EARLY MATERIAL STUDIES AT THE ATLAS EXPERIMENT

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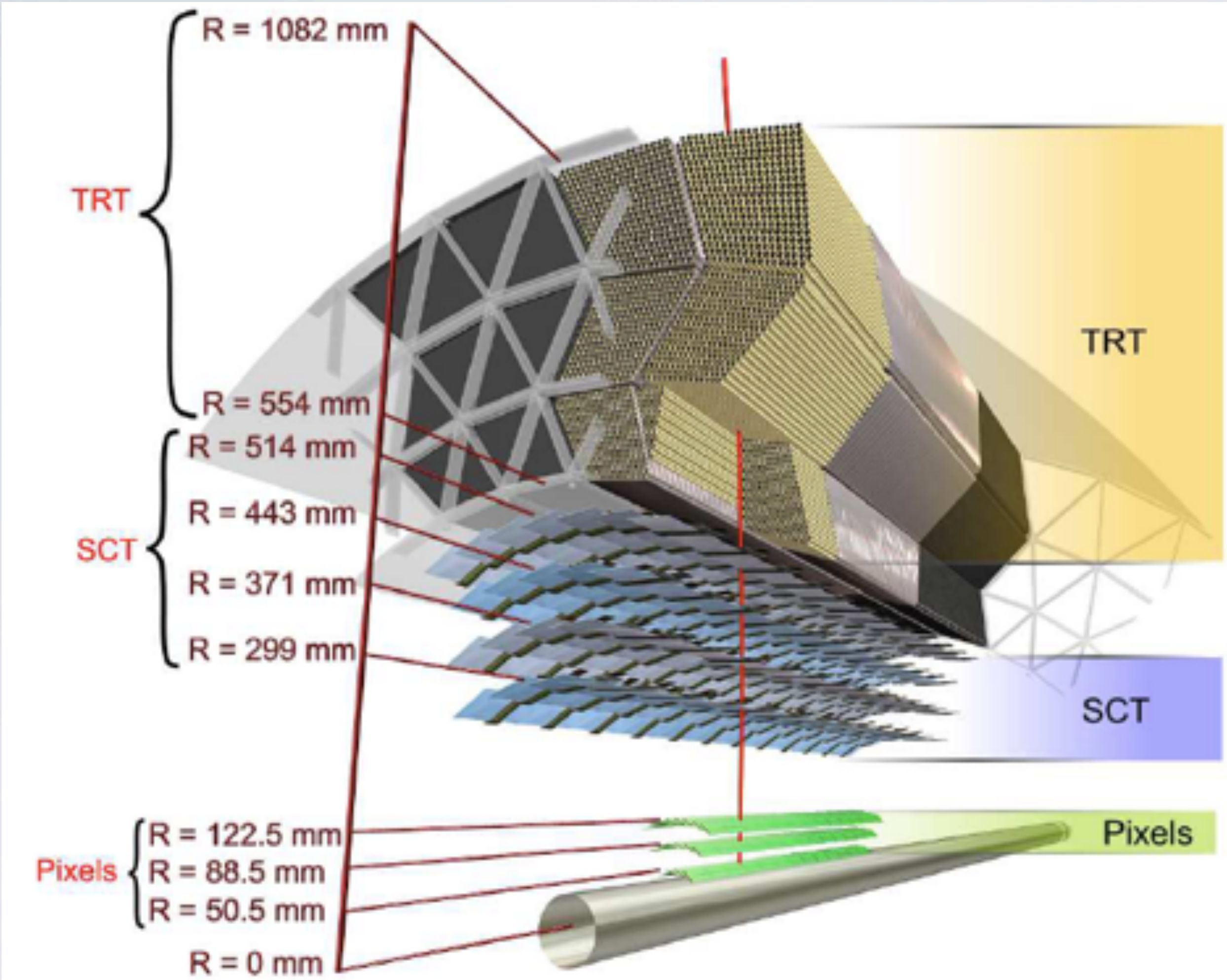
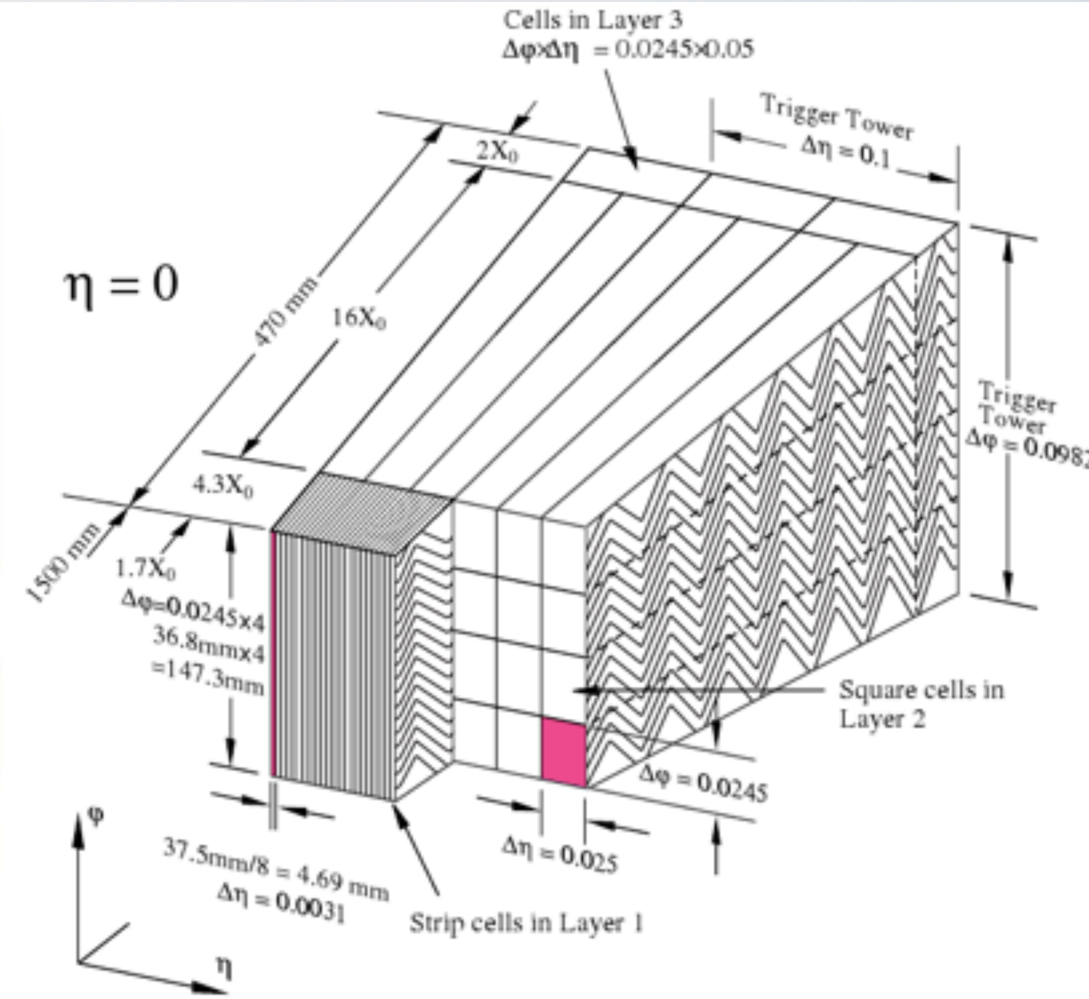
On behalf of the ATLAS Collaboration

