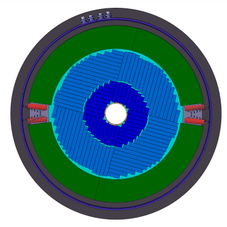
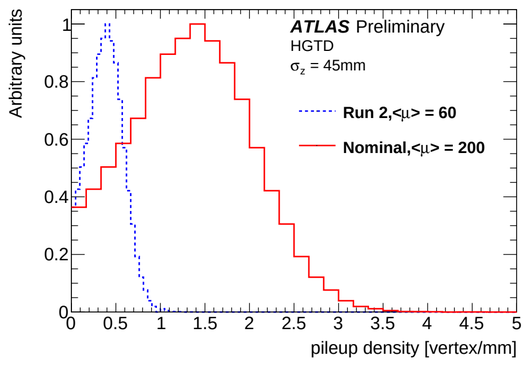
LHCC Poster Session – February 27th 2019

Characterization of front-end electronics for the High Granularity Timing Detector in ATLAS

The High Granularity Timing Detector (HGTD) [1] is a proposed silicon detector for the forward region of the ATLAS detector in the High Luminosity LHC. It's high granularity and excellent timing resolution open new possibilities in the particle reconstruction, physics analysis and luminosity measurement at the HL-LHC.



Motivation: Pile-up Mitigation

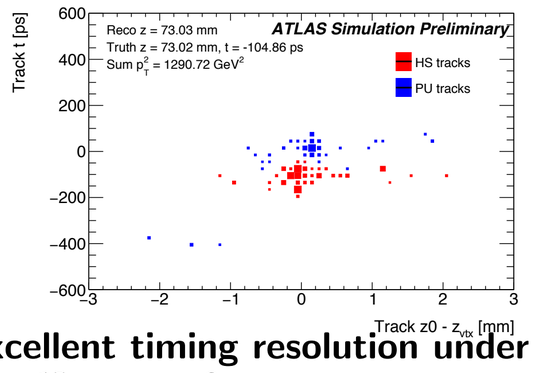


HL-LHC:

- 200 interactions/bunch crossing
- $\sigma_z = 45$ mm (150 ps)
- $\sigma_t = 175$ ps
- on average: 1.6 vertices/mm
- **ITk:** $z_0 > 1$ mm for $\eta > 3$, $p_T < 1.5$ GeV

HGTD:

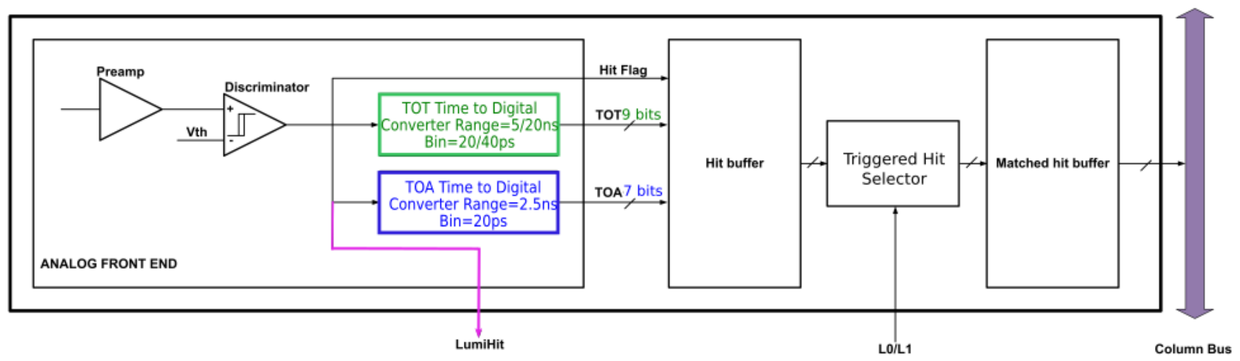
- Coverage: $2.4 < |\eta| < 4.0$
- z position = 3.5 m
- $\sigma_t =$ **30ps/MIP** (pre-irrad.)
- Resolve merged-in-space vertices



The HGTD has to maintain an excellent timing resolution under very high radiation doses = 5.1×10^{15} n_{eq}/cm^2 + 4.7 MGy TID!

