HIGH RATE PROTON IRRADIATION OF 15mm MUON DRIFTTUBES

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Future LHC luminosity upgrades will significantly increase the amount of background hits from photons, neutrons and protons in the detectors of the ATLAS muon spectrometer. At the proposed LHC peak luminosity of $5{*}10^{34}\frac{1}{cm^2 s}$, background hit rates of more than $10\frac{kHz}{cm^2}$ are expected in the innermost foreward region, leading to a loss of performance of the current tracking chambers.

Based on the ATLAS Monitored Drift Tube chambers, a new high rate capable drift tube detecor using tubes with a reduced diameter of 15mm was developed as an upgrade option.

To test the response to highly ionizing particles, a prototype chamber of 46 15mm drift tubes was irradiated with a 20MeV proton beam at the tandem accelerator at the Maier-Leibnitz Laboratory, Munich. Three tubes in a planar layer were irradiated while all other tubes were used for reconstruction of cosmic muon tracks through irradiated and nonirradiated parts of the chamber. To determine the rate capability of the 15mm drifttubes we investigated the effect of the high proton hit rate on pulse height, efficiency and spatial resolution of the cosmic Muon signals.

Keywords: LHC, ATLAS, MDT

1. Introduction

At the propsed LHC peak luminosity of $5{*}10^{34}\frac{1}{cm^2 s}$, the innermost foreward region of the ATLAS muon spectrometer will be confronted with a particle flux of about $10\ \frac{kHz}{cm^2}$, leading to a loss of performance of the current tracking chambers caused by high occupancy and space charge effects.

One upgrade option are MDT[a]-chambers with a reduced tube diameter of 15 mm. To study the high-rate capability, a prototype chamber with 46 tubes was irradiated with 20 MeV protons at the MLL Tandem-accelerator in Garching.

2. Experimental setup

Figure 1 shows the experimental setup.
A fast coincidence of the scintillation counters serves as trigger on cosmic muons. The proton beam was defocussed to a beam-spot of $3 * 0.5\ cm^2$ and wobbled with 800 Hz over a horizontal distance of 7 cm. Only the red marked tubes were irradiated by protons, that are - consistent with TRIM simulations - stopped by the second or third tube wall, depending on small angle scattering in the first two tubes.

The triggering scintillators are segmented, thus one can distinguish between muons crossing the irradiated and non-irradiated sections along the 1 m tubes, see fig. 1. Three different beam intensities were used during the measurements, 200 kHz, 1100 kHz and 1300 kHz. Reference runs with no beam were taken.

3. Signalheight

The MDT electronics provides dtrifttime (time between trigger and anode wire signal to reconstruct the distance of the track from the wire) and signalheight of the analog pulse from the wire. This signalheight is measured in ADC-counts, and the signal height spectra for the four tubes in the irradiated detector layer are shown in fig. 3 for the different proton irradiation levels.

In the case of no proton irradiation, all four tubes show a similar spectrum (black) with Landau like energy distribution. At 200 kHz proton irradiation (red), the tubes 22 ans 21, being the first ones hit by the beam, show an overlay of the muon signals with the ones, generated by the protons. The energy spectrum of these proton hits is very broad at high values, even above the dynamic range of the ADC, where the spectrum is cut off.

At the highest irradiation levels (blue and purple), the ADC spectra of tubes 22 and 21 are shifted to the left, where they are cut off by the ADC threshold for small signals. This is due to the reduction of the gas

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[a] Monitored Drift Tube

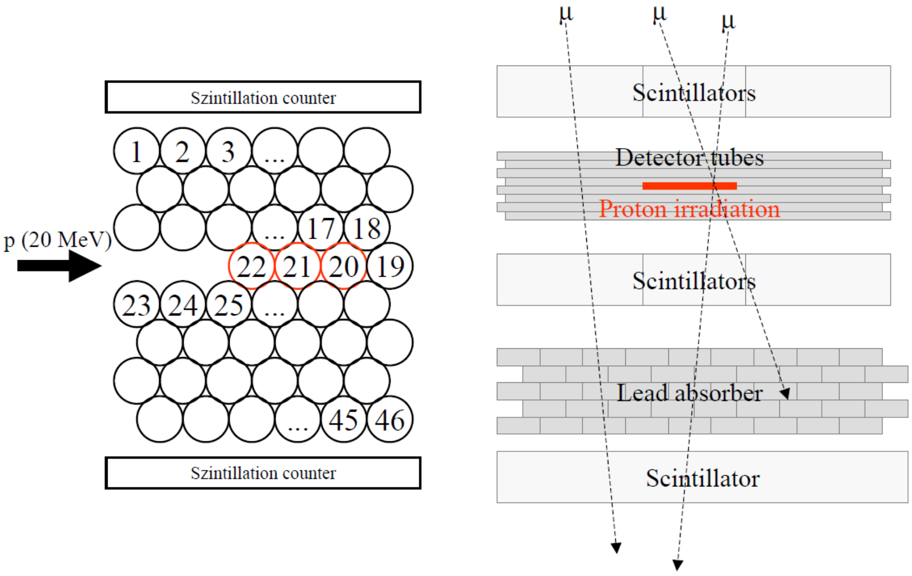
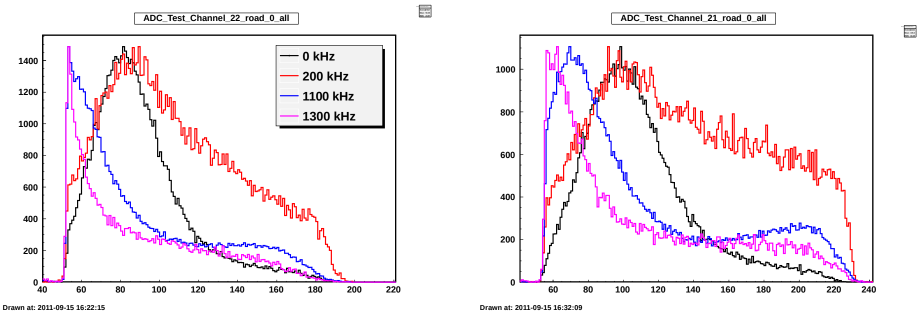


