Linear Collider Simulation Overview

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Linear Collider Environment

- Detectors designed to exploit the physics discovery potential of e^+e^- collisions at $\sqrt{s} \sim 1$TeV.
- Will perform precision measurements of complex final states.
- Require:
  - Exceptional momentum resolution
  - Excellent vertexing capabilities
  - “Energy Flow” calorimetry
  - Hermeticity

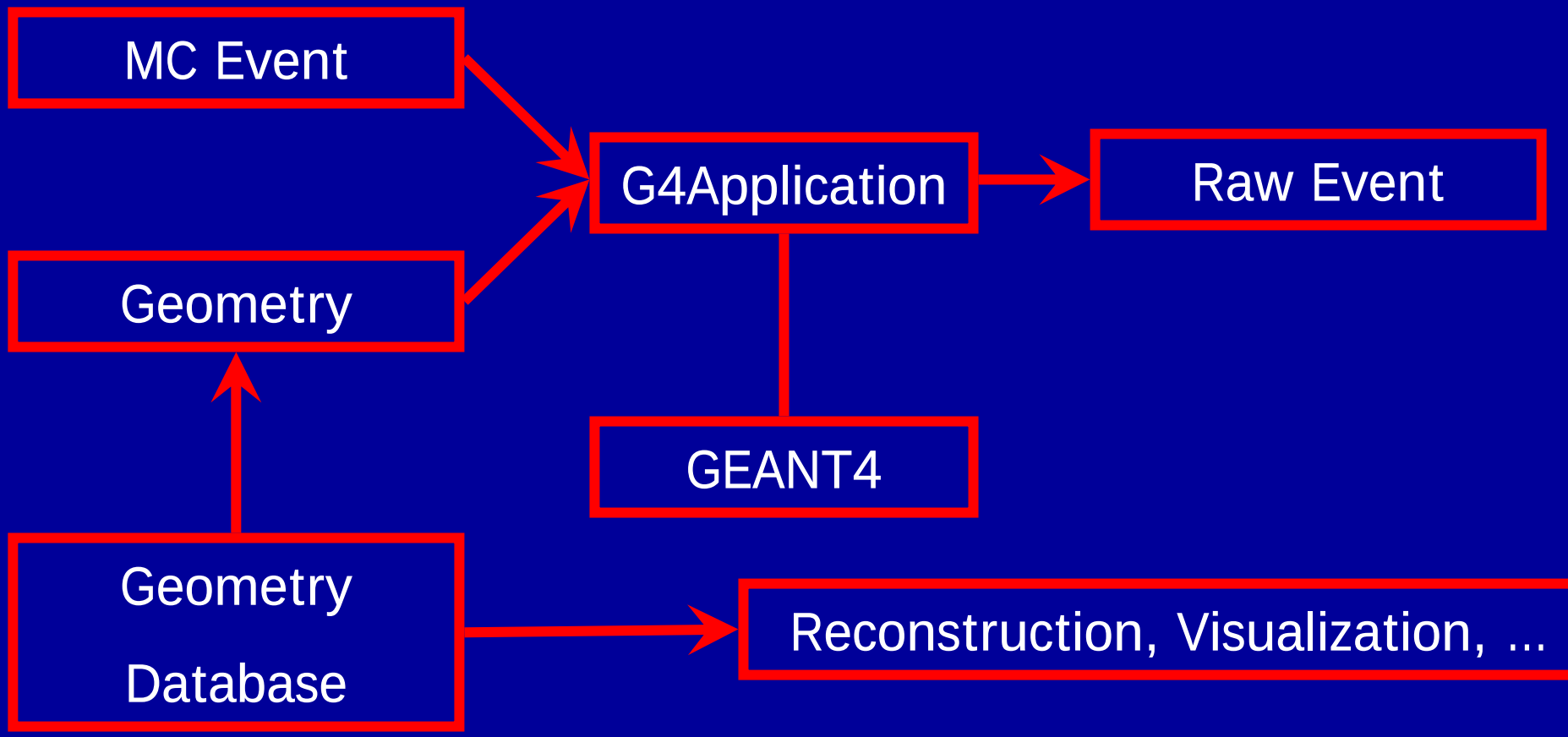
Mission Statement

- Provide full simulation capabilities for Linear Collider physics program:
  - Physics simulations
  - Detector designs
  - Machine-Detector interface & backgrounds
- Need flexibility for:
  - New detector geometries/technologies
  - Innovative reconstruction algorithms
- Limited resources demand efficient solutions, focused effort.

