55th Annual Users Meeting

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EDI Key note: ”My body, my science”

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Former physicist Dr. Cheng discusses what it means to be an Asian scientist in America.

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AI

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Scientific Computing/Engineering / 9

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Field Studies with Faraday Magnetometers for Muon g-2

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The Muon g-2 experiment measures the muon magnetic moment anomaly a_mu, investigating a possible discrepancy with its Standard Model predicted value. The search for a_mu is dependent on precisely measuring muon precession frequencies as they orbit inside a magnetic storage ring and relating them to the strength of the ring's magnetic field. One significant source of uncertainty in this measurement comes from the kicker transient magnetic field: a perturbation created by eddy currents induced in all nearby metal whenever the primary kicker field turns on and off. To measure the kicker transient field without altering its strength, three teams built new Faraday magnetometers that function without adding any metal into the system. These magnetometers send laser light through TGG crystals, where the polarization of light rotates proportionally to the strength of the surrounding magnetic field. This technique allowed us to reach milligauss-level sensitivity with megahertz-level bandwidth, and several successful measurements have been performed by each team. We present results from the UMass team's Fiber Optic Faraday Magnetometer, with an analysis of the kicker transient field and its newly reduced contribution to g-2's overall uncertainty.

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Mu2e Event Visualisation Development using TEve and Eve-7

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The Mu2e experiment will search for the CLFV neutrinoless coherent conversion of muons to electrons, in the field of an Aluminium nucleus. A custom Event Display has been developed using TEve, a ROOT based 3-D event visualisation framework. Event displays are crucial for monitoring and debugging during live data taking as well as for public outreach. A custom GUI allows event selection and navigation. Reconstructed data like the tracks, hits and clusters can be displayed within the detector geometries upon GUI request. True Monte Carlo trajectory of particles traversing the muon beam line, obtained directly from Geant4, can also be displayed. Tracks are coloured according to their particle identification and users have the option to select which trajectories to be displayed. Reconstructed tracks are refined using a Kalman filter and the resulting tracks can be displayed alongside the truth information, allowing visualisation of the track resolution. The user can remove/add data based on energy deposited in a detector or arrival time. This is a prototype and an online event display is being developed using REve. Many of the offline features have been transferred to the online display, which allows remote access for live data taking, and multiple users can simultaneously interact with display.

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Track Quality Analysis in Python

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Using a gradient boosted decision tree, we can improve momentum track quality selection on the mu2e tracker simulation data. Using a decision tree rather than an artificial neural network halves the training time and classification time. Eventually this machine learning model will be used in production to analyze real data.

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Performance of Highly Irradiated SiPMs Coupled to LYSO:Ce Crystals for the CMS MTD Barrel Timing Layer

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The MIP Timing Detector is a new detector developed for the CMS upgrade for the High Luminosity LHC era. The detector will bring the capability of measuring precisely the production time of particles generated in proton-proton collisions. In particular, the MTD will allow for the disentangling of the estimated 200 nearly simultaneous pileup vertices that occur in the interaction diamond at each

bunch crossing during high luminosity operation. The central Barrel Timing Layer of this detector will consist of an array of LYSO:Ce crystals coupled to SiPMs able to provide unprecedented time resolution under such conditions (30 ps). One of the important challenges that the detector will face is to keep its good performance (< 60 ps) during the lifetime of the experiment. It has been shown that the performance of SiPMs is affected when they are exposed to high levels of radiation. In order to quantify the impact of radiation on our prototype, we irradiated three pairs of SiPMs to different levels of 1 MeV neutron equivalent fluence comparable to those expected at the end of life conditions. We report on the preliminary performance results of time resolution measured in the laboratory and with the test beam of our detector prototype.

