

# Linear Collider Simulation Overview



Norman Graf

(SLAC)

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# Linear Collider Environment

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

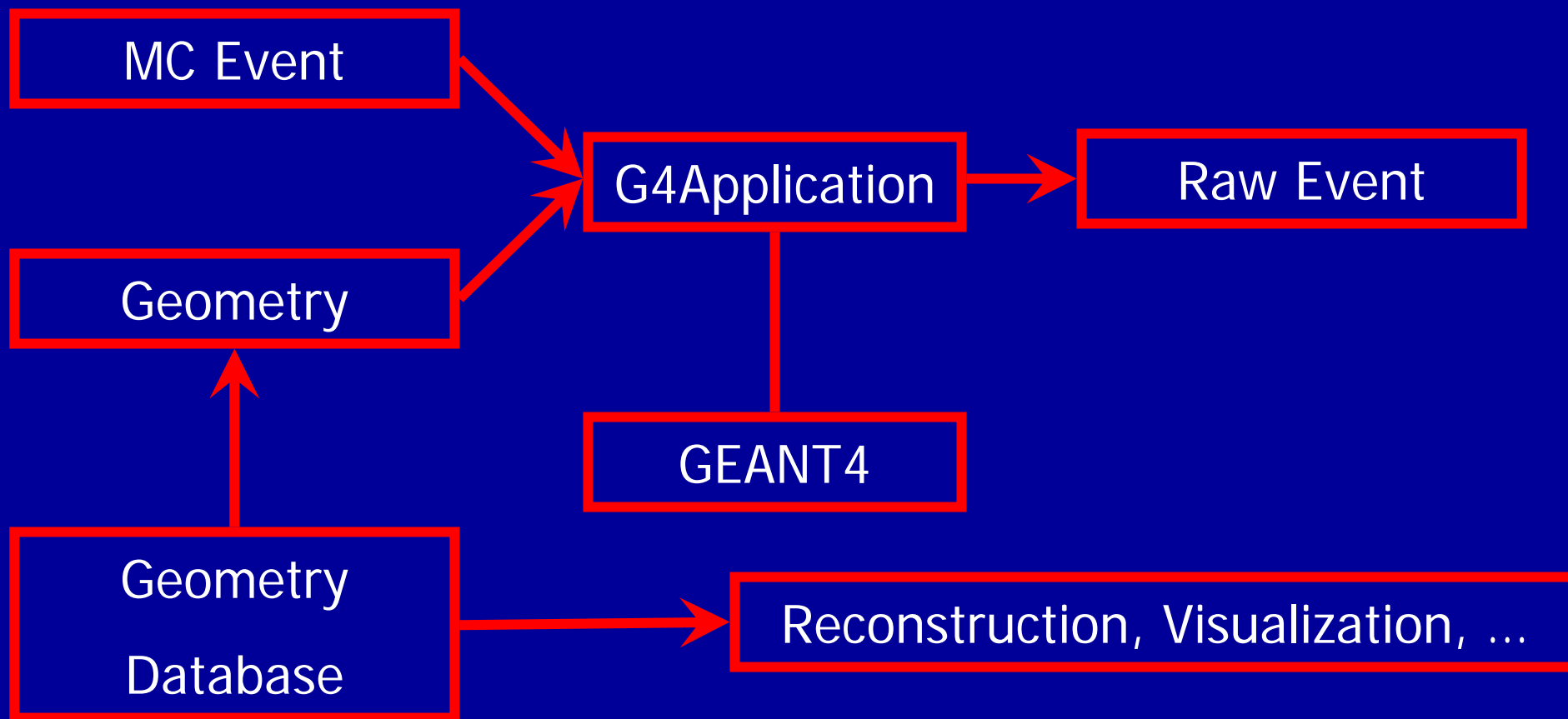
# Mission Statement

- 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

