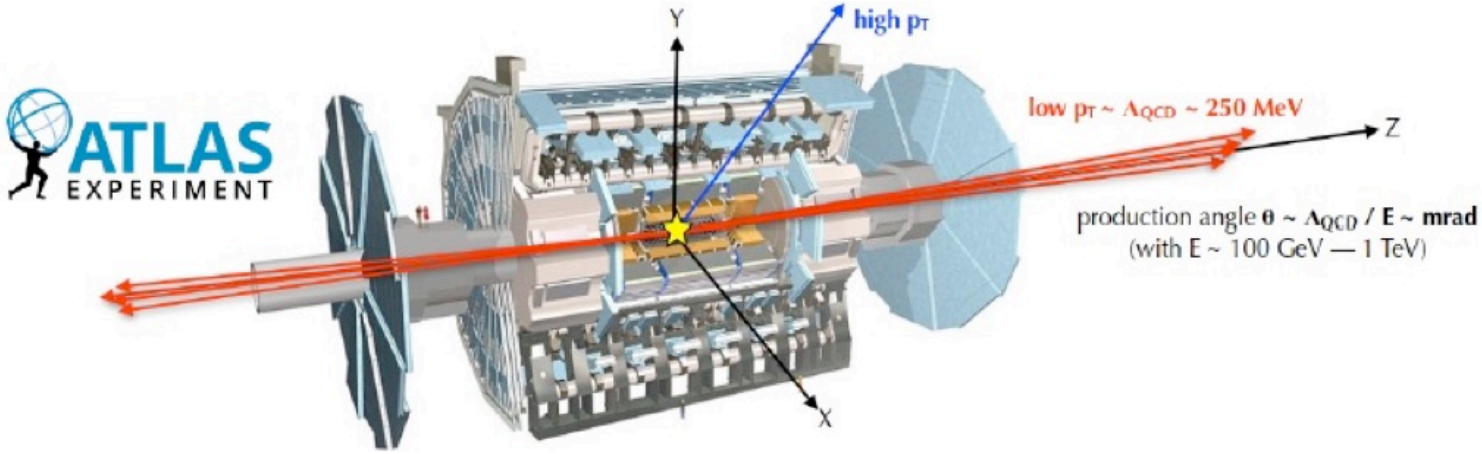
ForwArd Search ExpeRiment at the LHC

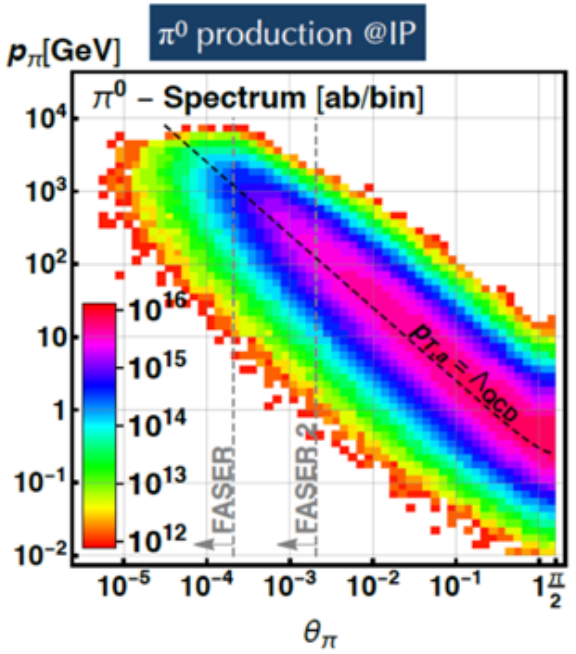
Hao Pang
Tsinghua University

18/08/2021

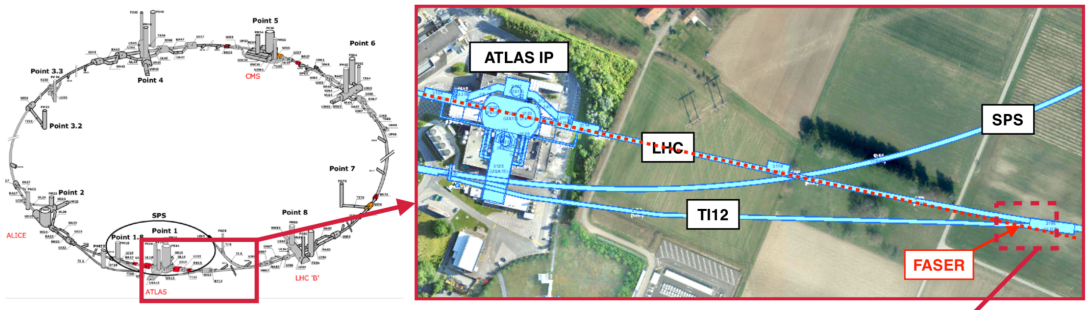
Motivation

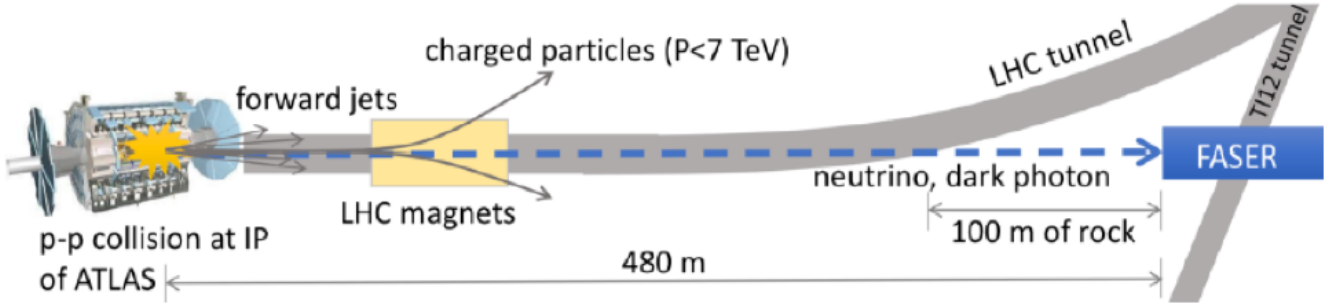
- ATLAS/CMS searches for heavy, strongly interacting new particles (high p_T, promptly decay)
- FASER is for new particles which are light and weakly interacting
- A complementary search in forward direction
- LHC will produce ~2.3×10^{17} π ,~2.5×10^{16} η,~1.1×10^{15} D,~7.1×10^{13} B in Run-3, most of which along beam collision axis





