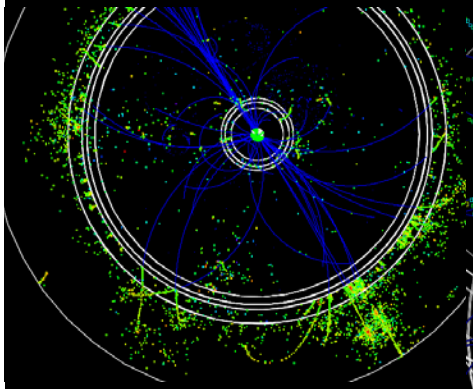
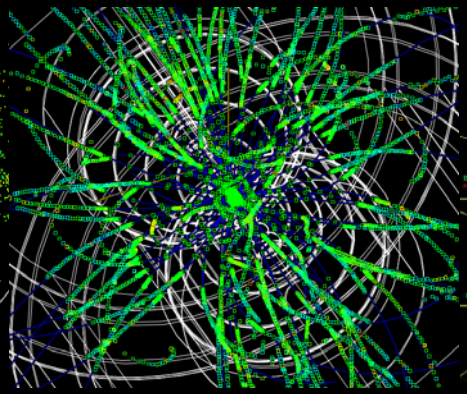
ILC Detector Simulation using SLIC

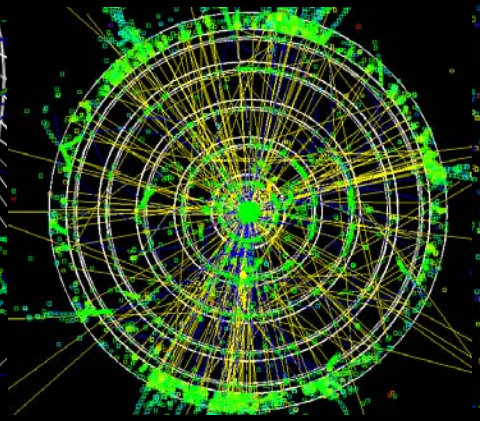
LDC: ttbar



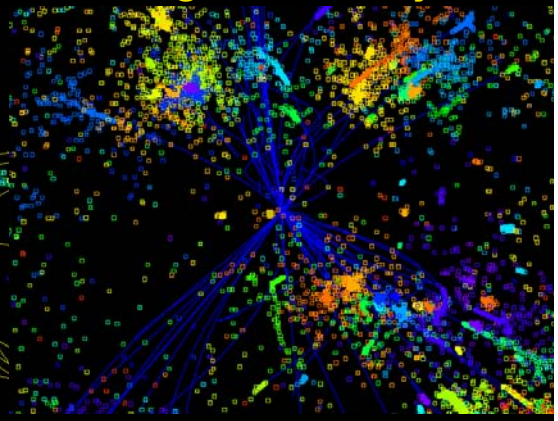
SiD May05: 100 muons



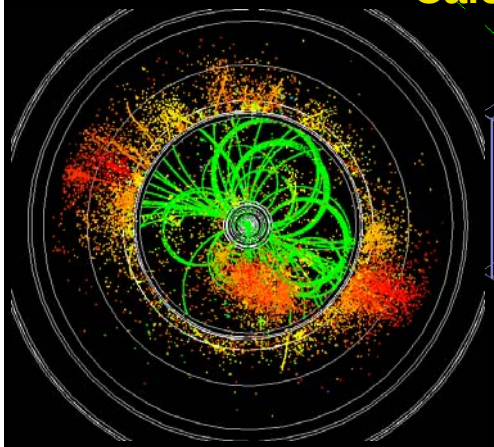
SiD Aug05: ttbar



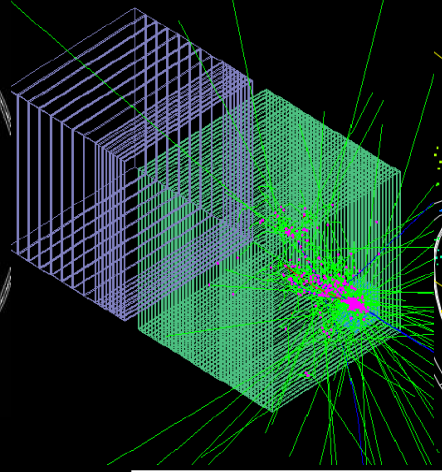
CDC Aug05: ttbar 6 jets



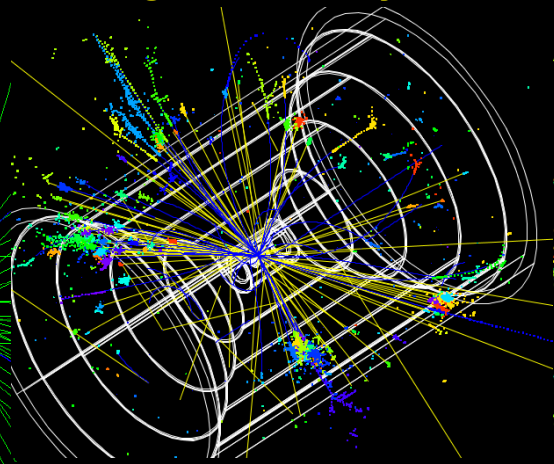
GLD: ttbar



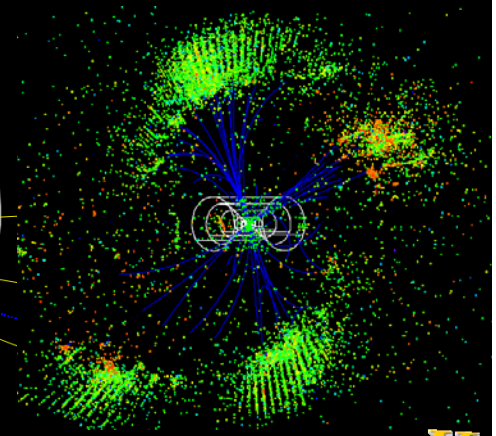
Calorimeter Testbeam



SiD Aug05: ttbar 6 jets



GLD: ZHiggs; M_H=120 GeV



Geant 4

Jeremy McCormick

SLAC LCD Simulations Group

World-Wide Studies of ILC Physics and Detectors

SLAC

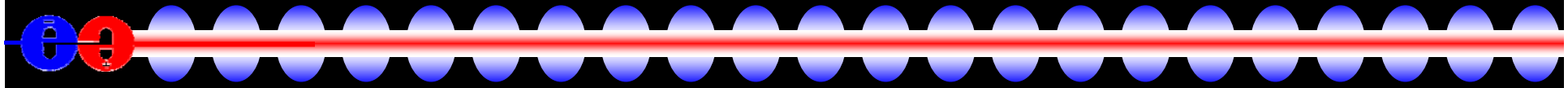
SiD

FREE HEP!

