TECH-X
SIMULATIONS EMPOWERING YOUR INNOVATIONS

LASP
Laboratory for Atmospheric and Space Physics
University of Colorado **Boulder**

Using SPENVIS for SUDA radiation modeling

Tech-X Corporation

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www.txcorp.com

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Thanks to:

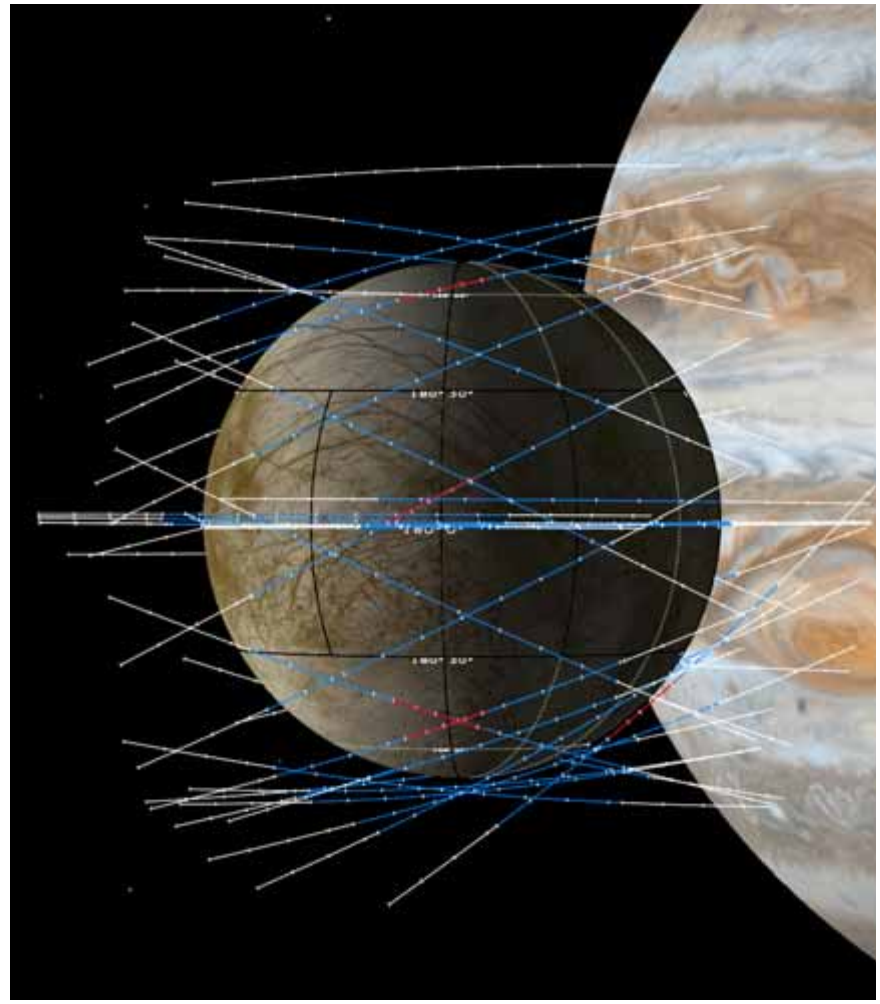
- SUDA team in LASP, University of Colorado
- SPENVIS team (Neophytos Messios)
- G. Santin and N. Altobelli (access to GRAS)
- Hans Wenzel (FNAL: help with G4 and first viz)
- Guy Barrand (Open Scientist, AIDA installs)

Overview

- SUDA and Europa Clipper mission
- Radiation modeling for SUDA
  - Radiation environment
  - Geometry and materials
  - Radiation analysis
- Summary

Europa Clipper Pre-Project

- Clipper concept
  - 45 flybys of Europa with the orbit to minimize exposure to radiation, no landing
- NASA formally selects Clipper as down selected flagship to Europa (March 2013). Explicit in 2015 Obama's budget.
- Launch June 2022 arrives May 2024
- Mass ~3000kg, $1.9B.

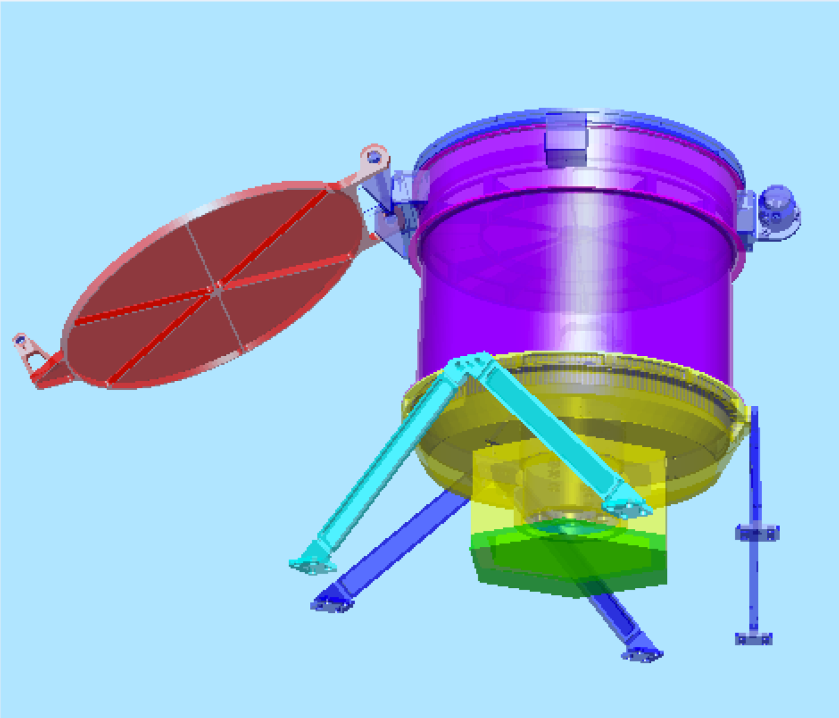


Europa Clipper Goals

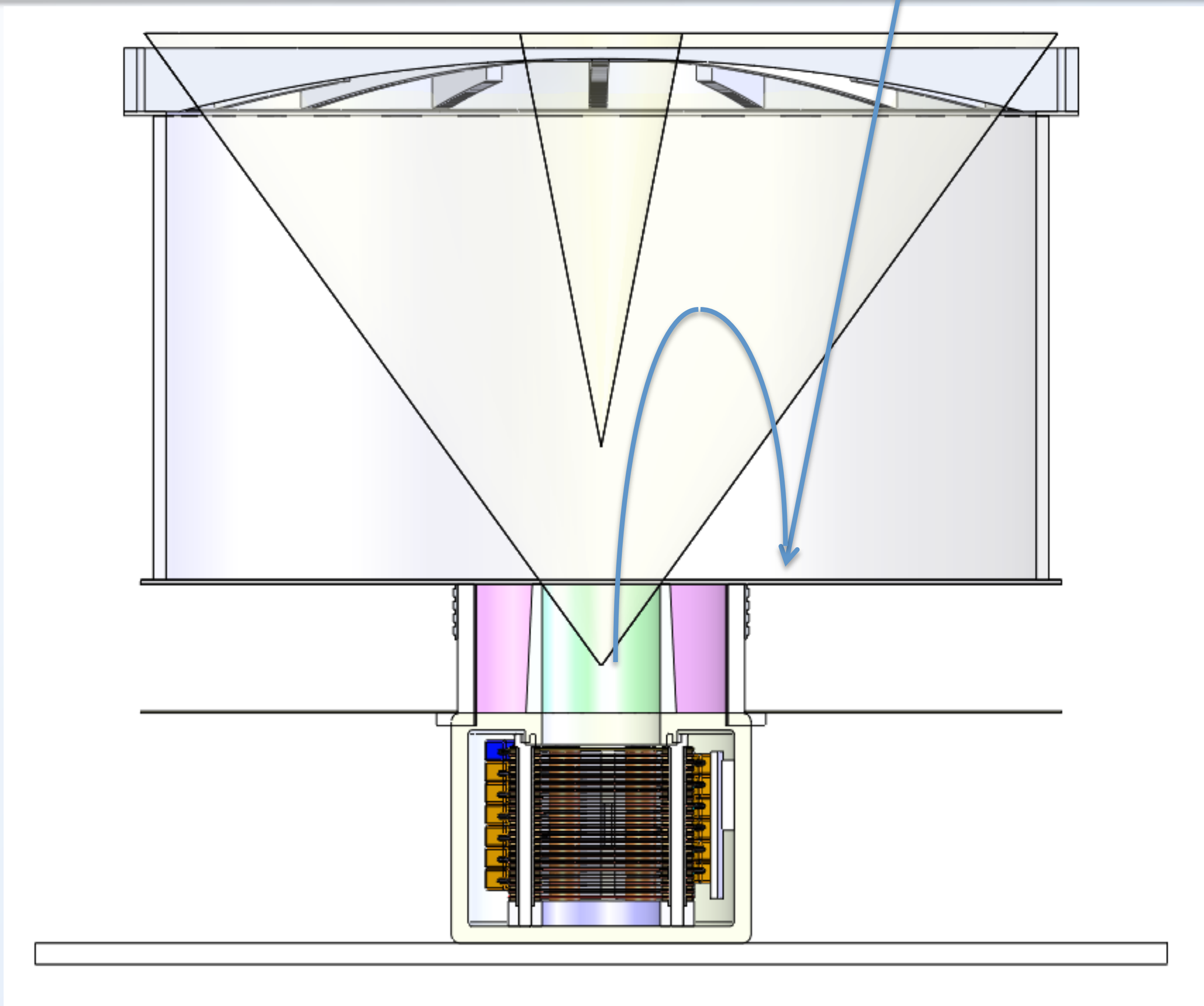
- Study the surface (ice and atmosphere) composition
- Ocean habitability
- Geology
- Recon for a Lander

SUDA (SUrface Dust Analyzer): LASP University of Colorado

- Mass spectrometer maps the surface composition by analyzing ejecta particles and timing data to a particular feature on the surface
- Goal: understand if the ocean is chemically-rich and capable of providing both the elements and chemical energy needed for life
- The instrument has to be OPEN to catch particles and is particularly vulnerable to radiation
- Pre-project (one year)



SUDA: collects dust, focuses generated ions to the top of the detector where they convert to electrons and electrons get multiplied in the detector



Tech-X tasks

- Optimizing the geometry and materials of ion detector to minimize the total ionizing dozes on all sensitive elements and minimize the instrument weight
- Advantage: real geometries (vs modeling of slabs)
- Prepare for testing facility (which part of the energy spectrum is important?)
- Calculate proton fluxes on the detector (to figure out the noise/signal ration)
- Prepare for more-in-depth studies for the next stages of the project (this project is 14 weeks of work)
- We used SPENVIS (“light users”) to get results quickly

