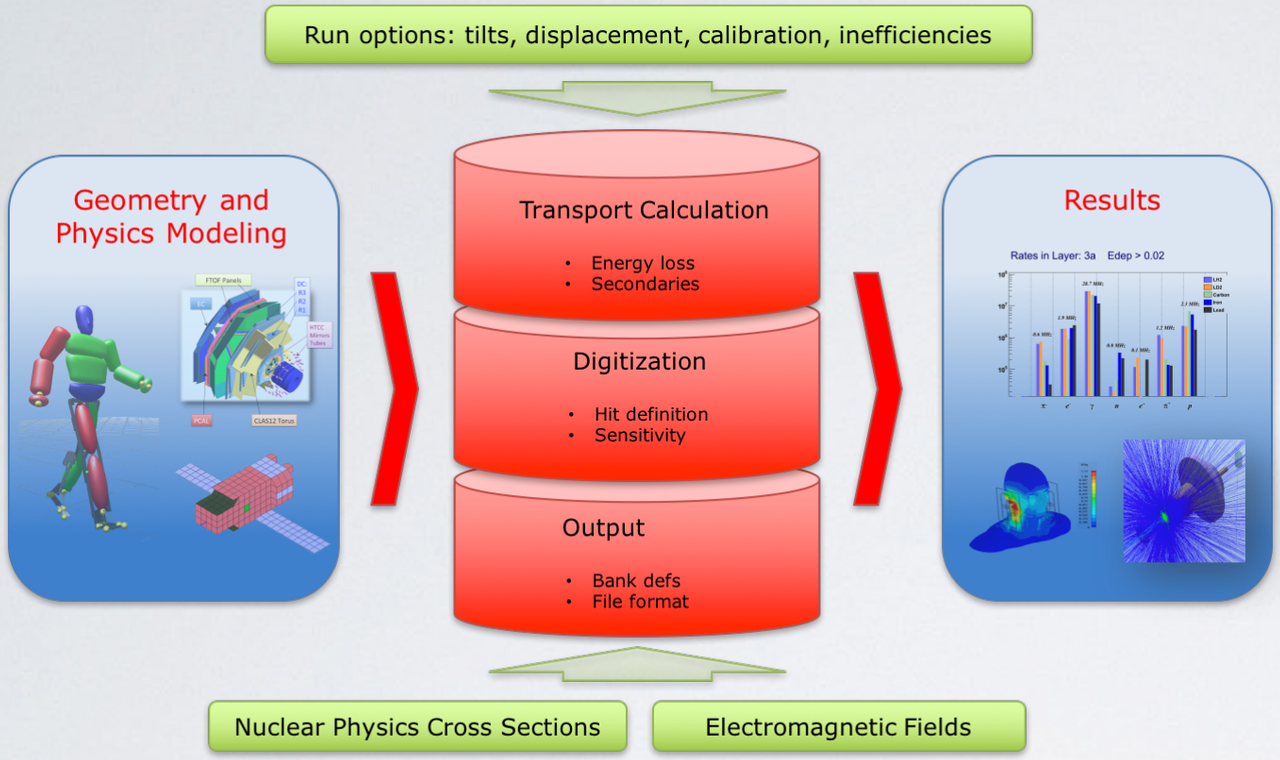
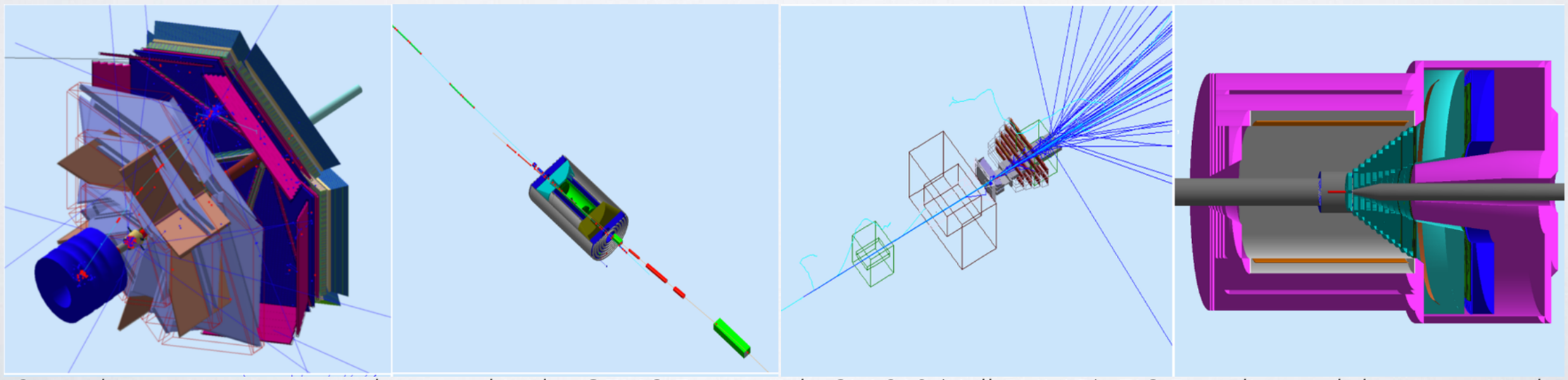
GEant4 **M**onte**C**arlo, and **CLAS12**



All parameters in databases

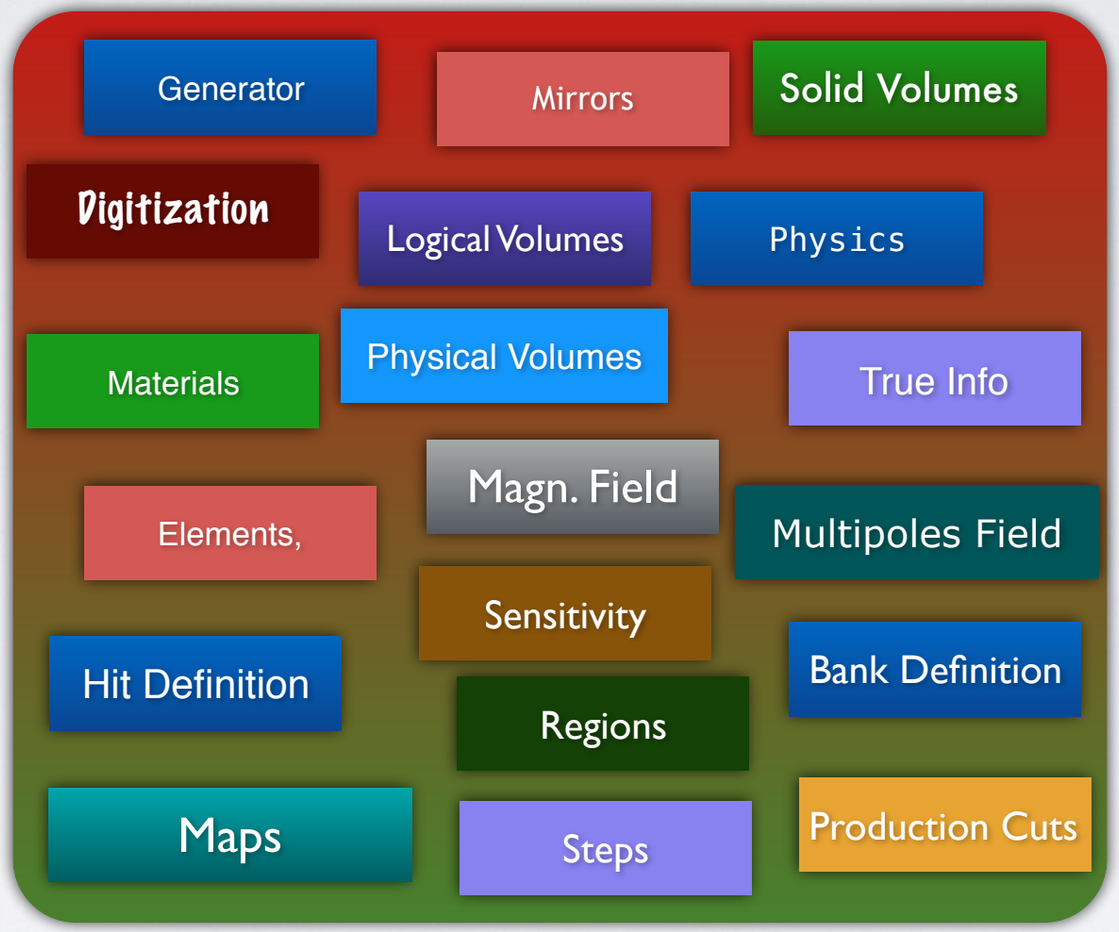
GEMC makes available all the powerful geant4 features w/o need of c++ or geant4 programming.

- application independent geometry description
- easy interface to build / run experiments
- cad/gdml imports, with "mix and match"
- "variation" mechanism for geometry / calibration / digitization"plugins" output format mechanism
- realistic hit definition, hit sharing, identifier generation
- background merging using experimental data



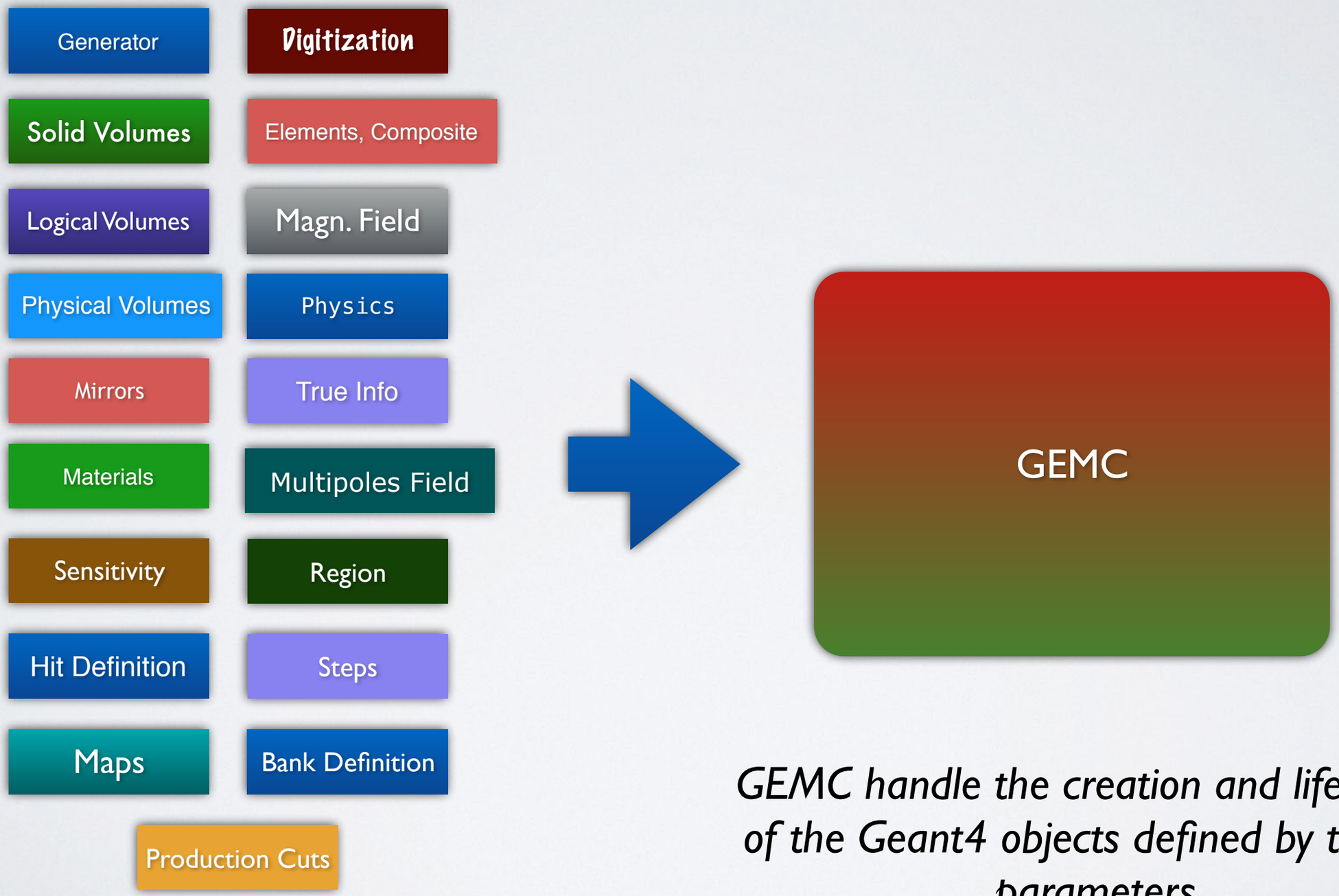
Several experiments are implemented in the GEMC Framework: CLAS12 (Hall-B JLAB), EIC Beamline and detectors, Heahy Photon Search, Solid (Hall-A JLAB)

GEANT4 ingredients



A real experiment setup can be quite complicated.
All these "ingredients" (Geant4 objects) interact with each other and with the user code to provide a final output

experiments defined by tables of parameters



GEMC handle the creation and life cycles of the Geant4 objects defined by the DB parameters

standardized api for all components

Generator
Digitization
Solid Volume
Elements, Composite
Logical Volume
Magn. Field
Physical Volume
Physics
Mirrors
True Info
Materials
Multipoles Field
Sensitivity
Region
Hit Definition
Steps
Maps
Bank Definition
Production Cuts

GEMC

parameters are in databases

GEMC handle the creation and life cycles of the Geant4 objects defined by the DB parameters

GEMC Example of detector definition

```
detector = MyDetector(name="paddle_01", mother="detectorMotherName")
detector.description  = "Si detector"

detector.type       = "Tube"
detector.dimensions = "0.*cm 1.*cm 5.*mm 0*deg 360*deg"

detector.material = "G4_Si"
detector.mfield   = "Torus"

detector.visible     = 1                # 1 visible, 0 to leave hidden
detector.style       = 1                # 1 displays as a solid, 0 as wireframe
detector.color       = “f4a988"

detector.sensitivity = "ctof"           # Use the “ctof” sensitivity: defines the output
detector.hit_type    = "ctof"           # Use the “ctof” digitization: identify plugin.
detector.identifiers = "paddle manual 1" # Identifies the detector being hit

print_det(configuration, detector)
```