Goal

- Have a common simulation environment used in all LC studies which allows sharing of detectors, algorithms, and code
- The system should be flexible, powerful, yet simple to install and maintain

LC Detector Full Simulation

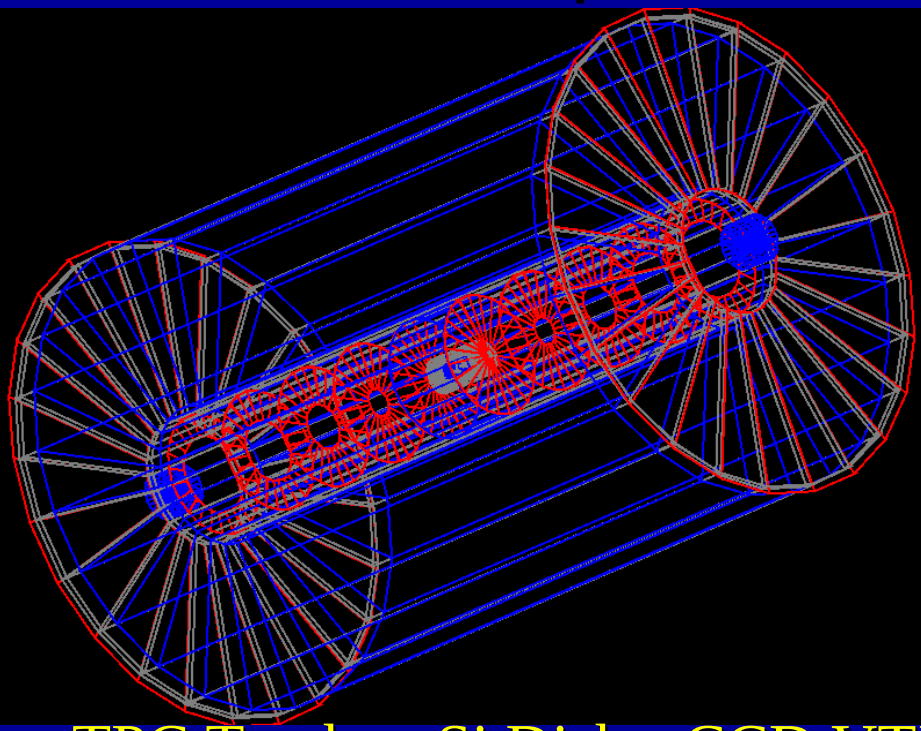


LCD Full Simulation

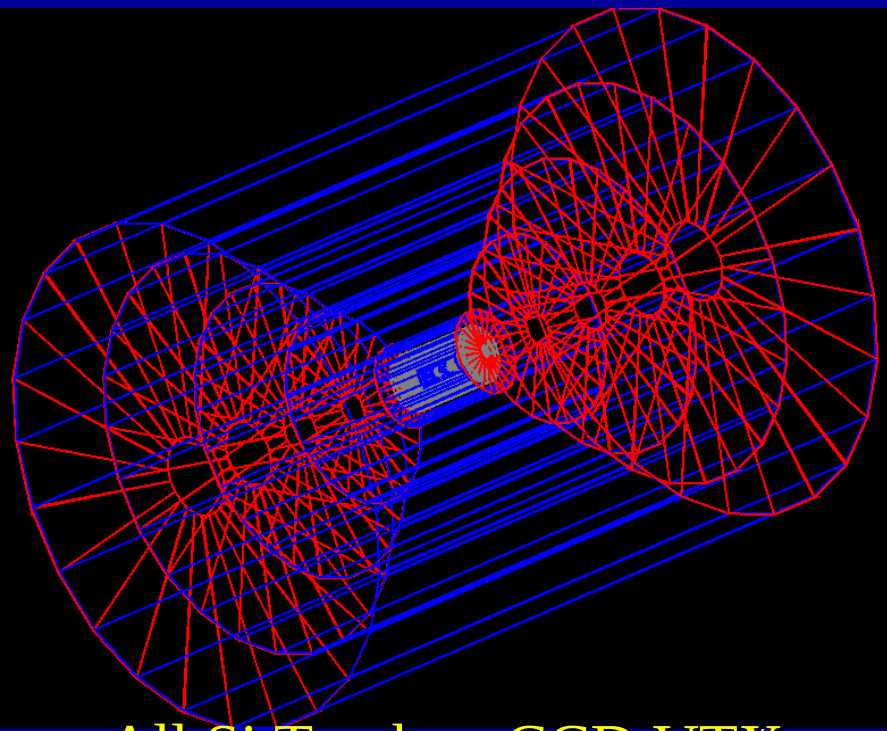
- Geometry defined in XML.
  - Flexible, but simplified volumes.
  - Projective readout of sensitive volumes.
- Dynamic topology, not just parameters.
- Have defined generic hit classes for sensitive tracker and calorimeter hits.
- LCIO bindings for I/O.

LC Detector Simulations

- Use simplified volumes to investigate larger number of designs, allowing dynamic topologies using single executable.
- Describe “optimal” detector in detail.



