First Results of the 2021 FASER Calorimeter Test Beam

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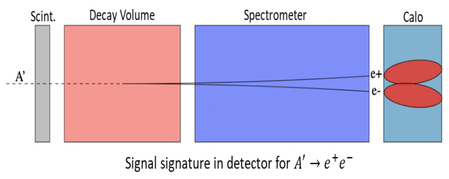
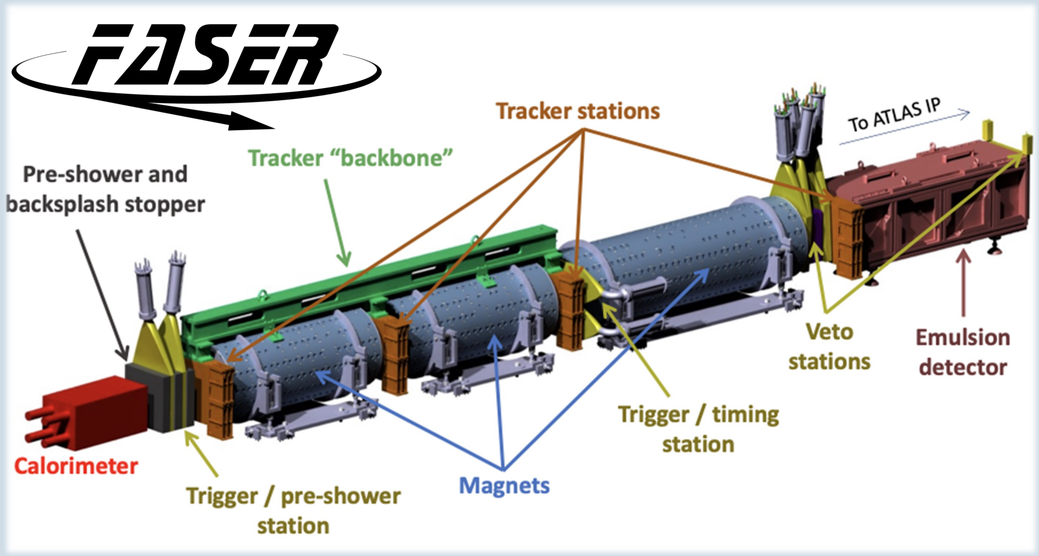
Experiment

FASER is a new experiment at CERN designed to complement the LHC's ongoing physics programme, extending its discovery potential to light and weakly-interacting particles such as long-lived dark photons (A'). These are characterised by a signature with two oppositely-charged tracks or two photons with very high energy (~TeV) that emanate from a common vertex inside the detector.



Signal signature in detector for $A' \rightarrow e^+e^-$

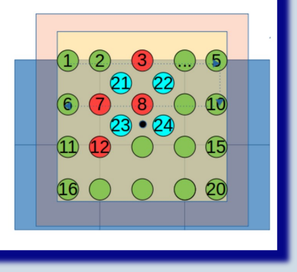


Test Beam

The main aims of the 2021 Test Beam are:

- Calibration of calorimeter using electron (5-300 GeV) and muon (150 GeV) beams, scanning through 24 spatial points across 6 modules
- Study uniformity of MIP response and pion scan

Setup consists primarily of the **tracking stations**, the **preshower** and the **calorimeter.**

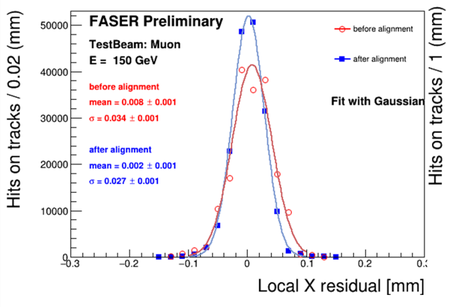


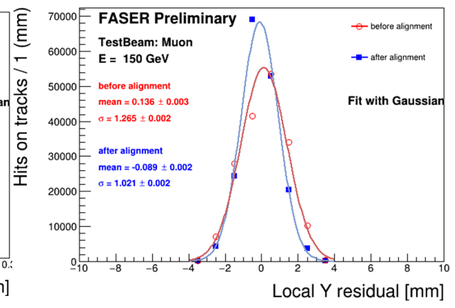
Tracking Studies

The FASER tracker consists of 72 double-sided silicon microstrip modules.