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Neutrino Theory

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ANNIE

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DUNE

Keynote session / 23

Keynote: OSC at IOTA: The World's First Experimental Demonstration of Optical Stochastic Cooling

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Jonathan Jarvis discusses his DOE award-winning accelerator physics work

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Astro/Dark Energy Session / 28

Dark Matter at Fermilab

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Status of the Accelerator Neutrino Neutron Interaction Experiment (ANNIE)

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The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a Gadolinium-loaded water Cherenkov detector located in the Booster Neutrino Beam at Fermilab with the primary goal of measuring the final state neutron multiplicity of neutrino-nucleus interactions. This measurement will improve our understanding of complex neutrino-nucleus interactions and help to reduce the associated systematic uncertainties, thus benefiting the next generation of long-baseline neutrino experiments. ANNIE is the first experiment to deploy an array of the Large Area Picosecond Photodetector (LAPPDs) in a neutrino detector. In this poster, we will briefly discuss the detector system, overall progress, and status of the experiment including recent data. In addition, future R&D efforts involving using the novel detection medium of water-based Liquid Scintillators will be briefly emphasized

Energy Session / 30

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Energy Session / 31

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Energy Session / 32

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Accelerator Session / 33

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Accelerator Session / 36

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Reconstruction Techniques in ANNIE - Neutrino 2022 Poster

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The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton Gd-doped water Cherenkov detector installed in the Booster Neutrino Beam (BNB) at Fermilab. The experiment has two complementary goals: (1) make a unique measurement of the neutron yield from neutrino-nucleus interactions to improve the systematic uncertainties in oscillation experiments and (2) demonstrate the power of new fast-timing, position-sensitive photodetectors by making the first deployment of Large Area Picosecond PhotoDetectors (LAPPDs) in a physics experiment. To realise these goals the ANNIE collaboration has developed several reconstruction techniques using the arrival time and position of photons in the detector photomultipliers (PMTs) and LAPPDs. A maximum-likelihood fit is used to reconstruct the neutrino interaction vertex and direction. Machine and Deep Learning techniques are used for the energy reconstruction, the particle identification and the ring counting. We present recent progress on ANNIE reconstruction techniques.

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A Machine Learning Model for Positron Detection in the Fermilab Muon g-2 Experiment

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A high-fidelity simulation is crucial in the study of systematic errors arising from beam dynamics and detector acceptance in the Muon g-2 experiment at Fermilab. Gm2ringsim, our current Geant4-based simulation package is computationally expensive and it has limited the amount of dataset that can be produced for various systematic studies. We propose a "divide and conquer" approach, where the typical Geant4 Monte Carlo simulation is divided into the beam and spin dynamics, muon decay, and positron detection. The last part which involves positron tracking and electromagnetic shower development in the calorimeter was modeled using time-efficient machine learning algorithms. In the first attempt, we trained an Adaptive Boosted Decision Tree (BDT) model to classify positron events according to the energy deposition. The performance of the model was compared with a heuristic variable cut approach. The model has a higher area under the Receiver Operation Characteristic (ROC) curve than the heuristic approach while maintaining high background rejection over a large range of signal efficiency. This demonstrates the potential of machine learning models for fast simulations.

We acknowledge support from the Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. DOE-OHEP. The authors are supported by the National Natural Science Foundation of China under Grant No. 12075151.

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ArCLight: Development of a novel light detector for modular liquid Argon detectors

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ArCLight is a compact dielectric light trap with a large sensitive area, coated with a thin layer of TPB, and read out by Silicon Photo Multipliers (SiPMs). The ArCLights were developed at the University of Bern, with the goal of having fast timing and good spacial resolution. These requirements are particularly driven by the demands for an efficient tagging of fast neutrons produced in neutrino interactions in liquid Argon environment.
In this poster the design features, production method, characterization studies and the photon detection efficiency of the ArCLight modules in liquid Argon, are presented.

