Abstract Booklet

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RESEARCH

ABSTRACTS

High Energy | Particle

Sarah Waldych
University Of Maryland

1. Simulating Higgs Boson Decay to a Bottom Quark Pair at the Future Circular Collider

Research Advisor(s): Christopher Palmer, Christoph Paus

We present a Monte Carlo analysis of a Higgs Boson decaying into two bottom quarks produced from electron-positron collisions at 240 GeV center-of-mass energy in the context of the Future Circular Collider (FCC) feasibility study. The Higgs boson decay to two bottom quarks is the most copious Higgs decay, and its measurement will allow for the most precise determination of the Higgs couplings to fermions. We present an analysis that outlines the key steps including a first take at the leading statistical uncertainties.

Yusuf Aamir
University Of Maryland

2. DD4hep as a Tool for Studying Dual-Readout Calorimetry

Research Advisor(s): Sarah Eno, Christopher Palmer

Dual-readout calorimetry, pioneered by the RD52 and DREAM collaborations, is a well-known technology that guarantees exceptional electromagnetic and hadronic resolution. It is being incorporated into a detector (IDEA) proposed for both the Future Circular Collider (FCC-ee) and the Circular Electron-Positron Collider (CEPC). Since the primary barrier for a calorimeter's construction is cost, we present studies on the resolution dependance on the length of the calorimeter as well as the energy timecut on the calorimeter.

Amii Matamoros Delgado
University of Rochester

3. Simulating Target Tests at AP0 Facility for the Mu2e Experiment

Research Advisor(s): Kevin R. Lynch

The Muon to Electron Conversion Experiment (Mu2e) has the goal of detecting the conversion of muons to electrons in the field of a nucleus without the emission of neutrinos, a charged lepton flavor violating process with an unmeasurably small cross section in the Standard Model. The predicted production of muons and energy deposition for the production target of the Mu2e experiment are dependent on the documentation of cross-sections values, the properties of the target's material, etc. Making real tests on similar targets before its use on the Mu2e experiment will be a good indicator of the accuracy of the simulations done for the experiment. We used the particle physics software G4Beamline to simulate a possible target test at the AP0 Target Facility (at Fermi National Accelerator Laboratory), previously used to create the muon beam for the Muon g-2 experiment. Results from the simulation will be used as input to engineering models of the target to produce predicted stress and surface temperature distributions, parameters that will later be measured in future beam runs to validate underlying cross section models.

Aneesh Anandanatarajan & Othello Gomes
University Of Maryland

4. Comparison of Simulation Tools for Precise Two-Photon Background EWK Z Boson Measurements

Research Advisor(s): Christopher Palmer, Christoph Paus, Lucca Lavezzo, Jans Eysermans

We investigate qualitatively the relative performance of various Monte Carlo event generators (including Pythia8, and Whizard3) for generating the two-photon back ground in the leptonic and hadronic final states at the FCC-ee. We consider e+e− interactions at the Z pole, where the two-photon background is a non-negligible background for various electroweak precision analyses such as the muon and hadronic cross-sections. The two-photon background is of particular interest due to simulation difficulties of the yy → hadron-hadron processes. We primarily study various kinematic variables for simulations of e+e− → yy → e+e− + μμ interactions. We extend this analysis to e+e− → e+e− + hadrons interactions.

Elaine Nieves
Florida International University

5. Energy Dependent Morphology of HAWC J2019+368, a Energetic Pulsar in the Dragonfly Nebula

Research Advisor(s): Jordan Goodman

Inside the Dragonfly nebula is the pulsar PSR J2021+3651, one of the brightest sources of TeV gamma rays. Data from the High Altitude Water Cherenkov (HAWC) observatory has resolved the MGRO J2019+37 region, where the pulsar and nebula are located, into two sources: HAWC J2019+368 and HAWC J2016+371. The study of this source's energy dependent morphology is indicative of the underling particles causing this gamma ray emission. Energy dependent morphology indicates that the size of the source is limited by energy lost in the particles producing gamma-rays. Using an expanded dataset from HAWC, we will search for energy dependent morphology. Measuring this energy dependent morphology will confirm the interpretation of HAWC J2019+368 as a TeV Pulsar Wind Nebula (PWN).

