Revised April 8, 2021 by Yuri Kamyshkov [kamyshkov@utk.edu]

Program of the P599 HEP and Astrophysics Seminar for Spring 2021

Seminar time 3:30-4:45 pm EST on Wednesdays
Please use https://tennessee.zoom.us/j/4029951348 for the seminar connection

Date	Speaker	Affiliation	Title	Abstract and links to video
Feb 3 (Josh)	Aleksandra Ćiprijanović	FNAL, Research Associate, Scientific Computing Division	Domain adaptation for cross-domain studies in astronomy	In physics and astronomy, neural networks are often trained on simulated data (source domain) with the prospect of being applied to real detector or telescope images (target domain). Unfortunately, simply training a deep neural network on images from one domain does not guarantee satisfactory performance on new images from a different domain. The ability to share cross-domain knowledge is the main advantage of modern deep domain adaptation techniques. The talk will cover the use of two techniques — Maximum Mean Discrepancy (MMD) and adversarial training with Domain Adversarial Neural Networks (DANN) — for the classification of distant merging galaxies from the Illustris-1 cosmological simulation. The inclusion of domain adaptation methods greatly improves the performance of the algorithm in the target domain when compared to conventional machine learning methods, thereby demonstrating great promise for their use in astronomy. Link to the talk: https://youtu.be/OtJYWtiLHNA
Feb 10 (YuriK)	Benedetta Belfatto	Physics Department, Pisa University, Italy	The CKM unitarity problem: A trace of new physics at the TeV scale?	After the recent high precision determinations of V_{us} and V_{ud}, the first row of the CKM matrix shows about 4σ deviation from unitarity. Two possible scenarios beyond the Standard Model can be investigated in order to explain the anomaly. A solution can come from the introduction of the gauge horizontal family symmetry acting between the lepton families and spontaneously broken at the scale of about 6 TeV. Since the gauge bosons of this symmetry contribute to muon decay in interference with Standard Model, the Fermi constant is slightly smaller than the muon decay constant so that unitarity is recovered. Alternative, and perhaps more immediate, possibility to solve the CKM first row anomaly can be the presence of vector-like quarks. The extra species should exhibit a large mixing with the first family in order to explain the deviation from unitarity and their mass should be no more than about 6 TeV. Also the neutron lifetime problem, that is about 4σ discrepancy between the neutron lifetimes measured in beam and trap experiments, is discussed in the light of these determinations of the CKM matrix elements. Link to the talk is here.
Feb 17 (Josh)	Tiffany Lewis	Universities Space Research Association	Modeling Blazar Jets with Particle Transport Methods	Blazars are luminous active galaxies with a jet pointed along our line of sight. They give us a unique view into one of the most extreme particle acceleration regions in the Universe, with observations across the entire electromagnetic spectrum. Blazars are the most numerous extragalactic sources in the gamma-rays and can have variability timescales on the order of minutes. However, the particle acceleration mechanisms that give rise to the power in these observed signals are not well understood. One method of addressing this problem intuitively is to simulate the particle energies from first principles, and then carefully calculate observables, like time lags, spectra, and polarization fraction, to compare with or predict signatures in data. In particular, Fermi-I and Fermi-II acceleration produce different distributions of particle energy, and therefore different broadband spectra. https://youtu.be/Vss9oK8m1mU

