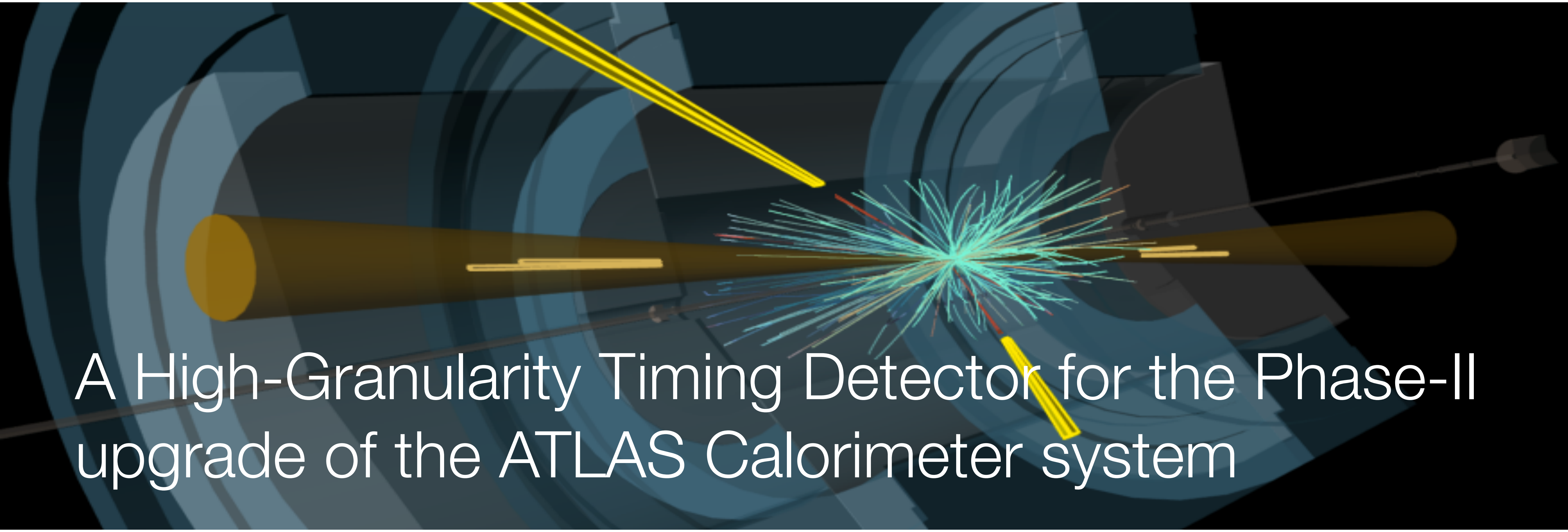


A High-Granularity Timing Detector for the Phase-II upgrade of the ATLAS Calorimeter system

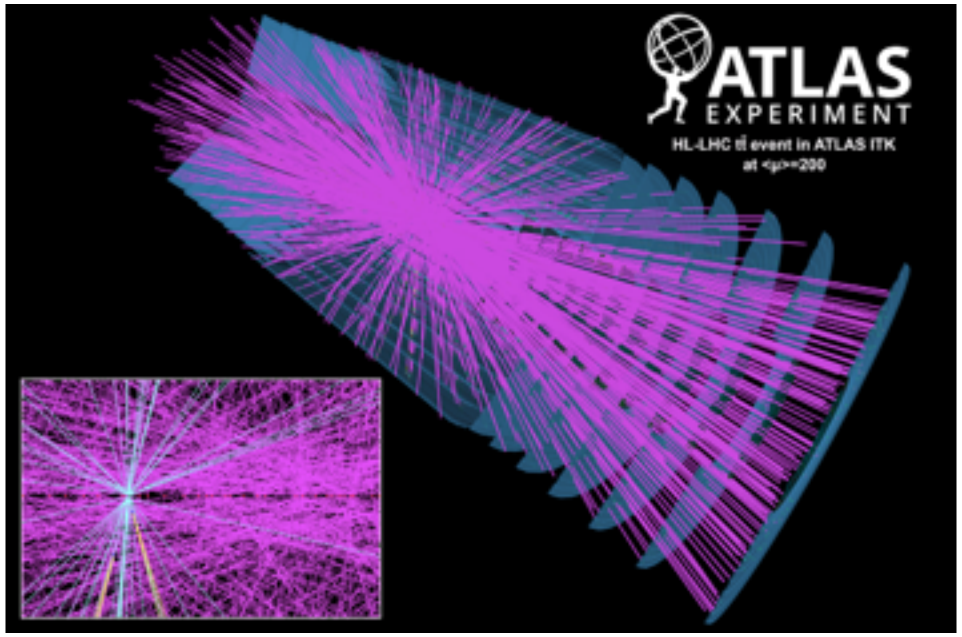
Bruno Lenzi
on behalf of the ATLAS collaboration

