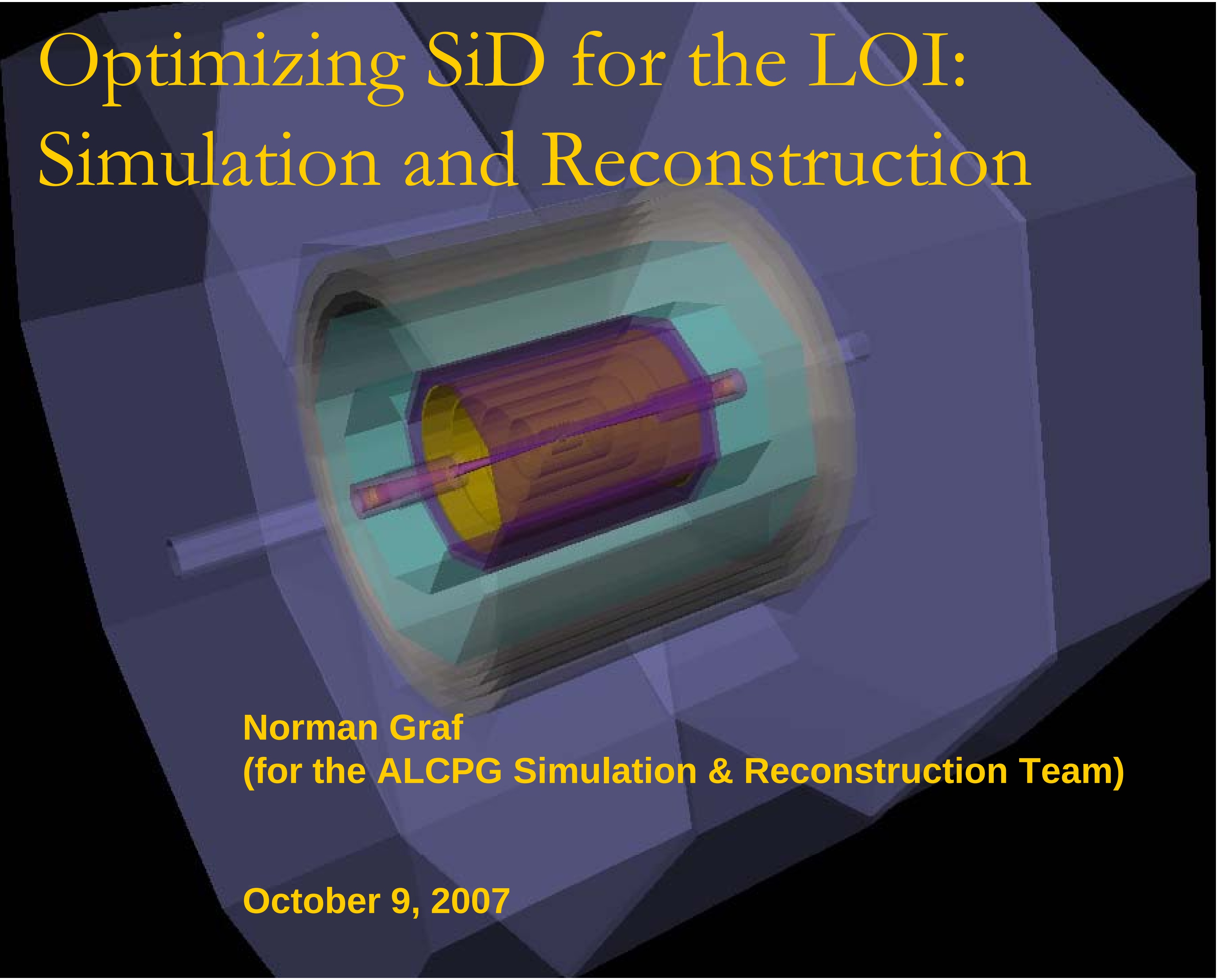
Optimizing SiD for the LOI: Simulation and Reconstruction



Norman Graf
(for the ALCPG Simulation & Reconstruction Team)

