PARTICLE IDENTIFICATION AND TRACKING IN CENTRAL DETECTORS

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Combining particle identification by dE/dx and tracking in central detectors for the coming generation of colliders, e^+e^- in the 100 GeV region and pp, $\bar{p}p$ in the 200 to 1000 GeV region, places constraints on these detectors which may force compromises on their performance as either identifiers or tracking devices or both. The average charged multiplicity for e^+e^- interactions at 100 GeV is $\langle n_{ch}\rangle \simeq 25$ with $\langle n_\gamma\rangle \simeq 25$, which imply a very fine granularity for both tracking and identification. A typical Monte Carlo generated Z° decay is shown in Figure 1 and Figure 2 is a histogram of the opening angle distribution between pairs of charged particles for a large sample of Monte Carlo generated Z° decays. The peak of this distribution is at $\theta_{opening} \cong 60$ mrads or 6 cm at 1 meter imposing a granularity requirement of $\simeq$ 1 cm for reasonable efficiency in both identification and tracking.

Ideally the chosen central detector would be a zero mass device with spatial resolution of better than 100 microns in all coordinates and a dE/dx resolution of better than 1% to assure complete identification of particles of all momenta with a granularity of a few millimeters. Coupled to this ideal detector would be a data acquisition and software reconstruction system which would require less than a few seconds of VAX CPU run time to completely reconstruct the event. Of existing detectors the projected performance of the TPC central detector of PEP-4 comes closest to this ideal detector. The initial cosmic ray test results from the TPC and the first colliding beam runs presented at this conference are very encouraging and hopefully their remaining problems will be quickly overcome.

What are the alternatives to the TPC, which has been a very long and expensive development program? The other central detectors which provide both particle identification and tracking are the JADE drift chamber at PETRA, the UA1 drift chamber at the $\bar{p}p$ collider at CERN, the AFS drift chamber at the ISR at CERN, the new ARGUS drift chamber at DORIS and, in the near future, the CLEO drift chamber at CESR. In all of these detectors the dE/dx resolution ($\sigma_{dE/dx} \leq 12\%$) is only sufficient to provide hadron identification in the non-relativistic ($1/\beta^2$) part of the dE/dx curve and partial electron identification for some momenta. The particle trajectories in these detectors are measured by drifting perpendicular to the sense wires and by either current division or small angle stereo in the coordinate along the sense wires.

Before comparing the performance of existing detectors it is useful to recall that the momentum resolution for a typical central detector illustrated schematically in Figure 3 operating in a uniform solenoidal magnetic field of magnitude B is given by

$$\left(\frac{dp_T}{p_T}\right)_{\text{measurement}} = \frac{p_T}{.03}\,\frac{\sigma_{r,\phi}}{L^2 B}\left(\frac{750}{N+5}\right)^{1/2} \qquad (1)$$

where p_T = momentum transverse to $\vec{B}$. The units are GeV/c, kilogauss, and meters with $\sigma_{r,\phi}$ = spatial resolution of the detector in the plan perpendicular to $\vec{B}$ and N = the number of equally spaced measuring points over the path length L of the particle through the detector. In addition there is a contribution due the multiple scattering in the material of the detector

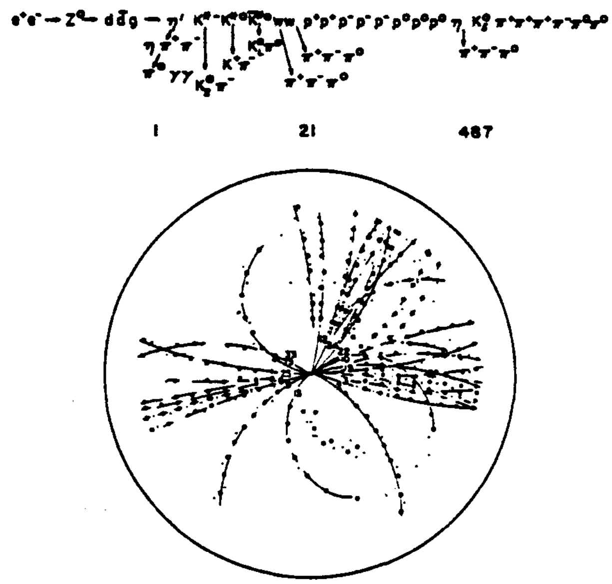

Fig. 1. Monte Carlo generated Z° decay.

