8th Forward Physics Facility Meeting

Tuesday 21 January 2025 - Wednesday 22 January 2025

CERN

Book of Abstracts

Contents

Parallel 2 / 2

Tau polarization effects in $\nu_\tau/\bar{\nu}_\tau$ - tungsten interactions at the LHC energies

Authors: Diego Gratieri[1]; Reinaldo Francener[2]; Victor Gonçalves[3]

[1] *Universidade Federal Fluminense*

[2] *Universidade Estadual de Campinas*

[3] *Universidade Federal de Pelotas*

Corresponding Authors: reinaldofrancener@gmail.com, drgratieri@id.uff.br, barros@ufpel.edu.br

Considering that the study of neutrino - nucleus interactions with incident neutrino energy ranges in the GeV - TeV range is feasible at the Large Hadron Collider, we investigate in this work the degree of polarization $calP$ of the (anti) tau lepton produced in (anti) tau neutrino - tungsten interactions. In this study we also investigate the impact of the tau polarization on the pions generated in its decay. In particular, we estimate the associated pion momentum, energy and angular distributions. The contribution of the F_5 structure function to these observables is also investigated. Our results indicate that the pion properties are sensitive to the tau polarization state as well as to the magnitude of F_5.

Parallel 2 / 3

Unravelling New Physics Signals at the HL-LHC with Low-Energy Constraints

Authors: Elie Hammou[None]; Maria Ubiali[1]

[1] *University of Cambridge (GB)*

Corresponding Authors: eh651@cam.ac.uk, ubiali@hep.phy.cam.ac.uk

Recent studies suggest that global fits of Parton Distribution Functions (PDFs) might inadvertently 'fit away' signs of new physics in the high-energy tails of the distributions measured at the high luminosity programme of the LHC (HL-LHC). This could lead to spurious effects that might conceal key BSM signatures and hinder the success of indirect searches for new physics. In this talk, I describe how future deep-inelastic scattering (DIS) measurements at the Electron-Ion Collider (EIC), and at CERN via FASERν and SND@LHC at LHC Run III, and the future neutrino experiments to be hosted at the proposed Forward Physics Facility (FPF) at the HL-LHC, provide complementary constraints on large-x sea quarks. These constraints are crucial to mitigate the risk of missing key BSM signals, by enabling precise constraints on large-x PDFs through a 'BSM-safe' integration of both high- and low-energy data, which is essential for a robust interpretation of the high-energy measurements.

Parallel 1 / 4

Cosmic Millicharge Background: Probing Reheating Cosmology, String Theory, and GUTs in FORMOSA & FPF

Author: Yu-Dai Tsai[1]

[1] *University of California, Irvine*

Corresponding Author: yudait1@uci.edu

We demonstrate that the searches for dark sector particles can provide probes of reheating scenarios, focusing on the cosmic millicharge background produced in the early universe. We discuss two types of millicharge particles (mCPs): either with, or without, an accompanying dark photon. These two types of mCPs have distinct theoretical motivations and cosmological signatures. We discuss constraints from the overproduction and mCP-baryon interactions of the mCP without an accompanying dark photon, with different reheating temperatures. We also consider the ΔNeff constraints on the mCPs from kinetic mixing, varying the reheating temperature. The regions of interest in which the accelerator and other experiments can probe the reheating scenarios are identified in this paper for both scenarios. These probes can potentially allow us to set an upper bound on the reheating temperature down to ~10 MeV, much lower than the previously considered upper bound from inflationary cosmology at around ~10ˆ16 GeV. In addition, we find parameter regions in which the two mCP scenarios may be differentiated by cosmological considerations. Finally, we discuss the implications of dedicated mCP searches and future CMB-S4 observations.

