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OBJECTIVE

This semester, I spent the majority of my time learning the GEANT4 simulation and ROOT data analysis code analysisMTS.C written by Ben Locke and the vx4d software written by Will Bittner. In addition to this, I began work on the coverage analysis of possible future MTS geometries, with the goal of constructing a larger station using mainly the same detectors currently used in the cubic-foot station.

GENERALIZED CUBIC-FOOT STATION SIMULATION

At the beginning of the semester, minor improvements were made to further generalize Ben's cubic-foot MTS simulation code. An extra command was added to the simulation's configuration file allowing users to specify box or cylindrical targets and their respective dimensions. This was achieved by initialing a new G4UIparameter nameded targetShape in the DetectorMessenger that reads in a string telling the simulation which geometry to use. The shape type determines how the simulation interprets the other size parameters supplied by the configuration file i.e. a box target is described in terms of its length, width and height and a cylindrical target is described in terms of height and inner and outer radius. The code can be found on our computing cluster at uscms1.fltech-grid3.fit.edu in the directory home/g4hep/geant4/examples/mytestapps/nathan/nathanGrandSimulation2. Instructions for how to use the new target commands are supplied in the configuration file config.txt.

VX4D

Along with Ben's generalized MTS simulation, I also familiarized myself with Will's vx4d software. I produced animations of the stacked target and lead cross scenarios using the real data taken with our cubic-foot MTS using the screen capture program XVidCap to record vx4d's "Cinematic Mode" output. Due to a mistake in labeling, we are currently unsure as to which scenarios some of the animations correspond to, and the animations need to be remade in order to verify the accuracy of current set of videos.

Beauty, the Ubuntu computer vx4d was written for and installed on, had to be reformatted in the middle of this semester because of driver conflicts caused by a system update. A build of vx4d had been saved to the computing cluster as a backup, which was installed on the newly formatted Beauty. I followed Will's online documentation for installing vx4d and all of the required drivers, but the final product proved to be considerably more buggy than the version that had been lost in the reformatting process. Currently, the vx4d display does not update to reflect minimum muon and minimum angle cuts applied in the Terminal. This has prevented me from verifying the labels on

the current set of videos because the data sets are nearly indistinguishable without any applied cuts.

COVERAGE ANALYSIS

Towards the end of this semester I began work on coverage analysis of possible future MTS geometries which would utilize the muon's average incident angle of 30° to the vertical in order to increase the coverage volume. At this point, most of the results are qualitative, and represent only the beginning of a more thorough analysis of the following geometries.

The first geometry I examined was thought of by graduate student Lenny Grasso, and is essentially the cubic-foot station with two detectors in front of and behind the main station as shown in Figure 1. This configuration increases the active volume from 27.5 cm x 27.5 cm x 27.5 cm to 27.5 cm x 27.5 cm x 108 cm.
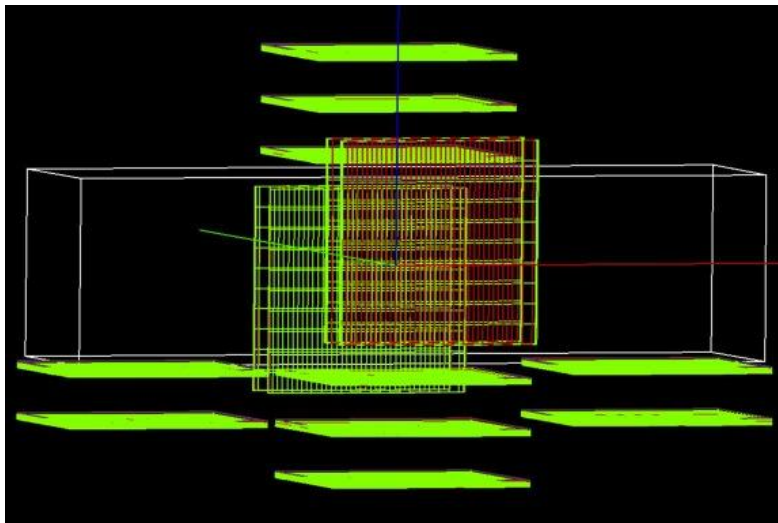

Figure 1: Extended Muon Tomography Station (EMTS)
Geometry

The EMTS Geometry also extends the coverage volume considerably, but the coverage in the volume gained was very weak i.e. it would take considerably longer to image a target placed in the added volume. Figure 4 shows the coverage of the EMTS Geometry at the center of the station. The data used to generate Figure 4 can be found on our computing cluster in the directory:
home/g4hep/geant4/examples/mytestapps/nathan/nathanGrandSimulationLenny.

