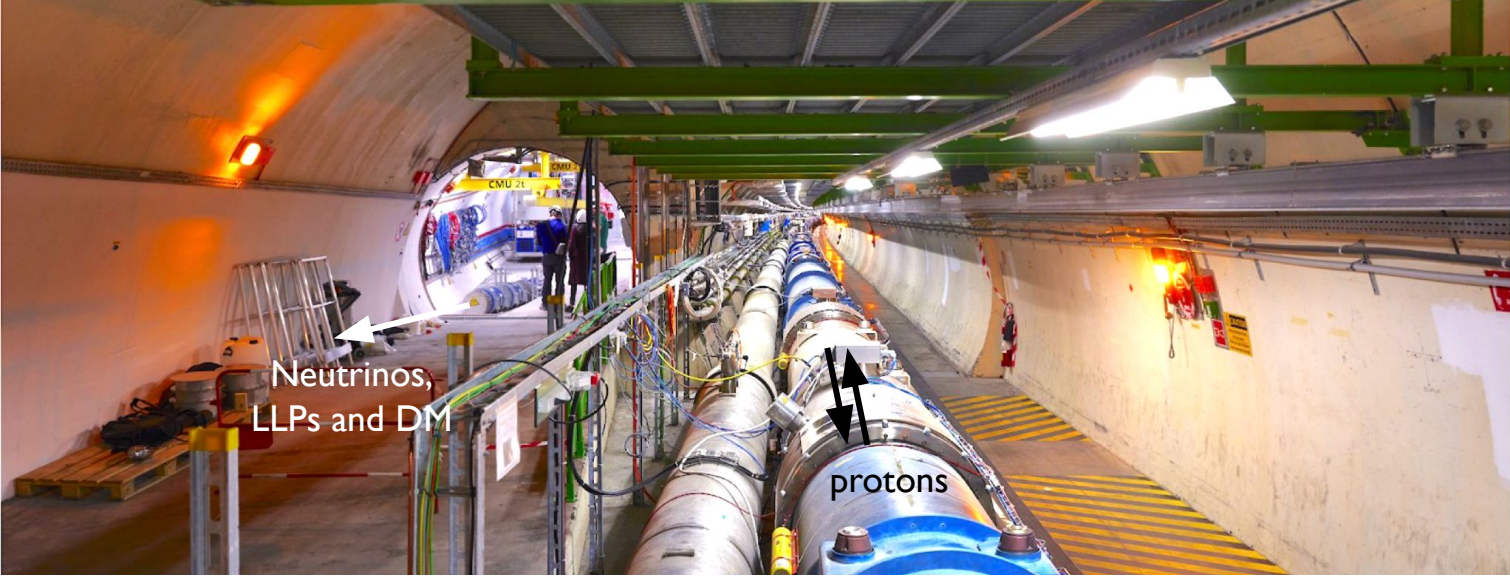
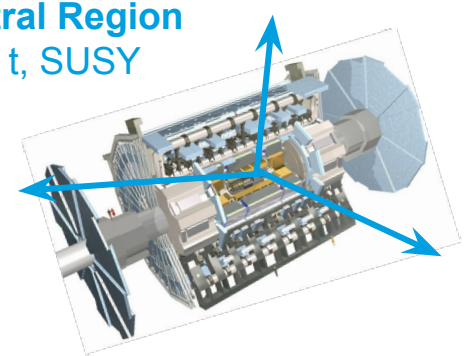


The Forward Physics Facility at the LHC.

Felix Kling
LLP 12 Workshop
11/03/2022

One Slide of Motivation.

Central Region
H, t, SUSY

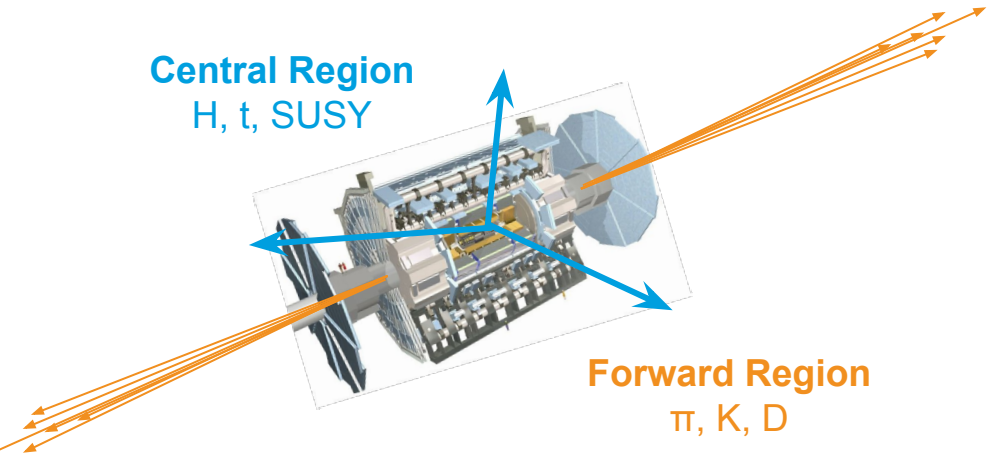


One Slide of Motivation.

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

10^{17} π0, 10^{16} η, 10^{15} D, 10^{13} B within 1 mrad of beam

Can we do something with that?



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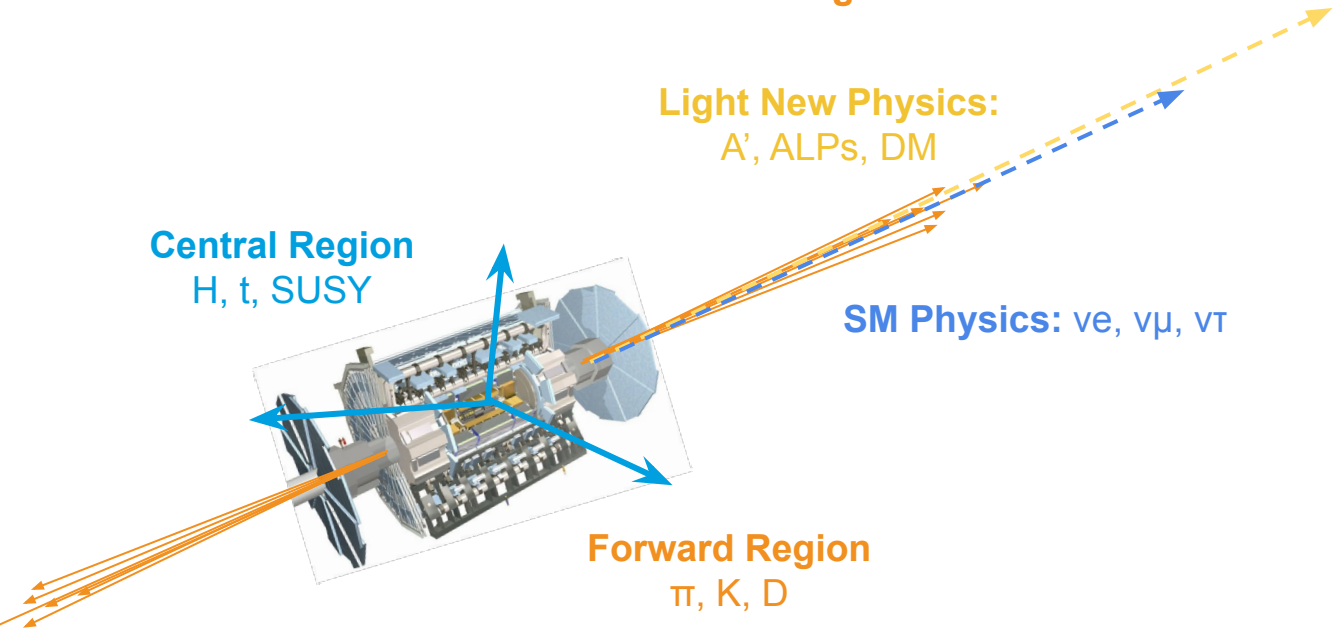

