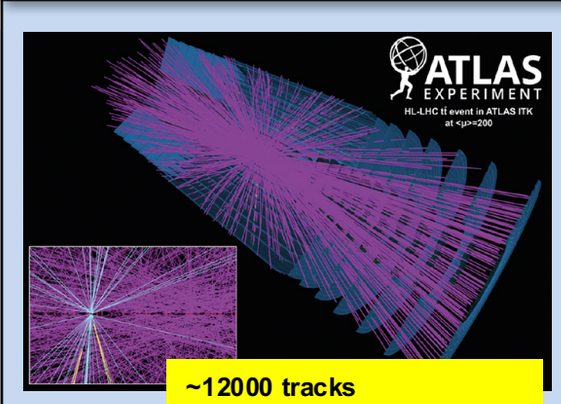
PM2018 - 14th Pisa Meeting on Advanced Detectors

# *Upgrade of the ATLAS detectors and trigger at the High Luminosity LHC: tracking and timing for pile-up suppression*


The High Luminosity-Large Hadron Collider is expected to start data-taking in 2026 and to provide an integrated luminosity of 3000 $fb^{-1}$, giving a factor 10 more data than will be collected by 2023. This high statistics will make it possible to perform precise measurements in the Higgs sector and improve searches of new physics at the TeV scale. The luminosity is expected to be $7.5 \times 10^{34}$ $cm^{-2}$ $s^{-1}$, corresponding to about 200 proton-proton pile-up interactions, which will increase the rates at each level of the trigger and degrade the reconstruction performance.
To cope with such a harsh environment some sub-detectors of the ATLAS experiment will be upgraded or completely substituted and the Trigger-DAQ system will be upgraded. In this talk an overview of two new sub-detectors enabling powerful pile-up suppression, a new Inner Tracker and a proposed High Granularity Timing Detector, will be given, describing the two technologies, their performance, and their interplay. Emphasis will also be given to the possibility of using tracking and timing information at the earliest, hardware based, ATLAS trigger stage.


## New Inner Tracker ( ITk)




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

*CERN-LHCC-2017-005, ITk Strip TDR*

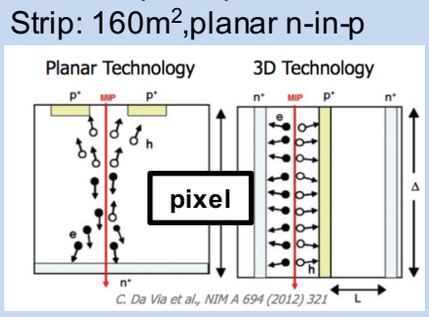
***Motivation***: To face the harsh environment at HL-LHC, the current inner detector will be replaced with a new full-silicon Inner Tracker (ITk).

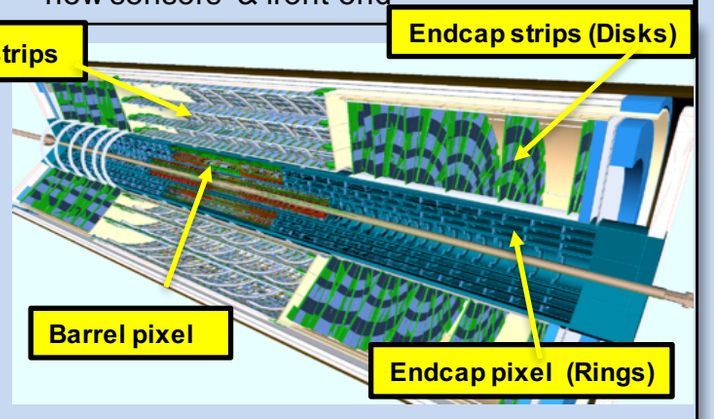
**Finer segmentation**
- More and smaller channels
- All silicon inner tracker with strips and pixel
- Extension up to $|\eta| < 4$

**Faster readout & more storage**
- Upgraded readout
- Track Trigger

**Increase radiation hardness**: new sensors & front-end

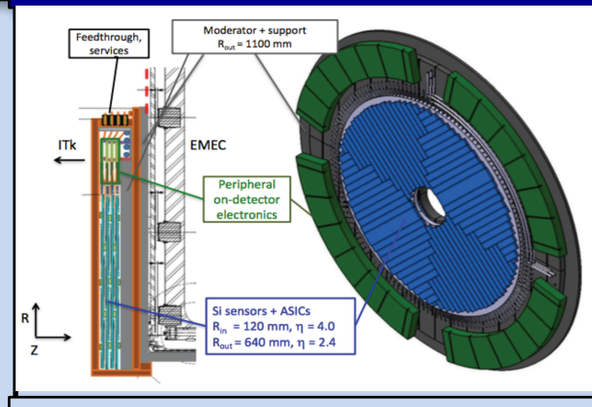
*Sensor Technology*
- Pixel, $15 m^2$
  - 3D for the inner most layers
  - Planar elsewhere
  - CMOS perhaps for outer barrel
- Strip: $160 m^2$,planar n-in-p



