The High Granularity Timing Detector for ATLAS: Motivation and Performance

LHCC

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on behalf of the ATLAS Collaboration

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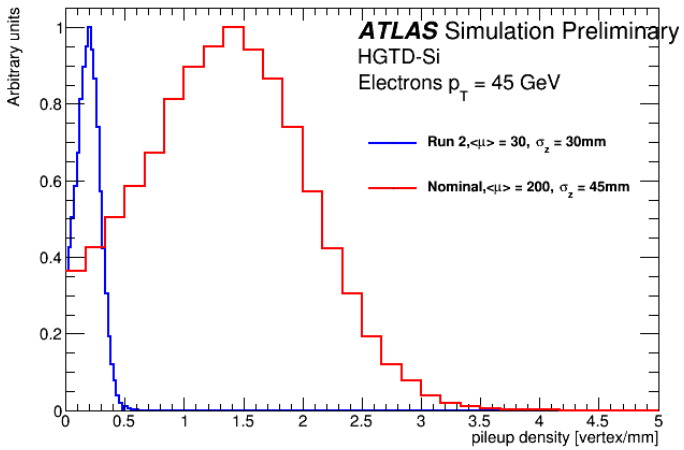
1. **Introduction**
2. **Object performance**
3. **Physics and luminosity measurements**
4. **Summary**

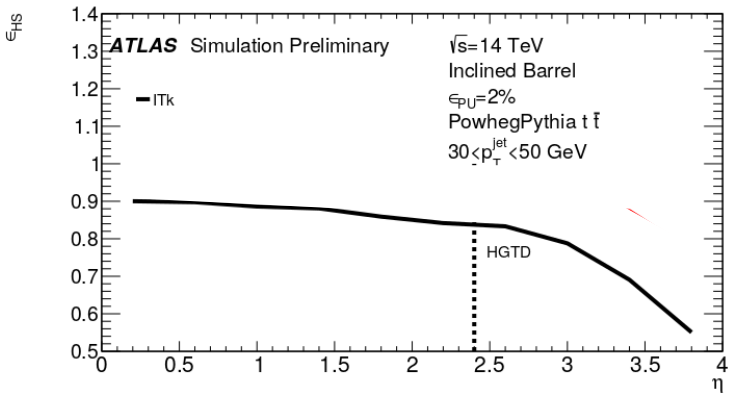
Expression of Interest submitted to the LHCC on Nov 20, 2017

HL-LHC: The Challenge

HL-LHC:

- **Pileup μ=200**
- **pileup density in 6mm window:**
  - **Most probable: order 1.6/mm**
  - **Tails up to 3/mm**

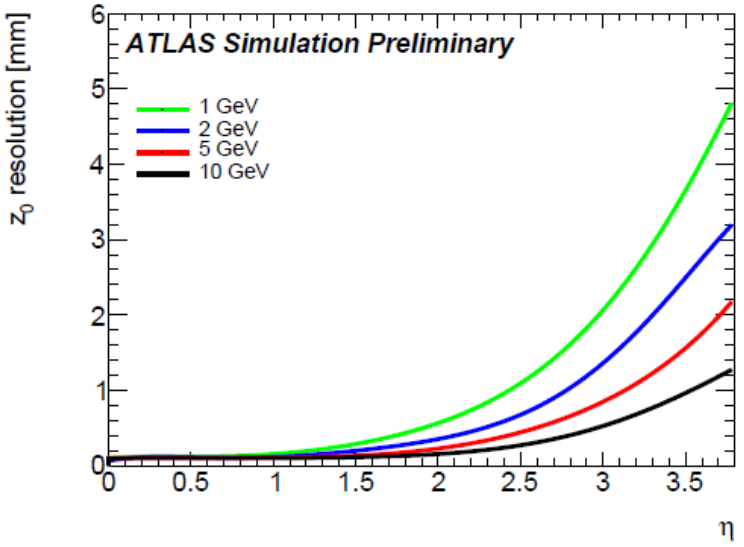


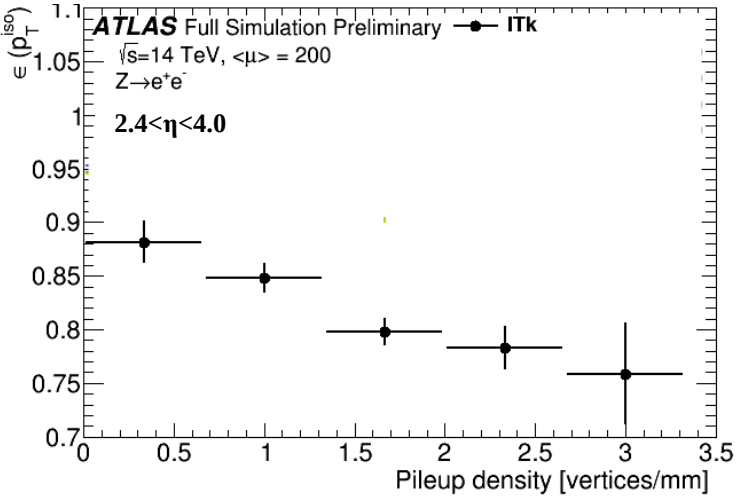


As a consequence and the hard scatter efficiency

Track reconstruction:

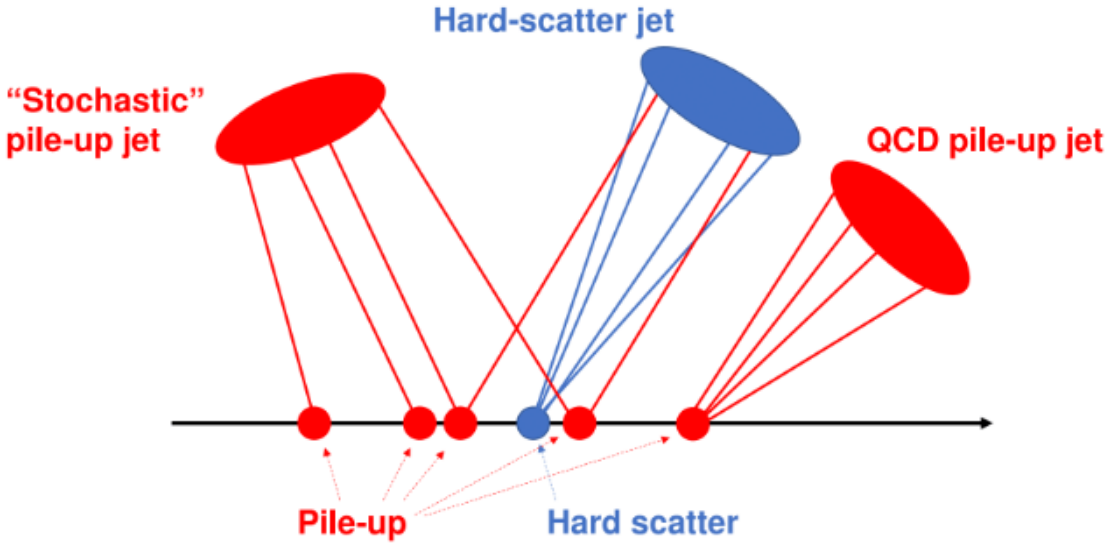
- **z0 resolution degraded as fct of eta**
- **z0 resolution degraded when pT decreases**

