LHCP2021

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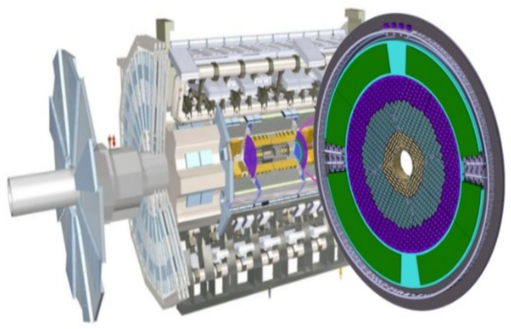
A High-Granularity Timing Detector for the ATLAS Phase-II upgrade



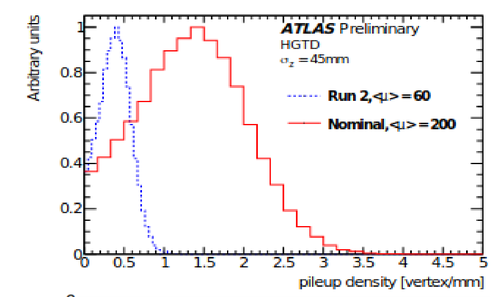
The High Granularity Timing Detector (HGTD)[1] is a proposed silicon detector for the forward region of the ATLAS detector phase-II upgrade. HGTD has a high granularity and excellent timing resolution that open new possibilities for particle reconstruction, physics analysis and luminosity measurement at the High Luminosity Large Hadron Collider (HL-LHC).

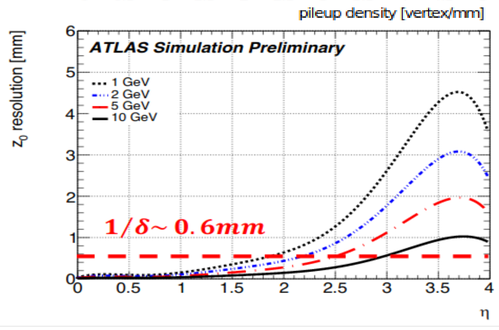
Pile-up Mitigation

HL-LHC
- 200 interactions/bunch crossing
- σ_z= 45 mm (150 ps)
- σ_t= 175 ps
- on average: 1.6 vertices/mm

The longitudinal IP resolution of low pt forward tracks is comparable or larger than the typical separation between pileup vertices

HGTD
- Coverage: 2.4<|η|<4.0
- End-caps: Z = ± 3.5m
- 30ps resolution per MIP
- Resolve merged-in space vertices

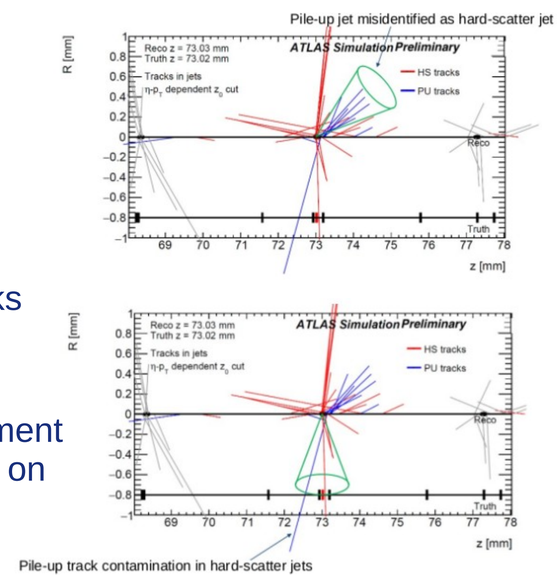




Object reconstruction : Jets

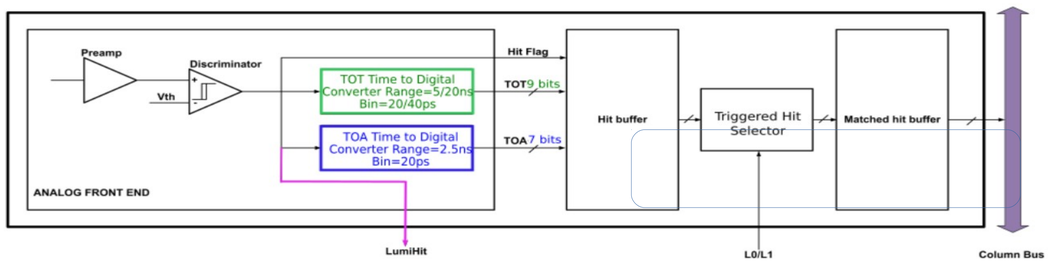
Pileup jets
- Can contaminate the jets of interest
- Can also produce additional jets :
  - As hard QCD process
  - As particles from multiple vertices

Solution : association of jets with tracks and primary vertices
- Improved by timing information
- With σ(t) = 30 ps, rejection improvement is between 20% and 50% (depending on jet pt).



