LCD Full Simulation & Reconstruction

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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

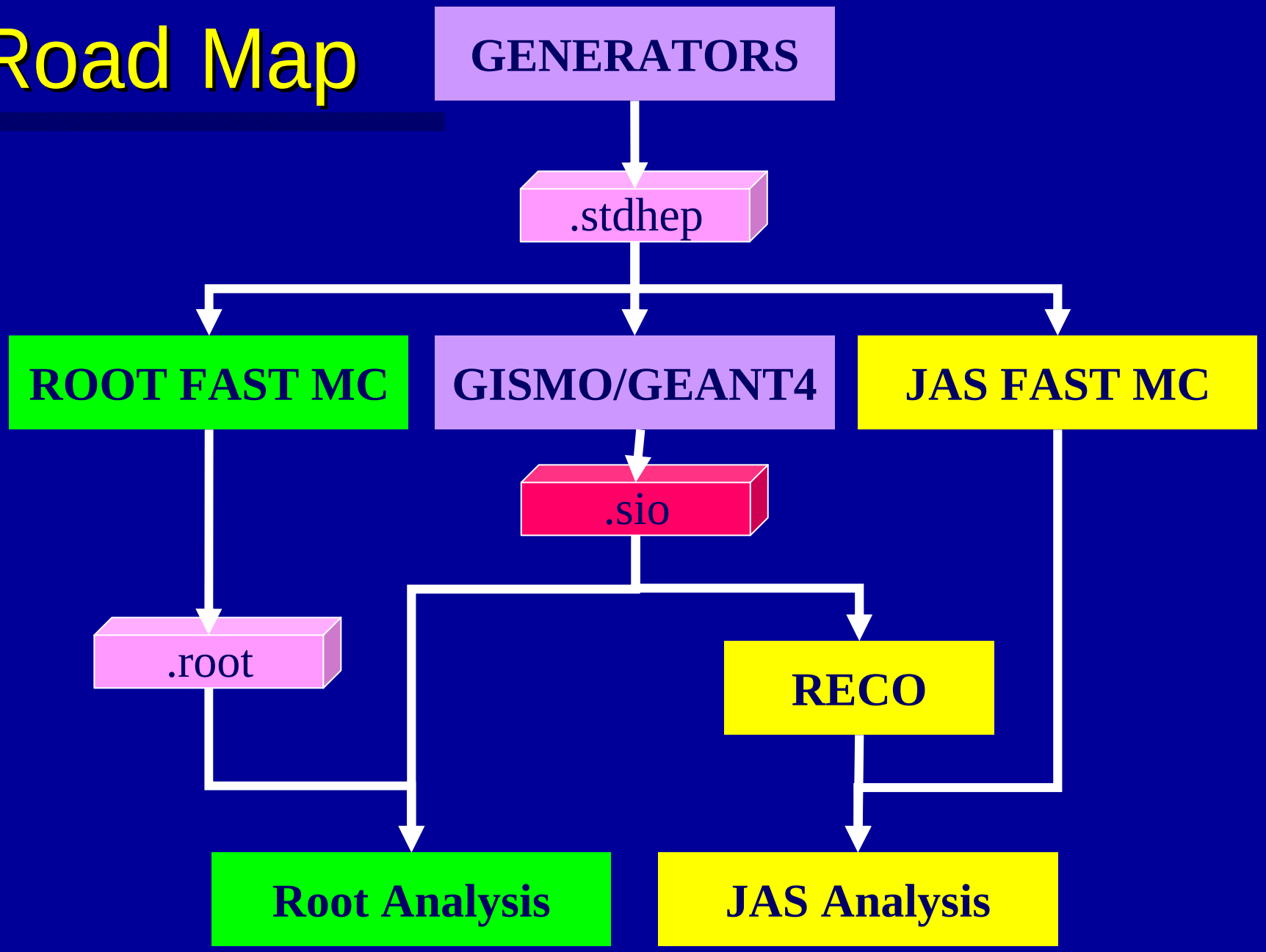
Mission Statement

- Provide full simulation capabilities for Linear Collider physics program:
  - Physics simulations
  - Detector designs
  - Reconstruction and analysis
- Need flexibility for:
  - New detector geometries/technologies
  - Different reconstruction algorithms
- Limited resources demand efficient solutions, focused effort.

Recent Focus

- Efforts devoted to providing physics analysis package for Snowmass meeting.
- Emphasis on integrated environment for event generation and fast detector simulation.
- Provided CD-ROM with precompiled executables (Windows and Linux), API, tutorials and example code.
- Less work on full reconstruction.

Road Map


GENERATORS
.stdhep
ROOT FAST MC
GISMO/GEANT4
JAS FAST MC
.sio
.root
RECO
Root Analysis
JAS Analysis

Physics Generators

- Any generator producing STDHEP-format output can be used as input.
- Provide precompiled versions of
  - PYTHIA, ISAJET, HERWIG
- Pandora is a general purpose OO event generation framework in C++ which simulates polarization, ISR, spin correlations and asymmetries, and arbitrary hard processes.
  - interface to PYTHIA exists to hadronize final state partons.

Full Simulations

- Detailed, realistic descriptions of the detector elements.
  - Including support material, cracks, etc.
- Complete accounting of physics processes, track swimming, particle showering, etc.
- Essential for detector development and derivation of fast simulation parameterizations.