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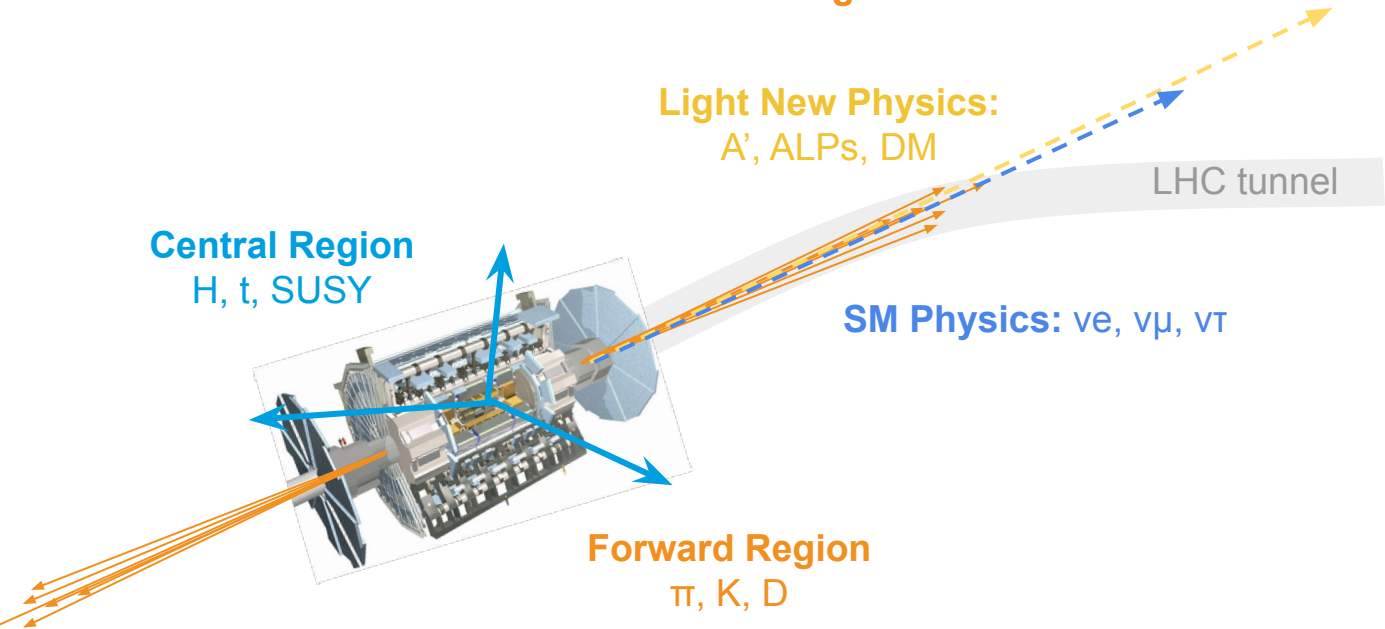

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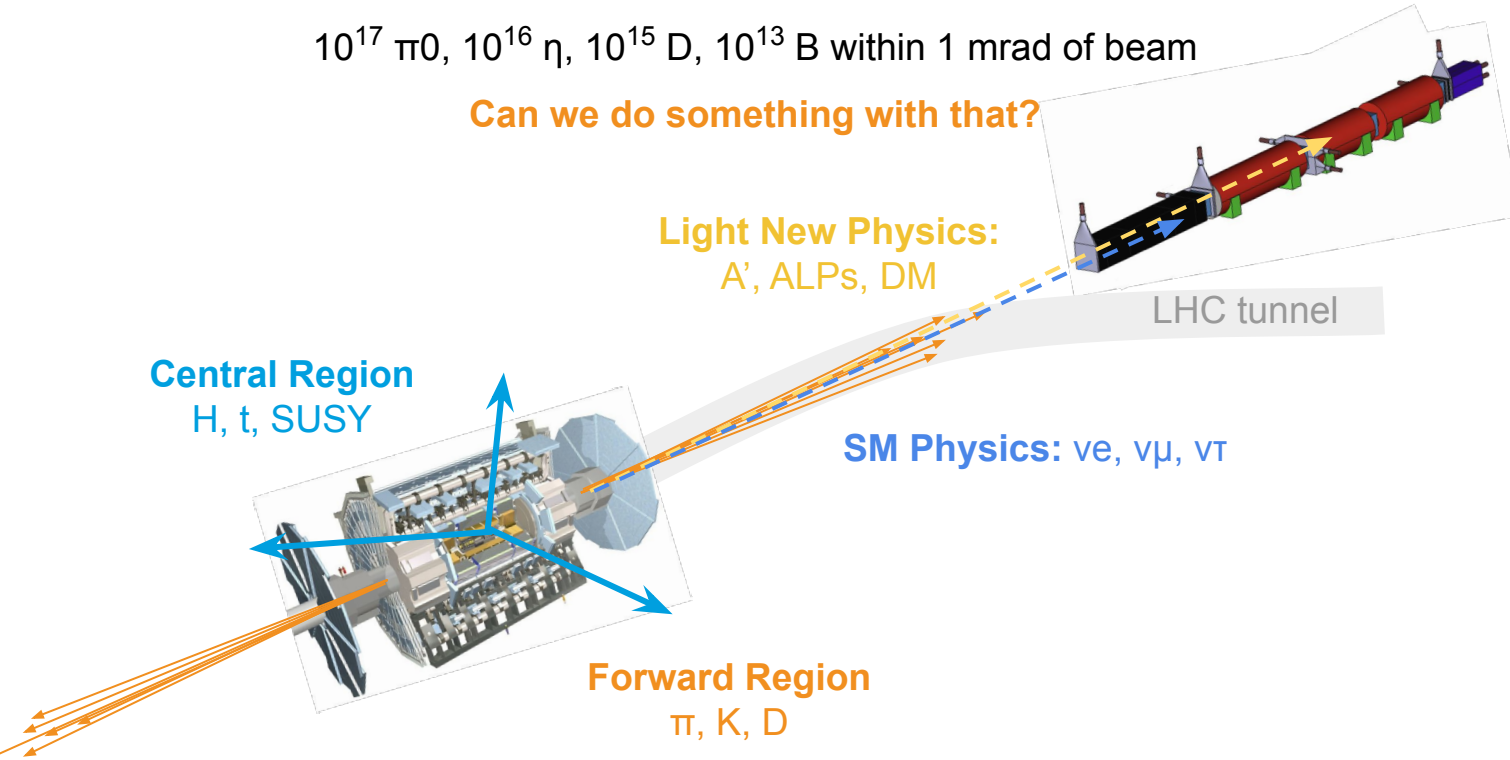


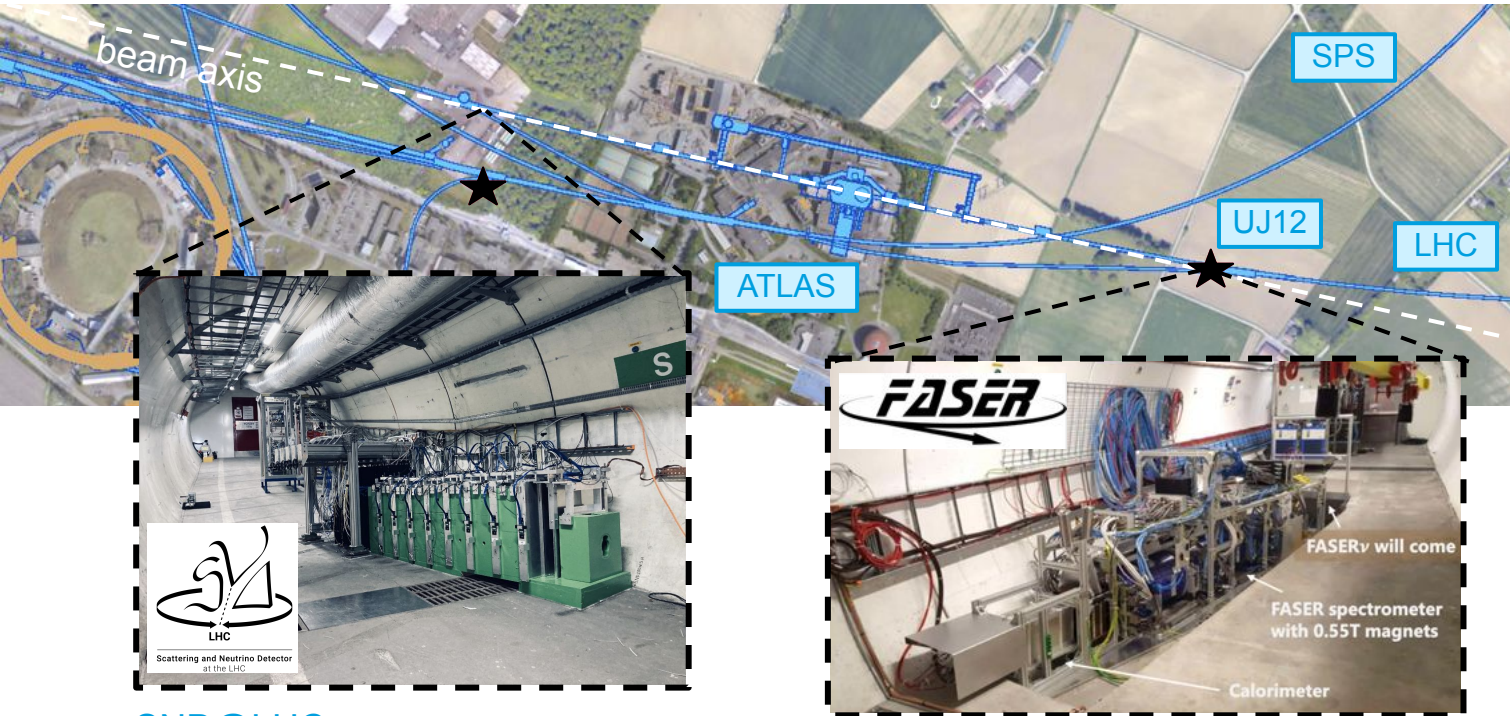
Facility and Experiments

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 **FASERν**).