ForwArd Search ExpeRiment

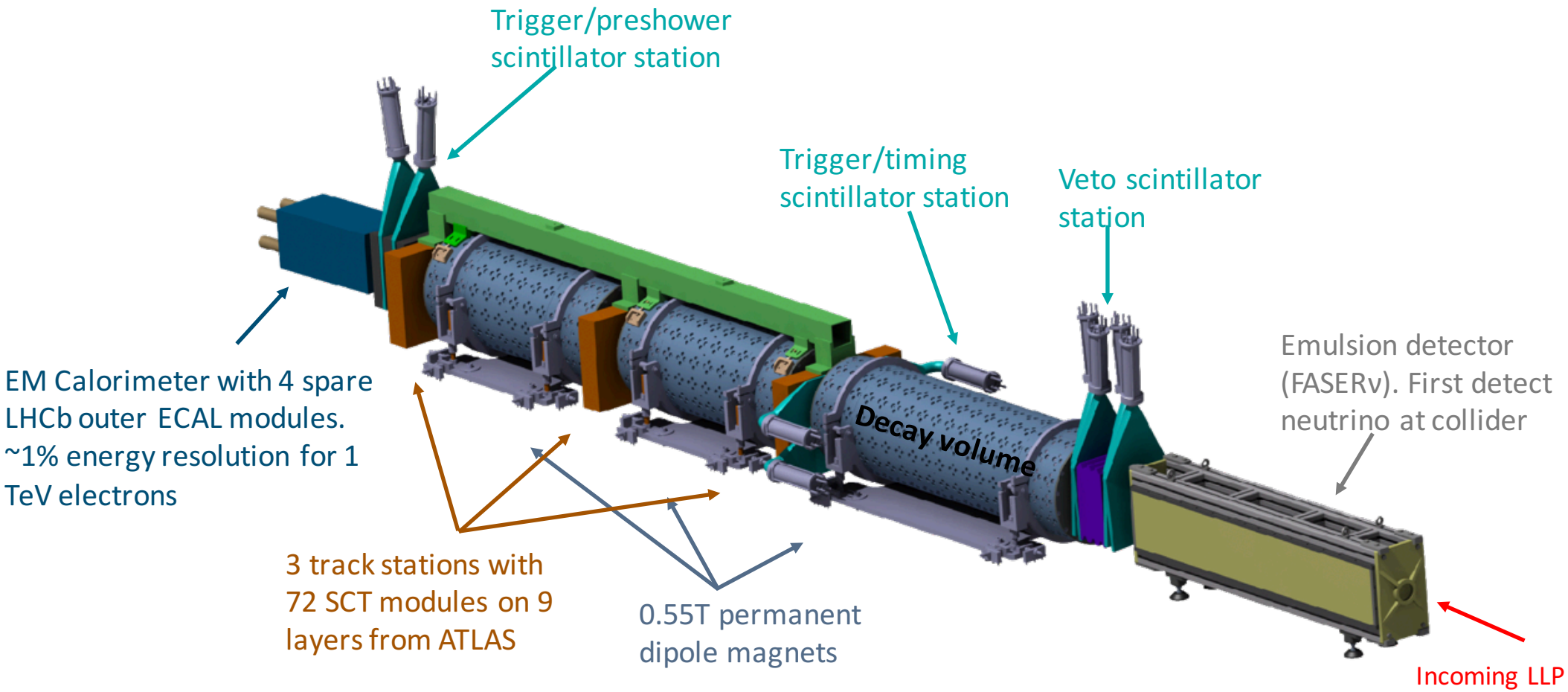




- A new small experiment to search for new long-lived particles(LLP) produced in Interaction Point 1 (IP1/ATLAS) at the LHC from Run-3
- First concept in 2017 (Feng, Galon, Kling, Trojanowski), approved by CERN in March 2019 (limited budget ~ 2M$)
- Detector design, construction and testing are progressing well in the Long Shutdown 2

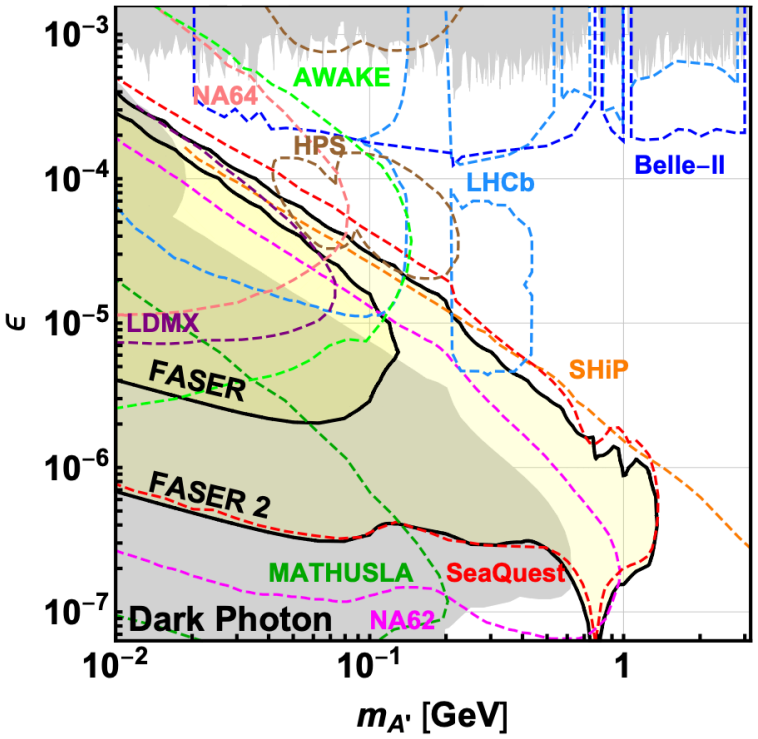
FASER detector

20 cm aperture (η>9.1)
5m long (1.5m decay volume)