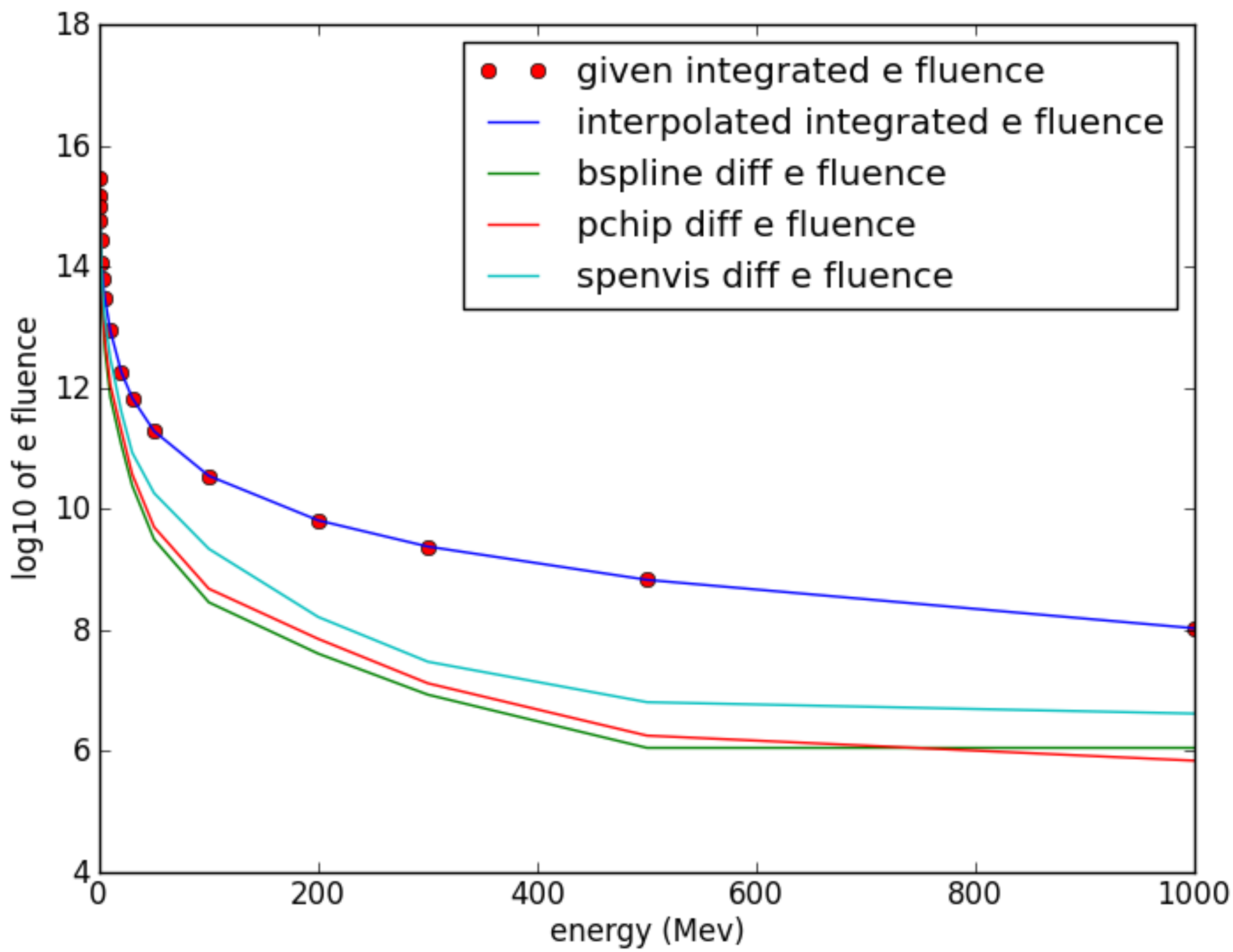
Workflow

- Create differential fluences and fluxes from integral data given by ICEE
- Create gdml (shapes and materials)
- Run GRAS through SPENVIS
- Change gdml
- Run GRAS…

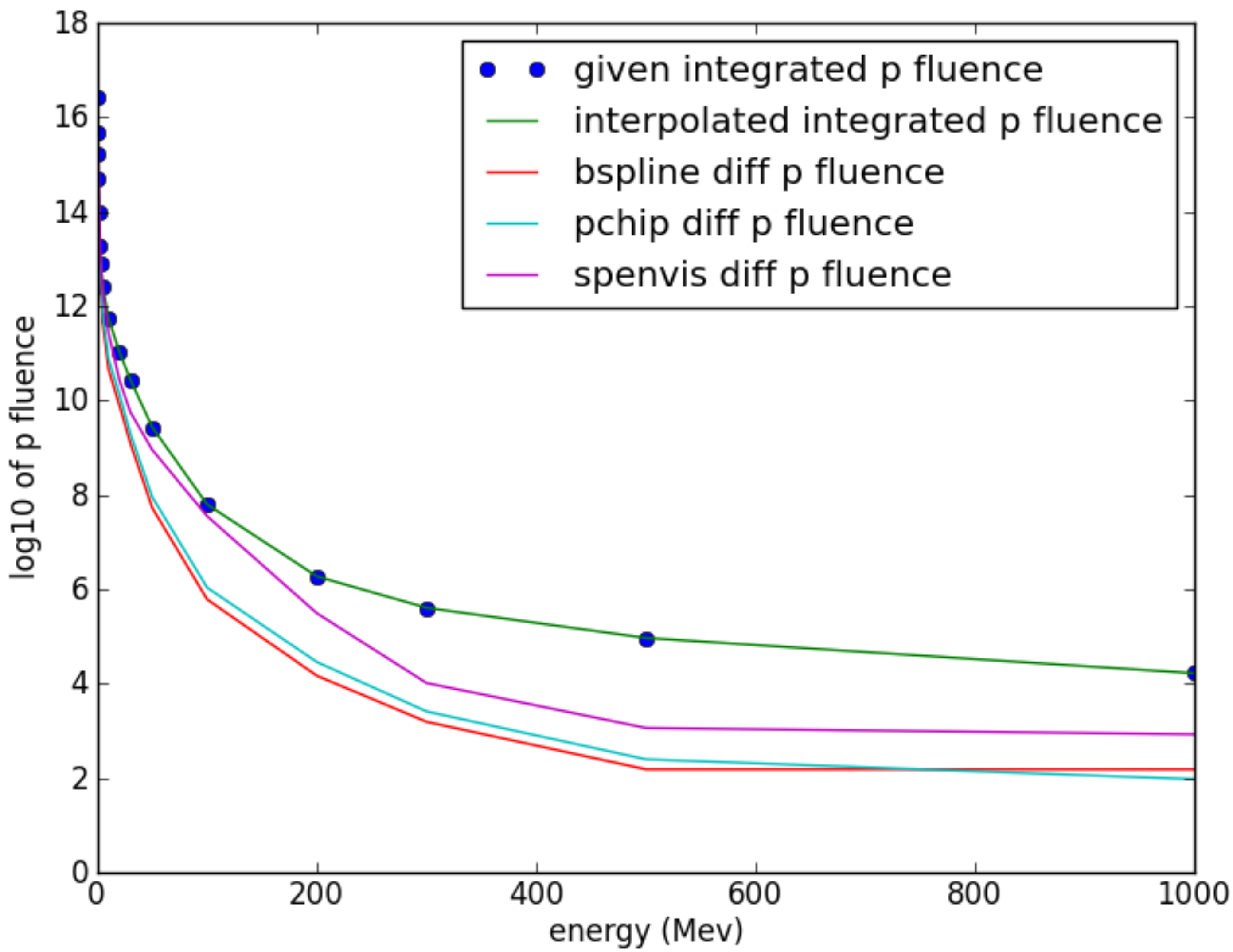
Calculating differential quantities

- 3 point interpolation as suggested by SPENVIS (ESA)
- Python (numpy)
  - Piecewise Cubic Hermite Interpolating Polynomial (pchip routine)
  - Bspline (bsplev routine)

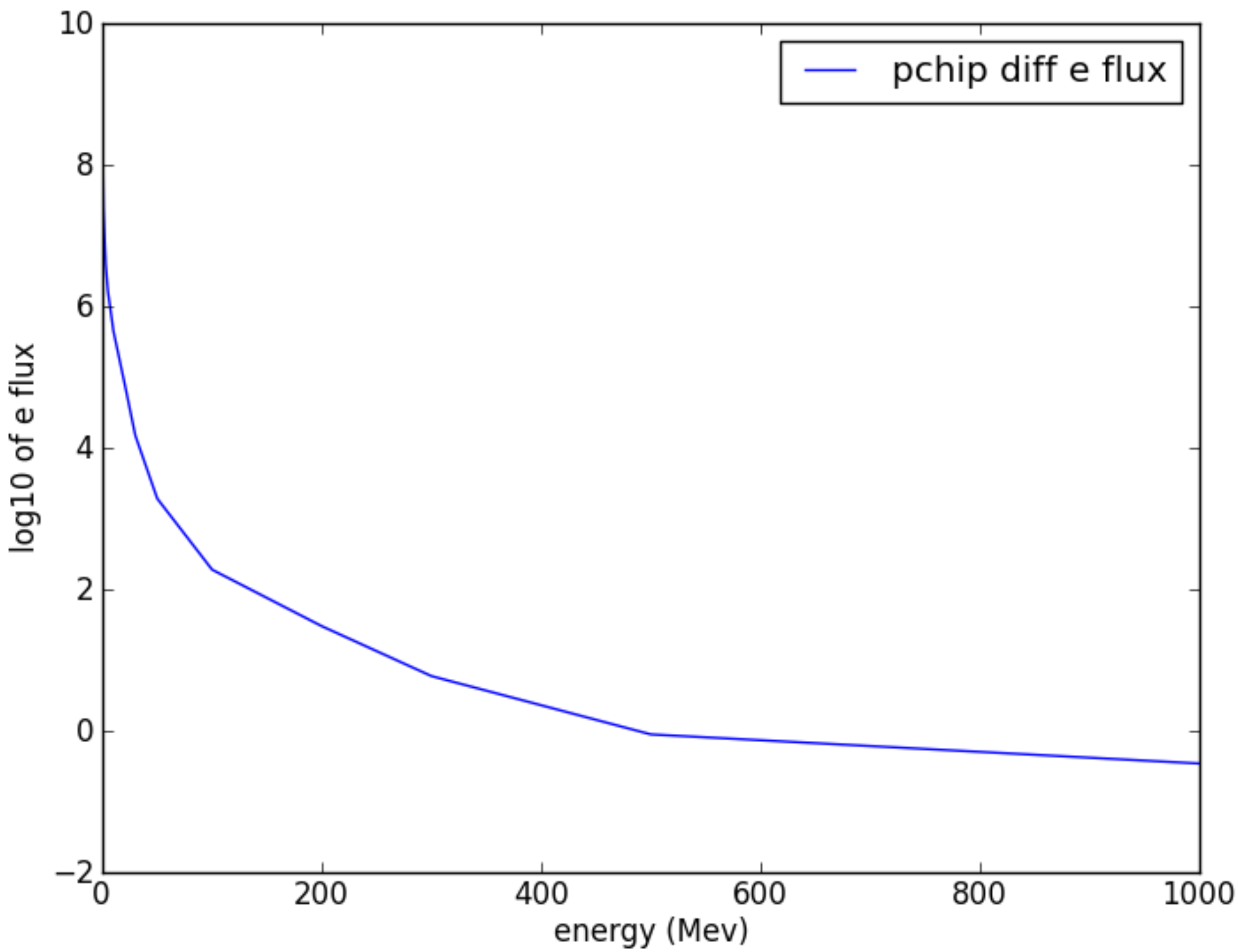
Differential fluence depends on approximation (spenvis is higher!)



