“A Comprehensive Java-based Simulation Environment for Particle Physics”

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SLAC
September 2006

What will I really talk about?

- This is actually one of a series of talks/tutorials at Fermilab this week
  - **Computing Techniques Seminar**
    - **Software Framework for ILC detector simulation**
      - **(Java, C++, XML)**
      - **Emphasis on Computing Techniques**
  - ILC R&D seminar (Wednesday, 11am)
    - Norman Graf will discuss the same framework, but with more emphasis on detector technology studies and related physics
  - Hands on Tutorials
    - This afternoon, and tomorrow morning.
      - We will show how to install and use this software.

Contents

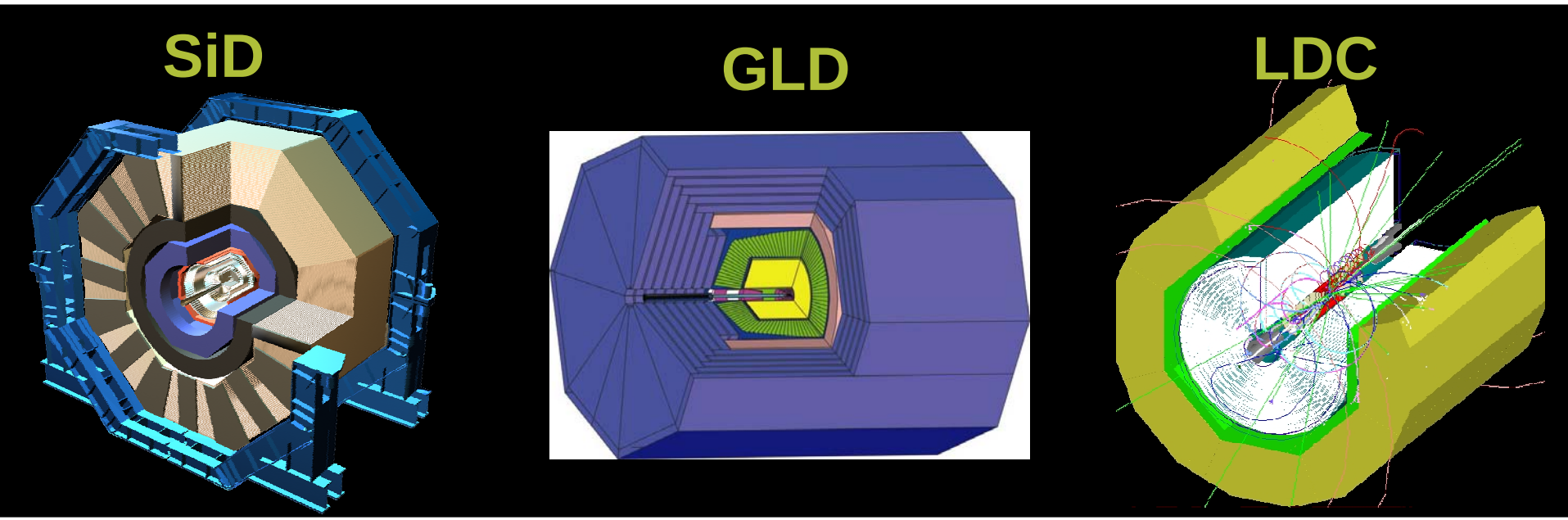
- Goals
- LCIO – Common IO for ILC detector studies
- SLIC – Simulation Package
- Geometry Description
- org.lcsim – Reconstruction and Analysis Package
  - Using org.lcsim with JAS3
  - Using org.lcsim with WIRED4
  - Using org.lcsim with “The Grid”
- How to get involved

Goals

- Enable full studies of ILC physics to optimize detector design and eventual physics output
  - Use realistic detector geometries
  - Full simulation (in combination with fast parameterized MCs)
  - Full reconstruction
    - Simulate benchmark physics processes on different full detector designs.
    - Encourage development of realistic analysis algorithms
    - See how these algorithms work with full detector simulations
- Facilitate contribution from physicists in different locations with various amounts of time available (normally not much!)
  - Software should be easy to install, learn, use
    - Goal is to allow software to be installed from CD with no external dependencies
    - Support via web based forums, tutorials, meetings.

Goals

- Use standard data formats, when possible.
  - Interoperate with other ILC software where possible
- Geometry, “Detector Concept” independent.

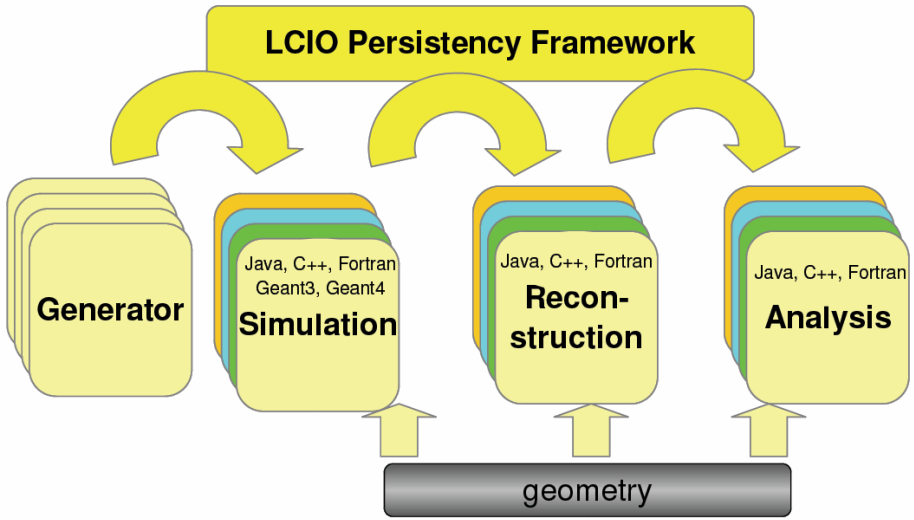


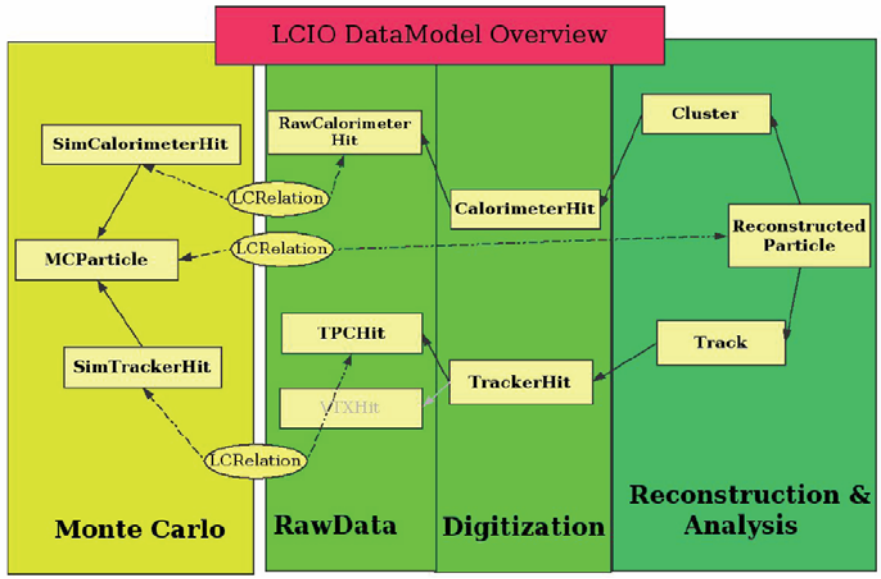
ILC software packages (circa 2004)

	Description	Detector	Language	IO-Format	Region
Simdet	fast Monte Carlo	TeslaTDR	Fortran	StdHep/LCIO	EU
SGV	fast Monte Carlo	simple Geometry, flexible	Fortran	None (LCIO)	EU
Lelaps	fast Monte Carlo	SiD, flexible	C++	SIO, LCIO	US
Mokka	full simulation â€Geant4	TeslaTDR, LDC, flexible	C++	ASCI, LCIO	EU
Brahms-Sim	Geant3 â€full simulation	TeslaTDR	Fortran	LCIO	EU
SLIC	full simulation â€Geant4	SiD, flexible	C++	LCIO	US
LCDG4	full simulation â€Geant4	SiD, flexible	C++	SIO, LCIO	US
Jupiter	full simulation â€Geant4	JLD (GDL)	C++	Root (LCIO)	AS
Brahms-Reco	reconstruction framework (most complete)	TeslaTDR	Fortran	LCIO	EU
Marlin	reconstruction and analysis application framework	Flexible	C++	LCIO	EU
hep.lcd	reconstruction framework	SiD (flexible)	Java	SIO	US
org.lcsim	reconstruction framework (under development)	SiD (flexible)	Java	LCIO	US
Jupiter-Satelite	reconstruction and analysis	JLD (GDL)	C++	Root	AS
LCCD	Conditions Data Toolkit	All	C++	MySQL, LCIC	EU
GEAR	Geometry description	Flexible	C++ (Java?)	XML	EU
LCIO	Persistency and datamodel	All	Java, C++, Fortran	-	AS,EU,US
JAS3/WIRED	Analysis Tool / Event Display	All	Java	xml,stdhep, heprep,LCIO,	US,EU

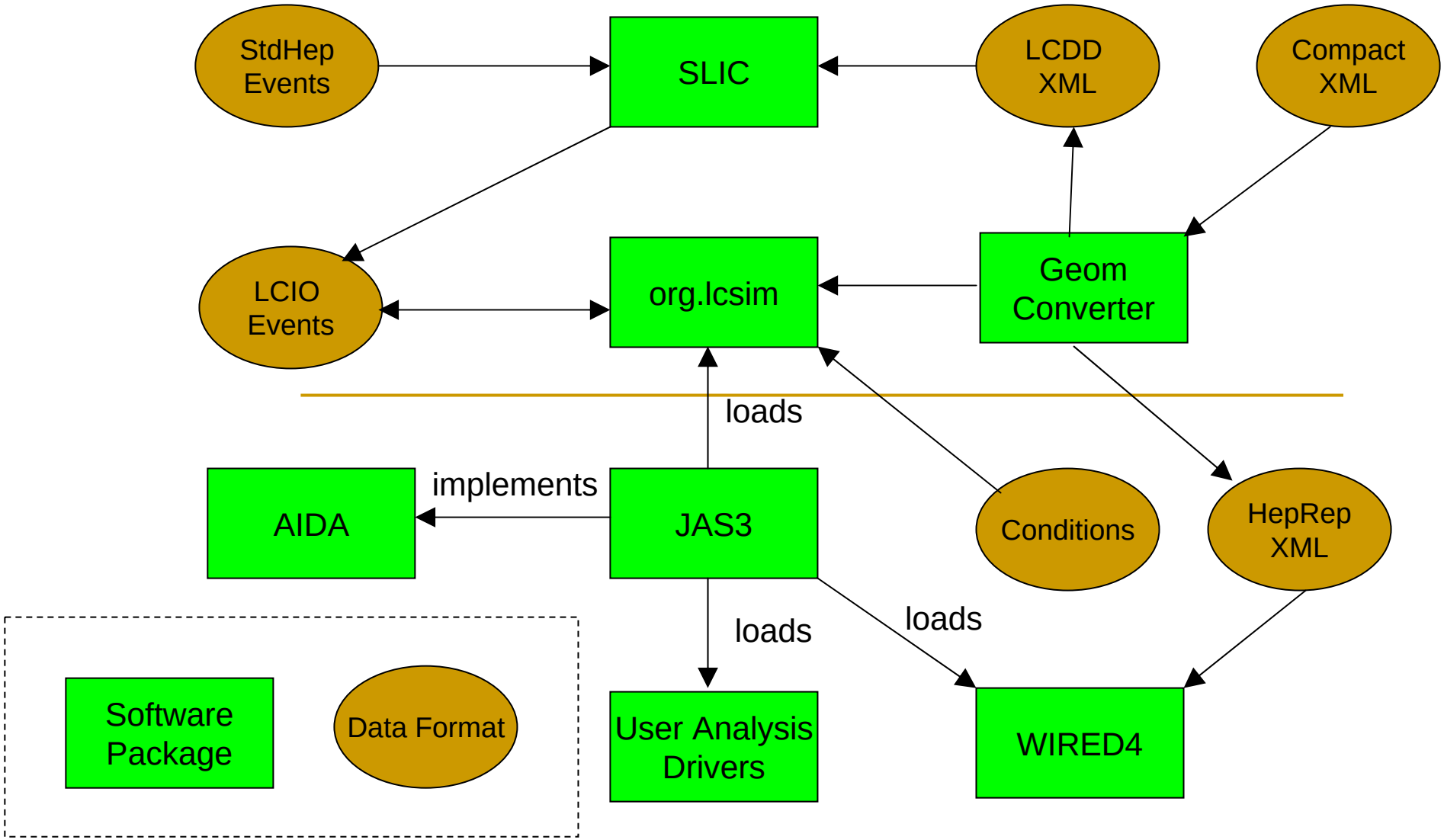
LCIO

- Object model and persistency
  - Events
    - Monte Carlo
    - Raw
    - Event and run metadata
  - Reconstruction
  - Parameters, relations, attributes, arrays, generic objects, …
- All the ILC simulators write LCIO
  - Enables cross-checks between data from different simulators
  - Read/write LCIO from
    - Fast MC / Full Simulation
    - Different detectors
    - Different reconstruction tools

