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Fermi National Accelerator Laboratory

Book of Abstracts

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Precise Measurement of Reactor Antineutrino Oscillation Parameters and Fuel-dependent Variation of Antineutrino Yield and Spectrum at RENO

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The RENO experiment has measured the neutrino mixing angle θ_13 and dm^2_ee, using reactor antineutrinos from the reactors at Hanbit Nuclear Power Plant since Aug. 2011. RENO has accumulated and analyzed ~2200 days of data with reduced backgrounds and thus decreased systematic uncertainties. Due to the improved statistics and systematic uncertainties we obtained precisely measured values of sin^2(2θ_13) and dm^2_ee. Using the data sample of roughly 1 M inverse beta decay (IBD) events, we also observed a fuel-composition dependent variation of reactor antineutrino yield. This observation indicates that reevaluation of the IBD yield per fission for the fuel isotope U235 may mostly solve reactor antineutrino anomaly. In this presentation, we will describe how to reduce the backgrounds and obtain the fuel-composition dependent variation of the IBD yield.

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Using Convolutional Neural Networks to Reconstruct Dead Channels in MicroBooNE

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The MicroBooNE experiment at Fermilab is a short baseline neutrino experiment. The experiment was created with the goal of examining the low-energy excess seen in MiniBooNE. The MicroBooNE detector is a LArTPC which relies on three wire readout planes to collect data. In order to examine the low energy excess, it is necessary to reject background with high efficiency while retaining high purity and efficiency of signal events. One major problem is about ten percent of the readout wires are either missing (dead) or noisy. Traditional cosmic ray taggers often fail due to these dead channels, especially in regions with clusters of dead wires. These algorithms involve clustering groups of charge together which is often broken up by the dead wires. This poster presents the results for implementing a generative neural network that reconstructs the ADC values in the dead channels in the context of improving the results of the cosmic ray tagging algorithms.

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Phenomenology of Atmospheric and Accelerator Neutrinos

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Tau neutrinos and upward-going air showers: stochastic versus continuous energy loss

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We discuss the detection of cosmogenic neutrinos by using the Earth as a tau neutrino converter for upward-going extensive air showers from tau decays and quantify the experimental detection capability based on our calculation, including using the Probe of Extreme Multi-Messenger Astrophysics (POEMMA) for optical air Cherenkov detection. The sensitivity of POEMMA will also be discussed. We go through the strategies and differences involved in modeling the Earth layers (water & rock) as being stochastic compared to continuous which has been described in an earlier work.

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Axial Form Factor and Neutrino Nucleus Cross Sections

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Including wave packet decoherence in sterile searches at long-baseline experiments.

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Most of literature usually consider massive neutrinos as particles with definite energy and momentum, formally plane waves. However, as plane waves
cover all space-time it is impossible to describe localized processes as neutrino
production and detection. Thus, in quantum mechanics, real particles can
only be described by wave packets. The spatial uncertainty of neutrino
wave packets are directly related to the overall energy uncertainty of neutrino
production and detection. For oscillation to occur in a given experiment, the
overall energy uncertainty must be greater than the difference in energies of
the neutrino mass eigenstates, so that they are kinematically indistinguishable and exhibit coherence. If this coherence condition is violated, the flavor

oscillation probabilitites change form and may impact experimental results. In this work we investigate how the coherence condition is violated in search for sterile neutrinos in experiments such as MINOS and MiniBooNE, and how it could impact the capability of these experiments to see sterile effects.

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Bi-probability plots and PMNS compatibility studies with the T2K experiment

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Bi-probability plots are a way of displaying the expected neutrino and antineutrino oscillation probabilities for long baseline neutrino experiments. They provide an easy visualisation of how δ_{CP} and mass hierarchy affect neutrino probabilities, and allow theorists to easily compare their theory predictions to experimental data fit results. We present the electron (anti)neutrino appearance bi-probability plots from the most recent T2K data fit. We also present bi-probability plots from fits with an extra parameter, β, that allows the fit additional freedom compared to the PMNS model and tests the compatibility of the T2K data with the PMNS model.

