Importing the downstream beamline from engineering models

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**Abstract**

Simulations of beam-related background show significant contributions from regions downstream of the torus. Up until now the existing shielding and beamline was only partially represented in the GEMC simulation. This note lists the new imports from the engineering models and the modifications applied to the existing geometry.

**CLAS12 Geant4 Simulation**

This CLAS12 spectrometer [1] is simulated using the GEant4 [2] Monte-Carlo (GEMC) package [3]. Its forward detectors are placed between the coils of the superconducting torus magnet [4]. The vacuum line goes through the hub of the magnet. Downstream of the torus, a ‘apex’ shielding, consisting of a steel frame filled with lead, is used to shield background back splashing into the electromagnetic calorimeter. Prior to these modifications, the apex structure was a partial representation of the actual volume, see Fig. 1.

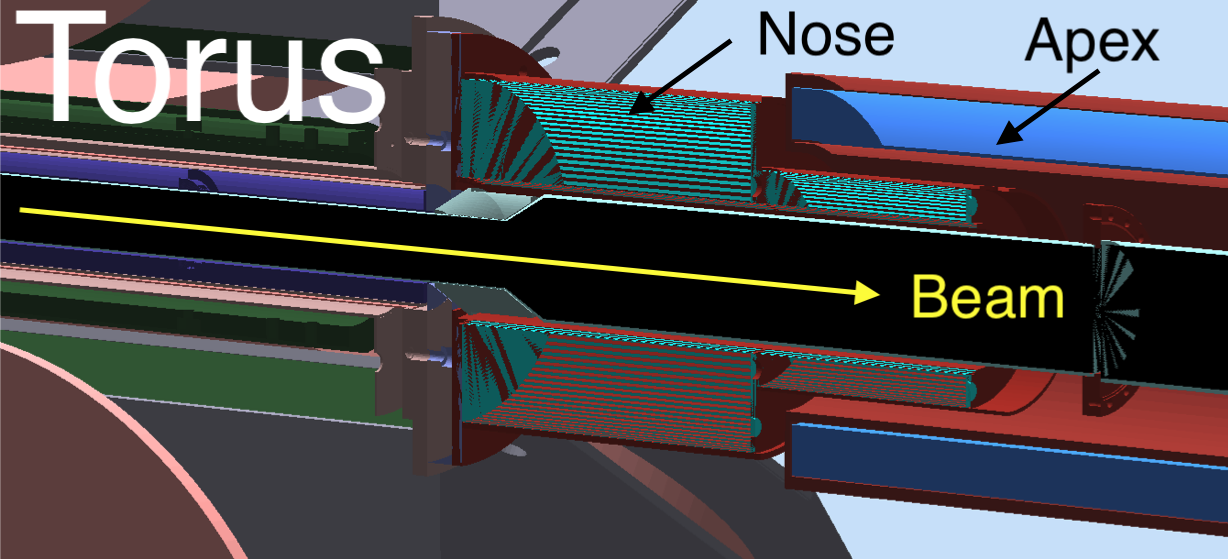


Figure 1. The implementation of the downstream beamline in gemc: a nose fills the air gap from the torus to the apex. The beam goes from left to right. The vacuum line radius increases from 33.3mm to 60.3mm inside the nose.

Detailed studies of beam related background showed backsplash of particles hitting the forward detectors from inside the nose and apex, due to the enlargement of the beam sausage hitting hardware components near the end of the torus hub. Further studies showed evidence of background even after the apex.

The complete vacuum line and beamline shielding is described in the next section.

**Engineering Model (Chris can you please add some description of this?)**

[Description, please add pics as necessary]

The model is distributed to GEMC through STEP file, with the solenoid center as frame origin and the beam direction along z. This involves a 180 degrees rotation around the Y axis and a shift of 1273.27mm to account for the different coordinate system used by the engineers.

In addition, the model has been simplified as follow to minimize the effects due to tessellation and volume overlaps, a process necessary to import it in Geant4 simulations:

* Bolts and nuts and their flange holes have been smoothed out
* Volumes of same materials, then touching, have been grouped into single volumes.

[Example of useful pic]

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*Figure 2 description*

**Geometry Modifications**

The changes are summarized in Fig. 3 for the FTOn configurations. The other configurations: FTOff, rghFTOn, rghFTOut, ELMO have also been checked.

