High Rate Proton- and Neutron Irradiation of a 15mm Drift tube Chamber

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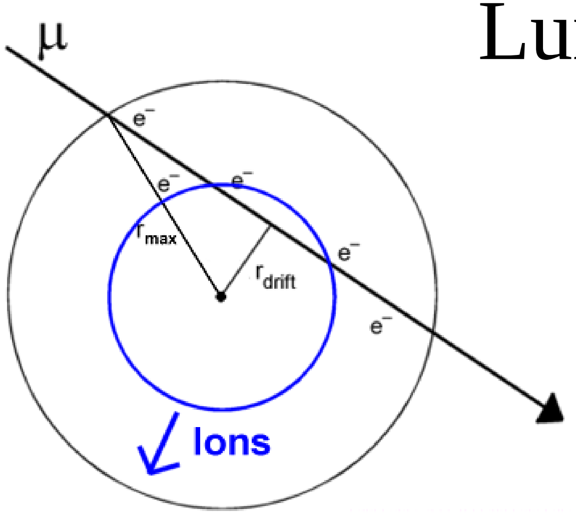
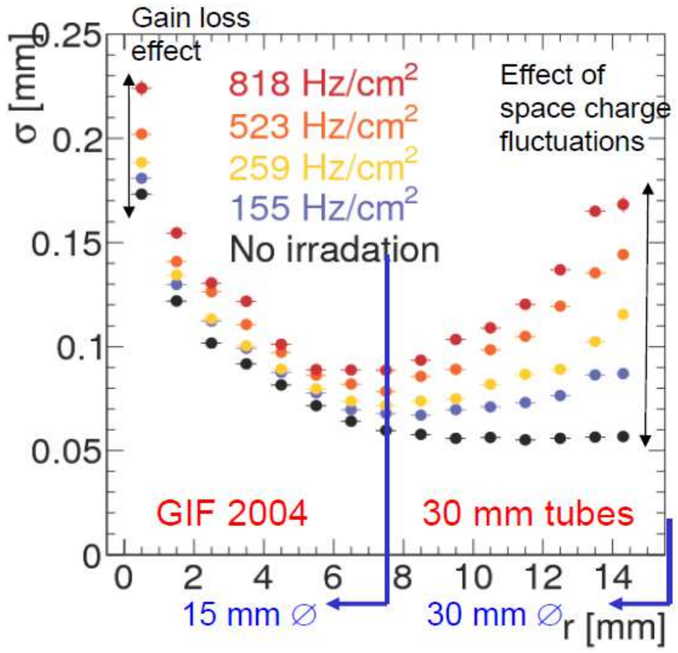
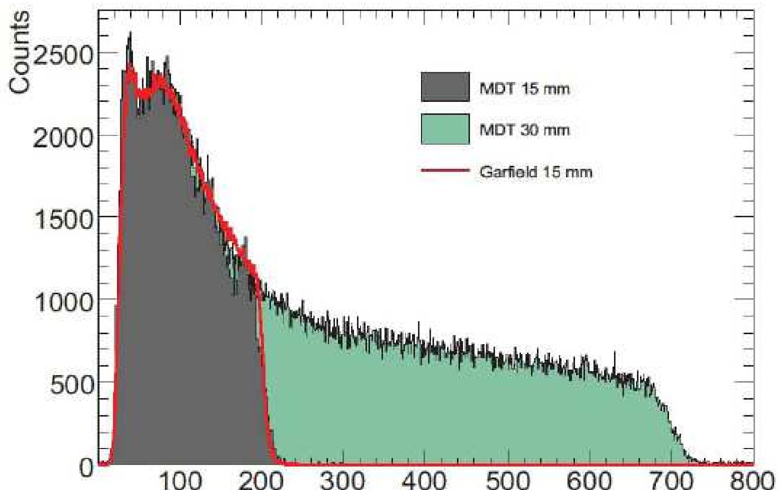
Optimized Drift Tube Geometry for High Luminosity LHC



15mm tubes	**30mm** tubes
D_{anode} = 50 μm	
U = 2730 V	U = 3080 V
$Ar:CO_2$ 93:7	
3000 mbar	
$t_{max} \cong 180$ ns	$t_{max} \cong 700$ ns
$t_{Ion} \cong 1$ ms	$t_{Ion} \cong 4$ ms





