FASER at the LHC

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on behalf of the FASER Collaboration

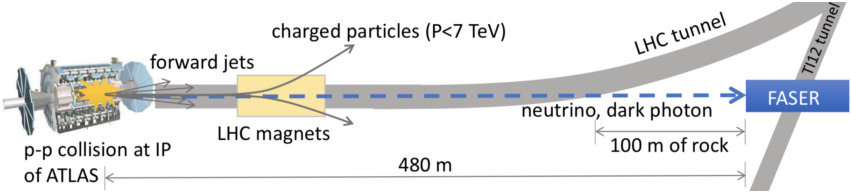
Dark Interactions
New Perspectives from Theory and Experiment

14 - 16 November 2022

ForwArd Search ExpeRiment

- Search for LLPs produced in inelastic pp collisions
  - Large inelastic pp cross-section $\sigma_{\text{inel}}(13.6\,\text{TeV}) \sim 80\,\text{mb} \rightarrow$ about 10^{16} inelastic pp scatterings in Run 3
  - Small production angle: $\theta \sim \Lambda_{qcd}/E \sim$ mrad
  - Macroscopic decay length: $\sim 100\,\text{m}$ for m in 10 MeV to 100 MeV, $\epsilon \sim 10^{-5}$
- Placed 480 m downstream of the ATLAS IP on the beam collision axis in TI12 tunnel
  - Quiet background environment

- FASER: search for new, weakly-interacting particles in the MeV - GeV range (e.g. A', HNL, ALPS)
- FASERν: first measurements of neutrinos from a collider and in unexplored energy regime (not covered in this talk)



Physics Program

- Sensitive to unprobed phase space for dark photons, ALPs, Neutral Heavy Leptons
- Future FASER 2 could probe further phase space

  See also talk from Sebastian Trojanowski

  Example: Dark Photons
- Mainly produced in decays of light mesons or via dark bremsstrahlung:

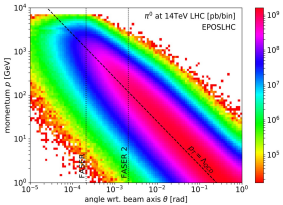
$$\mathrm{BR}(\pi^0 \to \gamma A') = 2\epsilon^2 \left(1 - \frac{m_{A'}^2}{m_\pi^2}\right)^3$$

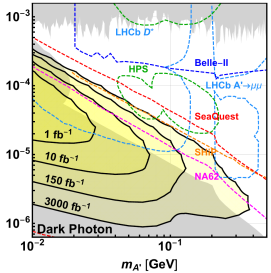
- Decay in pair of electrons, muons or pions:

  decay length $\overline{d} = 80\,\mathrm{m} \left[\frac{10^{-5}}{\epsilon}\right]^2 \left[\frac{100\,\mathrm{MeV}}{m_{A'}}\right]^2 \left[\frac{E_{A'}}{\mathrm{TeV}}\right]$

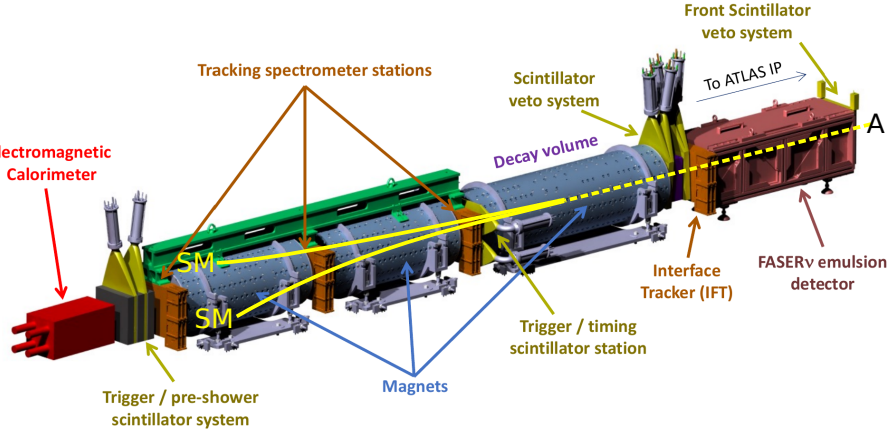
  $\to$ only A' with high energy reach FASER