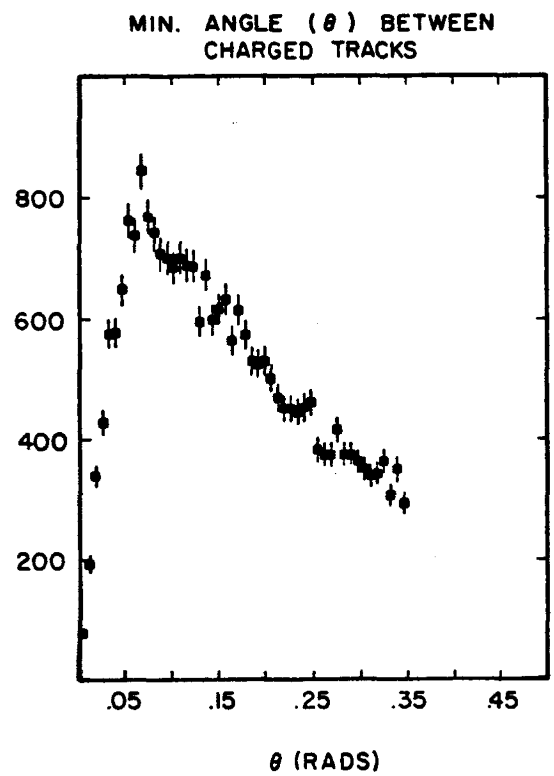

Fig. 2. Minimum opening angle θ between charged particle track pairs for Monte Carlo generated Z° decays.

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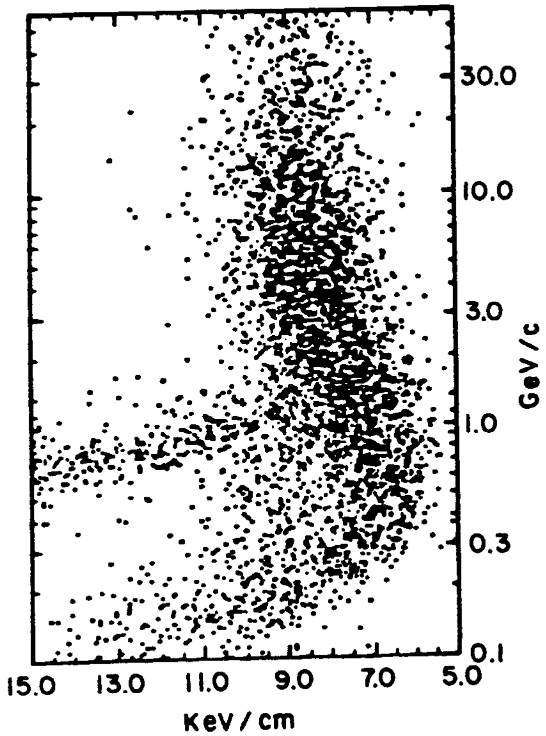

Fig. 5. Scatterplot of dE/dx measurements of hadrons with JADE.

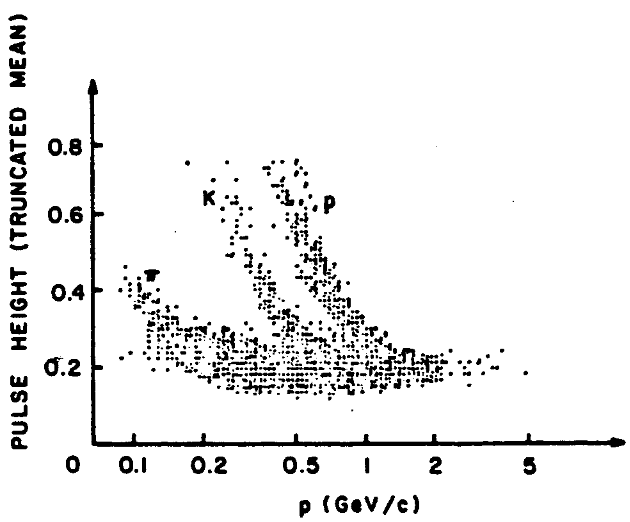

Fig. 6. Scatter plot of dE/dx measurements with AFS.

