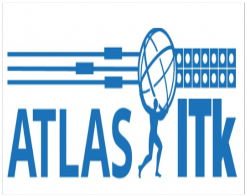

Expected performance of the ATLAS ITk detector for HL-LHC

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On behalf of the ATLAS ITk collaboration

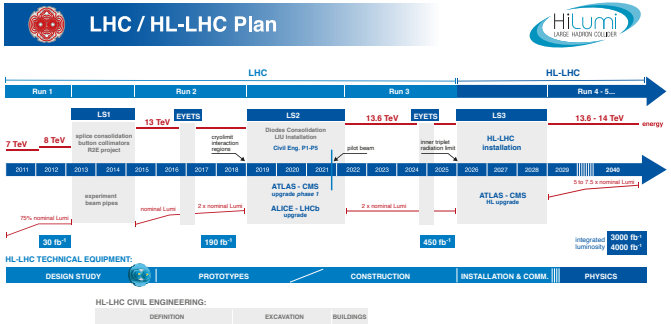
University of Science and Technology of China

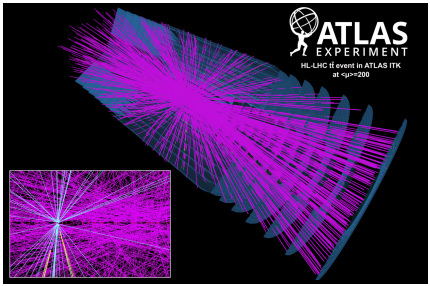
The XXXI International Workshop on Deep Inelastic Scattering and Related Subjects (DIS2024)

8-12 April 2024, Grenoble, France

High Luminosity LHC

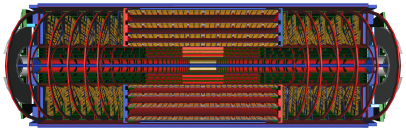
- The High Luminosity LHC (HL-LHC) will deliver an integrated luminosity of up to 4000 fb^{-1} (4 times higher luminosity than LHC)
  - → An instantaneous luminosity $\mathcal{L} = 7.5 \times 10^{34}$ cm^{-2}s^{-1}
  - → An average of 200 inelastic proton-proton interactions per bunch crossing (60 in Run 2)
  - → High radiation environment

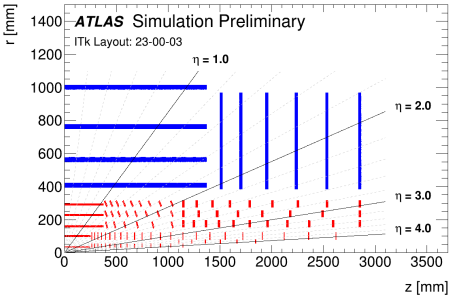




The ATLAS Inner Tracker for the Phase II upgrade

- To cope with the harsh environment at HL-LHC, the current inner detector (ID) will be replaced with a new full-silicon Inner Tracker (ITk).
- The ITk is composed by Strip and Pixel sub-detectors
  - Strip detector: 4 barrel layers + 6 end-cap disks
  - Pixel detector: 5 barrel layers + inclined and vertical rings
- Increase radiation hardness: new sensors and front-end
- Extend the pseudo-rapidity coverage up to $|\eta| = 4$
  - $\rightarrow$ Increasing lepton reconstruction
  - $\rightarrow$ Increasing jet flavor tagging acceptance
  - $\rightarrow$ Improved pile-up rejection





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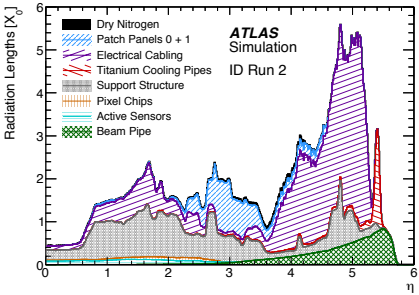
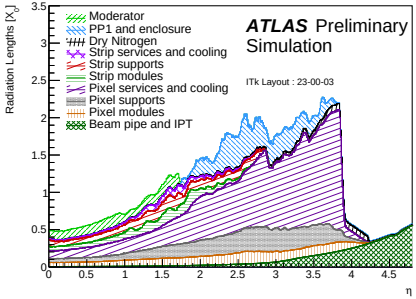
Material budget

CERN-LHCC-2017-005, ATL-PHYS-PUB-2021-024

- Low material budget compared to the ATLAS ID
- Evaporative CO2 cooling system with titanium pipes
- Carbon structures for local supports
- Optimised number of readout cables using link sharing
- Innovative Serial Powering (SP) scheme in the pixels





