Physics and Detector Simulations

Norman Graf

(SLAC)

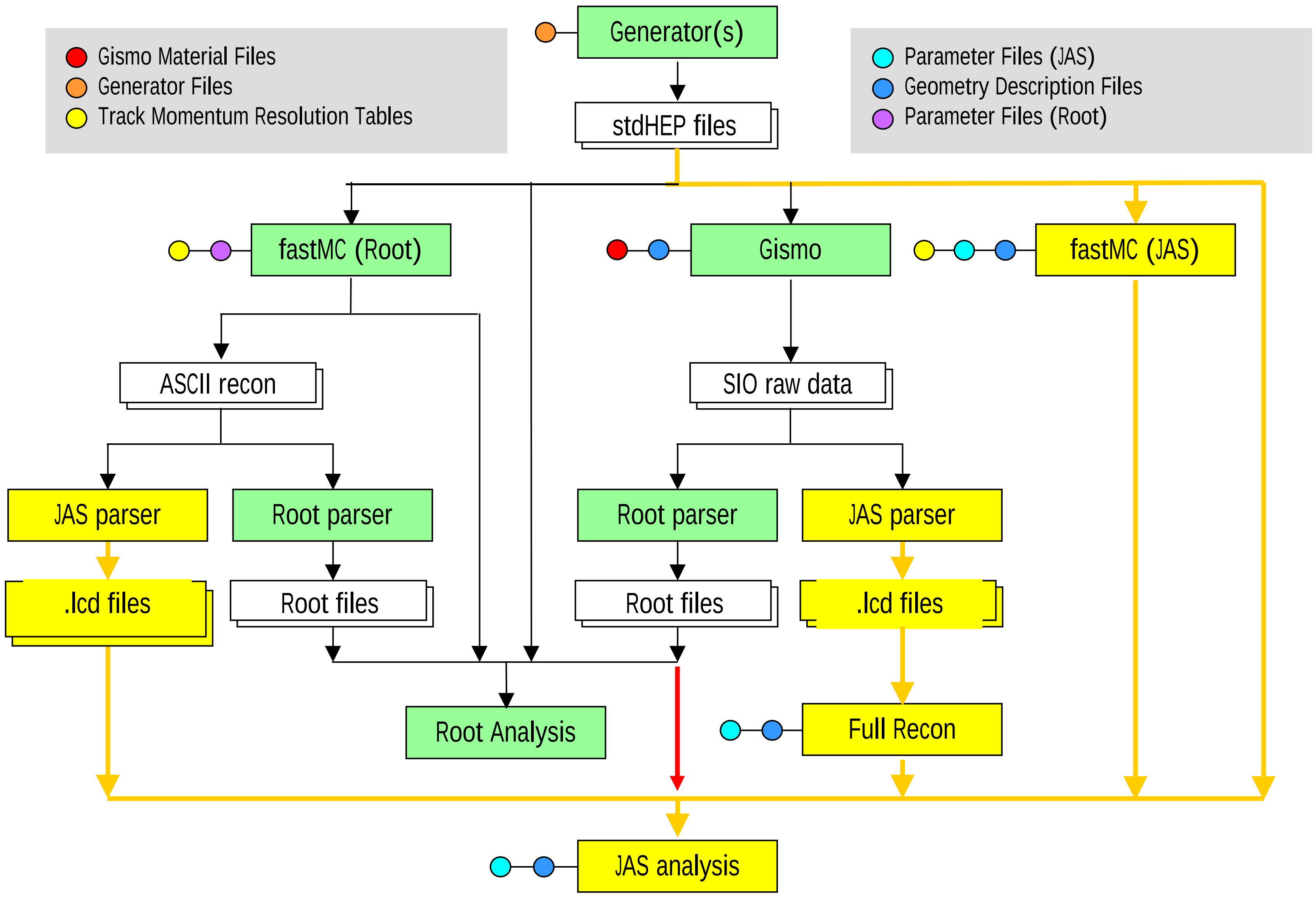
2nd ECFA/DESY Workshop

September 24, 2000

Simulation studies for a future Linear Collider

- We believe that the physics case for the LC has been made.
- We need now to optimize the detector design using more realistic physics studies based on full simulations and event reconstruction.
- Object-Oriented methodology provides the necessary flexibility to efficiently study multiple designs.

LCD Software Road Map



Physics Generators

Pandora is a general purpose Object-Oriented event generation framework implemented in C++ which allows polarization and initial-state interactions to be simulated.

The Pandora-Pythia interface exists to hadronize the final state partons.

Any generator producing STDHEP-format output can be used as input to LCD simulations (PYTHIA, ISAJET...)

Gismo: Full Simulation

Reasonably full-featured full simulation package - C++

- complex geometries
- EGS & GHEISHA
  - cutoffs set at 1 MeV
- multiple scattering, dE/dx, etc