  $\to$ small detector radius
- FASER can probe new phase space already with $10\,\mathrm{fb}^{-1}$





FASER Detector

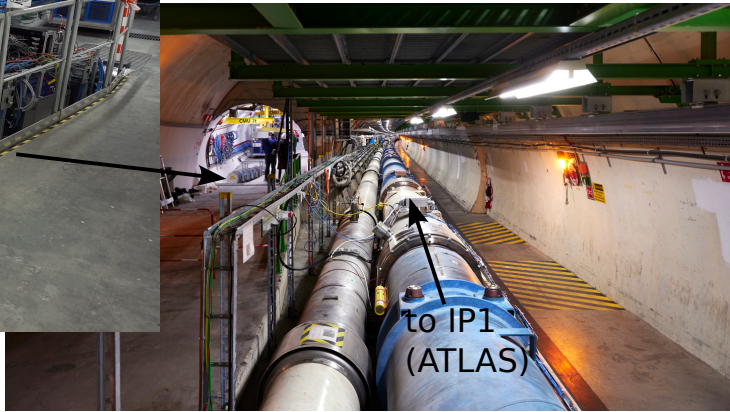


Signature:

- No signal in the veto scintillator
- Two high energy, oppositely charged tracks, consistent with originating from a common vertex in the decay volume, and with a combined momentum pointing back to the IP
- For $A' \to e^- e^+$: Large EM energy in calorimeter

