New Perspectives 2023

Monday, 26 June 2023 - Tuesday, 27 June 2023

Fermilab

Book of Abstracts

Contents

Neutrinos: ANNIE, ICARUS, SBND (part 1) / 1

ANNIE in 10 minutes

Author: Marvin Ascencio Sosa[1]

[1] *Iowa State University*

Corresponding Author: mascenci@iastate.edu

The Accelerator Neutrino Neutron Interaction Experiment (ANNIE) is a 26-ton Gd-doped water Cherenkov R&D detector located upstream of the Booster Neutrino Beam (BNB) at Fermi National Accelerator Laboratory (Fermilab). The ANNIE physics goal is to study the neutron yield of the neutrino-nucleus interaction. The R&D effort focuses on using new photodetector technology, chemical additives, and novel detection medium. Two cutting-edge detector technologies have been deployed in a neutrino beam by ANNIE for the first time: Large Area Picosecond Photodetectors (LAPPDs) and Water-based Liquid Scintillator (WbLS). This talk reports on ANNIE's physics goal and detector status.

DM, Cosmology, and CCDs / 2

Precision ionization calibrations of silicon skipper CCDs for dark matter detection

Author: Rachana Suthikshn Yajur[1]

[1] *University of Chicago*

Corresponding Author: rachanayajur@uchicago.edu

Direct dark matter detection experiments can reach the thresholds as low as $\mathcal{O}$(10eV). In that regime, we report precision ionization measurements induced by Compton scattering of gamma rays and nuclear recoils from neutrons. A skipper charge-coupled device (CCD) with single electron resolution developed for DAMIC-M experiment was used to collect data. Compton scattering on silicon atomic shell electrons down to 23 eV was measured using a ^{241}Am source and compared with Monte Carlo simulations and *ab initio* calculations. Nuclear recoil ionization efficiency of silicon nuclei was measured using a SbBe source and Monte Carlo simulations were used to model the nuclear recoil spectrum. Agreements with simulations for Compton scattering and the deviation of nuclear recoil ionization efficiency from the extrapolated Lindhard model will be dicussed.

Muons: Mu2e and g-2 / 3

The Muon g-2 Experiment in 10 minutes

Author: Paolo Girotti[1]

[1] *INFN Pisa*

Corresponding Author: paolo.girotti@phd.unipi.it

The Muon $g-2$ Experiment at Fermilab is a very high-precision experiment that aims to measure the muon magnetic anomaly with the unprecedented precision of 140 parts per billion. The muon anomaly, which is the relative deviation of the muon g-factor from 2, encodes all the possible virtual interactions between the muon and a magnetic field. In April 2021, the collaboration published the first measurement relative to the first year of data taking with a precision of 460 ppb. The result confirmed the previous experiment at BNL and increased the tension with the Standard Model prediction to 4.2 σ. This exciting discrepancy could be a hint of new physics and/or indirect detection of unknown particles. However, improved theoretical calculations involving Lattice QCD techniques are bringing new tensions within the theory side of the muon anomaly. A new measurement with twice the precision will be published later this summer. This talk will try to convey the importance of the g-2 experiment and the fascinating complexities involved when performing a sub-ppm measurement.

Neutrinos: NOvA, R&D, and Hadrons / 4

Dopant R&D in LArTPCs

Author: Raisa Tasnim Raofa[None]

Corresponding Author: rraofa@fnal.gov

Neutrinos interact with matter very weakly making it hard to detect despite being the most abundant particle in the universe. **L**iquid **Ar**gon **T**ime **P**rojection **C**hamber (**LArTPC**) detects neutrinos by measuring the resultant charge and light after the interaction between neutrino and argon particles. However, in LArTPCs, light collection efficiency is much lower than charge collection, which limits our ability to reconstruct low-energy signals. In our project, we explore adding photosensitive dopants to the liquid argon which are expected to convert the scintillation light into more ionization charge enabling us to explore the low-energy signals in the TPC. I will discuss the R&D endeavor in the Fermilab's Nobel Liquid Test Facility showcasing its ongoing efforts and advancements.

Neutrinos: MicroBooNE / 5

MicroBooNE in 10 minutes

Authors: Natsumi Taniuchi[None]; on behalf of the MicroBooNE Collaboration[None]

Corresponding Author: ntaniuchi@hep.phy.cam.ac.uk

MicroBooNE is an 85-tonne active volume Liquid Argon Time Projection Chamber (LArTPC) detector situated at Fermilab which receives both an on-axis Booster Neutrino Beam (BNB) and an off-axis beam component from the Neutrinos at the Main Injector (NuMI) beam. MicroBooNE collected data from 2015 until 2021 and acquired the highest statistics sample of neutrino-argon interactions to date. The state of the art capability of the LArTPC is utilized for fundamental physics searches. MicroBooNE's signature analysis is to determine the source of the low-energy excess of electromagnetic activity previously reported by MiniBooNE and LSND. In addition, MicroBooNE's analysis program ranges from a detailed investigation of neutrino-nucleus interactions, to a broad range of BSM physics searches, to detector simulation and event reconstruction developments, which will be useful to the broader short- and long-baseline oscillation programs. In this talk, we will present a brief overview of the current status of MicroBooNE's physics program, a summary of the latest major results, and future prospects.

Neutrinos: NOvA, R&D, and Hadrons / 6

NA61/SHINE Hadron Production Measurements for Accelerator-Based Neutrino Beams

Author: Dominic Battaglia[1]

[1] *University of Notre Dame*

Corresponding Author: dbattag2@nd.edu

Long-baseline neutrino experiments, such as NOvA, T2K, and DUNE, are working to measure neutrino oscillation parameters and will benefit from reduced neutrino flux uncertainties. The dominant source of neutrino flux uncertainty arises from an insufficient knowledge of parent hadron yields from neutrino production targets. Using external hadron production measurements, we can significantly reduce these flux uncertainties. The NA61/SHINE experiment at CERN provides measurements of many hadronic interactions for this purpose. Recent results from NA61, including 120 GeV incident proton measurements relevant to NuMI and DUNE, will be discussed, as well as progress on a measurement of hadron yields from a NuMI replica target.

Muons: Mu2e and g-2 / 7

Dark Matter search in the Muon g-2 experiment at Fermilab

Author: Byungchul Yu[1]

Co-authors: Breese Quinn [1]; On Kim [1]; Baisakhi Mitra [2]

[1] *University of Mississippi*

[2] *Fermi lab(University of Mississippi Graduate Student)*

Corresponding Authors: byu1@go.olemiss.edu, quinn@phy.olemiss.edu, bmitra@go.olemiss.edu, okim@olemiss.edu

Dark matter is one of the most interesting research topics in physics. Many particle physicists are trying to identify it because we know that dark matter could be a major component of a complete fundamental description of nature. The Muon g-2 Experiment at Fermilab measures the anomalous precession frequency of the muon. Oscillations of this precession frequency could be produced by dark matter coupling to muons. This talk will describe how we could observe DM signals in the Muon g-2 data. I will explain how we determine the Muon g-2 DM mass range sensitivity, and analysis strategies throughout the mass range. Finally, I will present the expected Muon g-2 experiment discovery/exclusion reach in selected DM model-dependent scenarios.

Computational Astrophysics / 8

The Dependence of Cooling and Heating Functions on Local Radiation Fields

Author: David Robinson[None]

Corresponding Author: dbrobins@umich.edu

Cooling and heating functions of gas determine its energy budget and the thermal pressure support it can provide. These functions are thus a key ingredient in the physics that control how stars and galaxies form. The radiative transfer physics shaping cooling and heating functions is known, but is too computationally expensive to include in hydrodynamic simulations for realistic local radiation fields within galactic halos. Instead, a fast approximation scheme is needed.
We use machine learning to investigate which wavelength bands of the radiation field most strongly affect cooling and heating functions. We use these results to develop more accurate approximation schemes to cooling and heating functions in the presence of a local radiation field.

