



# **FPF Theory Workshop**

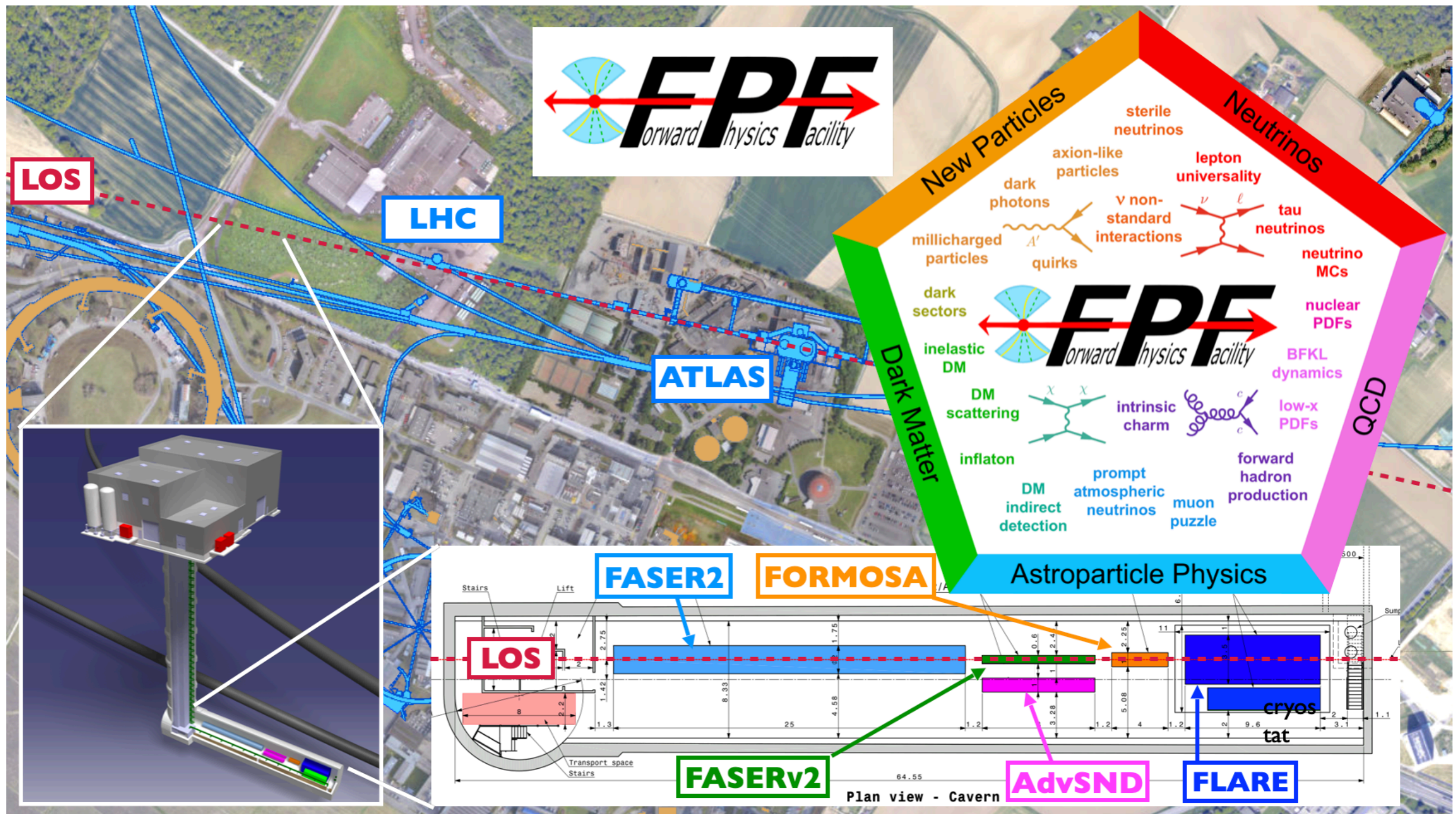
## **Introduction and Welcome**

**September 18th 2023**

**Felix Kling**

# The Forward Physics Facility

The FPF is a proposed facility that would house a suite of experiments to fully exploit the LHC's physics potential in the forward direction.





# Meetings and Documentation

**FPF workshop series:**

[FPF1](#), [FPF2](#), [FPF3](#),  
[FPF4](#), [FPF5](#), [FPF6](#)

**FPF Paper:**

[2109.10905](#)

~75 pages, ~80 authors

**Snowmass Whitepaper:**

[2203.05090](#)

~450 pages, ~250 authors

4th Forward Physics Facility Meeting

31 January 2022 to 1 February 2022  
Europe/Zurich timezone

Enter your search term

Overview

Call for Abstracts

Timetable

Contribution List

My Conference

My Contributions

Book of Abstracts

Registration

Participant List

Starts 31 Jan 2022, 16:00  
Ends 1 Feb 2022, 21:00  
Europe/Zurich

There are no materials yet.

