Optimization of the ATLAS (s)MDT readout electronics for high counting rates

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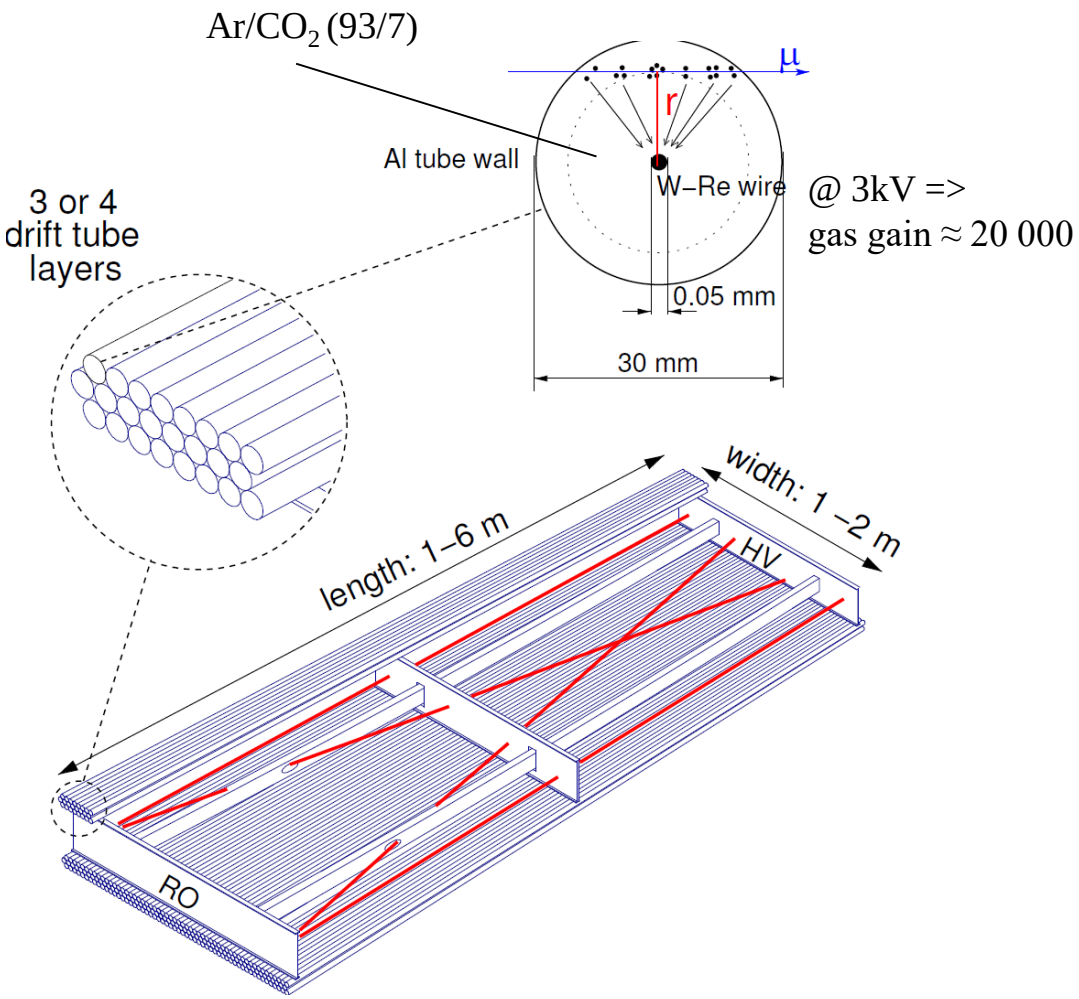
Korbinian Schmidt-Sommerfeld

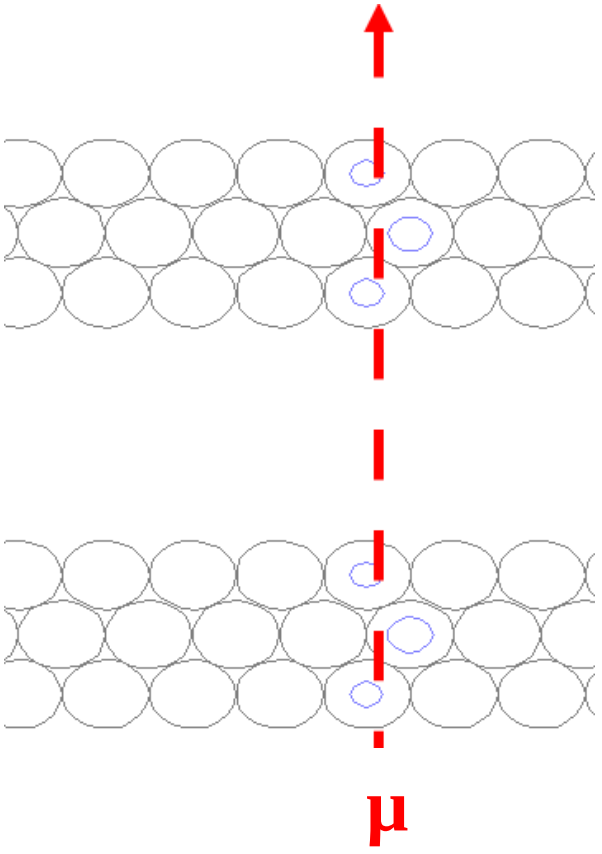
1. Drift Detectors in the ALTAS Muon Spectrometer
2. High Rate Effects and Detector Performance
3. Concepts and Performance of new Electronics

ATLAS Drift Tube Chambers

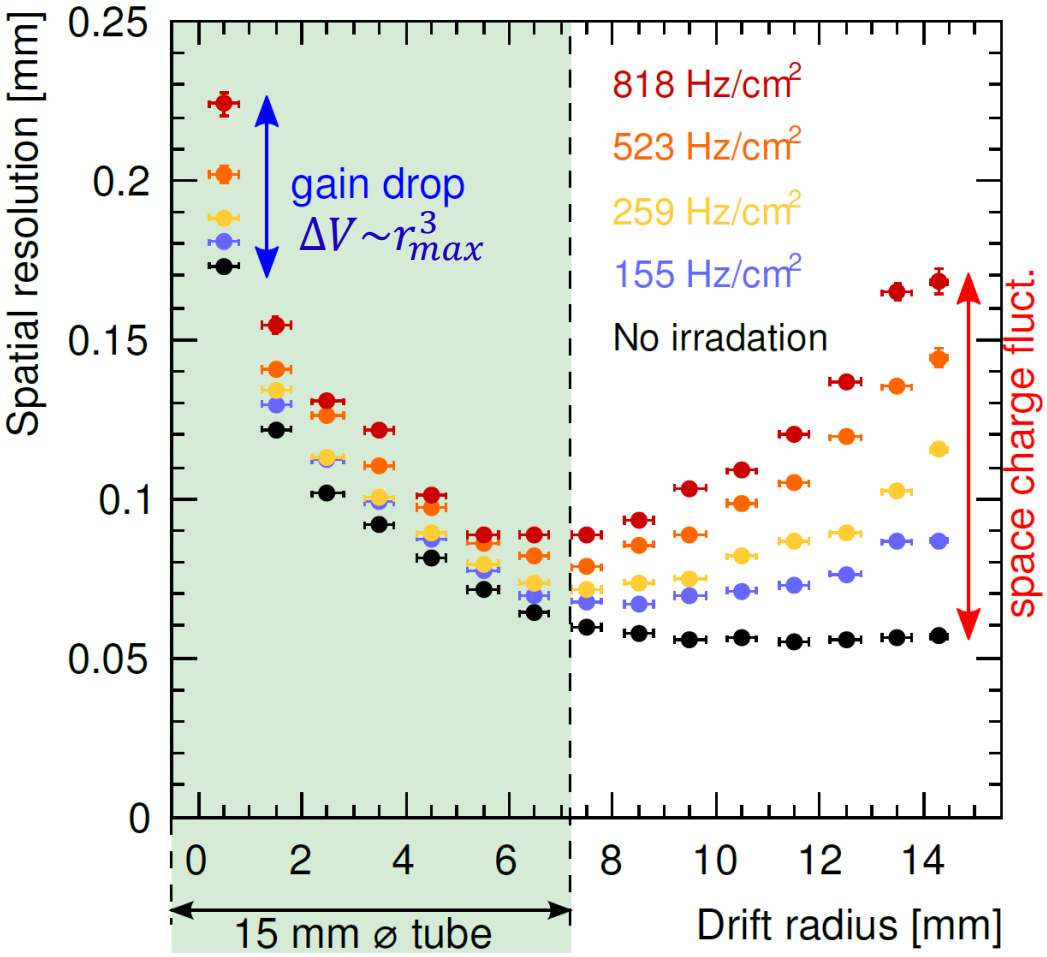
Two processes in the tubes: Drift and Amplification