ICHEP 2010
July 22 2010 Paris, France

ATLAS INNER DETECTOR AND EM CALORIMETER



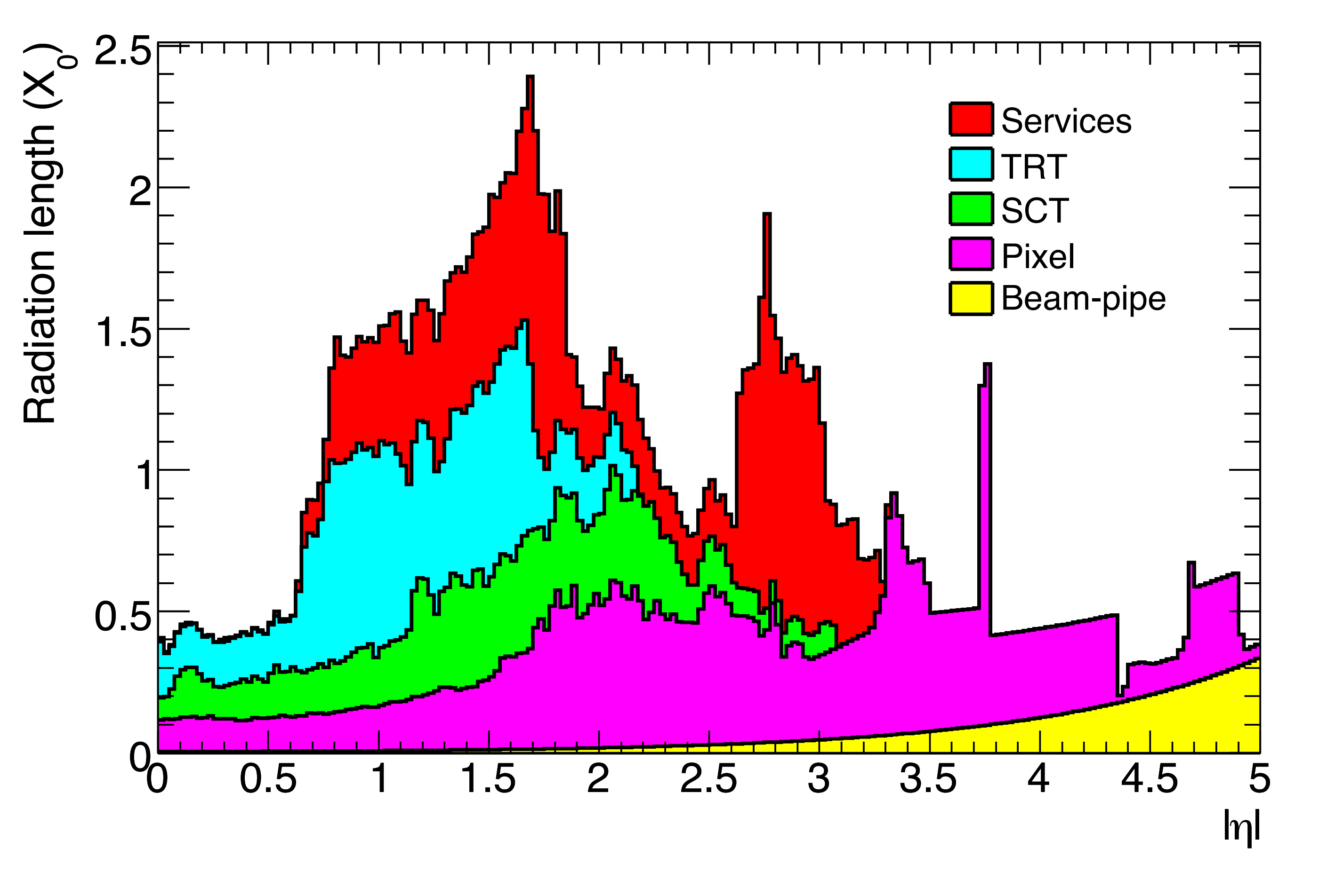


- $|\eta|<2.5$, Barrel and end cap geometry
- In the barrel a particle will pass through
  - 3 Si pixel layers
  - 8 layers of Si microstrip detectors (SCT) (4 space points)
  - On average 35 straws in the transition radiation tracker (TRT)
- Details were given in Antonio Limosani's presentation on Commissioning and Performance of the ATLAS Inner Detector

- $|\eta|<3.2$, Barrel and end cap geometry
- Liquid Argon active medium
- 3 longitudinal layers with a accordion geometry
- Pre sampler provides pre shower sampling inside the cryostat
- Details were given in Pascal Pralavorio's presentation on Commissioning and Performance of the ATLAS Calorimeter Systems

MATERIAL IN THE INNER DETECTOR

- A knowledge of the location and composition of the material is important for the physics performance of the detector
  - Calibration of the EM calorimeter
  - Track reconstruction performance
    - Multiple Coulomb scattering and ionisation
  - Electron and Photon analysis
    - Conversions and Bremsstrahlung

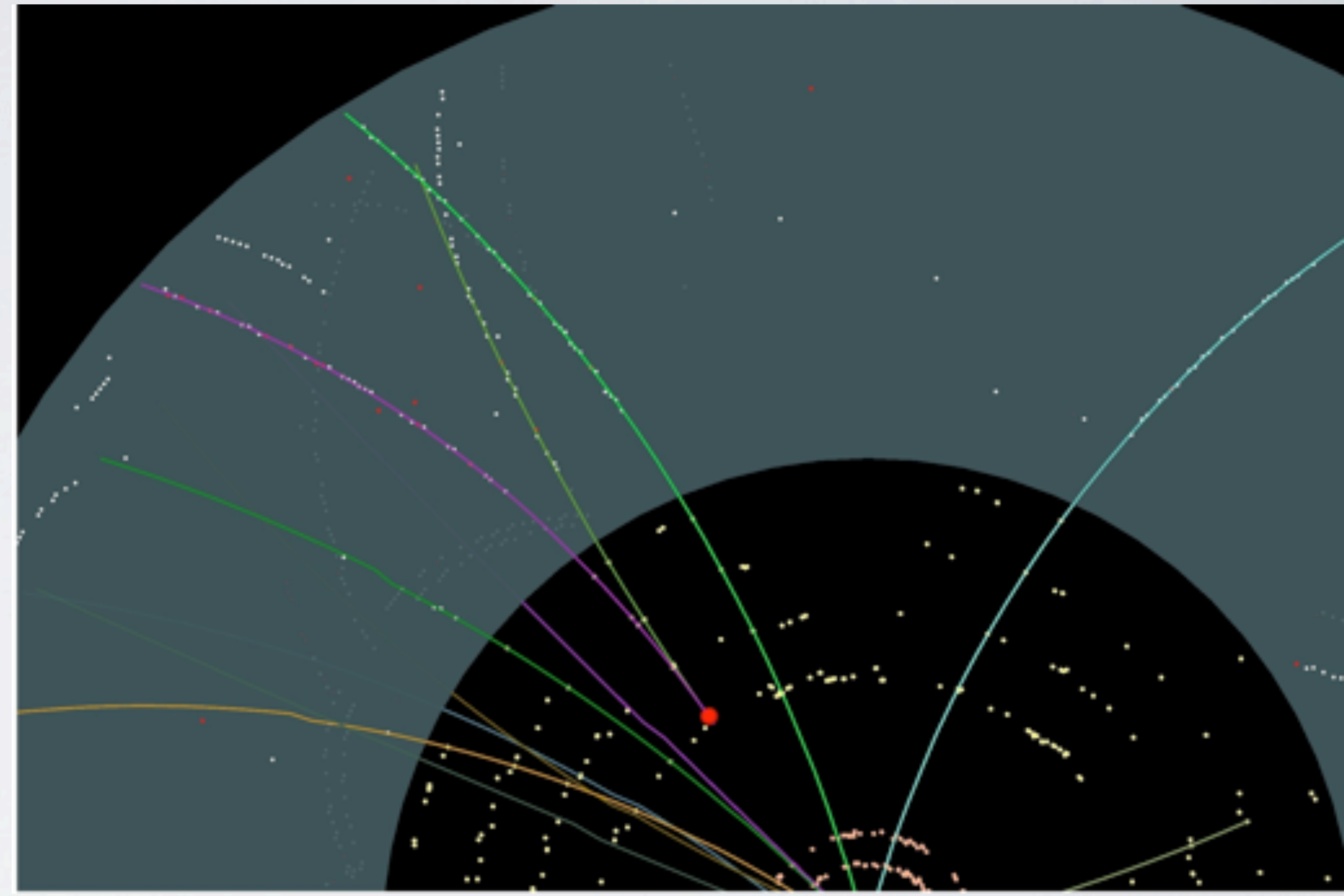


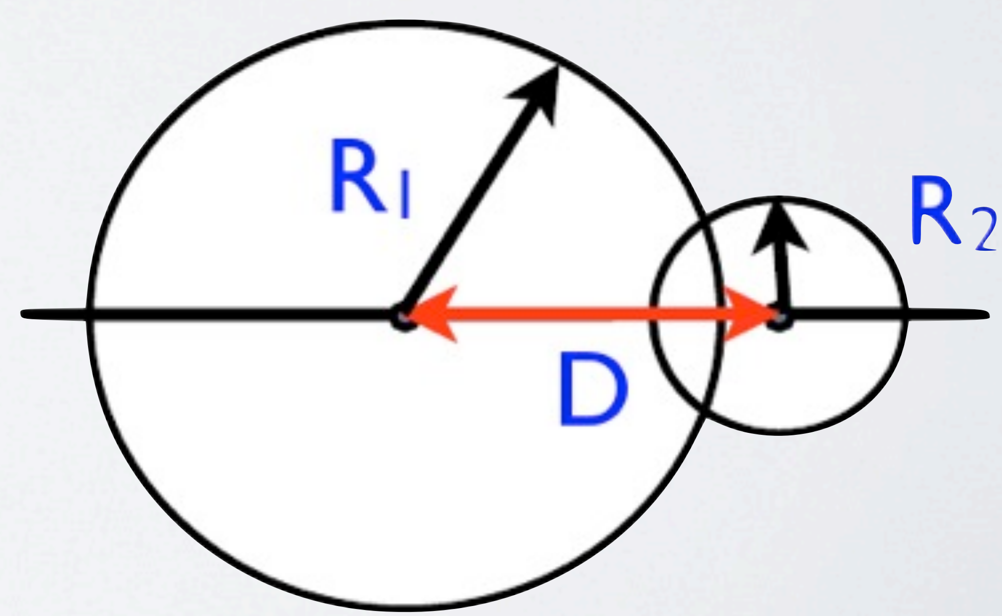
Methods to determine material

- Calorimeter based method
  - Energy Flow
- Tracking Based method
  - Photon Conversions
  - Hadronic Interactions
  - K_s mass vs p_T (not discussed here)