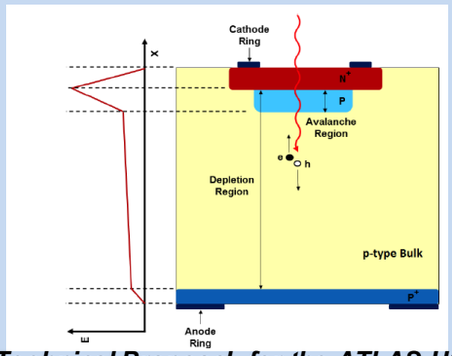

Radiation hardness:
~ $1 \times 10^{16}$ ($2 \times 10^{15}$) $n_{eq}/cm^2$ for Pixel (Strips)

## High Granularity Time Device (HGTD)



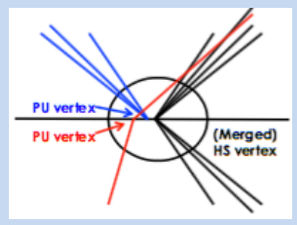

Located in front of encap calorimeter
$\Delta z$ ~6cm @ $|z|$ = 3.5 m 2.4<$|\eta|$<4

*Sensor Technology*
- Low Gain Avalanche Diodes
- Cell size $1.3 \times 1.3 mm^2$
- 50 um thick




***Technical Proposal for the ATLAS HGTD, in preparation***

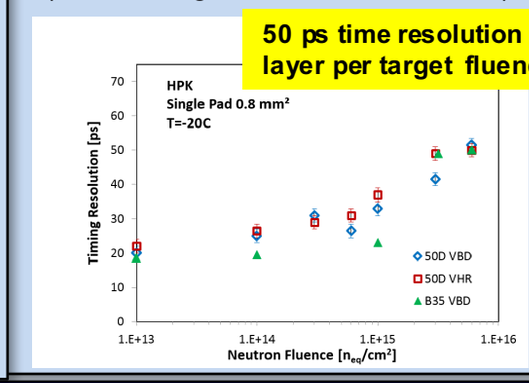
***Motivation***:
1) Improve pile-up suppression in the reconstruction
- At mu=200 5-7 vertices within tracker resolution at large $|\eta|$ due to larger $z_0$ resolution (vertices merging )




- Time information helps pileup rejection and isolation efficiency at large $|\eta|$ resolving nearby vertices

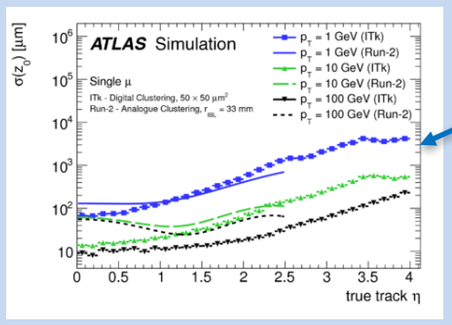
2) Improve Trigger capabilities at 40 MHz (no tracking information available)

**50 ps time resolution per layer per target fluence**




## Pile-up suppression in Jet with ITk and HGTD

**Resolution of $z_0$ impact parameter of tracks**

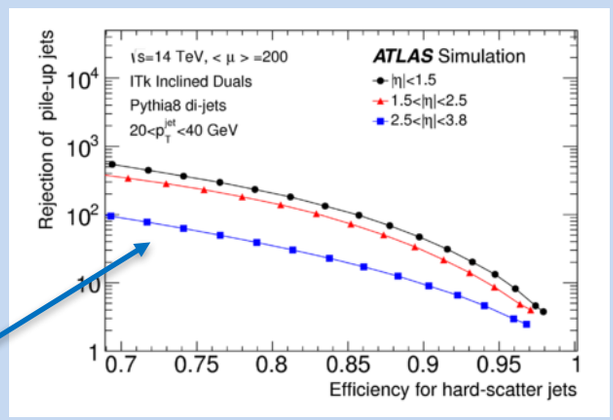



https://atlas.web.cern.ch/Atlas/GROUPS/PHYSICS/PLOTS/ITK-2018-001/
***( ITk Pixel TDR in preparation )***

