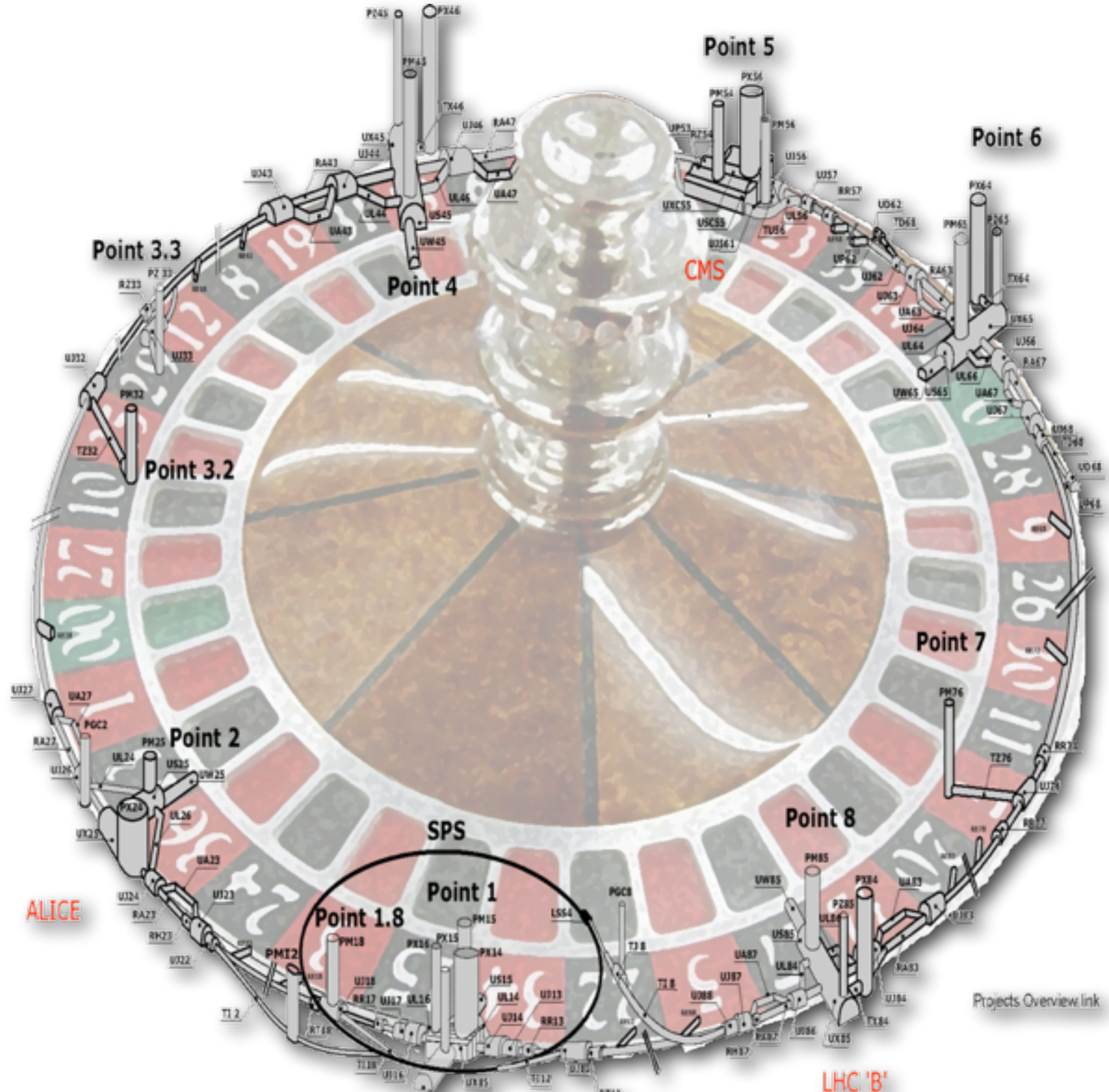
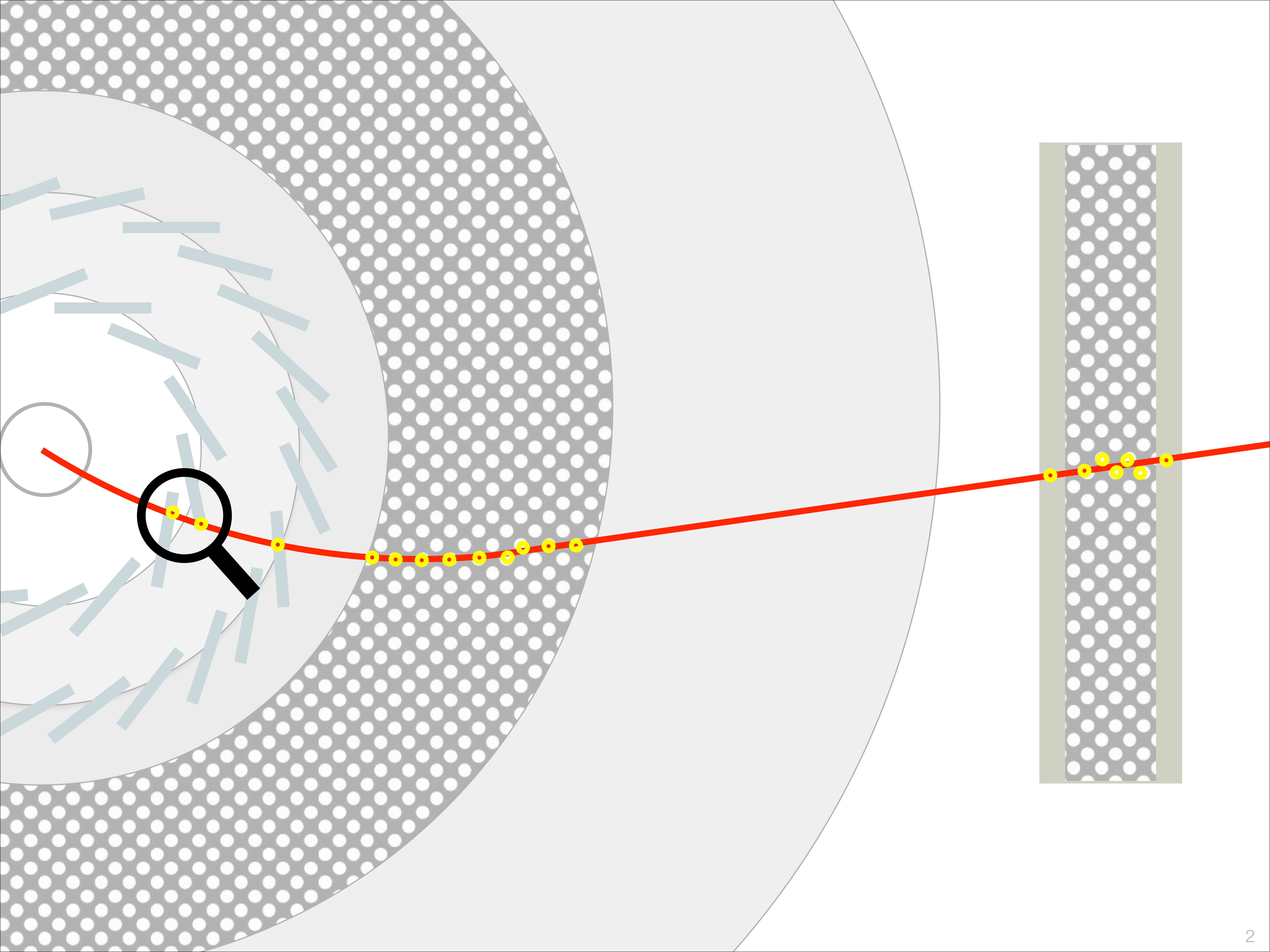


ATLAS Tracking Detectors

- a simulation centric view

LPCC Simulation Workshop - 18/03/2014

Andreas Salzburger (CERN)

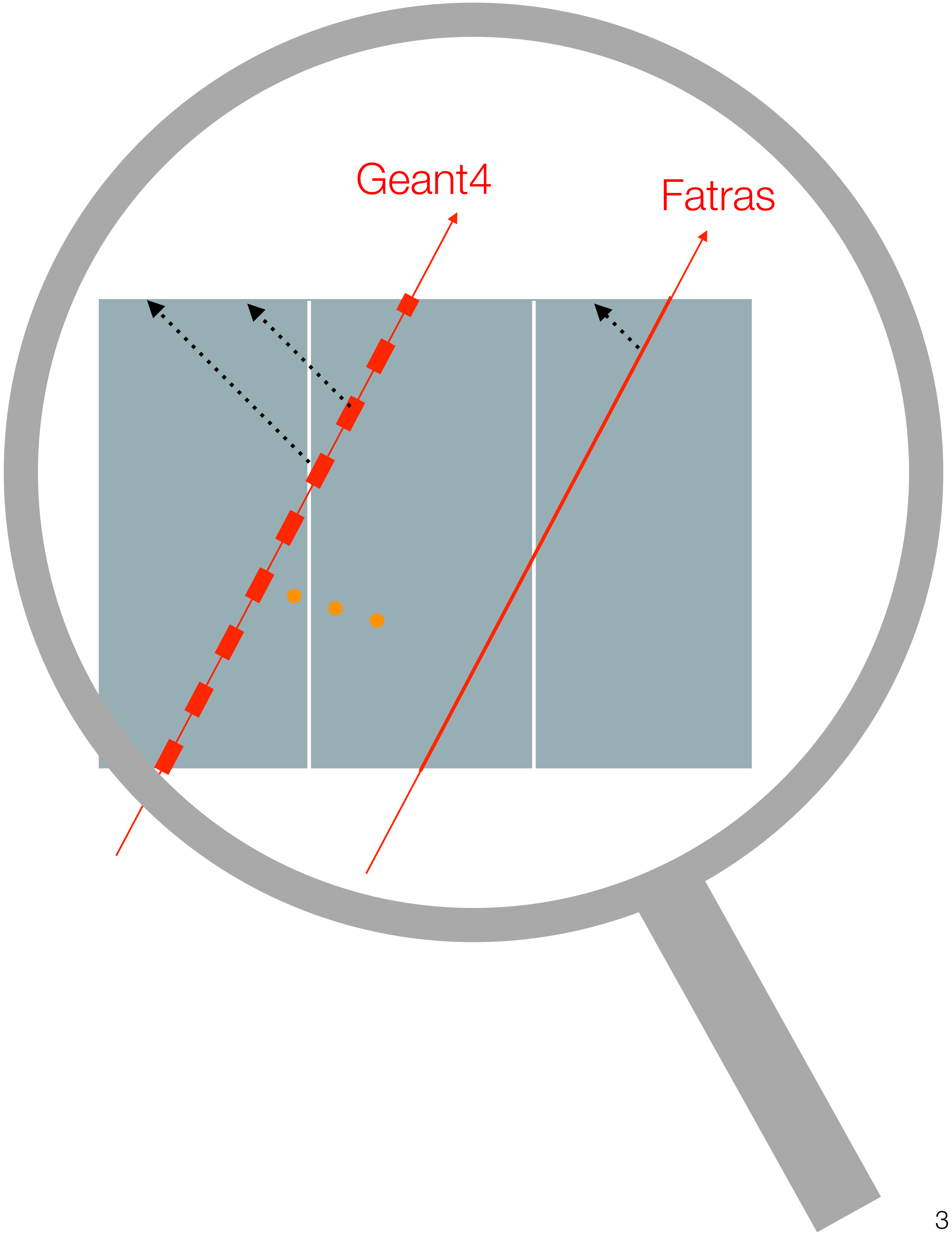


Silicon detectors

- Simulation
  - passage of particle through silicon
  - charge deposition
  - knock-out electrons

- Digitization
  - charge drift to surface (Lorentz angle)
  - channel cross talk
  - noise
  - read-out emulation
  - **for fast MC chain: a fast digitization prototype**

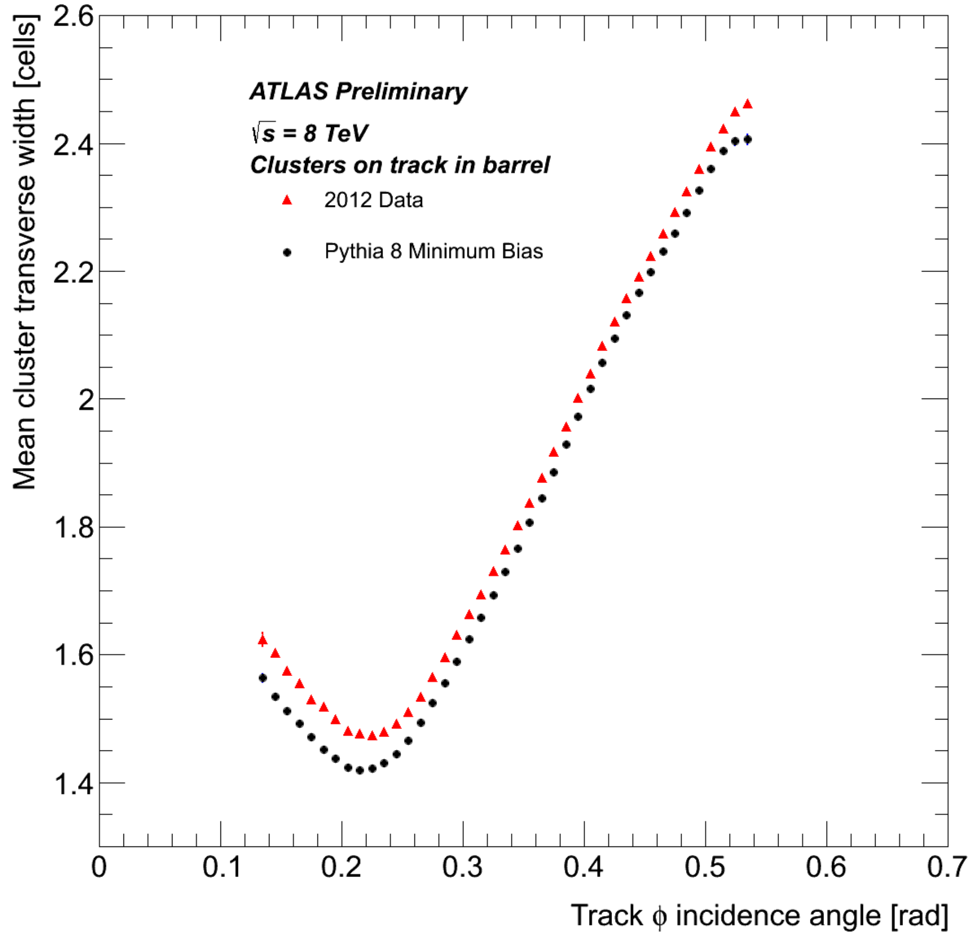
differences need to evaluated

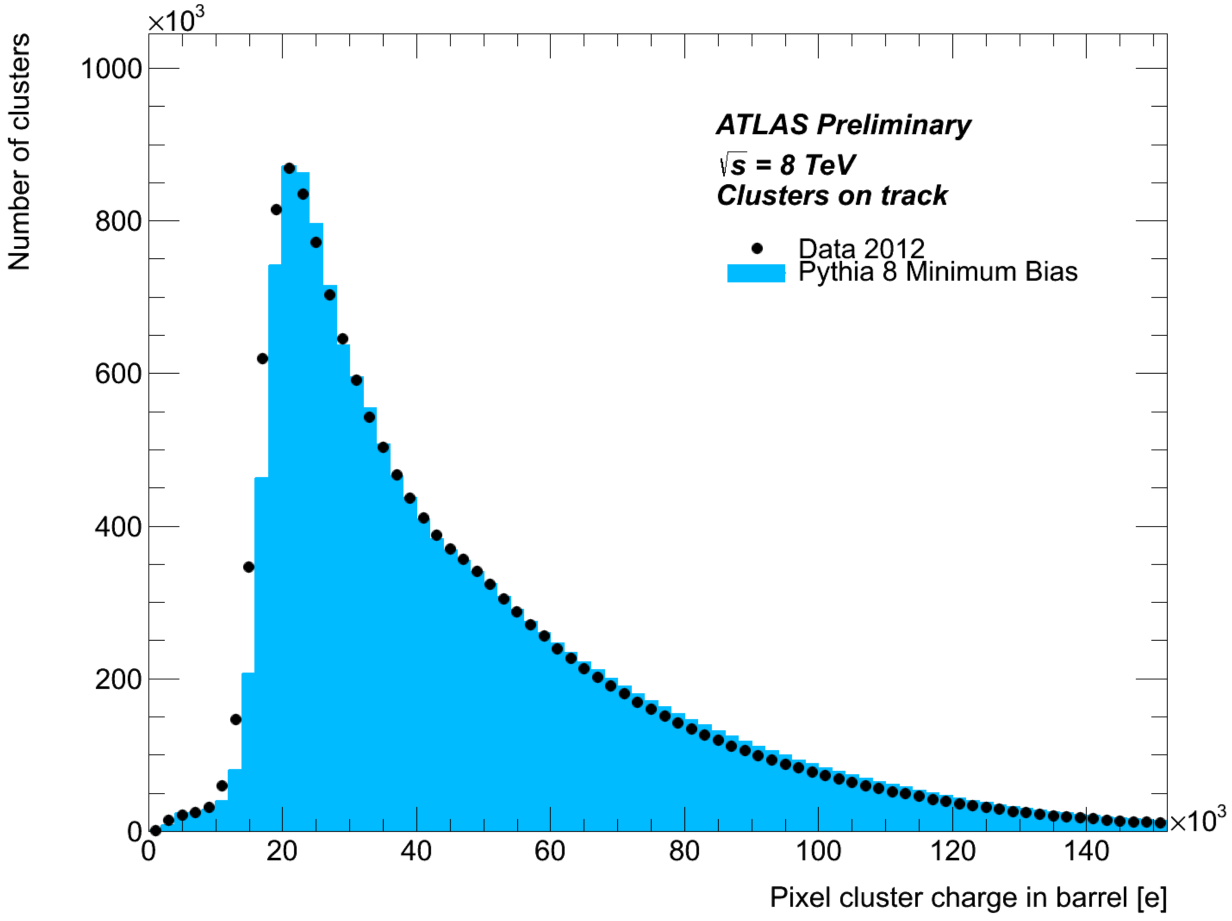


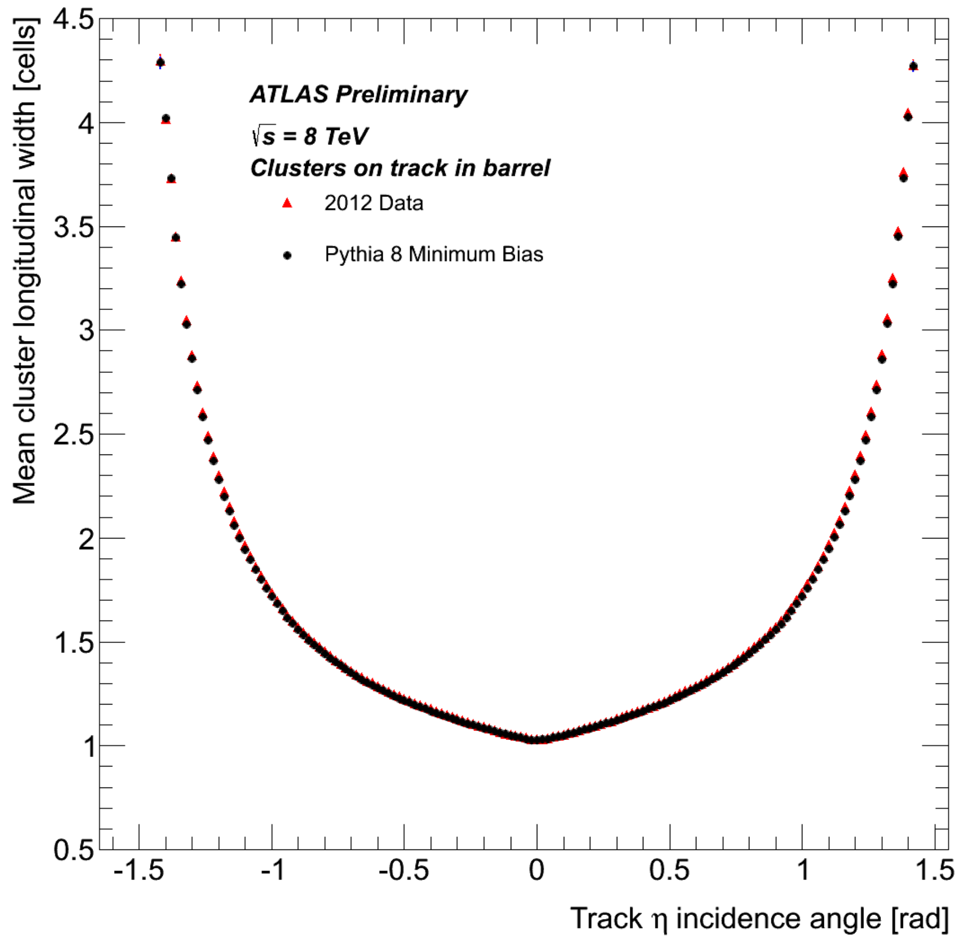
Cluster properties (1)

- Unresolved mystery of mis-matching cluster size in the pixels
  - seen throughout Run-1
  - affects also residuals since neural network clustering exploits this information

