

Simulation of a Truck Containing Threat Materials in GEANT4

Undergraduate Research Report for Fall 2008

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Introduction

This semester I performed two main tasks:

- (1) Wrote a ROOT script to analyze the variation of the mean scattering angle over different resolution, material, and Z position. These results and the script used to analyze them are now located in the common area.
- (2) Wrote a GEANT4 simulation to model the scenario featuring a passenger van containing threat materials in various locations.

This paper focuses on the second part, the truck simulation.

Purpose

The truck simulation was built on a 1994 Ford Aerostar and sought to simulate the objects in a van that were heavy and large enough to influence the visibility of high-Z materials within the volume. For this reason, the geometry consists of the chassis, engine, and battery, and not objects such as foam seating.

Simulation Geometry

The container was split up into two main cargo volumes for particle tracking purposes. The volumes represent the engine compartment and the passenger compartment. In Figure 1, we see views of the truck geometry from the top (XY plane), side (XZ plane), head-on (YZ plane). Refer to Figure 1 to see the geometry was set up. Diagrams such as these are useful in comparing the simulation results to the original geometry.

The reason that Iron is used to approximate Steel in the geometry is because Steel is predominantly Iron, with one or two percent Carbon, and a small contribution of other materials. (Stainless steel is an exception to this, consisting of around 10% of Chromium).

The size of the container geometry is set by default based on the dimensions of the real life vehicle: 4442 mm in length, 1820 mm in width, 1936 mm in height. This can be changed using the configuration file.