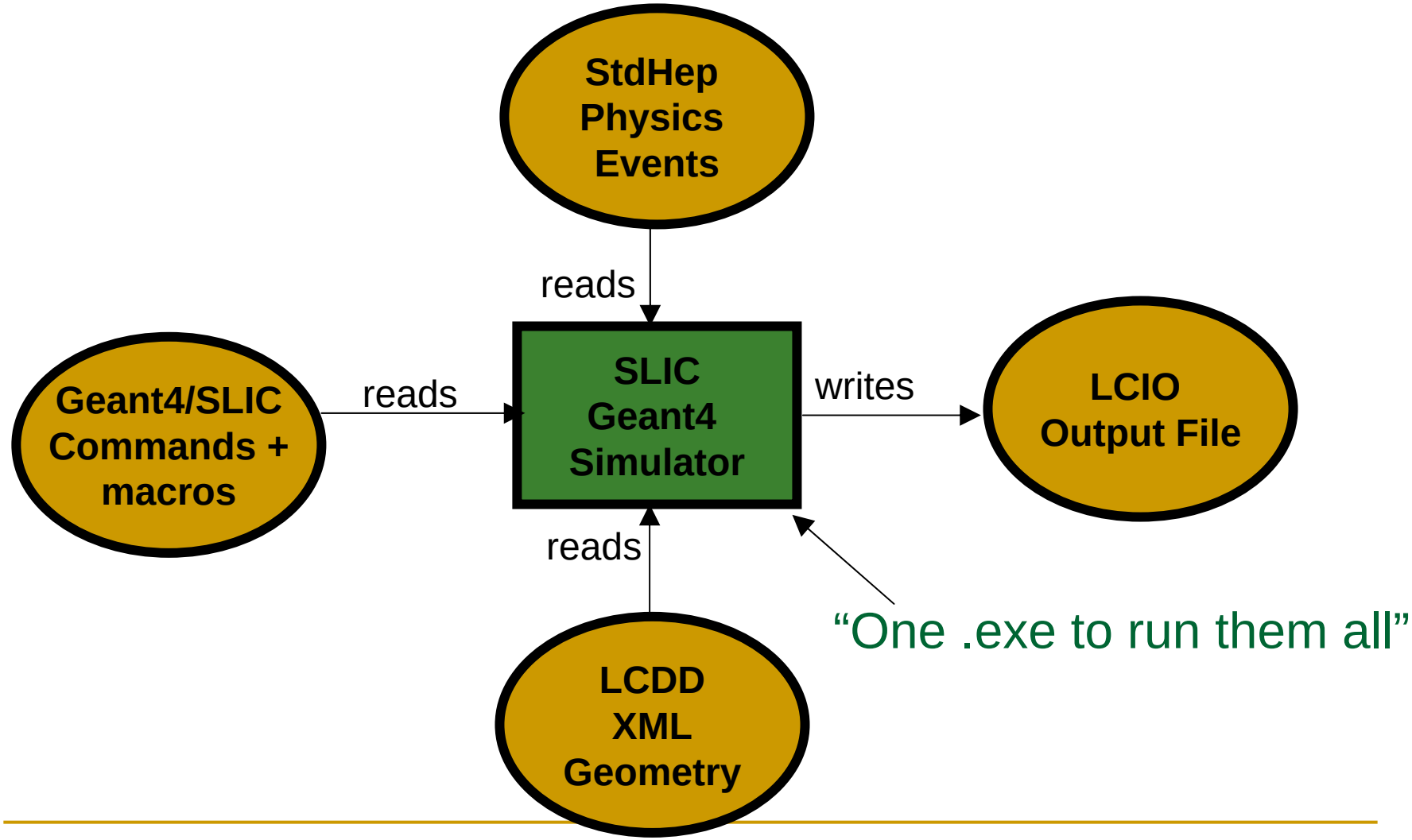




Overview: "ALCPG" Framework



SLIC – Simulator for LInear Collider



Prototyping Detectors using Geant4

- Traditional way to build Geant4 geometries is by writing C++ code
  - Positions sizes either hardwired into code or read from database or conditions framework
    - Advantages:
      - Most efficient way to define G4 geometries
      - Full access to G4 geometry features
      - Ideal for “fixed” geometry (e.g. LHC detector)
    - Disadvantages
      - Changes in geometry typically require recoding of C++
      - Access to geometry from other tools (visualization, reconstruction, analysis) difficult
      - Not ideal for prototyping detectors, test beams, thought experiments etc.
- Alternative approach is to use XML to define G4 geometries
  - Human readable and editable
  - Quick development cycle
    - no recompilation for geometry changes
    - properties easily “tweaked”
  - Portable standard: easy to import/export/exchange data
  - High quality, standardized tools in C++ and Java, Python
  - Self-descriptive with schemas (XSD)
    - validating parser quickly identifies errors
  - Natural representation of structured hierarchies, i.e. detector geometries
  - No database to install or access at runtime
    - Easy to run on Grid

Linear Collider Detector Description (LCDD)

- GDML (Geometry Description Markup Language)
  - Currently developed as part of LCG applications area
  - Tool available to generate GDML from any Geant4 program
- LCDD
  - Format developed for International Linear Collider (ILC) simulations
    - but generally applicable
  - Extends GDML to define full detector description

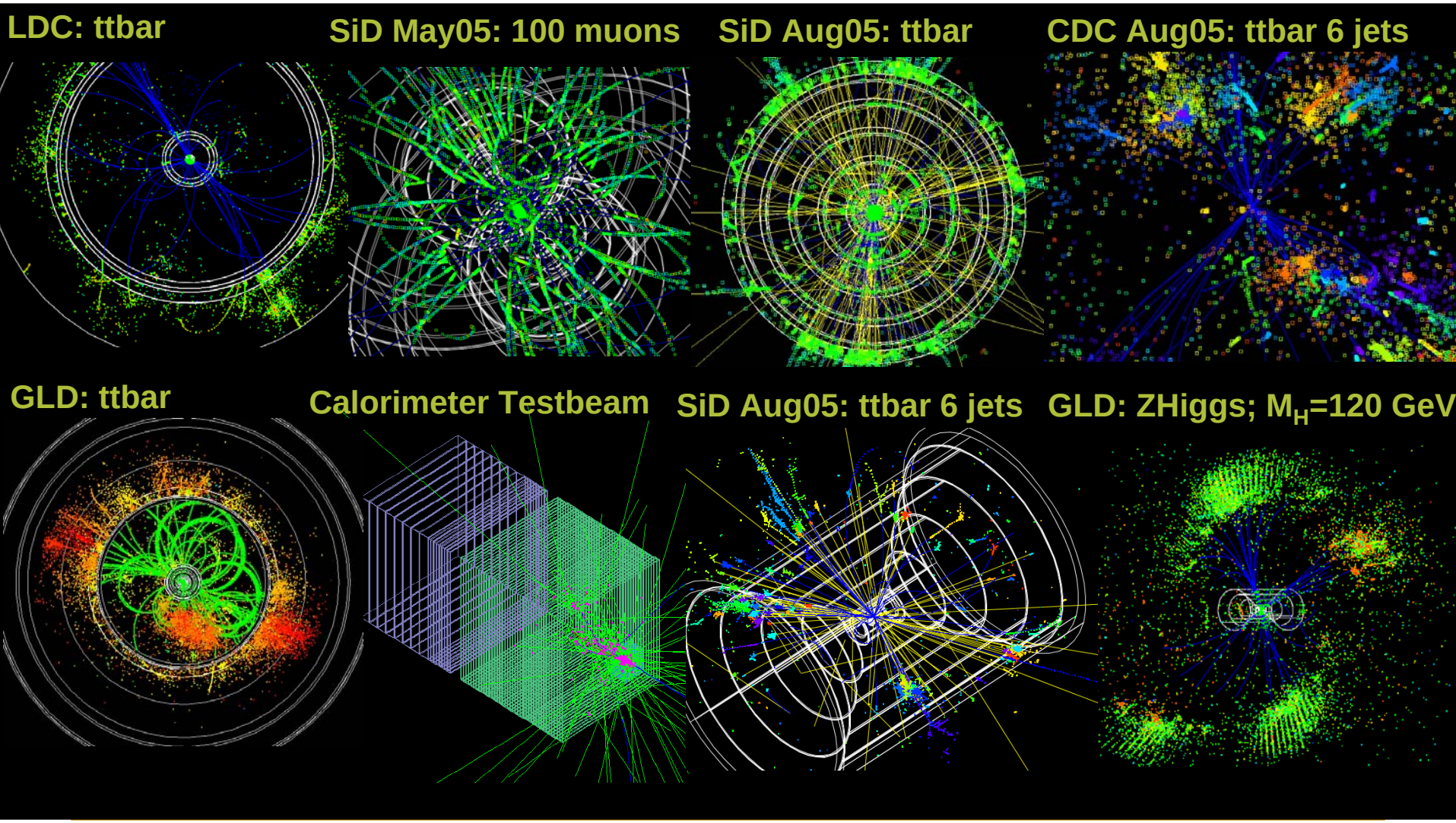
LCDD

Sensitive Detectors
Readouts
Regions
Physics Limits
Visualization Attributes
Magnetic Fields

GDML

Expressions (CLHEP)
Materials
Solids
Volumes

LCDD Examples



org.lcsim: Compact Geometry Description

- LCDD can describe essentially any detector
  - But very verbose
  - Changing e.g. # of layers in calorimeter can result in many changes in LCDD file
- org.lcsim uses “Comact Geometry Description” to define detector
  - Simple XML format for describing ILC detectors
  - Handles typical ILC detector geometries
    - Range of detectors handled is extensible (by writing Java modules)
- Allows rapid prototyping of new detector geometries
- Does not require network access or installation of database software to run
- Automatic generation of full Geant4 LCDD geometry for full compatibility with SLIC

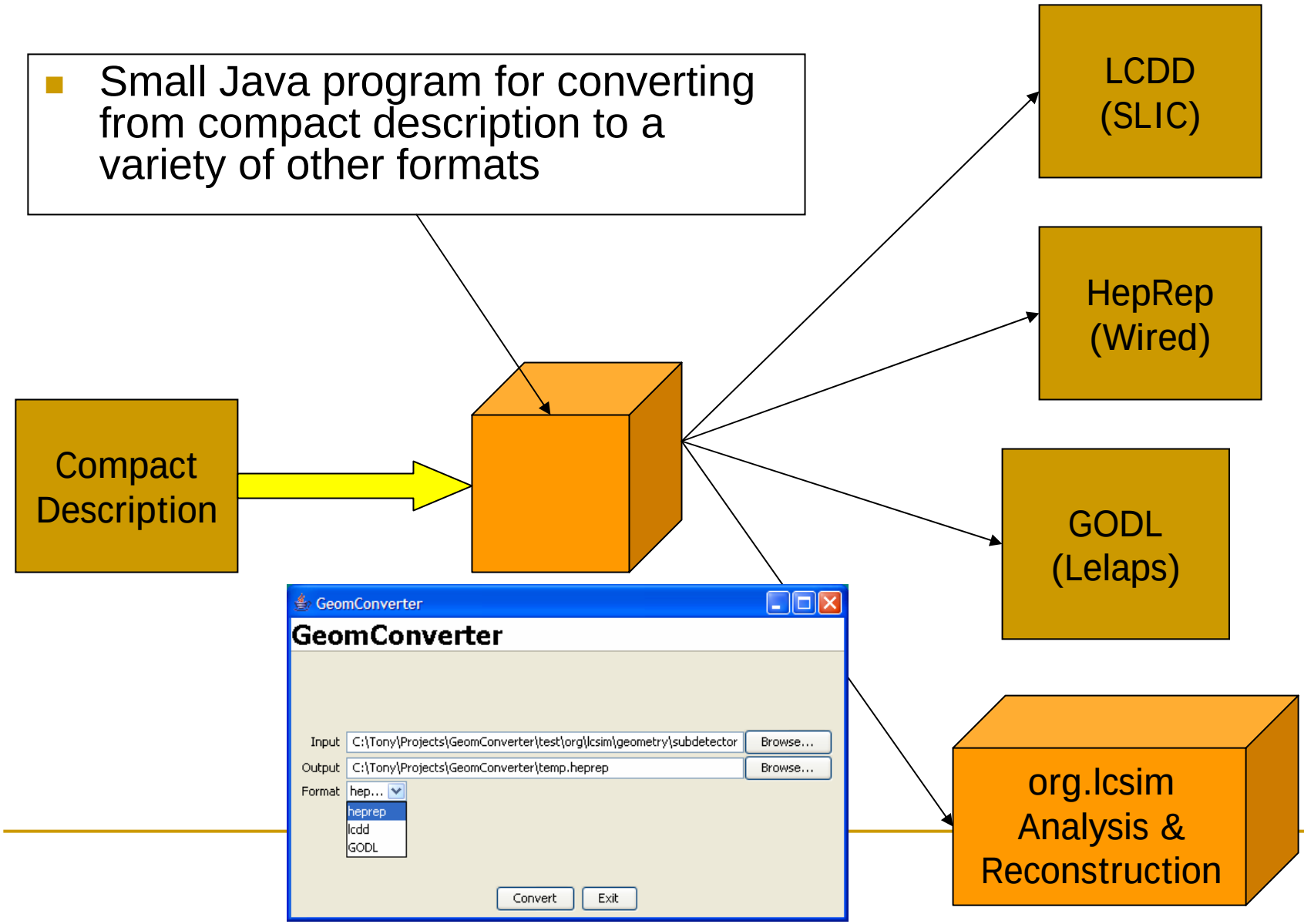
Detectors: Compact XML Example

Two layer stacks in an ECAL barrel

```
<detector id="2" name="EMBarrel" type="CylindricalBarrelCalorimeter"
          readout="EcalBarrHits">
    <dimensions inner_r = "150.1*cm" outer_z = "208.0*cm" />
    <layer repeat="20">
      <slice material = "Tungsten" thickness = "0.25*cm" />
      <slice material = "G10" thickness = "0.068*cm" />
      <slice material = "Silicon" thickness = "0.032*cm" sensitive = "yes" />
      <slice material = "Air" thickness = "0.025*cm" />
    </layer>
    <layer repeat="10">
      <slice material = "Tungsten" thickness = "0.50*cm" />
      <slice material = "G10" thickness = "0.068*cm" />
      <slice material = "Silicon" thickness = "0.032*cm" sensitive = "yes" />
      <slice material = "Air" thickness = "0.025*cm" />
    </layer>
  </detector>
```

org.lcsim: Geometry Converter

- Small Java program for converting from compact description to a variety of other formats

