LC Toolkit

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LCSim Workshop

May 22, 2003

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.

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.

LC Analysis Frameworks

- JAS/Java
  - Growing user community
  - Library of HEP utilities
  - Platform independence
  - Distributed computing
- ROOT/C++
  - Large HEP user community
  - Library of HEP utilities
  - Access to growing C++ software packages

LCDROOT Analysis

- Several useful analysis tools for future linear collider studies:
  - Jet Finders
  - Event Shape/Thrust Finder
  - Particle extrapolator
  - Kalman Track Fitting
  - Vertex Finder (ZVTop)
  - Flavor tagging (NN, high eff. & purity)
  - Event Display

LCDROOT Generators

- PANDORA (C++) by M. Peskin with PYTHIA/TAUOLA interface (M. Iwasaki)

  Include beam polarization, beamstrahlung, ISR

  Can be directly handled in LCDROOT

  → main generator of LCDROOT
- PYTHIA (TPythia6 for interface class)
- Diagnostic generator
- Output: ROOT or stdHEP

  Or can be directly linked to FastMC

LCDROOT Fast MC

- Tracks

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

  Transport tracks through field

- Calorimeter Clusters

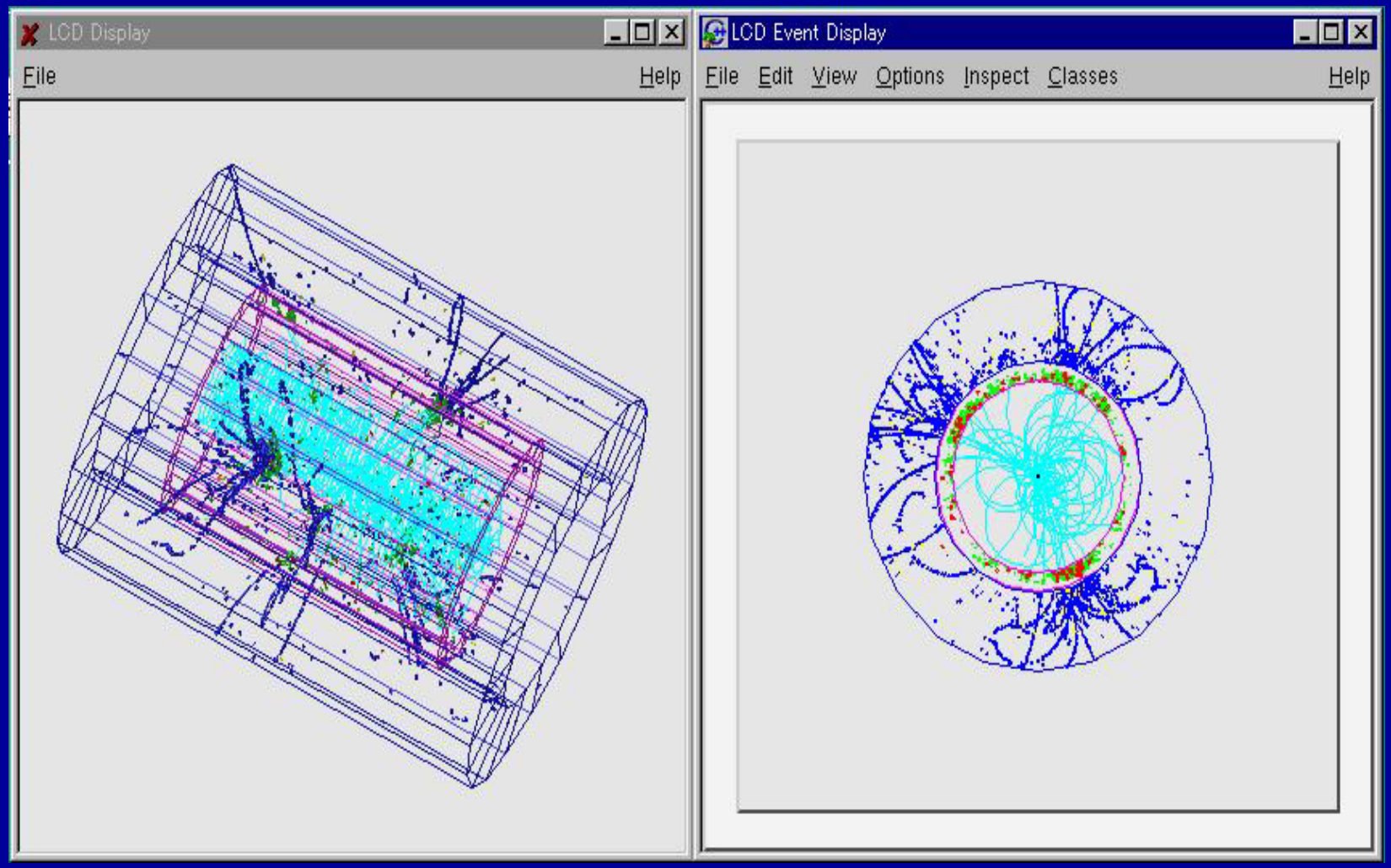
  Smear particle position and energy

  Cluster merging (for granularity study)

LCD Fast MC Analyses

- With correctly smeared tracks, can start undertaking sophisticated analyses with realistic flavor-tagging.
- Implementations of topological vertex finding algorithm ZVTOP in both C++ and Java.
- ROOT analysis implemented pT-corrected vertex mass, NN-based flavor tagging for b/c jet analyses.

LCDROOT Event Display



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 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 Physics Utilities