October 9, 2007

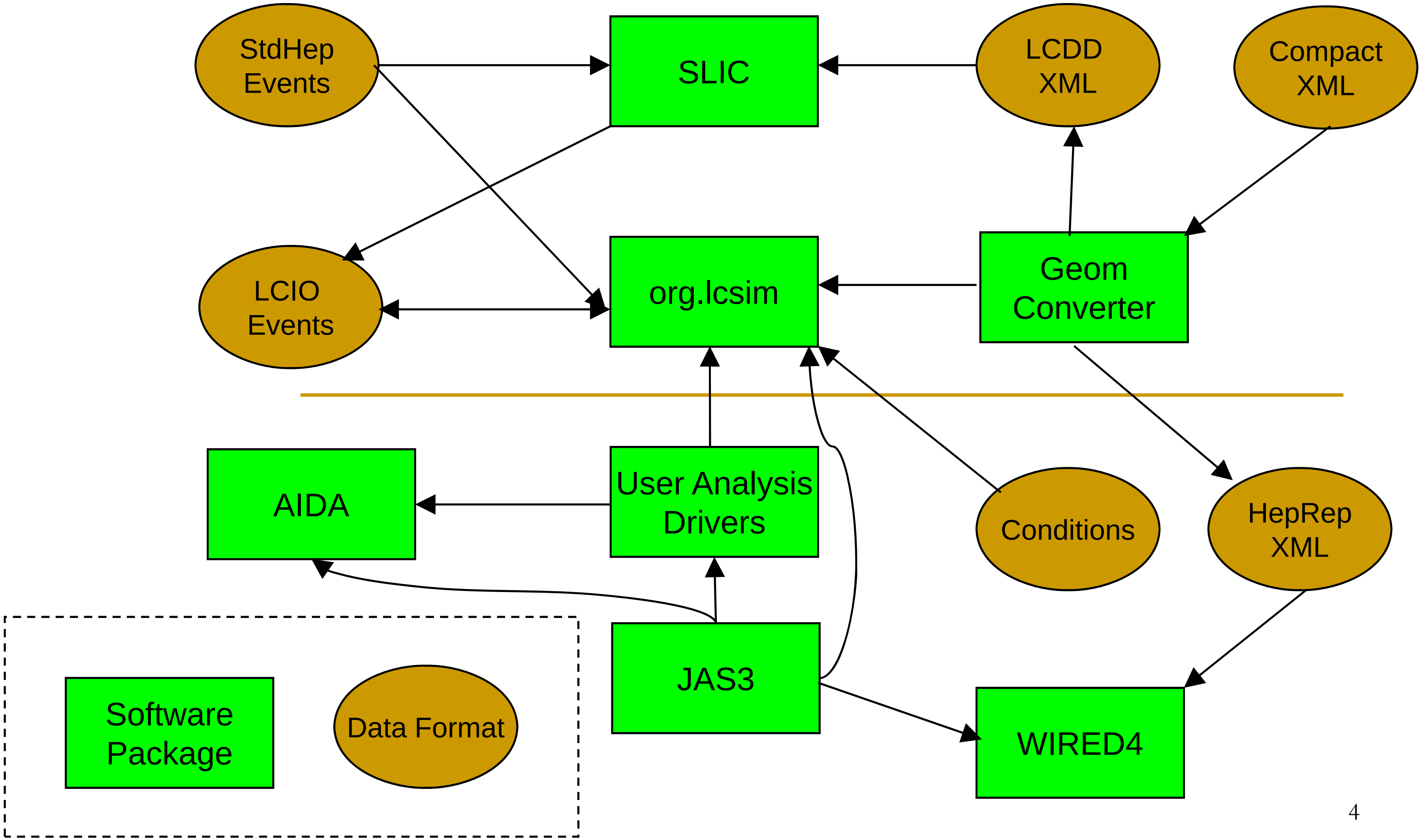
Goals

- The goal is not to make the physics case for the ILC, for this has already been done.
- The goal for this study is to improve the silicon detector concept sufficiently to demonstrate that an affordable, buildable detector can be designed which is able to extract the desired physics from the machine facility. In the long run we need to:
  - Use realistic detector geometries.
  - Employ full detector response simulation.
  - Utilize full event reconstruction.
  - Use the full power of sophisticated analyses.

Goals: Short Term

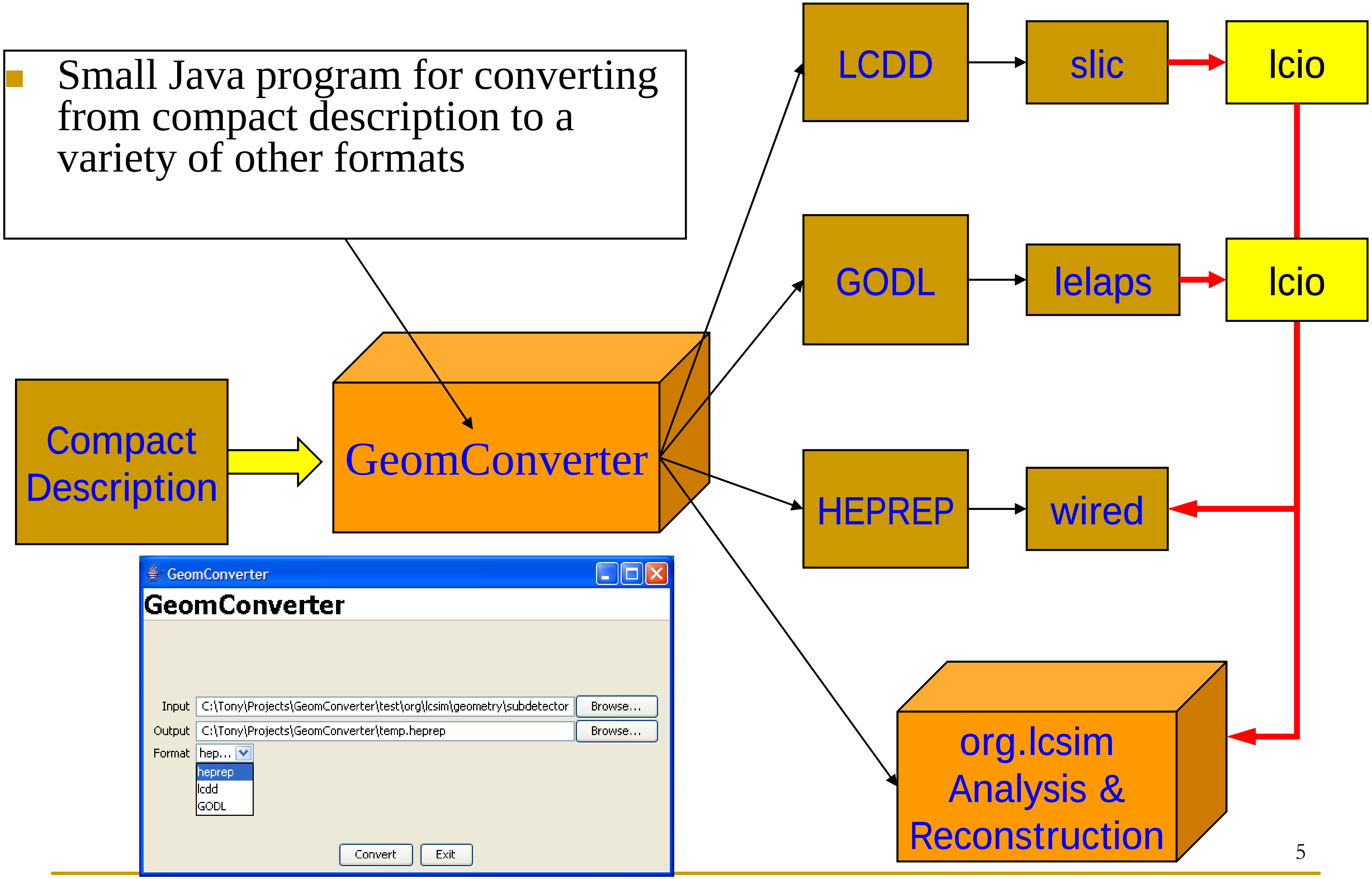
- To-date, almost all of the physics performance analyses have relied on fast MC results within custom analysis environments.
- Will be some need for continued studies using the fast MC as we investigate broader regions of detector phase space and as the full reconstruction matures.
- Full reconstruction not yet at the level of just running a job.
  - Much development still to be done.
  - Analysis results will get worse before they get better if you try to use the full reconstruction.
- However, benchmarking analyses can proceed in parallel with the reconstruction development.
- Would like to strongly encourage physics benchmarking groups to target LCIO ReconstructedParticle objects.
  - Use fast MC now, transition to full reconstruction when it becomes available

