Hadronic Interaction Vertices Analysis with the ATLAS Detector

Presented by: **Natasha Mahmood**

BS (Hons.) in Physics
Government College University
Lahore, Pakistan

M.Phil in High Energy Physics
University of the Punjab Lahore, Pakistan

EP-ADP Department

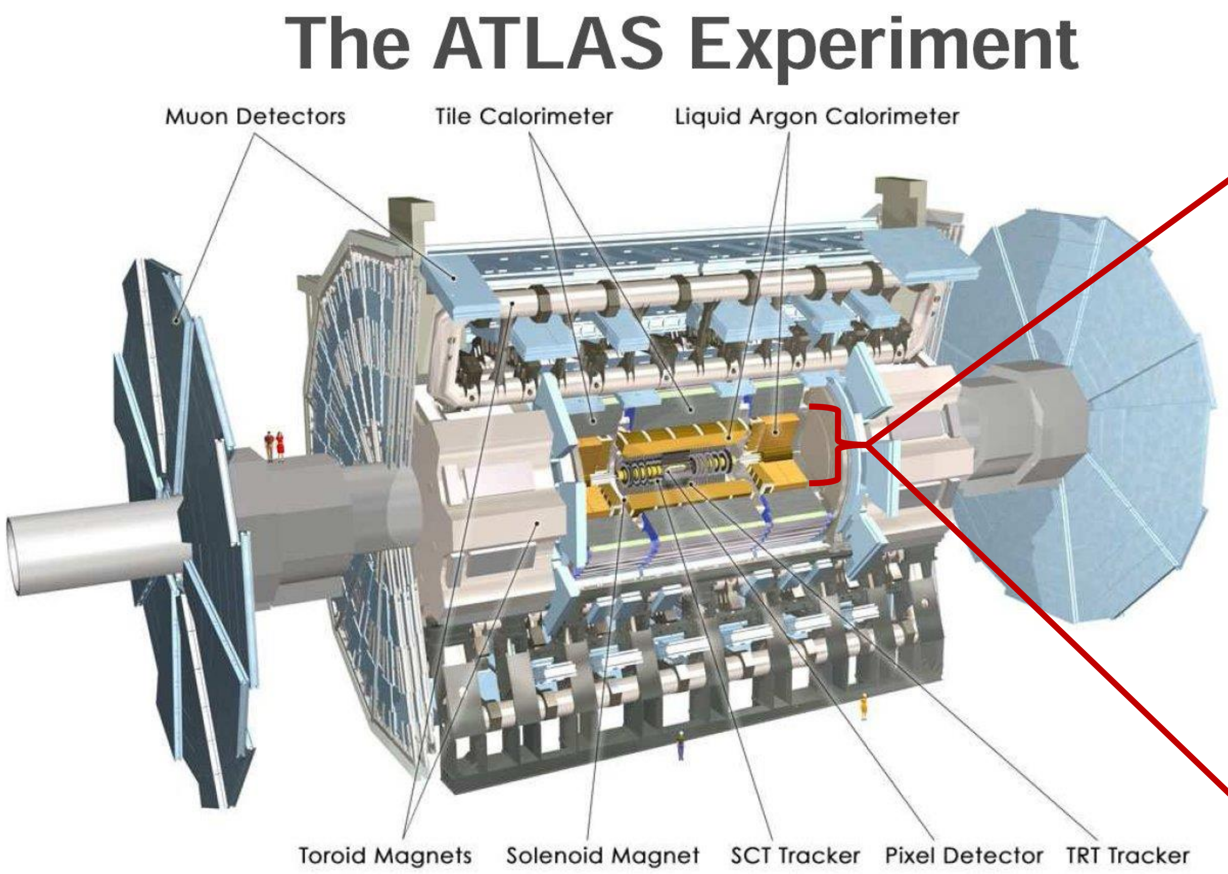
Supervisors: Dr. Anthony Morley & Dr. Valentina Cairo

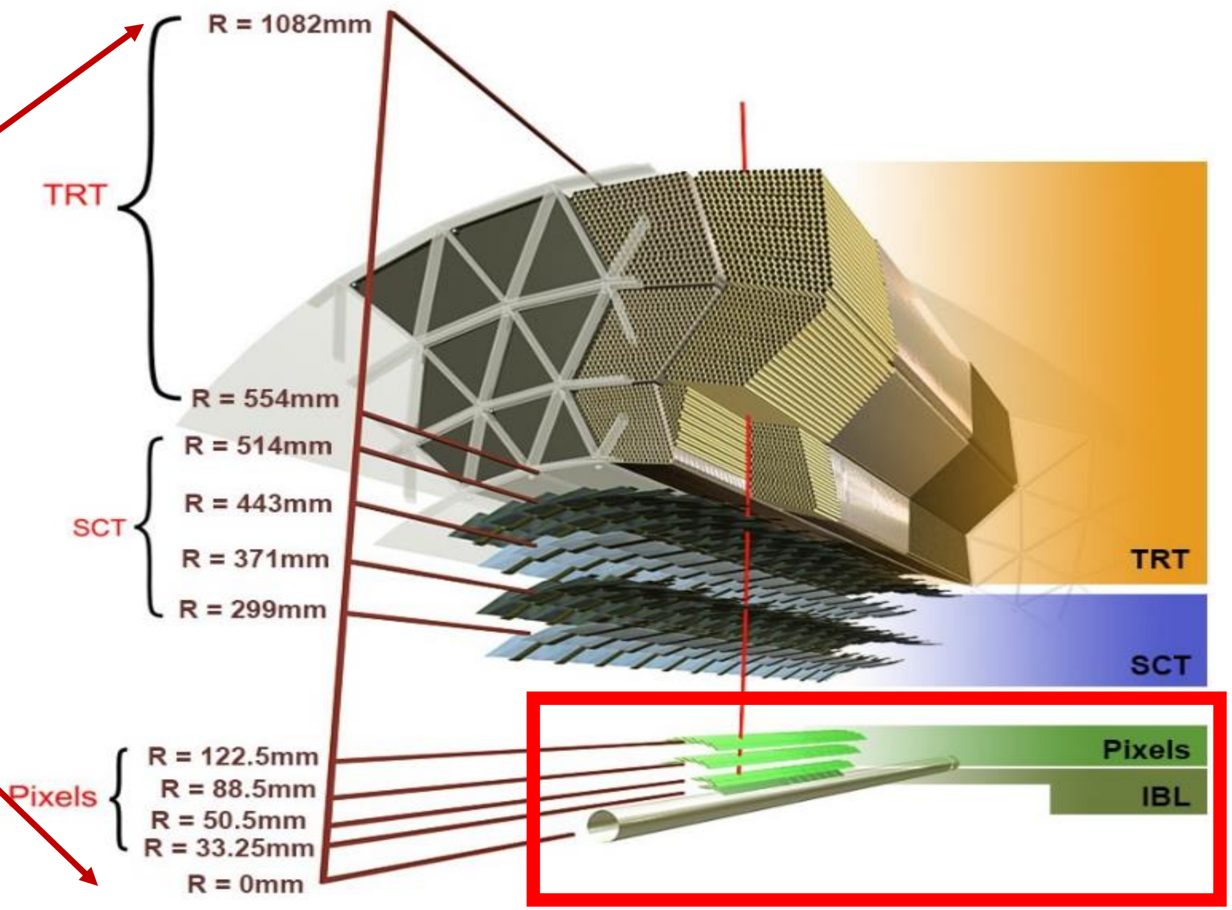
CERN Summer Student Session – 8 August 2018

