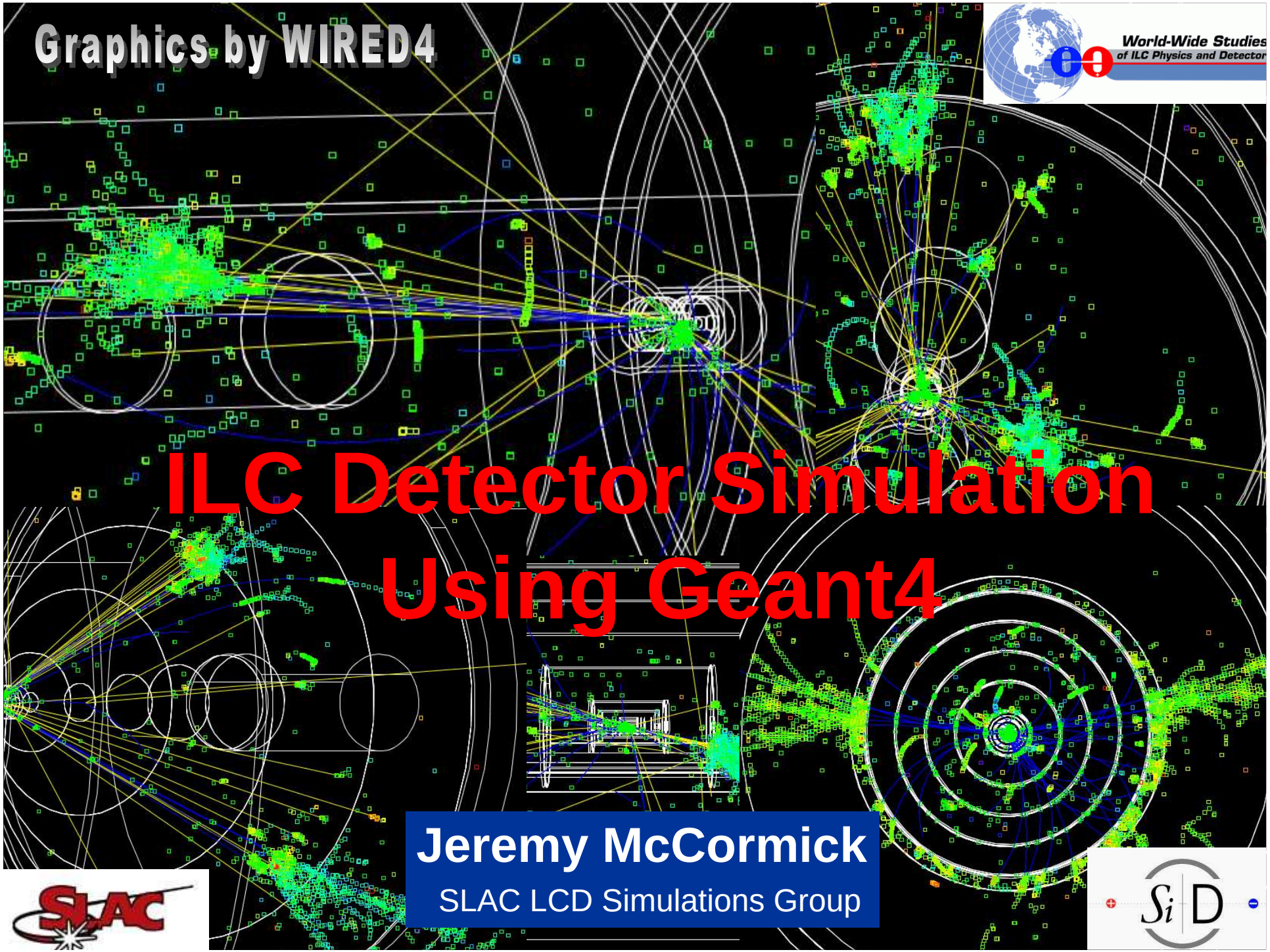
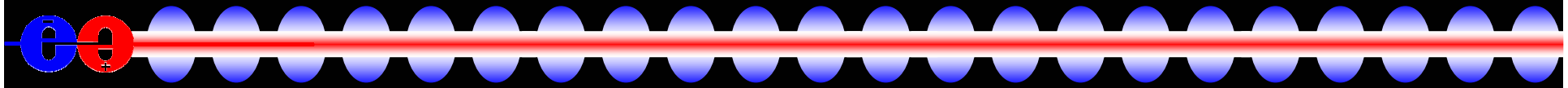


