STUDY OF THE ATLAS INNER DETECTOR MATERIAL BUDGET BY USING HADRONIC INTERACTIONS

INTRODUCTION

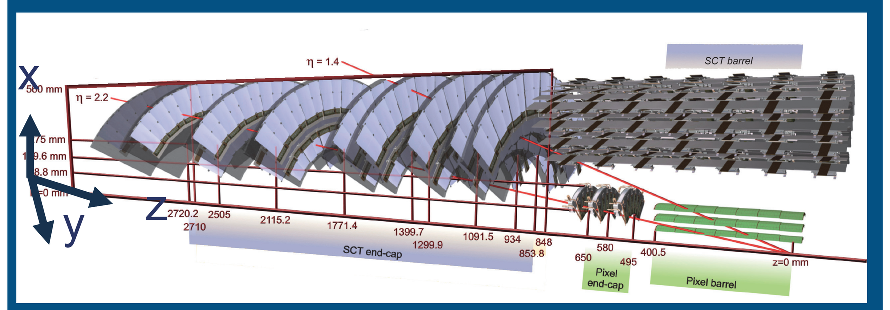
The dominant inefficiency in charged particle trajectory reconstruction (tracking) is associated with interactions of charged particles with the material of the detector. A good understanding of the material in the Inner Detector (ID) of ATLAS is a vital part of physics object reconstruction. In recent years a new technique has been developed, which reconstructs the nuclear interactions of primary particles with the detector material and allows the material budget to be quantified [1]. This technique is complementary to other material studies such as the γ-conversion method and a method that looks at the efficiency for extending the tracks from pixel-only tracks to the SCT [3]. Run-1 and Run-2 results are presented in this poster.

ATLAS INNER DETECTOR PIXEL AND SCT

Detector layout:
- Cylindrical Layers (Barrel)
- Disks in Forward Region (End-Cap)

Run-1 Layout:
- 3 Pixel Barrel Layers
- 6 Pixel Disks
- 4 SCT Barrel Layers
- 8 SCT Disks
- Transition Radiation Tracker (TRT)

Run-2 Layout (additions):
- New reduced material beam-pipe
- New pixel barrel layer (Insertable B-Layer (IBL))



MATERIAL BUDGET

ATLAS ID provides high precision tracking thereby gives excellent:
- Momentum resolution
- Spatial resolution
- Vertex reconstruction(primary / secondary)

Reconstruction efficiency:
- Inefficiency dominated by hadronic interactions
- Precise knowledge of the material is vital

DATA AND MC

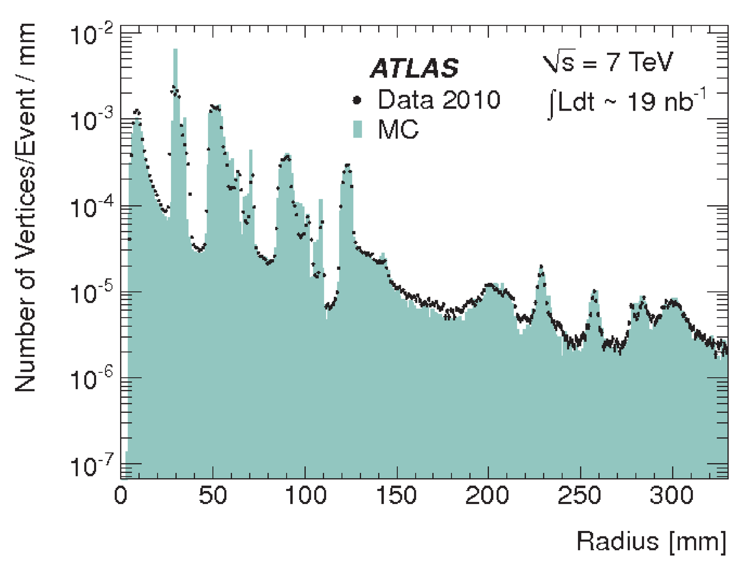
Data (Run-1):
- Collected in 2010 at 7 TeV
- Integrated luminosity 19 nb^{-1}
- Minimum bias trigger & low pile-up runs

Data (Run-2):
- Collected in 2015 at 13 TeV
- Minimum bias trigger & low pile-up runs

Simulation (Minimum bias):
- Generated with PYTHIA8
- Detector geometry made in GEANT4

