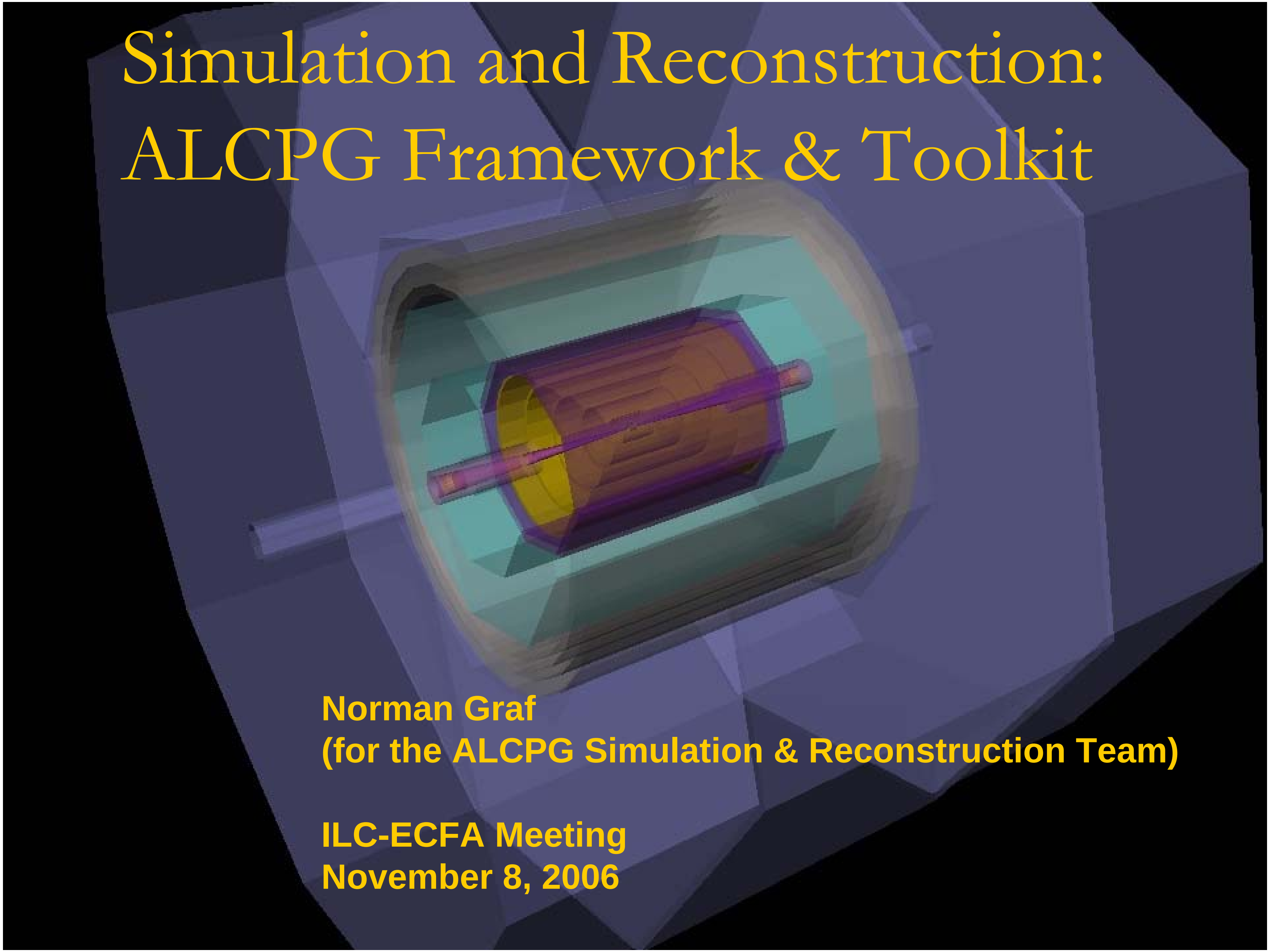
Simulation and Reconstruction: ALCPG Framework & Toolkit



Norman Graf
(for the ALCPG Simulation & Reconstruction Team)

ILC-ECFA Meeting
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Introduction

- This talk not meant to be an in-depth summary of all existing functionality.
  - Not enough time.
  - Been done many times in the past.
- Simply an update on some recent, added functionality.
- Stress simulation aspects, since reconstruction tends to be more personal.
- Improvements to “easy” detector simulations (i.e. via compact.xml).
  - Si wafers, TPC simulation with cuts by region
  - lelaps for fast MC hits generation.
  - polyhedral Calorimeters
- Reconstruction:
  - trf toolkit (see tracking session talk)
  - Individual particle reconstruction template
- lcio tools split/merge/concatenate etc.
- Event samples, both signal and backgrounds.

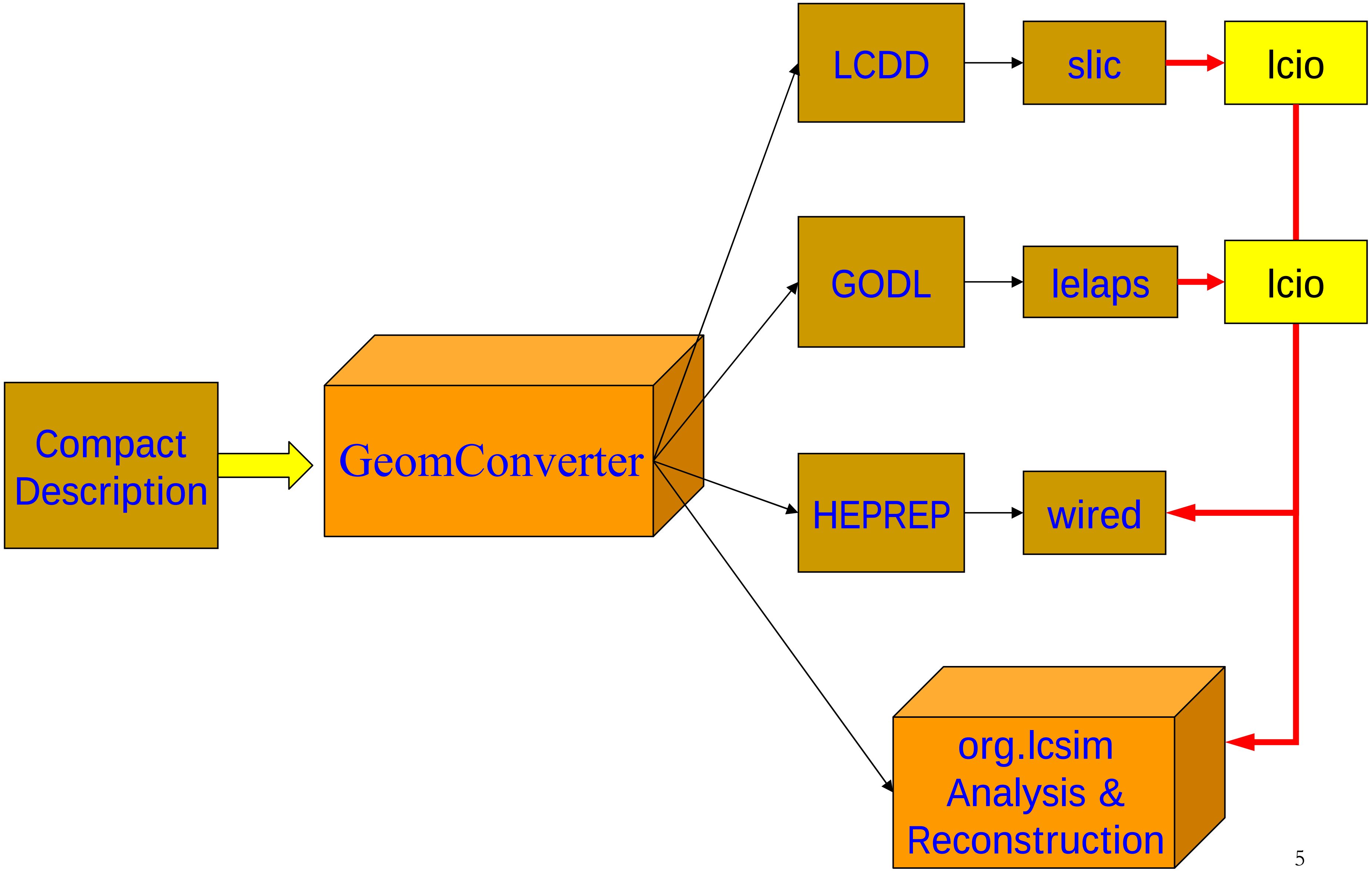
Improved Detector Simulations

- Need to clarify exactly what is required for the CDR and what is deferred to the TDR.
- However, generally agreed that the detector design should have some semblance to a detector which can be built.
  - e.g. no floating cylindrical calorimeters.
- Is the simulation infrastructure capable of modeling realistic detector geometries?
- Yes! The full simulation package slic reads in geometries in lcdd, which is a low-level format that targets Geant4 primitives.

Improved Detector Simulations

- The full simulation package slic reads in geometries in lcdd, which is a low-level format that targets Geant4 primitives.
  - Detectors of arbitrarily complex shape and readout can be simulated using only xml file as input.
- However, it would be extremely tedious to generate these files.
- Would also not provide a connection to the reconstruction, nor to the event display.
- Prefer (but not required) to define geometries using a “compact” description.
- Small Java program for converting from compact description to a variety of other formats.
  - GeomConverter.

GeomConverter



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.
- Have now introduced tilings of planar detectors (simulating silicon wafers) into the compact xml description.

