

# New Perspectives 2018

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## Book of Abstracts



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**Dark Matter and Astrophysics / 44****200 kg of Underground Argon - The Struggle for Radiopurity****Author:** Gary Forster<sup>1</sup>**Co-authors:** Andrea Pocar<sup>2</sup>; Henning Back<sup>3</sup><sup>1</sup> *Darkside-50*<sup>2</sup> *University of Massachusetts, Amherst*<sup>3</sup> *Pacific Northwest National Laboratory***Corresponding Author:** garyforster321@gmail.com

Argon is a very useful element for modern scientific endeavors, but its naturally occurring isotopes make it too 'noisy' for low-energy applications like Darkside-50's Dark Matter search. The struggle to produce argon that is free of radioactive isotopes has a decade of rich history, and much of efforts took place at the Proton Assembly Building (PAB) at Fermilab. This talk will address the physics of the many steps of argon purification, as well as some of the historical aspects of the personnel involved in the efforts.

**R & D / 52****A compact millimeter-wavelength Fourier-transform spectrometer****Author:** Zhaodi Pan<sup>1</sup>**Co-authors:** Bradford Benson<sup>2</sup>; Hazal Goksu<sup>3</sup>; Mira Liu-Sarkar<sup>1</sup>; Ritoban Basu Thakur<sup>1</sup>; Stephan Meyer<sup>1</sup><sup>1</sup> *The University of Chicago*<sup>2</sup> *The University of Chicago, Fermilab*<sup>3</sup> *CERN***Corresponding Author:** panz@uchicago.edu

Fourier Transform Spectrometers (FTSs) have been widely used in many fields for characterizing the power spectrum of radiation. In this talk we present development of an FTS operating between 50 GHz and 330 GHz. Our FTS design features a small size of 15"x10"x3" and weighs only 13 lbs. The hardware, operating software, and analysis software for the FTS have been standardized to make the production and application easy. The FTS has a throughput of 100 mm<sup>2</sup> sr and a frequency resolution of 4 GHz, with sensitivity to both polarization components. The optical transfer efficiency is 92%±5%, and the modulation contrast is -55±3% with a band-defining filter. Beam and frequency distortion properties are characterized by a frequency-mapping experiment and compared to ray-tracing simulations. We also discuss applications to detector and material characterizations, including detector spectrum measurements for the South Pole Telescope.

**SBN & DUNE / 45****A short travel for neutrinos in Large Extra Dimensions****Author:** Gabriela Vitti Stenico<sup>1</sup>**Co-authors:** David Vanegas Forero<sup>2</sup>; Orlando Luis Goulart Peres<sup>3</sup>

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The hypothesis of the existence of a fourth neutrino state comes from some experimental anomalies that cannot be explained with the present three lightest neutrinos. This demands the existence of sterile neutrinos. The sterile neutrino appears in many extensions of Standard Model, in the  $3 + 1$  model that considers three active neutrinos and one sterile state and also in Large Extra Dimensions (LED) models where some particles can travel through extra dimensions compacted in radius with magnitude from Planck scale, which are hidden from experiments, to few millimeters. LED models produce an infinite tower of sterile neutrinos. As the sterile neutrino states do not have any weak interaction, they can only be detected indirectly through their mixing with the active neutrinos and because of this, we want to study the neutrino oscillation physics when these LED sterile neutrinos are included. Then we will test the sensitivity of LED parameters based on the exclusion region of  $3 + 1$  model for the three LAr-TPC detectors located along the Booster Neutrino Beam (BNB) at Fermilab which are part of a Short Baseline Neutrino (SBN) program, that will perform the most sensitive search to date for sterile neutrinos at the eV mass-scale through both appearance and disappearance oscillation channels. We also investigated the capability of SBN to differentiate the LED model from the  $3 + 1$  neutrino model.

## Cross Section Neutrino Program / 35

### ANNIE in 10 Minutes

**Author:** Marcus O'Flaherty<sup>1</sup>

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The Accelerator Neutrino Nucleus Interaction Experiment (ANNIE) has recently completed its first phase of data taking. The main physics goals of ANNIE, to be completed in the upcoming Phase II, are a measurement of the neutron abundance from neutrino-nucleus interactions, and a charged-current inclusive cross-section measurement on Oxygen. To achieve these goals the collaboration will use Gadolinium-loaded water to detect neutrons from a neutrino beam, and Large Area Picosecond Photodetectors (LAPPDs) for precise event reconstruction. Phase I used a simplified detector to perform measurements of the neutron flux from upstream interactions, a relevant background for Phase II measurements. This talk will present the results obtained and discuss the progress towards Phase II, scheduled to begin taking data in Fall 2018.

## Long Baseline Neutrino Program / 26

### Accelerating Feldman-Cousins on NOvA using NERSC Supercomputers

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When fitting to data with low stats and near physical boundaries, extra measures need to be taken to ensure proper statistical coverage. The method NOvA uses is called the Feldman-Cousins procedure, which entails fitting thousands of independent pseudoexperiments to generate acceptance intervals that are then used to correct our fits. The scale required by the Feldman Cousins procedure makes it extremely computationally intensive. In past analyses, it has taken up to several weeks to complete,



bottlenecking our final results. Here I present recent work by members of the NOvA experiment and the SciDAC4 collaboration to enable the use of the super-computing facilities at NERSC to process our Feldman-Cousins corrections over 150x faster, allowing us to do more studies, increase the precision of our fits, and produce results quickly.