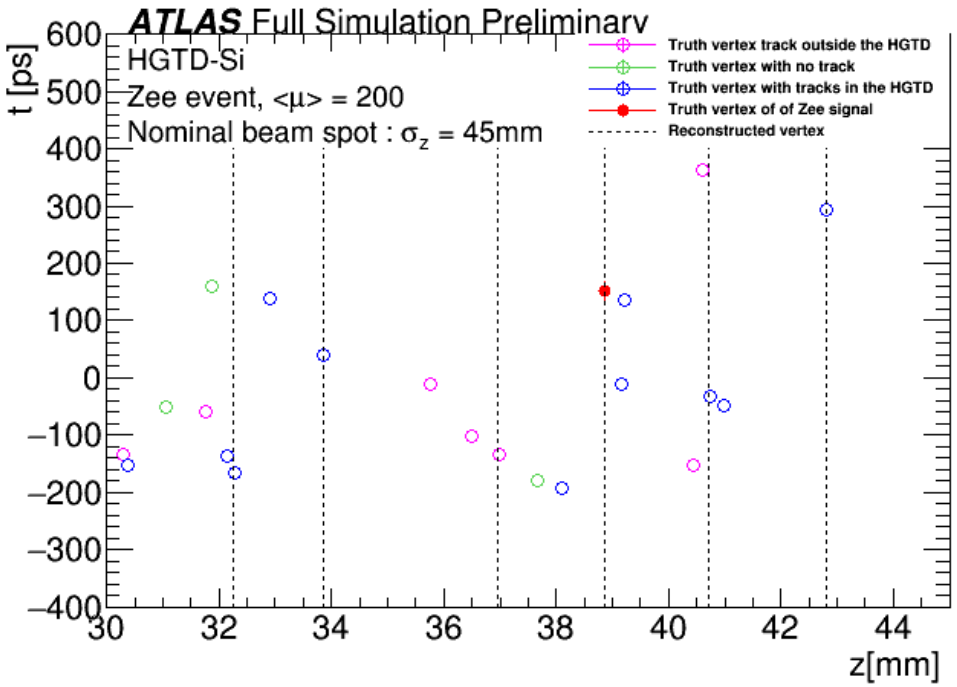




and the fwd electron ID are degraded

HL-LHC: The Challenge





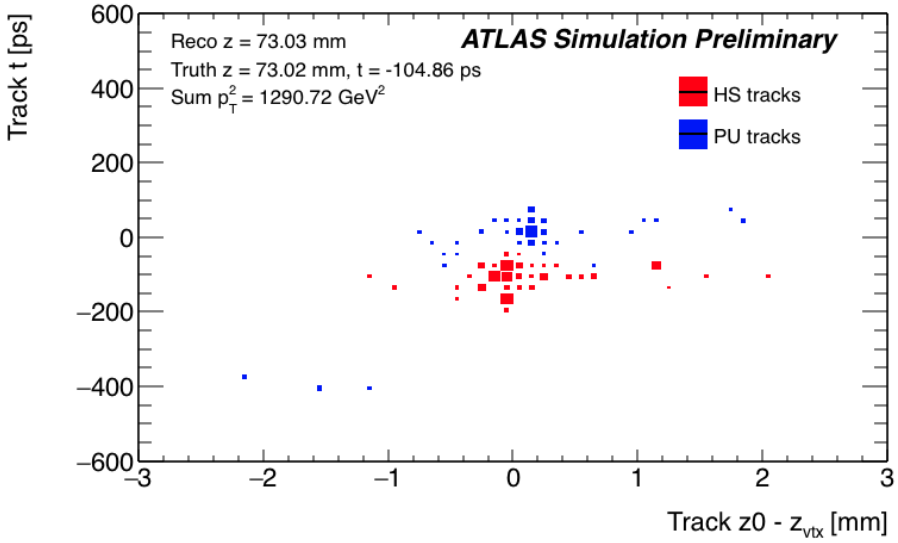
Beamspot:

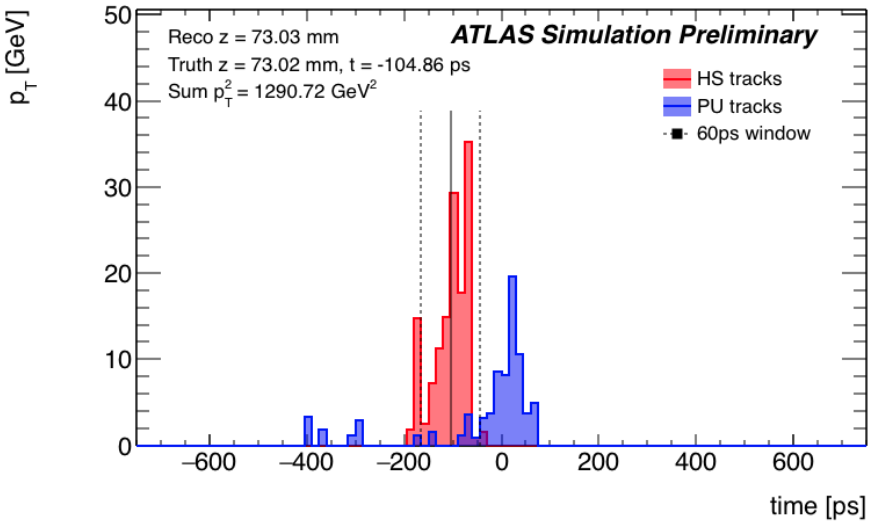
- **z ~50mm**
- **t ~180ps**

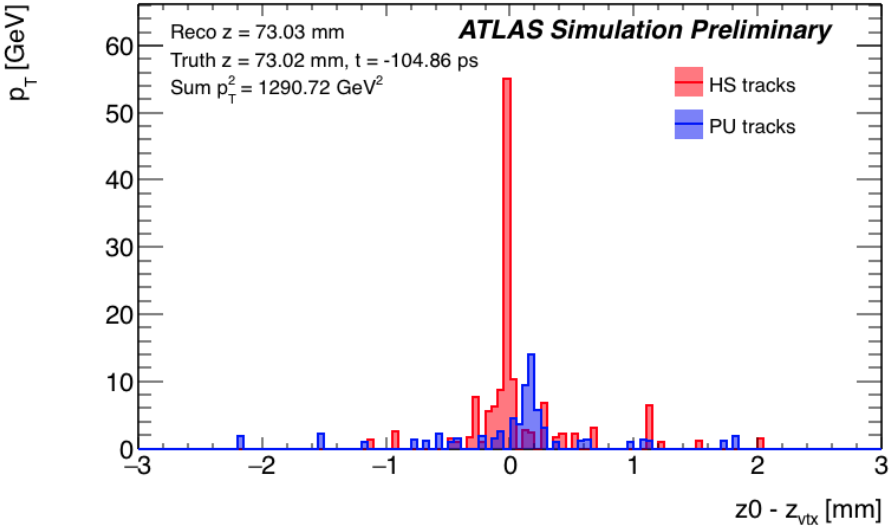
ITk+HGTD (Full Simulation):

