The ATLAS Phase II Upgrade

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April 26^{th} 2019

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The High Lumi LHC

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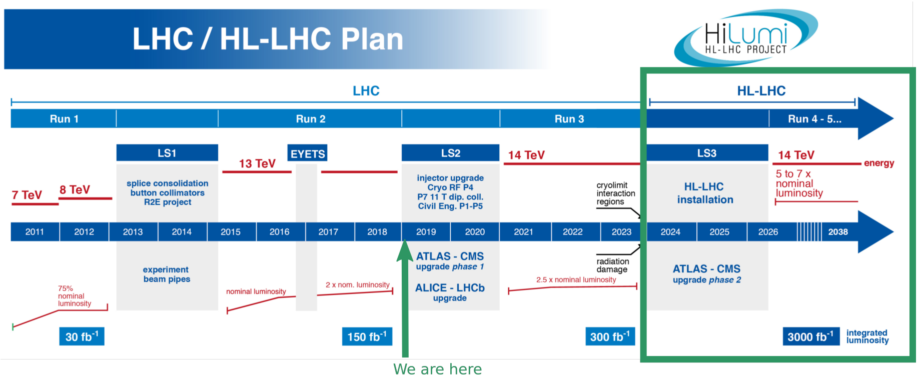
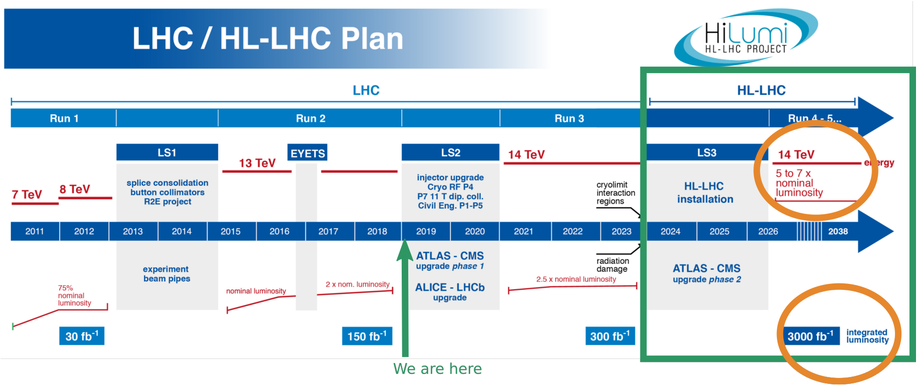


- Installation 2024-2026
- Begin operation in 2026

The High Lumi LHC



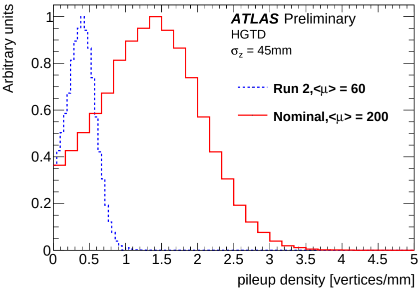
- Installation 2024-2026
- Begin operation in 2026
- Instant luminosity 7.5×10^{34} cm^{-2}s^{-1}
- Integrated luminosity 3000 fb^{-1}

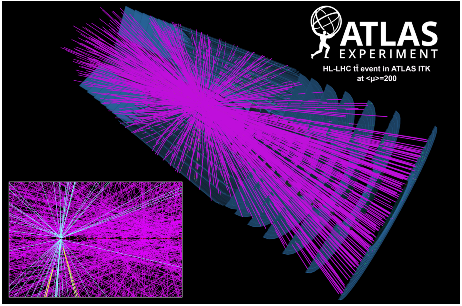
HL-LHC Conditions

Increased luminosity:

- Expected $\langle\mu\rangle$ = 200
- Average interaction density: $\sim$ 1.8 vtx/mm