- Charge modelling good

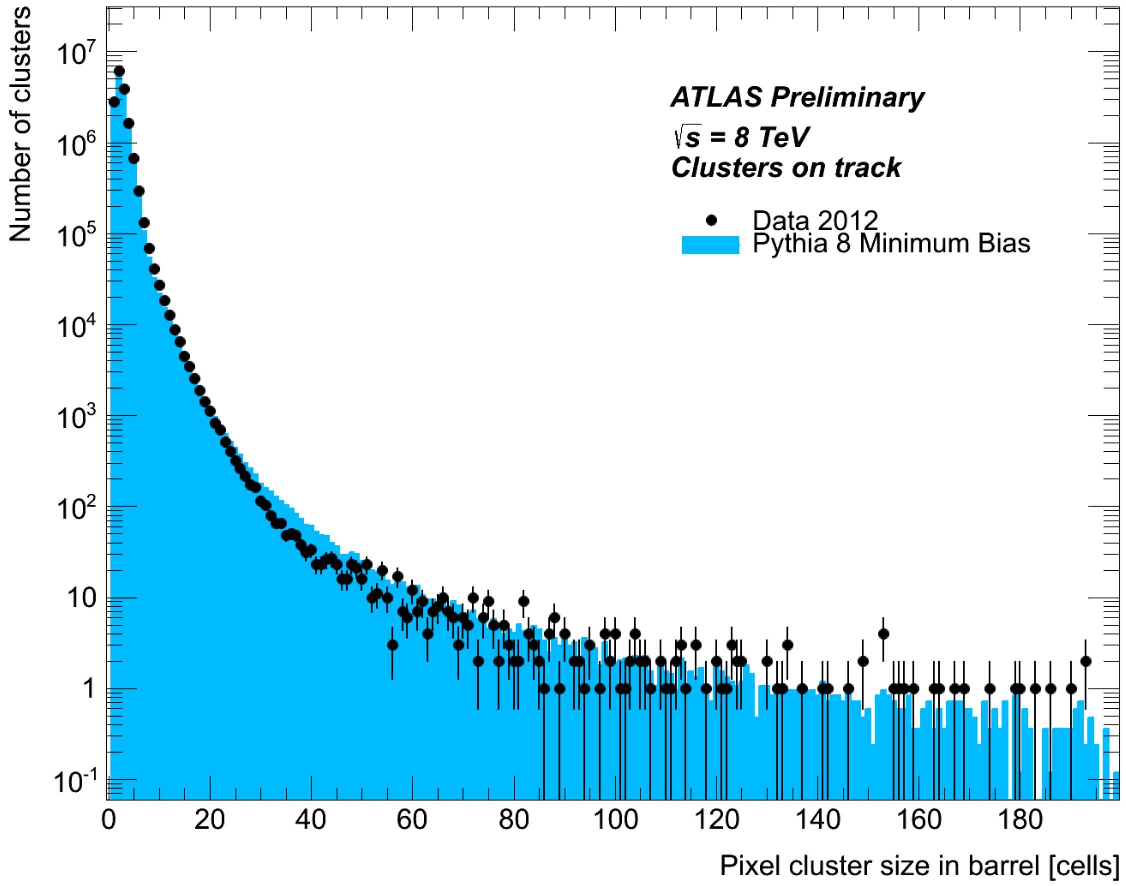


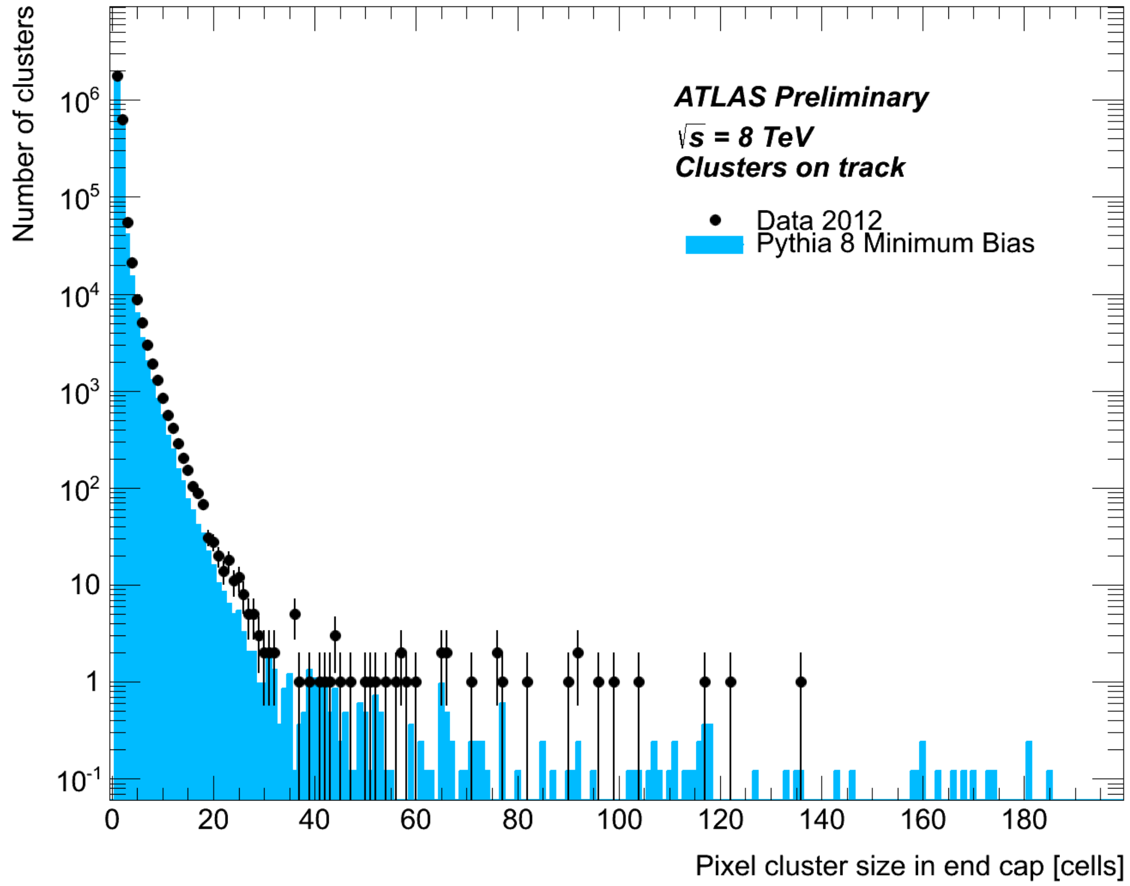




Cluster properties (2)

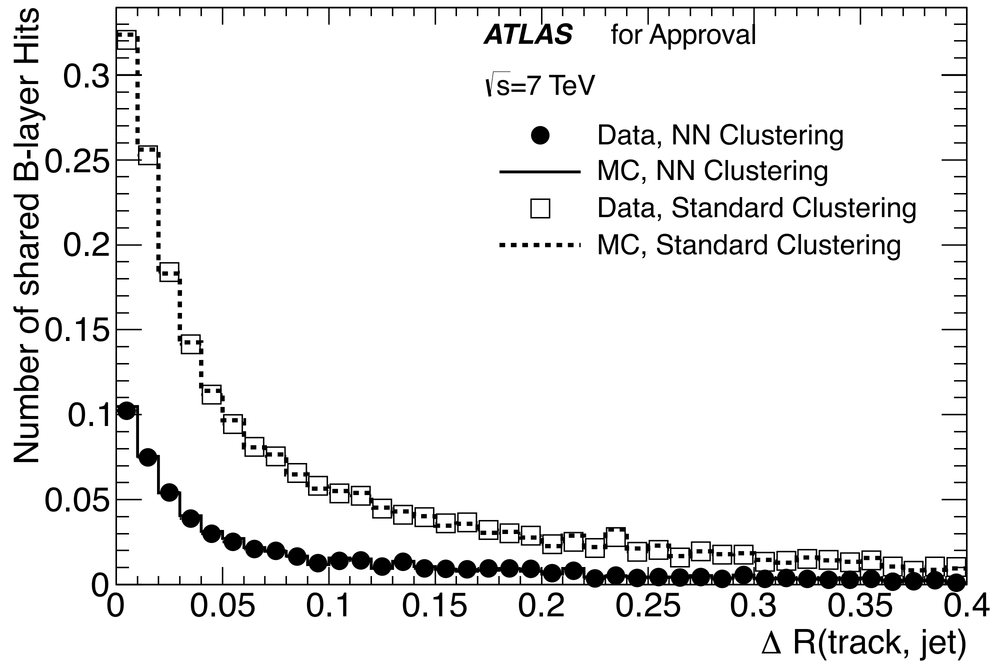
- Simulation does model the long tail in the cluster size well
  - very large cluster sizes come from very shallow* angles or loopers

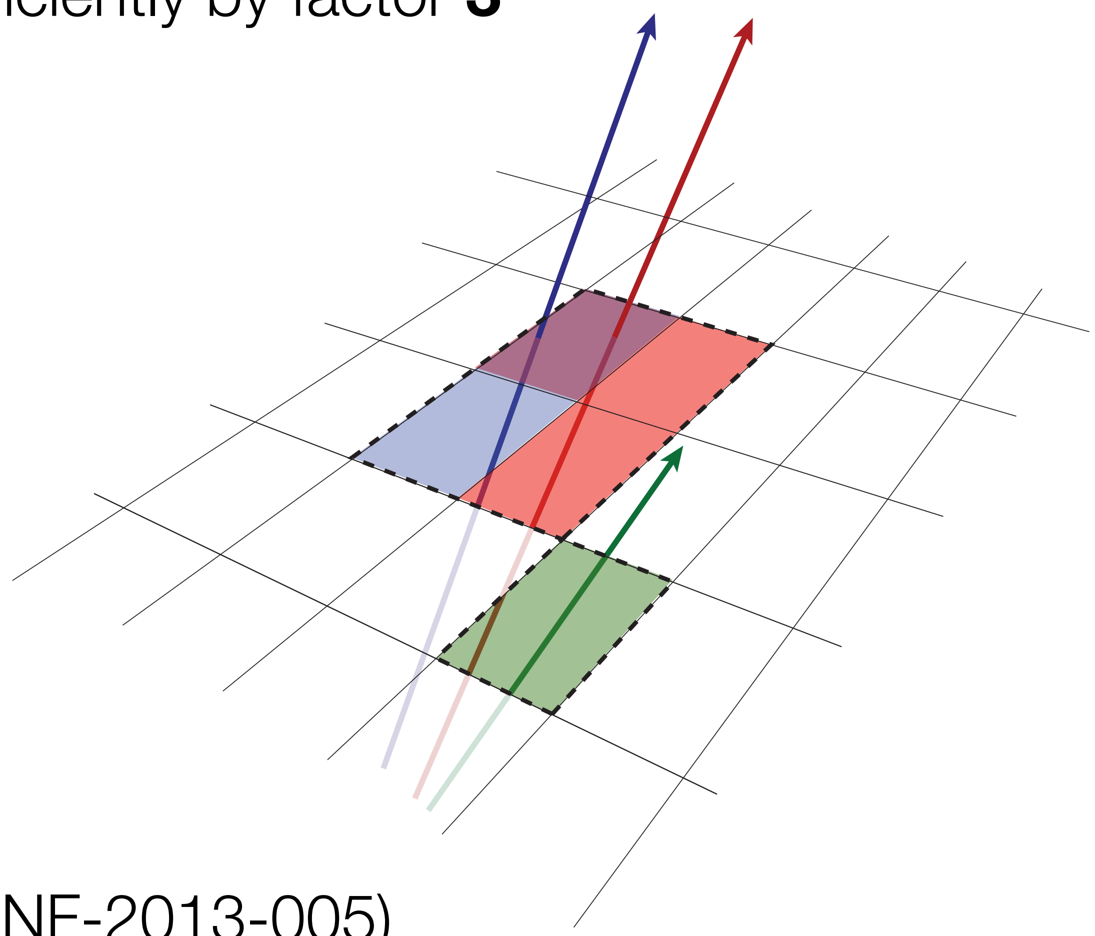




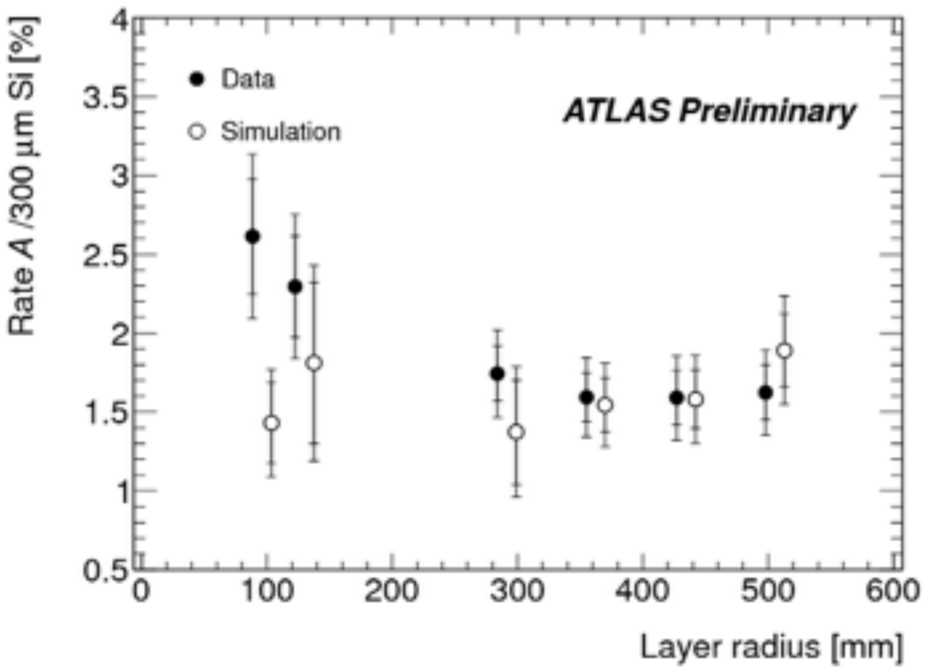
*particles traversing at almost 0 incident angle can also create disjoint clusters, since the probability of falling below threshold becomes higher.

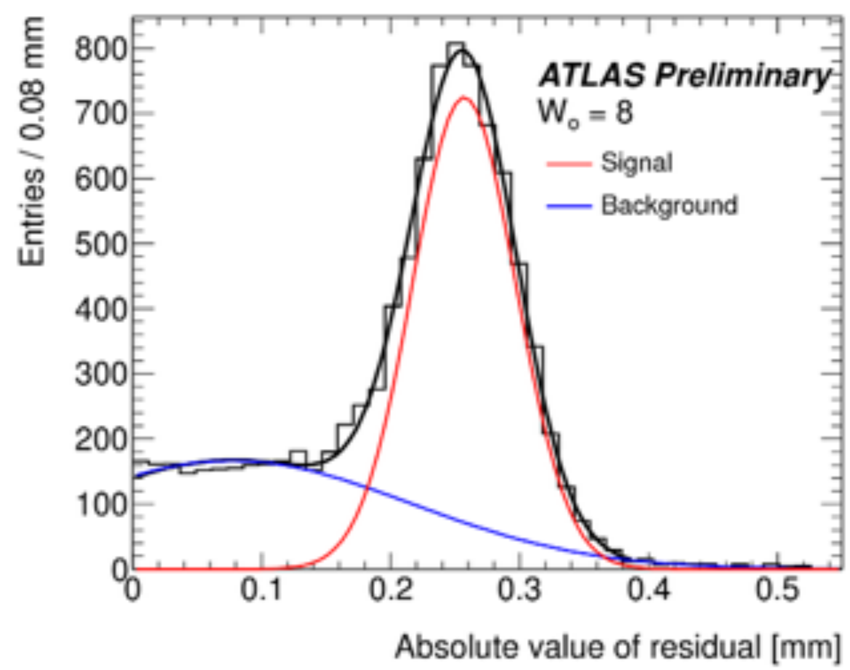
- Neural network based cluster splitter
  - reduces number of shared hits in dense jet cores efficiently by factor **3**





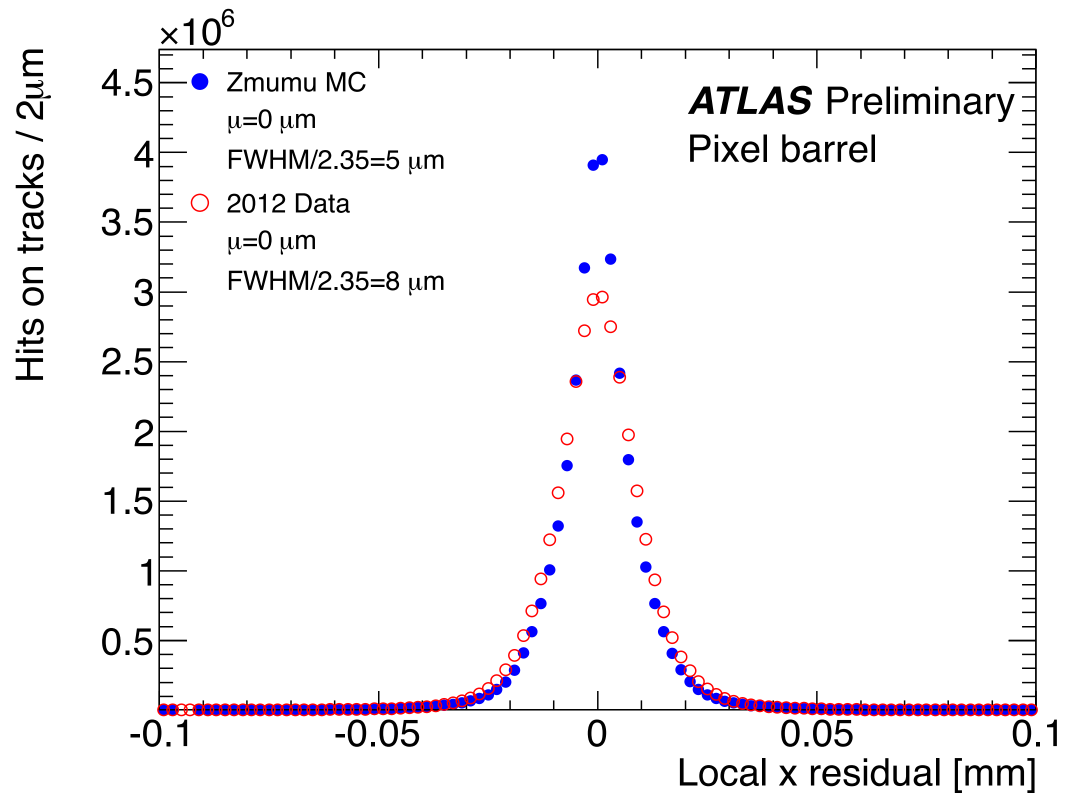
- Delta-ray rate measurement in SCT
  - using template fit to residual distribution (ATLAS-CONF-2013-005)

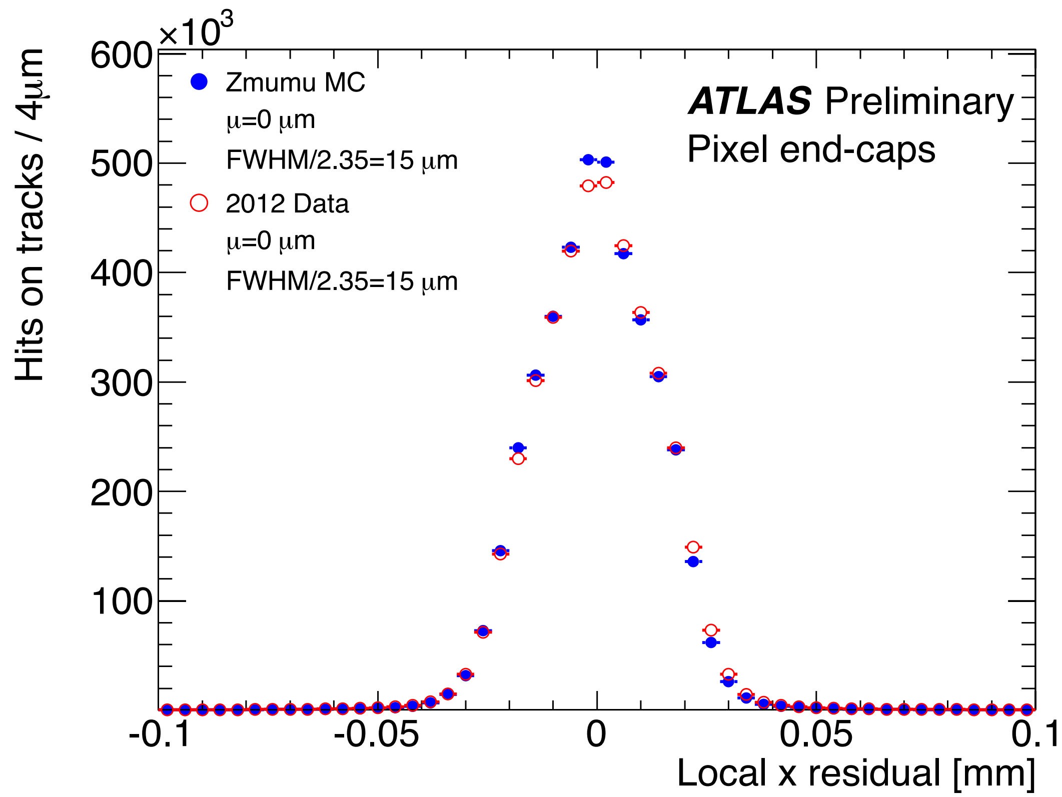




Residuals (1)