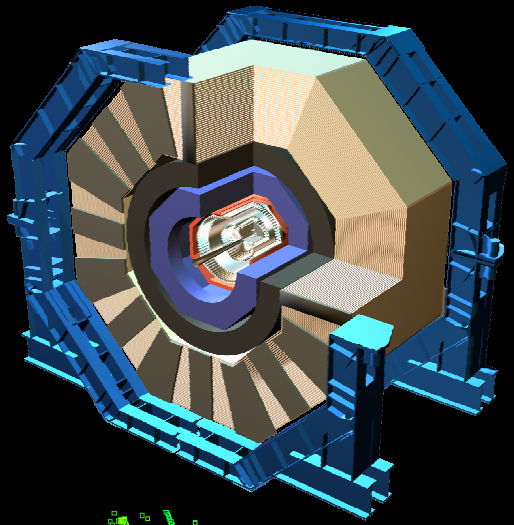
ILC Detector Simulation Using Geant4

Jeremy McCormick
SLAC LCD Simulations Group

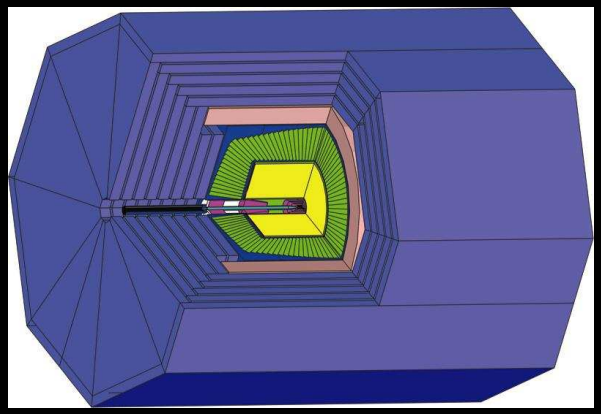
ILC Detector Concepts



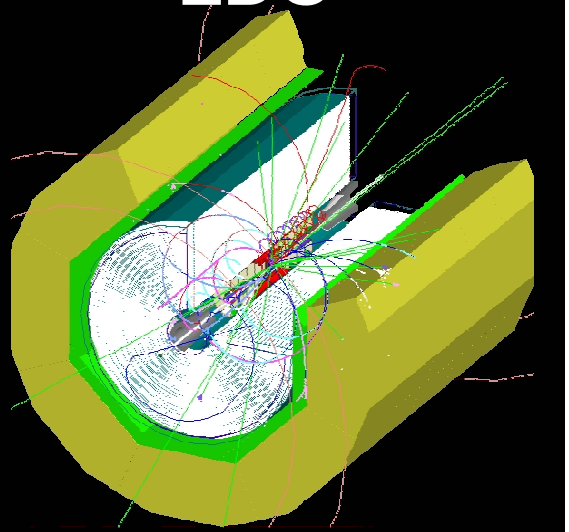
SiD

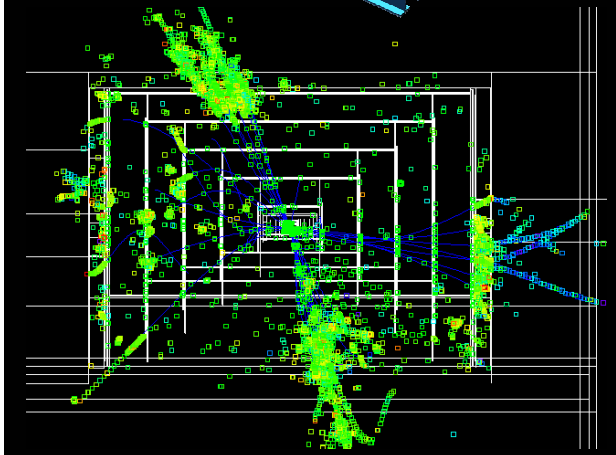


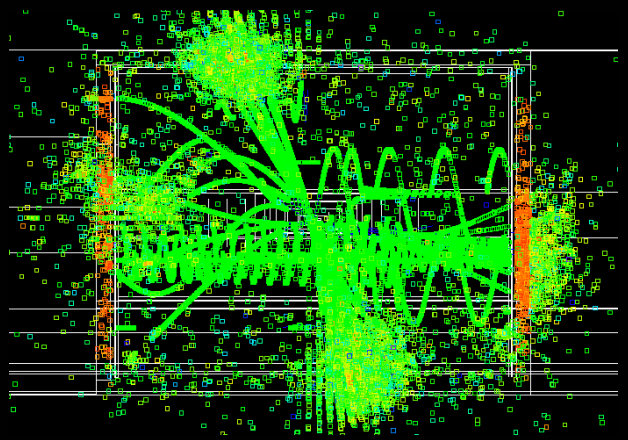
GLD

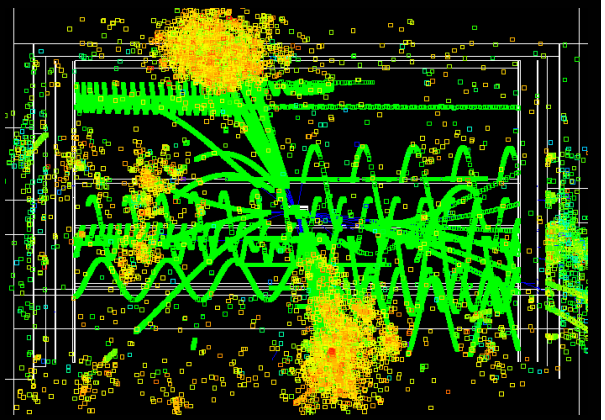


LDC



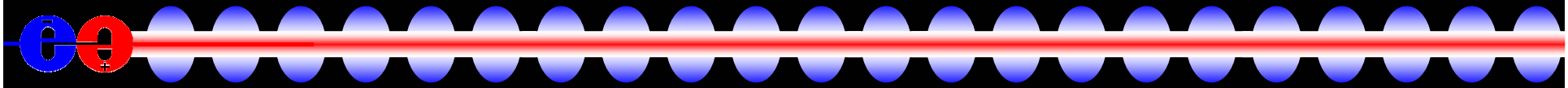






Z Higgs (M_H=120 GeV) event → same simulator, three different detector geometries