$\rightarrow$ need to keep vertexing and tracking performance



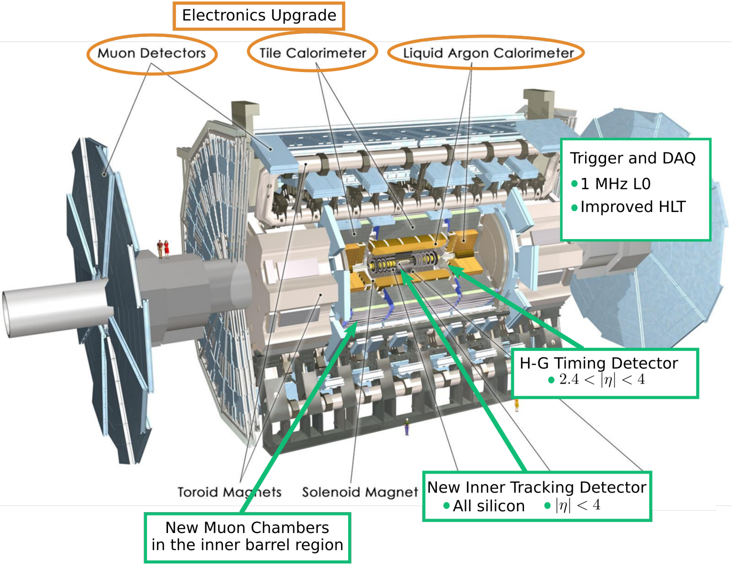


Upgrade motivations:

- High detector occupancy: need to improve reconstruction performance
- High irradiation levels: $\sim 10^{16}$ neq/cm^2 at large $|\eta|$
- Increased trigger rate
- Technology update ($\sim$20 years old!)

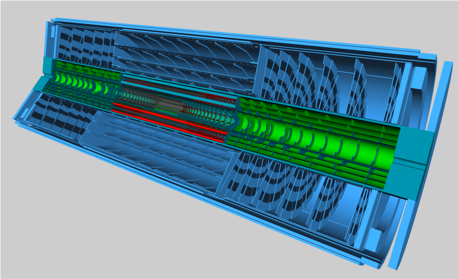
The ATLAS Phase II Upgrade

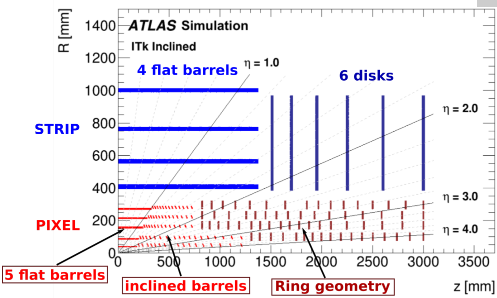
Update and improve the ATLAS detector to cope with challenging conditions



Inner Tracker: ITk

- Extended acceptance (2.5 $\rightarrow$ 4)
- Layout optimization:
  $\rightarrow$ maximize average number of hits
  $\rightarrow$ minimize material and silicon area
  $\rightarrow$ on-going
- Average $\sim$ 13 hits in barrel, and at least 9 pixel hits in the forward region





Pixel:

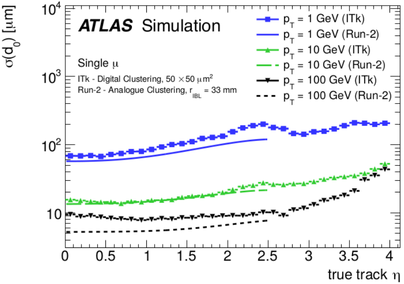
- 50 $\times$ 50 μm (25 $\times$ 100 μm)
- Innermost layer: 3D sensor
- Other layers: planar sensors
- single, dual and quad modules

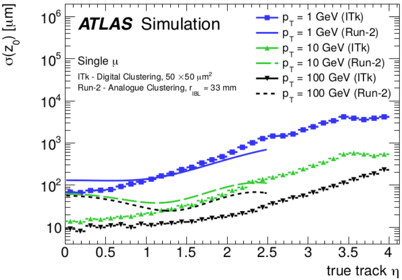
Strip

- Average 75μm width
- Length between $\sim$ 15 and 60 mm depending on layer/ring

ITk Performance

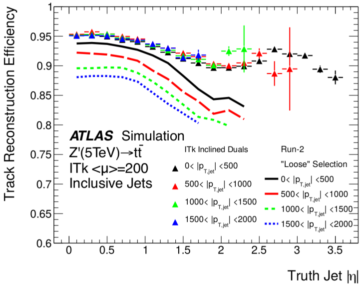
Track impact parameter: transverse (d_0) and longitudinal (z_0)





Track reconstruction efficiency in $<\mu>= 200$

- High p_{T} improvement thanks to higher granularity
- Track reconstruction up to higher η