PHOTON CONVERSION RECONSTRUCTION

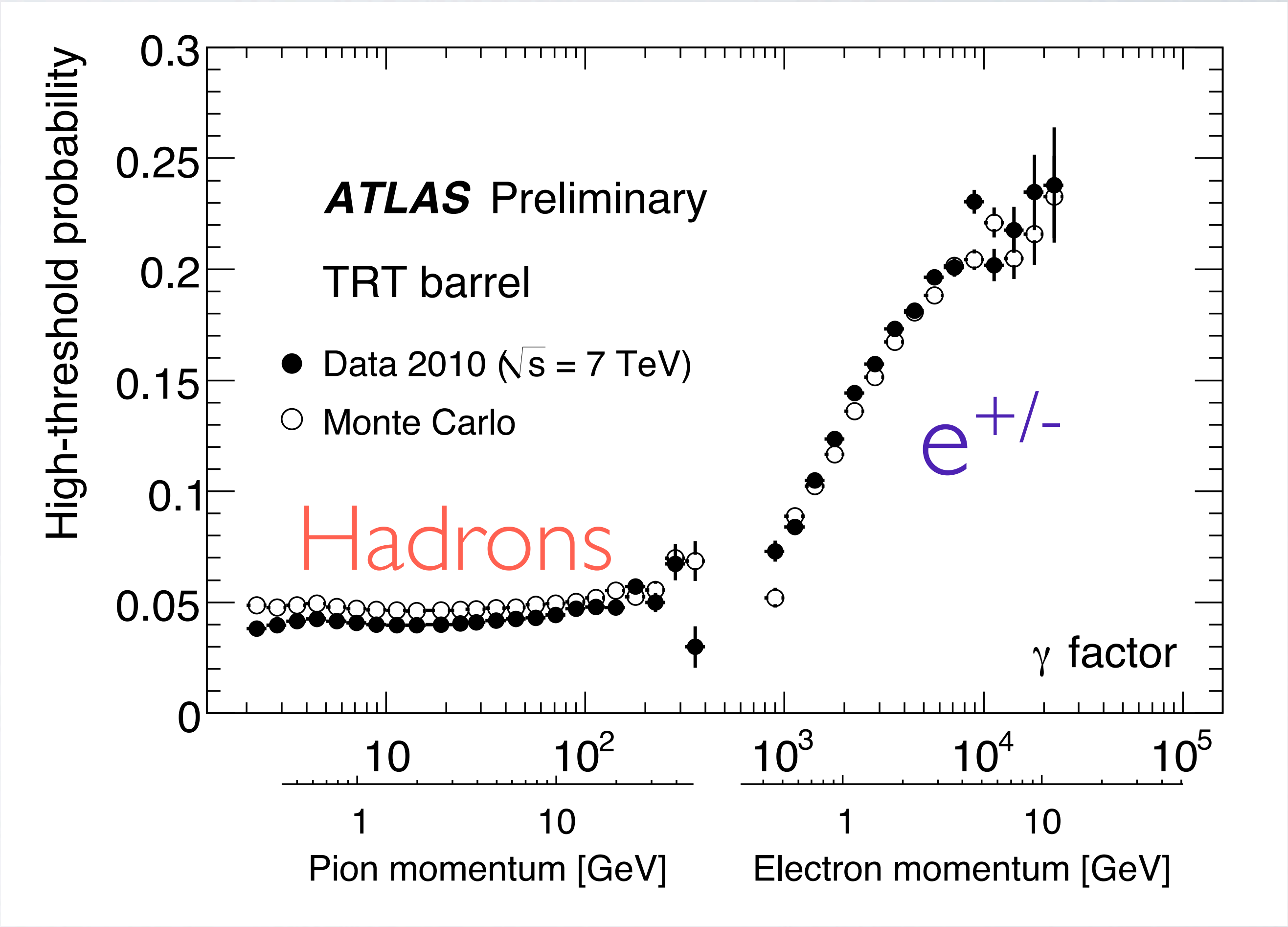
- Dominated by low energy conversions from π^0, etc. decays
- Tracks are reconstructed in the Inner Detector using:
  - Inside-out algorithm seeded by silicon hits
  - Backtracking seeded by the TRT (extended to Si)
- Conversion vertexing
  - Combinatorics reduced by using
    - Particle identification from the TRT
    - Geometric Cuts
      - Opening angles
      - Distance of minimum approach between tracks
      - $D-R_1-R_2$
  - Constrained Vertex Fit (χ^2)
    - $\Delta\phi = \Delta\theta = 0$





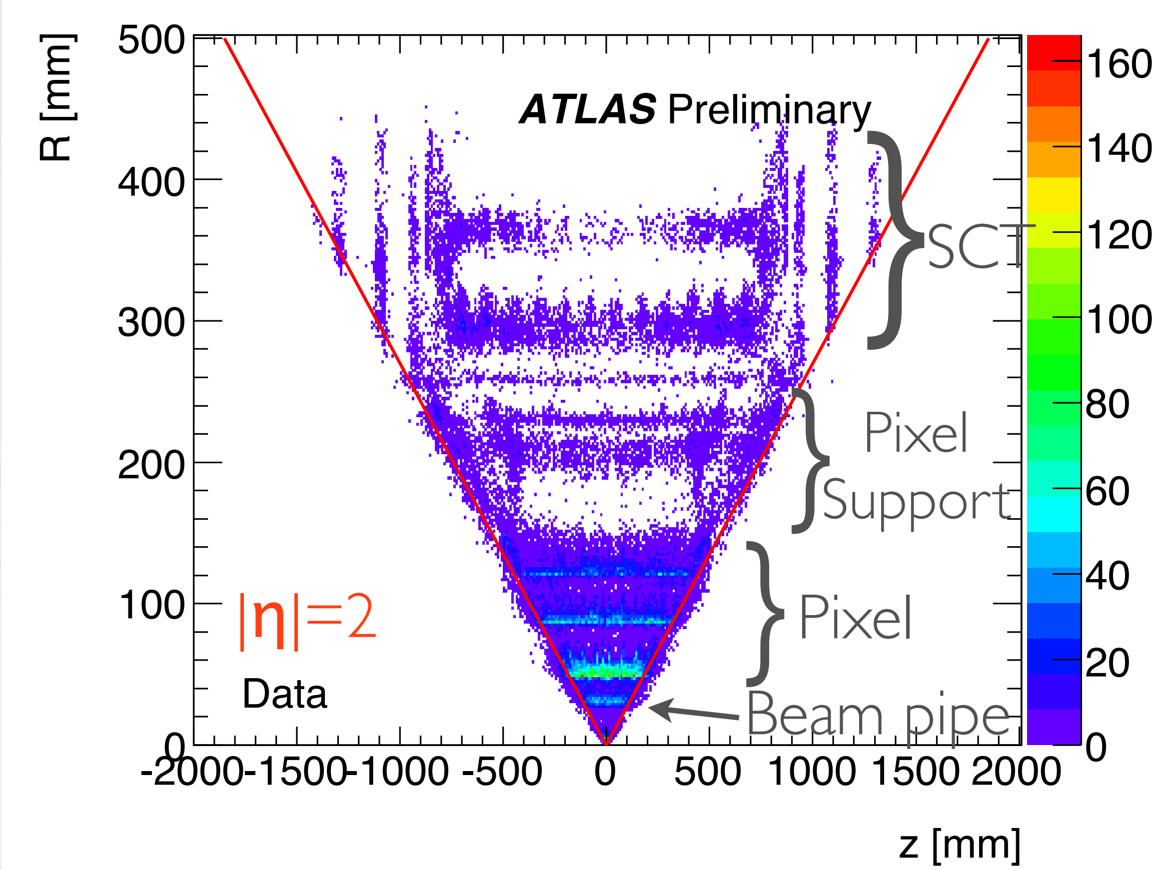
ELECTRON IDENTIFICATION FROM THE TRT

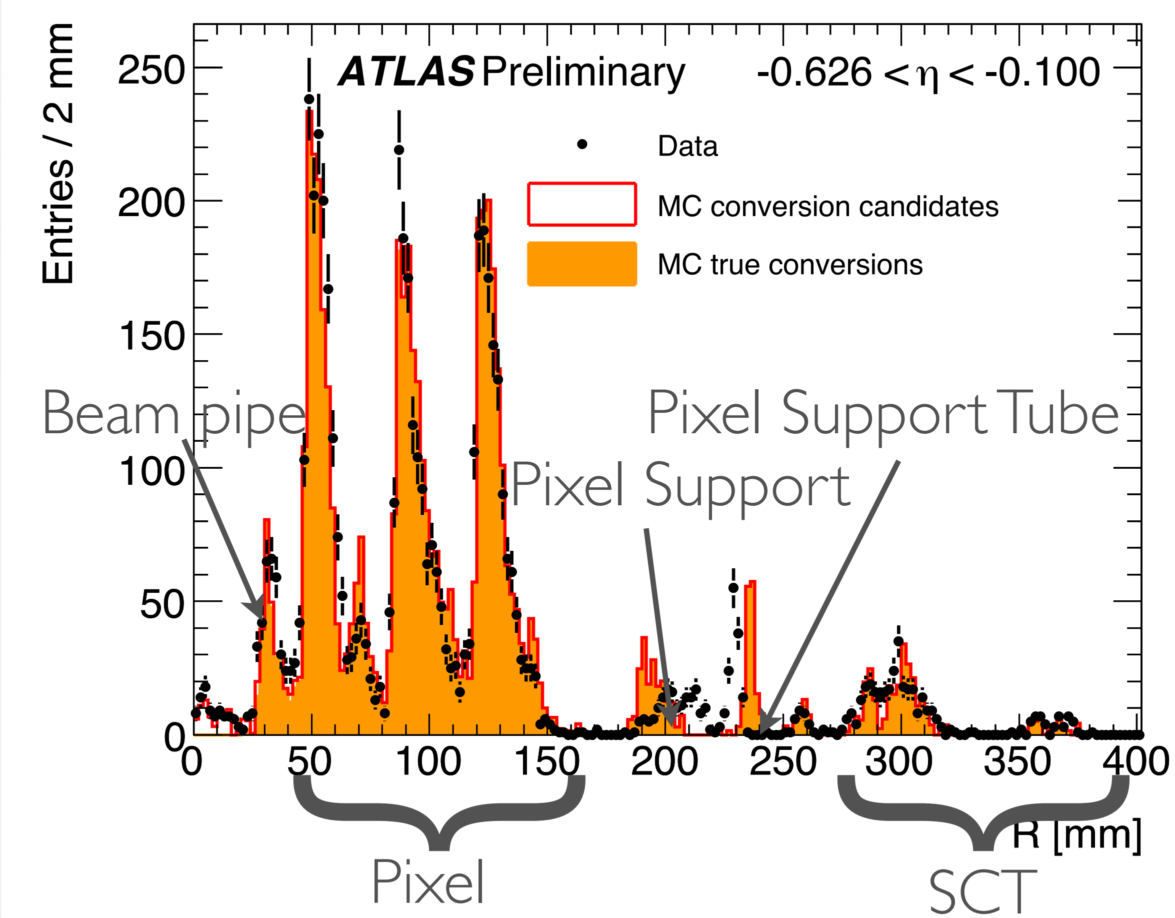
- Transition Radiation Tracker used to reduce hadronic background in photon conversion studies
- Transition radiation (dependant on Lorentz γ) in scintillating foils and fibre result in a larger fraction of high threshold (HT) hits in the TRT
- Photon conversions have been used as the first clean supply of electrons for an in situ measurement of the HT probability at large γ