- Deterioration at large $|\eta|$ due to increased material crossed
- Difficult to assign tracks to correct vertex due to merged vertices at large $|\eta|$
- Deterioration of performance of pile-up jet tagging at large $|\eta|$

- Crucial to assign tracks to the primary vertex and pile-up suppression techniques
- Better resolution wrt current Inner Tracker due to reduced material budget

- The merged vertices can be resolved using timing information of the tracks from the HGTD
- *The performances of jet-vertex tagging techniques are improved at high $|\eta|$*

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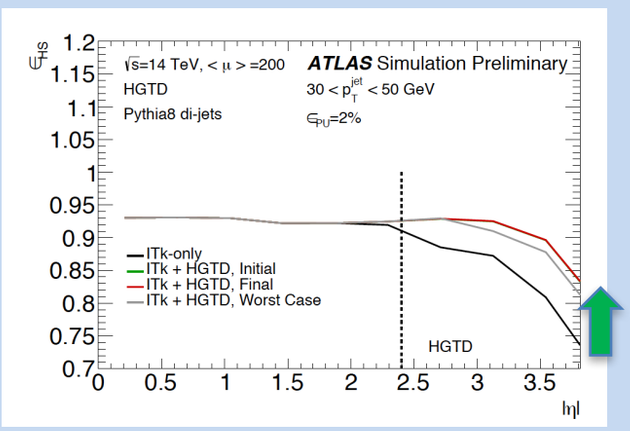



***Technical Proposal for the ATLAS HGTD, in preparation***

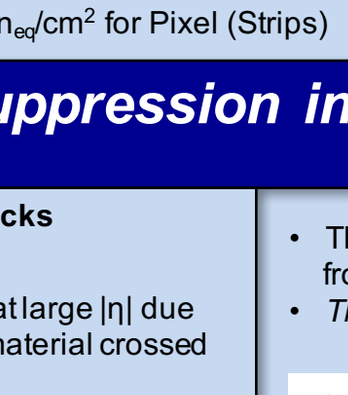
## Hardware Track trigger (HTT)

## Performance of HTT

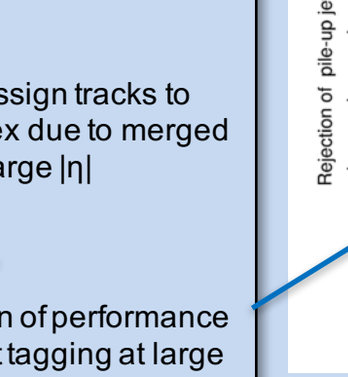
***TDR for the ATLAS TDAQ Phase-II Upgrade, in preparation***

- Tracking information is used in
  - Regional HTT (rHTT)
    - Only in relevant Region of Interest
    - Hits from 10% of ITk
    - Hits from the ITk strip system and outer pixel layers
    - Uses tracks with $p_T > 2$ GeV
  - Global HTT
    - Full detector
    - High-resolution full tracking down to $p_T > 1$ GeV
    - b-tagging, pile-up suppression, track-based jet calibration

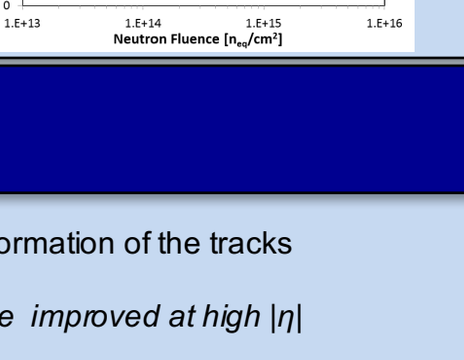
**Baseline**(**Evolved**) **Single** (**two**)-level hardware trigger




- Evolved Scenario L0 and L1, with L0 rate of 2 or 4 MHz
  - Regional Tracking information at L1: **L1track**
    - As rHTT with following differences:
      - Uses tracks with $p_T > 4$ GeV
      - Tight latency constraint of ~6μs
    - Allows coarse determination of the *z*-position of the primary vertex
    - 2/4 MHz—> 800(600) kHz




- Regional HTT allows:
  - L0 rate suppression requiring jets coming from the same interaction
  - Both for jet and Missing Transverse Energy (MET) trigger
- New VBF inclusive trigger:
  - Signal efficiency 6.6% in baseline scenario
- Evolved scenario:
  - 50% gain in VBF signal efficiency for the same rate as baseline scenario
  - Gain in VBF H →ττ signal acceptance: 30% → 55%











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