The recent status of the FASER experiment

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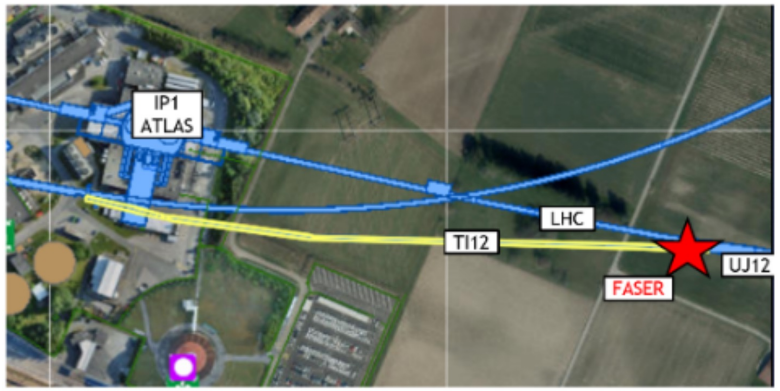
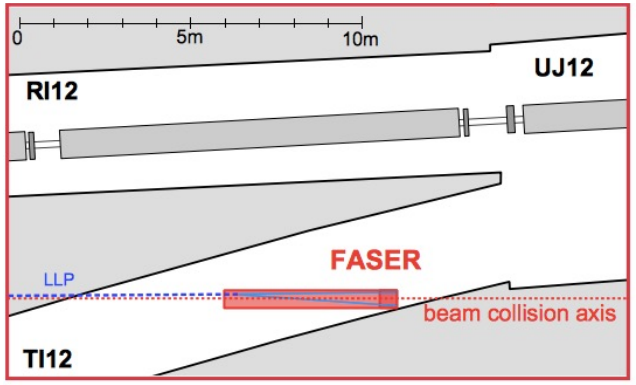
FASER experiment

FASER is a new forward experiment of LHC, located 480 m downstream from the ATLAS IP, getting ready to start data taking in Run 3 from summer 2022 for:

- New weakly-coupled particles in the MeV-GeV range
- All flavors of neutrinos at the TeV-energy frontier





Note that this picture was taken before the refurbishment

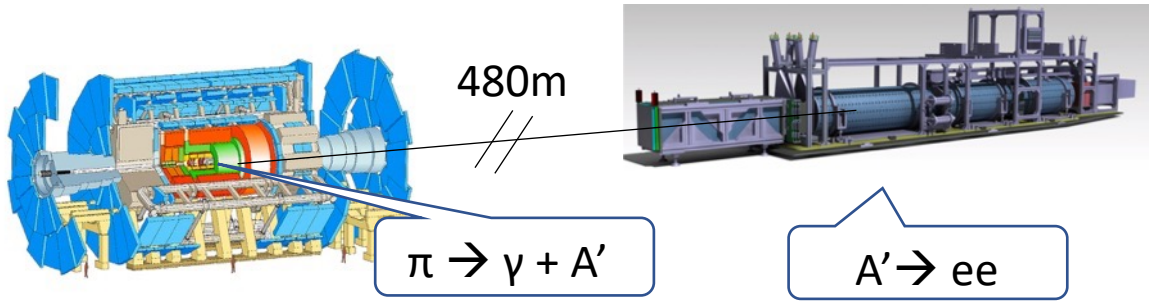
Favorable location, except that refurbishment is needed to be an experimental site

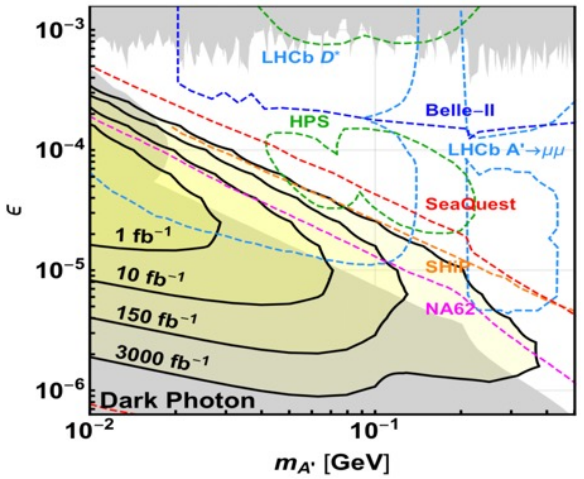
- Background from IP is attenuated by LHC infrastructure and only high-energy muon at about 1 /cm^2/sec
- Radiation level from LHC is quite low, around 4×10^{-3} Gy/year (= 4×10^7 *1*-MeV neutron/cm^2/year)

Search for new light weakly-coupled particles

LHC collisions produce an enormous flux of light mesons in the forward direction

- ~ 10^{15} π^0 in the FASER acceptance in LHC Run-3, which could decay into a new long-lived particle (LLP)
- These LLPs are supposed to be decaying into a pair of collimated SM particles, for example:
  - dark photon (A') -> ee, which appears with a new U(1) symmetry





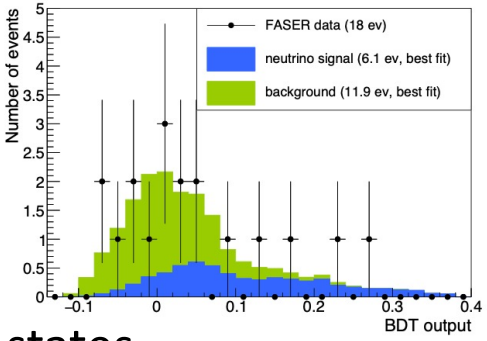
  - axion-like particle, heavy neutral leptons, ... (see Phys. Rev. D 99, 095011 (2019))
- FASER detector is designed to separately detect the two highly collimated tracks
  - assuming LLP with m = 200 MeV and E = 2 TeV, the separation is O(200) um at the first tracker station
  - no background event expected, which gives strong sensitivity