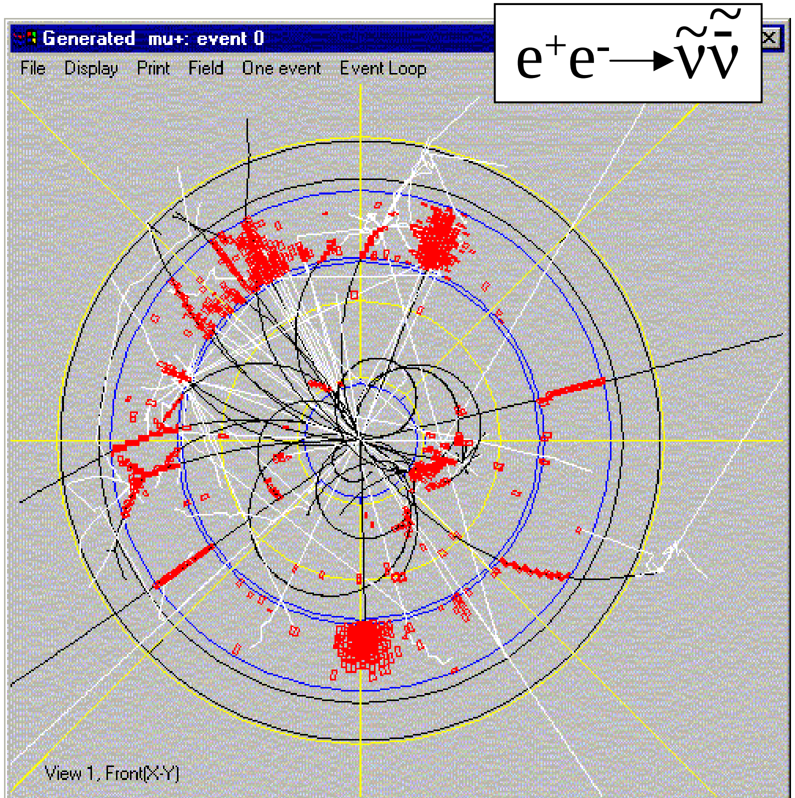
Generator input from /HEPEVT/ via FNAL STDHEP I/O package

Digitization

- tracking
  - hit points at tracking/VXD layers
- calorimeters
  - total energy per channel
- muon strips
- all digi's have full MC record

Output to SIO file

- allows parsers to translate to JAS & Root for further analysis/processing

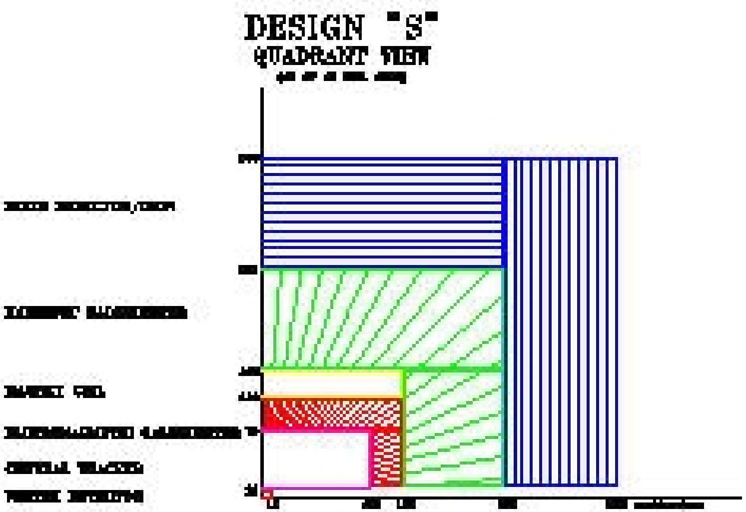


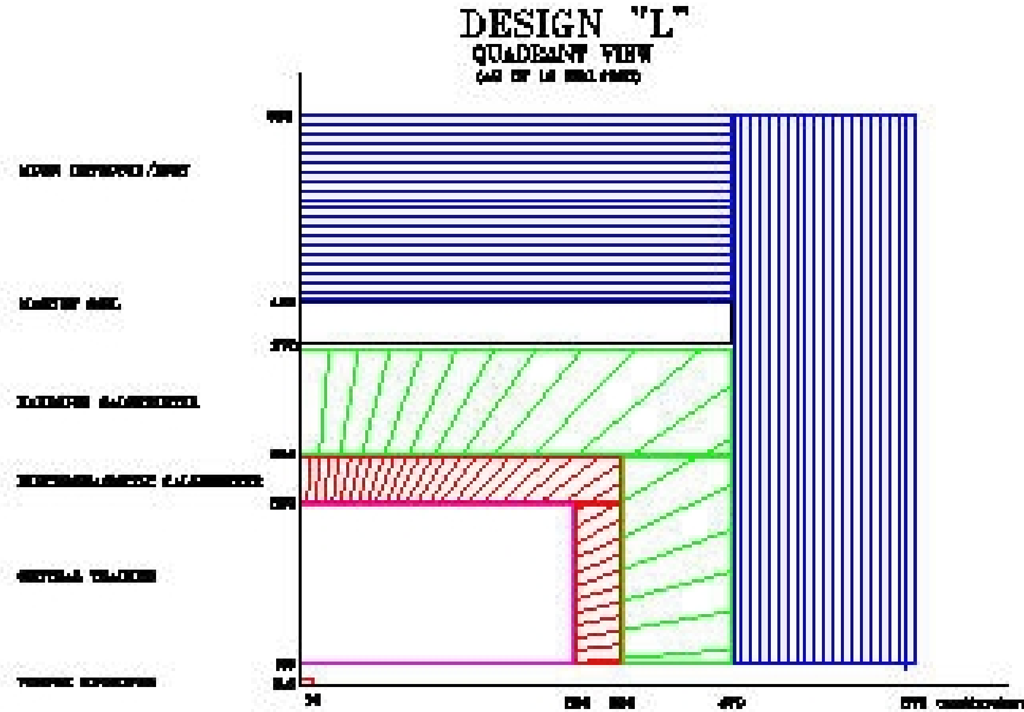
Full Sim: Geometry Elements

- Input by detector file in XML format
- trackers and calorimeters can have inner/outer skins and endplates
- tracker/VXD layers can be individually positioned and sized
- user sets longitudinal cell composition (multi-materials allowed) and ‘sensitivity’
- configurable conical masks

