Status of the FASER Experiment

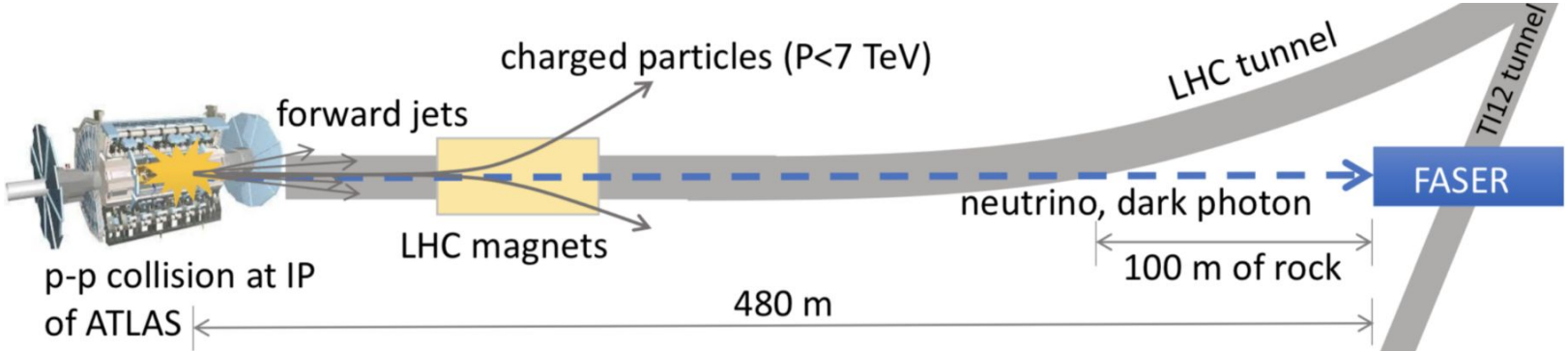
9 November, 2021
10th Workshop of the LLP Community

Tobias Böckh (University of Bonn)
on behalf of the FASER collaboration

ForwArd Search ExpeRiment

- Search for LLPs produced in inelastic pp collisions
  - Large inelastic pp cross-section σ_{inel}(13 TeV) ~ 75 mb → N_{inel} (Run 3, 150 fb^{-1}) ~ 10^{16}
  - Small production angle: $\theta \sim \Lambda_{qcd} / E \sim$ mrad
  - Macroscopic decay length: ~100 m for M ~ 10-100 MeV, $\varepsilon \sim 10^{-5}$
- Placed 480 m downstream of the ATLAS IP on the beam collision axis in TI12 tunnel
  - Quiet background environment
- Detector installed in March 2021, data taking during LHC Run 3 (2022-2024)

- 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



FASER Installation in TI12


August 2018, old LEP transfer line

April 2021, BSM search detector fully installed


April 2021, test installation of FASERν with testbox

- Full BSM search detector installed in March 2021
- IFT will be installed in two weeks
- Emulsion detector will be installed just before the start of Run 3

Tracker Commissioning

- In situ commissioning ongoing since April 2021 using internal calibration circuit and cosmic rays
  - ensure high fraction of operational channels, low noise occupancy, uniform threshold distribution

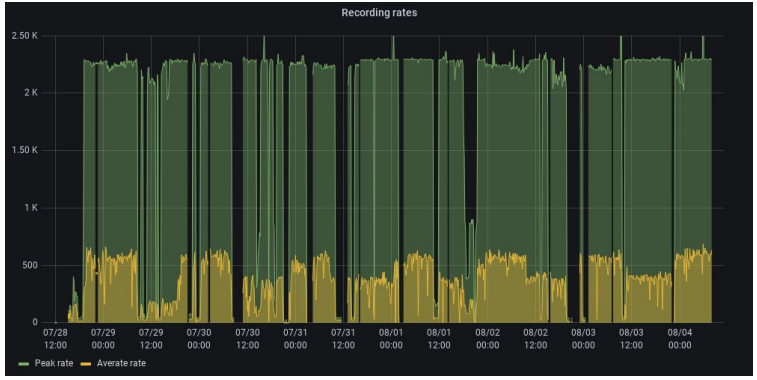
- Use cosmics to test full detector system including trigger, DAQ and tracker stations
  - Cosmic rate in TI12 (100m underground) is very low, especially for more horizontal cosmic rays
    Table shows the expected and measured rates for cosmics going through 1,2 or 3 tracker stations

