ATLAS Track Reconstruction in Dense Environments and its Inefficiency Measurements using Pixel *dE/dx*

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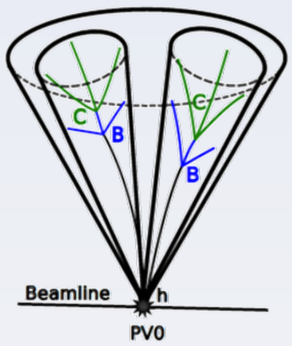
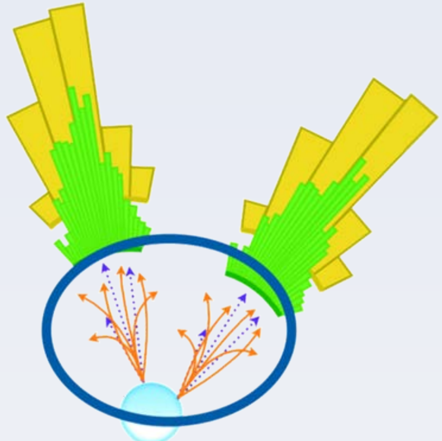
Tracking in Dense Environments (TIDE)

- Goal: resolve tracks even in core of high p_T jets
- Important for:
  - b-tagging and tau reconstruction
  - Boosted particle reconstruction & large jet substructure
  - Jet energy scale & mass calibration



