The incorporation of an NLO capability in to HzTool and refinements in the functionality of ZEVIS, an event display for ZEUS

Abstract

In this document I shall be highlighting the work that I have carried out during the first nine months of my phD. As the above title suggests, this work as been centred around two software packages which are extensively used on the ZEUS experiment. The first is *HzTool*, a package for Monte Carlo generation-data comparisons at HERA (and other accelerators). The second software package which I have been working on is the ZEUS event display *ZeVis*. More specifically, I have been working on improving the functionality of the *Central Tracking Detector* (CTD) display. In this document I shall present the developments and progress of this work.

1 Introduction

The past few months have seen a shut down of the HERA ep collider and the ZEUS detector in Hamburg, Germany. Following the 2000 shutdown there were serious problems with high background rates. The purpose of the original shut down was to increase the luminosity by up to five times and to install a *Micro Vertex Detector* (MVD) in to the central region of ZEUS. The two collider experiments (ZEUS and H1) can still tolerate only a fraction of the HERA 2 design luminosity because of high background rates in the main drift chambers. Although not completely understood the backgrounds can be resolved in to three distinct categories:

- Double-scattered synchrotron radiation, which is quite well understood, with measures for reduction in the final design stages.
- Lepton beam-gas scattering, which is also quite well understood but for which measures for only limited reduction have been identified and designed.
- Proton beam-gas scattering, which is the most serious problem, but is requiring continuing strong efforts to understand completely.

Work on the upgrades neccesary to counter this background as well as more general upgrades to the detector have taken place since the latest shutdown began in March of this year. The shutdown is in it's final stages and

data taking should take place towards the latter quarter of the year. Although the shut down has meant a cessation of data acquisition over this period, the year has been far from quiet with the analysis of data taken so far still continuing in earnest.

During this discussion I shall not begin with the obligatory introduction to the ZEUS experiment and detector as there are a multitude of such sources in the literature[1][2][3]. However I will later discuss the CTD in some detail, as this is directly relevant to the work on ZeVis that I've undetaken. This document will be split in to three main sections. In the first section I will discuss the work on HzTool that I have carried out. In the second section I will discuss the work that I have undertaken on ZeVis and lastly in the third section I will discuss my plans for the future, including my thesis project work.

2 HzTool

2.1 The principles of HzTool

HzTool is a fortran based program which principally consists of a library of fortran routines, each one been associated with a published paper. Each routine, which corresponds to a certain paper, contains the published data as well as information which is neccessary to build up Monte Carlo (MC) comparisons with that data. This information consists of the cut's used in the particular paper as well as such information as what type of jetfinder was used etc. These routines should ideally be written in conjunction with the publication of a paper. These routines can then be in corporated in to mother routines which are responsible for the generation of the MC events themselves. When these routines are run, an event is generated and the user written routines are called to check whether or not this event passes the cuts imposed by that routine. It is important to note that we can incorporate as many of the user written routines in to the mother program as we like. So we can generate MC comparisons for many different sets of publsihed results, simultaneously. By looping over the required number of events the MC comparisons are generated. Each mother program requires a control card which allows the user to select certain generator specific variables. More information on HzTool can be acquired from the HzTool manual[4].

2.2 Incorporation of DESY paper 02-228 in to HzTool

One of my principle acheivements during the past four months has been the incorporation of a new HzTool user routine (HZ0228) in to the HERA library. This routine was written for the ZEUS collaboration paper[5]. The interested reader can check the paper for exact details of the analysis. Here, we are more concerned with the HzTool routine that was implemented for this paper. I will however quickly present a synopsis of the abstract for this paper so that the plots shown in this document are not completely meaningless. During the study, differential cross sections for jet photoproduction in the reaction ep $\rightarrow$ e jet X were measured with the ZEUS detector at HERA using 82.2 pb^{-1} of integrated luminosity. Inclusive jet cross sections were presented as a function of the jet transverse energy E_T^{jet}, for jets with $E_T^{jet} > 17GeV$ and pseudorapdity $-1 < \eta^{jet} < 2.5$, in the γp centre-of-mass-energy range $142 < W_{\gamma p} < 293$ GeV. Also scaled jet invariant cross sections were presented as a function of the dimensionless variable $x_T \equiv 2E_T^{jet}/W_{\gamma p}$ for $< W_{\gamma p} >=$ 180 and 255 GeV. The plots from the paper as well as those generated from my HzTool routine are shown in figures 1 to 6. Please note, that all of these MC results have been obtained with the Herwig generator The HzTool plots are in fairly reasonable agreement with the paper[5]. There is still a bit of refinement to be done on the routine as the MC generated results are still not quite in agreement with the paper, but it is reasonably good.