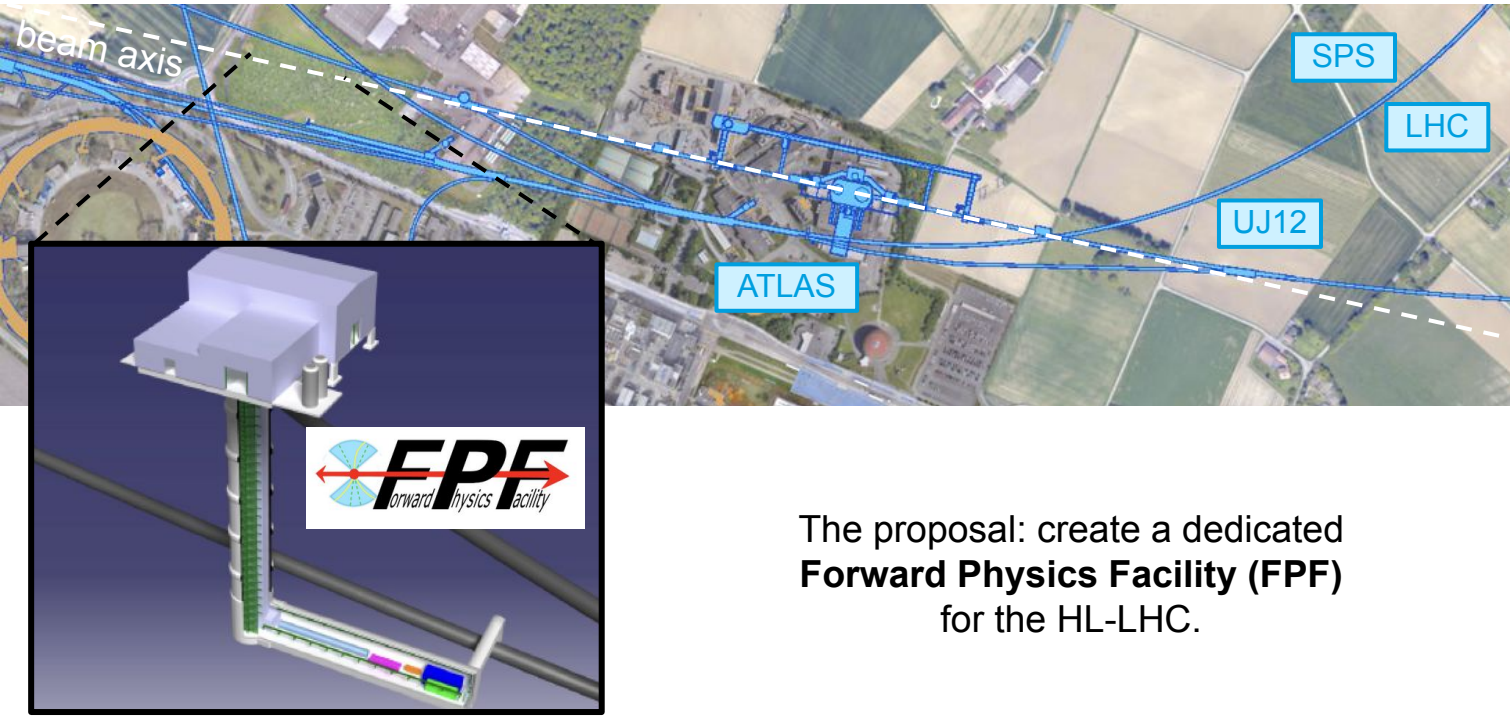
SND@LHC:
Martina Ferrillo's talk

FASER:
Charlotte Cavanagh's talk

FASERν:
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.

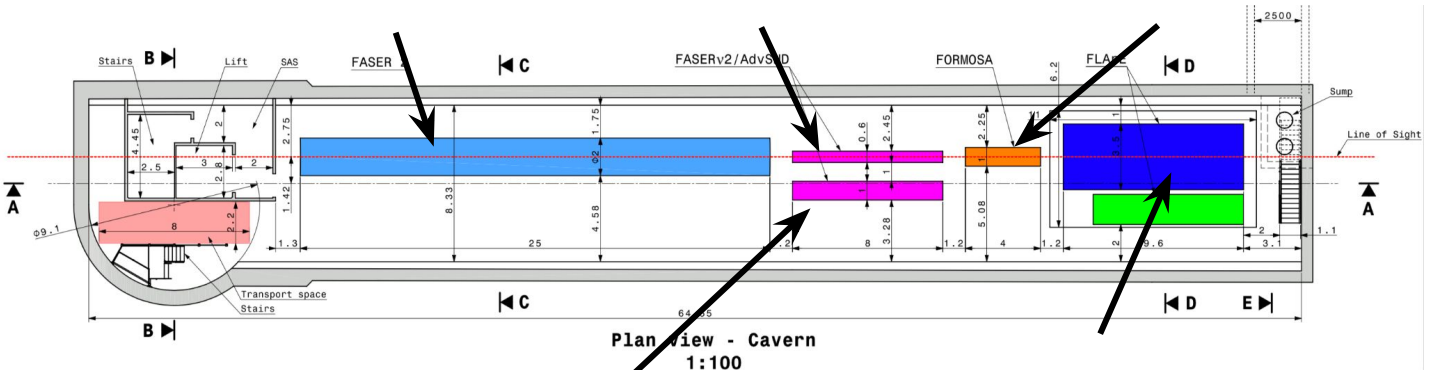
FPF: Experiments.

The FPF would house a suite of experiments that will greatly enhance the LHC's physics potential for BSM physics searches, neutrino physics and QCD.

FASER2
magnetized spectrometer
for BSM searches

FASERv2
emulsion-based
neutrino detector

FORMOSA
plastic scintillator array
for BSM searches



AdvSND
electronic
neutrino detector

FLArE
LAr based
neutrino detector

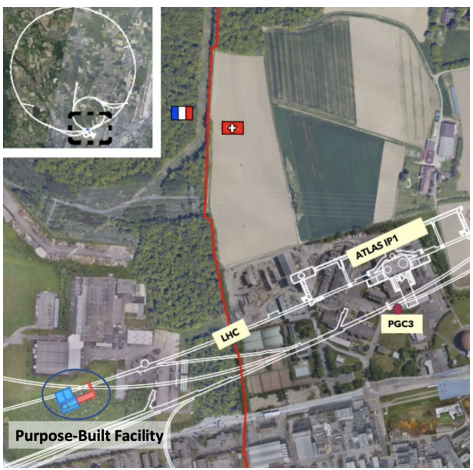
FPF: Facility.

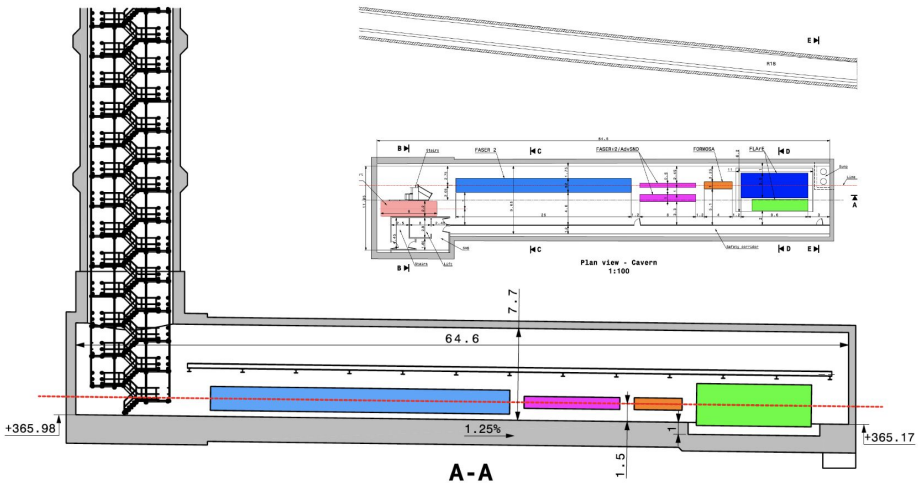
site selection completed: several sites considered by the CERN civil engineering team
preferred location on CERN land in France, 620-685 m west of the ATLAS IP

65 m-long, 8 m-wide cavern: 10 m from the LHC and disconnected from it

preliminary (class 4) cost estimate: 25 MCHF (CE) + 13 MCHF (services)

PBC allocated 75k CHF for a site investigation study (take core at the FPF site)



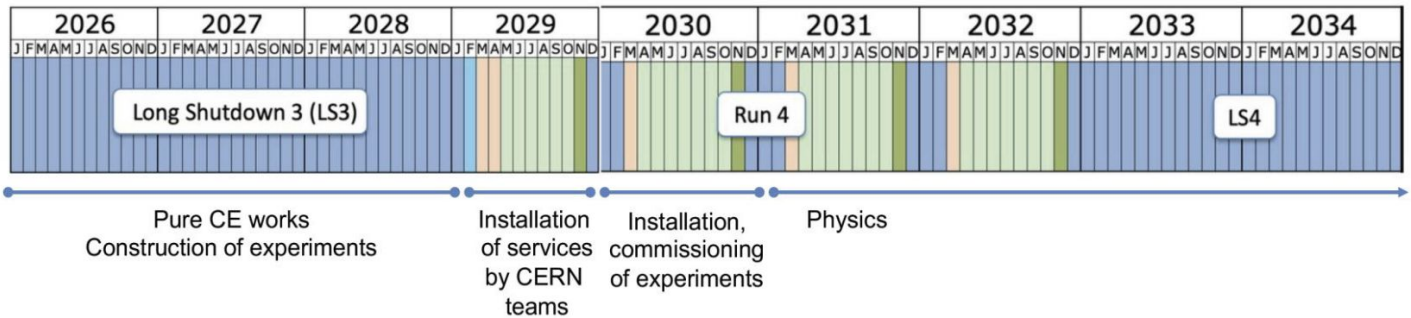


FPF:Timeline.