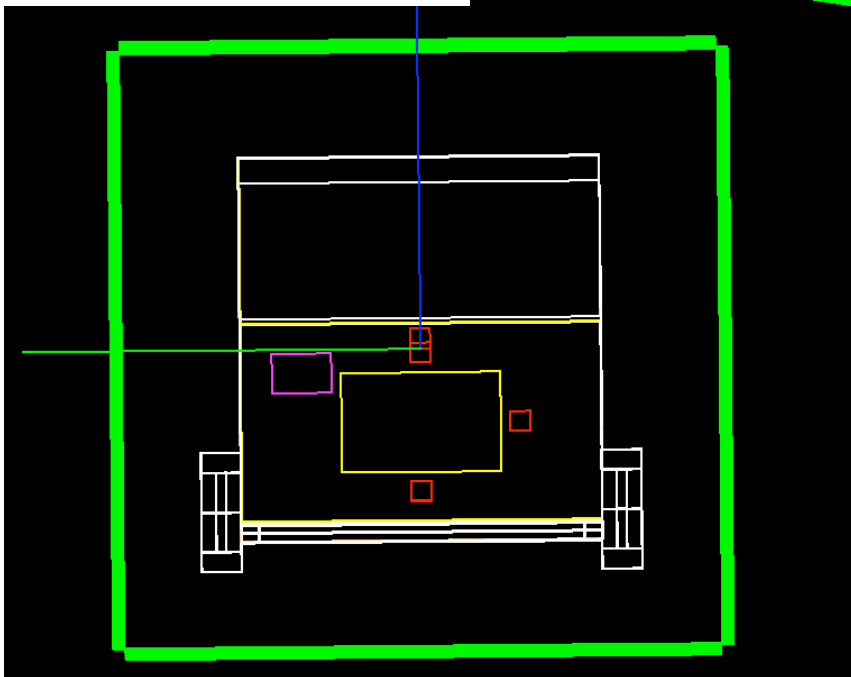
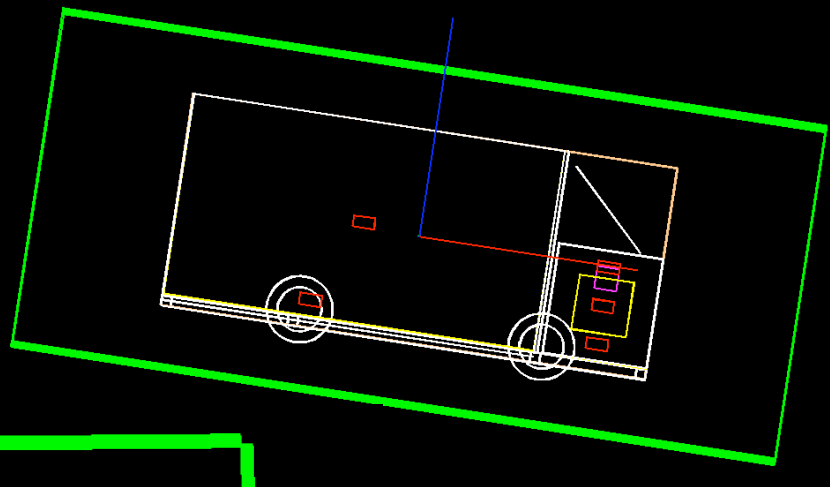
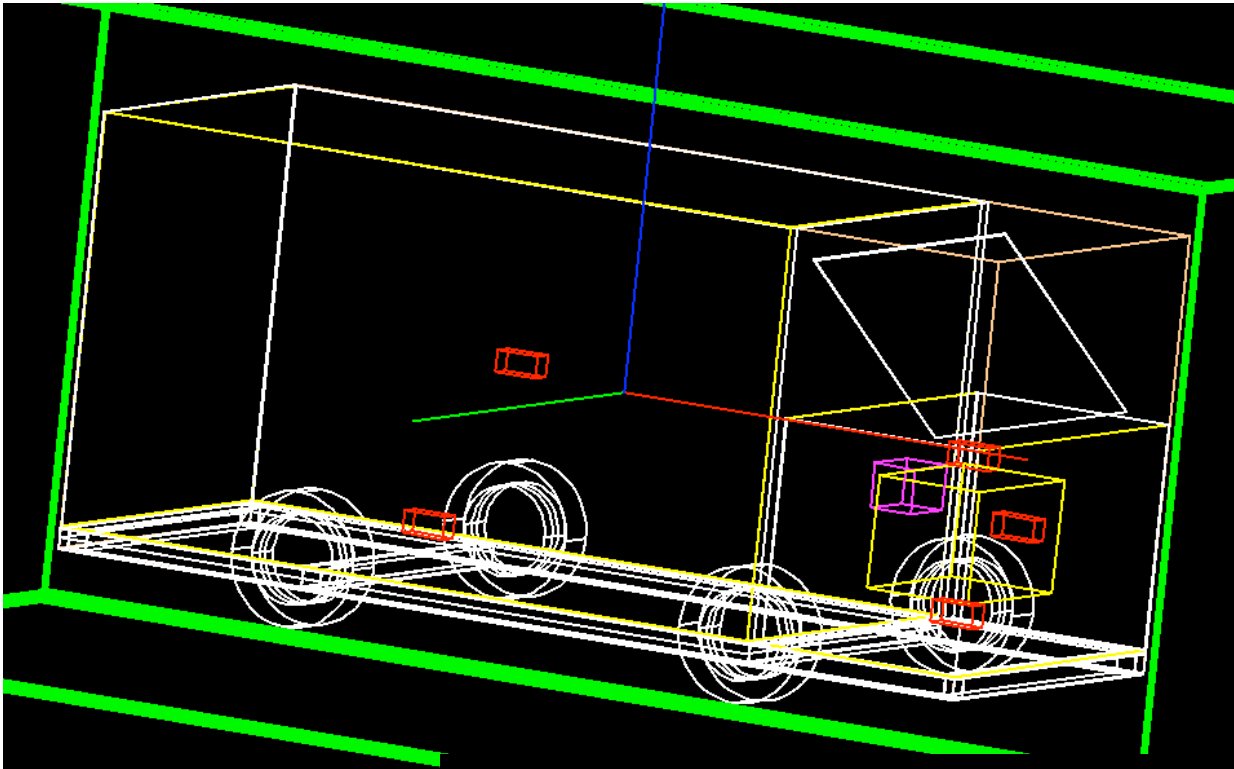


Figure 1: Images of the van geometry from multiple vantage points. All objects are indicated in these images.

Also refer to Table 1 to see each element of the geometry, and whether that can be edited using the configuration text file. The command that is used to edit that feature is shown in the Table for reference purposes. Most positions are automatically set, either to an absolute position, such as the center of that logical volume, or with respect to other objects. Note when changing the various parameters (especially size) that the program will not check if your volumes are overlapping. Be sure to examine the geometry using a visualization tool to ensure that all the volumes appear to be in the locations you expected.