Julian Jackson & Lauren Cadle

University of California San Diego

6. Symmetry-Preserving Attention Networks for Improved Multi-Topology Top Quark Identification

Research Advisor(s): Javier Duarte, Melissa Quinnan, Haoyang (Billy) Li

The Compact Muon Solenoid (CMS) and similar experiments at the Large Hadron Collider (LHC) aim to understand the fundamental nature of matter by studying the products of high-energy proton-proton collisions. Rare, heavy events such as those containing top quarks have great potential to lead to new discoveries beyond the Standard Model (SM) of particle physics and to possibly resolve mysteries like the makeup of dark matter. Such events are often detected as jets, or streams of smaller particles that serve as a "signature" of how a particle has decayed. The limiting factor in sensitivity is often identifying these jets and tracing them back to the heavy particles that produce them. Top quark signatures have three possible signatures: resolved jet topologies, with three clearly distinguishable smaller-radius jets from the W bosons and b-quark produced in a top decay; boosted signatures where decay products are merged into a single large high-momentum jet; and semi-resolved cases, an in-between case where some decay products are merged into boosted jets and another is distinguishable as a separate smaller radius jet. While signals featuring separately identified boosted or resolved top quarks are commonplace, semi-resolved events are often discarded due to their complexity. Symmetry-preserving attention networks ("SPANet") are proving to be a popular and powerful approach for jet assignment in particle physics applications, including in searches and measurements of top quarks and Higgs bosons in hadronic final states .

More recently, research suggests that SPANet may be able to effectively identify both resolved and boosted topographies, as well as semi-resolved cases with a single tagging algorithm when identifying the hadronic decays of multiple Higgs bosons. The purpose of this research is to extrapolate the simultaneous identification of resolved, boosted, and semi-resolved candidates to top quarks using SPANet. This has the potential to significantly enhance the sensitivity by increasing the fraction of jets correctly assigned to resonant heavy particles like the top quarks, and thus provide a powerful tool in the search for new physics. We plan to train and evaluate the performance of SPANet through the use of distributed computing resources provided by the National Research Platform and publicly available LHC simulation samples. This work is currently ongoing.

Marisol Velapatiño
University of Illinois Urbana Champaign

7. Path dependence for energy loss in jets due to Quark Gluon Plasma

Research Advisor(s): Anne M Sickles, Abraham Holtermann

Analyzing the behavior of jets traversing Quark Gluon Plasma (QGP) is pivotal in understanding the dynamics of high-energy collisions in heavy-ion experiments. This project addresses the path dependence in the energy loss of dijets interacting with QGP. Through computational simulations for collisions (using TRENTO, PYTHIA) and past work on high-energy collisions (ATLAS Collaboration Papers), we develop ways to accurately model energy loss. We use xj distributions to compare our results with those from ATLAS. Through models of energy loss of dijets in QGP, we aim to further understand their behavior to gain insights into the properties of QGP.

Zoe Brunton
University of Maryland | Anne Arundel Community College

8. Uncovering Different Galaxy Populations Using Webb Deep Field Images

Research Advisor(s): Dr. Marcio Melendez

We used the James Webb Space Telescope's (JWST) deep field capabilities as a tool in examining galaxy populations throughout the visible universe, with a focus on active galactic nuclei (AGN). Because of the depth of the images taken by JWST and the inherent isotropy of the visible universe, we can extrapolate that if a ratio is consistent in one part of the universe, it is consistent across the rest of the universe. We used a calibration image taken by NIRCam across 0.70μm, 1.15μm, 2.00μm, 2.77μm, 3.56μm, 4.10μm and 4.44μm, and analyzed the data by hand using SAOImageDS9. The results showed a large impact from redshift. From here, we used a Python notebook to expand the data set and ensure our results were consistent on a large scale. We then created ratios between the wavelengths to identify outliers that may be potential AGN or high-redshift galaxies. We were able to use the Lyman-break method on one of the outliers, giving us a likely candidate for future study.

