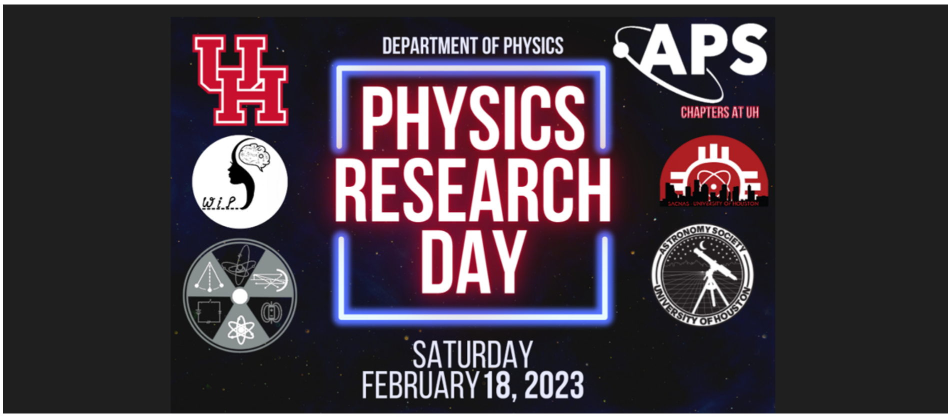
UH Physics Research Day - 2023

Saturday 18 February 2023 - Saturday 18 February 2023

University of Houston - Main Campus



Book of Abstracts

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Arrive at 101 Farish Hall

9:00am: Arrive at 101 Farish Hall

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Physics concepts, careers and applications

Presentations about physics concepts and careers, and how to apply for and succeed in STEM majors

3

Lab Tours

Guided tours of research labs in the department

Poster Session / 6

Two particle correlations of neutral and charged kaons in heavy-ion collisions

Authors: Anjaly Menon[None]; anthony timmins[None]

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Measurements of two particle correlations are sensitive to several characteristics of the medium created in heavy ion collisions. Looking at the correlations of charged and neutral kaons might provide information about the potential formation of disoriented chiral condensates (DCCs). Previous ALICE measurements have indeed shown a strong anti-correlation between charged and neutral kaons, which is qualitatively consistent with the formation of DCCs. The initial goal of this analysis is to perform charged and neutral kaon identification with high purity using the ALICE detector. Once the neutral and charged kaons are cleanly identified, they can be used to construct the two-particle correlation function. We will show measurements of a more differential analysis of these correlations as function of $\Delta\varphi$ and $\Delta\eta$ from Pb-Pb collisions at $\sqrt{s_{\mathrm{NN}}} = 5.02$ TeV.

Academic year:

5th year and/or beyond

Research Advisor:

Anthony Timmins

Poster Session / 7

Muyuan He Atmospheric neutrino abstract

Author: Muyuan He[None]

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Atmospheric neutrinos are typically formed 15 km above earth's surface, they form when cosmic ray strike atomic nucleus in Earth's atmosphere. By studying atmospheric neutrinos, we can learn neutrino oscillations and non-standard neutrino interactions. DUNE and NOvA are two neutrino experiments that observe neutrinos produced in Fermilab and atmospheric neutrinos. The main objectives of these two experiments are to investigate in neutrino oscillation and to help determine neutrino mass ordering to test cp violation in lepton sector, which help us understand matter-antimatter asymmetry in our universe. In this poster, I will present the reconstruction performance for atmospheric neutrinos in DUNE, as well as a sensitivity study for detecting non-standard neutrino interactions in atmospheric neutrinos in NOvA.

Academic year:

4th year

Research Advisor:

Lisa W. Koerner

Parallel Session 2 / 8

Vortical effects in chiral band structures

Authors: Pavan Hosur[1]; Swadeepan Nanda[None]

[1] *University of Houston*

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The chiral vortical effect is a chiral anomaly-induced transport phenomenon characterized by an axial current in a uniformly rotating chiral fluid. It is well-understood for Weyl fermions in high energy physics, but its realization in condensed matter band structures, including those of Weyl semimetals, has been controversial. In this work, we develop the Kubo response theory for electrons in a general band structure subject to space- and time-dependent rotation or vorticity relative to the background lattice. For continuum Hamiltonians, we recover the chiral vortical effect in the static limit. In the transport limit, we discover a new effect that we dub the gyrotropic vortical effect. The latter is governed by Berry curvature of the occupied bands while the former contains an additional contribution from the magnetic moment of electrons on the Fermi surface. The two vortical effects can be understood as analogs of the well-known chiral and gyrotropic magnetic effects in chiral band structures. We address recent controversies in the field and conclude by describing device geometries that exploit vortical effects in transport properties.

Academic year:

3rd year

Research Advisor:

Pavan Hosur

Parallel Session 1 / 9

Using Xenon-Doped Liquid Argon Scintillation for Full-Body, Time of Flight Positron Emission Tomography

Authors: Alejandro Ramirez[None]; Andrew Lee Renshaw[1]; Azam Zabihi[None]; Cristiano Galbiati[2]; Davide Franco[3]; Federico Gabriele[4]; Hanguo Wang[5]; Masayuki Wada[None]; Michela Lai[6]; Xinran Li[7]

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[3] *APC*

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Positron Emission Tomography (PET) is used to observe metabolic processes within patients. It works by reconstructing the annihilation origin of incident gamma rays produced by a positron emitting tracer. However, inefficiencies of current PET technology, such as the use of photomultiplier tubes, can result in poor imaging. In addition, current PET scanners possess a small field of view which limits the sensitivity. We propose 3Dπ: a full body, Time of Flight (TOF) PET scanner using Silicon Photomultipliers (SiPM) coupled with a Xenon-doped Liquid Argon (LAr+Xe) scintillator.
We simulated this design using Geant4 while following the National Electrical Manufacturers Association's evaluation tests (2018) for performance assessment. We will present results that highlight a 200-fold increase in sensitivity, spatial resolutions comparable to commercial PET scanners, performance based on the Noise Equivalent Count Rate metric and produce PET images from 15-30 second scans, faster than traditional non-full-body 30-35-minute scans. Further studies will involve optimizing the design of the scanner, understanding the noise produced by the detector and developing hardware prototype tests.
With the LAr+Xe scintillator and SiPMs of 3Dπ, we can use the precise TOF info of gamma rays to improve the localization of individual positron annihilations, and as one example benefit, provide low-dose PET scans for patients who may be at high risk for exposure to radiation.

