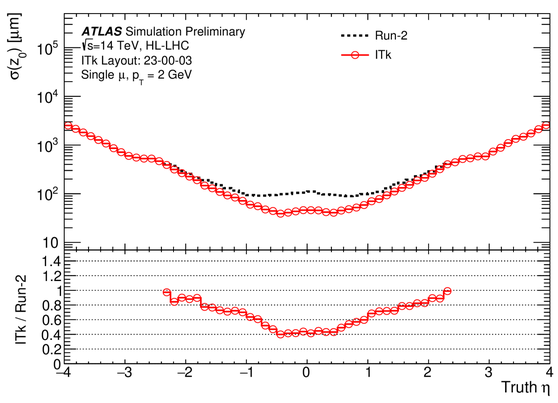
Overview of the ATLAS High-Granularity Timing Detector: *project status and results*

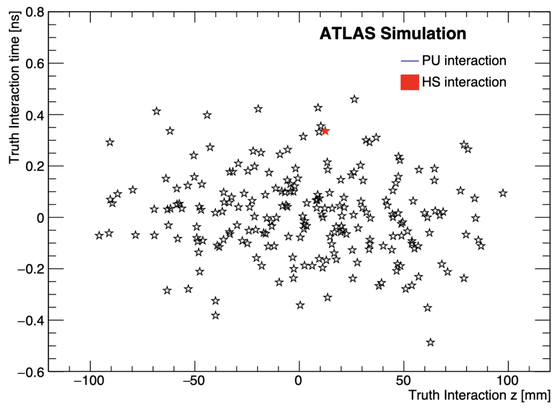
Yassine El Ghazali [1] On behalf of the ATLAS HGTD Group

[1]Faculté des Sciences, Université Ibn-Tofail, Kénitra

High-Luminosity LHC

- High-Luminosity LHC will deliver an instantaneous luminosity of up to $L \approx 7.5 \times 10^{34}$ cm^{-2} s^{-1}
- Very harsh environment with **200** pile-up events (p-p interactions on same bunch crossing)
- ATLAS will install a full-silicon Inner Tracker (ITk) to maintain its physics performance

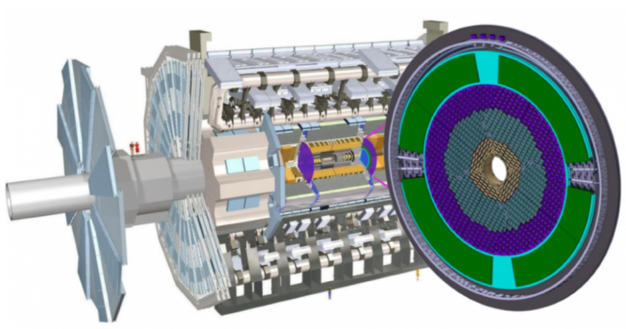


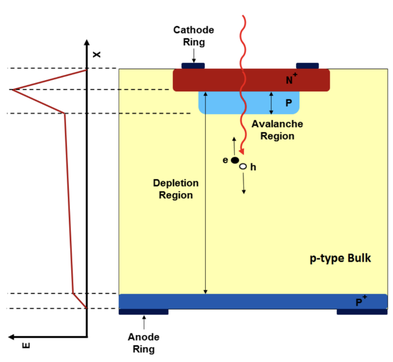


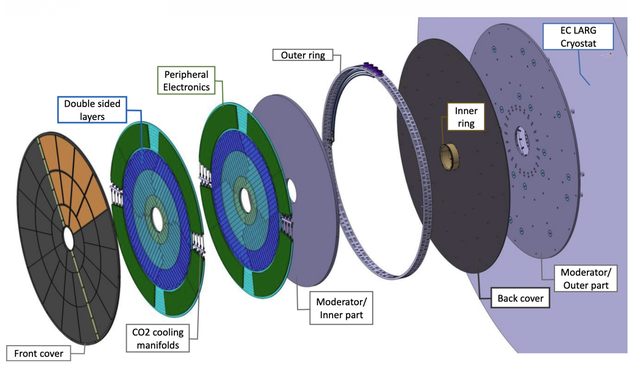
- ITk does great job, *but* in the forward region z_0 resolution worsens and becomes larger than distance between two vertices $\Longrightarrow$ Timing information allows to separate these vertices

