T 10: Axions/ALPS I

Time: Monday 16:15–18:00 Location: KH 01.013

T 10.1 Mon 16:15 KH 01.013

Search for the $K^+ \to \pi^+\pi^0 X$ decay — •Marco Ceoletta — JGU Mainz (DE) + CERN (CH)

This analysis aims to search for the hypothetical decay channel $K^+ \to \pi^+\pi^0 X$, where X is invisible and can be interpreted as an Axion-like particle (ALP, indicated as A) or as a massless Dark Photon (a), at the NA62 experiment (CERN). Obtaining a stringent upper limit on $\mathrm{BR}(K^+ \to \pi^+\pi^0 X)$ is important for constraints on several BSM theories. In particular, for $X = A$ the decay is sensitive to an axial-vector coupling of pseudo-scalar particles to quarks. A search on $K^+ \to \pi^+\pi^0 A$ therefore complements the extensive work already performed on the associated two-body decay $K^+ \to \pi^+ A$, that is sensitive only to the polar-vector coupling current. A preliminary upper limit of the branching ratio to ALPs, as part of a feasibility study done in 2022, already outperformed the best previous limit using less than 20% of the available data. The presentation describes the analysis, the selection, and the background estimation and and gives an outlook on the expected upper limits.

T 10.2 Mon 16:30 KH 01.013

Search for axion-like particles with gluon couplings in $B \to Ka, a \to \pi^+\pi^-\pi^0$ at the Belle II experiment — •Karlina Kröhnert, Priyanka Cheema, and Torben Ferber — Institute of Experimental Particle Physics, Karlsruhe Institute of Technology, Karlsruhe, Germany

Axion-like particles (ALPs) appear in different theoretical extensions to the Standard Model. This analysis targets ALPs within a mass range of 400 MeV to 1 GeV and with gluon couplings produced in hadronic B decays. A particularly interesting decay mode is $a \to \pi^+\pi^-\pi^0$ since, for ALP-gluon couplings within the reach of the Belle II sensitivity, it produces a long-lived ALP a.

Although large parts of the parameter space have been explored by beam dump experiments and former prompt searches by BaBar and Belle, the displaced signature of the ALP offers a promising possibility to significantly extend existing ALP-gluon coupling limits.

In this analysis we search for an ALP in $a \to \pi^+\pi^-\pi^0$ using $B \to Ka$ decays at Belle II. We highlight how the displaced signature offers the possibility of significantly suppressing the background, but leads to unique challenges regarding the π^0 reconstruction from displaced vertices.

This talk will show the status of this search and present sensitivity estimates based on the current Belle II data set.

T 10.3 Mon 16:45 KH 01.013

Search for Higgs decays into long-lived Axion-Like Particles with the ATLAS Experiment — •Janek Both, Volker Büscher, Christian Schmitt, and Emanuel Meuser — Johannes Gutenberg-Universität

Axion-Like Particles (ALPs) or more generally, pseudoscalars that are gauge singlets under the Standard Model gauge group, appear in many well-motivated extensions of the Standard Model. In scenarios where the ALP couples to the Higgs boson, collider searches can provide sensitivity to ALPs in the GeV range and thus offer a complementary approach to other experiments that mainly focus on lighter ALPs. Depending on the ALP lifetime, it might decay displaced from the primary vertex inside the calorimeters of the ATLAS detector. Such a decay leads to an exotic signature that clearly differs from promptly produced backgrounds, but also challenges conventional reconstruction and analysis methods.

In this talk, a search for Higgs boson decays into long-lived ALPs is presented. The analysis makes use of a graph neural network classifier that identifies ALP decays into photons within the ATLAS calorimeters. The analysis uses Run-3 data and a data driven background estimation. The search improves on the existing Run-2 analysis that focuses on promptly decaying ALPs.

T 10.4 Mon 17:00 KH 01.013

Search for top quark decays to long-lived axion-like particles (ALPs) with ATLAS: ALP candidate reconstruction — •Frederic Fischer, Martin Christiansen, Lucia Masetti, Hendrik Smitmanns, Jessica Höfner, and Annika Stein — Johannes Gutenberg-Universität Mainz, Institut für Physik

The Standard Model (SM), although it agrees with great precision with experimental measurements, is still insufficient to give answers to many fundamental questions. One prime example is the strong CP problem which axions could solve. Axions as well as the broader axion-like particles (ALPs) are introduced as electrically neutral scalar fields extending the SM to accomodate new physics. One way to approach ALPs is to parameterise ALP couplings to SM particles like top quarks. ALPs appear in flavour-changing exotic top decays where the top quark decays into an ALP and an up- or charm-quark. Within this decay mode, parts of the parameter space dictates ALPs to have lifetimes long enough to travel macroscopic distances before decaying. This search is dedicated to look for $t\bar{t}$ events with one SM leptonically decaying top quark and one exotically decaying top quark. In this topology the focus is on ALP decays in the hadronic calorimeter at ATLAS with a centre-of-mass energy of $\sqrt{s} = 13.6\,\mathrm{TeV}$. Being electrically neutral, they leave no signals in the ATLAS tracking system. Moreover, the ratio of signals in the electromagnetic calorimeter and hadronic calorimeter are used to suppress SM backgrounds. This talk presents the reconstruction strategy of the ALP candidate to be used in a search for long-lived ALPs from exotic top decays at ATLAS.

