Quality of the spare triple-GEM detectors

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Abstract

Triple-GEM chambers equip the inner region of the M1 muon station. In order to provide spare detectors in case of problems in the operating ones, new chambers have been assembled at the Frascati National Laboratories of the INFN. This note summarizes the results of the quality tests performed at the end of the production procedure.

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1 Introduction

The LHCb Muon System ([1], [2] and [3]) is composed by 5 rectangular stations (M1-M5) along the beam axis. Each station is divided in 4 regions (R1-R4) equipped with MWPCs. In the central region (R1) of the M1 station, where the particle flux is higher, 12 triple-GEM detectors are used in place of the multiwire chambers ([4], [5]). Each detector is made by two triple-GEM chambers both having a 3 mm sensitive drift gap.

During the last years of LHCb operations, GEM chambers have shown remarkable rate capability and high aging resistance. It's anyway crucial to have spare detectors to quickly replace problematic gap.

For this reason, a new small production of GEM based detectors was carried on at the Frascati National Laboratories of the INFN.

During the assembly procedure, several tests were performed to check the quality of the different parts and of the final chambers.

The results of these tests and the overall performance of the produced chambers are described in this note.

2 The triple-GEM detector

A GEM[a] [6] is made by a 50 μm kapton foil, clad on each side with a 5 μm copper layer and perforated with a high density of channels. By applying a voltage difference between the copper sides, in a suitable gas, the high electric field generated in the holes induces an avalanche multiplication process.

3 Test on GEM foils

Figure 1 shows a picture of a single GEM stretched and glued on the frame used for the assembly.

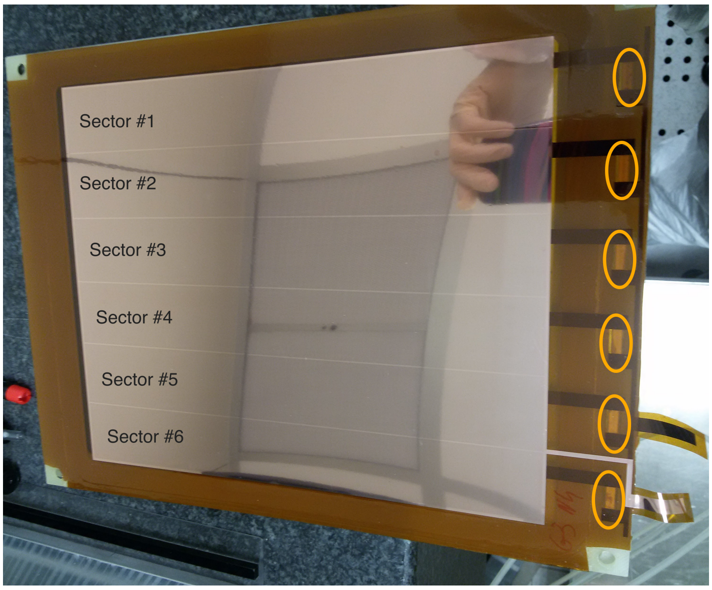

Figure 1 A single GEM foil, stretched and glued on its frame.

It is possible to see that in one of the sides, the GEM electrode is separated in 6 independent sectors. During the assembly, these sectors are electrically connected by soldering 1 MΩ resistors in the places indicated by the ellipses.

[a]Gas Electron Multiplier

3.1 Capacitance measurements

The first check, after the soldering, is the measurement of the GEM capacitance. If all resistors are properly connected, a total capacitance of 26 nF has to be verified.

A lower value indicates bad connections of some of the resistors. In case of a single resistor fault, for example, a value around 20 nF was measured.

All GEM foils have been checked and, in case, repaired before being used for final chambers.

3.2 High voltage test

Once the resistors were soldered, the GEM leakage current was measured.

