Workshop on BSM Physics at Eta-Factories

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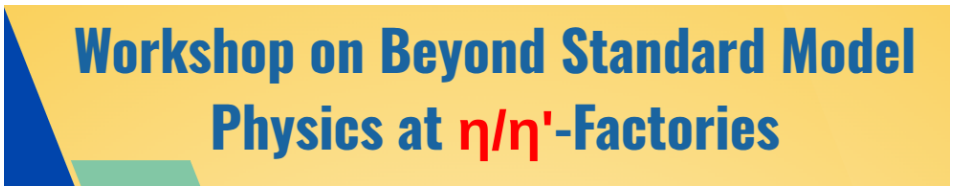
Lund University Fysiska Institutionen, Sweden



Book of Abstracts

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CP-violation in (semi)leptonic η decays within the SMEFT framework

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Currently and in the near future, a variety of η factories are exploring the potential to search for new physics through different η decays. One possibility being considered is to search for signs of CP-violation in eta decays. Since the Standard Model predicts an extremely suppressed rate for CP-violation in the η sector, any positive signal would be a clear sign of new physics. In this talk, we will focus on C-even P-odd signals, which are stringently constrained by electric dipole moments. Employing the Standard Model effective field theory, we will discuss such bounds and the prospects for detecting CP-violation at different η factories.

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Leptophobic B-boson searches through $\eta^{(\prime)} \to \pi^0\gamma\gamma$ and $\eta' \to \eta\gamma\gamma$ decays

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We analyse vector, scalar and tensor meson-exchange contributions to the doubly radiative decays $\eta^{(\prime)} \to \pi^0\gamma\gamma$ and $\eta' \to \eta\gamma\gamma$, and investigate the sensitivity of these processes to a leptophobic B boson in the sub-GeV mass range. Our results are relevant for measurements of these decays at existing (A2, BESIII, KLOE-2) and forthcoming η/η'-factories, such as the JEF and REDTOP experiments.

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Probing axion-like particles with different coupling pattern at eta-factories

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In this talk, I present a comprehensive discussion on how to search for generic axion-like particles (ALPs) coupled to quarks and gluons at Eta-Factories. First, I will review the phenomenology of the ALPs in the GeV mass range, and highlight existing open questions and complications in the field. Then, I will proceed with calculating the yields of ALPs from decays of pi0, eta, eta' mesons, and differentiating between the models with various coupling patterns.

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Axio-hadronic η/η' decays

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With upcoming η/η' factories in the horizon, dedicated searches for hadronic ALPs would open a new window into the exploration of strong CP solutions and low scale dark sectors. In this talk, we present branching ratio sensitivities of the axio-hadronic $\eta/\eta' \to \pi\pi a$ decays, where a is an axion or axion-like particle (ALP), using the leading order ALP-ChPT Lagrangian supplemented by dispersion relations to include the effects of pion-pion final state interactions. Decay channels with multiple emission of ALPs will be also briefly discussed.

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Sub-GeV leptophobic B-boson exchange in $\phi \to \pi^0\eta\gamma$ decays

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The sensitivity of the rare decay process $\phi \to \pi^0\eta\gamma$ to signatures of a leptophobic boson in the MeV-GeV mass range is analyzed in this talk. First, we improve the description of the dominant scalar contribution. Next, we incorporate an explicit B-boson resonance exchange alongside the Standard Model (SM) contributions from vector and scalar meson exchanges. By utilizing experimental data related to the associated branching ratios and invariant mass spectra, we are able to improve the current constraints on the B-boson mass, m_B, and its coupling to SM particles, α_B. However, the decays $\phi \to \pi^0\eta\gamma$ provide weaker constraints on the B-boson parameters compared to $\eta \to \pi^0\gamma\gamma$ below the mass of the η meson.

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Pseudoscalar mesons and emergent phenomena in QCD

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The structural properties of pseudoscalar mesons are closely linked with QCD's emergent phenomena, confinement and emergent hadronic mass, as well as to fundamental symmetries of the Standard Model. Two-photon transition form factors (TFFs) offer an efficient way to explore these phenomena, while tracing the transition between soft and hard energy scales. Moreover, these form factors are related to precision observables. This talk presents a unified treatment of two-photon TFFs based on continuum Schwinger methods, a framework extensively used to investigate hadron-related quantities.

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Theoretical calculation in the anomalous sector

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This talk will provide an overview of the precise higher-order calculation in the anomalous sector. The focus will be on the two-photon decays for pion and eta and on the corresponding Dalitz decays.

