Confronting improv... ...run 2 data

Track Reconstruction at the Energy Frontier

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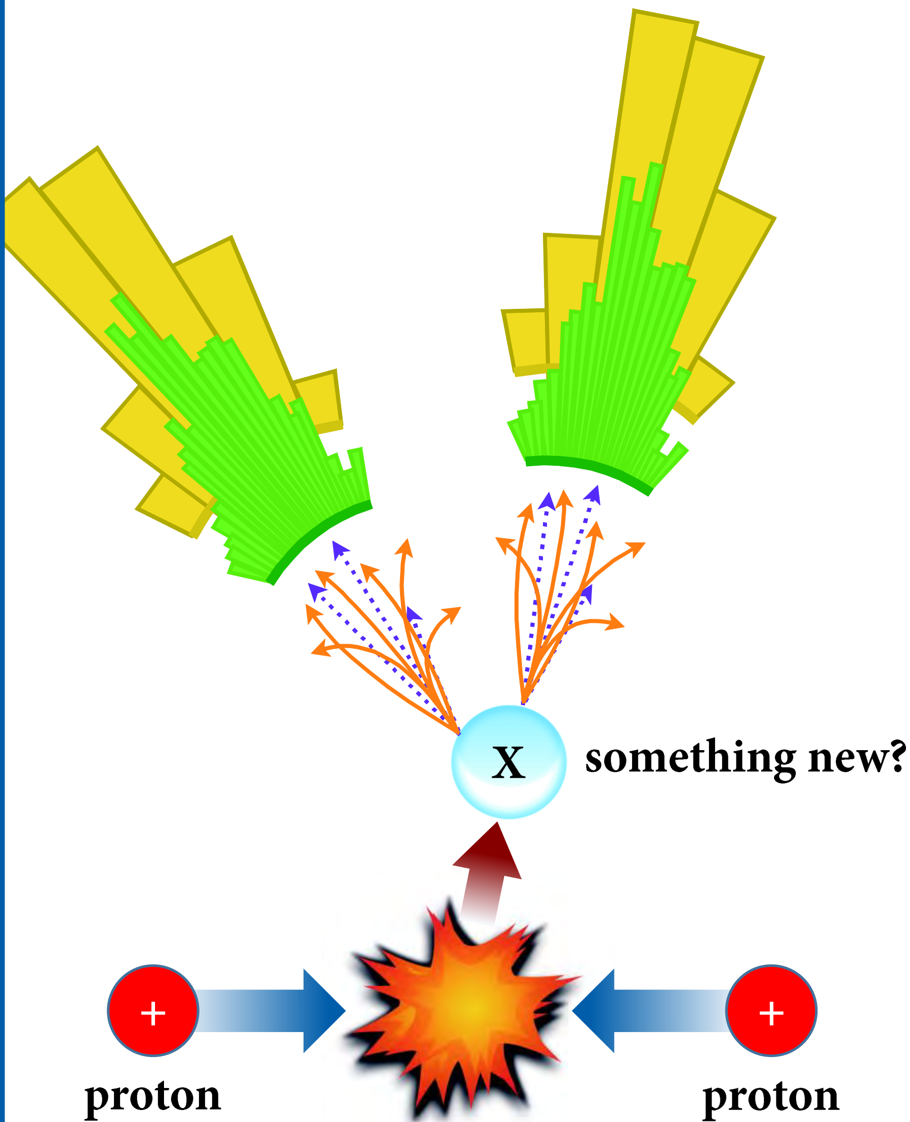
University of Innsbruck

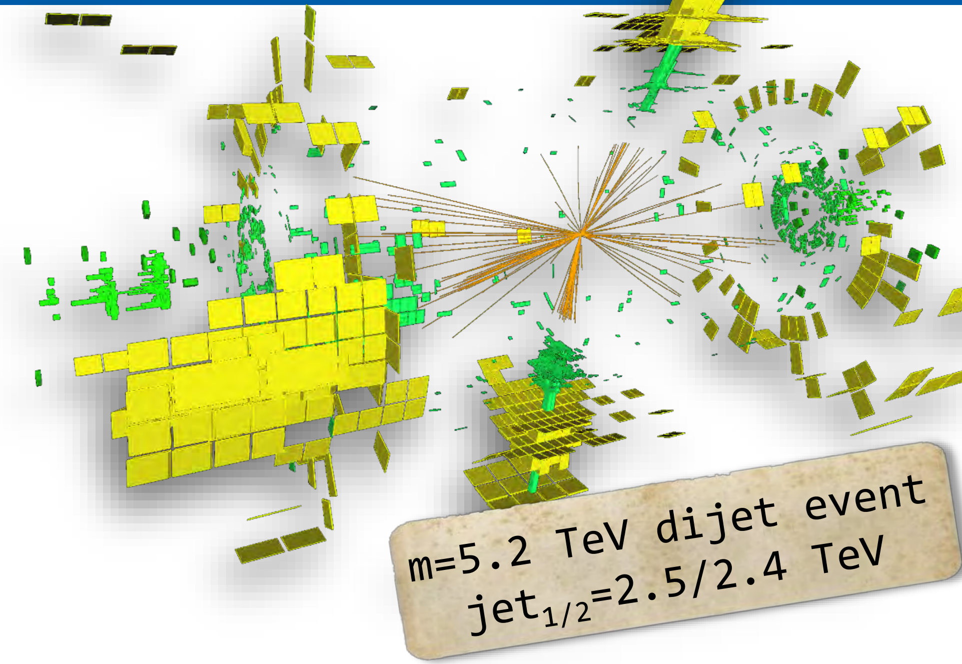
51st Rencontres de Moriond EW – 15th March 2016

