Study of Baseline Restoration Circuits for the Readout of Drift Tube Chambers at High Counting Rates

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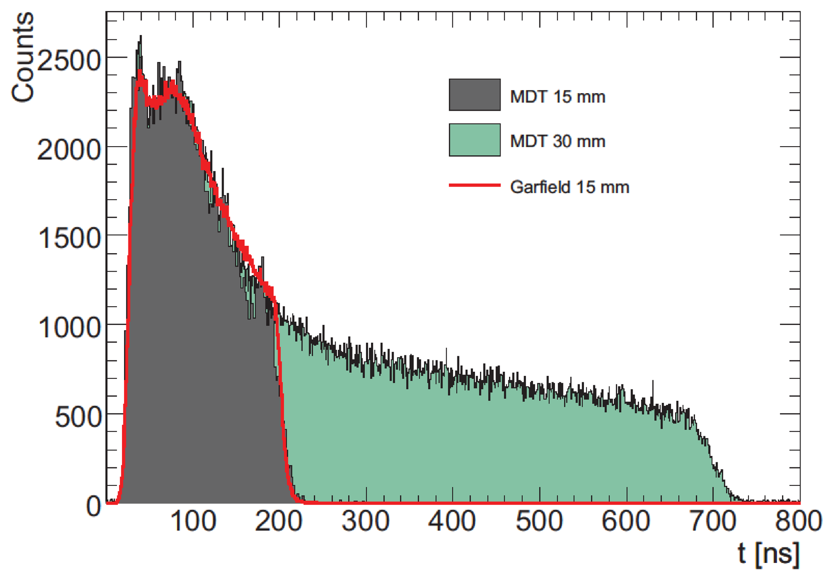
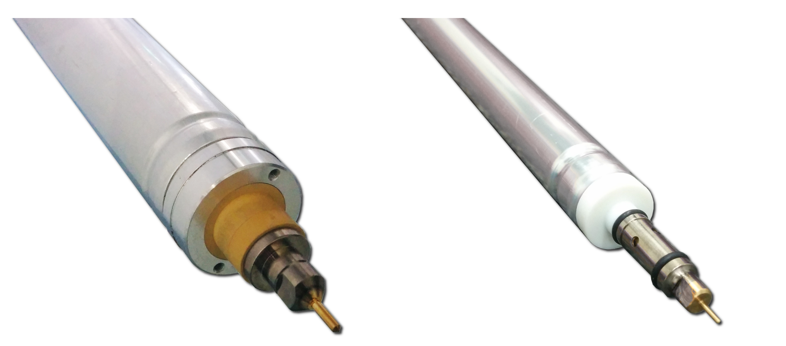
Small Diameter Monitored Drift Tubes (sMDT) for ATLAS



Drift time spectra: Reduction of the diameter from 30 mm to 15 mm reduces the max. drift time from 700 ns to 180 ns.



⌀30 mm MDT ⌀15 mm sMDT

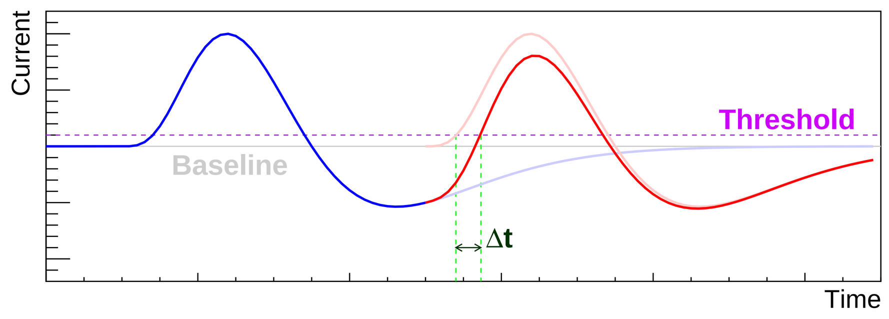
MDT chambers: Drift tube detectors with 30 mm tube diameter account for the majority of precision tracking chambers in the ATLAS muon spectrometer.

sMDT chambers:

- Rate capability increased by tube diamter reduction from 30 mm to 15 mm.
- Limited now by electronics signal pile up.

Limitation of the Current Front End Electronics

- Bipolar shaping used to guarantee baseline stability at high rates.
- Disadvantage: long undershoot after each signal.
- Effectively lower signal amplitude and increased dead time for subsequent pulses.