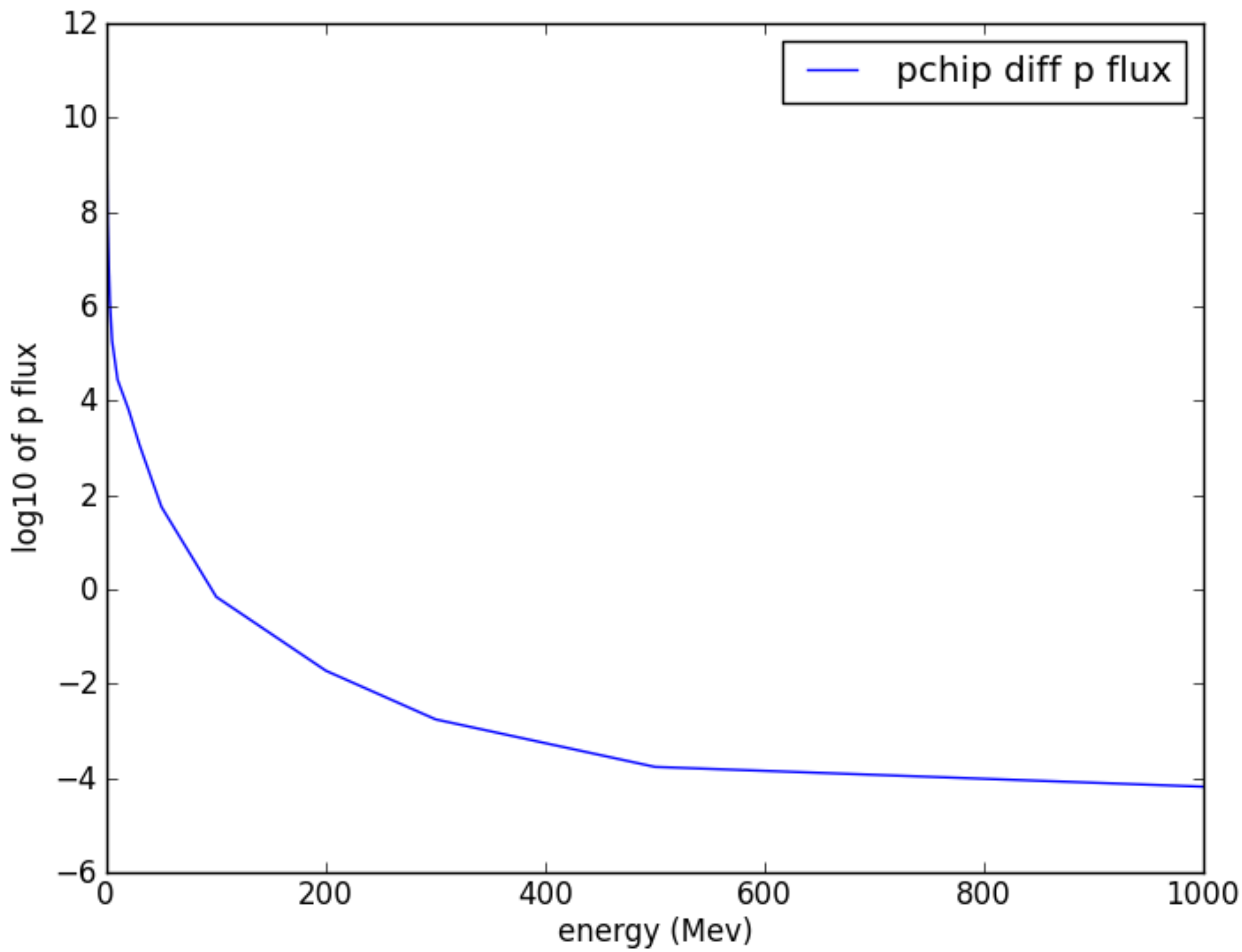
Differential fluence depends on approximation (spenvis's is higher!)



