Analysis of GEANT4 Muon Tomography Scenarios Using ROOT

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Introduction

Here we present some results modeling various scenarios of interest for detecting nuclear contraband. For each scenario, 2.5 million events were simulated using CrY cosmic ray muon generator.

Clutter Scenarios

Horizontal Clutter: Distinguishing Low and Medium Z Materials

In this scenario, there are three 200 mm x 200 mm blocks of Aluminum located at (X,Y,Z) positions of (0,0,0), (400,0,0) and (-400,0,0). In between these blocks lie two 1 liter (100 mm x 100 mm) blocks. There is a Copper block located at (-200,0,0) and an Iron block located at (200,0,0). All of the coordinates are in millimeters. These results below quite clearly show the importance of resolution on the detection of 1 L objects. The presence of the Aluminum in the 200 micron resolution detector makes resolving any of the higher Z materials difficult without using a significance analysis.

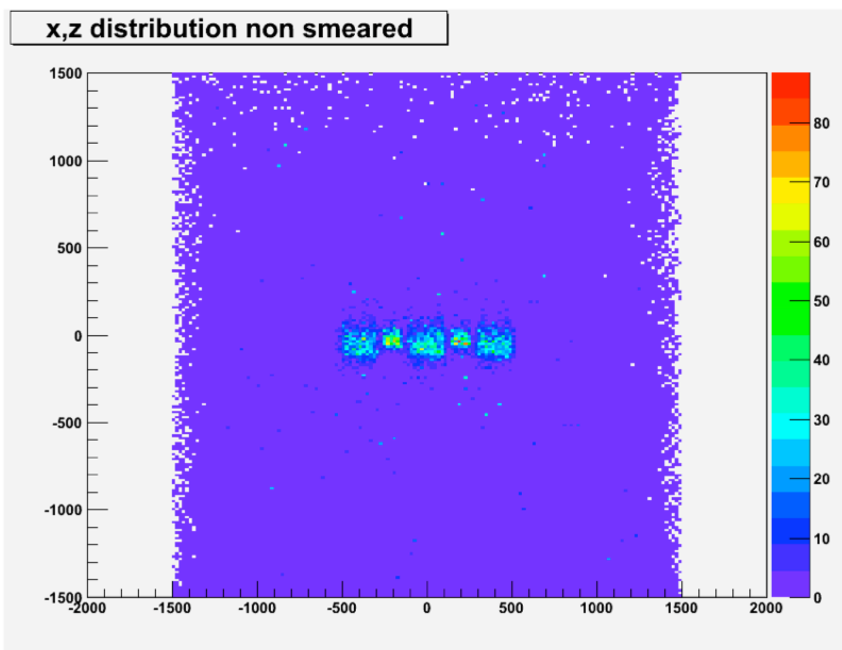
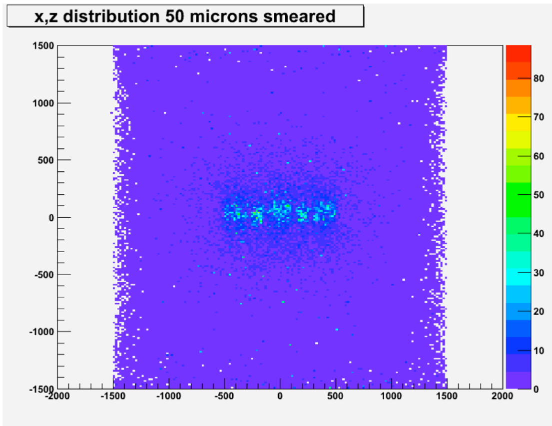


Figure 1: The nonsmeared XZ distribution for 2.5 million events (08_03_20AllPocaPointsVertClutterAlVariousStacks).