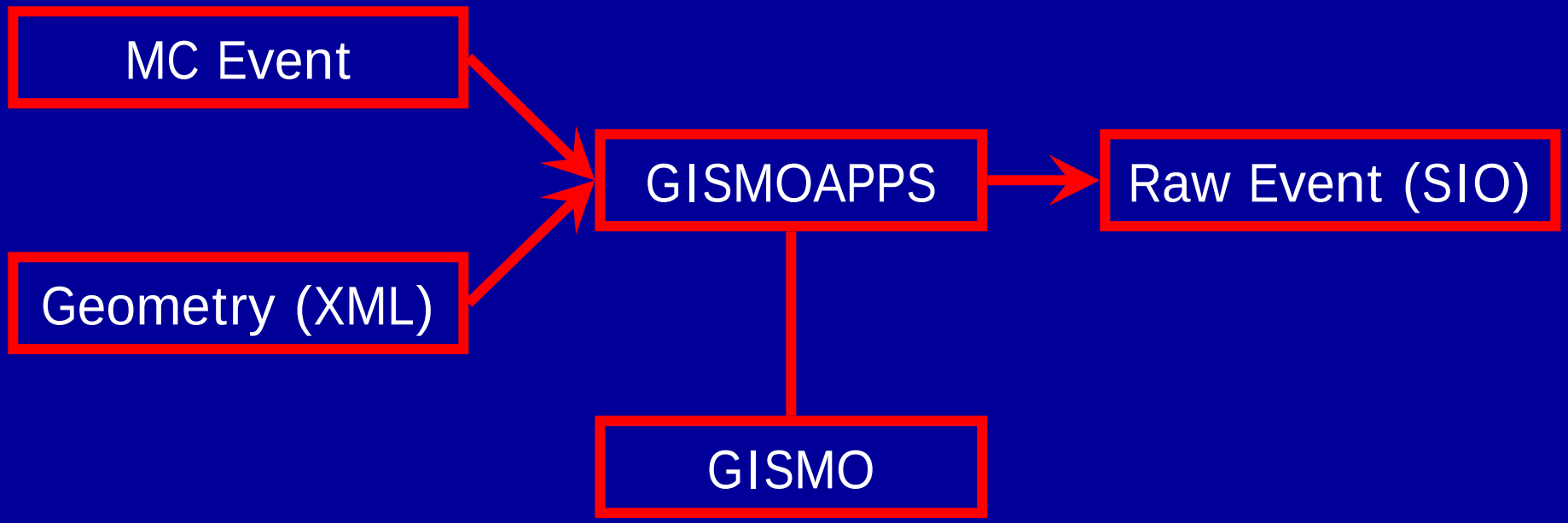
GISMO Full Simulation

- Reasonably full-featured full simulation package – Object-oriented C++
  - complex geometries
  - EGS & GHEISHA
  - multiple scattering, dE/dx, etc
  - available before GEANT4
- Generator input from /HEPEVT/ via FNAL STDHEP I/O package
- Detector geometry input via XML

