The new FASER experiment at the CERN LHC

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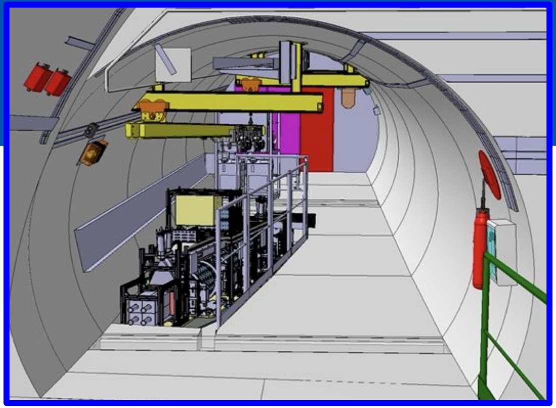
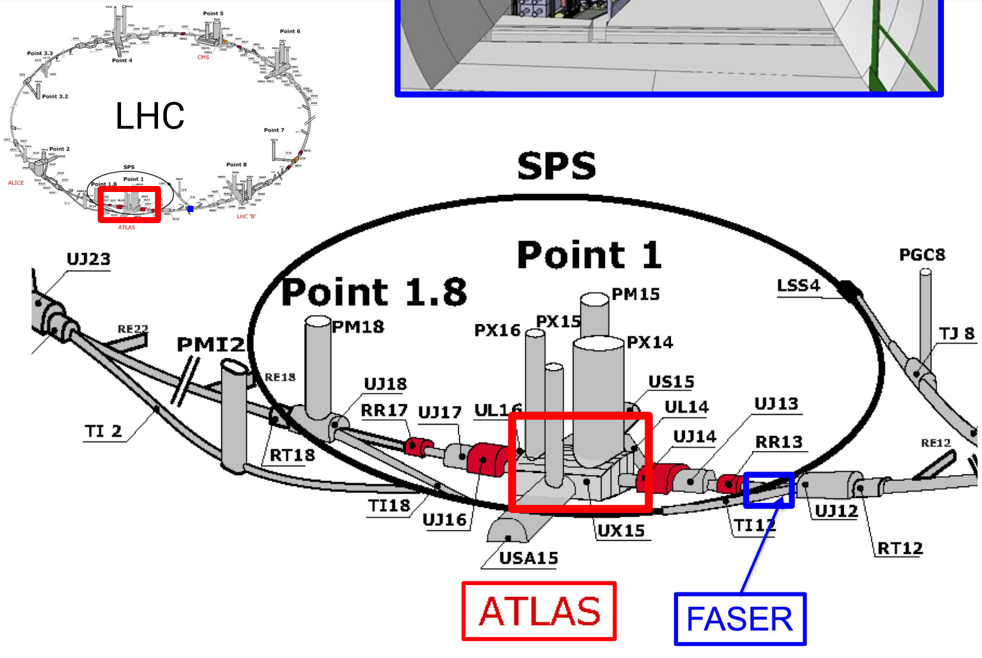
Direct search for new physics



Broadening chances of finding new physics

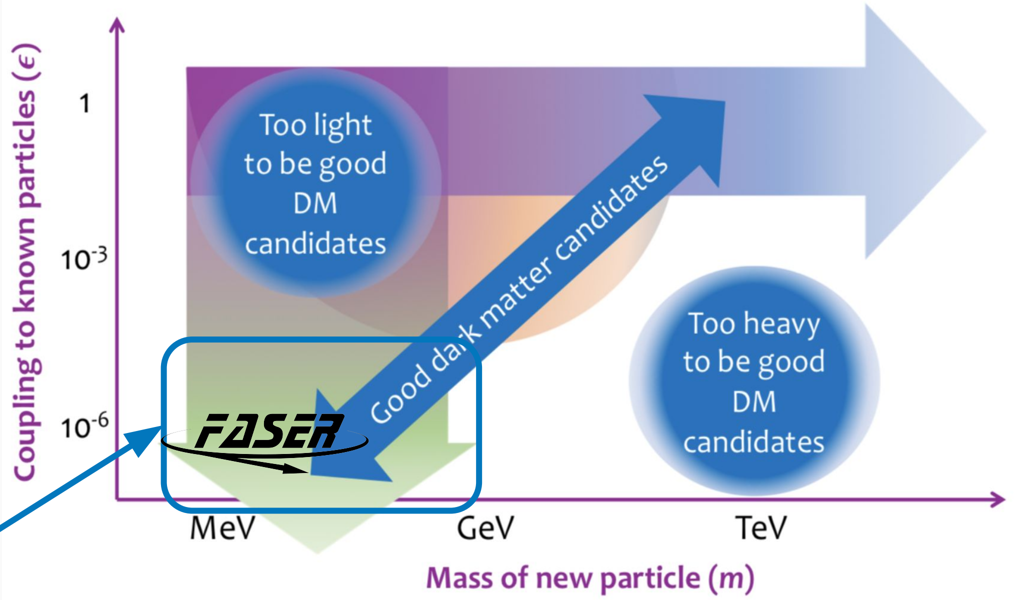
- ➔ Established LHC experiments focus on heavy, strongly interacting particles
- ➔ Large number of interesting models to test outside the focus of larger experiment
    - ◆ FASER targets light and weakly interacting particles
    - ◆ Low cost experiment
        - Reusing spare parts from other experiments
        - Total detector cost <2MCHF
        - Built in side tunnel TI12



FASER philosophy

Exploit high rate of light SM particles produced in collimated beam around the LHC beam

- ➔ Inelastic pp cross-section: ~0.1 barns, N ~ 10^{16} at Run 3
- ➔ Very forward production: $\theta \sim \Lambda_{QCD}/E$ ~mRad
- ➔ Decay length: ~100 m for m ~10-100 MeV $\varepsilon \sim 10^{-5}$



