High granularity timing detector

ATLAS Phase-2 upgrade

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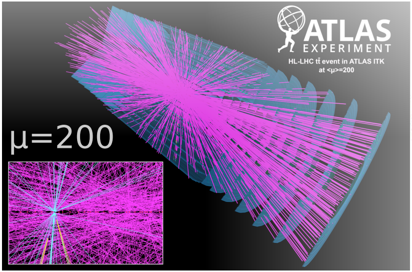
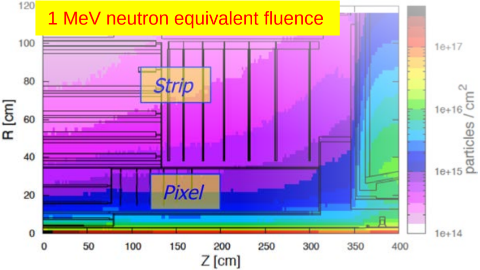
HL-LHC

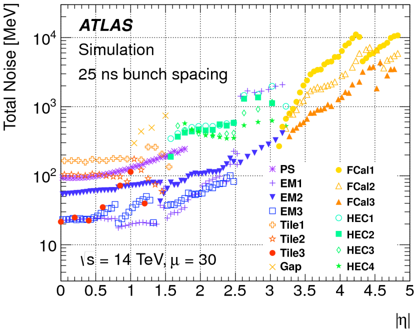
- start in 2026, same tunnel as LHC, new magnets, new cavities
- $3000/4000\,\text{fb}^{-1}$ in 10 years, $\sqrt{s} = 14\,\text{TeV}$
- Instantenous luminosty 5 times LHC, $L = 7.5 \times 10^{34}\,\text{cm}^{-2}\text{s}^{-1}$
- Main challenge: high-pileup ($\mu = 200$), high-radiation doses

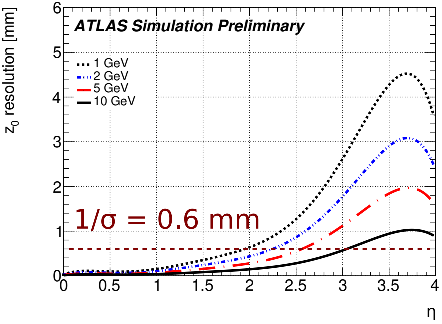




Pileup challenge

- Additional pileup jets
- Degradation of performances: flavour tagging, lepton isolation, energy resolution, missing-E_T, ...
- Resolution of the longitudinal track impact parameter (z_0) must be smaller of the average vertex spacing (0.6 mm)
- Extremely challenging in the forward region

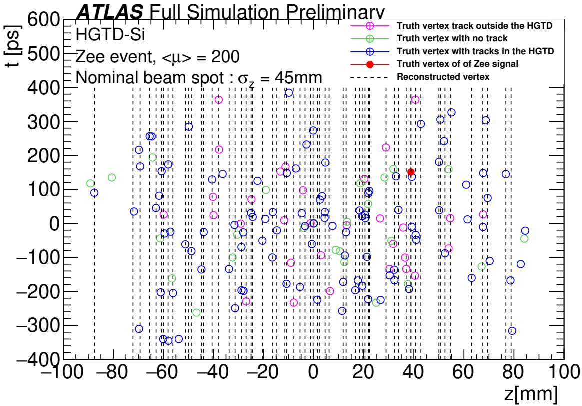




Pileup suppression

- Pileup mitigation: precise assignment of tracks to vertices
- z_0 resolution not enough in the forward region
- Usage of time information to separate track from different vertices
- Need time precision much smaller than the spread of the collision times (175 ps).
- HGTD new detector in the forward region reaching 30 ps time resolution per track