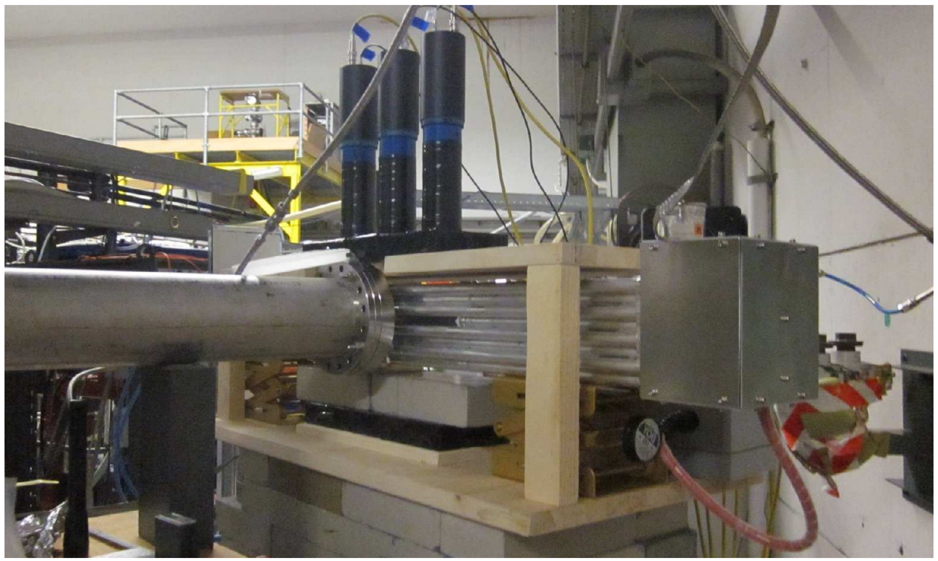
Drift time spectra

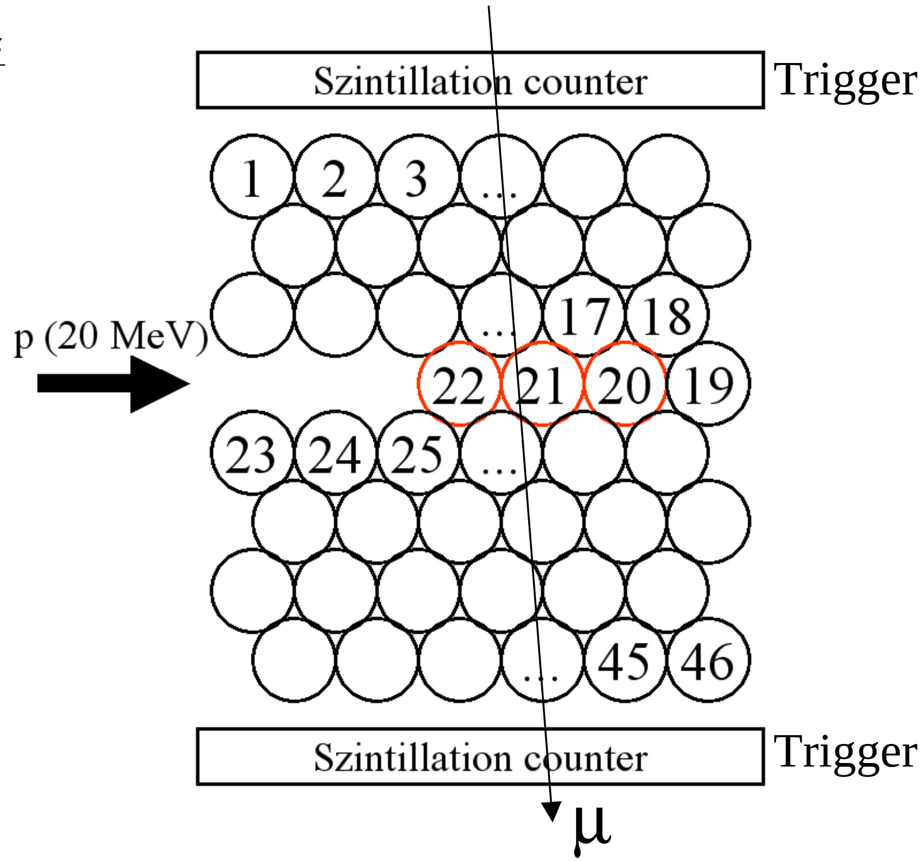
Well Localized 20 MeV Proton Irradiation at Garching Tandem Accelerator

- Beam Spot 7 x 0.5 cm² @800 Hz (Wobbler)
- $\Delta E_{proton} \cong 200$ keV/tube
- $Rate_{proton} \cong 0$ Hz, ~200 kHz, ~1100 kHz, ~1400 kHz /tube
- $Rate_{proton} \cong 0 \frac{kHz}{cm^2}, 19 \frac{kHz}{cm^2}, 105 \frac{kHz}{cm^2}, 133 \frac{kHz}{cm^2}$

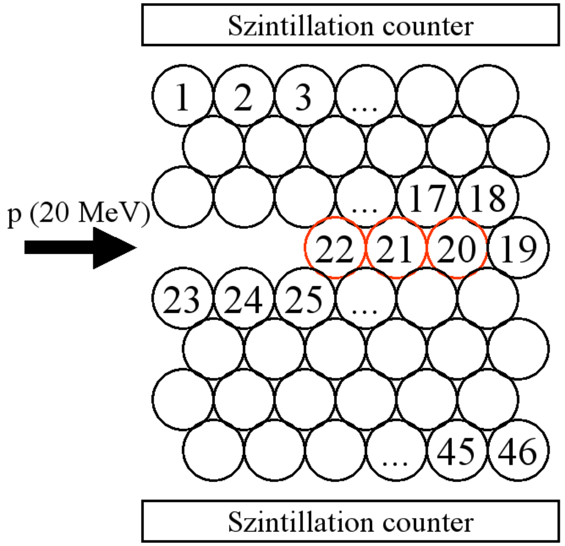
~ High luminosity LHC

- Goal: Efficiency and Resolution under Proton irradiation (neutron simulation)