Academic year:

4th year

Research Advisor:

Andrew Renshaw

Poster Session / 10

Fe doping and electrochemical reconstruction in Ni&Ni0.2Mo0.8N for large current density alkaline seawater electrolysis

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The industrial scale of fresh water electrolysis to produce hydrogen (H2) will make the shortage of fresh water resource even worse. Seawater, which consists of 97% of the water resource on earth, is much more abundant for water electrolysis. However, the presence of Cl−, Ca2+, and Mg2+ causes several critical problems for the seawater electrolysis. Firstly, the presence of Cl− introduces chloride oxidation reactions as the competitive reactions for oxygen evolution reaction (OER) at the anode

side. The chloride oxidation reactions are undesired since the produced Cl2 or ClO− will eventually become excessive and pollutants to the environment. Even though the chloride oxidation reactions are kinetically favorable, thermodynamically unfavorable over OER. In this work, we found that Fe doped Ni&Ni0.2Mo0.8N was electrochemically reconstructed into Fe, Mo co-doped NiO as an efficient alkaline OER catalyst to thermodynamically suppress the chloride oxidation reactions. Secondly, the Cl− is corrosive to the metal substrates and catalysts like Ni, Fe metal and their alloys, causing a stability issue to the electrode. Fe doped Ni&Ni0.2Mo0.8N and Fe, Mo co-doped NiO were introduced as the anti-corrosive catalysts for the stable seawater electrolysis. Thirdly, the Ca2+ and Mg2+ will form Ca(OH)2 and Mg(OH)2 precipitates under high pH condition, which will block several critical parts of the electrolyzer. Alkaline seawater electrolyte was employed and the Ca(OH)2 and Mg(OH)2 precipitates can be quickly removed via centrifugation. In result, the HER active Fe doped Ni&Ni0.2Mo0.8N and OER active Fe, Mo codoped NiO together achieved efficient and continuous alkaline seawater electrolysis at a current density larger than 500 mA cm-2, satisfy the industrial requirement.

Academic year:

4th year

Research Advisor:

Zhifeng Ren

Poster Session / 11

Role of scattering in the prediction of simulation based optical properties of dielectric TiO2 nanotubular materials.

Authors: David Waligo[1]; Varghese Oomman[1]; Schaffer Lilly[1]; Paulose Paulose[1]

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Understanding light-semiconductor interaction is critical for the development of absorbers for efficient solar energy to electrical or chemical energy (fuel) conversion. Numerical simulation methods are often used to support experimental results and explain various optical phenomena in materials. The finite Difference Time Domain (FDTD) method has emerged as a tool for simulating and modeling different materials with unique optical properties (e.g., photonic band gap materials and plasmonic nanostructures). Nonetheless, the method has not been proven effective in yielding an acceptable agreement between simulated optical properties including transmittance and reflectance, and the experimental results for polycrystalline nanostructures and thin films. We have solved this problem by accounting for the majority of the scattering that happens in these nanostructured materials. With our method, we could simulate the optical properties of semiconducting films and nanomaterials of different morphologies and dimensions used as absorbers in solar cells and PEC water-splitting devices. The results obtained through simulations were in excellent agreement with those determined experimentally. In this presentation, we discuss the details of our model using titania nanotubes as a case study.

Academic year:

3rd year

Research Advisor:

Oomman Varghese

Parallel Session 2 / 12

Machine Learning to Identify Gene Structure

Author: Ethan Speakman[None]

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The human genome is divided into exons and introns. Exons are the expressed portion of the gene and must be separated from the introns (the "junk"portion of DNA) during a process called splicing before they can be expressed as proteins. This division is import for alternate splicing, where the same gene can be expressed with different composite exons. But this can result in genes from two different locations fusing: this is a leading cause of cancer. Properly identifying exons and introns is an important step in studying gene structure and its role in cancer. Comparison of cancer fusion junctions (the location where two genes fuse) show a high prevalence of sequence similarity between exons of one gene and introns of its fusion. To measure this, we compared and scored sequences at the fusion junction, weighting their importance based on position from the fusion junction of the fusion genes to their expected sequence, what should be there if the genes were properly transcribed and spliced. While this suggests a splicing error it does not illuminate the underlying mechanism. For this reason, machine learning is being implemented to look for further structure. A convolution layer is added to identify exons, introns, and untranslated regions (a third region of the gene that plays a role in translation into proteins).

Academic year:

3rd year

Research Advisor:

Gemunu Gunaratne

Parallel Session 2 / 13

The significantly distinct performance of thermoelectric AMg2Sb2 (A = Ca, Sr, Sm, Yb, and Mg)

Author: Xin Shi[None]

Co-authors: Chunhua Li ; David J. Singh ; David Broido ; Zhifeng Ren

AM2X2 (A = alkaline earth metals or divalent lanthanides; M = divalent transition metals or Mg; X = nitrogen group elements) can represent a number of high-temperature superconductors and decent thermoelectric materials. One major mystery brought to our attention in thermoelectric AM2X2 compounds is the significantly distinct thermoelectric figures of merit (zT) of AMg2Sb2 materials that can vary orders of magnitude with different A elements, which is in sharp contrast to the very similar zT values of both their AZn2Sb2 and AMg2Bi2 pristine counterparts. In this talk, I will discuss the determining factor for such a huge discrepancy of AMg2Sb2 in thermoelectric performance. Time permitting, some other intriguing phenomena regarding their carrier and phonon transport will also be briefly introduced.