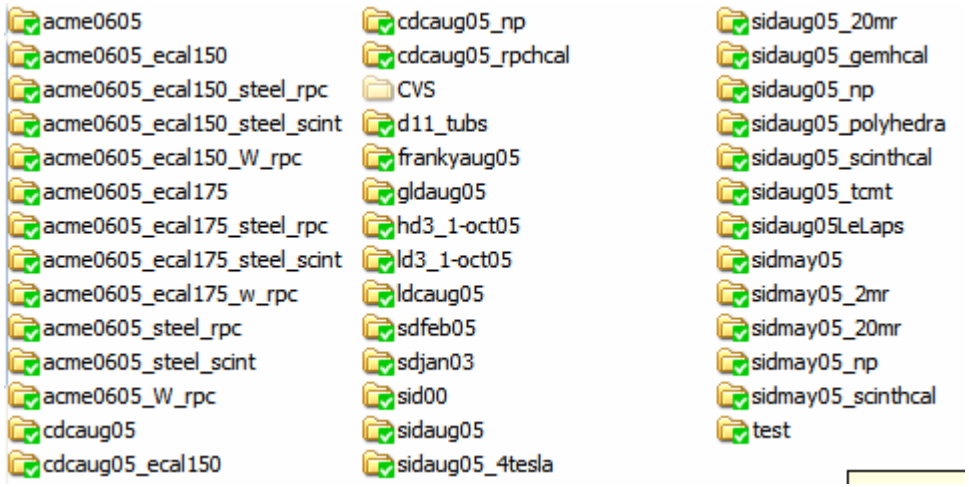


org.lcsim Conditions Data

- Provide access to a extensible set of conditions for each detector including:
  - Detector Geometry
  - Algorithm Specific Constants
    - E.g. FastMC smearing parameters
- Doesn't make assumptions about format of data
- Doesn't rely on internet access, or local database installation
  - Downloaded and cached on first use
- Detector Constants stored in .zip file
  - Typically contains:
    - Compact geometry file
    - Set of (ascii) constants for standard algorithms
  - Can additionally contain:
    - Arbitrary files (xml, ascii, binary) needed by other algorithms
    - Other geometry formats (HepRep, LCDD)
    - Full fieldmap
- To define a new detector just create a new .zip file.

Available Detector Descriptions

- Although detector descriptions can live anywhere we maintain a CVS repository of detector descriptions
  - Exported to lcsim.org web site for automatic download
- 40 detector variants as of July 2006
- Many SiD variants, but also some GLD, LDC



- Anyone can contribute more

org.lcsim Goals

- "Second generation" ILC reconstruction/analysis framework
  - Builds on hep.lcd framework used since 1999
  - Full suite of reconstruction and analysis tools
- Uses LCIO for IO and as basis for simulation, raw data and reconstruction event formats
  - Isolate users from raw LCIO structures
  - Maintain full interoperability with other LCIO based packages
- Detector Independence
  - Make package independent of detector, geometry assumptions so can work with any detector
  - Read properties of detectors at runtime
- Written using Java (1.5)
  - High-performance but simple, easy to learn, OO language
  - Enables us last 10 years of software developments in the "real world"
- Ability to run standalone (command line or batch) or in JAS3 or IDE such as Netbeans, Eclipse

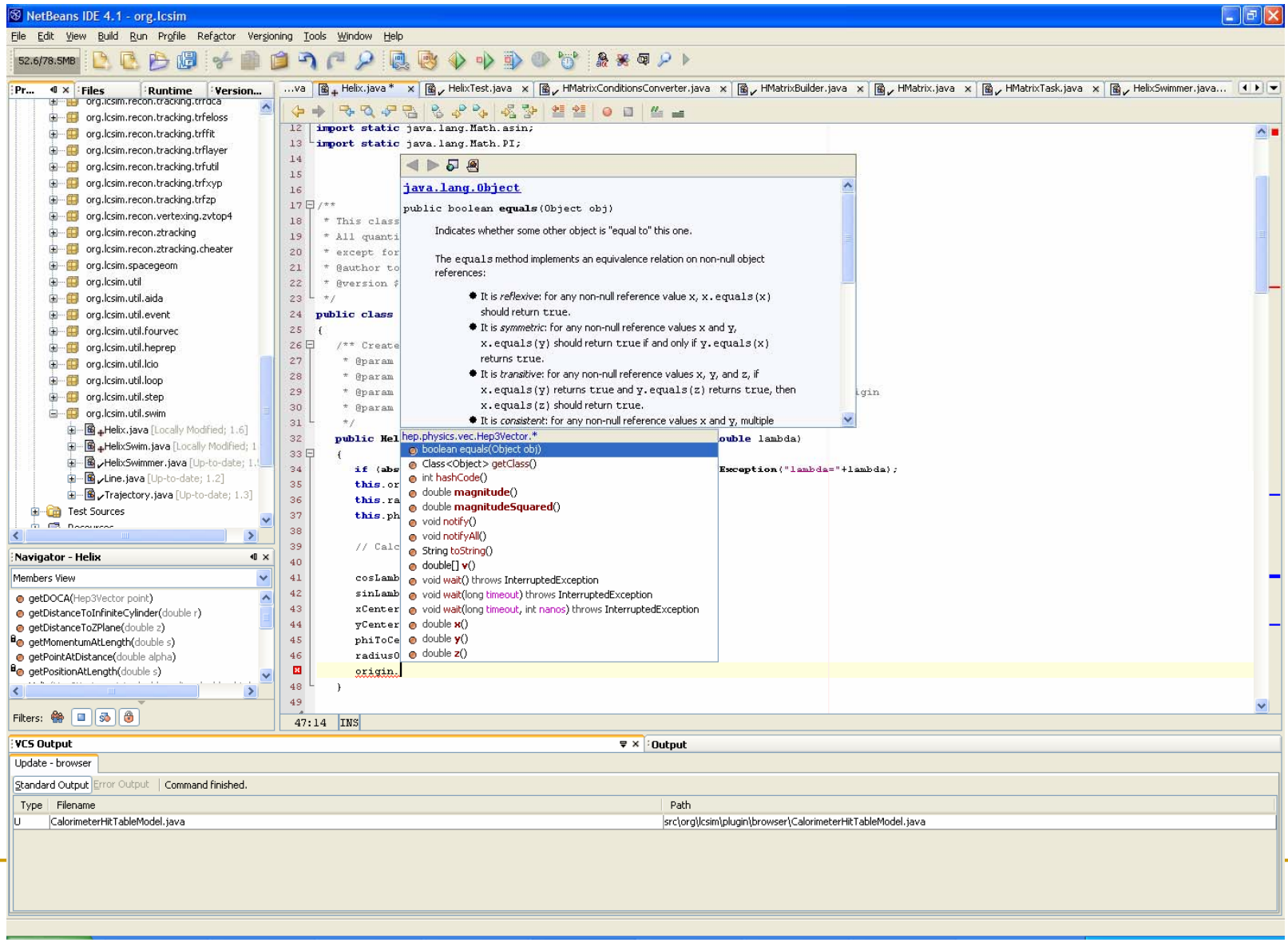
Why Java?

- Java is a pure Object Oriented Language
  - Simpler to learn and use than C++
    - Language design emphasizes ease-of-use over performance
    - Garbage collector takes care of freeing unused objects
      - Avoids distorting OO design by avoiding need for “ownership”
    - Very powerful standard library
      - Large number of open-source libraries including libraries for scientific computing
    - Platform independent, compile once just runs everywhere
      - Linux, Windows, Mac OSX)
- Physicist gets to concentrate on writing clean OO code to perform analysis tasks
  - Not understanding core dumps and learning difference between a pointer and a reference.
- Performance of Java code is close to that of C++
  - Dynamic (runtime) optimization can take into account actual usage patterns
    - not available to static optimizers used by Fortran, C++
  - Garbage collection often more efficient than user malloc/free (or new/delete)
- Java is mainstream language
  - Taught in university courses
  - Used by majority of sourceforge “open-source” projects

Why Java?

- Full access to runtime information makes interface to scripting languages easy
  - Jython, JRuby, Pnuts, …
- Open-source Java is rapidly becoming a reality
  - gcj (GNU), Harmony (Apache), Sun
- Wide availability of Tools
  - Several very powerful,free, IDE's now available:
    - E.g. Netbeans, Eclipse, (IDEA)
    - Support editing, code completion, GUI building, debugging, performance profiling, refactoring, version control (CVS, Subversion), etc…
  - Advanced tools such as maven (Apache) make project management easy
    - Maven is a Java based project management tool
    - After checking out code, single command "maven"
      - downloads dependencies,
        - Required libraries
        - Test Data
      - compiles code
      - runs test suite
      - deploys code
    - Maven can be integrated into IDE's like Netbeans

Why Java? – Netbeans IDE



Why Java? – Maven project management

- (After installing Java, cvs, maven)
- cvs –d :pserver:anonymous@cvs.freehep.org:/cvs/lcsim co GeomConverter
- cd GeomConverter
- maven
- cd ..
- cvs –d :pserver:anonymous@cvs.freehep.org:/cvs/lcsim co lcsim
- cd lcsim
- maven jar:install jas:install

Org.lcsim Reconstruction

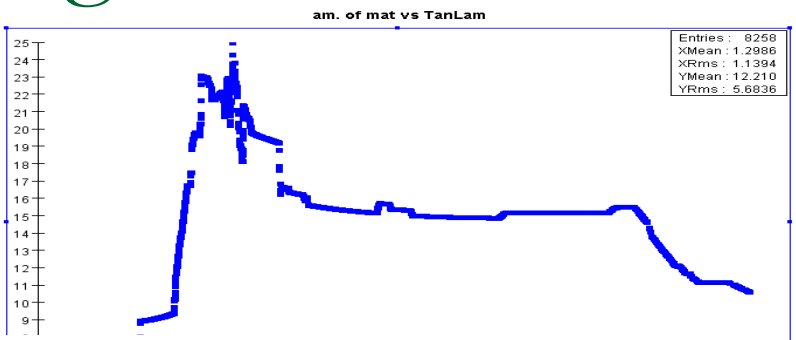
- Reconstruction package includes:
  - Physics utilities:
    - Jet finders, event shape routines
    - Diagnostic event generator, stdhep reader/translator
    - Histogramming/Fitting/Plotting (AIDA based)
    - Event Display
    - Processor/Driver infrastructure
  - Fast MC
    - Directly reads stdhep events (or LCIO events)
    - Track/Cluster smearing
    - Produces ReconstructedParticles
  - Reconstruction
    - Cheaters (perfect reconstruction)
    - Detector Response
      - CCDSim, Digisim
    - Clustering Algorithms
      - Cheater, DirectedTree, NearestNeighbour, Cone
    - Tracking Finding/Fitting Algorithms
      - TRF, SLD Weight Matrix, Kalman filter
    - Muon Finding, Stepper
    - Vertex Finding (ZvTop)

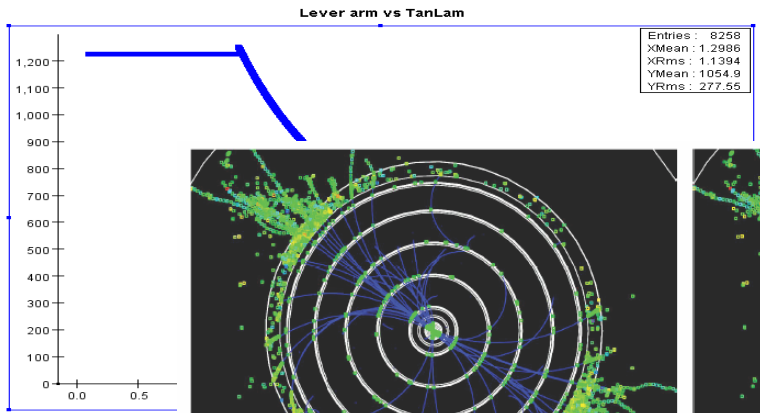
org.lcsim: Contrib Area

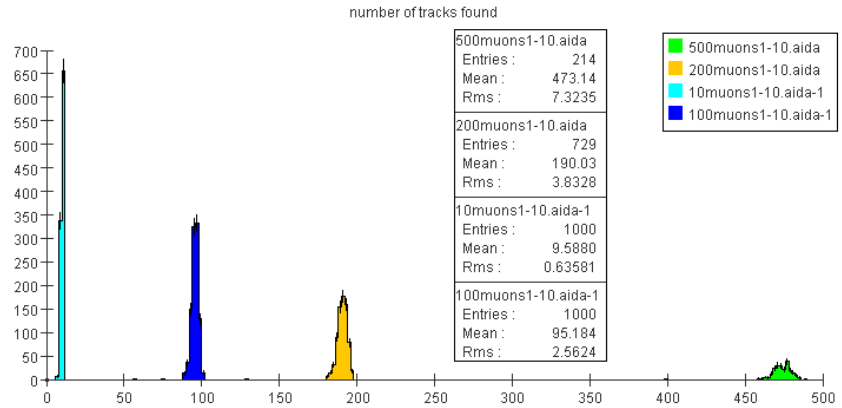
- Goal of org.lcsim is not to provide “A single reconstruction package” but rather a framework into which reconstruction algorithms can be plugged.
- We encourage users to contribute code to the “contrib” area as soon as possible.
  - Important to encourage collaboration, reuse, and as learning tool.
- Contributions from: SLAC, Fermilab, Berkeley, NIU, Brown, Colorado, Colorado State, Santa Cruz, Iowa, Kansas, Kansas State, Oregon, Penn, Michigan, UT Arlington, …
  - Many contributions added in last year:
    - HMatrix cluster analysis
    - Vertex Fitter
    - Particle Flow (PFA) algorithms/template
    - SODTracker
    - Garfield Tracker
    - Calorimeter Cell Ganging
    - FastMC improvements
    - Tracking finding/fitting
    - MIP Finder
    - Minimum Spanning Tree Clustering