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Reconstruction and selection tools for charged-current muon neutrino inclusive cross sections in SBND.

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SBND, a 112 ton liquid argon time projection chamber, is the near detector of the short-baseline neutrino program at Fermilab. Once data taking begins in 2020, it will provide flux constraints for sterile neutrino searches and produce world leading neutrino-argon cross-sections with seven million neutrino events in 3 years. This poster will describe the tools developed for selecting charged-current muon neutrino interactions over the beam and cosmic induced muon background whose provenance lies outside of the detector. The tools are evaluated using simulated data from the time projection chamber and cosmic ray tagger systems.

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ν_μ-Low recoil analysis in medium energy era of MINERνA Experiment

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The charged-current process($\nu_\mu A \rightarrow \mu X$) is analyzed using MINERνA detector. ν_μ interactions in the hydrocarbon scintillator tracker from the medium energy(ME) NuMI beam are used to study the nuclear effects at low three-momentum transfer q_3. In order to separate the quasielastic and resonance processes we used the observed hadronic energy and the muon kinematics following the procedure developed in the previous low energy beam analysis. We compare MINERνA reconstructed distribution with the GENIE simulation adding new bins in q_3 now available with the ME beam. The aim of this analysis is to measure flux integrated differential cross section as a function of q_3 and the reconstructed available energy E_{avail}.

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Development of Improved Noble Liquid Purity Measurements

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Liquid Argon Time Projection Chambers (LArTPCs) are high precision particle detectors whose performance strongly depends on the non-attenuation of ionization electrons, which must drift up to several meters before being collected, produced by the charged particles that cross its volume. For this to happen, the liquid argon used as active volume must be extremely pure of electronegative impurities that could absorb the ionization electrons. Thus, it is fundamental to monitor the argon's purity at all times during detector operation. Current approaches used for purity measurements have limitations, so there is room for improvement in this aspect of LArTPC detector technology that would be beneficial for future experiments. This work presents an alternative design concept for a technology to monitor liquid argon purity, still in its early development stages, which is an attempt to make such an improvement.

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Theories Beyond the SM and Neutrinos

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Solar WIMP Annihilation Search with IceCube

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Weakly interacting massive particles (WIMPs) can be gravitationally captured by the Sun and trapped in its core. The annihilation of those WIMPs into Standard Model particles produces a spectrum of neutrinos whose energy distribution is related to the dark matter mass. In this analysis, we focus on dark matter masses greater than 100 GeV and look for an excess flux of muon neutrinos in the direction of the Sun using 7 yrs of IceCube data. We expect this analysis to place the most stringent limits on spin-dependent dark matter searches.

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Towards Atomic Tritium in Project 8

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Rotational and vibrational excitations of molecular tritium (T2) perturb the beta spectrum endpoint, which limits neutrino mass sensitivity
in T2-based experiments to about 100 meV. Atomic tritium opens a path
for Project 8 to reach a neutrino mass sensitivity goal of 40 meV. To that
end, the collaboration is developing techniques needed to produce, cool,
and trap atomic tritium in a way that is compatible with Cyclotron Radiation Emission Spectroscopy.
These efforts include a hardware testbed for
characterizing the beam from a custom-designed, coaxial-current hydrogen atom source. The scope of the testbed will include magnetic focusing
and cooling of the beam, for eventual integration with an atomic hydrogentrapping demonstrator.
Here, progress is presented on the construction
and commissioning of the atom source and hardware testbed. This work
is supported by the US DOE Office of Nuclear Physics, the US NSF, the
PRISMA Cluster of Excellence at the University of Mainz, and internal
investments at all institutions.

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Short-baseline Experiments and Phenomenology

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Implementation of electrical wire-tension measurement method for liquid-argon time projection chambers

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Current liquid-argon time projection chambers make use of wire planes called anode plane assemblies to measure ionization electrons. For quality assurance reasons, the tension of those wires needs to be within tolerance. In kiloton-scale liquid-argon time projection chambers, the large number of

wires for which the tension needs to be measured becomes an issue due to the slow speed of the currently used laser-based measurement method. A new method based on applying AC and DC voltages on neighbouring wires has recently been published. Such a method allows to measure the tension of several wires simultaneously. This talk will present ongoing R&D efforts regarding a concrete implementation of this new method, which could be used during the production and installation of the upcoming DUNE detector.