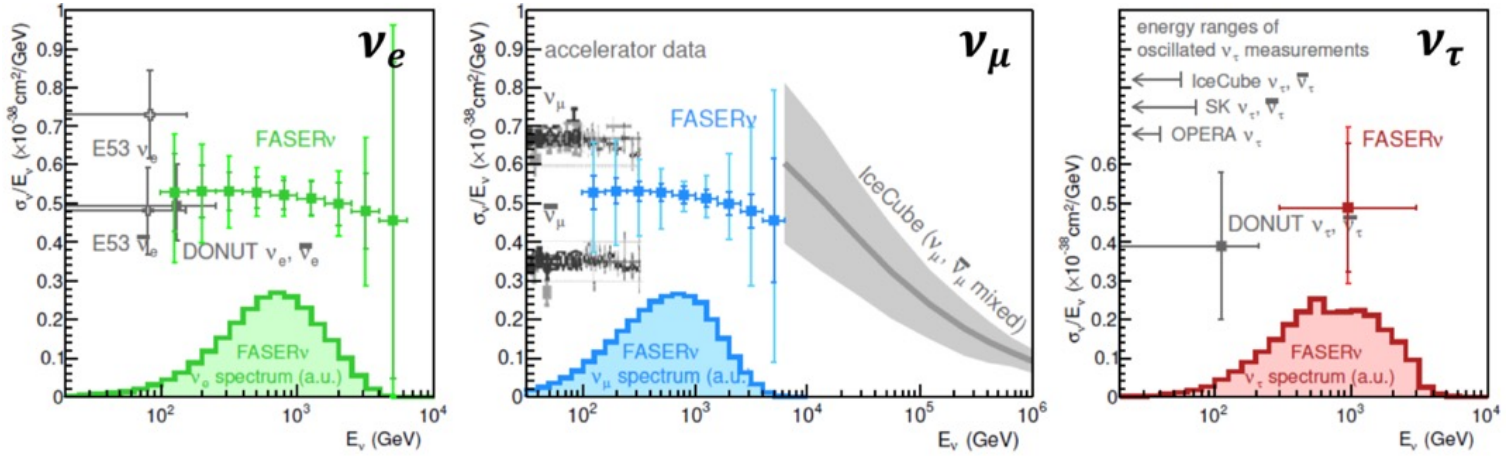
<u>FASER is the first dedicated far-detector collider experiment for new LLP searches</u>

Exploring neutrinos at the TeV-energy frontier

The LHC collisions also produce a copious number of neutrinos at uncharted energies

- In 2018, a 29 kg emulsion detector was already installed
  - exposed to 12.2 fb^{-1} data
  - found a few candidate events of TeV-neutrino interaction
  - published in 2021: [Phys. Rev. D 104, L091101]
- Sensitive to new physics by measuring scattering cross sections and studing the final states





[Eur.Phys.J. C80 (2020) no.1, 61]

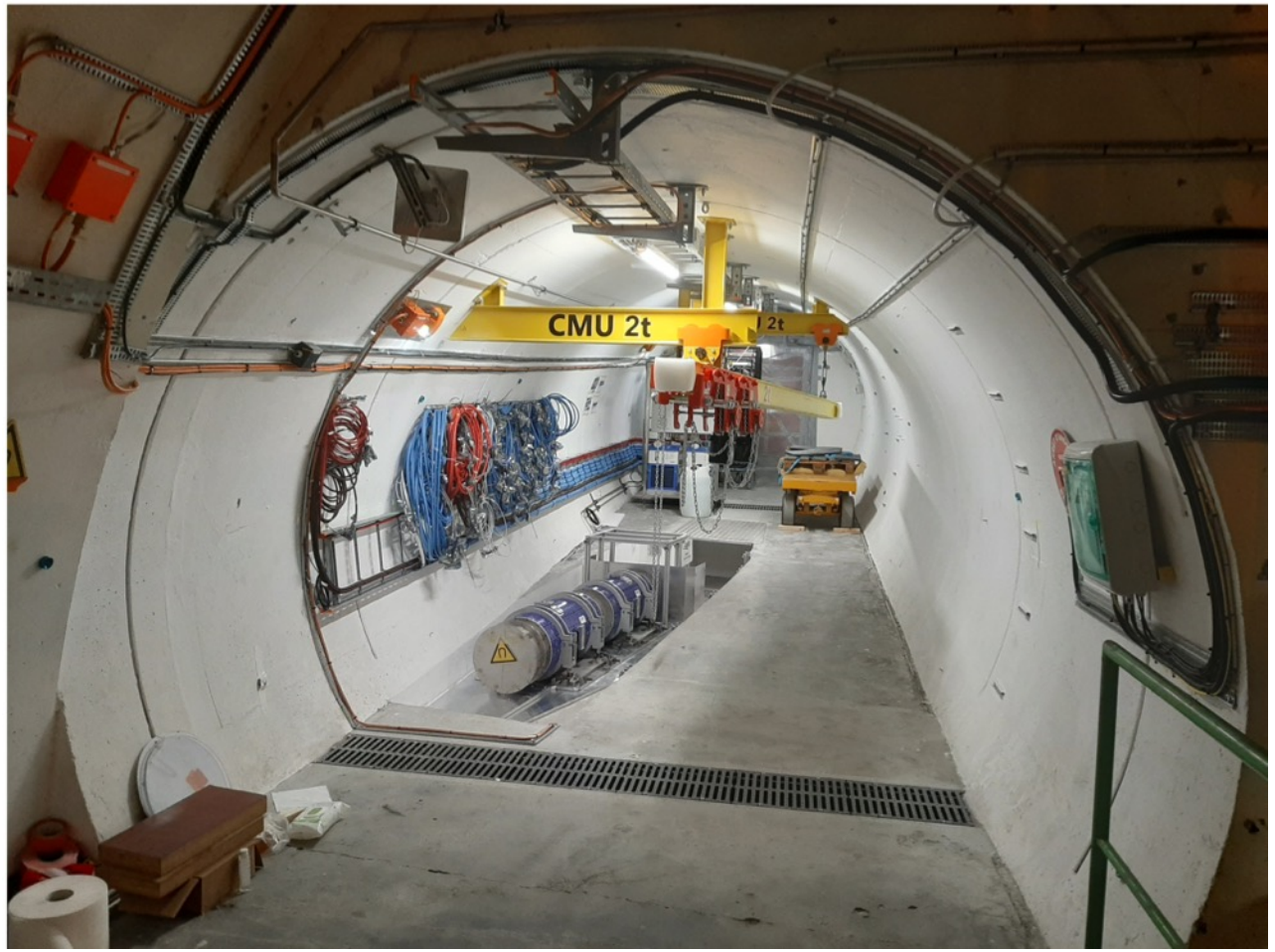
FASER is the first experiment to probe collider neutrinos