My Project

- Detailed **simulations of high-energy particle collisions are a vital tool for all measurements** performed at accelerators like the LHC.
- **ATLAS detector** able to reconstruct hadronic interaction vertices with high precision inside the pixel tracker
  - **target material** (silicon, beryllium, carbon, aluminium) **can be selected**
  - **secondary particle species can be identified** (pions can be separated from protons and kaons) with the use of information about dE/dx in tracking detectors
- Goal of this project: to study **the properties of secondary hadrons** from interactions of primary particles in specific layers of the inner detector. In particular, to provide information about the **species of the secondary particles** that assist in the tuning of the numerical models used to simulate these interactions.

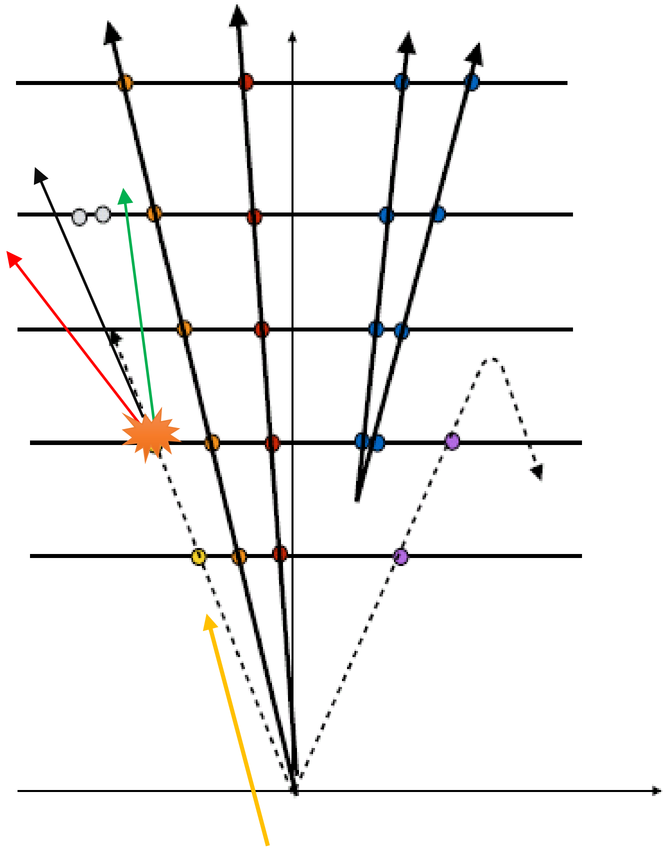
A Toroidal LHC Apparatus





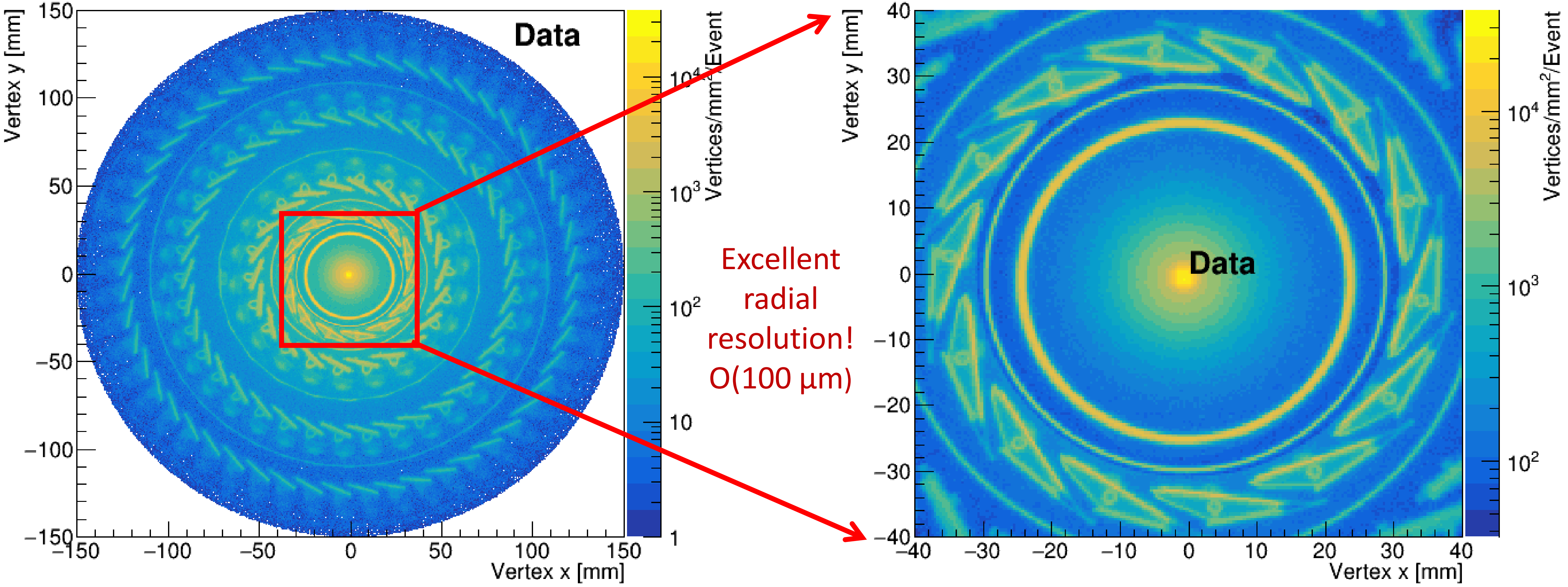
Track & Vertex Reconstruction

- In a High Energy Physics Experiment, the reconstruction of the charged-particle trajectories, ***tracking***, in magnetic field is a fundamental ingredient in any analysis
  - Particle Identification
  - Momentum and Mass reconstruction
- Charged-particles interact with all the material, not only the sensitive parts: multiple scattering, energy loss by ionization (all particles), energy loss by bremsstrahlung (mainly electrons)
- A detailed knowledge of the experimental setup is required to cope with those artifacts
- The material can be studied in a number of ways. I will focus on reconstructing:
  - Hadronic interactions



