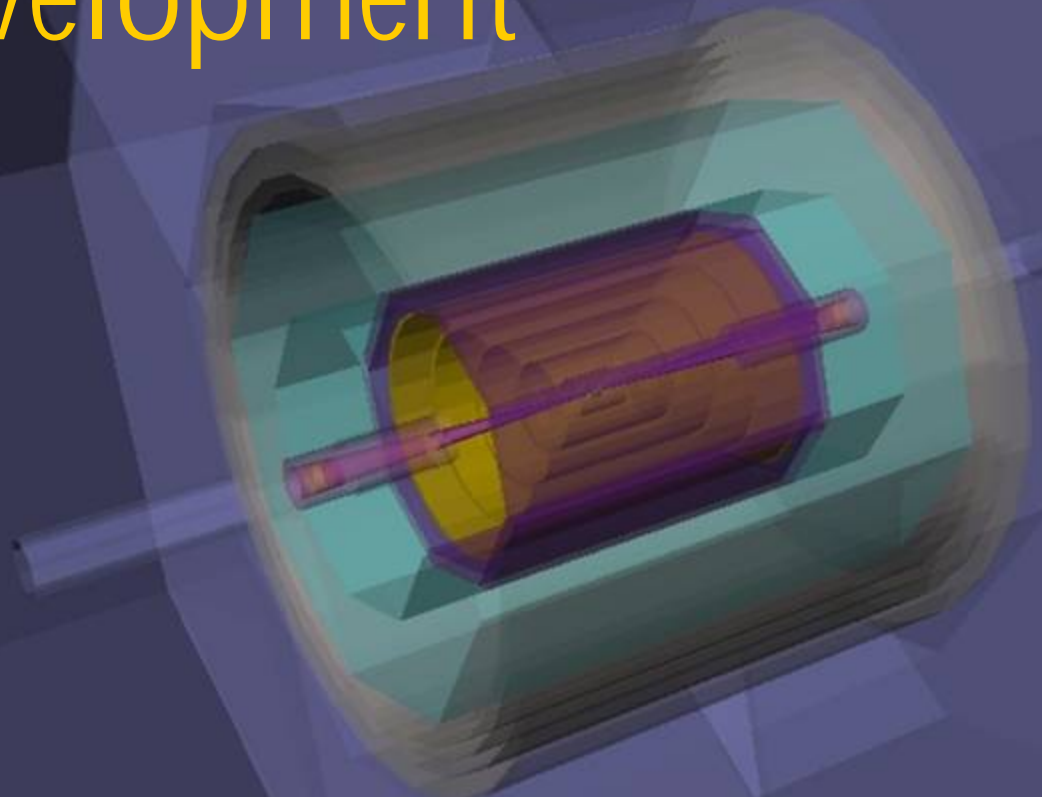


ALCPG Detector Software Development



Norman Graf (SLAC)

ALCPG Physics & Detector Simulation & Reconstruction Group

ACFA LC Meeting (TILC08)

Sendai, March 4, 2008

Software Development Overview

- Physics analyses.
 - Refine and strengthen the arguments for the ILC.
- Detector design.
 - Integrated system design for an optimal detector.
- Event reconstruction.
 - Demonstrate that proposed detector systems can conduct the physics program, and allows cost-benefit optimization to be done.
- Testbeam and prototype infrastructure.
 - Support subsystem design, readout and analysis.

LCD Simulation Mission Statement

- Provide full simulation capabilities for Linear Collider physics program:
 - ❑ Physics simulations
 - ❑ Detector designs
 - ❑ Reconstruction and analysis
- Need flexibility for:
 - ❑ New detector geometries/technologies
 - ❑ Different reconstruction algorithms
- Limited resources demand efficient solutions, focused effort.
 - ❑ Strong connections between university groups, national labs, international colleagues.

Goals

- Facilitate contribution from physicists in different locations with various amounts of available time.
- Use standard data formats, collaborate & cooperate.
- Provide a general-purpose framework for physics software development.
- Develop a suite of reconstruction and analysis algorithms and sample codes.
- Simulate benchmark physics processes on different full detector designs.
- Software is easy to install, learn, use. “0 to analysis in 15 min.”
 - Goal is to allow software to be installed from CD or web with no external dependencies.
 - Support via web based forums, tutorials, meetings.

Fast Monte Carlo

- Despite the move towards more realistic, fully engineered detector designs, the need for fast Monte Carlo still exists.
 - Large statistics physics studies (see talk by T. Rizzo)
 - Understand full reconstruction needs and/or systematics
 - Perform first-pass filter on SM background sample & reduce number of events needed to be processed through GEANT
- FastMC
 - covariant track smearing, parameterized cluster smearing
- lelaps
 - fast track extrapolation with MCS & dE/dx , decays, tracker & cal. hit generation, param. shower shapes

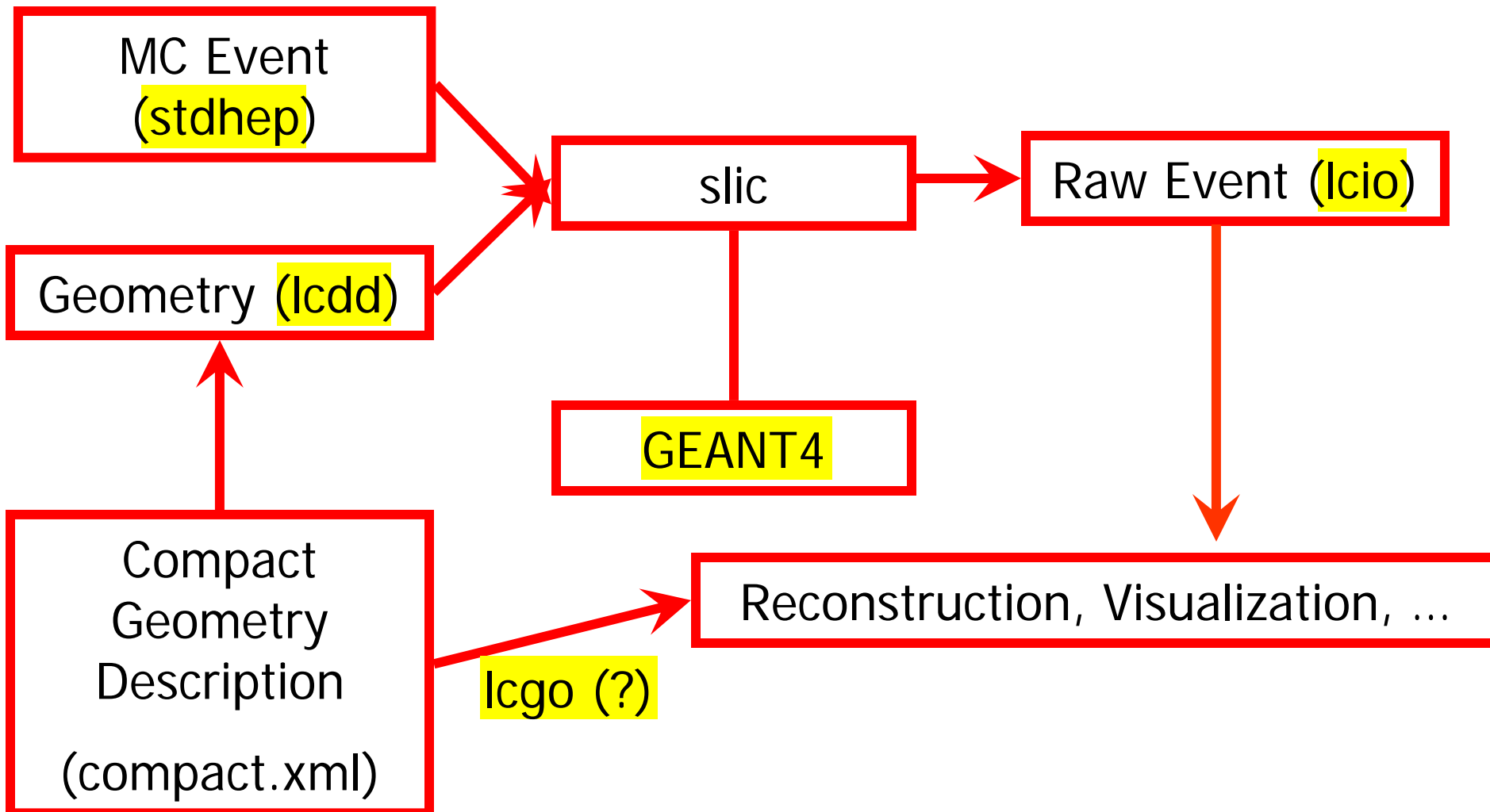
Fast Monte Carlo

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- lelaps
 - ❑ fast track extrapolation with MCS & detector cracker & cal. hit generation, param. shower shapes