Overview: ALCPG Framework



GeomConverter

- Small Java program for converting from compact description to a variety of other formats



Geometry updates in org.lcsim

- hierarchical detector model & geometry model
- parameters & identifiers
- solids & materials
- navigation, point location
- logical and physical volumes
- readout
- coordinate transformation
  - local to global
  - global to local
  - parent to local

Silicon Tracking Detectors

- For the purposes of quickly scanning the parameter space of number of tracking layers and their radial and z positioning, etc. have been simulating the trackers as cylindrical shells or planar disks.
- Are now moving beyond this to be able to realistically simulate buildable subdetectors.
- Have always been able to simulate arbitrarily complex shapes in slic using lcdd, but this is a very verbose format.
- Introduced Geometry and Detector Element trees to handle arbitrary hierarchies of detector elements.
- Have now introduced tilings of planar detectors (simulating silicon wafers) into the compact xml description.

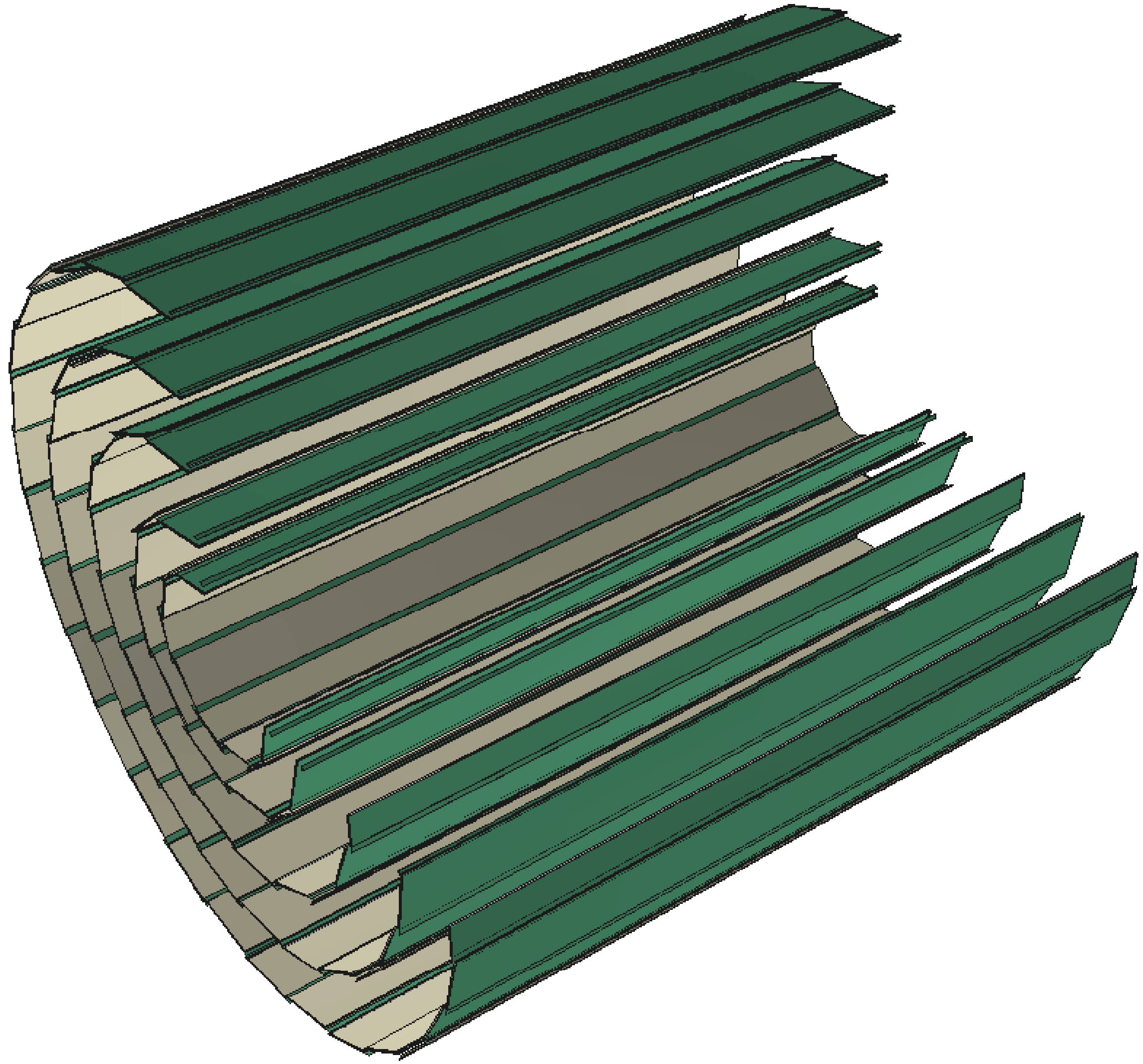
xml: Defining a Module

```
<module name="VtxBarrelModuleInner">
  <module_envelope width="9.8" length="63.0 * 2" thickness="0.6"/>
  <module_component width="7.6" length="125.0" thickness="0.26"
                    material="CarbonFiber" sensitive="false">
                   <position z="-0.08"/>
  </module_component>
  <module_component width="7.6" length="125.0" thickness="0.05"
                    material="Epoxy" sensitive="false">
                   <position z="0.075"/>
  </module_component>
  <module_component width="9.6" length="125.0" thickness="0.1"
                    material="Silicon" sensitive="true">
                   <position z="0.150"/>
  </module_component>
</module>
```

