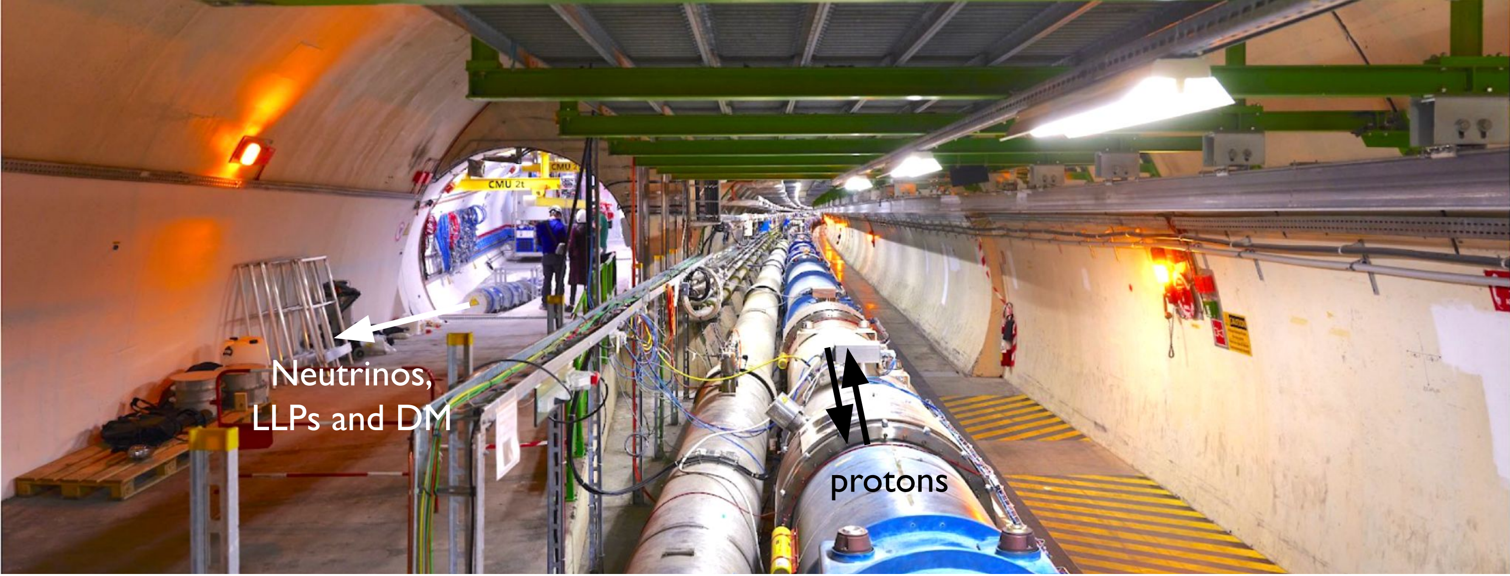
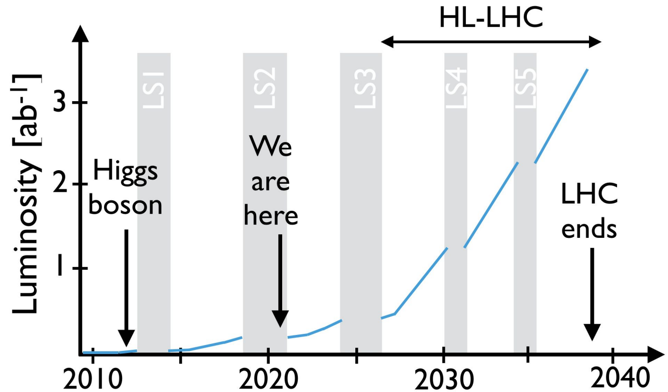


Looking Forward to New Physics with the Forward Physics Facility.

Felix Kling
DESY Theory Workshop 2021

DESY.

Looking Forward at the LHC.



The LHC will soon start to prepare for its high-luminosity phase.

Can we do something to enhance its physics potential?
If yes, we need to do it now or lose them for many decades.

Explore a rich BSM and SM physics program in the far forward region that greatly expands the LHC physics potential with relatively little additional investment

Looking Forward at the LHC.

