ILC Detector Simulation Works

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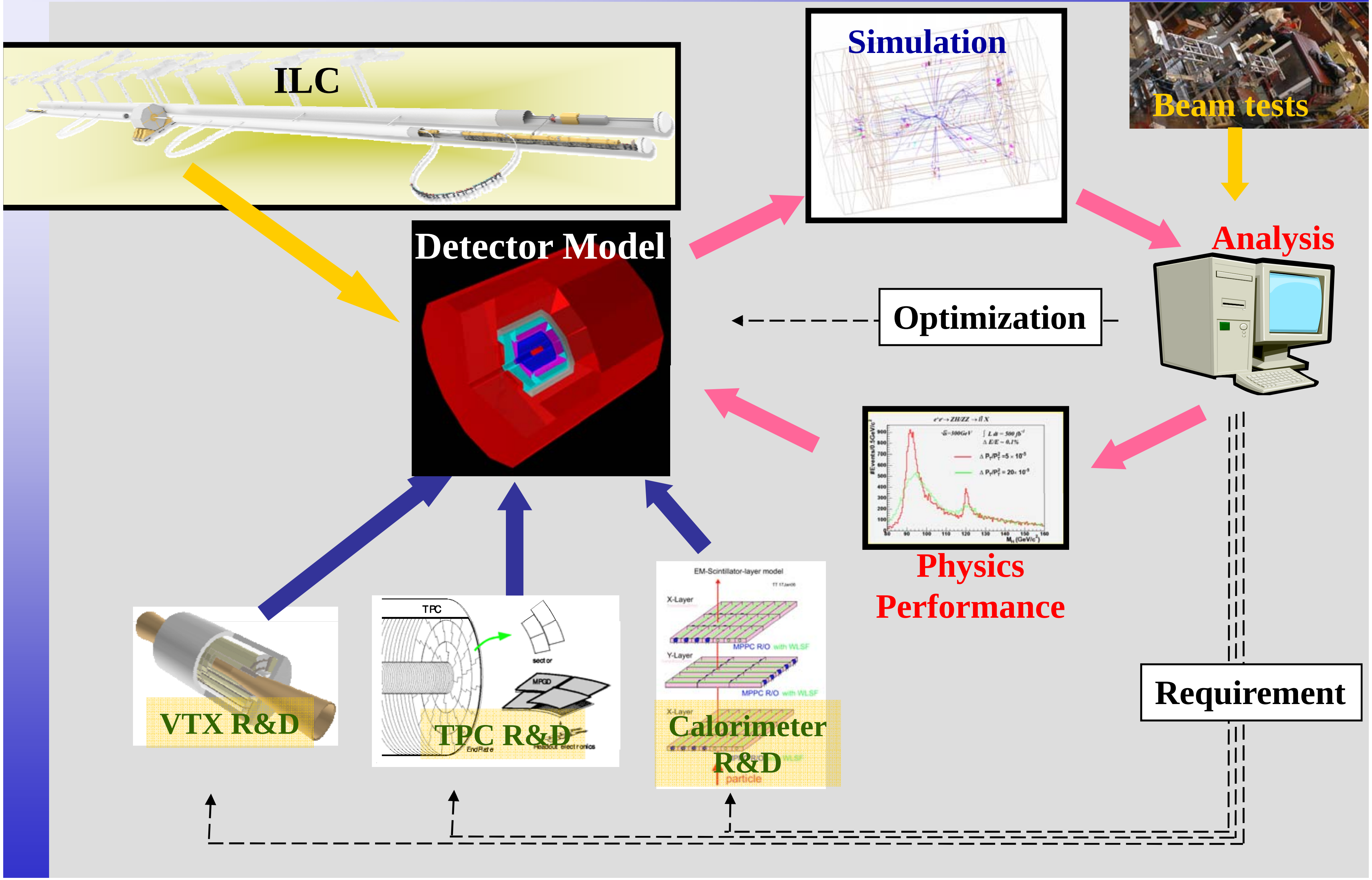
9th ACFA Workshop @ IHEP
Feb. 4th-7th, 2007
Tamaki Yoshioka
ICEPP, Univ. of Tokyo
on behalf of the GLD colleagues

Objective of Software Tools



Software Tools in the World

	Description	Detector	Language	IO-Format	Region
Simdet	Fast Monte Carlo	TeslaTDR	Fortran	Stdhep/LCIO	EU
SGV	Fast Monte Carlo	flexible	C++	None(LCIO)	EU
Lelaps	Fast Monte Carlo	SiD, flexible	C++	SIO, LCIO	US
QuickSim	Fast Monte Carlo	GLD	Fortran	ROOT	Asia
Brahms-Sim	Full sim. - Geant3	TeslaTDR	C++	ASCII, LCIO	EU
Mokka	Full sim. – Geant4	TeslaTDR, LDC	C++	LCIO	EU
SLIC	Full sim. – Geant4	SiD	C++	LCIO	US
ILC-ROOT	Full sim. – Geant4	4th	C++	ROOT	US+EU
Jupiter	Full sim. – Geant4	GLD	C++	ROOT, LCIO	Asia
Brahms-Reco	Reconstruction framework	TeslaTDR	Fortran	LCIO	EU
Marlin	Reconstruction Analysis framework	Flexible,LDC	C++	LCIO	EU
Org-lcsim	Reconstruction packages	SiD(flexible)	Java	LCIO	US
Satellites	Reconstruction packages	GLD	C++	ROOT	Asia
LCCD	Conditiions data toolkit	LDC, SiD, ..	C++	MySQL, LCIO	EU
GEAR	Geometry Description	Flexible	C++	XML	EU
LCIO	Persistency/Datamodel	All	C++,Java, Fortran	-	EU,US,As ia
JAS3/WIRED	Analysis tool/Event display	LDC, SiD …	Java	XML,LCIO,stdhep, heprep,	US, EU
JSF	Analysis framework	All	C++	ROOT/LCIO	Asia

