Alternate gas mixture for the operation of RPCs at INO-ICAL

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Abstract

The dynamics of any gaseous detector like an RPC is critically dependent upon the filling gas mixture. The processes include primary ionization due to passage of a radiation/particle, drift of primary electrons/ions and their multiplication through secondary ionization and finally signal induction on pickup strips due to their movements. The usual gas mixture used for the operation of RPCs at the r&d phase for INO-ICAL consists of different compositions of Freon (R-134A), Argon, Isobutane, SF_6 etc. with R-134A as the major component ($\sim 95\%$). A typical gas mixture used for avalanche mode of operation of an RPC is **R134A : IsoButane : SF_6 = 95 : 4.5 : 0.5**.
In this work, possibility of using an alternate gas mixture for proper functioning of an RPC has been investigated keeping in mind the price, availability and the lower Global Warming Potential (GWP). Few gas mixtures like Argon + CO_2, Argon + Isobutane + CO_2, Argon + N_2 + CO_2 in different proportions have been investigated as possible alternatives. MagBoltz [2] has been used to compute the transport properties of the gas mixtures, HEED [3] has been used to calculate primary ionization and Garfield [4] framework has been used for calculation of signal induced on the RPC pickup strip with neBEM [5] taking care of the electric field calculation.

Motivation

- Under the **Kyoto protocol**, UN countries have committed themselves to reduce the emission of greenhouse gases including HFCs, SF_6 etc.
- In June, 2013 US and China have agreed to phase down the use of HFCs. India is expected to follow the same line and control their emission in near future.

GWP : It represents how much a given mass of a chemical contributes to global warming over a given time period compared to the same mass of carbon dioxide.

$$GWP(x) = \frac{Amount\ of\ heat\ trapped\ in\ the\ atmosphere\ by\ gas\ X}{Amount\ of\ heat\ trapped\ in\ the\ atmosphere\ by\ CO_2} = \frac{\int_0^{TH} a_X\,[X(t)]\mathrm{d}t}{\int_0^{TH} a_r\,[r(t)]\mathrm{d}t} \quad (1)$$

Properties of few gases :

Gas mixture	Atmospheric lifetime (years)	GWP (100 years)	ODP	Ionization energy (eV)
R-134A	13.8	1300	0	10.12
Isobutane	774	3.3	0	10.74
SF_6	3200	22800	0	15.33
Argon	87	0	0	15.76
CO_2	variable	1 (reference)	0	13.77
N_2		0	0	14.534

$$ODP = \frac{Global\ \Delta O_3\ due\ to\ gas\ X}{Global\ \Delta O_3\ \ due\ to\ CFC-11\ of\ same\ amount} \quad (2)$$

Criterion for gas selection

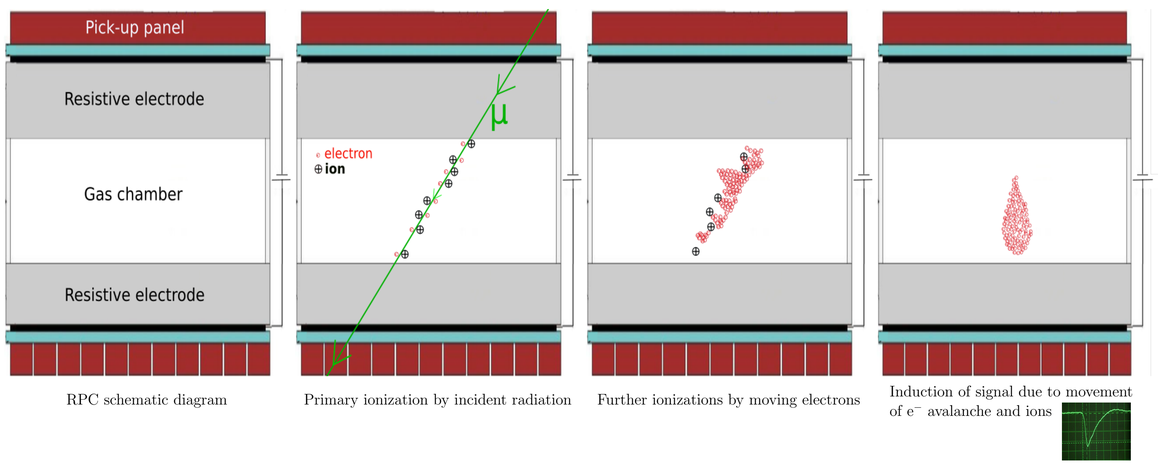

Figure 1: Steps of signal induction on RPC pickup strip.

- Lower the ionization potential of the gas mixture, greater is the primary ionization due to passage of radiation.
- Large value of Townsend co-efficient (α) and small value of attachment co-efficient (η) helps in efficient avalanche production.
- Proper quenching of photons, for proper functioning of the detector.
- Price, availability and environment friendliness of the gas.