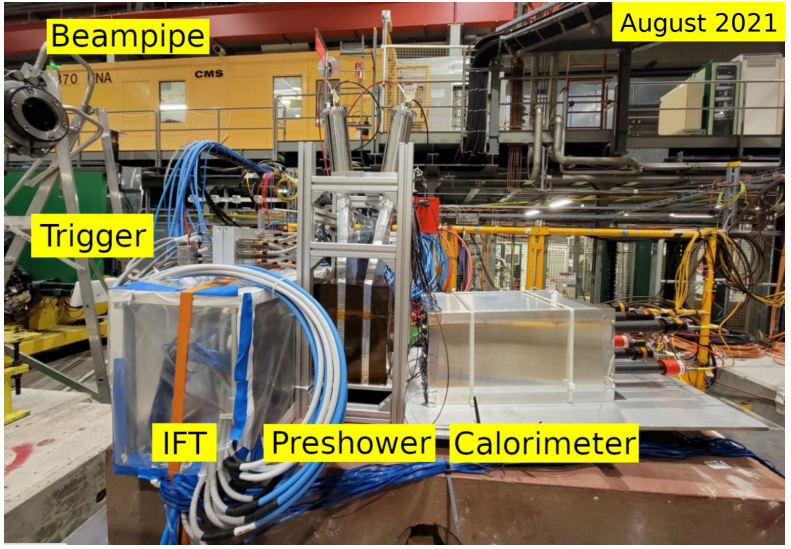
	track rate	two-station track rate	three-station track rate
expected	0.011 Hz	1/(28 hrs)	1/(82 days)
measured	0.012 ± 0.001 Hz	1/(33.5 ± 8.9 hrs)	*Not yet measured*

- The Tracker is described in more detail in “The tracking detector for the FASER experiment” which will be submitted in the next weeks

Testbeam

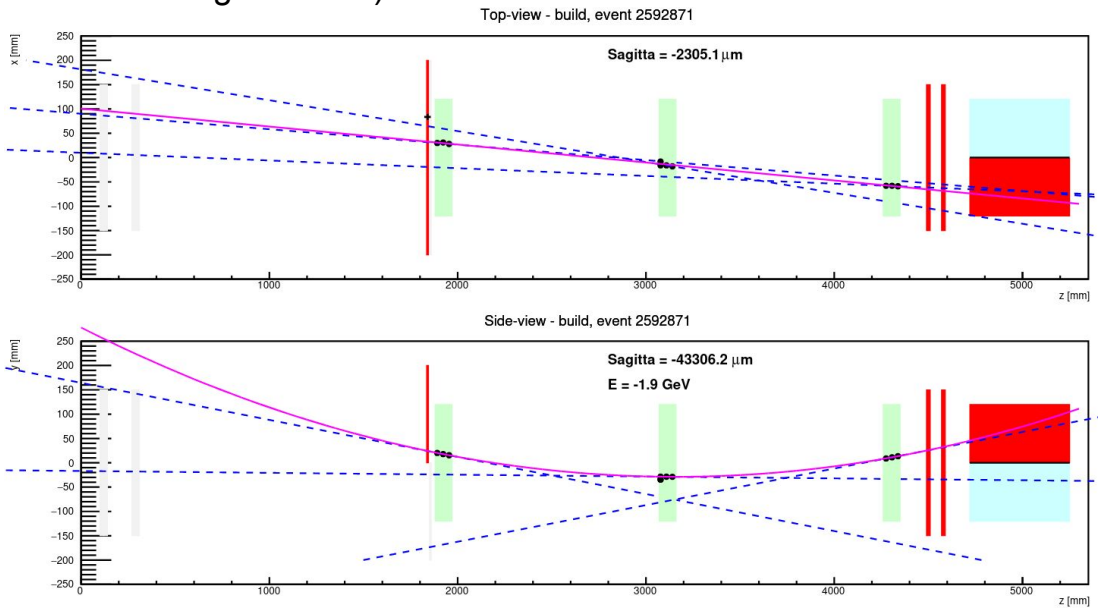
- Carried out testbeam campaign from July 28 to August 4 using CERN SPS beam
- Goal: energy calibration of preshower and calorimeter modules and characterize overall performance
  - Measure absolute calorimeter response, electron vs muon response, particle identification, ...
- 5 GeV - 300 GeV electron beam, 200 GeV muon beam and 200 GeV pion beam from CERN SPS
- Setup: two trigger scintillators, 3-layer tracker station (IFT), preshower scintillator station and 6 calorimeter modules
  - Positioned on top of large scissor table to measure different scan points
- Recorded more than 150 million events!
- Analysis ongoing