- **HS Vertex**
- **Reconstructed vertices**
- **Track(s) pT>1GeV in HGTD**
- **no track pT>1GeV in HGTD**
- **No track pT>1GeV**
- **Track(s) pT>1GeV in HGTD (order 50%)**

Tracking and Timing



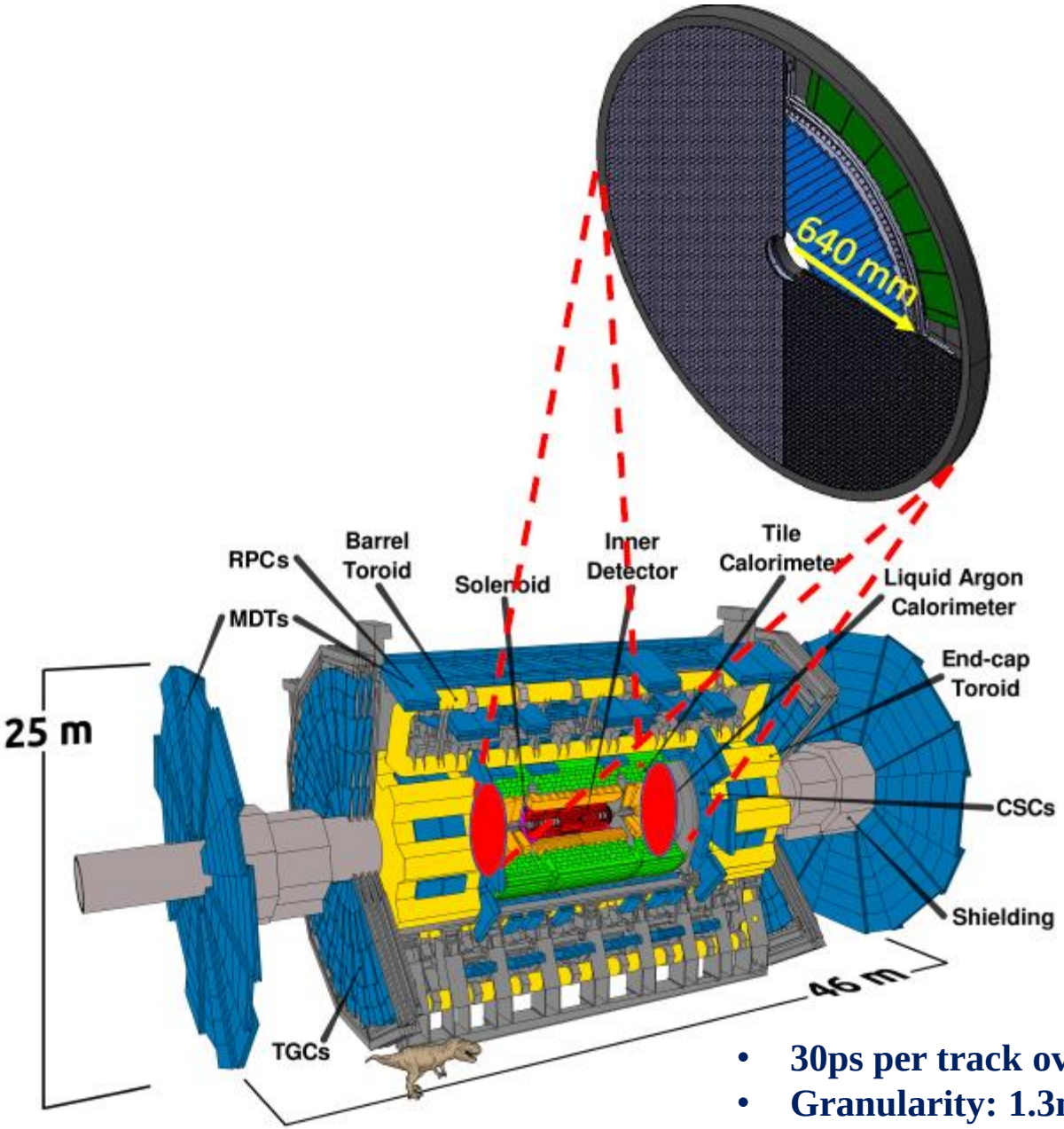




Separation in

- **z through ITk**
- **t through HGTD**

High Granularity Timing Detector



- z=3500mm
- 2-4Layers

- η>2.4 (R=640mm)
- η<4.0 (R=120mm)