Neutrinos: ANNIE, ICARUS, SBND (part 1) / 9

SBND in 10 minutes

Author: Henry Lay[1]

[1] *Lancaster University*

Corresponding Author: h.lay@lancaster.ac.uk

The Short-Baseline Near Detector (SBND) will be one of three Liquid Argon Time Projection Chamber (LArTPC) neutrino detectors positioned along the axis of the Booster Neutrino Beam (BNB) at Fermilab, as part of the Short-Baseline Neutrino (SBN) Program. The detector is anticipated to begin operation later this year. SBND is characterized by superb imaging capabilities and will record over a million neutrino interactions per year. Thanks to its unique combination of measurement resolution and large statistics, SBND will carry out a rich program of neutrino interaction measurements and novel searches for physics beyond the Standard Model (BSM). It will enable the potential of the overall SBN sterile neutrino program by performing a precise characterization of the unoscillated event rate, and constraining BNB flux and neutrino-argon cross-section systematic uncertainties. In this talk, the physics reach, current status, and future prospects of SBND are discussed.

Neutrinos: MicroBooNE / 10

Demonstrating Calorimetry and Particle Discrimination at MeV Energy Scales with Ambient Backgrounds in the MicroBooNE LArTPC

Author: Diego Andrade[1]

[1] *Illinois Institute of Technology*

Corresponding Author: dandradealdana@hawk.iit.edu

MicroBooNE is an 85 tonne liquid argon time projection chamber (LArTPC) detector situated at Fermilab exposed to both the Fermilab neutrino beams. It collected data from 2015 until 2021, which have been used for a plethora of physics analyses. Using MC samples of single electrons, photons, and protons that produce low-energy blips of ionization activity spanning the energy range 0-8 MeVee, we have developed a particle-ID (PID) metric related to the ratio of a blip's total charge to its size. This metric is able to provide substantial electron-proton and photon-proton separation above roughly 3 MeVee in reconstructed blip energy (roughly 15 MeV true proton energy). MicroBooNE's lower-energy ambient blip population contains specific radiogenic spectral features that can be used to calibrate the energy scale and energy resolution of MicroBooNE's MeV-scale reconstruction, while the higher-energy blip population contains cosmogenically-produced electron- and proton-generated blips useful for calibrating MeV-scale particle discrimination metrics. To validate the PID metrics at the MeV scale, a calibration was performed in this regime by measuring the energy spectrum of blips at hotspots in the detector, identifying the Compton edge in this spectrum, and matching this edge to that in an MC sample of 2.614 MeV gammas from Tl-208 radioactive decay.

Computational Physics / 11

HEP Software Training with HSF/IRIS-HEP

Author: Guillermo Fidalgo-Rodríguez[1]

[1] *University of Puerto Rico at Mayagüez*

Corresponding Author: guillermo.fidalgo@upr.edu

HEP software requires both general computational skills and domain knowledge of the field. In my experience, more and more young students lack the software knowledge needed to contribute to the HEP community. IRIS-HEP and the HSF have programs designed to bridge this gap for young scientists through training events. Specifically, I mention the Software Basics Training workshops that teach young researchers about the basic tools and skills needed not only in HEP but in general computer science. In this talk, I will go through my contributions as an HSF and IRIS-HEP mentor experiences as a mentor, facilitator, and instructor of some of these events and I will invite the community to join the efforts of developing, maintaining, and improving the content for the training events.

Neutrinos: MINERvA and 2x2 / 12

Applying Machine Learning to vertex recognition for neutrino interactions

Author: Oscar Moreno Palacios[None]

Corresponding Author: oemorenopalaci@email.wm.edu

The MINERvA experiment studies neutrinos cross sections with different nuclei. Neutrino vertex recognition plays a key role in reconstructing neutrino interactions. This research aims to enhance previous Machine Learning neutrino vertex recognition models produced in MINERvA using Deep Convolutional Neural Networks (DCNN). The approach focuses on extending neutrino interaction image information used as input to generate the models. The extension allows the DCNN to look for neutrino interactions in new regions not studied before. A Domain Adversarial Neural Network (DANN) was also implemented to penalize differences between simulated data images and real data images. The model performance is evaluated using recall, precision, and the harmonical mean F1 score, a traditional well-known metric used in this field. The F1 score considers both precision and recall, providing a comprehensive assessment of the model's performance. An extra label to recognize background activity was also implemented. The new models generated are the next version to use for the MINERvA experiment, it enables analysis of all events in the detector including the calorimeters enabling new high statistics analysis in MINERvA.

Neutrinos: ANNIE, ICARUS, SBND (part 1) / 13

Commissioning SBND's Time Projection Chambers

Author: Maria Flavia Cicala[1]

[1] *UCL*

Corresponding Author: f.cicala@ucl.ac.uk

The Short Baseline Near Detector is an integral element of the SBN program at Fermilab. Two Time Projection Chambers (TPCs) constitute the heart of the detector, which is also equipped with a groundbreaking light detection system and a Cosmic Ray Tagger (CRT) system. SBND will begin cold commissioning in 2023, and will proceed to physics data-taking as soon as possible. SBND's commissioning program aims to maximise the quality of the data that will be collected to advance the program's ambitious physics program. During the commissioning process we will characterise and optimise the performance of the TPCs. This will enable precise measurements of the drifted electrons from particle interactions in the detector and will facilitate the excellent spatial and calorimetric resolution that LArTPCs are known for.

Neutrinos: SBND (part 2) / 14

What Physics Can We Learn about in SBND from its ”Prehistoric Era”?

Author: Jiaoyang Li[1]

[1] *The University of Edinburgh*

Corresponding Author: jiaoyang.li@ed.ac.uk

The Short-Baseline Near Detector (SBND) is a 100-ton scale Liquid Argon Time Projection Chamber (LArTPC) neutrino detector positioned in the Booster Neutrino Beam (BNB) at Fermilab. SBND is an on-surface detector, and will therefore be surrounded by an external cubical sub-detector, the Cosmic Ray Tagger (CRT) system, which is designed to reduce the cosmic ray background. The CRT system employs plastic scintillation coupled with silicon photo-multipliers (SiPMs) to detect photons emitted when charged particles from cosmic rays deposit energy. The CRT system is the first SBND subsystem to have entered the installation and commissioning stage. One of goals for the commissioning is to understand the SiPM response to individual photo-electrons. In the past, SBND has taken data using the bottom layer of the CRT system, which was installed in the detector hall from 2017 to 2019. This data was used to test the CRT performance, but it is also very useful to validate our simulation with this real physics data. In this talk, I will present a part of results of CRT commissioning and preliminary data-to-MC comparisons with data taken from 2017 to 2019.

Neutrinos: SBND (part 2) / 15

Neutrino Electron Scattering for Flux Constraint on SBND

Author: Brinden Carlson[1]

[1] *University of Florida*

Corresponding Author: bcarlson1@ufl.edu

Neutrino electron elastic scattering is a process with a precisely known cross-section that provides a standard candle for improving our knowledge about the neutrino flux in accelerator-based neutrino beams. This process also has a distinct experimental signature leveraging the kinematics of the scattering process that allows us to directly measure these events. The Short Baseline Neutrino Detector (SBND) is a liquid argon time projection chamber (LArTPC) detector situated along the Booster Neutrino Beam (BNB) at Fermilab. One of the dominant systematic uncertainty for the experiment is the neutrino flux, which arises from uncertainties in hadronic processes in the creation of the BNB. We demonstrate that by measuring these events we can constrain the normalization uncertainty on the neutrino flux.