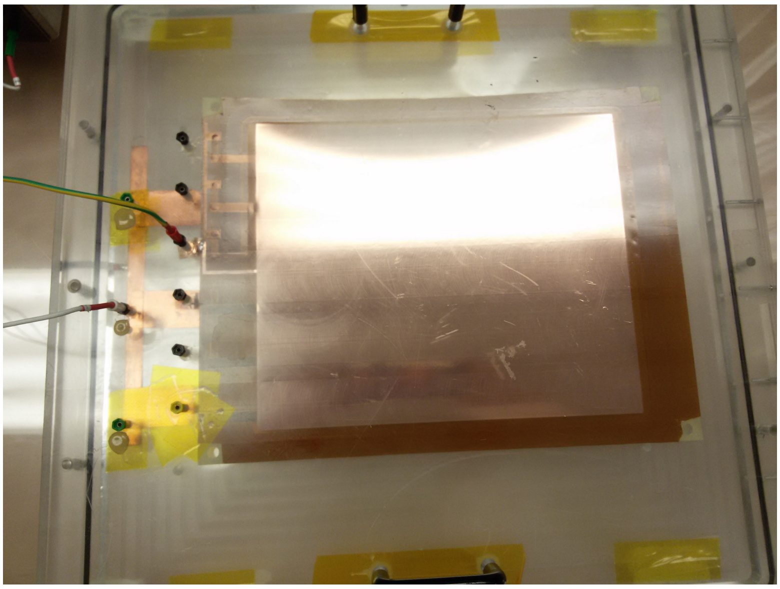

Figure 2 A GEM foil, in nitrogen atmosphere, during the high voltage test.

The foils were tested in a pure nitrogen atmosphere, with a relative humidity of about 10% within a plexiglass box. A voltage difference (V_{GEM}) was applied between the two sides and the drawn current was recorded.

All foils have been tested up to V_{GEM} = 600 V and all had residual currents between 5 and 10 nA. The foils were all declared good for the final assembly.

4 Test on triple-GEM chambers

A triple-GEM chamber consists of 3 GEM foils sandwiched between an anode and a cathode plane, as shown in figure 3 and filled with a suitable gas mixture.

Four gaps are present between the chamber components (see Fig. 3):

- **drift gap** 3 mm thick between the cathode and GEM #1;
- **transfer gap #1** 1 mm thick between GEM #1 and GEM #2;
- **transfer gap #2** 2 mm thick between GEM #2 and GEM #3;
- **induction gap** 1 mm thick between GEM #3 and the anode;

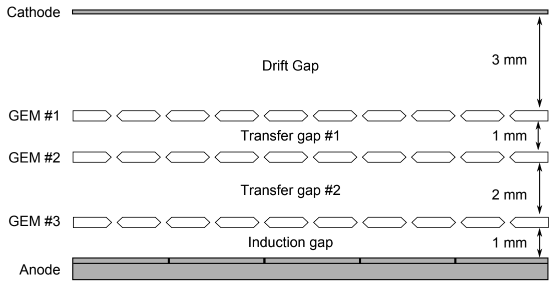

Figure 3 Cross section of a triple-GEM detector.

The anode plane is segmented in pads following a chessboard texture, where each pad is 1×2.5 cm^2.

The LHCb Triple-GEM detectors are made by two chambers with the readout pad logically OR-ed to ensure the desired detection efficiency. The two types of chambers composing a detector are completely symmetric and are called *left* and *right*.

3 chambers of *left* type ($L01$, $L02$ and $L03$) and 3 chambers of *right* type ($R01$, $R02$ and $R03$) were assembled in order to have 3 complete detectors.

Figure 4 shows a stack of the assembled chambers, under gas flow.

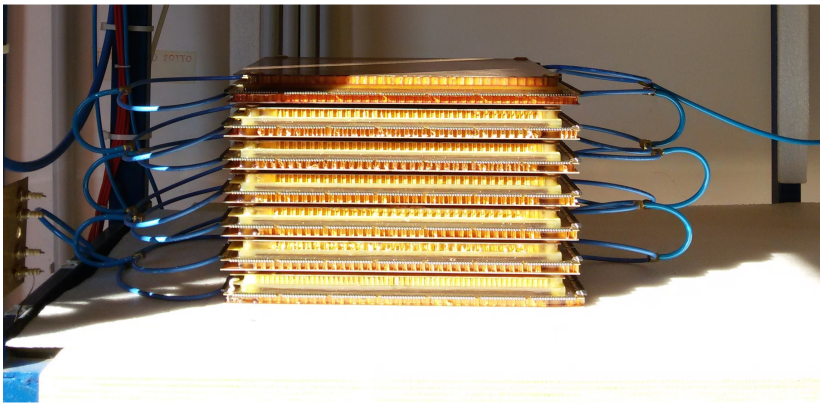

Figure 4 The 6 assembled triple-GEM chambers under gas flow after the assembly.

4.1 Capacitance measurements

After the chambers were closed and glued, in order to check their thickness, the capacitance of the drift, transfer and induction gaps were measured by means of a PAN 188 multimeter[b]. Table 1 summarizes the results of these measurements.

Data of Tab. 1 show how the measurements of the capacitances are sensitive to the device effective layout. Results are very similar except from the gaps of $L01$ for which the multimeter was unable to indicate a stable capacitance value.

Transfer gaps # 1 and induction gaps (thickness: 1 mm) have an average capacitance of 590 pF, transfer gaps # 2 (thickness: 2 mm) 374 $\pm$ 5 pF and drift gaps (thickness: 3 mm) have 222 $\pm$ 5 pF.

