SiD Simulation & Reconstruction

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The LOI Physics Benchmarks Process

- The Letter of Intent (LOI) process required a number of physics analyses to be conducted with full-detector simulation, *ab initio* event reconstruction, and analysis.
- Although still far from “real”, the physics benchmarking requirements presented us with a large-scale, end-to-end exercise which stressed most aspects of the software systems.
  - Event Generation
  - Detector Simulation
  - Event Reconstruction
  - Physics Analysis
- Let’s do it again!
- But let’s fix (and improve) a few things before doing so…

Simulation Overview

Framework	Software
Event Generation	Pythia, whizard, etc., [Stdhep]
↓	↓
Detector Simulation	SLIC, LCDD, Geant4, [LCIO]
↓	↓
Event Reconstruction	lcsim, GeomConverter, [LCIO]
↓	↓
Physics Analysis	lcsim, [AIDA], [LCIO]

Work Plan for 2012

1. Demonstrate proof of principle on critical components.
2. Define a feasible baseline design.
3. Complete basic mechanical integration of the baseline design…
4. Develop a realistic simulation model of the baseline design, including the identified faults and limitations.
5. Develop a push-pull mechanism, …
6. Develop a realistic concept of integration with the accelerator …
7. Simulate and analyze updated benchmark reactions with the realistic detector model.

   Include the impact of detector dead zones and updated background conditions.
8. Simulate and study some reactions at 1 TeV, including realistic higher energy backgrounds, demonstrating the detector performance.

   For 7 and 8, Specific physics channels will be investigated and defined by the Physics Common Task Group and supported by the Software Common Task Group.
9. Develop an improved cost estimate.