The following modifications to the code were done for each of the volume imported from CAD:

* Apex\_Shield\_Lead\_Fill: replaces volume leadInsideApex from Elmoline.pl, rghline.pl, vacuumLineNew.pl. See Figure 4.
* Apex\_Shield\_PCAL\_Hub: new volume, added beamline\_CarbonSteel material. See Figure 4.
* Torus\_Exit\_Shield\_Casing, Torus\_Exit\_Shield\_Lead\_Fill: replace file afterTorusShielding.pl, now deleted
* Downstream\_Beam\_tube\_Segment 1 and 2.: removed stl volume downstreamPipeFlange and connectUpstreamToTorusPipe

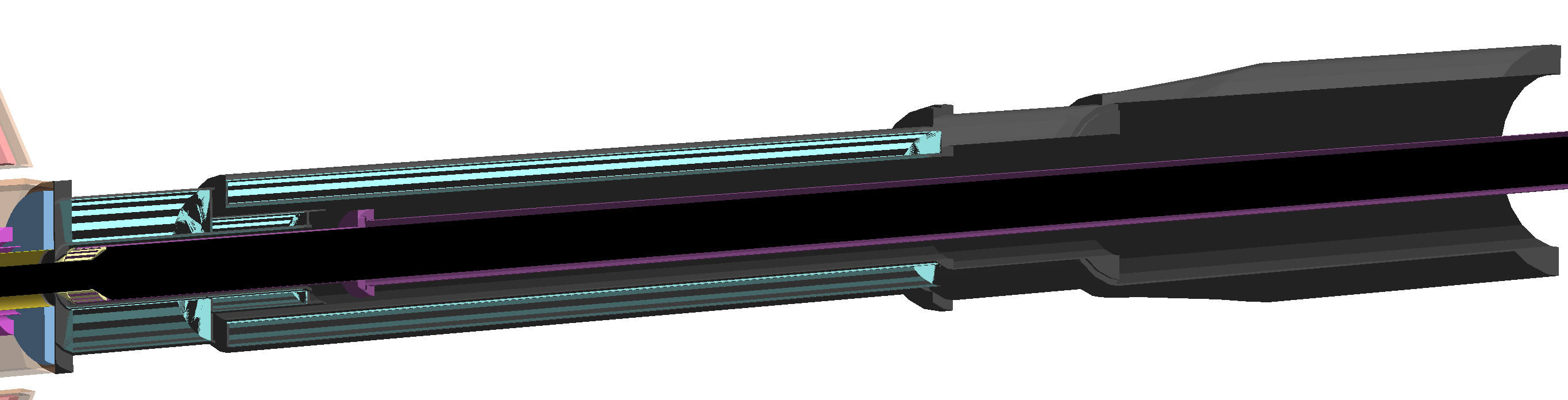
from vacuumLine dir. Increased fc z span by 3m to include additional pipes. Notice that FC will be deprecated in further iteration of CLAS12 geometry. vacuumPipe and vacuumPipeToAlcove are removed, and their vacuum volumes are replaced by a fc\_beam\_vacuum volume. Notice: this change show that the radius of the vacuum line inside Segment 1 was wrong (overlap with pipe) and corrected, from 60.325mm to 59.8, and in Segment 2 from 64 to 63.7mm.

* Torus\_Beam\_Tube\_Reducer\_2: new volume, replaced vacuumPipe structure. A new step has been introduced

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*Figure 3: summary of downstream beamline in GEMC. From left to right: the “nose” shield inserts into the Apex, which develops into the PCAL hub. The beamline pipe is one stainless steel volume that includes a flange inside the Apex. The vacuum volume have been adjusted to fit inside the pipe*

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*Figure 4: the nose just downstream of the torus (volumes Torus\_Exit\_Shield\_Casing, Torus\_Exit\_Shield\_Lead\_Fill), the Apex and PCAL hub (Apex\_Shield\_PCAL\_Hub and Apex\_Shield\_PCAL\_Fill). The nose and the apex are filled with lead (cyan color volumes) and encased in Carbon Steel.*

**Materials Modifications**

A new material beamline\_CarbonSteel was added with the following chemical composition (numbers are percentages):

* Iron: 98
* Carbon 0.3
* Silicon 0.2
* Manganese 1
* Phosphorous 0.3
* Copper 0.2

**GCard Modifications**

The following gcards have been added to better organize the various experiment configurations:

* beamline\_FTOn.gcard
* beamline\_FTOff.gcard
* beamline\_ELMO.gcard
* beamline\_rghFTOn.gcard
* beamline\_rghFTOut.gcard

The file beamline.gcard has been removed.

The vacuumLine directory has been removed and its reference in all gcards in the clas12-config repository have been removed.

**Summary and Conclusions**

The beamline vacuum line and components have been added to the GEMC simulation. Vacuum components have been simplified and corrected because of these additions.

**References**

*[1] The CLAS12 spectrometer at Jefferson laboratory, Burkert V.D., et al., Nucl.Instrum.Meth.A 959 (2020) 163419*

*[2] Recent Developments in Geant4, J. Allison et al., Nucl. Instrum.Meth.A 835 (2016) 186-225*

*[3] The CLAS12 Geant4 simulation, Ungaro M., et al., Nucl.Instrum.Meth.A 959 (2020) 163422*

*[4] The CLAS12 superconducting magnets, Fair R., et al., Nucl.Instrum.Meth.A 959 (2020) 163578*