

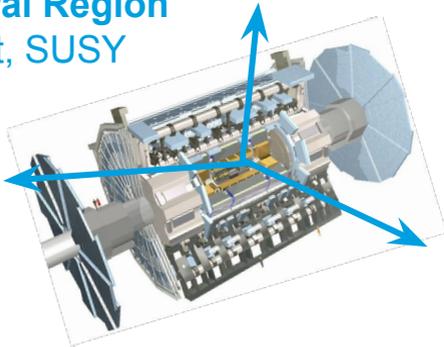
The Forward Physics Facility at the LHC.

Felix Kling
LLP 12 Workshop
11/03/2022



One Slide of Motivation.

Central Region
H, t, SUSY

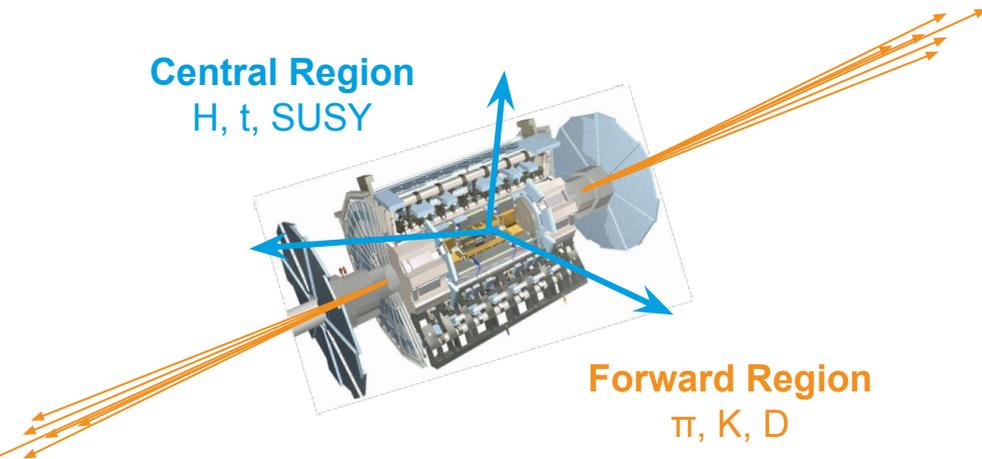


One Slide of Motivation.

The LHC produces an **intense** and strongly **collimated** beam of highly **energetic** particles in the forward direction.

10^{17} π^0 , 10^{16} η , 10^{15} D, 10^{13} B within 1 mrad of beam

Can we do something with that?

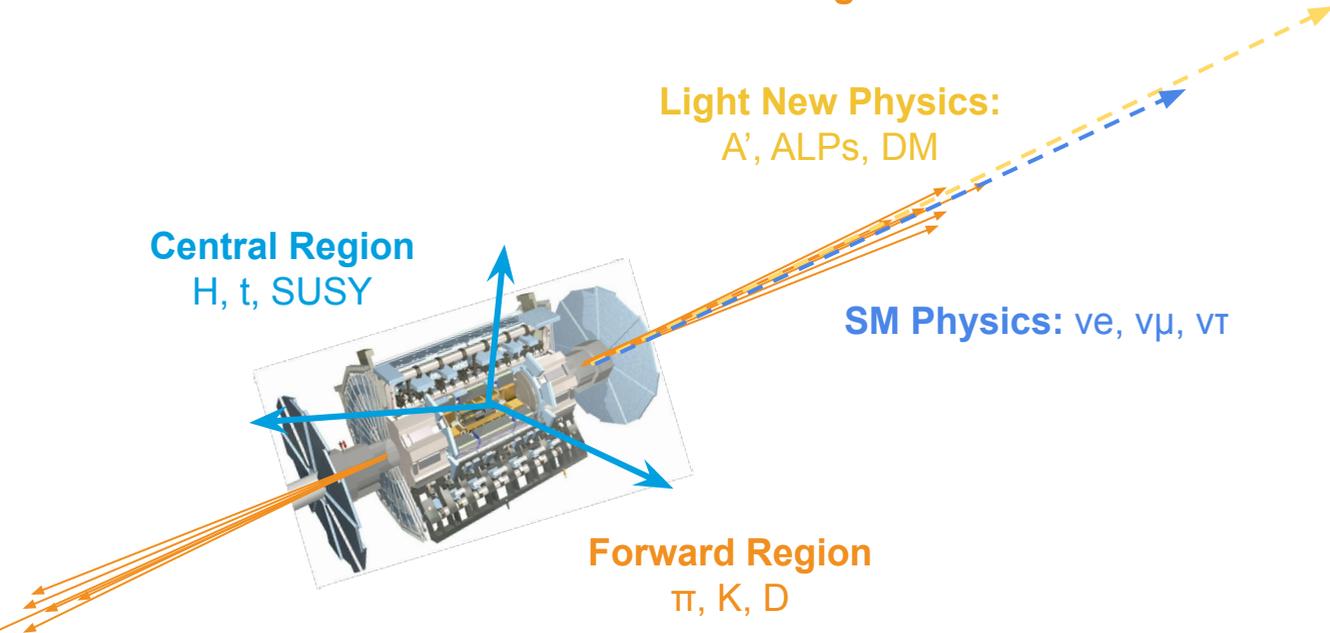


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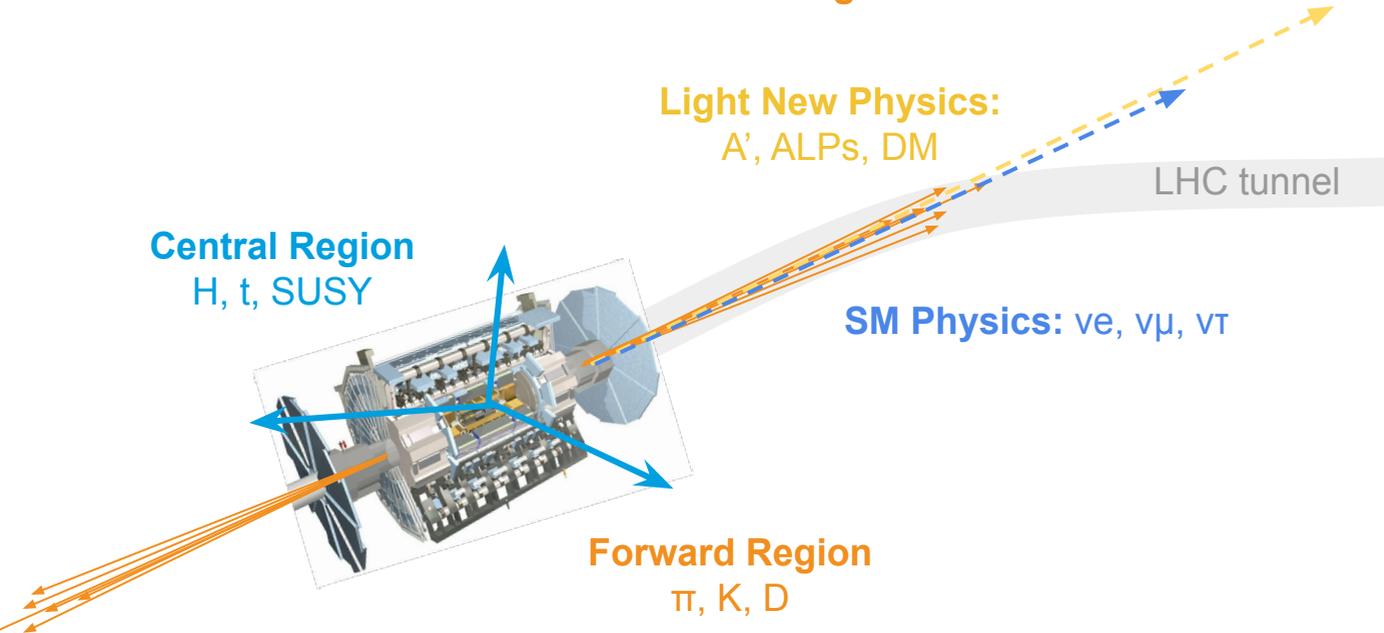