ITk Performance

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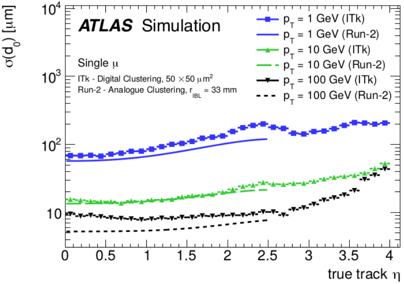
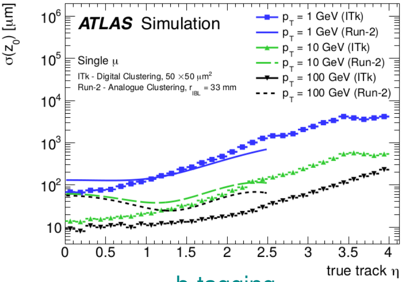
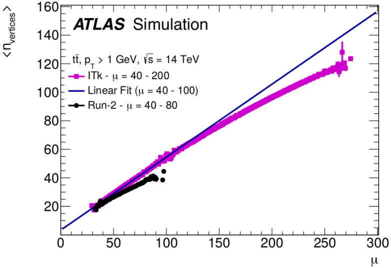
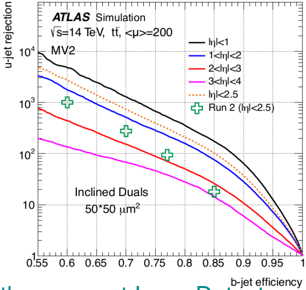




Vertexing



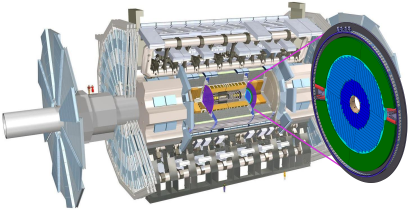
b-tagging



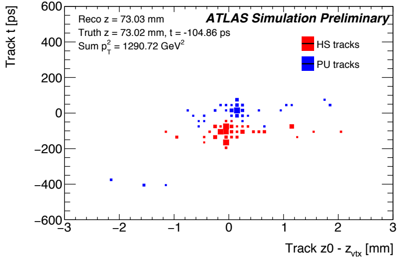
Equal or better performance than current Inner Detector

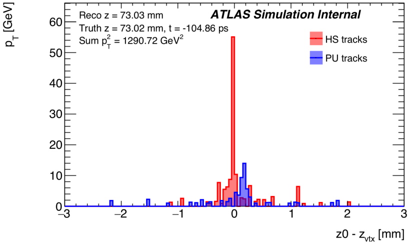
High Granularity Timing Detector: HGTD

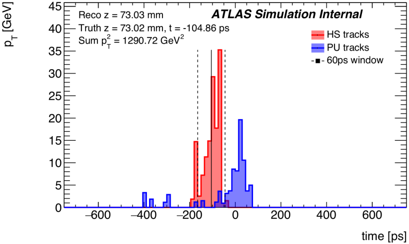
$2.4 < |\eta| < 4.0$



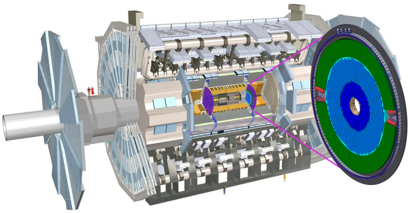
→ Use timing information as additional handle to discriminate hard-scatter and pile-up activity







High Granularity Timing Detector: HGTD



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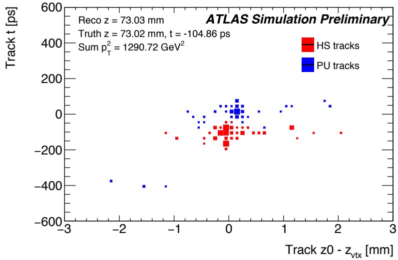


- Low-Gain Avalanche Detector (LGAD): novel silicon sensors with excellent timing performance

Goal:

- Provide a time measurement for tracks in the forward region with a resolution of 30-50 ps.
- Bunch-by-bunch luminosity measurement.