COMPARISON OF MATERIAL

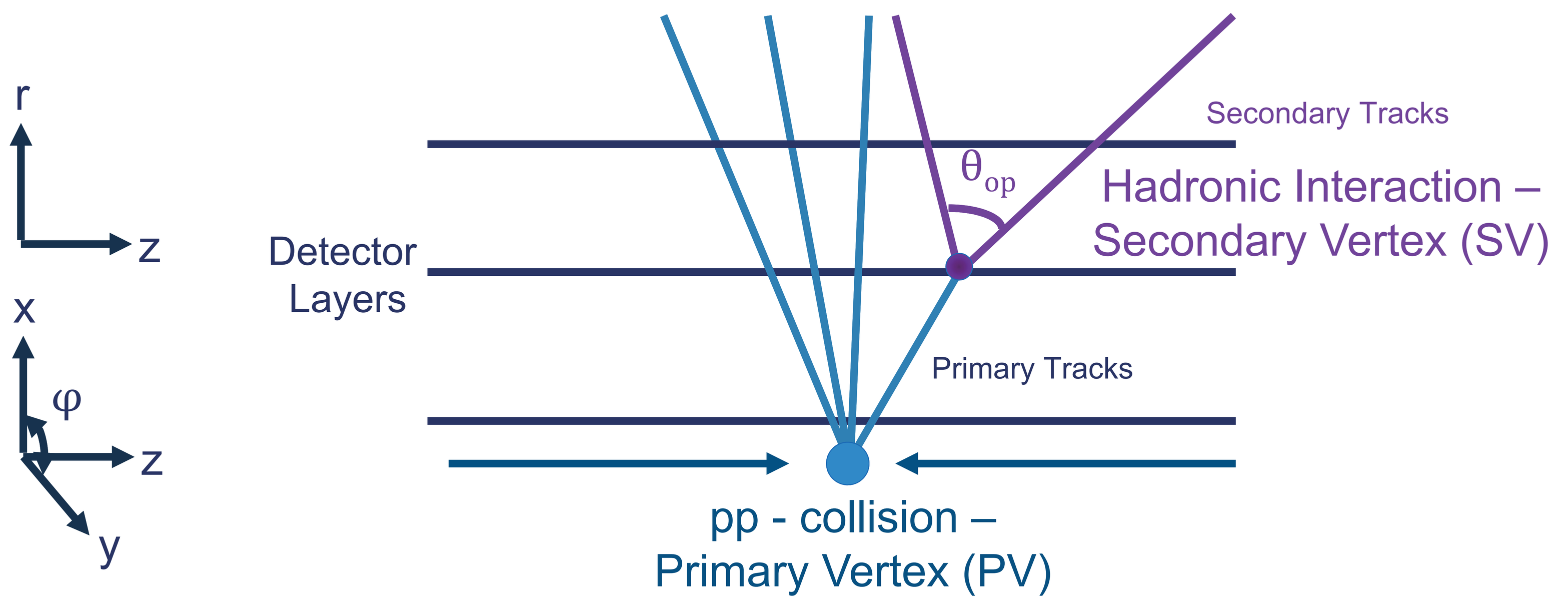
The material budget is quantified with the number of SV reconstructed in data and MC. Plotting the yield of SV versus the radial region of the detector provides an quick comparison.



Peaks at certain radius corresponds to regions with dense material. Good agreement is seen for the whole ID with r < 350 mm [1].

HADRONIC INTERACTION TECHNIQUE

Particles crossing the detector may interact with the material. The location of the hadronic interactions are reconstructed from the outgoing secondary charged particle tracks. Relative large opening angles θ_{op} yield superb resolutions.



Several millions of hadronic interactions are reconstructed in data and in simulation and used to map the material of the ID.
The tracks are required to be well measured with at least one silicon hit per track, this limits the range to r < 400 mm.

Large radius tracking:
- Developed for decays at large radii
- Standard tracking has low efficiency for secondary tracks
- Loosen cuts to increase efficiency to reconstruct secondary tracks