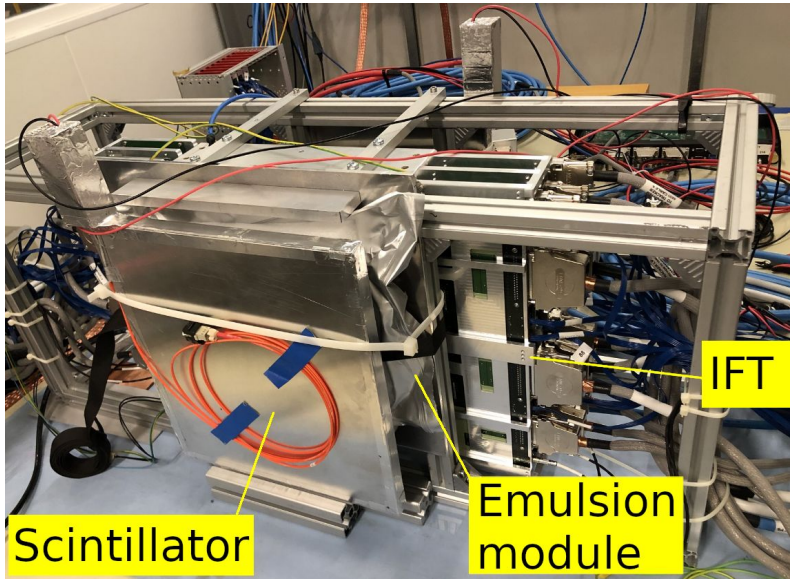
LHC Pilot Beam

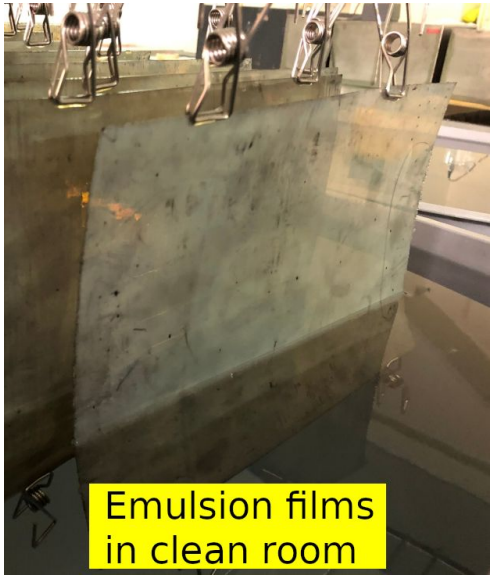
- Collecting data during pilot beam test in the last two weeks in October
- Beam splash events (beam is driven in closed collimator, producing large shower of muons)
  - See particles from splashes in front of ATLAS and LHCb
- See many tracks during alignment of collimators between ATLAS and FASER in the outgoing beam
- Stable beam: 900 GeV collisions, 2 x 10^{28}cm^{-2}s^{-1} luminosity
  - 14 tracks collected over 26 hours, probably originating from beam background not collisions at ATLAS IP (7 events from non-colliding bunches, 7 from colliding bunches)
- Continuing to study beam background
- First three-station tracks!
- First track with low enough momentum too see obvious bending in mag. field



