slic
A Geant4-based detector simulation package

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Mission Statement

- Provide full detector response simulation capabilities for Linear Collider physics program.
- Need flexibility for new detector geometries and readout technologies.
- The system should be flexible, powerful, yet simple to install and maintain.
- Limited resources demand efficient solutions, focused effort.

Full Detector Response Simulation

- Use Geant4 toolkit to describe interaction of particles with matter.
- Thin layer of non-G4 C++ provides access to:
  - Event Generator input
  - Detector Geometry description input
  - Detector Hits output
- Geometries fully described at run-time!
  - In principle, as fully detailed as desired.
  - Uses lcdd, an extension of GDML.
- Solution is applicable beyond LC problem domain.

Geometry Definition

- Goal was to free the end user from having to write C++ code to define the detector.
- All of the detector properties should be definable at runtime with an easy to use format.
- Selected xml, and extended the existing GDML format for pure geometry description.

Why XML?

- Simplicity: Rigid set of rules
- Extensibility: easily add custom features, data types
- Interoperability: OS, languages, applications
- Self-describing data, validate against schema
- Hierarchical structure ↔ OOP, detector/subdetector
- Open W3 standard, lingua franca for B2B
- Many tools for validating, parsing, translating
- Automatic code-generation for data-binding
- Plain text: easily edited, cvs versioning

LCDD and GDML

- Adopted GDML as base geometry definition, then extended it to incorporate missing detector elements.

LCDD

- detector info
- identifiers
- sensitive detectors
- regions
- physics limits & cuts
- visualization
- magnetic fields

GDML

- expressions (CLHEP)
- materials
- solids
- volume definitions
- geometry hierarchy

LCDD Structure

<lcdd>	LCDD Root Element
<header>	Information about the Detector
<iddict>	Identifier Specifications
<sensitive_detectors>	Detector Readouts
<limits>	Physics Limits
<regions>	Regions (sets of volumes)
<display>	Visualization Attributes
<gdml>	GDML Root Element
<define>	Constants, Positions, Rotations
<materials>	Material Definitions
<solids>	Solid Definitions
<structure>	Volume Hierarchy
</gdml>	
<fields>	Magnetic Field
</lcdd>	

lcdd Features

- **Regions**: production cuts
- **Physics limit**s: track length, step length, etc.
- **Visualization**: color, level of detail, wireframe/solid
- **Sensitive detectors**
  - calorimeter, optical calorimeter, tracker
  - segmentation
- **ID**s
  - volume identifiers (physvolid)
- **Magnetic field**s
  - dipole, solenoid, field map
- utilities
  - information on Geant4 stores
  - GDML load/dump