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Timing Characterization of LAPPDs in ANNIE Using Laser Calibration

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The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton gadolinium-loaded water Cherenkov detector located on the Booster Neutrino Beam at Fermilab. The experiment has a two-fold motivation: to perform a physics measurement and to advance new detector technologies. The measurement of final state neutron multiplicity from neutrino interactions in water as a function of momentum transfer will lower systematic uncertainties for future long-baseline neutrino experiments. In March 2022, the experiment deployed the first Large Area Picosecond Photodetector (LAPPD) with four more to be deployed soon. LAPPDs are capable of spatial resolution of less than 1~cm and time resolution of less than 100~ps. The utilization of LAPPDs places unprecedented requirements on the time calibration of the LAPPDs relative to each other and to the photomultiplier tubes. The experiment is set to use laser-based calibrations to achieve picosecond-level precision for the LAPPDs. This poster will show recent studies with laser calibration data.

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Simulation based models for more realistic galaxy cluster mass and profile estimates

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I will discuss the scatter modeling of the cluster gas pressure profiles with the aim of generating more realistic Y_{SZ} mock observables for the Baryon Pasting (BP) algorithm. To do so, I use the Illustris-TNG300 catalog to model the correlation of the intrinsic scatter of cluster gas pressures at different radial bins using the Kernel Localized Linear Regression (KLLR) method. Applying KLLR on the cluster mass removes the bias and additional scatter due to the variance in mass which can be as much as 12%. Additionally, I will present an ongoing analysis that quantifies the intrinsic correlated scatter of cluster weak lensing observables and how correcting for this additional secondary term in the mass modeling could lead to percent-level changes in cluster mass estimations. These simulation based models could set informative priors for upcoming analyzes such as DES-Y3 and the Legacy Survey of Space and Time (LSST) survey.

Neutrino Session / 42

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Neutrino Session / 43

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Neutrino Session / 45

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Neutrino Session / 49

DUNE

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Phenomenological Demonstration of Deep Neural Networks in the search for BSM Physics with LArTPCs

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The high intensity of POT and excellent particle identification and reconstruction capabilities of LArTPCs make experiments within the SBN program sensitive to a multitude of BSM models. One such example is the demonstrated sensitivity of the program's detectors to dilepton pairs originating from exotic Higgs Portal Scalar decays. Columnated showers that come from scalar decays to electron/positron pairs have topologies similar to those of photon pair production or single showers, making them difficult to distinguish from background. In this work, `Geant4` is used to generate the distribution of charge deposited by Higgs Portal Scalar events within a box of ^{40}Ar. This configuration of `Geant4` provides theorists and phenomenologists a fast and accessible way to simulate LArTPC data. We then apply projections to create two dimensional images of each simulated event, similar to those captured by wire planes in operating detectors. Finally we harness the power of deep neural networks to distinguish images of signal and background events for the Higgs Portal Scalar model at the SBN program, improving upon the projected sensitivity from cut-and-count techniques by 30% in $\sin\theta$ for the benchmark scalar mass of 10 MeV.

Energy Session / 51

The Upgrade of the CMS detector for the HL-LHC

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Measuring the Neutral Current Neutral Pion Cross Section on Argon in MicroBooNE

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MicroBooNE, a short-baseline neutrino experiment, sits on-axis in the Booster Neutrino Beamline at Fermilab where it is exposed to neutrinos with $\langle E_\nu \rangle$ ~ 0.8 GeV. Since this energy range is highly relevant to the Short Baseline Neutrino and Deep Underground Neutrino Experiment programs, cross sections measured by MicroBooNE will have implications on their searches for neutrino oscillation and charge-parity violation measurements. Additionally, MicroBooNE's use of liquid argon time projection chamber technology makes it well-suited to precisely measure a wide range of final states, including those produced by neutral current (NC) interactions. NC π^0 interactions in particular are a significant background in searches for Beyond the Standard Model (BSM) e^+e^- production and are an irreducible background to rare neutrino scattering processes such as NC Δ radiative decay and NC coherent single-photon production at low energies. Therefore, understanding the rate of NC π^0 production will improve the modeling of this background channel, reducing uncertainties in measuring BSM signatures and single-photon production processes. In this poster, I will report the highest-statistics measurement to date of the neutral current (NC) π^0 production cross section for neutrino-argon interactions.