xml: Placing the modules

```
<layer module="VtxBarrelModuleInner" id="1">
        <barrel_envelope inner_r="13.0" outer_r="17.0" z_length="63 * 2"/>
        <rphi_layout phi_tilt="0.0" nphi="12" phi0="0.2618" rc="15.05" dr="-1.15"/>
        <z_layout dr="0.0" z0="0.0" nz="1"/>
</layer>
<layer module="VtxBarrelModuleOuter" id="2">
        <barrel_envelope inner_r="21.0" outer_r="25.0" z_length="63 * 2"/>
        <rphi_layout phi_tilt="0.0" nphi="12" phi0="0.2618" rc="23.03" dr="-1.13"/>
        <z_layout dr="0.0" z0="0.0" nz="1"/>
</layer>
<layer module="VtxBarrelModuleOuter" id="3">
        <barrel_envelope inner_r="34.0" outer_r="38.0" z_length="63 * 2"/>
        <rphi_layout phi_tilt="0.0" nphi="18" phi0="0.0" rc="35.79" dr="-0.89"/>
        <z_layout dr="0.0" z0="0.0" nz="1"/>
</layer>
<layer module="VtxBarrelModuleOuter" id="4">
        <barrel_envelope inner_r="46.6" outer_r="50.6" z_length="63 * 2"/>
        <rphi_layout phi_tilt="0.0" nphi="24" phi0="0.1309" rc="47.5" dr="0.81"/>
        <z_layout dr="0.0" z0="0.0" nz="1"/>
</layer>
<layer module="VtxBarrelModuleOuter" id="5">
        <barrel_envelope inner_r="59.0" outer_r="63.0" z_length="63 * 2"/>
        <rphi_layout phi_tilt="0.0" nphi="30" phi0="0.0" rc="59.9" dr="0.77"/>
        <z_layout dr="0.0" z0="0.0" nz="1"/>
</layer>
```

