Detection of Gamma rays with Multigap Resistive Plate Chamber

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Introduction

Positron Emission Tomography (PET) is a biomedical imaging technique in which a radionuclide labelled with a positron emitter is administered into the object being studied. The coincident detection of the two almost co-linear, 511 keV photons establishes the occurrence of the positron-electron annihilation along the line joining the events (referred as Line-Of-Response, LOR). Multigap Resistive Plate Chambers (MRPC) are gaseous detectors being used worldwide in high energy physics experiments for charged particle detection [1]. Despite the challenges of gamma detection with MRPC's mainly in terms of low detection efficiency, their simple and economic construction paves the way for stacking large number of MRPC detectors to increase gamma conversion. An increase in detection efficiency, along with their excellent timing resolution and position resolution can suitably make MRPC's an alternative to the currently used highly expensive scintillator-based systems for PET. The preliminary gamma detection efficiency results of a six-gap MRPC prototype operated in avalanche mode, using a ^{22}Na source as the β^+ emitter is presented.

Fabrication and testing of the six-gap MRPC

A six-gap MRPC prototype of dimensions 16 cm × 10 cm, is built with seven float glass plates, each of thickness 600 μm, obtained from GSI, Germany [2]. The gas gap between the plates is defined by 200 μm polycarbonate buttons. The prototype is operated in the avalanche mode with a gas mixture of eco-friendly Freon (R-134a) and Iso-butane, in the ratio 95/5. The ^{22}Na source is placed between the MRPC prototype and a plastic scintillator of dimensions 5 cm × 1.2 cm as shown in Fig. 1 .

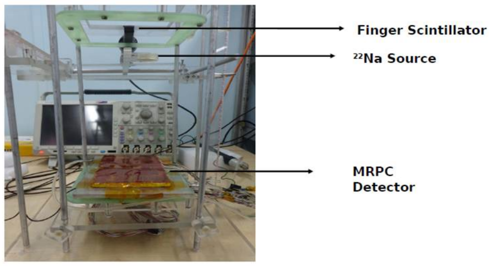

FIG. 1: Experimental Set-up

The positrons emitted by the source travel a very short path length before annihilating with electrons producing two almost anti-parallel 511 keV photons. Coincidence count rate between the signals obtained from the MRPC strips and the scintillator is measured with and without the source.

Results

With the increase of the applied high voltage, the coincidence count rate increases. The coincidence count rate as a function of the applied high voltage is shown in Fig. 2 and it clearly establishes the effect of the source.

The ratio of the two fold coincidence count rate between the MRPC signal and scintillator signal to the number of photons counted by the scintillator is defined as the photon-pair

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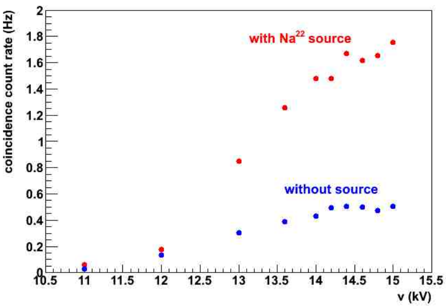

FIG. 2: The coincidence count rate as a function of the high voltage.

detection efficiency. The variation of gamma detection efficiency as a function of the high voltage is shown in Fig. 3. The efficiency increases with that of the high voltage and tends to saturate at higher voltages. A photon-pair detection efficiency of 0.9 % is obtained at a high voltage of 15 kV after correcting for geometrical acceptance and cosmic ray effect measured in non-source configuration [3].

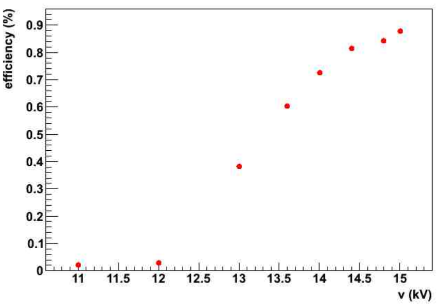

FIG. 3: The pair detection efficiency as a function of the high voltage.

In an effort to locate the source position, the distance between the scintillator and the MRPC is fixed at 44.5 cm and the time difference between the signals from the scintillator and the MRPC is measured by varying the source position. A simple mathematical calculation assuming a photon velocity of 30 cm/ns gives the expected time difference between the signals. The calculated and measured time difference as a function of source distance (source distance is measured from the MRPC prototype) is shown in Fig. 4 and they match within error bar.

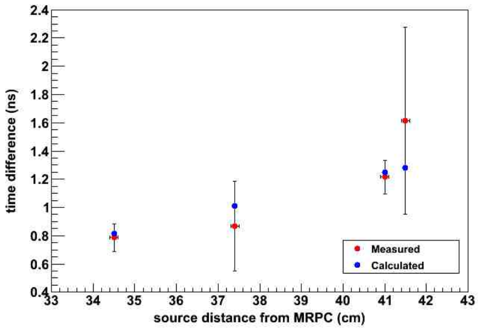

FIG. 4: Time difference as a function of source distance

Conclusions and Outlook

A six-gap glass MRPC is built and tested in the avalanche mode with 511 keV photon pairs from a ^{22}Na source. A clear signal of photon pairs is observed above background in the presence of the source as detected by a scintillator and MRPC coincidence. There has not been any effort to measure the 1.2 MeV photons that accompany the 511 keV photons which would lead to an overestimation of the pair-detection efficiency by 25% [4]. We are working towards building a two MRPC coincidence set-up, which is expected to give better estimation as scintillator resolution is too large. Stacks of MRPC's with converters to increase gamma conversion as seen by simulation [3] will be studied.

References

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