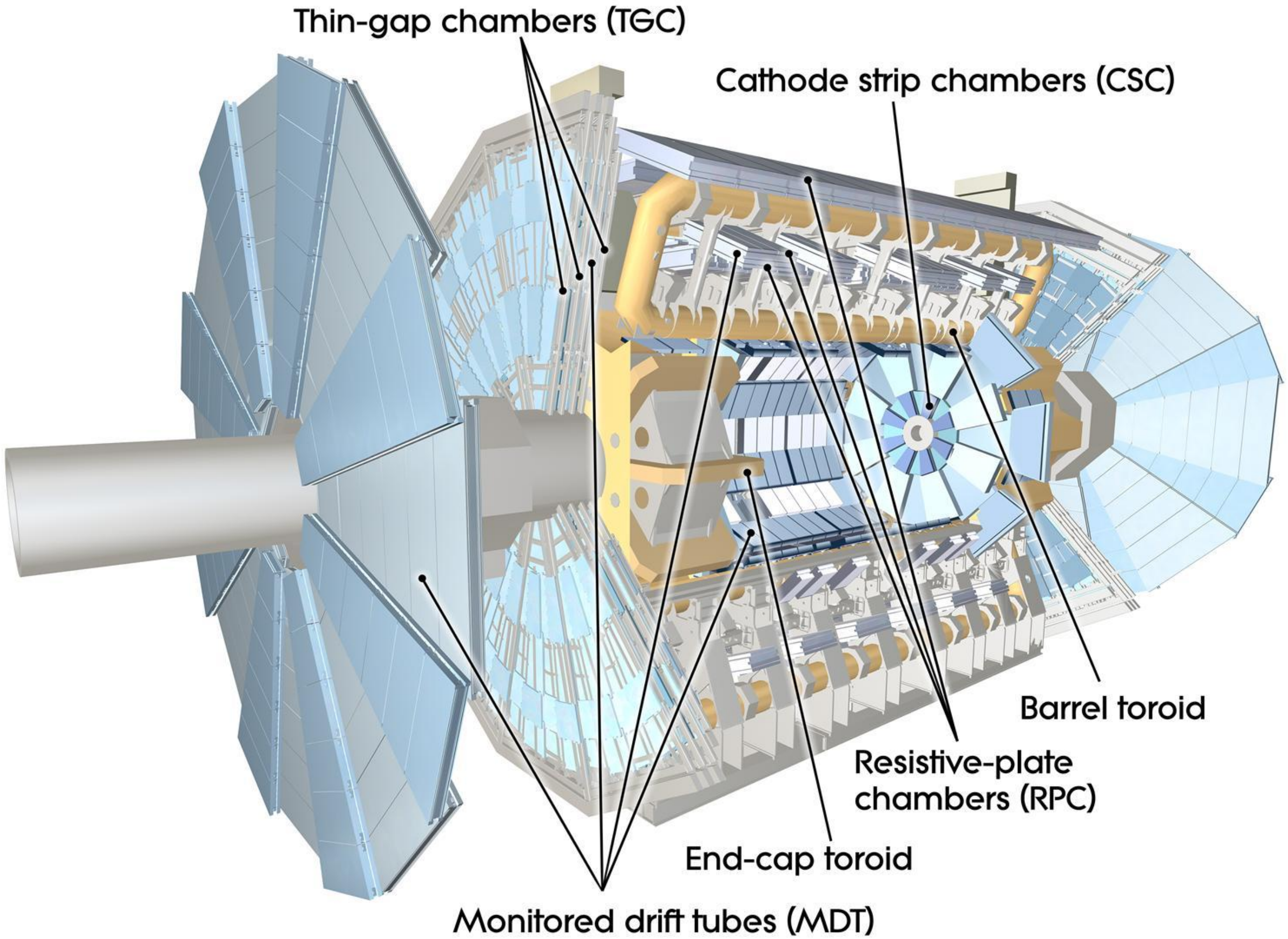
Test and Optimization of the ATLAS (s)MDT chamber readout electronics for high counting rates

Korbinian Schmidt-Sommerfeld

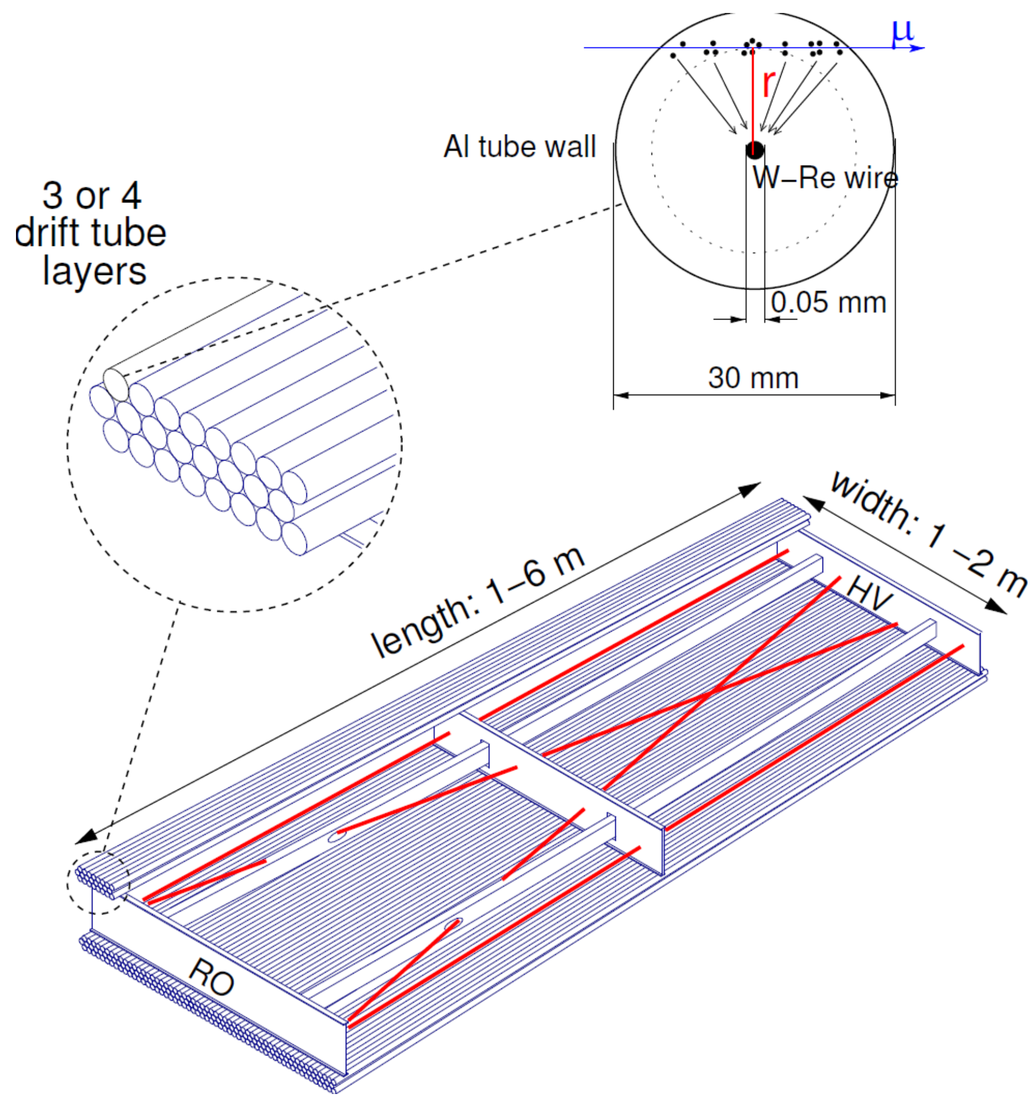
Max-Planck-Institut für Physik
(Werner-Heisenberg-Institut)
Föhringer Ring 6
80805 München

