HIGH DENSITY SPIRAL PROJECTION CHAMBER (HDSPC):

Design of the end-cap detectors of the OBELIX experiment at LEAR

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A B S T R A C T

We discuss the design of a cylindrical high density projection chamber¹⁾ that uses the spiral projection chamber²⁾ geometry and will instrument the end-caps of the proposed OBELIX³⁾ experiment at LEAR. This detector -High Density Spiral Projection Chamber (HDSPC⁴⁾)- has axial symmetry, radial drift electric field, a radiator made of converter disks alternating with drift volumes and the amplification and readout region in the outer part of the cylinder. It is equipped with FADC electronics and reconstructs in three dimensions primary ionization produced in the active volume. It features fine granularity and high angular resolution near the beam pipe and appears particularly advantageous for γ and prong detection in the forward and very forward region of storage rings and extracted beam experiments.

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1. INTRODUCTION

High density projection chambers (HPC) have been proposed¹⁾ to achieve fine granularity and three dimensional reconstruction capability in gas sampling calorimeters. In these devices the ionization produced in a gas sampled radiator drifts to a detection wire plane and the pulses on the wire plane are used to reconstruct in space with a high degree of segmentation the image of the primary ionization produced in the active volume of the calorimeter.

Here we discuss the design of a detector of this type that has a cylindrical detection surface. The device is called High Density Spiral Projection Chamber (HDSPPC)⁴⁾ as it is obtained by inserting a cylindrical radiator segmented along its axis into the centre of a Spiral Projection Chamber²⁾. The detector has cylindrical symmetry with a hole along its axis. It is suitable as end-cap detector to obtain high angular resolution in the region near the beam pipe in fixed target and colliding beam experiments. We plan to build two HDSPPC's to be used as end-caps of the OBELIX experiment³⁾, proposed to study annihilations of low energy antinucleons at LEAR. These two HDSPPC's will sandwich the central detector of OBELIX and will be assembled together with it, as a tube surrounded by the jet drift chambers of the AFS spectrometer⁵⁾. This detector assembly will be positioned along the axis of the Open Axial Field Magnet⁵⁾ that should be installed in the LEAR experimental hall at the beginning of 1987. The two HDSPPC's will measure gammas and prongs from annihilations in the centre of the detector.

2. DETECTOR STRUCTURE

Fig. 1 shows the layout of the detector, which is constituted by a cylindrical radiator with gas sampling and drift volumes and by a surrounding amplification and detection region.

The radiator is made of converter disks made of isolating material, coated on both planar surfaces with a high resistance layer and on the external cylindrical surface with a conducting layer. The disks are centered on and supported by a metallic tube and are spaced by metallic rings mounted on the tube. The stack of converters and rings is kept pressed to ensure mechanical stability and electrical contact of the rings with the support tube and the coating of the converters.

The external surface of the spacing rings constitutes the internal cathode of the chamber. A drift grid made of low resistance wires parallel to the radiator axis connects all the converters in parallel at their periphery. A radial drift electric field is established in all the gas volume of the radiator by applying negative high voltage to the central cathode rings (via the support tube) and negative voltage to the drift grid. Current flows from the drift grid to the central cathode via the high resistance layers. The resistance to this current flow has a $1/r$ dependence, hence there is a $1/r$ dependence of the radial electric field both on the converter surfaces and in the space between the converter plates (electric field of a cylindrical condenser). The radiator is inserted as a plug in unit into the amplification region of the detector and can therefore be extracted and modified without affecting the surrounding cylindrical chamber, its wiring, electronics and cabling. This leaves as free parameters in the design the number, spacing, thickness and internal diameter of the radiator disks.