Academic year:

4th year

Research Advisor:

Zhifeng Ren

Poster Session / 14

Module Readiness Tests and Data Quality Management for DUNE Near Detector

Author: Dat Tran[1]

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The Deep Underground Neutrino Experiment (DUNE) is a next generation long-baseline neutrino oscillation experiment. DUNE is aiming to make groundbreaking discoveries, some of which are characterization of neutrino oscillations, search for nucleon decay, observation of supernovae neutrino bursts. DUNE will employ two detectors to measure neutrino oscillations over a long baseline, a near detector and a far detector. Detection using liquid argon time projection chamber technology (LArTPC) is crucial to the performance of the Near Detector and the Far Detector of DUNE. The Near Detector will operate with 35 LArTPC modules when it fully operates.

Meanwhile, a small-scale prototype is taking place at Fermilab with four modules arranged in two rows of two modules. Hence, it is named ArgonCube 2x2. This project has two components. First, QA/QC tests are performed on the LArTPC modules after they have arrived at Fermilab. Here, we ensure satisfactory performance of both the charge readout and light readout systems. Second, in preparation for commissioning runs, we are developing a display application where future shifters and analyzers can access live Data Quality Management plots.

Academic year:

2nd year

Research Advisor:

Lisa Koerner

Poster Session / 15

Measuring Charmed baryon to meson ratio at ALICE experiment, investigation for hadronization

Author: Oveis Sheibani[1]

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Atoms are held by the electromagnetic force between electrons and protons while a proton itself is composed of quarks bounded together with strong force or gluon exchange. To understand the nature of strong force one way is to smash the protons or lead nuclei (Pb) in high kinematic energy to reach a certain penetration depth to probe that length scale. In ALICE the energy is in order of a few tera-electron volts per nucleus. After the collision, thousands of new particles come out of interaction volume, and by counting and measuring those particles and using our theories, we can find a mapping of the inner structure of nuclei. ALICE experiment detectors are capable of processing and measuring significant amounts of charged particles'data, where the software architecture of CERN allows to manipulate the data and invent methods of analyzing visualization, and simulation.
Heavy quarks such as charm quarks are produced in the early stages of collisions and traverse through the evolution of the system, like a memory to record the interactions between deconfined medium and charm quark. By measuring the ratio of different species of hadrons made of charm quarks we can investigate their interaction with light quarks. This research focuses on measuring the ratio of charmed baryon to charmed mesons to understand their hadronization which is the

complex process of binding free quarks into one hadron. These measurements put the pieces of the puzzle together in time to gain a consistent picture of the space-time evolution of heavy ion collisions.

Academic year:

5th year and/or beyond

Research Advisor:

Rene Bellwied

Poster Session / 16

Introduction to Edge-Illumination X-ray Phase Contrast Imaging

Authors: Jingcheng Yuan[None]; Mini Das[1]

[1] *University of Houston*

Corresponding Author: jcyuan06@gmail.com

Over recent years, many techniques have been developed to improve the performance of medical x-ray imaging. Traditional x-ray imaging is based on x-ray attenuations. However, the attenuation contrast is low for light elements or density-similar materials such as soft tissues. X-ray phase contrast imaging (PCI) has drawn many researchers' attention in the past years since phase contrast is much more sensitive than attenuation contrast. The edge-Illumination method is one of the most promising techniques of x-ray phase contrast imaging. In this talk, we will introduce this technique and show the benefits of phase contrast imaging.

Academic year:

4th year

Research Advisor:

Mini Das

Parallel Session 1 / 17

QCD equation of state at finite density with a critical point from an alternative expansion scheme

Author: Micheal Kahangirwe[None]

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In Ref. [1], results for the QCD equation of state from the lattice Taylor expansion were combined with the 3D Ising model critical behavior, to build a family of equations of state which match first principle results and contain a critical point in the expected universality class for QCD. This family of equations of state was limited to chemical potentials $0 \leq \mu_B \leq$450 MeV, due to the limitations of the Taylor expansion. In Ref.[2], an alternative expansion scheme was introduced, for extrapolating the lattice QCD equation of state to finite chemical potential. In this research, we combine these two approaches to obtain a family of equations of state in the range $0 \leq \mu_B \leq$ 700 MeV and $30MeV \leq T \leq$ 800 MeV, that match the lattice QCD results at small density and contain a 3D-Ising

model critical point. With these new equations of state, we substantially extend the coverage of the QCD phase diagram.
Our open-source code allows the user to choose the position and strength of the critical point. Our results provide an input for hydrodynamical simulations at finite T and unprecedentedly large μ_B and will help constrain the location of the critical point through a comparison with experimental data from the Second Beam Energy Scan at RHIC.

[1] Parotto, P., Bluhm, M., Mroczek, D., Nahrgang, M., Noronha-Hostler, J., Rajagopal, K., … & Stephanov, M. (2020). QCD equation of state matched to lattice data and exhibiting a critical point singularity. Physical Review C, 101(3), 034901.

[2] Borsányi, S., Fodor, Z., Guenther, J. N., Kara, R., Katz, S. D., Parotto, P., … & Szabó, K. K. (2021). Lattice QCD equation of state at finite chemical potential from an alternative expansion scheme. Physical review letters, 126(23), 232001.

Academic year:

3rd year

Research Advisor:

Prof. Claudia Ratti

Poster Session / 18

Synthesis of cubic boron arsenide single crystal with ultrahigh thermal conductivity

Author: Fengjiao Pan[None]

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As the dimensional shrinkage of modern electronic and optoelectronic devices, materials with high thermal conductivity are required for the significantly increased demand for heat dissipation. Among metals and other bulk materials, cubic boron arsenide (c-BAs) is considered a promising material for heat dissipation of its ultrahigh thermal conductivity, κ, and outstanding semiconductor properties. Unlike in a common process, the ultrahigh thermal and electrical transport properties of c-BAs were first predicted by the numerical calculation research using the first-principles method. Later, experimental researchers synthesized high-quality crystals, which properties matched the theoretical prediction.

The traditional method to synthesize c-BAs single crystals is a chemical vapor transport (CVT) method. In this research, the CVT process to synthesize c-BAs will be introduced and discussed. Also, some potential solutions will be proposed to improve the quality of the c-BAs single crystals.