Track reconstruction by combination of several drift measurements:



New small diameter **M**onitored **D**rift **T**ubes

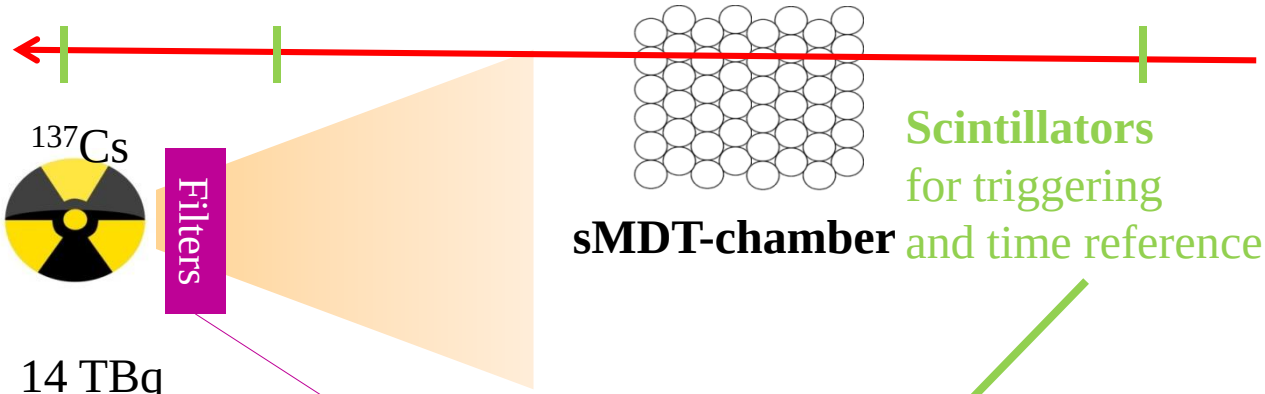


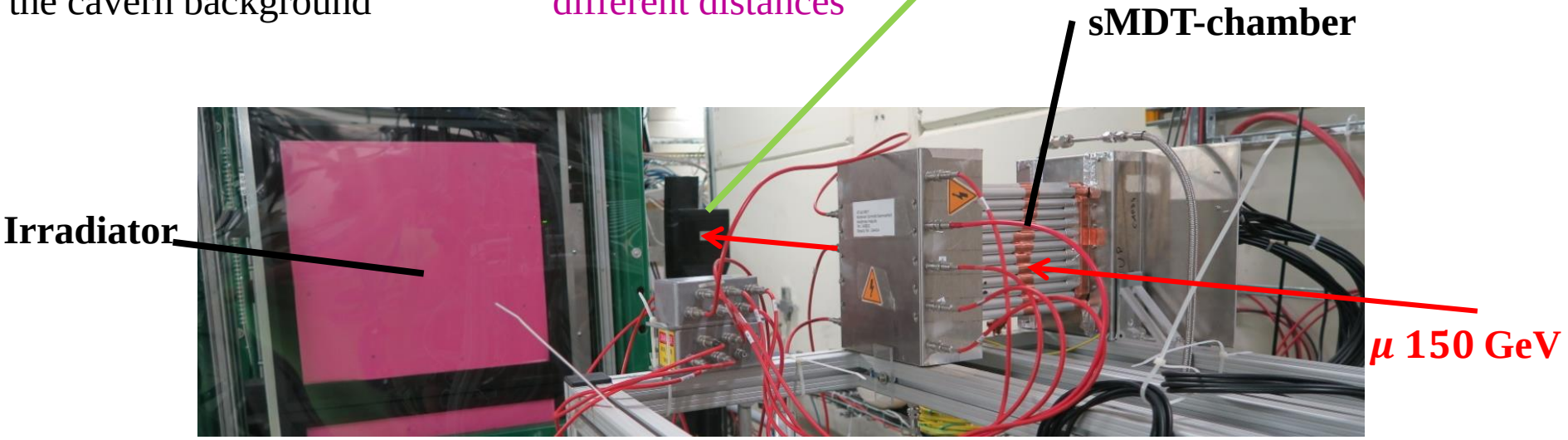
Tube diameter [mm]	30	15
Max. drift time [ns]	730	190
Avg. tube resolution (no irr.) [µm]	80	105
Typ. Chamber resolution [µm]	40	40

- Hit rate reduced by a factor 2
- Further occupancy reduction by $\frac{730\ \text{ns}}{190\ \text{ns}}$
- Gain drop reduced by $\left(\frac{14.6\ \text{mm}}{7.1\text{mm}}\right)^3$

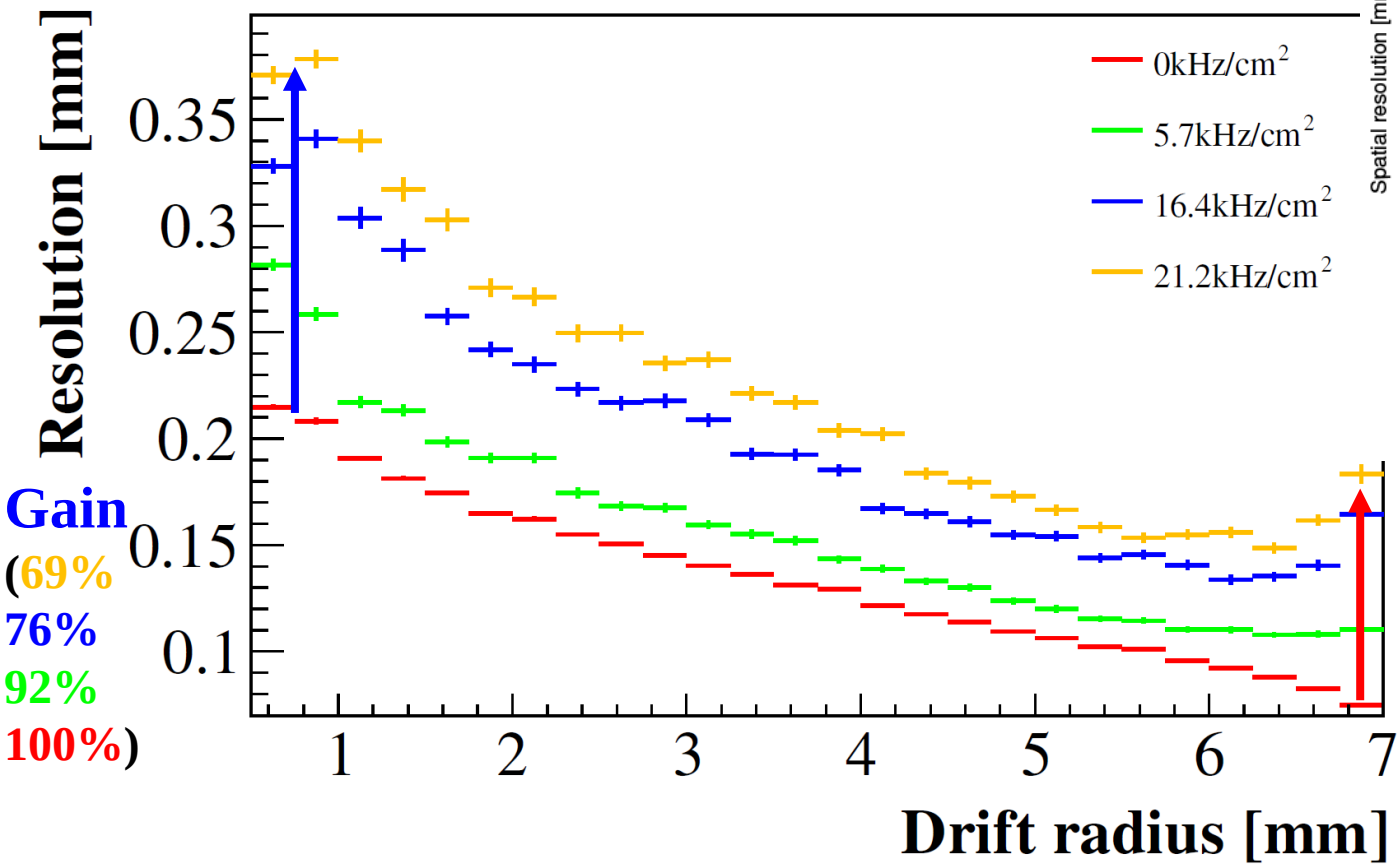
=> Rate capability increased by one order of magnitude.