These results indicate that all the chambers were assembled with nominal gap heights.

[b]For more details visit http://www.pancontrol.at

Table 1 Results of the capacitance measurements of the assembled detectors.

chamb.	Drift	Transf. #1	Transf. #2	Induct.
R01	220 pF	580 pF	380 pF	610 pF
R02	220 pF	590 pF	370 pF	570 pF
R03	220 pF	580 pF	380 pF	585 pF
L01	220 pF	n/a	n/a	575 pF
L02	220 pF	600 pF	370 pF	570 pF
L03	230 pF	600 pF	370 pF	595 pF
Avrg.	222 pF	590 pF	374 pF	590 pF
RMS	4 pF	10 pF	5 pF	20 pF

5 Test with X-rays

The response of all chambers to an X-ray flux produced by a 20 kV tube with an iron anode, was studied as a function of the tube filament current (i.e. the beam intensity). During the measurements, chambers were put under gas flow with the nominal LHCb mixture ($Ar/CO_2/CF_4$ 45/15/40) and all readout pads were connected to ground. The nominal voltage settings used during the measurements are summarized in Tab. 2 and compared with the nominal settings foreseen on the LHCb apparatus.

Table 2 High voltage configuration of the chambers during the X-ray measurements and on LHCb apparatus.

	$V_{GEM\#1}$	$E_{Transf.\#1}$	$V_{GEM\#2}$	T $E_{ransf.\#2}$	$V_{GEM\#3}$	$E_{Ind.}$
X-ray test	440 V	3.5 kV/cm	430 V	3.5 kV/cm	410 V	5.0 kV/cm
Nominal LHCb	410 V	3.0 kV/cm	410 V	3.0 kV/cm	410 V	5.0 kV/cm

In all chambers it was possible to reach the nominal voltage configuration (see Tab. 2) except for $L01$. For that device, GEM #2 started to draw high currents even at low voltages. This behavior, together with the capacitance measurement results (see Tab. 1), indicates that the GEM #2 foil has a too low resistance. Therefore it cannot properly work and cannot be used on the LHCb apparatus.

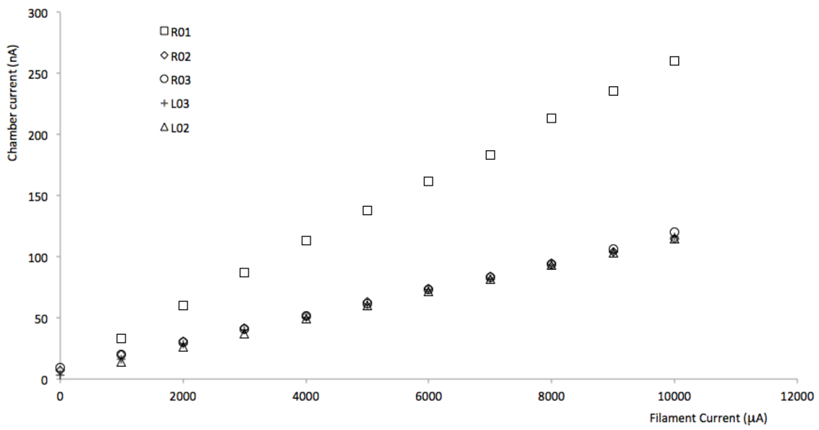

Figure 5 Currents drawn by GEM # 3 upper electrodes during the tests with the X-ray tube as a function of the filament current.

Figure 5 shows the behavior of the currents drawn by the upper electrode of the third GEMs in the tested detectors as a function of the filament current.

All chambers have responses that show a very good linearity as a fuction of the X-ray flux. In particular, $R02$, $R03$, $L02$ and $L03$ have almost the same response. The chamber $R01$ draws about the double of the current with respect ot the other chambers. Since the chamber $R01$ was the first to be assembled and different panels were used, the larger current could likely be due to a different interaction of X-photons with the detector material.

This behavior could also be due to a larger detector gain, but several other checks didn't indicate a possible source for it. A larger gain, anyway, wouldn't be a problem for using it in LHCb.

6 Conclusion

Six triple-GEM chambers have been built at the Frascati National Laboratories to provide 3 complete spare detectors for the LHCb experiment. During the assembly, the capacitance and the dark current were measured for all the 18 GEM foils that were declared of good quality for the final detector assembly.

Test with X-ray performed on the final chambers indicated that one ($L01$) has a broken GEM and cannot be used on the LHCb apparatus. All other chambers showed correct responses.

7 References

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