Will store infos on file or DB

GEMC Example of detector definition

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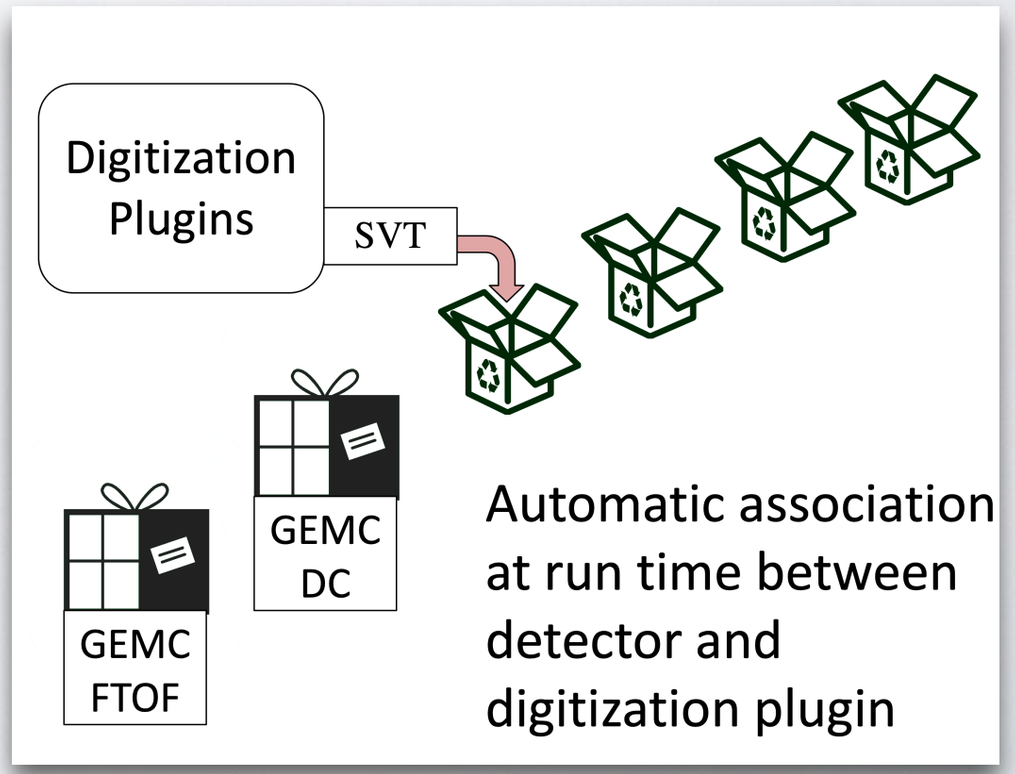
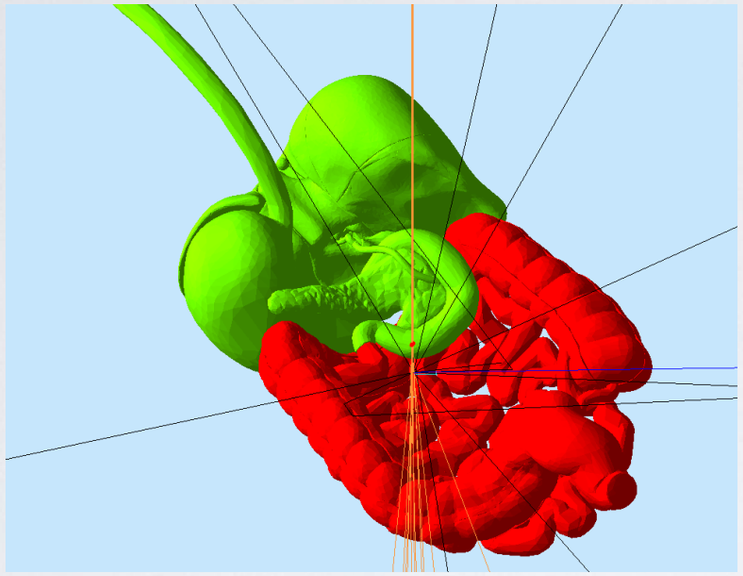
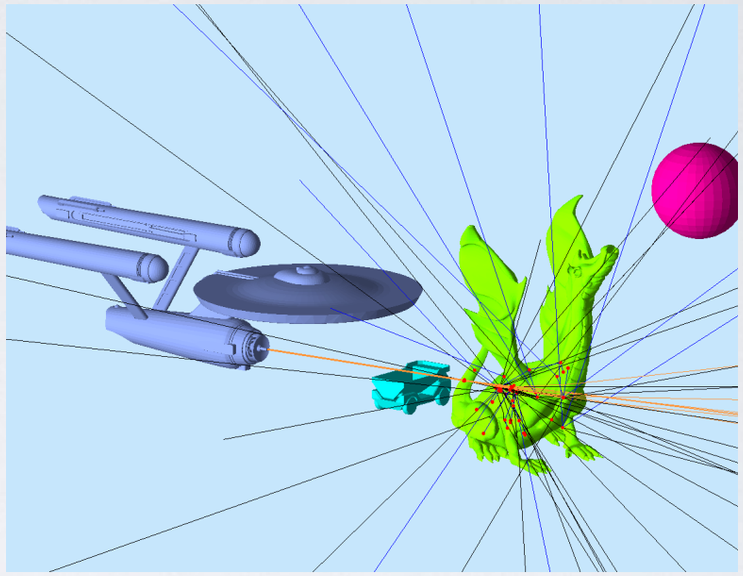
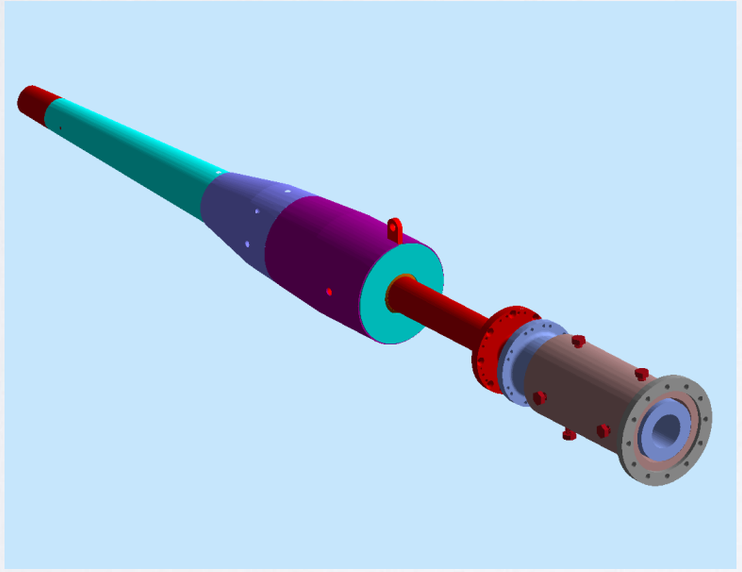


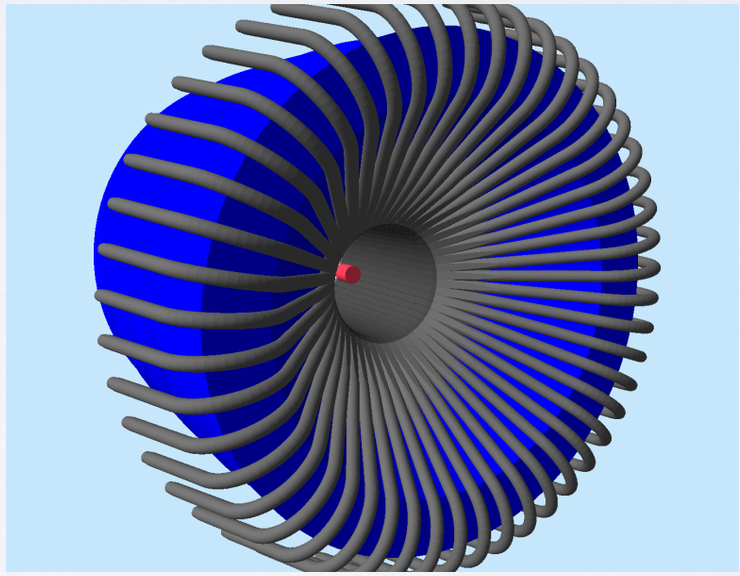
Geometry Factories "mix and match"





CLAS12 Beamline: CAD engineering drawings





CLAS12 CTOF and light guides: CAD engineering drawings

- CAD: objects can be made sensitive at run time.
- Attributes (material, mother volume, position, rotation, touchable ID) can be assigned at run time.
- Mix and match of several factories: **TEXT** (perl and python), **GDML**, **CAD**, **CLAS12 java geometry services**

Variations: life cycles of detectors and experiment

- Detectors alignments, placements/rotations
- Experiment configurations
- Field polarities, intensities, placements/rotations
- Design studies of several configurations
- Geometry description improvements
- Detector calibration changes with time

1.5 years of CLAS12 experiments, we have already 5 experiments configurations, a combination of:

- target (LH2 or LD2)
- central detector alignment
- a forward tracker present / absent
- a Cherenkov detector gas change, sector changes
- torus field polarity switches

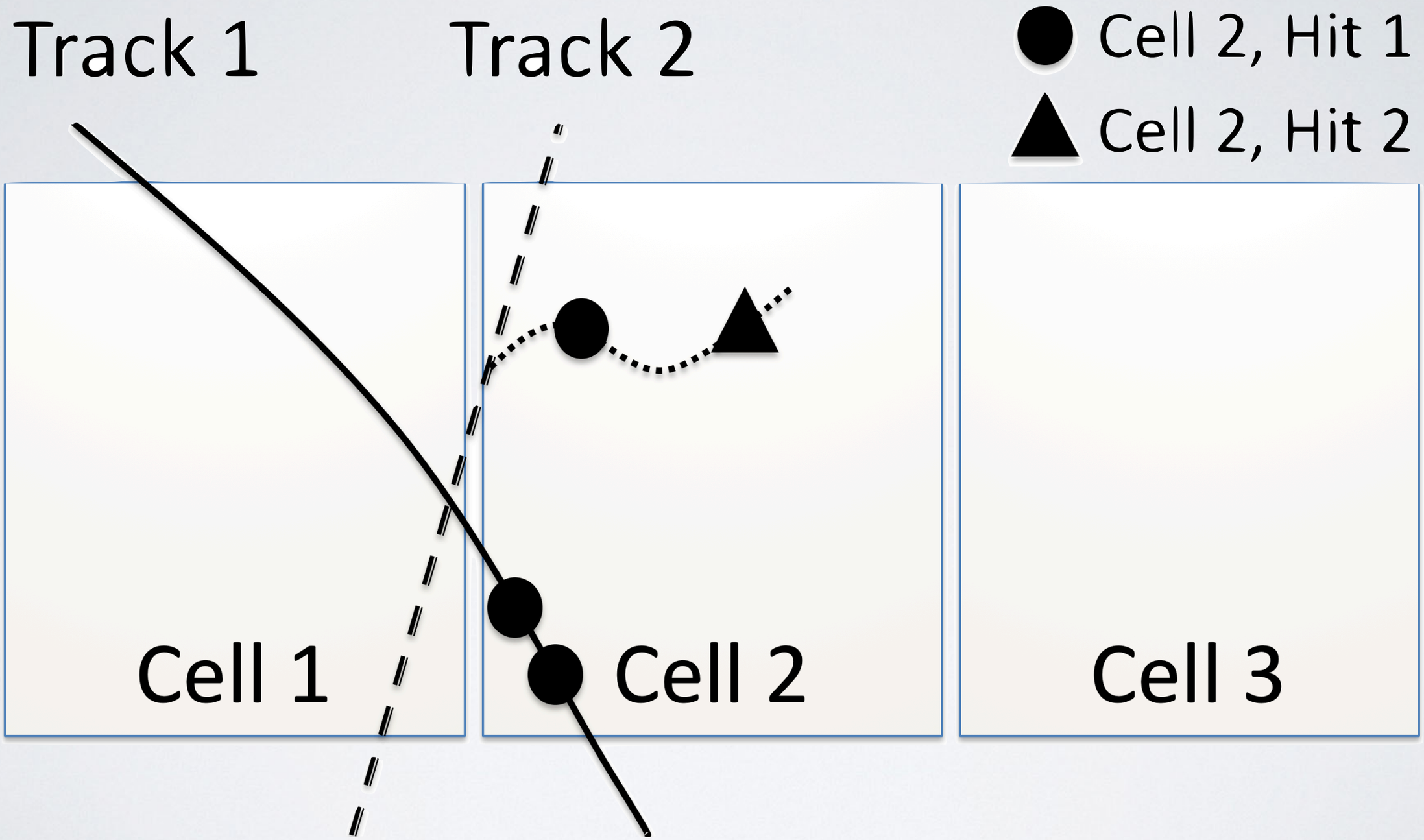
Variations: life cycles of detectors and experiment

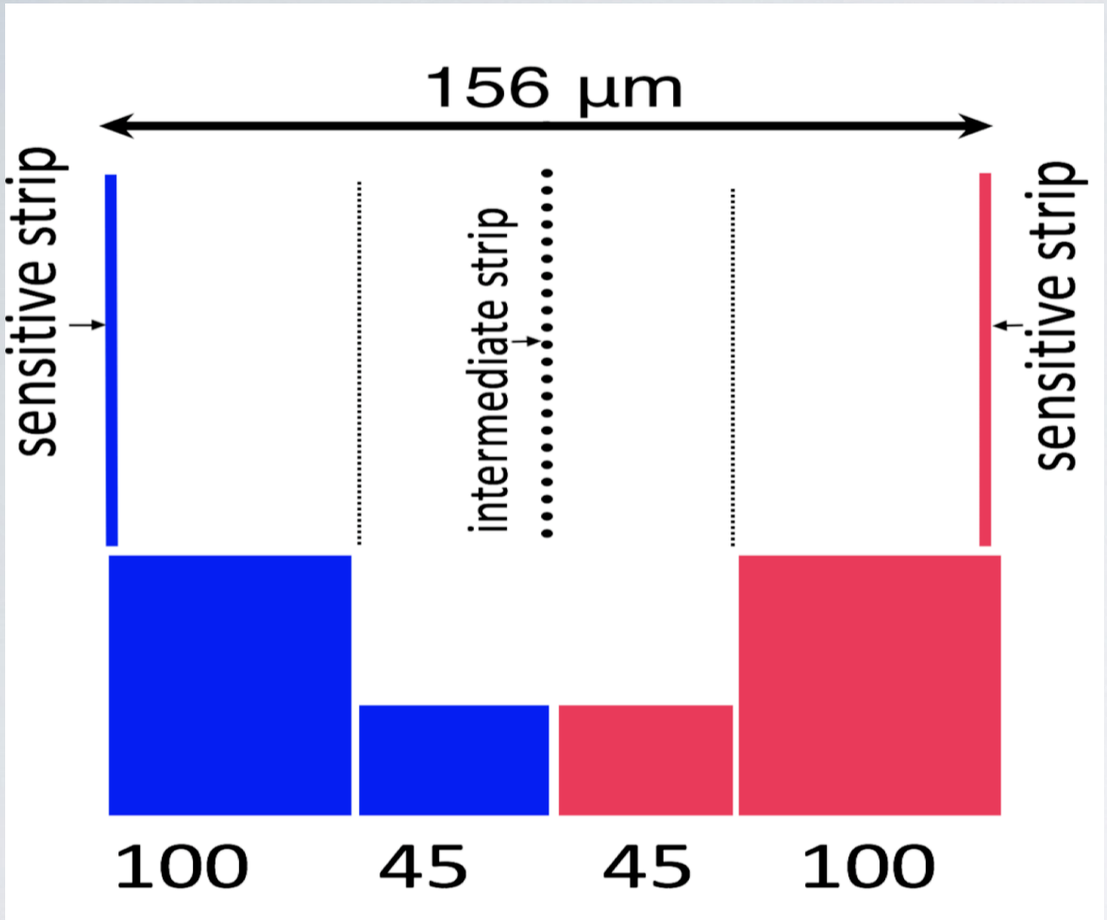
- Detectors alignments, placements/rotations
- Experiment configurations
- Field polarities, intensities, placements/rotations
- Design studies of several configurations
- Geometry description improvements
- Detector calibration changes with time

```
<!-- target. Notice variation give the target type. Can be: lH2, lD2, ND3 -->
<detector name="experiments/clas12/targets/cad/"   factory="CAD"/>
<detector name="experiments/clas12/targets/target" factory="TEXT" variation="lH2"/>

<!-- central detectors  -->
<detector name="experiments/clas12/bst/bst"                factory="TEXT" variation="default"/>
<detector name="experiments/clas12/micromegas/micromegas" factory="TEXT" variation="michel"/>

<!--ctof, cad  -->
<detector name="experiments/clas12/ctof/ctof"                       factory="TEXT" variation="rga_spring2018"/>
<detector name="experiments/clas12/ctof/javacad_rga_spring2018/"    factory="CAD"/>
<detector name="experiments/clas12/cnd/cnd"                         factory="TEXT" variation="original"/>

<!--high threshold cherenkov -->
<detector name="experiments/clas12/htcc/htcc"      factory="TEXT" variation="original"/>
```