Our Software Tools

Event Generator
- Pythia
- CAIN
- StdHep

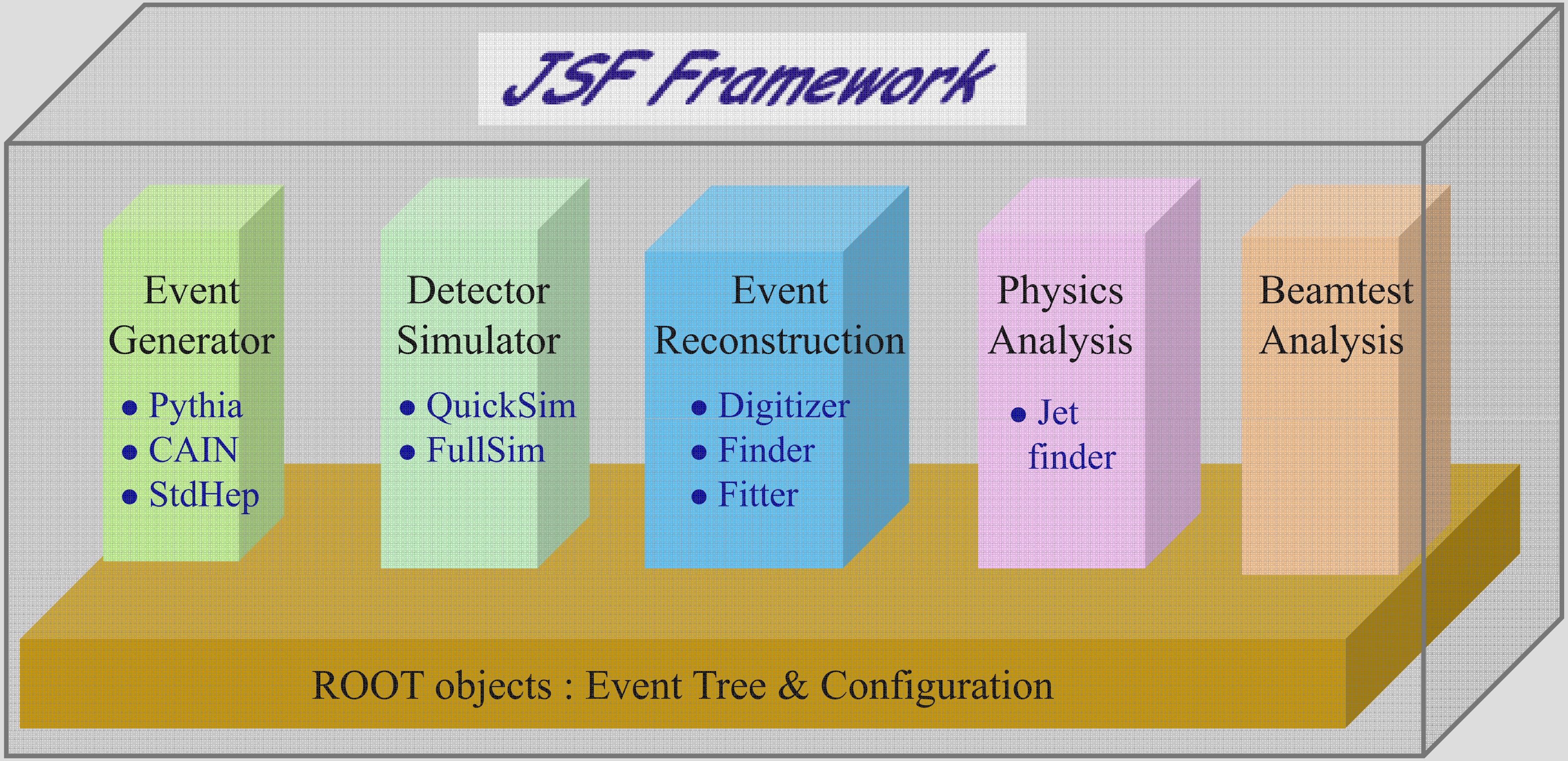
Detector Simulator
- QuickSim
- FullSim

Event Reconstruction
- Digitizer
- Finder
- Fitter

Physics Analysis
- Jet finder

Beamtest Analysis

Our Software Tools



Based on a common framework : JSF and ROOT

JSF

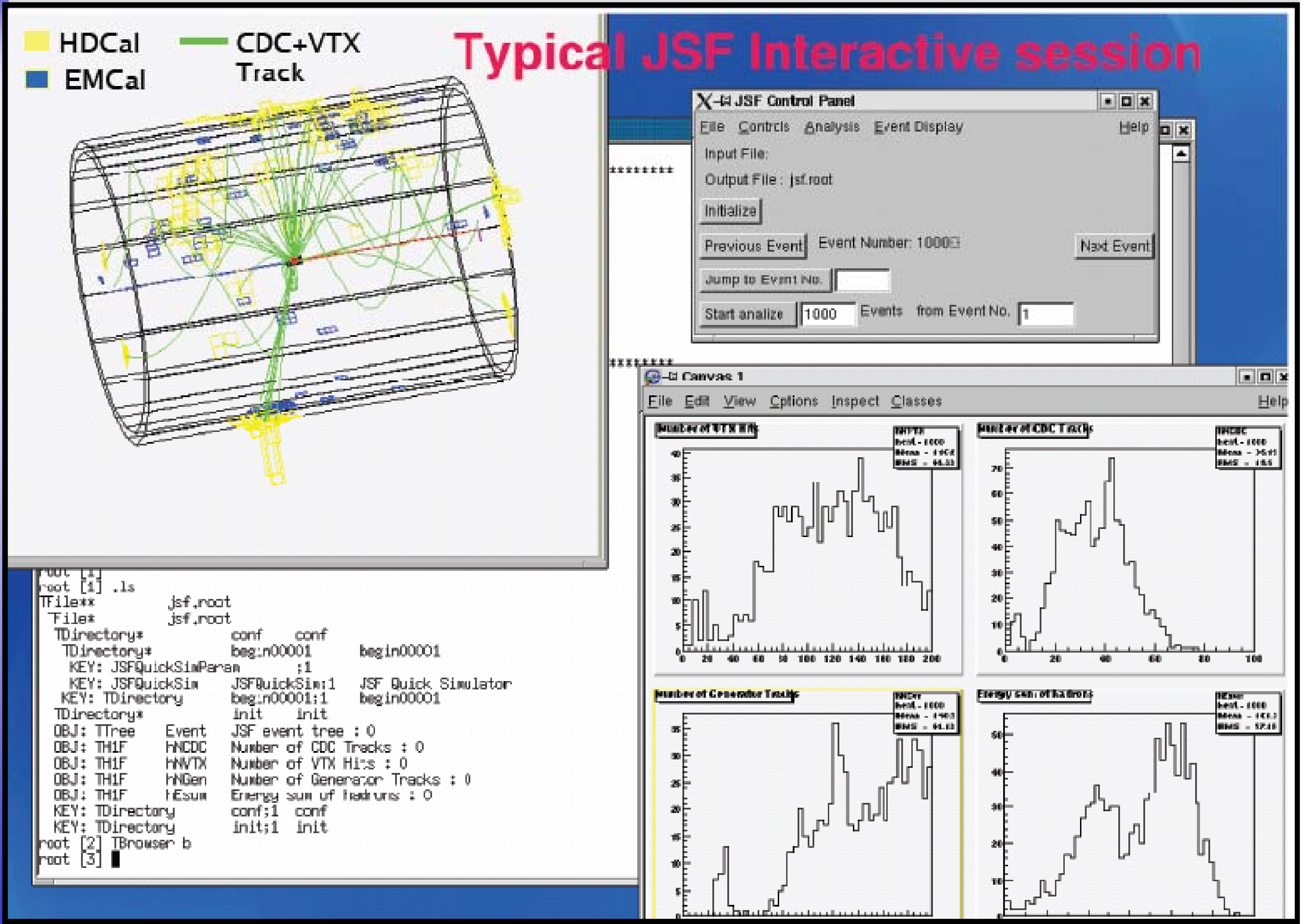
- Framework : JSF = ROOT based application
  - All functions are based on C++, compiled through CINT.

  - Provides common framework for event generations, detector simulations, analysis and beam test data analysis.

  - Unified framework for interactive and batch jobs

  - Data are stored as root objects; root trees, ntuple, etc..

Typical JSF Interactive session

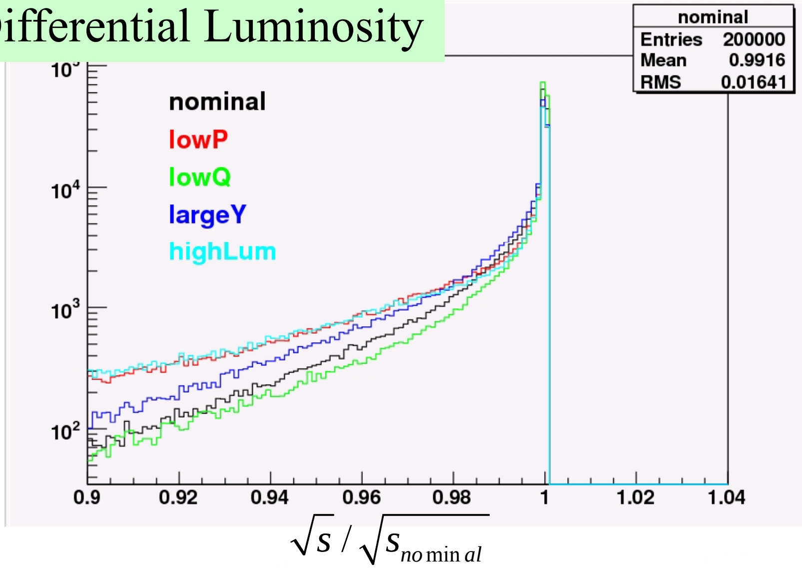


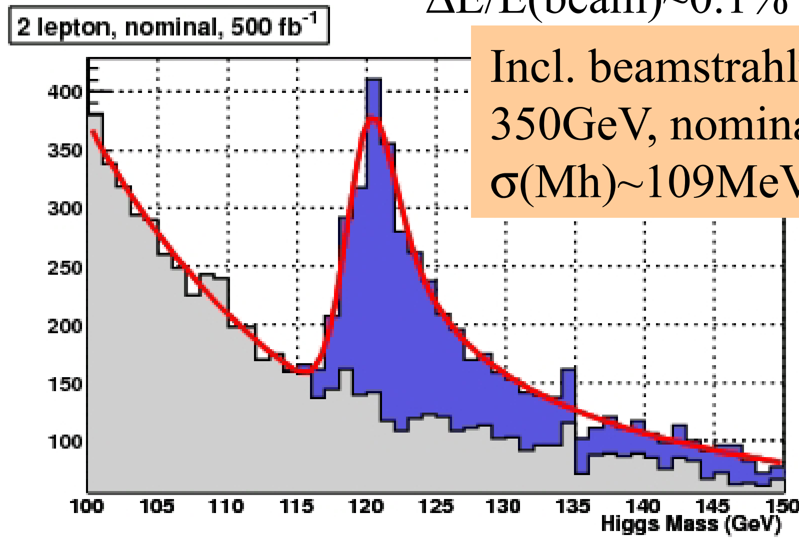
QuickSim Analysis Example

$$e^+e^- \to \ell\bar{\ell}X\,;\ \ell = e,\mu$$

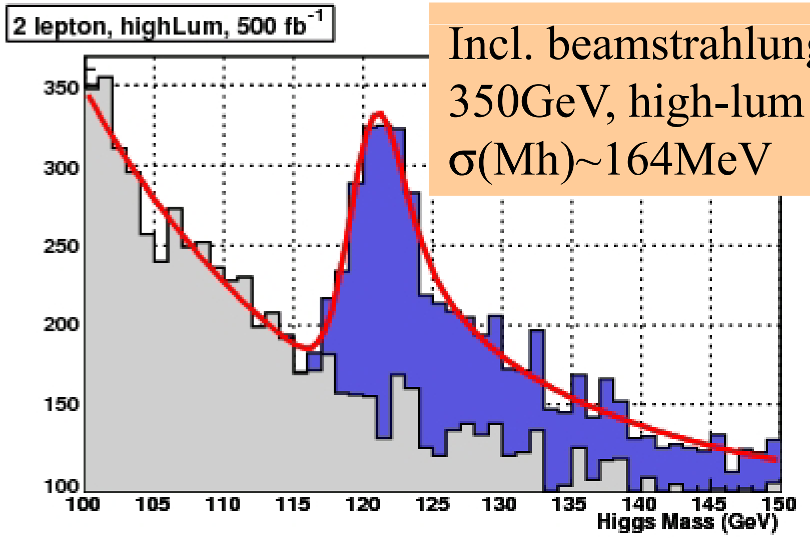
ΔE/E(beam)~0.1%

Differential Luminosity

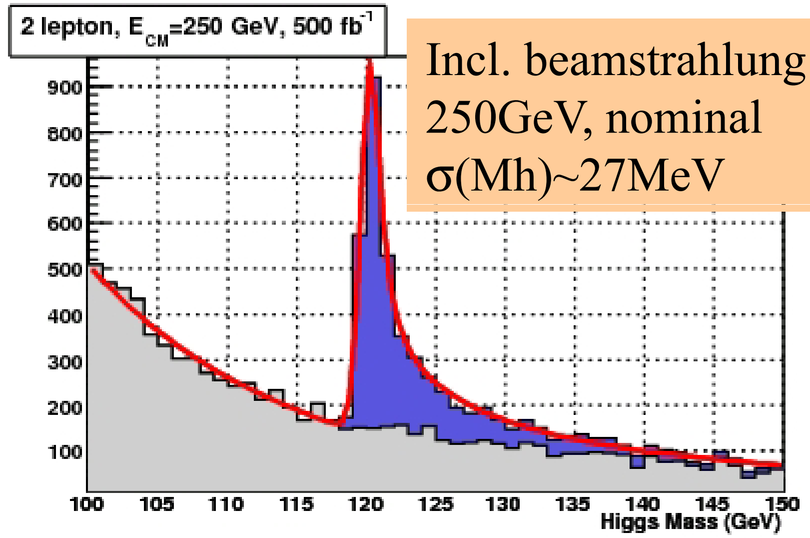




Incl. beamstrahlung
350GeV, nominal
σ(Mh)~109MeV



Incl. beamstrahlung
350GeV, high-lum
σ(Mh)~164MeV



Incl. beamstrahlung
250GeV, nominal
σ(Mh)~27MeV

Jupiter/Satellites Concepts

Tools for simulation Tools

For real data

JUPITER
JLC **U**nified
Particle **I**nteraction
and
Tracking **E**mulato**R**

Geant4 based Simulator

Satellites

IO
Input/**O**utput
module set

METIS
Monte-Calro **E**xact hits **T**o
Intermediate **S**imulated output

LEDA
Library **E**xtension
for
Data **A**nalysis

URANUS
Unified **R**econstruction
and
ANalysis **U**tility
Set

JSF/ROOT based Framework

MC truth generator

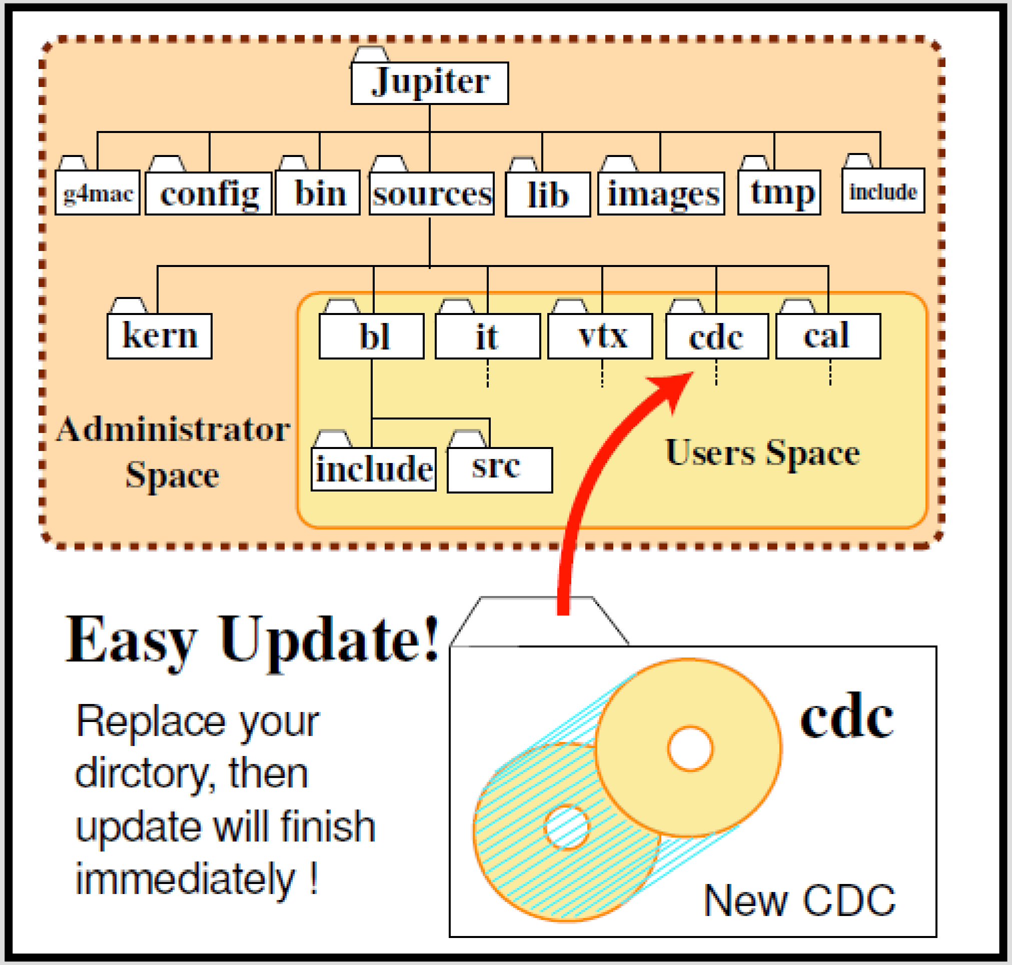
Event Reconstruction

JSF: analysis flow controller based on ROOT. The release includes event generators, Quick Simulator, and simple event display.