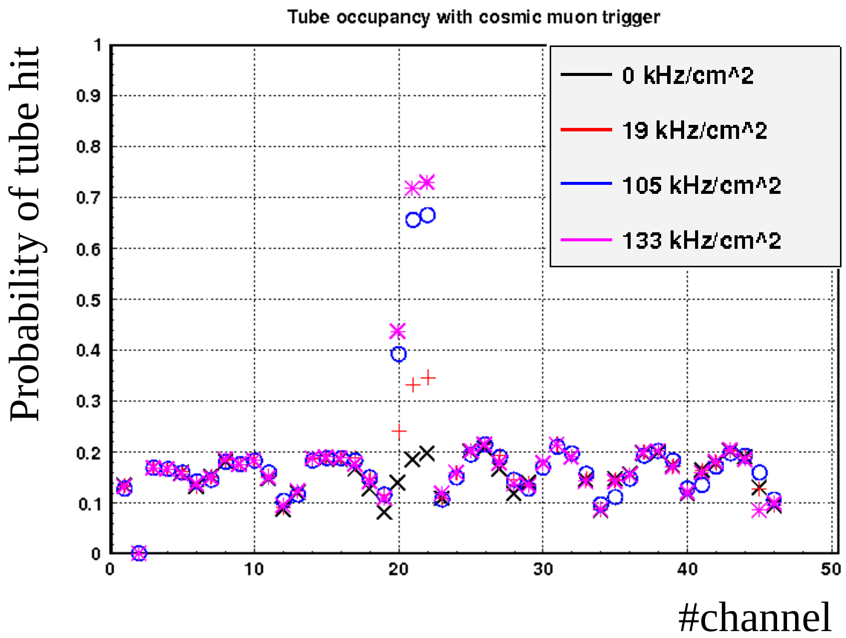


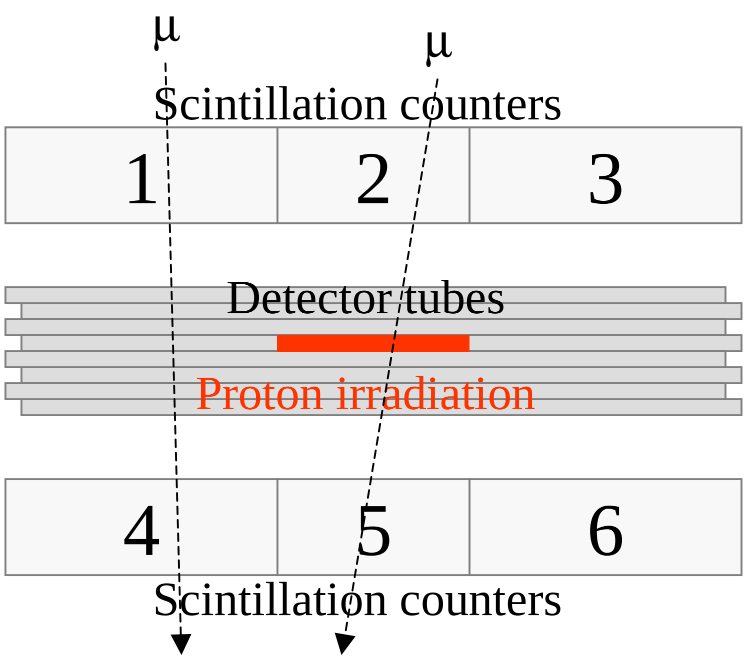


Muon Occupancies



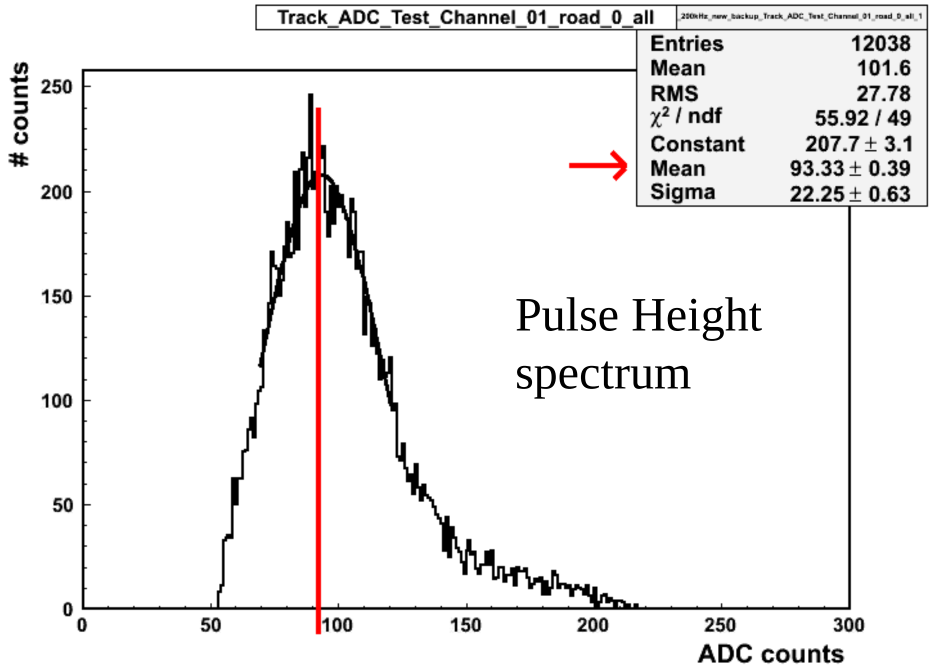
- Three-fold muon trigger to identify tracks through the irradiated area (Scintillator combinations 1-6, 2-5, 3-4)
- Comparison to trigger combinations 1-4, 3-6, non-irradiated areas
- Only one tube layer is hit by protons