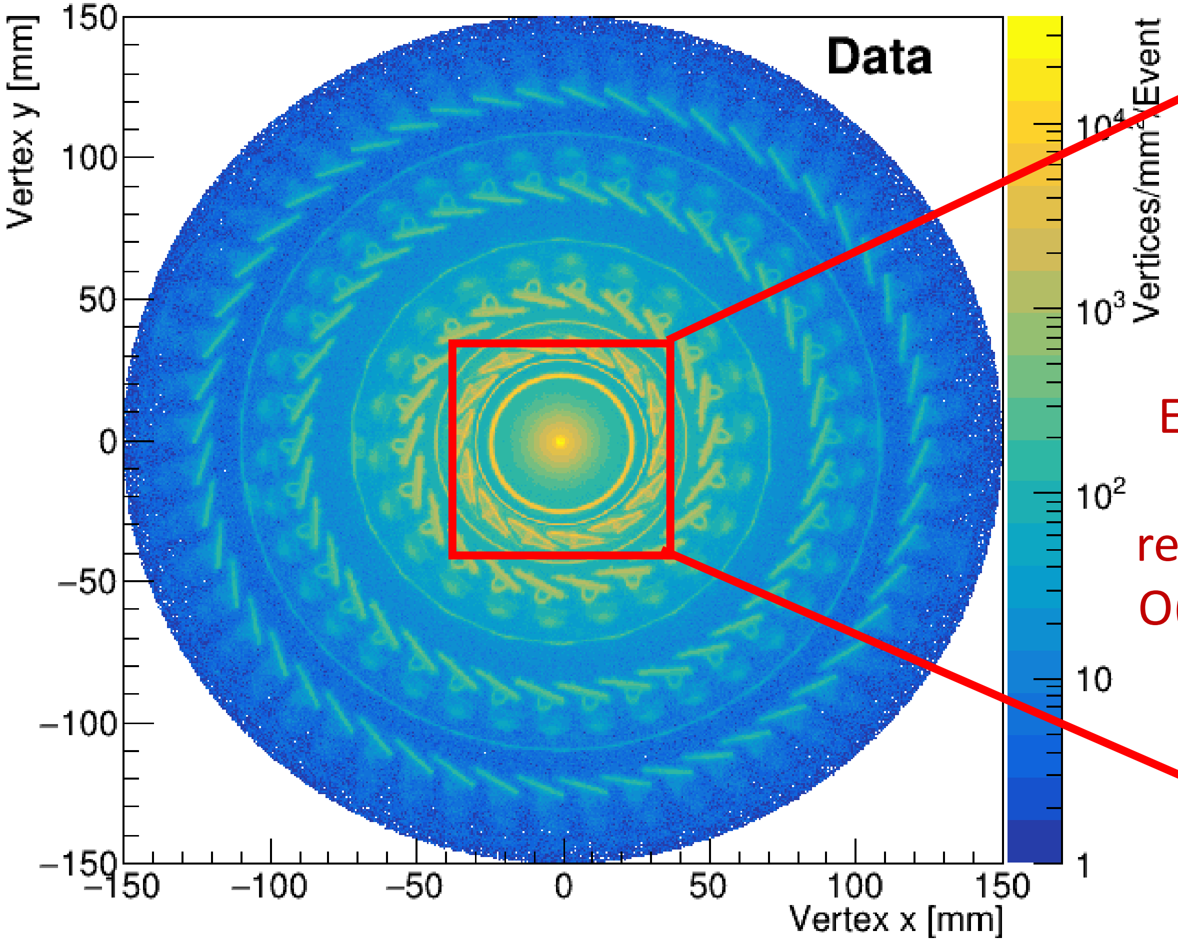
Lost due to
hadronic interactions

Hadronic Interaction radiographies

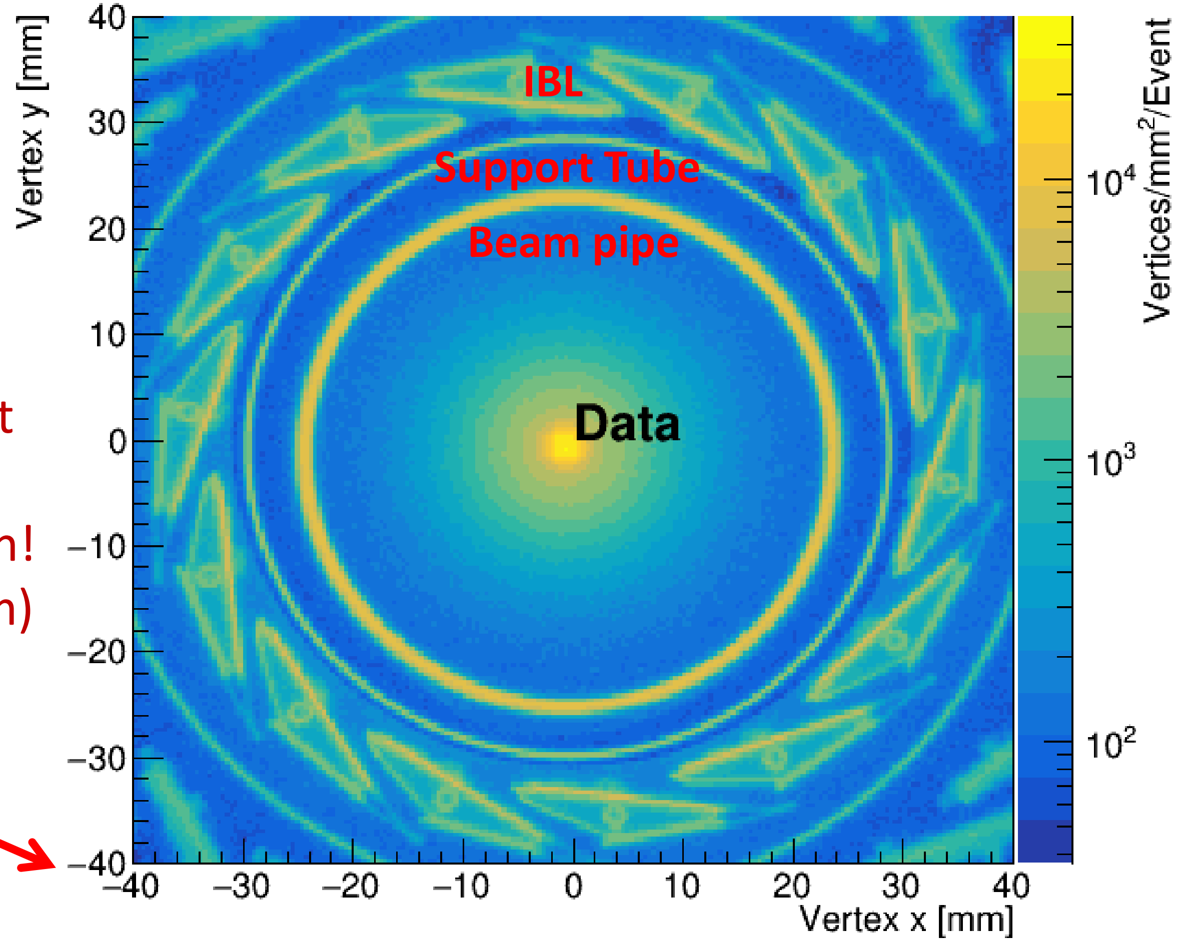


Excellent radial resolution! O(100 μm)