Parallel 2 / 5

FASERCal: High-Energy Neutrino Measurements at FASER

Author: Charlotte Cavanagh[1]

Co-authors: Andre Rubbia [1]; Anna Sfyrla [2]; Davide Sgalaberna [1]; Johannes Martin Wuthrich [1]; Umut Kose [3]

[1] *ETH Zurich (CH)*

[2] *Universite de Geneve (CH)*

[3] *ETH-Zurich*

Corresponding Authors: charlotte.cavanagh@cern.ch, umut.kose@cern.ch, andre.rubbia@cern.ch, anna.sfyrla@cern.ch, davide.sgalaberna@cern.ch, johannes.wuethrich@cern.ch

To address the challenges of higher muon background in addition to the increase in luminosity in LHC Run 4, ETH Zurich proposes a novel detector system which aims to provide highly granular 3D tracking, calorimetry and muon identification with a design that is compact, modular and scalable. The proposed FASERCal detector is designed to detect both charged-current and neutral-current neutrino interactions. FASERCal will consist of 15 modular units, each composed of 20 layers of optically-isolate 1 cm^3 plastic scintillator cubes inspired by the recent upgrade of the T2K near detector and 2 layers of high-resolution pixel detectors. Following the modules, the RearCal will provide an electromagnetic calorimeter containing 25 radiation lengths. Finally, the MuonTag component will consist of absorber and scintillator to provide identification for muons passing through the calorimeter.

Parallel 2 / 6

Data-driven constraints on the prompt neutrino fluxes

Authors: Felix Kling[1]; Jelle Koorn[None]; Juan Rojo Chacon[2]; Jukka John[3]; Peter Krack[None]

[1] *DESY*

[2] *Nikhef National institute for subatomic physics (NL)*

[3] *Nikhef Theory Group*

Corresponding Authors: pkrack@nikhef.nl, flxkling@gmail.com, j.rojo@cern.ch, jukkajohn2002@gmail.com, jkoorn@nikhef.nl

The detection of TeV-energy neutrinos by the LHC far-forward detectors FASER/FASERν and SND@LHC enables novel opportunities to validate theoretical predictions of of forward light particle production. In this work we present work in progress towards using the FASER and FPF event rate measurements to extract the LHC forward neutrino fluxes in a theory-agnostic manner by means of machine learning techniques. We parametrise these neutrino fluxes with neural networks and train them to available and projected FASER data, differential in neutrino energy and pseudo-rapidity. This way one can estimate the expected precision for this determination of the LHC neutrino fluxes and use this information to constrain models of forward D-meson production. This approach aims to demonstrate that FASER/FPF neutrino measurements provide an efficient data-driven approach to calibrate the prompt neutrino fluxes at neutrino telescopes such as IceCube and KM3NET.

Parallel 1 / 7

Discovering Light Scalars Beyond Minimal Flavor Violation

Authors: Jonathan Lee Feng[1]; Noam Burger[None]; Reuven Balkin[2]; Yael Shadmi[None]

[1] *University of California Irvine (US)*

[2] *UC Santa Cruz*

Corresponding Authors: yshadmi@physics.technion.ac.il, noam.burger@campus.technion.ac.il, rebalkin@ucsc.edu, jlf@uci.edu

We study a simple class of flavored scalar models, in which the couplings of a new light scalar to standard-model fermions are controlled by the flavor symmetry responsible for fermion masses and mixings. The scalar couplings are then aligned with the Yukawa matrices, with small but nonzero flavor-violating entries. D-meson decays are an important source of scalar production in these models, in contrast to models assuming minimal flavor violation, in which B and K decays dominate. We show that FASER2 can probe large portions of the parameter space of the models, with comparable numbers of scalars from B and D decays in some regions. If discovered, these particles will not only provide evidence of new physics, but they may also shed new light on the standard model flavor puzzle.

Parallel 2 / 9

Optical readout option for the FLArE detector

Author: k Mavrokoridis[1]

[1] *University of Liverpool (GB)*

Corresponding Author: k.mavrokoridis@cern.ch

I will present results obtained using the ARIADNE fast optical readout system and on how these inform the design of a FLArE optical LArTPC. A conceptual design of the FLArE TPC with a light readout plane and fast TimePix cameras will be discussed as well as a vacuum insulated cylindrical cryostat for this TPC option.