HGTD Front-End Electronics

ALTIROC: 225 channels - 2x2cm^2 ASIC for measurement and digitization of LGAD signal



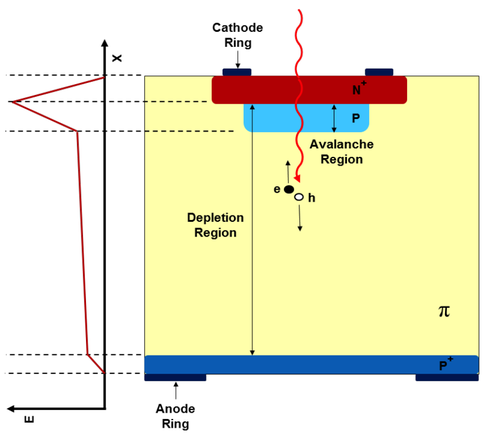
Requirements:

- Excellent time resolution
- radiation hardness
- trigger rates of HL-LHC

In each channel:

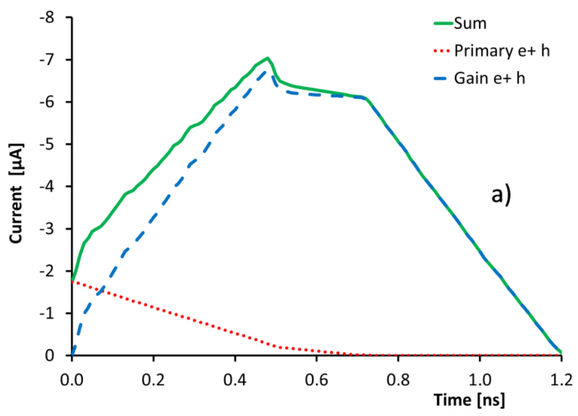
- Preamplifier
- TOT Discriminator - time walk correction
- 2 TDCs - digitization of time measurements
- Memory - information storage until trigger

Sensor Technology: Low Gain Avalanche Detector



LGAD:

- n-on-p Si detector with extra doped p-layer
- x20 Gain and increased S/N ratio
- **Expected time resolution before irradiation = 30 ps**



Timing resolution:

$$\sigma_{det}^2 = \sigma_{Landau}^2 + \sigma_{electronics}^2$$

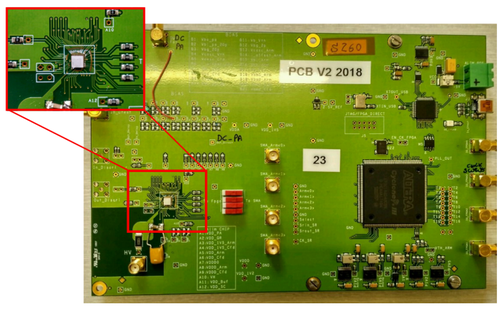
Dimensions to optimize σ_{det}^2:

- thin sensors - 50 μm
- small area - 1.3x1.3 mm^2 pads

Testbeam measurements with ALTIROC prototype

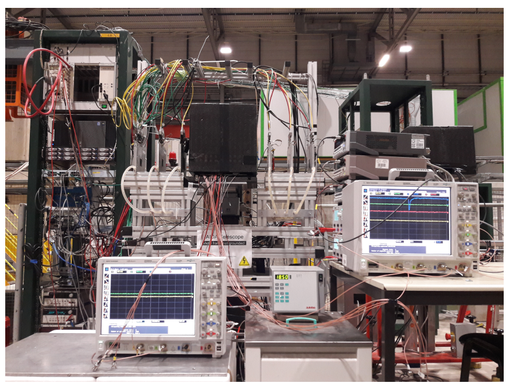
ALTIROC0:

- 8-channel prototype
- only analog (preamp + discri)
- 4-pad unirradiated sensor bump-bonded



Testbeam with ALTIROC0:

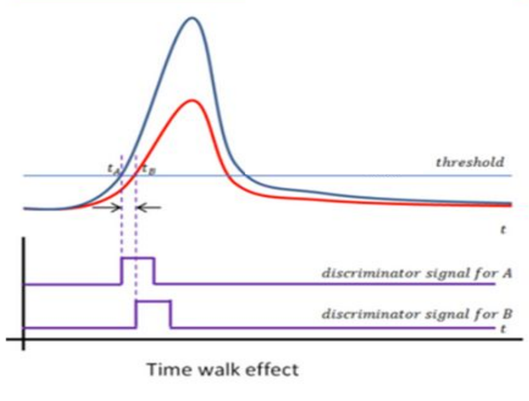
- @CERN SPS North Area
- 120 GeV pions
- tracking from AIDA Telescope
- SiPM + quartz bar system for time reference

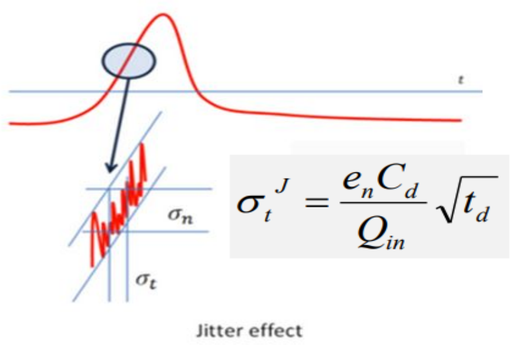


Electronics contributions to the time resolution

$$\sigma_t^2 = \sigma_{jitter}^2 + \sigma_{TimeWalk}^2 + \sigma_{TDC}^2 + \sigma_{Clock}^2$$

- **Jitter:** Noise contribution to the signal - **fast signals**, **small detector capacitance**
- **Time Walk:** large signals cross a constant threshold faster than small ones - **Time-Over-Threshold** measurement
- binning of the **Time-to-Digital Converter** (TDC) - **fine binning**
- **Clock** contribution → online calibration

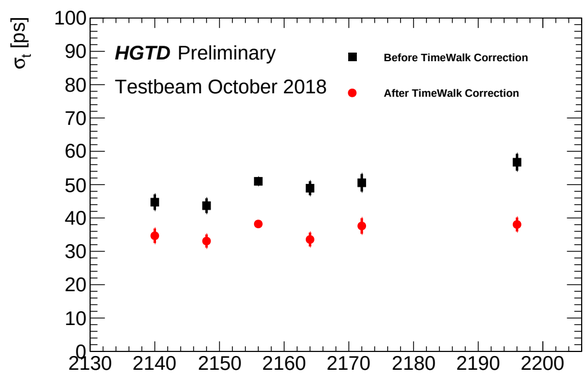


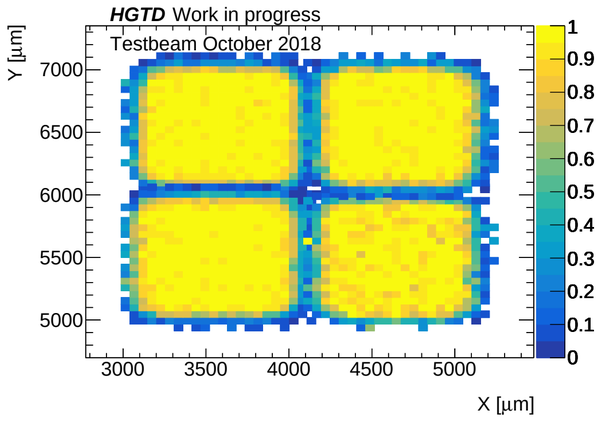


Results

Time Resolution:

- time resolution of the SiPM subtracted
- time walk correction → 30% improvement
- best achieved $\sigma_t =$ **35 ps**





Efficiency:

$$\frac{\text{Number of tracks with LGAD response}}{\text{Total number of tracks}}$$

- uniform among channels
- above **95%** in the bulk of the pad

[1] *Technical Proposal: A High-Granularity Timing Detector for the ATLAS Phase-II Upgrade*, CERN-LHCC-2018-023. LHCC-P-012, CERN, 2018

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