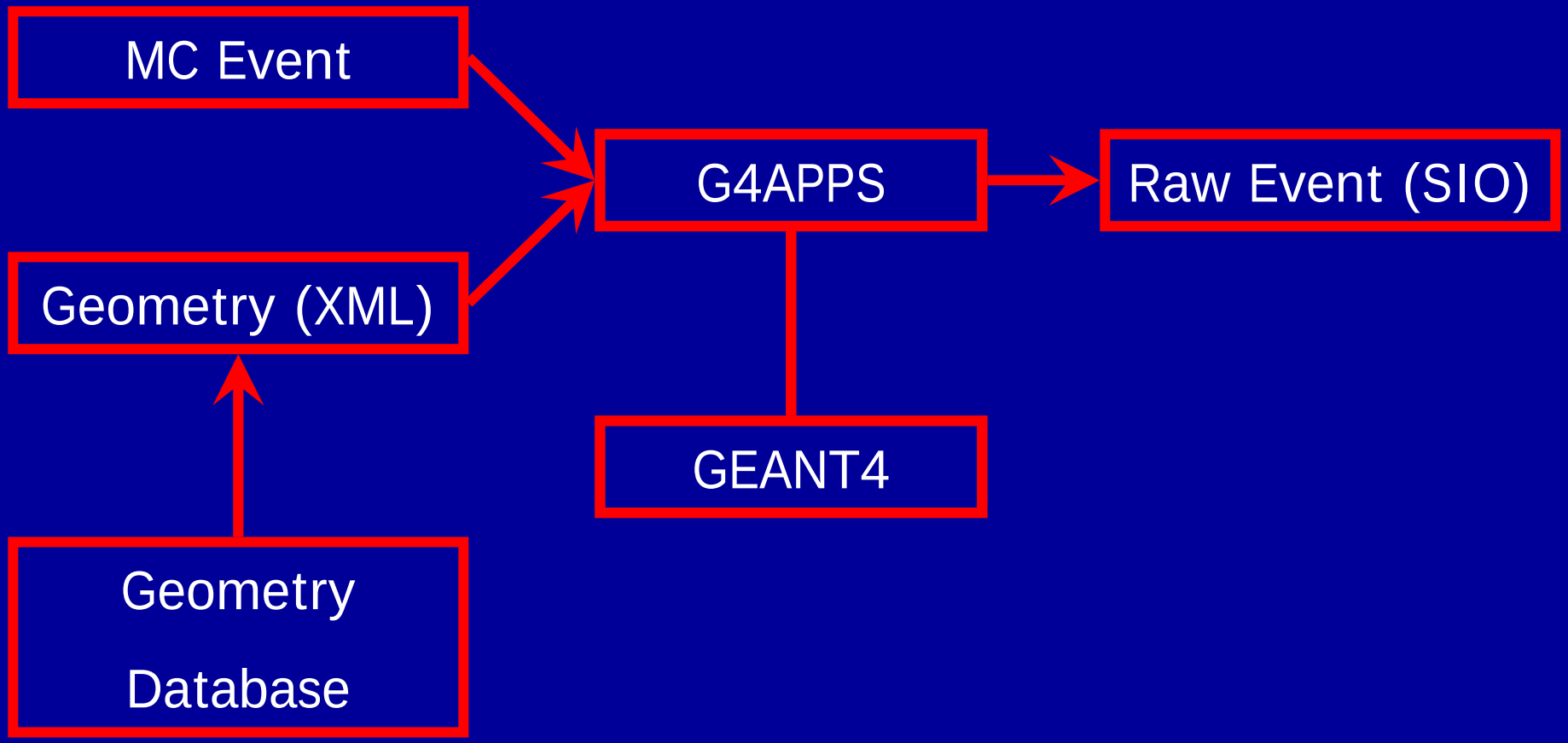
GEANT 4

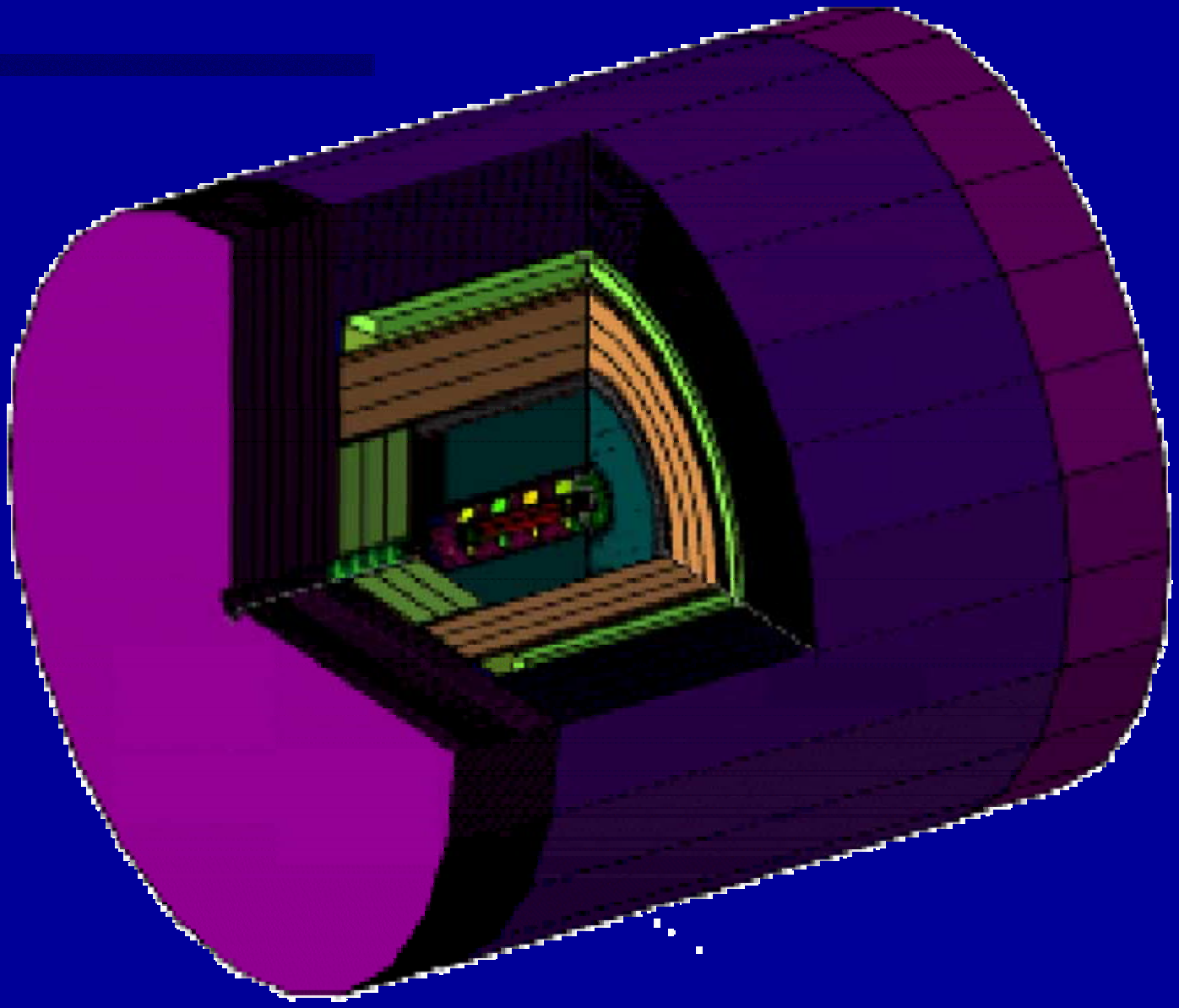
- We have begun the transition to GEANT4 by incorporating the existing XML geometry-parsing code.
- Have defined generic hit classes for sensitive tracker and calorimeter hits.
- Latest parser (xerces) supports XML Schema. Very useful for “compile-time” type safety and bounds checking.
- Prefer a common G4 XML-based solution.