Test of Emulsion module

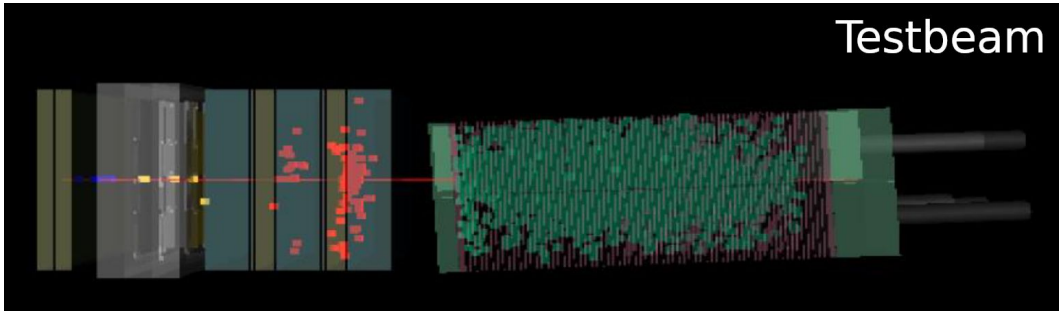
- Combined test of emulsion module (20 emulsion films and tungsten plates), 3-layer tracker station (IFT) and two scintillators
- Study matching of tracks in the emulsion detector and IFT

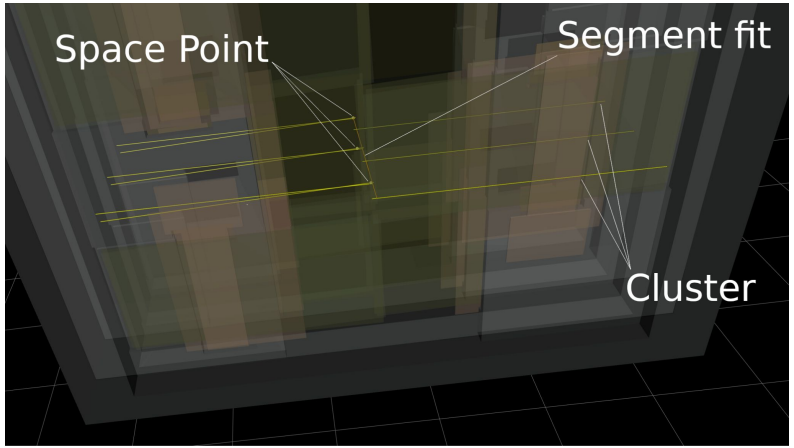




Recent Offline Development Work

- Updated TI12 and testbeam geometry with passive material
- Segment finder allows to fit tracks with at least 4 clusters and multiple tracks per event
- Improved ECAL simulation (tested different physics models, comparison with LHCb and testbeam data)
- Work on ACTS-based tracking and alignment ongoing
- First studies of FASERν simulation



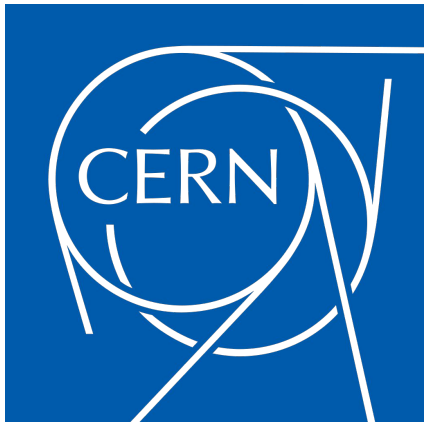


Acknowledgements

We are grateful for the generous support of the Heising-Simons Foundation, the Simons Foundation and CERN