Table 1: Reference table for geometry elements that can be easily modified.

Object	Material	Size	Position (X,Y,Z)
expHall	/mydet/setExpHallMat	Set automatically	Located at origin of expHall: (0, 0, 0)
container	/mydet/ setContainerMat	/mydet/setContainerWidth /mydet/setContainerLength /mydet/setContainerHeight /mydet/ setContainerThickness	Located at origin of expHall: (0, 0, 0)
cargoVol	/mydet/setCargoMat	/mydet/setCargoSizeX	Defined relative to other objects
cargoVol2	/mydet/setCargo2Mat	/mydet/setCargo2SizeZ /mydet/setCargo2SizeX	Defined relative to other objects
GEMs	/mydet/setGemMat	/mydet/setGemSizeX /mydet/setGemSizeY /mydet/setGemThickness /mydet/setInterGemGap /mydet/setTheLateralGEMs	/mydet/setGapToOrigin
Engine	/mydet/setEngineMat	/mydet/setEngineSizeX /mydet/setEngineSizeY /mydet/setEngineSizeZ	Located at origin of cargo2 (engine compartment): (0, 0, 0)
Battery	/mydet/setBatteryMat	/mydet/setBatterySizeX /mydet/setBatterySizeY /mydet/setBatterySizeZ	(0, engineSizeY/2 + batterySizeY/2, engineSizeZ/2)

Object	Material	Size	Position (X,Y,Z)
Threat 1	/mydet/setThreatMat	/mydet/setTheThreats /mydet/setThreatSizeX /mydet/setThreatSizeY /mydet/setThreatSizeZ	$(0, 0, (\text{engineSizeZ}/2 + \text{threatSizeZ}))$
Threat 2			Located at origin of cargo (passenger compartment): $(0, 0, 0)$
Threat 3			$((-1*\text{cargo2SizeX}/2 + 3*\text{threatSizeX} + (\text{cargo2SizeX}/2 - 0.4375*\text{containerLength}/2)), 0, (-1*\text{cargoSizeZ}/2 + 2*\text{threatSizeZ}))$
Threat 4			$(0, 0, -1*(\text{engineSizeZ}/2 + \text{threatSizeZ}))$
Threat 5			$(0, -1*(\text{engineSizeY}/2 + \text{threatSizeY}), 0)$
Chassis	/mydet/setChassisMat	/mydet/setChassisGap /mydet/ setChassisThickness	Defined relative to other objects
Tire	/mydet/setTireMat	/mydet/setTireInnerRadius /mydet/setTireOuterRadius /mydet/setTireThickness	Defined relative to other objects (by the chassis)
Tire Rim	/mydet/setTireRimMat	/mydet/ setTireRimThickness innerRadiusRim = 0 outerRadiusRim = innerRadius (of the Tire)	Positions for the tire rims set to the same as for the tires.
Windshield	/mydet/ setWindshieldMat	/mydet/ setWindshieldThickness	Defined relative to other objects

Barring any bugs that are discovered, the truck simulation is now at a point such that a user can (relatively) easily run simulations, while varying the sizes of the geometry objects. From the configuration file, you can change the size of many of the geometry objects and materials. The DetectorConstruction file will use the input from the user from the configuration file and calculate what the appropriate position for each object should be. Note that each one of the commands shown in Table 1 can be used interactively.

Results from 1 Million Event Sample

In Figure 3, we see the POCA point reconstruction from a 1 million event sample, representing one minute of exposure time. The GEM planes were seven meters long

and 3 meters wide in this simulation, and there were five GEM planes per side. There were GEM planes on the top, bottom, and laterally.

Referring to Figure 3, we see there are very few POCA points with an angle higher than that of the cutoff angle. In both plots, we clearly see two clusters of points with warm (high angle) colors. The two clusters are located at the same position in both scenario, which corresponds to the position of the two threat objects in the passenger compartment. Remember that there was one threat object located at the origin of the passenger compartment and another located near to the chassis bar, at the bottom of the passenger compartment.