“Compact” Description

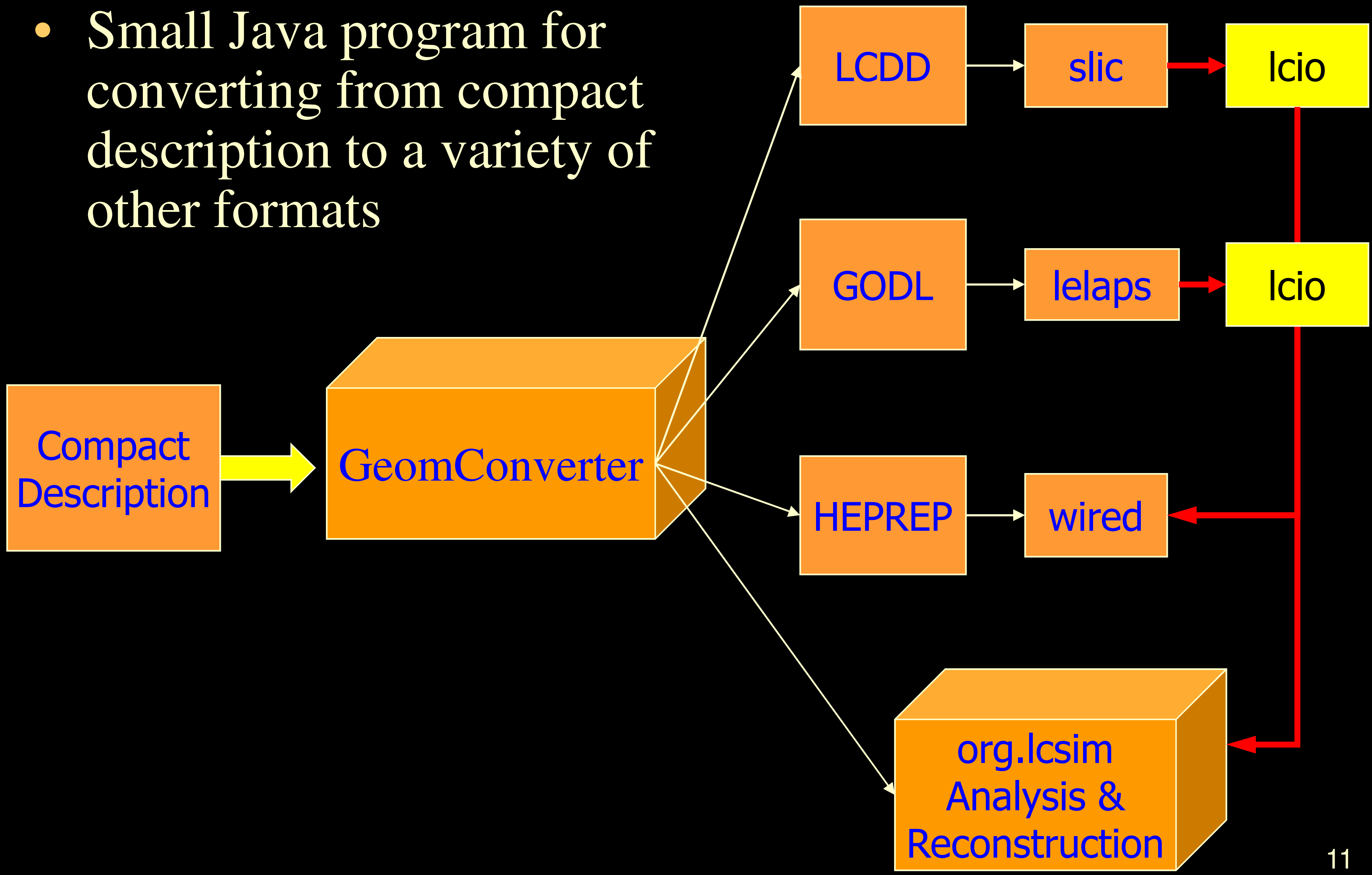
- The lcdd file is very descriptive, but therefore also very verbose.
- Can be written by hand, but prone to human error.
  - Also, just specific to the simulation and not easily accessible to reconstruction and visualization.
- Developed a “compact” detector description which encapsulates the basic properties of a detector and which is further processed by code to produce the input specific to different clients.

Compact Detector Description

- A number of generally useful detector types (at least for HEP collider detectors) have been developed, such as:
  - sampling calorimeters
  - TPCs
  - Silicon trackers (microstrip as well as pixel)
  - Generic geometrical support structures
- Can also incorporate GDML snippets
  - Allows inclusion of more complicated volumes derived for instance from engineering (CAD) drawings.

GeomConverter

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



Compact Description - Example

```
<detector
    id=“3”
    name=“HADBarrel”
    type=“CylindricalBarrelCalorimeter”
    readout=“HcalBarrHits”
    vis=“HADVis”>
  <dimensions inner_r = "141.0*cm" outer_z = "294*cm" />
  <layer repeat=“40”>
    <slice material=“Steel235” thickness=“2.0*cm”/>
    <slice material=“RPCGasDefault” thickness=“0.12*cm”
      sensitive=“yes” region=“RPCGasRegion”/>
  </layer>
</detector>
```

- id: global unique identifier
- name: global unique name
- type: detector type
- readout: readout collection
- vis: visualization settings
- layer repeat: layering
- Steel235 slice: absorber
- sensitive: sensitive layer