Academic year:

4th year

Research Advisor:

Zhifeng Ren

Parallel Session 2 / 19

Proton Exchange Membrane for Fuel Cell and Water Electrolysis Application

Author: Subash Bhandari[None]

Co-author: Anima Bose [1]

[1] *University of Houston*

Corresponding Author: scbhandari@uh.edu

Proton exchange membrane fuel cell (PEMFC) and water electrolysis (PEMWE) systems have been paying attention in recent decades in order to adapt to the increase in demand for green hydrogen and the fast development of electric vehicles. The proton exchange membrane (PEM) is one of the prime components of those technologies which plays a vital role to obtain the high efficiency and stability of the system. It also acts as barrier between cathode and anode to prevent the electron and gas crossover. To adopt the requirements of the global market, current research is focusing on the sustainable and high ion-conductive electrolyte membranes. The NafionTM, perflurosulfonic acid is the state-of-art proton exchange membrane used in PEMFC and PEMWE over 50 years. However, the hydrogen crossover through the membranes is the primary issue as it leads to the membrane degradation and directly affect the performance and stability of the PEM system. Herein, our research focus on blocking the hydrogen crossover through the membrane by modifying the Nafion membrane.

Keywords: Proton Exchange Membrane, gas crossover, NafionTM , membrane degradation

Academic year:

3rd year

Research Advisor:

Anima Bose

Parallel Session 1 / 20

Lightning Protection of the Artemis Spacecraft

Author: Nathan Roberts[None]

Corresponding Author: nathan.s.roberts@nasa.gov

The Artemis I space vehicle was exposed to Florida weather for several weeks before it was finally released for launch on November 16, 2022. Florida sustains more lightning strikes than any other state in the US because sea breeze fronts blow from two coasts, forming many cumulonimbus clouds. Fortunately, Artemis missions are also guarded by three towers comprising a Lightning Protection System (LPS), which are featured on the Artemis I mission patch. The LPS includes catenary and instrumentation systems which record the magnitude and coordinates of each nearby lightning strike, but aren't alone be enough to determine if a strike caused damage to sensitive instruments on the vehicle. The proposed thesis utilizes LPS data from any given strike to calculate the associated electromagnetic fields appearing at the position of the Artemis vehicle. This information is used to determine whether to proceed with launch, retest, or rollback to the Vehicle Assembly Building (VAB) for more serious inspection following a lightning event. A combination of Computational Electromagnetics (CEM) modeling, verification testing, and analysis is used to develop tools capable of obtaining solutions quickly in order to avoid impacting launch windows.

Academic year:

5th year and/or beyond

Research Advisor:

Dr. Edgar A. Bering

Poster Session / 21

Fundamental Constitutive Effects of Anomalous Diffusion in Lévy Walk

Author: Abhijit Bera[1]

Co-author: Kevin Bassler [1]

[1] *University of Houston*

Corresponding Author: abera@uh.edu

Diffusive behavior is normally governed by the Central Limit Theorem (CLT), which states that the displacement $x(t)$ in the limit of large time t has a Gaussian distribution with a width that increases as $t^{1/2}$. However, diffusive behavior that differs from the CLT is found in a wide array of experimental systems.
In many cases, the dynamics in these systems can be modeled with non-linearly coupled Lévy Walks that have steps of random duration τ chosen from a probability distribution that decays as $\tau^{-1-\gamma}$ and a velocity in each step of random direction with magnitude proportional to $\tau^{\nu-1}$.
The root causes of anomalous diffusive behavior can be identified by decomposing the behavior into three fundamental constitutive effects, each of which are associated with the violation of an assumption of the CLT. The anomalous diffusive behavior produced by coupled Lévy Walks is a complex combination of the three effects.
We show that for $\gamma \in [0, 1]$ the distribution of $x(t)$ scales with t and the behavior can be straightforwardly decomposed into the three effects, but that for $\gamma \in (1, 2]$ the bulk and the tails of the distribution of $x(t)$ scale differently with t and there is a crossover in the results of the decomposition.

Academic year:

3rd year

Research Advisor:

Kevin E. Bassler

Poster Session / 22

Investigating the Local Structure of MoTe2 Using Atomic Pair Distribution Function and EXAFS Techniques.

Authors: Byron Freelon[1]; Sumit Khadka[1]

[1] *University of Houston*

Corresponding Author: skhadka3@uh.edu

At temperatures below 250K, 1T'$MoTe_2$ undergoes a first-order structural phase transition (SPT) to a non-centrosymmetric orthorhombic T_d phase, marked by the appearance of Weyl points protected by broken inversion symmetry. Despite the similar structures of these two phases and a small energy barrier between them, distortions are evident at both macroscopic and atomic scales. This study investigates the local structure of 1T'$MoTe_2$ at temperatures ranging from 95K to room temperature using more advanced scattering techniques. Results show that lowering the temperature leads to

significant changes in interlayer atomic distances, but not in intralayer distances. Using large box modeling approach reveals the effects of stacking faults and layer rotations on interlayer distances, consistent with experimental observations. Understanding the interlayer behavior in $MoTe_2$ through local structure study could help clarify the mechanisms of the SPT and the emergence of Weyl points at low temperatures.

Academic year:

5th year and/or beyond

Research Advisor:

Byron Freelon

Poster Session / **23**

A brief overview of Systematics and their implementation in the T2K P0D

Author: Donnie Munford[None]

Co-author: Daniel Cherdack

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Neutrinos are a fundamental particle with a strange and unique characteristic: they have mass states that describe how they travel through space and time and flavor states that describe how they interact. In order to study the relationship between the neutrino's mass and flavor quantum states, it's important to understand how readily they will interact with the neutrino detector by measuring the interaction cross section. T2K is a Japanese-based experiment designed around two main detectors: Super-Kamiokande (SK), a 50,000 metric ton water Cherenkov detector located 295 km away from the beam target, and ND280, a collection of smaller detectors located 280 meters away from the beam target. Due to the nature of the SK detector, ND280 is designed around making water cross-section measurements through a water subtraction method where two measurements are made, one with water in the detector and one without water. ND280 is comprised of three primary detectors to make these measurements, the two Fine-Grain Detectors (FGDs) which are used in tandem to allow measurements that have consistent temporality but inconsistent spatiality, and the Pi-Zero Detector (P0D) which allows for consistent spatiality but inconsistent temporality. Many models are used to simulate these interactions for study, but all models have uncertainties which will propagate through to the final measurements. Understanding and implementing systematic uncertainties related to the interaction models is crucial to constraining the uncertainty on neutrino cross section measurements.