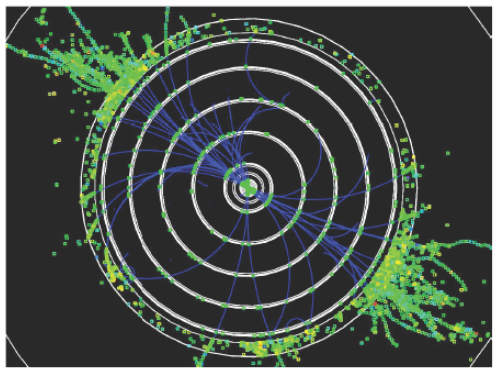
org.lcsim results

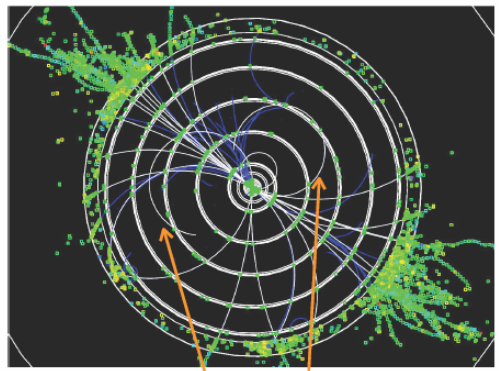
(See Norman Graf's talk tomorrow)

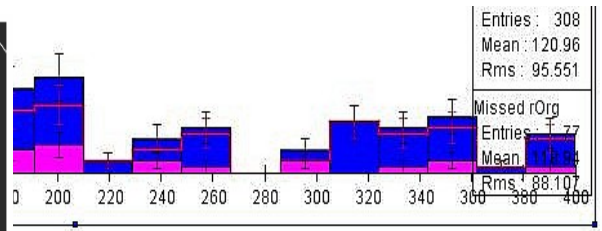


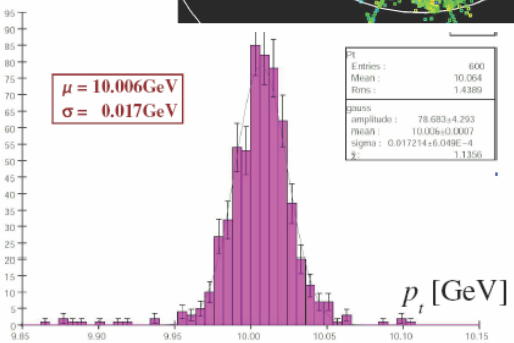


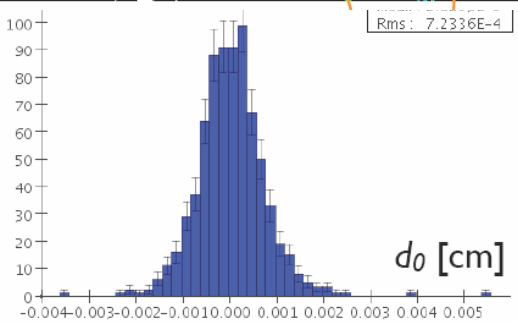


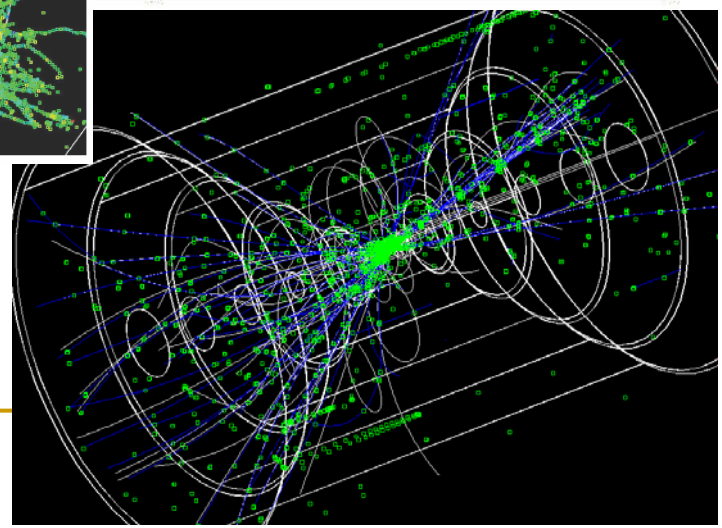












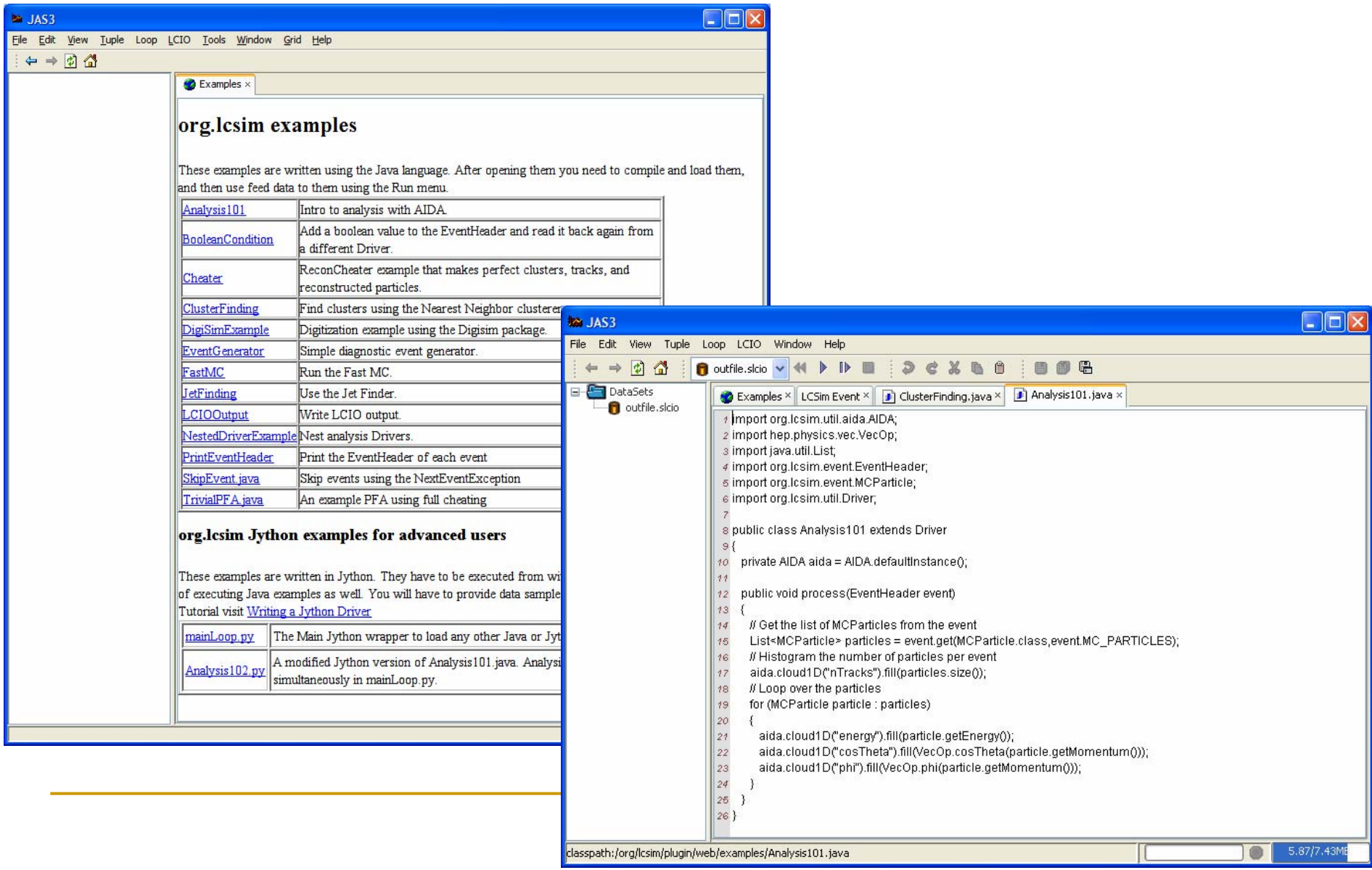
org.lcsim Contributors

- SLAC, Fermilab, Berkeley, Santa Cruz, Iowa, Kansas, Kansas State, Oregon, Penn, Michigan, UT Arlington

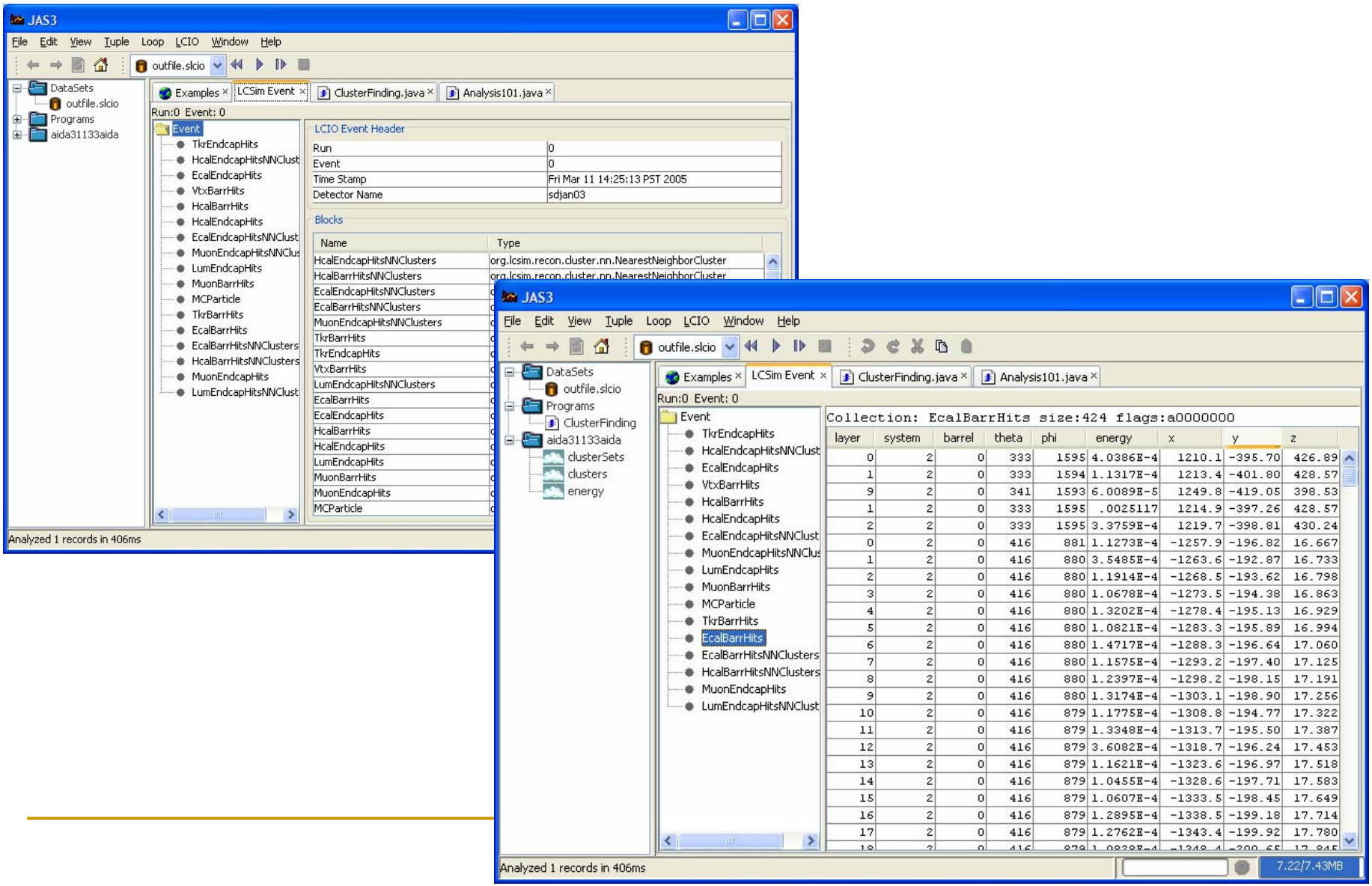
Using org.lcsim with JAS3

- The org.lcsim can be used standalone, with an IDE, or inside JAS3. Same code can be used in all modes, so easy to move back and forth
  - E.g. develop in IDE and run in JAS3
  - E.g. develop in JAS3 and run in batch
- JAS3 org.lcsim plugin adds:
  - Example Analysis Code
  - org.lcim Event browser
  - Easy viewing of analysis plots
  - WIRED event display integration