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Dark photon portal to dark matter, long-lived particles and gravitational waves

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Dark photons arising at or below the GeV scale from a spontaneously broken gauge symmetry are one of the simplest and most exciting extensions of the Standard Model. They couple to known particles via kinetic mixing with the Standard Model gauge bosons and can act as mediators between visible matter and new hidden states, such as sub-GeV dark matter particles. I will show that these models can satisfy all current constraints from laboratory experiments, astrophysical observations and cosmological data and predict new signals that can be targeted with future accelerator experiments. Moreover, if the dark sector features a classically conformal symmetry, spontaneous symmetry breaking can happen via a strong first-order phase transition. For MeV-scale dark sectors, the resulting gravitational wave signals are predicted to lie in the nano-Hertz frequency range and can fit the stochastic background observed by pulsar timing arrays.

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eta(') transition form factors, the muon g-2, and beyond

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The uncertainty of the Standard Model prediction of the anomalous magnetic moment of the muon $(g-2)_\mu$ is dominated by hadronic contributions. As part of these hadronic inputs, the pseudoscalar-pole contribution in hadronic-light-by-light scattering plays a vital role. The currently sought precision of the Standard Model prediction of $(g-2)_\mu$ requires a careful evaluation not only of the pion-pole contribution but also of the η and η'.
We report on the first dispersive, data-driven determination of the η and η' transition form factors in the space-like regime, which can be unambiguously related to their pole contributions. The analysis takes into account all of the lowest-lying singularities and encapsulates factorization-breaking effects by means of a left-hand-cut contribution due to the impact of the $a_2(1320)$ tensor meson.

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JLab Eta Factory

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The system of η and η′ offers a flavor-conserving laboratory to test the low-energy QCD and to search for new physics Beyond the Standard Model. The symmetry properties of QCD at low-energy, such as the chiral symmetry or the axial anomalies, are manifested in the decays of η and η′. Thus, a study of η/η′ will yield light on our understanding of the origin and the dynamics of QCD confinement. In addition, the η/η′ meson has quantum numbers of vacuum (except parity) with its strong and electromagnetic decays being either anomalous or forbidden to the lowest order due to symmetries or angular momentum conservation. This enhances the relative importance of higher order contributions, making rare η/η′ decays a sensitive hadronic probe for weakly-coupled new forces. Searching for sub-GeV dark gauge boson candidates and the C-violating, P-conserving interactions in various η/η′ decays will extend our knowledge of the dark sector and explore new sources of CP violation that are needed to explain the observed matter and anti-matter asymmetry in the universe. The JLab Eta Factory experiment is aimed at simultaneous measurements of η and η′ decays, with emphasis on rare neutral mode. This experiment will start in spring 2025 using the GlueX apparatus with a newly upgraded Forward calorimeter. The status and the new experimental opportunities for the η/η′ physics will be presented.

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eta decays at KLOE/KLOE-2 and prospect at the future e+e- collider

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The talk will include recent progress and insights on eta/eta' decays at KLOE/KLOE2 and the propest in this field that could be achieved with the future e+e- collider proposed like STCF.

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Rare eta meson decays at the CMS experiment

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Novel trigger strategies, combined with the large proton-proton collision datasets collected by the CMS experiment, have extended its sensitivity to rare flavor decay processes. Leveraging CMS's ability to efficiently trigger on and reconstruct low-momentum muons, the experiment offers complementary sensitivity to rare meson decays.

This contribution presents recent results on η meson decays from the CMS experiment. We report the first observation of the rare double Dalitz decay $\eta \to \mu^+\mu^-\mu^+\mu^-$, achieved through the use of dedicated low-pT dimuon triggers. We also discuss the innovative trigger developments introduced for Run 3 and outline the future prospects for probing rare η and η' decays at CMS.

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Low-scale dark sectors motivated by the evidence of a stochastic gravitational waves background

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The recently reported evidence of a Stochastic Gravitational Wave Background (SGWB) in the nHz frequency range is in tension with standard astrophysical expectations, motivating the study of new physics beyond the Standard Model. A preferred explanation relies on a supercooled first order phase transition at the 100 MeV - GeV scale. I will present a minimal model that can account for the SGWB, featuring a new U(1) gauge group and a dark scalar that dynamically breaks the symmetry, and discuss how the observed signal constrain the parameter space. Possible extensions of the model required to open new decay channels into the SM particles will also discussed.