Performance Requirements



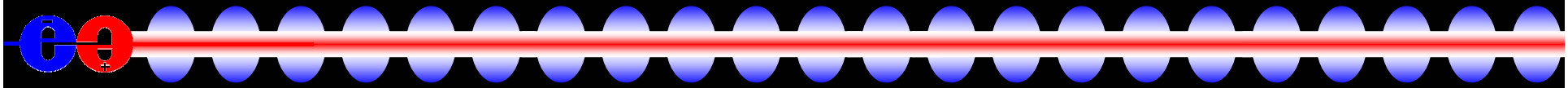
To measure complex final states

of e+e- collisions at $\sqrt{s}$ = ~1 TeV,

a detector must have

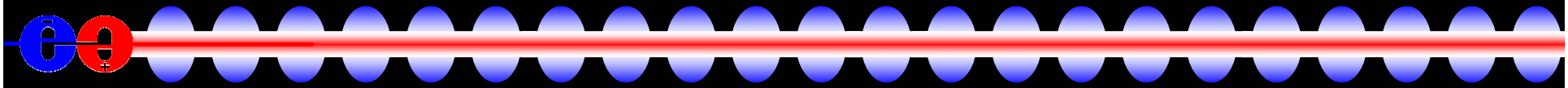
- Exceptional momentum resolution
- Excellent vertexing capabilities
- Highly granular readout in all subdetectors
- Hermiticity (especially in forward region)

Detector Design using Geant4



- one of the first collaborations to use Geant4 for ground-up design of a major HEP detector
- model different detector concepts and their variations, using Geant4 for prototyping and benchmarking
- detector description should not be hard-coded into the application → load and build at runtime
- "Let a thousand detectors bloom!" (or at least 2-3 dozen)

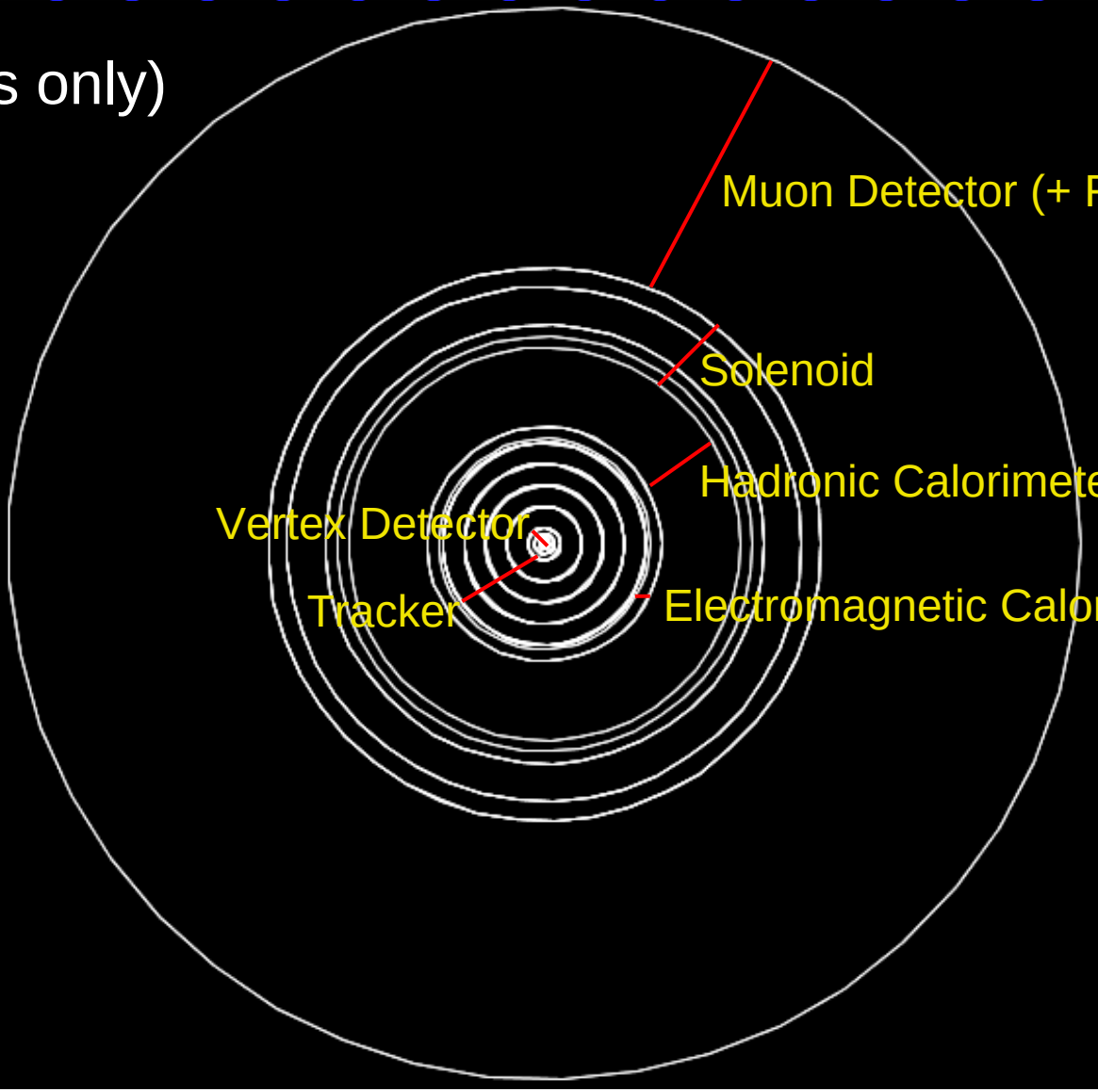
Readout Technologies



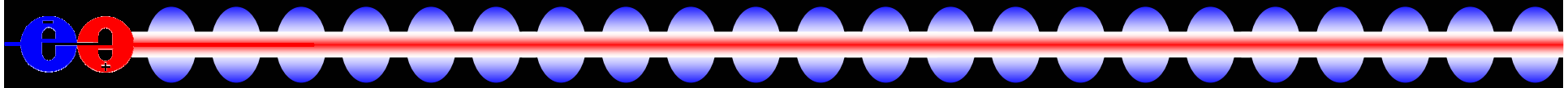
- trackers
  - pixel, Silicon microstrip, TPC
- sampling calorimeters
  - Electromagnetic: Silicon, scintillator, hybrid
  - Hadronic: scintillator, GEM, RPC
    - absorbers: Steel, Tungsten (others?)
- Machine Detector Interface / Beam Delivery System (MDI-BDS)

