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Development and Testing of a High-Rate Capable Resistive Plate Chamber at GIF++, CERN in 2023

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Introduction

The Compressed Baryonic Matter (CBM) experiment, set to take place at the upcoming Facility for Anti-proton and Ion Research (FAIR) in Darmstadt, Germany, will incorporate a range of advanced detector systems, including the Silicon Tracking System (STS), Ring Imaging Cherenkov (RICH) detector, and the Muon Chamber (MuCh)[1], among others. The MuCh system will serve as the primary muon detection apparatus. It will feature absorbers interspersed with muon detectors, enabling momentum-dependent track identification and enhancing the detection efficiency of low-momentum muons. Resistive Plate Chambers (RPCs) will be installed in the 3rd and 4th stations[2]. The particle rates in these stations are expected to reach up to 30 kHz/cm^2 and 10 kHz/cm^2, respectively. In preparation for this, a full-scale RPC prototype with a 2 mm gas gap was developed and rigorously tested at the Gamma Irradiation Facility (GIF++) at CERN. The objective of these tests was to evaluate key detector parameters, including time correlation, efficiency, and rate-handling capabilities, under varying conditions of photon flux, operating voltage, and threshold settings. The following sections present the experimental setup, followed by a discussion of the preliminary results.

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FIG. 1: RPC detector inside aluminium box with Front-end elctronics. Left to right there are 46 sectors and in each sector there are 10 channels.

Experimental Set-up

GIF++ accommodates a Cs-137 gamma source with an activity of approximately 14 TBq (as of 2014). This facility features various attenuation filters to adjust the photon flux. Positioned on the H4 beamline at the EHN1 North Area of CERN, it offers a high-energy muon beam (up to 150 GeV/c). The RPC Fig.1 was housed within a rectangular aluminum enclosure equipped with an adjustable support structure, allowing for flexibility in positioning the detector relative to both the gamma source and the muon beam impact point on the detector. A photograph of experimental hall along with the setup has been shown in Fig.2.

To create a trigger signal, we utilized a coincidence of signals from three distinct scintillators, two positioned in the upstream and

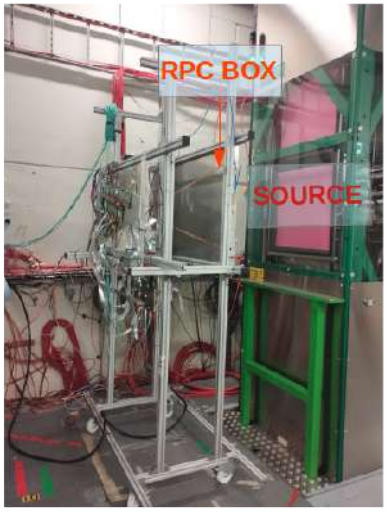

FIG. 2: Experimental Set-up at GIF++, CERN. The RPC box was positioned 60 cm away from the source wall in the downstream direction.

other in downstream direction.The detector was supplied with a wet gas mixture consisting of R134a : iC4H10 : SF6 in a ratio of 95.2 : 4.5 : 0.3, along with 40% humidity, at a constant flow rate of 4.0 lt/hr.

Result

Time correlation with the trigger system is essential for calculating the detector's efficiency. Genuine RPC hits must align with the trigger signals. Figure 3 shows a typical time correlation spectrum of the detector at 9200 V using a muon-only setup. The secondary peak, caused by cross-talk, appears in lower ADC regions. It has been observed that the secondary peak becomes insignificant when photon source is on(as shown in figure 4). Detector rate handling capability was measured using photon source. Maximum rate is found to be 60 KHz/cm^2, as shown in Fig. 5.

Summary

The real size single gap RPC has been tested with muon for time-correlation, efiiciency, rate handling capability. Detector shows more than

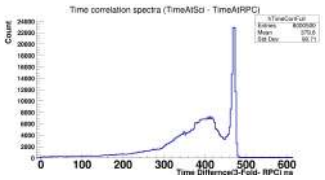

FIG. 3: Time correlation of muon without Gamma source

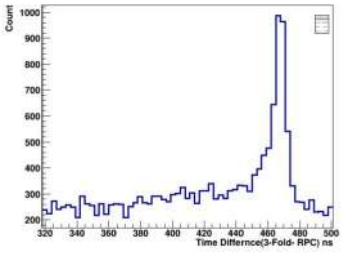

FIG. 4: Time correlation with Gamma source

90 percent muon detection efficiency at operating voltages. We found the highest digi rate is around 60 KHz/cm^2. Initial results of time-correlation, efficiency, cross-talk anlysis is presented here.

References

[1] Technical Design Report for the CBM : Muon Chambers (MuCh), https:// repository.gsi.de/record/161297.

[2] Development and performance studies of a real size RPC tested at GIF++, CERN CBM-MuCh at FAIR, Germany, R.Ganai et. al

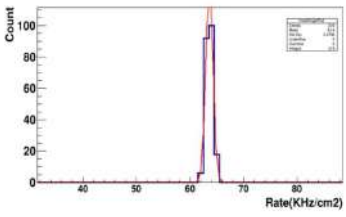

FIG. 5: Maximum rate of the detector