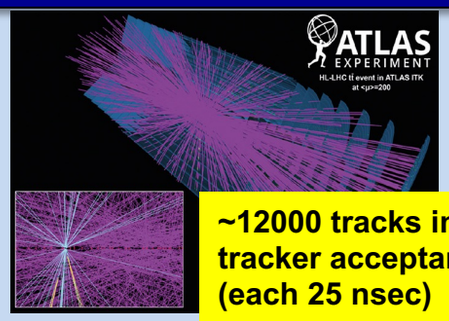
PM2024 - 16th Pisa Meeting on Advanced Detectors

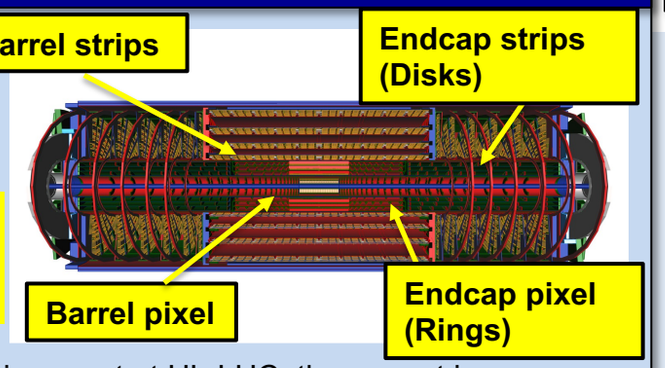
Performance of the new tracker and timing ATLAS detectors at HL-LHC for pile-up suppression

The High-Luminosity LHC (HL-LHC), currently foreseen to start towards 2029, will operate at an instantaneous luminosity of up to 7.5 × 10^{34} cm^{-2} s^{-1} corresponding to an unprecedented average number of proton proton collisions per bunch crossing of up to 200. Efficient techniques to identify and and suppress jets originating from pile-up interactions are critical to achieve the physics potential of the HL-LHC. The ATLAS Inner Detector for the HL-LHC Run 4 will be upgraded to a full-silicon Inner Tracker (ITk). Thanks to the extended coverage of ITk, the techniques to tag and suppress pile-up currently in use will be applicable also to the high eta region, however, with expected worse performance compared to that in the central region, due to the higher amount of material and the harsher environment. The High-Granularity Timing Detector (HGTD) that will be installed in the forward region for Run 4, will improve the pile-up suppression in that region through timing information at the 30-50 ps level. In this poster an overview of the ITk and HGTD sub-detectors will be given, with a focus on their performance on the pile-up suppression for the reconstruction of high level objects. Also, the impact of a possible additional timing detector in the central region, enabling 4D Tracking beyond the Run 4 will be discussed.

New Inner Tracker (ITk)



~12000 tracks in the tracker acceptance (each 25 nsec)



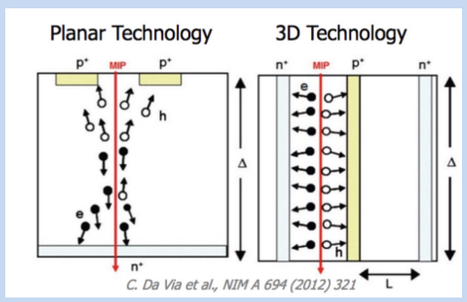
Motivation: To face the harsh environment at HL-LHC, the current inner detector will be replaced with a new full-silicon Inner Tracker (ITk).

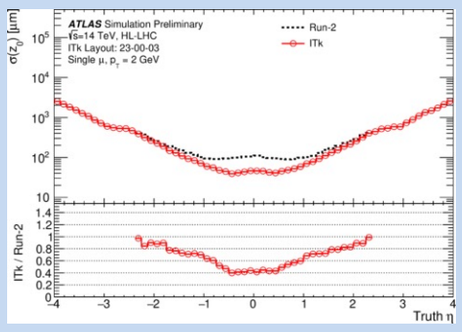
Sensor Technology
Pixel, 13m^2
- 3D for the inner most layer
- Planar elsewhere
- pitch size 50 x 50 μm^2 except 25 x 100 μm50 x 50 μm for barrel most inner layer

Strip: 165m^2, planar n-in-p

- **Finer segmentation**
- Extension up to $|\eta| < 4$
- **Increase radiation hardness**: new sensors & front-end
- **Improved impact parameter resolution** Reduced at high $|\eta|$ due to larger amount of materal crossed and harsher environment

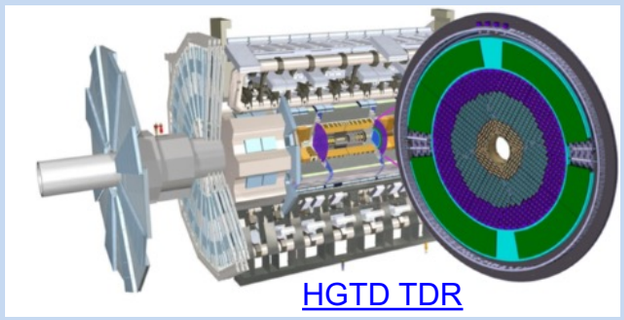
ITk Strip TDR
ITk Pixel TDR





High Granularity Time Detector (HGTD)