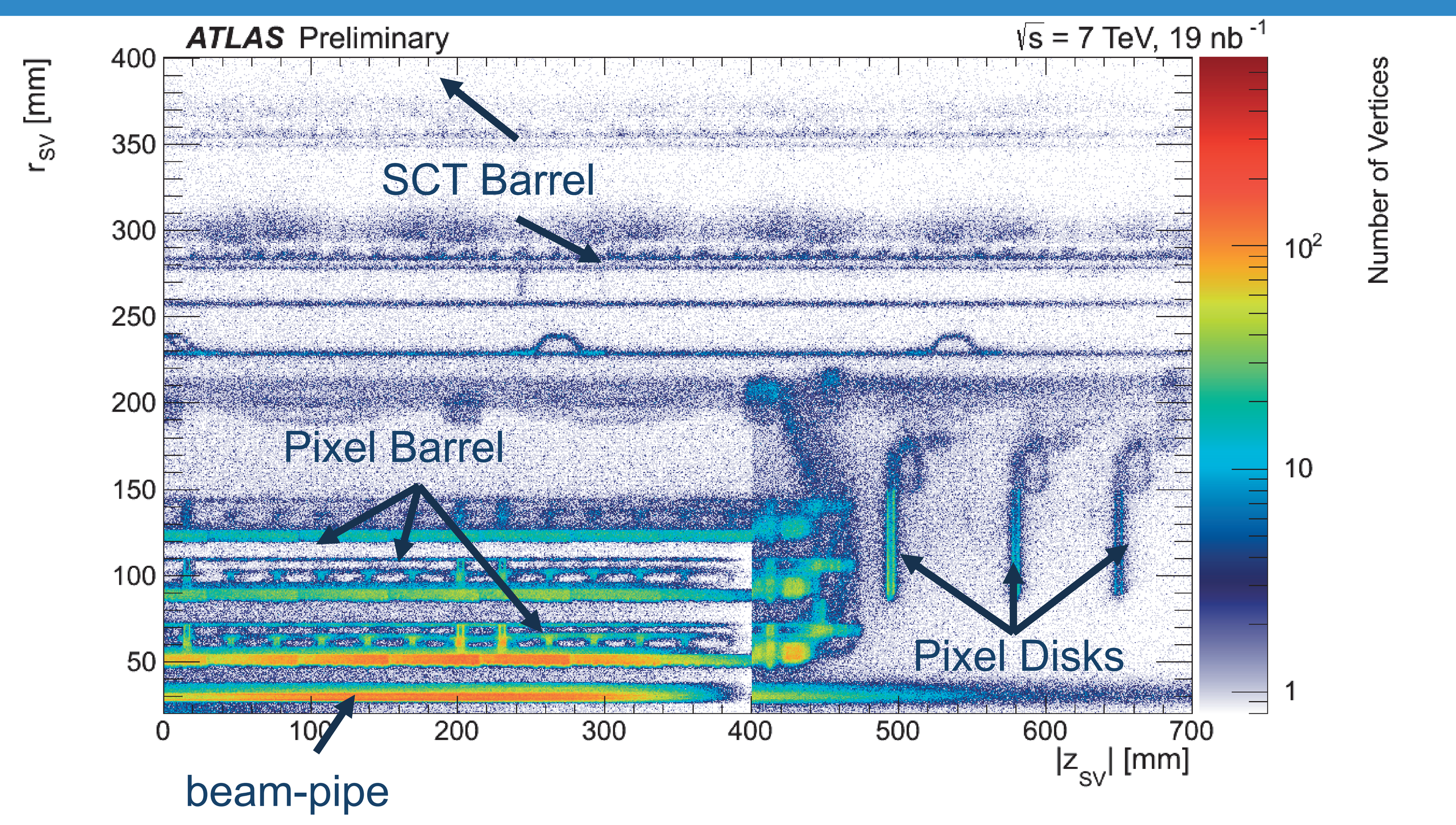
Secondary vertex reconstruction:
- Select secondary tracks by $|d_0^{PV}| > 5$ mm (d_0 transverse impact parameter)
- p_T >400 MeV (300 MeV in Run-2)