10

Opening Remarks from Organizers

Corresponding Authors: jamie.boyd@cern.ch, jlf@uci.edu

11

PBC and the FPF

Corresponding Author: gunar.schnell@cern.ch

12

New Results from FPF Pathfinder Experiments

Corresponding Author: michaela.queitsch-maitland@cern.ch

13

New Particles: Opportunities and Perspectives

Corresponding Author: pospelov@umn.edu

14

Collider Neutrinos: Opportunities and Perspectives

Corresponding Author: flxkling@gmail.com

15

Civil Engineering: Update and Status

Corresponding Author: tamara.alice.bud@cern.ch

16

Integration: Update and Status

Corresponding Author: julien.prosic@cern.ch

17

An event generator for neutrino-induced Deep Inelastic Scattering and applications to neutrino astronomy

Corresponding Author: rgauld@mpp.mpg.de

18

An event generator for Lepton-Hadron Deep Inelastic Scattering at NLO+PS with POWHEG including mass effects

Corresponding Author: giovanni.limatola@unito.it

19

A Phenomenological Analysis of LHC Neutrino Scattering at NLO Accuracy Matched to Parton Showers

Corresponding Author: j.rojo@cern.ch

20

DIscussion

Corresponding Author: flxkling@gmail.com

21

FASERnu2

Corresponding Author: tomoko.ariga@cern.ch

22

FASER2

Corresponding Authors: alan.barr@physics.ox.ac.uk, alan.barr@cern.ch

23

FASER2 Magnet

24

FORMOSA

Corresponding Author: j.tafoya.vargas@cern.ch

25

FLArE Simulations

Corresponding Author: matteo.vicenzi@cern.ch

26

FLArE Design

Corresponding Author: slinden1@bnl.gov

27

LHC neutrinos in Surface Detectors

Corresponding Author: toni.makela@cern.ch

28

ESPPU: Document and Plans

Corresponding Authors: j.rojo@cern.ch, flxkling@gmail.com, alan.barr@physics.ox.ac.uk, alan.barr@cern.ch, jamie.boyd@cern.ch, aderoeck@cern.ch

29

Timeline, Funding, Project Management

Corresponding Authors: jamie.boyd@cern.ch, diwan@bnl.gov, aderoeck@cern.ch

Parallel 2 / 31

Sweeper Magnet study

Author: Kohei Chinone[1]

[1] *Chiba University (JP)*

Corresponding Author: kohei.chinone@cern.ch

At the FPF site, the background muon levels are expected to be similar to those at the current FASERν site. While the FASERν experiment requires replacing the detector 2-3 times per year, we aim to reduce this to once per year for FASERν2. To achieve this, We studied possibilities to use a sweeper magnet to reduce the background muons to one-third.
In this study, I performed GEANT4 simulations using background muons generated by BDSIM to evaluate the magnet's effects. The results demonstrate that the magnet can be effective depending on its placement. Furthermore, placing the magnet 370 meters from the ATLAS interaction point in the LHC tunnel and relocating the FPF to a position 700 meters away from the ATLAS IP was shown to reduce the background muons by up to 40%.

Parallel 1 / 32

Dark Vector Splitting Functions in Proton Bremsstrahlung

Authors: Adam Ritz[None]; Peter Reimitz[None]; Saeid Foroughi-Abari[None]

Corresponding Authors: saeidf@physics.carleton.ca, peter@if.usp.br, aritz@uvic.ca

Experiments at the Forward Physics Facility are sensitive to new weakly coupled degrees of freedom across a broad mass range. Among the various production modes in proton-proton collisions, bremsstrahlung is particularly important for dark sector degrees of freedom with masses between 0.5 and 2.0 GeV, due to mixing with hadronic resonances. In this talk, I will revisit the calculation of dark vector production via initial state radiation in non-single diffractive scattering, using an improved treatment of the splitting functions and timeline electromagnetic form factors at the proton vertex, including the dipole coupling. Resonant enhancements impact the sensitivity above the ρ/ω mass range. The approach is benchmarked by applying an analogous calculation to model inclusive ρ-meson production. (based on 2409.09123)

Parallel 1 / 33

FASER-2 simulation and detector design performance document

Authors: Josh McFayden[1]; Marija Vranjes Milosavljevic[2]; Olivier Salin[3]