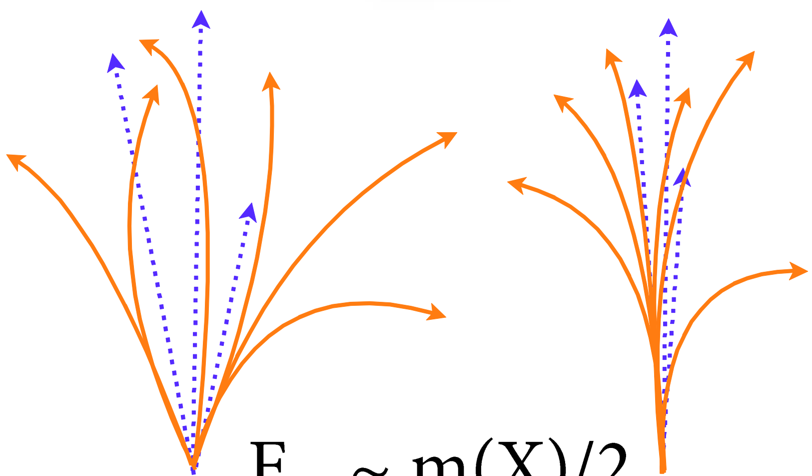
ATLAS EXPERIMENT

universität innsbruck

Energy Frontier: Jets at 13 TeV



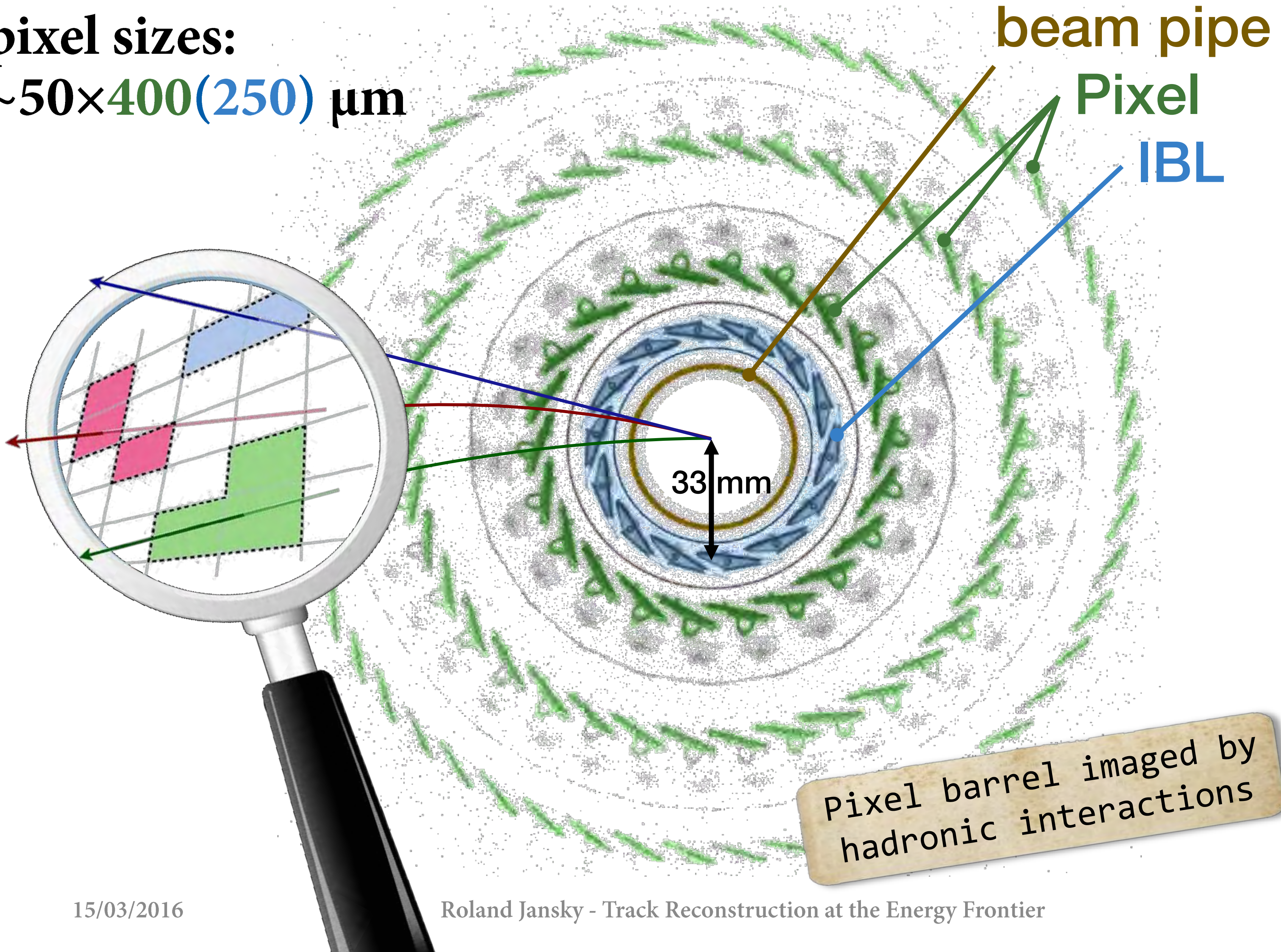




$$E_{jet} \sim m(X)/2$$

Tracking with Pixel Detectors

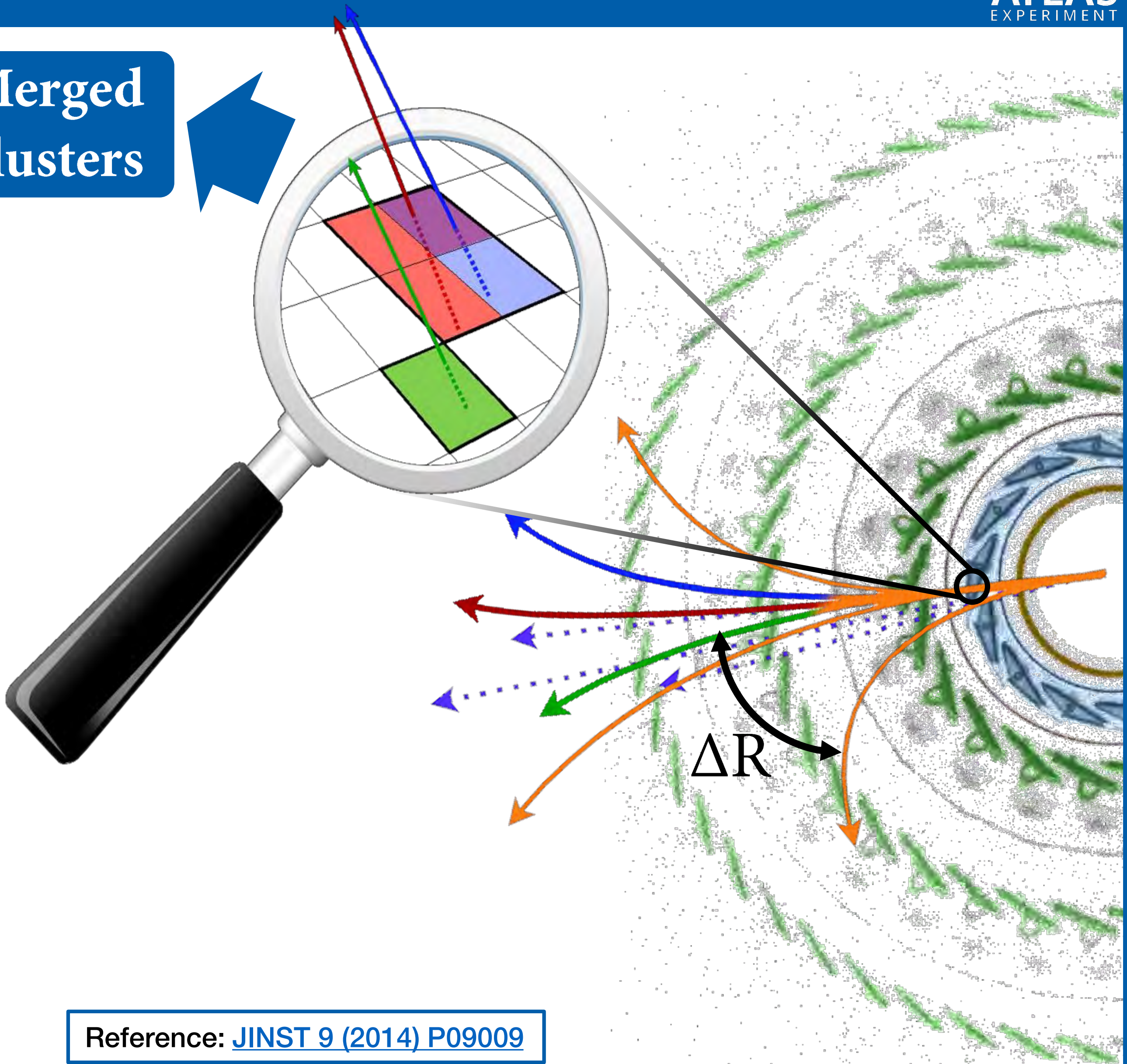
pixel sizes:
~50×400(250) μm



Tracking in Dense Environments

Difficult for Tracking

Merged clusters



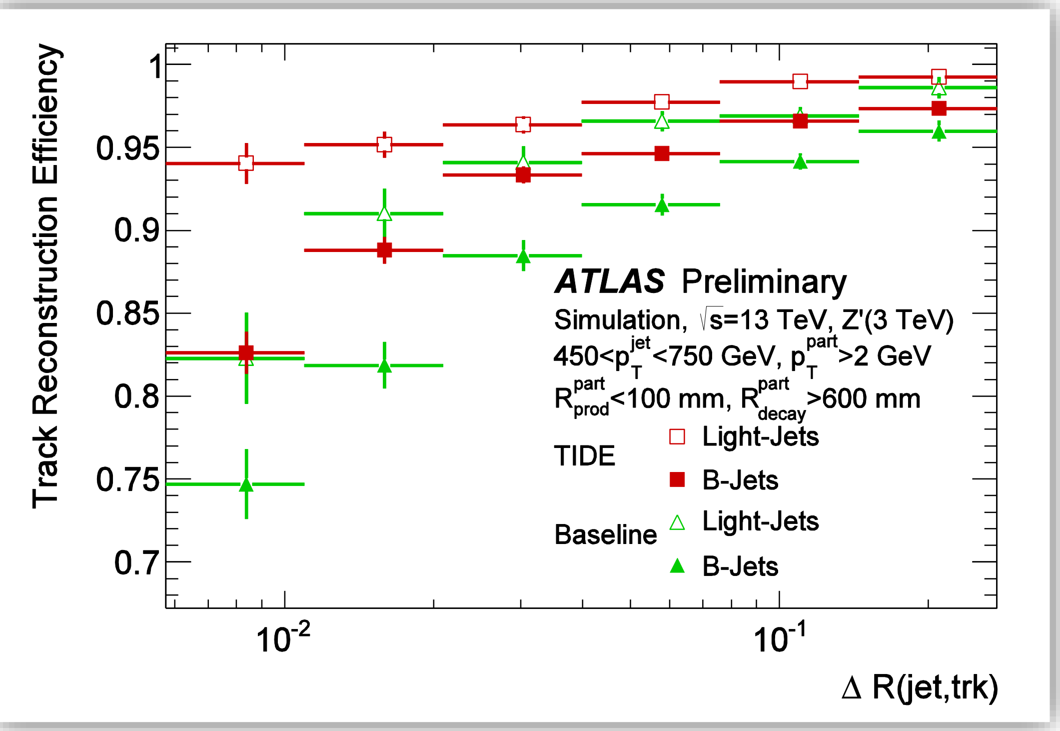
Reference: JINST 9 (2014) P09009

Tracking Performance in Jets

Merged clusters

Difficult for Tracking

Studied & Improved



Reference: ATL-PHYS-PUB-2015-006