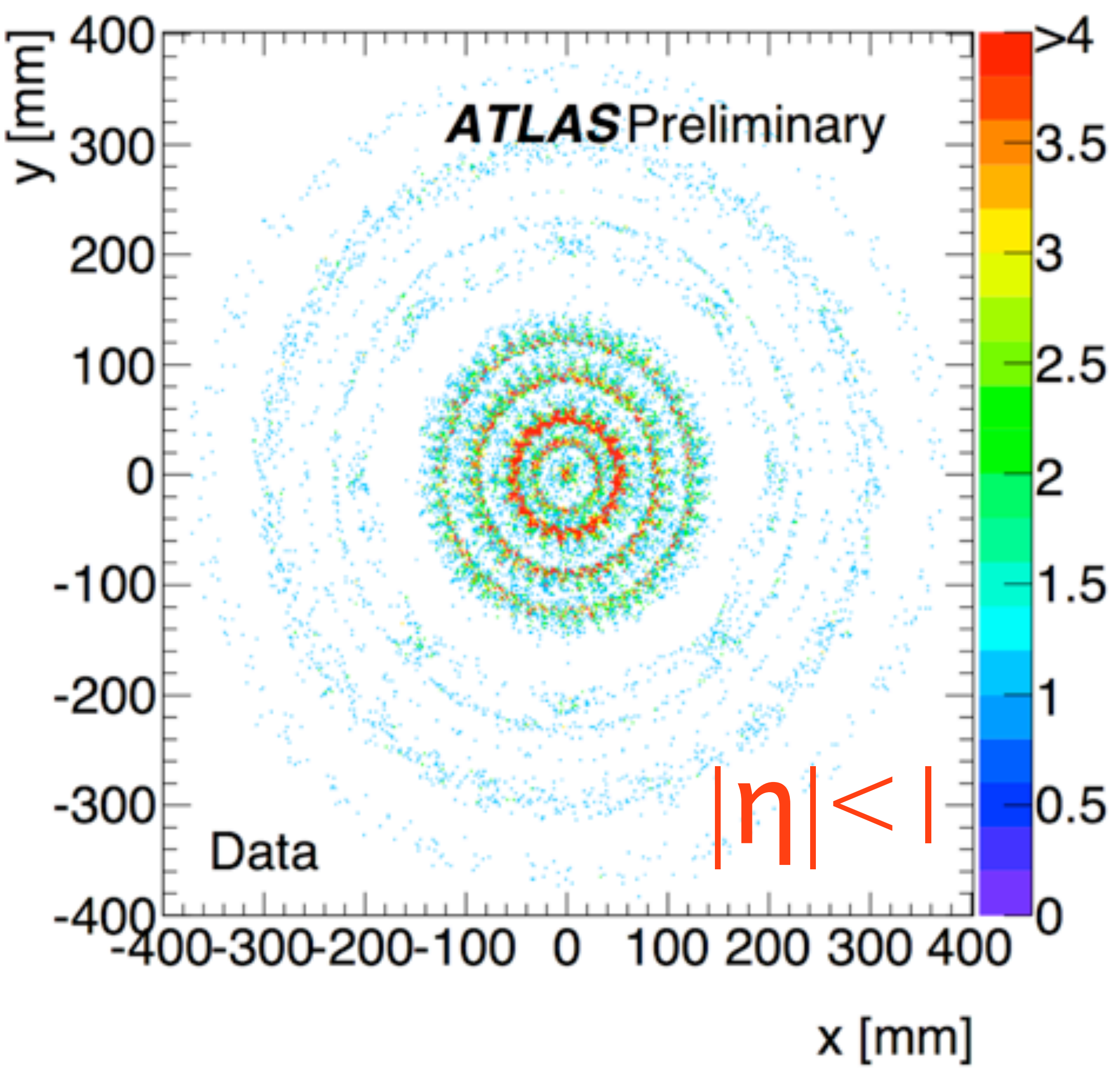
MATERIAL MAPS FROM PHOTON CONVERSIONS

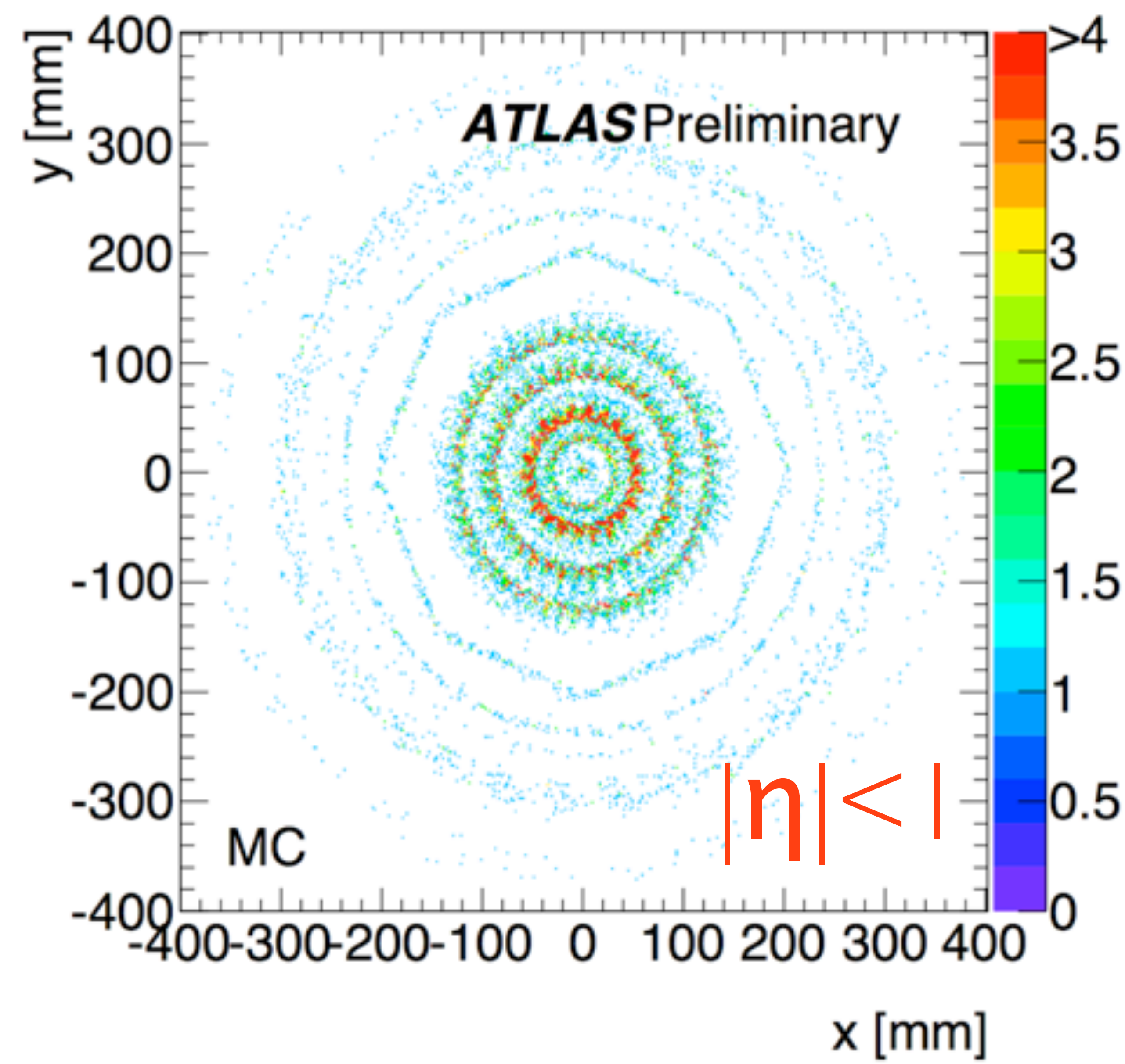
- Conversion Selection
  - Silicon Hits required on both tracks
  - Electron identification from TRT high threshold hits
  - Vertex fit χ^2 <5
  - Results in > 90% purity
- Good spatial resolution, ~4 mm in R
- Good agreement between data and simulation
- Pixel support structure and tube shifted by ≈1cm in the simulation