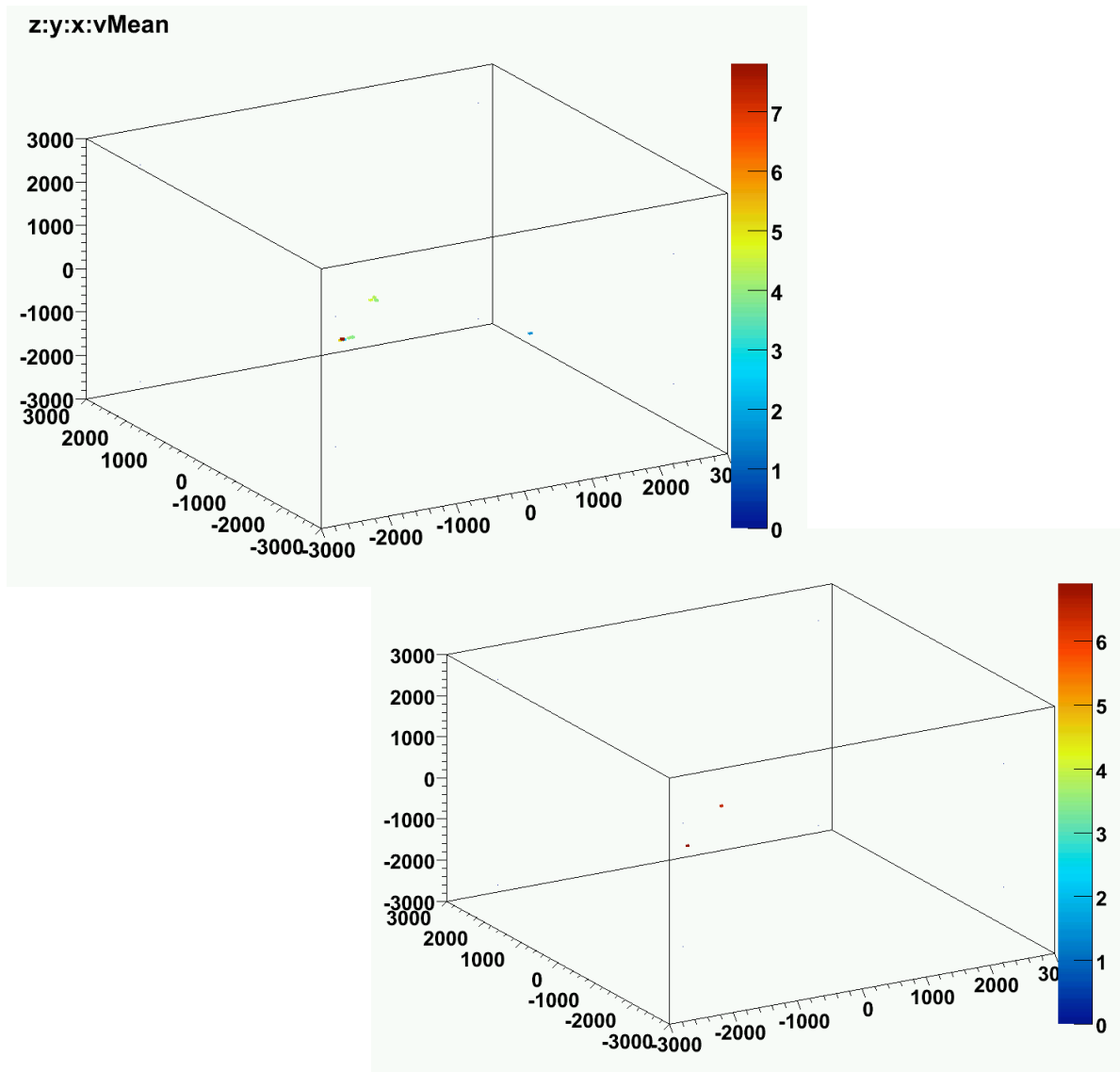


Figure 3: Reconstructed POCA points for one minute of exposure time. The above plot is for perfect resolution (0 Microns), while the lower plot is for 50 Micron resolution. The plots for 100 Micron resolution and 200 Micron resolution are not shown as there were no POCA points with an angle greater than that of the cutoff angle.

It is interesting to note that no clusters of points are seen in the 50 Micron resolution image in the engine compartment. However, in the unsmearred image, there is a point with blue colors found in the engine compartment.