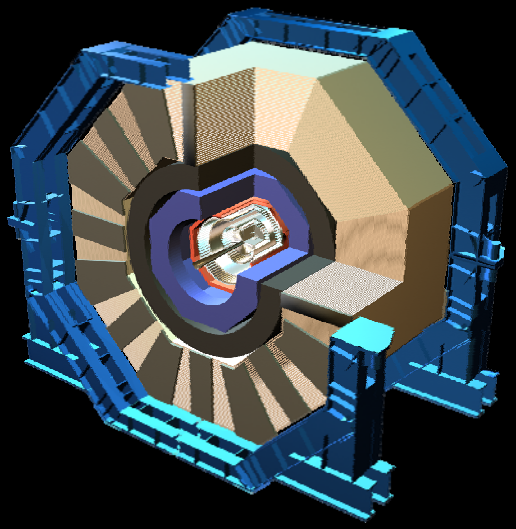
ECFA Study

Physics and Detectors for a Linear Collider

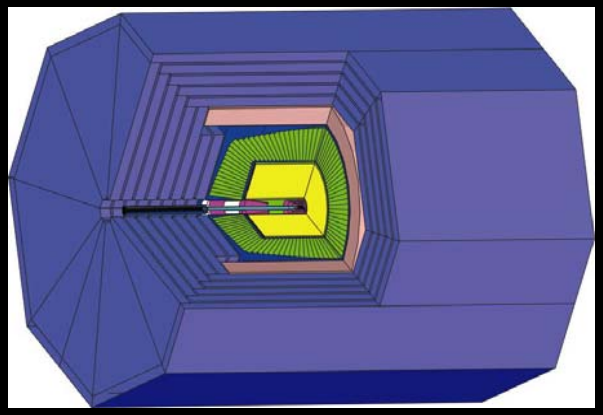
Requirements



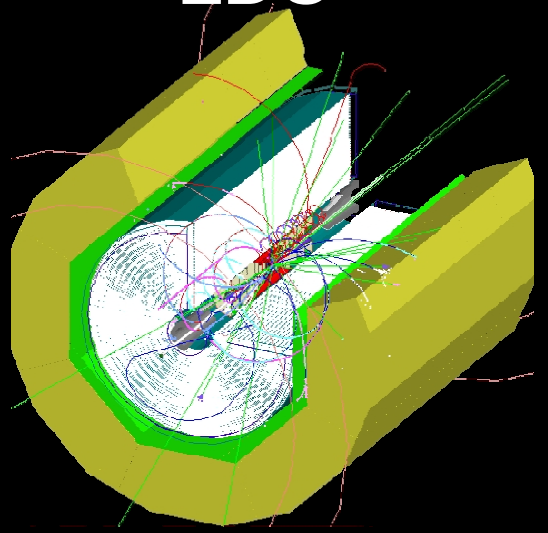
SiD



GLD

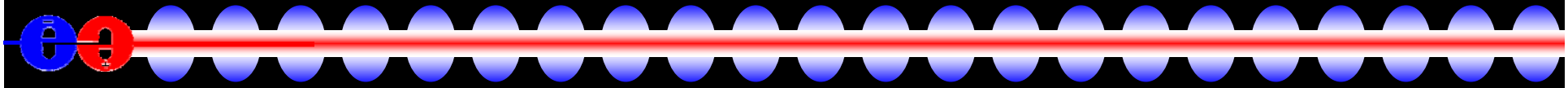


LDC



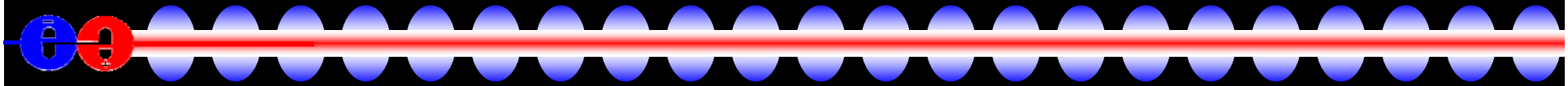
- model different detector designs and their variations
  - subdetector technologies, layering schemes, segmentation
- change running parameters
  - physics range cuts, physics list, mag field
- iteration (change geom → rerun), flexibility, utility

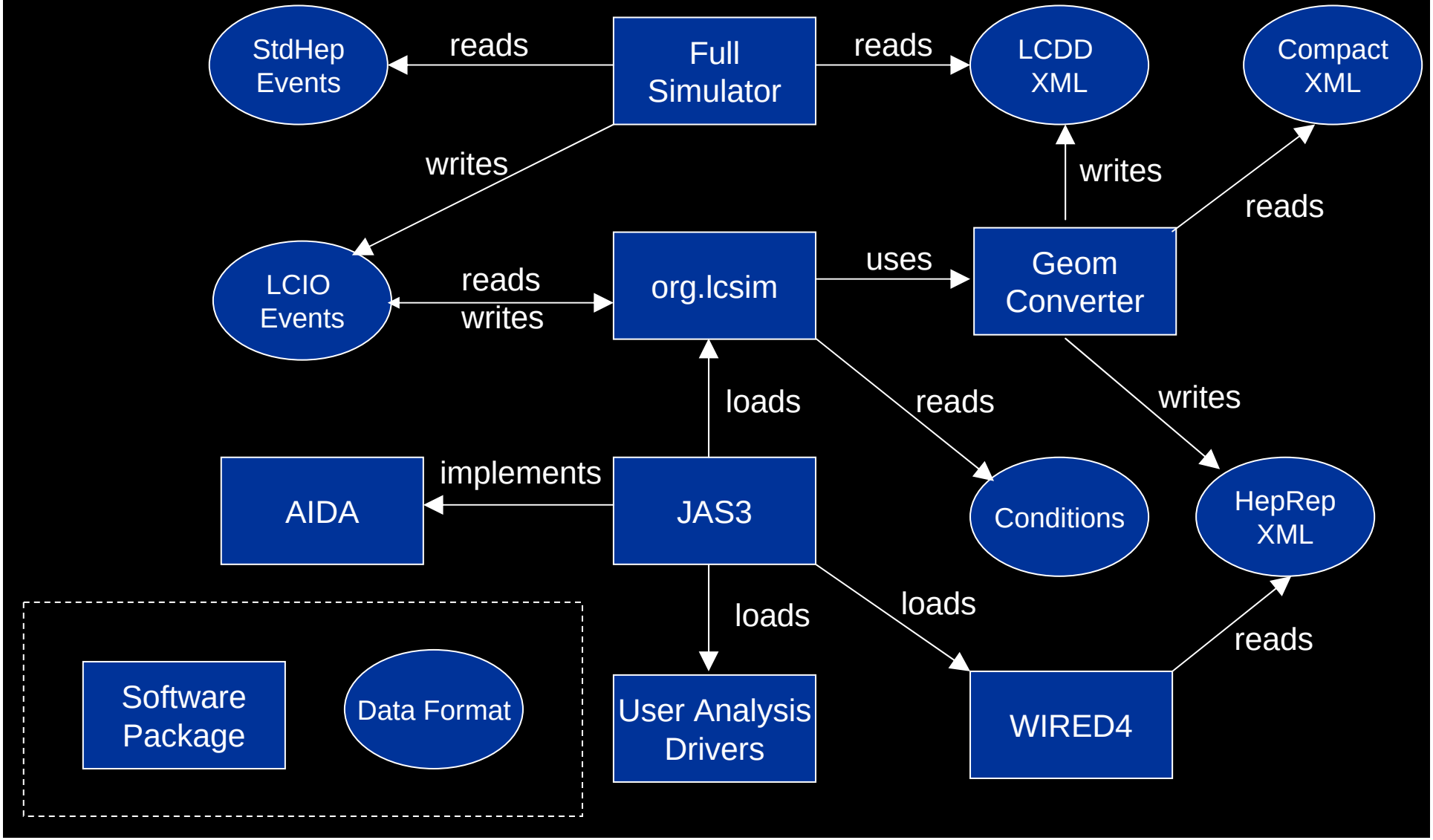
Detector Design using Geant4



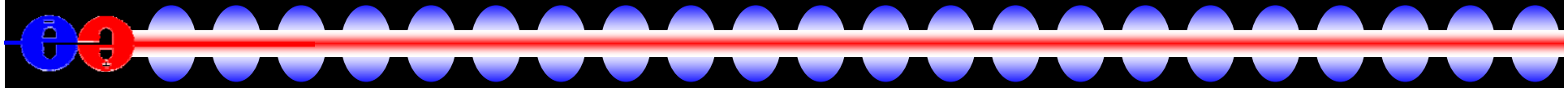
- The ILC is one of the first collaborations to use Geant4 for the ground-up design of a major HEP detector.
- Use Geant4 for prototyping and benchmarking.
- The detector description cannot be hard-coded → geometry is a runtime parameter.

