dortmund
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FSP 101
ATLAS

Tracking and Vertexing with the ATLAS Detector at the LHC

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PIXEL 2010, Grindelwald

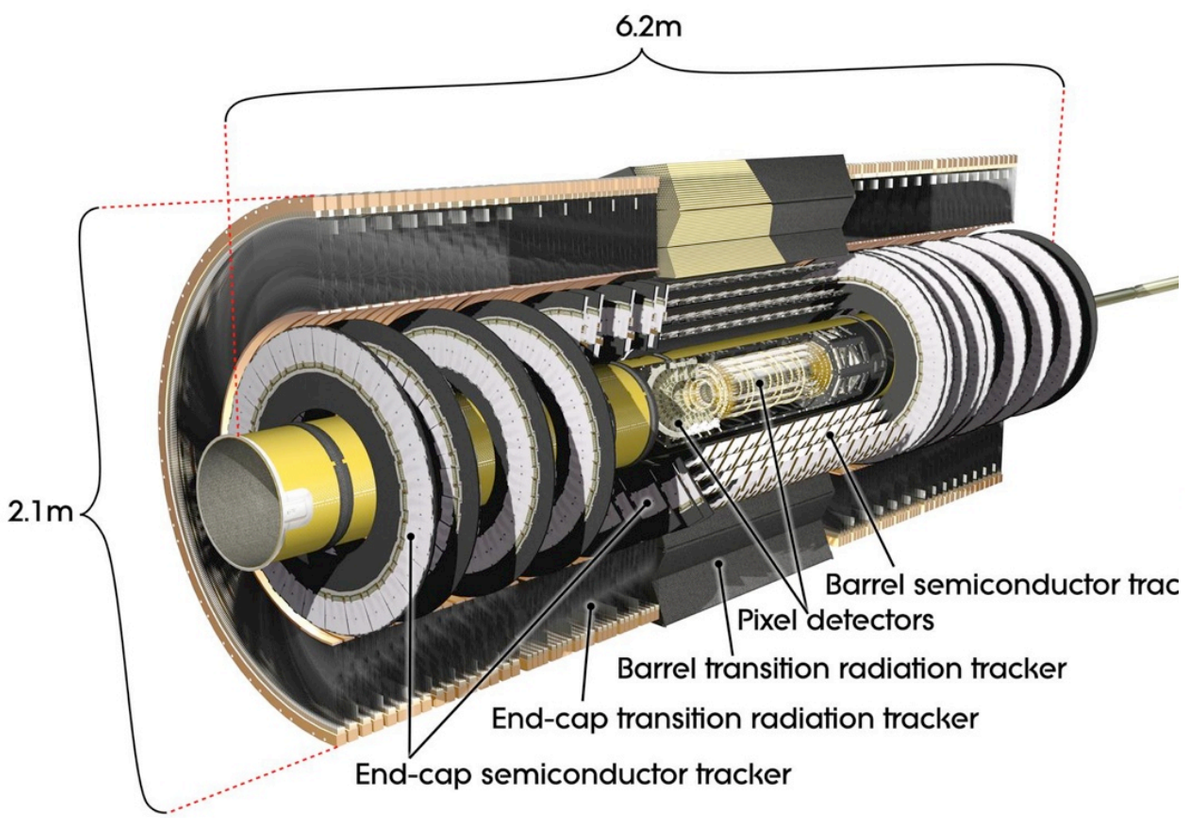
GEFÖRDERT VOM
Bundesministerium
für Bildung
und Forschung

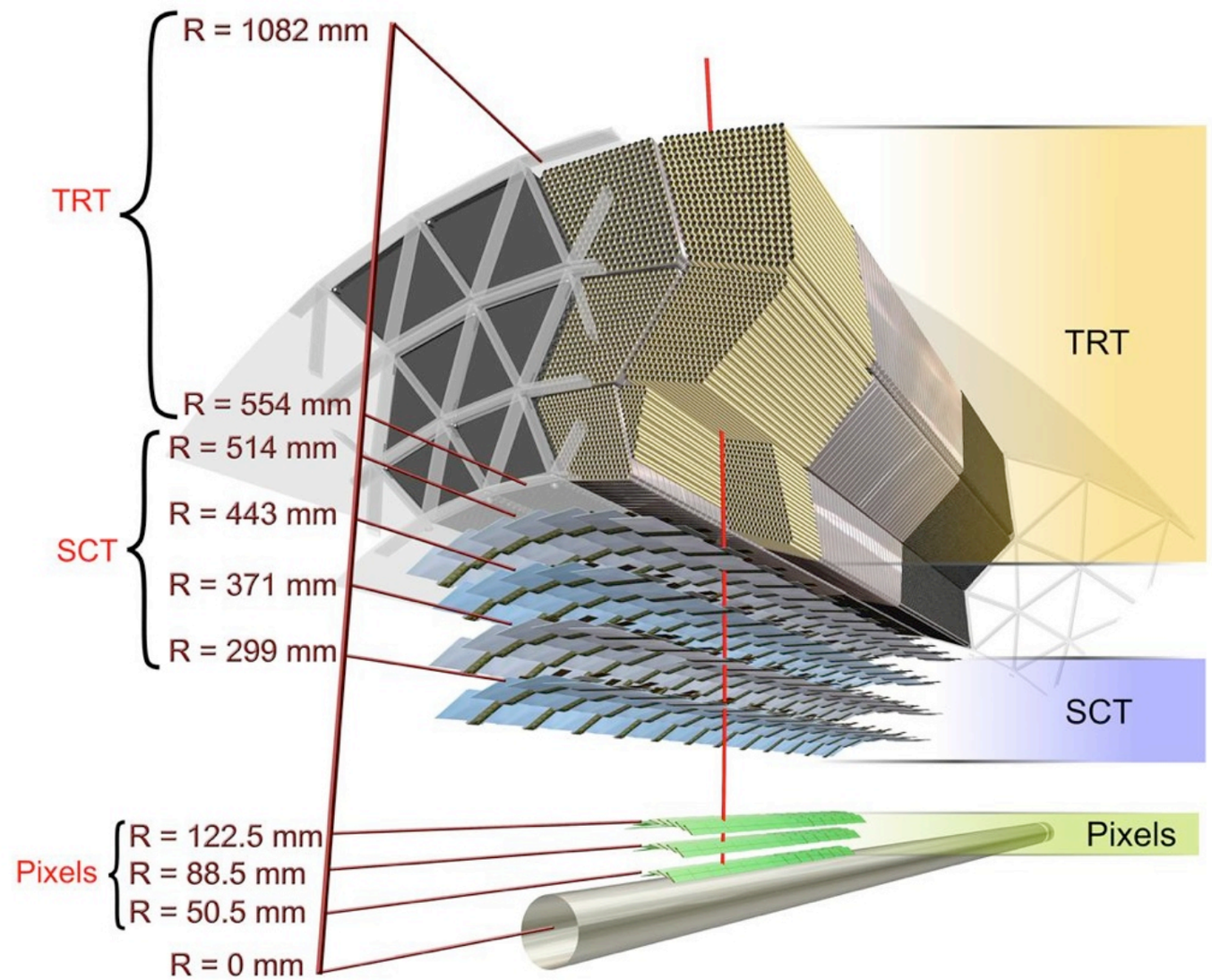
Outline

- Overview of the tracking system
- Tracking and application
  - algorithm description
  - basic quantities
  - application for b-tagging and physics
- Primary vertex finding and application
  - algorithm description
  - primary vertex quantities and interpretation
- Secondary vertices and b-tagging
- Further results with vertexing

ATLAS Inner Detector

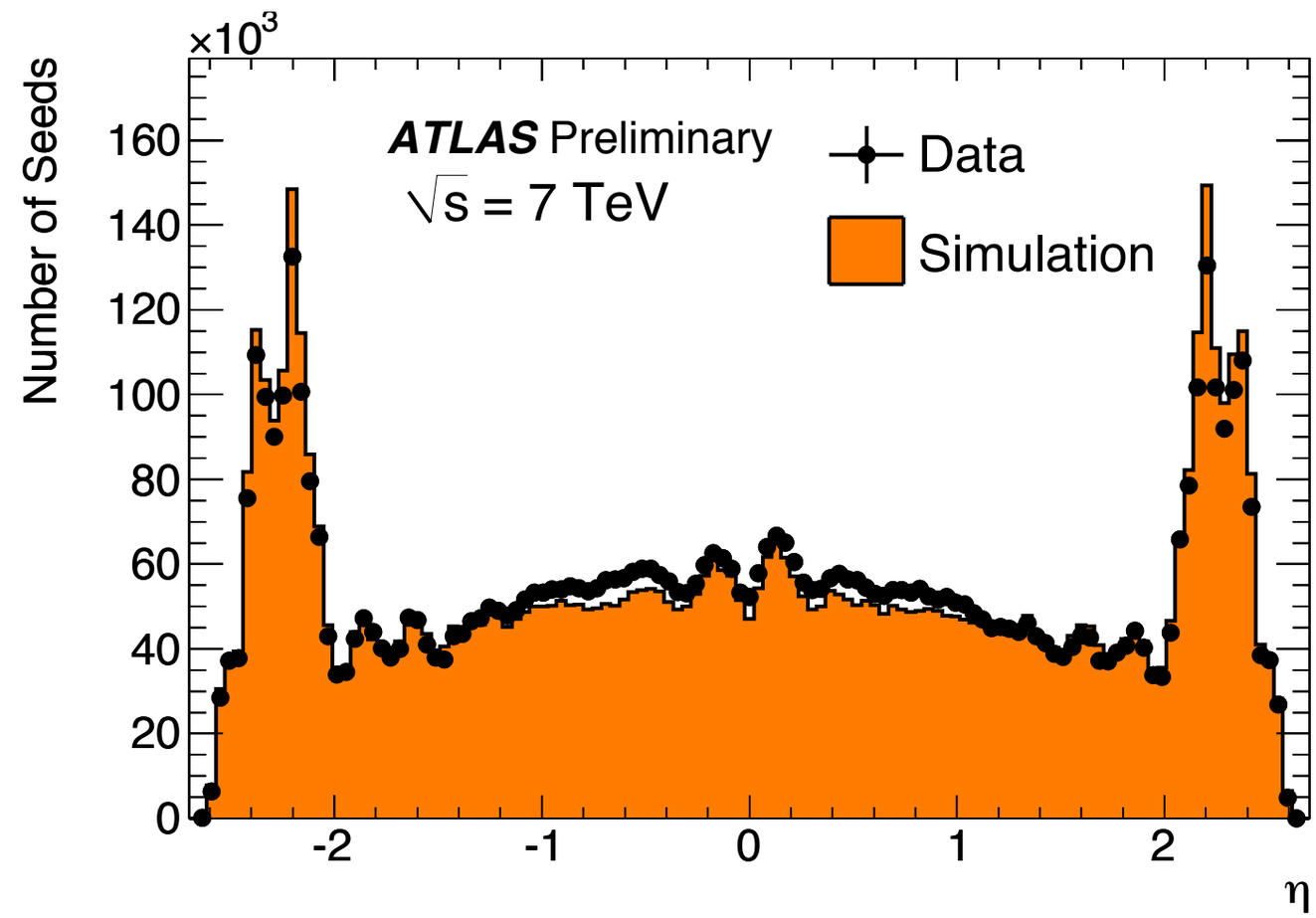
- Three-component tracking system immersed in a 2 T solenoidal magnetic field
- Silicon based Pixel Detector and Semiconductor Tracker (SCT)
- Drift tube based Transition Radiation Tracker (TRT)
- Excellent resolution of track kinematics
- Focus on silicon parts in this talk