MATERIAL MAPS FROM PHOTON CONVERSIONS

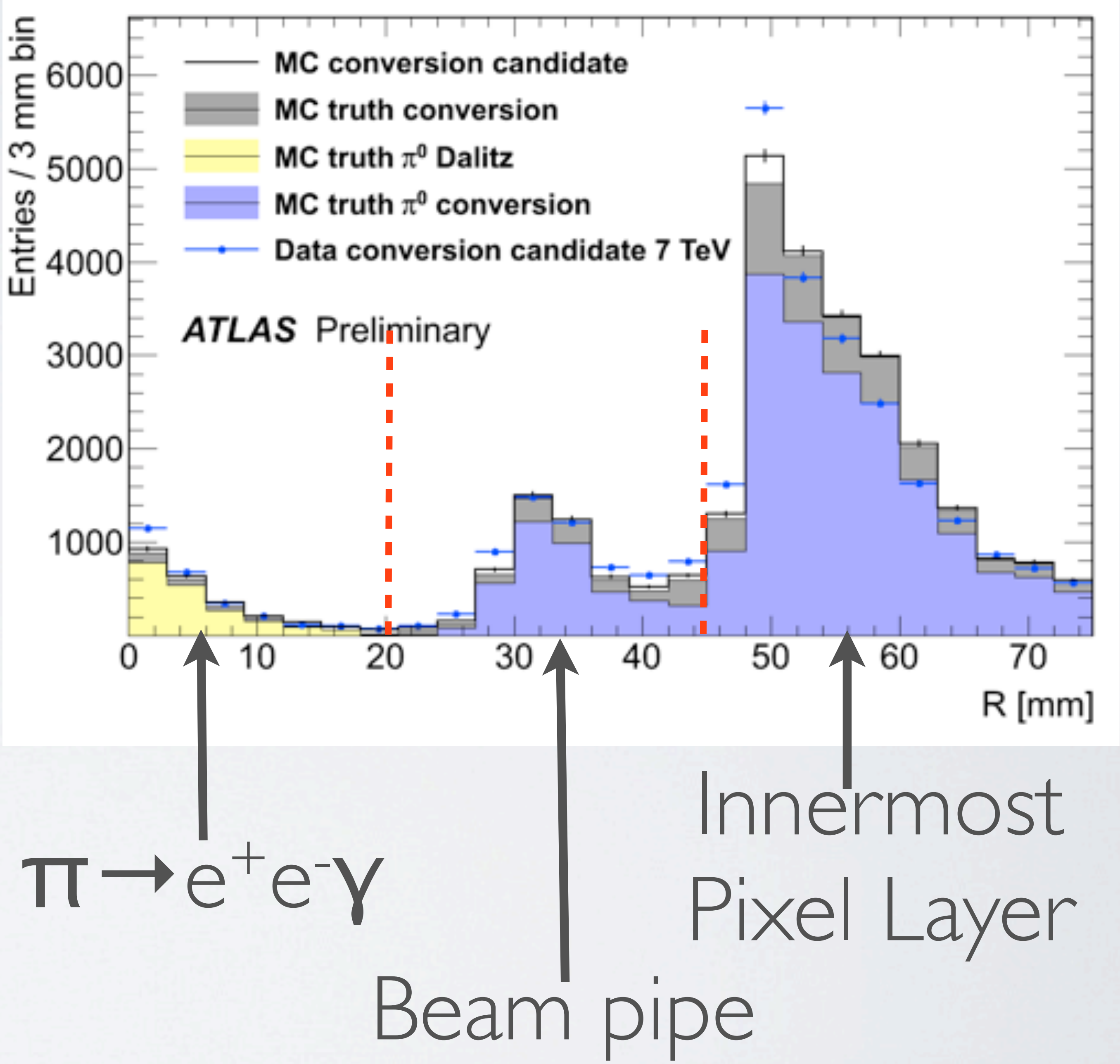




- Structure of the Pixels and first SCT layers are resolved
- Support structures from pixel detector are visible
- Octagonal support structure at incorrect radius in simulation

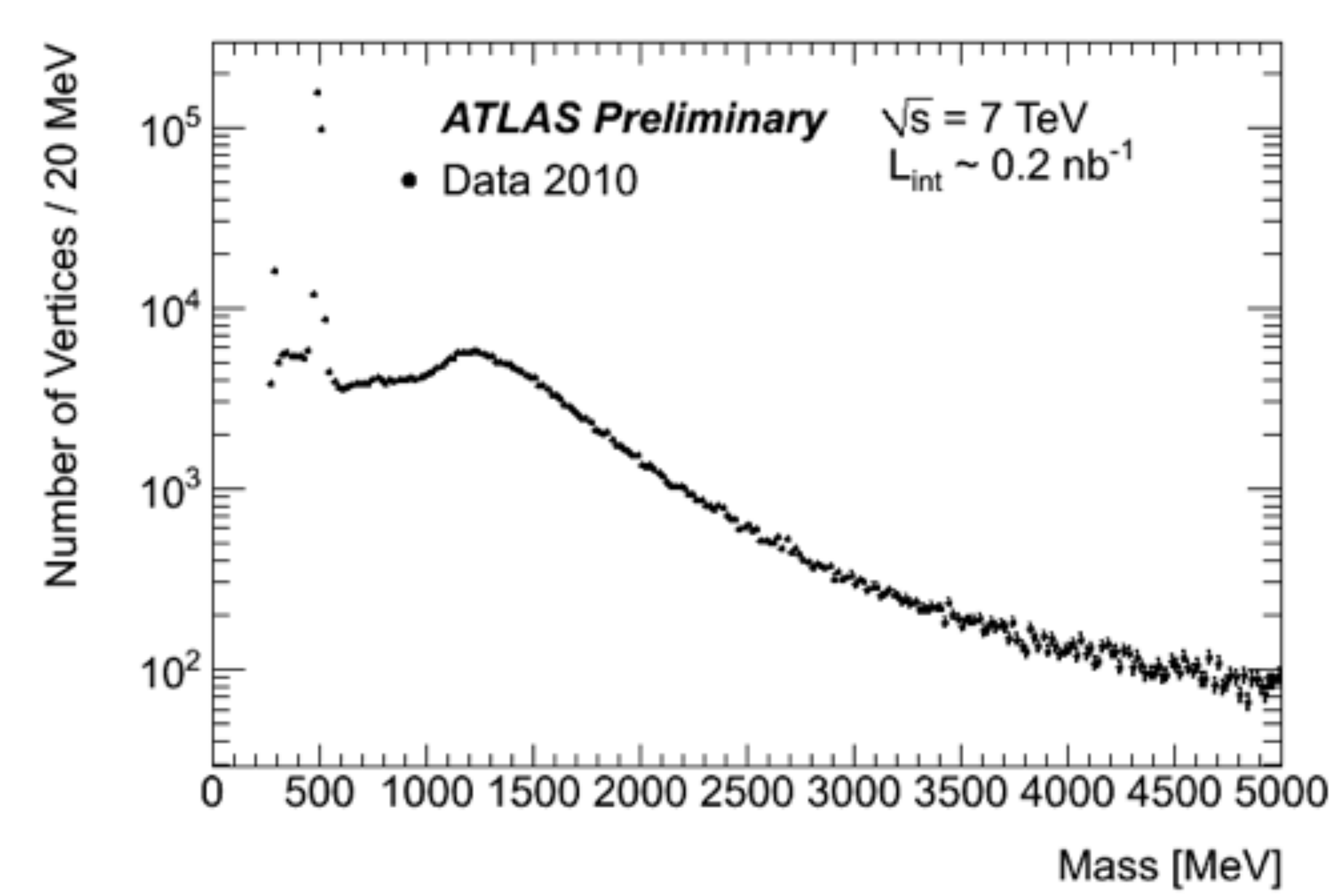
NEUTRAL MESON DALITZ DECAYS

- Dalitz decays to be used as crosscheck of the beam pipe material
- Same selections as material mapping analysis
- Good agreement between data and MC
- Calibration of conversion rate:
  - Use Dalitz decays to measure the rate of π^0 decay
  - Check ratio of conversions in the beam pipe and Dalitz decays to extract a conversion rate and hence the material.
  - Use the well known beam pipe geometry and material to normalise the material estimates



MATERIAL MAPPING WITH HADRONIC INTERACTIONS

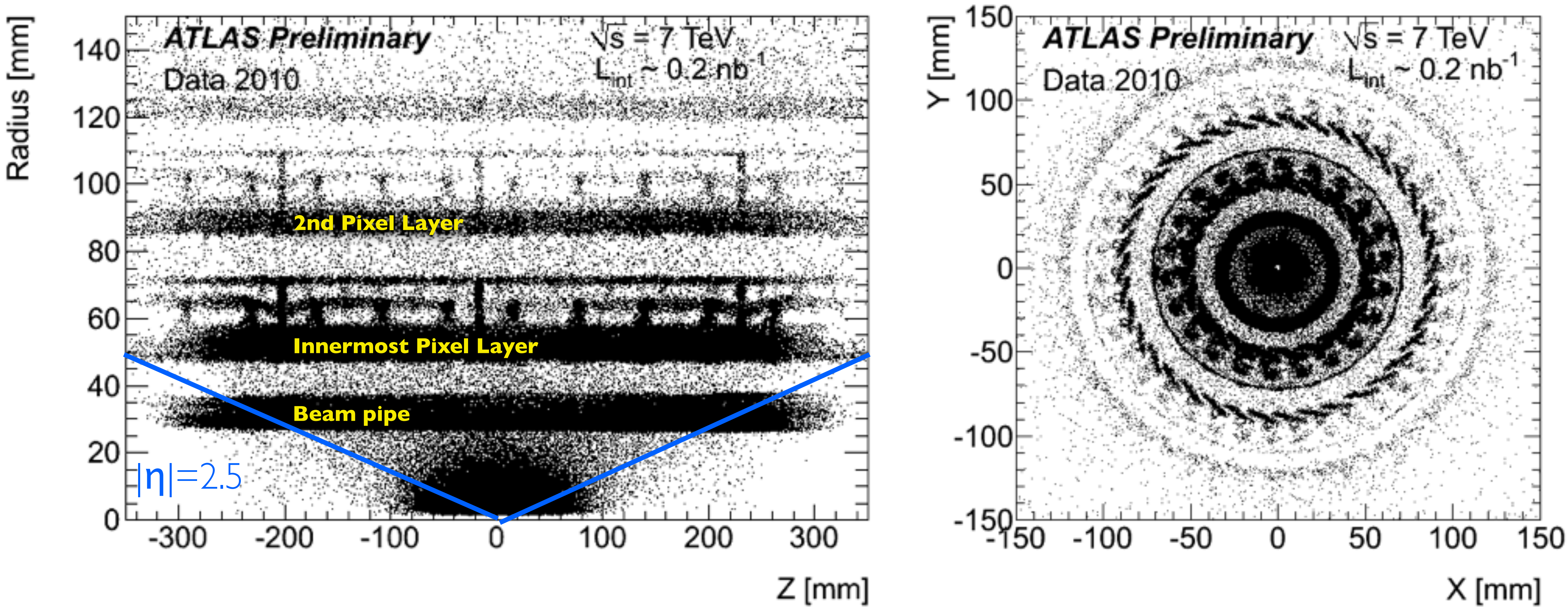
- Hadrons created at the primary interaction will interact with material layers
  - Secondary hadronic interactions can produce more than two outgoing particles
- Reconstructed vertices of hadronic interaction can provide information about the material distribution
- Vertex reconstruction procedure:
  - Tracks from the primary vertex are vetoed
    - Transverse impact parameter < 2mm
  - Find all two track vertices and merge all two track vertices that are compatible with each other
  - Finally it is ensured that all track-vertex combinations are unique



Reconstructed mass of the vertex assuming the particle mass is equal to that of a pion