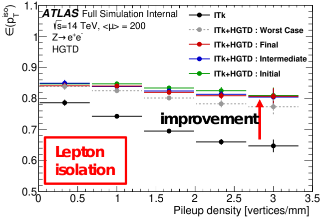
Pileup suppression

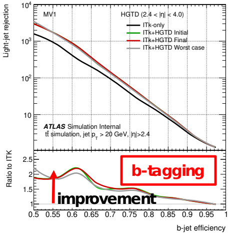


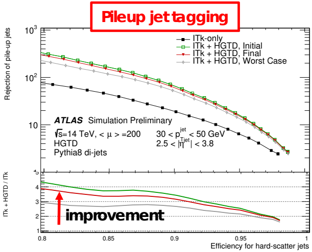
- Pileup suppression: $30\,\mathrm{ps}/175\,\mathrm{ps} \simeq 6$
- In addition online and offline luminosity determination

Performance improvement

- For the first time a forward tracker in an environment in which the pileup density is higher than its z spatial resolution
- The use of precise timing information enables the assignment of low pT forward tracks to vertices with high precision
- complementing the capabilities of the inner tracker

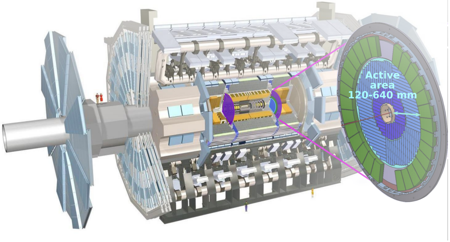






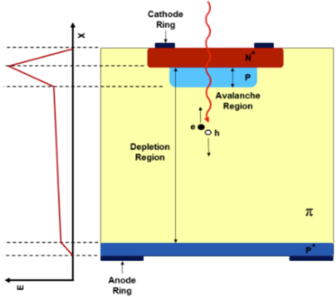
HGTD concept

- In front of the endcap calorimeters, $\eta \in [2.4, 4.0]$, $12\,\text{cm} < R < 64\,\text{cm}$
- Must be very granular and very thin, due to space constraints.
- Silicon-based timing detector technology is preferred
- Low Gain Avalanche Detector (LGAD) pixel of $1.3 \times 1.3\,\text{mm}^2$ (occupancy $< 10\%$) with active thickness of 50 µm or 35 µm has been chosen.
- 2 double planar layers per endcap: 2-3 hits per track
- Time resolution: 30 ps per track



LGAD sensors

- 30-50 ps per hit, small rise time, low noise
- radiation hard format
  - requirements: up to 3.7×10^{15} neq/cm^2 and 4.1 MGy
  - sensors and ASICs at $R < 300$ mm need to replaced after 1/2 lifetime
- n-on-p planar silicon detectors with internal gain thanks to the high field created by an extra highly-doped p-layer



HGTD status

- Approved by ATLAS as upgrade project for Phase 2 in March 2018
- Technical proposal submitted to LHCC
- Step 1 approval by LHCC on May 2018
- TDR preparation ongoing with technical and financial details, then final approval by LHCC in 2019

Milano activities

- Not yet approved by INFN
- One PRIN submitted, together with CMS, possible other application (medical)
- This kind of technology can be basis for future detector
- Many facilities already present locally (synergies with ITK): clean room, probe station, . . .
- Interested both in hardware and detector performance
  - characterization LGAD sensors in lab and test beam
  - test sensors for production (Hamamatsu, FBK, IMB-CNM)
  - low-voltage power supply
  - simulation and performance study
- Manpower: A. Andreani, L. Carminati, M. Lazzaroni, F. Ragusa, S. Resconi, F. Tartarelli, R. Turra

Grant per neoassunti

- 20k euros: 17k inventario, 3k missioni.
- 3 years: 9/2018 – 8/2021
- Asking for support from INFN electronic local service 0.3 FTE/year
- Electrical measurements (I/V, C/V) single pad and multi-pad before and after irradiation
- timing measurement with laser
- test-beam data-analysis
- study impact HGTD on physical analysis (e.g. VBF $H \to \gamma\gamma$)