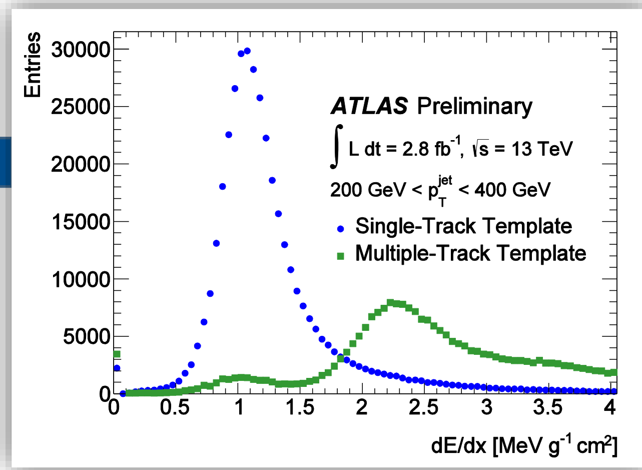
Measuring Tracking Efficiency in Data

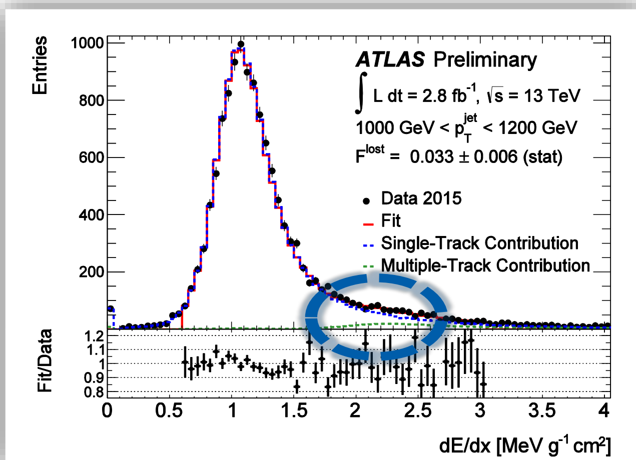
Merged clusters

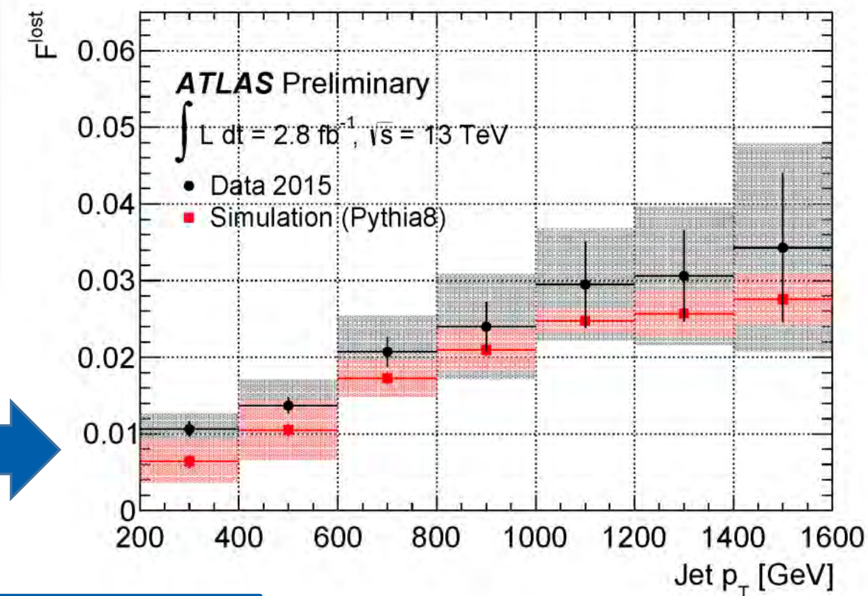
Difficult for Tracking

Studied & Improved

Measured in Data







Reference: ATL-PHYS-PUB-2016-007

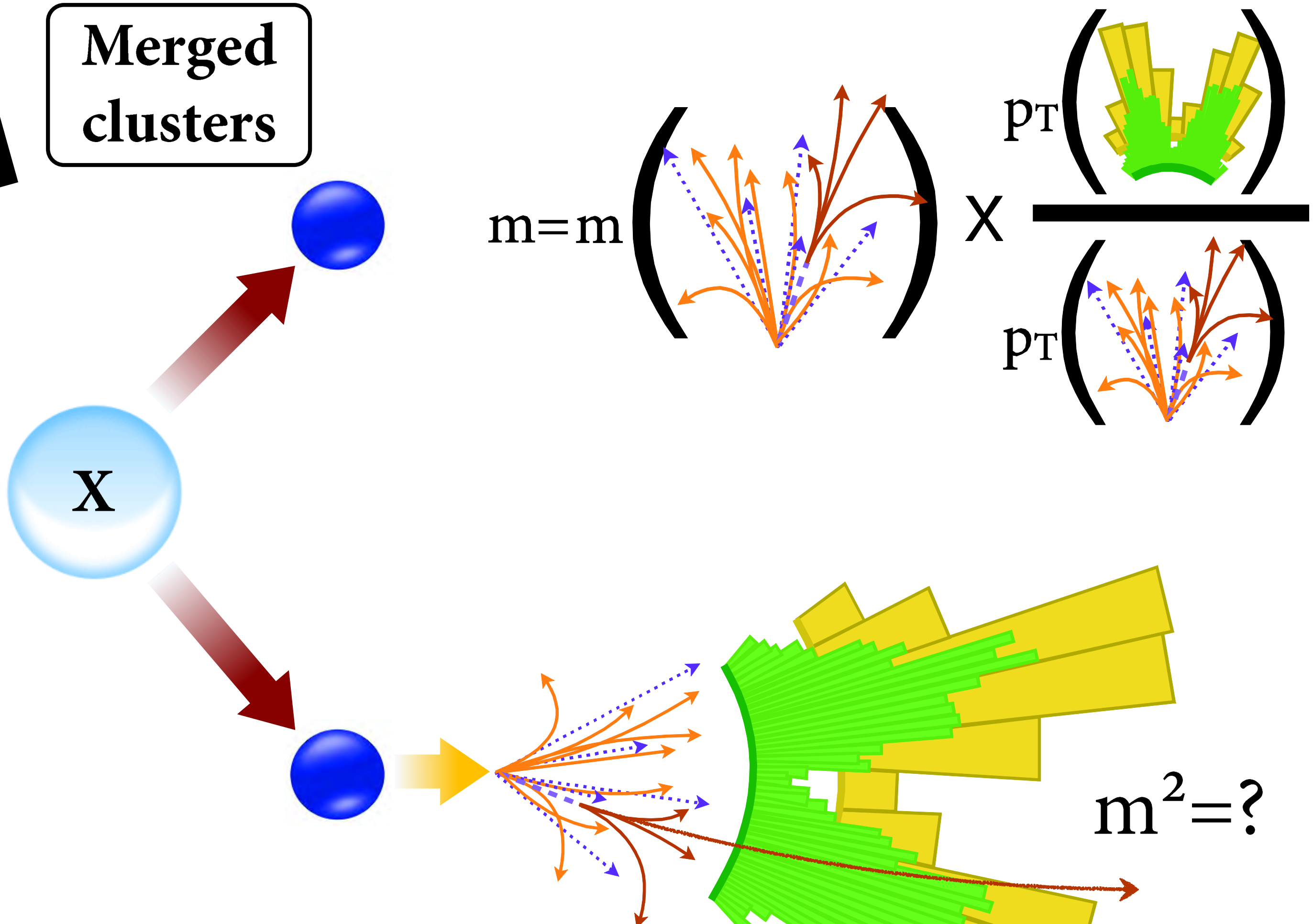
Harvesting the Fruits of our Labour

Merged clusters

Difficult for Tracking

Studied & Improved

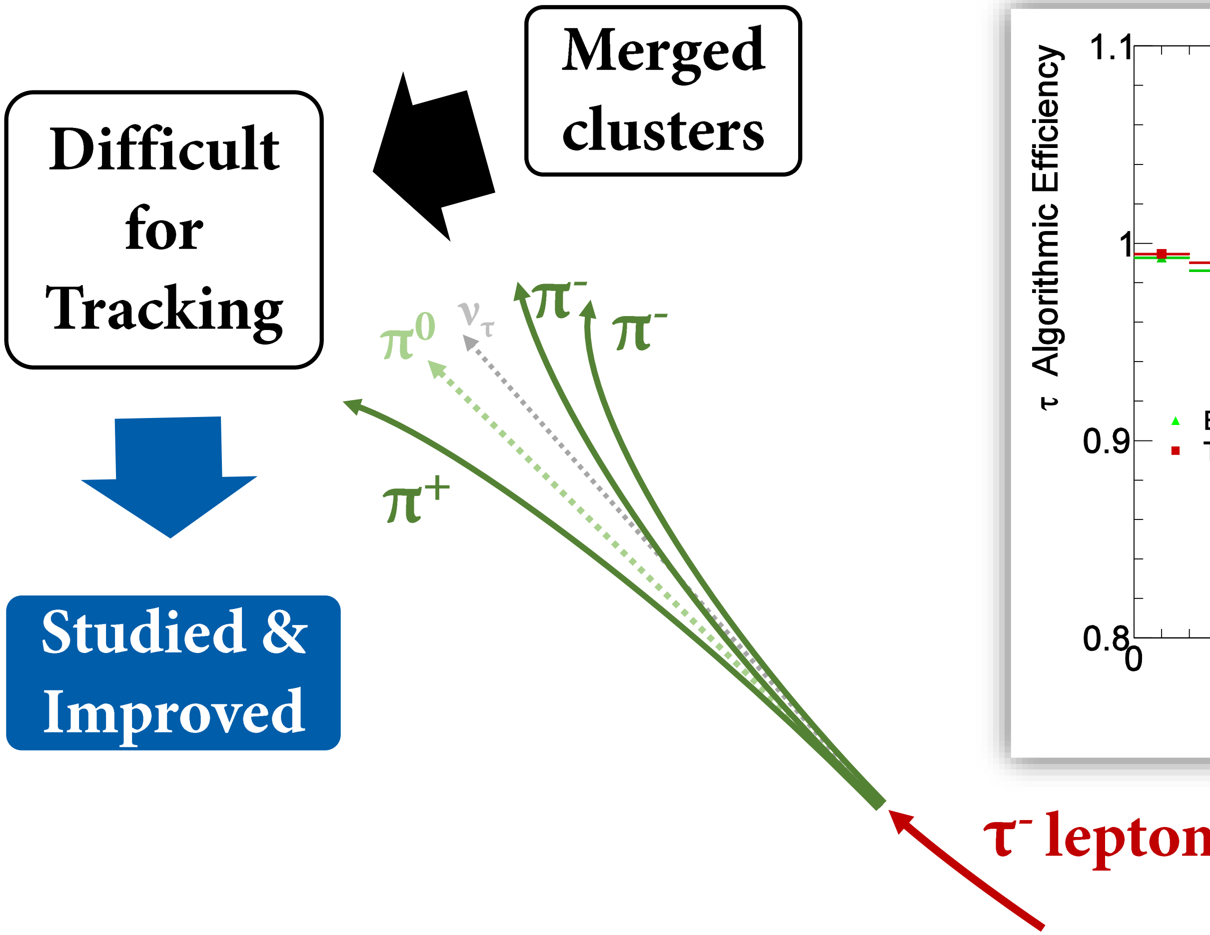
Measured in Data

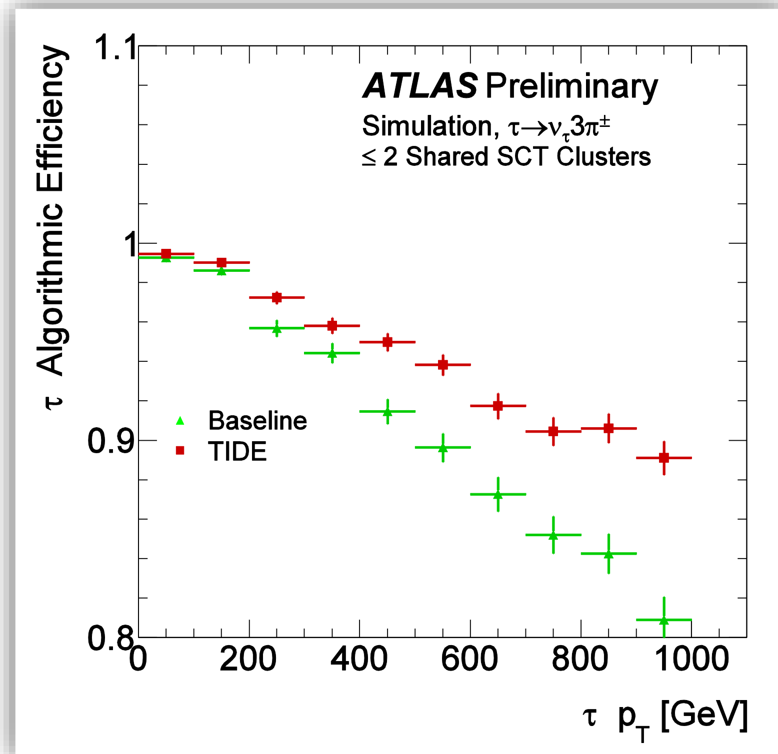


Ready for Discovery!