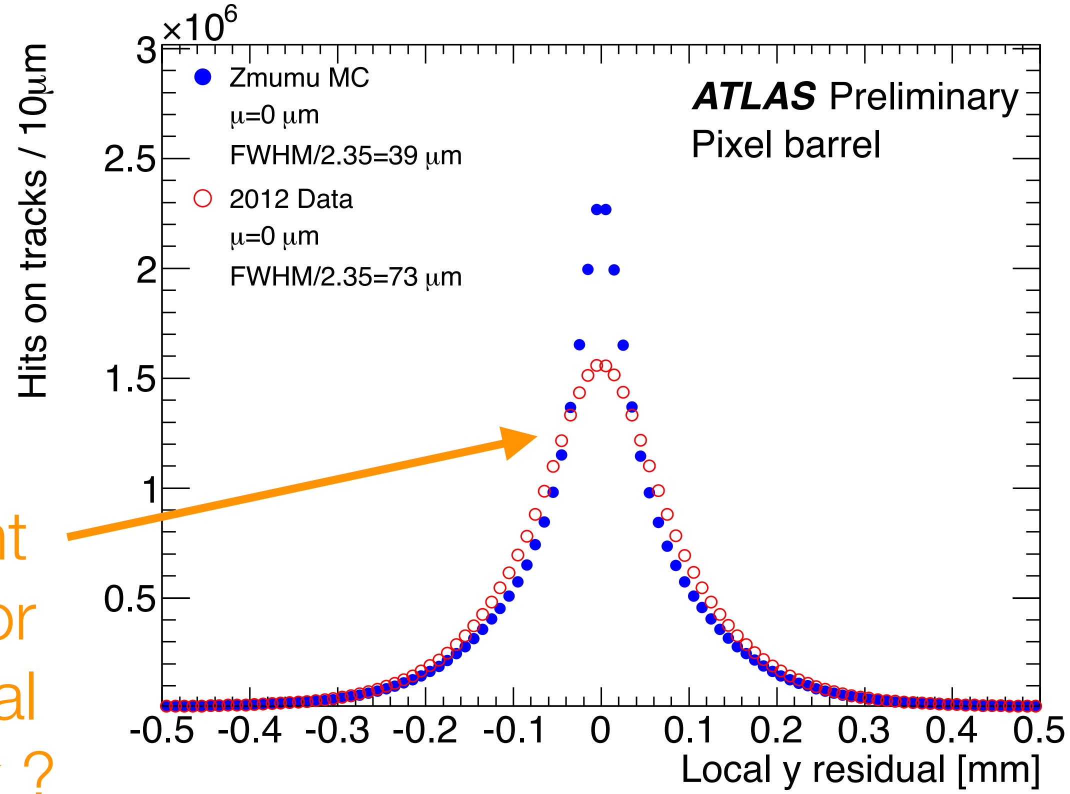
- Neural network based residual calculation (together with pixel cluster splitter)
  - **less than 10 µm** residuals for isolated muons from Z boson



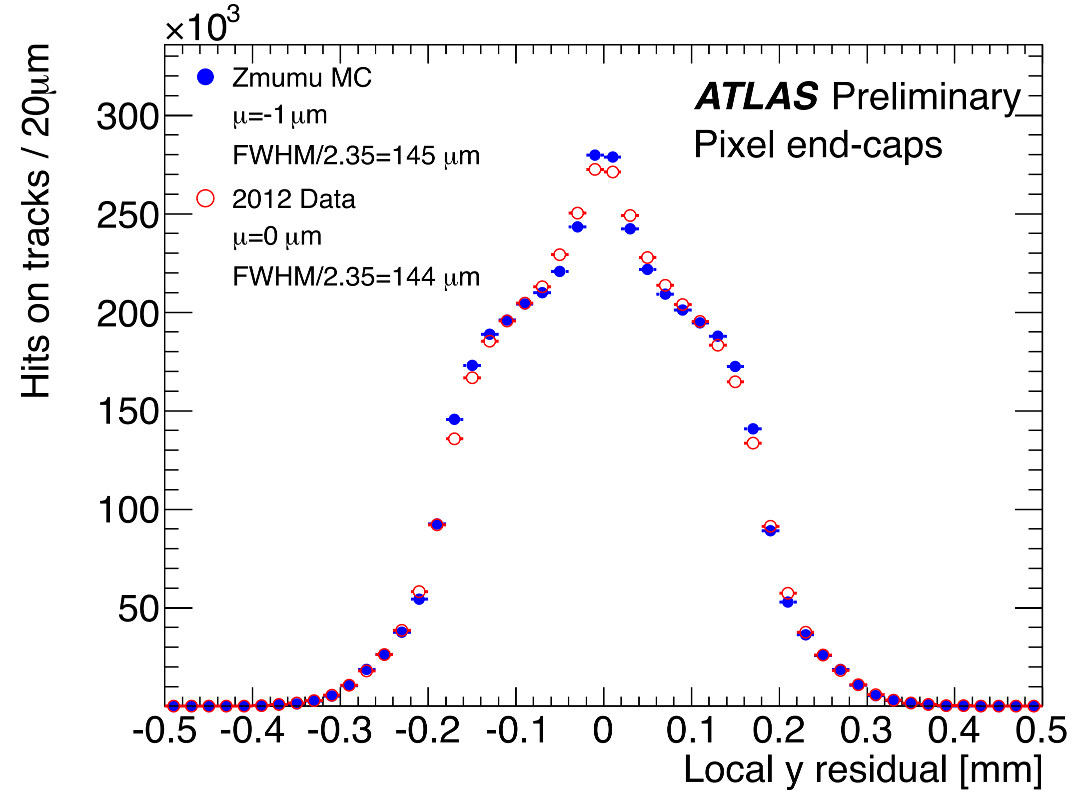


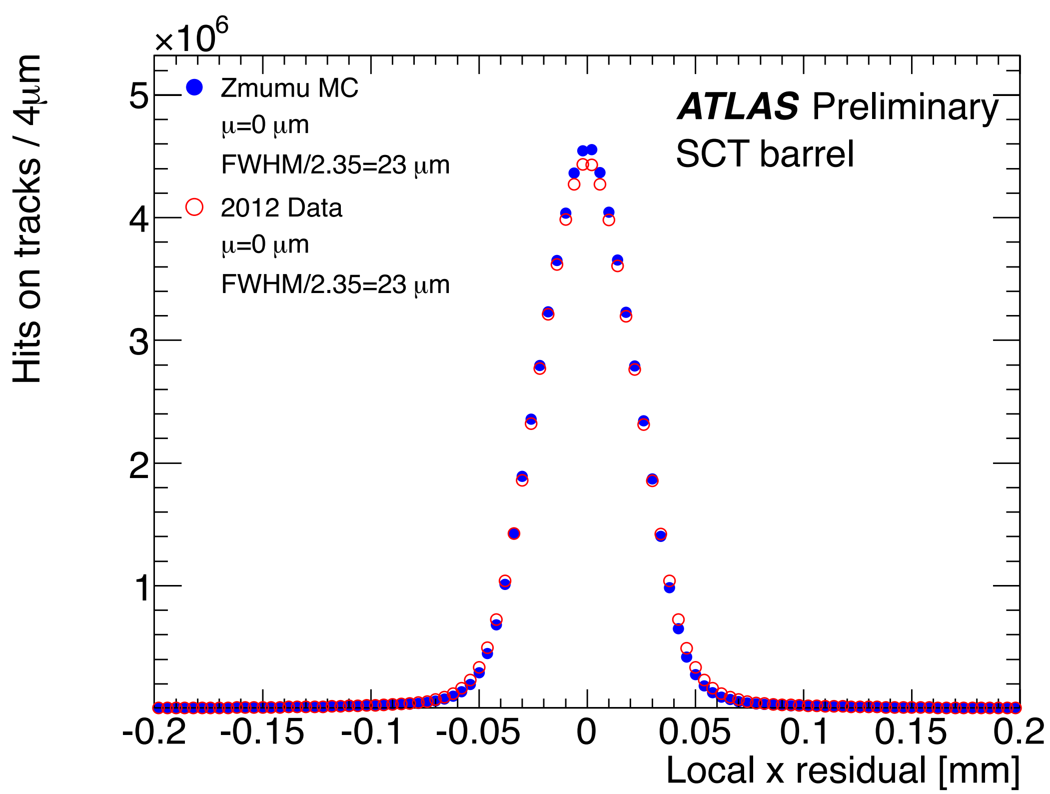
- small misalignment component still present (~2 µm)

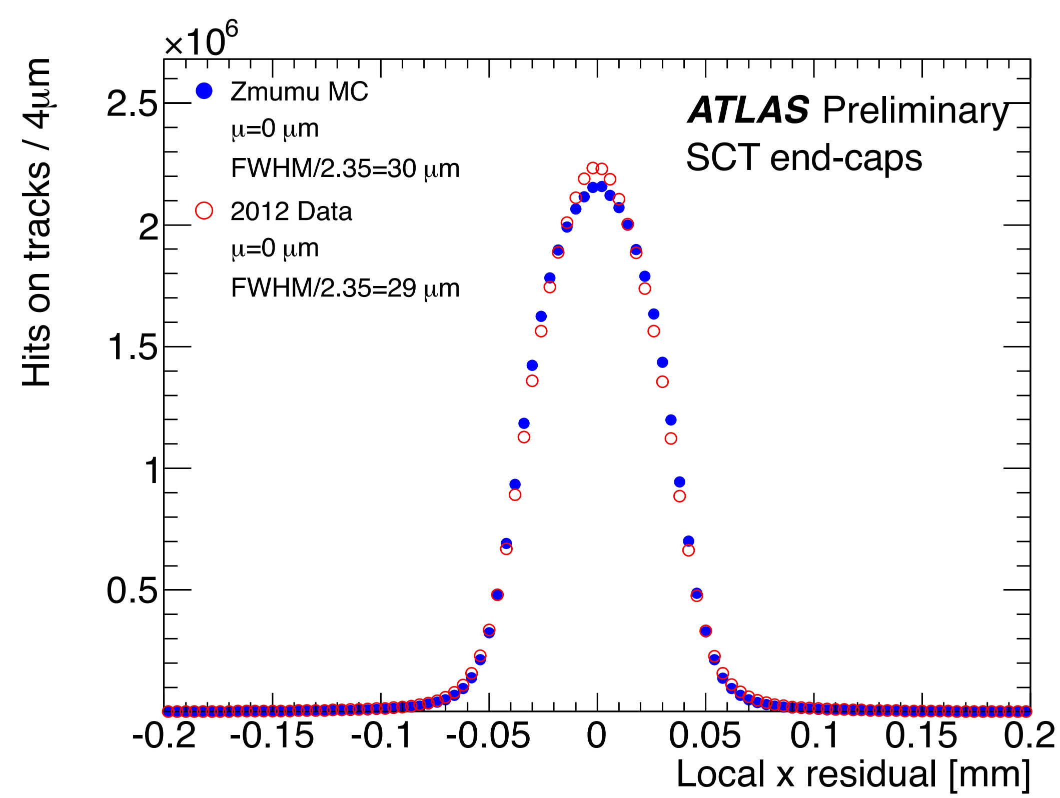
Residuals (2)



different behavior of neural network ?

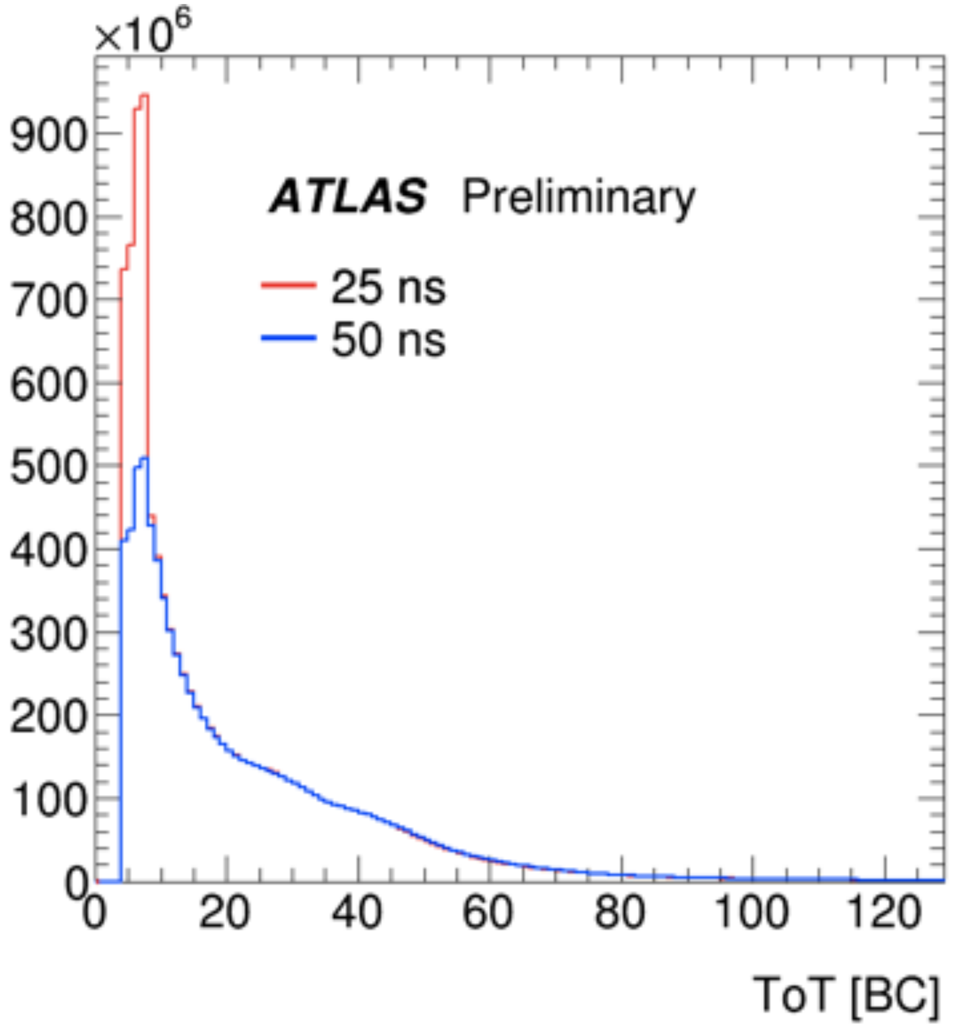


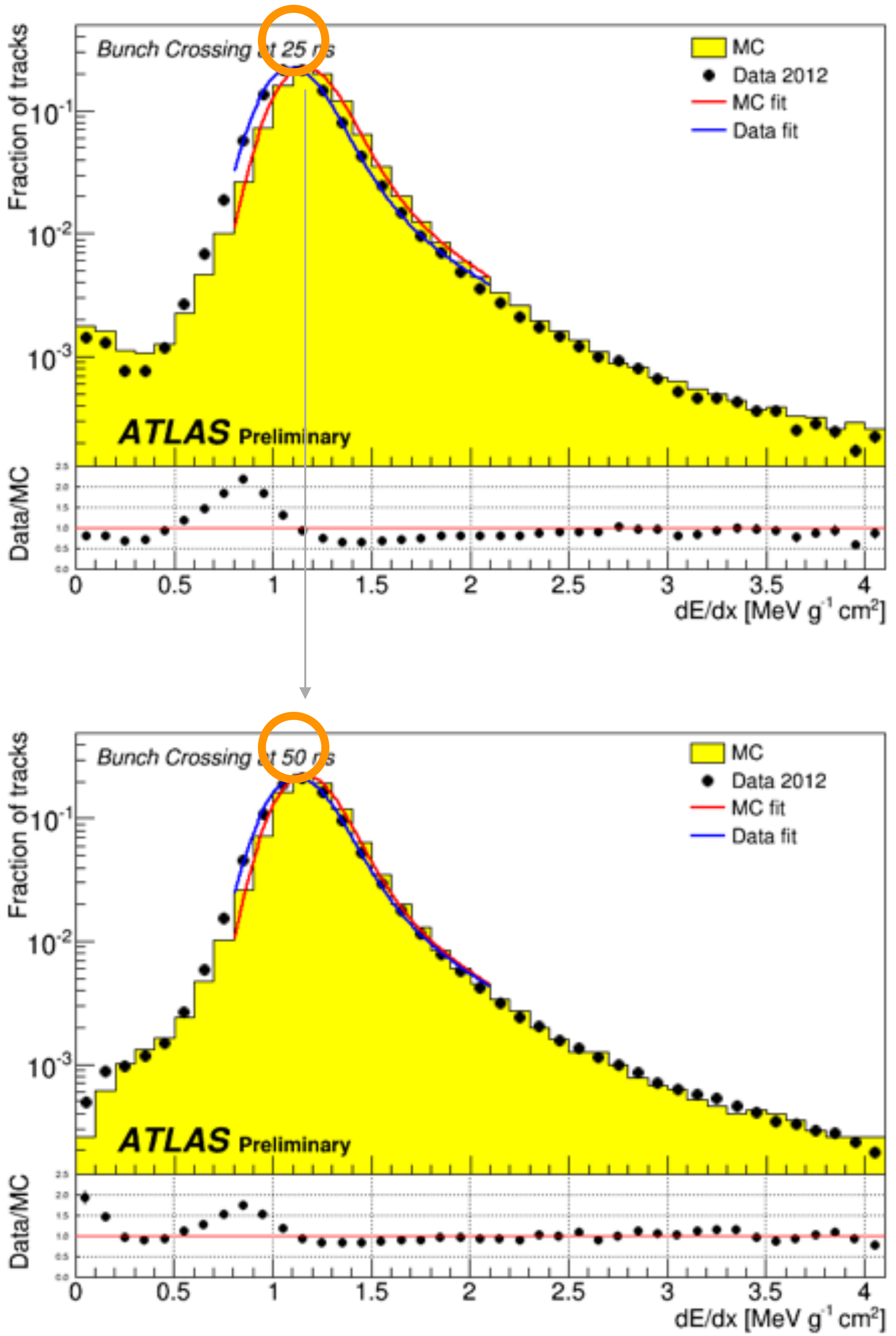


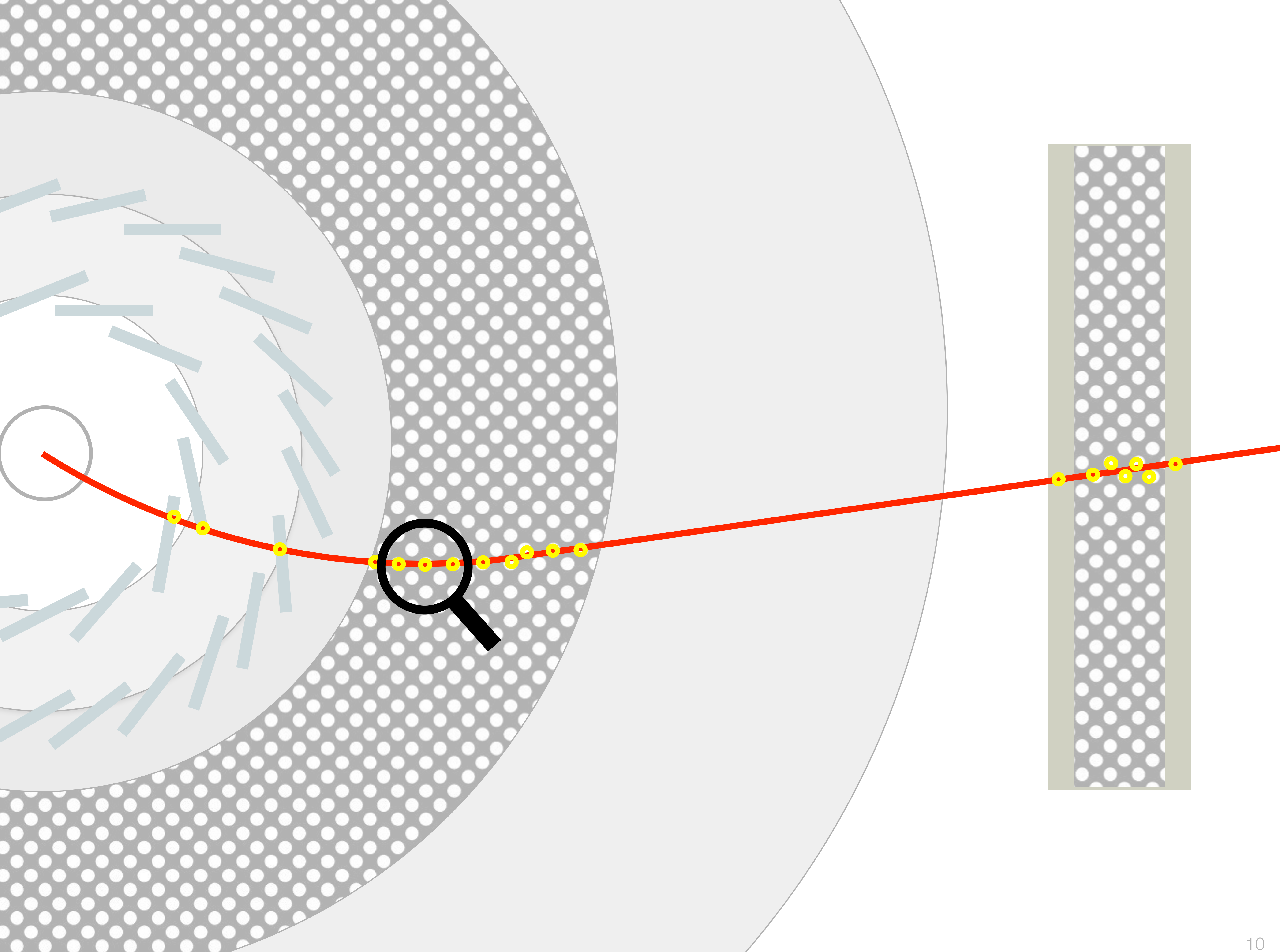


Run-2 preparations

- 25/50 ns needs recalibration of many detector components
  - e.g. adjustment of readout validity gate