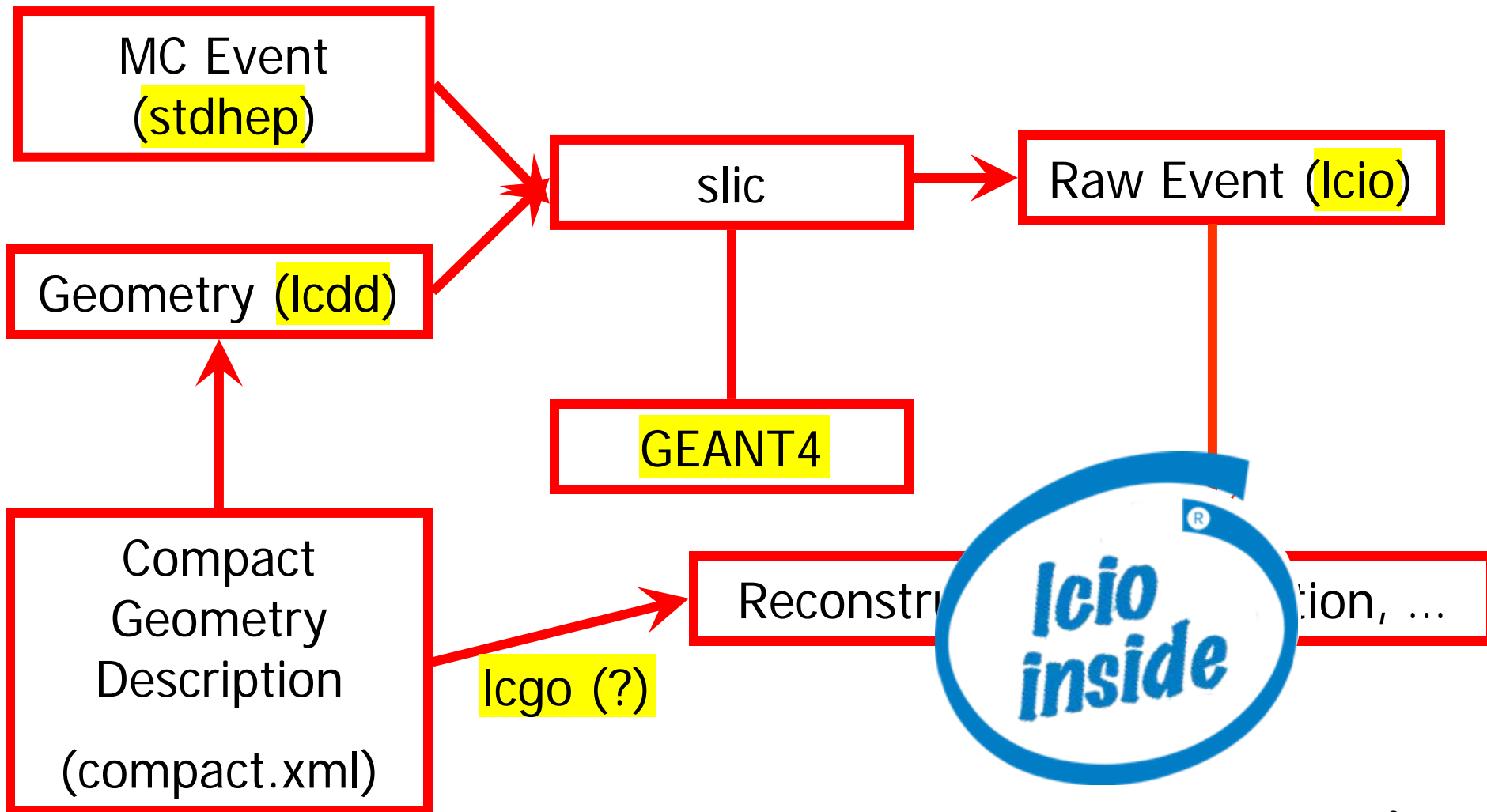
LC Detector Full Simulation

Items highlighted in yellow represent common standards



LC Detector Full Simulation

Items highlighted in yellow represent common standards



slic

- Number of internal optimizations and refactorings.
 - Should not be noticed by end users.
- Upgrades to recent version of Geant4 (9.1p1) has essentially eliminated problem of event aborts when particle tracking became stuck.
- Output file autonaming option provides provenance.

panpyZmumuh120-0-500_SLIC-v2r3p10_geant4-v9r0p1_LCPhys_sid01.slcio
input stdhep file name generator & version geant version physics list det name

- slic from scratch:

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

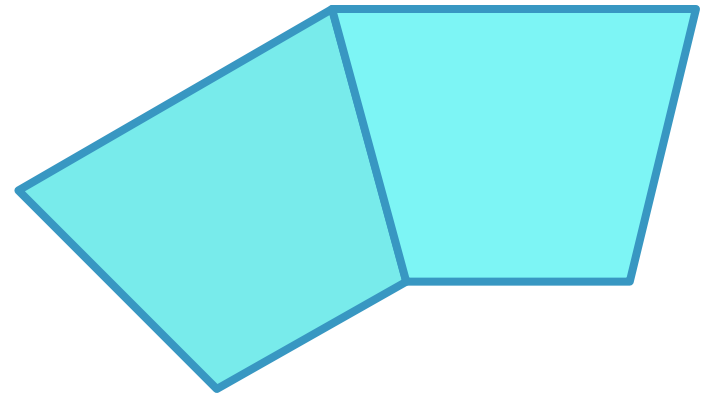
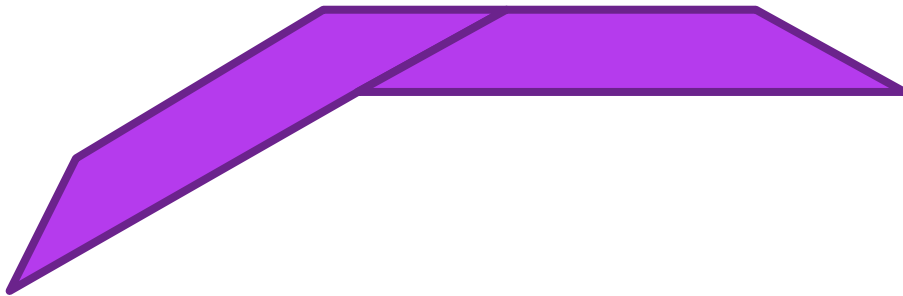
- Binaries also available for Windows, Mac, Linuxes

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 vs. dual readout
 - Layering (radii, number, composition)
 - Readout segmentation (size, projective vs. nonprojective)
 - Tracking detector technologies & topologies
 - TPC, Pixels, Silicon microstrip, SIT, SET
 - “Wedding Cake” Nested Tracker vs. Barrel + Cap
 - Field strength
 - Far forward MDI variants

Improved Calorimeter Simulations II

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



- Can define ~arbitrary layerings (and boundary stay-clears) within these envelopes to simulate sampling calorimeters.
- Additional geometries (e.g. tilted polyhedra) will be developed on an as-needed basis.
- Support for dual readout, e.g. optical processes, included.