BACKUP

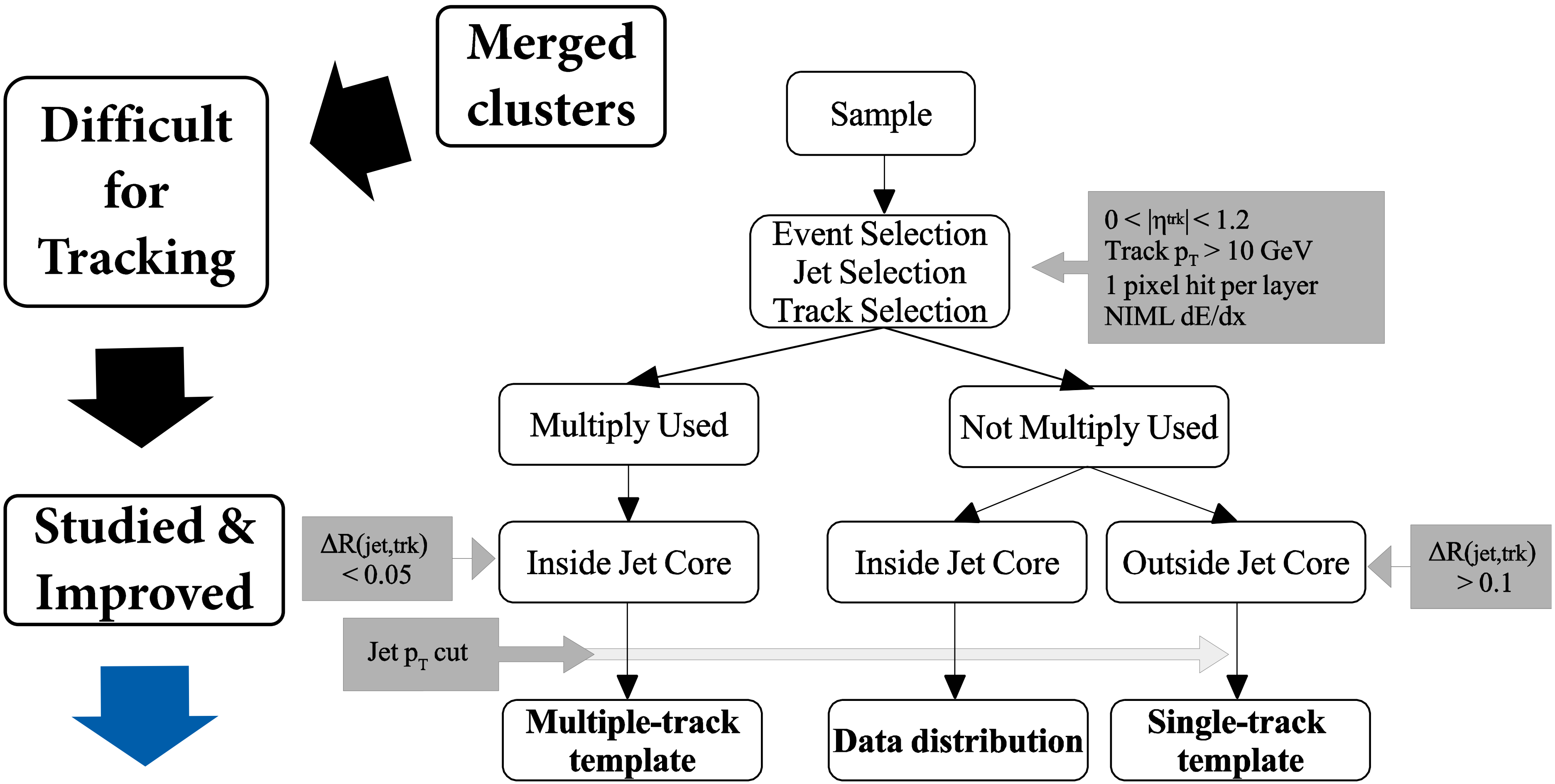
Reconstruction performance for taus





Reference: ATL-PHYS-PUB-2015-006

Measuring Tracking Efficiency in Data

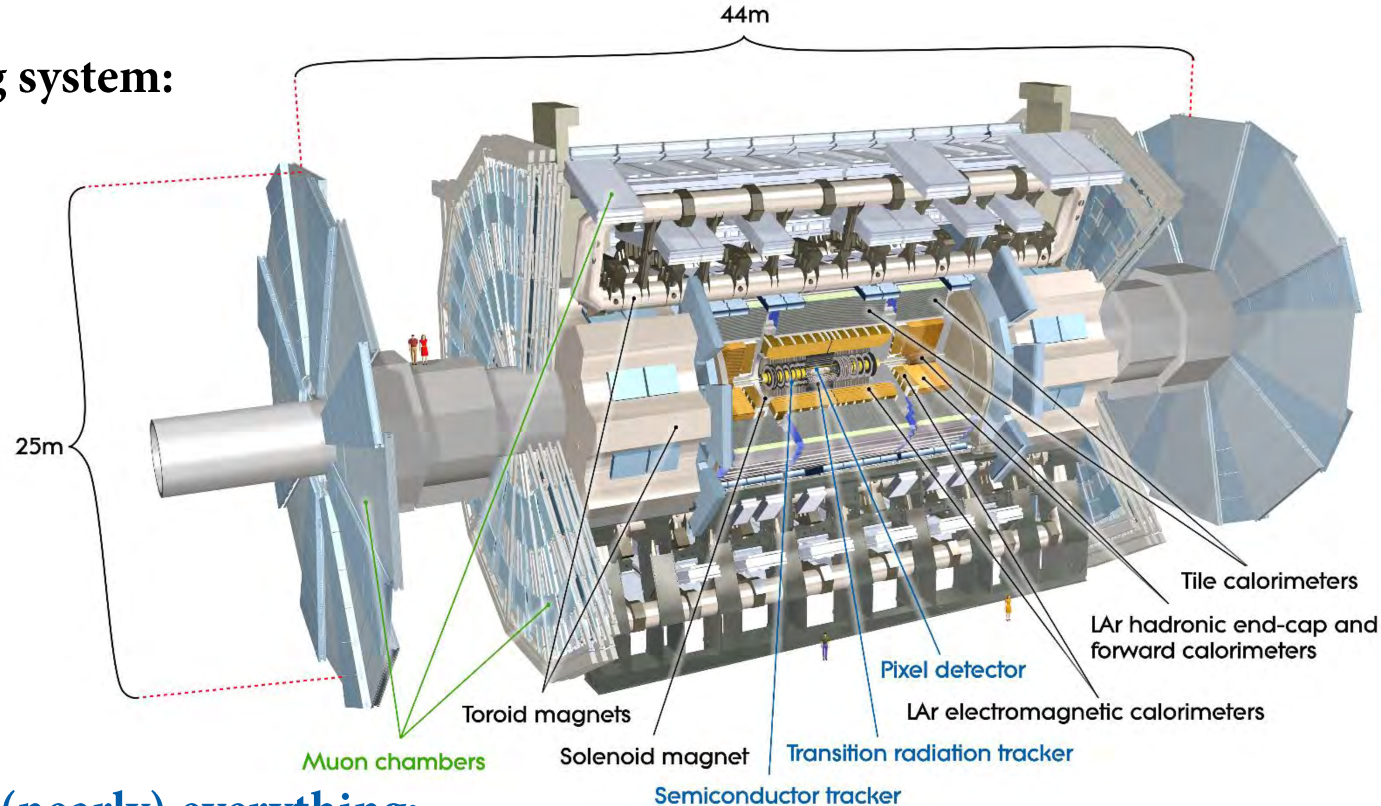


Measured in Data

Reference: ATL-PHYS-PUB-2016-007

ATLAS detector & Track reconstruction

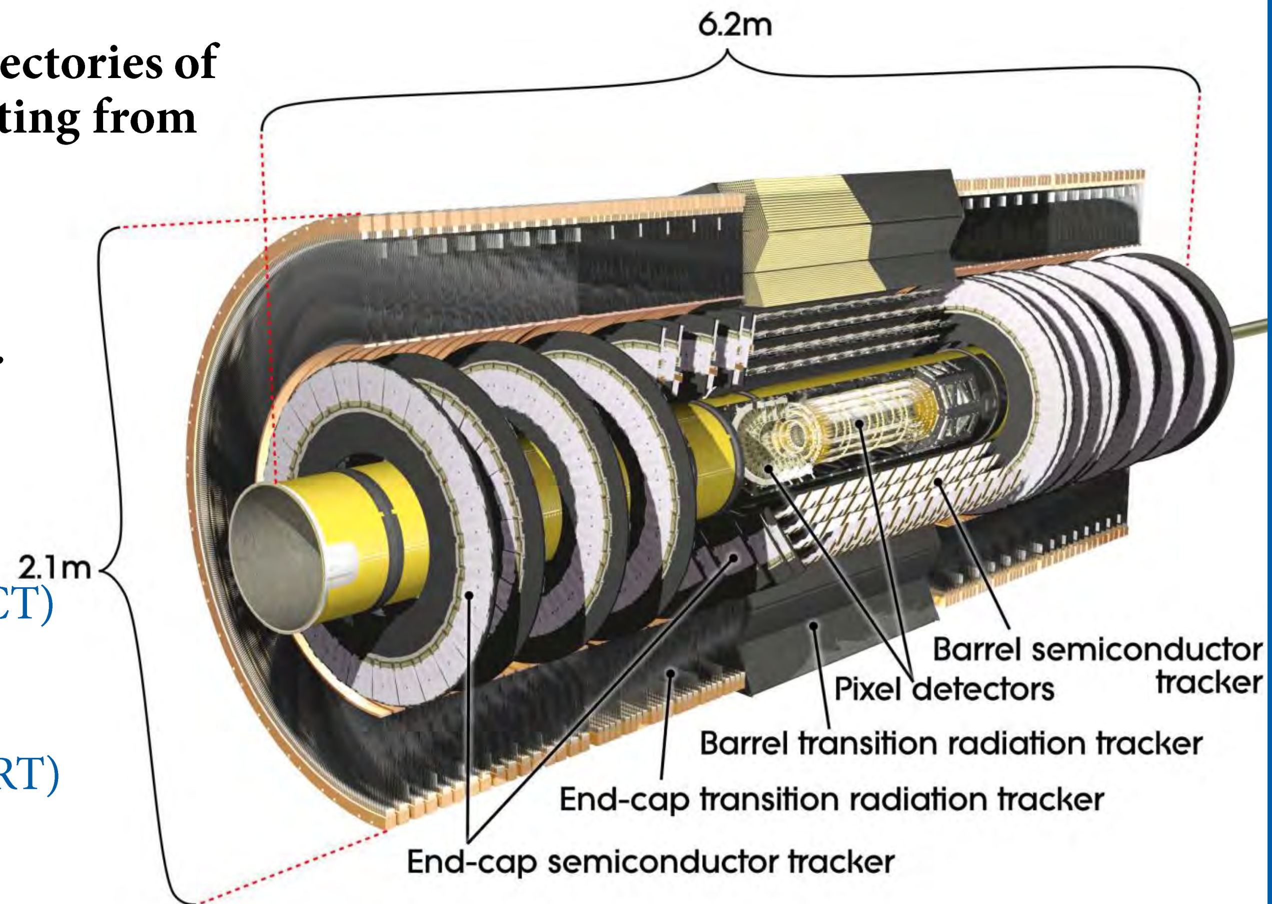
- **Two major tracking system:**
  - **Muon System**
  - **Inner Detector**
- Used in both offline reconstruction and the trigger.



