MPRC performance evaluation in a heavy ion beam test at GSI∗

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The CBM Time-of-Flight-wall will be composed of Multi-gap Resistive Plate Chambers (MRPCs) [1]. In order to approach a final MRPC design several counters from different groups were tested in October 2014 in a heavy ion test beam time in the Hades-cave of GSI. A Sm beam of an incident energy of 1.1 AGeV beam energy was used to produce a spray of reaction products by hitting a 5 mm thick lead target. By this a full illumination of the counters has been achieved that is extremely important for determining the counter properties under real usage condition.

Figure 1 depicts the test beam setup that is constituted from two parts. Each part consist of two MRPC counters under test, a reference MRPC and a plastic scintillator in front and behind the counter stack. The scintillators were read on both sides with PMTs. The counters in the upper part of the setup were located close to the beam line in order to get the highest possible particle flux. The counters under test were a narrow strip prototype from Bucharest [2] (called Buc2013) and a PAD-MRPC [3] from Tsinghua University, China. These two counters were mounted in the upper part on a rail in order to exchange their position. The measured flux (estimated from the plastic scintillator) at this position was about 1 kHz/cm². In the lower part of the setup the counter under test was a full size prototype from Heidelberg [4] (called HDMRPC-P2) that was exchanged after half of the beam time by a strip counter from Tsinghua University. These two counters have similar dimensions and the same pickup electrode geometry. However, they differ significantly in the design of the HV regions (single stack (P2) vs. double stack (Tsinghua). The measured flux at the location of these counters was about a few hundred Hz/cm². Additional timing information was provided by a diamond detector which was installed a few cm in front of the target.

The data acquisition during this in-beam test was based on the TRB3 platform [5] providing trigger and readout handling more than 30 FPGA-TDCs with 32 timing channels each. The TDCs digitize the arrival times of both leading and trailing edges of LVDS signals created by the preamplifier/discriminator ASIC PADI [6] directly connected on the MRPC readout electrodes. The width of these LVDS signals corresponds to the time over discrimination threshold (ToT) of the analog detector signals. The TDC core [7] is implemented on Lattice ECP3 FPGAs, residing both on the TRB3 board and on TDC front-end cards (CBM-TOF-FEE1) hooked up in close vicinity to the MRPCs [8].

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The analysis of the data proceeds in the following steps:

1) Data unpacking and TDC nonlinearity calibration: For the nonlinearity calibration 8 hours of data taking is used for a calibration file in order to have a statistical sufficient data sample that ensures sufficient population in every TDC bin.

2) Time and position offset calibration, cluster building and walk correction: A firing strip delivers a time information on both ends of the strip. The mean of the two signals provides the arrival time of the signal of the strip. The difference delivers in combination with the signal velocity the position of the hit along the strip. Neighboring firing strips in the MRPC are grouped together to a cluster if they are correlated in time and space. The correlation window was set to 500 ps in time and about 8 cm in space. The cluster time is calculated by taking the mean of the strip times weighted with the time over threshold information. In an event several cluster can occur on the MRPC surface.

3) Particle velocity spread and hit position correction. Steps 2 and 3 are done iteratively.

4) Data analysis with different cut settings: Cuts are applied on the reference counters in order to provide an as clean as possible event sample.

Here we present the results obtained with the Heidelberg prototype HDMRPC-P2. Figure 2 shows the counter efficiency as function of the applied high voltage (HV) for a PAD16 threshold of 150 mV (red triangles) and for 200 mV (blue squares). The efficiency is calculated by comparing the matched hits between the counter under test and the ref-
erence MRPC with the matched hits between the diamond start counter and the reference MRPC. At an applied high voltage of ±10.5 kV the effect of the discriminator threshold is visible. A smaller electric field produces smaller signals that can be detected with a lower threshold. This effect disappears with higher HV i.e. with higher electrical field. The outlier at ±12.5 kV needs further investigation. An overall efficiency of larger than 98 % is observed at the nominal working voltage (±11 kV to ±11.5 kV). The statistical errors are too small to be visible in the plot. The system time resolution obtained between HDMRPC-P2 and HD-ref is presented in Fig. 3. It is calculated by subtracting the time of those clusters from both counters that have the best $\chi^2$ - matching value i.e. those that are best correlated in time and space. The excitation function of the time resolution shows a broad minimum at about ±11.0 kV (corresponding to an electrical field of 125 kV/cm) for both threshold settings. The best system time resolution is about 62 ps. Assuming both MRPCs have the same performance the individual MRPC has a time resolution in the order of 44 ps including the jitter of all electronic components. The increase towards higher voltages can be explained by two facts: 1) with higher voltage more and more streamers are produced and 2) the increasing noise rate disturbs the cluster time. The results at a PAD6 threshold of 150 mV are slightly worse than for 200 mV. The statistical error is about 0.5 ps.

Figure 4 illustrates the mean cluster size as function of the applied high voltage (HV) for a PAD6 threshold of 150 mV (red triangles) and 200 mV (blue squares). The data show an almost linear increase with HV for both thresholds reaching a maximum at ±12.0 kV. At ±12.5 kV the mean cluster size drops again and has the same value for both threshold settings. This behavior is still under investigation. We acknowledge the contributions of all members of the CBM-TOF group to this report.

References


Figure 2: Efficiency as function of the applied high voltage at a PAD6 threshold of 150 mV (red triangles) and 200 mV (blue square).

Figure 3: System time resolution as function of the applied high voltage at a PAD6 threshold of 150 mV (red triangles) and 200 mV (blue square).

Figure 4: Mean cluster size as function of the applied high voltage at a PAD6 threshold of 150 mV (red triangles) and 200 mV (blue square).