European Laboratory for Particle Physics

Summer Student Project

Making Physics tangible

Event Display for the L_3 Detector

Christian Buth
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Abstract

In this report I describe my work on the L_3 event display. I implemented the display of data generated by a *Monte Carlo* simulation, the dumping of event related data when objects are selected by the user, the performing of simple calculations with selected objects in the event and I improved the rendering of tracks and hadron calorimeter hits. I tried to assure the quality of the program by extensive testing and error correction.

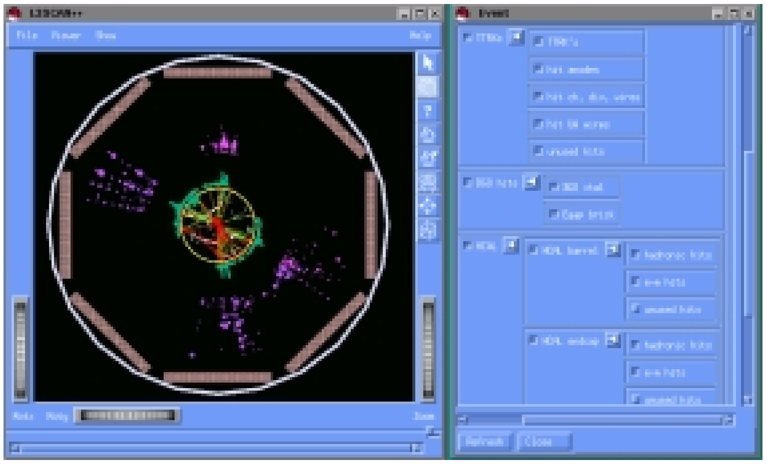

Figure 1: Classical display of a reconstructed event. You are looking along the beam pipe.

1 The issue of an event display

When a positron and an electron collide deep below the surface of the earth in one of the four LEP[1] detectors there are only voltages measured and, after a preselection, these sets of voltages are written on tapes. All readings taken for one event are stored in a so-called event file. These files are very large, around *300 Kilobyte*, and thus there is no sense in taking a dump of this data and looking at it to see what actually happened in the detector. Typical examples are shown in the figures in this report. A classical view is figure 1.

At this point an event display ist introduced. These programs present the recorded data in such a form that human beings are able to understand them. The detectors are three-dimensional devices so all information collected of an event is also inherently spacial. This causes some difficulties in designing an display program, because it must be able to visualise three-dimensional data on a two-dimensional media, i.e. on a screen or a sheet of paper.

If this problem is solved properly using advanced visualisation technics then people can actually understand what happens in events by looking at the produced graphics.

2 The event display of L_3

The event display of the L_3 detector was written by a small group of physicists and it is called `L3 Scan`. The finishing touch was done by my supervisor Thomas Paul whom I joined during the summer in course of a *Summer Student Program*.

`L3 Scan` heavily relies on the modern *object oriented* 3D graphics library *OpenInventor*. This library provides the event display with a convenient interface to the underlying render engine. The programmers thus are free to tackle the problems arising from physics and do not have to cope with too many computational problems. This makes rapid development possible.

When I arrived at CERN this program was nearly finished. My task was to implement

[1] LEP is and abbreviation for Large Electron Positron collider.

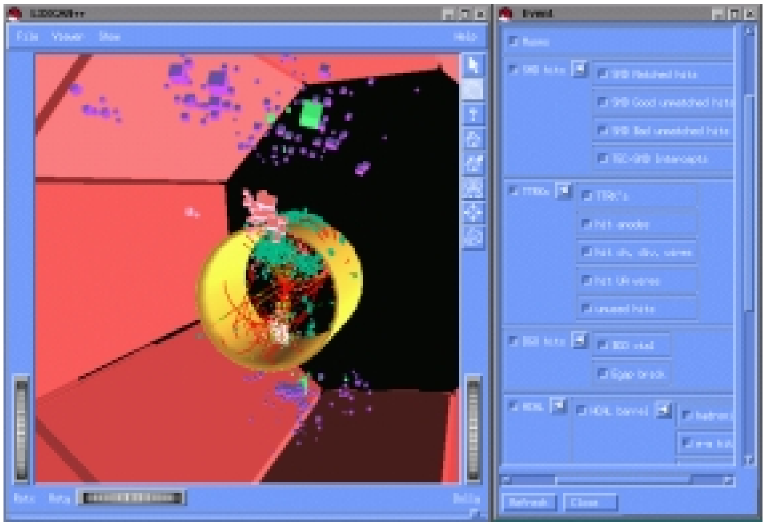

Figure 2: W pair. On the right hand side there is the control panel to control which objects shall be displayed.

