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Expected tracking and related performance with the future ATLAS Inner Tracker at the HL-LHC

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To extend the potential of discoveries for new physics beyond the Standard Model as well as precision measurements the High Luminosity phase of the Large Hadron Collider at CERN aims to deliver an integrated luminosity of up to 4000 fb^{-1}. To face the challenging environment associated with the high number of collisions per bunch crossing, the current ATLAS inner detector will be replaced with a new all-silicon Inner Tracker (ITk) which will cover up to $|\eta| <4$. We present results of the expected tracking performance as well as some representative high-level object reconstruction and identification, including primary vertices, jet flavour-tagging, electrons, and converted photons using an updated layout of the ITk pixel detector.

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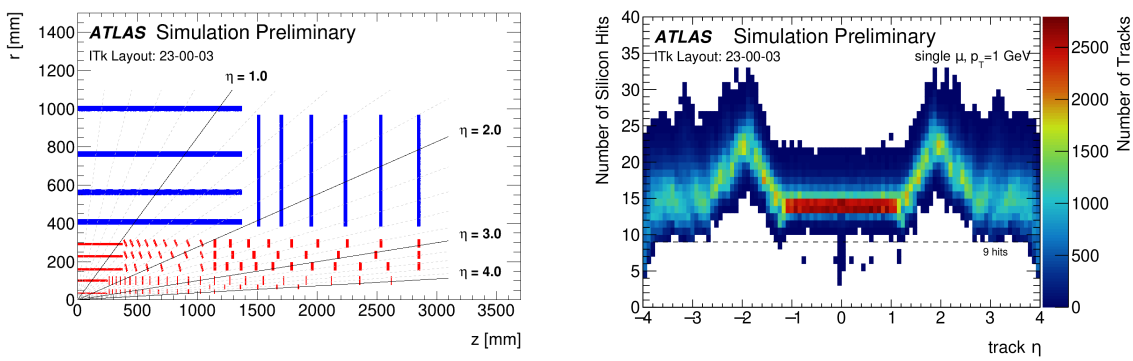
1. The ATLAS Inner Tracker (ITk)

The High-Luminosity (HL) phase of the Large Hadron Collider (LHC) at CERN is expected to deliver an integrated luminosity of up to 4000 fb^{-1}, corresponding to an increase of a up to a factor of seven in the average number of inelastic pp collisions per bunch crossing with respect to the current LHC phase. This will allow physicists to make more precise measurements of Standard Model processes as well as increase the potential of discoveries. To cope with challenges posed by the increased instantaneous luminosity the current ATLAS Inner Detector (ID) [1] will need to be upgraded to a new all-silicon Inner Tracker (ITk) with a higher granularity. After the Technical Design Reports of the strip [2] and pixel [3], new ITk designs have been proposed [4]. The recent ITk pixel detector design reduces the radius of the innermost pixel layer from 39 to 34 mm. The pixel pitch in the central part of this layer was also fixed to 25×100 μm^2 while a pixel pitch of 50× 50 μm^2 is used in the rest of the detector. These changes significantly improved the transverse impact parameter resolution of the reconstructed tracks.

The ITk is made of two subsystems: a Pixel Detector [3] surrounded by a Strip Detector [2] The Strip Detector has four strip double-module layers in the barrel region and six end-cap disks, covering the pseudorapidity range up to $|\eta| = 2.7$. The Pixel Detector consists of five flat barrel layers and multiple inclined or vertical ring-shaped end-cap disks, extending the coverage up to $|\eta| = 4.0$. The new layout of the ITk namely 23-00-03 with which the results presented in this paper are made is shown in Figure 1 [5]