- Fast MC: smear tracks, create calorimeter clusters
- Track Finding & Fitting
- Calorimeter Clustering
- Topological Vertexing
  - Implementation of SLD's ZVTOP
- Contributed Area
  - Analysis Utilities and sample analyses provided by users

Full Simulation Detector Hits

- Tracking
  - 3D hit points at tracking layers
  - smeared later with appropriate resolution
- Calorimeters
  - total energy per channel
  - generate at very fine resolution, rebin later to study optimal segmentation
- All hits have full MC record

Beam Background Overlays

- Take output from full beam simulation (from IR/backgrounds group)
- Feed into full detector 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

Full Reconstruction

- Reconstruction of fully simulated MC data is primarily 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.

LC Tracking Reconstruction

- Hit Smearing/Efficiency (since detector simulation puts out "perfect" hits)
- Random Background overlay
- Track Finding:
  - Full pattern recognition in the Central Barrel region
    - Tuned for Large and Silicon Detectors
- 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)
  - Detector digitization to simulate hit merging, ghosting, electronics noise and dead channels, etc.

Calorimeter Reconstruction

- Cluster Finding
  - Several Clustering Algorithms Currently Implemented
  - Cluster QA package developed
- Cluster Refinements
  - Combine HAD + EM clusters
  - Endcap + Barrel overlap region
  - Identify cluster as originating from charged/neutral hadron, EM
- In Progress: Track-Cluster Association, ReconstructedParticle
- Several independent developments
  - Please feed back to the community!
  - Doesn't need to be final to be in cvs.