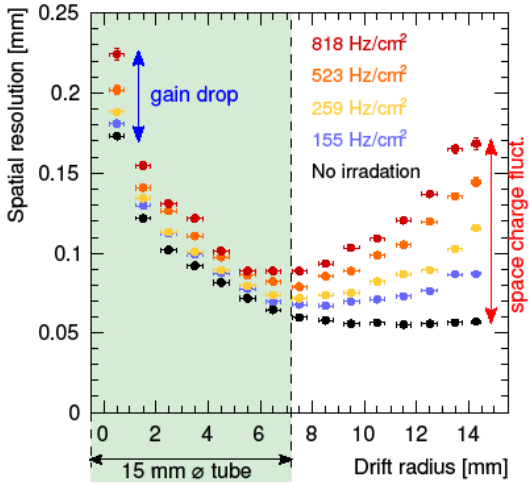
Setup at CERN's New γ-irradiation Facility





Measurement of the sMDT Resolution with the standard ATLAS electronics

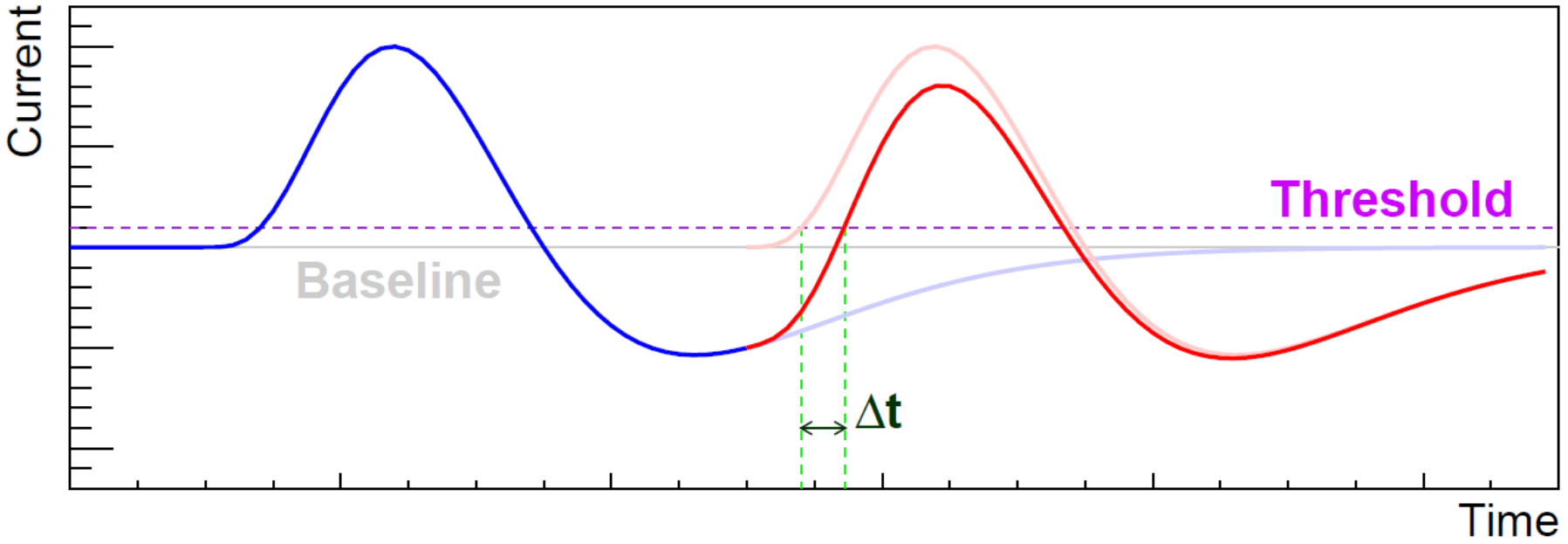




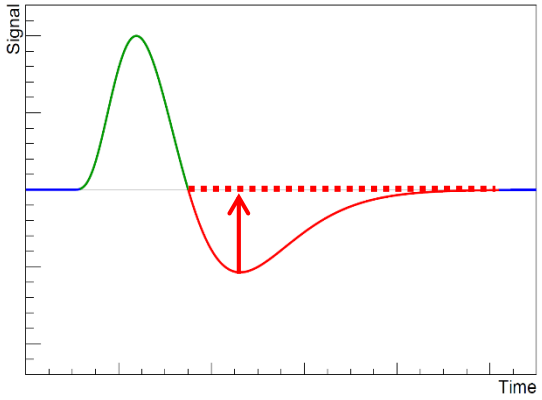
Space charge fluctuations

- Not irradiated case reproduces previous results.
- Gain drop effects significantly reduced.
- Only tiny space charge fluctuation effects even at very high (twice the expected HL-LHC) hit rates.

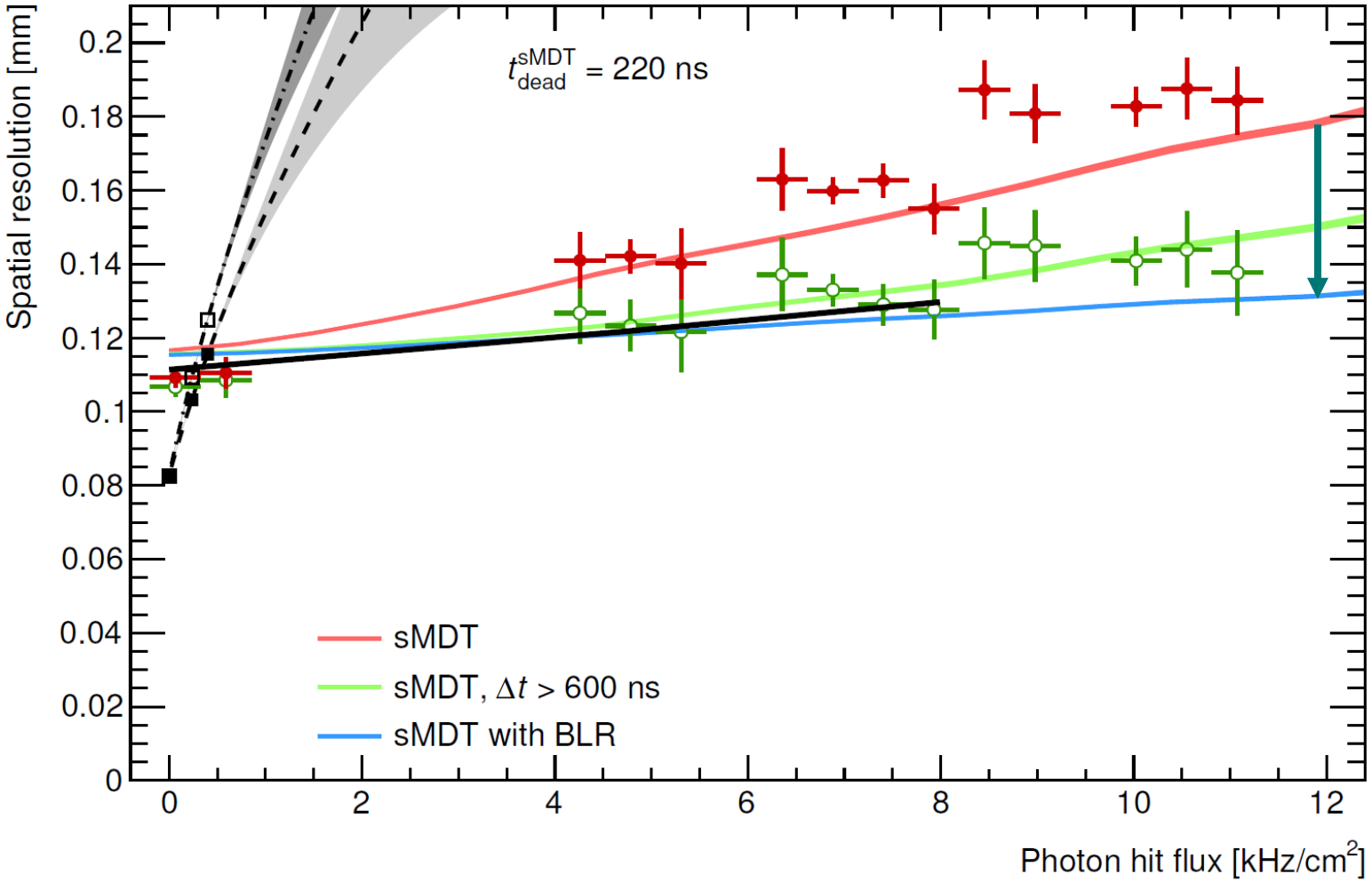
Signal Deterioration at High Rates



- Electronics with bipolar pulse shaping
- Pulse ~ 100 ns
- Undershoot ~ 400 ns due to bipolar pulse shaping
- Decreased spatial resolution in case of pileup
- Reducing the undershoot with active baseline restauration



