Fermilab Muon g-2

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Using 3D Engineering Models in a Geant4 Simulation

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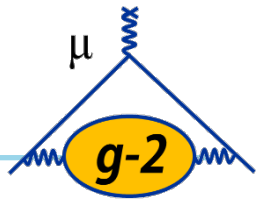
Outline



- Discovery of a difference between the material in our Geant4 simulation and the engineering models led us to re-evaluate how we build our models.
- Old code was complicated and messy.
- Changes were coming in to several of our vacuum chambers and we didn't want to recode all that with native Geant4 volumes
- How can we make our lives easier?
- The 3D engineering models already existed, can we use those?

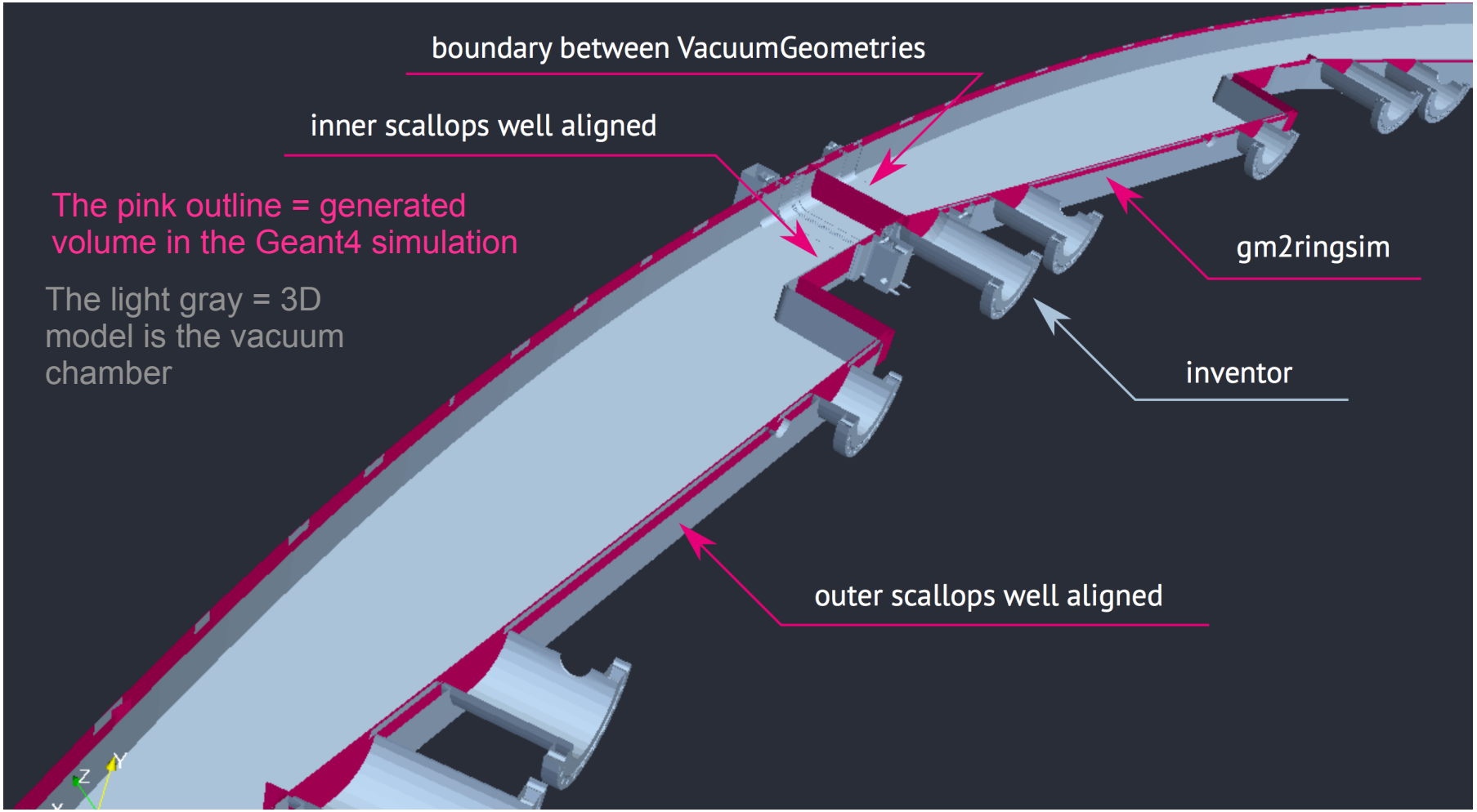
Material Differences

- Using Paraview we had the ability to overlay engineering drawings over what was in the current simulation.
- What we found was that there was a disagreement in the shape of the vacuum chamber as well as a misplacement of the calorimeter.
- The vacuum chamber volumes are complicated shapes that were being estimated with Geant4 native volumes.

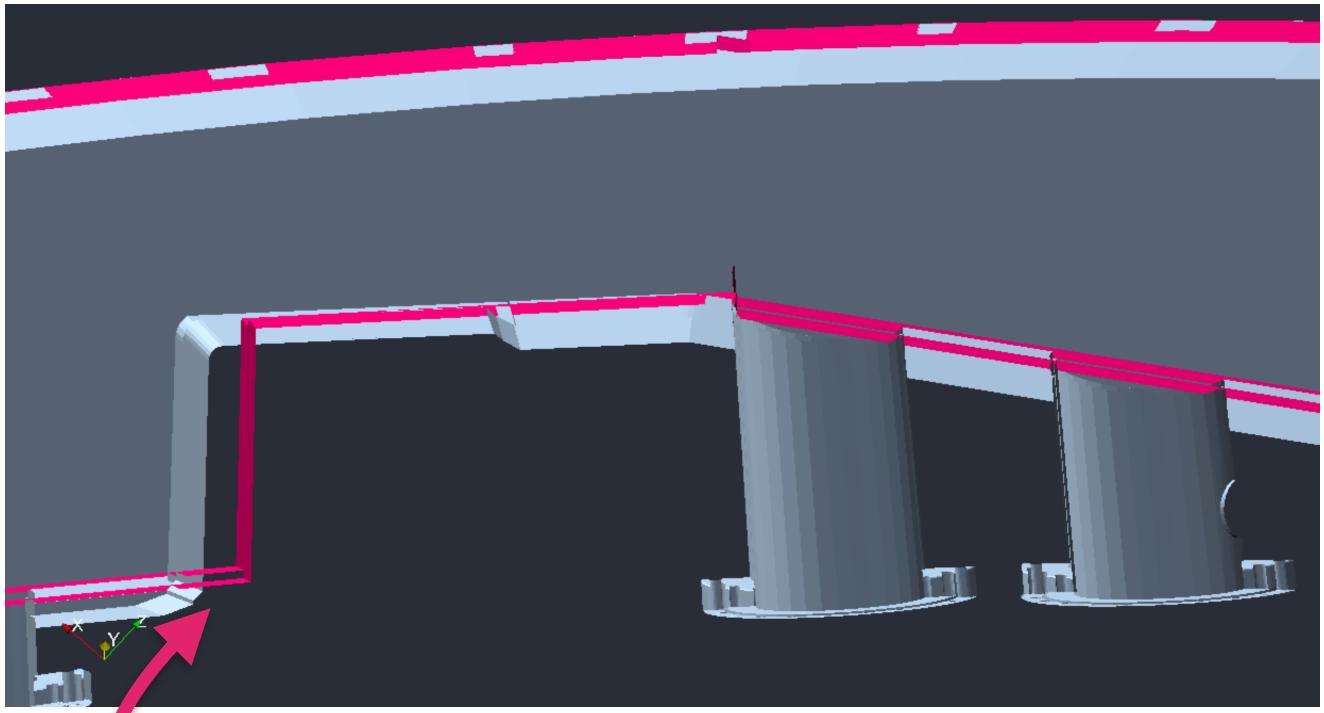
Paraview Description

- A scientific visualization application with rich capabilities
- DOE supported with strong HPC community
- Based on established VTK library
- Moving to VTK-m - a merger of several advanced architecture visualization solutions
- ParaView uses advanced visualization techniques to maintain a good user experience (decimating image during manipulation)
- Very active developer/user base and development (v5.1 released this week with new Intel ray-tracer)
- Scriptable in python

