discussed.
Recently, the need of sharing work load and develop synergy between underground laboratories has been growing. A couple of examples are reported.

10

Neutrinoless $\beta\beta$ nuclear matrix elements using IVSD $J^\pi = 2^-$ data

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Ground-state-to-ground-state neutrinoless double beta ($0\nu\beta\beta$) decays in nuclei of current experimental interest are revisited. In order to improve the reliability of the nuclear matrix elements (NMEs) for the light Majorana-neutrino mode, the NMEs are calculated by exploiting the newly available data on isovector spin-dipole (IVSD) $J^\pi = 2^-$ giant resonances obtained at RCNP, Osaka.

In order to correctly describe the IVSD up to and beyond the giant-resonance region, the present computations are performed in extended no-core single-particle model spaces using the proton-neutron quasiparticle random-phase approximation (pnQRPA) with two-nucleon interactions based on the Bonn one-boson-exchange G matrix. The appropriate short-range correlations, nucleon form factors, higher-order nucleonic weak currents, and partial restoration of the isospin symmetry are included in the calculations. The results are compared with earlier calculations of Hyvärinen and Suhonen [Phys. Rev. C **91**, 024613 (2015)] performed in much smaller single-particle bases without access to the IVSD $J^\pi = 2^-$ giant-resonance data reported here.

The study offers a new way of fitting the g_{ph} parameter of pnQRPA to the measured IVSD giant resonance instead of fitting it to the Gamow-Teller giant resonance in the traditional way. In fact, we study three different combinations to fit this parameter to available data and study the associated errors in the $0\nu\beta\beta$ NMEs.

11

Ordinary muon capture as a probe of $\beta\beta$ decays

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A reliable description of the double-beta-decay processes needs a possibility to test the involved virtual transitions against experimental data. Unfortunately, only the virtual transitions trough lowest J^π states can be probed by the traditional electron capture or β^--decay experiments. The ordinary muon capture (OMC) offers a versatile tool to analyze the nuclear structure of the intermediate states involved in double-beta-decay processes. In the present work the OMC rates for muon captures on the nuclei ^{24}Mg, ^{32}S and ^{56}Fe populating the low-lying states of the nuclei ^{24}Na, ^{32}P and ^{56}Mn are calculated.

The nuclear states for isobaric doublets ^{24}Mg, ^{24}Na, ^{32}S, ^{32}P and ^{56}Fe, ^{56}Mn are computed by the nuclear shell-model code NuShellX@MSU. The $A = 24$ and 32 states are computed in the sd-shell and $A = 56$ states in the pf-shell using different interactions without any configuration restrictions. The nuclear matrix elements and partial capture rates to the lowest J^π states of the daughter nuclei are computed using the one-body transition densities (OBTDs) given by the shell-model code.

It has been found that the two lowest 1^+ intermediate states play a significant role in the OMC processes. Also, the
lowest 2^+ state has a strong impact on the transition rates. The OMC process can be used to probe the structure of the
intermediate states appearing in the double-beta-decay process since the associated momentum exchange is of the
order of 100 MeV, i.e. the same amount which is carried by the virtual Majorana neutrino in the neutrinoless
double beta decay. Experimental measurements in the near future can help
fine-tune the nuclear-structure parameters for the double-beta-decay calculations, but also give access to the
effective values of the axial-vector coupling g_A and the induced pseudoscalar coupling g_P.

Parallel Session 2-2 / 12

The Dark Sector Physics at the Belle II Experiment

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The Belle II experiment is a next-generation upgrade of the Belle detector and will operate at SuperKEKB, an energy-asymmetric e^+e^- collider. The accelerator has completed the first phase of commissioning in 2016, and the first electron-positron collisions in Belle II are expected in 2018. The design luminosity of SuperKEKB is $8 \times 10^{35}\mathrm{cm}^{-2}\mathrm{s}^{-1}$ and the Belle II experiment aims to record 50 ab^{-1} of data, a factor of 50 more than the Belle experiment. This data set offers the possibility to search for a large variety of dark sector particles in the GeV mass range, complementary to LHC and dedicated low energy experiments. These searches will profit both from the size of the Belle II data, and from specifically designed triggers for the early running phase of Belle II. This talk will review planned dark sector searches with a focus on the discovery potential of the first data.

Parallel Session 1-6 / 13

Double-charge exchanges for double beta decays

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The reach of neutrinoless double-beta (0νββ) decay searches that aim to observe lepton number violation and show that neutrinos are Majorana particles, depends on the nuclear matrix elements that govern the decay. The calculated nuclear matrix elements, however, suffer from several limitations. Predicted matrix-element values depend on the many-body method used to obtain them and, in addition, they may need to be "quenched", albeit by an unknown amount. These uncertainties are hard to figure out from theoretical calculations alone because of the unique character of 0νββ decay, not clearly related to other nuclear structure observables.

In this presentation I will note the relation between the 0νββ decay, and double Gamow-Teller (DGT)transitions that can in principle be measured in double charge-exchange reactions. Shell model calculations in a very wide range of nuclei, covering from Ca-48 to Xe-136, suggest a linear correlation between 0νββ decay and DGT transitions. Furthermore, the correlation is in agreement with results from energy-density functional theory. These findings open the door to informing the value of 0νββ decay nuclear matrix elements in nuclear structure experiments.

Parallel Session 1-8 / 14

Forbidden spectral shapes: Implications to reactor-antineutrino anomaly

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Highly-forbidden non-unique beta-decays are known to have electron-spectrum shapes which depend on the effective value of the axial vector coupling constant g_A [1, 2]. Resent calculations show that this is also the case for many first-forbidden non-unique decays. Moreover, the spectral shapes of first-forbidden $J^+ \leftrightarrow J^-$ decays with $J \neq 0$ are found to depend also on the value of the axial-charge matrix element, which is known to be enhanced in nuclear medium due to meson-exchange effects [3, 4].

In the reactor-antineutrino analysis the beta decays contributing to the cumulative electron spectrum are usually assumed to have allowed spectral shapes. However, about 30 \% of these decays are actually first-forbidden. In some cases, like in the case of the ground-state-to-ground-state decay of ^{140}Cs (see figure), this is found to be a rather poor approximation. Based on the recent results, the use of the allowed-approximation can at least partially explain the so called reactor antineurtino anomaly.

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15

Development of surface alpha ray detector with a low alpha-emitting μ-PIC

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In a direct search for the dark matter, leading experiments makes use of massive and low background detectors. Particularly, the detector is required to design with low radio purity materials, whose impurities such as U-238 and Th-232 are in the ppb level. We have been developing a new detector of alpha-rays emitted from the material surface based on a time projection chamber technology. NEWAGE-0.3a, which was used to a direction-sensitive dark matter direct search in Kamioka mine underground, was modified and used. The detector has an advantage of a position sensitivity in comparison with a conventional alpha-ray detector, thus it is possible to obtain alpha–rays'emission distribution in the sample surface. NEWAGE-0.3a was upgraded with a low alpha-emitting μ-PIC,

whose impurities were reduced less than 10^{-4}alphas/hr/cm^2. Furthermore, a new algorithm to determine the sense of the alpha-ray track, whether from the sample or from the μ-PIC, and the sensitivity was improved by another factor 2. As a result, the sensitivity as background level was improved by factor 10, to 10^{-2}alphas/cm^2/hr. Upgradable plans to achieve the goal of less than 10^{-4}alphas/cm^2/hr are also presented.

Parallel Session 1-1 / **16**

Status of CALDER: Kinetic Inductance light detectors for neutrinoless double beta decay

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The development of large area cryogenic light detectors is one of the priorities of next generation bolometric experiments searching for Majorana neutrinos. The simultaneous read-out of the heat and light signals enables particle identification, provided that the energy resolution and the light collection are sufficiently high. CALDER (Cryogenic wide-Area Light Detectors with Excellent Resolution) is developing phonon-mediated silicon light detectors using kinetic inductance detectors (KIDs), with the goal of sensing an area of 5x5 cm^2 with an energy resolution of ~ 20 eV RMS. I will present the latest results obtained with aluminum chips and with newly developed multilayer titanium-aluminum chips featuring unprecedented sensitivity.
Work based on arXiv:1801.08403 and given on behalf of the CALDER collaboration.

Plenary Session 5 / **17**

Status and Results of the XENON1T Dark Matter Search

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XENON1T is a dark matter search experiment located at the Gran Sasso Underground Laboratory in Italy. It uses two tonnes of liquid xenon to search for interactions from the weakly interacting massive particles. Recent results from XENON1T and the status of its upgrade XENONnT, will be presented.

Parallel Session 2-2 / **18**

Dark Side of the Neutron?

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There is a long-standing discrepancy between the neutron lifetime measured in beam and bottle experiments. We propose to explain this anomaly by a dark decay channel for the neutron, involving one or more dark sector particles in the final state. If any of these particles are stable, they can be the dark matter. We construct representative particle physics models consistent with all experimental constraints.

Parallel Session 1-3 / 19

Status of the KamLAND-Zen experiment

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KamLAND-Zen is a double beta decay experiment with the enriched xenon-loaded liquid scintillator. Increasing the number of double beta-decay nucleus is a key to improve the sensitivity on the neutrinoless decay mode. Among a dozen of target nuclei, xenon gas is easily solved in the liquid scintillator by about 3 wt%, so the experiment with about 400 kg xenon (KamLAND-Zen 400) became feasible early and demonstrated excellent sensitivity after the intensive purification. Our search constrains the effective neutrino mass scale below ~100 meV, and the most advantageous nuclear matrix element calculations indicate the limit reaches near the bottom of the quasidegenerate neutrino mass region. We will soon start the next phase with about 800 kg xenon (KamLAND-Zen 800) to start to constrain the inverted mass hierarchy region.

Parallel Session 1-2 / 20

The latest results of the Majorana Demonstrator

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The Majorana Demonstrator is an ultra-low background experiment searching for neutrinoless double-beta decay in ^{76}Ge at the Sanford Underground Research Facility. The high radiopurity of the detectors and components, combined with the excellent energy resolution of the HPGe detector array, allows the Demonstrator to double as both a neutrinoless double beta decay experiment at higher energy, and a dark matter and solar axion experiment at low energies. The search for neutrinoless double-beta decay could determine the Dirac vs Majorana nature of neutrino mass and provide insight to the matter-antimatter asymmetry in the Universe. In my talk, I will discuss the latest results of the Demonstrator's neutrinoless double-beta search and its low energy program.

This material is based upon work supported by the U.S. Department of Energy, Office of Science, Office of Nuclear Physics, the Particle Astrophysics Program of the National Science Foundation, and the Sanford Underground Research Facility. We acknowledge the support of the U.S. Department of Energy through the LANL/LDRD Program.

Plenary Session 5 / 21

First results from DAMA/LIBRA–phase2

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The first results obtained by the DAMA/LIBRA–phase2 experiment are presented. The data have been collected over 6 independent annual cycles corresponding to a total exposure of 1.13 ton × yr, deep underground at the Gran Sasso National Laboratory of the I.N.F.N. The DAMA/LIBRA–phase2 apparatus, about 250 kg highly radio-pure NaI(Tl), profits from a second generation high quantum efficiency photomultipliers and of new electronics with respect to DAMA/LIBRA–phase1. The improved experimental configuration has also allowed to lower the software energy threshold. The DAMA/LIBRA–phase2 data confirm the evidence of a signal that meets all the requirements of the model independent Dark Matter annual modulation signature, at 9.5 σ C.L. in the energy region (1–6) keV. In the energy region between 2 and 6 keV, where data are also available from DAMA/NaI and DAMA/LIBRA–phase1, the achieved C.L. for the full exposure (2.46 ton × yr) is 12.9 σ.