Analog Signal Pile-up

⇒ Additional time slewing and reduced efficiency (signal pile-up effects).

Use baseline restoration (BLR)

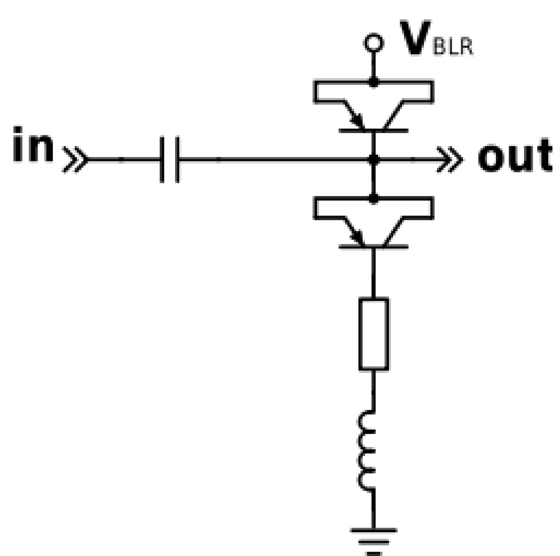
With baseline restoration also unipolar shaping can be used.

Discrete Electronics with Baseline Restoration Functionality

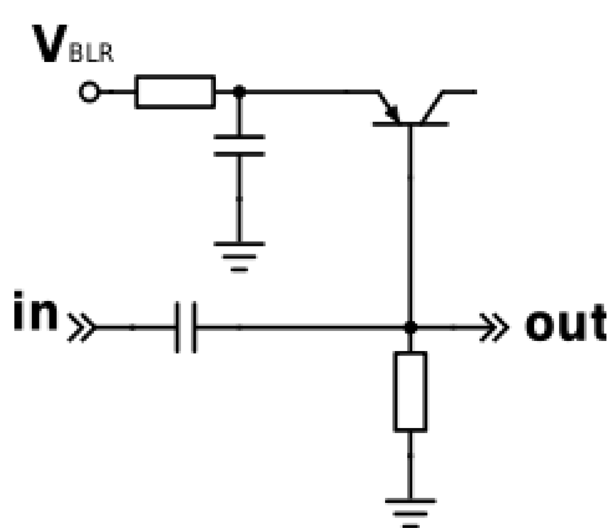
- High bandwidth ($B = 700$ MHz) transimpedance amplifier used as a preamp.
- Second bipolar or unipolar shaping stages
- optonal BLR circuit followed by a comparator to measure the signal threshold crossing time.
- 24-channel board for mounting on a chamaber to keep parasitic capacities small.

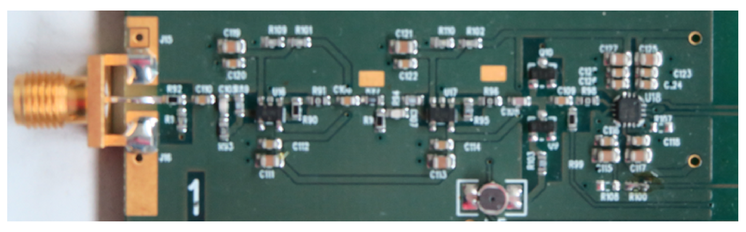
Baseline restorer circuits

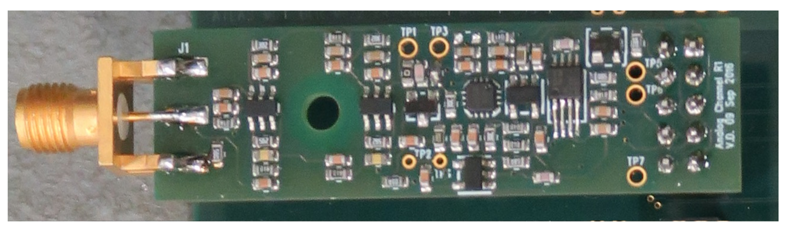
For **bipolar** shaping:



For **unipolar** shaping:







Principle:

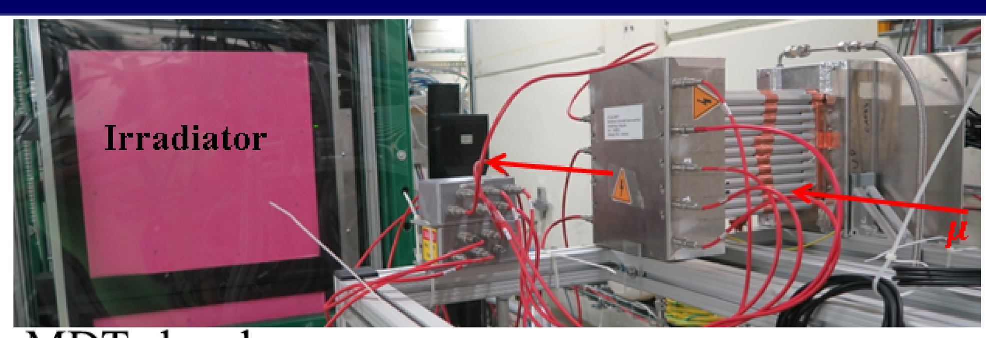
- Transistors slightly conducting at working point ($V_{BLR} > 0$).
- Transistors non-conducting for positive signal polarity ⇒ small signal change.
- Transistors conducting for negative signal polarity ⇒ signal drained to ground ⇒ Undershoot eliminated for bipolar shaping, positive tail eliminated for unipolar shaping.

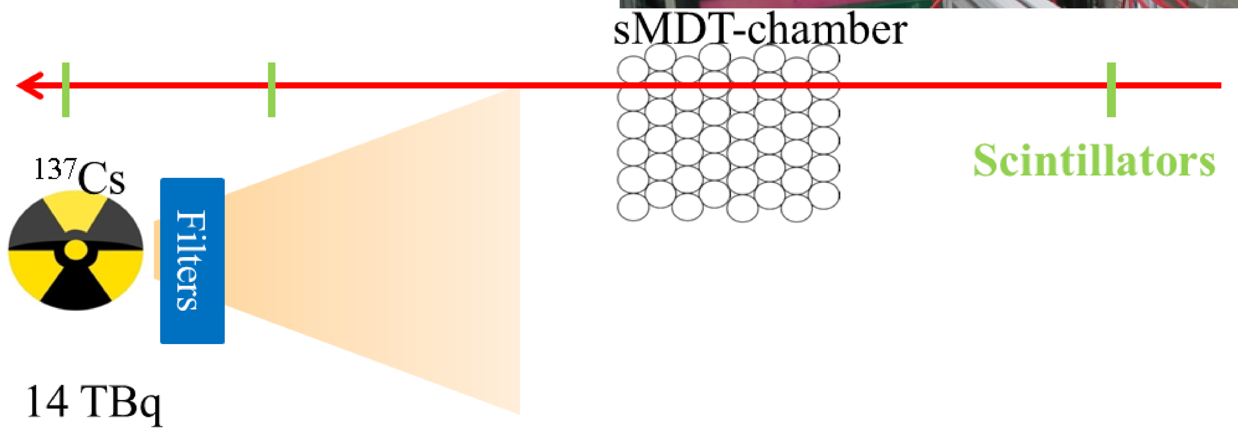
Performance Studies in the CERN Gamma Irradiation Facility (GIF)

- sMDT chamber (8 tube layers)
- μ-beam ($p = 150\frac{\text{GeV}}{c}$)