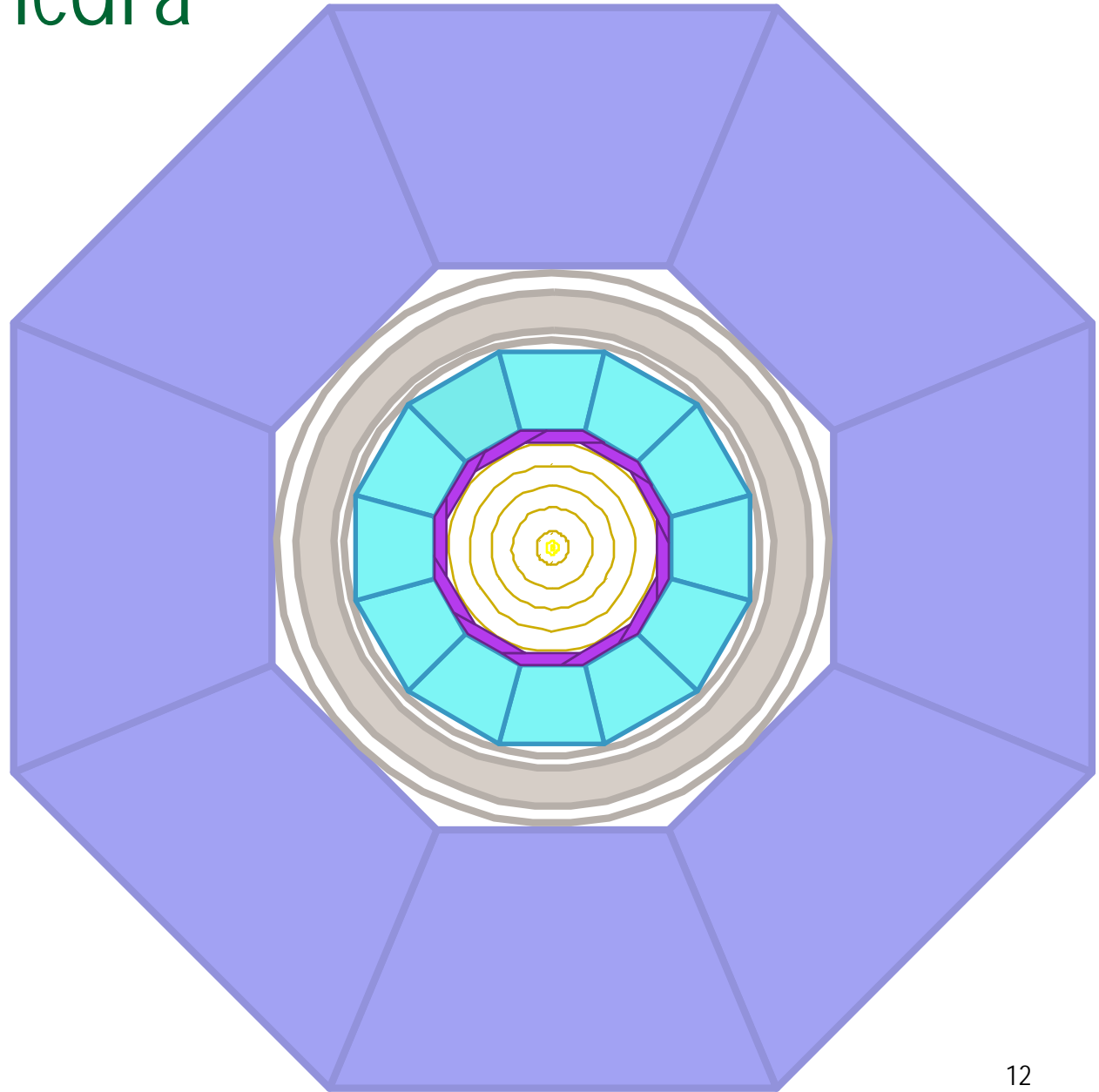
sid01_polyhedra

Dodecagonal,
overlapping
stave EMCal

Dodecagonal,
wedge HCal

Cylindrical
Solenoid with
substructure

Octagonal,
wedge Muon



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.