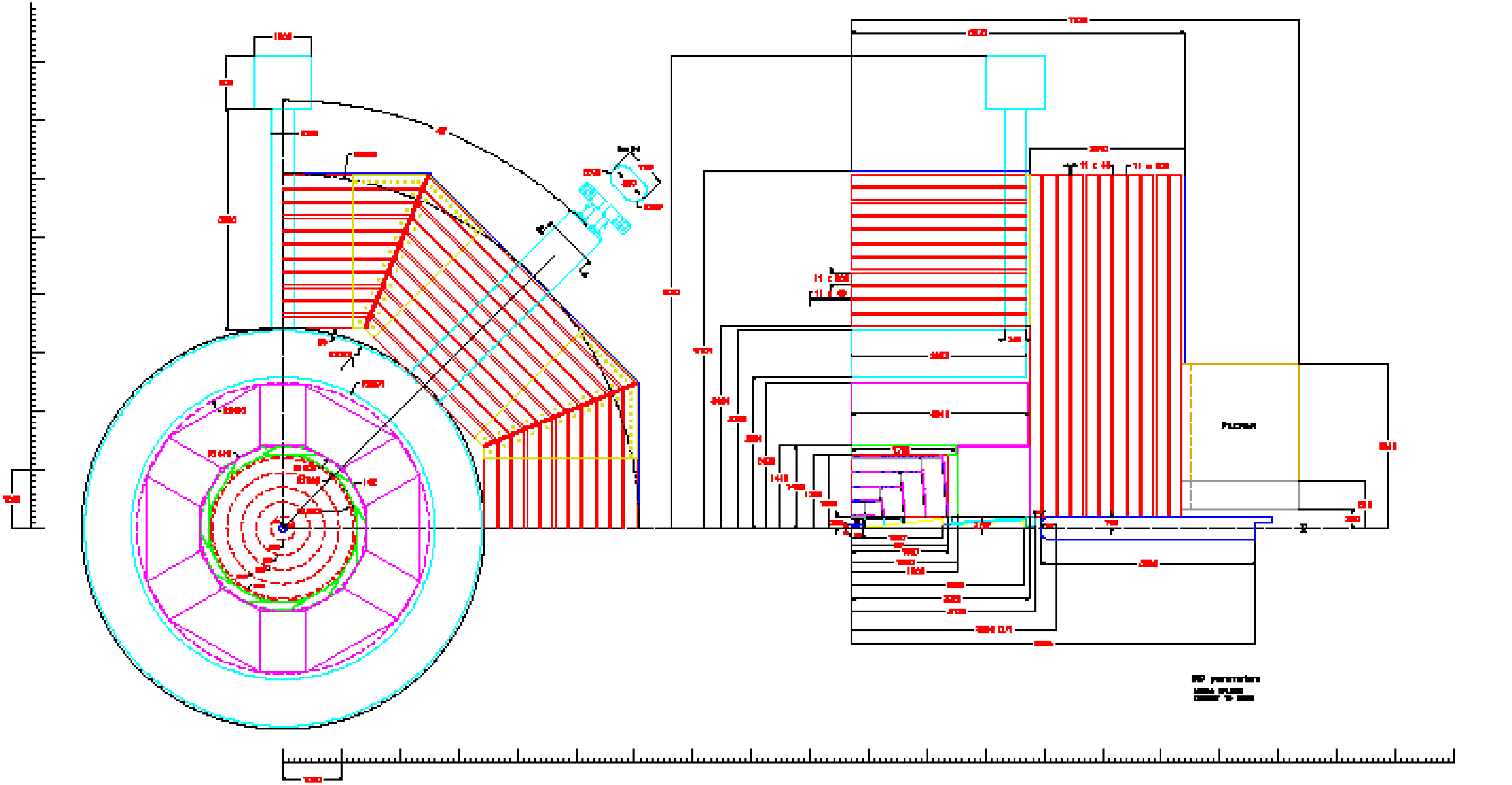
Detector Design

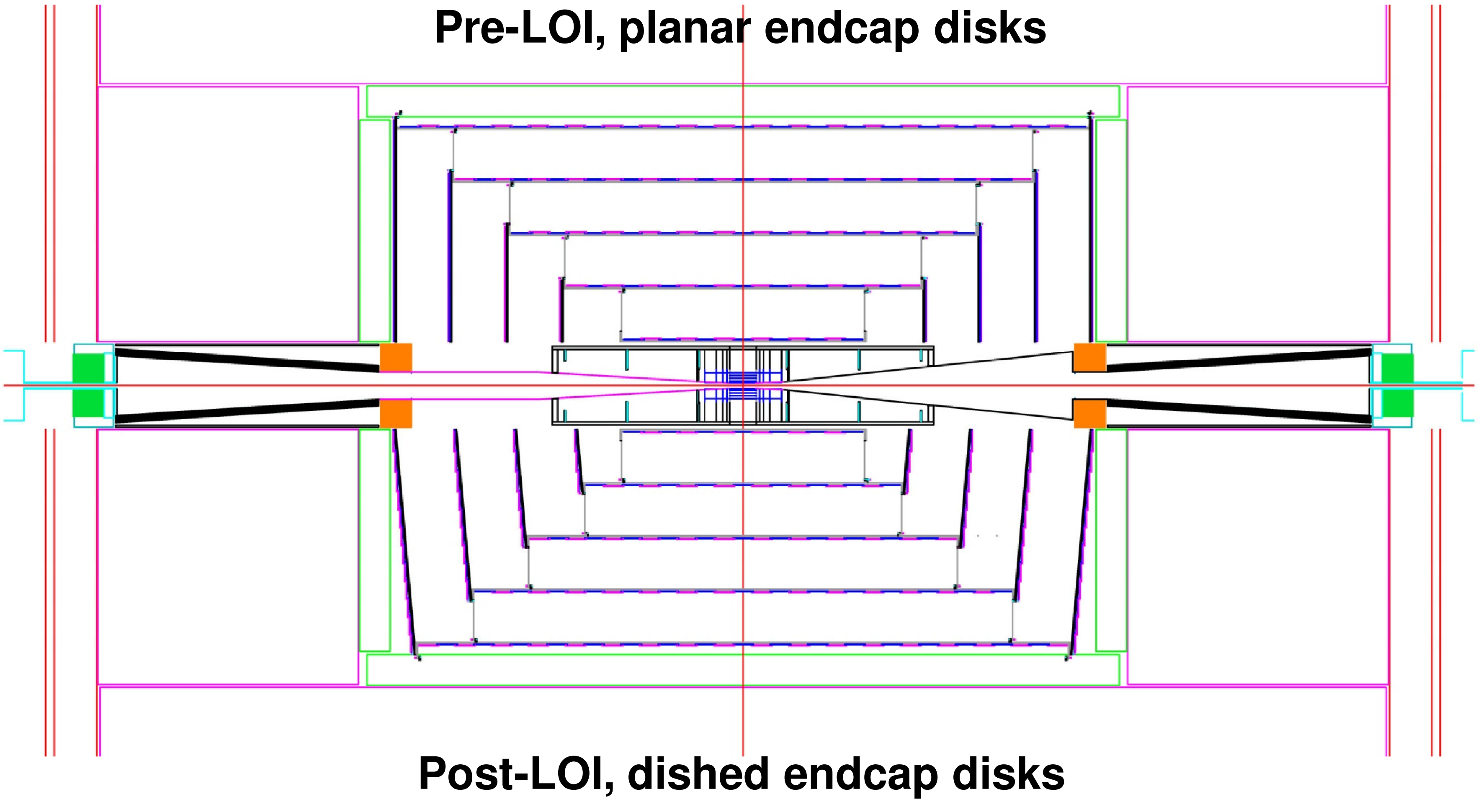
- Develop a realistic simulation model of the baseline design, including the identified faults and limitations.
- LOI studies were conducted with the sid02 geometry, using simplified geometries.

Beyond sid02

- The detector model sid02 was a necessary compromise between the desire to include all the details of the engineering designs and the need to complete the large-scale physics benchmarking simulations in a timely fashion.
- Since then have developed a detector model which includes more realistic detectors.
  - Benefits from engineering work done for the LOI.
  - Allows much more realistic subdetector performance studies to be undertaken.