[1] *University of Sussex*

[2] *Institute of Physics Belgrade (RS)*

[3] *Université Paris-Saclay*

Corresponding Authors: marija.vranjes.milosavljevic@cern.ch, olivier.salin@ens-paris-saclay.fr, joshua.angus.mcfayden@cern.ch

This talk will aim to present and discuss the in-progress FASER-2 simulation and detector design performance document, which outlines the physics goals, detector requirements, simulation studies, and conceptual design scenarios for the proposed detector. The simulation framework developed uses Geant4 to describe detector geometry for sensitivity studies, along with the ACTS toolkit for track reconstruction and track alignment. These tools enable detector optimisation studies to compare various magnet and tracker configurations, which can be performed using key metrics including momentum resolution, sensitivity to BSM scenarios, and geometrical acceptance to other FPF experiments. This document aims to serve as a reference for the FPF collaboration and a possible resource for the European Strategy Process and further.

Parallel 1 / 34

DELIGHT and FOREHUNT: dedicated detectors at FCC-hh for light long-lived particles

Authors: BIPLOB BHATTACHERJEE[1]; Herbi Dreiner[None]; NIVEDITA GHOSH[1]; Shigeki Matsumoto[2]; Rhitaja Sengupta[3]; Prabhat Solanki[4]

[1] *Indian Institute of Science*

[2] *Kavli IPMU*

[3] *BCTP and Physikalisches Institut der Universität Bonn, Germany*

[4] *Universita & INFN Pisa (IT)*

Corresponding Authors: ghosh.nive@gmail.com, biplob@iisc.ac.in, rsengupt@uni-bonn.de, shigeki.matsumoto@ipmu.jp, prabhat.solanki@cern.ch, dreiner@uni-bonn.de

Our efforts in searching for hints of new physics require close attention to the signatures of light particles arising in theories beyond the Standard Model (BSM) physics, as they could have eluded our searches. In many theories, these light BSM particles can have long lifetimes and are worth exploring. We focus on light long-lived particles (LLPs) coming from the decay of the discovered Higgs boson and B-mesons. Given the need to optimise the designs of dedicated LLP detectors for future colliders, we propose dedicated LLP detectors for the 100 TeV collider experiment, DELIGHT (Detector for long-lived particles at high energy of 100 TeV) and FOREHUNT (FORward Experiment for HUNdred TeV), and study their sensitivities for LLPs in the Higgs portal.

Parallel 1 / 35

Dark photon pair production via off-shell dark Higgs at FASER

Author: Yohei Nakashima[None]

Co-authors: Kento Asai [1]; Takashi Shimomura ; Takeshi Araki [2]

[1] *ICRR*

[2] *Ohu University*

Corresponding Authors: asai@hep-th.phys.s.u-tokyo.ac.jp, t-araki@den.ohu-u.ac.jp, nakashima.youhei.775@s.kyushu-u.ac.jp, shimomura@cc.miyazaki-u.ac.jp

We consider a dark photon model in which the dark U(1) gauge symmetry is spontaneously broken by a vacuum expectation value of a new scalar boson. We focus on the ForwArd Search ExpeRiment (FASER) and calculate its sensitivity to the dark photon produced from the off-shell decay of the new scalar boson. It is found that the off-shell production extends the sensitivity region beyond the kinematical threshold of the on-shell decay of the scalar boson, and that the sensitivity region can be spanned to unexplored region. We also show the parameter space in which perturbative calculation is valid for the unitarity of an S matrix.