Rate Dependence of the Resolution

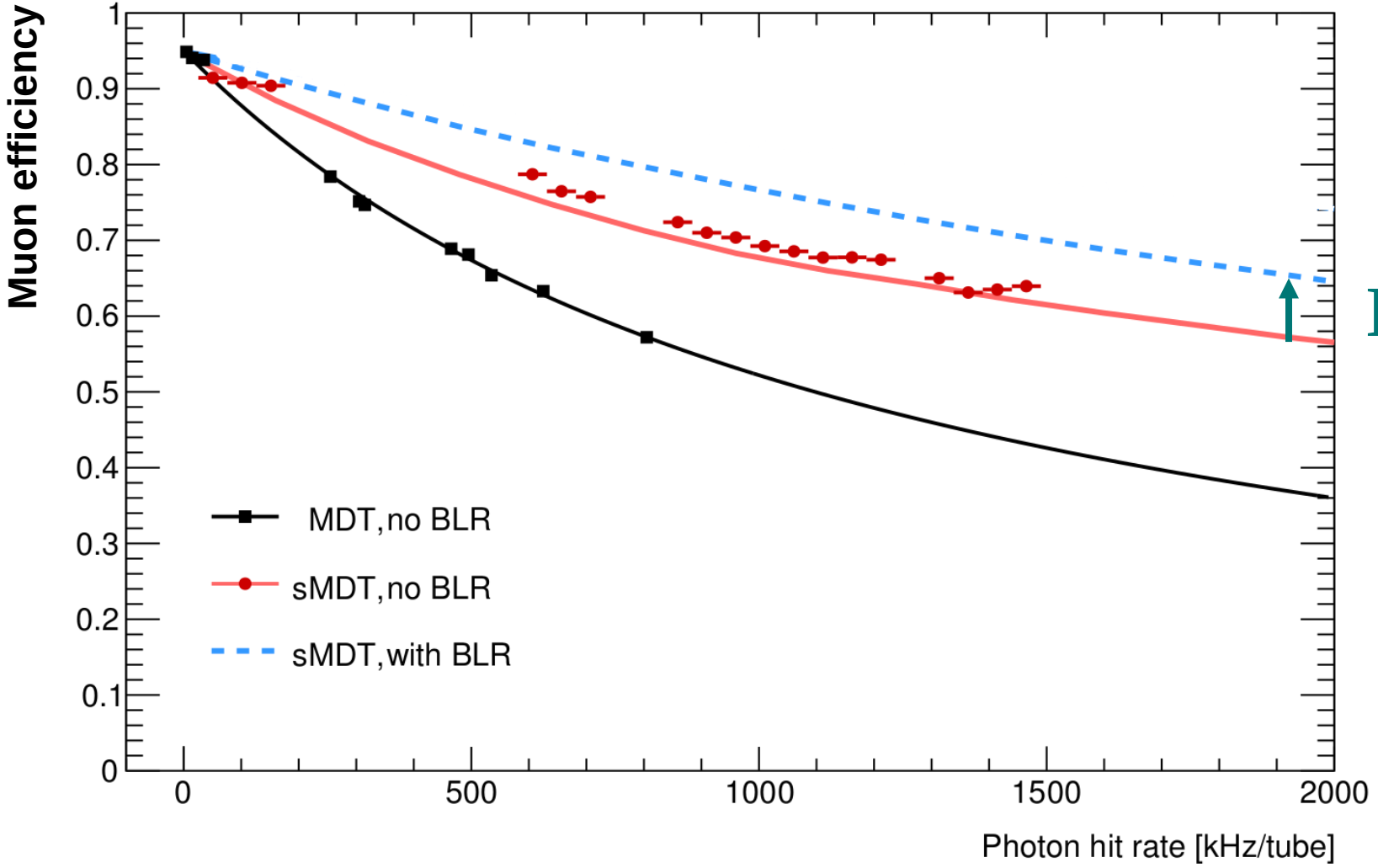


BLR

- Resolution deterioration strongly reduced with tube diameter.
- Increased electronic dead time not suitable.

=> High sMDT rates require optimized electronics.

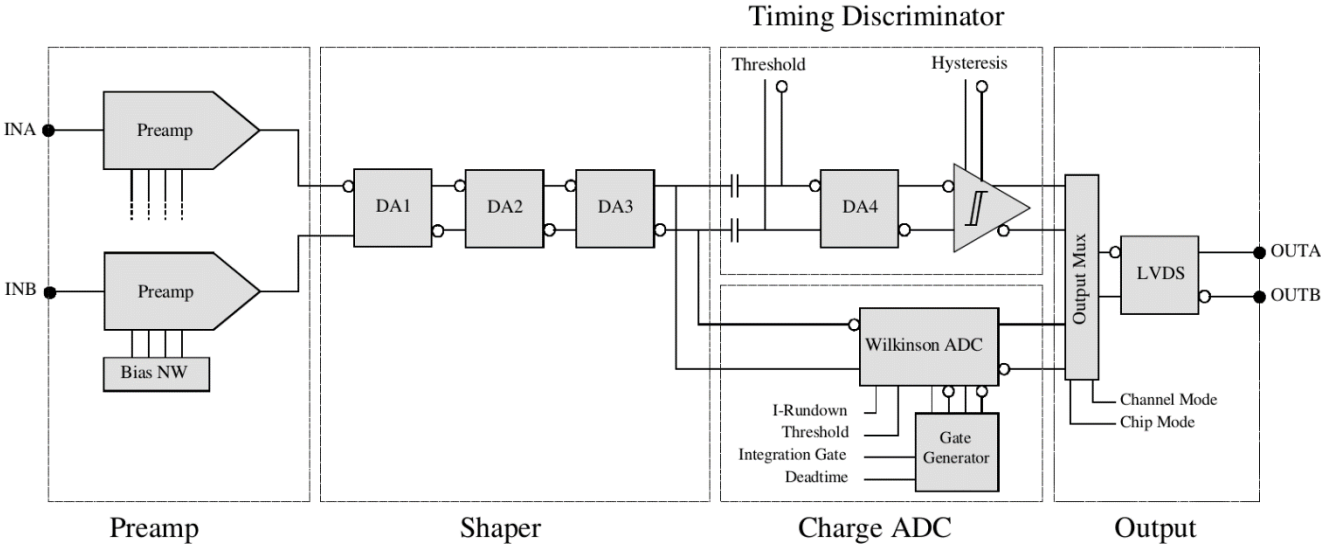
Rate Dependence of the μ-Efficiency



- Efficiency at high rates increases with decreasing dead time.
- Even short dead times leave room for optimization of the electronics.

Readout Electronics

Amplifier **S**haper **D**iscriminator
Application-**S**pecific **I**ntegrated **C**ircuit

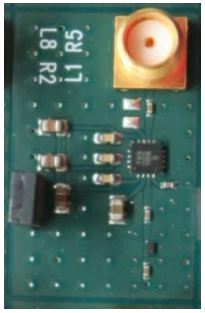


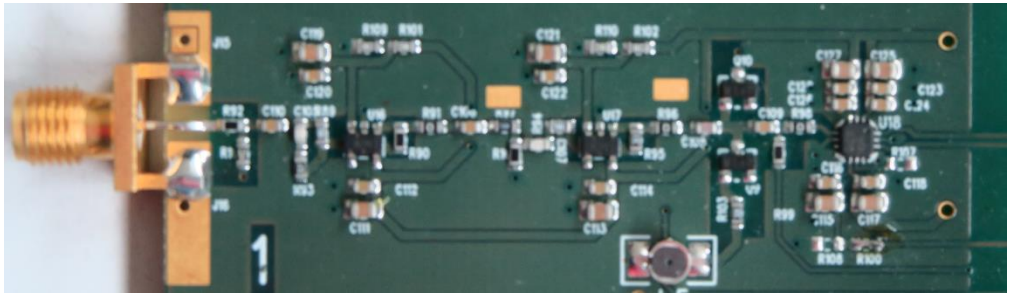
Changes to the ATLAS ASD not possible. Instead:

Resembling multichannel chips to readout a whole chamber with additional functionality.