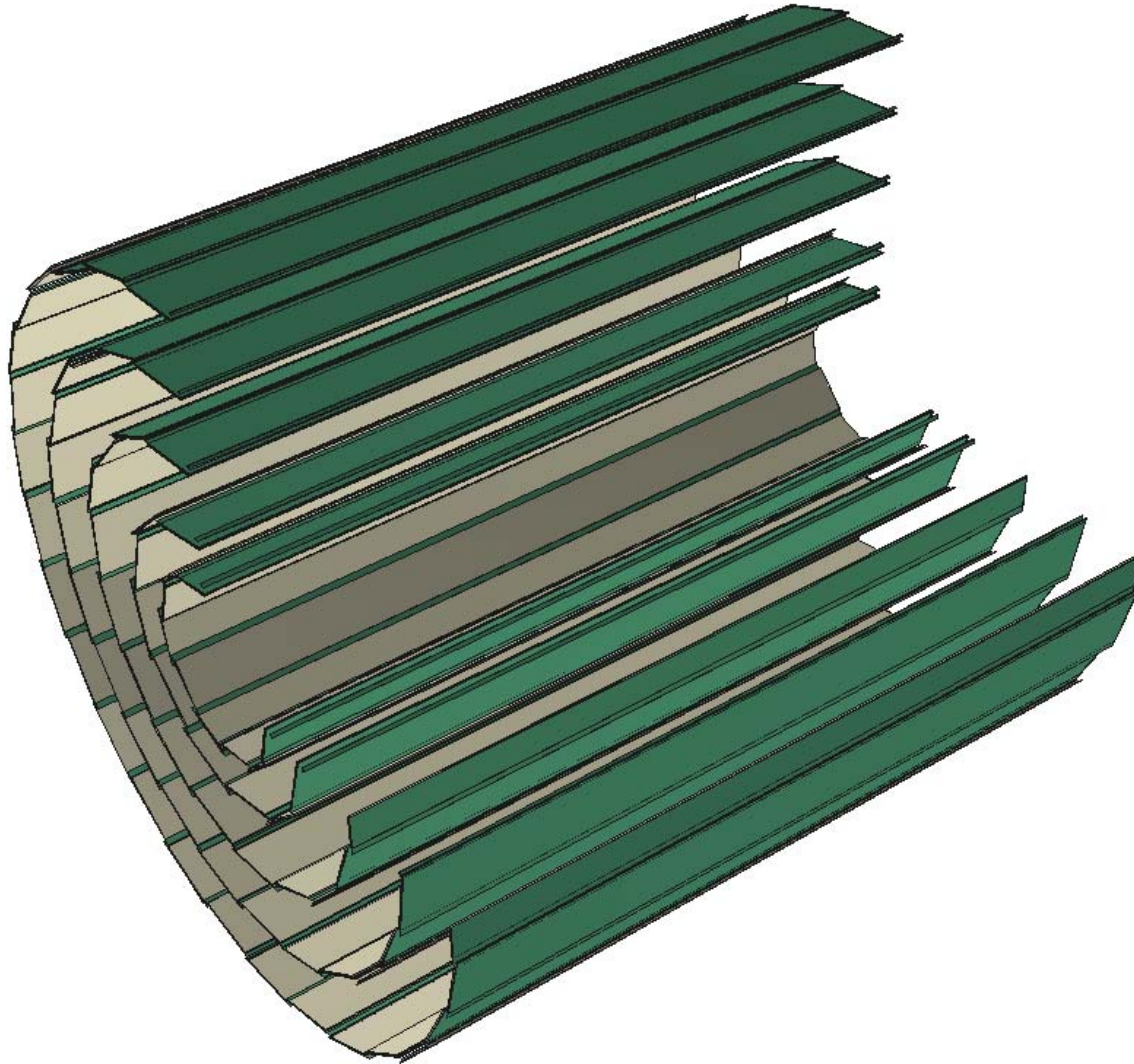
xml: Defining a Module

```
<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

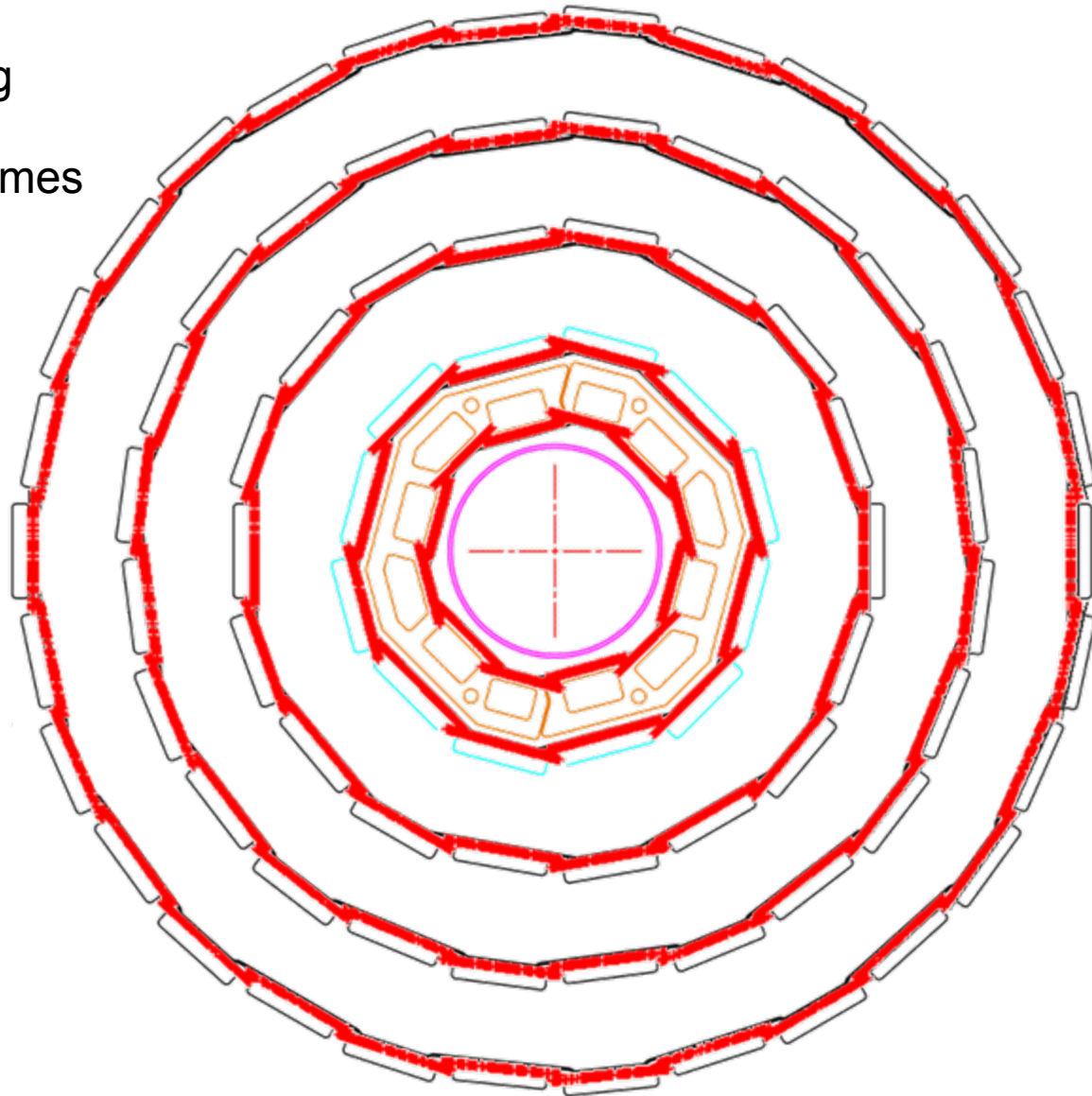


LCIO SimTracker Hits from Vertex

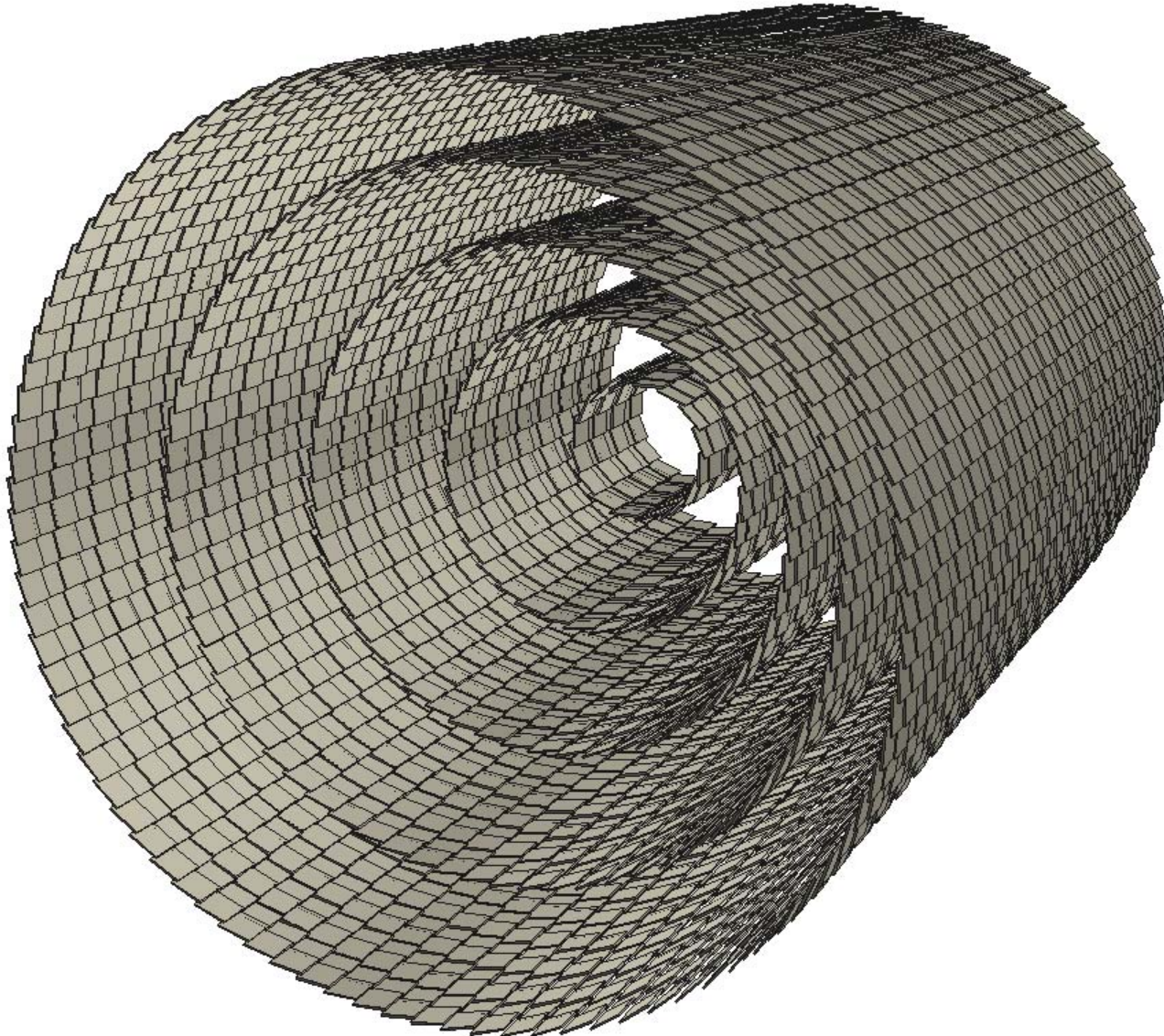
CAD Drawing

GEANT Volumes

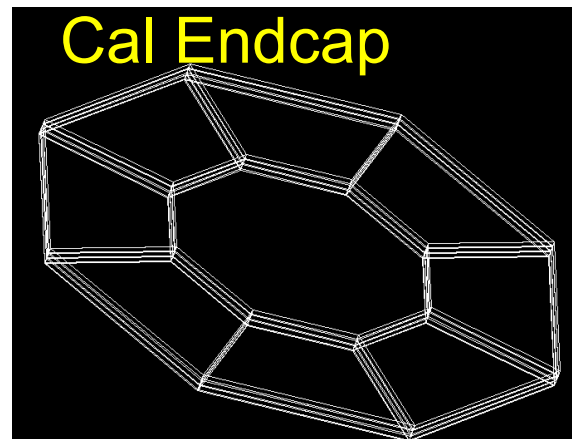
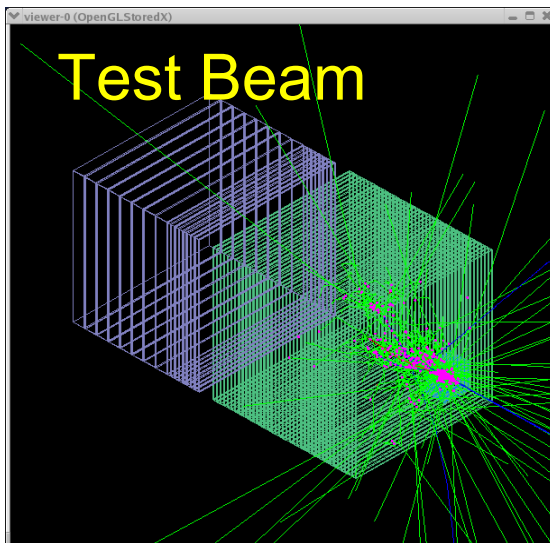
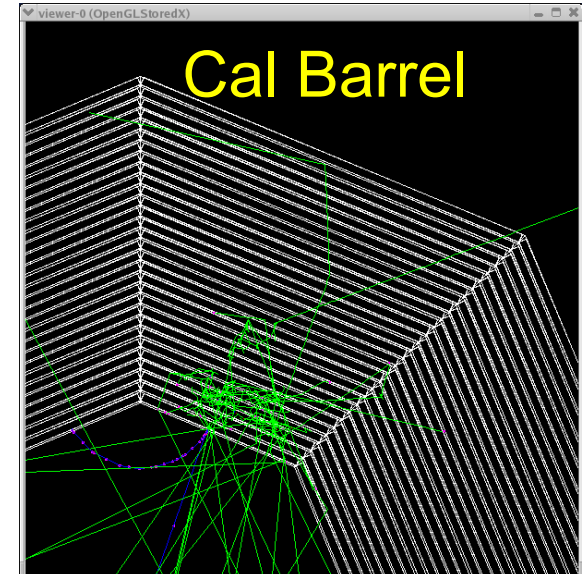
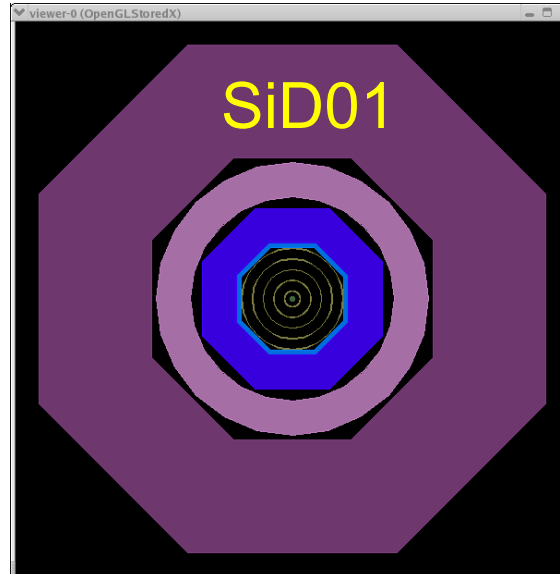
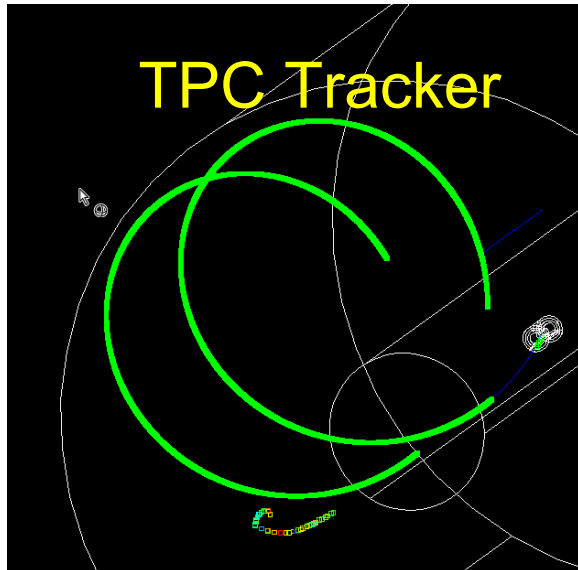
LCIO Hits



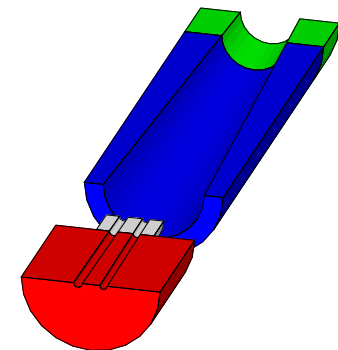
The Barrel Outer Tracker



Example Geometries (same exe)



MDI-BDS

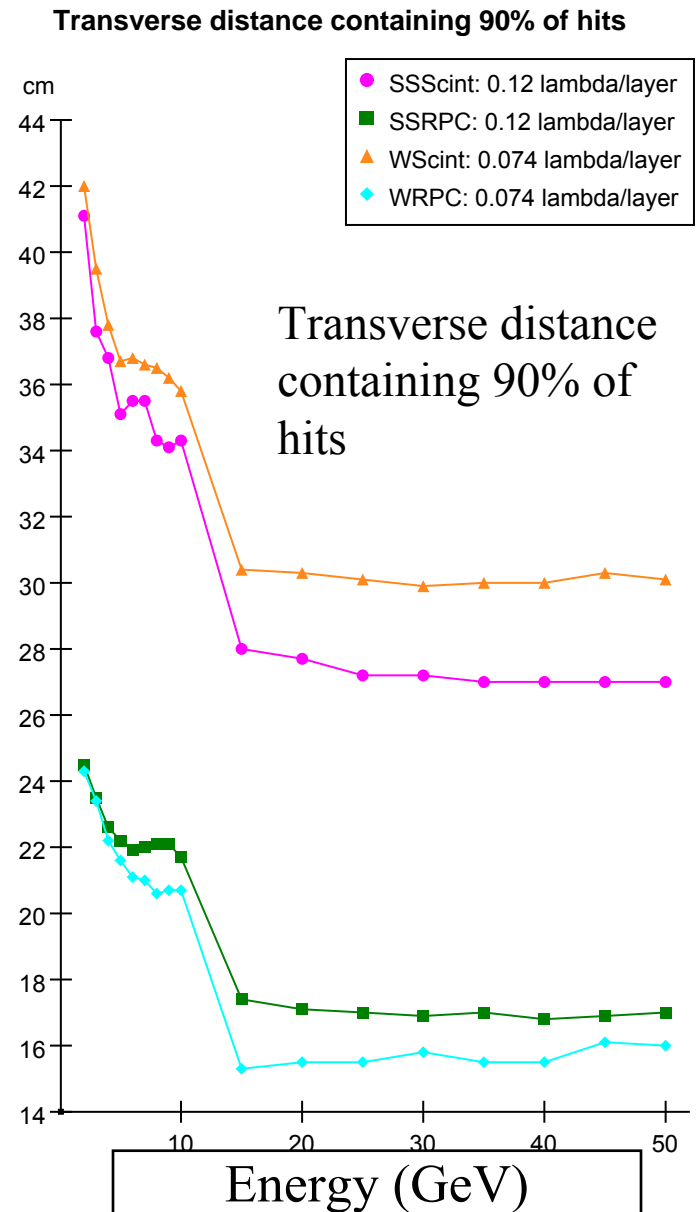


More complex geometries

- Arbitrarily complex geometries can be accommodated in the lccd detector description, but these will not be propagated to the reconstruction system.
 - May be appropriate for supports, readouts, and far-forward BDS/MDI elements.
- CAD to GEANT functionality implemented, and tested for simple elements, so engineering drawings for some elements can be adopted ~as-is.
- Will, of course, have an impact on performance due to use of BREPS in Geant.

Physics Lists & Hadron Showers

- Number of issues still unresolved with choice (or not) of showering models.
- For many neutral hadrons LHEP (Gheisha-inspired) is only choice.
- Transition regions still very worrisome.
- LCPhys is still default, but all lists available.
- FTFP_BERT looks good.



Diagnostic Histograms

- Diagnostic plots of event data
 - MCParticles, hits, clusters
- Runs on different detectors
 - must have compact description
 - also need sampling fractions
- Easy to use and setup
- on the web at

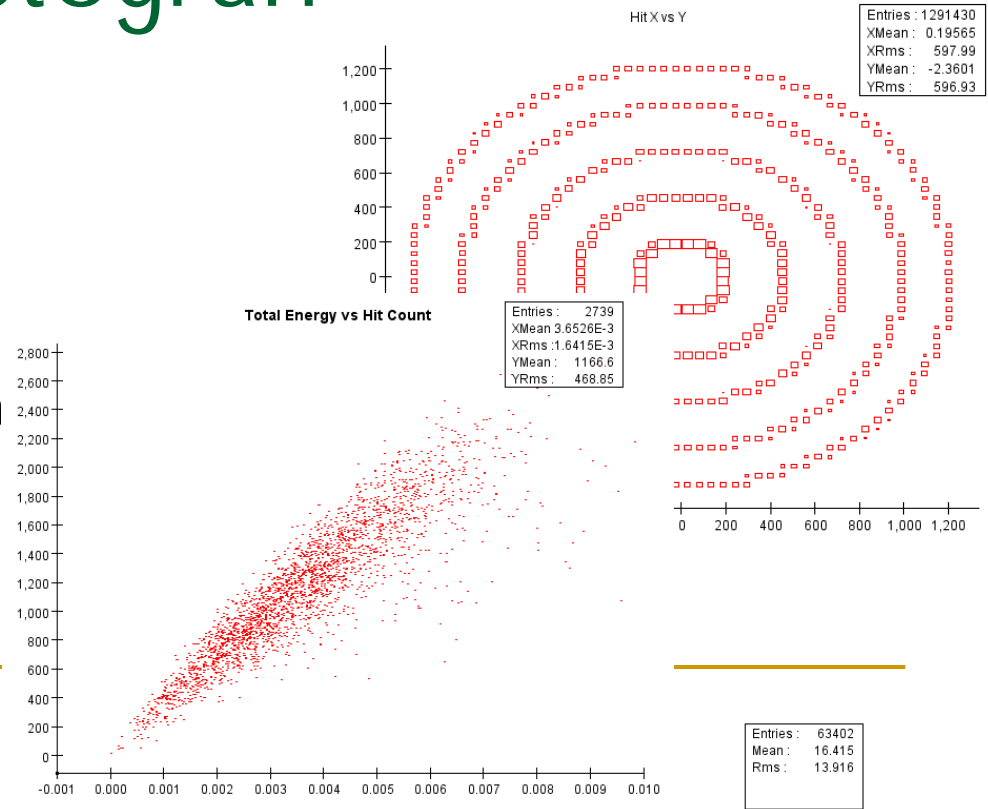
<http://lcsim.org/SlicDiagWeb/>

- SLAC CVS project

• `cvs -d :pserver:anonymous@cvcs.freehep.org:/cvs/lcd co SlicDiagnostics`

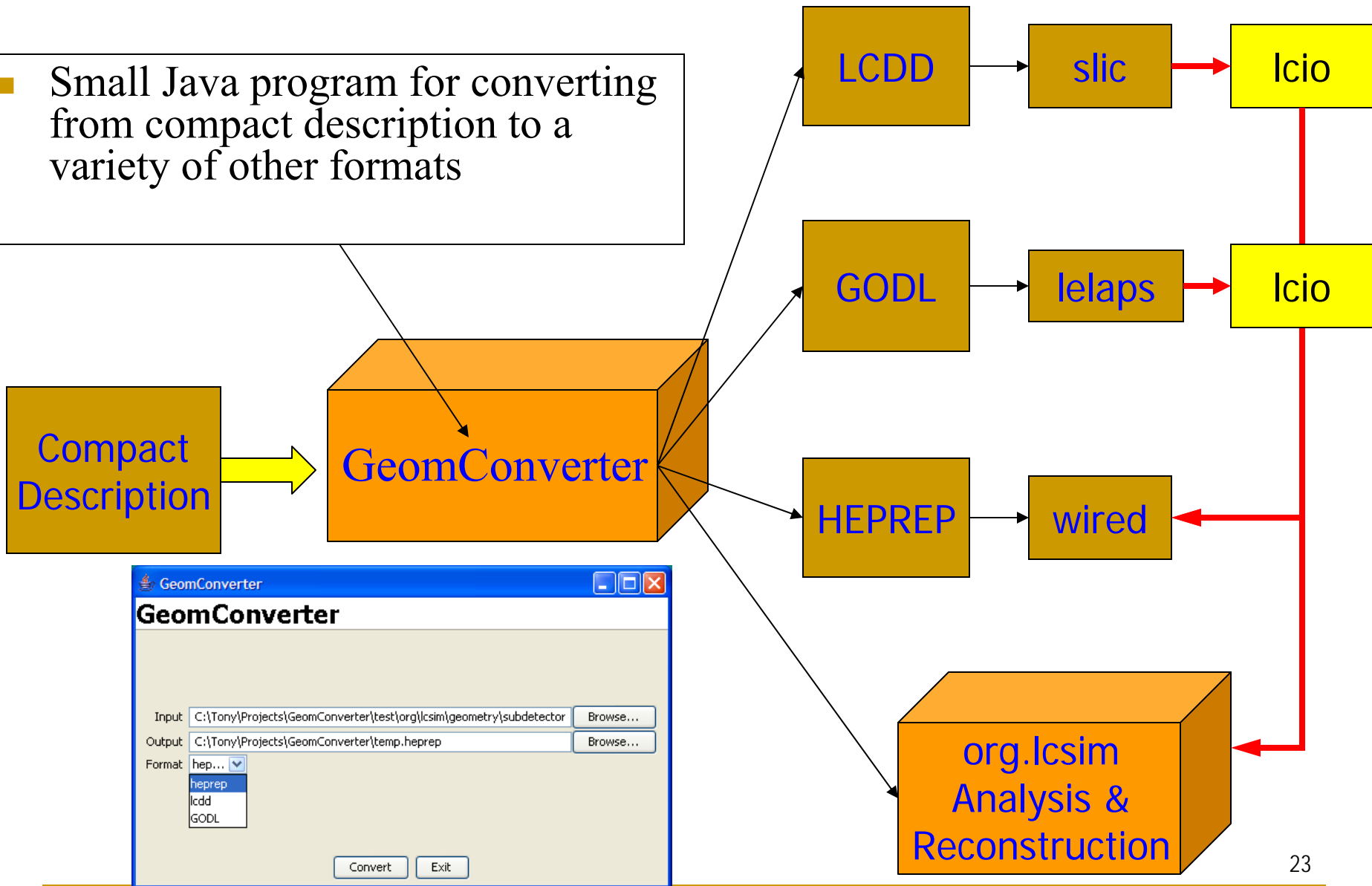
• `./build.sh`

• `./bin/SlicDiagnostics [...]`



GeomConverter

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



Hit modules and strips in Wired



Event 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 , $t\bar{t}$, $q\bar{q}$, tau pairs, mu pairs, $Z\gamma$, Zh
- beam pairs, muons, $\gamma\gamma \rightarrow$ hadrons, etc. backgrounds
- inclusive 1 ab^{-1} Standard Model sample
- Web accessible <http://www.lcsim.org/datasets/ftp.html>
- Additive at the detector hit level, with time offsets.
 - Investigate effects of full backgrounds.

Beam Background Overlays

- Take output from full beam simulation (from IR/backgrounds group)
- Feed into full detector simulation
- Build library of simulated background bunches
- Overlay backgrounds on signal events at start of reconstruction
 - Adjust timing of hits (for TPC e.g.)
 - Add energy in calorimeter cells
- Allows to change #bunches/train, bunch timing

Reconstruction Toolkit

- Core reconstruction algorithms (track finding, fitting, calorimeter clustering, etc.) are in place.