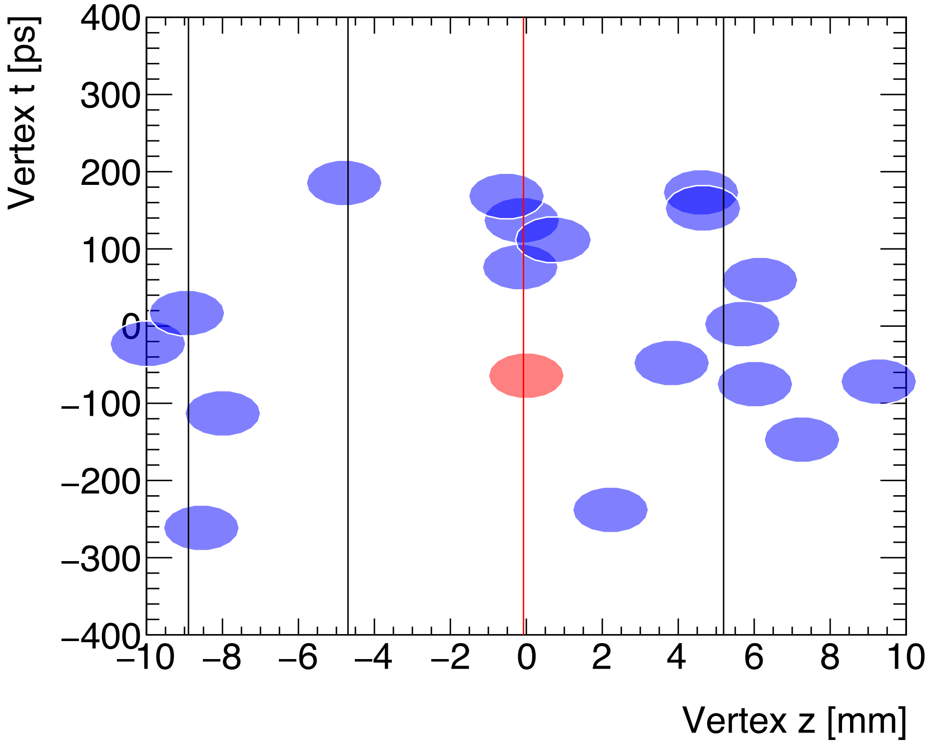
TIPP 2017 - Beijing, China

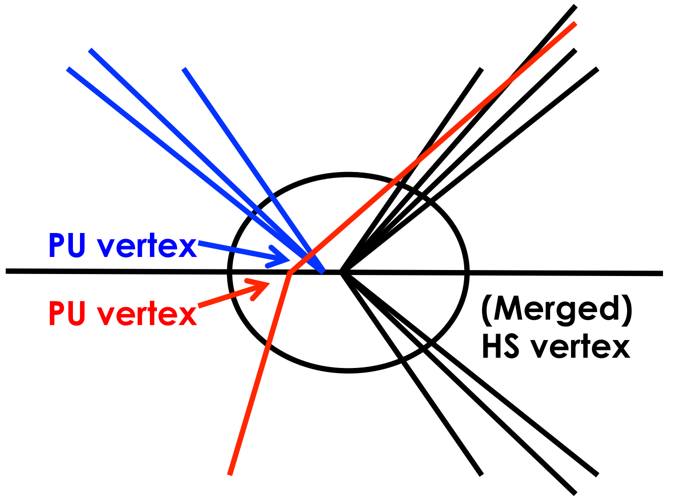
24/05/2017

HL-LHC environment

- $\sqrt{s}$ = 14 TeV and luminosity up to 7.5 x 10^{34} cm^{-2} s^{-1}
  - Pileup up to 200 (180 ps, 50 mm)
  - Additional energy, extra jets, reducing the performance of several physics objects and particularly important for trigger
- Extended tracking coverage up to |η| = 4.0
  - Main handle against pileup
  - 5-7 vertices within tracker resolution at large |η| (only 1/3 of the effect in the central region)

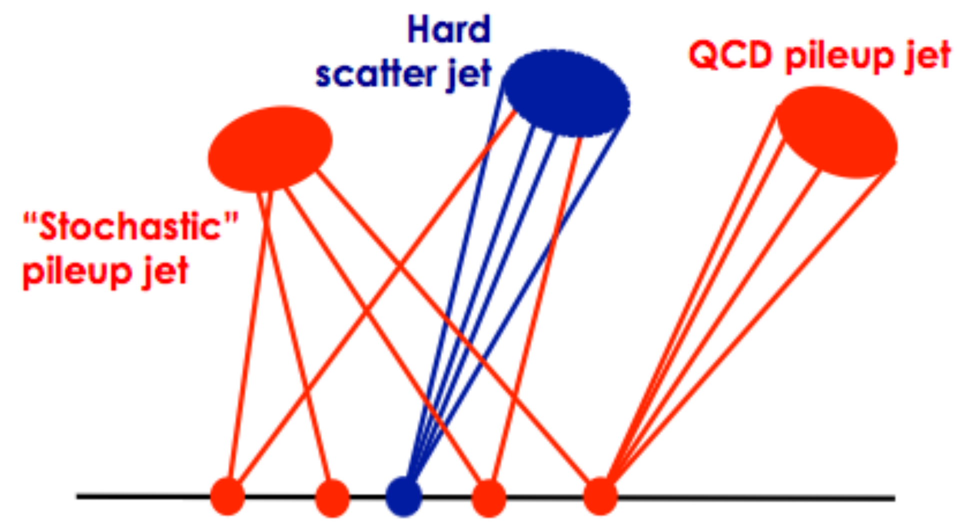




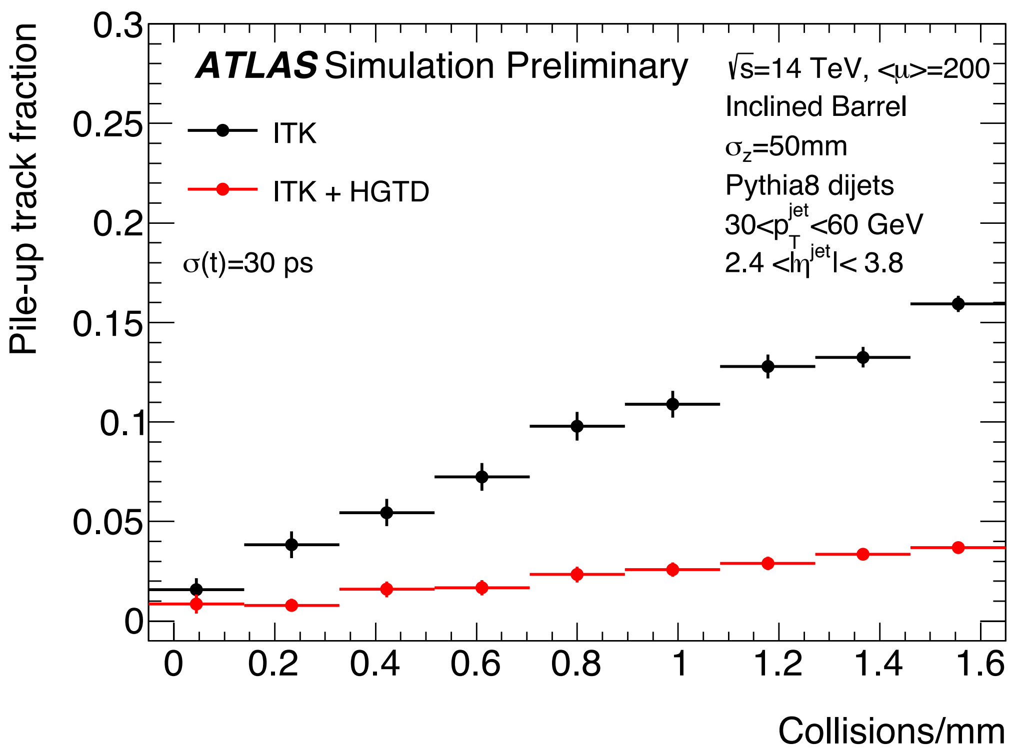


High Granularity Timing Detector (HGTD)

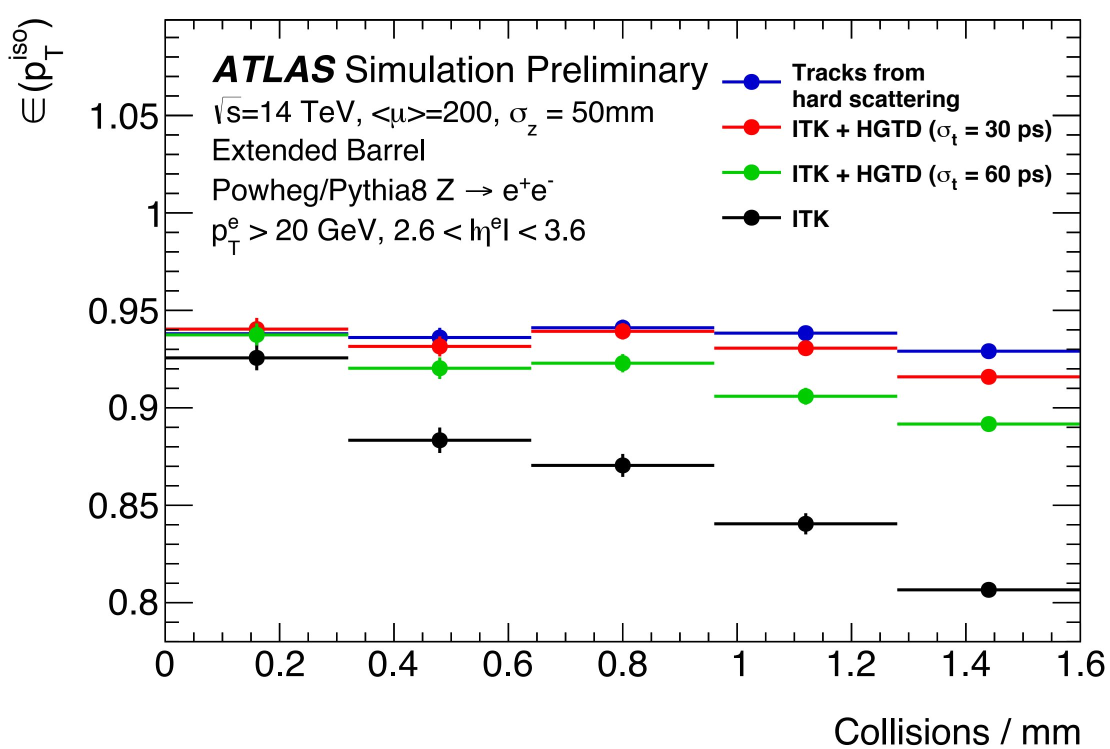
- Timing detector with σ_t = 30 ps in forward region: (most sensitive region to pileup)
  - Offline pileup mitigation in addition to tracker
  - Trigger capabilities (40 MHz)
  - Potential for luminosity determination and tagging beam-induced background