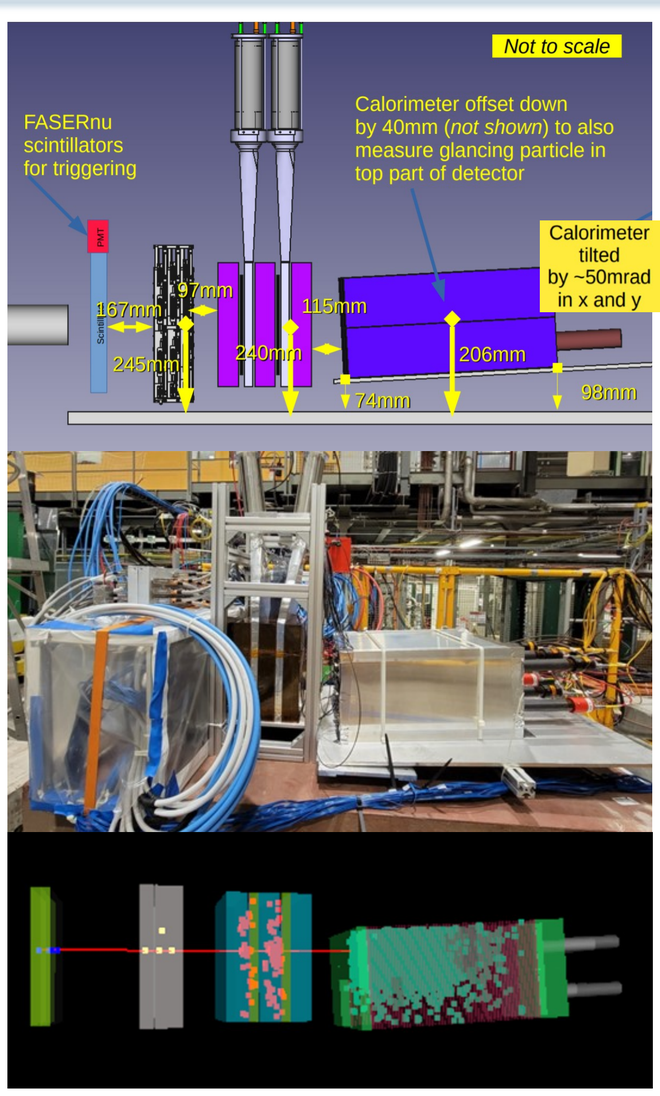
Tracking stations = 3
Planes per station = 3
Modules per plane = 8

- A 150 GeV muon beam with approx. 3.5M tracks was used to study local alignment in middle layer of 1 station





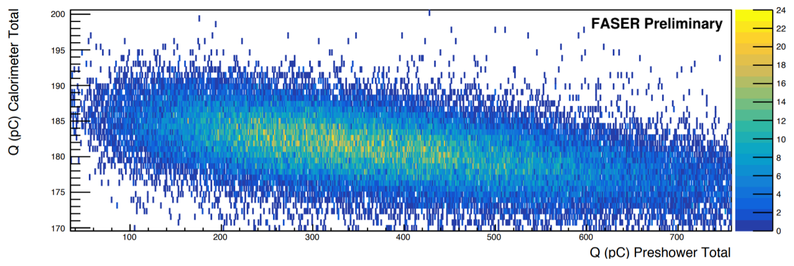
- Local x and y residuals before (after) alignment shown in red (blue) displaying the results after alignment
- Global alignment results are in progress

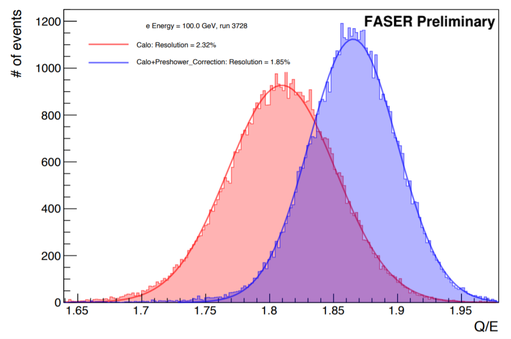


Test Beam setup and event display.

Pre-shower Correction

- When the pre-shower sees more charge, the calorimeter sees less charge
- A correction factor was derived and applied to calorimeter energy measurements to account for this imbalance in charge
- The resulting calorimeter response increases mean charge/energy deposition and improves resolution