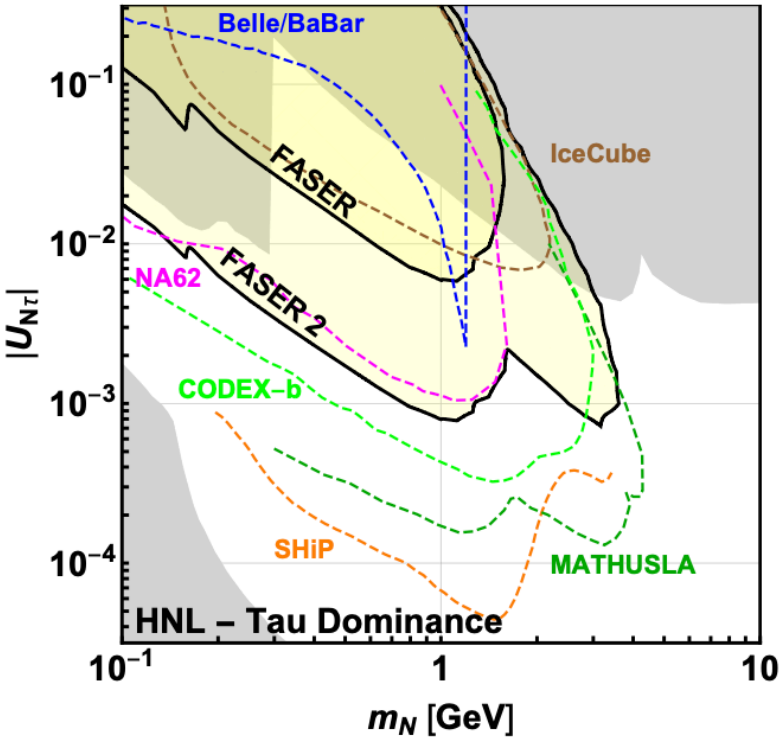


Physics potential

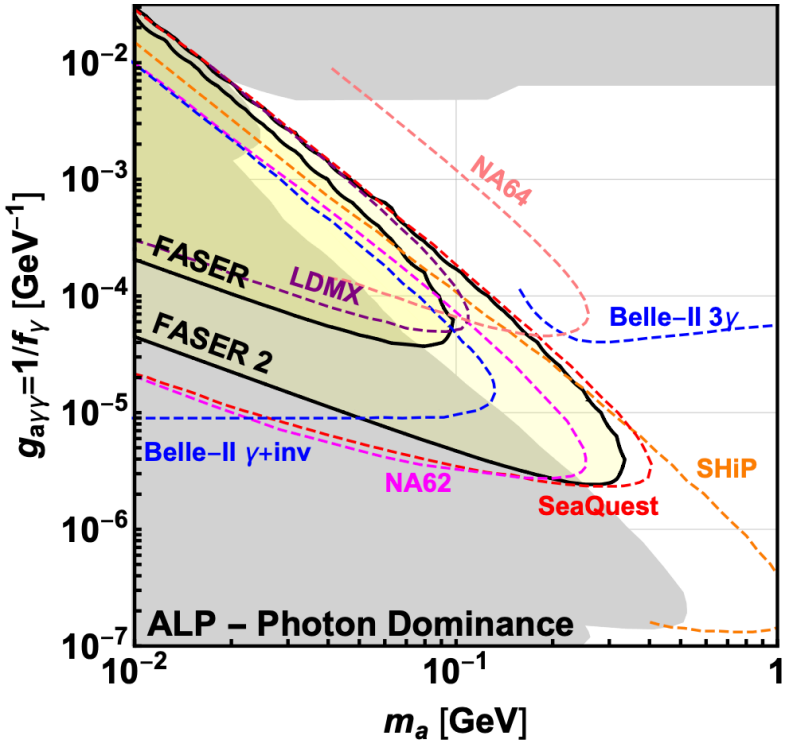
Dark photons (A')



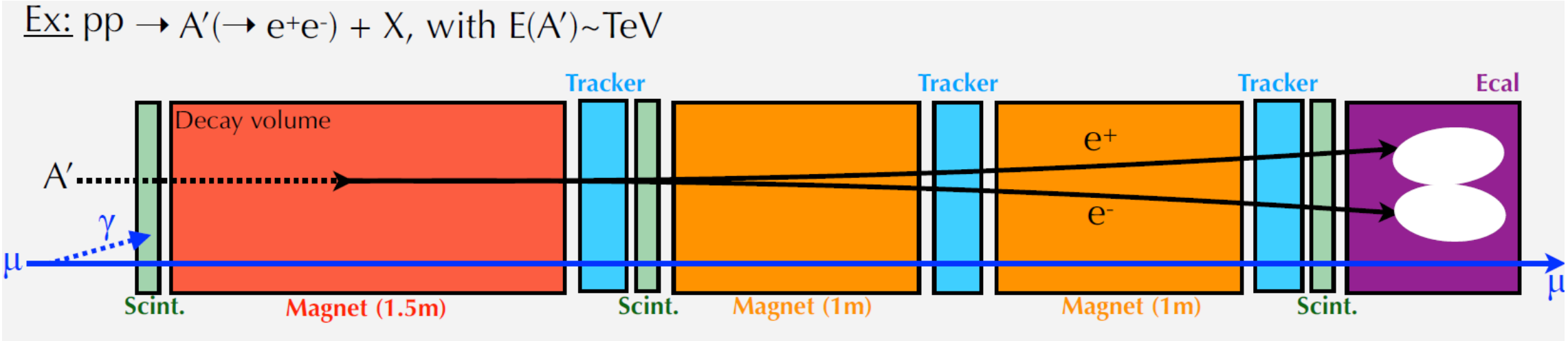
Heavy Neutral Leptons (HNLs)



Axion-like particles (ALPs)