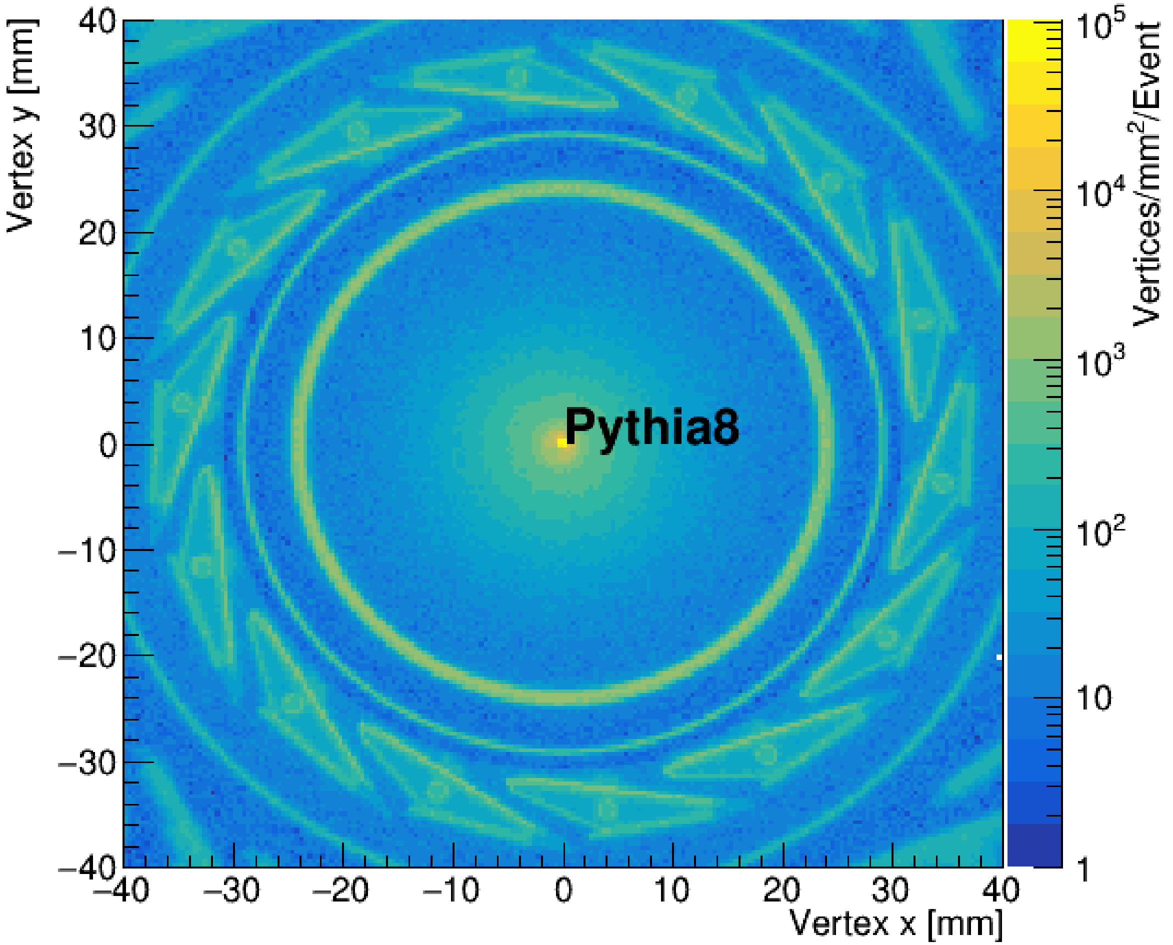
Hadronic Interaction radiographies

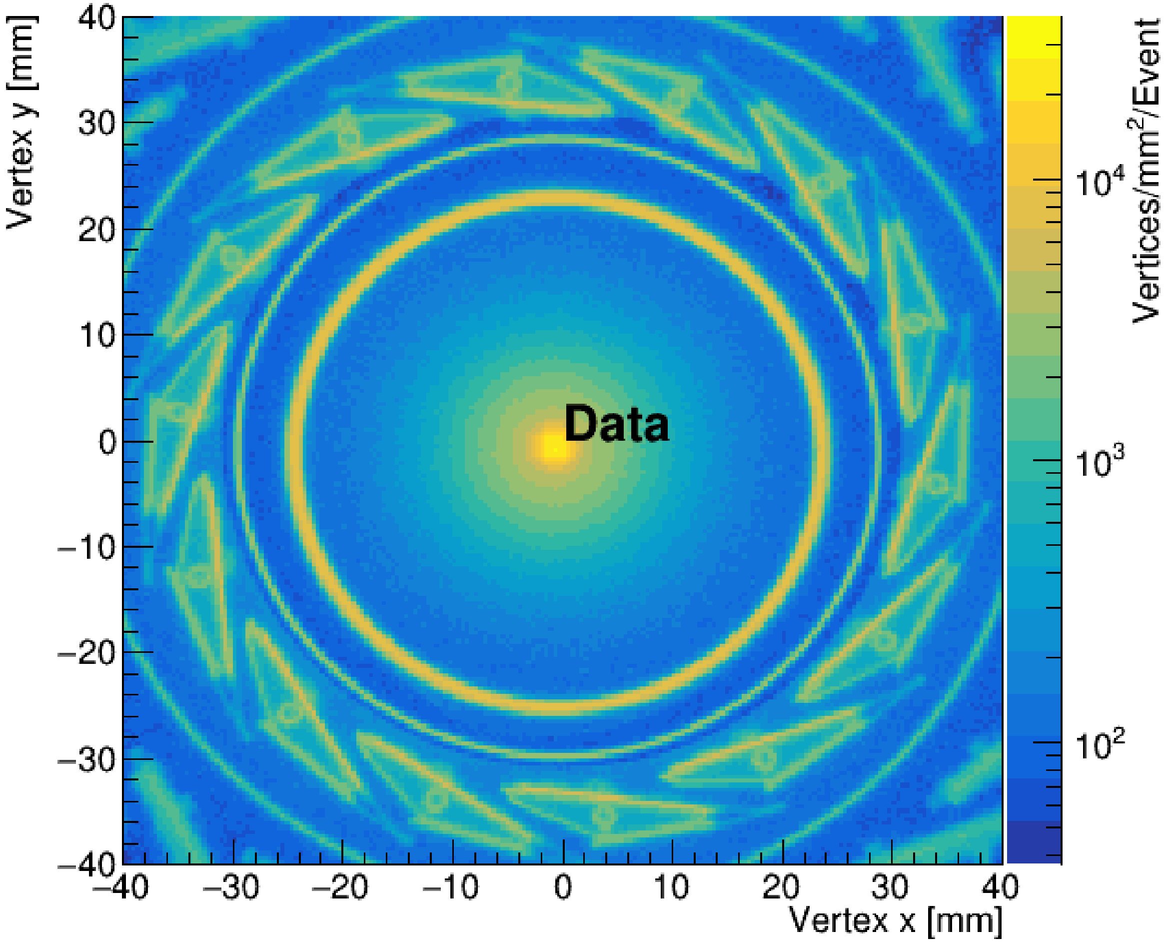


Excellent radial resolution! O(100 µm)



Hadronic Interaction radiographies - DATA Vs MC





Particles Identification via dE/dx

- The various elementary particles gives different characteristic