Detector Modeling




Pre-LOI, planar endcap disks
Post-LOI, dished endcap disks

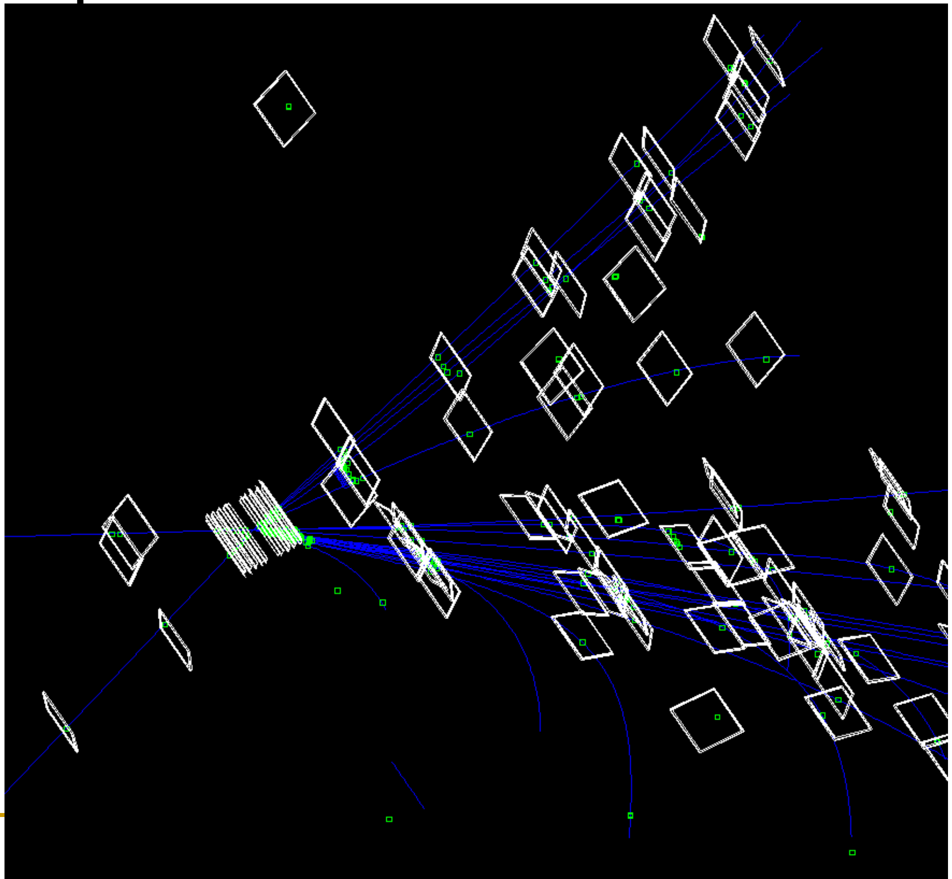
sidloi

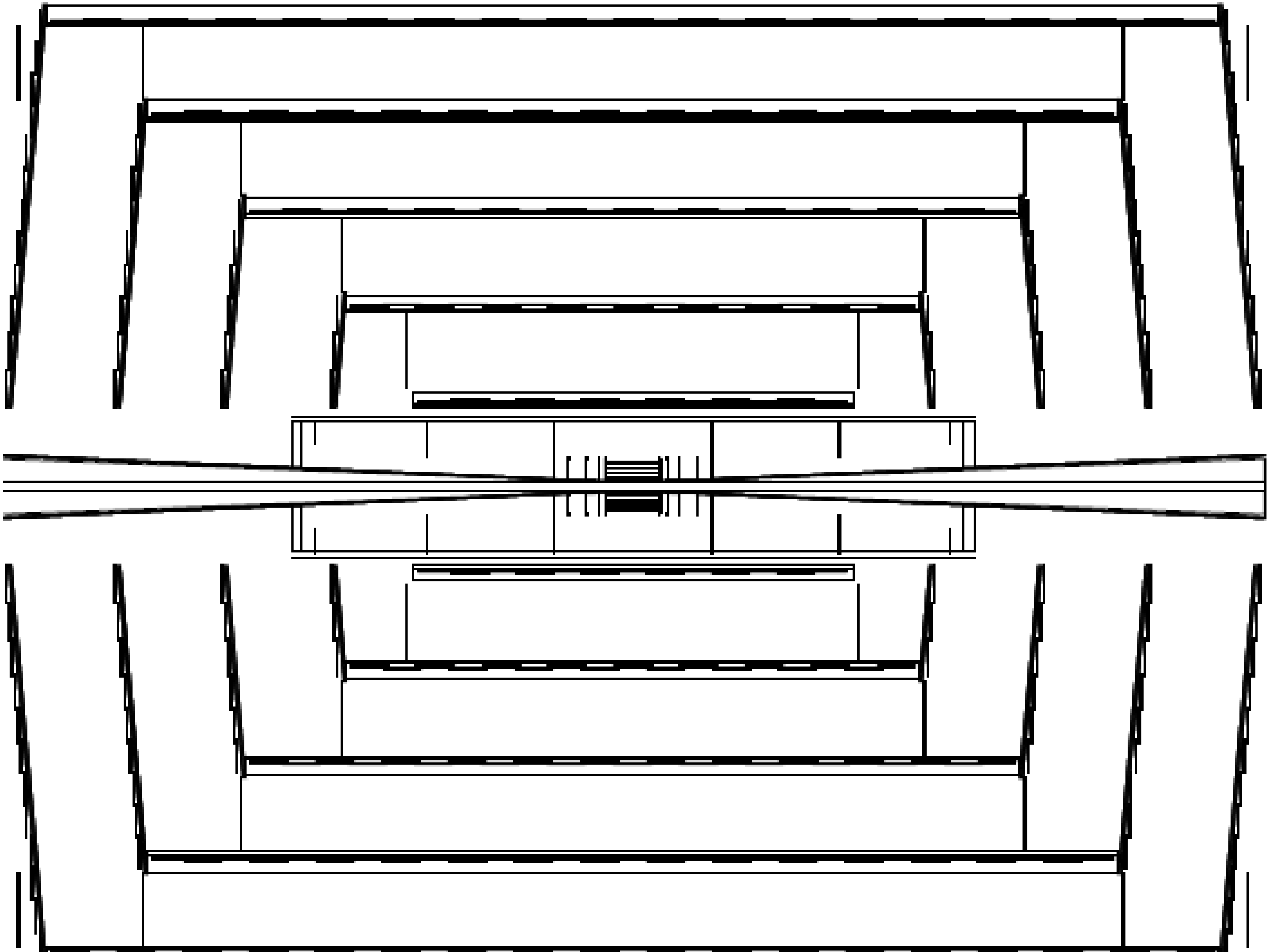
- This model attempts to incorporate the detector as described in the LOI in as much detail as possible.
- Trackers composed of silicon wafers with support structures and readout.
- More realistic modular calorimeters, but much more detail needs to be incorporated.
- Still a work in progress, as many of the details remain to be documented.