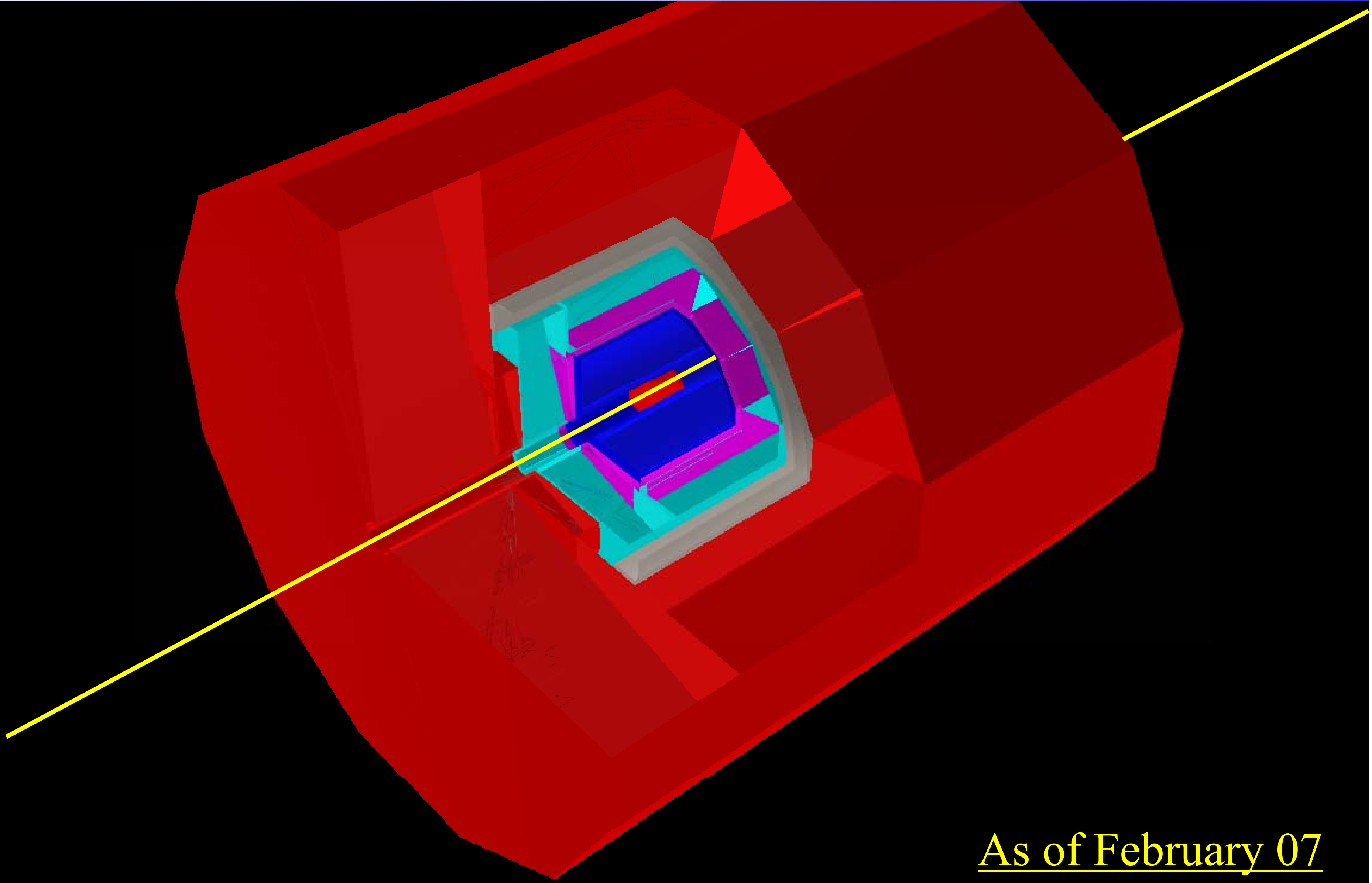
Jupiter

Jupiter Feature

- Based on Geant4.8.0p1 (As of February 07)
- Modular structure
  → easy installation of sub-directories.
- Geometries
  - GLD-baseline geometry has been implemented.
  - Parameters (size, material etc.) can be modified by input ASCII file.
    → Parameters are saved as root object for use in Satellites later.

