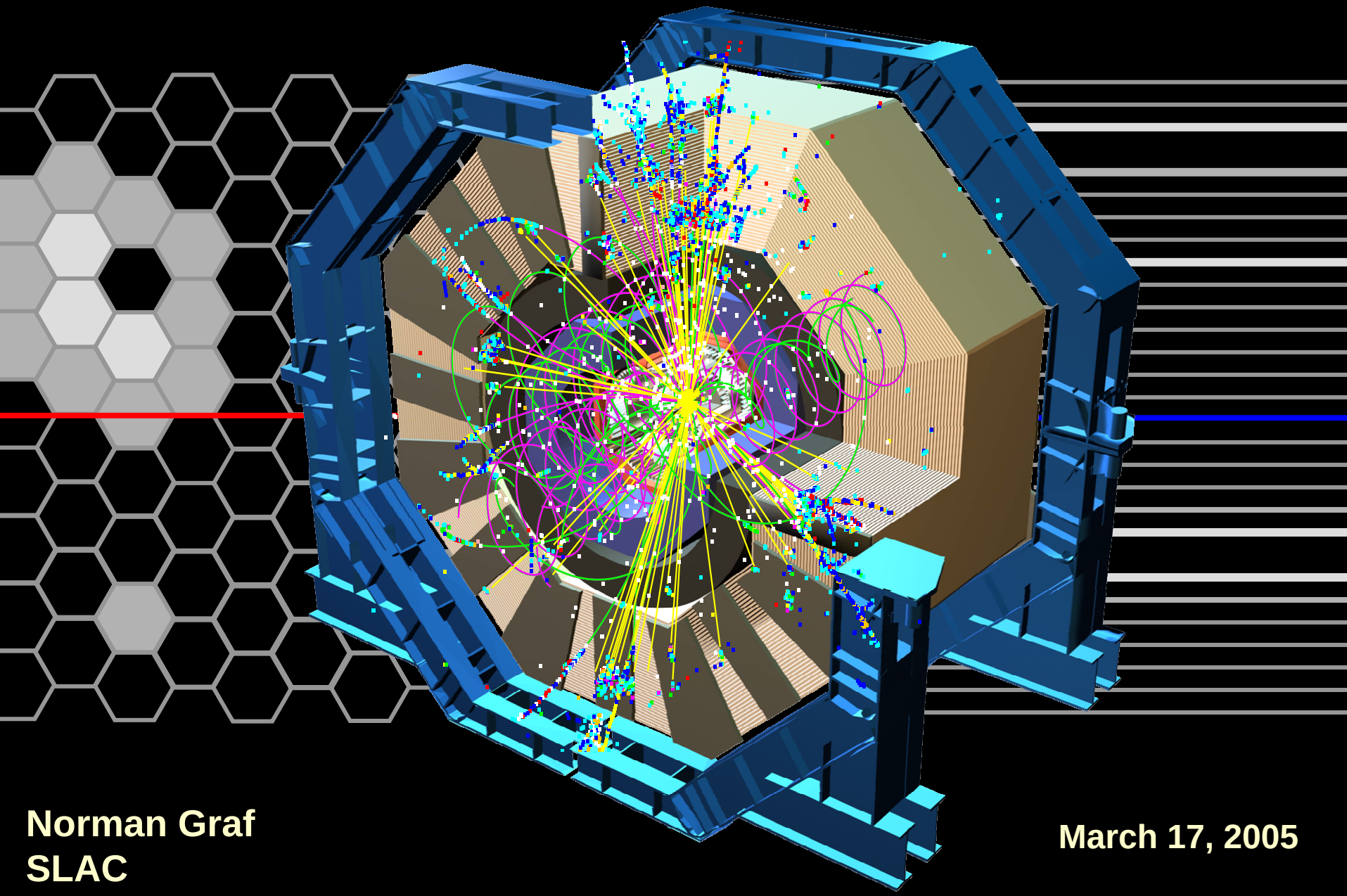
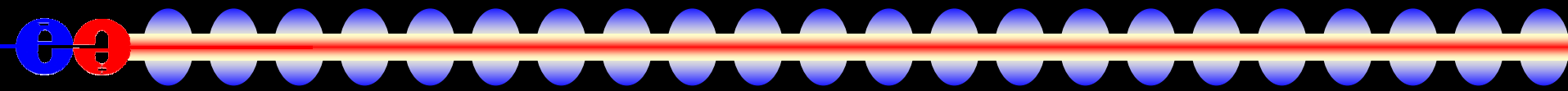
Simulating the Silicon Detector