Vacuum Chamber Comparison



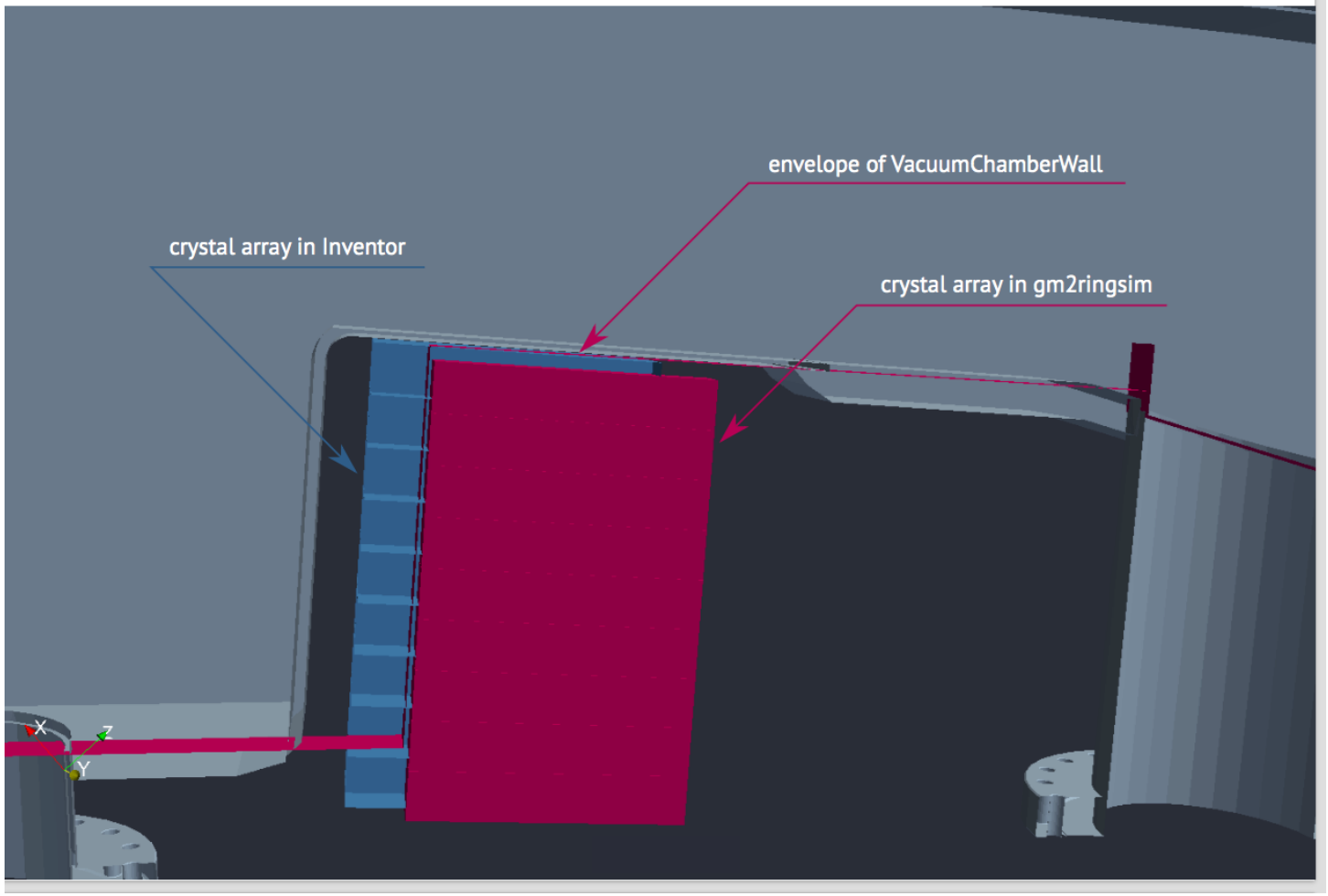
A closer look



The big issue is at the vacuum chamber corners, where the calorimeter sits.

A closer look

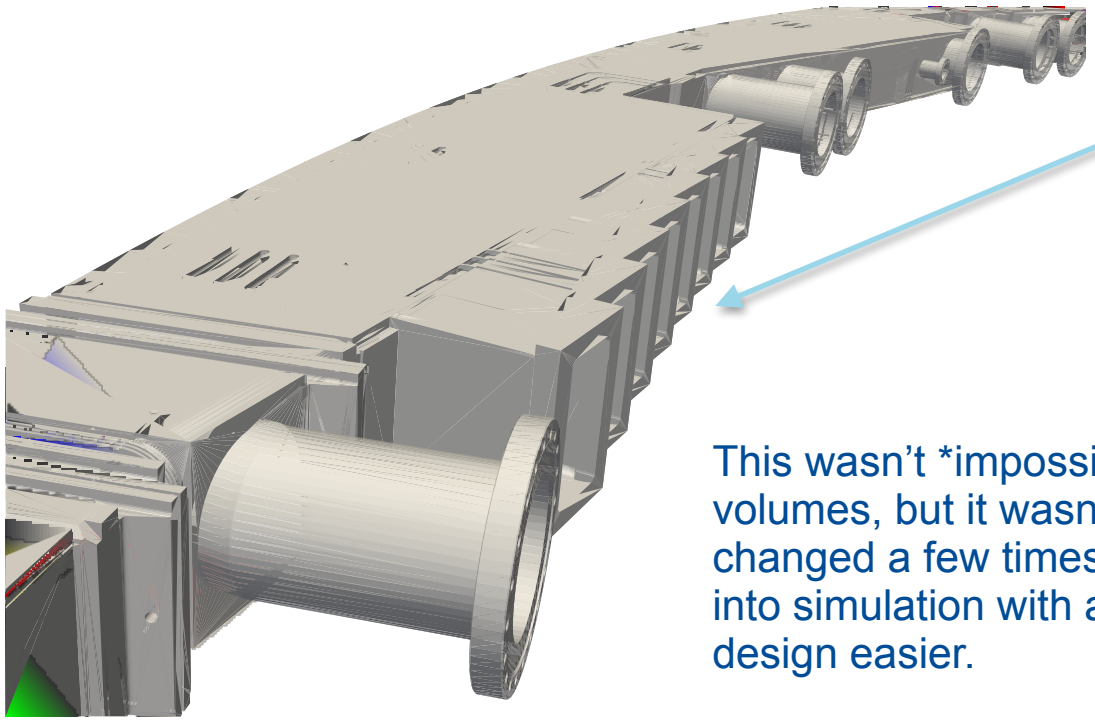
The placements of the first crystal array. Inventor in blue, gm2ringsim in red.



The Geant4 geometry built the chamber too large, relatively pushing the calorimeter farther back from the actual location.

New Tracking Chambers

- Three of the vacuum chambers have tracking chambers.
- At the same time the difference in the vacuum chamber was found, we also knew a new design for tracking chambers was coming.

