Magnificent CEvNS 2023

Wednesday, 22 March 2023 - Wednesday, 29 March 2023

Book of Abstracts

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Radiative corrections to low-energy neutral-current neutrino scattering and DAR sources

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One-loop radiative corrections introduce the dependence on the neutrino flavor in CEvNS. To consistently account for radiative corrections, we present the effective field theory of neutrinolepton and neutrino-quark interactions, embed quarks into nucleons and nucleons into nuclei. We calculate CEvNS cross sections and flavor asymmetries on the spin-0 nucleus at energies below 100 MeV including all kinematic dependence of radiative corrections. We provide a complete error budget accounting for uncertainties at nuclear, nucleon, hadronic, and quark levels, and add a perturbative error in quadrature. At 20-100 MeV energies, the uncertainty is limited by the knowledge of neutron distribution inside nuclei. Going to lower energies, hadronic contributions become the dominant source of uncertainty. To describe low-energy (anti)neutrino fluxes in modern coherent elastic neutrino-nucleus scattering experiments as well as high-energy fluxes in precision-frontier projects such as the Enhanced NeUtrino BEams from kaon Tagging (ENUBET) and the Neutrinos from STORed Muons (nuSTORM), we evaluate (anti)neutrino energy spectra from radiative muon, pion, and kaon decays at O(⊠) level and quantify corresponding uncertainties. We discuss the corresponding changes to fluxes and neutrino-nucleus cross sections.

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Recent results from the CONUS experiment

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The CONUS experiment looks for coherent elastic scattering of reactor antineutrinos on Ge nuclei. It is based on four 1 kg sized point contact Germanium detectors within an elaborated shield located at 17 m distance from the 3.9 GW_th reactor core of the nuclear power plant in Brokdorf, Germany. Data collection was initiated in April 2018 and stopped in December 2022. This talk presents new results from the final run occurred in the years 2021 and 2022. Compared to the previous runs, it includes a larger reactor ON and OFF statistics, an improved energy threshold based on a new DAQ system, the development of a pulse shape background discrimination method down to the sub-keV region as well an improved environment and detector stability. These improvements allowed to search for CEvNS reactions induced by reactor antineutrinos with unprecedented sensitivity.

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The CONUS+ experiment

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The CONUS+ experiment is a new project which aims to detect coherent elastic neutrino-nucleus scattering (CEvNS) of reactor antineutrinos on germanium nuclei in the fully coherent regime, continuing in this way the CONUS physics program. The CONUS+ experiment will be installed during 2023 in the Leibstadt nuclear power plant, Switzerland, at a distance of about 20 m from the 3.6

GWth reactor core. The CEvNS signature will possibly be measured with the four 1 kg point-contact high-purity germanium (HPGe) detectors of the former experiment, which have been refurbished, further improving their energy thresholds.

The CONUS+ design will be presented here for the first time, together with the background characterization of the new experimental location and the physics potential of the project.

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Physics implications of recent Dresden-II reactor data

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Very recently, the Dresden-II Collaboration has reported a suggestive piece of evidence pointing to the first ever observation of CEνNS using reactor $\overline{\nu}_e$ [1]. The new Dresden-II data have prompted phenomenological analyses that resulted in complementary constraints on various parameters within and beyond the Standard Model (SM). In this talk I will briefly discuss our findings from our recent work [2], where prompted by this Dresden-II reactor data we examine its implications for the determination of the weak mixing angle, and also determine the resulting constraints on the unitarity of the neutrino mixing matrix, as well as on the most general type of nonstandard neutral-current neutrino interactions using CEνNS.

References

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[2] A. Majumdar, D. K. Papoulias, R. Srivastava, J. W. F. Valle. "*Physics implications of recent Dresden-II reactor data*", **Phys. Rev. D 106 no. 9 (2022) 093010, arXiv:2208.13262 [hep-ph]**.

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New physics implications of COHERENT CsI+LAr data

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The observation of coherent elastic neutrino nucleus scattering (CEvNS) has opened the window to many physics opportunities. In this talk I will discuss the implication of the observation of CEvNS by the COHERENT Collaboration using two different targets, CsI and argon, on several new physics scenarios. These include neutrino nonstandard interactions and the most general case of neutrino generalized interactions, as well as new light mediators.

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Probing electroweak physics with COHERENT data

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In recent years, coherent elastic neutrino nucleus scattering (CEvNS) has proven to be a useful tool for probing low-energy electroweak physics [1]. In this talk I will present the new constraints extracted on the weak mixing angle and nuclear physics [2] in the light of the latest CEvNS data reported by the COHERENT collaboration [3]. I will finally discuss briefly the implications of the new data to electromagnetic neutrino properties.

References

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[3] [COHERENT Collaboration] D. Akimov et al., *Measurement of the Coherent Elastic Neutrino-Nucleus Scattering Cross Section on CsI by COHERENT*, **Phys.Rev.Lett. 129 (2022) 8, 081801**

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First Search For Neutrino-Induced Nuclear Fission

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Over 50 years ago, it was predicted that it is possible to split an atom with a neutrino interaction, but there has never been a concerted experimental effort to confirm this phenomenon. The existence of this process would inform nuclear astrophysics, nuclear reactor monitoring and give a vantage into a process that bridges both the weak and strong fundamental interactions. This would add the neutrino to the selective group of particles confirmed to induce nuclear fission. To that end, the NuThor Detector was built in 2022 as a dedicated neutrino-induced nuclear fission (hereafter referred to as "nuFission") detector on thorium. The NuThor Detector hermetically seals 52.0 kgs of thorium metal inside a novel, custom-made neutron multiplicity meter built to efficiently capture and detect fission neutrons peeled off of the fissioned thorium nuclei. Said neutron multiplicity meter is composed of gadolinium-doped water to moderate and capture the aforementioned neutrons. Then an array of 36 7.7 kg NaI[Tl] scintillator crystals from the Homeland Security Advanced Spectroscopic Portal Program is affixed all around the complex of thorium and Gd-Water to detect neutron-capture gamma rays. This entire apparatus is exposed to the stopped-pion neutrino flux of the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory. The intense, pulsed neutrino source is coupled with the seasoned neutrino experimenters of the COHERENT collaboration to present a unique and promising opportunity to conclusively put this half century mystery of nuFission to rest. This work reports the design, deployment and sensitivity of the NuThor detector.

