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Assembly and operation of a baseline-design MSGC detector module for the CMS forward tracker

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Abstract

We report on the assembly and test beam results of a baseline-design MSGC detector prototype as foreseen for the CMS forward tracker. Particular attention is given to the optimization of assembly procedure and tooling. We present the detector response as a function of operational parameters and give results on the detection efficiency and spatial resolution.

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1 Introduction

In the CMS tracker the largest fraction of the sensitive volume is planned to be equipped with MSGCs. In the forward–backward region, these chambers will feature wedge–shaped MSGC substrates with anode strips pointing to the center of the beam pipe. A certain number of substrates will form a ring–sector shaped detector module. These modules are mounted on support disks.

A milestone prototype (MF1) was set up to study the system aspects of the construction and operation of such detector modules with wedge–shaped substrates [3]. In particular two different construction concepts, "closed design" and "open design", had to be evaluated. In this framework the Karlsruhe CMS group produced an "open" detector module. As a result of this milestone experiment, the concurrent "closed" design was chosen as baseline solution described in the tracker technical design report [1]. The reason for this choice was a more robust assembly procedure. A detailed description of the two design scenarios can be found in references [1] and [2].

Consequently, the different groups involved in the construction of the forward MSGC tracker have to demonstrate their capability to build detector modules of the new baseline type and have to set up a feasible production scenario adapted to the local infrastructure.

Here we describe the production aspects of a closed forward prototype detector. Like in MF1, it was not our goal to evaluate the survival potential as needed for the operation at LHC conditions. For this reason, no best performance prototype MSGC substrates were used. We present, however, the performance of the Karlsruhe prototype detector in a 100GeV muon beam at CERN SPS (X5).

2 Concept of the prototype detector module

As the design is described in detail in the CMS tracker technical design report [1] we will give here only a brief description.

The module consists of 4 wedge shaped MSGC substrates with 512 read-out channels each, arranged side by side in a common gas volume to achive wall–less φ–cracks between the substrates. The substrates are glued onto a support frame (figure 1 left). This frame has spokes below the substrate boundaries for mechanical rigidity. On top of the substrates a 3mm thick distance frame is glued which defines the conversion volume of the gas detector (figure 1 middle). The gas volume is closed by means of 4 individual metalized glass plates acting as drift field cathode plane. These glass plates are glued to the bottom of a top support frame (figure 1 right). The resulting sandwich is sealed on both sides with a thin aluminized polyimide foil glued onto the support frames. A system of holes in the spokes of the support frames conducts the exhaust gas through the volumes between the cover foils and the substrates/drift cathodes. This eliminates any pressure difference on the thin plates. The anode strips are connected to Premux128 [5] electronic hybrids, which are glued to the substrate support frame.

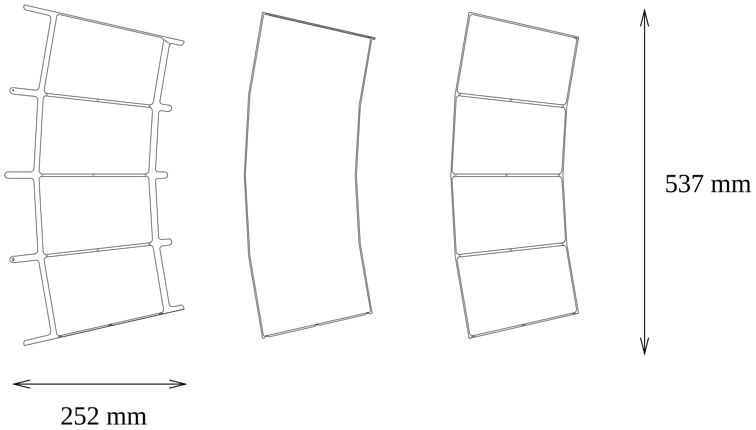

Figure 1: *The three frames of a closed MSGC detector module.*

In the detector module described here the two outermost substrates are replaced by dummy glasses in order to reduce expenses. The substrates used are of the same type as for MF1 (500nm gold artwork on bare D263 glass).