## Dark Matter and Astrophysics / 29

### Bayesian Hierarchical Models for parameter inference with missing data: Supernova cosmology case study.

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Large scale astronomical surveys are going wider and deeper than ever before. However, astronomers, cosmologists and theorists continue to face the perennial issue that their data sets are often incomplete in magnitude space and must be carefully treated in order to avoid Malmquist bias, especially in the field of supernova cosmology. Historically, cosmological parameter inference in supernova cosmology was done using  $\chi^2$  methodology; however, recent years have seen a rise in the use of Bayesian Hierarchical Models. In this paper we develop a Bayesian Hierarchical methodology to account for magnitude limited surveys and present a specific application to cosmological parameter inference and model selection in supernova cosmology.

## Muon Physics / 38

### Calorimeter Clustering Studies for the Mu2e Experiment at Fermilab

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Mu2e (muon-to-electron-conversion), an Intensity Frontier experiment at Fermilab set to begin data taking in 2022, will search for flavor violation in charged leptons with a muon decaying to only an electron without any neutrinos. Protons will be accelerated by the 8GeV proton beam before reaching Mu2e's production target. From there, pions enter an S-shaped Transport Solenoid and travel through a series of absorbers and collimators to select low-energy negatively charged muons from pion decay that will hit the stopping target. Downstream from the stopping target are a curved straw tracker and two annular disk crystal calorimeters. The signal will be a mono-energetic  $e^-$  with an energy close to the rest mass of a muon. The Mu2e expected single event sensitivity is  $2.87e^{-17}$ . The complimentary trigger strategy will take advantage of both online track searches from the tracker and calorimeter reconstruction. The trigger requires a rejection factor greater than 100 and must make its decision within a 3ms time budget. In order to provide high efficiency on signal events, our calorimeter clustering algorithms must be accurate and meet the timing performance.

I will discuss the expected performance of two clustering algorithms: a fast algorithm to be used at the trigger level and a more accurate clustering algorithm to be used in the offline reconstruction. The fast algorithm defines clusters by only selecting crystals adjacent to a high energy crystal seed. The full-blown algorithm can find smaller clusters separated from the main cluster, within a distance

and timing window, and combine them into one cluster. We have analyzed the topology of the reconstructed clusters by the two algorithms on events with only a conversion electron and combined signal and background events. The goal of these studies is to improve the performance of the fast algorithm to better reconstruct the cluster energy and work within the strict timing budget.

**Short Baseline Neutrino Program / 7**

## **Cold Electronics and Signal Processing in the MicroBooNE LArTPC**

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MicroBooNE is an 85-ton single-phase Liquid Argon Time Projection Chamber (LArTPC) and the first of a trio of LArTPCs in the Short Baseline Neutrino (SBN) program which will search for a light sterile neutrino and measure neutrino-argon interaction cross sections. Located in the Booster neutrino beam at Fermi National Accelerator Laboratory, MicroBooNE has been taking neutrino data since October 2015. MicroBooNE pioneered the usage of ultra-low noise cryogenic electronics, an enabling technology for large LArTPC detectors allowing excellent calorimetric capability and the ability to discriminate between electron and photon electromagnetic showers. In this talk I will show the excellent performance of the cold electronics in MicroBooNE along with mitigation of detector noise and TPC issues. I will also describe the development of drifted-charge extraction methods to accurately convert raw digitized TPC waveforms into the distribution of ionized electrons passing through both induction and collection wire planes. Finally I will use MicroBooNE data to demonstrate improved signal processing performance, including the first-ever accurate charge matching across wire planes, that is expected to benefit the reconstruction of neutrino interactions.

**Dark Matter and Astrophysics / 39**

## **DES in 10 minutes**

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The Dark Energy Survey (DES) is a five year (with half-year extension approved) ground-based optical and near-infrared survey covering ~5,000 square degrees (~12%) of the sky. The DES international collaboration is comprised of several hundred members working toward understanding dark energy and cosmic acceleration. In this talk, I will begin with an overview of several DES working groups and briefly describe their science goals. Next, I will focus on a specific DES endeavour: Balrog, an image simulation tool. I will present Balrog products and discuss Balrog's potential to characterize measurement biases in the DES Data Management system. Developing an understanding of measurement biases will allow all the DES working groups to utilize a greater fraction of DES data.

**SBN & DUNE / 5**

## **DUNE in 10 minutes**

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The DUNE Science Collaboration is currently made up of over 1500 collaborators from 175 institutions (60% non-US) in 31 countries (35% of developing countries) plus CERN. The aim of this research program is to discover some of the greatest mysteries of the universe; origin of matter, unification of forces, black holes formation, among others. This project has a cooperative structure of consortia, working groups, task forces, boards and committees who have been working academically and administratively on the different key areas such as physics research, development of the detectors and prototypes, coordination of interfaces, and data analysis. One of the main objectives of this experiment is to motivate young people into science; leaders and members of the experiment, are very encouraging with younger members. On the other hand, this experiment goes beyond the experimental and practical outcomes in developing countries such as Colombia. This experiment is providing us with opportunities for doing science in our country, promoting progress, engaging new generations of Colombians and placing science on the political agenda.

## Dark Matter and Astrophysics / 54

### Darkside in 10 minutes

**Author:** Alissa Monte<sup>1</sup>

<sup>1</sup> *UMass Amherst*

DarkSide-50 is the current phase of the DarkSide direct dark matter search program, operating underground at the Laboratori Nazionali del Gran Sasso in Italy. The detector is a dual-phase argon Time Projection Chamber (TPC), designed for direct detection of Weakly Interacting Massive Particles, and housed within a veto system of liquid scintillator and water Cherenkov detectors. We will highlight recent results from a 532.4 live-days exposure using a target of low-radioactivity underground argon, including a low-mass dark matter search based on the ionization signal, which extends the exclusion region for spin-independent dark matter-nucleon coupling below previous limits in the mass range of 1.8-6 GeV/c<sup>2</sup>. [<https://arxiv.org/abs/1802.06994>, <https://arxiv.org/abs/1802.06998>, <https://arxiv.org/abs/1802.07198>]

## Muon Physics / 16

### Design of the Mu2e Straw Tracker

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Mu2e will search for the neutrinoless conversion of a muon to an electron in the presence of a nucleus,  $\mu + N(A, Z) \rightarrow e + N(A, Z)$ , more commonly known as charged lepton flavor violation (CLFV). A decay of this sort is extremely suppressed in the Standard Model, on the order  $10^{-54}$ . A process of this kind may never be observed in a lab so detecting it would be an unambiguous evidence of new physics.