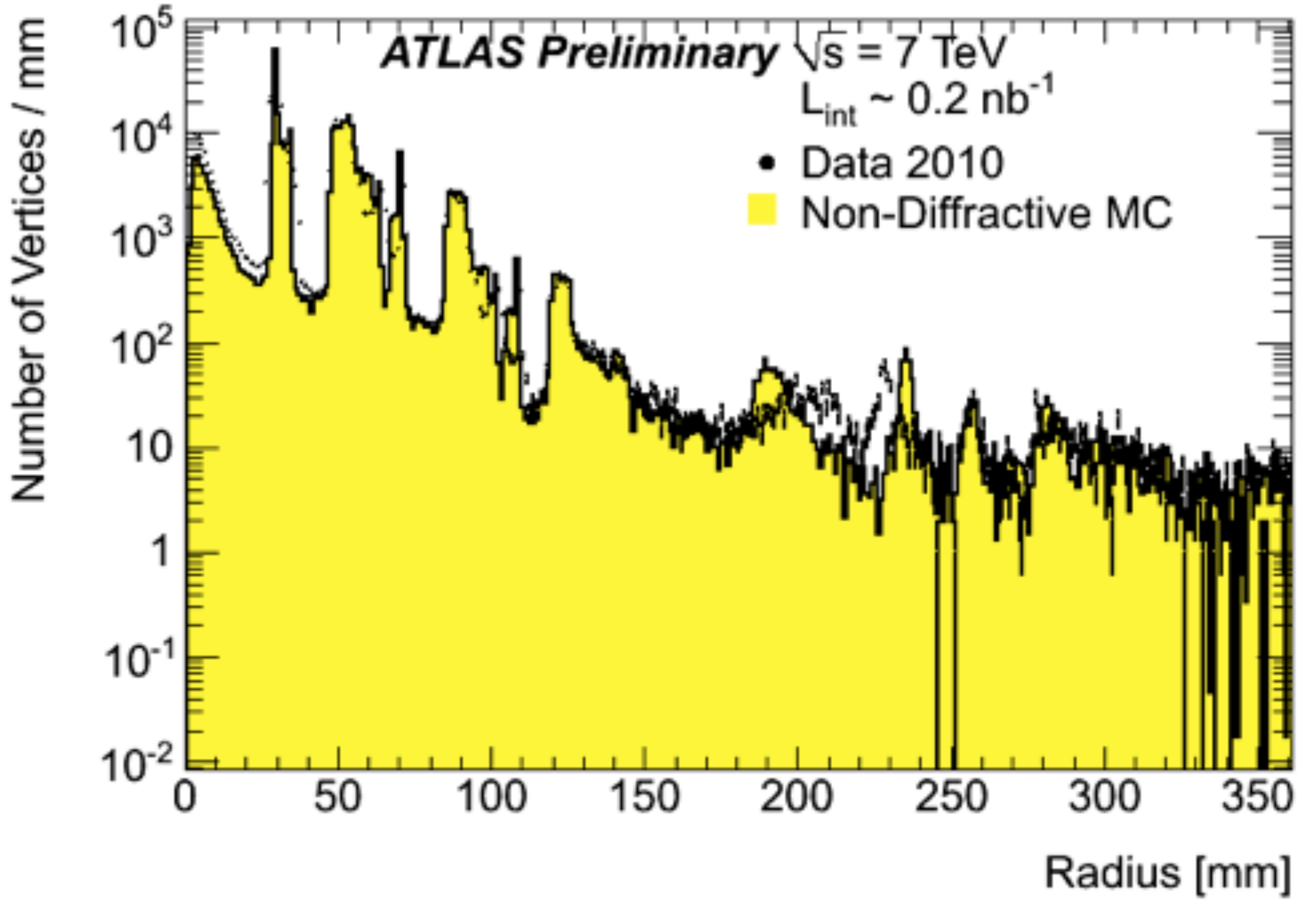
- Vertices from K^0_S's, γ's and Λ's are vetoed after vertices are constructed by mass selection

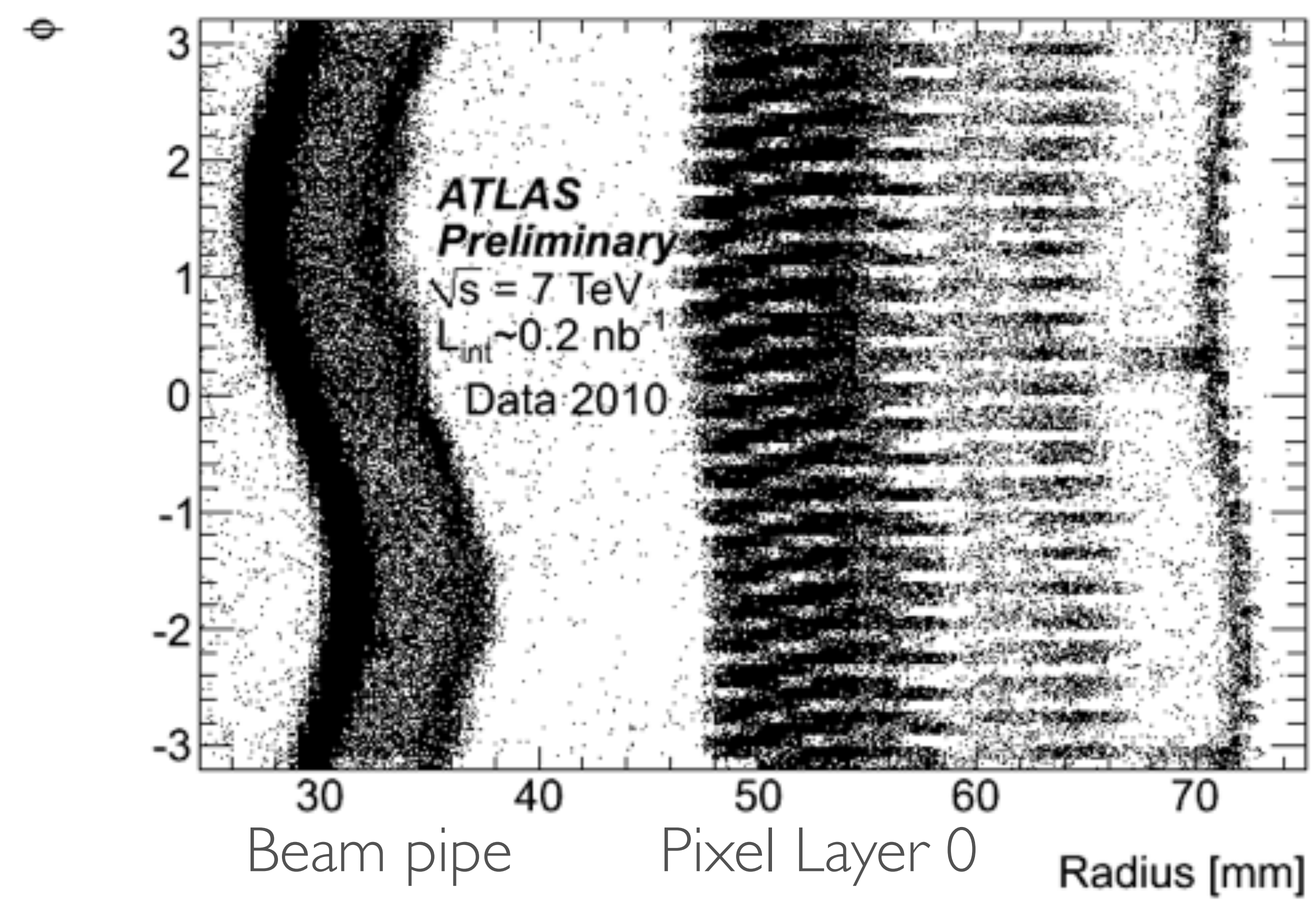
MATERIAL MAPS FROM HADRONIC INTERACTIONS



- Structure of beam pipe, pixels layers and supports visible
- Vertex resolution ≈250μm in R and Z for R <100mm

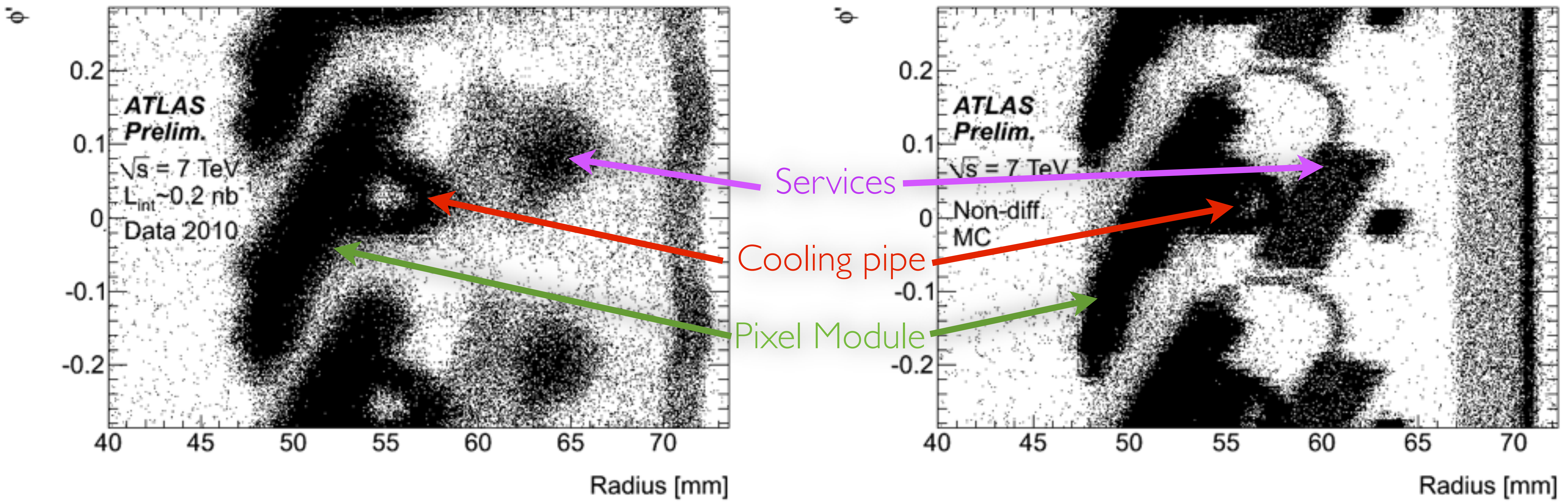
MATERIAL MAPS FROM HADRONIC INTERACTIONS





- Overall good agreement between data and simulation
- Pixel support structure and tube shifted by ≈1cm in the simulation, in good agreement with what was observed with conversions
- Evidence that beam pipe is not in the centre of the detector
  - Possible implications for conversion studies

