unequal response to e and h, comparison between Monte Carlo and real data should be made with care.

One of the detector effects that is not covered by calibrations is dead material(coils, pipes, cables) in front of the CAL. These dead materials(with thickness up to a few radiation lengths depending on direction) absorb some energy of a particle or a jet before it reaches the CAL. This effect may be more significant for low energy particles. Noise suppression(removal of low energy cells) performed in the CAL reconstruction may also affect energy measurement of low energy particles. These will be discussed in more detail later.

3.2.4 CTD and VXD

J/ψ reconstruction relies on precise momentum measurements made by the tracking chambers. Tracking for charged particles was provided by the CTD(central tracking detector) and the VXD(vertex detector) during the 1993 runs.

Table 4: CTD superlayer parameters

superlayer	no. cells	stereo angle			radius	θ range
		mean	min	max	of cell	
1	32	$0°$			20.97cm	$11.3° - 168.2°$
2	40	$4.98°$	$4.64°$	$5.32°$	27.23cm	$14.5° - 164.8°$
3	38	$0°$			35.00cm	$18.4° - 160.7°$
4	56	$-5.31°$	$-5.06°$	$-5.55°$	41.30cm	$21.5° - 157.3°$
5	64	$0°$			48.73cm	$24.9° - 154.0°$
6	72	$-5.51°$	$-5.31°$	$-5.69°$	55.52cm	$27.9° - 151.0°$
7	80	$0°$			62.74cm	$30.9° - 147.9°$
8	88	$5.62°$	$5.46°$	$5.77°$	69.46cm	$33.5° - 145.2°$
9	96	$0°$			76.54cm	$36.1° - 142.6°$

The CTD is a cylindrical drift chamber,[39] bounded by two coaxial cylindrical shells of radius $18.2cm$ and $79.4cm$ and two end plates at $z = -105cm$ and $100cm$(all these numbers are for the active volume). A total of 24192 wires are stretched between the two end plates. These wires are organized into 576 drift

Figure 17: The layout of the wires in the CTD. One octant is shown at the end plates. Sense wires are indicated by the larger dots.

cells in 9 superlayers (5 axial layers and 4 stereo layers), as shown in Figure 17. Each drift cell contains 42 wires, of which 8 are sense wires. Some parameters of the CTD wire configuration are listed in Table 4. A thin superconducting coil of thickness $0.9X_0$, located between the BCAL and the outer shell of the CTD, provides a magnetic field of 1.43 Tesla in 1993 in the z direction, approximately uniform in the central region of the CTD(Figure 18). For a particle of charge Ze moving in a magnetic field B(in Tesla) its transverse momentum p_t(in GeV) and the radius of curvature R(in meter) are related by

$$p_t = 0.3zBR \tag{48}$$

The exact magnetic field distribution map had been measured and was used in track momentum reconstruction.

Figure 18: Isocontour lines of the magnetic field in percent of the axial field in the region of the calorimeter.

Table 5: Some design parameters of the CTD

Magnetic field	1.5-1.8 T
Gas(atmos. pressure)	$A_r/ethane$: $50/50 + 1.49\% ethanol$(B=1.8T) or $A_r/CO_2/ethane$: $85/13/2 + 0.96\% ethanol$(B=1.8T) or $A_r/CO_2/ethane$: $90/8/2 + 0.84\% ethanol$(B=1.43T)
Max. drift time	$\approx 500ns$
Lorentz angle	$45°$
Position resolution	100-120μm
z resolution (stereo)	$1.4mm$
z resolution (timing)	$30mm$
Two track resolution	$< 2.5mm$
dE/dx resolution	$< 6\%$
Momentum resolution at 90°	$\sigma_p/p = 0.0021p(GeV) \oplus 0.0029$

Some design parameters are shown in Table 5. The momentum resolution in the table is for normal incidence. The polar angle dependence of momentum and angular resolutions are shown in Figure 19. The resolution becomes worse for low momentum tracks due to multiple scattering. For track momentum between $1 \sim 3$ GeV, which is the relevant range for J/ψ measurement, momentum resolution is expected to be better than 1%, and angular resolution is at about 0.1% level. dE/dx(energy lost along the path) can help identify electrons. With our present

Figure 19: Polar angle dependence of the momentum resolution(a) and angular resolution(b) of the ZEUS inner tracking system.

understanding of the electron drift and calibration of the chamber constants, the resolution in the drift direction is around $260\mu m$. The transverse momentum resolution for reconstructed tracks passing through all layers of the CTD and VXD is $\sigma(p_t)/p_t(GeV) \approx 0.005p_t(GeV) \oplus 0.016$. The primary vertex can be reconstructed from charged tracks with a resolution of $0.4cm$ in z and $0.1cm$ in the transverse plane.

The VXD is a high precision cylindrical drift chamber built between the beam pipe and the CTD, mainly for detection of the decays of short-lived particles.[40] It also improves momentum and angular resolution of charged tracks in general.

Figure 20: x-y view of the VXD.

The layout of the VXD is shown in Figure 20. It consists of 120 drift cells, each with 12 layers of sense wires, with all wires running parallel to the beam axis. The VXD is filled with a slow gas DME(dimethyl ether, electron drift time is $5\mu m/ns$ in this gas) to allow for high spacial resolution. The VXD spacial resolution is $50\mu m$ in the central region and $150\mu m$ near the edges of the drift cells. Some parameters of the VXD are listed in Table 6

Table 6: Some design parameters of the VXD

Inner cylinder radius + thickness	99mm + 1.2mm
Outer cylinder radius + thickness	159mm + 0.72mm
Total thickness	$1X_0$
Active radial length	36mm
Active wire length	1590mm
Angular acceptance	$8.6° - 165°$
Number of cells	120
Number of sense wires per cell	12
Lorentz angle	$5°$
Gas	pure dimethyl ether

3.3 ZEUS trigger and data acquisition system

The background event rate due to beam-gas, beam halo, cosmic rays and unwanted soft photoproduction events is 5 orders of magnitude higher than the event rate from interesting physics which is only a few Hz at the HERA design luminosity. The task of the ZEUS trigger and data acquisition system is to select and write out interesting events to tape at a rate not exceeding 5 events per second. This is accomplished by a three-level trigger system.[41] The overall architecture of the system is shown in Figure 21. The first level trigger(FLT) works on a subset of partially digitized data. It looks at every bunch crossing(about 10MHz) and brings the trigger rate down to $1kHz$. An accepted event is then completely digitized and sent to the second level trigger(SLT), which is a network of microprocessors. It examines the FLT selected events and reduce the trigger rate to below $100Hz$. The EVB(event builder) collects event data of the SLT selected events from all components and sends the assembled event data to the SGI computer farm of the third level trigger(TLT). At the TLT, a complete reconstruction is performed and selections are made thereupon. Events selected by the TLT are sent to the DESY IBM computer and eventually written to data cartridges.