2.3 Additon of HZ02228 to JetWeb

2.3.1 Overview of Jetweb

JetWeb is a World Wide Web (WWW) interface for Monte Carlo tuning and validation[6]. The aim of the package is to allow rapid and reproducible comparisons to be made between detailed measurements at high-energy physics colliders and general physics simulation packages. The package includes a relational database, a Java servlet query and display facility, and clean interfaces to simulation packages (namely HzTool) and their parameters. A detailed overview of Jetweb is available elsewhere[7].

2.3.2 Incorporation of HZ02228

The HzTool routine HZ02228 described in section 2.2 has now been fully implemented in to JetWeb and the plots from the zeus paper[5], upon which the routine is based, are now available when searching the JetWeb database. An example of a search result for this paper is shown in figure 7. Although the fit in this case is obviously not particularly pleasing, I have merely showed

an example of a search result from the "Herwig latest" option of the JetWeb homepage, to indicate that the HZ02228 routine has been incorporated in to JetWeb.

2.4 Incorporation of an NLO capability in to HzTool/JetWeb

My other main area of work, and which has taken up the majority of my efforts during the past months is the incorporation of an NLO generator in to HzTool so that *Next to Leading Order* (NLO) comparisons can be made with data. As it stands, only *Leading Order* (LO) MC comparions, using Herwig and Pythia, can be carried out. We have chosen Frixione's NLO code to incorporate in to HzTool and much of the work in doing so was carried out a couple of years ago by John Butterworth. Having lain dormant for a while, I have restarted this work. As of yet, there are no results of any note to actually show. I am still having difficulty reconciling the ouput of the stand alone version of Frixione's NLO code with that of the version which has been incorporated in to HzTool, a crucial test of the HzTool version of the code. Once this NLO capability has been incorporated in to HzTool then JetWeb can be suitably modified to provide a clean interface to this new functionality.

3 Refinements to the CTD display functionality of ZeVis

3.1 Brief introduction to the ZEUS central tracking detector

The CTD is a large vloume cylindrical gas container with an inner and outer radius of 18.2cm and 79.4cm respectively and an active length of 205cm. The chamber was designed around the use of an Argon, ethane and carbon dioxide mixture which is bubbled through alcohol before been pumped in to the CTD chamber. The majority of the total angular acceptance of the tracking detectors of the ZEUS detector is provided by the CTD with an angular coverage of $15^\circ < \theta < 164^\circ$. The wire chamber consists of nine superlayers containing wires with eight sense wires per cell (figure 9). The odd numbered superlayers have wires parallel to the chamber axis; so called axial layers, whereas the even numbered superlayers are at a small stereo angle ($\sim \pm 5^\circ$), thereby providing good z position measurement. Superlayers one, three and five are also equipped with a z-by-timing system for trigger

purposes. This determines the z position of a hit by considering pulse arrival times at each end of the chamber.

3.2 The new ZEUS event display, ZeVis

ZeVis is the new event display for the ZEUS experiment. The idea for ZeVis was originally conceived in early 2001 as a replacement to ZeVis's predecessor LAZE. LAZE was a very accomplished tool which, over the years, has provided invaluable services to the experiment. However it suffered badly from a lack of maintenance over many years and so it was decided to introduce a new initiative for a common, integrated event display. ZeVis is written in C++ and is written within the ROOT framework. There were many advantages to choosing ROOT

- Root is a powerful package for mass storage, analysis and display.
- Written in C++ (and also uses C++ as a macro language)
- Well developed by many authors and often released
- Well documented and supported
- High portability
- Widely used in other event displays, most notably CDF and BaBar.

Figure 10 shows an example screenshot from ZeVis. More information on the event display and particularly the coding behind it can be found on the ZeVis website[8].