Fen 24 (Josh)	**[Christoph Alt]**	**Institute for Particle Physics and Astrophysics, ETH Zürich, CH-8093 Zürich, Switzerland**	**Proton Decay in Dual Phase DUNE**	**Direct experimental observation of proton decay would constitute evidence for Grand Unification, an appealing theory in which the electromagnetic, weak and strong interactions are combined into a single gauge. With many of the simpler theories ruled out by recent results from Super-Kamiokande, supersymmetric extensions of Grand Unification (SUSY GUTs) gain more interest as they push the proton lifetime above the current experimental lower limit and open up new decay modes via the exchange of heavy supersymmetric particles. The dominant decay mode in numerous SUSY GUTs is $p \to \bar{\nu} K^+$ with lifetimes of $10^{34} - 10^{35}$ years. In this seminar, a sensitivity study for is $p \to \bar{\nu} K^+$ using a 10kt *dual phase* liquid argon time projection chamber at the Deep Underground Neutrino experiment with atmospheric neutrinos as background is presented, covering the validation of the detector simulation with data from a smaller prototype, the simulation of nuclear effects in the signal and background samples and the neural-network-driven analysis that results in a sensitivity of $\tau/Br(p \to \bar{\nu} K^+) \geq 7\times 10^{34}$ years at 90% confidence level and an exposure of 1 megaton·year in quasi-background-free conditions. https://youtu.be/5vsK7STFf4s**
Mar 3 (Josh)	Jessica Turner	Inst. for Par. Phys. Phen., Durham University	Leptogenesis and low-energy CP-violation	I will provide a general overview of the matter anti-matter asymmetry and how this can be linked to the generation of light neutrino masses. I will discuss the possibility of producing the observed baryon asymmetry of the Universe via thermal leptogenesis, where CP violation comes exclusively from the low-energy phases of the neutrino mixing matrix. I will demonstrate the viability of thermal leptogenesis across seven orders of magnitude and clarify that at very high scales T > 10^12 GeV is sensitive to the low-energy phases, in contradiction with what is usually claimed in the literature. https://youtu.be/Ml_6iNqU3HA
Mar 10 (YuriK)	Massimo Mannarelli	Gran Sasso National Laboratories, INFN, Italy	Neutron - mirror neutron mixing and neutron stars	The oscillation of neutron n into mirror neutron n' , its exactly or nearly mass degenerate twin from dark mirror sector, can have interesting implications for neutron stars (NS). An original NS can be gradually transformed into a mixed star (MS) consisting in part of mirror neutrons. The mass–radius relation of MS and its maximum mass depend on the equation of state (EoS) of nuclear matter (which should be the same for ordinary and mirror components), and on the proportion between these components inside the star. Namely, if 50% − 50% proportion between ordinary and mirror fractions can be reached asymptotically in time, then the maximal mass of such a "twin star" star (TS) should be √2 times smaller as compared to the maximum mass of pure NS with the same EoS. The NS with masses larger than Mmax_TS = Mmax_NS /√2 should collapse into black holes after certain evolution time which we evaluate here. In addition, the star becomes more compact in the process of NS → MS transformation, and the radius of the asymptotic TS is about √2 times smaller than the radius of the original NS. We also briefly discuss implications for the neutron star mergers and associated signals of gravitational waves, kilonove and gamma ray bursts. https://youtu.be/KoPClDbiPBo
Mar 17	Garvita Agarwal	SUNY Buffalo	Searches for top-antitop resonances with the CMS detector at √s = 13 TeV	Numerous extensions of the Standard Model predict the production of new massive particles that decay preferentially to a top-antitop pair. Resonances decaying to top quark pairs can be found in models that have but are not limited to: massive spin-1 color-singlet Z-like bosons (Z') in extended gauge theories and from Simplified Dark Matter models, spin-1 colour-octet Kaluza-Klein excitations of gluons (gKK) in various extensions of the Randall-Sundrum model. The search for the aforementioned resonances is performed in the dileptonic final state using data collected during Run 2 of proton-proton collisions at √s = 13 TeV by the CMS detector at the LHC. https://youtu.be/LEjSX77y8X0