Interpolated differential e flux

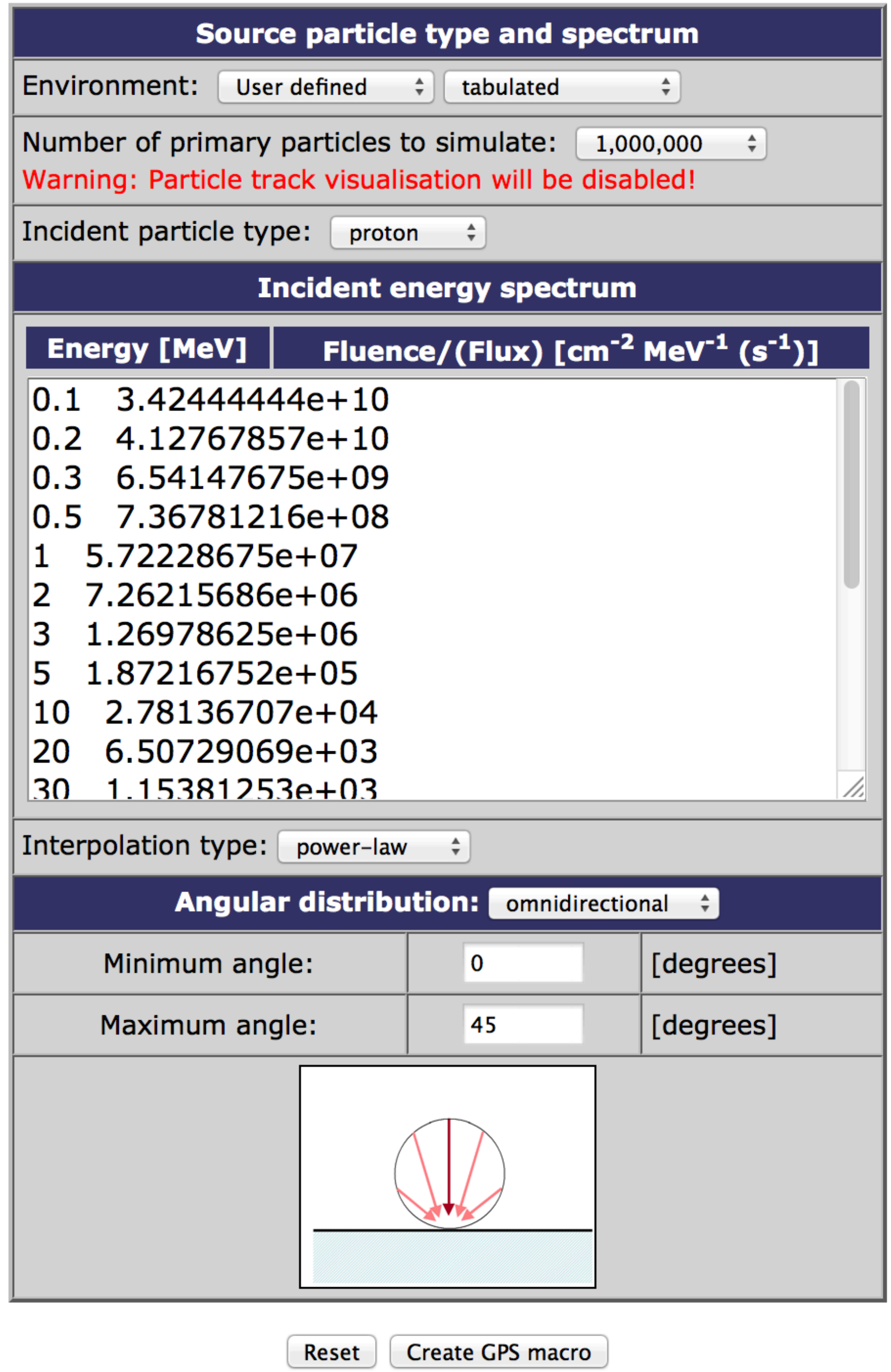


Interpolated differential p flux

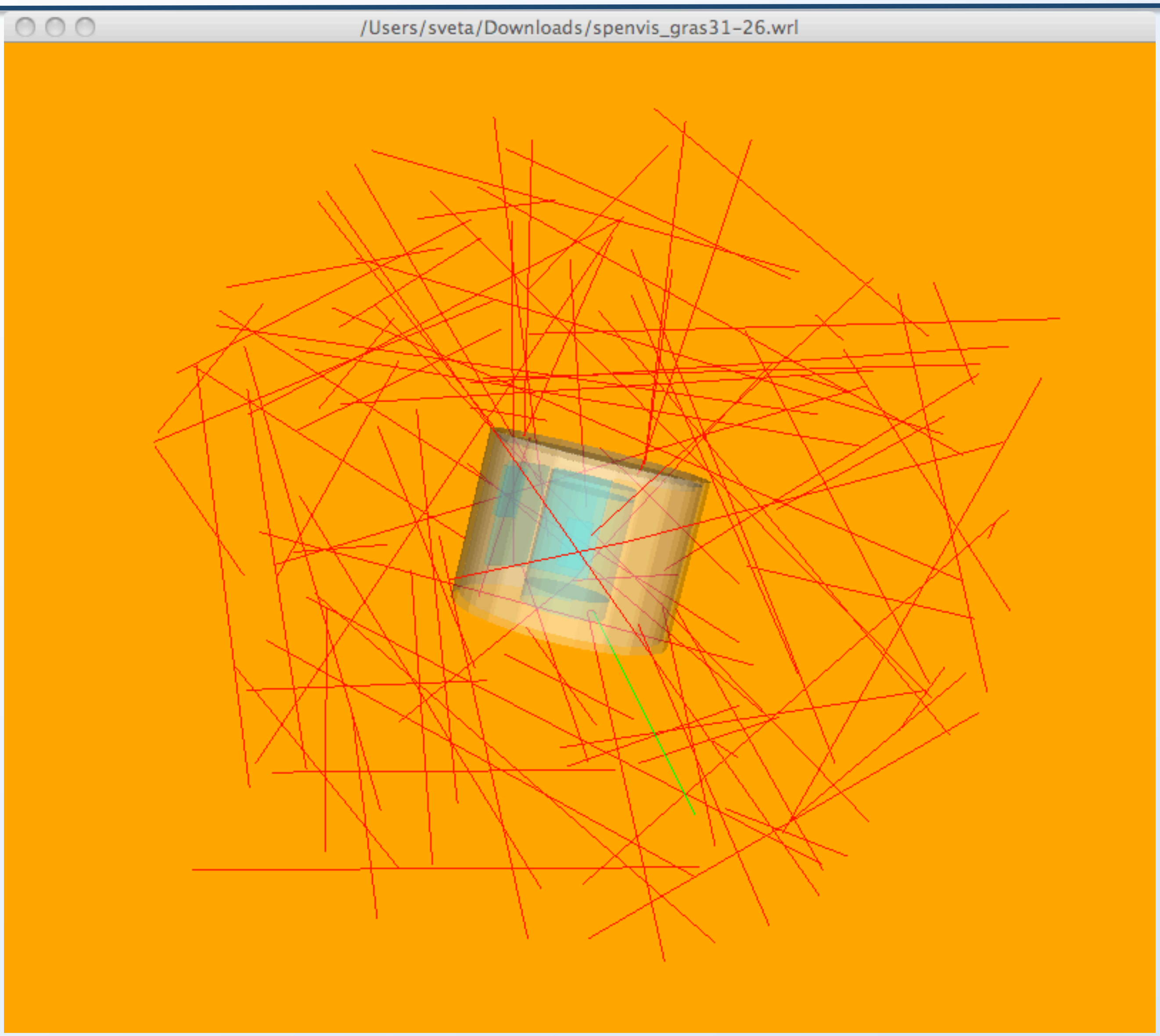


Particles macros created using SPENVIS

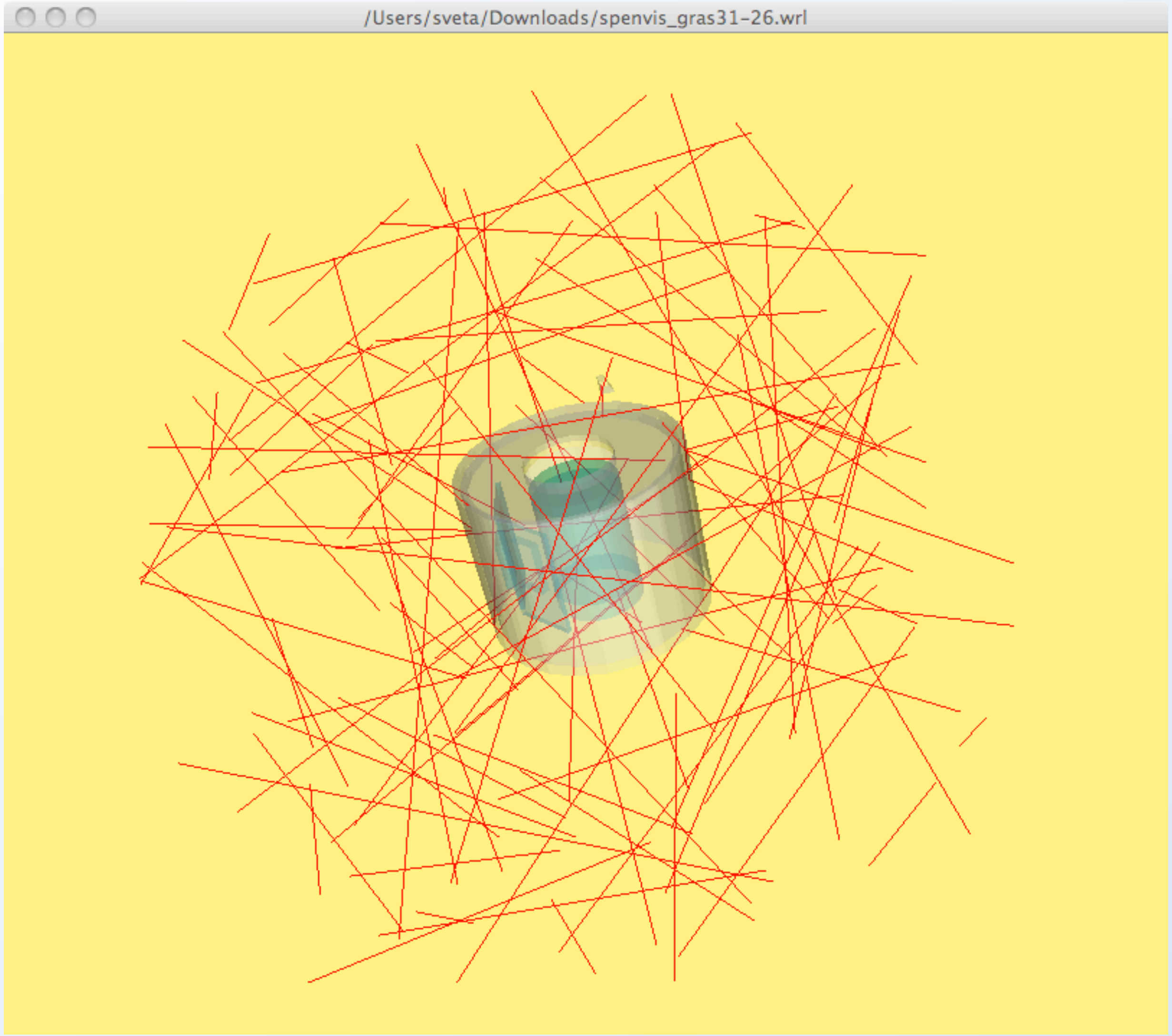
- Spherical source 13cm, angle to 45 degrees
- 1M protons and electrons
- Tabulated data
- Power law interpolation



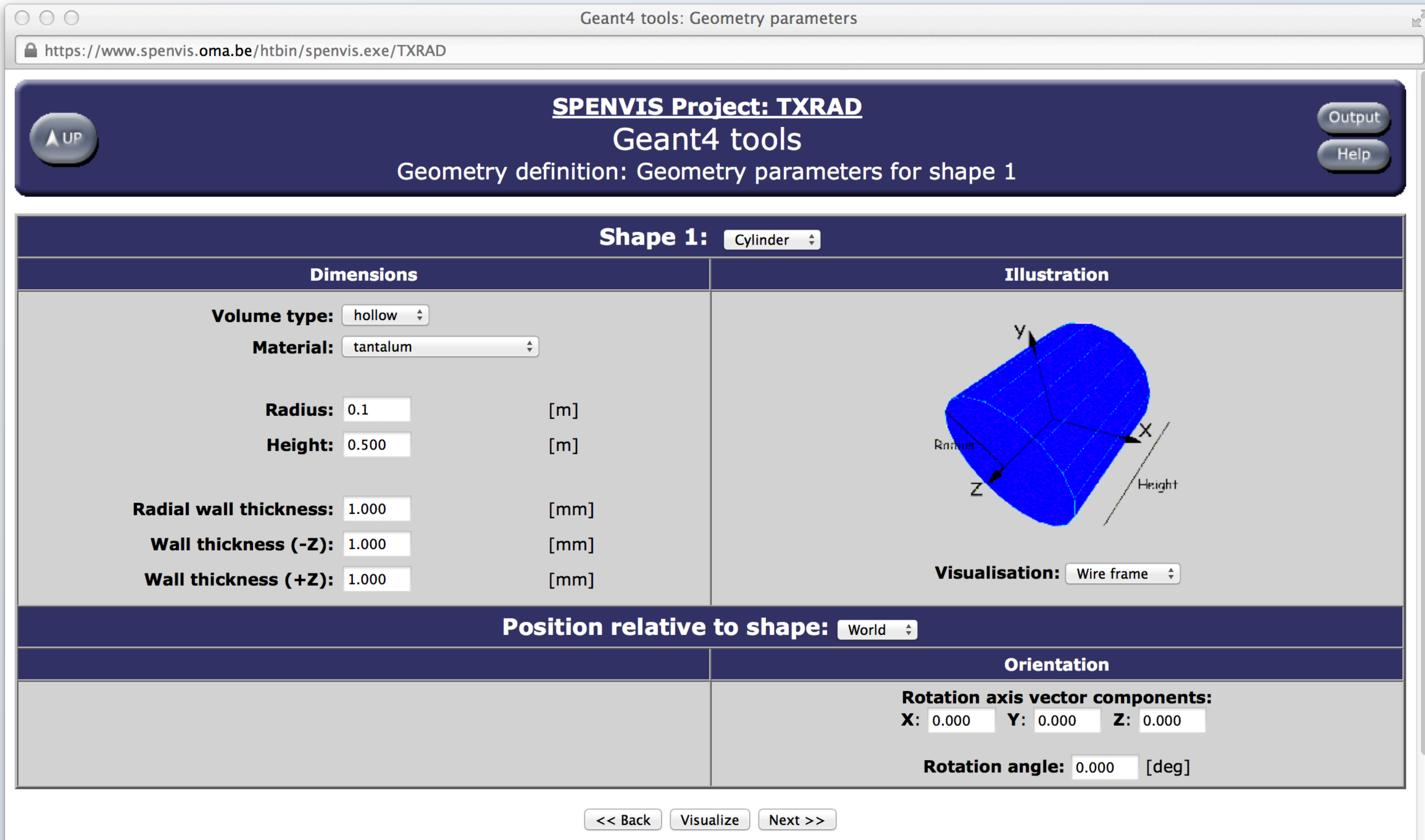
Visualizing (100 e, closed shield, angle up to 45 degrees)



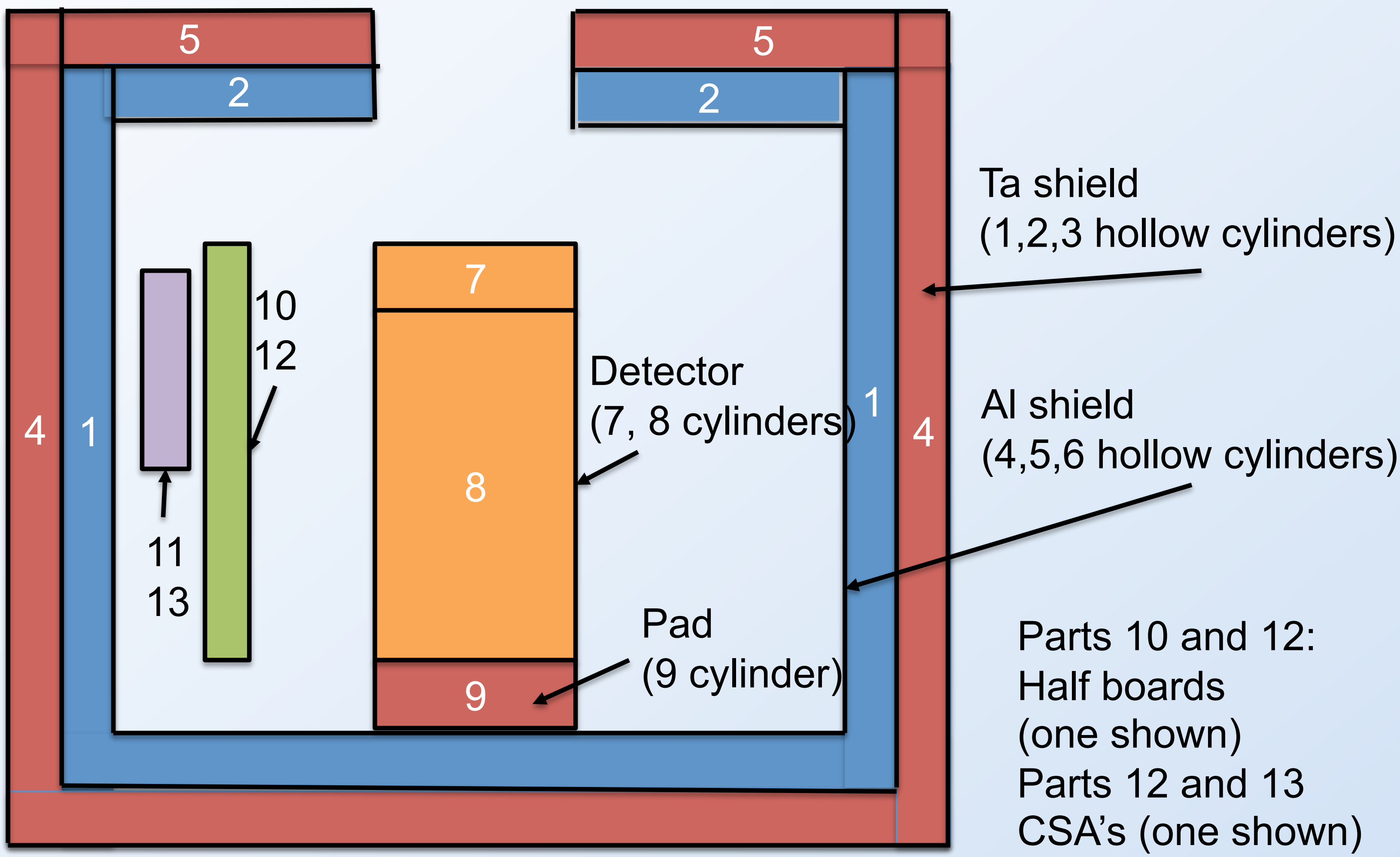
Visualizing (100 e, closed shield, angle up to 90 degrees)