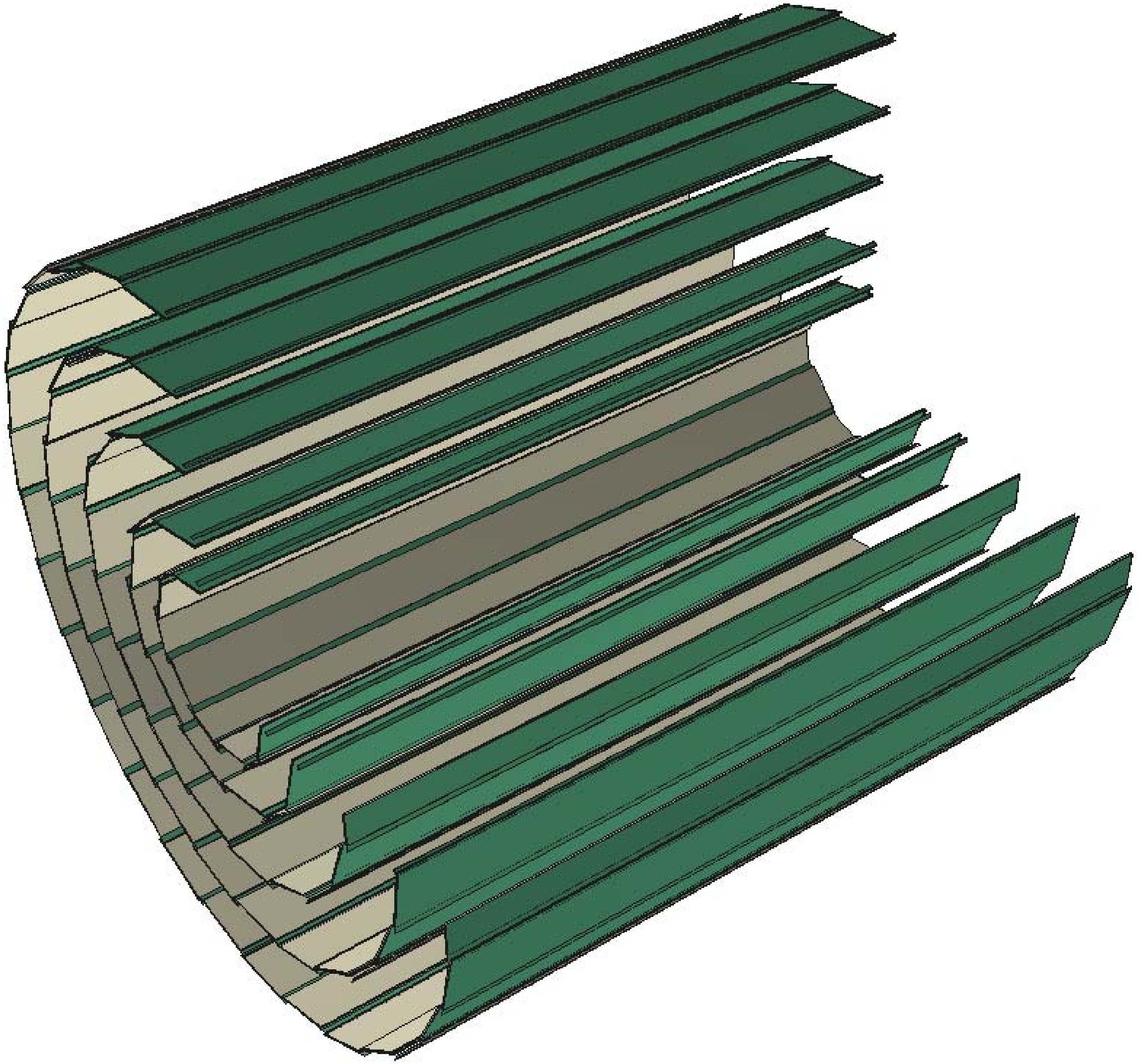
xml: Defining a Module

```
<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

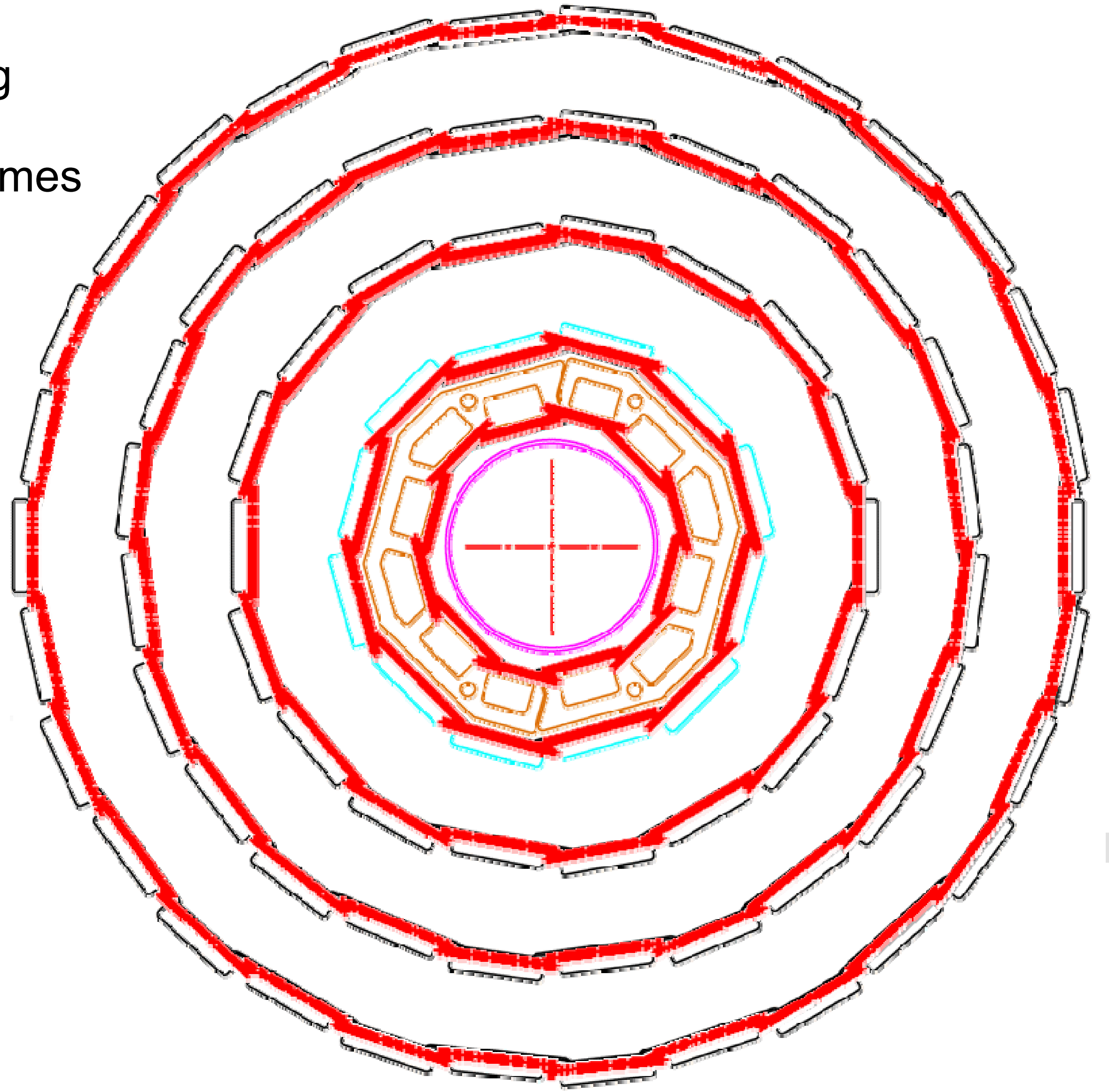


LCIO SimTracker Hits from Vertex

CAD Drawing

GEANT Volumes

LCIO Hits



Silicon Strip Outer Tracker

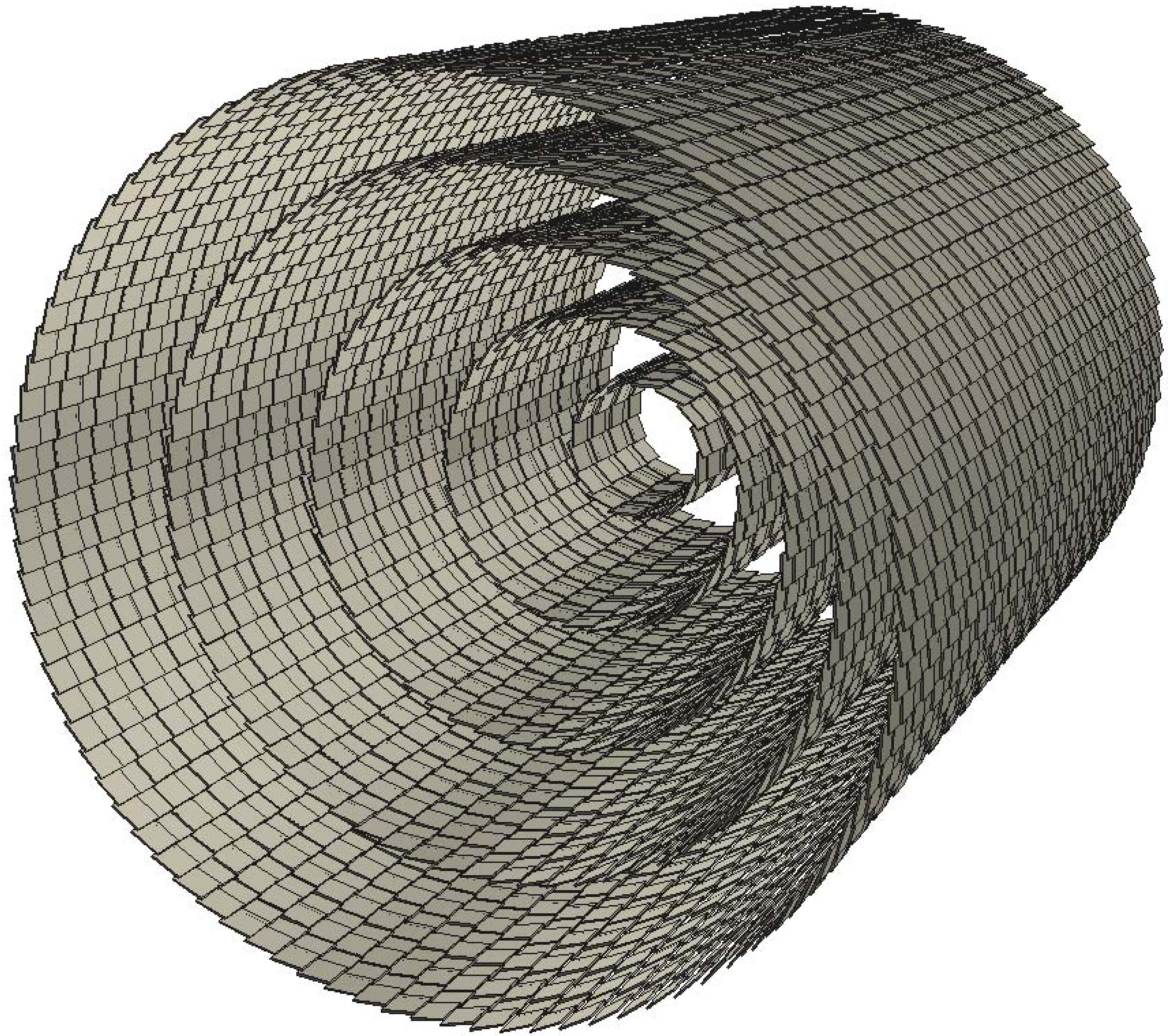
- Defining a Module:

```
<module name="SiTrackerModule">
  <module_envelope width="97.79" length="97.79" thickness="5.5" />
  <module_component width="97.79" length="97.79" thickness="0.228"
    material="CarbonFiber">
  <position z="-1.702" /> </module_component>
…