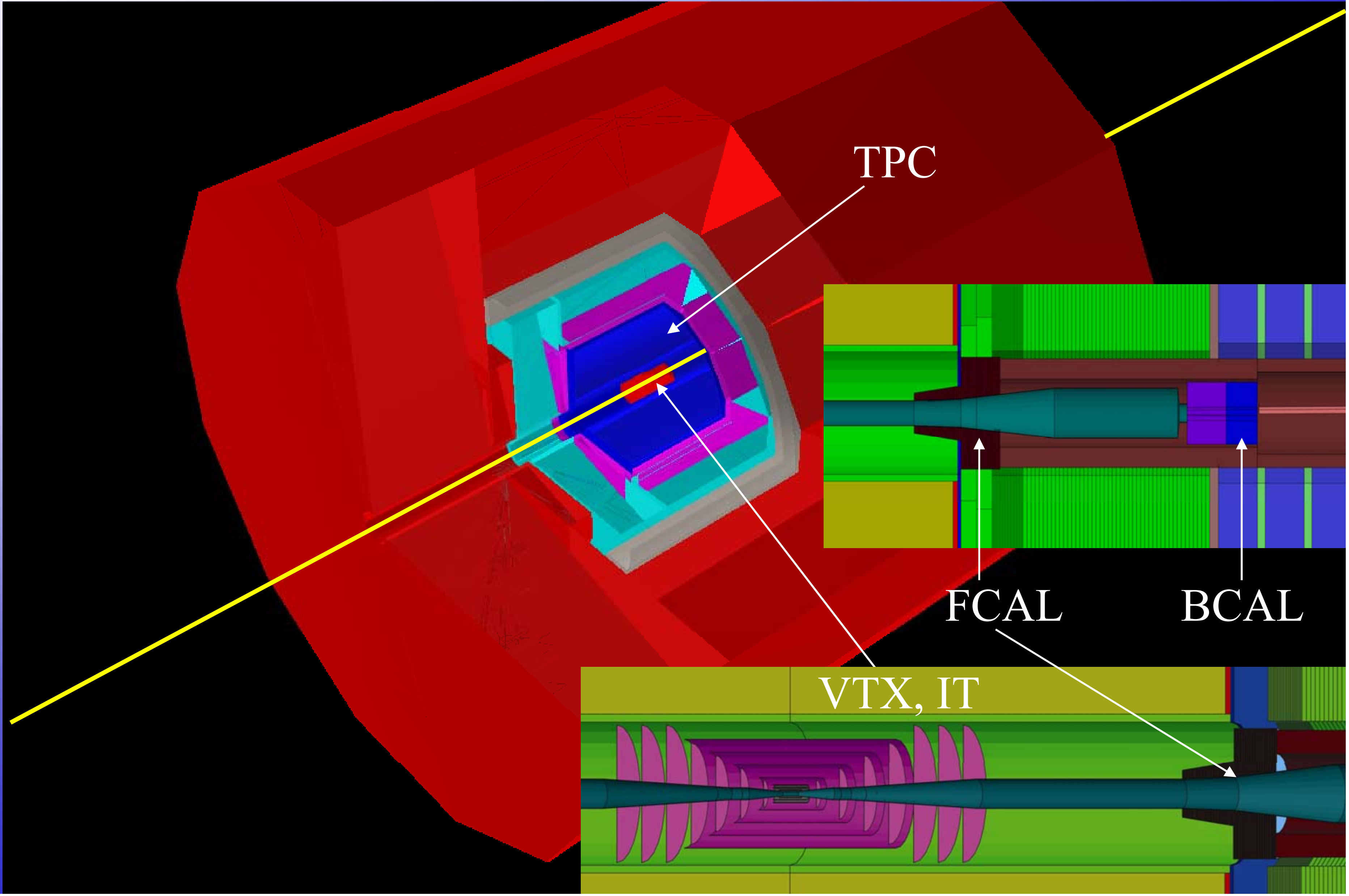


GLD Geometry in Jupiter

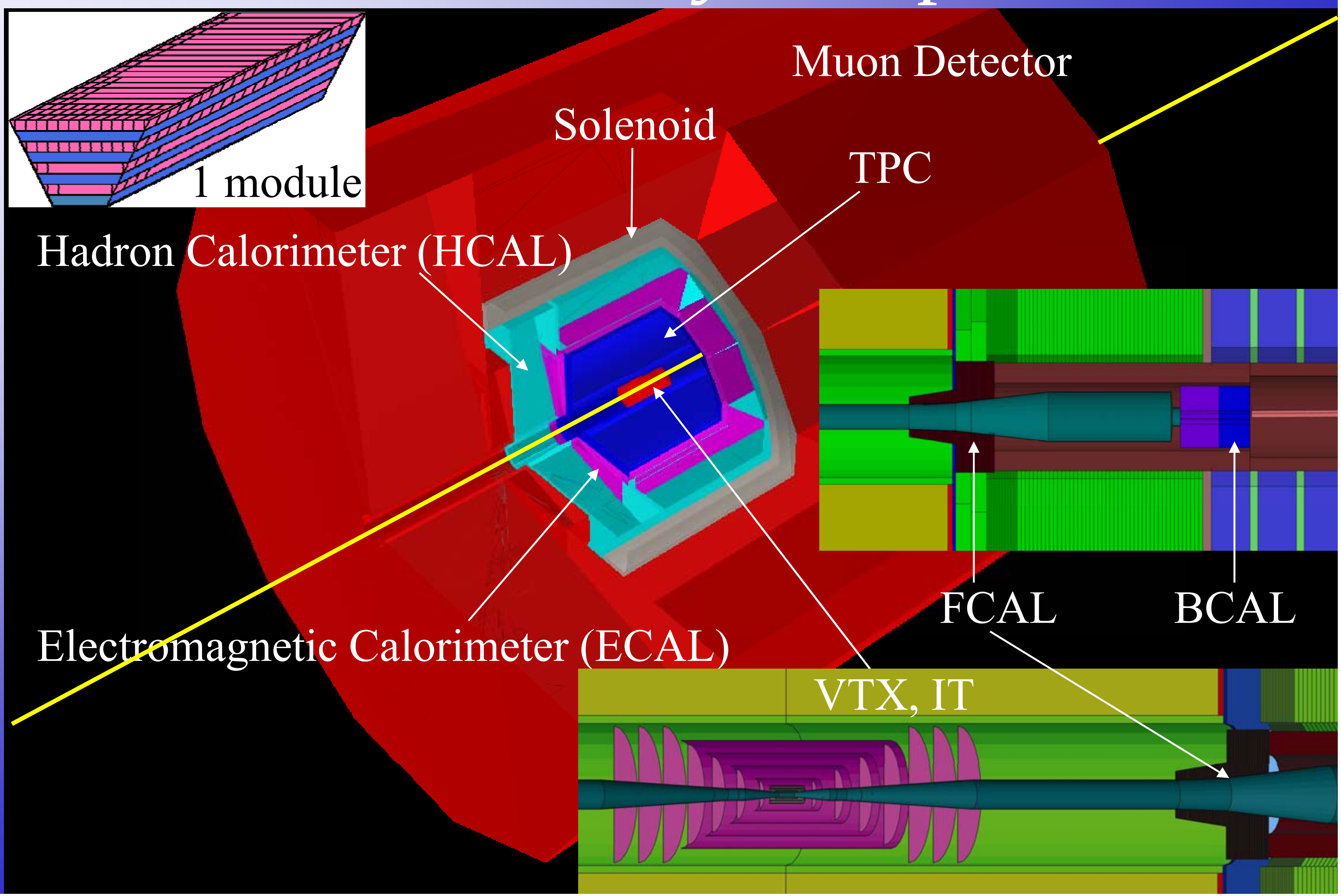


As of February 07

GLD Geometry in Jupiter

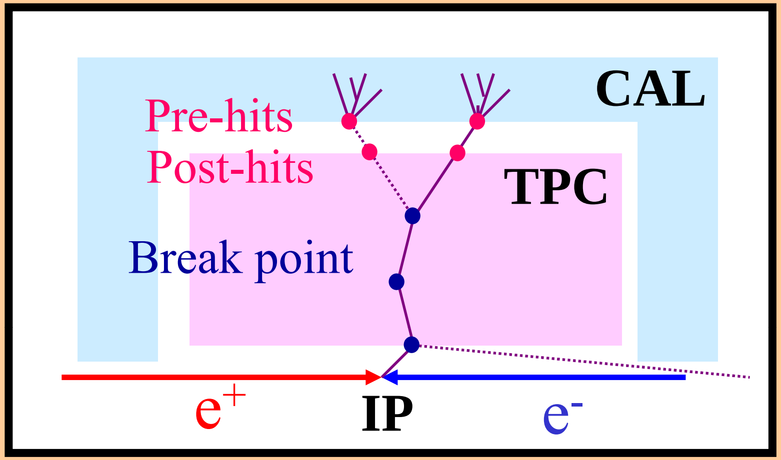


GLD Geometry in Jupiter



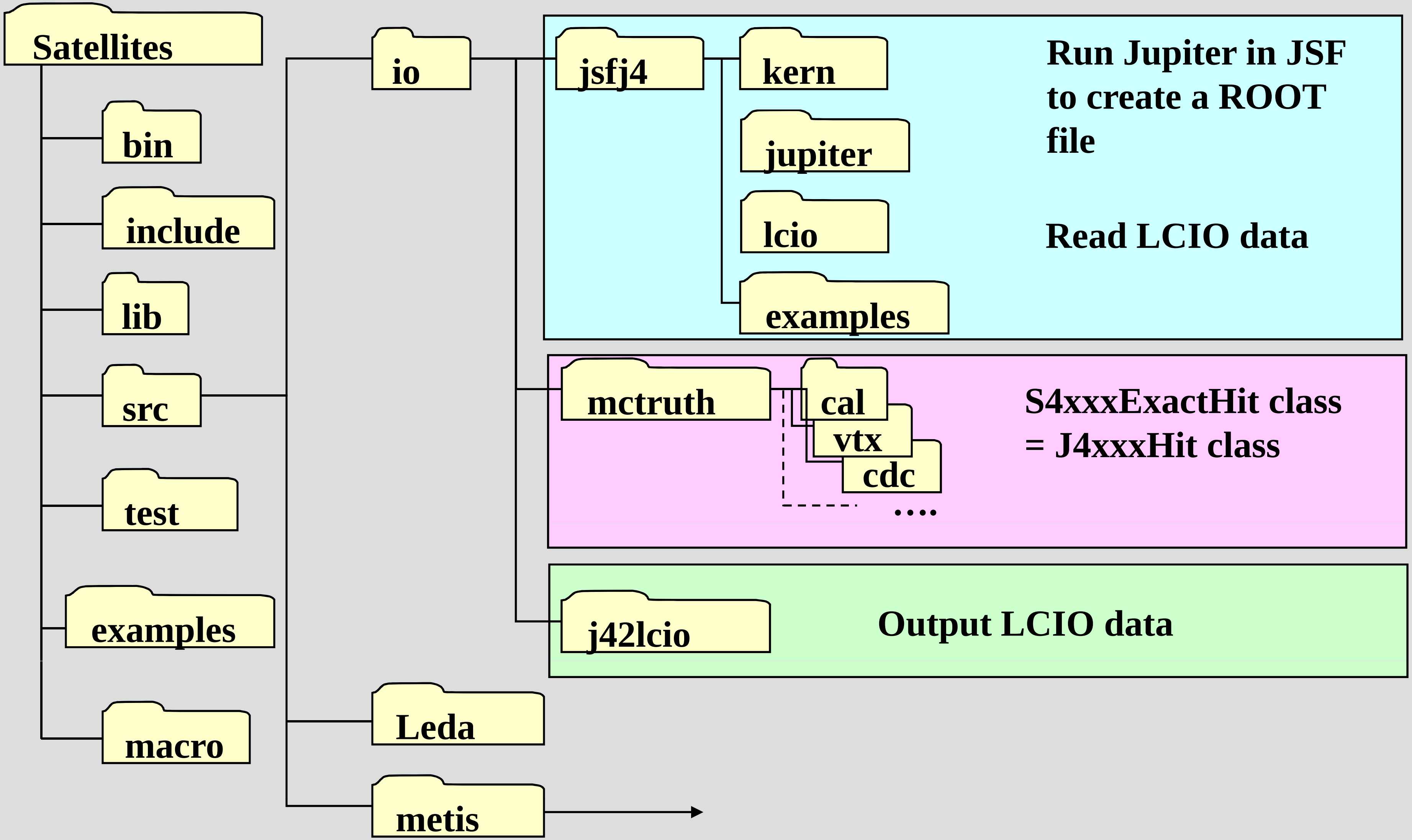
Jupiter Feature (Cont'd)

- Input :
  - StdHep file (ASCII), HepEvt, CAIN, or any generators implemented in JSF.
  - Binary StdHep file interface was implemented.
- Output :
  - Exact Hits of each detector components (Smearing in Satellites).
  - Break points in tracking volume.
  - Pre- and Post- Hits at before/after Calorimeter.
    → Used to record true track information which enter CAL/BCAL/FCAL.
  - Interface to LCIO format is prepared in JSF framework.
- Run Mode :
  - A standalone Geant4 application.
  - JSF application to output a ROOT file.