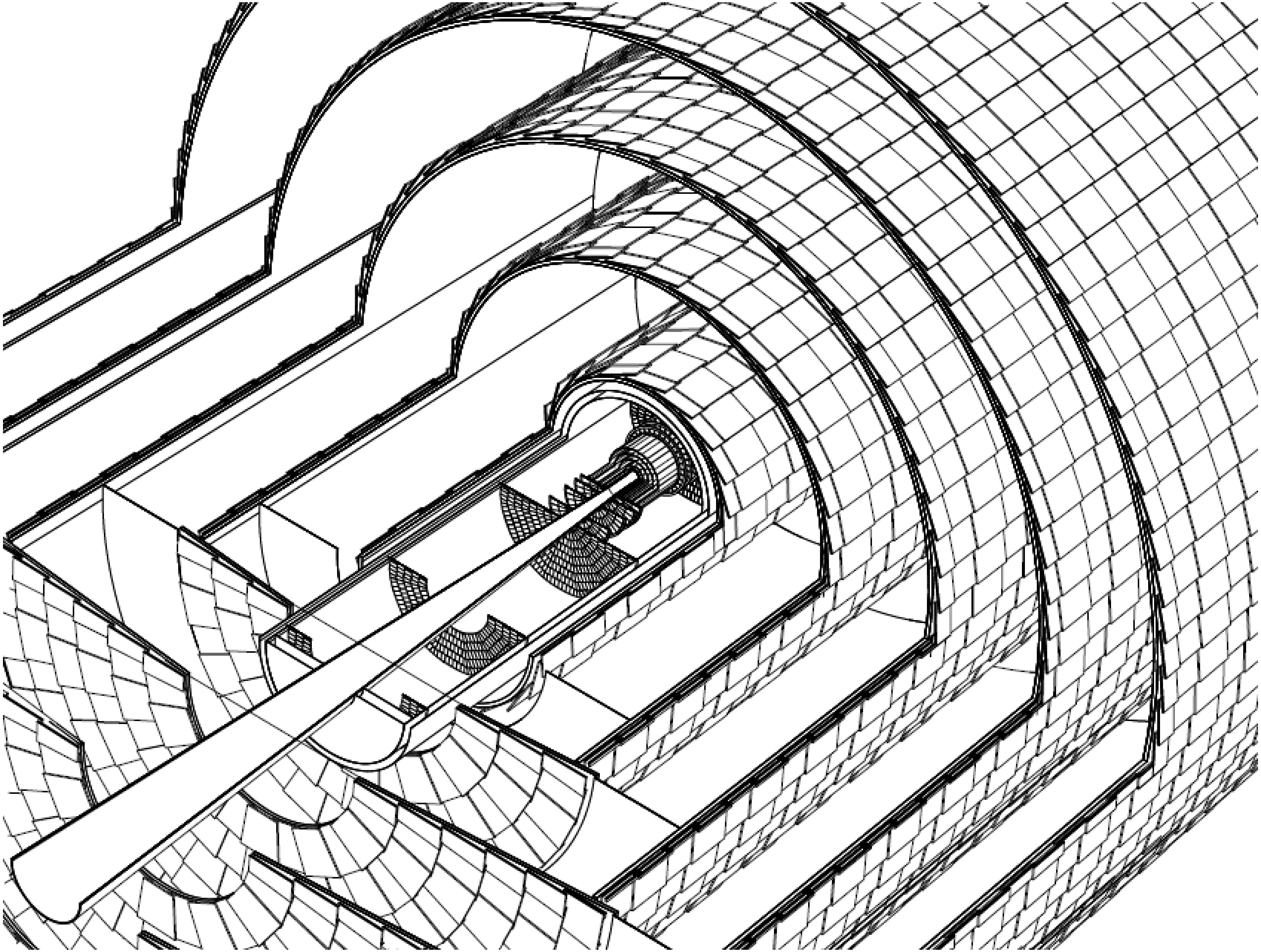
GeomConverter – Planar Trackers

- Si trackers and vertex detectors
- planar modules
- size/layout/material parameters specifiable
- segmented into pixels/strips
  - full digitization
  - full clustering

sidloi2

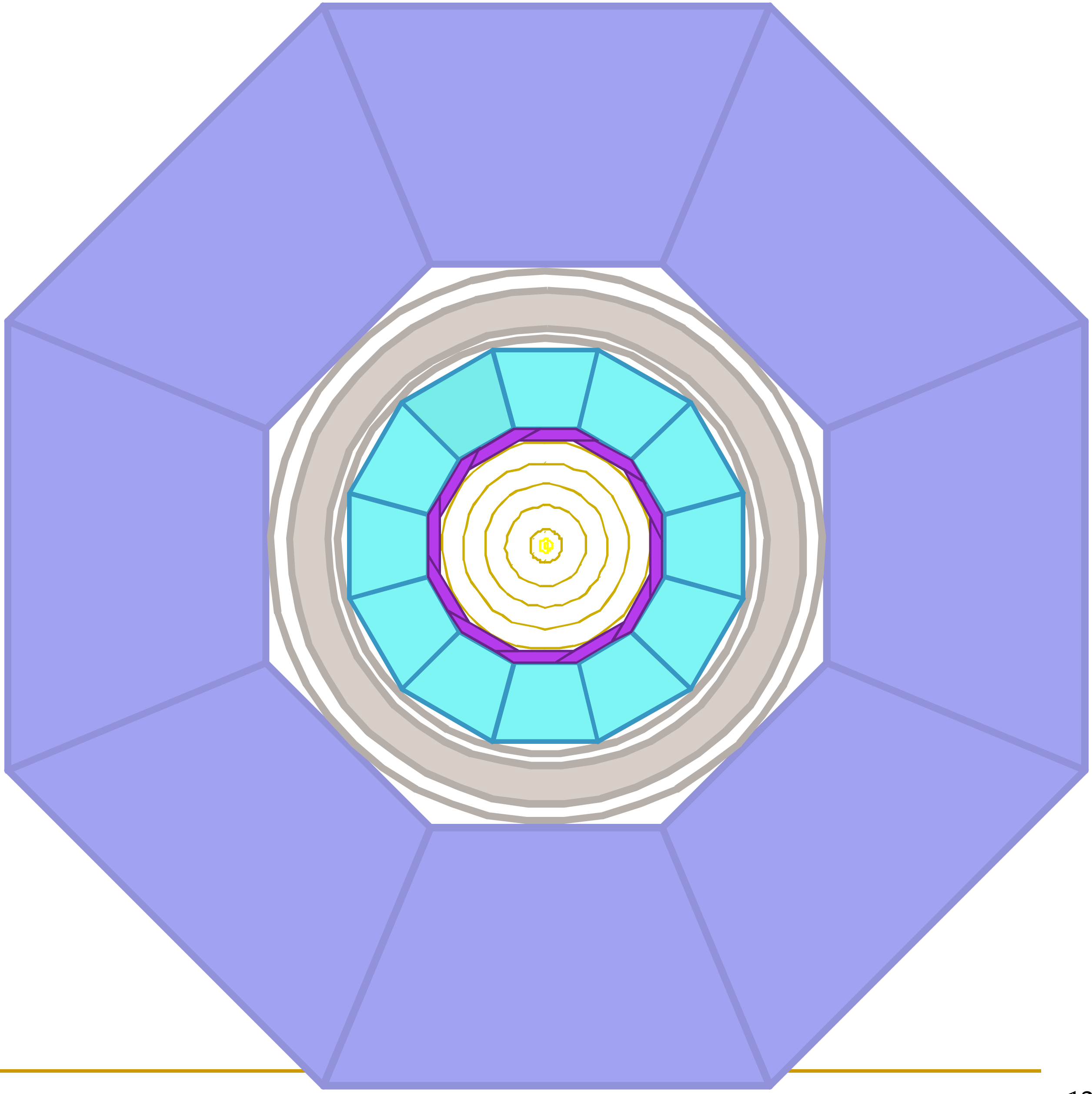






sidloi

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



Silicon Detector Definition

- Expect that the detector design will change going forward.
- Need to implement some form of Change Control Board to ensure that the modifications motivated by physics studies or engineering constraints are formally communicated to the subdetector, simulation and reconstruction groups.
- Optimization of SiD is an area where new groups could profitably contribute.