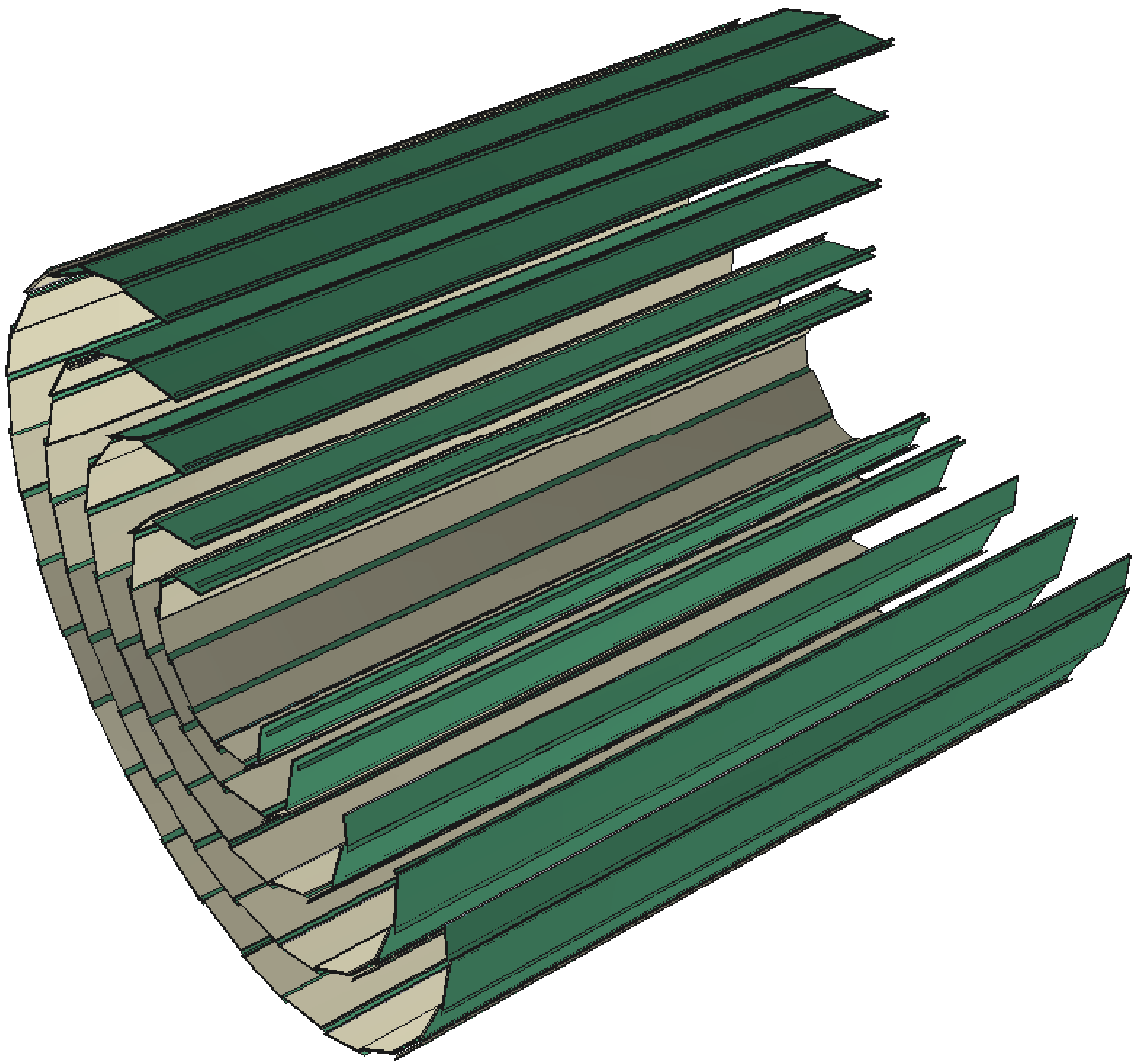
xml: Defining a Tracker Module

```
<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>
```

