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lcsim: An integrated detector simulation, reconstruction and analysis environment

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slic: Geant4 simulation program

As the complexity and resolution of particle detectors increases, the need for detailed simulation of the experimental setup also increases. Designing experiments requires efficient tools to simulate detector response and optimize the cost-benefit ratio for design options. We have developed efficient and flexible tools for detailed physics and detector response simulation which builds on the power of the Geant4 toolkit but frees the end user from any C++ coding. The primary goal has been to develop a software toolkit and computing infrastructure to allow physicists from universities and labs to quickly and easily contribute to detector design without requiring either coding expertise or experience with Geant4.

Geant4 is the de facto high-energy physics standard for simulating the interaction of particles with fields and materials. However, the end user is required to write their own C++ program, and the learning curve for setting up the detector geometry and defining sensitive elements and readout can be quite daunting. We have developed the Geant4-based detector simulation program, slic, which employs generic IO formats as well as a textual detector description. Extending the pure geometric capabilities of GDML, LCDD enables fields, regions, sensitive detector readout elements, etc. to be fully described at runtime using an xml file. We also describe how more complex geometries, such as those from CAD programs, can be seamlessly incorporated into the xml files. We provide executable programs for Windows, Mac OSX and Linux, allowing physicists to design detectors within minutes.

We present the architecture as well as the implementation for several candidate ILC, CLIC and Muon Collider detector designs. We also describe the implementation of a fixed target experiment (HPS at JLab) and a proton computed tomography (pCT) implementation, demonstrating both the flexibility and the power of the system.

org.lcsim: event reconstruction and analysis

Maximizing the physics performance of detectors being designed for the ILC, while remaining sensitive to cost constraints, requires a powerful, efficient, and flexible simulation, reconstruction and analysis environment to study the capabilities of a large number of different detector designs. The preparation of Letters Of Intent for the ILC involved the detailed study of dozens of detector options, layouts and readout technologies; the final physics benchmarking studies required the reconstruction and analysis of hundreds of millions of events.

We describe the Java-based software toolkit (org.lcsim) which was used for full event reconstruction and analysis. The components are fully modular and are available for tasks from digitization of tracking detector signals through to cluster finding, pattern recognition, track-fitting, calorimeter clustering, individual particle reconstruction, jet-finding, and analysis. The detector is defined by the same xml input files used for the detector response simulation, ensuring the simulation and reconstruction geometries are always commensurate by construction. We discuss the architecture as well as the performance.

In addition to the ILC LOI studies, we describe the use of the org.lcsim software at CERN for CLiC physics and detector studies which culmintaed in the successful completion of their CDR, its application for dual-readout crystal calorimeter detector R&D at Fermilab, and detector design and event reconstruction, including an online trigger, for the proposed "heavy photon" experiment HPS at JLAB.

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