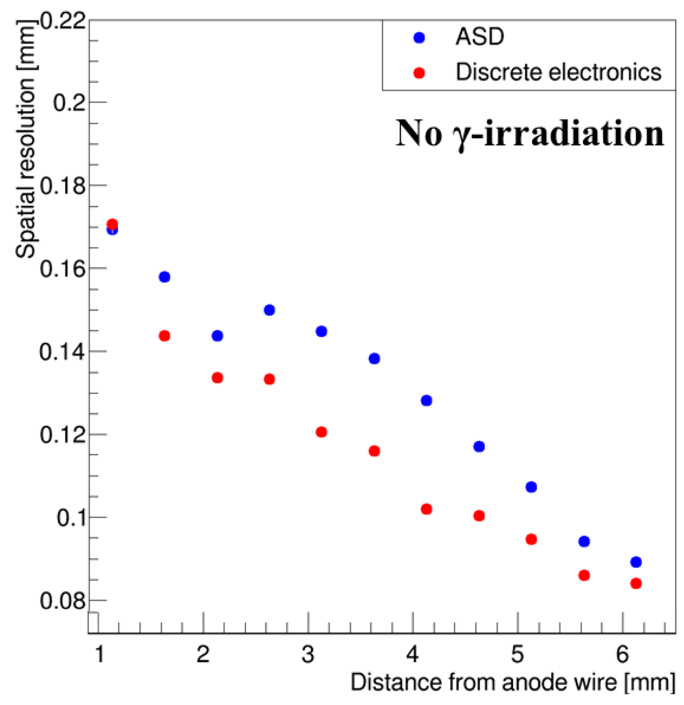
⇒ negligible scattering

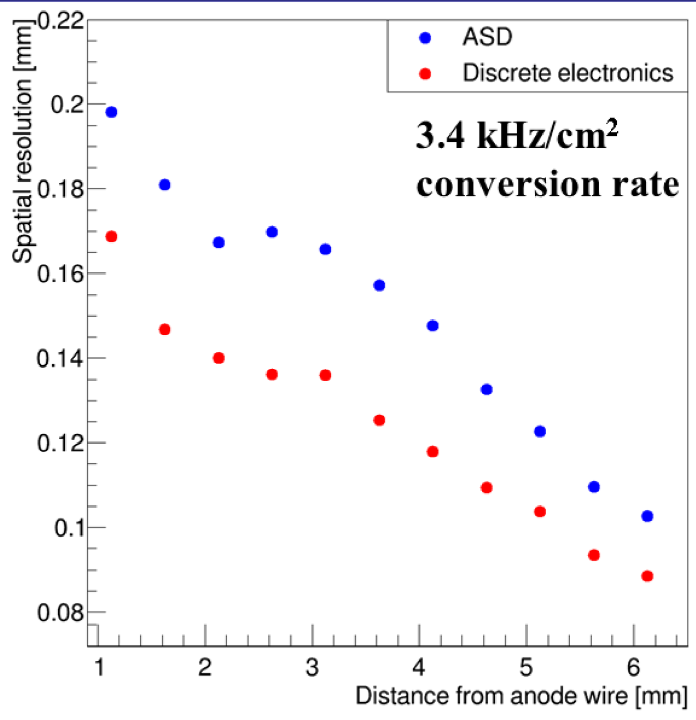
⇒ high statistics





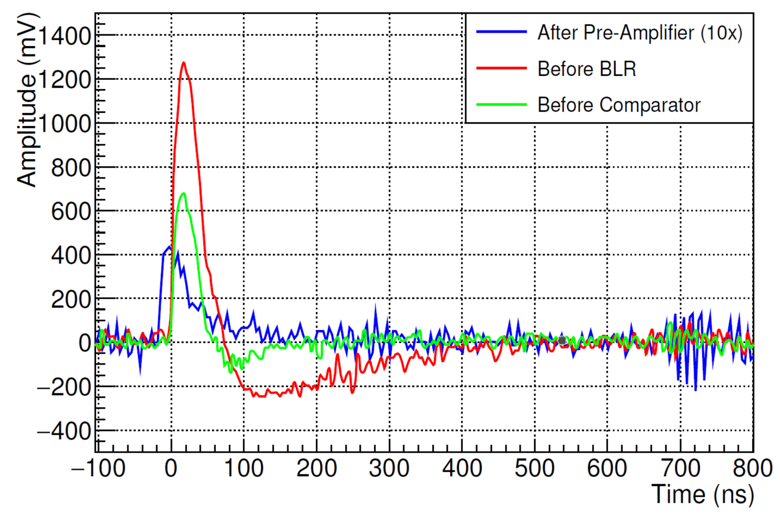
Muon Reconstruction Resolution



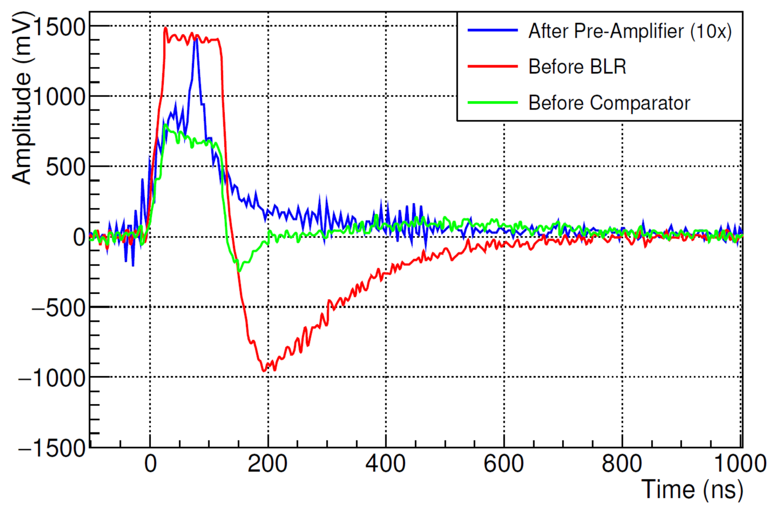


- significantly improved resolution with discrete electronics compared to currently used ASD due to higher bandwidth of the preamplifier
- resolution deterioration by the BLR due to signal reduction
- baseline fluctuations at high rates due to AC-coupling leading to fluctuations in the effective threshold and thereby resolution loss

Electronics Response to Drift Tube Pulses



Muon

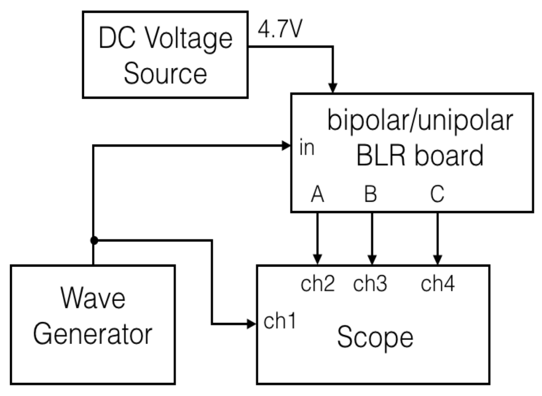


Gamma