The next geometry examined, shown in Figure 2, is a further departure from the cubic-foot geometry. The top and side detectors have been replaced by two sets of detectors rotated by 30° and -30° respectively. Angling the detectors in this manner increases the number of incident muons whose trajectory is normal to the detector plane. Muons that hit the detectors at 0° with respect to the vertical yield a cleaner reconstruction of their tracks and are therefore better for imaging.

The Pavilion Geometry simulated does not increase the active volume over the current cubic-foot MTS, but it does offer an overall strong coverage and requires only six
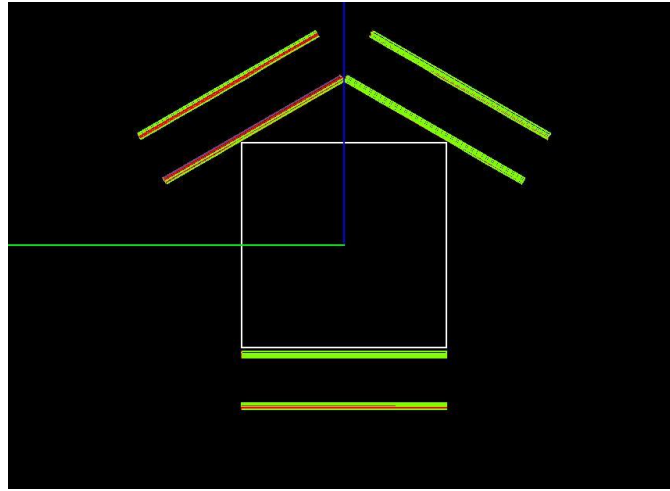

Figure 2: Pavilion Geometry

detectors, whereas the current MTS geometry uses ten. Figure 5 shows the coverage of the Pavilion Geometry at the center of the station. The data used to generate Figure 5 can be found on our computing cluster in the directory: home/g4hep/geant4/examples/mytestapps/nathan/pavilionGeometry.

The final geometry considered, known as the Large Pavilion Geometry (LPG), utilizes the angled detectors of the Pavilion Geometry and the extended detector base of the EMTS Geometry. Figure 3 shows the LPG and its two active volumes. Due to constraints imposed by the ROOT script used to create coverage plots, the active volume must be a rectangular prism. So in order to get a clear picture of the LPG's coverage volume, the two volumes had to be analyzed separately.
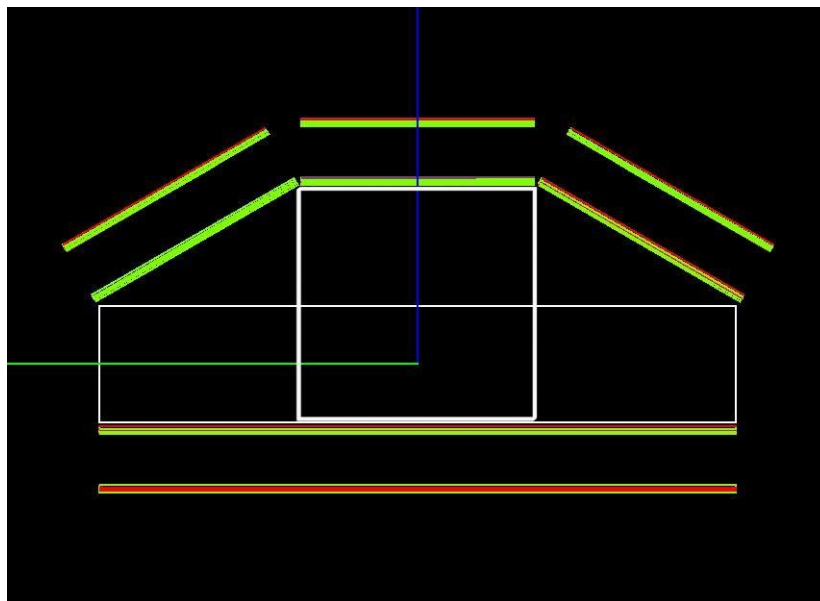

Figure 3: Large Pavilion Geometry

The LPG gives strong coverage throughout both of the active volumes except in the upper corners of the middle square volume, as shown in Figures 6 and 7 respectively. The data used to generate Figures 6 and 7 can be found on our computing cluster in the directory: home/g4hep/geant4/examples/mytestapps/nathan/largePavilionGeometry. The lack of coverage in these corners may be a result of the gaps in the top layer of detectors, but this area is unlikely to contain the target being imaged so strong coverage in those areas in not vital. This geometry as it is simulated here would require a much larger GEM detector to be constructed for its base. The larger base though extends the total active volume considerable with the lower active volume being 30 cm x 30 cm x 82 cm and the middle active volume being 30 cm x 30 cm x 30 cm.

