ForwArd SearcH ExpeRiment at the LHC

Felix Kling (UC Irvine) for the FASER Collaboration

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**The Idea**

**transverse region:** high pT
- searches for heavy strongly coupled physics
- typical rates $\sigma \sim \text{fb} - \text{pb}$
  
  $N_H = 10^7$ at 300fb$^{-1}$

**forward region**
- **enormous** event rates $\sigma_{\text{inel}} \sim 100\text{mb}$: $N_\pi = 10^{17}$ at 300fb$^{-1}$
- extremely weakly-coupled particles may be produced sufficiently
- most particles have small $p_T \sim \Lambda_{\text{QCD}}$ and high $E \sim \text{TeV}$
- particles highly **collimated** $\theta \sim \Lambda_{\text{QCD}}/E \sim \text{mrad}$
- weakly coupled particles can be **long-lived**
  
  $\rightarrow$ decays outside downstream from IP

- we propose small ($\sim 1\text{m}^3$) inexpensive ($\sim 1\text{M}$) detector
  
  $\sim 500\text{m}$ downstream to search for LLP

$\rightarrow$ **FASER:** ForwArd Search ExpeRiment at the LHC
FASER: Forward Search Experiment at the LHC

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Status and Timeline

05/2017 - first idea on blackboard

09/2017 - original FASER paper arXiv:1708.09389

01/2018 - FASER joins PBC

Spring 2018 - FASER collaboration forms
identification of location / FLUKA background study
first detector design


Technical Proposal - 11/2018
location in TI-12 / in-situ measurements
civil engineering, transport, and integration
technical details of FASER detector components

11/2018 - LLP Physics Potential
arXiv:1811.12522

12/2018 - Funding

Detector Construction and Integration - 2019-2020

Collecting Data - 2021-2023

FASER 2 Upgrade - HL-LHC era
FASER’s Location

Cylindrical Decay Volume

<table>
<thead>
<tr>
<th></th>
<th>FASER</th>
<th>FASER 2</th>
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</thead>
<tbody>
<tr>
<td>Radius</td>
<td>10cm</td>
<td>1m</td>
</tr>
<tr>
<td>Length</td>
<td>1.5m</td>
<td>5m</td>
</tr>
<tr>
<td>Luminosity</td>
<td>150fb⁻¹</td>
<td>3ab⁻¹</td>
</tr>
</tbody>
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FASER: ForwArd Search ExpeRiment at the LHC
The detector consists of:
- scintillator veto
- 1.5m long decay volume
- 2m long spectrometer
- EM calorimeter
**FASER Magnet**

- 0.6T permanent dipole magnets
- Halbach array design
  - LOS to passes through the magnet center
  - minimum digging to the floor in TI12
  - minimized needed services (power, cooling etc.)
- to be constructed by the CERN magnet group

Detector Design
**FASER Tracker**

- 3 tracking stations, each with 3 tracking layers
- double sided silicon micro-strip detectors
- ATLAS SCT spare modules will be used
  - 80µm strip pitch, 40mrad stereo angle
  - many thanks to the ATLAS SCT collaboration!
  - 72 SCT modules for the full tracker
**FASER ECAL**

- EM energy measuring / triggering / electron/photon identification

- FASER will use spare LHCb outer ECAL modules
  - ~1% energy resolution for 1 TeV electrons
  - Many thanks for LHCb for allowing us to use these!

**FASER Scintillators**

- vetoing charged particles entering the decay volume / triggering

- to be produced at CERN scintillator lab
FASER Integration in T112
Signaling is striking
- two opposite-sign, high energy (E > 500 GeV) charged particles
- originate from a common vertex in a small, empty decay volume
- point back to the IP through 90 m of rock

Background considerations
- shielding: natural (rock) and LHC infrastructure (concrete, magnets, absorbers)
- only muons/neutrino can transport TeV energies through ~100m rock

FLUKA Study
- CERN STI group performed FLUKA simulation
- most backgrounds associated with muon from collision debris
  → estimated flux: 0.2 Hz/cm\(^2\) for E>100GeV
  → can be vetoed with scintillators
**In-Situ Measurements**
- using emulsion detectors
- first measurements already performed in TI18 and TI12
- consistent with FLUKA simulations
  
  \[
  \text{FLUKA: } 2 \cdot 10^4 \text{ fb/cm}^2 \quad \text{Emulsion Detector: } (1.2-1.9) \cdot 10^4 \text{ fb/cm}^2
  \]
- data analysis on-going
FASER’s Physics Potential

