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Production and quality control of the new chambers with GEM technology in the CMS muon system

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Summary. — The CMS Collaboration has approved the installation of an additional set of muon detectors based on triple-GEM technology in the first endcap muon station known as GE1/1. The chambers are currently under construction and will be installed in 2019 during the second Long Shutdown (LS2) planned by LHC. About half of the required 144 chambers have been already built by different production sites in Europe, Asia and the United States. Systematic inspections and strict quality controls, scheduled for the GE1/1 chambers approval by the central site (CERN), were carried out successfully in Bari and Frascati (Italy). The results of the quality control procedures concerning the effective gain and the response uniformity of the delivered detectors will be shown together with the results on other relevant parameters like internal pressure drop and maximum spurious signal rate.

1. – The GE1/1 muon detector upgrade with GEM technology

After the upgrade of the LHC injector chain, which is currently planned to take place around 2019, the instantaneous luminosity will approach or exceed $2 \cdot 10^{34}\,\mathrm{cm}^{-2}\mathrm{s}^{-1}$. The installation of an additional station GE1/1 [1], in the first endcap muon, will improve the forward muon triggering and reconstruction in the region with pseudorapidity $1.6 < |\eta| < 2.2$. The muon station GE1/1 based on triple GEM detectors is currently under construction. The installation will be complete during the second Long Shutdown (LS2). A GE1/1 chamber consists of three large area trapezoidal foils gas filled, sandwiched between a drift electrode and a readout board. A GEM foil [2] is a thin polymer foil ($50\,\mu$m), coated with $5\,\mu$m copper on each side and pierced with a high density of biconical holes. A large difference of potential applied between the two sides creates a high field in the holes accelerating the electrons causing ionization with the gas molecules. A fraction of the electrons produced in the avalanche leave the multiplication region and transfer into the lower GEM. A pair of triple-GEM detectors is combined to form a superchamber obtaining two detection planes.

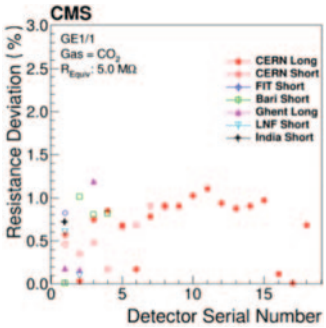

Fig. 1. – QC_4: the deviation of the measured resistance of the detector from the nominal value.

2. – Quality Control (QC)

The quality control procedure of GE1/1 chambers ensures robust results and good performance during the operation in CMS for all detectors in each production site. The QC_3 test is performed on the assembled chamber to check the gas tightness by monitoring the drop pressure inside the detector for an hour. All the detectors produced by the different production sites show a pressure drop below 3 mbar. The QC_4 test is performed with the aim to measure the current voltage curve and measure the rate of spurious signal in pure CO_2. The QC_4 criteria evaluate the deviation of the measured resistance of the detector from the nominal value and quantify the linear response of the detector with respect to the high voltage applied. The linear behavior is confirmed by a deviation of normalized resistance under 1.8% (fig. 1).

2·1. QC_5 *effective gas gain and response uniformity.* – In QC_5 the effective gas gain is normalized with the pressure (P) and the temperature (T) in the central production site of CERN. The measure of the effective gain with $ArCO_2$ (70/30) is performed as a function of the applied voltage as the ratio between the output current and the rate of converted photo-electrons created in the detector gas volume with a beam of X-ray photons of 22 keV energy (fig. 2). The photons are absorbed by the copper atoms of the drift electrode that emits X-ray 8 keV photons by fluorescence. The effective gas gain is strictly correlated to the measurement of response uniformity of the detector. The detector is read out from 3072 strips grouped together in a slice of 4 strips. The copper

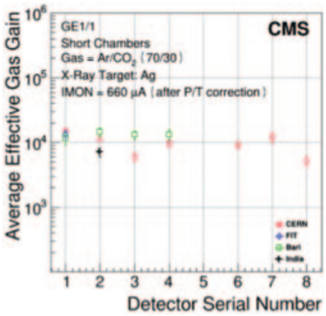

Fig. 2. – QC_5: average effective gas gain for GE1/1 detectors.

fluorescence peak position obtained from the fit of the cluster charge ADC spectrum from each slice is assigned to the corresponding slice. The set of the obtained peak position from each slice is then normalized to the average peak position to quantify the response uniformity through the relation σ/μ, where σ is the standard deviation and μ the mean of the fit of the photopeak positions. A stable operation is assured for values of $(\sigma/\mu)\%$ under 30%.

3. – Conclusions

The production of the GE1/1 chambers has started in different production sites all over the world and about half of the chambers required for GE1/1 have been constructed and tested. A set of quality tests has been developed to ensure the quality of the constructed chambers, consisting of gas leakage and electrical measurements, absolute gain and response uniformity. New detectors with exactly the same GEM technology used in GE1/1 have been already approved for the station GE2/1 [3] for the Phase2 Upgrade and the new ME0 station has been also proposed to improve the muon trigger and the tagging of high-eta muons in the region with $2.0 < |\eta| < 2.8$ once again with GEM technology for further CMS muon system upgrades.

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