The Forward Physics Facility (FPF) project is moving forward!

At the 4th Forward Physics Facility Meeting we will discuss the facility, experiments, and physics goals of the proposed FPF at the HL-LHC. The meeting takes place just before the completion of the FPF Snowmass White Paper and will provide an opportunity to summarize the current status of the White Paper and the final steps in its preparation. The whole event will be held online.

The Zoom links are:  
Plenary sessions (both Monday and Tuesday): <https://uci.zoom.us/j/91591021575>  
[u-iive.zoom.us](https://u-iive.zoom.us/j/94645515841)  
[RQnRzTjlpdz09](https://u-iive.zoom.us/j/94645515841)  
[s://uiowa.zoom.us/j/94645515841](https://u-iive.zoom.us/j/94645515841)  
[oom.us/j/97280888150](https://u-iive.zoom.us/j/97280888150)

**The Forward Physics Facility:  
Sites, Experiments, and Physics Potential**

Luis A. Anchordoqui,<sup>1,\*</sup> Akitaka Ariga,<sup>2,3</sup> Tomoko Ariga,<sup>4</sup> Weidong Bai,<sup>5</sup> Kincsó Balazs,<sup>6</sup> Brian Batell,<sup>7</sup> Jamie Boyd,<sup>6</sup> Joseph Bramante,<sup>8</sup> Adrian Carmona, Francesco G. Celiberto,<sup>11,12,13</sup> Grigorios Chachamis,<sup>14</sup> Matthew Citre, Albert de Roeck,<sup>6</sup> Hans Dembinski,<sup>18</sup> Peter B. Denton,<sup>19</sup> Antor Milind V. Diwan,<sup>20</sup> Liam Dougherty,<sup>21</sup> Herbi K. Dreiner,<sup>22</sup> Yong Yasaman Farzan,<sup>25</sup> Jonathan L. Feng,<sup>26,†</sup> Max Fieg,<sup>26</sup> Patric Foroughi-Abari,<sup>28</sup> Alexander Friedland,<sup>29,\*</sup> Michael Fucilla,<sup>30</sup> Maria Vittoria Garzelli,<sup>33,‡</sup> Francesco Giuliani,<sup>34</sup> Victor P. Gonca, Francis Halzen,<sup>37</sup> Juan Carlos Helo,<sup>38,39</sup> Christopher S. Hill,<sup>4</sup> Ameen Ismail,<sup>42</sup> Sudip Jana,<sup>43</sup> Yu Seon Jeong,<sup>44</sup> Krzysztof Jo Kumar,<sup>20</sup> Kevin J. Kelly,<sup>46</sup> Felix Kling,<sup>29,47,§</sup> Rafal Maciula, Abraham,<sup>41</sup> Julien Manshanden,<sup>33</sup> Josh McFayden,<sup>49</sup> Mohammed Pavel M. Nadolsky,<sup>50,\*</sup> Nobuchika Okada,<sup>51</sup> John Osborne,<sup>6</sup> Hic Pandey,<sup>52,46,\*</sup> Alessandro Papa,<sup>30,31</sup> Digesh Raut,<sup>53</sup> Mary Hall R Adam Ritz,<sup>28</sup> Juan Rojo,<sup>55</sup> Ina Sarcevic,<sup>56,\*</sup> Christiane Scherb Holger Schulz,<sup>59</sup> Dipan Sengupta,<sup>60</sup> Torbjörn Sjöstrand,<sup>61,\*</sup> Tyler B. Anna Stasto,<sup>62</sup> Antoni Szczurek,<sup>48</sup> Zahra Tabrizi,<sup>63</sup> Sebastian Yu-Dai Tsai,<sup>26,46</sup> Douglas Tuckler,<sup>66</sup> Martin W. Winkler,<sup>67</sup> Kepin

Submitted to the US Community Study  
on the Future of Particle Physics (Snowmass 2021)