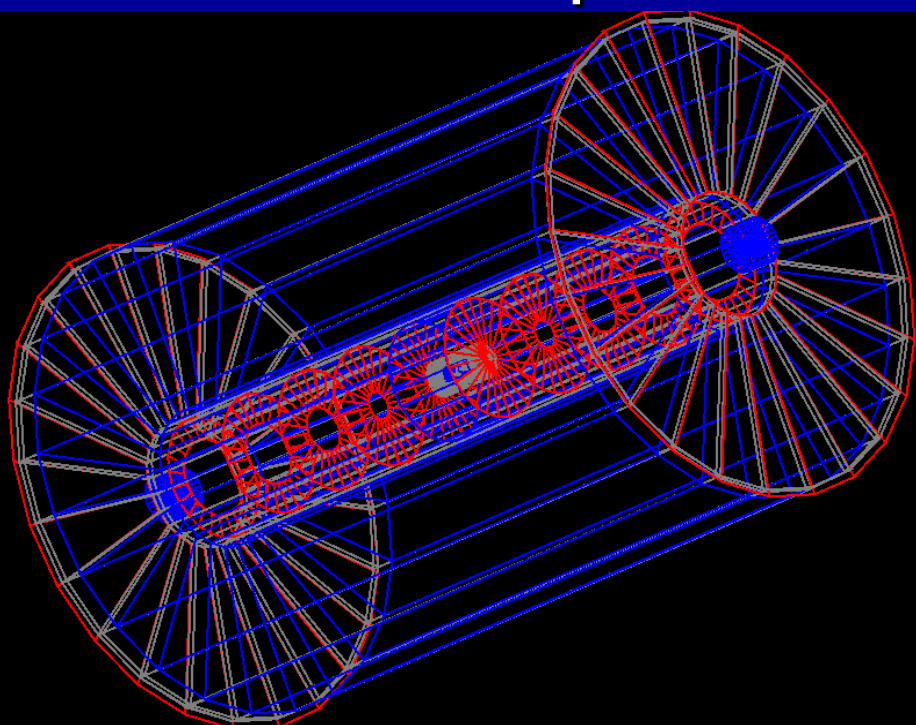


# LCD Full Simulation

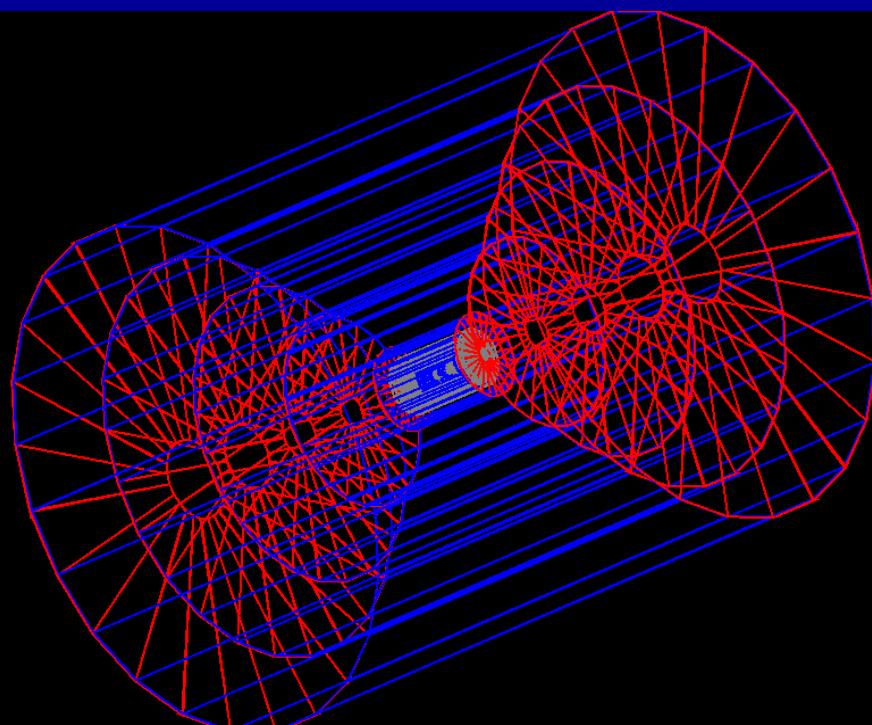
- Geometry defined in XML.
  - Flexible, but simplified volumes.
  - Projective readout of sensitive volumes.
- Dynamic topology, not just parameters.
- Have defined generic hit classes for sensitive tracker and calorimeter hits.
- LCIO bindings for I/O.