Results from 10 Million Event Sample

Refer to Figure 4 to examine the results of a ten minute exposure (10 million events) of the truck in the four different resolutions. The GEM planes were seven meters long and 3 meters wide in this simulation, and there were five GEM planes per side. There were GEM planes on the top, bottom, and laterally.

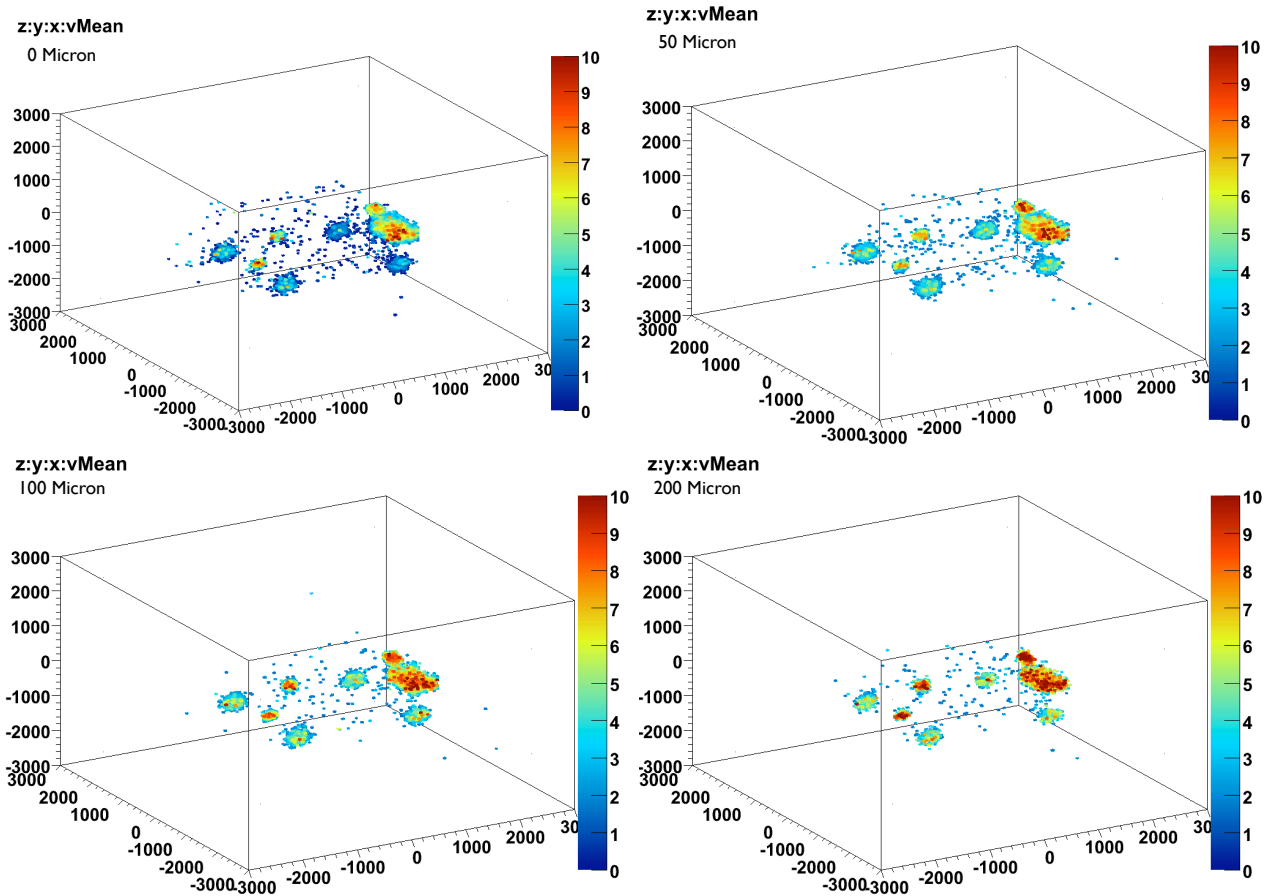


Figure 4: Reconstructed POCA points for ten minutes of exposure time. The above plot are for perfect resolution (0 Microns) [top left], 50 Micron resolution [top right], 100 Micron resolution [bottom left], 200 Micron resolution [bottom right].