A Barrel Vertex Detector

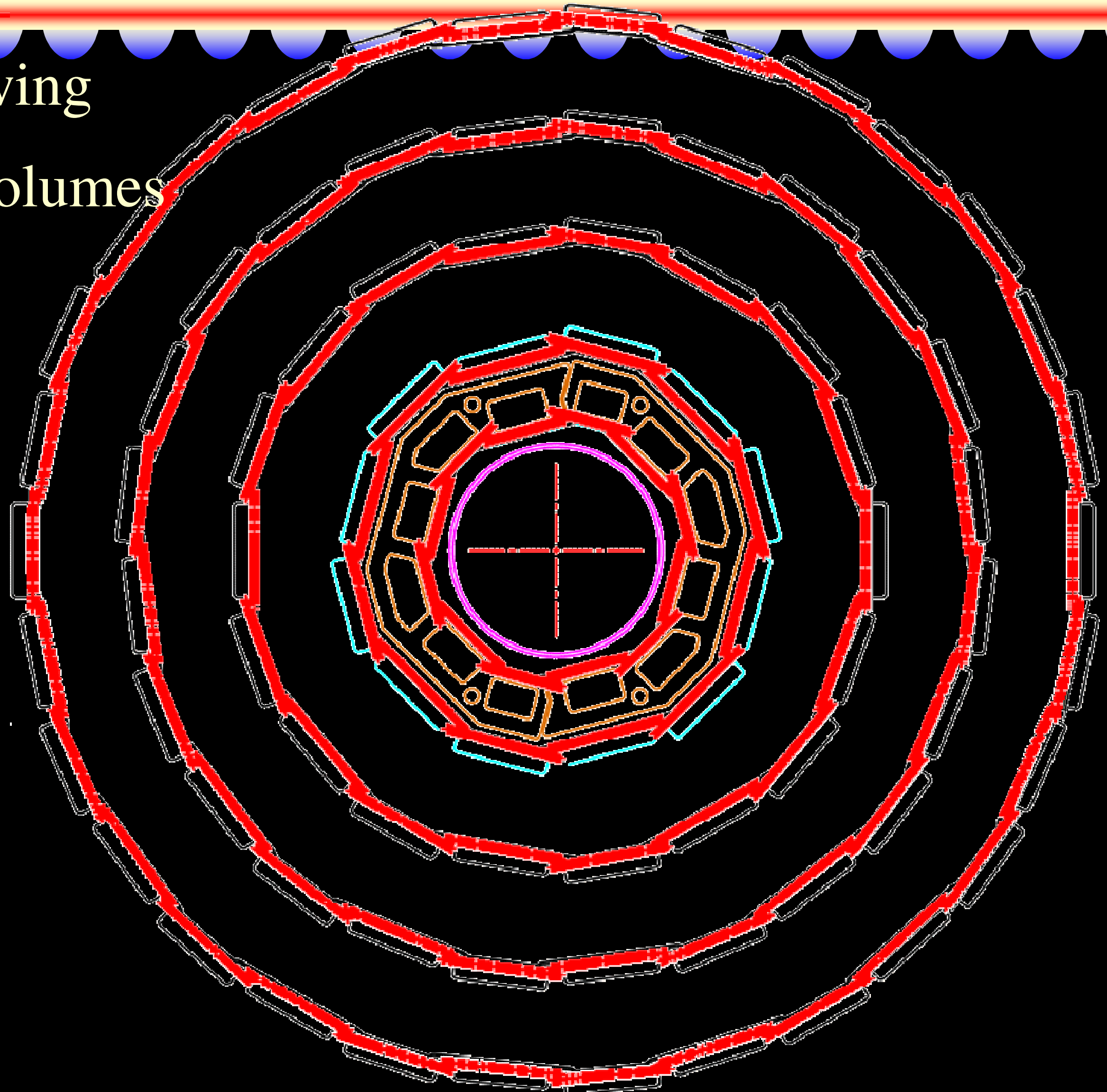


Example Vertex Detector

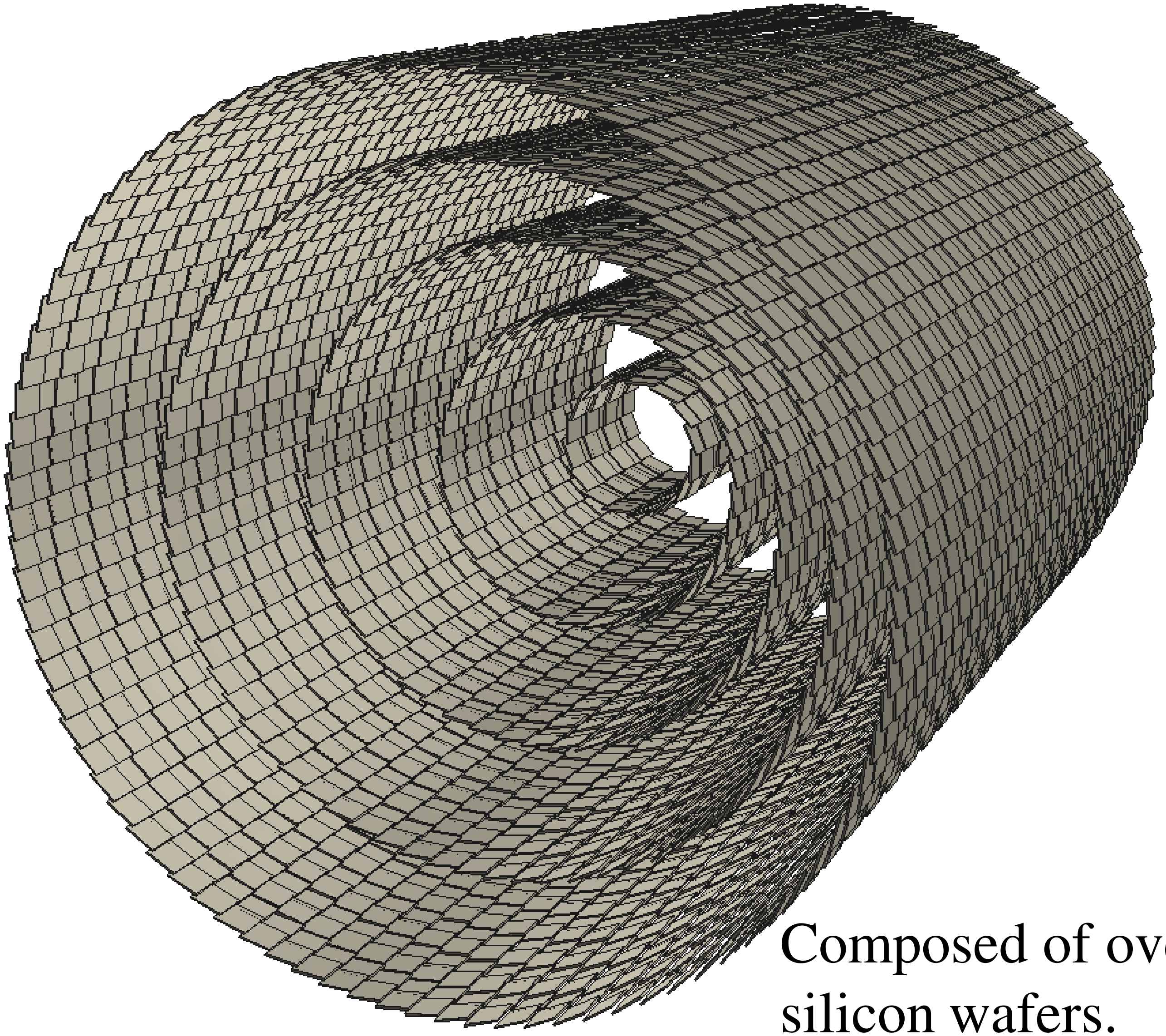
CAD Drawing

GEANT Volumes

LCIO Hits

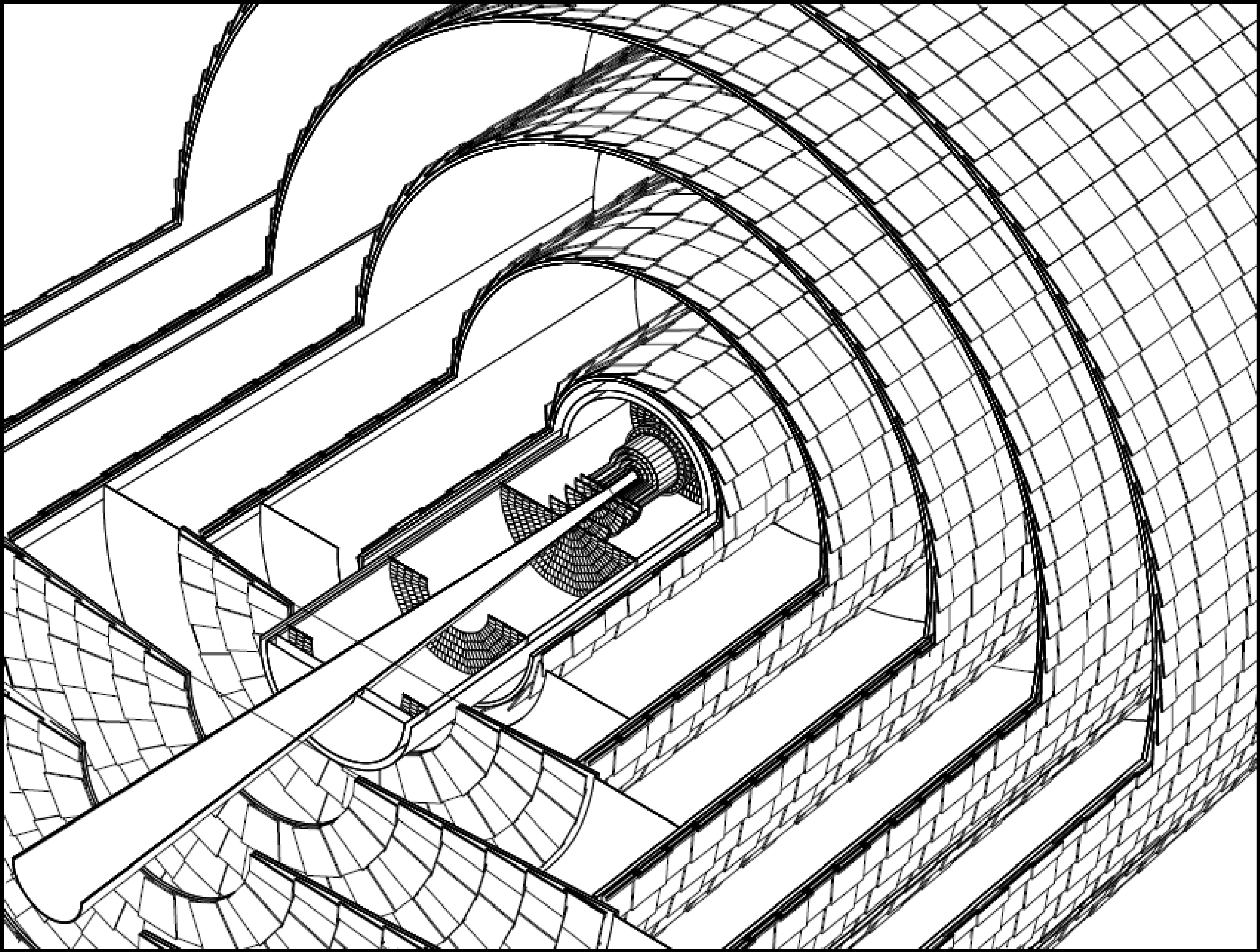


Barrel Outer Tracker



Composed of overlapping silicon wafers.

Complete Silicon Tracker



Generic Hits Problem Statement

- We wish to define a generic output hit format for full simulations of the response of detector elements to physics events.
- Want to preserve the “true” Monte Carlo track information for later comparisons.
- Want to defer digitization as much as possible to allow various resolutions, readout technologies, etc. to be efficiently studied.

Types of Hits

- "Tracker" Hits
  - Position sensitive.
  - Particle unperturbed by measurement.
  - Save "ideal" hit information.
- "Calorimeter" Hits
  - Energy sensitive.
  - Enormous number of particles in shower precludes saving of each "ideal" hit.
  - Quantization necessary at simulation level.

Tracker Hit

- **MC Track handle**
- Encoded **detector ID** (detector dependent)
- **Hit position** in sensitive volume
- **Track momentum** at hit position.
- **Energy deposited** in sensitive volume.
- **Time** of track's crossing.
- **Path length** in sensitive volume.

Calorimeter Hit

- Encoded detector ID (detector dependent)
- MC IDs for tracks contributing to this cell.
- Energy deposited.
- Time of energy deposition.
- Repeated for each energy contribution.
- Support recently added for optical calorimeters
  - Can store Cerenkov and scintillation light.
  - See other talks at this workshop.