Example Detector Topology

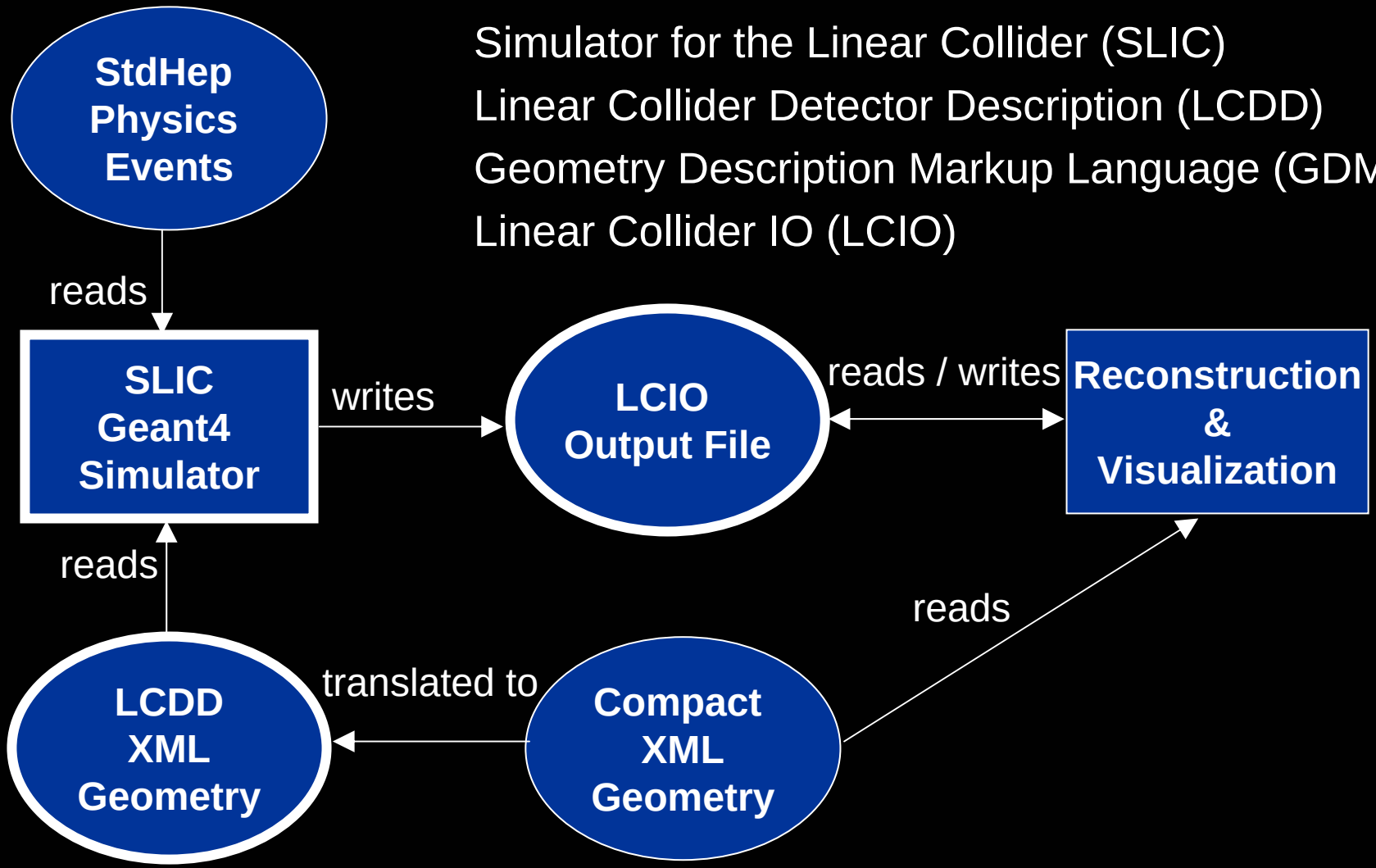
SiD (barrels only)



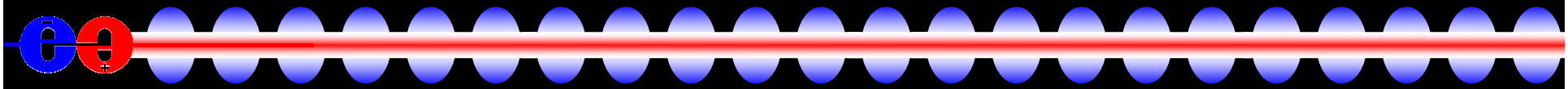
Simulation Framework



Simulator for the Linear Collider (SLIC)
Linear Collider Detector Description (LCDD)
Geometry Description Markup Language (GDML)
Linear Collider IO (LCIO)