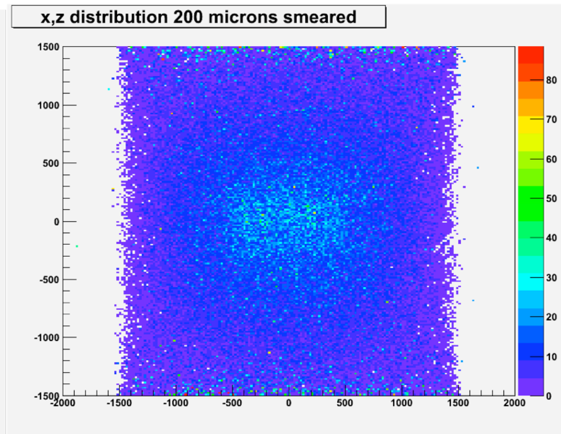


Figure 2 (left), Figure 3 (right): The smeared XZ distributions for two resolutions: 50 and 200 microns (08_03_20AllPocaPointsVertClutterAlVariousStacks).

Horizontal Clutter: Distinguishing Low and High Z Materials

In this scenario, there are three 200 mm x 200 mm blocks of Aluminum located at (X,Y,Z) positions of (0,0,0), (400,0,0) and (-400,0,0). In between these blocks lie two 1 liter (100 mm x 100 mm) Uranium blocks. They are located at (-200,0,0) and (200,0,0), where all coordinates are in millimeters. It is clear in both resolutions where the Uranium is located.

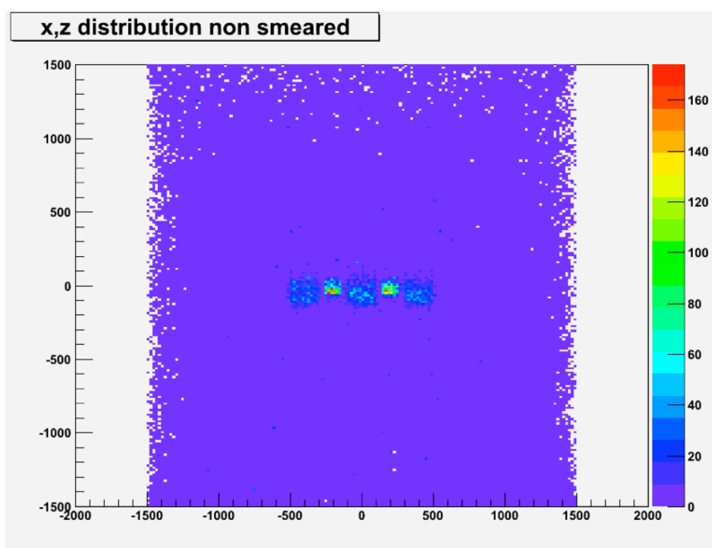


Figure 4: The nonsmeared XZ distribution for 2.5 million events (08_03_20AllPocaPointsVertClutterAlUStacks).

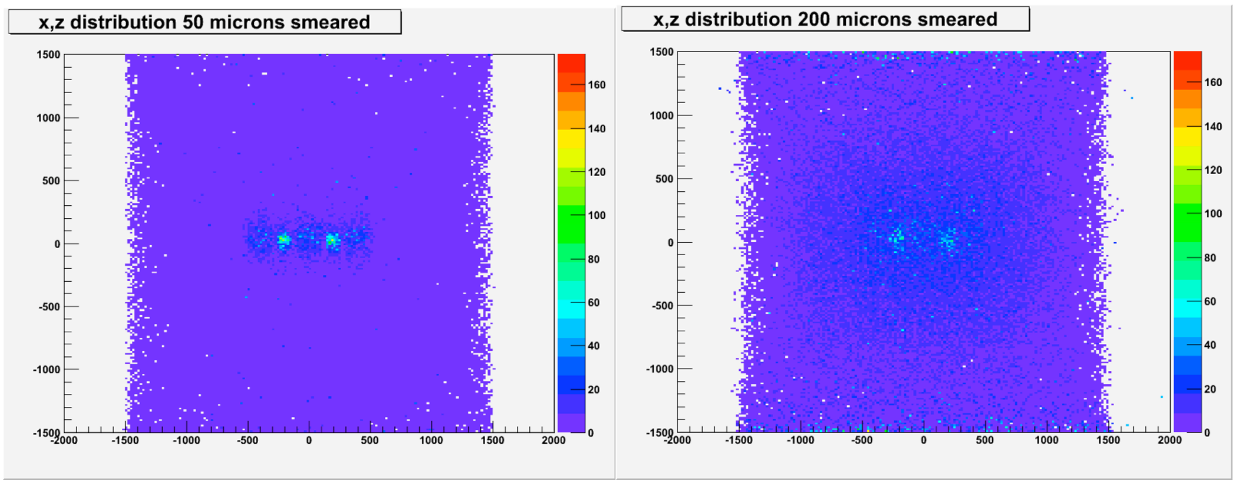


Figure 5 (left), Figure 6 (right): The smeared XZ distributions for two resolutions: 50 and 200 microns (08_03_20AllPocaPointsVertClutterAlUStacks).