Dark Photon Signal and Backgrounds

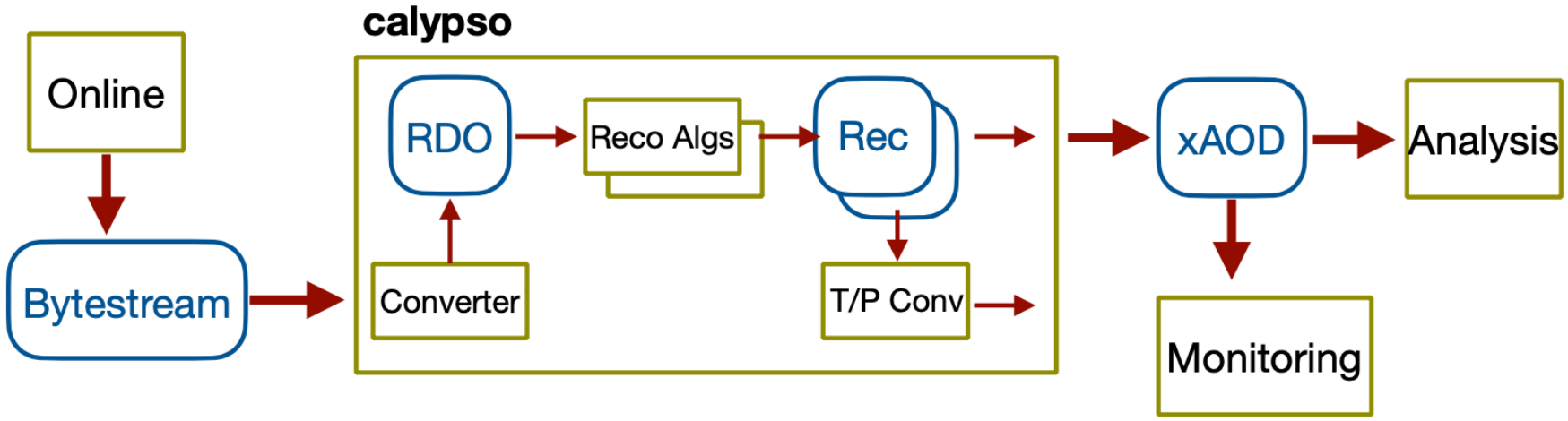


- Signal is two oppositely-charged tracks originating in decay volume, pointing back to IP1 and depositing nearly all their measured momentum as electromagnetic energy in the Ecal

- FLUKA simulations and in-situ measurements used to assess expected backgrounds
  - ✓ IP1 collisions (neutrino, muon)
  - ✓ off-orbit protons hitting beam pipe aperture close to FASER
  - ✓ beam-gas interactions

Offline software

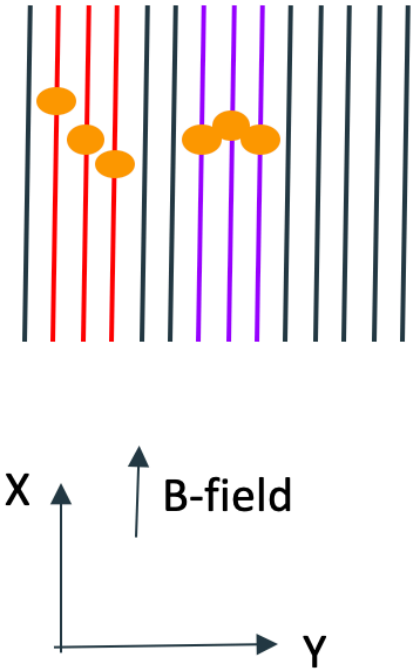
- Adapt open source ATLAS Athena (→ "Calypso") framework for offline: https://gitlab.cern.ch/faser/calypso



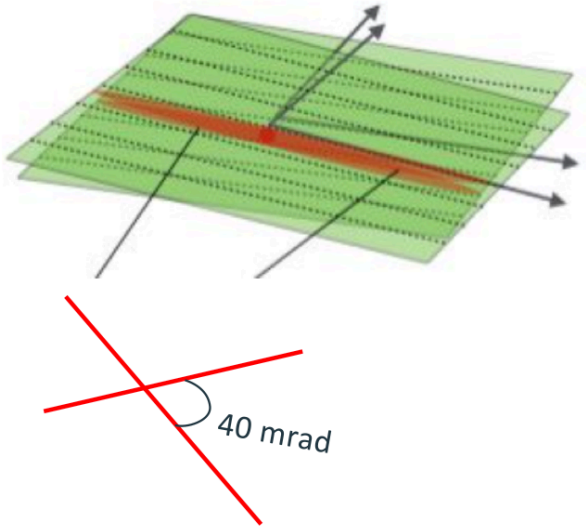
- Bytestream - files written by online, array of bytes
- RDOs - Raw Data Objects, start of reconstruction
- Calypso data is transient, must 'persist' it (i.e write it to a file)
- xAOD - Analysis Object Data - output file (root-readable data format)