signature in the separate detector that make up the experiment

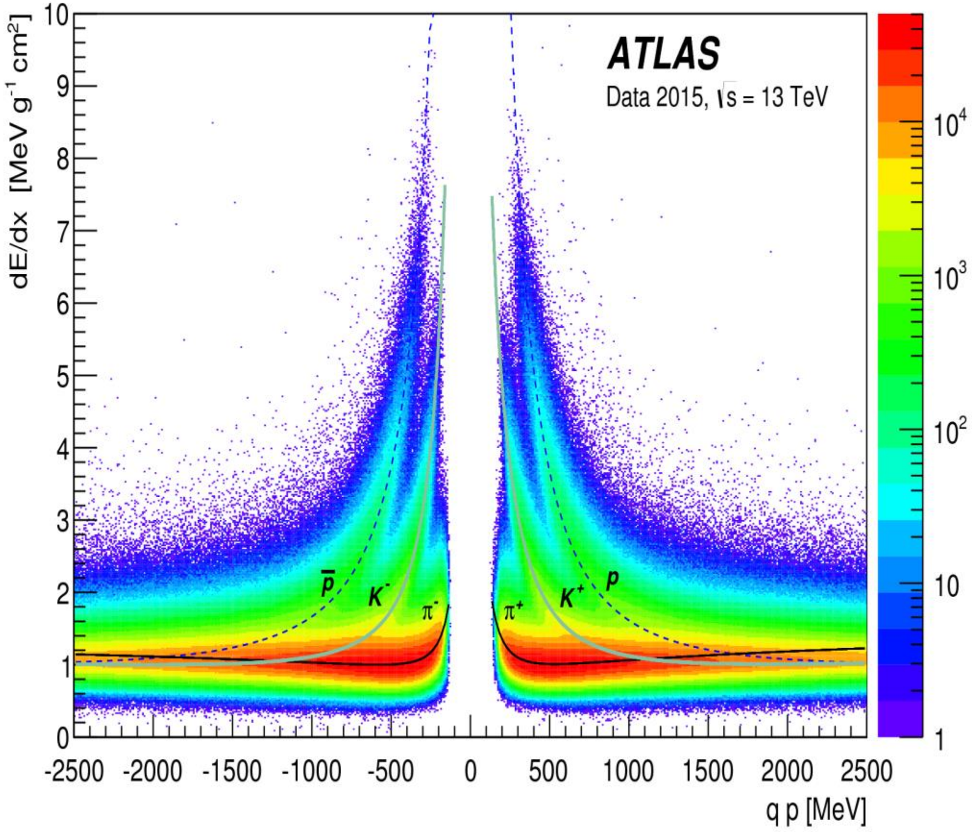
- Bethe-Bloch formula gives average energy loss

$$< -\frac{dE}{dx} > = Kz^2 \frac{Z}{A}\frac{1}{\beta^2} \; [\frac{1}{2} ln \frac{2m_e c^2 \beta^2 \gamma^2 W_{max}}{I^2} - \beta^2 - \frac{\delta(\beta\gamma)}{2}]$$