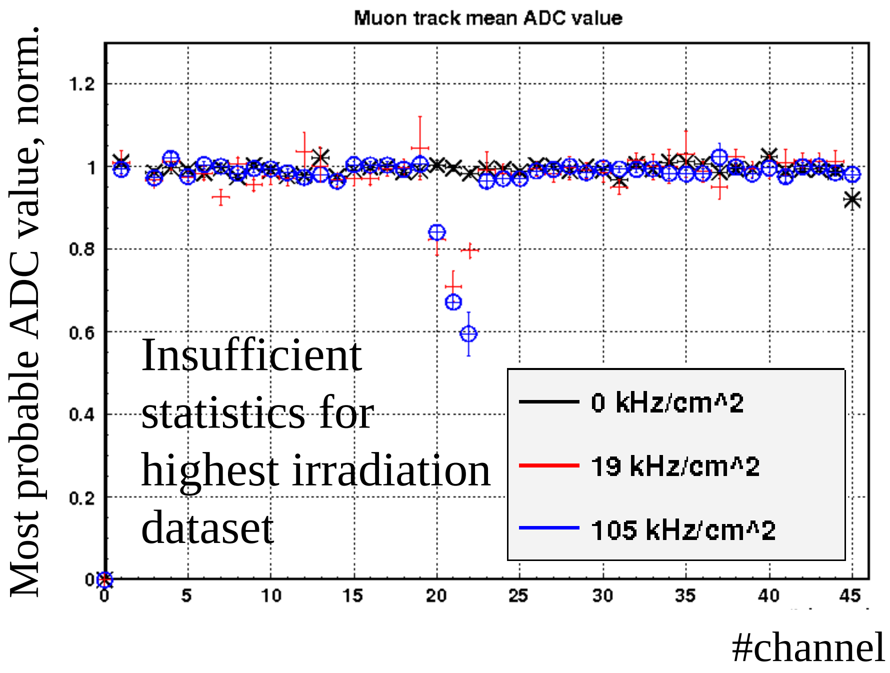




Mean ADC Values for μ-Tracks

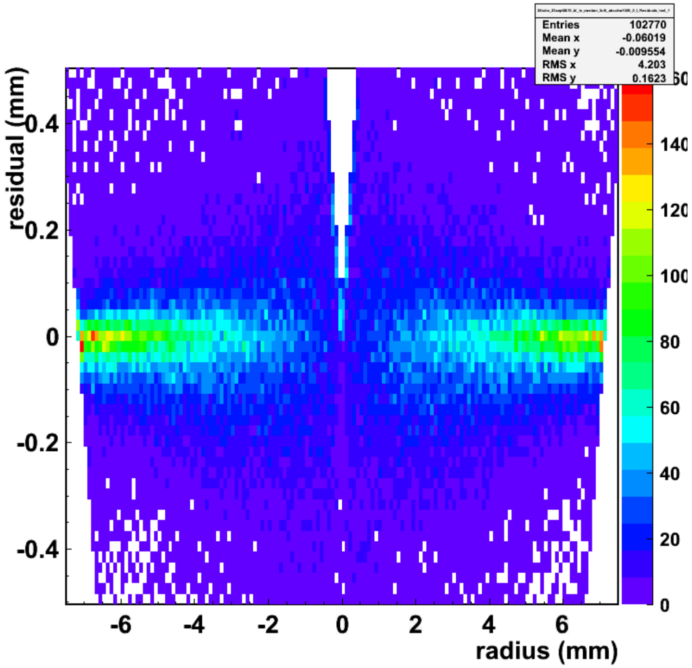
- ADC values for reconstructed muon tracks define gas gain
- Normalised at non-irradiated tube section
- Drop in gas gain by 25% @ 19 kHz/cm²