3.3 CTD display refinements

A lot of the CTD functionality that was in the old event display LAZE has already been incorporated in to ZeVis. The user is able to draw tracks, raw hits and reconstructed hits. There are a couple of issues that remain to be addressed. The first, and one of the most important, is the display of Z by timing raw hits. This information is available from the hit data on superlayers one, three and five(as discussed earlier). The second issue, concerning the CTD display, is the display of drift times. Lastly, the third issue is that we would like to have an option that if the user clicks on a specific track in the CTD then all the hits corresponding to that track are drawn. I have completed the first task and I have made reasonable progress on the second.

3.4 The display of Z by timing raw hits

Physics data that is recorded by the ZEUS detector is stored in ADAMO tables. A CTD raw hit is recorded in terms of the superlayer number, cell number and wire number of the hit wire. The most general raw hits do not contain any Z[1] information. Such a raw hit is therefore represented by a two dimensional point that may only be drawn in the XY view of ZeVis (as there is no Z information). The hit can not be drawn in ZR view (see figure 10 for what these two views, ZR and XY, actually look like). But Z information is available for the CTD raw hits via the TCBZ Adamo table which store hit information from superlayers one, three and five which are equipped with a Z by timing measurement system. I have now incorporated new routines in to the ZeVis code which decode the TCBZ Adamo table and allow hits to be drawn in all views. An example of this new display functionality is shown in figure 11.

4 Final remarks and future plans

In the preceding sections I have illustrated the work that I have carried out to date. I've also illustrated some of the future work that I need to carry out. With regard to ZeVis I need to complete the coding which will allow track specific hits to be drawn on the CTD display. I also need to complete the incorporation of NLO routines in to HzTool. Presently I have had a good opportunity to do this by assisting Matthew Lightwood with the NLO MC comparisons that he has had to generate for his charm analysis[9]. This should provide me with a clearer understanding of how the NLO routines work and assist me in incorporating the routines in to HzTool. I also want to get involved with the Java programming side of JetWeb so that I can build on my programming skills. Also an opportunity has arisen recently to work on the PDF fitting group here at DESY which sounds very interesting and for which I am presently making inquiries. On top of this I also have my standard ZEUS responsibilities for doing shifts as well as been a member of the CTD on-call team and also the resident CTD gas expert. And finally, not to forget my thesis work, I will be working on studies concerning the high-x_p gluon structure of the proton.

[1]The ZEUS coordinate system is referenced from zero at the interaction point having the proton beam direction defining the z-axis. The x-axis is perpendicular to the beam direction pointing towards the center of the ring and the y-axis upwards

References

[1] See any ZEUS thesis e.g B J West, Charm and the Virtual Photon at HERA and a Global Tracking Trigger for ZEUS, RAL-TH-2001-008.

[2] The ZEUS Detector Status Report 1993, DESY 1993

[3] Lots of introductory detector information, with pictures at http://www-zeus.desy.de.

[4] "HzTool - A Package for Monte Carlo Generator-Data Compariosns at HERA (version 2.0)", June 2000.

[5] "Scaling violations and determination of α_s from jet production in γp interactions at HERA", DESY-02-228, Decemeber 2002.

[6] http://jetweb.hep.ucl.ac.uk/

[7] "JetWeb:A WWW Interface and Database for Monte Carlo validation and Tuning", October 2002, UCL/HEP 2002-04

[8] The ZeVis homepage can be found at http://www-zeus.desy.de/∼zevis

[9] http://www-zeus.desy.de/∼lightwd

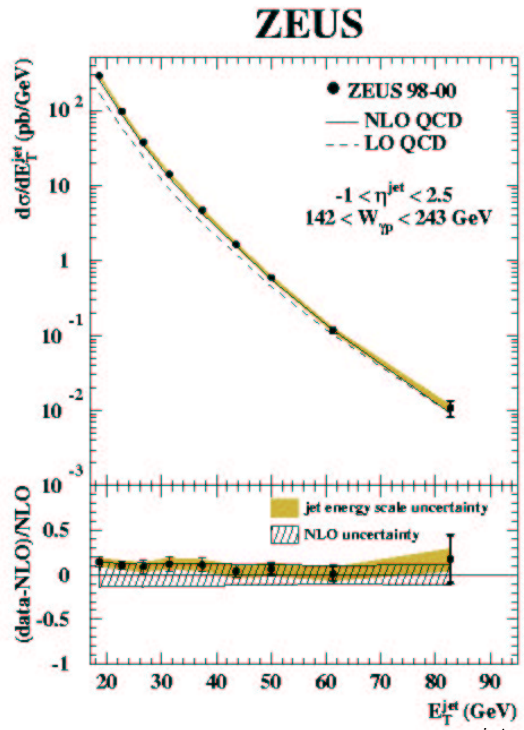

Figure 1: Measured inclusive jet cross section, $\mathrm{d}\sigma/\mathrm{d}E_T^{jet}$ (dots), taken from the paper DESY-02-228

