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Development of New Front-end Electronics for the Upgrade of the ATLAS Muon Drift Tube Chambers at High LHC Luminosity

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New ATLAS Monitored Drift Tube (MDT) chambers with reduced tube diameter (sMDT) - 15 mm instead of 30 mm - have been developed for LHC luminosity upgrades. The shorter lengths of the pulse trains due to the smaller tube diameter allow to operate the sMDTs at much higher rates, however the gain in efficiency is limited by the shaping scheme of the current ASD (Amplifier-Shaper-Discriminator) chip. We present measurements and simulations with alternative shaping using active baseline restoration (BLR), evaluate the possible improvement in efficiency, and report on the design of a new front-end chip implementing this feature (BLR).

Summary

We report on the development of a new front-end chip for the Monitored Drift Tube (MDT) chambers of the ATLAS muon spectrometer. This chambers consist of aluminum tubes with 30 mm diameter and a central sense wire with 50 μm diameter which is set to a potential of +3080 V. The drift tubes are operated with Ar/CO_2 (93/7) gas mixture at 3 bar, resulting in a gas amplification of 2×10^4. The maximum electron drift time for hits near the tube wall is ~700 ns, ions can drift for several ms and cause long tails in the pulses.

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 fully sufficient for the referred rates and the typical MDT pulse lengths.

For high luminosity upgrades of the 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 the slightly lower operating voltage of 2730 V. As the drift velocity in the gas mixture used decreases with increasing drift radii, the maximum drift time is reduced from ~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 current MDT ASD chip under γ and proton irradiation rates of up to 1.5 MHz per channel show the efficiency gain at high background rates. The improvement is limited, however, by the undershoot of the bipolar shaping and the long baseline restoration time of 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 further from ~61% to ~76%.

A possible approach for faster baseline restoration has already been implemented in the front-end chip of the ATLAS Transition Radiation Tracker (TRT), the ASDBLR chip, with active baseline restorer (BLR). We present simulations and measurements of such a chip with active baseline restoration on sMDT chambers and evaluate the possible improvement on the efficiency. Furthermore, we report on the development of a new front-end chip in IBM 130 nm CMOS technology as a replacement for the current MDT ASD which will be needed in the course of ATLAS MDT chamber and trigger upgrades. Active baseline restoration is planned to be be implemented in this new chip as an optional feature, especially for high rate operation of sMDT chambers.

Primary authors: KROHA, Hubert (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D); KORTNER, Oliver (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D); SCHWEGLER, Philipp (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D); RICHTER, Robert (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D); NOWAK, Sebastian (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D); Mr OTT, Sebastian (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D)

Co-authors: WEBER, Bradley Michael (Max-Planck-Institut fuer Physik-Max-Planck-Gesellschaft (MPG)); Mr FINK, David (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D); FRAS, Markus (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D); Mr ABOVYAN, Sergey (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D); Mr DANIELYAN, Varuzhan (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D)

Presenter: SCHWEGLER, Philipp (Max-Planck-Institut fuer Physik (Werner-Heisenberg-Institut) (D)

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