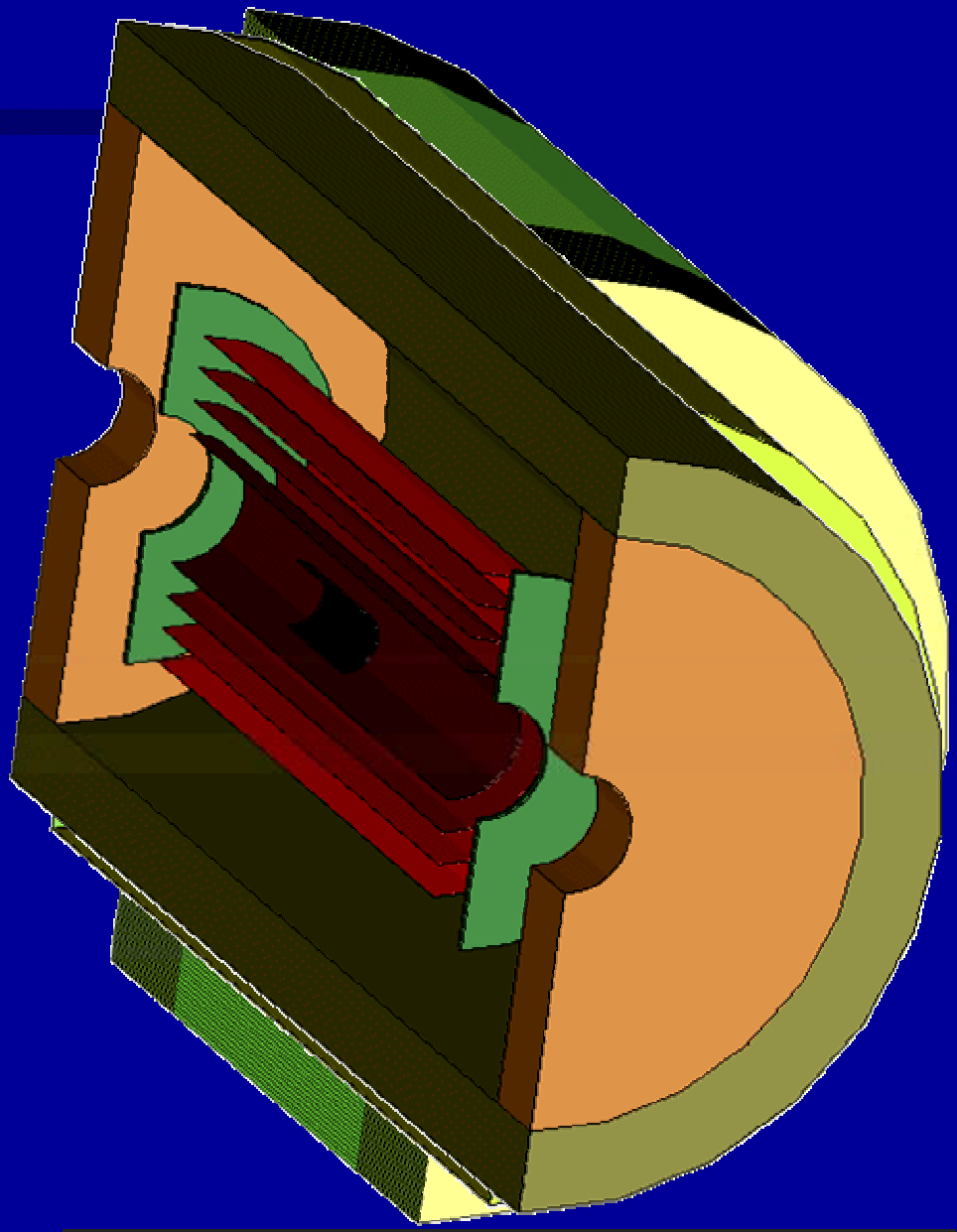
LCD Full Simulation Overview



LCD Full Simulation Overview







Generic Hits

- Tracking
  - Position, dE/dx, time and four-momenta at tracking sensitive volumes.
  - Smeared or digitized later with appropriate resolution and combine overlapping hits.
- Calorimeters
  - Energy per channel/particle.
  - Generate at very fine resolution, rebin later to study optimal segmentation.
- All hits have GUID and full MC record.

Towards Internationalization

- Suggest that Tesla, NLC and JLC full simulation groups could run a single GEANT4 executable.
- Geometry determined at run-time (XML).
- Write out common “ideal” hits (~flat-file).
- Digitize as appropriate with plug-ins.
- Enormous savings in effort.
- Makes comparisons easy.
- Prefer common GEANT4 solution.

Full Simulations

LCD Full Sim	BRAHMS	JIM
GISMO	GEANT3	GEANT3
C++	FORTRAN	FORTRAN

Common GEANT4 executable

XML-based geometry

Generic Hit output

Full Reconstruction

- Reconstruction of fully simulated (i.e. detector-level) MC data is Java-based.
- Architecture is defined in terms of Java interfaces to allow easy implementation of different algorithms.
- Reconstructs “low-level” objects: tracks and calorimeter clusters.
- Further reconstruction (jets, flavor-tagging,...) deferred to analysis stage.

LCD Tracking Reconstruction

- Hit position smearing, efficiency and merging (since Gismo gives “perfect” hits)
- Random Background overlay
- Track Finding:
  - Full pattern recognition in the Central Barrel region
    - Tuned for Large & Small detector

LCD Tracking Reconstruction

- Track Fitters:
  - SLD Weight Matrix Fitter
  - Can do Single Detector or Combined fit (e.g. VTX+TPC)
- What's still needed:
  - More Track Finding Algorithms (Pure Projective Geometry)
  - Better End Cap tracking
  - Kalman Fitter

Calorimeter Reconstruction

- Cluster Finding
  - Several Clustering Algorithms
    - Cluster Cheater (uses MC truth to “cheat”)
    - Simple Cluster Builder (Touching Cells)
    - Radial Cluster Builder
- In Progress
  - Track-Cluster Association
  - Tracking in Calorimeter
  - “Energy Flow Objects”
- Still Need Particle ID: e, μ, h

Beam Background Overlays

- Take output from full beam simulation (from IR/backgrounds group)
- Feed into full Gismo simulation
- Build library of simulated background bunches
- Overlay backgrounds on signal events at start of reconstruction
  - Adjust timing of hits (for TPC e.g.)
  - Add energy in calorimeter cells
- Allows to change #bunches/train, bunch timing

Fast Simulations

- Simulations based on parameterized, or simplified detector responses
  - Fast, can be flexible, but have limitations.
- We believe that energy flow and vertexing are the key elements for future Linear Collider experiments.
  - Concentrate on smearing tracks and calorimeter clusters.
- Represents “ideal” reconstruction!

Fast MC

- Tracks

  Covariantly smear charged particle vectors and set 5-parameter error matrix (B.Schumm)

  Transport tracks through field

- Calorimeter Clusters

  Smear particle position and energy

  Cluster merging (for granularity study)

