

Session W – Physics (Alphabetical)

Sensitivity Analysis of the BTEC Thermal Model

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Mentors: G. D. Buffington at Fort Hays State University and Michael Cross

The BTEC Thermal model has been developed to accurately describe the interactions of lasers with biological tissues and has been used to determine laser safety standards for many situations. The model has undergone extensive validation against experimental results to ensure accuracy under specifically known conditions, but it is unknown how sensitive the model results are to varied input, such as uncertainties in biological tissue properties. The objective of this project is to examine how the results of the model vary if input uncertainties are applied to known solution inputs. An understanding of the sensitivity of the solution is important as it may be difficult to determine accurately biological tissue properties which could then cause extremely different model results. An understanding of which inputs significantly affect the model results is of paramount importance so as to ensure a safe operating environment is maintained at all times.

Analysis of the Observed Phase Diagram of Cs_2CuBr_4

Christian Griset

Mentor: Gil Refael

Cs_2CuBr_4 is a material where electrons live on a 2D antiferromagnetic triangular lattice which is frustrated, meaning that spin interactions cannot all be simultaneously satisfied. Experiments involving Cs_2CuBr_4 show a complex phase diagram arises, which is poorly understood theoretically. In particular, there are phases at rational fractions of the saturation magnetization, the critical field strength which all spins want to point along the field axis. Simple models have made some predictions, but a more realistic model needs to be considered to capture the full physics of the material. We approach a more microscopically faithful model by running Monte Carlo simulations, which motivate further analytic work that takes into account crucial entropic effects which distinguish between favorable spin states. This type of analysis may help us better understand the phases in Cs_2CuBr_4 , and may shed light on other related materials such as Cs_2CuCl_4 .

Detecting the Fermiophobic Higgs at the LHC

Joshua Hardenbrook

Mentors: Harvey Newman and Yousi Ma

The Higgs Boson in the Standard Model provides an explanation and mechanism for the individual masses to all elementary particles. The existence of the Higgs Boson remains to be verified and is one of the main motivations for the Large Hadron Collider (LHC). Rather than the standard Higgs mechanism, I examine an alternative. As there is no reason to believe the same interaction which generates fermion masses also generates boson masses, I consider the case in which the Higgs Boson has no couplings to fermions i.e. fermiophobia. In this paper, I present a search strategy for the Fermiophobic Higgs Boson at the LHC, using the CMS detector. The analysis will be completed with computer generated Monte Carlo data in preparation for data collection later this year. The channel $H \rightarrow \gamma\gamma$ has been chosen for its enhanced branching ratio times cross section due to fermiophobic scaling. The selection is optimized using statistical pattern recognition utilizing boot-strap aggregating decision trees. The results are then interpreted for the start up scenario of the LHC at 200 pb⁻¹ and exclusion limits are determined.

Development of a Compact All-Optical Atomic Magnetometer

Brian Lester

Mentors: Dmitry Budker and Bradley Filippone

The development of a compact all-optical atomic magnetometer, based on amplitude modulated nonlinear magneto-optical rotation (AM NMOR), is described. The magnetometer is designed to make high-precision, localized measurements with tight size restrictions, specifically those required for measuring the magnetic field within the neutron electric dipole moment experiment (nEDM). For use in the nEDM experiment, the magnetometer must have 10 nG sensitivity in a field of magnitude 10mG. Additionally, the magnetometer must be able to make measurements localized to $\sim 1\text{cm}^3$. The design described utilizes a small paraffin-coated cesium vapor cell along with polarization maintaining (PM) input fibers and multimode, large core output fibers to take the optical signal back to the electronics for analysis. This design allows the magnetometer head to be completely isolated from electronics and any other possible sources of stray magnetic field. The prototype device is currently being assembled and the results of its performance test will be presented at the meeting.

The Simulation for the Backgrounds In the Daya Bay Antineutrino Detector Due to an ^{241}Am - ^{13}C Neutron Source

Dongyoon Oh

Mentor: Robert McKeown

The Daya Bay reactor antineutrino experiment is an international project aimed at determining the last unknown neutrino mixing angle θ_{13} with uncertainty at 0.01 or $\text{Sin}^2\theta_{13}$ in 90% confidence level. Backgrounds in the Daya Bay antineutrino detector due to an ^{241}Am - ^{13}C neutron source were simulated and the neutron capture position, nuclei and the emitted gamma rays were analyzed. The simulated signals in the detector were compared with the expected anti-neutrino signal to estimate the background rate.

Order Parameter Symmetry In Superconducting Iron-pnictides

Eugeniu Plamadeala

Mentors: Gil Refael and Tami Pereg-Barnea

Iron-pnictides are a class of materials with superconductive properties that are not fully understood. The order parameter symmetry is an important characteristic of the transition and the superconducting phase. Upon eliminating a large class of possible symmetries we are left with a small set of likely candidates. We propose an experimental probe that would distinguish between the different symmetries - Scanning Tunneling Microscopy in magnetic field. This probe measures the local density of states (LDOS). Using a two-band mean-field model calculation we show that the LDOS behavior in magnetic field is sensitive to the order parameter symmetry. We directly calculate the LDOS both numerically in full lattice model and analytically in an approximate model.