actual CLAS12 "rga-spring2018" steering card ("gcard") at run time

Hit definition: Time Window



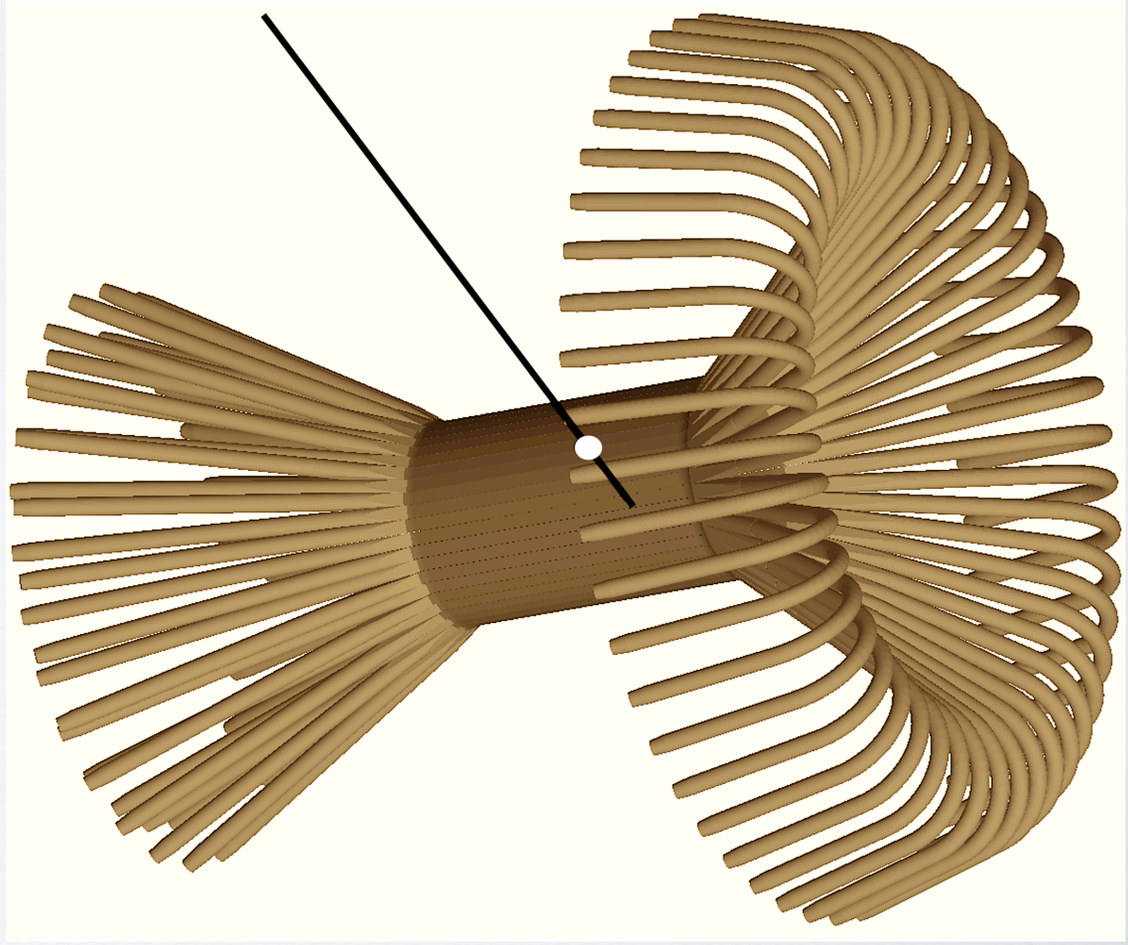


Hit Sharing:

example: strips in Silicon Tracker share energy if energy deposited is near border

Hit by **Process ID**:

example: energy deposited in scintillator is collected at both ends



Output: TEXT, EVIO, (hipo), (root)

Tag purposes

```
> BST  100, 0

  > True Step by Step infos   (101, 0)
    - Edep                    (101, 1)
    - Pid                     (101, 2)
    - positions               (101, 3)

  > Dgtz Step by Step infos   (102, 0)
    - ADCL                    (102, 1)
    - ADCR                    (102, 2)

  > True Integrated infos     (103, 0)
    - Edep                    (103, 1)
    - Pid                     (103, 2)
    - positions               (103, 3)

  > Dgtz Integrated infos     (104, 0)
    - ADCL                    (104, 1)
    - ADCR                    (104, 2)

  > Voltage as a function of time (105, 0)
    - Identifier                    (105, 1)
    - Time                          (105, 2)
    - Voltage                       (105, 3)

> Trigger Bank                (106, 0)
    - Identifier              (106, 1)
    - Time                    (106, 2)
    - Voltage                 (106, 3)
```

sector
SuperLayer
Layer
wire
LR
Doca
SDoca
time
Stime

Variable	Description
pid	ID of the FP
mpid	ID of the mother of the FP
tid	Track ID of the FP
mtid	Track ID of the mother of the FP
otid	Track ID of the ancestor of the FP
trackE	Total energy of the FP
totEdep	Total energy deposited (in MeV)
avg_x	Average x position (in mm)
avg_y	Average y position
avg_z	Average z position
avg_lx	Average local x position
avg_ly	Average local y position
avg_lz	Average local z position
px	x of momentum of the FP (in MeV)
py	y of momentum of the FP
pz	z of momentum of the FP
vx	x of the FP's origin (in mm)
vy	y of the FP's origin
vz	z of the FP's origin
mvx	x of the FP mother's origin
mvy	y of the FP mother's origin
mvz	z of the FP mother's origin
avg_t	Average time
nsteps	Number of Geant4 steps
procID	Process that created the FP.
hitn	Hit ID

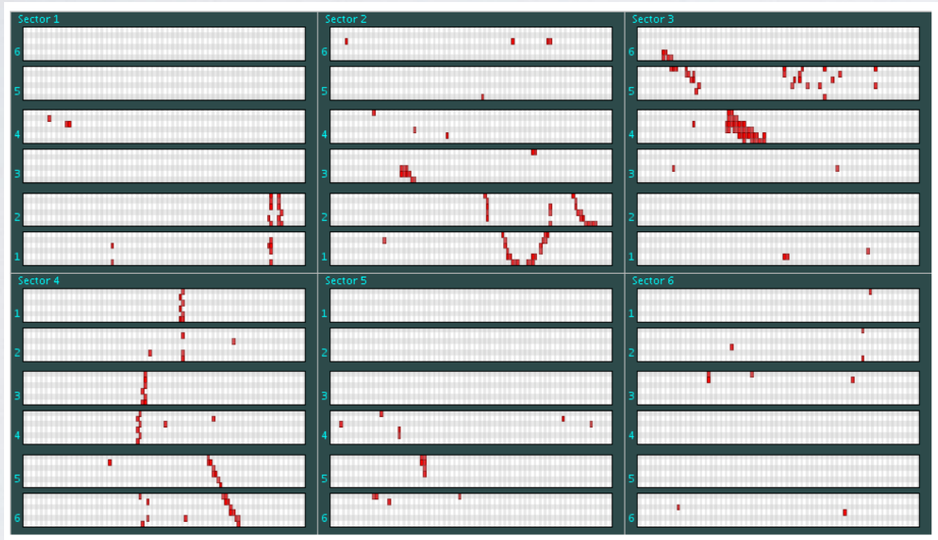
Background Merging using experimental data

Example: random trigger is collected, pre-scaled by factor of 100 in CLAS12

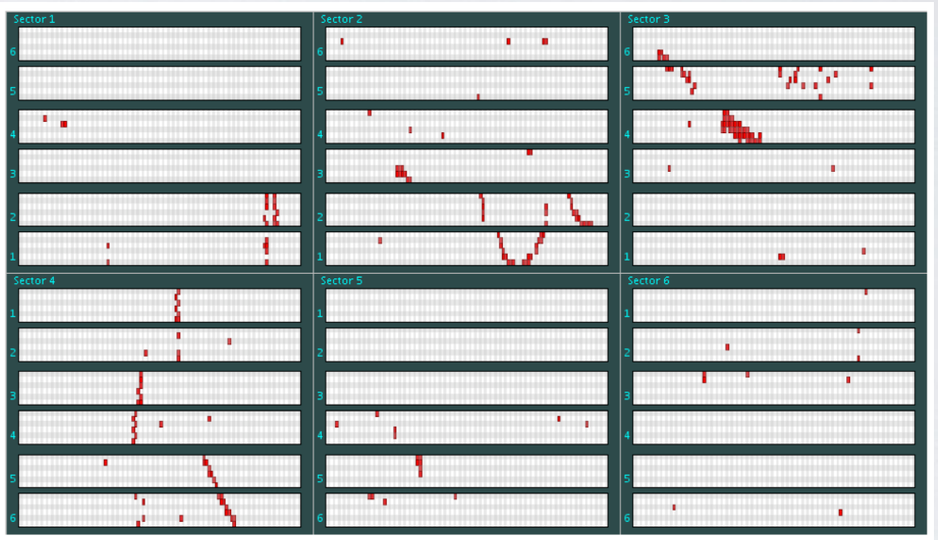
Info saved in generic text file, injected in simulation with simulated events

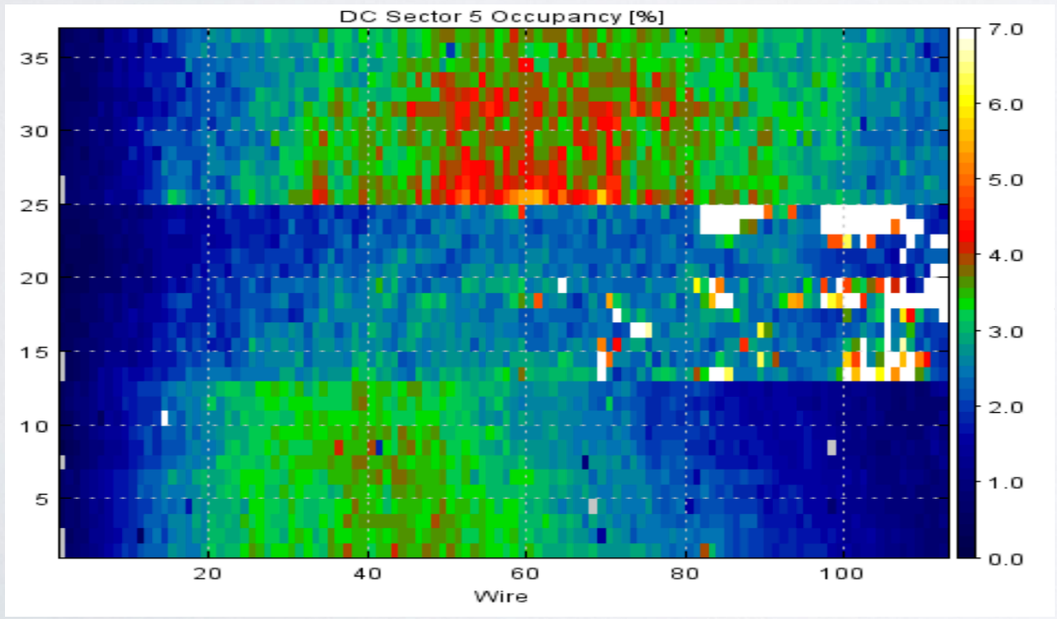
(kind of cool: can also collect multiple events to double, triple luminosity)