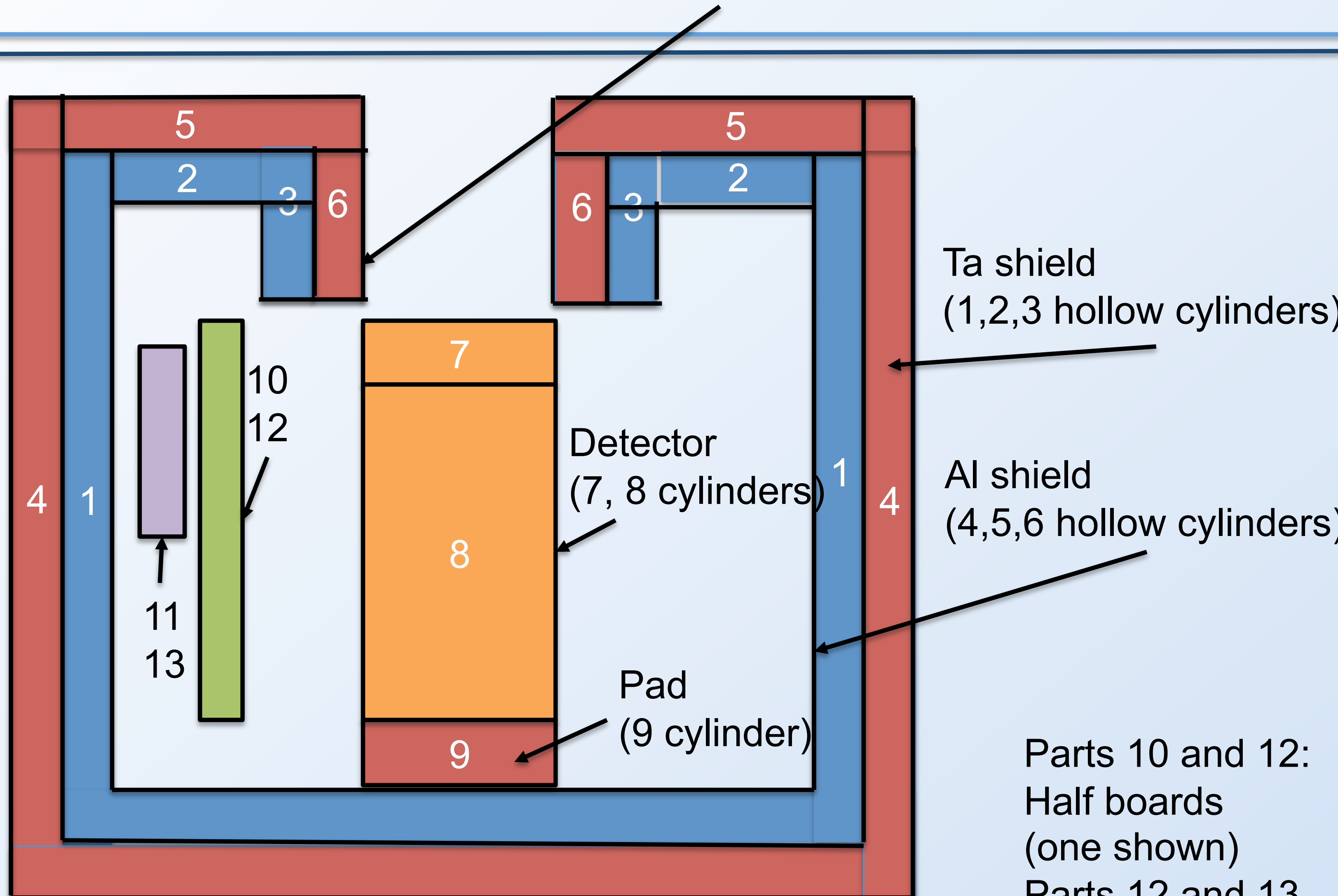
Gdml generated by geometry definition tool and edited as needed



No lip

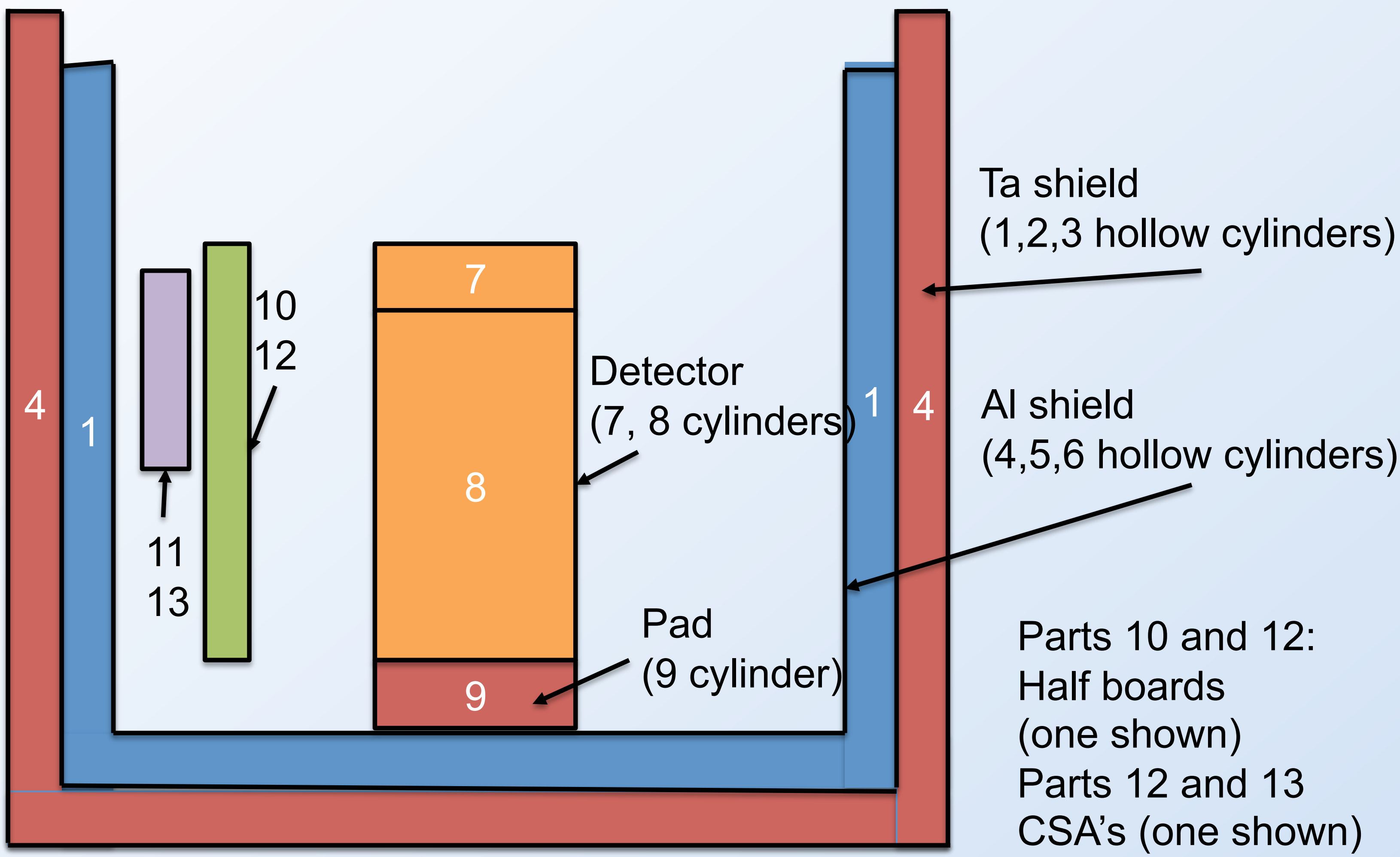

5
2
5
2
4
1
10
12
11
13
7
8
9
Detector
(7, 8 cylinders)
1
4
Pad
(9 cylinder)
Ta shield
(1,2,3 hollow cylinders)
Al shield
(4,5,6 hollow cylinders)
Parts 10 and 12:
Half boards
(one shown)
Parts 12 and 13
CSA's (one shown)

“Lip”



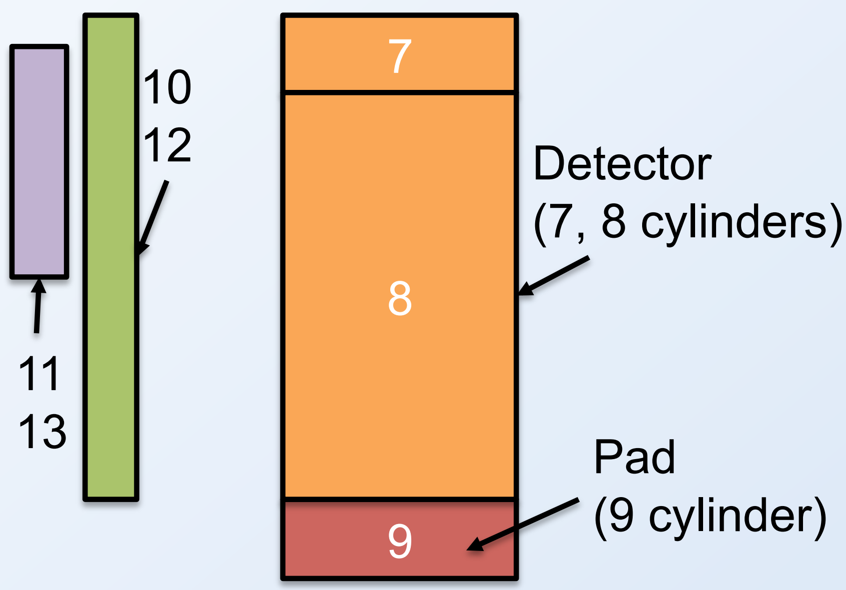
Parts 10 and 12:
Half boards
(one shown)
Parts 12 and 13
CSA’s (one shown)