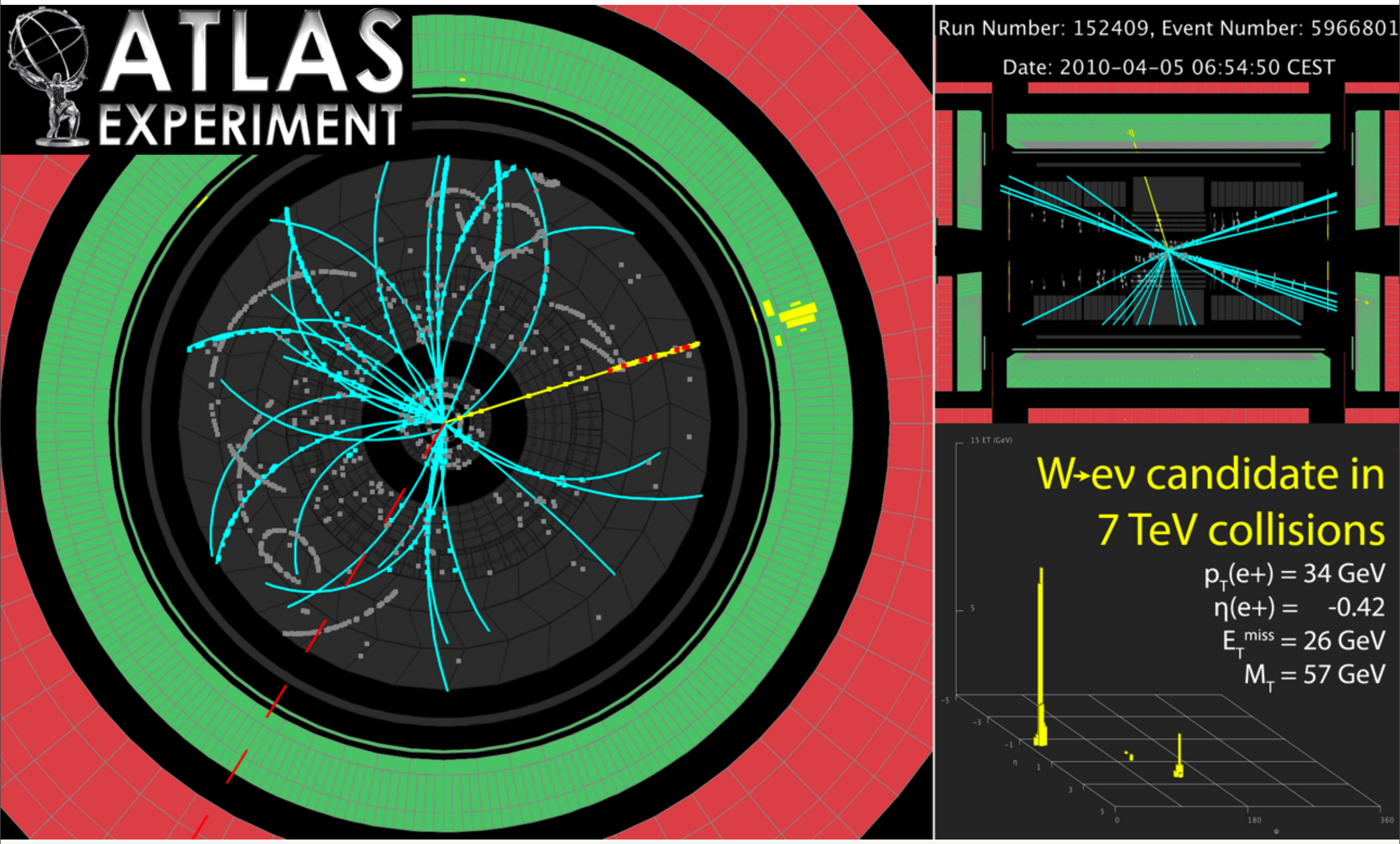


Finding Tracks

- Most commonly a pattern recognition algorithm seeded by hits in silicon detectors is used
  - seeds are found in the silicon layers and a preliminary track direction is constructed; three space points in the silicon detectors are required to form a seed
  - hits on these preliminary track paths are collected and a track candidate is fitted with an algorithm implementing a Kalman filter
  - ambiguities between track candidates are solved with a pattern recognition algorithm assigning track scores based on hits-on-track and fit quality

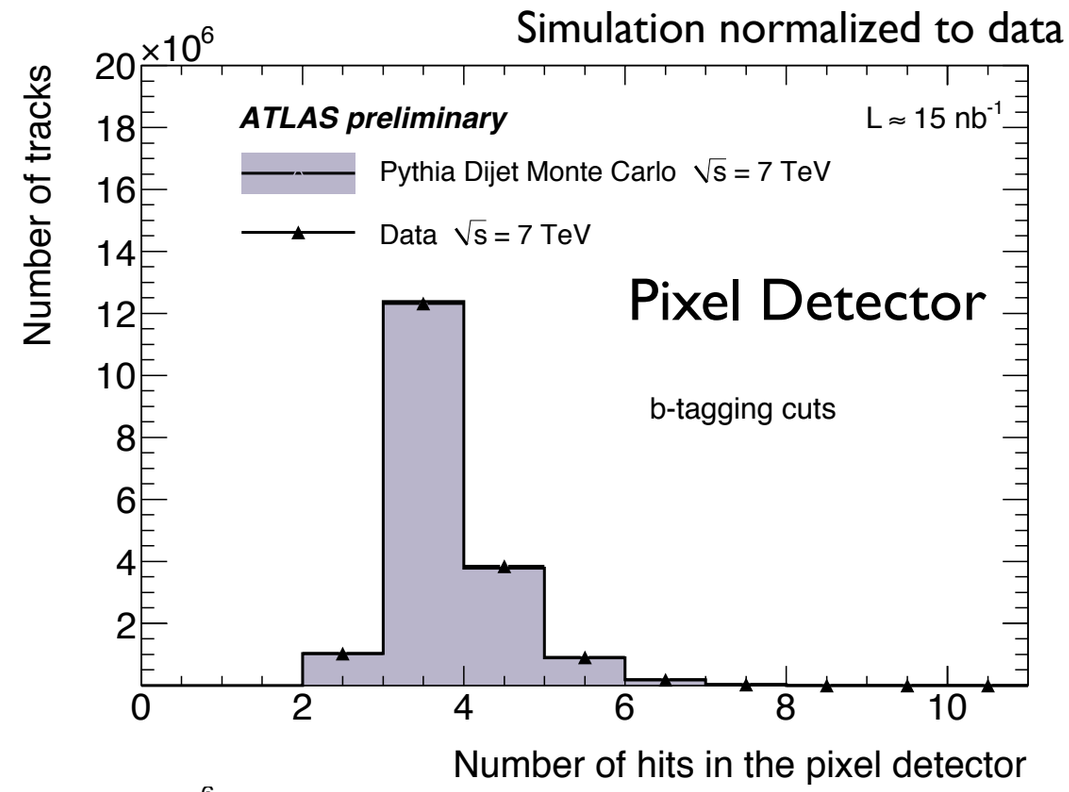


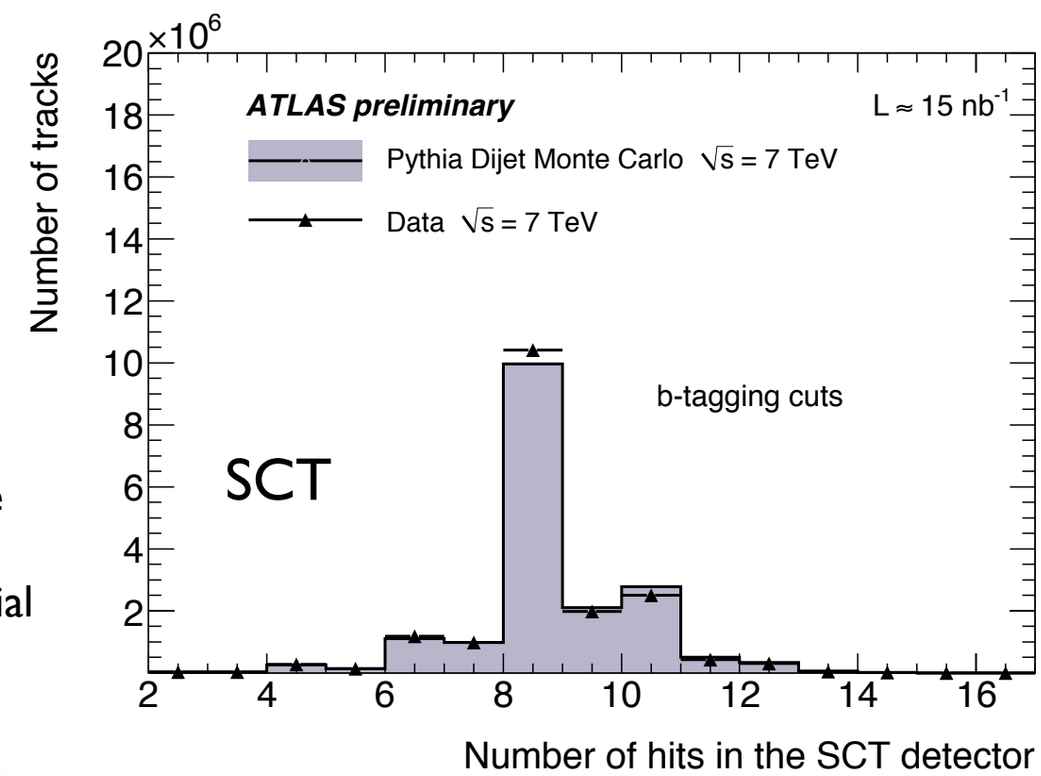
Event Display with Tracks

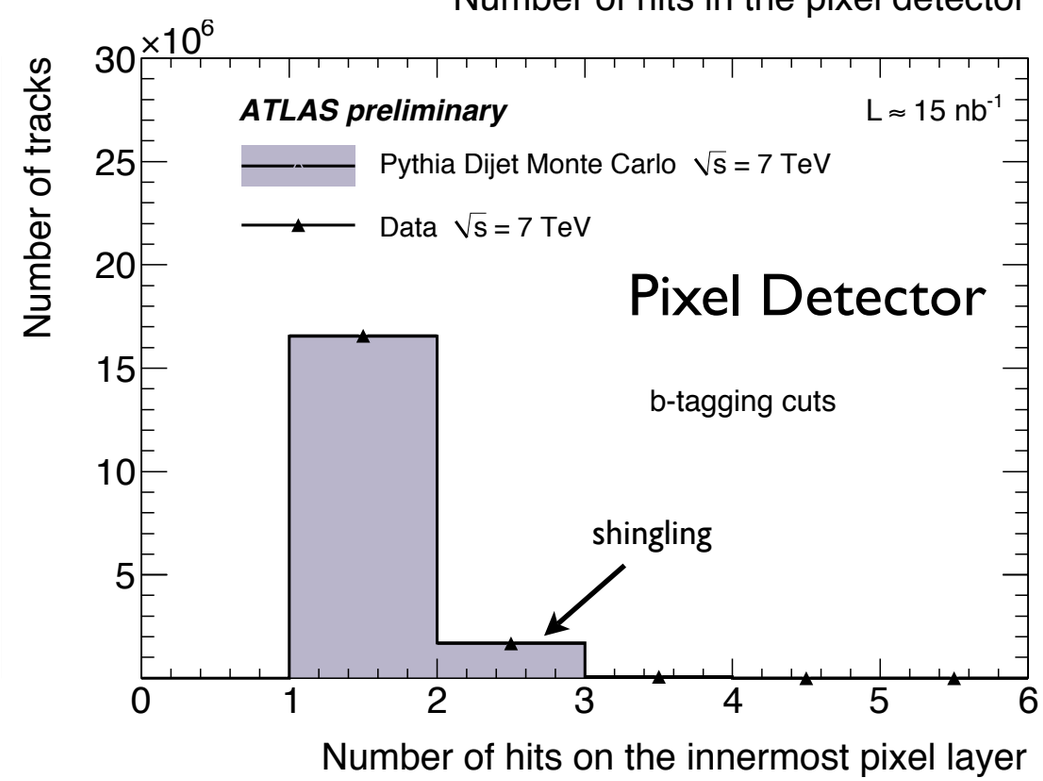


Hits on Track

Tracks are built from Inner Detector hits.
A different number of hits on a track is expected depending on the tracks' kinematics due to detector geometry and conditions.
To establish tracks and use them, it is therefore crucial to have a good understanding of the hit patterns.
Distributions of the number os hits-on-tracks show very good agreement for data and simulation.





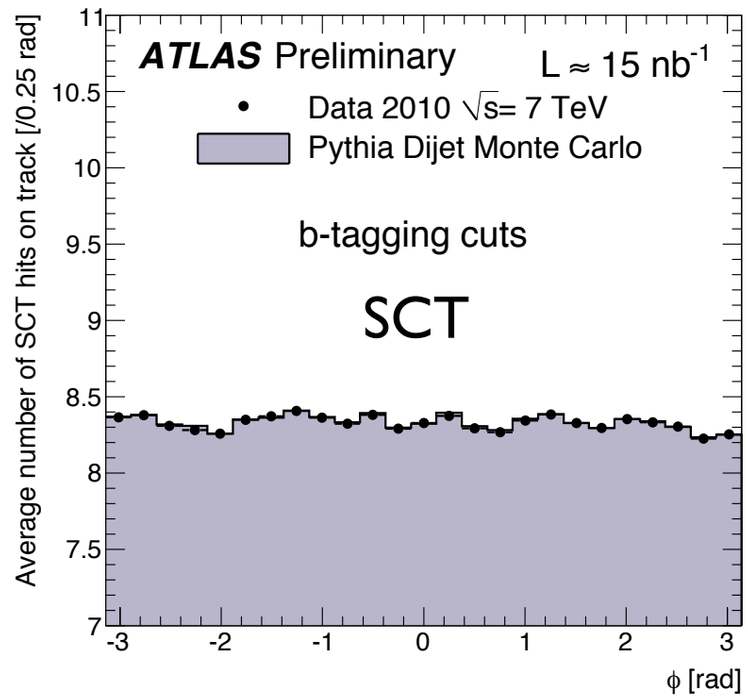


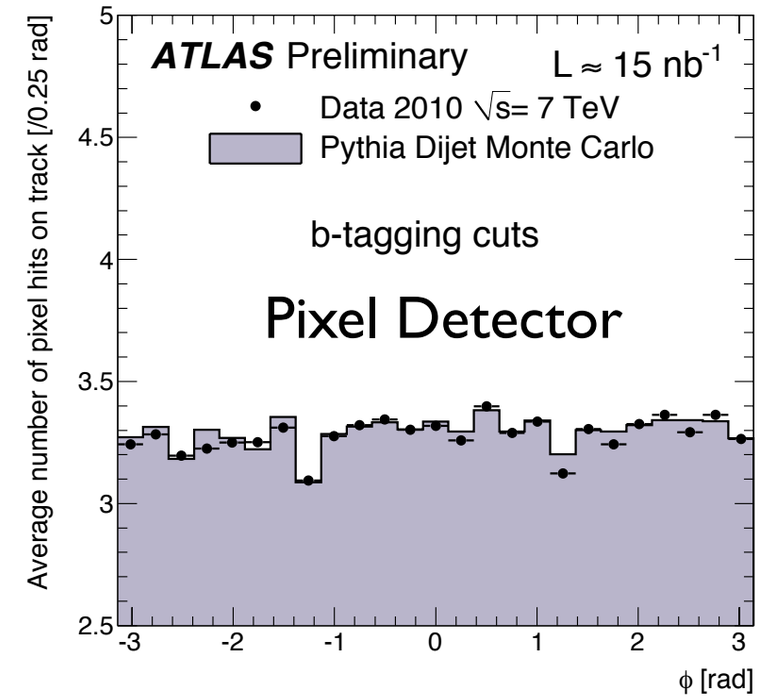
Only tracks in jets are shown in these plots since they are of special importance for flavor tagging.