HEISING-SIMONS FOUNDATION

SIMONS FOUNDATION



Conclusions

- FASER has been installed in the LHC tunnel
  - IFT will be added in two week
  - In situ commissioning using internal calibration circuit and cosmics ongoing since April 2021
- Collected > 150 million events during testbeam
  - Analysis of energy calibration of preshower and calorimeter, tracker efficiency, … ongoing
- LHC pilot beam
  - Observed first three-station events
  - Studying beam backgrounds
- First combined test of emulsion detector and IFT
- Improvements on offline reconstruction
  - Work on tracking, alignment, …

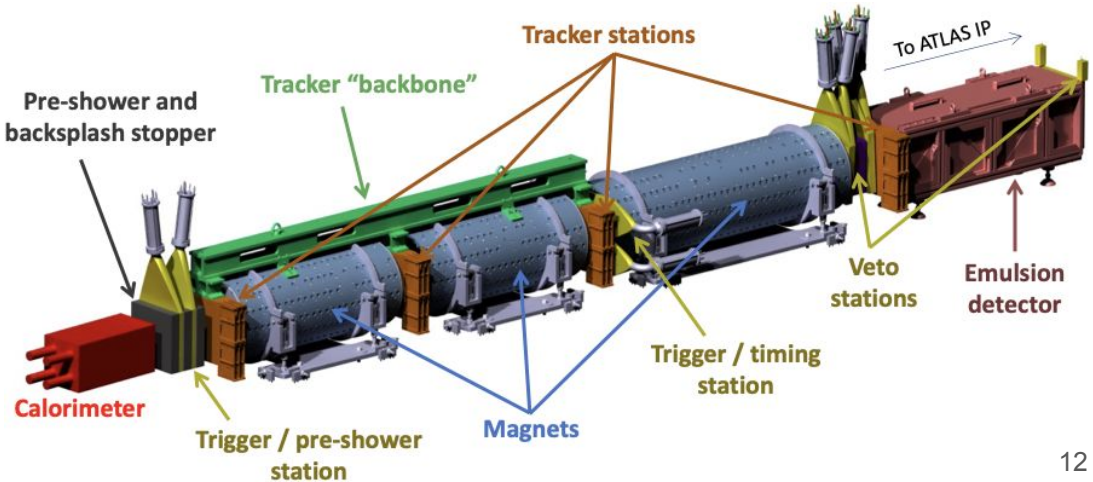
Looking forward to first high-energy LHC collisions of Run 3

Additional slides

FASER Detector

- 0.55 T permanent dipole magnets
  - Separate the pair of charged particles arising from the LLP decay
- Veto, timing and pre-shower scintillator stations
  - Ensure that the LLPs decay inside the decay volume or the emulsion detector
- Three tracker stations and Interface tracker (IFT)
  - Use 96 ATLAS semiconductor strip tracker modules (SCT)
    Thanks to the ATLAS Collaboration!
  - Measure the position and momentum of charged particles
  - IFT: match tracks from neutrino interaction in emulsion detector to main tracker
- Electromagnetic calorimeter
  - Use 4 LHCb outer ECAL modules
    Thanks to the LHCb Collaboration!
  - Discriminate electrons from muons
  - Measure the em. energy
- Tungsten/emulsion detector
  - Detect all three neutrino flavors
- Trigger
  - Expect 650 Hz trigger rate
    https://arxiv.org/abs/2110.15186

1.5 m decay volume
20 cm diameter



Emulsion production for FASERν

- emulsion film: vertex detector with intrinsic resolution of ~ 50 nm
- emulsion readout system HTS-1
- upgrade of emulsion facility completed
- confirmed sufficient track-finding efficiency (> 96 %) using cosmic rays