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Neutrino mixing and CP violation from an asymmetric Yukawa texture

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We construct an *asymmetric* Yukawa texture motivated by $SU(5)$ grand unified theory (GUT) where the seesaw matrix is diagonalized by the tribimaximal (TBM) matrix. This texture reproduces the mass ratios of down-quarks and charged-leptons at the GUT scale, the CKM matrix, and the Gatto relation. It overestimates the reactor angle; however, introducing a *single* parameter as phase in the TBM matrix aligns all three neutrino mixing angles to their Particle Data Group (PDG) value. It predicts a CP violating Dirac phase of 1.32π, consistent with PDG. We also calculate the Majorana phases predicted by this texture and relate the effective Majorana mass $m_{\beta\beta}$ to the lightest neutrino mass. Finally, we propose that the underlying family symmetry for this texture is the nonabelian discrete group $\mathcal{T}_{13}$, semidirect product of $\mathcal{Z}_{13}$ with $\mathcal{Z}_3$.

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Characterization Process of WLS for photon detection system of the DUNE Experiment

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The photon detection system of the Deep Underground Neutrino Experiment (DUNE) will operate detecting scintillation light on Liquid Argon (LAr). The wavelength of scintillation lies in the vacuum ultraviolet (VUV) range, silicon photomultipliers (SiPMs) and tube photomultipliers (PMTs) will be used as devices to detect photons, being necessary to convert the wavelengths to the visible. For these light conversions wavelength shifter compounds (WLS) are used, which are able to absorb light at one wavelength and reemit at another wavelength. Cryogenic tests were performed to evaluate that WLS and deposition technique are good choices in order for the film to have the best shifting efficiency and withstand the conditions that will be submitted. To compare the adhesion and stress suffered by the films on the substrate when subjected to temperature differences it was used characterization techniques.

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Double beta decay searches in the NEXT experiment

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Natural radioactivity represents one of the main backgrounds in the search for neutrinoless double beta decay. Within the NEXT physics program, the radioactivity induced backgrounds are measured with the NEXT-White detector, at the Laboratorio Subterráneo de Canfranc. After a data taking period with xenon depleted in 136-Xe, the radiogenic background model Monte Carlo is fitted to the data in order to obtain both the overall rates and the energy and spatial distributions of the isotopes affecting the bb signal. Assuming this best-fit background model, a value of the sensitivity to the two-neutrino double beta decay is found to be 3.5 sigmas after 1 year of data taking. Currently, a run with 136-Xe with a 90.9% enrichment is being taken, and preliminary results will be presented.

0

Search for Heavy Neutral Leptons in the MicroBooNE LArTPC

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Heavy Neutral Leptons (HNLs) offer a possible extension of the Standard Model via mixing with the three active neutrino flavours. HNLs with masses up to 493 MeV can be produced from kaon and pion decays in the high-intensity Booster Neutrino Beam. These particles would then travel to the MicroBooNE detector where some fraction would decay in-flight to detectable Standard Model particles. This poster presents work to perform the first search for these particles in a liquid argon TPC. A number of methods are used to distinguish the HNL decays from the neutrino and cosmic ray background including utilising the time of flight of the massive HNL with respect to the active neutrinos. As the first search of its kind in a LArTPC this work pioneers techniques applicable for future large scale searches in the both the full Short Baseline Neutrino program and DUNE.