Aluminum Blocks Present Horizontally

In this scenario, there are two large 1000 mm x 500 mm blocks of Aluminum located at (X,Y,Z) positions of (850,0,0) and (-850,0,0). In between these blocks lies a stack of three different materials: one 100 mm x 100 mm Copper block at (-10,10,-200), one 100 mm x 100 mm Iron at (10,10,200), and one 100 mm x 100 mm Uranium block at (0,0,0). All coordinates are in millimeters.

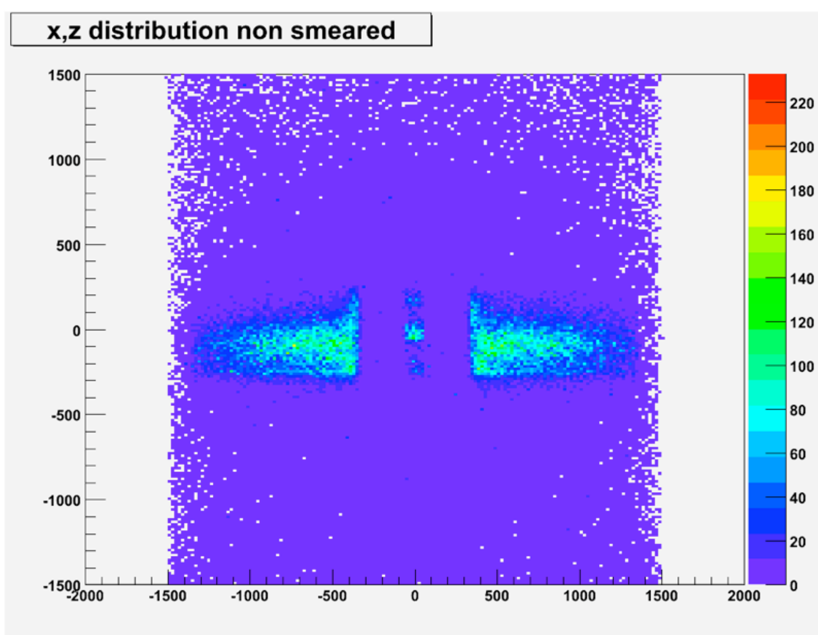
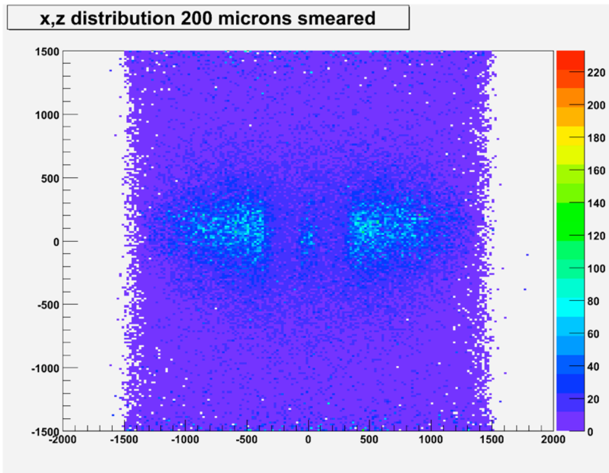


Figure 7: The nonsmeared XZ distribution for 2.5 million events (08_03_20AllPocaPointsVertClutterAlBlocks).