High Granularity Timing Detector (HGTD)

- HGTD will be installed in the forward region of ATLAS
  - $2.4 < |\eta| < 4$
  - ± 3.5 m from IP
  - $12 < R < 64$ cm
  - 3 ring layout
  - Resolution per track 30-50 ps
  - Resolution per hit 35-70 ps
  - Radiation hard: 2.5×10^{15} n_{eq}/cm^2
- **Sensor technology:** Low Gain Avalanche Detectors (LGADs)
  - n-p planar silicon diodes with additional p-type doped layer
  - Moderate gain **10-20** compared to APD and SiPM
  - Thin (50 μm): radiation hardness and faster rise time
  - LGAD pad size 1.3×1.3 mm^2 (low occupancy)

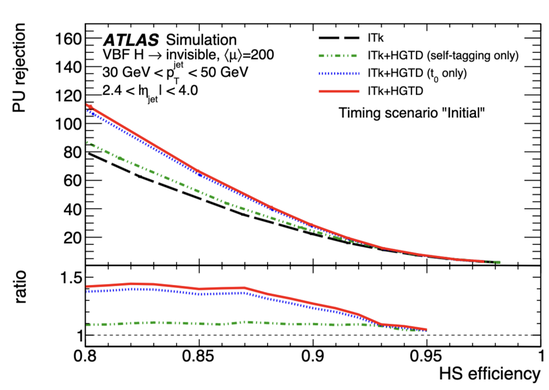


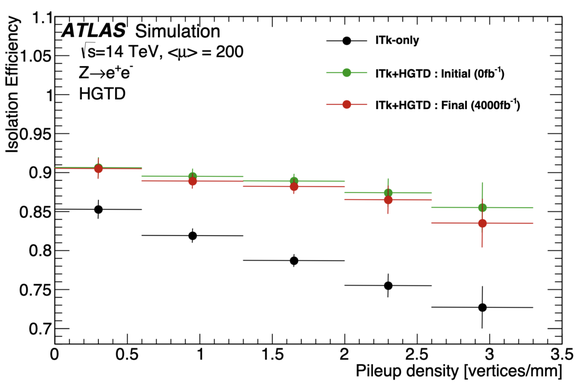




Physics prospects

- Pile-up rejection and maintained as the ring will be replaced every 1000 fb^{-1}
- Improvements on lepton isolation $\Longrightarrow$ W mass precision measurements
- b-tagging performance enhancement by rejecting pileup tracks



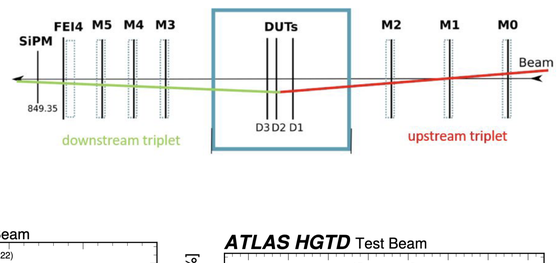


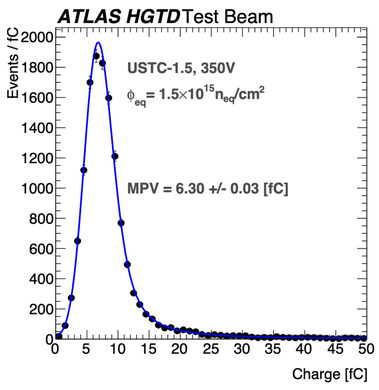
HGTD will act as a luminometer $\Longrightarrow$ luminosity uncertainties reduction which would benefit most of the precision measurement analyses

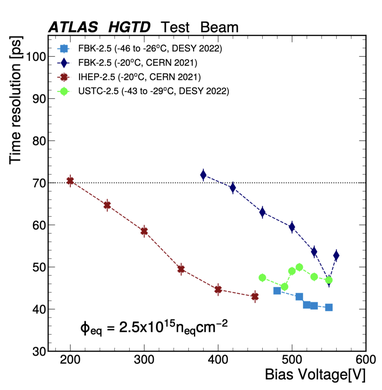
Sensor performances

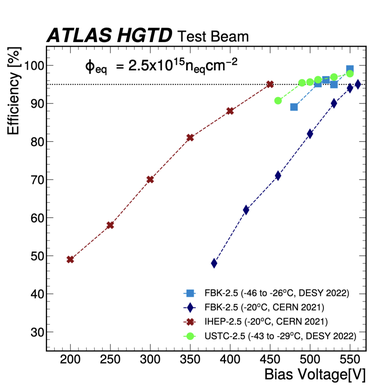
Several beam tests performed at DESY and CERN to assess the performance of sensors focusing on carbon-enriched LGADs