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Development of low-energy event selection method for the NEON experiment

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NEON (Neutrino Elastic-scattering Observation with NaI) aims an observation of the coherent elastic neutrino-nucleus scattering (CEvNS) using reactor anti-electron neutrino with NaI(Tl) crystal detectors at Hanbit nuclear power plant in Yeonggwang, South Korea. For the observation of the CEvNS with the NEON detector, we need to achieve 0.2 keV energy corresponding to five photoelectrons threshold. Due to plenty of noise events induced by photomultipliers, we developed a multivariable event selection technique using the boosted decision tree (BDT) aiming to discriminate the scintillation events from the PMT-induced noise events. For training of the signal-like scintillation events, the waveform simulation was developed and tuned with the measured single photoelectron shape, NaI(Tl) scintillation decay time, and pedestal fluctuation. The same trigger condition and digitization were applied to the simulated waveforms stored in the same format as the NEON physics data. In this presentation, I will discuss the development of the waveform simulation of the NaI(Tl) crystal detectors and the progress of the event selection using the BDT with the simulated waveform of the scintillation events.

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Detecting SN neutrinos with RES-NOVA archaeological Pb cryogenic detectors

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The RES-NOVA project will hunt neutrinos from core-collapse supernovae (SN) via coherent elastic neutrino-nucleus scattering (CEνNS) using an array of archaeological lead (Pb) based cryogenic detectors. The high CEνNS cross-section on Pb and the ultra-high radiopurity of archaeological Pb enable the operation of a high statistics experiment equally sensitive to all neutrino flavors with reduced detector dimensions in comparison to existing neutrino observatories. The first phase of the RES-NOVA project is planned to operate a detector with a volume of (60 cm)^3. It will be sensitive to SN bursts from the entire Milky Way Galaxy with >3σ sensitivity while running $PbWO_4$ detectors with 1 keV energy threshold. RES-NOVA will discriminate core-collapse SNe from black-holes forming collapses with no ambiguity even with such small volume detector. The main SN parameters can potentially be constrained with a precision of few % while looking at $\nu_{\mu/\tau}/\overline{\nu}_{\mu/\tau}$. We will present the performance of the first prototype detectors, and sensitivity projections for the full detector. We will demonstrate that RES-NOVA has the potential to lay the foundations for a new generation of neutrino observatories, while relying on a very simple and modular experimental setup.

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Mineral Detection of CEvNS

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Minerals are solid state nuclear track detectors - nuclear recoils in a mineral leave latent damage to the crystal structure. Depending on the mineral and its temperature, the damage features are retained in the material from minutes to timescales much larger than the age of the Solar System. The damage features from the fission fragments left by spontaneous fission of heavy unstable isotopes have long been used for fission track dating of geological samples. Laboratory studies have demonstrated the readout of defects caused by nuclear recoils with energies as small as ˜1 keV. Using natural minerals, one could use the damage features accumulated over geological timescales to measure astrophysical neutrino fluxes (from the Sun, supernovae, or cosmic rays interacting with the atmosphere) as well as search for Dark Matter. Research groups in Europe, Asia, and America have started developing microscopy techniques to read out the nanoscale damage features in crystals left by keV nuclear recoils. The research program towards the realization of such mineral detectors is highly interdisciplinary, combining geoscience, material science, applied and fundamental physics with techniques from quantum information and Artificial Intelligence. In this talk, I will highlight the scientific potential for CEvNS in mineral detectors and briefly describe status and plans of the Mineral Detection of Neutrinos and Dark Matter (MDvDM) community.

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Status of Neutrino Elastic-scattering Observation with NaI(Tl) experiment (NEON)

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Neutrino Elastic scattering Observation with NaI (NEON) is an experiment to detect a coherent elastic neutrino-nucleus scattering (CEvNS) using reactor electron antineutrinos. NEON is based on an array of six NaI(Tl) crystals corresponding to a total mass of 15 kg, located at the tendon gallery of the Hanbit nuclear reactor that is 24 m far from the reactor core. The installation of the NEON detector was completed in December 2020 and the detector is currently taking data with full power of the reactor since May 2021. The current status of the NEON experiment will be presented in this talk.

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The role of the elastic neutrino-electron scattering in constraining the neutrino magnetic moment and millicharge using the LUX-ZEPLIN data

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Elastic neutrino-electron scattering represents a powerful tool to investigate key neutrino properties. In view of the recent results released by the LUX-ZEPLIN Collaboration, we will present a first determination of the limits achievable on the neutrino magnetic moment and neutrino millicharge, whose effect becomes non-negligible in some beyond the Standard Model theories. In particular, we will discuss the impact of different approximations to describe the neutrino interaction with atomic electrons which is of particular importance when including this contribution also in CEvNS analyses. We will show that the new LUX-ZEPLIN data allows us to set a very competitive limit on the neutrino magnetic moment when compared to the other laboratory bounds, namely μeff<1.2×10−11 μB at 90% C.L., which improves by almost a factor three the Borexino Collaboration limit and represents the second best world limit after the recent XENONnT result. Moreover, exploiting the so-called equivalent photon approximation, we obtain the most stringent limit on the neutrino millicharge, namely |qeff|<1.8×10−13 e0 at 90% C.L., which represents a great improvement with respect to the previous laboratory bounds.

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Updated constraints on light mediators from CEvNS data

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The observation of coherent elastic neutrino-nucleus scattering (CEvNS) performed at the COHERENT experiment with a cesium iodide detector and with a liquid argon detector, represents an innovative and powerful tool to study many physical phenomena.
In particular, CEvNS represents a sensitive probe for interactions that are not included in the Standard Model, as for instance interactions mediated by yet-to-be-discovered light-neutral vector bosons.
We present the constraints on the parameters of several light boson mediator models, considering a variety of vector boson mediator models: the so-called universal, the B−L and other anomaly-free U(1)′ gauge models with direct couplings of the new vector boson with neutrinos and quarks, and the anomaly-free Le−Lμ, Le−Lτ, and Lμ−Lτ gauge models where the coupling of the new vector boson with the quarks is generated by kinetic mixing with the photon at the one-loop level. We also consider a model with a new light scalar boson mediator that is assumed, for simplicity, to have universal coupling with quarks and leptons. We compare these constraints with the limits obtained by other experiments and with the values that can explain the muon g−2 anomaly. We show that the COHERENT data allow us to put stringent limits on the light vector mediator mass and coupling parameter space. Finally, we discuss the impact of future CEvNS experiments on these searches, highlighting the importance of complementary approaches.