- **Tracks are used for (nearly) everything:**
  - Lepton reconstruction
  - Single vertex identification
  - Pileup removal (jets and MET reconstruction)
  - Jet reconstruction & flavour tagging

ATLAS Inner Detector

- **Designed to measure trajectories of charged particles originating from the interaction point.**
- **Comprises three detector technologies:**
  - Silicon pixels
    - ~86M channels
  - Silicon microstrips (SCT)
    - 6M channels
  - Drift tubes (Transition Radiation Tracker – TRT)
    - 700k straws & PID



- Located within a 2T magnetic field created by a solenoid

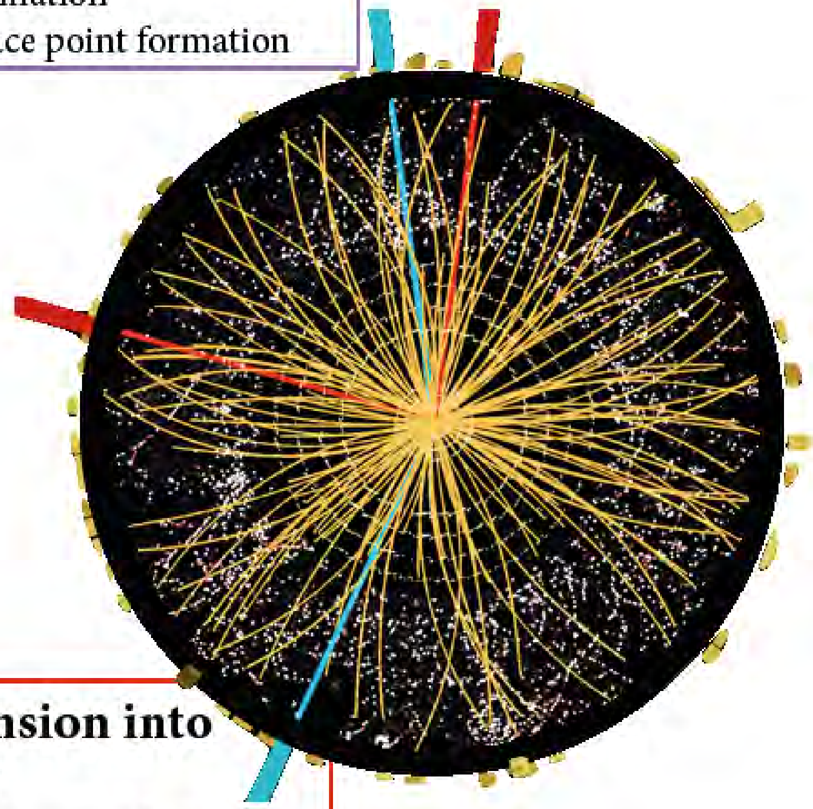
Tracking in ATLAS

Pre-processing
- Pixel+SCT clustering
- TRT drift circle formation
- space point formation

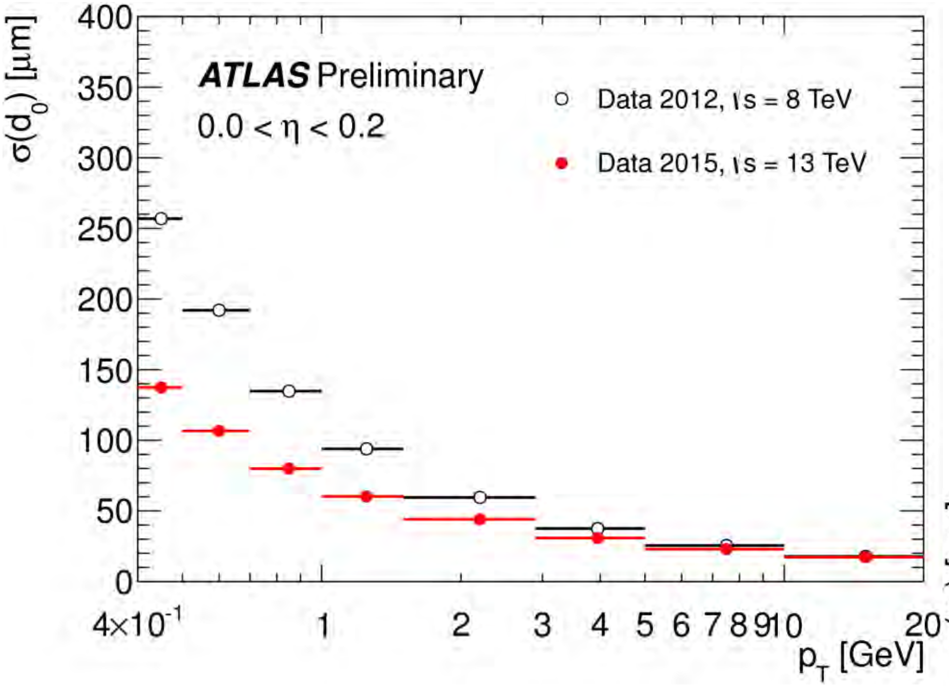
Combinatorial track finder
- iterative :
  1. Pixel seeds
  2. Pixel+SCT seeds
  3. SCT seeds
- restricted to roads
- removal of duplicate candidates

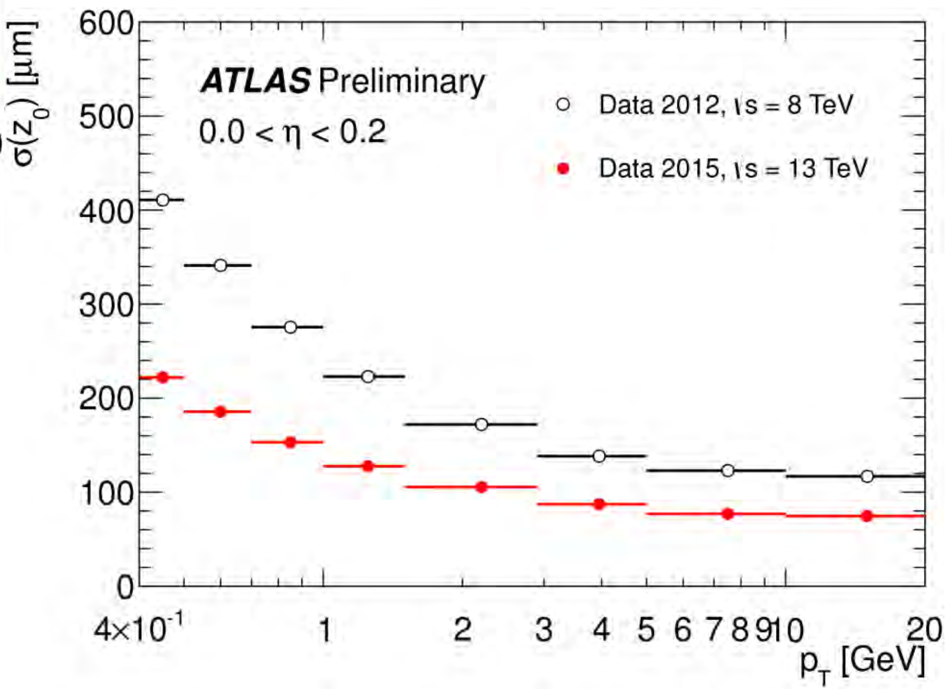
Ambiguity solution
- precise least square fit with full geometry
- use of neural network pixel clustering
- select best silicon tracks using:
  1. hit content, holes
  2. number of shared hits
  3. fit quality…