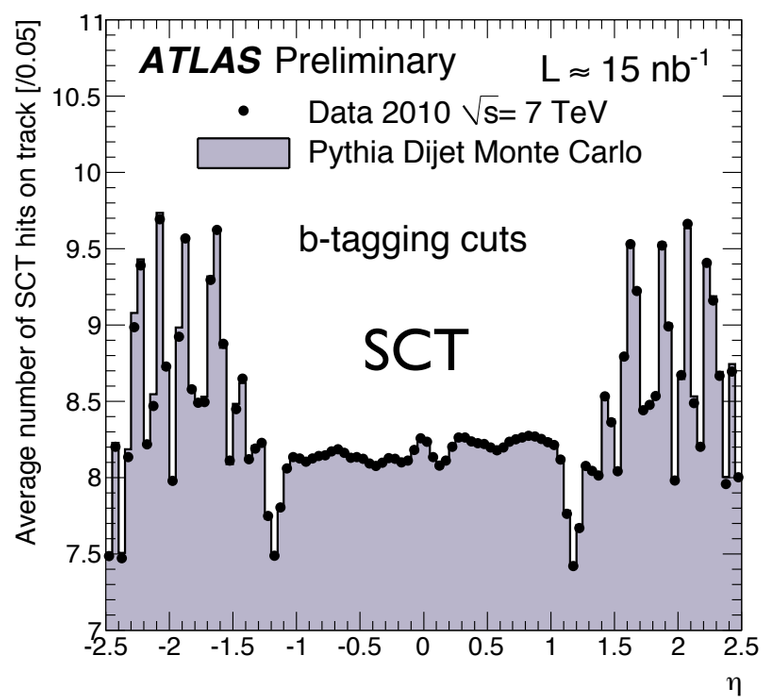
Hits on Track

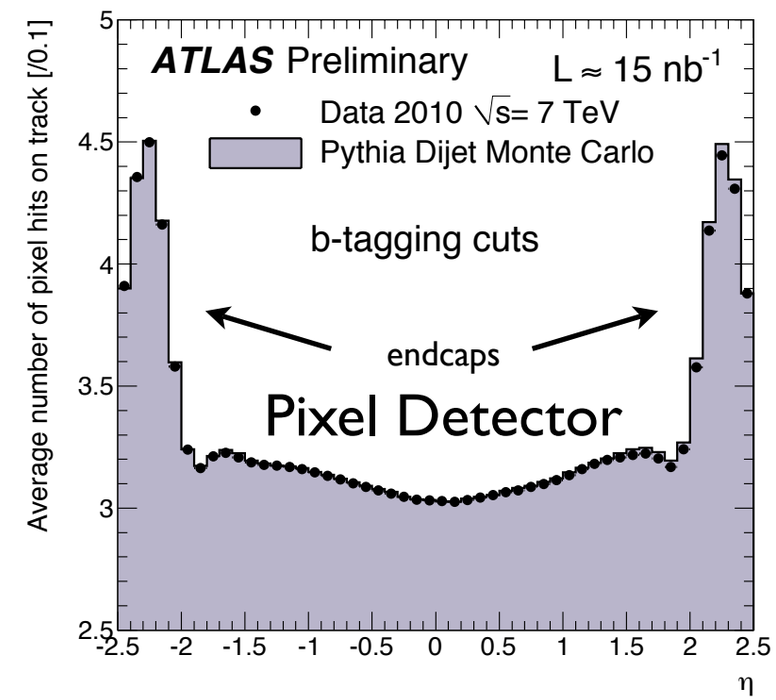
A good description of data by simulation in different kinematic regions is important due to the detector layout.
Displayed are the average hit multiplicities in bins of eta and phi.

The agreement is good, the detector structure is well described by the simulation.







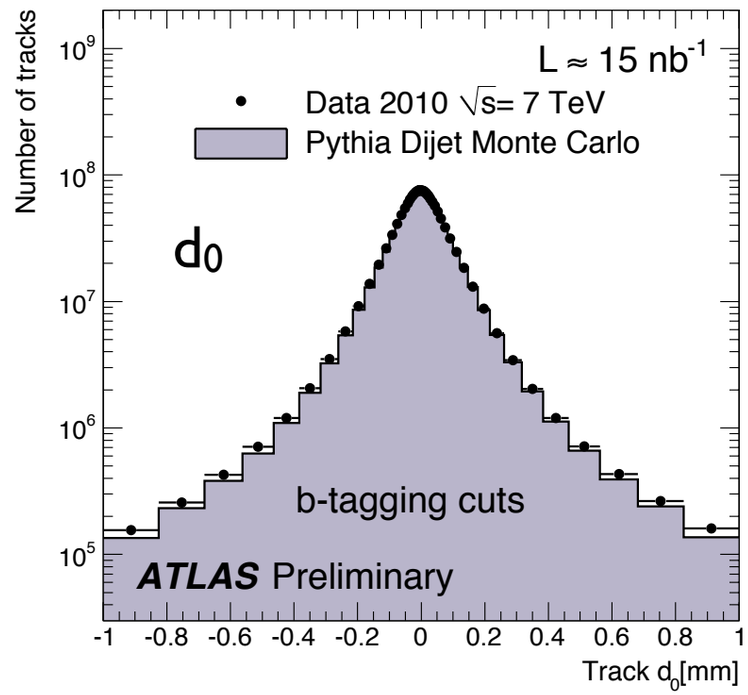


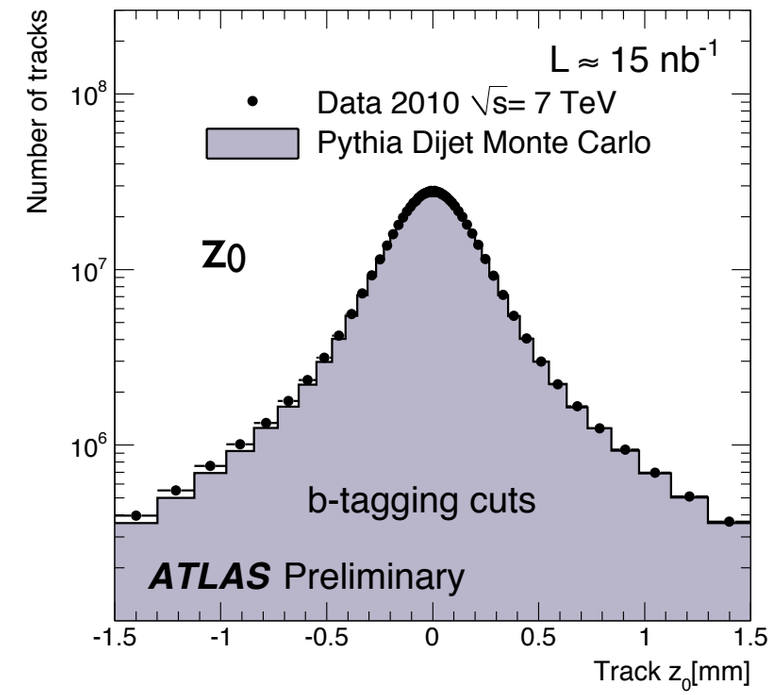
Only tracks in jets are shown in these plots since they are of special importance for flavor tagging.

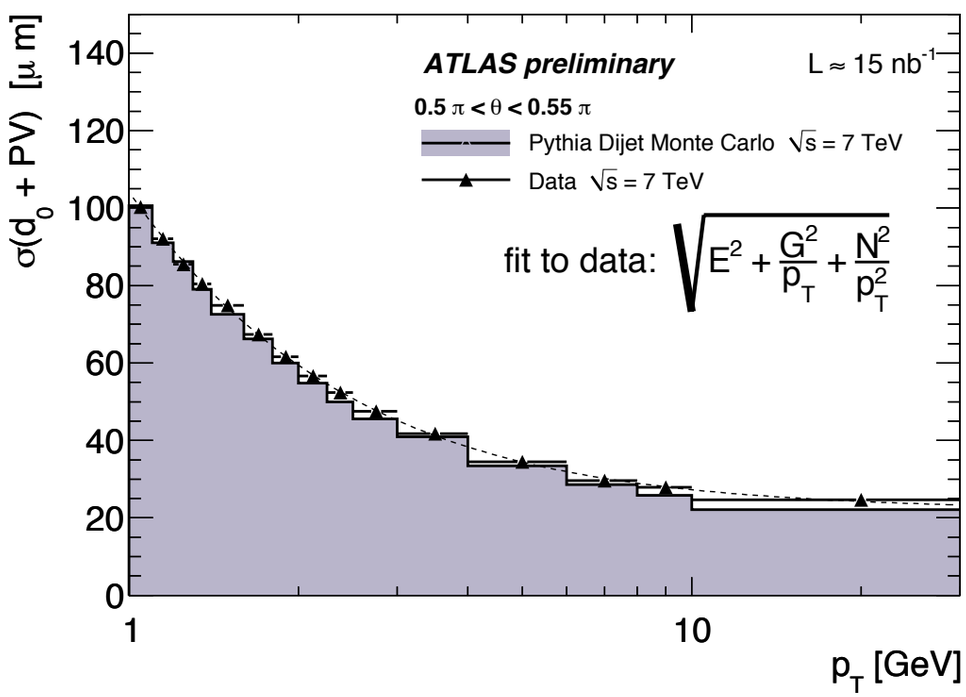
Impact Parameters

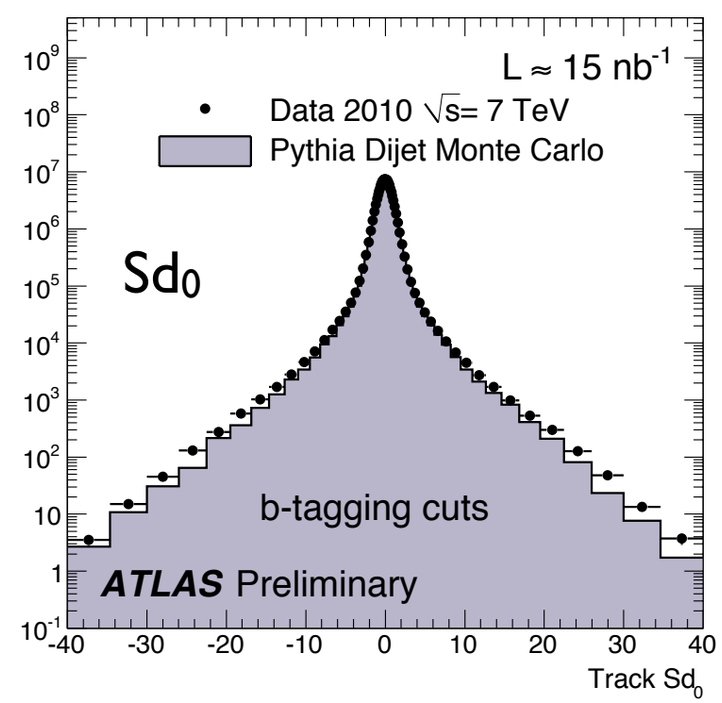
An important track quantity is the distance of the point of closest approach to the interaction.
d_0 is the transverse impact parameter and z_0 is the longitudinal one.