- 30ps per track over the lifetime of HL-LHC
- Granularity: 1.3mm x 1.3mm

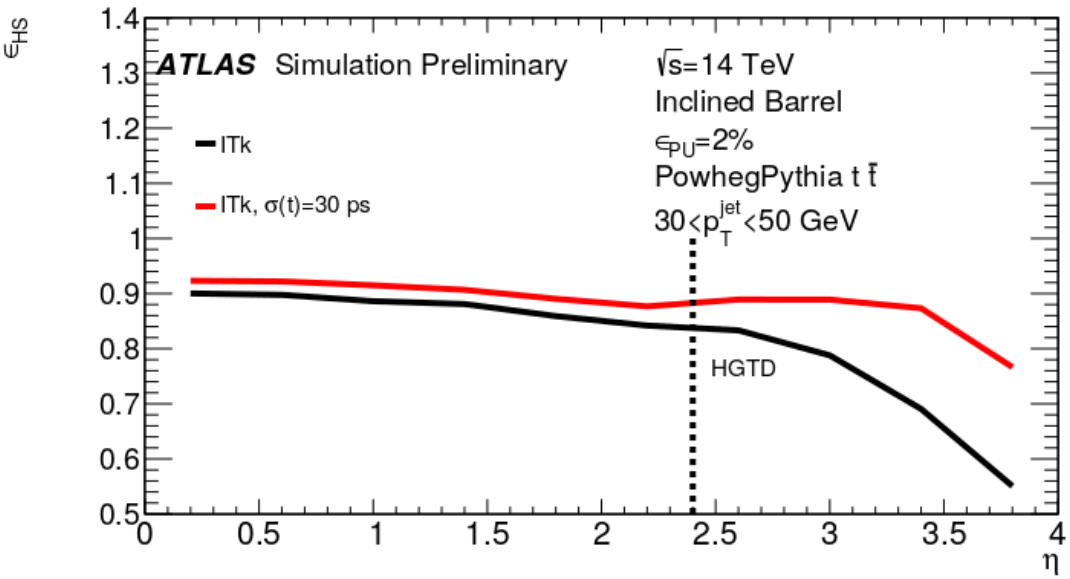
Jets

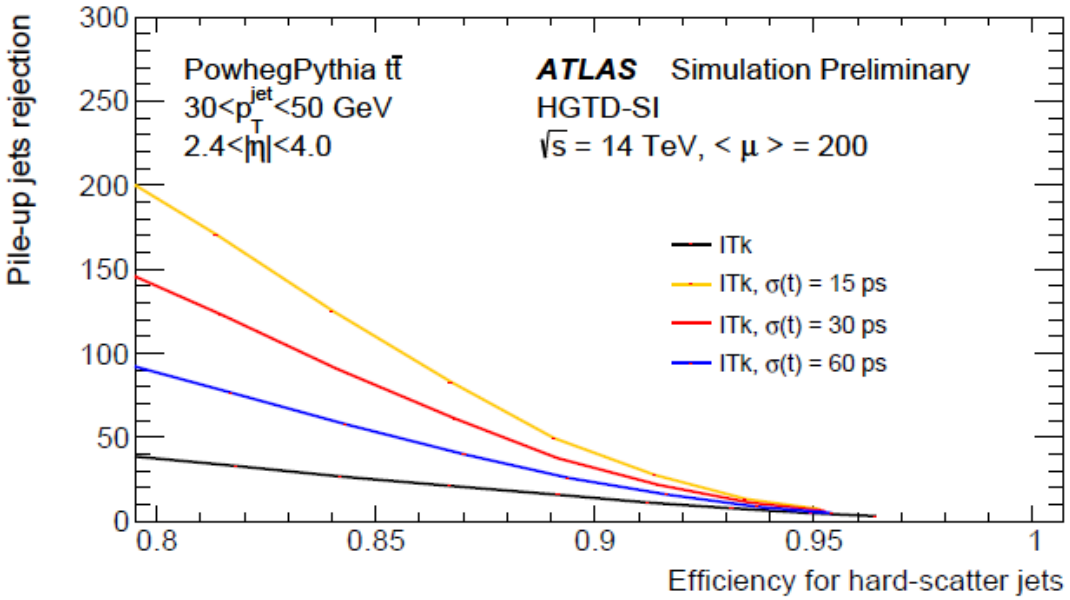
Jets

- **Reject pileup jets**

$$R_{PT} = \frac{\Sigma p_T^{trk}(PV_0)}{p_T^{jet}}$$

- **ratio tracks/Jet PT**
- **small for pileup jets**
- **HGTD timing to remove pileup tracks**

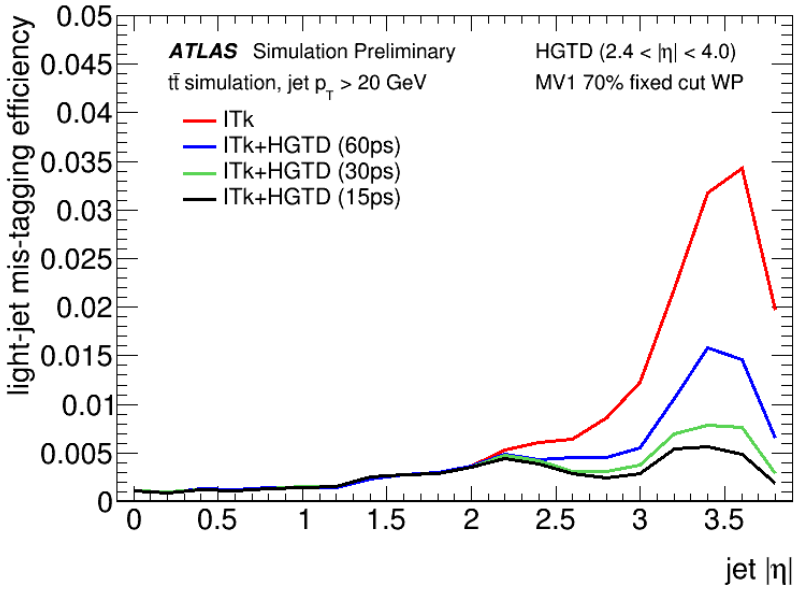


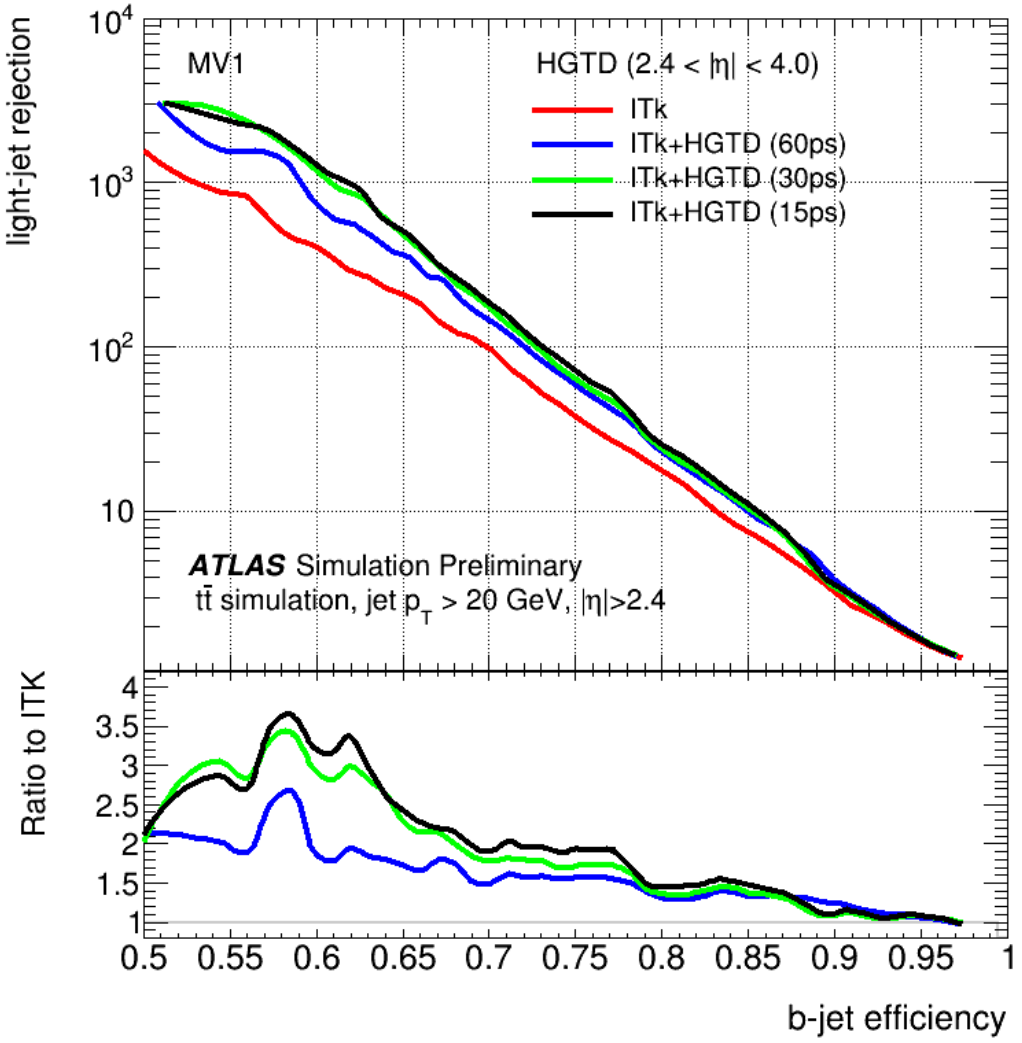


Jets

- **At PU=2%: HGTD improves fwd performance to barrel level**
- **Gain a factor 4 in rejection for HS 60% with 30ps per track at «low» jet pT (most difficult region)**