  <module_component width="93.531" length="93.031" thickness="0.3"
    material="Silicon" sensitive="true">
  <position z="2.082" /></module_component>
</module_component>
  </module>
```

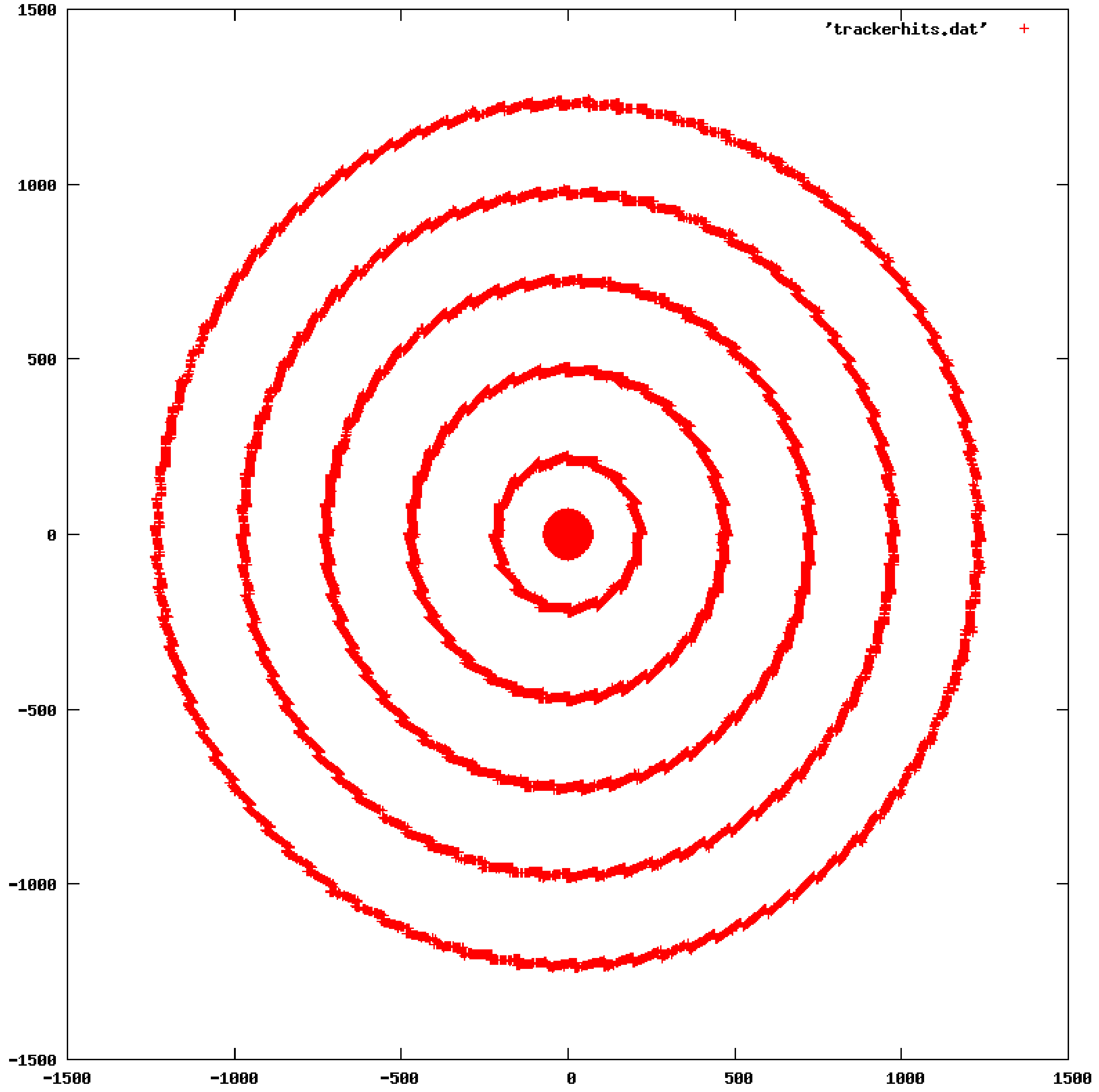
- Placing Modules:

```
    <layer module="SiTrackerModule">
        <barrel_envelope inner_r="195.0" outer_r="245.0" z_length="267.0 * 2.0" />
      <rphi_layout phi_tilt="0.19" nphi="16" phi0="0.196" rc="205.0" dr="0" />
      <z_layout dr="5.5" z0="218.0" nz="7" />
      </layer>
```

The Barrel Outer Tracker

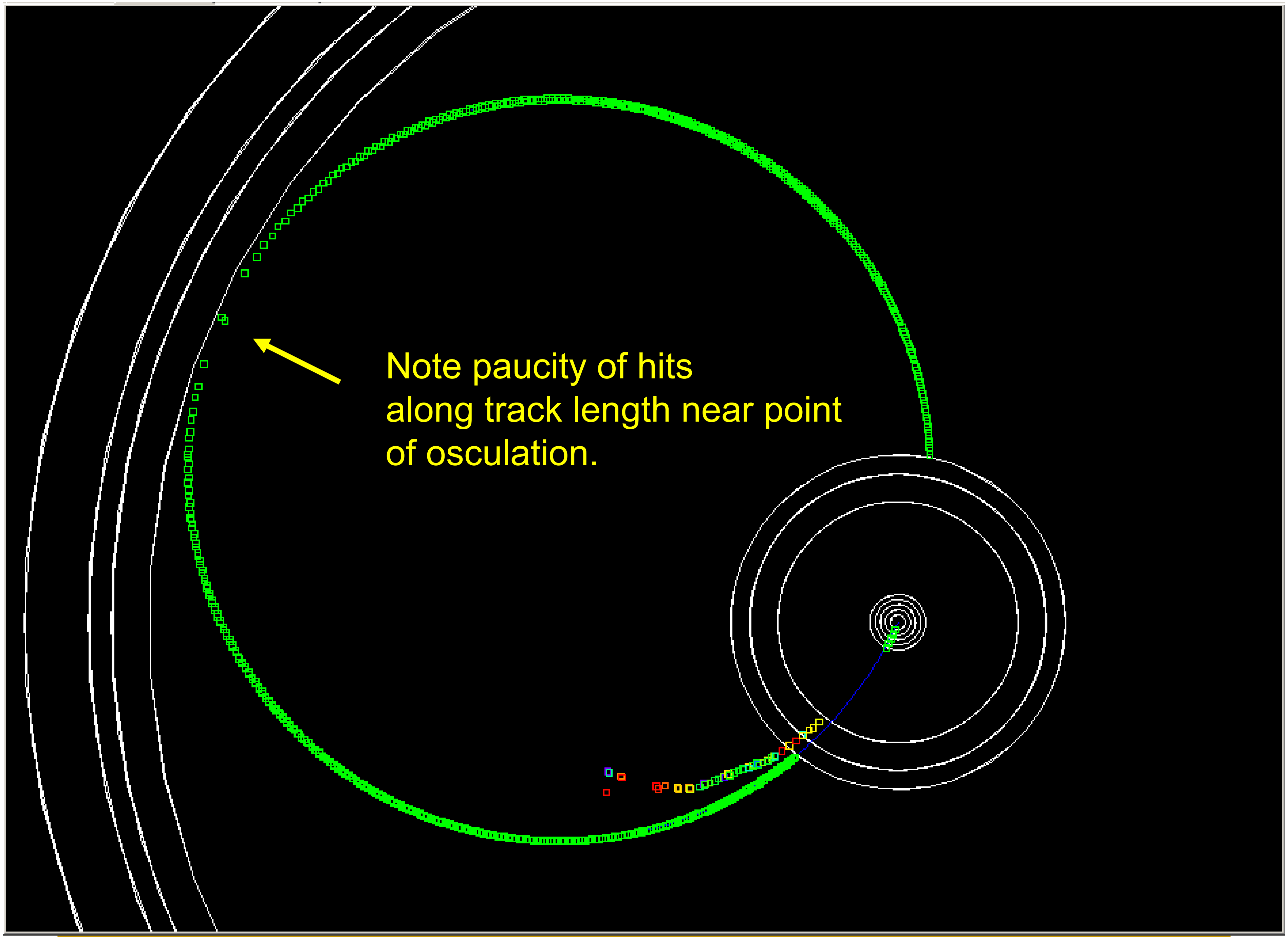


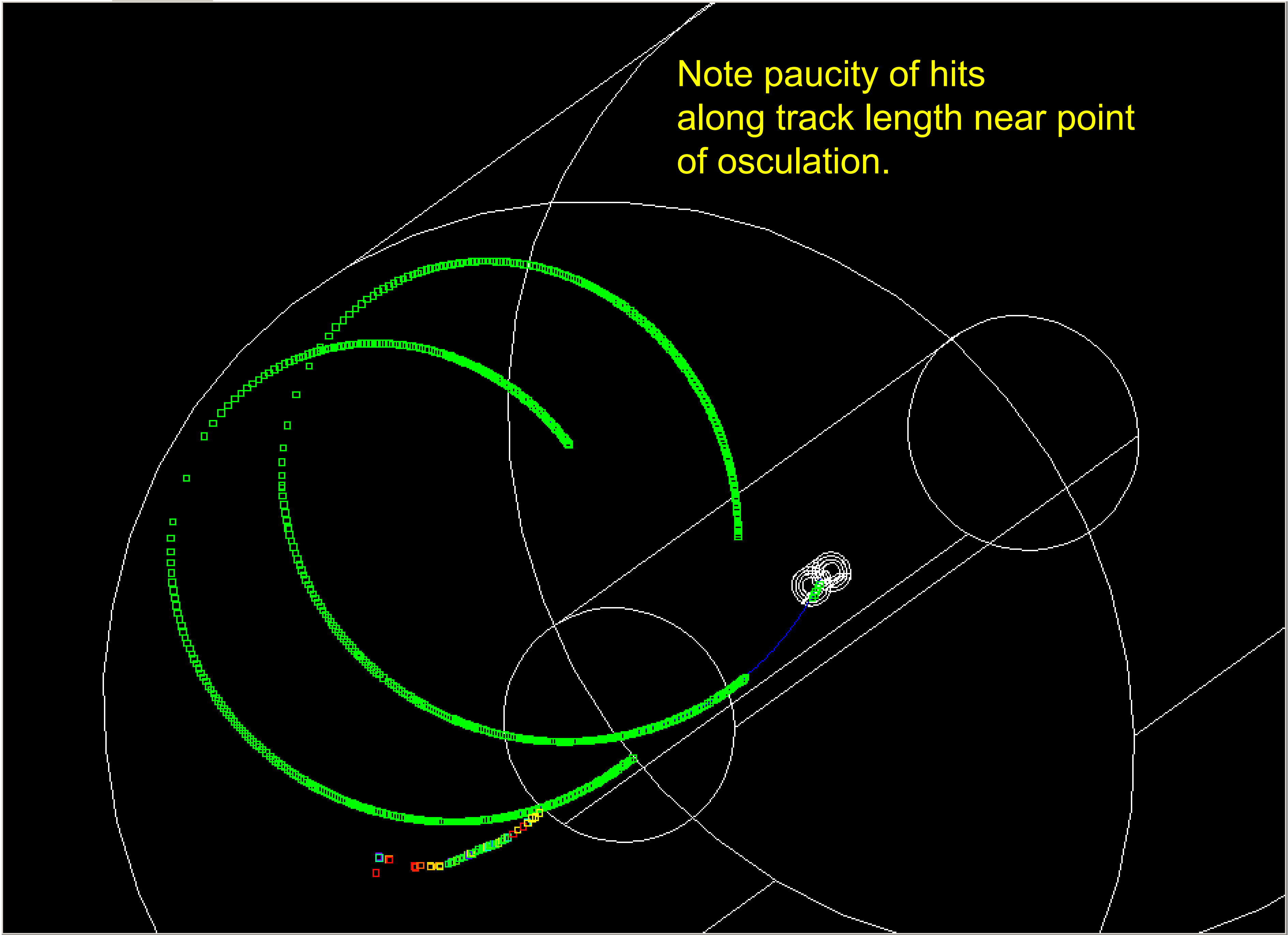