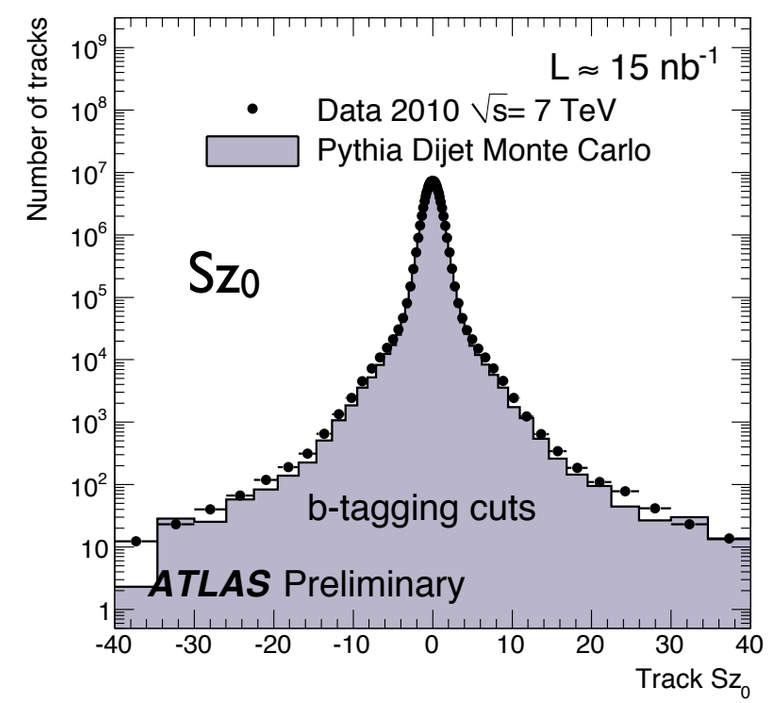
Simulation normalized to data









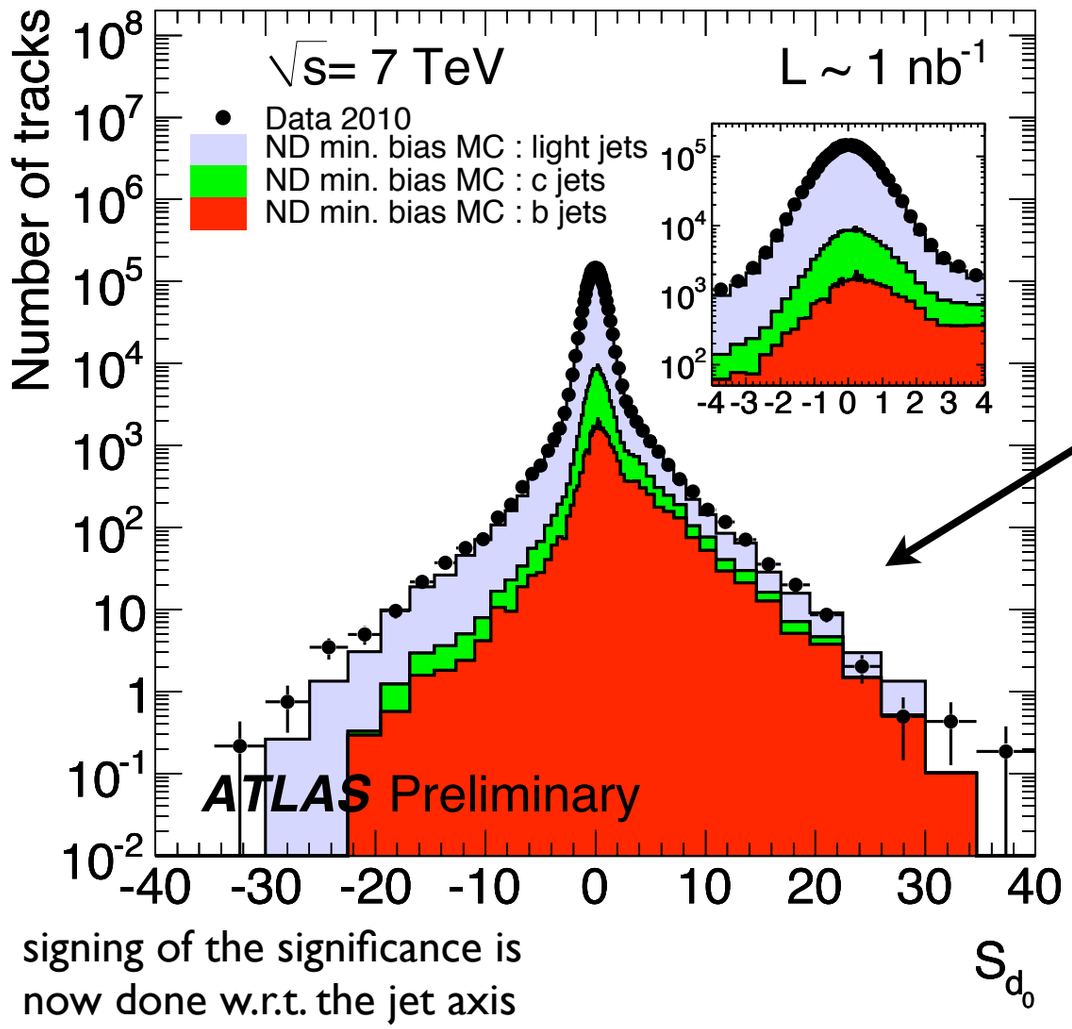


Only tracks in jets are shown in these plots since they are of special importance for flavor tagging.

$Sd_0 = d_0/\sigma(d_0)$.
d_0 and z_0 are unbiased w.r.t. primary vertex.

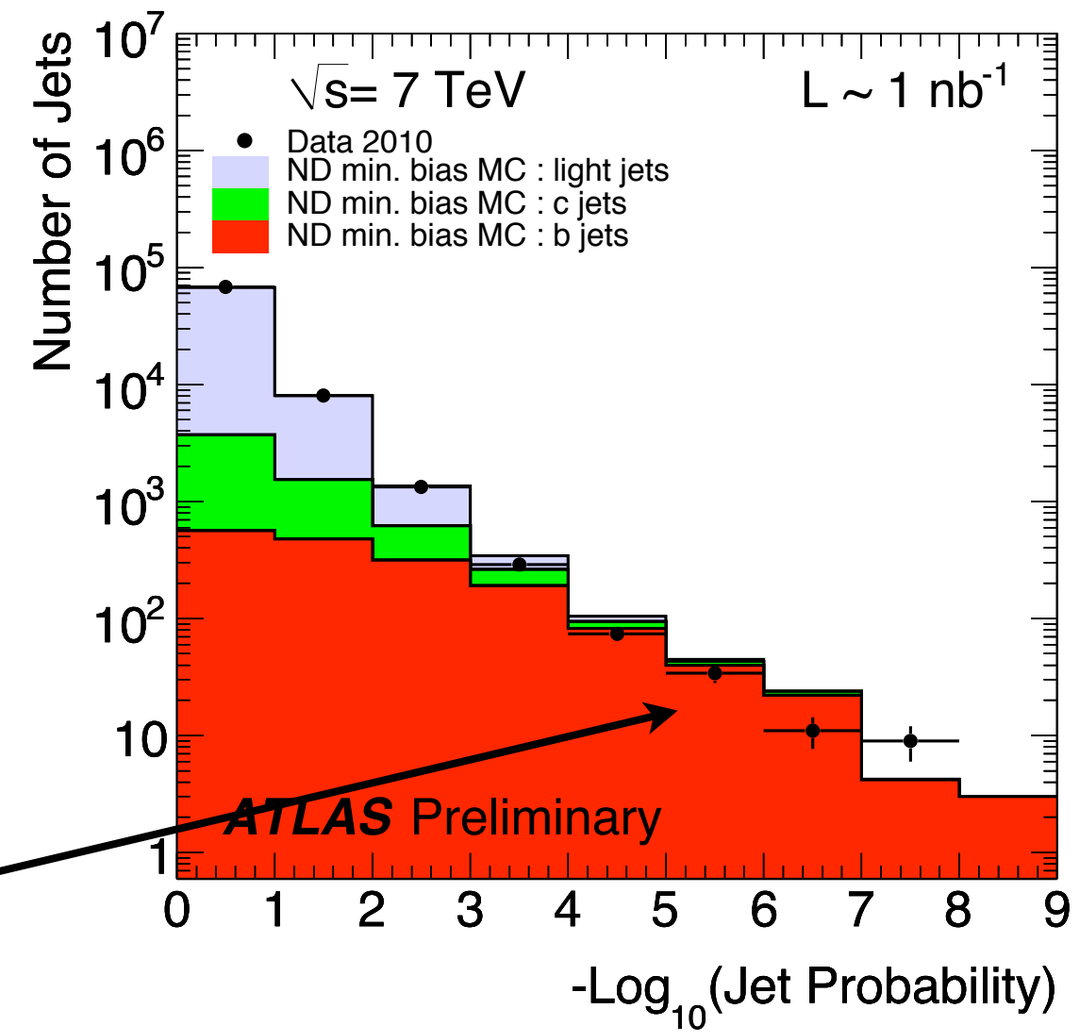
Tracking for b-tagging

Simulation normalized to data



signing of the significance is now done w.r.t. the jet axis

The impact parameter can be used to identify the flavor of a jet using its corresponding tracks. Here the JetProb tagger is shown as an example.
Simulation shows that b-jets are more prominent in regions where the impact parameter significance is high.



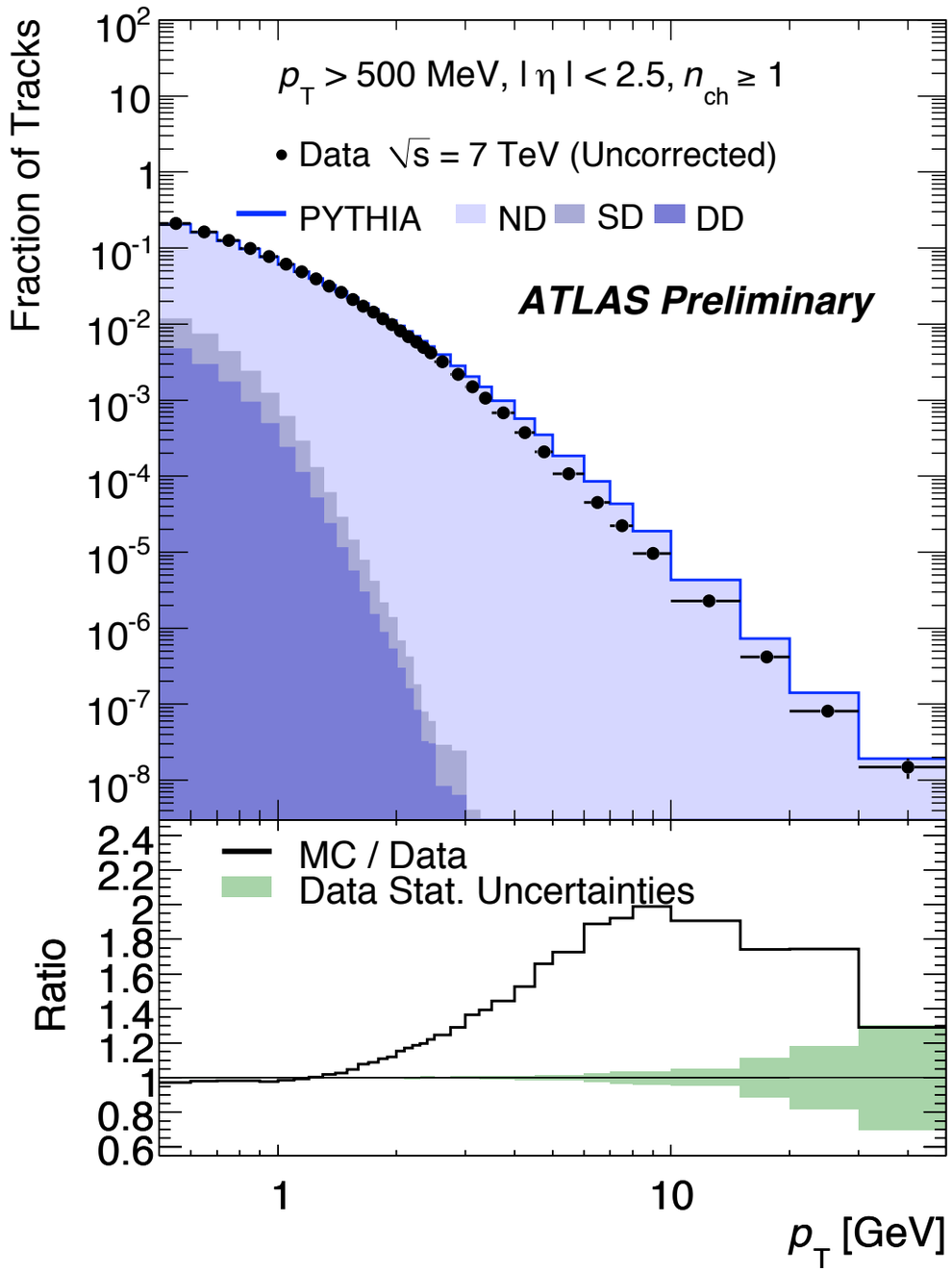
The probability of the jet being a light quark jet is derived from a calibration function which exploits the symmetry of the light jet distribution around 0.
It is clearly visible that a cut on this probability yields samples with increased b-content.