**The Forward Physics Facility  
at the High-Luminosity LHC**

High energy collisions at the High-Luminosity Large Hadron Collider (LHC) produce a large number of particles along the beam collision axis, outside of the acceptance of existing LHC experiments. The proposed Forward Physics Facility (FPF), to be located several hundred meters from an LHC interaction point and shielded by concrete and rock, will host a suite of experiments to probe standard model processes and search for physics beyond the standard model (BSM). In this report, we review the status of the civil engineering plans and the experiments to explore the diverse physics signals that can be uniquely probed in the forward region. FPF experiments will be sensitive to a broad range of BSM physics through searches for new particle scattering or decay signatures and deviations from standard model expectations in high statistics analyses with TeV neutrinos in this low-background environment. High statistics neutrino detection will trace back to fundamental topics in perturbative and non-perturbative QCD and in weak interactions. Experiments at the FPF will enable synergies between forward particle production at the LHC and astroparticle physics to be exploited. We report here on these physics topics, on infrastructure, detector and simulation studies, and on future directions to realize the FPF's physics potential.

# FPF in Snowmass

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The FPF was prominently featured in many Snowmass Reports  
(Thanks to the efforts of many of you!)

*Additionally, auxiliary experiments and facilities are proposed to take advantage in far forward kinematic regions. Forward physics facilities allow to further extend the breadth of the HL-LHC physics: they can study regions of parameter phase space for BSM, for example in LLPs and DM searches, that would otherwise remain uncovered, and can perform novel QCD and neutrino measurements in the very forward region*

Vision Section of Energy Frontier Report

*Auxiliary forward-physics facilities will further extend the physics potential of the HL-LHC both for SM measurements and BSM discoveries. In view of all these considerations, the EF supports continued strong U.S. participation in the success of the LHC, and the HL-LHC construction, operations, and physics programs, including auxiliary experiments.*

Energy Frontier Section of Snowmass Summary Report

# FPF in Snowmass

## Executive Summary (10 pages)

**The Energy Frontier (Science Drivers 1 – 3 & 5):** The Energy Frontier currently has a top-notch program with the Large Hadron Collider (LHC) and its planned High Luminosity upgrade (HL-LHC) at CERN, which sets the basis for the Energy Frontier vision. The fundamental lessons learned from the LHC thus far are that a Higgs-like particle exists at 125 GeV and there is no obvious and unambiguous signal of BSM physics. This implies that new physics either occurs at scales higher than we have probed, must be weakly coupled to the SM, or is hidden in backgrounds at the LHC. The immediate goal for the Energy Frontier is to continue to take and analyze the data from LHC Run 3, which will go on for about three more years, and carry out the 2014 P5 recommendations to complete the HL-LHC Upgrade and execute its physics program. The HL-LHC will measure the properties of the Higgs Boson more precisely, probe the boundaries of the SM further, and possibly observe new physics or point us in a particular direction for discovery.

A new aspect of the proposed LHC program is the emergence of a variety of auxiliary experiments that can use the interactions already occurring in the existing collision regions during the normal LHC and HL-LHC running of the ATLAS, CMS, LHCb, and ALICE experiments to explore regions of discovery space that are not currently accessible. These typically involve observing particles in the far forward direction or long-lived particles produced at larger angles but decaying far outside the existing detectors. These are mid-scale detectors in their own right and provide room for additional innovation and leadership opportunities for younger physicists at the LHC. The EF supports continued strong U.S. participation in the success of the LHC, and the HL-LHC construction, operations, and physics programs, including auxiliary experiments.

New colliders are the ultimate tools to extend the EF program into the next two decades thanks to the broad and complementary set of measurements and searches they enable. With a combined strategy of precision measurements and high-energy exploration, future lepton colliders starting at energies as low as the Z-pole up to a few TeV can shed substantial light on some of these key questions. It will be crucial to find a way to carry out experiments at higher energy scales, directly probing new physics at the 10 TeV energy scale and beyond. The EF supports a fast start for the construction of an  $e^+e^-$  Higgs Factory (linear or circular), and a significant R&D program for multi-TeV colliders (hadron and muon). The realization of a Higgs Factory will require an immediate, vigorous, and targeted accelerator and detector R&D program, while the study towards multi-TeV colliders will need significant and long-term investments in a broad spectrum of R&D programs for accelerators and detectors.

Finally, the U.S. EF community has expressed renewed interest and ambition to develop options for an energy-frontier collider that could be sited in the U.S., while maintaining its international collaborative partnerships and obligations with, for example, CERN.