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

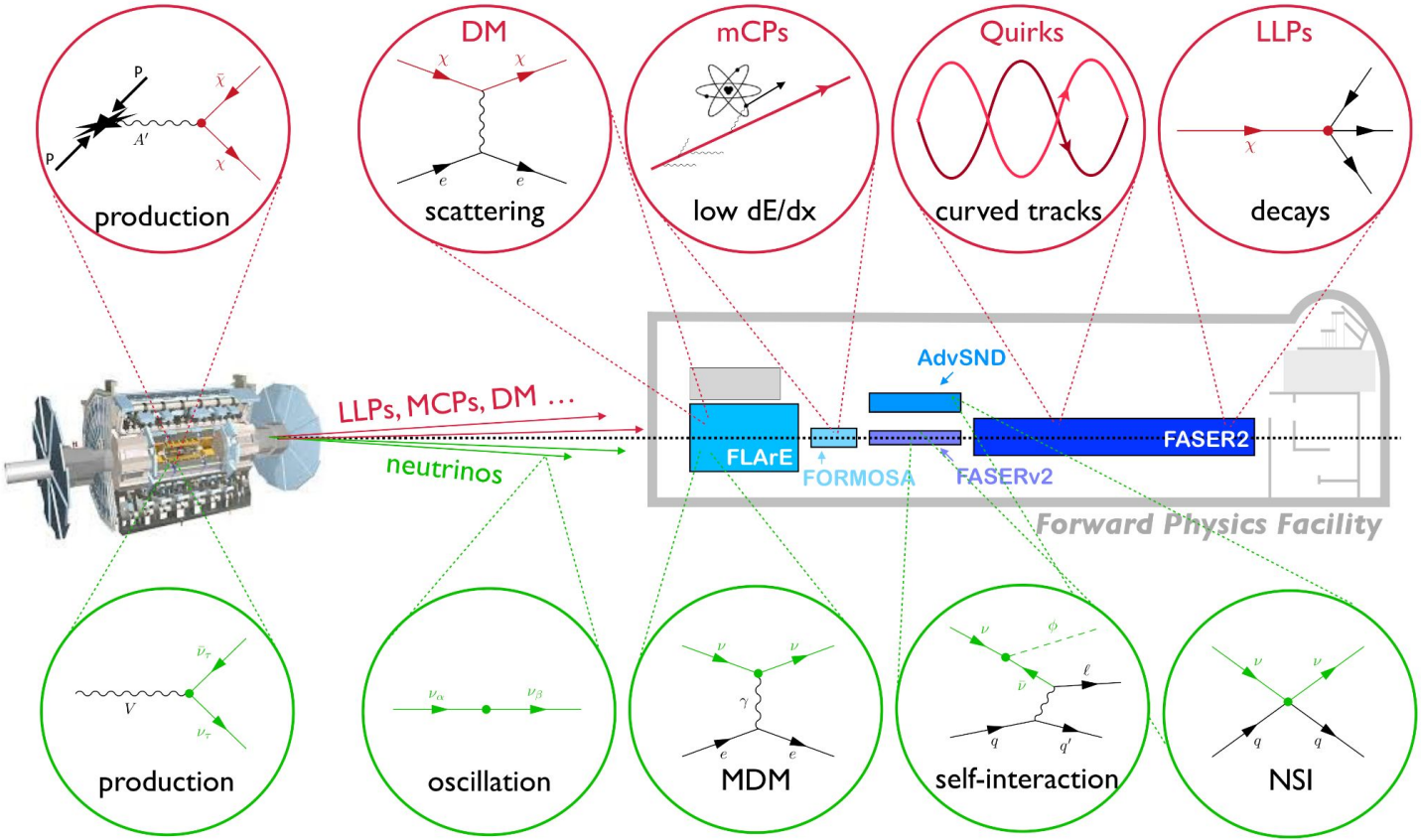
Snowmass Whitepaper:
2203.05090
~450 pages, ~250 authors

