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P. Spillantini: A TIME PROJECTION SECTOR DEVICE  
FOR A TOROIDAL CENTRAL DETECTOR.

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If a magnetic spectrometer for the large angle region around the intersection region of a storage ring is based on a toroidal coil, the momentum is determined measuring the values of the longitudinal coordinate ( $z$ ) at several radii. If these measurements are obtained registering the drift time of the primary ionization produced by the measured particle (as in solenoids it normally happens for the transverse ( $R \times \varphi$ ) coordinate measurement - see Fig. 1a), the sense wires have to be arranged transversely to the beam axis direction to collect the "longitudinal" drift (see Fig. 1b).

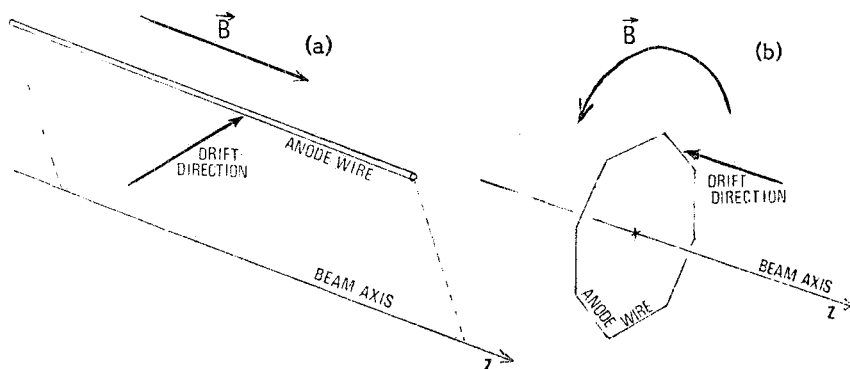


FIG. 1

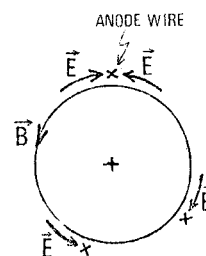


FIG. 2

This involves mechanical difficulties, implying some material on the trajectories and a considerable number of read-outs.

However, since present day techniques allow a precise read-out ( $\sigma \leq .2$  mm) of the position along a wire at a reasonable price, recourse can be made to a different solution: the "z" coordinate measurement could be obtained on a set of anode wires stretched longitudinally as in a solenoid.

Furthermore the electric field guiding the drift charge could be shaped with its force lines exactly coincident with the force lines of the magnetic field (see Fig. 2); in this manner the magnetic field can help in limiting the diffusion of the drifting charge, and measurement precision can be maintained despite the longer drift spaces.

We can indeed project all primary ionization produced in a given azimuthal sector  $\Delta\phi$  on a radial plane, reading-out from it either the arrival times of the drifting charges (i.e. the transverse coordinates) or the arrival positions along the anode wires (i.e. the longitudinal coordinates). Indeed a three-dimensional read-out sector by sector could be foreseen, very similar to that carried-out for each half-solenoid in the Time Projection Chamber<sup>(1)</sup> (TPC) for PEP. Such a sector could be called for analogy a Time Projection Sector (TPS) (see Fig. 3).

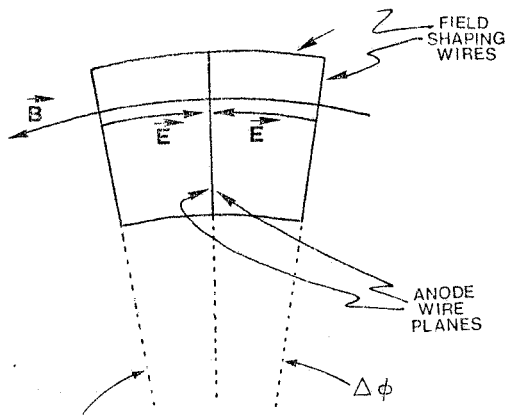


FIG. 3

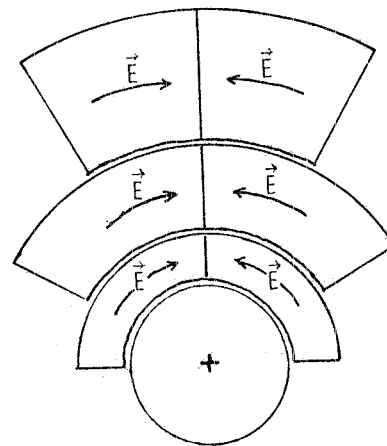


FIG. 4

The geometrical dimensions of a TPS are conditioned by two limiting factors:

- (1) The precision that can be obtained on the read-out radial plane of a sector depends on the length of the drift space and on the strength of the magnetic field. This limits the maximum azimuthal opening  $\Delta\phi$ , which has to be evaluated at the greatest radius, where the drift distance has its maximum and the magnetic field reaches its minimum.
- (2a) The magnetic field is effective in reducing the diffusion only if it is very strong in comparison with the electric field (at NTP). Measured values of the diffusion reduction exist at relatively weak electric fields<sup>(3)</sup> (0.1 - 0.6 Volts/cm-Torr), where the drift velocity is still field dependent. Working in this condition the radial extension of the sector could be made so large as to cover a large fraction of the radial extension of the toroid.
- (2b) Instead, in order to work with saturated drift velocities, the radial extension of the sector has to be limited since the drift velocity can be kept constant in a relatively narrow interval of electric field. Practically ratios of more than 2 between the maximum and the minimum value of the electric field cannot be used; the possibility to cover all the radial extension of a toroidal coil with one sector is ruled out and more independent sectors have to be used to cover a radially extended region (see Fig. 4).

As a limit solution all the radial space could be covered by thin cylindrical chambers with one sense per cell, each having its own shaping of the electric field: in this way the basic principle of the TPS could be exploited in a very traditional structure, and furthermore the drift length could be optimized chamber by chamber. However it must be observed that, disregarding the real radial structure of the track detector, if electric fields saturating the drift velocity have to be used, extrapolation of the TPC test measurement<sup>(3)</sup> indicates that a sensible reduction of the charge diffusion (for a factor of 2 + 3) can be obtained only for very high magnetic fields (15 + 20 kgauss), i.e. only in the innermost part of the track

detector, while a negligible diffusion reduction can be reached in the outermost part, where instead longer drift paths could save the more relevant part of "z" coordinates to be read-out.

In the following the complexity of a track detector for momentum measurement to be placed in the superconducting toroid discussed in ref. (2), and based on TPS's will be evaluated in the hypothesis that relatively weak electric fields could be used, for which the results of the TPC tests<sup>(3)</sup> could be applied directly.

The following assumptions will indeed be made:

- 1) (from ref. (2)). The toroidal magnetic field is produced by a current of 4MA running in a cylindrical inner conductor 0.3 m in radius, and its induction amounts to 2,67 Tesla at this radius, diminishing with  $R$  as  $R^{-1}$ .
- 2) (from ref. (2)). The track device to measure the magnetic extends radially to 1.2 m.
- 3) The track device is operated in a 80% Argon + 20% Methane mixture at NTP, with an electric field of 400 V/cm at the minimum radius 0.3 m, which reduces to 100 V/cm to the maximum radius 1.2 m, as only one sector could cover all the radial extension of the toroidal coil; this is supposed only for convenience, but no hypothesis have to be introduced for the real radial structure of the track detector, which could eventually consist of many cylindrical drift chambers, each with its own cell distribution in  $\varphi$ .
- 4) (as in ref. (2)). The sagitta is supposed to be measured with a  $\sigma_x = \frac{1}{2} \sigma$  error, where  $\sigma = \pm 0.2$  mm is the (standard) error of single measurement in "z". To obtain this precision 16 points (at least) have to be measured, 4 at the beginning, 8 half way through and 4 at the end of the magnetic path.
- 5) Each anode wire is supposed to collect primary ionization charges on a 8 mm radial length of track, i.e.  $\sim 30$  electrons.

The assumptions 1), 2), 3) and 5) allow to evaluate (as a function of the radius and for several fixed values of the "intrinsic" error  $\sigma_c$  of the center of the arrival positions of the drifting charges along the anode wire) the drift lengths giving rise to fluctuations smaller than  $\sigma_c$  (see Fig. 5).

Choosing  $\sigma_c = \pm 0.1$  mm, which negligibly contributes to the total error  $\sigma$ , the assumption 4) allows to evaluate the number of "z" coordinates to be registered:

- 2 x 4 = 8 at the beginning of the magnetic path, for a total length of 12 m in "z";
- 5 x 8 = 40 half way through the magnetic path, for a total length of 112 m in "z";
- 16 x 4 = 64 at the end of the magnetic path, for a total length of 254 m in "z".