Norman Graf
SLAC

March 17, 2005

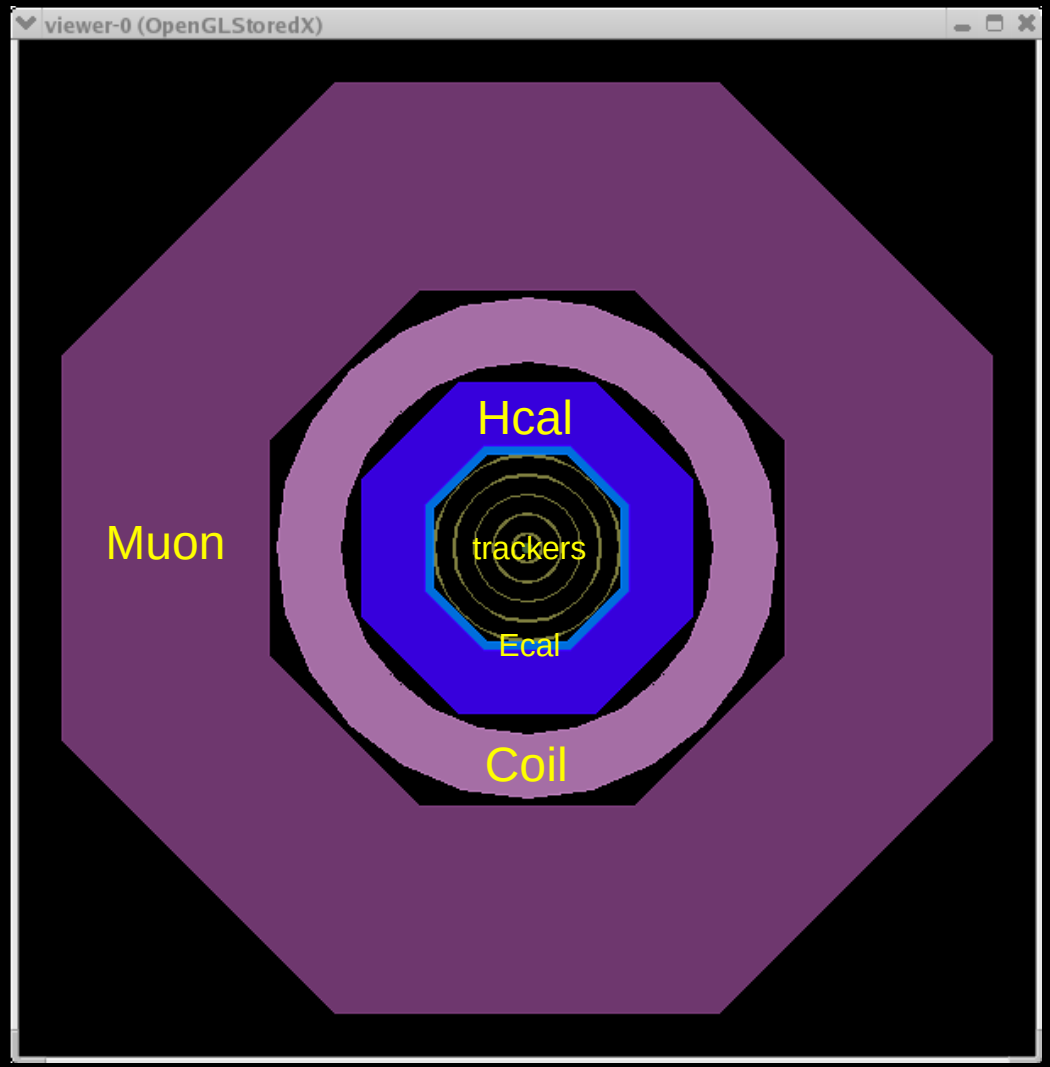
Detector Response Simulation



- Use Geant4 toolkit to describe interaction of particles with matter.
- Thin layer of LC-specific C++ provides access to:
  - Event Generator input (binary stdhep format)
  - Detector Geometry description (XML)
  - Detector Hits (LCIO)
- Geometries fully described at run-time!
  - In principle, as fully detailed as desired.
  - In practice, will explore detector variations with simplified approximations.

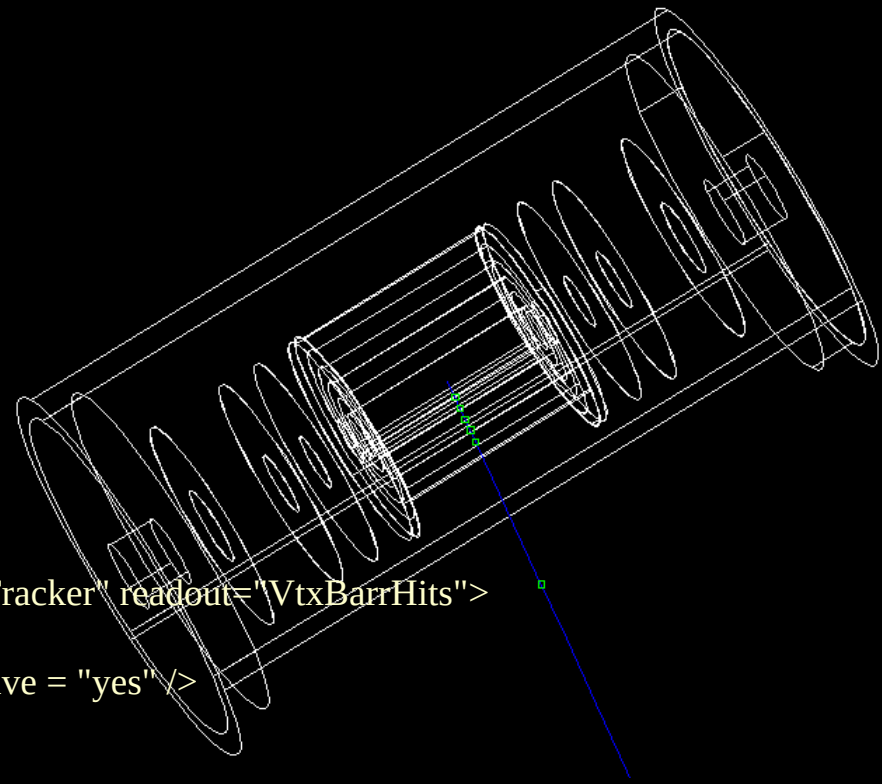
SiDFeb05 Detector Envelopes

- **./sid/SiDEnvelope.lcdd**
- *toy example* without real materials or layer structure
- polyhedra for calorimeter envelopes
- illustrates possibility of modeling realistic detector designs with “corners”
    - add trapezoid-shaped readout modules with box layers



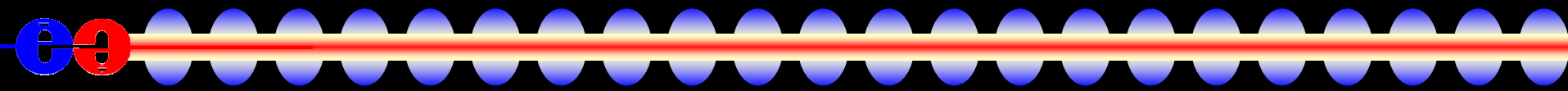
Vertex Detector

- 5 Layer CCD Barrel
- 4 Layer CCD Disks
- Be supports
- Foam Cryostat



```
<detectors>
  <detector id="0" name="BarrelVertex" type="MultiLayerTracker" readout="VtxBarrHits">
    <layer id="1" inner_r = "1.5*cm" outer_z = "6.25*cm">
      <slice material = "Silicon" width = "0.01*cm" sensitive = "yes" />
    </layer>
    <layer id="2" inner_r = "2.6*cm" outer_z = "6.25*cm">
      <slice material = "Silicon" width = "0.01*cm" sensitive = "yes" />
    </layer>
    <layer id="3" inner_r = "3.7*cm" outer_z = "6.25*cm">
      <slice material = "Silicon" width = "0.01*cm" sensitive = "yes" />
    </layer>
    <layer id="4" inner_r = "4.8*cm" outer_z = "6.25*cm" >
      <slice material = "Silicon" width = "0.01*cm" sensitive = "yes" />
    </layer>
```