Canonical Data Samples

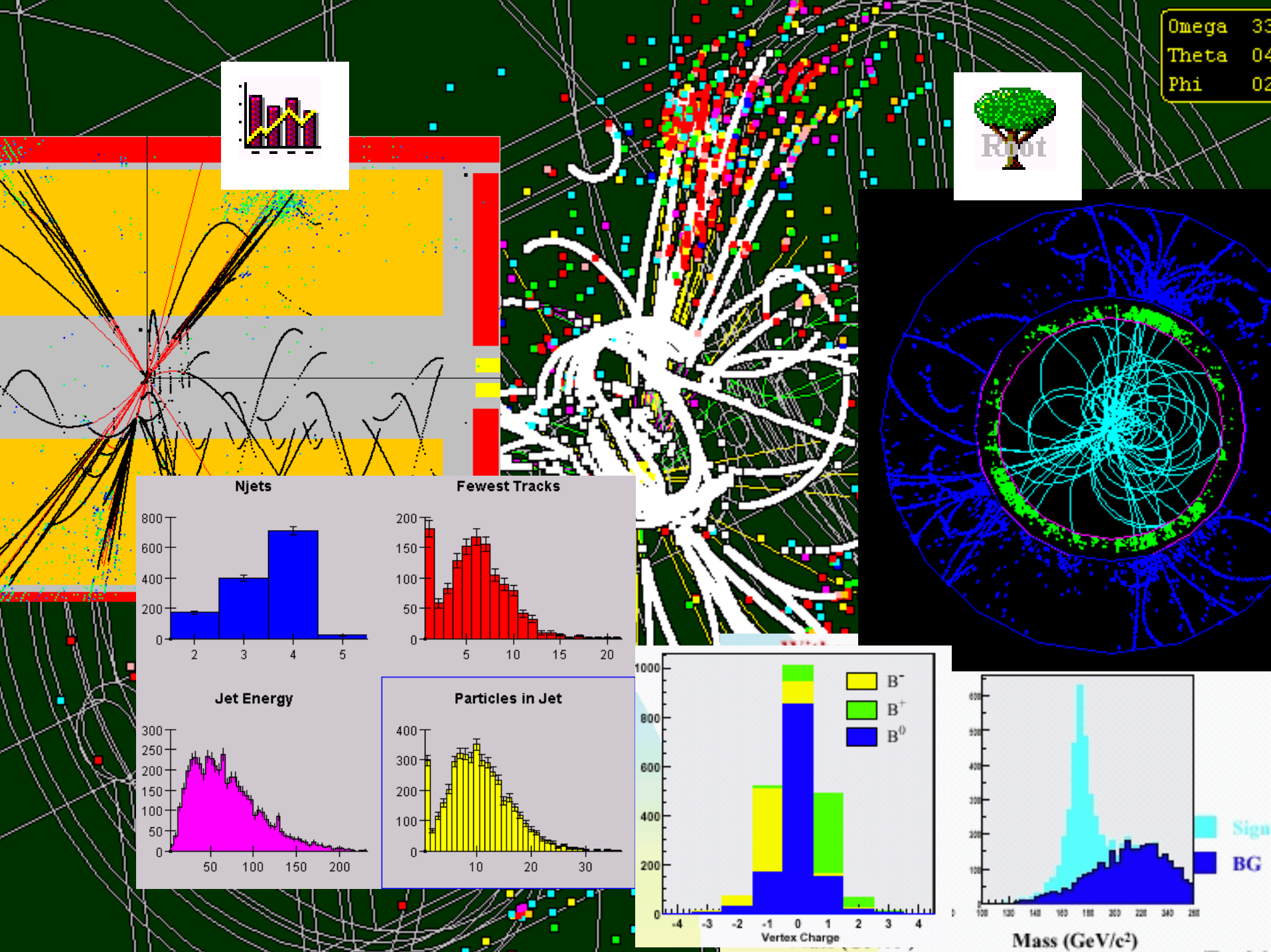
- 2 ab^{-1} SM Sample @ .5, 1.0, 1.5 TeV (stdhep)
- $q\bar{q}$, $t\bar{t}$, ZZ, WW, ZH full simulation (SIO)
- Backgrounds
  - Guineapig machine backgrounds
  - $\gamma\gamma \rightarrow$ hadrons
- "Single Particle" diagnostics samples
- On-demand generation (e.g. NICADD farm)
- Available on server for distributed analysis

Communication

- Mailing Lists: lcd-l, lcd-sim, lcd-dev
- HyperNews forums (soon)
  - open, threaded, interactive
- Propose regular (informal) VRVS meetings
  - Forum to discuss technical as well as analysis issues
- Feedback
  - Your comments (what's missing, what's wrong)
  - Your code!

Summary

- The LCD group has developed modern simulation and analysis tools for future Linear Collider experiments
- Simulation & analysis tools available in both C++ and Java implementations.
- Root and JAS analysis frameworks.
- The architectures support various combinations of fast and full simulation and reconstruction.


Omega 33
Theta 04
Phi 02
Root
Njets
Fewest Tracks
Jet Energy
Particles in Jet
B⁻
B⁺
B⁰
Vertex Charge
Sign
BG
Mass (GeV/c²)