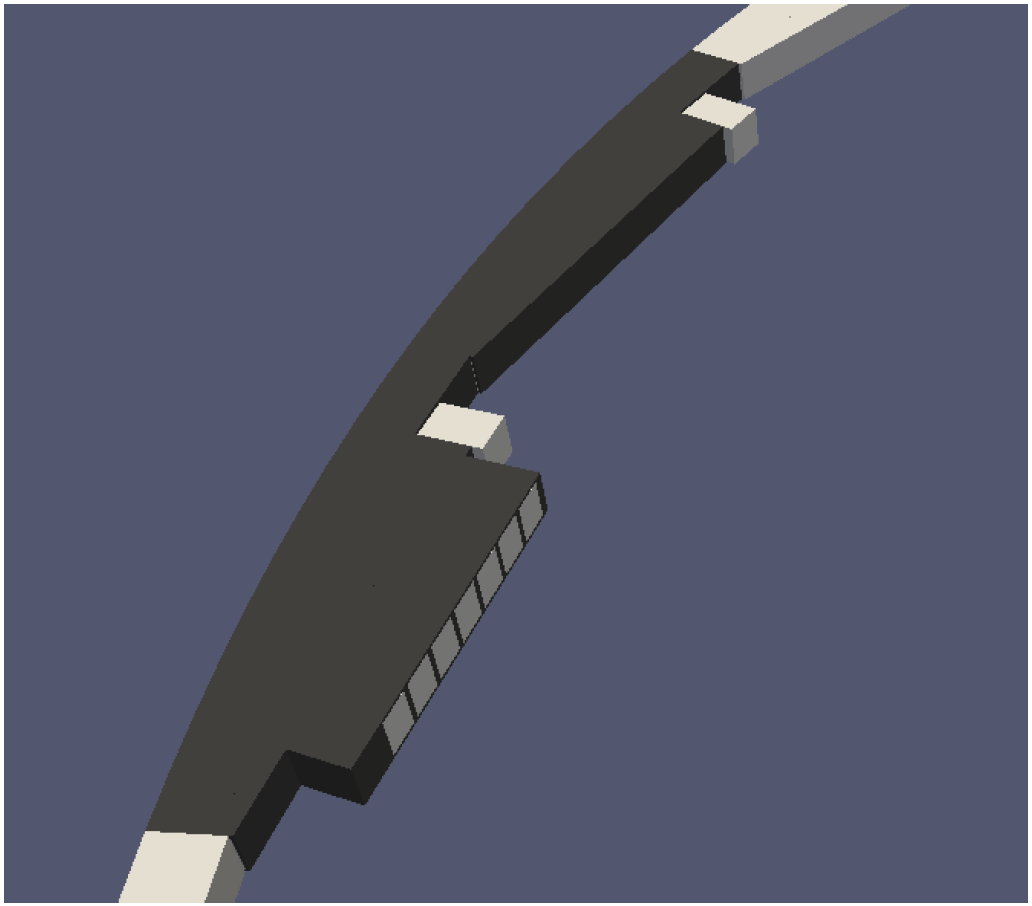


Staircase Extension added to the existing shape.

This wasn't *impossible* to design with native volumes, but it wasn't easy, and the design had changed a few times, so how to make it easy to insert into simulation with allowances for changes to the design easier.

History

- The design kept changing
  - Not extending the vacuum chamber and placing trackers inside through the ports
  - Bumping out the scallop region to contain the tracking chambers
  - Different sized tracking detectors in order to maximize the straws in front of the calorimeters
  - The final staircase solution
- A simulation estimation was done at the middle step (bumping out the scallop region)
- Kept massaging that design as updates were coming in
  - Because it was “fine”



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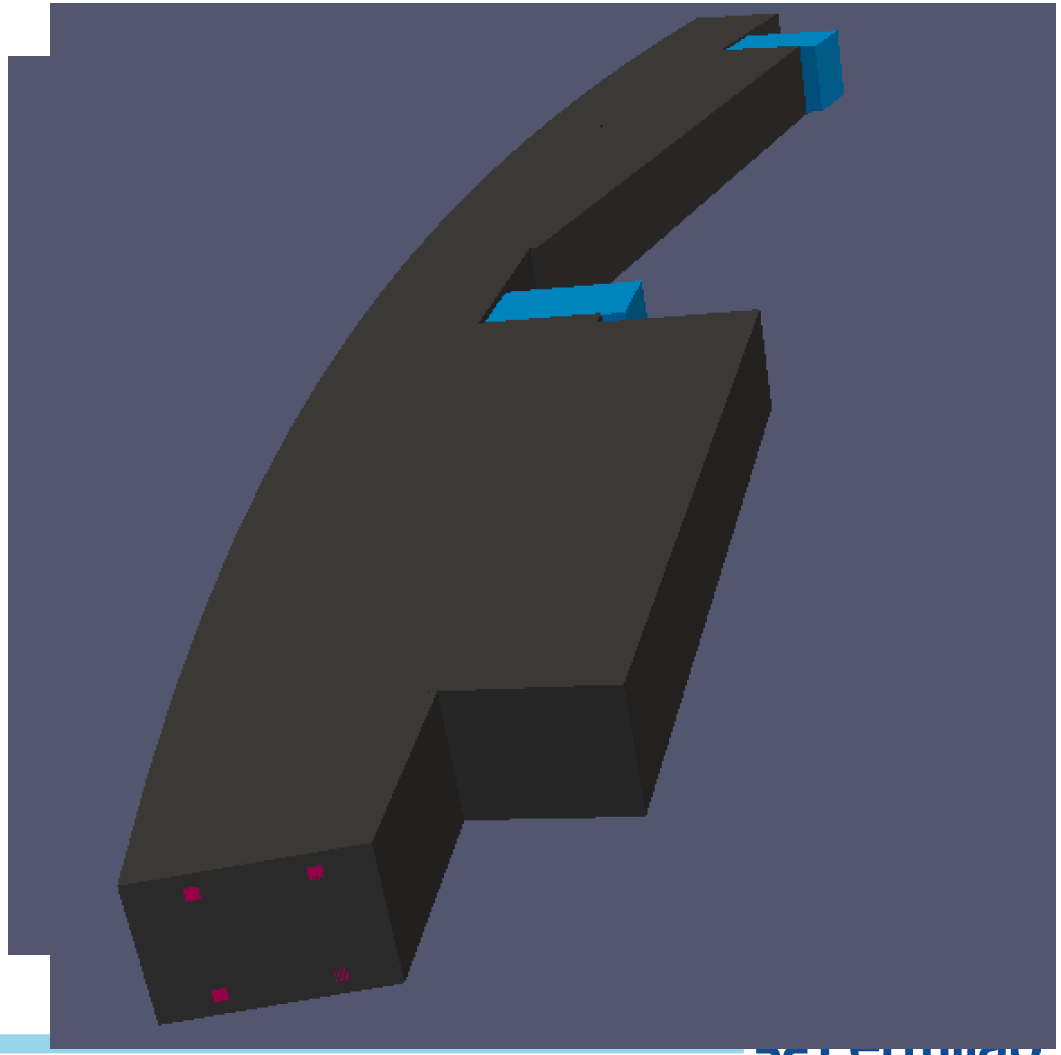

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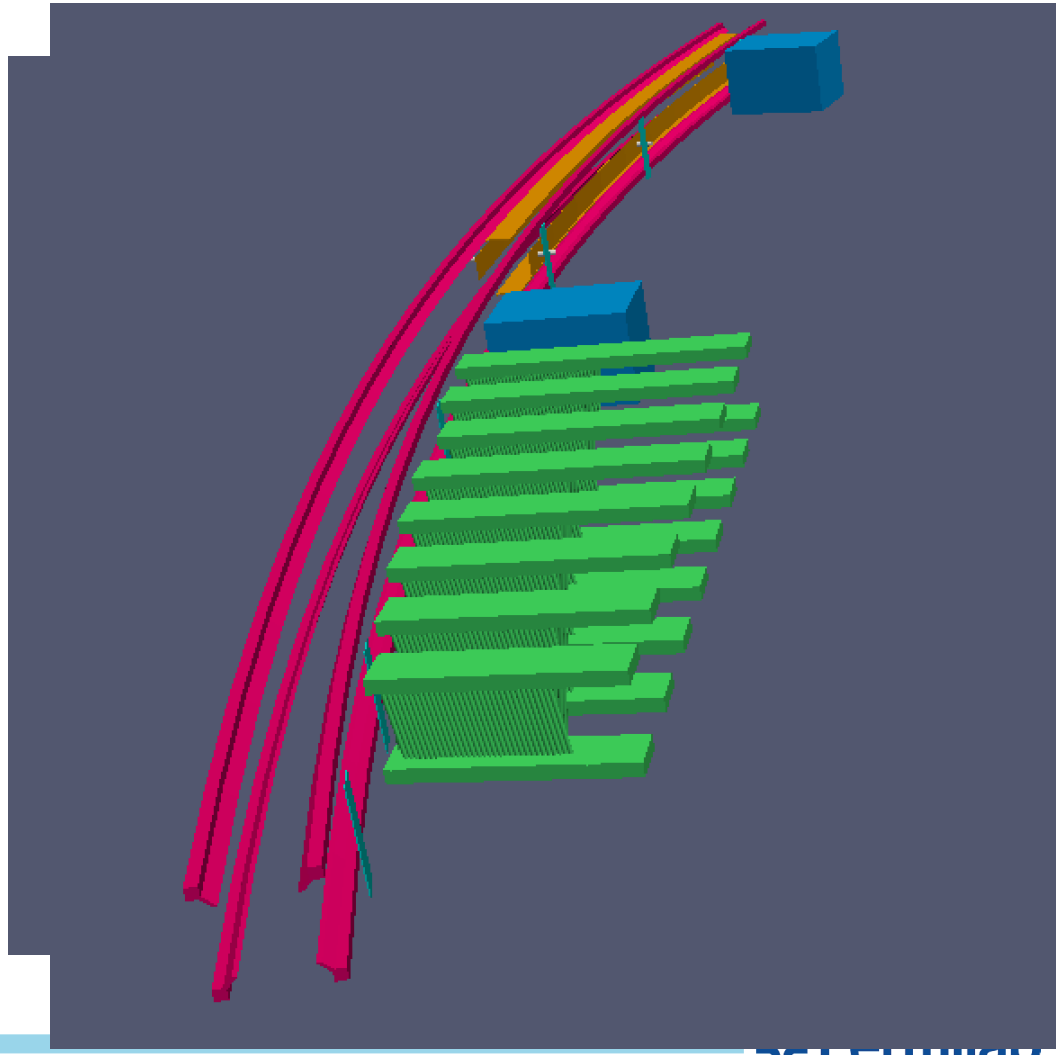

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In this experiment we really want to know exactly what is in front of the calorimeters, and exactly where those things are.

