2017 Departmental Poster Competition

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Science Building

Book of abstracts

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LabVIEW Implementation of Single-Laser Alternating Target Pulsed Laser Deposition

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Alternating target pulsed laser deposition is a thin-film growth technique used for fabricating complex materials. While it is possible to adapt a standard PLD system to accommodate alternating target PLD, little literature exists to assist in this effort. I have developed a LabVIEW implementation to synchronize and control the necessary components to facilitate alternating target PLD. To test this implementation, we chose to grow thin films of tungsten-doped vanadium dioxide, a material with a metal insulator transition, the temperature of which is linearly dependent on the tungsten doping fraction. By verifying this linear relationship in films grown using this method, the validity of my implementation was confirmed.

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Search for Dark Matter in Jets plus MET final state for Non-thermal Dark Matter model using data from Proton-Proton Collisions at $\sqrt{s}$ = 13 TeV.

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We will present a search for dark matter in events with one or more jets and large missing transverse energy using proton-proton collisions at center-of-mass energy of 13 TeV. The data was collected in 2016 by the CMS detector at the LHC correspond to an integrated luminosity of 35.9 fb-1. The results are interpreted in terms of non-thermal dark matter model which explains the presence of dark matter in universe and justifies baryon asymmetry as well.

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Searching for Compressed Supersymmetric Spectra at the Large Hadron Collider

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Searches for supersymmetry at the Large Hadron Collider in electroweak final states are kinematically limited by softness of the leptonic scattering products in the regime of narrow mass splitting between the slepton and neutralino. After requiring a hard initial-state jet in order to provide the visible system a large transverse boost, we cut on the reconstructed OSSF dilepton mass, as well as the ditau-mass variable and the missing transverse energy. We find that the most difficult residual background is the topologically identical WW+jets final state. We leverage two subtle differences in these processes, namely the mass of the invisible species (zero for background, or around 100 GeV for our signal hypothesis) and the spin of the parent species (vector for background, or scalar for signal) in order to improve discrimination.

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Gravitational Waves emitted by an oscillating Neutron Star

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The structure and composition of Neutron Stars (NS) is an open problem in Physics. The Equation of State (EoS) of matter in NS cores is very uncertain because there is a lack of knowledge about how matter behaves at such very high energy.
The aim of our work is to predict some observables that may impose constraints on the EoS, at present limits are obtained mainly through the mass-radius relationship, but in the near future we expect to obtain stronger constraints with the Gravitational Waves (GW) that LIGO and VIRGO may observe.
We computed the Quasi-Normal-Mode (QNM) oscillations of NSs assuming some EoSs, mainly we can divide the EoS used as NS and Strange Stars (SS). Specifically we computed the frequency of the fundamental mode and the first pressure mode and we found that these frequencies strongly depend on the EoS used. We found that different compositions relate to different kinds of frequencies.
These predictions may allow to distinguish mainly between NSs and SSs, and then it will be possible to understand if SS actually exist, since as of today they are hypothetical stars.

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Selection effects on the orbital period distribution of Low Mass X-ray Binaries.

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Observations show a lack of Low Mass Black Hole Binaries with orbital periods below 4 hours. While it is known that Black Hole Binaries (BHBs) tend to have lower peak luminosities in outburst compared to their Neutron Star counterparts, it is unclear if selection effects can account for the difference in the numbers. Studying the effect of these selection biases is important for binary population studies. Here we report on the implications for the inferred orbital period distribution of these BHBs after a simulation that accounts for extinction of the optical counterpart, absorption of X-ray counts and detectability of the outburst.

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Heat Flow across an Oxide Layer in Si

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We describe the first ab-initio (classical) molecular-dynamics (MD) simulations of heat flow across an amorphous SiO2 layer in Si. The host material is modeled by a Si nanowire which contains a thin oxide layer. The ab-initio calculations are performed using density-functional theory for the electronic states and the newly-developed supercell preparation technique to initiate the MD runs. The time constants required to achieve thermal equilibrium are obtained at two different temperatures with and without the oxide layer. It is shown that oxide layers are substantial barriers to heat flow.