A **T**oroidal **L**HC **A**pparatus

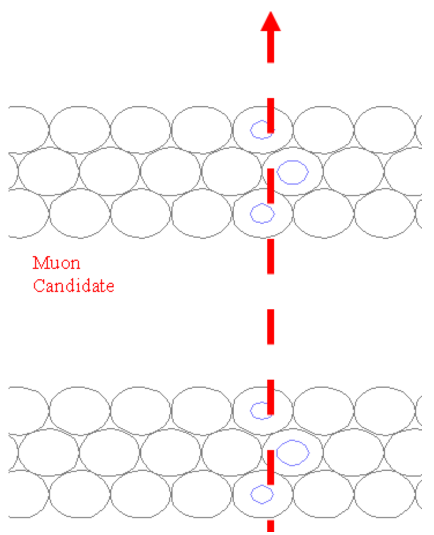


LHC upgrade: $\mathcal{L}_{\mathrm{HL}}=7 \cdot \mathcal{L}_{\mathrm{nomial}}$

MDT chambers

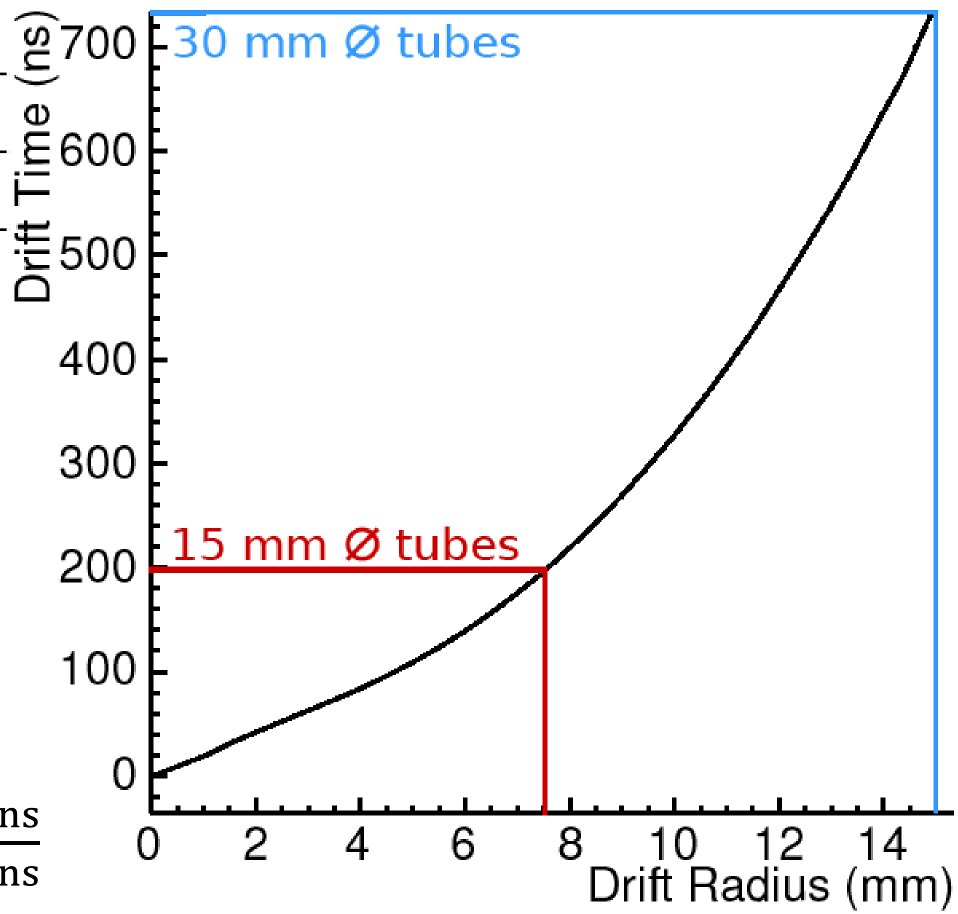


- Ar/CO_2 (93/7)
- $p_{abs} = 3\ bar$
- Gas gain $G = 2 \cdot 10^4$



New sMDT Chambers

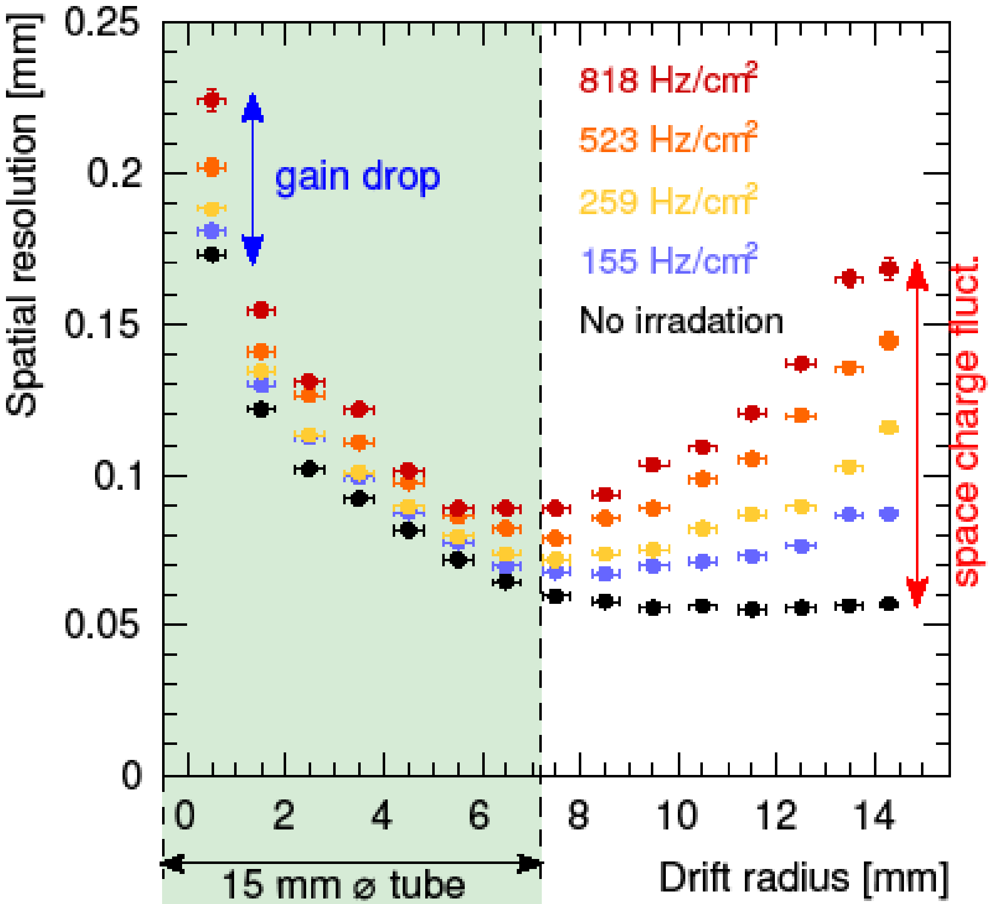
Tube diameter [mm]	30	15
Max. drift time [ns]	730	185
Tube resolution [μm]	80	105
Typ. Chamber resolution [μm]	40	40



- Hit rate reduced by a factor 2
- Further occupancy reduction by $\frac{730\text{ ns}}{185\text{ ns}}$

=> Same efficiency at 8 times higher hit rate.

MDT Resolution under Irradiation



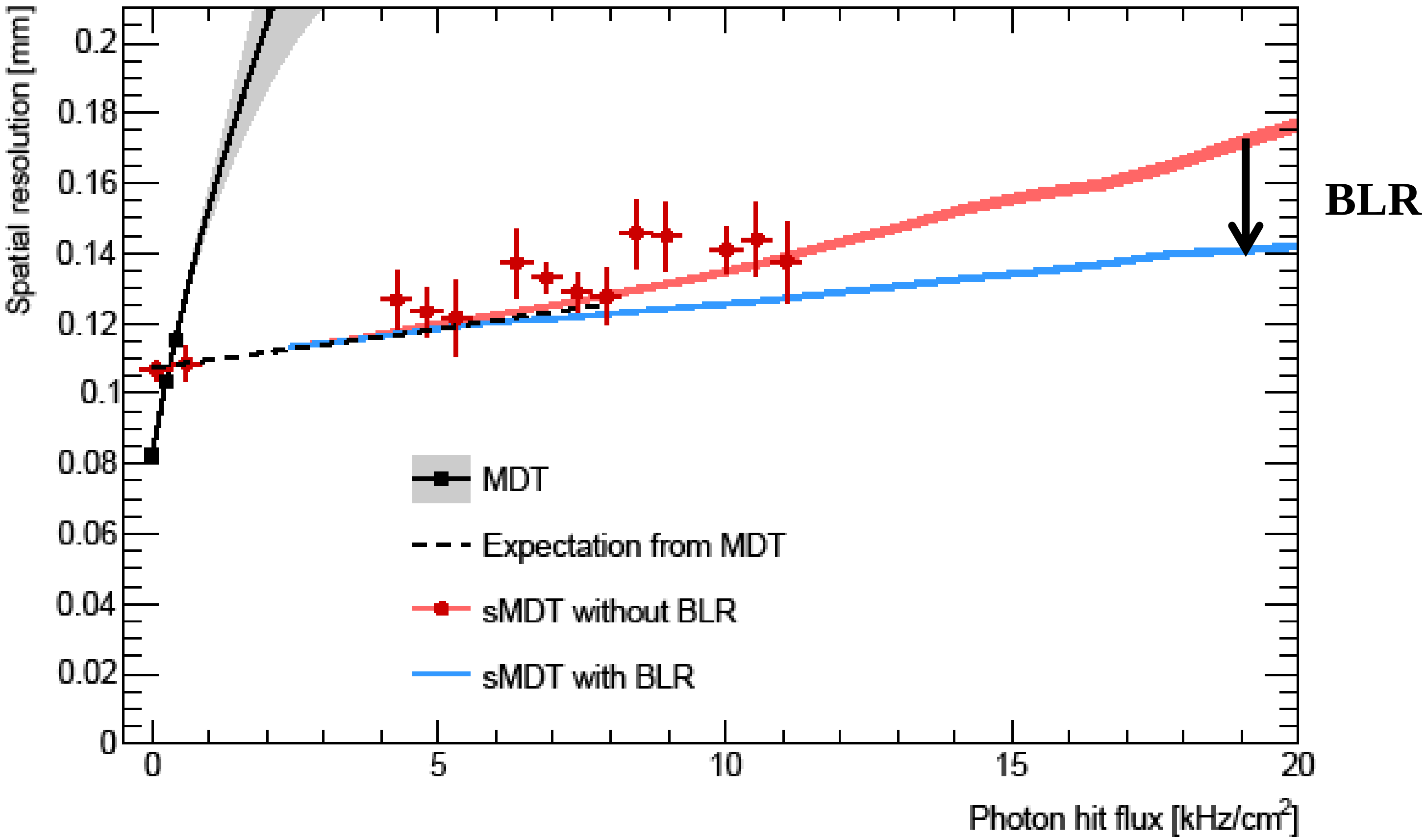
Gain drop:

- Follows radial signal dependence
- Eff. Voltage drop $\delta V \sim r_{max}{}^{3}$

Space charge fluctuations:

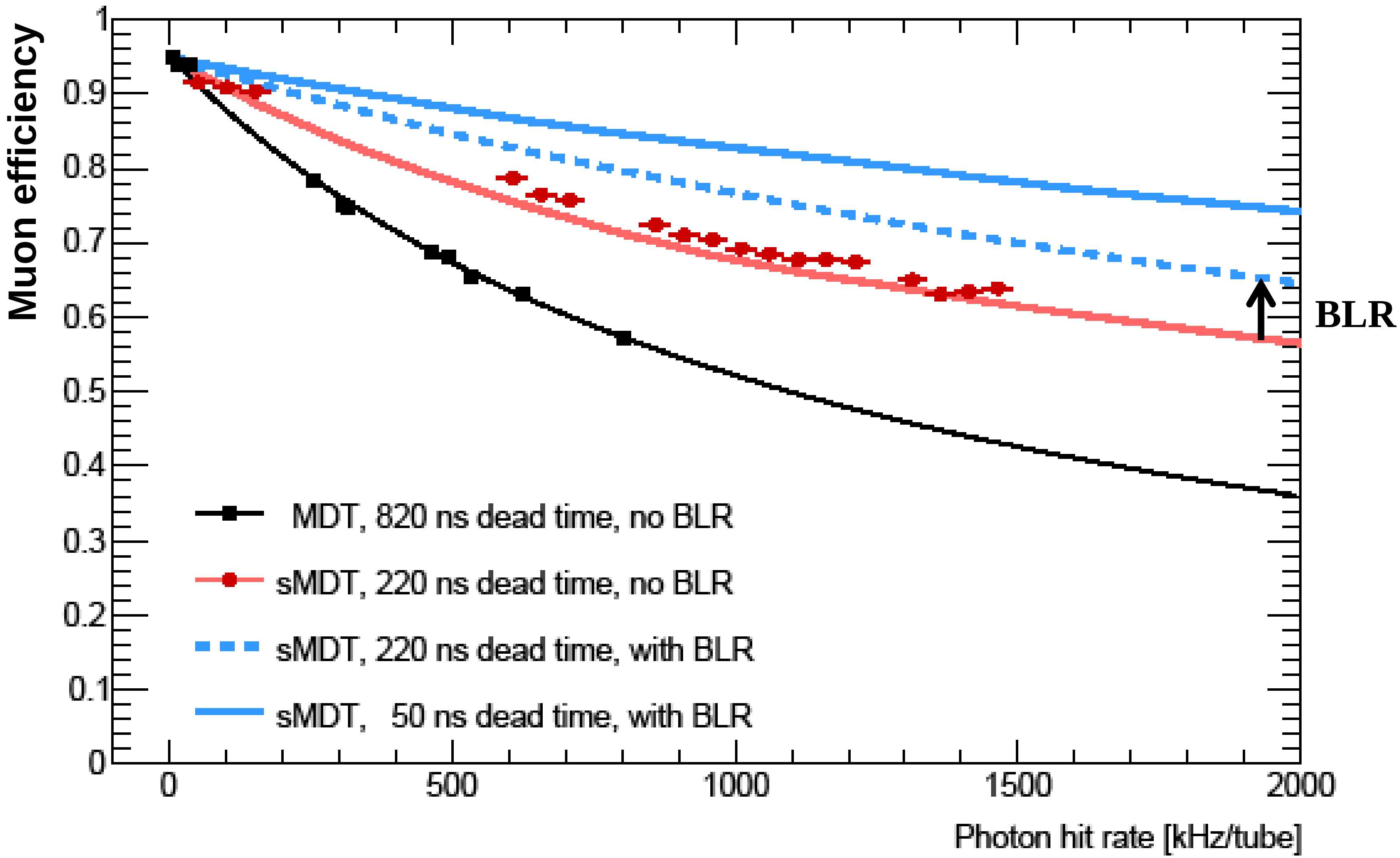
- Distorted $r(t)$-relation
- Relevant for $r > 5\text{mm}$

sMDT Resolution under Irradiation



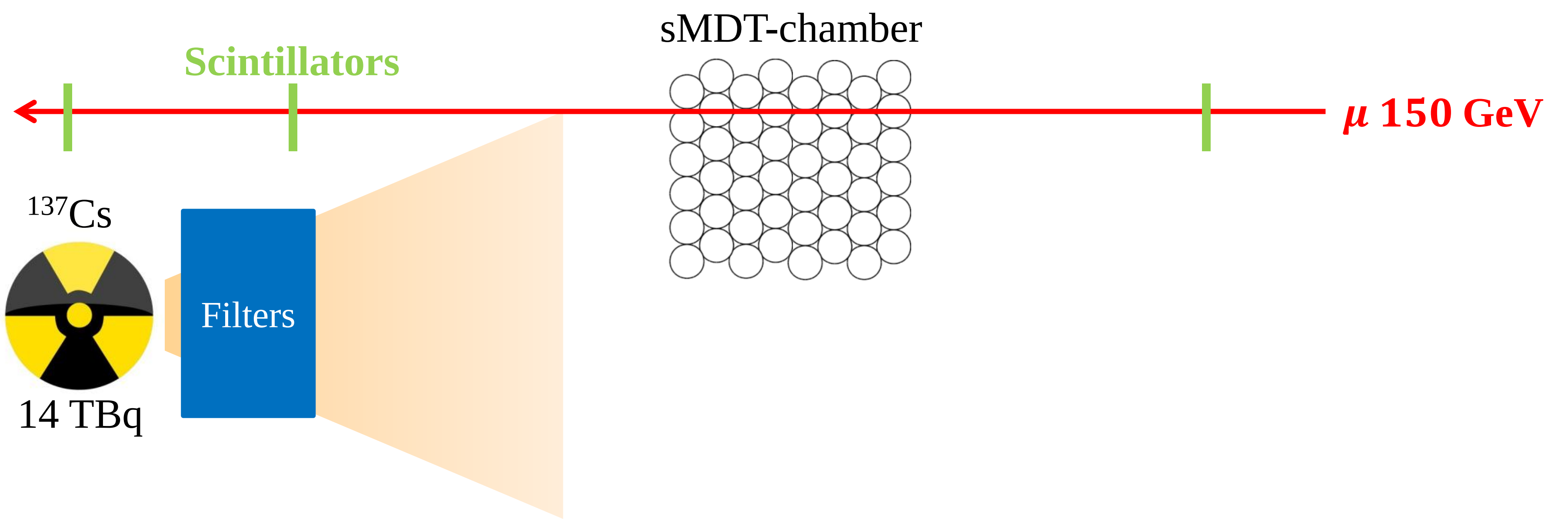
- Improved resolution of sMDT
- Further possibilities by pile up reduction (**B**ase**L**ine **R**estauration)