Physics Benchmarking

- Simulate and analyze updated benchmark reactions with the realistic detector model.
  - Include the impact of detector dead zones and updated background conditions
- Physics Common Working Group has first draft proposal. See plenary talk by K. Fujii.
- New machine configuration (SB2009?) and cms energy (350GeV?) means starting from scratch.
  - Running GuineaPig to calculate e+, e-, γ spectra
  - Generating SM Backgrounds
  - Generating Signal

Recent Benchmarking Activities

- ILC Physics Common Task Group delivered proposed benchmarks to Yamada on Nov 13, 2009
- The proposed benchmarks have been discussed at Physics and Exp board meetings, Software Common Task Group meetings and the Jan 2010 ILD workshop in Paris.
- GDE has been asked for a Ecm=1TeV machine parameter set.
- IDAG met with Physics CTG members. ILD, SiD and Software CTG representatives were also present for benchmarking discussion and review.
- No conclusions yet. At least one more iteration.

Going Forward on Benchmarking

- Processes & machine parameters have to be finalized before MC event generation can begin. This shouldn't be a problem since we don't plan to begin benchmarking MC generation until early 2011.
- The event generation workload will be more equally distributed between SLAC, DESY and KEK this time around. Of course, new groups are welcomed.
- Biggest benchmarking problem within SiD remains the identification of a new group of students and postdocs to do the analyses for the 2012 DBD.

Processing Strategy

- Successfully completing the LOI exercise required the use of all available resources.
- The 500 GeV events were primarily processed using the LCG.
  - Analysis groups were at RAL & Oxford.
- The 250GeV sample was primarily processed at SLAC, on the FermiGrid and the OSG.
  - Analysis groups primarily at SLAC.
- Use of SLAC lsf batch system by far the easiest.
  - Borrowed “fair shares” from BaBar and ATLAS
- Will we have Grid access when LHC starts?

The Grid

- Made extensive use of both the LCG and OSG grids.
  - LCG: DESY, RAL Tier 1, in2p3, …
  - OSG running opportunistically on the CMS grid
- In general, no problems with the concept software
  - SiD software (slic & org.lcsim) just worked (also ran MarlinReco on LCG where it was installed).
- Number of issues with Grid job submission, monitoring and file transfers.
- Grid is still high-maintenance & very LHC-centric.
- This process can no longer rely on individuals, it has to be institutionalized, automated and coordinated with ILD & CLIC within the ILC VO. New groups could contribute.

lcsim Reconstruction

- Tracking reconstruction now features planar silicon wafers, full hit digitization, clustering to form hits (with hit-size dependent uncertainties) and ab initio track-finding.
- Calorimeter code has been modified to support polygonal modules (e.g. neighboring)
- PFA code is being improved and also adapted to the new geometries.
- Reconstruction is run-time configurable
  - Allows new users to begin running reconstruction without having to code Drivers, etc.

Tracking

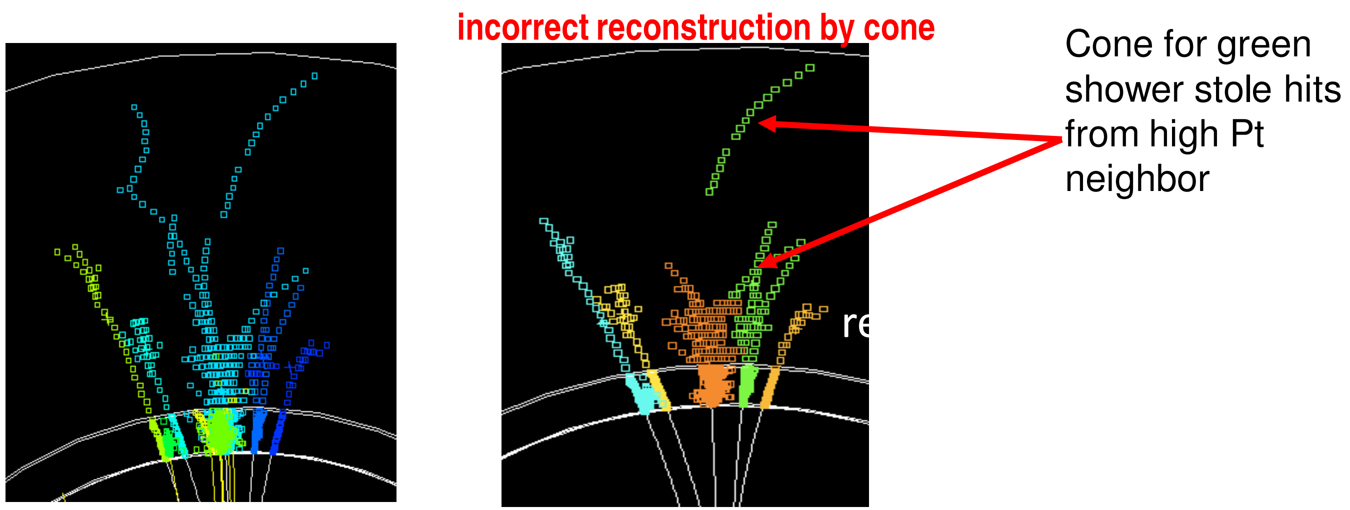
- Digitization improves from the virtual segmentation used in the LOI to full digitization of SimTrackerHits into ADC counts in pixels and strips, using detailed drift, diffusion, readout, …
- Full clustering of neighboring hits, giving cluster-dependent measurement position and uncertainties.
- Tracking works well out of the box.
  - currently characterizing performance.
  - Much testing and optimization remains to be done.
- Need to implement full fitting accounting for multiple scattering and energy loss.