Offline track reconstruction

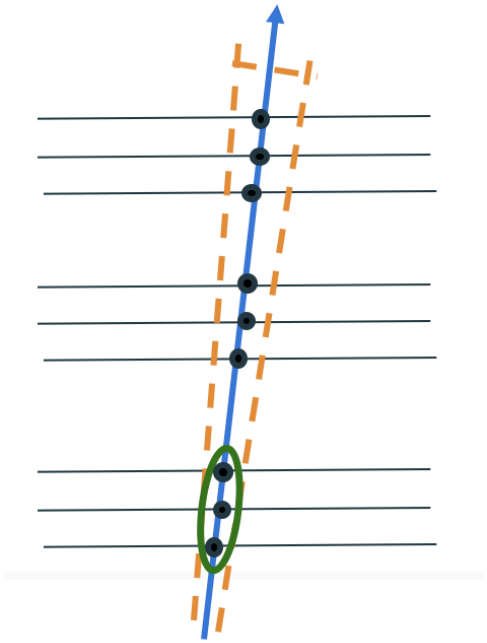
Group adjacent hit strips as clusters



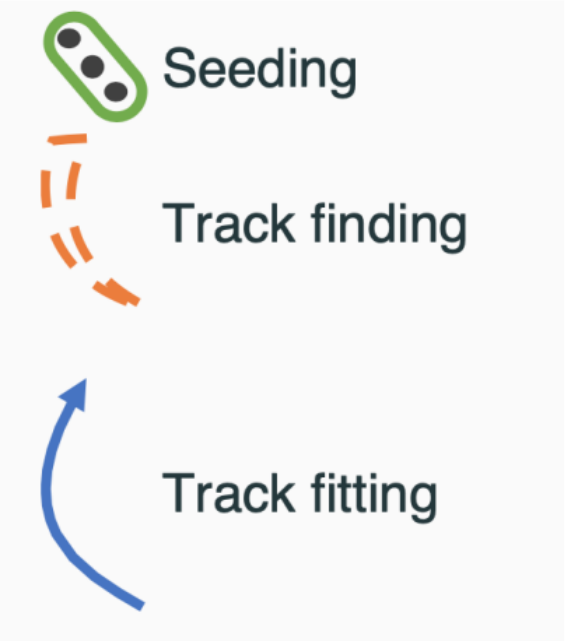
Combine the clusters on front and back sensor of one SCT modules to form space points



Pattern recognition and ambiguity solving



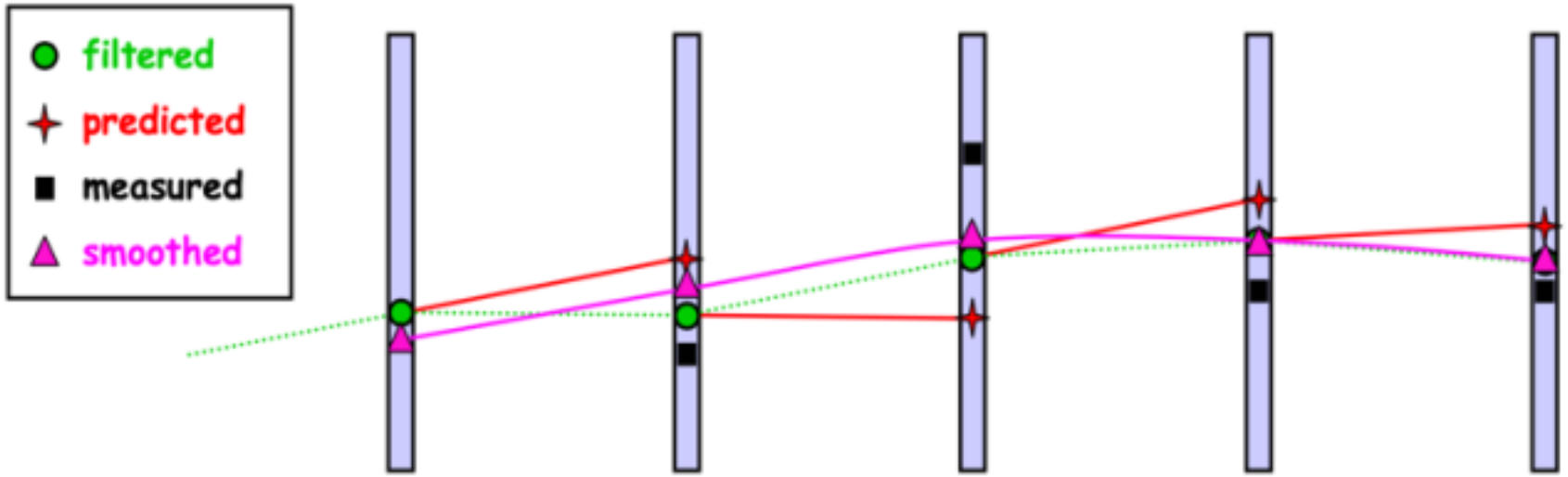
Track fitting with selected space points



A Common Tracking Software (ACTS)

- Based on the ATLAS tracking software
- Provide a toolbox with experiment-independent components
- Minimal dependencies (e.g. no required ROOT dependency)
- Allow building (possibly) experiment-specific applications like seeding, track finding, vertex finding
- Primary goal: ATLAS run 3 and beyond

Kalman filter



- The filtering is a weighted average of the measurements y_n and prediction y_p

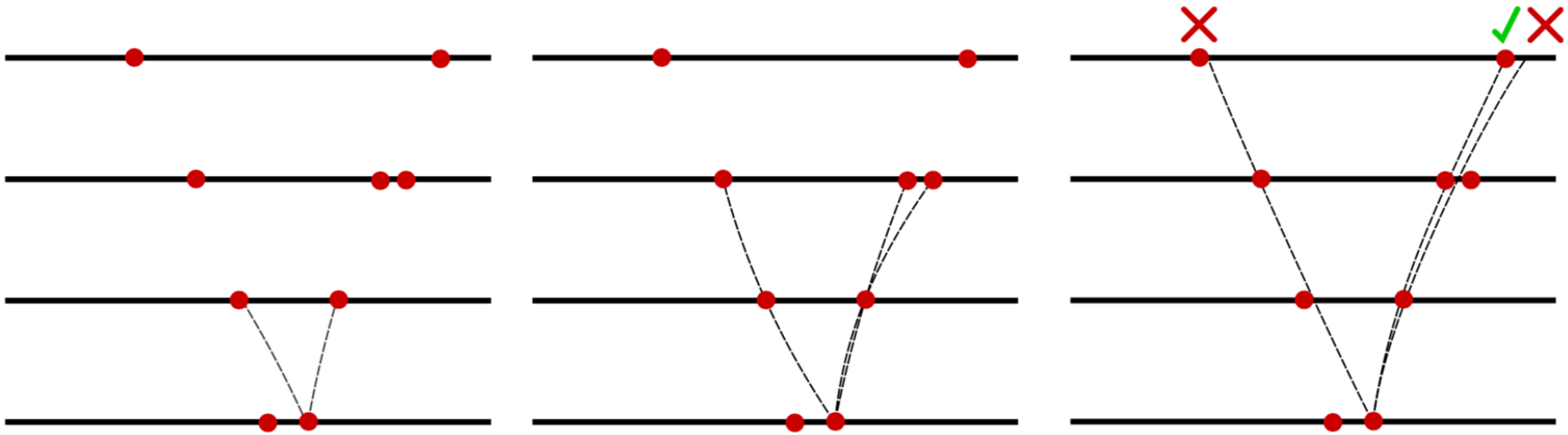
$$y_f = \frac{\frac{1}{\sigma_p^2} y_p + \frac{1}{\sigma_n^2} y_n}{\frac{1}{\sigma_p^2} + \frac{1}{\sigma_n^2}}$$