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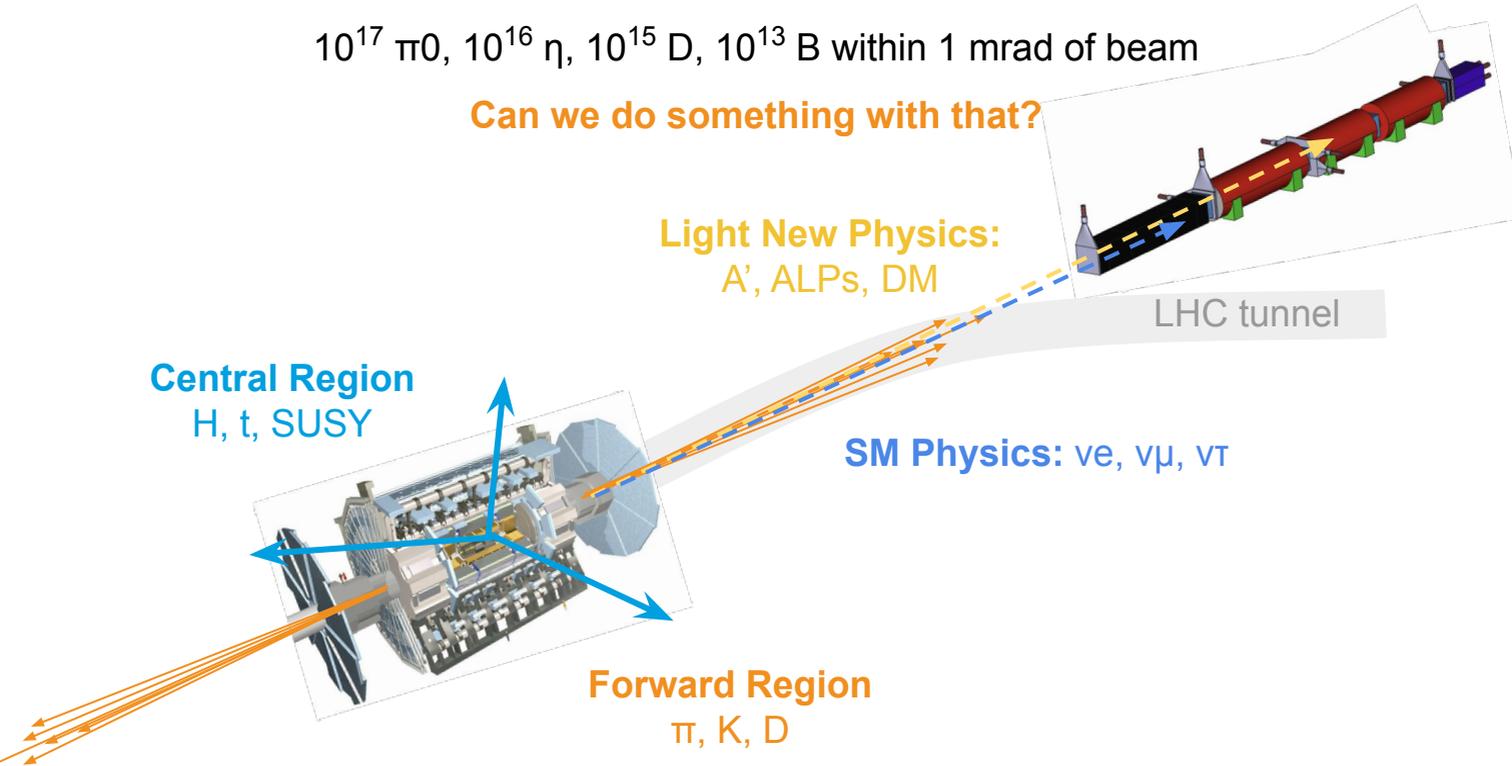
Light New Physics:
 A' , ALPs, DM

LHC tunnel

Central Region
 H , t , SUSY

SM Physics: ν_e , ν_μ , ν_τ

Forward Region
 π , K , D



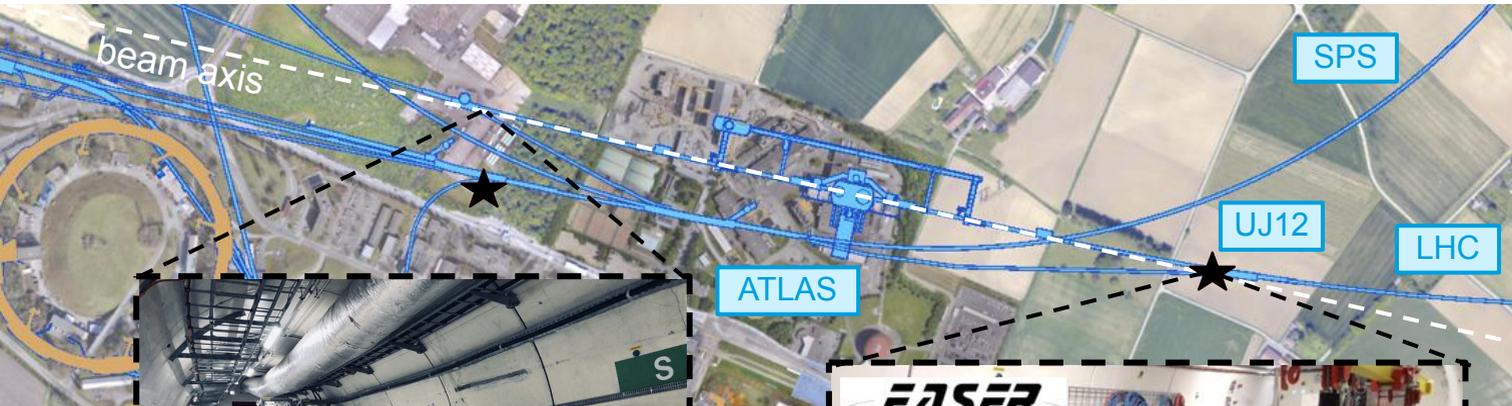
Facility and Experiments

Searches for Dark Sectors

Neutrino Measurements

Run3: FASER and SND@LHC.

Two new experiments have started their operation with the start of LHC Run 3:
SND@LHC and **FASER** (including **FASERv**).



SND@LHC:
Martina Ferrillo's talk

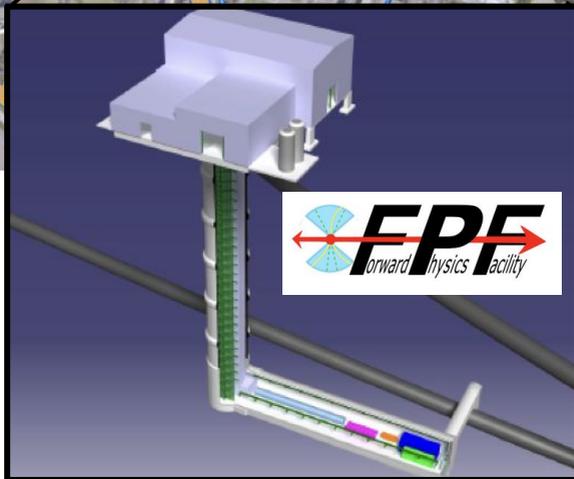
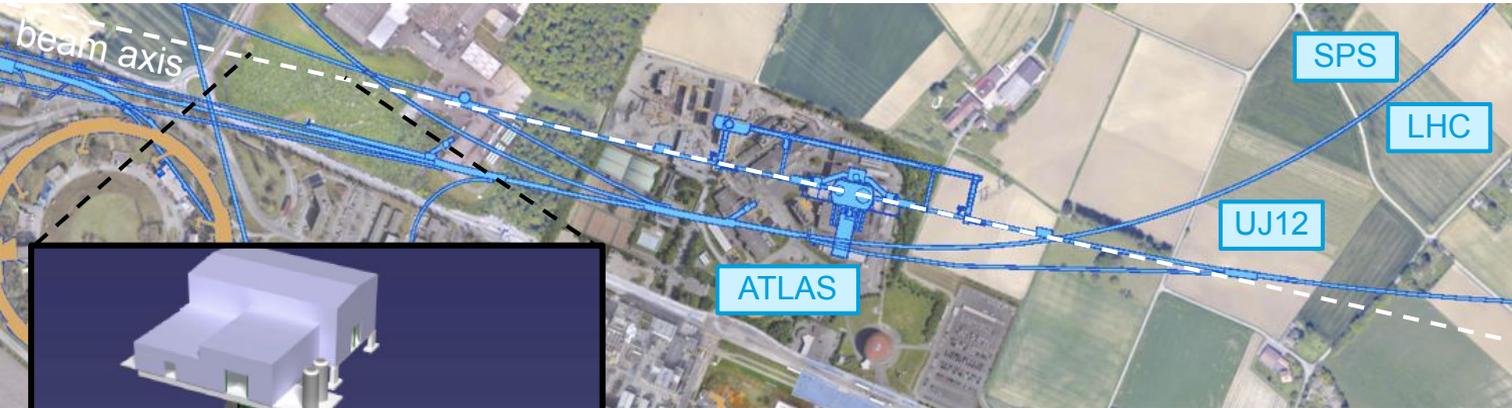


FASER:
Charlotte Cavanagh's talk

FASERv:
Hiroaki Kawahara's talk

Forwards Physics Facility.