CLAS12 Data, 1 event

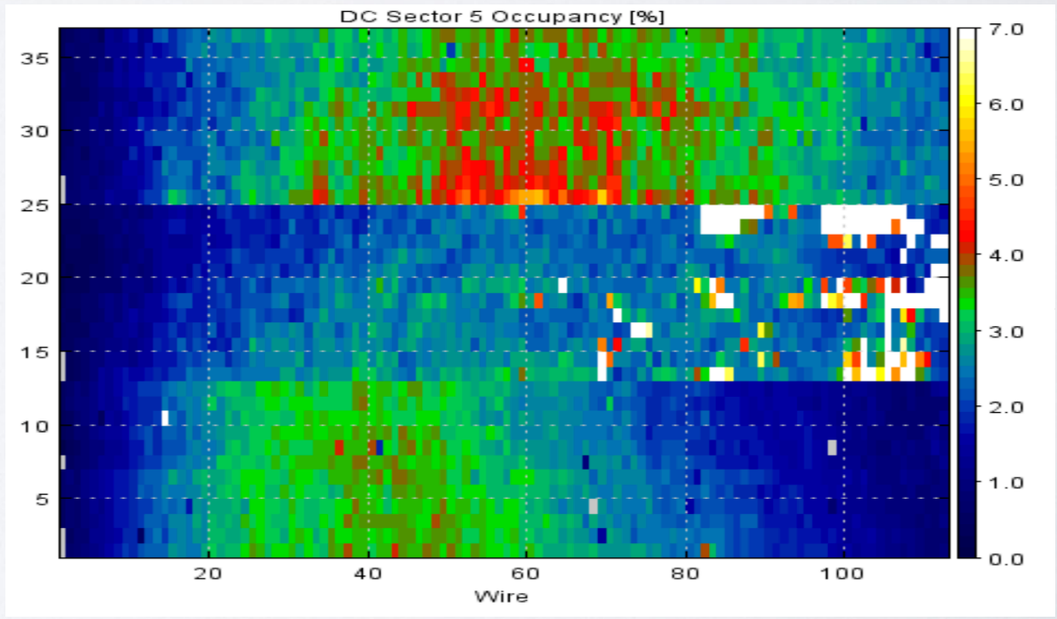


CLAS12 GEMC, 1 event



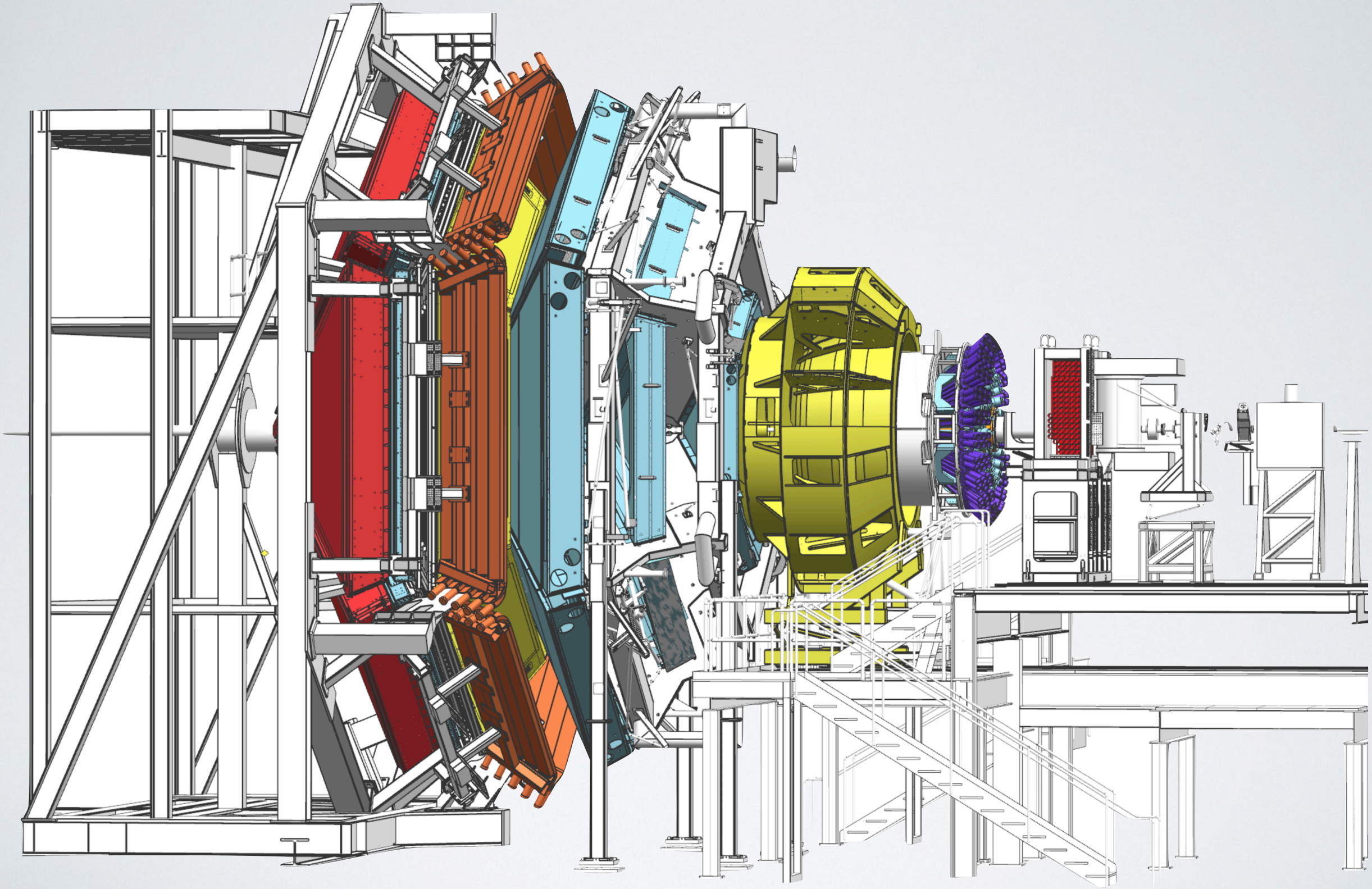


CLAS12 Data, 1000 events

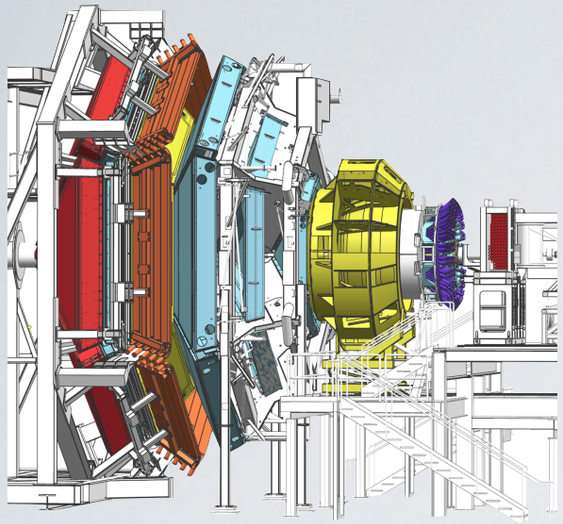


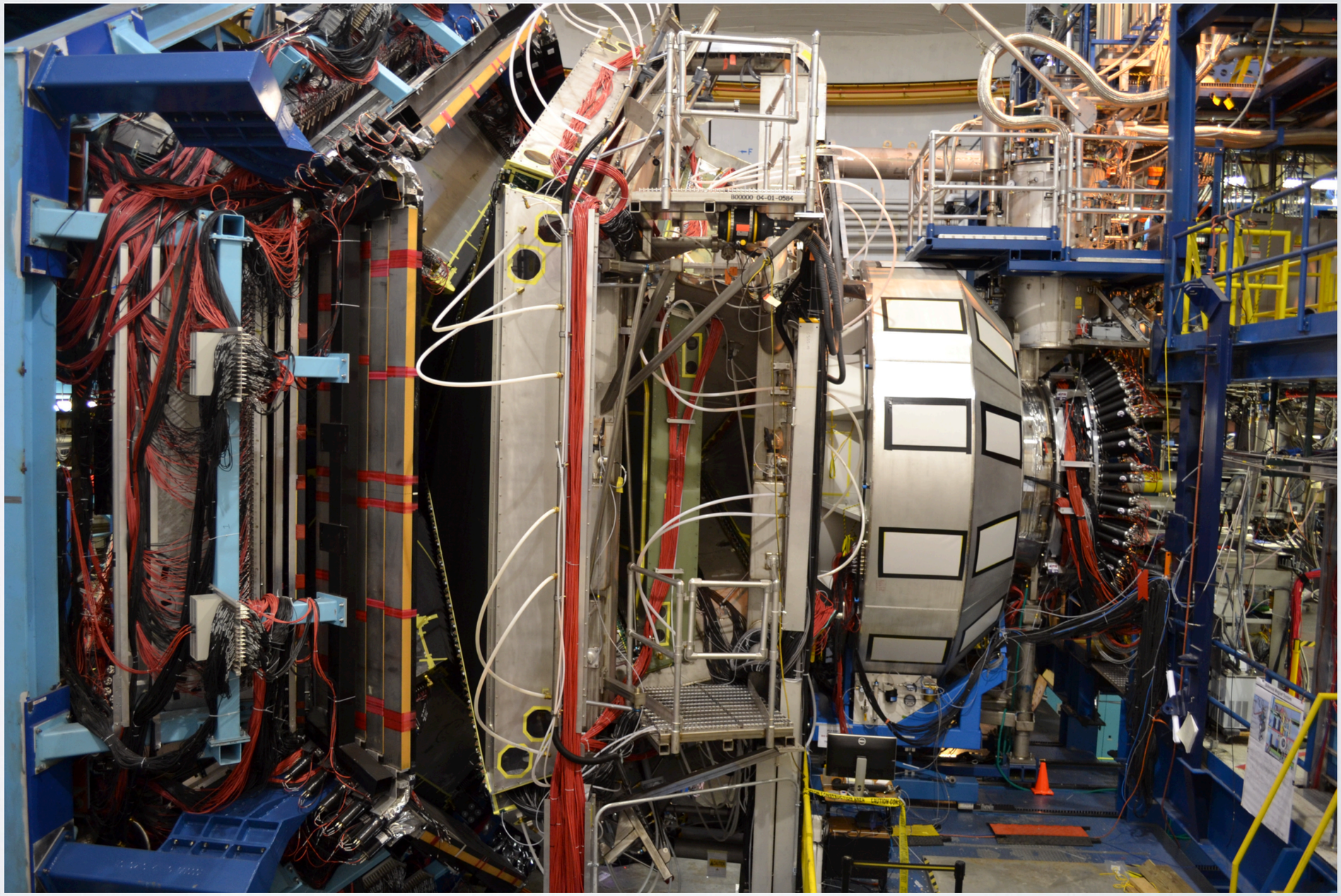
CLAS12 GEMC, 1000 events

CLAS12 Simulations



CLAS12 Simulations

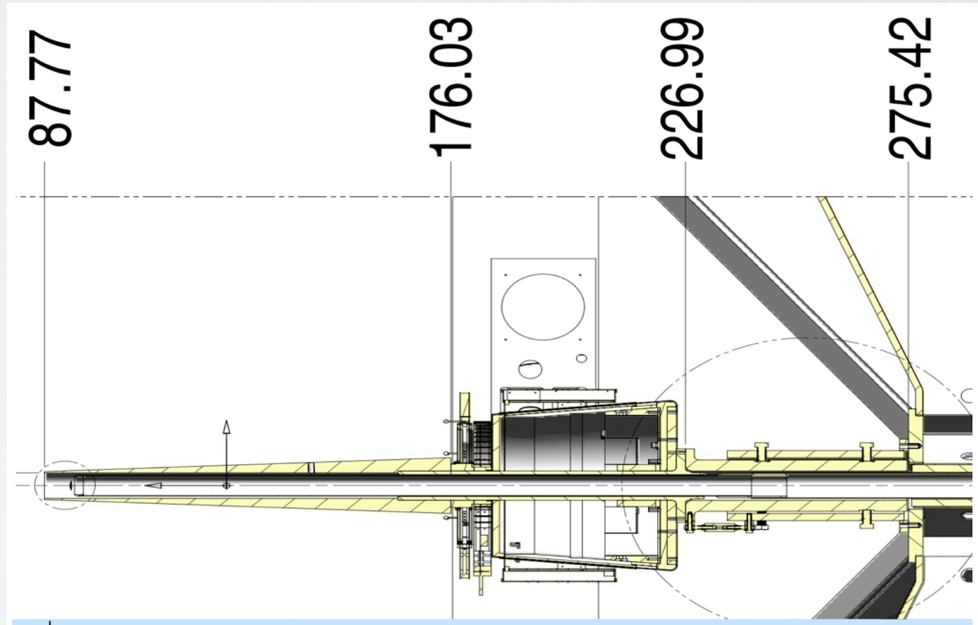




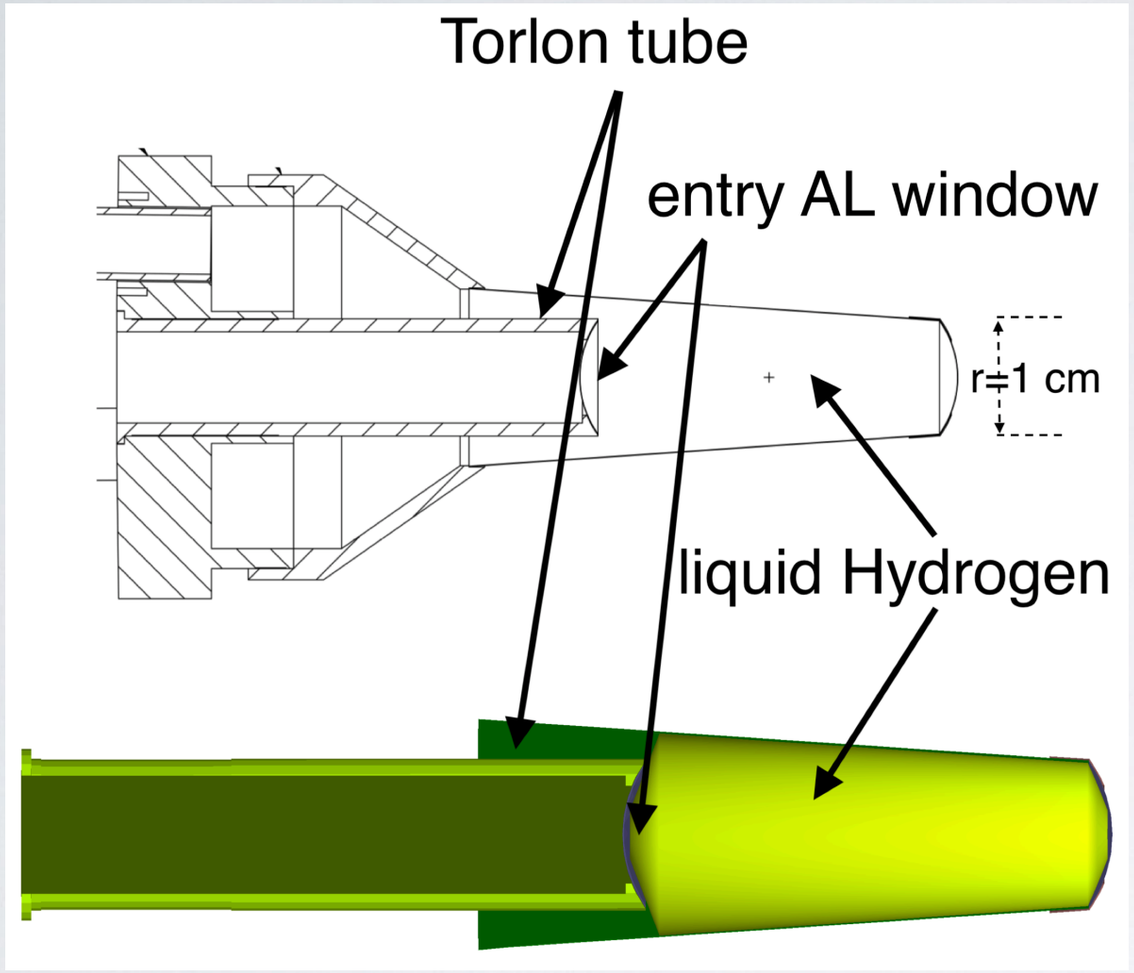
CLAS12 Simulations

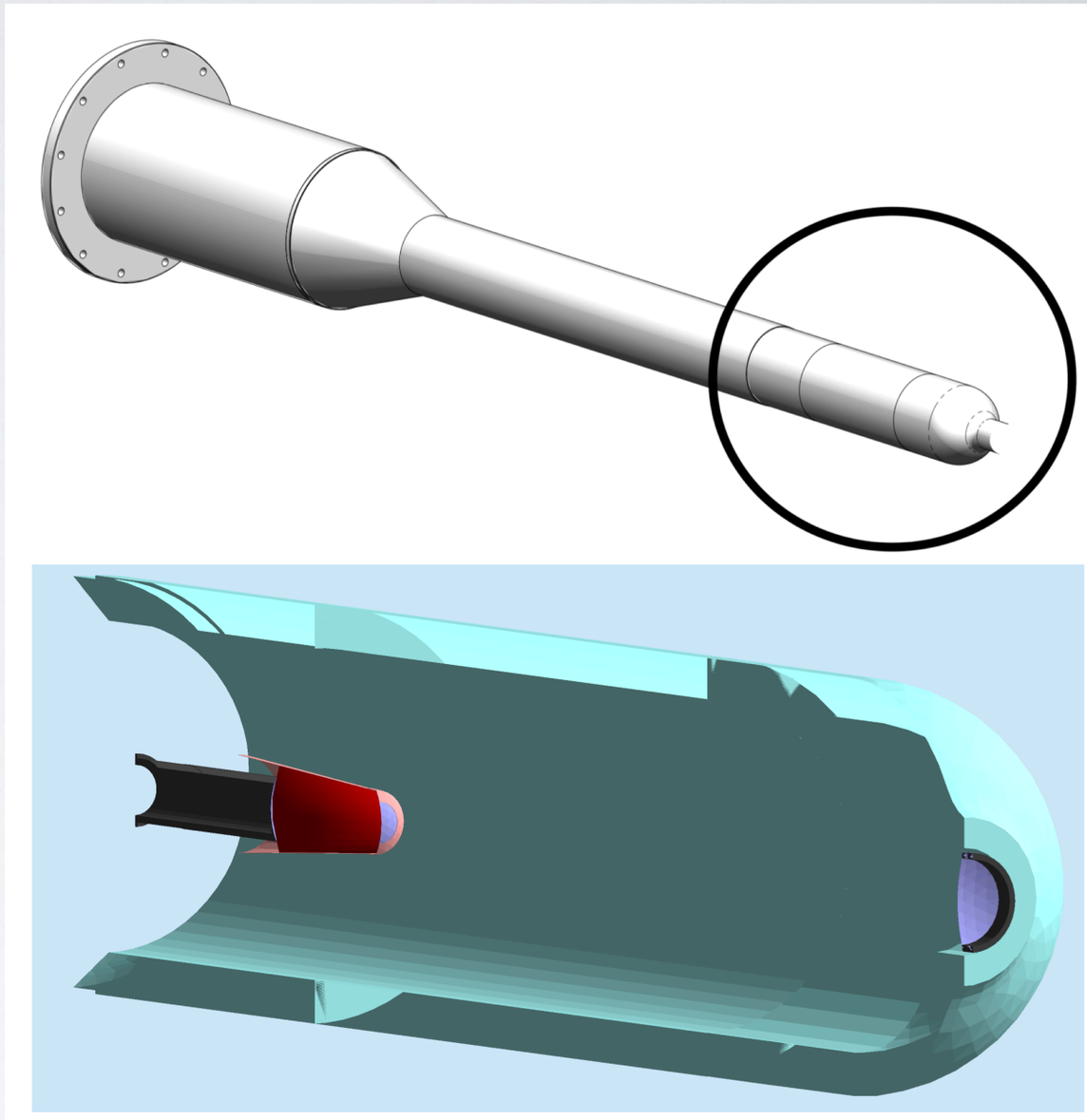
- GEMC native API (Geant4 traditional Volume defs)