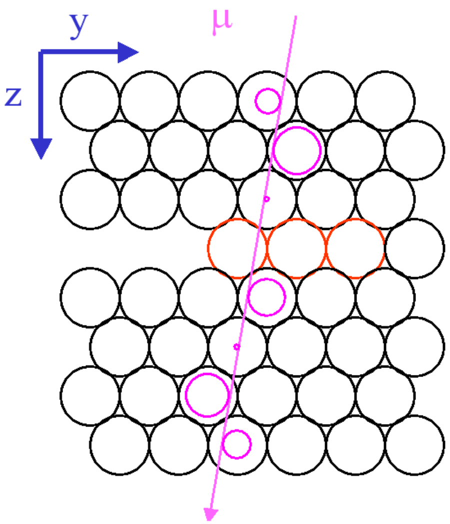


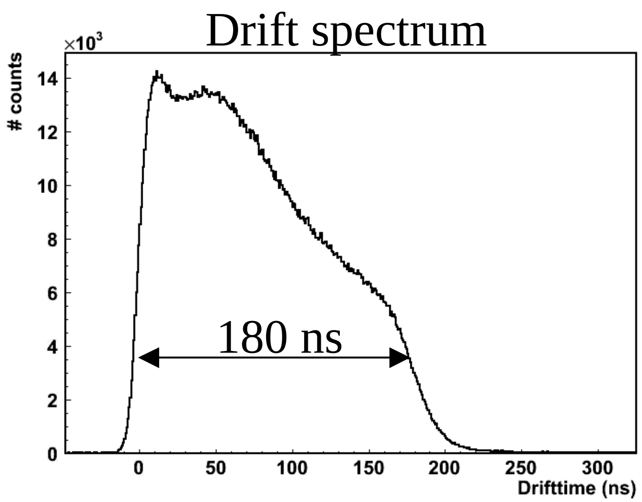


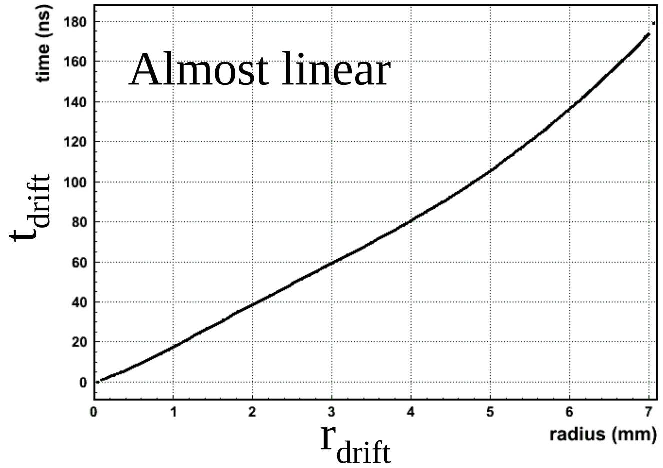
Muon Tracking

- no proton irradiation
- linear fit: y = a * z + b
- Track: 7 layers in Fit, a < 0,3
- Residual := (track prediction radius
  - measured radius)



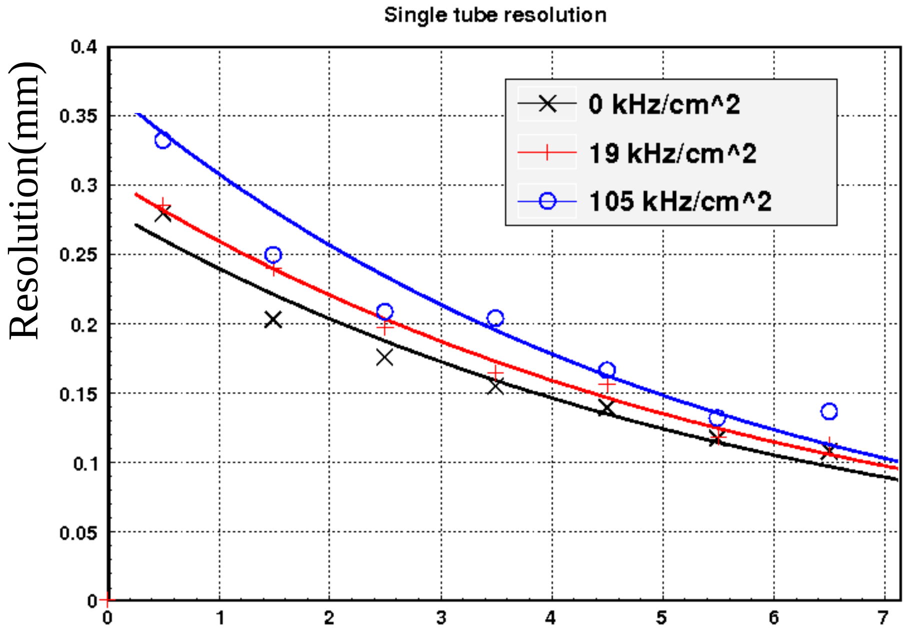


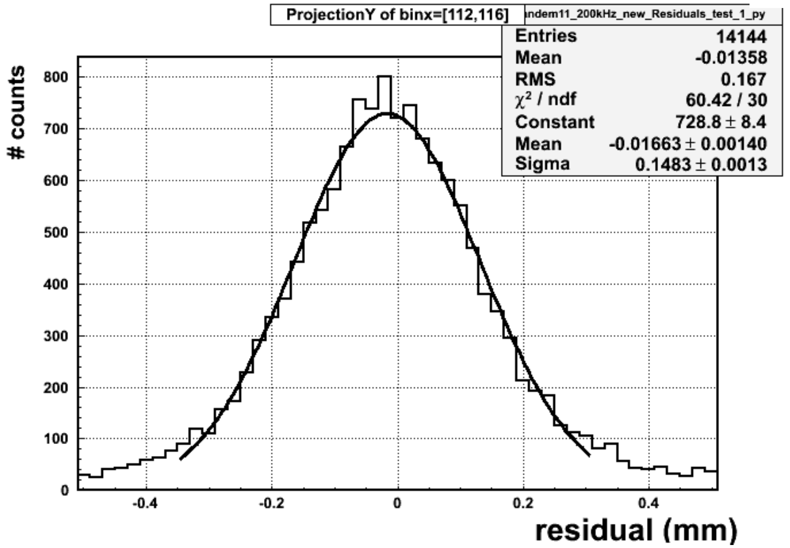




Radius dependent Spatial Resolution

- Determination of spatial resolution:
  - Slice in residual distribution as f(r)
  - Gaussian fit to slice -> Sigma
  - subtract error of track prediction