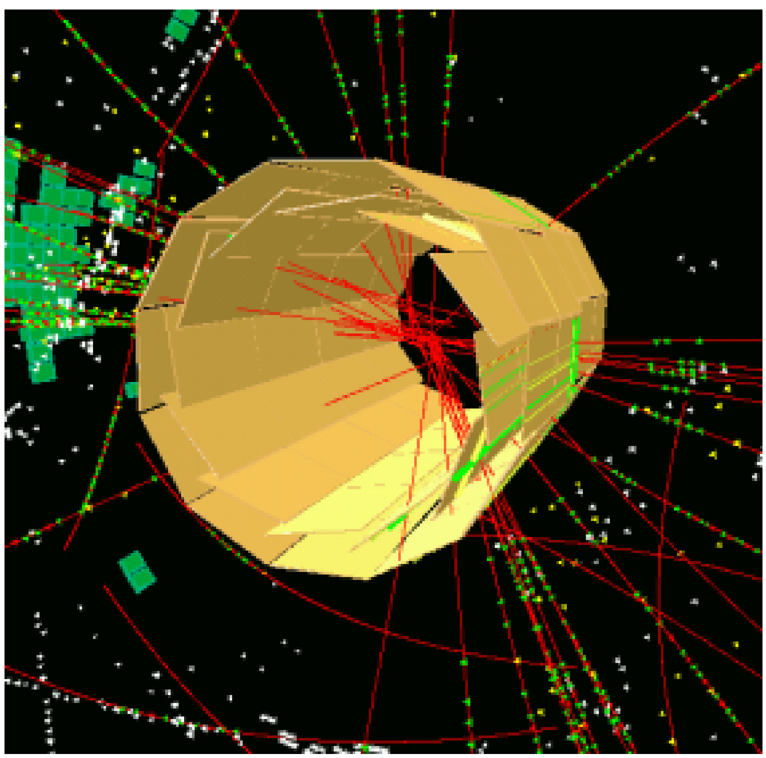

Figure 3: Reconstructed event in the silicon microvertex detector (SMD).

small new features that make the program more advantageous for users. My achivements are

1. Implementing the display of data generated by a *Monte Carlo* simulation.
2. Displaying event related data when objects are selected by the user.
3. Performing simple calculations with selected objects in the event.
4. Improving the rendering of tracks and hadron calorimeter hits.
5. Assuring the quality of our product by extensive testing and error correction.

In the following sections I will describe how I managed to implement these new features.

3 Display of Monte Carlo Simulations

Monte Carlo simulations are an important tool to investigate the response of a detector to a physical event. Real events can be compared to simulated ones and conclusions can be drawn from this, for example the quality of the simulation can be investigated and improved. This leads to a deeper understanding of the underlying physics that is involved. Simulated events are also crucial to disentangle effects of physics and effects of the detector response.

The simulated event has nearly the same data format as the real one, so `L3 Scan` can be used to display this data, too. The extra information available in the Monte Carlo files is used for a *decay tree* where the whole decay chain, starting with the collision of a positron with an electron, is drawn and each particle in the event can be selected for display individually. Figure 3 shows a simulated event and its traceback.

My task was to render helicoidal tracks according to the strength of the magnetic field of the L_3 magnet. A main difficulty arose from the fact, that the Monte Carlo simulation does not account for L_3's magnetic field and thus decay points of secondary particles with charged mothers where displaced a little. I had to find out how to allow for the magnetic field and how to displace the secondary particles according to the bent tracks of their mothers.

In the business of visualisation the issue of strong impression and feeling for what is going on is of paramount importance to make the display a helpful and beneficial aid to the physicists. Bearing this in mind I designed a colour scheme for particle tracks in my Monte Carlo simulation display. It should be simple that it does not confuse the user and it should distinguish clearly between certain classes of particles.

My supervisor and I chose to give each lepton a distinct colour. The neutrinos are then drawn with a broken line style to visualise the difference to the associated leptons. Mesons and Baryons are coloured all the same.

Implementing these neat new features was my major contribution to `L3 Scan`.

4 Information at your Fingertips

A design goal of the event display is to provide physicists with all relevant data about events by clicking on them. To achieve this one has to extract the relevant information