1984 — 2018 — 2022 — 2028

Neutrinos detected from many sources, but not from colliders.

But there is a huge flux of neutrinos in the forward direction, mainly from π, K and D meson decay. [De Rujula et al. (1984)]

ATLAS provides an intense and strongly collimated beam of TeV-energy neutrinos along beam collision axis.

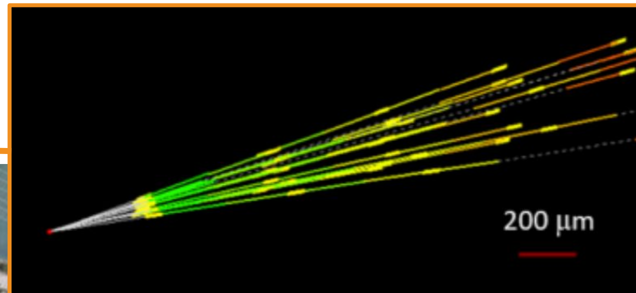
Looking Forward at the LHC.

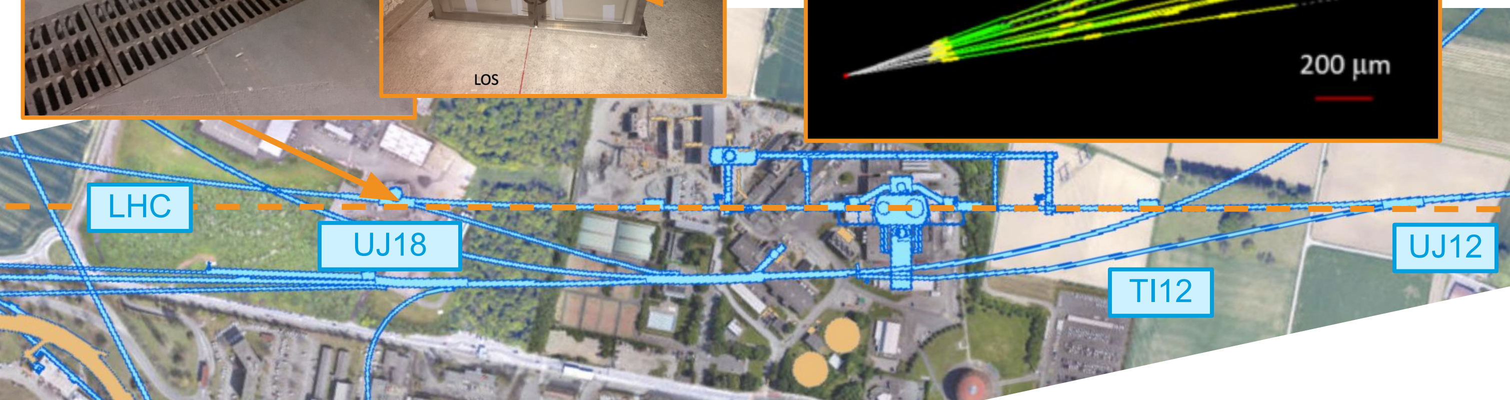
1984 — 2018 — 2022 — 2028

In 2018, the FASER collaboration placed ~30 kg pilot emulsion detectors in TI18 for a few weeks. O(10) neutrino interactions expected

First neutrino interaction candidates were recently reported.

[FASER, 2105.06197]