No top



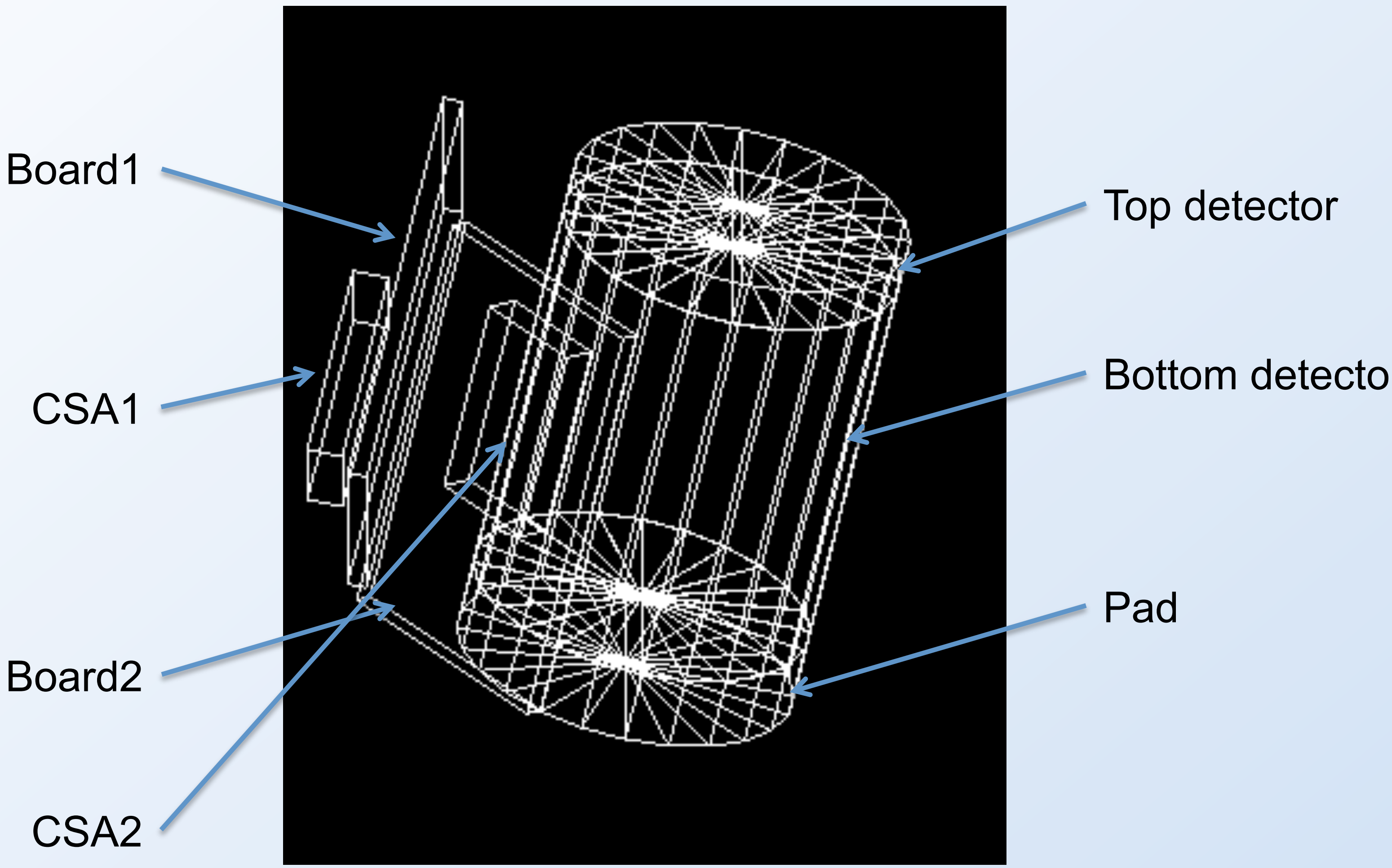
Parts 10 and 12:
Half boards
(one shown)
Parts 12 and 13
CSA's (one shown)

No shield

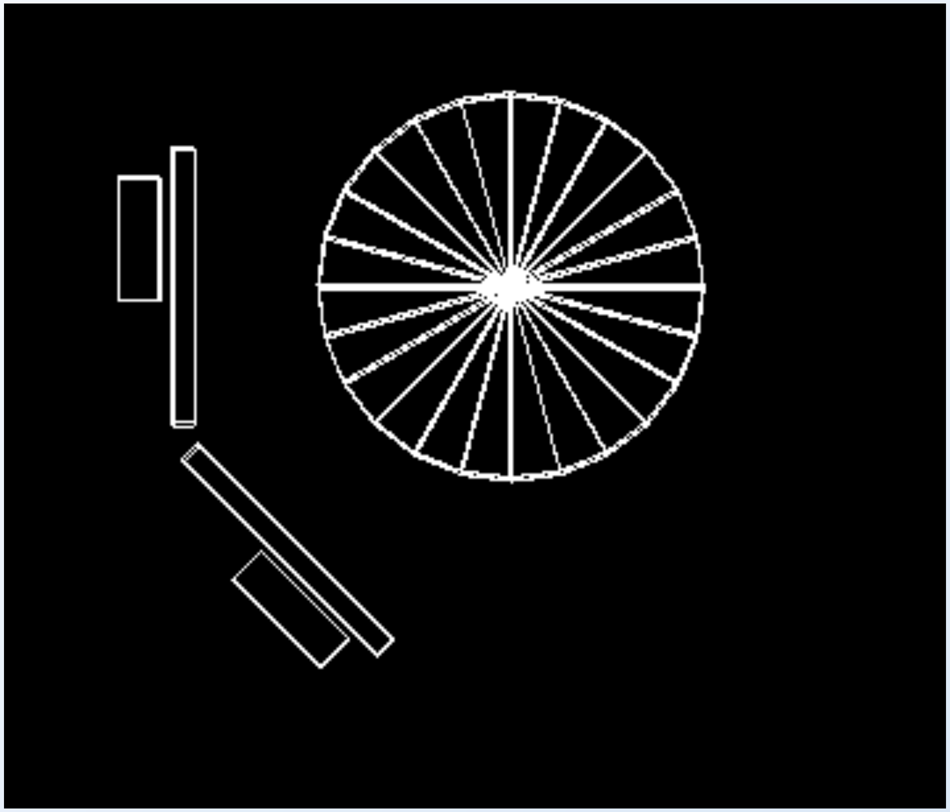


Parts 10 and 12:
Half boards
(one shown)
Parts 12 and 13
CSA's (one shown)

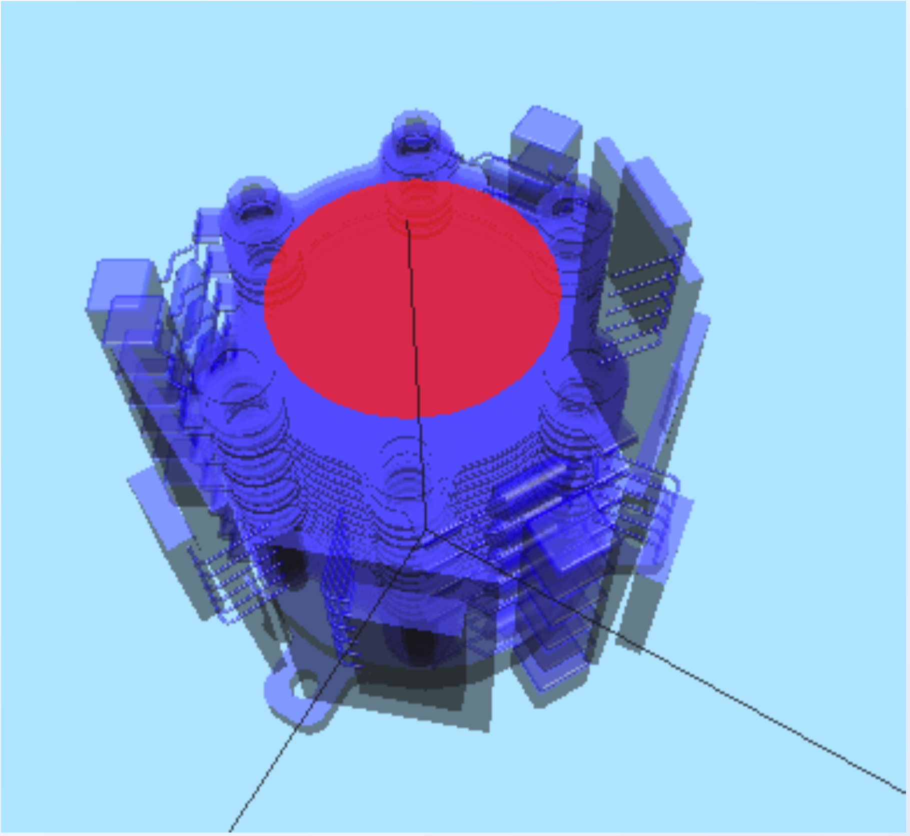
GDML version (no shield)

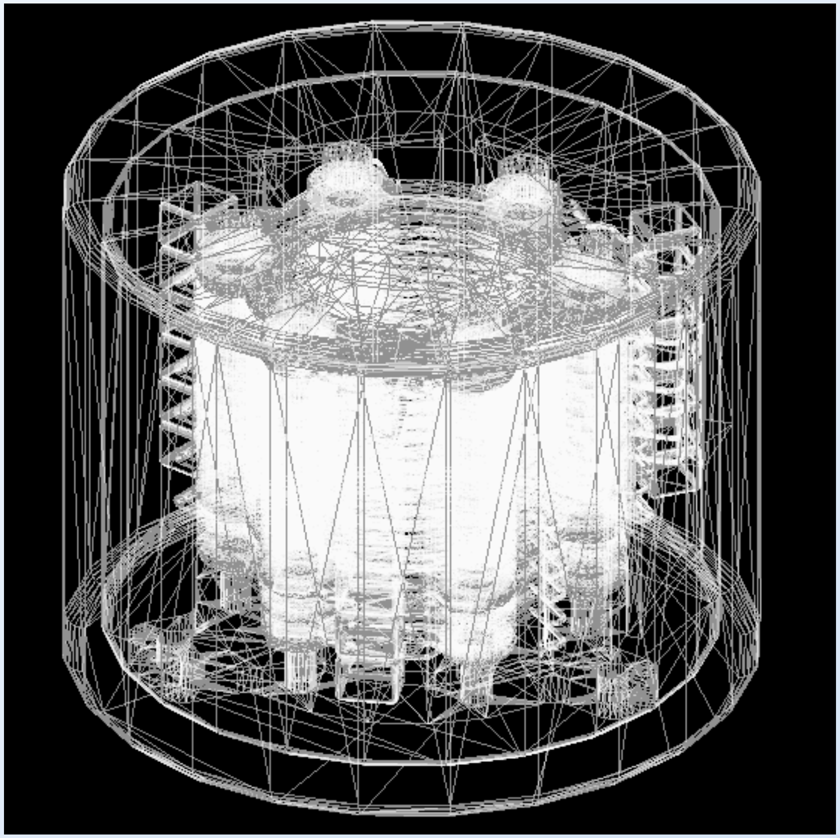


Top view (no shield)