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Reactor Neutrino Spectral Distortions Play Little Role in Mass Hierarchy Experiments

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The Coulomb enhancement of low energy electrons in nuclear beta decay generates sharp cutoffs in the accompanying antineutrino spectrum at the beta decay endpoint energies. It has been conjectured that these features will interfere with measuring the effect of a neutrino mass hierarchy on an oscillated nuclear reactor antineutrino spectrum. These sawtooth-like features will appear in detailed reactor antineutrino spectra, with characteristic energy scales similar to the oscillation period

critical to neutrino mass hierarchy determination near a 53 km baseline. However, these sawtooth-like distortions are found to contribute at a magnitude of only a few percent relative to the mass hierarchy-dependent oscillation pattern in Fourier space. In the Fourier cosine and sine transforms, the features that encode a neutrino mass hierarchy dominate by over sixteen (thirty-three) times in prominence to the maximal contribution of the sawtooth-like distortions from the detailed energy spectrum, given $3.2\%/\sqrt{E_{\mathrm{vis.}}/\mathrm{MeV}}$ (perfect) detector energy resolution. The effect of these distortions is shown to be negligible even when the uncertainties in the reactor spectrum, oscillation parameters, and counting statistics are considered. This result is shown to hold even when the opposite hierarchy oscillation patterns are nearly degenerate in energy space, if energy response nonlinearities are controlled to below 0.5%. Therefore with accurate knowledge of detector energy response, the sawtooth-like features in reactor antineutrino spectra will not significantly impede neutrino mass hierarchy measurements using reactor antineutrinos.

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Neutrino Decay in Density Matrix Formalism

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We studied neutrino invisible decay, for two types of neutrinos, where we assumed that only the heaviest one can decay.
If we include decay in the neutrino oscillation framework, the hamiltonian of the system is no longer hermitian. We approach this problem using the density matrix formalism. In particular, we study the density matrix in the interaction picture, where we treat the decay as a perturbation, using standard perturbation theory. The time evolution equation in this formalism depends only on the perturbative part of the total hamiltonian.
We derivate neutrino oscillation probabilities, including decay, in the exact or perturbative form, giving an idea on how to apply this study to more complicated problems in the future.

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Constraining Systematic Uncertainties at T2K using Near Detector Data

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VEP effect in neutrino oscillations at DUNE

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The aim is to study the effects of a term in the Hamiltonian of neutrino propagation that violates Einstein's Equivalence Principle. The original idea was proposed by M. Gasperini (Gasperini, M. (1988). Testing the principle of equivalence with neutrino oscillations. Physical Review D, 38(8), 2635.) It constituted an attempt to explain neutrino oscillations. However, in the present case, this effect is treated as a small correction to the Standard Oscillation mechanism in matter.

We present perturbations of the different probabilities used to study and explain the effects in the detection of neutrinos at DUNE and how this term affects the confidence levels and best fit of the usual parameters of the Standard Oscillation, θ_13 and δ_cp.

The authors of this study are Dr. Alberto Gago and students Felix Diaz (PhD student)and Jaime Hoefken (Master's Student).

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Neutrino Portals to Dark Matter

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We explore the possibility that dark matter interactions with Standard Model particles are dominated by interactions with neutrinos. We examine whether it is possible to construct such a scenario in a gauge invariant manner. We first study the coupling of dark matter to the full lepton doublet and confirm that this generally leads to the dark matter phenomenology being dominated by interactions with charged leptons. We then explore two different implementations of the neutrino portal in which neutrinos mix with a Standard Model singlet fermion that interacts directly with dark matter through either a scalar or vector mediator. In the latter cases we find that the neutrino interactions can dominate the dark matter phenomenology. Present neutrino detectors can probe dark matter annihilations into neutrinos and already set the strongest constraints on these realisations. Future experiments such as Hyper-Kamiokande, MEMPHYS, DUNE, or DARWIN could allow to probe dark matter-neutrino cross sections down to the value required to obtain the correct thermal relic abundance.

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X-ARAPUCA efficiency tested in Liquid Argon

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In this work we present the preliminary results for the X-ARAPUCA single-sided efficiency test in liquid argon. This test consists of completely submerging the device in liquid argon and exposing it to an ionizing radiation. A well-known alpha source is placed in front of the X-ARAPUCA in a way that the scintillation light from liquid argon can hit the detector acceptance window. The energy spectrum of the alpha particles is then recovered in the photo-electron unit by integrating the alpha particle signals and correcting the charge obtained by the gain of the silicon photomultiplier (SiPM). In addition to the SiPM gain correction, a correction for the liquid argon purity was made by measuring the slow-time component of the scintillation light in the mean signal of the alpha particles. A Monte Carlo simulation for the experimental setup was performed to determine the number of photons reaching the detector acceptance window. Only two scale parameters separate the experimental and MC simulation spectra, by $\chi 2$ minimization the efficiency of the X-ARAPUCA is retrieved by the scaling factor between the number of photons reaching the detector and the number of detected photo-electrons

