PIKIMO 18, University of Kentucky, 19 April 2025

Saturday 19 April 2025 - Saturday 19 April 2025

Chemistry Physics (CP) Building

Book of Abstracts

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New Physics from Light Scalars in Rare Kaon Decay

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We introduce and investigate the effects of a light scalar interacting with the short-lived kaon and the KS → μ+μ− decay. We use the results of searches performed at kaon factories as well as the Standard Model predictions for this decay to constrain the couplings of a ϕ particle with a mass mϕ of the order of MeV. In addition to this we find the allowed parameter space for further CP violating effects in this decay mode as well as to one loop order. We also examine the time evolution of the kaon beams with the full mixing considered and the effect of its lifetime on extractable experimental parameters.

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Electron EDM and $\Gamma(\mu \to e\gamma)$ in the 2HDM

Authors: Benoit Assi[1]; Daniil Volkov[1]; J. Julio[2]; Joachim Brod[3]; Nick Hamer[4]; Patipan Uttayarat[5]; Wolfgang Altmannshofer[4]

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We present the first complete two-loop calculation of the electric dipole moment of the electron, as well as the rates of the lepton-flavor violating decays μ→e+γ and τ→e/μ+γ, in the unconstrained two-Higgs doublet model. We include the most general Yukawa interactions of the Higgs doublets with the Standard Model fermions up to quadratic order, and allow for generic phases in the Higgs potential. A python implementation of our results is provided via a public git repository.

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Enhancing Solar Neutrino Sensitivity with Neutron Tagging

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Solar neutrinos provide crucial insights into the Sun's fusion processes and neutrino oscillations in matter. However, detecting them requires effective suppression of backgrounds. One of these is spallation backgrounds—beta decays of unstable isotopes produced by cosmic-ray muons—which pose a major challenge above 6 MeV. We show that neutron tagging, made possible by the recent addition of dissolved gadolinium, provides a powerful new method to identify and reject these backgrounds. This technique is particularly relevant for future shallower detectors like Hyper-Kamiokande and JUNO.

Morning contributed talks (chairperson R. Hill) / 5

Non-Gaussianity from explicit $U(1)$-breaking interactions

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We investigate primordial non-Gaussianity (NG) that arises from explicit $U(1)$ symmetry-breaking interactions during inflation, focusing on a nearly massless axial component of a complex scalar field P. We compute the resulting NG parameter $f_{\rm NL}$, allowing the axial field to act as either a curvaton or cold dark matter (CDM). We consider two scenarios in which the interaction emerges from an explicit $U(1)$ symmetry-breaking potential and from explicit $U(1)$ symmetry-breaking kinetic mixing. We also explore the role of a heavy radial field in generating oscillating correlation signals, noting that such signals can dominate the shape of the mixed adiabatic-isocurvature bispectrum. In certain cases, an oscillatory isocurvature bispectrum signal may be observable in the future, aiding in distinguishing between certain types of the $U(1)$-breaking self-interactions of the axial field.

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The Z \alphaˆ2 order radiative correction to nuclear beta decays

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Superallowed nuclear beta decays offer one of the most precise ways of extracting the CKM matrix |V_ud|, which is an important parameter in the Standard Model. QED radiative corrections play an important role in the precision computation of nuclear beta decays, which can be expressed in a series of Z \alpha and \alpha. Given the current experimental uncertainty, the order Z \alphaˆ2 correction should be taken into account. In this talk, I show how the virtual contribution to the Z \alphaˆ2 correction can be computed using factorization in the limit of small electron mass. I demonstrate the formalism by reproducing Sirlin's g function at one loop order, and discuss the inclusion of real photons and finite electron mass for the Z \alphaˆ2 correction.