# 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

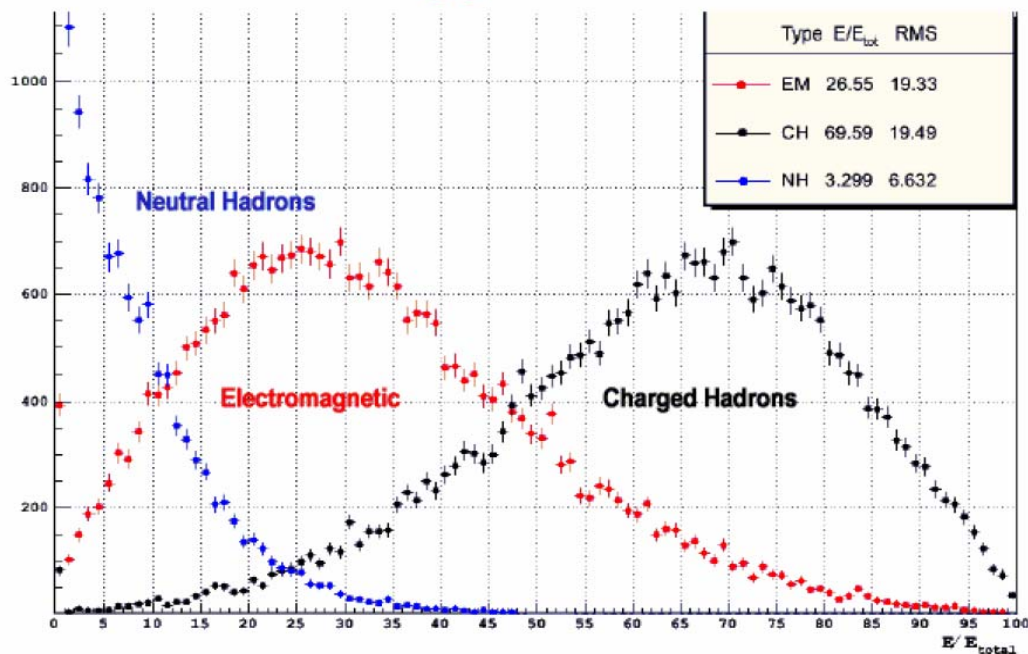


All Si Tracker, CCD VTX

# Particle Flow Motivation

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

## Fraction Energy of Particles in Jets



11/24/2003

DHCal Study at UTA-A Report  
Venkatesh Kaushik

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# 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

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

$$\sigma_{E_{\text{jet}}}^2 = \sigma_{E_{\text{charged}}}^2 + \sigma_{E_{\text{photons}}}^2 + \sigma_{E_{\text{neut. had.}}}^2 + \sigma_{\text{confusion}}^2$$

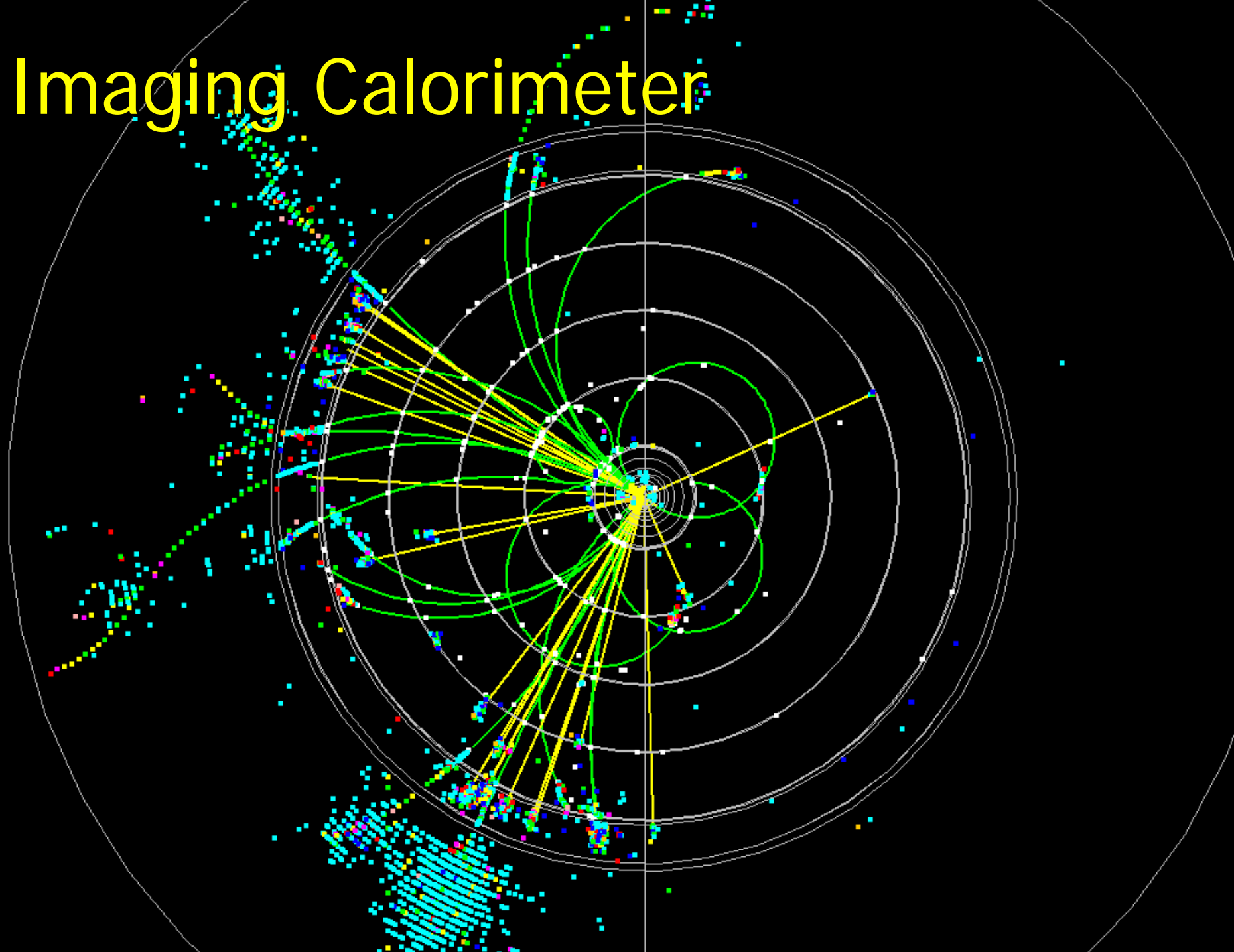
$$\sigma_{E_{\text{jet}}}^2 \approx (0.14)^2 (E_{\text{jet}} \cdot \text{GeV}) + \sigma_{\text{confusion}}^2 \approx (0.3)^2 (E_{\text{jet}} \cdot \text{GeV})$$