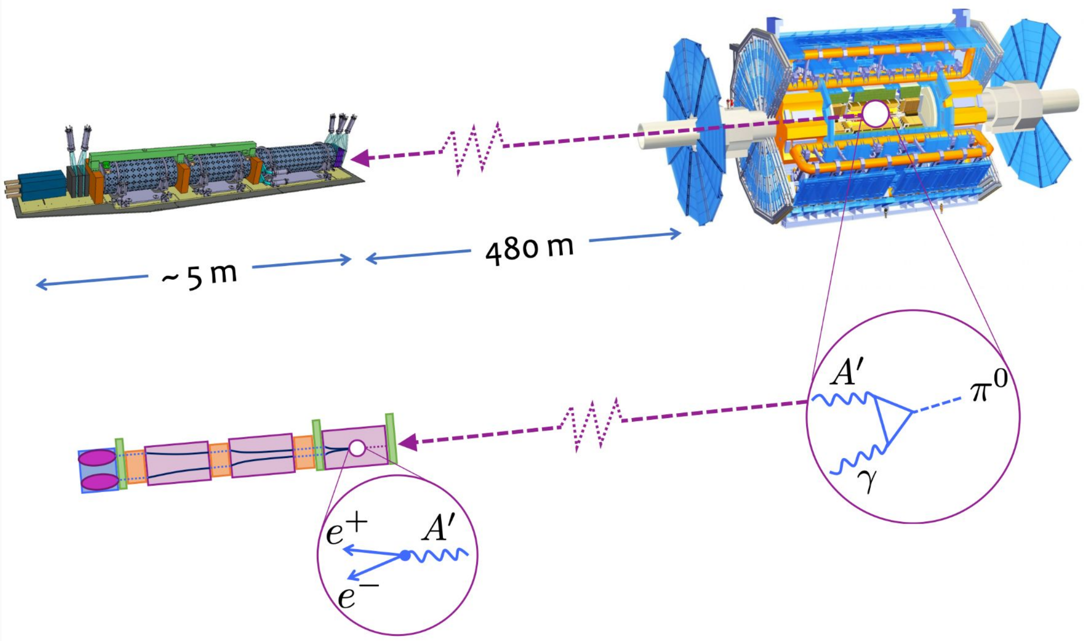
Phasespace where FASER is sensitive

Physis process

Target Dark photons A' as benchmark physics process

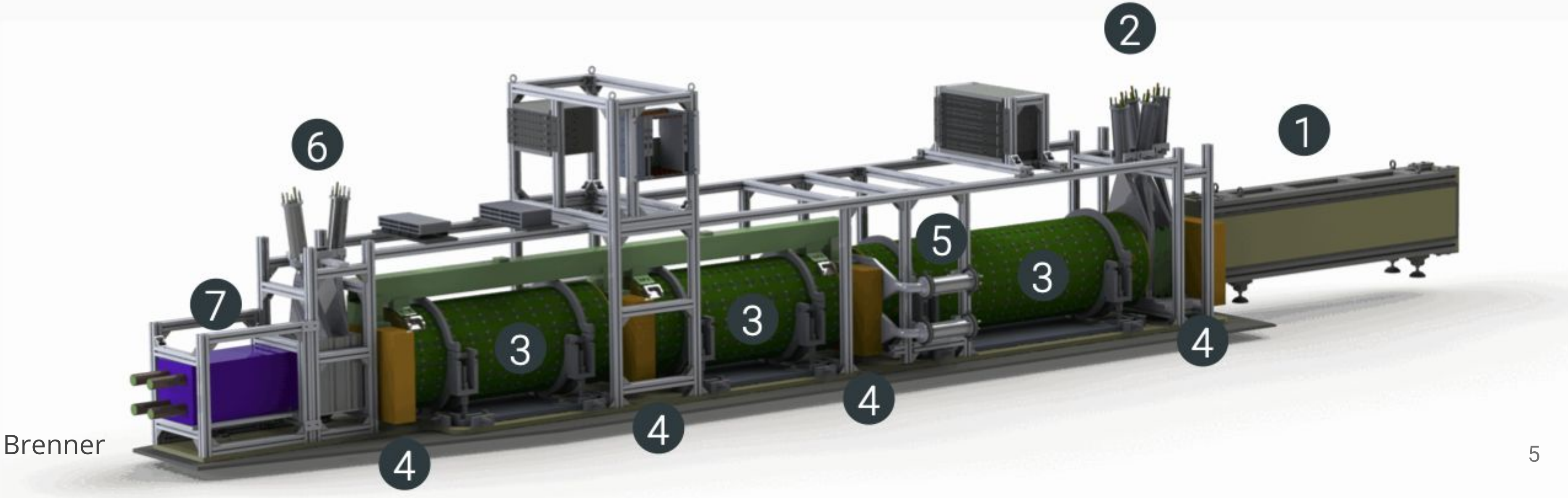
- ➔ Produced via kinetic mixing from e.g. π^0 decays
- ➔ BF ~ 10^{-10}
- ➔ Detected in decay to e^+e^- in FASER decay volume
- ➔ Sensitive to other LLPs and decay modes as well

Physics potential: Phys. Rev. D 99, 095011



Detector overview

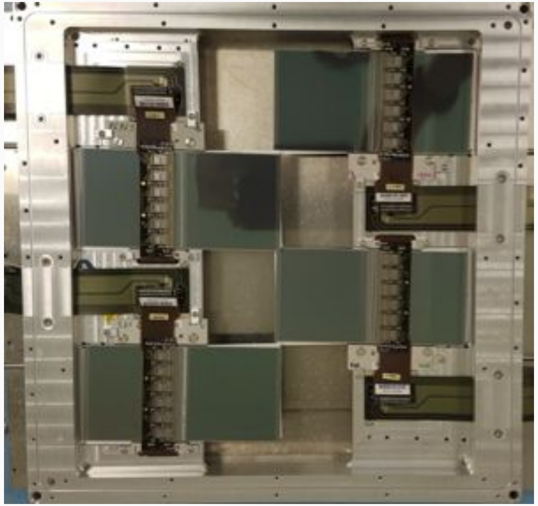
1. FASERν neutrino detector
2. Veto scintillators
3. Dipole magnet (0.6 T)
4. Tracker stations
5. Scintillator (precise timing)
6. Scintillator based preshower
7. Calorimeter