Parallel Session 2-4 / **22**

CDEX dark matter experiment at CJPL : status and plans

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Germanium detectors with sub-keV sensitivities 1 offer a unique opportunity
to search for light WIMP Dark Matter and axion-like particles. We will highlight our results and status of CDEX dark matter experiment [2] at the China Jinping Underground Laboratory (CJPL) [3] in China. The detector R&D programs which allow us to experimentally probe this new energy window will be discussed, especially the new bulk/surface events separation scheme. Recent results from axion searches, as well as results from non-modulated and modulated dark matter searches [2] will be described. Status of the construction of CJPL-II will be presented.

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Plenary Session 1 / **23**

Neutrino masses, double beta-decay nuclear matrix elements and quenching of axial-vector coupling constant

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The present-day results of the calculation of the $0\nu\beta\beta$-decay nuclear matrix elements are discussed. The progress in the calculation of the double beta decay NMES within the QRPA is presented. A

connection between the $2\nu\beta\beta$-decay and $0\nu\beta\beta$-decay matrix elements is analyzed. An impact of the quenching of the axial-vector coupling constant on double-beta decay processes is investigated and a novel approach to determine the quenched value of axial-vector coupling constant is proposed. The question is addressed whether light and heavy neutrino contributions to $0\nu\beta\beta$-decay are experimentally distinguishable. In that context the "interpolating formula"for the $0\nu\beta\beta$-decay is revisited. Several simplified benchmark scenarios within left-right symmetric models are considered and the conditions for the dominance of the light or heavy neutrino mass mechanisms are analyzed

Parallel Session 1-7 / 25

Direct Detection Prospects for the Cosmic Neutrino Background and Other Cosmic Relics

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The Cosmic Neutrino Background is a solid prediction of the Standard Model of Cosmology and Particle Physics. There is plenty of indirect evidence for its existence but so far it escaped direct detection. I will explain the difficulties in such an endeavor and present some recent ideas and proposals for it. Interestingly, some of the proposals could act simultaneously as a dark matter experiment.

Plenary Session 6 / 26

Status of COSINE-100 experiment

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The COSINE-100 experiment searches for dark-matter interactions using an array of scintillating NaI(Tl) crystals that serve both as a WIMP-interaction target and detector in the low-background environment of the Yangyang underground laboratory. The main goal is to check the annual modulation signal observed by DAMA/LIBRA in an NaI(Tl) crystal array. The experiment has been running for more than 1.5 years stably. Several analyses in addition to the annual modulation analysis are actively ongoing. Here, the performance of the detector and recent results will be presented.

Plenary Session 10 / 27

Interpretation of results on astrophysical neutrinos

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The results on astrophysical neutrinos are discussed, such as the possible origin of the diffuse flux, the implications of multi-messenger constraints, and the interpretation of observations from individual sources. Furthermore, the role of photo-nuclear interactions in neutrino astrophysics is highlighted.

Parallel Session 1-1 / 28

Neutrino properties deduced from the neutrinoless double beta decay study

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Double beta decay is a rare nuclear process of great interest due to its potential to provide information about physics beyond the Standard Model (BSM). For example, the discovery of the neutrinoless double-beta decay mode could give key information regarding conservation of symmetries: as lepton number, CP and Lorentz, or neutrino properties as: neutrinos character (are they Dirac or Majorana particles?), neutrino absolute masses and their hierarchy, existence of sterile neutrinos, etc. Theoretically, the DBD study consists in the precisely computation of the nuclear matrix elements (NME) and phase space factors (PSF) entering the DBD half-lives formulas, for different decay modes and transitions to final ground or excited states of the parent nuclei. Reliable computations of these quantities result in reliable predictions of DBD half-lives and constrains of the BSM parameters appearing in the possible mechanisms that may contribute to the neutrinoless double-betadecay.

In my talk I give first a short review of the theoretical challenges in the study of neutrinoless double-beta decay. Then I present a new, more reliable, approach to calculate the products NMEs x PSFs and I deduce new limits for the neutrino mass parameters for the light and heavy neutrino exchange scenarios.

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Parallel Session 1-6 / 29

Precise Q-Value Measurements for Neutrino Physics

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The list of open issues in neutrino physics is long. We do not know, for instance, the absolute neutrino mass value, the neutrino type (Majorana or Dirac), or whether there are sterile neutrinos.
Penning-trap mass spectrometry can help solve some of these issues by determining the Q-values of certain beta and double-beta processes with high precision.
This contribution will give a brief overview of an extended and diverse experimental campaign carried out with existing high-precision Penning-trap facilities in the field of neutrino physics. The focus will be put on our past and present activity at SHIPTRAP and on a future physical program for the next generation Penning-trap mass spectrometer PENTATRAP.

Plenary Session 2 / 30

SNO+

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The SNO+ experiment is the successor to the Sudbury Neutrino Observatory. It will contain 780 tonnes of 0.5% Te-loaded liquid scintillator in order to search for neutrinoless double beta decay of Te-130. Prior to loading with tellurium in 2019, SNO+ will be filled with unloaded liquid scintillator and will detect solar, reactor and geo neutrinos. The SNO+ detector is currently filled with water and has been taking data (water-filled detector) since May 2017. Results and background studies from the SNO+ water phase will be presented.

Parallel Session 2-7 / 31

Solar neutrino flux at keV energies

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We calculate the solar neutrino and antineutrino flux in the keV energy range. The dominant thermal source processes are photoproduction ($\gamma e \to e\nu\bar{\nu}$), bremsstrahlung ($e+Ze \to Ze+e+\nu\bar{\nu}$), plasmon decay ($\gamma \to \nu\bar{\nu}$), and $\nu\bar{\nu}$ emission in free-bound and bound-bound transitions of partially ionized elements heavier than hydrogen and helium. These latter processes dominate in the energy range of a few keV and thus carry information about the solar metallicity. To calculate their rate we use libraries of monochromatic photon radiative opacities in analogy to a previous calculation of solar axion emission. Our overall flux spectrum and many details differ significantly from previous works. While this low-energy flux is not measurable with present-day technology, it could become a significant background for future direct searches for keV-mass sterile neutrino dark matter.

Parallel Session 1-1 / 32

Status of the AMoRE neutrinoless double beta decay experiment

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The AMoRE (Advanced Mo-based Rare process Experiment) intends to find an evidence for neutrinoless double beta decay of Mo-100 by using a cryogenic technique with molybdate based crystal scintillators. The crystals, which are cooled down to 10~20 mK temperatures, are equipped with MMC-type phonon and photon sensors to detect both thermal and scintillation signals produced by

a particle interaction in the crystal to achieve high energy resolution and efficient particle discrimination. The AMoRE-pilot, almost completed as an R&D phase, is an array of six 48deplCa100MoO4 crystals with a total mass of about 1.9 kg and is running at the 700-m-deep YangYang underground laboratory. The AMoRE-I will have about 5 kg of crystals, mostly 48deplCa100MoO4 and several R&D crystals such as Li2100MoO4 and Na2100MoO7. Significant improvement of effective Majorana neutrino mass sensitivity at the level of inverted hierarchy of neutrino mass, 20-50 meV, could be achieved by the AMoRE-II with 200 kg of molybdate crystals at the new 1,000 m deep underground laboratory excavated by the end of 2019 in the Handeok iron mine. We have already secured 50 kg of Mo-100 isotope out of 120 kg contracted for the AMoRE-II experiment. Results of the AMoRE-pilot and status of the AMoRE-I and AMoRE-II preparation will be presented.

Parallel Session 1-7 / 35

First observation of coherent elastic neutrino-nucleus scattering and continued efforts of the COHERENT Collaboration

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More than 40 years after its theoretical description, the process of coherent elastic neutrino-nucleus scattering (CEνNS) has been observed for the first time by the COHERENT Collaboration, using a 14.6-kg CsI[Na] detector at the Spallation Neutron Source of Oak Ridge National Lab. COHERENT and other groups continue to work towards additional CEνNS measurements because of the breadth of physics sensitivity shown by the process, including connections to nuclear structure, astrophysics, dark sector physics, and other physics beyond the Standard Model. Details of the initial observation of CEνNS will be presented along with an overview of the physics program within the COHERENT Collaboration, comprised of measurements of both CEνNS on other target nuclei as well as additional neutrino processes, including charged-current interactions on iodine and neutrino-induced neutron production on lead. The complementarity of additional CEνNS measurements will be explored, emphasizing the importance of additional, diverse experimental efforts.

Parallel Session 2-1 / 36

Low energy neutrino reactions induced by supernova neutrinos with some artificial neutrino sources

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In this talk, we discuss some feasible low energy neutrino sources and possible physics by the neutrinos emitted from them. One of them is the search for the existence of the fourth neutrino, we propose two experimental methods for short baseline electron antineutrino disappearance study.

One is a source from 8Li generator under non-accelerator system. For 8Li production, we suggest to use 252Cf source which is an intense neutron emitter and thus produces 8Li isotope through 7Li(n,g)8Li reaction, effectively. Using the 8Li generator, one does not need any accelerator or reactor facilities because the generator can be placed on existing and/or planned any neutrino detectors as closely as possible.

The other is a method using 13C beams and a 9Be target. The production of secondary unstable isotopes which can emit neutrinos from the 13C + 9Be reaction is calculated with three different nucleus-nucleus (AA) reaction models. Different isotope yields are obtained using these models, but the results of the neutrino flux are found to have unanimous similarities. This feature gives an opportunity to study neutrino oscillation through shape analysis.

For the effect of possible sterile
neutrinos, by using the two methods, we obtain the results of expected neutrino flux and event rates, and show neutrino
disappearance features and possible reaction rate changes by the sterile neutrino using the spectral shape analysis.

Finally, we discuss possible low energy neutrino-induced reactions from the neutrino sources and give a short introduction of the neutrino window concept which can be useful for the neutrino-induced reactions in the supernova explosion.

Plenary Session 1 / **37**

Neutrino nuclear responses for astroneutrinos and double beta decays

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We report briefly recent studies of neutrino nuclear responses for astro-neutrinos and double beta decays by using charge exchange reactions (CERs). Neutrino nuclear responses (square of nuclear matrix elements NMEs) are crucial for neutrino studies in nuclei.
Subjects discussed include experimental studies of nuclear muon and neutrino CERs at RCNP Osaka Univ. and the re-normalization (quenching) of the axial vector weak coupling. It is shown that the axial vector NMEs for GT and SD transitions are re-normalized (quenched) in a nucleus by the coefficient of k=0.5-0.6 with respect to the pnQRPA NMEs in a wide momentum region of 2-80 MeV/c. This is considered to be due to nucleonic and non-nucleonic correlations and nuclear medium effect.

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Parallel Session 2-1 / **39**

Leptogenesis in the minimal Scotogenic Model through annihilation and coannihilation of scalar Dark Matter

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In this letter we have explored the possibility of embedding the genesis
of lepton asymmetry within the well studied *Scotogenic* model. We have shown that in this model one can have a Dark Matter in the TeV scale. The model is highly constrained in the context of dark matter,neutrino mass, Flavor Physics and now also gets an additional constraint on the relative complex phases from the required lepton asymmetry which eventually converts to the observed baryonic asymmetry
through the spheleron transition during the electroweak phase transitions.

