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THE SPIRAL PROJECTION CHAMBER (SPC):
A CENTRAL DETECTOR WITH HIGH RESOLUTION AND GRANULARITY
SUITABLE FOR EXPERIMENTS AT LEP

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ABSTRACT

A new type of projection chamber with cylindrical structure and radial electric drift field is proposed. This detector should improve by one order of magnitude the spatial accuracy and double-track resolution obtainable with other types of wire-chamber configurations in the region close to the beam pipe in colliding beam machines.

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In this letter we propose a new configuration of projection chamber¹⁻⁵⁾, which should be capable of reaching a spatial and double-track resolution of about 200 μm in the azimuthal direction and a resolution of about 200 μm in the radial direction in the neighbourhood of the pipe of a colliding beam machine.

The structure of the proposed chamber is shown schematically in Fig. 1. It consists essentially of two coaxial cylindrical cathodes and of N resistive sense wires alternating with N field wires positioned at a radius R_s near to the external cathode. The internal cathode at a radius R_c is set at a high negative potential V and the sense wires are at ground potential. Field shaping is applied at the two extremities of the cylindrical chamber, so that the electric field in the whole active volume is directed radially with no component along the axis of the chamber (z direction). Thus the radial dependence of the electric field is that of an infinitely long cylindrical condenser: $E(r) \propto 1/r$. Primary electrons produced by ionizing particles that traverse the chamber migrate towards the sense wires along radial drift lines if no magnetic field is present, or along spiral drift lines when the chamber is positioned on the axis of a solenoidal magnet. Hence the name of Spiral Projection Chamber (SPC) for the proposed detector. The SPC requires higher voltage than other types of projection chambers; however the higher electric field far from the sense wires should help to minimize recombination effects and thus to preserve the amplitude information. Moreover the high electric field in the centre of the chamber favours a fast collection of positive ions, thus reducing the space-charge effects that can spoil the performance of large-volume drift chambers⁶⁾.

The active volume of the SPC is sliced into N drift cells of length L in the z direction. All drift cells are equal. Their shape depends on the counter gas, on V , R_s , R_c , and on the intensity B of the magnetic field in the solenoid. Their width in the direction normal to the drift direction at a distance r from the centre of the chamber is $w \leq (r/R_s)s$, where s is the spacing between two contiguous sense wires. The three coordinates r , ϕ , and z that localize the segment of a track in the chamber contained in a drift cell would be given by:

a) the time of arrival at the sense wire (drift-time),

- b) the position of the sense wire,
- c) the pulse-sharing between the two ends of a sense wire (charge division).

The resolution attainable in the radial direction is $\Delta r \lesssim 200 \mu\text{m}$, as usually obtained with drift chambers. The resolution in the ϕ direction depends on the cell width $w \lesssim (r/R_s)s$ and therefore improves towards the centre of the detector. For instance, with a sense-wire spacing of 2 mm and a ratio $R_s/R_c > 10$ the ϕ resolution near to the central cathode would be $R_c \Delta\phi < 200 \mu\text{m}$. The z resolution would be the one typical of charge division. Notice also that with this chamber both the spatial and double-track resolutions in ϕ are, in principle, no longer limited by the electronics.

By equipping an SPC with projection-chamber electronics, for example of the type developed in the UA1 Collaboration⁷⁾, tracks traversing the chamber could be fully reconstructed with a resolution $\Delta r \lesssim 200 \mu\text{m}$, $r\Delta\phi \lesssim (r/R_s)s$, and $\Delta z/z \sim 1\%$, and one could also sample the energy deposited by ionization in each drift cell.

Because of the r dependence of E , the drift velocity will not be constant along a drift cell and it will be necessary to map it by using a tagged source (soft X-ray, Auger e^- , or laser pulse) moved along r . The maximum and minimum drift-times and their stability could be checked permanently with a tagged source located on the internal cathode and with cosmic-rays crossing a cell near to the sense wire, respectively. Once the drift velocity in one cell has been mapped, the cylindrical symmetry of the SPC should make the software reconstruction of one event simpler than other devices, since all drift cells are equal.

The SPC can, in addition, easily be used for triggering purposes (multiplicities, topologies, etc): by setting a gate of width G simultaneously for all the SPC cells with a delay D with respect to the minimum drift-time, one defines a virtual cylindrical chamber inside the SPC with inner and outer radii given by D and $D + G$, respectively. By fanning out the signal of each sense wire through n gates with n different delays one would have information equivalent to that produced by a set of n cylindrical wire chambers positioned in the volume of the SPC. These virtual chambers have, of course, the same number of wires which are, however, dephased in ϕ owing to the spiral shape of each drift cell.

The cylindrical symmetry of the SPC, the peripheral positioning of the sense and field wires, and the absence of field-shaping wires make its construction simple. A long SPC is feasible with the insertion of intermediate supports for the wires. Pressurization would be facilitated by the cylindrical structure. In order to improve on the resolution permitted by charge division, segmentation in z is possible without the need for additional field-shaping electrodes. Cathode strips could also be deposited onto the surface of the external cathode again for the purpose of improving the z resolution. For a large SPC a construction modular in ϕ and in z would be feasible, with panels holding the wires and defining the external cathode mounted on a cylindrical support frame.

An SPC with, say, $R_c = 5$ cm, $R_s \approx 30$ cm, and $s \approx 2$ mm, surrounded with a projection chamber of the jet type^{3,4)}, would provide a compact, light, and conceptually simple central detector with high resolution at all radii and with virtual cylindrical chambers embedded in the SPC. This could be useful for experiments at LEP making use of a solenoidal magnetic field. The same structure, but with smaller dimensions ($R_c \approx 1$ cm, $R_s \approx 10$ cm) would be suitable to reconstruct $\bar{p}p$ annihilation events occurring in a cylindrical H_2 target with $\phi \approx 2$ cm.

In the laboratory the magnification effect of the SPC could be used to study in detail the effects limiting the ultimate resolution obtainable with wire chambers.

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Fig. 1

Scheme of the Spiral Projection Chamber with contours of one of the drift cells

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