Extension into TRT
- progressive finder
- refit of track and selection



Impact Parameter Run 1/2 Comparison

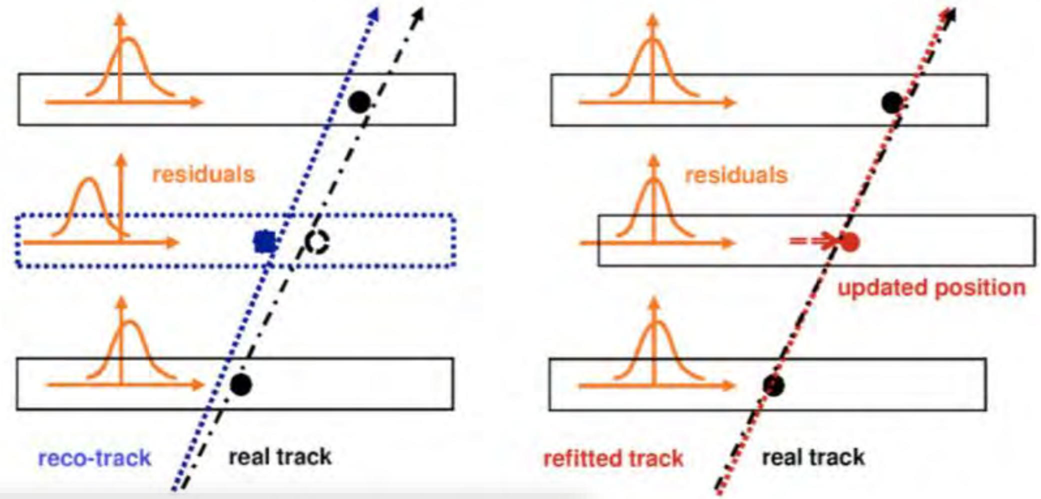


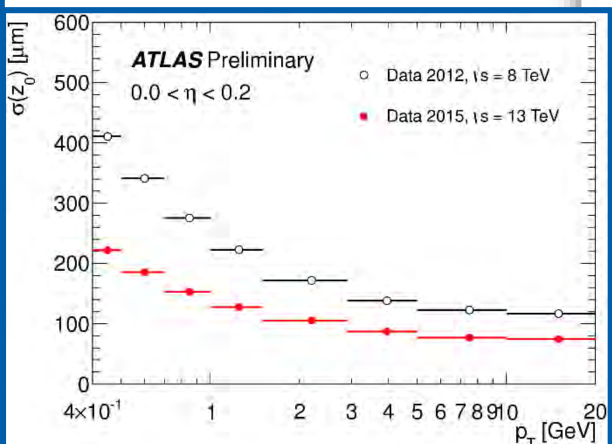


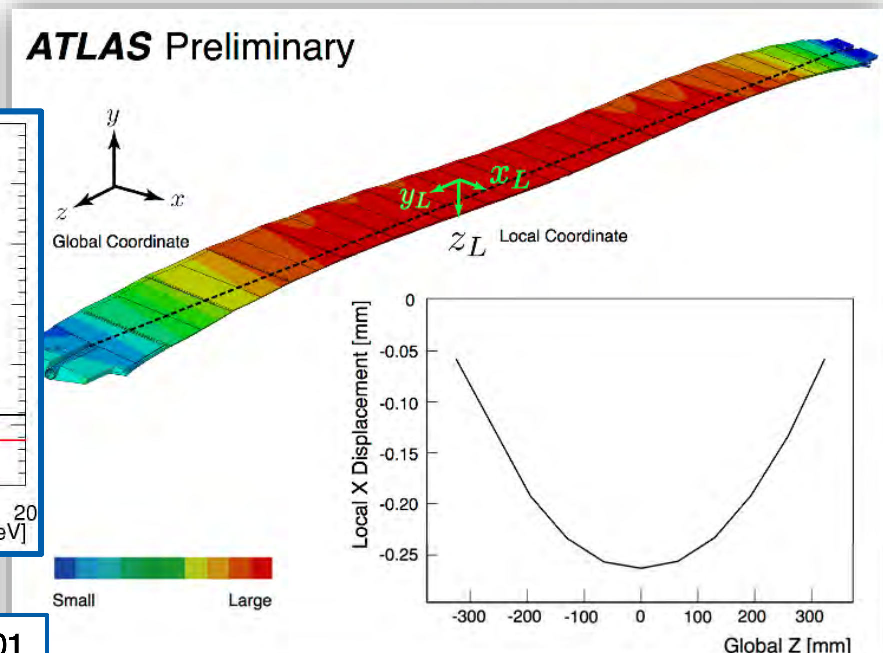
Detector alignment for ATLAS & IBL

- **Detector positions used in track reconstruction do not correspond to actual positions during data taking.**
- **Can be corrected for by minimizing χ^2 for large number of tracks, where**

$$\chi^2 = \left(\frac{\left|x_i^{meas} - x_i^{fit}\right|}{\sigma_i}\right)^2.$$







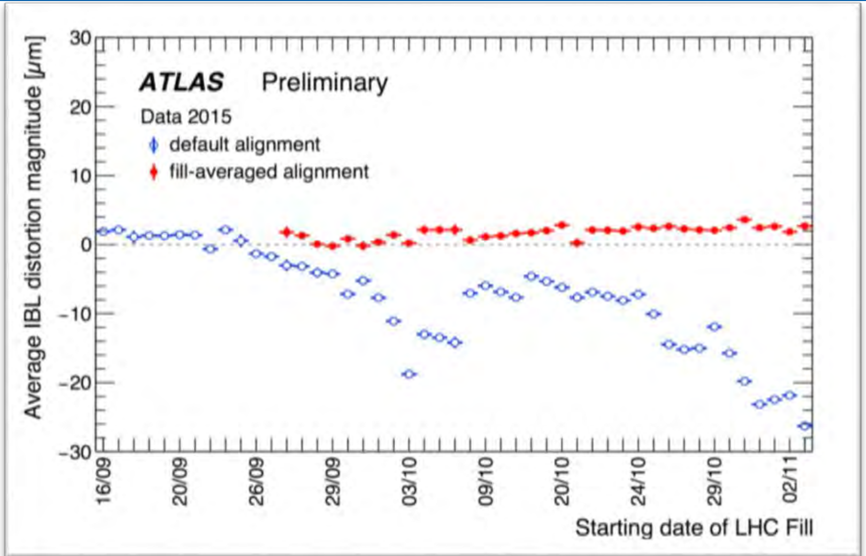
Reference: ATL-INDET-PUB-2015-001

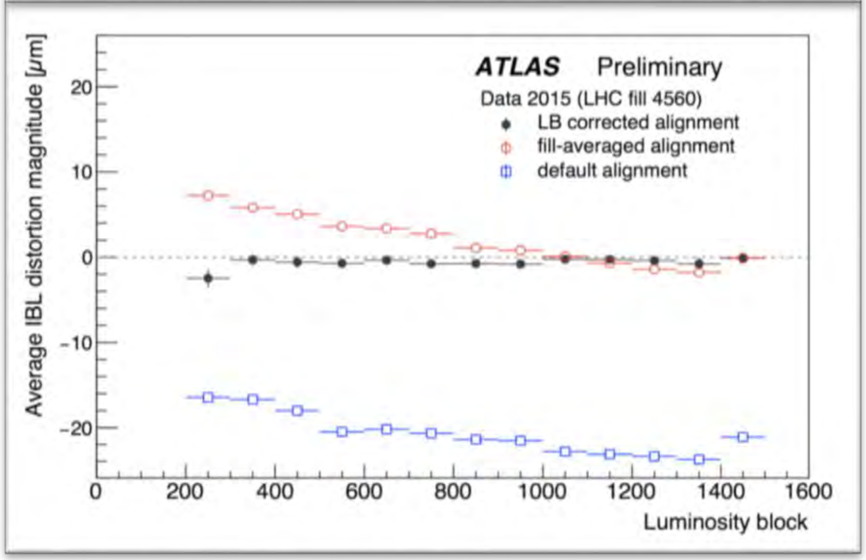
- **Installed new innermost pixel layer (IBL) before run 2.**
- **Significant improvements to tracking performance.**
- **Can exhibit local distortions.**

Time dependent alignment for ATLAS

- **Non-constant IBL distortion magnitude observed from end of September.**
  - Related to an increase of power consumption of IBL modules correlated with increasing integrated luminosity.
- Triggered major change to how alignment is performed within ATLAS.
- To mitigate such effects: **time dependent correction for pixel detector.**

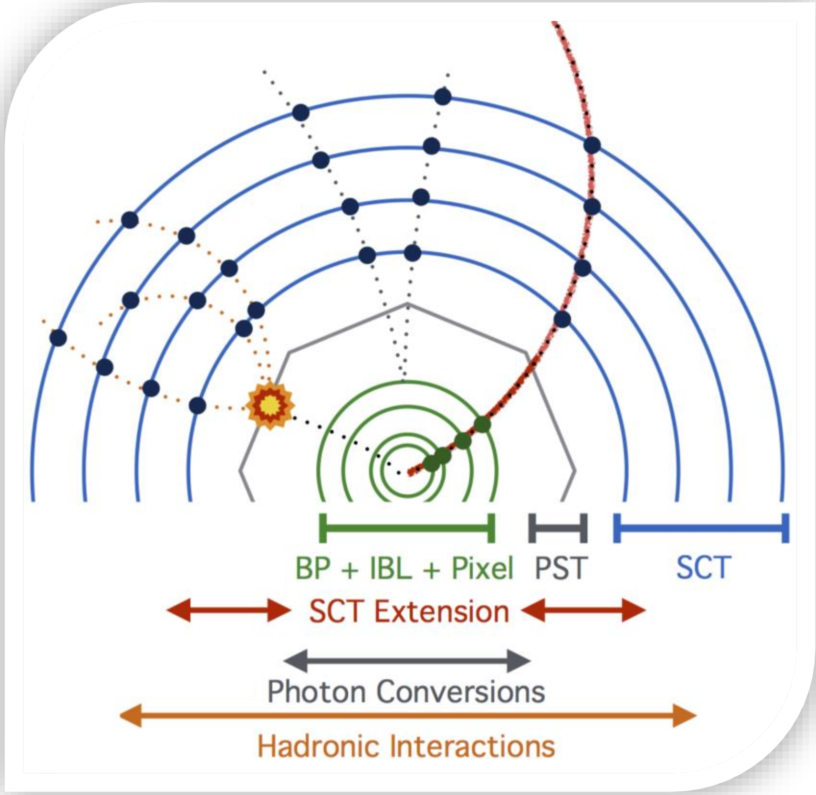
1. **Changes from run to run of the LHC:**
   - Corrected directly at so called calibration loop
   - Using additional DoF to include IBL distortion
   - Reminder: Effect of 20 μm distortion on flavour-tagging:
     → Light-jet rejection reduced by 50%
2. **Changes within a single run:**
   - Bowing is corrected for every 100 luminosity blocks.