MAKING COVERAGE VIDEOS

The coverage videos found at the end of this report were made using the Mac application iMovie and the images generated by Ben's ROOT script. The instructions for creating these types of videos are as follows:

1. Launch iMovie
2. Start a new project by clicking File > New Project or using the keyboard shortcut ⌘+N.
3. Name your project and select the "No Theme" option under Project Themes. Click Create.
4. Order the coverage images by name and drag them into the New Project area.
5. Once the images have been added to your project, use the keyboard shortcut ⌘+A to select all of them and hover your mouse cursor over one of the images. Click on the blue gear icon to reveal a drop-down menu and select Cropping, Ken Burns & Rotation.
6. In the top left corner of the right-hand window, select the Fit option and then click Done in the upper right corner.
7. If all of the images are not still highlighted, use the ⌘+A shortcut again and access the same blue-gear drop-down menu. This time select Clip Adjustments.
8. Change Duration to 0.4 s and check the option to Apply to all stills. Click Done.
9. Click the Play button in the lower left corner of the Project area to view your video and make sure it is formatted correctly.
10. Click the arrow in the upper left corner of the application to go back to your Project Library.
11. Right-click or ⌘+click your project and select Export using QuickTime. Change the format to AVI in the drop-down menu and click Save.

FUTURE WORK

The goal in exploring these new geometries is to find a configuration that would allow us to image an object the size of a suitcase or piece of luggage with the same detectors used in the current cubic-foot station. To achieve this, the next step is to increase the active volume to the size of a suitcase and see how well these new geometries perform on the larger volume, while making any modifications to the station's

design to increase coverage. I have also just begun working on a method for comparing the coverage of the different geometries quantitatively. This will consist of frequency plots of the different coverage values for a given geometry, allowing us to directly compare their maximum coverage values and modal distribution. These plots will be produced through ROOT and incorporated into Ben's analysis script. Also, the vx4d plots need to be reproduced once the code has been fully debugged.

COVERAGE PLOTS

The following plots are taken at the center of the respective geometries where coverage is strongest.
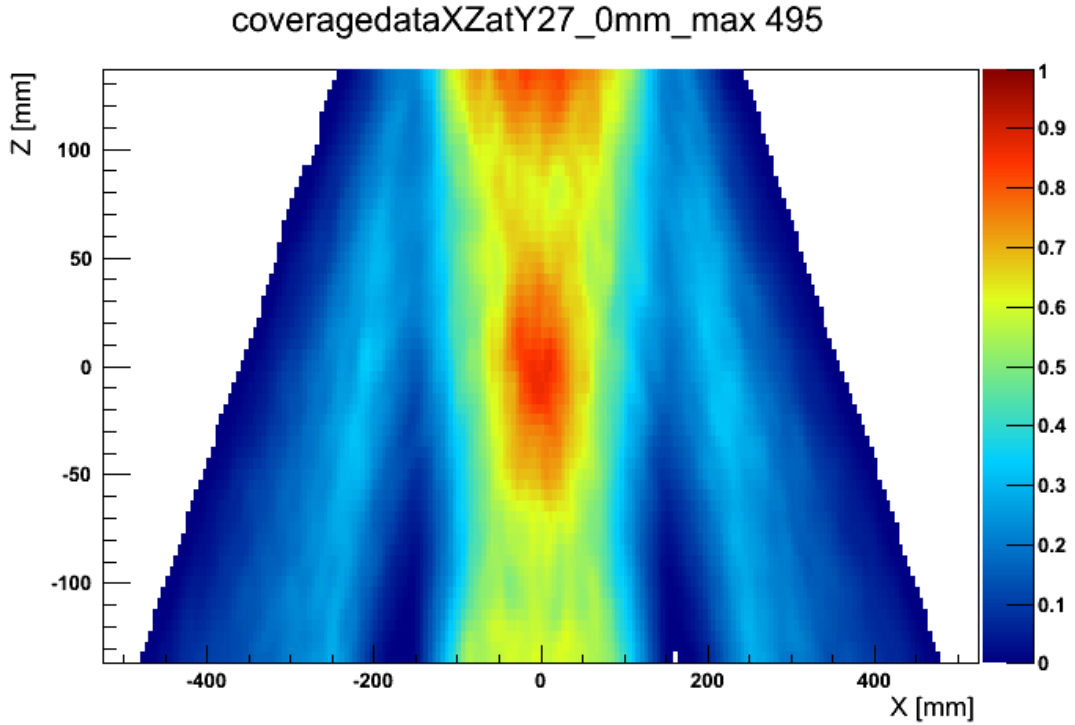
Figure 4: Coverage of EMTS Geometry