Tracking Efficiency

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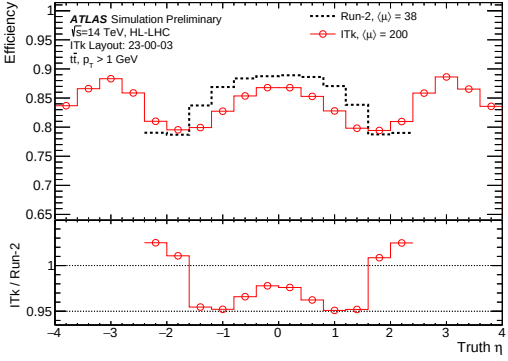
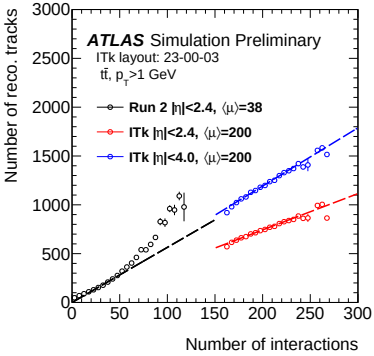
- Tracks are formed by charged clusters from individual readout channels with a hit in the strip and pixel detectors
- Excellent tracking efficiency in the central region of the ITk ($< \mu >= 200$) detector is within 5% to the one of the Run 2 ID ($< \mu >= 38$)



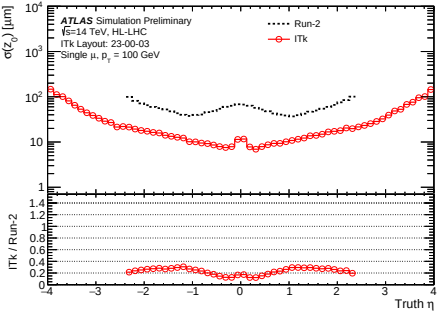


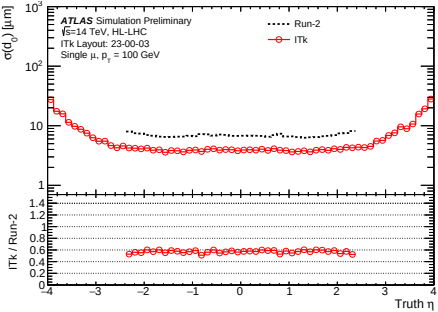
→ Robustness of the tracking efficiency over a large pileup range, thanks to the deployement of an optimised seeding strategy + hit requirements (More than 9)

→ **Negligible fake rate O(10^{-4})**

Track parameter resolution

- Improved longitudinal parameter resolution (z_0) thanks to the exploitation of the smaller pixel pitch used in the ITk pixel detector (25×100 or 50×50 μm^2 for ITk 50×250 μm^2 for IBL)
- Improved transverse momentum resolution (d_0) thanks to the better resolution in the bending direction associated with the silicon strip sensors used in ITk
- Degradation in the forward region will be recovered by the exploitation of timing information from HGTD





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Vertexing performance

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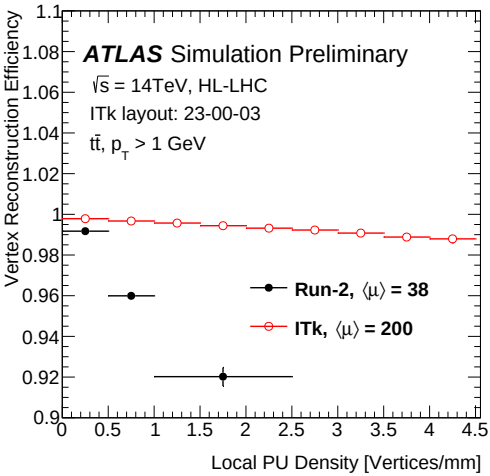
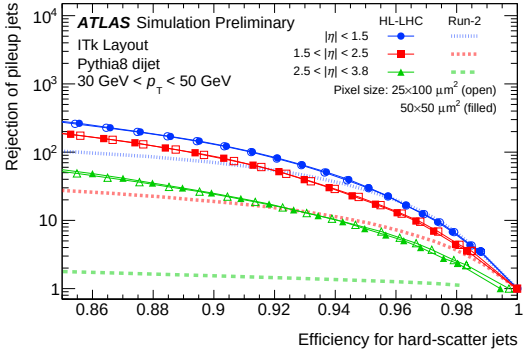
- Adapt a new algorithm **Adaptive Multi-Vertex Finder (AMVF)** for vertex reconstruction $\Longrightarrow$ pile-up robustness and better reconstruction efficiency
- Primary vertex identified as the reconstructed vertex with the largest $\sum p_T^2$ of associated tracks
- Stable reconstruction efficiency even with $< \mu >= 200$
- Direct impact on high-level objects performance
  - Lepton isolation
  - b-tagging
  - pile-up rejection