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An improved pulse-fitting procedure for calorimeter event reconstruction in the Muon g-2 experiment at Fermilab

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In the anomalous precession frequency analysis of the Fermilab Muon g-2, pulse-fitting plays a vital role in the calorimeter data reconstruction. The energy and time of a muon or positron event are reconstructed by performing a template fit to the recorded digitizer islands of each calorimeter channel. Several fitting thresholds are defined in the pulse-fitter to distinguish the signal from the noise. We optimized these thresholds by implementing the same thresholds for both primary and secondary pulses for pulse-pileup events. The thresholds are re-defined in MeV units by considering the absolute-scale energy calibration and time-dependent gain corrections at the fitter level. In this poster, we report on the status of the new fitter and its implication for the anomalous precession frequency analysis.

We acknowledge support from the Fermi Research Alliance, LLC under Contract No. DE-AC02-07CH11359 with the U.S. DOE-OHEP. The authors are supported by the National Natural Science Foundation of China under Grant No. 12075151.

Keynote session / 54

AI-on-chip: Enabling data reduction at source

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Keynote Introduction

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Search for a permanent muon electric dipole moment at the Fermilab Muon g-2 experiment

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A new source of CP violation beyond the Standard Model is needed to explain the Baryon Asymmetry in the Universe (BAU). Assuming CPT symmetry, a permanent electric dipole moment (EDM) for an elementary particle can provide a new source of CP violation as it violates time-reversal symmetry and, therefore, CP symmetry. The current experimental limit of the muon EDM is 10^{-19} e cm, about 17 orders of magnitude above the Standard Model prediction of 10^{-36} e cm. The smallness of the SM value means that it is not reachable experimentally in the near future and therefore any detected muon EDM signal will be a strong hint of new physics. At Fermilab, we aim to perform a more sensitive search of the muon EDM using both tracker-based and calorimeter-based analyses. In this poster, we will present the calorimeter-based approach where the muon EDM signal is extracted from the relationship between the muon g-2 phase and the vertical hit position of positrons on the calorimeter.

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SpinQuest

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URA Session / 58

Introduction of the awardees

URA Session / 59

Early Career Award Talk

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URA Session / 60

Graduate Thesis Award Winner: Cosmology with type Ia Supernovae: challenges and results of the Dark Energy Survey

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Type Ia Supernovae are one of the most powerful tools to study the expansion history of our Universe and they are the first cosmological probe that directly measured cosmic acceleration.

The recently concluded Dark Energy Survey SN program (DES-SN) has obtained the largest and deepest high-redshift cosmological SN Ia sample to date.
In my talk, I will give an overview of the current status of the cosmological analysis of the DES-SN sample. I will present the set of simulations generated to accurately and robustly model the DES-SN survey, and I'll show how these simulations can be used to assess different sources of systematic uncertainties, in particular "contamination" from non-Ia SN events.

The DES-SN analysis will provide the best SN measurement of the cosmic acceleration to date, and will inform the design of the next generation of SN experiments (e.g.,Vera Rubin Observatory) which are expected to observe millions of SNe Ia in the next decade.

URA Session / 61

Tollestrup Award Winner: Dark Energy Survey weak lensing: pixels to cosmology

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I will present the cosmological weak lensing results from the Dark Energy Survey (DES) using its first three years of data taken using the Dark Energy Camera on the 4m Blanco telescope. This analysis spans the full DES footprint, roughly 1/8th of the night sky, with the final galaxy catalogue containing more than 100 million galaxies in riz photometric bands, constituting the most powerful

weak lensing dataset to date. The comparison of DES cosmological constraints on dark matter and dark energy from weak lensing in the low-redshift Universe to those from the Cosmic Microwave Background provides an unprecedented test of the standard cosmological model, across high and low redshift. I will mention the main challenges that our analysis is susceptible to, and the summarise the approach our team took to account for these and deliver robust cosmological constraints.