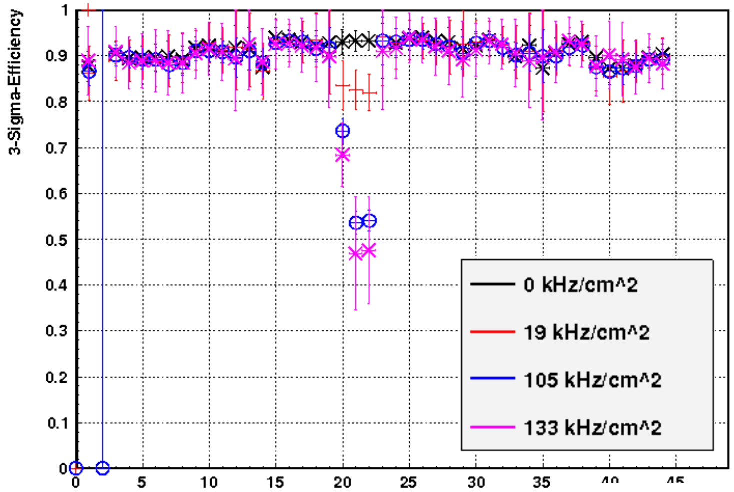
-> Small changes in spatial resolution for the whole chamber, even at very high irradiation levels

Efficiency of irradiated tubes

• 3-sigma-efficiency: percentage of hits with residual smaller than 3 times the spatial resolution

• **non-irradiated tube sections**: drop in efficiency to ~83% due to high channel occupancy

3-sigma-efficiency

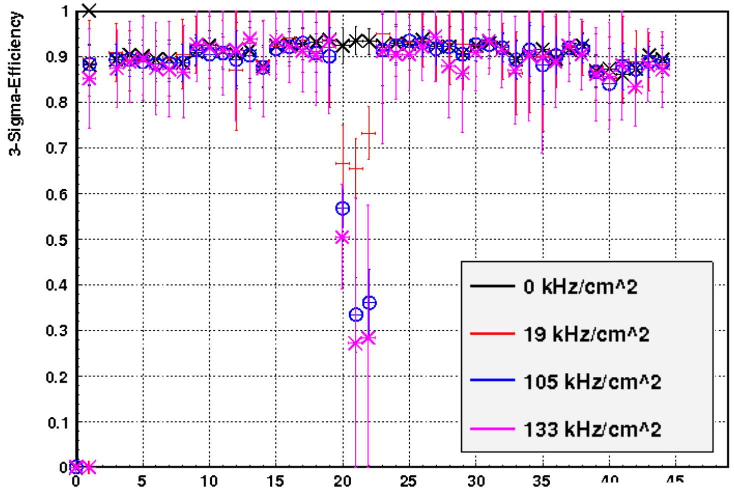


#channel

• Larger efficiency drop in **irradiated tube sections**, ~70%.

• Possible reason: space charge fluctuations lead to changes in drift velocity and misreconstruction of driftradii

3-sigma-efficiency



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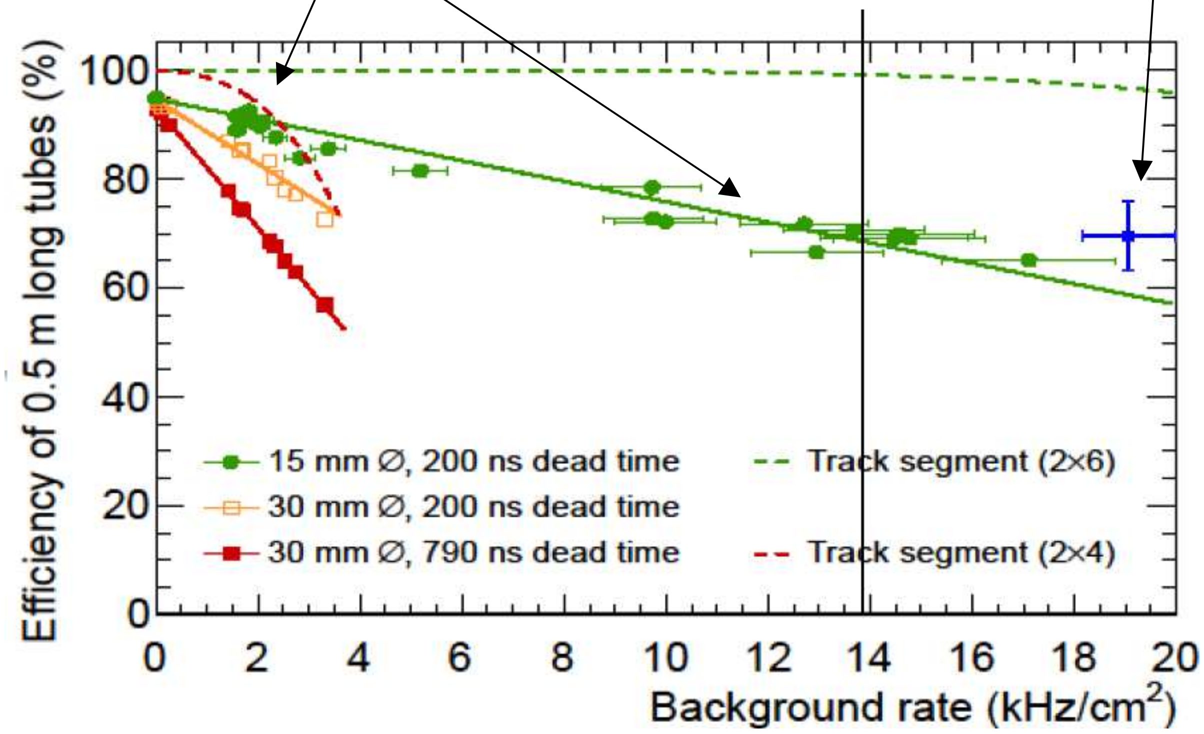
Comparison of measurements