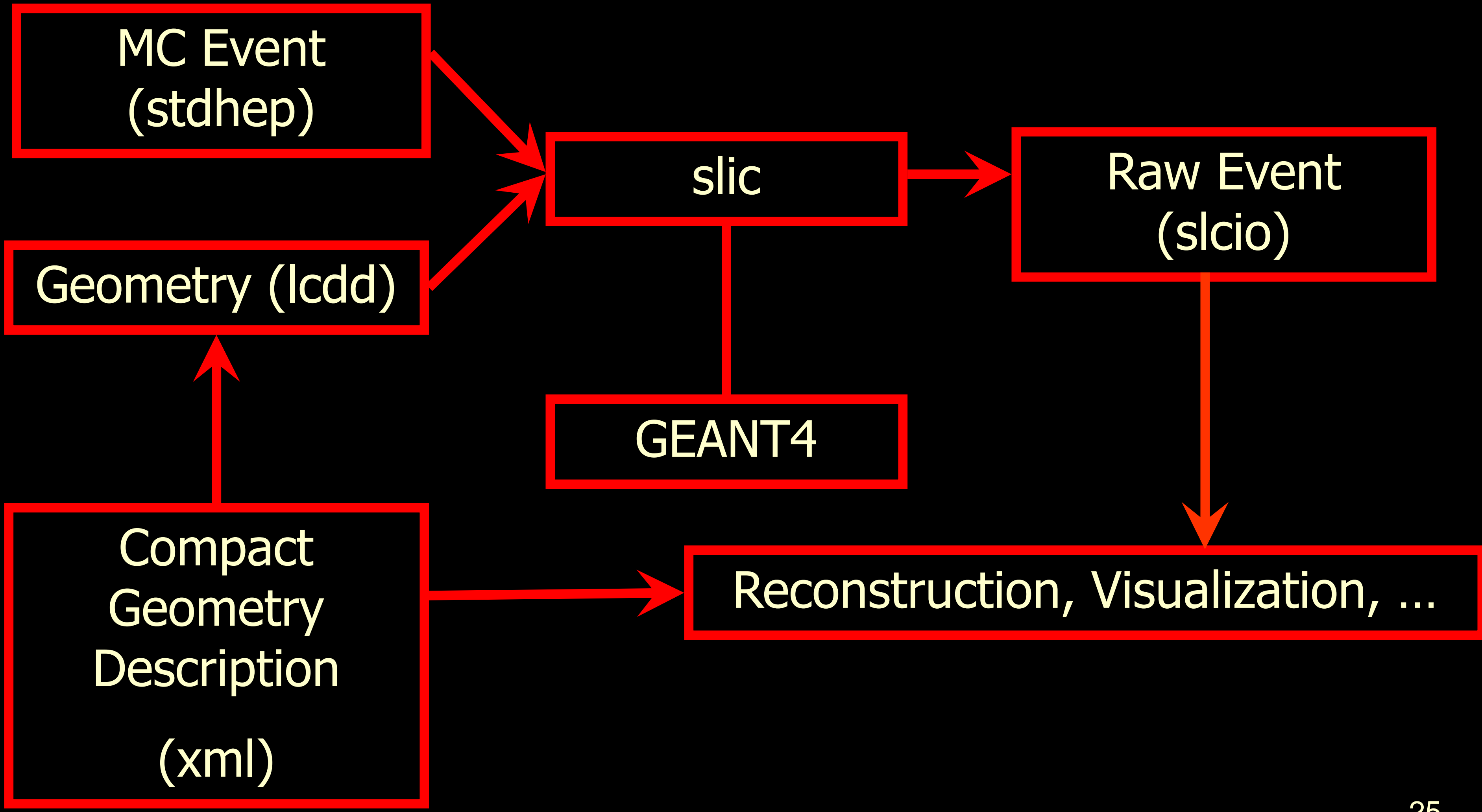
LCIO

- Persistency framework for LC simulations.
- Currently uses SIO: Simple Input Output
  - on the fly data compression
  - some OO capabilities, e.g. pointers
  - C++, Java (and FORTRAN!) implementations available
- Changes in IO engine designed for (e.g. root).
- Extensible event data model
  - Generic Tracker and Calorimeter Hits.
  - Monte Carlo particle heirarchy.

slic: The Executable

- Build static executable on Linux, Windows, Mac.
  - SimDist build kit uses GNU autoconf
- Commandline or G4 macro control.
- Only dependence is local detector description file.
  - Trivial Grid usage (no database call-backs, etc.)
  - Grid ready, Condor and lsf scripts available.
- Event input via stdhep, particle gun, …
- Detector input via GDML, lcdd
- Response output via LCIO using generic hits.

Detector Full Simulation

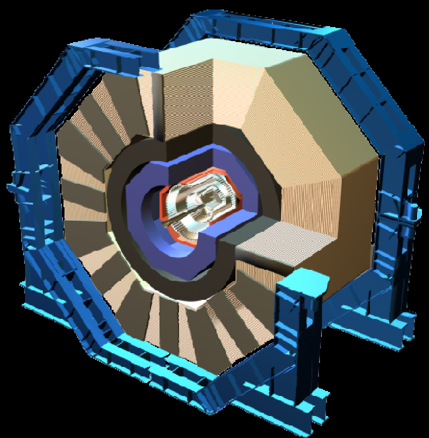


Detector Variants

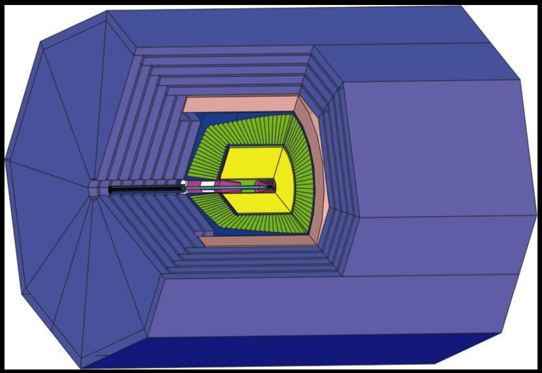
- Runtime XML format allows variations in detector geometries to be easily set up and studied:
  - Sampling calorimeters:
    - absorber materials, dimensions
    - Readout technologies, e.g. RPC, scintillator
    - Layering (radii, number, composition)
    - Readout segmentation (size, projective vs. nonprojective)
  - Total absorption crystal calorimeters
    - Optical properties
  - Tracking detector technologies & topologies
    - TPC, silicon microstrip, silicon pixels