TRT Detector

- **Simulation:**

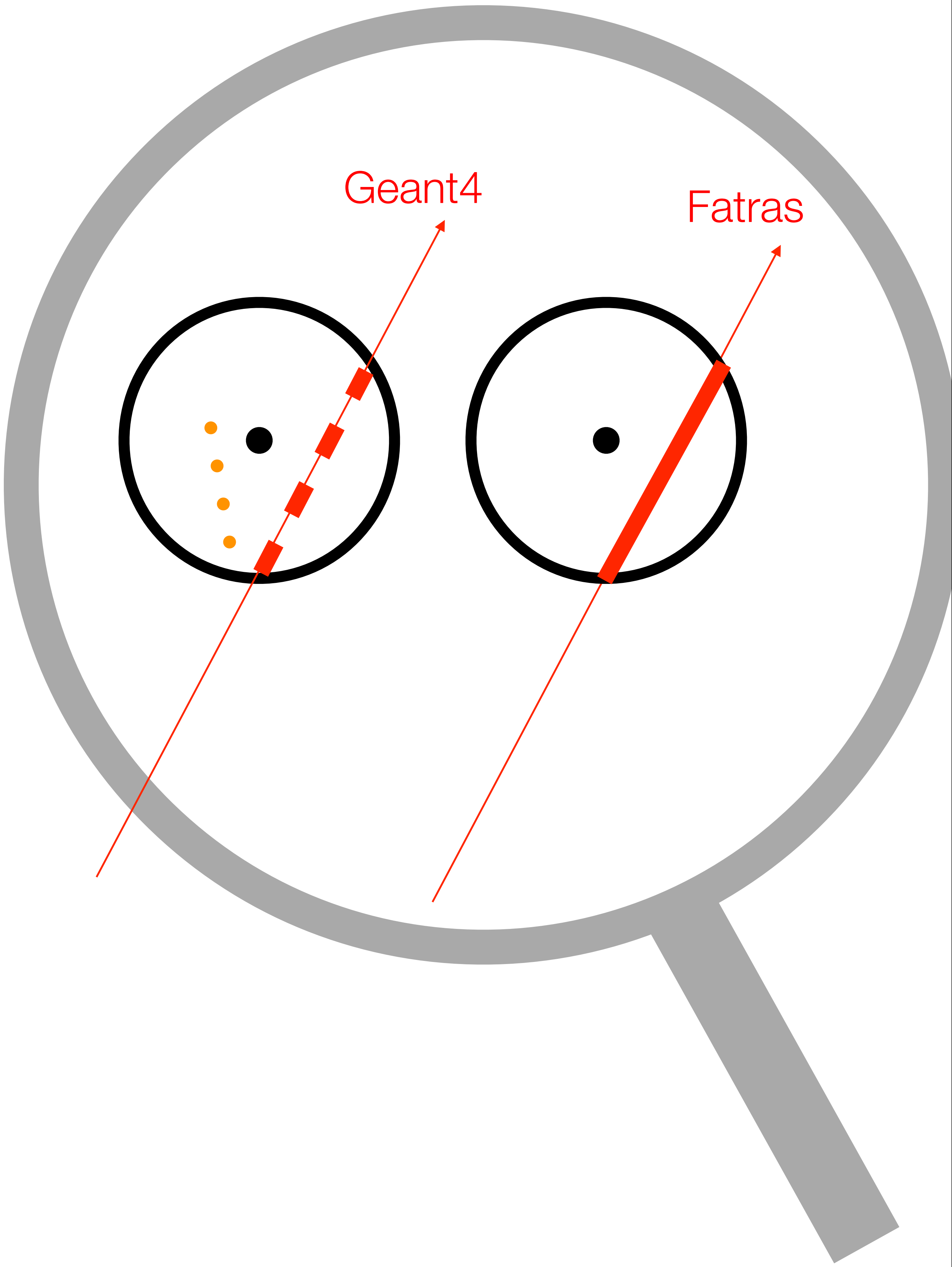
  - local entry/exit into straw
  - for full simulation:
    dedicated transition radiation model

    (emulated directly from measured high threshold probability in fast simulation)

- **Digitization:**

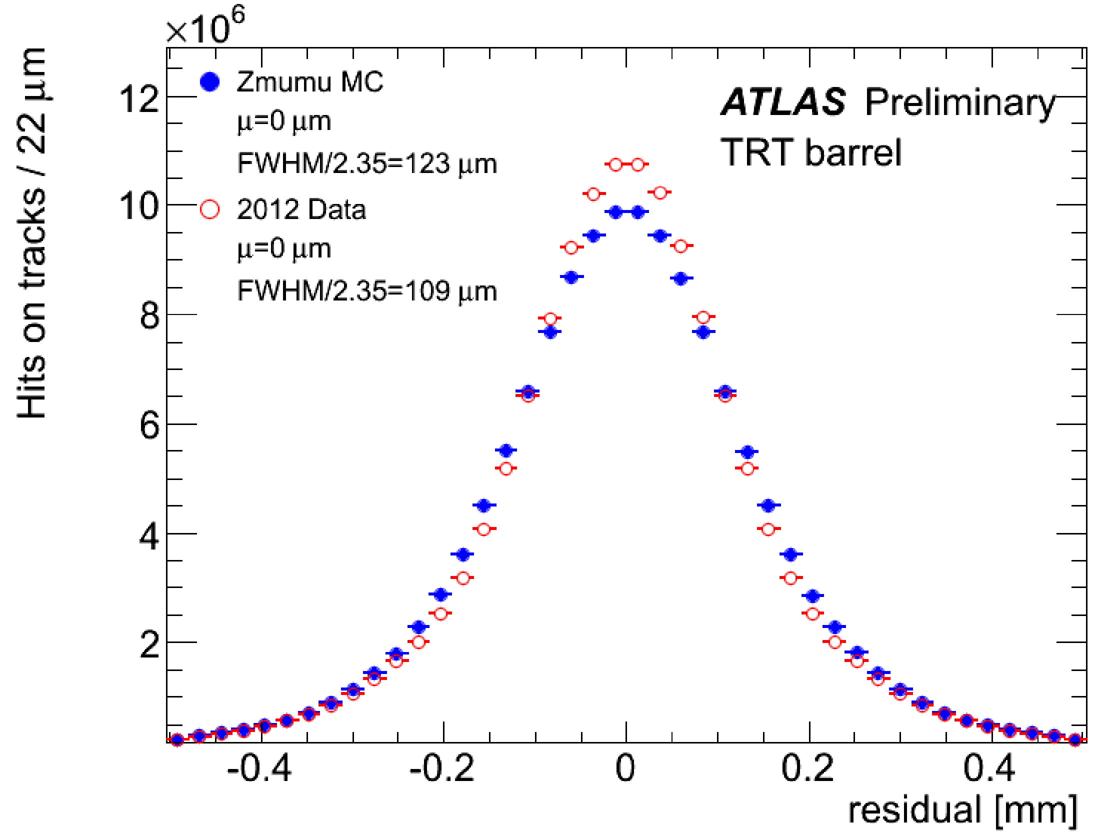
  - charge drift to wire
  - time over threshold emulation
  - **for fast MC chain:**
    a fast digitization prototype

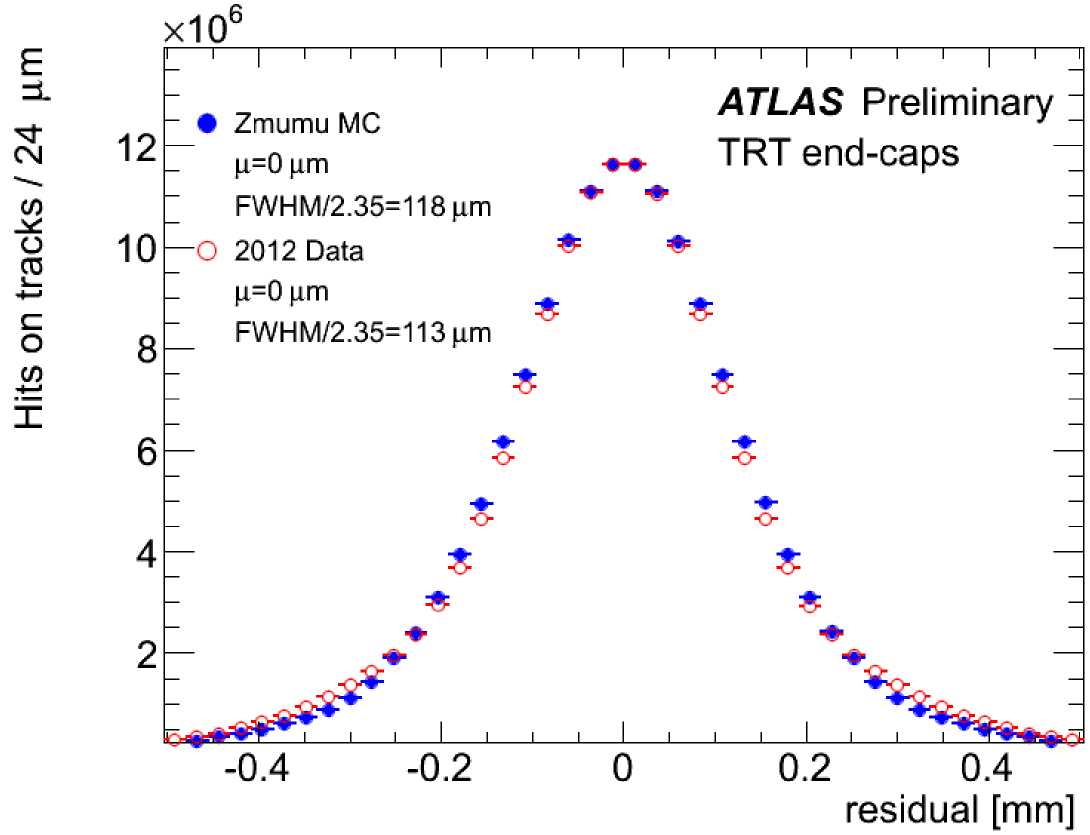
differences need to evaluated



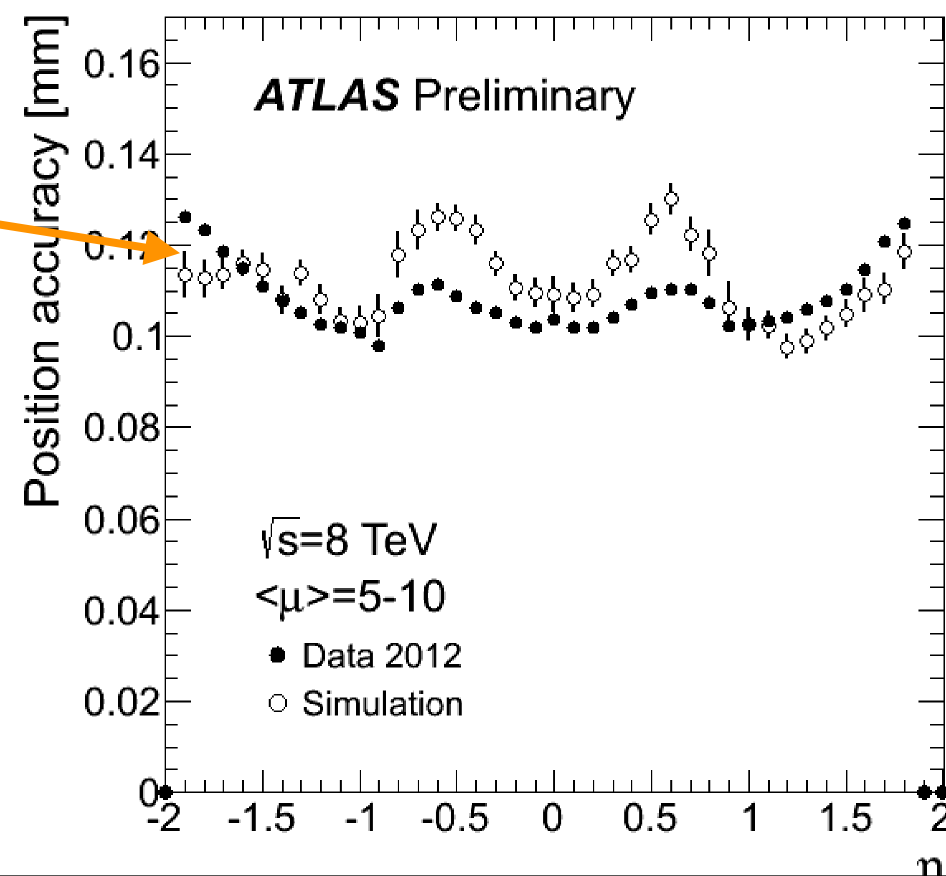
Resdiuals

- TRT (barrel) residuals in data slightly narrower than in simulation



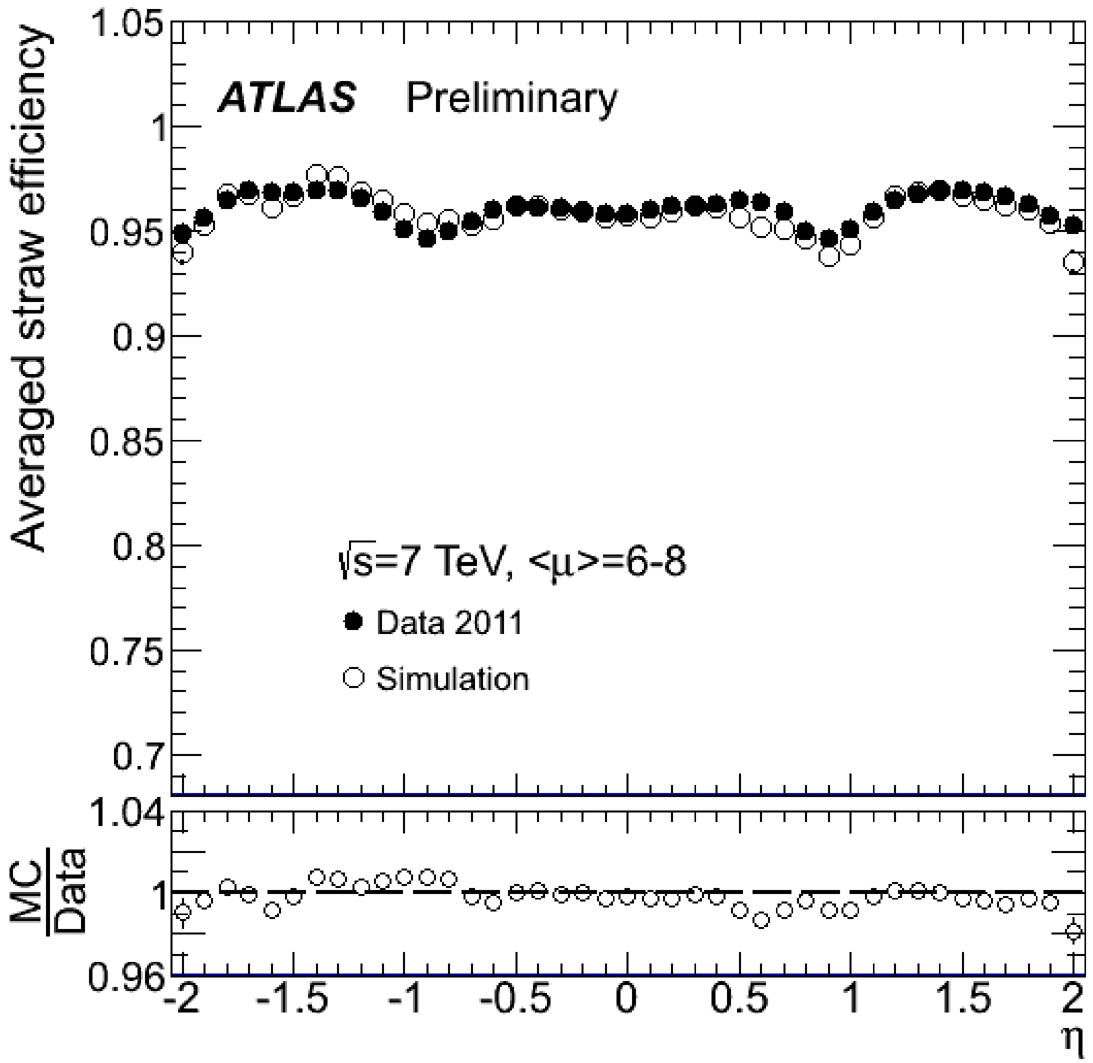


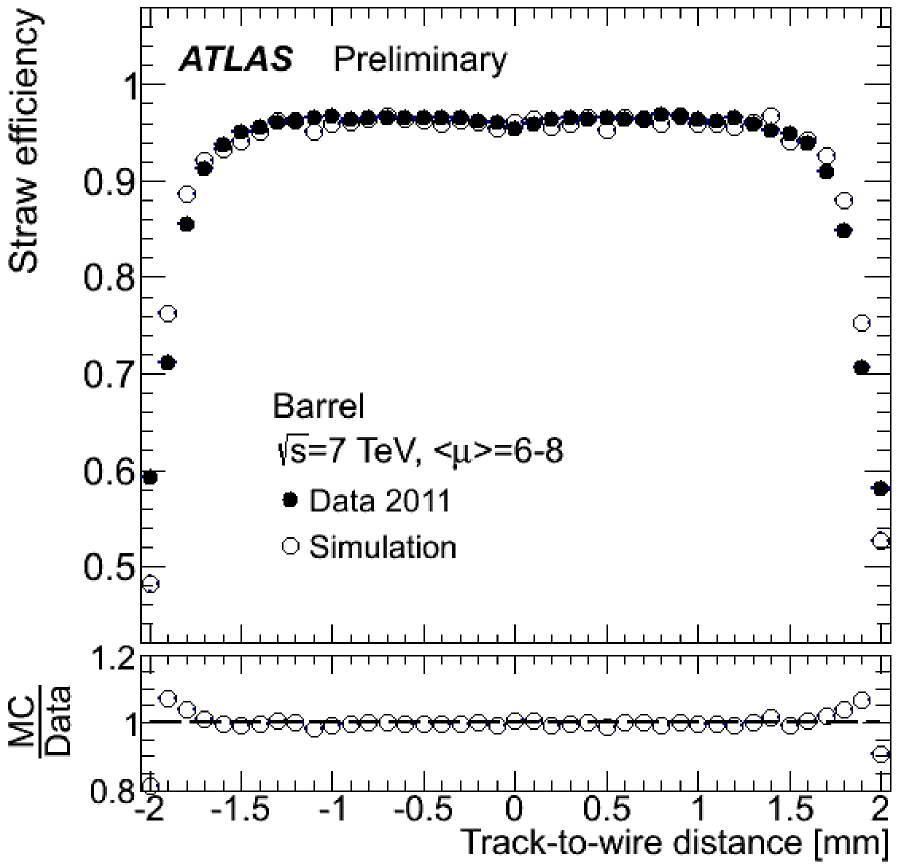
end-cap slightly better described, might needs some more refined digitisation model. Data has individual straw calibration with threshold setting