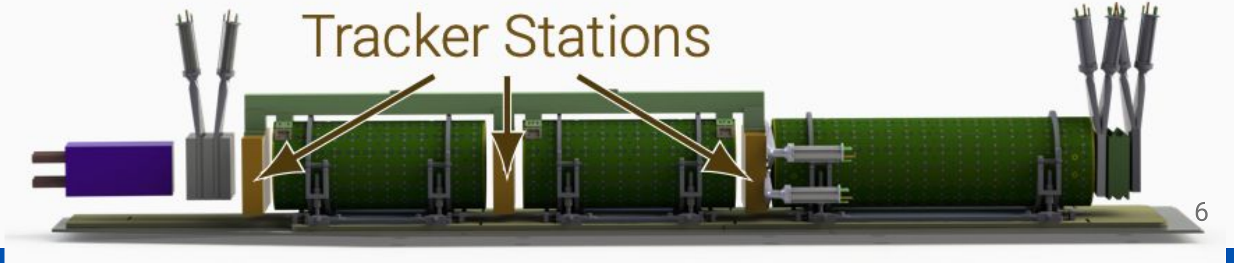


Tracker

Made from spare Si strip detector (SCT) modules from ATLAS

- ➔ Each module tested and best quality modules used
- ➔ Consists of 3 tracker stations with each 3 layers consisting of 8 modules
  - ◆ 72 modules with O(10^5) channels in total
- ➔ Extensive testing on the surface shows expected performance
  - ◆ 25 μm resolution
  - ◆ <0.1% defect strips

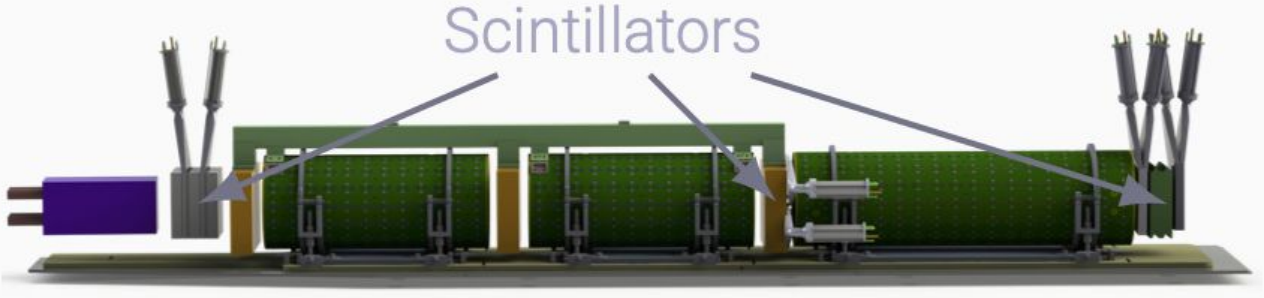




Scintillators

Trigger capabilities in 3 scintillator stations

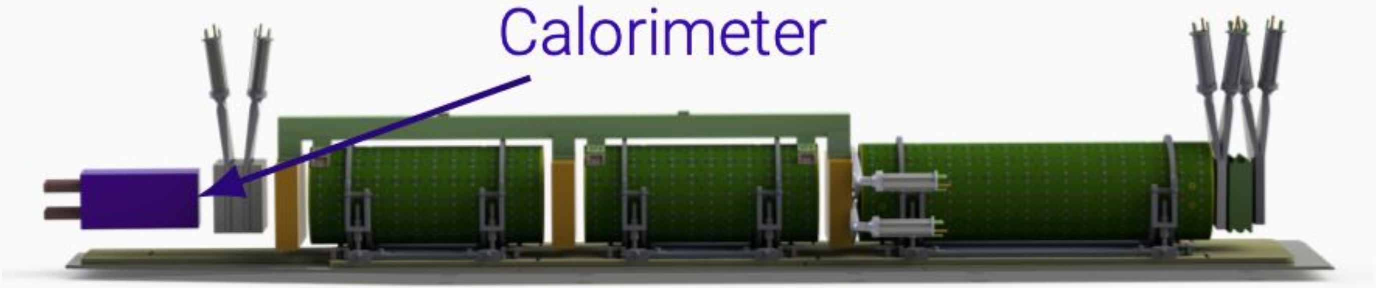
- ➔ High efficiency veto station for vetoing charged particles
- ➔ Efficiency generally measured to be >99.995% for a single layer
  - ◆ Based on cosmic data
  - ◆ Used a tracker station and three scintillators



Calorimeter

Made from four calorimeter modules from LHCb outer ecal

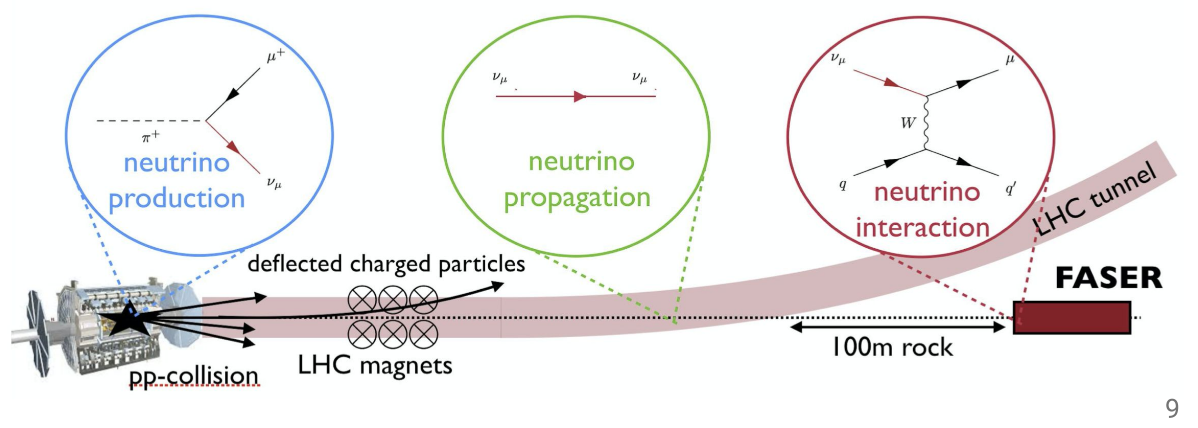
- Readout using PMTs from LHCb with custom voltage divider base
- Consists of 66 layers of lead/scintillator
  - 25 radiation lengths in total
- Calibrated using LED calibration
- Energy resolution ~ 1% for TeV deposits