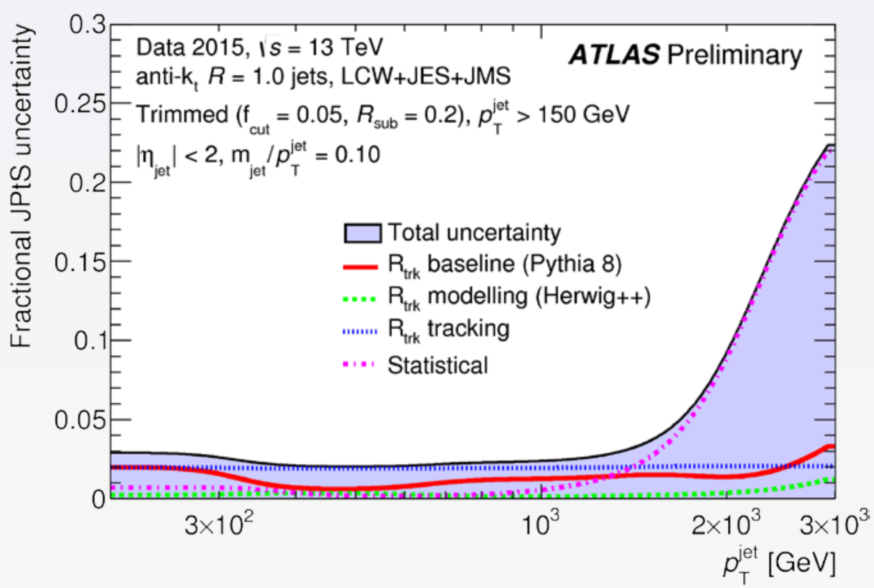


- Leading source of systematic uncertainty often track reconstruction

⇒ Ensure constantly high tracking efficiency also inside of jets

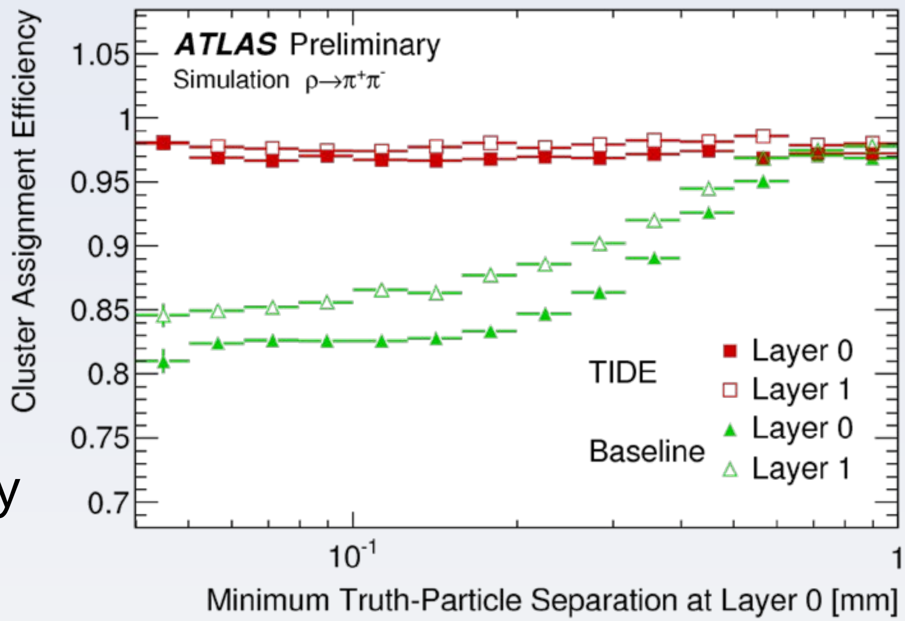
⇒ Determine tracking efficiency precisely

Jet p_T scale uncertainties for large-R jets



Tracking in Dense Environments – NN

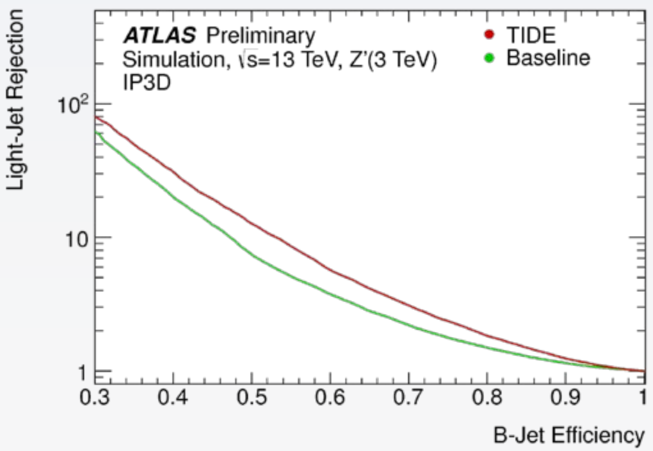
- Clusters shared between tracks penalized during track reconstruction → ensure high quality tracks
- Disadvantage in dense environments where clusters naturally merge
- Use artificial neural network (NN) to identify merged clusters and not penalize them



⇒ Probability of correct association of clusters to tracks at small separations greatly increased

⇒ Improved b-tagging and tau reconstruction performance:

⇒ At 60% b-tagging working point, 10% increase in efficiency for same light-jet rejection