HGTD Front-End Electronics

ALTIROC: 225 channels – 2x2cm² ASIC for measurement and digitization of LGAD signal

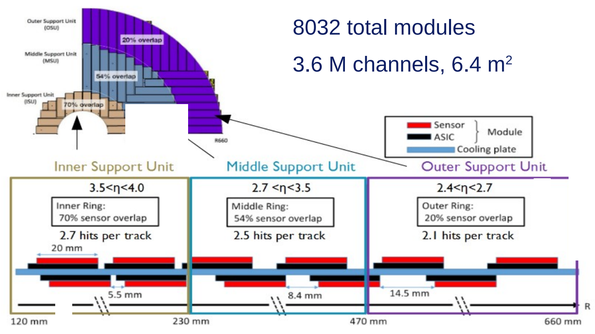


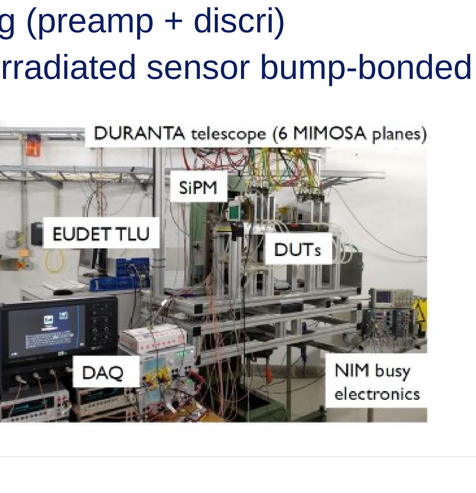
Requirements
- Excellent time resolution
- Radiation hardness
- Trigger rates of HL-LHC

In each channel:
- Preamplifier
- TOT Discriminator - time walk correction
- 2 TDCs: Achieves a 20 ps resolution by combining two lines of fast (120 ps) and slow (140 ps) cells.
- Memory - information storage until trigger

HGTD Modules

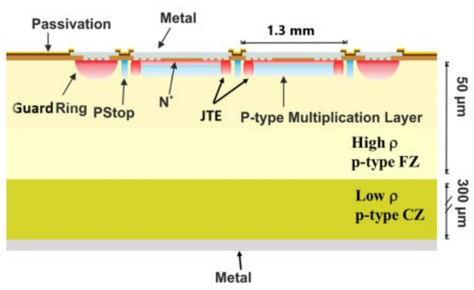
Module
- Sensor: 15x30 pads of 1.3x1.3 mm²
- Bump-bonded to two readout ASICs
- Flex-PCB glued on top
- Flexible tail to outer radius electronics





- Modules on both sides of layer
- Overlap decreases with radius to maintain average N hits per ack 2

Sensor Technology: Low Gain Avalanche Detector



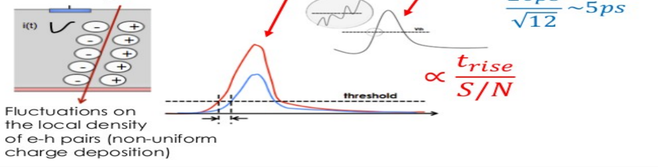
LGAD
- n on p sensor with p-type multiplication layer
- Low gain (G~10): to improve signal slope but control noise
- Thin sensors ≈ 50 μm
- Expected time resolution before irradiation = 30 ps

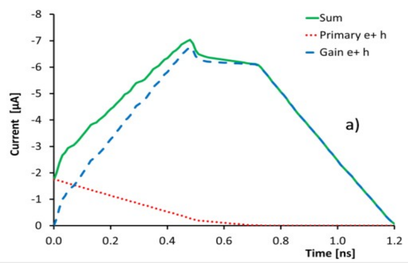
Timing resolution

$$\sigma_t^2 = \sigma_{Landau}^2 + \sigma_{time-walk}^2 + \sigma_{jitter}^2 + \sigma_{TDC}^2 + \sigma_{clock}^2$$

$$\frac{20ps}{\sqrt{12}} \sim 5ps$$

$$\propto \frac{t_{rise}}{S/N}$$



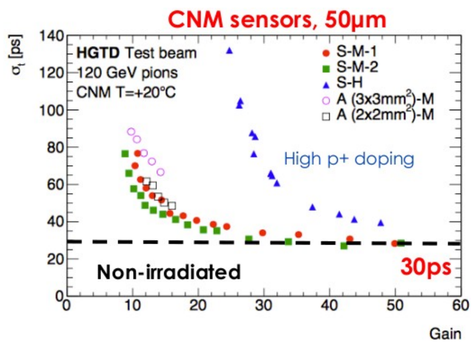


Test beam measurements with ALTIROC prototype

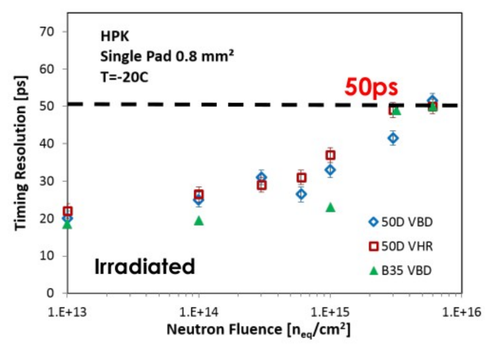
ALTIROC0:
- 8-channels prototypes
- only analog (preamp + discri)
- 4-pads unirradiated sensor bump-bonded

Testbeam with ALTIROC0:
- Test beam with pion/electron beams
- Telescope planes to provide track reconstruction
- Record wave-forms to perform analysis
- Tested single diodes and 2x2 arrays

Results



- **Ultimate time resolution is about 30 ps, limited by "Landau" term**
- **Time resolution smaller than 50 ps up to 5 x 10¹⁵ n_{eq}/cm² with bias voltage (VHR) 10% below breakdown voltage (VBD)**
- **35 μm thickness: similar time resolution to 50 μm at high fluence, better below 1 x 10¹⁵ n_{eq}/cm² , but larger capacitance**



[1] ATLAS Collaboration. Technical design report: A high-granularity timing detector for the atlas phase-ii upgrade. Technical report, 2020.

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ATLAS EXPERIMENT