FASERν

Neutrinos are produced in abundance in the Standard Model

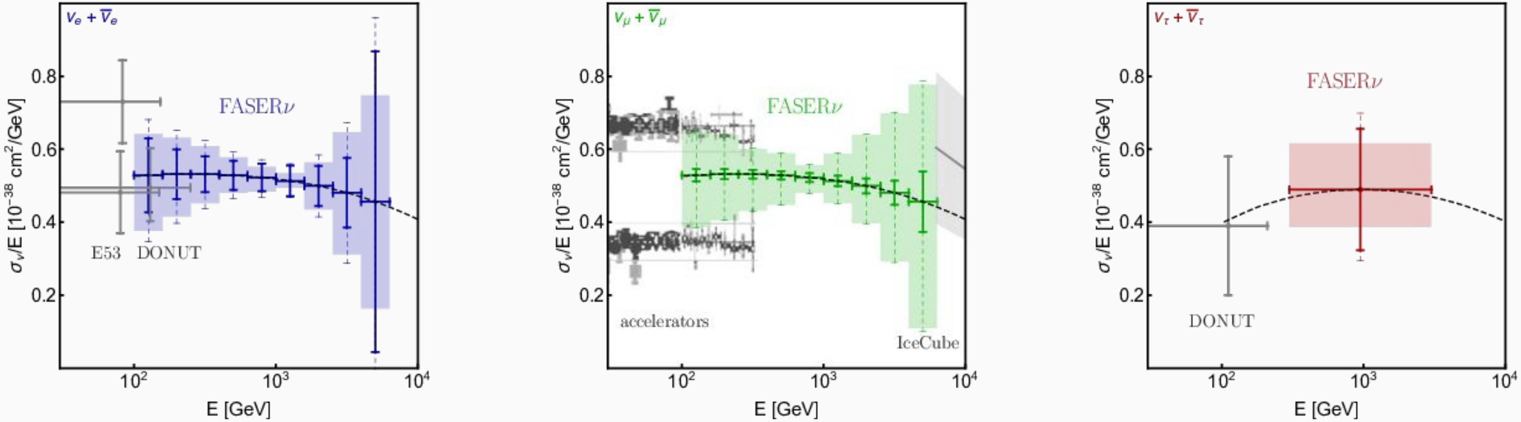
- ➔ Goal to measure neutrino cross-section in collider energy range 100 GeV - few TeV
- ➔ Additional detector at front of FASER
    - ◆ 1.1m long
    - ◆ ~1 ton tungsten-emulsion stack



FASERν

A huge number of neutrinos produced in the LHC collisions (hadron decay) traverse the FASER location covering an unexplored neutrino energy regime.

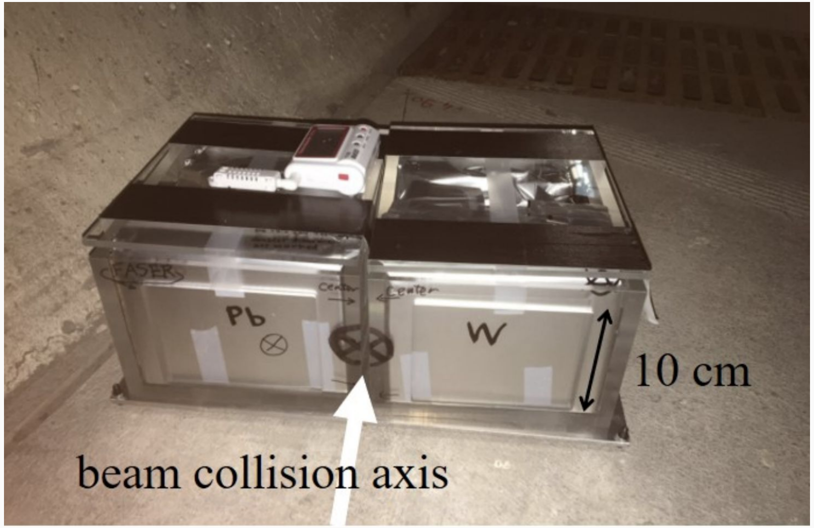
➔ Primary physics goal – cross section measurements at high energy. Projected results:



➔ Uncertainty from neutrino production important

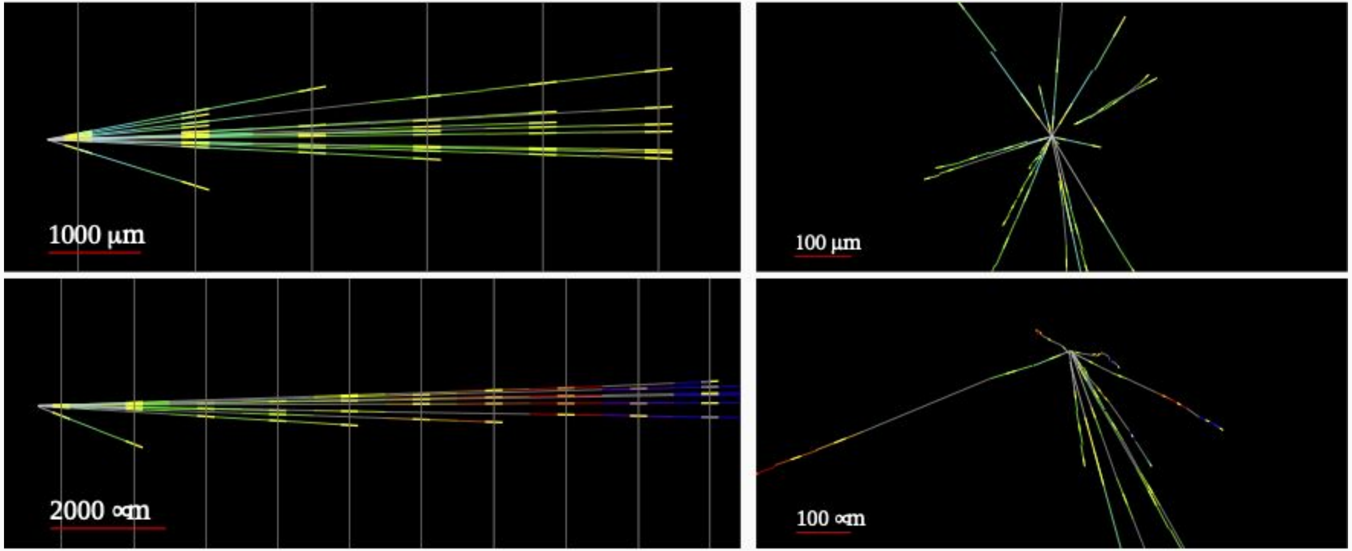
Recent results

- ~30 kg prototype built and installed in the FASER location
  - Collected ~4 weeks of collision data in 2018
  - Exposed to 12 fb^{-1}
- Using BDT to classify between signal and background events
  - Background consists of neutral hadrons produced from muon interactions in the rock in front of the detector



Recent results

- ➔ Determined 6 neutrino candidates with 3.3 events expected
- ➔ 2.7 sigma significance of rejecting the no-neutrino hypothesis

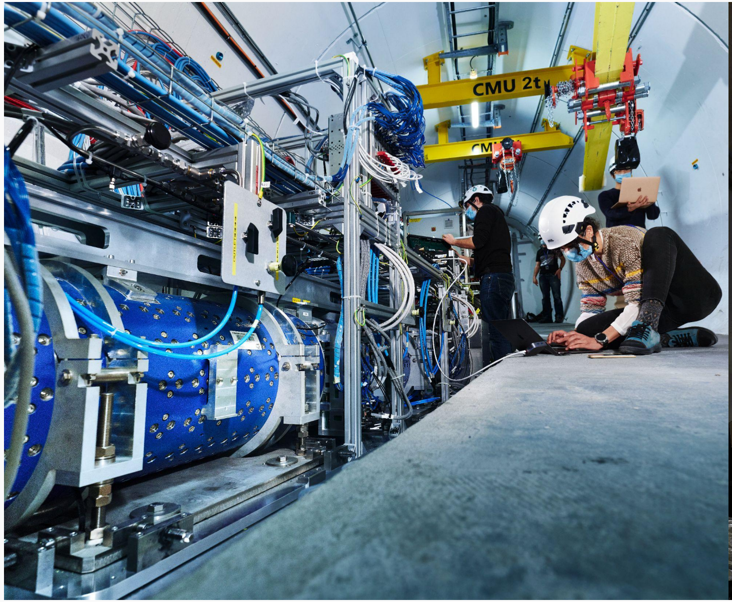


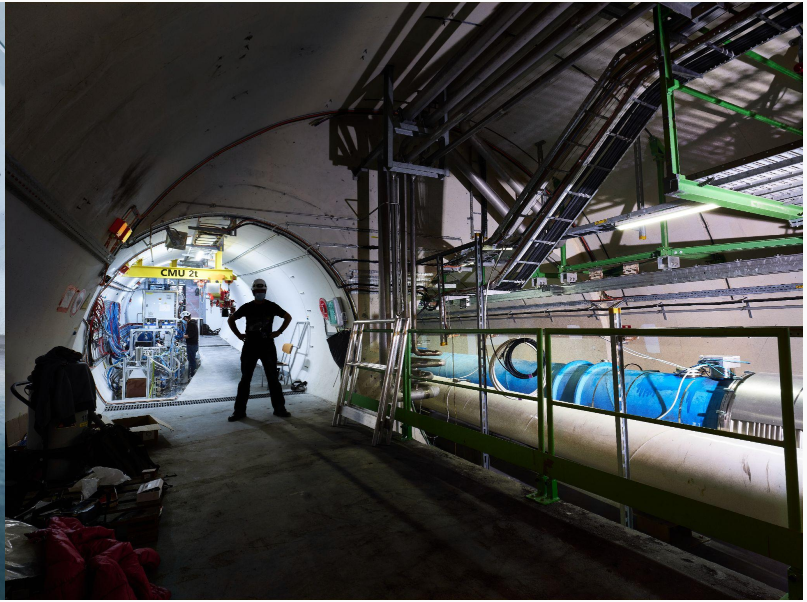
More details: First neutrino interaction candidates at the LHC (arXiv:2105.06197)

FASER installation

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

➔ Has since then been taking cosmic ray data.