LCIO SimTracker Hits from Tracker



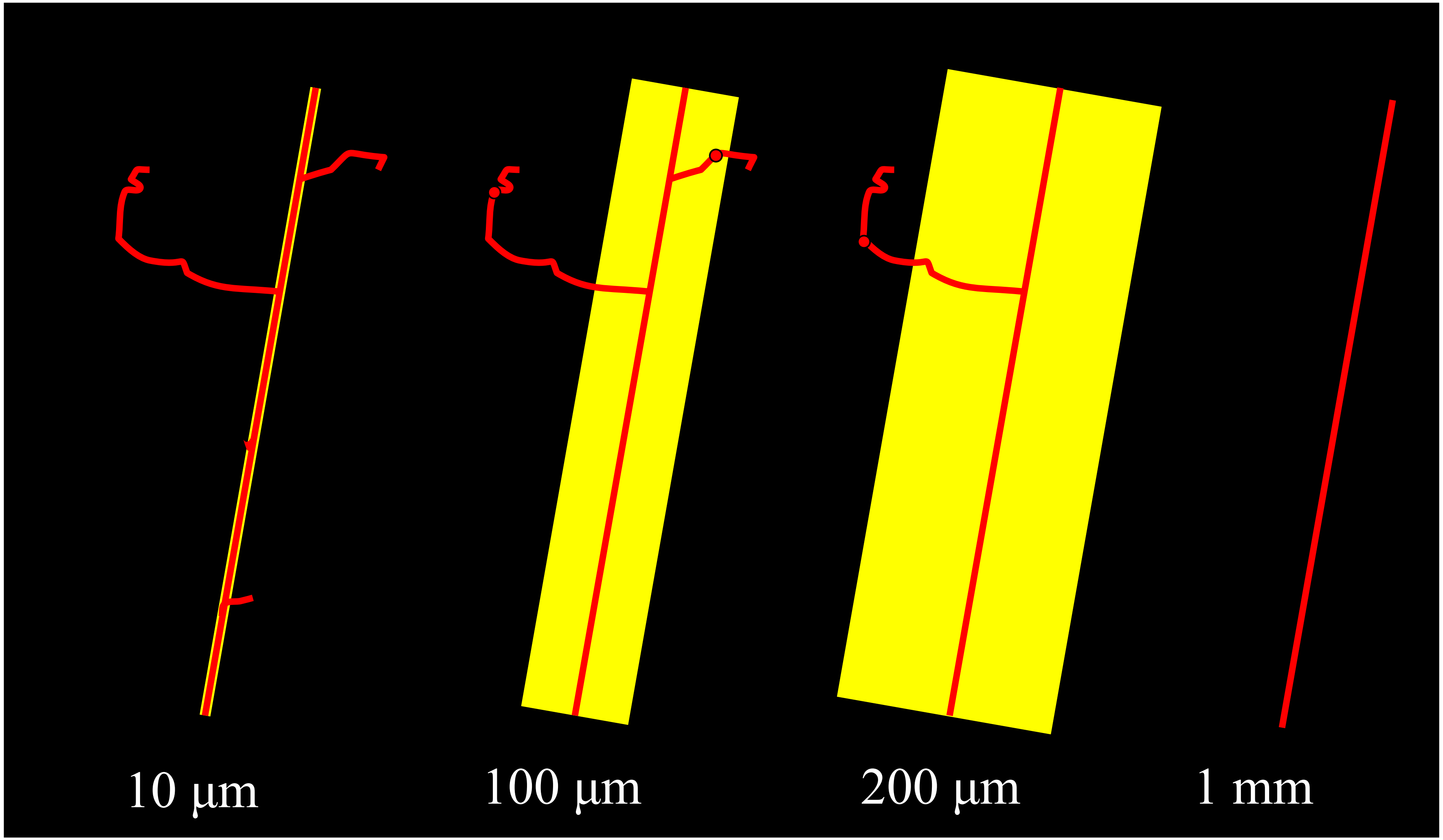
TPC Simulations

- Most simulations to-date have created single hit at intersection with pad row “cylinder”.
- Not too bad an approximation for stiff tracks, but causes problems for loopers.
- Can improve simulations with a combination of range cuts and maximum step size cuts.
- These are configurable by region (themselves configurable) in the compact description.
  - Can define them differently for silicon and TPC.
  - Can change them at runtime to study settings.


Note paucity of hits
along track length near point
of osculation.