Academic year:

5th year and/or beyond

Research Advisor:

Dr. Daniel Cherdack

Poster Session / **24**

Entanglement degradation in a bipartite system with a finite lifetime observer

Authors: Abhijit Chakraborty[1]; Carlos Ordóñez[1]; Horacio Camblong[None]; Pablo Lopez-Duque[1]

[1] *University of Houston*

Corresponding Author: pabl3inz@gmail.com

A bipartite system composed by an inertial observer (Alice) and an accelerated observer (Charlie) has been used in previous studies to show a connection between entanglement degradation and the Unruh effect. The degradation in entanglement between two modes of a non-interacting scalar field is attributed to the relative acceleration between the observers. In this work, we analyze the influence of an observer finite lifetime in the entanglement of a bipartite system where the other observer is inertial. The finite lifetime observer is restricted to move in a causal diamond, which helps establish a connection with the constantly accelerated observer case. The system is initially in a maximally entangled state, observed form the perspective of inertial observers, and it becomes less entangled as the lifetime shortens. We argue that this effect is due to the presence of the causal horizons.

Academic year:

5th year and/or beyond

Research Advisor:

Carlos Ordonez

Parallel Session 2 / **25**

Quantum Transport of Charge Density Waves

Authors: John Miller[None]; Johnathan Sanderson[None]; Martha Villagran[None]

The charge density wave (CDW) is a condensate known to carry electric current en masse, but collective CDW transport remains poorly understood at the microscopic level. Its quantum nature is clearly revealed by oscillations of period $h/2e$ in CDW conductance vs. magnetic flux, sometimes accompanied by telegraph-like switching, in $TaS3$ rings above 77 K. Here we show evidence for quantum time evolution, via a matrix element with Zener-like field dependence, which couples evolving macrostates. We find that, for temperatures ranging from 9 to 474 K, current-voltage plots of three CDW materials agree almost precisely with a modified Zener-tunneling curve and with time-correlated soliton tunneling model simulations. In the model we treat the Schrödinger equation as an emergent classical equation that describes fluidic Josephson-like coupling between evolving topological states. We find that an extension of this “classically robust” quantum picture explains both the $h/2e$ magnetoconductance oscillations and switching behavior in CDW rings. Finally, we discuss hybrid CDW-superconductor qubit device concepts, to enable quantum computer operation at higher-than-milli-Kelvin temperatures.

Academic year:

3rd year

Research Advisor:

Dr. John H. Miller, Jr.

Parallel Session 1 / **26**

Integrating Darkside-20K into the SuperNova Early Warning System and Implementing Recurrent Neural Networks for Supernova Neutrino Detection

Author: Sebastian Torres-Lara[None]

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During a stellar core collapse, a large flux of neutrinos (1-100 MeV) is produced, escaping the core before any light can. If detected, these neutrinos can play a crucial role in providing both preliminary evidence of a stellar collapse, and an understanding of the mechanisms behind it.
The SuperNova Early Warning System 2.0 (SNEWS 2.0) is a worldwide network of neutrino detectors whose primary purpose is to detect supernova neutrinos. Armed with a diverse array of neutrino detectors, SNEWS 2.0 can triangulate a supernova's direction and notify astronomers up to one day before any photons reach Earth. SNEWS 2.0 has streamlined the connection between the host server and all participating detector by having SNEWS collaborators use its home-brewed Python API, allowing participating detector to connect to SNEWS with minimal coding overhead.

With the discovery of Coherent Elastic Neutrino-Nucleus Scattering (CEνNS) proving that low-energy nuclear scatterings are observable within noble liquid detectors, next generation of ultra-sensitive dark matter detectors will be suitable for observing the neutrinos from a supernova. Thanks to its 50 kt liquid argon time projection chamber (TPC) Darkside-20K will be capable of observing several dozen CEνNS during the first 0.25 sec of a core collapse. These signals are prevalent near the noise the threshold. The Darkside-20K supernova trigger must be able to identify these events and quickly notify the SNEWS network. To accomplish this, a recurrent neural network (RNN) pipeline will be designed to trigger on any outlying events in a time sequence from the noise spectrum, said outlier(s) will then be analyzed to confirm they meet CEνNS characteristics, finally triggering Darkside-20K to send an alert to SNEWS.

The work presented will showcase development of the SNEWS 2.0 communications API, how RNNs such as Long-Short Term Memory (LSTM) and Gated Recurrent Unit (GRU) will leveraged on Darkside-20K's supernova trigger, and the Monte Carlo simulations being developed to understand Darkside-20K's response to a supernova neutrino flux and train the neural networks.

Academic year:

4th year

Research Advisor:

Dr. Andrew Renshaw

Parallel Session 2 / **27**

Conventional superconductivity at the surface of a Type-I Weyl Semimetal

Authors: Aymen Nomani[1]; Pavan Hosur[1]

[1] *University of Houston*

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Recent experiments have seen surface superconductivity in Weyl semimetals, which raises the question of whether Fermi arcs can support superconductivity without any proximity effect from the bulk. This question is of further interest as the 2D surface is lower in dimensionality but has a finite density of states. In contrast, the 3D bulk is higher in dimensionality, but the density of states is zero due to the point-like Fermi surface. Thus, it is interesting to ask which of the two competing effects will win. A conclusive answer to this question is hindered by the absence of a well-defined surface Hamiltonian since the Fermi arcs merge with the bulk states at their endpoints. We circumvent this issue by adopting an alternate, Green's functions-based approach tailored to a layering model from which arbitrary Fermi arcs can be obtained by tuning phenomenological parameters. We find that Fermi arcs, indeed, can support a standard Cooper instability, while their leakage into the bulk has a negligible effect on the nature of the superconducting state for low doping around the Weyl nodes.