S

L





B=6T

B=3T

Small Detector

3 Tracker Doublets

1.1 mm G10, 600 μm Si

r = 14, 42, 71 cm

outer layers extend to z=149 cm

5 EC Tracker disks

z = 31, 61, 91, 121, 149 cm

inner r follows cos θ=0.99

Luminosity monitor (Si/W)

active from 30-116 mrad

'Vestigial' mask

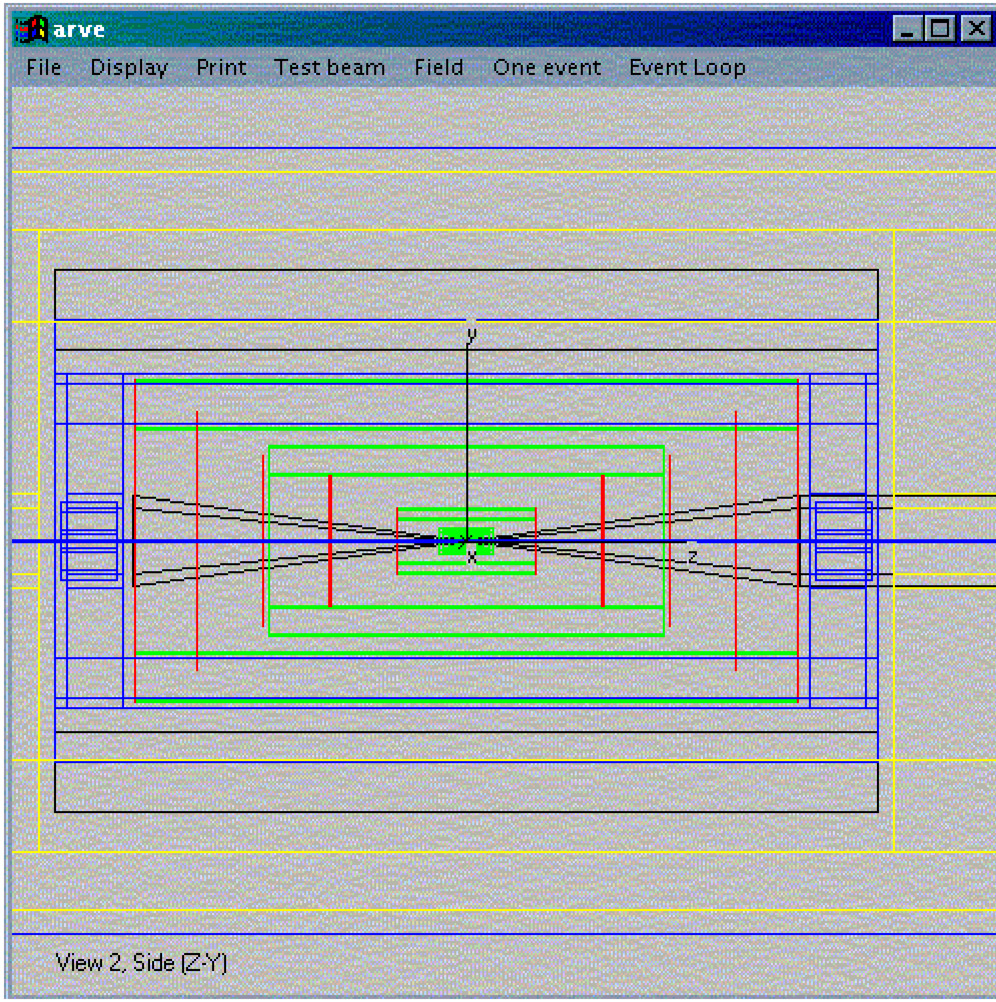
cone from r=1.2 cm at z=10 cm to r=20cm at z=155 cm