Mar 24 (Tova)	Mariel Pettee	Yale University	AI Methods for Particle Physics and Choreography	As part of a comprehensive plan to investigate the many combinations of production and decay of the Standard Model Higgs boson using the full Run 2 ATLAS dataset at the LHC, I will present a search for the SM Higgs boson produced in association with a leptonically-decaying vector boson (i.e. a W or Z boson) and decaying into a pair of tau leptons. Efficient identification of hadronically-decaying tau leptons at the trigger level is essential to this analysis, so I will also discuss my technical work in deploying an RNN-based tau identification scheme in the ATLAS High-Level Trigger (HLT) in Run 2. Lastly, I will show highlights of my independent AI work in leading teams of researchers across academia and industry to pioneer the state-of-the-art in AI-generated choreography using techniques including Variational Autoencoders (VAEs) and Graph Neural Networks (GNNs). https://youtu.be/S0swZazPsyY
Mar 31 (Tova)	Lipi Gupta	University of Chicago and SLAC	Machine Learning Methods at the SLAC Linac Coherent Light Source (and Beyond!)	Abstract: Particle accelerators are powerful tools in many fields of science such as high energy physics, biology, and material science. However, there are still many challenges which limit their operation. User-facilities such as light sources have to be tuned to different settings frequently, since different experiments can require very different and specific beam conditions. Time spent switching operational modes can limit the number of experiments that are able to use the powerful, bright photon pulses produced at accelerators such as the Linac Coherent Light Source (LCLS), at SLAC National Accelerator Lab. To improve the control and tuning of particle accelerators at SLAC, we are exploring using neural network based surrogate models to aid in finding optimal machine settings quickly and reliably. In this talk, I will present the process by which we created an accurate surrogate model of the LCLS-II electron injector. The method for creating these models is largely agnostic to the physical system, making it possible to apply the ML techniques broadly. https://youtu.be/KpCsVqB7sUc
Apr 7	Joshua Barrow	University of Tennessee	Electromagnetic Cross Sections from Nuclear Response Functions in the GENIE Monte Carlo Event Generator	Abstract: The GENIE Monte Carlo event generator now permits simulation of electron scattering alongside their neutrino cousins, allowing for detailed validation and comparisons of underlying nuclear modeling assumptions against prodigious electromagnetic cross section world data. Further still, S. Gardiner has recently incorporated a tool into GENIE (the HadronTensor framework) to integrate the nearly universal lepton scattering nuclear response function into event generation. From nuclear response outputs originating from theoretical frameworks such as the Quantum Monte Carlo Short-Time Approximation (QMC STA), one can thus generate cross sections and full events without the direct use of approximate, quasi-classical nuclear models. Though an intranuclear cascade is currently not available, I will review the QMC STA GENIE implementation for leptonic variables of electromagnetic scattering on He-4, our interpolation techniques using the HadronTensor, current comparisons to data, and future directions with even more fundamental response density objects. I will also review the uses of Monte Carlo event generators for experiment and point toward a way forward for neutrino scattering. https://youtu.be/rWtaWdp9c8E
Apr 14 (Yuri K)	Giorgio Gratta	Stanford University	Measuring gravity at micron scale and other fun tricks with optically levitated microspheres	Abstract: I will describe a new program of measurements in fundamental physics using optically levitated dielectric microspheres. The focus of the talk will be the recently completed first search for new, gravity-like interactions at micron scale using this novel technique. I will also show an array of other results, including searches for millicharged particles, Chameleon fields and techniques to manipulate the various degrees of freedom of the trapped microspheres. Presentation slides: here and video https://youtu.be/c1F0kKJRlll