Plenary Session 6 / 40

Ab Initio Calculations and Double-Beta Decay

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Ab-initio calculations of weak processes are making progress. Here I discuss the ab initio framework for double beta decay and the explanation of the quenching of gA that emerges from calculations within the Green's function Monte-Carlo, coupled-clusters, and in-medium similarity-renormalization-group approaches.

Plenary Session 9 / 41

Results on 0ν Double Beta Decay with CUPID-0

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CUPID-0 represents the first demonstrator of **CUPID**, CUORE Upgrade with Particle IDentification. It exploits the scintillating bolometer technique in order to disentangle the nature of the interacting particles.
The detector consists of an array of 24 ZnSe crystals 95% enriched in ^{82}Se and two natural ZnSe crystals for a total mass of 10.5 kg installed in a dilution refrigerator located underground in the Laboratori Nazionali del Gran Sasso.
We will report the first result of the search for neutrinoless double beta decay (0νDBD) in ^{82}Se based on the data collected between June and November 2017. We find no evidence in a 3.45 kg· yr exposure and we set the most stringent lower limit on the 0νDBD ^{82}Se half life >2.4· 10^{24} yr (90% C.I.) which corresponds to an effective Majorana neutrino mass $m_{\beta\beta}$ < (376-770) meV.
Thanks to the simultaneous readout of the heat and light signals we reach the lowest background level ever achieved with bolometric experiments: $(3.6^{+1.9}_{-1.4})\cdot 10^{-3}$ counts/(keV·kg·yr).

Parallel Session 2-5 / 42

Present and projected sensitivities of Dark Matter direct detection experiments to effective WIMP-nucleus couplings

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Assuming for WIMPs a Maxwellian velocity distribution in the Galaxy we explore in a systematic way the relative sensitivity of present and projected Dark Matter direct detection experiments to each of the 14 couplings that parameterize the most general non-relativistic effective Hamiltonian allowed by Galilean invariance for the elastic scattering off nuclei of WIMPs up to spin 1/2. We perform our analysis in terms of two free parameters: the WIMP mass and the ratio between the WIMP-neutron and the WIMP-proton couplings.

43

Non-linear neutrino flavor transitions beyond the mean-field approximation

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Large numbers of neutrinos are produced in several cosmological and astrophysical sites such as the early universe, core-collapse supernovae and neutron-star mergers. Neutrino self-interactions in such luminous neutrino backgrounds are believe to induce non-linear neutrino flavor transitions which transform the spectra of all species of neutrinos dramatically. Increased electron type neutrinos through neutrino flavor transitions enhance reaction rates of neutrino absorptions on free nucleons, which affects macroscopic hydrodynamics and nucleosynthesis. Therefore, a precise neutrino transport is required to reveal the mechanism of astrophysical phenomena. Previous numerical studies always assume the mean-field approximation and employ the effective one-body Hamiltonian. However, there is no quantitative discussion which guarantees the validity of such approximation.

In this presentation, we mention the equations of self-interacting neutrinos using exact two-body Hamiltonian. The higher order effects beyond the mean-field approximation are reduced to neutrino collisional terms. The sufficient condition of this approximation is revealed quantitatively. The order estimate shows that the mean-field approximation proves to be a good approximation in previous numerical studies.

Parallel Session 2-3 / 44

Latest results from the XMASS experiment

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XMASS is a multi-purpose experiment using a single-phase liquid-xenon scintillator
detector located underground at Kamioka Observatory in Japan. We are continuously taking data since November 2013 for more than four years. Leveraging a low-energy threshold and low background, XMASS has performed various researches especially in fields of dark matter and neutrinos, both of which are in the scope of this NDM conference. We conducted not only the standard WIMP search, but also various dark matter searches such as annual modulation, bosonic super-WIMPs, and WIMP-129Xe inelastic scattering searches. XMASS is also pursuing various researches

in particle and astroparticle physics such as supernova neutrino observation, solar axion, and two-neutrino double electron capture searches. In this talk, we will present the latest physics results from XMASS.

Parallel Session 1-2 / 45

DOUBLE BETA DECAY WITH NEMO-3 AND SUPERNEMO

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Neutrinoless double beta decay ($0\nu\beta\beta$) is the only
practical way to understand the neutrino nature (i.e. whether it is a Dirac or a Majorana
particle) and to observe full lepton number violation required by most beyond the standard model scenarios.

The goal of the SuperNEMO experiment is to search for $0\nu\beta\beta$ decay. Its technology is based on a successful design approach of the NEMO-3 experiment which was running at the Modane Underground Laboratory in the Frejus Tunnel under the French-Italian Alps in $2003 - 2011$. The unique features of this approach are the ability to study almost any $\beta\beta$ isotope and reconstruction of the event topology which produces a "smoking gun" evidence for the process and may allow the underlying physics mechanism to be disentangled.

The latest updates on the final NEMO-3 results obtained with 7 different $\beta\beta$ isotopes are presented.
The physics reach of the SuperNEMO project is
discussed and the status of the integration and commissioning of its first module, the Demonstrator, as well as its physics sensitivity are presented.

Plenary Session 10 / 46

Status of JUNO

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The Jiangmen Underground Neutrino Observatory (JUNO) is a medium-baseline reactor neutrino experiment, currently under construction in South China. The chosen site is equidistant from two nuclear power plants at the 53 km solar oscillation maximum. The combined projected thermal power of the reactors will be 35.8 GWth. The central detector will consist of a large acrylic sphere, 35.4 m in diameter, supported by a stainless-steel truss. The primary goal of JUNO is to resolve the neutrino mass hierarchy with at least 3σ significance by reconstructing energy spectrum of reactor neutrinos registered using 20 kT of liquid scintillator. To reach this goal an unprecedented energy resolution of 3% @ 1 MeV must be achieved, and a multitude of technical challenges solved. JUNO is also expected to improve the precision of solar oscillation parameters and the atmospheric mass-squared splitting to better than 1%. As a multi-purpose detector, JUNO can also detect geoneutrinos, neutrinos from core-collapse supernovae, search for dark matter, sterile neutrinos, and other non-standard interactions. The excavation of the experimental hall started in March 2018. JUNO collaboration has now 550 members from 72 institutes in 16 countries and continues to grow. This talk will present the physics case, the design, and the latest status of JUNO.

Co-Authors (Collaboration):

JUNO Collaboration

Plenary Session 2 / **47**

Study of the neutrinoless double beta decay of Mo-100 with the CUPID-Mo demonstrator

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The LUMINEU project has recently set up a technology for the development of high-performance scintillating bolometers containing the nuclide ^{100}Mo, in the framework of the R&D activities towards the tonne-scale neutrinoless double beta decay ($0\nu2\beta$) experiment CUPID. Using in particular $Li_2{}^{100}MoO_4$ detectors, high energy resolution (~5-6 keV FWHM at 2615 keV), excellent α background rejection (~99.9 %) and extreme radiopurity (below 10 μBq/kg U/Th intrinsic activity) have been demonstrated in multiple tests with remarkable reproducibility. Moreover, with only ~0.1 kg$\times$yr of ^{100}Mo exposure, the measured two-neutrino 2β decay half-life is one of the most precise values ever reported. As a follow-up of this activity, a demonstrator named CUPID-Mo is ready to collect data in the Modane underground laboratory in France. CUPID-Mo consists of twenty 0.2-kg ^{100}Mo-enriched Li_2MoO_4 scintillating bolometers (containing more than 2 kg of ^{100}Mo) to be operated for at least 0.5 yr, providing a sensitivity to $0\nu2\beta$ of ^{100}Mo larger than 10^{24} yr. A prolongation of the experiment and its extension to available ~7 kg of ^{100}Mo are under consideration.

Parallel Session 1-5 / **48**

Cosmological Lithium Problem

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Big Bang nucleosynthesis (BBN) theory predicts the abundances of the light elements D, ^{3}He, ^{4}He and ^{7}Li produced in the early universe. The primordial
abundances of D and ^{4}He inferred from observational data are in good agreement with predictions, however, the BBN theory overestimates the primordial ^{7}Li
abundance by about a factor of three. This is the so-called "cosmological lithium problem". Solutions to this problem using conventional astrophysics and nuclear
physics have not been successful over the past few decades, probably indicating the presence of new physics during the era of BBN. We have investigated the impact on
BBN predictions of adopting a generalized distribution to describe the velocities of nucleons in the framework of Tsallis non-extensive statistics. This generalized
velocity distribution is characterized by a parameter q, and reduces to the usually assumed Maxwell-Boltzmann distribution for q = 1. We find excellent agreement
between predicted and observed primordial abundances of D, ^{4}He and ^{7}Li for $1.069 \leq q \leq 1.082$, suggesting a possible new solution to the cosmological
lithium problem.

Parallel Session 2-2 / **50**

Self-interacting dark matter, muon g-2, and neutrino physics in a gauged Lmu-Ltau model

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Our current understanding of the large-scale structure of the Universe is based on the cold dark matter model.
Observed small-scale (sub-galactic) matter distribution, on the other hand, appears to challenge this standard paradigm.
Self-interaction between dark matter particles reconciles small-scale issues by flattening the dark matter density profile inside halos.
I will present a particle physics model of self-interacting dark matter with the cross section diminishing with increasing velocity, which maintains the success of the cold dark matter model above galactic scales.
The model is based on a gauged Lmu-Ltau extension of the standard model, where the mu and tau leptons and neutrinos in addition to dark matter particles couple to a new gauge boson.
Interestingly, it ameliorates the discrepancy of the measured muon g-2 with the standard model prediction and the small-scale issues in the structure formation at the same time.
I will demonstrate how the neutrino physics experiments, such as Borexino (solar neutrino experiment), IceCube (high-energy neutrino observatory), and Planck (cosmological measurement of effective number of neutrino degrees of freedom), constrain its parameter space.

Parallel Session 1-4 / 51

PandaX-III neutrinoless Double beta decay experiment and its prototype detector

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The PandaX-III (Particle And Astrophysical Xenon Experiment III) experiment will search for Neutrinoless Double Beta Decay (NLDBD) of ¹³⁶Xe at the China Jin Ping underground Laboratory (CJPL). PandaX-III exploits the tracking capability of gaseous TPC to effectively identify possible signal and suppress background. The first TPC will contain 200 kg of enriched xenon at 10 bar. Fine pitch micro-pattern gas detector (Microbulk Micromegas) will be used for the charge readout to reconstruct tracks of NLDBD events and provide good energy resolution (3% FWHM) and millimeter level spatial resolution. A 20 kg scale prototype TPC with 7 Micromegas modules, the first application of Microbulk Micromegas in TPC of this size, has been built and commissioned. In this talk, I will give an overview of recent progress of PandaX-III, including data taking of the prototype TPC.

Parallel Session 2-6 / 52

Measuring the Neutrino Mass Hierarchy with the KM3NeT/ORCA Detector

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The ORCA detector (Oscillations Research with Cosmics in the Abyss) is an underwater Cherenkov neutrino telescope that constitutes the low energy branch of the KM3NeT project, a next generation neutrino oscillation experiment located in the Mediterranean. The primary goal of KM3NeT is to solve the question of neutrino mass ordering through the measurement of matter oscillation effects using atmospheric neutrinos. The ORCA detector has a design optimized for low (<100GeV) energies of neutrinos, with densely configured detection units, and is being deployed at the French KM3NeT site ~40 km offshore Toulon, at a depth of 2500 m. ORCA will use multi-PMT modules, called Digital Optical Modules (DOMs), to exploit the optical properties of deep seawater for accurate reconstruction of cascade and track neutrino event topologies. The current status of the ORCA detector and the current sensitivities for determining the neutrino mass hierarchy, as well as potential for constraints on other oscillation parameters, will be presented in this talk.