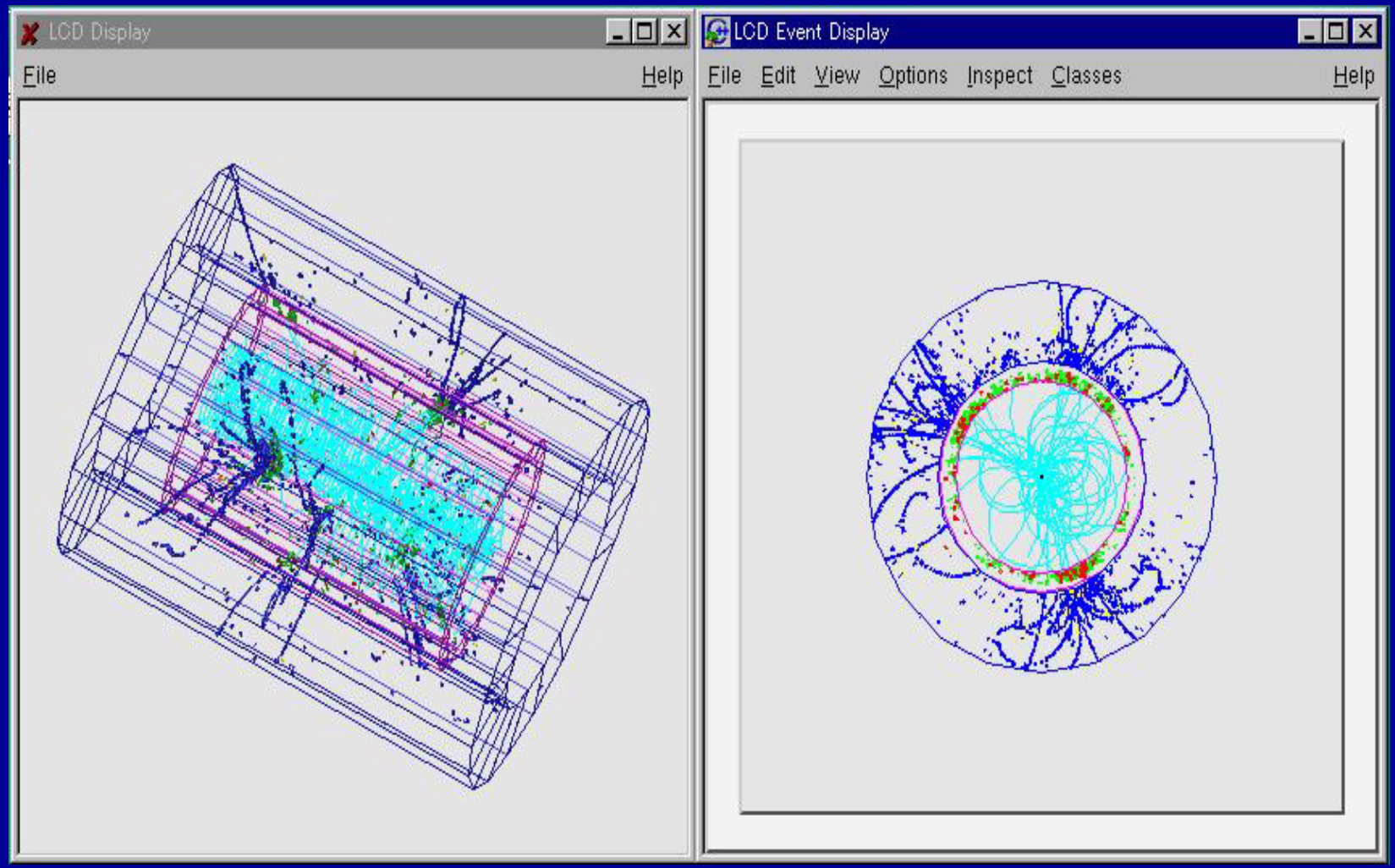
~Fast MC

- Create Tracker hits using fast swimmer
  - Account for MS and energy loss, but no secondaries
- Create Calorimeter hits using shower library
  - Could also use parameterized shower shape
- Run full reconstruction on output hits.