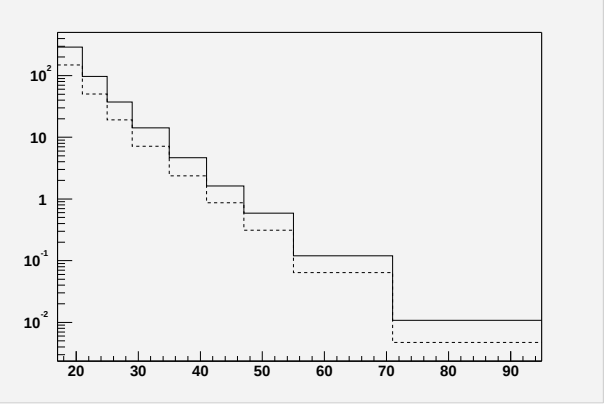

Figure 2: The HzTool generated plot for the above figure. The axes of this plot are labelled identically to the axes in figure 1. The solid line shows the data from the paper and the dashed line shows the MC comparison.

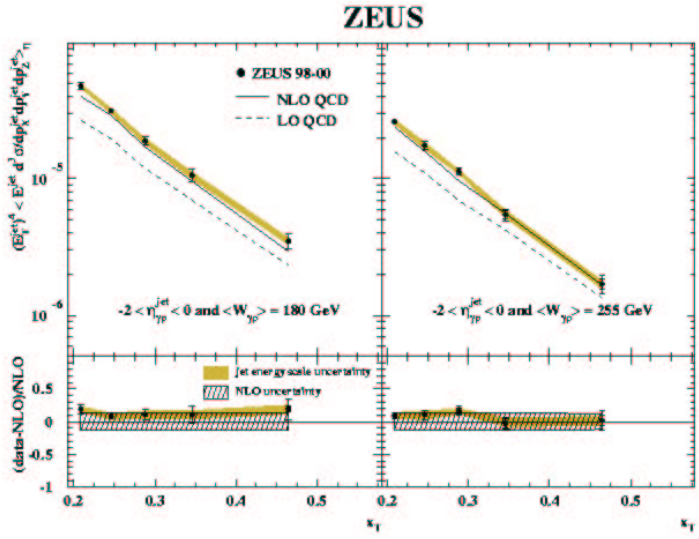

Figure 3: Measured scaled jet invariant cross section, taken from the paper DESY-02-228

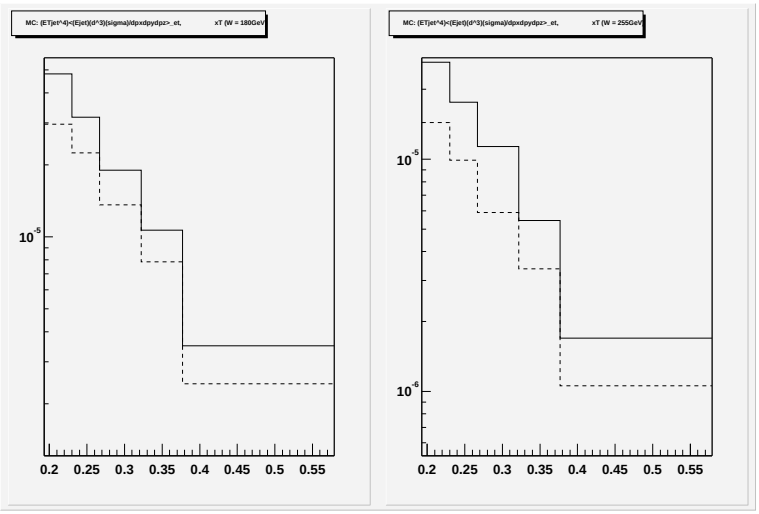

Figure 4: The HzTool generated plots for the above figures. The axes of these plots are labelled identically to the axes in figure 3. The solid lines show the data from the paper and the dashed lines show the MC comparisons.