Parallel Session 2-8 / 53

Search for Boosted Dark Matter at Surface Detectors

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Searching for cosmic-origin rare new physics signals at Earth-surface-based detectors is usually challenging because of huge cosmic backgrounds.
In order to avoid such a challenge, underground experiments are thus strongly motivated.
If a signal of interest involves many features, however it becomes possible to isolate signal events from background ones.
Along this line, I discuss boosted dark matter (BDM) searches at ProtoDUNE putting a particular focus on the so-called inelastic BDM (iBDM) whose experimental signatures come with many features.
Moreover, if the expected signal signature is featureless, quarrying the rare signals out of cosmic backgrounds is believed almost hopeless.
However, I claim that surface-based detectors can achieve remarkable sensitivities even for featureless signals, by restricting to the events coming from the bottom side of the detector.
Potential cosmic backgrounds are thus significantly rejected while penetrating the Earth by the "Earth Shielding"effect.
To validate this "Earth Shielding"effect, I discuss the detection prospects of BDM as a benchmark scenario, at several surface experiments including SBN Program (MicroBooNE, ICARUS, and SBND) and ProtoDUNE.

Parallel Session 1-8 / 54

Status of the KATRIN experiment and the first tritium measurements

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The goal of the \textbf{KA}rlsruhe \textbf{TRI}tium \textbf{N}eutrino (KATRIN) experiment is the determination of the electron neutrino mass $m(\nu_\mathrm{e})$ with a sensitivity of 0.2\,eV/c^2 (90% C.L.) by measuring an integrated energy spectrum of electrons from tritium β-decay.
The measurement of the tritium β-spectrum close to its endpoint at $E_0 = 18.6\,\mathrm{keV}$ enables a model-independent investigation of the absolute neutrino mass scale.

The KATRIN experiment consists of a 70~m long beam line where electrons from a windowless gaseous tritium source (WTGS) are guided by magnetic fields to an electrostatic retardation spectrometer (MAC-E filter, energy resolution $\Delta E = 0.93$ eV for $E = 18.6$ keV) and counted with a segmented silicon detector.
After a comprehensive construction and commissioning phase using photoelectrons and conversion electrons from ^{83m}Kr, tritium data-taking with KATRIN commences this year. In preparation for nominal tritium operations, a measurement campaign with an initial concentration of about 1~\% tritium in a deuterium-tritium gas mixture in the WGTS was carried out.
This run allows in-depth studies of hardware performance, systematic effects, and overall stability of the systems.
The talk gives an overview of the current status of the experiment, focusing on the results of the recent first data-taking period with tritium.

This project is supported by BMBF project 05A17VK2, the Helmholtz Association and the Helmholtz Young Investigator Group VH-NG-1055.

Parallel Session 1-5 / 56

The effects of an extended neutrino sphere on supernova neutrino oscillations

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The neutrino flavour evolution in a supernova can be described either in terms of neutrino fields or as the evolution of individual neutrinos. There is no reason to think that the two approaches should give contradicting results, and both have their advantages. One of the advantages of using individual neutrinos is that it becomes clear that the finite width of the neutrino sphere must lead to averaging over the oscillation phase due to the different emission points, and therefore to a reduction of the effective mixing angle. This very significant effect is usually ignored in the literature. In this talk, I will explain the details of the argument and interpret it in terms of the density matrix formalism by taking into account the often neglected collision term.

Parallel Session 1-7 / 58

Exploring coherent neutrino-nucleus scattering with NU-CLEUS

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The detection of coherent-neutrino nucleus scattering opens up new opportunities to probe physics beyond the Standard Model of Particle Physics such as the search for a neutrino magnetic moment or sterile neutrinos. We present a novel cryogenic neutrino experiment at a nuclear power reactor which allows for precision measurements with a miniaturized detector size. With a recent demonstrator we have achieved ultra-low thresholds of 20eV, one order of magnitude lower than previous devices, using a novel type of detector based on CRESST technology. We have initiated the NU-CLEUS experiment which aims to operate at close distance to a power reactor and observe coherent neutrino-nucleus scattering within a measuring time of a few weeks. This poster will report on the most recent results on the NU-CLEUS cryogenic detector, ongoing background measurements and the experimental strategy of NU-CLEUS.

59

Measurements of detector material samples with two HPGe detectors at the YangYang Underground Lab.

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Two major experiments, the AMoRE (Advanced Mo based Rare process Experiment) searching for neutrino-less double beta decay and the COSINE searching for dark matter WIMPs (Weakly Interacting Massive Particles), are running in the Yangyang underground laboratory (Y2L). To understand their signals, it is necessary to know the backgrounds from their detector materials like fasteners, crystal, cables, connectors, and etc. By using two 100% HPGe detectors at the Y2L, the background levels of each material samples were measured and analyzed by using efficiencies estimated by a Geant4 simulation tool kit. We will present background measurements of the samples together with an improvement in the efficiency calibration using a mixed source including 10 known radioactive isotopes in this poster.

Plenary Session 8 / 62

The CYGNUS directional search for dark matter below the neutrino floor

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An update is presented on progress towards realising a direction sensitive WIMP dark matter detector called CYGNUS with eventual sensitivity to probe below the neutrino floor. Latest R&D and simulations are presented towards underpinning sensitivity in this region, including new work on

use of SF6+He4 gas mixtures to allow sensitivity in the low WIMP mass regime with both direction sensitivity and electron recoil discrimination.

Parallel Session 1-5 / **63**

Overview of the Hyper-K 2nd Detector in Korea

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Hyper-Kamiokande (Hyper-K) succeeds the very successful Super-Kamiokande (Super-K) as a future water Cherenkov neutrino detector which will consist of two 260 kilo-ton water tanks with 40,000 photo-sensors per tank deep underground. The 1st detector will be built in Japan and the collaboration is considering to build the 2nd detector in Korea.
Thanks to longer baseline and deeper candidate sites in Korea, physics sensitivities are improved with the Japan-Korea configuration far than with both detectors in Japan.

The physics program is broad covering from particle physics using J-PARC neutrino beam to astrophysics and astronomy observing solar, Supernova burst/relic neutrinos as well as indirect dark matter search. Testing Grand Unification Theory will be also performed through proton decay search. It is expected that Hyper-K could answer important questions remained in these fields as well as unexpected new physics.

In this talk, I introduce Hyper-K and explain the benefits of locating the 2nd detector in Korea. Physics potentials and sensitivities are also presented.

Parallel Session 1-7 / **64**

Nuclear Physics from coherent neutrino-nucleus scattering data

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The coherent neutrino scattering with nuclei provides a novel way to measure the distribution of neutrons in nuclei. This interaction has been theoretically predicted more than 40 years ago, but the difficulty of measuring the very small nuclear recoil made possible its experimental observation only in 2017 by the COHERENT experiment.

Using the COHERENT data, we are able to determine for the first time the average radius of the neutron distributions of the Caesium and Iodine nuclei, which turns out to be of about 5.5 millionths of a nanometer. It was also possible to evaluate the so called "neutron skin", which is the difference between the radii of the neutron and proton distributions.

In the present talk, the measurement of the neutron radius and the neutron skin from COHERENT data will be presented, and the implications in nuclear physics, astrophysics and the cosmology will be elaborated.

65

Muon and muon-induced phosphorescence events in the COSINE-100 Dark Matter Searches

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The COSINE experiment has been taking physics data which aim to confirm or refute the annual modulation signal reported by DAMA/LIBRA by using the same technique. In order to tag and suppress cosmic-ray muons, a muon detector was constructed using plastic scintillator panels that completely surround the crystal detector array. High energy muons in the NaI(Tl) crystals and low energy scintillation signals corresponding to muon-induced phosphorescence events with half-lives longer than a few seconds were observed. The muon flux and a study of muon-induced phosphorescence events in the COSINE-100 experiment will be presented.

66

Cosmogenic activation study of the COSINE-100 experiment NaI(Tl) crystals

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The COSINE-100 is a direct dark matter (WIMPs) search experiment with a 106 kg array of NaI(TI) crystals at Yangyang deep underground laboratory.
Dark matter search experiments require ultra-low background conditions, thus
background understanding and reduction are crucial to improve the sensitivity of the detectors.
One of the dominant background contributions on the NaI(Tl) crystals is caused by activated radioisotopes that were primarily produced by previous exposures to cosmic rays.
In this presentation, results of cosmogenic activation studies for the NaI(Tl) crystals will be presented based on data from the COSINE-100 experiment.

Plenary Session 4 / 67

The status of CONUS

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The talk will cover coherent neutrino scattering and the status of the CONUS experiment.

Parallel Session 2-5 / 68

Dark matter search project PICOLON ~Present status and future~

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The PICOLON project aims to search for cosmic dark matter candidates by means of highly radiopure inorganic crystal. Present detector is NaI(Tl) since it is needed to verify an annually-modulating signal in low energy region below 6 keVee. The annual modulation which is supposed to be a WIMPs signal has been observed only by DAMA/LIBRA group. All other groups which applied other target nuclei excluded the modulating signal. The annual modulating signal must be verified by using the same target nuclei and more sensitive detector. A large mass (~250 kg) and high purity (less than 1dru) is indispensable properties to find a significant signal of dark matter. The PICOLON group has concentrated to reduce radioactive impurities in NaI(Tl) crystal and developed highly radiopure NaI(Tl) crystal. The present status of impurities in NaI(Tl) crystal, basic properties (energy resolution and energy threshold), background component, and the future plan of PICOLON project will be described.

69

Measurements of the fast neutron flux at the Yangyang underground laboratory for the COSINE-100 experiment

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Measurements of the environmental neutron flux in the vicinity of dark matter search experiments are important because signals induced by these neutrons can mimic those that are expected from dark matter interactions. In order to establish a systematic understanding of the environmental neutron flux at the location of the COSINE-100 experiment, we developed a liquid scintillator neutron detector and studied its pulse shape discrimination capabilities and background contamination levels. In this poster, the neutron monitoring detector will be described and a measurement of the neutron flux in the COSINE-100 room at the Yangyang underground laboratory will be presented.

70

The COSINE-100 Simulation and Background Assessment

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COSINE-100 is a dark matter direct dark matter search experiment that uses an array of scintillating NaI(Tl) crystals as a target/detector. The experiment started taking data in September 2016 and has been running stably since that time. We have fit the measured energy spectra in the NaI(Tl) crystals with a MC model that contains a variety of background components. The background sources will be discussed and preliminary results from a dark matter search analysis will be presented.

Parallel Session 2-3 / **71**

particle cosmological search for the light dark matter

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A few examples for the light dark matter will be
presented along with their cosmological (e.g. radio astronomy search) and
the particle physics (dark matter search experiments) constraints to illustrate the complementarity between the particle physics and cosmology probes.