Neutrinos: SBND (part 2) / 16

Heavy Neutral Lepton Searches at the Short Baseline Near Detector

Author: Vu Chi Lan Nguyen[1]

[1] *University of Sheffield*

Corresponding Author: vclnguyen1@sheffield.ac.uk

The Short-Baseline Neutrino (SBN) program at Fermilab aims to carry out precision searches for new neutrino physics [1]. Being the closest detector of the program to the Booster Neutrino Beam (BNB), Short Baseline Near Detector (SBND) is expected to measure an extremely high neutrino flux, allowing for world leading neutrino-nucleus interaction measurements as well as searches for physics Beyond Standard Model (BSM). SBND aims to achieve high timing resolution within the order of a few nanoseconds, allowing for the reconstruction of the BNB substructure. The precise timing enables identification of an interaction inside the detector whether it is in-time with the neutrino spill. This opens up possibilities not only to reject out-of-time cosmics muons background, but also to select delayed interactions from the BNB which can be signatures of BSM physics. A candidate for BSM long-lived particles is the Heavy Neutral Leptons (HNLs) [2]. HNLs interact with the SM by mixing with neutrinos, and can provide hints to the neutrino mass mechanism. This talk will explore the searches for HNLs produced from the BNB, that subsequently decay into a SM neutrino and a neutral pion inside SBND. The HNLs can be selected by utilising the delayed interaction time, as well as the unique highly boosted di-showers topology.

[1] P. Machdao, O Palamara and D. Schmitz, arxiv 1903.04608 (2019)
[2] Anupama Atre et al, JHEP05(2009)030

Neutrinos: SBND (part 2) / 17

The UV Laser Calibration System for measuring the electric field in the SBND detector

Author: Shivaraj Mulleria Babu[None]

Corresponding Author: shivaraj.mulleriababu@lhep.unibe.ch

The Short-Baseline Near Detector (SBND) is a LArTPC located approximately 110 meters from the target in Fermilab's Booster Neutrino Beam (BNB). It will measure neutrino cross sections and the unoscillated neutrino flux to reduce uncertainties in the aid searches for anomalous oscillations.

The electric field is one of the key to detect the particle interaction inside the SBND-Time projection chamber(TPC), which may have distortions for several reasons, such as the space charge effect. The space charge effect comes from the abundant cosmic rays that ionize the argon, producing copious positive argon ions. A precise determination of the electric field distortion inside the TPC volume is required along a procedure to compensate for the distortion in the spatial coordinate. These spatial distortions, if not understood, would affect both the topological and calorimetric reconstruction of events in the detector. The UV calibration system is the detector system that will perform this measurement.

In this talk, I will give a brief explanation of the UV laser calibration system for SBND. I'll discuss the progress made in constructing and installing it at SBND, how we determine spatial distortion and electric field, and how we can fix them when analyzing data in a very simple and understandable manner.

Neutrinos: ANNIE, ICARUS, SBND (part 1) / 18

Perspectives for measuring NuMI neutrino-Ar cross-section @ ICARUS and cosmic background constraints in the muon neutrino inclusive selection

Author: Guadalupe Moreno[1]

[1] *Cinvestav*

Corresponding Author: guadalupe.moreno@cinvestav.mx

Presently experimental neutrino physics is going through an exciting time due to the high-precision measurements, in massive detectors, expected from future experiments, e.g. DUNE. The ICARUS experiment is the far detector of the Short-Baseline Neutrino program (SBN) at Fermilab. This program consists of a near and far detector that use the LAr TPC technology and are located along the axis of the Booster Neutrino Beam (BNB), with the main goal to search for sterile neutrino signatures. In particular, ICARUS is sited 5.7° off-axis from the NuMI beamline. This feature provides a unique dataset before DUNE comes online. We expect to have neutrino interactions from a few hundred MeV to several GeV (an energy range close to the one we expect in DUNE). As part of the efforts to measure cross-section, we have studied the muon neutrino charge current inclusive channel, where we had focused on studying muons coming from muon neutrino interaction to try to distinguish them from the ones that come from cosmic interactions. This work will discuss the status of these studies and will highlight the cosmic background rejection procedure.

CMS/Theory / 19

Search for neutral long-lived particles decaying in the CMS Muon System

Author: James Sheplock[None]

Corresponding Author: sheplock@ucsb.edu

A search for long-lived particles decaying in the CMS Muon System is presented. The search utilizes the full Run 2 dataset totaling 138 fb^{-1} of proton-proton collisions recorded by the CMS experiment at $\sqrt{s} = 13$ TeV. Hits in the Muon System are clustered together and properties of the cluster are used to reject backgrounds. The results of the search are interpreted using a Twin Higgs model, showing sensitivity to Higgs-mediated long-lived particle production with many final states, proper lifetimes up to 100m and masses from 0.01 to 55 GeV. A previously untested Dark Shower model is also interpreted, setting the first LHC limits for a dark QCD that couples to the Higgs in five different portals.

Neutrinos: ANNIE, ICARUS, SBND (part 1) / 20

Tagging neutrino events with the SBND's Photon Detection System

Author: Francisco Nicolas-Arnaldos[1]

[1] *University of Granada*

Corresponding Author: fnicolas@fnal.gov

Liquid Argon Time Projection Chambers (LArTPCs) have become one of the main detection technologies in the field of neutrino physics. In addition to the ionization electrons produced by charged particles, used to reconstruct near photographic images of neutrino interactions, LAr is also a very prolific scintillator. New experiments like the Short Baseline Near Detector (SBND) are focusing on harnessing the potential of the light signals. Its pioneering Photon Detection System (PDS) is a hybrid concept combining photomultiplier tubes and X-ARAPUCAs devices. Furthermore, covering the cathode plane with highly reflective panels coated with a wavelength shifting compound enables recovering part of the light emitted towards the cathode, where no optical detectors exist. Among the advanced capabilities of the SBND PDS, we will focus on its excellent time resolution and its ability to independently reconstruct the location of the events. This will enable SBND to accurately tag neutrino events with a predicted resolution $\mathcal{O}(2\ \mathrm{ns})$ and ultimately retrieve the pulse structure of the Booster Neutrino Beam (BNB).

CMS/Theory / 21

SMEFT probes in future precision DIS experiments

Authors: Chiara Bissolotti[1]; Kaan Simsek[2]; Radja Boughezal[3]

[1] *University of Pavia and INFN*

[2] *Northwestern/Argonne*

[3] *Argonne National Laboratory*

Corresponding Authors: rboughezal@anl.gov, chiara.bissolotti01@universitadipavia.it, ksimsek@u.northwestern.edu

We analyze the potential of future high-energy deep-inelastic scattering (DIS) experiments to probe new physics within the framework of the Standard Model Effective Field Theory (SMEFT). We perform a detailed study of SMEFT probes at a future Large Hadron-electron Collider (LHeC) and a Future Circular lepton-hadron Collider (FCC-eh) machine, and extend previous simulations of the potential of a Electron-Ion Collider (EIC) to include Z-boson vertex corrections. Precision Z-pole constraints on vertex corrections suffer from numerous degeneracies in the Wilson-coefficient parameter space. We find that both the LHeC and the FCC-eh can help remove these degeneracies present in the existing global fits of precision Z-pole observables and LHC data. The FCC-eh and LHeC will in many cases improve upon the existing precision electroweak bounds on the SMEFT parameter space. This highlights the important role of precision DIS measurements for new physics studies.

