FASER: ForwArd Search ExpeRiment at the LHC

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**Introduction**

**transverse region:** high $p_T$
- mostly used for SM measurement
- typical rates $\sigma \sim \text{fb} - \text{pb}$
  
  $N_H = 10^7$ at 300fb$^{-1}$

**forward region**
- mostly used for SM measurement
- enormous event rates: $\sigma_{inel} \sim 75$ mb: $N_\pi = 10^{17}$ at 300fb$^{-1}$
  
  $\Rightarrow$ extremely weakly-coupled **long-lived** particles may be produced sufficiently
- most particles have small $p_T \sim \Lambda_{QCD}$
  
  $\Rightarrow$ energetic particles highly **collimated** $\theta \sim \Lambda_{QCD}/E \sim \text{mrad}$ for $E \sim \text{TeV}$

- we propose small ($\sim 1 \text{ m}^3$) inexpensive detector a few 100 m downstream
  
  $\Rightarrow$ **FASER:** ForwArd Search ExpeRiment at the LHC
- LLP produced at ATLAS/CMS IP, collimated around beam axis

→ place FASER along beam axis after the LHC curves
FASER’s Location

- LLP produced at ATLAS/CMS IP, collimated around beam axis
  - Place FASER along beam axis after the LHC curves
- LHC infrastructure acts as natural filter in forward direction

**Diagram Description**

- **IP**: LLP produced at ATLAS/CMS interaction point
- **D&Q**: magnets deflect charged particles
- **TAN**: forward n,γ absorbed by Target Neutral Absorbers
- **Arc**: beam starts to curve at L=272m
FASER’s Location

- LLP produced at ATLAS/CMS IP, collimated around beam axis
  ➞ place FASER along beam axis after the LHC curves
- LHC infrastructure acts as natural filter in forward direction
- promising location: service tunnel TI-18
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**FASER**: ForwArd Search ExpeRiment at the LHC

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**Signal, Detector Design and Backgrounds**

\[ pp \rightarrow LLP + X, \quad LLP \text{ travels } \sim 480 \text{ m}, \quad LLP \rightarrow \text{charged tracks} + X \]

- **Features of the Signal:**
  - two oppositely charged energetic tracks: \(E > 500\) GeV
  - vertex inside detector volume
  - combined momentum points towards IP

- **Proposed Detector Design:**
  - FASER needs tracking, charge identification, rough energy estimate
    - tracking based technology, with magnet and calorimeter

- **Background considerations:**
  - rock + absorbers + magnets eliminate most BG
  - remaining BG mostly infrastructure induced:
    - collisions of beam halo with beam pipe near FASER + subsequent shower
    - have different kinematics: energy, direction, track multiplicity
    - scintillating veto layer
  - best estimated with experimental data (prototype)
  - ongoing detailed simulation by CERN accelerator section
New Physics Discovery Potential

Motivation
- dark matter solid evidence for new particles
- thermal freeze out:
  \[ \Lambda_{DM} \sim \langle \sigma v \rangle^{-1} \sim m^2 / g^4 \]
- WIMP miracle:
  \[ m \sim m_{\text{weak}}, \ g \sim g_{\text{weak}} \]
- broader WIMP:
  \[ m < m_{\text{weak}}, \ g < g_{\text{weak}} \]
  \( \rightarrow \) light-weakly interacting new physics

Portals do Dark Sectors
- Dark Photon Portal: \( \epsilon F^\mu\nu F'^\mu\nu \)
- Dark Higgs Portal: \( \epsilon |H|^2 \phi^2 \)
- Neutrino Portal: \( yLHN \)
- Axion Portal: \( g\alpha F^\mu\nu \tilde{F}_{\mu\nu} \)
New Physics Discovery Potential

**Dark Photon**

\[ \epsilon F^{\mu\nu} F'_{\mu\nu} \]

\[ \pi^0, \eta \rightarrow \gamma A' \]

Bremsstrahlung

**Dark Higgs**

\[ \epsilon |H|^2 \phi^2 \]

**HNL**

\[ y LH N \]

\[ B^+ \rightarrow \ell N, \ B \rightarrow D \ell N \]

\[ D_s \rightarrow \ell N, \ D \rightarrow K \ell N \]
**Summary and Outlook**

**Forward Physics**
- large event rates
- energetic particles very forward $\theta < 1$ mrad
- search for light extremely weakly coupled particles

**FASER**
- cheap small size $\sim 1 \text{ m}^3$ detector, operates concurrently
- located in service tunnel TI-18
- signature: 2 energetic tracks with $E \sim \text{TeV}$
- equipped with tracking system, magnet, calorimeter
- Physics Examples: Dark Photon, Dark Higgs, ...

**Current Developments & Next Steps**
- detailed background simulation with FLUKA
- first background measurements in TI-18
- GEANT4 simulations & detector design
- explore more physics opportunities

We look forward to feedback and suggestions