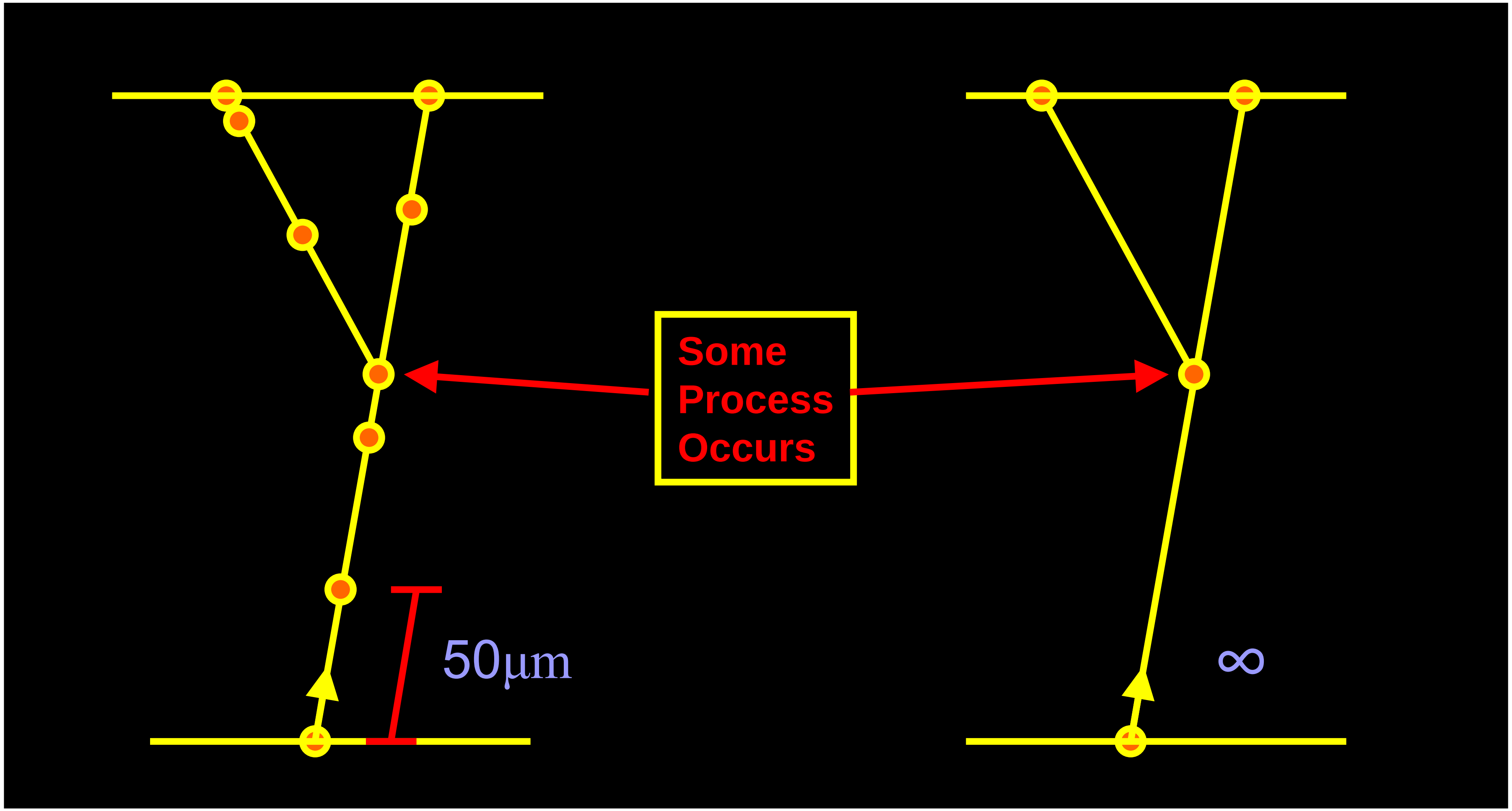

Note paucity of hits
along track length near point
of osculation.

G4 Cuts - Range Cuts



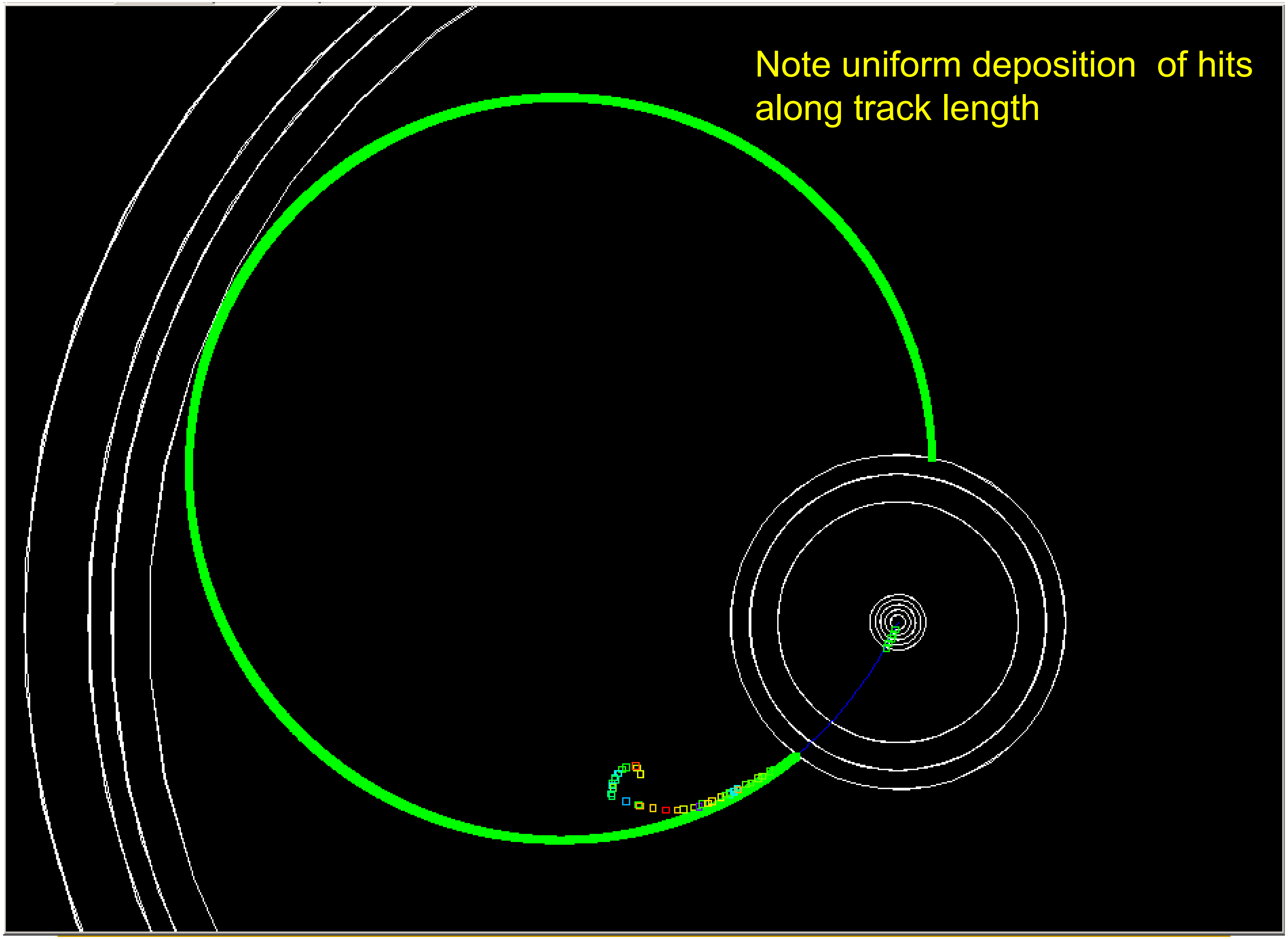
Reducing range cuts increases number of secondaries produced and explicitly tracked

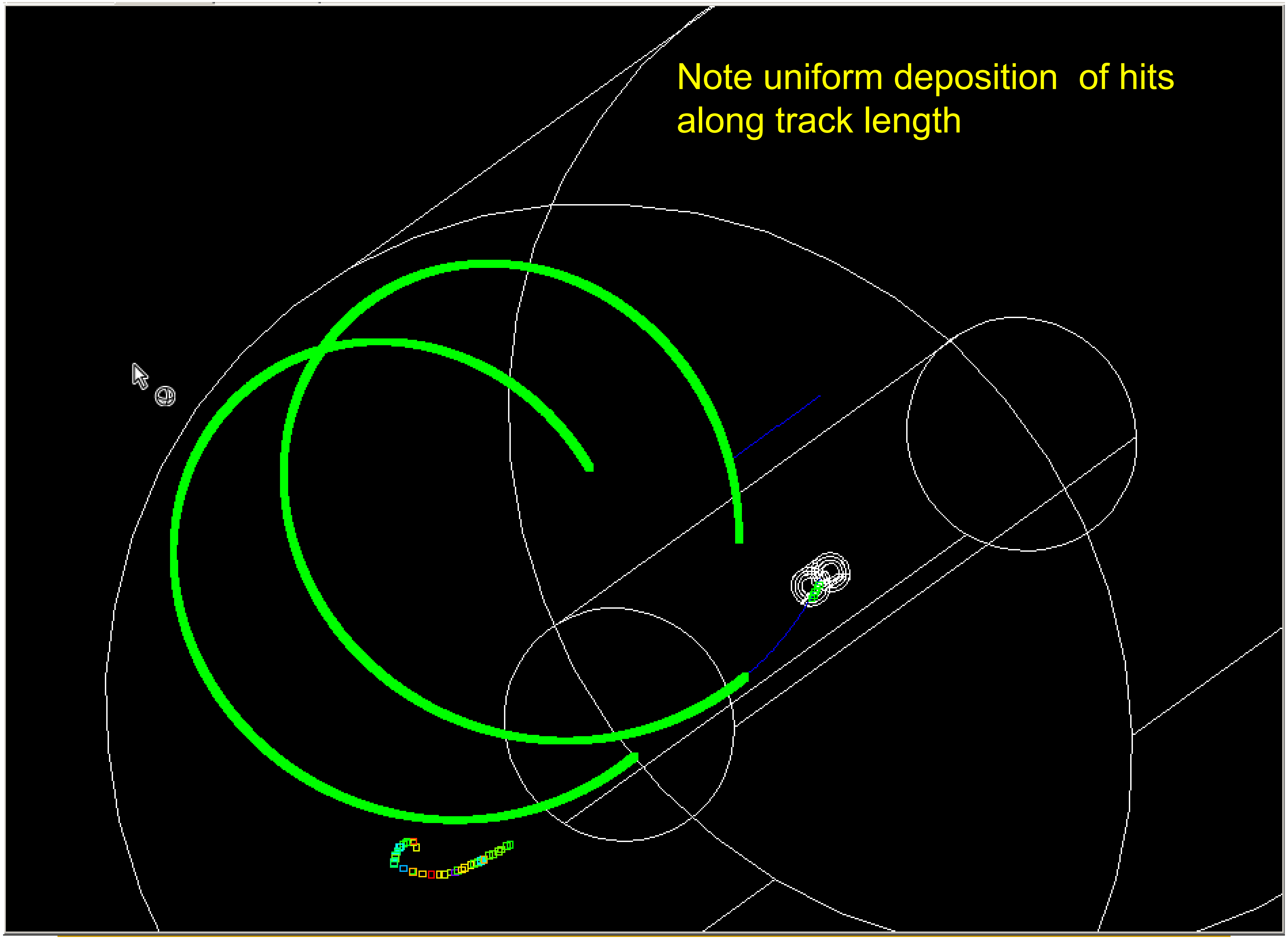
G4 Cuts - Max Step Length



Limits step when no other process occurs in that distance.