Central Tracking Detector

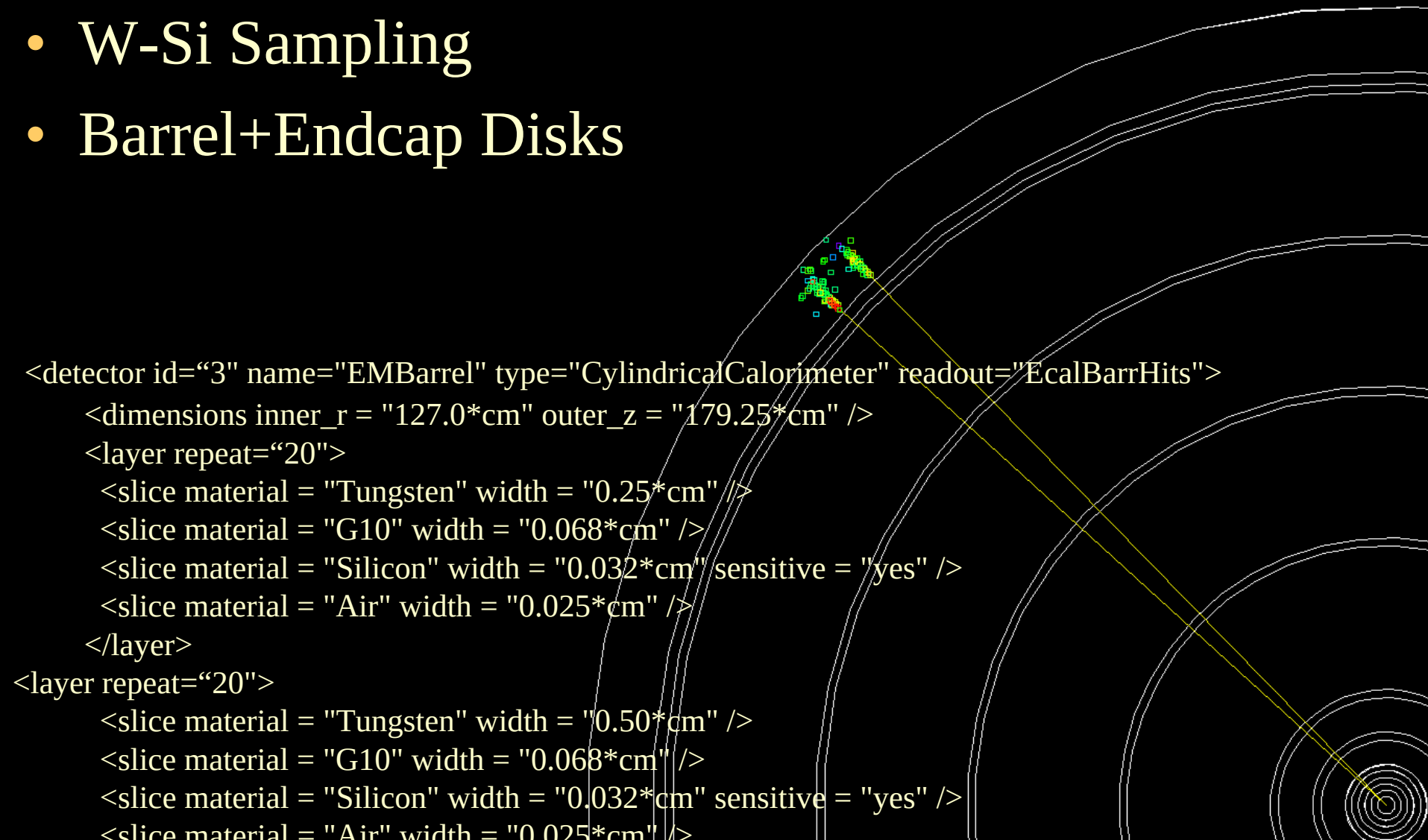


- 5 Layer Si μ-strips
- Barrel+Disk
- C-Rohacell-C supports

```
<detector id="2" name="BarrelTracker" type="MultiLayerTracker"  readout="TkrBarrHits">
    <layer id="1" inner_r = "18.635*cm" outer_z = "26.67*cm">
        <slice material = "CarbonFiber" width = "0.025*cm" />
        <slice material = "Rohacell31" width="1.3*cm" />
        <slice material = "CarbonFiber" width=".025*cm" />
        <slice material = "Silicon" width = "0.03*cm" sensitive = "yes" />
    </layer>
    <layer id="2" inner_r = "44.885*cm" outer_z = "61.67*cm">
        <slice material = "CarbonFiber" width = "0.025*cm" />
        <slice material = "Rohacell31" width="1.3*cm" />
        <slice material = "CarbonFiber" width=".025*cm" />
        <slice material = "Silicon" width = "0.03*cm" sensitive = "yes" />
    </layer>
```