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MeV-scale BSM Physics at Stopped-Pion Facilities

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Stopped-pion facilities pose a unique opportunity to probe new physics at MeV energy scales, a totally different but complementary phenomenology to the usual keV-scale nuclear recoil probes of CEvNS and neutrino NSI. I will discuss searches for axion-like particles and tests of the MiniBooNE excess at Coherent CAPTAIN Mills (CCM) using the 800 MeV proton beam source at the Lujan target (LANL). These searches set a proof-of-concept for BSM searches at GeV-scale proton beam targets by looking for new physics signatures in the 100 keV to 10 MeV energy range. I will also discuss and hint at some new theoretical thoughts that would apply to neutron sources.

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CEνNS as a tool to investigate nuclear and electroweak properties: current status and prospects

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Coherent elastic neutrino-nucleus scattering (CEνNS) has been demonstrated to be an essential tool to investigate key electroweak physics parameters and nuclear properties since its first observation in 2017 at COHERENT.
In this presentation, we show for the first time the results obtained using the latest CsI dataset, which allows us to achieve a precise measurement of the average neutron rms radius of 133Cs and 127I. In combination with the atomic parity violation (APV) experimental result, we derive the most precise measurement of the neutron rms radii of 133Cs and 127I, disentangling the contributions of the two nuclei. By exploiting these measurements we determine the corresponding neutron skin values for 133Cs and 127I. This analysis allows us to also obtain a data-driven APV+COHERENT measurement of the low-energy weak mixing angle with a percent uncertainty, independent of the value of the average neutron rms radius of 133Cs and 127I.
In this contest, exploiting the recent detection of such a process with antineutrinos produced by the Dresden-II reactor scattering off a germanium detector, we also present the limits achieved on the weak mixing angle at the low-energy scale, highlighting the impact of the germanium quenching factor and the reactor antineutrino flux. To conclude, prospects for the future will be reviewed, with particular emphasis on the current limiting factors and a list of desiderata to improve these measurements.

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CEνNS bounds on neutrino electromagnetic properties

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In this talk, I discuss the possibility to set limits on neutrino electromagnetic properties using the data of the COHERENT experiment and the Dresden-II reactor. I discuss neutrino magnetic moments, charge radii and millicharges. In order to obtain the bounds, the contribution of elastic neutrino-electron scattering, which can become strongly effected for some of the parameters that are considered, must be included, too. I show the dependence of the limits on different hypotheses for the germanium quenching factor and the reactor antineutrino flux. Interestingly, we were able to set a new best upper limit on the electron neutrino charge radius and significantly improve the other CEvNS-related limits on the neutrino electric charge and magnetic moment.

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Neutrino-nucleus interactions and the axial coupling

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Neutrino-nucleus interactions play a role in (anti)neutrino scatterings off nuclei, nuclear beta and double beta decays, nuclear electron and muon captures, etc. These processes involve nucleons, protons and neutrons, and their (collective) conglomerates, the nuclei. Neutrino-nucleus interactions are driven by the weak neutral and charged currents, consisting of a vector and an axial-vector part. The vector part scales by the weak vector coupling g_V, and its value $g_V = 1$ is protected by the conserved vector current (CVC) hypothesis. The axial part is scaled by the weak axial-vector coupling g_A, with its quark-level value $g_A(quark) = 1$. At the nucleon level the value of g_A is, however, not so well protected by the partially conserved axial-vector current (PCAC) hypothesis, and in the decay of a free neutron its measured value turns out to be $g_A(nucleon) = 1.27$.

In nuclei an effective value $g_A(eff)$ has to be adopted for various reasons: (1) to take into account non-nucleonic degrees of freedom, (2) the deficiencies in the nuclear many-body models (too small single-particle valence spaces and/or restricted numbers of many-nucleon configurations and/or lack of three- and higher-body nucleon-nucleon forces) used to describe the neutrino-nucleon interactions at the nuclear level, and (3) omission of the meson-exchange two-body currents in the nucleon-nucleon interactions. For neutrino-nucleus scatterings in the low momentum-exchange regime (reactor, solar and supernova neutrinos, and sub-leading effects in the CEνNS) $g_A(eff)$ can be studied by surrogate processes like beta and two-neutrino double beta decays. For the accelerator neutrinos with momentum exchanges of few MeV the nuclear muon capture turns out to be a suitable surrogate. The recent reviews [1,2] shed light on these aspects of neutrino-nucleus interactions.

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CEvNS with the nuBDX-DRIFT detector

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The νBDX-DRIFT detector is a directional low-pressure TPC that uses carbon disulfide as target material, but is flexible enough to operate with other target materials such as carbon tetrafluoride or tetraethyllead. Using decay-in-flight neutrino fluxes at Fermilab (NuMI or LBNF), the νBDX-DRIFT detector offers a CEvNS program complementary to other CEvNS projects at the SNS, the ESS or those relying on reactor neutrino fluxes. In this talk I will discuss the different measurements that can be done as well as a recent analysis of the rock neutron background to which the detector will be subject to if operated at Fermilab.

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Fission Product Yields and their Impact on the Reactor Antineutrino Anomaly and CEvNS

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The reactor antineutrino anomaly features a spectral bump in the 5-7 MeV range. Previous analyses have suggested that current models can be improved upon through use of the summation method for spectral calculation. However, this method suffers from compounding uncertainties from fission product yield data in nuclear databases. Moreover, nineteen and twenty fission products have been identified as the primary contributors to the spectral bump in the U^{235} and Pu^{239} spectra, respectively. New measurements of these yields in particular are underway to reduce uncertainties in the summation method. Potential effects of this anomaly on CEνNS spectra from reactor antineutrinos are being investigated.