Victor Mattison
Clemson University

9. Advancing Blazar and Galactic Source Identification with Multiwavelength Machine Learning

Research Advisor(s): Dr. Marco Ajello, Scott Joffre

In 2012, Massaro et al identified the ‘blazar strip’ in infrared color space. We seek to use machine learning (ML) to improve the accuracy to identify blazar types and galactic sources using infrared (IR) colors by implementing ML algorithms. Additionally, we seek to leverage not just IR properties, but other multiwavelength emission such as gamma-rays. Our current algorithms have a >80% accuracy when tested with a validation set, and our final aim will be to achieve a >95% accuracy.

Anshuraj Sedai
Caldwell University

10. Tracing Stardust: Exploring Metal Abundance in Galaxy Evolution with Galacticus

Research Advisor(s): Mia Bovill

Understanding galaxy evolution is crucial in comprehending the evolution of the universe. As the galaxy evolves, it's going through a baryonic cycle which enriches the galaxy with heavier metals. We can understand galaxy evolution by accessing the metal abundances (mostly O and Fe) in galaxies throughout its lifetime. To better understand data from the James Webb Space Telescope and decipher the mysteries of metal abundances during the galaxy evolution, we are using Galacticus, a semi-analytic model, to model the metal abundances in galaxies. We read the HDF5 formatted output file of Galacticus using Jupyter Notebook and the Matplotlib package. We investigated the correlation between the abundance of iron relative to hydrogen ([Fe/H]), oxygen relative to hydrogen ([O/H]) and the stellar mass of the galaxy. To show that our modeled galaxies are reproducing the real universe, we compare the [Fe/H] of our modeled galaxies to the [Fe/H] values measurement from observations of the Milky Way dwarfs. We've observed a noticeable increase in metal abundance as stellar mass grows within a specific time frame. Additionally, metal abundance rises as the universe ages! The total amount of metal increases as the galaxy forms additional generations of stars because successive generations of stars produce heavy elements and eject them into space as they reach their end of life. Galacticus does a great job in modeling these data to match with our physical observations of the universe.

Samriddhi Bhatia
University of Illinois Urbana Champaign

11. Thermal Chamber Design For Liquid Crystal Calibration In Quantum Entanglement Experiments

Research Advisor(s): Paul G. Kwiat

In quantum entanglement experiments, precise calibration of liquid crystals is essential for accurate data analysis. This project addresses the challenge of unstable temperatures affecting the calibration process by designing and implementing a thermal chamber for the Quantum Information Lab at UIUC. The chamber was developed to stabilize temperature, enabling precise calibration of liquid crystals used in SEAQUE (Space Entanglement and Quantum Annealing Experiment), which focuses on testing platforms for quantum communication technology in space, and other lab experiments. The design process involved using Fusion 360 CAD software to model the chamber. Quantum state and process tomography were employed to characterize the liquid crystals, ensuring accurate calibration. Testing revealed that the chamber could maintain temperatures between 14°C and 39°C, with a heating rate of approximately 1°C every 3 minutes. The maximum temperature deviation during idle time was 0.08°C, usually remaining below this threshold. The successful implementation of the thermal chamber will significantly improve the accuracy and efficiency of the calibration process, ensuring reliable data analysis.