CAD (STEP) data is converted by GDML but was not used



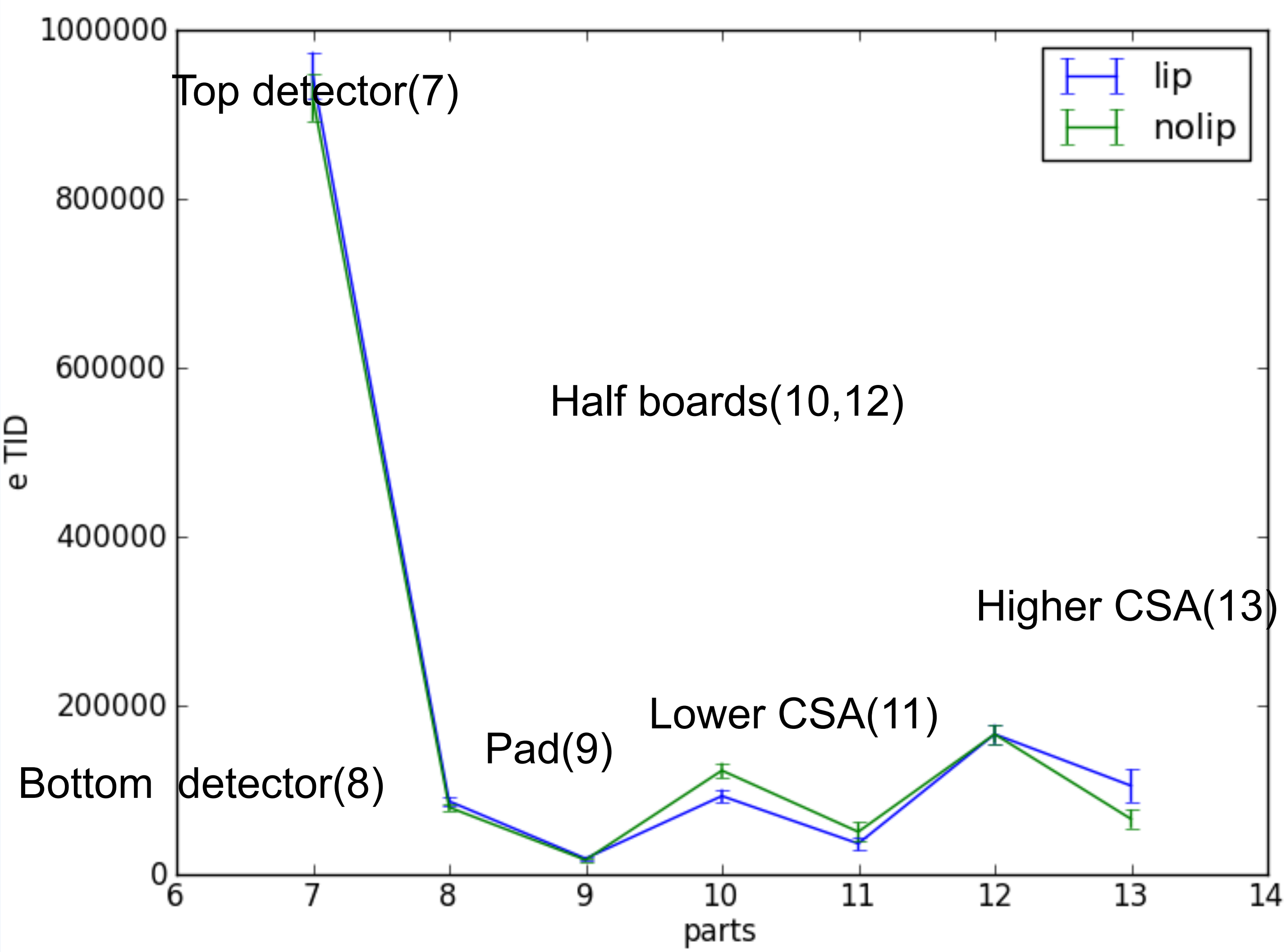


Can create complex materials for G4 (FR4)

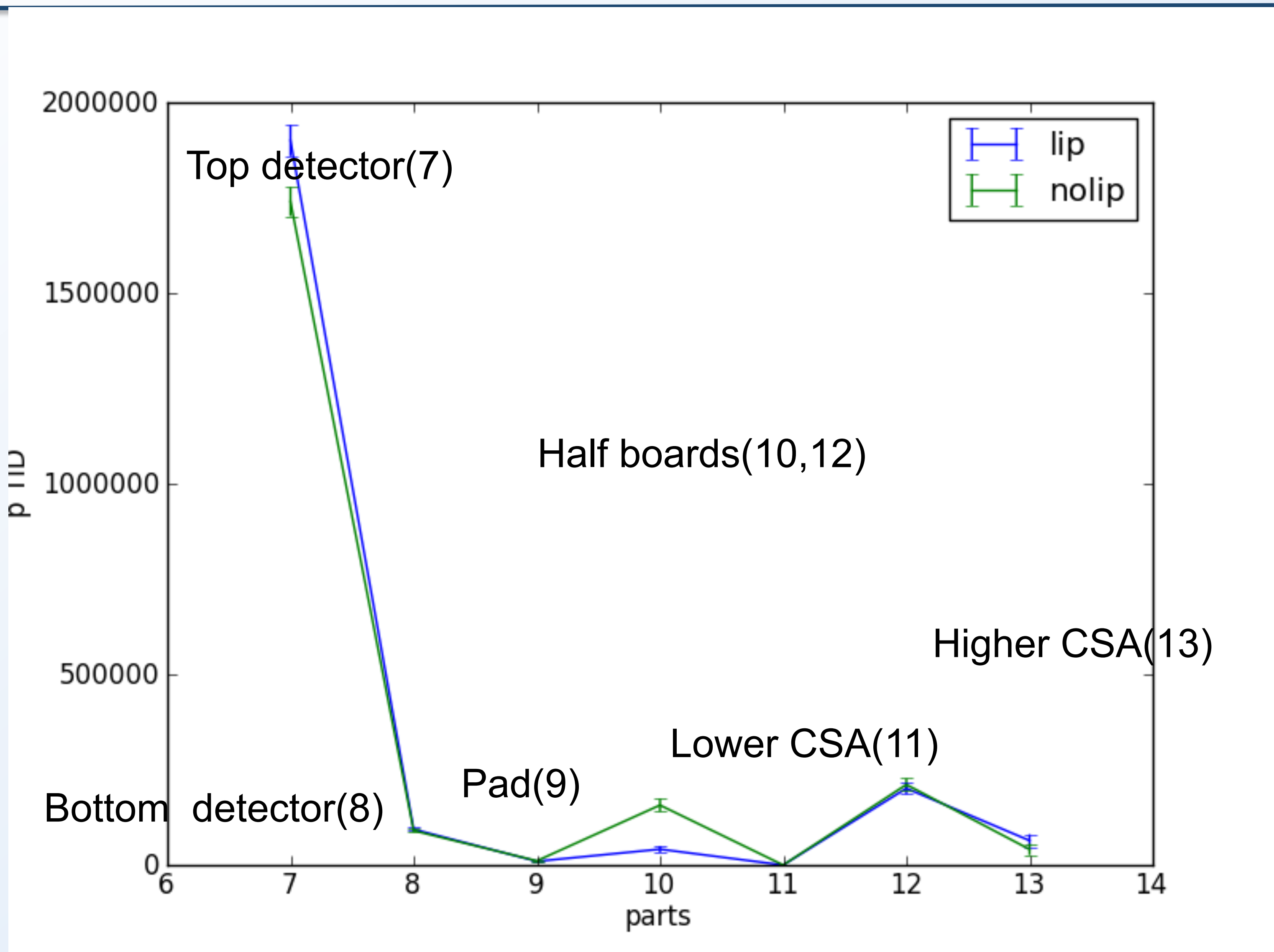
```
<material name="epoxy_resin"
formula="C38H40O6Br4">
  <D value="1.1250" unit="g/cm3"/>
  <composite n="40" ref="G4_H"/>
  <composite n="38" ref="G4_C"/>
  <composite n="6" ref="G4_O"/>
  <composite n="4" ref="G4_Br"/>
</material>
<material name="SiO2" formula="SiO2">
  <D value="2.2" unit="g/cm3"/>
  <composite n="1" ref="G4_Si"/>
  <composite n="2" ref="G4_O"/>
</material>
<material name="Al2O3" formula="Al2O3">
  <D value="3.97" unit="g/cm3"/>
  <composite n="2" ref="G4_Al"/>
  <composite n="3" ref="G4_O"/>
</material>
<material name="Fe2O3" formula="Fe2O3">
  <D value="5.24" unit="g/cm3"/>
  <composite n="2" ref="G4_Fe"/>
  <composite n="3" ref="G4_O"/>
</material>
<material name="CaO" formula="CaO">
  <D value="3.35" unit="g/cm3"/>
  <composite n="1" ref="G4_Ca"/>
  <composite n="1" ref="G4_O"/>
</material>
```

```
<material name="MgO" formula="MgO">
  <D value="3.58" unit="g/cm3"/>
  <composite n="1" ref="G4_Mg"/>
  <composite n="1" ref="G4_O"/>
</material>
<material name="Na2O" formula="Na2O">
  <D value="2.27" unit="g/cm3"/>
  <composite n="2" ref="G4_Na"/>
  <composite n="1" ref="G4_O"/>
</material>
<material name="TiO2" formula="TiO2">
  <D value="4.23" unit="g/cm3"/>
  <composite n="1" ref="G4_Ta"/>
  <composite n="2" ref="G4_O"/>
</material>
<material name="fibrous_glass">
  <D value="2.74351" unit="g/cm3"/>
  <fraction n="0.600" ref="SiO2"/>
  <fraction n="0.118" ref="Al2O3"/>
  <fraction n="0.001" ref="Fe2O3"/>
  <fraction n="0.224" ref="CaO"/>
  <fraction n="0.034" ref="MgO"/>
  <fraction n="0.010" ref="Na2O"/>
  <fraction n="0.013" ref="TiO2"/>
</material>
<material name="FR4">
  <D value="1.98281" unit="g/cm3"/>
  <fraction n="0.47" ref="epoxy_resin"/>
  <fraction n="0.53" ref="fibrous_glass"/>
</material>
```