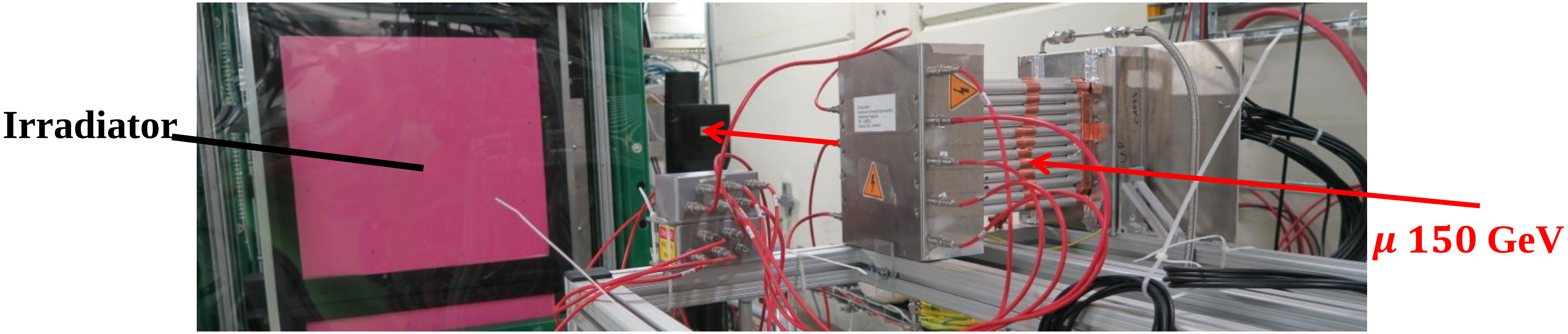
Rate dependence of the muon efficiency



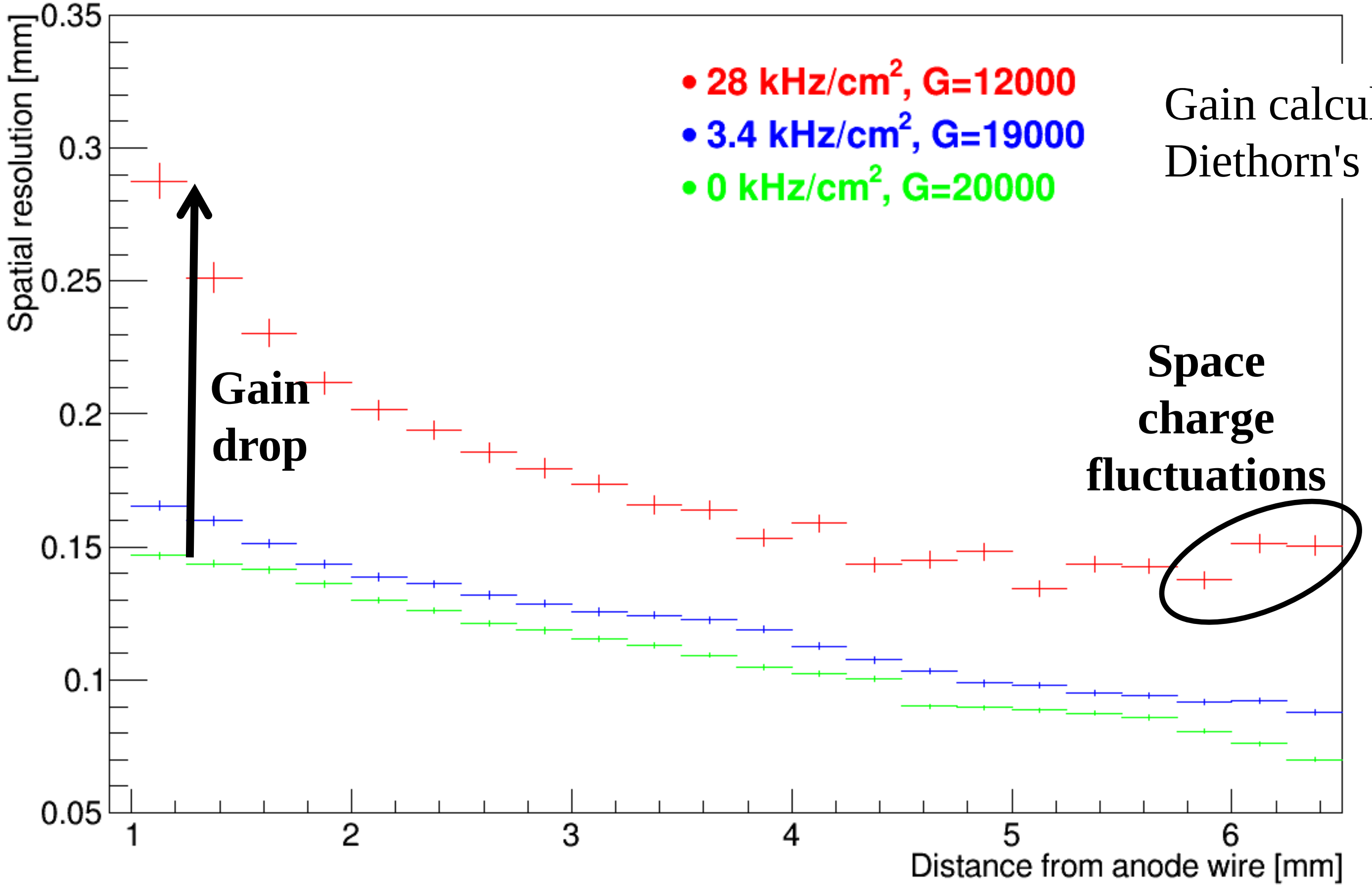
Muon efficiency increased by reducing tube diameter or dead time.

Setup at CERN's new γ-irradiation facility





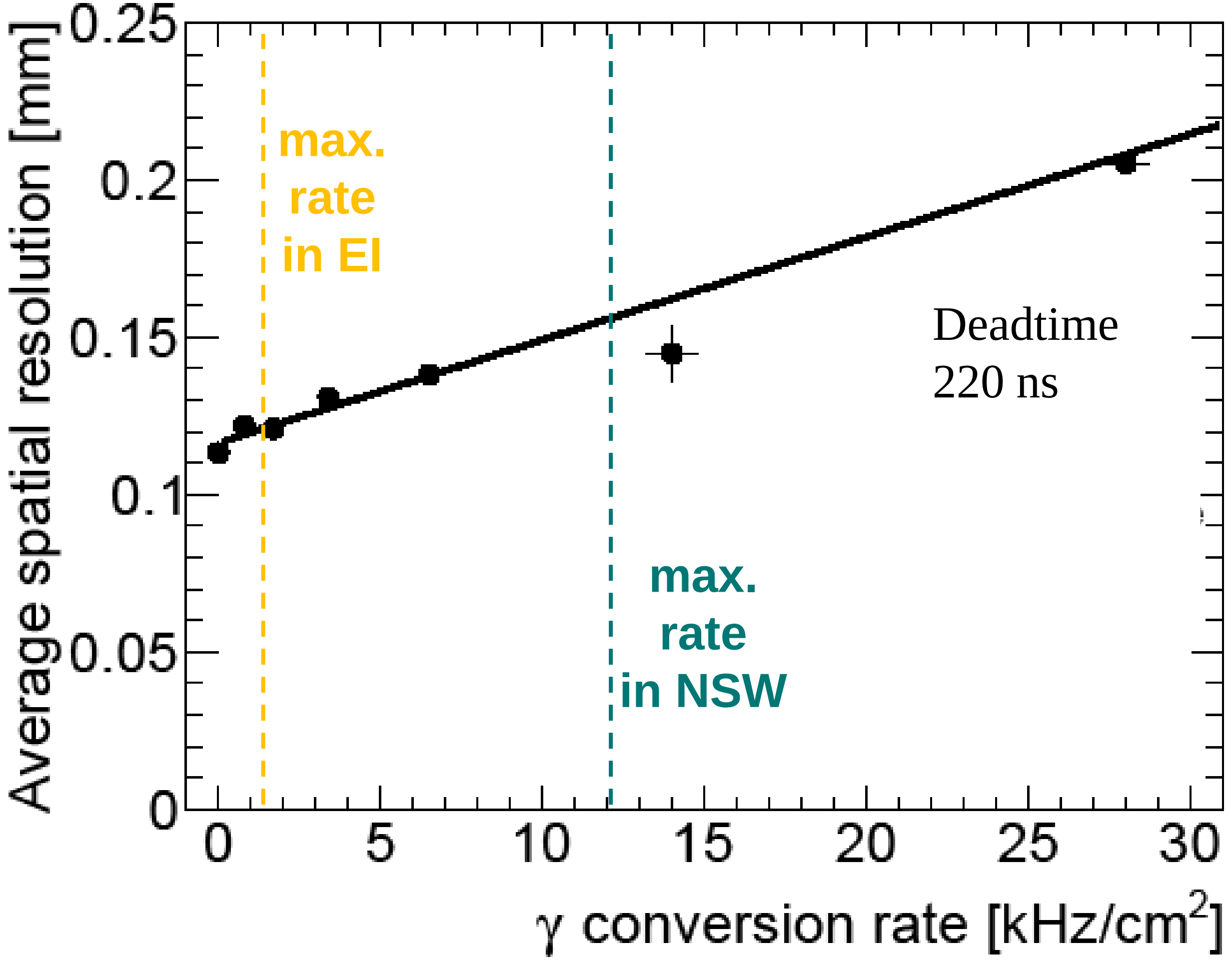
sMDT resolution using the standard MDT RO electronics (ASD chip)



Gain calculated with Diethorn's formula

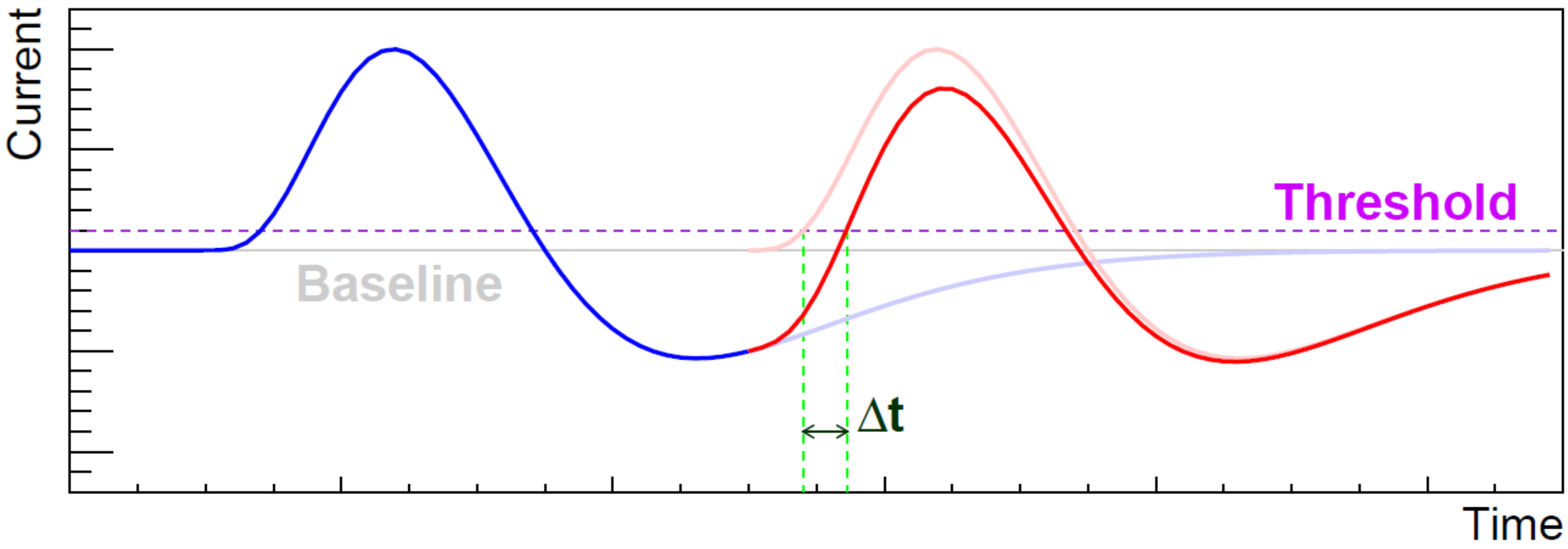
=> Reasonable resolution even at extreme hit rates.