- java algorithms used by both simulation and the CLAS12 Event Reconstruction Software, or “java geometry services”
- CLAS12 Engineering model: CAD (converted to STL)

An example of comparing volumes in the GEMC simulation to the engineering drawings, in this case to validate the cone shield position.



CLAS12 Targets

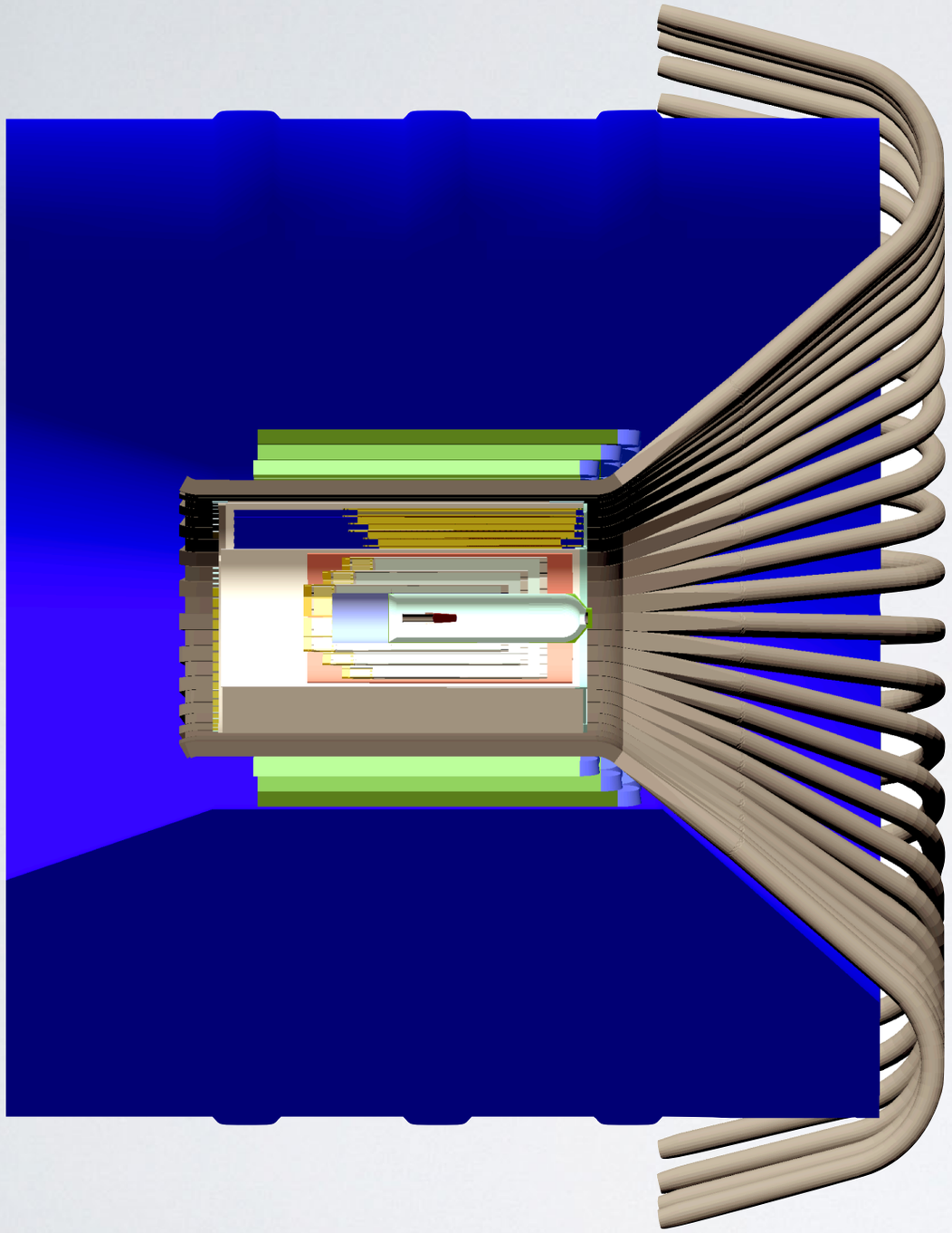


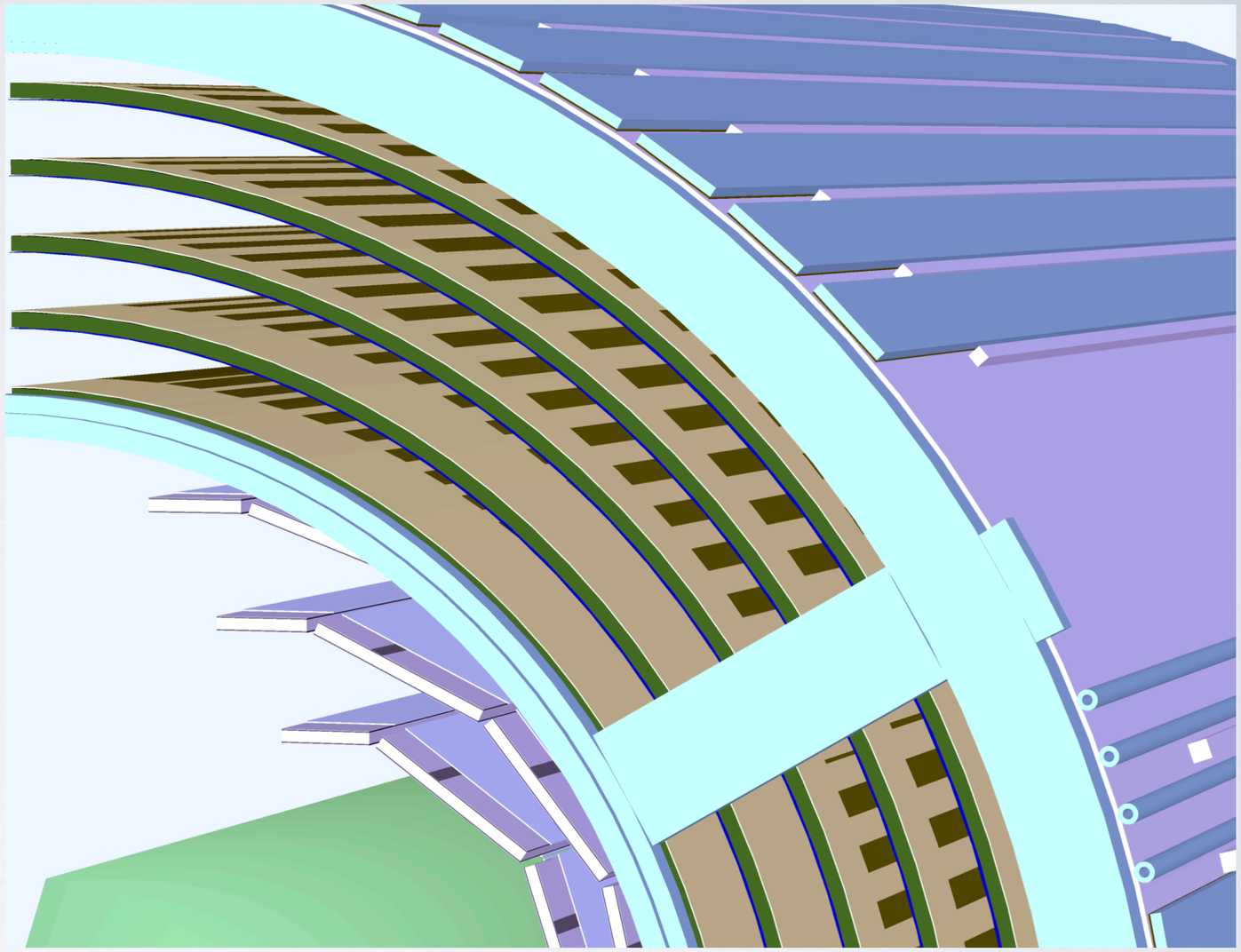


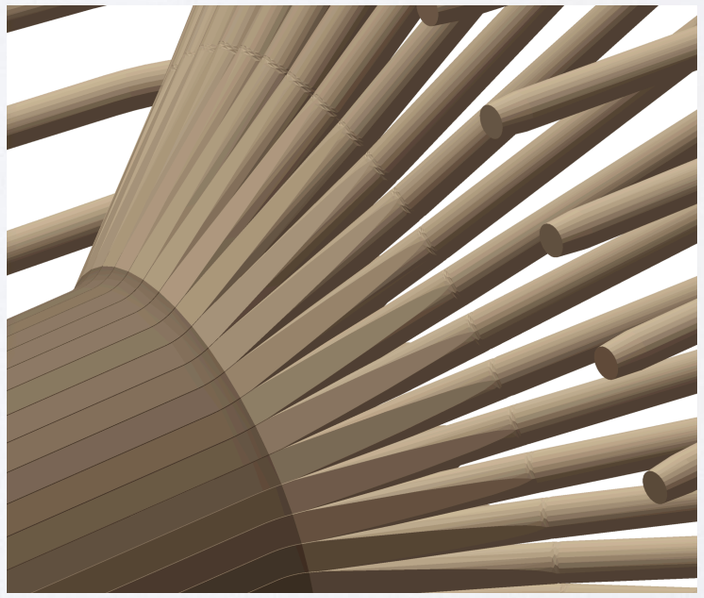
Variations:

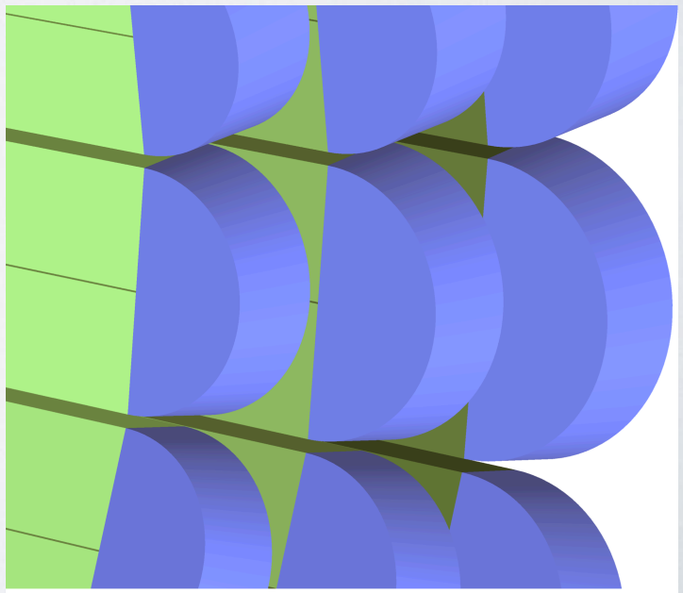
"lH2", "lD2", "ND3", "PolTarg",
"12C", "63Cu", "118Sn", "208Pb", "27Al"