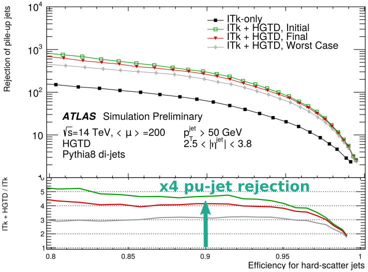
HGTD Performance

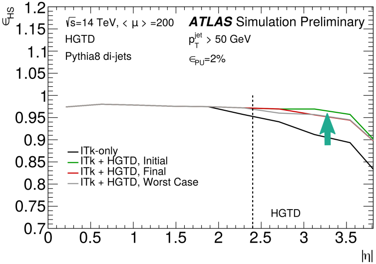
Pile-up jet rejection

- Improved id of PV0 tracks
  $\rightarrow$ Boost discrimination power of

$$R_{p_T} = \frac{\Sigma p_T^{\mathrm{trk}}(\mathrm{PV}_0)}{p_T^{\mathrm{jet}}}$$

- HS-jet efficiency in the forward region similar to central barrel





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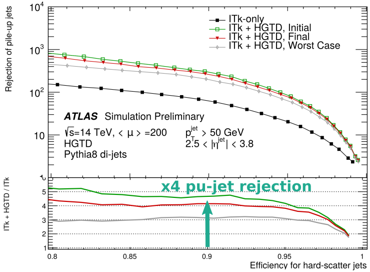
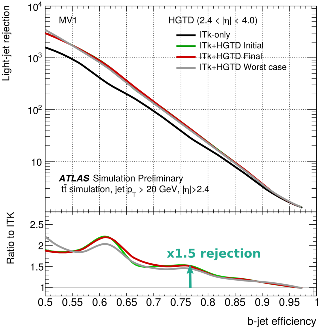


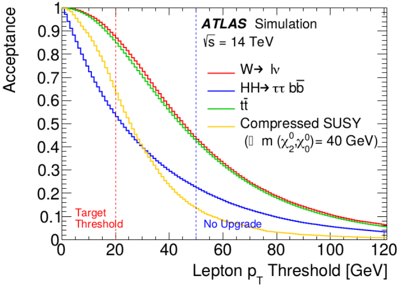
Jet b-tagging

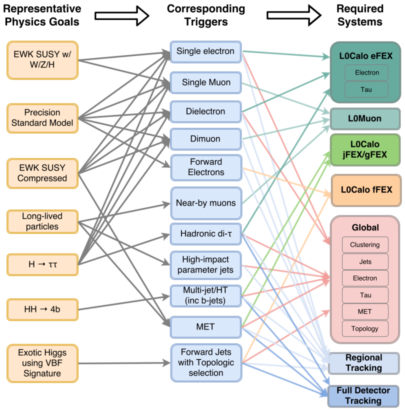
- Addition of HGTD helps remove PU tracks
  → increased light-jet rejection



Trigger and DAQ: physics motivation

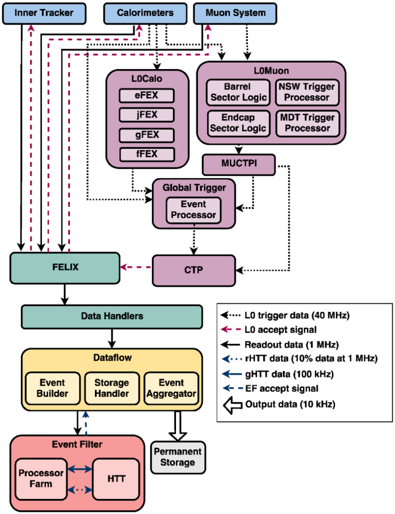
- Development/performance improvement of dedicated trigger for different analyses
- Searches for new physics require to keep the p_T of the different trigger objects as low as possible
- i.e : lowest p_T of the lepton trigger would be 50 GeV without upgrade

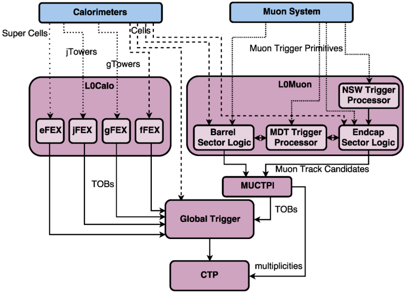




TDAQ upgrade summary

Major upgrade: L0 rate of 1 MHz and 10 μs latency (from 100 kHz and 2.5 μs)