- Iterative
- The computation time increases only linearly with the number of measurements
- The estimated track parameters closely follows the real path of the particle

Combinatorial Kalman Filter (CKF)

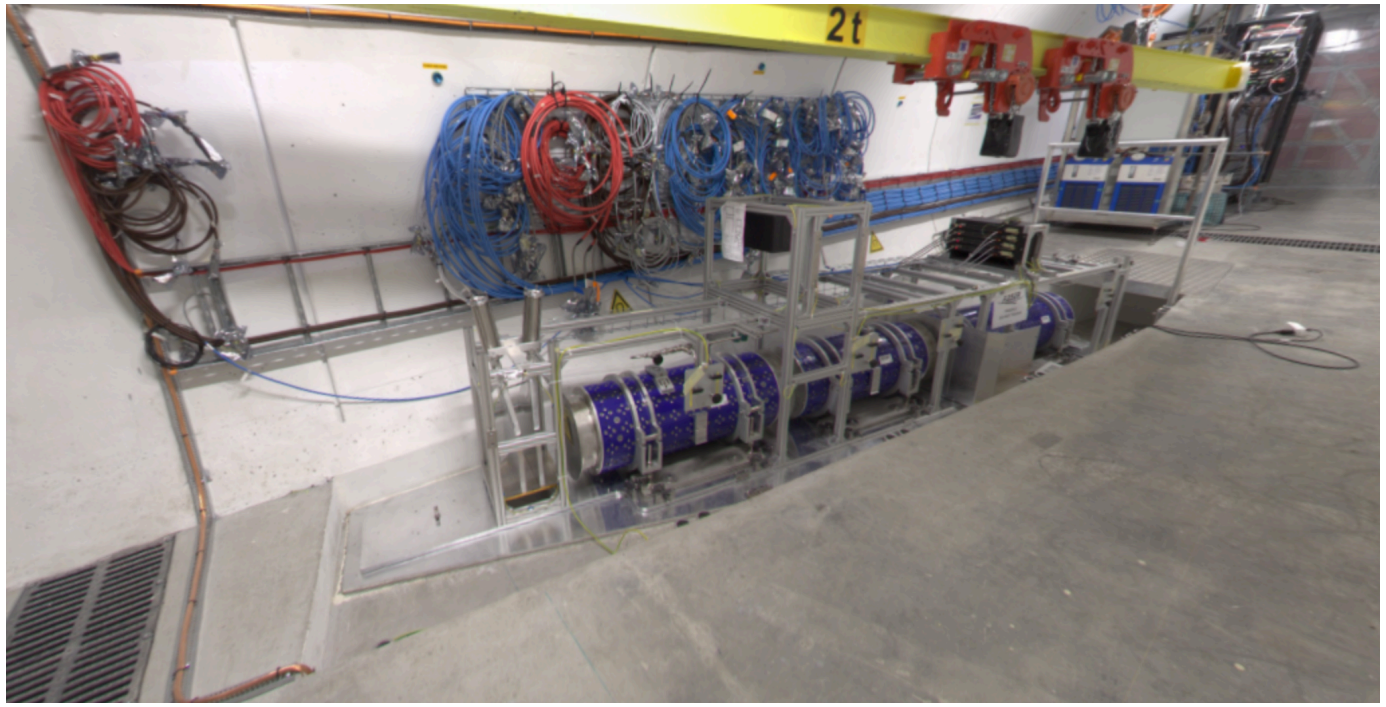
combine track finding and track fitting:

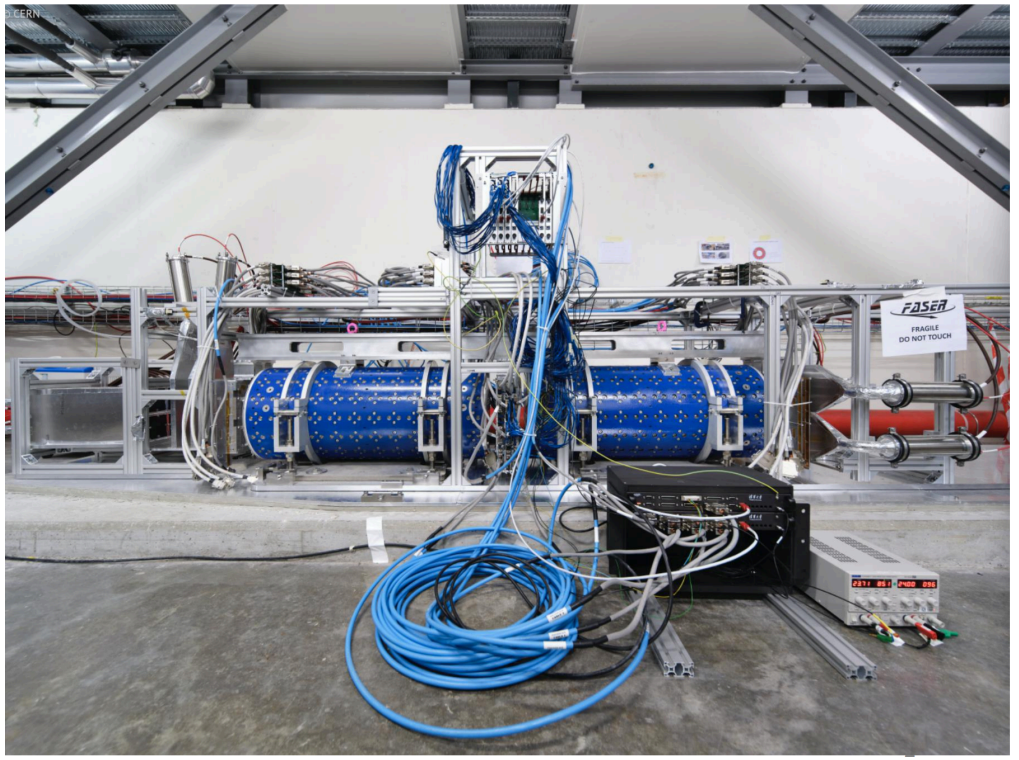
- create new trajectory for each possible hit
- beat combinatorics: cut on max. χ^2 value, #trajectories
- final selection: trajectory with least χ^2 value



TimeLine

- Refurbishment of TI12 to be an experiment site was completed in winter 2020
- All detectors have been installed in TI12
- Testing and calibration now
- Data taking will start at LHC RUN-3 2022





Summary

- FASER is a new experiment at the LHC to search new long-lived particles, which complements the current physics program

- FASER is on track for LS2 installation, and plan to take data from Run-3

  - The first version of offline software based on Athena is done, and getting maturer

  - All detectors have been installed in TI12, the status is on testing part.

