

# Fall 2007 Research Report

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December 17, 2007

## 1 Introduction

This semester, GEANT4 simulations were developed to model the passage of cosmic ray muons through matter. The investigations were designed to determine the feasibility of using a setup consisting of GEM detectors to find possible nuclear contraband entering the country through shipping containers.

## 2 Monoenergetic Analysis

This semester, single muons were fired into a 10 cm box of varying materials - iron, copper, uranium, lead, and aluminum. The energy of the muons were 1 GeV, 3 GeV, 10 GeV, and 20 GeV for each material. For each simulation, 250000 events were used. Based on the rate of muon flux, this equates to one minute of cosmic ray exposure. The geometry was placed in argon gas.

### 2.1 ROOT Script

Output from GEANT4 is converted to ROOT files through the use of the following script. GEANT4 actually creates a text file which is then read into a ROOT tree.

```
include "Riostream.h"
void basic() {
    TString dir = gSystem->UnixPathName(TCint::GetCurrentMacroName());
    dir.ReplaceAll("basic.C","");
    dir.ReplaceAll("/./","/");
    ifstream in;
    in.open(Form("%sbasic.dat",dir.Data()));

    Float_t v;
    Int_t nlines = 0;
    TFile *f = new TFile("basic.root","RECREATE");
    TH1F *h1 = new TH1F("h1","Scattering Angle Distribution",100,0,180);
    TNtuple *ntuple = new TNtuple("ntuple","data from ascii file","v");
```

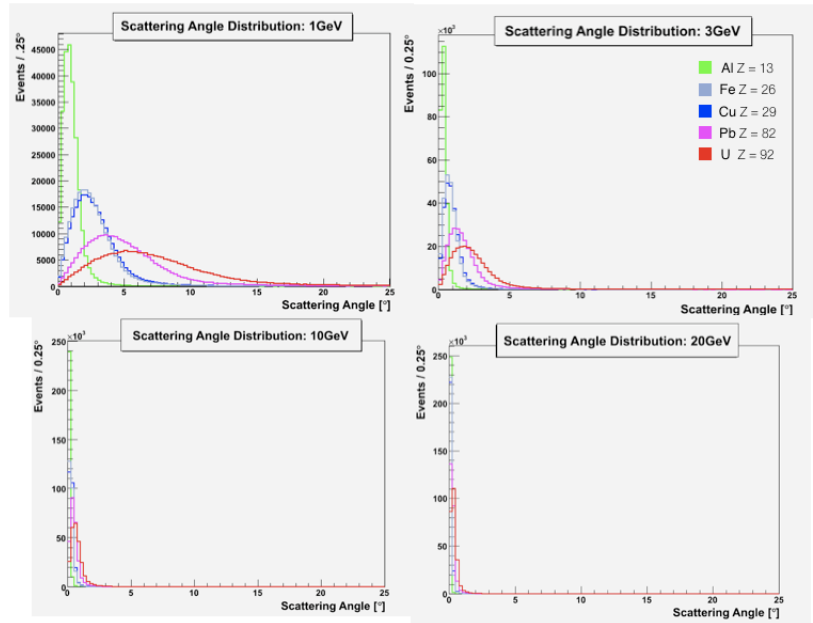


Figure 1: Results on the same scale showing the dependence of scattering angle on energy. The higher the energy, the lower the scattering angles.

```

while (1) {
    in >> v;
    if (!in.good()) break;
    if (nlines < 5) printf("v=%8f\n",v);
    h1->Fill(v);
    ntuple->Fill(v);
    nlines++;
}
printf(" found %d points\n",nlines);

in.close();

f->Write();
}

```

### 3 Complex Simulations

More complex simulations were attempted, using two GEM planes. The geometry can be seen in the figure below. The world sits in air.

#### 3.1 ROOT analysis scripts

For creating POCA plots, I wrote a short script in ROOT, two snippets of which can be seen below. The script opens the text file and creates a ROOT file with an NTuple containing the data. The script then creates a scattering angle distribution, a POCA scatter plot with colored points zoomed in on the box, as well as a POCA scatter plot with colored points of the whole world. This code snippet below shows the creation of the ROOT file and NTuple:

```

include "Riostream.h"
void basic() {
    TString dir = gSystem->UnixPathName(TCint::GetCurrentMacroName());
    dir.ReplaceAll("basic.C","");
    dir.ReplaceAll("/./","/");
    ifstream in;
    in.open(Form("%sbasic.dat",dir.Data()));

    Float_t x,y,z,v;
    Int_t nlines = 0;
    TFile *f = new TFile("basic.root","RECREATE");
    TH1F *h1 = new TH1F("h1","x distribution",100,-4,4);
    TNtuple *ntuple = new TNtuple("ntuple","data from ascii file","x:y:z:v");

    while (1) {