Framework Diagram





Geometry System



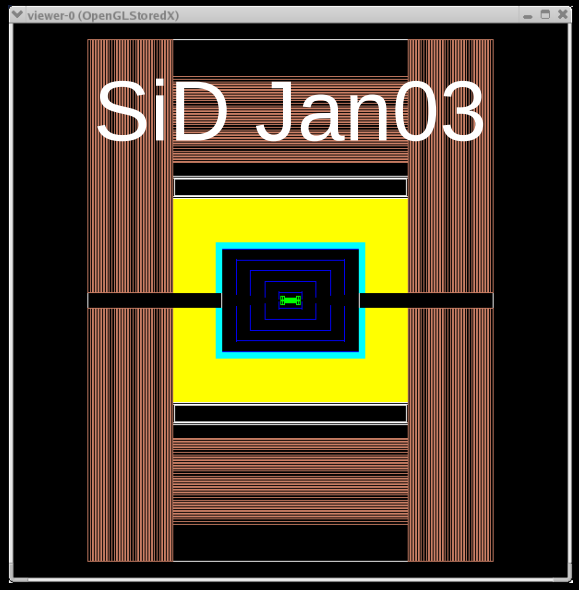
LCDD

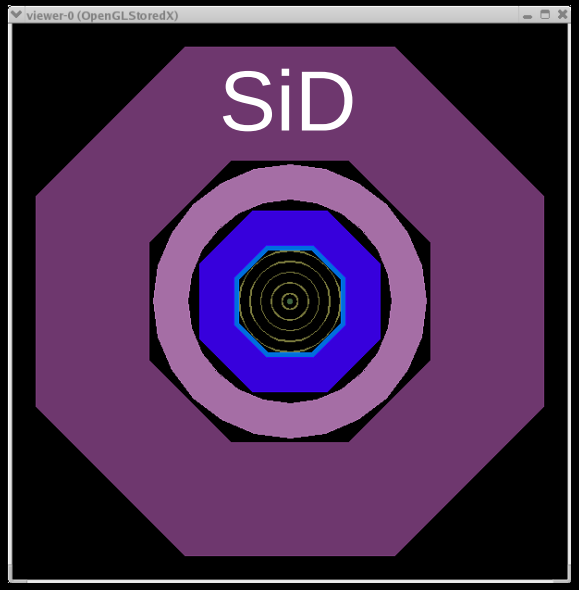
- Identifiers
- Sensitive Detectors
- Regions
- Physics Limits
- Visualization
- Magnetic Fields

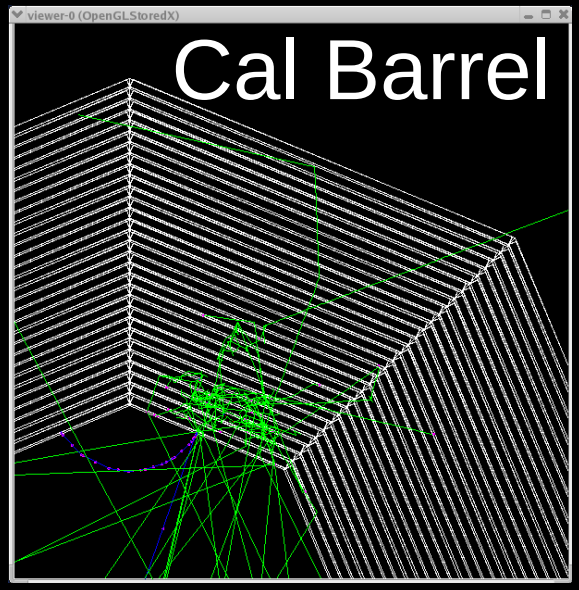
GDML

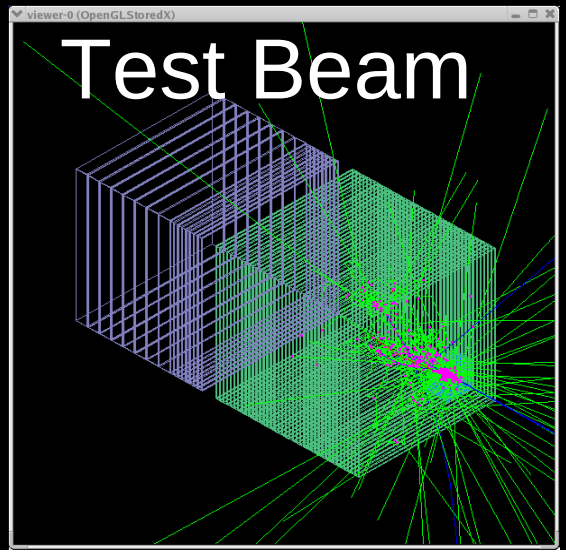
- Expressions (CLHEP)
- Materials
- Solids
- Volumes