From the trackers to the trolly rails, to the trolly supports, to the staircase design. it just kept getting more and more complicated to match the real design of the detectors to what was in the simulation.

So we asked ourselves, "Can we come up with a better way?" A way that takes the pain of redesign away? While at the same times solves problems of overlaps, and problems of placement?

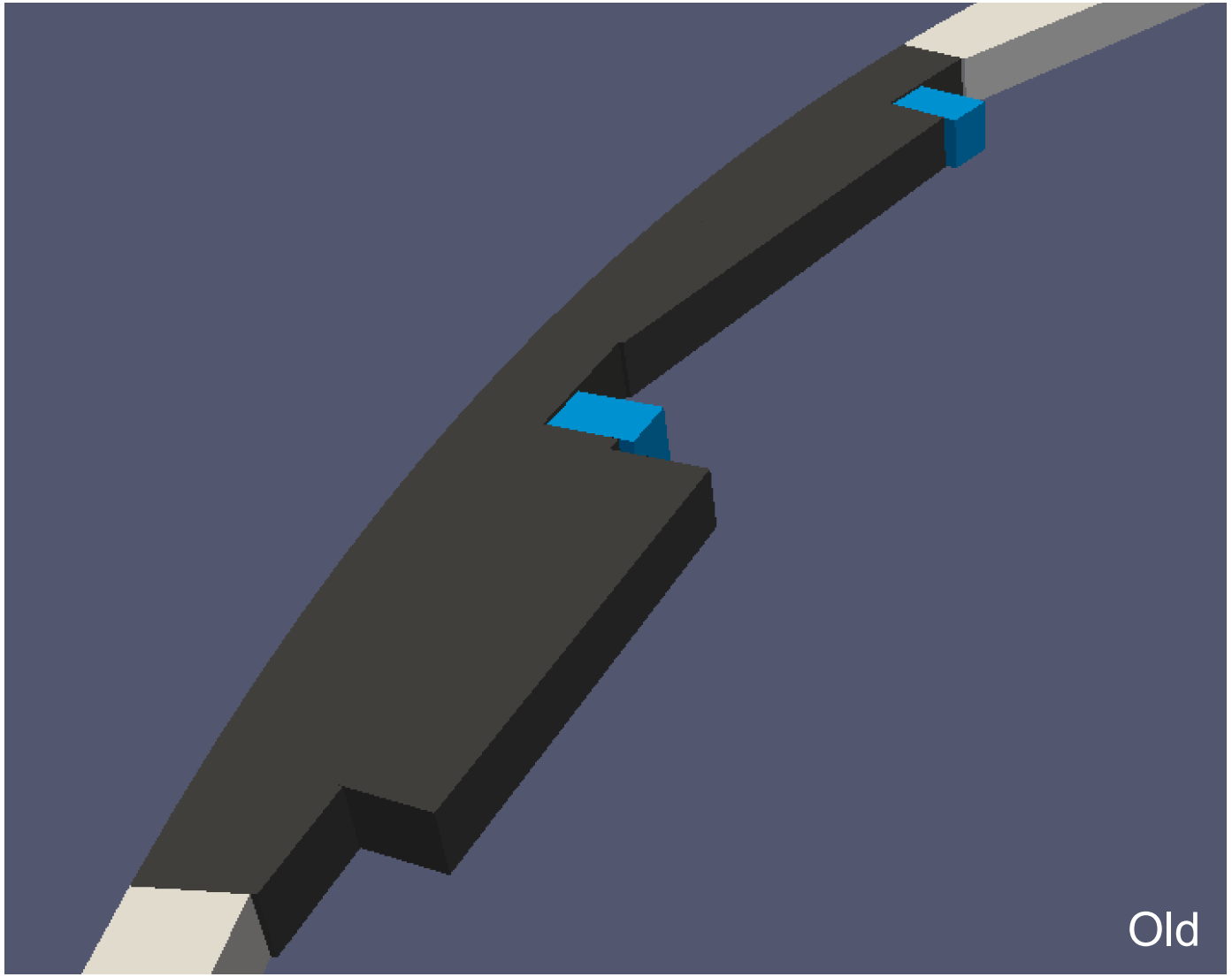
Enter CADMesh

- Some research led us to the CADMesh libraries
  - https://github.com/christopherpoole/CADMesh
- It's a direct CAD model import interface for Geant4
- Supports the import of triangular facet surface meshes defined in formats like STL and PLY.
- A G4TessellatedSolid is returned and can be used in detector construction
- From there you can create a solid from that mesh.

```
auto mesh = std::make_unique<CADMesh>("detector.stl");
G4VSolid *detector = mesh->TessellatedMesh();
```

- The 3D model changes?
  - Just get the updated file and done. No more monkeying around with design changes.

Exact-ness in Simulation



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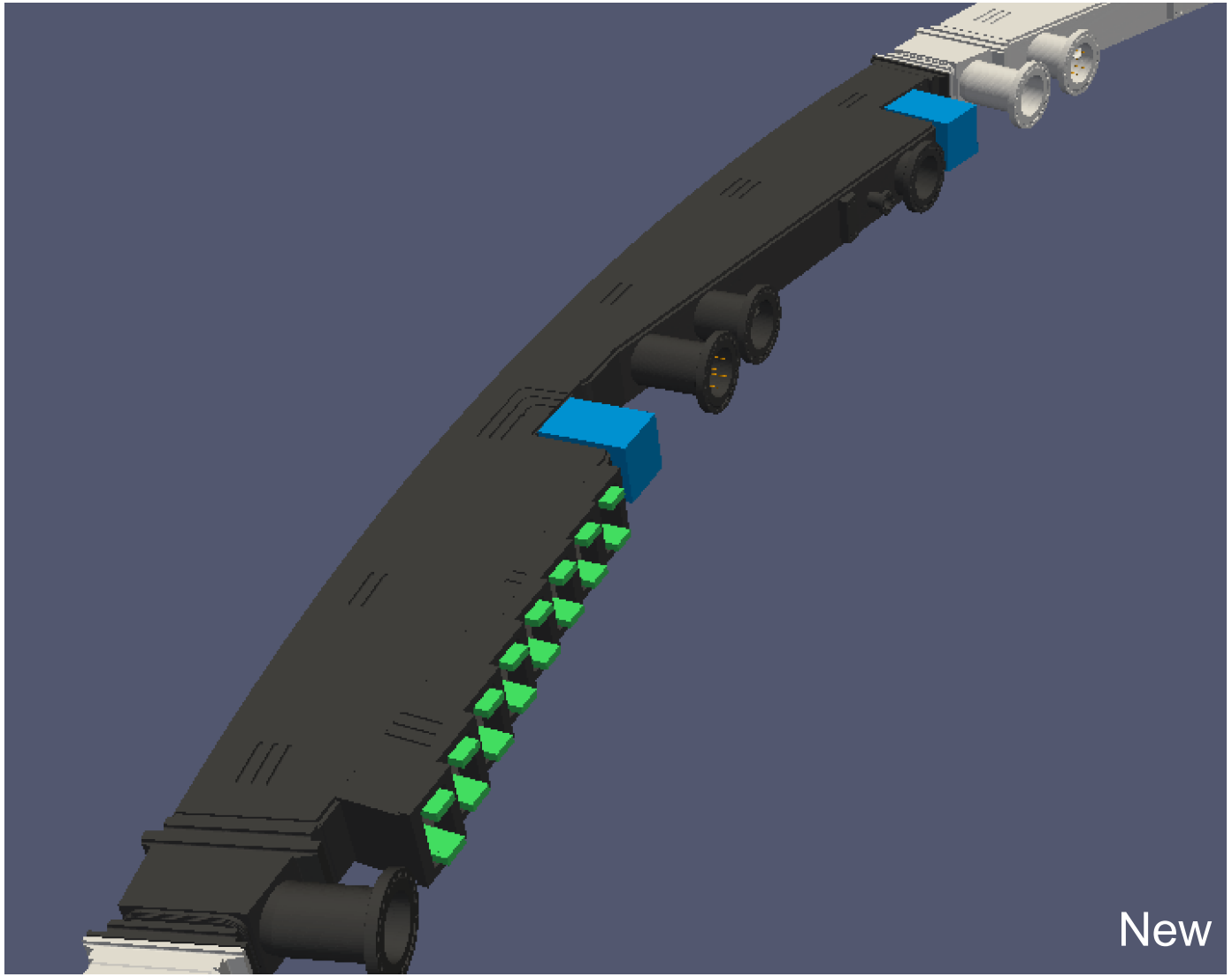