Pile-up rejection

ATL-PHYS-PUB-2019-014

- Discrimination between jets from pileup vertices and those from the HS vertex relies on the track reconstruction and z_0 resolution
- Performance in central detector region is better thanks to the low material
- Dramatic improvement in the forward region thanks to the extended ITk coverage (no tracker acceptance for Run 2 ID)
- Degradation at high $|\eta|$ is due to the worsening of the impact parameter resolution
- **Benefit VBF/VBS analyses**



b-tagging

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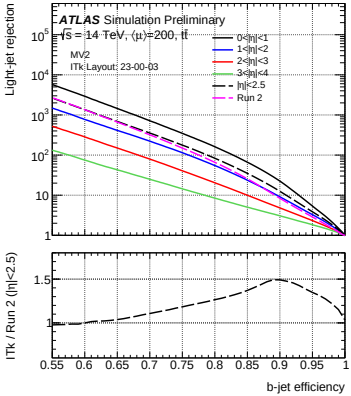
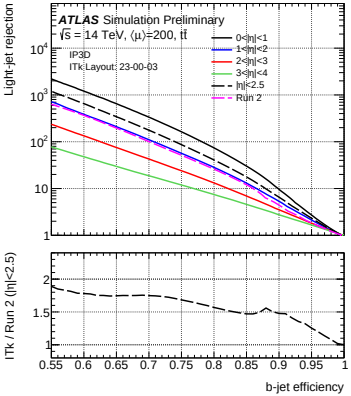
- Identification of heavy flavour jets is based on several low-level b-tagging algorithms: IP3D, SV1, and JetFitter
- Improvement of impact-parameter based flavour-tagging algorithm (IP3D) mainly coming from improved ITk IP resolution
- Direct impact on the high-level b-tagging algorithm MV2
  $\Longrightarrow$ **Benefit DiHiggs analyses**
- Expect more improvement with recent b-tagging developments (GN2X)

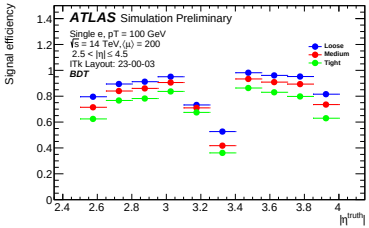


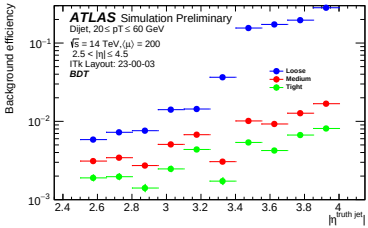


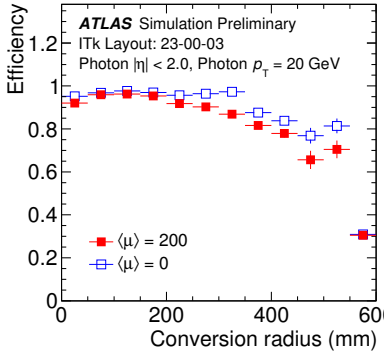
Forward electrons and photons

ATL-PHYS-PUB-2021-024

- ITk will extend the pseudo-rapidity coverage up to $|\eta| = 4$ which will enable tracking reconstruction in the forward region
- More than 80% photon conversion reconstruction efficiency to the first ITk strip layer







Conclusion

- ITk will replace the current ID to meet the HL-LHC challenges
- High pseudo-rapidity coverage allows tracking in the forward region
- Excellent tracking performance w.r.t. current ID despite 200 pile-up events
- Improvements on track reconstruction yield to better performance of high-level object reconstruction and identification. Hence, increase of physics analyses sensitivity with expected HL-LHC dataset

Backup

HL-LHC Pile-up conditions

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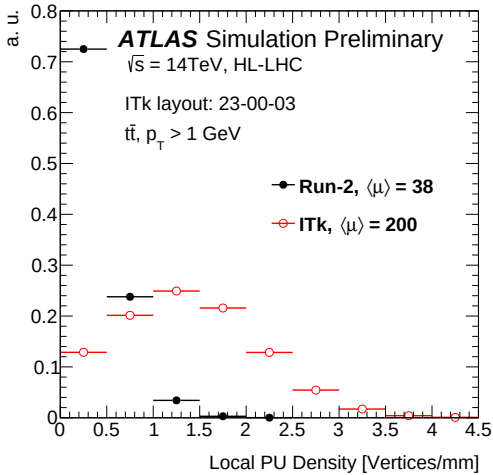
- Larger average number of pile-up interaction per bunch crossing
- Increased fraction of events where a reconstructed vertex is within 0.1 mm of the true hard-scatter position in the longitudinal direction