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Observation of Supernova Neutrinos via CEvNS

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Coherent elastic neutrino-nucleus scattering (CEvNS) is a neutral-current process in which a neutrino scatters off an entire nucleus, depositing a tiny recoil energy. The process is important in core-collapse supernovae and also presents an opportunity for detection of a burst of core-collapse supernova neutrinos in low-threshold detectors designed for dark matter detection. Here we present an ongoing study of prospects for supernova burst detection via CEvNS in existing and future large-scale detectors.

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Understanding gain changes in single photoelectron

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Super-Kamiokande (SK) water Cherenkov detector is located in Kamioka mine in Japan. The detector was designed to search for proton decay, study solar and atmospheric neutrinos, and keep watch for supernovae. It came into operation in 1996. The SK operation periods are divided into phases where is saw its various upgradations and refurbishments. The last phase was SK-IV where the electronics were updated with QTC-Based Electronics with Ethernet (QBEE).

Over the years, the gain of High Voltage (HV) had naturally and gradually increased therefore, the observed number of hits has increased even if it is same number of photons arriving at the photomultiplier tubes. So, the study was done to check the consistency of number of hits versus QBEE threshold slope with tuned HV settings. The study of relationship between HV gain and QBEE threshold was done in-order to make gather information regarding it. The large systematic uncertainties in solar neutrino spectrum comes from the directional/spacial energy scale non-uniformity. The uncertainties come from the time variation in PMT gain and dark rate. This in-turn affects the time variation of trigger efficiency. So, an improved method of the existing was developed which

included the time variation in PMT gain. An assumption was made that the number of hits increases because small charge 'single photoelectron' events are more likely to cross the QBEE threshold with gain increase.

In this presentation, the relationship between the number of hits vs gain slope using real data for the first time in SK is discussed.

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Organize Working Groups

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Neutron Transport Simulations in DUNE Using LArSoft

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The Pulsed Neutron System (PNS) is a key calibration system in the DUNE single-phase far detector. 40Ar has an antiresonance for neutron capture for neutrons of 57keV kinetic energy that allows neutrons to travel long distances (tens of meters) throughout the detector. Neutron capture on 40Ar releases 6.1 MeV gammas which can be used as a "standard candle" to test detector response. Detector response is dependent on several factors which may vary throughout the detector. Because the PNS can distribute neutrons to all locations of the detector, it is capable of providing location specific electron lifetime and energy resolution measurements. These are relevant to a broad range of DUNE physics goals, particularly for supernova and solar neutrino physics in DUNE. This study simulated the transport of neutrons through a full 10kt detector in LArSoft. The simulations show only a small fraction of neutrons were lost to inelastic interactions with insulation, APAs, and CPAs. Three PNS sources is sufficient to provide coverage for the entire 10kt far detector.

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Neutrino Cosmology

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Experimental Searches for Beyond the Standard Model Physics with Neutrinos

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Cross section model tuning and multiplicity studies in NOvA

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NOvA is a long baseline neutrino experiment based at Fermilab that studies neutrino oscillation parameters via electron neutrino appearance and muon neutrino disappearance. The oscillation measurements compare the Far Detector data to an oscillated prediction which accounts for the Near Detector (ND) data and our understanding of neutrino interactions and cross-sections by using GENIE simulation. By tuning the cross section model to better represent neutrino scattering data from NOvA's ND and other experiments, we can extract oscillation parameters with a more accurate representation of cross section uncertainties. This tuning process is performed in the ND, before the oscillations occur. The effectiveness of the tuning will be discussed through studies of subsets of different multiplicities in the final state. Potential improvements to the cross section tune used for NOvA's 2018 joint neutrino and antineutrino analysis will also be discussed.

