the "close" pairs. Two elements from a pair are combined to a new (longer) track element, if acceptable. If in this sequence one element of a pair has already been used in the construction of a new element, the fit to the modified element(s) is repeated and rejected eventually. By this process longer and more accurate track elements are formed, starting with the simple and clear cases, thus avoiding with high probability a wrong combination of short track elements.

For the final improvement of the track finding efficiency and precision the expected drift length is calculated for all possible wires and for all track elements ordered by their length. Hits at the expected wires which are not already used by another track are collected. The differences between measured and expected drift length are analysed to reject incompatible hits. Tracks found are allowed to contain rather large gaps of several wires, since parts of tracks may be invisible, especially within jets, due to the limited double track resolution. The fits for the track parameters are repeated using all acceptable hits.

Very short track candidates are rejected, unless they start with the first few wires of a ring. The energy loss dE/dx for a given track is determined from the mean of single-hit values $1/\sqrt{k_i} = 1/\sqrt{(dE/dx)_i}$, excluding hits which are close to another track. An analysis based on a likelihood method has improved the dE/dX to below 10 % (see [9]).

2.1.4.3 Vertex determination The $e-p-$interaction vertex region in the xy-plane extends over a few hundred μm with a rather stable mean position for a sequence of runs. The mean vertex coordinates (x_v, y_v) are determined using long high momentum tracks with a small value of d_{ca} from a few hundred events and minimizing the sum of squares of the distance of the tracks to the vertex.

The known (x_v, y_v) position of the run vertex can be used as a constraint to improve the parameters of tracks originating from this vertex, if the effect of multiple scattering in the beam pipe and the CJC wall for low-momentum tracks is taken into account. Since the standard deviation of the curvature value is roughly inversely proportional to the track length squared, the track precision is significantly improved by this vertex fit in the xy-plane. A z-value of the primary interaction vertex in an event is determined from all tracks fitting to the xy-vertex. The polar angle θ for these tracks is changed accordingly .

Within the standard reconstruction program a search is made for neutral particles decaying into a pair of oppositely charged particles with tracks in the CJC; in addition to K^0_S, Λ and $\bar{\Lambda}$ particles also e^+e^--pairs from conversion are found by this module. Candidate pairs are determined using simple geometrical cuts. For each candidate pair a fit is performed applying geometrical (common secondary vertex of the charged particles) and kinematic constraints. Use is made of the known position of the primary vertex. Momentum balance perpendicular to the direction of the neutral particle is used as kinematic constraint, but no masses are assumed. For a very small opening angle of the pair the transverse momenta in the xy-plane are both constrained to zero, to improve the stability of the fit for e^+e^--pairs. Pairs with an acceptable χ^2-probability are stored.

At later stages of the analysis alternative methods for reconstructing secondary vertices are also employed (see references [10, 11] and Figure 33 of reference [1]). Kalman filtering techniques have also been shown to be useful [12].

2.2 Central $z-$ chambers

The central inner and outer $z-$chambers (CIZ, COZ) surround the inner half of the jet chamber and complement the measurement of charged track momenta in the latter chamber. These two chambers deliver track elements with typically 300 μm resolution in z, which can be linked to those obtained from the jet chamber for the final accuracy on both the longitudinal as well as the transverse momentum components. The polar angles covered by CIZ and COZ are $16° < \theta < 169°$ and $25° < \theta < 156°$, respectively. Since the CIZ uses the inner carbon fiber wall of the CJC for closing its gas volume, and the COZ uses the outer carbon fiber cylinder for its basic structural element, the thickness of both chambers could be kept small, namely 0.6 % X_0 for CIZ and 0.7 % X_0 for COZ in the active zones and 1.2 % and 1.5 %, respectively averaging over the cell wall material. Furthermore the total amount of dead zones in azimuth imposed by readout channels and wire supports is only 7.7 % and 5.3 % of 2π respectively. The basic parameters of both chambers are given in Table 2 and the gas mixtures used are given in Table 7. A first level, background rejecting trigger [13] combines CIZ and COZ hits to trigger on straight tracks pointing to the interaction region (see Section 5.3.1.7 of reference [1]).

2.2.1 CIZ

For CIZ a laminar construction technique similar to that described below for CIP was used, starting from a steel mandril with an inner diameter of 347 mm. Successive layers include 25 μm Kapton with a 2.5 μm Al coating for electrical shielding, a 6 mm thick Rohacell [14] cylinder with its outer surface machined and polished to produce 16 flat surfaces forming a regular polygon in cross-section (see Figure 3), and a 25 μm Kapton foil with 10 μm Cu field forming strips on both sides. The 15 independent cells are separated by printed circuit boards, 1.6 mm thick with 5 μm Cu on each side serving as cathode planes. The cells are closed electrically with another Kapton foil identical to that on the bottom of the cell, here backed by 1 mm Rohacell. The end flanges of the CIZ are sealed against the CJC end plates with O-rings. Further constructional details, e.g. on the specially designed wire feedthroughs, can be found in references [15, 16, 17].