- Interfaces defined for tasks, with many different plug-&-play implementations (e.g. calorimeter clustering).
- Standardized algorithm comparison tools.
- Analyses targeted to ReconstructedParticles
 - 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.
 - Physics analyses can be developed and tested using fast Monte Carlo smearing, seamlessly transition to full reco.

Individual Particle Reconstruction

- Reconstruction is complex & you have to get many individual steps right:
 - track finding, fitting & extrapolation
 - track-cluster matching
 - MIP identification
 - photon identification
 - hadronic shower clustering (digital vs analog, scintillator vs gaseous readout)
 - handling of displaced secondaries
 - calibration of photons
 - calibration of neutral hadrons
 - E/p cut (including calibration)
- Algorithm development isn't about finding the "magic bullet" perfect algorithm. It's about iteratively
 - finding the worst problems that are limiting performance
 - fixing them
 - hopefully seeing things improve a little
 - finding the next worst problems

M. Charles

Individual Particle Reconstruction

- Algorithms being developed with minimal coupling to specific detector designs.
 - Will allow full phase space of detector designs to be studied in a common framework.
- Finishing development of common infrastructure tools
 - Calibration method for detector models
 - Perfect PFA prescription
- Released reconstruction template
 - Enables e.g. Cluster algorithm substitution, CAL hit/cluster accounting
 - Migrating individual analyses into this framework
- Optimization & Standardization of reconstructors
 - Photon & muon finders fairly mature, close to release (meeting @ Clermont-Ferrand in July)
- Use of LCIO allows (in principle) exchange of algorithms across language, OS and regional boundaries.
- Analysis emphasis on dijet invariant mass resolution in physics events
 - Currently $e^+e^- \rightarrow ZZ \rightarrow (v\bar{v})(q\bar{q})$ (No jet combinatorics, uds) (2)
 - Next in line $e^+e^- \rightarrow ZZ \rightarrow (q\bar{q})(q\bar{q})$ & $e^+e^- \rightarrow ZZv\bar{v}, WWv\bar{v}$ (4)
 - $\rightarrow t\bar{t}$ (6)
 - $\rightarrow t\bar{t}h$ (8)
- Plan to release “canned” physics analyses to reduce systematic uncertainties in e.g. jet-finding, combinatorics, constrained fits, ...

Performance Comparisons

- Reconstructing boson decays into dijets requires exceptional jet energy and direction resolution, is one of the driving forces in the current round of software development and will be used as a metric in the design of the detectors.
- Community benefits from close cooperation & collaboration.
 - Common input data samples (events in stdhep format)
 - Common simulation/reconstruction output formats
 - List of ReconstructedParticles in LCIO format
- Most important aspect of interoperability with other regional simulation and reconstruction efforts is a common data model!

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Root(?)