Geometry Examples

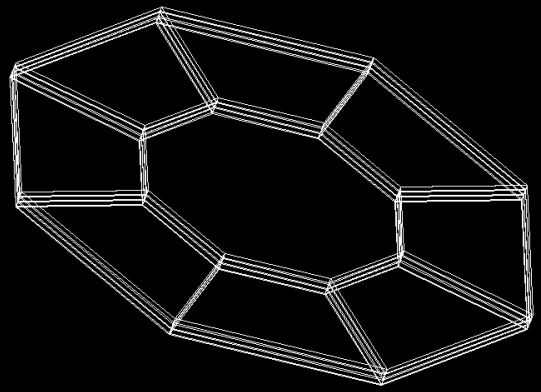




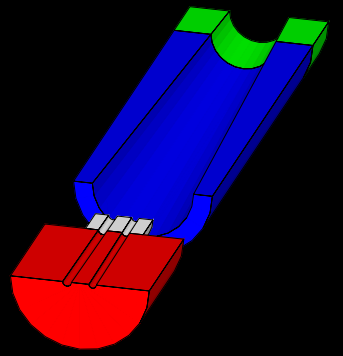




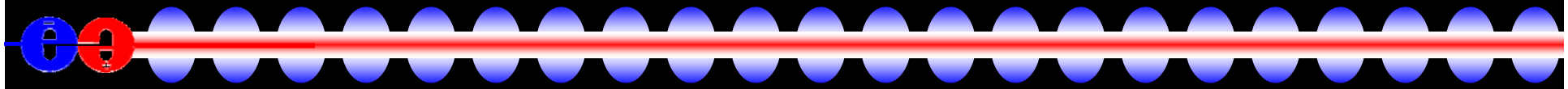
Cal Endcap



MDI-BDS

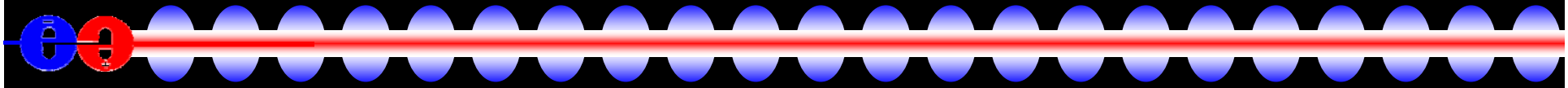


Geant4 Data Binding



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



<lcdd>

Container Elements

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

GDML

</lcdd>

Core Elements

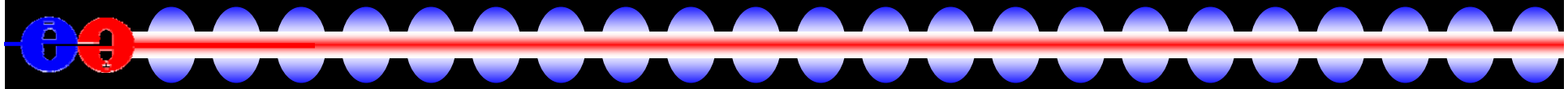
<idspec> – identifier
<sd> - sensitive detector
<region> – geometry region
<limitset> – set of physics limits
<vis> – visualization attributes

references

Volume Extensions

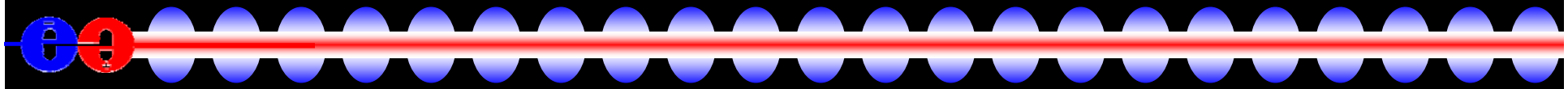
<sdref> – reference to subdetector
<regionref> – reference to region
<limitsetref> – reference to limits
<visref> – reference to vis attributes

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>
```

Sensitive Detectors and Identifiers



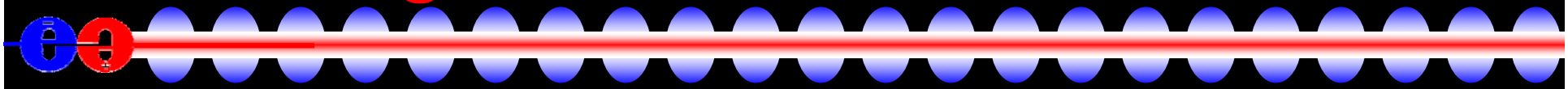
Sensitive Detectors

```
<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>
```

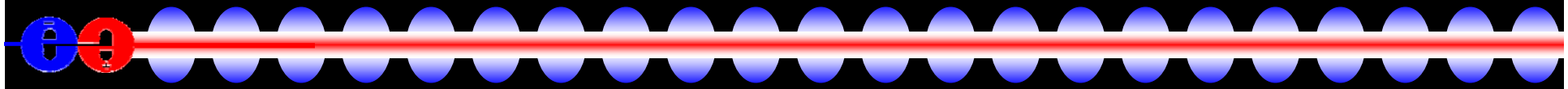
Fields

```
<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>
```

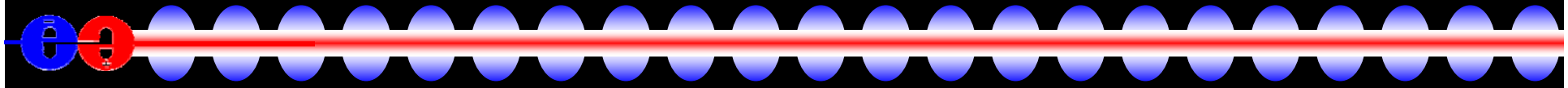
Compact Description Example



Two different layer stacks in same Ecal.

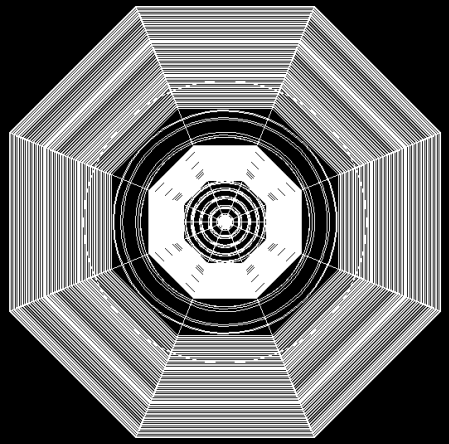
```
 <detector id="2" name="EMBarrel" type="CylindricalBarrelCalorimeter"
readdout="EcalBarrHits">
        <dimensions inner_r = "150.1*cm" outer_z = "208.0*cm" />
        <layer repeat="20">
          <slice material = "Tungsten" thickness = "0.25*cm" />
          <slice material = "G10" thickness = "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