EM Calorimeter

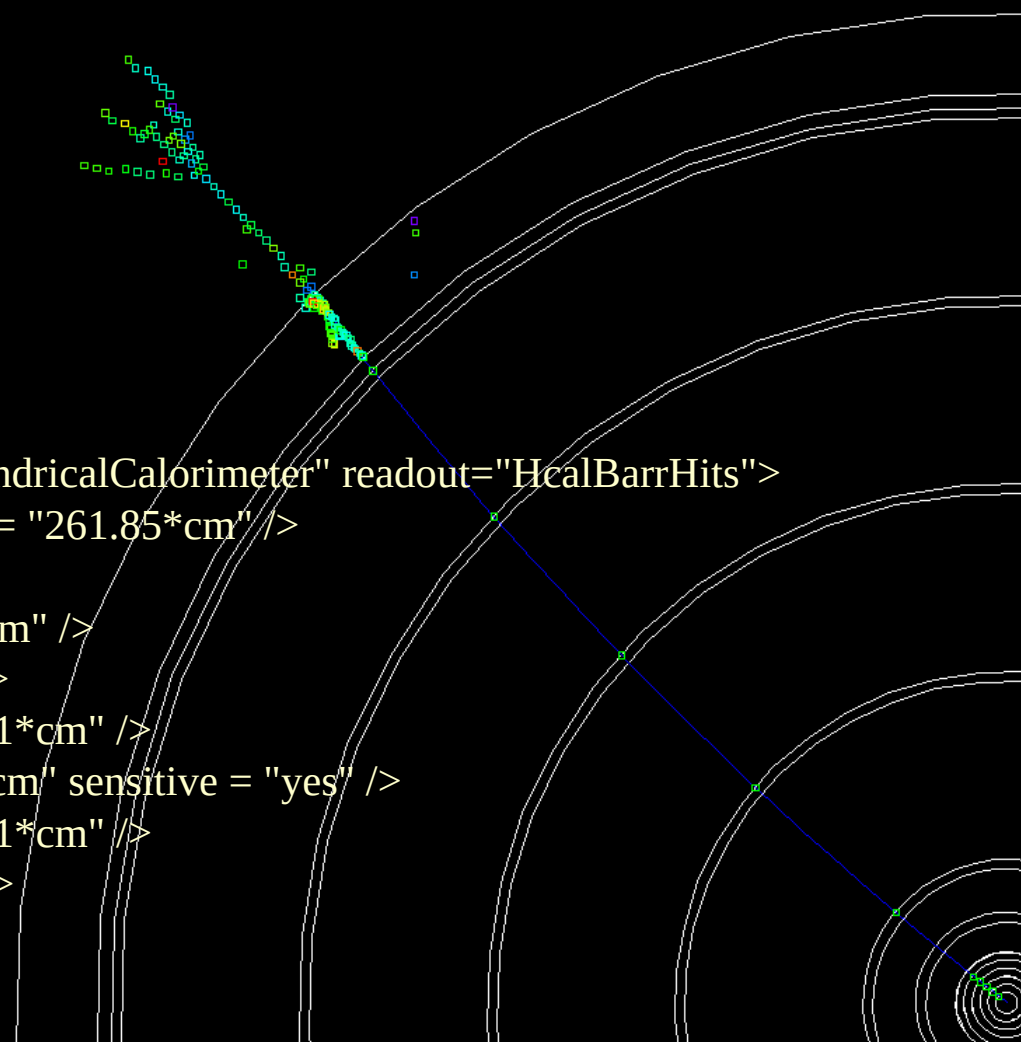
- W-Si Sampling
- Barrel+Endcap Disks



```
<detector id=“3" name="EMBarrel" type="CylindricalCalorimeter" readout="EcalBarrHits">
      <dimensions inner_r = "127.0*cm" outer_z = "179.25*cm" />
      <layer repeat=“20">
        <slice material = "Tungsten" width = "0.25*cm" />
        <slice material = "G10" width = "0.068*cm" />
        <slice material = "Silicon" width = "0.032*cm" sensitive = "yes" />
        <slice material = "Air" width = "0.025*cm" />
      </layer>
<layer repeat=“20">
        <slice material = "Tungsten" width = "0.50*cm" />
        <slice material = "G10" width = "0.068*cm" />
        <slice material = "Silicon" width = "0.032*cm" sensitive = "yes" />
        <slice material = "Air" width = "0.025*cm" />
```

Hadronic Calorimeter

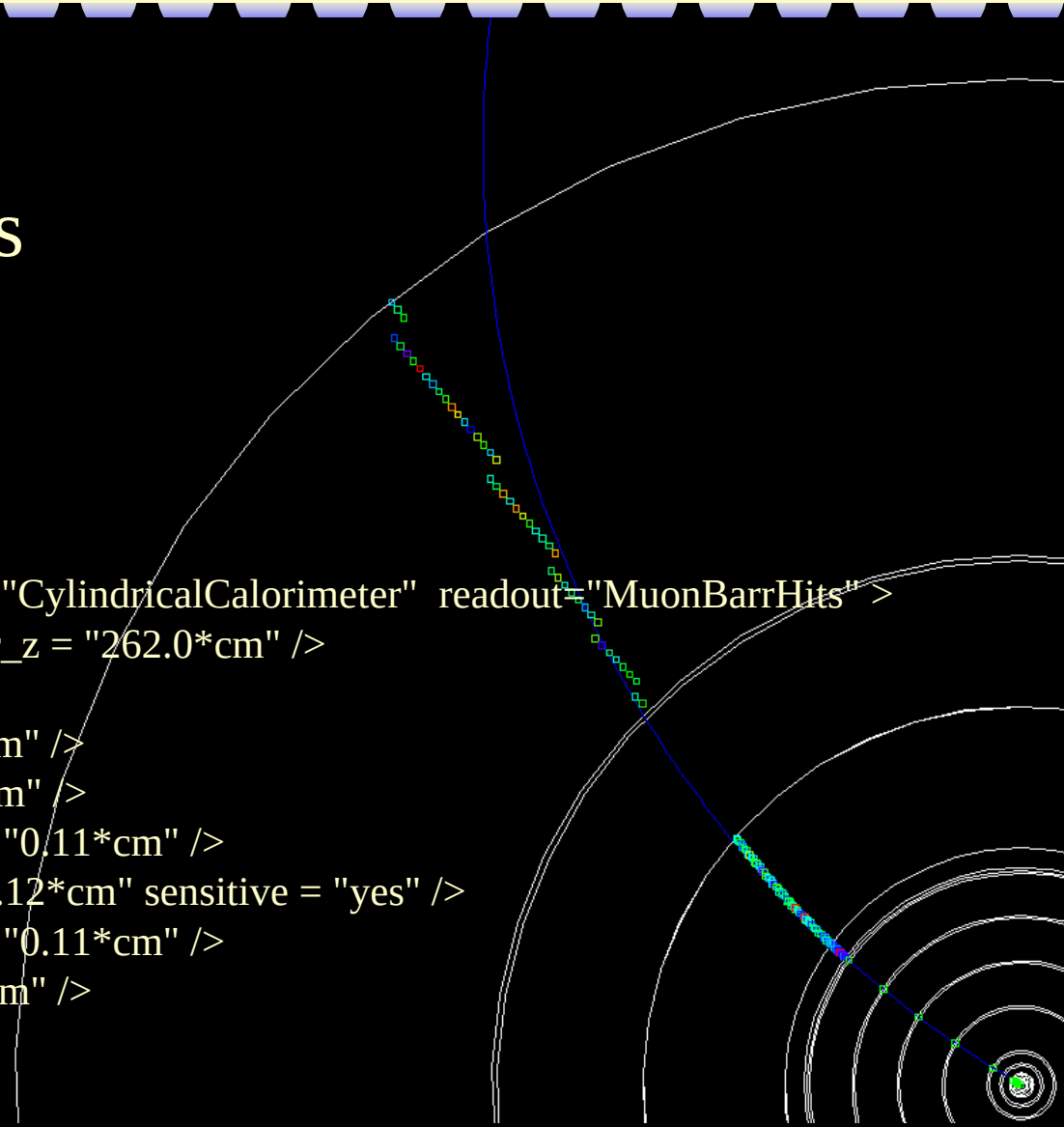
- W(SS)+RPC (Scint.) Sampling
- Barrel+Endcap Disks



```
<detector id="3" name="HADBarrel" type="CylindricalCalorimeter" readout="HcalBarrHits">
    <dimensions inner_r = "138.26*cm" outer_z = "261.85*cm" />
    <layer repeat="55">
      <slice material = "Tungsten" width = "0.7*cm" />
      <slice material = "G10" width = "0.3*cm" />
      <slice material = "PyrexGlass" width = "0.11*cm" />
      <slice material = "RPCGas" width = "0.12*cm" sensitive = "yes" />
      <slice material = "PyrexGlass" width = "0.11*cm" />
      <slice material = "Air" width = "0.16*cm" />
    </layer>
  </detector>
```