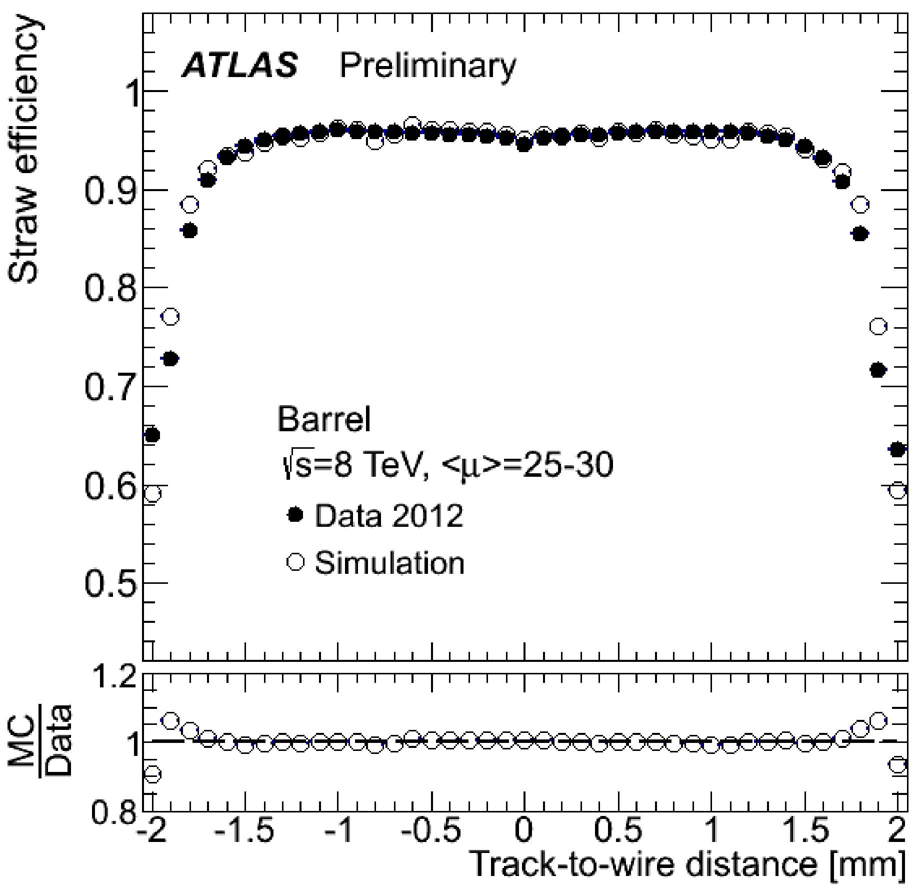


Drift measurement properties

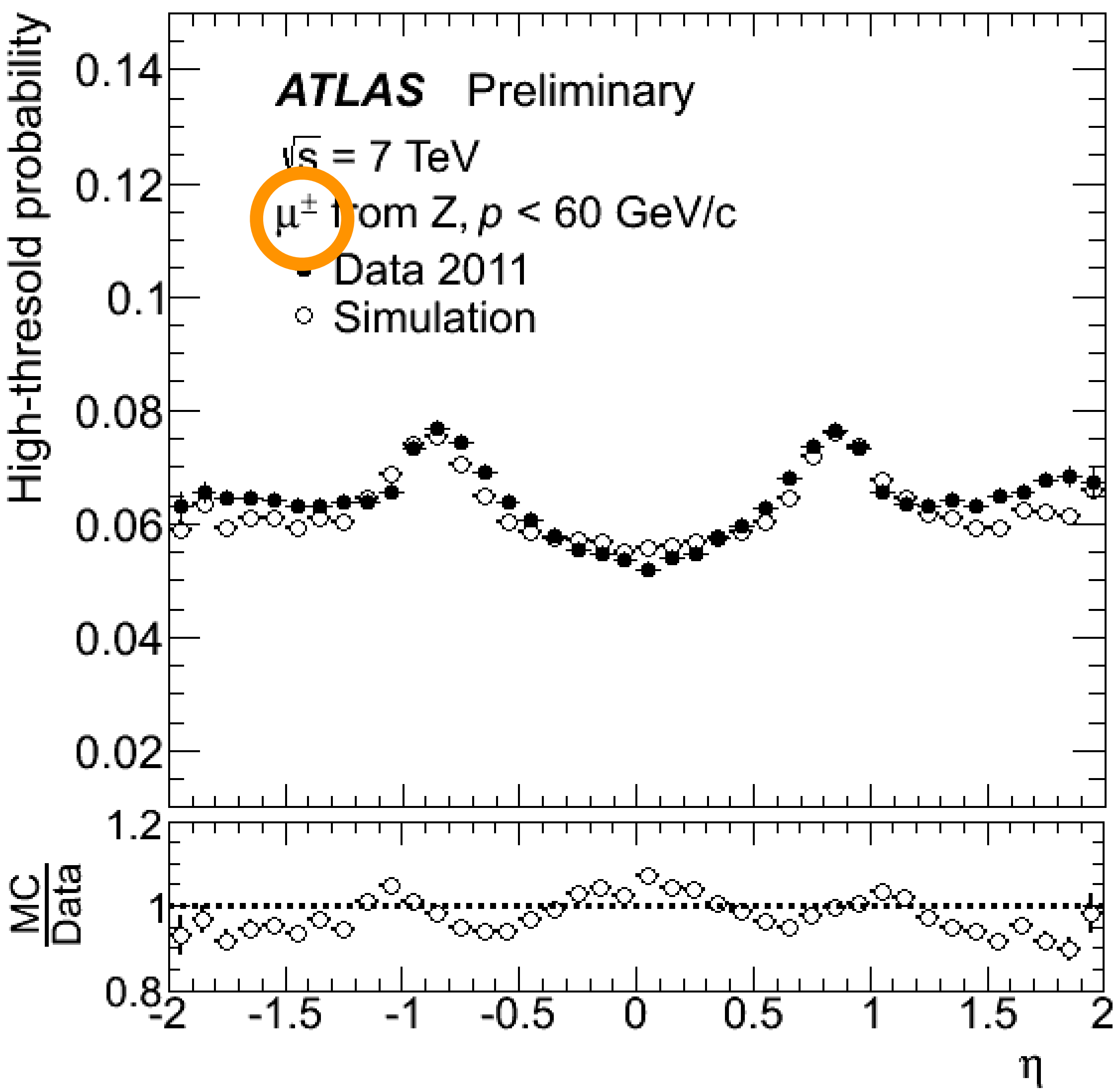
- Straw efficiency in the TRT well described
  - μ from Z used
  - stable modelling vs. pile-up
  - well modelled in all detector regions

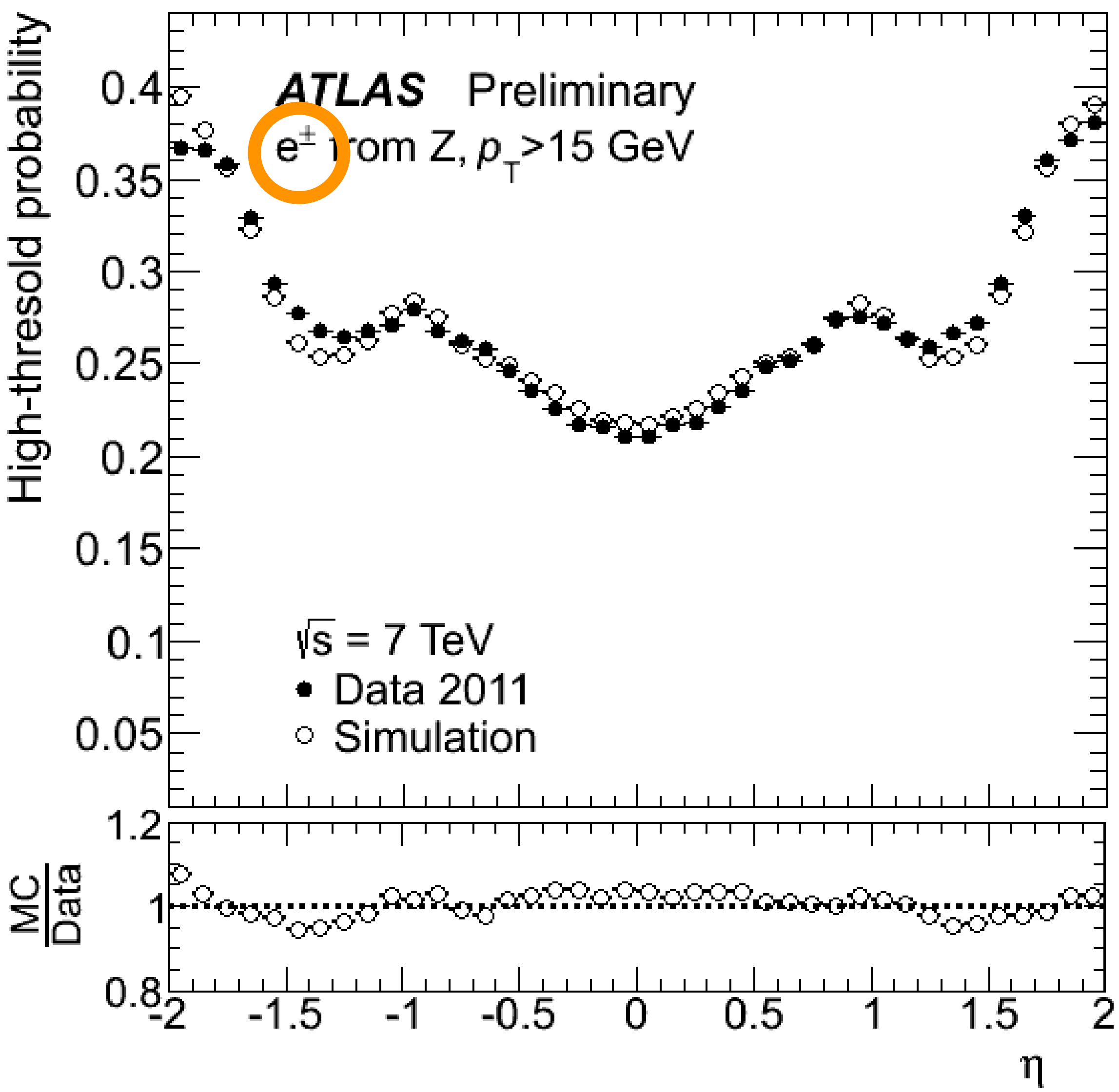


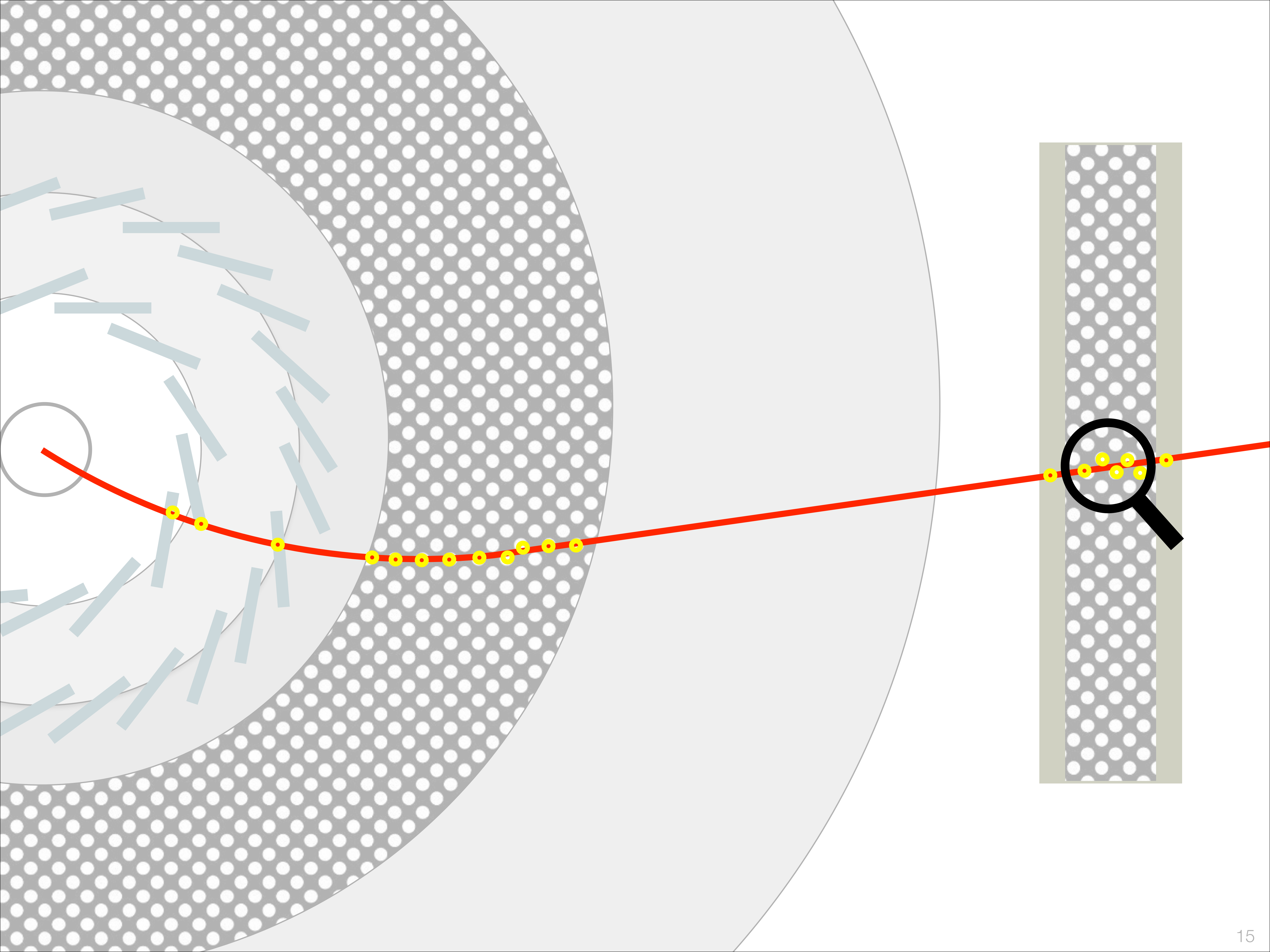




- High threshold hit probability used as an input for particle identification
  - stems mainly from transition radiation (TR)
  - μ are used for tuning of the HT probability for particles which almost no TR
  - electron performance tuned to observed HT probability rates in data (initial yield in MC was higher)

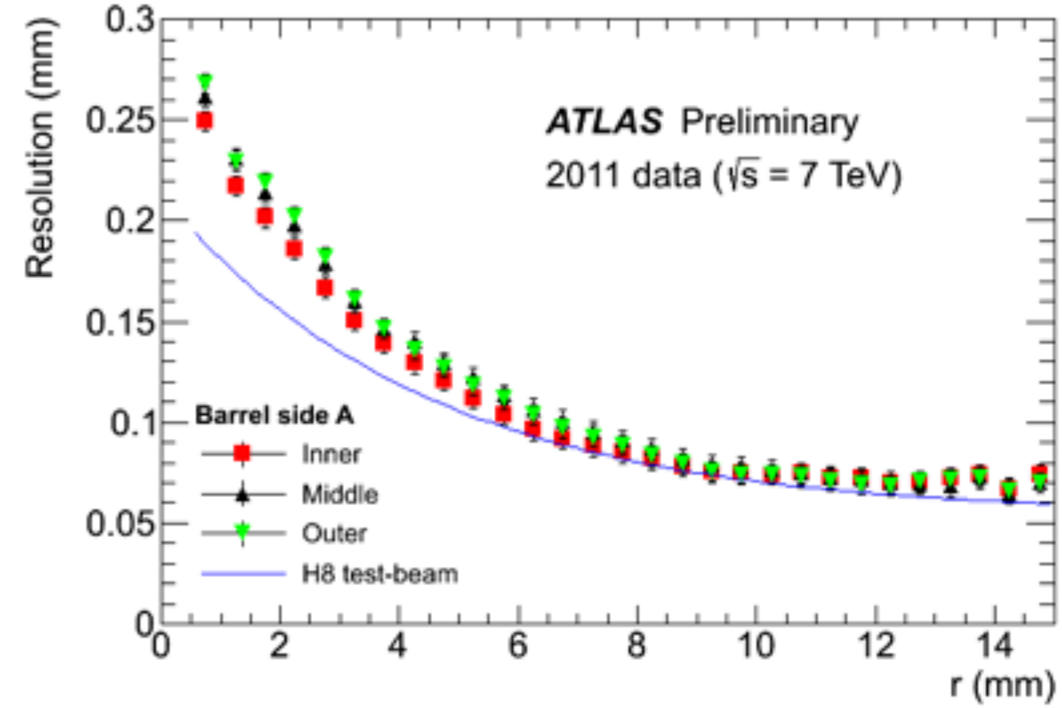


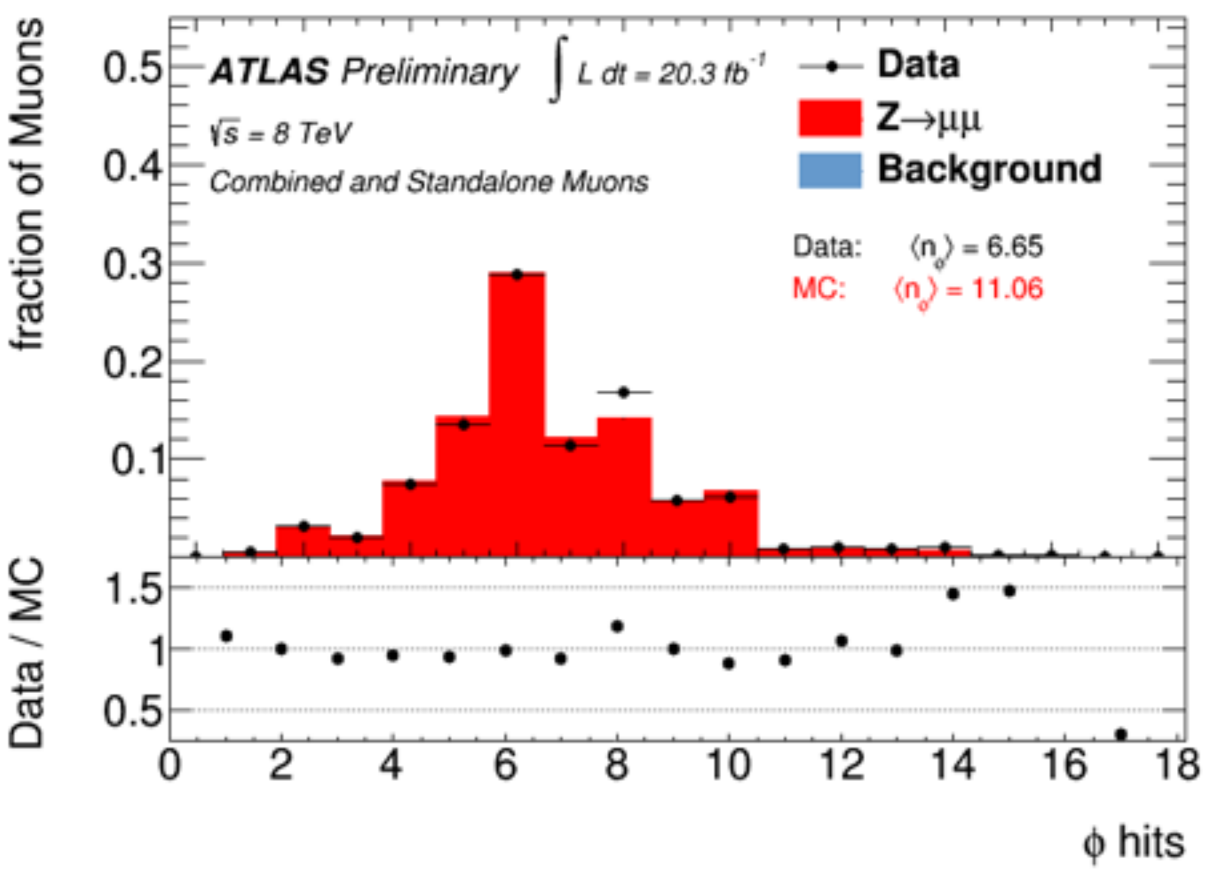


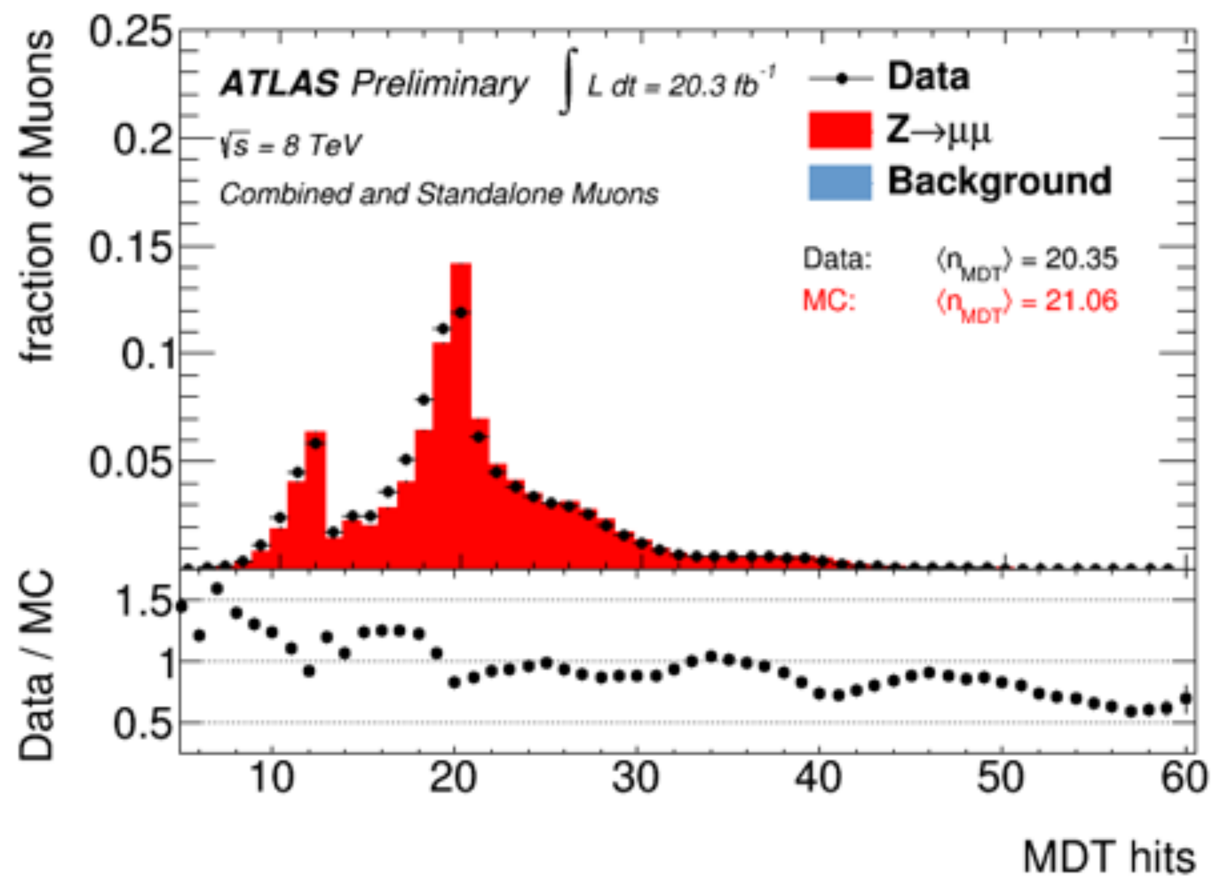


Muon detectors

- Precision tracking detector at large radii
  - alignment is a very important issue (inter-detector alignment with ID)
  - a lot of upstream material
  - very inhomogeneous magnetic field

