Development of a 4-GEM large-size prototype for the ALICE TPC upgrade *

P. Gasik[†1,2], *L. Fabbietti*[1,2], *A. Mathis*[1,2], *R. Muenzer*[1,2], *and the ALICE TPC collaboration*
[1]TU München, Excellence Cluster ‘Origin and Structure of the Universe‘, Boltzmannstr. 2, 85748 Garching, Germany;
[2]TU München, Physik Department E12, James-Franck-Str. 1, 85748 Garching, Germany

ALICE at the LHC at CERN is planning a major upgrade of the central barrel detectors, including the TPC, to cope with an increase of the LHC luminosity after 2018. A full-size prototype of a TPC Inner Read-Out Chamber (IROC) was produced and tested during the test-beam campaign in the fall of 2014. It was equipped with a quadruple Gas Electron Multiplier (GEM [1]) employing GEM foils with a pitch of 140 μm ("Standard" - S) and 280 μm ("Large Pitch" - LP). The subsequent GEM foils in the stack have been installed according to the S-LP-LP-S configuration presented schematically in fig. 1. The design and assembly procedure of the 4-GEM prototype follows closely that of the triple GEM prototype built and tested in 2012 and described in details in [2, 3]. A notable modification with respect to the 2012 setup is that the induction gap (between GEM4 and the pad plane) was reduced from 4 mm to 2 mm. The new 4-GEM IROC employs also a cover electrode, which is used to minimise drift-field distortions at the edges of the GEM stack.

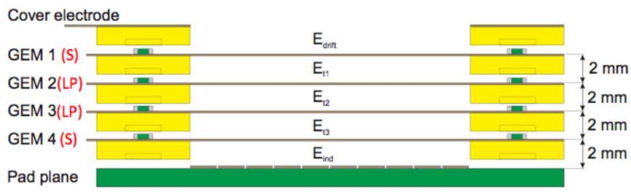

Figure 1: Schematic picture of the 4-GEM IROC

Several HV settings were used with the prototype, including the one defined as 'baseline' for the ALICE GEM readout chambers optimised for the ion backflow and energy resolution [4]. A resistor chain was used to supply the potentials on the subsequent GEM electrodes. The GEM IROC was installed in a test field cage with a drift length of $115\,\mathrm{mm}$ and commissioned with radioactive sources. The prototype is operated in Ne-CO_2-N_2 (90-10-5) gas mixture, which is the nominal gas mixture for the upgraded TPC.

Figure 2 shows a gain curve obtained for the prototype using a ^{55}Fe source. The gain is scaled with a common scaling factor (SF) applied to all GEM potentials. The nominal gain of 2000 is obtained for $SF \approx 100\%$. The value of ion backflow corresponding to this setting is 0.63% and the energy resolution of a ^{55}Fe peak $\sigma = 11.3\%$ [4].

The dE/dx resolution of the prototype was evaluated in a test beam campaign at the CERN PS with

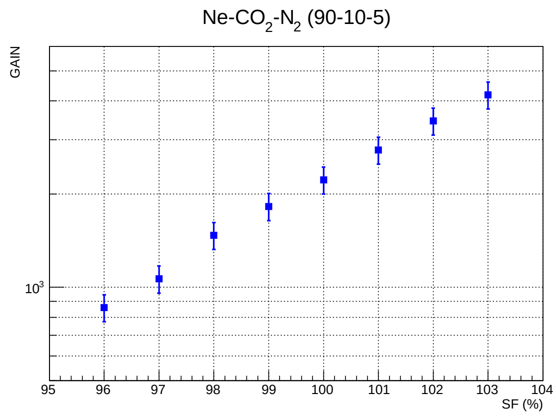

Figure 2: Gain curve obtained in Ne-CO_2-N_2 (90-10-5) for the 4-GEM IROC using scaled 'baseline' HV settings.

1 GeV/c pions and electrons. The relative energy resolution $\sigma\left(\mathrm{d}E/\mathrm{d}x\right)/\langle\mathrm{d}E/\mathrm{d}x\rangle$ obtained for electrons ($\sim 9.1\%$) and pions ($\sim$ 10.4%) is comparable to the resolution of the MWPC IROC [4].

Stability of the chamber was evaluated in a test beam at the CERN-SPS. The discharge probability was measured using showers of hadrons produced by a high-intensity secondary pion beam with a momentum of 150 GeV/c impinging on a 30-40 cm thick iron absorber. The average beam intensity was $\sim 6\times10^6$ particles per spill, resulting in an average in-spill rate of $\sim$1.2 MHz. The number of particles accumulated during the experiment is $N_{\mathrm{tot}}^{\mathrm{SPS}} = (4.7 \pm 0.2) \times 10^{11}$. The chamber was operated with the 'baseline' settings at the gain of 2000. In total, three discharges were detected in the detector. This translates into a discharge probability of $(6 \pm 4) \times 10^{-12}$ per incoming hadron. This result is of the same order of magnitude as the one obtained by the LHCb Collaboration where the discharge probability of 3-GEM detectors operated with an isobutane-CF_4-based gas mixtures was measured under similar conditions [5].

References

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† p.gasik@tum.de

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