```

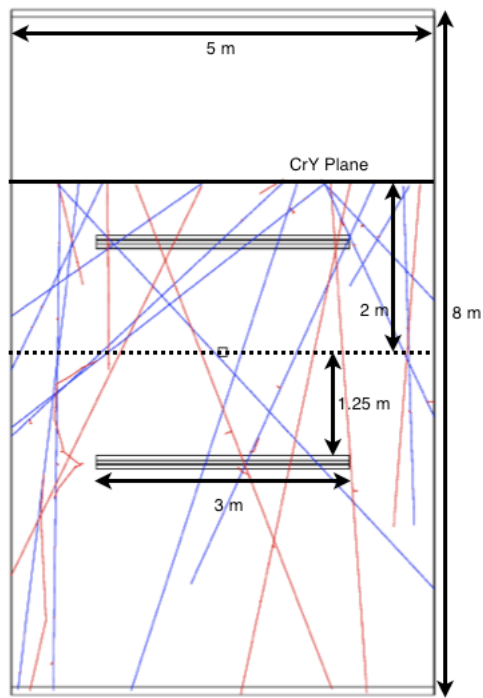


Figure 2: GEANT4 geometry. Blue tracks represent positive muons, and red tracks represent negative muons. Each GEM detector plane is 1 mm thick, with 5 cm between each.

```

        in >> x >> y >> z >> v;
        if (!in.good()) break;
        if (nlines < 5) printf("v=%8f, x=%8f, z=%8f, y=%8f\n",x,y,z);
        h1->Fill(x);
        ntuple->Fill(x,y,z,v);
        nlines++;
    }
    printf(" found %d points\n",nlines);

    in.close();

    f->Write();
}

```

POCA plots with colored scatter plots are created using code as follows in ROOT:

```

TFile g("analysis.root");
TCanvas c1;
c1->cd();
ntuple->SetMarkerStyle(6);
ntuple->SetMarkerColor(4);
ntuple->Draw("z:x:y>>
hist(100,-100,100,100,-100,100,100,-1000,1000)", "(v>=0.5) && (v<1)");
ntuple->SetMarkerColor(9);
ntuple->Draw("z:x:y", "(v>=1) && (v<1.5)", "SAME");
ntuple->SetMarkerColor(38);
ntuple->Draw("z:x:y", "(v>=1.5) && (v<2)", "SAME");
ntuple->SetMarkerColor(30);
ntuple->Draw("z:x:y", "(v>=2) && (v<2.5)", "SAME");
ntuple->SetMarkerColor(3);
ntuple->Draw("z:x:y", "(v>=2.5) && (v<3)", "SAME");
ntuple->SetMarkerColor(8);
ntuple->Draw("z:x:y", "(v>=3) && (v<3.5)", "SAME");
ntuple->SetMarkerColor(30);
ntuple->Draw("z:x:y", "(v>=3.5) && (v<4)", "SAME");
ntuple->SetMarkerColor(5);
ntuple->Draw("z:x:y", "(v>=4) && (v<4.5)", "SAME");
ntuple->SetMarkerColor(41);
ntuple->Draw("z:x:y", "(v>=4.5) && (v<5)", "SAME");
ntuple->SetMarkerColor(2);
ntuple->Draw("z:x:y", "(v>=5)", "SAME");
ntuple->SetMarkerColor(1);

```

### 3.2 10 cm Box

For this 2.5 million event sample, we used a box of 10 cm. The box was made of lead. From POCA (Point of Closest Approach), 93.6% of the "Voxels" were covered so almost all of the voxels, or small boxes within the 10 cm box, had at least one scatter point in it. 0.174601% of the scatter points were in the 10 cm target box. Out of the 2.5 million events, 315576 events hit both the top and bottom detectors. Out of the 2.5 million events, 11199 events were plotted in 3D plots. Next semester, these same 10 cm box simulations will be investigated using different materials, as done with the monoenergetic simulations.

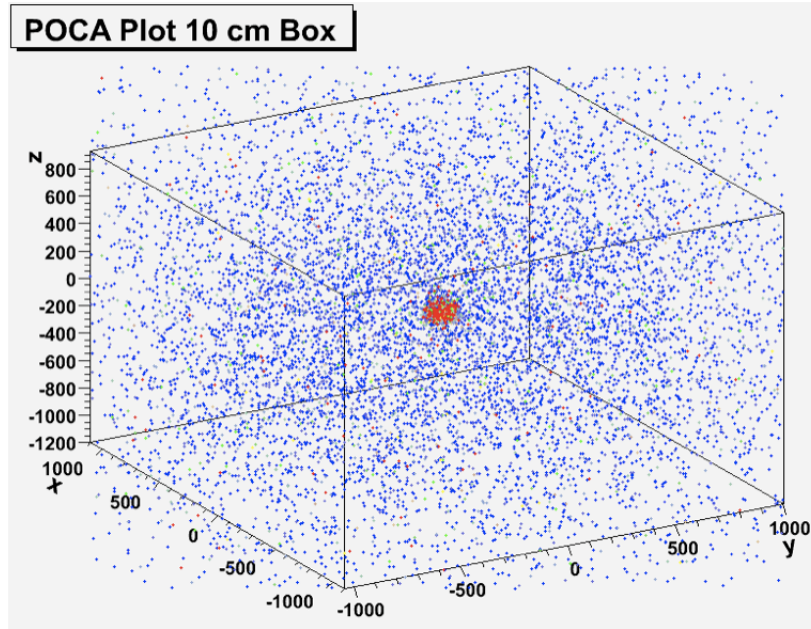


Figure 3: Results of the POCA reconstruction.

### 3.3 Other Scenarios

I also ran simulations of a 50 cm box as well as an empty box. The empty box showed many scatters in the blue range but it was clear that no false positives were present.