3 Assembly

The assembly procedure described below is performed entirely inside our clean room.

3.1 Cleaning

Before assembly, the frames are cleaned with isopropanol. The drift–cathode plates are cleaned in an ultrasonic bath of deionized water at 60°C. For the substrates, additional baths of acetone and isopropanol are applied. When transfering from one bath to another, the substrates are rinsed with deionized water. At the end of the cycle, the substrates are dried using nitrogen gas.

3.2 Alignment and glueing

The drift cathode glasses are glued to the drift support frame. The spacer frame is glued on top of the substrates. For this prototype, all glueing was done using Araldit AV116, which cures at room temperature within 24h. Figure 2 shows the upper half–module consisting of drift support frame, drift cathodes and spacer frame during the curing process in a flow box.

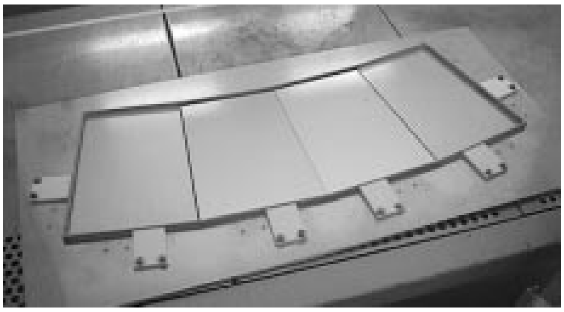

Figure 2: *The upper half–module curing in the flow box. The two outermost glasses are unmetalized dummy drift planes.*

Figure 3: *Lower half–module: The substrates are aligned with respect to the support frame. The two outermost glasses are unmetalized dummy substrates.*

The MSGC substrates are aligned with respect to the substrate support frame using a dedicated glueing jig on a 3D coordinate measurement table. As shown in figure 3 the position of the fiducial marks on the substrates is monitored via a CCD microscope head mounted on the arm of the positioning machine.
After alignment the position of the substrates on the support frame is fixed with dots of a fast curing glue (outside of the gas volume). After allowing these fixations to harden for 1h, the upper half–module is glued on top of the lower half which is still fixed to the glueing jig. After 24h the chamber is turned upside down and the gas volume is sealed from the backside of the substrates.

Finally the two foils which seal the gas return system are glued on both sides of the module.

3.3 Electrical connection

All the connection pads on the substrates are outside of the gas volume of the detector. The cathode groups are wire-bonded to a high voltage hybrid with on–board protection resistors; each group of 16 cathode strips is protected by an effective resistance of $2 \times 4,7\text{M}\Omega$.
The Connection to the drift cathodes is made by glueing a thin wire to a small piece of the metallized glass drift electrode extending out of the frame using conductive glue.
The anodes are wire-bonded to the pitch adaptors residing on the MF1–style Premux hybrids. The hybrids are connected to the server board electronics developed in the framework of MF1.

4 Assembly experiences

During the assembly two major problems were detected. It turned out that the unfavourable viewing angle of our bonding microscope would make the bonding of the anode strips impossible, because the bond pads would be hidden by the sandwich of spacer frame, drift glasses, upper support frame and top foil. The bonding was only

Figure 4: *The two half–modules are glued together.*

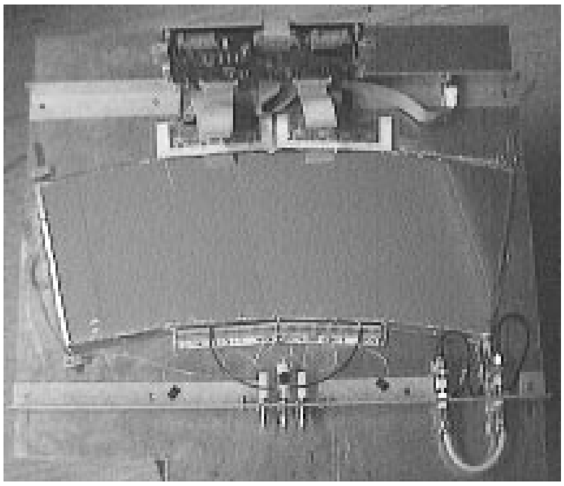

Figure 5: *The chamber ready for operation*

possible by postponing the glueing of the top foil. Even in this configuration the bonding was still difficult, as only a small fraction of the anode bond pads was visible through the microscope. As a result, the bonding yield on the read–out side was not satisfactory.