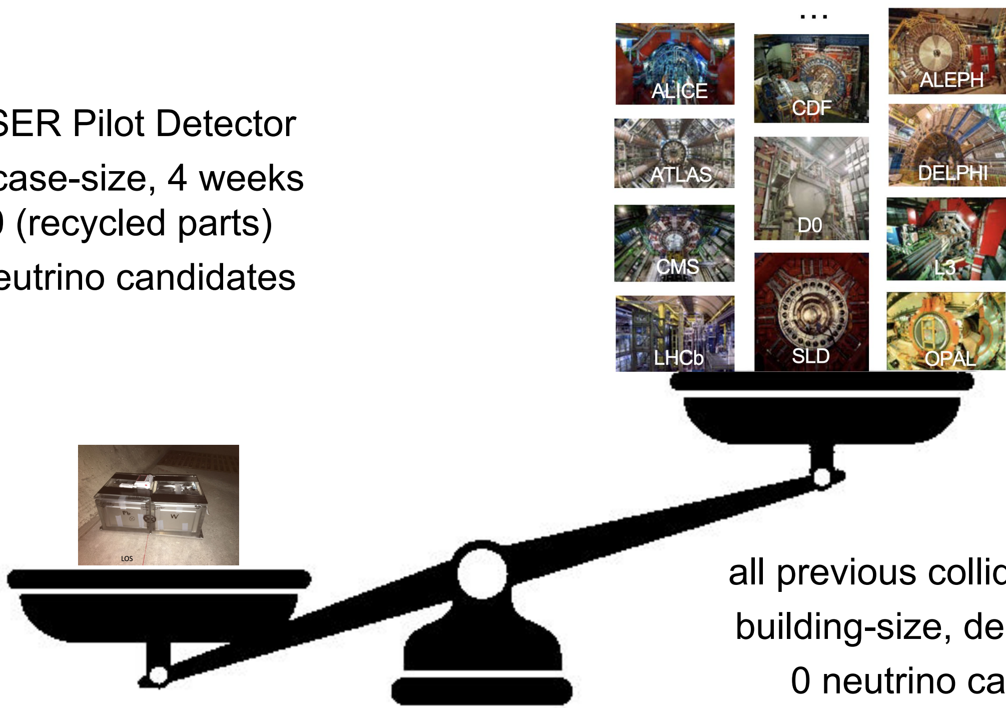


Looking Forward at the LHC.

FASER Pilot Detector

suitcase-size, 4 weeks
$0 (recycled parts)