# Calorimeter Design

$\sigma_{\text{confusion}}^2$  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
    - Smear 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

The screenshot displays the JAS3 software interface for event analysis. The main window shows a detector event visualization with colored points and tracks. A sidebar on the left shows a tree view of data sets and analysis programs. A bottom window shows two histograms: one for pi- Energy (yellow) and pi+ Energy (cyan) on a log scale, and another for pi- Energy (red) on a linear scale. A table of event parameters is visible on the right, and a terminal window at the bottom shows event processing logs.

is	Parent	PX	PY	PZ	E
tadi...	0	0	0	0	0
tadi...0	0	0	250.00	250.00	
tadi...1	0	0	226.70	226.70	
tadi...2	155.27	29.223	2.4095	183.31	
tadi...3	159.82	42.380	12.954	165.85	
te 4	159.82	42.380	12.954	165.85	
tadi...3	-4.5439	-13.157	-10.545	17.463	
te 6	-4.5439	-13.157	-10.545	17.463	
tadi...2	-155.27	-29.223	60.320	207.37	
tadi...8	-26.318	-36.387	-26.126	51.954	
ate 9	-13.383	-9.7228	-8.5963	18.645	
ate 10	-155.27	-29.223	60.320	207.37	
ate 11	-5.5212	-3.9421	-3.9711	7.8982	
ate 12	-1.0293	-0.50015	-0.48886	1.2523	
ate 12	-4.4918	-3.4419	-3.4823	6.6459	
te 14	-3.5031	-2.7531	-2.7510	5.2364	
tadi...15	-2.8628	-2.2499	-2.2482	4.2793	
tadi...15	-0.64030	-0.50321	-0.50263	0.95710	
te 14	-0.98864	-0.88880	-0.73125	1.4094	
tadi...18	-0.70786	-0.49267	-0.52349	1.0087	
tadi...18	-0.28104	-0.19595	-0.20785	0.40072	
ate 11	-4.6577	-4.4684	-3.8128	7.5933	
te 21	-3.6985	-3.2898	-2.8354	5.7814	
tadi...22	-0.15145	0.39345	-0.40765	2.8698	
tadi...22	-1.7998	-2.7772	-1.7572	3.8627	
tadi...22	-0.57529	-0.50687	-0.64138	1.3718	

```
hep.lcd.util.driver.LCDHepEvent Run: 0 Event: 96
hep.lcd.util.driver.LCDHepEvent Run: 0 Event: 97
hep.lcd.util.driver.LCDHepEvent Run: 0 Event: 98
hep.lcd.util.driver.LCDHepEvent Run: 0 Event: 99
```