Tracks in jets, σ_t = 30 ps

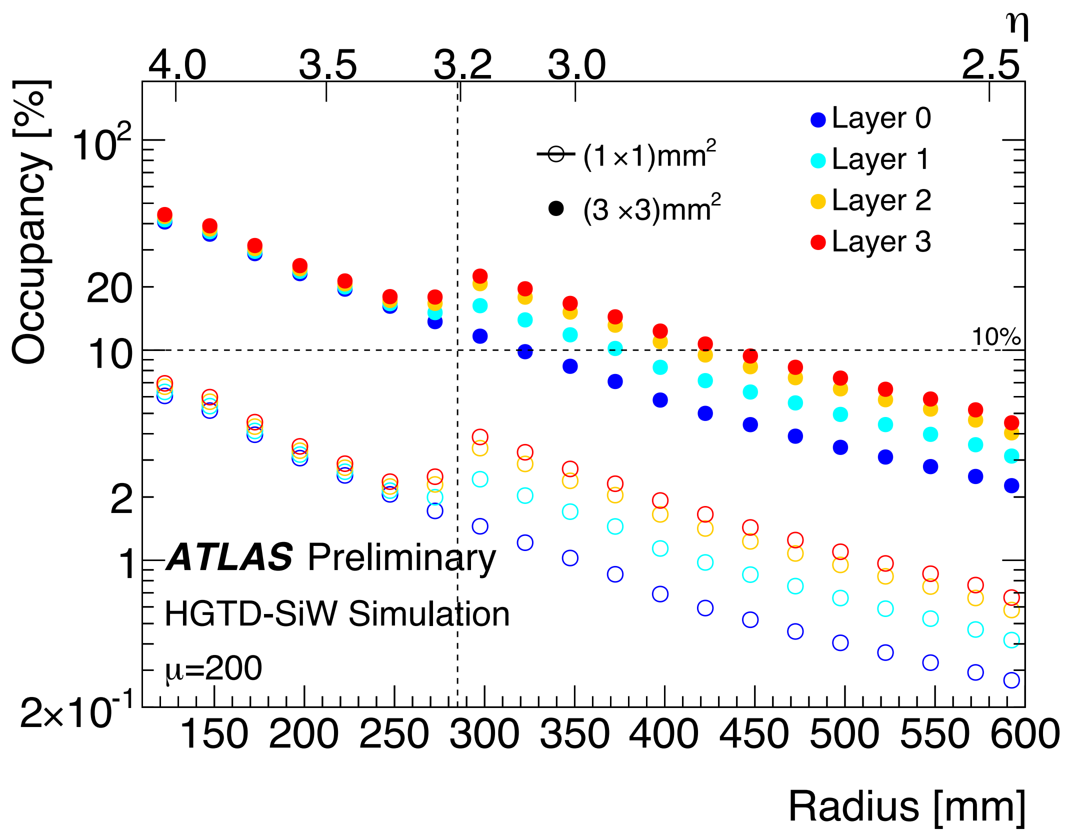


Lepton isolation, σ_t = 30 - 60 ps

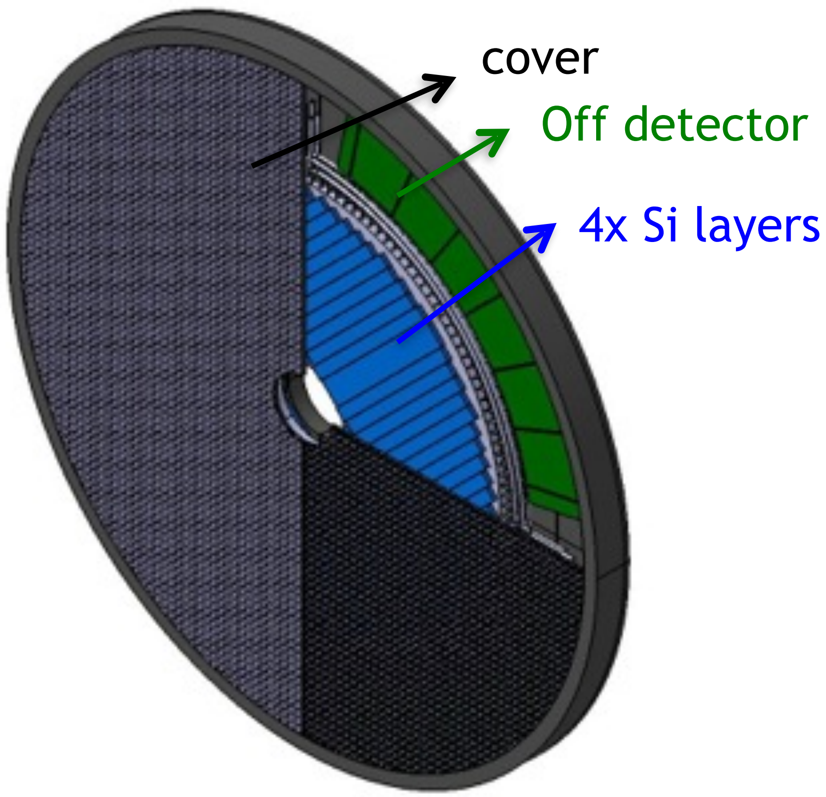


HGTD: requirements and overal specifications

- Available space: 65 mm @ |z| = 3.5 m (2.4 < |η| < 4.2)
- Radiation levels up to 3 MGy, 4 x 10^{15} N_{eq}/cm^2
- Occupancy < 10% → pads of 1x1 - 2x2 mm^2
  - Granularity also defined by initial studies of electronics / time resolution
  - 4 Si (LGAD) layers . Option to have $3X_0$ W absorber (|η| = 2.4 - 3.2)