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Current and future sensitivities to Non-Standard Interactions using CEvNS

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The process of Coherent Elastic Neutrino-Nucleus Scattering (CEvNS) has shown to be sensitive to constrain new physics parametrized by Non-Standard Interactions (NSI). In this talk, we review the current bounds on NSI parameters when combining the recent results from the COHERENT collaboration using CsI and LAr detectors [1]. In addition, we present the expected sensitivities that can be reached with different detection technologies such as germanium, xenon, and silicon, when using the European Spallation Source proposal as a neutrino source [2]. We show that detectors could be combined to break some of the degeneracies that arise when considering two non-vanishing NSI parameters.

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Nuclear Data Needs for Low Energy Neutrino Scattering Experiments

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Accurate calculations of B(GT) are essential for predicting rates in low energy neutrino scattering experiments. However, past experiments have shown discrepancies between theoretical calculations and experimental measurements of B(GT) in some isotopes. This poster presents the current state of B(GT) measurements for isotopes relevant to neutrino scattering, including both charged-current and neutral-current scattering. The various experimental techniques and facilities capable of performing these measurements are also discussed. The importance of experimental B(GT) measurements in improving our understanding of neutrino scattering and advancing our knowledge in nuclear physics is emphasized.

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Preliminary results of a Skipper-CCD inside a nuclear power plant

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Due to its low energy threshold, in the eV range, the Skipper-CCD technology has proved its potential to probe neutrino detection exploiting the CEvNS interaction channel [1]. CCDs are already being used for experiments using antineutrinos from a nuclear reactor, where they have shown their ability in constraining new physics models [2]. In addition, sensitivities to a variety of standard and beyond standard models have been evaluated for a Skipper-CCD in a reactor neutrino experiment [3, 4]. Here we report preliminary results from the first Skipper-CCD sensor inside the dome of a nuclear power plant. The detector, consisting of 0.675 gr effective-active mass, enclosed in a 5 cm lead shield and extra neutron shield based on polypropylene, was installed at 12 m from the center of the reactor core inside the containment building of the Atucha II nuclear power plant. Atucha II is a 2 GWth commercial nuclear reactor situated 100 km north of Buenos Aires City. The system is remotely monitored and operated on continuous readout mode with a sub-electron readout noise of 0.17 e. We discuss the commissioning of the Skipper CCD detector inside Atucha II, evaluate its current performance compared to that reported for the same detection system above ground in [5], and present preliminary data acquired during reactor-ON and reactor-OFF periods during the end of the year 2022.

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Reactor CEvNS constraints improve robustness of neutrino mass ordering determination

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In neutrino oscillation physics numerous exact degeneracies exist under the name LMA-Dark which make it impossible to determine the sign of the atmospheric mass splitting in oscillation experiments. I will discuss how new data from the Dresden-II experiment completely removes the degeneracies in the ν_e sector for mediators down to the MeV scale at which point constraints from the early universe take over. While the LMA-Dark degeneracy is lifted in the ν_e sector, it can still be restored in the ν_μ and ν_τ sector or with very specific couplings to up and down quarks, and we speculate on a path forward.

Phenomenology/ Theory / 25

EFT analysis of New Physics at COHERENT

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Using an effective field theory approach,we study coherent neutrino scattering on nuclei, in the setup pertinent to the COHERENT experiment. We include non-standard effects both in neutrino production and detection, with an arbitrary flavor structure, with all leading Wilson coefficients simultaneously present, and without assuming factorization in flux times cross section. A concise description of the COHERENT event rate is obtained by introducing three generalized weak charges, which can be associated (in a certain sense) to the production and scattering of ν_e, ν_μ and $\bar{\nu}_\mu$ on the nuclear target. Our results are presented in a convenient form that can be trivially applied to specific New Physics scenarios. In particular, we find that existing COHERENT measurements provide

percent level constraints on two combinations of Wilson coefficients. These constraints have a visible impact on the global SMEFT fit, even in the constrained flavor-blind setup. The improvement, which affects certain 4-fermion LLQQ operators, is significantly more important in a flavor-general SMEFT. Our work shows that COHERENT data should be included in electroweak precision studies from now on.

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BULLKID: Monolithic array of particle absorbers sensed by Kinetic Inductance Detectors

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We present BULLKID, a project aiming to deliver a scalable cryogenic detector for coherent neutrino nucleus scattering and low-mass Dark Matter direct detection.
The device consists of an array of silicon targets sensed by multiplexed Kinetic Inductance Detectors (KIDs).
The prototype we present is made of 64 cubic voxels of $5.4 \times 5.4 \times 5$ mm^3 each carved out of a 5 mm thick 3” silicon wafer.
The carvings leave intact a 0.5 mm thick common disk acting as a holder for the dices and as substrate for the KID structures.
The resulting array is monolithic and highly segmented in order to avoid individual holding structures that may generate backgrounds.
The operation of this still nonoptimized prototype has led to an average baseline resolution of 26 ± 7 eV, demonstrating that it is suitable for the detection of low energy processes.
We present the status of the project and the steps towards a further improvement of the energy resolution and towards a first measurement of the background.

Poster advertisment / 27

Muon-Induced Neutron Backgrounds for the COHERENT Germanium CEvNS Experiment

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Ge-mini is a germanium detector subsystem, part of the COHERENT experiment at the Spallation Neutron Source at Oak Ridge National Lab. As a CEvNS experiment, Ge-mini is sensitive to backgrounds from varying sources, mitigated by multiple layers of shielding including High Density Polyethylene (HDPE), copper, and approximately 6 US tons of lead. Since Ge-mini is located at a depth of ˜ 8 m.w.e., cosmic muon-induced neutron production is expected at non-negligible rates, due predominantly to muon interaction in the lead shielding. Monte Carlo N-particle Transport (MCNP) code is utilized to simulate the propagation of muon-induced neutrons through Ge-mini’s shielding. Results of estimated background rates in the Ge-mini CEvNS signal due to cosmic-induced neutrons will be presented.

Poster advertisment / 28

Cryogenic inorganic scintillator for the detection of non-standard neutrino interactions and low-mass dark matter

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Inorganic scintillating detectors are widely used in the detection of dark matter and neutrinos due to their relatively high light yields and easy light readout with PMTs at room temperature. Our prototype, pure CsI coupled with SiPMs at cryogenic temperature, can achieve a much higher light yield. The high light yield illustrates the great potential of this novel combination for neutrino and low-mass dark matter detection, particularly at accelerator-based neutrino sources, where the random background can be highly suppressed by requiring coincident triggers between SiPMs and beam pulse timing signals. The scientific motivations, key ingredients, prior work, future plans, and sensitivities will be presented in detail.