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TDAQ and slow control production systems installation in the Mu2e experiment at Fermilab

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The Mu2e experiment at the Fermilab will search for a coherent neutrinoless conversion of a muon into an electron in the field of an aluminum nucleus with a sensitivity improvement by a factor of 10,000 over existing limits. The Mu2e Trigger and Data Acquisition System (TDAQ) uses otsdaq framework as the online Data Acquisition System (DAQ) solution. Developed at Fermilab, otsdaq integrates several framework components - an artdaq-based DAQ, an art-based event processing, and an EPICS-based detector control system (DCS), and provides a uniform multi-user interface to its components through a web browser.
Data streams from the Mu2e tracker and calorimeter are handled by the artdaq-based DAQ and processed by a one-level software trigger implemented within the art framework. Events accepted by the trigger have their data combined, post-trigger, with the separately read out data from the Mu2e Cosmic Ray Veto system.
Foundation of the Mu2e DCS, EPICS – an Experimental Physics and Industrial Control System – is an open-source platform for monitoring, controlling, alarming, and archiving.
A prototype of the TDAQ and the DCS systems has been built and tested over the last three years at Fermilab's Feynman Computing Center, and now the production system installation is underway. The poster will present their status and focus on the installation for racks, workstations, network switches, gateway computers, DAQ hardware, slow controls implementation. It will also show the network design.

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Development of Ionization Laser Calibration System for DUNE

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The Deep Underground Neutrino Experiment (DUNE) is a forthcoming neutrino oscillation experiment that will be the largest of its kind. Utilizing liquid argon time projection chamber (LArTPC) technology, DUNE's far detector will consist of four 17 kiloton modules and be located approximately 1,500 meters underground at Sanford Underground Research Facility (SURF). Due to its large size, improved calibration techniques are required to ensure accurate particle trajectory reconstruction. Small defects in anode-cathode alignment, electric field distortions, and wire response uniformity can negatively affect reconstruction. As DUNE is still under construction, prototype technologies for DUNE are developed and tested at ProtoDUNE, a 700 ton LArTPC located at CERN in Switzerland. At Los Alamos National Laboratory (LANL), prototype ionization laser systems are being developed for implementation in the second run cycle of ProtoDUNE. The ionization laser system (IoLaser) will allow for detector calibration by generating tracks with a known direction and energy throughout the detector volume. In this poster, I will discuss calibration challenges for DUNE and present an overview of the IoLaser system, including progress on current prototyping efforts for deployment in ProtoDUNE.

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Searches for Dark Matter with the Light Dark Matter eXperiment

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The constituents of dark matter are still unknown, and the viable possibilities span a very large mass range. Specific scenarios for the origin of dark matter sharpen the focus to within about an MeV to 100 TeV. Most of the stable constituents of known matter have masses in the lower range, and a thermal origin for dark matter works in a simple and predictive manner in this mass range as well. The Light Dark Matter eXperiment (LDMX) is a planned electron beam fixed-target experiment at SLAC that will probe a variety of dark matter models in the sub-GeV mass range using a missing momentum technique. Although optimized for this technique, LDMX is effectively a fully instrumented beam dump experiment, making it possible to search for visibly decaying signatures. This would provide another outlet for LDMX to probe complementary regions of dark matter phase space for a variety of models, provided that the additional technical challenges can be met. This contribution will give an overview of the motivations for LDMX and focus on the technical challenges of searches for visible signatures at LDMX.