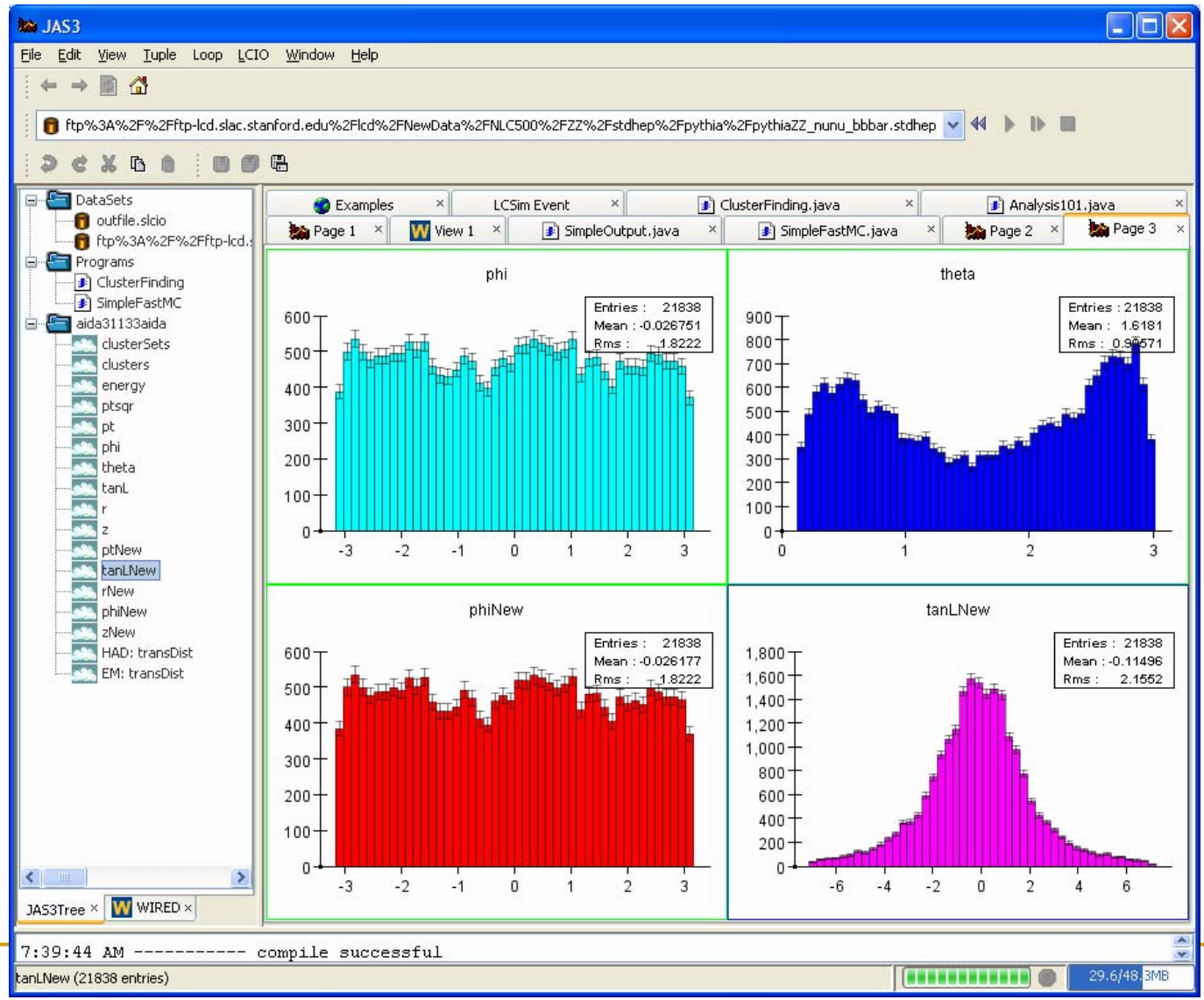
org.lcsim: Examples



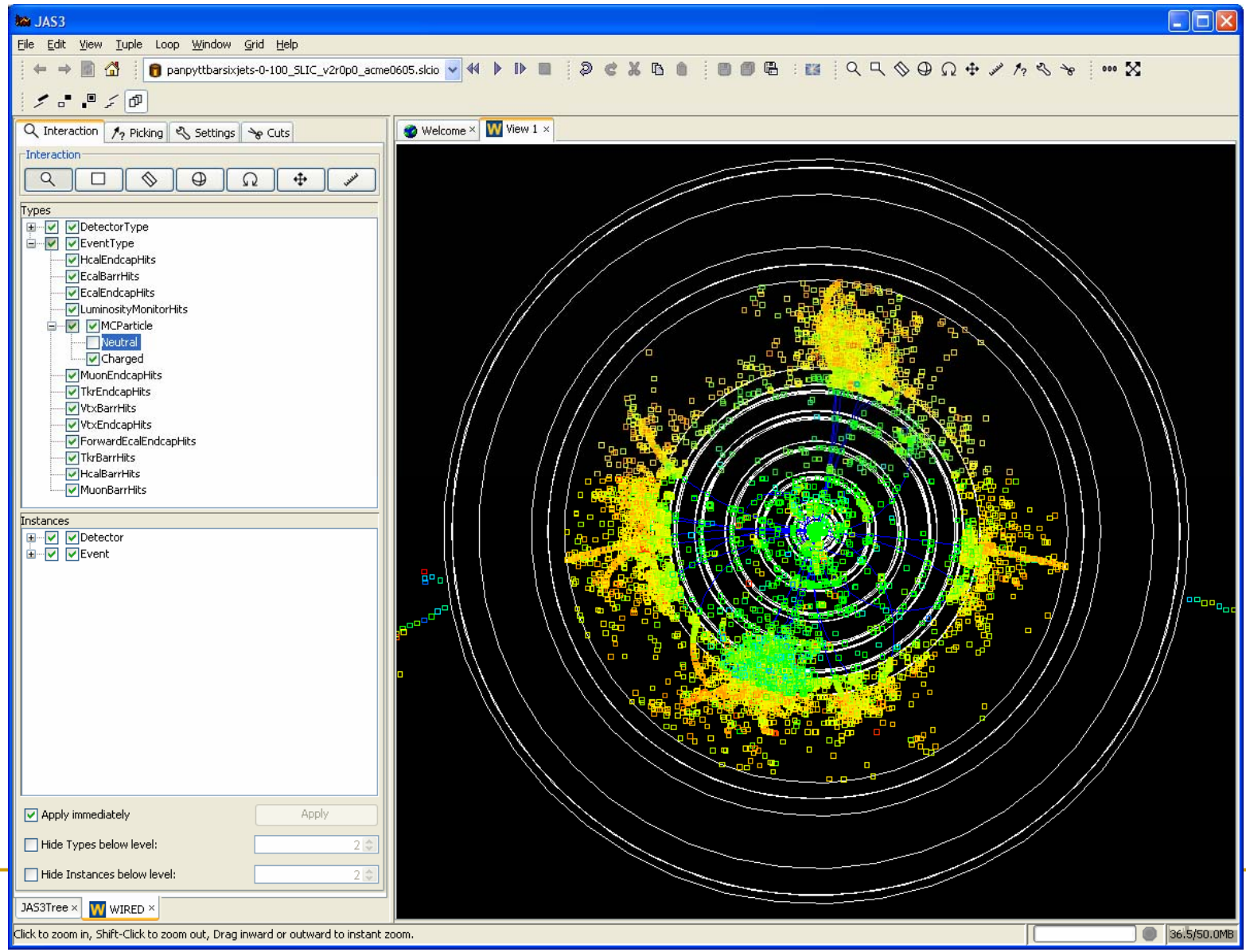
org.lcsim: Examples



org.lcsim: Plot Viewing



Using org.lcsim with WIRED4



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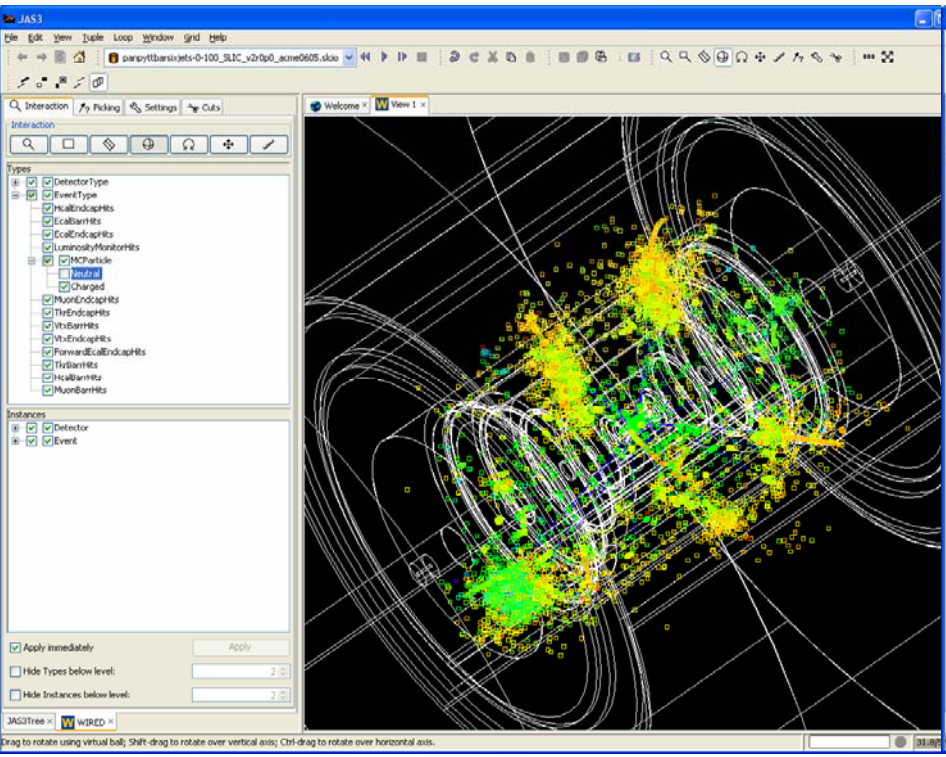