Coil: 23 cm Al - **between EM & HAD cals!**

Calorimetry

HAD cal: 2 cm Cu; 0.5 cm scint

EM cal: 0.2 cm W; 0.03 cm Si



Large Detector

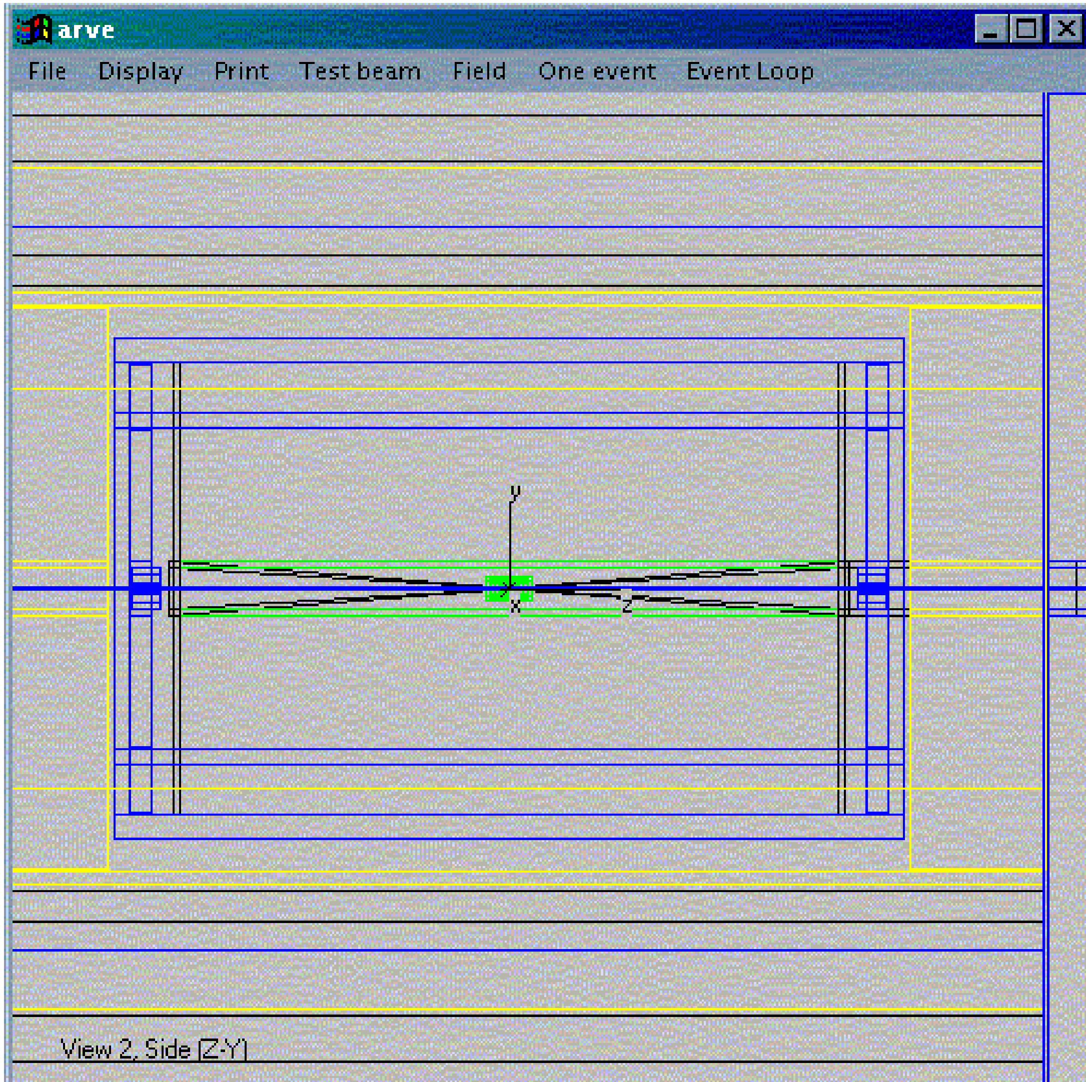
144 Layer TPC
- r = 25-200 cm
- length = 5.8 m
- 4.5 cm Al endplates
- 0.18 cm Al inner/outer skins

Luminosity monitor (Si/W)
- active from 16-83 mrad

'Vestigial' mask
- cone from r=1.2 cm at z=10 cm to r= 25 cm at z=300 cm

Coil: 40 cm Al - between HAD and MU cals

Calorimetry
- HAD cal: 0.8 cm Pb; 0.2 cm scint
- EM cal: 0.4 cm Pb; 0.1 cm scint



Recent Improvements

Detector Descriptions in XML

- **More control over detector configuration**
- **Easier to change detector configurations**

ASCII to SIO File format improved resolution.

Calorimeter very finely segmented in full simulation

- **Allows fast resolution studies by ganging cells in θ, φ, or layer coordinate.**

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**

Tracking Reconstruction

- **Hit Smearing/Efficiency (since Gismo gives "perfect" hits)**
- **Random Background overlay**
- **Track Finding:**
  - **Full pattern recognition in the Central Barrel region**
    - Tuned for Large + Small detector
- **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)**
  - **End Cap tracking**
  - **Hit Merging**
  - **Kalman Filter (incorporating multiple scattering) coming soon**

Calorimeter Reconstruction

Cluster Finding

Three Clustering Algorithms Currently Implemented

Cluster Cheater (uses MC truth to “cheat”)

Simple Cluster Builder (Touching Cells)

Radial Cluster Builder

- All algorithms tend to produce many very low energy clusters - important to set sensible thresholds

Still Needed - Cluster Refinement Stage

Combine HAD + EM clusters

Endcap + Barrel overlap region

In Progress - Track Cluster Association

Need to Extend Definition of Clusters

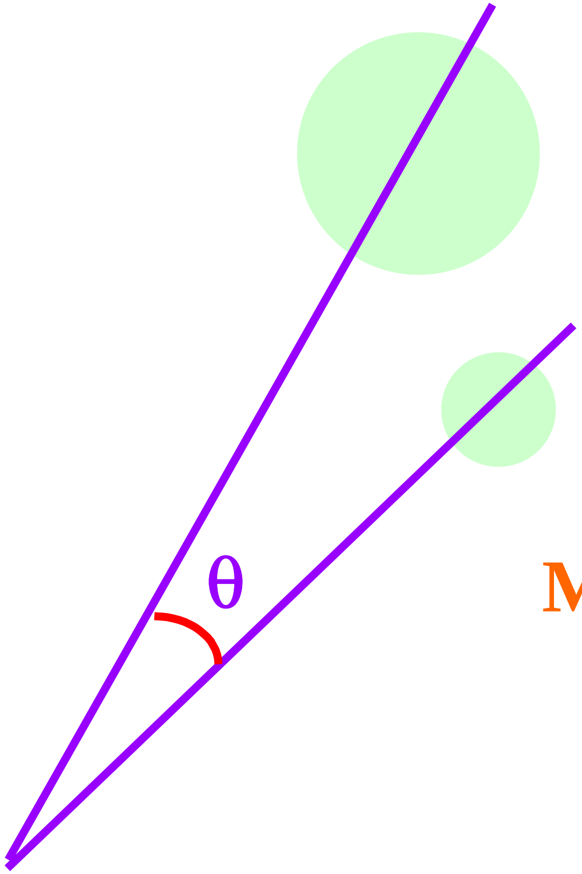
Directionality, Entry point to calorimeter

Fast MC Simulations

ChargedTracks Smear track parameters using the full 5x5 covariance matrix, extrapolate to calorimeter face.