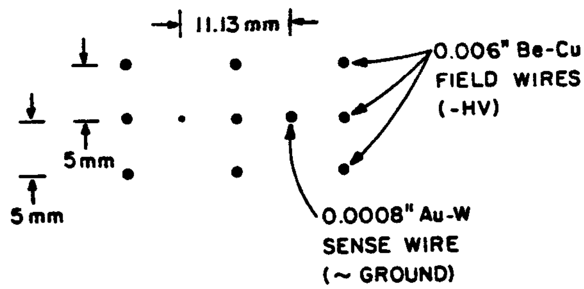

Fig. 7. Electrode configuration of CLEO Drift Chamber cell.

CLEO drift chamber) and full length wires, the typical pulse height distribution for normally incident minimum ionizing particles for a single layer is shown in Figure 8. The gas gain was 10^4 and the gas mixture used was 50% Argon + 50% Ethane. The cell to cell gain uniformity was better than 10% and the variation along the wires was also better than 10%. The fwhm of

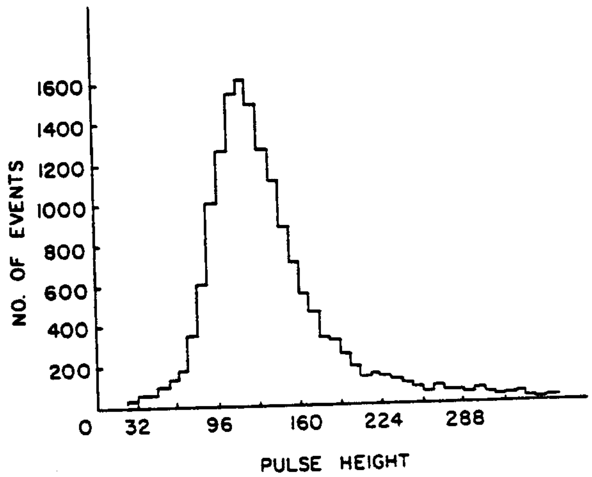

Fig. 8. Pulse height distribution of dE/dx for minimum ionizing particles passing through a single layer of CLEO Drift Chamber.

this pulse height distribution divided by the most probable pulse height is 65%. Using the smallest 5 of the 9 pulse heights the distribution narrows by $\sqrt{5}$ as expected. Extrapolating this performance to the CLEO chamber we expect $\sigma_{dE/dx} \leq 12\%$ which will be adequate to identify low energy K's and protons. The new electronics to accommodate the simultaneous timing and pulse height measurement will be installed during the fall of 1982.

In summary it is possible to combine both tracking and dE/dx in central detectors. Using current division to measure the z coordinate is in conflict with the limits on total charge collected to avoid saturation of the relativistic rise for electrons. The dE/dx resolution that can be achieved for an 80 cm path length with an ARGUS type chamber with as many wires installed as possible is probably limited to 8%. This combined with a spatial resolution of $\sigma_{r,\phi} \simeq 150$ microns and $\sigma_Z \simeq 1.5$ mm (small angle stereo) provides an excellent central detector. For particle identification in the relativistic rise region $\sigma_{dE/dx} \leq 4\%$ which can only be obtained with a TPC like device. The high pressure TPC has yet to demonstrate an r,ϕ spatial resolution better than $\sigma_{r,\phi} \simeq 300\ \mu$ which is about a factor of 2 worse than the JADE or CLEO type chamber, and which may be a problem.

References

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