Studies on the physics of Resistive Plate Chambers in relation to the INO experiment

Abhik Jash*
Saha Institute of Nuclear Physics, HBNI,
1/AF Bidhannagar, Kolkata - 700064, INDIA

Introduction

The proposed ICAL [1] setup at INO which will be dedicated for unambiguous and precise determination of the neutrino oscillation parameters, will deploy about 30,000 Resistive Plate Chambers (RPCs) [2] as its active detection unit. The timing information from the RPCs will be utilized to distinguish the up-going muon tracks from the down-going ones which is necessary for determining the path length of the neutrinos. In the present thesis work a systematic investigation on the bakelite RPC for its optimized application in the ICAL has been carried out. The simulated response of the bakelite RPC for different operating conditions, such as, applied voltage, mixing proportions of the gas components etc., were compared to the experimental data. The effects of different design parameters and their imperfections, like, spacer components, use of composite bakelite plates, their surface roughness [3] etc. on the electric field were investigated numerically which were otherwise difficult to measure experimentally. A study to check possible operation of RPCs using gas mixtures with less global warming potentials was also initiated [4].

Experimental measurements

A few Bakelite RPCs of size 30 cm $\times$ 30 cm were fabricated and operated in avalanche mode using the typical R-134A based gas mixtures. The effect of applied voltage and gas mixtures on the detector response has been studied utilizing a telescopic arrangement formed using three scintillators. The timing properties of the RPC were measured using a TDC where the signal arrival time from the RPC was measured compared to the trigger generated by the scintillator telescope. The efficiency was found to increase with the applied voltage. The average signal arrival time and time resolution of the detector were found to improve with the increase in applied voltage [5] but deteriorate with the amount of SF_6 present in the gas mixture.

Numerical results

A detailed numerical simulation of RPC dynamics was carried out to understand its operation and influence of different factors on it. The primary ionization in different gas mixtures was calculated using HEED [6] due to passage of muons of different energy and incidence angles through it. Magboltz [7] was used to calculate the transport properties of electrons at various field values in different mixtures. A special care was taken in performing the field simulation in this work as the electric field plays an important role in all the physics processes inside the device. COMSOL Multiphysics [8] and neBEM [9] which works on two different methods (FEM and BEM, respectively) were used to compute the field maps within the detector. Garfield [10] took care of overall charge movements and signal induction on the readouts. The detector properties were calculated by analysing the signal shapes in ROOT [11]. The efficiency of the detector was calculated as the fraction of events that can produce a signal greater than a specified threshold. For any event, the time to cross a specific set threshold was defined as the signal generation time for that event. A distribution of signal generation times was obtained for 20000 events and the average signal generation time and intrinsic time resolution

*Electronic address: `abhik.jash@niser.ac.in`

of the detector were defined as the mean and the standard deviation of the distribution, respectively.

Effect of operating parameters

The response of the RPC was found at different applied fields using a gas mixture containing R-134A, 5% isobutane and variable amount of SF_6 (0.0% - 0.5%) by passing muons through a region away from any imperfection. The variation of RPC efficiency with the change in the applied field for different amounts of SF_6 in the gas mixture has been calculated for a set threshold of 10 nA and is displayed in figure 1. The trend is similar as observed experimentally. It can be noted that

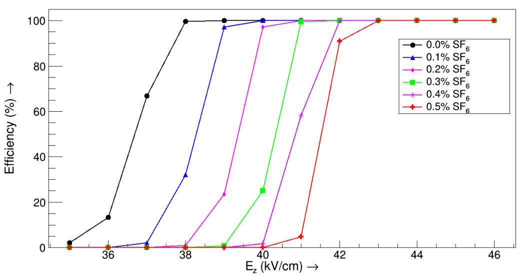


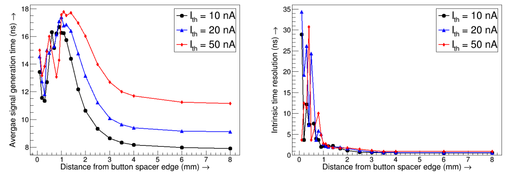
FIG. 1: Variation of RPC efficiency (I_{th} = 10 nA) with the applied field for different amounts of SF_6 in the gas mixture R-134A+isobutane (5%)+SF_6.

the detector with higher amount of SF_6 should be operated at higher voltages to achieve better efficiency.

The average signal generation time and the time resolution were found to improve at higher field values, but deteriorate with higher amount of SF_6 in the gas mixture [5]. The results are at per with the experimental observations and proves the suitability of the simulation framework.

Effect of geometrical components

The calculation of electric field using two different methods showed a distorted field map near the edge and button spacer of the RPC [12] which is expected to alter the detector response at those regions. Muons were passed at different distances away from the spacers and the detector response was calculated when the applied field at a normal region is E_z = 42 kV/cm and it is operated with the mixture, R-134A (94.8%) +isobutane (5%) + SF_6 (0.2%). The detector efficiency was found to reduce near both the spacers. The timing properties were also found to worsen near the spacers with a special trend seen near the button spacer due to its typical shape and special way of distorting the field map [12]. Figure 2 shows the variation of the two timing parameters near a button spacer for different set thresholds.



(a) (b)

FIG. 2: Variation of (a) average signal generation time and (b) intrinsic time resolution of a bakelite RPC near button spacer for different thresholds.

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References

[1] A. Kumar, A.M.V. Kumar, A. Jash *et al.*, Pramana - J Phys. **88** : 79 (2017).
[2] R. Santonico *et al.*, NIMA **187** 377 (1981).
[3] A. Jash *et al.*, JINST **11** C06010 (2016).
[4] J.Datta, A. Jash *et al.*, Springer Proceedings in Physics **201** 129 (2018).
[5] A. Jash *et al.*, JINST **11** C09014 (2016).
[6] I.B. Smirnov, NIMA **554** 474 (2005).
[7] S.F. Biagi, NIMA **273** 533 (1988).
[8] COMSOL Multiphysics® - multiphysics simulation tool `www.comsol.com`.
[9] N. Majumdar and S. Mukhopadhyay, JINST **2** P09006 (2007).
[10] R. Veenhoff, NIMA **419** 726 (1998).
[11] ROOT @ cern `root.cern.ch`.
[12] A. Jash *et al.*, JINST **10** P11009 (2015).