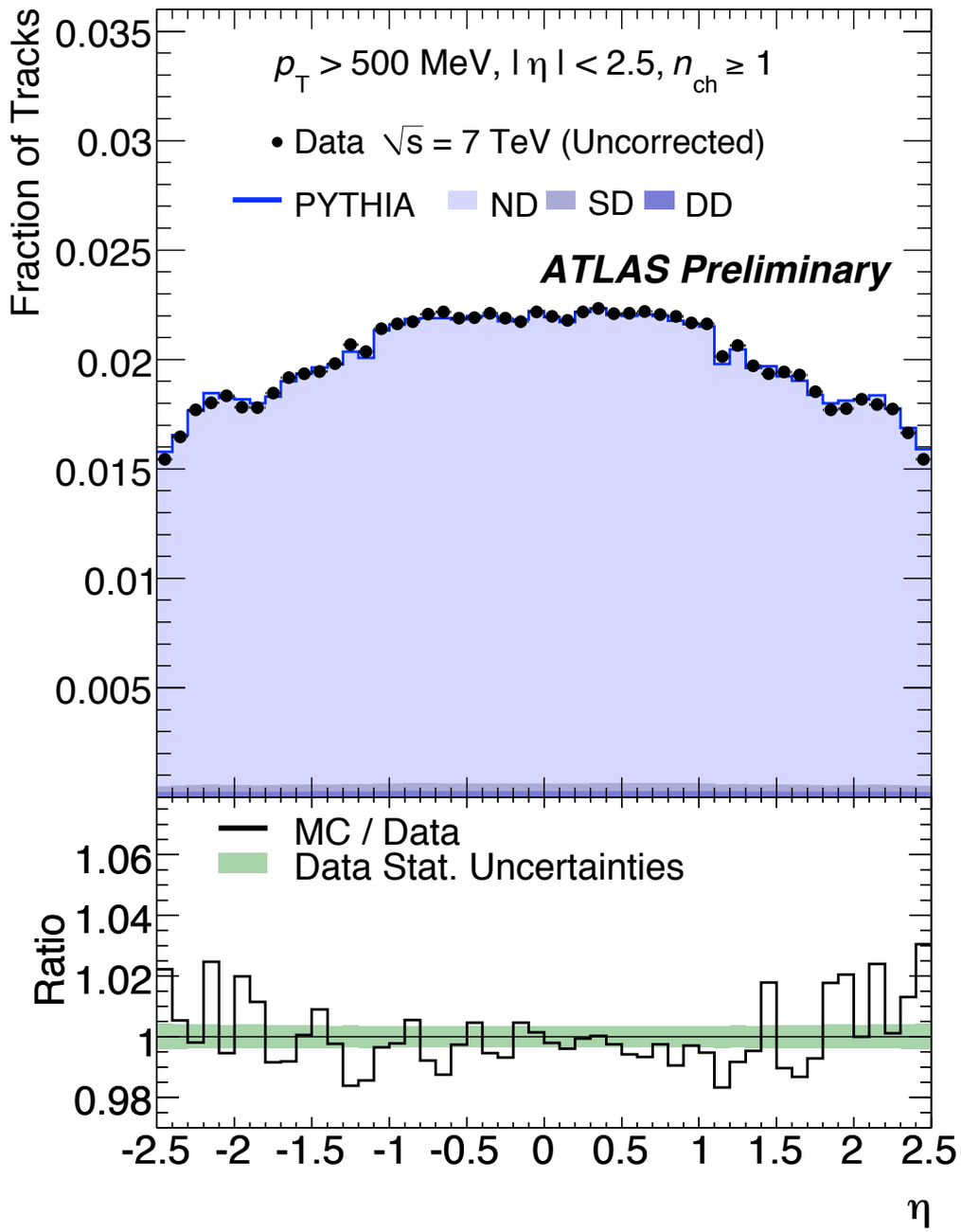
Kinematic Properties of Tracks

Another important track quantity is the transverse momentum. The description of data by simulation is good and the track momenta can be used to form vertex masses.

The description of the track eta distribution by simulation is also shown and in good agreement with data.

Normalized to unit area

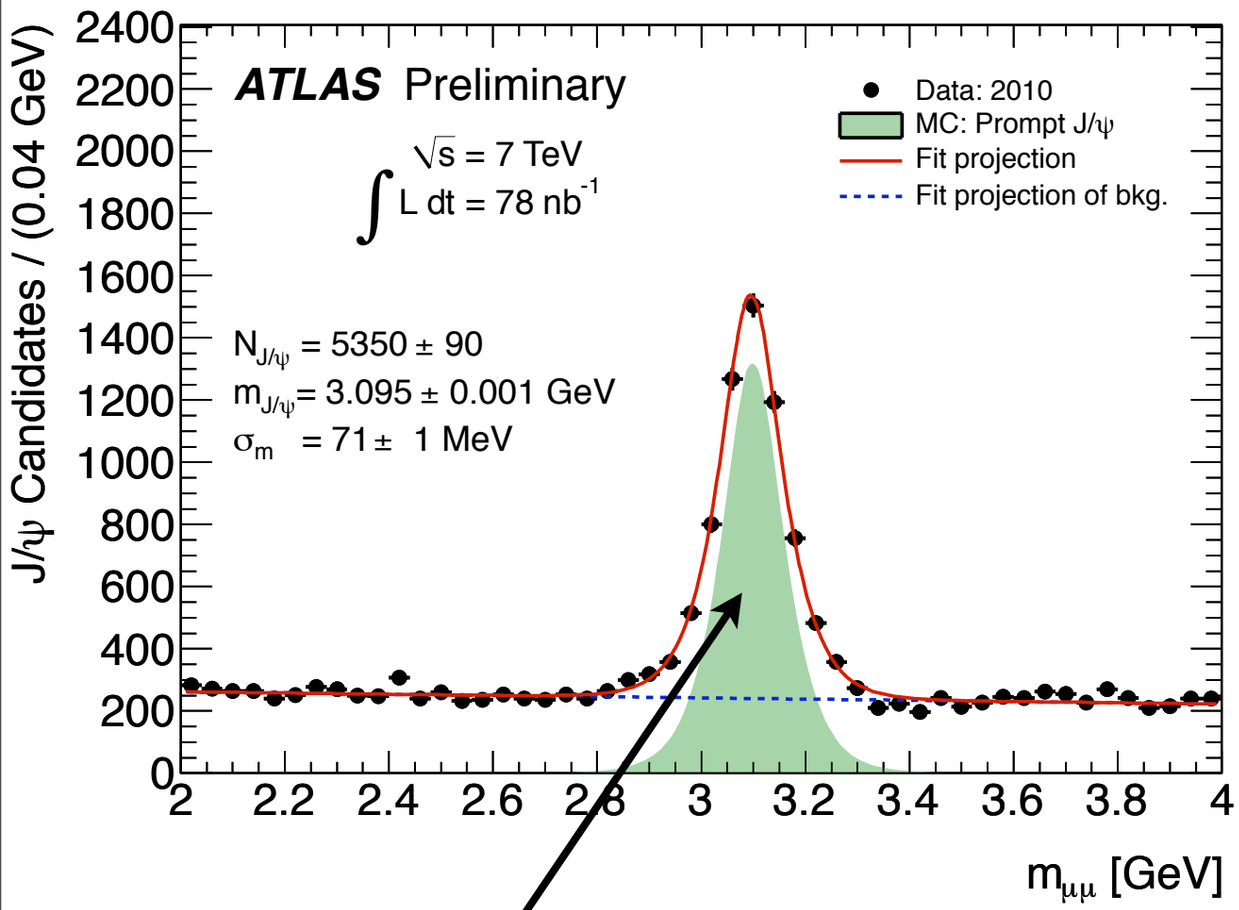




ND = non diffractive
SD = single diffractive
DD = double diffractive
Tracks from minimum bias events are shown.
They are no longer required to be in jets.

Physics with Tracking

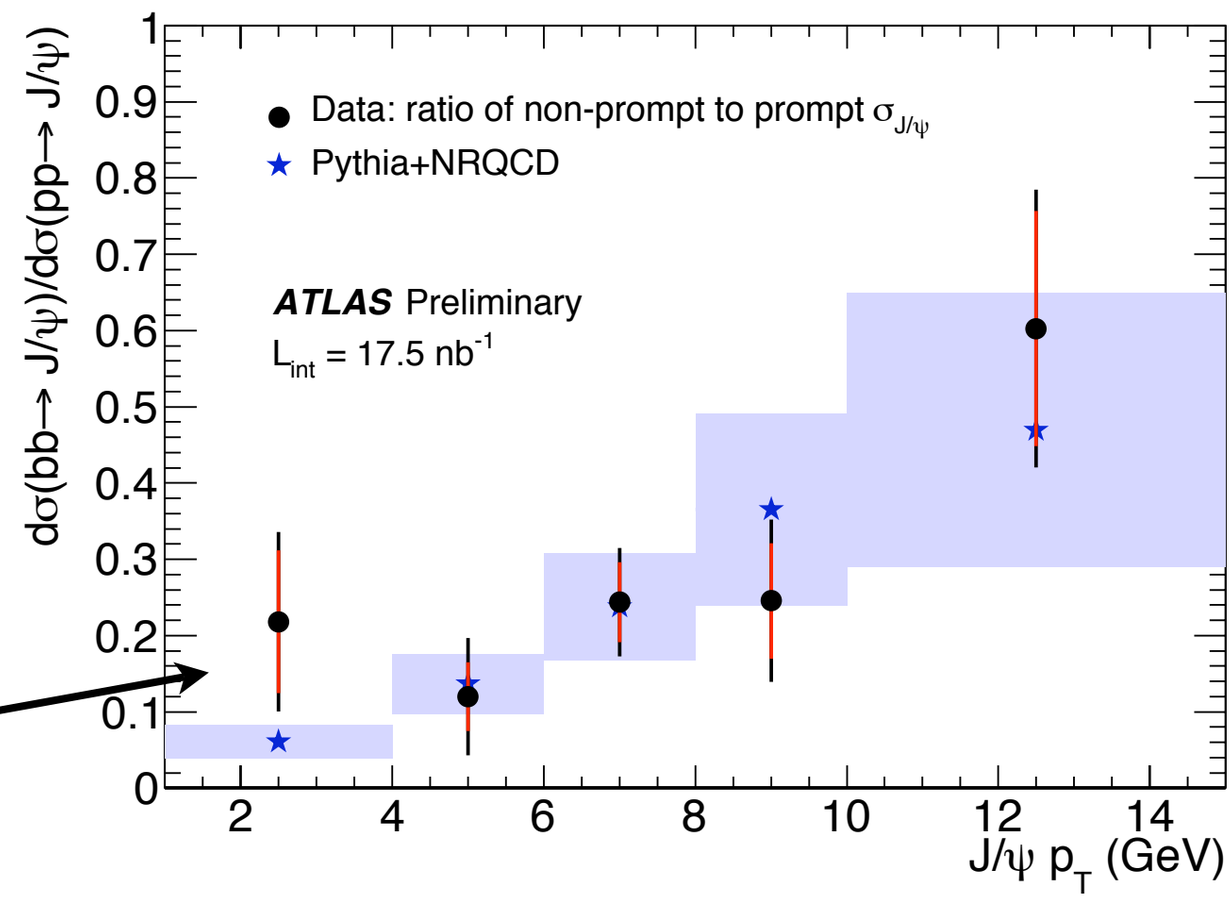
Simulation normalized to data



Here the J/Ψ → μμ decay is reconstructed by combining two tracks to a decay vertex if both tracks have been identified as muons (with the muon system).

The J/Ψ mass peak is clearly visible and the measured mass agrees with previous measurements.