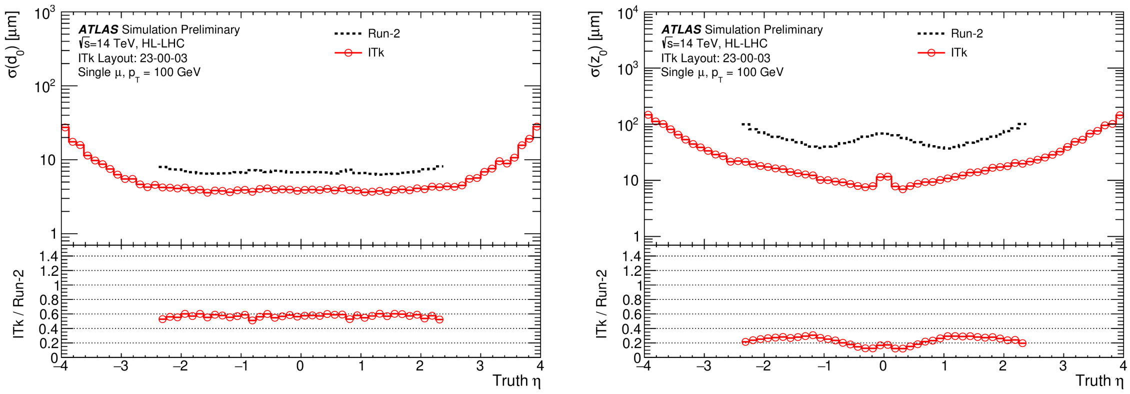


(a) (b)

Figure 1: (a) A schematic depiction of the ITk Layout 23-00-03, and (b) expected of the number of silicon hits on a track as a function of η for p_T = 1 GeV single muon events [5].

2. Track parameter resolution

Figures 2 presents a comparison of the ITk layout 23-00-03 and the Run 2 ATLAS ID of the expected track parameter resolutions in the transverse (d_0) and longitudinal (z_0) planes for simulated muons with p_T = 100 GeV. The d_0 and z_0 resolutions are respectively improved by a factor two and four thanks to the smaller ITk pixel pitch (25 × 100 or 50 × 50μm^2 for ITk, 50 × 250 for the insertable B-layer).

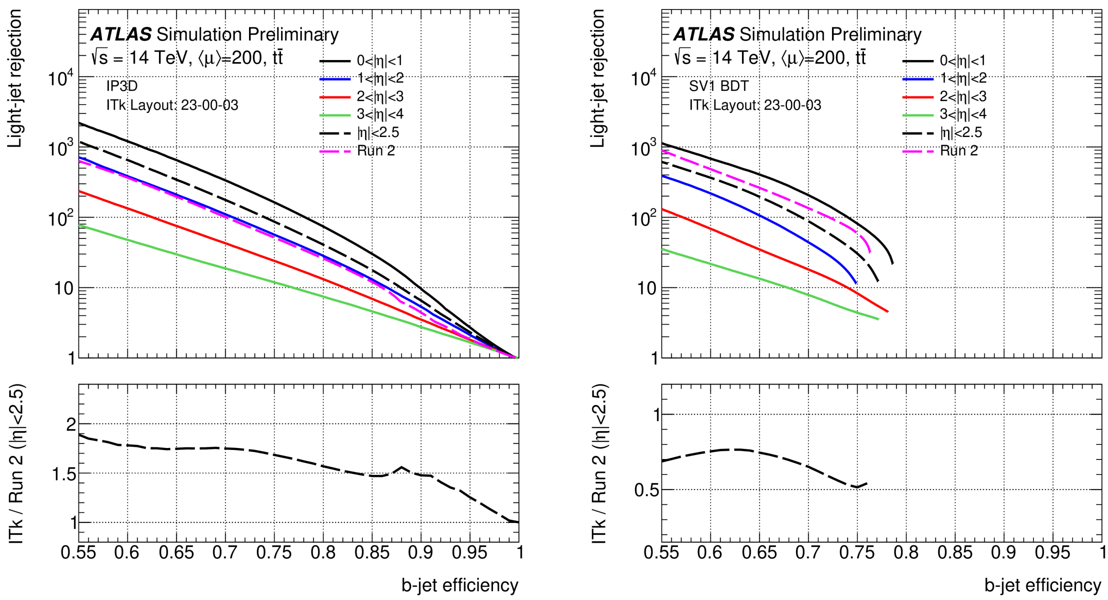


(a) **(b)**

Figure 2: Transverse impact parameter d_0 (a) longitudinal (z_0) (b) resolutions as a function of η for p_T = 100 GeV muons without pileup, compared between the Run 2 detector and the updated ITk layout [5].