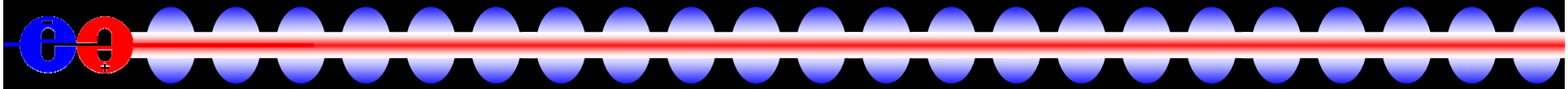


SLIC Simulator



- C++ user application using Geant4 toolkit
- hub package → most of functionality implemented in subpackages
- standard data formats for ILC
  - LCIO (output): HEP data model with generic Calorimeter and Tracker hits
  - StdHep (input): physics events
  - LCDD (input): GDML-based geometry system
- command line or macro commands / interactive

LCDD Geometry System



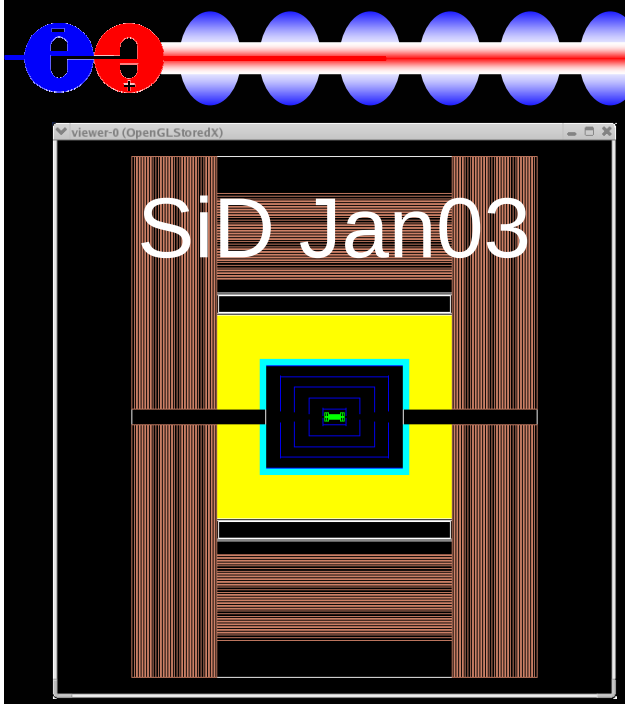
LCDD

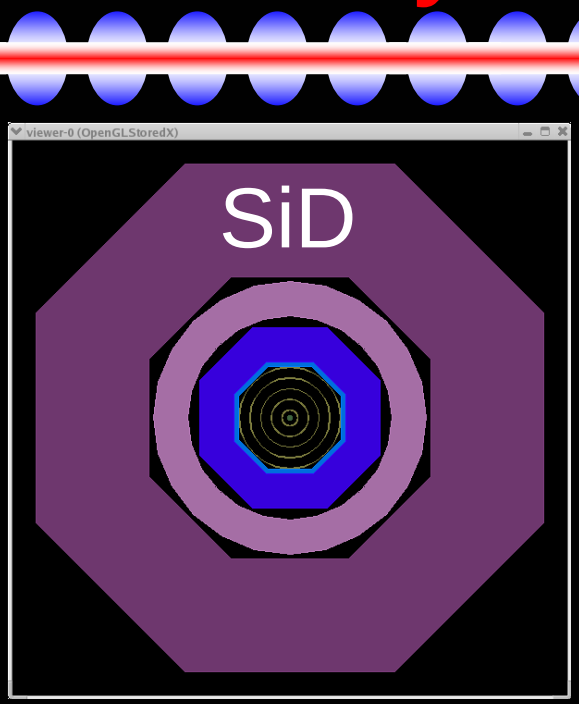
- Identifiers
- Sensitive Detectors
- Regions
- Physics Limits
- Visualization
- Magnetic Fields

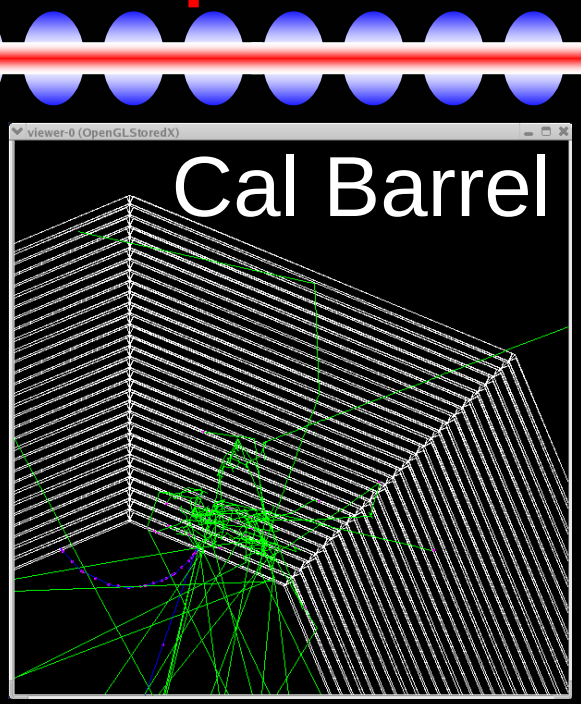
GDML

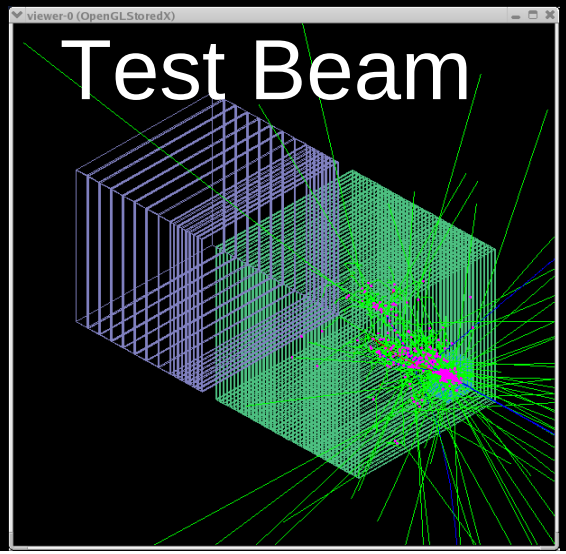
- Expressions (CLHEP)
- Materials
- Solids
- Volumes