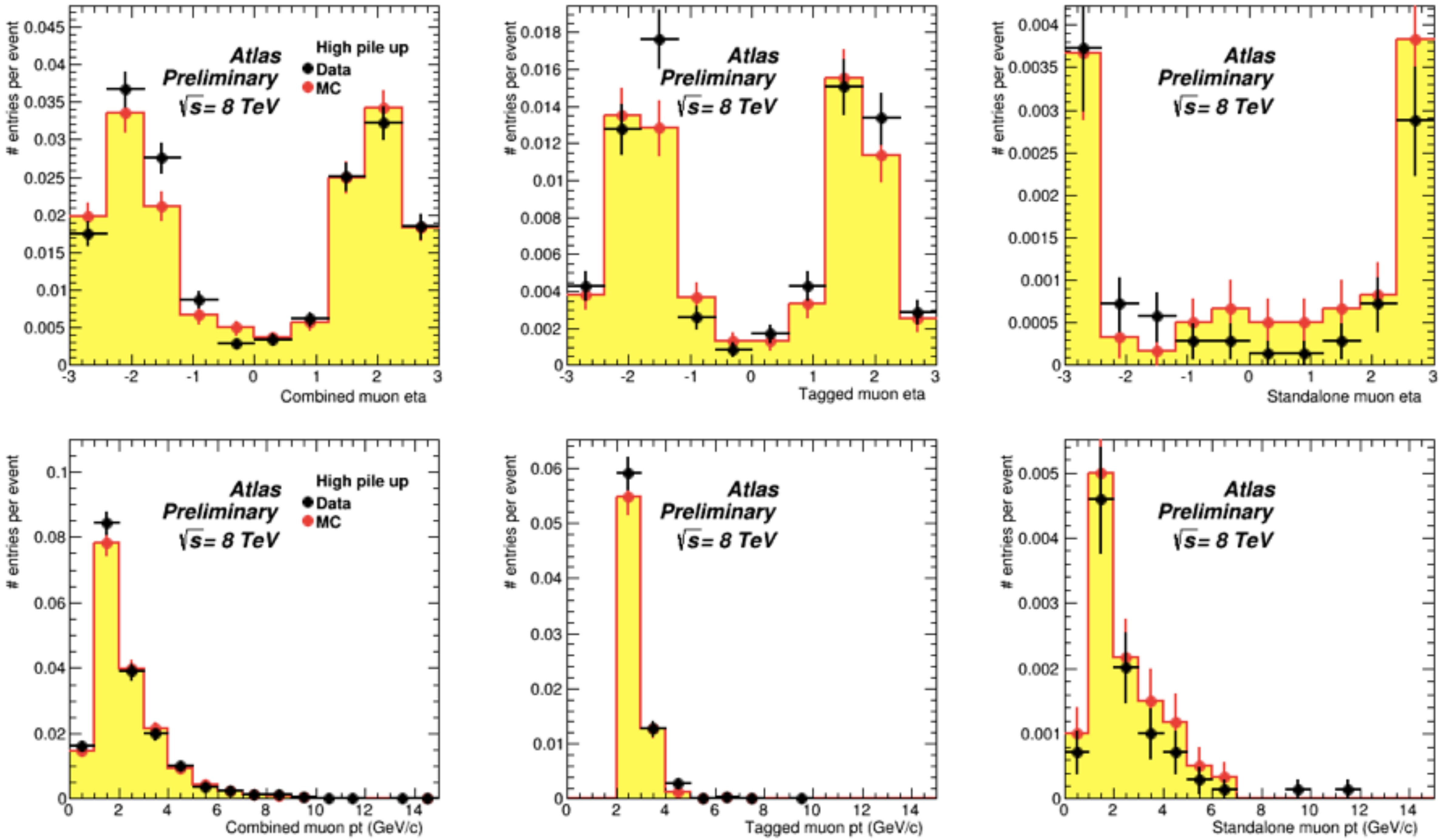


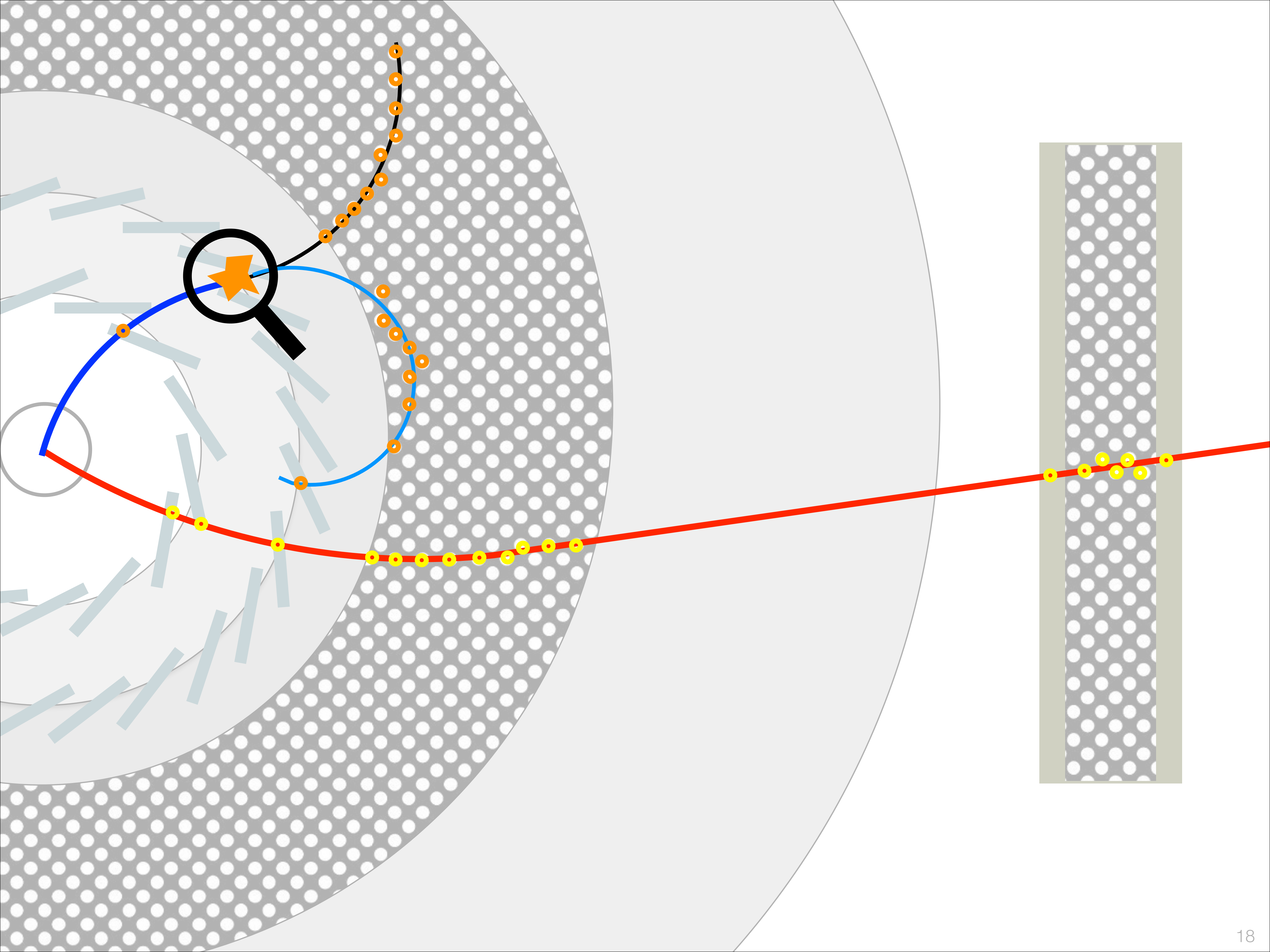




‣ Muon background modelling in high pile-up run

- data is from 2012 high pile up run 206725 with <μ> of 52 and dedicated MC
- study to show the background contribution in the MS in high luminosity scenarios
- MC has no cavern background information (-> talk of Jochen)

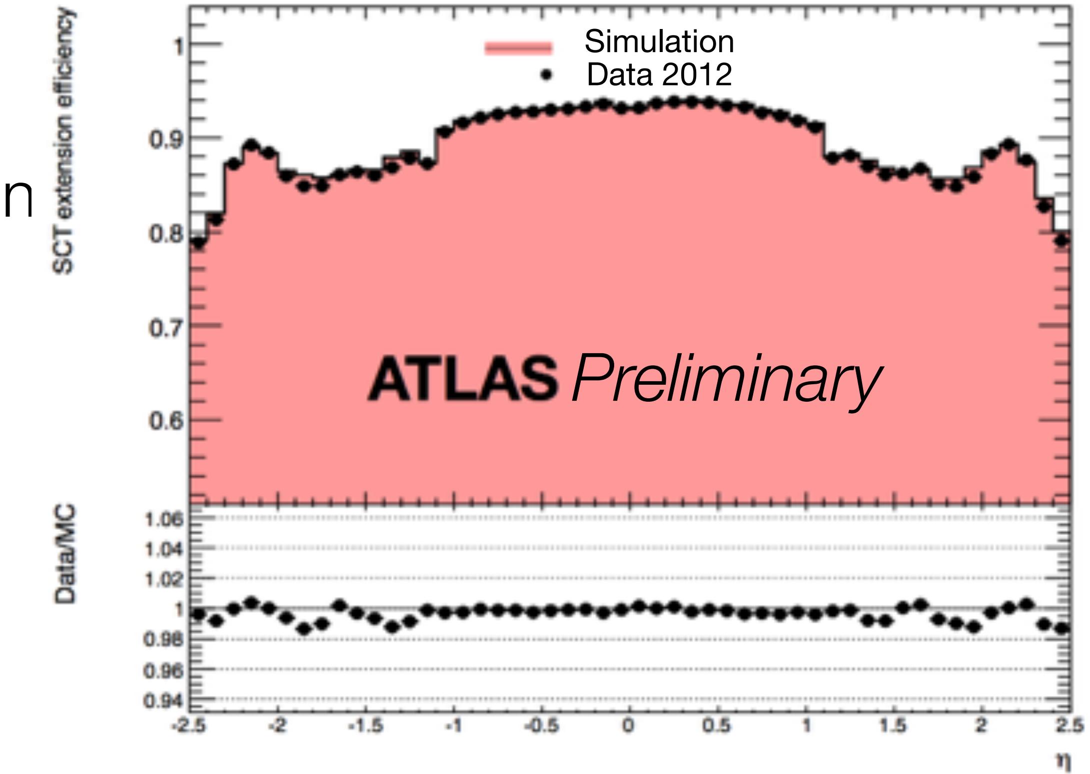




Interaction with matter

look how we started in 2009

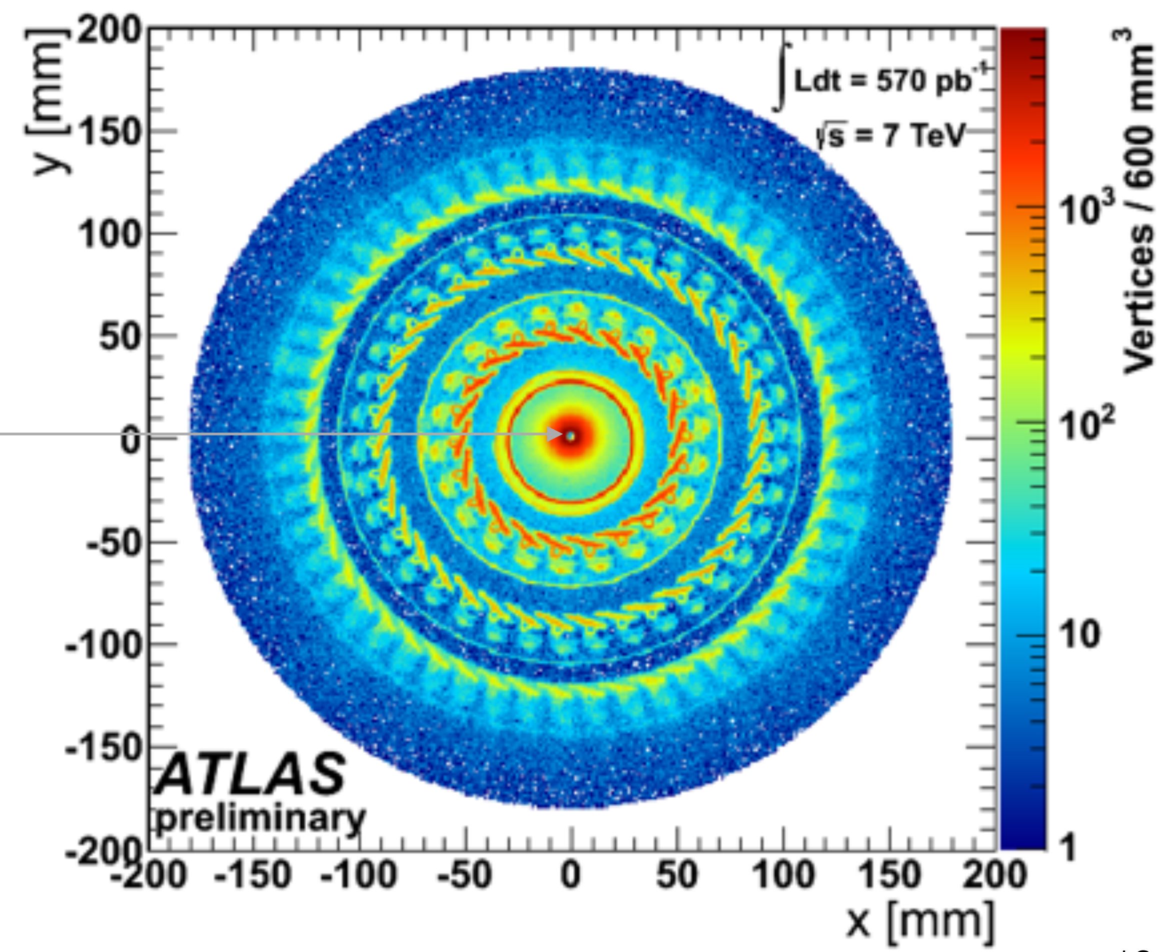
- Material description of the detector
  - ATLAS refined the simulation detector description (in particular for ID) throughout Run-1
  - photon-conversions, residuals measurements, K_S mass, hadronic interactions
  - material between last ID measurement and calorimeter measured by longitudinal shower shape comparisons (-> Marco)
  - none of the techniques could be more accurate than **5%**, relates to about **2%** of generic track reconstruction uncertainty



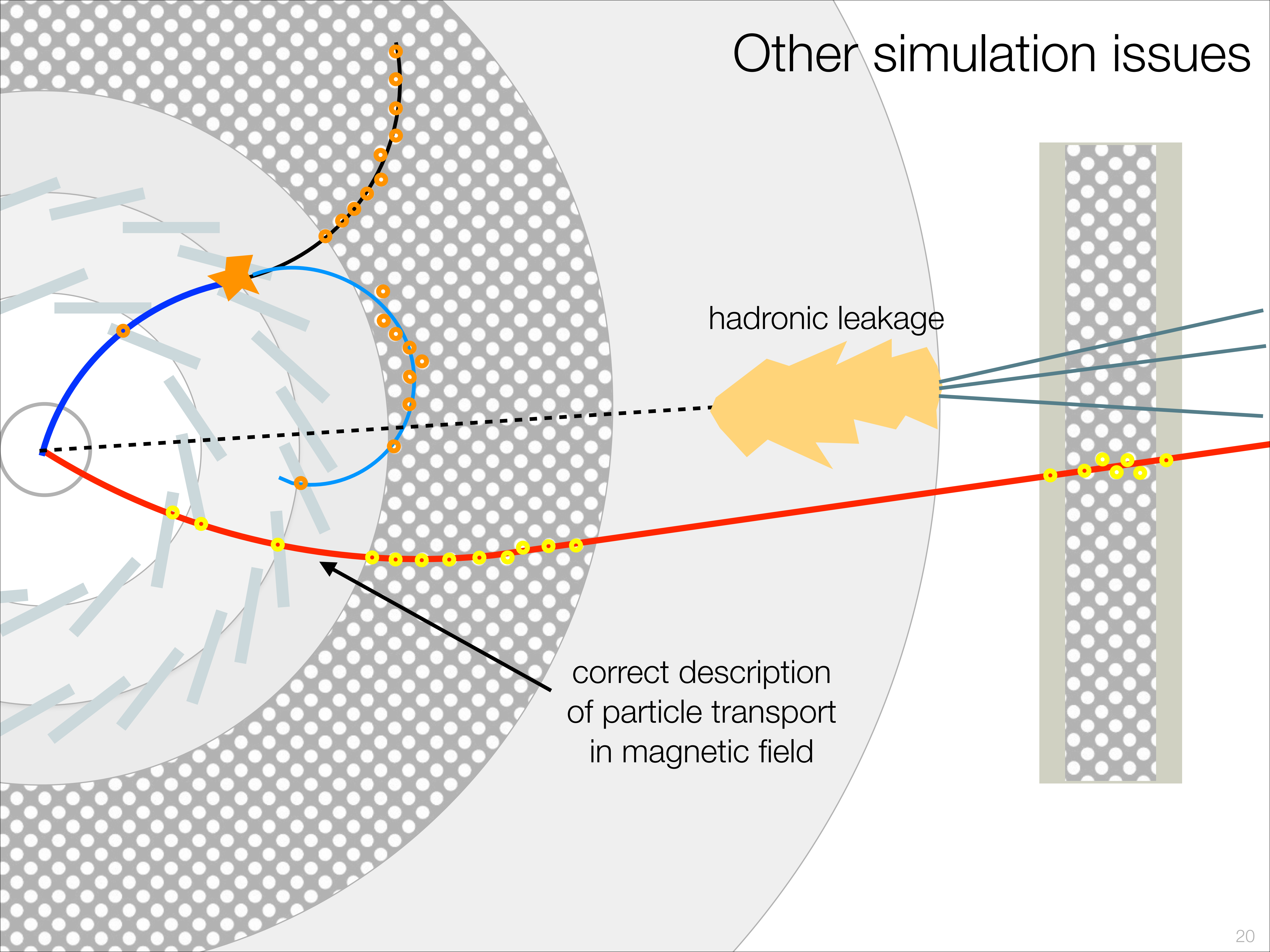
- shifted beam pipe, corrected in simulation

- revealed cooling fluid description problem

- opening up the detector helped !