Gas mixtures studied

- R-134A : Isobutane : SF_6 = 95 : 4.5 : 0.5 (reference)
- Ar : CO_2 = 30 : 70
- Ar: Isobutane : CO_2 = 15 : 5 : 80
- Ar : N_2 : CO_2 = 25 : 5 : 70

Primary ionization and gas related parameters

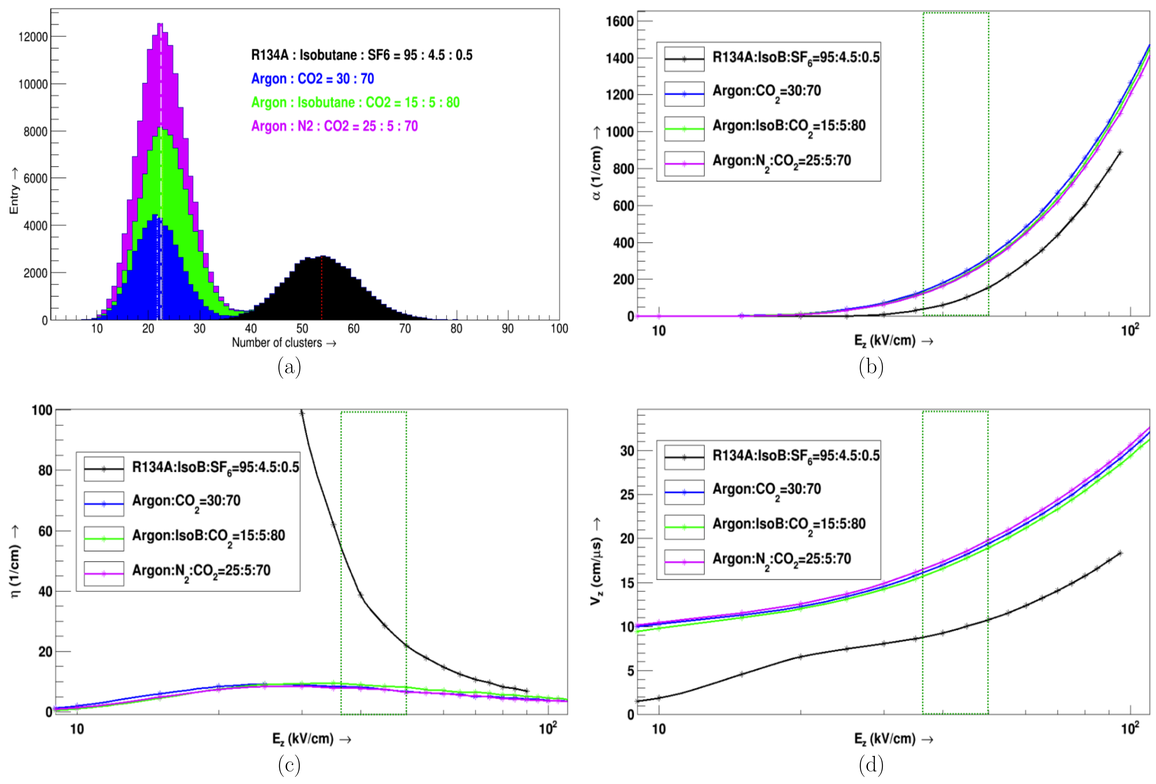

Figure 2: (a) Histogram for number of primary clusters generated by 1 GeV muons (HEED). Variation of (b) Townsend coefficient, (c) attachment coefficient and (d) electron drift velocity with the z-component of electric field for various gas mixtures (MagBoltz).

Induced signal

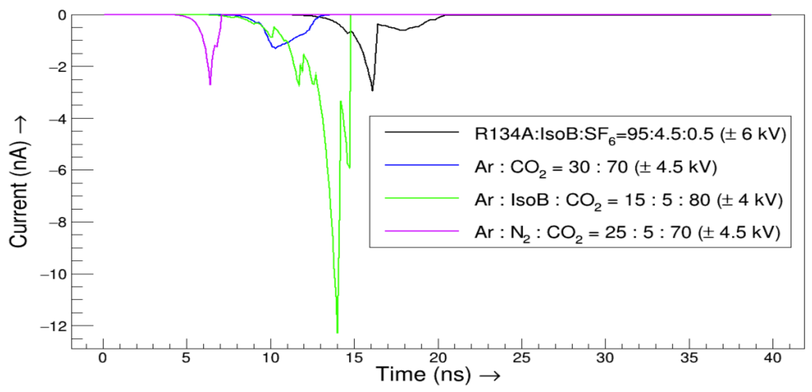

Figure 3: Signal induced on RPC pickup plane due to passage of 1 GeV muon in different gas mixtures operated at different voltages (Garfield).

Conclusions and further work

- Initial study indicates the mixture of Argon, CO_2 with little amount of Isobutane may become a possible alternative for the R-134A based gas mixture already in use.
- More detail study in this topic is in progress.
- Experiments have been planned to pursue to choose the optimum gas mixture.

References

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