- **Time resolution**: measured with a time reference device $\sigma_{i,j} = \sigma_i \oplus \sigma_j < 50$ ps (well below requirement < 70 ps)
- **Collected charge**: Maintain a minimum of 4 fC needed by ASIC
- **Efficiency**: $> 95\%$ for track with charge > 2 fC



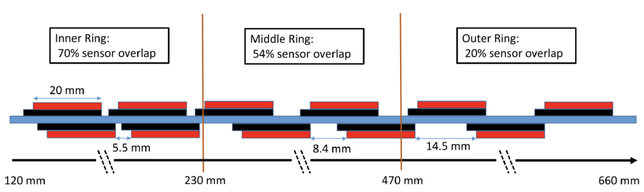


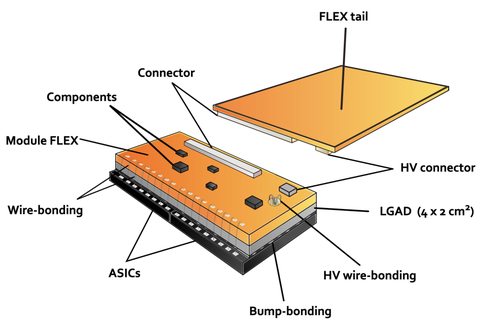




Detector module

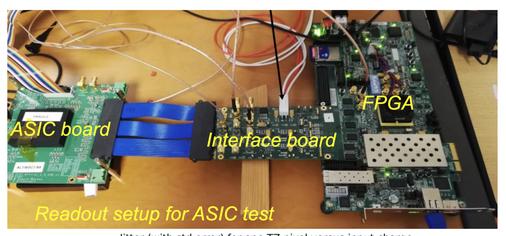
- **HGTD module** consists of 2 LGAD sensors + 2 ALTIROC ASICs bump-bonded and glued to a module flex
- HGTD will have 8032 modules $\Longrightarrow$ 3.6 M channels
- Modules mounted on cooling plate, connected to the surrounding Peripheral Electronics Boards via FLEX cables

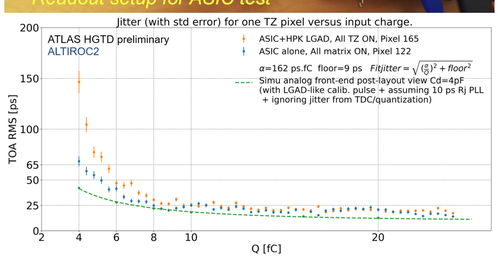


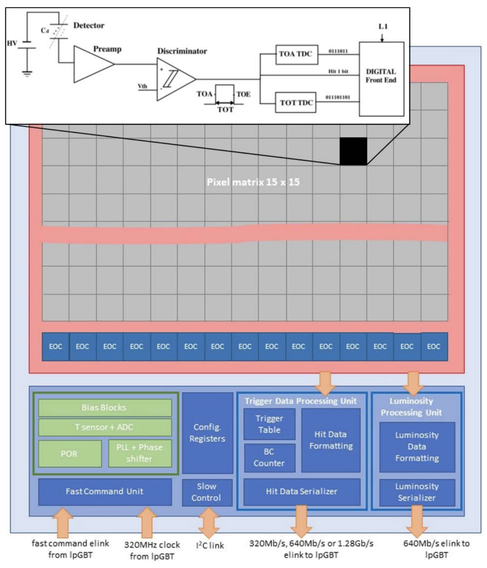


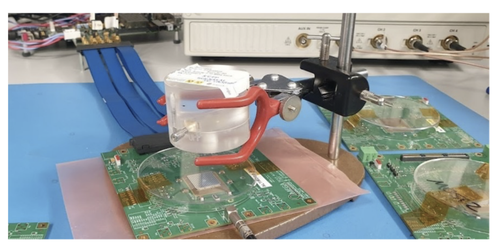
ATLAS LGAD Timing Integrated Readout Chip (ALTIROC)