Studies of Inner Detector material (1/4)

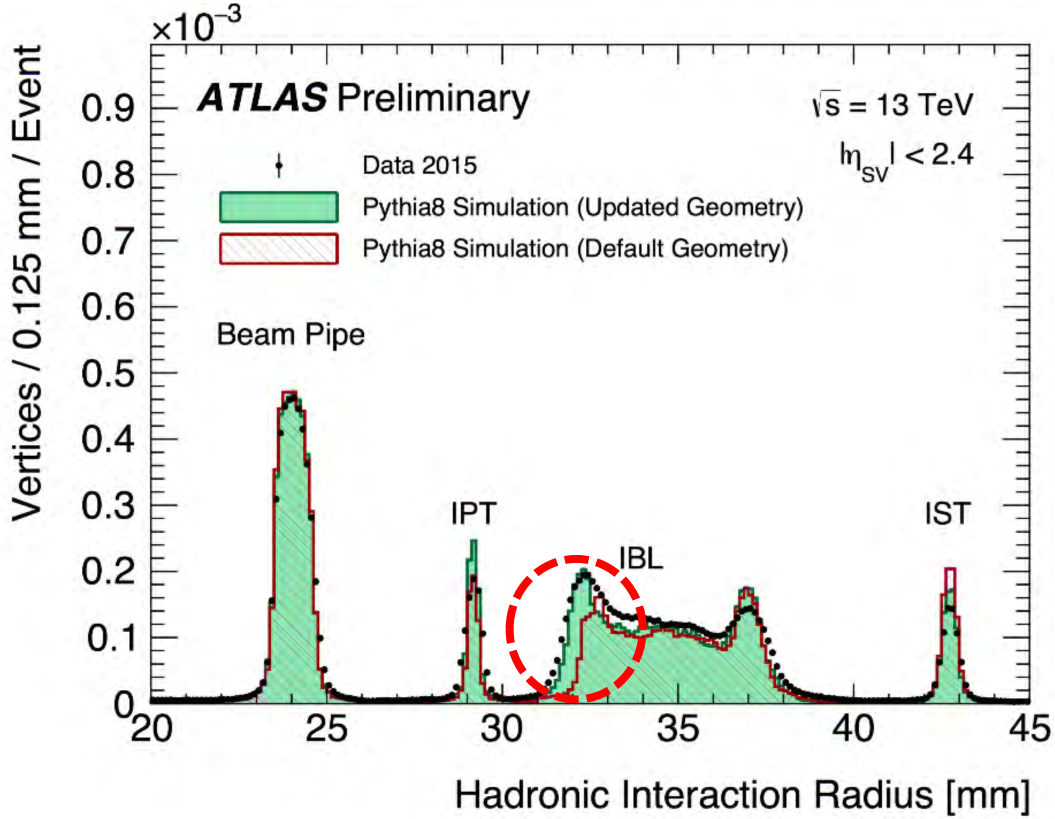
- Precise knowledge of material in inner detector **crucial** for good tracking performance and several other applications.
- Material description used in extrapolating particles trajectories through the inner detector.
  ➔ crucial for best tracking performance (e.g. resolution of reconstructed tracks).
- Material description used in detector simulation.
  ➔ important for accuracy of Monte Carlo simulation.
- Three independent measurements:
  1. **vertices from hadronic interactions**
  2. **vertices from photon conversions**
  3. **efficiency to extend tracks from pixel into the SCT**
- Precise measurement of material allows for improved description.

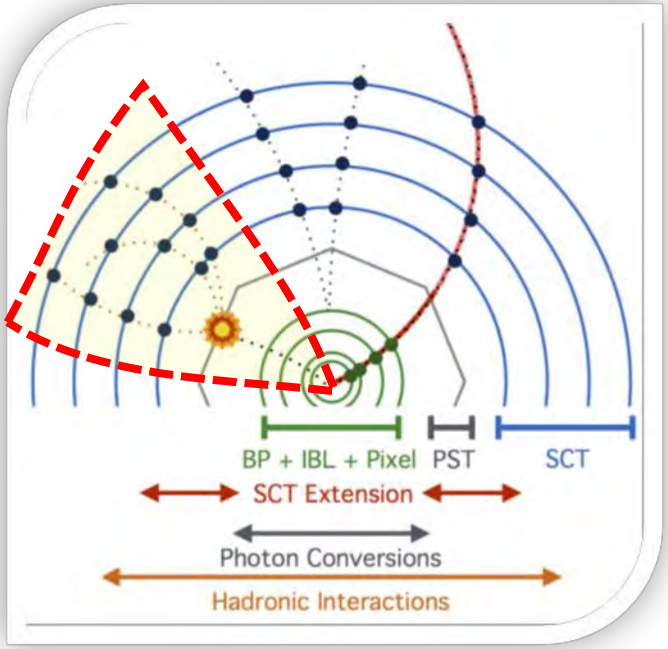


Studies of Inner Detector material (2/4)

1. vertices from hadronic interactions

- Inelastic hadronic interactions produce multiple daughter charged particles when hadrons traverse detector material.



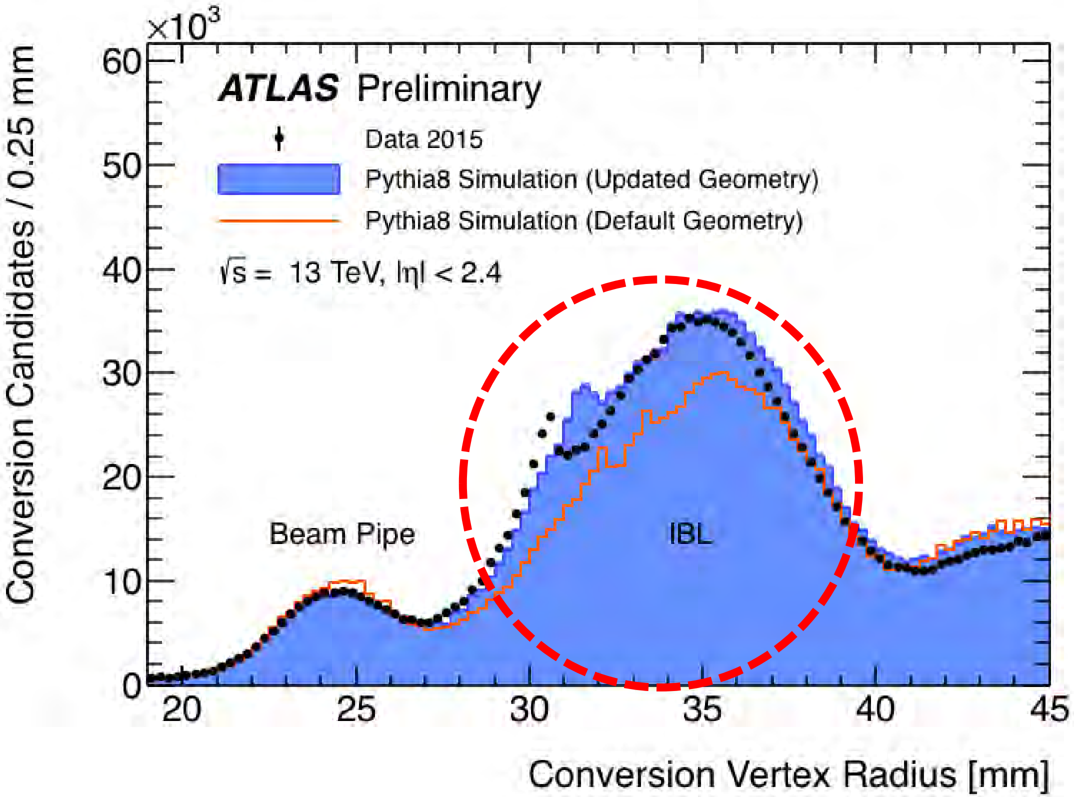


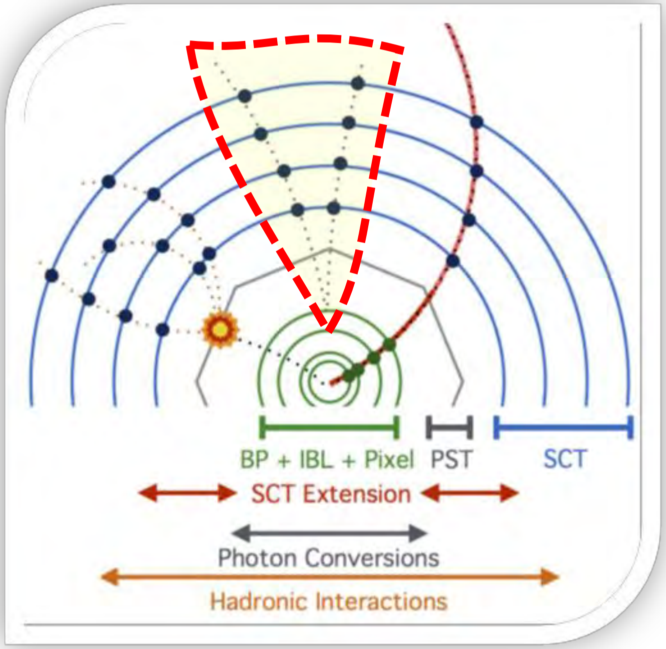
Reference: ATL-PHYS-PUB-2015-050

Studies of Inner Detector material (3/4)

2. vertices from photon conversions

- Interaction of photons with material of inner detector can lead to conversion of photon into e^+e^-.
- Probability to convert directly proportional to amount of material it traverses.