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The NOvA Test Beam Program

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NOvA is a two-detector long-baseline neutrino oscillation experiment which aims to make a determination of the neutrino mass hierarchy, the octant of θ_{23}, and measure possible CP violation. The NOvA Test Beam program consists of a scaled-down NOvA detector placed in a beamline capable of delivering 0.3 - 2.0 GeV/c protons, electrons, pions, and kaons. The beamline detectors provide us with particle identification and momentum measurements so we can study our detector technology with known inputs. Studying these particles will provide us a more detailed understanding of our calibration, detector response, and energy scale, which are some of the largest sources of systematic uncertainty in NOvA analyses. We will also collect a selection of single-particle data events for training particle identification algorithms. I will present the current status of the NOvA Test Beam program and discuss plans for data taking and analysis.

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ARIADNE - An Argon Imaging Detection Chamber

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ARIADNE is a state-of-the-art 1-ton two-phase Liquid Argon Time Projection Chamber (LArTPC), featuring an innovative optical readout utilising single photon sensitive, Electron-Multiplying (EM)CCD cameras, to image the secondary scintillation light produced by a THick Gaseous Electron Multiplier (THGEM). ARIADNE underwent testing at the T9 beam line, in the CERN East Area, in Spring 2018. ARIADNE is the first two-phase LArTPC with photographic capabilities to be positioned in a charged particle beamline, and successfully imaged particle-LAr interactions.
Recently, ARIADNE has successfully undergone further enhancement through integration of an ultra-fast, data driven, imaging system, based on the well-established TimePix3 sensor. With this technology data is naturally 3D and zero-suppressed. The system is ideal for future large two-phase LAr neutrino detectors. Results from the beam-test and the 3D TimePix3 TPC system will be presented detailing the benefits and capabilities of this technology.

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Low Energy Event Classification in the IceCube DeepCore Detector

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The IceCube Neutrino Observatory is a cubic kilometer detector consisting of 5,000 optical sensors used to detect Cherenkov light from neutrinos. The DeepCore subarray is a more densely instrumented region optimized to look for neutrinos produced in Earth's atmosphere. This allows for measurement of atmospheric neutrino oscillations. This poster will discuss a new method for classifying events in the DeepCore subarray.

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Calibration of Outer Detector PMTs For Super-Kamiokande V

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In order to increase physics sensitivity - mainly to diffuse supernova neutrino background (DSNB) - with neutron tagging, Super-Kamiokande (SK) detector is being prepared for gadolinium (Gd) loading. A major step of this preparation was the refurbishment of the detector to reduce water leaks and replace dead photomultiplier tubes (PMT). Successful completion of this refurbishment marks the beginning of SK-V. In the outer detector (OD) of SK over 200 PMTs were replaced and high voltages of all PMTs were rearranged to enhance uniformity of light response across the detector. Following these changes, charge and time calibration constants of all OD PMTs were recalculated using dark hits and cosmic ray muons, respectively. In addition, saturation characteristics of OD PMTs were obtained using laser light at multiple intensities, which is used to make more accurate detector simulations. Overall, these calibrations led to a more accurate charge calculation, as well as lower timing bias and spread.

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Scintillation light triggering efficiency in MicroBooNE

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The MicroBooNE Liquid Argon Time Projection Chamber (LArTPC) has been running since 2015 as part of the Short-Baseline Neutrino (SBN) program at Fermilab and is designed to contribute to address the elusive eV sterile neutrino anomaly. MicroBooNE records both the ionisation charge and scintillation light produced inside the TPC. The latter is collected through PhotoMultiplier Tubes (PMTs) and used for accurate timing and triggering. Having an accurate knowledge of the triggering efficiency at low energies is a key element for the success of MicroBooNE analyses, and the methods developed to obtain can be used by future LArTPCs, especially in the SBN program. For this reason MicroBooNE is developing a data driven method to estimate the trigger efficiency of scintillation

light. The goal of this poster is to present a preliminary analysis of calculating this efficiency in MicroBooNE using cosmic ray muons. Results of this analysis will be crucial for many analyses that aim to measure low energy interactions, and inform triggering strategies in LArTPCs in the SBN and future DUNE program.