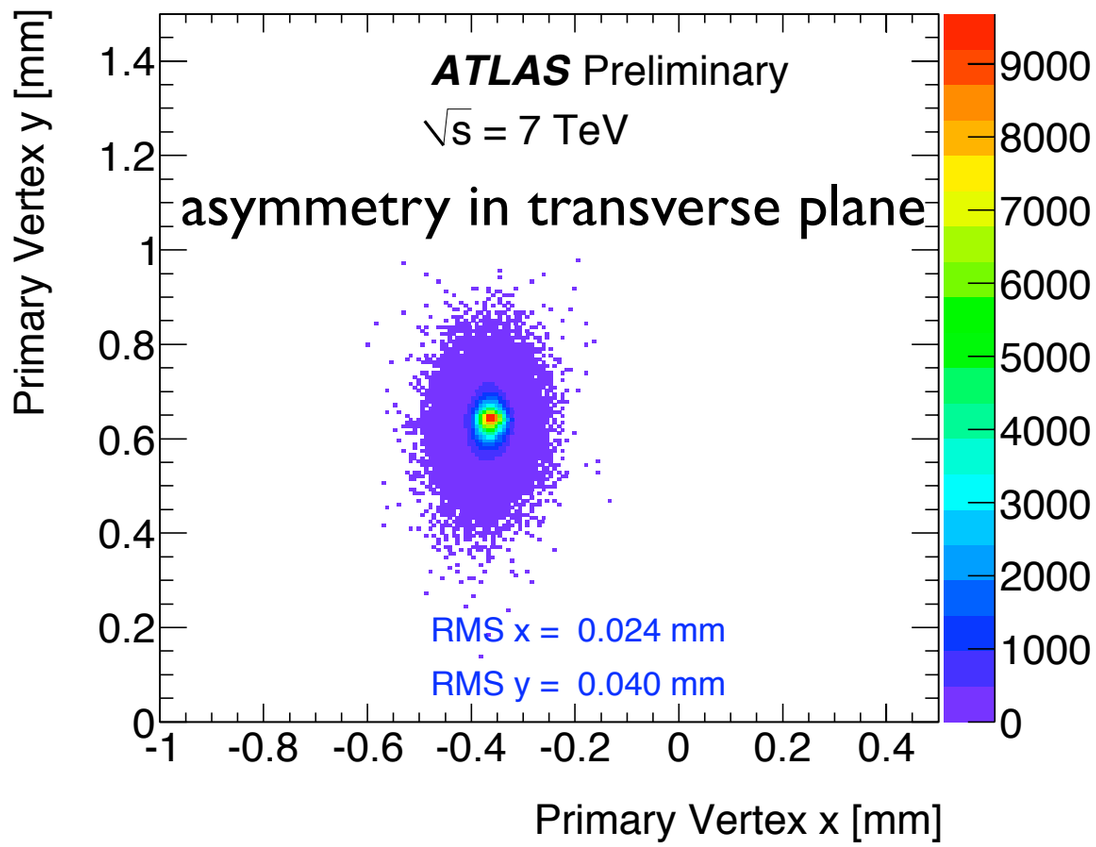
Also the cross-section and the ratio of non-prompt to prompt J/Ψ was measured.

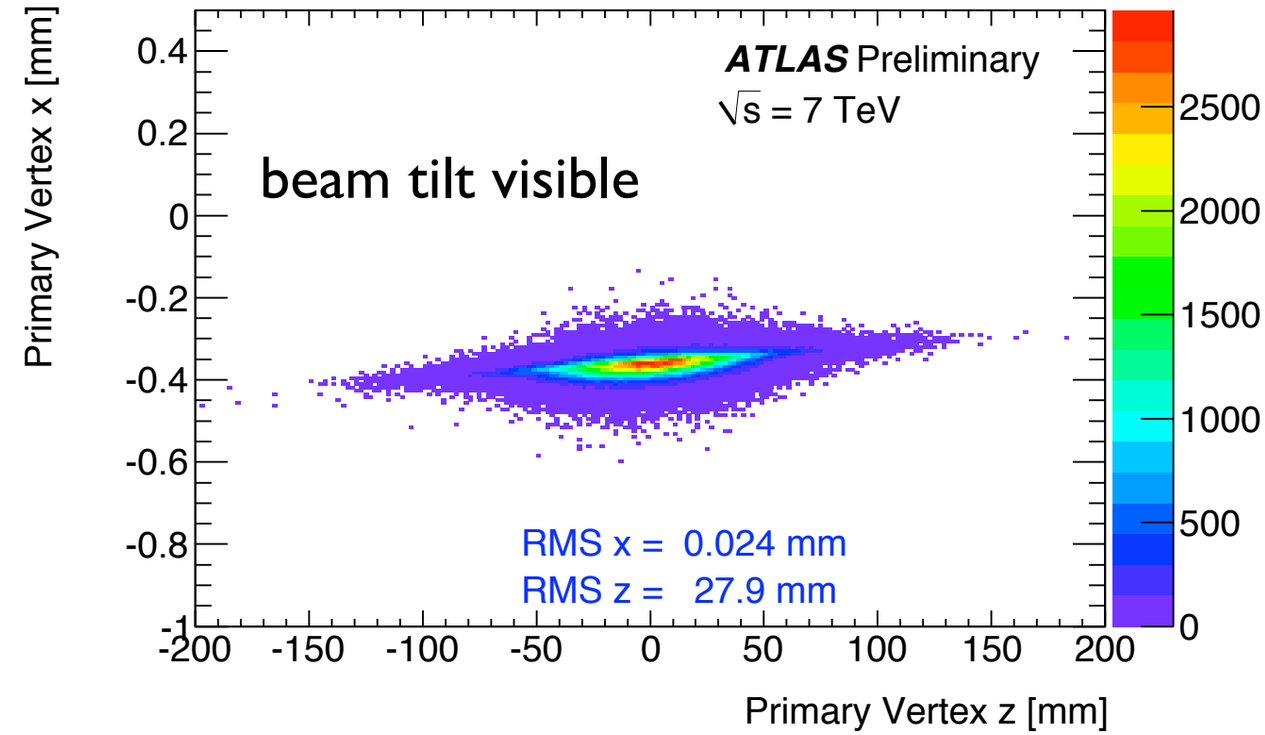


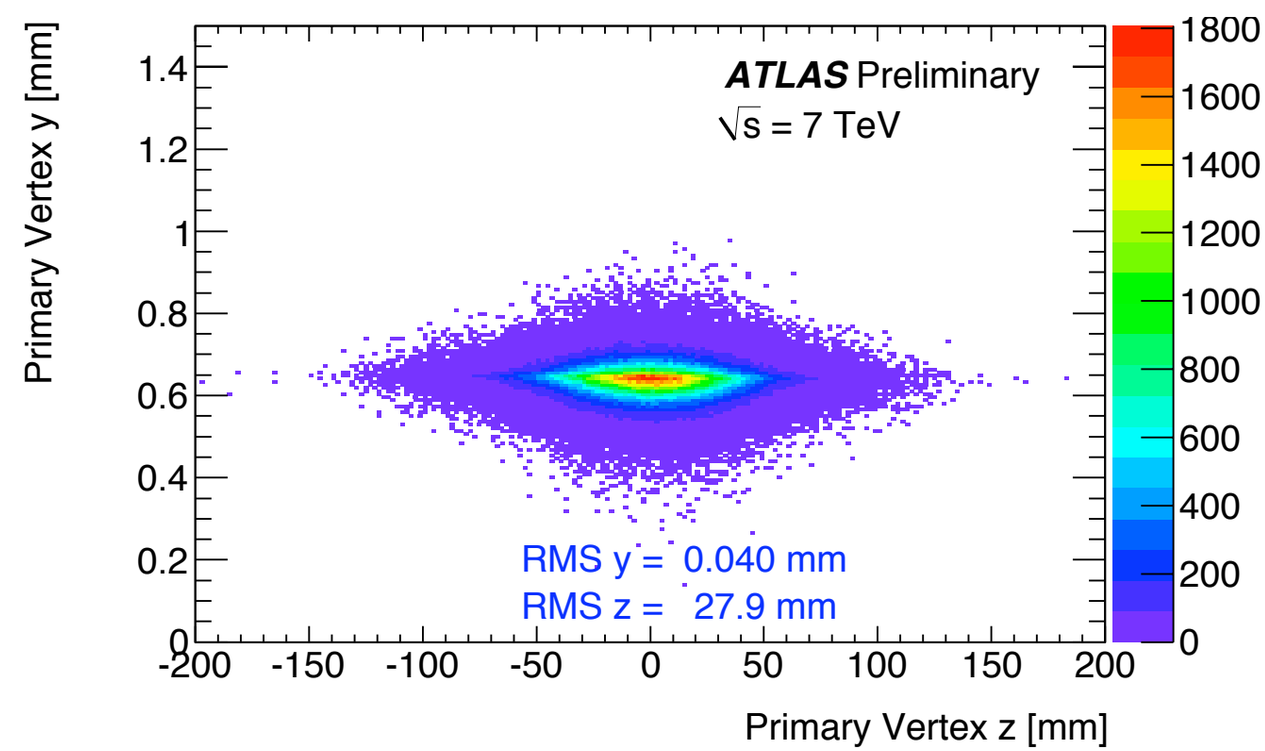
Finding Primary Vertices

- Primary vertices have to be reconstructed to
  - measure the interaction point (vital for physics)
  - measure luminous region
  - measure pile-up
- A primary vertex is reconstructed in two steps
  - a vertex seed is found by selecting tracks compatible with coming from the interaction region (beamspot constraint)
  - an adaptive vertex fitter is applied to fit the vertex parameters from those tracks
  - multiple vertices can be found by creating new seeds from tracks incompatible with the first primary vertex and iterating the algorithm

Beamspot Position



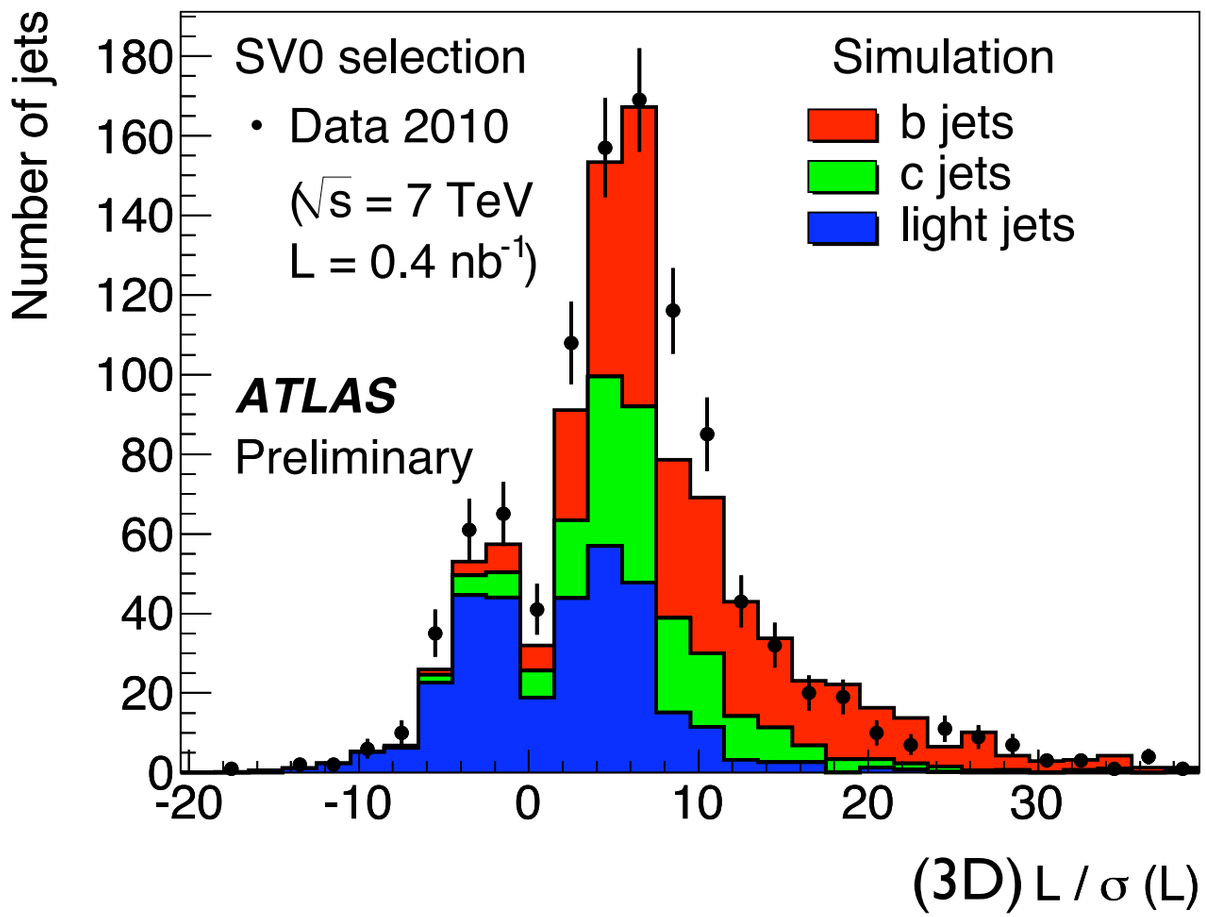




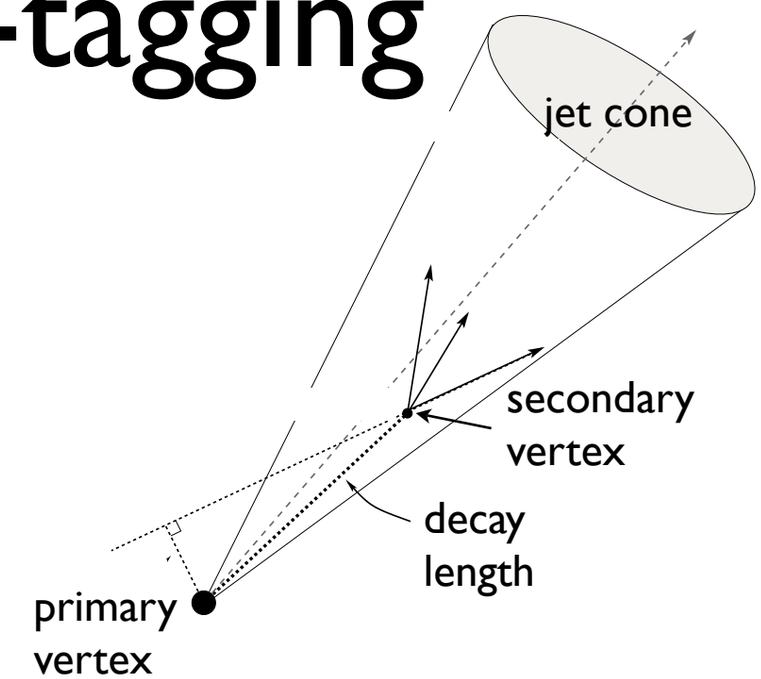
Reconstructed primary vertex position in 2D projections with beamspot constraint.