Average Resolution
Dependency on the Irradiation Rate



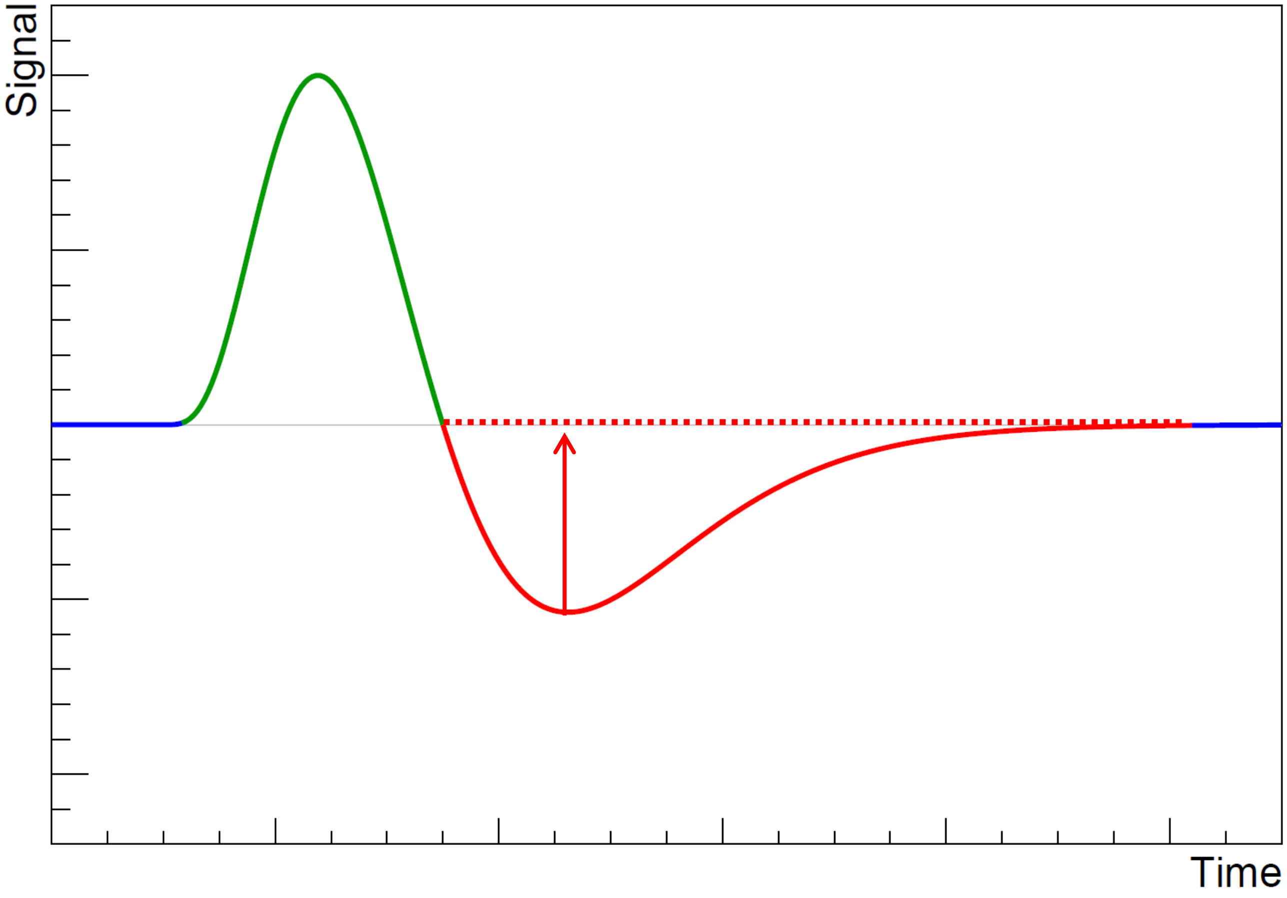
Even at 30 kHz/cm^2: Only linear resolution deterioration.

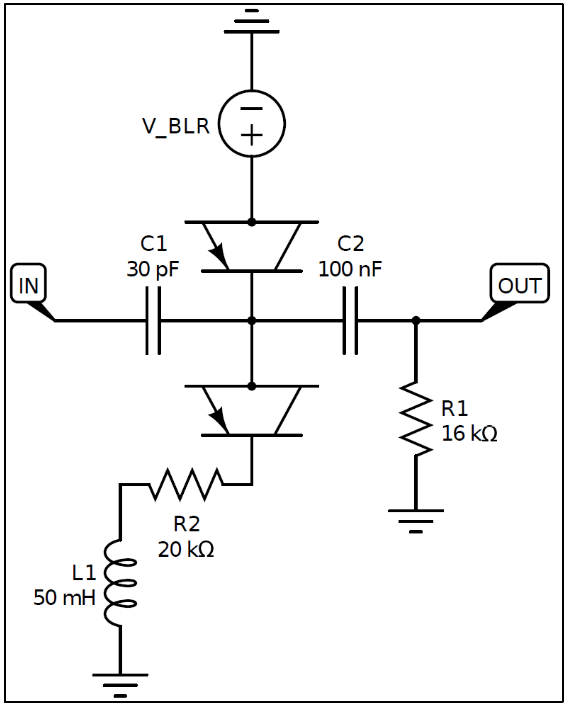
Signal Deterioration at High Rates



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

Baseline Restauration (BLR)



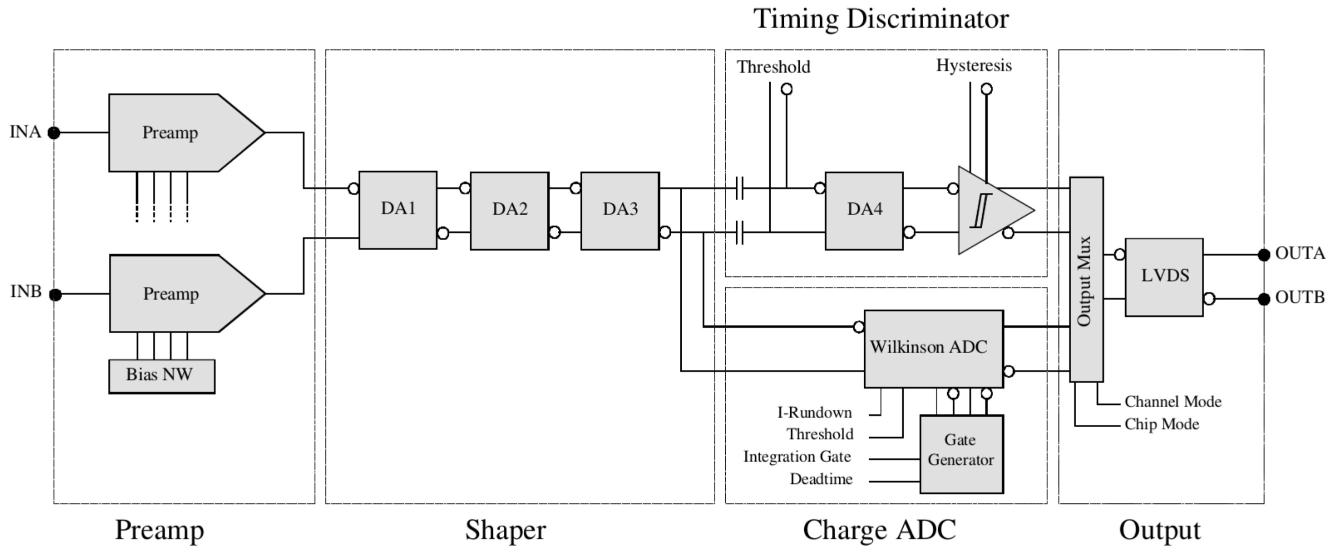


Similar to the
“Robinson double diode restorer”
[Rev. Sci. Instrum. 32 (1961) 1057]

=> Avoiding pile up effects even at short dead times.

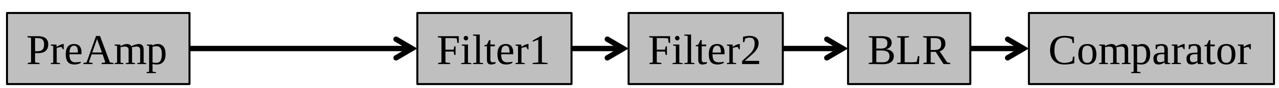
Readout chain

ASD ASIC

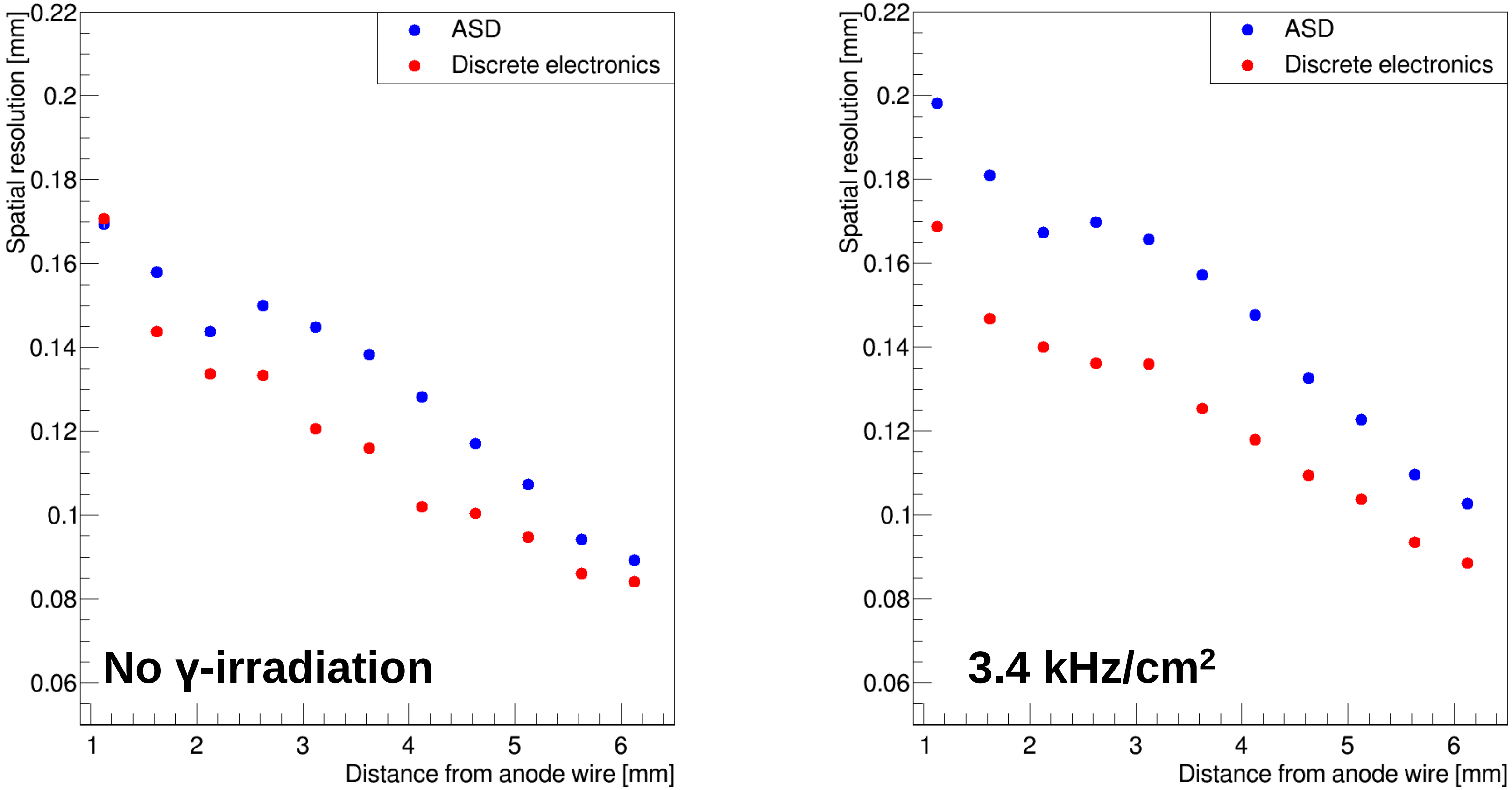


Resembling Multichannel boards to readout a whole chamber:

Discrete Electronics



Comparison of the resolution with two different electronics

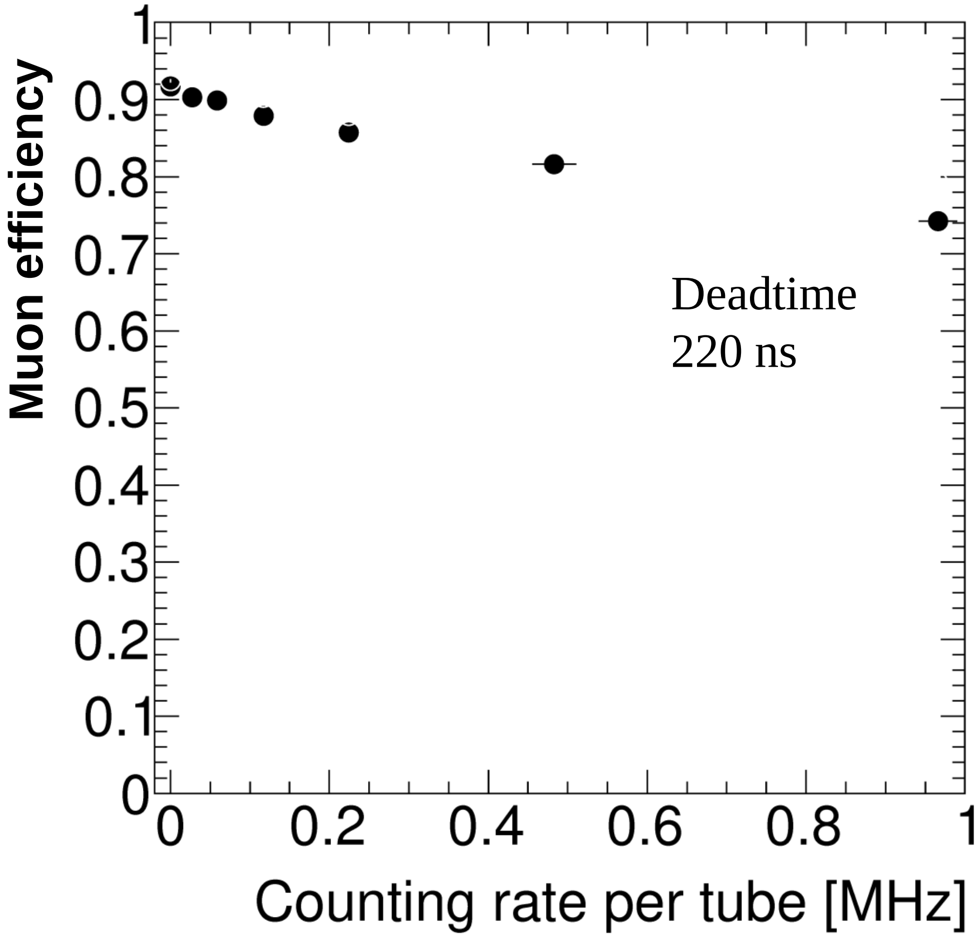


Better resolution due to higher PreAmp bandwidth.

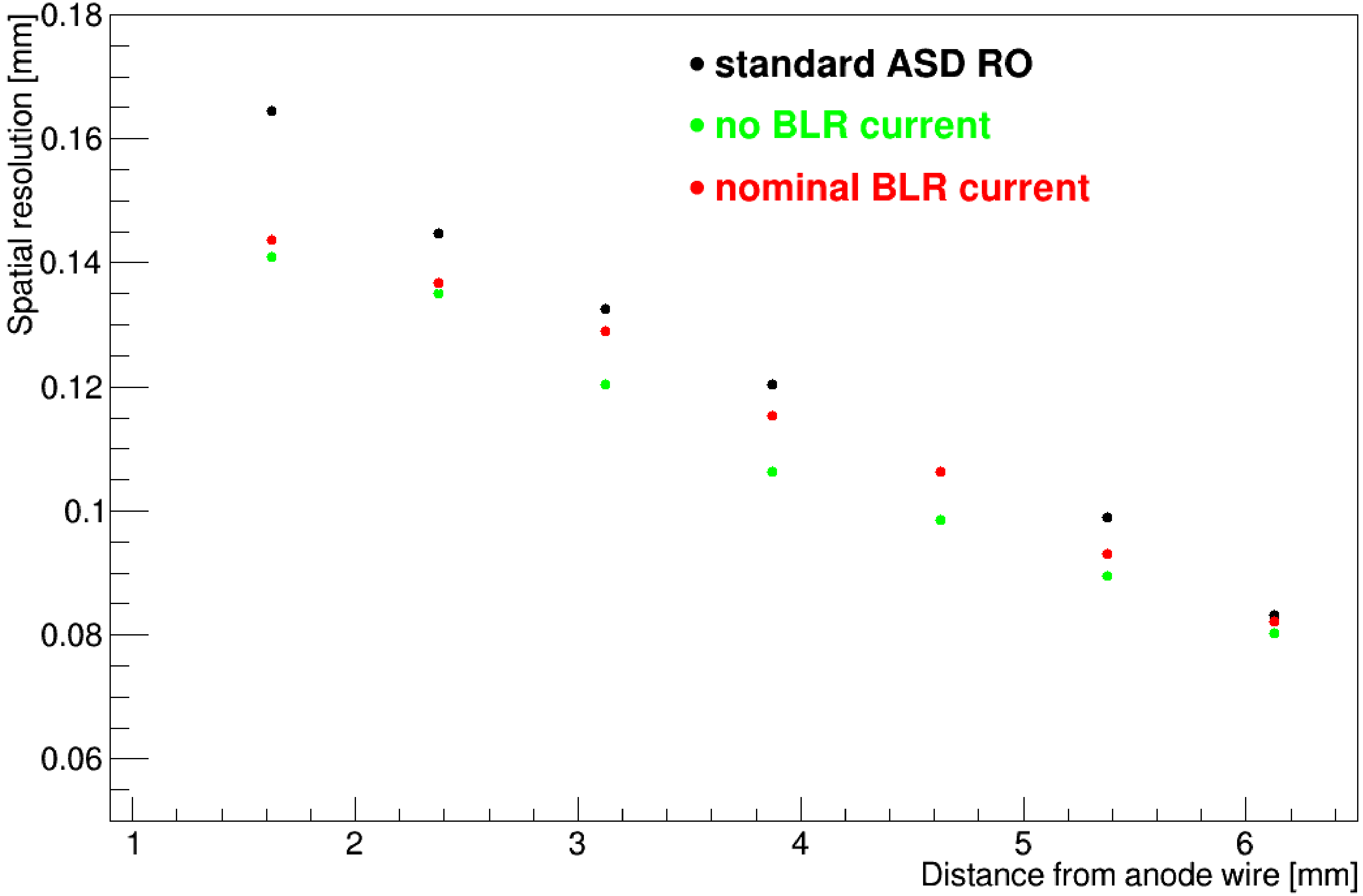
Conclusion

- MDT rate capability increased by ~1 order of magnitude by reducing the tube diameter to 15 mm
- Tested up to 28 kHz/cm^2 (i.e. far beyond HL-HLC)
- Improved electronics needed exploit their full potential
- Promising results from multichannel prototype

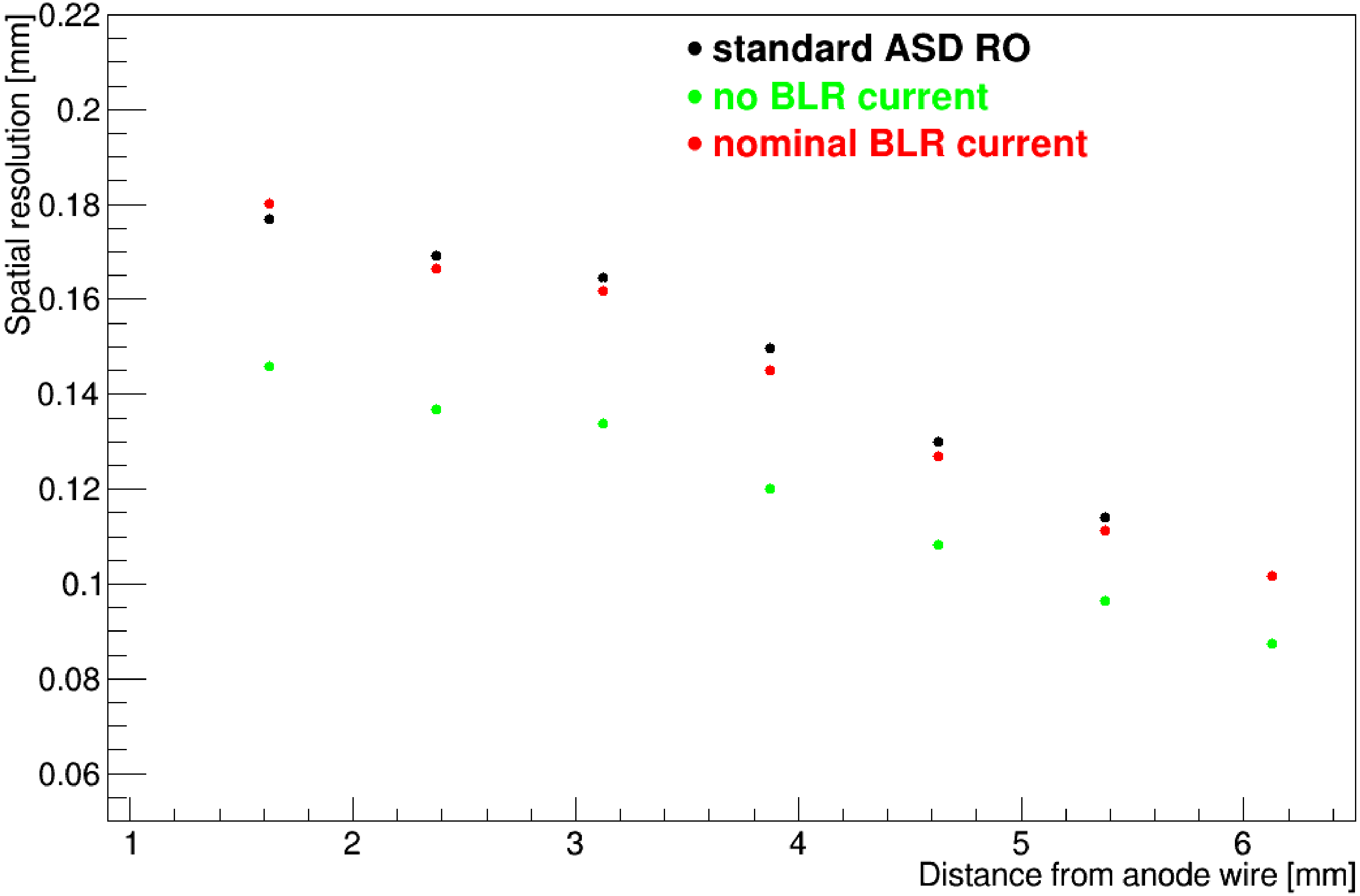
Efficiency
Dependency on the Irradiation Rate