Refurbishment of TI12 completed in 2020

2020 winter

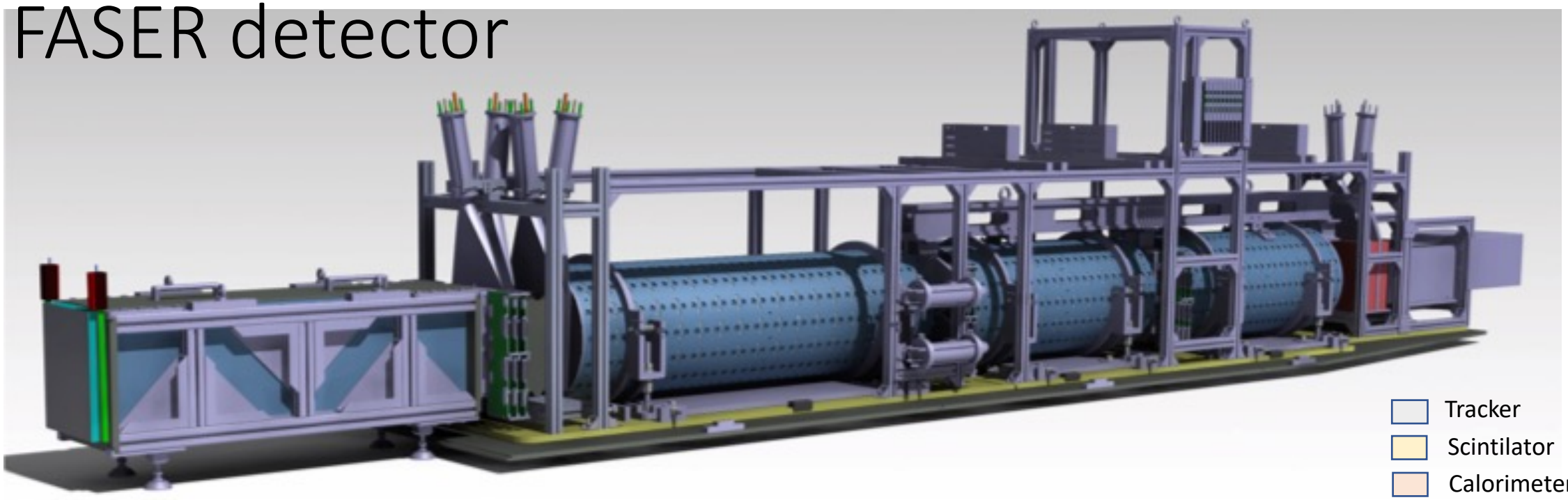
2019 spring

2020 autum



Thanks a lot to CERN for their support for FASER!!

FASER detector

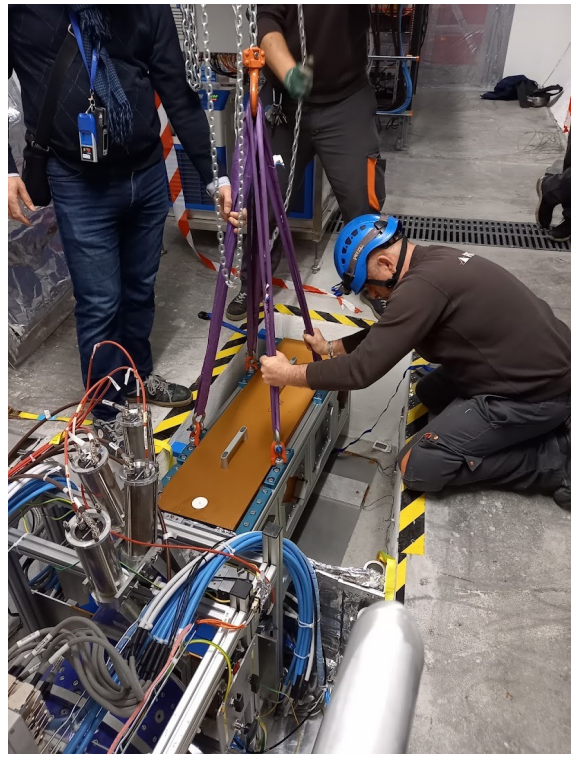


For neutrino physics:
installation completed 2022 March

For new particle search:
installation completed in 2021 March

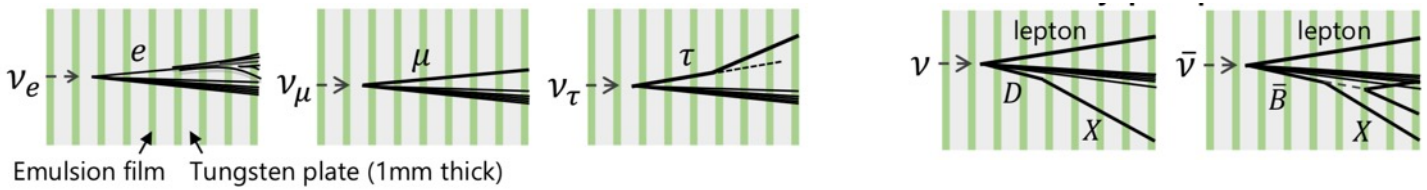
Emulsion/Tungsten detector

Installation on 15th March, which would be retrieved right after starting Run 3.

