

*lcsim*  
*A Java-based Reconstruction  
package for Particle Physics*

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on behalf of

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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

The screenshot displays the WIRED event display software interface. The main window is titled "JAS3" and contains several panels and views.

**Left Panel (Cuts and Conditions):**

- Cuts:** A table with columns "Apply", "Name", and "Invert". It lists "Energy cut" and "multi".
- From Types:** A list of event types with checkboxes, including "DetectorType", "EventType", "EcalBarrHits", "EcalEndcapHits", "ForwardEcalEndcapHits", "HcalBarrHits", "HcalEndcapHits", "LuminosityMonitorHits", "MCParticle", "MuonBarrHits", "MuonEndcapHits", "TkrBarrHits", and "TkrEndcapHits".
- Conditions:** A table with columns "Apply", "Name", "Accept if", and "Invert". It lists "dedx", "energy", "mcenergy", "momentum", "pt", "radius", and "time".

**Right Panel (Views):**

- View 1:** A 3D wireframe view of the detector geometry with colored lines representing particle tracks.
- View 1-1:** A 2D projection of the detector geometry and tracks.
- View 2:** A 2D projection showing a dense cluster of tracks and hits, with a central region highlighted in green.

**Bottom Panel:**

- Energy Scale:** A vertical logarithmic scale from  $1.0e-8$  to  $1000.0$ . The current value is  $1.37e-8$ .
- Buttons:** "Log", "Apply", and "Reset".
- Status Bar:** "Click and drag a rectangle to pick objects." and "Prosto tak | 40.3/83.3MB".

# *Reconstruction/Analysis Overview*

- Fast MC → Smearred tracks and calorimetry clusters
- Full Event Reconstruction
  - Beam background overlays at detector hit level, including time offsets.
  - detector readout digitization (CCD pixels, Si  $\mu$ -strips, TPC pad hits)
  - *ab initio* track finding and fitting for  $\sim$ 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 ( $x \pm \delta x$ )
- Correctly study occupancies, overlaps, ghost hits, etc.
- Standalone pattern recognition code for 1D (e.g. Si  $\mu$ strip) 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>