Cluster Smear particle position & energy according to detector and particle type.

Cluster merging tool



Merge the clusters when

$\theta < \theta_{max}$

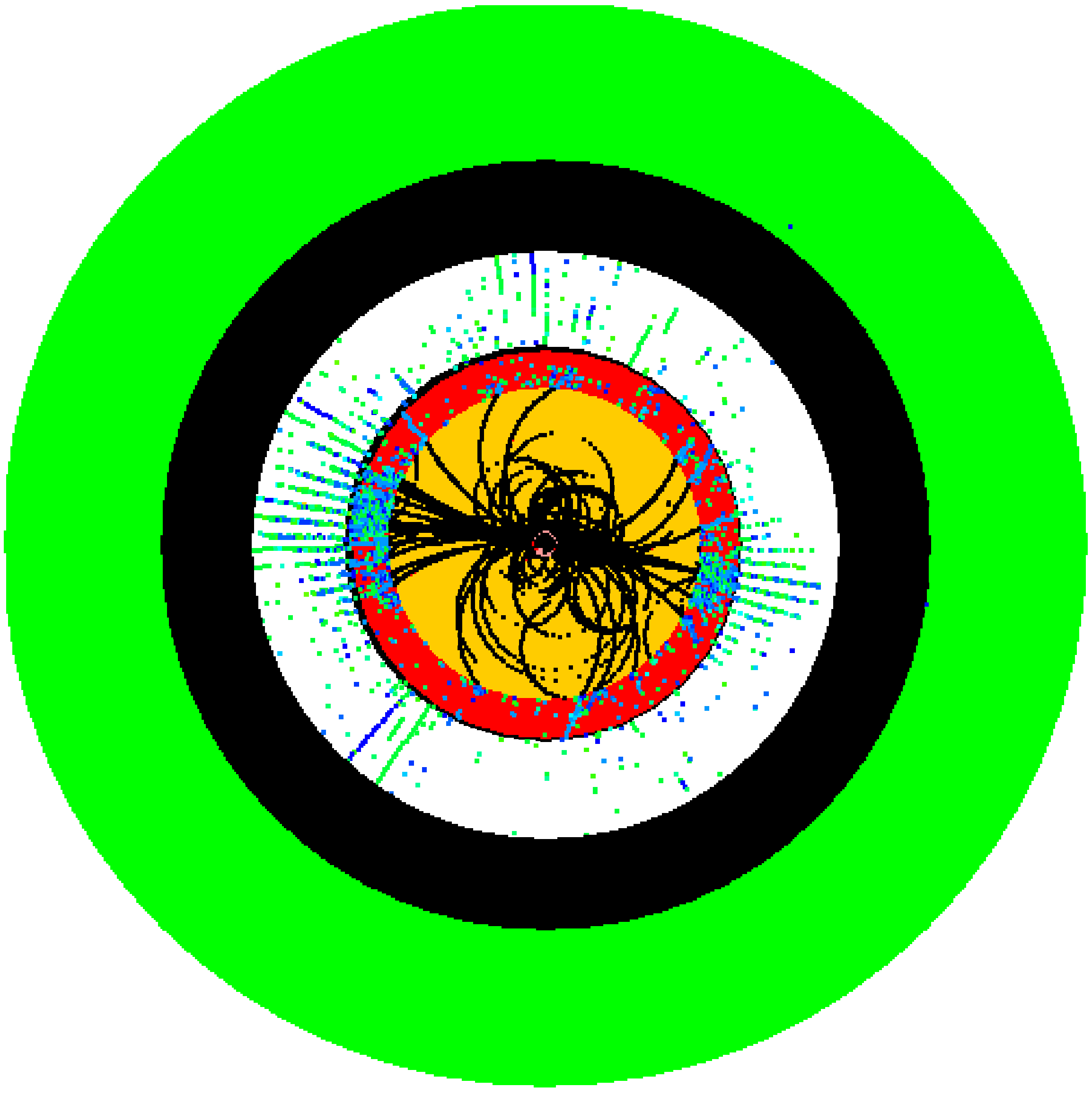
Cluster merging

.. Start from the Highest energy cluster

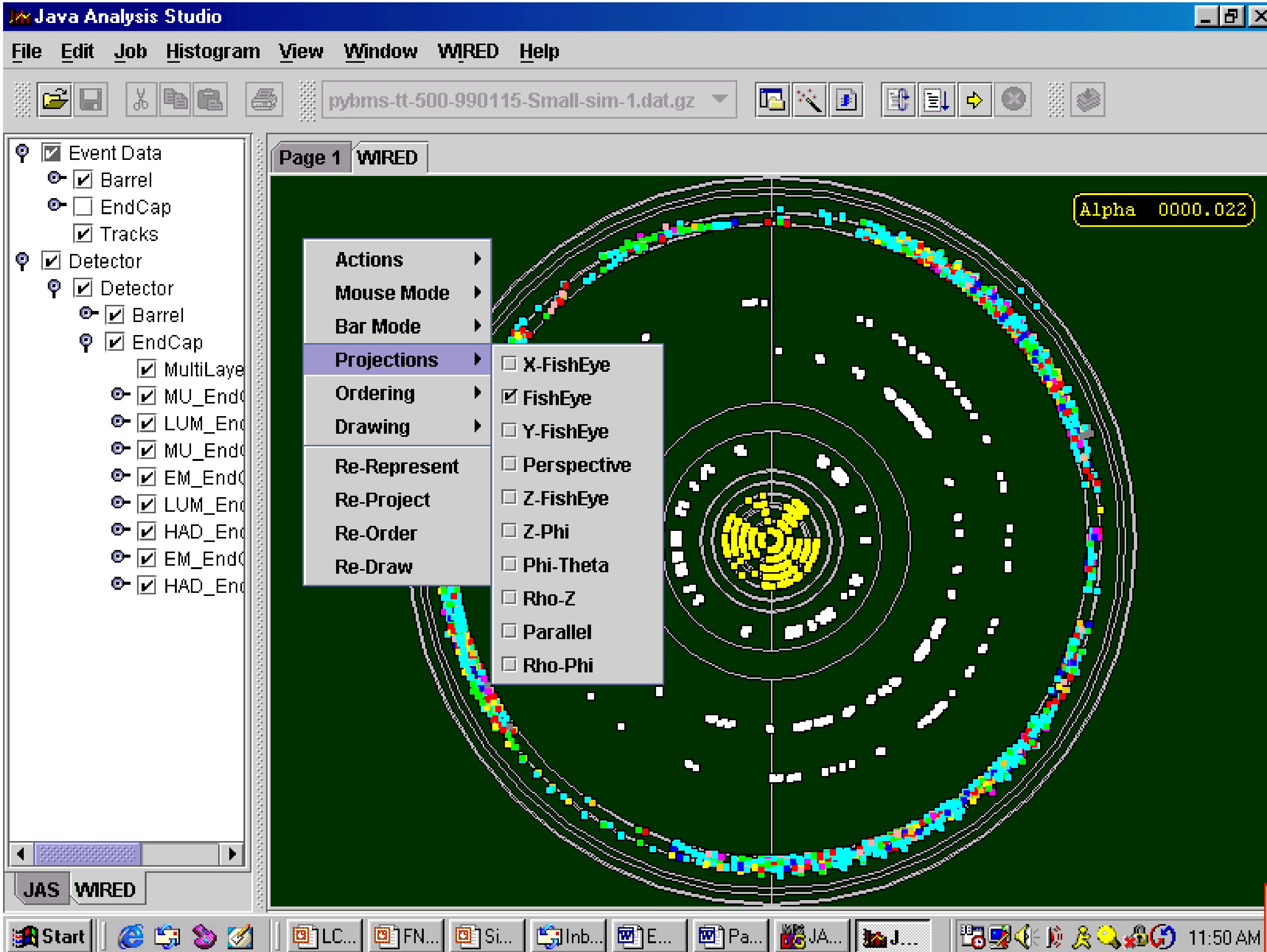
JAS Physics Utilities

- **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
- **Contributed Area**
  - **Analysis Utilities and sample analyses provided by users**
- **2 Event Displays**
  - **2D - Suitable for debugging reconstruction and analysis**
  - **Wired for full 3D support**
- **Particle Hierarchy Display**

2D Event Display



Wired (M. Dönszelmann – CERN)



Event Reconstruction

Jet-Finding

Currently have the Jade, Jade-E and Durham jet-finding algorithms implemented. Abstract interface allows others to be simply added.