■ Tutorial: <http://jas.freehep.org/jas3/Tutorial/index.html>

# WIRED3 Event Display

JAS3

File Edit View Tuple Run LCD LCIO Window Help

tshtt.slcio

Welcome x View 1 x

- Type Tree for Geometry, version
- Instance Tree for Detector, vers
- Type Tree for EventType, versio
- Instance Tree for Event, versio
  - CENTCollection
  - EMcalCollection
  - HADcalCollection
  - MCParticle
    - MCParticle[1]
      - Charged
    - MCParticle[2]
      - Neutral
  - MUONcalCollection
  - VXDtCollection

Tree controls visibility.

JAS3 x WIRED x

Analyzed 1 records in 321ms

39.7/56.5 MB

# WIRED3 Event Display

Supports nonlinear transformations such as fish-eye view.

The screenshot shows the JAS3 software interface with the WIRED3 event display. The main window displays a complex network of particle tracks in blue and green, with a fish-eye view of the detector geometry. A 'Selected Item(s)' dialog box is open, showing physics attributes for selected EMcalCollection and HADcalCollection objects.

EMcalCollection[5311]		EMcalCollection[5324]		EMcalCollection[5325]	
Attribute	Value	Attribute	Value	Attribute	Value
energy	6.4623E-4	energy	2.1914E-4	energy	7.1306E-4