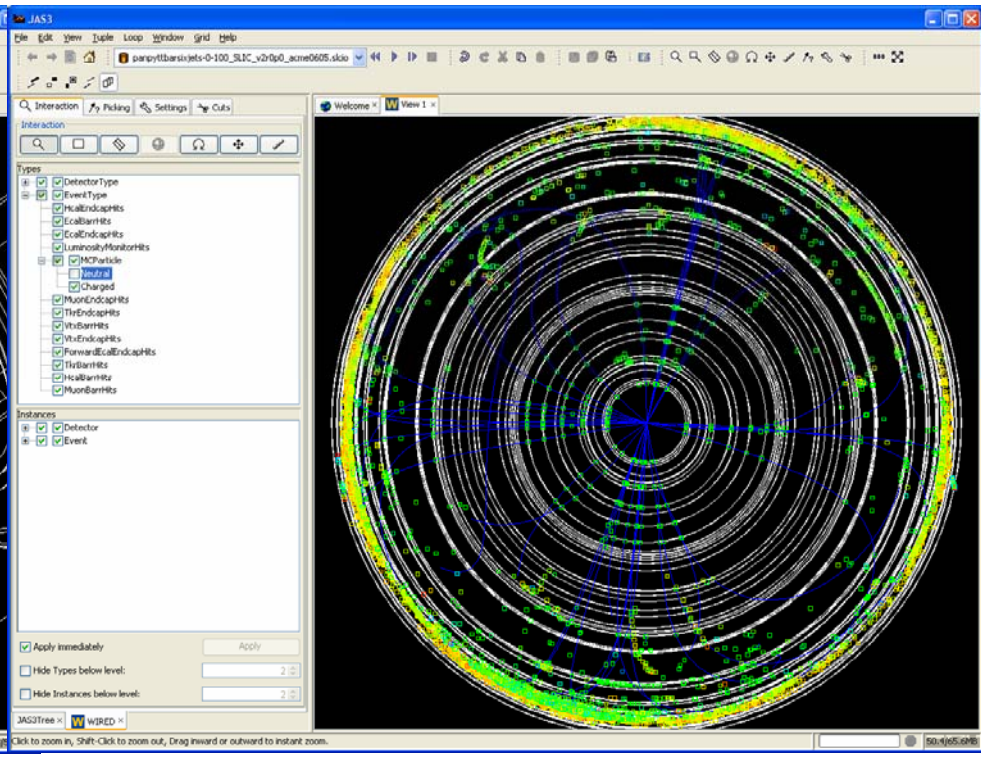

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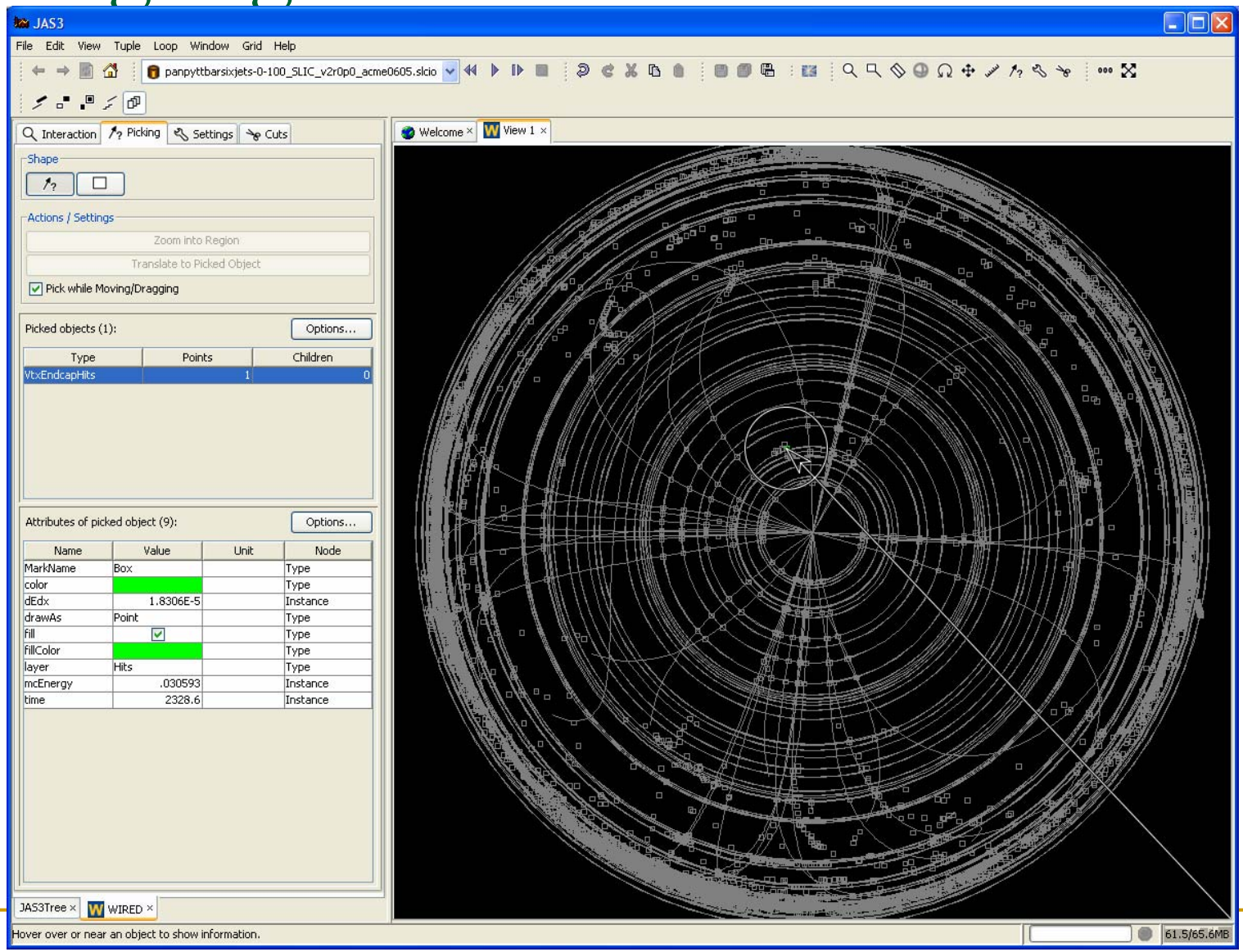

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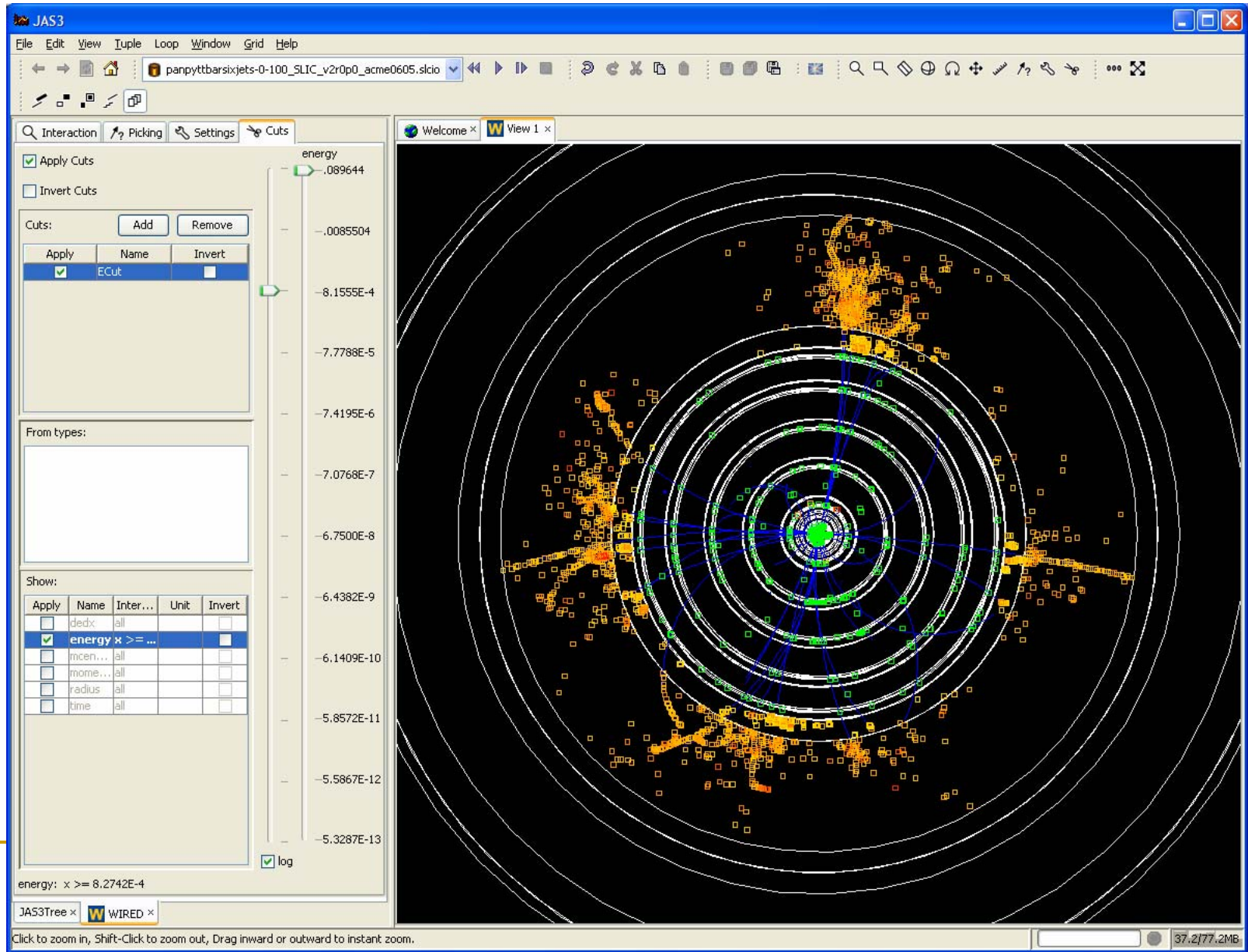
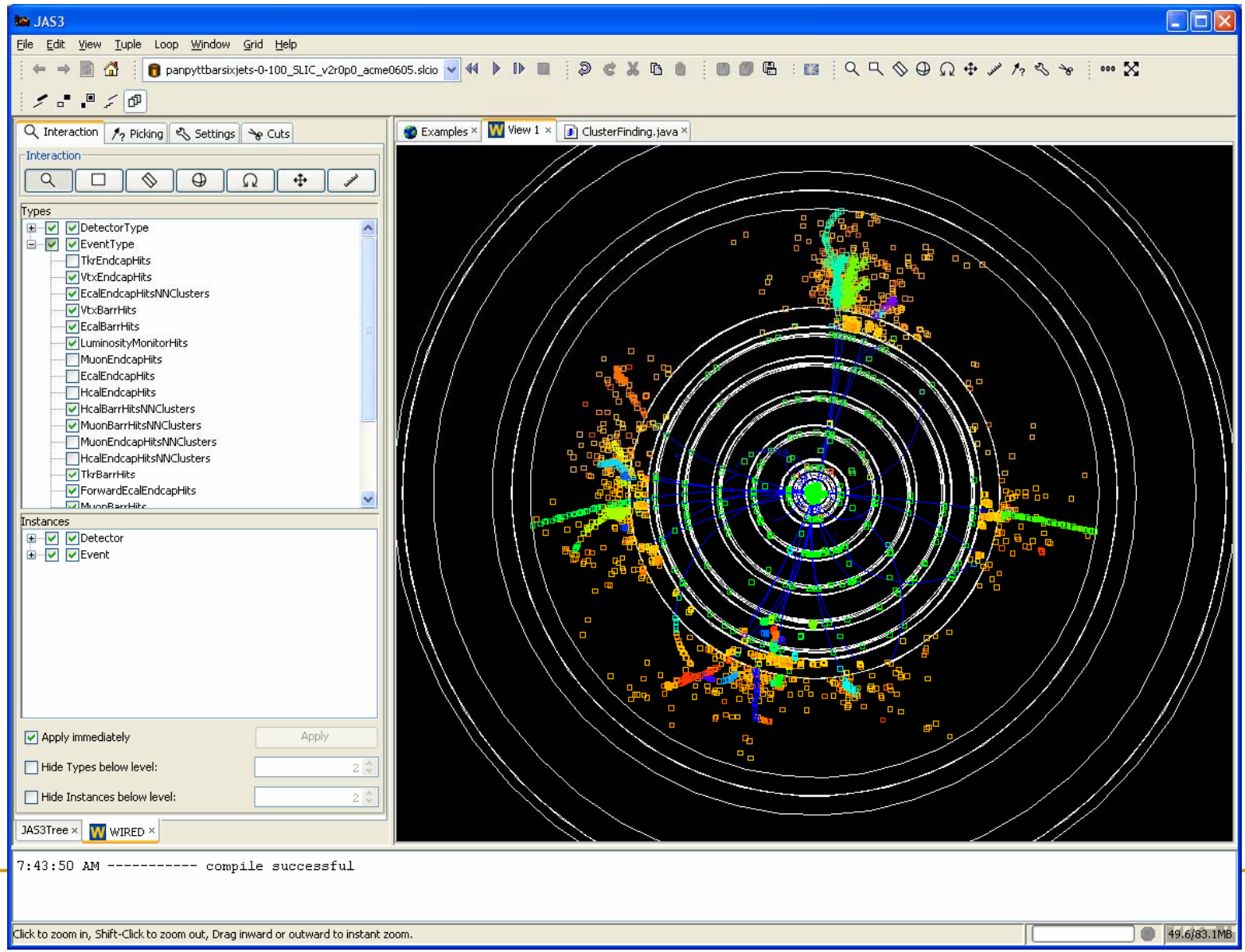
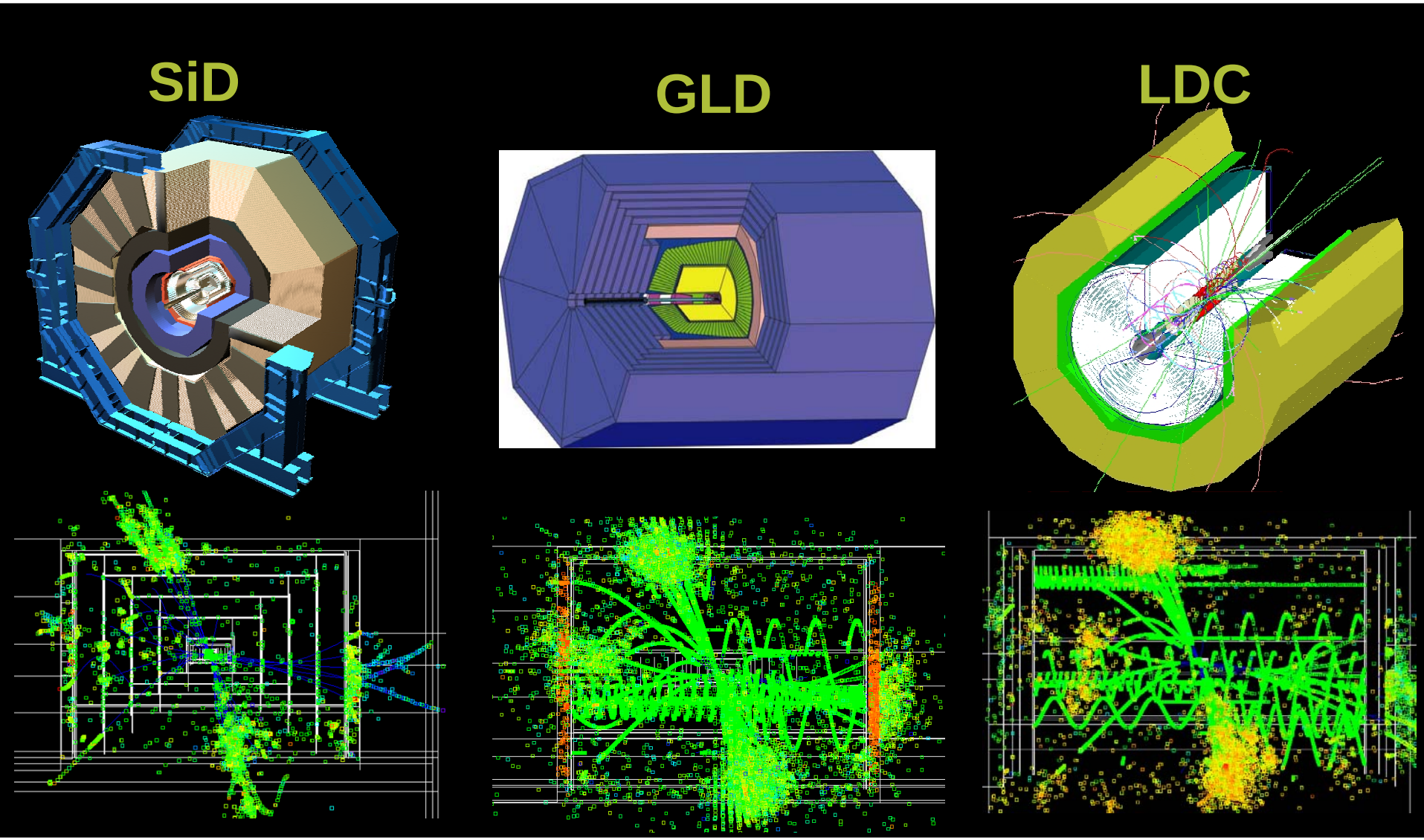