72

A study of cryogenic Li2MoO4 phonon-scintillation detectors for AMoRE-II

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We studied phonon and scintillation properties of Li2MoO4 crystals for the AMoRE-II (Advance Molybde- num based Rare process Experiment - phase II), an experiment aiming at detecting neutrinoless double beta decay of 100Mo. e Li2MoO4 is one of promising crystal candidates among molybdate crystals containing Mo element for a simultaneous detection of heat and light signals at mK temperatures. It is advantageous to use the crystal in terms of crystal growth and internal background control. We tested Li2MoO4 crystals in a low-temperature detection system for high resolution phonon-scintillation measurement based on a metallic magnetic calorimeter (MMC) readout technology. We will present tests results of the Li2MoO4 crystals as tar- get material and discuss a feasibility for the large scale experiment, AMoRE-II, with about 200 kg of molybdate crystals.

Parallel Session 2-8 / **73**

Ultra-light dark matter search with the spherical detector

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The Spherical Proportional Detector is a new type of radiation detector based on a spherical geometry. It consists of a large spherical gas volume with a central electrode forming a radial electric field.
A small spherical sensor located at the center is acting as a proportional amplification structure.
Combination of sub-keV energy threshold and versatility of the target (Ne, He, H) opens the way to search for ultra light dark matter WIMPs down to 100 MeV. Recent results obtained with a low radioactivity detector, 60 cm in diameter operated at LSM underground laboratory will be presented.
First results with Ne as target nuclei, exclude above 4.4 • 10-37 cm2 for a 0.5 GeV/c2 WIMP.
The next project, under development, is a larger detector that consists of a selected pure copper sphere with a diameter of 1.4m to be installed at SNOLAB. This will allow benefiting from a 40 times larger volume, relative to the current detector and a much lower background level to reach unprecedented sensitivity in the range 100MeV to 1GeV.
Other potential applications for low energy neutrino physics will be also discussed.

Parallel Session 2-7 / 75

Full pp-chain solar neutrino spectroscopy accomplished with Borexino

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Borexino is running at the "Laboratori del Gran Sasso"in Italy since 2007. Its technical distinctive feature is the unprecedented ultralow background of the inner scintillating core, which is the foundation for the outstanding achievements accumulated by this experiment.
In over a decade Borexino has performed the simultaneous real time spectroscopy of the neutrinos from the entire pp nuclear fusion chain in the Sun.
The remarkable 2.7% accuracy of the Be7 flux has opened the era of precision measurements also in the realm of the sub-MeV solar neutrinos.
In terms of their flavor conversion interpretation, such results put Borexino in the unique situation of performing alone the full validation of the MSW-LMA paradigm across the solar energy range.

Plenary Session 3 / 77

PROSPECT: The Precision Reactor Oscillation and Spectrum Experiment

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PROSPECT is a short-baseline reactor antineutrino experiment designed to make a reactor model-independent search for eV-scale sterile neutrino oscillation and measure the 235U antineutrino energy spectrum from the High Flux Isotope Reactor at Oak Ridge National Laboratory. PROSPECT consists of a 4-ton, highly-segmented 6Li-loaded liquid scintillator detector operated at baselines ranging from 7-9m from the compact, highly-enriched uranium reactor core. Extensive prototyping

has shown excellent light collection efficiency and background rejection capabilities. This talk will report on the status and initial performance of the experiment.

Parallel Session 2-7 / 78

Solar models and neutrinos - Where do we stand?

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In this talk I will present an overview on the current status of solar modeling and neutrinos from the perspective of a stellar astrophysicist. The fundamental problem in solar models still is the uncertainty related to the true solar composition and the radiative opacity in the solar interior. A combination of both determines the rate of energy transport in the Sun, and thus its thermal structure. New semi-empirical determinations of the solar opacity profile, using helioseismology and solar neutrinos, point either to a high-metallicity Sun or to a missing opacity source in current atomic opacity calculations. New opacity calculations only seem to make the problem worse, as shown by using experimental results for ^{8}B and ^{7}Be neutrinos. This uncertainty is ever more important in the so-called era of precision stellar physics, powered by the development of asteroseismology, because it poses a fundamental problem for stellar physics. At the end of the talk, the fundamental relevance of measuring CN-neutrinos as a tiebreaker will be emphasized strongly.

Parallel Session 2-5 / 79

The SABRE experiment

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The SABRE (Sodium Iodide with Active Background Rejection Experiment) project aims to directly reveal the Dark Matter through the annual modulation signature due to the Earth's motion within the galactic halo. The DAMA experiment, at the Gran Sasso National Laboratory (LNGS, Italy), has detected such modulation over a period of 14 years but its results appear in contrast with other Dark Matter experiments. As confirmation of this observation SABRE intends to use the same sensitive material of DAMA, NaI(Tl) crystals, with four major improvements: ultra-high radiopure crystals, an active veto of liquid scintillator, a very low energy threshold and a double-site strategy. Indeed, twin detectors will be placed in both the hemispheres, at LNGS in Italy and at SUPL in Australia, in order to disentangle any possible seasonal effects that could mimic the DM signature. The current experimental phase, called Proof of Principle (PoP), is designed to characterize the first ~5 kg NaI crystals produced by the collaboration. In this talk an overview of the scientific program with its key features will be given, in addition to an update on the status of Sabre PoP and its future prospects.

Plenary Session 8 / 80

Solar neutrinos in dark matter experiments

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I will discuss the prospects for identifying solar neutrinos in future direct dark matter detection experiments. I will discuss them as a background for dark matter searches, and also the implications for constraining the properties of neutrinos and their sources. I will also discuss the complementarity of these future measurements with terrestrial coherent neutrino scattering experiments.

Plenary Session 8 / 81

The Electron Capture in ^{163}Ho experiment –ECHo

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Direct determination of the electron neutrino $m(\nu_e)$ and anti-neutrino mass $m(\bar{\nu}_e)$ can be obtained by the analysis of electron capture and beta spectra respectively. In the last years experiments analyzing the ^{3}H beta spectrum reached a limit on $m(\bar{\nu}_e)$ of 2 eV. The upper limit on $m(\nu_e)$ is still two orders of magnitudes higher, at 225 eV.
The Electron Capture in ^{163}Ho experiment, ECHo, is designed to investigate $m(\nu_e)$ in the sub-eV region. In ECHo, high sensitivity on a finite $m(\nu_e)$ will be reached by the analysis of the endpoint region in high statistics and high resolution calorimetrically measured ^{163}Ho spectra. To perform this experiment, high purity ^{163}Ho sources will be enclosed in a large number of low temperature metallic magnetic micro-calorimeters which are readout using the microwave multiplexing technique. This approach allows for a very good energy resolution, below $\Delta E_{\mathrm{FWHM}} < 5$ eV and for a fast time resolution well below 1 s.
Thanks to the modular approach, the ECHo experiment is designed to be stepwise up-graded. The first on-going phase, ECHo-1k, is characterized by a ^{163}Ho activity of about 1 kBq enclosed in about 100 pixels. The statistics of 10^{10} events in the ^{163}Ho spectrum will allow for improving the limit on $m(\nu_e)$ by more than one order of magnitude.
In this talk, the present status of the ECHo-1k experiment will be discussed as well as the plans for the next phase, ECHo-100k.

Co-Authors (Collaboration):

ECHo Collaboration

82

A dark matter search with NaI(Tl) crystals by using a pulse shape discrimination analysis

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KIMS-NaI is an experiment aimed at directly detecting Weakly Interacting Massive Particle (WIMP) via weak interactions with the nuclei in low-background NaI(Tl) crystals. Underground data for the WIMP search were obtained in the Yangyang underground laboratory with two NaI(Tl) crystals that have unprecedentedly high light-output. Since the scintillation characteristics of nuclear recoils

from WIMP interactions and electron recoils produced by many background processes are different, it is possible to distinguish between the two types of events by means of pulse shape discrimination (PSD) methods. We characterized the pulse shapes produced in an NaI(Tl) test crystal by neutrons from a deuteron-based generator and gamma rays from a radioactive source. Surface nuclear recoils that could be misidentified as candidates for WIMP-induced events were also investigated and taken into account in the analysis. Preliminary results based on a PSD analysis of a 2967 kg*day data exposure will be presented.

Plenary Session 3 / 83

Low-mass dark matter search with CRESST-III

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CRESST (Cryogenic Rare Event Search with Superconducting Thermometers) is a direct dark matter search experiment located in the underground site of the Laboratori Nazionali del Gran Sasso (LNGS) in Italy. It uses scintillating CaWO4 crystals operated as cryogenic calorimeters at mK temperatures optimized for the detection of nuclear recoils of 100eV and below. The experiment in its current stage, CRESST-III phase 1, is leading the field of low-mass dark matter detection and has recently extended the sensitivity of nuclear-recoil based direct searches to dark matter masses of below 500MeV/c^2. In this contribution, we will review the experimental technique of CRESST-III and report in detail about the most recent dark matter results. We will conclude with a discussion on future challenges and prospects of this experimental approach

84

Neutrino-nucleus reactions and e-capture rates based on new shell-model Hamiltonians

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Co-authors: Baha Balantekin [2]; Michio Honma [3]; Satoshi Chiba [4]; Toshitaka Kajino [5]

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Neutrino-nucleus reaction cross sections relevant to supernova neutrino detection and nucleosynthesis are evaluated for ^{12}C, ^{13}C, ^{16}O, ^{40}Ar and ^{56}Ni with new shell-model Hamiltonians. Cross sections for various gamma and particle emission channels as well as for coherent scattering are obtained for ^{12}C, ^{13}C and ^{16}O. The updated cross sections are compared with available experimental data as well as previous calculations. Advantage of using light targets for coherent scattering is discussed.
Charged-current cross sections folded over neutrino spectra with and without the neutrino oscillations are compared to each other to see how they are sensitive to the MSW and/or collective neutrino oscillation effects.
We also discuss electron-capture rates for supernova explosions and evolution of stars updated with new shell-model Hamiltonians for sd- and pf-shells. Evaluations of the rates for two-major shells such as sd-pf and pf-g shells are also in progress.

85

Amore-Pilot background Simulation

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The AMoRE (Advanced Mo Rare process Experiment) project is the experiment searching for neutrinoless double beta decay of 100Mo.
Monte Carlo simulation using the Geant4 toolkit was performed to understand background level of detector configuration.
Decays of radioactive isotopes such as 232Th, 238U, 40k, 235U and their daughter nuclei were simulated in six CaMoO4 crystals, and in near-by detector materials.
Background spectra of crystals from the recent pilot measurements were fitted with simulation results to identify dominant background sources.
In this poster, the simulation results and fitting results will be presented.

Co-Authors (Collaboration):

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86

An enriched 100MoO3 powder measurement by an array of HPGe detectors

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The AMoRE (Advanced Mo based Rare decay Experiment) phase-II requires pure crystals with ultra-low radioactive contamination (< 4 micro Bq/kg of Th-228) to achieve the zero background level in the ROI (Region of Interest) of the neutrinoless double decay from the Mo-100. The raw material of the crystals, enriched 100MoO3 powder, should have very low contamination. An array of 14 HPGe detectors (980%) was constructed at the Yangyang underground laboratory in spring 2017 for measuring a small amount of radioactive isotopes by using coincidence signals from two detectors. Activities of various radioactive isotopes in a sample of 100MoO3 powder measured with data taken for about 80 days will be presented in this presentation.