PreAmp → Filter1 → Filter2 → BLR → Discriminator

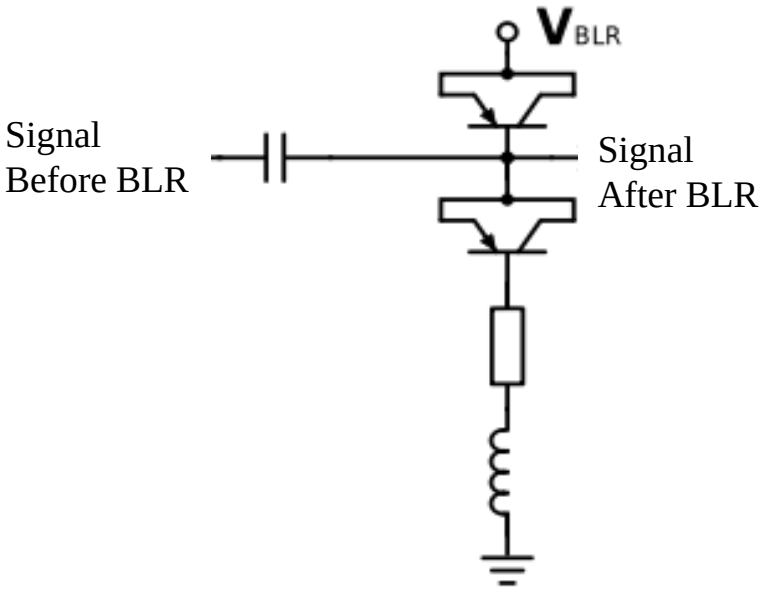
Discrete Electronics

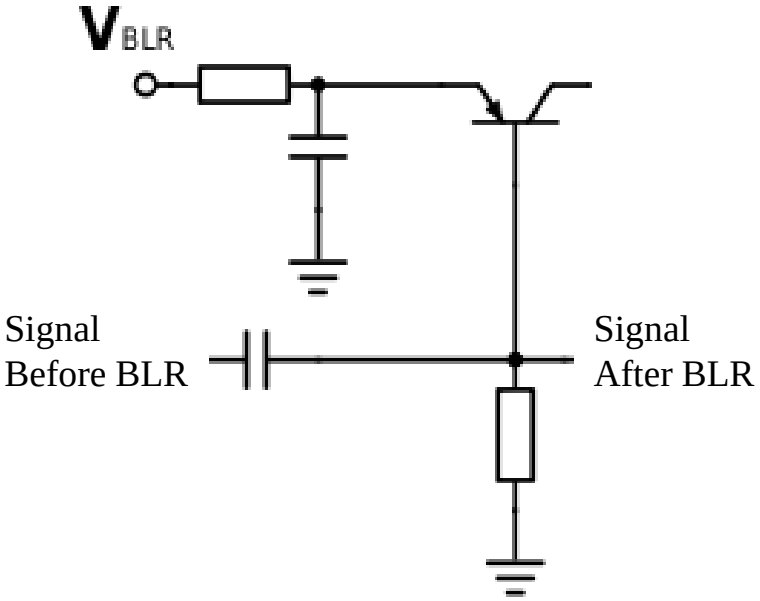




Baseline Restauration (BLR)

With baseline restauration also unipolar shaping can be used.





For bipolar shaping

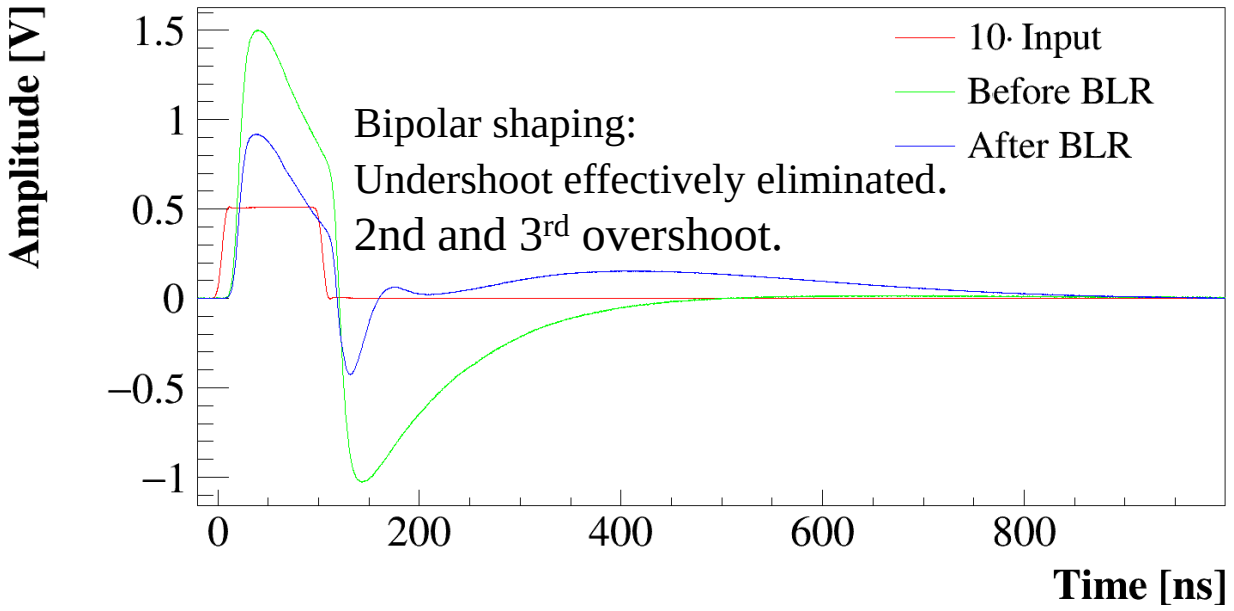
For unipolar shaping

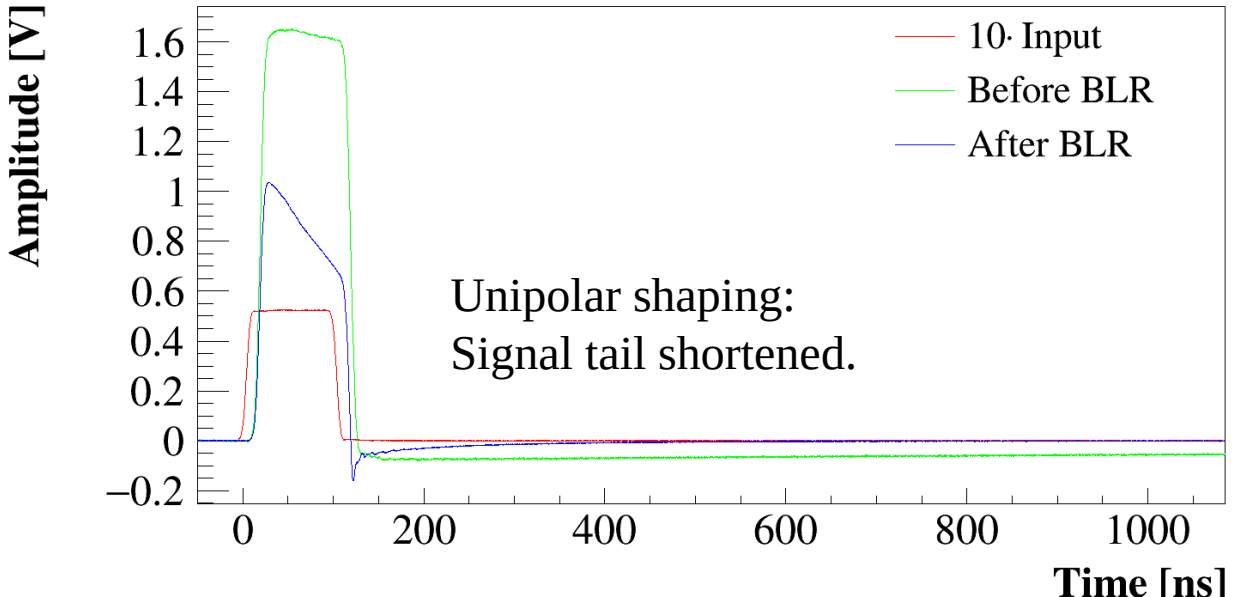
Transistors conducting for negative signal polarity => signal drained to ground =>
Undershoot eliminated for bipolar shaping, positive tail eliminated for unipolar shaping.

Pulse Generator Response

Characterization of the electronics with **pulser** response at diffent BLR settings:

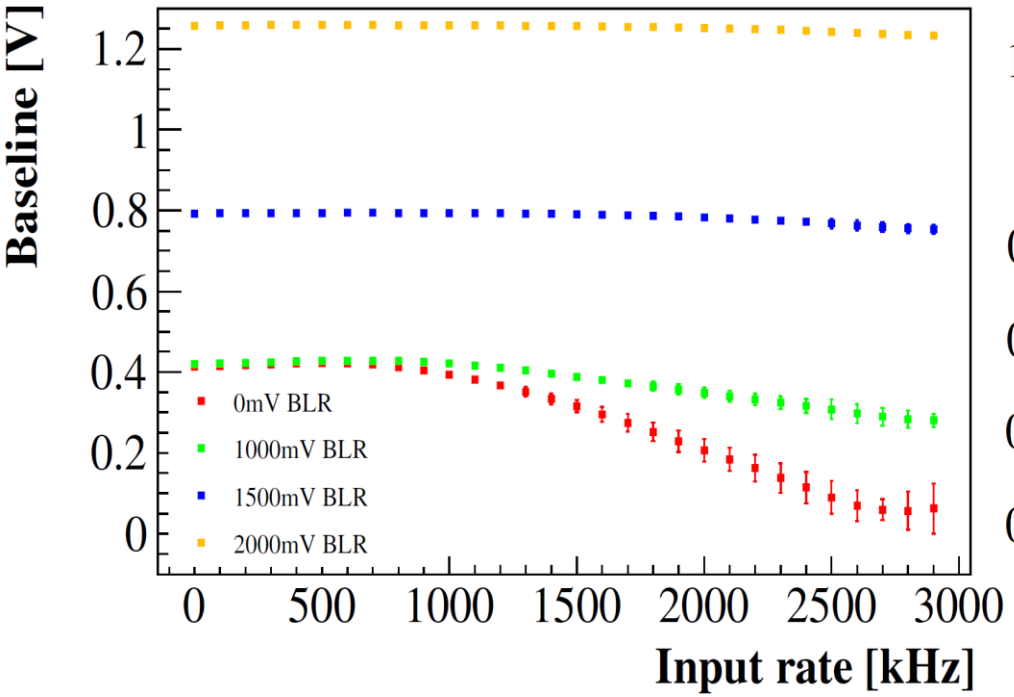
- 3 different pulse types
- Variation of input amplitude and charge
- Single pulses (=low rates)
  => Linearity
  => Gain
- High rates
  => Pile up
  => Baseline shift