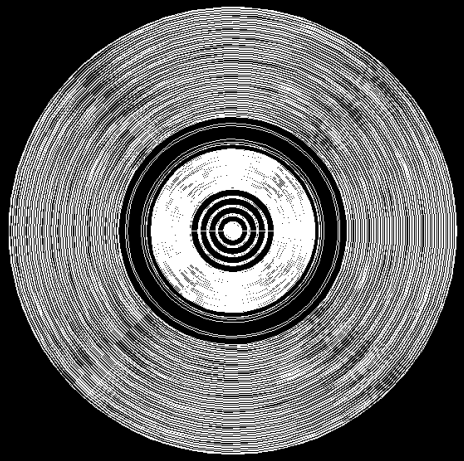


cdcaug05_ecal150

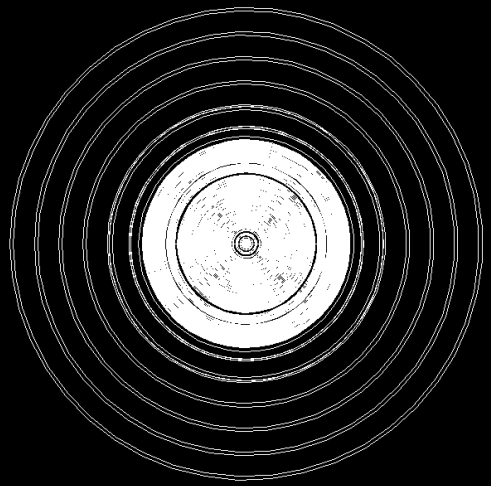
sidaug05_polyhedra



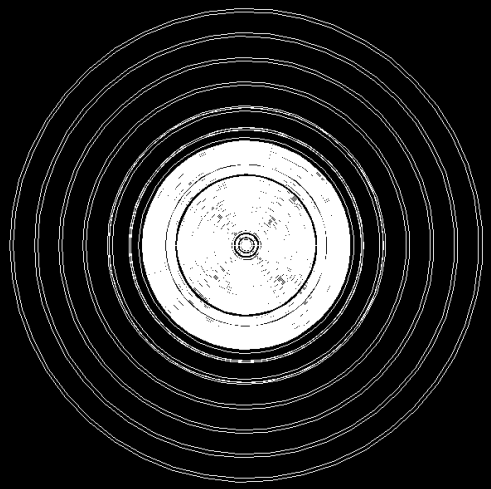
sid00



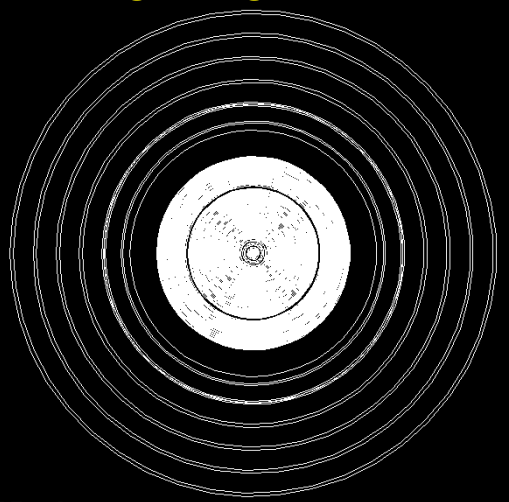
hd3_1-oct-05



ld3_1-oct-05

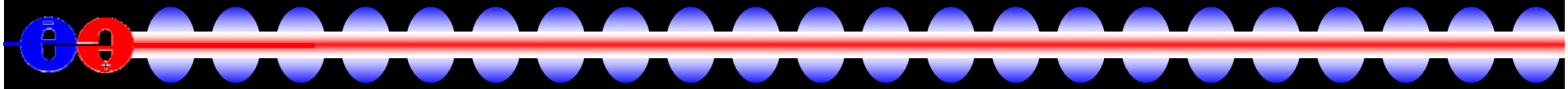


gldaug05

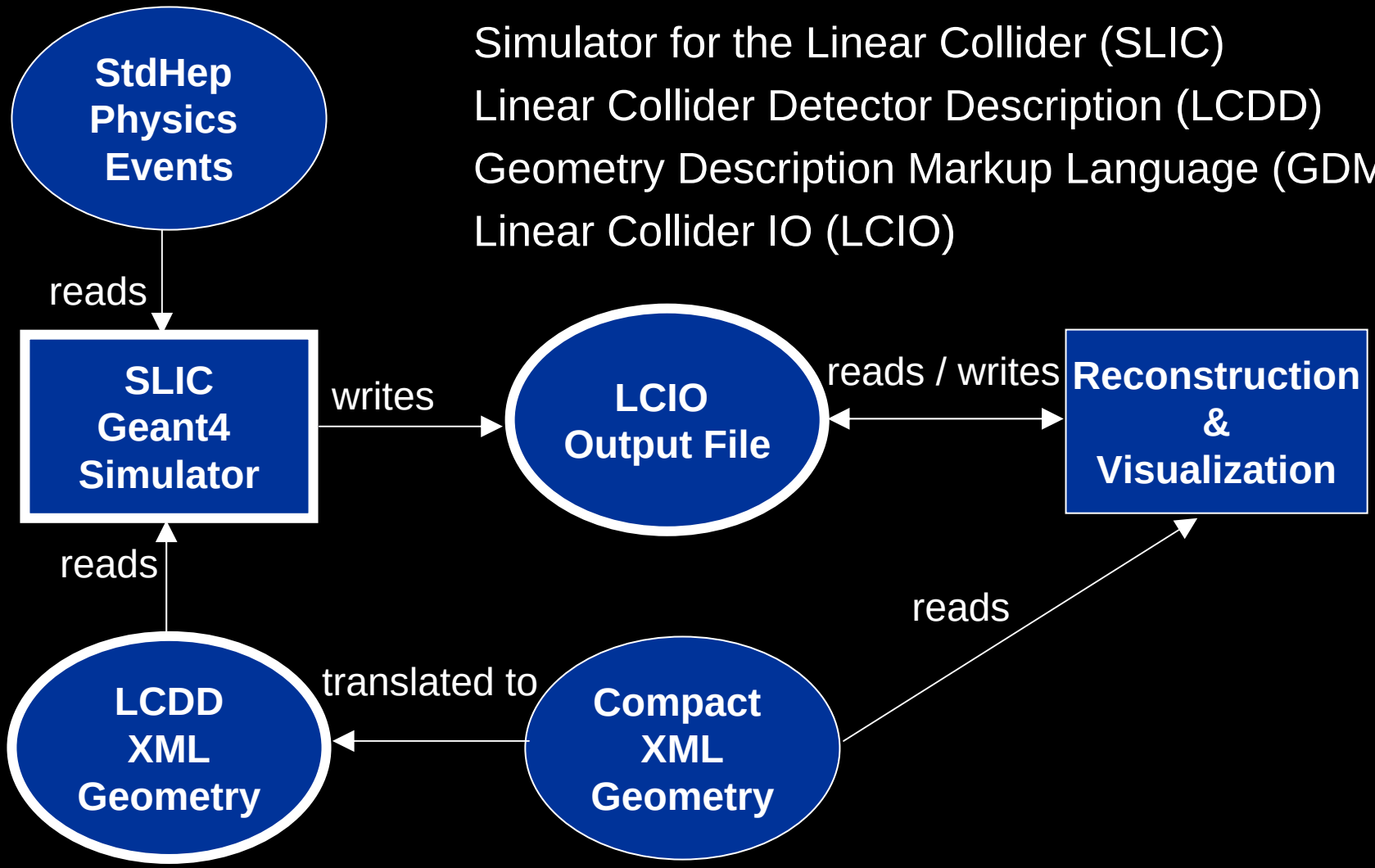


Geant4-generated HepReps drawn by WIRED4.