The drifting charges are supposed to be collected on the same read-out plane from both sides (as in Fig. 3).

At this point, in order to continue usefully, technical means must be specified for the read-out of the position along an anode wire.

In principle a very accurate determination of the longitudinal position could be obtained measuring the center of gravity of the pulse-height distribution of the pulses induced on a row of pads printed on a supporting strip stretched to face the wire (Fig. 6).

This is the technique used for the TPC, for which a 8 mm step for the pads along the row<sup>(4)</sup> was chosen.

Assuming this same spacing for our toroid, to measure the total length of "z" found above 48k pads have to be read-out in pulse-height, so subdivided:

- 2k pads at the beginning of the magnetic path,
- 14k pads half way through the magnetic path,
- 32k pads at the end of the magnetic path.

These figures increase quadratically by improving the intrinsic precision  $\sigma_c$ , as shown in Fig. 5.

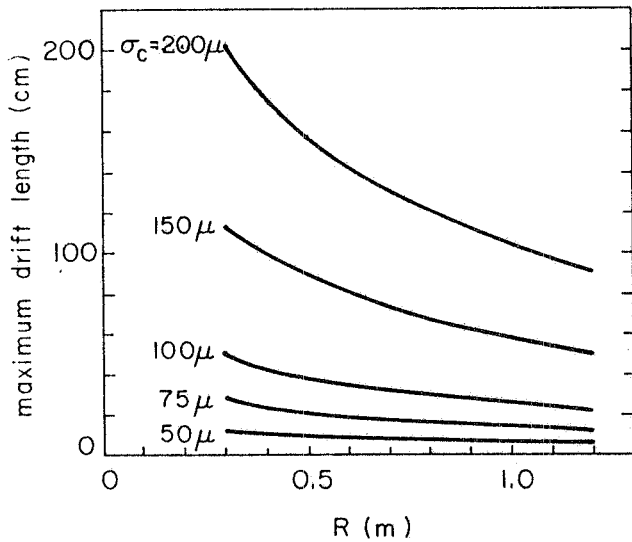


FIG. 5

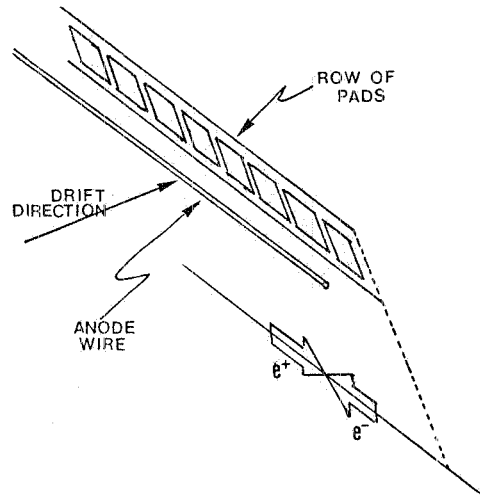


FIG. 6

However it must be observed that at both ends of the magnetic path the multiple scattering in possible mechanical structures supporting "transverse" anode wires does not affect the momentum measurement precision, so that only the pads half way through the magnetic field are strictly necessary, while the two extreme points of the track could be measured by the drift times toward "transverse" anode wires (as in Fig. 1b). Hence, such a device, for  $\sigma_c = \pm 0.1$  mm, would need a total of 14k pulse-height read-outs for the pads and about 3k drift time read-outs to get the  $\pm \frac{1}{2}\sigma$  precision sought above for the sagitta measurement.

#### REFERENCES

- (1) Proposal for a PEP facility based on the Time Projection Chamber (TPC), Johns Hopkins-LBL-UCLA-Riverside-Yale (Dec. 1976).
- (2) P. Spillantini and T.M.Taylor, A multipurpose central detector using a toroidal magnet, ECFA/LEP Working Group-SSG/13/7 (1979), and Frascati report LNF-79/50 (1979).
- (3) In various Argon + Methane mixtures; see D.R. Nygren, PEP-198 (1975), and appendix 6 of ref. (1).
- (4) See pag. 21 of ref. (1).