North American Linear Collider Detector Simulations

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Abstract

The detector simulation facility in use by the North American study group provides both a fast parametrized and a detailed full simulation of generic detector designs. It allows comparison of a range of detector design options. MC farms have been set up at several institutions to generate sizeable datasets for the collaboration. The simulation code is C++ with output allowing for reconstruction and analysis in JAS/Java and Root/C++ environments.

Keywords: simulations

1 Introduction

The North American study group (LCD) has as its goal the ability to compare a variety of contrasting detector models. We have constructed a simulation facility that allows considerable flexibility in defining the detector layout via an input ASCII configuration file.

Full simulation is done using the Gismo package. It is a full-featured simulator with a rich geometry description and full calorimetry simulation using EGS and Gheisha. Gismo also features a built-in 3-D event display.

The simulation is customized to LCD by definition of the detector geometry and of the digitization for the tracking, calorimeter and muon systems. All digitizations carry a full record of their particle parentage. The underlying physics events are input in standard HEPEVT format using the FNAL StdHep I/O package, while output goes to a compressed ASCII file. This latter format is being replaced by a custom binary format readable from both C++ and Java. The primary reasons for the binary format are numerical precision, better control of versioning and modularity of subsystem data blocks.

The detector components are typically cylindrical; all are rotationally symmetric. This design choice was based on the belief that the early stages of the simulation effort would not require fine detail in the apparatus description. Additioally it assumed that the range of detector types to choose from is limited. Once the higher level design choices had been made (eg TPC vs silicon strip tracker). the facility would migrate to a more custom and detailed geometry description.

Multi-layer units can be defined allowing specification of materials, thickness and whether the material response is read out or not. Some custom elements are coded in, for example the instrumented masks and the beampipe layout, though their dimensions are still externally set. As an example of the flexibility of the package, it is possible to easily specify from the input parameter file such different devices as a silicon strip tracker or a TPC to be the tracker. These are specified just by the description of the physical layout, not as pre-defined devices.

2 Simulation Strategies

The LCD group decided to focus on two quite different designs for its initial studies. See the talk by Jim Brau at the 1999 Sitges meeting for details on the designs. One of these designs was of a compact detector featuring a very strong magnetic field and solid state tracking. The calorimeter is also compact and composed of Si-W. The second design is of a much larger device with a lower magnetic field and larger tracker (TPC) and calorimeter composed of Pb-scintillator. Both devices feature pixel-based vertex detectors.

These two designs are also featured for Fast MC simulation. Track smearing is done via lookup tables binned in momentum vs polar angle. See Bruce Schumm's talk at the Sitges conference for details on the algorithm for generating the tables. Calorimetry simulation follows extrapolating the particle trajectory through the magnetic field and smearing the observed energy. Clusters can be merged based on their width and position.

An important study is how good energy flow can be in these detector designs. It is envisaged that track momenta will be used for the charged particles, and unassociated calorimeter clusters will give the energy deposited by neutrals. This will depend on details of charged and neutral shower overlap in the calorimater, segmentation and magnetic field magnitude. Output data structures need sufficient information to untangle the mess. We achieved this in the calorimeter by keeping track of every MC particle's contribution to each tower segment. For bookkeeping purposes, all energy in a shower was attributed to the particle incident on the calorimeter, ie all energy deposited by shower secondaries were attributed to the original parent hitting the calorimeter. Albedo leaking back into the central detector were put on the real particle stack. Shower secondaries originating in the central detector were all treated as real particles. Since we record each trajectory point and energy loss in the tracking systems, it is also possible to keep track of the full parentage of tracking hits.

Hit smearing in the tracking systems is postponed to the reconstruction stage to allow maximum flexibility in modelling the response, both in terms of position resolution and hit merging. The particle's position, direction and energy loss crossing the tracking plane are recorded in the output file. Calorimeter tower energies are summed up in the digitization phase.

3 Event Generation

Several sites across North America are engaged in event production for the LCD effort. The full simulation takes about 2 minutes per event on a 400 MHz Sun machine. The code has been ported to several platforms: Solaris, Linux, AIX, DEC unix and Windows NT/9x. The University of Pennsylvania acts as a repository for the output of the MC farms. Automatic scripts push the data from the farms to Penn, which then automatically converts the output files for JAS and Root analysis and generates web catalogues of the files.

4 Event Reconstruction and Analysis

Once the Gismo output files are converted at Penn, they are available for reconstruction and analysis. Our policy so far has been to restrict development of reconstruction algorithms to be in Java, mostly with the JAS analysis system. Event analysis in Root is also supported. See Tony Johnson's talk at this conference for a description of the JAS system and the LCD reconstruction code status.

5 Future Plans

After gaining experience with the Gismo simulation package, it has become clear that it does not have all the features it needs for a general purpose HEP detector. It also does not have sufficient manpower for its support for the HEP community. It is currently supported by the GLAST collaboration for its own specific use.

Hence it is our plan to convert to GEANT4. We are, however, disappointed that GEANT4 only allows Gheisha for its hadronic shower simulation.

An important addition to our simulations will be handling the machine backgrounds that accompany the beams. Potentially there will be many thousands of such low energy particles to handle. We expect to generate libraries of such particles and then superimpose them on the physics events at reconstruction time.

We have become aware that a truly flexible simulation facility requires that the parameters be made easily available to all steps of the event handling. To this end, we have made use of XML to give self-describing ASCII parameter files and general utilities to extract the parameters from the file. We expect this strategy to solve the problems of ubiquitous access to the parameters. We still have not adequately dealt with the problem of guaranteed binding of the input parameters to the output dataset. The fact that the datasets are distributed to collaborators makes it difficult to be sure the parameter files follow along.