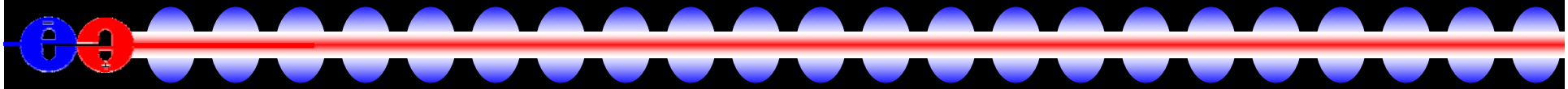
SLIC Diagram



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

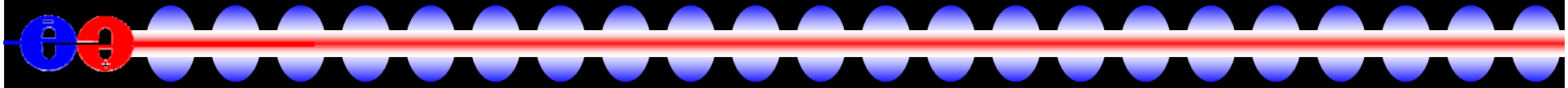


SLIC Overview



- 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

SLIC Commands



- All command-line options have equivalent Geant4 command
- Sample command

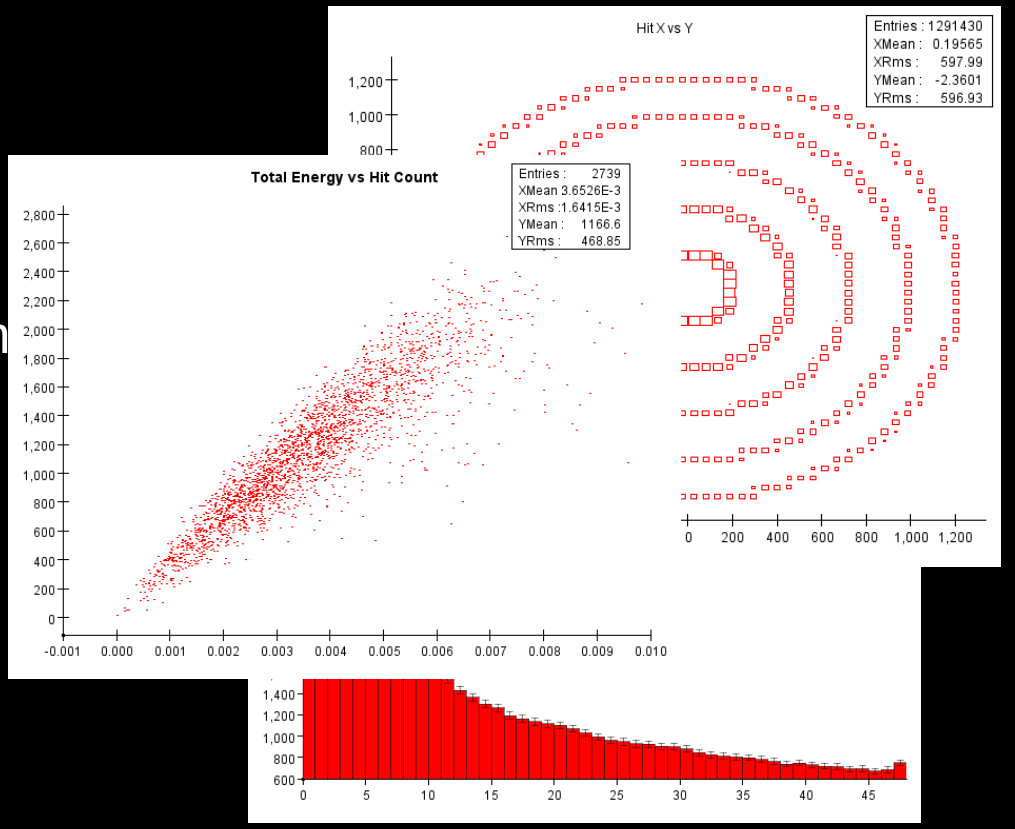
```
slic -g geometry.lcdd -i events.stdhep -x -O -l LCPhys -r 1000
```

- Equivalent macro

```
/lcdd/url geometry.lcdd
/run/initialize
/physics/select LCPhys
/generator/filename events.stdhep
/lcio/fileExists delete
/lcio/autoname
/run/beamOn 1000
```

Diagnostic Histograms

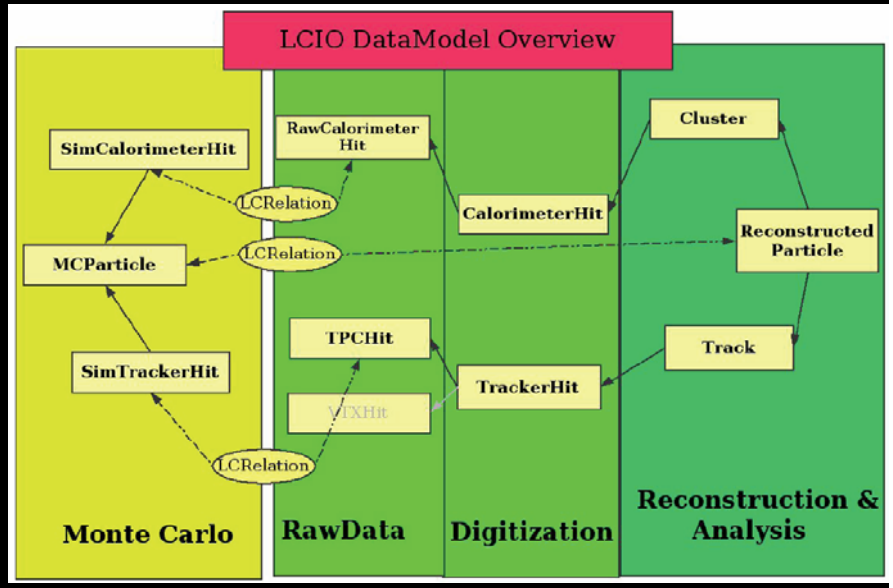
- Diagnostic plots of event data
  - MCParticles, hits, clusters
- Runs on different detectors
  - must have compact description
  - also need sampling fractions
- Easy to use and setup

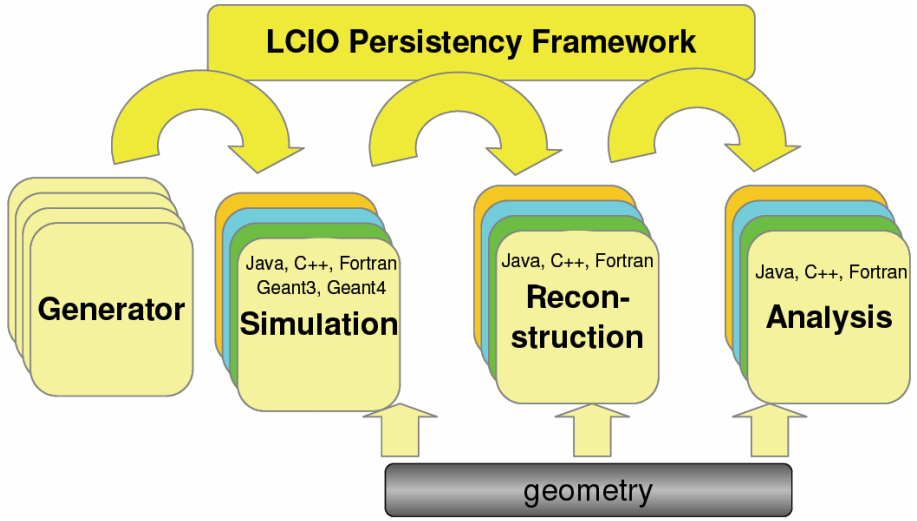


- SLAC CVS project
  - cvs –d :pserver:jeremy@cvs.freehep.org:/cvs/lcd co SlicDiagnostics
  - ./build.sh
  - ./bin/SlicDiagnostics [...]

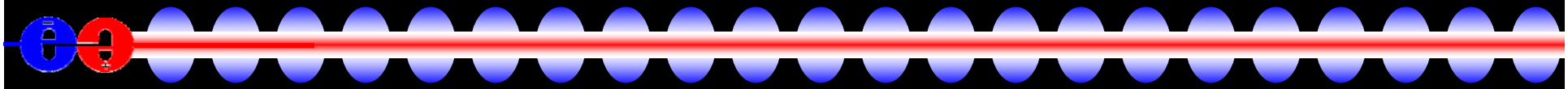
LCIO Overview

- Object model and persistency
  - Events
    - Monte Carlo
    - Raw
    - Event and run metadata
  - Reconstruction
  - Parameters, relations, attributes, arrays, generic objects, …
- All the ILC simulators write LCIO
  - Enables cross-checks between data from different simulators
  - Read/write LCIO from
    - Fast MC / Full Simulation
    - Different detectors
    - Different reconstruction tools





LCIO Data Samples

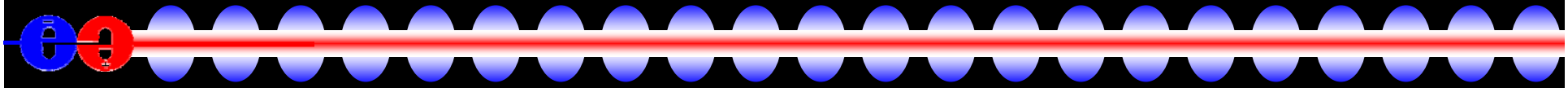


- LCIO data samples available via anonymous FTP
  - http://www.lcsim.org/datasets/ftp.html
- Data sets
  - ILC500
    - 500 GeV machine parameters
  - ILC1000
    - 1 TeV machine parameters
  - singleParticle
    - Single particle diagnostic events
  - Zpole
    - Zpole diagnostic events