Facility and Experiments

Searches for Dark Sectors

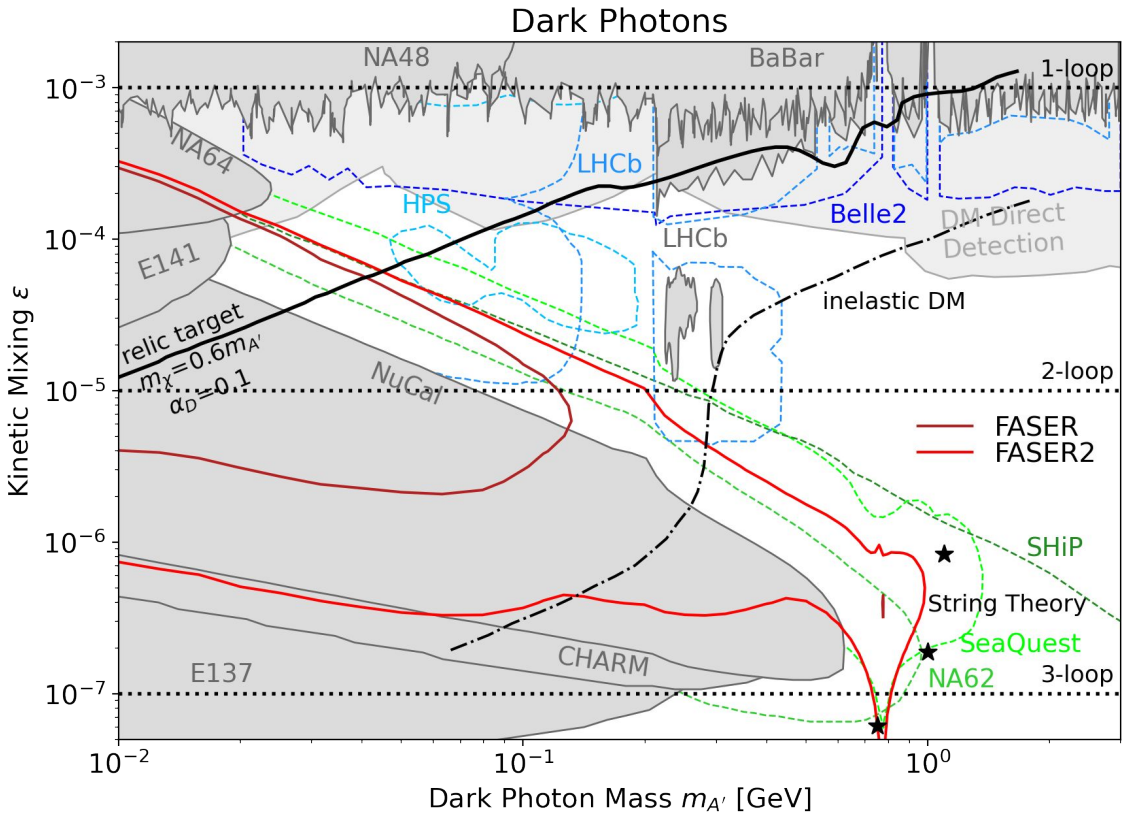
Neutrino Measurements

More Searches for BSM Physics



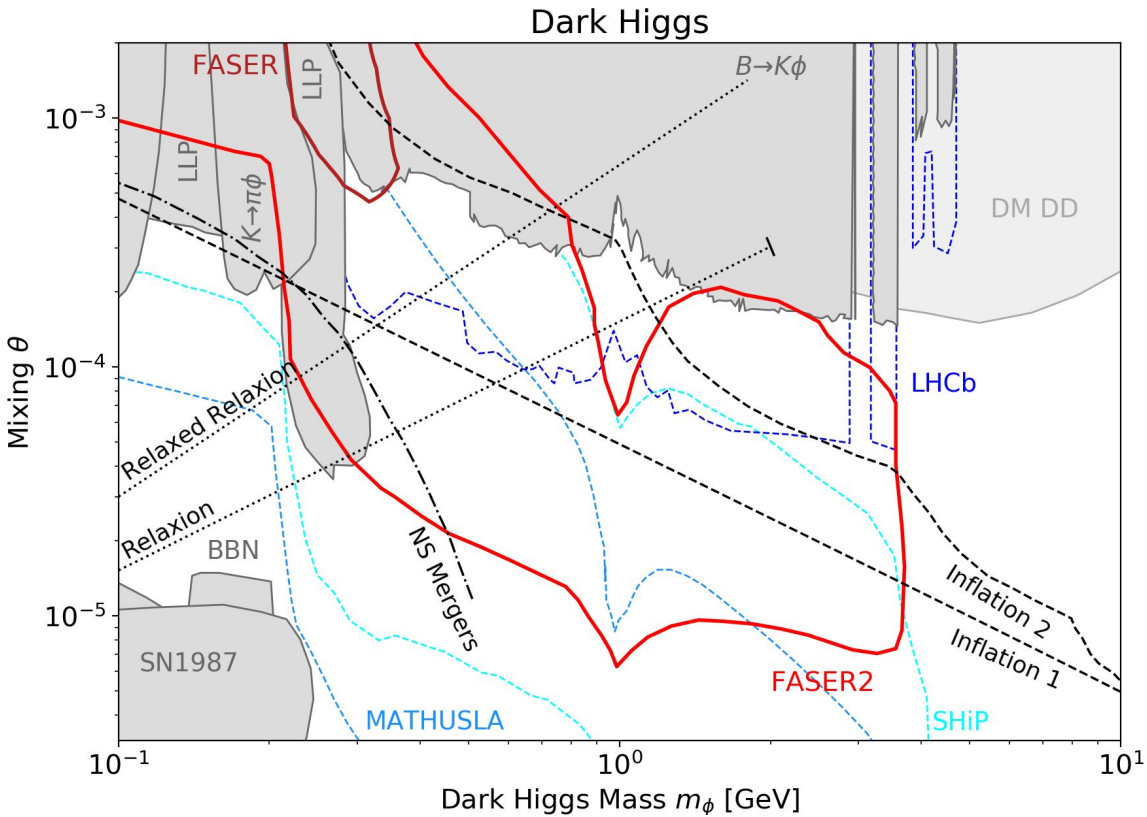
Long-Lived Particles: Dark Photon.

Dark Photon = gauge boson mixing with photon: $\mathcal{L} \sim -\frac{1}{2} m_{A'}{}^2 A'^2 - \epsilon e q_f \bar{f} \not{A}' f$



Long-Lived Particles: Dark Higgs.

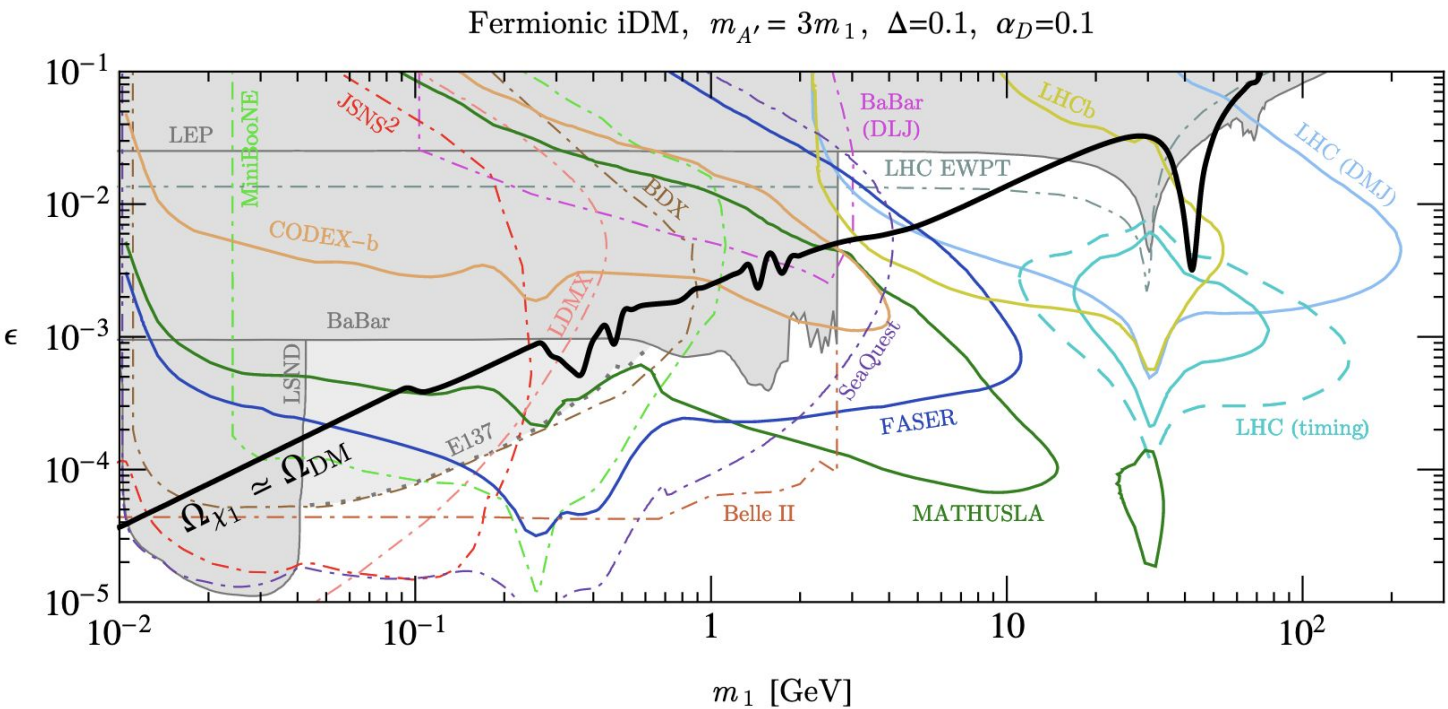
Dark Higgs = light scalar mixing with SM Higgs: $\mathcal{L} \supset m_\phi{}^2 \phi^2 + \sin\theta\, y_f \phi \bar{f} f$



Long-Lived Particles: inelastic DM.

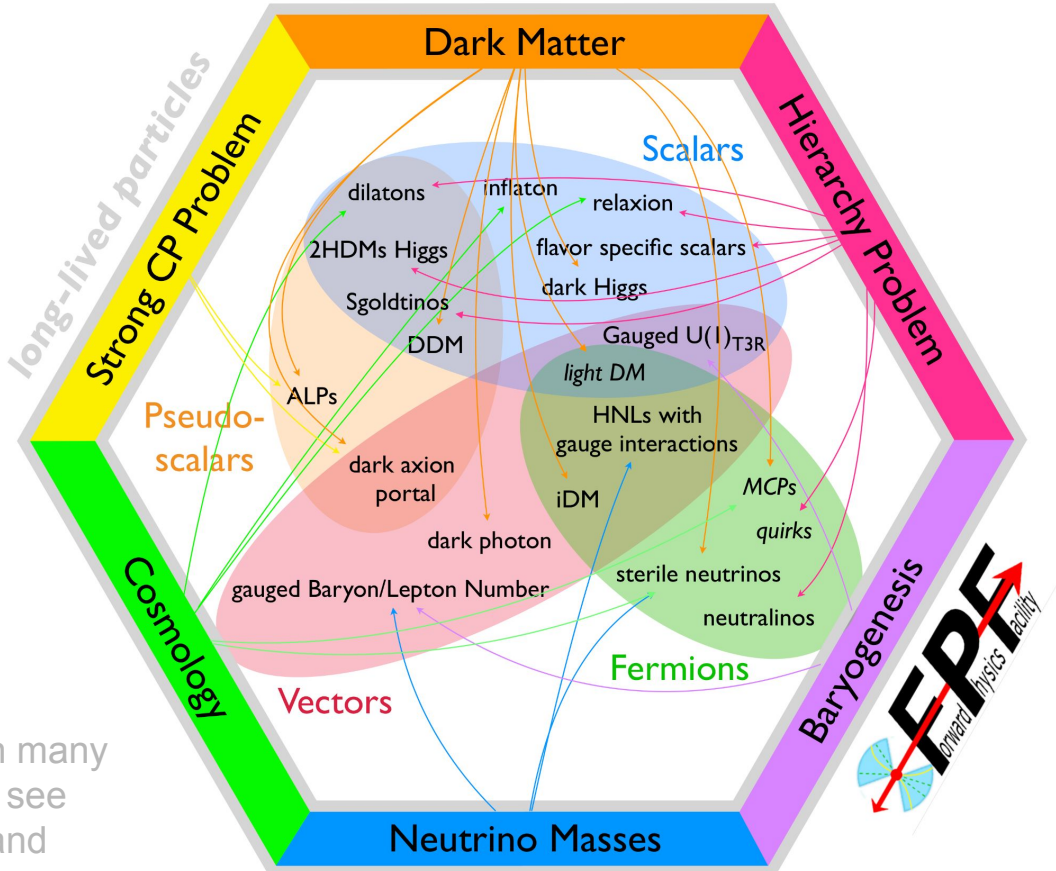
non-minimal model: here higher energy can really help

qq → A' → X1 X2 X2→X1+SM



For details see 1810.01879

Long-Lived Particles.



For details on many more models see 1811.12522 and 2203.05090.

