New Long-Lived Particle Searches at the LHC with *FASER*: *ForwArd Search ExpeRiment*

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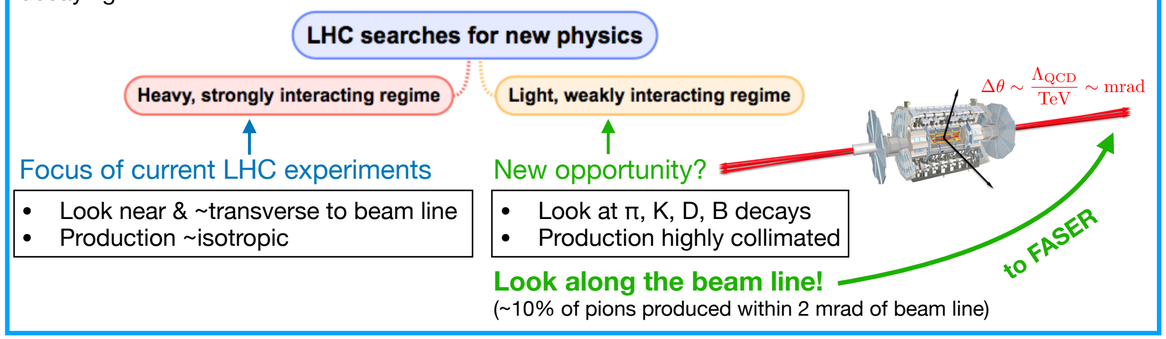
The Concept

The ForwArd Search ExpeRiment[1] (FASER) is a new LHC experiment aiming to probe for new physics in the far-forward region of phase space inaccessible to existing experiments. FASER will target light, weakly interacting particles able to travel long distances (~10^2-10^3 m) through rock and concrete before decaying.

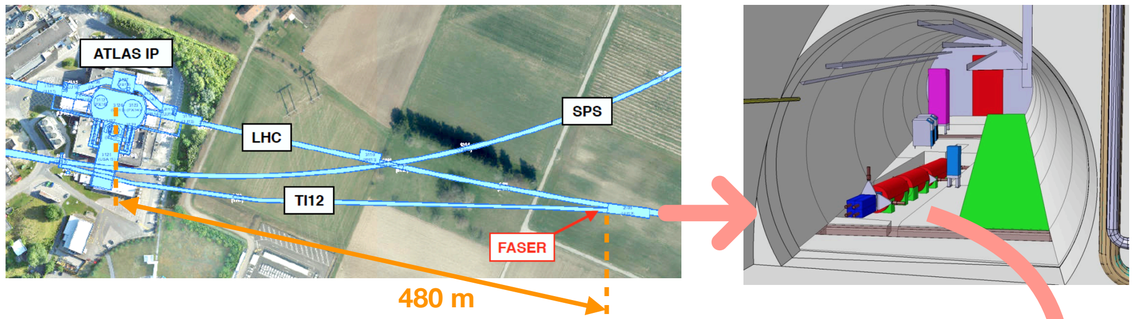


- Look near & ~transverse to beam line
- Production ~isotropic

- Look at π, K, D, B decays
- Production highly collimated

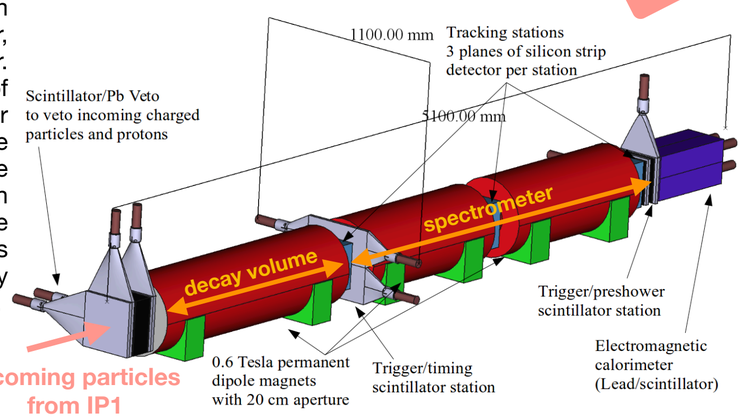
Look along the beam line!
(~10% of pions produced within 2 mrad of beam line)

The Detector



Above: The FASER detector will be positioned directly on the beam collision axis line-of-sight inside tunnel TI12, 480 m downstream from the ATLAS interaction point IP1 and a few meters from LHC beam line. The detector radius will be 10 cm, covering the millirad regime.

Right: The FASER detector will include 0.6-T permanent dipole magnets, a scintillator veto, a 1.5-m decay volume, a 2-m spectrometer, and an electromagnetic calorimeter. The spectrometer will use a total of 72 spare ATLAS semiconductor tracker (SCT) modules and the electromagnetic calorimeter 4 spare LHCb outer ECal modules. An emulsion detector (not shown) at the front for neutrino measurements[3] has also been proposed. The latter may require additional tracking detectors.



Components:
- Scintillators (gray)
- Dipole magnets (red)
- Tracking stations (blue)
- EM calorimeter (purple)
- Support structures (green)

The Physics

Right: FASER will be sensitive to dark vectors, dark scalars and pseudoscalars, heavy neutral leptons, and axion-like particles in the far-forward regime. The proposed FASERν addition[3] would offer the possibility of the first detection of collider neutrinos for further discovery opportunities.