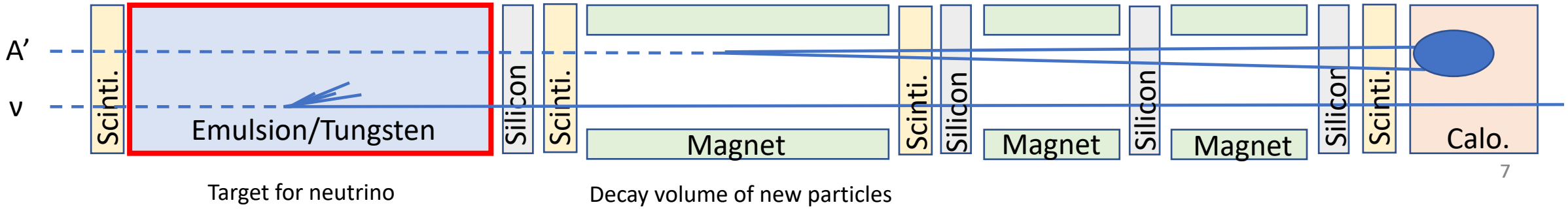


All flavors of neutrino interactions can be identified

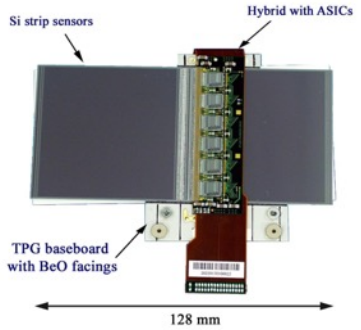
- Heavy quark production also can be distinguished



- 770 x 1-mm-thick tungsten plates, interleaved with emulsion films
- 25 x 30 cm^2, 1.1 m long, 1.1 ton detector (220 X_0 / 8 λ_{int})
  - ~10000 ν_μ, ~1000 ν_e and ~10 ν_τ expected in Run3
- 9 replacements in LHC Run 3; emulsion will be produced a few months before installation



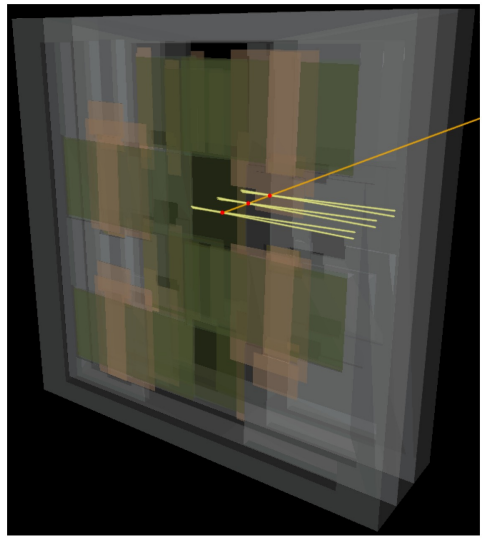
Tracking detector

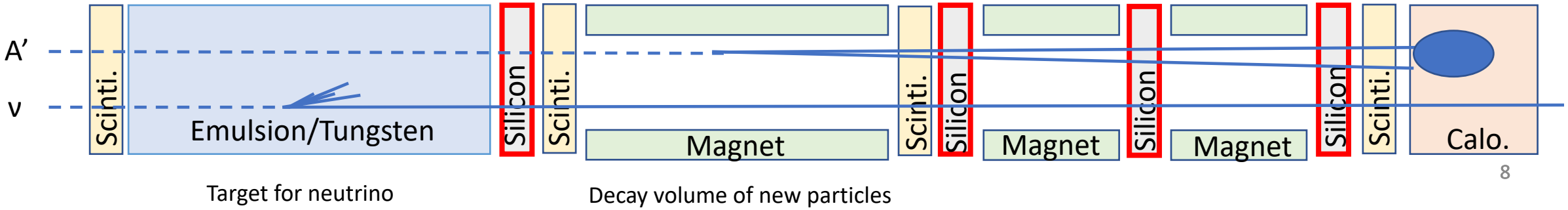


ATLAS SCT module:
- 6cm x 12cm x 2 side (40 mrad)
- 80 um pitch/ 768 strips per side
- Resolution: 17 um x 580 um
- 6 ASICs per side

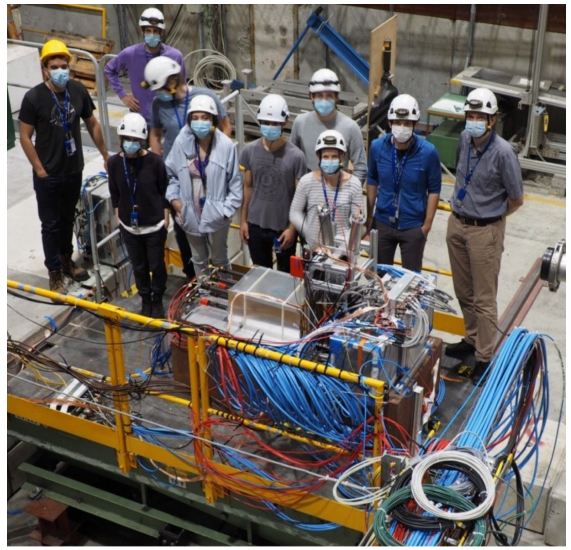
Two highly collimated tracks, e.g., from A' decay, can be separated; tracks in emulsion films can be matched

