

8th Beam Telescopes and Test Beams Workshop



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A High-Granularity Timing Detector for the Phase-II upgrade of the ATLAS Calorimeter system: beam test results

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The expected increase of the particle flux at the high luminosity phase of the LHC (HL-LHC) with instantaneous luminosities up to $L \approx 7.5 \times 10^{34} \text{ cm}^{-2} \text{ s}^{-1}$ will have a severe impact on the ATLAS detector performance. The pile-up is expected to increase on average to 200 interactions per bunch crossing. The reconstruction and trigger performance for electrons, photons as well as jets and transverse missing energy will be severely degraded in the end-cap and forward region, where the liquid Argon based electromagnetic calorimeter has coarser granularity and the inner tracker has poorer momentum resolution compared to the central region. A High Granularity Timing Detector (HGTD) is proposed in front of the liquid Argon end-cap calorimeters for pile-up mitigation and for bunch per bunch luminosity measurements.

This detector should cover the pseudo-rapidity range from 2.4 to about 4.0. Two silicon sensors double sided layers are foreseen to provide a precision timing information for minimum ionizing particle with a time resolution better than 50 ps per hit (i.e. 30 ps per track) in order to assign the particle to the correct vertex. Each readout cell has a transverse size of $1.3 \times 1.3 \text{ mm}^2$ leading to a highly granular detector with about 3 millions of readout electronics channels. Low Gain Avalanche Detectors (LGAD) technology has been chosen as it provides an internal gain good enough to reach large signal over noise ratio needed for excellent time resolution. A 4 period test-beam campaign in 2019 has been conducted at the DESY T22 beamline. Proton and neutron irradiated LGAD prototypes for the HGTD were tested from different technologies and manufacturers. Gallium, boron and carbon implanted $1 \times 1 \text{ mm}^2$ diodes and 2×2 arrays are compared for achieved timing performance, post-irradiation efficiency and uniformity at fluences up to $3 \times 10^{15} \text{ neq/cm}^2$. A time resolution of $< 50 \text{ ps}$ is observed in most cases, while integrating timing information to the EUDET system allows for a surface resolution of less than $50 \mu\text{m}$. 2-dimensional timing maps are exploited to establish noise occupancy levels and lateral field expansion at high fluences. The triggering architecture, picosecond synchronization scheme and analysis logic will also be presented as well as application-specific electronics and components.

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