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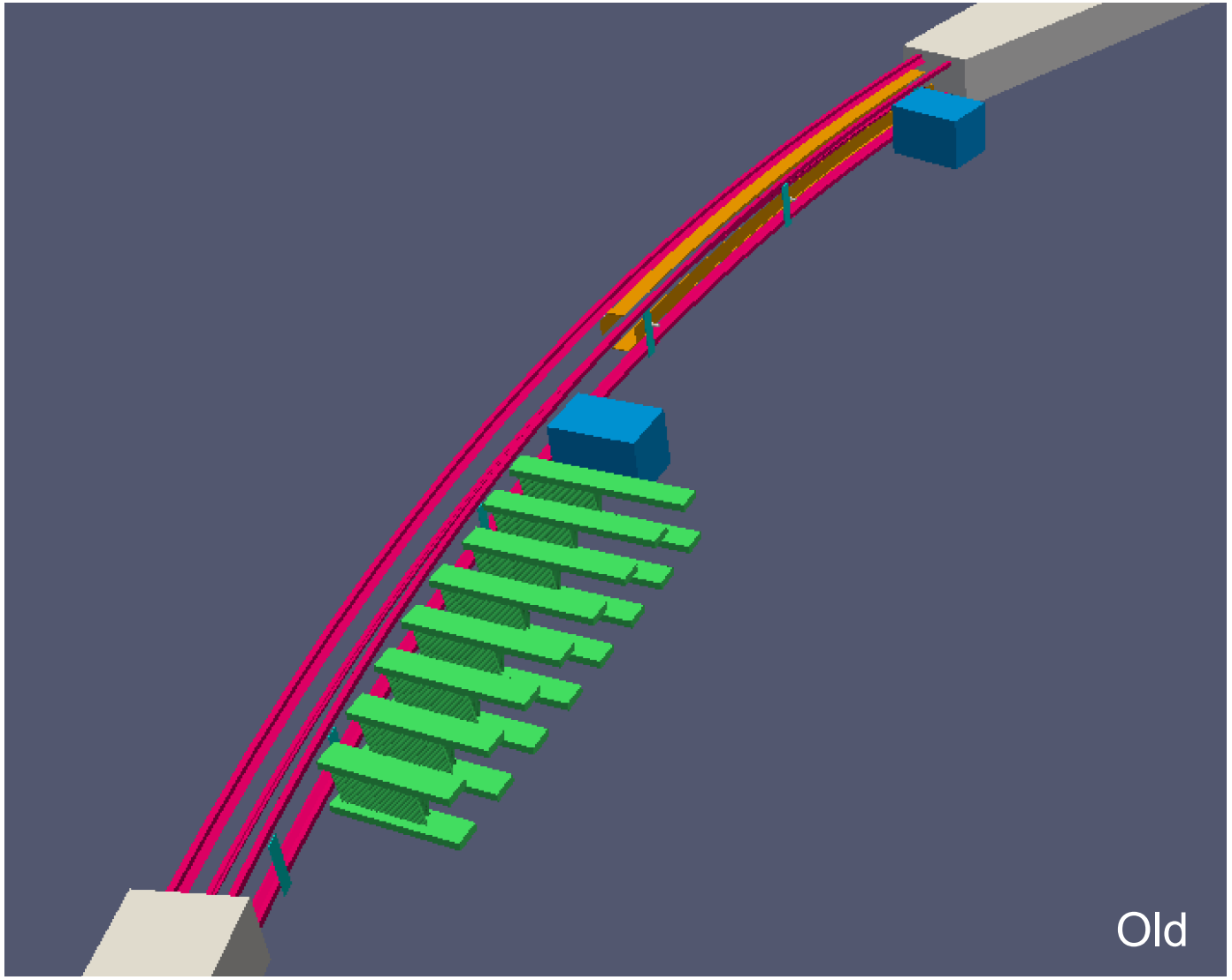