Within the mean-field theory, we realise a peculiar situation where the surface of a system orders while the bulk is disordered, even though the latter has higher dimensionality. Another question raised is whether the leakage into the bulk protects the superconductivity from being destroyed by fluctuations. The calculation of fluctuation yields the result that thermal fluctuations destroy superconductivity similar to a 2D metal, and the resultant superconductivity is presumably due to a Kosterlitz-Thouless phase.

Academic year:

4th year

Research Advisor:

Pavan Hosur

Poster Session / **28**

AI-SNIPS: A Platform for Network Intelligence-Based Pharmaceutical Security

Authors: Timothy Burt[1]; Nikos Passas[2]; Ioannis Kakadiaris[3]

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I present AI-SNIPS (AI Support for Network Intelligence-based Pharmaceutical Security), a platform that enables stakeholder decision-making, secure data sharing, and interdisciplinary research in the fight against Illicit, Substandard, and Falsified Medical Products (ISFMP). AI-SNIPS takes as input cases: a case consists of one or more URLs suspected of ISFMP activity. Cases can be supplemented with ground-truth structured data (labeled keywords) such as seller PII or case notes. First, AI-SNIPS scrapes and stores relevant images and text from the provided URLs without any user intervention. Salient features for predicting case similarity are extracted from the aggregated data using a combination of rule-based and machine-learning techniques and used to construct a seller network, with the nodes representing cases (sellers) and the edges representing the similarity between two sellers. Network analysis and community detection techniques are applied to extract seller clusters ranked by profitability and their potential to harm society. Lastly, AI-SNIPS provides interpretability by distilling common word/image similarities for each cluster into signature vectors. I will share our current results and the opportunities that this platform paves the way for.

Academic year:

5th year and/or beyond

Research Advisor:

Ioannis Kakadiaris

Parallel Session 2 / **29**

Extreme Value Statistics of Community Detection in Complex Networks with Reduced Network Extremal Ensemble Learning (RenEEL)

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Arguably the most fundamental problem in Network Science is finding structure within a complex network. One approach is to partition the nodes into communities that are more densely connected than one expects in a random network. "The"community structure corresponds to the partition that maximizes a measure that quantifies this idea. Finding the maximizing partition, however, is a computationally difficult NP-Complete problem. We explore the use of a recently introduced algorithmic scheme [Guo, Singh, and Bassler, Sci. Rep. 9, 14234 (2019)] to find the structure of a set of benchmark networks. The scheme, known as RenEEL, creates an ensemble of k partitions and updates the ensemble by replacing its worst member with the best of k'partitions found by analyzing a simplified network. The updating continues until consensus is achieved within the ensemble. Varying the values of k and k', we find that the results obey different classes of extreme value statistics and that increasing k is generally much more effective than increasing k'for finding the best partition.

Academic year:

3rd year

Research Advisor:

Dr. Kevin E. Bassler

Parallel Session 1 / 30

Contribution of Hadron Families to the QCD Equation of State

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Currently Lattice QCD simulations provide the best method of deriving the pressure of QCD as a function of the temperature. In the low-temperature regime, the thermodynamics can be understood in terms of a gas of non-interacting hadrons and resonances, but the contribution of the single hadronic species cannot be easily isolated. In this work we propose linear combinations of susceptibilities of conserved charges, that isolate the contribution of hadrons to the pressure of QCD according to their baryon number B, electric charge Q and strangeness S content. We build these partial pressures such that they vanish in the Stefan-Boltzmann limit. This generates a non-monotonic behavior which can be used to identify the melting temperature of each hadron family. We test the validity of these linear combinations in the Hadron Resonance Gas (HRG) model and compare them to available lattice QCD results.

Academic year:

Undergrad

Research Advisor:

Claudia Ratti

Poster Session / 31

Effects of Curvature on the Conformational Properties of Confined Semi-Flexible Polymers

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Biomolecules experience confined conditions during many biological processes in vivo. The behavior of these biomolecules depends strongly on the local curvature of the confining geometry, inducing conformational changes which may affect binding activity in vitro and in vivo. An effective coarse-grained approach consists of modeling biomolecules as semi-flexible polymers, facilitating the formulation of tractable computational methods and theoretical predictions. Here, the relationship between confined semi-flexible polymers and the one-dimensional telegraph is detailed. The telegraph model's characteristic global parameters (the global persistence length) are shown to be directly related to average configurational properties such as the number of turns and the distance between turns of a semi-flexible polymer. This motivates a formal definition of a hairpin backfold for three-dimensional worm-like chains under cylindrical and toroidal confinement geometries. Simple theoretical models are proposed to account for the change in global properties of the chain due to the difference in curvature of these geometries. Analytic results are compared to data obtained from Monte-Carlo simulations which agree with established theory.

Academic year:

5th year and/or beyond

Research Advisor:

Greg Morrison

Poster Session / 32

Electronic structure analysis of air stable 2D magnet CrSBr using RIXS

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CrSBr is a new 2D magnetic material that has received enormous research interest recently. The material shows exceptional properties including air stability compared with other highly studied 2D magnets. Recent findings of this material have shown reversible strain-induced magnetic phase transitions, strong spin-orbit (SOC), and magneto-electronic coupling (MEC) effects.
In our work, we study the strain-dependent electronic structure of this material using resonant inelastic X-ray scattering (RIXS). RIXS is a powerful technique that can probe elementary excitations by measuring their energy, momentum, and polarization. We plan to analyze resonant excitations of electronic states: d-d, ligand to metal charge transfer (LMCT), phonon, and magnetic excitations of this new material. We started collecting RIXS data at different strain levels and excitation energies at the Advanced Light Source (ALS) in Berkeley. The strain device for this experiment was built in our lab and it can apply ~3% maximum tensile strain. This is comparatively higher than strain values that have been published. We have been awarded two proposal beamtimes at BESSY II (Germany) and DLS (UK) RIXS beamlines (they have higher energy resolution than ALS) to perform strain-dependent and momentum-dependent RIXS experiments on this material.

The expected scientific outcomes are two-fold. First, the determination of precise energy scales will enable the development of relevant Hamiltonians of this new material using the obtained RIXS data. By applying the atomic multiplet-based software, Quanty, the electronic correlation (Racah) parameters can be extracted from the collected spectra. These energy scales will enable the prediction of both magnetic and electronic Hamiltonians. The second outcome will be the determination of the electron-phonon coupling (EPC) in CrSBr. This material shows considerable lattice coupling to electronic and magnetic degrees of freedom.