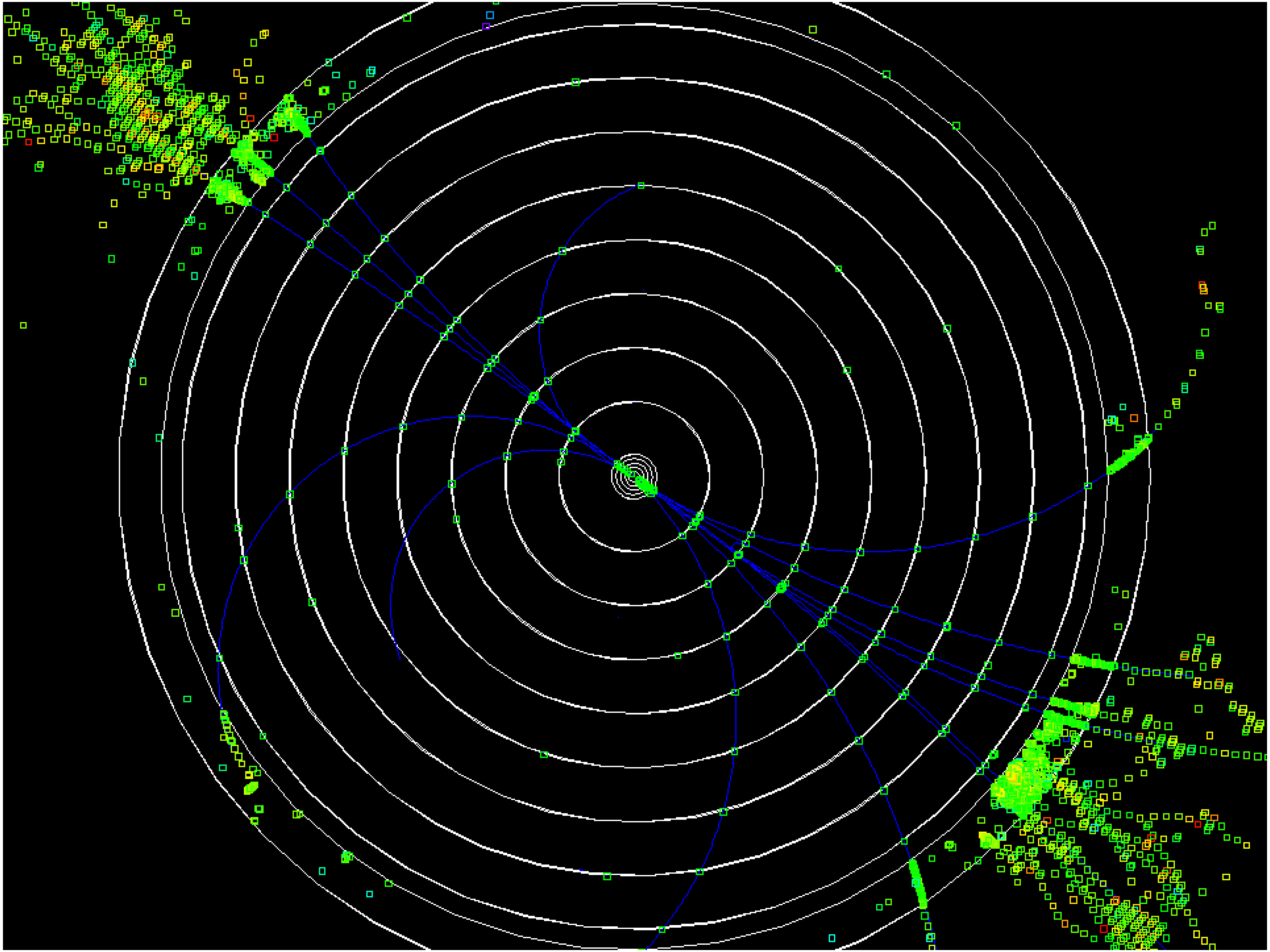
Reducing size limit increases number of hits produced.


Note uniform deposition of hits along track length


Note uniform deposition of hits
along track length

Big Picture Decisions

- There is still a need for people to investigate larger issues, such as the number and layout of tracker and vertex barrel and disk layers.
- This is most easily done with the simplified geometries.
- For example, changing from the 5-layer cylindrical barrel geometry to an 8-layer geometry took less than 15 minutes.
- The work lies in the analysis and comparisons.

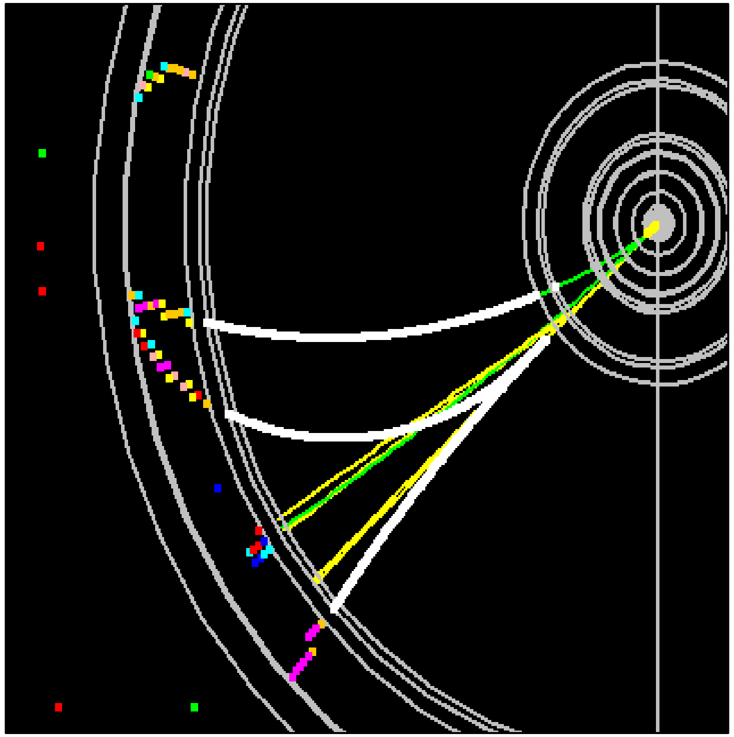


lelaps

- Fast detector response package.
- Handles decays in flight, multiple scattering and energy loss in trackers.
- Parameterizes particle showers in calorimeters.
- Produces lcio data at the hit level.
- Uses runtime geometry (compact.xml $\rightarrow$ godl).
- An excellent tool for designing tracking detectors!

http://lelaps.freehep.org/index.html

Lelaps: Decays, dE/dx, MCS

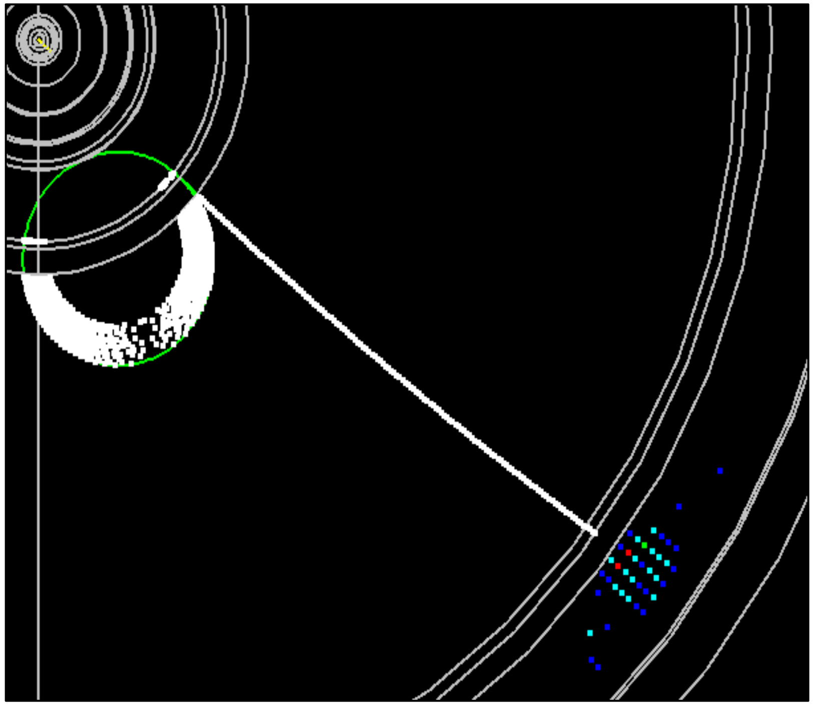


$\Omega^- \rightarrow \Xi^0 \pi^-$

$\Xi^0 \rightarrow \Lambda \pi^0$

$\Lambda \rightarrow p \pi^-$

$\pi^0 \rightarrow \gamma \gamma$ as simulated by Lelaps for the LDC model.