Combining Shear Statistics to Constrain Cosmological Parameters

Sedona Price

Mentors: Jason Rhodes and Joel Bergé

Weak gravitational lensing causes shear in the images of distant galaxies. Shear statistics can be measured from high-quality astronomical images and then fit to theoretical expectations. Thus constraints can be made on dark matter structures and on dark energy. Code to measure the two-point correlation function (2PCF) including tomography (redshift information) is modified and developed. Code to measure the signal-to-noise peak counts is adapted. The 2PCF and peak counts are measured on a shear catalog derived from the Hubble Space Telescope COSMOS survey. Constraints on cosmological parameters are then derived from the measured 2PCF and from the peak counts. These constraints are combined to break the degeneracy between the matter mass density (Ω_m) and the amplitude of density fluctuations (σ_8), making the overall set of constraints tighter.

The Search for ADD Large Extra Dimensions at the LHC

Daniel Sexton

Mentors: Harvey Newman and Marat Gataullin

The Arkani-Hamed, Dvali, and Dimopolous (ADD) model with large extra dimensions is one theory that attempts to solve the enormous gap between the relative strengths of the gravitational force and the electroweak force of the Standard Model of particle physics. The ADD model predicts the existence of extra dimensions through which the gravitational force alone can propagate, thus diluting its strength in the 3 + 1 dimensions of spacetime. The Large Hadron Collider (LHC) will allow us to probe for such extra dimensions in the previously inaccessible region. In my project, I investigate the method which searches for graviton production in the $q\bar{q} \rightarrow \gamma G$ channel at the Compact Muon Solenoid (CMS) detector of the LHC. This event topology is characterized by the presence of the large transverse energy in the event, as the graviton would escape undetected to the extra dimensions. I develop a search method that maximizes the CMS discovery potential by optimizing my selection criteria, in particular the photon identification cuts. I show that already after the first year of the LHC operation, we can search for manifestations of large extra dimensions for new gravity scales up to one TeV.

Spin-Polarized Scanning Tunneling Spectroscopic Studies of Heterostructures based on Ferromagnetic Manganites

Jing Shi

Mentors: Nai-Chang Yeh and Cameron Hughes

"Spintronics" has emerged as an active research field because of its potential applications to non-volatile memory storage based on electron spin. In this project $\text{La}_{0.7}\text{Ca}_{0.3}\text{MnO}_3$ (LCMO) is investigated with scanning tunneling microscopy (STM) for potential use as a ferromagnetic component in the spin-valve configuration. Additionally, spin-polarized STM (SP-STM) is employed for studying the spin and charge transport in LCMO because spin-polarized electrons injected from SP-STM can resolve spatially varying

spin-dependent tunneling conductance in the LCMO sample. Previous STM studies have shown tunneling conductance spectra largely agreeing with band structure calculations of the LCMO density of states (DOS), particularly two high conductance peaks associated with the majority and minority bands in the ferromagnetic state. However, an unexpected low-energy gap in the conductance spectra is also observed. To understand the origin of the gap, we carried out SP-STM in 0, 3 and -0.3 Tesla magnetic fields at 7K, and observed that the energy of the gap decreased in large magnetic fields. Further, the magnitude of the gap and the energy where the maximum DOS occurred were positively correlated and independent of the height of the tip. These results suggest that the low-energy gap may be associated with an antiferromagnetic underdoped surface phase.

Search for Low Mass Strings at the Large Hadron Collider

Andy Yen

Mentors: Harvey Newman, Marat Gataullin, and Vladimir Litvine

One of the strengths of the physics program at the Large Hadron Collider (LHC) is the sensitivity to numerous beyond the Standard Model (SM) physics scenarios. Of the various beyond SM hypotheses, superstring theory is an appealing alternative because of its ability to incorporate quantum gravity and solve the hierarchy problem by exploiting the extra degrees of freedom gained by extending into extra spacetime dimensions. Recent theoretical work has demonstrated that the string mass scale (M_s) can be as low as 1 TeV meaning that Regge resonances can occur and string effects can be seen at LHC energies through a modification of the SM $\gamma + \text{jet}$ amplitude due to the non-SM scattering process $gg \rightarrow g\gamma$. In this paper, we present a search strategy to probe for low mass strings using the Compact Muon Solenoid (CMS) detector. The search method uses a cut-based selection which takes advantage of the high precision electromagnetic calorimeter in CMS to cleanly identify the high transverse momentum direct photon that results. The results demonstrate that with just 1 fb^{-1} of integrated luminosity, it is possible to probe for deviations from the SM due to TeV-scale strings at the 5σ level for M_s up to 1 TeV.

Measuring Electrical and Mechanical Properties of Nanoscale, Metal-metal Contacts Using an Atomic Force Microscope

Matthew Yu

Mentors: M.L. Roukes and X.L. Feng

We study nanoscale metal-metal contacts and measure their electrical and mechanical properties using very sharp conductive scanning probes in an atomic force microscope (AFM). By creating genuinely nanoscale contacts between the probes and gold (Au)-coated surfaces, we examine the forces and impedance and their variations in cycles of contact and separation. Using the AFM's force curve mode, an AC voltage is applied to the AFM probe as it approaches and then detaches from the sample surface, allowing simultaneous force and resistance measurements. For sharp probes with diameters of 54nm and with stiffness of $k_{\text{tip}} = 36 \text{ N/m}$, as the probe approaches a contact force of about $0.5 \mu\text{N}$ of force, a drop of contact resistance from high resistance ($\text{M}\Omega$) to low resistance (tens of Ω) is consistently observed. Due to adhesion between the probe and sample upon retraction, there is a hysteresis in the data.