lcsim
A Java-based Reconstruction package for Particle Physics

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What is lcsim?

- Reconstruction and Analysis suite
  - Developed for linear collider physics studies
    - 10+ years, 100+ developers
  - Supports
    - General detector development/prototyping
    - Small experiments
- Companion program to SLIC
  - See Jeremy's talk yesterday in simulation session
  - Like SLIC reads detector description from XML
    - SLIC and lcsim share same XML description
  - Like SLIC uses standard IO formats
    - StdHEP, lcio, AIDA, …

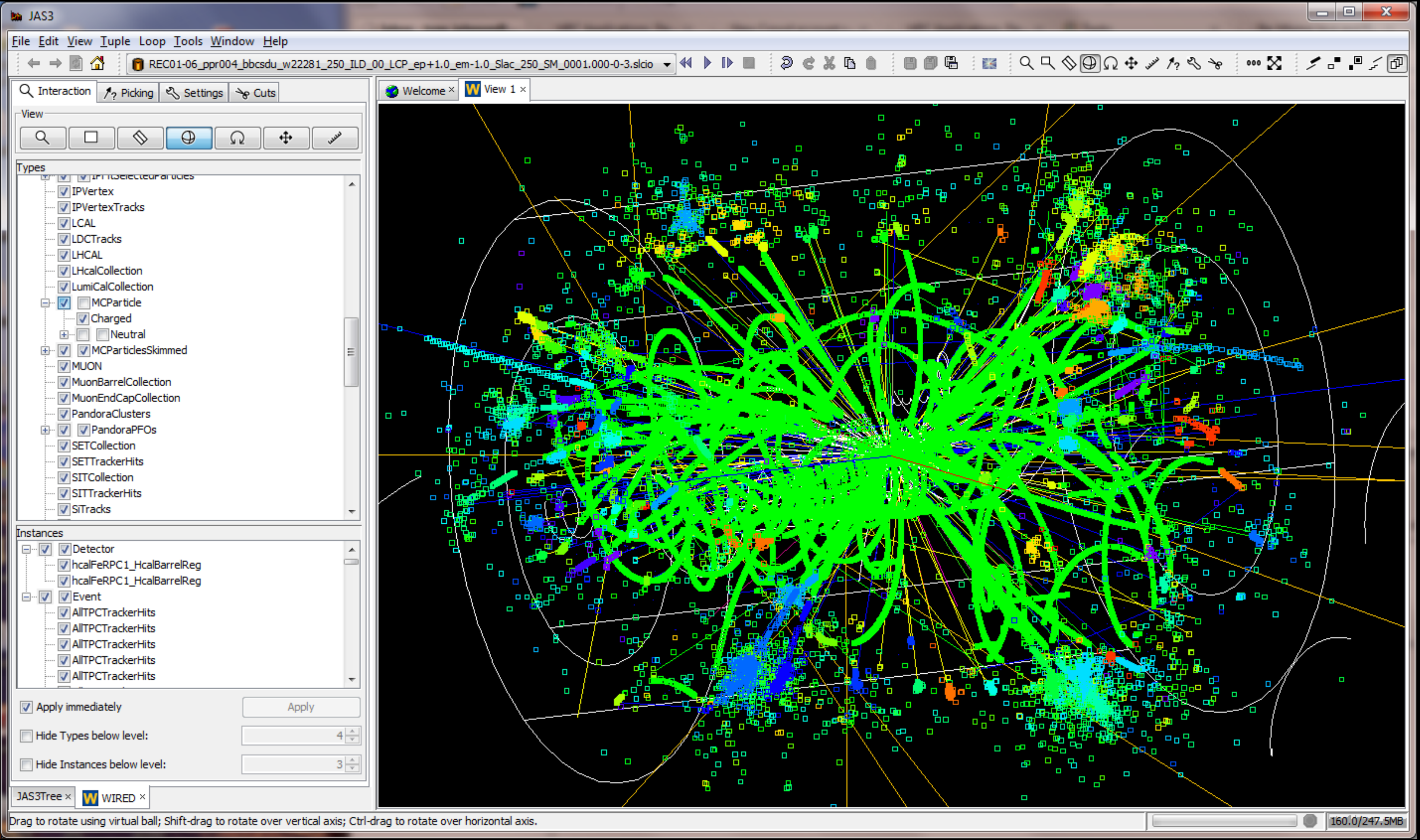
Key Features of lcsim

- Facilitate contribution from physicists in different locations with various amounts of time available.
    - Beginning students or postdocs often do detector development
    - Very easy for individual users to install
        - Doesn’t require local expertise
    - Extensive tutorials make getting started easy
    - “Zero to physics in 15 minutes”
- Modular suite of reconstruction and analysis tools
    - Extensive set of generic reconstruction algorithms
        - With examples of use
    - Allows new algorithms to be plugged into framework
        - Encourages development of experimental reconstruction and analysis algorithms

Lcsim Implementation

- lcsim is implemented in Java
  - Mainstream language familiar to most students
    - Easy to learn, foot shooting resistant
      - Garbage collection greatly simplifies OO design
    - Excellent open-source tools available
      - IDE’s, refactoring, debugging, project management, build systems
      - Many high-quality, open-source science libraries available
    - High performance
      - Most important metric is
        - Ease with which physicist having an idea can implement and test its effect!
  - Compile once and run on Mac, Windows, Linux
- Can be run either
  - Standalone with XML steering file (batch, Grid friendly)
  - Interactively inside Java Analysis Studio (JAS)
    - Renaming all classes to begin with T not required

WIRED event display



☑ Apply immediately

☐ Hide Types below level: 4

☐ Hide Instances below level: 3

Drag to rotate using virtual ball; Shift-drag to rotate over vertical axis; Ctrl-drag to rotate over horizontal axis.