Muon System

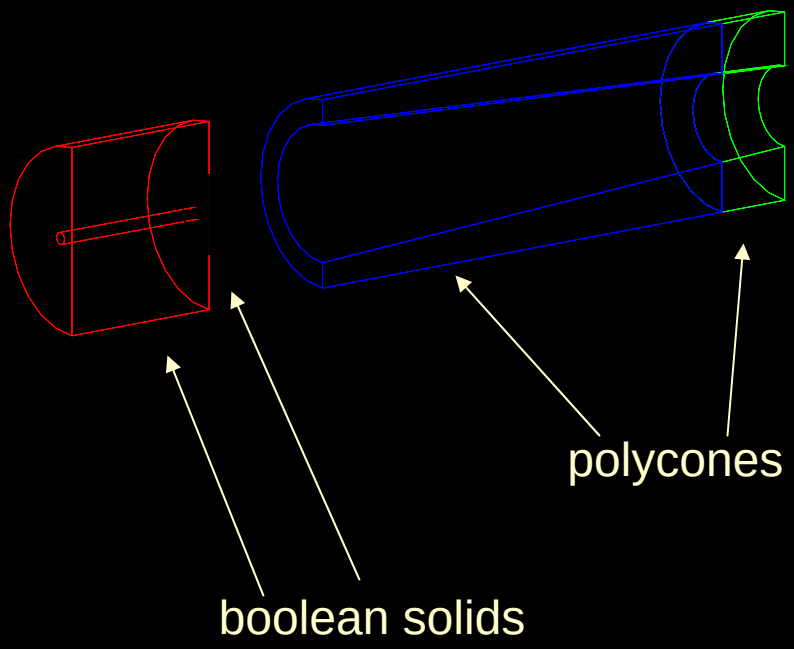
- Fe + RPC (Scint.)
- Barrel+Endcap Disks

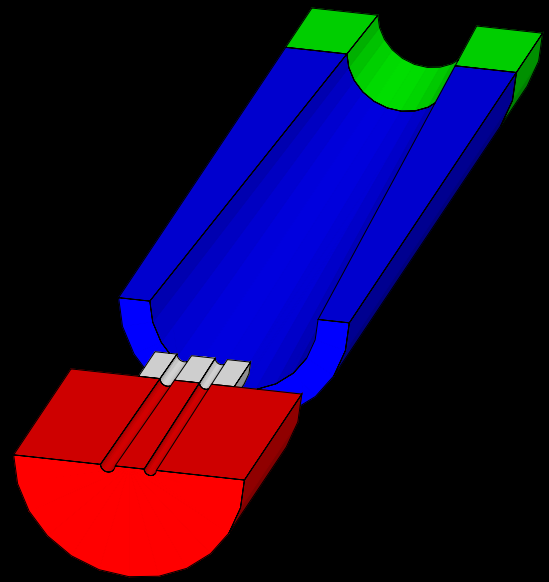


```
<detector id="4" name="MuonBarrel" type="CylindricalCalorimeter"  readout="MuonBarrHits" >
    <dimensions inner_r = "309.0*cm" outer_z = "262.0*cm" />
    <layer repeat="48">
      <slice material = "Iron" width = "5.0*cm" />
      <slice material = "G10" width = "0.3*cm" />
      <slice material = "PyrexGlass" width = "0.11*cm" />
      <slice material = "RPCGas" width = "0.12*cm" sensitive = "yes" />
      <slice material = "PyrexGlass" width = "0.11*cm" />
      <slice material = "Air" width = "0.16*cm" />
    </layer>
 </detector>
```

MDI - BDS

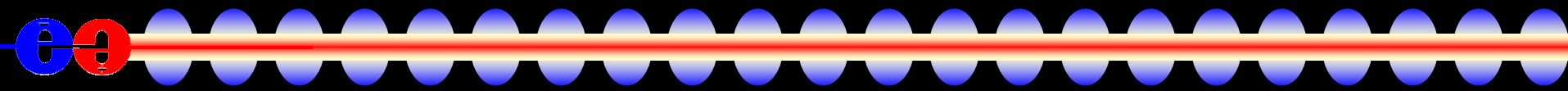
Machine Detector Interface and Beam Delivery System