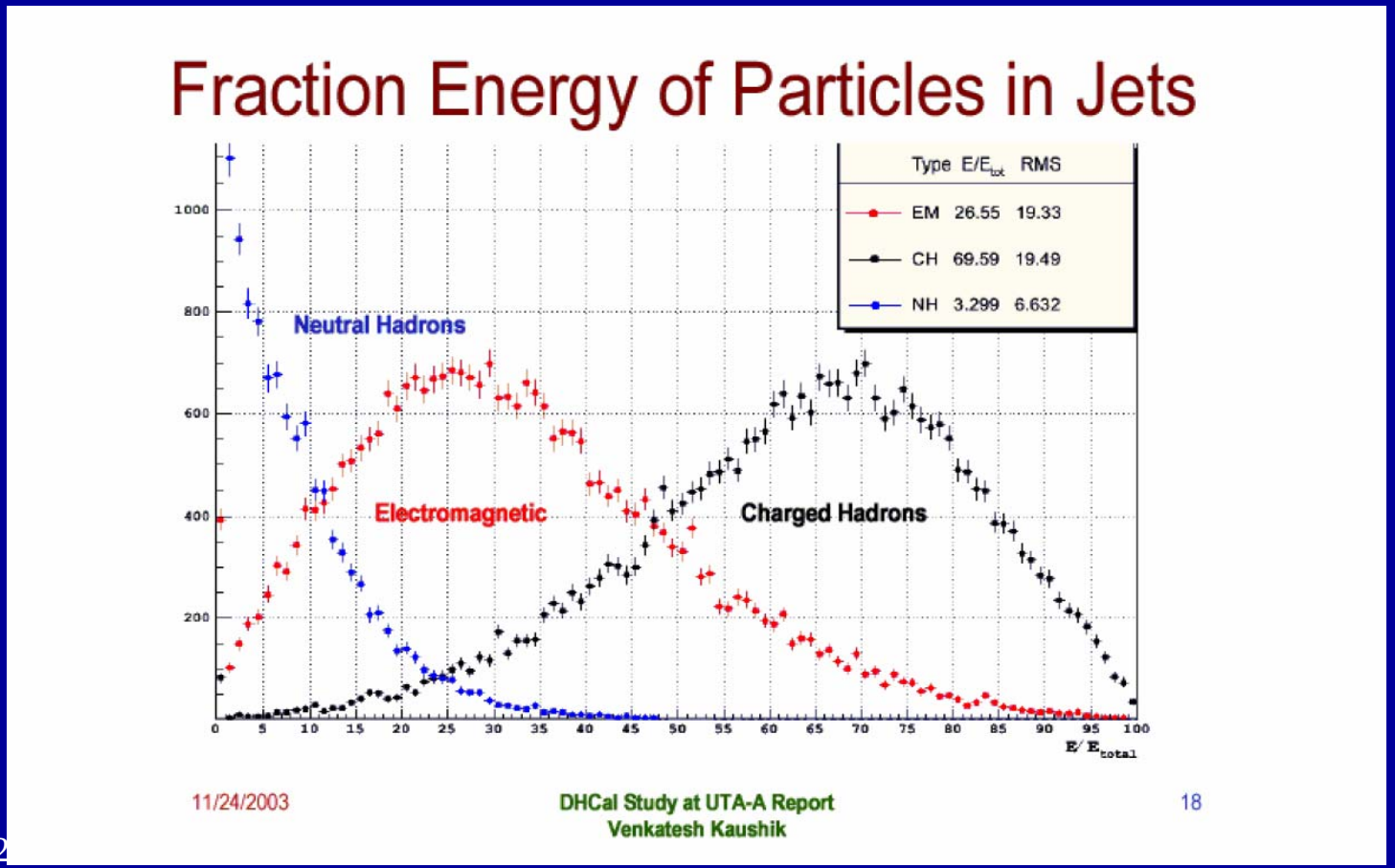
TPC Tracker, Si Disks, CCD VTX



All Si Tracker, CCD VTX

Particle Flow Motivation

- Emphasize jet energy and jet-jet invariant mass resolution.



Particle Flow Motivation

- Measure momenta of charged tracks in the tracker with superb resolution.
- Measure photons in highly segmented EM calorimeter with reasonable resolution.
- Remaining neutral hadrons measured in

$$E_{\text{jet}} = E_{\text{charged}} + E_{\text{photons}} + E_{\text{neut. had.}}$$

$$\sigma^2_{E\text{jet}} = \sigma^2_{E\text{charged}} + \sigma^2_{E\text{photons}} + \sigma^2_{E\text{neut.had.}} + \sigma^2_{\text{confusion}}$$