FASER Physics

Dark Sector Searches

Discovery potential for:
- Dark vectors
- Dark scalars & pseudoscalars
- Heavy neutral leptons (HNLs)
- Axion-like particles (ALPs)

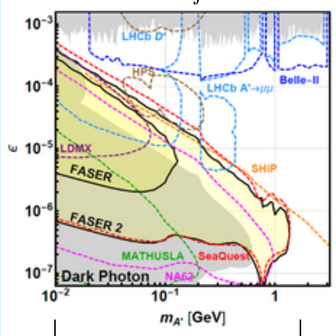
(proposed) Neutrino Measurements

Potential for:
- First collider detection
- New forward production constraints
- TeV-scale cross sections
- BSM neutrino physics

Below: Projected exclusion reach in corresponding coupling-vs.-mass planes in example scenarios[2] of dark photons, dark Higgs, heavy neutral leptons, and axion-like particles with the reach of FASER and FASER 2 highlighted in yellow.

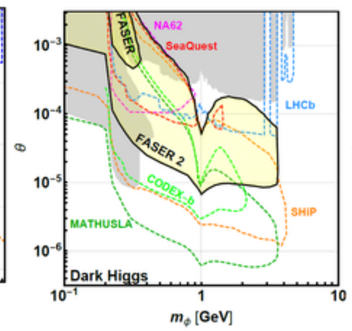
Dark Photon

$$\mathcal{L} \supset -\epsilon e \sum_f q_f \bar{f} \not{A}' f$$



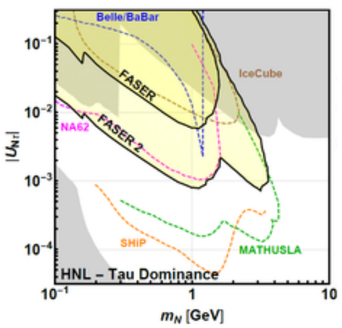
Dark Higgs

$$\mathcal{L} \supset -\theta\, \phi^2 |H|^2$$



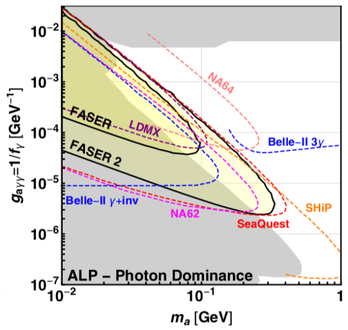
Heavy Neutral Leptons

$$\mathcal{L} \supset -\sum y_{\alpha I} \bar{L}_\alpha H N_I$$

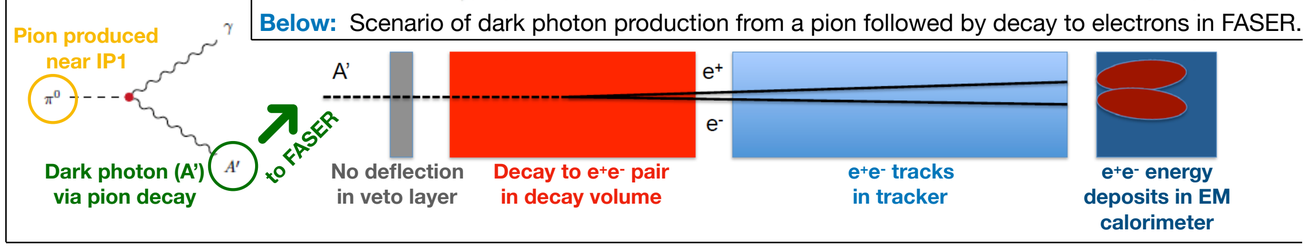


Axion-like Particle

$$\mathcal{L} \supset -\frac{1}{4} g_{a\gamma\gamma} a F^{\mu\nu} \tilde{F}_{\mu\nu}$$



Below: Scenario of dark photon production from a pion followed by decay to electrons in FASER.

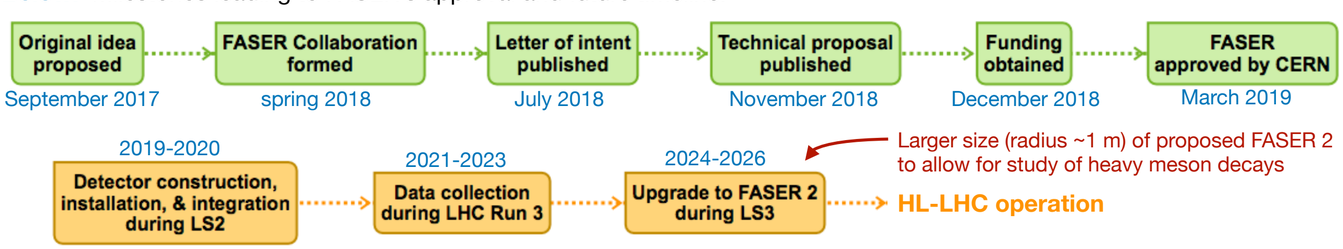


Neutrinos: LHC Run 3 is expected[3] to produce ~1300 ν_e, ~20000 ν_μ, and ~20 ν_τ inside FASERν.

Beam backgrounds: FLUKA simulations and *in situ* measurements have evaluated dominant beam backgrounds. FLUKA simulations performed include IP1 collisions, off-orbit proton interactions with the LHC beam pipe near FASER, and beam-gas interactions. Emulsion detectors placed in the TI12 tunnel during the 2018 LHC running have validated the expected particle fluxes. High-energy muons from IP1 will form a dominant background.

The Timeline

Below: Milestones leading to FASER's approval and future timeline.



[1]FASER home page: https://twiki.cern.ch/twiki/bin/view/FASER

[2]FASER's Reach for LLPs: https://arxiv.org/abs/1811.12522

[3]FASERν: https://arxiv.org/abs/1908.02310