Preliminary design



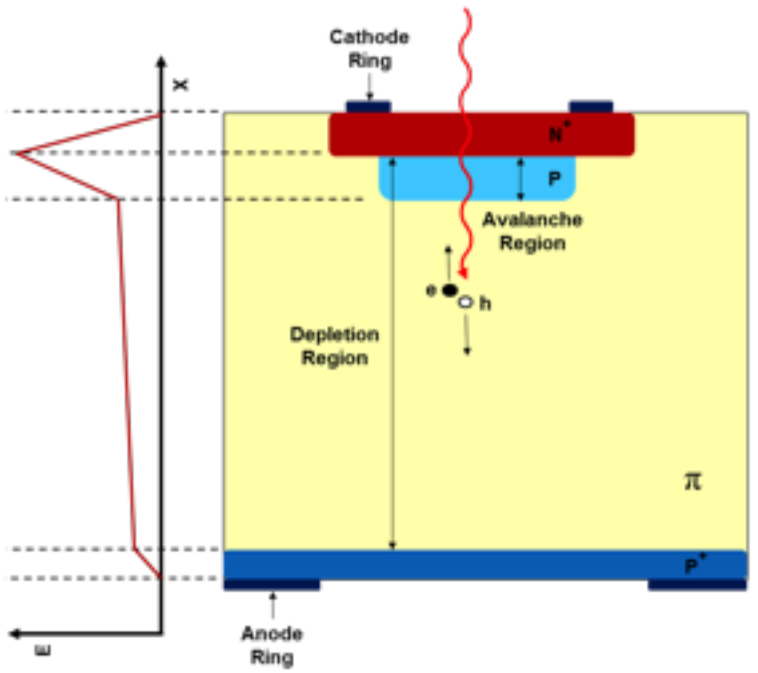
HGTD: requirements and overal specifications

- σ_t = 30-50 ps for MIPs: thin sensors, large signals, low jitter

$$\sigma_{tot}^2 = \sigma_{Landau}^2 + \left(\frac{t_{rise}}{S/N}\right)^2 + \left(\left[\frac{V_{thr}}{S/t_{rise}}\right]_{RMS}\right)^2 + \left(\frac{\mathrm{TDC}_{bin}}{\sqrt{12}}\right)^2$$

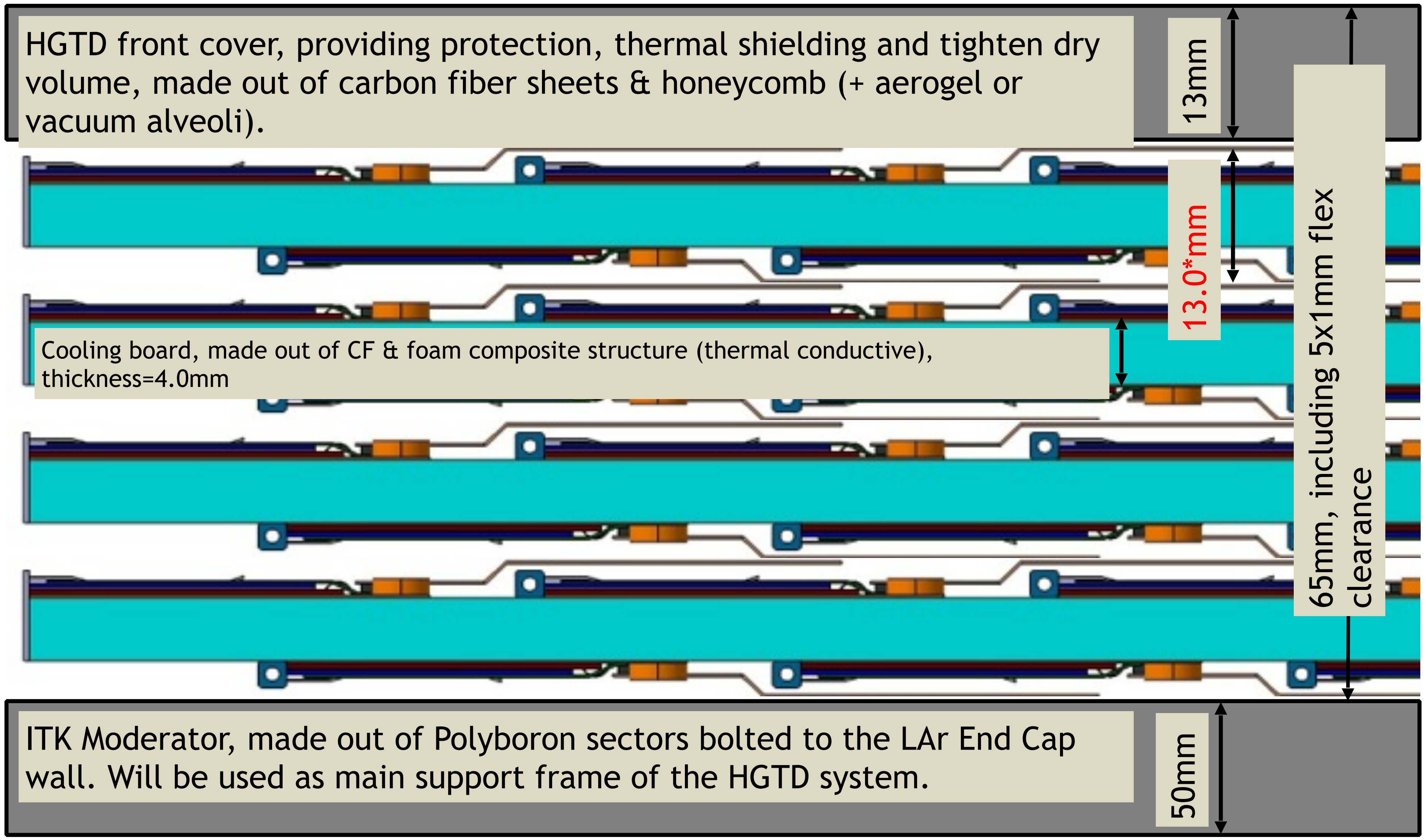
thin sensor (50 μm) | fast signals large S/N | timewalk correction with CFD small TDC bins

- Low gain avalanche diodes (LGADs,NIMA765 (2014) 24) close to the requirements
  - Extra doping layer: high field and S/N
  - Needs cooling to -20ºC or -35ºC
  - Manufacturers: CNM (within RD50), FBK and HPK
    - Initial tests show comparable gain and overall performance
  - Sensors with new ideas to improve radiation hardness on the way



HGTD: preliminary design (being optimised)