Dark Matter Scattering.

mA' > 2mX

↓

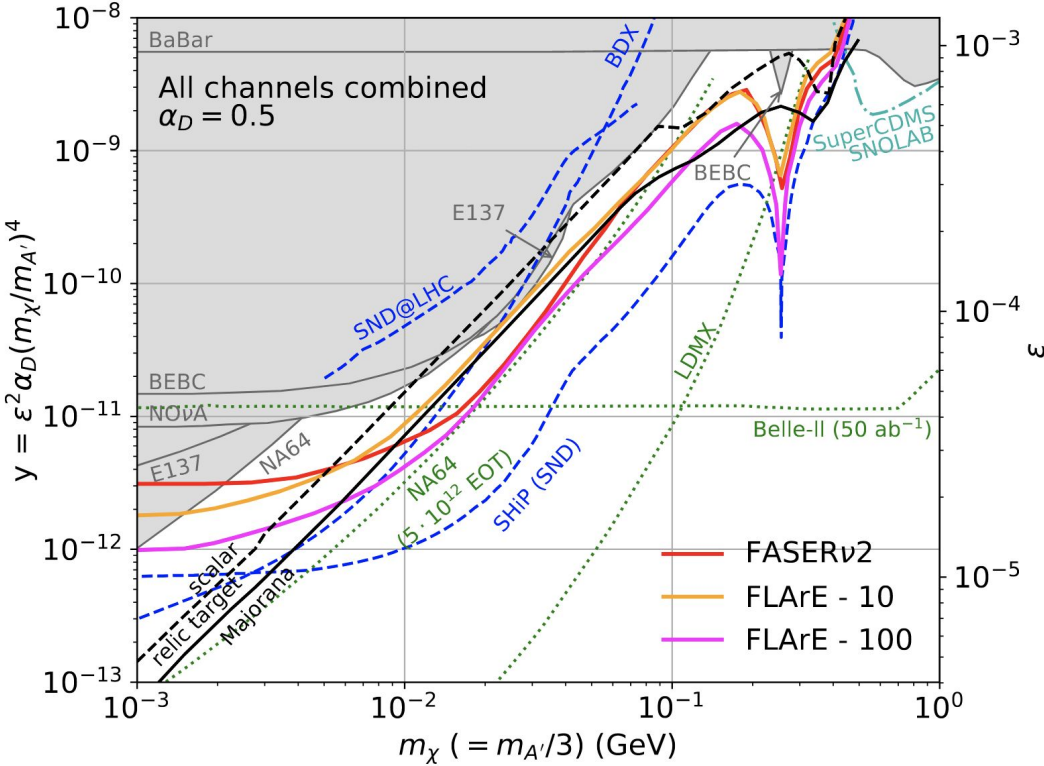
dark photon promptly decays in DM

↓

LHC produces DM beam

↓

DM scattering in neutrino detector



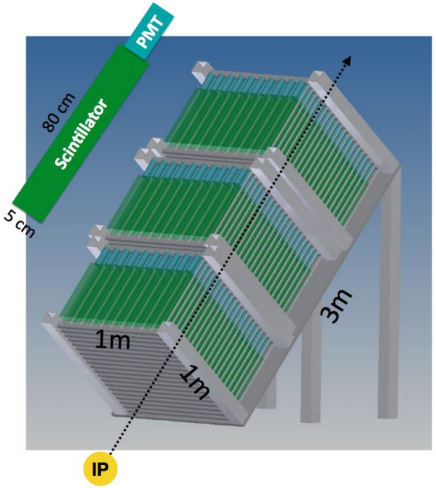
for more details see: 2101.10338

MilliCharged Particles.

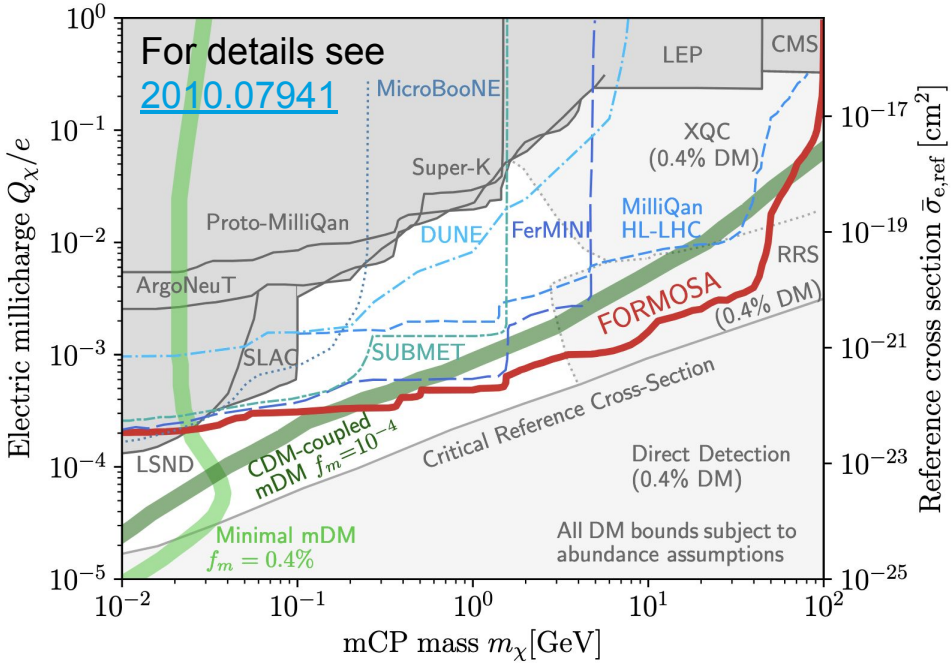
If mA'=0: X is effectively milli-charged with Q=εe → search for minimum ionizing particle with very small dE/dx

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



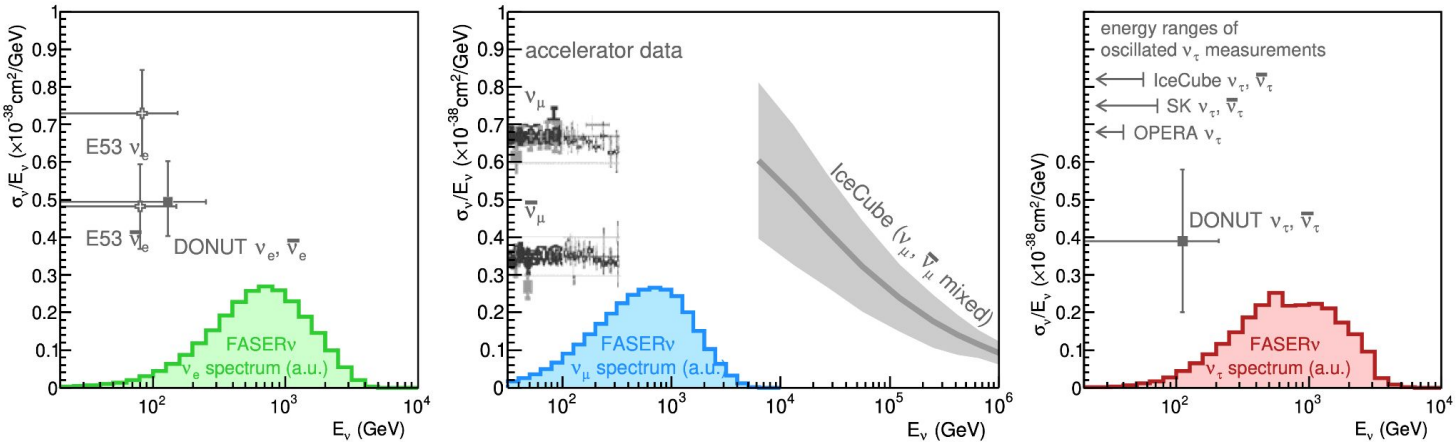
Facility and Experiments

Searches for Dark Sectors

Neutrino Measurements

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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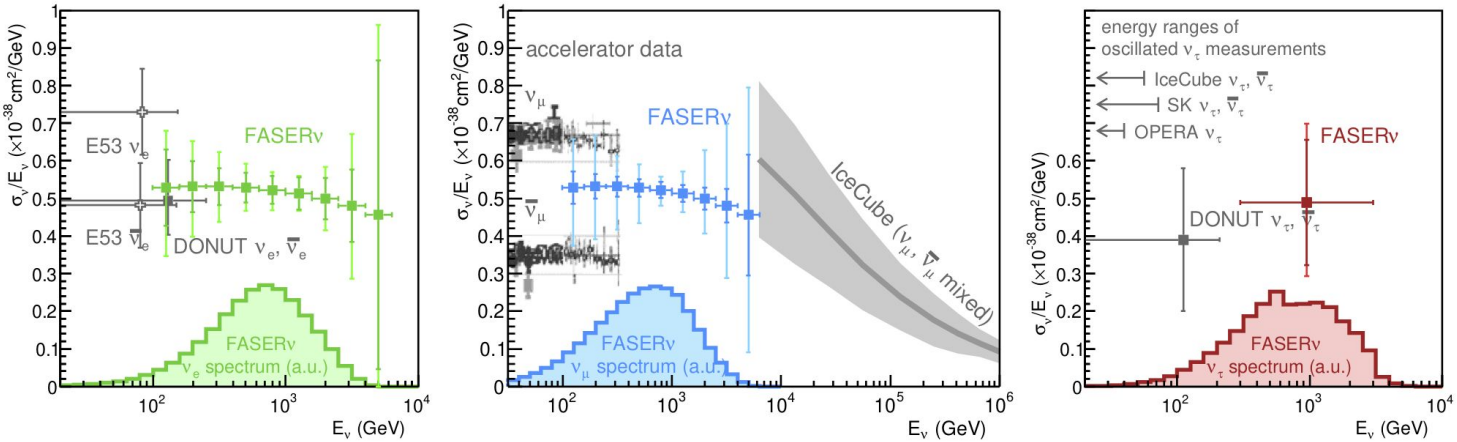

FASERν and SND@LHC will detect O(10k) neutrinos.