Computational Physics / 22

Enhanced Slip-Stacking Techniques for Particle Accelerators: Analytical, Numerical, and Experimental Investigation

Authors: Jeffrey Eldred[1]; Mohammad Habibeh[None]

[1] *Supervisor*

Corresponding Authors: mhabibeh@fnal.gov, jseldred@fnal.gov

Particle accelerators employ slip-stacking configurations to store two particle beams with disparate momenta within a single ring. Additionally, A novel slip-stacking configuration employing a harmonic RF cavity was proposed and studied. Anticipated benefits of the harmonic cavity include mitigating parametric resonances, minimizing emittance growth, and significantly expanding the stable longitudinal phase-space area. By surpassing the requirements of PIP-II operation, the harmonic RF cavity will support extending slip-stacking operation for subsequent beam power upgrades of Main Injector, including a proposed cycle rate improvement. Our ongoing research will verify the simulation of harmonic slip-stacking (HSS) operation under RF phase-errors, such as those causes by beam-loading effects.

Neutrinos: SBND (part 2) / 23

Sterile Neutrino Oscillation Searches using the VALOR Fitting Framework at SBN

Author: Beth Slater[None]

Corresponding Author: b.slater2@liverpool.ac.uk

The Short Baseline Neutrino (SBN) programme has an extensive physics program where one of the key aims is to investigate the existence of light sterile neutrinos. It comprises 3 LArTPC detectors along the Booster Neutrino Beam (BNB), a muon neutrino () beam. The near detector of the programme (SBND) sits at a distance of only 110m from the BNB target; this, along with the size of

SBND, will result in a large neutrino flux being measured at SBND. SBND will carry the main burden of reducing systematic error for the programme. With the high statistics and excellent imaging capabilities, the detector will fully characterise the neutrino flux and neutrino-Argon cross-section and enable sensitive oscillation searches with the full SBN. Additionally, due to its short baseline, SBND is sensitive to very fast oscillations, characterised by large squared mass splittings.

The VALOR Neutrino Fitting Framework is a well established and validated framework that has been developed within T2K and used for many published results. It is fully integrated within the SBN analysis chain where it will support standalone analysis of each of the three oscillation channels available to SBND; disappearance, $_e$ appearance, and $_e$ disappearance along with joint multi-channel analyses. VALOR will incorporate a combination of inclusive and exclusive samples and exploit the SBND-PRISM capabilities to provide robust systematic constraints and definitive tests of the light sterile neutrino hypothesis. This talk will cover the VALOR analysis procedure and preliminary sensitivity results along with a discussion of a novel analysis technique known as PRISM.

Computational Astrophysics / 24

Domain Adaptation in Gravitational Lens Analysis

Authors: Paxson Swierc[None]; Yifan Megan Zhao[None]

Co-authors: Brian Nord [1]; Aleksandra Ciprijanovic [2]

[1] *Fermilab*

[2] *Fermi National Accelerator Laboratory*

Corresponding Authors: pswierc@uchicago.edu, nord@fnal.gov, aleksand@fnal.gov, yifanzyf@uchicago.edu

Upcoming surveys are predicted to discover galaxy-scale strong lenses on the magnitude of 10^5, making deep learning methods necessary in lensing data analysis. Currently, there is insufficient real lensing data to train deep learning algorithms, but training only on simulated data results in poor performance on real data. Domain adaptation can bridge the gap between simulated and real datasets. We adopt domain adaptation on the estimation of Einstein radius in simulated galaxy-scale gravitational lensing images. We evaluate two domain adaptation techniques - domain adversarial neural networks (DANN) and maximum mean discrepancy (MMD). We train on a source domain of simulated lenses and apply it to a target domain with emulation of DES survey conditions. We show that both domain adaptation techniques can significantly improve the model performance on the more complex target domain datasets. Our results show the potential of using domain adaptation to perform analysis on future survey data with a deep neural network trained on simulated data.

CMS/Theory / 25

Quasiparticle Searches for Axions

Author: Alexander Millar[None]

Corresponding Author: amillar@fnal.gov

I will give an overview of the many uses of quasiparticles to search for axions, including the most notable, the plasmon which has been used in both experimental and astrophysical searches, as well as condensed matter axions and phonon-polaritons.

Neutrinos: NOvA, R&D, and Hadrons / 26

"Freight Train" production model on the NOvA experiment and NOvA efforts at Argonne Leadership Computing Facility

Author: Andrew Dye[None]

Corresponding Author: ajdye11190@gmail.com

A significant challenge for many experiments is how to store, move, and process large amounts of data in an effective manner. The NuMI Off-axis ν_e Appearance (NOνA) experiment is one such experiment. The freight train model aims to alleviate this strain by improving upon the way data files are processed. Data from NOνA is stored on physical tapes at Fermilab, in the past the basic production principle was to decide on a type of event to get the information of, and then pull all tapes that had these types of events. This led to pulling tapes multiple times, which caused a bottleneck for production. Freight train production has changed this methodology and now pulls tapes in order and processes every event type that we wish to have. Another feat in efficiency that NOνA is performing is shipping off files to Argonne Leadership Computing Facilities Theta GPU farm, to undergo cosmic filtering. This is a computationally expensive task and harnessing the parrallelization power of a GPU is highly beneficial.

Neutrinos: MicroBooNE / 27

Exploring the Dark Sector in MicroBooNE Through e+e- Final States

Author: Leon Tong[1]

[1] *Los Alamos National Laboratory*

Corresponding Author: lntong@lanl.gov

MicroBooNE is a neutrino experiment at Fermilab that ran from 2015 to 2020. It uses a liquid Argon time projection chamber (LArTPC) to detect neutrino events from a flux of predominantly muon neutrinos. In 2018, its predecessor MiniBooNE published results showing the detection of a significant excess of electromagnetic events in its data compared to expectation. The MiniBooNE anomaly defied traditional models of three-neutrino oscillations, and MicroBooNE was designed to explore various explanations. Some dark sector theories posit the production of e^+e^- pairs through a heavy neutrino intermediary. These would be indistinguishable from single electrons or photons in MiniBooNE if produced with sufficiently low opening angle. MicroBooNE has the potential to distinguish between such events because it spatially resolves the entire path of ionizing particles. This talk describes two methods of calculating the opening angle of e^+e^- pairs: traditional line-fitting and a graph neural network based on PointNet++. By utilizing these methods, MicroBooNE has the potential to shed light on the nature of the dark sector and its influence on neutrino interactions.

Computational Astrophysics / 28

Searching for Dwarf Galaxies Around Isolated, Low-Mass Hosts

Author: Jonah Medoff[1]

[1] *University of Chicago*

Corresponding Author: jmedoff@fnal.gov

Dwarf galaxies are the oldest, least evolved, and most dark-matter-dominated galaxies in the universe, therefore studying them can shed light on the formation of some of the first galaxies to exist, the evolution of larger host galaxies like our Milky Way, as well as the abundance and distribution

of dark matter across the Local Universe. Most research to date involving dwarf galaxies has focused specifically on those orbiting the Milky Way and Andromeda. However, despite being more difficult to observe, it is important to also study dwarf galaxies beyond the Local Group in order to learn about the properties of dwarf galaxies located in different environments – i.e., those orbiting galaxies with different masses and morphologies than that of the Milky Way. To do this, the DECam Local Volume Exploration (DELVE) - DEEP Survey performs 135 deg^2 of deep imaging in the g and i bands around four Magellanic analogs in the Local Volume: NGC55, NGC300, Sextans B, and IC 5152. I will present an overview of our survey around one of these galaxies, NGC55, and our efforts to search for dwarf galaxy satellites around this low-mass host. With the full DECam coverage of its dark matter halo, our efforts will be able to produce the first complete satellite luminosity function for a distant LMC-mass galaxy down to an unprecedented limit of M_V ~ −7.