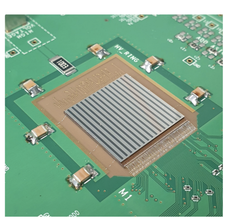
- Provides time-of-arrival (TOA) + time-over-threshold (TOT) data per channel
- Radiation hard + Jitter < 25 ps @ 10 fC/ < 65 ps @ 4 fC
- Integrated temperature measurement + calibration between LHC fills to maintain resolution @ system level
- Assess the performance of ALTIROC2 using dedicated PCB and interface board

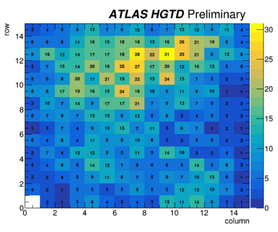








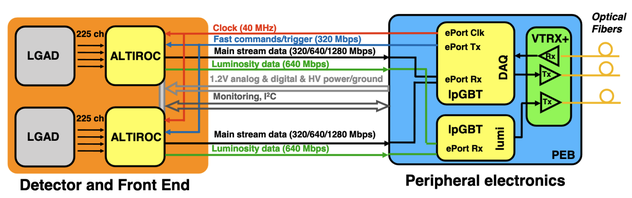


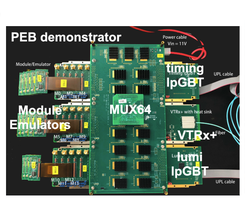


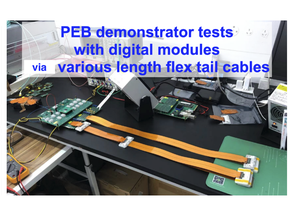
- Test a hybrid prototype (Sensor + ALTIROC)
- Use test pulses to ensure the functionality
- Tests with Sr90 source to validate bump-bonding connectivity

Peripheral Electronic Board (PEB)

- 48 PEBs located outside the active area (front- and back-side of the disks), connected via pigtails to outer-ring
- Radiation hard components: lpGBTs, DC-DC converters, VTRX+
- DC-DC converter bPOL12V - in depth investigated regarding space constraints, power efficiency
- Communication through lpGBTs with FELIX card
- Successfully dumped digital module data through FELIX



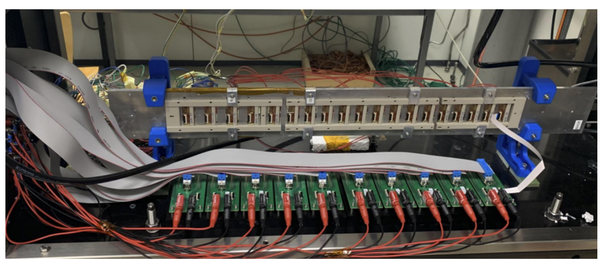


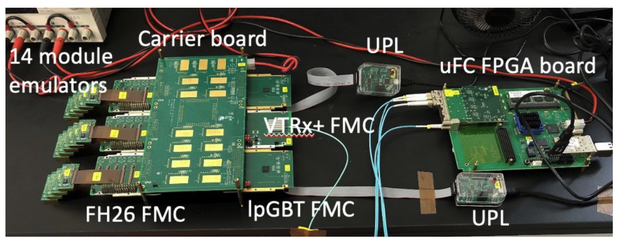


Demonstrator

Several demonstrator prototypes are being built to test different components of the system

- Heater demonstrator
  - Stave with 19 silicon heaters
  - Mounted on a cooling plate to verify CO_2 cooling capabilities as well as identify best thermal media between modules and cooling plate
- DAQ Modular PEB demonstrator
  - Up to 14 modules with two lpGBTs and one VTRx+
  - Timing and luminosity data reach the required benchmark bandwidth
  - Digital module





Ongoing preparation for full demonstrator with 55 full HGTD modules connected to prototype PEBs

Conclusion

- HGTD will significantly improve the physics performance in the forward region of ATLAS
- Significant progress has been made on LGAD sensors, readout chips and modules
- Exciting time ahead in the near future as HGTD is moving towards construction

References

[1] CERN-LHCC-2020-007, ATLAS-TDR-031 [2] 2023 JINST 18 P05005