Mass veto removes background:
- K^0-decays
- Λ-decays
- γ-conversions

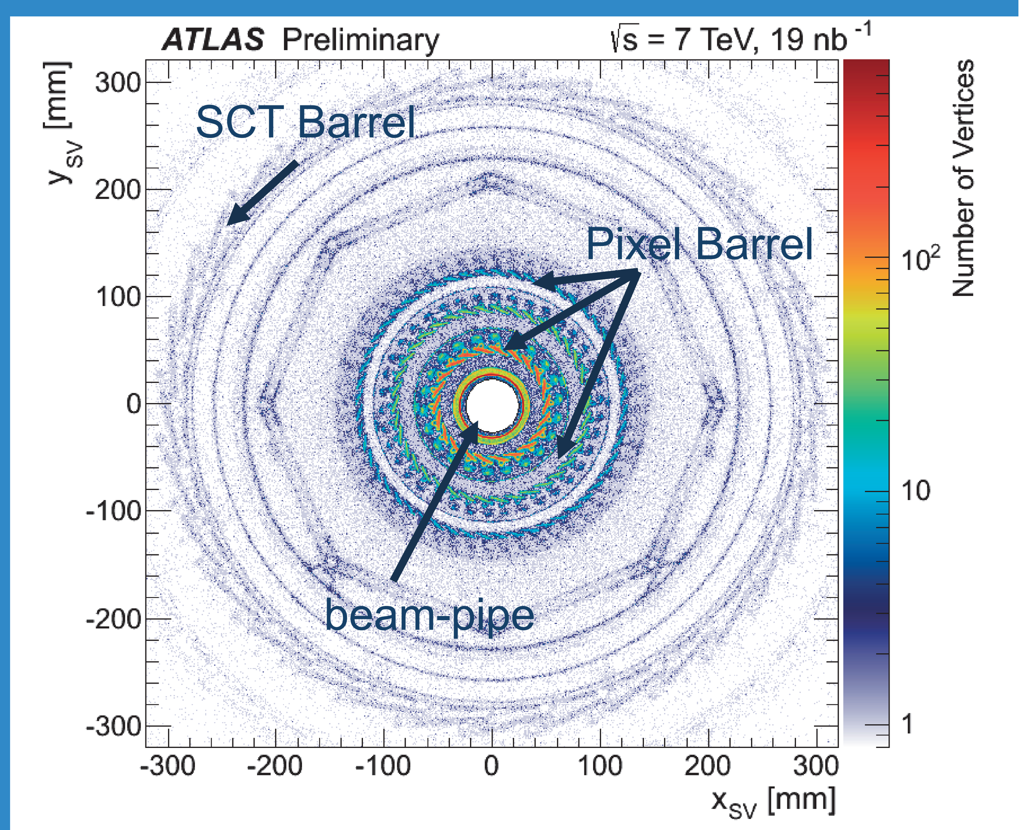
Superb resolution - large θ_{op}:
- 0.2 mm in r and z (2 mm γ-conversions)

Fiducial region:
- r < 400 mm and |z| < 700 mm

RUN-1



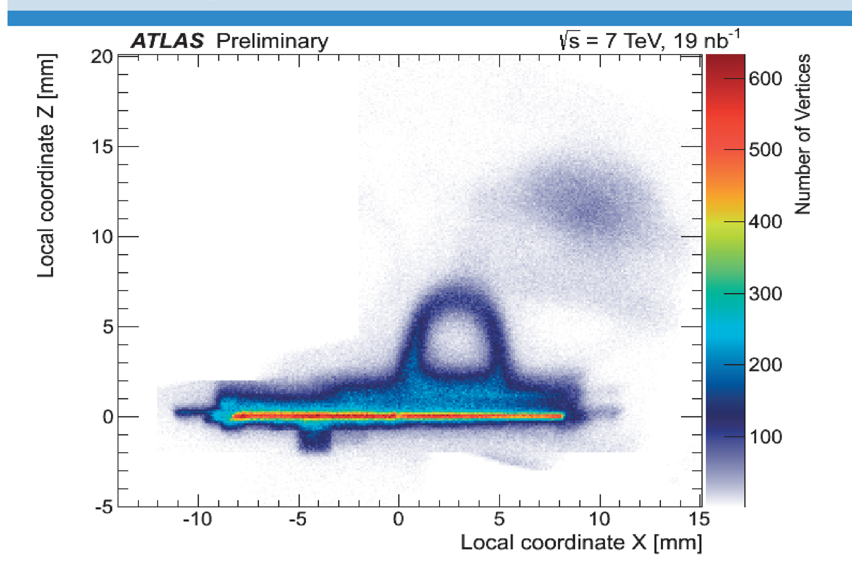
The beam-pipe (r_{sv} = 34.3 mm), the three pixel barrel layers (r_{sv} = 50.5, 80.5, 122.5 mm), the first two SCT barrel layers (r_{sv} = 299, 371 mm) and three disks in the pixel forward region (r_{sv} < 200 mm and |z| > 450) are clearly visible [2].