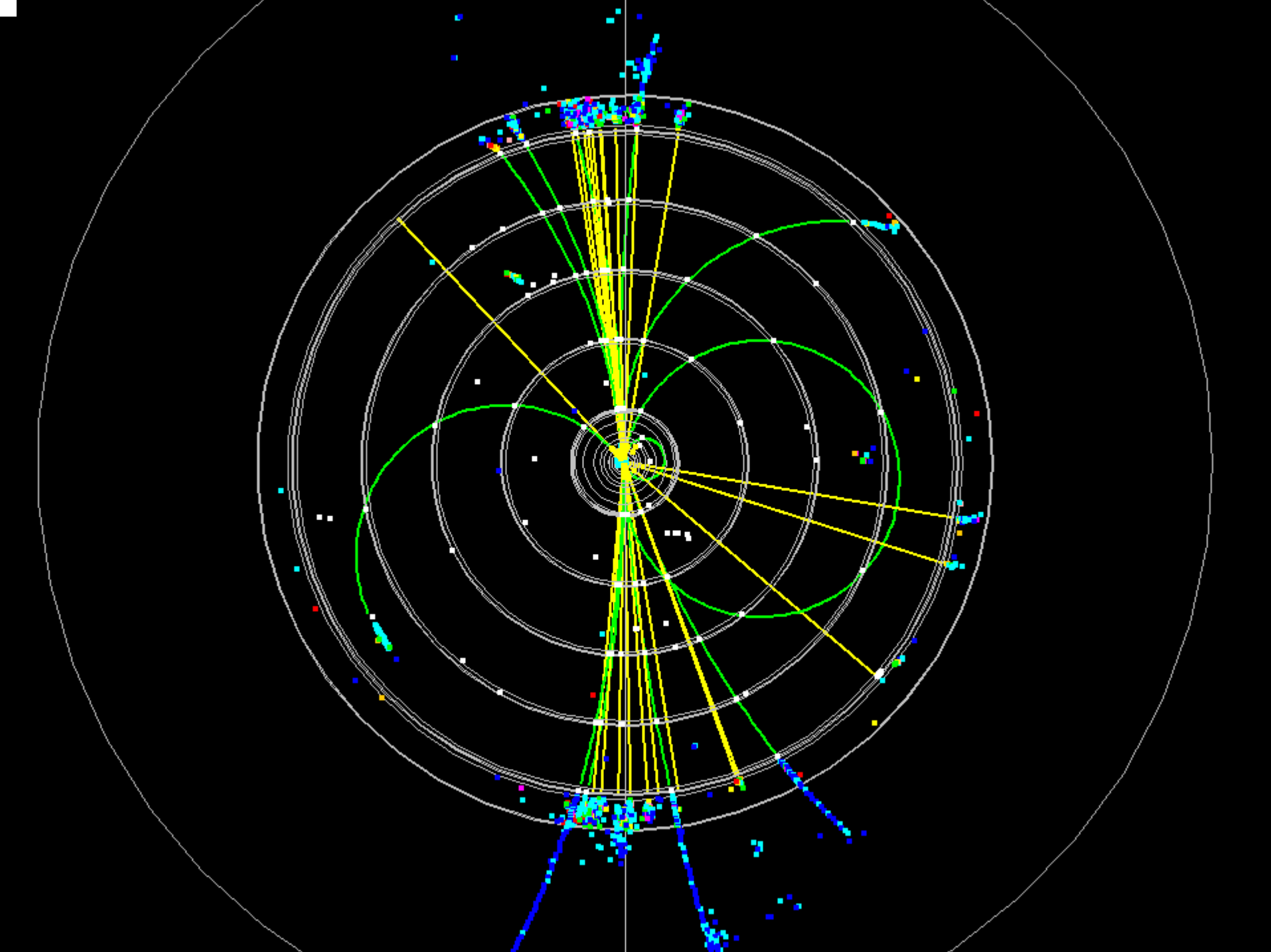


Visualized with dawn and dawncut.

Detector Variants



- XML format allows variations in detector geometries to be easily set up and studied:
  - Stainless Steel vs. Tungsten HCal sampling material
  - RPC vs. Scintillator readout
  - Layering (radii, number, composition)
  - Readout segmentation
  - Tracking detector topologies
    - “Wedding Cake” Nested Tracker vs. Barrel + Cap
  - Field strength



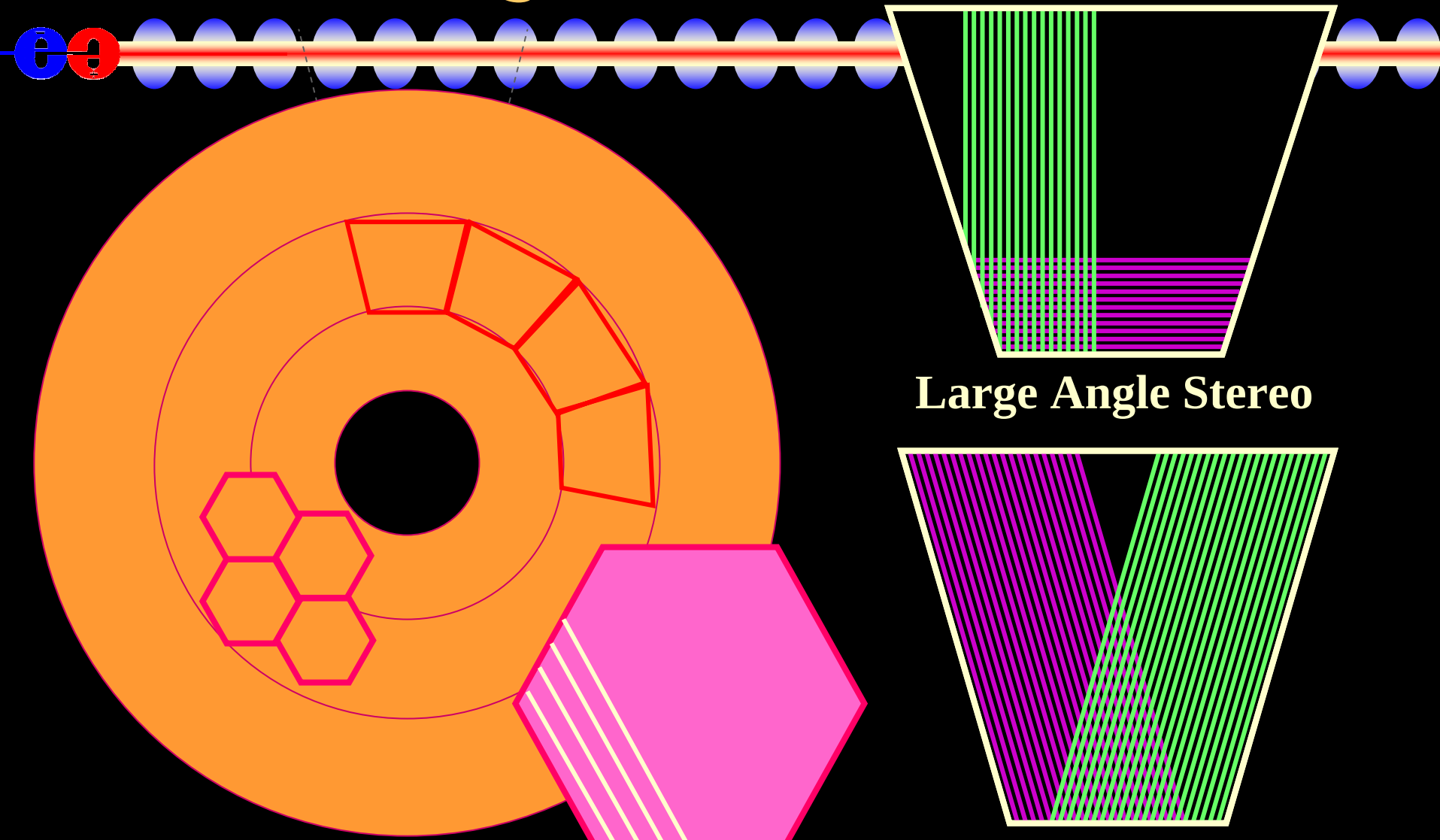
Tracking Detector Readout

- Hits in Trackers record full MC information.
- Digitization is deferred to analysis stage.
- Nick Sinev has released a package to convert hits in silicon to CCD pixel hits.