Italian Johnson
Jackson State University

12. Ni 2 Si Thin Films for Nano eEectronics Applications

Research Advisor(s): John Philip, Andrew Forbes

Thin films of the intermetallic ferromagnet Ni 2 Si (thickness from 50 nm) were synthesized via molecular beam epitaxy. Investigation using X-ray diffraction shows the expected hexagonal crystal structure. For the first time, we report on the magnetic properties of this compound. Ni 2 Si is a ferromagnet with magnetic order stable up to a high Curie temperature. To investigate the electronic properties of the material, we present a detailed look into the contributions to its longitudinal resistivity, which indicates a half-metallic band structure. Additionally, for the first time, measurements of the ordinary Hall resistivity and anomalous Hall conductivity were undertaken.

Jada Emodogo
Jackson State University

13. The Effects of Lens Curvature on Rhabdomeric Energy in the Megaphragma Viggianii

Research Advisor(s): David Lipshutz, Dmitri Chklovskii

Insects are heavily dependent on their visual sensory systems to effectively perceive and extract information from their surrounding environment, thereby facilitating their acquisition of essential energy resources vital for their survival. Due to the pivotal role that photoreceptors in the retina play in the sampling of visual information, it is imperative to have an understanding of optics to effectively investigate the spatial and spectral characteristics of these photoreceptors. However, there are obstacles to investigating visual processing in the brains of model organisms, such as fruit flies or honeybees, due to a lack of high-resolution maps or the complexity of these systems. Because of its small size and simplified visual system, the Megaphragma viggianii, or miniwasp, presents a unique opportunity for addressing these issues. With only 29 ommatidia per eye and six different types of lamina neurons, the miniwasp visual system is significantly less complex than those of other model organisms. By applying Maxwell's Equations in 2D Transverse Electric Polarization, we can gain insights into the optimal curvature of the miniwasp's lens, thus revealing intricate visual processing mechanisms in various organisms.

Yash Anand
University Of Maryland

14. Large Anisotropic Magnetoresistance and Magnetic properties of Single Crystalline, Tb2Al3Si2

Research Advisor(s): Johnpierre Paglione

Silicides hold significant scientific and technological relevance and have undergone extensive examination over the past few decades. Large magnetoresistance (LMR) materials, with their remarkable ability to exhibit substantial changes in electrical resistance in response to magnetic fields, are increasingly pivotal in various cutting-edge applications spanning from data storage technology to magnetic sensing and spintronic devices. The compound Tb2Al3Si2 crystallize in the C-centered monoclinic YAl3Si2-type, which contains wavy layers of Al and Si atoms linked together by additional Al atoms and linear Si-Al-Si bonds, has been reported to show antiferromagnetic order below TN~16 K. However, there is a lack of extensive data concerning its magnetic and transport characteristics. In response to this deficit, we grew high-quality single crystals through the self-flux method, resulting in needle-shaped formations. Magnetic and transport measurements were carried out with the magnetic field aligned parallel and perpendicular to the needle's presumed direction along the b-axis. Due to the low symmetry (monoclinic), the orientation of the a- and c-axes to the magnetic field remained undetermined. Detailed temperature and field dependent magnetic and transport results exposed a pronounced magnetic anisotropy in the system. Notably, transport measurements unveiled a substantial anisotropic magnetoresistance (AMR) as well as a LMR in Tb2Al3Si2.

Kerdeem Nurse Farrell
University Of Maryland

15. Development of Magneto-responsive SMART Materials through 4D Printing

Research Advisor(s): Kevin Daniels

This research will focus on developing an electromagnetic-responsive SMART material that can self-repair, self-assemble, change phase reversibly between liquid and solid, morph mechanically, and be actuated using electromagnetic fields. The proposed material will be capable of performing tasks required of its user, assembling and repairing through self-automation, and can reversibly shift between liquid and solid states of matter. The overall objective of this research will be separated into three phases, each focusing on developing a material that displays one or more of the intended properties in response to select external stimuli. The final goal will be synthesizing each material into a single composite material that inhibits the properties of its parents in response to their external stimuli. The first phase will focus on developing a magneto-responsive SMART material, through 4D printing, that possesses mechanical actuation and dimensional morph ability. The second phase will focus on developing an electro-responsive SMART material that possesses reversible liquid/solid phase changeability, and the third will focus on developing a SMART material that possesses self-repairability and properties of self-assembly in response to an external magnetic stimulus. Once we develop the materials, we will synthesize each one into a composite material that possesses self-repairability, self-assembly, reversible liquid/solid phase changeability, dimensional morph-ability, and mechanical actuation properties in response to external electromagnetic stimuli.