B-tagging





Fwd B-tagging:

- **Pileup contamination of tracks associated to jets**
- **Timing rejects pileup tracks**
- **Fwd performance improved almost to barrel level**
- **At 70% efficiency with a 30ps timing resolution per track improvement by factor 1.8**

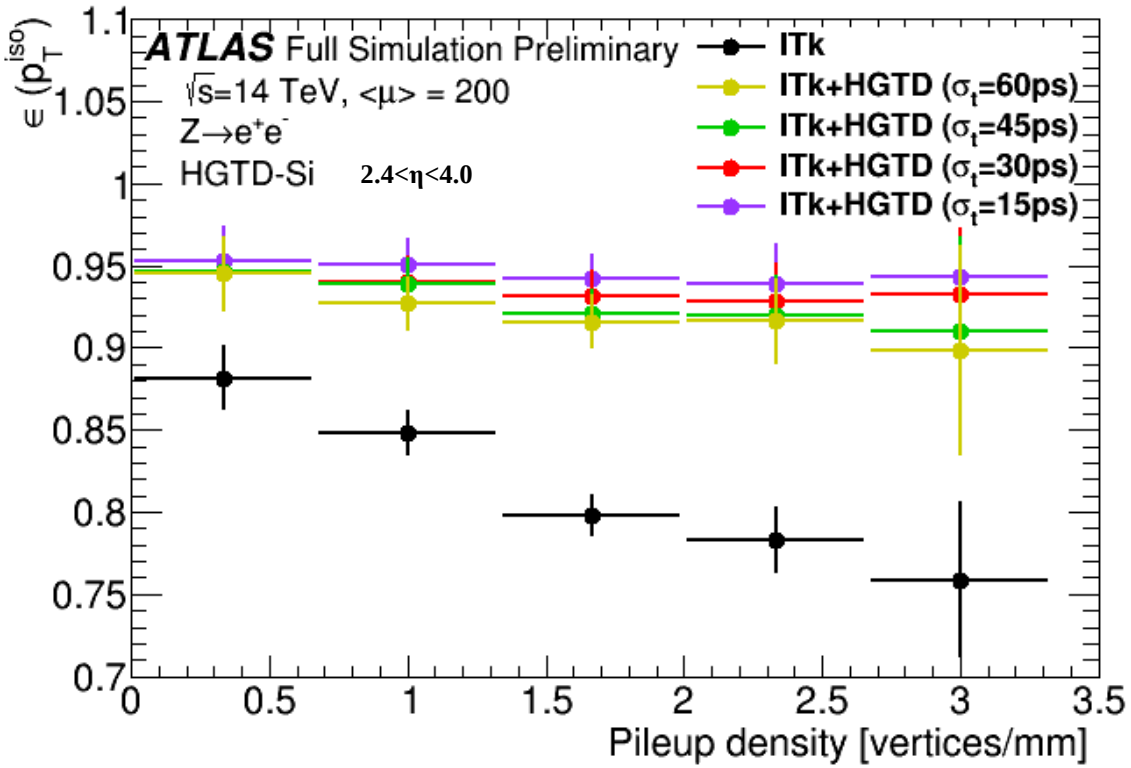
Electrons

Electron isolation:

- **Pileup tracks in ID cone**
- **ITk less efficient at high pileup densities**
- **HGTD: Improvement to 95%**

HGTD for electrons (Full simulation):

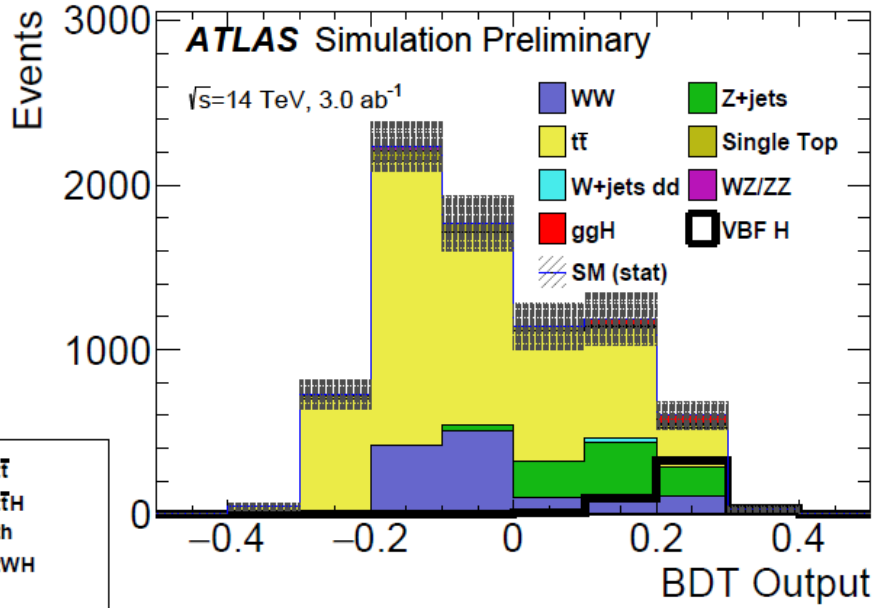
- **Small impact in barrel**
- **Large impact in HGTD acceptance**
- **Same level as barrel**
- **Independent of pileup density**
- **30ps per track**
- **At 1.6 vertices/mm: 13% improvement**