The Barrel Vertex Detector

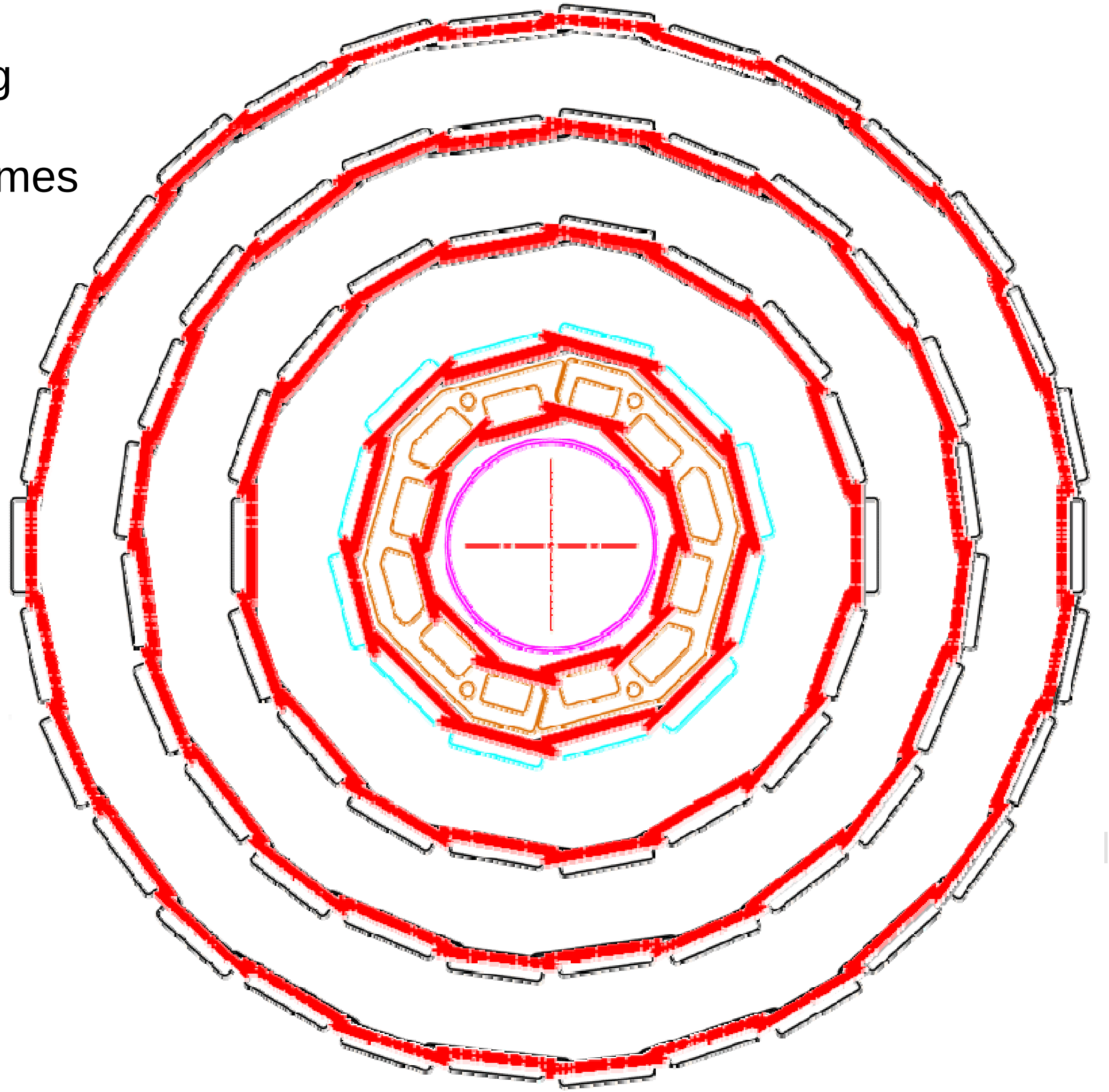


LCIO SimTracker Hits from Vertex

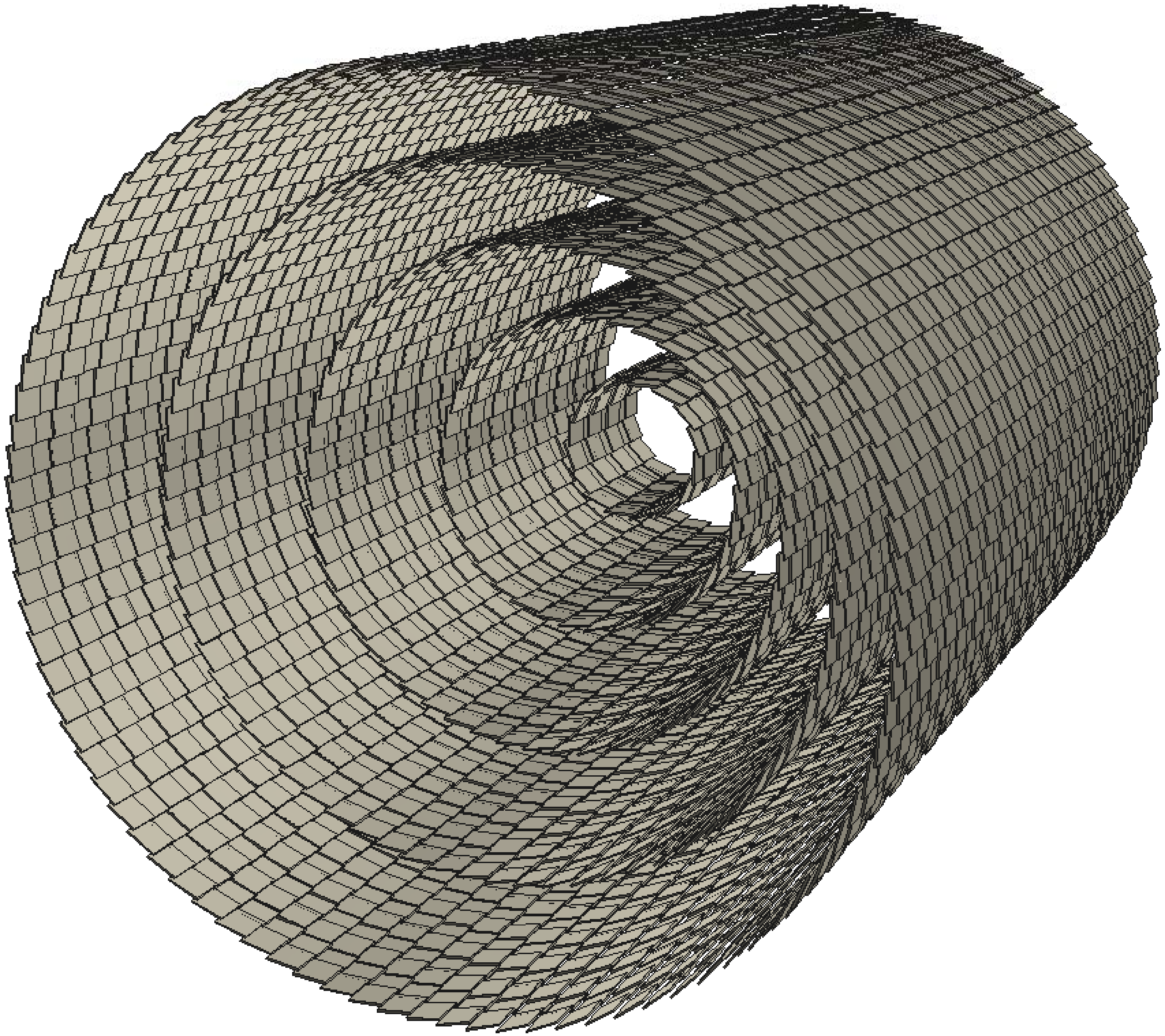
CAD Drawing

GEANT Volumes

LCIO Hits



The Barrel Outer Tracker



Reconstruction

- We are able to simulate arbitrarily complex tracking detectors.
- However, the bottleneck has been to turn the SimTrackerHits into TrackerHits.
  - SimTrackerHit $\rightarrow$ channel number & ADC
  - Associate adjacent channels $\rightarrow$ Clusters
  - Clusters $\rightarrow$ TrackerHit (measurement + uncertainty)
- Dima Onoprienko has made a lot of progress recently and has release a number of classes to handle this for the simplified detectors.

Tracker Digitization

- Will probably still be a long time before we have designs for realistic silicon wafer tilings and realistic digitization of SimTrackerHits.
- Dima's packages provide a virtual segmentation of the cylindrical and planar detectors currently being simulated.
  - More than sufficient to investigate questions of detector placement, numbers of layers, strip pitch, etc.

Tracking reconstruction

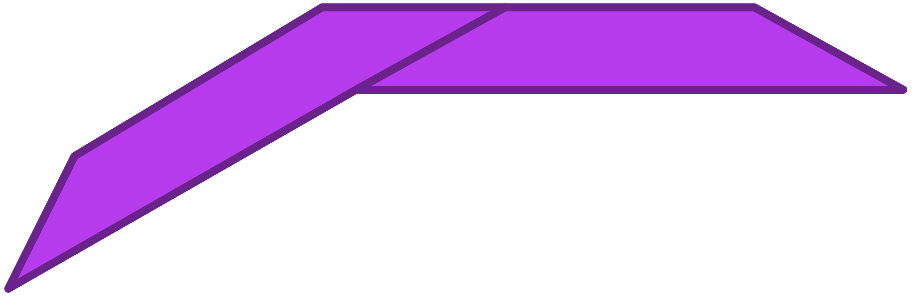
- Dima, Hans Wenzel and Rob Kutschke to talk this afternoon about:
  - Virtual segmentation and digitization
  - Producing TrackerHits in sid01
  - Fitting tracks
- Aim is to very soon have released code which will provide the full chain of functionality from SimTrackerHit to Track.