*A new aspect of the proposed LHC program is the emergence of a variety of auxiliary experiments that can use the interactions already occurring in the existing collision ... to explore regions of discovery space that are not currently accessible. These typically involve observing particles in the far forward direction or long-lived particles ... decaying far outside the existing detectors. These are mid-scale detectors in their own right and provide room for additional innovation and leadership opportunities for younger physicists at the LHC. The EF supports continued strong U.S. participation ... including auxiliary experiments.*

LHC

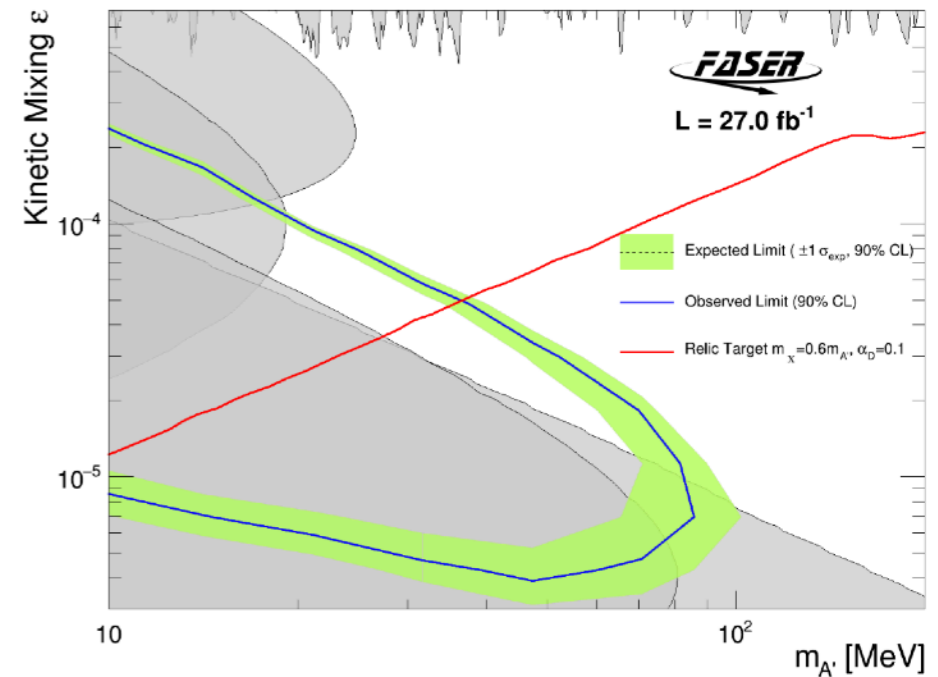
future collider



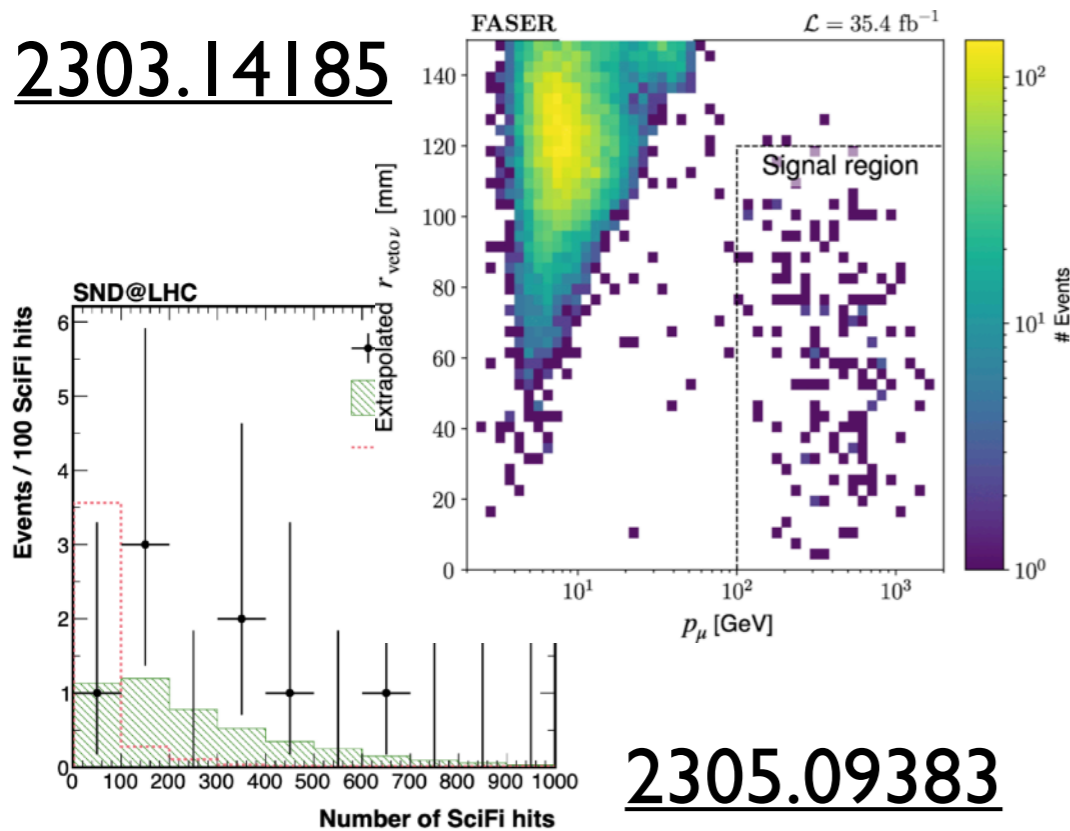