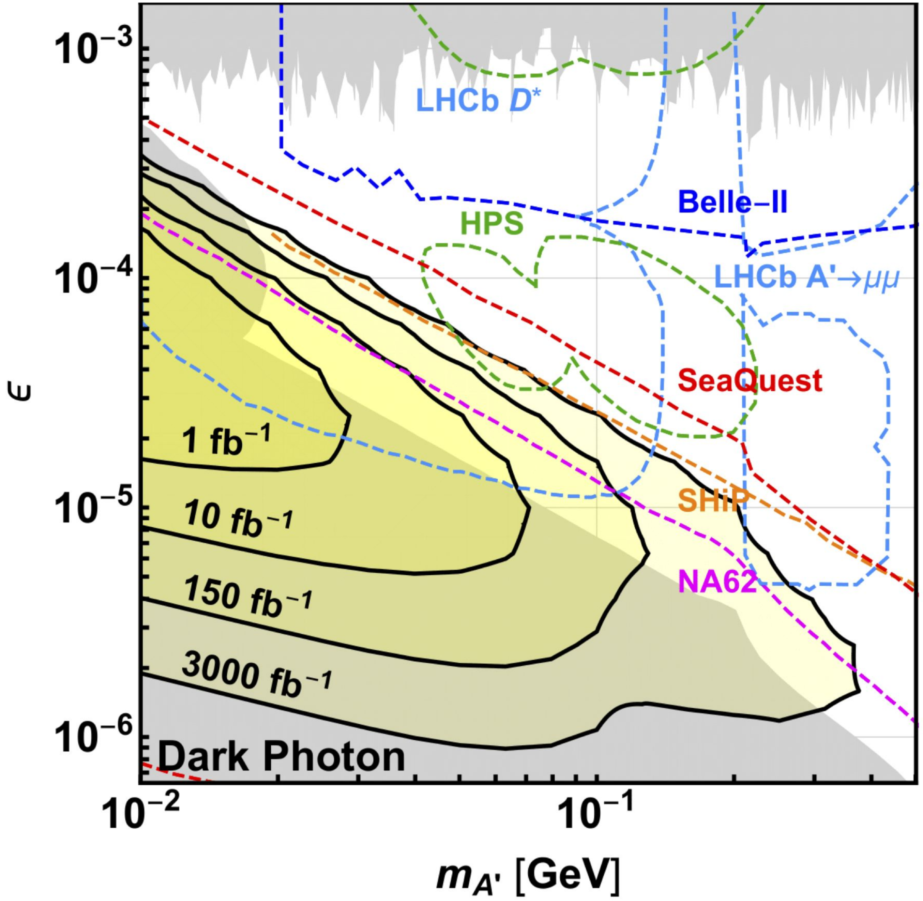




FASER commissioning and projections

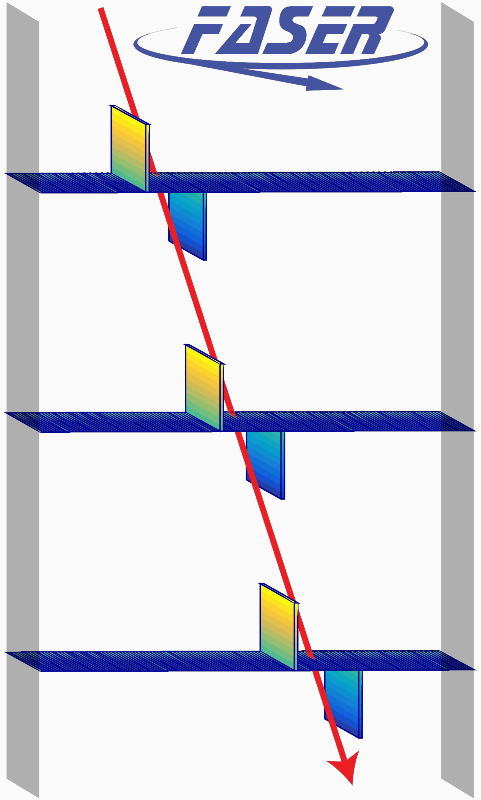
- ➔ First cosmic run with full detector on March 23rd
- ➔ Continuously running
  - ◆ To test remote operation and monitoring
- ➔ Successful triggers with scintillator coincidence
- ➔ Tracker performance matching surface tests
- ➔ Automated DQ/monitoring