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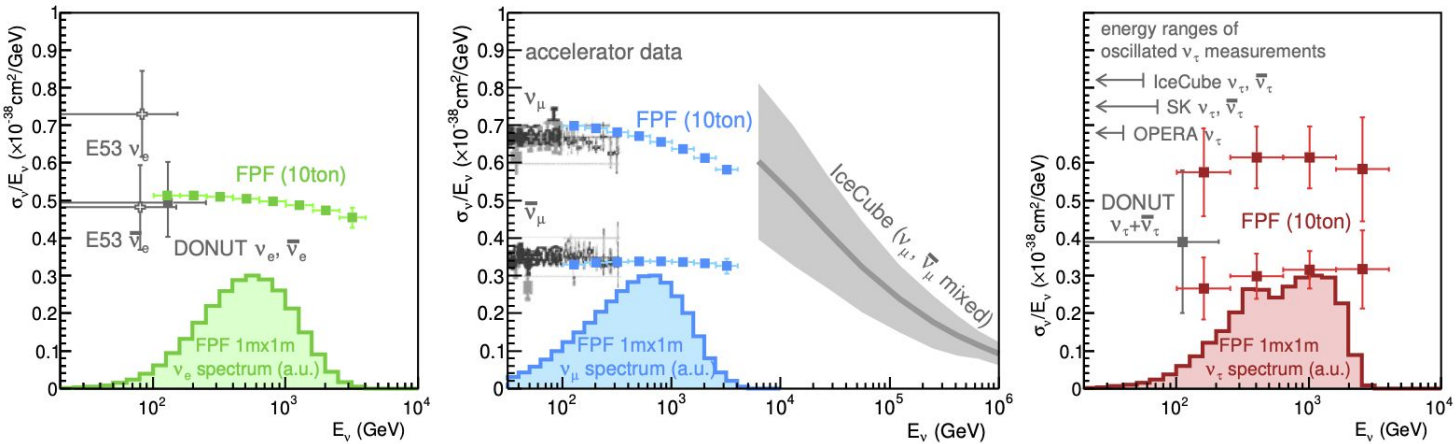
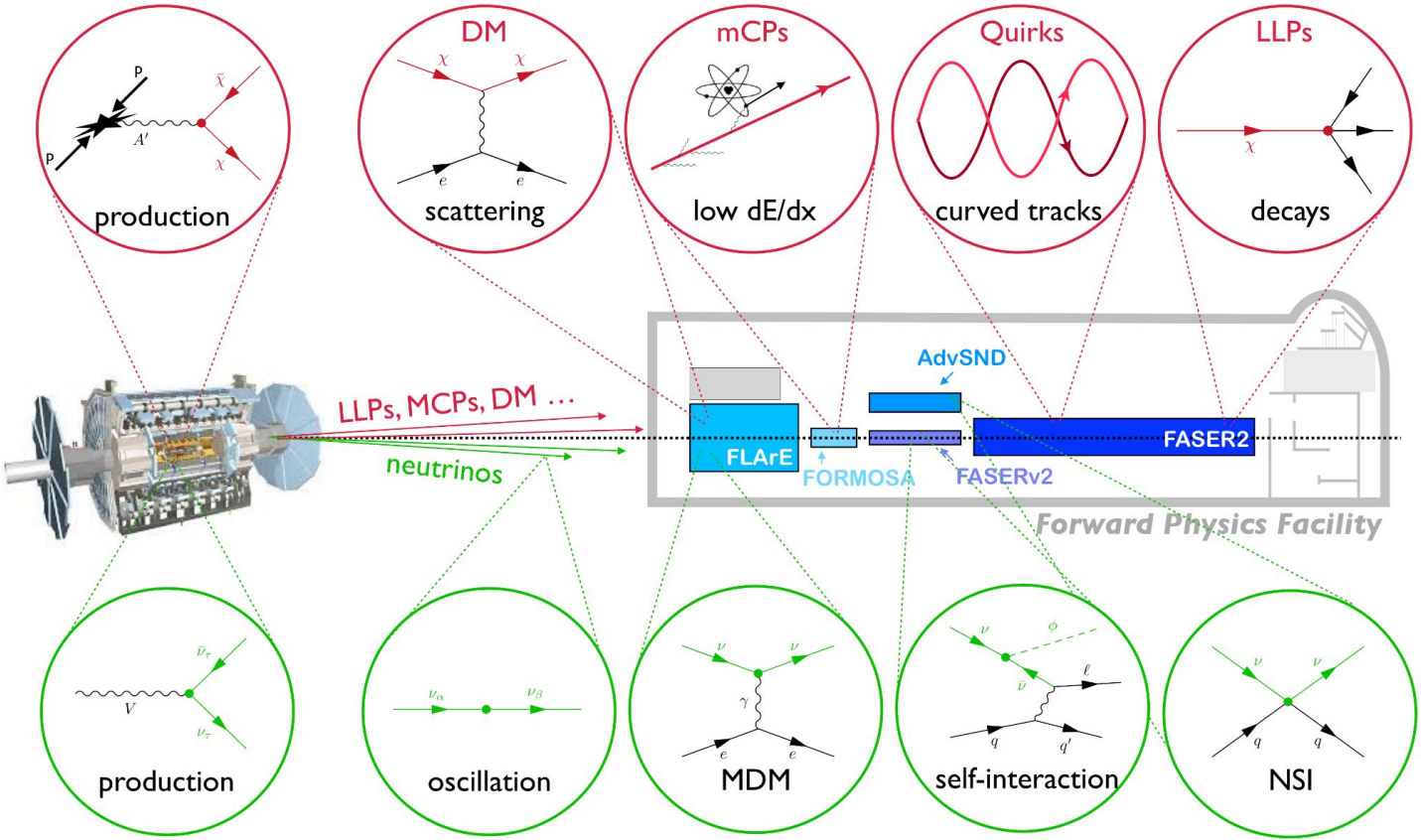


FASERν and SND@LHC will detect O(10k) neutrinos.

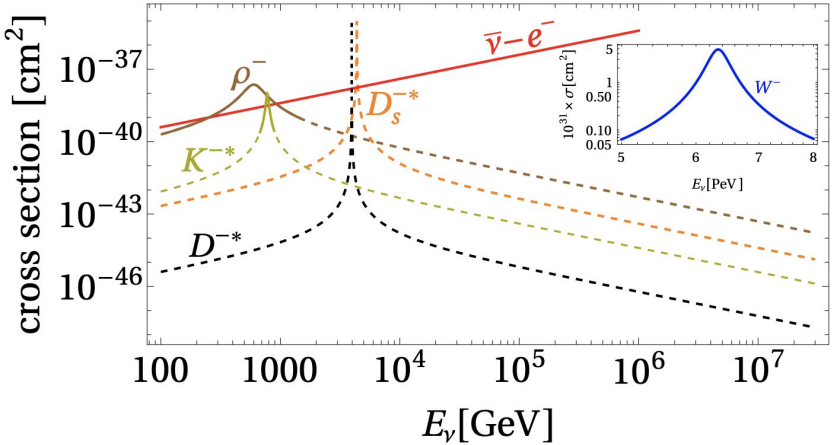
Proposed FPF experiment have potential to detect O(1M) neutrinos.

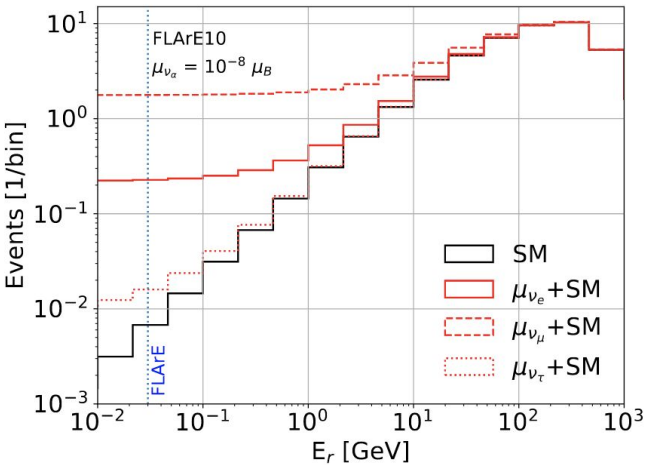
Neutrino BSM Physics



Application: Neutrinos Properties.

hadronic hesonances in v-e scsattering
[Brdar et al: 2112.03283]