Neha Nair
Frederick Community College

16. A Preliminary Study on the Effects of Solar Proton Events on the South Atlantic Anomaly

Research Advisor(s): Steffi Yen & Eileen Chestnutt

The cause of the continual weakening of the weakest part of the geomagnetic field- the South Atlantic Anomaly (SAA)- is currently unknown. The research problem discusses if Solar Proton Events (SPEs) affect the magnetic field strength of the SAA. The purpose of researching SPEs' effect on the SAA is to know if and how solar activity should be considered when observing the SAA. Using the CHAOSmagpy python program, SAA data was extracted and algorithmically processed from SWARM satellite files 5 days before, after, and during each SPE event from 2013-2017. SPE data was gathered from NASA's SPEs Affecting the Earth Environment dataset. The overall, positive, and negative correlations were 0.0104, 0.1187, and -0.2602, respectively. The average slopes before and after the SPE were 5.3133 nT/day and 13.3426 nT/day. During the SPE, 21% had weak flux strength and no extrema, 43% had weak flux strength and extrema, 21% had strong flux strength and no extrema, and 14% had strong flux strength and extrema. There was no correlation between changes in the magnetic field of the SAA and SPEs. The slope changes indicate that the SPE significantly increased the rate at which the magnetic field was increasing. The sinusoidal pattern analysis of the magnetic field strength graphs of the SAA showed that the strength of the SPEs do not have a significant effect on the extrema of the graphs. Further calculations with larger data samples may determine if the impact of the SPEs on the SAA magnetic field is consistent.

Maalini Krishna
Cornell University

17. Observation of Linear and Circular Dichroism in Ellipsometric Studies of Chiral Metallic Nanostructures

Research Advisor(s): Timothy Gay, Keith Foreman

Optical interactions of 635-nm and 405-nm light with chiral nanostructures of titanium were studied by shining incident linearly and circularly polarized light on two arrays of chiral 800-nm tall helices. The intensity pattern of the specularly reflected light is recorded at different wavelengths and angles of incidence using an ellipsometer. The chirality of the nanostructures is determined by the direction of the substrate's rotation, with right-handedness corresponding to clockwise rotation. The nature of the interaction of chiral light with chiral structures is manifested by the mirror symmetry of our data. An explanation for the observed symmetry is in progress.

Jaden He
University of Texas at San Antonio

18. Picosecond Quantum Network Node Synchronization

Research Advisor(s): Thomas Gerrits

Optical Time Domain Reflectometry (OTDR) is a common technique to non-destructively characterize optical fibers and obtain information such as length, attenuation, and location of splices and faults. The technique involves sending laser pulses down an optical fiber and measuring the Rayleigh backscatter with a photo diode, obtaining a trace of light intensity vs. measurement time. Single photon OTDR (v-OTDR) uses single photon detectors that register photon counts rather than light intensity, which allows for better two-point resolution and a shorter integration time to achieve a similar OTDR trace.

In v-OTDR, photon counts are registered in a specified bin size, creating a histogram of photon counts vs. measurement time, which is then converted into decibel loss vs. length along the fiber. If the optical fiber achieves a certain length, the v-OTDR trace will end in a noise floor, where the Rayleigh backscatter is too weak to be registered on a single photon detector. The purpose of this project is to measure fiber end reflection time, and therefore fiber length, as accurately as possible. We use a superconducting nanowire single photon detector (SNSPD) with near unity detection efficiency and almost no after pulsing or dark count error, a picosecond pulsed laser for precise selection of pulse width and frequency, a modulator to achieve a high extinction ratio, and a calculation of Allan deviation to find the optimal integration time for the lowest end-reflection time measurement error. We found error of ~1mm (3.5ps) in 42km long fiber, confirmed through our Allan deviation calculation, and we will use this technique to measure length fluctuations over time of a deployed fiber from NIST to UMD.