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Introduction to the Physics of Massive Neutrinos I

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MicroBooNE's Search for a Photon-Like Low Energy Excess

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A model for realistic neutrino mixing with discrete flavour symmetry

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The model deals with discrete flavour symmetry that can radiatively generate the observed neutrino mixing
at one-loop level. The Standard model (SM) particle content was extended by
SM gauge singlet right-handed neutrinos and $SU(2)_L$ doublet scalars both inert and non-inert. The lightest among the inert $SU(2)_L$ doublet scalars can be a suitable dark matter candidate, therefore the model is scotogenic. When the discrete flavour symmetry is conserved, the model exhibits $\theta_{13} = 0$ and $\theta_{23} = \pi/4$ and solar mixing of any value. In particular θ_{12} corresponding to the Tribimaximal (TBM), Bimaximal (BM) and Golden Ratio (GR) mixing viz. 35.26^o (TBM), 45.0^o (BM), 31.7^o (GR) were considered. Soft breaking of this symmetry at the right-handed neutrino mass scale can produce non-zero θ_{13}, deviation of θ_{23} from maximality and small corrections to θ_{12} allowed by the data.

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Solar and Reactor Neutrino Theory

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The NOvA Test Beam Program

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Characterization of the temporal emission profile of Wavelength Shifters

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The next generation of neutrino experiments offers major challenges in collection of scintillation light. The ARAPUCA device, developed by our group, stands as a promising candidate in the scenario of new light detectors for these experiments. Its operation is based on a clever combination of Wavelength Shifters and a Dichroic Filter. In this work, we studied this compounds, characterizing some of their physical properties.

The temporal emission pattern of the most common wavelength shifters was measured using the TGM beamline in the LNLS, operating in the bunched beam mode. The result of these measurements shows the existence of delayed light emission and its characteristic time. This fact corroborates the hypothesis of ionization of these compounds when exposed to high energy photons, such as those from the liquid argon scintillation.

As a further study of ionization, the relative conversion efficiency of these compounds was measured. This analysis presents a first step in the understanding of how the ionization of these molecules can contribute to the efficiency of this compound. A result obtained from these measurements is the conversion efficiency of liquid argon scintillation photons for different thicknesses of TPB. The results agree with what is found in the literature, with good precision and in a wider range with respect to the previous measurements

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A High Pressure TPC for future long-baseline neutrino experiments

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Future long-baseline neutrino experiments, such as Hyper-Kamiokande (Hyper-K) and the Deep Underground Neutrino Experiment (DUNE), will have sensitivity to measure Charge-Parity (CP) violation in the neutrino sector to 5 sigma. To reach this level of precision, systematic uncertainties have to be reduced significantly from their current level, typically from 5-10% to 1-2%. In particular, understanding neutrino-nucleus interaction cross-sections is key to reducing systematic errors.

A High Pressure gas Time Projection Chamber (HPgTPC) is a good candidate for a future near detector to reach this level of uncertainty on neutrino-nucleus cross-sections. An HPgTPC has a low momentum threshold and is ideal for reconstructing low momentum particles exiting the nucleus. This combined with optical readout means that low-momentum tracks can be reconstructed and cross-section measurements in regions with little to no data can be measured.

An HPgTPC proto-type has been built and commissioned at Royal Holloway, University of London. The proto-type underwent a beam test at the CERN East Area T10 beamline from August to September 2018 with the goals being to test the technology as well as to measure low-momentum proton-scattering in gaseous Argon.

The future DUNE HPgTPC will be built from readout chambers used by the ALICE experiment until 2018. In preparation for this the HPgTPC will be used to test one of the ALICE outer readout chambers at high pressures.

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Long-baseline Oscillation Experiments

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Statistical Methods in Neutrino Physics

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Flavor Conversion in A Two Dimensional Dense Neutrino Gas.