FASER and SND@LHC are currently highly constrained by 1980's infrastructure that was never intended to support experiments



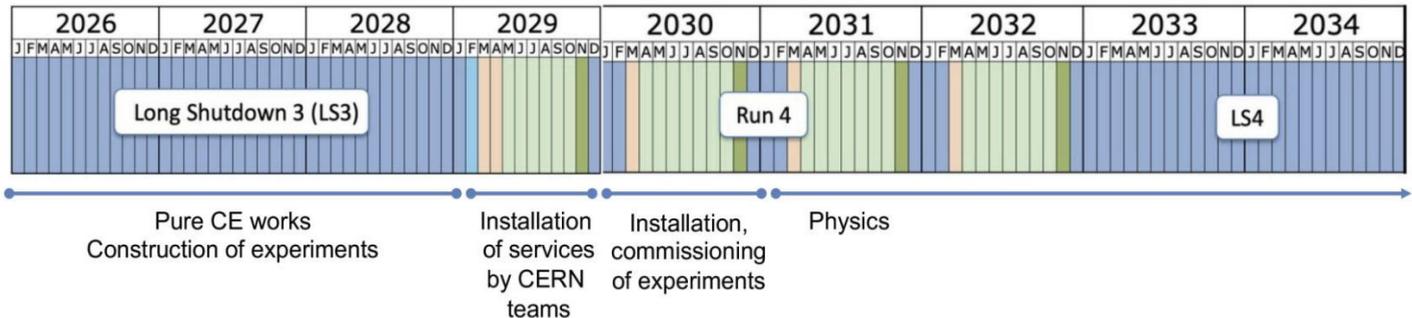
The proposal: create a dedicated **Forward Physics Facility (FPF)** for the HL-LHC.

FPF:Timeline.

radiation protection studies indicate that there is no danger from working in the FPF while the LHC is running

vibration studies indicate that construction of the FPF, installation of services, experiments, will not interfere with LHC operations

possible timeline presented at Chamonix (Jan 2022)



conceptual designs for the FPF and its 5 experiments by mid-2023

FPF: Documentation.

FPF workshop series:
[FPF1](#), [FPF2](#), [FPF3](#), [FPF4](#), [FPF5](#)

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:
Please see sessions (both Monday and Tuesday): <https://ucf.zoom.us/j/91591021570>
[live zoom us](https://ucf.zoom.us/j/91591021570)
<https://ucf.zoom.us/j/91591021570>
<https://ucf.zoom.us/j/91591021570>

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

Luis A. Anchordoqui,^{1,*} Akitaka Ariga,^{2,3} Tomoko Ariga,⁴ Weidong Bai,⁵ Kinoshita Balazs,⁶ Brian Batell,⁷ Jamie Boyd,⁸ Joseph Bramante,⁹ Adrian Carmona, Francesco C. Cellier,^{10,11,12} Gábor Cséreg, Chiara Dabaglio,¹³ Matthew Dole, Albert de Roeck,¹⁴ Hans Dembinski,¹⁵ Peter B. Denton,¹⁶ Anton Milad V. Divan,¹⁷ Liam Dougherty,¹⁸ Herbi K. Dreiner,¹⁹ Yong Yessman Farzan,²⁰ Jonathan L. Feng,^{20,1} Max Fieg,²⁶ Patrick Fowcight-Ahnt,²⁸ Alexander Friedland,^{29,1} Michael Fusella,³⁰ Maria Vittoria Garzelli,^{30,1} Francesco Giuli,³¹ Victor P. Gonzales Francis Halzen,³² Juan Carlos Hebo,^{33,39} Christopher S. Hill, Ameen Ismail,³³ Sulpit Jana,³³ Yu Seon Jeong,³⁴ Krzysztof Jo Koma,³⁵ Kevin J. Kelly,³⁶ Felix Kling,^{36,41} Rafael Maciula, Abraham,⁴² Julien Marchand,⁴³ Josh McFayden,⁴⁰ Mohammed Pavel M. Nadolsky,^{40,*} Nobuchika Okada,⁴¹ John Osborne,⁴ Ilia Pandoz,^{44,45} Alessandro Papa,⁴⁶ Digshi Ran,⁴⁷ May Hall R. Adam Ritz,⁴⁸ Juan Rojo,⁴⁹ Iva Starevic,^{50,*} Christiane Schab, Holger Schulz,⁴⁹ Dipan Sengupta,⁴⁰ Terjévi Sijstani,^{41,*} Tyler B. Anna Staato,⁴² Antoni Szczurek,⁴⁸ Zahra Tabrizi,⁴⁹ Sebastia Yu-Dai Tsai,^{45,46} Douglas Tucker,⁴⁶ Martin W. Winkler,⁴⁷ Kevin

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



The Forward Physics Facility at the High-Luminosity LHC

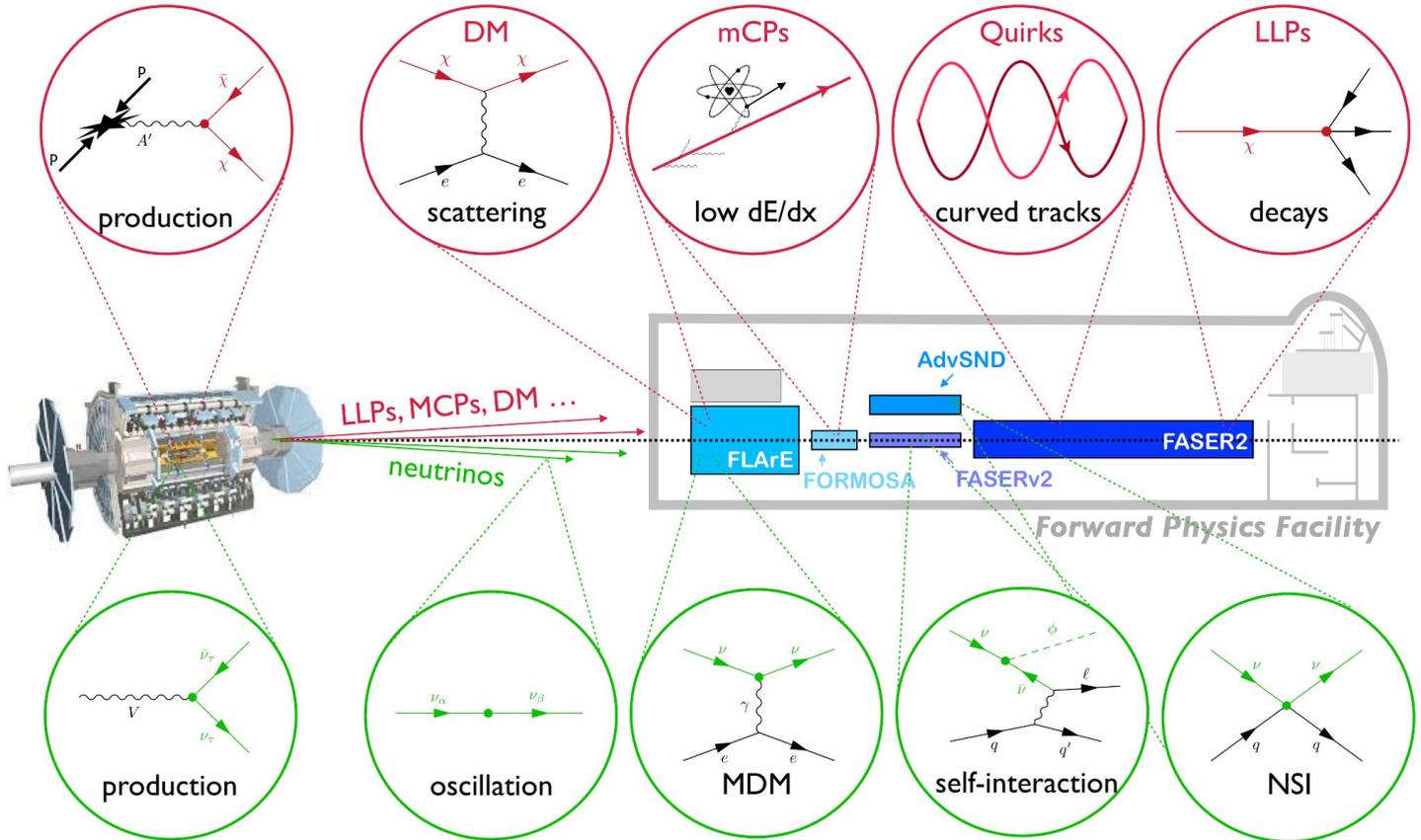
High energy collisions at the High-Luminosity Large Hadron Collider (LHC) produce a large number of particles along the beam collision axis, outside of the acceptance of existing LHC experiments. The proposed Forward Physics Facility (FPF), to be located several hundred meters from an LHC interaction 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.