CLAS12 Central Detector

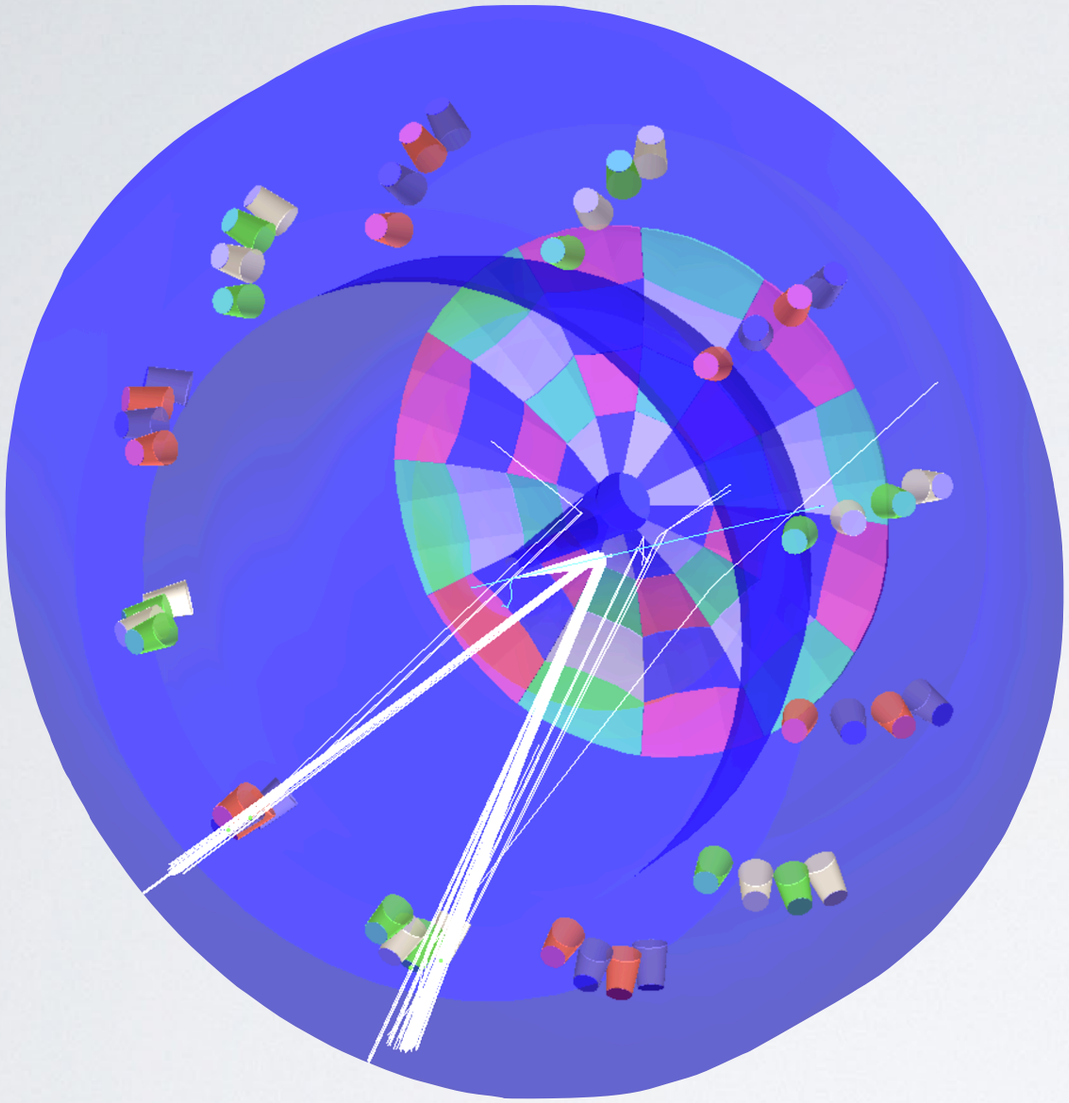


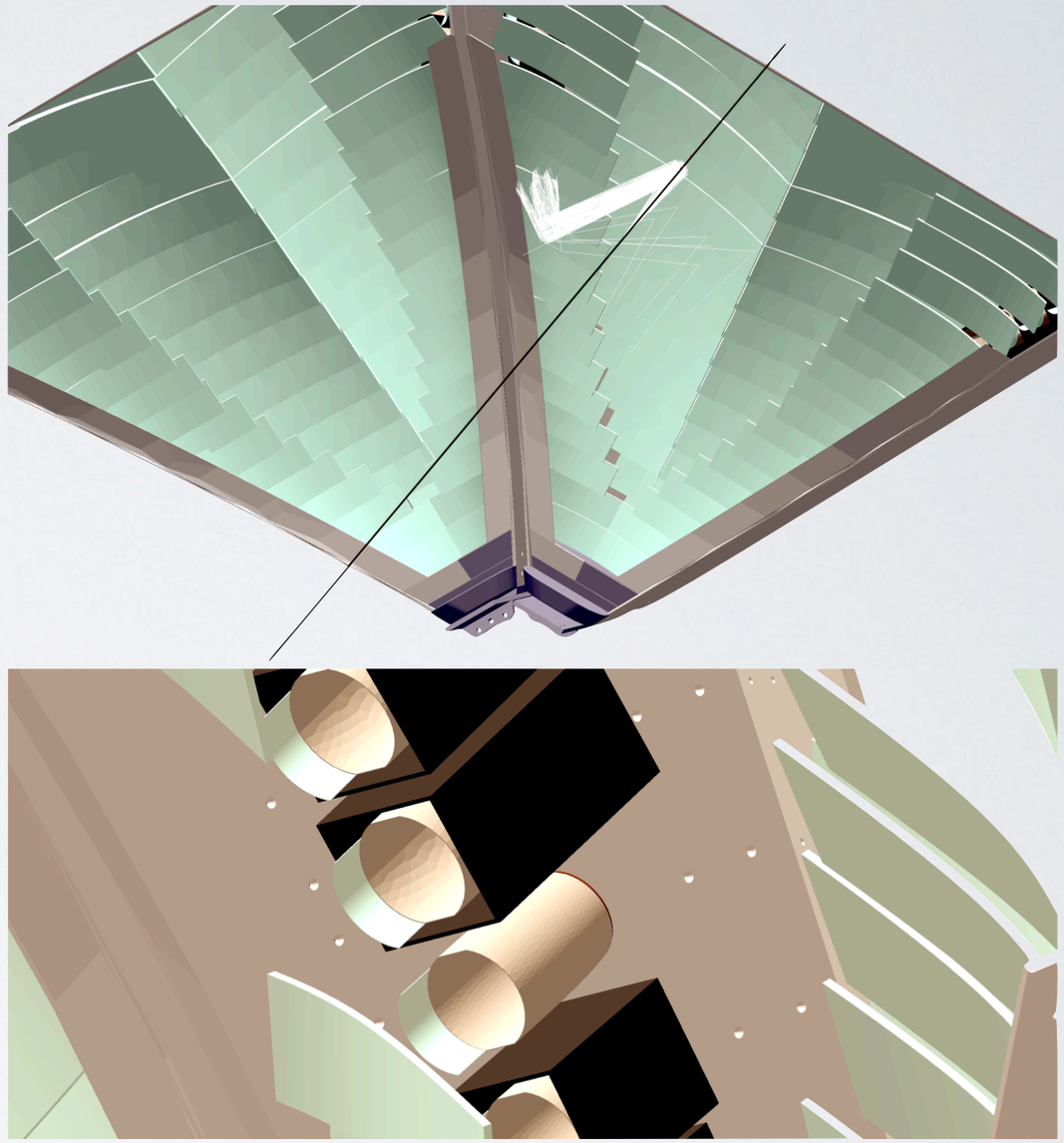






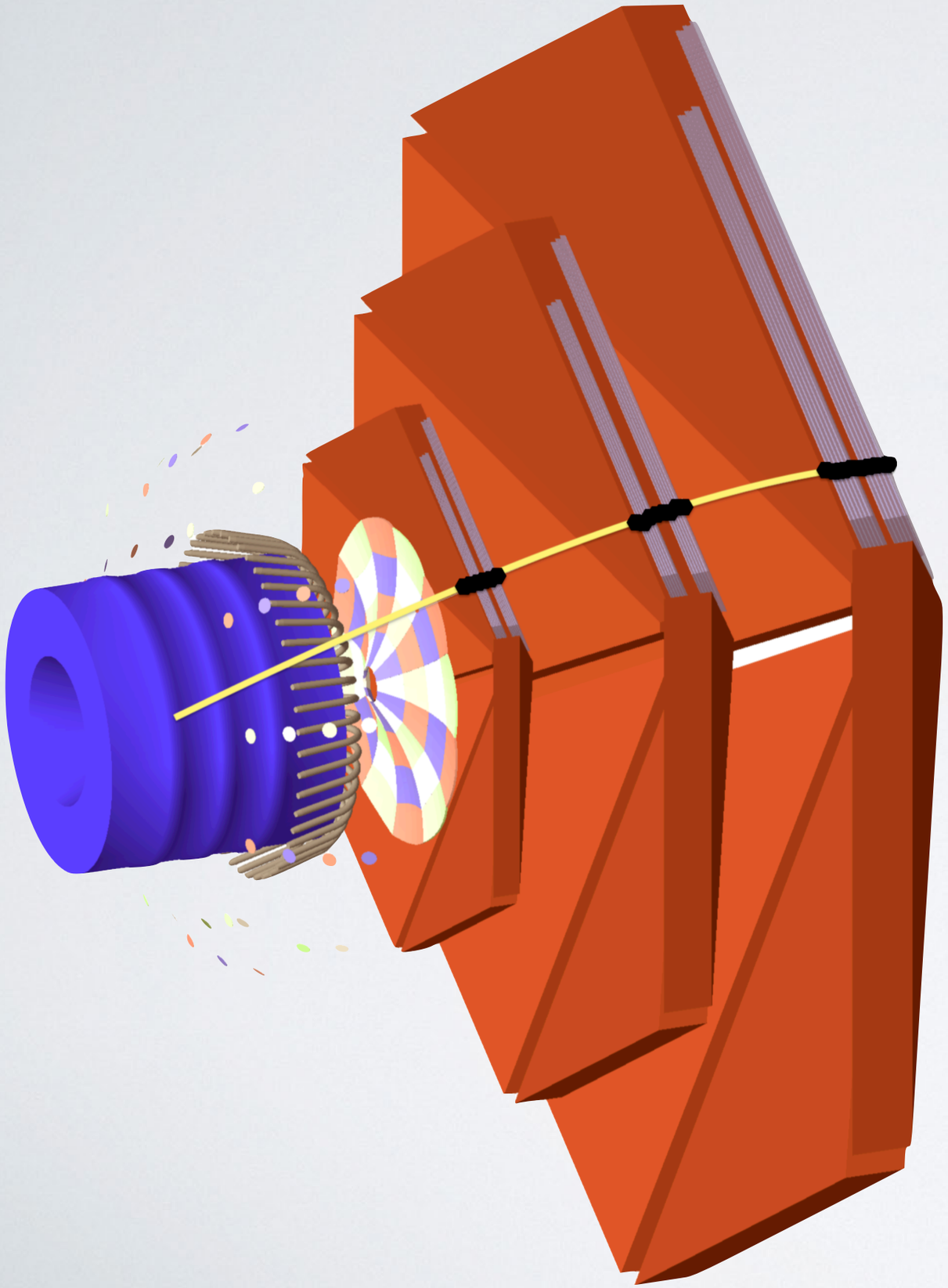
CLAS12 Cherenkovs

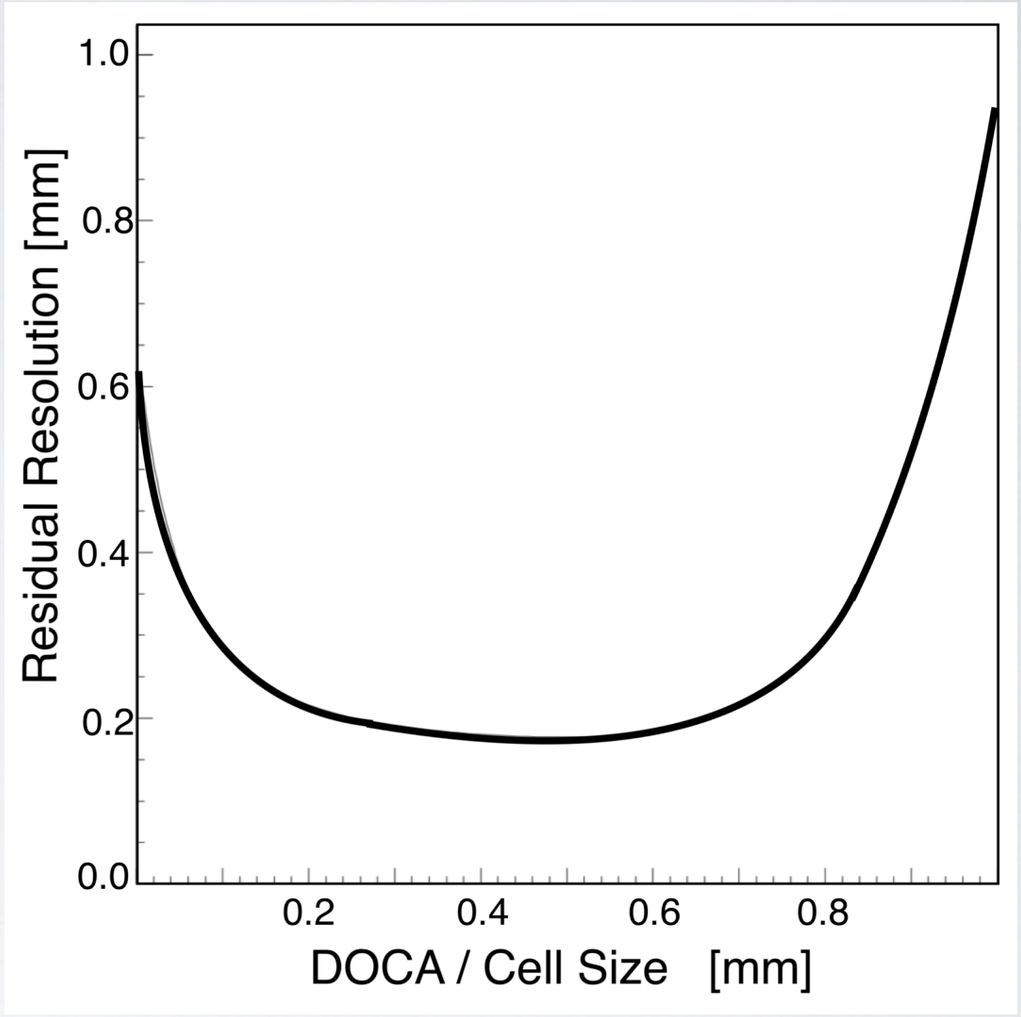




Refraction index (as function of wavelength). Quantum efficiency of PMTs. Mirror reflectivity. Gas transparencies.