- ALCPG sim/reco group fully supported a Root-based environment starting in 1999.
- See, for instance, nice talk by M. Iwasaki at LCWS00 http://conferences.fnal.gov/lcws2000/web/Iwasaki_sessionD1/Iwasaki_sessionD1.pdf
- Documentation at: http://www-sldnt.slac.stanford.edu/nld/New/Docs/LCD_Root/intro.htm
- Support lapsed due to developers (M. Iwasaki, T. Abe) moving on and lack of user base at the time.
- Jupiter & satellites written within a Root environment.
- Note that using Root does not provide interoperability
 - CDF/DØ @ TeVatron, CMS/ATLAS @ LHC all use Root, but have completely different event data models. No commonality!

Resources for getting started

■ <http://lcsim.org/> Web Site

□ Tutorials

- Software installation
- Using tools
- Simple Analysis Examples
- Developers Guide

□ Datasets

□ Documentation

■ Confluence Wiki

- More tutorials
- More documentation
- Frequently asked Questions
- Users are encouraged to comment on, add to, or correct existing documentation
 - <https://jira.slac.stanford.edu/signup>

The screenshot shows the ILC Wiki page with the following sections:

- Introduction**: This site is designed to provide physicists the tools needed to investigate the physics potential of a linear e^+e^- collider. Many of the tools necessary to generate Monte Carlo events, simulate the response of typical detectors, and conduct the ensuing analysis of the "data" can be found at this site or others linked from here.
- Getting Started**
 - [collider Tutorial](#) - instructions on setting up and using the Java reconstruction framework
- Datasets**
 - [ILC Datasets](#) - instructions for accessing datasets via anonymous FTP
- Detectors**
 - [Detectors](#) - list of available compact format detector descriptions
- Wiki**
 - [ILC Confluence Wiki](#) - collaborative documentation site
- Feedback**
 - [LinearCollider.org Forum](#) - get feedback from the experts

The page also features a search bar, a "Contributing to the ILC Wiki" notice, and a "Links" section with the following items:

- [ana-tools-tutorial](#)
- [ana-tools-wiki](#)
- [ana-tools-proprietary-licenses-overview](#)
- [ana-tools-homepage](#)
- [detector-overview-homepage](#)
- [LCSIM](#)
- [Marlin](#)

The "Recently Updated" section includes:

- [ana-tools-package-overview](#) by Jane Johnson (16 hours ago)
- [ILC Frameworks Links](#) by Jennifer McCreesh (14 hours ago)
- [Java Links](#) by Jennifer McCreesh (14 hours ago)
- [New ana-tools Package overview](#) by Jennifer McCreesh (10 hours ago)
- [How do I install/develop in Private Java](#) by Tara Johnson (03 April 2012)
- [ana-tools](#) by Jane Johnson (02 April)
- [How can I write out an LCIO file from on.isim?](#) by Jane Johnson (04 April)
- [Contributing to ILC Software Projects](#) by Jennifer McCreesh (02 April)

Resources for getting started

Discussion Forums

❑ <http://forum.linearcollider.org/>

■ SLIC, org.lcsim