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Electrical switching and charge oscillation in VO2 micro-channel devices

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Stoichiometric vanadium dioxide (VO2) undergoes a metal-to-insulator phase transition (MIT) at ~68°C temperature. This is accompanied by a pronounced decrease in electrical resistivity. This phase change can also be achieved with the application of an external electric field or by optical excitation. In this work we demonstrate the electrical switching characteristics, hysteresis and negative differential resistance (NDR) of VO2 material when incorporated into micro-channel devices. We designed, fabricated and tested planar VO2 micro-channel devices on sapphire(c-cut) with different channel dimensions using standard photolithography and lift-off techniques. These micro-channels exhibit self-sustained charge oscillations when connected to dc power source and does not require any external capacitive or inductive components. We demonstrate that the oscillation frequency of the investigated devices can be systematically tuned using an external laser source focused on the VO2 micro-channels. We quantitatively studied the mechanism of this oscillation and explain its origin as a consequence of NDR and changing resistivity of the channel.

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Search for a heavy resonance decaying into ZZ/WZ final state in proton-proton collisions at 13 TeV using the CMS detector

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Beyond the standard model theories like Extra-Dimensions predict heavy resonances corresponding to a graviton (a spin 2 particle) dominantly decaying to a pair of standard model bosons. We present the search for heavy resonances decaying to a pair of vector bosons ZZ or ZW, where Z decays to a pair of neutrinos, and W or Z decays to a merged jet due to the boost. The search has been performed using a data sample collected with the CMS detector in 2016 and the results are interpreted in the context of Randall-Sundrum Warped Extra Dimensions model. Since the W or Z decays to a merged jet, jet substructure techniques are utilized for W- and Z-tagging, which results in better signal selection.

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Discovery of a New Millisecond Pulsar

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The Fermi Space Telescope has detected a large excess of gamma-ray emission towards the galactic center. The leading hypothesis is that this emission originates from a population of pulsars at the galactic center. However, these pulsars cannot be easily detected by looking for radio pulsations due to the large angular scattering that smears the pulsed emission at the galactic center. We thus searched for radio sources within a 2.5 degree radius of the galactic center, and identified as pulsar candidates the ones whose power-law spectra is characteristic of pulsars. After creating a list of potential candidates, we conducted radio observations with the Karl G. Jansky Very Large Array to identify whether our candidates could be a plausible pulsar candidate. Following this, we conducted pulsation searches at different frequencies with the Green Bank Telescope, to identify whether the candidate is a pulsar. I will be presenting on our method of identifying pulsar candidates, the radio observations and our findings. Following this, I will be explaining how this hybrid method applies into one of my current graduate projects.

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Molecular Dynamics simulation of Cholesterol Maze Pattern at High Cholesterol Concentration Using Coarse-Grained Force Field

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Cholesterol and phosphatidylcholine (PC) are major components in many cell membranes. According to the Umbrella Model [1], the lateral packing of cholesterol and PC molecules in a lipid membrane with the lowest energy at the cholesterol mole fraction of 0.67 is that cholesterol and lipid acyl chains form alternating straight lines as shown in Figure 1a. However, this packing pattern has a small entropy, thus a large overall free-energy. So the equilibrium formation (i.e., the one with the lowest free-energy) is the so-called "maze pattern", as shown in Figure 1b. The maze pattern was first predicted in a lattice model using Monte Carlo simulation with a simple force-field based on the Umbrella Model [1]. The pattern has not yet been confirmed experimentally due to technical challenges. In this study, using more advanced coarse-grained Molecular Dynamics simulation with no assumption of any conceptual model, we show that cholesterol and PC molecules in deed form the predicted maze pattern. We systematically characterized the maze pattern in nano-meter scale and directly tested some essential predictions by the Umbrella model. Some cell membranes, such as lens membrane in human eye, have extremely high cholesterol content (50% - 65%). This study will help us to understand the unique properties of such biomembranes.

References:

[1] Huang, J., and G. W. Feigenson. 1999. A microscopic interaction model of maximum solubility of cholesterol in lipid bilayers. Biophys. J. 76, 2142-57.