# News since FPF Whitepaper

## First experimental results from pathfinder experiments!

First search results on dark photons: [2308.05587](#)



[2303.14185](#)



[2305.09383](#)

First observation of collider neutrinos:  
153 events (FASER) + 8 events (SND@LHC)

Received lot's attention:  
[see here for viewpoints article](#)

### VIEWPOINT

## The Dawn of Collider Neutrino Physics

Elizabeth Worcester

Brookhaven National Laboratory, Upton, New York, US

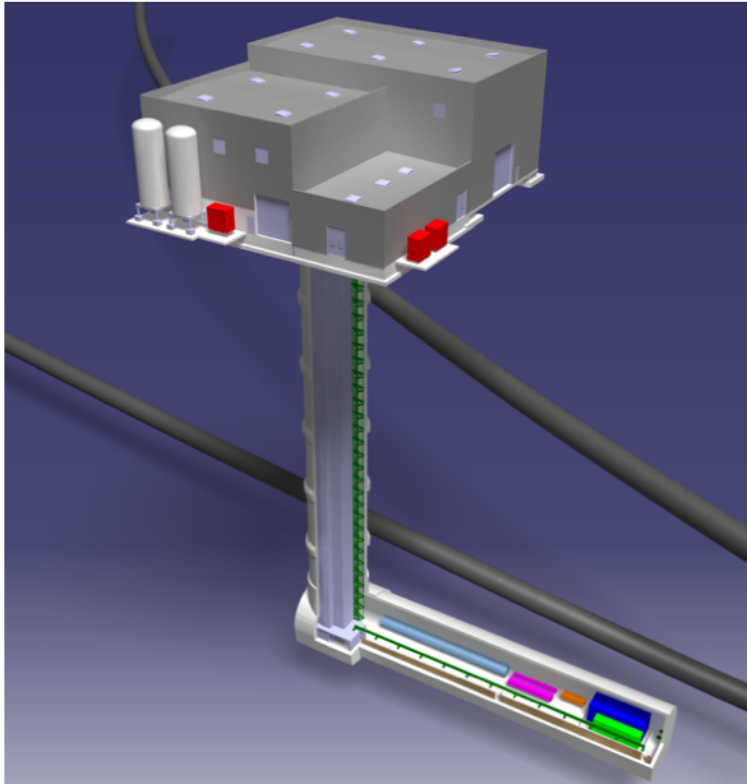
July 19, 2023 • *Physics* 16, 113

The first observation of neutrinos produced at a particle collider opens a new field of study and offers ways to test the limits of the standard model.

# News since FPF Whitepaper

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## Progress on design of FPF experiments