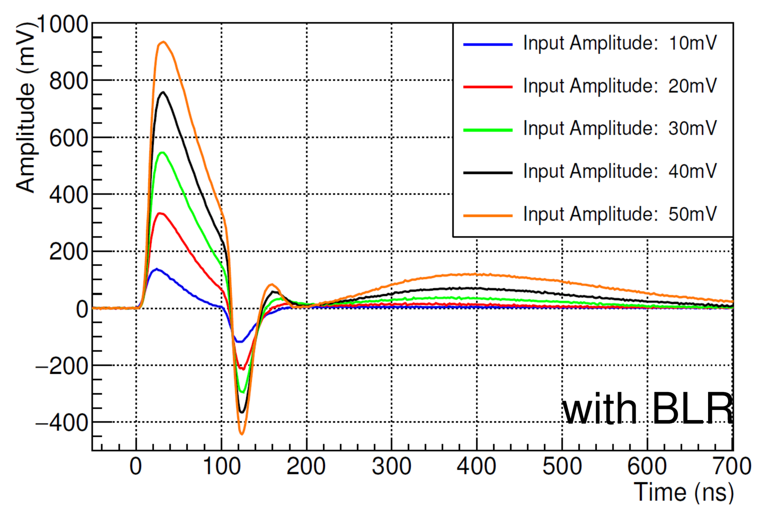
- operation of a sMDT chamber under adjustable γ-irradiation in a 150 GeV μ-beam in the new Gamma Irradiation Facility (GIF++) at CERN.
- Signal shapes of the same pulse after different electronics stages.
- BLR (green) eliminates the negative undershoot but also the positive signal amplitude for bipolar shaping.
- Another long overshoot with low amplitude is hard to avoid, especially for large input pulses from γ-irradiation.

Measurement Setup with Pulse Generator

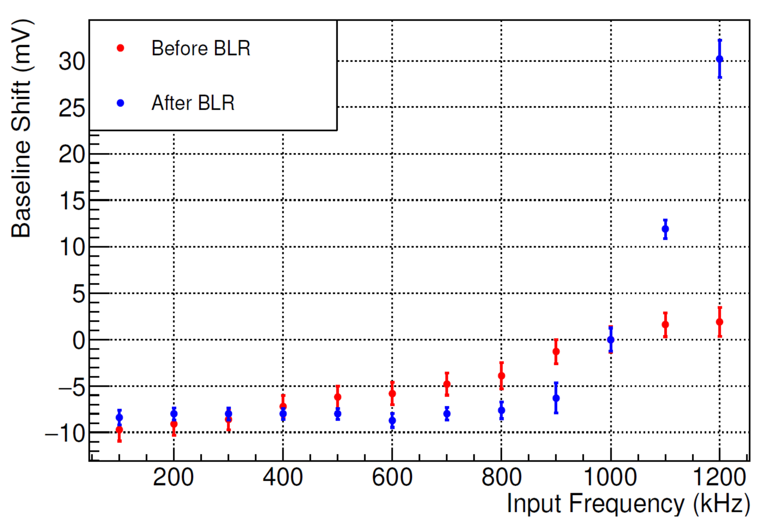
Measurement of the response of bipolar and unipolar shaping electronics to rectangular input pulses of varying amplitude (50 mV), width (100 ns) and pulse frequency.