FASER will cover large unexplored section of phase-space

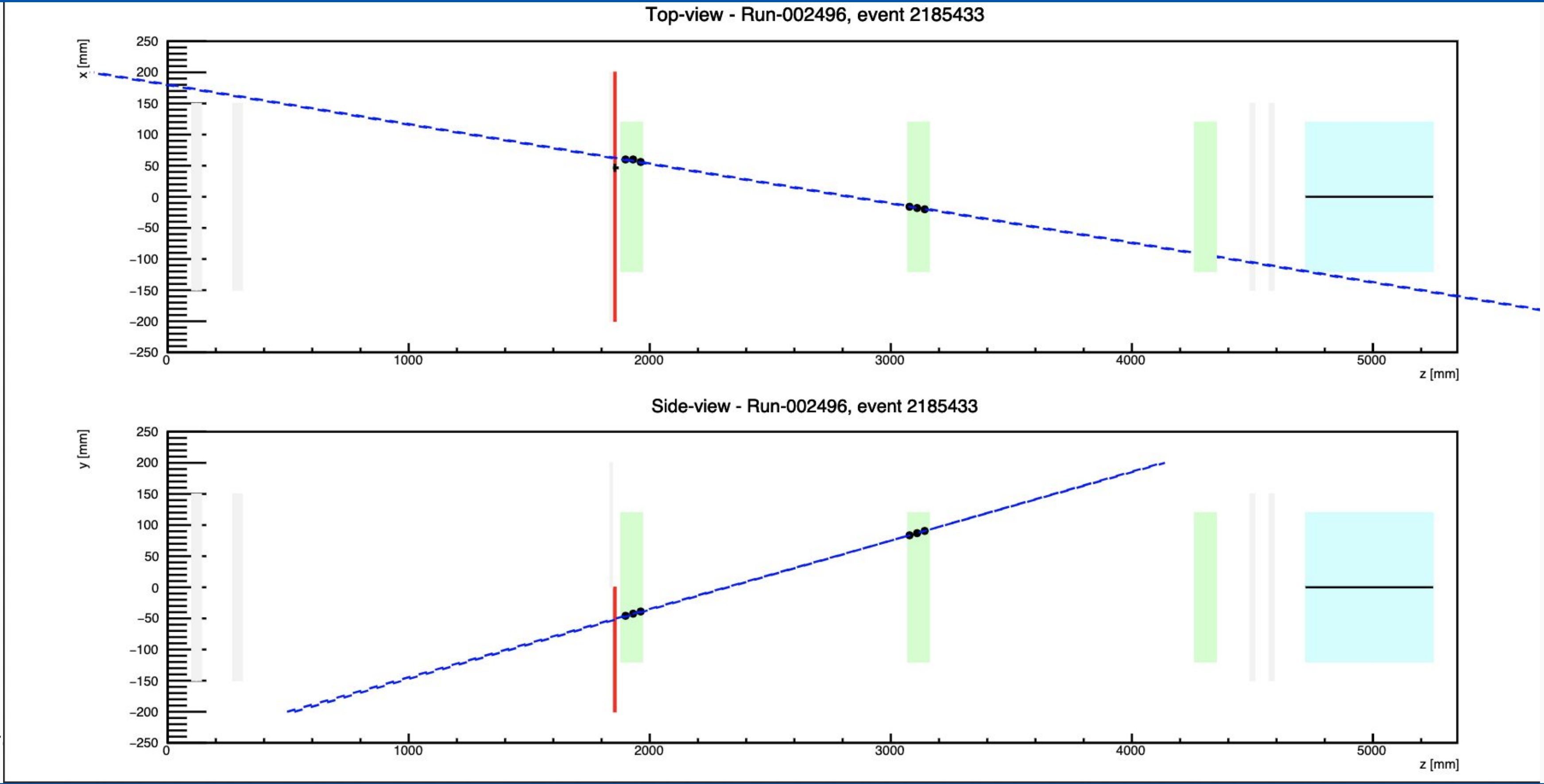


FASER cosmics

- Single station tracks
  - Go through three layers of the station
  - Triggered by nearby scintillator
  - Rate around 1/min
- Double station tracks
  - Couple per day
- Triple station tracks
  - Expected to be very rare
  - First candidates observed



FASER cosmics



Summary

➔ FASER has been installed in the LHC tunnel

➔ Initial commissioning in tunnel has gone smoothly

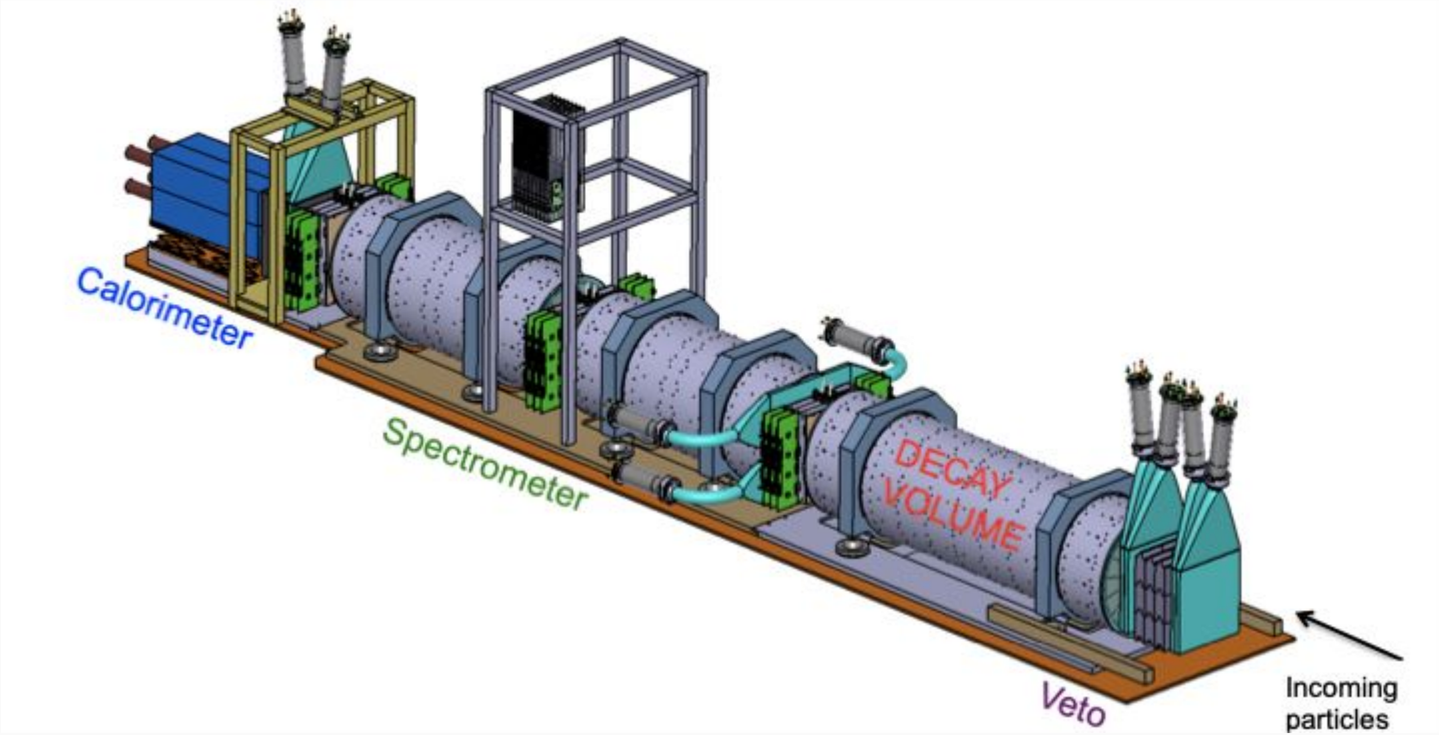
➔ First physics results from neutrino pilot run submitted for publication

Looking forward to first results from LHC collisions of Run 3

Thanks to the Heising-Simons foundation, Simons Foundation and CERN for their support