LCDD Geometry Examples

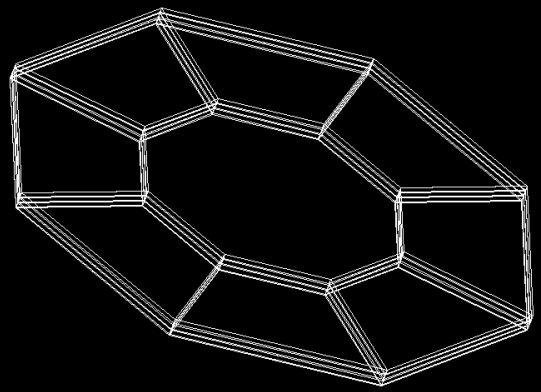




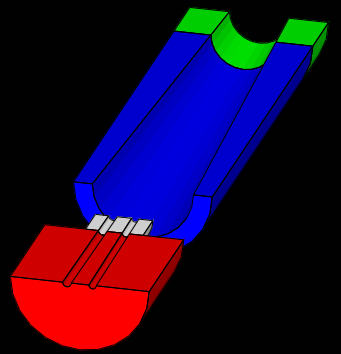




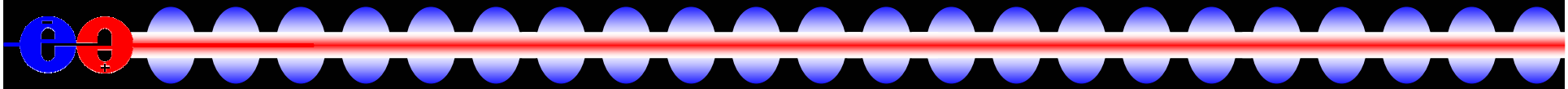
Cal Endcap



MDI-BDS

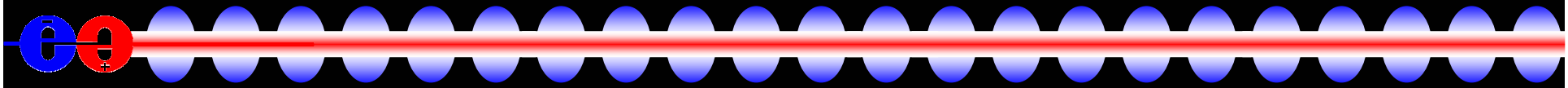


Geant4 Data Binding



Area	Root Element	Geant4 Class(es)
Sensitive Detectors	<sensitive_detectors>	G4VSensitiveDetector
Identifiers	<iddict>	NA (custom classes)
Regions	<regions>	G4Region, G4VUserRegionInformation
Physics Limits	<limits>	G4UserLimits
Visualization	<display>	G4VisAttributes
Magnetic Fields	<fields>	G4MagneticField
Constants	<define>	NA (CLHEP expressions)
Materials	<materials>	G4Material, G4Element
Shapes	<solids>	G4VSolid
Volumes	<structure>	G4LogicalVolume, G4VPhysicalVolume

LCDD XML Format



Container Elements

<lcdd>

<header>
<iddict>
<sensitive_detectors>
<regions>
<limits>
<display>
<gdml>
<define>
<materials>
<solids>
<structure>
<volume>
</structure>
<setup>
</gdml>
<fields>

</lcdd>

GDML

Core Elements

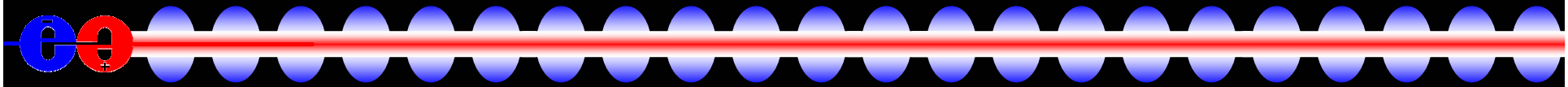
<idspec> – identifier
<sd> - sensitive detector
<region> – geometry region
<limitset> – set of physics limits
<vis> – visualization attributes

references

Volume Extensions

<sdref> – reference to subdetector
<regionref> – reference to region
<limitsetref> – reference to limits
<visref> – reference to vis attributes

Sensitive Detectors and Identifiers



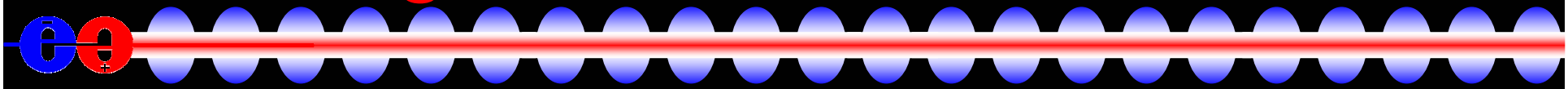
Sensitive Detectors

```
<calorimeter name=“EMBarrel” hits_collection=“EcalBarrHits”>
    <idspecref ref=“EcalBarrHits”/>
    <projective_cylinder ntheta=“1000” nphi=“2000”/>
</calorimeter>
```