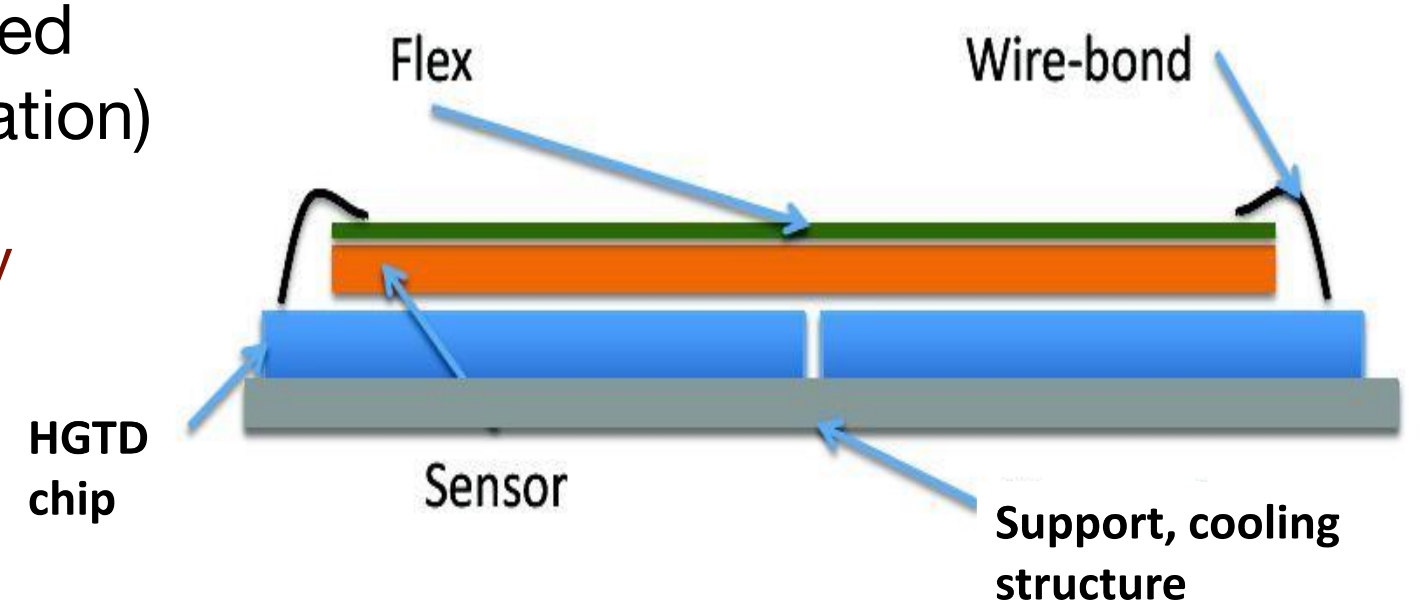
4 Si (LGAD) layers . Option to have 3X0 W absorber (|η| = 2.4 - 3.2)



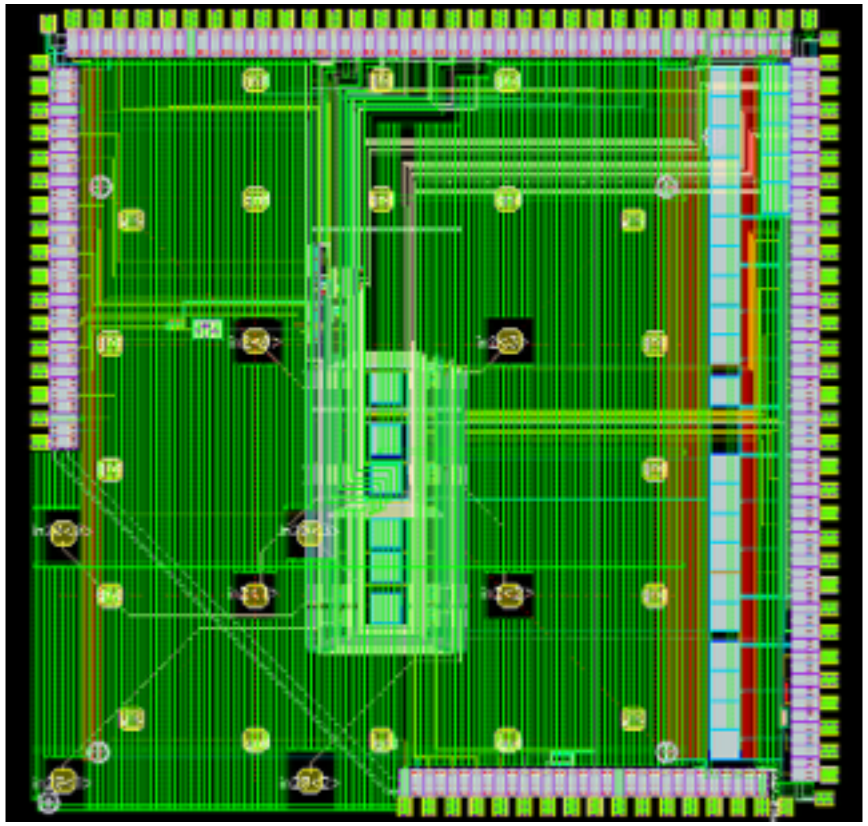
** Full layer thickness, CF cooling panels limited to 4.0mm & Stave flex maxi stack up 4.5mm.*

HGTD: preliminary design and readout electronics

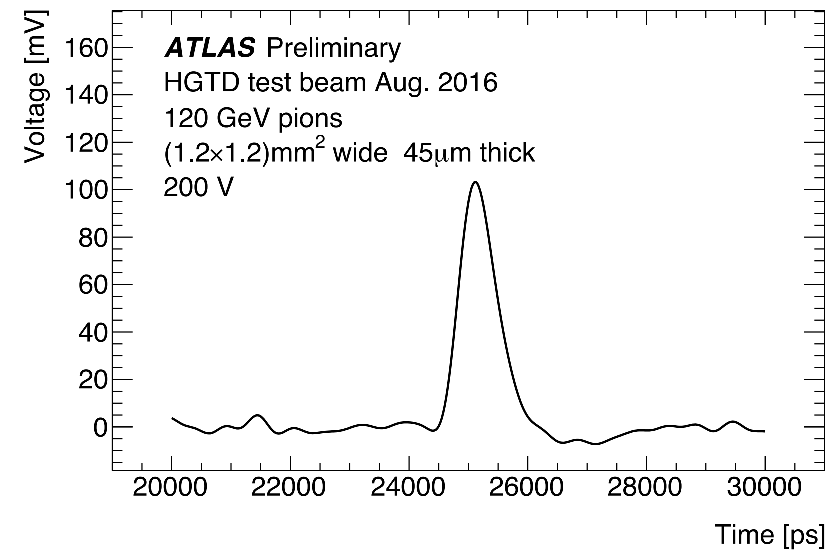
- 2x2 array of sensors bump-bonded to ASICs (prototype under fabrication)
  - TSMC 130nm CMOS Technology
  - 3.4 x 3.4 mm^2 total area
  - Integrated Preamplifiers, ToT and CFD
- Flex used for readout signal and voltage distribution
- Modules staggered to minimise dead areas
- 1x1 mm^2 pads everywhere
  - Group 4 channels in 1 (2x2 mm^2) at large radius