New physics models predict a muon-to-electron conversion rate of order  $10^{-14} - 10^{-16}$ . There are many experiments looking for a flavor-violating muon in the presence of a nucleus. Mu2e is improving the current limit set by these experiments by 4 orders of magnitude to reach a single event sensitivity of  $3 \times 10^{-17}$ . This sensitivity will help reduce the number of possible new physics theories to lead us to the correct one. Achieving the 10,000-fold improvement requires a tracker that is very efficient at separating background events from signal events and can reduce the background to less than half an event over the three-year run period. In this talk we will focus on the design challenges of the tracker and how we overcame them. A low mass tracker to minimize the energy loss of the electrons as they propagate through it and a momentum resolution better than 180 keV/c are just two of such challenges. Also, we will mention the stages a signal electron will go through

from the moment of its birth near an aluminum nucleus to its eventual resting place in the shielding behind the detector.

### Short Baseline Neutrino Program / 20

## Evaluating the Performance of Multiple Coulomb Scattering Based Momentum Reconstruction with MicroBooNE Data

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MicroBooNE is a short baseline neutrino oscillation experiment based at Fermilab that uses Liquid Argon Time Projection Chamber (LArTPC) technology primarily to investigate the excess of low energy events observed by MiniBooNE study neutrino-argon cross-sections, and perform LArTPC R&D for future experiments, such as DUNE. Multiple Coulomb scattering (MCS) is the only way to determine the momentum of exiting muons in the MicroBooNE detector, essential for reconstructing the neutrino in energetic events. This talk will discuss the status and performance of using multiple Coulomb scattering on exiting tracks in MicroBooNE data.

### SBN & DUNE / 30

## Exploring the Potential of Short-Baseline Physics at Fermilab

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We study the capabilities of the short baseline neutrino program at Fermilab to probe the unitarity of the lepton mixing matrix. We find the sensitivity to be slightly better than the current one. Motivated by the future DUNE experiment, we have also analyzed the potential of an extra liquid Argon near detector in the LBNF beamline. Adding such a near detector to the DUNE setup will substantially improve the current sensitivity on non-unitarity. This would help to remove CP degeneracies due to the new complex phase present in the neutrino mixing matrix. We also comment on the sensitivity of this setup to light sterile neutrinos for various configurations

### Muon Physics / 24

## Extinction monitor for the Mu2e experiment

**Author:** Avery Archer<sup>1</sup>

<sup>1</sup> *Purdue University*

The Mu2e experiment at Fermi National Accelerator Laboratory will study charged lepton flavor violation (CLFV) through the measurement of the ratio of the rate of neutrinoless, coherent conversion of muons into electrons in the field of a nucleus to the rate of muon capture on the nucleus. The goal of the experiment is to achieve a single event sensitivity of  $2.8 \times 10^{-17}$ , leading to an upper limit on the muon conversion rate of  $6.7 \times 10^{-17}$ . Muons will be generated by using a pulsed proton beam on a tungsten target. To achieve and maintain this level of sensitivity out-of-time protons must be suppressed at the  $10^{-10}$  level. Extinction is the ratio of out-of-time protons to in-time protons. We will present on the experimental design of the extinction monitor system and the current status of the project.

**FSPA Report / 57**

## **FSPA Report**

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**R & D / 42**

## **First Results of GaInP Based Light Sensors for High Energy Physics and Future Directions**

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Measurements in particle physics often rely on measuring the light produced in particle interactions with detector materials. Highly sensitive and fast detectors are frequently required. This is frequently accomplished with the use of Silicon photomultipliers (SiPMs), a type of avalanche photodiode operated in Geiger-mode (GAPD) with high detection efficiency and single photon resolution capability. However, in the brutal radiation environments of particle physics experiments, SiPMs degrade, pushing for the development of new, radiation hard, GAPDs. This work presents a first look at Gallium-Indium-Phosphide based light detectors, evidencing their promise as a viable alternative to the SiPM. As a large band-gap, compound semiconductor, GaInP possess the prerequisites for radiation hardness. In addition to measurements of the performance properties of these single-photon sensors, we will present radiation studies on the two most recent generations of prototype devices. Also new to this analysis is a long-exposure photography technique to understand the spatial extent of the radiation damage. These devices demonstrate that functional GaInP based APDs can be made, and these early studies suggest methods for improvement in future prototype generations. We will also discuss future physics analyses of cascade decays and new hardware directions.

**Collider Physics / 34**

## **Introduction to the LHC and CMS**

**Author:** Douglas Berry<sup>1</sup>

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The LHC is the world's highest energy proton-proton collider with a center-of-mass energy of 13 TeV. The world's largest machine is currently running at twice its designed luminosity and represents forefront of the energy frontier. The CMS detector is a multipurpose detector that features a 4 Tesla magnet and over a 100 million active channels taking data every 25 ns. It, along with its sister experiment ATLAS, is measuring the precise properties of the recently discovered Higgs boson, and leading the search for new and exciting physics: such as supersymmetry, dark matter, and extra dimensions.