Plenary Session 1 / 87

Neutrino properties and their astrophysical consequences

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A brief survey of our present understanding of neutrino properties will be presented. A good fraction of the heavier nuclei were formed in the rapid neutron capture (r-process) nucleosynthesis scenario. Although an astrophysical site of the r-process is not yet identified, one expects such sites to be associated with explosive phenomena since a large number of interactions are required to take place during a rather short time interval. Candidate sites include core-collapse supernovae and neutron-star mergers. The dynamics of these sites very much depend on neutrinos. Implications of neutrino properties especially on various nucleosynthesis scenarios will be discussed with particular emphasis on collective neutrino oscillations. These oscillations of neutrinos represent emergent nonlinear flavor evolution phenomena instigated by neutrino-neutrino interactions in astrophysical environments with sufficiently high neutrino densities.

Parallel Session 1-8 / 88

Status of the HOLMES neutrino mass experiment

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The assessment of the neutrino absolute mass scale remains one of the most crucial challenges in today particle physics and cosmology. Nuclear beta decay spectrum end-point study is currently the only experimental method to provide a model independent measurement of the lowest neutrino mass. HOLMES is an experiment to directly measure the electron neutrino mass by performing a calorimetric measurement of the energy released in the electron capture decay of ^{163}Ho.
In a calorimetric configuration the detector measures all the energy released in the decay process, except for the fraction carried away by the neutrino. This approach eliminates both the issues related to the use of an external source and the systematic uncertainties arising from decays on excited final states.

HOLMES plans to deploy a large array of low temperature micro\-calorimeters implanted with ^{163}Ho nuclei. The neutrino mass statistical sensitivity is expected in the eV range, thereby making HOLMES an important step forward in the direct neutrino mass measurement with a calorimetric approach as an alternative to spectrometry. HOLMES will also establish the potential of this approach to achieve a sub-eV sensitivity.
HOLMES is designed to collect about 3×10^{13} decays with an energy resolution of about 1 eV FWHM and a time resolution of about 1 μs. This will be achieved in three years of measuring time using 16 sub-arrays of TES microcalorimeters. Each sub-array has 64 pixels ion implanted with ^{163}Ho ions to give an activity of about 300\,Bq per pixel. The TES arrays are read out using microwave multiplexed rf-SQUIDs in combination with a Software Designed Radio data acquisition system.
The current HOLMES activity will culminate with the deployment of the first implanted sub-array which will provide crucial high statistics data about the EC decay of ^{163}Ho together with a preliminary limit on the electron neutrino mass.

In this contribution we outline the HOLMES project with its physics reach and technical challenges, along with its status and perspectives. In particular we will present the status of the HOLMES activities concerning the ^{163}Ho isotope production by neutron irradiation and purification, the TES pixel

and multiplexed array read-out, the cryogenic set-up, and the isotope embedding process optimization.

Co-Authors (Collaboration):

on behalf of the HOLMES collaboration

Parallel Session 1-2 / **89**

The two-neutrino double beta decay and a determination of the effective axial-vector coupling constant

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We present an improved formalism of the two-neutrino double-beta decay rate. The dependence of energy denominators on lepton energies via the Taylor expansion is considered. The $2\nu\beta\beta$-decay rate depend on phase-space factors weighted by the ratios of $2\nu\beta\beta$-decay nuclear matrix elements with different powers of the energy denominator. For nuclei of experimental interest all phase-space factors are calculated by using exact Dirac wave functions with finite nuclear size and electron screening. For isotopes with measured $2\nu\beta\beta$-decay half-life the involved nuclear matrix elements are determined within the quasi-particle random-phase approximation with partial isospin restoration. The importance of correction terms to the $2\nu\beta\beta$-decay rate due to Taylor expansion is established and the modification of shape of single and summed electron energy distributions is discussed. It is found that the improved calculation of the $2\nu\beta\beta$-decay predicts slightly suppressed $2\nu\beta\beta$-decay background to the neutrino-less double-beta decay signal. Further, an approach to determine the value of the effective weak-coupling constant in nuclear medium $g_{\mathrm{A}}^{\mathrm{eff}}$ is proposed.

Co-Authors (Collaboration):

Fedor Simkovic, Dusan Stefanik

Parallel Session 2-7 / **90**

Updates on Super-Kamiokande results

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Super-Kamioknde IV has just finished in June 2018 for upgrading the detector via the addition of water-soluble gadolinium (Gd) salt. By that time, the Super-Kamiokande experiment has accumulated atmospheric neutrino and solar neutrino events and has made improvements in their measurement over the last 20 years. With the atmospheric neutrino data, precise measurements of mixing angles and mass squared difference, and a study on the mass hierarchy, leptonic CP violation are being performed. The observation of solar neutrinos provides precise measurements of their energy spectrum and terrestrial matter effects. With a recent improvement, the solar neutrino measurement has a full efficiency at 3.5MeV electron kinetic energy. The most updated results based on all Super-Kamiokande data set will be presented.

Co-Authors (Collaboration):

The Super-Kamiokande Collaboration

Plenary Session 3 / 91

Status and prospects of the LZ dark matter experiment

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LUX-ZEPLIN (LZ) is an astroparticle experiment under construction at the 4850'level of the Sanford Underground Research Facility (SURF) in Lead, South Dakota, USA. LZ will explore the hypothesis that dark matter is comprised of weakly interacting massive particles (WIMPs). The centerpiece of the experiment is a two-phase liquid xenon TPC containing seven active tonnes of WIMP target material. Rejection of backgrounds is enhanced by a set of veto detectors, including a liquid scintillator Outer Detector. LZ has been designed to explore much of the parameter space available for WIMP models, with excellent sensitivity overall for WIMP masses between a few GeV and a few TeV. The cross section sensitivity is 1.6x10^-48 cm^2 at 40 GeV/c^2 and 90% C.L. LZ will also observe, for the first time, coherent scattering of 8B solar neutrinos on xenon nuclei. This talk will review the design and construction of LZ, its sensitivity to WIMP dark matter, and its additional scientific prospects.

Parallel Session 2-6 / 92

Recent Results from RENO

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The Reactor Experiment for Neutrino Oscillation (RENO) has been taking data from August, 2011 using the two identical near and far detectors at Hanbit Nuclear Power Plant in Korea. The neutrino mixing angle θ_13 and the squared mass difference Δm2_ee have been successfully measured by observing the energy dependent disappearance of reactor antineutrinos tagged by neutron capture by gadolinium. In this talk, improved results of θ13 and Δm2_ee measurements and the first measured value of θ_13 using neutron capture on hydrogen will be presented. We also briefly report results on the evolution of reactor antineutrino flux and a search for light sterile neutrino mixing.

Parallel Session 1-5 / 93

Role of sterile neutrino in particle physics and cosmology

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We study how sterile neutrino with keV mass can be a dark matter candidate by proposing a new mechanism for the production of sterile neutrino in early universe. By estimating the average momentum of the sterile neutrino, we investigate whether sterile neutrinos can be warm dark matter or not. We briefly discuss how sterile neutrinos can be probed indirectly by using X-ray telescopes that can detect the photon line signal produced from radiative decay of the sterile neutrino.
We also disucss the role of sterile neutrino in partice physics and investigate
how such a sterile neutrino can be probed in the low energy laboratory experiments as well as at colliders.

Plenary Session 7 / 94

First Results from the ADMX G2 dark matter axion search

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The axion is a well-motivated dark matter candidate inspired by the Peccei-Quinn solution to the Strong-CP problem. After decades of work, the US DOE flagship axion dark matter search, ADMX G2, is the first experiment to be sensitive to dark matter axions from the plausible DFSZ coupling model, and has begun to search the theoretically-favored axion mass region 2-40 micro-eV. ADMX G2 could now discover dark matter at any time. I will report the first results from exploring the range around 2.7 micro-eV last year, discuss this year's operations and review the ADMX G2 plans to continue the search to cover the entire mass range.

Co-Authors (Collaboration):

ADMX Collaboration

Parallel Session 1-8 / 95

Project 8: Towards using Cyclotron Radiation Emission Spectroscopy of Tritium decay to measure the neutrino mass.

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Project 8 has demonstrated Cyclotron Radiation Emission Spectroscopy (CRES) as a novel technique for performing electron spectroscopy. Applying this method to highest energy electrons from tritium beta decay will lead to a direct neutrino mass measurement. A proof of this concept was performed with a waveguide detector utilizing monoenergetic 83mKr conversion electrons. The demonstrator has expanded our knowledge of rich spectral features in CRES signals. As a next step, we have upgraded our hardware to meet the requirements for a demonstration with tritium. Here I

present both the hardware and analysis progress which will lead us to the first continuous spectrum measurement

Co-Authors (Collaboration):

Project 8 Collaboration

Plenary Session 7 / 96

Axion Dark Matter Search at IBS/CAPP

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The center for axion and precision physics (IBS/CAPP) is moving from the construction phase into operation mode regarding a number of axion dark matter experiments. I will describe our status in setting up the ultimate axion dark matter experiments in a wide frequency range. We are commissioning high-field, high-volume magnets and we are developing the required quantum-noise-limited amplifiers as well as the required know-how to reach the required sensitivity to answer whether or not axions are the dominant source of the local axion dark matter for the most promising axion frequency range of 1-50 GHz. I will also describe the status of the storage ring proton EDM experiment development.

97

Application of Metallic Magnetic Calorimeters to Neutrinoless Double Beta Decay Search

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Metallic Magnetic Calorimeters (MMCs) are a type of low temperature detectors operating at millikelvin temperatures that demonstrated high energy resolution. They read temperature increase due to an energy input by sensing magnetization change of paramagnetic sensor material with superconducting niobium sensing coils and a superconducting quantum interference devices (SQUID). Because of their high sensitivity and good linearity at a broad energy range, MMCs are one of competitive candidates for a rare event search experiment at MeV scale, such as neutrinoless double beta decay (0nbb) search. We develop a high resolution detection scheme composed of a large scintillating crystal and an MMC sensor. We present how the energy deposit in an absorber crystal is measured with an MMC sensor together with the current application of the detection scheme in Advanced Molybdenum-based Rare-process Experiment (AMoRE), an international collaboration which aims to search for the neutrinoless double beta decay (0nbb) of Mo-100 in scintillating molybdenum-based crystals using MMCs.

Co-Authors (Collaboration):

AMoRE Collaboration

98

A muon simulation study for the AMoRE-II experiment

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The AMoRE (Advanced Molybdenum based Rare process Experiment) phase-II is an experiment to search neutrino-less double beta decay of Mo-100 which is the later phase of the AMoRE experiment. If the double beta decay is found, it means that the neutrinos are Majorana particles and we can measure their masses. The experiment is going to be carried out in the deep underground in order to observe the extremely rare events free from the backgrounds coming from the cosmic ray particles. However, even in the deep underground, there are still some cosmic ray particles that can affect the measurement and must be excluded as much as possible. A muon veto counter is a sort of detector that can veto cosmic muons coming to the inner space where the CaMoO4 (CMO) crystals and detectors are located. We studied effects of veto materials in the AMoRE-II experiment configuration. In detail, we compared the background values in CKKY unit when the veto material is 3m of water or 30cm of lead. Also, we investigated the effect of thickness of water tank. Detail results with discussions will be shown in the poster.