- $\beta = p/mc$ for a given momentum, β and dE/dx are different for particles with different masses

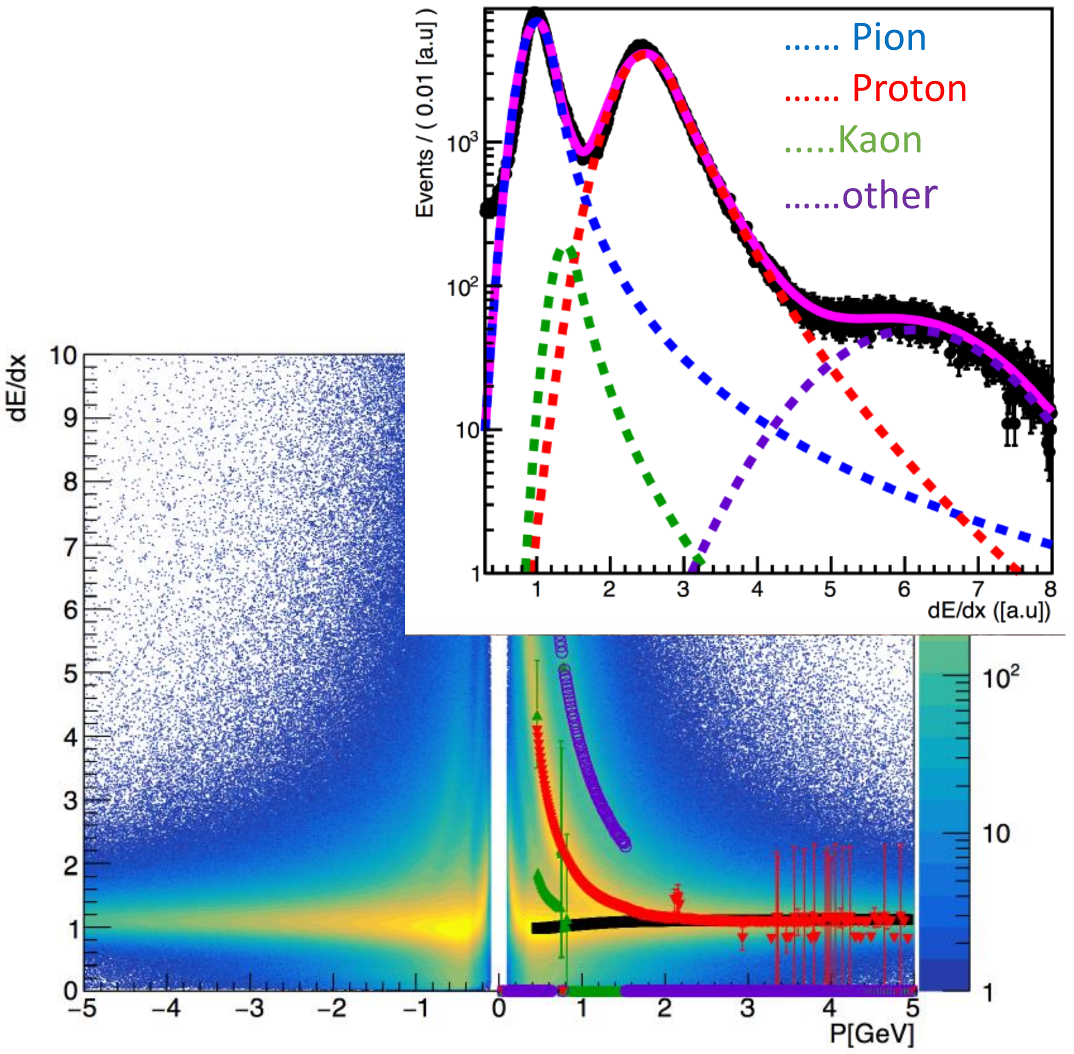
$$\frac{dE}{dx} \rightarrow \frac{1}{\beta^2} \rightarrow \frac{m^2}{p^2}$$

- Measurement of both p and dE/dx can be used to distinguish between different type of charged particles