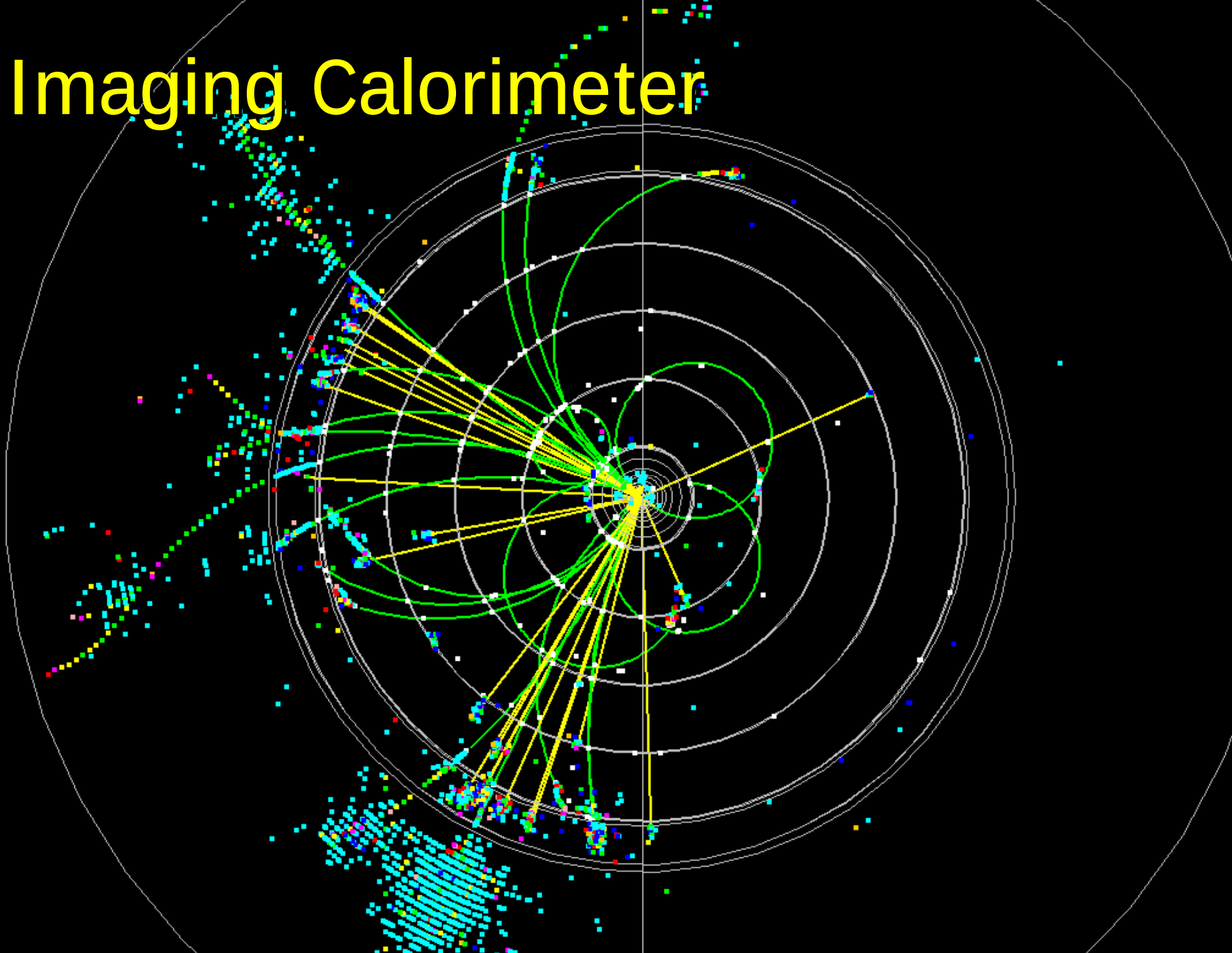
$$\sigma^2_{E\text{jet}} \approx (0.14)^2 \left(E_{\text{jet}} \cdot \text{GeV}\right) + \sigma^2_{\text{confusion}} \approx (0.3)^2 \left(E_{\text{jet}} \cdot \text{GeV}\right)$$

Calorimeter Design

$\sigma^2_{\text{confusion}}$ is the largest term $\rightarrow$ "imaging" cal.

- EM Calorimeter: dense w small Moliere radius
  - fine transverse segmentation to accurately determine photon shower locations
  - fine longitudinal segmentation for efficient charged particle tracking through the EM Cal, and to separate charged and neutral particles.
- Hadron Calorimeter: Emphasize segmentation/granularity (transverse & longitudinal) over intrinsic energy resolution.