Identifiers

```
<idspec name="EcalBarrHits" length="54">
    <idfield signed="false" label="layer" length="7" start="0" />
    <idfield signed="false" label="system" length="6" start="7" />
    <idfield signed="false" label="barrel" length="3" start="13" />
    <idfield signed="false" label="theta" length="11" start="32" />
    <idfield signed="false" label="phi" length="11" start="43" />
</idspec>
```

Regions, Fields & Limits



Regions

```
<region name="TrackingRegion"
        store_secondaries="true"
        cut="10.0"
        lunit="mm"
        threshold="1.0"
        eunit="MeV">
  <limitsetref ref="TestLimitSet"/>
 </regions>
```

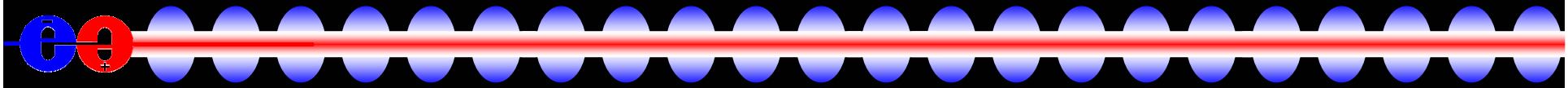
Fields

```
<solenoid name="GlobalSolenoid"
          inner_field="solenoid_inner_field"
          outer_field="solenoid_outer_field"
          zmin="solenoid_zmin"
          zmax="solenoid_zmax"
          inner_radius="solenoid_rmin"
          outer_radius="solenoid_rmax"
          funit="tesla"
          lunit="mm"/>
```

Physics Limits

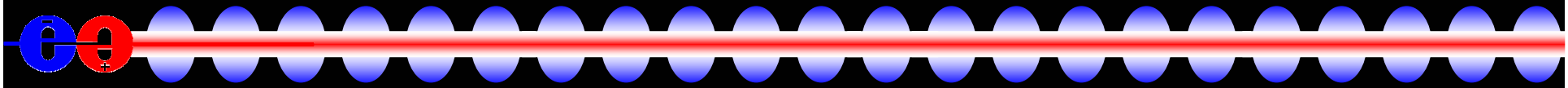
```
<limits>
   <limitset name="TestLimitSet">
     <limit name="step_length_max"  particles="*" value="1.0"   unit="mm"/>
     <limit name="track_length_max" particles="pi+, pi-, p0" value="100.0" unit="cm"/>
   </limitset>
 </limits>
```

Volume Element



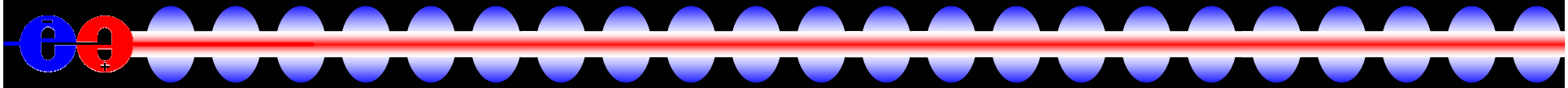
```
<volume name="EcalBarrelEnvelope">
        <materialref ref="Air"/>
        <solidref ref="EcalBarrelTube"/>
        <sdref ref="EcalSD"/>
        <regionref ref="EcalBarrelRegion"/>
        <limitsetref ref="EcalBarrelLimits"/>
        <visref ref="EcalBarrelLimits"/>
        <phsvol>
                <volumeref ref="EcalLayer1"/>
                <physvolid id="1"/>
        </physol>
</volume>
```

Compact Detector Description



- geometry format for reconstruction and analysis & event display
- core concepts
  - detectors, layers, slices, readouts
- translate Compact to other formats
  - LCDD (simulation)
  - HepRep (event display)
  - GODL (fast simulation with lelaps)
  - Java runtime (reconstruction)
- easy to change → regenerate target formats

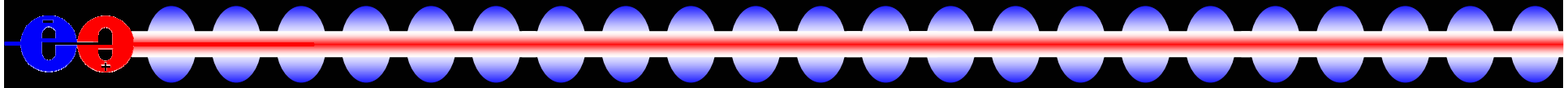
Compact Description Example



Two different layer stacks in same Ecal.

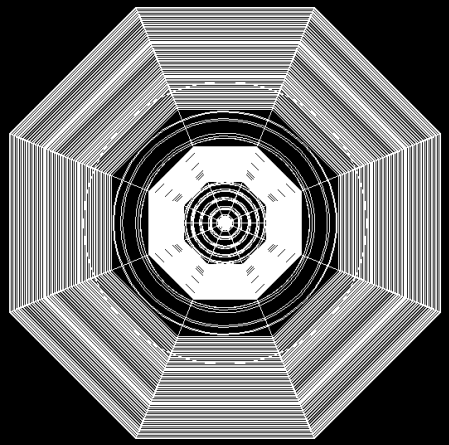
```
 <detector id="2" name="EMBarrel" type="CylindricalBarrelCalorimeter"
readdout="EcalBarrHits">
        <dimensions inner_r = "150.1*cm" outer_z = "208.0*cm" />
        <layer repeat="20">
          <slice material = "Tungsten" thickness = "0.25*cm" />
          <slice material = "G10" thickness = "0.068*cm" />
          <slice material = "Silicon" thickness = "0.032*cm" sensitive = "yes" />
          <slice material = "Air" thickness = "0.025*cm" />
        </layer>
        <layer repeat="10">
          <slice material = "Tungsten" thickness = "0.50*cm" />
          <slice material = "G10" thickness = "0.068*cm" />
          <slice material = "Silicon" thickness = "0.032*cm" sensitive = "yes" />
          <slice material = "Air" thickness = "0.025*cm" />
        </layer>
    </detector>
```