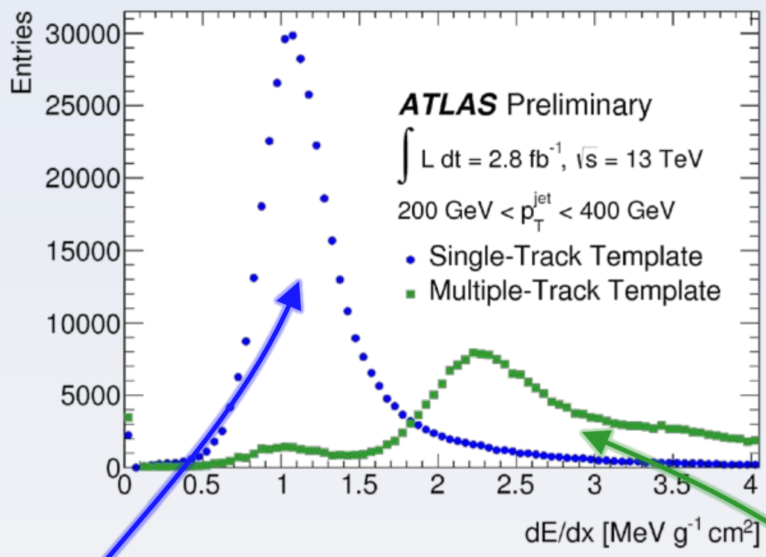


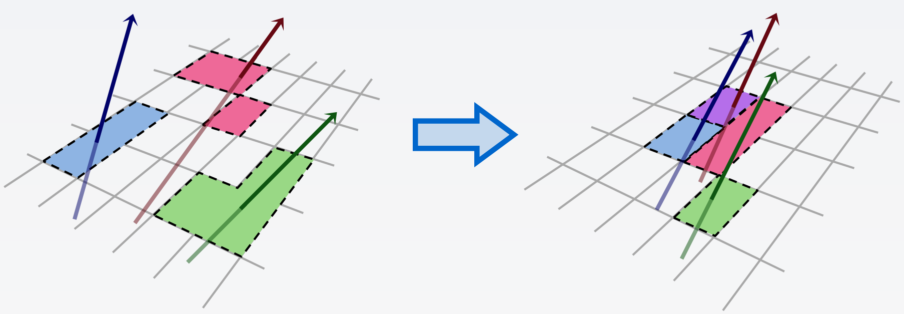
Plots from [ATL-PHYS-PUB-2015-006]

Efficiency from Energy Deposition (*dE/dx*)

Data driven method to determine fraction of lost tracks in jets

- Single particles, thin layers
  → *dE/dx* is Landau distribution
  (to first approximation)
- Multiple tracks close by or through same pixel → contribute to same cluster (merged)

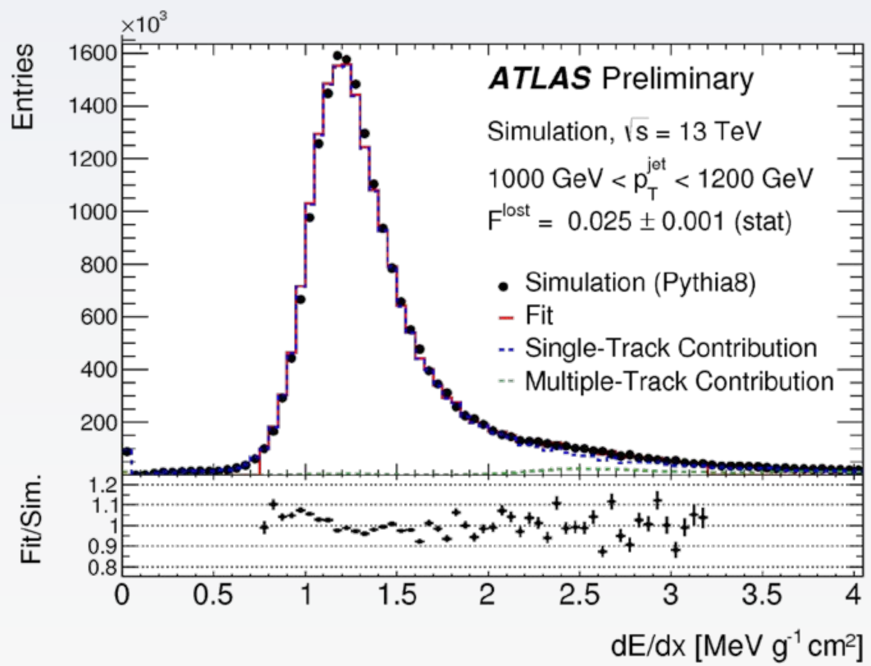




- Single particle: peak at MIP energy, two particles: peak at 2x MIP energy
- Ratio of events beneath two peaks gives probability to loose track due to merging