Satellites

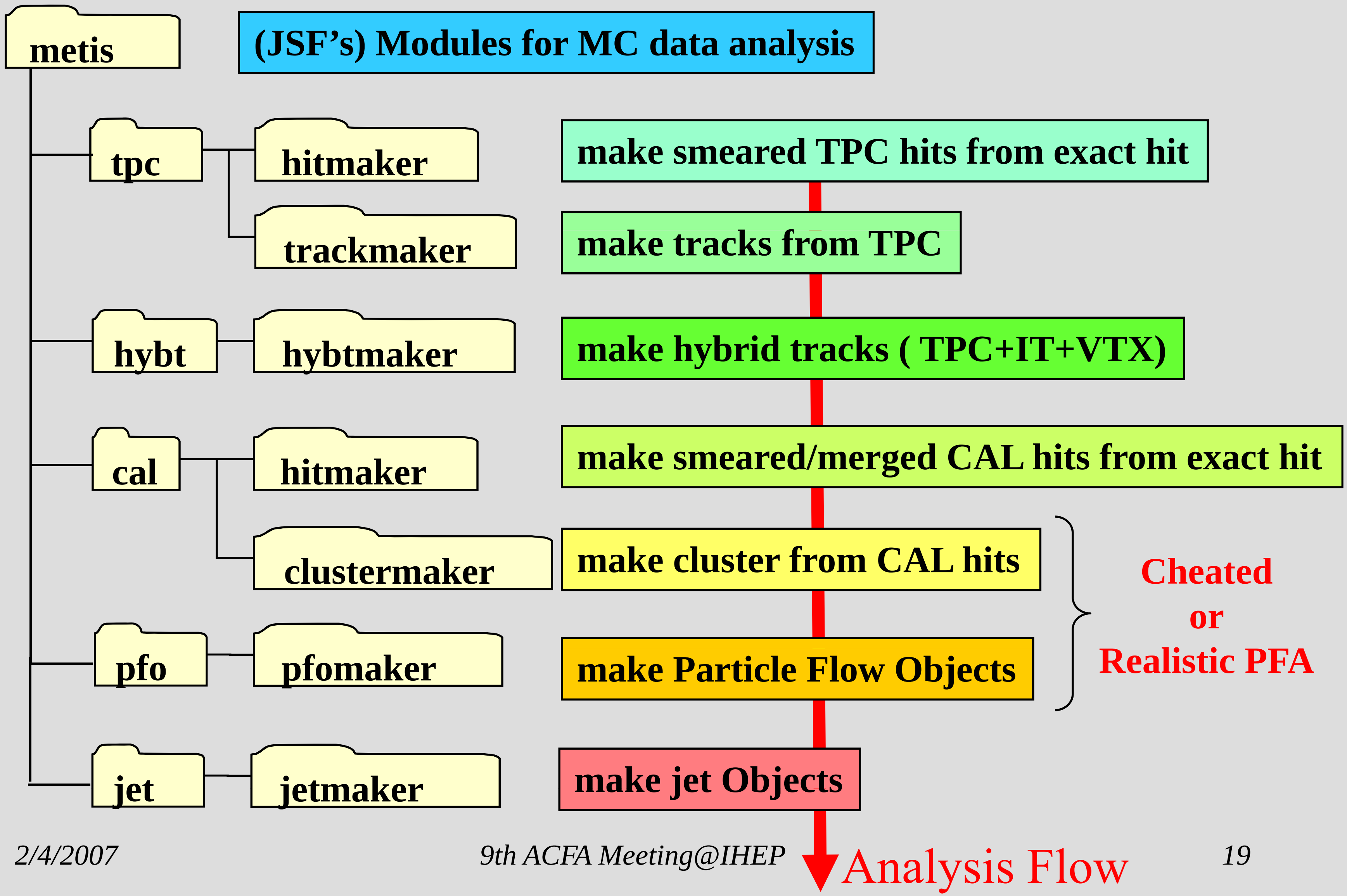
Satellites Directory Structure



Metis Package

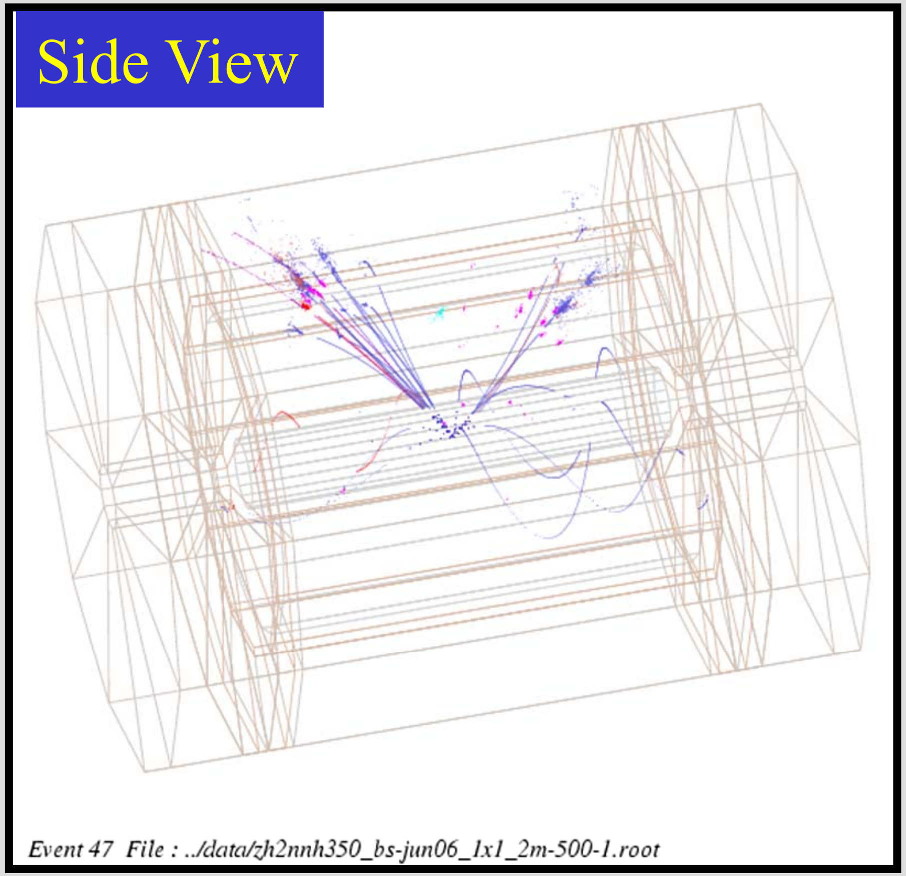
- Metis is a collection of reconstruction tools for Jupiter data.
- Each module is relatively independent, thus easy to implement different reconstruction algorithm.
- Packages under development include
  - Hit digitizer : Mostly simple smearing of exact hits
  - Kalman filer : for TPC, VTX and IT.
  - Both cheat and realistic Particle Flow Algorithm
  - Jet clustering
- Novice users will be able to do physics analysis by using information of PFO classes.

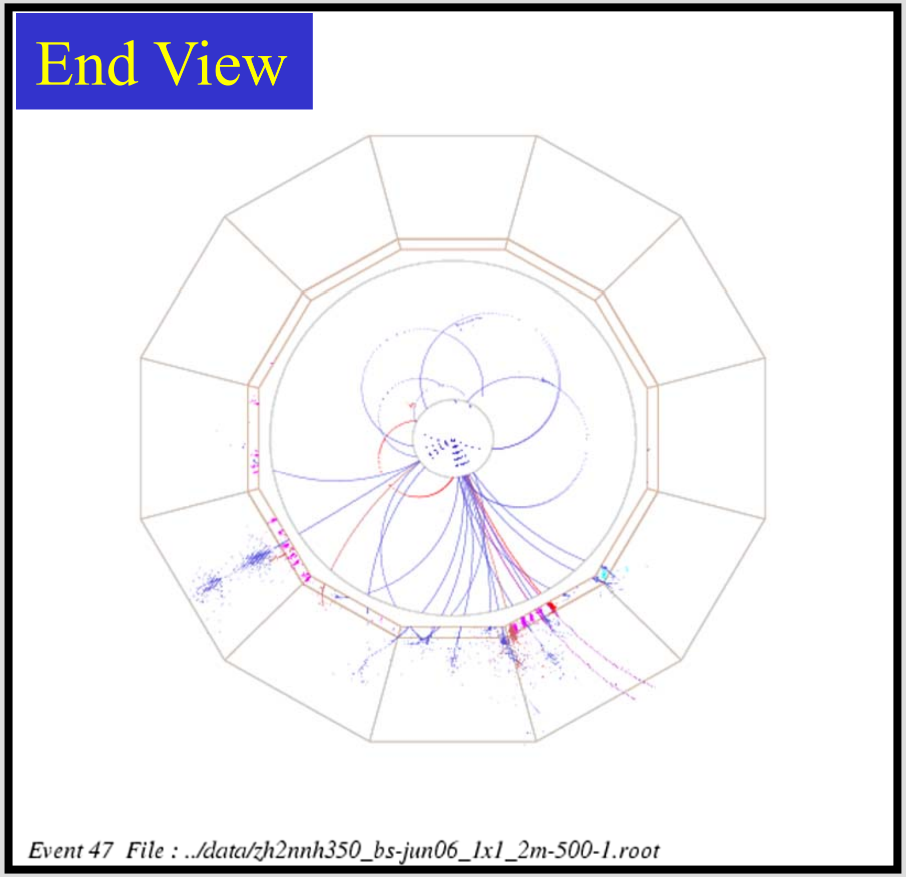
Metis Directory Structure



Performance

Typical Event Display

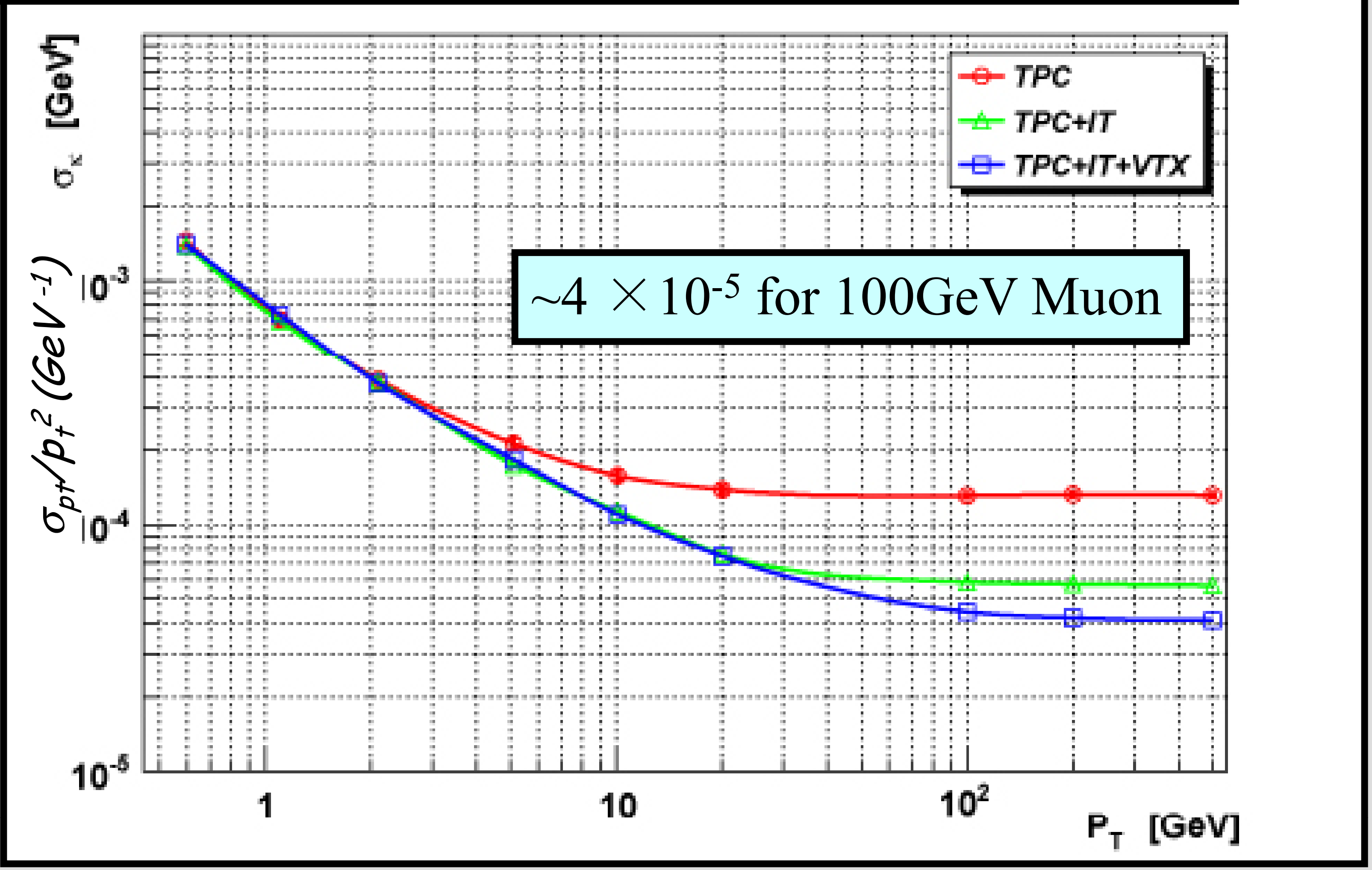




- ZH → ννh : Two jets from Higgs can be seen.