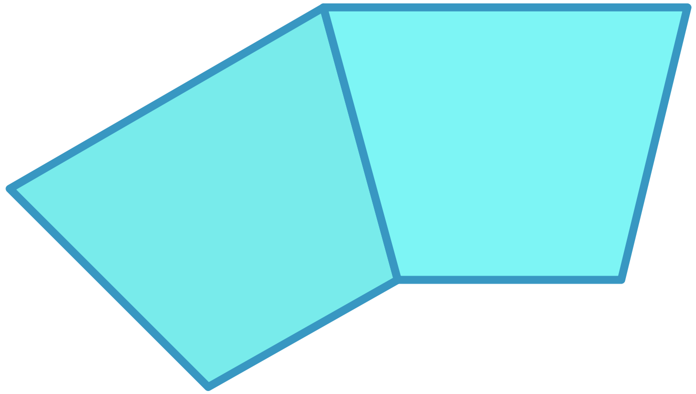
Calorimeter Improved Simulations

- Having settled on a concept with the requisite performance, will have to design a detector which can be built.
- Engineering will have to be done to come up with the plans, but the existing simulation package can already handle arbitrarily complex shapes.
- Can then study effects of support material, dead regions due to stay-clears, readout, power supplies, etc.
- However, again, the hard work is in analyzing this, not simulating it.

Improved Calorimeter Simulations II

- Have two types of polygonal barrel geometries defined in the compact description:
- Overlapping staves: Wedge staves:





- Can define ~arbitrary layerings within these envelopes to simulate sampling calorimeters.

