Kinematic of Charged Particles in Magnetic Field

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Abstract. In the former ZEUS detector at HERA, the study of particle kinematics from the electron-proton collision provided insights into the structure of the subatomic particles in the collision. The path of charged particles were deflected by a 1.6Tesla field. In this paper, we described the kinematics of particles moving in such magnetic field.

KINEMATICS VARIABLES. During the electron-proton-collision, charge particles produced and hitting the sense wire inside the central tracking detector (CTD) would be deflected from its origin. **Figure 3** gives the helix of a CTD hit , where ϕ is the outbound tangent angle in XY plane and, θ as the angle of dip wrt the XY plane, with the reconstructed momentum as:

$$(p_x, p_y, p_z) = (p\cos\phi\sin\theta, p\sin\phi\sin\theta, p\cos\theta)$$

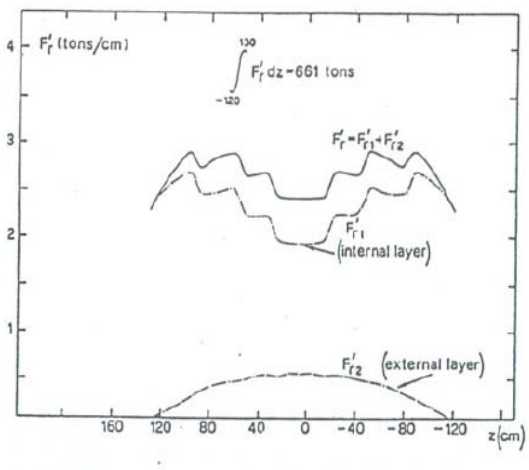

Figure 2. Radial force distribution along the coil axis of the magnetic field in central tracking detector (CTD) with radial force of $\int_{-120}^{130} F_r dz = 661 tons$.

In **Figure 4,** The proton with momentum P collides with electron with momentum(k) - the electron loses some of its energy with the emission of virtual photon γ with a momentum q,. resulting in a formation of a new quark, which may decay shortly after, depending the mean life. The momentum is measured using the CTD of the ZEUS detector.

In the study of $K_s^0 \to \pi^+\pi^-$, the momentum of π^+ and π^- (with invariant mass =0.139GeV), candidates of pions selected should full certain criteria [4], one of them being that the candidate should at least reach superlayer 3 outwards to fulfill the decay length of $\pi^\pm$. Table 1 gives the centre radius of superlayers in the CTD of ZEUS detector. Assuming that pions should reach at least superlayer 3 of the CTD, candidates are selected such it should reach superlayer 3, 5,7 and 9.

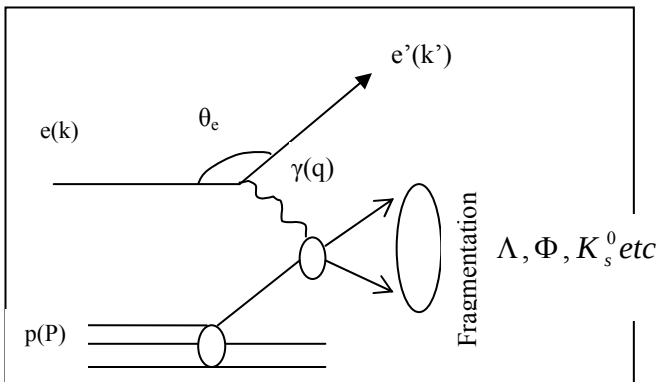

Figure 4. Kinematic variables in the electron-proton collision, with P, k , q as them momentum of proton, electron, and photon respectively (generated in the process).

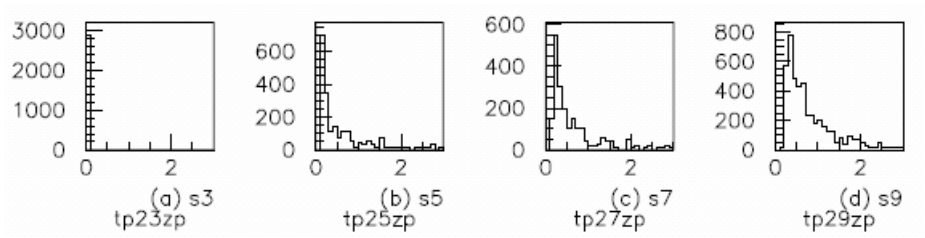

Figure 5. Momentum of pions at (a) superlayer 3 (b) superlayer 5; (c) superlayer 7; (d) superlayer 9 of the Central Tracking Detector (CTD) of the ZEUS detector (x-axis in GeV)

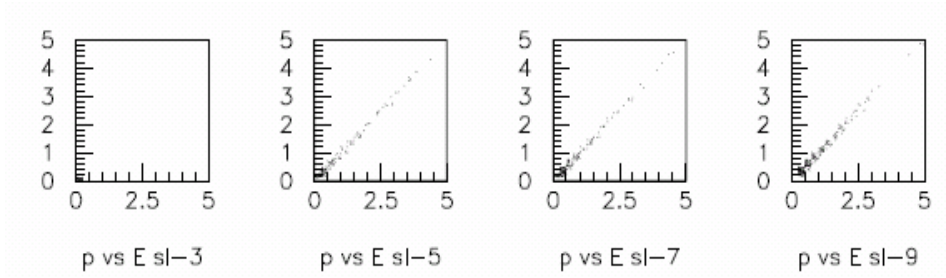

Figure 6. Momentum vs energy of pions at (a) superlayer 3 (b) superlayer 5; (c) superlayer 7; (d) superlayer 9 of the Central Tracking Detector (CTD) of the ZEUS detector (x-axis in GeV)

RESULTS: The momentum $\pi^\pm$ of reaching superlayer 3,5,7 and 9 were given in **Figure 5**. The figure shows that at superlayer 3, no significant entries were found. At superlayer 9, the pion entries were higher then that at superlayer 7 and 5.