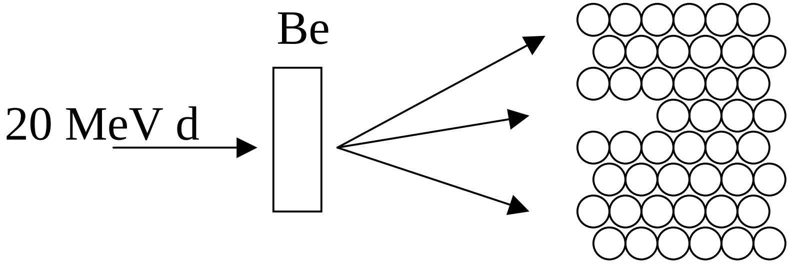
2010/11 GIF measurements

2011 Tandem measurement
100cm tubes, 200kHz proton beam



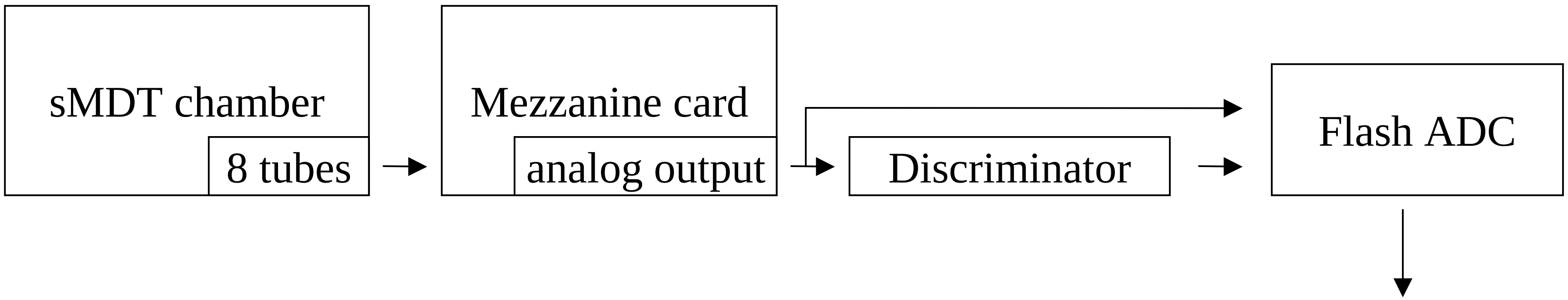
- Efficiency drop of ~24% at 19 kHz/cm²
- ~11% due to Channel Occupancy, ~13% Space Charge

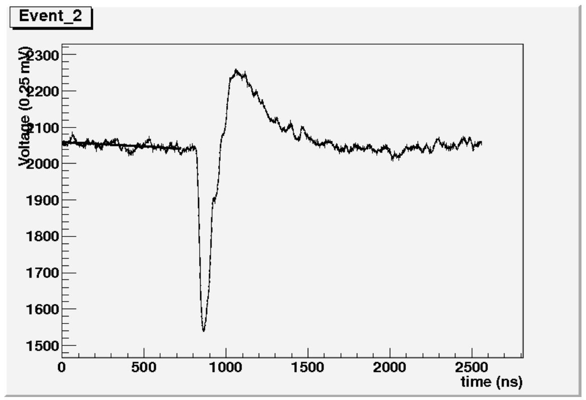
Pulse Shapes under n-Irradiation

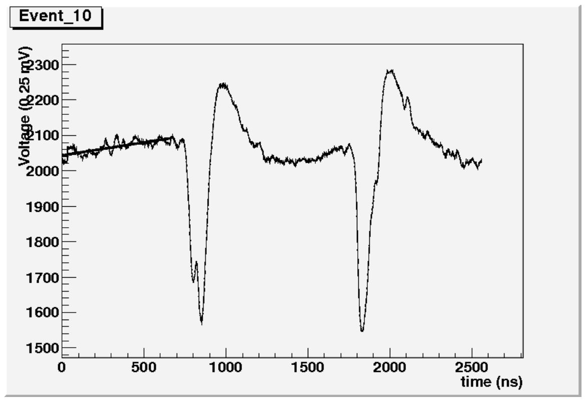


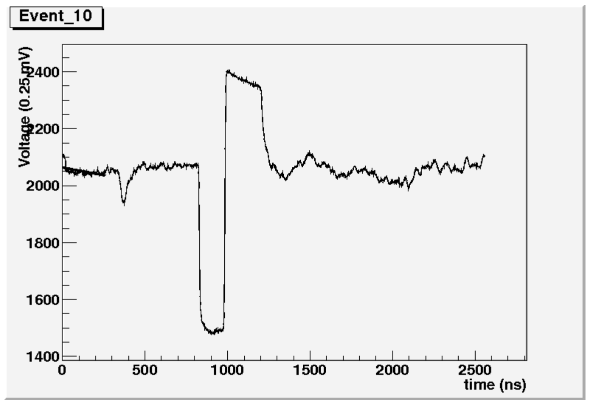
- 11 MeV n +- 5 MeV
- <= 10^7 n/cm²s @ 1 μA d