Imaging Calorimeter



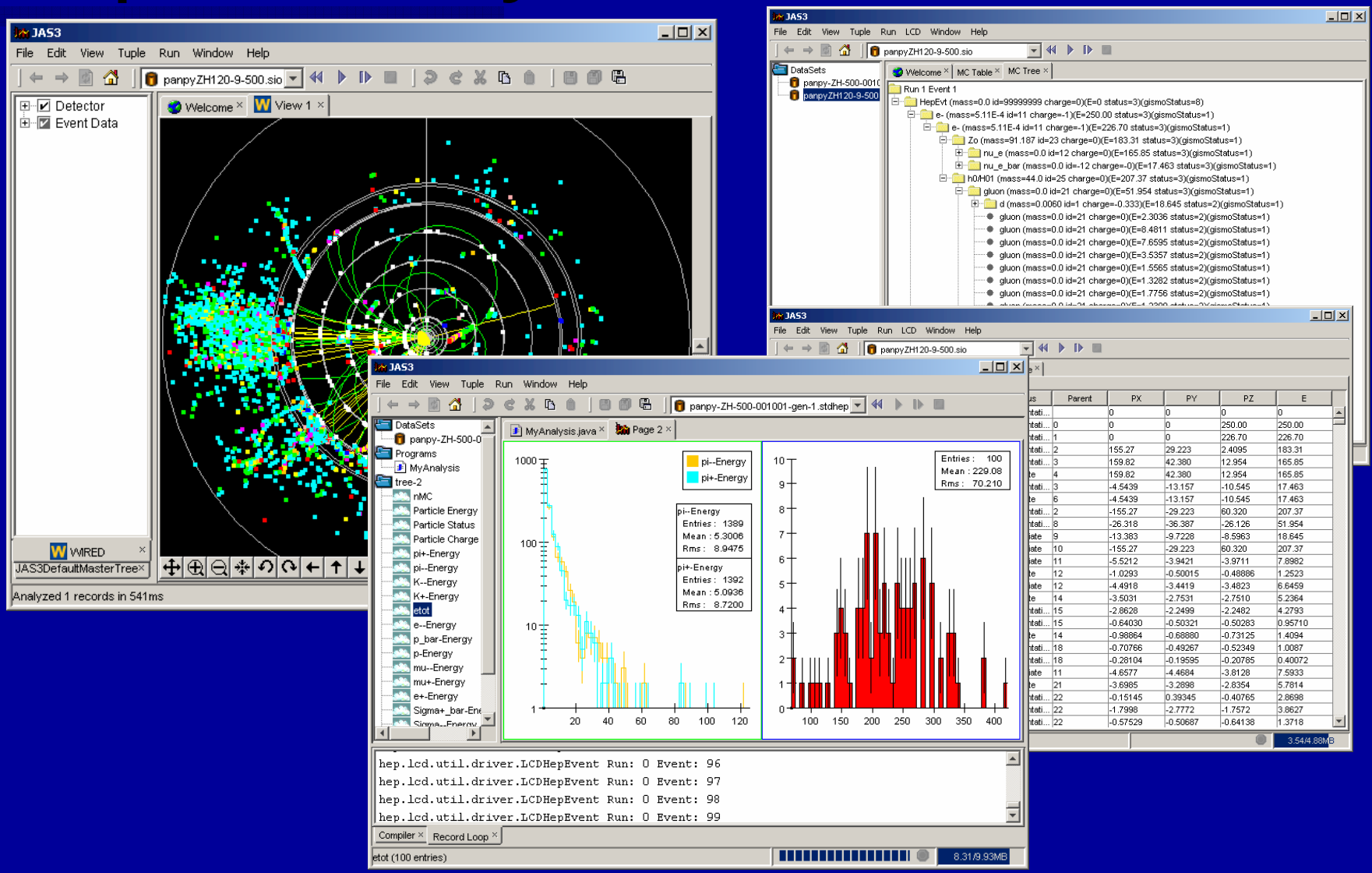
Reconstruction/Analysis Overview

- Java based reconstruction and analysis package
  - Runs standalone or inside Java Analysis Studio (JAS)
  - Fast MC
    - Smeared tracks and calorimetry clusters
  - Full Reconstruction
    - track finding and fitting
    - calorimeter clustering
    - Individual Particle reconstruction (cluster-track association)
  - Analysis Tools (including WIRED event display)
  - Physics Tools (Vertex Finding, Jet Finding, Flavor Tagging)
  - Beam Background Overlays