Experiments / **29**

Recent results of the RED-100 experiment

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RED-100 is a two phase emission detector with 130 kg of Xe as a target material designed to study coherent elastic neutrino-nucleus scattering (CEvNS). In 2021-2022, this detector was deployed 19 meters from the reactor core of Kalinin NPP (Udomlya, Russia) to search for CEvNS of reactor antineutrinos. Both reactor ON and reactor OFF data were acquired during the exposition. At the present moment the analysis of the collected data is underway. This talk describes the methods of analysis and presents the recent results of the experiment. The possibility to use argon as a target material in the detector is also discussed.

New Ideas / **30**

Characterisation of particle interactions in superconducting calorimeters

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The Ricochet experiment aims to detect coherent elastic neutrino-nucleus
scattering at the Institut Laue-Langevin nuclear reactor in Grenoble, France. The experiment is expected to start data-taking in 2024 with two complementary detector technologies, both employing cryogenic calorimeters. One of the two detector technologies envisaged by Ricochet has a target mass consisting of superconducting crystals.

When a neutrino interacts coherently with a nucleus in a superconducting crystal lattice, the recoil energy produces phonons and excites cooper pairs into Bogoliubov quasiparticles. The millielectronvolt-scale bandgap of superconductors might enable a significantly lower energy threshold with respect to semiconductor-based detectors.

In this work, we demonstrate the detection of particle-induced pulses in a superconducting calorimeter, read out using a manganese-doped aluminium transition-edge sensor. In addition, we investigate and characterise the detector response to muon, gamma and neutron interactions.

Experiments / 31

Status of the nuGeN experiment

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The νGeN experiment is aimed to study neutrino properties at the close vicinity of the reactor core of Kalinin Nuclear Power Plant (KNPP) at Udomlya, Russia. The experimental setup is installed under reactor unit #3 of KNPP at the moving platform which allow to change distance from the center of the 3.1 GW$_{th}$ core from 11.1-12.2 m. In this way, we obtain an enormous antineutrino flux of (3.6-4.4)x10^{13} ν/cm^2/s. Materials of the reactor surrounding provide about 50 m w.e. overburden, that serves as a good shielding against cosmic radiation. In combination with a low ambient background, it gives us a unique opportunity to investigate antineutrino properties at the best experimental location in the world. To detect signals from the neutrino scattering we use high-purity low-threshold germanium detector surrounded by passive and active shielding. A specially developed acquisition system allows suppressing events that correspond to noise. The current status of the experimental setup, data taking and results of comparison of the spectra with reactor on and off regimes will be presented.

Poster advertisment / 32

Background study in RED-100 experiment

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RED-100 is a two phase emission LXe detector exposed at Kalinin NPP to study coherent elastic neutrino nucleus scattering (CEvNS) in a flux of reactor antineutrinos. Several campaigns were carried out to study external background at the detector location under the reactor core. During RED-100 data taking, continuous monitoring was organized in order to check the external background flux dependence on the reactor operational periods. The main background in the region of interest was caused by the spontaneous single electron noise inspired by the cosmic muons. Methods of the background study and recent results are presented in this poster.

Phenomenology/ Theory / 33

Light vector bosons and the weak mixing angle in the light of new reactor-based CEνNS experiments

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After the first CEνNS detections, further experiments with different technologies have been established and the question arises how to further exploit this signal for a wide variety of investigations in the future. In this context, nuclear reactors with their intense emission of low-energy antineutrinos in combination with high-purity germanium detectors have already shown their potential for CEνNS studies and represent a scalable technology for future precision experiments. Such measurements are interesting because deviations from the CEνNS prediction of the Standard Model could indicate the existence of new neutrino interactions. In particular, a light vector boson may imply corrections to the Weinberg angle, so increasing the precision of this observable will help to probe additional U(1) extensions of the Standard Model. In this talk, we discuss the potential of future germanium-based reactor experiments for precision measurements of the weak mixing angle as well as for the search for a new light vector boson that may exist. Using a data-based reactor antineutrino prediction, we present the experimental sensitivity for both topics with particular emphasis on their interrelation. In addition, the effects of characteristic experimental parameters such as detector mass and energy threshold are presented. In this way, we show where improvements in detector design could have the strongest impact on physics investigations.

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COHERENT's New Tonne-Scale NaI Detector

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The COHERENT collaboration operates a multi-target suite of low-threshold neutrino detectors at the Spallation Neutron Source (SNS) at Oak Ridge National Laboratory. These detectors are uniquely equipped to observe the dominant low-energy ($E_\nu \sim 10$s of MeV) interaction of coherent elastic neutrino-nucleus scattering (CEνNS). The only experimental trace is a nuclear recoil of mere tens of keV. To probe the distinctive neutron-number-squared scaling of CEνNS's Standard Model cross sections, COHERENT invokes the spice of life: variety. The CEνNS detector targets thus far range across CsI, LAr, Ge, and NaI.

The COHERENT program is expanding, and a large scintillating NaI[Tl] detector—christened NaI Neutrino Experiment TonnE-scale (NaIνETe)—is among the new generation. Tasked with measuring CEνNS on the relatively light ^{23}Na nucleus, its design capitalizes on a custom dual-gain PMT base to facilitate simultaneous measurements of CEνNS on ^{23}Na and of charged-current interactions on ^{127}I. Each of the five modules will contain 63 of the 7.7-kg crystals, a total mass of over 2.4 T. The first test module (470kg) of NaIνETe is configured for a CEνNS search and taking production data. Adding to this successful deployment, subsequent modules are in construction and will be deployed in 2023.

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Status of the NUCLEUS experiment

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Coherent elastic neutrino nucleus scattering (CEvNS) is a well-predicted Standard Model process only recently
observed for the first time. Its precise study could reveal non-standard neutrino properties and open a window
to search for physics beyond the Standard Model.
NUCLEUS is a CEvNS experiment conceived for the detection of neutrinos from nuclear reactors with
unprecedented precision at recoil energies below 100 eV. Thanks to the large cross-section of CEvNS, an ultra-
low threshold cryogenic detector of 10g of CaWO4 and Al2O3 crystals is sufficient to provide a detectable
neutrino interaction rate.
NUCLEUS will be installed between the two 4.25 GW reactor cores of the Chooz-B nuclear power plant in the
French Ardennes, which provide an anti-neutrino flux of 1.7 x 10ˆ12 v/(s cm2). At present, the experiment is
under construction. The commissioning of the full apparatus is scheduled for 2023, and will them be moved to
the reactor site.