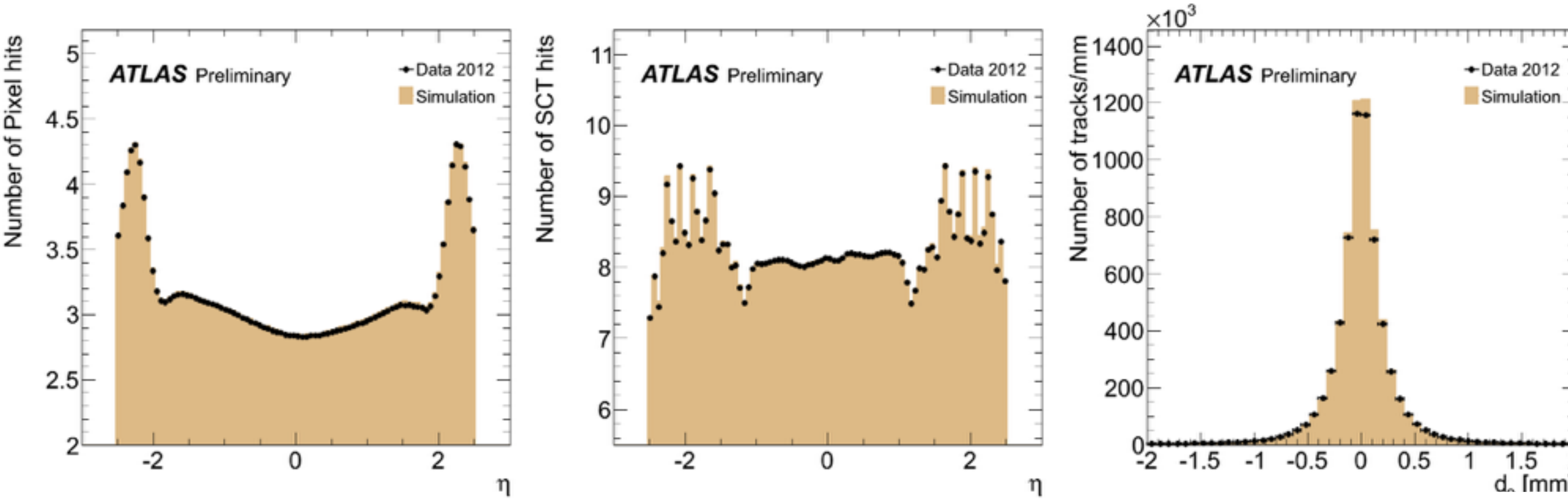


Other simulation issues



Putting it all together: tracks

- Building tracks in the Inner Detector

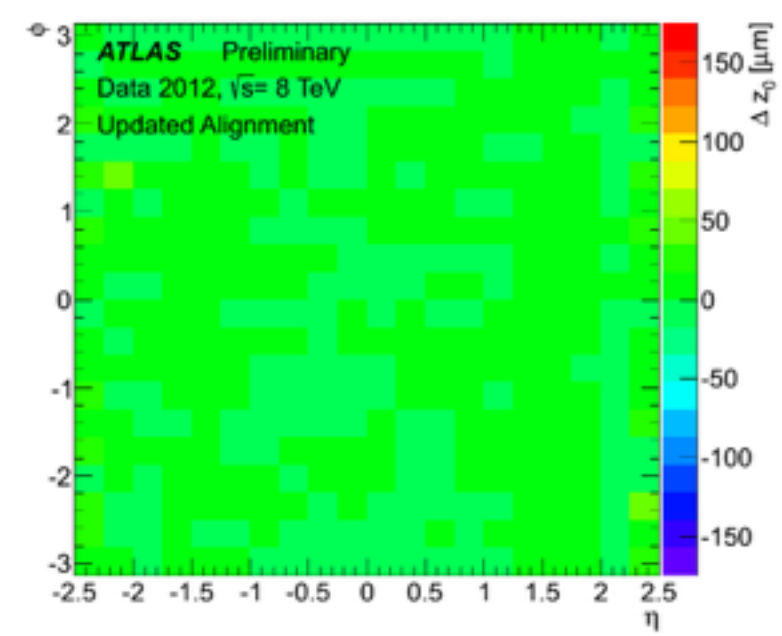


- Excellent description of the hit statistics

  - needs correct modelling of the inactive channels, beam-spot

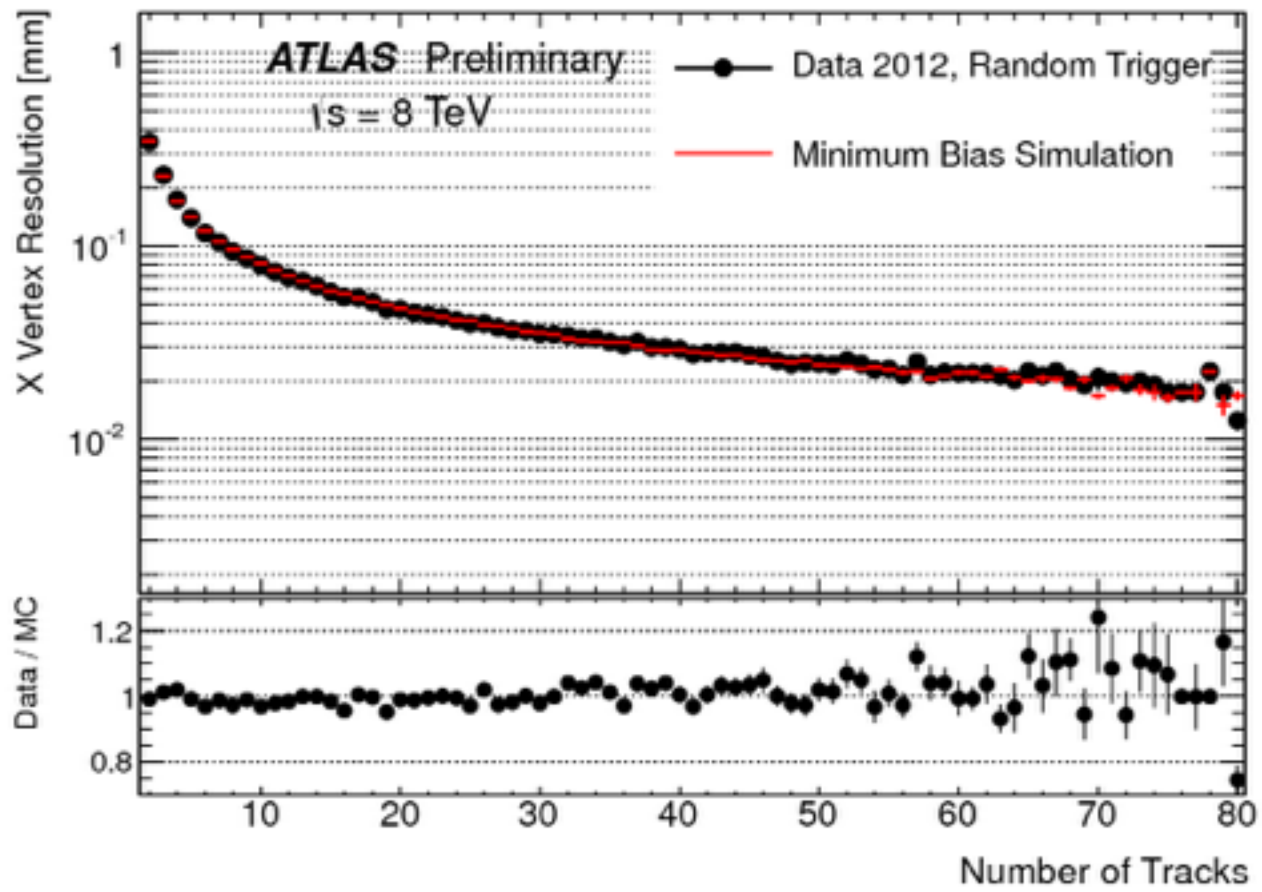
- Good description of resolution

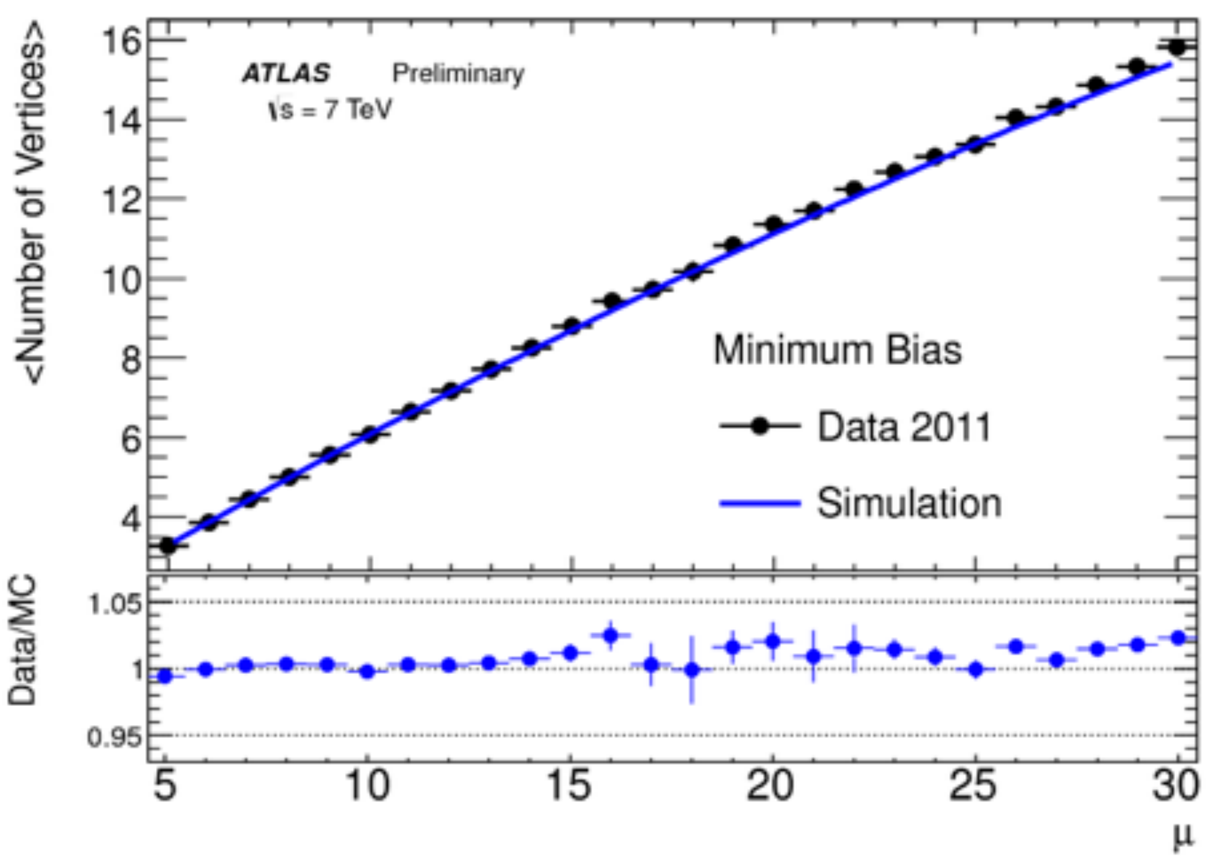
  - little biases left from random module mis-alignment



Putting it all together: vertices

- Vertex reconstruction increasingly important with pile-up during Run-1
  - excellent resolution description by simulation



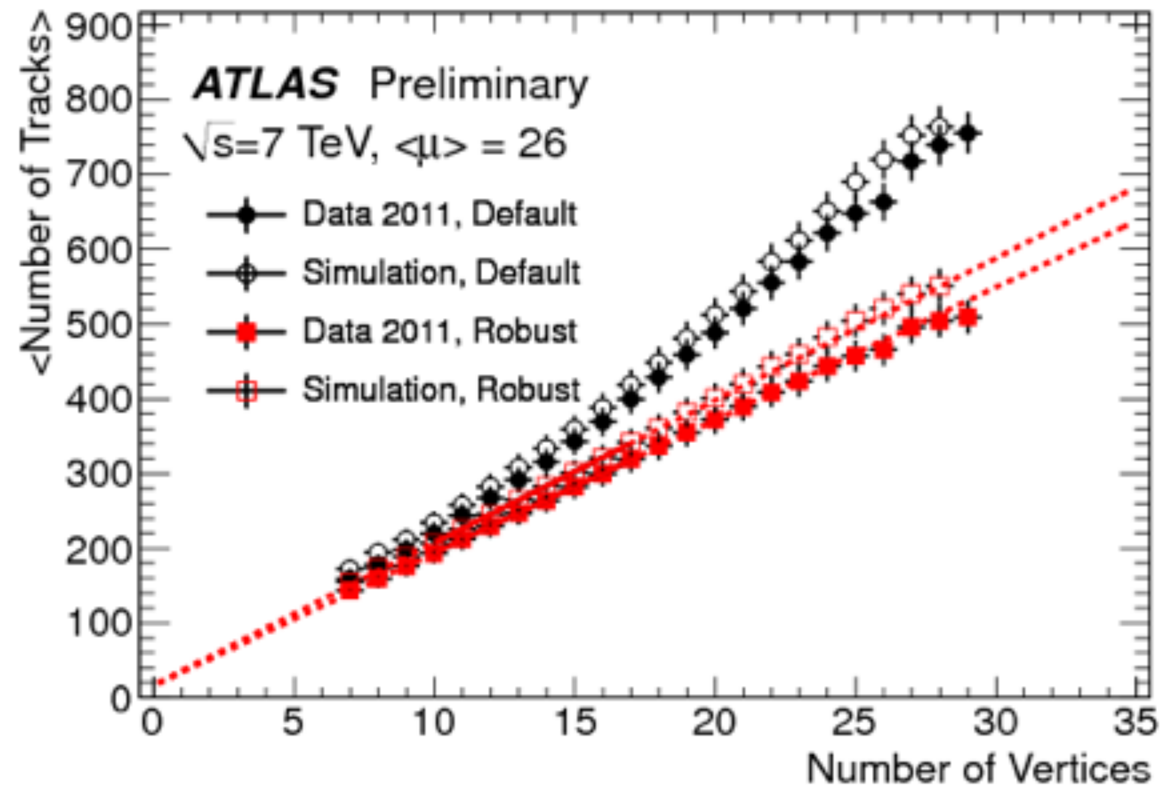


- Pile-up description well understood
  - effects from shadowing/merging/splitting

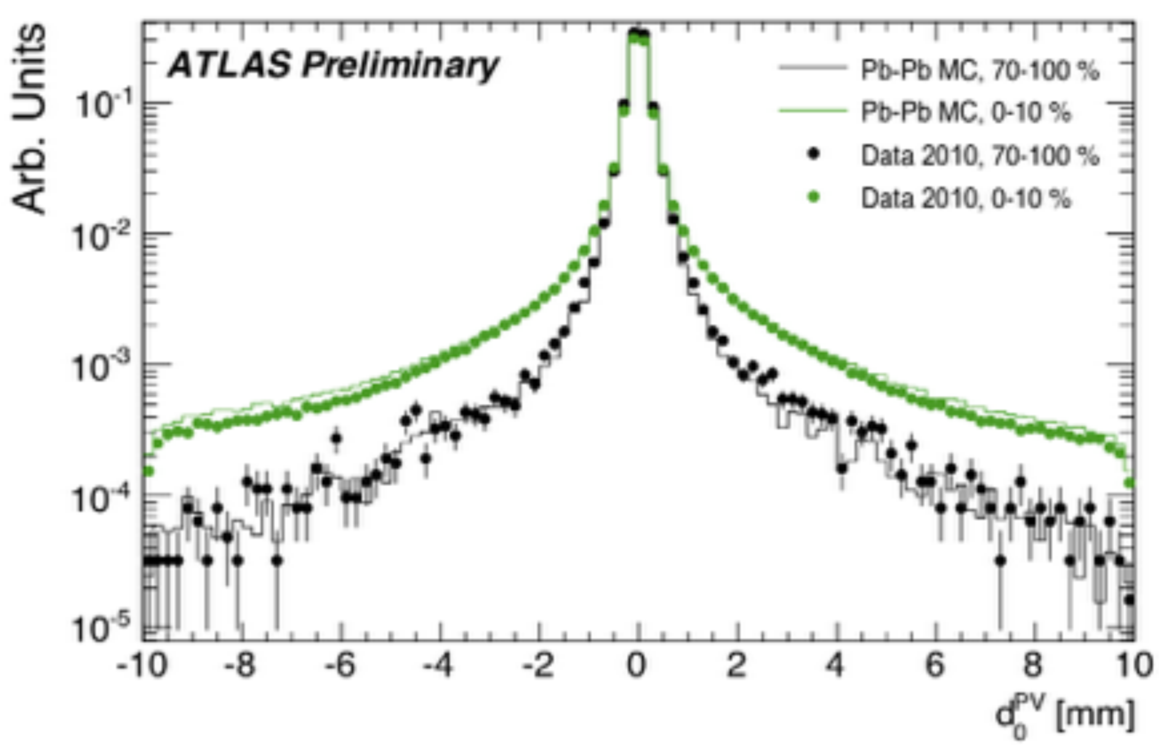
- **Important for simulation:**
  - correct modelling of beam spot and μ

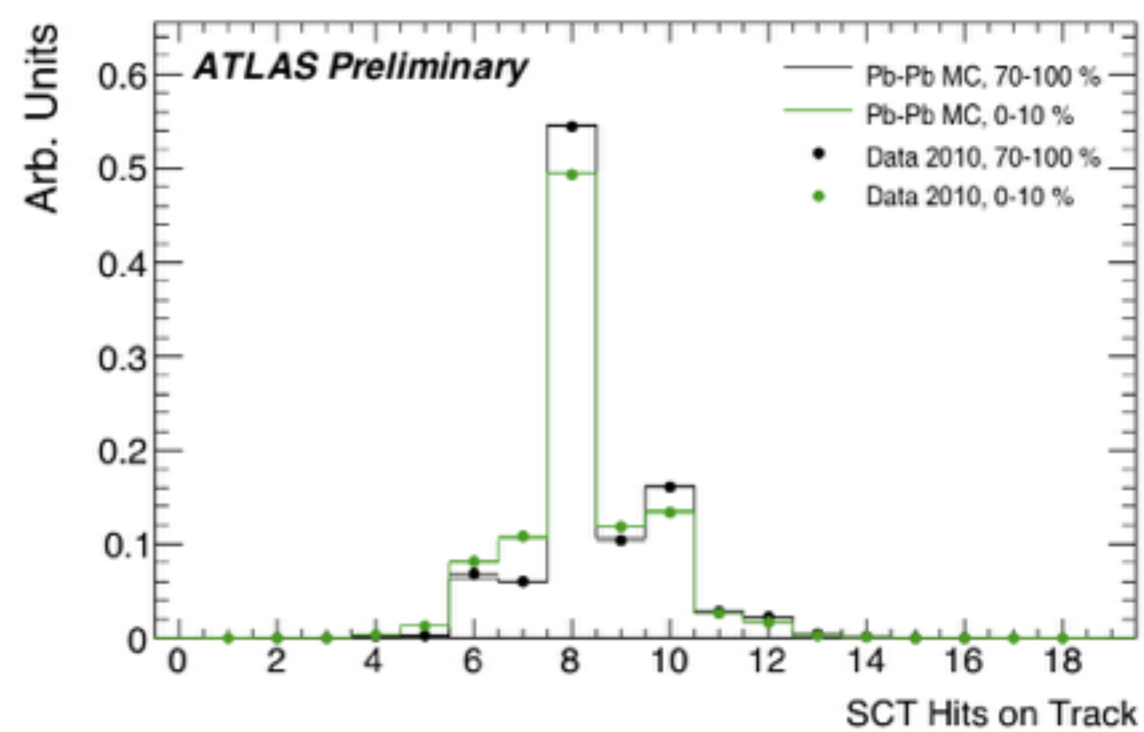
High pile-up preparation

- Simulation is the only(*) tool to prepare for upcoming high pile-up
  - was used extensively for the 2012 data taking preparation



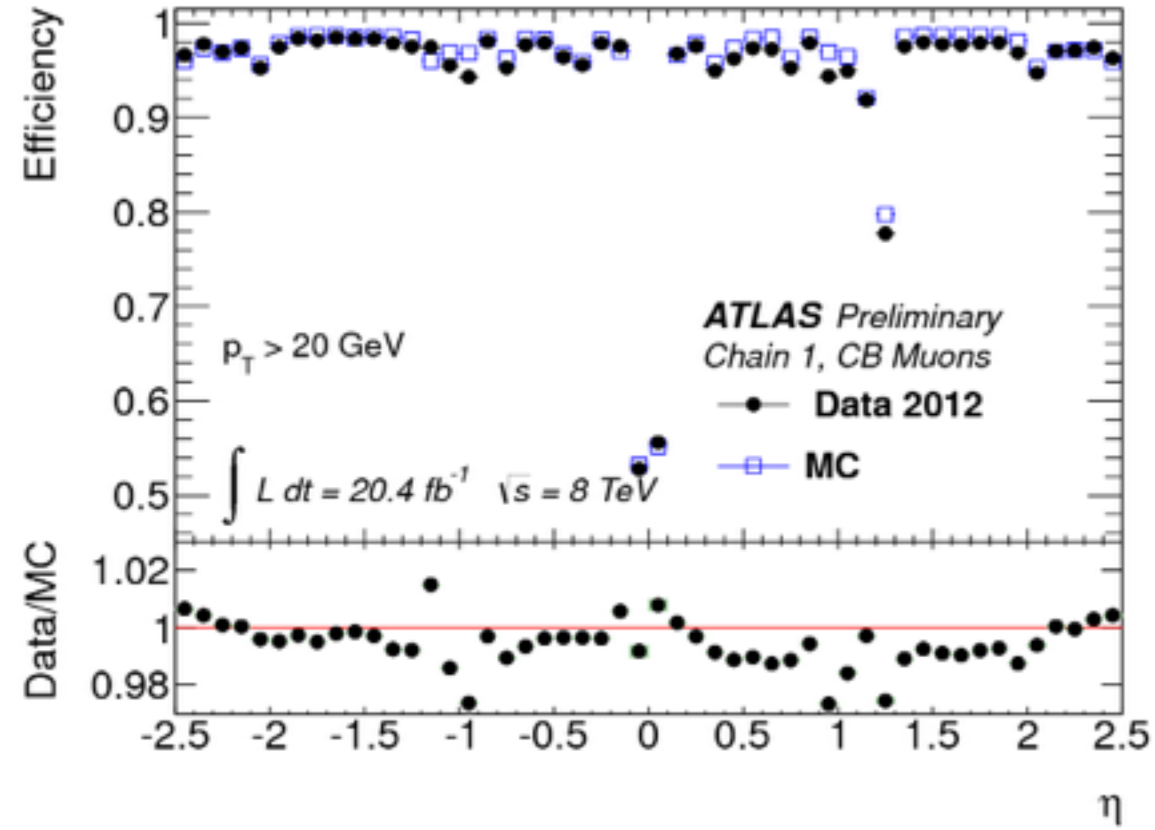
- (*) also heavy ion data gives opportunity to prepare for very high pile-up