Facility and Experiments

Searches for Dark Sectors

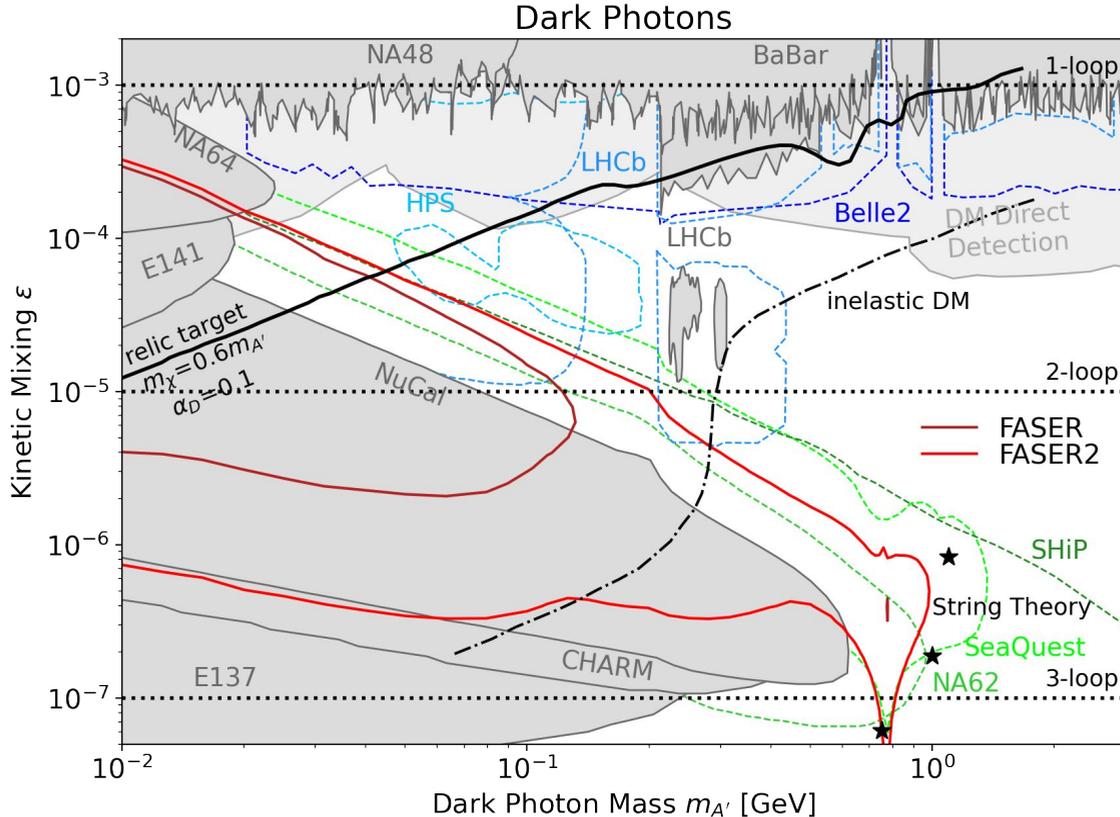
Neutrino Measurements

More Searches for BSM Physics



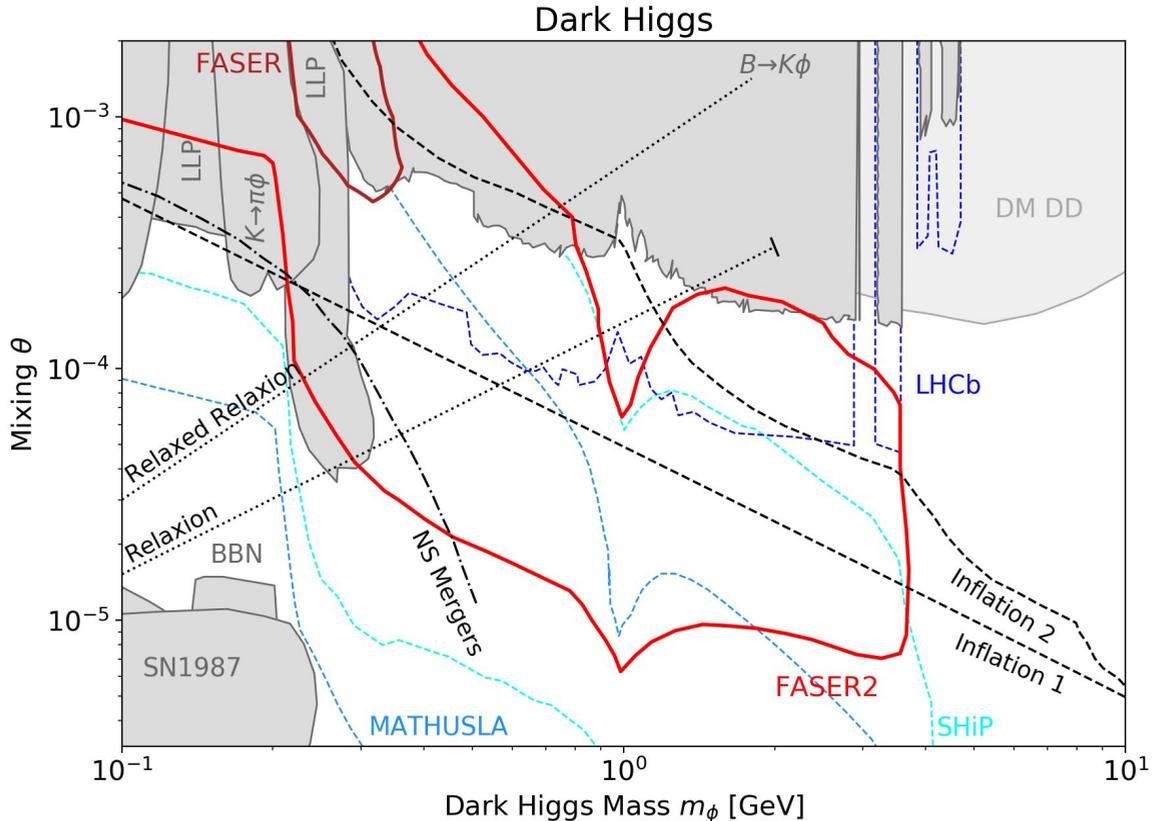
Long-Lived Particles: Dark Photon.

Dark Photon = gauge boson mixing with photon: $\mathcal{L} \sim -\frac{1}{2}m_{A'}^2 A'^2 - \epsilon e q_f \bar{f} A' f$



Long-Lived Particles: Dark Higgs.

Dark Higgs = light scalar mixing with SM Higgs: $\mathcal{L} \supset m_\phi^2 \phi^2 + \sin \theta y_f \phi f \bar{f}$