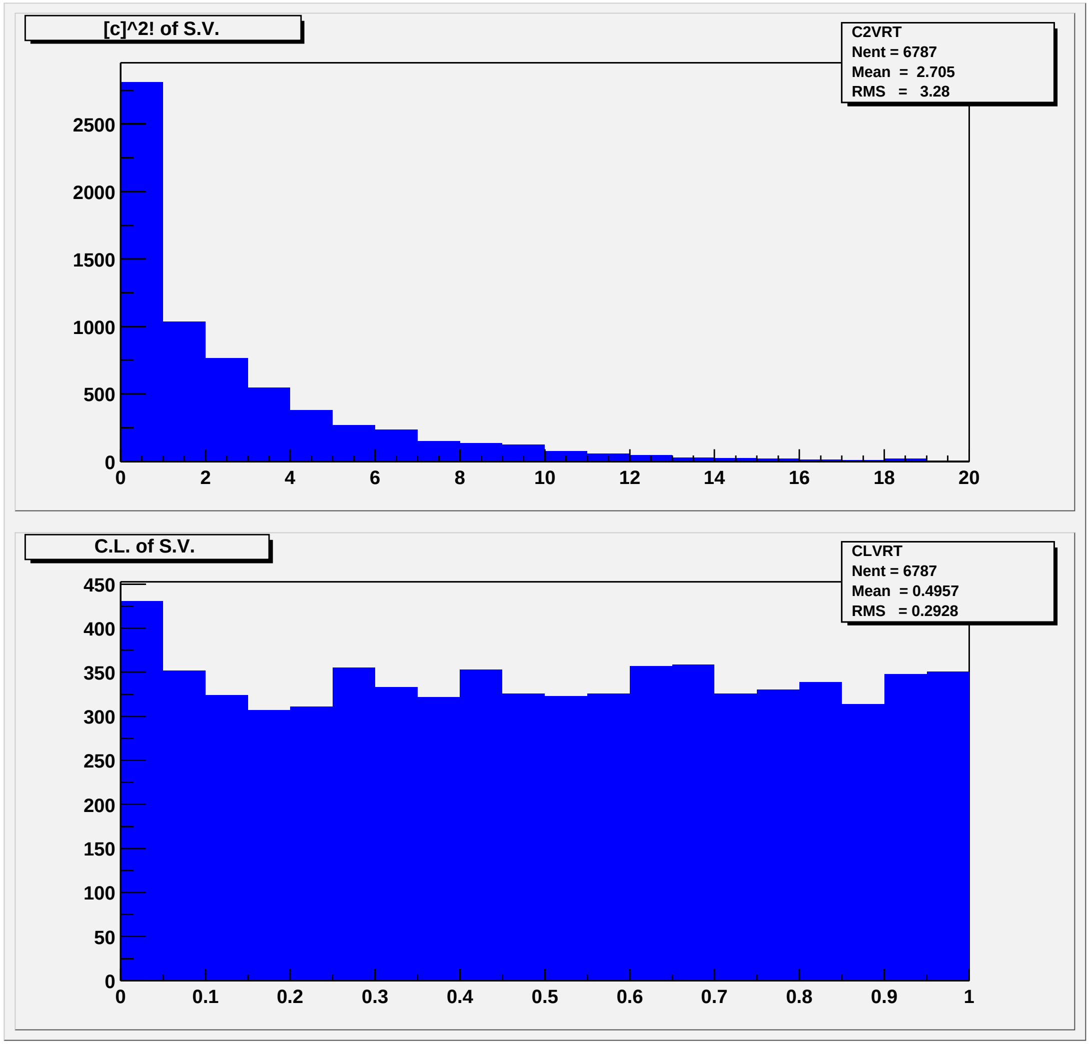
Vertex Reconstruction

Have OO implementations in C++ for Root and Java for JAS (soon) of the SLD topological vertex finder ZVTOP, enabling b and c tagging of jets.

Particle ID

e and μ algorithms still need work.

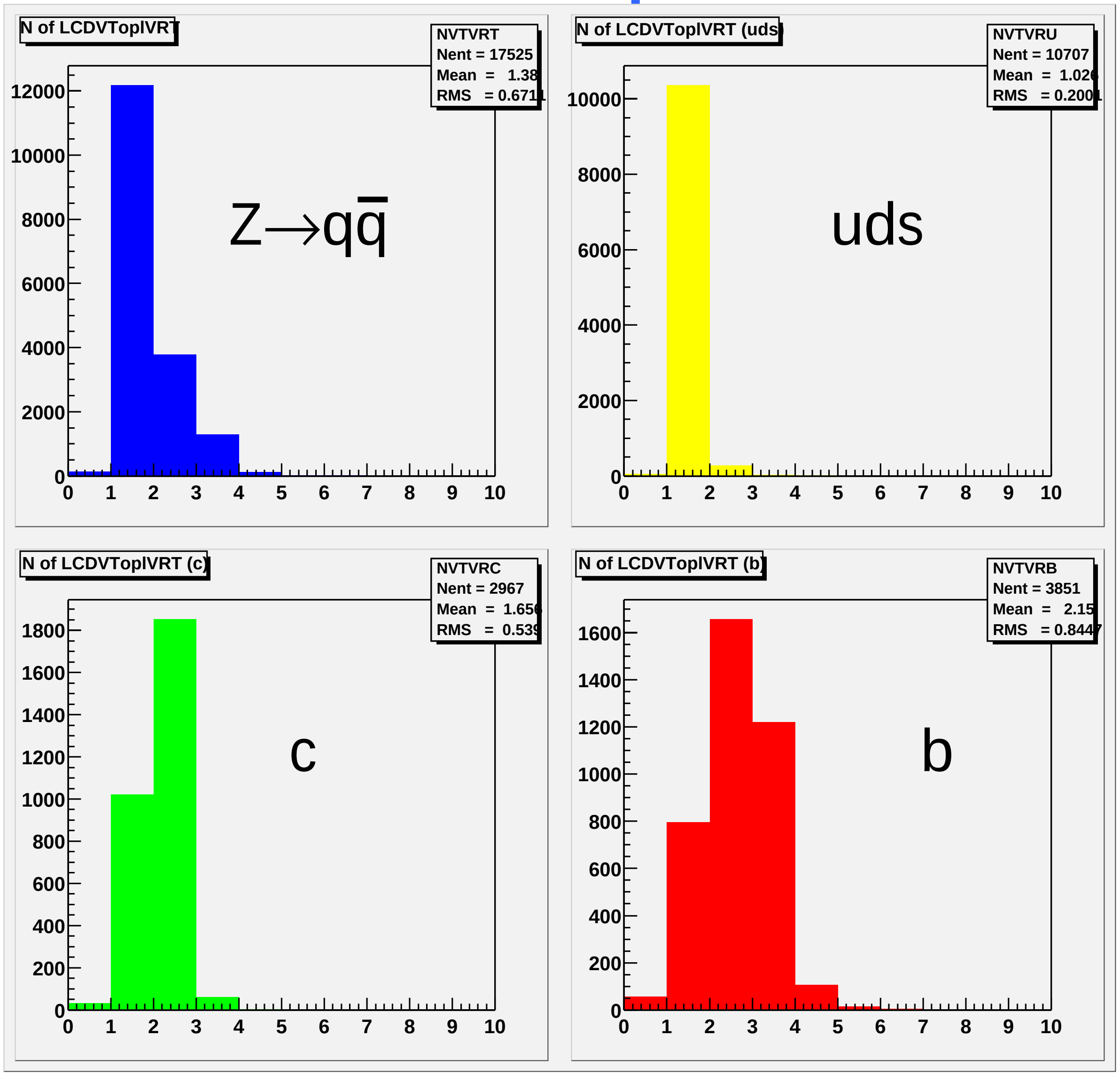
ZVTOP (preliminary)