Parallel 2 / 36

Discovering neutrino tridents at FASERν2

Author: Toni Makela[1]

Co-authors: Bei Zhou [2]; Keping Xie [3]; Sebastian Trojanowski ; Subir Sarkar [4]; Wolfgang Altmannshofer [5]

[1] *University of California, Irvine*

[2] *Fermilab*

[3] *Michigan State University*

[4] *University of Oxford*

[5] *UC Santa Cruz*

Corresponding Authors: xiekepi1@msu.edu, toni.makela@cern.ch, beizhousuper@gmail.com, subir.sarkar@physics.ox.ac.uk, waltmann@ucsc.edu, strojanowski@gmail.com

Neutrino trident production of di-lepton pairs is well recognized as a sensitive probe of both electroweak physics and physics beyond the Standard Model. Although a rare process, it could be significantly boosted by such new physics, and it also allows the electroweak theory to be tested in a new regime. We demonstrate that the forward neutrino physics program at the Large Hadron

Collider offers a promising opportunity to measure for the first time, dimuon neutrino tridents with a statistical significance exceeding 5σ, improving on the previous claims at the $\sim 3\sigma$ level by the CHARM-II and CCFR collaborations while accounting for additional backgrounds later identified by the NuTeV collaboration. We present predictions for various proposed experiments and outline a specific experimental strategy to identify the signal and mitigate backgrounds, based on "reverse tracking" dimuon pairs in the FASERν2 detector. We also discuss prospects for constraining beyond Standard Model contributions to neutrino trident rates at high energies.

Parallel 1 / 37

Exploring the LHC as a TeV Muon Beam Dump: Muonphilic Scalars at FASER

Author: Roshan Mammen Abraham[1]

[1] *University of California Irvine (US)*

Corresponding Author: rmammena@uci.edu

At FASER, neutrinos are predominantly produced from meson decays, which also result in an intense energetic flux of muons in the forward direction, which are regularly observed by FASER. So far, these muons are treated only as backgrounds to neutrino and new physics studies, and extensive effort is required to suppress them. Here, we consider the opposite scenario and use muons produced in the forward direction to produce new muonphilic scalars, which can then be searched for at the FASER detector. To minimize background for this search, we make use of an upgraded preshower component, which is expected be installed at FASER before the end of Run 3, and is capable of spatially resolving two energetic photons. We find that FASER and FASER2 can probe currently unconstrained regions of parameter space, including regions that can potentially explain the (g – 2)μ anomaly. This highlights the physics opportunities that the intense TeV muon beam at the LHC can bring.

Parallel 1 / 38

Unlocking the Inelastic Dark Matter Window with Vector Mediators

Authors: Ana Luisa Foguel da Silva[1]; Peter Reimitz[None]; Renata Zukanovich Funchal[None]

[1] *Universidade de São Paulo*

Corresponding Authors: afoguel@usp.br, zukanovich@gmail.com, peter@if.usp.br

Despite the robust cosmological and astrophysical evidence confirming the existence of a non-baryonic matter component in the Universe, the underlying nature of Dark Matter (DM) remains a mystery. Among the several possible scenarios, light DM candidates thermally produced in the early Universe are especially interesting, since their abundance could be set via the standard freeze-out mechanism. Additionally, new light states can present a rich phenomenology and are attracting increasing attention due to recent experimental capabilities to probe dark sectors with feeble interactions. In particular, inelastic DM (iDM) candidates are an appealing option, since they can avoid cosmic microwave background (CMB) radiation bounds as well as indirect and direct detection searches. Although such models have been intensively studied in the literature, the usual scenario is to consider a secluded dark photon mediator. In this work, we consider the case of iDM with general vector mediators and explore the consequences of such a choice in the relic density computation, as well as for the cosmological and experimental bounds. We examine models with couplings to baryon and lepton number and show new viable parameter regions for inelastic dark matter models. Especially, anomaly-free gauge groups with non-universal couplings to leptons open new windows of the parameter space

for thermal dark matter yet unexplored by experiments. We also provide a numerical Python library to compute the relic densities for user-defined gauge charges.

Parallel 2 / 39

FORTVNE: scintillator bar-tungsten detector for FASER upgrades

Authors: Wenjie Wu[1]; Wenjie Wu[1]

[1] *University of California, Irvine*

Corresponding Authors: wenjieww@uci.edu, wenjie.wu@cern.ch

We discuss results from simulations and CNNs to distinguish neutrino CC and NC events with a scintillator bar-tungsten detector in the FASER location.

40

Status of Neutrino Interactions with GENIE

Corresponding Author: alfonso.a.garcia@uv.es