Monte Carlo simulation for estimation of trigger rate in Cosmic Hodoscope at NPD-BARC

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Introduction

Hodoscope is an instrument which is used to detect the path of the particle. The hodoscope at NPD-BARC [1, 2] is used to detect the path of cosmic muons and to generate trigger. It consists of 16 scintillator paddles arranged side by side in two planes (8 on each plane). Each scintillator paddle is composed of a scintillator 180 cm × 18 cm × 1 cm in dimension, coupled to two photomultipliers. Fig. 1 shows the top plane arrangement of scintillator paddles. The bottom plane arrangement is exactly the same. The distance between the top and the bottom plane is 2.1 m. The total area covered by the scintillators on one plane is 2.6 m^2. Applying suitable logic, coincidence of the top and bottom plane signals is used as the trigger.

FIG. 1: Top plane

Cosmic muon flux and generation of zenith angle θ

The flux of the muons is not uniform over all zenith angles. The intensity varies with the zenith angle θ as

$$I(\theta) = I_0 \cos^n \theta, \quad (1)$$

where I_0 is the intensity at 0° zenith angle and n is a constant. From various experiments the constant n is found to be approximately equal to 2. The muon events we generate should follow a $\cos^2 x$ distribution. Acceptance-rejection method [3] has been used to do so. A comparison function $f(x)$, which is above the functional form of the required distribution, i.e., $p(x) = \cos^2 x$, has to be chosen to apply the method. The function we have chosen is the familiar Lorentzian distribution function,

$$f(x) = \frac{1}{1 + x^2}. \quad (2)$$

A $\cos^2 x$ distribution of 1 million events generated using builtin `ran` generator and Acceptance-rejection method is shown in Fig. 2.

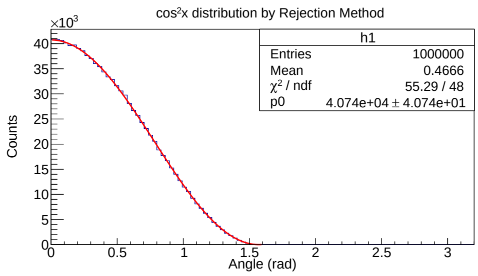

FIG. 2: $\cos^2 x$ distribution

Procedure

The geometry of the hodoscope is as shown in the Fig. 3. An event is characterized by a random x_1, y_1, θ and ϕ. x_1, y_1, and ϕ are uniform deviates generated within the intervals $(0, 1.44)$ (m), $(0, 1.8)$ (m) and $(0, 2\pi)$

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respectively. θ would be a deviate following the $\cos^2 x$ distribution in the interval $(0, \pi/2)$. From Fig. 3, it can be worked out that, considering $y_1 = y_2$

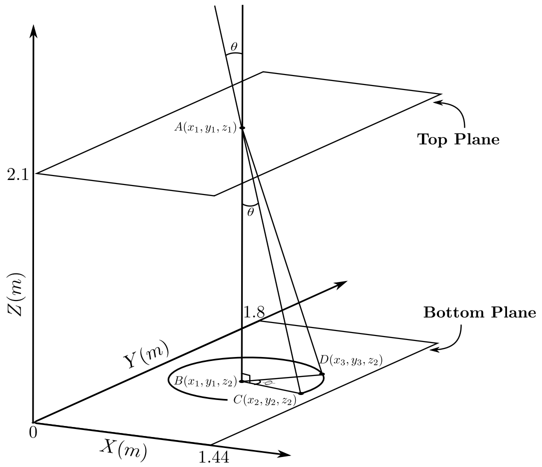

FIG. 3: Geometry of the setup.

$$x_3 = x_1 + \overbrace{AB \tan\theta}^{BC} \cos\phi \qquad (3a)$$
$$y_3 = y_1 + \underbrace{AB \tan\theta}_{BC} \sin\phi. \qquad (3b)$$

where $AB = z_1 - z_2 = 2.1$ m. The event will be accepted if and only if x_3 lies in the interval $(0, 1.44)$ and y_3 lies in $(0, 1.8)$.

Observations

1 million muon events were generated on the top plane. Out of them 389 203 were found to be triggering events. The 2D distribution of triggering events is shown in Fig. 4. The acceptance of the hodoscope is therefore $a = 0.389\,203$. The area of the top plane of the hodoscope is 2.6 m^2. The general value for the intensity of the cosmic muons at sea level is 1 cm^{-2}min^{-1}. It has a dependence on the latitude. The value of I_0 in (1) as determined by [4] is $(6.050 \pm 0.001) \times 10^{-3}$cm^{-2}s^{-1}sr^{-1}. The total flux on the top plane per second can be calculated as follows. If J is the total flux per second, then

$$J = \int I(\theta) \cos\theta \, d\Omega. \qquad (4)$$

Substituting (1) in (4), J is calculated to be 94.26 m^{-2}s^{-1}. The rate of muons falling on the top plane would be $94.26 \times 2.6 \approx 245$ Hz. The trigger rate we should observe in the hodoscope is therefore $245 \times a \approx 95$ Hz.

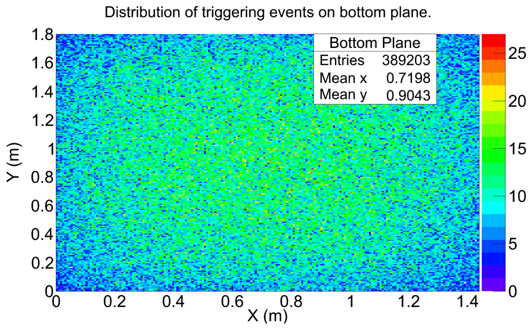

FIG. 4: Distribution of triggering events.

Conclusions

The trigger rate is ~95 Hz as determined by this simulation. In the simulation, the Hodoscope is considered to be 100% efficient, which is not practically possible. Inefficiency may be due to the attenuation of generated photons in the scintillator, muons passing through gaps between scintillators et cetera. They have to be quantified.

References

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[3] William H. Press. *Numerical Recipies in C++*. The Art of Scientific Computing. 2nd edition, Cambridge University Press, 2009.

[4] Sumanta Pal, Study of the Angular Distribution of Cosmic Muons using INO-ICAL Prototype Detector at TIFR, `http://www.hecr.tifr.res.in/~bsn/I-NO/SPal_RPC2012.pdf`