Apr 21	Lawrence Lee	Harvard University	What RPV Supersymmetry Can Do For You	The Standard Model (SM) of particle physics is plagued with a number of major inadequacies — grotesque fine-tuning in the Higgs sector, a lack of an explanation for dark matter, or unnaturally small levels of CP violation from the strong nuclear force, to name a few. A particularly popular solution for many of our SM woes comes from supersymmetry (SUSY), but despite a decade of searches at the LHC, we're left without the discoveries we had initially dreamed of. An often-overlooked variant of SUSY involves allowing for violation of R-Parity (RPV). This talk will present the status of RPV SUSY and the optimism that particle physics may draw from it. It will argue that RPV SUSY should even be considered the default SUSY, and that perhaps we've steered ourselves in the wrong direction thus far. Seminar video recording : here
Apr 28	1. Eli Mygatt Ward	University of Tennessee	Optimizing Pulse Shape Discrimination in a PEN Scintillator	Abstract: Polyethylene naphthalate (PEN) offers several advantages as a scintillator material: it has a high yield strength at cryogenic temperatures, making it useful in conjunction with germanium detectors, and it is chemically resistant, which allows it to be aggressively cleaned with acids to minimize radiation contamination for low background measurements. Here we have detected in a PEN scintillator incident gamma rays and neutrons, each producing in the scintillator their own characteristic light pulse shapes. Previously, we distinguished between scintillation pulses from different particles by estimating the ratio of the area under the tail of the light pulse to the area of the total light pulse. This method is inexact for a number of reasons, not the least of which is the arbitrary division of the "tail" of the light pulse from the rest of the light pulse. We seek to improve pulse shape discrimination using machine learning, specifically a classification algorithm with a binary cross entropy cost function. Preliminary results suggest such a classification algorithm can distinguish between gamma ray scintillation pulses and neutron scintillation pulses with a high degree of accuracy. His talk.
	2. James T Ternullo	University of Tennessee	Neutron to Sterile Neutron Oscillations for NIST Neutron Lifetime Experiment (APS talk)	The "Neutron Lifetime Anomaly'' is an unexplained difference in measurements of the neutron lifetime (τ_n) between two precision measurements. The cold neutron (CN) beam experiment, from NIST in 2013, measured a value if 888.7 s. This value is higher than the lifetime measured using ultracold neutrons (UCN) by several experiments including the UCNτ experiment in Los Alamos (which measured a value of 877.7 s). As an explanation for this difference, Z. Berezhiani proposed that in the beam experiment, neutrons (n) could oscillate into sterile neutrons (n') which belong to a parallel, hidden, dark, mirror sector. The n' then would decay through an invisible mirror channel within the dark sector, artificially increasing the apparent neutron lifetime, thus providing an explanation for the missing decays in the NIST experiment. It was shown that transformations, in a magnetic field, can be amplified due to Landau-Zener transitions, where a small mass splitting (Δm), between n and (n'), is compensated by the applied magnetic field. To explain the anomalous 1% difference in τ_n, a predicted range of possible mixing angles were compared and plotted vs Δm in the range of (277 neV–400 neV). In this study we reproduce Berezhiani's calculations and extend them to the region of (10 neV–277 neV) using the Liouville von-Neumann evolution of the density matrix. This produces an extended limit for transformation in terms of parameters that can be challenged by a new search being performed with a cold neutron beam at ORNL. His talk.

Special Seminar on Wednesday May 5 at 10 am EDT				
May 5, 10 am	Alexander Dolgov	Novosibirsk State University, ITEP Moscow, and the University of Ferrara	Primordial black holes in old and young universe.	Recent astronomical observations of surprisingly dense population of black holes in the contemporary and the early universe at redshifts about 5-10 are reviewed. The masses of these black holes vary from a few solar masses up to hundred thousand, and possibly much higher up to billion solar masses. It is argued that the observed black holes are mostly primordial. A mechanism of their formation in the early universe is described. According to this mechanism the mass spectrum of PBH has log-normal form. This prediction very well agrees with the data. The possibility that the cosmological dark matter is black is discussed. Slides here. Video of seminar.
Date	Speaker	Affiliation	Title	Abstract and links to video

Agreed speaker for the next-semester seminar

Date	Speaker	Affiliation	Title	Abstract
TBD	Sudhakantha Girmohanta	YITP, Stony Brook, Theory	Baryon-Number-Violating Nucleon and Di-nucleon Decays in a Model with Large Extra Dimensions	