- Based on ATLAS SCT modules - 4 station x 3 layers x 8 modules = 96 modules
- 4 stations commissioned and installed
  - 99.9% strips are active
  - Expected noise/gain are confirmed
  - Thermal performance looks good
  - Interlock/safety are carefully verified
- Paper submitted: arXiv:2112.01116





Scintillator and calorimeter

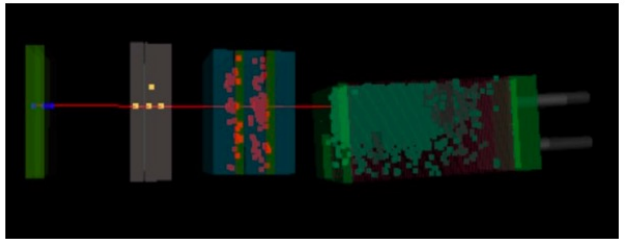


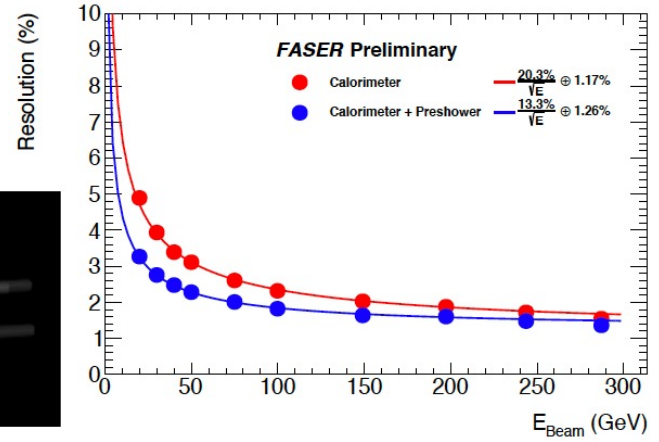
Four scintillator stations are commissioined and installed

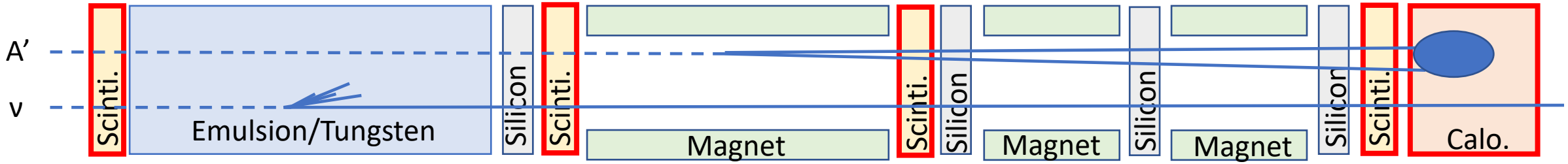
- > 99.9% efficiency, enough to trigger LLP decay inside the FASER detector

Calorimeter based on LHCb ECAL module is also installed

- one module has:
  - 12 cm x 12 cm (25 X_0)
  - 66 layers of (2mm lead and 4mm scintillator)
- testbeam at SPS in 2021 summer
  - Tracker + preshower scintillator + Calorimeter
  - Analysis in progress