After the assembly of the module, the bonding machine was modified to have a better adapted viewing angle. The feasibility of bonding a closed module on the modified machine has been demonstrated with the construction of a closed GEM+MSGC module [4], with an even more restrictive geometry.

Since the drift plane is confined completely by the frames, a small triangular piece has to extend out of the sealed volume to enable HV connection to the drift cathodes using conductive glue. Producing glass plates of such shape is difficult. To avoid this problem in the future, we studied an alternative glass–less drift plane design. It is implemented in the closed GEM+MSGC module which was succesfully operated in a high rate pion beam at PSI.

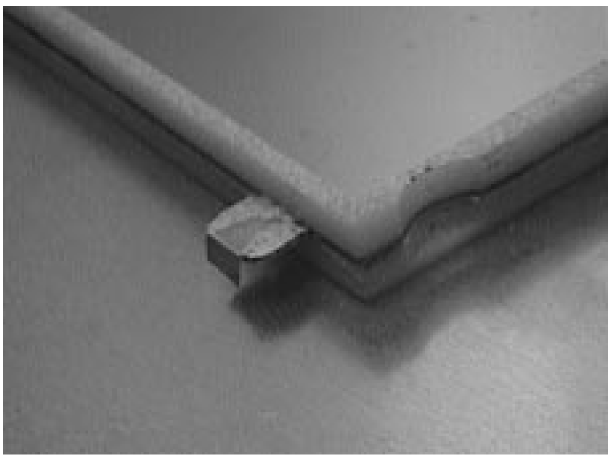

Figure 6: *Voltage connection of the glass–less drift plane.*

Figure 6 shows the drift voltage feed–through of the glass–less drift plane which consists of a $370\mu m$ fiber composite material (Ferrozell[1)] EGS 619). Besides the easier implementation of the feed–through the new drift design

[1)] Ferrozell GmbH, D–86199 Augsburg, Germany has additional advantages:

- As the material can easily be cut to any shape, the segmentation into four individual planes is no longer needed (for the GEM+MSGC module a two–fold segmentation was chosen).
- The material is sufficiently strong to withstand the pressure in the chamber. The Δp–protective gas return of the closed design can thus be omitted for the upper half–module.
- Due to the low density of the composite material, the mass thickness correspond to $200\mu m$ glass only.

5 Test beam results

5.1 Setup

The chamber was operated in a 100GeV muon beam at the X5b area of CERN SPS. The position of the chamber relative to the telescope and trigger can be seen in figure 7, which shows the experimental set up. White boxes represent other groups' silicon and gas detectors which are not subject of this note.

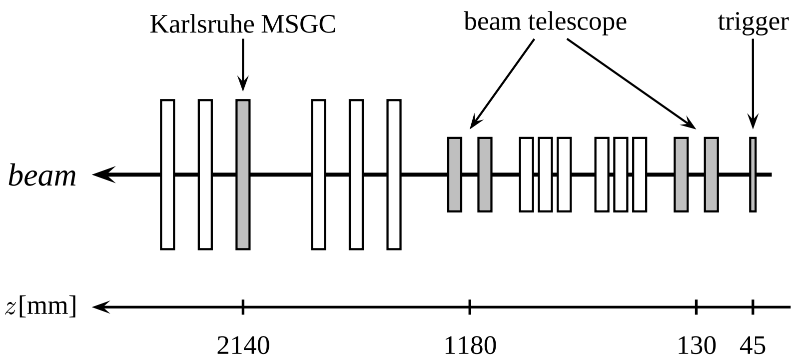

Figure 7: *Beam test set up.*

5.2 Data analysis

For the processing of raw event data, the same procedure was adopted as used for the data analysis in MF1. This procedure is described in detail in reference [3]. Please keep in mind that we use the following natural definition of *signal to noise ratio* (snr):