Figure 5: Coverage of Pavilion Geometry
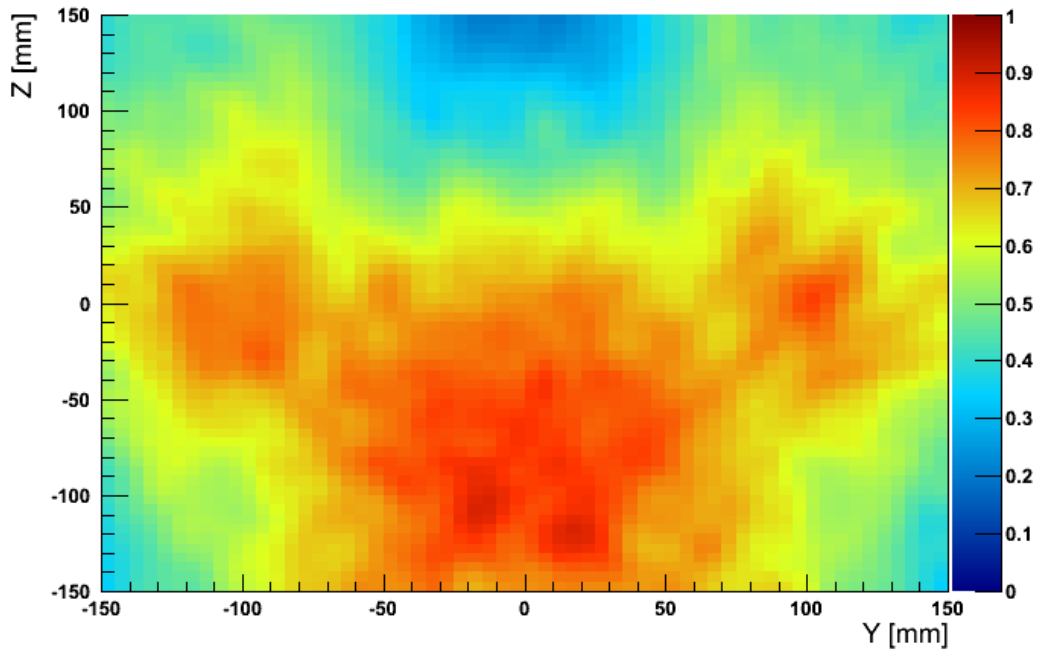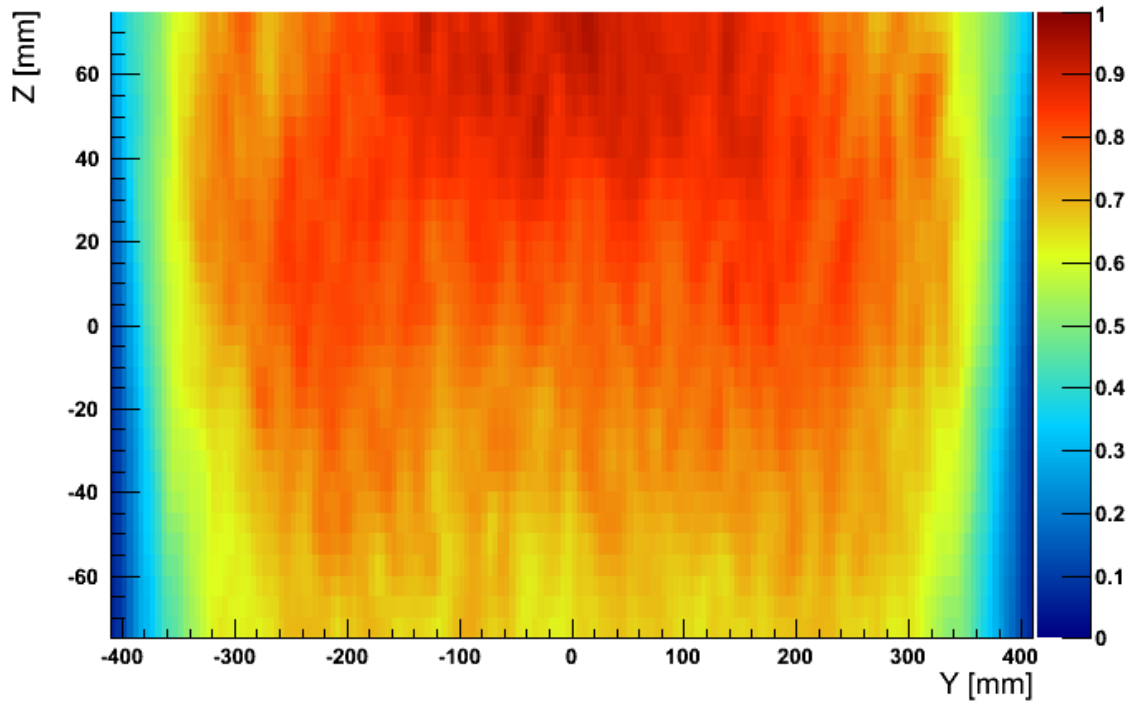
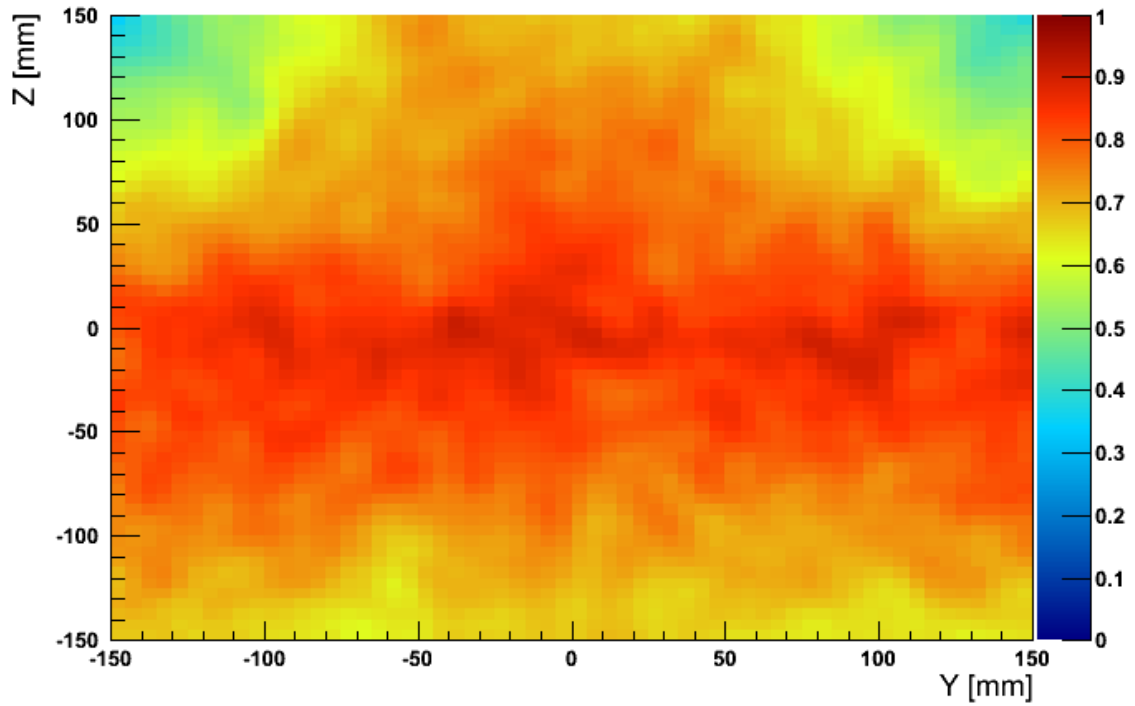Figure 6: Coverage in lower active volume of Large Pavilion Geometry

Figure 7: Coverage in middle active volume of Large Pavilion Geometry