It is interesting to note that in all of the resolutions, the two threat materials located in the passenger volume are easily seen. The tires and tire rims are also easily seen, along with the engine block.

Future Improvements

If another student were to work on this project, some improvements could be made to make the simulation more realistic and useful:

- (1) Create further items present in a van, such as the fuel line and petrol tank.
- (2) Place various objects into the passenger and engine compartment to simulate the clutter usually present in a twenty year old van. This could be written efficiently such that it could be compiled once and then simulated many times while changing the geometry on the configuration file.
- (3) Ensure that the user is given an error when creating nonsensical geometries (such as overlapping geometries).

Appendix: Configuration File

Here you can see the configuration file used for this simulation. Here we can see the default values of the various options that simulate a model of a passenger van based on a 1994 Ford Aerostar. All the commands shown are currently implemented. Use with caution when modifying sizes (i.e. double check the geometry using Heprapp).

```
/event/verbose 0
/tracking/verbose 0
/CRY/input returnMuons 1
/CRY/input returnGammas 0
/CRY/input returnNeutrons 0
/CRY/input returnElectrons 0
/CRY/input returnPions 0
/CRY/input returnProtons 0
/CRY/input date 2012.5
/CRY/input latitude 90.0
/CRY/input altitude 0
/CRY/input subboxLength 10
#/CRY/input returnGammas 2
#/CRY/input
/CRY/update

##/vis/verbose 1
##/vis/scene/create
##/vis/open HepRepFile
##/vis/open OGLIX
##/vis/drawVolume
##/vis/viewer/zoom 1.2
##/vis/scene/add/axes 0 0 0 2000 mm
##/vis/viewer/set/upVector 0 0 1
##/vis/viewer/set/viewpointThetaPhi 100 -65 deg
#/vis/viewer/set/viewpointThetaPhi 0.001 -90 deg
##/vis/scene/add/hits
##/vis/scene/add/trajectories
##/vis/viewer/zoom 1.2
#/vis/viewer/flush
##/vis/viewer/set/style wireframe
##/vis/viewer/set/style surface
##/vis/scene/endOfEventAction accumulate 1

#### Detector geometry

#/mydet/setExpHallMat G4_AIR
```



```

#/mydet/setCargoMat      G4_AIR
#/mydet/setContainerMat  G4_AIR
#/mydet/setGemMat        Kapton
#/mydet/setCargo2Mat     G4_AIR
#/mydet/setEngineMat     Iron
#/mydet/setBatteryMat    Lead
#/mydet/setThreatMat     Uranium
#/mydet/setChassisMat    Iron
#/mydet/setTireMat       Rubber
#/mydet/setTireRimMat    Iron
#/mydet/setWindshieldMat Glass
#/mydet/setContainerWidth 1820 mm
#/mydet/setContainerLength 4442 mm
#/mydet/setContainerHeight 1936 mm
#/mydet/setContainerThickness 1.5 mm
#/mydet/setCargoSizeX    3406 mm
#/mydet/setCargo2SizeX   954 mm
#/mydet/setCargo2SizeZ   1000 mm
#/mydet/setEngineSizeX   500 mm
#/mydet/setEngineSizeY   800 mm
#/mydet/setBatterySizeX  200 mm
#/mydet/setBatterySizeY  300 mm
#/mydet/setBatterySizeZ  200 mm
#/mydet/setEngineSizeZ   500 mm
#/mydet/setThreatSizeX   100 mm
#/mydet/setThreatSizeY   100 mm
#/mydet/setThreatSizeZ   100 mm
#/mydet/setChassisGap    90 mm
#/mydet/setChassisThickness 3 mm
#/mydet/setTireInnerRadius 20 cm
#/mydet/setTireOuterRadius 30 cm
#/mydet/setTireRimThickness 2.5 cm
#/mydet/setTireThickness 10 cm
#/mydet/setWindshieldThickness 1.5 mm

/mydet/setTheLateralGEMs yes
/mydet/setGemSizeX      5000 mm
/mydet/setGemSizeY      5000 mm
/mydet/setGemThickness  2 mm
/mydet/setInterGemGap   10 mm
/myanalysis/setOutputPocaFileName test100Events
/mydet/setGapToOrigin   1500 mm
/run/beamOn 100

```