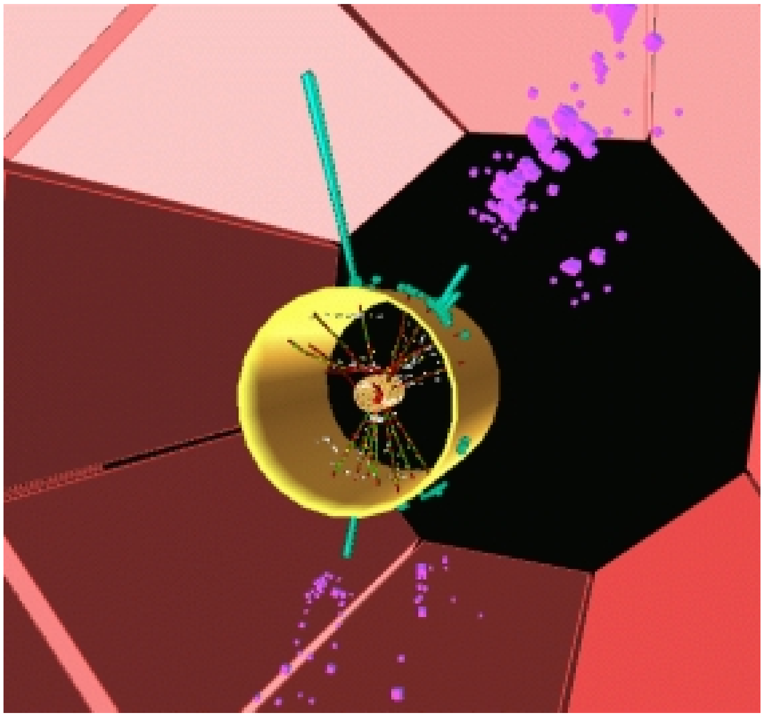

Figure 4: W pair $e^+e^- \to W^+W^-$, $W^+ \to e^+\nu_e$ and $W^- \to q\bar{q}$.

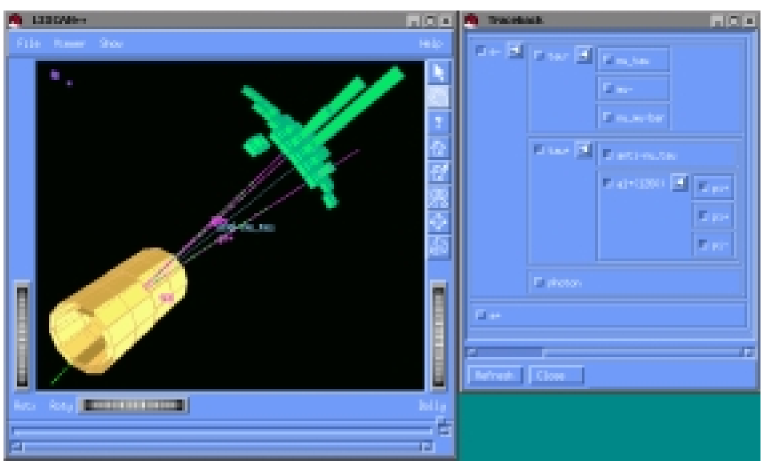

Figure 5: Monte Carlo traceback. Here you can see the decay tree on the right.

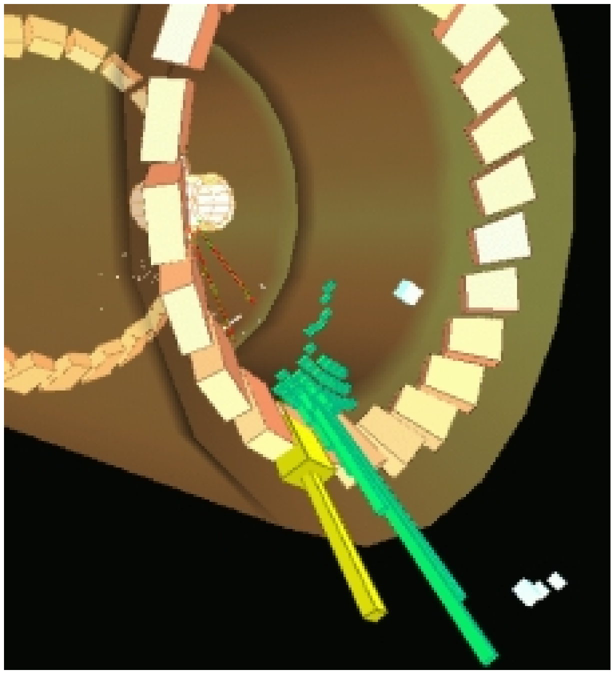

Figure 6: A hit in the electromagnetic calorimeter gap.

out of the event files and present them in a useful manner. There are dozens of distinct detector components that deliver data. The readings depend highly on the specific technical design of each component.

To judge the relevance and usefulness of events the *invariant mass* serves as an important criteria. So I implemented code to calculate the invariant mass. This can be done by clicking on several tracks while holding down the `SHIFT` key to select a selected group. After each selection the invariant mass is recalculated and displayed.

5 Rendering of event components

I improved the rendering of tracks and hadron calorimeter hits. The former were rendered using an abundance of control points connected by simple lines. As this is very slow and inaccurate, so I revised the rendering and reduced the number of control points needed. The latter were simple cubes where the volume of each cube was proportional to the deposited energy. By enclosing these cubes with a wire frame I could make the three-dimensional impression of the hadron calorimeter stronger.

6 Quality Software

I put much effort in assuring the reliability and usability of `L3 Scan`. Later on other physicists will use this program to get a clue of how their physical topic looks like and to illustrate their papers. These people will not likely have any idea of how this program works. This knowledge shall not be required to run it. Its aims are to be a useful standard tool for L_3 physicists which they like to use.