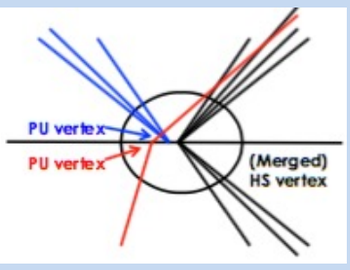
Located in front of encap calorimeter
Δz envelope~ 12.5 cm @ |z| = 3.5 m, 2.4<|η|<4



HGTD TDR

Motivation: Improve pile-up suppression in the reconstruction in the forward region

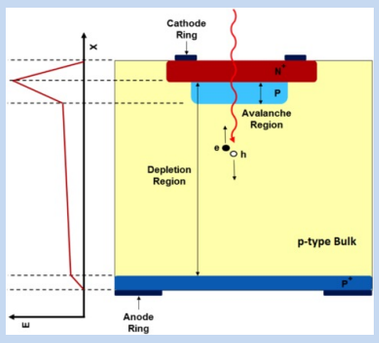
- At mu=200, 5 -7 vertices from forward tracks are merged due to larger z_0 resolution at large |η |



- The merged vertices can be resolved using timing information of the tracks from the HGTD
- Main strategy is to reconstruct the time of the primary vertex using timing information of the tracks from the HGTD
- **Limitation**: performance of reconstructing the time of the primary vertex depends on number of forward tracks in the event and event topology

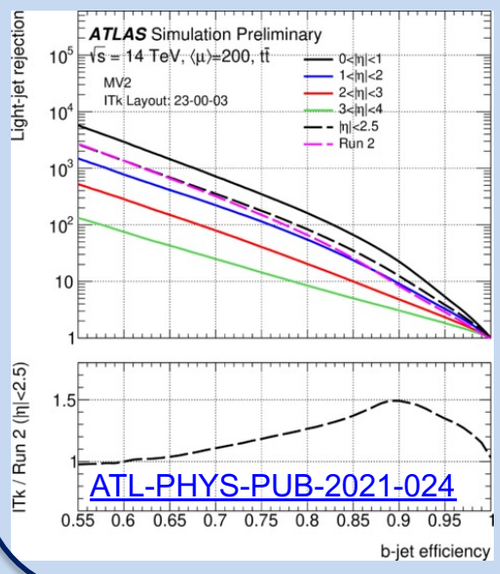
Sensor Technology
- Low Gain Avalanche Diodes (LGAD)
- Cell size 1.3 × 1.3mm^2
- 50 μm active thickness

Time resolution of LGAD+ASIC < 50 ps



B-Tagging and Pile-up Jet tagging

B-tagging improved with ITk up to a factor 1.5 wrt Run2 with MV2C10



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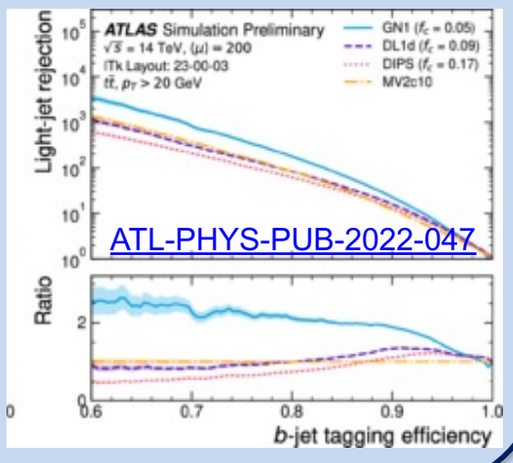
B-tagging further improved at HL-LHC using graph neural networks