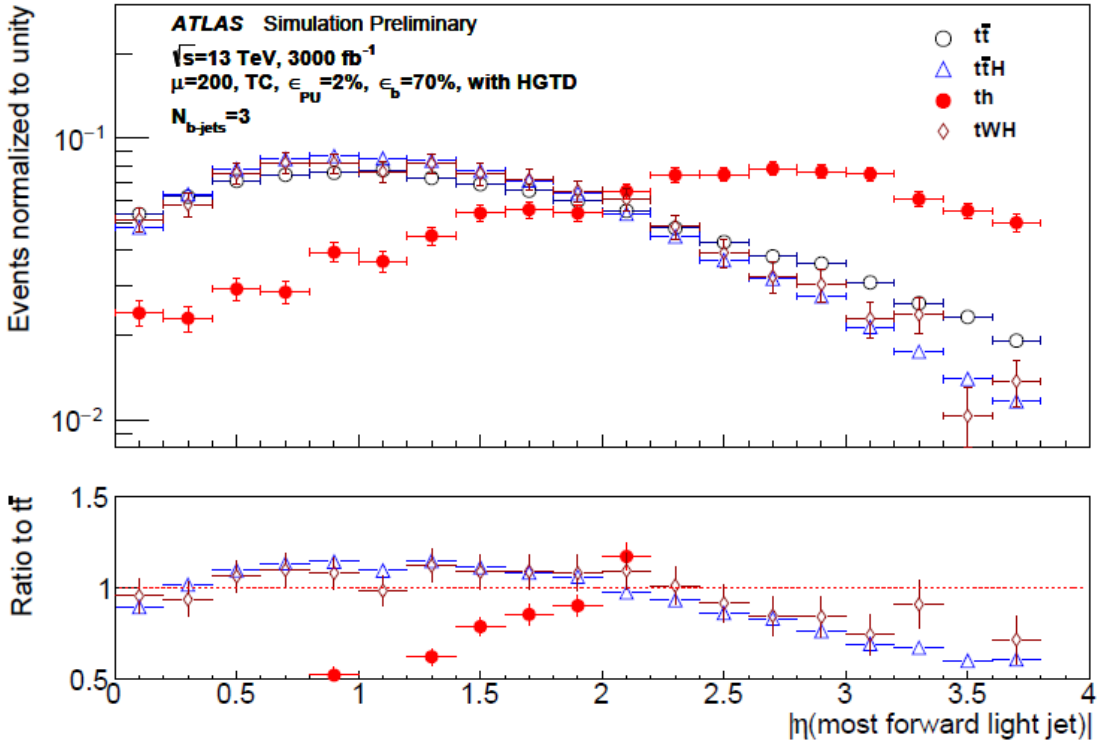


Physics channels (examples)

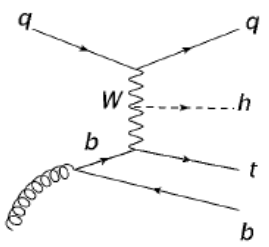
VBF: qqH→qqWW* → qq ενμν:

- **BDT**
- **43% bg reduction**
- **dominated by top background rejection (fwd b-tagging)**
- **3% pileup rejection**
- **Relative improvement: 8% (0.088 wrt 0.096)**



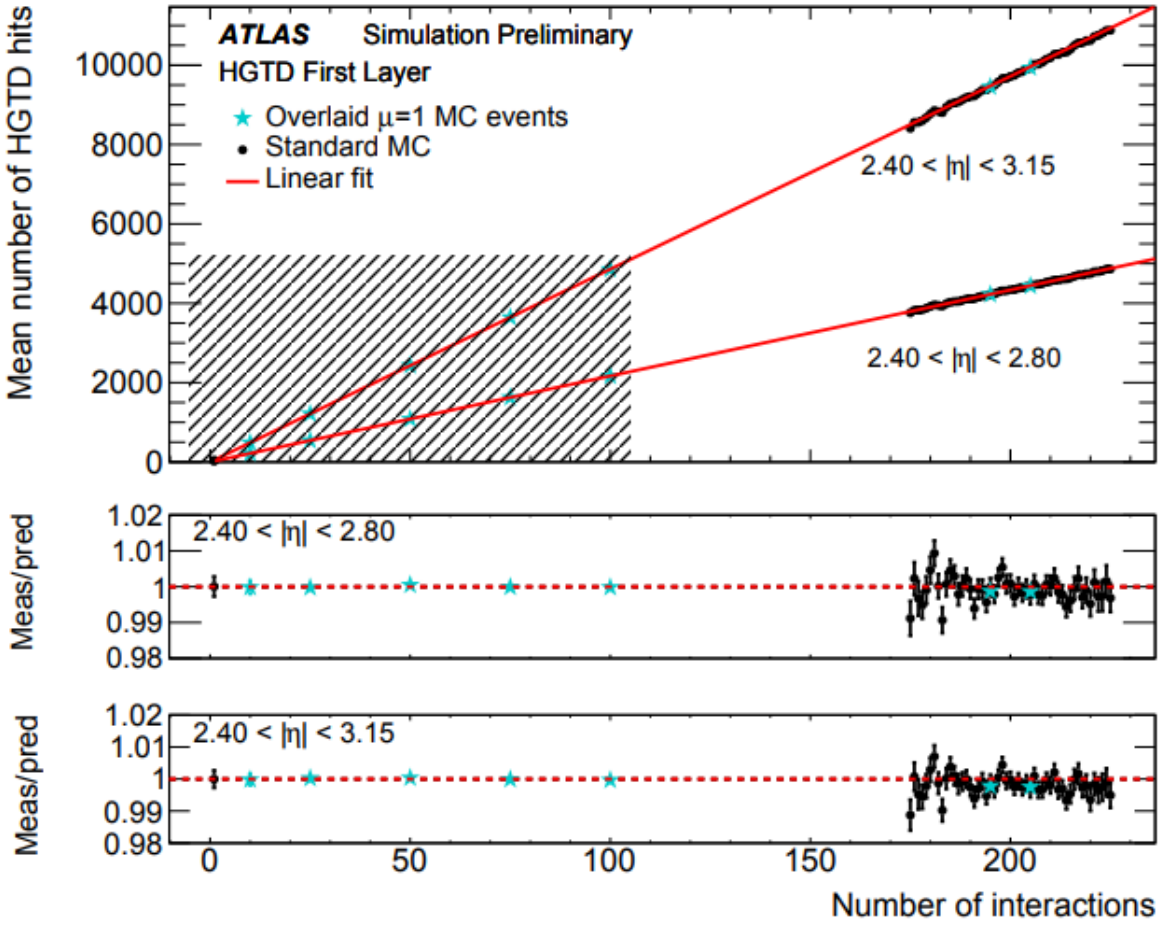


tH with H to bbar:



Relative improvement: 11%
(significance: 1.42 wrt 1.28)

Luminosity



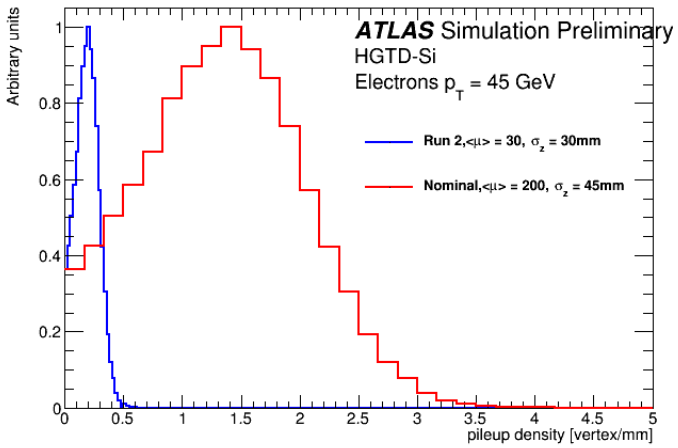
Order 1% error on luminosity measurement important for many physics analyses:

- **HGTD will provide 40MHz bunch by bunch measurements**

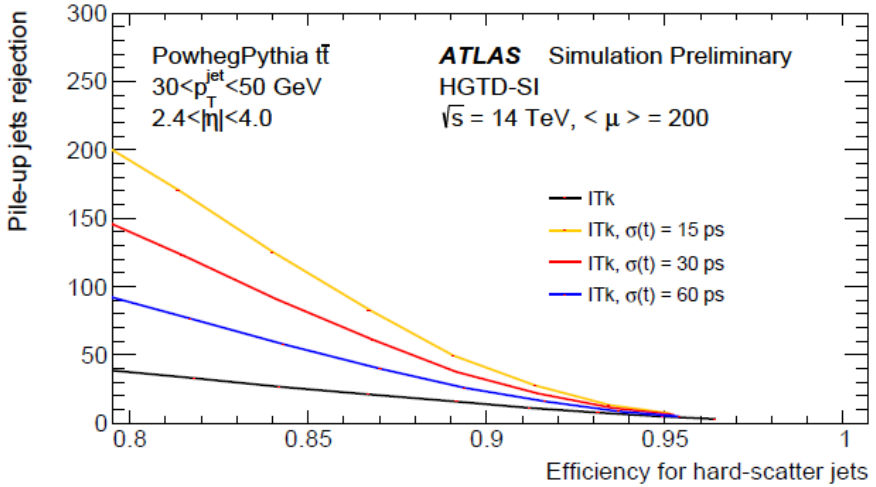
Full simulation and reconstruction:

- **Truth vertices versus HGTD hits in an eta ring**
- **Good linearity (fit low, extrapolate high)**
- **Better than % stat error in 1s**

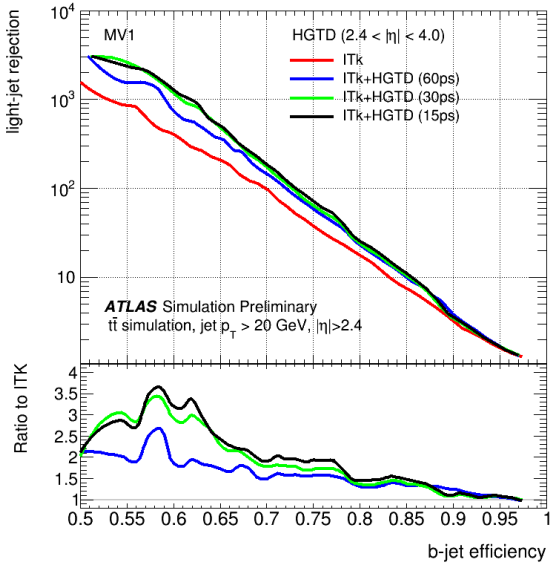
Summary



The HL-LHC pileup density is a challenge



which is mitigated with the HGTD for e.g. jets



and e.g. b-tagging

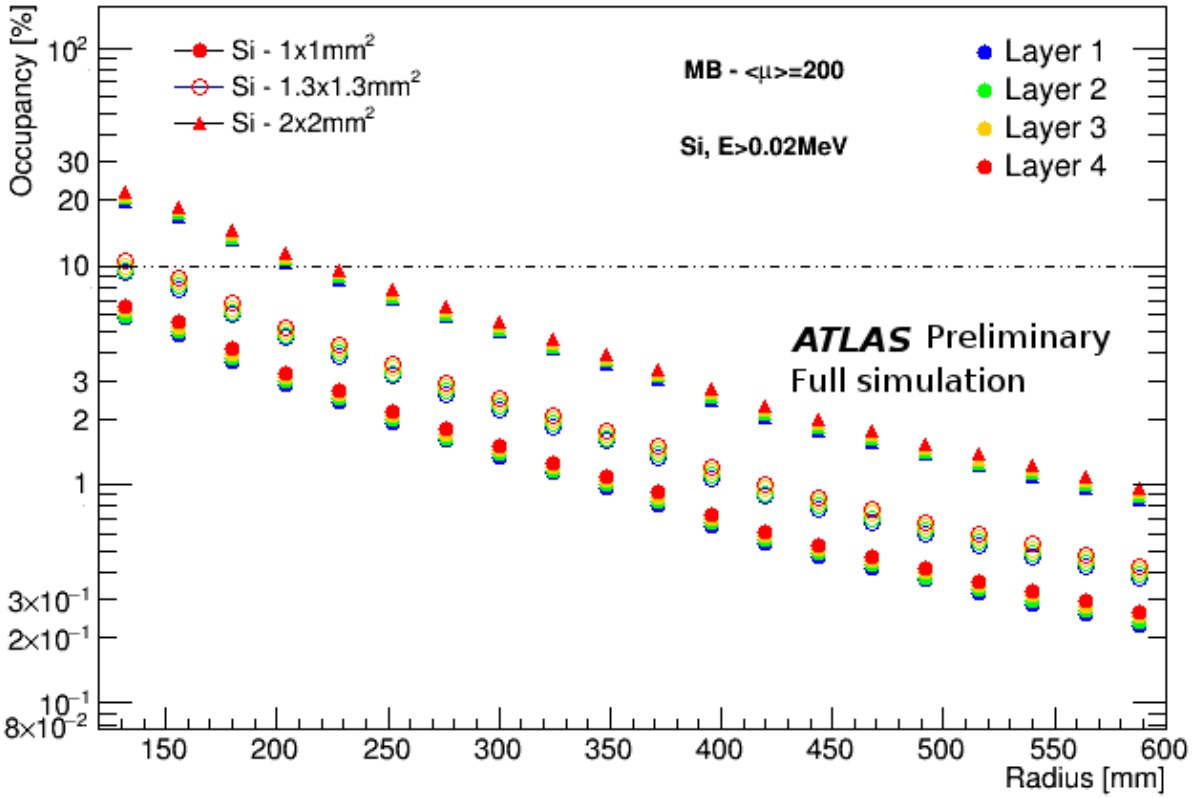
The HGTD:

- Will add redundancy for pileup mitigation
- Improve object reconstruction
- Improve measurements eg VBF HWW, tH
- Precise luminosity measurement

Several other applications being studied:

- L0/L1 trigger
- VBF →H →τ τ
- Electron ID for: $\sin^2\theta_W$
- Long Lived Particles
- …