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Measurement of the muon neutrino charged-current interactions with low hadronic activity in the NOvA near detector

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The NOvA near detector (ND), located at Fermilab (Batavia, IL), records a high rate of neutrino interactions with energies ranging from 1-5 GeV. This rate and well understood systematic uncertainties allow to study neutrino-nucleus interactions with good precision. The muon neutrino charged-current interaction channel with low hadronic activity presents an opportunity to measure observables with enhanced nuclear effects, particularly, short-range nucleon correlations in neutrino-nucleus interactions. These effects are one of the major systematic uncertainties in the measurement of the oscillation parameters.
In this poster, we present a cross-section measurement of this channel as a function of the outgoing muon energy and angle in the NOvA ND. In addition, we present the status of our efforts to extract the nuclear effect component, particularly, the meson exchange current (MEC), using this sample.

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Overview of the Short Baseline Neutrino Program Far Detector (ICARUS)

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The ICARUS detector is a Liquid Argon Time Projection Chamber (LArTPC) that is part of a program dedicated to resolve short baseline neutrino anomalies at the eV mass scale. ICARUS was originally commissioned underground at LNGS in Italy, operating for three years as the first large scale LArTPC. After moving to CERN for upgrades and refurbishments, the ICARUS detector was installed at Fermilab and now serves as the Far Detector in the SBN Program. The detector has been filled and cooled with liquid argon since last spring, and we have been operating in a commissioning phase as the final installation activities are wrapped up. The installation of the Cosmic Ray Tagging system is complete and the 3-m thick concrete overburden is near completion. In this poster, I will give an overview and status of the ICARUS neutrino detector.

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Status of the measurement of the muon neutrino charged-current coherent pion production in the NOvA near detector

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Charged Current (CC) coherent neutrino-nucleus pion production is characterized by little momentum transferred to the nucleus, which is left in its ground state. Despite the relatively large uncertainties on the production cross-section, coherent production of mesons by neutrinos represents an important process, as it can shed light on the structure of the weak current and can also constitute a potential source of background for modern neutrino oscillation experiments and searches for Beyond Standard Model (BSM) physics. We will present the status of a new measurement of CC coherent pion production in the NOvA near detector at the Fermi National laboratory (Fermilab). The analysis is based on the use of both particle identification and kinematic selection criteria based on Convolutional Neural Networks (CNN). Given the energy range 1-5 GeV accessible with the available NOvA exposure in the NuMI beam, the results will also be relevant for upcoming neutrino experiments like the Deep Underground Neutrino Experiment (DUNE).

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Modeling and Analysis of Ionization Laser Calibration for the DUNE Time Projection Chamber

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The Deep Underground Neutrino Experiment (DUNE) is a next-generation neutrino oscillation experiment consisting of a near detector at Fermilab and a far detector located 1,480 meters underground and 1285 km away in Lead, South Dakota. The far detector will consist of four modules, at least three of which will be Liquid Argon Time Projection Chambers (TPC), intersecting the neutrino beam produced at Fermilab. Among other physics goals, DUNE will measure charge-parity violation in neutrinos, a possible mechanism allowing for matter-antimatter asymmetry to arise in the early universe. At 17 kilotonnes per module, DUNE's TPCs will be the largest of their kind, resulting in new instrumentation challenges. As TPCs grow in size, improved calibration techniques are required to ensure accurate position and energy reconstruction. DUNE will require fine-grained measurement of detector response parameters such as electric field distortions, electron drift velocity, and defects such as cathode-anode misalignment. DUNE's Ionization Laser (IoLaser) system will enable these measurements by generating tracks of known origin and direction throughout the active volume. In this poster, I will explain how the signals introduced by this calibration hardware can be converted to a robust measurement of electric field uniformity in the DUNE TPC, with a focus on the analysis and data science methods used.

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Mu2e Cosmic Ray Veto Aging Studies

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The Mu2e Cosmic Ray Veto (CRV) is an active shield that detects and rejects Mu2e's largest source of background – cosmic rays. Segments of the CRV, called modules, are being delivered to Fermilab as we prepare to construct the complete CRV which surrounds the Mu2e Experiment's detector solenoid. Currently, single CRV modules are being tested to measure many properties of this detector. One property of particular interest is how the CRV ages with time. This poster reports recent studies to quantify aging using data collected in the past year.