$$snr = \frac{Q^{\text{cluster}}}{\sigma^{\text{cluster}}}$$

The cluster charge Q^{cluster} is defined as the sum of the signals of all accepted strips belonging to that cluster. The cluster noise σ^{cluster} is the gaussian sum of all strip noise values of these strips.
The coordinates of detected particles are calculated using the center of gravity method. As the chamber measures only on coordinate (φ), the telescope data has to be used for the calculation of spatial (x, y) coordinates.

5.3 Charge response and noise

We estimate the noise of a given strip as the standard deviation of the ADC value after correction for common mode noise for this strip in events where it collects no charge from a passage of a beam particle. Figure 8 shows the distribution of this value for all strips in an arbitrarily selected range of runs.
The mean strip noise for all strips is 9.7 counts, which is consistent with the strip noise found for the F1 detectors [3].
For the same runs, the collected charge for the highest strip within a cluster and for the whole cluster is shown in figure 9. Taking into account a cluster size of ≈ 2 a snr of about 30 can be extracted from this figures.

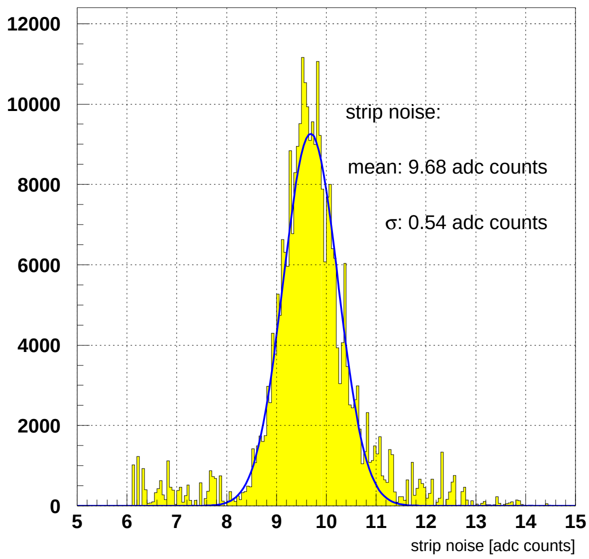

Figure 8: *Strip noise.*

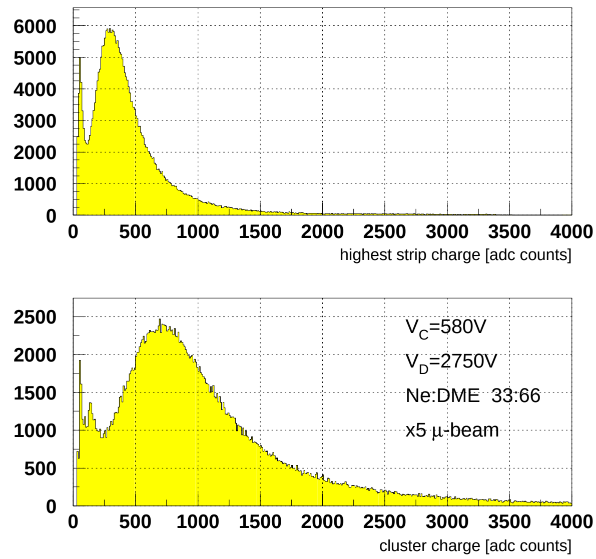

Figure 9: *Collected charge.*

5.4 Detection efficiency

The chamber was operated at cathode voltages of at least $500V$, where the efficiency plateau starts. In order to determine the detection efficiency, the silicon telescope is taken as trigger reference. An event is accepted if the beam particle produced a signal in all eight telescope planes. Tracks pointing into dead space or outside of the sensitive area of the MSGC are rejected.

Clusters in the chamber are accepted if the difference between the measured impact position of the beam and the prediction from the telescope does not exceed 3σ.