Neutrinos: MINERvA and 2x2 / 29

Double differential charged current $\bar{\nu}_\mu$ DIS cross section analysis at MINERvA

Author: Sayeed Akhter[1]

[1] *Aligarh Muslim University*

Corresponding Author: akhtersayeed65@gmail.com

The (anti)neutrino interaction with nucleons and nuclei is important in order to understand the hadronic interaction in the weak sector and modeling neutrino interaction cross sections for extracting the Pontecorvo-Maki-Nakagawa-Sakata (PMNS) mixing matrix parameters. MINERvA (Main Injector Neutrino ExpeRiment to study $\nu - A$ interactions) is an experiment designed to study the (anti)neutrino-nucleus scattering cross sections in the few GeV energy region using NuMI beamline facility at Fermi National Accelerator Laboratory. We will present the status of a double differential charged current antineutrino Deep Inelastic Scattering (DIS) cross section analysis versus Bjorken variable (x_{Bj}) and Inelasticity (y) using medium energy $\bar{\nu}_\mu$ ($< E_{\bar{\nu}_\mu} >$ 6GeV) interactions on different nuclear targets viz. C, Fe, Pb and CH. The Bjorken variable (x_{Bj}) is the fractional momentum of the struck quark and Inelastic (y) is the ratio of hadron recoil energy to (anti)neutrino energy. This analysis will allow us to understand the hadron dynamics involved in these interactions as well as nuclear medium effects in neutrino interactions.

Muons: Mu2e and g-2 / 30

Mu2e in 10 Minutes

Author: Rose Powers[1]

[1] *Yale University*

Corresponding Author: rose.branson@yale.edu

The Mu2e experiment, scheduled to begin its first run in 2025 at Fermi National Accelerator Laboratory, will search for charged lepton flavor violation (CLFV) in the form of neutrinoless muon-to-electron conversion in the field of an aluminum nucleus. The current sensitivity limit on neutrinoless muon-to-electron conversion is on the order of 10^{-13}; Mu2e will improve sensitivity by four orders of magnitude. An observation of CLFV at this sensitivity would provide definitive evidence of physics beyond the standard model, possibly including but not limited to supersymmetry (SUSY), heavy neutrinos, and leptoquarks. The experiment is on track to finish construction and take data before the long shutdown for PIP-II tie-in to the Booster. This talk will give an overview of the physics, experimental layout, and status of Mu2e.

DM, Cosmology, and CCDs / 31

Constraining Cosmological Parameters from Galaxy Cluster Observables: an SBI Approach

Authors: Aleksandra Ciprijanovic[1]; Brian Nord[1]; Moonzarin Reza[None]; Louis Strigari[2]; Simone Shevchuk[1]; Yuanyuan Zhang[3]

[1] *Fermilab*

[2] *Texas A&M University*

[3] *NOIRLab*

Corresponding Authors: aleksand@fnal.gov, moonzarin@tamu.edu, nord@fnal.gov, yuanyuan.zhang@noirlab.edu, strigari@tamu.edu

Modeling the universe and determining its ultimate fate requires accurate and precise estimation of cosmological parameters such as baryonic density, Hubble's constant, spectral index, etc. Terabytes of galaxy data would soon be made available by current projects on powerful telescopes like the JWST or future ones like LSST. Analyzing these data requires efficient computational tools, which can accurately process bulk data in a reasonable amount of time. In this work we use Simulation-Based Inference (SBI) method to estimate the five fundamental cosmological parameters, and three astrophysical parameters which quantify the mass-richness relationship of galaxy clusters. SBI does not use an explicit form of the likelihood (unlike MCMC), which leads to loss of information due to simplifying assumptions (Gaussian likelihood). SBI's flexibility can help with modeling uncertainties due to systematic errors caused by complex phenomena like astrophysics of AGN feedback, blackhole accretion, etc. In this work, we train a neural network embedded in the SBI framework using simulated data of optical galaxy cluster abundance. We train our model using Fast-Forward models, based on simple analytical equations and test on Quijote simulations to examine if the models developed can capture the complexities of the Quijote Simulations. Our results show that SBI can successfully recover the true values of all eight parameters within the 2σ limit, which is comparable to the state-of-the-art MCMC-based inference method. In addition, the bias obtained for SBI is ~10% smaller for 3 parameters than MCMC.

DM, Cosmology, and CCDs / 32

SuperCDMS in 10 minutes

Author: Shubham Pandey[1]

[1] *University of Minnesota, Twin Cities*

Corresponding Author: pande230@umn.edu

The existence of dark matter is strongly indicated by various astronomical observations. However, its exact nature and properties are yet to be discovered. The SuperCDMS experiment, currently being built 2 km underground at SNOLAB in Canada, is a collaborative scientific effort to search for dark matter via direct detection. It will employ an array of silicon and germanium crystals instrumented with either phonon sensors, called HV detectors, or, phonon and charge sensors, called iZIP detectors. HV detectors make use of the Neganov-Trofimov-Luke effect to amplify phonon signals, thereby achieving a lower energy threshold. iZIPs are capable of exquisite electronic versus nuclear recoil discrimination thus reducing background effectively. Combining these two detector types gives the SuperCDMS experiment a potential opportunity for low mass, low cross-section dark matter discovery as well as producing world leading limits. In this talk, I will give an overview of SuperCDMS detector technologies and its scientific reach.

Neutrinos: MINERvA and 2x2 / 33

Inclusive nubar-A Scattering Analysis at MINERvA

Author: Prameet Gaur[1]

[1] *Aligarh Muslim University*

Corresponding Author: prameetgaur@gmail.com

The MINERvA experiment at Fermilab uses ≈ 3 GeV(LE) and ≈ 6 GeV(ME) NuMI neutrino and antineutrinos beams interacting on different nuclear targets (He, C, Fe, Pb, Water and CH) located throughout the detector. My analysis targets the measurement of antineutrino inclusive double differential charged current cross section as a function of Bjorken x and four momentum transfer squared (Q^2) i.e. $\frac{d^2\sigma}{dxdQ^2}$, on several of these targets. By measuring the cross sections on these targets in the same beamline, the cross sections can be compared with reduced flux and detector uncertainties to determine nuclear effects. This measurement will ultimately help future neutrino experiments on heavy nuclear targets by benchmarking models that may be used by those experiments.

CMS/Theory / 34

The Compact Muon Solenoid (CMS) Experiment in 10 minutes

Author: Grace Cummings[1]

[1] *Fermilab*

Corresponding Author: gec8mf@virginia.edu

The Compact Muon Solenoid (CMS) Experiment is one of the two large general purpose detectors at the Large Hadron Collider (LHC) at CERN. Now in the middle of Run 3 of the LHC, CMS is taking data at an unprecedented center of mass energy of 13.6 TeV, continuing to analyze the Run 2 data set, and is preparing detector upgrades to thrive in the High Luminosity LHC era beyond Run 3. This talk will give an overview of the physics analysis possibilities with the CMS detector with recent result highlights and will showcase the detector upgrades that make our physics program possible.

Neutrinos: NOvA, R&D, and Hadrons / 35

Detection of MeV-Scale Gammas from Pion/Muon Nuclear Capture With the LArIAT Liquid Argon TPC

Author: Miguel Angel Hernandez Morquecho[1]

[1] *Illinois Institute of Technology*

Corresponding Author: mhernandezmorquecho@hawk.iit.edu

LArIAT (Liquid Argon In A Testbeam) is a LArTPC experiment which aims to understand and characterize interactions of neutrino final-state products with Argon. Differentiation between muons and pions in LArTPCs is difficult since the tracks for both particles exhibit very similar ionization densities. We are exploring unique new particle discrimination capabilities for pions and muons by exploiting information from small, isolated ionization depositions, referred to as "blips", reconstructed near the endpoint of stopping tracks. These blips are formed by gammas emitted when an at-rest pion or muon captures on the argon nucleus. The relatively low beam energy provided by LArIAT makes it uniquely suited for performing this demonstration. In this talk, I will provide an overview of how we select candidate events and reconstruct blips corresponding to our signal of

interest, nuclear captures of pions and muons at rest inside LArIAT's TPC, and how we estimate and subtract backgrounds from these capture-at-rest blip signals.