❑ Not recommended

■ Spray E-mail to developers

❑ Banging head against wall

❑ Uninstall and reinstall software 3 times

❑ Recommended

■ Post questions on the forum

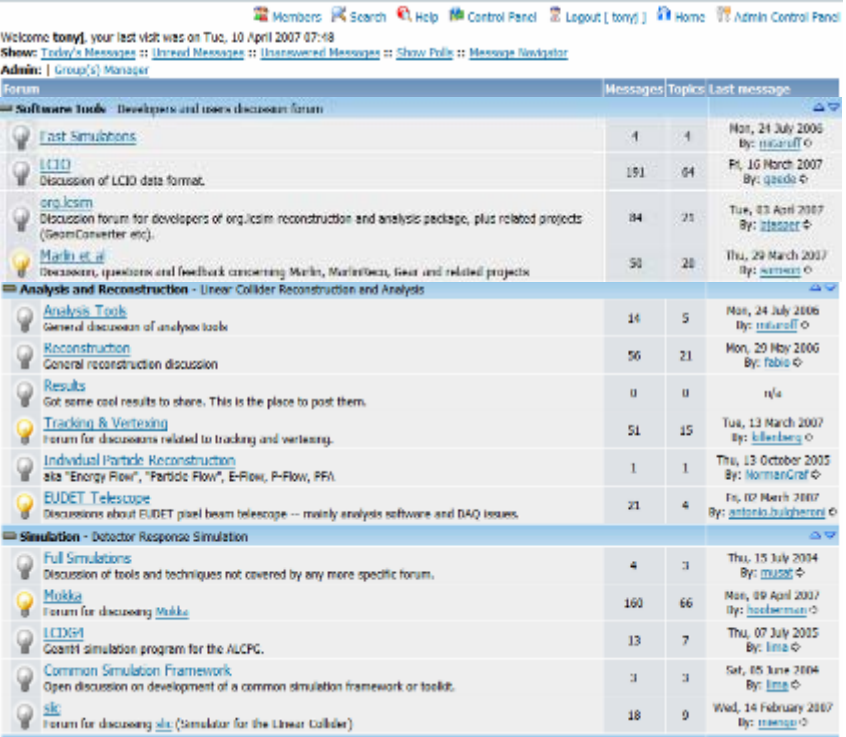
❑ You will get faster answers

❑ You will get more accurate answers

❑ Others will benefit from seeing answers to your questions

■ Discuss what you would like to do

❑ get feedback on best practices



Welcome **tonyj**, your last visit was on Tue, 10 April 2007 07:48
Show: [Tony's Messages](#) :: [Unread Messages](#) :: [Unanswered Messages](#) :: [Show Profile](#) :: [Message Linkinator](#)
Admin: | [Group's Manager](#)

Forum	Messages	Topics	Last message
Software Tools - Developers and users discussion forum			
Fast Simulations	4	4	Mon, 24 July 2006 By: mrsault
LCIO Discussion of LCIO data format.	191	64	Fri, 16 March 2007 By: quade
org.lcsim Discussion forum for developers of org.lcsim reconstruction and analysis package, plus related projects (GeomConverter etc).	84	25	Tue, 03 April 2007 By: jlsassat
Marlin et al Discussions, questions and feedback concerning Marlin, MarlinBench, Gear and related projects	50	28	Thu, 29 March 2007 By: sarnes
Analysis and Reconstruction - Linear Collider Reconstruction and Analysis			
Analysis Tools General discussion of analysis tools	14	5	Mon, 24 July 2006 By: mrsault
Reconstruction General reconstruction discussion	56	21	Mon, 20 May 2006 By: fabio
Results Got some cool results to share. This is the place to post them.	0	0	n/a
Tracking & Vertexing Forum for discussions related to tracking and vertexing.	51	15	Tue, 13 March 2007 By: kberberg
Individual Particle Reconstruction aka "Energy Flow", "Particle Flow", E-Flow, P-Flow, PFI	1	1	Thu, 13 October 2005 By: NormanCraf
EJDET Telescope Discussions about EJDET pixel beam telescope -- mainly analysis software and DAQ issues.	21	4	Fri, 02 March 2007 By: antonio.hulsterson
Simulation - Detector Response Simulation			
Full Simulations Discussion of tools and techniques not covered by any more specific forum.	4	3	Thu, 15 July 2004 By: mrsault
Mokka Forum for discussing Mokka	160	66	Mon, 09 April 2007 By: hooberman
LCIOsim Geant4 simulation program for the ALPCG.	13	7	Thu, 07 July 2005 By: lima
Common Simulation Framework Open discussion on development of a common simulation framework or toolkit.	3	3	Sat, 05 June 2004 By: lima
slc Forum for discussing slc (Simulator for the Linear Collider)	18	9	Wed, 14 February 2007 By: mrsault



Re: [Chester example](#)

By: [tonyj](#) on Thu, 24 March 2007 14:10

Re: [Chester example](#)

By: [tonyj](#) on Thu, 23 March 2007 13:16

Re: [Chester example](#)

By: [jlsassat](#) on Sat, 31 March 2007 22:10

Re: [Chester example](#)

By: [tonyj](#) on Mon, 02 April 2007 17:02

Re: [Chester example](#)

By: [tonyj](#) on Tue, 03 April 2007 14:04

By: [jlsassat](#) on Tue, 03 April 2007 23:10

Re: [org.lcsim frequently asked questions](#)