Calorimeter Clustering & PFA

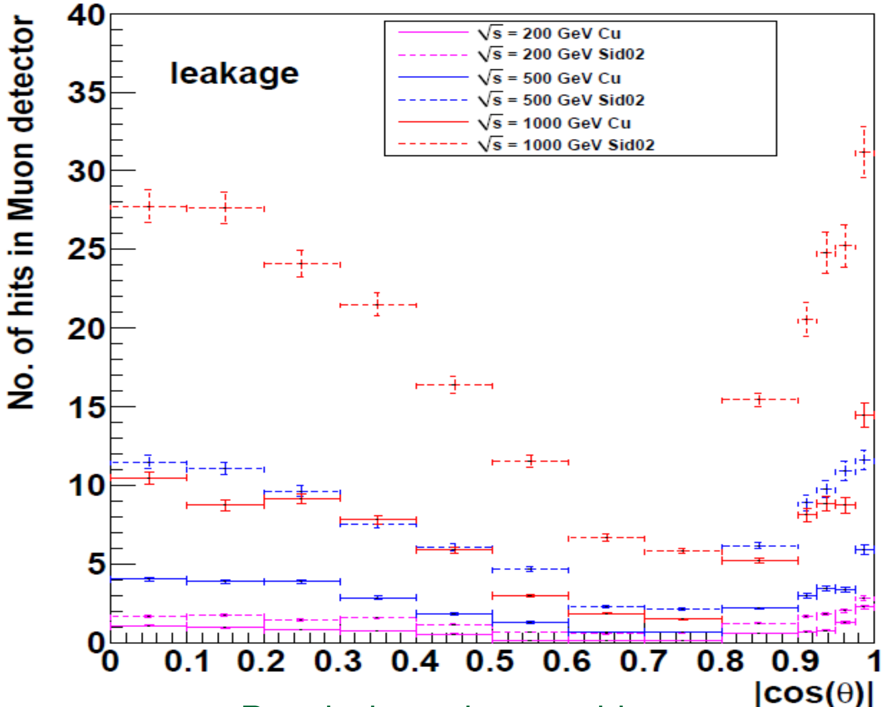
- Code has been developed to provide full functionality for modular calorimeters
  - Return list of neighboring cells within module
  - Given position, return ID
  - Given ID, return position
- Testing that clustering code works with new geometries (e.g. across modules), modifying or augmenting as necessary.
- Modifying existing PFA code to make it work with new geometries, modify or replace as necessary.

PFA Development

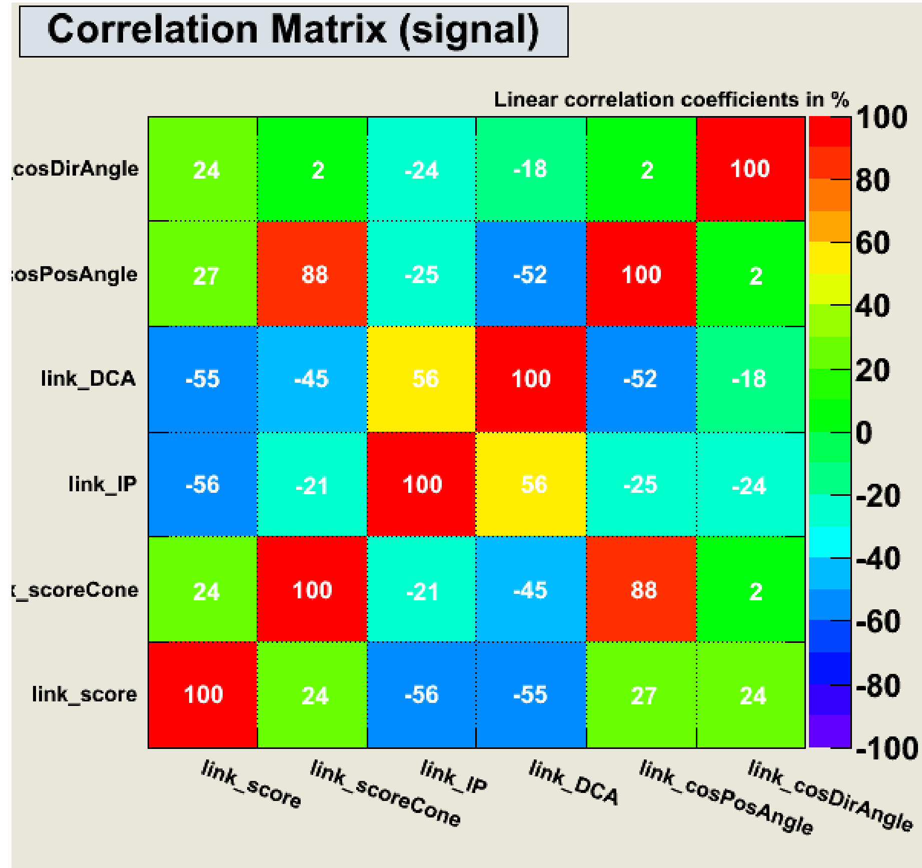
- Ongoing development of SiD (Iowa/SLAC/MIT) PFA
- Focus on reduction of wrongly assigned hits (confusion) and leakage.