Momentum Resolution

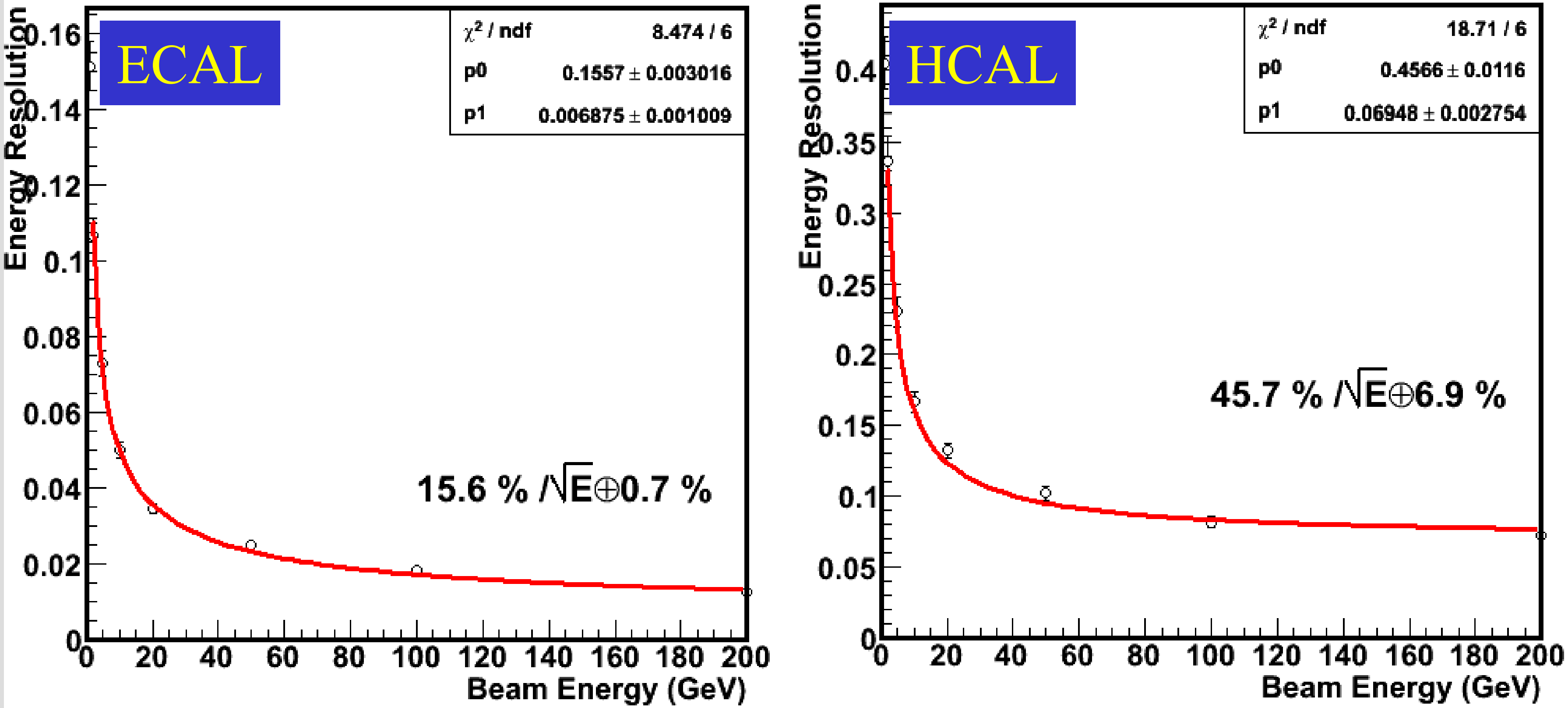
- Exact hit points created by single μ are fitted by Kalman filter package



Calorimeter Performance

- Energy resolution obtained by injecting single gamma/KL.

cosTheta<0.8 cut



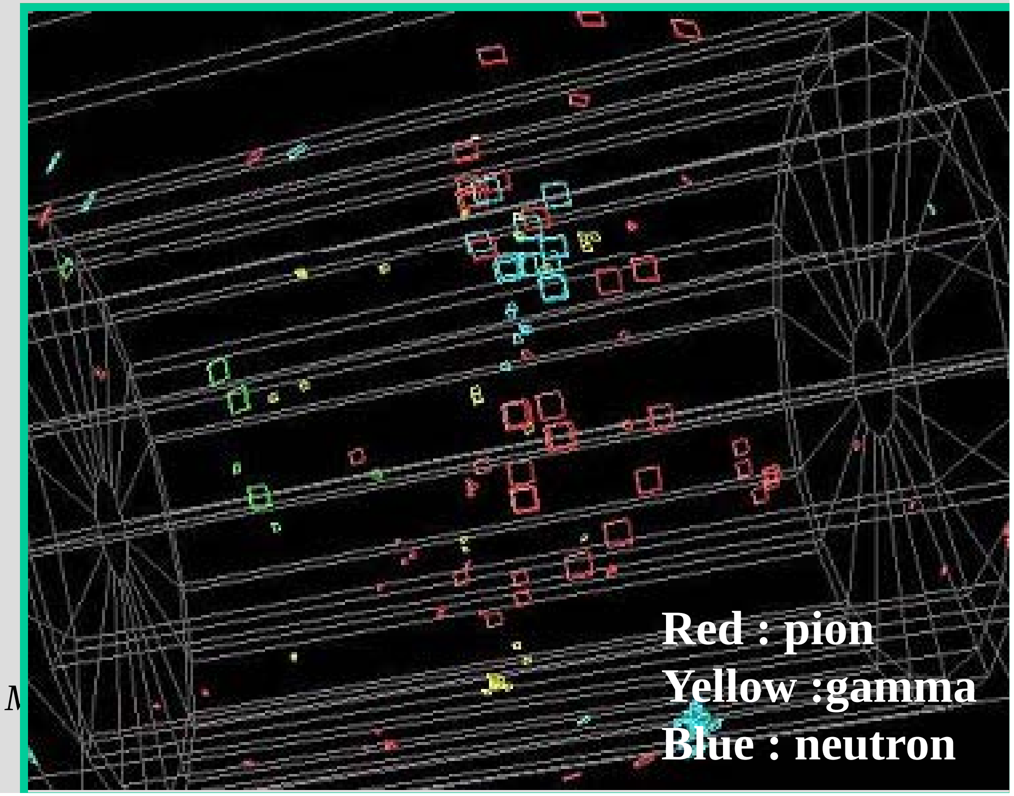
Performances have to be verified/confirmed by beam tests in coming years.

Particle Flow Algorithm

- Critical part to complete detector design.
  - Large R & medium granularity vs. small R & fine granularity
  - Large R & medium B vs. small R & high B
  - …

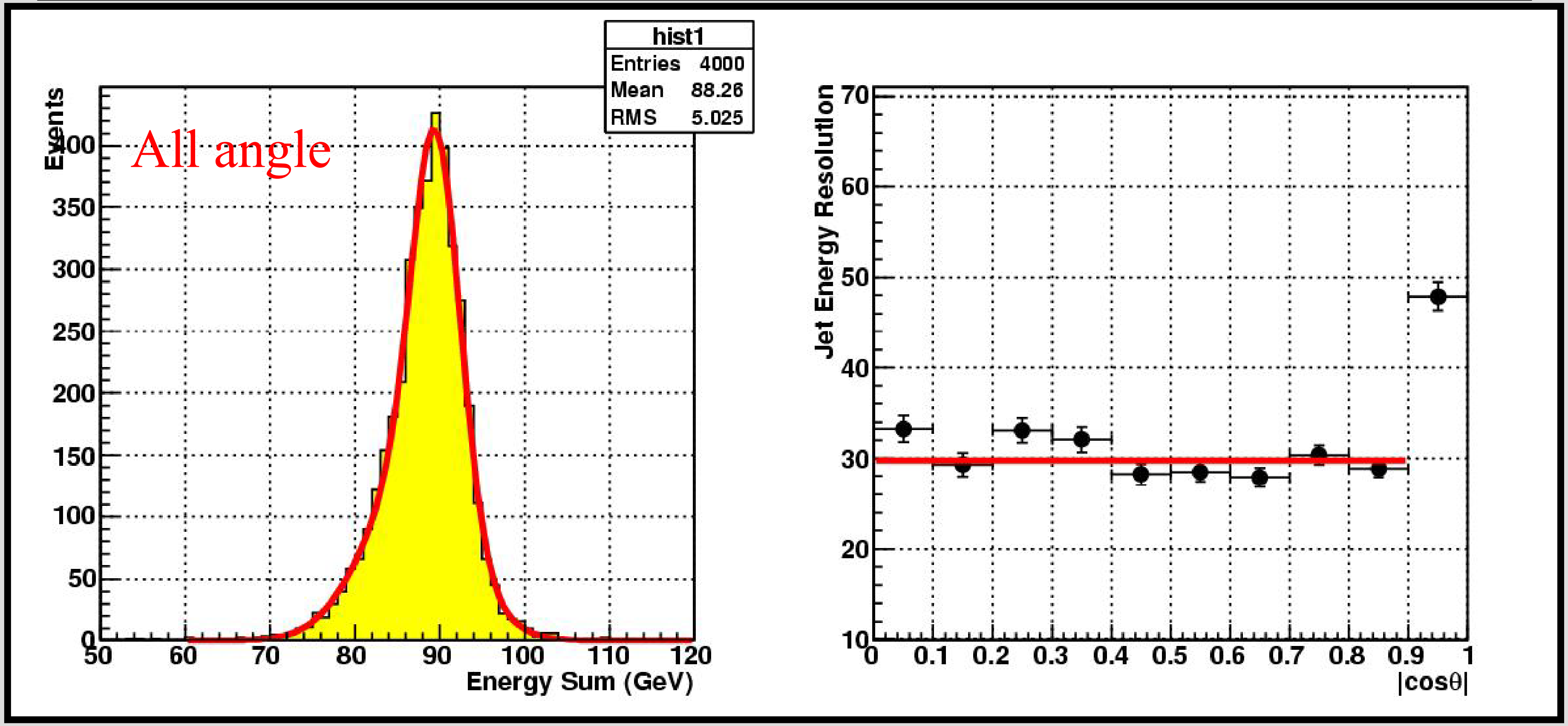
- Algorithm developed in GLD: consists of several steps

  - Gamma Finding
  - Cluster-Track Matching
  - Neutral Hadron Finding



Jet Energy Resolution (Z-pole)

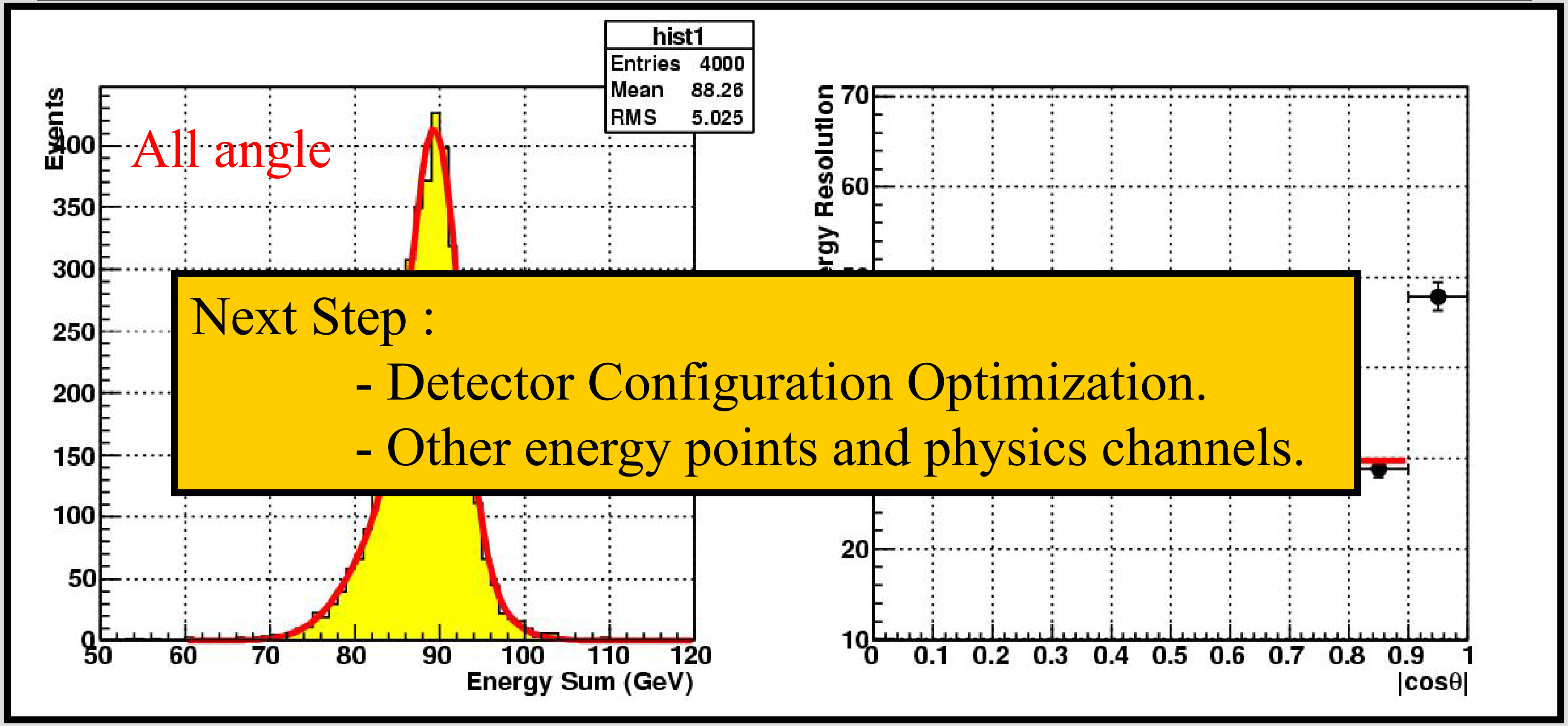
- Z → uds @ 91.2GeV, tile calorimeter, 1cm x 1cm tile size