Fig. 1. Schematic side-view of the detector and view from beam direction. The lead absorber and the additional trigger scintillator are used to harden the muon spectrum.



amplification close to the anode wire, caused by the positive ions, drifting slowly to the tube walls. The electric field of these space charges shields the area around the wire and reduces the effective electric potential for gas amplification.

Protons reaching the gas volume of the third tube are stopped there, depositing several MeV of Energy. Because the impact to the ADC spectrum is different, this tube is excluded from consideration here.

Tube 19 shows equal ADC spectra for all irradiation levels, as protons are stopped at last in the third tube.

Figure 2 (left) shows the probability of a detected signal in each tube for a muon trigger. In the case of no irradiation (black), the acceptance of the detector can be observed, with its periodical 8-layer structure with low acceptance at the chamber edges. Due to random coincideces of a proton hit wth a cosmic muon, at 200 kHz there is a 1:1 weighting of muon and proton hits in the irradiated layer, that reaches up to 2.5:1 at 1300 kHz irradiation.

If one considers only the most probable ADC value for hits, that could be matched to tracks of cosmic muons, this can be taken as an indicator for the amount of gas amplification. Figure 2 (right) shows these values for all tubes and irradiation levels, normalised to their values at non-irradiated sections of the tubes.

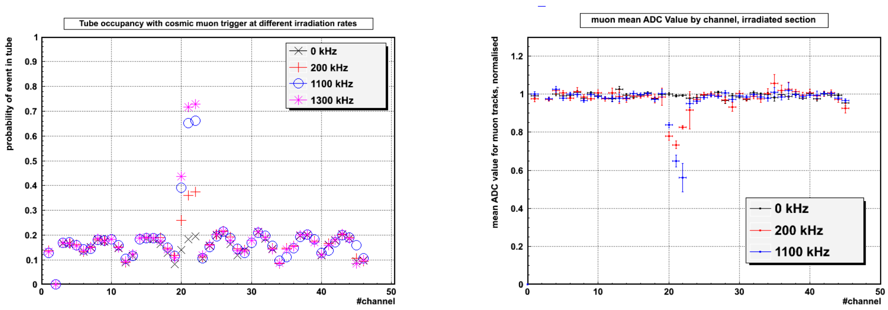


Fig. 2. Occupancy for all events and mean ADC values for muon tracks through the chamber tubes at different irradiation levels

4. Efficiency and Tracking resolution

The spatial resolution of a drifttube can be obtained, by comparing its radius prediction with the one, derived from the track fit through the non-irradiated tubes. Comparing these two different radii introduces the 3-sigma-efficiency, giving the fraction of events where this difference lies within 3 times the spatial resolution of the tube.

Radius dependent resolution and 3-sigma-efficiency are shown in fig. 3. The resolution deteriorates by a few ten μm due to space charge effects at irradiation. Efficiency drops from above 90% to around 40% at the highest irradiation level due to muon hits, masked by preceeding proton hits in the irradiated tubes.

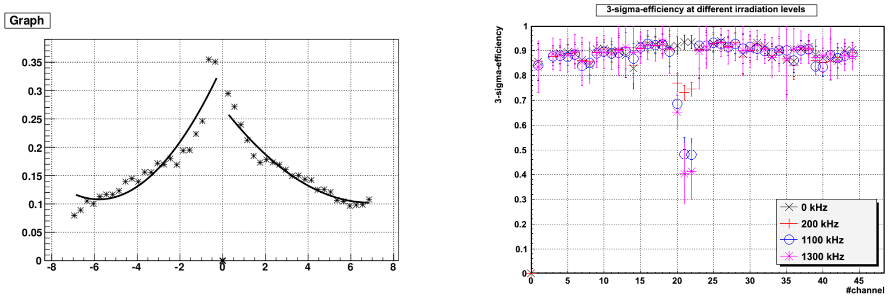


Fig. 3. Spatial resolution and 3-sigma-efficiency for the different irradiation rates

5. Conclusion

With the Garching Tandem accelerator, the predicted values for background irradiation with highly ionizing particles at high-luminosity-LHC could be simulated. The irradiated drift tube chamber with reduced diameter of 15mm shows a decrease of tracking efficiency and gas amplification, due to dead-time and space charge effects.

Proton rate (kHz)	rate in $\frac{kHz}{cm^2}$	Efficiency
0	0	0.93 +- 0.03
200	4.9	0.75 +- 0.03
1100	27.1	0.48 +- 0.06
1300	32.1	0.41 +- 0.1

These effects are small compared to detectors of the currently used drifttubes with 30mm diameter, where the occupancy is about eight times higher, and the degradation of efficiency and resolution is much worse. The number of tube layers per 15mm MDT chamber is doubled compared to a 30mm tube chamber, the overall tracking efficiency of the system is sufficient for the ATLAS detector.

If the irradiation is concentrated to a small tube volume, one can see the effects of space charges as a loss of gas amplification.