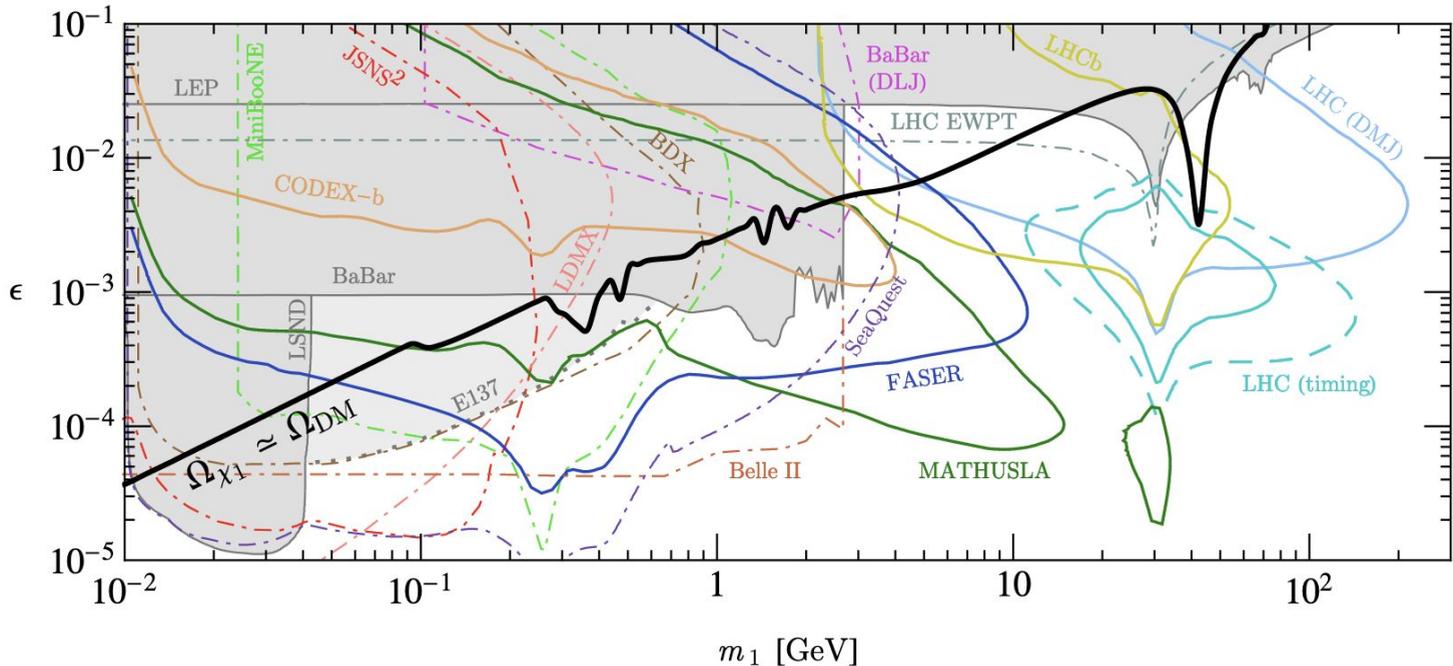


Long-Lived Particles: inelastic DM.

non-minimal model: here higher energy can really help

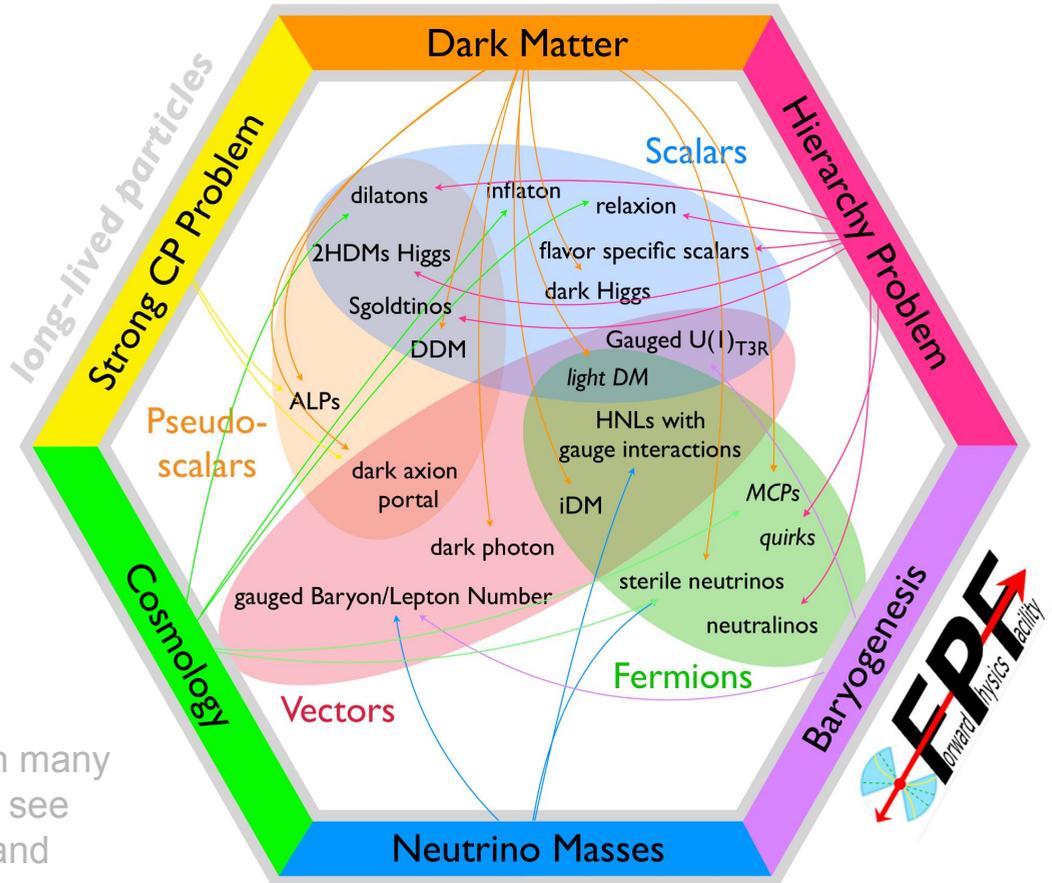
$$qq \rightarrow A' \rightarrow X1 X2 \quad X2 \rightarrow X1 + \text{SM}$$

Fermionic iDM, $m_{A'} = 3m_1$, $\Delta = 0.1$, $\alpha_D = 0.1$



For details see [1810.01879](https://arxiv.org/abs/1810.01879)

Long-Lived Particles.

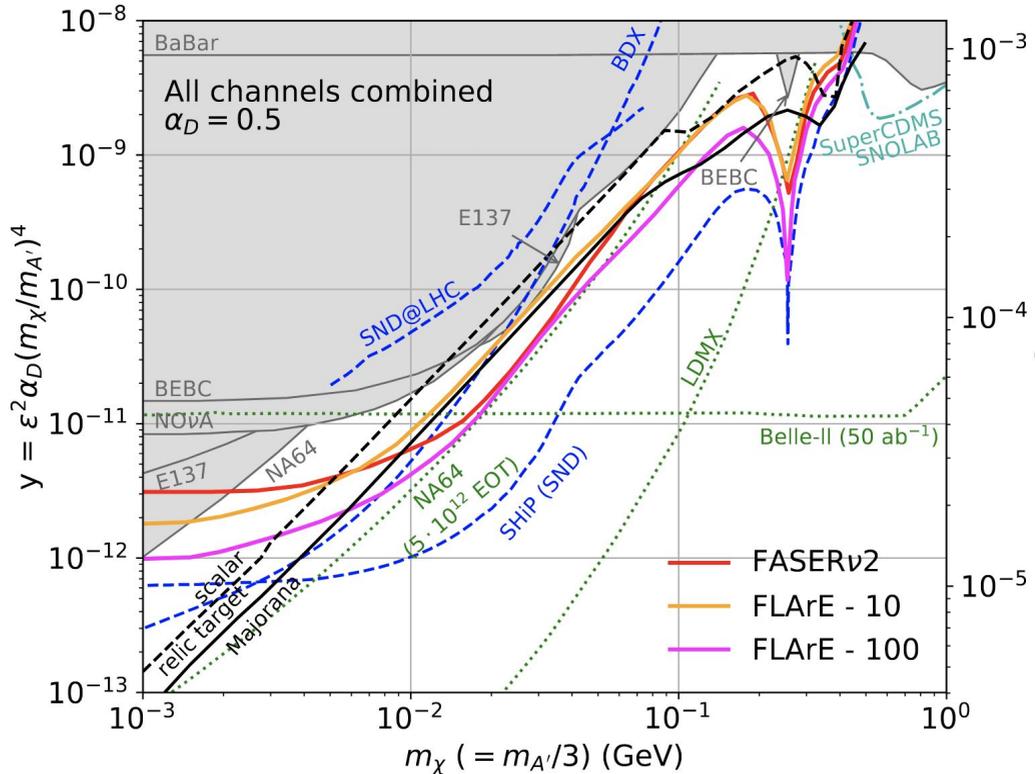


For details on many more models see [1811.12522](https://arxiv.org/abs/1811.12522) and [2203.05090](https://arxiv.org/abs/2203.05090).



Dark Matter Scattering.

$m_{A'} > 2m_X$
 ↓
 dark photon promptly
 decays in DM
 ↓
 LHC produces DM beam
 ↓
 DM scattering in
 neutrino detector



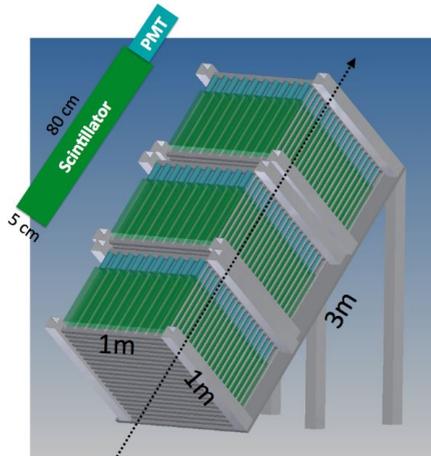
for more details see: [2101.10338](https://arxiv.org/abs/2101.10338)

MilliCharged Particles.