CLAS12 Drift Chambers

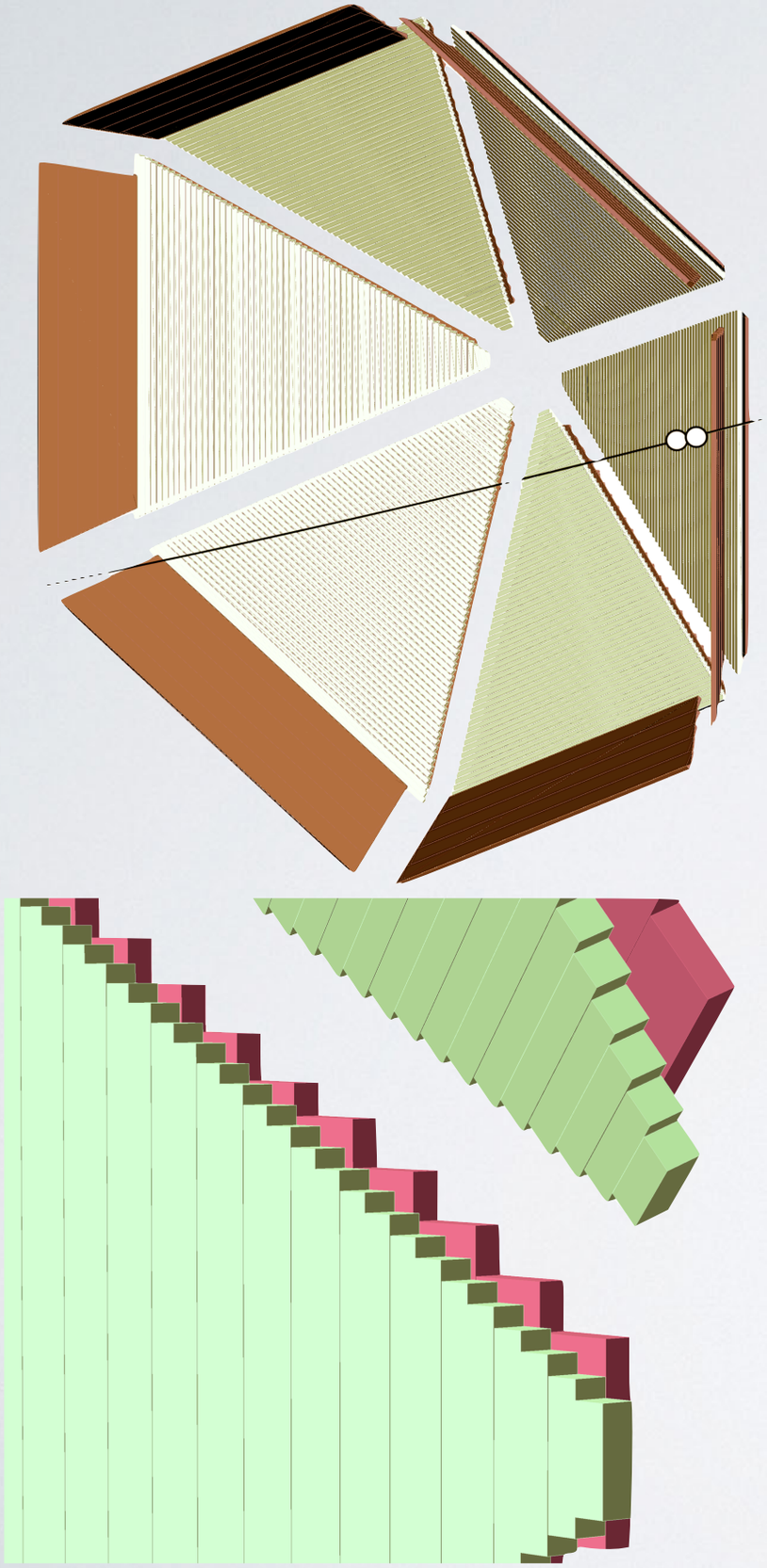


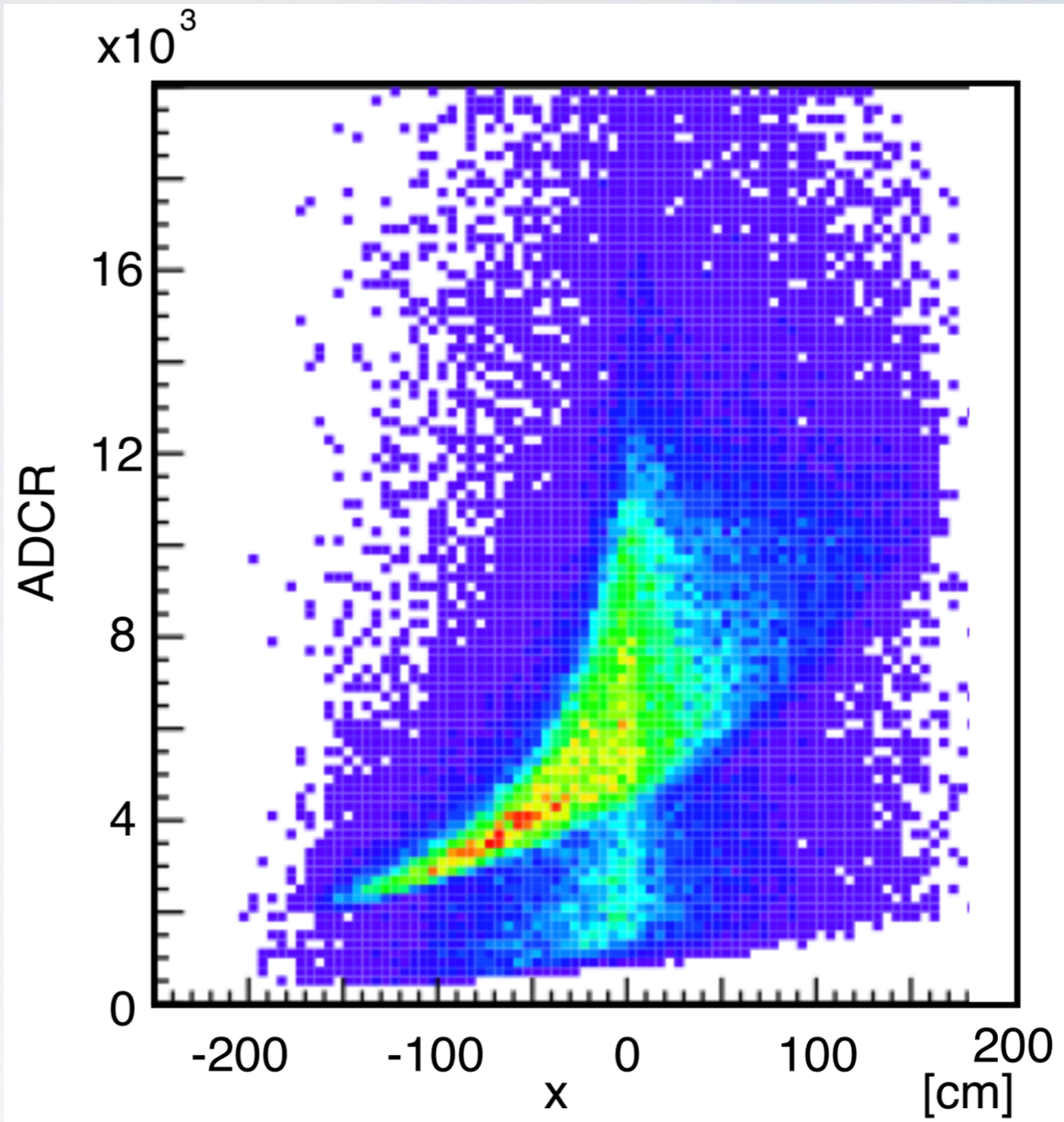


Calibration pars from Data:

- time to distance function
  intrinsic time walk correction
- wire efficiency
- wire resolution

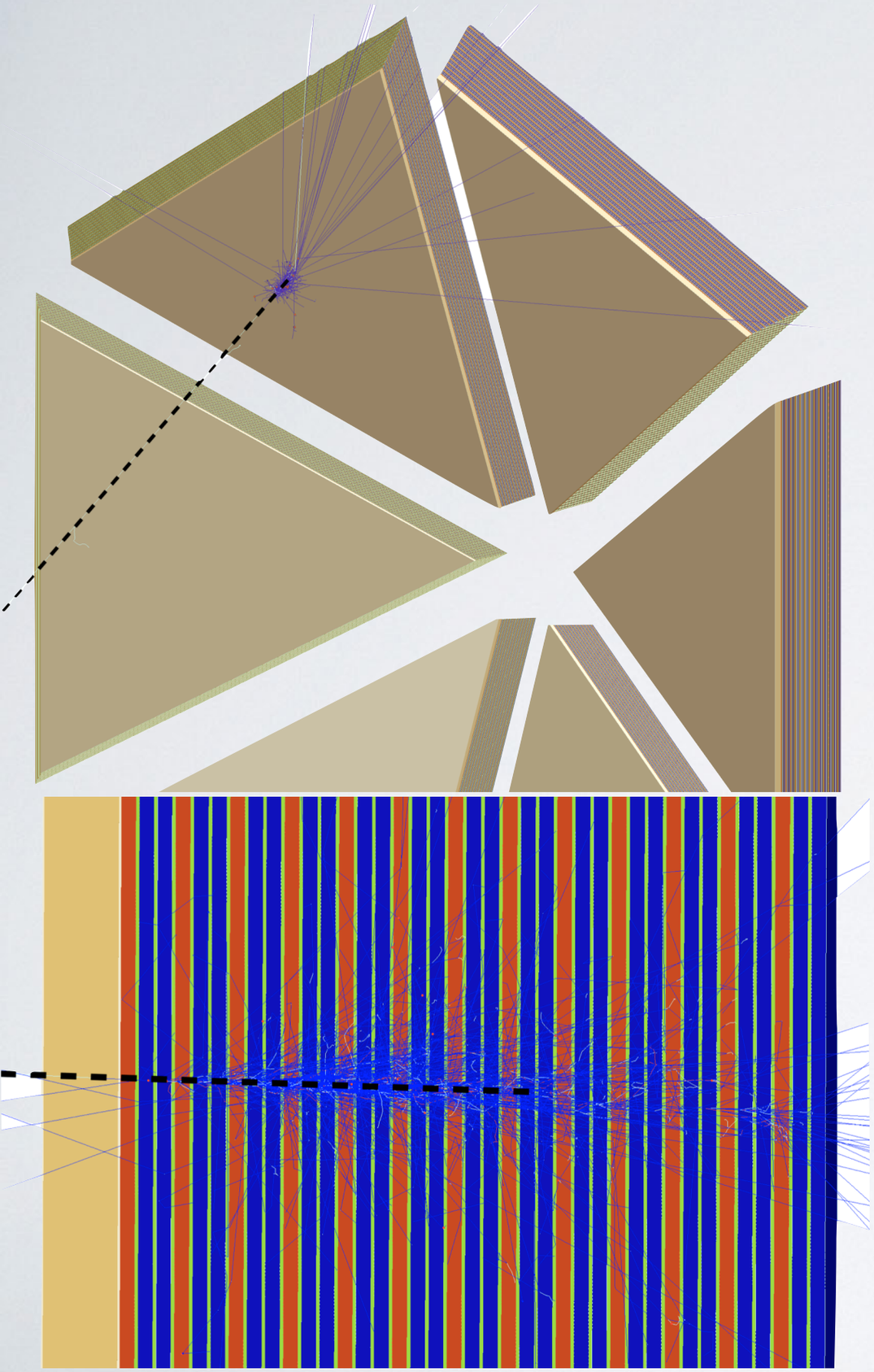
CLAS12 FTOF





The ADC of the FTOF right paddle PMTs as a function of the relative position of the hit in the paddle. The effects of attenuation length and smearing using realistic constants from the CCDB database make the FTOF simulation response very similar to the real data.