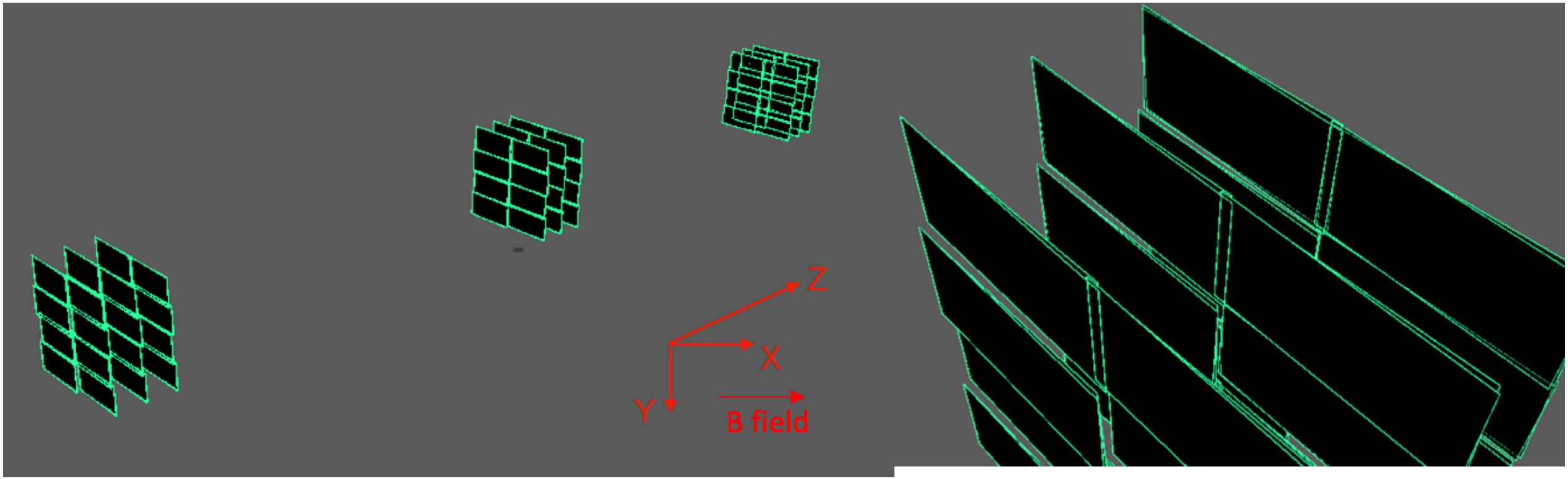
FASER Collaboration

65 collaborators, 18 institutions, 8 countries

https://faser.web.cern.ch/home

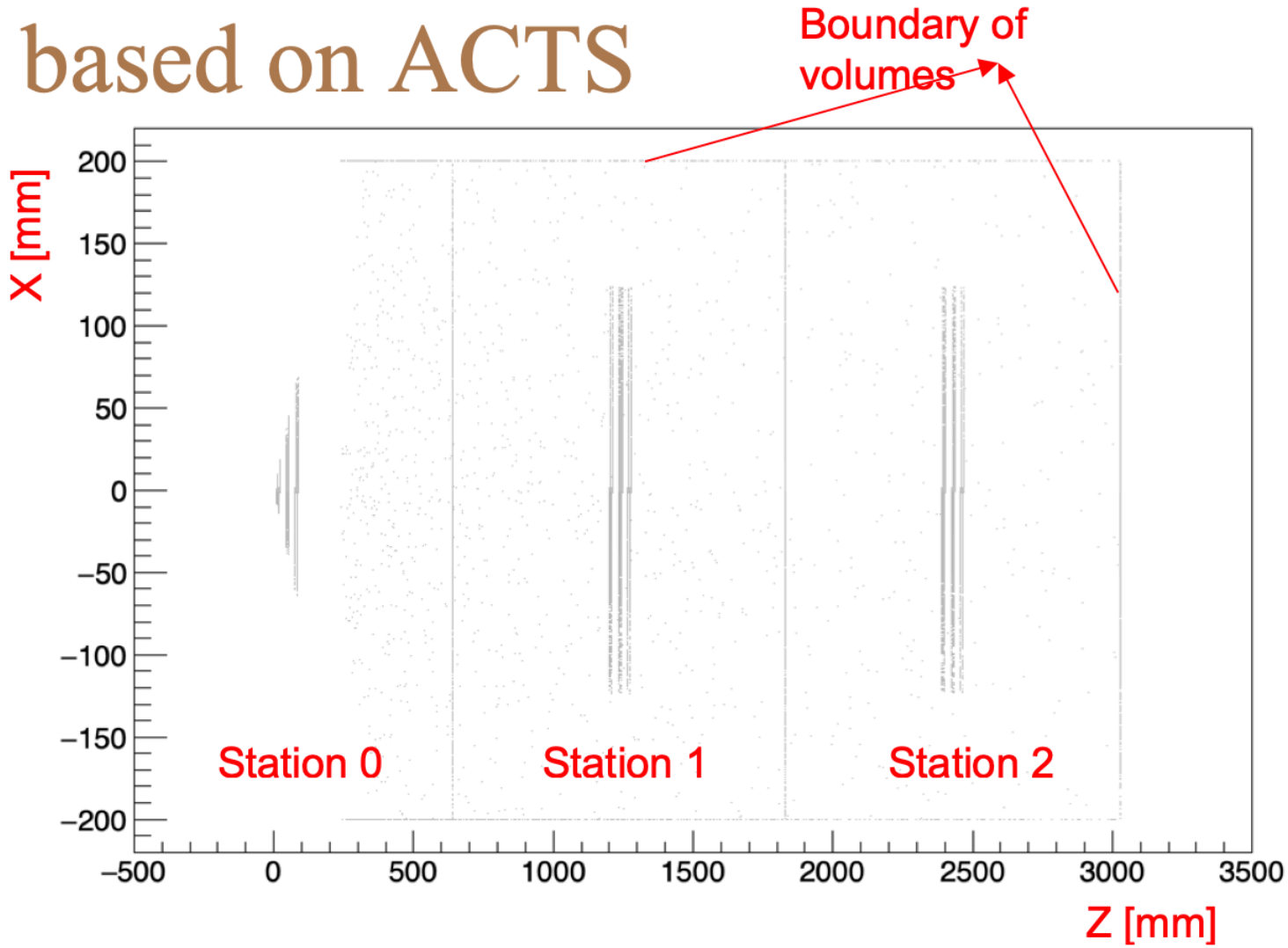
Back up

Tracking geometry with ACTS



- Build the TrackingGeometry with ACTS CuboidVolumeBuilder
- One cuboid volume for one station
- Retrieve SCT elements from DetectorStore and construct ACTS surfaces
- Keep two-sided sensor and staggering structure of each layer

Extrapolator based on ACTS



- Based on ACTS propagator
- Shoot particles from (0,0,0) and extrapolate the particles step by step
- Read the realistic FASER magnetic field from condition directly