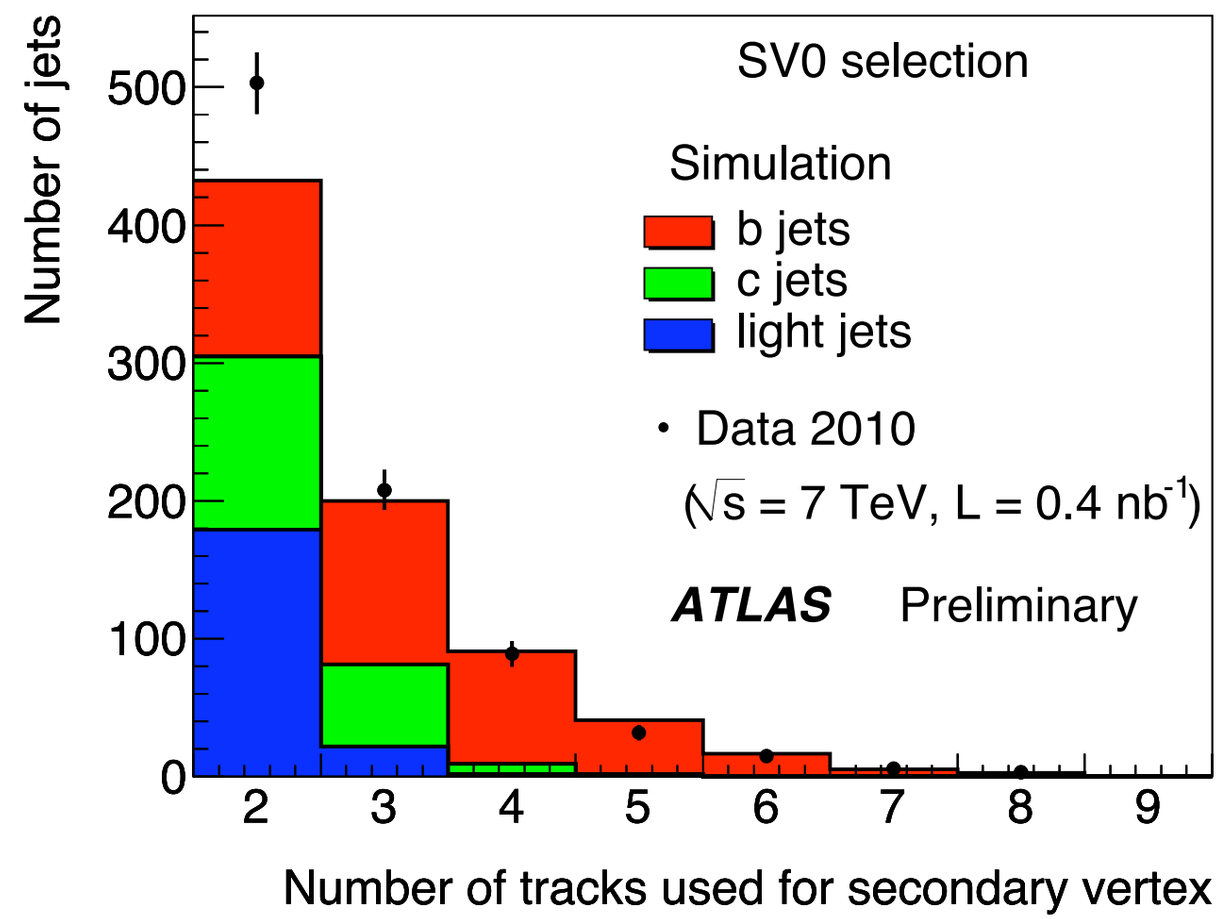
The distribution of primary vertices is used to measure the luminous region in ATLAS. In return this is used to constrain the primary vertex to the beam spot.

Secondary Vertices for b-tagging



Simulation normalized
to number of jets in data



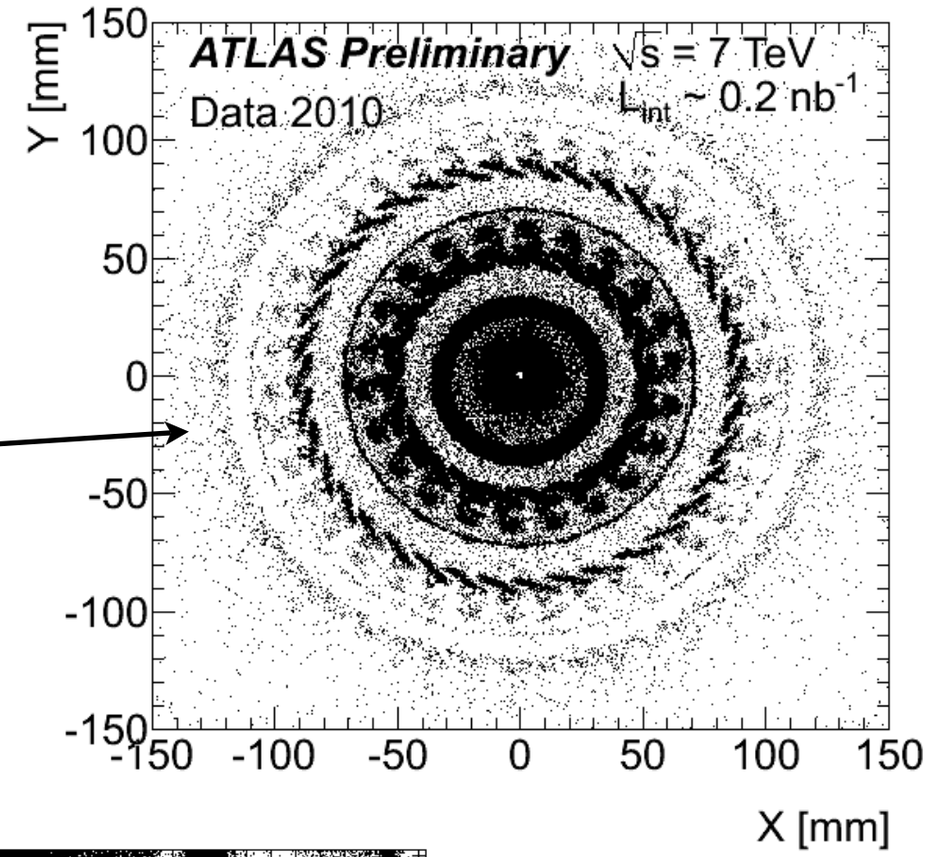


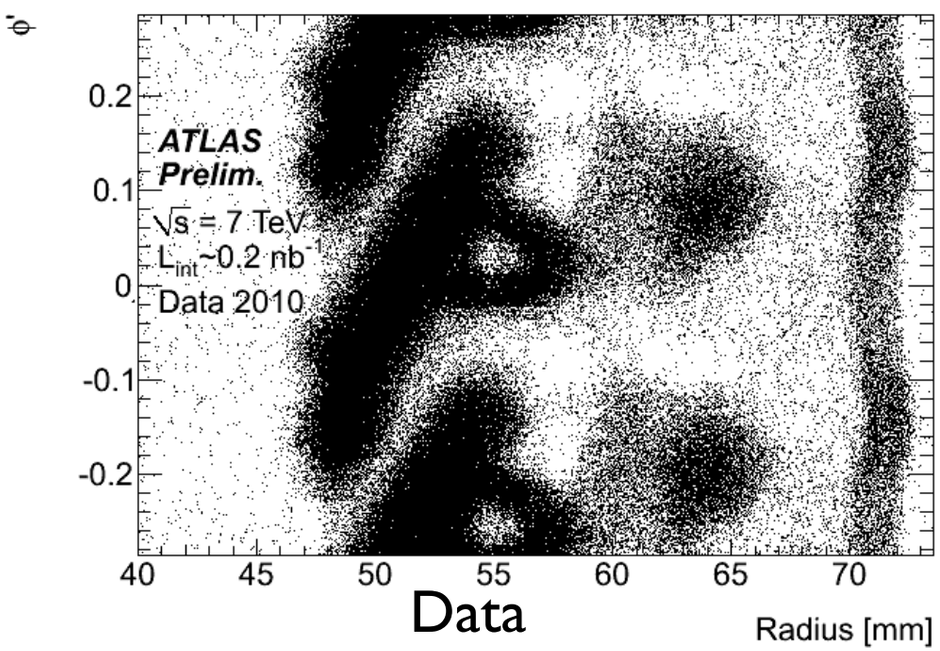
Secondary vertices can be used to identify particles with significant lifetimes.
This example shows how the SV0 tagger enriches the sample with b-jets.

More on Vertices

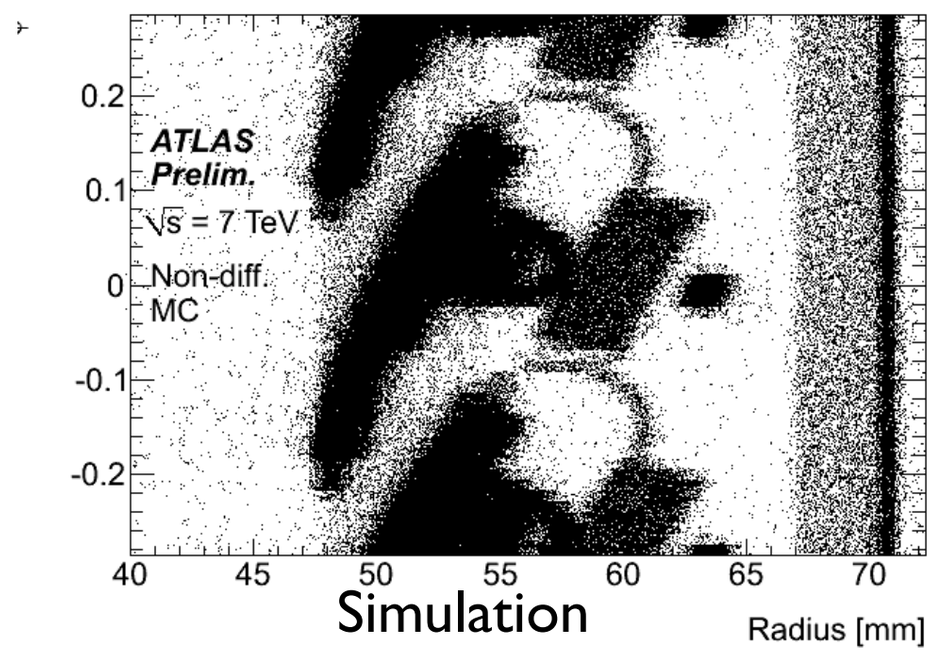
Vertex reconstruction can also be used to map the material of the Pixel Detector.
Here tracks compatible with the primary vertex or with γ-conversions or decays of light hadrons are rejected to find vertices from material interactions.

The beampipe and the different layers of the Pixel Detector are clearly visible as are services especially for the b-layer.





