Quality Assurance of Leak Rate of Large Size Triple GEM Chambers used for CBM Experiment at FAIR

Aarjo Mukherjee[1] and Anand Kumar Dubey[2]
[1] *Department of Nuclear and Atomic Physics, Tata Institute of Fundamental Research, Mumbai, 400005, INDIA** and
[2]*Experimental High Energy Physics & Applications Group, Variable Energy Cyclotron Centre, Kolkata - 700064, INDIA*

Introduction

Among the various gas-based detectors used in high-energy physics and nuclear experiments, GEM detectors stand out due to their exceptional high-rate detection capabilities. These detectors operate under flowing gas at near atmospheric pressure. Figure 1 shows a chamber developed at VECC, which is a Triple GEM Detector with an active area approximately 80 cm long on the parallel sides and 40 cm wide at its broadest section. The module was assembled using the "ns2" technique, a no-glue assembly method. The drift and readout PCBs are secured onto a trapezoidal G10 edge frame using numerous brass or steel pillars, spaced regularly along the boundary of the drift region. Each pillar is drilled with M2.5 or M3 tapped holes, allowing the PCBs to be fastened with screws and washers. A total of 42 pillars are used, creating 84 potential points for gas leakage.

In addition to nylon washers, a 2mm O-ring is placed along the perimeter of the edge frame to enhance gas tightness. These detectors are intended for use in the Compressed Baryonic Matter (CBM) experiment at FAIR. Sixty such large-area chambers will be constructed for the Muon Chamber (MuCh) station. Ensuring the gas tightness of these chambers is a critical part of the quality assurance (QA) process during production as leaks in the detector lead to a loss of gas and allow impurities such as dust particles, oxygen and water vapour to enter the detector which causes deterioration in its gain characteristics. While traditional gas leak sniffers are commonly employed to detect leaks, they do not provide a quantitative measurement of the leak rate. In this paper, we present the results of tests conducted at VECC to quantitatively assess the gas tightness of the GEM detector modules.

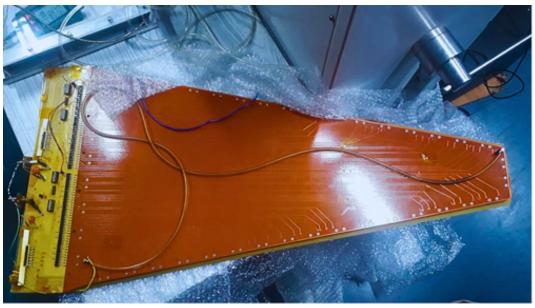

FIG. 1: Large Size GEM Chamber

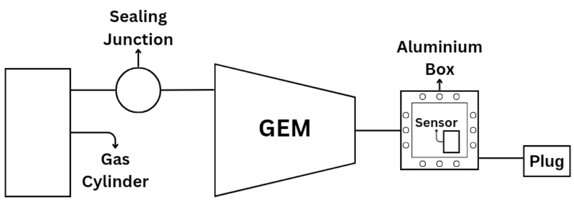

FIG. 2: Experimental Setup

*Electronic address: aarjo.mukherjee@tifr.res.in

The method used for leak rate calculation was a Pressure Decay test. We have carried out such a test on the initial version of real size

GEM module of station-1. This module was already tested in the mCBM-19 test beam campaign. One end of the GEM chamber was connected to an aluminium box of volume 3.17 L with an O-ring system which contained a temperature and pressure sensor (Extech SD700). The other end of the sensor box was sealed. The other end of the GEM had a gas inlet through which Ar-CO_2 was supplied as shown in Fig 2. The leak tightness of the aluminum chamber was checked before the experiment and was determined to be leak-tight (no pressure drop in 24 hours). The setup was filled to an excess pressure of 30 mbar, 20 mbar, and 10 mbar.

Results and Discussion

Figure 3 shows the fit of the pressure decay. Considering exponential decay of the internal pressure the graph was fit with the function $\Delta P = \Delta P_0 e^{-t/\tau}$ and the parameters were evaluated. τ is the time constant which depends on the dimensions of the leak points. The typical results of pressure decay at different excess pressures (Fig 4) shows that the leak rate (at P_{atm} = 997 hPa) was below the limit of 0.01 L/h (2.04 mbar/h), which was a standard calculated by assuming a 1% loss [1] at 1 L/h with an internal excess pressure of 5 mbar. The leak rate of the detector was very low and based on the standard amounted to a loss of around 0.6%.

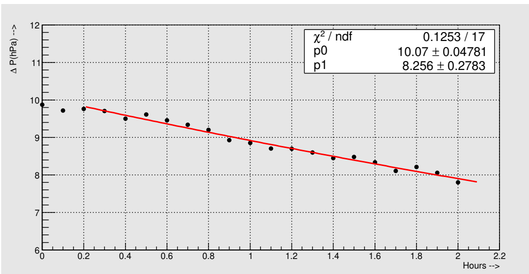

FIG. 3: Pressure Decay Profile at 10mbar Excess

This method of leak testing is simple and does not require specialized apparatus. It can be used for quality checks of other modules to ensure leak tightness of the entire station, to minimize loss of gas as well as prevent pollution of the detectors with contaminants present in the ambient air which can lead to degradation.

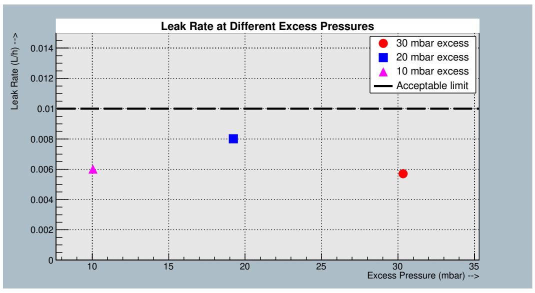

FIG. 4: Leak Rates at different Excess Pressures

This method provides a systematic way of evaluating a leak rate and determining the standards for the quality checks of similar detector modules. The leak rate for the 30 mbar excess should have been higher as per theory. A setup for more accurate measurements with more control on ambient parameters will be explored in the future.

References

[1] M. Abbas, M. Abbrescia, H. Abdalla, A. Abdelalim, S. AbuZeid, A. Agapitos, A. Ahmad, A. Ahmed, W. Ahmed, C. Aimé, and others, *Quality control of mass-produced GEM detectors for the CMS GE1/1 muon upgrade*, *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, vol. 1034, p. 166716, 2022.

[2] CBM Collaboration, S. Chattopadhyay, Y. P. Viyogi, W. F. J. Müller, C. J. Schmidt, and P. Senger, "Technical Design Report for the CBM: Muon Chambers (MUCH)," *GSI Repository*, 2015. [Online]. Available: `https://repository.gsi.de/record/161297`