- Analog output of the amplifier/shaper electronics captured by Flash ADC



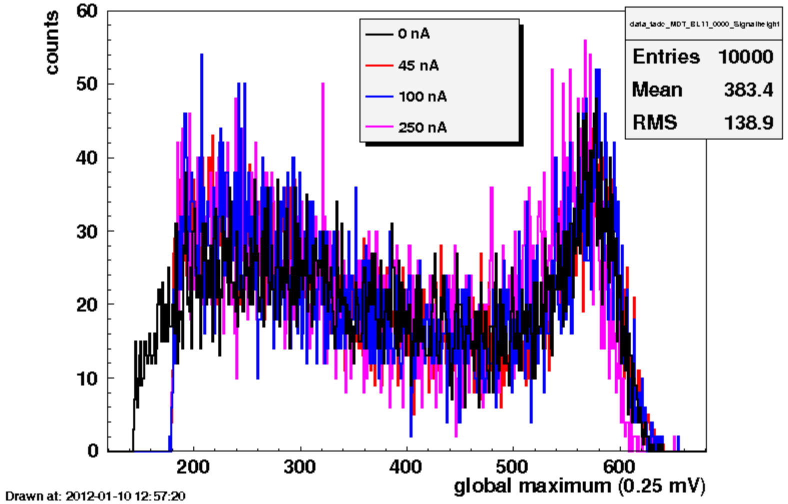




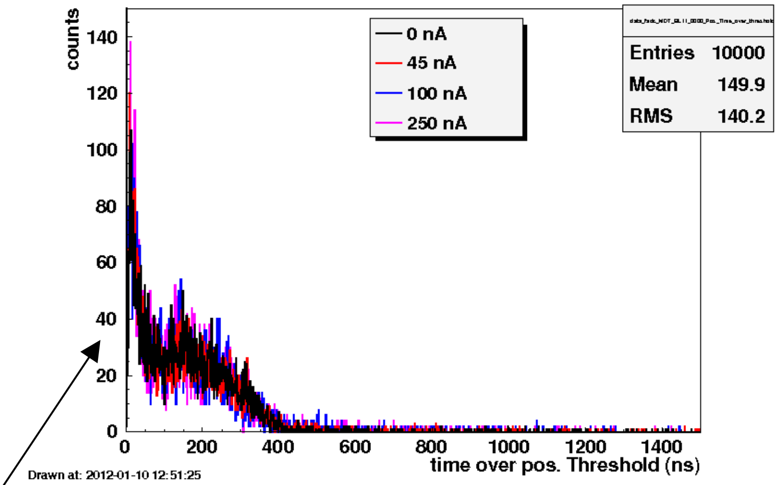


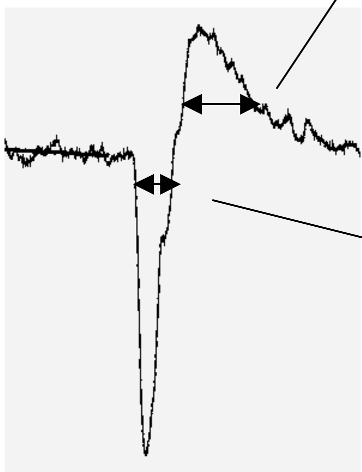
Signal Shape Analysis

Signal Height

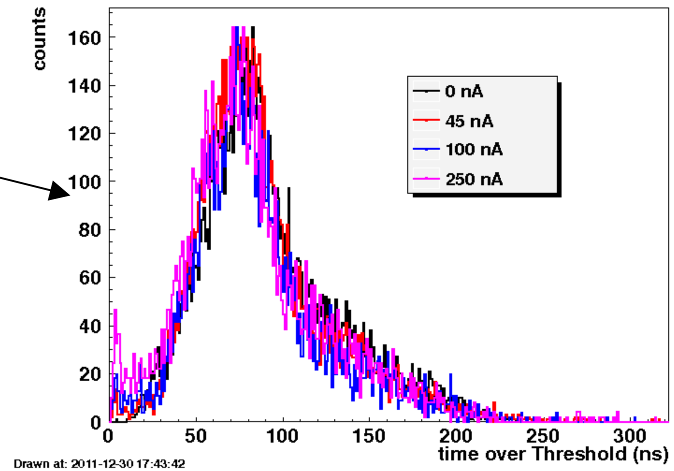


Time over Threshold, pos.





Time over Threshold, neg.



- No difference in distribution of signal height or ~length for all irradiation levels
- No long-term saturation of electronics observed

Summary

• Garching MLL Tandem accelerator: **20 MeV proton and 11 MeV Neutron beams** to simulate high luminosity LHC environments.

• 200 kHz Proton irradiation equals ~**19 kHz/cm²**, about **two times** the hitrate expected at high luminosity LHC.

• Irradiation shifts ADC spectrum to lower values due to space-charge effects.
19 kHz/cm²: **~25 % effect**.

• **Minor effect** on spatial resolution at 19 kHz/cm².

• Efficiency of a single tube drops to **~70%** at this rate. Nevertheless the tracking efficiency of a sMDT chamber with multiple layers fullfills requirements (high luminosity LHC: ~10 kHz/cm²)

• Neutron irradiation seems to have **no negative effect** on the MDT signal shape