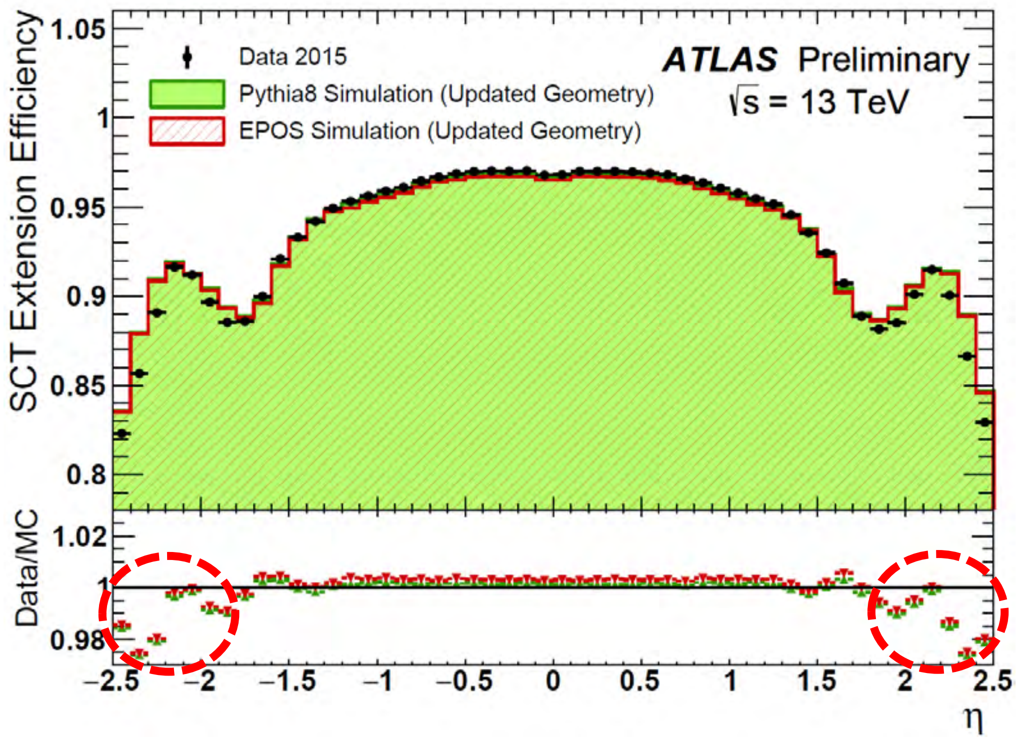


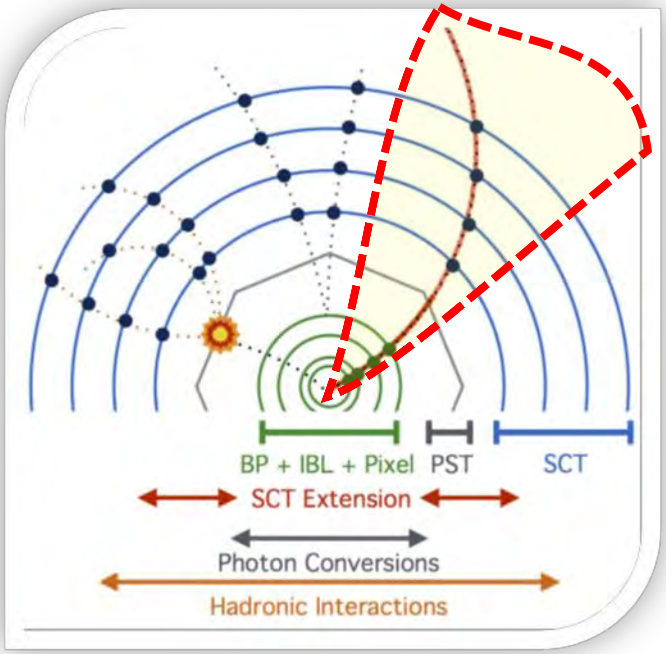


Reference: ATL-PHYS-PUB-2015-050

3. SCT extension efficiency

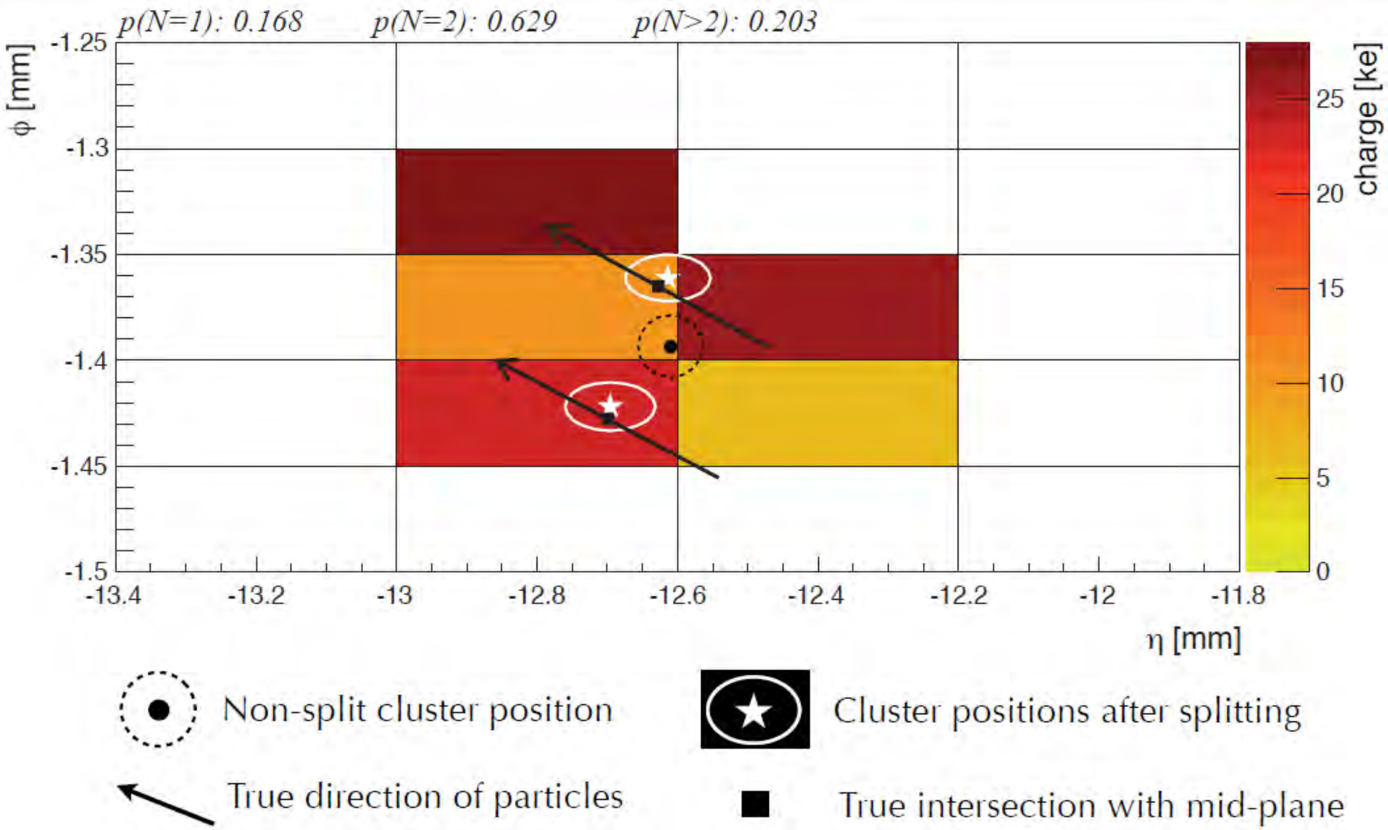
- Efficiency = rate to successfully add measurements from SCT to track candidate from pixel detector.
- More material ➔ less efficiency.
- Good probe for material between pixel and SCT.





Reference: ATL-PHYS-PUB-2015-050

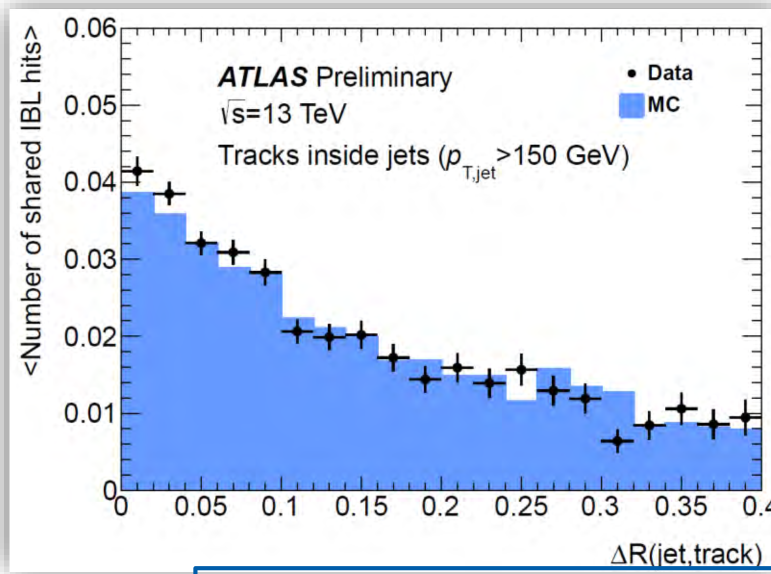
(Neural Network) Pixel Clustering



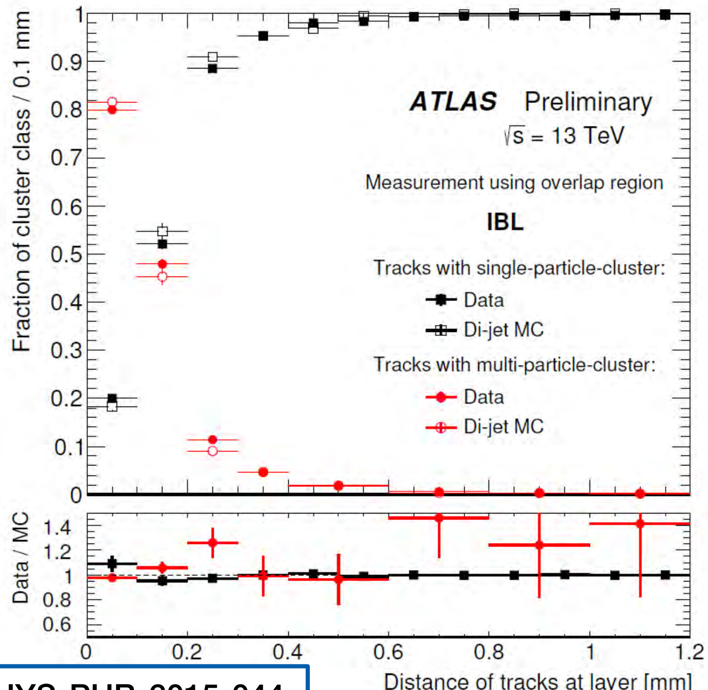
Example output for a cluster with 2 particles

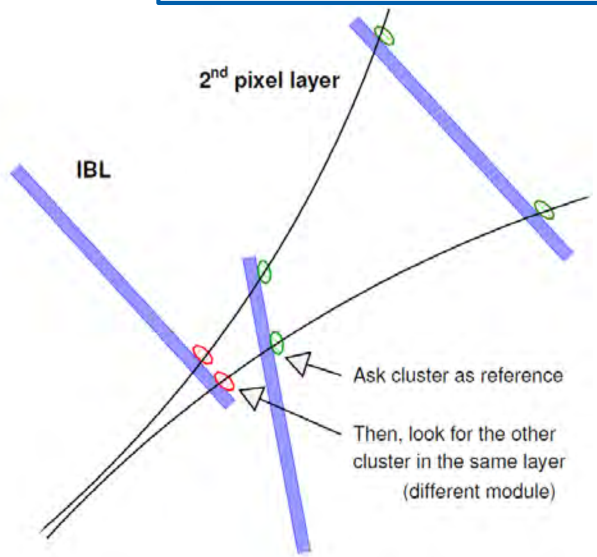
TIDE performance – data/MC agreement

- Comparison of **data and MC** for tracks in dense environments **show good agreement** for:
  - **Basic properties** (comparing clusters on track).
  - **Response of neural networks** (studying clusters on close by tracks using overlap regions in pixel detector).



Reference: ATL-PHYS-PUB-2015-018





Ref: ATL-PHYS-PUB-2015-044