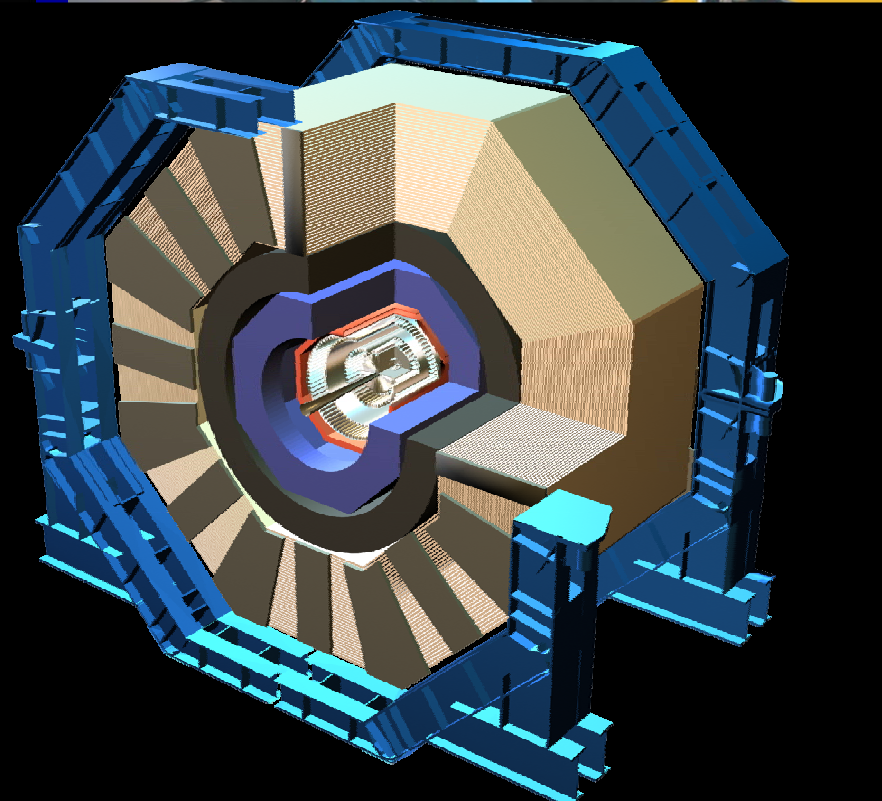
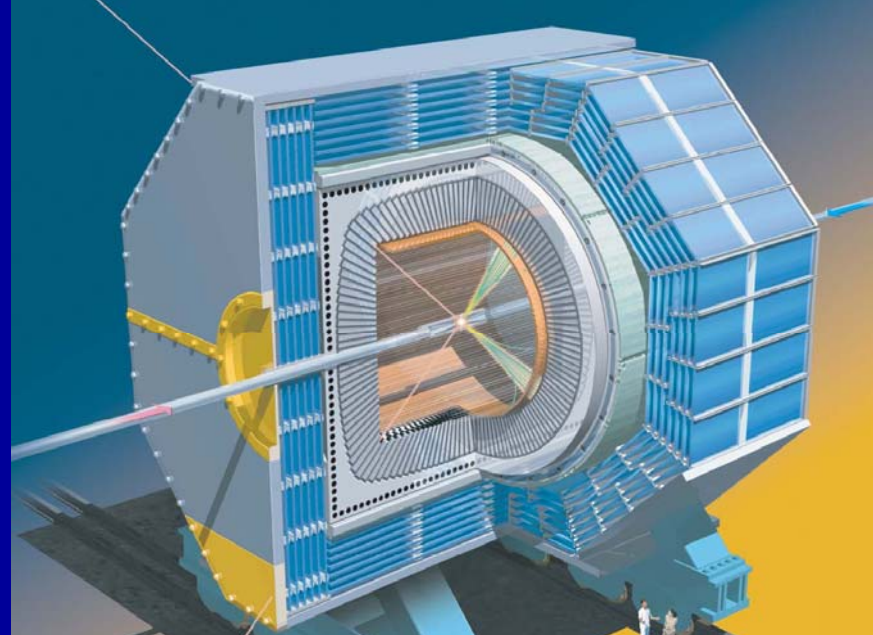
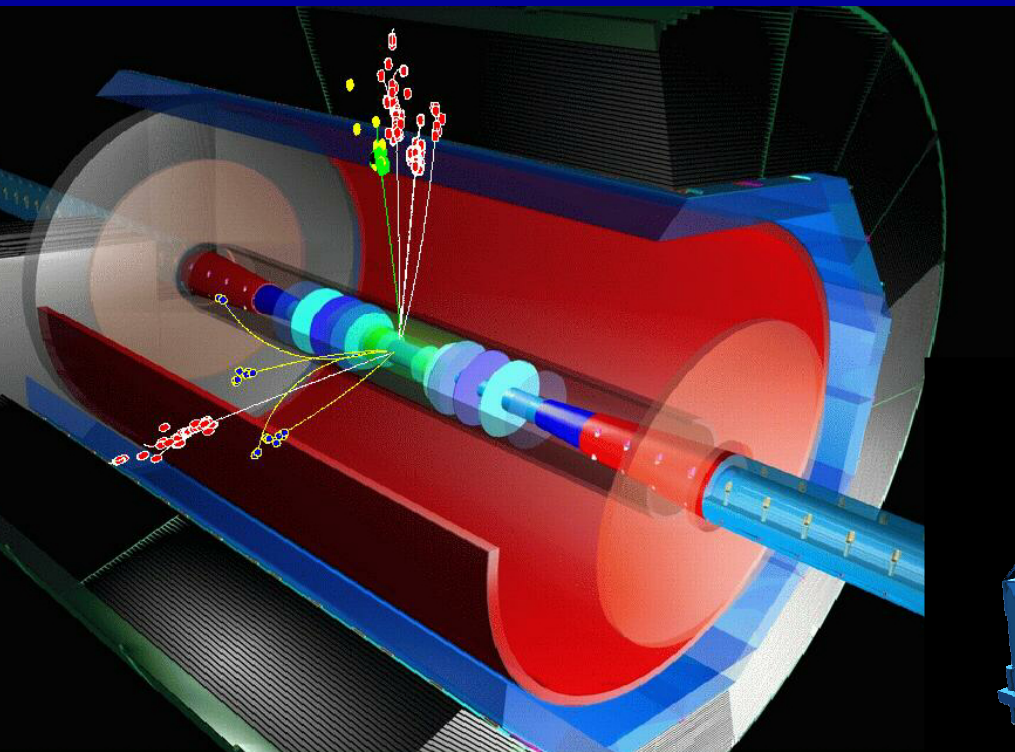
  

EMcalCollection[5310]		HADcalCollection[818]		Charged[66]	
Attribute	Value	Attribute	Value	Attribute	Value
energy	1.8286E-3	energy	6.9748E-4	pdgid	211
				energy	0.80024

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.



1/24/2005

Norr

# Links

- [linearcollider.org](http://linearcollider.org)
- LC Simulations: <http://lcsim.org>
- JAS3: <http://jas.freehep.org/jas3>
- WIRED: <http://wired.freehep.org/>
- **Discussion Forums:**
  - <http://forum.linearcollider.org>