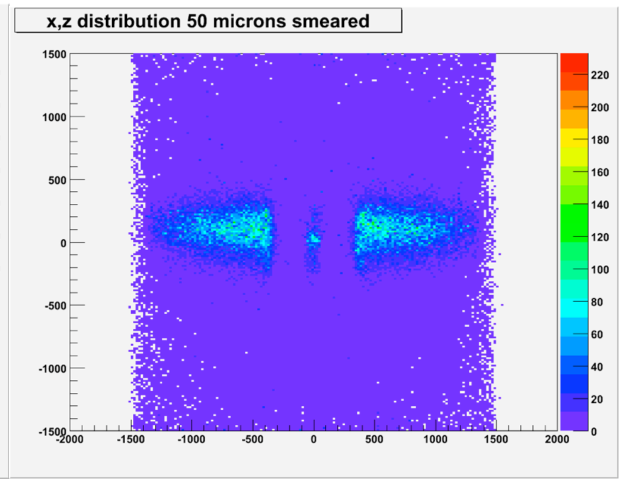


Figure 8 (left), Figure 9 (right): The smeared XZ distributions for two resolutions: 50 and 200 microns (08_03_20AllPocaPointsVertClutterAlBlocks).

Aluminum Blocks Present Vertically

In this scenario, there are two large 1000 mm x 500 mm blocks of Aluminum located at (X,Y,Z) positions of (0,0,850) and (0,0,-850). In between these blocks lies a stack of three different materials: one 100 mm x 100 mm Copper block at (-10,10,-200), one 100 mm x 100 mm Iron at (10,10,200), and one 100 mm x 100 mm Uranium block at (0,0,0). All coordinates are in millimeters.

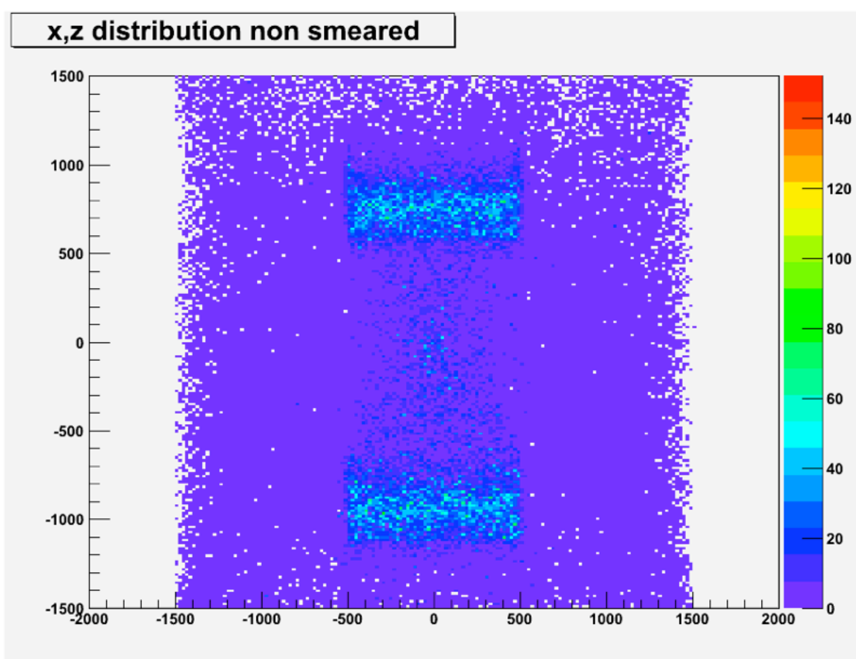
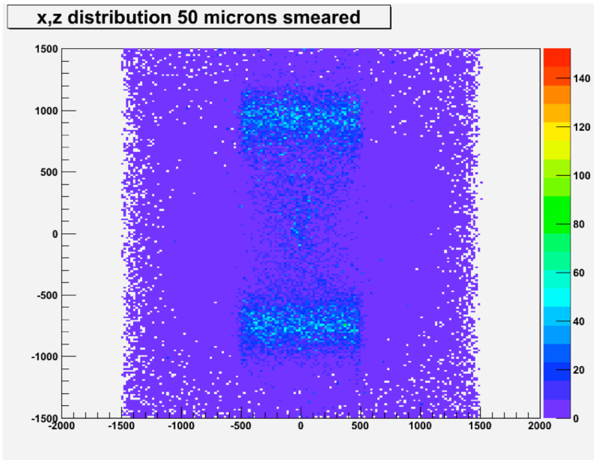


Figure 10: The nonsmeared XZ distribution for 2.5 million events (08_03_22VertClutterAlBlocks).