6 neutrino candidates



all previous collider detectors

building-size, decades ~$1B

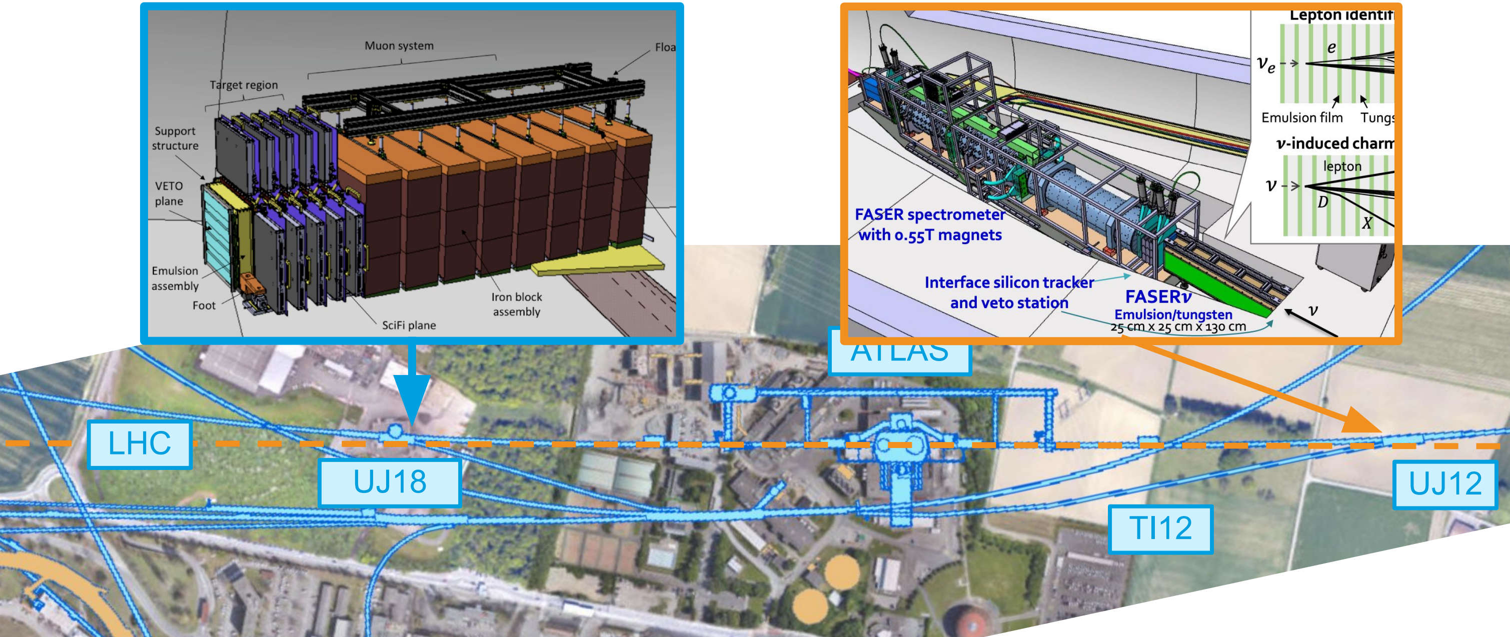
0 neutrino candidates

Looking Forward at the LHC.

1984 | 2018 | 2022 | 2028

During Run 3 of the LHC, two new experiments will detect LHC neutrinos.
FASERv: O(1k) nu_e, O(10k) nu_mu and O(10) nu_tau.

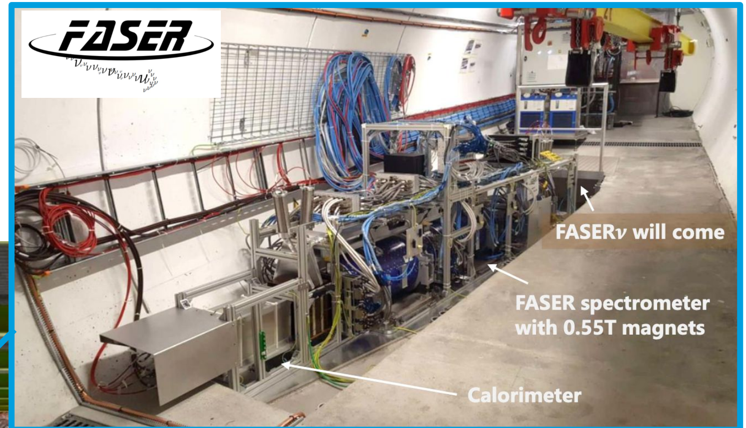
SND@LHC **FASERv**

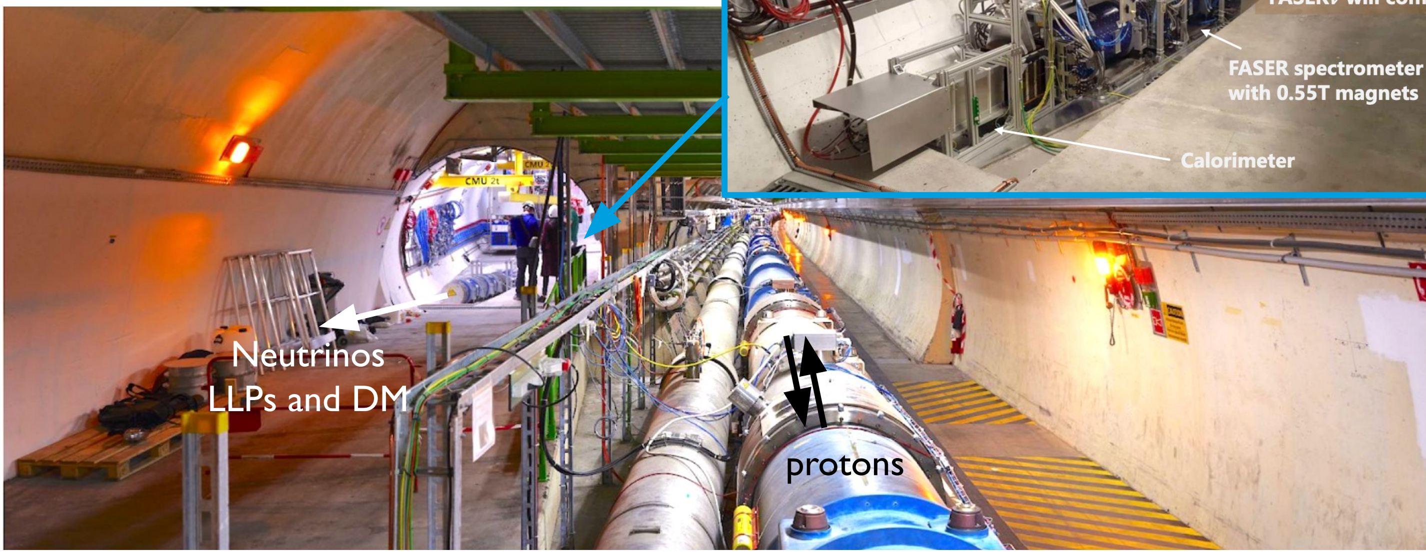


Looking Forward at the LHC.