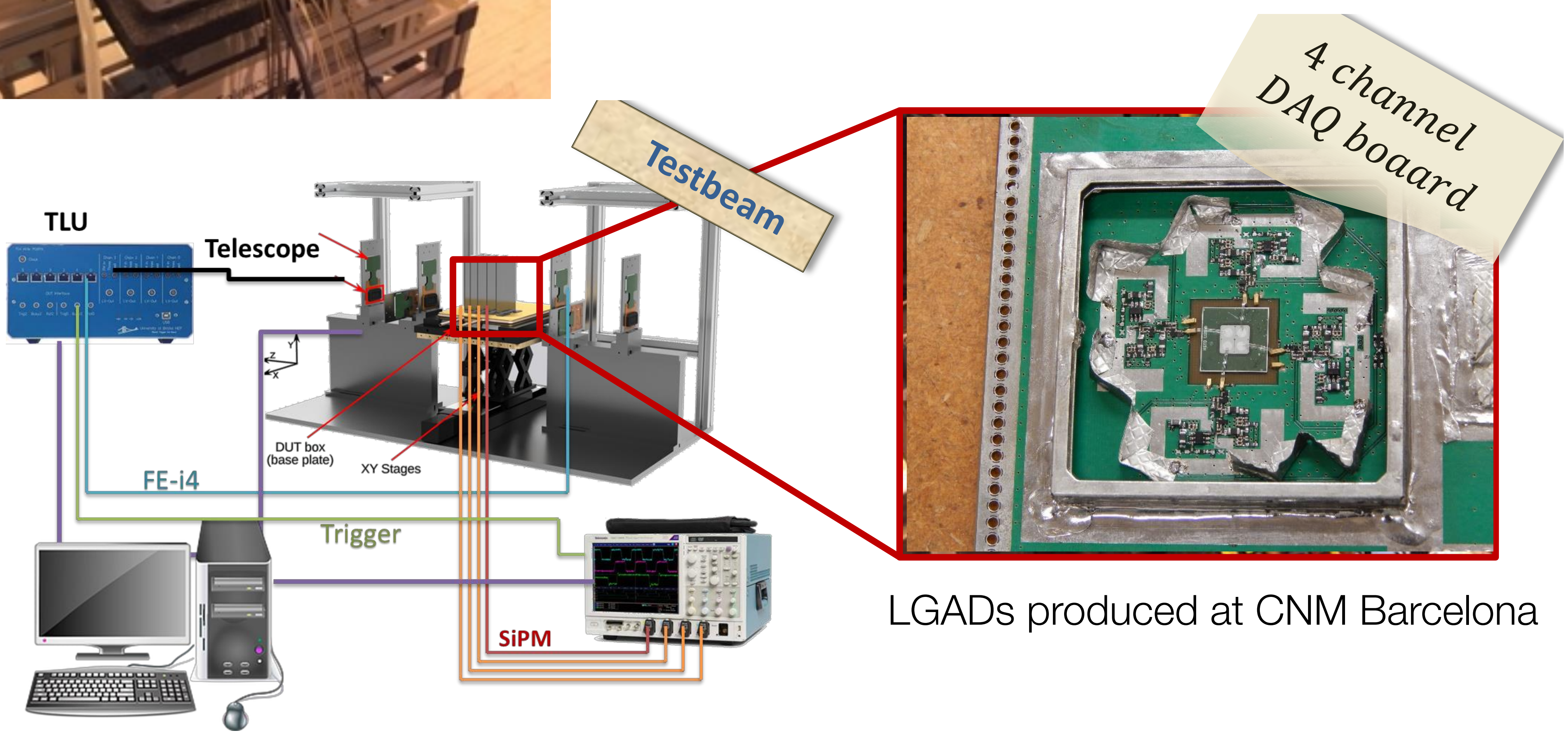


Chip layout with wire bonds in the periphery



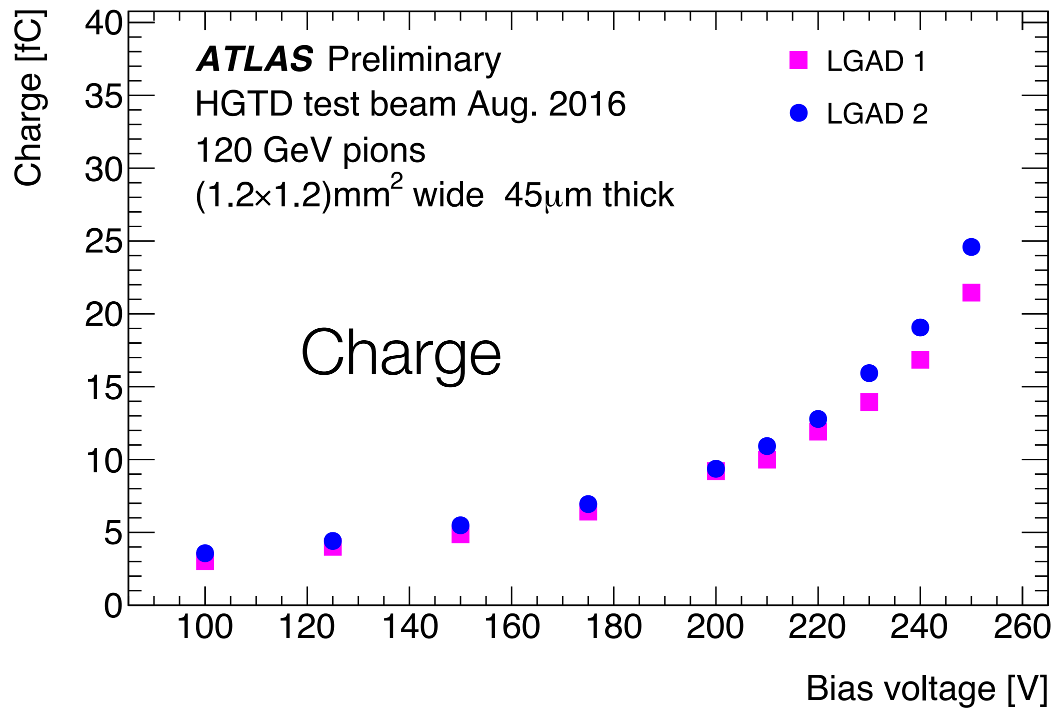
Test-beam at CERN SPS (Aug and Oct 2016)

