Towards a novel silicon timing detector: ATLAS HGTD

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Currently, the Large Hadron Collider (LHC) is entering a long shutdown period (LS3), during which it will be upgraded to the High-Luminosity LHC (HL-LHC). The HL-LHC will deliver an unprecedented wealth of new data with a targeted total integrated luminosity of $3000\,\mathrm{fb}^{-1}$. The increase in luminosity is achieved through several hardware and technology upgrades, such as stronger focusing magnets. The increased luminosity also introduces new challenges for the LHC experiments.
To prepare the ATLAS experiment for the increased radiation levels and large pile-up, it is being upgraded in parallel with the LHC.
The ATLAS upgrades include, but are not limited to, trigger and DAQ upgrades, a full silicon Inner Tracker (ITk), and a novel silicon timing detector, the **High Granularity Timing Detector (HGTD)**.

The HGTD is a 4D hybrid pixel timing detector. In total, 8032 pixel detector modules are arranged in two instrumented double-sided layers mounted on two cooling disks. The layers are rotated by 15°. As shown in Fig. 1, the HGTD will be installed on the extended calorimeter barrels.
The HGTD comprises different pixel module designs for the various detector regions. According to their specific requirements and positions, multiple modules are glued together to form so-called detector units. Multiple such units are arranged to form the wheels.
The HGTD has to meet strict spatial constraints, with a total thickness of less than 13 cm per disk.

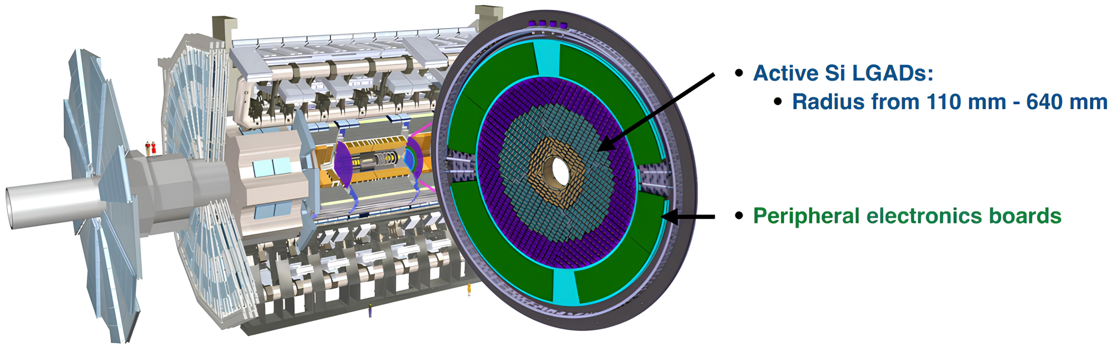

Abbildung 1: Schematic of the instrumented double-sided layers and their position within the ATLAS experiment.

The HGTD provides precise time measurements for particles in the forward region of ATLAS, covering $2.4 < |\eta| < 4.0$. It has a total active area of $6.3\,\mathrm{m}^2$ and is based on $1.3 \times 1.3\,\mathrm{mm}^2$ silicon pixels on $2 \times 4\,\mathrm{cm}^2$ sensors. The detector operates at $-30\,^\circ\mathrm{C}$ using a two-phase CO_2 cooling system. The sensors are designed to withstand radiation levels of up to $5.1 \times 10^{15}\,\mathrm{n_{eq}/cm^2}$ and $4.7\,\mathrm{MGy}$. The readout is performed by the CMOS-based ALTIROC ASIC, the ATLAS LGAD Timing Integrated Read-Out Chip. The HGTD aims to provide precise timing measurements with a resolution of 30–50 ps to distinguish closely spaced collision vertices. It enables an instantaneous and unbiased measurement of the luminosity. The precise timing information helps reject jets originating from pile-up interactions. Time information also improves lepton isolation by associating leptons with their production vertex.

The timing resolution is achieved using Low-Gain Avalanche Detectors (LGADs), which are silicon sensors with a highly doped gain layer. The gain layer creates a strong electric field of approximately $300\,\mathrm{kV/cm}$, causing controlled avalanche multiplication of charge carriers. LGADs typically provide an internal gain of about 10–30, which increases the signal-to-noise ratio. This internal gain enables precise particle timing measurements with a resolution of approximately $30 - 50\,\mathrm{ps}$.

The full HGTD detector integration will take place at CERN from 2027 to 2029 in the clean room in B180. During this project, I will contribute to testing the assembly procedure and commissioning on the surface using pre-production elements. The project will also involve testing the modules and detector units during the assembly procedure. A full quality-assurance method will be developed for use during the assembly on the surface. In addition, I will work on the final quality checks at operating temperature with CO_2 cooling.
To gain experience with the system, full system tests will be performed using pre-production elements from all parts of the HGTD detector. This includes testing the full electronics and readout chain, as well as developing testing scripts and quality-control criteria for this procedure.
The final element of the project will be the commissioning of the full HGTD detector within ATLAS and its integration with the trigger and data-acquisition system of the experiment. This is expected to begin with the installation of the first of the two HGTD vessels in the ATLAS cavern during LS3.