1984 — 2018 — 2022 — 2028

FASER detector was successfully installed into the TI12 tunnel in March 2021

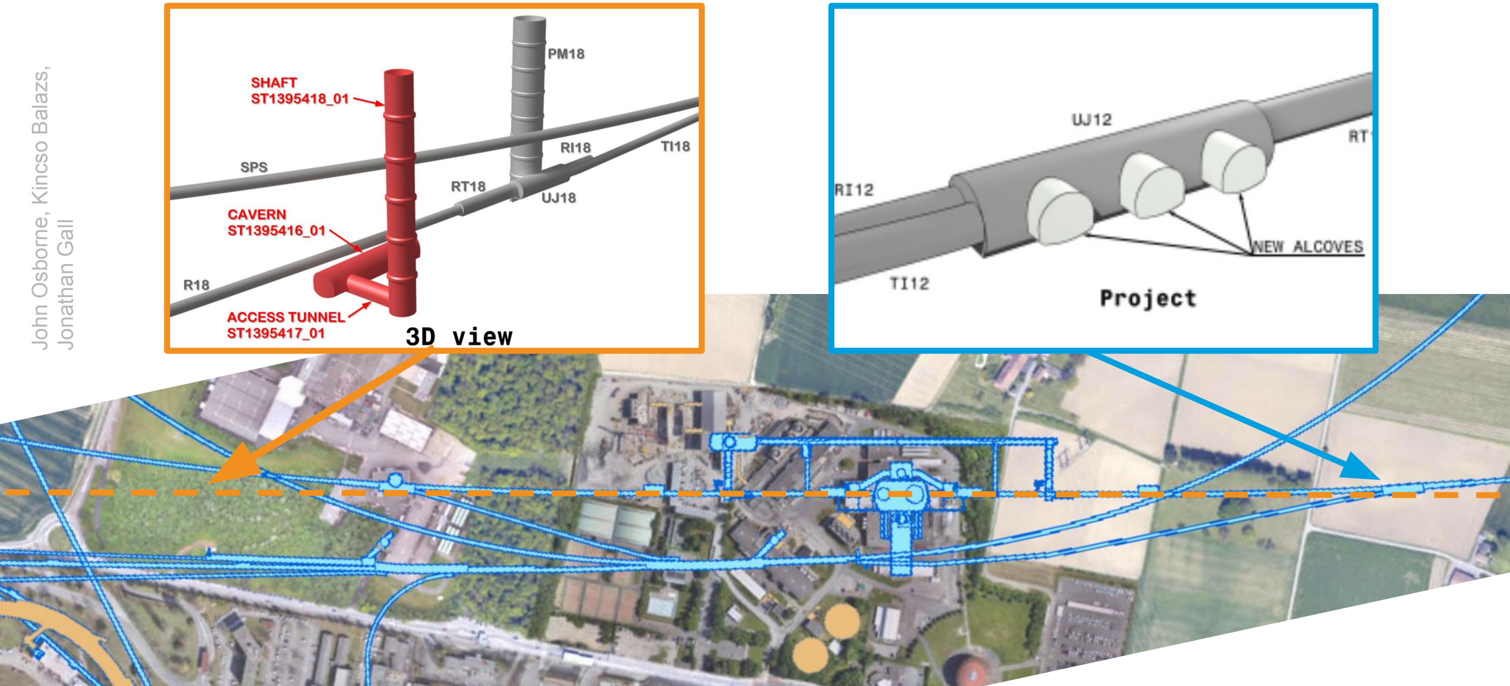




Forward Physics Facility.

1984 — 2018 — 2022 — 2028

The proposal: create a Forward Physics Facility (FPF) for the HL-LHC to house a suite of experiments. Two promising locations were identified.