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The intense neutrino fluxes emitted during a core-collapse supernova may experience a nonlinear flavor transformation which is induced by the neutrino-neutrino coupling. Based on an 1D spherical supernova model, it has been shown that sharp spectral splits/swaps can form through this nonlinear phenomenon. Here we present the preliminary results of a numerical survey based on a 2D ring model. These results suggest that the formation of the neutrino spectral splits critically depends on where the flavor transformation begins. If the neutrino flavor transformation is suppressed by, e.g., a large matter density and does not start until relatively far away from the neutrino sphere/ring, the

spectral splits can still occur like in the 1D model. If, however, the flavor transformation begins at a smaller radius, it can become so incoherent along the transverse direction (i.e., orthogonal to the radial direction) that the spectral splits are partially or even completely smeared out. This result can have important implications for the interpretation of the neutrino signals from the next galactic supernova.

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Neutrino Detection I

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Searching for Majorana Neutrinos with the NEXT-100 TPC

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Currently, it is unknown if neutrinos are Majorana particles, a discovery that would transform our understanding of the nature and mass of neutrinos. The NEXT experiment is searching for Majorana neutrinos through neutrinoless double beta decay ($0\nu\beta\beta$) in a high pressure gaseous xenon time projection chamber (HPGTPC). The NEXT collaboration has shown through prototypes that this method can achieve excellent energy resolution and tracking capabilities. The construction of the NEXT-100 detector is underway with commissioning planned for 2020. NEXT-100 will use 100 kg of xenon and after three years of run time is projected to achieve a sensitivity to the $0\nu\beta\beta$ half-life at 90% confidence level of 6.0 x 10^25 years and a background rate of 4 x 10^-4 counts keV^-1 kg^-1 yr^-1. This poster presents the NEXT-100 detector and the projected results from simulations.

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Michel electron timing resolution at SuperFGD detector

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Super Fine Grained Dectertor(SFGD) is part of the Near Detector upgrade for the T2K experiment. A detailed study on the electronics timing response of the Michel electrons is needed for this. Michel electrons are originated from the muon decay or capture at rest, this gives us a good idea of when to look for this signal. The Simulated timing information is smeared with the beam test data timing resolution to see how much it affects the final observation.

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Current status of CUORE, a search for neutrinoless double beta decay

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The Cryogenic Underground Observatory for Rare Events (CUORE), is an underground bolometric experiment at the Laboratori del Gran Sasso in Assergi, Italy. The primary objective of CUORE is to search for neutrinoless double beta decay. This hypothetical process involves two neutrons simultaneously undergoing beta decay with no neutrinos emitted, and if discovered, can bring to light the Dirac or Majorana nature of neutrinos. CUORE uses tellurium dioxide crystals, which act as both source and detector to measure the energy deposited by various particles. The expected signal is a peak at about 2528 keV, the Q value of neutrinoless double beta decay of ^{130}Te. Since this decay, if it occurs at all, is expected to be rare, the search requires low backgrounds and high energy resolution near the Q-value. To maximize energy resolution the crystals are cooled to a temperature of 11 mK using a specially designed low-background cryostat. In this poster we describe the CUORE experiment and some of the data analysis tools that are employed.

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Neutrino event reconstruction in the DUNE experiment

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The Deep Underground Neutrino Experiment (DUNE) is a long-baseline neutrino oscillation experiment. It will allow us to assess fundamental features of neutrino oscillation physics, such as leptonic CP violation and the mass hierarchy, as well as supernovae and proton decay physics. It consists of two detectors placed in the path of an intense neutrino beam created at Fermilab. The far detector will be a time-projecting chamber filled with liquid argon. It is expected to give us, with a very high resolution, the 3D picture of the products of a neutrino interaction happening inside the detector along with their calorimetric information. The DUNE collaboration is currently studying two smaller prototypes of this far detector, one with and one without a gaseous argon phase at the top of the detector, before launching the full-scale version. A part of this study is to develop the most efficient tools to analyze the upcoming data. One of these tools is called Pandora and it tries, via pattern recognition algorithms, to reconstruct the 3D trajectories of particles that come out of a neutrino interaction inside the detector. One can summarize to track-like and shower-like the possible topologies that one can encounter with a neutrino interaction although a full neutrino event reconstruction does not end up here. We will present in this poster the reconstruction chain and the strategies involved in DUNE from the energy deposition of the particle to its 3D trajectory for some of the main interaction regimes encountered in DUNE.