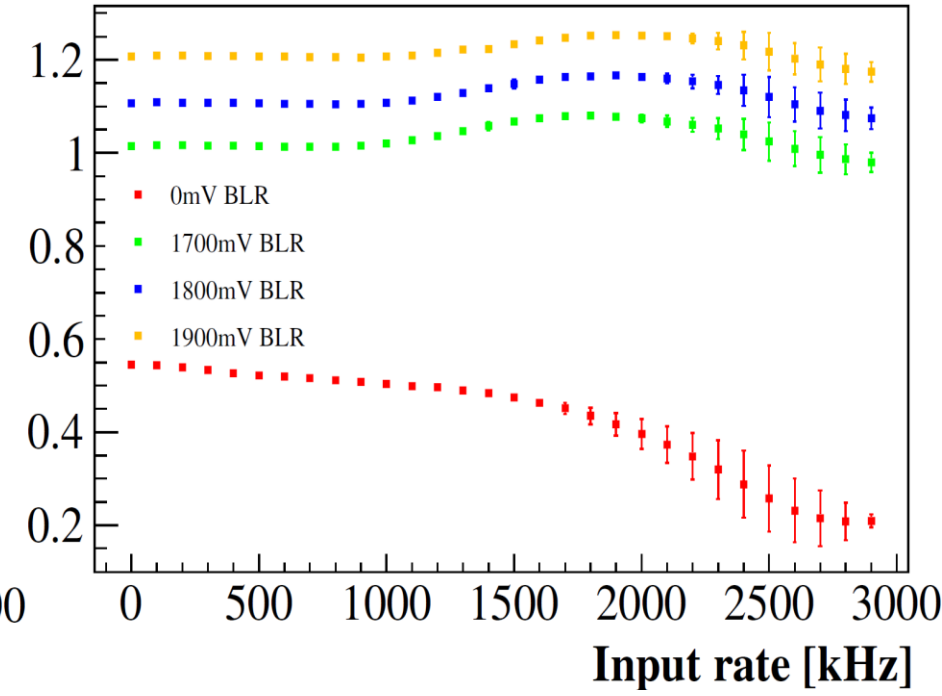




Baseline Shift

Triangular pulses with 127 pC at varying rate.
Baseline level after the BLR stage (=discriminator input):

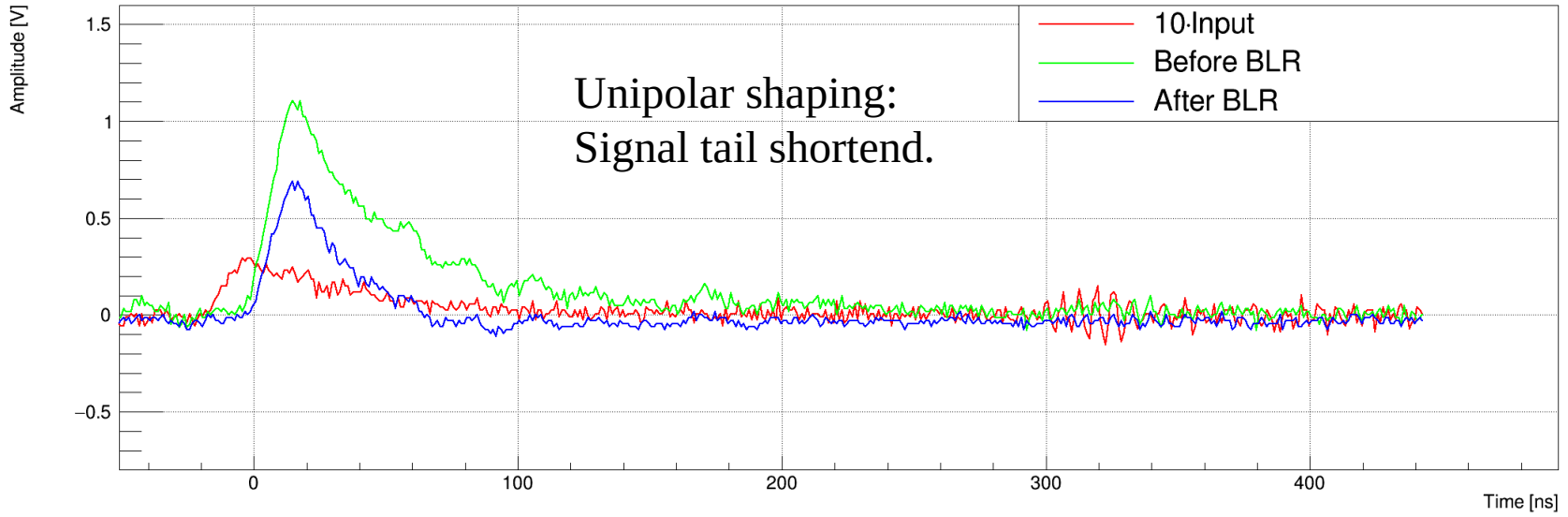


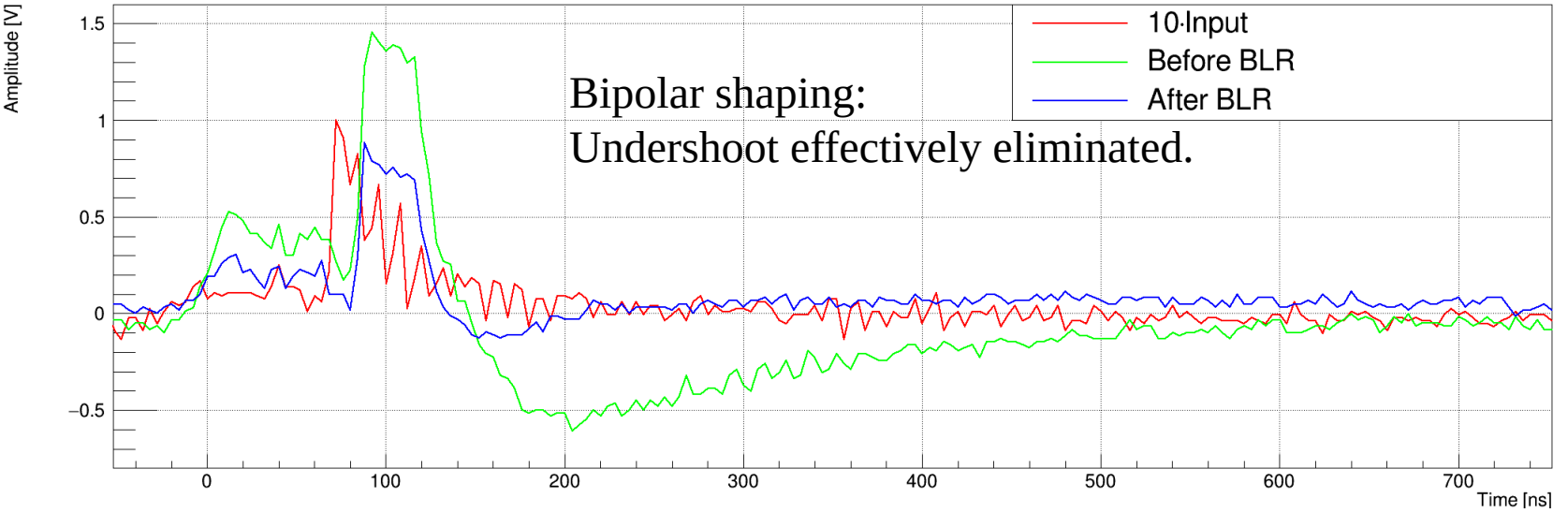


Unipolar BLR:
BLR needed above 1 MHz.
Baseline stable for V_{BLR}>1000mV

Bipolar BLR:
BLR needed above 1.3 MHz.
Signal overlap for f>1.5 MHz
due to $2^{nd}/3^{rd}$ overshoot