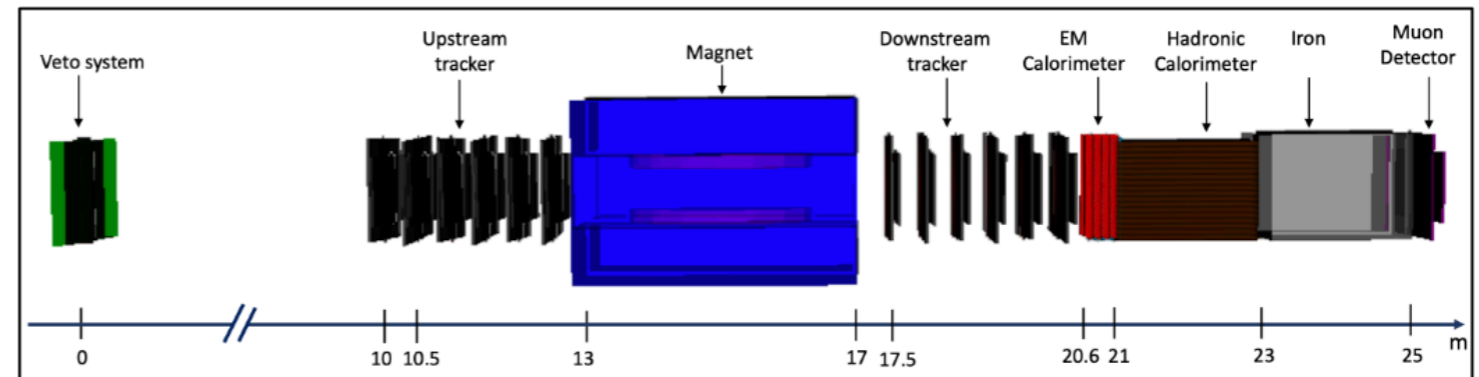
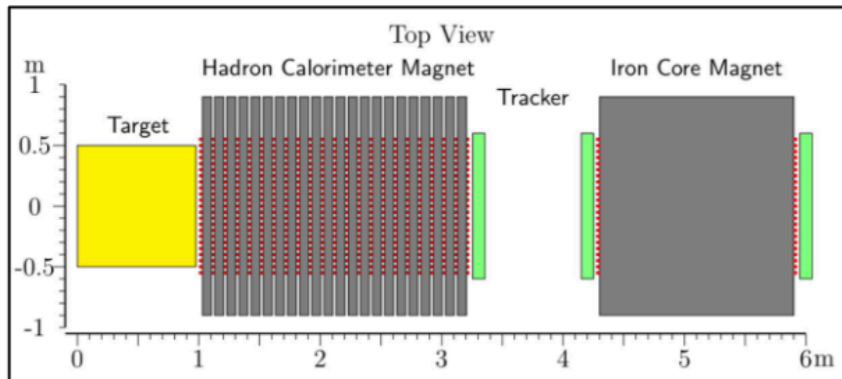
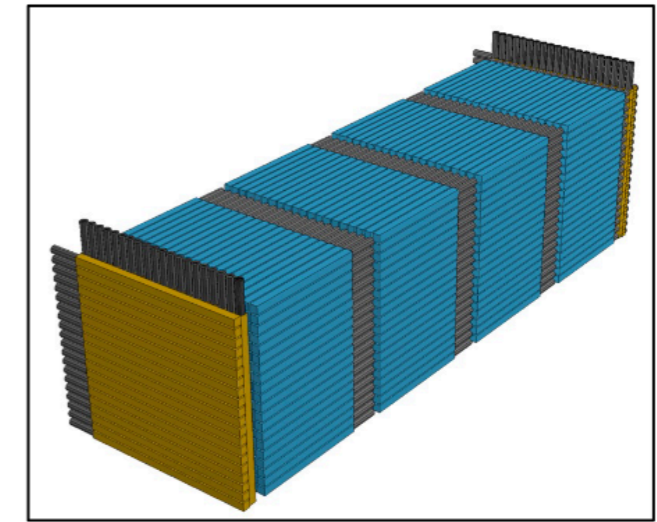
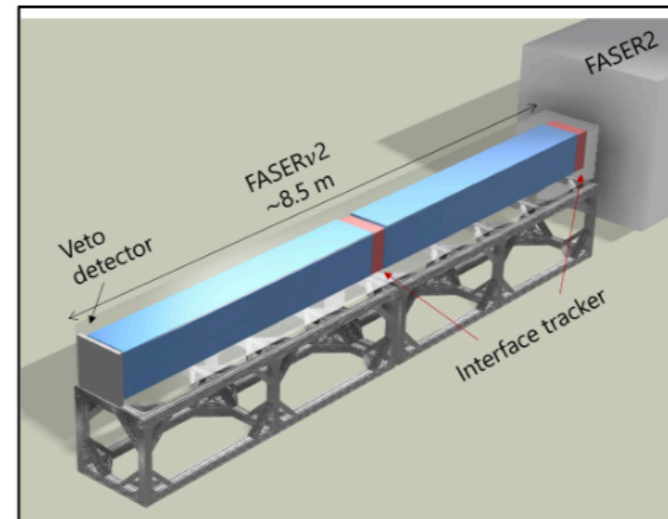
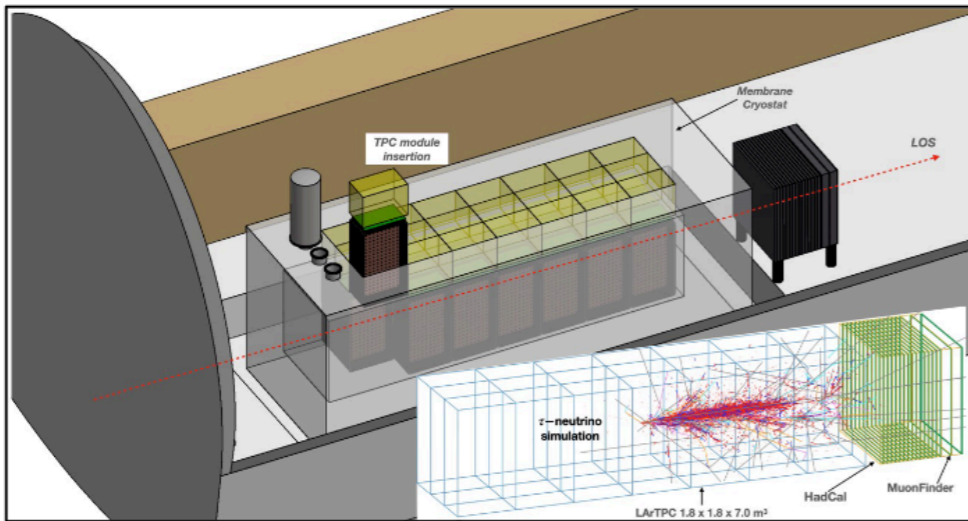
New results on civil engineering, ventilation, background particle rate, radiation protection studies, vibration studies: [CDS: 2851822](#)