John Osborne, Kincso Balazs,
Jonathan Gall

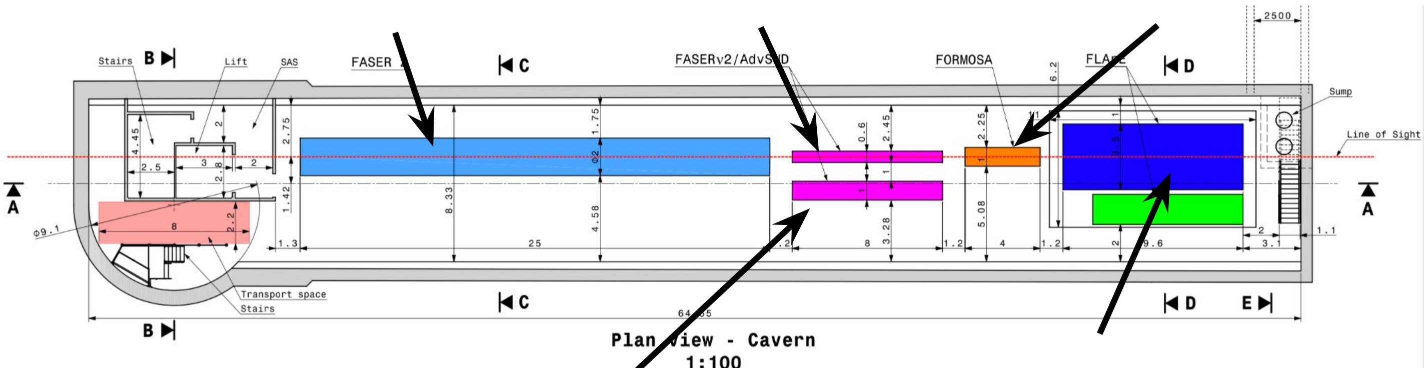
Forward Physics Facility.

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

Forward Physics Facility.

Two dedicated FPF workshops in November 2020 (https://indico.cern.ch/event/955956) and May 2021 (https://indico.cern.ch/event/1022352)

Results summarized in paper discussing the facility, proposed experiments and physics potential for BSM Physics, Neutrinos, QCD and Astroparticle Physics.

~75 pages, written over last ~3month by ~80 authors

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

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The Forward Physics Facility (FPF) is a proposal to create a cavern with the space and infrastructure to support a suite of far-forward experiments at the Large Hadron Collider during the High Luminosity era. Located along the beam collision axis and shielded from the interaction point by at least 100 m of concrete and rock, the FPF will house experiments that will detect particles outside the acceptance of the existing large LHC experiments and will observe rare and exotic processes in an extremely low-background environment. In this work, we summarize the current status of plans for the FPF, including recent progress in civil engineering in identifying promising sites for the FPF; the FPF experiments currently envisioned to realize the FPF's physics potential; and the many Standard Model and new physics topics that will be advanced by the FPF, including searches for long-lived particles, probes of dark matter and dark sectors, high-statistics studies of TeV neutrinos of all three flavors, aspects of perturbative and non-perturbative QCD, and high-energy astroparticle physics.

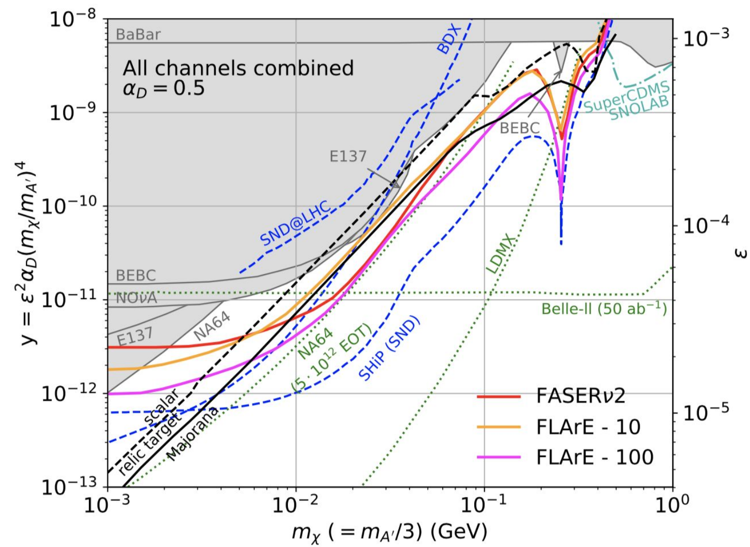
Physics Potential: BSM.