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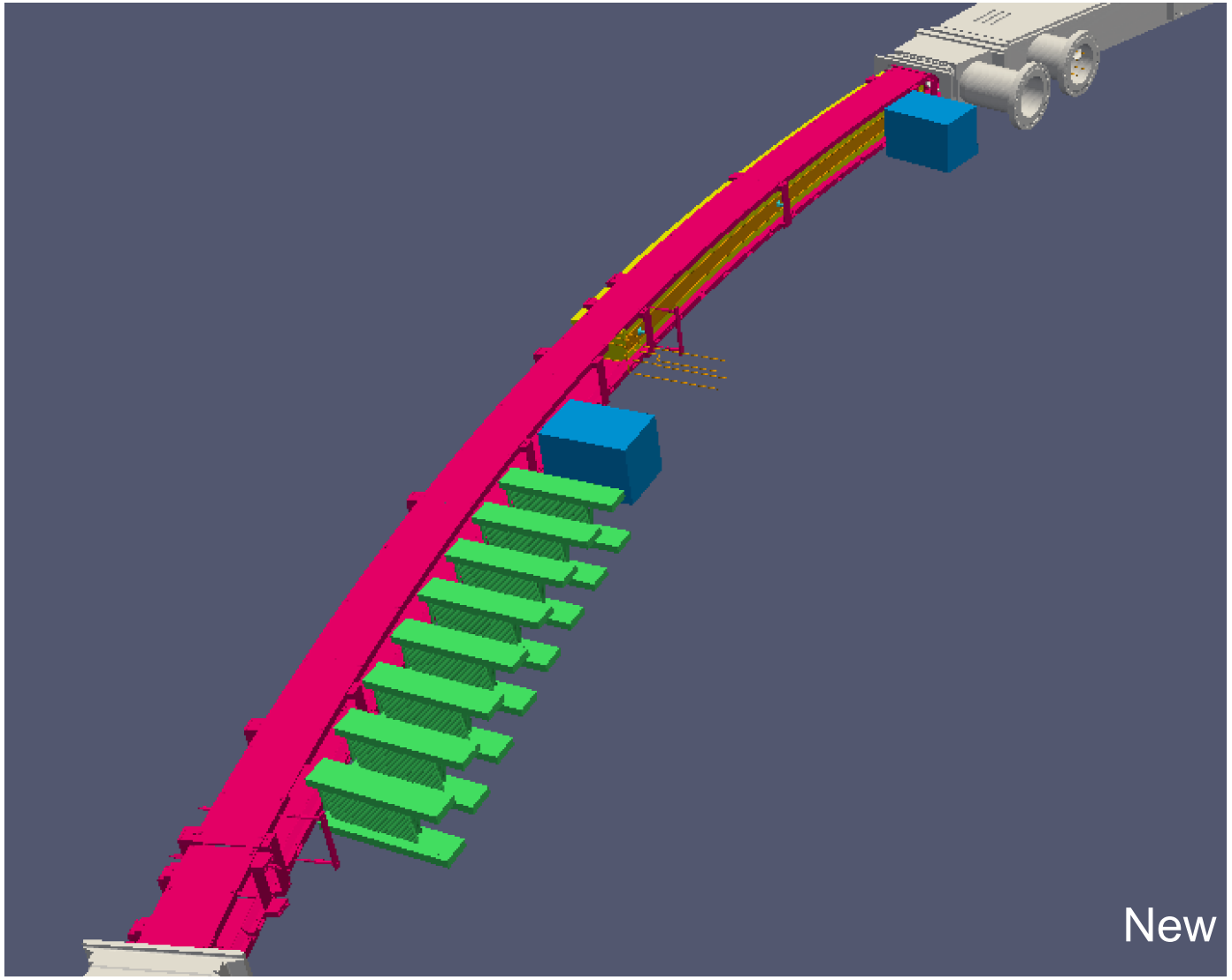
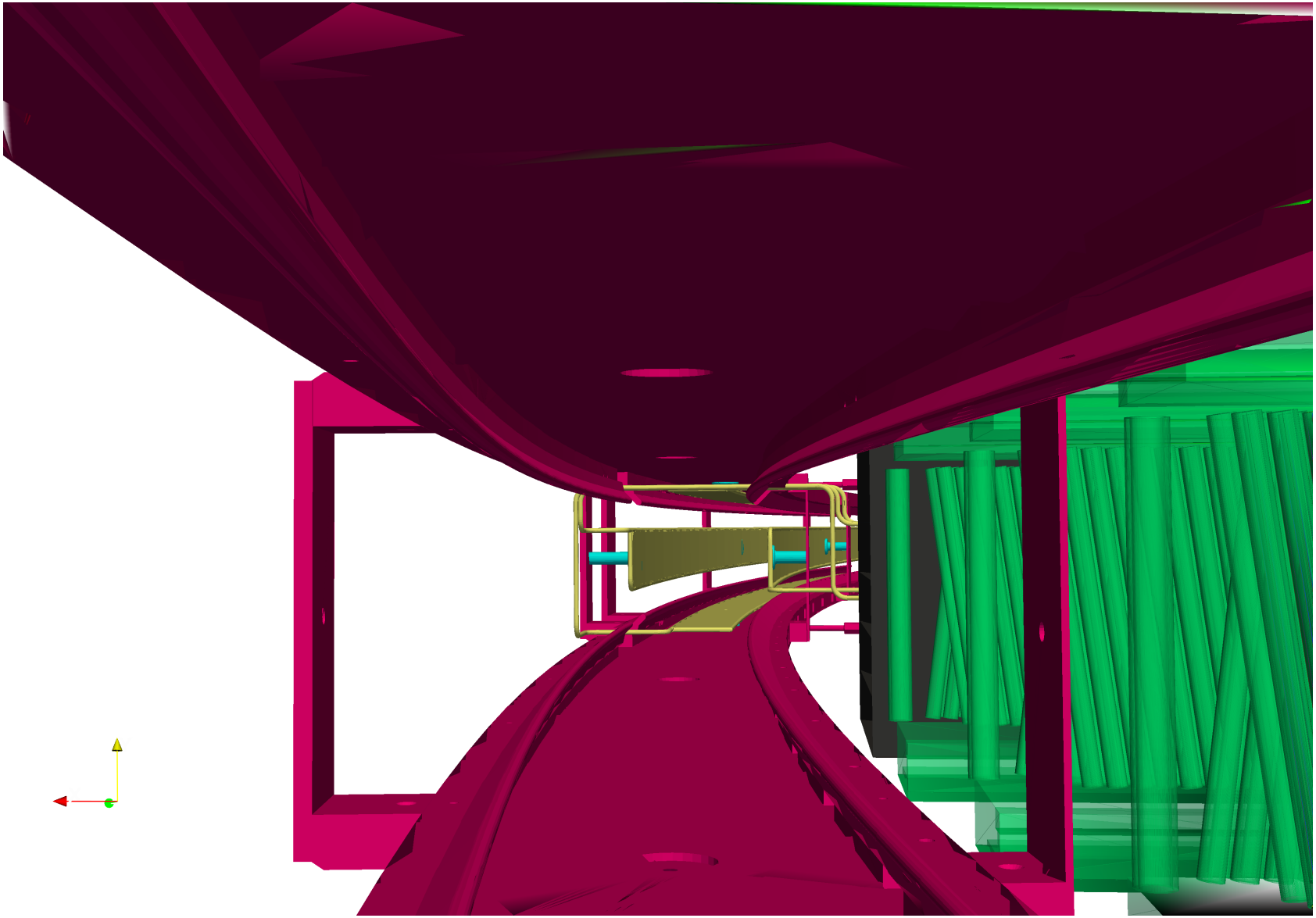
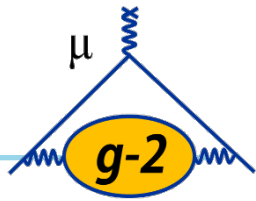




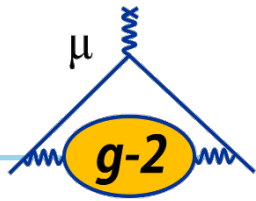
http://hep.ph.liv.ac.uk/~wturner/Files/FinalParaviewVids/InsideTheRingNoEventsBasic.mp4

Things we Learned



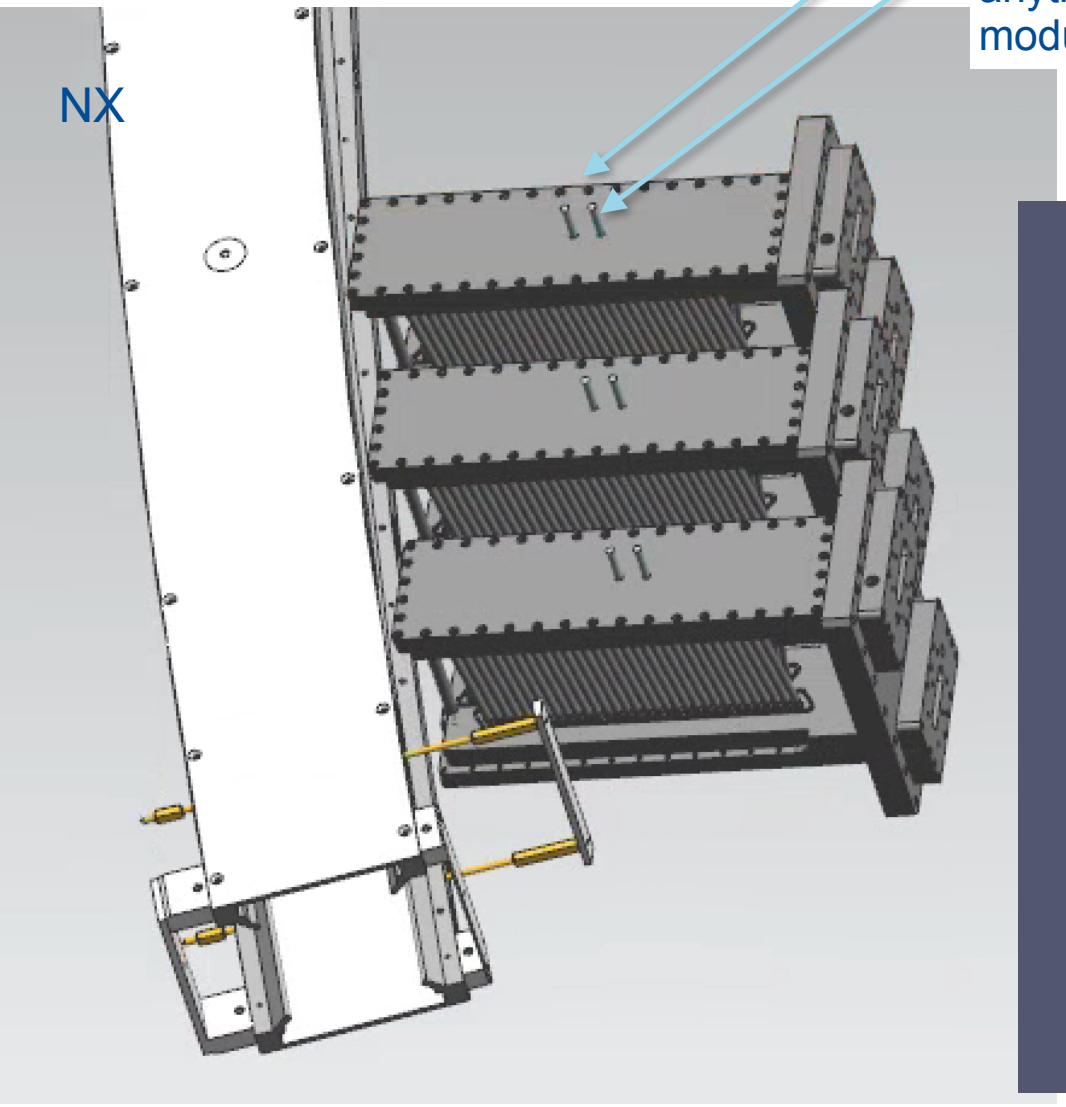
- When files come from the engineers there are lots of separate pieces for each volume
- If you create a .stl file from that, you will find lots of “warnings” about “stuck tracks”
- If however you unite the material so the volume is one solid piece, this issue goes away.
- Good to have someone that can be the go between of the physicists and the engineers that can “fix” the drawings from the engineers so the physicists can use them.
- Easy to mix .stl volumes and native Geant4 volumes.
- Keep your 3D Models in the same frame of reference as your detectors.