PFA Development



Punch-through muon hits

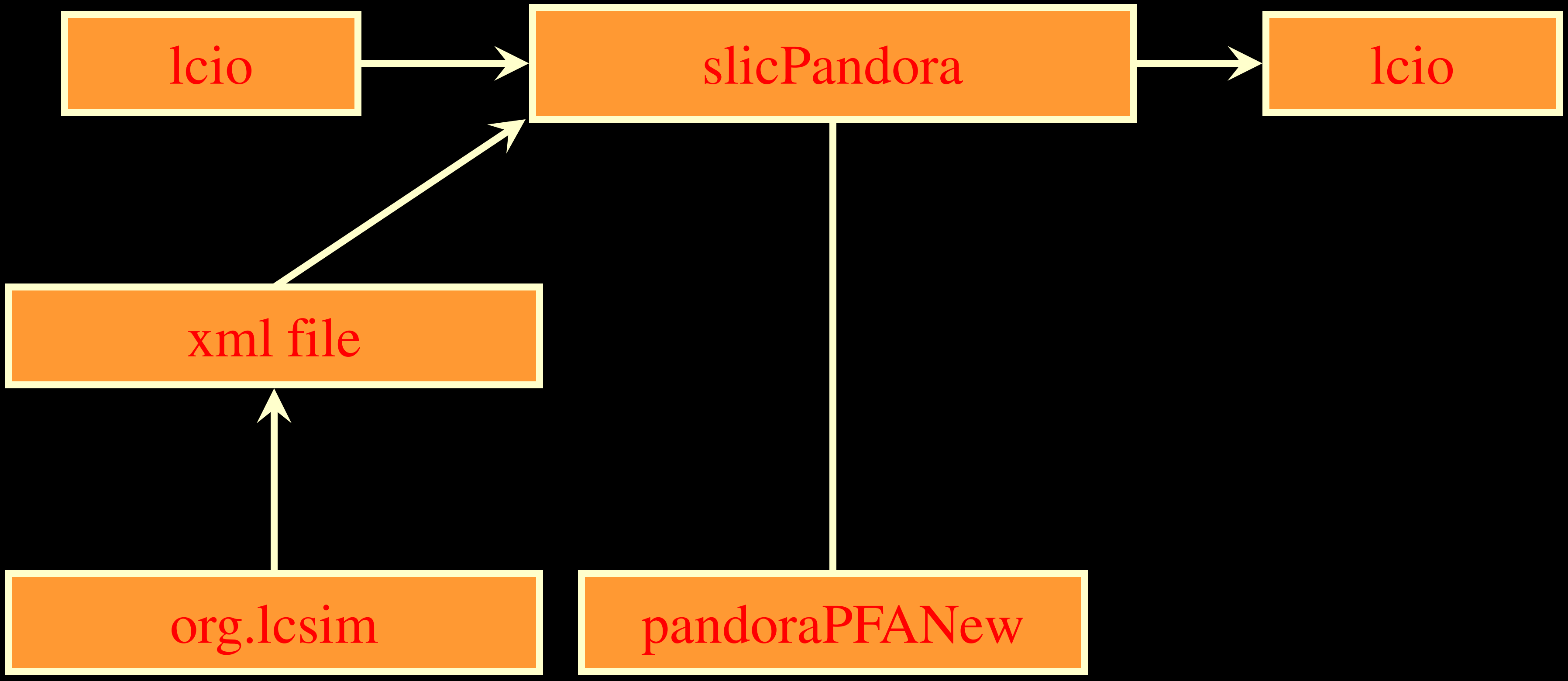


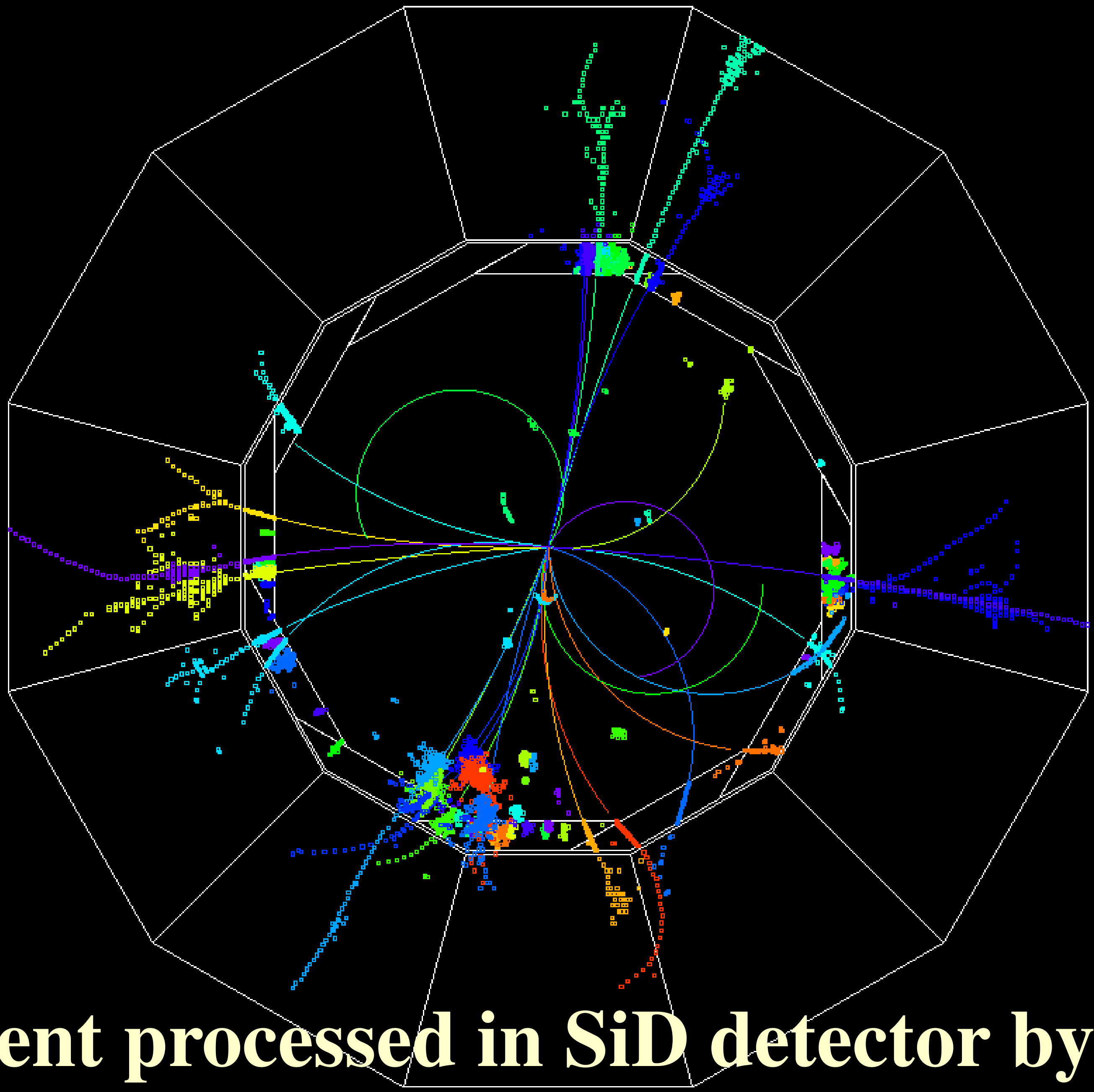
Code is also being adapted to the new, planar, polygonal calorimeter geometries. Neutral showers being found, work ongoing to handle charged track/shower extrapolation.