- Almost no angular dependence : ~30%/√E for |cosθ|<0.9.
- cf. 60 %/√E w/o the PFA (sum up the calorimeter energy)

Jet Energy Resolution (Z-pole)

- Z → uds @ 91.2GeV, tile calorimeter, 1cm x 1cm tile size



Next Step :

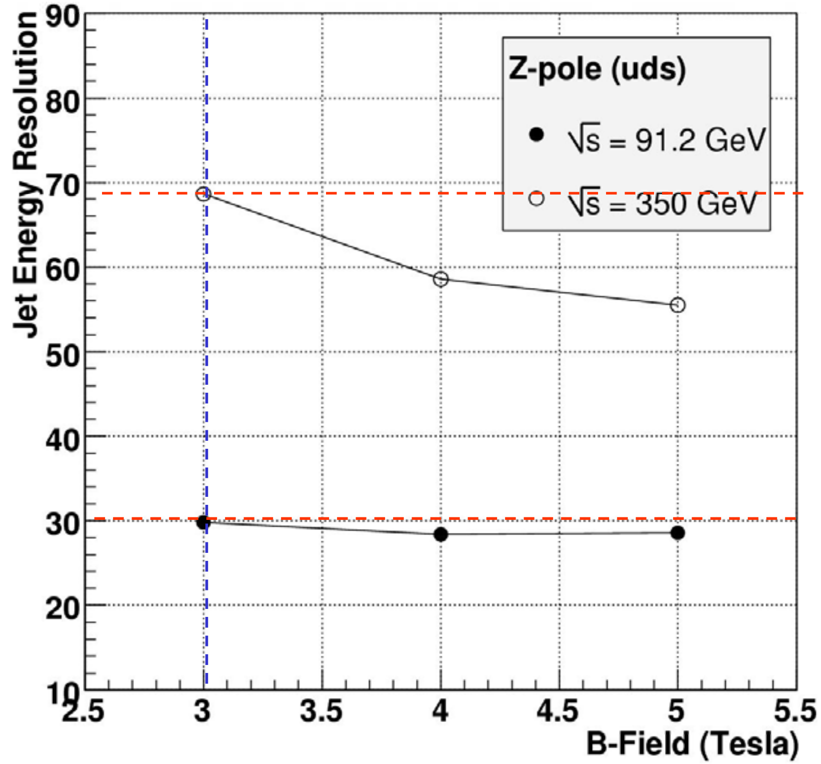
- Detector Configuration Optimization.
- Other energy points and physics channels.

- Almost no angular dependence : ~30%/√E for |cosθ|<0.9.
- cf. 60 %/√E w/o the PFA (sum up the calorimeter energy)

Detector Optimization

- Detector optimization using PFA
  - B-field
  - Calorimeter granularity (transverse/longitudinal)
  - Calorimeter radius
  - Cal. absorber material
  - TPC endplate thickness
  - etc …

Details will be reported at simulation/reconstruction session on Feb. 5.



Ex) PFA performance for Z->qq events w/ different B-field.

Full Simulation Physics Study

- Benchmark processes recommended by the Benchmark Panel.

0. Single $e^\pm$, $\mu^\pm$, $\pi^\pm$, π^0, $K^\pm$, K_s^0, γ, u, s, c, b; $0 < |\cos\theta| < 1$, $0 < p < 500$ GeV

1. $e^+e^- \to f\bar{f}$, $f = e, c, b$ at $\sqrt{s}$=1.0 TeV;

2. $e^+e^- \to Zh, \to \ell^+\ell^- X$, $m_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;

3. $e^+e^- \to Zh$, $h \to c\bar{c}, \tau^+\tau^-, WW^*$, $m_h = 120$ GeV at $\sqrt{s}$=0.35 TeV;

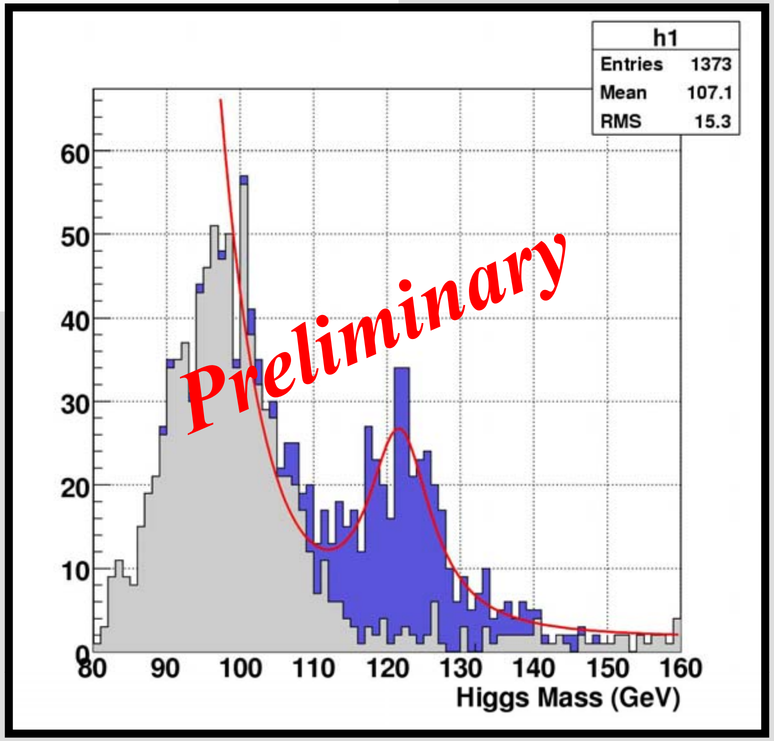
4. $e^+e^- \to Zhh$, $m_h = 120$ GeV at $\sqrt{s}$=0.5 TeV;

5. $e^+e^- \to \tilde{e}_R\tilde{e}_R$ at Point 1 at $\sqrt{s}$=0.5 TeV;

6. $e^+e^- \to \tilde{\tau}_1\tilde{\tau}_1$, at Point 3 at $\sqrt{s}$=0.5 TeV;

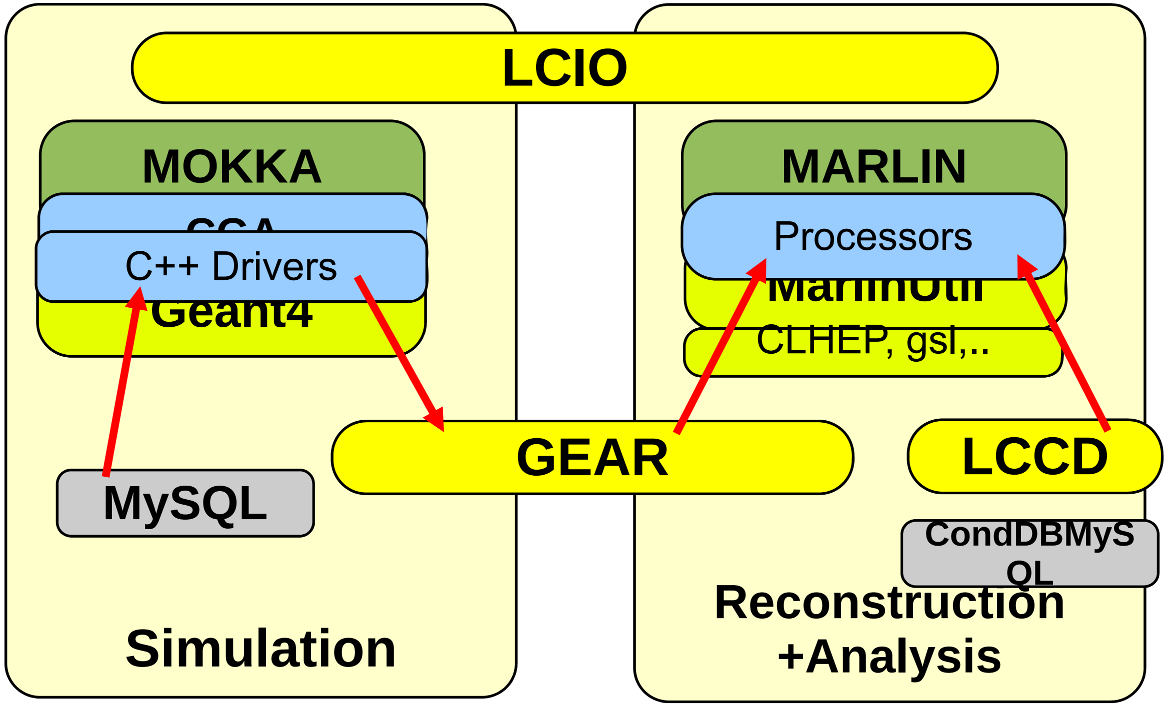
7. $e^+e^- \to \chi_1^+\chi_1^- / \chi_2^0\chi_2^0$ at Point 5 at $\sqrt{s}$=0.5 TeV;

- Full simulation physics study with the PFA.
  - Signal : $Zh \to \nu\nu h$
  - Background : ZZ only
  - $55 fb^{-1}$



Software Tools for Other Regions

European ILC software framework



Mokka
- geant4 full simulation
- MySQL geometry
- LCIO output
- GEAR geometry output

LCIO
- event data model
- persistency
- intl. standard for ILC data

Gear
- geometry API

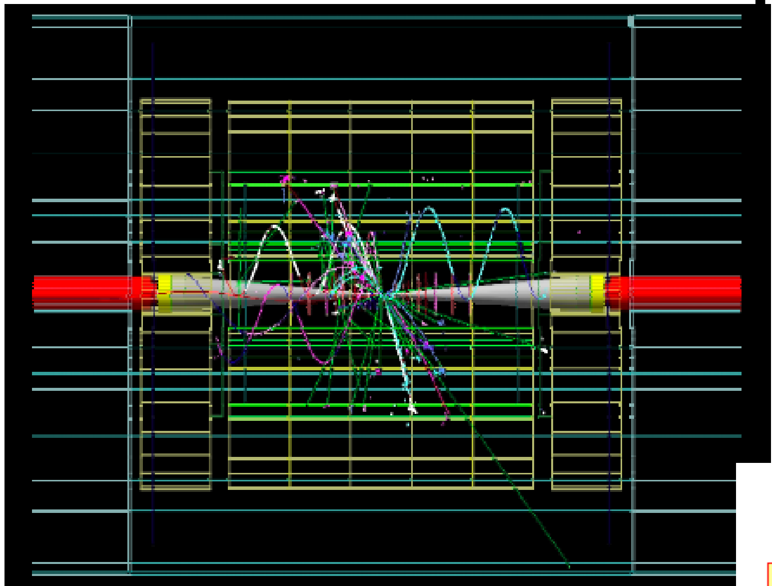
Marlin
- based on LCIO
- application framework
- C++

LCCD
- conditions data

flexible and lightweight framework used for
- LDC concept studies
- detector optimization
- ILC R&D testbeams (EUDET)
- calice, TPC, PixelTelscope,...