By: [tonyj](#) on Thu, 15 March 2007 11:05

Re: [org.lcsim frequently asked questions](#)

By: [mrsault](#) on Thu, 22 March 2007 15:04

Re: [org.lcsim frequently asked questions](#)

By: [jlsassat](#) on Thu, 22 March 2007 07:00

Re: [SimTrackerHk getLayer method](#)

By: [mrsault_jon](#) on Thu, 15 February 2007 14:00

Re: [SimTrackerHk getLayer method](#)

By: [mrsault_jon](#) on Thu, 15 February 2007 08:04

Re: [SimTrackerHk getLayer method](#)

By: [mrsault_jon](#) on Mon, 19 February 2007 22:15

Re: [SimTrackerHk getLayer method](#)

By: [mrsault_jon](#) on Mon, 19 February 2007 22:15

Re: [SimTrackerHk getLayer method](#)

By: [DmitryDrozhdenko](#) on Tue, 20 February 2007 18:05

Re: [SimTrackerHk getLayer method](#)

By: [mrsault_jon](#) on Mon, 20 February 2007 21:17

Summary

- ALCPG Sim/Reco team supports an ambitious physics and detector simulation, reconstruction & analysis 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.
- Effort sorely lacking in manpower. Any additional support provides immediate detector performance results.

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>

Backup Slides

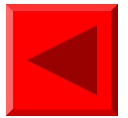
Fast Detector Response Simulation

- Covariantly smear tracks with matrices derived from geometry, materials and point resolution using Billoir's formulation.

<http://www.slac.stanford.edu/~schumm/lcdtrk>

- Derivative of TRKERR.
- Provides smeared tracks with full covariance matrix.
- Electromagnetic showers smeared in energy and position according to parameterized EM cal response.
- Hadron showers smeared in energy and position according to parameterized HCal response.
 - can mimic some aspects of confusion.
- “Jet Energy Resolution” can be input, will tweak the ratio of neutral to charged response to deliver “correct” a/\sqrt{E} .

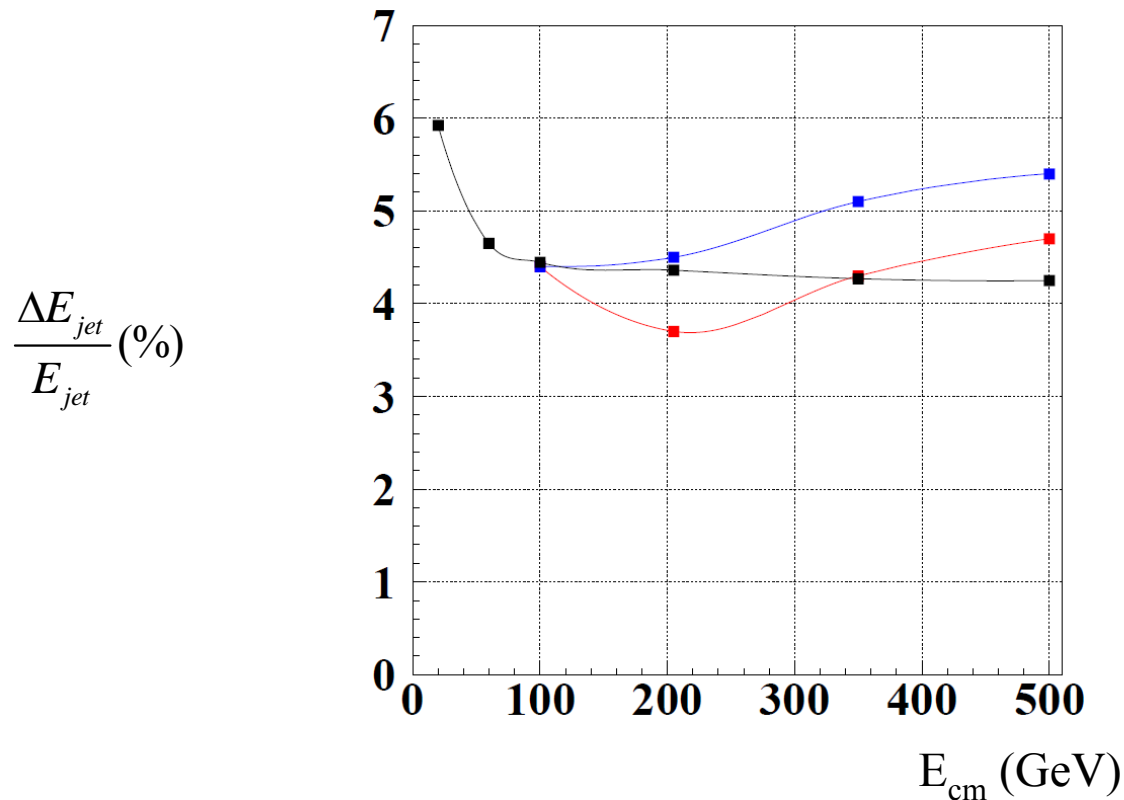
FastMC simulation of Calorimeter/PFA output



account for confusion term by blowing up single particle resolution for neutral hadrons

— GLD PFA — LDC PFA — org.lcsim
FASTMC with

$$\frac{\Delta E_\gamma}{E_\gamma} = \frac{0.18}{\sqrt{E_\gamma}} \quad \frac{\Delta E_{n,K_L^0}}{E_{n,K_L^0}} = 0.28$$



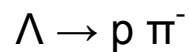
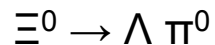
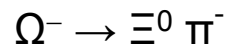
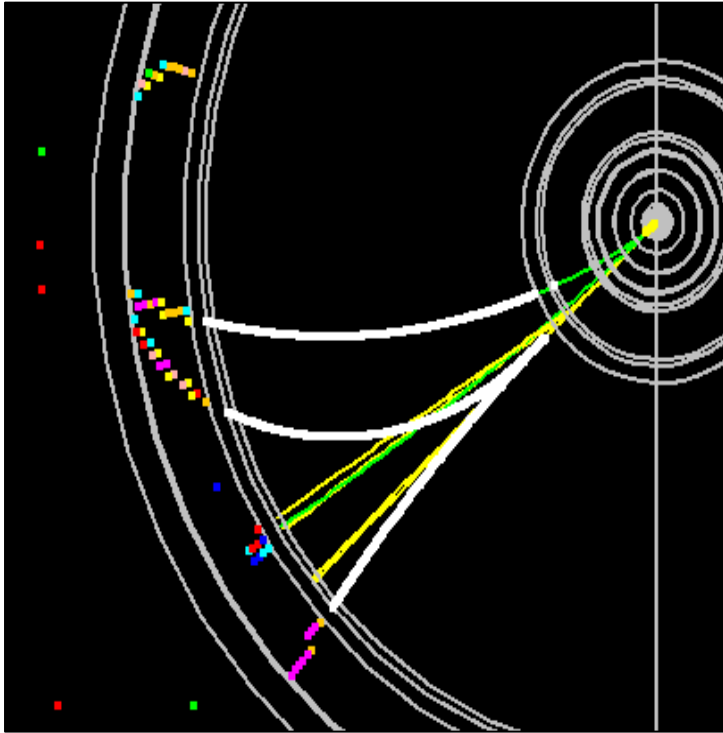
Light quark jets $ee \rightarrow qq$

lelaps

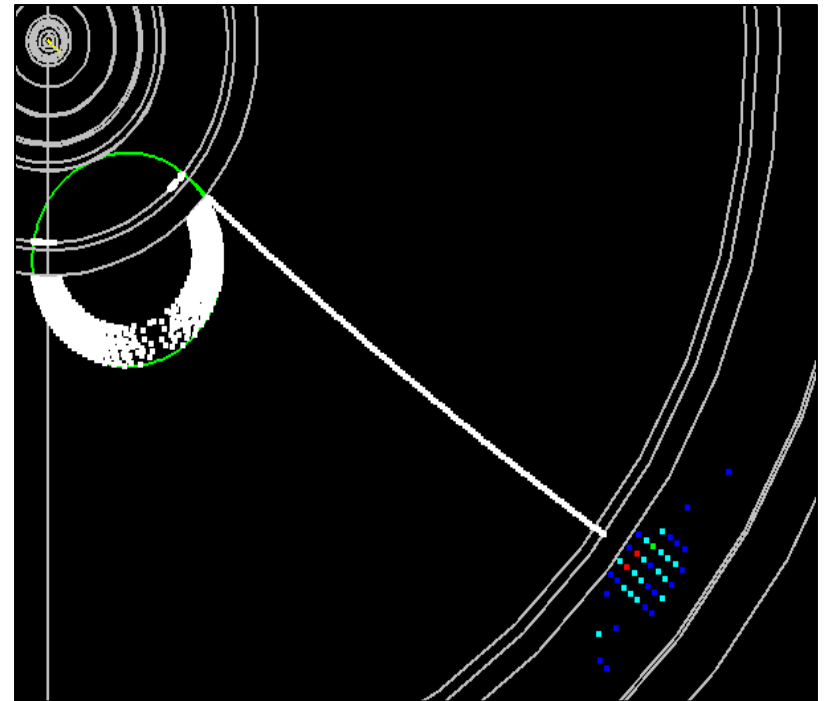
- Fast detector response package.
- Handles decays in flight, multiple scattering and energy loss in trackers.
- Parameterizes particle showers in calorimeters.
- Produces lcio data at the hit level.
- Uses runtime geometry (compact.xml → godl).
- An excellent tool for designing tracking detectors!

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

Lelaps: Decays, dE/dx, MCS



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



gamma conversion as
simulated by Lelaps for the
LDC model.

Note energy loss of electron. 41