Detector Variants

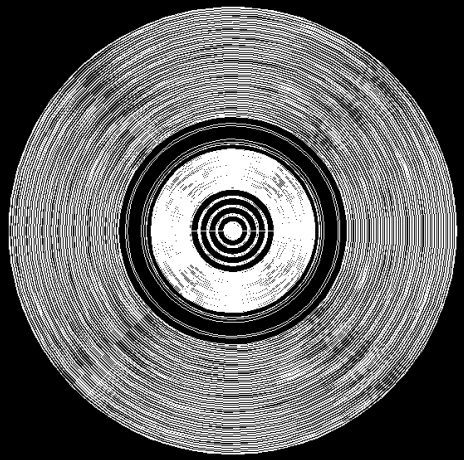


cdcaug05_ecal150

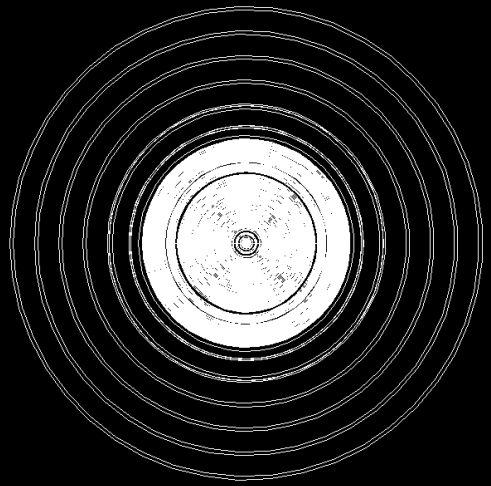
sidaug05_polyhedra



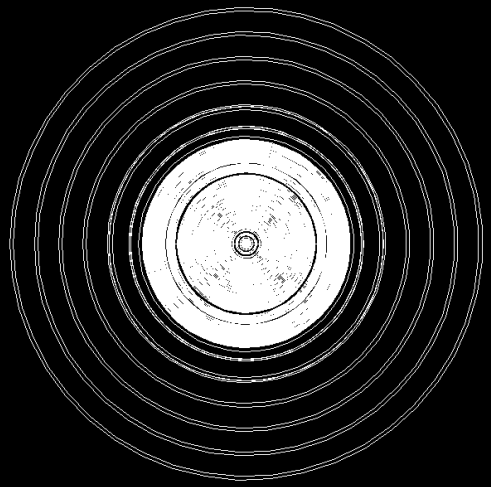
sid00



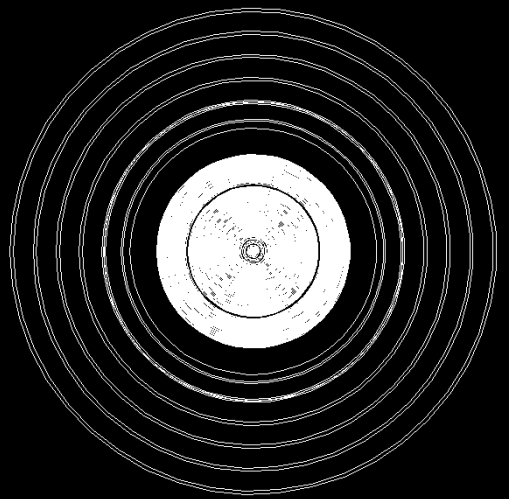
hd3_1-oct-05



ld3_1-oct-05

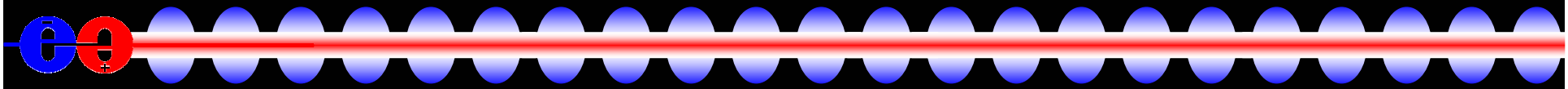


gldaug05



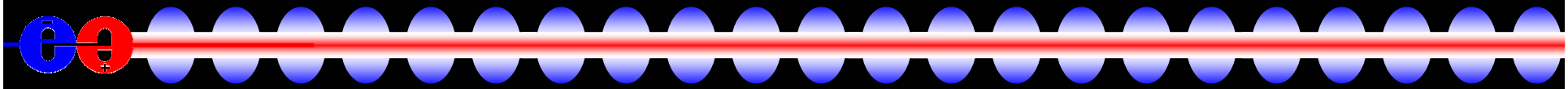
Geant4-generated HepReps drawn by WIRED4.

How do we work with Geant4?



- ILC physics list
  - LCPhys by Dennis Wright (Geant4 team)
- GDML (geometry sub-project)
  - build system, bug fixing, features
- bug finding
  - parameterized volumes (2004)
  - EM/HAD physics “anomalies” (ongoing)
- model test beam geometries (CALICE)

Links



LCSim Homepage	http://www.lcsim.org
Detector Resources	http://www.lcsim.org/detectors
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
ILC Sim Wiki	http://confluence.slac.stanford.edu/display/ilc/
SiD	http://www-sid.slac.stanford.edu/
LDC	http://www.ilcldc.org/
GLD	http://ilcphys.kek.jp/gld/