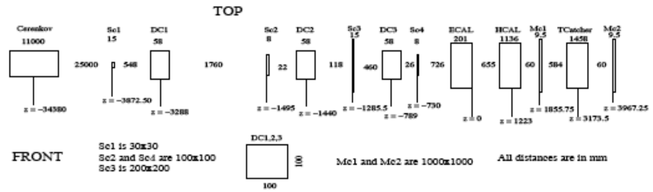
Frank Gaede

ILC detector simulation w. Mokka



CERN August 2006 test beam

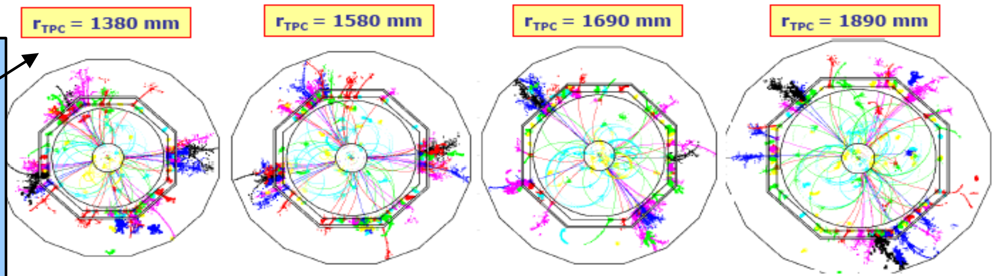
- New model for the simulation of the CERN test beam setup of August 2006



Mokka simulations for ILC:

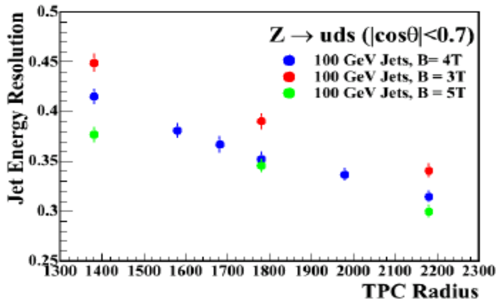
- full LDC detector
  - scalable geometry drivers
  - -> detector optimization
  - 500 k evts fully simulated
- special geometry models
  - MDI/background studies
- testbeam simulations
  - calice DESY/CERN setups
  - pixel telescope (EUDET)
- also: SID model

e.g. Radius/Field



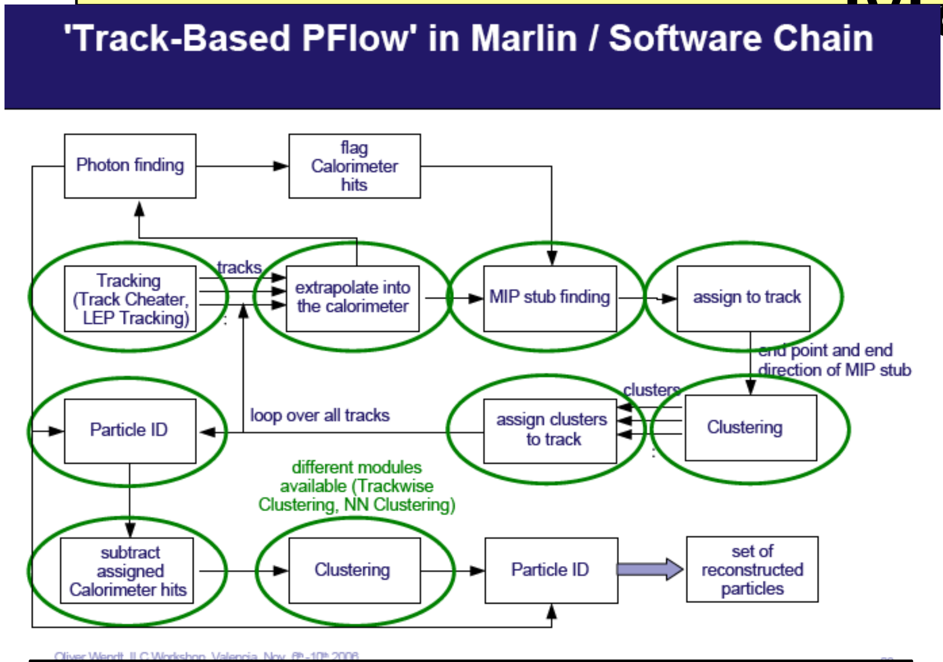
e.g. 100 GeV uds Jets in Barrel

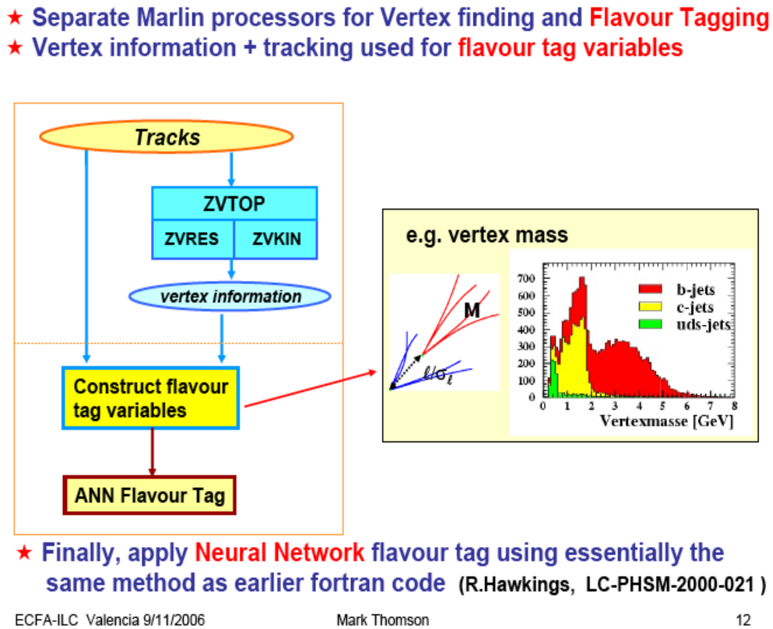
- ★ Performance vs. radius/B (Tesla TDR detector)
- ★ Argues for large high field
- ★ With a reasonable cost model for ECAL+HCAL and Solenoid could identify "optimal" parameters



Frank Gaede

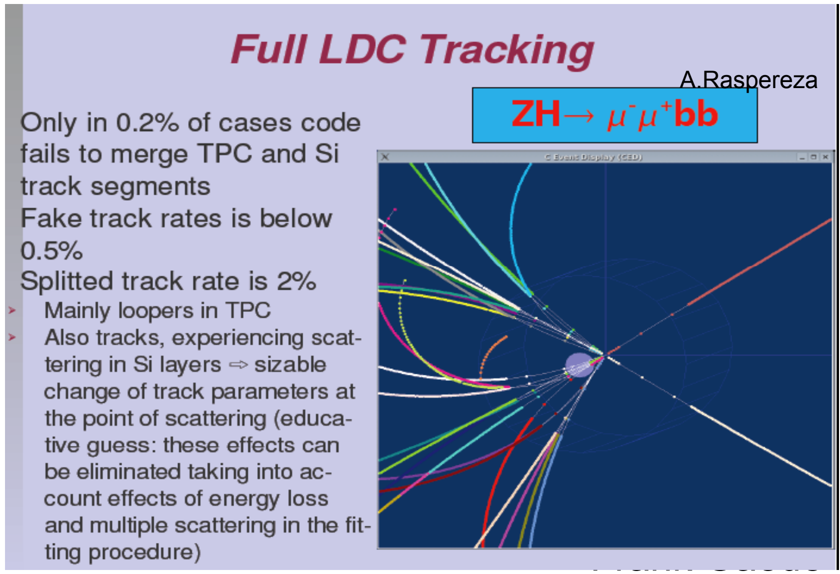
ILC reconstruction/PFA w. Marlin





Marlin serves as a modular plattform for the distributed development of PFA code:

- MarlinReco (DESY/MPI)
  - modular suite of reco algorithms
  - tracking, clustering, cheater,...
  - vtx tracking
- PandoraPFA (M.Thomson)
  - PFA processor
- ZVTOP (LCFI)
  - vertexing toolkit
- ...



ALCPG Simulation 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

Detector Simulations

- ***FastMC*** for studies using 4-vector smearing $\rightarrow$ ReconstructedParticles.
- ***lelaps*** for fast tracking and parameterized calorimeter showers $\rightarrow$ hits in detectors, so can study track finding and cal clustering.
- ***slic*** is full-featured, GEANT4-based detector simulation $\rightarrow$ hits in detectors.
- All detector simulation and event reconstruction packages use same geometry source.
  - ASCII file provides runtime detector description.
  - Can change detector without writing any code.

Event Reconstruction (org.lcsim)

- Java based reconstruction and analysis package
  - Runs standalone or inside Java Analysis Studio (JAS)
  - Fully LCIO compliant, ∴ works well with other frameworks.
  - Full Event Reconstruction
    - event overlay at hit level (arbitrary # & type of events)
    - hit digitization
    - 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)

Additional Information

- lcsim.org - http://www.lcsim.org
- ILC Forum - http://forum.linearcollider.org

- Wiki - http://confluence.slac.stanford.edu/display/ilc/Home
- org.lcsim - http://www.lcsim.org/software/lcsim
- Software Index - http://www.lcsim.org/software
- Detectors - http://www.lcsim.org/detectors

- LCIO - http://lcio.desy.de
- SLIC - http://www.lcsim.org/software/slic
- LCDD - http://www.lcsim.org/software/lcdd
- JAS3 - http://jas.freehep.org/jas3
- AIDA - http://aida.freehep.org
- WIRED - http://wired.freehep.org

Summary

- Main objectives to software tools within couple of years are detector optimization and physics performance study.
- GLD-baseline geometry has been implemented to full simulator (Jupiter) and analysis tools including PFA have been developed. → Now detector optimization and physics performance study just have been started based on the full simulation. Stay tuned.
- There are still a lot of things to do. Contributions are highly welcomed.

How to Get Our Tools

- Our software tools are maintained in CVS server,

  http://jlccvs.kek.jp .
  - Description about how to download the latest version.
- Link to various tools at

  http://acfahep.kek.jp/subg/sim/soft .
- GLD Software at

  http://ilcphys.kek.jp/soft .
- Simulation/Reconstruction Parallel Session
  - Feb. 5, Morning, room B326.