High Z sensitivity test of the Muon Tomography System

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Introduction

As a part of 12th plan, a cosmic ray muon tomography system (MTS) is being developed at the RPC lab, NPD, BARC, primarily to explore the possibility of non-destructive mapping and evaluation of spent nuclear fuel using cosmic ray muons. Tomography based on cosmic ray muons is proving to be an important non-destructive method to discriminate high Z material against a low Z surrounding [1]. Precision data along with powerful algorithms allow not only discrimination but also three dimensional reconstruction of the high Z material [2]. The envisaged tomography system consists of a stack of 6 position sensitive glass resistive plate chambers (RPC) placed inside a scintillator hodosope [3]. While the cosmic hodoscope [4] provides an unambiguous muon trigger, the RPCs provide the incoming and deflected trajectories of the given muon. The deflection angle along with its projection on the X and Y planes uniquely identifies the scattering material and its dimensions. We report here, our preliminary results showing the sensitivity of the cosmic hodoscope to the presence of a block of high Z material (Pb) in the sensitive volume of the tomography system.

Experimental setup

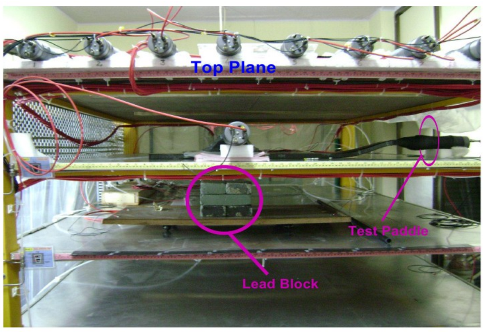

Fig. 1. Photograph showing the hodoscope with Pb blocks inside the sensitive volume.

The trigger system of the MTS comprises of a scintillator hodoscope with top and bottom scintillator planes, each plane consisting of 8 plastic scintillators (180 cm x 18 cm x 1 cm). The total area covered by the scintillators on one plane is 2.6 m^2. For our test setup we have placed a block of Lead bricks of the dimension 20 cm x 20 cm x 13.8 cm on a movable wooden trolley just below the top plane of the scintillator hodoscope (see Fig 1).

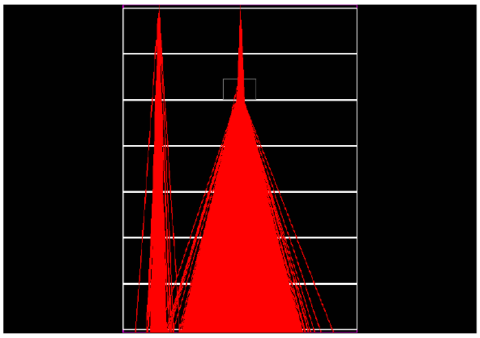

Fig. 2. Expected re-distribution of cosmic ray muon tracks due to the presence of Pb block.

The electronic setup of the system is described in detail in Ref[5]. While the master hardware trigger is generated by the two-fold coincidence between the top plane and the bottom plane indicating the passage of a muon through top and bottom scintillator planes, individual triggering pattern of all the 16 scintillators are also recorded in an event-by-event mode in the CAEN 128 channel multi hit TDC which operate in trigger matching mode. The triggering pattern of individual scintillators enables us to obtain a gross angular sensitivity ~ 4^0 by applying suitable software cuts. In this case a 3-fold coincidence between one of the top scintillators (just above the Pb block) and the paddle scintillator and the bottom plane (all 8 scintillators) is chosen. This restricts the muon tracks to be confined mainly in a vertical plane with the incident muons falling on the lead blocks almost normally. A simulation of the above scenario is done using GEANT4 [6] and is shown in Fig. 2. Only normal incidence is shown in the simulation although in reality there is a spread in the incident angle due to the finite size of the scintillator.

Preliminary results

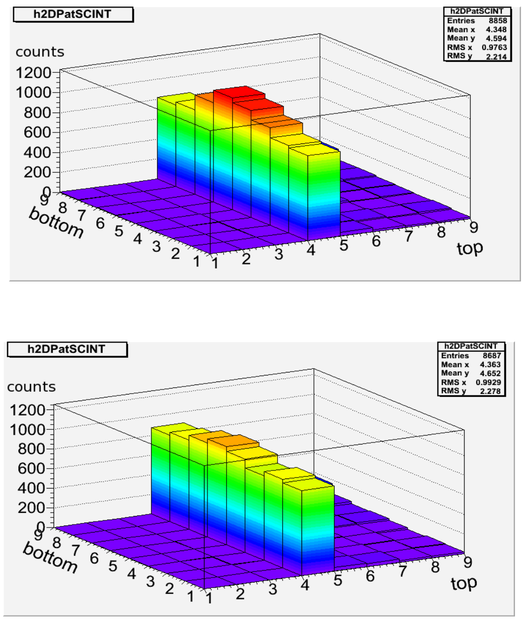

Fig. 3. Trigger pattern observed for the three-fold coincidence (see text) without the Pb blocks (top) and with the Pb blocks (bottom).

Fig. 3 shows the trigger pattern obtained in the bottom plane with the above mentioned criteria for two cases viz. (i) without the lead blocks and (ii) with the lead blocks placed inside the sensitive volume. The redistribution of the muon flux is quite visible from the two figures. 5,00,000 valid muon events (cosmic triggers) were collected for both the cases. As the system is insensitive in the y-dimension at present, we have restricted the spread in y-direction by applying the coincidence condition with another scintillator paddle kept orthogonal to the hodoscope scintillators.

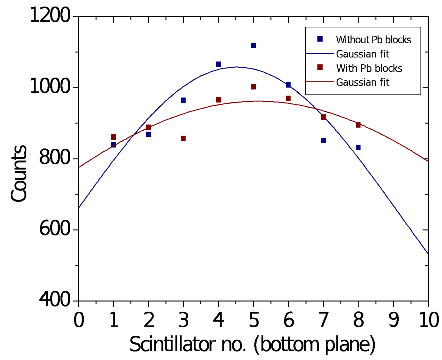

Fig. 4. Gaussian fits to the experimental data shown in Fig. 3 for the two cases.

Gaussian fits to the intensity distributions for the two cases are shown in Fig. 4. It is found that the distribution with the Pb blocks has a standard deviation (σ) of 7.8, whereas the corresponding value for the distribution without the Pb blocks is only 4.6. This significant difference in the width of the distributions indicates the sensitivity of the setup to the presence of materials with high scattering density. Though a quantitative estimate with the present setup is not possible, the marked change in the width of the flux distributions in the both cases indicates the sensitivity of the system to the presence of high Z materials on the muon trajectories. Efforts are in progress to obtain σ for materials of different scattering density using the current setup. Six glass RPCs (1m x 1m) with bi-dimensional read out strips and associated electronics are being integrated to the system. Development of image reconstruction algorithms and related analysis software are also in progress.

References

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