Organization

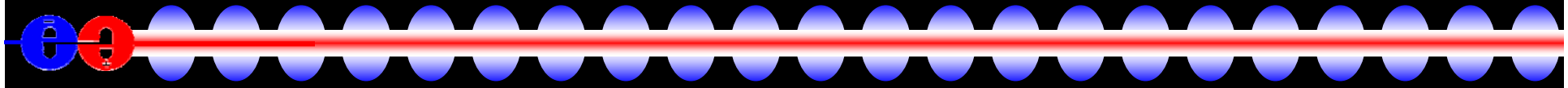
- **[event type]** - complex or single particle event type, e.g. ZZ, ZPole, muons, etc.
  - **stdhep** - input StdHep files used to generate the events
  - **[detector name]** - detector geometry tag, such as sidaug05
    - **[data file format]** - output datafile format, e.g. LCIO or SIO
      - **[simulator]** - simulator that generated the events, e.g. lcdg4, slic, lelaps, mokka, etc.
        - **logs** - simulator job logs

Software Distribution

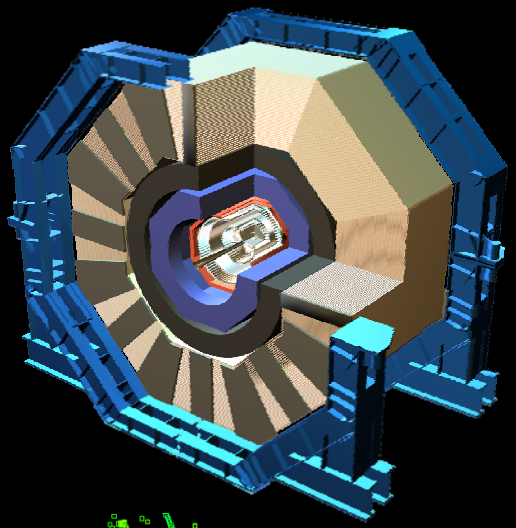


- SLIC requires
  - Geant4, CLHEP, GDML, LCDD, Xerces, LCPhys, LCIO
  - Automated build system provided
- Binary downloads
  - http://www.lcsim.org/dist/slic
  - Linux, Windows (Cygwin), OSX
  - All packages (dist) or just runtime dependencies (bin)
- Or checkout and build from scratch
  - cvs –d :pserver:anonyous@cvs.freehep.org:/cvs/lcd co SimDist
  - cd SimDist; ./configure; make
- Installed at SLAC, NICADD, FNAL, IN2P3, UC, ...
- Report any problems to jeremym@slac.stanford.edu