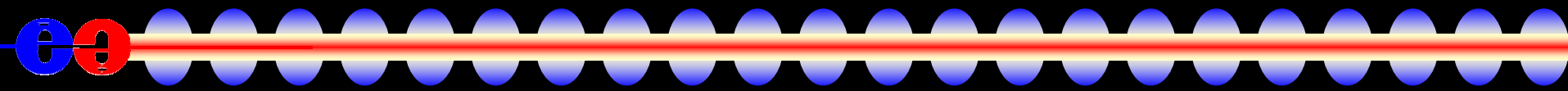
  MC Hits$\rightarrow$ Pixels & PH$\rightarrow$ Clusters$\rightarrow$ Hits ($x \pm \delta x$)
- UCSC developed long-shaping-time μ-strip sim.

  MC Hits$\rightarrow$ Strips & PH$\rightarrow$ Clusters$\rightarrow$ Hits ($\varphi \pm \delta\varphi$)
- Tim Nelson developing short-strip simulation.

Tiling Forward Disks

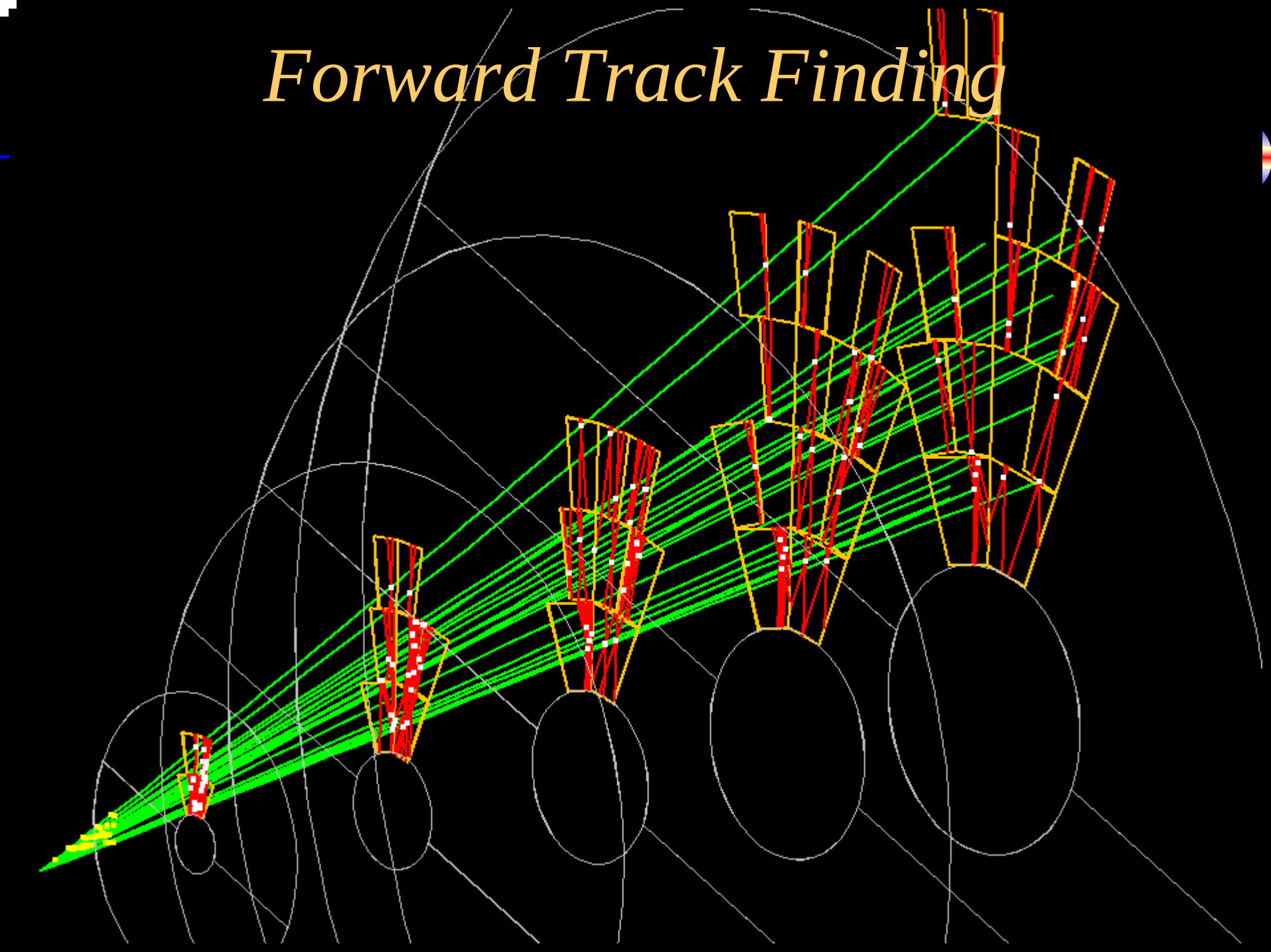


Track Finding

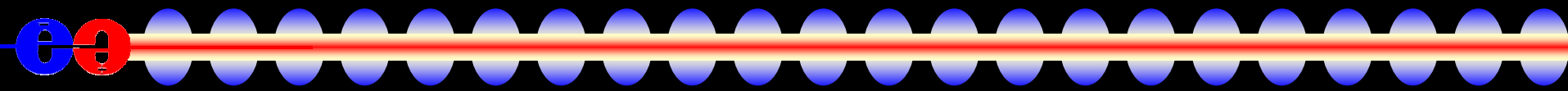


- Nick Sinev has released standalone pattern recognition code for the 2D Barrel VXD hits.
  - High efficiency, even in presence of backgrounds.
  - Efficient at low momentum.
  - Propagates tracks into Central Tracker to pick up φ hits
- Conformal-mapping pattern recognition also available. Fast, but not yet tuned (97% vs 99+%).
- Work also ongoing to find MIP stubs in Cal and propagate inwards (Kansas State, Iowa).