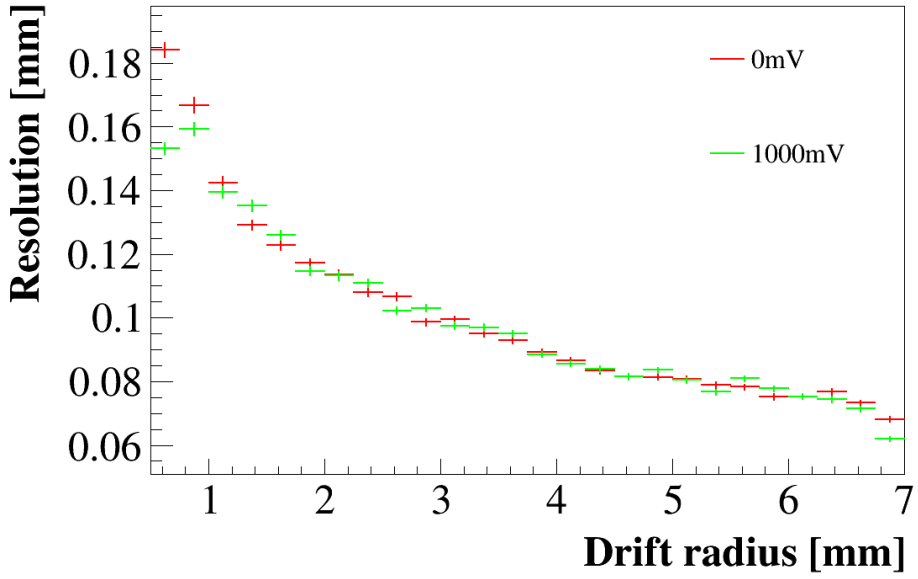
µ-Pulse Response

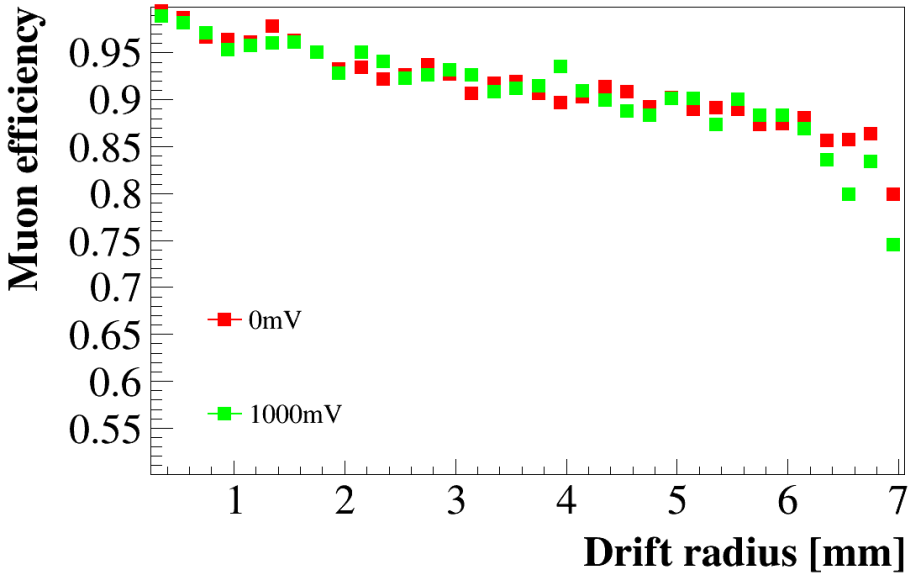




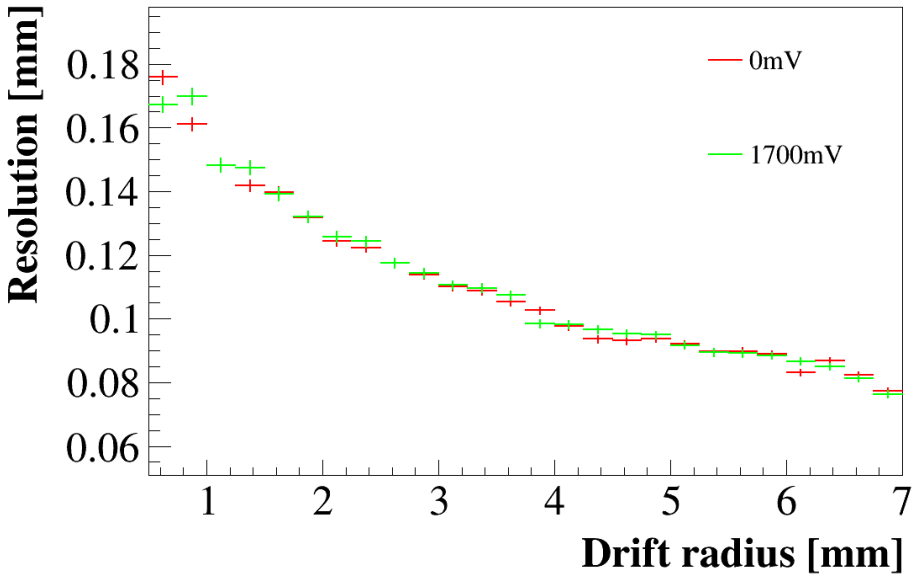
Electronics Performance on sMDT

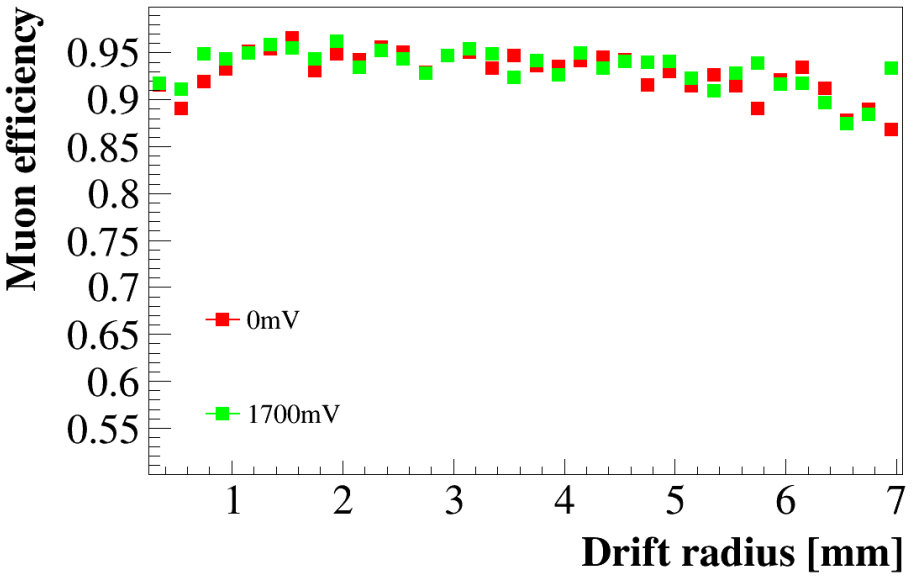
Unipolar



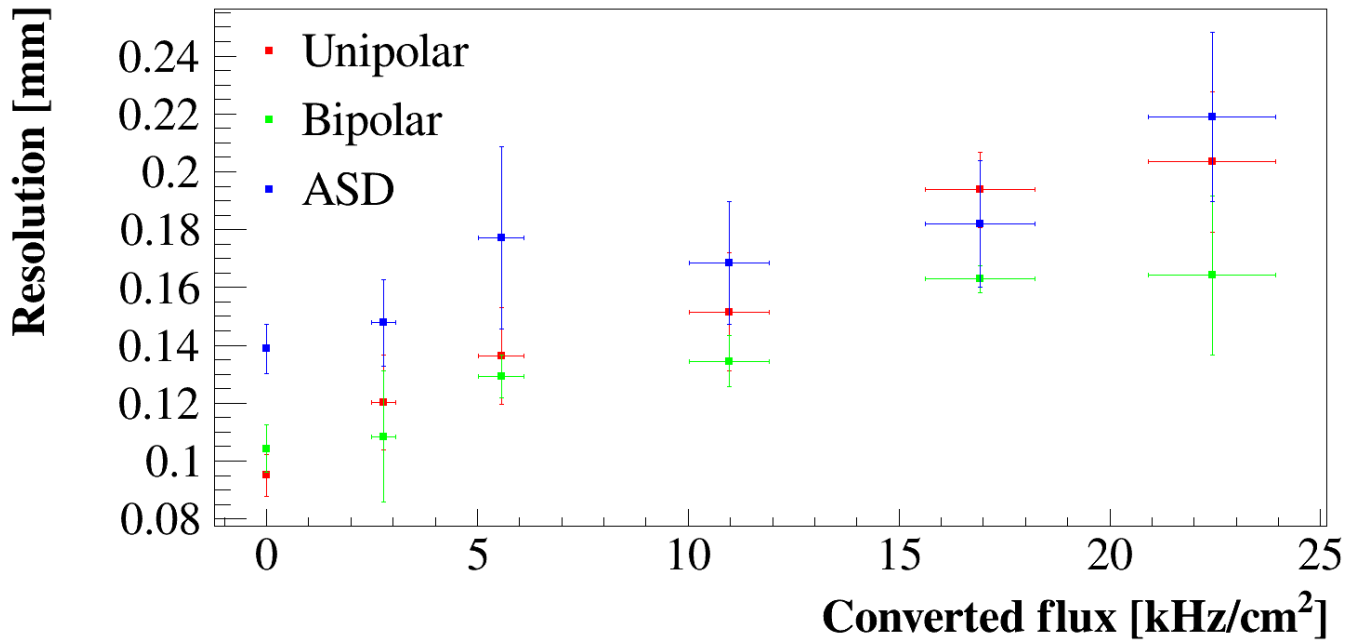


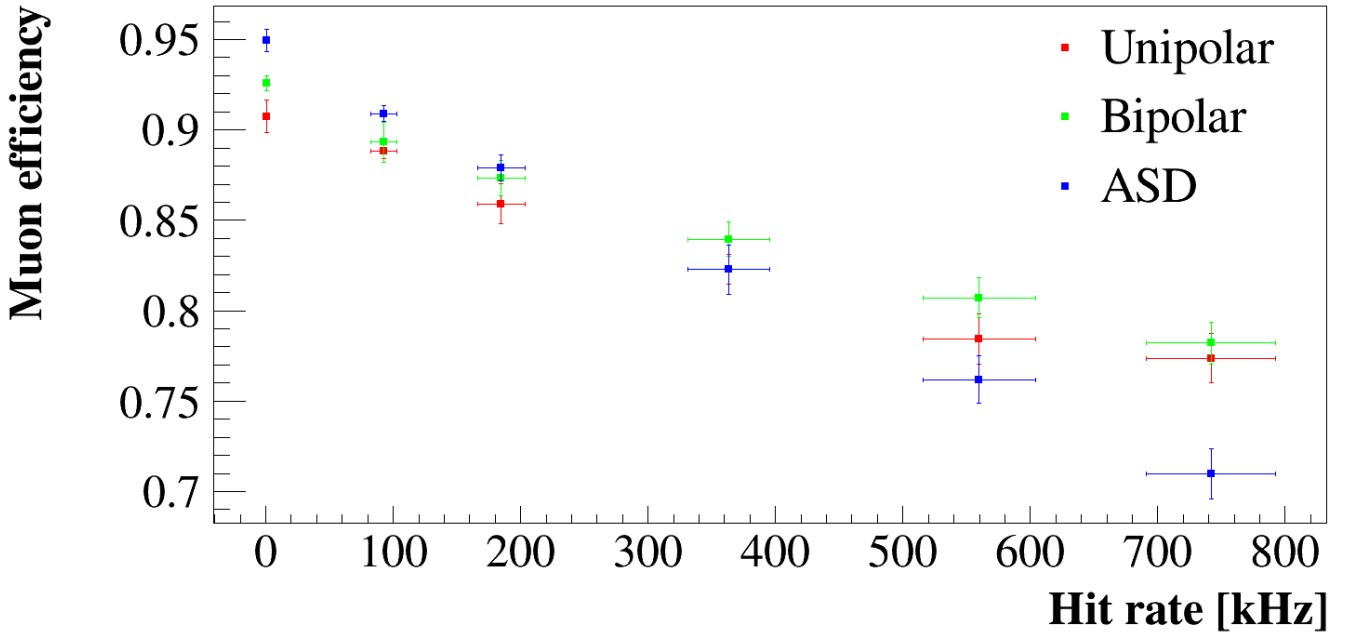
Bipolar





Comparison of Electronics Performance

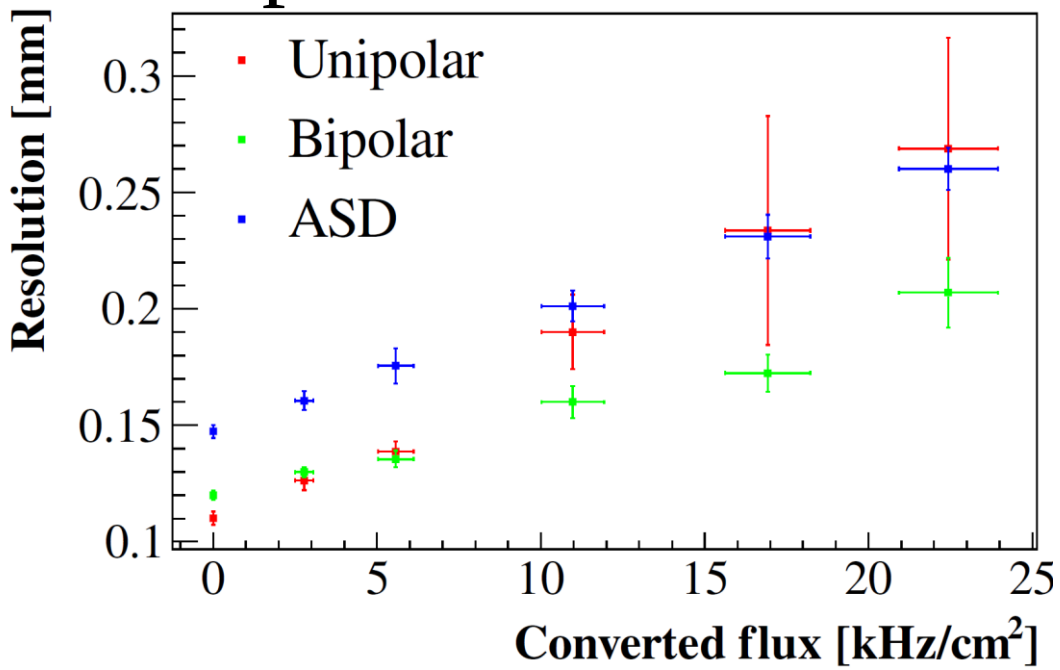


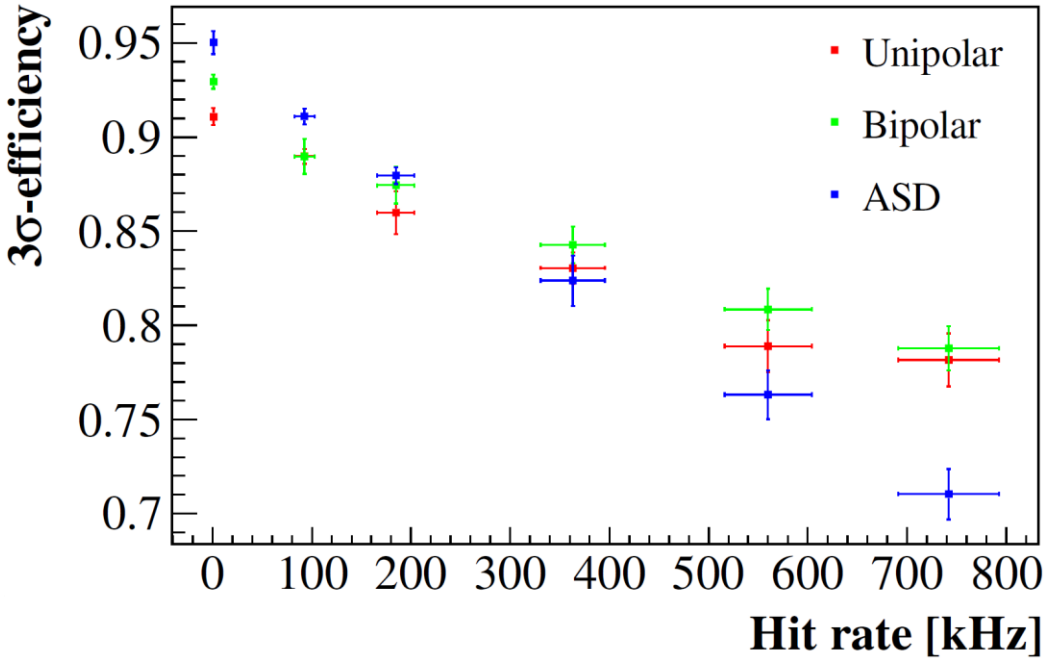


Conclusion

- 15 mm diameter tubes have an order of magnitude higher rate capability in terma of efficiency and resolution.
- The BLR electronics allows the exploitation of the full sMDT potential for muon systems in future hadron colliders.

Comparison of Electronics Performance





- Resolution over all improved by discrete electronics
- Room for improving the noise of the unipolar electronics

- Efficiency of the discrete electronics improved at high rates.