Numerical studies on transport properties of gas mixtures for triple GEM detectors in CMS experiment

Prasant Kumar Rout[1],* Deb Sankar Bhattacharya[1,2], Purba Bhattacharya[3], A. R. Sahasransu[4],† Supratik Mukhopadhyay[1], and Nayana Majumdar[1]
[1] *Applied Nuclear Physics Division, Saha Institute of Nuclear Physics , Kolkata - 700064, India*
[2] *DSM/IRFU/SPP, CEA Saclay, 91191, Gif Sur Yvette, France*
[3] *Weizmann Institute of Science, Herzl St. 234, Rehovot - 7610001, Israel and*
[4] *Indian Institute of Science Education and Research, Kolkata - 700064, WB, India*

Introduction

The muon detection system of CMS aims to provide an efficient and fast identification of the muons produced in the $p-p$ collisions[1]. A cascade of three GEMs called the triple GEM detectors have been proposed to instrument some of the vacant high η region of the muon end caps of CMS muon system called GE1/1 chambers[2]. They are capable of operating in the forward ($1.6 < \eta < 2.2$) region sustaining the high fluxes of radiation with detection performance compatible with the CMS requirements[2].

The GEM technology was introduced in 1997 by Fabio Sauli at CERN[3]. A typical GEM foil consists of two copper layers of thickness 5 μm separated by a thin insulator of polymide material (usually Kapton) having thickness 50 μm with bi-conical shaped holes of outer radius 70 μm and inner radius 50 μm etched with a pitch of 140 μm. Being a gaseous ionization detector, the gas mixture determines the gain uniformity, energy resolution and drift velocity to a great extent. Ar and CO_2 mixed 70:30 by volume have shown optimized detector performance for the triple GEM detectors[2]. In addition to this, a mixture of Ar(45%), CO_2(15%) and CF_4(40%) has also been used in the CMS experiment. The resulting mixture is significantly faster than the Ar-CO_2 mixture which is very advantageous for triggering purpose, but CF_4 is hazardous to the environment. In search for an eco-friendly gas mixture that is also fast, the simulation results of electron transport properties of five Ar based gas mixtures including Ar(45%), CO_2(15%) and N_2(40%) are presented in this paper.

*Electronic address: prasant.rout@saha.ac.in
†Electronic address: ars12ms062@iiserkol.ac.in

Transport properties

The mixing ratio and the gas used determine the nature of electron transport through the detector volume. The electron transport properties of gas mixture include townsend coefficient, attachment coefficient, longitudinal and transverse diffusion coefficient and drift velocity.

TABLE I: Electric fields in a triple GEM differ form region to region[2].

Region	Gap size(mm)	ΔV(V)	E(kV/cm)
Drift	3	770	2.6
GEM1	0.06	380	64.0
Transfer1	1	300	3.0
GEM2	0.06	370	62.0
Transfer2	2	600	3.0
GEM3	0.06	350	60.0
Induction	1	430	4.3

Simulation results

In our present work, we have used Garfield [4] simulation framework which provides interface to software package Magboltz[5] for numerically estimating the transport properties. It is clear from TABLE I, the operation of the detector is in the 1 - 5 kV/cm range in

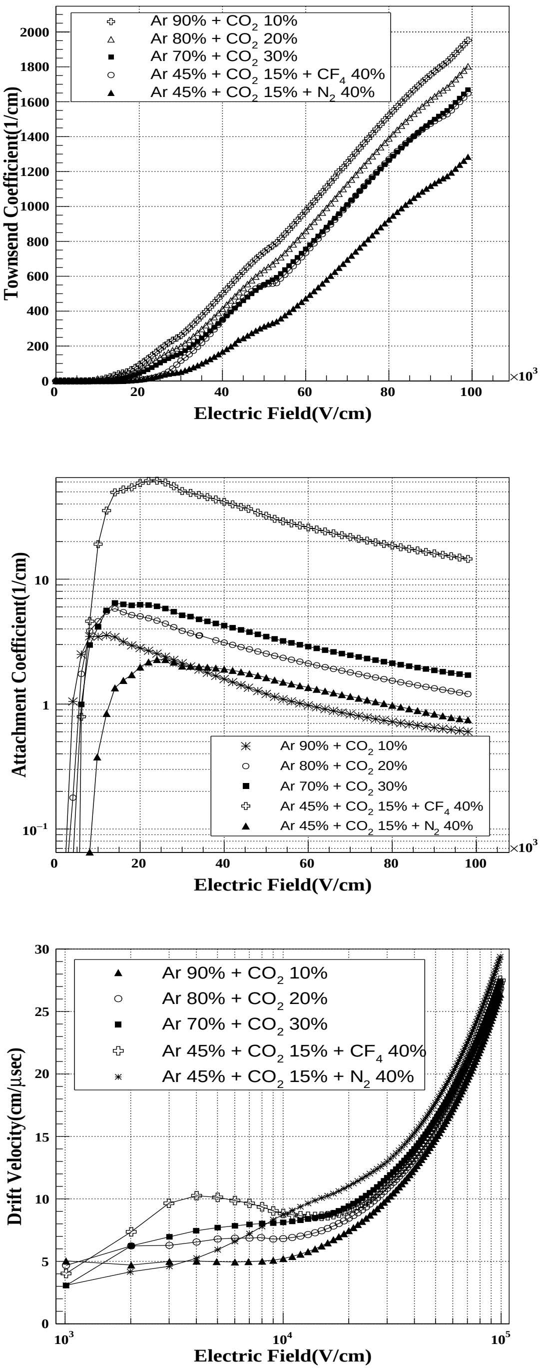

FIG. 1: From Top to Bottom - Variation of townsend coefficient, attachment coefficient and drift velocity with electric field

the drift, transfer and induction volumes and around 60 kV/cm in the GEM holes. Hence, the transport properties have been calculated for a given electric field range(10 - 10^5)V/cm with no applied magnetic field. Fig.1 given alongside shows the results of our simulation.

The Ar-CO_2-N_2 gas mixture has shown increased drift velocity at higher electric field in comparison to all other gas mixtures. In the operating range of the drift, transfer and induction volumes the CF_4 included mixture shows higher drift velocity which is good for triggering. The townsend coefficient is low for Ar-CO_2-N_2 at around 60 kV/cm, the operational field at GEM holes, implying low detector gain. The CF_4 included gas mixture shows a large attachment coefficient at the detectors operational value for electric fields which can results in electron loss and thus reduced energy resolution.

Currently, the CF_4 included gas mixture is showing good detector performance because of reasonably good gain and high drift velocity in the operating range. However, N_2 based gas mixture is a promising candidate because it is showing a very low attachment coefficent with comparable townsend coefficient. Further optimization of the gas mixture is required and experimental tests need to be conducted before a conclusion can be drawn about using nitrogen as a substitute for carbon tertrafluoride.

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