Forward Track Finding



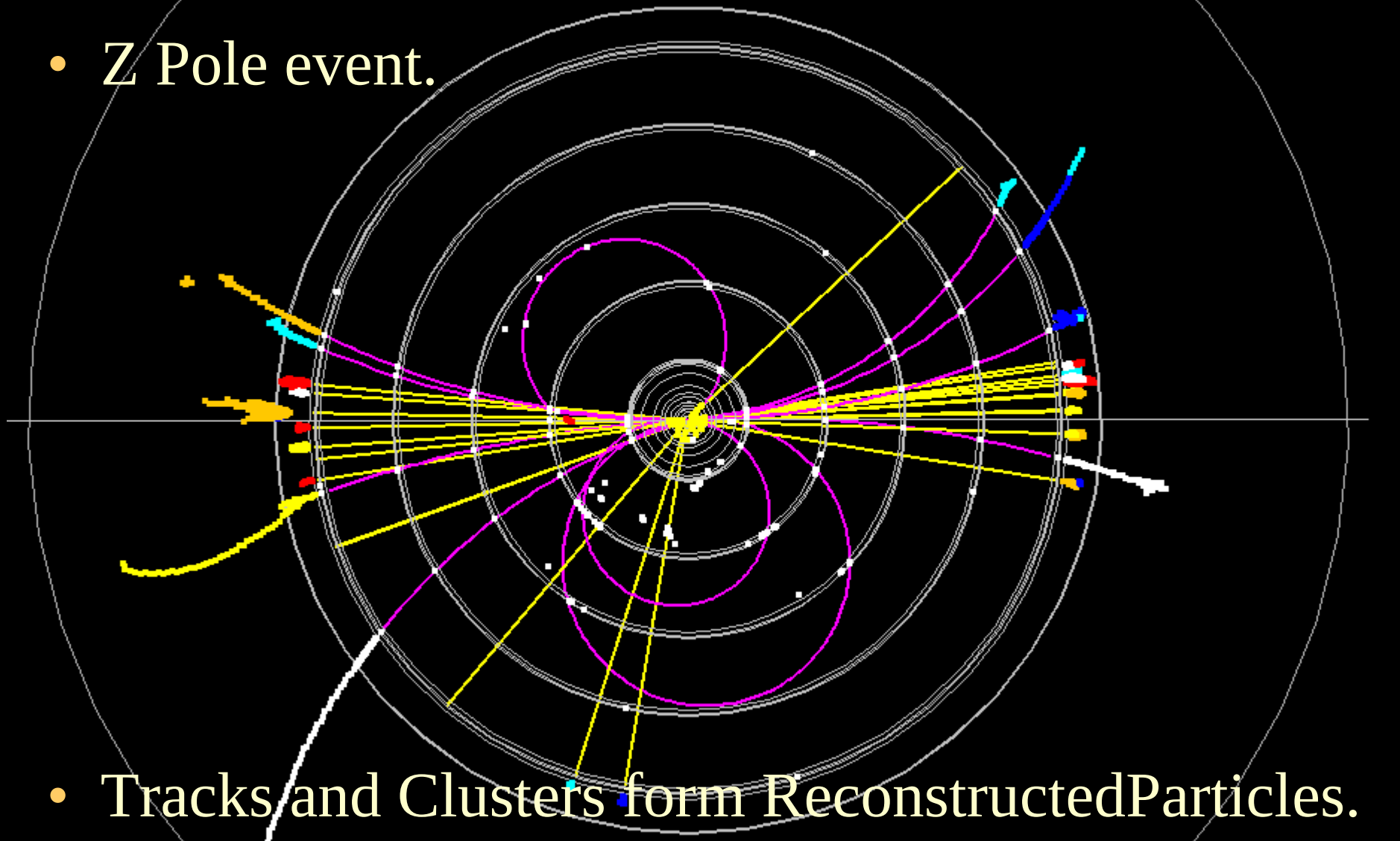
Calorimeter Reconstruction



- A number of groups are following different approaches towards individual particle reconstruction
- Argonne, NICADD, FNAL, Kansas, Kansas State, Iowa, Colorado, UTA, SLAC, …
- Identifying photon, electron, charged & neutral hadron showers and muons in the calorimeter.
- Tracking in the calorimeter assisting pattern recognition in the trackers!

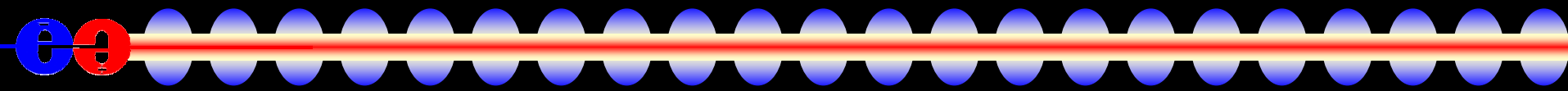
Individual Particle Reconstruction

- Z Pole event.



- Tracks and Clusters form ReconstructedParticles.
- Goal is 1:1 ReconstructedParticle ⇔ MCParticle

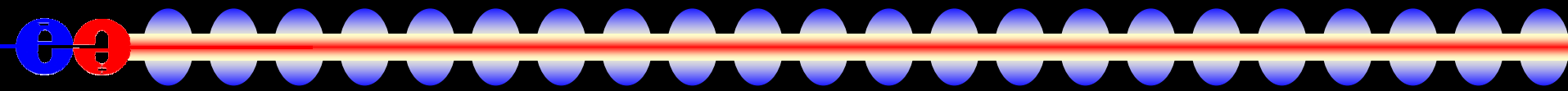
Data Samples



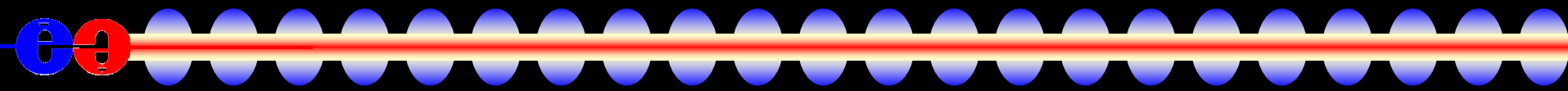
- Have generated canonical data samples and are processing them through full detector simulation.
- Variants include HCal sampling material &readout, field strength, adding tracker layers, changing EMCal radius,…
- single particles of various species
- Z Pole events
- WW, ZZ, ttbar, qqbar, tau pairs, mu pairs, Zγ, Zh

www.lcsim.org/datasamples/

Summary



- Framework exists for straightforwardly defining detector geometries.
- Digitization of tracker hits at analysis stage provides more degrees of freedom (pixel size, strip pitch, length, orientation, …)
- Reconstruction & analysis framework is available, tuning and improvements welcomed.
- Data samples for several configurations available.
- Expect to fully define canonical SiD at this workshop, characterize performance by Snowmass



"Without tools man is nothing, with tools he is all."

Thomas Carlyle

"Give us the tools and we will finish the job.“

Winston Churchill

“As a rule, software systems do not work well until they have been used, and have failed repeatedly, in real applications.”

Dave Parnas