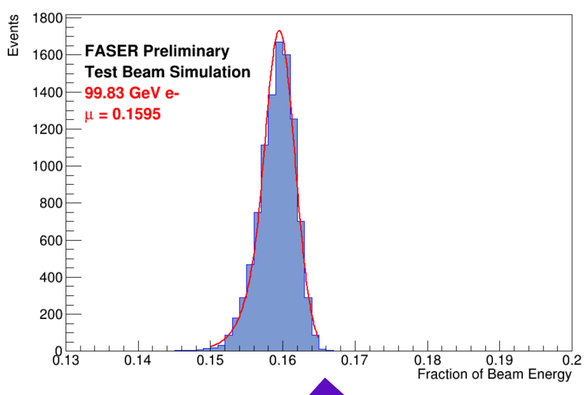


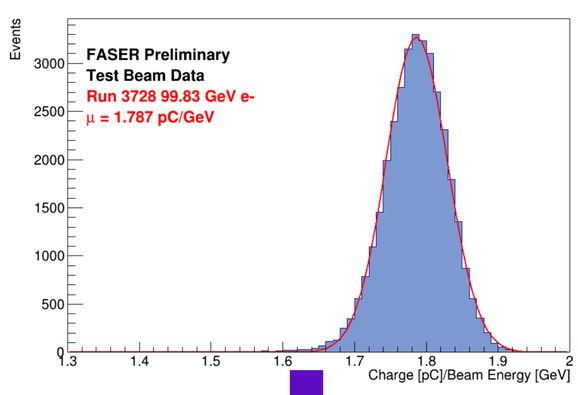


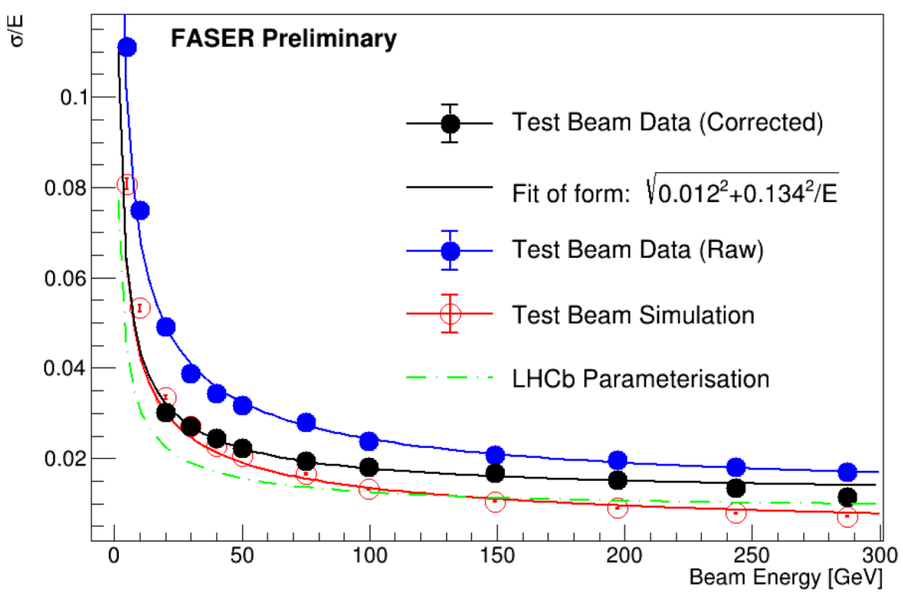
Calorimeter Performance

A full simulation of the calorimeter system is implemented in FASER's Calypso framework.

- Specific test beam geometry designed to compare simulation to data
- Crystal ball fitted to distributions to extract μ and σ, where σ is derived from width of crystal ball, converting to energy resolution (σ/E) allows for direct comparison (see table)







Errors on plot are too small to be visible at this scale.

Corrected data - includes pre-shower correction, removal of noisy channels, 5 + 10 GeV data points excluded (limit of beam) to further reduce resolution

Raw data - no corrections, event selection applied to waveform, μ = deposited charge/beam energy

Simulated data - no pre-shower correction, comparable to raw data, μ = fraction of energy deposited in calorimeter

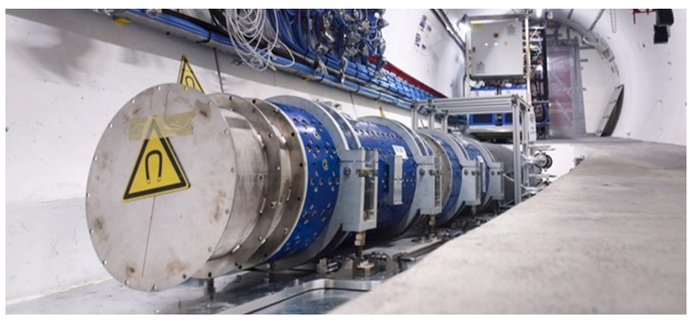
Previous LHCb results - 2004 test beam extending to 100 GeV, using same ECAL modules but without a pre-shower, comparable to corrected data

$\sigma_E/E = a/\sqrt{E} \oplus c$		
	a	**c**
Corrected Data	0.134 ± 0.001	0.0117 ± 0.0002
Raw Data	0.215 ± 0.001	0.0115 ± 0.0002
Simulation	0.135 ± 0.001	0.0000 ± 0.0017
LHCb	0.094 ± 0.004	0.0083 ± 0.0002

Next stage: calibrate response of calorimeter in terms of energy.

Outlook

- The test beam saw efficient data taking with good overall beam quality and purity
- The relative calorimeter response to different electron energies and MIPs (high energy muons) were measured
- Tracking studies have provided local alignment results
- Preliminary results have been compared to simulation and fair agreement has been found in terms of energy resolution
- Raw calorimeter data has been analysed and corrected to account for pre-shower, improving resolution
- Analysis continues as an ongoing process, more than 150 million events were recorded during the week of the test beam
- Detector once again situated in TI12, ready for data taking during Run 3



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