Figure 10 shows the efficiency for various voltage settings. The full plateau efficiency is found to be 98.1% and extents from about $520V$ up to $620V$. This was the highest cathode voltage applied during this beam test.

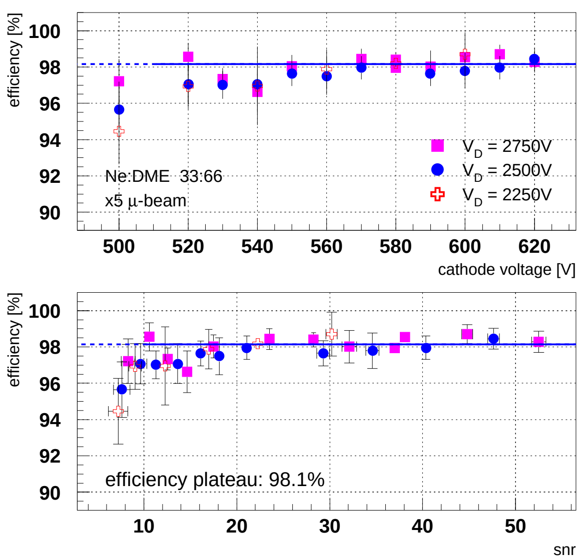

Figure 10: *Detection efficiency corrected for dead space.*

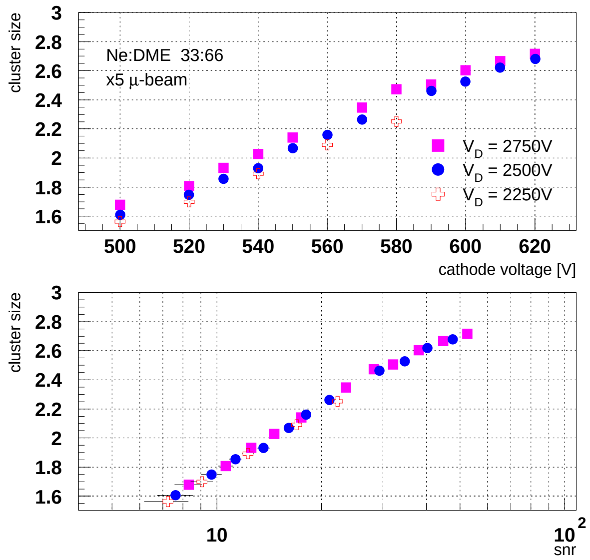

Figure 11: *Cluster size as a function of the operation parameters.*

5.5 Cluster size

Figure 11 shows the cluster size for various voltage settings. The cluster size grows with increasing fields in the amplification region. It turns out to grow fairly proportional to $\log(snr)$, at least for $snr \lesssim 30$.

