A New Octal Amplifier Shaper Discriminator Chip for the ATLAS MDT Chambers at HL-LHC

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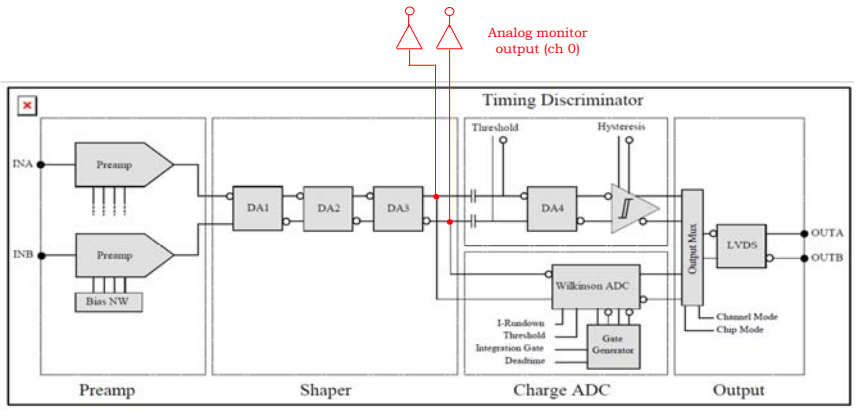
The task

For the luminosity upgrade of the LHC (2025), the ATLAS Muon Spectrometer needs to be prepared for the higher data rates due to background γ radiation by increasing the bandwidth of the readout. In addition, unlike in the past, the data recorded in the MDT drift tubes will be used to sharpen the p_T selection of the the first-level muon trigger and must be available to the trigger processors after a latency of 10 μs.

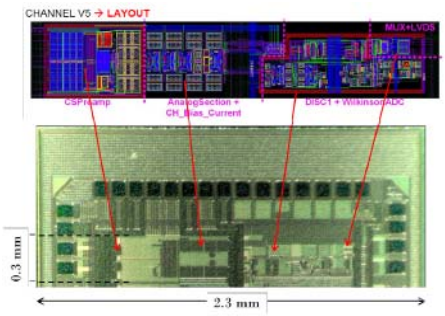
As a consequence, the complete readout electronics of the 1050 Muon Drift Tube (MDT) tracking chambers needs to be replaced. For this purpose a new Amplifier-Shaper-Discriminator (ASD) chip in modern radiation hard technology had to be designed. It is now ready for mass production of 60000 chips.

18 prototype chips tested. High uniformity of channel performance, much improved w.r.t. present chip.

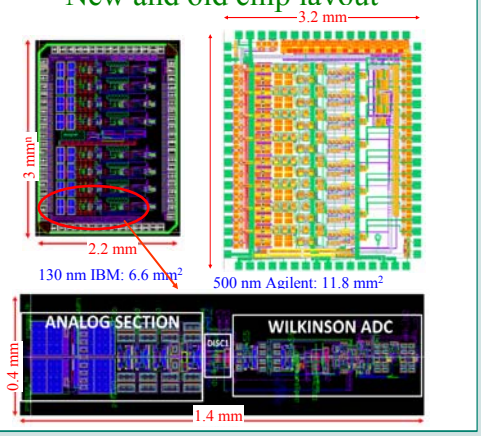
Functional diagram of the ASD using bipolar shaping



Design of a new ASD chip in 130 nm Global Founderies (former IBM) CMOS technology

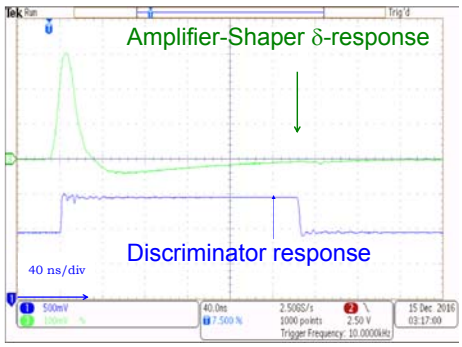


New and old chip layout

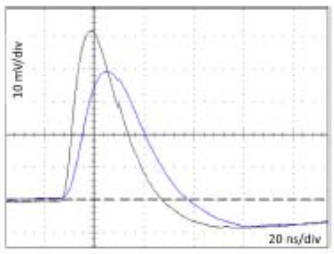


Signal shape

No feedback from signal to analog part.
Prevented by isolation of both in the substrate.