Figure 7 shows the geometry of the drift cell. The sense wire planes are tilted by 45° with respect to the normal to the chamber axis, with the first nine cells in the backward direction tilted backward and the last six in the forward direction tilted forward, i.e. following the direction of the tracks crossing the respective cells. As explained in ref. [15] this tilt produces a distortion of the equipotential lines resulting in a non-uniform distribution of the charge collected on the four wires and an equivalent tilt of the isochrones. This unusual wire arrangement solves the left-right ambiguity automatically without a need for wire staggering and furthermore eliminates the dependence of the resolution on the crossing angle. The wires are soldered to both side walls of a 23 mm wide cable channel at $\phi = 0°$. Here the signal wires are connected to line drivers and the potential wires to HV cables. The line drivers provide the impedance matching to the preamplifiers mounted on the end plate. A high resistivity alloy (Elgiloy [18], 3 kΩ/m) was selected as sense wire material (Ø 20 μm) to improve the measurement of the ϕ coordinate along the wire by charge division. The potential wires are made from Au (Ø 120 μm). To save space the HV cables to the electrodes and cathodes are buried in the Rohacell chamber body and the miniaturized 10 MΩ resistors (1.25 mm $\times$ 2 mm $\times$ 0.5 mm), which supply the field forming strips are embedded in the printed circuit board chamber partitions. The structure of the field shaping electrodes is indicated in Figure 7. For the gas mixture listed in Table 7 the chamber is operated with a cathode voltage of 4500 V, a potential wire voltage of 2250 V and a field gradient of 53 V/mm.

Since the CIZ is the drift chamber closest to the interaction point, a dedicated current monitoring system (see ref. [19] for details) was included into each potential wire supply line. It allows to measure the currents in the nA range. These wires control the gas amplification in the chamber. In this way the activity introduced by interaction products or stray beam can be monitored. Typically we found 10 nA current increase per ring for a luminosity of 20 mb^{-1}s^{-1}. This corresponds to an accumulated charge of 10 Cb/m per wire for an integrated luminosity of 100 pb^{-1}.

Apart from a narrow strip near the cell walls the chamber efficiency was measured to 98 % in test beams at PSI [16]. From test beam data the resolution was found to be $\sigma_z = 320\ \mu$m independent of the drift distance and the crossing angle in the range $10° < \theta < 110°$. These results could be confirmed with cosmics ray data, where central jet chamber tracks were extrapolated into the z-chambers and then linked to the corresponding track elements. The average deviation from a straight line fit (in the $r - z$ plane) is $\sigma_z = 260\ \mu$m for CIZ internal track elements and 400 μm for linked tracks. For the $\phi-$projection a resolution of 2.4 % of the wire length was measured. Double pulses can be resolved, if their separation exceeds 90 ns, which converts into 4.6 mm spatial separation in z [16].

2.2.2 COZ

This chamber was also built on a Rohacell body with the cross-section of a regular 24-edge polygon (Figure 3), but resting on a cylinder of carbon fiber reinforced plastics. The Kapton foils with field shaping copper strips were glued to the Rohacell surfaces. Guided by a mechanical positioning device the wire supporting rods (G10 with Cu strips, double sided) were placed and soldered to the Kapton foil. Between these rods planar cathodes were introduced made of G10/Cu with holes to enable the gas flow through the chamber. The top cover of the drift cell structure consists of a Kapton-Rohacell sandwich which is fixed at the cathodes. The chamber has a cylindrical shape due to its G10-Cu gas cover held by the endflanges. Further details can be found in references [17, 20]. Figure 8 shows a schematic view of the COZ. The dead zones for the wire readout are distributed in azimuth which allows a corresponding distribution of the preamplifiers at the end flanges and minimises the dead area of the chamber. The anode signals are transmitted by twin readout lines (signal-ground signal, length 20 to 120 cm) from the wire ends to the preamplifiers on both chamber ends.

Each drift cell is 24 mm high, the maximum drift length is 46 mm which limits the drift time to about 1 μs. Each cell has four sense wires (Stablohm [18], Ø 48 μm, 0.6 kΩ/m) in the symmetry plane of the cell and three pairs of potential wires (CuBe, Ø 127 μm). The wire feedthroughs in the supporting rods are kept in their nominal position to about 30 μm (σ). No wire stagger is implemented. Mirror tracks can be removed in the analysis since they do not point to the vertex.

The COZ is typically operated with a cathode voltage of 3000 V, a potential wire voltage of 2250 V and field gradient of 82 V/mm. For the gas mixture listed in Table 7 this gives a drift velocity of 48.5 mm/μsec, as determined from tracks crossing the sense wire plane and the cathode plane, respectively.

Inefficiencies along the cell walls and other performance parameters were studied in test beams (3 GeV electrons at DESY and low energy pions and electrons at PSI, see references [21, 20]). Apart from a small region near the sense wire feedthroughs the efficiency was determined to be 98 % over the full drift cell. For a 90° crossing angle the resolution measured at HERA is about 200 μm, deteriorating to 500 μm for low crossing angles. The azimuthal angle is determined by charge division to an averaged accuracy of 7.2 °, i.e. 2 % of the wire length. Double pulses can be resolved if their separation is larger than 70 ns which corresponds to 3.5 mm distance. For a discussion of the optimum method to resolve double tracks and a comparison of different algorithms for (Q, t) analysis we refer to [20, 21, 22].

2.3 Forward tracking detector

The forward tracking system is designed to provide an accurate measurement of charged particles in the forward direction (momentum resolution $\sigma_p/p^2 < 0.003$ GeV^{-1} and track angular