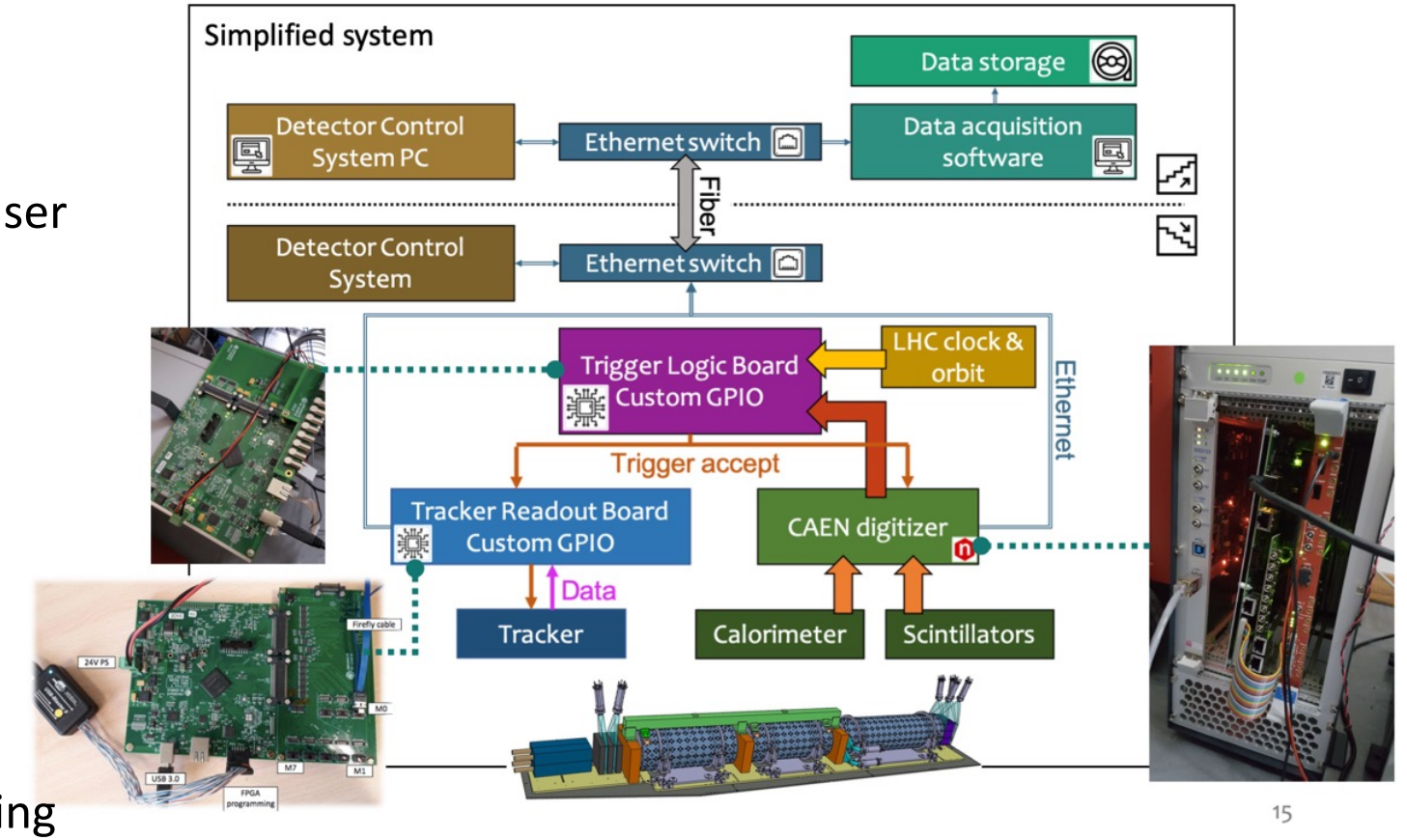
Trigger and Data acquisition

Readout electronics in TI12

- Tracker: Custom GPIO board
- Scintillator and Calorimeter: CAEN digitiser
- Trigger: Custom GPIO board
  - 500 Hz expected rate
  - Clock and bunch taken from LHC
- Ethernet switch -> Servers on surface

All components are installed

- High rate test at 1 kHz successful
- Monitoring tool in place
  - Status of the detector and data taking



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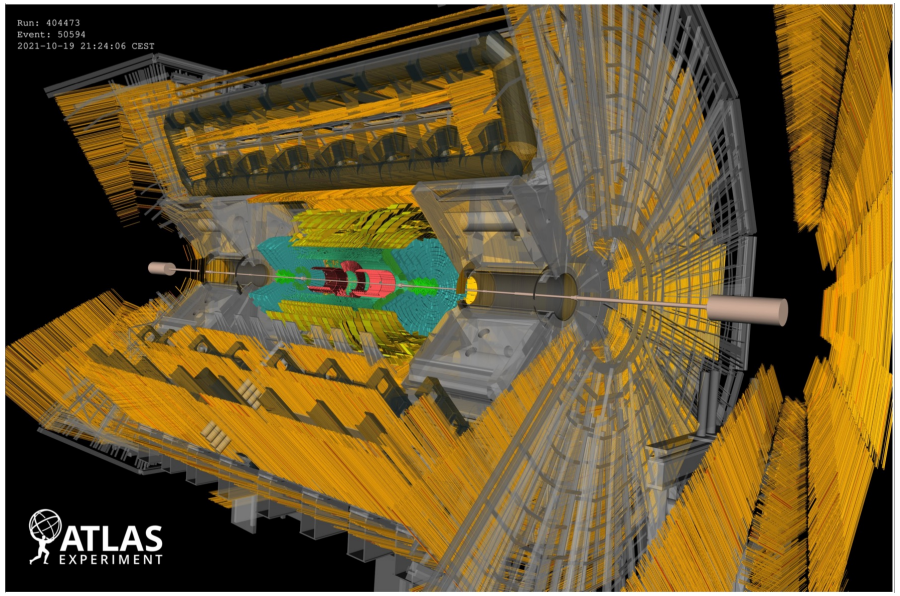
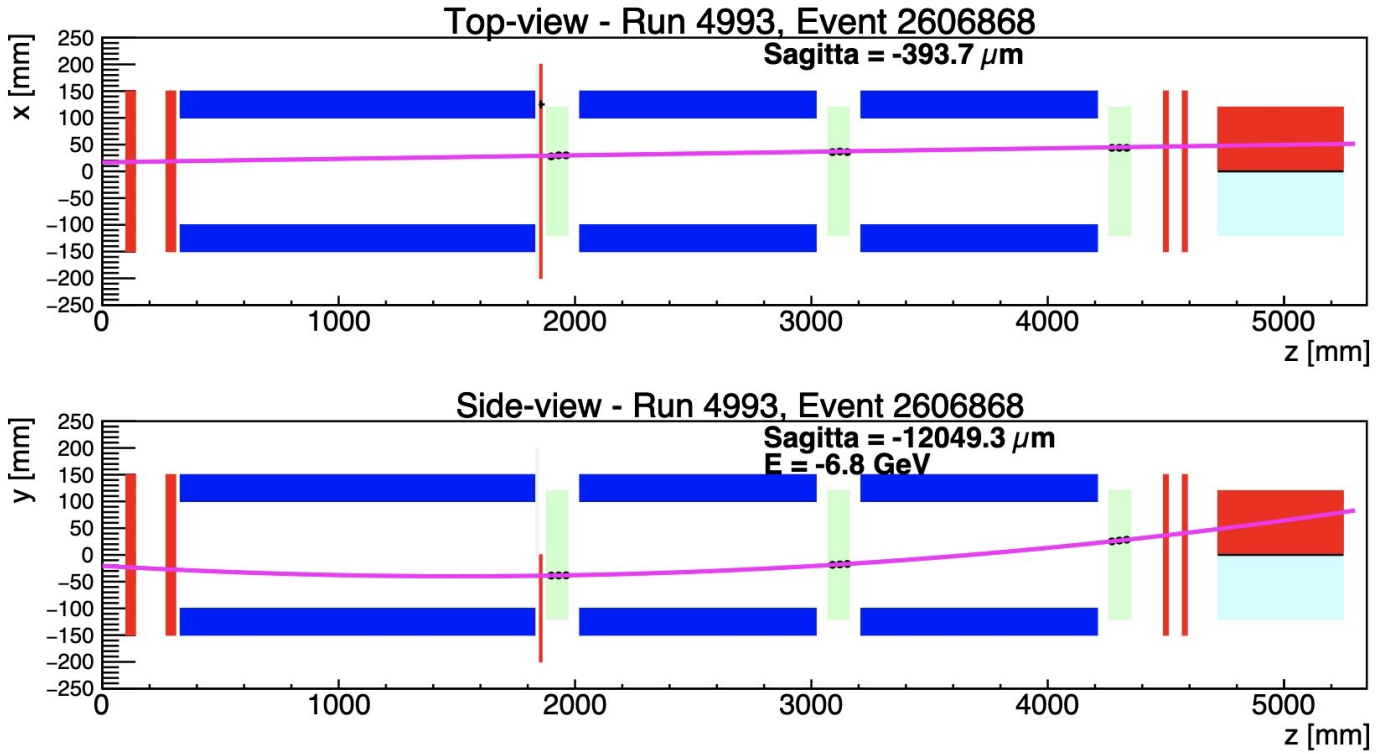
Paper is published: [2021 *JINST* **16** P12028]