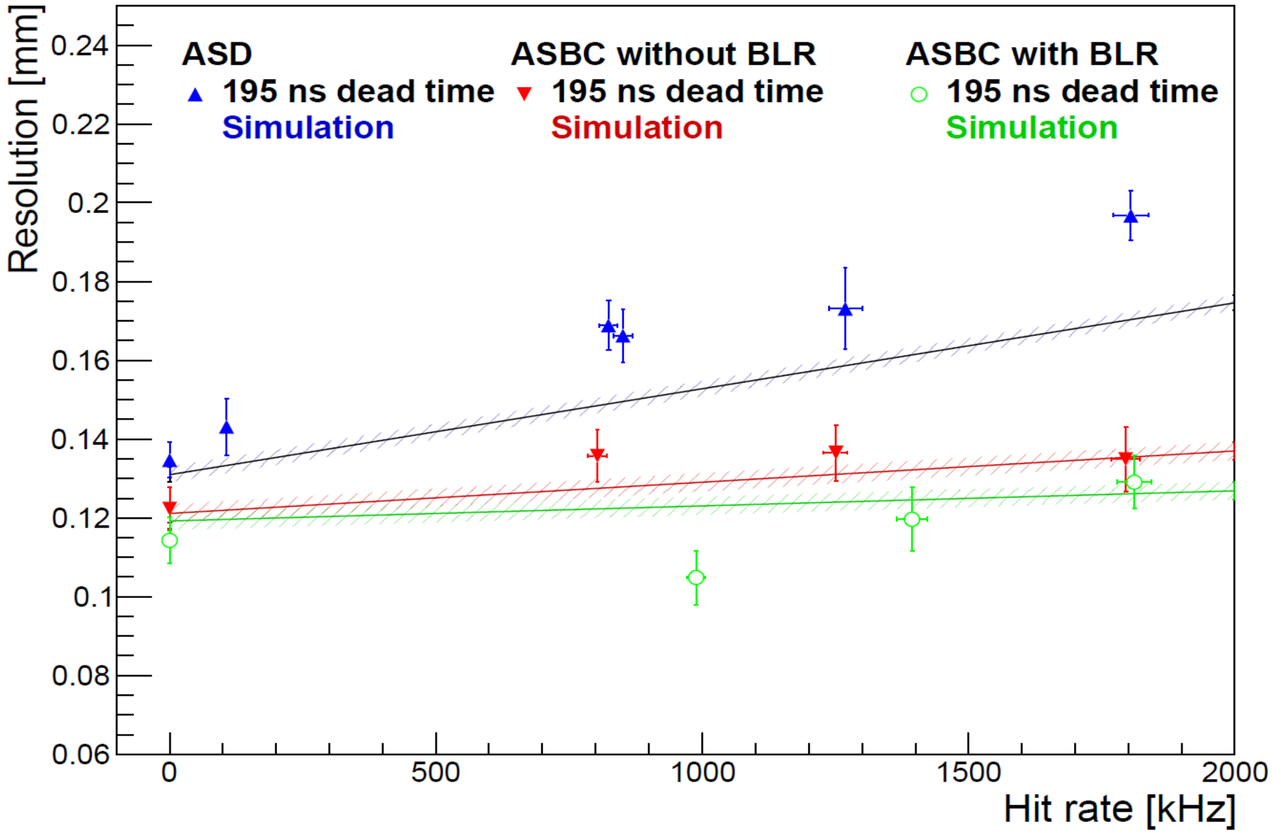
Drift tube resolution



Drift tube resolution under γ-irradiadtion



BLR Performance



- Improved resolution with discrete electronics due to shorter peaking time.
- Further improvement by active BLR.
- Measurements in agreement with simulation.

High Rates Effects: Muon Masking and Space Charge

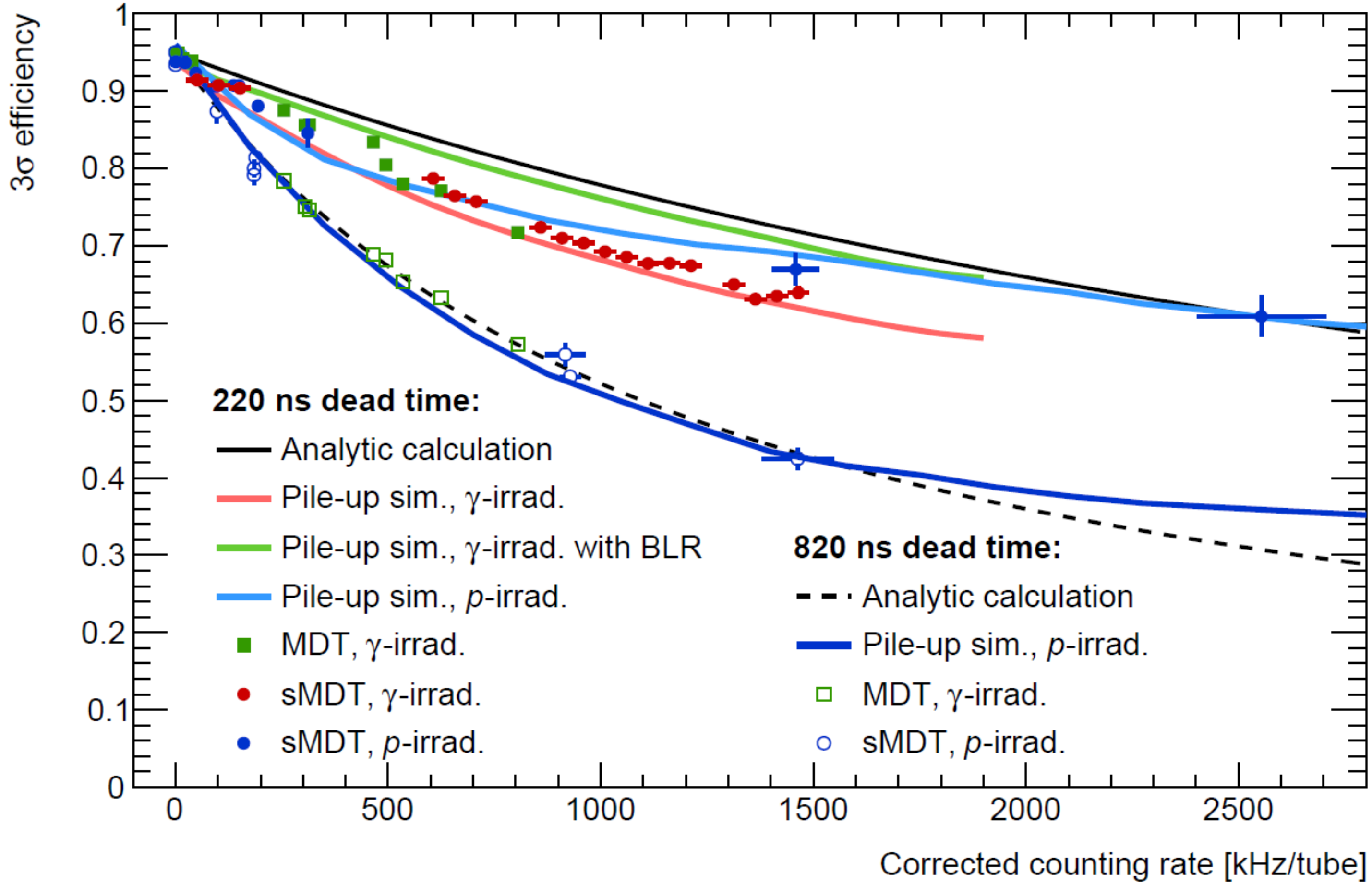
- Masking of Muon during dead time (tube and electronics)

=> Efficiency loss

- Ion drift $\tau_{MDT}{\sim}3$ ms
- Permanent space charge above $\sim 100\,\frac{\text{Hz}}{\text{cm}^2}$

=> Modified $\vec{E}$

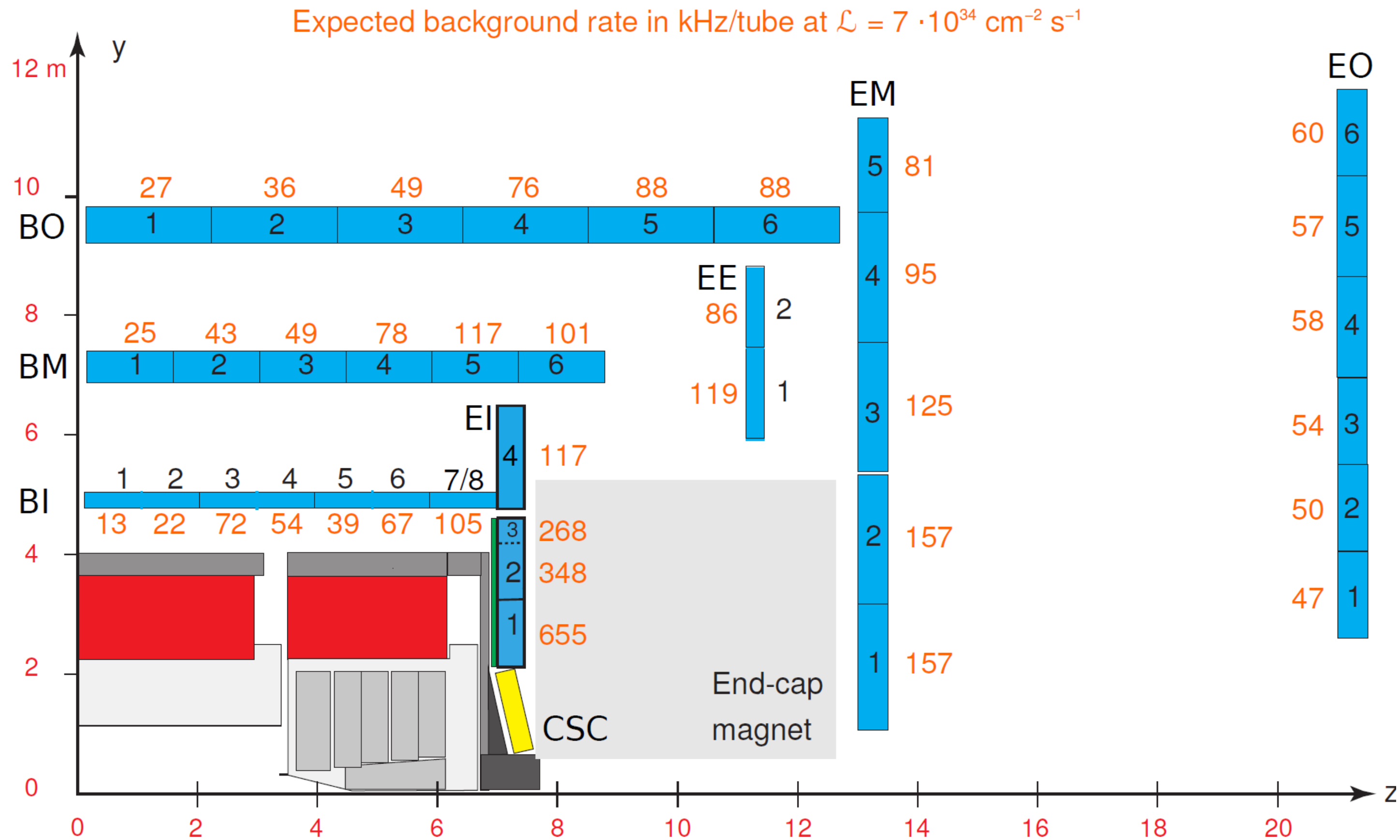
sMDT Efficiency under Irradiation



Efficiency improvements possible by dead time reduction.

kos@mpp.mpg.de

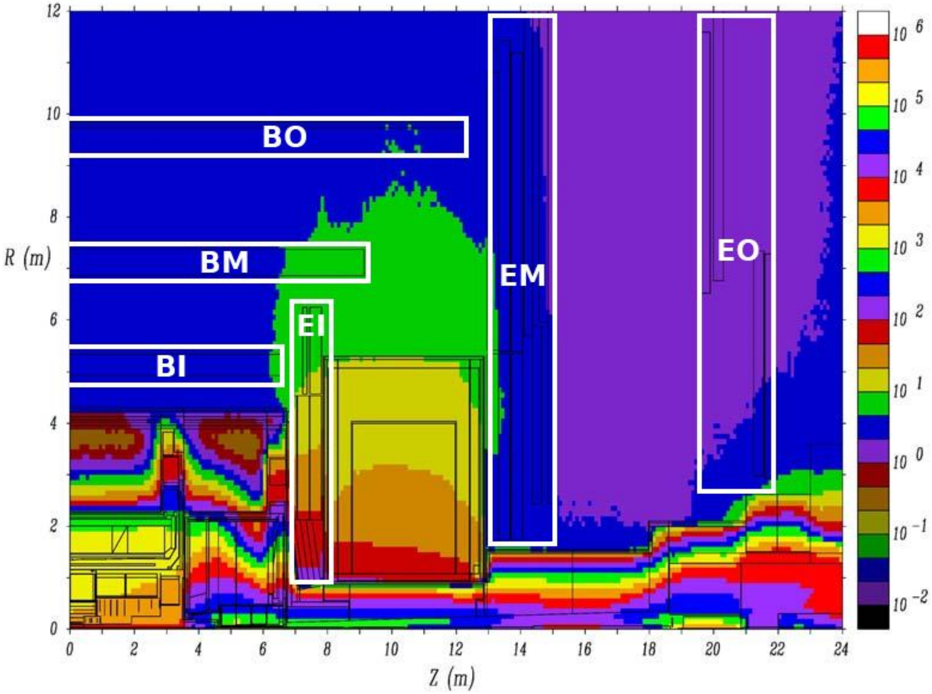
Background Rates



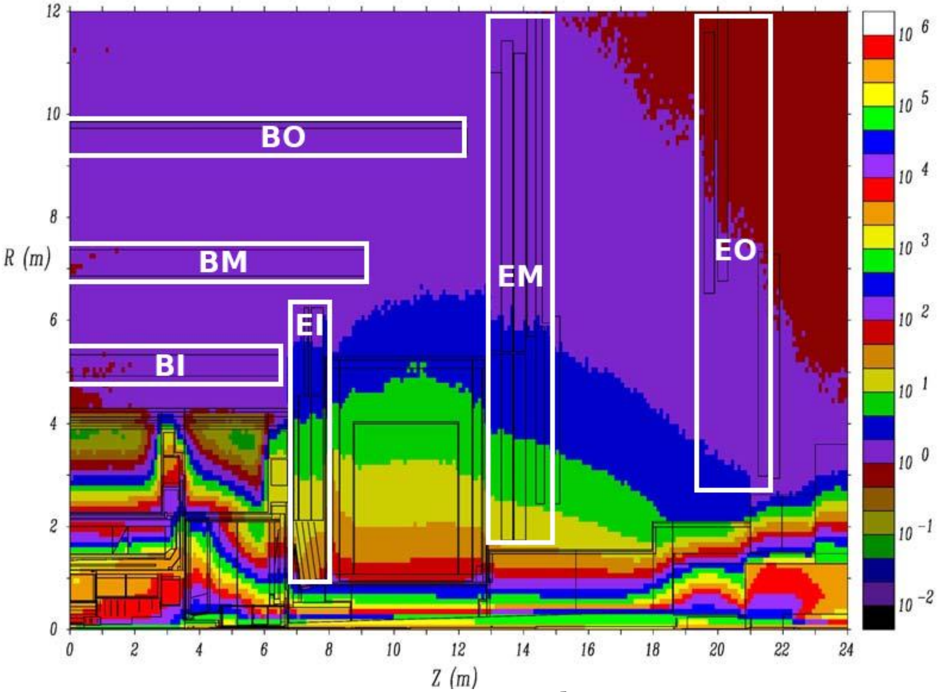
Most hits from γ and n (uncorrelated with $\mu^{\pm}$).