Simple Example: Light Dark Matter charged under U(1)

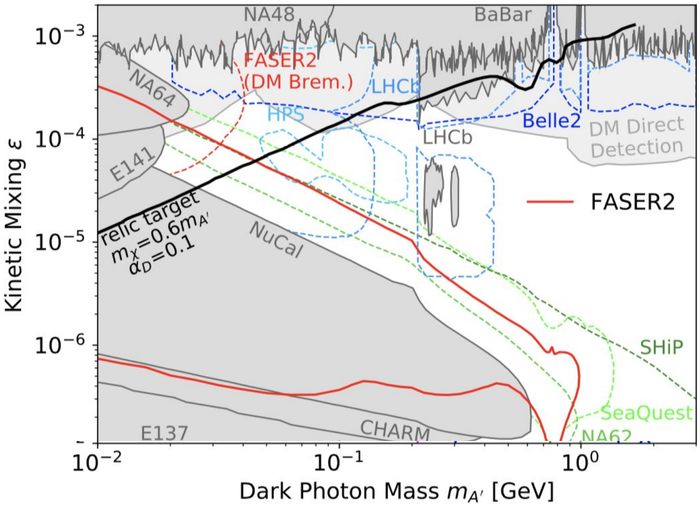
$$\mathcal{L} \supset -\frac{\epsilon}{2} F^{\mu\nu} F'_{\mu\nu} - \frac{1}{2} m_{A'}^2 A'^2 - m_\chi^2 \chi^2 - i g_D A' \chi^2$$

Scattering of Light Dark Matter

mA' > 2mX: A' promptly decays in DM and produces DM beam



Physics Potential: BSM.