gamma conversion as simulated by Lelaps for the LDC model.

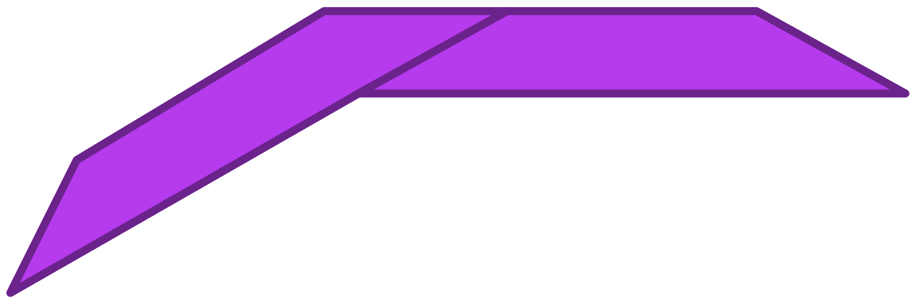
Note energy loss of electron.

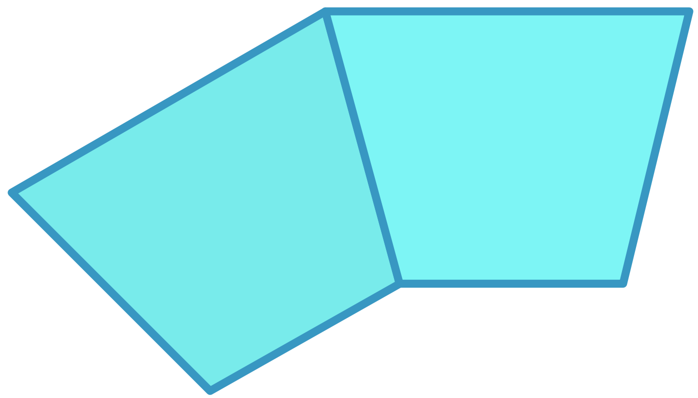
Calorimeter Improved Simulations

- 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, 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:

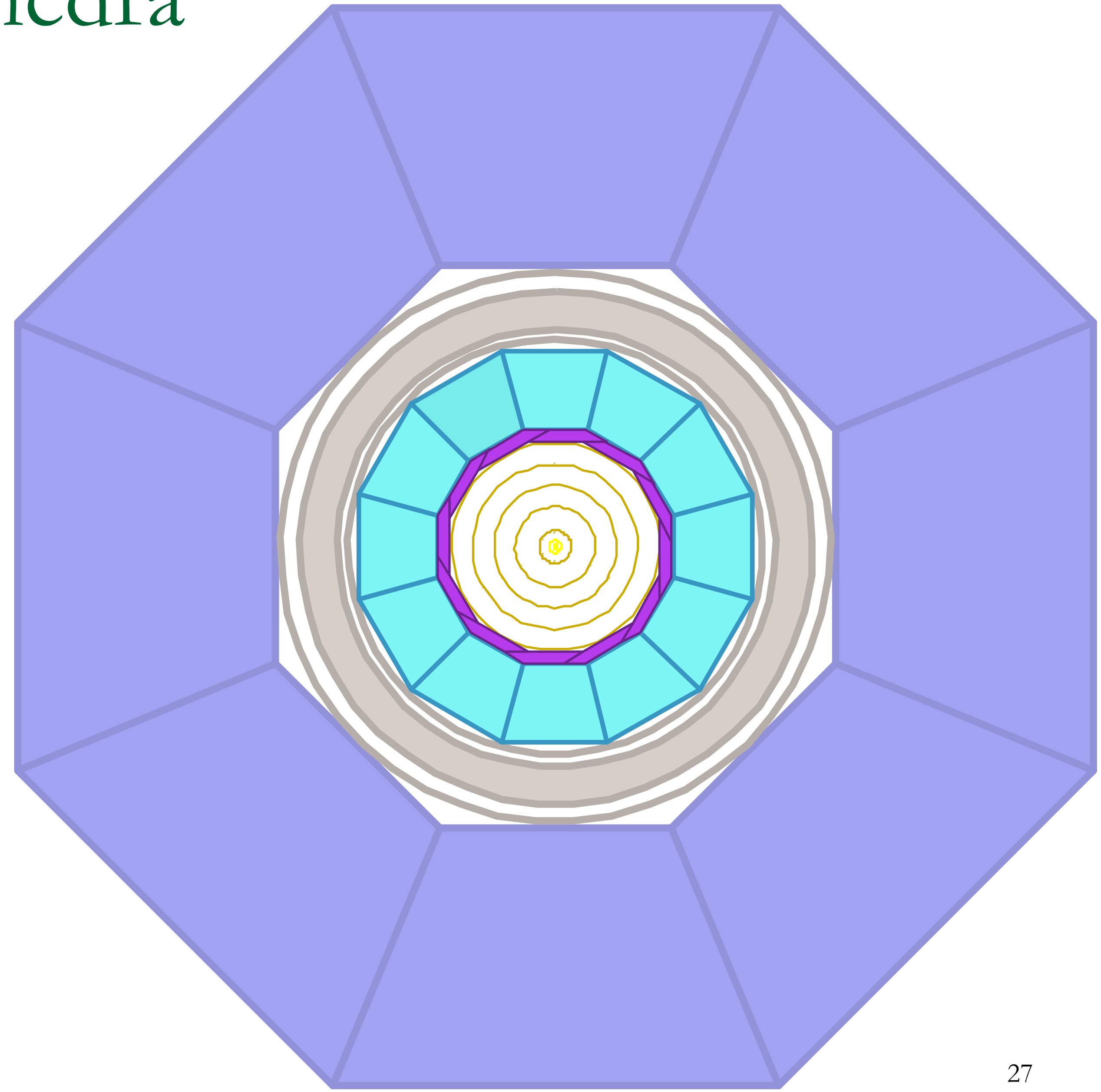




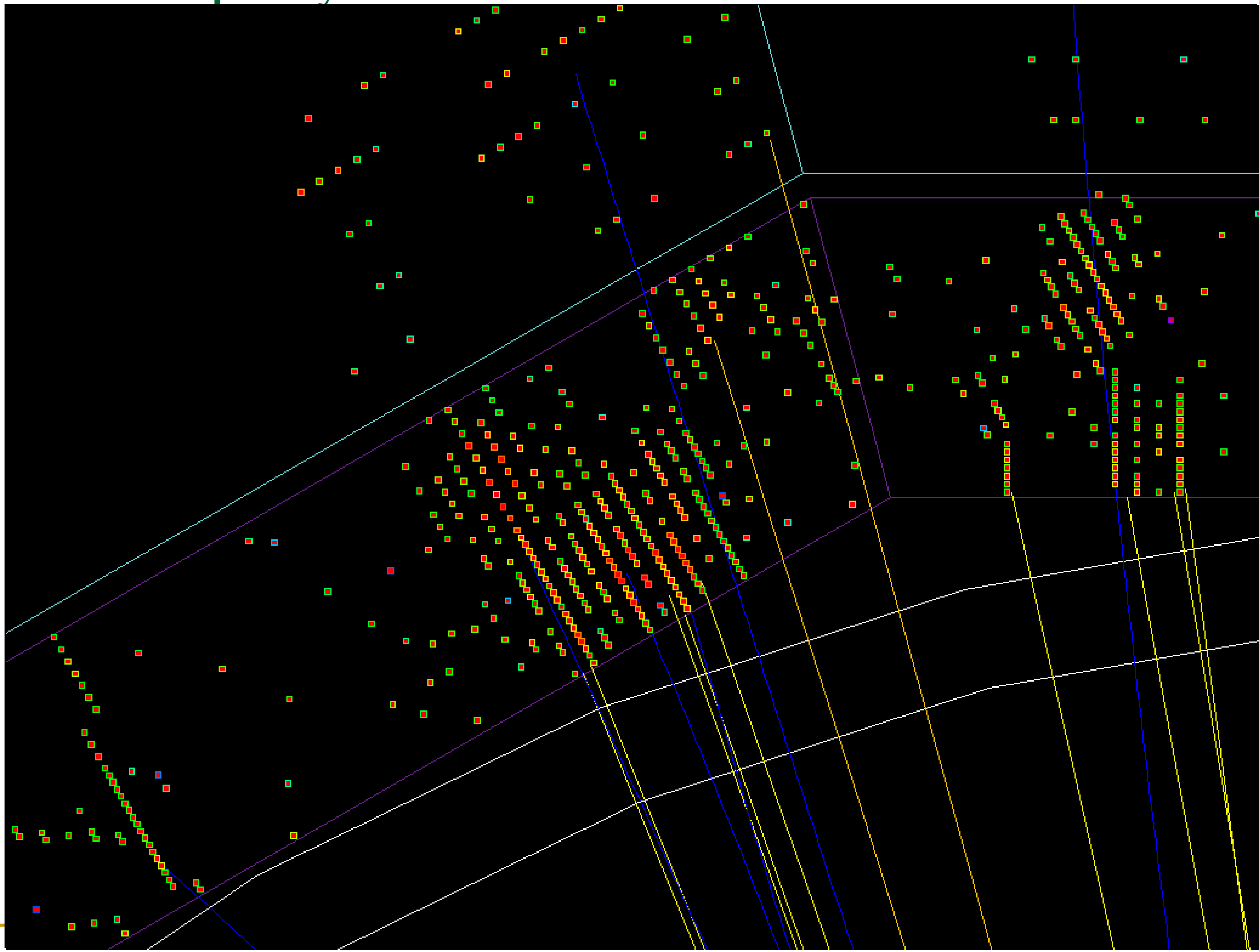
- Can define ~arbitrary layerings within these envelopes to simulate sampling calorimeters.