Co-Authors (Collaboration):

AMoRE Collaboration

99

Measurements of internal alpha activities in the AMoRE-pilot CaMoO4 crystals

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AMoRE (Advanced Mo-based Rare process Experiment) is an experimental search for neutrino-less double beta decay of Mo-100. A pilot experiment, AMoRE-Pilot, has been operating with six 40Ca100MoO4 (CMO) crystals, total mass 1.9 kg, in a cryostat at the Yangyang underground laboratory (Y2L), with an overburden of 700 m. It is unavoidable that the materials of the crystals suffer from some contaminations of radioactive isotopes such as U-238, Th232, U-235, and their decay particles. They can originate from the chemical powders that were used to grow the crystals and/or may be introduced during the crystal growing and polishing procedures. From fits to the measured energy spectra for background alpha decay events, the levels of contamination from U-238, Th-232, U-235, and their decay particles can be estimated. The estimated information can be used to provide important input to the development strategies for reducing backgrounds in the future crystals. We will present preliminary results of internal alpha activity measurements in the AMoRE-Pilot crystals.

100

AMoRE Muon Veto Counter and Event Selection

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The AMoRE (Advanced Mo-based Rare process Experiment) is an experiment searching for a neutrinoless double beta decay of Mo-100. A pilot experiment, AMoRE Pilot, has been running with a total of ~1.8 kg of six 40Mo100MoO4 (CMO) crystals in a cryostat at the Yangyang underground laboratory (Y2L, 700 m overburden from the surface). The AMoRE muon veto counter covers the AMoRE cryostat with 10 plastic scintillator counters (28 PMTs). We have developed several methods to select the muon events in the muon counter and checked the coincident background signals from the crystals. We will present on how to select muons, the muon rate at the AMoRE experiment, and the background level of the crystals by the muons.

101

Silicon PIN photodiode based radon detectors for an underground experiment environment.

Author: Kyungmin Seo[1]

Co-authors: Hyeyoung Lee [2]; Hyunsoo Kim [3]; Moo Hyun Lee [4]; Wootae Kim [2]; Yeongduk Kim [5]

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It is very important to monitor the amount of radon (Rn-222) in the underground experiments such as rare decay search and dark matter experiments with ultra low background requirements. The radioactivity from the radon can be a significant background source to the experiments and need to be measured precisely. We upgraded a radon detector with a volume of ~70 L which was used in the KIMS (Korean Invisible Matter Search) experiment by replacing a Hamamatsu silicon PIN photodiode and a Hamamatsu pre-amplifier. The positively charged radon's daughter particles (Po-214 and Po-218 mostly) produced in the air of the detector chamber are collected by the photodiode in a negative high voltage. The energy resolutions of alpha particles emitted from the decays of the daughter particles are measured to be better than 0.6% with very clean signals to be be identified. In this presentation, We also made two more radon chamber detectors and have been testing them to be used in the underground experiment facility. We will present performances of the radon chamber detectors in the tests.

Parallel Session 1-6 / 102

Dark pion dark matter : WIMP vs. SIMP

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In this talk, I discuss a possibility that dark matter is a composite dark pion in the strongly interacting hidden sector. Depending on the mass scale of dark pion and couplings, it could make either weakly interacting massive particle (WIMP) or strongly interacting massive particle (SIMP).

Parallel Session 2-8 / 103

Decaying dark matter solving small scale problems

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We consider a model of decaying dark matter whose lifetime is comparable to the age of the universe. Its late decay to slightly lighter dark matter particle plus "non-interacting" particle can solve small scale problems. We will also show a smoking-gun signature of "non-interacting" particles from the dark matter decay.

Parallel Session 1-3 / 105

Recent results on heavy-ion induced reactions of interest for neutrinoless double beta decay at INFN-LNS

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In order to get quantitative information on neutrino absolute mass scale from the possible measurement of the $0\nu\beta\beta$ decay half-lives, the knowledge of the Nuclear Matrix Elements (NME) involved in such transitions is mandatory. The use heavy-ion induced double charge exchange (DCE) reactions as tools towards the determination of information on the NME is one of the goals of the NUMEN 1 project in Italy. The basic point is that there are a number of similarities between the two processes, mainly that the initial and final state wave functions are the same and the transition operators are similar, including in both cases a superposition of Fermi, Gamow-Teller and rank-two tensor components [2].

The availability of the MAGNEX magnetic spectrometer [3] for high resolution measurements of the very suppressed DCE reaction channels is essential to obtain high resolution energy spectra and accurate cross sections at very forward angles including zero degree. The measurement of the

competing multi-nucleon transfer processes allows to study their contribution and constrain the theoretical calculations.
An experimental campaign is ongoing at INFN-Laboratori Nazionali del Sud (Italy) to explore medium-heavy ion induced reactions on target of interest for 0νββ decay.
Recent results obtained by the (20Ne,20O) DCE reaction and competing channels, measured for the first time using a 20Ne cyclotron beam at 15 AMeV, on 116Cd, 130Te and 76Ge targets will be presented at the Conference.

1 F.Cappuzzello et al., Eur. Phys. J. A (2018) 54: X (in press)

[2] F.Cappuzzello et al., Eur. Phys. J. A (2015) 51: 145

[3] F.Cappuzzello et al., Eur. Phys J. A (2016) 52: 167

Co-Authors (Collaboration):

NUMEN collaboration

107

Recent results of the AMoRE-pilot experiment, a search for neutrinoless double beta decay of Mo-100

Author: Young Soo Yoon[1]

[1] *CUP, IBS*

The Advanced Mo-based Rare Process Experiment (AMoRE) is a search for neutrinoless double beta decay of ¹⁰⁰Mo in calcium molybdate (CaMoO₄) crystals, made of Molybdenum enriched on ¹⁰⁰Mo (≥95%) and Calcium depleted on ⁴⁸Ca isotopes (≤0.002%), by using cryogenic detectors.
The ongoing pilot-phase experiment at the YangYang underground laboratory consists of a number of commissioning runs using six ⁴⁰Ca¹⁰⁰MoO₄ crystals of a total mass ~1.9 kg.
In parallel, the fist phase of the AMoRE experiment with about 5 kg of CaMoO₄ crystals and additional R&D crystals is in preparation.
The background data of the AMoRE-pilot were analyzed and compared with Monte Carlo simulation results to identify their background sources.
In this presentation, the background modeling results will be presented and discussed.

Co-Authors (Collaboration):

AMoRE Collaboration

108

The ANDES Underground Laboratory Project

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This talk will be devoted to the presentation of the ANDES underground
laboratory project, which is a component of the Agua Negra Tunnel road

complex, a 14 Km long tunnel under the Andes high mountains connecting Argentina and Chile. We shall talk about the motivations, prospects and design of this facility, which will be the first of its type in the southern hemisphere. The lab will be located at the deepest site under the mountains and the place is shield by about 5000 m.w.e.. The physics involved, as well as other potential applications to biology, geology and material sciences, are discussed.

Co-Authors (Collaboration):

The ANDES collaboration

Plenary Session 4 / 109

Effective value of the weak axial coupling: A review

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We still do not know if the neutrino is a Majorana or a Dirac particle, i.e. if the neutrino is its own antiparticle or not. Also the absolute mass scale of the neutrino is unknown, only the relative scale is known from the neutrino-oscillation experiments. These unknown features of the neutrino can be tackled by experiments trying to detect the neutrinoless double beta ($0\nu\beta\beta$) decay. The rate of $0\nu\beta\beta$ decay can be schematically written as
\begin{equation}
0\nu\beta\beta-\mathrm{rate} \sim \left\vert M^{(0\nu)}{\rm GTGT}\right\vert^2 =
g{{\rm A},0\nu}^4 \left\vert \sum_{J^{\pi}}
(0^+f||\mathcal{O}^{(0\nu)}{\rm GTGT}(J^{\pi})||0^+_i)\right\vert^2 \,,
\end{equation}
where $M^{(0\nu)}_{\rm GTGT}$ is the double Gamow-Teller nuclear matrix element, $\mathcal{O}^{(0\nu)}_{\rm GTGT}$ denotes the transition operator mediating the $0\nu\beta\beta$ transition through the various multipole states J^{π}, 0^+_i denotes the initial ground state, and the final ground state is denoted by 0^+_f (for simplicity, we neglect the smaller double Fermi and tensor contributions). Here $g^{\rm eff}_{{\rm A},0\nu}$ denotes the effective (quenched) value of the weak axial-vector coupling for $0\nu\beta\beta$ decay and it plays an extremely important role in determining the $0\nu\beta\beta$-decay rate since the rate is proportional to its $4th$ power. The amount of quenching has become an important issue in the neutrino-physics community due to its impact on the sensitivities of the present and future large-scale $0\nu\beta\beta$-decay experiments 1.

The quenching of $g_{\rm A}$ is traditionally related to shell-model calculations of Gamow-Teller β-decay rates. Similar quenchings can also be obtained in some other nuclear-model frameworks, like the proton-neutron quasiparticle random-phase approximation (pnQRPA) and the microscopic interacting boson model (IBM-2). The quenching of $g_{\rm A}$ has also been addressed in calculations of the rates of two-neutrino double beta ($2\nu\beta\beta$) decays where the $g_{\rm A}^4$ dependence is present like in the $0\nu\beta\beta$ decays but the quenching can be of different magnitude since the scale of the exchanged momentum between the nucleons and the neutrino is different. For a recent review on this topic, see [2].

Novel ways to address the quenching problem are offered by the studies of
forbidden non-unique β decays. Rates of the
forbidden non-unique β transitions are complex combinations of lepton
phase-space factors and many nuclear matrix elements. The shapes of the corresponding
spectra of the emitted electrons (β spectra) can, however, be very sensitive
to the value of g_{A}, and thus the measured β spectra can give information
on the effective value of g_{A}. In addition, the shapes of β
spectra play a role in the context of the reactor-antineutrino anomaly which
is currently of great interest in the neutrino-physics community.

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1 J. Suhonen, Impact of the quenching of g_{A} on the sensitivity of
$0\nu\beta\beta$ experiments, Phys. Rev. C 96 (2007) 055501.

[2] J. Suhonen, Value of the axial-vector coupling strength in β and
$\beta\beta$ decays: A review, Front. Phys. 5 (2017) 55.

Parallel Session 2-1 / 112

Physics of Neutrinos Interaction around 1-10 GeV

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Neutrino oscillation physics has been entered in the precision era. In this context accelerator-based neutrino experiments need a reduction of systematic errors to the level of a few percent. Today one of the most important sources of systematic errors are neutrino-nucleus cross sections which in the hundreds-MeV to few-GeV energy region are known with a precision not exceeding 10-20%. In this talk, I will review the main processes of neutrino-nucleus interactions in this energy region, and describe state-of-the-art theoretical work and open questions.

Parallel Session 2-4 / 113

Status and Future Prospects of the DEAP-3600 Dark Matter Search

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DEAP-3600 is a single phase dark matter detector located at SNOLAB, in Sudbury, Ontario. The detector consists of 3.3 tonnes of liquid argon (LAr), viewed by an array of 255 PMTs through 50 cm of acrylic. DEAP-3600 began operations in May 2016, and it has been running stably since November 2016. Analysis of the data taken so far demonstrates the power of pulse shape discrimination to reject electron-recoiling backgrounds and record low levels of radon contamination. Results from the current analaysis and future plans will be presented.

Co-Authors (Collaboration):

DEAP-3600 Collaboration

Parallel Session 1-3 / 114

Status and perspectives of the NEXT program

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The NEXT program is developing the technology of high pressure xenon chamber TPCs with electroluminescent readout for neutrinoless double beta decay searches. In this talk I will present the current status of the project, which is operating a 10-kg demonstrator (NEXT-White) in the underground laboratory of Canfranc, in Spain, and starting the construction of a 100 kg detector (NEXT-100). I will also describe the prospects for extending the technology to the ton-scale.