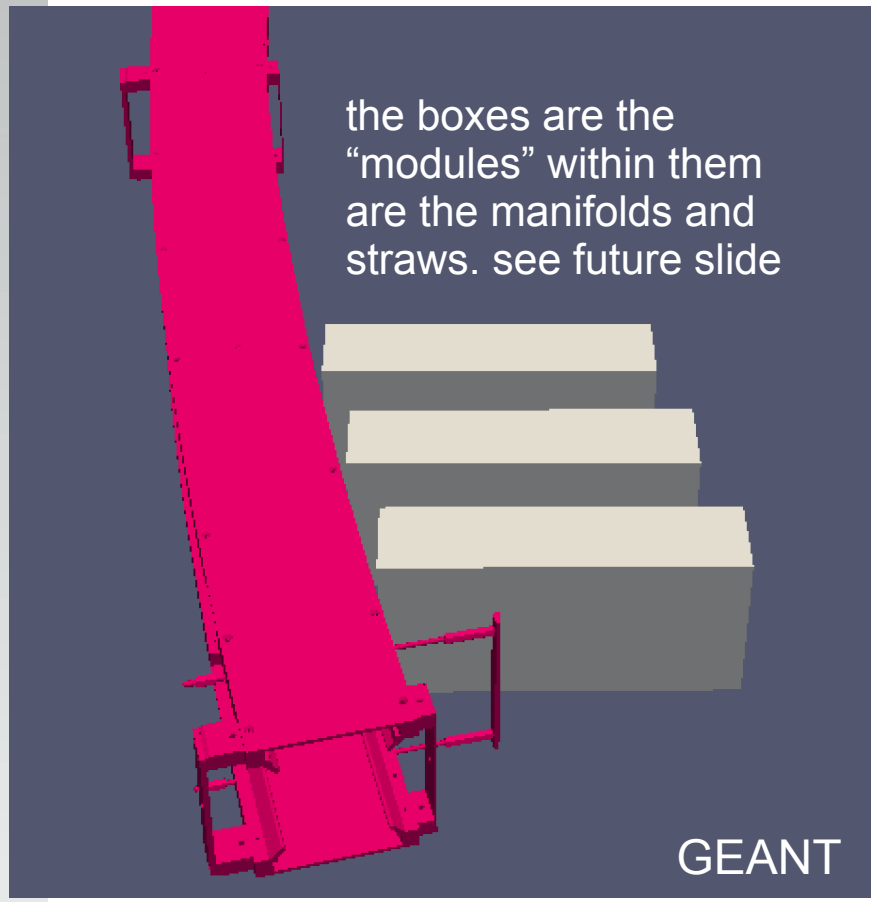
Use for Placement



- All of our drawings are done in same frame of reference as the detector.
  - Meaning the vacuum chambers are placed at the correct radius away in the drawings.
  - This means when it's exported you don't have to do any placement, other than rotations, it's EXACTLY where it needs to be.
- This is true for all the components.
- Our 3D drawings have the straw trackers in place even though these are done as native volumes.
  - We can still find the *location* in which they are at, since we know we are in the same frame of reference.
  - If we know the (x,y) coordinate of the center, then we can just use that for placement.

This structure (the two posts) has been created by me in order to find the (x,y) positions of the modules, they don't have anything to do with actual structure of the modules and aren't included in the code))





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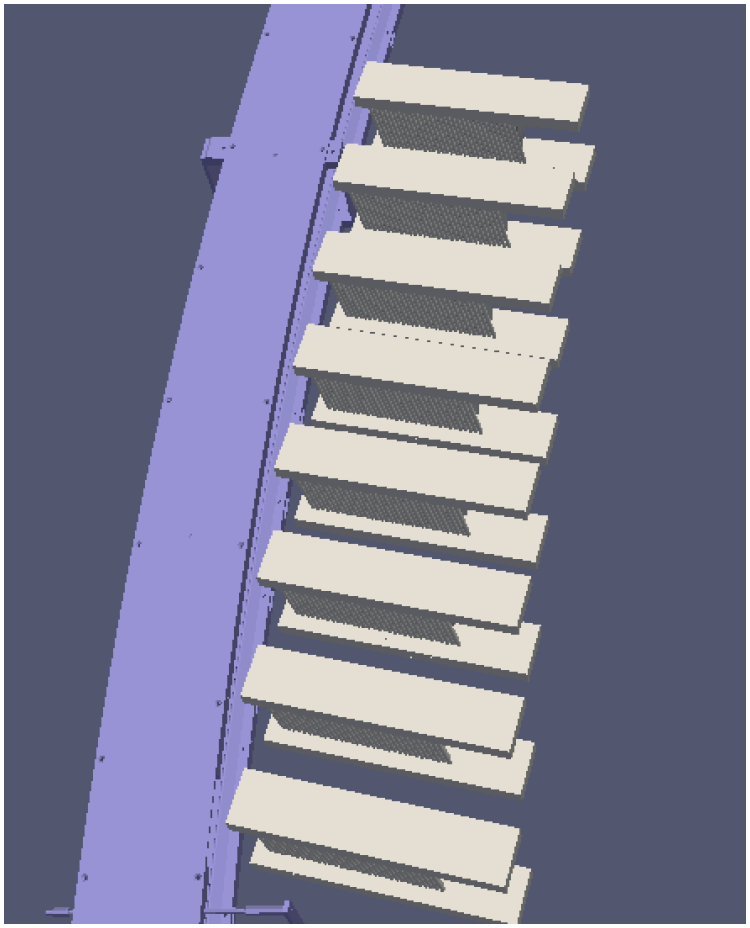
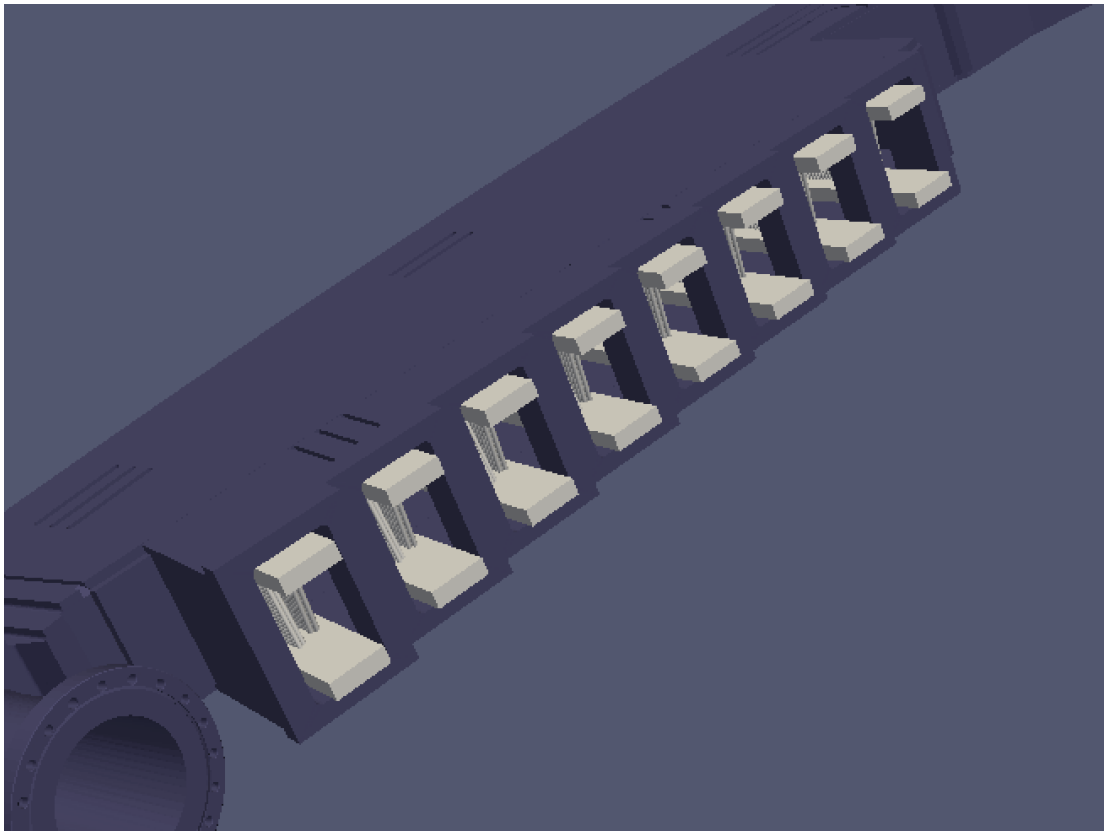
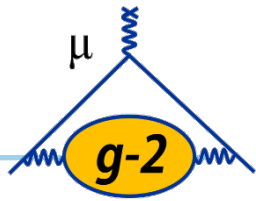