**R & D / 9**

## **LArIAT In 10 Minutes**

**Author:** Hunter Sullivan<sup>1</sup>

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The LArIAT (Liquid Argon In A Test Beam) experiment at Fermilab's Test Beam Facility exposes a Liquid Argon Time Projection Chamber (LArTPC) to a charged particle test beam in order to calibrate and characterize LArTPCs response. This is a perfect environment in that particle species and momentum can be preselected while event reconstruction tools, particle identification algorithms, and new detector technologies can be tested. The LArIAT exploration of LArTPC capabilities will provide critical input to existing liquid argon neutrino experiments and will help to improve future precision neutrino oscillation measurements such as the Deep Underground Neutrino Experiment (DUNE). The work presented here will give an overview of the experiment and highlight recent results.

**Long Baseline Neutrino Program / 27**

## **Long-baseline searches for sterile neutrinos using neutral current interactions in NOvA**

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This talk discusses an updated analysis of neutrino data from the NOvA experiment to search for sterile neutrino oscillations. NOvA consists of two functionally identical liquid scintillator detectors in Fermilab's NuMI neutrino beam: a 300 ton near detector at a 1km baseline, and a 14,000 ton far detector 810km away in Ash River, MN, 14.6 mrad off the beam's central axis. Sterile neutrino oscillations are constrained by searching for neutrino disappearance in neutral current interactions between the near and far detectors. A covariance matrix approach is utilised to cancel systematic uncertainties between the two detectors over a broad range of  $\Delta m^2_{41}$  parameter space. This analysis uses neutrino data collected between February 2014 and February 2017, corresponding to an exposure equivalent to  $8.85 \times 10^{20}$  protons on target. A summary is provided of methods and results, including limits on the sterile neutrino mixing parameters  $\theta_{24}$  and  $\theta_{34}$  as a function of  $\Delta m^2_{41}$ .

**R & D / 17**

## **MICE in 10 minutes**

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The Muon Ionization Cooling Experiment (MICE) at Rutherford Appleton Laboratory, an important R&D step towards a future muon collider or neutrino factory has studied ionization cooling of muons. Several million individual muon tracks have been recorded passing through a series of focusing magnets and a liquid hydrogen or lithium hydride absorber in a variety of magnetic configurations. Identification and measurement of muon tracks upstream and downstream of the absorber are used to study the evolution of the 4D (transverse) beam phase-space volume. This talk presents and discusses these results.

**Cross Section Neutrino Program / 32**

## **MINERvA in 10 minutes**

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Based in the NuMI beam line at Fermi National Laboratory, the on-axis MINERvA experiment is aimed at precision measurements of neutrino interactions in nuclei for energies up to 50 GeV. The experiment provides measurements of neutrino and antineutrino cross sections off of nuclear targets which are important for both neutrino oscillation experiments and probing of the nuclear medium. The most recent results from the MINERvA experiment will be shown as well as a look to the future.

**Collider Physics / 53**

## **Machine Learning in DQM at CMS Experiment**

**Author:** Guillermo Fidalgo<sup>1</sup>

<sup>1</sup> *University of Puerto Rico Mayaguez*

The Data Quality Monitoring (DQM) of CMS is a key asset to deliver high-quality data for physics analysis and it is used both in the online and offline environment. The current paradigm of the quality assessment is labor intensive and it is based on the scrutiny of a large number of histograms by detector experts comparing them with a reference. This project aims at applying recent progress in Machine Learning techniques to the automation of the DQM scrutiny. In particular the use of convolutional neural networks to spot problems in the acquired data is presented with particular attention to semi-supervised models (e.g. autoencoders) to define a classification strategy that doesn't assume previous knowledge of failure modes. Real data from the hadron calorimeter of CMS are used to demonstrate the effectiveness of the proposed approach.

**Muon Physics / 10**

## **Magnetic Field Status of the Muon g-2 Experiment**

**Author:** Rachel Osofsky<sup>1</sup>

<sup>1</sup> *University of Washington*

The muon  $g-2$  experiment at Fermilab (E989) aims to measure the anomalous magnetic moment of the muon  $a_\mu$  to a precision of 140 parts per billion (ppb). This new measurement will shed light on the 3.5 sigma deviation between Standard Model calculations and the previous measurement (E821) at Brookhaven National Laboratory, and will test Standard Model extensions. The muon  $g-2$  experiment measures the difference between the cyclotron and spin precession frequencies of muons in a highly uniform magnetic field, where the magnetic field over a muon's trajectory must be known to 70 ppb.

The magnetic field in the muon storage region is mapped by a trolley carrying a circular array of 17 nuclear magnetic resonance (NMR) probes, but because the trolley can not be present while muons are being stored, the magnetic field drift is tracked using a suite of 378 NMR probes embedded in the top and bottom of the vacuum chambers.

The trolley NMR probes use a petroleum jelly sample and, in order to measure the field absolutely, must be calibrated against a water filled probe with very well understood characteristics. The calibration process is underway to calibrate all 17 trolley probes to a 30 ppb precision, with the inner ring of trolley probes now calibrated.

The other important step in achieving the desired precision is making the magnetic field in the storage region as homogeneous as possible. The last passive step in achieving the required field homogeneity was the adjustment and installation of over 10,000 iron shims in and around the muon storage region. Higher order multipole moments of the magnetic field distribution across the storage region are controlled using 100 concentric coils located above and below the vacuum chambers. The current distribution in these so called surface coils is adjusted to reduce magnetic field variations across the storage region to less than 2 parts per million.

An overview of the magnetic field hardware, calibration, and shimming status will be presented.