Template method

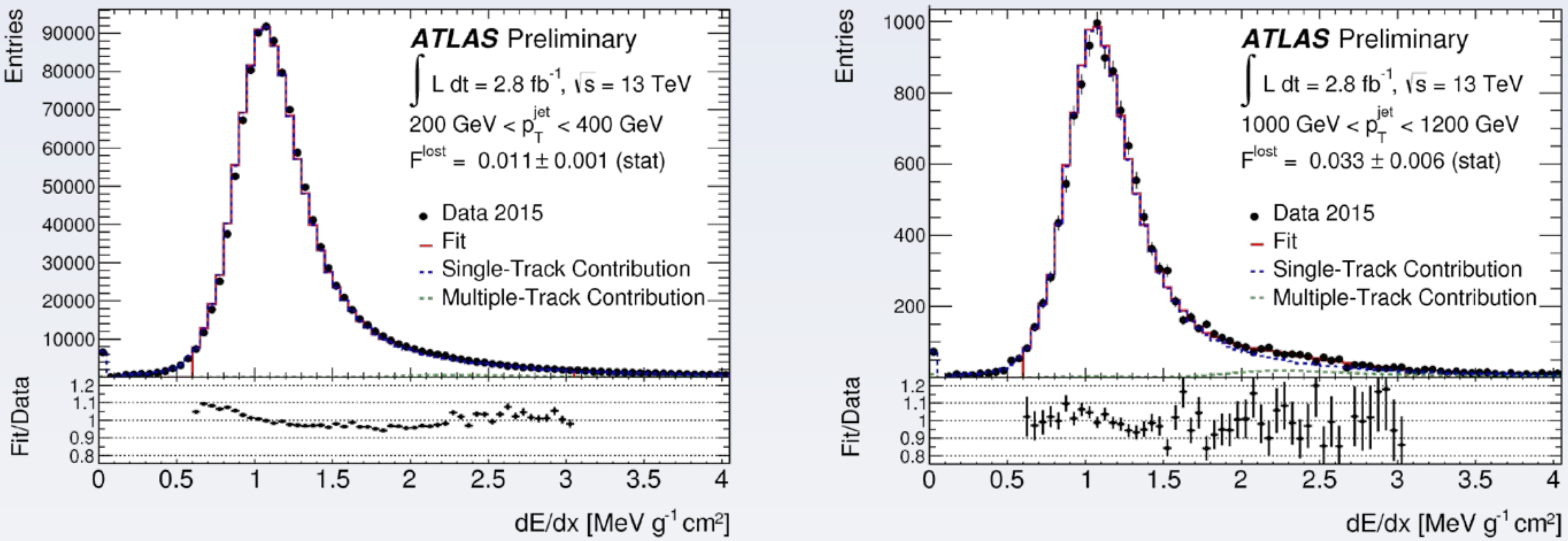
- Clusters hit by multiple reconstructed tracks
  - In jet core ($\Delta R < 0.05$) → **Multiple-Track Template**
- Clusters hit by single reconstructed tracks
  - In jet core ($\Delta R < 0.05$) → **Data**, to be fitted
  - Outside of jet core ($\Delta R > 0.1$) – suppress Multi-Track contamination → **Single-Track Template**



- Fit data with linear combination of templates
- Fraction of lost tracks is given by