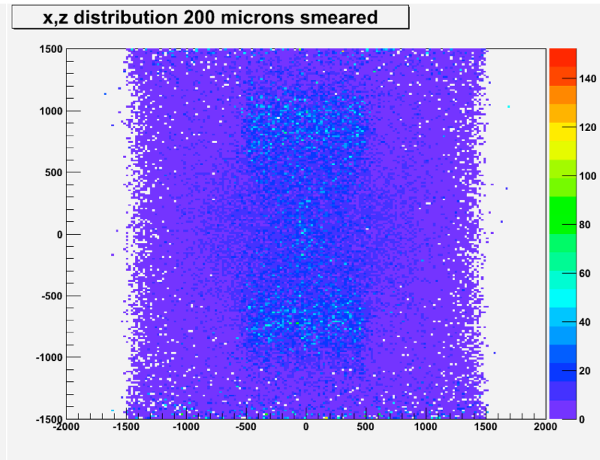


Figure 11 (left), Figure 12 (right): The smeared XZ distributions for two resolutions: 50 and 200 microns (08_03_22VertClutterAlBlocks).

Vertical Clutter: Distinguishing Low and Medium Z Materials

In this scenario, there are three 200 mm x 200 mm blocks of Aluminum located at (X,Y,Z) positions of (0,0,0), (0,0,-400) and (0,0,400). In between these blocks lie two 1 liter (100 mm x 100 mm) blocks. There is a Copper block located at (0,0,-200) and an Iron block located at (0,0,200). The ability to resolve these blocks based on this analysis is not very good. More advanced analysis methods could be used on this data to improve the results.

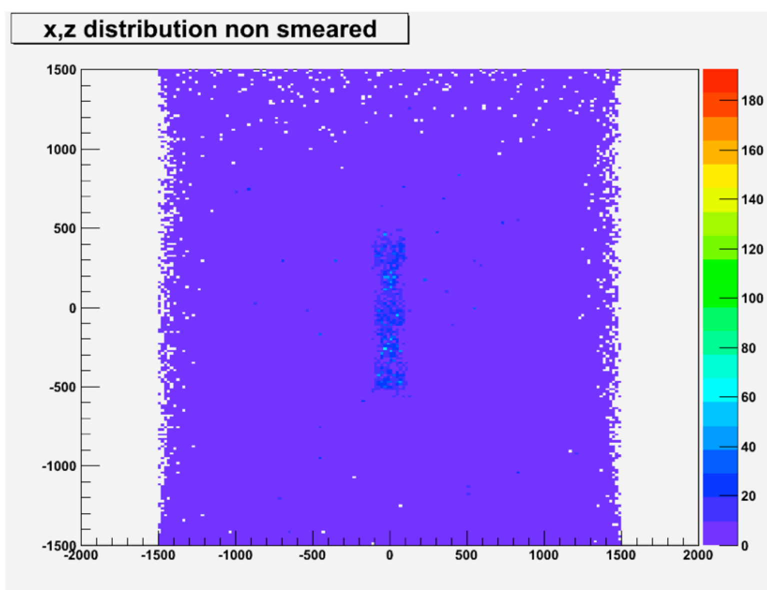
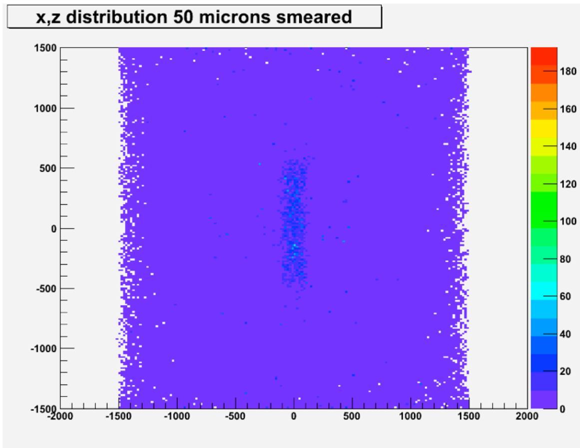


Figure 13: The nonsmeared XZ distribution for 2.5 million events (08_03_22VertClutterAlVariousStacks).