Computational Physics / **36**

WavPool: A New Block for Deep Neural Networks

Authors: Margaret Voetberg[1]; Samuel McDermott[2]

Co-author: Brian Nord [3]

[1] *Fermi National Accelerator Laboratory*

[2] *UChicago Dept of Astronomy & Astrophysics*

[3] *Fermilab*

Corresponding Authors: nord@fnal.gov, samueldmcdermott@gmail.com, maggiev@fnal.gov

Modern deep neural networks comprise many operational layers, such as dense or convolutional layers, which are often collected into blocks.In this work, we introduce a new, wavelet-transform-based network architecture that we call the multi-resolution perceptron: by adding a pooling layer, we create a new network block, the WavPool.

The first step of the multi-resolution perceptron is transforming the data into its multi-resolution decomposition form by convolving the input data with filters of fixed coefficients but increasing size. Following image processing techniques, we are able to make scale and spatial information simultaneously accessible to the network without increasing the size of the data vector. This makes it promising for problems such as particle classification, where both size and spatial relationship of input images is important, and increasing the size of the networks through adding stacked convolutional layers is computationally prohibitive.

WavPool outperforms a similar multilayer perceptron while using fewer parameters, and outperforms a comparable convolutional neural network by 10% on relative accuracy on CIFAR-10.

CMS/Theory / **37**

High Yield Muon Catalyzed Fusion

Author: Erica Garcia Badaracco[None]

Corresponding Author: ericagb@fnal.gov

Fusion holds great promise as a clean and abundant energy source. However, traditional thermonuclear fusion encounters significant challenges due to the extreme temperatures required to overcome the coulomb barrier for two nuclei to fuse. In contrast, muon-catalyzed fusion presents an alternative approach that can surmount this barrier at significantly lower temperatures. Muons, with properties resembling those of electrons but 200 times heavier, can effectively reduce the atomic orbital radius, enabling central nuclei to overcome the coulomb force through the strong force. By introducing muons into a mixture of deuterium and tritium (two hydrogen isotopes), fusion is facilitated, releasing a 3.5MeV alpha particle and a 14.1MeV neutron. In the majority of cases, the muon is liberated and can initiate further fusions. However, approximately 0.8% of the time, it adheres to the alpha particle and remains bound until it either decays or undergoes reactivation through collisional ionization. To maximize the number of fusions per muon, it is crucial to enhance the cycling rate and reactivation fraction. Theoretical predictions and experimental data both suggest that the sticking rate decreases with increasing density. However, there exists a discrepancy between experimental observations and theoretical estimations regarding the extent of this decrease. To address these disparities, this experiment aims to investigate the cycling rate and sticking fraction under higher temperatures and pressures than previously explored.

Additionally, search for Muonium (M ≡ μ+ e −, chemically a light isotope of hydrogen) to Antimonium conversions, antimatter gravity and M atomic spectrum measurements are in need of a reliable high-efficiency source of Muonium.
Both experiments can be supported at the MeV Test Area (MTA) experimental hall using the secondary production beamline. This beamline uses the 400 MeV Fermilab proton Linac beam and a tungsten target. I will be contributing to data analysis as well as simulations for this experiment.

Neutrinos: MINERvA and 2x2 / 39

CC nu_mu 1 pi+ production in the MINERvA tracker.

Author: Everardo Granados Vazquez[1]

[1] *Universidad de Guanajuato*

Corresponding Author: granadosve2012@licifug.ugto.mx

Long-baseline neutrino experiments such as NOvA, T2K, DUNE, and Hyper-Kamiokande measure neutrino oscillations using charged current (CC) neutrino interactions. CC interactions in long-baseline experiments consist of three types of interactions, whose relative fraction depends on the neutrino energy quasielastic (QE), resonant (RES) or Deep Inelastic Scattering (DIS). Precise measurements of neutrino oscillations require precise models of these three types of interactions. Although there have been many recent measurements of charged-current quasi-elastic scattering to improve quasielastic models, there is much less data available for resonant pion production, The RES events are characterized by the production of neutral and charged pions on the final state. A large quantity of the resonant interactions are produced between 1 GeV < invariant mass (W) < 1.7 GeV, this region is between the QE and DIS regions. So the selection of RES events contains a lot of noise from the other types of interactions, for which we have to develop different techniques to identify the RES events. The MINERvA experiment has measured the cross section for single pion production. The measurements of single and double differential cross sections of 1-pion events in the scintillator tracker region of the MINERvA detector, including results from both the LE (<E$_n u >= 3GeV)eraandtheMEera(< E_n u >= 6GeV)aredescribedinthistalk.$

Neutrinos: ANNIE, ICARUS, SBND (part 1) / 40

Baseline monitoring for SBND PDS Trigger

Author: Gajendra Gurung[1]

Co-author: Gabriela Vitti Stenico [2]

[1] *The University of Texas at Arlington*

[2] *University of Texas at Arlington*

Corresponding Authors: gajendra.gurung@mavs.uta.edu, gabivstenico@gmail.com

The Short Baseline Near Detector is a Liquid Argon TPC designed to study neutrino physics at a distance of 110 m from the Booster Neutrino Beamline Target. SBND is also uniquely sensitive to Beyond the Standard Model (BSM) physics owing to the proximity to the target. SBND relies on triggers from different components to record interesting physics events inside the detector. SBND has a photon detection system (PDS) that consists of photomultiplier tubes (PMTs) and ARAPUCAS. PMT digitizers output the multiplicity of the PMT pair of channels above a threshold to the Master Trigger Card/Analog which performs the analog sum of the PMT pairs and compares them to some set trigger threshold. Therefore, the MTC/A generates trigger primitives, monitoring the overall light activities inside the detector. This process is crucial for SBND's primary physics trigger pathway.

However, determining suitable threshold values for the MTC/A is challenging due to the fluctuating baseline of electronics caused by temperature variations. Consequently, it becomes necessary to monitor the MTC/A baseline to accurately configure the thresholds. This presentation outlines my endeavors in creating a tool capable of real-time baseline monitoring during data acquisition.

Neutrinos: ANNIE, ICARUS, SBND (part 1) / 41

Boosted Dark Matter Search in the ICARUS T-600 Detector at Gran Sasso

Author: Hector Carranza[1]

[1] *University of Texas at Arlington*

Corresponding Author: hector.carranza@mavs.uta.edu

Boosted Dark Matter (BDM) is a dark matter (DM) model that uses a minimal U(1)' extension to the Standard Model (SM) of particle physics. By introducing three DM particles $_{0}$,$_{1}$,and $_{2}$ and the dark photon (DP) X to the dark sector, gravitational anomalies can be explained, and the interactions with the SM can exist via a kinetic mixing between the DP and the SM photon. An interesting aspect of this model is the search for inelastic BDM (iBDM). A pair of the abundant dark matter $_{0}$ annihilates in the galactic center and produces a pair of lighter dark matter $_{1}$, which is kinetically boosted. $_{1}$ enters the detector and inelastically scatters with an electron, making $_{1}$ upscatter to the excited state $_{2}$. This particle decays via X emission back to a $_{1}$ and an e^+e^- pair via photon conversion because of the dark photons couple with the SM photon. The total process is $_1e^- \to _2e^- \to _1Xe^- \to _1e^+e^-e^-$. The goal is to detect the recoil electron from the initial interaction and the e^+e^- pair produced at the final stage of the $_{2}$ decay. In this presentation, I will detail the search for iBDM events in the ICARUS T-600 Liquid Argon Time Projection Chamber (LArTPC) detector during its operation in the Gran Sasso underground laboratory in Italy. I will present the different stages to simulate iBDM events in the detector and event topologies along with the status and plans for the analysis on the monte carlo iBDM signal and real data.