Benjamin Schreyer
University Of Maryland

19. Realization of Phase Perturbations by Deformable Mirror Towards Testing Statistical Nonlinear Optics

Research Advisor(s): Dmitri Kaganovich

It is well documented that nonlinear optical systems can exhibit chaotic behavior. This behavior even appears in air when the light intensity is large enough. Chaotic behavior is well characterized by statistical means, because of sensitivity to initial conditions. Beam quality, M^2 or the beam propagation parameter, is a key propagation parameter that is dependent on the spatial distribution of the optical field and deviations the medium makes from homogeneity or linearity. In order to better understand beam quality statistics for random fields in a nonlinear medium, an experimental system has been developed, and undergone initial testing. A Boston Micromachines Multi-DM 140 12x12 rectangular deformable mirror (DM) is used to induce phase screens on a 532nm visible beam, which then enters a lens-based beam profiling unit. Using computer controls and data pipelines, thousands of phase-screened beams can be measured for beam quality automatically. Experimental testing shows stability of beam quality measurement across thousands of trials, and beam ensembles with long (of order beam size) coherence lengths to be feasible. Upon refinement of DM modeling with the insertion of a nonlinear medium the system can be made to test statistical models of nonlinear optics.

Hannah McCright
University Of Maryland

20. Precision Technique for Creating Solitons in an Electron Beam

Research Advisor(s): Brian Beaudoin

The University of Maryland Electron Ring (UMER) is a low energy, high current circular storage ring for beam physics research as well as education. UMER was the first accelerator to observe soliton trains on electron beams. Prior work has shown that these localized persistent waves act like particles as they maintain their properties such as shape and velocity over long distances and through collisions with other solitons. In this work, we explore the use of an optical setup in order to have better control of the injection laser. This increase in precision will allow for a more detailed analysis of solitons created in UMER. We present the current optical setup revised from the original experiment and simulations of data. Simulations were done using WARP, the particle-in-cell (PIC) code to create a basis for future experimentation. A more precise study of solitons would have practical applications in many fields including plasma physics, beam physics, and condensed matter physics to see how such noise propagates in similar systems.

Cheyenne Valles
University of Texas at San Antonio

21. Utilization of NPoM Cavities to Create Strong Coupling

Research Advisor(s): Dr. Nick Vamivakas, Trevor Ollis

This research outlines the designing and characterizing process of photonic crystals and nanoparticle-on-mirror (NPoM) cavities for light-matter coupling. With the utilization of the process of Fabrication, as well as the software of Ansys Lumerical FDTD, my team and I are able to computationally and experimentally construct a visual representation of potential efficiency for quantum dot coupling in NPoM cavities.

Rafael de Farias
University of Rochester

22. Analyzing Cryogenic Implosion Data

Research Advisor(s): Jim Knauer

This project analyzed the necessary adjustments due to instrument error for the detectors measuring neutron and x-ray data from cryogenic implosion shots performed with the OMEGA Laser System. Data from the scattered x-ray and neutron from the fusion reaction is collected in one of ten detectors. Each detector is equipped with four channels, three channels which record the measured voltage produced by the photomultiplier tube with respect to time, and a fiducial channel for calibrating the timing of the data. This project used thirteen calibration shots that were adjusted using fiducial data. The x-ray data for these shots was then fitted to an Instrument Response Function (IRF) to take into account instrumental error. With this data analysis tool available, neutron and x-ray peak data for non-calibration shots can be analyzed with more precision.

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