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Feasibility of solar neutrino measurement with the CYGNO/INITIUM experiment.

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The CYGNO project aims to develop a gaseous high-precision Time Projection Chamber with an optical readout for directional Dark Matter searches and solar neutrino spectroscopy. The innovative features of CYGNO are the use of a He-CF_4 scintillating gas mixture, at atmospheric pressure and room temperature, together with a triple GEM amplification system optically coupled to PMTs and sCMOS cameras. By combining the information of the high-granularity camera with the fast sampling of the PMT, it is possible to perform 3D tracking with head-tail capability and particle identification down to O(keV) energy. The ERC project INITIUM, in synergy with CYGNO, aims to develop negative ion drift operations within the CYGNO 3D optical approach.

DM detectors are known to be sensitive to neutrino interaction through CevNS, which represents a nearly irreducible background if no directional information is employed to handle it. Directional DM detectors, as high precision gaseous TPCs, are not only able to discriminate this background from a DM signal but even better, to promote neutrino from an inconvenience to a physics case. Directionality can indeed be exploited not only on NR induced by CEvNES but also on ER generated by the elastic scattering of O(100) keV neutrinos on the target atomic electrons.

With a TPC, it is possible to well identify the signal by reconstructing the electron direction. The angular distribution of the electron recoil will show indeed a peak in the opposite direction of the Sun (produced by neutrinos) over a flat background component. In addition, because of the low density of the gas which determines a low multiple scattering, the reconstruction of the electron direction is feasible down to an energy of few tens of keV corresponding to about 60 keV threshold on neutrino energy.

In the presentation, we will show the latest results of the CYGNO experiment, with a particular focus on the overground commissioning of the LIME prototype, with a 33x33 cm^2 readout area and a drift length of 50 cm. We will discuss the development of the MC simulation of sCMOS images, and the data/MC agreement obtained between these and the X-ray data. We will then show, exploiting simulated data, the ability to reconstruct the direction of low-energy electron recoil, and we will finally illustrate the sensitivity limits for a solar neutrino measurement obtained by performing a bayesian analysis on the Monte Carlo.

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Studies of Coherency Effects in Neutrino-Nucleus Elastic Scattering using PCGe Detectors

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Neutrino nucleus elastic scattering (νAel) is the direct test for electroweak interaction in the Standard Model of particle physics. Several experimental programs are being actively pursued in the observation of low energy νAel. The TEXONO research program at Kuo-Sheng neutrino laboratory (KSNL) uses state-of-art point contact Germanium detector technology with $\mathcal{O}$(100 eV) threshold to probe such low energy interactions. We will highlight the current status and results of the νAel activities at the TEXONO experiment. The studies of analytical formulation and the constraints on coherency effects in νAel will also be presented.

[1] "Coherency in neutrino-nucleus elastic scattering", S. Kerman et al., TEXONO Collaboration, Phys. Rev. D 93, 113006 (2016).

[2] "Studies of quantum-mechanical coherency effects in neutrino-nucleus elastic scattering", V. Sharma et al., TEXONO Collaboration, Phys. Rev. D 103, 092002 (2021).

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A Ton-Scale LAr CEvNS Detector at ORNL

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Coherent elastic neutrino-nucleus scattering (CEvNS) was detected on liquid argon (LAr) using the CENNS-10 detector at Oak Ridge National Laboratory in 2021. Ongoing research is focused on developing a ton-scale LAr detector that can measure CEvNS with greater precision, including sensitivity to charge-current neutrino interactions and an increased detection rate twenty times greater than that of the CENNS-10. The COH-Ar-750 detector is currently being designed with photomultiplier tubes for light collection, but we are exploring the incorporation of silicon photomultipliers to reduce the energy threshold and increase the detector's dynamic range. Additionally, an updated liquefier design is being tested. Simulation work and related results will be presented, along with physics cases for the use of underground argon (UAr) and xenon-doping to enhance sensitivity to non-standard neutrino interactions and beyond the Standard Model physics. CEvNS is a key area of research in the field of neutrino physics, and detection of this process has the potential to provide valuable insights into the properties of neutrinos and the broader field of particle physics.

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Solar Neutrino Nucleus Coherent Scattering at Direct Dark Matter Detectors

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Direct dark matter detectors can be sensitive to detection of solar neutrinos through the CEvNS process at low thresholds. We analyse the possibility of detecting radiative correction to the tree level cross-sections at the dark matter detectors. Utilizing neutrino flavour oscillation of solar neutrinos as a source of flavour dependent flux, we explore the likelihood of detecting radiative corrections at percent level which make the neutrino nucleus interaction flavour-dependent.

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The CONNIE experiment with Skipper CCDs

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The Coherent Neutrino-Nucleus Interaction Experiment (CONNIE) aims to detect the coherent elastic neutrino-nucleus scattering (CEvNS) of reactor antineutrinos off silicon nuclei using fully depleted high-resistivity charge-coupled devices (CCDs). The experiment, located at a distance of 30 m from the core of the 3.8 GW Angra 2 nuclear reactor in Rio de Janeiro, was able to set upper limits on the coherent scattering rate and place stringent constraints on simplified extensions of the Standard Model with light mediators. The detector was upgraded in 2021 to host 2 Skipper CCDs with the purpose of further reducing the detection energy threshold. Since then, CONNIE has achieved stable operation of the new sensors with a readout noise of 0.15 electrons and a single-electron rate of about 0.05 e-/pix/day. In addition, new methods of event extraction and selection are being developed, based on the sharper images that allow the effects of instrumental backgrounds to be identified and masked, thus permitting to lower the threshold to 15 eV. The performance of the Skipper CCDs is presented, together with the improved selection and the resulting low-energy background spectrum, measured by CONNIE in the 2022 reactor-off period. The prospects for detecting CEvNS with the Skipper-CCD technology are also discussed.