Fixed target, SpinQuest, and SeaQuest / 42

Iterative Unfolding of the Angular Distribution of Drell–Yan Production in p+Fe Interactions at 120 GeV Beam Energy

Author: Md Forhad Hossain[1]

[1] *New Mexico State University*

Corresponding Author: mhossain@fnal.gov

In the naive Drell–Yan model, the angular distribution of the Drell–Yan process has zero $\cos 2\phi$ modulation, where ϕ denotes the azimuthal angle of dimuons in the Collins–Soper frame. However, a sizable $\cos 2\phi$ dependence was observed in pion-induced Drell–Yan experiments, such as the NA10 and E615 experiments. The Boer–Mulders function is a transverse momentum dependent distribution that represents the correlation between the transverse spin and the transverse momentum of the quark. A non-zero Boer–Mulders function can produce a $cos2\phi$ modulation in Drell–Yan angular distribution. We present an update on the measurement of the $\cos 2\phi$ modulation of proton-induced Drell–Yan dimuons produced at the SeaQuest/E906 Fermilab experiment, using a 120 GeV proton beam on an Fe beam dump upstream of the dimuon spectrometer. Our analysis of SeaQuest data provides an opportunity to extract the Boer–Mulders function for the Fe nucleus. To extract the Drell–Yan signal, a combinatoric background subtraction method was developed. We use the two Data Unfolding methods, Bayesian and singular value decomposition (SVD), to correct

all inefficiencies and account for bin migration. As part of the unfolding, we have developed an iterative technique that improves the response matrix based on the outcome of the previous unfolding step.

Neutrinos: NOvA, R&D, and Hadrons / 43

Pions as a path to neutrino oscillations

Author: Panos Stamoulis[None]

Corresponding Author: pstamoul@phys.uoa.gr

The new neutrino beamlines under construction at Fermilab will run at energies producing many single-pion producing interactions at the corresponding detectors. The detectors themselves will facilitate the detection and reconstruction of this kind of interactions.
We try to examine if this "extra signal" can be used to accelerate the determination of oscillation parameters, and, mainly, how the experiments need to prepare for this kind of analysis.

Fixed target, SpinQuest, and SeaQuest / 44

Estimation of Combinatoric Background in SeaQuest using an Event-Mixing Method

Author: Abinash Pun[1]

[1] *New Mexico State University*

Corresponding Author: apun@fnal.gov

The J/ψ particle is a spin-1 charmonium state with significant decay fraction towards lepton pairs. The distribution of decay particles from the J/ψ is influenced by its spin alignment, which provides insights into different production mechanisms. SeaQuest, a fixed target experiment at Fermilab, was designed to observe muon pairs from charmonium and Drell-Yan production in pp and pd interactions. The dimuons, produced from $J/\Psi \rightarrow \mu^+\mu^-$ decays, recorded by SeaQuest can be utilized to examine the spin alignment of the J/ψ particle. In addition to the desired dimuon signals, the recorded data also includes combinations of two muon tracks that do not originate from a common physics vertex. We present an event-mixing method that accurately calculates this combinatorial background with appropriate normalization. This method can be extended for use in other experiments that observe dilepton pairs.

45

Domain Adaptation in Gravitational Lens Analysis

Authors: Paxson Swierc[None]; Yifan Zhao[None]

Co-authors: Aleksandra Ciprijanovic [1]; Brian Nord [2]

[1] *Fermi National Accelerator Laboratory*

[2] *Fermilab*

Corresponding Authors: yifanzyf@uchicago.edu, aleksand@fnal.gov, pswierc@uchicago.edu, nord@fnal.gov

Upcoming surveys are predicted to discover galaxy-scale strong lenses on the magnitude of 10^5, making deep learning methods necessary in lensing data analysis. Currently, there is insufficient real lensing data to train deep learning algorithms, but training only on simulated data results in poor performance on real data. Domain adaptation can bridge the gap between simulated and real datasets. We adopt domain adaptation on the estimation of Einstein radius in simulated galaxy-scale gravitational lensing images. We evaluate two domain adaptation techniques - domain adversarial neural networks (DANN) and maximum mean discrepancy (MMD). We train on a source domain of simulated lenses and apply it to a target domain with emulation of DES survey conditions. We show that both domain adaptation techniques can significantly improve the model performance on the more complex target domain datasets. Our results show the potential of using domain adaptation to perform analysis on future survey data with a deep neural network trained on simulated data.

CMS/Theory / 46

Measurement of the top quark antiquark pair charge asymmetry in events with highly boosted top quarks in proton-proton collisions at 13 TeV with the CMS detector.

Author: Beren Ozek[None]

Corresponding Author: bozek3@uic.edu

The top quark is the heaviest elementary particle, making it a unique tool to search for new physics. In this talk, I will present a new measurement of the top quark pair charge asymmetry for highly boosted top quarks decaying to a single lepton, missing transverse momentum and jets. The analysis is performed on 13TeV proton-proton collision data recorded by the CMS experiment during Run 2. We have defined a dedicated phase space that selects top quark-antiquark pairs with invariant mass greater than 750GeV in a semileptonic final state where the lepton is not necessarily isolated. This highly boosted sample is enhanced in valence quark production and thus expected to be more sensitive to deviations in the charge asymmetry caused by BSM processes. Dedicated tagging techniques are used to identify the decay products of hadronic top quarks and W bosons. An unfolding procedure is used to correct for detector resolution and acceptance, and inefficiencies in the event reconstruction. The result is presented in the full phase space at parton level and can be used as input to global EFT interpretations. In my talk, I will also share our preliminary work on EFT interpretation.

Neutrinos: NOvA, R&D, and Hadrons / 47

NOvA in 10 minutes

Author: David Duenas[1]

[1] *University of Cincinnati*

Corresponding Author: dueasdf@mail.uc.edu

NOvA is a long-baseline oscillation neutrino experiment composed by two functional identical detectors, a 300 ton Near Detector and 14kton Far Detector separated by 809 km and placed in an off-axis neutrino beam created at Fermilab, this configuration provides NOvA with a rich neutrino physics program to measure neutrino mixing parameters, determine the neutrino mass hierarchy and CP violation in the leptonic sector. In this talk an overview and results from the NOvA experiment are presented

Fixed target, SpinQuest, and SeaQuest / 48

Extraction of Drell-Yan Angular Coefficients using Neural Network-based Classifiers

Author: Dinupa Nawarathne[1]

[1] *New Mexico State University*

Corresponding Author: dinupa@nmsu.edu

Study of angular distributions in the Drell-Yan process is a valuable tool for unraveling the structure of hadrons. Measuring the $\cos 2\phi$ angular dependence, where ϕ denotes the azimuthal angle of dimuons in the Collins-Soper frame, can be used to extract the Boer-Mulders (BM) function. The BM function describes the transverse-polarization asymmetry of quarks within an unpolarized hadron and is a result of the coupling between transverse momentum and transverse spin of the quarks inside the hadron. Conventional methods for extracting the angular-distribution coefficients typically involve unfolding low-dimensional detector data, which may not fully exploit the complete phase space for best parameter optimization. To overcome this limitation, we propose a novel approach utilizing Neural Network-based Classifiers to directly extract the angular coefficients using high-dimensional information at the detector level. In this presentation, we will explain the design of the neural network architecture, training strategies, and outline our plans to achieve conclusive results.