$$F_{\text{lost}} = \frac{N_{\text{Multiple}}}{N_{\text{Single}}}$$

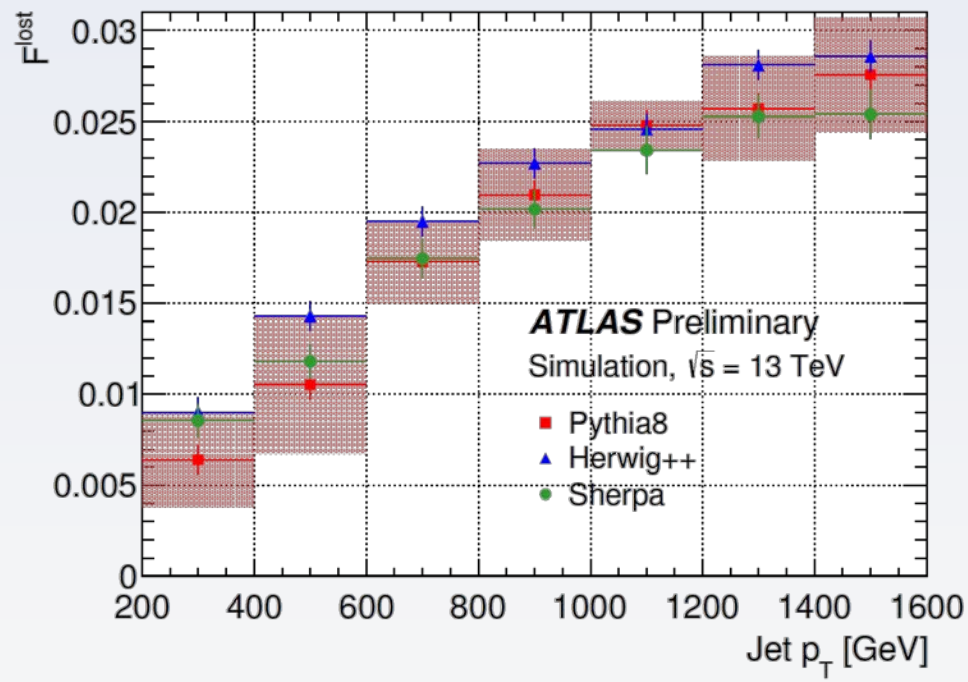
Fit Results



- Repeat in seven p_T bins from 200 - 1600 GeV
- Few events in high p_T → use low p_T templates in that region
- Minimize three-track contamination → perform fit in Region 0.67 - 3.07 (0.8 - 3.2) MeV g^{-1} cm^2 for data (simulation)