hep.lcd Physics Utilities

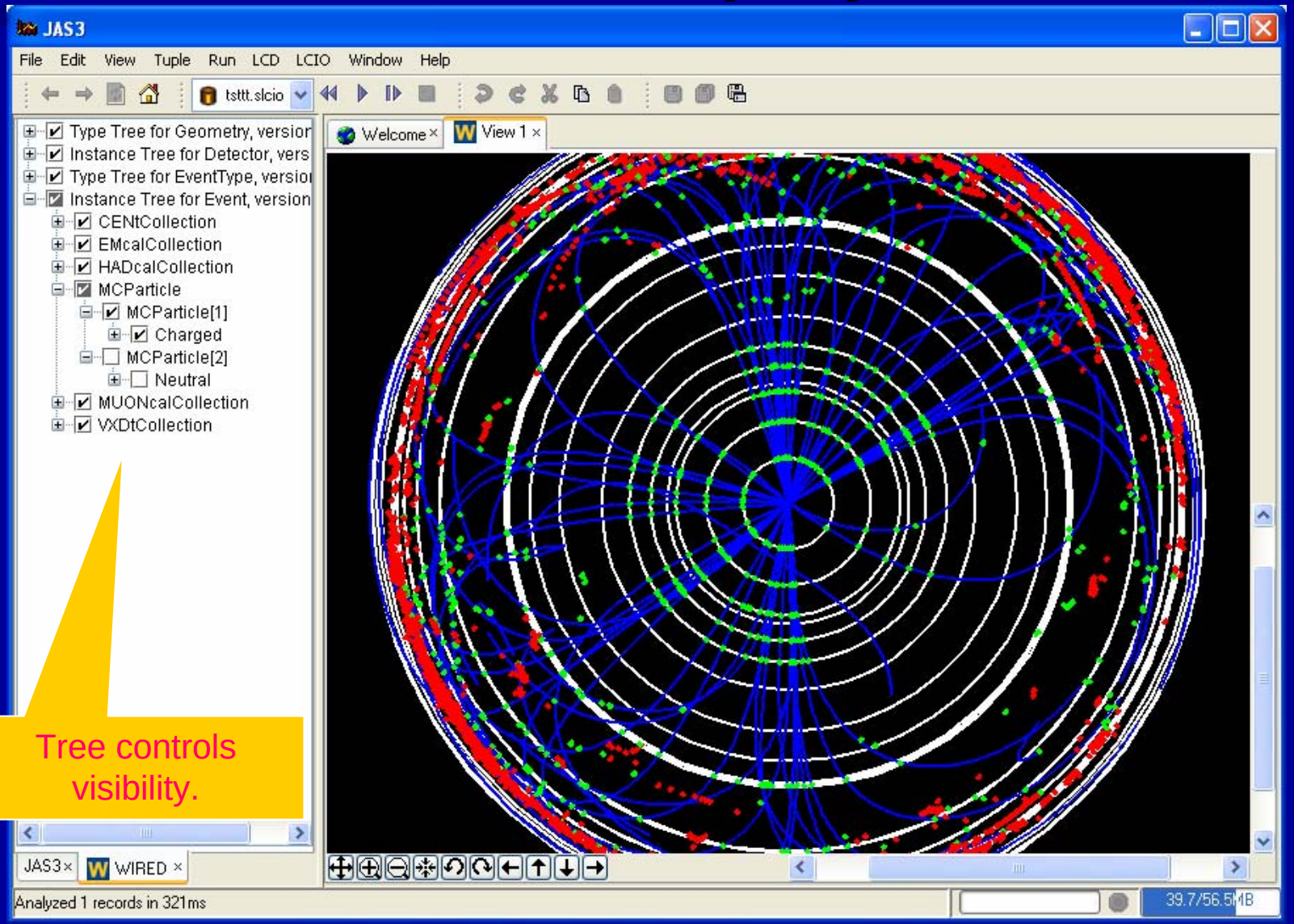
- Physics Utilities
  - 4-vector, 3-vector classes
  - Event shape/Thrust finder
  - Jet Finders
    - Many kT algorithms implemented (e.g. Jade and Durham)
    - Extensible to allow implementation of other algorithms
  - Event Display
  - Topological Vertexing
    - Implementation of SLD's ZVTOP
- Event Generators
  - Can be run directly in FastMC
  - Can be run standalone, e.g. for writing stdhep files
  - Diagnostic Generator
    - User-defined particle mix, momenta and vertices.
  - Generator framework extensible for other generators
    - PYTHIA, HERWIG, ISAJET, ...