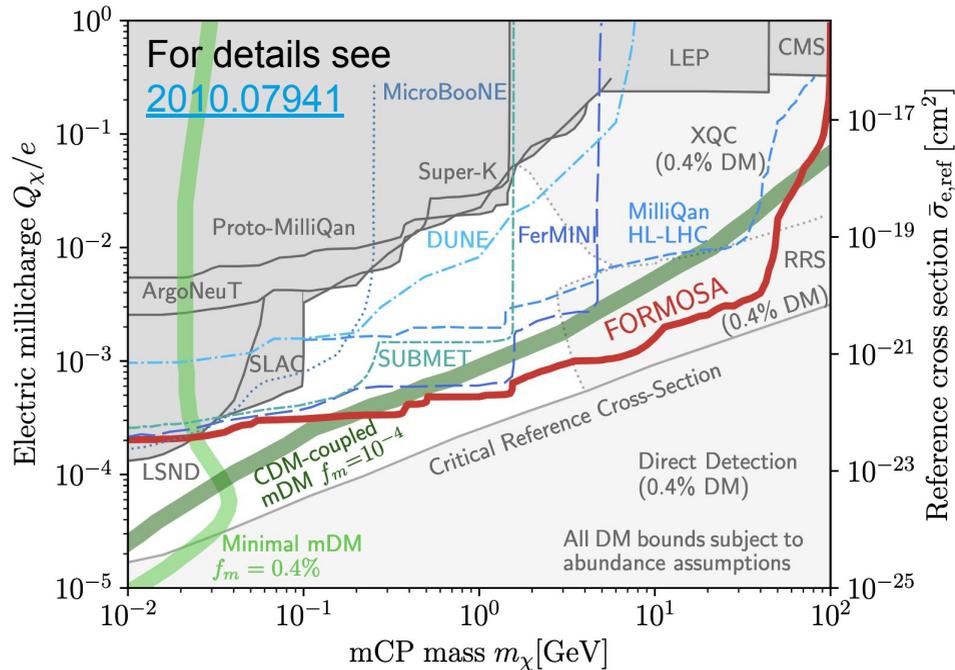
If $m_A=0$: X is effectively **milli-charged** with $Q=\epsilon e \rightarrow$ search for minimum ionizing particle with very small dE/dx

MilliQan was proposed as dedicated LHC experiment to search for MCPs near CMS

But it was noted that sigal flux is ~ 100 times larger in forward direction.



milliQan detector: [1607.04669](#)



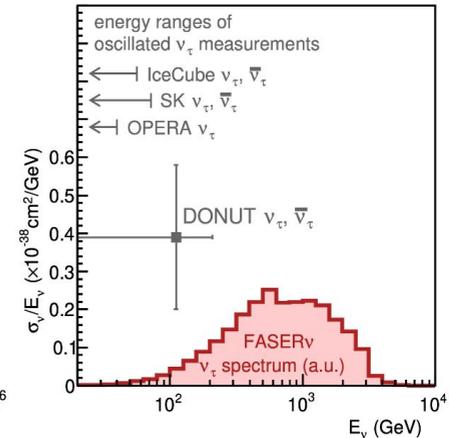
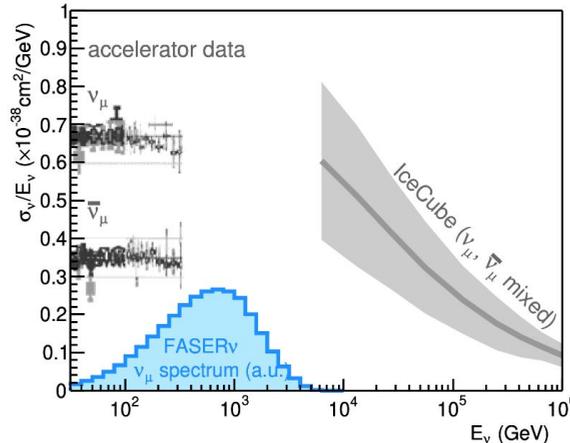
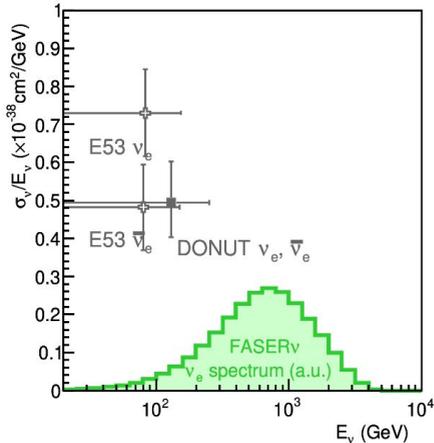
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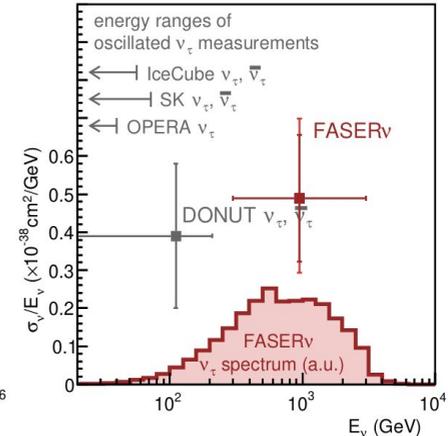
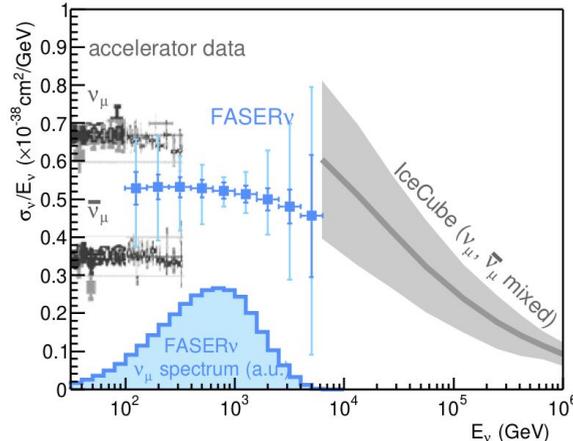
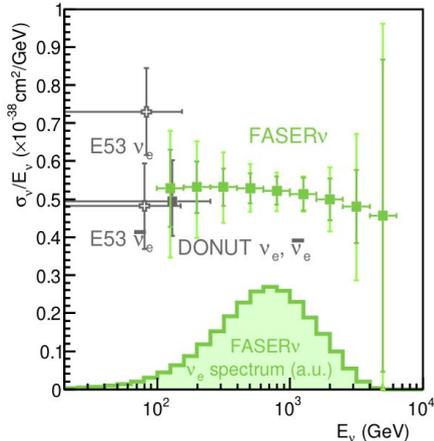
Neutrinos at the LHC.

LHC provides a **strongly collimated** beam of **TeV energy** neutrinos of **all three flavours** in the far forward direction.



Neutrinos at the LHC.

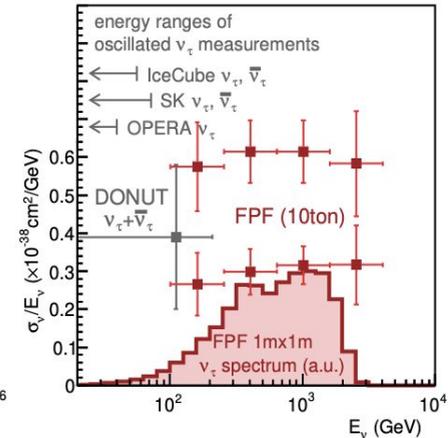
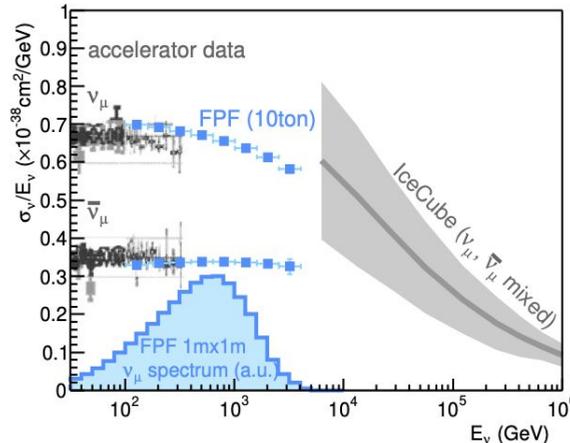
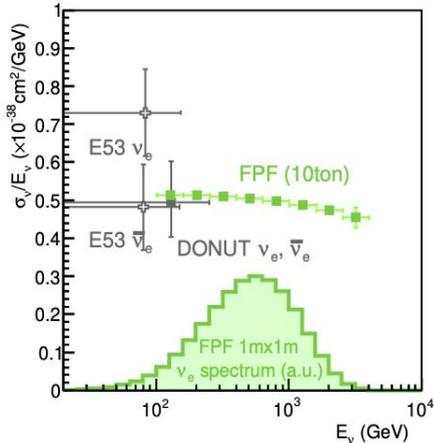
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FASERv and SND@LHC will detect O(10k) neutrinos.