Computational Astrophysics / 49

Telescopes Drive Themselves: Optimizing Cosmic Survey Scheduling with Reinforcement Learning

Author: Franco Terranova[None]

Co-authors: Margaret Voetberg [1]; Brian Nord [2]; Eric Neilsen [2]

[1] *Fermi National Accelerator Laboratory*

[2] *Fermilab*

Corresponding Authors: neilsen@fnal.gov, maggiev@fnal.gov, francot@fnal.gov, nord@fnal.gov

The planning and execution of observational cosmology campaigns have undergone a substantial increase in complexity, particularly for advanced telescopes like the Rubin Observatory's LSST, JWST, and the Nancy Grace Roman telescope.
Traditionally, astronomical observatories have relied on manual planning to scan a predefined list of astronomical objects, which usually results in suboptimal observations.
We are developing a framework for statistical learning-based optimization of telescope pointings to gather data that is most useful for a pre-defined scientific reward.
We frame the observational campaign as a Markovian Decision Process, which captures the nature of sequential decision-making.
We implement this through reinforcement learning (RL), which has emerged in the field of artificial intelligence as a powerful approach to training autonomous systems.
In this study, we focus on the application of RL algorithms on an offline dataset containing simulated observations with a discrete set of sky locations the telescope is allowed to visit, referred to as the "action space."
Two key aspects are investigated: 1) the preprocessing of the dataset using normalization techniques and potential observation space reduction, and 2) the application of value-based networks for decision-making.
Considering the range of well-known RL algorithms, this study has mainly targeted value-based networks, and in particular Deep Q-Networks (DQNs), since they outperform policy-based networks on the offline dataset.
Our experimental results demonstrate that the combination of preprocessing techniques, along with

value-based networks, yields high performances and capabilities to generalize on unseen data for our task.
Furthermore, the analysis highlighted how varying certain hyperparameters led to a significant impact on the obtained results.
Our results contribute to the advancement of autonomous systems, specifically in the context of process scheduling.

CMS/Theory / 50

Tile Module Assembly for the CMS High Granularity Calorimeter at Fermilab

Author: Ryan Kim[1]

[1] *Florida State University*

Corresponding Author: rkim2@fsu.edu

The upcoming High Luminosity LHC promises an integrated luminosity of 3000 fb⁻¹ by the end of its operation. The High Granularity Calorimeter (HGCAL) is the proposed solution to replace the calorimeter endcaps of the CMS detector. The HGCAL is the first 5D imaging calorimeter to be used in a collider physics experiment, designed to withstand radiation and handle large pileup through the full operation of the High Luminosity LHC. The HGCAL will be constructed with radiation-hard silicon sensors in the layers closest to the proton-proton interaction point and scintillator tile modules based on SiPM-on-Tile technology in the farther layers. Around 2000 of these tile modules will be assembled here at Fermilab, corresponding to about half of the detector. In this talk, I will discuss the construction and development of the pick-and-place machines utilized to achieve this assembly, other related assembly efforts at Fermilab, and plans for quality control during final production.

51

Opening Remarks

Neutrinos: MINERvA and 2x2 / 52

2x2 demonstrator in 10 minutes

Author: Thomas Murphy[None]

Corresponding Author: thmurphy@syr.edu

The 2x2 demonstrator is a prototype of the DUNE Near Detector (ND). Like the DUNE ND, the 2x2 features an array of modular, pixelated, LArTPCs and a muon tagging system (MINERvA) Following its installation within the NuMI beam line later this year, the 2x2 will become the first pixelated LArTPC to take neutrino data. The detector has an active LAr mass of 2.6 metric tons and is equipped with 377k charge-sensitive pixels with 4mm pixel pitch and thin-profile scintillation traps that will provide 25% optical coverage. Initial analysis efforts will be searching for charged track multiplicities, N-P inelastic scattering, using beta decays for calibrations,
39
and MeV scale energy resolution. Additional studies include measurements of the mesonless anti-νμ CC cross section, and decays involving Compton scattering photons. Aside from these π0 measurements, the 2x2 will provide insight into the performance and capabilities of the DUNE ND.

Computational Physics / 53

DAMSA: A Novel Dark Sector Particle Search Experiment at Fermilab PIP-II and Beyond

Author: Wooyoung Jang[1]

[1] *University of Texas at Arlington*

Corresponding Author: wyjang@fnal.gov

The search for dark sector particles has been a subject of significant interest in particle physics due to its potential to explain several long-standing mysteries in the universe. In this presentation, I will discuss a novel beam dump experiment concept called Dump-produced Aboriginal Matter Searches at an Accelerator (DAMSA), a pioneering experimental challenge designed to overcome beam-induced neutron background and tackle the dark sector particle searches at high-intensity proton accelerator facilities, such as Fermilab's PIP-II and beyond. DAMSA experiment utilizes the high intensity proton beam from accelerator, a tungsten (W) beam dump and the neutron absorber surrounding the dump, followed by a decay chamber, and a total absorption electromagnetic calorimeter (ECAL) with high precision spatial and temporal resolution. Based on our benchmark physics study, searching for axion-like particle (ALP), I will discuss the overall key points of the experiment and the expected sensitivity reach at a PIP-II LINAC beam dump.

DM, Cosmology, and CCDs / 54

The next generation of Cosmic Microwave Background experiments

Author: Matthew Young[None]

Corresponding Author: myoung@fnal.gov

The cosmic microwave background (CMB) – relic radiation from soon after the Big Bang – contains a wealth of information on the structure, evolution, and underlying physics of our Universe. Data taken from surveying the CMB has helped to inform and constrain many different models across numerous frontiers in physics, from theories of cosmic inflation, to uncovering the nature of dark matter. The sensitivity of CMB survey experiments has exploded over the past decade, thanks in part to advancements in multichroic pixel design, and huge increases to the number of detectors that can be installed into a single focal plane array. This upward trajectory continues today, with several of the next-generation CMB survey instruments being developed at Fermilab. I will provide a brief overview of our work on three of these upcoming experiments, SPT-SLIM, SPT-3G+, and CMB-S4, and touch on some of the new exciting physics we aim to uncover with each instrument.

DM, Cosmology, and CCDs / 55

Regional Selection with Skipper CCDs for Astronomical Applications

Authors: Rachel Hur[None]; Alex Drlica-Wagner[1]; Edgar Marrufo Villalpando[2]

[1] *Fermilab*

[2] *The University of Chicago*

Corresponding Authors: rhur@uchicago.edu, kadrlica@fnal.gov, emarrufo@uchicago.edu

The Skipper CCD, through the use of a floating gate output stage, allows for multiple, non-destructive charge measurements per pixel and thus, a tunable readout noise level which has been shown to reach down to .04 e- rms. In the next coming months, a Skipper CCD composed focal plane is planned to replace the current conventional CCD detector at the SOAR Integral Field Spectrograph (SIFS) with the goal of targeting both confirmed and potential faint, strong gravitational lensing systems, making this the first application of Skipper CCDs in astronomy. However, the drastic reduction in readout noise with Skipper CCDs comes at the cost of increased readout time - time which could alternatively be used to collect more photons from the already faint system. In this work, we construct a smart readout procedure which can use pre-identified regions of interest (ROIs), estimated through precursor observations, to reduce readout time and moreover, aid in optimizing the signal-to-noise ratio. Specifically, we (1) build a tool that can, on the fly, construct the sequence of instructions associated with selecting a particular set of ROIs and (2) build a predictive model which can correct for transient noise artifacts incurred by regional selection and thus calibrate the baseline for *any* set of ROIs. We show that, given stability of the system over time, the predictive model can robustly mitigate noise transients and we outline future steps required to implement regional selection at SIFS as a first proof-of-concept in a real observing scenario.