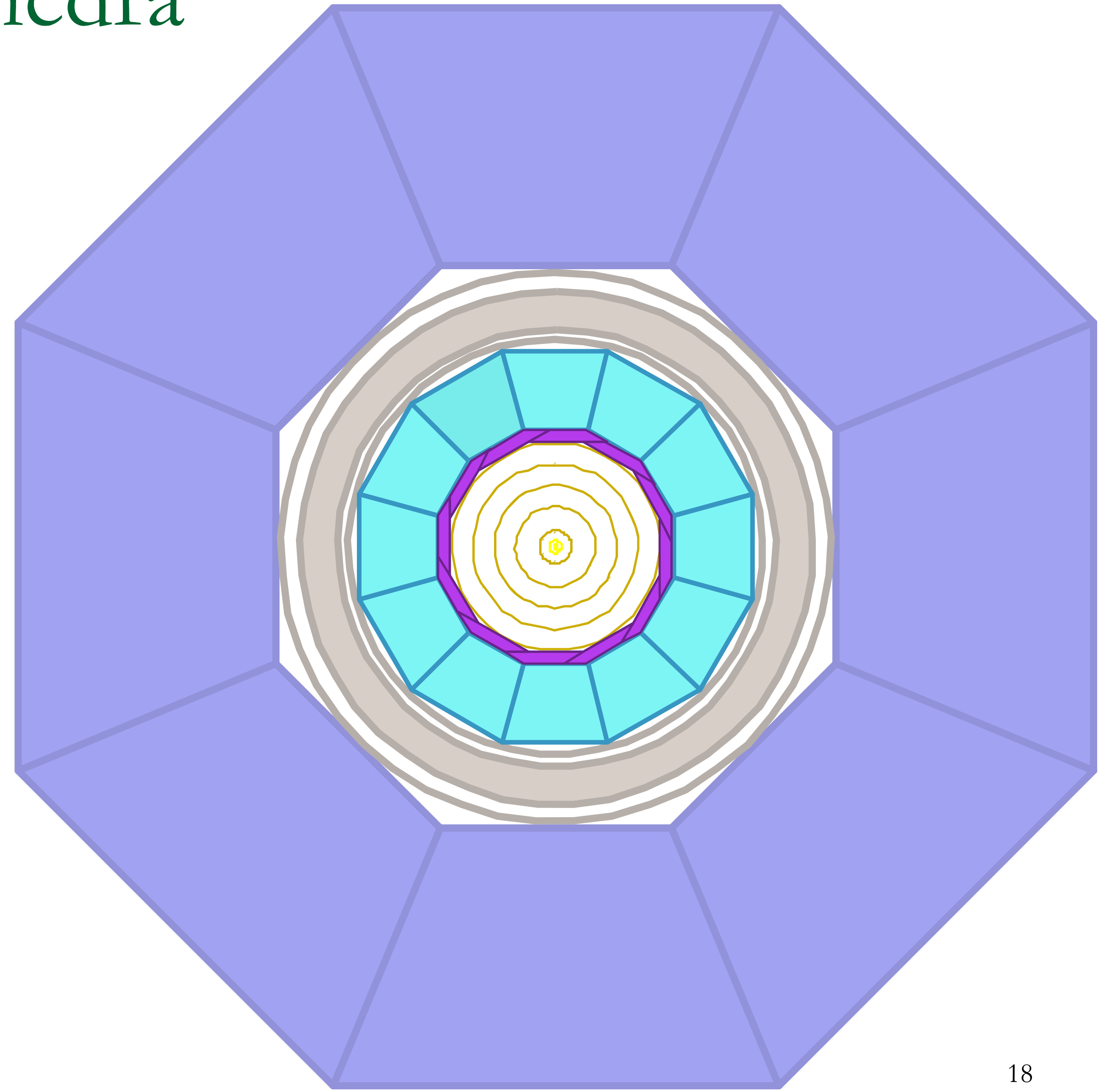
sid01_polyhedra

Dodecagonal, overlapping stave EMCal

Dodecagonal, wedge HCal

Cylindrical Solenoid with substructure

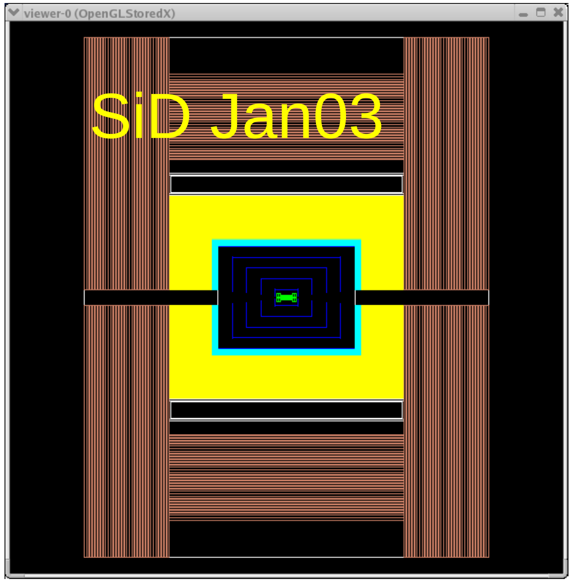
Octagonal, wedge Muon

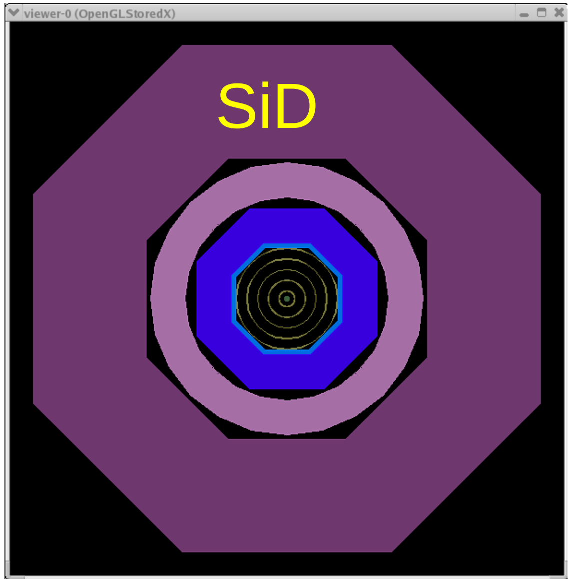


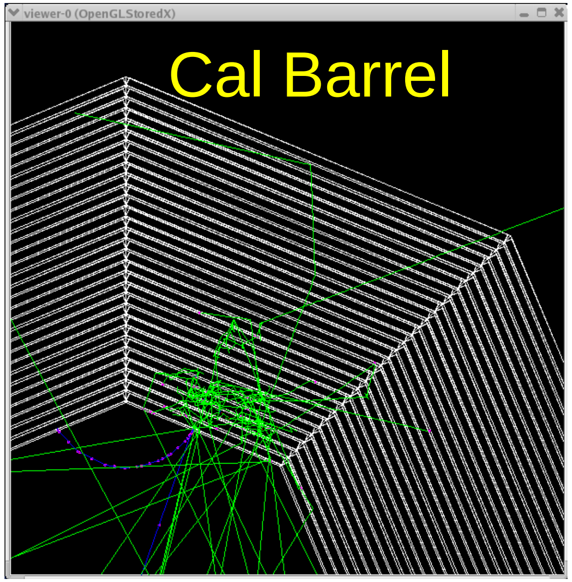
Detector Variants

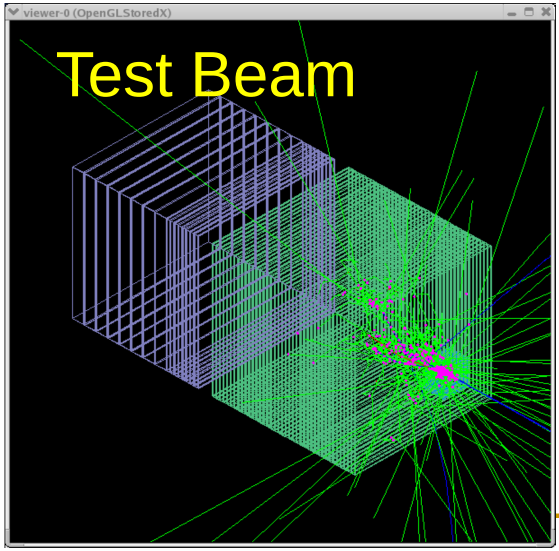
- Runtime XML format allows variations in detector geometries to be easily set up and studied:
  - Stainless Steel vs. Tungsten HCal sampling material
  - RPC vs. GEM vs. Scintillator readout
  - Layering (radii, number, composition)
  - Readout segmentation (size, projective vs. nonprojective)
  - Tracking detector technologies & topologies
    - TPC, Silicon microstrip, SIT, SET
    - “Wedding Cake” Nested Tracker vs. Barrel + Cap
  - Field strength
  - Far forward MDI variants (0, 2, 14, 20 mr)

