Test of New Fast Muon Drift Tube Detectors in a High-Intensity Proton Beam

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The muon detectors of the LHC experiments require high precision tracking detectors covering large areas. The only viable and affordable solution are gaseous detectors. The muon spectrometer of the ATLAS experiment uses 1150 Monitored Drift Tube (MDT) chambers built of 2 $\times$ 3 (or 4) layers of densely packed aluminium tubes of 30 mm diameter, each equipped with a single central anode wire, resulting in 350000 readout channels. Operated with an Ar/CO_2 gas mixture at 3 bar absolute, the maximum drift time of primary ionization electrons to the anode wires is about 700 ns. Up to background counting rates of about 0.5 kHz/cm^2, the MDT chambers reach a spatial resolution of 40 μm and a tracking efficiency of almost 100%. Spatial resolution and detection efficiency degenerate at higher rates due to space-charge effects occupancy for the long drift times, respectively. Upgrades of the LHC beyond its design luminosity of 1×10^{34} cm^{-2} s^{-1} will require a rate capability of the muon tracking chambers of up to 10 kHz/cm^2. A cost-effective and robust upgrade solution for the ATLAS muon spectrometer consists of substituting the muon chambers in the high–rate endcap regions by drift-tube chambers with smaller tube diameter of 15 mm. Keeping the operating parameters (gas mixture, pressure, and gain) like for the present MDT chambers allows for integration into the muon spectrometer using the existing gas distribution system. The smaller tube diameter significantly improves the rate capability:

- The maximum drift time is reduced by a factor of 3.5 to about 200 ns and the tube cross section by a factor of 2 reducing the occupancy by a factor of 7.
- Gain drop effects due to space charge near the wire are suppressed by a factor of about $(1/2)^3$ while the effects of space charge fluctuations for drift radii larger than 7 mm deteriorating the spacial resolution are eliminated, keeping the resolution almost constant up to high rates.
- The increased number of tube layers fitting within the same geometrical envelope allows for significant improvements of the tracking efficiency.

The performance of the 15 mm diameter drift tubes under irradiation with highly ionising particles was studied with a high-intensity proton beam at the Van-der-Graaf-Tandem accelerator of the Meier-Leibnitz-Laboratory (MLL) at Garching, Germany. For this test a special chamber with 46 15 mm diameter tubes was built allowing for irradiation of tubes in the centre of the detector (see Figure 2). To measure the influence of the proton background radiation on the reconstruction efficiency of muons, a trigger for cosmic muons covering the whole irradiated region was set up. A picture of the setup is shown in Figure 1. To ensure precise and reliable tracking of the cosmic muons, the lower 4 and top 3 layers are shielded from the beam. This setup allows for the measurement of the single tube efficiency and resolution as a function of the proton rate with high precision. The efficiency of detecting a muon hit with the correct drift radius with 3 times the tube resolution (3σ tube efficiency) was measured up to a maximum background counting rate of 0.9 MHz per tube.

Results for the single-tube efficiency and single-tube resolution will be reported. Other test measurements at CERN with the new 15 mm diameter drift tubes at high γ background rates as well as in a high momentum muon beam will be compared to the new results.

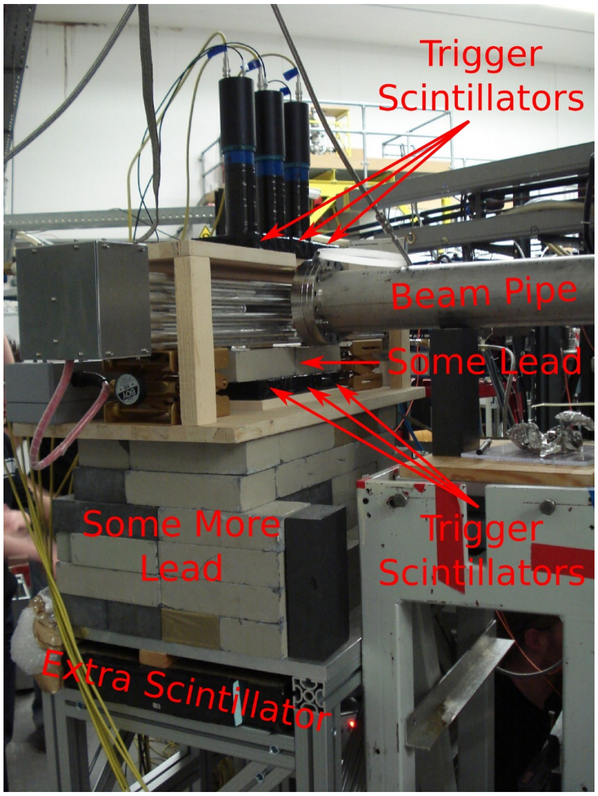

Figure 1: Setup used for the studies with a high intensity proton beam.

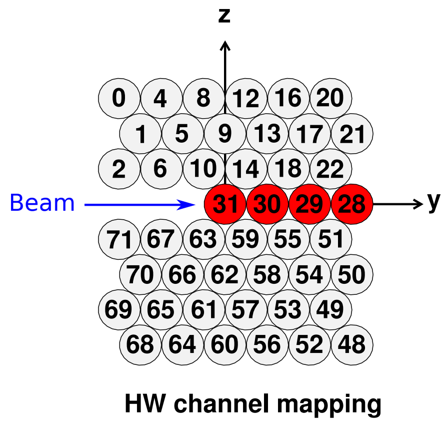

Figure 2: Layout of the test chamber layout. Irradiated tubes are marked in red (dark).

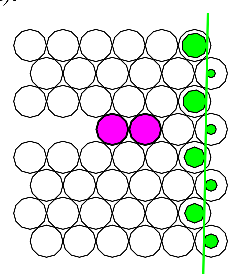

Figure 3: Sample event display: muon hits are indicated in green (grey), proton hits in pink (dark)