## Short Baseline Neutrino Program / 22

### MicroBooNE in 10 Minutes

**Author:** Colton Hill<sup>1</sup>

<sup>1</sup> *The University of Manchester*

Located at the Fermi National Accelerator Laboratory, MicroBooNE is the largest currently operating liquid argon neutrino detector in the world, making it an excellent source of valuable physics discoveries and R&D advancements for future liquid argon experiments. While MicroBooNE's flagship physics goal is investigating the low-energy short-baseline neutrino appearance anomaly seen in MiniBooNE and LSND, MicroBooNE's broader goals include studying many forms of oscillations, neutrino interactions, and exotics using excellent positional and energy resolution of the liquid argon TPC. Supplementing the rich physics program, MicroBooNE's greater understanding of detector level designs have and continue to inform decisions for detectors such as the Short Baseline Neutrino Detector (SBND) and DUNE.

## Long Baseline Neutrino Program / 11

### NOvA In 10 Minutes

**Author:** Justin Vasel<sup>1</sup>

<sup>1</sup> *Indiana University*



NOvA is a long-baseline neutrino oscillation experiment which uses the NuMI neutrino beam at Fermilab. Our detectors are functionally-similar liquid scintillator calorimeters, situated 810km apart and 14 mrad off-axis with respect to the the NuMI beam. NOvA's primarily physics goal is a measurement of electron neutrino appearance and muon neutrino disappearance from a muon neutrino beam to constrain mass ordering,  $\Delta m_{23}^2$ , the  $\theta_{23}$  octant, and  $\delta_{CP}$ . Sterile neutrino searches are also underway. In this talk, I will present an overview of the NOvA experiment and summarize recent results.

**Long Baseline Neutrino Program / 47**

## NOvA Muon Disappearance Results 2018

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An overview of the recent results from the NOvA muon neutrino disappearance analysis is presented. NOvA is an accelerator based neutrino experiment designed to study the electron neutrino appearance in the muon neutrino beam as it travels from the Near Detector facility at Fermilab to the Far Detector in the Northern Minnesota. The NOvA muon neutrino disappearance group has recently introduced new analysis techniques which greatly improved the experiment's sensitivity. And now for the first time we have data from the beam operating in the antineutrino mode. This, together with an updated detector simulation and new neutrino selection algorithms, allowed NOvA to achieve jointly the world leading estimation of the neutrino oscillation parameter  $\Delta m_{23}^2$ .

**Long Baseline Neutrino Program / 41**

## NOvA Reconstruction using Deep Learning

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The NOvA experiment has made measurements of the disappearance of  $\nu_\mu$  and the appearance of  $\nu_e$  in the NuMI beam at Fermilab. Key to these measurements is the identification of the neutrino flavor and measurement of the neutrino energy, for which NOvA has implemented deep learning algorithms utilizing tools from the field of computer vision. These algorithms, first applied to NOvA's 2016 results, showed significant improvement over previous reconstruction methods.

I will present NOvA's implementation of deep learning algorithms using convolutional neural networks for identification of event neutrino flavor and single particles used in the 2018 analysis.

**Long Baseline Neutrino Program / 40**

## NOvA's Short-Baseline Tau-Neutrino Appearance Search

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The primary goal of the NOvA experiment is to perform sensitive searches for standard three-flavor neutrino oscillations. The experiment is designed to measure electron-neutrino appearance at the Far Detector using the Near Detector to control systematic uncertainties; however, the Near Detector is well suited for searching for possible anomalous short-baseline oscillations. The LSND and MiniBooNE experiments obtained hints of electron-antineutrino appearance, which does not fit the three-flavor neutrino paradigm and can be explained by the addition of a sterile neutrino at a larger mass scale than the existing three-flavor mass states. This talk will present a novel method for selecting tau neutrino interactions at the Near Detector using a convolutional neural network. Based on this method, this talk will present NOvA's sensitivity to anomalous short-baseline tau-neutrino appearance and muon neutrino disappearance due to sterile neutrino oscillations.

## Long Baseline Neutrino Program / 36

### New electron (anti-)neutrino appearance analysis from NOvA

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NOvA (the NuMI Off-Axis  $\nu_e$  Appearance Experiment) utilizes a near detector at Fermilab and a far detector 810km away in Ash River, MN, to study the properties of neutrinos. Using a beam originating at Fermilab, NOvA studies neutrino oscillation via the disappearance of  $\nu_\mu, \bar{\nu}_\mu$  in the beam and the corresponding appearance of  $\nu_e, \bar{\nu}_e$ . Prior results from NOvA have studied  $\nu_\mu \rightarrow \nu_e$  with the accumulated neutrino interactions from approximately  $9 \times 10^{20}$  protons on target (POT), full detector equivalent. In the time since, NOvA has accumulated antineutrino data to study  $\bar{\nu}_\mu \rightarrow \bar{\nu}_e$  with approximately  $7 \times 10^{20}$  POT. Though adding to the level of complexity in the analysis, this combined data set provides enhanced sensitivity to important unresolved oscillation parameters, such as mixing angles, mass splitting and ordering, and the CP violating phase. Aspects of the appearance channel ( $\nu_e$  and  $\bar{\nu}_e$ ) analysis and results for NOvA's first study combining neutrino and antineutrino data will be discussed.