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First demonstration of 30eVee ionization energy resolution with RICOCHET germanium cryogenic bolometers

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The RICOCHET reactor neutrinos observatory is planned to be installed at Laue Langevin Institute (ILL) starting in mid-2022. The scientific goal of the RICOCHET international collaboration is to perform a low-energy and percentage-precision CEvNS measurement. To that end, RICOCHET will host two cryogenic detector arrays : the CRYOCUBE (Ge target) and the Q-ARRAY (Zn target).

The CryoCube will be composed of 27 Ge crystals of 30g instrumented with NTD-Ge thermal sensor as well as aluminum electrodes operated at 10 mK in order to measure both the ionization and the heat energies arising from a particle interaction. One of the specifications the Cryocube has to follow to be a competitive CENNS detector is to attain a low energy threshold (˜50 eV), which requires a low ionization energy resolution.

In this poster, we present the latest developments in the optimization of the measure of the ionization energy that led to a first demonstration of a 30eVee ionization energy resolution. This poster will include the presentation of the experimental setup and the analysis of the data that presents this world-leading resolution.

Experiments / **42**

CYGNUS: Rare event searches with directional TPCs

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Directional and particle identification capabilities can play a critical role in rare event searches, and it becomes especially challenging when very low energy thresholds need to be reached. Large gaseous detectors with high granularity readout could represent a groundbreaking solution, by combining detectable flight length at low recoil energy, very good discrimination between nuclear and electronic recoils and the possibility of tuning the gas mixture to improve the sensitivity to specific processes and energy ranges. The CYGNUS community is exploring several different technological solutions for the detection of nuclear recoils from light dark matter in gaseous TPCs with high granularity readout. It will also open a new path for the detection of coherent neutrino scattering, with the additional capability of reconstructing electron recoils from elastic neutrino scattering. The different options under study and the status of the ongoing experimental tests will be reviewed.

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Cosmogenic & reactogenic background estimations of the RICOCHET experiment

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Currently under installation at the Institut Laue-Langevin nuclear reactor, the RICOCHET experiment aims to detect reactor antineutrinos via the CEvNS process with great precision and look for new physics beyond the Standard Model. This experiment will use cryogenic bolometers with low energy threshold (50 eV) and particle identification to achieve these goals. A crucial part to the success of this experiment is the estimation of the background level of the site, such as the cosmogenic and reactogenic backgrounds. Extensive simulations using GEANT4 have been performed to design the shielding and the muon veto geometries needed to mitigate the reactogenic and cosmogenic backgrounds. Details of these simulations will be presented in this talk. Using the results on the simulated background rates and the expected signal, we then estimate the sensitivity to the CEvNS process and physics beyond SM.

Experiments / 44

Results from a Prototype TES Detector for the Ricochet Experiment

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Coherent elastic neutrino-nucleus scattering (CEvNS) offers valuable sensitivity to physics beyond the Standard Model. The Ricochet experiment will use cryogenic solid-state detectors to perform a precision measurement of a CEvNS spectrum at the ILL nuclear reactor. The experiment will employ an array detectors, each with a mass of approximately 30 g and an energy threshold of 50 eV. Nine of these detectors (the 'Q-Array') will be based on a novel Transition Edge Sensor (TES) readout style, in which the TES devices are thermally coupled to the target using an Au wirebond. I will present our initial characterization of a Q-Array-style detector architecture using a 1-gram Si target.

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Multi-Channel processing of solid-state cryogenic detectors for CEvNS precision measurement using the MPS Python library

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In precision CEvNS experiments like RICOCHET at Laue Langevin Institute reactor, the recoil energy is encoded in the amplitudes of pulses. In such experiments, detectors like the CRYOCUBE use multi-channel cryogenic solid-state detectors which is a promising technology to achieve low threshold gamma/neutron discrimination by measuring the ionization yield against heat energy. The CEvNS detection sensitivity and ultimate performances can only be achieved using performant and characterized signal processing techniques that allows for automated pulses detection and fitting. The proposed algorithm developed for RICOCHET implements low-threshold pulses detection, correlated noise reduction and efficient baseline noise estimation to manage the high event rate environment that we observe during calibration and above ground operations.

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Reactorgenic neutrino detection using liquid neon

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Reactor neutrinos are useful for both applied and fundamental measurements. To date, these neutrinos have only been observed via charged current interactions requiring large liquid or solid scintillators. With the advent of CEvNS, new opportunities to monitor the status of reactors which requires smaller detectors are an appealing possibility to future integrated non-proliferation technology. This work explores the feasibility of using liquid neon rather than liquid argon in a single-phase scintillation detector for this purpose.

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The Neutrino Laboratory at the Spallation Neutron Source

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The first observations of coherent elastic neutrino nuclear scattering (CEvNS) on multiple nuclei were recently made by the COHERENT experiment at the Spallation Neutron Source at the Oak Ridge National Laboratory. This basic interaction now lays the foundation for a new era in developing compact neutrino detectors as well as a new probe of physics topics including electromagnetic properties, searches for physics beyond the standard model, and nuclear form factors. The Spallation Neutron Source is ideally suited for not only CEvNS studies but also a broader set of high-precision neutrino physics measurements and dark matter searches due to the accelerator's intensity, pulsed structure, and proton-beam energy. We present an overview of the compelling scientific opportunities in particle physics enabled by proton power upgrades now underway and a future upgrade of a new target facility at the SNS.

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Calibrating CEvNS Detectors

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The experimental characteristic for a CEvNS detection is a low-energy nuclear recoil. For many detector technologies, the total energy of the recoil is not fully transferred into the signature —e.g. scintillation, ionization. In this case, the "quenching factor"needs to be calibrated. I will briefly present a set of the most common techniques to measure these effects with precision, and touch on the impact for the CEvNS community.

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The NEWS-G3 Experiment

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The NEWS-G3 experiment is planning to use a Spherical Proportional Counter (SPC) for the measurement of coherent elastic neutrino-nucleus scattering at a nuclear reactor. The detector consists of a low-radioactivity copper sphere enclosed in a compact shield made of layers of copper, polyethylene and lead. The shield is equipped with an active muon veto made of twelve plastic scintillation panels. A choice of low atomic mass gaseous targets and the SPC's low energy threshold provides high sensitivity to low-energy recoil. A novel multi-anode sensor, named ACHINOS, placed at the center of the SPC, allows for operations at high pressures. The NEWS-G shielding is now installed at Queen's university. Preliminary measurements for the estimation of background levels, veto efficiency and livetime are ongoing. The detector is planned to operate in argon or neon-based mixtures, in a 60 cm diameter low radioactivity copper sphere, which is planned to arrive at Queen's this summer.