hep.lcd analysis tools



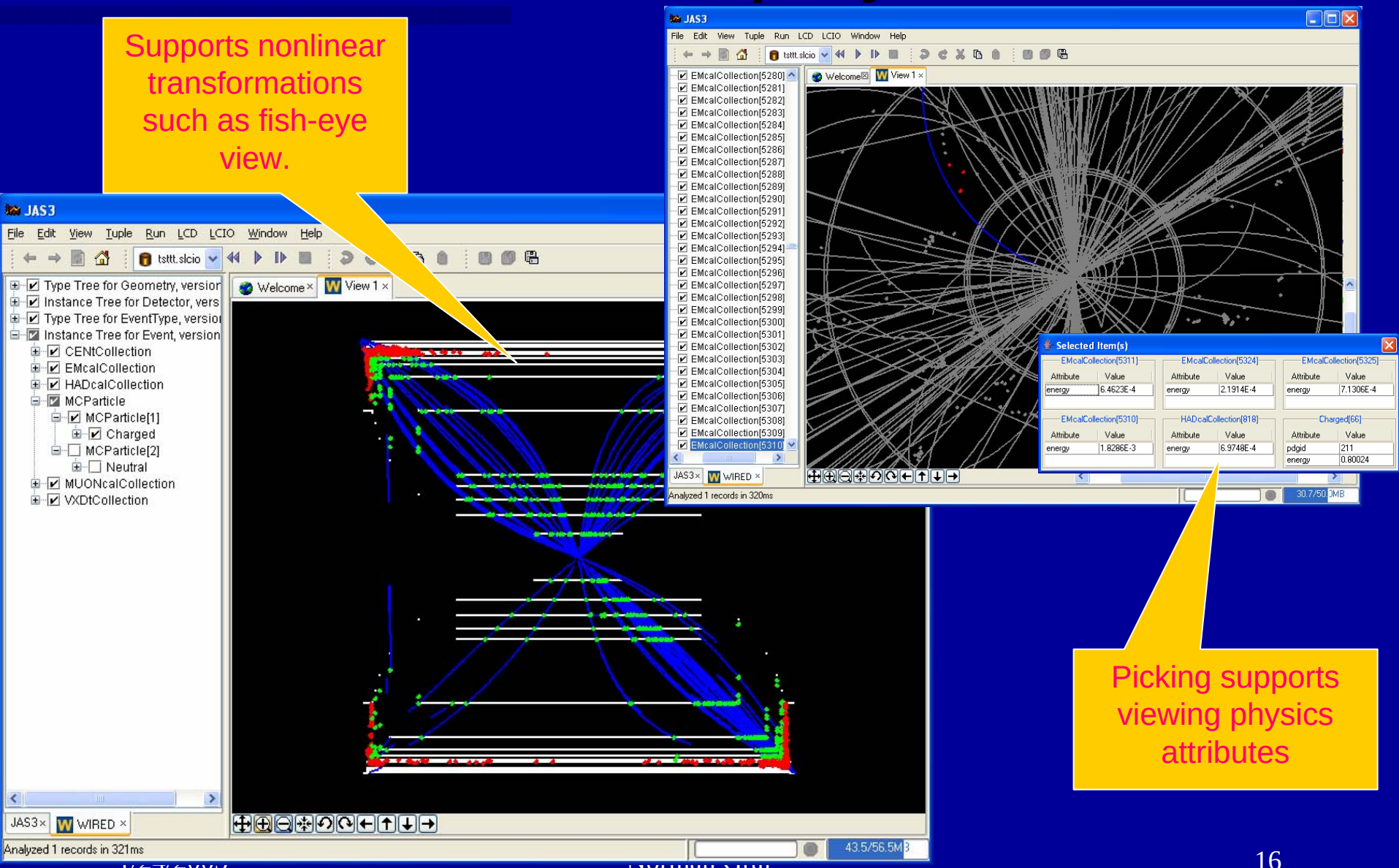
- Tutorial: http://jas.freehep.org/jas3/Tutorial/index.html

WIRED3 Event Display



WIRED3 Event Display

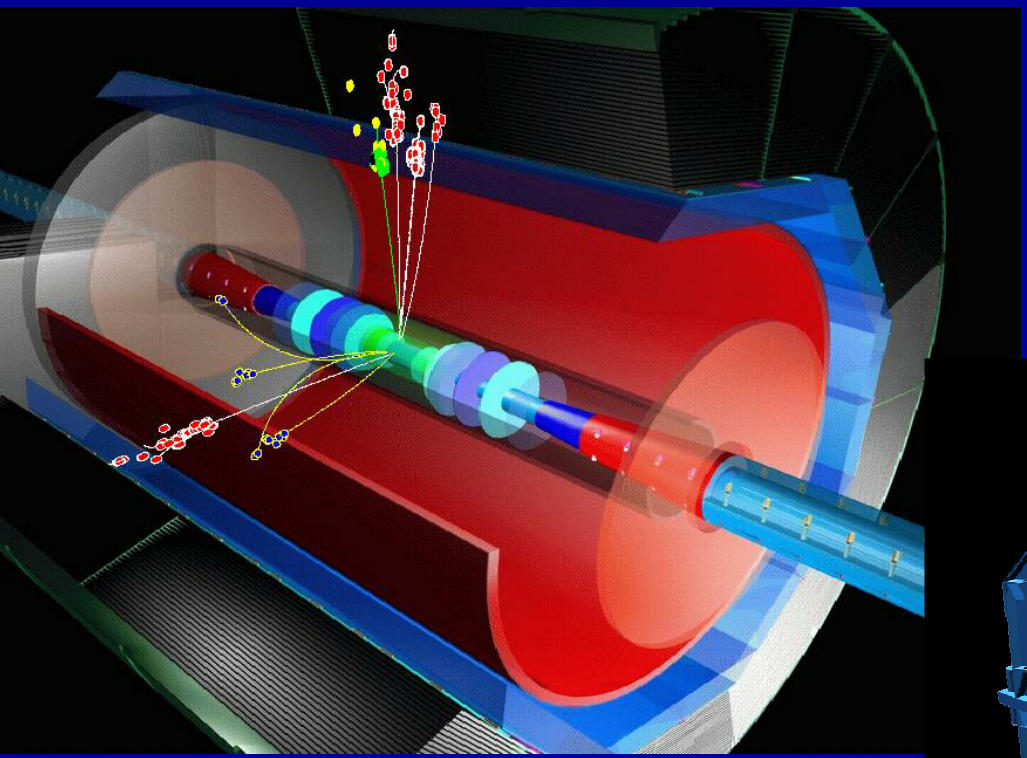
Supports nonlinear transformations such as fish-eye view.