Academic year:

4th year

Research Advisor:

Dr. Byron Freelon

Poster Session / 33

Investigating the Magnetic Ordering and Atomic Structure of Strained CrSBr by Neutron Diffraction

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Since the discovery of graphene, two-dimensional (2D) materials have sparked great interest among condensed matter physicists. These materials exhibit new physical properties, and their magnetic versions promise numerous applications for spintronics, optoelectronic devices, and quantum computing hardware. 2D magnets are attractive, but the van der Waals (VdW) form has exhibited new and exotic effects. One example is Chromium Sulphur Bromide (CrSBr), which is multi-functional and air-stable among magnetic 2D magnets.
The recent discovery of 2D VdW magnets provides a new platform for manipulating magnetic properties with versatile methods to control, including electric and nanomechanical means. Strain ε engineering is a practical approach to tuning fundamental properties of 2D materials. Examples include the strain control of nematic, superconducting, and topological phases by modifying a given crystal's lattice constant and symmetry. Strain can also influence the magnon's VdW magnets. Strain has been shown to change the lattice structure and affect the exchange interaction between magnetic ions, leading to changes in the magnon spectrum and the magnon density of states. Theoretical studies have suggested that strain can modify magnetic ordering and magnetic anisotropy. Our work will study the structural properties and magnetic ordering of CrSBr using neutron diffraction. These measurements will be compared to non-strained results that were previously published.

Academic year:

3rd year

Research Advisor:

Dr. Byron K. Freelon

Parallel Session 1 / 34

LIMITED FREQUENCY BANDWIDTH ON THE INVERSE SCATTERING SERIES AND THE EFFECTS ON SEISMIC PROCESSING GOALS

Authors: Ana Carolina Gonzalez Romero[1]; Mark Meier[1]

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When a source of sound waves is active near the ocean surface, sound waves travel through the water and beneath the seafloor into the earth. The waves reflect from impedance changes in the earth and return to the ocean surface where sound measurements are recorded to then be processed and analyzed. From this study, a "picture"of the subsurface can be obtained that includes details such as layer locations, rock properties and pore fluid content (hydrocarbons). This information is valuable to the oil industry, helping to improve probability of success in the exploration and production of hydrocarbons. The seismic sources used for these measurements are a key technology, and characteristics such as frequency bandwidth are important to seismic exploration objectives and oil industry success. An important area of research and method of analysis of recorded seismic waves is the inverse scattering series (ISS). The object of this study is to determine how a source with limited frequency bandwidth effects ISS and examine the impact that improving bandwidth has on achieving seismic processing goals. To pursue this study, the first two terms (□1 and □2) of the perturbation parameter □ of the ISS were found for the case of a simple layered acoustic medium (no absorption or dispersion) with constant density and varying velocity. The study starts with an examination of normal incidence for a source with high frequencies missing, then for another one with low frequencies missing and lastly for a bandlimited one. The results are compared to the case when all frequencies are present to develop an understanding of the effects of missing bandwidth.

Academic year:

4th year

Research Advisor:

Dr. Mark Meier

Parallel Session 2 / 35

Spectroscopic Determination of Electronic and Magnetic key energy scales of Chromium Trihalides

Authors: Byron Freelon[1]; Chamini Pathiraja[1]; Jayajeewana Ranhili Pelige[1]; Yi-De Chuang[2]; Yu Cheng Shao[3]

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The recent discovery of ferromagnetism (FM) in two dimensional (2D) van der Waals (vdW) materials down to the monolayer has led, 2D vdW chromium trihalides CrX_3 (X=Cl,Br and I) to gain recent research attraction because of their interesting electronic and magnetic properties. In the monolayer, all CrX_3 display in-plane FM order. The bilayer of CrX_3 becomes antiferromagnetic (AFM), while in tri-layer/bulk, CrI_3 and $CrBr_3$ changes back to FM, but $CrCl_3$ remains AFM. Their magnetic ground states are sensitive to the degree of ligand–metal hybridization and relevant modulations in the Cr d-orbital interactions. Because of the strong spin-lattice interaction and the hexagonal stacking order, the magnetic properties of CrX_3 depend sensitively on the number of layers and can be manipulated by electric and magnetic fields, pressure, and strain. This makes CrX_3 prime candidates for spintronics and magneto-resistive memory applications. These observations also highlight the importance of determining the key energy scales properly to understand the physics of CrX_3 and build a more reliable base Hamiltonian as the atomic part of the Hamiltonian has been used very satisfactorily in ligand field theory for the interpretation of optical data of such magnetic compounds. We have measured Cr L-edge soft X-ray absorption spectroscopy (XAS) and resonant inelastic X-ray scattering (RIXS) spectroscopy for all CrX_3 under different conditions. With the assist of atomic multiplet simulations using quantum many-body script language QUANTY, we have reliably extracted the energy scales of CrX_3 with varying degrees of ligand-metal charge-transfer effect. These parameters reproduce the experimental RIXS spectra better than methods found in the literature e.g., optical and XAS. Through this systematic study, we show that our approach compared to the literature has yielded a set of more reliably determined parameters for building a base Hamiltonian for CrX_3.

Academic year:

4th year

Research Advisor:

Byron Freelon

Parallel Session 2 / 36

Centrality Measures for Directed Signed Networks

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Complex networks represent the relationships between interacting objects in a wide range of contexts, where nodes represent the interacting entities and edges represent interactions between them. In a directed signed network, the interactions can be positive (+1) or negative (-1), with the state of a node dictated by the state of its upstream neighbors. Biological regulatory networks are an example of directed signed networks. A network is said to be frustrated if the states of pairs of nodes do not match the sign of their interactions. Previous studies have shown that biological regulatory networks are minimally frustrated compared to randomized networks with similar topologies. In recent studies, highly frustrated stable states of these regulatory networks have been associated with cancer cells. Despite the importance of these regulatory networks, there is a lack of robust centrality models that can be used in these cases. In this talk, we used a Boolean model and a new centrality measure to determine the downstream effects of nodes in network activity. We show that this measure of centrality is anti-correlated with activity, with the deletion of positively central nodes decreasing activity and the deletion of negatively central nodes increasing activity. We further developed another centrality measure to predict the importance that individual nodes have on the overall network frustration. Node frustration from network topology can potentially help to determine target nodes for gene therapy in the future.