Using org.lcsim with WIRED4



Interoperability: Event Display

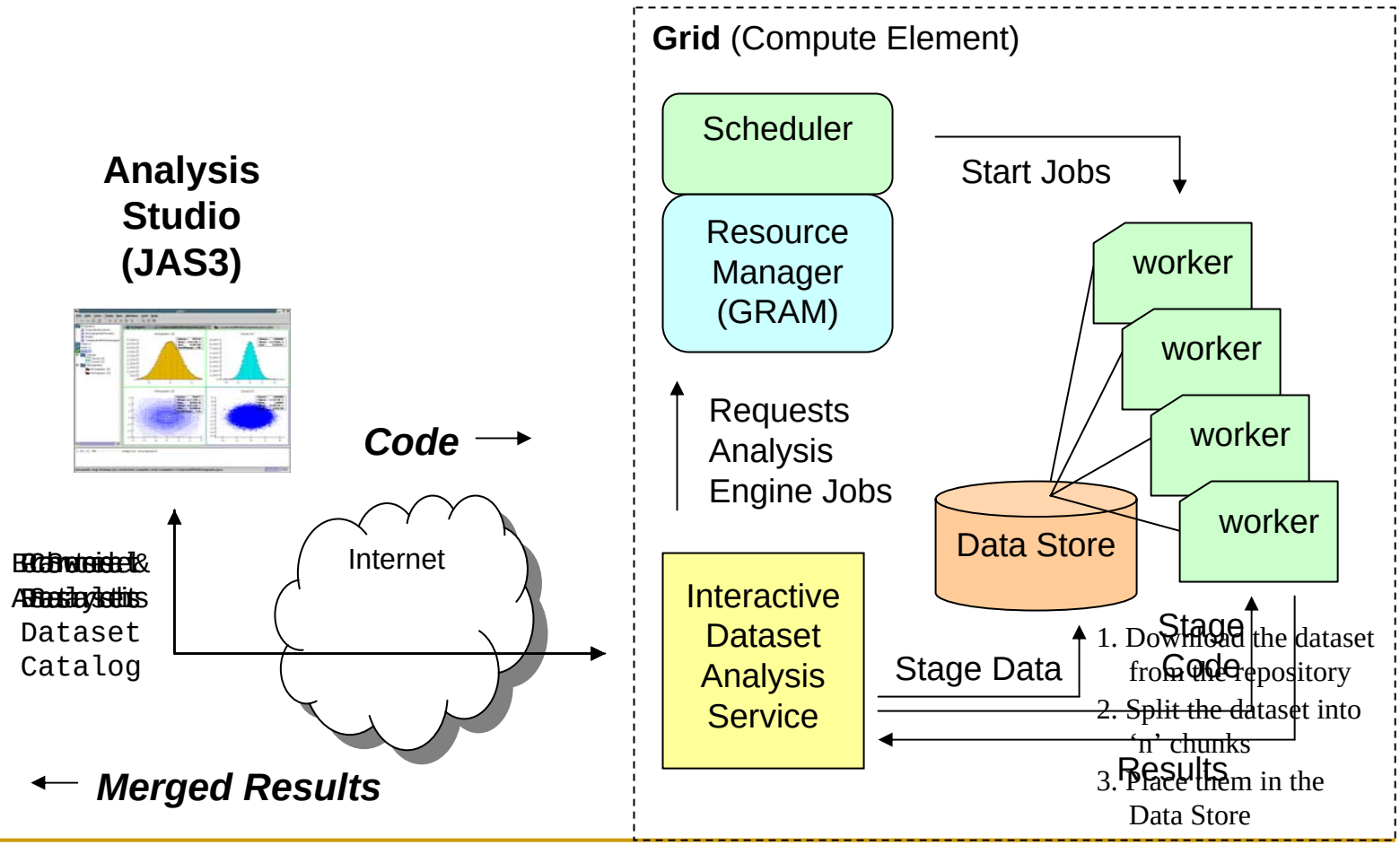


Z Higgs (M_H=120 GeV) → same simulator, three different full detector geometries

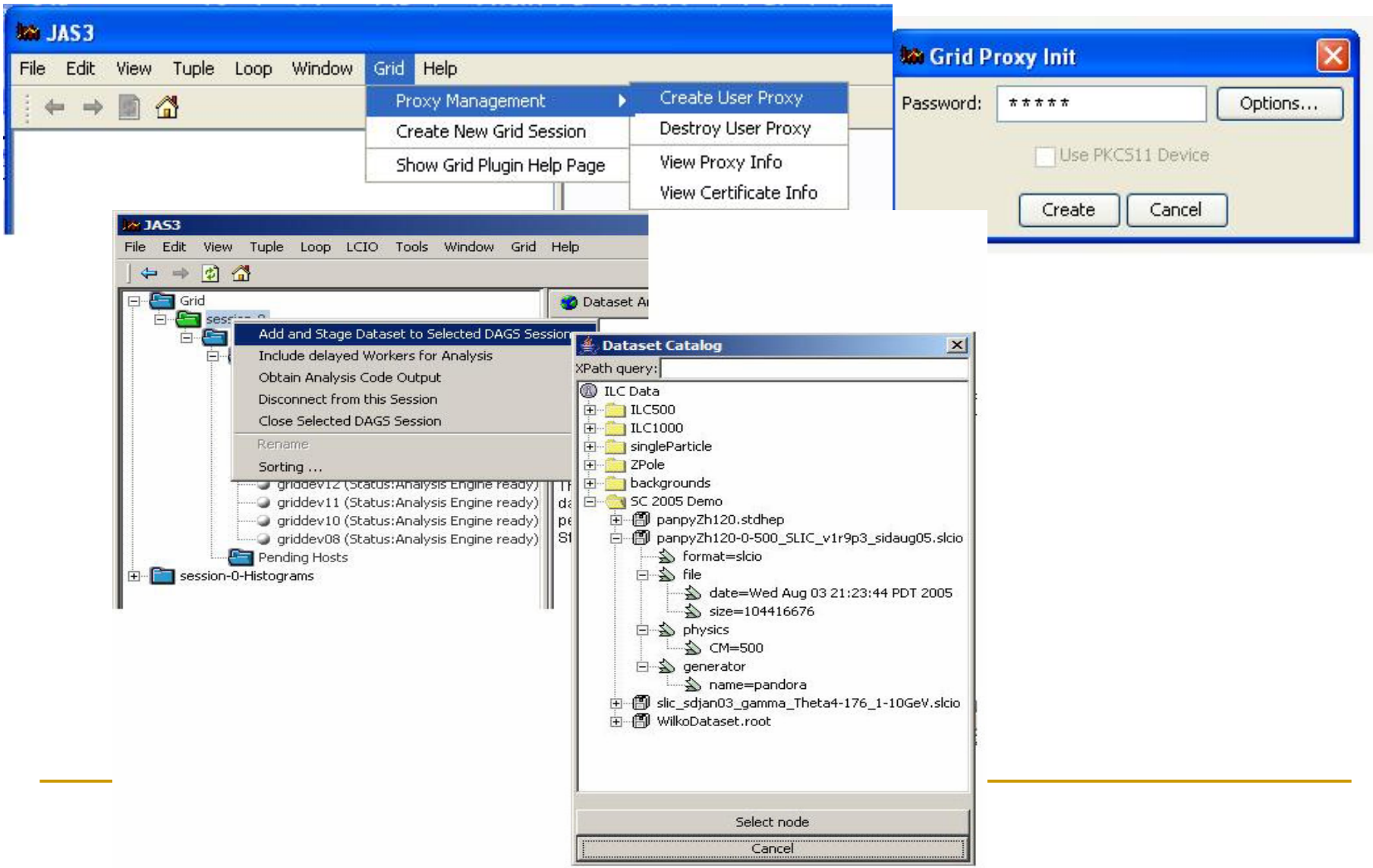
Using JAS3 and org.lcsim on the Grid

- In collaboration with Tech-X we have developed prototype “Interactive Parallel Analysis” system.
  - Allows interactive analysis of (ilc) data using a farm of machines to run analysis in parallel
  - Maintains full interactivity using JAS3

