PoCA Point Cloud Filteration algorithm for Muon Tomography

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Introduction

Muon tomography is very promising technique for the detection of high Z materials. The two famous reconstruction algorithms are Point of Closest Approach (PoCA) and Maximum Likelihood Expectation Maximization (MLEM). PoCA is fast but purely geometrical and hence give a lot of false positives ie. sometimes the PoCA lie outside the target object. On the other hand MLEM is iterative algorithm whose convergence depends on initial guess that we feed. Here our primary objective is to use Voxelization method to remove the false positive from PoCA point cloud and provide useful information in terms of regions or voxels within a Voxelized volume 'V'. We will present the preliminary results of its application on simulated data generated using Geant4[1].

Principle of Muon Tomography

While passing through material muon undergoes multiple coulomb scattering and is deflected in many small angles. The traversal is totally stochastic and it emerges at an average scattered angle of Ɵ, and displaced from unscattered exit point by distance x. The angular distribution of scattered muon is approximately Gaussian (with long tails), but the central 98% is well described by gaussian with zero mean and standard deviation is given by

$$\sigma_{\Theta} = \frac{13.6MeV}{\beta cp}\sqrt{\frac{L}{X_0}}\left[1 + 0.038ln\left(\frac{L}{X_0}\right)\right]$$

Here p and βc are momentum and velocity of muon, L is the length of the medium traversed and X_0 is the radiation length.

Simulation Setup

Geant4 Simulation is done on the setup as defined in [2], where we have placed 4 Resistive Plate Chambers (RPC)[3] in Z direction, Each RPC is of 1m x 1m surface area and having two readout planes placed orthogonal to each other. Each readout plane is having 32 readout strips.

PoCA Point Cloud Filteration Algorithm

In this work we are trying to approach the problem of false positive faced by PoCA. As mentioned before that distribution of angular deviation of muon during passage through the material follows gaussian distribution. The algorithm takes the advantage of this correlation and work on the basis that that the PoCA ponits of muon tracks passing through the material will also be correlated and form cluster in 3D space. This implies that if we remove all the uncorrelated PoCA points then we may get the material location and if we reconstruct enough number of points then it may give the overall reconstructed image of the object under test. In order to find the correlated points in 3D space, the algorithm works by dividing the 3D space into N number of 3D voxel as shown in fig 1.

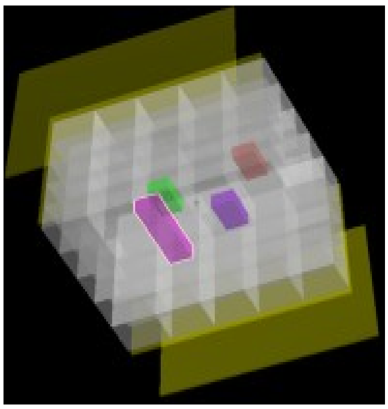

Fig.1 : 3D Voxelized Region superimposed with scatterers

The pseudo code of the algorithm is as follows

1. Divide the region of interest in N number of Voxels, and set threshold (minimum. number. of points required) T

2. For each event E do :
3. Find the hit points on all the detector plane.
4. Draw the incoming line L_i and the outgoing Line L_o
5. Find the PoCA point.
6. Locate the Voxel to which this PoCA point belongs to, and increment its counter(C)
7. After processing all events
    for each Voxel $\boldsymbol{V_i}$:
        if $\boldsymbol{C_i}$ < T then
            ignore all the PoCA points belonging to Voxel V_i .
        else
            keep all the PoCA points belonging to Voxel V_i .

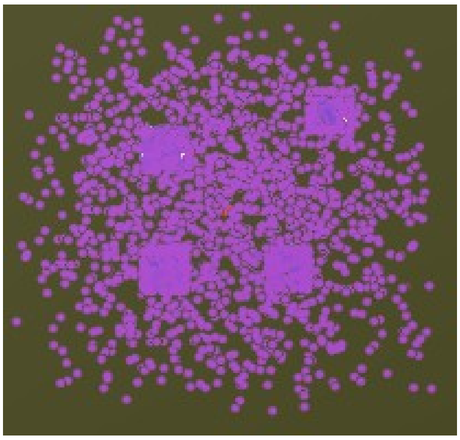

Fig. 2 : Raw PoCA points

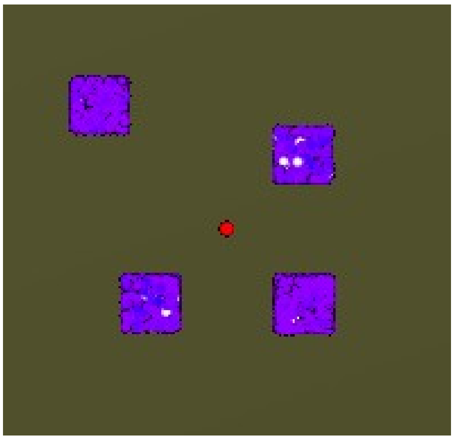

Fig. 3 : Filtered PoCA points

Threshold Selection : The selection of threshold is done by plotting the 1D histogram of PoCA point counter for all the Voxels, and then from the histogram choosing a threshold value that will remove the uniformly distributed PoCA point in 3D space. From the histogram in fig. 4 below one can clearly see that if we chose 50 as the threshold value, then it remove most of the uncorrelated points (smaller spikes), and the big spikes correspond to the Voxel numbers where the material is placed. The above mentioned threshold based filtration algorithm has shown encouraging results as shown in fig. 2 & 3. Fig 2. shows top view of raw PoCA points cloud. Figure 3. shows the top view of filtered PoCA points which remains after application of threshold value 50. Fig 4. shows 1D Histogram of PoCA points in a 8000 Voxels.

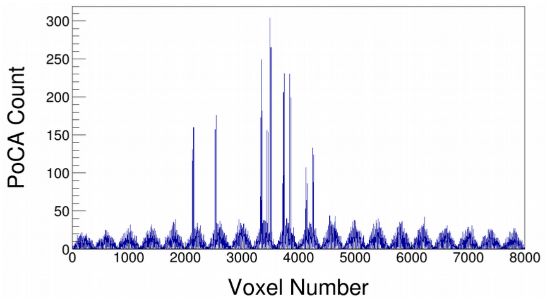

Fig. 4 : 1D Histogram of 8000 Voxels

Conclusion and Outlook

A filteration algorithm is proposed which works very well with simulated data, generated by shooting monoenergetic muon of 2 GeV. Next step is to do some advance simulation that will introduce some more realistic parameters and to see how well the the proposed algorithm removes false positives. In future we will also work on the implemenation of MLEM and some good clustering algorithm that will help to find the clusters from filtered PoCA points. This will eventually be useful in distinguishing one material from another. Next we will collect the cosmic data using experimental setup exists in RPC lab, (NPD, BARC), which is equipped with a cosmic hodoscope, having 4 Glass RPCs of 1m X 1m, and two scintillator based triggering planes. We will try to compare the results of application of above mentioned algorithm on experimental and simulated data.

References

[1] http://geant4.cern.ch
[2] DAE Symp. On Nucl.Phys. 62, 1000-1001 (2017) .
[3] DAE Symp. On Nucl.Phys. 61, 1034-1035 (2016)