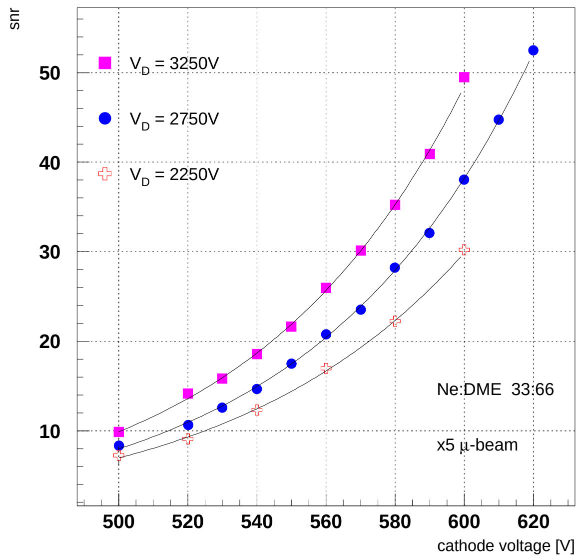

Figure 12: *Variation of snr with cathode voltage.*

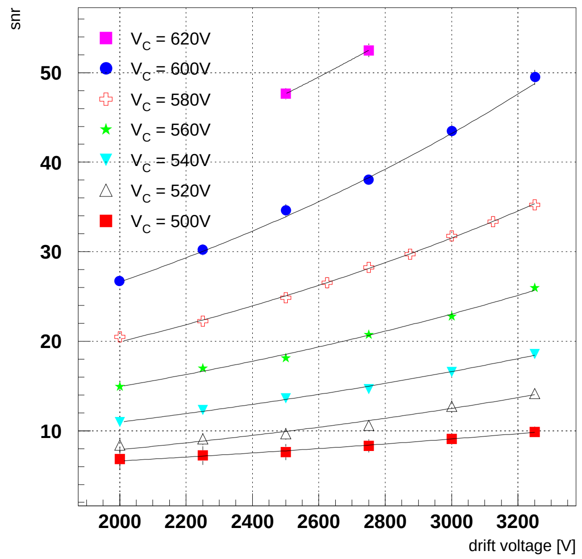

Figure 13: *Variation of snr with drift field voltage*

5.6 Voltage scan

The chamber was operated with cathode voltages of $V_C = 500V \ldots 620V$ (see figure 12) and drift voltages of $V_D = 2000V \ldots 3250V$. (see figure 13).For this voltage scans, the read–out was triggered by a $2 \times 2cm$ scintillator (in coincidence with a larger scintillator) and the beam spot was centered on the φ–crack, the region where the two substrates meet.

5.7 Spatial resolution

The spatial resolution of the chamber was studied using the tracking information obtained with the Bari beam telescope[6]. As the forward module only measures the φ–coordinate, the r–coordinate was calculated from the impact position predicted by the telescope. Figure 14 shows the distribution of the difference between predicted and detected particle impact position in cartesian coordinates for a high statistics tracking run. The beam was centered at a radial position of $r = 1030mm$. This corresponds to a mean anode pitch of $225\mu m$.
The resolution of the beam telescope is $4.5\mu m$ perpendicular to the center strips of the chamber and $2\mu m$ parallel

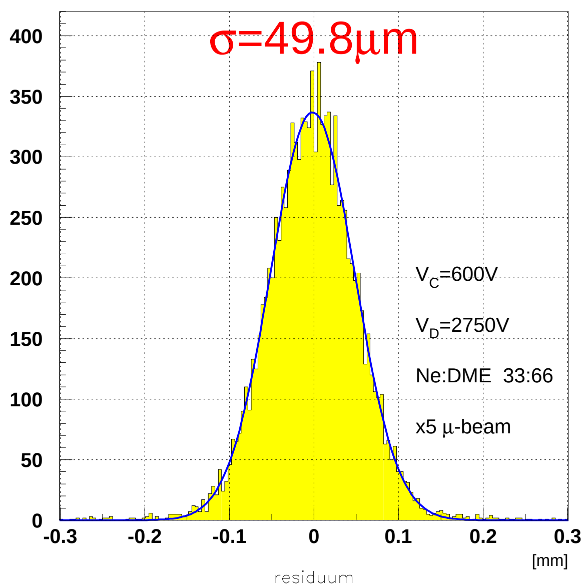

Figure 14: *Residuum width for the Karlsruhe MSGC module.*

to the strips. Neglecting the contribution of the telescope, a resolution of $49.8\mu m$ can be extracted from figure 14 for $snr = 38$. At the start of the efficiency plateau, where $snr \approx 10$, the resolution was found to be 10% worse. This can be attributed to the smaller cluster size at low fields.

6 Conclusions

A baseline design MSGC detector module for the forward CMS tracker was built to study the local feasibility of the design and production scenario. Problems concerning design (glass drift plane connection) and production (bonding yield) were detected and solutions were found.
The prototype module was operated in a CERN SPS muon beam with the nominal CMS gas mixture. Signal to noise ratios higher than 50 were obtained.
Spatial resolution was studied using the high resolution Bari silicon beam telescope. It was found to be in the order of $50\mu m$.

References

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[6] L. Celano et al., **Nucl. Instr. and Meth. A 381 (1996) 49-56** *A high resolution beam telescope built with double sided silicon strip detectors.*