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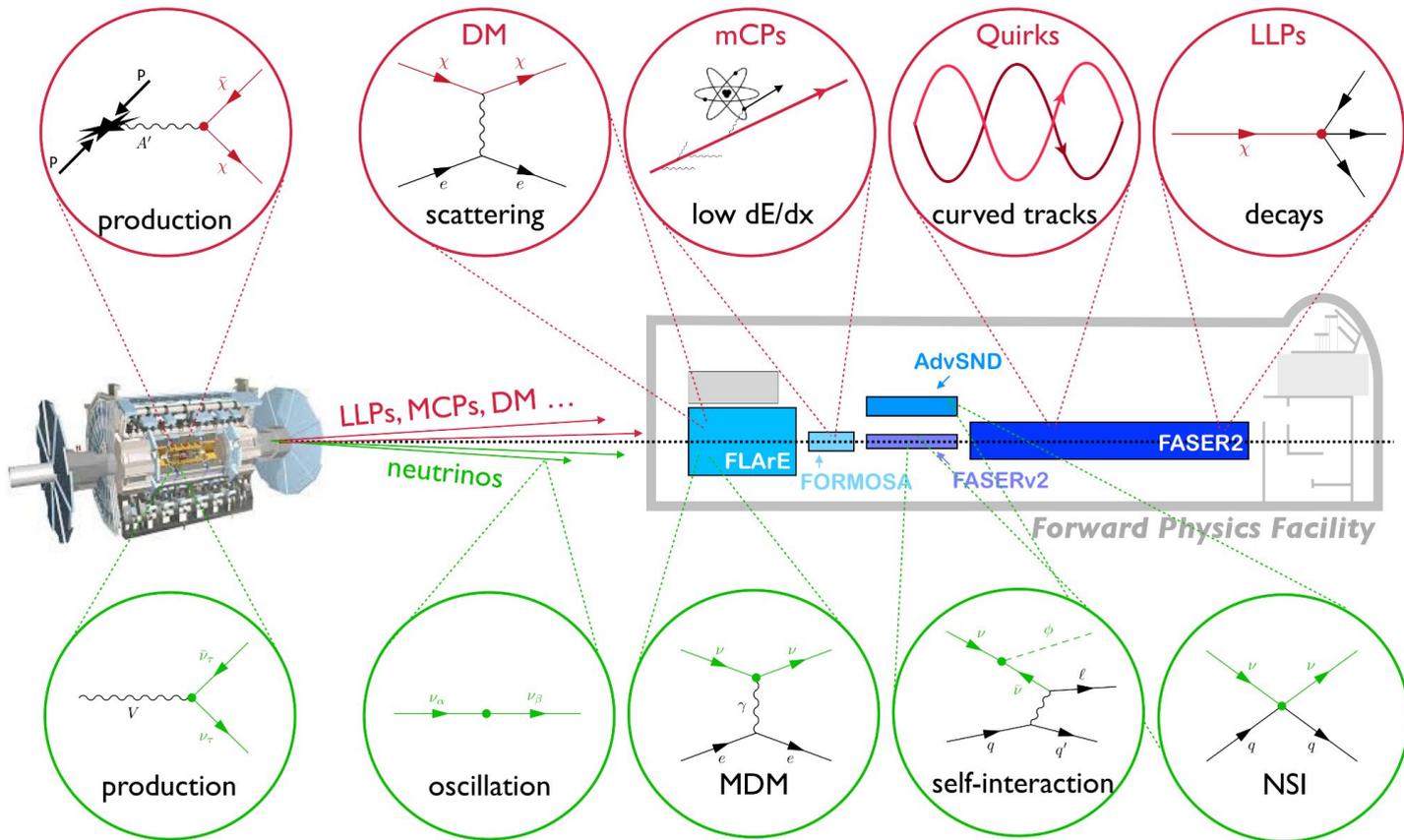
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FASERv and SND@LHC will detect O(10k) neutrinos.

Proposed FPF experiment have potential to detect O(1M) neutrinos.

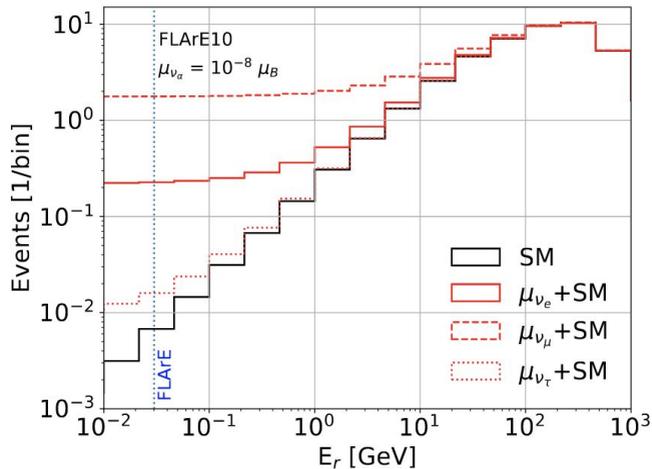
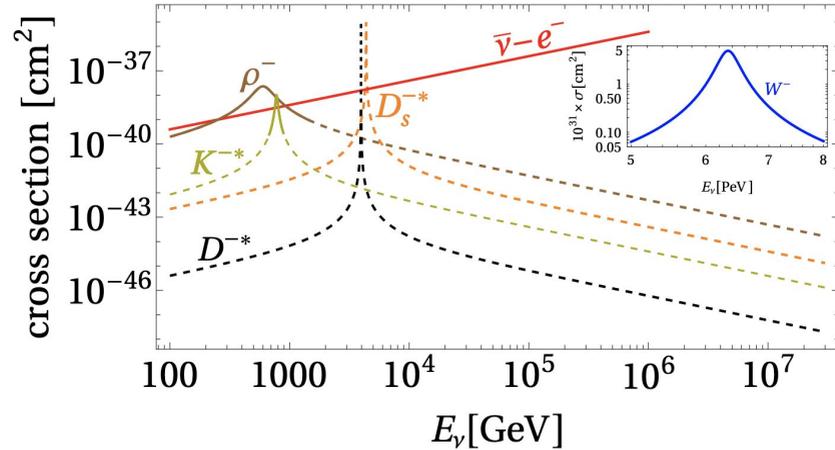
Neutrino BSM Physics



Application: Neutrinos Properties.

hadronic resonances in ν -e scattering

[Brdar et al: 2112.03283]