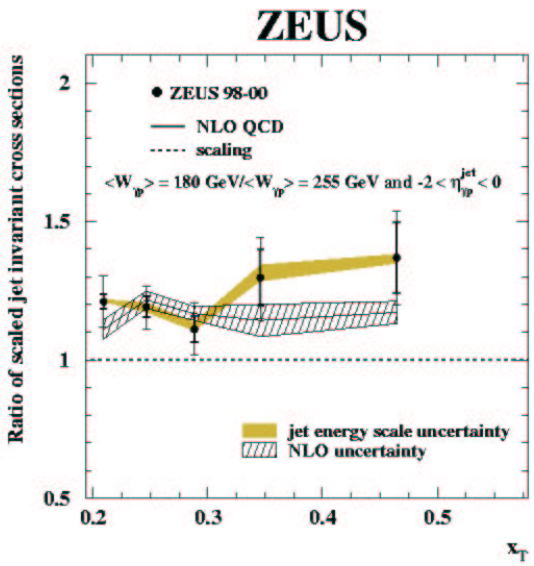

Figure 5: Measured ratio of scaled jet invariant cross sections, after correcting for the difference in the photon flux between the two $W_{\gamma p}$ intervals, as a function of x_T (dots)

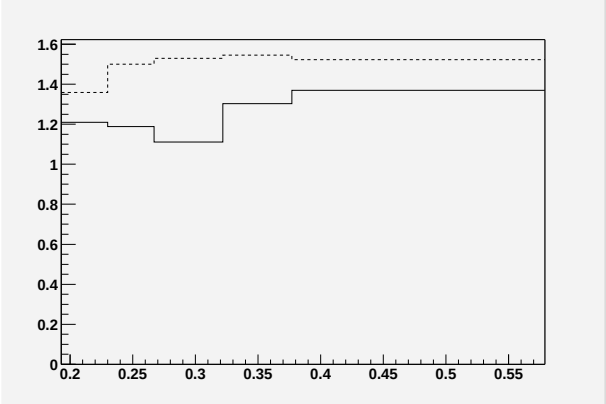

Figure 6: The HzTool generated plots for the above figure. The axes of this plot are labelled identically to the axes in figure 5. The solid lines show the data from the paper and the dashed lines show the MC comparisons.

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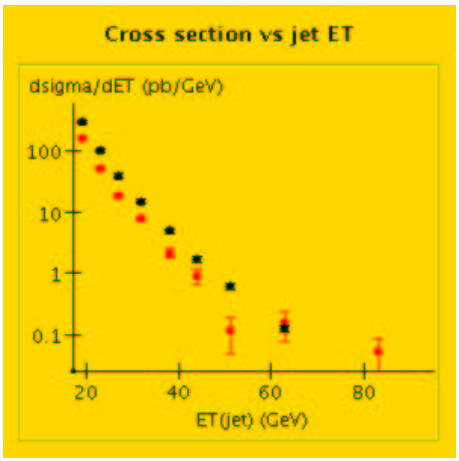

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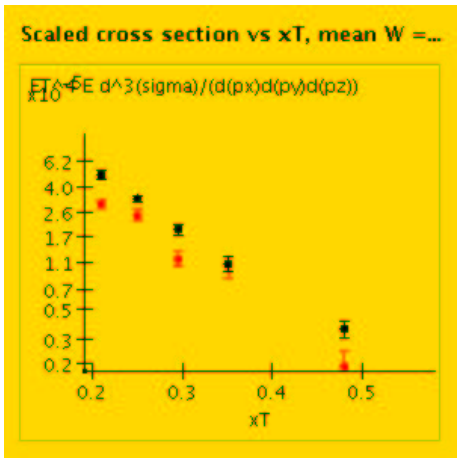

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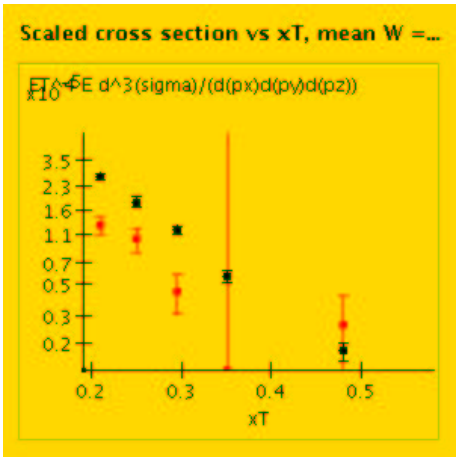