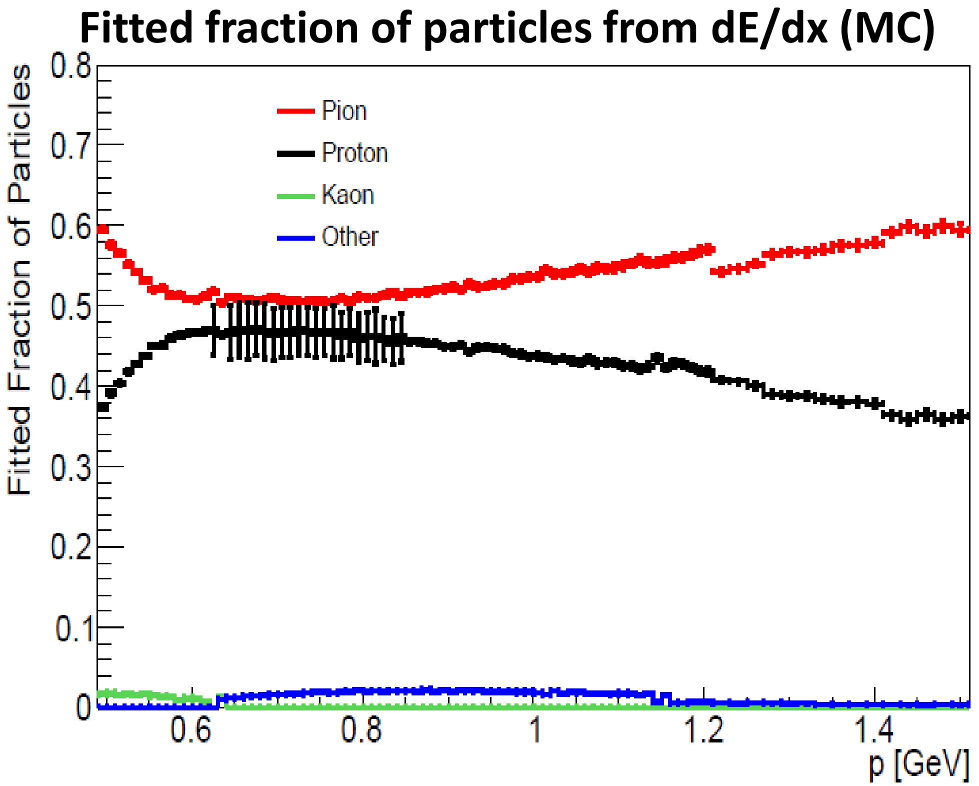


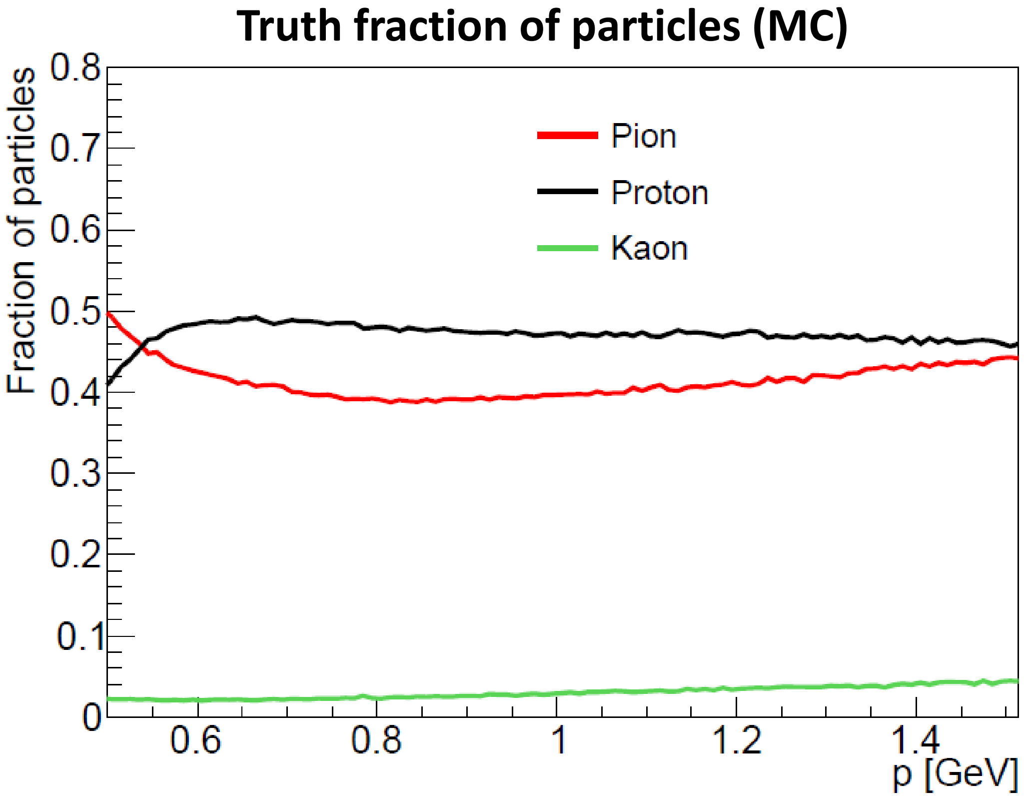
Extracting Fraction of Particles from dE/dx

- The first step in the particle identification process consists of parameterizing the probability density function (pdf) for the specific energy loss dE/dx and the βγ of a charged particle
- The function is expressed via parameters whose values are obtained via a fitting procedure that doesn’t rely on any prior knowledge of particle species
- Given a sufficiently large sample of reconstructed tracks whose dE/dx and p are measured, the sample is divided in slices of p and the free parameters are obtained via a fit of the corresponding dE/dx under the hypothesis that the sample contains three charged particles species: pions, protons and kaons.
- Data and MC samples are fitted separately and the relative fraction of pions, protons and kaons is extracted and compared