Exceeding of MDT rate capability in some regions at HL-LHC.

Radiation Background



Neutron flux $[\frac{kHz}{cm^2}]$

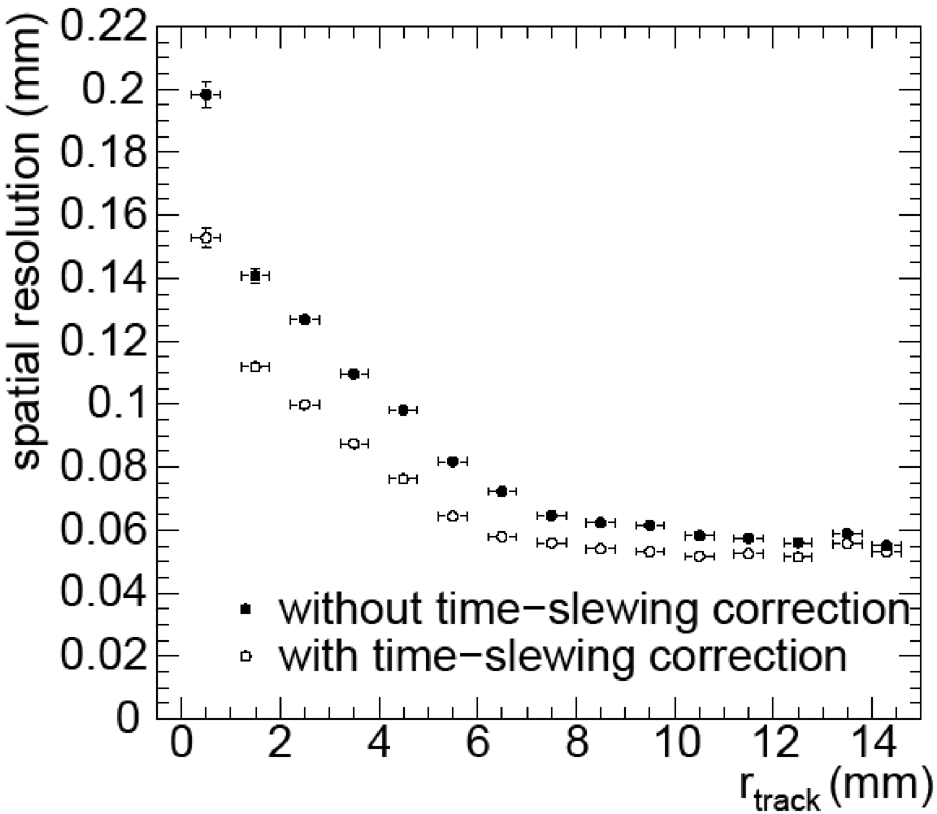


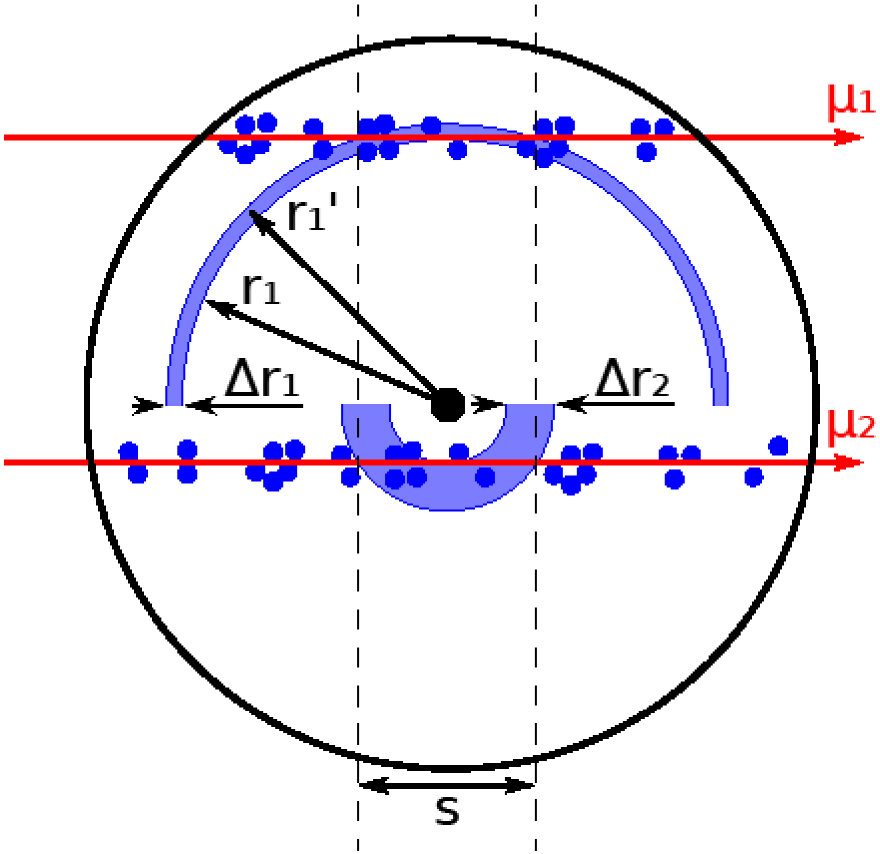
Photon flux $[\frac{kHz}{cm^2}]$

Cavern background from excited detector nuclei

-> Main source of hits in muon system

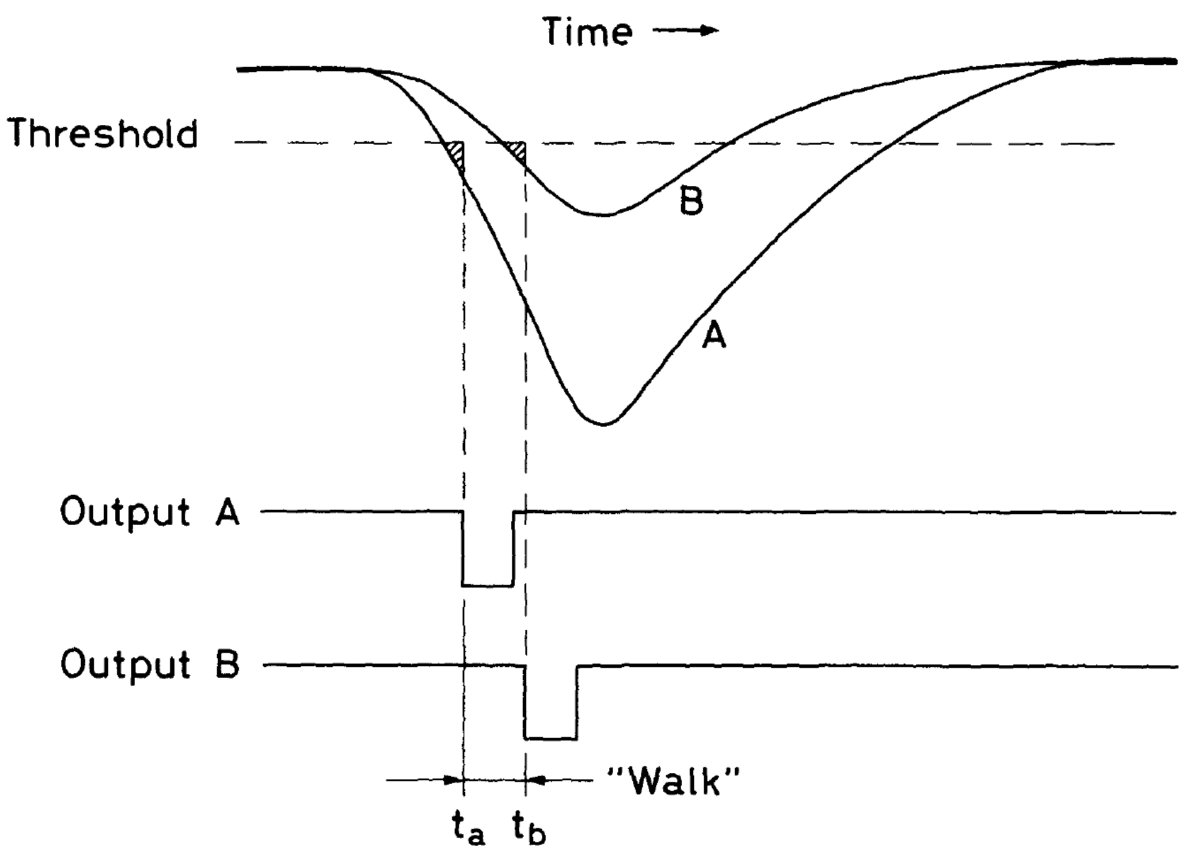
Resolution w/o irradiation





Spatial resolution deteriorates at small drift radii.

Time slewing corrections



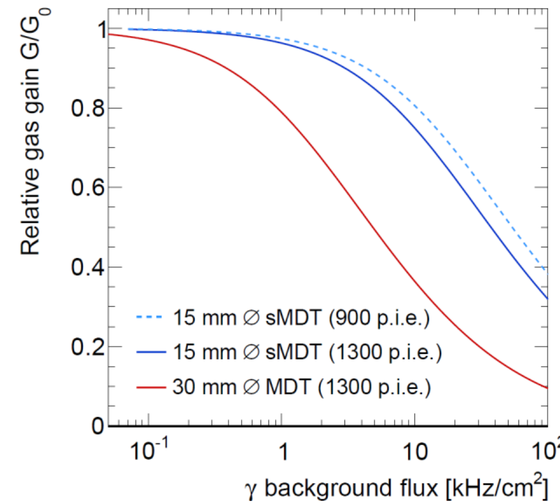
- Time of threshold crossing depends on pulse height
- Can be corrected by measuring pulse height

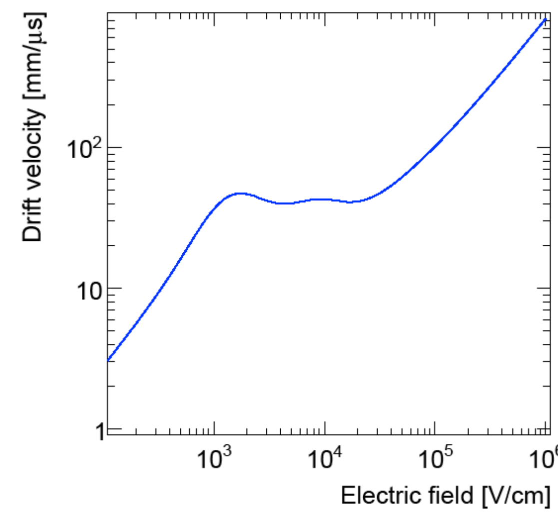
Space charge

- e^-/ion pairs created in avalanches
- Drift time $\tau_{ion} \sim 3$ ms
- Permanent space charge above $\sim 100\,\frac{\text{Hz}}{\text{cm}^2}$
- Reduced $\vec{E}$