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Constraining Cosmological Phase Transitions through Curvature Perturbations

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Cosmological first order phase transitions proceed via the random nucleation and expansion of bubbles throughout space. This inherently stochastic process leads to statistical fluctuations across causally disconnected patches from which super-horizon curvature perturbations emerge. I will discuss how such phase transitions generate scalar perturbations that follow a universal power-law scaling in the phase transition parameters. By numerically modelling the resulting curvature perturbation, we can set constraints on the phase transition parameters in light of cosmological data such as CMB, Lyman-alpha, and the observation of dynamical heating in ultra-faint dwarf galaxies. This gives us a handle on constraining cosmological phase transitions even if they occur in a dark sector that interacts with us only gravitationally.

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The Fermi Function, Factorization and the Neutron's Lifetime

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The neutron lifetime is a precision observable of the Standard Model probing the CKM matrix element $|V_{ud}|$ and beyond the Standard Model physics. For nuclear beta decay, in the region of small electron velocity or the limit of large nuclear charge Z, a Fermi function is used to account for enhanced perturbative effects. In this talk, I will present the derivation of the quantum field theoretic analog of the Fermi function valid for neutron beta decay in which neither of the aforementioned limits apply. This QFT analog is related to renormalization group effects of objects occurring in the context of a factorization formula valid in the limit of small electron mass. I will introduce this factorization formula and present results through two-loop order. The main phenomenological results are two-loop input to the long-distance corrections to neutron beta decay and an accompanying calculation of $|V_{ud}|$.

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Observable CMB B-modes from Cosmological Phase Transitions

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New Tools for Dark Matter and Gravitational Wave Detection: Cryogenic Optical Resonators and Long-Baseline Atom Interferometers

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Abstract: The search for dark matter and for new sources of gravitational waves offers potentially revolutionary opportunities to learn about the fundamental properties of the Universe. Strong astrophysical evidence indicates that dark matter makes up most of the matter in the Universe, yet its nature remains a great mystery. The detection of gravitational waves in currently unexplored frequency ranges could provide unique insights into astrophysics and cosmology. In this talk, I will discuss two emerging techniques for probing dark matter and gravitational waves. The first method involves precise optical comparisons of the lengths of cryogenic, vibration-isolated optical resonators. I will discuss the results from the first dark matter search using this approach, as well as prospects for using this method for high-frequency gravitational wave detection. The second method, long-baseline atom interferometry, involves the coherent splitting of the wavefunctions of atoms over large distances and the subsequent observation of interference of the recombined wave packets. I will introduce MAGIS-100—a 100-meter-tall atom interferometer currently under construction at Fermilab—and describe experimental demonstrations of a new approach to atom interferometry that paves the way for long-baseline atom interferometers to reach their full scientific potential.

Afternoon contributed talks (chairperson S. Gardner) / 11

Primordial black holes and induced gravitational waves from an underdamped axion-like curvaton

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We explore the generation of primordial black holes (PBHs) and second-order induced gravitational waves (GWs) arising from underdamped isocurvature fluctuations of an axion-like curvaton field. During inflation, the radial component of the curvaton undergoes underdamped evolution, leading to a resonant amplification of the curvaton's quantum fluctuations. This mechanism imprints scale-dependent oscillations and localized bumps in the blue-tilted isocurvature power spectrum. In large regions of parameter space, these enhancements can exceed three orders of magnitude. While standard quadratic curvaton models fail to produce dark matter-like PBHs from Gaussian fluctuations, we show that the dynamically induced non-adiabatic features in our scenario can successfully overcome this limitation. As a result, both PBHs and a detectable stochastic GW background are generated, with distinctive oscillatory signatures in the GW spectrum offering a new observational avenue.

Afternoon contributed talks (chairperson S. Gardner) / 12

Direct detection of ultralight dark matter with charged lepton flavor violation

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I will discuss a class of ultralight dark matter models with charged-lepton-flavor violating couplings that can induce potentially observable time-dependent signals at the intensity frontier. I will highlight the sensitivity of current/future experiments and outline possible UV completions.