ForwArd Search ExpeRiment

• Search for LLPs produced in inelastic pp collisions
  - Large inelastic pp cross-section \( \sigma_{\text{inel}}(13.6 \text{ TeV}) \sim 80 \text{ mb} \to \) about \( 10^{16} \) inelastic pp scatterings in Run 3
  - Small production angle: \( \theta \sim \Lambda_{\text{qcd}}/E \sim \text{mrad} \)
  - 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)
• FASER\( \nu \): 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:
  \[
  \text{BR}(\pi^0 \rightarrow \gamma A') = 2\epsilon^2 \left(1 - \frac{m_{A'}^2}{m_{\pi}^2}\right)^3
  \]
- Decay in pair of electrons, muons or pions:
  \[
  \text{decay length } d = 80 \text{ m} \left[\frac{10^{-5}}{\epsilon}\right]^2 \left[\frac{100 \text{ MeV}}{m_{A'}}\right]^2 \left[\frac{E_{A'}}{\text{TeV}}\right]
  \]
  \[
  \rightarrow \text{only } A' \text{ with high energy reach FASER}
  \]
  \[
  \rightarrow \text{small detector radius}
  \]
- FASER can probe new phase space already with 10 fb$^{-1}$
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 $A' \rightarrow e^- e^+$: Large EM energy in calorimeter
Detector Installation
FASER Operations

- Collecting 13.6 TeV collision data since July 2022
- Recorded over 30 fb$^{-1}$ data
- The maximum trigger rate is $\sim 1.2 \text{ kHz}$ (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 \(1.0\) fC and sensor bias \(150\) V
• Tracker SCT modules fine time tuned with \(390\) 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 \(\pm 5\) 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 $O(10^8)$ 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 than 30 fb$^{-1}$ of data recorded and detector performance looking good
- Aiming for first physics results in spring 2023

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