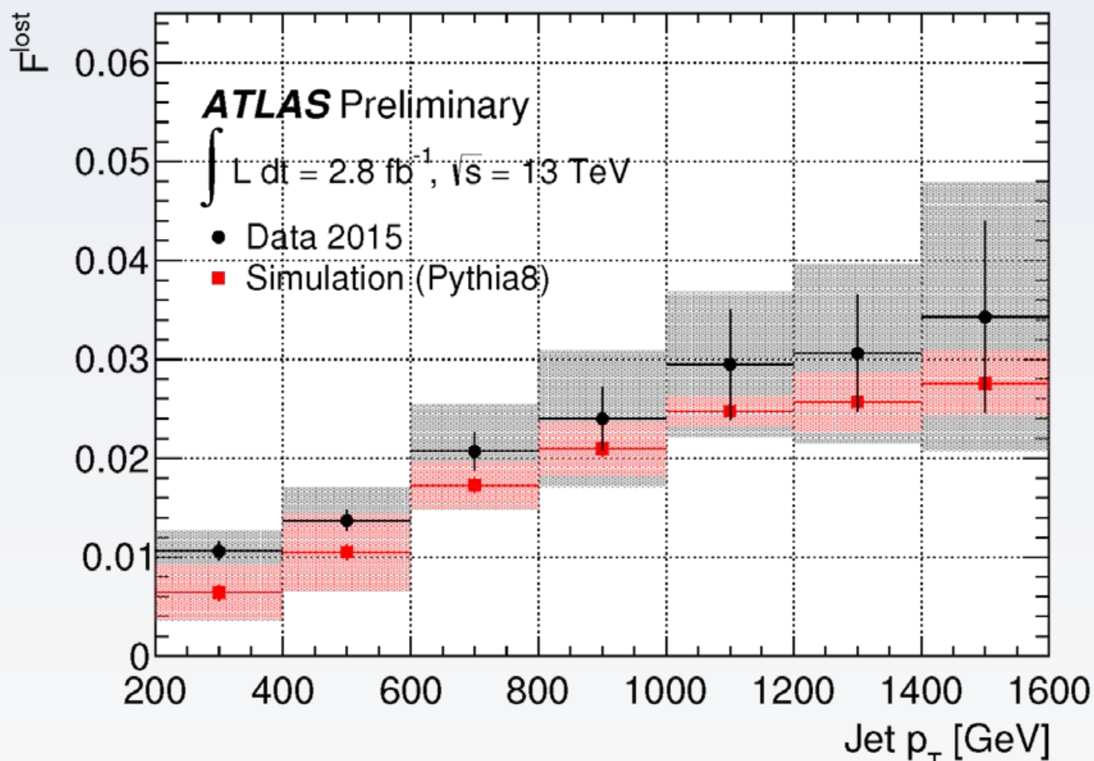
Uncertainties

- Data: Mostly statistics, and template method systematic which also decreases with more data
- Simulation: dominated by MC generator differences (better agreement with Herwig, ≈ 5% uncertainty on F_{lost})
- Additional uncertainty from choice of fit region (due to 3rd peak contamination)



Results – Fraction of Lost Tracks

- Data and Simulation agree well (within systematic uncertainties)
- Lost fraction within 1 - 3.5%
- Fraction reduced vastly since Run I (6 - 12% from 200 - 1200 GeV)



ATLAS Note ATL-PHYS-PUB-2016-007:
"Measurement of track reconstruction inefficiencies in the core of jets via pixel *dE/dx* with the ATLAS experiment using $\sqrt{s}$ = 13 TeV *pp* collision data"

Summary

- Tracking in dense environments especially important to understand high p_T jets
- Use neural network to detect merged pixel clusters and retain tracking efficiency in jet cores
- Applied method to determine tracking efficiency in dense environments from pixel *dE/dx*
- Tracking inefficiency found to be 1 - 3.5%, significantly improved since Run I and in good agreement with simulation

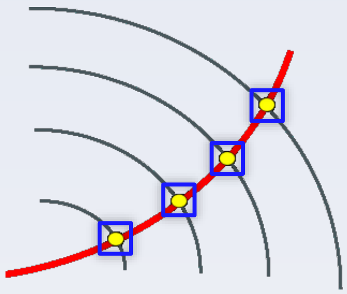
Thanks for your attention!

Backup

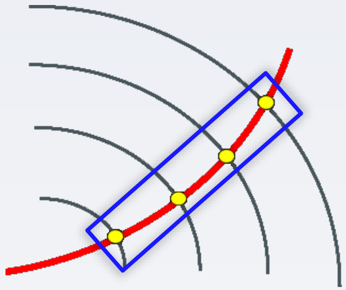
dE/dx Variables

ATLAS uses multiple dE/dx definitions:

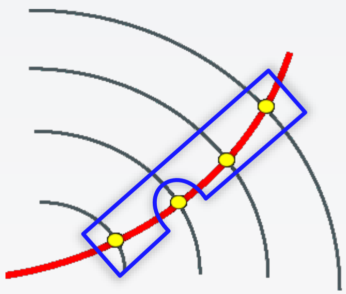
- Cluster dE/dx:
  - dE/dx deposited at each layer of the detector
  - Used in this analysis