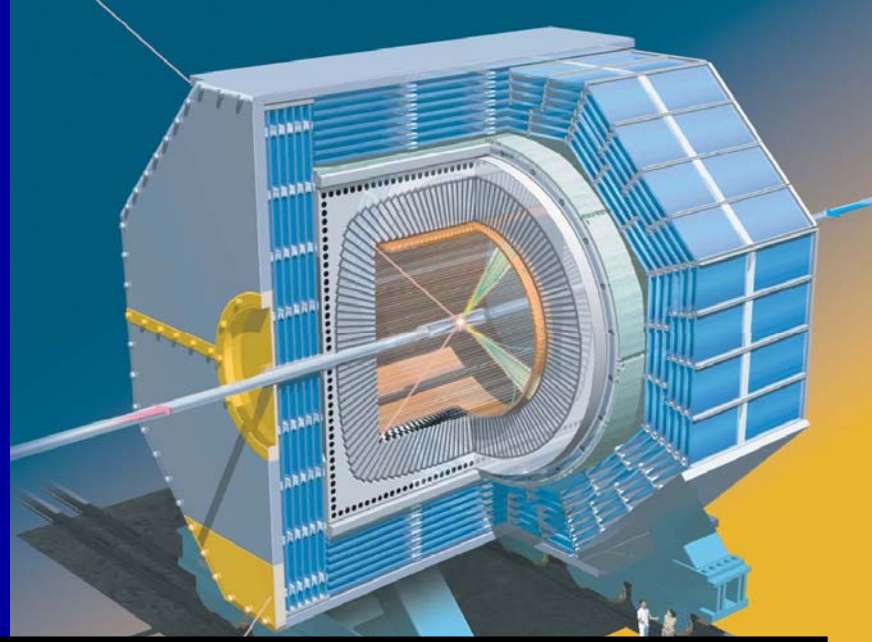


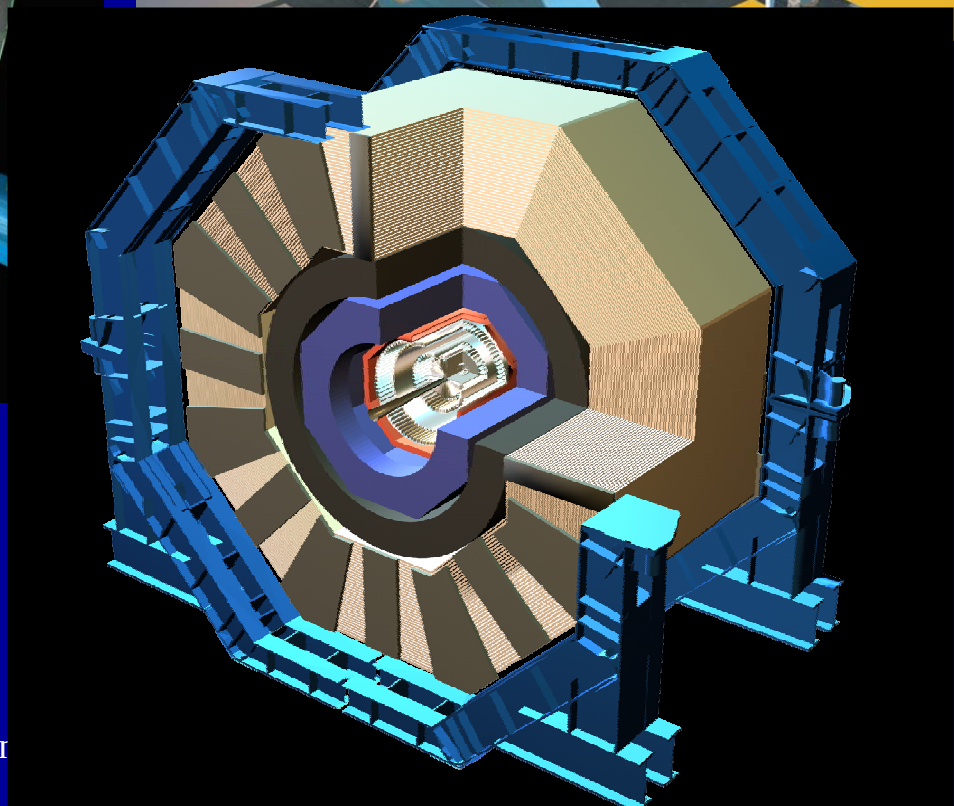
Picking supports viewing physics attributes

Conclusions

- A fairly complete suite of simulation tools exists for LC physics and detector studies.
- Current emphasis is on detector designs incorporating a “Particle Flow” paradigm.
- LC Detector design is an area of active development with many design choices.
- Close coupling of design, simulation, and reconstruction.







Links

- linearcollider.org
- LC Simulations: http://lcsim.org
- JAS3: http://jas.freehep.org/jas3
- WIRED: http://wired.freehep.org/
- **Discussion Forums:**
  - http://forum.linearcollider.org