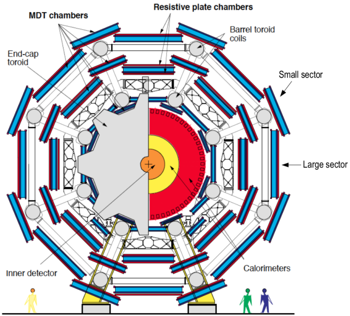
Detailed view of L0 Trigger:
Use of full calorimeter granularity and input from MS

$\rightarrow$ offline-like object reconstruction

$\rightarrow$ possible to implement more sophisticated algorithms

$\rightarrow$ major upgrades needed in LAr, Tile and MS

Muon Spectrometer

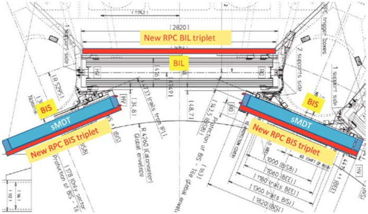


Chamber replacement:

- Phase I: New Small Wheel using sTGC and MicroMegas for triggering and precision tracking ($1.3 < |\eta| < 2.7$)
- Additional RPC BI triplet
  $\rightarrow$ compensate for reduced efficiency
  $\rightarrow$ improved trigger capabilities
  $\rightarrow$ robustness against failures

Trigger and readout electronics replacement:

- on- and off-detector
- All data streamed @40 MHz
- include MDT position
  $\rightarrow$ enables more refined and flexible trigger algorithms

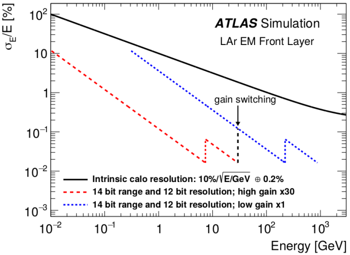


- Need to replace BIS MDTs for thinner sMDT

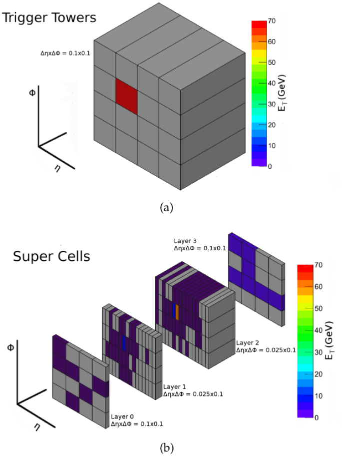
Calorimeters: LAr and TileCal electronics

LAr full electronics upgrade:

- Currently: sampling @40 MHz, send 4 samples on L1 accept (110 kHz)
- New preamp/shaper design with dual gain,
- followed by dual ADC
- Stream all digitized data @40 MHz



Phase I upgrade: finer granularity at L1 trigger



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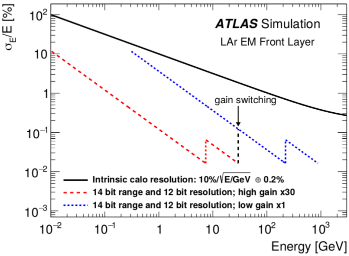
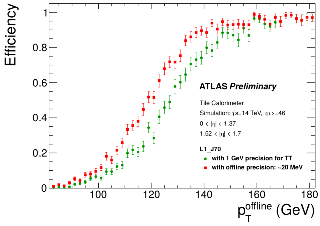


TileCal mechanics and electronics:

- Currently: analog summing boards combine PMT signals in towers for L1Calo
- New scheme: shaper, dual ADC, data transfer @40 MHz
- High precision of the digital L0 calo trigger improves jet-trigger performance:



- Mechanical improvements to the drawers for better accessibility

Summary

- The HL-LHC will provide 3000 fb^{-1} at 14 TeV, reaching unprecedented levels of instant luminosity and, therefore, at the expense of increasing pile-up
- The ATLAS Phase II upgrade presented in this talk will allow to cope with this harsh conditions
- All upgrade projects are well documented in Technical Design Reports or Proposals (links below):

ITk Strip: ATLAS-TDR-025
ITk Pixel: ATLAS-TDR-30
LAr: ATLAS-TDR-027

TileCal: ATLAS-TDR-028
HGTD: LHCC-P-012
Muon: ATLAS-TDR-026

TDAQ: ATLAS-TDR-029