Back-up

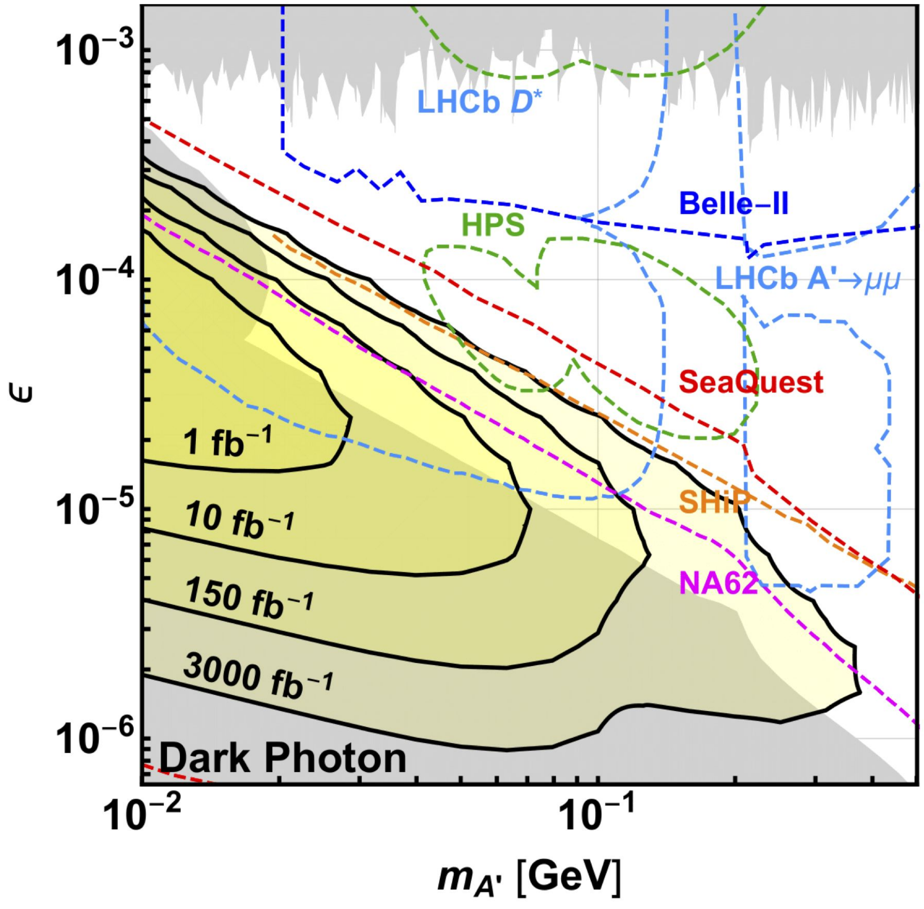
FASER schematic



FASER offline development

- ➔ Detector simulation well advanced
  - ◆ Recently added cosmic generator
  - ◆ FaserNu detector geometry included
- ➔ Reconstruction code development
  - ◆ ACTS-based tracking code making progress
  - ◆ Fast segment finder for cosmics also developed
- ➔ Automated production system
  - ◆ Implementing light-weight job scheduling with Redis rq
- ➔ IFT (FaserVersion = FASER-02) is fully working
  - ◆ Submission of calibration jobs, reco, monitoring, streaming

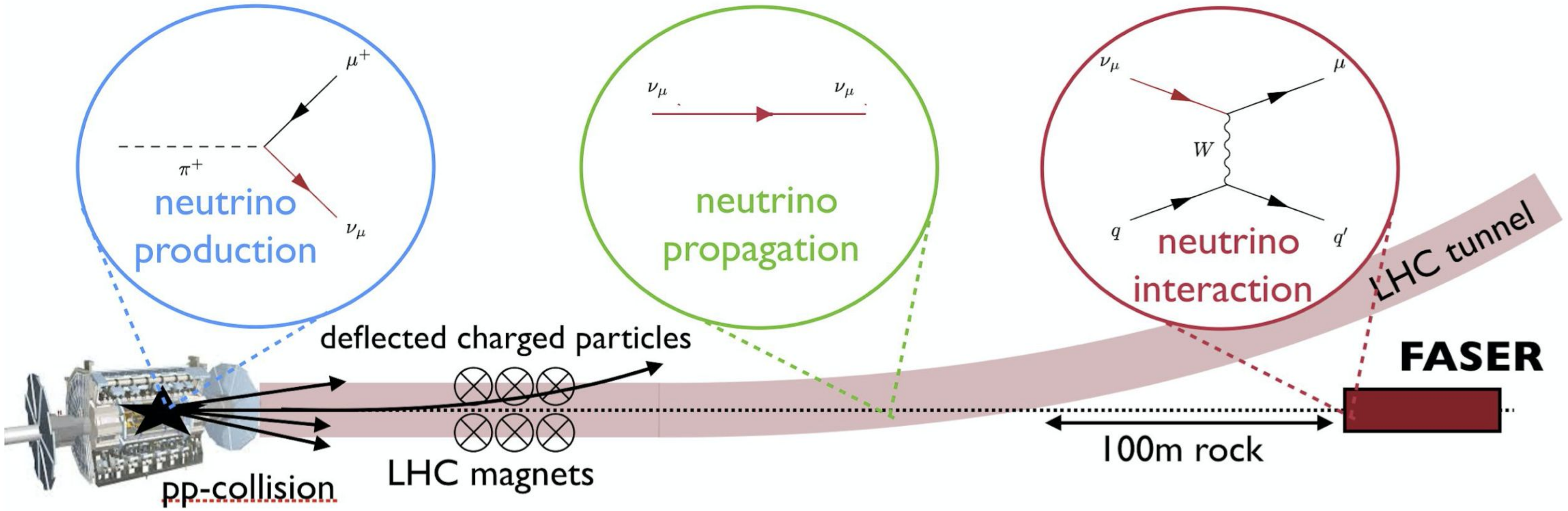
Faser projections



FASER takes advantage of the the huge number of light mesons (π_0, η,..) that are produced at the LHC, predominantly in the very forward direction.

Run 3 (0.15/ab) will produce a huge number of π_0s in FASER angular acceptance. Even with large suppression ($e^2 \sim 10^{-8} – 10^{-10}$ for relevant region of parameter space) can still have very large number of dark photons produced. **LHC can be a dark photon factory!**

FASERnu



μ^+
π^+
ν_μ
neutrino production
ν_μ
ν_μ
neutrino propagation
ν_μ
μ
W
q
q'
neutrino interaction
LHC tunnel
FASER
deflected charged particles
LHC magnets
pp-collision
100m rock

FASERnu: Details

• Emulsion film made up of ~80μm emulsion layer on either side of 200μm thick plastic

• Emulsion gel active unit silver bromide crystals (diameter 200nm)

• Charged particle ionization recorded and can be amplified and fixed by chemical development of film • Track position resolution ~50nm, and angular resolution ~0.35mrad

• But no time resolution!