Academic year:

4th year

Research Advisor:

Dr. Greg Morrison

Poster Session / 37

A Lock-in-Amplifier system for performing Intensity Modulated Photovoltage Spectroscopy measurement in photoelectrochemical cells, tested on TiO2 thin films

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A system for measuring Intensity Modulated Photovoltage Spectroscopy (IMVS) data on photoelectrodes was built utilizing a standard laboratory lock-in amplifier. IMVS measurement was performed on TiO2 thin film photoanodes under UV illumination to determine recombination time for electrons and holes, and charge transfer efficiency at the photoelectrode/electrolyte interface. Results from the lab-built device were compared with electrochemical impedance spectroscopy (EIS) data obtained using a commercial electrochemical analyzer, and are discussed with relation to the crystallinity, conductivity, and mobility of charge carriers within the thin films. Finally, the electronic transfer function for the lab-built system is shown to be constant in the frequency range of interest, from 1 Hz to 100 kHz.

Academic year:

5th year and/or beyond

Research Advisor:

Dr. Varghese

Parallel Session 1 / 38

Entaglement entropy in p-p collisions

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In an effort to better understand thermal behavior and particle yields in p-p collisions we recast the problem using the language of quantum information. In the last 50 years physicists have used the parton model, very successfully, to describe particle collisions. In the parton model the proton is put into a high momentum frame in which constituents are viewed as quasi-free. However, quantum mechanics tells us that the proton exists in a pure quantum state, characterized by zero von Neumann entropy. This pure state of quasi-free particles can be achieved through entanglement of the proton's constituents. We seek to show that this entanglement in the initial state has a measurable effect on the evolution of the system and is the driving mechanism behind the thermal-like behavior and particle yields observed. Recent studies have demonstrated that entanglement in the initial state could survive in a strongly coupled system. Therefore, we make an entanglement entropy calculation on the initial state of the system using known PDF's and compare this to the entropy of the final state hadrons. We find that when comparing these entropy values, at low x where the used initial entropy formula is valid, they are very similar in magnitude.

Academic year:

4th year

Research Advisor:

Rene Bellwied

Poster Session / 40

Muon Neutrino –Nucleus Charge Current Interactions with Low Hadronic Activity Cross Section Measurements with NOvA

Author: James Lesmeister[None]

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NOvA (NuMI Off-Axis ν_e Appearance experiment) is an experiment located at the Fermi National Accelerator Laboratory studying neutrino oscillations, a quantum mechanical effect in which neutrinos change flavor as they travel. This poster presents a study of ν_μ CC (muon neutrino charged-current) interactions with a nucleus accompanied by low hadronic activity using data from the NOvA Near Detector. These interactions are marked by an enhancement of quasielastic and meson exchange current (MEC) events, and a suppression of resonance and deep inelastic scattering events. This analysis will allow for the study of nuclear effects in the ν_μ CC events via the enhancement of the MEC; these nuclear effects are one of the major sources of systematic uncertainty in the measurement of neutrino oscillation parameters. This analysis will extend previous work in two dimensions sensitive to nuclear effects from the muon perspective(cosine of the muon angle vs muon kinetic energy) to three dimensions (adding in available hadronic energy) to study nuclear effects from the hadronic perspective.

Academic year:

5th year and/or beyond

Research Advisor:

Lisa Koerner

Poster Session / 41

Photoacoustic laser streaming for liquid handling operations.

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The world is seeking for the appropriate and efficient mixing technologies due to current approaches exhibit poor mixing performances and it requires a long operation time in mixing. In this project, our goal is to introduce a disruptive mixing technology that is rapid and cost-effective than current available mixing technologies.
Our proposed naval mixing method is mainly based on photo-acoustic streaming phenomenon. Optical fluid control can be advantageous over conventional mechanical methods because it offers a contact-free. But Unfortunately, most methods that utilize optical effects, cannot provide strong enough liquid driving forces. The photoacoustic laser streaming resulting from metal implanted materials, or MIMs, overcomes this limitation, providing streaming velocities of over 10 mm per second. MIMs consist of substrates, generally quartz or glass, with metal nanoparticles implanted beneath the surface. These nanoparticles are formed by treating the surface of the substrate with an ion beam from a particle accelerator. When a pulsed laser hits the implanted surface of the MIM, the laser's energy is absorbed by the metal nanoparticles that in turn generate an ultrasound wave, driving the fluid via acoustic streaming. Because laser beams can be arbitrarily patterned and timed, the fluid can be controlled by laser in a fashion similar to musical water fountains. We will explore performance in smaller volumes, where we expect performance to improve mixing solutions while reaction volume decrease.

Academic year:

3rd year

Research Advisor:

Prof wei-kan chu

Parallel Session 1 / 42

Elliptic flow measurement in Xe-Xe collisions at \sqrt{S_{NN}}=$5.44 Tev$

Author: Iris Likmeta[1]

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In heavy-ion collisions at relativistic energies that Large Hadron Collider (LHC) achieves, a hot and dense medium called quark-gluon plasma (QGP) is created. Intriguingly, the collective motion of produced particles forms an almond shape, that is thought to be the signature of QGP formation. Colliding Xe-Xe nuclei in ALICE experiment at the LHC we can determine the initial state of the collision by measuring the flow parameter v_2. In this talk, we present how to measure the elliptic flow coefficient v_2 in Xe-Xe collisions using direct calculations from Q-cumulant method. The centrality dependence of v_2 shows that is increasing from ultra central to mid peripheral collisions because of the initial geometry of the system. For higher order multi-particle cumulants $v_2\{m\}$ we observe the suppression of non flow effects, as well as, the fact that the system is driven by flow fluctuations.

Academic year:

3rd year

Research Advisor:

Anthony Timmins