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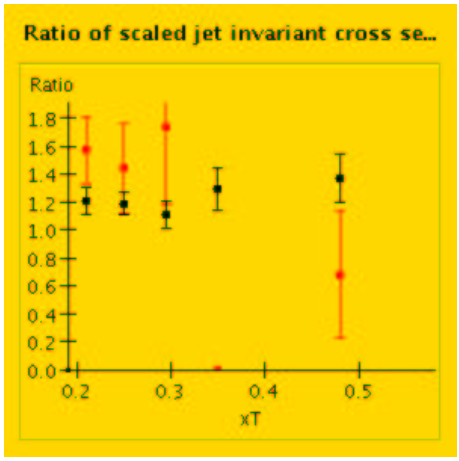

Figure 7: Example of a JetWeb search result (Herwig) for the ZEUS paper[5].Starting in the top left corner and moving clockwise these plots correpsond to those shown in figures 1,3 and 5 respectively.

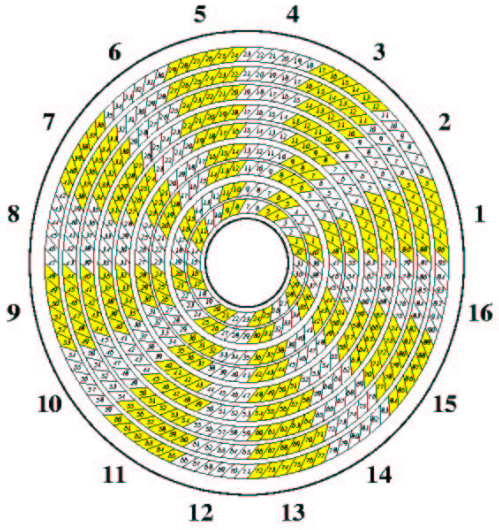

Figure 8: Cross sectional view of the ZEUS CTD showing the organisation of sectors, superlayers and cells

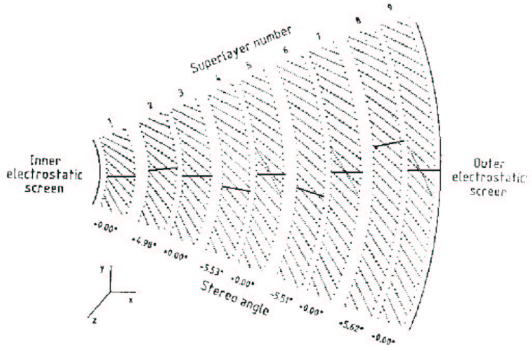

Figure 9: A closer look at a sector of the CTD. This diagram clearly shows the elevation of the wires that constitute the even numbered superlayers

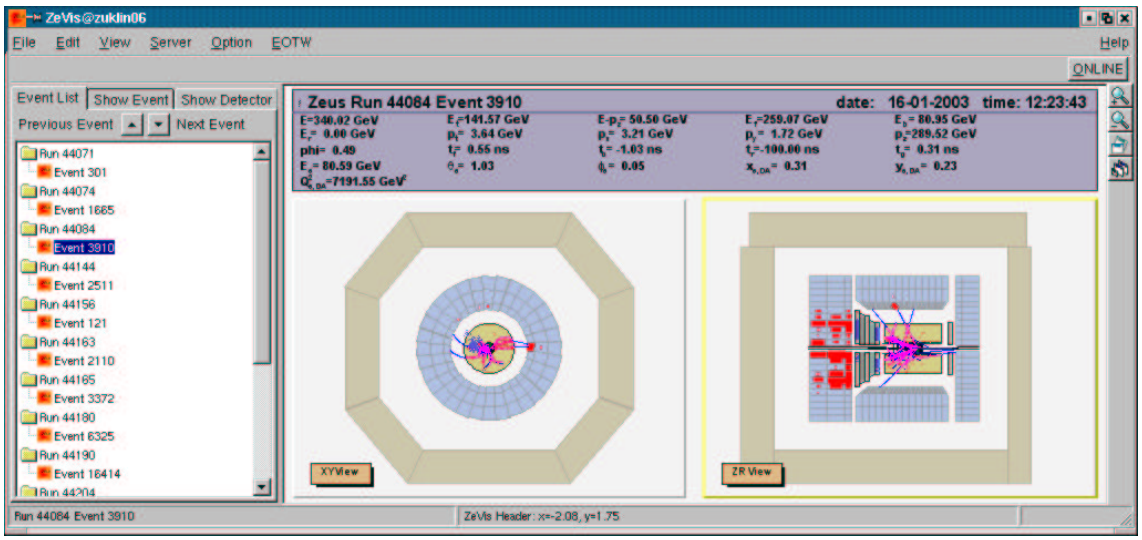

Figure 10: An example screenshot from the ZeVis event display. The event is one of the current events of the week from the ZEUS experiment.