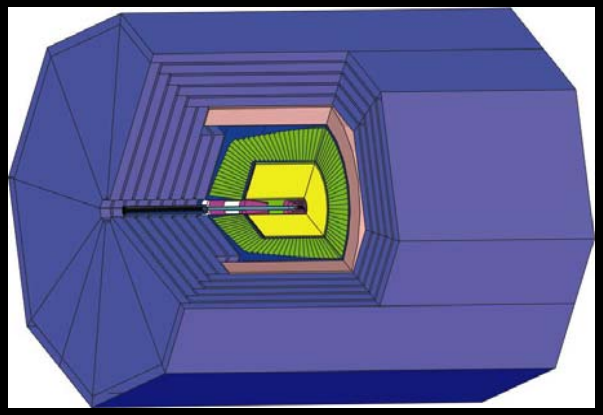
WIRED Event Display



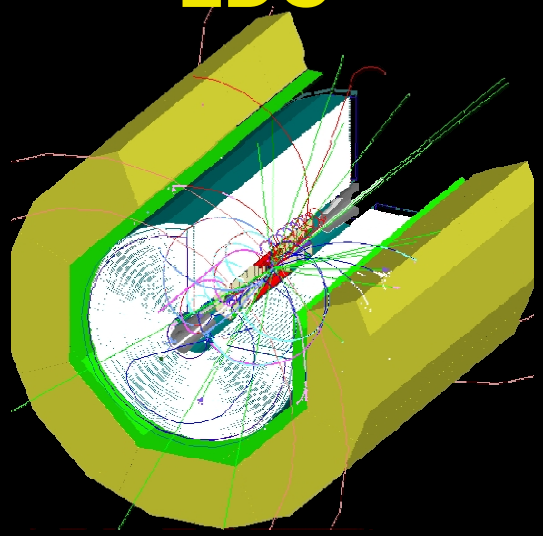
SiD

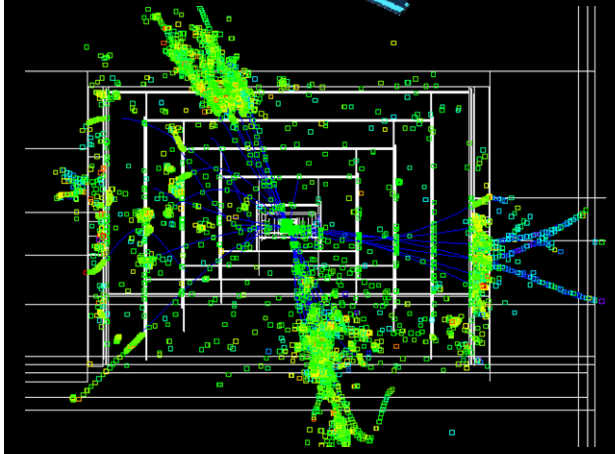


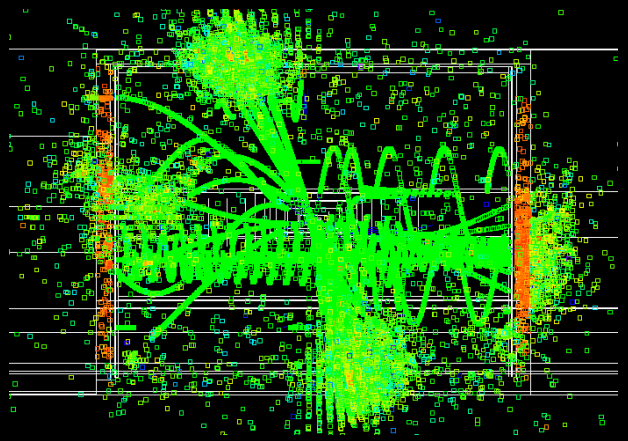
GLD

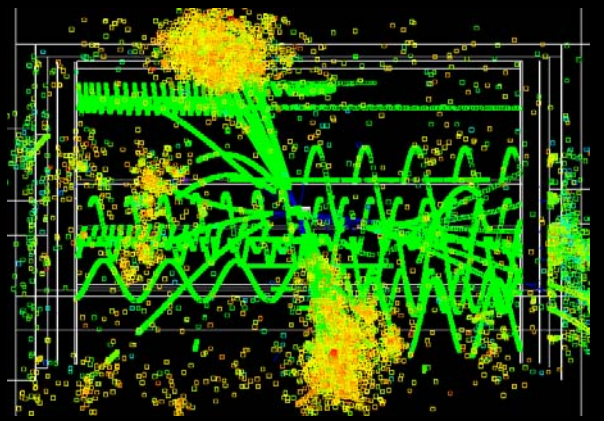


LDC



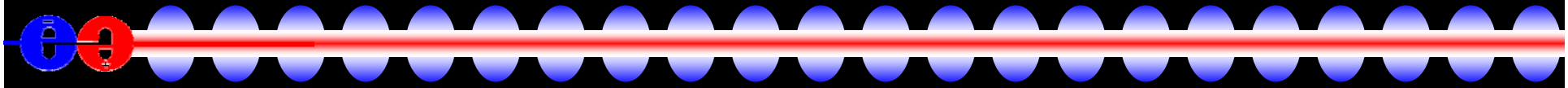






Z Higgs (M_H=120 GeV) → same simulator, three different full detector geometries

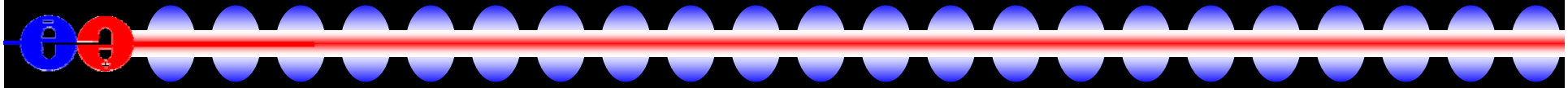
Links



- Wiki - http://confluence.slac.stanford.edu/display/ilc/Home
- lcsim.org - http://www.lcsim.org
- org.lcsim - http://www.lcsim.org/software/lcsim
- Software Index - http://www.lcsim.org/software
- Detectors - http://www.lcsim.org/detectors
- ILC Forum - http://forum.linearcollider.org
- 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

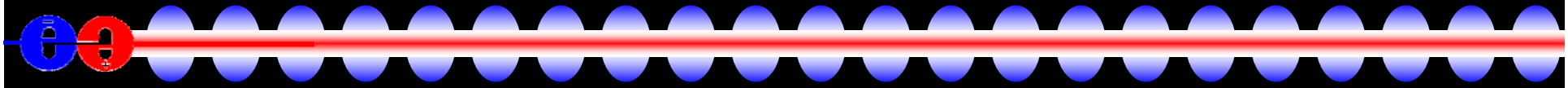
BACKUP SLIDES

LCIO Autonaming



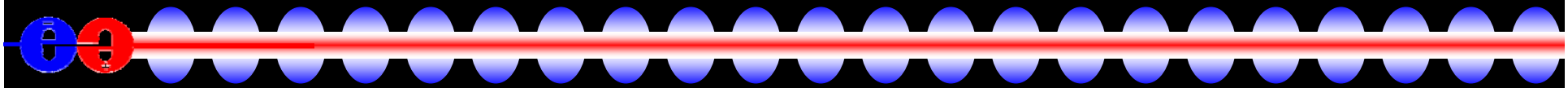
- Automatically generate sensible output file names from input parameters.
- Use the “-O” switch from the command-line.
- Example macro usage
  - /lcio/autoname geometry application version event date
  - → mygeom_SLIC_v2r0p5_myevents_2006-07-19.slcio
- Use it when making files for bug reports.
- Good for making unique filenames “on the fly”.

Other Available Physics Lists



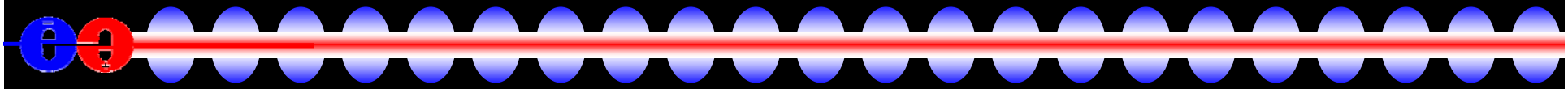
- FTFC
  - Fritjof with CHIPS
- FTFP
  - Fritjof with precompound
- LHEP
  - low / high energy parameterised
- QGSC
  - Quark-Gluon String with CHIPS
- QGSP
  - Quark-Gluon String with precompound
- QGSP_BERT
  - Quark-Gluon string with precompoind + Bertini Cascade
- LHEP_BERT
  - low / high energy parameterised + Bertini Cascade

LCPhys



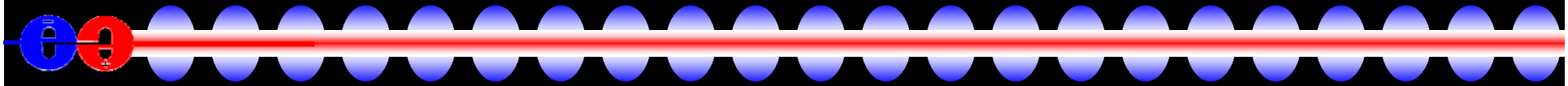
- standard Geant4 EM physics
- hadronic models
  - Bertini Cascade
    - 0 to 9.9 GeV for p, n, pi+, pi-
    - 0 to 13 GeV for K+, K-, K0L, K0S, Lambda, Sigma+, Sigma-, Xi0, Xi-
  - Low energy parameterized models
    - 9.5 to 25 GeV
  - Quark-Gluon String Model: use for
    - 12 GeV to 100 TeV for p, n, pi+, pi-, K+, K-, K0L, K0S
- additional neutron processes
  - neutron-induced fission
  - neutron capture
- gamma-nuclear

Event Sources



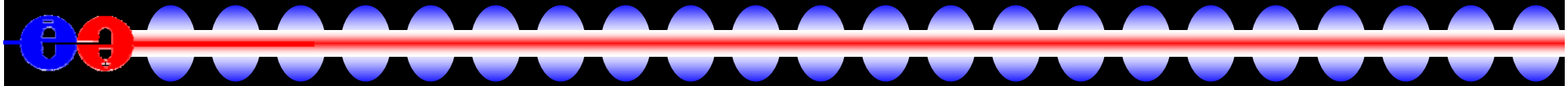
- General Particle Source (GPS)
  - advanced single particle source builtin to Geant4
  - angular distributions
  - randomized energy
  - one or more particles
  - generate in volume (box, tube, etc.)
- StdHep
  - common binary format for event generators
  - HEPEVT block
  - your favorite event generator
    - PYTHIA, HERWIG, WHIZARD, etc.
- LCIO
  - converts LCIO MCParticle block into G4PrimaryParticles
  - read output from other simulators (Mokka, JUPITER, etc.)
  - EXPERIMENTAL

Event Source Conversion



- use LCIO MCParticle data structure for bookkeeping during simulation\\
- GPS or G4ParticleGun
  - no initial MCParticle collection necessary
  - convert directly from Geant4 trajectory container
- StdHep or LCIO event source
  - create initial LCIO MCParticle tree
  - make G4PrimaryParticles for each MCParticle if
    - travels > mininum tracking distance
    - intermediate or final (documentation not tracked)
  - predecays
    - preassigned decays from the generator
    - assign time, daughters, etc.
    - Geant4 may still override (e.g. if it interacts before predecay occurs)
    - no vertex → determined from parent particle

MCParticle Tree



- Final MCParticle tree written to LCIO file built from a number of sources
  - Initial MCParticle collection (see “Event Source Conversion”)
  - Geant4 trajectory collection
    - custom trajectory class maintains information for setting MCParticle flags
  - G4PrimaryParticle collection
  - G4Track objects
  - maps
    - TrackID → MCParticle
    - MCParticle → TrackID
    - Trajectory → Initial MCParticle
    - G4PrimaryParticle → daughter MCParticle
    - initial MCParticle → final MCParticle
    - MCParticle → G4PrimaryParticle