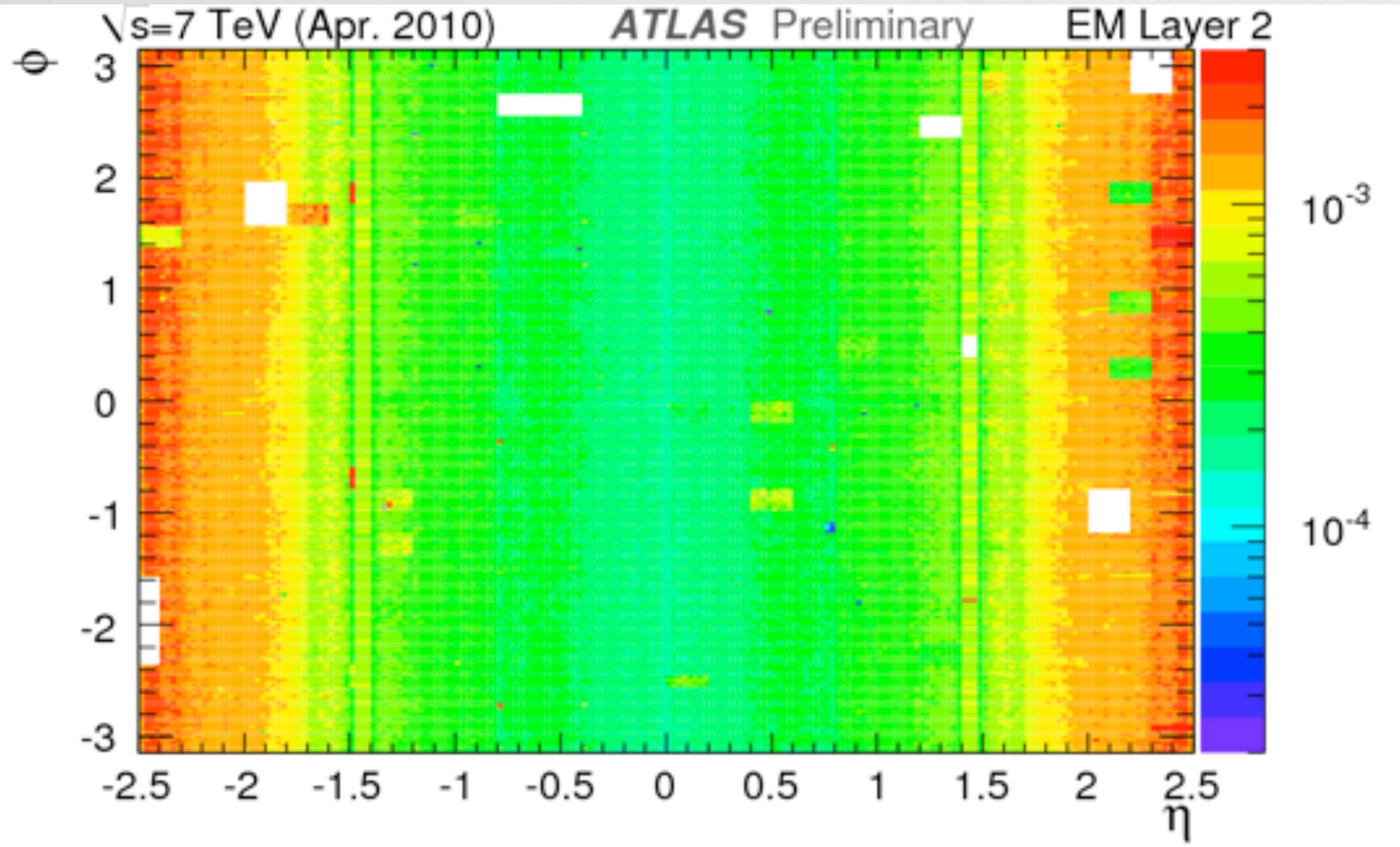
MATERIAL MAPS FROM HADRONIC INTERACTIONS



Innermost Layer of the Pixel Detector

- Hadronic interaction vertices prove to be a very useful tool
- Fine details of the detector description can be tested

ENERGY FLOW IN THE EM CALORIMETER



Occupancy in the 2nd sampling layer of the calorimeter

- Hot and cold zones due to noisy cells, readout problems and non-nominal high voltage
- More details in Pascal Pralavorio's presentation on Commissioning and Performance of the ATLAS Calorimeter Systems

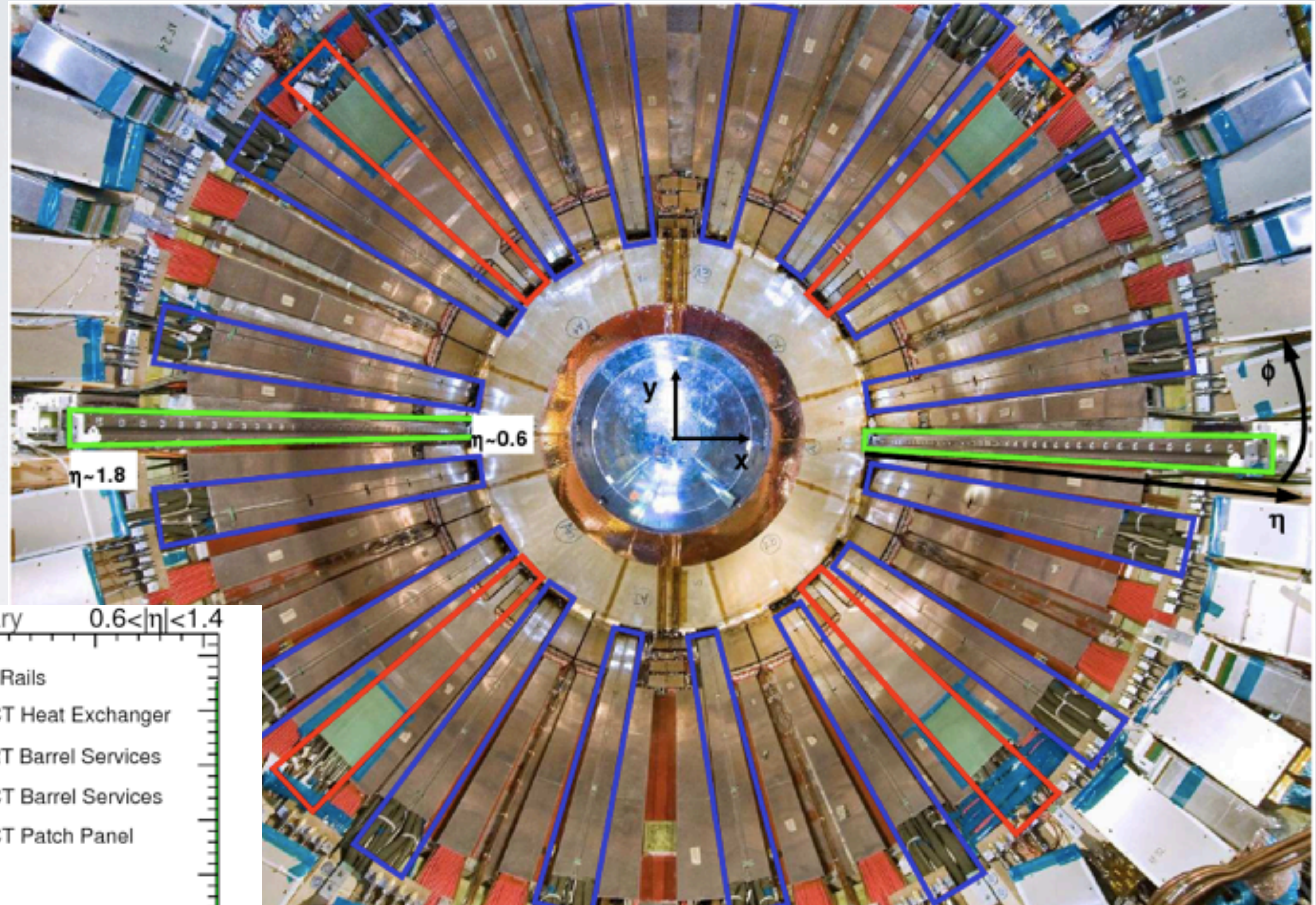
- Calorimeter occupancy variation in ϕ (at constant η) is sensitive to the total material in front of the calorimeter
  - Calorimeter intrinsically uniform in ϕ
- The occupancy is defined as the fraction of events in which the energy is above a fixed threshold (5 times the electronic noise level)