Fraction of Particles – Fitted vs Truth



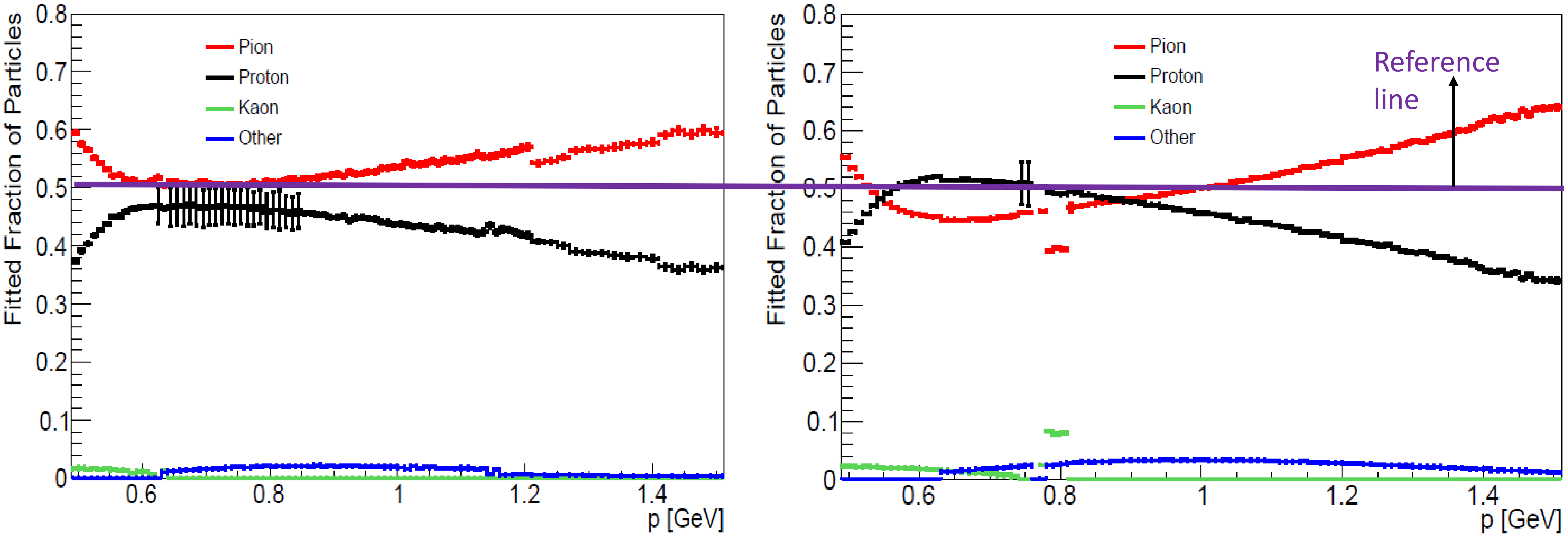


- First attempt to fit the fraction of particles, just preliminary results
- The shapes of the distributions of the particles' fractions obtained from the fits look consistent with the shapes of the "true" distributions, but an overall normalization difference is visible (~10%)
    - The fits **overestimate** (**underestimate**) the fraction of **pions** (**protons**)

Fitted Fraction of Particles – Data vs MC

Fitted Fraction of particles from dE/dx (MC)

Fitted fraction of particles from dE/dx (Data)



- First attempt to fit the fraction of particles, just preliminary results
- Larger fraction of **protons** in data with respect to simulation

Conclusions and Next steps

- Hadronic interactions are used to study the properties of secondary hadrons from interactions in specific layers of the inner detector
- Particle identification can be done in ATLAS via dE/dx and p measurements
- Being able to identify precisely pions, kaons and protons allows us to compare data and MC and eventually improve the simulation of particles interactions with material

What Next?

- Improve fit for energy loss
- Study very specific region of the detector (silicon, beryllium, carbon, aluminium)
- Take into account the detector efficiency


Thank you

BACKUP SLIDES

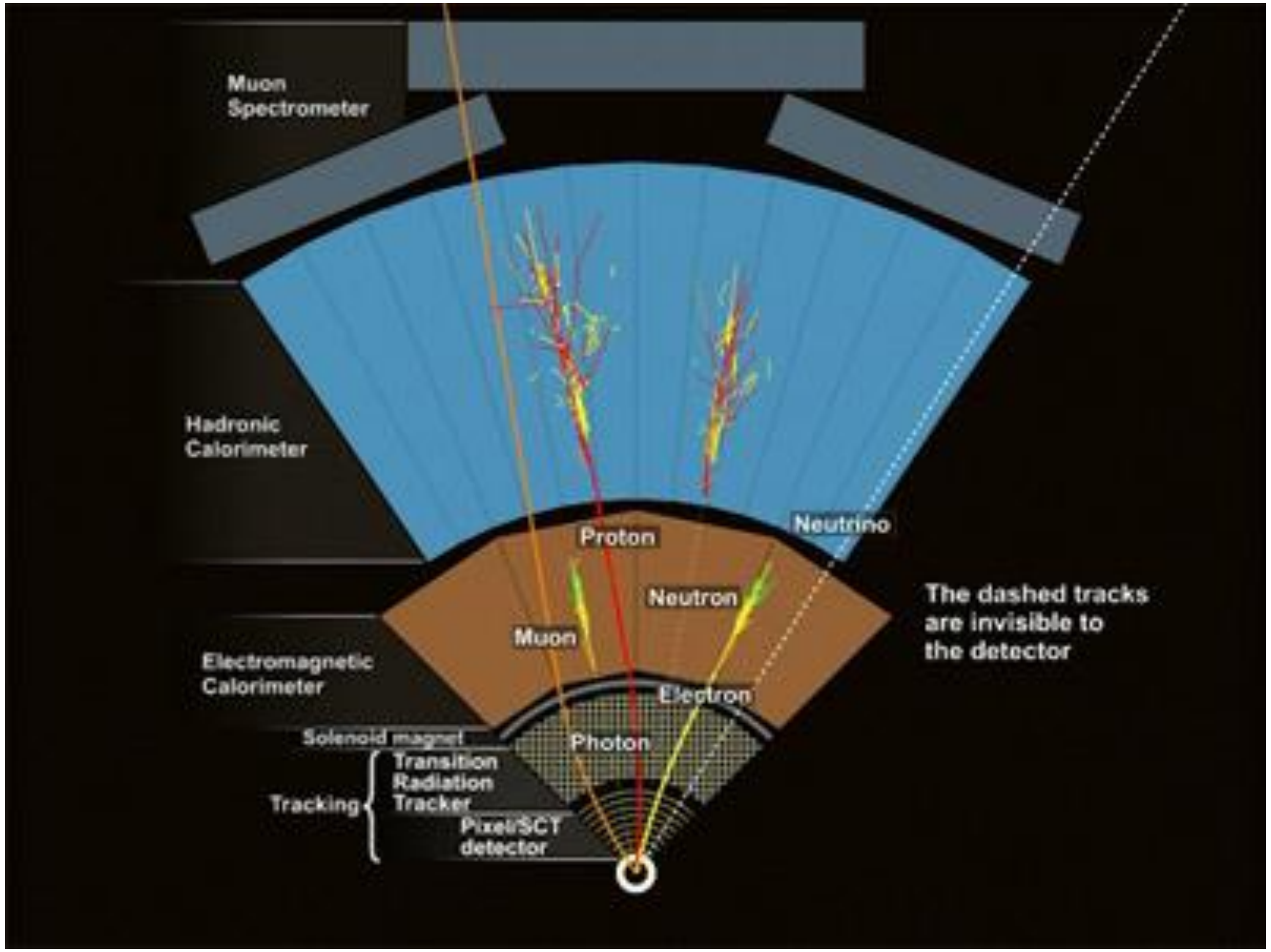
DETECTOR AND PARTICLE INTERACTION

Tracking Detector
Measure charge and momentum of charged particles in magnetic field

Electromagnetic Calorimeter
Measure energy of electrons, positrons and photons

Hadronic Calorimeter
Measure energy of hadrons(particles containing quarks) such as proton, neutrons and pions etc

Muon Detector
Measure charge and momentum of muons



Strange Hadrons' masses and dE/dx