The detection region is made by a light cylindrical frame with 90 amplification cells defined by 90 sense wires stretched alternating with 90 intermediate decoupling wires at the same radius (see Fig. 2) . The sense wires are positioned between a ring of 180 cathode field wires stretched at a larger radius and a ring of 90 drift field wires stretched at a smaller radius in correspondence of the intermediate field wires. The sense wires have high resistivity for good charge division resolution and are connected on both sides to preamplifiers and FADC pulse sampling and digitizing electronics. The sense wires are set at ground potential. The cathode, intermediate and drift wires are set at negative voltages and control the amplification of the chamber. The voltage difference between drift wires and the drift grid is set to optimize the transparency for electrons moving from the drift region to the amplification region. The drift wires could be used for gating purposes.

3. OPERATION PRINCIPLES

Primary ionization electrons produced in the gas sampling regions -by charges particles that enter the radiator or result from conversion of gammas- drift under the action of the radial electric field to the amplification region. This ionization can be localized by hit wire number, charge division and drift time and its density can be derived by the pulse amplitude and shape.

The direction and radial dependence of the drift electric field in the gas filled part of the radiator of a HDSPC are the same as in a Spiral Projection Chamber. The operation principles are identical. A Spiral Projection Chamber has been constructed⁶⁾ and successfully in operation in the ASTERIX experiment⁷⁾ at LEAR during the last three years, and has collected so far about $3 \cdot 10^7$ $\bar{p}$ annihilation events.

Charge division has enough resolution to distinguish ionization produced in two contiguous gas volumes separated by one converter disk. The gas volumes comprised between contiguous converters are virtually subdivided in 90 drift cells that expand transversally with increasing radius and are directed radially towards the sense wires in the absence of a magnetic field. When a magnetic field is applied parallel to the detector axis, the drift cells take a spiral shape due to the $E \propto 1/r$ dependence of the electric drift field (see fig. 3). The drift cells are all equal and their transverse size reduces linearly with reducing radius, no matter the distortion of their shape introduced by the effect of the magnetic field. The detector has constant angular granularity in ϕ at all radii. The fine granularity down to the central cathode makes the HDSPC particularly advantageous for the forward and very forward region of storage ring magnetic detectors. Indeed the cathode can embrace directly the beam pipe and instrument the region where prongs and showers from γ 's produced in the interaction vertex are nearly parallel to the sense wires.

The spacial resolution in r and ϕ for track segments between converters depends whether tracks cross the boundary region of a drift cell or not. If they do, precisely measurable track points are located at the interception with the drift cell boundary line and their position is determined by the time measurement of the leading edge of the pulse associated to the track. Accuracy is limited by diffusion, time measurement errors and eventually clustering. Good resolution requires the measurement of the absolute drift time. The zero time in OBELIX is the time of annihilation of an antiproton in the target, that is located between the two HDSPC's and on their common axis. A time of flight system made by two concentric barrels of plastic scintillators measures the annihilation time independently of the time necessary for slow antiprotons that have entered the target to interact inside it. Good resolution requires also a precise mapping of the drift lines and of the equidrift time lines of the cells of the detector. Fig. 3 shows one example of calculation of the drift cells. These calculations are based on a program⁸⁾ that adapts to the cylindrical geometry of our detector a drift chamber simulation program that was developed for planar structures and that can take into account all the known effects concurring to the signal formation⁹⁾. With a well calibrated detector the location of track points on the boundary of a cell should be measured with typically $\sigma_r \sim 200 \mu\text{m}$ and $\sigma_{r\phi} \sim 200 \mu\text{m}$ for tracks not on the shadow of other ones.

For tracks that do not cross a cell boundary, track points are localized in the $r\phi$ plane along the equidrift time arcs that go from the left to the right boundary of a drift cell, with no determination of their position along the arcs. This corresponds to a ϕ angular resolution $\sigma(\phi) \sim 20$ mrad and to $\sigma_r \sim 1$ mm. Gammas emitted from the target have directions nearly orthogonal to the converter plates. The good spacial resolution in the $r\phi$ plane of the HDSPC permits to reconstruct precisely the two coordinates of the γ conversion point that are relevant for a precise measurement of the γ direction. The z coordinate is not critical to this purpose. The error on the z coordinate of the conversion point is given by the thickness of the radiator plates as by charge division it can be identified in which plate conversion occurred. Notice that an exceptional z resolution may be attainable with radiator plates thicker than the charge division absolute error σ_z . Due to the quantized structure of the radiator, charge division identifies from which gas gap a pulse comes and, for all tracks not parallel to the radiator axis, the leading edge of the pulse corresponds to primary ionization produced near to the surface of one of the two contiguous converters embracing the gas gap.