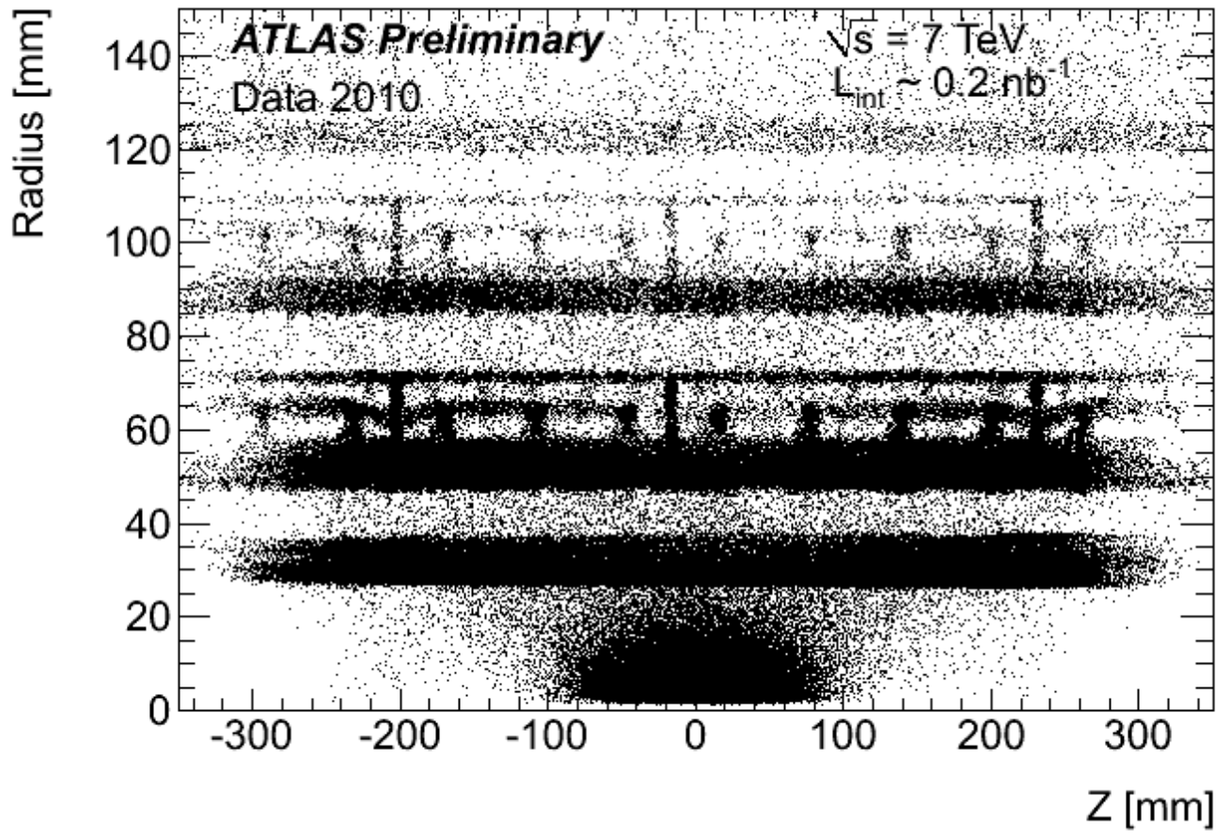
Data



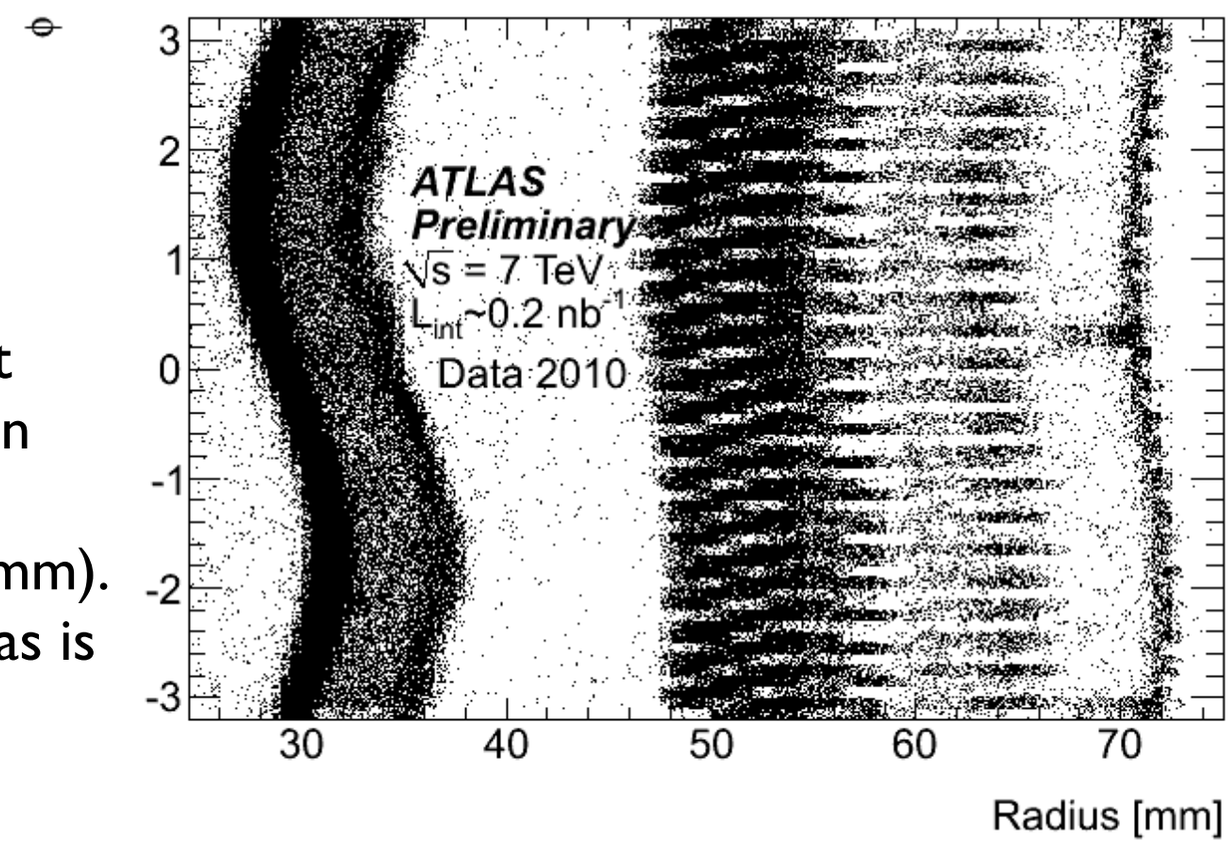
Simulation

Comparison of data and simulation for pixel modules.

More on Vertices



Projections of the mapped material in the z-r plane and the r-phi plane. The z-r projection shows the services along the staves of the innermost and the second pixel layer.
There is a prominent accumulation of vertices at radii smaller than the beam pipe which are identified as fake vertices by comparison with simulation.



The r-phi projection is especially interesting since it shows that the beampipe is offset relative to (0,0) in ATLAS coordinates.
The real center is calculated to be at (-0.2mm,-1.9mm).
This is important input to the detector simulation as is the exact shape of pixel modules and services.

Summary

- ATLAS features a three-component Inner Detector which is designed for tracking and vertexing
  - we observe good agreement between data and Monte Carlo for basic quantities showing that we have a good understanding of the detector performance
  - we also observe discrepancies in more sophisticated measurements which yield a lot of information about Monte Carlo tunings and the underlying physics
- Tracking and vertexing are vital for many applications
  - they allow measurements of LHC conditions and a mapping of detector material
  - also physics measurements like measuring the J/Ψ mass and the J/Ψ cross-section are possible and have been conducted
  - flavor tagging algorithms depend strongly on precise track quantity measurements and an enhancement of heavy quark jets using these taggers has been shown

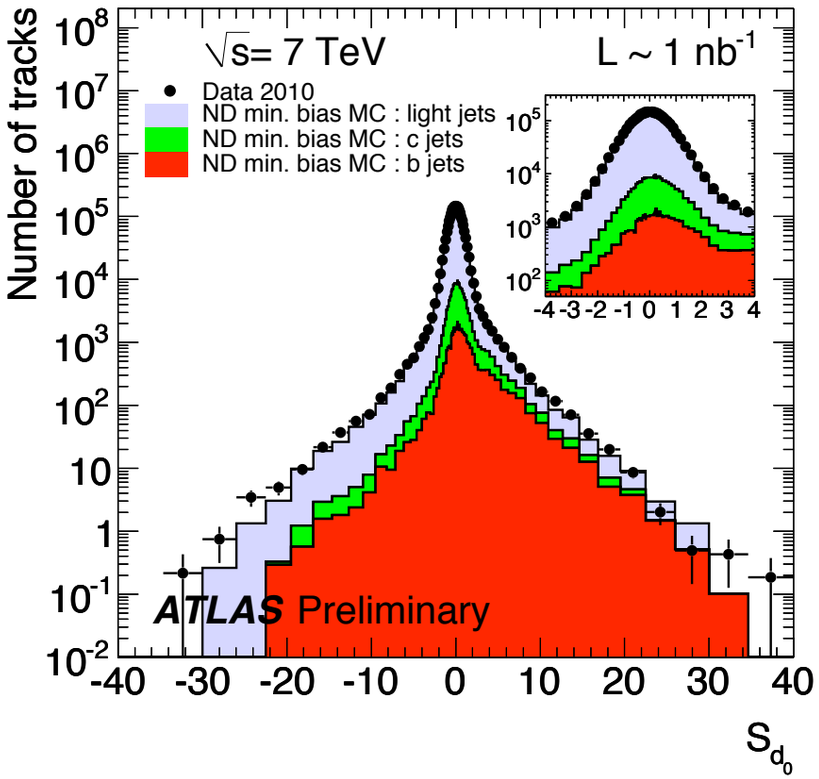
Backup

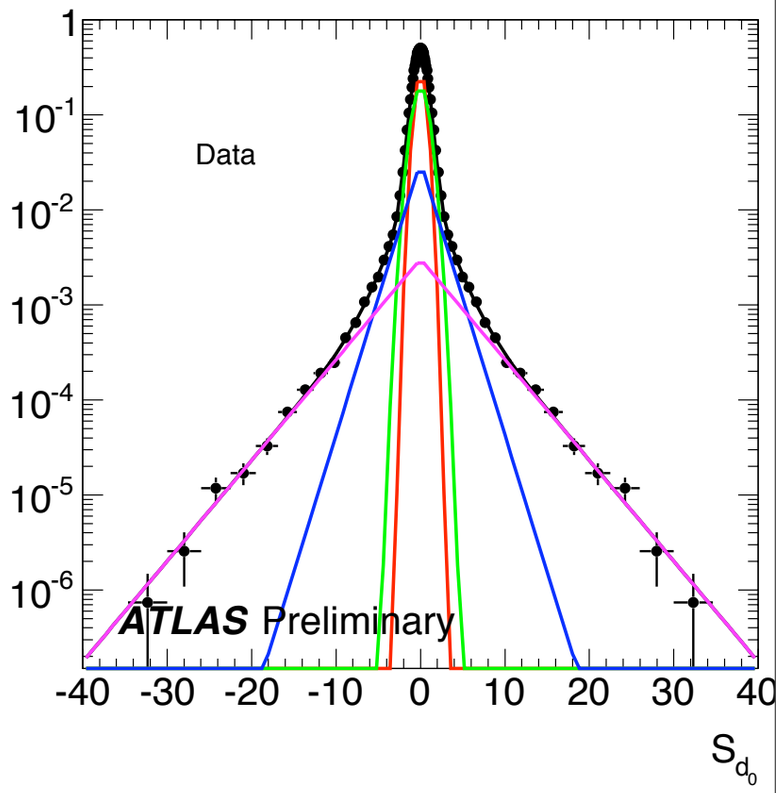
JetProb Tagger

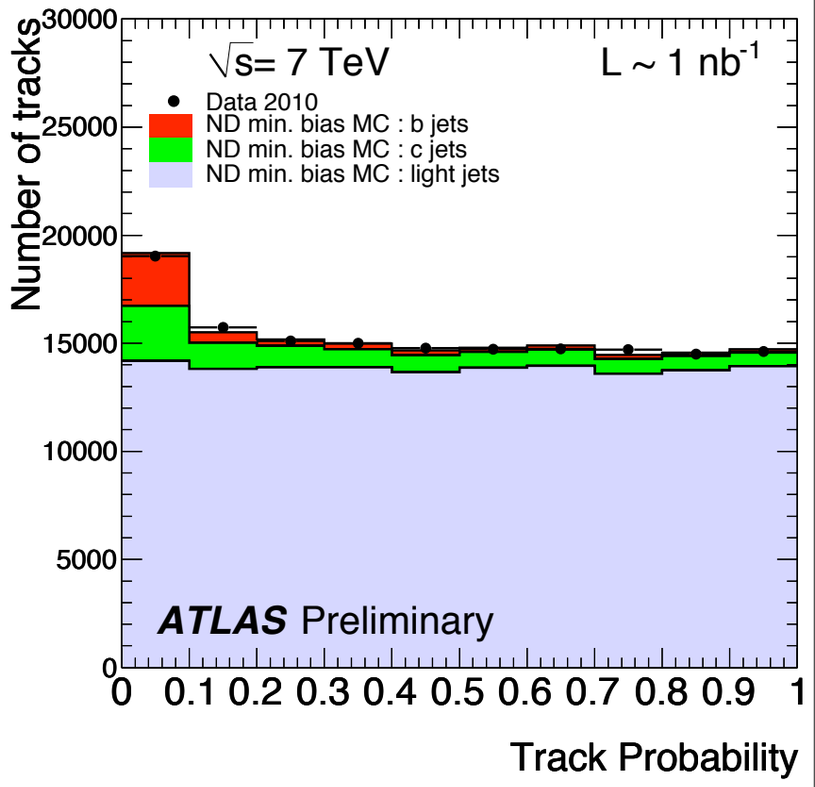
The JetProb tagger is a robust tagger which is being commissioned on early data.

It uses the shape of the negative side of the signed decay length distribution of tracks to derive a calibration function. The calibration function yields a per track likelihood that the track is a prompt track, the sum over those likelihoods gives a similar probability for the associated jet.

Jets with low JetProb probabilities are therefore likely to be b-jets.







SV0 Tagger

The SV0 tagger is a robust tagger which is being commissioned on early data.

It uses a secondary vertex finder which rejects tracks compatible with the primary vertex and rejects vertices compatible with V0-decays, conversions and material interactions. The tagging weight is the signed decay length significance of the reconstructed secondary vertex (in the jet).

Vertices with a high signed decay length significance are likely b-decays.