Beam splash in October 2021

900 GeV proton beam circulated in the LHC in October 2021

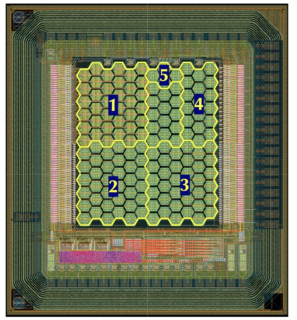
- Collimator is used to make beam splashes, FASER successfully records tracks from the ATLAS interacation point !!

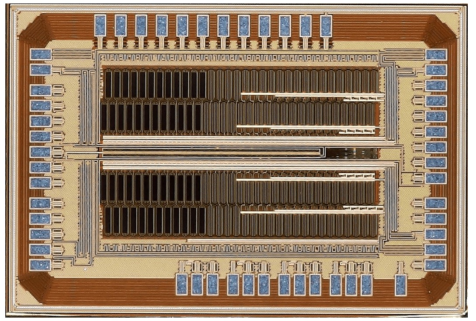




Good readiness confirmed toward Run3

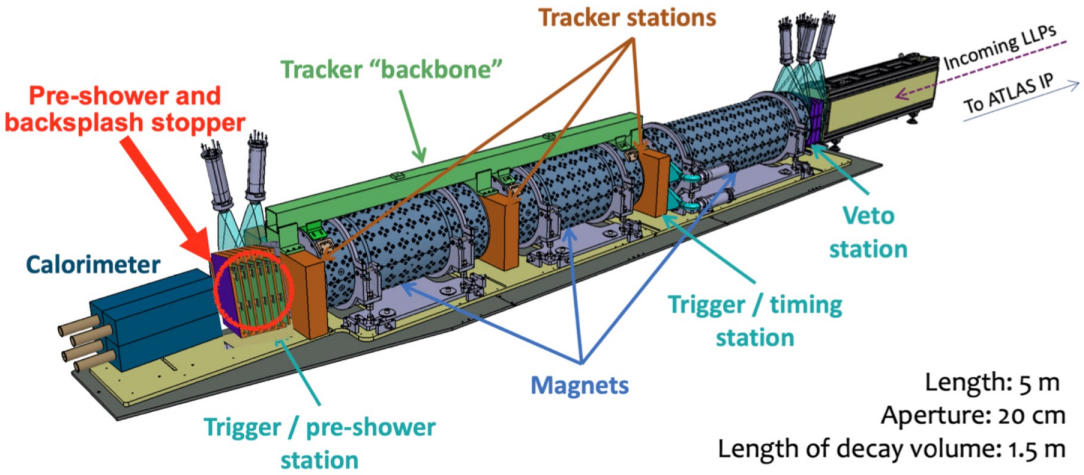
Upgrade planned for 2023/2024

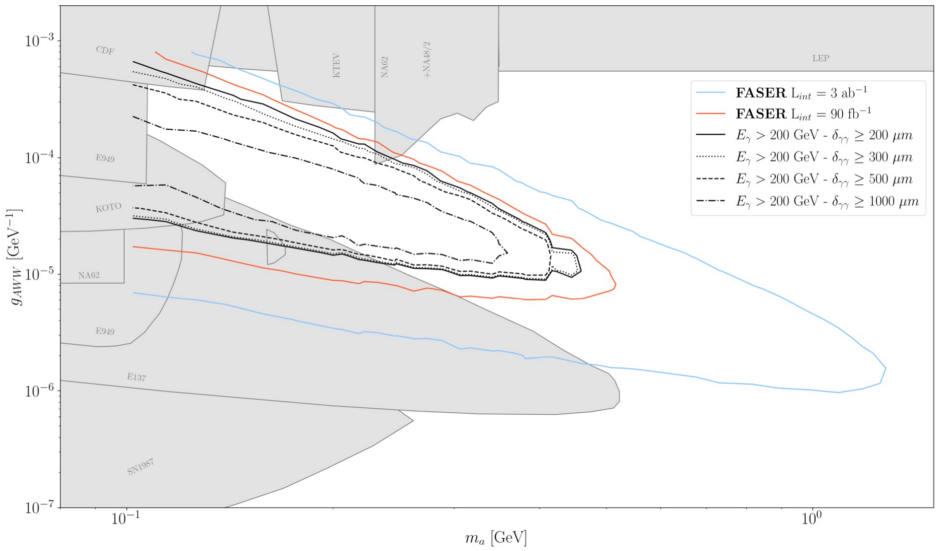




Preshower scintilator will be replaced by silicon pixel detector (130nm SiGe BiCMOS)