slic + PandoraPFANew

- PandoraPFA being rewritten to make it modular and framework independent
- Effort is underway to provide a binding between the slic LCIO output and the compact.xml geometry description and this new package.
- Developed and implemented an xml format for geometrical information needed by pandoraPFA.
- Developed C++ front end to read lcio files + geometry.xml + pandoraPFA.xml and process events.

Architecture





$t\bar{t}$ event processed in SiD detector by slic, reconstructed using pandoraPFANew.

Detector Optimization

- MIT group engaged in systematic study of detector variants based on simplified SiD geometry (sid02) using slic + SiD PFA.
  - extending studies done for the LOI by Marcel Stanitzki using Mokka + Marlinreco (SiD-ish)
  - primarily studying HCal depth and layout.
- Expect that once the reconstruction framework fully supports the detailed geometry we will engage in a similar global exercise, studying:
  - Tracker layouts
  - Detector aspect ratios
  - HCal absorber materials, layout, readout technologies.

Testbeams?

- "Demonstrate proof of principle for critical components"
- Will require SiD-specific testing of detector components.
- Simulation and reconstruction demands for a testbeam effort are different, and in some cases much more demanding, than what was done for the LOI.
- Excellent opportunity for new groups to contribute.

Summary

- Much was done for the LOI, but much more will need to be done for this exercise.
- Simulation and Reconstruction code being adapted for complex geometries.
- Workflow being streamlined & automated.
- Expect a round of detector optimization studies before major event production.
- Many areas in which new groups or individuals can contribute.
- Volunteers?

Backup Slides

Proposed benchmarks for 1 TeV

1. $e^+e^- \to \nu\overline{\nu}h^0$ at $E_{\rm CM} = 1$ TeV, where h^0 is a Standard Model Higgs boson of mass 200 GeV, in the final states $h^0 \to b\overline{b}$ and $h^0 \to \mu^+\mu^-$. The goal is to measure the cross section times branching ratio for these reaction.

2. $e^+e^- \to t\overline{t}h^0$ at $E_{\rm CM} = 1$ TeV, where h^0 is a Standard Model Higgs boson of mass 200 GeV, in the final state $h^0 \to WW, ZZ$, in the 10 jet mode. The goal is to measure the Higgs boson coupling to $t\overline{t}$.

3. $e^+e^- \to \tau^+\tau^-$ at $E_{\rm CM} = 1$ TeV. The goal is to measure the forward-backward asymmetry and the final-state τ polarization.

4. $e^+e^- \to b\overline{b}, c\overline{c}$ at $E_{\rm CM} = 1$ TeV. The goal is to measure the cross section and the forward-backward asymmetry of each reaction.

5. $e^+e^- \to \nu\overline{\nu} + WW, ZZ$ at $\sqrt{s} = 1$ TeV. The goal is to measure the effective Lagrangian parameters α_4 amd α_5 in strongly interacting models of the Higgs sector.

Proposed benchmarks supporting the ILC physics case - early LHC discovery

1. $e^+e^- \rightarrow \nu\bar{\nu}h^0$ with $h^0 \rightarrow b\bar{b}$ and $e^+e^- \rightarrow t\bar{t}h^0$, , where h^0 is a Standard Model Higgs boson of mass 200 GeV, at $E_{\rm CM} = 1$ TeV. The goal is to measure the Higgs coupling to b and t quarks.

2. $e^+e^- \rightarrow \tau^+\tau^-$, $b\bar{b}$, $c\bar{c}$, at $E_{\rm CM} = 500$ GeV and at 1 TeV. The goal is to measure the pair-production cross section and forward-backward asymmetry and the τ polarization for each beam polarization.

3. $e^+e^- \rightarrow t\bar{t}$ at $E_{\rm CM} = 500$ GeV. The goal is to measure the pair-production cross section and forward-backward asymmetry and the top quark polarization as a function of production angle, for each beam polarization.

4. $e^+e^- \rightarrow \tilde{\tau}^+\tilde{\tau}^-$, $\tilde{e}_1^+\tilde{e}_1^-$, $\chi_1^0\chi_1^0$ at $E_{\rm CM} = 500$ GeV, in a gauge-mediated model of supersymmetry in which the $\tilde{\tau}$ is the lightest Standard Model superpartner. The goal is to determine the masses, quantum numbers, and couplings of these particles to extremely high precision.

Proposed benchmarks supporting the ILC physics case - precision Higgs analysis

1. $e^+e^- \to h^0 Z^0$ at $E_{\mathrm{CM}} = 230$ GeV, where h^0 is a Standard Model Higgs boson of mass 120 GeV, in the final states $h^0 \to b\bar{b}, c\bar{c}, WW^*, ZZ^*, \tau^+\tau^-, \gamma\gamma$. The goal is to estimate the ultimate precision on these Higgs boson branching ratios that is achievable at the ILC.

2. $e^+e^- \to h^0 h^0 Z^0, \nu\bar{\nu}h^0 h^0$ at $E_{\mathrm{CM}} = 500$ GeV, where h^0 is a Standard Model Higgs boson of mass 120 GeV. The goal is to estimate the accuracy with which the ILC will measure the triple Higgs coupling.