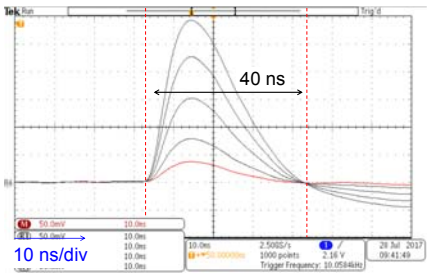


Signal rise time



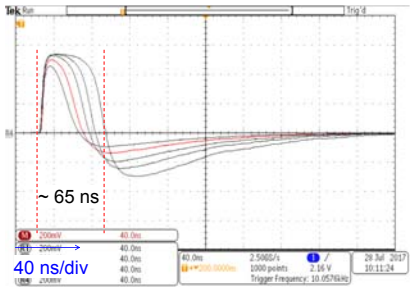
Signal peaking time of 12 ns **without** capacitive load as required (**with 60 pF** capacitive load 15 ns.)
Typical capacitance load of ATLAS MDTs 30 pF.
The gain of the new chip is increased by a **factor 2.**

Dynamic range



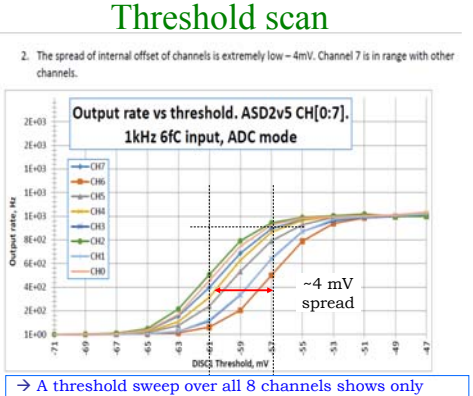
Response for 5,10,20, 30 and 40 fC input charge in linear range.

Pulse shape for input overload



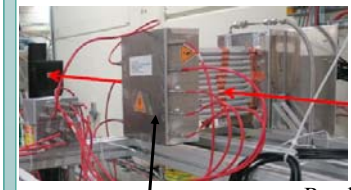
Response for 100, 200, 500, 1000, 2000 fC input charge → Negligible increase of zero-crossing time w.r.t. linear range

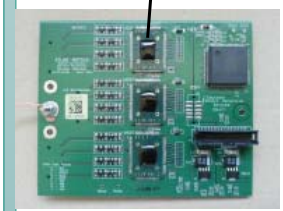
Threshold scan



→ A threshold sweep over all 8 channels shows only 4 mV variation.
→ All 8 channels very close to each other

Test on a MDT chamber

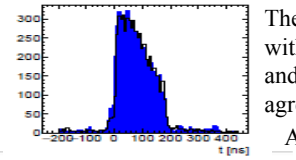


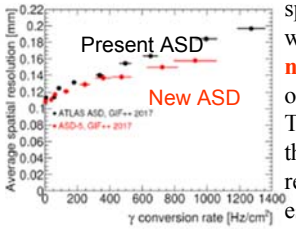


15 mm ∅ drift tube detector in a muon beam and under high γ irradiation at CERN.
Readout board with 3 new ASD chips and a TDC chip.

Survives X-ray irradiation of at least 1 MRad, 100 x requirement

Beam test results





The drift time spectra with the **present ASD** and with the **new ASD** agree very well.

Average drift tube spatial resolution with **present** and **new ASD** as a fct. of the γ count rate. The higher gain of the new ASD reduces time-slewing esp. at high γ rates.

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