3. Jet flavour tagging

The identification of heavy flavour jets is based on low-level b-tagging algorithms, IP3D [6], SV1 [7] and the JetFitter algorithm [8]. Their performance are presented in Figure 3

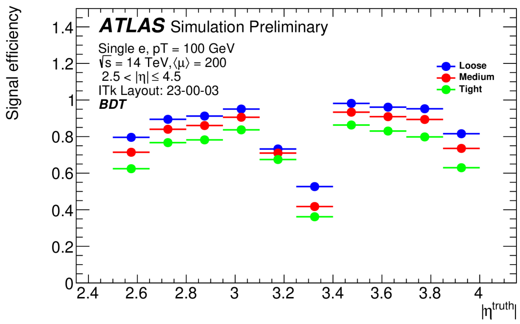


(a) **(b)**

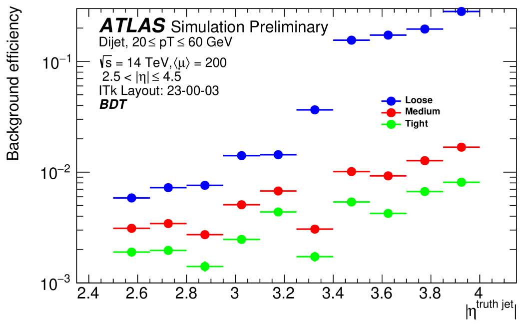
Figure 3: Light-jet rejection vs b-tagging efficiency for the IP3D (a) and SV1 (b) tagging algorithms for different η ranges, using a $t\bar{t}$ with 200 pileup events, the lower panel shows the ratio with respect to Run 2 [5].

4. Forward Electron reconstruction

The ITk expands the tracking capabilities from $|\eta| = 2.5$ up to $|\eta| = 4.0$ providing the tracking information of electrons falling in the forward region. The identification of forward electrons relies on the association of a track measured in the forward region of ITk and a topological cluster reconstructed in one of the two sections of the forward calorimeter. First the track is extrapolated to the calorimeters, then the association is performed by selecting separately on the quantities $\Delta\phi$ and $\Delta\eta$. A BDT is used to enhance the separation between signal and background. The training was done using electron and dijet events with a total of eight inputs variables, six of them are related to shower shape in the calorimeters and two linked to track-cluster matching. The performance is evaluated with single electron samples with $p_T = 100$ GeV in Figure 4a. The fake-electron rate is estimated from a sample of dijet events and is shown in Figure 4b. Finally, the charge misidentification is also estimated in the forward region as shown in Figure 4c



(a)



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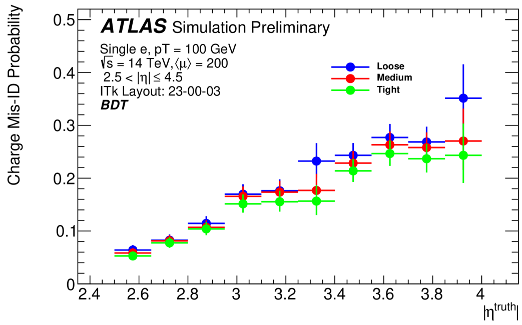

(c)

Figure 4: (a) Signal efficiency for electrons with a $p_T = 100$ GeV. b) Background efficiency in dijet events. c) Fraction of electrons reconstructed with the wrong charge for events with pileup as a function of η [5].

5. Conclusion

As part of the ATLAS Phase-II upgrade, a new full silicon Inner Tracker will be installed replacing the current Inner Detector. Despite the challenging data-taking conditions at the LHC the new ITk is expected to deliver equal or better tracking performances with respect to Run 2 ID. The presented results demonstrate the good baseline already achieved by ITk and they are expected to evolve over next years thanks to developments in both hardware and software.

References

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