The HDSPC will permit to measure the energy of fully contained showers by counting the number of track segments and by measuring their ionization and to identify by dE/dx and range low momentum prongs that stop into the radiator. For better energy resolution and identification thinner converters are advantageous. Performances comparable with structures with planar amplification regions are expected. A large dynamical range is required from the pulse sampling and digitizing electronics to measure the dE/dx of prongs that enter the calorimeter as minimum ionizing particles and ionize one order of magnitude more as they are decelerated to rest by the converter plates.

Transverse diffusion in the $r\phi$ plane does not reduce the signal amplitude nor disturb the position resolution as it is overcompensated by the expansion of the cells in the transverse direction. Instead transverse diffusion in the z direction will cause loss of primary electrons hitting the converter plates. This effect will require to be calibrated and corrected for in dE/dx measurements.

4. CONSTRUCTION ASPECTS

The design characteristics of the detector are given in the table, which gives orientative values: no parameter is critical in the design.

The construction technology of the cylindrical amplification wire array will be similar to the one of the ASTERIX SPC⁶⁾ with further improvements to the connectors. For the radiator plates we are exploring two possibilities: disks made of lead oxide powder mixed to araldite glue and coated with a uniform layer of high resistive painting and disks made of lead glass with a thin coating of metallic lead obtained by reduction with hydrogen. This last possibility is already under test in a drift collection calorimeter with planar amplification region¹⁰⁾ and permits to obtain layers with resistivity in the 10^8 - 10^{12} Ω/sq range. Thin circular conducting strips could be printed onto the converters to stabilize the electric potential distribution against non radial electric fields. If necessary it will be possible to increase the resistance of the surface layer of the converters by shaping the drift field with circular conducting strips printed regularly and densely onto the radiator plates and connected by a few radial sectors of high resistance layer. The simplicity of construction of the radiator elements and of the field shaping electrodes should enable to segment the radiator into as many converter plates (for a given total radiator thickness) as thin as their mechanical stability is not affected.

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TABLE: Detector parameters

ACTIVE REGION

Wire	Number	Diameter	Radial position	Length	Material	Typical potential
Cathode	180	100 μ	16 cm	40 cm	Cu/Be	-2 kV
Sense	90	30 μ	15.5 cm	" "	Ni/Cr	ground
Intermediate	90	100 μ	15.5 cm	" "	Cu/Be	-2 kV
Drift	90	100 μ	15 cm	" "	Cu/Be	-2 kV

RADIATOR

Total length	40 cm
Inner diameter	6 cm
Outer diameter	27 cm
Plate thickness	$\frac{1}{2}$ radiation length
Nr of plates	20
Grid wires	100 μ Cu/Be
Drift voltage	15-25 kV
Gas mixture	Ar/C ₂ H ₆ 50/50

Figure captions

- Fig. 1: Structure of OBELIX HDSPC. a) Cut side view along detector axis. b) Same view of radiator before insertion into the active region.
- Fig. 2: Structure of OBELIX HDSPC. Cut view along a plane orthognal to the detector axis not intersecting a converter plate.
- Fig. 3: Drift lines and equidrift lines calculated with $B=0.5$ Tesla; -2.1 kV on field wires, sense wires grounded, no drift grid, central cathode at -21 kV, gas mixture Ar/C₄H₁₀ 90/10.

Fig. 1

Fig. 2

Fig. 3