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High-Rate Properties of Drift Tube Chambers for HL-LHC

The Monitored Drift Tube (MDT) chambers of the ATLAS experiment provide muon track reconstruction with a spatial resolution of about 35 µm and efficiency of almost 100% up to the maximum expected background rates at nominal LHC luminosity. For much higher background rates, as they are anticipated for LHC luminosity upgrades (HL-LHC), sMDT chambers with 15 mm tube diameter, which is half the diameter of the MDT chambers, have been developed. Compared to MDT chambers, they suffer much less from space charge caused by background hits and provide more redundancy due to the higher packing density of the drift tubes. In the existing MDT front-end electronics, bipolar shaping is used to eliminate the long signal tail caused by the slowly drifting ions and to guarantee baseline stability at high rates. The undershoot of the bipolar shaping causes, however, signal pile-up of fast successive pulses. The impact of signal pile-up is equivalent to a higher discriminator threshold for the subsequent pulse and implies additional time slewing and degradation of the detection efficiency. A technical solution consists in an active baseline restorer. We present measurements of (s)MDT chambers under irradiation with the existing front-end electronics and with an alternative front-end chip featuring active baseline restoration and compare the performance. We also report on the development of a new version of the MDT front-end chip as a replacement for the existing one and with the option of a baseline restorer for future electronics upgrades.

Summary

The ATLAS Monitored Drift Tube (MDT) chambers consist of aluminum tubes with 30 mm diameter and a central sense wire with 50 µm diameter set to a potential of +3080 V. The drift tubes are operated with Ar/CO_2 (93/7) gas mixture at 3 bar absolute pressure, resulting in a gas amplification of 2×10^4. The maximum electron drift time for hits near the tube wall is approximately 700 ns, ions can drift for several milliseconds causing long tails in the corresponding pulse shapes.

The existing ASD (Amplifier-Shaper-Discriminator) front-end chip has been optimized for typical pulses of muon and background hits at rates of up to a few hundred kHz per channel. Bipolar shaping is used for baseline restoration, compensating partly the long ion tails. The typical time needed to arrive at the baseline after a hit is approximately 500 ns which is sufficient for the referred rates and the typical lengths of the MDT pulse trains.

For the high luminosity upgrade of the LHC (HL-LHC), new drift tube chambers (sMDT) with reduced tube diameter - 15 mm instead of 30 mm - have been developed. They are operated with the same gas mixture and amplification as the 30 mm MDTs, leading to an operating voltage of 2730 V. As the drift velocity in the gas decreases with increasing drift radii, the maximum drift time is reduced from about 700 to 185 ns, resulting in considerably shorter pulse trains. This allows to operate the sMDT chambers at much higher rates with high efficiency.

Measurements of sMDT chambers equipped with the existing ASD chip under photon and proton irradiation at rates of up to 1.5 MHz per channel show a considerable gain in the 3σ efficiency of sMDTs compared to MDTs with 30 mm diameter at high background rates. The improvement is limited, however, by the undershoot of the bipolar shaping and the long baseline restoration time of approximately 500 ns, respectively. Simulations suggest that reducing the baseline restoration time has the potential to improve the efficiency at rates of 1.5 MHz per channel from ˜61% to ˜76%. With increasing rates the yield is even higher.

A possible approach for faster baseline restoration has been implemented in the front-end chip of the ATLAS Transition Radiation Tracker (TRT), the ASDBLR chip, with active baseline restorer (BLR). We present measurements and simulations of such a chip with active baseline restoration on sMDT and MDT chambers and evaluate the possible improvement on the efficiency and spatial resolution. A new version of the ASD chip is in development as a replacement for the existing one, with the option of a baseline restorer for future electronics upgrades. First simulation results with the new ADC chip will be shown.

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Track Classification: Sensors: 1c) Gaseous Detectors