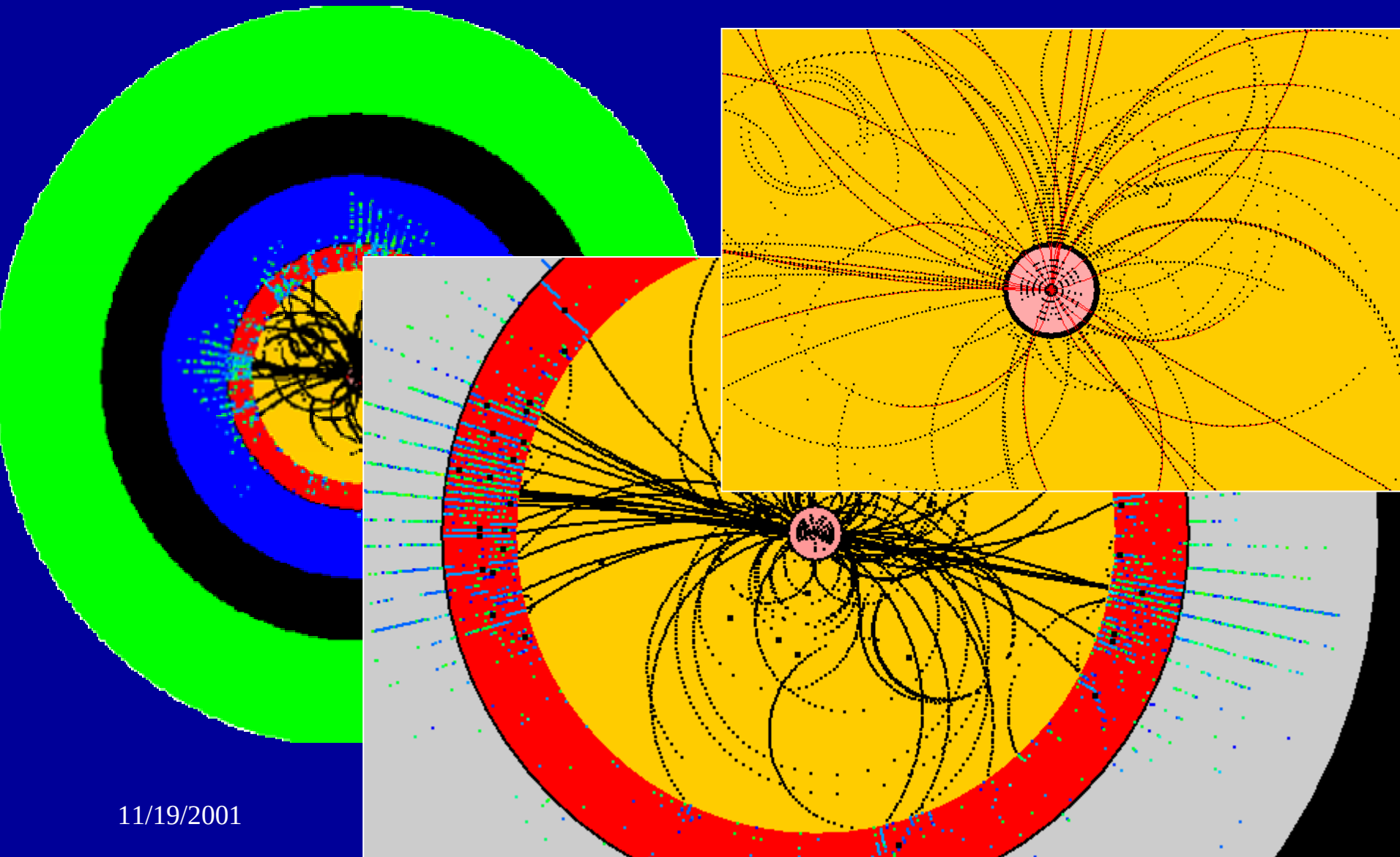
Analysis Frameworks

- Inclusive environment; support both ROOT/C++ and JAS/Java frameworks.
- Jet-Finding algorithms, invariant mass calculations, vertexing (based on SLD ZVTOP), flavor tagging, etc. are all available.
- Displays for event visualization.
- Histograms, fitting, etc.