100 m-deep core sample taken to study geology at the site



# News since FPF Whitepaper

## Progress on design of FPF experiments



Many recent results also summarized  
in [FPF P5 Input Document](#)



# Slack Channel

Much of the organization and communication of the FPF Working Groups takes place in the **FPF Slack Workspace**. To be added to this workspace, contact Juan Rojo (Nikhef).

The screenshot shows a Slack interface for a channel named "# general". The left sidebar lists various channels, including "wg1\_neutrino\_interactions" through "wg9\_formosa", and a "Channels hinzufügen" button. Below the channels are "Direktnachrichten" and a list of users including "Slackbot", "Felix Kling", "Bhavesh Chauhan", "Brian Batell", "Dennis Soldin", "Hallsie Reno", "Juan Rojo", "Tanjona Rabemananjara", and "Toni Mäkelä".

The main content area shows a message from "@Channel" dated "Samstag, 8. Juli". The message text is as follows:

Self-join invite link PPF Contacts +

@Channel Please see the meeting announcement below (it has also been sent to the FPF mailing list):

Dear Colleagues,

As plans for a dedicated Forward Physics Facility (FPF) at the LHC are picking up momentum, we are pleased to announce a topical workshop on theoretical and phenomenological developments related to the FPF.

This hybrid (in person + Zoom) workshop will take place on September 18+19, 2023 in the European afternoon, with the in-person component hosted at CERN.

The workshop's Indico page is <https://indico.cern.ch/event/1296658/>, where you will also find the registration form as well as the possibility to submit an abstract for a talk. Both in-person and on-line talks are encouraged. Applications for in-person participation and for contributed talks should be submitted before \*July 31st, 2023\*. (Applications for online-only participation will still be possible after that date.)

There is no registration fee, and limited travel support may be available through CERN's short-term visitor program in theoretical physics, which requires a separate application (<https://theory.cern/short-term-visitor-form>).

We hope to see many of you at CERN or on Zoom in September!

Luis Anchordoqui  
Brian Batell  
Felix Kling  
Joachim Kopp  
Juan Rojo  
Anna Stasto

**Indico**  
**Forward Physics Facility Theory Workshop**  
The goal of this hybrid workshop is to discuss physics opportunities at the proposed Forward Physics Facility at the LHC. Topics include High-energy neutrino interactions Forward meson production Hadron structure with neutrino beamsImplications to astroparticle physics (cosmic rays, UHE neutrinos)Searches for physics beyond the Standard ModelThe program will include presentations by the

The bottom of the screenshot shows the Slack message input area with a toolbar containing icons for bold, italic, link, list, code, and other formatting options. The text "Nachricht an #general" is visible in the input field.

# Organization

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**Steering Committee:** Jamie Boyd, Albert De Roeck, Milind Diwan, Jonathan Feng, Felix Kling

**WG0 Facility** Jamie Boyd (CERN)

**WG1 Neutrino Interactions** Juan Rojo (Nikhef)

**WG2 Charm Production** Anna Stasto (Penn State)

**WG3 Light Hadrons / Astroparticle** Luis Anchordoqui (Lehman), Dennis Soldin (KIT)

**WG4 New Physics** Brian Batell (Pittsburgh), Sebastian Trojanowski (Warsaw)

**WG5 FASER2** Alan Barr (Oxford), Josh McFayden (Sussex), Hide Otono (Kyushu)

**WG6 FASERnu2** Aki Ariga (Chiba), Tomoko Ariga (Kyushu)

**WG7 FLArE** Jianming Bian (UC Irvine), Milind Diwan (Brookhaven)

**WG8 Advanced SND** Giovanni De Lellis (Napoli)

**WG9 FORMOSA** Matthew Citron (UC Davis), Chris Hill (Ohio State)



**Physics**



**Detector**

# FPF Theory Workshop

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Theory and physics have been a main driver of the FPF since the beginning.