LLP Searches at FASER
- FASER has a full physics program: Dark photon, dark Higgs, HNL, ALPs

### Dark Photon

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

[1708.09389]

### Dark Higgs

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

[1710.09387]

### HNL

\[ y L H N \]

[1801.08947]
### FASER’s Physics Potential

#### LLP Searches at FASER
- FASER has a full physics program: Dark photon, dark Higgs, HNL, ALPs
- contribution to PBC study

#### Benchmark Model

<table>
<thead>
<tr>
<th>Benchmark Model</th>
<th>PBC</th>
<th>FASER</th>
<th>FASER 2</th>
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<tbody>
<tr>
<td>Dark Photons</td>
<td>BC1</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>$B - L$ Gauge Bosons</td>
<td>—</td>
<td>✓</td>
<td>✓</td>
</tr>
<tr>
<td>$L_i - L_j$ Gauge Bosons</td>
<td>—</td>
<td>—</td>
<td>✓</td>
</tr>
<tr>
<td>Dark Higgs Bosons</td>
<td>BC4</td>
<td>—</td>
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<tr>
<td>Dark Higgs Bosons with $hSS$</td>
<td>BC5</td>
<td>—</td>
<td>✓</td>
</tr>
<tr>
<td>HNLs with $e$</td>
<td>BC6</td>
<td>—</td>
<td>✓</td>
</tr>
<tr>
<td>HNLs with $\mu$</td>
<td>BC7</td>
<td>—</td>
<td>✓</td>
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<tr>
<td>HNLs with $\tau$</td>
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<td>✓</td>
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<tr>
<td>ALPs with Photon</td>
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</tr>
<tr>
<td>ALPs with Fermion</td>
<td>BC10</td>
<td>✓</td>
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<tr>
<td>ALPs with Gluon</td>
<td>BC11</td>
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- **inelastic DM**

- **RPV Susy**

#### Possible additional physics applications
- large neutrino flux: neutrino measurements
- coverage $\eta > 10$: forward SM physics, eg. Monte Carlo validation

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**FASER:** ForwArd Search ExpeRiment at the LHC  
UCIrvine
The **FASER collaboration**: 27 collaborators, 15 institutions, 8 countries

Akitaka Ariga,\(^{1}\) Tomoko Ariga,\(^{1,2}\) Jamie Boyd,\(^{3}\) Franck Cadoux,\(^{4}\) David W. Casper,\(^{5}\) Yannick Favre,\(^{4}\) Jonathan L. Feng,\(^{5}\) Didier Ferrere,\(^{4}\) Iftah Galon,\(^{6}\) Sergio Gonzalez-Sevilla,\(^{4}\) Shih-Chieh Hsu,\(^{7}\) Giuseppe Iacobucci,\(^{4}\) Enrique Kajomovitz,\(^{8}\) Felix Kling,\(^{5}\) Susanne Kuehn,\(^{3}\) Lorne Levinson,\(^{9}\) Hidetoshi Otono,\(^{2}\) Brian Petersen,\(^{3}\) Osamu Sato,\(^{10}\) Matthias Schott,\(^{11}\) Anna Sfyrla,\(^{4}\) Jordan Smolinsky,\(^{5}\) Aaron M. Soffa,\(^{5}\) Yosuke Takubo,\(^{12}\) Eric Torrence,\(^{13}\) Sebastian Trojanowski,\(^{14,15}\) and Gang Zhang\(^{16}\)
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Summary and Outlook

**FASER**
- search for light weakly coupled particles at LHC
- quick, small and inexpensive experiment

**Status**
- Letter of Intent and Technical Proposal submitted
- funding from Heising-Simons Foundation and Simons Foundation
- advanced stage of CERN approval

**Envisioned Timeline**
- build/install FASER in LS2 (2019-20)
- take data during Run 3 (2021-23, 150 fb^{-1})
- upgrade to FASER 2 in LS3 (2023-25) for HL-LHC (2026-35, 3 ab^{-1})

For more information, see
https://twiki.cern.ch/twiki/bin/view/FASER/WebHome

We look forward to feedback and suggestions