Plenary Session 6 / 115

Neutrinoless double beta decay with EXO-200 and nEXO

Author: Giorgio Gratta[1]

[1] *Stanford University*

Large and homogeneous TPCs using enriched liquid xenon have proven to be excellent tools in the search for neutrinoless double beta decay with ultra-low background and state of the art sensitivity. I will report on the physics results obtained with EXO-200, a 200kg detector currently taking data, and on the plans for nEXO, a 5-tonne detector with sufficient sensitivity to entirely cover the inverted hierarchy region.

Parallel Session 2-3 / 116

The DAMIC Experiment at SNOLAB and beyond

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The Dark Matter in CCDs (DAMIC) Collaboration takes advantage of developments made in the realm of astronomical imaging technology to perform searches for a variety of dark matter candidates with masses below 10 GeV/c^2 using silicon CCDs. An array of 7, 675-μm thick silicon CCDs, representing ~40 grams of mass, has been collecting data at SNOLAB since early 2017. The collaboration has engaged in an extensive campaign of characterization efforts to understand the response of these CCDs to low-energy nuclear recoils and their unique capabilities, including the use of high spatial resolution for both the rejection and study of backgrounds. This talk will discuss the devices and the current status of the DAMIC at SNOLAB experiment, as well as plans for the next-generation DAMIC-M Experiment, which will deploy 1 kg of improved CCDs to the Modane Underground Laboratory.

Co-Authors (Collaboration):

The DAMIC Collaboration

117

Some aspects of Dark photon physics

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A dark gauge boson refers to a hypothetical gauge boson with a small mass and small coupling. Because of the small coupling, it could easily escape the existing experimental constraints, which is why it is called 'dark'. I will overview the dark gauge boson physics with some examples including my own research.

Plenary Session 9 / 118

New neutrino phenomena

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I will describe the phenomenology of some new physics scenarios.

Parallel Session 2-3 / 119

Neutrino non-standard interactions and dark matter direct searches

Author: Diego Aristizabal[1]

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In this talk I will discuss the role that neutrino-quark non-standard interactions (NSI) might play in dark matter searches with multi-ton scale detectors. I will show that constraints from neutrino oscillations and COHERENT data still allow for sufficiently large NSI couplings, therefore if present they can either enhance or diminish the irreducible neutrino background present in this type of experimental setups. The results include both solar and atmospheric neutrino fluxes.

120

(Cancelled Intived Talk/ For the reference) Detecting the Cosmic Neutrino Background: Expected Rates for the Standard and Beyond Standard Models

Author: Renata Zukanovich Funchal[1]

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We will discuss the possibility of observing the Cosmic Neutrino Background (CNB) in the near future by an experiment based on neutrino capture on tritium and what can be learned by measuring the total CNB capture rate. In particular, we will review why such a measurement could differentiate between
Dirac and Majorana neutrinos if only Standard Model interactions are considered. We will also show that the total capture rate can be substantially modified
for Dirac neutrinos if scalar or tensor right-chiral currents, with strength consistent with current experimental bounds, are at play.
We find that the total capture rate for Dirac neutrinos can be made substantially modified, in particular, it can be made as large as what is expected for
Majorana neutrinos with only Standard Model interactions. We briefly discuss the effect of a non-negligible primordial abundance of right-handed neutrinos on our
conclusions.

121

Neutrino-nucleus scattering

122

Nuclear reactions for neutrinos

123

Sub-GeV dark matter search

124

Nuclear reactions for double beta decays

125

Mirror Matter

126

TBD

Plenary Session 5 / 127

Phenomenology of dark matter

128

GERDA and LEGEND experiment

Parallel Session 2-1 / 129

Recent physics results on ν-Ar scattering from MicroBooNE

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MicroBooNE is an 85-tonne active mass Liquid Argon Time Projection Chamber (LArTPC) neutrino experiment on the Booster Neutrino Beamline at the Fermi National Accelerator Laboratory. One of MicroBooNE's primary physics goals is to understand neutrino-argon scattering in the [0.5-2] GeV neutrino energy. This knowledge, in addition to being of intrinsic scientific interest, will be used in the future liquid argon technology-based experiments such as DUNE. In this talk, I will present the recent cross-section physics results from the MicroBooNE collaboration.

Co-Authors (Collaboration):

MicroBooNE Collaboration

Parallel Session 2-6 / 130

Search for sterile neutrino at the NEOS Experiment

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There are neutrino anomalies which cannot be explained with 3-neutrino hypothesis. A 3+1 neutrino framework including light sterile neutrino can be an alternative hypothesis to explain those anomalies. NEOS is a reactor neutrino experiment to search for sterile neutrino. The detector was installed in the tendon gallery at 24-meters distance from a 2.8-GWt reactor core, with 20-m.w.e overburden. The number of inverse beta decay (IBD) candidates is about 2,000 per day during reactor-on period, with the signal-to-background ratio higher than 20. As a result of significance test with pseudo-data sets, there is no strong evidence for 3+1 neutrino hypothesis. An exclusion limit at 90% CL for the alternative hypothesis is obtained via shape-only analysis. The measurement will be resumed in this summer to figure out the evolution of reactor neutrino spectrum along with the variation of fission fraction.

Co-Authors (Collaboration):

NEOS Collaboration

131

DANSS

132

IAC Meeting

Parallel Session 1-4 / 133

Mark Shirchenko on behalf of DANSS collaboration

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DANSS is a detector of the reactor antineutrino/ It consists of 2500 intercrossing polystyrene-based plastic scintillator strips (100x4x1 cm) with the total mass of 1.1 tn. The light signal is read out with 2500 individual SiPMs and with 50 conventional compact PMTs via WLS fibers, thus providing 3D space pattern of each event. It is mounted just under the cauldron of the 3 GW_th reactor WWER-1000 of Kalinin NPP (Russia) on a special lifting platform which varies the distance to the reactor core from 10.7 to 12.7 m within few minutes once per 2-3 days. Due to such location, DANSS is perfectly shielded against cosmic neutrons by 50 mwe of reactor body, cooling pond and other hydrogen-containing elements of the building. As a result, DANSS detects about 5,000 IBD events per day with a background at the level of few percent. In addition to the reactor monitoring, DANSS is used to search for short-range neutrino oscillation to a steryle state. The data analysis consists in comparison of the neutrino energy spectra measured at different distances, it does not use any theoretically calculated spectrum and therefore is completely model-independent; systematic errors caused by long-term variation of the reactor fuel and detector efficiency are eliminated as well. In one year of the detector operation we have collected more than 1,000,000 IBD events and could exclude a big part of steryle neutrino parameters region. In particular, the Reactor Antineutrino Anomaly optimum point is excluded with a confidence level higher than 5σ.

134

Indirect dark matter searches with IceCube

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135

Effects of neutrinos on supernova nucleosynthesis

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Plenary Session 9 / 136

New results from GERDA and prospects for LEGEND: background-free search for neutrinoless double beta decay of 76Ge

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The GERDA collaboration searches for 0νββ decay of 76Ge by operating bare high-purity germanium detectors, enriched in the isotope 76Ge, in liquid argon. We will report the latest results of GERDA Phase II. The potential of an essentially background-free search for 0νββ decay motivated the foundation of the new LEGEND collaboration. The LEGEND collaboration pursues a staged implementation with the ultimate goal to operate one ton of enriched germanium detectors. In its first stage, we plan to operate up to 200 kg of germanium detectors in the GERDA infrastructure at LNGS.

Plenary Session 7 / 137

Effects of neutrinos on supernova nucleosynthesis

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A huge number of neutrinos are emitted from a neutron star at the core-collapse supernova (SN) explosion. These neutrinos interact with nucleons and nuclei, and proton and neutron abundances are affected via charged-current (CC) reactions of electron neutrinos and antineutrinos in the inner region of SNe. As a result, some of light proton-rich nuclei (p-nuclei) are produced in a proton-rich condition realized by those SN neutrino reactions. Production of 7Li and 11B occurs in an outer region of the SN, i.e., C-rich and He-rich layers. It has been suggested that neutrino oscillations in SNe significantly affect yields of 7Li and 11B in core-collapse SNe. During the propagation of neutrinos from the proto-neutron star, their flavors change. As a result, the CC neutrino reaction rates of 12C and 4He are affected. In this talk, we show updated results on the neutrino process nucleosynthesis in SNe. Neutrino spallation cross sections for 4He and 12C are corrected, and new reactions for production of 98Tc and 92Nb are included in our calculation. Initial abundances involving heavy s-nuclei are derived from a new calculation of the SN 1987A progenitor. We analyze a dependence of SN yields of 7Li and 11B on the neutrino mass hierarchy in several stellar locations. In the normal hierarchy case, the CC reaction rates of electron neutrinos are enhanced, and yields of proton-rich nuclei including 7Be and 11C are increased. In the inverted hierarchy case, the CC reaction rates of electron antineutrinos are enhanced, and yields of neutron-rich nuclei including

7Li and 11B are increased. We also find that the presupernova s-process abundances and metallicity affect the yields since the neutron abundance during SN nucleosynthesis are determined by the s-process abundances.

Parallel Session 1-3 / **138**

Nuclear Double Gamow-Teller Responses – little known aspects of nuclear structure –

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In a long history of nuclear physics, double Gamow-Teller responses have been
hardly studied, at least experimentally. Existing data include half-lives of only ~10 double beta nuclei. This exhibits a striking contrast to the case of single Gamow-Teller responses where data of half-lives exist for more than 2000 nuclides together with cross section data of charge exchange reactions.
One possible way to access double Gamow-Teller responses in nuclei other than double beta-decay ones and to the excited states is to use double charge exchange reactions. However, previous attempts with pion and heavy-ion double charge exchange reactions provided us with limited information.
We started a new experimental program to investigate double Gamow-Teller responses in a wide excitation energy range with a newly invented experimental method to use the (12C,12Beγ) reaction. One of the highlight of the program is a discovery of the double Gamow-Teller giant resonances that exhaust a major part of the sum-rule value. The first experiment was carried out with a 100-MeV 12C beam at Research Center for Nuclear Physics (RCNP), Osaka University. We have found indication of the double Gamow-Teller giant resonances in 48Ca which is among double beta-decay nuclei. We plan high-statistics experiments with a high intensity 12C beam at RI Beam Factory (RIBF) which will be scheduled in 2019.
In the symposium, I will present results of the RCNP experiment and show future plans at RIBF, after brief introduction to nuclear double Gamow-Teller responses and its relevances to double beta-decay physics.

Parallel Session 2-2 / **139**

IceCube and Dark Matter

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Latest results from IceCube including dark matter searches will be presented

Co-Authors (Collaboration):

IceCube Collaboration

140

Status of COSINE-100 experiment

The COSINE-100 experiment searches for dark-matter interactions using an array of scintillating NaI(Tl) crystals that serve both as a WIMP-interaction target and detector in the low-background environment of the Yangyang underground laboratory. The main goal is to check the annual modulation signal observed by DAMA/LIBRA in an NaI(Tl) crystal array. The experiment has been running for more than 1.5 years stably. Several analyses in addition to the annual modulation analysis are actively ongoing. Here, the performance of the detector and recent results will be presented.

141

Break