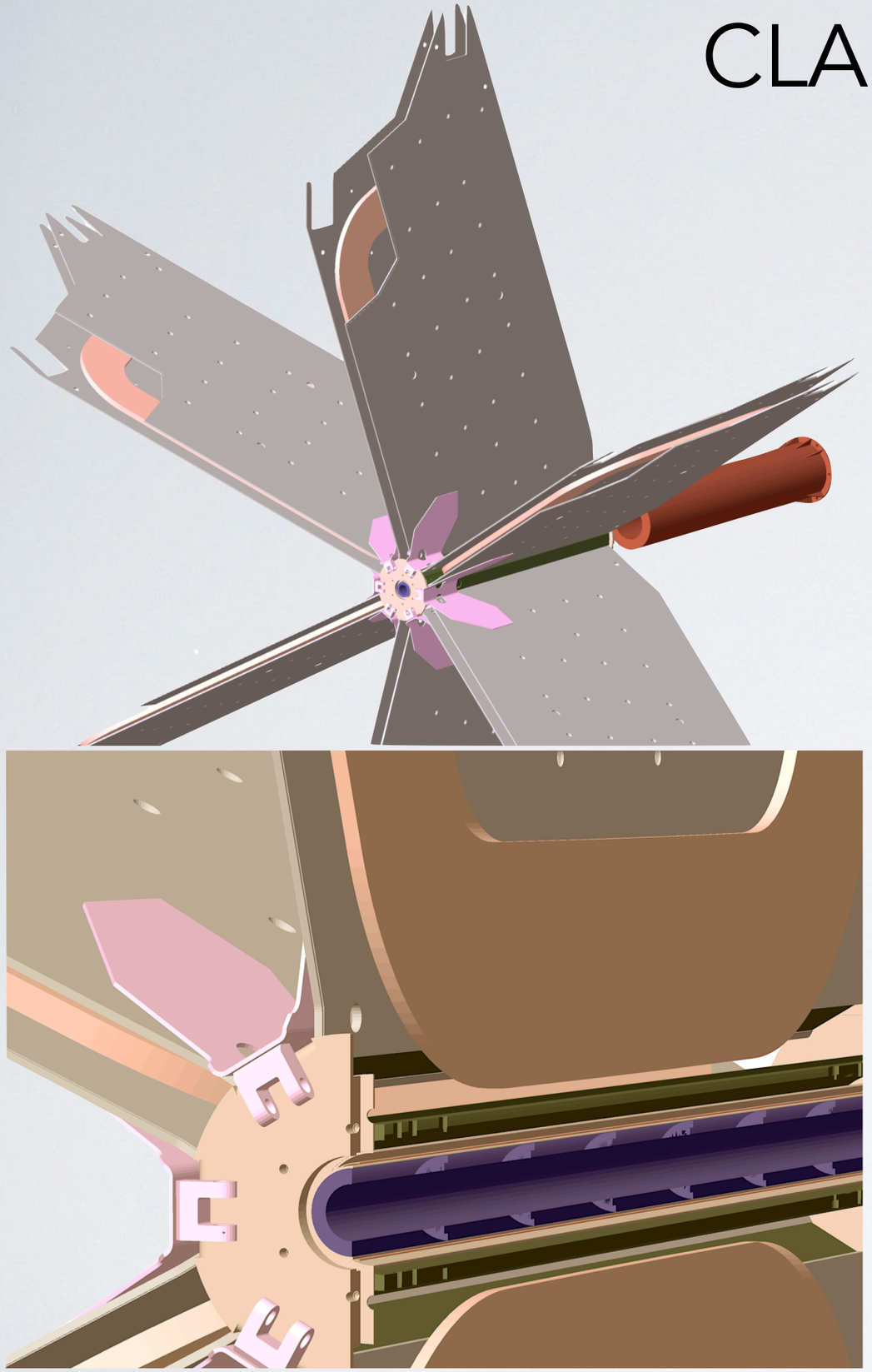
CLAS12 Calorimeters



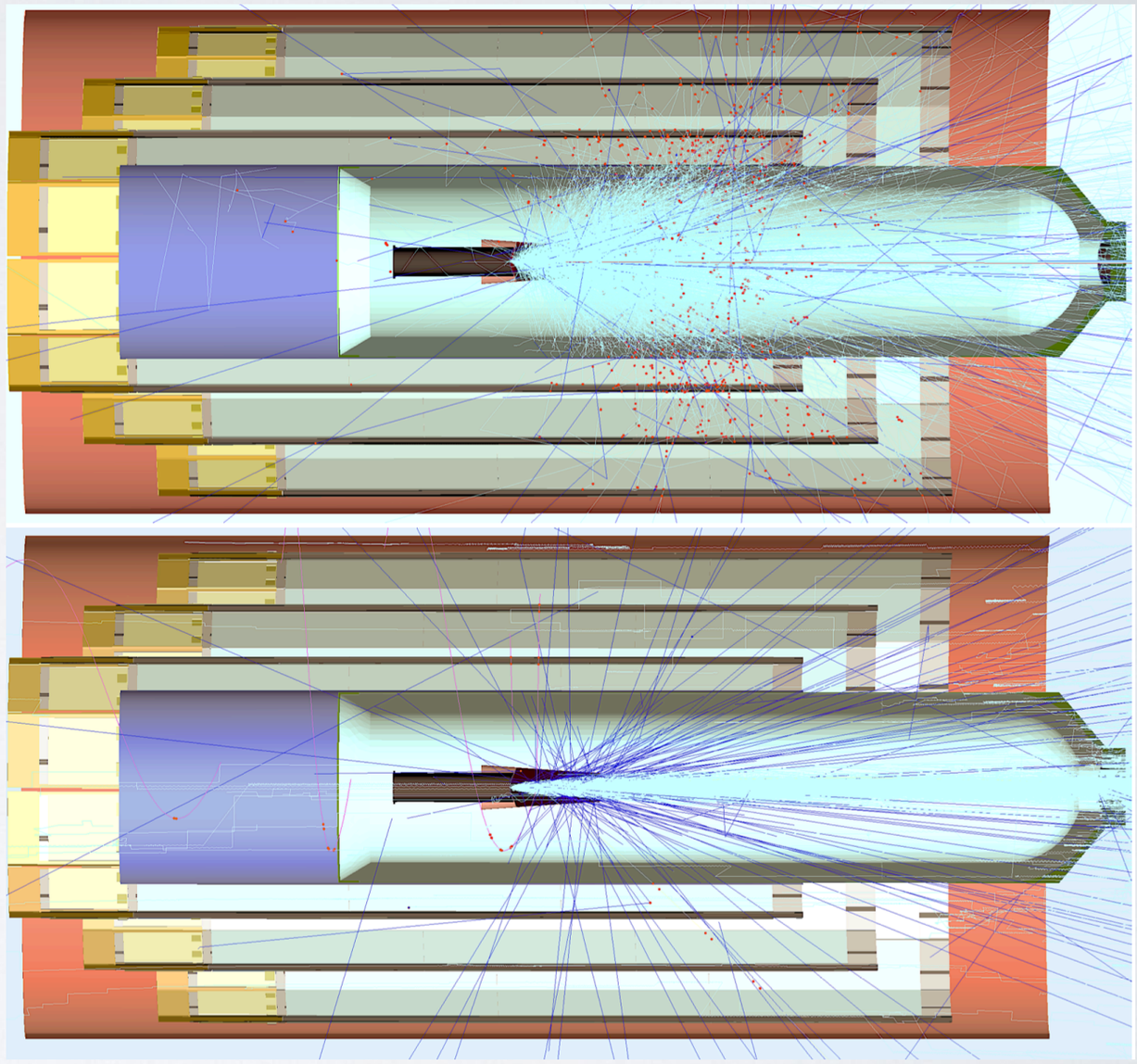
Calibration pars from Data:

- attenuation length
- number of photo-electrons from energy
- scintillator resolution
- time walk correction

CLAS12 Magnets

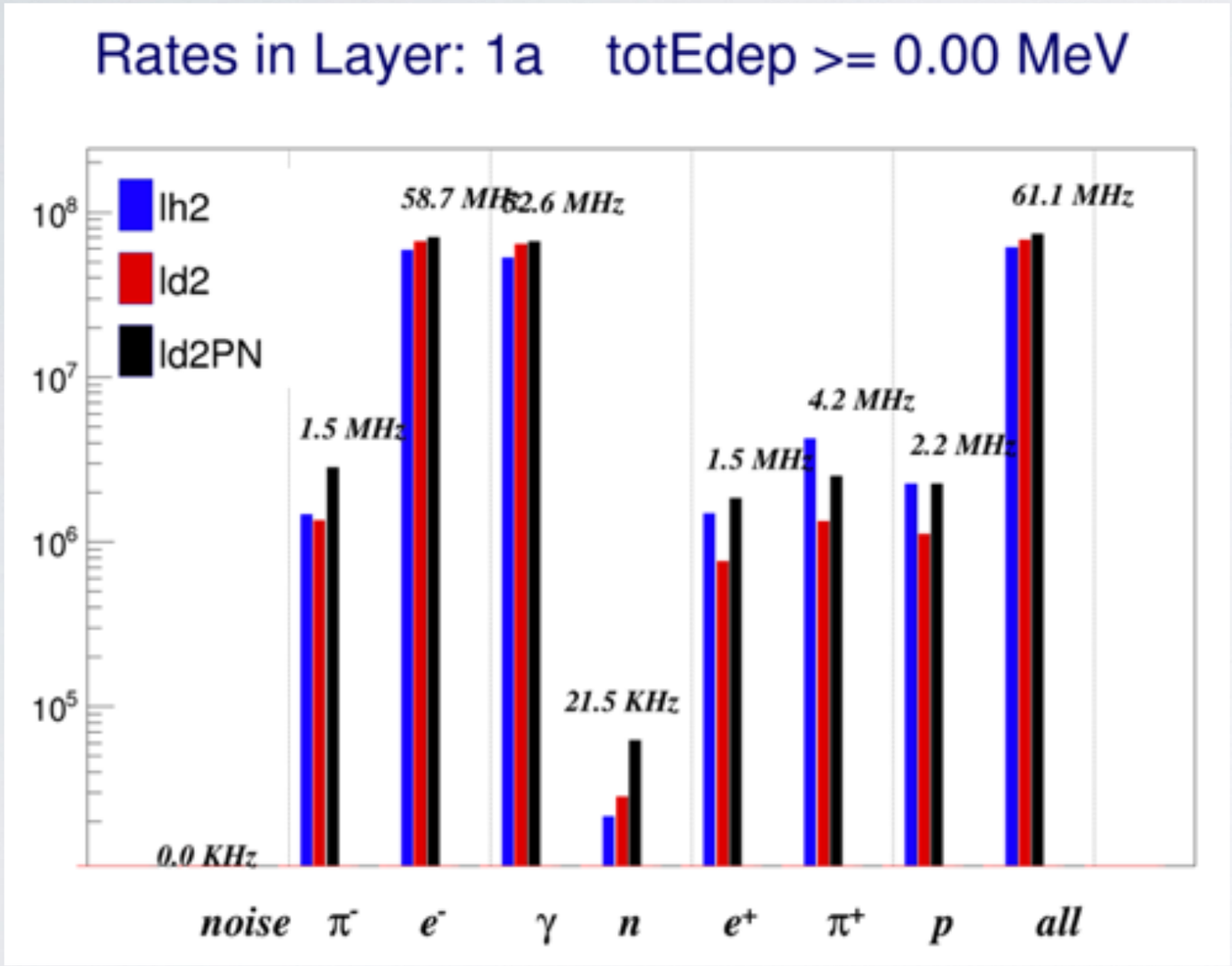


- Torus: forward analyzing magnet



- Solenoid: central analyzing magnet

CLAS12 Radiation Studies



particle	rate (MHz)	1 MeV Neutron Damage Rate (MHz)
e-	67.2124	0.329577
pions	1.21853	0.809765
neutrons	0.0374612	0.0204375
protons	1.1229	8.50723
Total:	69.5913	9.667

particle	rate (MHz)	1 MeV Neutron Damage Rate (MHz)
e-	69.0779	0.431341
pions	2.51686	1.66231
neutrons	0.104969	0.0362654
protons	2.25628	17.257
Total:	73.956	19.3869

CLAS12 Tags

Software, Geometry Tags

Production:

- 4.3.1:
  - FTOF Time resolution updated based on data
  - Option SAVE_SELECTED, RERUN_SELECTED to save RNG state for certain particles, detector
  - Option SAVE_ALL_ANCESTORS to save complete particles hierarchy in output (evio2root also updated)
  - gcards for rg-a different run-periods
  - gcards for rg-b different run-periods
  - ec, pcal digitization removed obsolete constants
  - moved ftof shield in the correct position
  - Option written in JSON format
  - rga_fall2018 variations for: FTOF, EC, PCAL, CTOF geometry services
  - default variation for DC geometry service
  - ltcc variarions for different run periods
  - added Geometry variation as a gcard option: DIGITIZATION_VARIATION, to be used by digitization routines.
  - target position added to BMT, CTOF digitization position shift, read from CCDB using DIGITIZATION_VARIATION
  - beam background merging is extended to all detectors
  - FTOF and CTOF resolutions matched to data

In development:

- 4.3.2:
  - FILTER_HADRONS option to write out events that have hit from specific hadrons in them
  - Rich sector 4 passive materials
  - Background merging memory check SOON
  - Hipo 4 output SOON
  - arbitrary number of sequential rotations in the detector definition SOON
  - BMT digitization with global coordinates instead of locals SOON
  - TOFs resolutions pars from CCDB SOON
  - Move LUND vertex based on gcard entry SOON
  - Time propagation in DC digitization SOON
  - Rich sector 4 digitization SOON
  - 3D Cylindrical map field SOON
  - Detector time signal shift to match data SOON

Packages of software and geometry, grouped by git "tags"

Distributed with Docker images

Run Configurations

- Run group A Spring 2018:
  - Central detector shifted 19.4mm upstream
  - target (LH2) at (0, 0, -19.4) mm
  - HTCC shfted 10mm upstream
  - FT On configuration
  - FMT present
  - LTCC sectors: 2 (N2), 3 (N2), 5 (old C4F10), 6
  - Torus polarity: -1, 1, -0.75, 0.75
  - Solenoid polarity: -1
  - Beam Current: from 5 to 75 nA
- Run group A, K Fall 2018:
  - Central detector shifted 30 mm upstream
  - target (LH2) at (1.2, 1.1, -30) mm
  - HTCC shfted 20 mm upstream
  - FT On configuration
  - FMT not present
  - LTCC sectors: 3 (50% C4F10), 5 (N2)
  - Torus polarity: -1, 1,
  - Solenoid polarity: -1
  - Beam Current: from 5 to 75 nA

Summary

GEMC Framework, adopted by CLAS12
CLAS12 Simulations NIM paper (in progress)
GEMC paper (started)
CLAS12 Software Distribution:

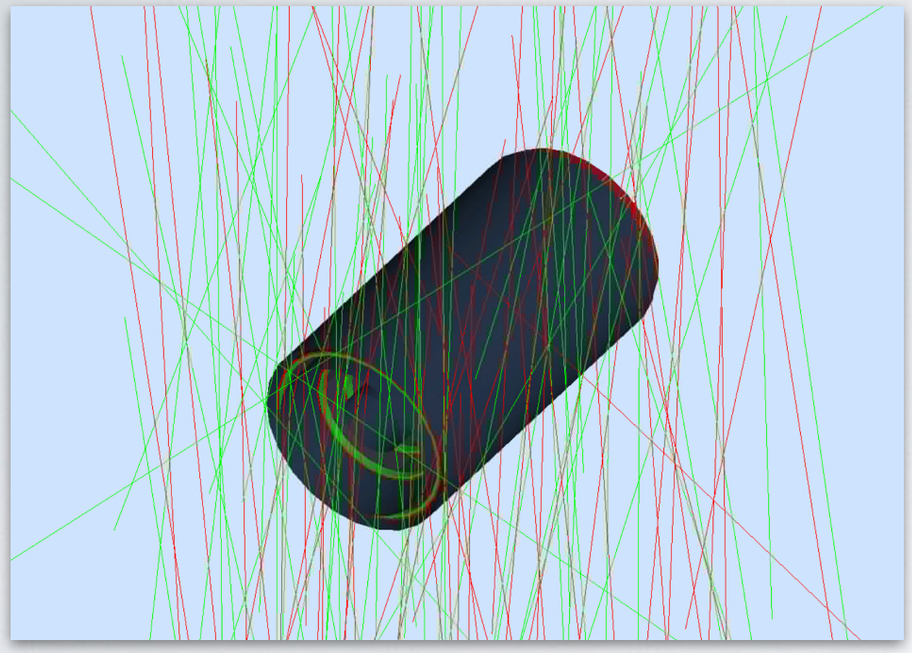
`https://clasweb.jlab.org/clas12/clas12SoftwarePage/html`

Quickstart: Full chain using docker

Use the following command to run the clas12 software image using a "~/mywork" local directory, and run clasdis events through the GEMC/COATJAVA chain:

```
mkdir -p ~/mywork
docker run -it --rm  -v ~/mywork:/jlab/work/mywork jeffersonlab/clas12simulations:iprod bash
cd mywork
clasdis --trig 1000 --docker --t 25 35
gemc -USE_GUI=0 -N=100 -INPUT_GEN_FILE="lund, sidis.dat" /jlab/clas12Tags/gcards/rga-spring2018.gcard
evio2hipo -r 11 -t -1.0 -s -1.0 -i out.ev -o gemc.hipo
createClaraCook.csh gemc.hipo rga-spring2018 1
clara-shell cook.clara
```

Generators



Cosmic Rays mechanism
with various tunable
parameterization models, for
example:

A. Dar, Phys.Rev.Lett,
51,3,p.227 (1983)

- Three independent "beams" (will be unlimited)
- LUND
- BEAGLE
- STDHEP
- (root)
- Time window event to generate luminosity
  beam on target