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Illumination-Direction Multiplexing Fourier Ptychographic Microscopy Using Hemispherical Digital Condensers

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Fourier Ptychographic Microscopy (FPM) is an image reconstruction technique based on directionally varying sample illumination conditions. In this work, we used a hemispherical digital condenser (HDC) to implement illumination-direction multiplexing (IDM) Fourier ptychographic microscopy. Many simulations were conducted where we explored four possible illumination patterns using the HDC. This technique was successfully used to image a sample and recover it's associated phase. We found that the illumination-direction multiplexing(IDM) technique with ring-like illumination patterns could be used to image photonic crystals with subwavelength periods using traditional microscope condensers with variable numerical aperture.

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MonoTop Chirality

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The heaviest quark, the top quark, will be produced with a particular property called “chirality” that can be either left-handed (LH) or right-handed (RH) in an interaction to related to the dark matter in the Universe. The handedness can be reflected in several kinematic distributions of the decay products of the top quark ($t \longrightarrow W+b$). We choose a ratio of the bottom-quark energy to the top-quark energy, $R=E(b)/E(t)$, to examine the chirality. A study of Monte Carlo simulations is performed to evaluate what would happen at the LHC if there exists a model of particle physics with a new mediating particle that decays into either a LH or RH top quark along with a dark matter particle. The simulation shows that the handedness of the top quark in such a model can be discerned to a high degree of accuracy at the LHC, providing a robust test of the model.

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Using Btag to search for bstar and coloron in dijet final state

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Btag requirement is developed to increase the sensitivity to final states with jets coming from the hadronization of b-quarks. This algorithm is based on the reconstruction of tracks with large impact parameter and the identification of displaced secondary vertices. In this analysis, we use the >=1btag category with tight WP(Working Point) to search for bstar and 1btag category with medium WP to search for coloron.

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Search for R-modes from neutron star.

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R-modes are the non radial oscillation where the Coriolis force acts as a restoring force.R-modes are driven unstable by the gravitational wave radiation(CFS instability) in rapidly rotating neutron star. CFS instability happens when the oscillating modes are traveling in one direction as observed in rotating frame and in opposite direction in an inertial frame. R-modes frequencies depends on compactness parameter(M/R) of star which gives its range from 1.39 -1.57 times the spin frequency.
R-modes detection will help us to understand the interior of neutron star which is opaque in electromagnetic waves.

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First-Principles Computational Study of the Properties of Some Silicon-based Type II Clathrate Compounds

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Type II Si-based clathrate materials with alkali metal atom guests in the lattice cages have shown great promise for use as high-performance thermoelectric materials. Studying these materials can also reveal some very interesting basic physics. Here, we report the results of a systematic, first principles, theoretical and computational study of the structural, electronic, thermal and vibrational properties of some Type II Si-based clathrate materials. Our calculations are based on density functional theory and utilize the VASP code. Our predictions include the guest atom composition (x) dependence of the lattice parameters in the binary compounds AxSi136 (A=alkali metal atom, 0<x≤24). For these materials, we find that as x increases, the lattice contracts for 0<x<8 and expands for 8<x<24, in agreement with recent observations. We also present results for the x dependence of the elastic constants, the electronic densities of states, and the vibrational modes in these binary materials. The results of our investigation of guest-framework coupling in the compounds CsRb8Al8Si128, Cs8Na16Al24Si112 are also presented. Finally, we discuss results for the composition (x) dependence of the volume thermal expansion coefficient in the alloy clathrate SixGe136-x (x=8,32,40,96,104,128) (with empty cages). The mode Grüeneisen parameters for the transverse acoustic (TA) and longitudinal acoustic(LA) phonons along different high-symmetry lattice directions are also explored for these alloys. For these same materials, by using a quasiharmonic approximation method to treat the lattice vibrations, we find a negative thermal expansion coefficient for some temperatures.

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Effects of Membrane Protein nAChR on Phase-Separated Model Membranes.