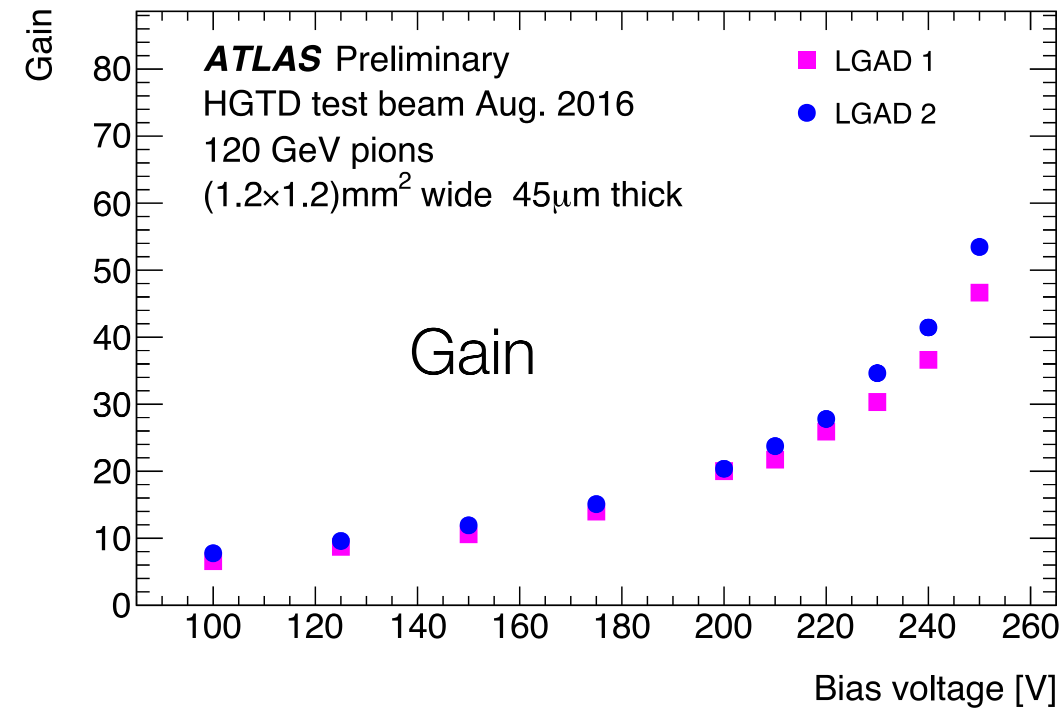


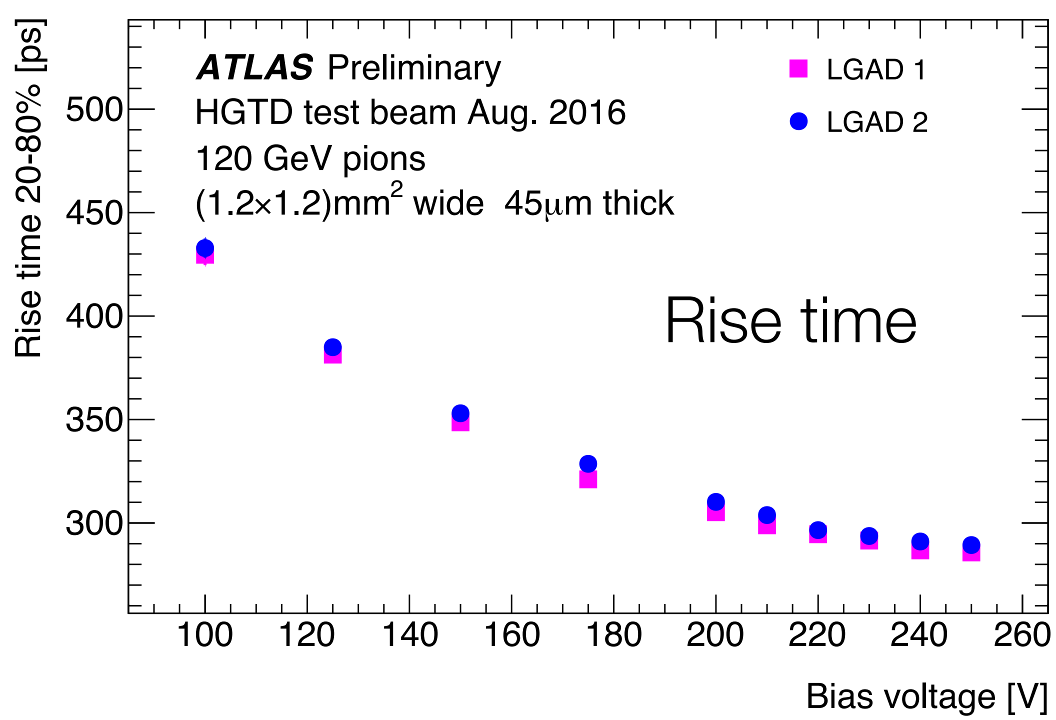


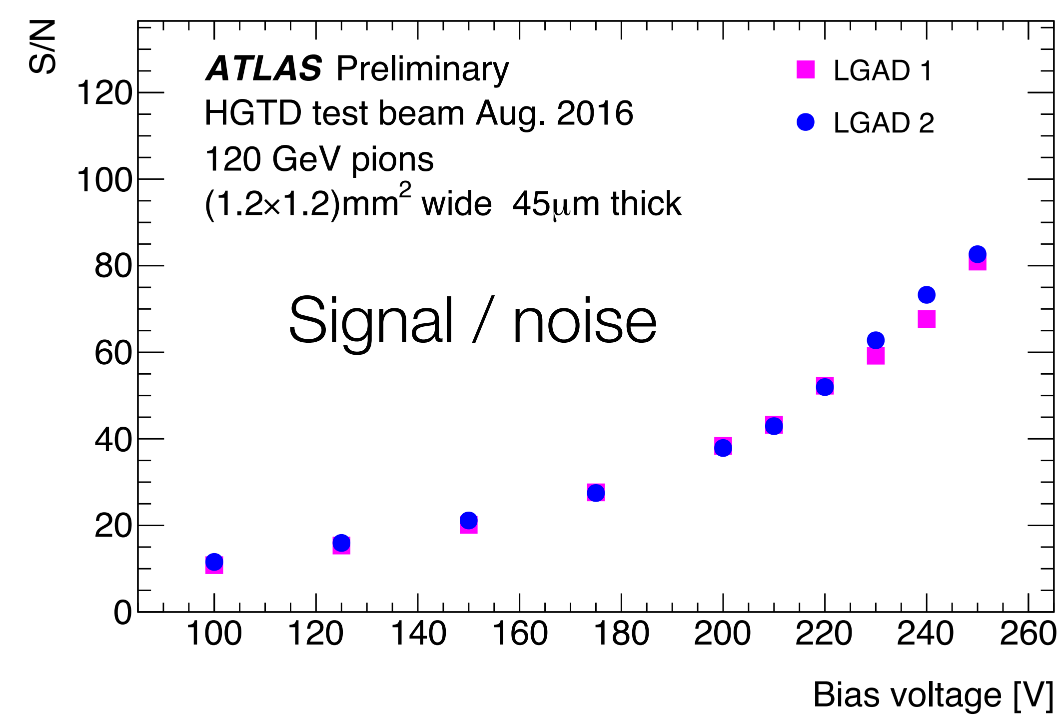
LGADs produced at CNM Barcelona

Test-beam results



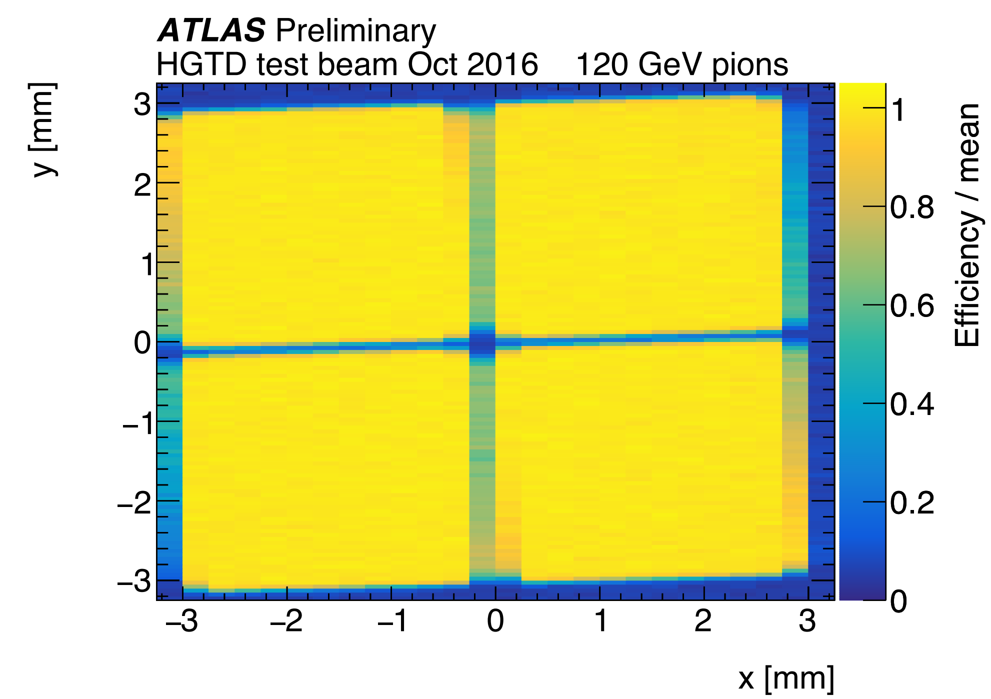


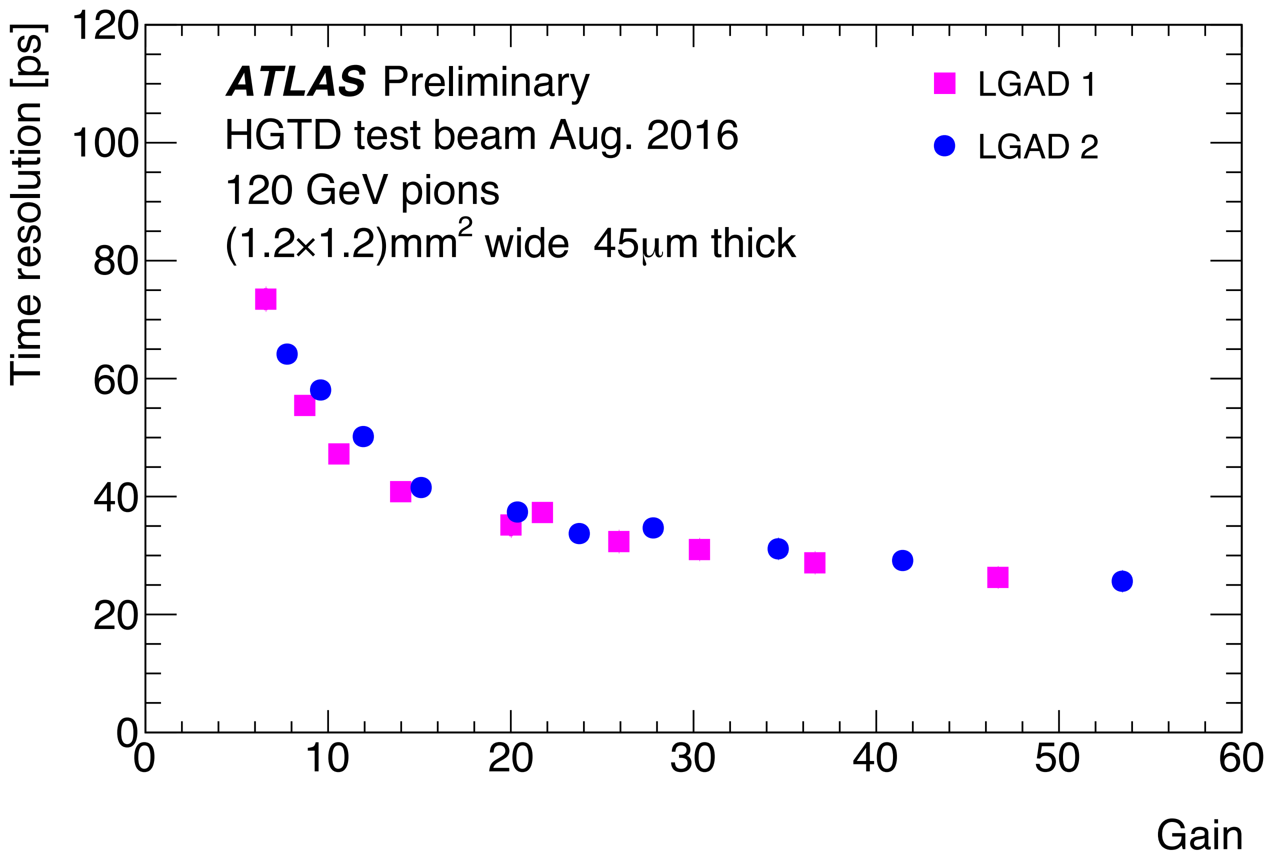


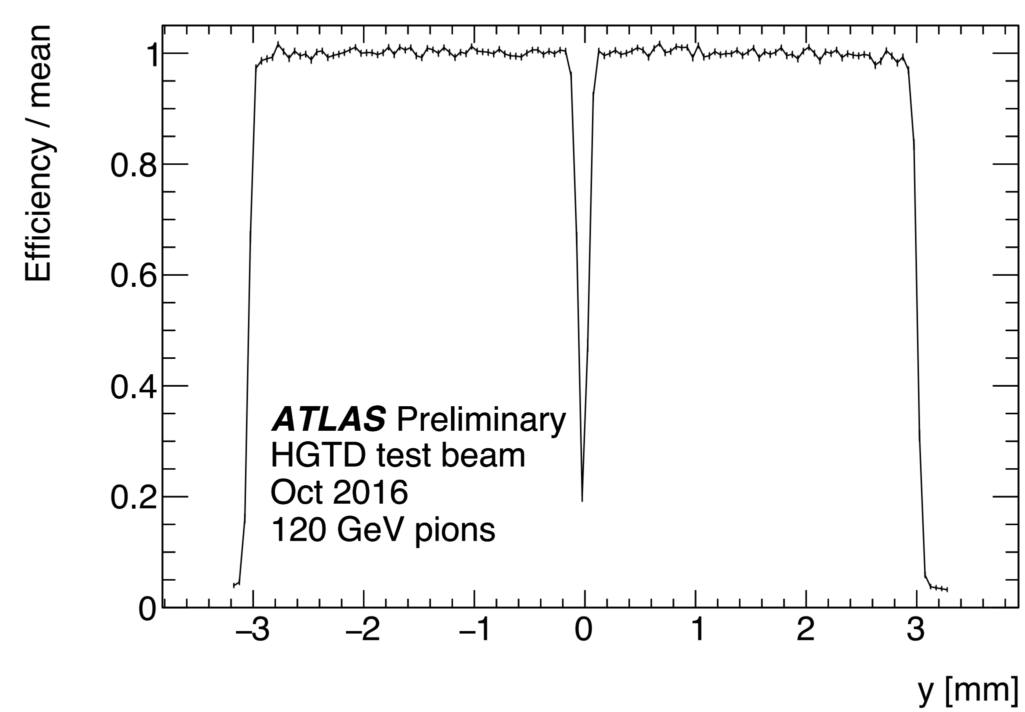


Test-beam results

- Gains up to 50, time resolution < 30 ps for 1x1 mm^2 pads, dominated by Landau fluctuations
- Good efficiency and signal uniformity for arrays
    - Refined analyses ongoing







Summary

- Relatively new project focusing on precise timing measurement for ATLAS at HL-LHC. Already ~20 institutes involved
- Additional pileup mitigation, trigger and luminosity measurement capabilities, electron reconstruction
    - Studies with full simulation ongoing
- Defining layout of electronics, mechanics, integration
- Good progress on sensors, intense R&D on radiation resistance (within RD50)
- Promising tests with beams in 2016, more to come this year
    - First tests of ASIC, radiation hardness, etc
- Initial Design review planned in September 2017