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Potential to discover new physics with CEvNS detectors at the Second Target Station of the Spallation Neutron Source

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Oak Ridge National Laboratory has begun a decade-long upgrade to its Spallation Neutron Source (SNS) accelerator which will double the beam power and commission a second target station for neutron production. This machine will also produce a world-leading source of 0-53 MeV neutrinos produced as a byproduct of neutron production. The COHERENT collaboration has already exploited neutrinos at the SNS to make the first detection of coherent elastic neutrino nucleus scattering (CEvNS) and the strongest constraint yet placed on dark matter particles with masses near 25 MeV. In this talk, we will focus on opportunities for further advances in fundamental physics at the second target station. Of interest, we will cover future constraints of BSM neutrino interactions, limits on sterile neutrinos and exotic oscillations, and searches for dark matter. These large detectors will also allow for a measurement of the weak mixing angle at low Q2 and measurement of the weak charge radius of target nuclei. We will also discuss future measurements of inelastic neutrino scattering on nuclei relevant for other neutrino experiments within the field but whose cross sections are currently poorly understood.

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Commissioning the COHERENT ge-mini Detectors

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The COHERENT High Purity Germanium detector array (ge-mini) is a dedicated low background CEνNS experiment deployed at the Spallation Neutron Source (SNS) at Oak Ridge National Lab. The SNS delivers a pulsed source of neutrinos which provides an excellent suppression of steady state backgrounds as well as unique challenges in data acquisition. In this poster we will report on the commissioning of the ge-mini detector system as well as the data acquisition scheme put in place. We will highlight an initial look at background measurements in-situ as well as energy resolution measurements as we prepare nominal operations.

Poster advertisment / 53

A fast, easily multiplexable, high Z cryogenic scintillator for γ tagging or veto in very low noise experiments

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By combining a BGO scintillator crystal, and a Kinetic Inductance Detector light readout, we can take advantage of the BGO's high density, high Z, high radiopurity, high light-yield at cryogenic temperatures and relatively fast timing, and combine it with a KID's fast response time, ease of readout, natural multiplexing and sub-0.1keV resolution, to obtain a fast sensor that is well suited to read out γs from the full 4π solid angle around the detector, with a low threshold and no dead layer. The combination of these factors makes this detector well suited for applications such as γ tagging and γ+μ veto, which rely on proximity to the detector, large solid angle coverage and a short readout time.

Welcome / **54**

Welcome/ Introduction

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MINER Experiment

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Ricochet Experiment

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CRAB : Calibration of nuclear recoils at the 100 eV scale in cryogenic detectors using neutron capture

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Cryogenic detectors have reached extremely low energy thresholds, making them useful tools to detect sub-keV nuclear recoils induced by Coherent Elastic Neutrino-Nucleus Scattering (CEνNS), or interactions with light Dark Matter. However, these detectors lack calibration for nuclear recoils at this energy scale. We propose using nuclear recoils produced by γ de-excitation after thermal neutron capture in the cryogenic detector to provide calibration peaks in the region of interest [1]. In particular, single-γ transitions of several MeV induce well-defined nuclear recoil peaks in the 100eV-1keV range. The suggested method is so far the only calibration method offering pure nuclear recoils in the bulk of the detector, and in this energy range.

Combining GEANT4 Monte-Carlo simulations, and γ de-excitation predictions from the FIFRELIN code, we have studied the expected energy spectrum in various cryogenic detectors widely used in the community. We report the first measurement with a $CaWO_4$ cryogenic detector of the NUCLEUS experiment [2] and a portable thermal neutron source. It shows a nuclear recoil peak at around 112eV with a 3σ significance and evidence at the 6σ level of the full spectrum of nuclear recoils induced by thermal neutron captures, in very good agreement with simulations [3]. To our knowledge, this result constitutes the first direct observation of a nuclear recoil peak at the 100eV scale and demonstrates the feasibility of the CRAB method as an in-situ non-intrusive calibration of cryogenic detectors for CEνNS and Dark Matter experiments.

In a second experimental phase, the CRAB project intends to perform high-precision measurements with a thermal neutron beam at the low-power TRIGA reactor in Vienna. The sensitivity of the CRAB method is significantly increased by the detection of the emitted γ in coincidence with the subsequent nuclear recoil and by the interplay between the γ-cascade timing and the timing of the nuclear recoil in matter. Potential applications for lower recoil energies and to other materials, such as germanium or silicon, will be presented.

[1] L. Thulliez, D. Lhuillier et al., Calibration of nuclear recoils at the 100 eV scale using neutron capture, JINST, 16, 7 (2021)

[2] G. Angloher et al. (NUCLEUS), Exploring CEvNS with NUCLEUS at the Chooz nuclear power plant. Eur. Phys. J. C 79, 1018 (2019)
[3] H. Abele et al. (CRAB and NUCLEUS), Observation of a nuclear recoil peak at the 100 eV scale induced by neutron capture. arXiv:2211.03631 [nucl-ex] (2022)

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Low-Energy Excess

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Experimental Summary

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Theory Summary

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Solar Neutrinos with Dark Matter Detectors

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A Direct Detection View of the Neutrino NSI Landscape

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Neutrino non-standard interactions (NSI) have been extensively explored in the context of dedicated neutrino experiments. However, the next generation of direct detection experiments is on course to observe a significant number of solar neutrino events, and the sensitivities of these experiments within the NSI landscape are yet to be determined. Due to their sensitivity to neutrino-nucleus and neutrino-electron scattering, as well as to tau neutrinos, direct detection provides a complementary view of the NSI parameter space to that of spallation source and neutrino oscillation experiments. To study their potential in the NSI landscape, we develop a re-parametrisation or the NSI framework that explicitly includes a variable electron contribution and allows for a clear visualisation of the complementarity of the different experimental sources. For the first time, we compute the NSI sensitivity limits from the first results of the XENONnT and LZ experiments, and we obtain future

xenon-based projections. Our results demonstrate indicate that next-generation direct detection experiments will form powerful probes of neutrino NSI.

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