The definition of 5 track parameters

- Local x and local y are the local position on the side 0 sensor of the SCT module where the track pass through the 1st layer
- θ is the polar angle of the momentum in global coordinate system at the 1st layer
- φ is the azimuthal angle of the momentum in global coordinate system at the 1st layer
- q/p is charge over momentum at the 1st layer

Momentum resolution in technical proposal

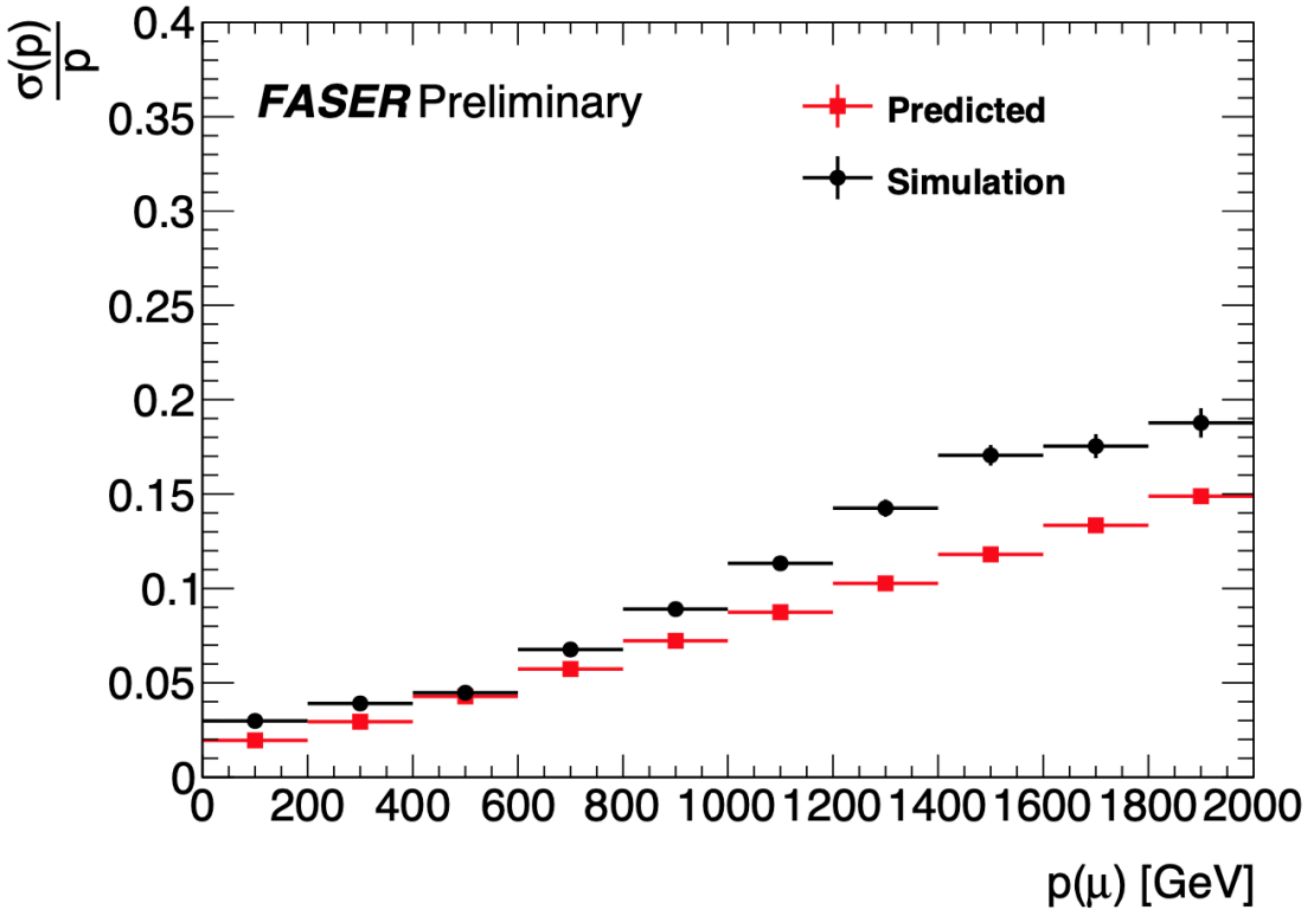


FIG. 56. Fractional momentum resolution (σ_p/p) for reconstructed muon tracks as a function of momentum, compared to the predicted resolution from Karimaki [39].