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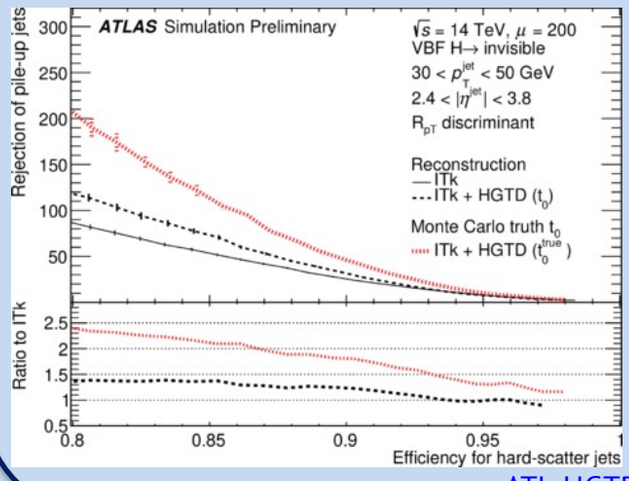
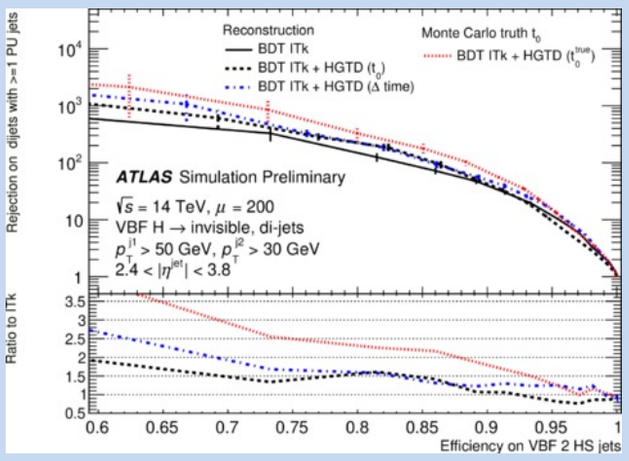
Pile-up jet tagging improved up to 1.4 using timing information from HGTD



Double Pile-up Jet tagging improved up to 3(2) using time of primary vertex (only Δt between jet time) from HGTD through a BDT



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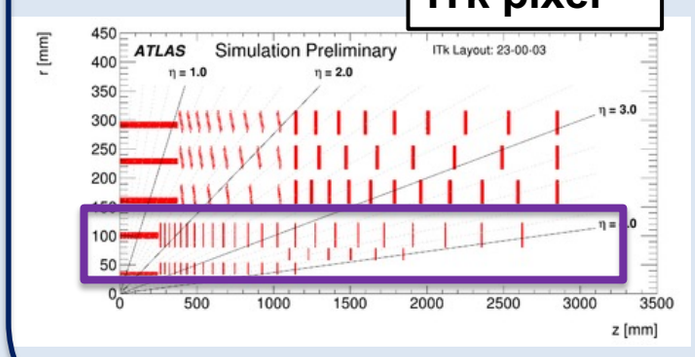
Impact of 4D tracking

After 2 ab^{-1}, two innermost layers of ITk will be replaced
→ Opportunity to include a **4-dimensional (4D) tracker in the central region** capable of measuring simultaneously spatial and temporal coordinates

ITk pixel



- Time of the primary vertex can be reconstructed using also central tracks
- Resolution down to 7.2 ps with single track resolution of 30 ps

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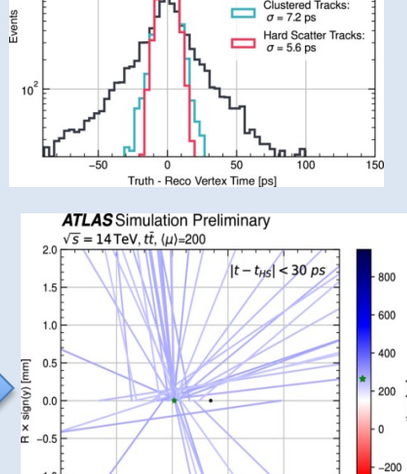
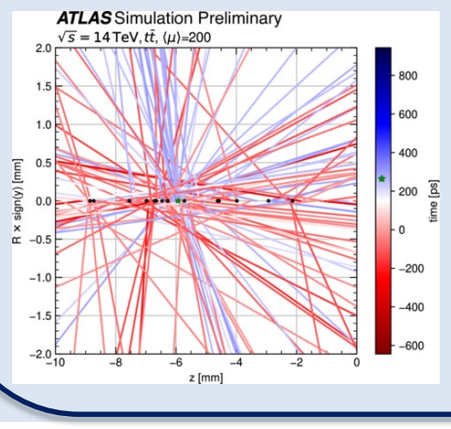
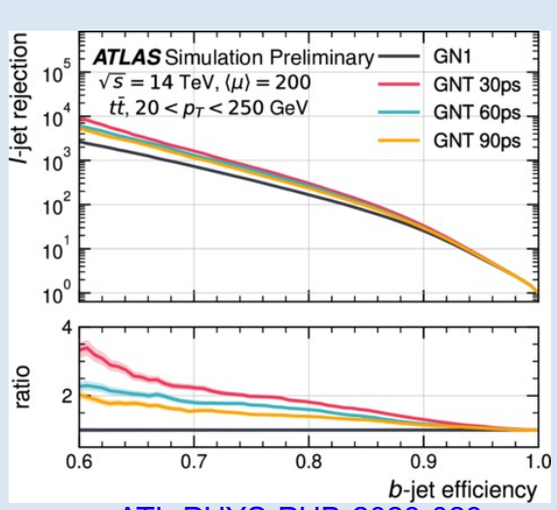




B-tagging improved up to a factor 3.5 using timing information also in the central region



ATL-PHYS-PUB-2023-023

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