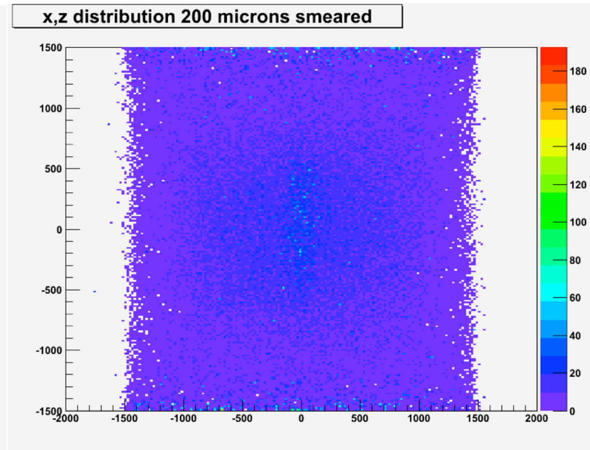


Figure 14 (left), Figure 15 (right): The nonsmeared XZ distribution for 2.5 million events (08_03_22VertClutterAlVariousStacks).

Vertical Clutter: Distinguishing Low and High Z Materials

In this scenario, there are three 200 mm x 200 mm blocks of Aluminum located at (X,Y,Z) positions of (0,0,0), (400,0,0) and (-400,0,0). In between these blocks lie two 1 liter (100 mm x 100 mm) Uranium blocks. They are located at (-200,0,0) and (200,0,0), where all coordinates are in millimeters. It is still fairly clear in both resolutions where the Uranium is located.

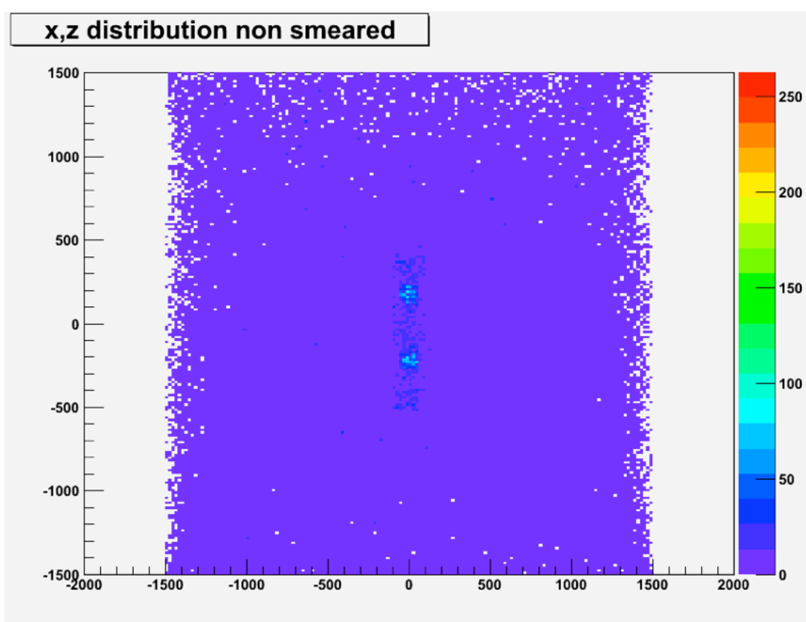


Figure 16: The nonsmeared XZ distribution for 2.5 million events (08_03_22VertClutterAlUStacks).