Bipolar BLR Response

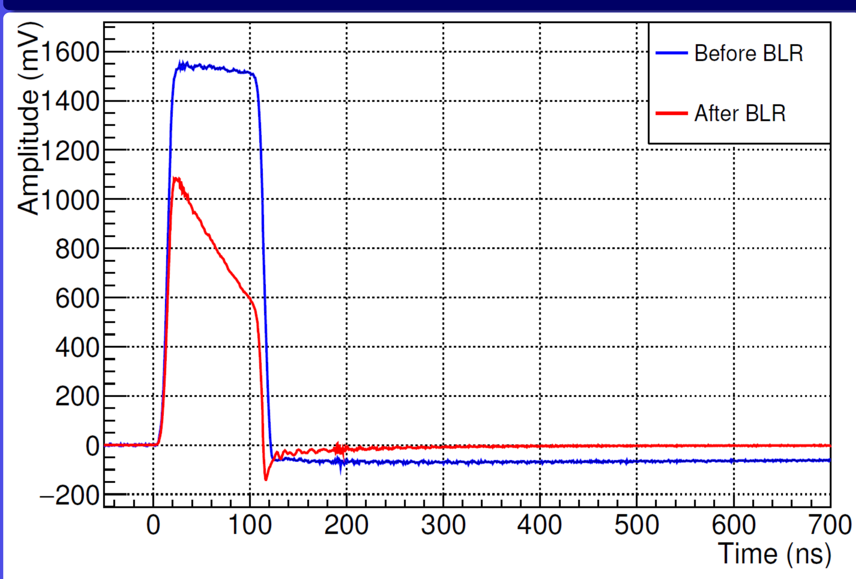


- Large bipolar undershoot effectivly eliminated up to high input signal amplitudes.
- A long seccondary overshoot remains and increases with input signal charge.

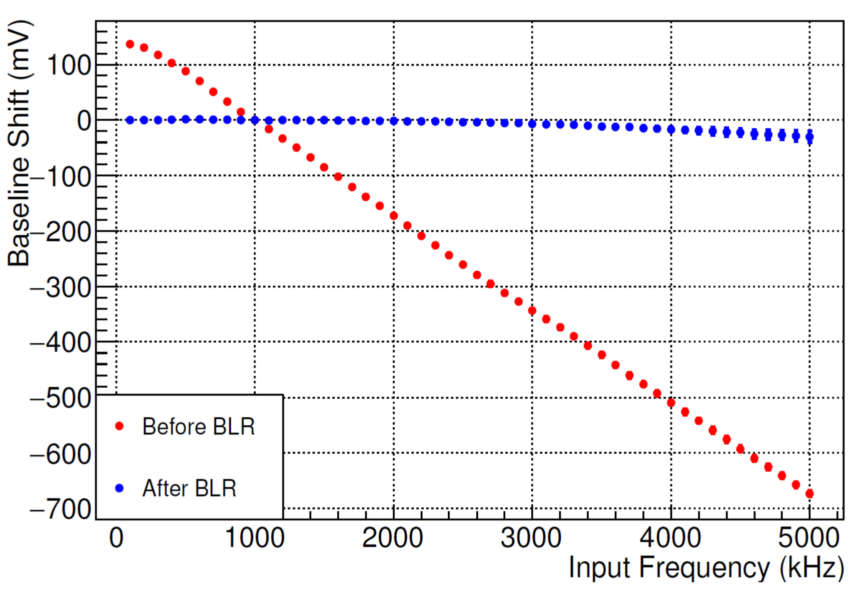


- Baseline shift with BLR increases with pulse frequency. suppressed eith DC coupling between BLR circuit and comparator up to high frequencies (< 1 MHz).

Unipolar BLR Response



- Unipolar shaping response: No secondary overshoot.



- Baseline kept stable up to high signal frequencies.
- Easier to maintain the baseline after the signal with unipolar shaping combined with BLR.

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