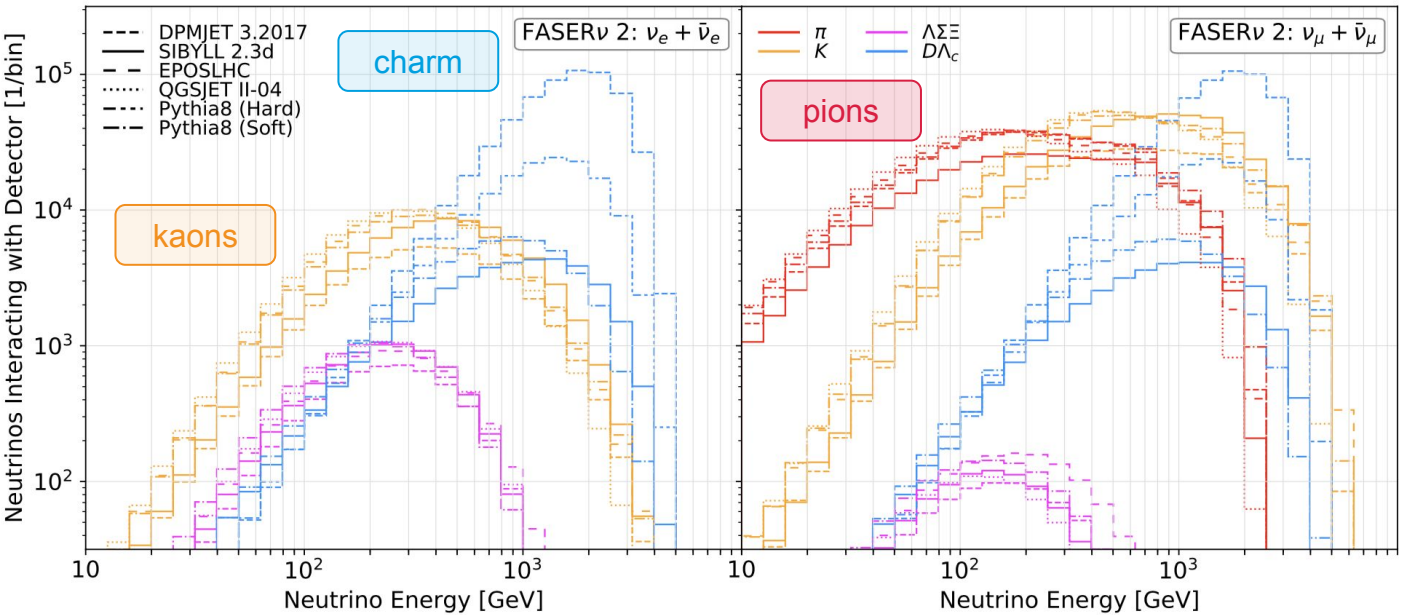




Neutrino electromagnetic properties
[Ismail et al: 2012.10500], [Ismail et al: 2109.05032]

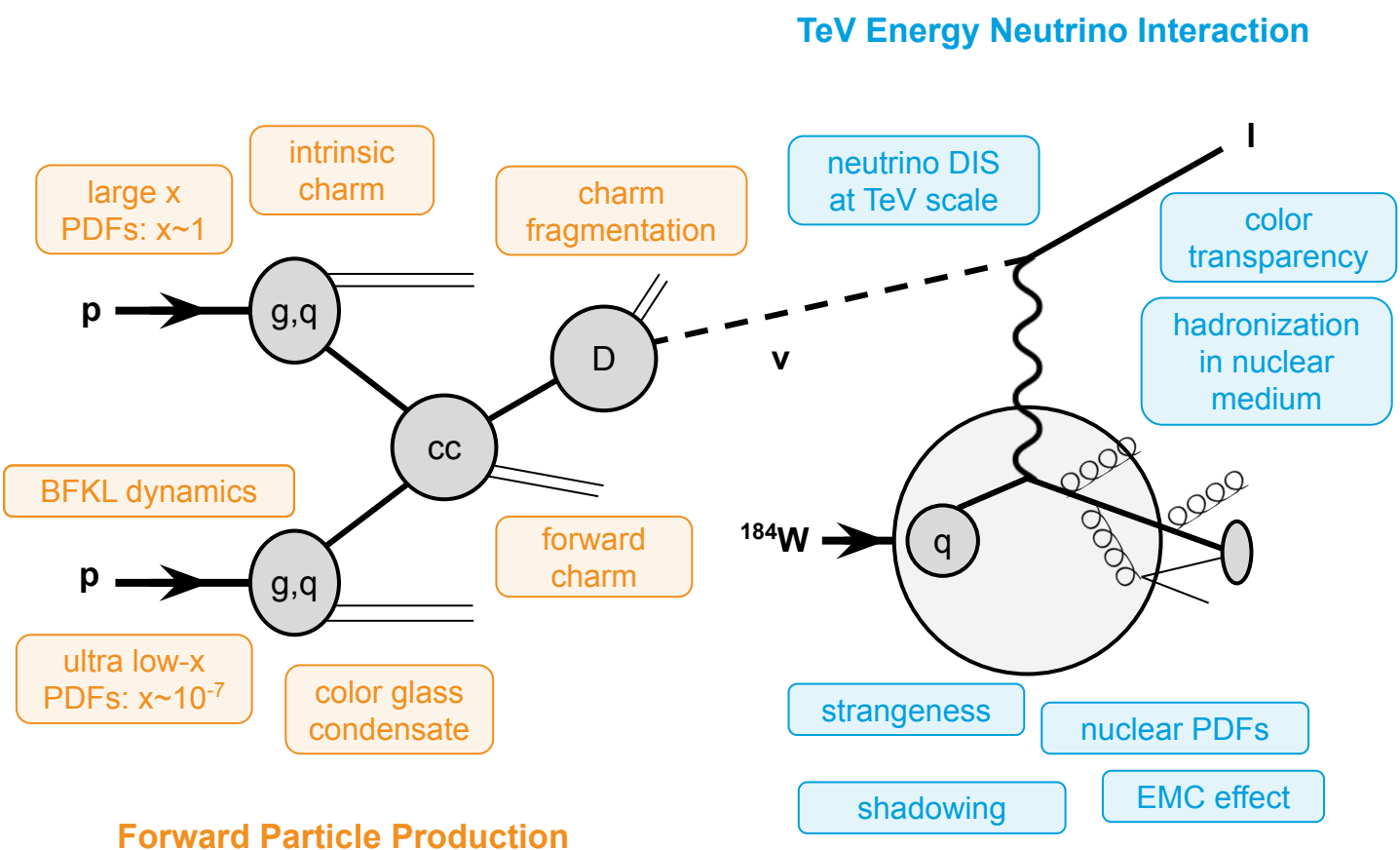
Application: QCD.

Where do the LHC neutrinos come from?



LHC neutrinos = probe of forward particle production

Application: QCD.

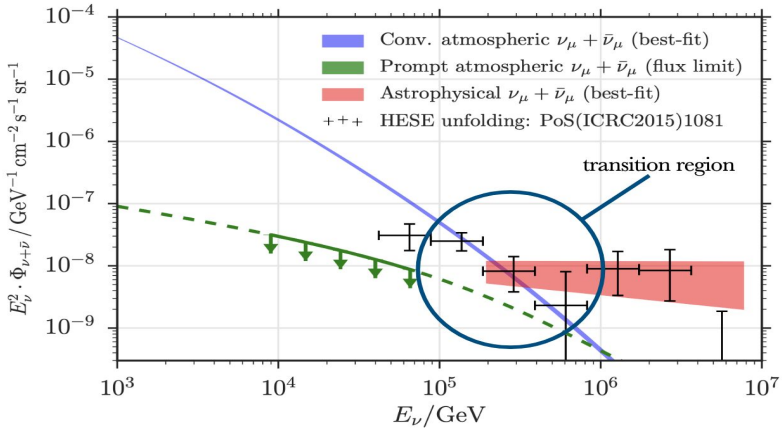


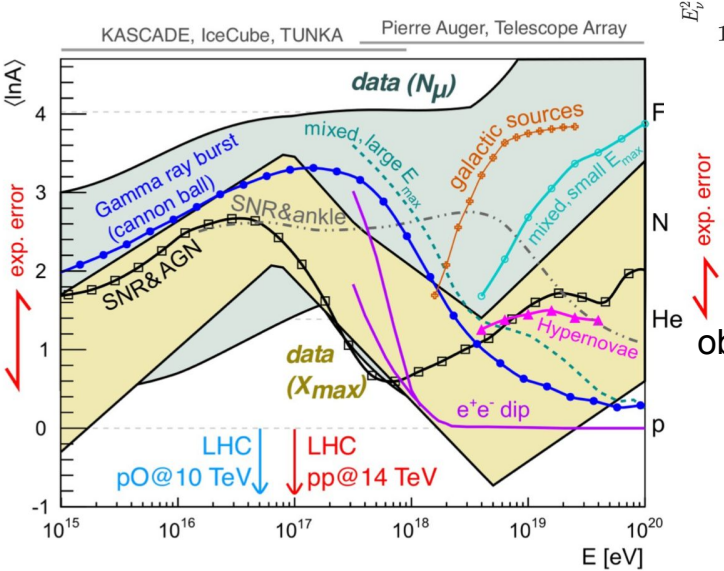
Application: Astroparticle Physics.

forward charm production at the LHC

↓

constraints on prompt atmospheric neutrino flux at IceCube





Based on Kampert & Unger, Astropart. Phys. 35 (2012) 660

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