⇒ Gain drop

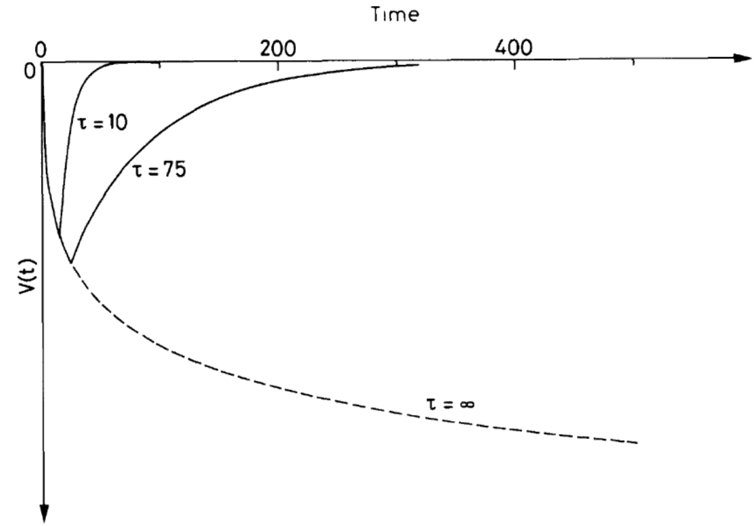
⇒ Drift velocity fluctuations



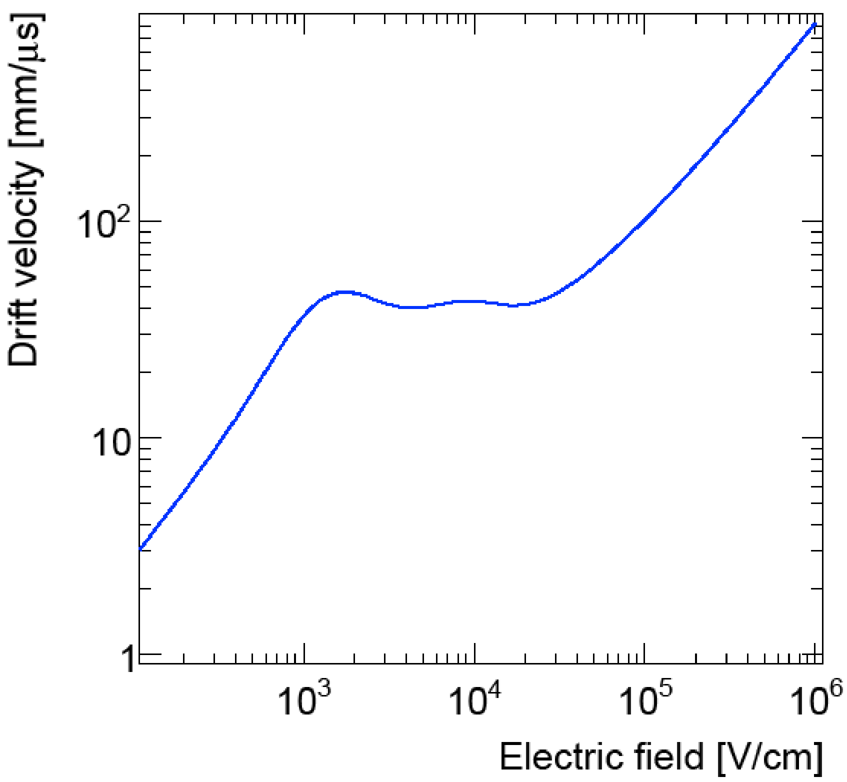


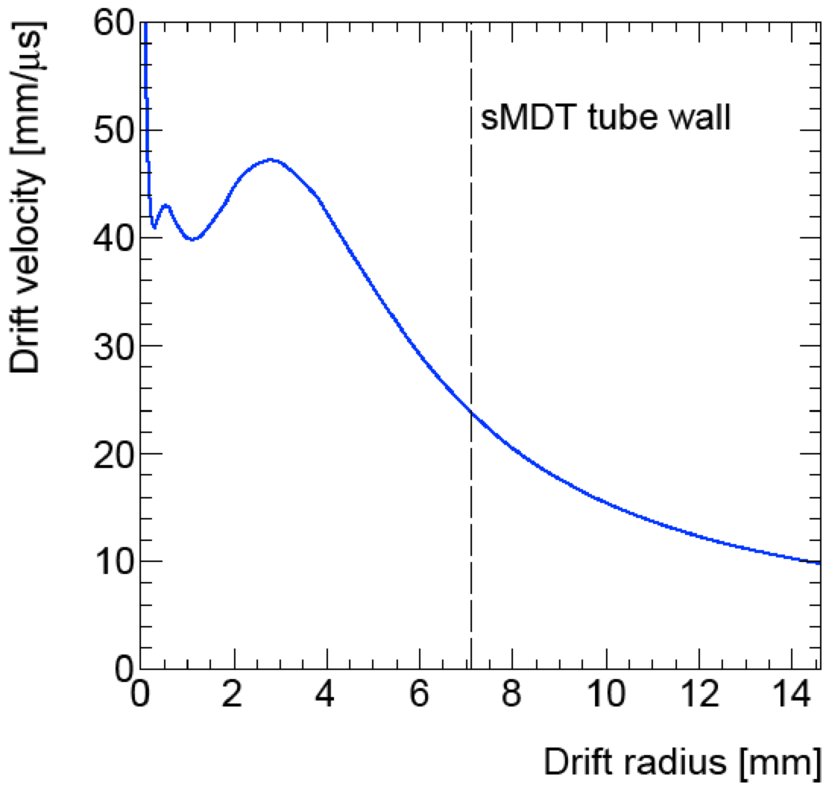
Pulse Shaping

- e^-/ions induce voltage
- Avalanche in wire vicinity
- Negligible e^--contribution
- $V(t) \sim \ln\left(1 + \frac{t}{t_0}\right)$
- Shortening pulse by differentiating RC circuit

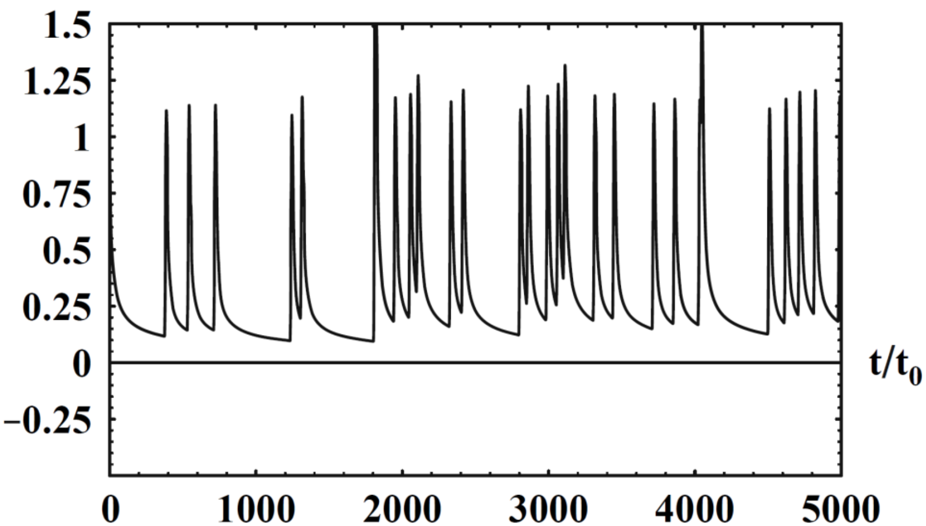


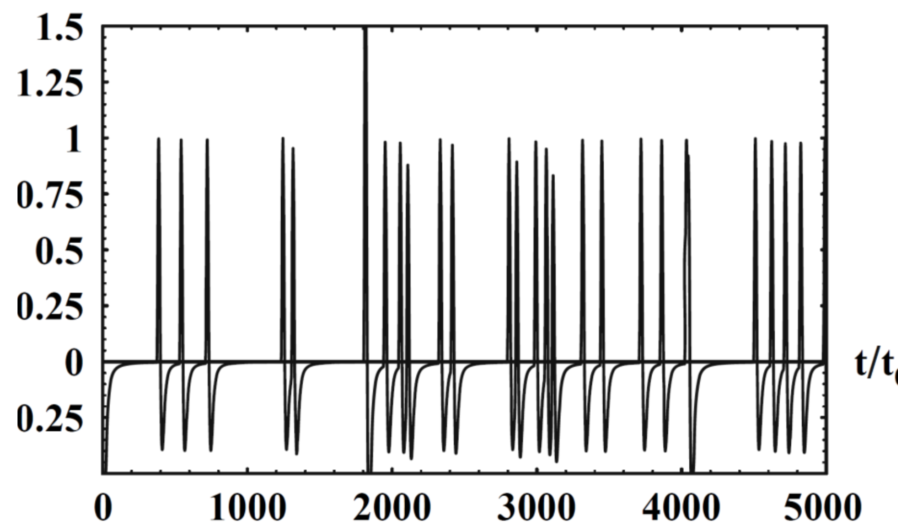
Drift velocity

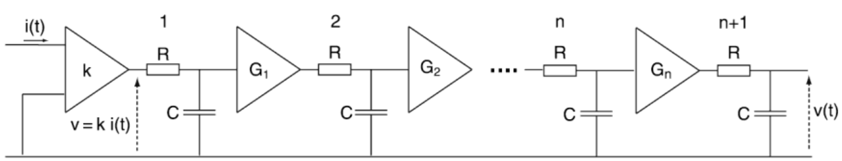


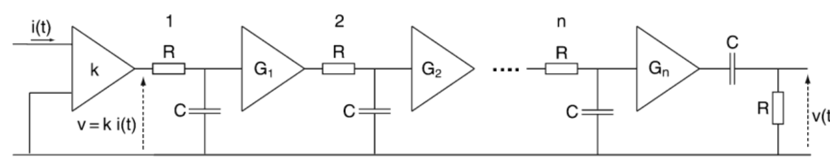


Uni- vs. Bipolar Shaping



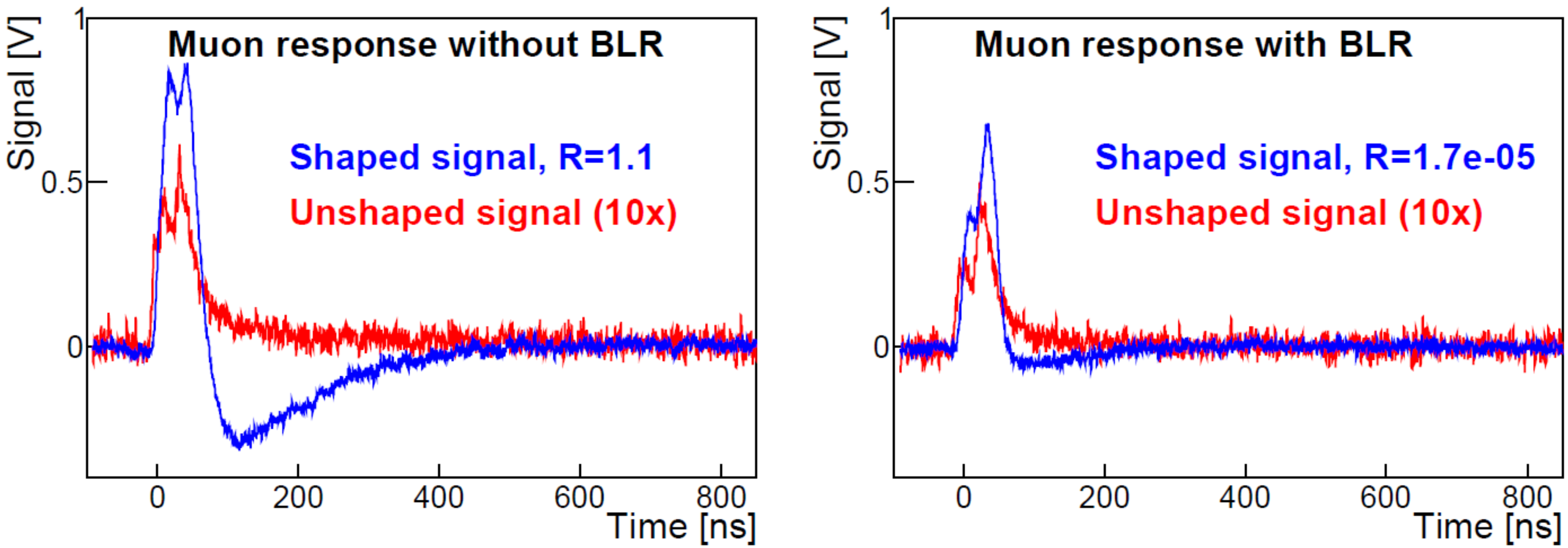






Bipolar shaping preventing a baseline shift.

Reasons for low resolution



– Signal damping

– Higher threshold