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In this study, the effects of adding 2 mol% of membrane protein nAChRs to DOPC/DSPC/cholesterol lipid bilayers containing coexisting phases are investigated. Previously, no 4-component phase diagram, with nAChRs protein as one of the components, has been studied. This work is the first study of this kind that investigates the effect of ion-transmitter nACHRs on Lo+Ld phase boundaries. The modification of phase boundary by nAChRs is determined using fluorescence microscopy on giant unilamellar vesicles (GUVs). After phase boundaries are determined, thermodynamic tie-lines and protein's partition coefficients will be measured. Those data will allow us to precisely determine the exact concentrations of nAChRs in various cell membrane domains. Accurate measurement of the perturbations of the phase boundaries by the protein could serve as a means to quantitatively understand the universal behavior of a range of membrane proteins.

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Mechanical Feedback in the Drosophila melanogaster Embryo: Robustness and Intercellular Coordination

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Successful embryonic development of any organism hinges on multiple morphogenetic processes working seamlessly in concert and requires both cellular coordination and the ability to continue development in spite of perturbations. We believe that this coordination and robustness are largely accomplished through intricate intercellular communication via mechanical stress fields and through associated feedback mechanisms. The importance of chemical signaling to biological development is undeniable; however, mechanical stress has been shown to play an important role in the sculpting of developing tissues. Systematic methods of studying the harmonization of cellular activities through mechanical stress and feedback within a tissue have yet to be developed. Motivated by the need for such methods, we introduce two novel modeling platforms which successfully capture different aspects of ventral furrow formation during the gastrulation of a Drosophila melanogaster embryo. Both modeling platforms represent cells as mechanically excitable objects which experience pairwise interactions; however, the first considers cells to be fully three dimensional, soft, non-spherical objects while the second hones in on the outer surface by simplifying cells into discs. Using both of these models we explore how mechanical feedback can facilitate the robustness of ventral furrow formation, the initiating morphogenetic process of gastrulation in the Drosophila embryo.

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Methods to Search for New Physics in proton-proton collisions at the LHC - in case of search for lepton number violation

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The Standard Model of particle physics is a very successful model to explain matters and interactions of matters in the universe with quarks, leptons, vector bosons and Higgs particle. On the other hand, it is incomplete. For example, the model does not explain the existence of dark matter and gravitation in the universe. After the discovery of Higgs particle in 2012, searches for dark matter, graviton and other new physics beyond the Standard Model continued at the LHC. We explain methods used in search for lepton number violation in proton-proton collisions at the LHC.

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A systematic search for dwarf counterparts to ultra compact high velocity clouds

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Observations of the Universe on scales smaller than typical, massive galaxies challenge the standard Lambda Cold Dark Matter paradigm for structure formation. It is thus imperative to discover and characterize the faintest dwarf galaxy systems, not just within the Local Group, but in relatively isolated environments as well. Here we report on a systematic search of public ultraviolet and optical archives for dwarf galaxy counterparts to so-called Ultra Compact High Velocity Clouds (UCHVCs), which are compact, isolated HI sources found in surveys by the Arecibo radio observatory. Our search has uncovered five dwarf galaxies. We also present follow up data from the Hubble Space Telescope that can help determine distance, structural properties and star formation rates.

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Calculation of phase shifts in potential scattering

A phenomena known scattering provide standard tolls to look at a solid state system. Types of scattering include neutron, x-ray scattering …etc. It is essential and are the most important ways to get information of the microscopic structure of quantum systems. In general, scattering is when an atom in the ground state is excited by some projectile electrons in discharge collisions with other target particles. Also, it is powerful idea in fields such as higher energy, nuclear or condensed matter physics can't be overstated. So, scattering tell us how we can find the cross section and solve the Schrödinger equation for the wave function of quantum mechanics. Moreover, it is helping us to learn about particles physics and how we calculate phase shift in a different potential in partial wave analysis by numerically solving the radial Schrodinger equation and we use Numerov's method to compute the wave function. Moreover, we see the result the positive and negative Yukawa potential have phase shift is positive for attractive potentials and negative for repulsive potential.