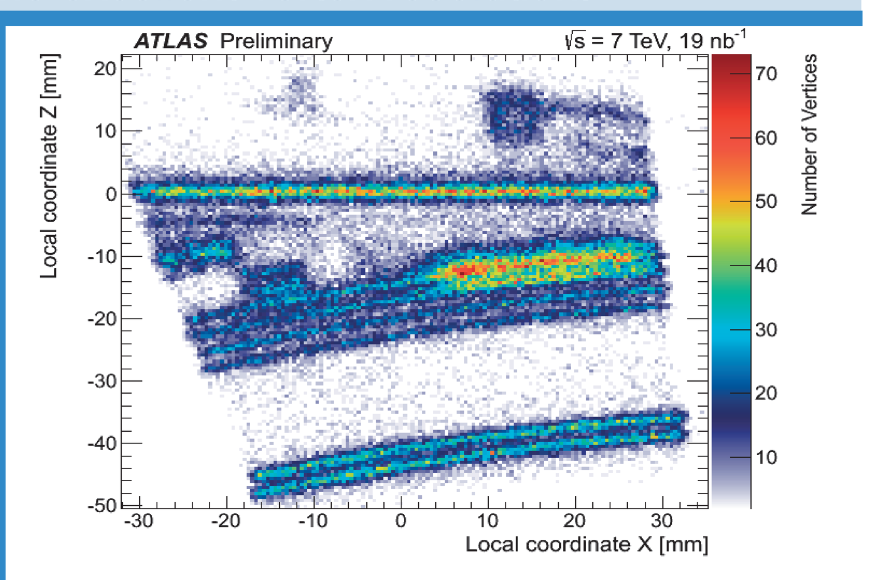
Going from the centre out, the beam pipe, the three pixel barrel layers and the first two SCT barrel layers are clearly visible [2].

DETAILED VIEW OF PIXEL AND SCT MODULES

Pixel and SCT modules are regularly mounted in cylinder layers (barrel) and are more easily studied by transforming from the global coordinates (xyz) to local coordinates (XYZ). Stack all modules in the local coordinate frame to increase statistics. Minute details are visible due to the excellent vertex resolution.



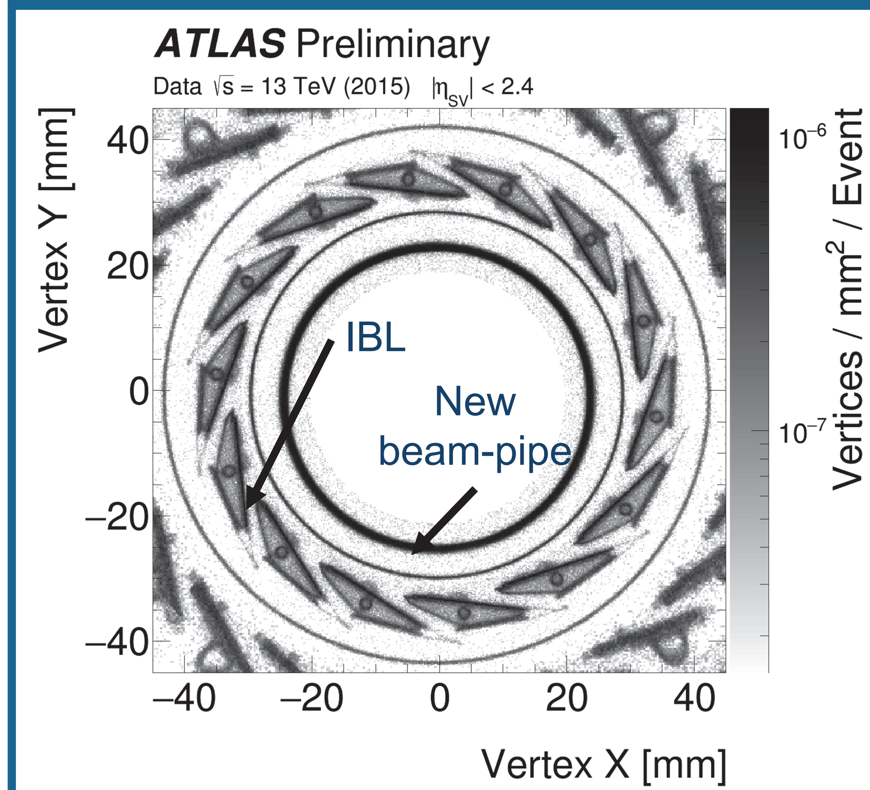
An image of pixel modules in the first pixel layer, The silicon sensor is indicted by the high vertex density at Z = 0 [2].



An image of SCT modules in the SCT layer. The SCT module is the flat structure at Z = 0 [2].

RUN-2

The new additions to the ATLAS ID in Run-2 are beautifully mapped by the hadronic interaction technique. Shown below for r < 45 mm; new thinner beam-pipe and the IBL are clearly visible.



Zoomed in view of the new addition to the ATLAS ID for Run-2 operation [3]. The beam-pipe is a r = 24 mm and the IBL at r = 34 mm.

CONCLUSION

Excellent performance of the hadronic interaction technique has been demonstrated. The superb spatial resolutions make it possible to study minute details of the detector, e.g. silicon modules. The study provides precise feed back and has been used to improve the modelling of the material budget.

References:
[1] JINST 7 (2012) P01013, [2] IDTR-2016-001, [3] ATL-PHYS-PUB-2015-050

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