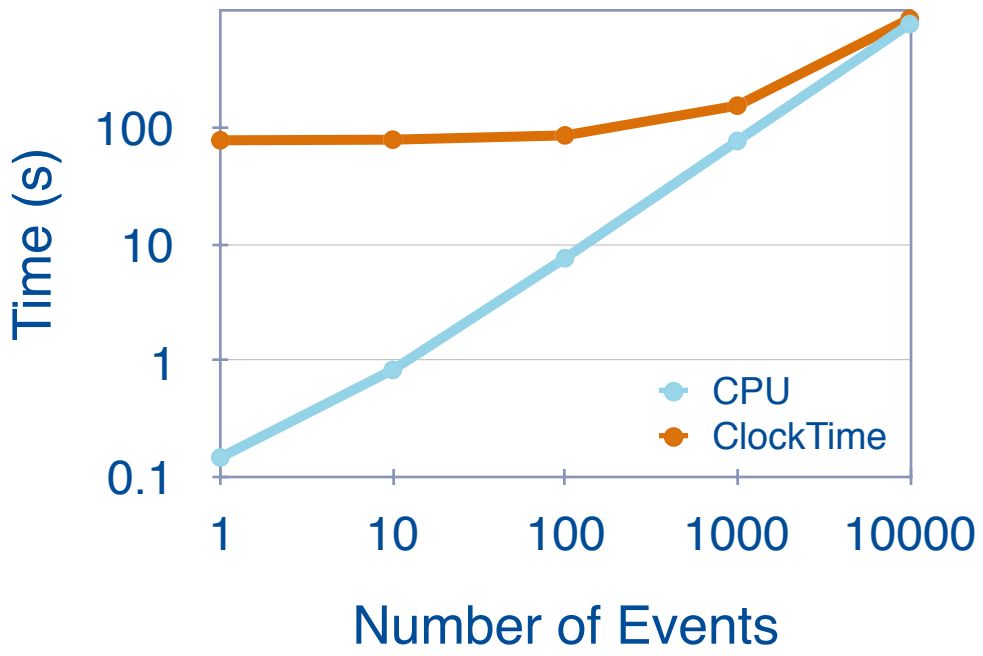
Find Overlaps.



- When Geant runs, it will warn you if you have overlaps and give you an (x,y,z) location.
- You can “fly” to that position in NX to see exactly where the overlap is occuring and fix it (usually trimming an edge of a volume by a tiny amount).

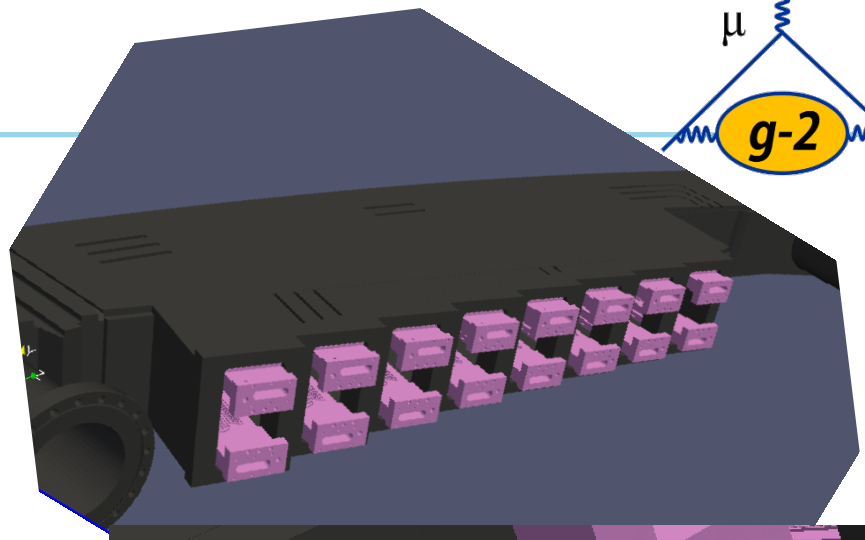
Timing

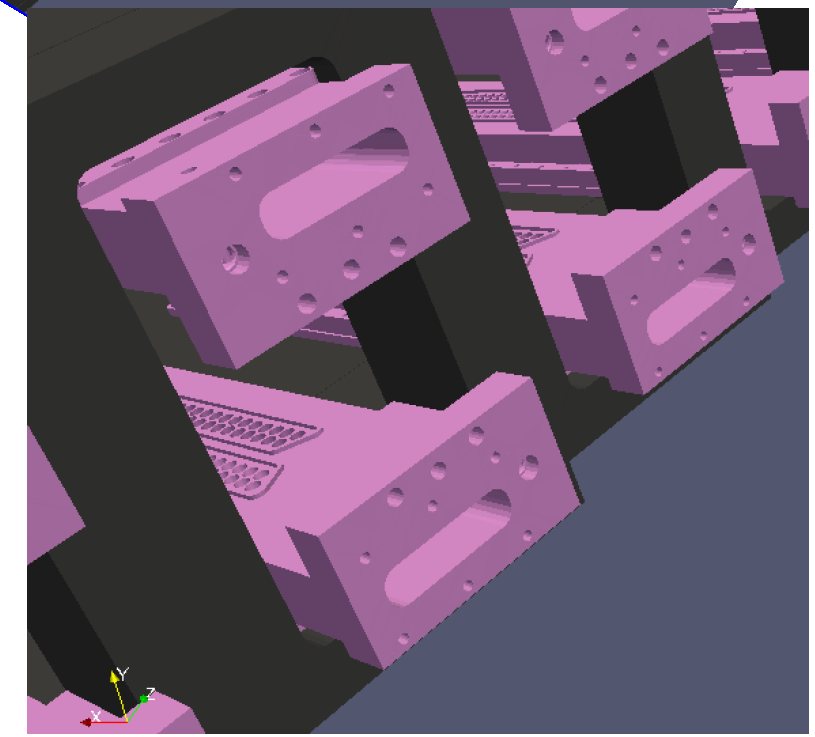
- We note that it takes much longer to build the geometry using this method.
- However, it doesn't slow down anything on subsequent events.
- It takes time to open it in Paraview, but once open, Paraview handles it beautifully.



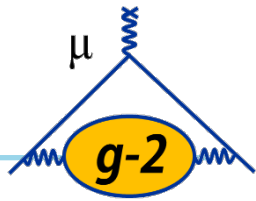
Simulation Geometry To Dos

- The straw module manifolds need to be updated with the correct shape
  - There is a “lip” around the straws that needs to be taken into account.
  - Right now these are native volumes, but we want to test using 3D models.
  - Can a simpler estimation be used.
- Needs
  - There are times there are not enough NX licenses and if that happens I can’t work on the 3D models.





Conclusions



- We abandoned some of the native Geant4 volumes for 3D models within the simulation
- The models are created from an ".stl" file, which goes through the CADMesh libraries to make a tessellated solid that can be used in our simulation.
- This has allowed us to have the exact shape of volumes within the simulation
- Ability to mix and match native Geant volumes with 3D model volumes
- Ease of updating the simulation when volumes are updated.
- Ability to easily find placements of volumes and find overlaps when Geant4 displays them