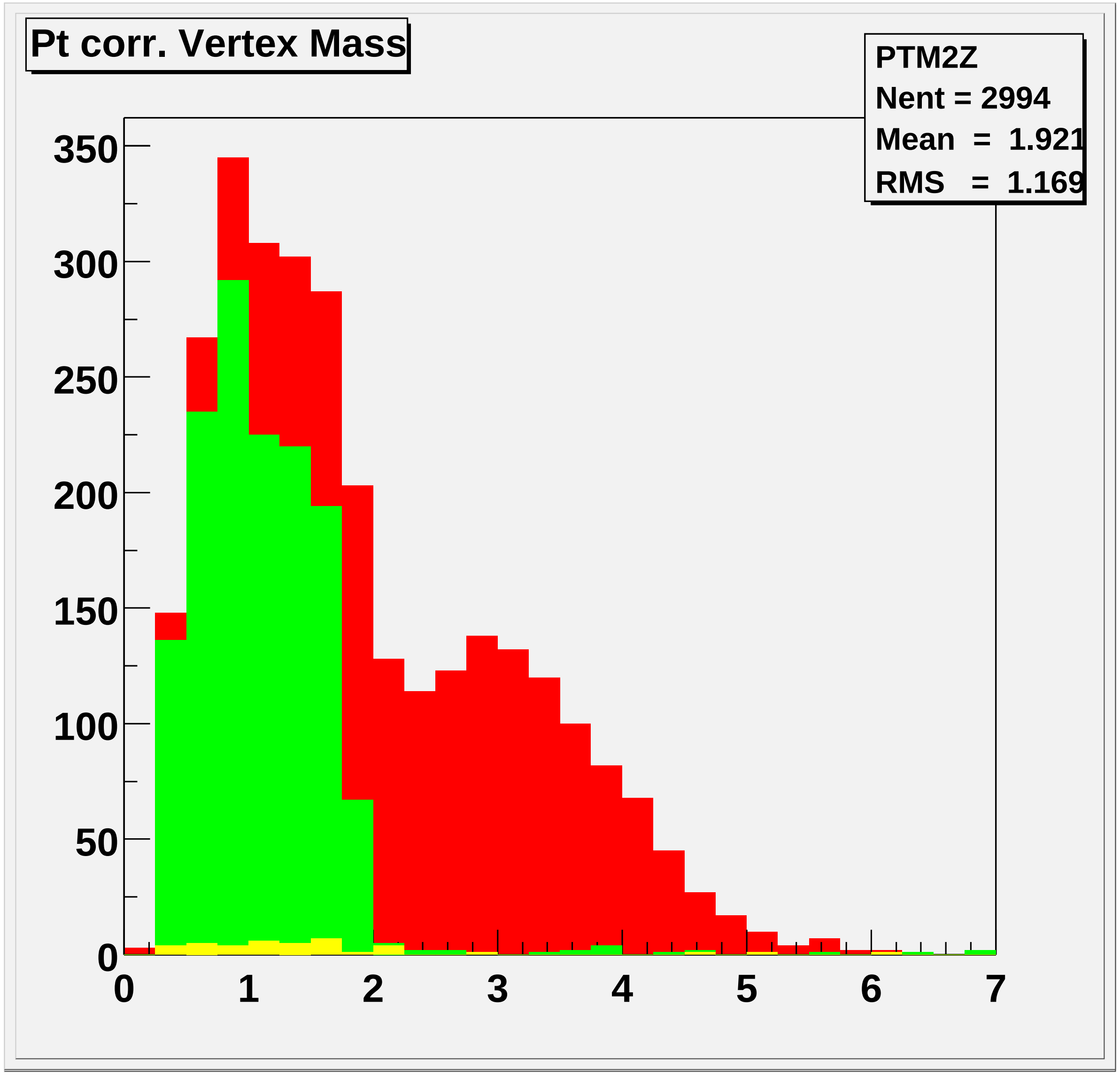
$\chi 2$ /d.o.f.

Prob($\chi 2$)

ZVTOP Multiplicities



ZVTOP Vertex Mass



Future Plans

Fully document existing tools.

Improve reconstruction

track finding/fitting Forward regions

calorimeter clustering Split/Merge

Develop event data model and implement persistence for reconstructed events.

Common Goals

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

Full Simulations

Detailed descriptions of the detector elements, complete accounting of physics processes, track swimming, particle showering, etc. Essential for detector development and derivation of fast simulation parameterizations.

Full Sim	GEANT4	BRAHMS
GISMO	Object-Oriented Approach	GEANT3
C++		FORTRAN

Fast Simulations

Simulations based on parameterized, or simplified detector responses

Fast, can be flexible, but limited.

MCFAST

FORTRAN

FastMC

ROOT

C++

JAS

Java

Common (Object-Oriented) Approach

SIMDET

FORTRAN

SGV

FORTRAN

Conclusions

Both full and fast simulation programs exist in OO implementations, providing flexible frameworks for detailed studies of physics and detector issues.

We currently support both Java (JAS) and C++ (ROOT) analysis environments.

We are starting the transition to GEANT4 and welcome a wider collaboration on simulation efforts.

URL

American Linear Collider Detector simulation efforts are documented at:

www-sldnt.slac.stanford.edu/nld

mail to:

Norman.Graf@slac.stanford.edu

Code Availability

Reconstruction (Java)

- **Code recently moved to CVS for universal access**
  - Browse CVS repository on Web
  - Connect with you favorite CVS client
- **Platform independent make (jmk) now used.**
  - Most development currently done on NT
  - Now Unix development should be easy too

Simulation (C++)

- **Stored in DEC, downloadable from simulation web site**
  - AIX, Solaris, DEC Unix, Linux, Windows