## R & D / 28

### PROSPECT in a Nutshell

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PROSPECT is a short-baseline reactor-based antineutrino experiment designed to precisely measure the  $^{235}\text{U}$  antineutrino spectrum and search for oscillations due to the existence of an  $\text{eV}^2$ -scale sterile neutrino. Deployed at the High Flux Isotope Reactor (HFIR) at Oak Ridge National Laboratory (ORNL) in early 2018, the optically segmented 4-ton  $^6\text{Li}$ -loaded liquid scintillator anti-neutrino detector utilizes pulse-shape discrimination and temporal and spatial topology to identify anti-neutrinos and reject most cosmogenic backgrounds. In addition, preparatory background measurement campaigns have enabled deployment of localized shielding to minimize reactor-related backgrounds to anti-neutrino measurement. This talk will serve as introduction to PROSPECT experiment and will also report on the results of these PROSPECT-external background measurements at HFIR.

## Collider Physics / 33

## Performance of b jet identification in the ATLAS Experiment at CERN

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The efficient identification of jets from bottom quarks (b-jets) is one of the most important techniques for many physics analyses at the Large Hadron Collider, including studies of the Higgs boson, the top quark, and searches beyond the Standard Model. The performance is characterized by b-tagging efficiency (probability to identify a b-jet as such) and the mistag rate (probability to mistakenly accept a non-b-jet). The mistag occurs as a result of finite detector resolution, presence of long-lived particles, and material interactions. As these effects can be different between the experimental data and Monte Carlo (MC) simulation, it is important to measure the b-tagging performance in data and derive the MC correction factors. I will describe various methods to measure the performance of b jet identification in pp collisions at  $\sqrt{s} = 13$  TeV with the ATLAS detector and will report on Direct Tag method which is recently developed in the ATLAS collaboration for Light jet calibration.

**Cross Section Neutrino Program / 6**

## Preliminary Analysis in MINERvA's Nuclear Targets for CCQE-like Events

**Author:** Jeffrey Kleykamp<sup>1</sup>

<sup>1</sup> *University of Rochester*

Minerva is a precision cross section experiment for neutrino scattering processes on various nuclei. Charged-Current Quasi-Elastic (CCQE) cross sections are relevant for neutrino oscillation experiments such as T2K, NOvA and DUNE. This talk describes how MINERvA's nuclear targets are used to measure the scaling in CCQE-like event rates as function of target nucleus. CCQE-like is defined as events with no detected pion. Preliminary results are shown for rates of CCQE-like events produced in the MINERvA medium energy run on water, hydrocarbon, iron, and lead targets. The presented data gives a taste of upcoming cross sections in muon, proton and combined variables.

**Cross Section Neutrino Program / 14**

## Proton and Neutral Pion Identification at ME in MINERvA

**Author:** Barbara Yaeggy<sup>1</sup>

<sup>1</sup> *Universidad Tecnica Federico Santa Maria*

Neutrinos, the quarry of the MINERvA experiment, are subtle and difficult to capture. Accelerator based oscillation experiments look for electron neutrino appearance, where a neutrino is observed to interact in the electron-type state rather than in the produced muon-type state. This observation is based on the observation of a produced electron and absence of a produced muon in the detector. Due to the low interaction cross section of neutrinos, the detection material must also serve as the target material and be relatively dense. This can cause neutral pions to be mistaken in the detector for electrons. We present here progress towards a study using the medium energy NuMI  $\nu_\mu$  beam to measure semi-exclusive neutral pion production in the MINERvA detector. In particular, we present changes in the event selection from the formerly presented low energy studies.

**R & D / 46**

## Radiation hard scintillator research and development

**Author:** Cory Rude<sup>1</sup><sup>1</sup> *CERN/Fermilab*

A crucial component of scintillators in current and future collider experiments is their ability to operate after exposure to radiation. The University of Iowa HEP group is developing scintillators for use in both HEP and medical fields. This talk will focus on our progress so far.

**SBN & DUNE / 50**

## Repurposing MINOS Scintillator Modules for the Short Baseline Neutrino Program Far Detector (ICARUS) Cosmic Ray Tagger

**Author:** Christopher Hilgenberg<sup>1</sup>**Co-authors:** Anne Schukraft<sup>2</sup>; Robert Wilson<sup>1</sup>; Simone Marcocci<sup>2</sup><sup>1</sup> *Colorado State University*<sup>2</sup> *Fermilab***Corresponding Author:** [chilge@rams.colostate.edu](mailto:chilge@rams.colostate.edu)

The ICARUS T600 liquid argon time-projection chamber will be the far detector for the short baseline neutrino program. The detector will operate at shallow depth and therefore be exposed to the full surface flux of cosmic rays, which poses a problematic background to the electron neutrino appearance analysis. A direct way to remove this background is to utilize a detector external to the liquid argon active volume capable of tagging thoroughgoing cosmic muons with high efficiency. Ideally, this cosmic ray tagger (CRT) would provide full geometric coverage of the T600 amounting to about  $1000m^2$ . This is achieved through adopting a system based on extruded organic scintillator, wavelength-shifting fibers, and silicon photomultipliers. Due to the large area, the CRT is broken into 3 subsystems: the top portion will be new construction, the side coverage will be provided by salvaged MINOS scintillator modules, and the bottom will be covered by Double Chooz veto modules. To cope with high rates of cosmic muons, the MINOS system requires a new optical readout and front-end electronics. Here, I present results from the research and development of this new readout scheme and testing of the salvaged modules.

**SBN & DUNE / 43**

## SBND in 10 minutes

**Author:** Thomas Brooks<sup>1</sup><sup>1</sup> *University of Sheffield*

SBND (Short-Baseline Near Detector) is a 112 ton liquid argon time projection chamber being constructed 110 m from the target of the Fermilab Booster Neutrino Beam. One of its primary objectives is to test the eV scale sterile neutrino hypothesis by studying short-baseline oscillations along with MicroBooNE and ICARUS T-600 as part of the Short-Baseline Neutrino program. Due to the proximity to the beam, SBND will observe millions of neutrino interactions and will produce an extensive set of neutrino-argon cross section measurements. SBND will also facilitate crucial research and development of liquid argon technology for the future Deep Underground Neutrino Experiment. This

talk will summarize the physics program of SBND and the recent progress towards achieving these goals.