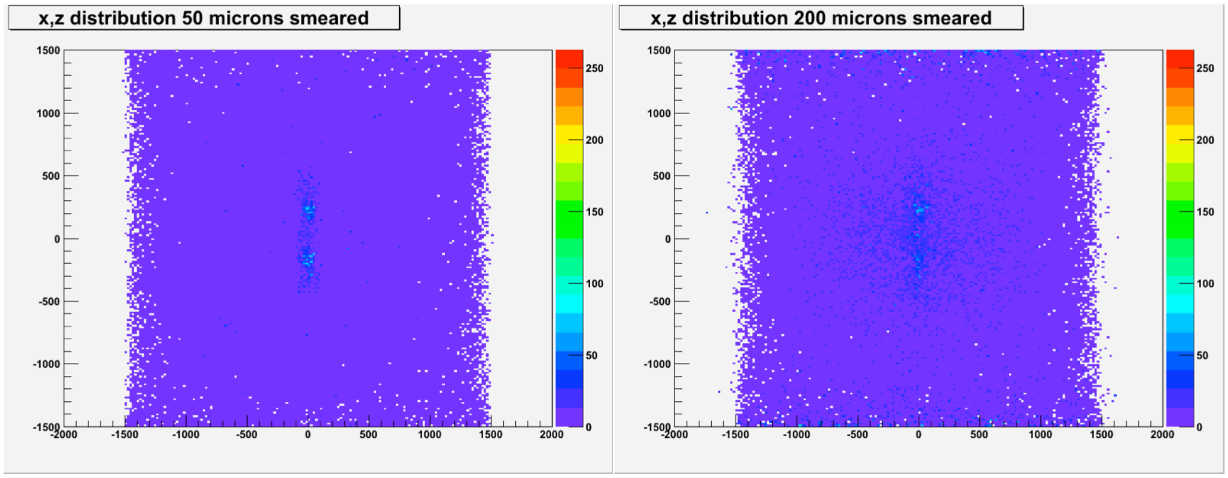


Figure 17 (left), Figure 18 (right): The smeared XZ distributions for two resolutions: 50 and 200 microns (08_03_22VertClutterAlUStacks).

Appendix: Usage of ROOT Scripts in Analysis

There are currently two main scripts for analysis as of May 2008. There is a tool for analyzing the results from the coverage analysis, called analysisCoverage.C, and the other tool is for analyzing the POCA output from any muon tomography scenario, analysisPocaPoints.C.

General Information for Running Named ROOT Scripts

All scripts are executed from the ROOT command prompt. Open ROOT in a terminal by typing "`root`". Simply type:

```
.x myScript.C(parameter1,parameter2,parameter3);
```

where myScript.C represents the name of the script you wish to run and parameters[1-3] represent the parameters you wish to hand the analysis. Currently the scripts are implemented such that they require you to input certain information such as the size of the world and the number of "slices" you wish to have (for the POCA points analysis).

After you have typed the above command, ROOT will output one histogram at a time briefly to the screen and will then save each histogram as a *.png file in the current directory, whereupon the histogram window will close. These histograms should have the correct axes, labels, etc., and should indicate what cuts were used. In addition, all the results are saved in a *.root file in case you wish to edit how the histogram is displayed at a later time.

Coverage Analysis

The parameters here are just the size of the world in XY and in Z, as well as the title of the text file you are using to input the coverage data, i.e. coverage4x4x3. This script will produce 30 plots, at various slices through the detector. Each plot's color scale is normalized to the other plots such that they can be easily compared. The highest color, at 1, represents the maximum value of muons per voxel. The maximum value of muons per voxel is placed in the title. So at the command line, you would type:

```
.x analysisCoverage.C("coverage4x4x3",4000,3000);
```

to run the coverage analysis on the text file coverage4x4x3.txt, where it is a world with size in Z of 3000 mm and size in XY of 4000 mm.

POCA Points Analysis

The parameters here are just the size of the world in XY and in Z, as well as a string that is used as a descriptor for your scenario and should be a prefix to your data files from POCA, i.e., if you hand “simuFeUMay2008” to the script, then your input files should all be called:

```
simuFeUMay20081MinUnsmeared.txt
simuFeUMay20081MinRes50.txt
simuFeUMay20081MinRes200.txt
simuFeUMay20084MinUnsmeared.txt
simuFeUMay20084MinRes50.txt
simuFeUMay20084MinRes200.txt
simuFeUMay200810MinUnsmeared.txt
simuFeUMay200810MinRes50.txt
simuFeUMay200810MinRes200.txt
```

This script will produce a variable number of plots (based on the number of slices you select), at various slices through the detector. Each plot’s color scale is normalized to the other plots such that they can be easily compared. The highest color, at 1, represents the maximum value of muons per voxel. The maximum value of muons per voxel is placed in the title. So at the command line, you would type:

```
.x analysisPocaPoints.C(“simuFeUMay2008”,
4000,3000,3000,10,10,10,100,100);
```

where the parameters are (“descriptor”,sizeX,sizeY,sizeZ,numberSliceX,numberSliceY,numberSliceZ,binSize,voxelSize) all in millimeters. The size* options set the size of your world. The numberSlice* options set the number of slices you would like along each axis. ROOT will then save your plots as *.png files in the same directory along with a *.root file of all the data.