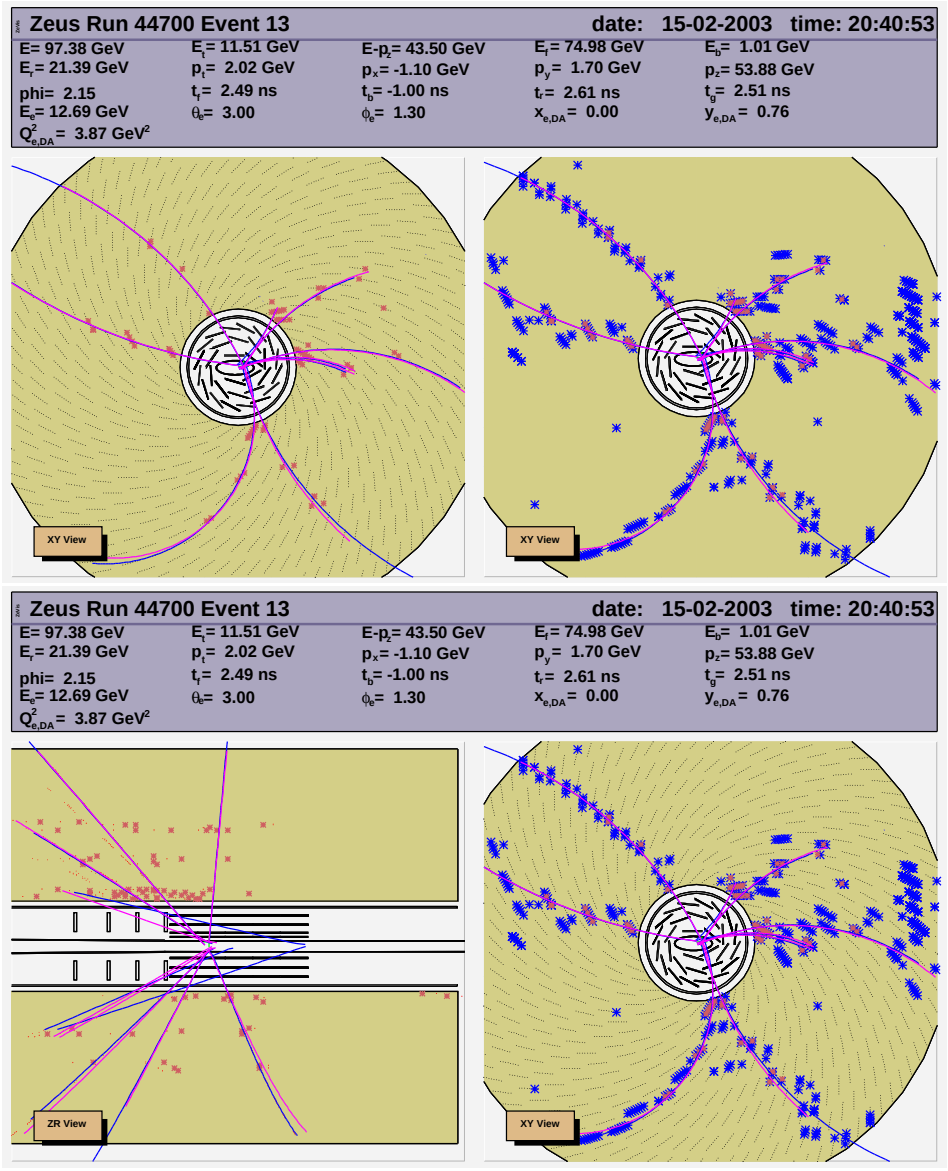

Figure 11: An example of the new CTD display functionality which displays Z by timing raw hits. The top view emphasises the XY view. The blue points show the old general raw hits and the red points show the new Z by timing hits. The bottom figure shows the ZR view, from which you can clearly see the Z by timing hits displayed.