**Collider Physics / 49**

## **Search for Dark Matter in a Coannihilation Codex Model**

**Author:** Orgho Neogi<sup>1</sup>

**Co-author:** Christina Snyder<sup>1</sup>

<sup>1</sup> *University of Iowa*

Coannihilation Codex is a classification of models for Dark Matter which lead to a variety of new signatures at colliders. One signature features a Dark Matter field as well as a new particle X and a Leptoquark. We are beginning a search which includes the first-generation leptoquark, leading to a signature with a high-pt electron, jets, and missing ET. We will show kinematic distributions and discuss optimization of the analysis to search the 2016 CMS data for this signature.

**Collider Physics / 31**

## **Search for Large Extra Dimensions and Compositeness in $\mu+\mu-$ and $e+e-$ channels in proton-proton collisions at $\sqrt{s}=13$ TeV in CMS”**

**Author:** Prakash Thapa<sup>1</sup>

**Co-author:** Leonard Spiegel<sup>2</sup>

<sup>1</sup> *Wayne State University*

<sup>2</sup> *FNAL*

Non-resonant excesses in dilepton invariant mass spectra are predicted by several beyond the standard model (BSM) theories. In this search, two theoretical models, large extra dimensions (LED) and Compositeness are considered, and the status of the search in the mass range 400-5000 GeV will be presented using 2016 data collected by CMS detector. In LED, space-time is extended by an additional number (n) of compactified dimensions. In this model, all standard model particles are localized in a (3+1) dimension (the brane). However, gravity propagates to all (n+3) +1 dimensions (the bulk). In Compositeness, quarks and leptons are composite structures, bound states of more fundamental constituents called preons. Below the interaction energy scale  $\Lambda$ , the strength of binding of constituents is very strong and binds preons to a composite state. At this energy scale, the effect of Compositeness can be visible as a four-fermion contact interaction. In our search three helicity models LL, LR and RR are considered. The signature of LED and Compositeness might be observed as a deviation from the prediction of the SM Drell-Yan process at high masses.

**Collider Physics / 48**

## **Search for supersymmetry in proton-proton collisions at 13 TeV using identified top quarks**

**Author:** Hui Wang<sup>None</sup>

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My presentation is based on the analysis of searching for supersymmetric particles, with the data collected by CMS detector in 2016, at a center-of-mass energy of 13 TeV and correspond to an integrated luminosity of 35.9 inverse fb. This analysis focuses on simplified SUSY models with top quarks and large missing transverse momentum in all hadronic final states. These channels have distinctive signatures and a powerful customized top tagger further optimizes the events selection. No statistically significant excess of standard model is observed but the previous limits of the masses of supersymmetric particles are extended.

**Collider Physics / 3**

## Simulation of CMS Phase 2 Pixel Tracker for HL-LHC

**Author:** Bahareh Roozbahani<sup>1</sup>

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The High-Luminosity Large Hadron Collider (HL-LHC) aims to increase luminosity by a factor of 10 beyond the LHC's design value. To cope with the increased rate of particle production without compromising physics performance, the LHC detectors will undergo an extensive upgrade. CMS will replace the current inner tracker system with a new silicon tracker which will feature increased forward acceptance, improved radiation hardness, higher granularity, and compatibility with higher data rates. We present a simulation study of the CMS Phase 2 pixel tracker that investigates the expected occupancy and tracking performance for various geometric and sensor granularity options.

**Short Baseline Neutrino Program / 18**

## Studying Track Distortions From the Space Charge Effect at MicroBooNE

**Author:** Christopher Barnes<sup>1</sup>

<sup>1</sup> *University of Michigan*

I present a study of the distortions on track reconstruction caused by the space charge effect within the MicroBooNE Liquid Argon Time Projection Chamber (LArTPC). The space charge effect is the accumulation of slow-moving positive ions in a detector primarily from ionization by cosmic ray muons. Spatial and temporal distortions of ionization electrons result from this effect in addition to differences in the magnitude of charge yield throughout the detector. For a drift electric field value of 273 V/cm, the electric field within the detector varies by up to ~15%. To study the reconstructed track trajectories affected by the space charge effect within the detector, we utilized a pure sample of cosmic ray muons. We found that a data-driven method of measuring track distortions due to the space charge effect is necessary, and that total track distortion is decreasing as

a function of time at the LArTPC top. This measurement technique may be applied to future LArTPC experiments.

## Dark Matter and Astrophysics / 25

### SuperCDMS in 10 Minutes

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Dark matter is a hypothetical form of matter that, if it exists, may account for more than a quarter of the energy density of our universe. Despite the variety of astrophysical evidence pointing to its existence, the direct interaction of dark matter in a terrestrial detector is yet to be observed. The Super Cryogenic Dark Matter Search (SuperCDMS) experiment tries to observe a dark matter signal in silicon and germanium detectors operated around 50 milliKelvin. In this talk, I will discuss the technology, the current status, and the projected sensitivity of the next generation SuperCDMS experiment.

## SBN & DUNE / 8

### Supernova Neutrino Detection Efficiencies in DUNE

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The DUNE Single Phase Far Detector will be sensitive to neutrinos from supernova neutronization bursts from within the Milky Way. In order to fully reconstruct these interactions, signals from the charge collection system need to be correctly matched to signals from the photon detection system. The challenge is to distinguish flashes of light produced by low energy supernova neutrinos from those produced by trace radioactive decays within the liquid argon. Currently there are multiple potential designs of the photon detection system that deliver different flash matching capabilities. This presentation is an analysis and comparison of the flash matching capabilities of different detector schemes.