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The Jefferson Lab Eta Factory Experiment and Applications of $PbWO_4$ Calorimeters in Future Experimental Facilities

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The goal of the new JLab Eta Factory (JEF) experiment, conducted with the GlueX detector in Hall D at Jefferson Lab, is to perform measurements of various $\eta^{(\prime)}$ decays with a primary focus on rare neutral modes. The experiment's physics program ranges from precision tests of low-energy QCD to searches for gauge bosons with masses below 1 GeV that could couple the Standard Model (SM) sector to the dark sector. The experiment will collect a high-statistics data sample of $\eta^{(\prime)}$ mesons produced via a beam of tagged photons. The GlueX detector features a large, nearly uniform acceptance for both neutral and charged particles, enabling efficient identification of complex multi-particle final states. To meet the requirements of the JEF experiment, the inner section of the forward lead-glass calorimeter in the GlueX detector has been upgraded with lead tungstate ($PbWO_4$) scintillating crystals. $PbWO_4$ offers exceptional characteristics, such as a small radiation length and Molière radius, and large light yield, that make it ideal for constructing high-granularity, high-resolution, radiation-hard detectors. These properties enable excellent spatial separation and energy resolution of reconstructed electromagnetic showers, establishing $PbWO_4$ as the material of choice for many high-precision experiments. The JEF experiment began data collection in April 2025 and will operate concurrently with the GlueX experiment, whose primary objective is the search for gluonic excitations in the meson spectrum. I will give an overview of the JEF experiment, the GlueX detector, and the feasibility of further upgrades to support future η physics studies. Special attention will be given to the newly constructed $PbWO_4$ scintillating calorimeter and recent advancements in calorimeter instrumentation.

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Perspectives on C and CP violation in eta to 3pi decay from SMEFT

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The decay $\eta \to \pi^+\pi^-\pi^0$ is an ideal channel in which to study flavor-conserving C and CP violation beyond the Standard Model. We use Standard Model Effective Field Theory (SMEFT) to deduce the mass-dimension-six operators that can contribute to its signature, i.e., an observed breaking of mirror symmetry in its Dalitz plot. Using chiral-effective theory, we present the leading hadron-level operators associated with the $I = 0$ and $I = 2$ transitions, and we use KLOE-2 and BES-III data to determine their strength. With this, we show how future $\eta \to \pi^+\pi^-\pi^0$ decay measurements at different experimental facilities can reveal the landscape of C and CP violation.

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Welcome and introduction

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New Physics near a GeV

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LFV eta/eta' decays and their relation to mu -> e conversion in nuclei

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Overview of the High-Intensity Heavy-Ion Accelerator Facility (HIAF) in China

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Opportunities for non-perturbative QCD at future high intensity eta/eta' factories

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On general parameterization for the hadronic form factors

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Status of eta, eta-prime lattice studies

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Anomalies in Particle Physics

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The REDTOP experiment: a η/η′ factory to explore dark matter and physics beyond the Standard Model

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HV-MAPS Detectors in HEP Experiments

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ESS Facility

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NA64 hadron mode: Search for η and η'to invisible decays

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Studies of Exclusive η Production with HADES

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Proton-proton collisions at 4.5 GeV beam kinetic energy, measured with the High Acceptance Di-Electron Spectrometer (HADES) operating at GSI Helmholtzzentrum have been used to study exclusive η meson production. This energy range is particularly interesting as it lies in an intermediate regime —between near-threshold energies, where effective Lagrangian models are typically applied, and higher energies (√s˜30 GeV), where Regge phenomenology and exchanges such as Pomeron–Reggeon become dominant. Despite their importance for testing and connecting different theoretical approaches, this intermediate region remains poorly explored experimentally. Existing data are limited and often come from older experiments with large uncertainties.
In this talk, we present new results on the total and differential cross sections for exclusive η production at 4.5 GeV, and we discuss prospects for further studies in this energy regime.

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New Particles, opportunities and perspectivesFocus on Eta's

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Pseudoscalar transition form factors and $P \to \gamma\gamma$ decays from Lattice QCD

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The process eta(') –> l+l- and pseudoscalar/axialvector mediators

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eta/etaprime physics at BESIII

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Whither studies of eta to pi pi — probes of CP violation or of dark sectors?

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Search for Axion-Like-Particles in the η->pi+pi-e+e- decay with the HADES Detector

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Whither studies of eta to pi pi — probes of CP violation or of dark sectors?

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The decay rate for $\eta \to \pi\pi$ is known to be vanishingly small in the SM, and it is similarly so in the presence of strong CP violation. Here we consider whether new sources of CP violation, as encoded in SMEFT, or the emission of a dark-sector particle, such as the axion, can give rise to potentially observable effects — and how the two mechanisms might be distinguished.