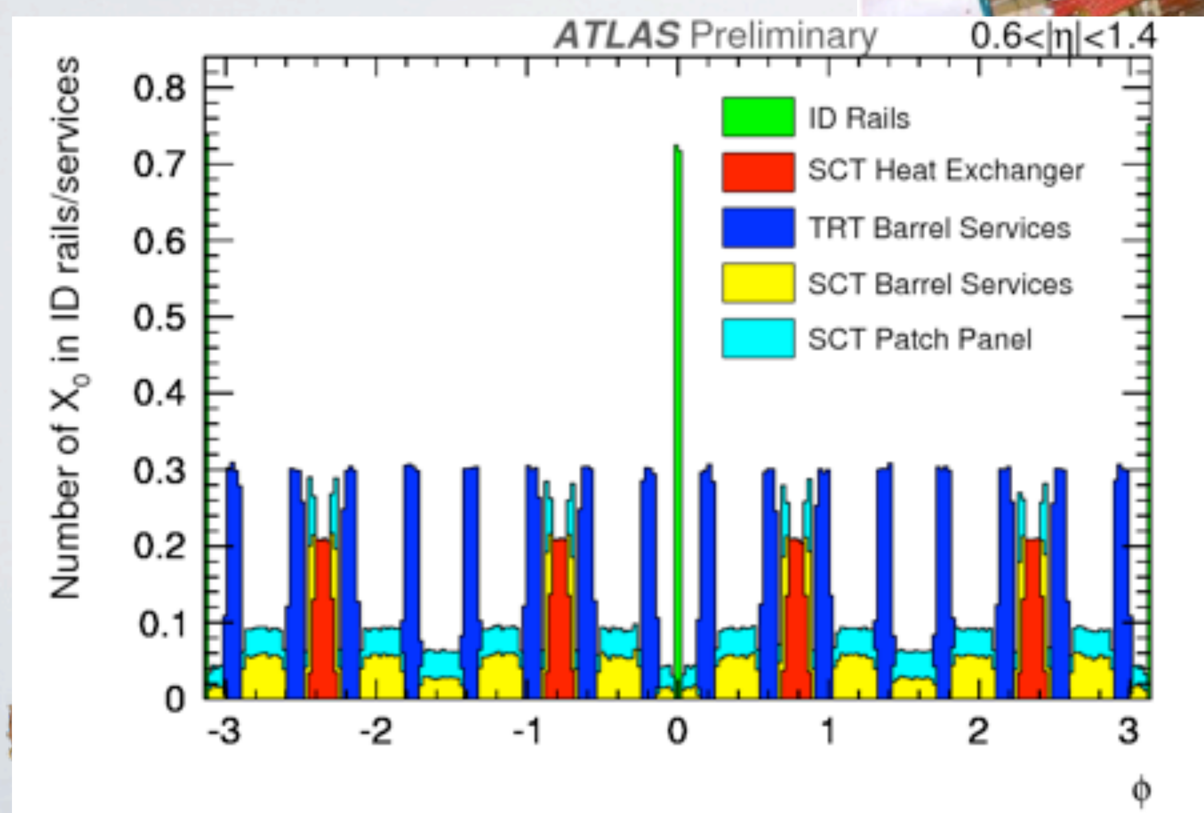
$$R = \frac{Occ_{\phi,\eta-slice} - \langle Occ_{\eta-slice} \rangle}{\langle Occ_{\eta-slice} \rangle}$$

- R<0 implies larger amount of material w.r.t. material in the slice

INNER DETECTOR SERVICES

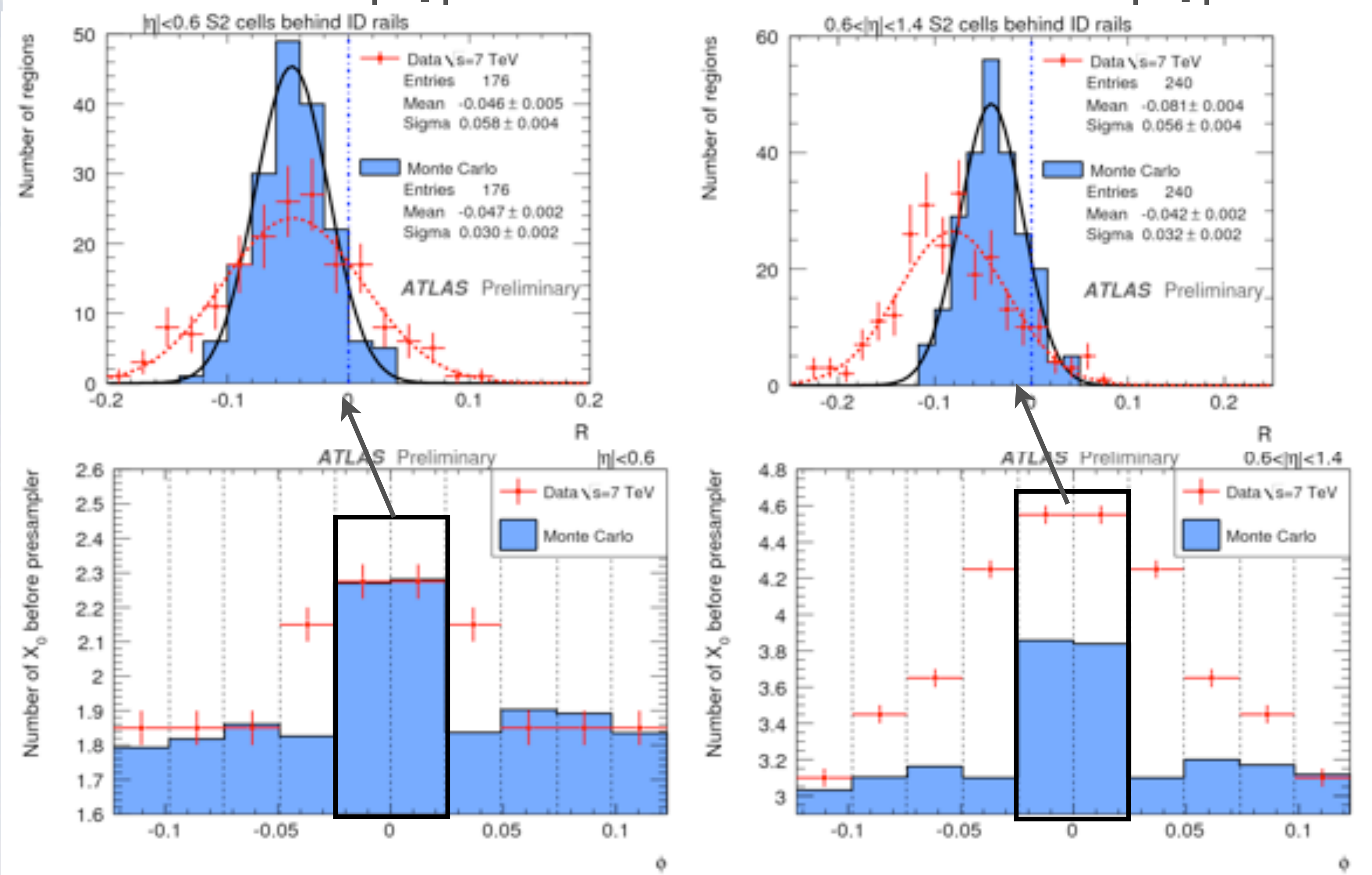
- Inner wall of Barrel Liquid Argon cryostat before ID endcap insertion.
- Note that services etc. run at constant Φ.



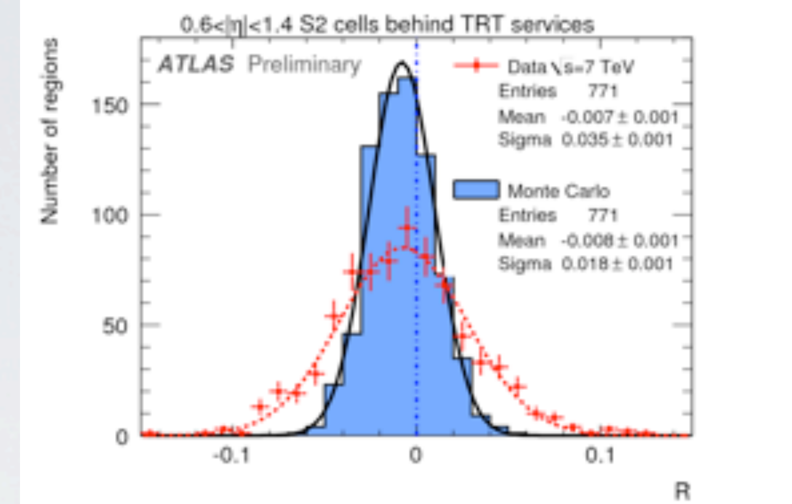


ENERGY FLOW IN THE EM CALORIMETER

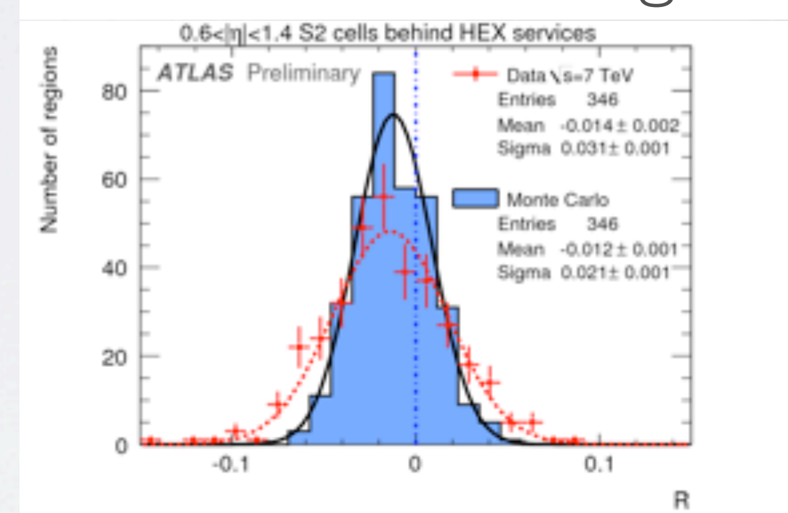
ID Rails $|\eta|<0.6$ ID Rails $0.6<|\eta|<1.4$



TRT Services



SCT heat exchangers



- Up to 1 X_0 of material missing in a very localised region near ID rails for $0.6 < |\eta| < 1.4$
- Good description of SCT heat exchangers and TRT services

SUMMARY

- A variety of complementary techniques have been used to probe the material in the ATLAS Detector
- Generally the Monte Carlo is in very good agreement with data
    - Small differences between data and Monte Carlo have been observed and understood
- Systematic studies of the material throughout the whole detector are underway to quantify any difference between data and simulation
- Simulation geometry will be updated to accurately model the detector

EXTRA SLIDES

ID MATERIAL ESTIMATION

- Radiation length of a given detector layer

$$\frac{X}{X_0} = -\frac{9}{7}\ln\left(1 - F_{conv}\right)$$

with:

$$F_{conv} = \frac{N_{reco}}{N_{tot}}\frac{F_{comb}F_{mis}}{\epsilon}\frac{1}{\exp\left(-7/9M_{up}\right)}$$

- F_{conv} fraction of converted photons
- N_{reco} number of reconstructed conversions
- N_{tot} initial numbers of photons
- M_{up} material upstream of a given layer
- F_{comb} correction for combinatorial background
- F_{mis} correction for resolution effects
- ε efficiency
- F_{comb}, F_{mis} and ε are currently evaluated on simulation