Figure 6 gives the momentum of pions versus its energy at different superlayers. While there is no entries at at superlayer 3 as in **Figure 6**, the correlation is strong at superlayer 5,7 and 9. At superlayer 9, the entries are higher in the lower range as compared to superlayer 5 – this might due to the pions losing some of its energy as it travel from the inner to the outer superlayer of the CTD.

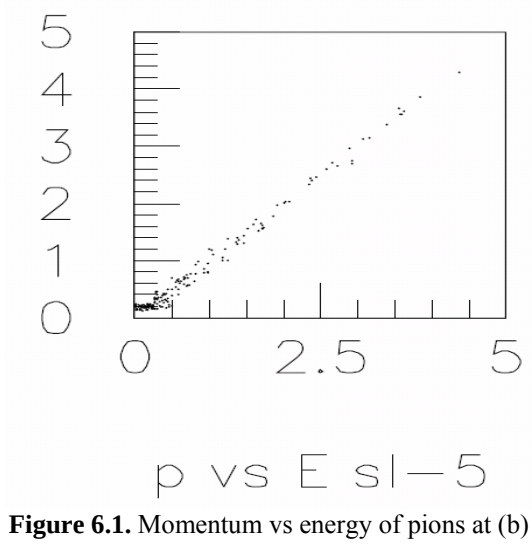

Figure 6.1. Momentum vs energy of pions at (b) superlayer 5 of CTD of the ZEUS detector (x-axis in GeV) with slight see-saw edge at lower range

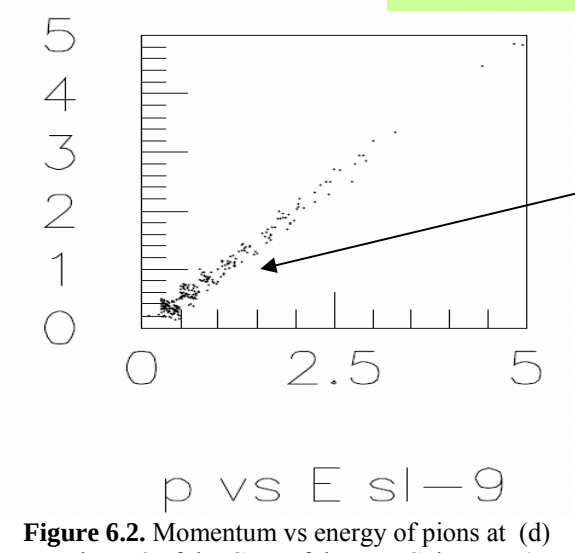

Figure 6.2. Momentum vs energy of pions at (d) superlayer 9 of the CTD of the ZEUS detector (x-axis in GeV) with see-saw edge more prominent at lower range

- At superlayer 9, see-saw edge more prominent - perhaps due the effect of magnetic field surrounding the CTD.

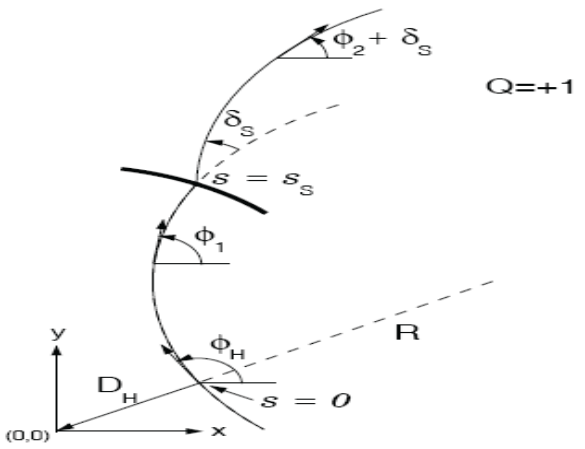

Figure 3. A helix in XY plane, where ϕ is the outbound tangent angle in XY plane in the CTD [2]

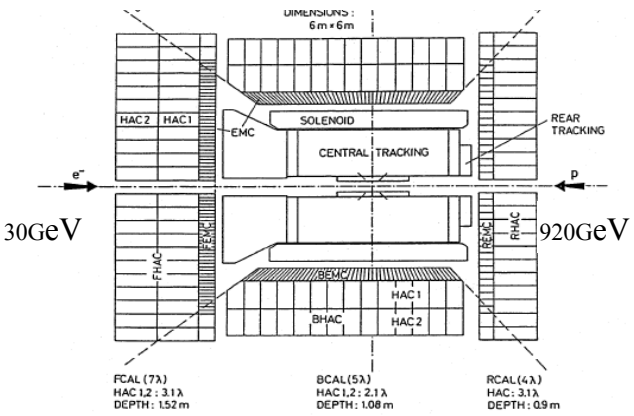

Figure 1.1 ZEUS detector in the X-Y plane showing the central tracking detector (CTD) at the centre, with proton and electron accelerated at 920 GeV and 30 GeV respectively [3]

Table 1. Centre radius of superlayers in the CTD of ZEUS detector [1]

Superlayer	Centre radius of cell (cm)
1	20.97
3	35.00
5	48.73
7	62.74
9	76.54