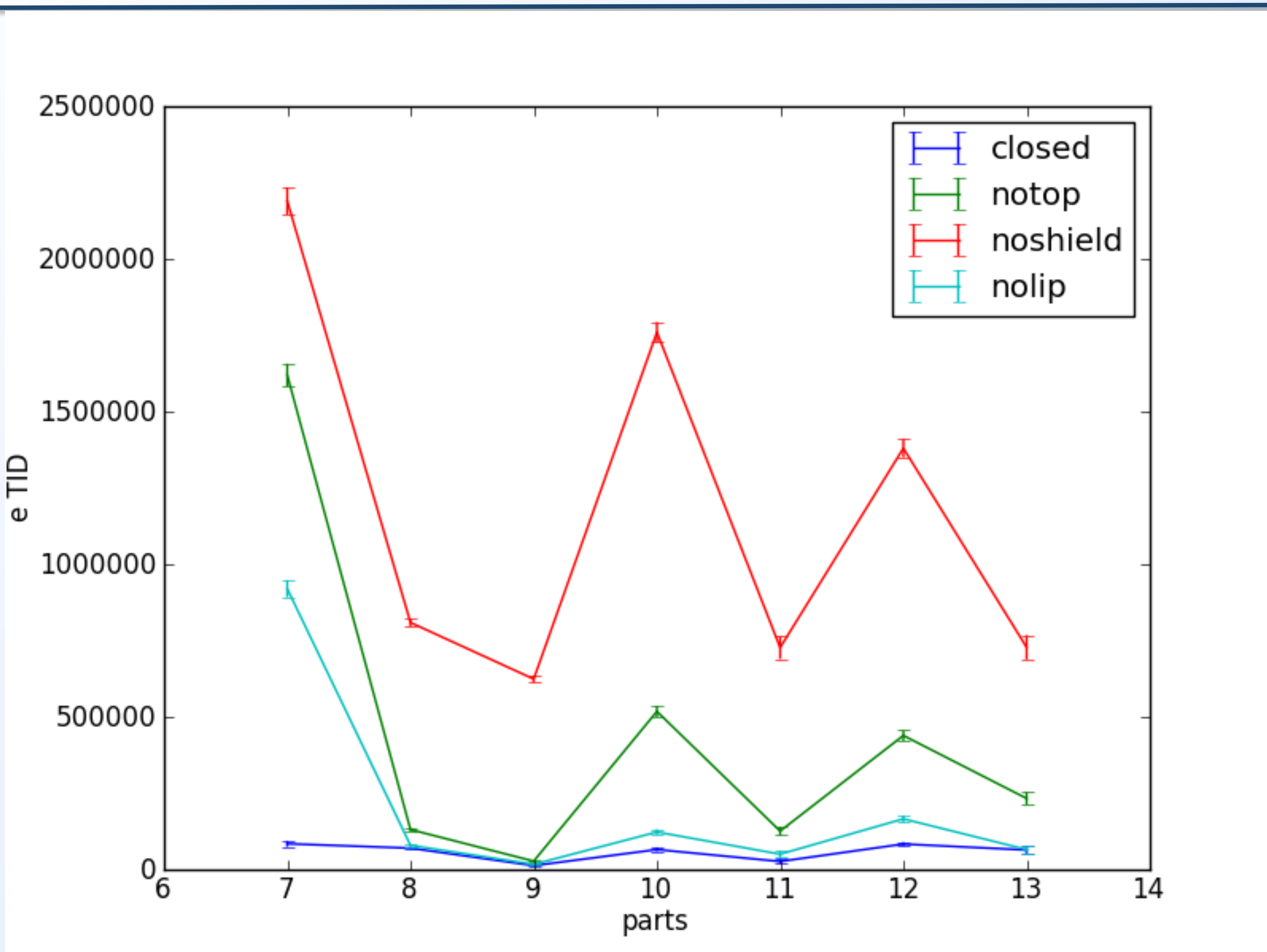
Lip vs no-lip configuration: no significant difference: ignore lip from now on



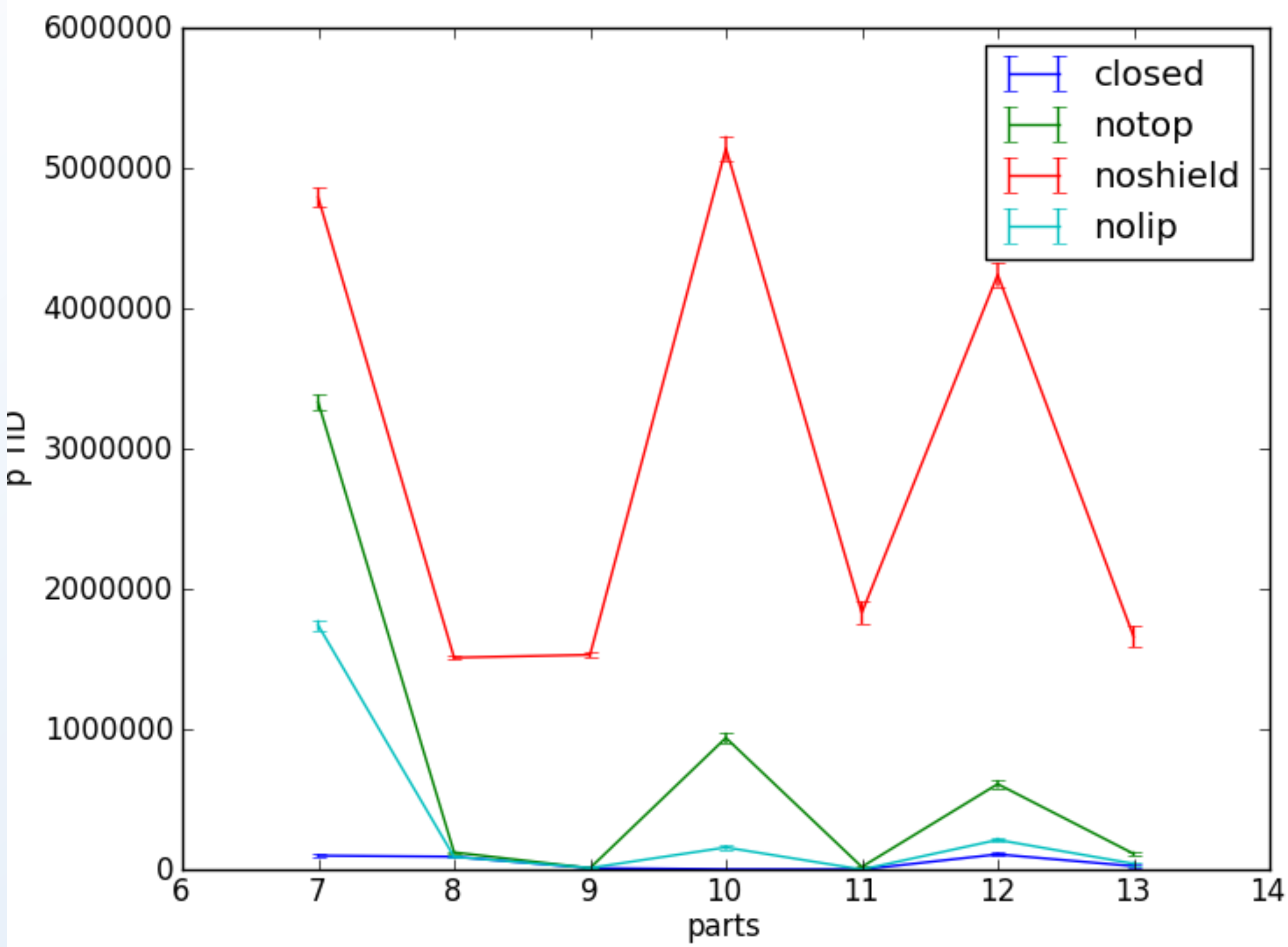
Lip vs no-lip configuration: no significant difference for p TID: ignore lip from now on



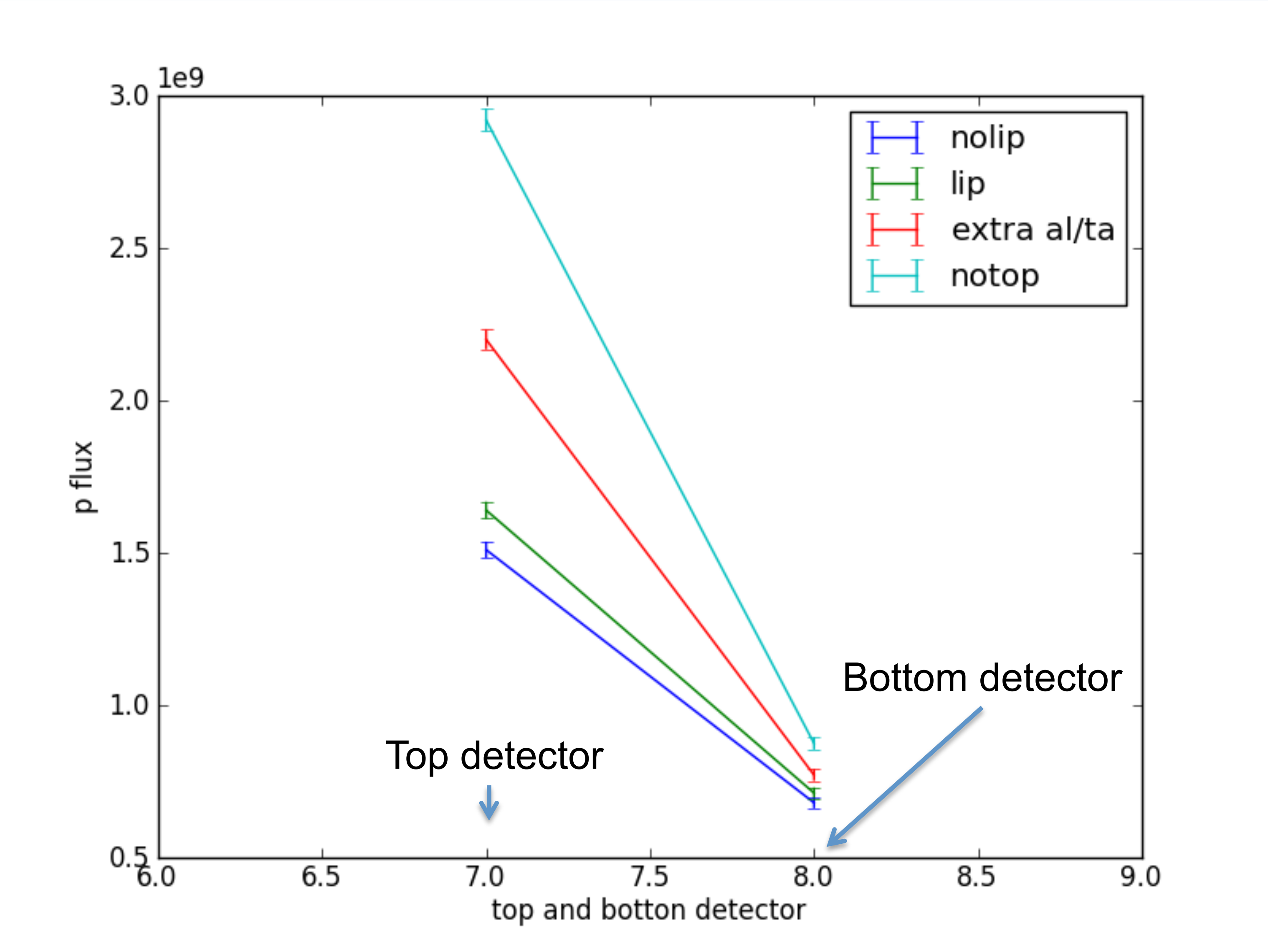
Shielding effects for e TID



Shielding effects for p TID



Proton fluxes (in number of p/(cm^2*sec) on the top and bottom of the detector (order of 1.5e+9)



Summary

- Electrons > 30 MeV and protons > 20 MeV not important for TIDs
- Electronics are better off on the bottom of the shield, TIDs on the order of 0.5-1E+5 rad
- Al/Ta shield 2mm each works

Notes

- SPENVIS rules!
- Apologize for ignorance of bare G4
- Could not run GRAS locally (empty bins: do we need AIDA tool?)
- Could not load our GDML generated from CAD to SPENVIS (too big), need to run GRAS or Geant4 locally
- Bug in GRAS (TID is correct only for MeV: need to be normalized to Gy or rad and mass)
- Runs and data management are error prone (manual copying of files and looking through csv data)
- Choosing source (angle and radius) seems to be dark art