Reconstruction/Analysis Overview

- Fast MC → Smeared tracks and calorimetry clusters
- Full Event Reconstruction
  - Beam background overlays at detector hit level, including time offsets.
  - detector readout digitization (CCD pixels, Si μ-strips, TPC pad hits)
  - *ab initio* track finding and fitting for ~arbitrary geometries
  - multiple calorimeter clustering algorithms
  - Individual Particle reconstruction (cluster-track association)
- Analysis Tools (including WIRED event display)
- Physics Tools (Jet Finding, Vertex Finding, Flavor Tagging)

Tracking

- Analytic covariance matrices available for fast MC smearing for each detector.
- Track “cheater” available for studies of full detector simulation events. Assigns hits on basis of MC parentage.
- Ab initio track finding packages.
- Fitting code incorporating multiple scattering and energy loss via weight matrix or Kalman Filter available.

Track Reconstruction

- Hits in Trackers record full MC information.
- Module tiling and signal digitization is deferred to analysis stage.
  - Used to rapidly study many possible solutions.
- Fully-featured package to convert MC hits in silicon to pixel hits. Fully configurable at runtime.

  MC Hits→ Pixel ID & ADC→ Clusters→ Hits (x ± δx)
- Correctly study occupancies, overlaps, ghost hits, etc.
- Standalone pattern recognition code for 1D (e.g. Si μstrip) and 2D (e.g. Si pixel) hits.
  - High efficiency, even in presence of backgrounds.
  - Efficient at low momentum.
- Track finding strategies automated.

Individual Particle Reconstruction

- Many clustering algorithms available for calorimeter shower reconstruction.
- Track-cluster association (aka Particle Flow Algorithm, PFA) implemented.
- Algorithms available for electron and muon ID
- Secondary vertex capabilities identify jet flavor
- Multiple jet-finding algorithms available.
- Plug-and-play reconstruction driven by runtime XML

Java Analysis Studio (JAS)

- Cross-platform physics analysis environment with iterative, event-based analysis model
  - quick development, debugging, ad hoc analysis
  - additional functionality with plugins
- Dynamically load / unload Java analysis drivers
  - Supports distributed computing.
- Plotting and fitting and analysis (cuts, scripting) engine
  - 1D, 2D histograms, clouds, profiles, dynamic scaling, cuts
  - high-quality output to vector or raster formats
- Integrated event browser and event display (WIRED)

Validated

- This suite of software tools provides:
  - Physics event generation & bindings to most legacy generators through the stdhep format.
  - Full detector response simulation using precompiled binaries & runtime geometry definition (no coding!).
  - Full detector digitization (x-talk, noise, diffusion, etc.)
  - Hit-level overlay of arbitrary background events.
  - Access to other LCIO-compliant software frameworks.
  - Full ab-initio event reconstruction and analysis suites.
  - Tested on hundreds of millions of events.

Simulation Summary

- ALCPG sim/reco supports an ambitious international detector simulation effort. Goal is flexibility and interoperability.
- Provides a complete and flexible detector simulation package capable of simulating arbitrarily complex detectors with runtime detector description.
- Reconstruction & analysis framework was used to characterize the Silicon Detector and was essential to that concept's successful validation in the LOI process.
- LCIO provides interoperability with tools developed in other regions (e.g. jet flavor tagging (LCFI), particle flow (Pandora)), other languages (FORTRAN, java, C++, python) and other analysis frameworks (e.g. Marlin, root).

Lcsim Status

- Performance
  - 1 years ILC data (~50 million events) simulated for ILC LOI
    - Slightly idealized geometries
      - SLIC/Geant4 (simulation, C++)
        - ~48 seconds/event, Peak memory ~480MB, Event Size: 165kB/event
      - org.lcsim (reconstruction, Java)
        - ~8 seconds/event, Peak memory ~450MB, Event Size: 220kB/event
- User base
  - ILC physics and detector community
    - primarily US and UK members of SiD
  - CLIC physics and detector community
    - CERN-based SiD' studies
  - Muon collider physics and detector community
    - Joint proposal for future lepton-collider studies submitted to DOE
  - JLAB heavy-photon search proposals
    - HPS: SLAC-based, fixed target, forward detector
    - DarkLight: MIT-based, gas-jet, asymmetric detector.
  - FNAL dual-readout crystal calorimetry

Additional Information

- Wiki - http://confluence.slac.stanford.edu/display/ilc/Home
- lcsim.org - http://www.lcsim.org
- 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