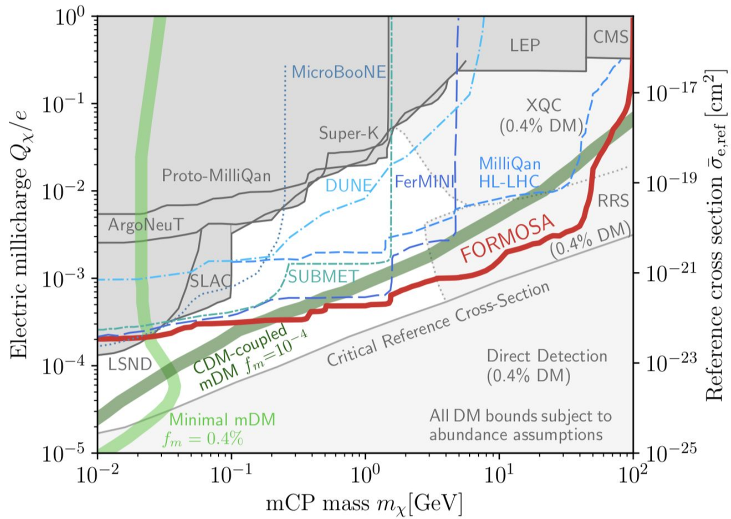


Decay of long-lived Particles

mA' < 2mX : A' can only decay to SM and becomes long-lived

Millicharged Particles

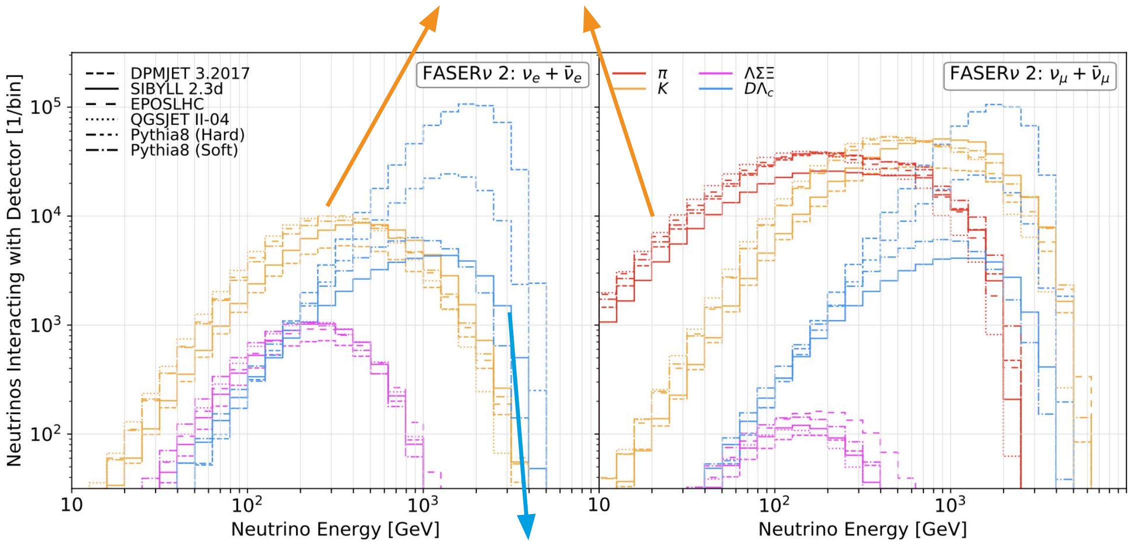
mA' = 0 : dark matter becomes millicharged



Physics Potential: SM.

The measurement of neutrinos fluxes at the FPF will provide novel complimentary constraints on forward particle production.

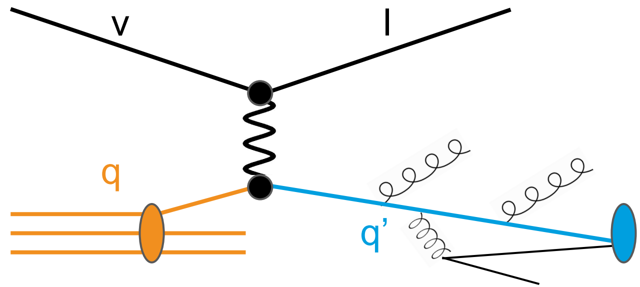
pions & kaons: improve MC generators, cosmic ray muon puzzle



charm: perturbative QCD, test transition to small-x factorization, constrain low-x gluon PDF, probe gluon saturation, probe intrinsic charm, constrain prompt atmospheric neutrino flux at IceCube.

Physics Potential: SM.

The FPF is essentially a Neutrino-Ion collider with sqrt(s)~50GeV

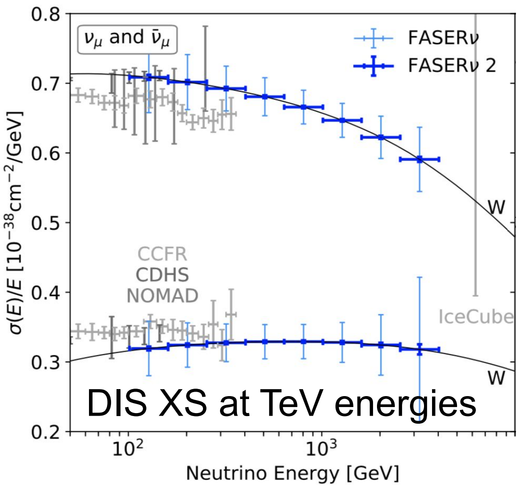


Initial State

nuclear PDFs via measurements on different targets

strange quark PDFs via v s → l c

Hard Scattering



Final State

response of cold nuclear matter to fast moving quarks

medium-induced energy losses

fragmentation functions

final state interactions

Summary.

With FASER and SND@LHC, the first experiments will soon start to perform searches for new particles and neutrino measurements in the far-forward region of the LHC.

We propose to continue this program with improved detectors as part of a Forward Physics Facility at the HL-LHC. This will open up many many new opportunities for BSM physics searches, neutrino physics and QCD, significantly extending the LHC's physics program.

↓

We would like to invite the HEP community to help us explore and better understand the physics potential of this program.
You are welcome to join!

For questions and comments, please contact me via felixk@slac.stanford.edu