Silicon hits

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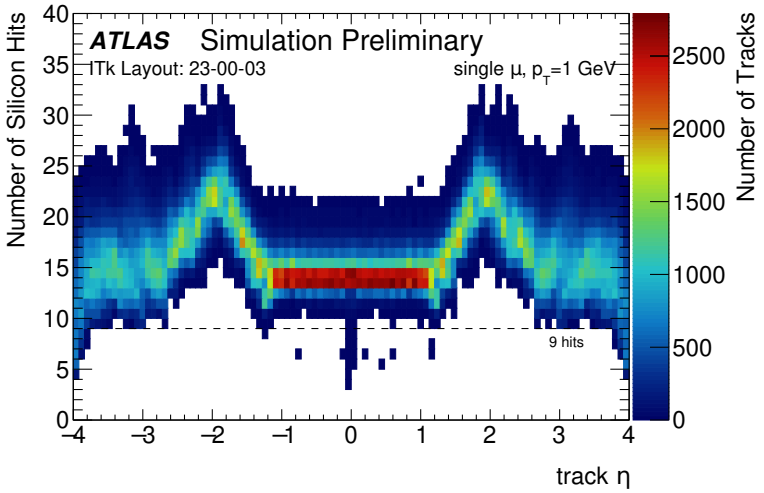
Requirements	Pseudorapidity interval		
	$\|\eta\| < 2.0$	$2.0 < \|\eta\| < 2.6$	$2.6 < \|\eta\| < 4.0$
pixel + strip hits	≥ 9	≥ 8	≥ 7
pixel hits	≥ 1	≥ 1	≥ 1
holes	≤ 2	≤ 2	≤ 2
p_T [MeV]	> 900	> 400	> 400
$\|d_0\|$ [mm]	≤ 2.0	≤ 2.0	≤ 10.0
$\|z_0\|$ [cm]	≤ 20.0	≤ 20.0	≤ 20.0



Relative transverse momentum resolution

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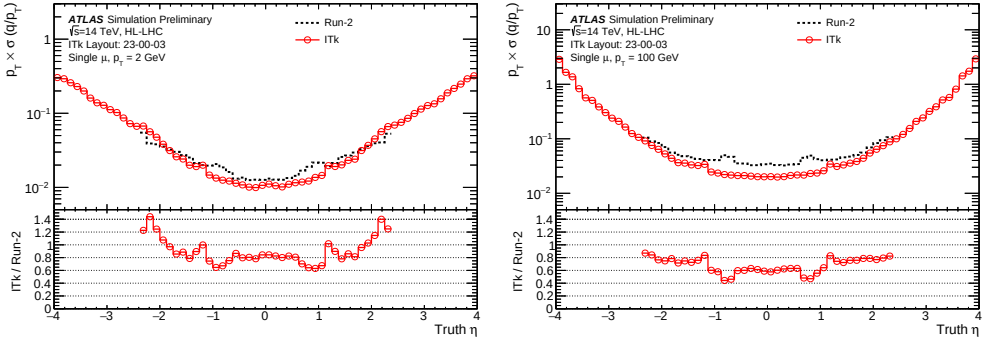

Central electrons

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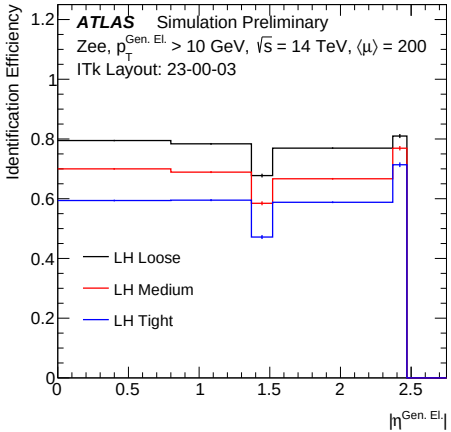

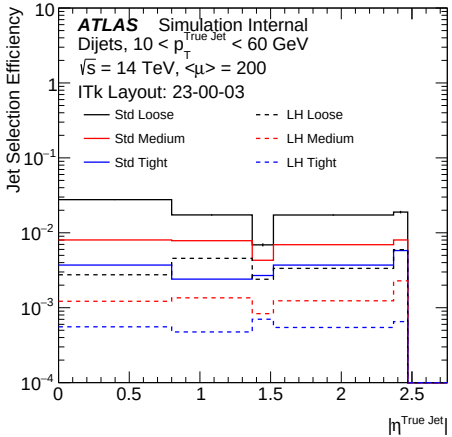

Low-level b-tagging algorithms

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