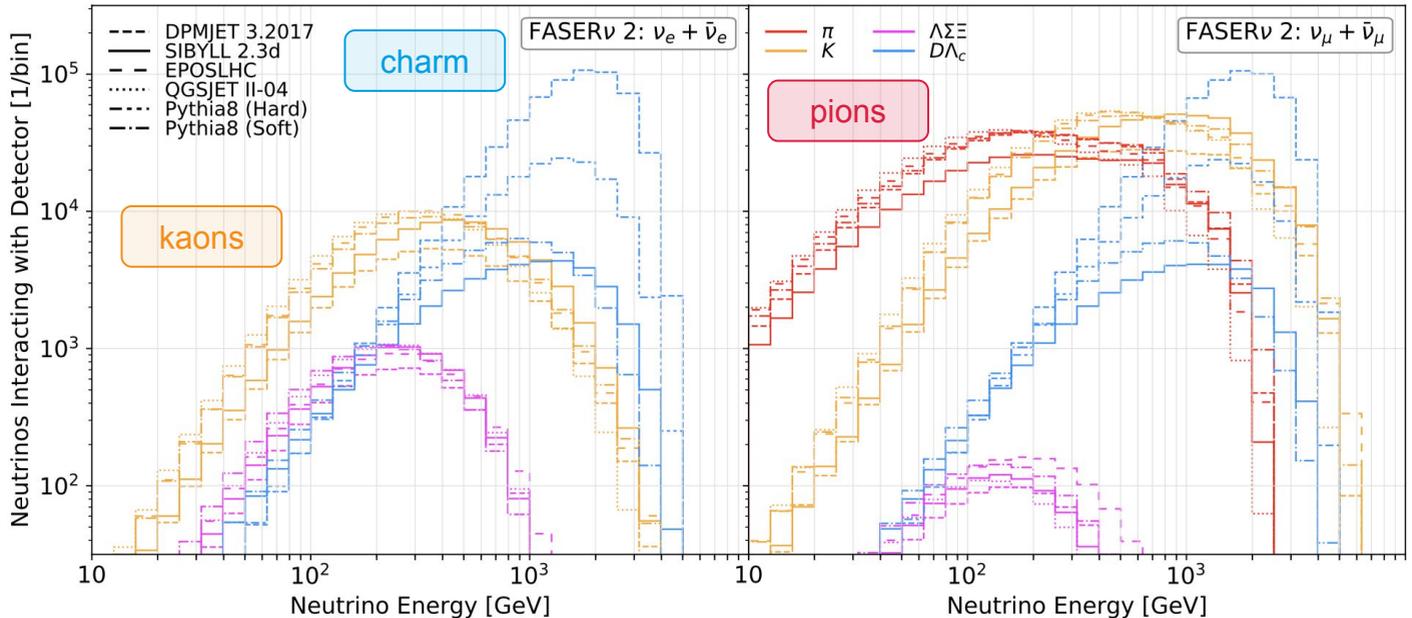


Neutrino electromagnetic properties

[Ismail et al: 2012.10500], [Ismail et al: 2109.05032]

Application: QCD.

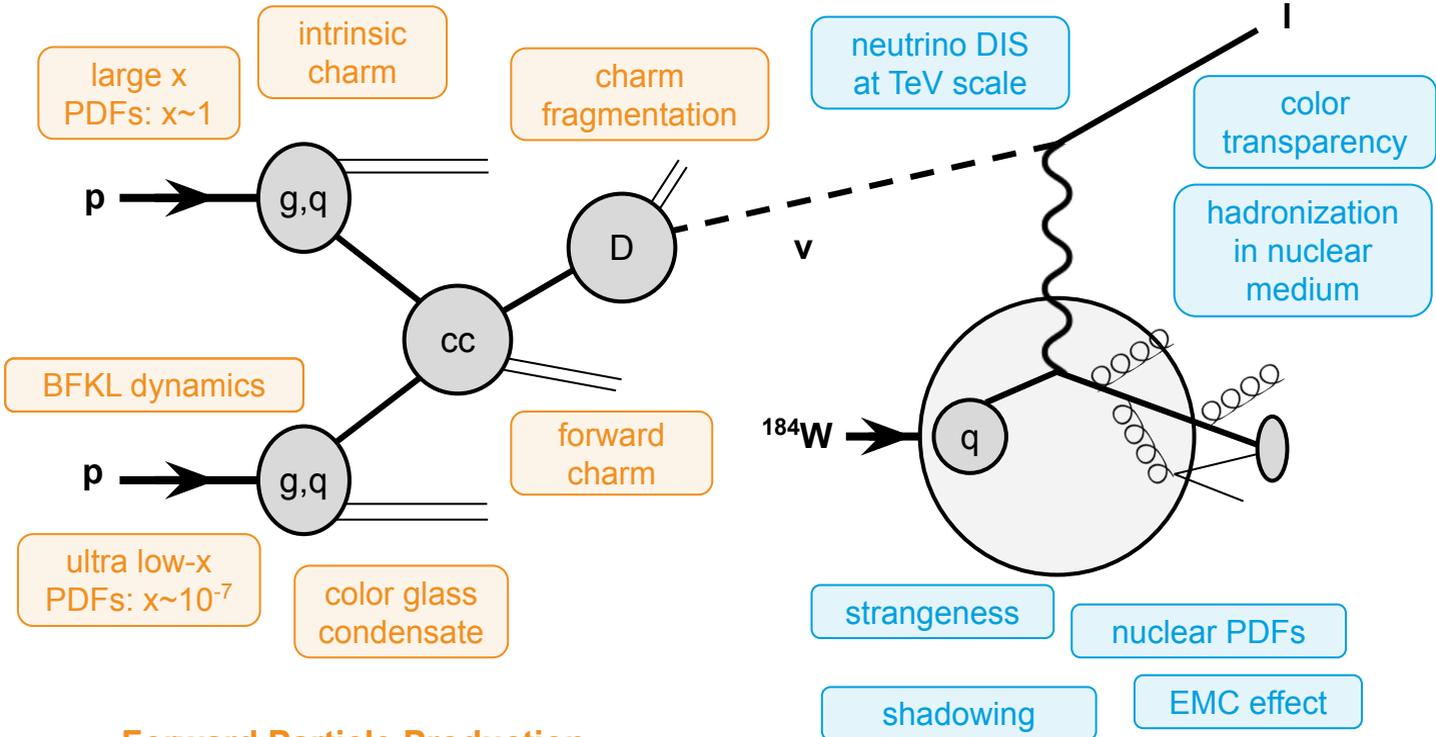
Where do the LHC neutrinos come from?



LHC neutrinos = probe of forward particle production

Application: QCD.

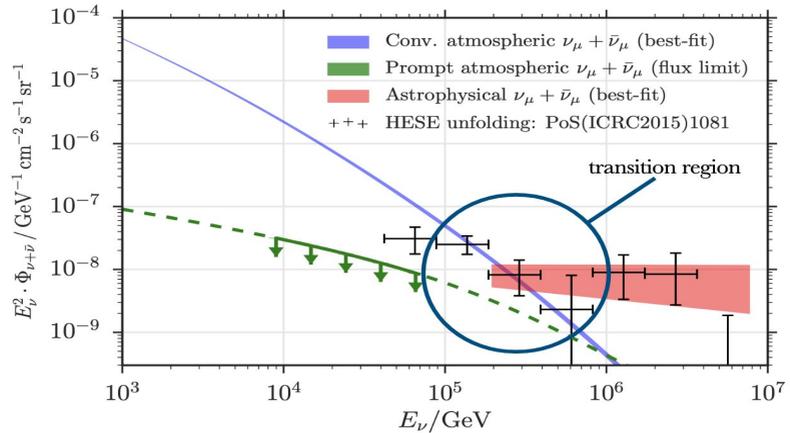
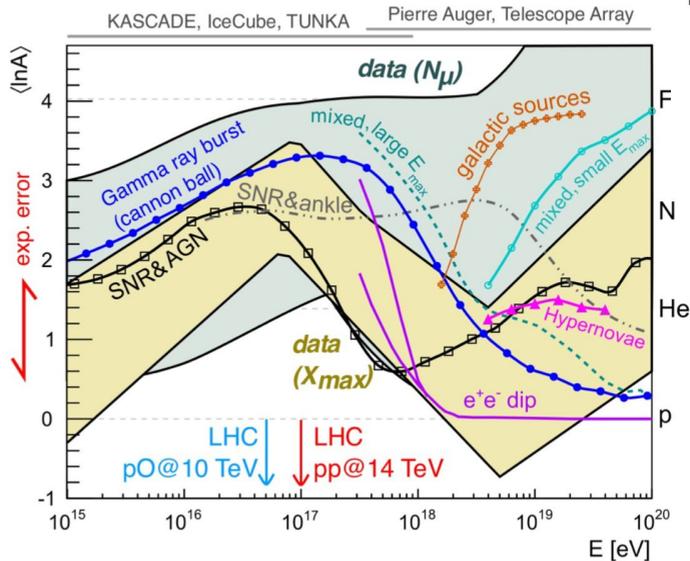
TeV Energy Neutrino Interaction



Forward Particle Production

Application: Astroparticle Physics.

forward **charm** production at the LHC
 ↓
 constraints on **prompt atmospheric neutrino flux** at IceCube



cosmic ray muon puzzle:
 observed excess of muons compared to hadronic interaction models

forward **pion/kaons** fluxes will provide crucial input

Summary.

FASER and SND@LHC have started to take data in LHC's forward direction.

The FPF is proposed to continue this program during the HL LHC era.

Significant extension of the LHC's physics program.

We invite the LLP community to participate in this program.
You are welcome to join!

For questions and comments, please contact me via felix.kling@desy.de