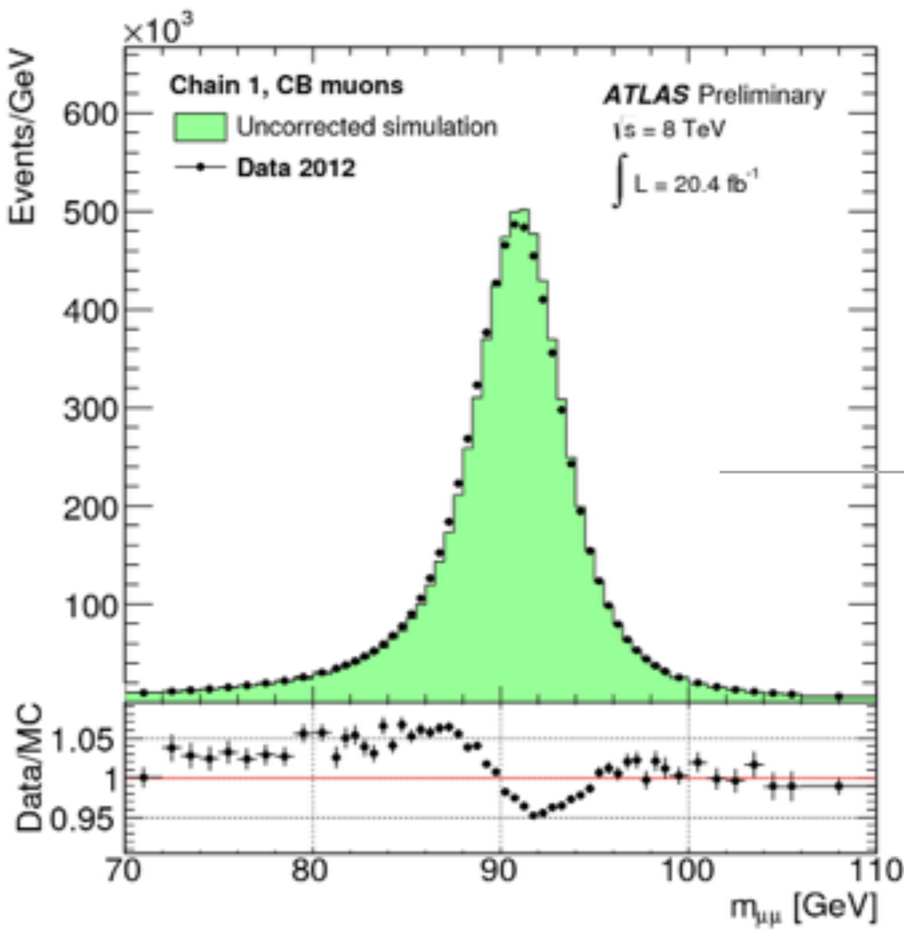




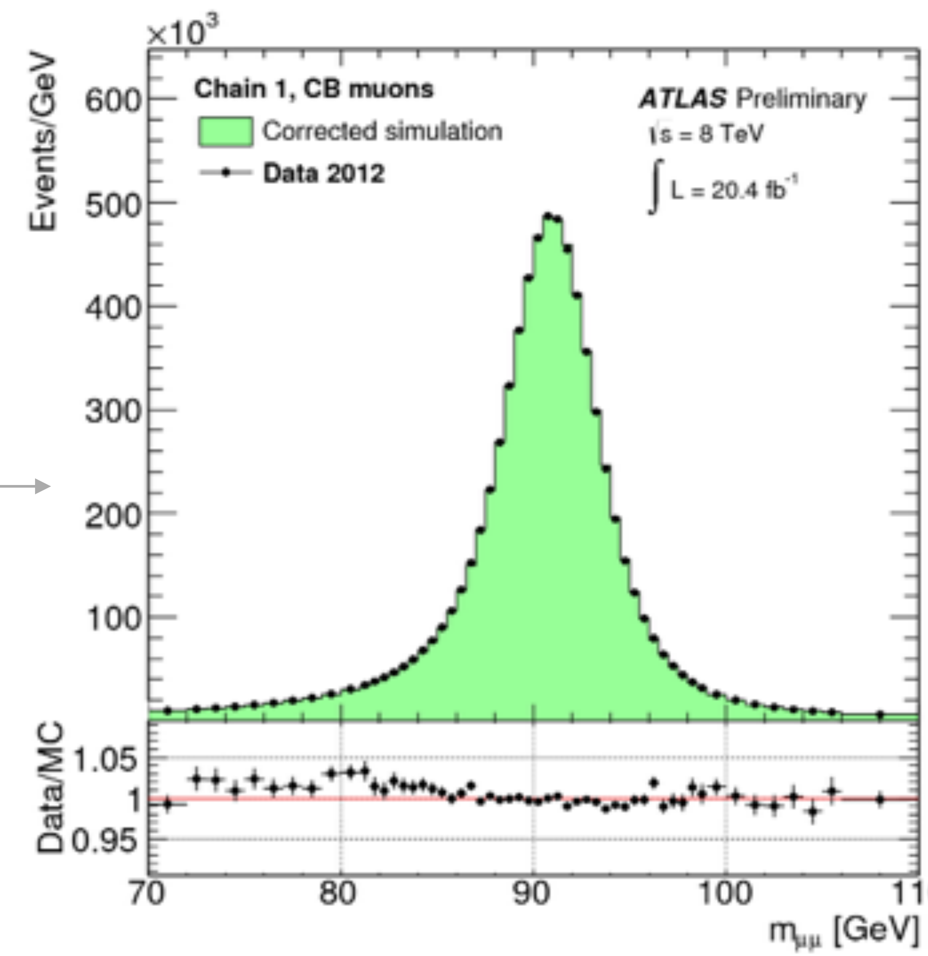
Combined μ reconstruction

- Di-muon resonances gave a great testbed to calibrate the ID & MS during Run-1
  - data/MC scale factors fitted using Z and J/Psi data set



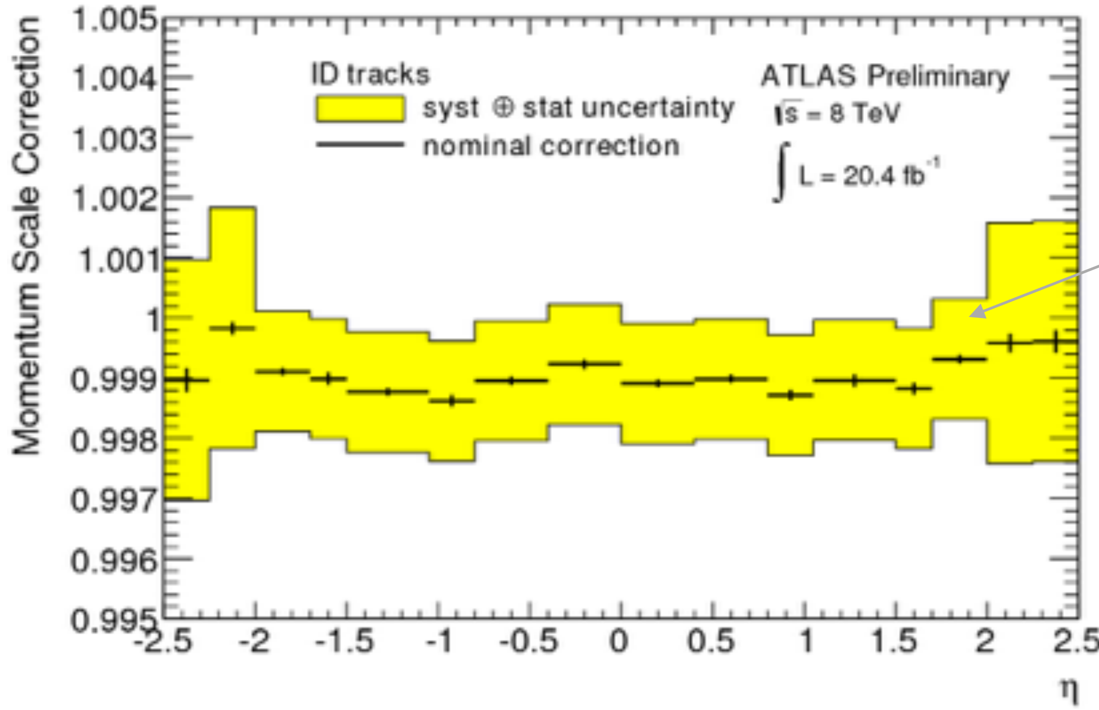


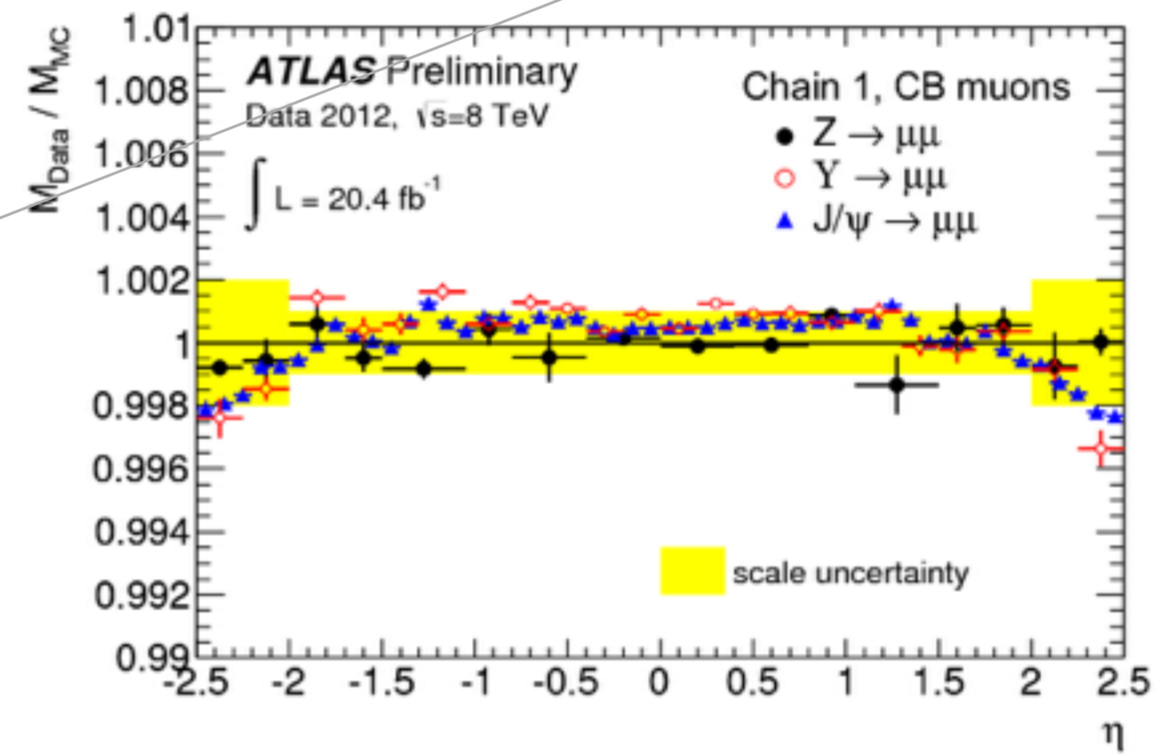
scale & smearing correction



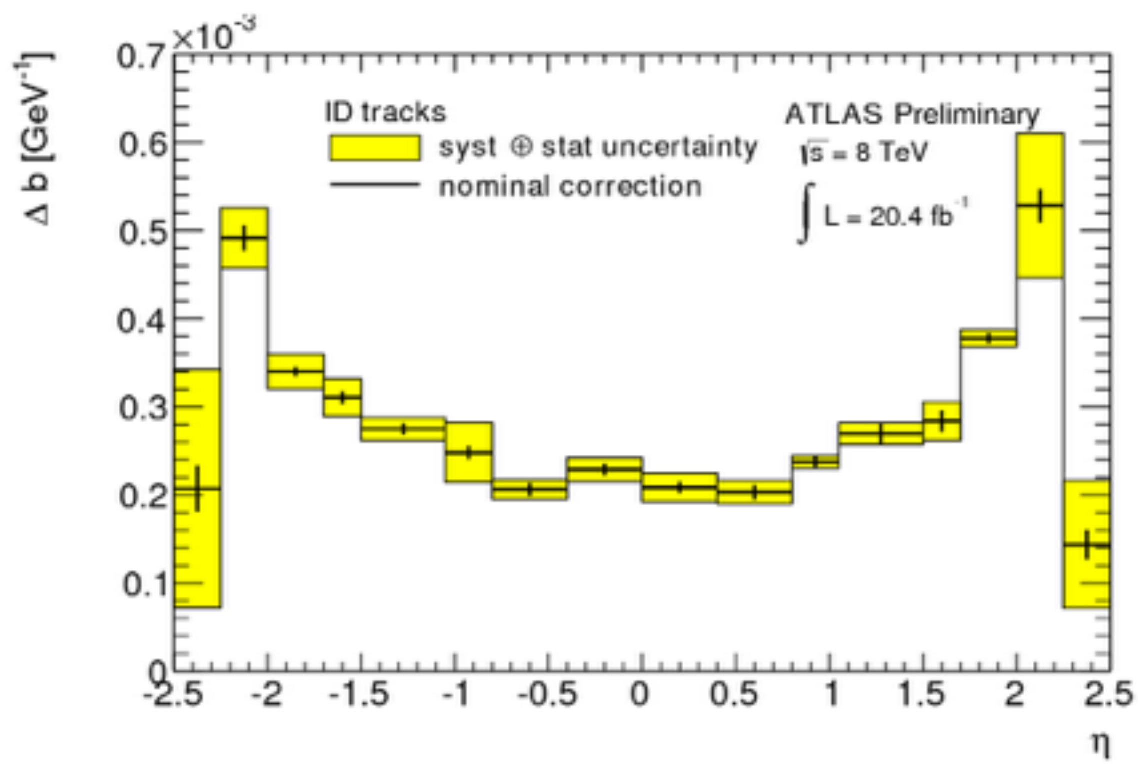
ID & MS momentum scale

- Scale uncertainties measured from data/MC differences and Z and J/Psi





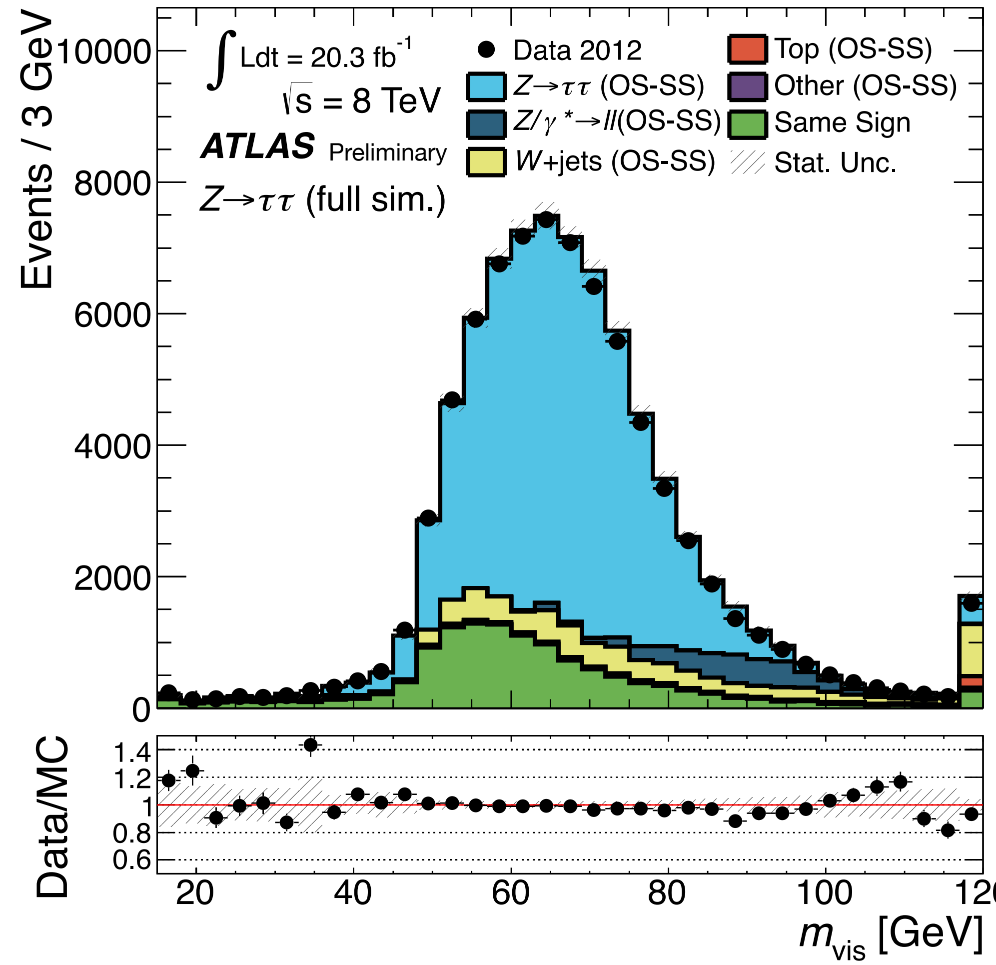
- Not fully understood resolution uncertainty for ID tracks
  - MC needs additional smearing to describe the data
  - many sources possible for this: alignment weak mode, clustering, material

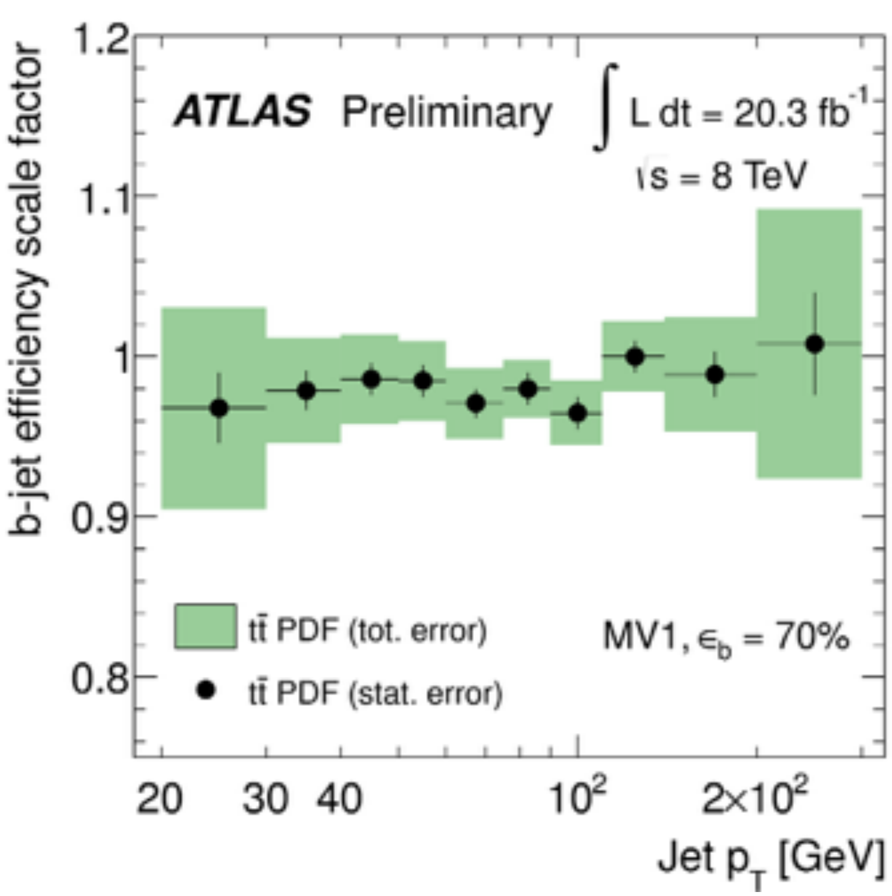


Higher level reconstruction objects

tau-reconstruction calibration

- very good description data through full (Geant4), fast (AF2) and embedding technique achieved





- using di-leptonic tt events
  - requiring both b quarks to decay semi-leptonically
  - event-based b-tagging calibration using a PDF combining flavour correlations
  - reduces uncertainties on data/MC scale factors to **2%** at around 100 GeV jet p_T

Summary

- Run-1 performance is very well understood
  - description of data through simulation in general very well
  - few puzzles still to resolve:
    understanding those will help to start-off from a even better ground in Run-2

- Run-2 will bring different challenges
  - different **data** conditions
  - new **fast** detector simulation needed to cope with the MC demands
  - detector ageing effects will increase
  - these will make data/MC comparisons even more tricky to understand

Backup

Run-2 preparations

- Description & simulation of new detector
  - Insertable B-layer in Inner Detector
  - Additional/complete muon chambers

- Preparing for 25 ns bunch crossing
  - using special 25 ns run from 2012
  - dedicated Monte Carlo with matching conditions