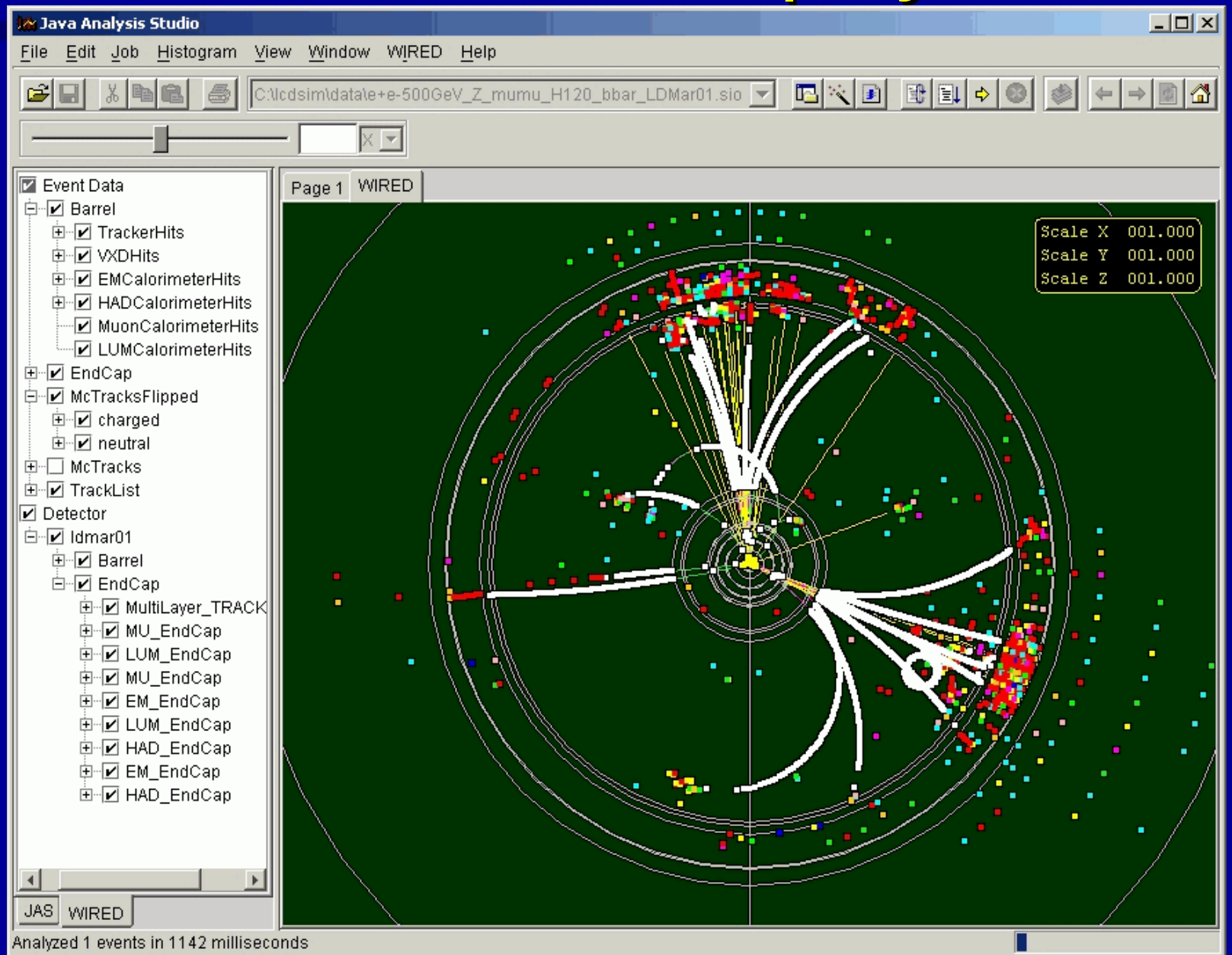
LCDROOT Event Display



JAS 2D LCD Event Display

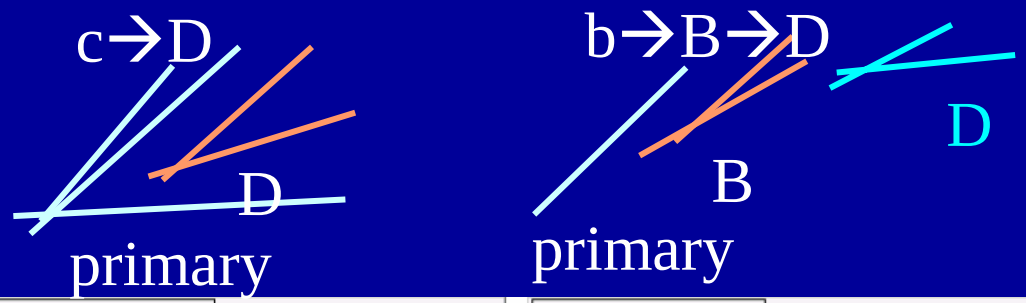


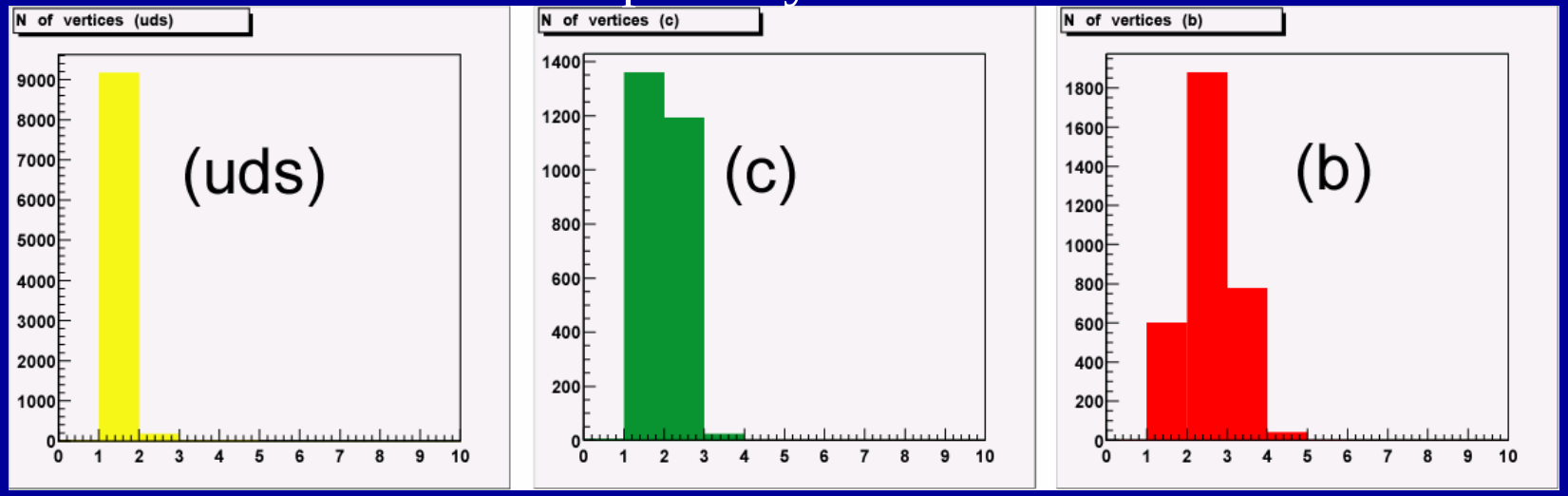
Wired LCD Event Display



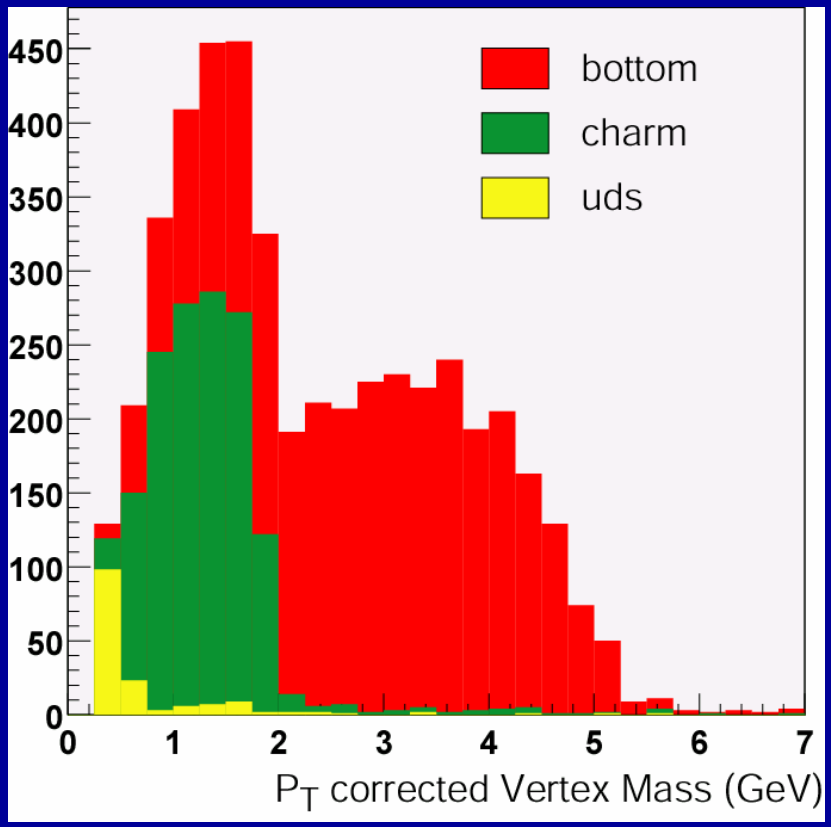
Topological Vertex Finder

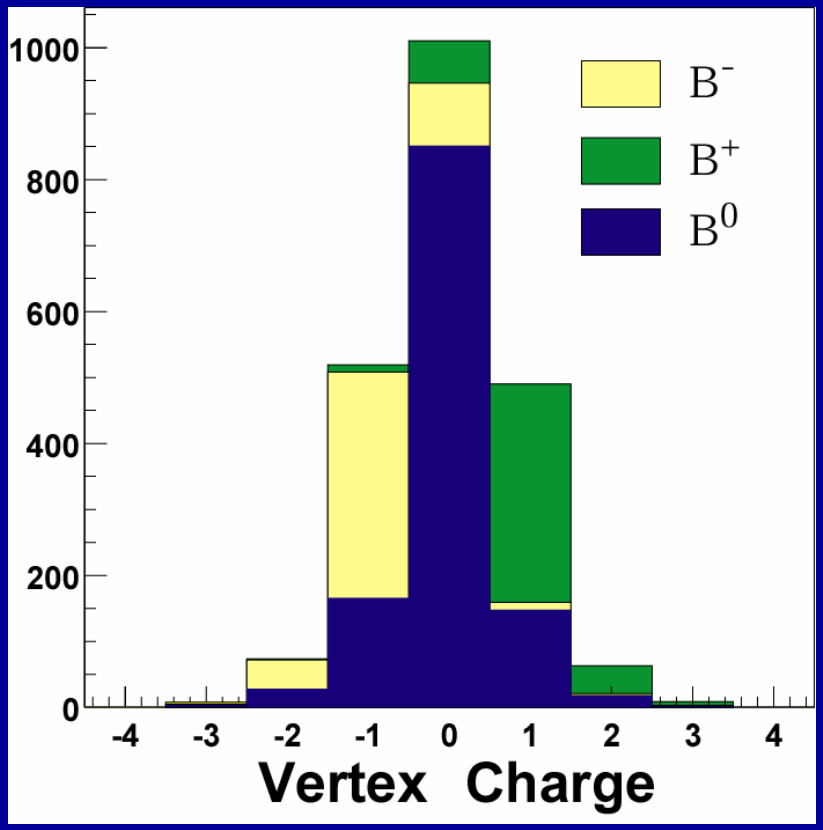
- SLD's unique topological vertex finder + mass tag
  D.J.Jackson NIM A388, 247 (1997)
  SLD collaboration PRL 80, 660 (1998)