With the FPF maturing, the focus of the FPF meetings increasingly shifted towards experimental, technical and organizational discussions.

At the same time, a successful proposal for the FPF requires to further explore and quantify the physics sensitivity studies. In addition, the operating pathfinder experiments will also greatly benefit from further theory input.

Indeed, there have been a large number of interesting developments on the theory side in the last year.



**FPF Theory Workshop**



# FPF Theory Workshop

< Mon 18/09 Tue 19/09 All days >

Print PDF Full screen Detailed view Filter  
Session legend

BSM Physics Parallel Session  SM Physics Parallel Session

14:00	<b>Welcome and Introduction</b> 4/3-006 - TH Conference Room, CERN	Felix Kling et al. 14:00 - 14:20
	<b>Talk: FPF Connection to Astro-Particle Physics</b> 4/3-006 - TH Conference Room, CERN	Prof. Subir Sarkar 14:30 - 15:00
15:00	<b>Physics with Muons at the FPF</b> 4/3-006 - TH Conference Room, CERN	Alexander Sandrock et al. 15:00 - 16:00
16:00		
	<b>Looking forward to photon-coupled sub-GeV long-lived p...</b> Krzysztof Jodkowski	<b>Investigating the reach of FPF via information geometry ...</b> Dr Toni Makela
	<b>Light Scalars at FASER</b> 4/3-006 - TH Conference Room, CERN	<b>The Swampland and Neutrino Physics</b> 4/3-001, CERN
	<b>Quirks at the Forward Physics Facility</b> 4/3-006 - TH Conference Room, CERN	<b>Forward Neutrinos from Charm at Large Hadron Collider</b> Dr Atri Bhattacharya
17:00	<b>ISR and FSR of Dark Photons</b> 4/3-006 - TH Conference Room, CERN	<b>Forward D-meson production</b> 4/3-001, CERN
	<b>Benchmarking Proton Bremsstrahlung for Dark Sector Pr...</b> Saeid Foroughi-Abari	<b>CT18 Fitted Charm: possibilities at the Forward Physics ...</b> Dr TIMOTHY J HOBBS
	<b>SensCalc: public and unified calculations of sensitivities t...</b> Jean-Loup Tastet	<b>Tuning Pythia for Forward Particle Production at the FPF</b> Max Fieg
18:00	<b>Probing Reheating Cosmology at FORMOSA and FPF: Co</b> Yu-Dai Tsai	<b>Electromagnetic Properties of Neutrinos and the Weak M...</b> Roshan Mammen Abraham

< Mon 18/09 Tue 19/09 All days >

Print PDF Full screen Detailed view Filter  
Session legend

14:00	<b>Neutrino Cross Sections at TeV Energies</b> 4/3-006 - TH Conference Room, CERN	Dr Tanjona R. Rabemananjara et al. 14:00 - 14:30
	<b>Neutrino Interaction Tools for the FPF</b> 4/3-006 - TH Conference Room, CERN	Dr Alfonso Andres Garcia Soto 14:30 - 15:00
15:00	<b>BSM Physics Opportunities with LHC Neutrino Beams</b> 4/3-006 - TH Conference Room, CERN	Kevin James Kelly 15:00 - 15:30
	<b>Hadronic Physics in Neutrino Interactions and Complementarities to the EIC</b> 4/3-006 - TH Conference Room, CERN	Dr Ivan Vitev 15:30 - 16:00
16:00		
	<b>WG1 Summary: Neutrino Interactions and DIS</b> 4/3-006 - TH Conference Room, CERN	Dr Juan Rojo 16:30 - 16:45
	<b>WG2 Summary: Forward Charm Production</b> 4/3-006 - TH Conference Room, CERN	Anna Stasto 16:45 - 17:00
17:00	<b>WG3 Summary: Light Hadron Production and Astroparticle Connections</b> 4/3-006 - TH Conference Room, CERN	Dennis Soldin et al. 17:00 - 17:15
	<b>WG4 Summary: BSM Physics</b> 4/3-006 - TH Conference Room, CERN	Sebastian Trojanowski 17:15 - 17:30
	<b>Discussion and Next Steps</b> 4/3-006 - TH Conference Room, CERN	Felix Kling et al. 17:30 - 18:00
18:00		