## Short Baseline Neutrino Program / 1

### Testing a Neutrino Event Generator against Electron Scattering Data

**Author:** Afroditi Papadopoulou<sup>1</sup>

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Neutrino physics is entering an age of precision measurements. A number of experiments have firmly established the existence of

neutrino oscillations and determined the corresponding squared mass differences and mixing angles. These measurements have provided unambiguous evidence that neutrinos have non-vanishing masses. The large  $\theta_{13}$  mixing angle will enable future experiments to search for leptonic CP violation in appearance mode, thus addressing one of the outstanding fundamental problems of particle physics. These searches will involve high precision determinations of the oscillation parameters, which in turn require a deep understanding of neutrino interactions with the atomic nuclei comprising the detectors. In view of the achieved and planned experimental accuracies, the treatment of nuclear effects is indeed regarded as one of the main sources of systematic uncertainty. In this context, a key role is played by the availability of a wealth of electron scattering data. In this analysis, data from the CLAS detector at Jefferson Lab have been used to test the accuracy of the neutrino energy reconstruction methods against the predictions of the commonly used GENIE neutrino event generator.

### Muon Physics / 23

## The Mu2e experiment at Fermilab: a search for lepton flavor violation

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The Mu2e experiment at Fermilab will search for the charged lepton flavor violating process of neutrino-less  $\mu \rightarrow e$  coherent conversion in the field of an aluminum nucleus. About  $7 \cdot 10^{17}$  muons, provided by a dedicated muon beam line in construction at Fermilab, will be stopped in 3 years in the aluminum target. The corresponding single event sensitivity will be  $2.5 \cdot 10^{-17}$ . In this presentation, a brief overview of the physics explored by the  $\mu \rightarrow e$  conversion will be given, followed by a description of the Mu2e experimental apparatus and the expected detector performance.

### Cross Section Neutrino Program / 51

## Track and vertex reconstruction in ANNIE Phase II

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The primary physics goal of Phase II of the Accelerator Neutrino Neutron Interaction Experiment (ANNIE), is to measure the nuclear final states from neutrino interactions in water, with a particular focus on the production and multiplicity of final-state neutrons. The detector sits in the SciBooNE Hall, on Fermilab's Booster Neutrino Beam (BNB). The upgraded detector will have  $\sim 125$  photomultiplier tubes in Phase II, increasing our detection efficiency for neutron captures, and will also incorporate at least five Large Area Picosecond Photodetectors (LAPPDs). ANNIE will be the first application of a multi-LAPPD system in a physics measurement and the introduction of these LAPPDs will provide the precise vertex and track reconstruction capabilities required to achieve our physics goals. In this talk, we discuss the simulation of beam



neutrino interactions in the Phase II detector. Then, using these simulations, we demonstrate the increase we can achieve in the precision of our vertex and track resolution with optical coverage from five LAPPDs, in addition to photomultiplier tubes, over coverage from photomultiplier tubes alone.

**Dark Matter and Astrophysics / 55**

## **Triaxiality in Weak Lensing Cluster Mass Estimates in DES Y3**

**Author:** Zhuowen Zhang<sup>None</sup>

My talk summarizes the modeling of triaxiality on weak lensing galaxy cluster mass estimates for DES Y3 analysis. We use Buzzard dark matter halos and particle simulations to measure the shapes of halos and the redMaPPer algorithm to detect clusters to redshifts up to  $z < 0.90$ . We show that triaxiality biases the selection of the redMapper algorithm primarily as a bias in orientation, with a secondary selection effect on the ellipticity of selected halos. The selection bias presents itself observably as a shift in the richness-mass relation, which is best characterized by a linear relation with an upward shifted amplitude for halos orientated with their major axes toward the line of sight. In addition, the surface density shows a significant dependence with orientation in both the one halo and two halo regime, which can be well modeled by a Cauchy function fit. The orientation dependent template for the richness-mass relation and surface density, combined with the appropriate halo mass function for a given cosmology, outputs the stacked weak lensing cluster surface density that largely minimizes the systematics from triaxiality. Our model will largely reduce the systematics from triaxiality in the systematics-limited DES Y3 cosmological analysis.

**UEC Report / 56**

## **UEC Report**

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**R & D / 21**

## **Working Toward a Precision Neutrino Beam**

**Author:** Tyler Rehak<sup>None</sup>

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As the Deep Underground Neutrino Experiment nears construction, the existing neutrino facilities at Fermilab provide opportunities to test and refine methods characterizing high precision neutrino beams. MARGARITA is a water Cherenkov stopped muon detector that features twin photomultiplier tubes and two small, slightly differing detector volumes. The two detector volumes are designed to exploit the difference between the lifetimes of positive and negative muons in matter in order to characterize a neutrino beam. MARGARITA is currently being developed in the Neutrinos at the Main Injector (NuMI) beamline. The NuMI beamline also contains an existing muon monitoring system that has been underutilized. Improved analysis via ROOT and simulation via Geant4 of past, current, and future data from the muon monitors during an array of operating conditions could provide useful insights for any experiment at Fermilab utilizing a precision neutrino beam.

**Muon Physics / 13**

**g-2 in 10 minutes**

**Author:** Cristina Schlesier<sup>None</sup>

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This talk will give a brief overview of the Muon g-2 experiment currently running at Fermilab. Muon g-2 seeks to measure the anomalous magnetic moment of the muon to an unprecedented precision of 0.14 ppm, with the goal of testing the Standard Model and possibility providing evidence of physics beyond the Standard Model.