- Separation of 2 close-by gammas enables us to get strong sensitivity for ALP -> 2 gamma





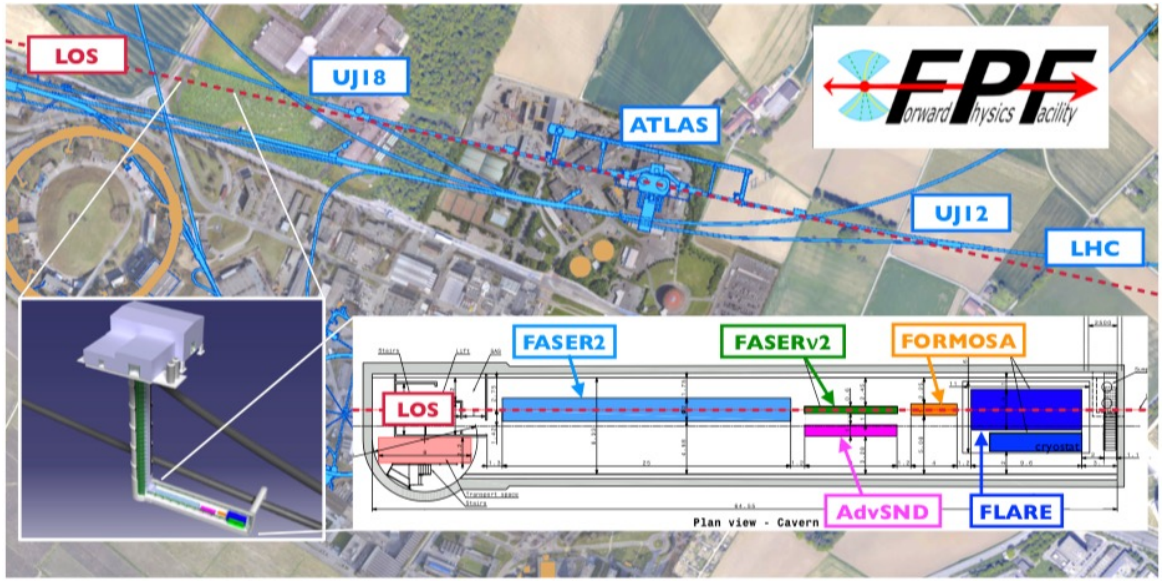
CERN reserch board formally approved this preshower project in March 2022

- Technical proposal is public: https://cds.cern.ch/record/2803084/
- Installation is planned at the end of 2023, aiming to start data taking from 2024

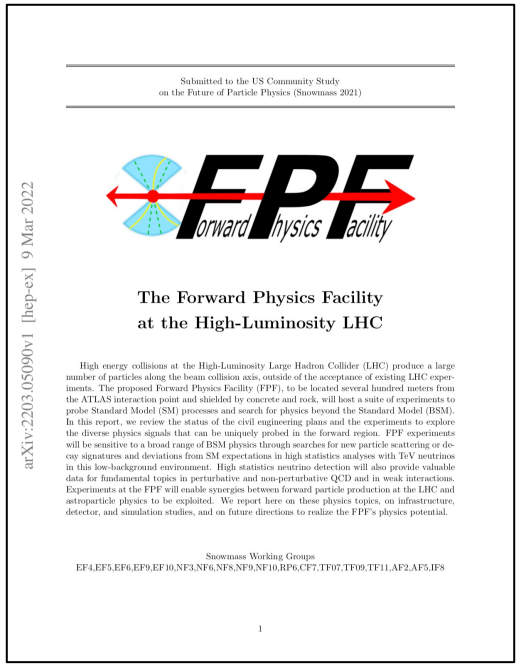
Toward HL-LHC

A new facility called the Forward Physics Facility (FPF) under intensive discussion

- 4th FPF Meeting, 31 Jan-1 Feb 2022: https://indico.cern.ch/event/1110746



White Paper has been submitted in March 2022
to the Snowmass frontiers
429 pages, 236 authors, 156 endorsers


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

FPF Forward Physics Facility

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 the ATLAS interaction point and shielded by concrete and rock, will host a suite of experiments to probe Standard Model (SM) 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 SM expectations in high statistics analyses with TeV neutrinos in this low-background environment. High statistics neutrino detection will also provide valuable data for 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.

Snowmass Working Groups
EF4,EF5,EF6,EF9,EF10,NF3,NF6,NF8,NF9,NF10,RP6,CF7,TF07,TF09,TF11,AF2,AF5,IF8

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arXiv:2203.05090v1 [hep-ex] 9 Mar 2022

https://arxiv.org/abs/2203.05090

FPF plans to house several experiments:

- Enhance physics reach of FASER
- Extend reach to probe dark matter, milli-charged particles
- Provide brand new inputs for QCD and astroparticle physics.

Conclusion

FASER is a new forward experiment at the LHC in the unused tunnel, TI12.

- Refurbishment of TI12 to be an experimental site was completed in winter 2020.

Aiming to start data taking in LHC Run 3 from 2022 for:

- discovery of a light weakly-coupled particle in MeV-GeV range
  - All detectors have been installed in TI12 as of March 2021
  - The beam splash event from ATLAS observed in October 2021
- probe all flavors of neutrinos at the TeV-energy frontier
  - Design and strategy are all defined; 9 replacements of emulsion during the Run 3
  - All detectors are installed March 2022

Preshower upgrade is approved by CERN research board in March 2022

Towards HL-LHC, white paper for Forward Physics Facility is submitted in March 2022

Steady progress for exploring the frontier!!