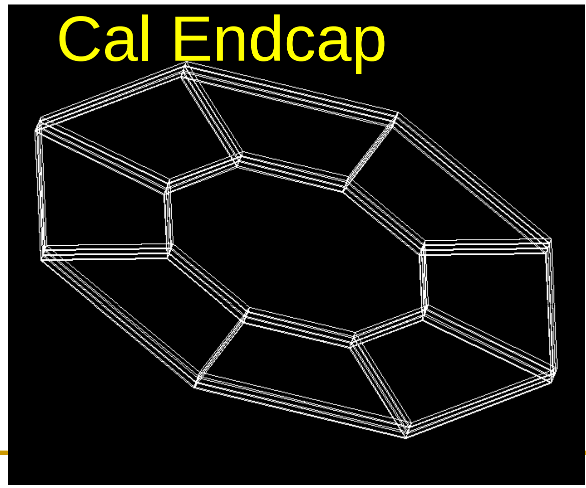
Example Geometries



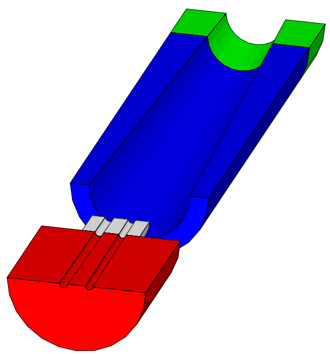




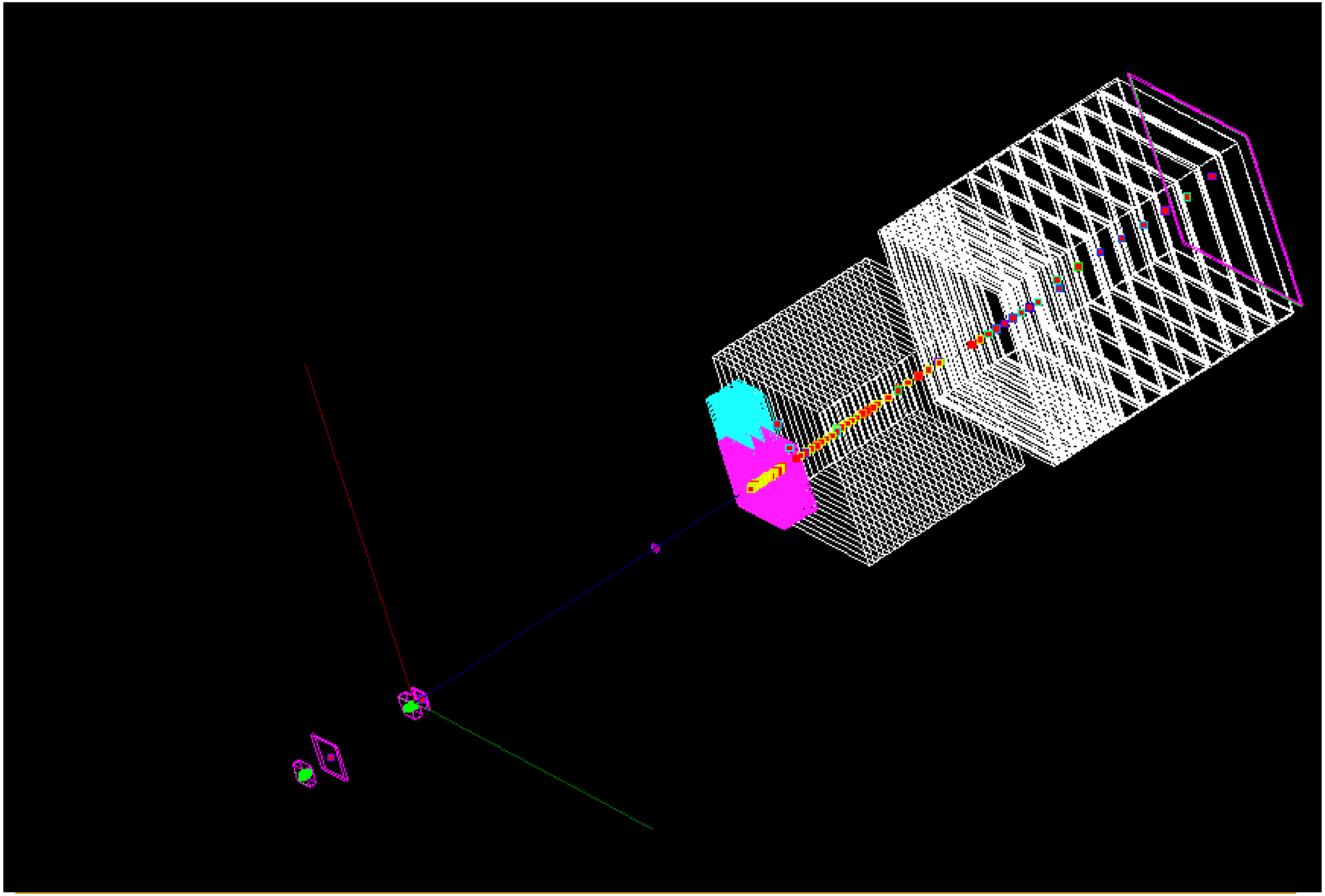




MDI-BDS



Example of Test Beam Analysis



Calorimeter Reconstruction

- There is not yet a canned analysis which efficiently and precisely reconstructs individual particles in the detector.
- PFA group has been meeting weekly to discuss status and plan future activities.
- Three ALCPG meetings devoted to this:
  - Oct. 4: Steve Magill
  - Oct. 11: Mat Charles
  - Oct. 18: Ron Cassell
- Stay tuned…

slic

- Number of internal optimizations and refactorings.
  - Should not be noticed by end users.
- Upgrades to recent version of Geant4 has essentially eliminated problem of event aborts when particle tracking became stuck.
- slic from scratch:

```
cvs -d :pserver:anonymous@cvs.freehep.org:/cvs/lcd co SimDist
cd SimDist
./configure
make
```

- Binaries also available for Windows, Mac, Linuxes

"Signal" and Diagnostic Samples

- Have generated canonical data samples and have processed them through full detector simulations.
- simple single particles: γ, μ, e, $\pi^{+/-}$, n, …
- composite single particles: π^0,ρ, $K^0{}_S$,τ, ψ, Z, …
- Z Pole events: comparison to SLD/LEP
- WW, ZZ, tt, qq, tau pairs, mu pairs, Zγ, Zh:
- Web accessible:

http://www.lcsim.org/datasets/ftp.html

Standard Model Sample

- Access to the Standard Model MC dataset has been cumbersome to-date.
  - required a slac computing account, running slac-specific scripts, and having to completely run over the full set of input files.
- Have produced a set which represents the anticipated ILC data sample:
  - 500 fb^{-1} with 80% e^- / 30% e^+ polarization.
  - events from individual processes are mixed in each file.
    - can run over arbitrary numbers of events and will get a representative sample.

Additional Information

- lcsim.org - http://www.lcsim.org
- ILC Forum - http://forum.linearcollider.org

- Wiki - http://confluence.slac.stanford.edu/display/ilc/Home
- org.lcsim - http://www.lcsim.org/software/lcsim
- Software Index - http://www.lcsim.org/software
- Detectors - http://www.lcsim.org/detectors

- LCIO - http://lcio.desy.de
- SLIC - http://www.lcsim.org/software/slic
- LCDD - http://www.lcsim.org/software/lcdd
- JAS3 - http://jas.freehep.org/jas3
- AIDA - http://aida.freehep.org
- WIRED - http://wired.freehep.org