T 10.5 Mon 17:15 KH 01.013

Search for Axion-Like Particles via Top Quark Decays with ATLAS: Statistical Methods — •Martin Christiansen, Frederic Fischer, Annika Stein, Jessica Höfner, Hendrik Smitmanns, and Lucia Masetti — Johannes Gutenberg-Universität Mainz, Institut für Physik

A search for long-lived Axion-like particles (ALPs) originating from exotic top quark decays is performed using the ATLAS detector at a center-of-mass energy of $\sqrt{s} = 13.6\,\mathrm{TeV}$. ALPs can be investigated by parameterizing their couplings to Standard Model (SM) particles. This analysis targets top-antitop events characterized by one top quark decaying leptonically and one decaying via a flavour-changing neutral current $t \to a + u/c$, where a denotes the ALP. Portions of the viable parameter space predict ALP lifetimes sufficiently long for macroscopic displacement prior to decay. Focusing on ALPs decaying within the ATLAS hadronic calorimeter, the ratio of energy deposits in the electromagnetic and hadronic calorimeters is utilized to mitigate SM backgrounds. Statistical methods play an important role in this context. The event topology is reconstructed based on χ^2 minimization combined with b-tagging information, and the resulting loglikelihood score becomes relevant also for cutflow optimization. In addition, a Boosted Decision Tree is trained on the background and signal model. With the help of this multivariate analysis technique, variables are identified that are highly discriminative yet statistically independent and that can be used for data-driven methods, further improving the sensitivity of the analysis.

T 10.6 Mon 17:30 KH 01.013

Sensitivity of the FCC-ee to axion-like particles — Juliette Alimena[1], Freya Blekman[1,2], Jeremi Niedziela[1], Giacomo Polesello[3], •Anna Przybyl[1,2], and Lovisa Rygaard[1,2] — [1]Deutsches Elektronen-Synchrotron DESY, Notkestr. 85, 22607 Hamburg — [2]Universität Hamburg, Luruper Chaussee 149, 22761 Hamburg, Germany — [3]INFN Sezione di Pavia, Via Bassi 6, 27100 Pavia, Italy

The electron-positron stage of the Future Circular Collider (FCC-ee) has incredible potential for particle physics. Not only does the clean collision environment at this stage allow for high-precision measurements, but it also allows for direct searches for new particles. The FCC-ee is preferred by the German particle physics community as the next flagship collider at CERN, and it is scheduled to operate with center-of-mass energies at the Z pole, the WW threshold, the ZH production maximum, and the tt threshold.

Axion-like particles (ALPs) are pseudoscalars that appear in many extensions of the Standard Model of particle physics, and they could potentially explain the nature of dark matter. We study ALPs at the FCC-ee. This talk will present the sensitivity of the FCC-ee to ALPs at all planned center-of-mass energies.

T 10.7 Mon 17:45 KH 01.013

Searching for ALPs in $H \to 4K$ at FCC-ee — Juliette Alimena[1], •Sarah Alshamaily[2], Sofia Giappichini[2], Johannes

Hornung[2], Markus Klute[2], and Matteo Presilla[2] — [1]Deutsches Elektronen-Synchrotron (DESY), Hamburg, Germany — [2]Institute for Experimental Particle Physics (ETP), Karlsruhe Institute of Technology (KIT), Karlsruhe, Germany

This study investigates a rare Higgs decay at the Future Circular Collider (FCC-ee). The e^+e^- stage is investigated at a center-of-mass energy of 240 GeV, with an integrated luminosity of 10.8 ab^{-1}. Following the axion-like particle (ALP) effective theory framework of Bauer et al., which provides a model-independent description of light pseudoscalar particles that commonly arise in theories beyond the Standard Model, the processes explored are $e^+e^- \to ZH$, where the Higgs boson decays into a pair of ALPs that subsequently decay into pairs of charged kaons. FCC-ee is an excellent experimental environment for such a study due to the improved momentum resolution and clean environment compared to hadronic colliders. We explored the parameter space where ALPs are long-lived particles, where background can be almost fully eliminated by exploiting their displaced decay vertices, obtaining sensitivity contours and limits on the Higgs-ALP coupling.