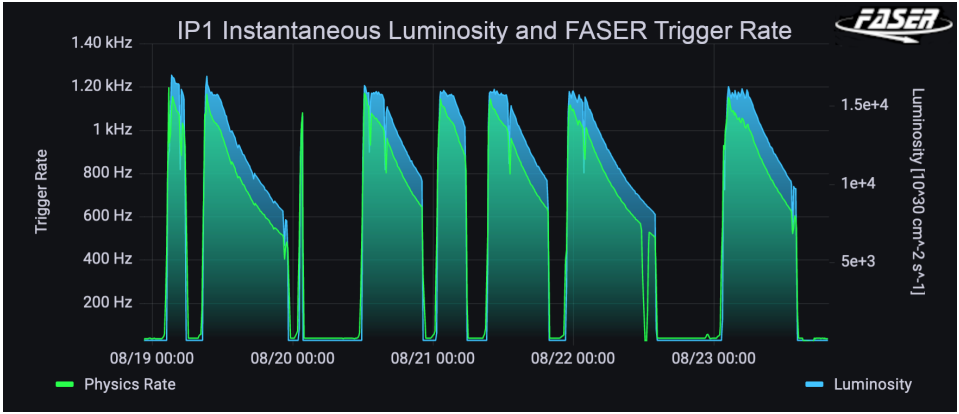
FASER Detector:
arxiv: 2207.11427

Detector Installation



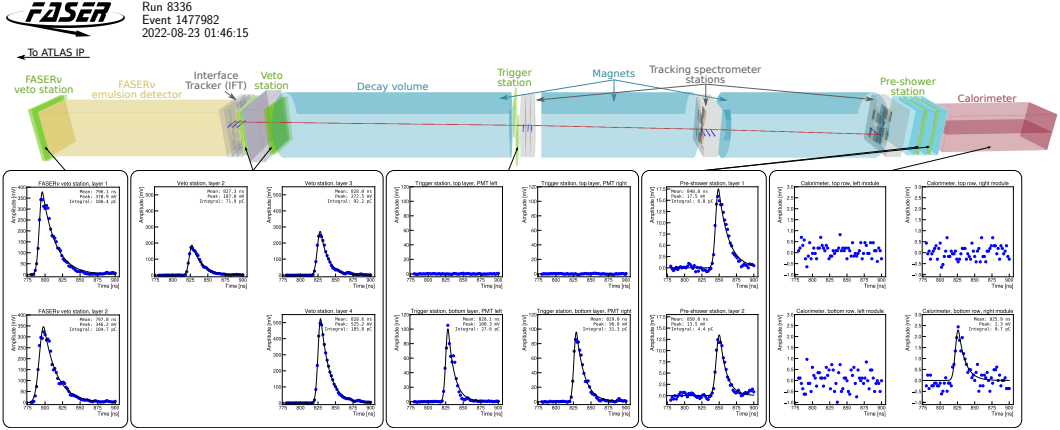
FASER Operations

- Collecting 13.6 TeV collision data since July 2022
- Recorded over 30 fb^{-1} data
- The maximum trigger rate is ~ 1.2 kHz (nearly $2\times$ the expectation), but no problem for physics



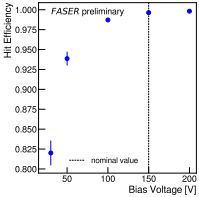
Event Display

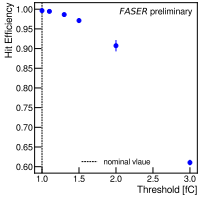
- Collision event with a 21.6 GeV muon traversing FASER
- PMT waveforms show muon passing through all scintillators and one of the calorimeter modules
- The magnets bend the track in the vertical plane

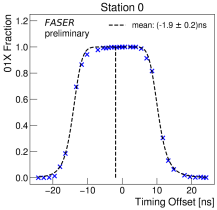


Tracker Performance

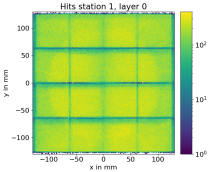
- Hit efficiency of $(99.64 \pm 0.10)\,\%$ at threshold of $1.0\,\mathrm{fC}$ and sensor bias $150\,\mathrm{V}$
- Tracker SCT modules fine time tuned with $390\,\mathrm{ps}$ precision in special runs

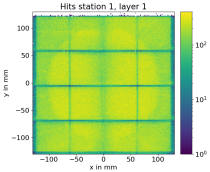


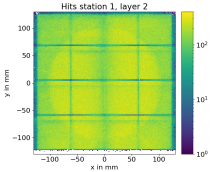




- Distribution of clusters on track show excellent detector coverage in all layers
- Inefficiencies in between modules from module edges expected $\rightarrow$ layers shifted by $\pm 5\,\mathrm{mm}$
- Total number of dead / noisy strips $< 0.5\,\%$

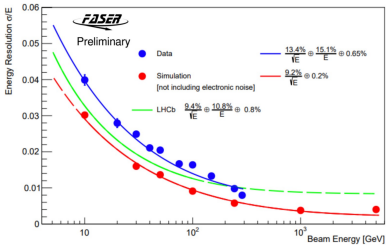


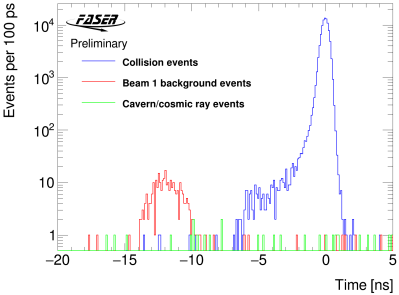




Scintillator & Calorimeter Performance

- Veto scintillator efficiency measured in data:
  - each efficiency $> 99.99\,\%$
  - combination of 4 layers is expected to veto $\mathcal{O}(10^8)$ muons
- Calorimeter energy resolution measured in dedicated Test Beam at CERN SPS in June 2021:
  - about 1 % for high energies
- Time resolution is about 250 ps
  - Source of triggered events can be established from proton bunch-crossing dependence:
    BCID consistent with colliding bunch ID (blue), beam-1 background (red), or neither (green)





Summary

- FASER is a new experiment that just started running at the LHC
- Targeting discovery (exclusion) of light weakly coupled new particles such as dark photons
- Detector operating well so far with more that $30\,\mathrm{fb}^{-1}$ of data recorded and detector performance looking good
- Aiming for first physics results in spring 2023

FASER is supported by:

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