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Minimum bias at $\sqrt{s} = 13\,\text{TeV}$: Tracking and material distribution studies in ATLAS

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Summary. — Run II of the LHC offers new challenges to track and vertex reconstruction with higher energies, denser jets and higher rates. A major upgrade to the Inner Detector of the ATLAS Experiment during the shutdown period has been the installation of the Insertable B-Layer, a fourth pixel layer located at a radius of 33 mm. In this context, each aspect of the tracking and vertex reconstruction programs was re-optimized and improved. This contribution discusses the improvements to the track reconstruction algorithms and the studies of the material distribution in the Inner Detector which represent the main sources of systematic uncertainty for the Minimum Bias Analysis.

1. – ATLAS inner detector and experimental motivation

The Inner Detector (ID) [1] of the ATLAS Experiment [2] was designed to reconstruct with high efficiency and precision the trajectories and the transverse momentum of charged particles and to measure precisely the positions of primary and secondary vertices. The main new features of the ID to cope with the experimental conditions of the LHC Run II (13 TeV centre-of-mass energy, high pile-up, high radiation dose) are a fourth pixel layer, the Insertable B-Layer (IBL) [3], positioned at 33 mm from the beam line, the new thinner beam pipe coupled with the IBL and new more robust pixel service connections installed at the same time. These new parameters foreseen for the LHC Run II and the new layout of the ATLAS Detector, require to improve the reconstruction and analysis stategies. In particular, it is necessary to

- Optimize track and vertex reconstruction setups, trying to improve the efficiency and to cover the largest momentum spectrum;

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- Evaluate the impact of the new material distribution within the ID on fundamental parameters like photons conversion probability, multiple scattering, etc.

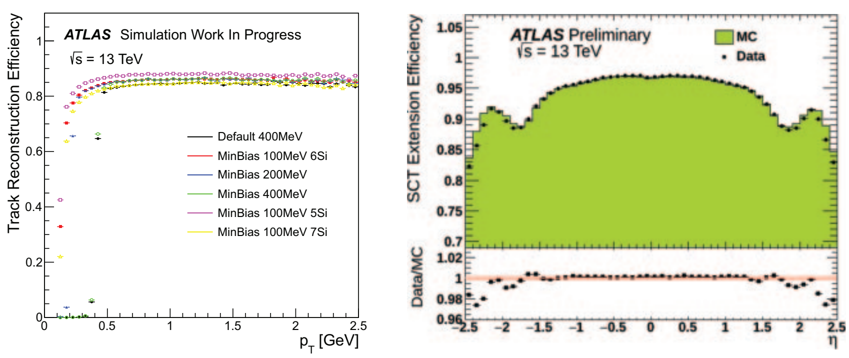
2. – Track reconstruction efficiency

The Minimum Bias events are an ideal testbed to optimize reconstruction and tracking algorithms and to study backgrounds and systematics for other more complex physics analyses. Several reconstruction setups on Monte Carlo samples have been investigated, taking into account the IBL, to evaluate the track reconstruction efficiency. In particular, the effect of changing the transverse momentum p_{T} threshold (100, 200 and 400 MeV) and the number of silicon clusters (5, 6 and 7) has been thoroughly analyzed to establish the best reconstruction setup for RUN II. In fig. 1(a) the track reconstrucion efficiency as function of the track transverse momentum p_{T} for those samples is shown. The same samples have been also analized to establish a cut flow able to keep high efficiency and low fraction of spurious tracks using a selection optimized for the new RUN II features of the Inner Detector. With these studies, a new recostruction setup with a p_{T} threshold equal to 100 MeV and 5 Silicon Clusters and a new track quality selection which keep high efficiency ($\sim 80\%$) and low rate of spurious tracks ($\ll 0.1\%$) have been defined.

3. – Material distribution studies

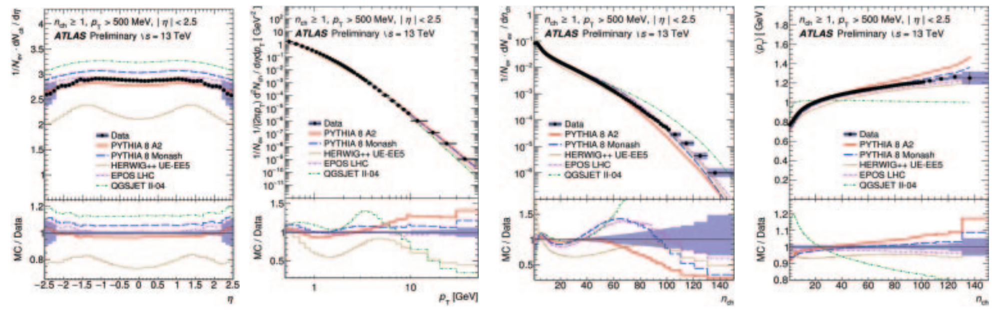
The accuracy with which the amount of material in the ID is known contributes the largest source of uncertainty on the simulation-based estimate of the track reconstruction efficiency. The material description is being cross-checked using three methods relevant to specific regions:

- Hadronic interaction rate (beam-pipe/Pixel region);
- Photon conversion rate (beam-pipe/Pixel region);
- SCT-extension efficiency (Pixel/SCT region).



(a) (b)

Fig. 1. – Track reconstruction efficiency (a) as a function of the track transverse momentum p_{T} and SCT-Extension efficiency (b), *i.e.* rate (*vs.* pseudorapidity η) of pixel stand-alone tracks successfully extended to include SCT clusters and to build a silicon track in a comparison between Data at 13 TeV and Monte Carlo Simulation.



(a) (b) (c) (d)

Fig. 2. – Charged-particle multiplicities as a function of (a) pseudorapidity and (b) transverse momentum, (c) multiplicity distribution and (d) mean transverse momentum *vs.* charged-particle multiplicity for events containing at least one charged particle with $p_{\mathrm{T}} > 500\,\text{MeV}$ and $|\eta| < 2.5$.

The SCT-extension efficiency method probes the inactive material in the region between the Pixel and SCT detectors by evaluating the rate of pixel stand-alone tracks that have been successfully extended to include SCT clusters and to build a silicon track. In fig. 1(b) a comparison between Data at 13 TeV and Monte Carlo Simulation is shown. The observed discrepancies are rather small ($\sim 2\%$ at high η) and agree with the uncertainty expected from the material description. The impact on the tracking efficiency systematics is estimated to be $\sim 5\%$ [4].

4. – Minimum bias analysis

Charged-particle multiplicity (or minimum bias) measurements at $\sqrt{s} = 13\,\text{TeV}$ [5] have been performed by studying the properties of nearly 9 million events collected on June 9 and June 10 2015. In fig. 2, the final distributions are shown. The selected kinematic range and the precision of this analysis highlight clear differences between Monte Carlo models and the measured distributions.

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