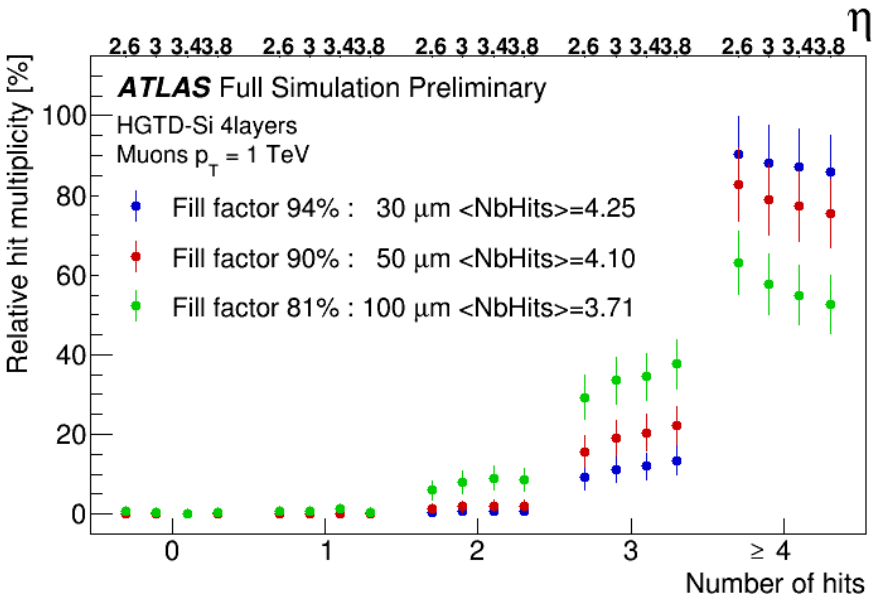
Occupancy

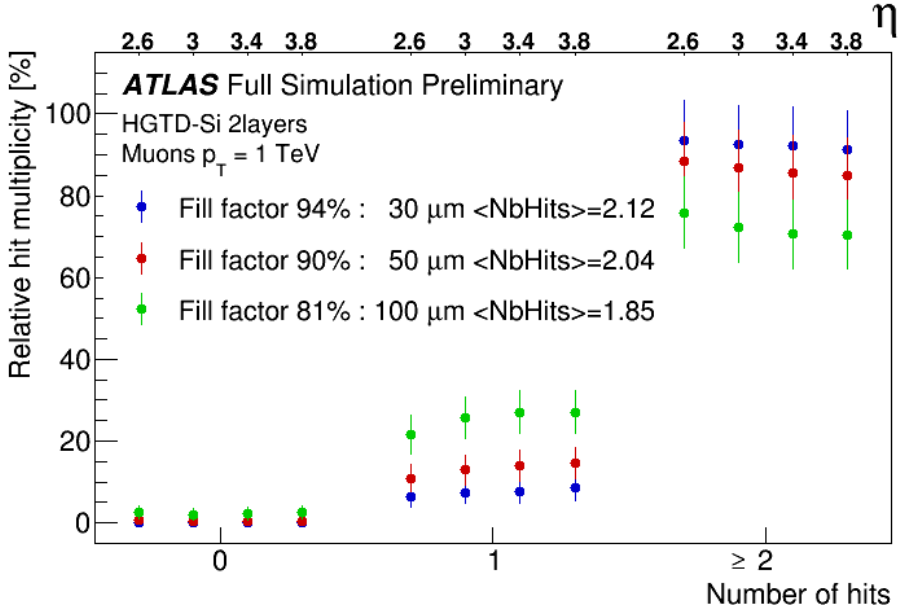


Occupancy (Full simulation):

- **< O(10%)**
- **Pileup is radius dependent**
- **Keep design simple**
- **best timing resolution for small readout cells**
- **Pixel size: 1.3mm x 1.3mm**

Expected Timing Performance





	Two layers	Three layers	Four layers
$N_{\text{hits}} \geq N_{\text{layers}}$	86%	82%	78%
$N_{\text{hits}} = 0$	0.5%	0.11%	0.07%
$< N_{\text{hits}} >$	2.04	3.08	4.1
$< \sigma_t >$	43 ps	37 ps	32 ps

- **99% coverage**
- **97% track-hit matching efficiency**

- **30ps per hit before irradiation**
- **60ps per hit after irradiation**
- **Fill-factor effect compensated by double hit: 32ps-43ps (after irradiation)**

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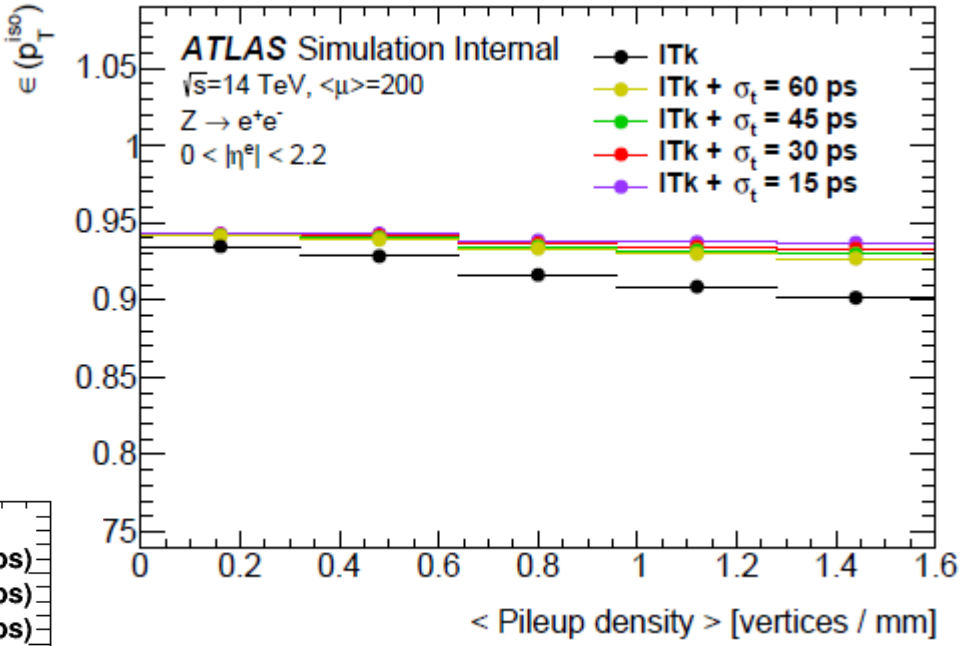

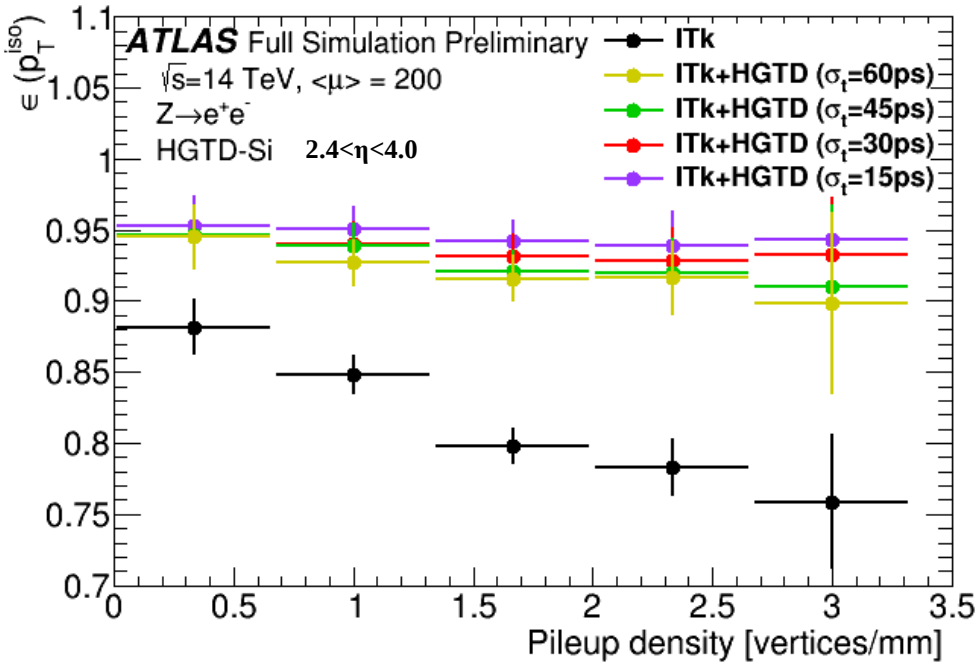

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