ILC Full Detector Concepts

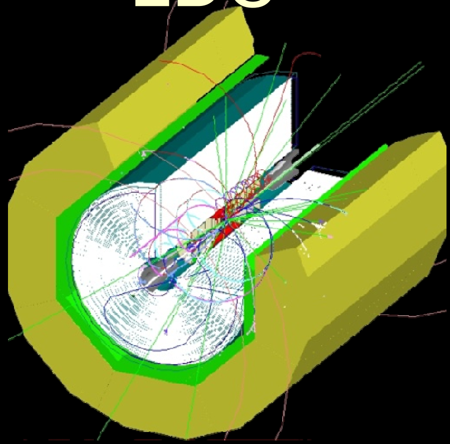
SiD

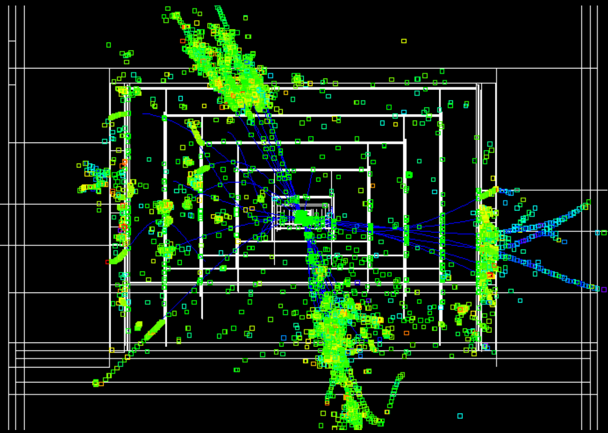


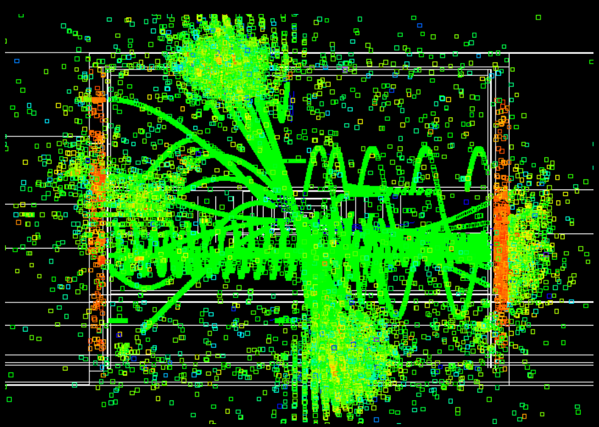
GLD

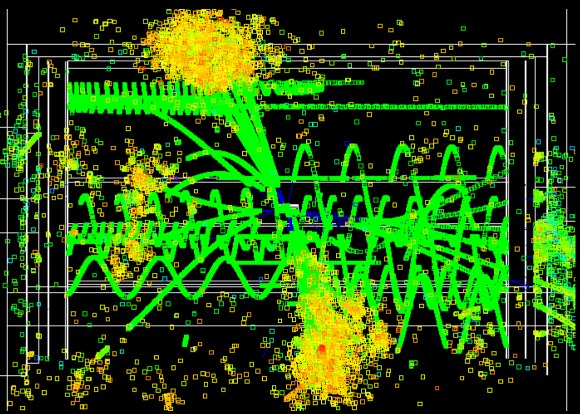


LDC









slic & lcdd: Summary

- Provides a complete and flexible detector simulation package capable of simulating arbitrarily complex detectors with runtime detector description.
- Being used by ILC detector community for simultaneous and iterative evolution of different detector concepts and their variations.
- Being used for ATLAS upgrade tracking studies
- Has been applied to CPT simulations.
- Could be used by other communities (astro, medical) for rapid prototyping or simulation.

Additional Information

- ILC Detector Simulation http://www.lcsim.org
- ILC Forum http://forum.linearcollider.org
- SLIC http://www.lcsim.org/software/slic
- LCDD http://www.lcsim.org/software/lcdd
- GDML http://gdml.web.cern.ch/GDML/
- LCIO http://lcio.desy.de