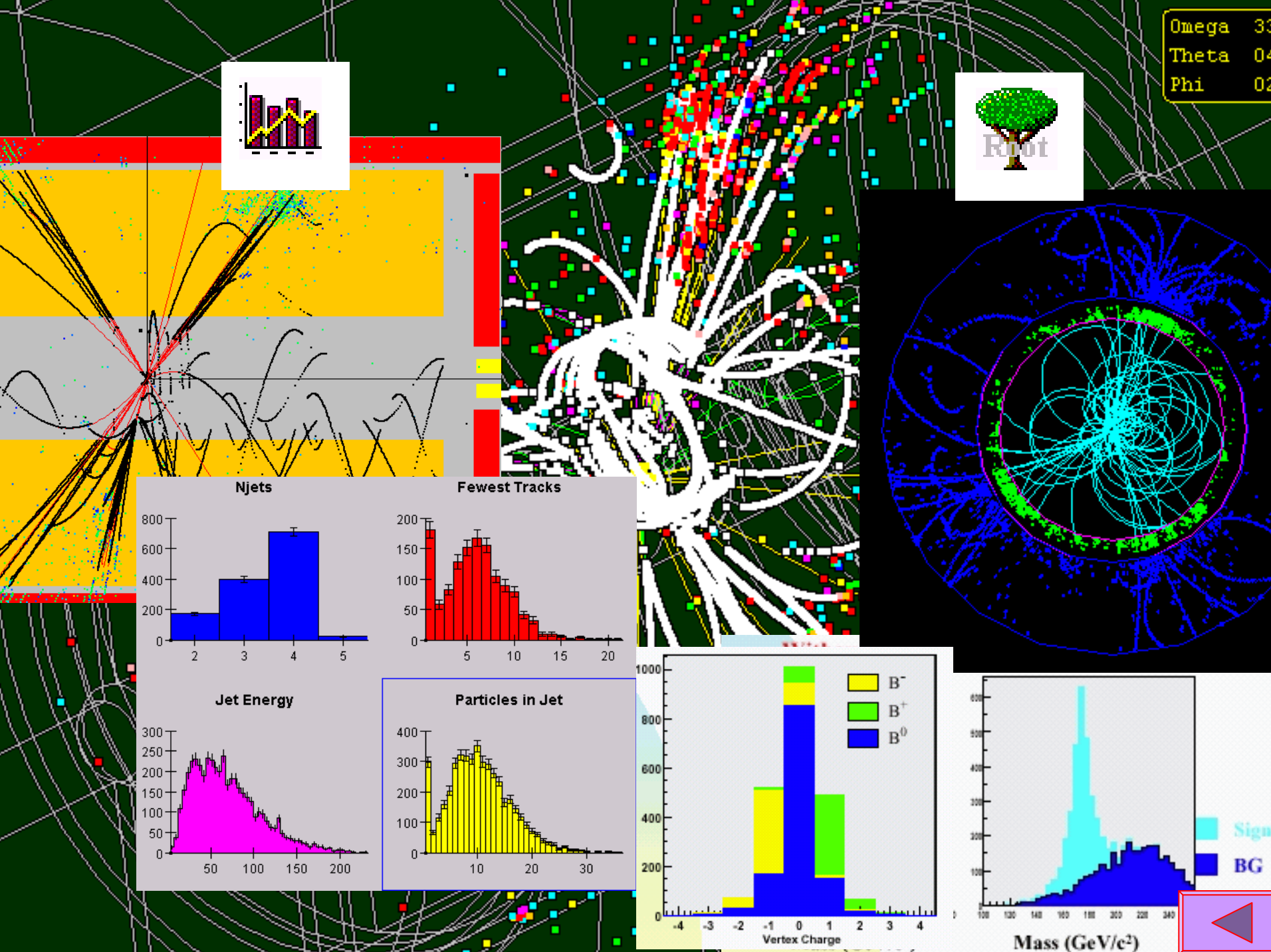




Vertex Mass and Charge






Omega
Theta
Phi
Root
Njets
Fewest Tracks
Jet Energy
Particles in Jet
B⁻
B⁺
B⁰
Vertex Charge
Sign
BG
Mass (GeV/c²)

Summary

- The LCD group has developed a very dynamic detector design, data reconstruction and physics analysis simulation environment.
- This talk has only scratched the surface on a large body of work conducted by a remarkably small community of dedicated individuals.
- Much work remains to be done and we could all benefit from collaborative effort.

Plans

- Concentrate on GEANT4 full detector simulation.
- Emphasize results from full reconstruction.
- Iterate detector design based on above.

- Upcoming Meetings
  - North American LCD meeting scheduled for January 7-9, 2002 in Chicago.
  - LCWS 2002 Chengdu Korea, August.

URL

- American Linear Collider Detector simulation efforts are documented at:

  www-sldnt.slac.stanford.edu/nld

- Binaries, full source, API, tutorials, etc.
- Thanks to:

  A. Johnson, G. Bower, R. Cassell, T. Abe,

  M. Iwasaki, W. Walkowiak, M. Ronan, B. Schumm, *et al.*

- Mail to: Norman.Graf@slac.stanford.edu