sid01_polyhedra

- Dodecagonal, overlapping stave EMCal
- Dodecagonal, wedge HCal
- Cylindrical Solenoid with substructure
- Octagonal, wedge Muon



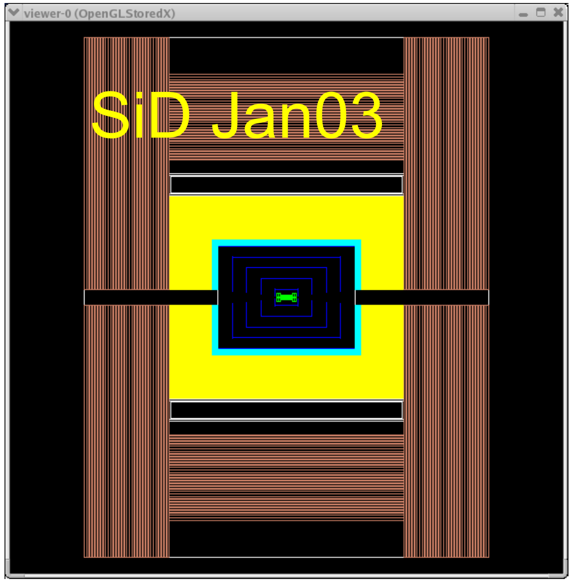
sid01_polyhedra

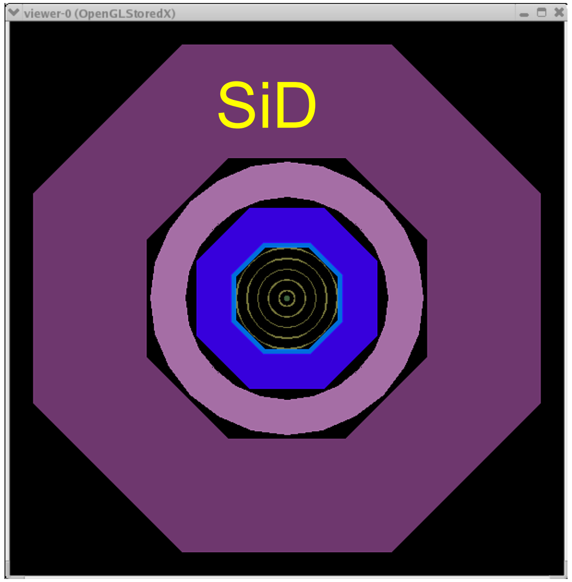


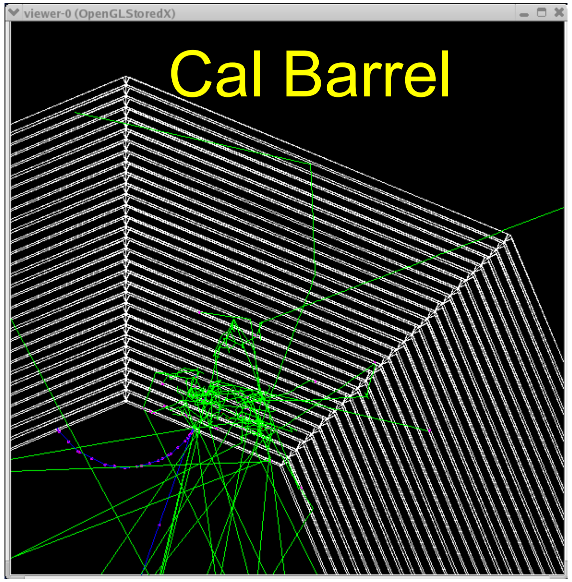
Detector Variants

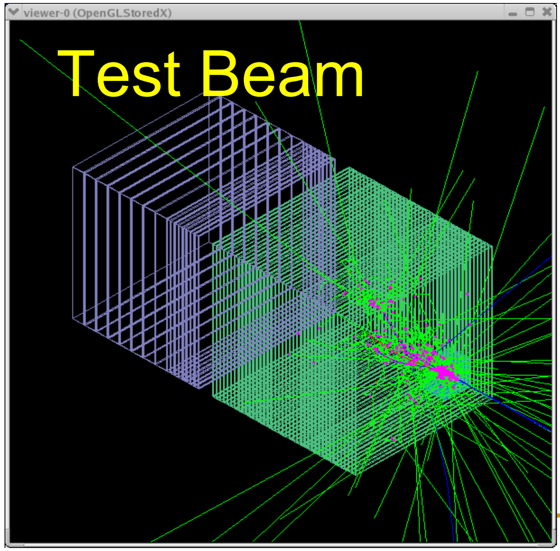
- Runtime XML format allows variations in detector geometries to be easily set up and studied:
  - Stainless Steel vs. Tungsten HCal sampling material
  - RPC vs. GEM vs. Scintillator readout
  - Layering (radii, number, composition)
  - Readout segmentation (size, projective vs. nonprojective)
  - Tracking 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)

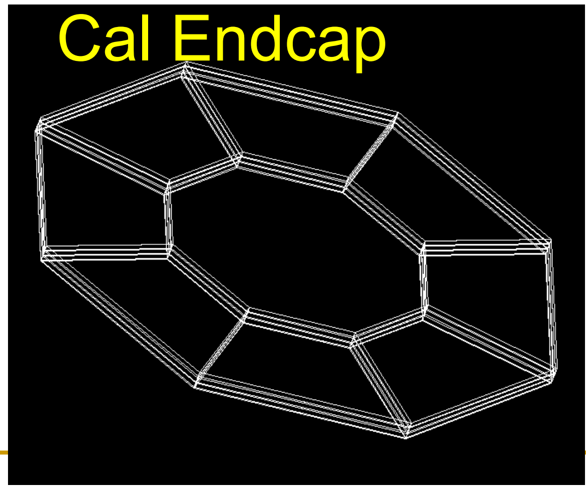
Example Geometries



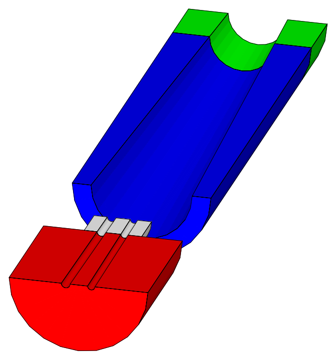








MDI-BDS



Reconstruction

- Many of the core reconstruction algorithms (track finding, fitting, calorimeter clustering, etc.) are in place.
- Have defined interfaces for a number of tasks, with many different plug-&-play implementations (e.g. calorimeter clustering).
- Standardized algorithm comparison tools.
- Standard calorimeter calibration procedures.
- Concentrating on implementing a template for individual particle reconstruction:
  - Decouples interdependencies of different tasks.
  - Allows comparisons between different algorithms or implementations.
  - Easily swap in MC "cheater" to study effects of particular analysis task, independent of other tasks.

LCIO Utilities

- A number of LCIO file-handling tasks have been assembled and are available as command-line options.

  > lcio -h

  usage: LcioCommandLineTool

  Commands:

  compare

  concat

  validate

  siodump

  print

  stdhep

  split

  random

  count

  merge

  -h Print lcio command-line tool usage.

  -v Set the verbosity.

LCIO split / concat

- *split* simply splits input file into smaller parts

  > lcio split

  usage: split

  -i The input LCIO file.

  -n The number of events to split.

- Similarly, *concat* concatenates many lcio files into one single file.

  > lcio concat -h

  usage: concat

  -f List of input files, 1 per line.

  -i Add an input file.

  -o Set the name of the output file.

LCIO stdhep

- *stdhep* converts MC files in stdhep format into LCIO format.
- *merge* combines events, merging MC particle and detector hit lists, including time offsets:

  > lcio merge -i file1.slcio -i file2.slcio -o merged.slcio

  can also specify a file with a list of files to merge:

  > lcio merge -f mergefiles.txt -o merged.slcio

  The file mergefiles.txt should have the following format:

  [file_name],[n_reads_per_event],[start_time],[delta_time]

  So this would pileup 5 backgrounds onto some events:

  events.slcio,1,0,0

  backgrounds1.slcio,5,0,1

“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 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

Backgrounds

- Once machine parameters decided, generate Cain & GuineaPig pairs and photons.
  - Add crossing angle, convert to stdhep
- Generate muons and other backgrounds from upstream collimators & convert to stdhep.
- $\gamma\gamma \rightarrow$ hadrons generated as part of the “2ab^{-1} SM sample.” Redo with new machine settings.
- All events then capable of being processed through full detector simulation.
- Additive at the detector hit level, with time offsets, using LCIO utilities.

ALCPG Simulation Summary

- ALCPG Sim/Reco team supports an ambitious detector simulation effort.
- Goal is flexibility and interoperability, not technology or concept limited.
- Provides full data samples for ILC physics studies.
  - Stdhep and LCIO files available on the web.
- Provides a complete and flexible detector simulation package capable of simulating arbitrarily complex detectors with runtime detector description.
- Reconstruction & analysis framework exists, core functionality available, individual particle reconstruction template developed, various analysis algorithms implemented.
- Need to iterate and apply to various detector designs.

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