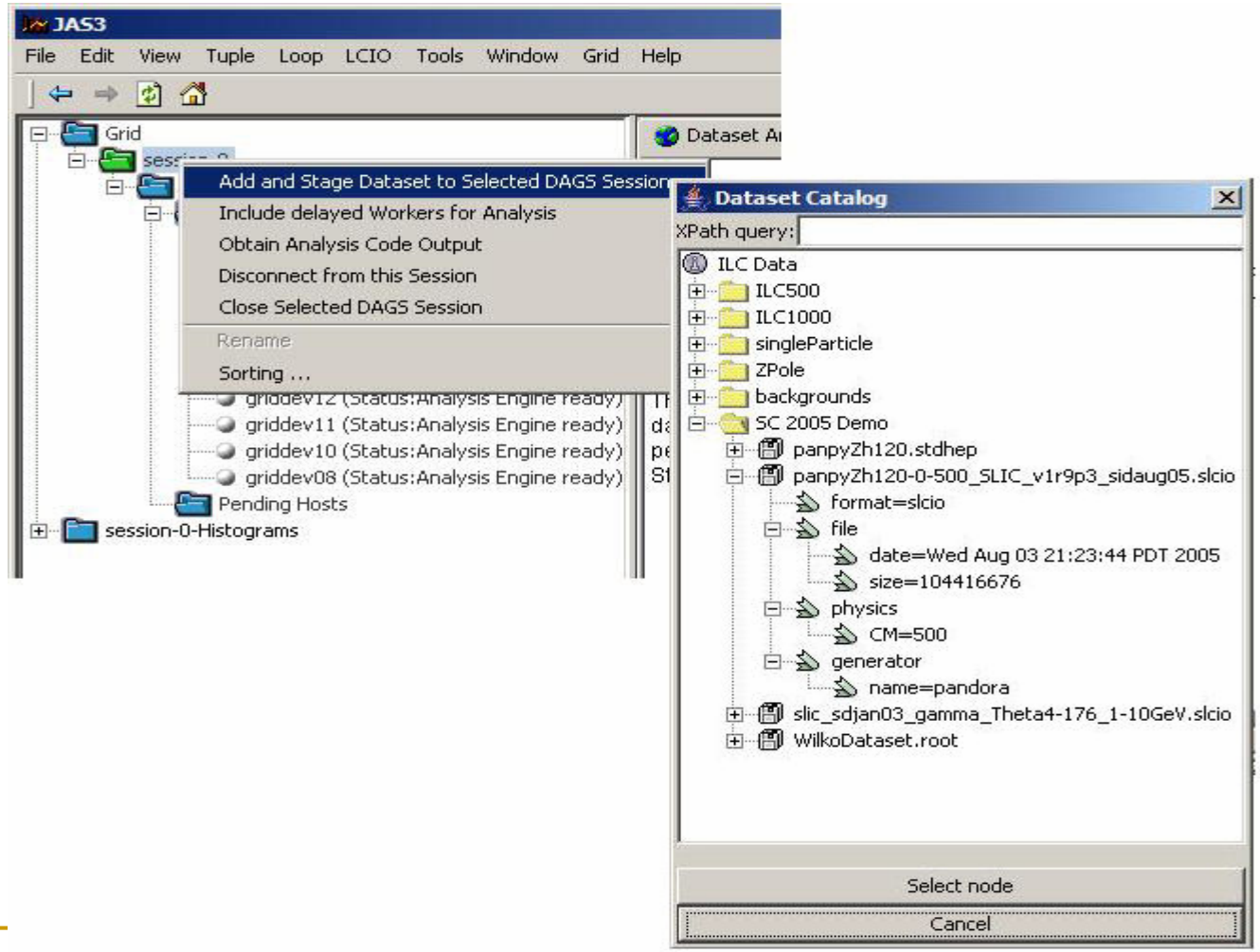
Sending Code and Merging Results



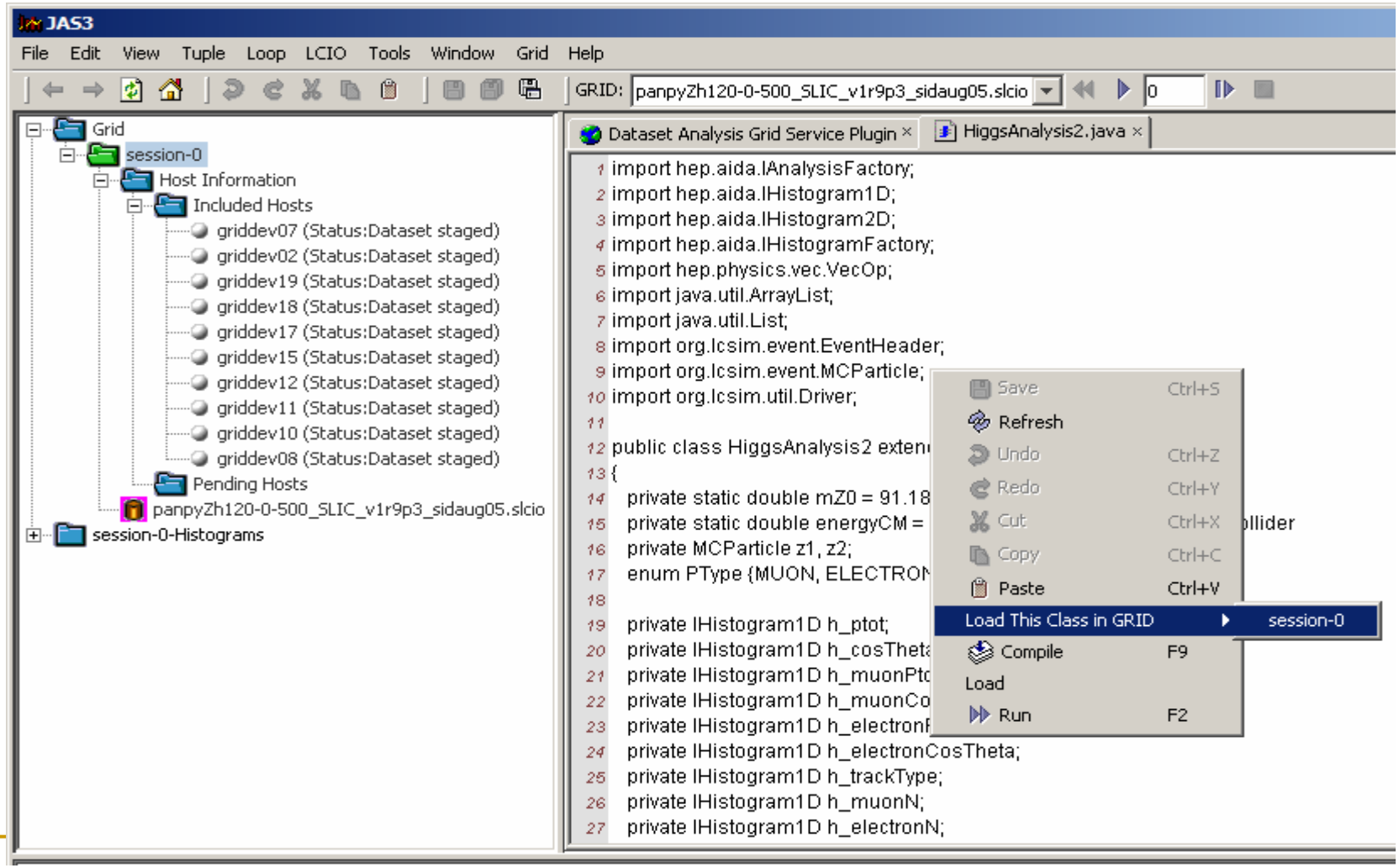
Secure Login + Catalog Browser



Catalog Service to Browse and Search Datasets



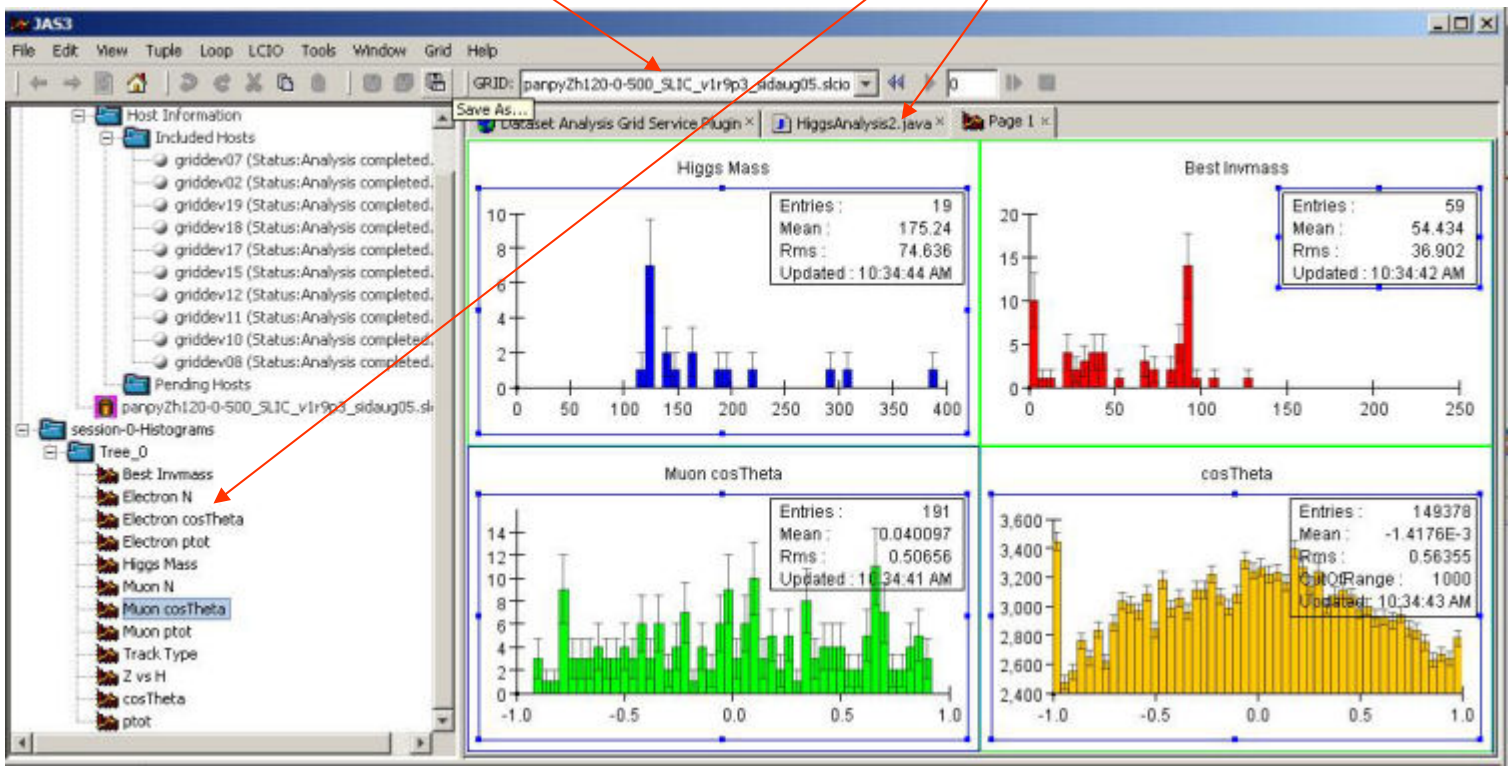
Integrated Development Environment



Interactive Graphical Results in Seconds

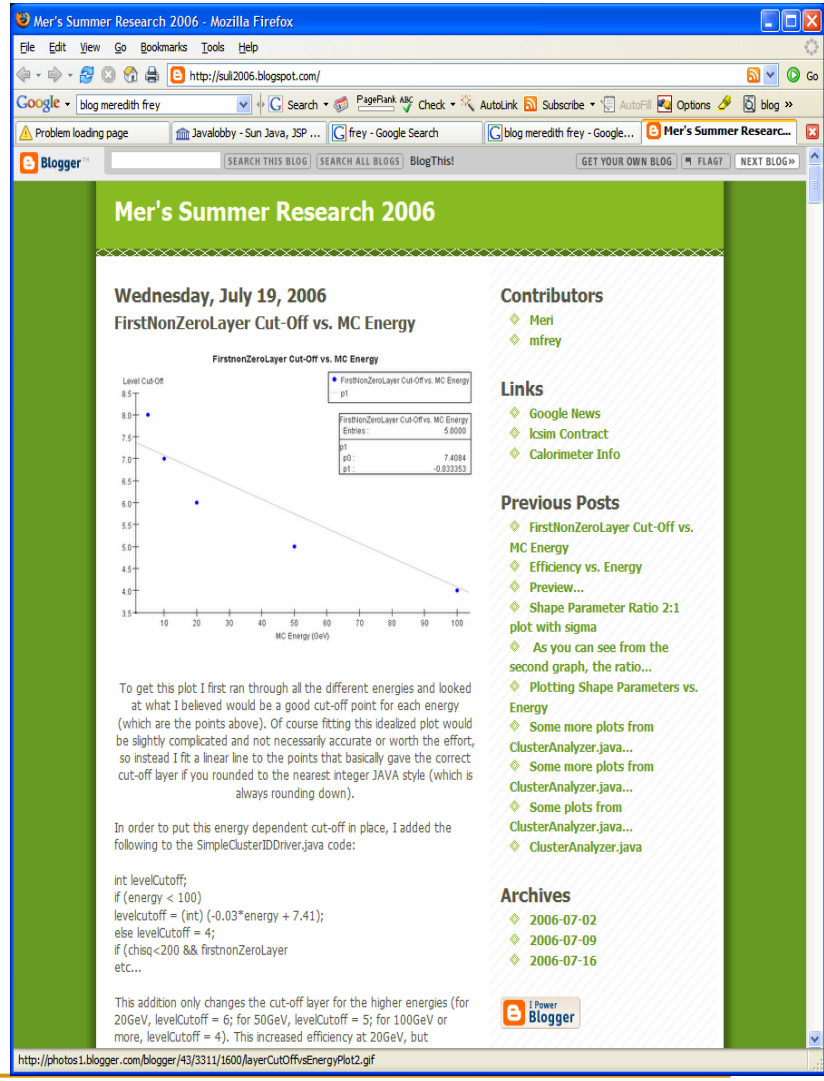
Controls to Start/Stop Analysis

Can change analysis code, clear graphs, and restart



How hard is it to get started with org.lcsim?

- Works on Linux, MacOSX, Windows
  - Should take about 15 minutes to install JAS3 and org.lcsim plugin.
- Case Study: SLAC Summer student
  - 2 semesters of Java experience
    - (no C++, Fortran *etc*)
  - Using tutorial on lcsim.org Wiki; installed software, downloaded data, and got useful results in one day (and fixed a few errors in the documentation along the way).
  - Regular analysis updates have been appearing on her blog ever since!
- Even if you don't have Java experience you can get started almost as fast
  - (the only thing you will miss is the core dumps)
- Start here:
  - https://confluence.slac.stanford.edu/display/ilc/lcsim+Getting+Started
  - Problems? Attend Tuesday afternoon "Simulation" phone meeting or use discussion forum at http://forum.linearcollider.org/



LCIO: Data Samples

- LCIO data samples available via anonymous FTP
  - http://www.lcsim.org/datasets/ftp.html
- Data sets
  - ILC500
    - 500 GeV machine parameters
  - ILC1000
    - 1 TeV machine parameters
  - singleParticle
    - Single particle diagnostic events
  - Zpole
    - Zpole diagnostic events

- **[event type]** - complex or single particle event type, e.g. ZZ, ZPole, muons, etc.
  - **stdhep** - input StdHep files used to generate the events
  - **[detector name]** - detector geometry tag, such as sidaug05
    - **[data file format]** - output datafile format, e.g. LCIO or SIO
      - **[simulator]** - simulator that generated the events, e.g. lcdg4, slic, lelaps, mokka, etc.
        - **logs** - simulator job logs

Organization

Becoming an org.lcsim developer

- To get started you just need “Java”, “cvs”, “maven”
  - Maven is a Java based project management tool
  - Single command “maven”
    - downloads dependencies, compiles code, runs tests, deploys code
- **All code in CVS**
- To check-out and build all code:
  - set CVSROOT=“pserver:anonymous@cvs.freehep.org:/cvs/lcsim”
  - cvs co GeomConverter
  - cd GeomConverter
  - maven
  - cd ..
  - cvs co lcsim
  - cd lcsim
  - maven
- Find more documentation at:
  - http://lcsim.org/
  - Read/Contribute to the Wiki at: https://confluence.slac.stanford.edu/display/ilc/Home
  - Discuss at: http://forum.linearcollider.org/
- We strongly encourage developers to use IDE
  - Netbeans, Eclipse both free, easy to learn, very powerful
  - Use mevenide to teach IDEs about maven system
  - Instructions for installing Netbeans in out Wiki (confluence).

Interoperability – Next Step

- LCIO has been very successful in providing some interoperability between disparate ILC tools
- Obvious next step is to attempt “common geometry” system
  - org.lcsim and Marlin (GEAR) geometry already very similar
  - Will have small workshop at SLAC next week to discuss directions
  - Follow up workshop at DESY at beginning of November
    - Goal (ambitious) too have something to discuss/show at ECFA workshop in Valencia in November
  - This might be a good area for someone interested in ILC software to get involved.
- Java -> C++ interoperability
  - Ability to call C++ (MarlinReco) modules from org.lcsim??
    - Some experimentation ongoing with using SWIG to build glue code
    - See somewhat related (pre-alpha) project G4Java
      - http://java.freehep.org/sandbox/G4Java/

Links

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

Conclusion

- SLIC + org.lcsim provide complete framework for ILC detector studies
  - Many reconstruction algorithms exist
    - Plenty of work still to do done
      - Adding/improving algorithms
      - Performing physics studies and detector benchmarking
    - All software is developed using an “open-source” model
      - All code available in CVS (even before it is complete)
    - Anyone is welcome to become involved
  - Interoperability with other linear collider software is provided by using LCIO
    - Work is ongoing to further improve interoperability