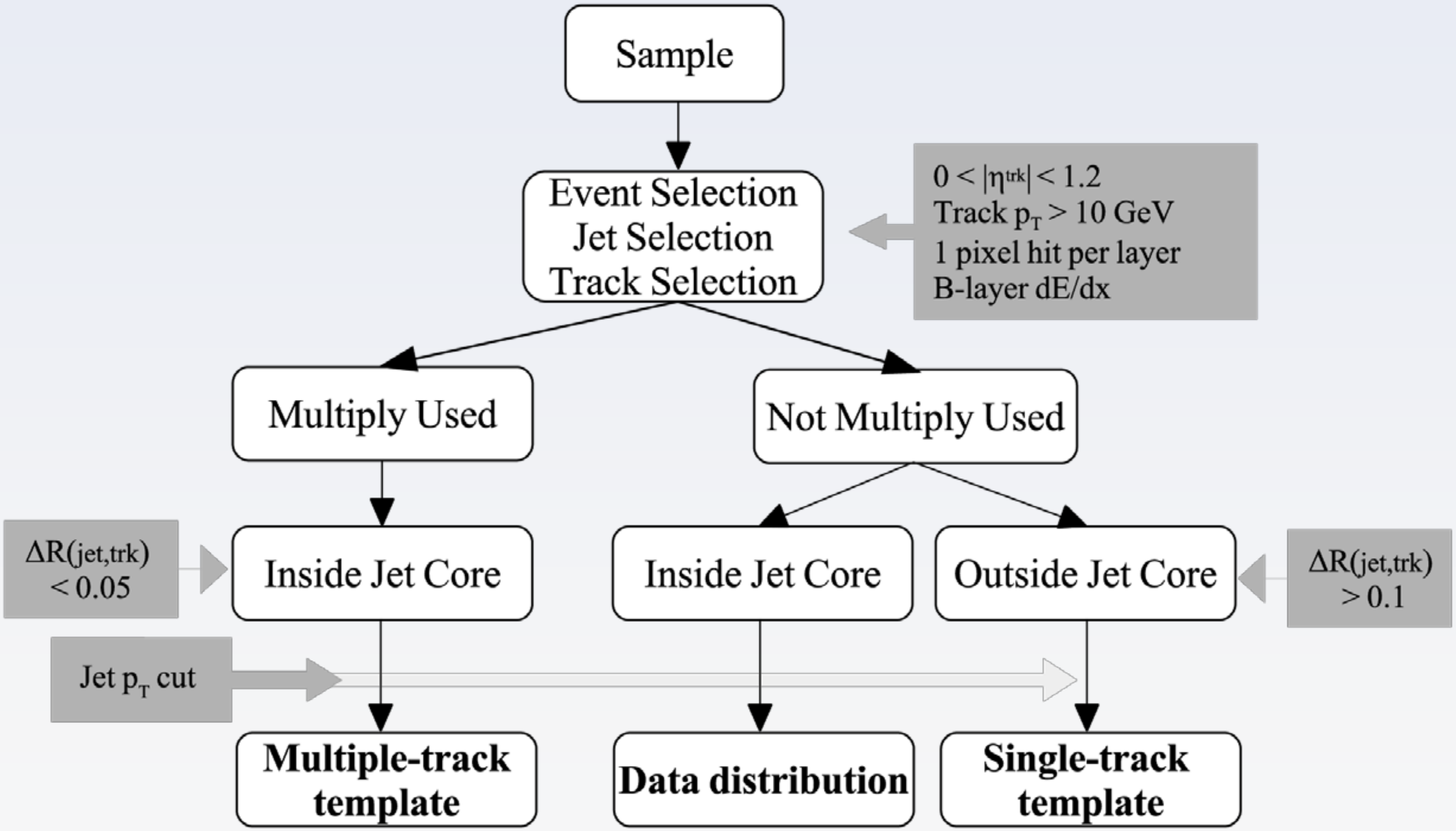
- Track dE/dx:
  - Averaged over all clusters of a reconstructed track



- Truncated dE/dx
  - Averaged over all clusters of a track, but disregarding the largest dE/dx cluster



Definition of templates



ATLAS Inner Tracker

From outside in:

- Transition radiation tracker (TRT)
- Silicon microstrip tracker (SCT)
- Silicon pixel detector
  - Pixel dimensions 50µm (transverse) × 400µm (longitudinal), different in outer layers
  - Different modules: FEI3 modules with 8 bit time-over-threshold (ToT), FEI4 modules only 4 bit ToT
- Since Run II (2015): Insertable B-layer (IBL)
  - Close to beam pipe (R=33mm) for superior impact parameter measurement (e.g. for b-tagging)
  - Planar and 3D silicon pixel sensors
  - Pixel dimensions 50µm × 250µm