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THE MICRO SPIRAL PROJECTION CHAMBER (μ SPC)

U. Gastaldi*, G. Maron*, L. Vannucci* and G. Vedovato*
INFN-LNL, via Romea 4, 35020 Legnaro (PD), Italy

V. Filippini*
INFN-Sezione di Pavia, via Bassi 6, 27100 Pavia, Italy

Abstract

The Spiral Projection Chamber (SPC) is one of several types of cylindrical imaging gas chambers. The SPC has, because of its geometry, the following properties: axial symmetry, modularity, high transparency, high efficiency, and constant segmentation at all distances from the axis (magnification). The magnification property of the SPC has not been studied or exploited so far. This report outlines our project, which aims at: i) investigating processes of charge deposition in gases with spatial samplings of a transverse size below $30\ \mu\text{m}$, by exploiting the SPC magnification capabilities, and ii) constructing and operating a μ SPC with the amplification region instrumented with microstrips, by adapting the techniques successfully developed in microstrip chambers to the cylindrical geometry.

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* Visitor at CERN, 1211 Geneva 23, Switzerland.

1 Introduction

Spiral Projection Chambers (SPCs) and Radial Projection Chambers (RPCs) have operated successfully and are currently in use in experiments at LEAR and at the FNAL antiproton accumulator [1, 2]. The advantages of imaging detectors with the SPC/RPC geometry, which have not, so far, been exploited completely, make them interesting also for e^+e^- colliding-beam machines and other experimental environments.

In particular, the property of magnification of the SPC/RPC geometry has not been studied or exploited so far. The angular resolution for localization of an isolated cluster of ionization, at any radial position inside the active volume of an SPC, is given by the inverse of the number of sense wires positioned all around the periphery of the detector. The radial resolution for isolated clusters is controlled by the distance between two contiguous sense wires, which fixes the radial extension of the equidrift curves in the drift region of the SPC cells (see fig. 1 of ref. 2). For a given target (or beam-pipe) radius, it is possible to increase the angular resolution for isolated clusters by increasing the radius of the detector and installing more sense wires. If the volume of the detector is not an optimum, this solution is penalizing, because the necessary memory depth, as well as the longitudinal and the transverse diffusion, increases. Reducing the spacing between the sense wires for a fixed detector radius increases both the angular and radial resolutions. The limit to this process is set by the technology of fixing and connecting the sense wires: pitches of 1 mm are already technological achievements.

Recently, the new approach of microstrip gas chambers has been developed on planar structures [3–9]. With this technique, pitches of 200 μm between active elements are currently set, and even smaller ones have been employed, albeit with a lower gas gain.

We have initiated a project with a view to exploiting the advantages of the SPC geometry and of the microstrip gas chamber amplification region. The project can be divided into two parts.

The first part is a study of the magnification properties of the SPC by using a detector with a conventional wire structure in the amplification region; with this set-up, processes of charge deposition in gases can be studied, with spatial samplings of a transverse size below 30 μm (which should allow us to count clusters of primary ionization and have a measure of their size).

The second part of our project is the design, construction, and operation of a μSPC , with the amplification region instrumented with microstrips. The aim is to develop a prototype with maximum spatial resolution in the transverse plane.

2 Conventional SPC and magnification

We plan to set up and operate, initially without magnetic field, a conventional SPC with sense wires at a radius ≈ 15 cm and a pitch ≈ 1 cm. The RPC active volume will be divided into 90 equal cells. With a central cathode of a radius of 15 μm , the transverse size of the 90 cells will decrease linearly from 1 cm in the amplification region to 1 μm at the surface of the central cathode. At 1.5 mm radius, the cell's transverse size will be 100 μm ; at 5 mm radius, it will be about 300 μm , and the equidrift curves will have the shape of narrow U's about 5 mm deep. The radial separation between two contiguous equidrift curves is given by the FADC electronics sampling time, which is 10 ns in the commercial FADC electronics that we have chosen. Therefore the distance, in the radial direction, between two contiguous equidrift curves will typically be 500 μm . The active volume of the detector in the region around the central cathode (with radius below 1.5 mm) will

therefore be sliced into cell pixels of radial extension ≈ 5 mm, $500\text{ }\mu\text{m}$ radial thickness and $< 100\text{ }\mu\text{m}$ transverse extension. The longitudinal diffusion will enlarge the radial thickness. The transverse diffusion will cause mixing between contiguous cells.

In Ar gas at NTP, there is typically one cluster of about 30 eV per $300\text{ }\mu\text{m}$, generated by the passage of a minimum-ionizing particle, and one cluster of about 400 eV per 1.5 cm [10]. A minimum-ionizing particle orthogonal to the RPC axis and traversing the RPC at a distance < 1.5 mm from the central cathode will therefore generate ionization in at most one of three cells orthogonal to the track. It will therefore be possible to count the number of clusters that are generated by tracks, in the cells they crossed almost perpendicularly, just by counting the cells with hits and those without. Moreover, the number of contiguous cells with signal will be controlled by the cluster size and by the transverse diffusion. The parameters of a minimum-ionizing particle track through the RPC can be determined by measuring its minimum distance from the sense wires at the entrance and the exit of the chamber. The minimum distance from this track to the chamber axis can thus be defined.

We will also make use of sources of soft X-rays and Auger electrons deposited on the central cathode of the RPC. The sources will be ^{54}Mn and similar ones, emitting in tight coincidence γ -rays, which are well suited to providing the timing and trigger for the chamber [11]. The number of contiguous cells firing will give information about transverse diffusion and cluster size for soft X-ray events, and about transverse diffusion and effective electron range for Auger electrons.

In these measurements, the bulk of the active volume of the RPC will be used as a conventional reference drift chamber. The relatively large size is intrinsically necessary to provide the spatial magnification, but the large drift path causes large longitudinal and transverse diffusion.

3 The μSPC layout

Figure 1 shows a schematic drawing of a μSPC prototype. The central cathode is a wire with, for instance, $10\text{ }\mu\text{m}$ radius, set at negative voltage. The amplification region is instrumented with microstrips parallel to the chamber axis and deposited on a thin plastic foil [8] bent at a radius of, say, 1 cm. We plan to adopt a pitch of about $200\text{ }\mu\text{m}$, with which several groups have successfully operated planar structures. Instrumenting the full active volume of the chamber will require 300 readout channels. A printed-circuit board, orthogonal to the chamber axis, will connect the strips to the preamplifiers and to the HV power supply. The body of the μSPC will be enclosed inside a vessel; this will allow us to evacuate the active volume and to operate the chamber at pressures up to 4 atm. The length of the active volume will be a few centimetres. The field shaping in the two end-caps will be provided by two uniform layers of germanium coating, ensuring a $1/r$ decrease of the resistance [12, 13].

With this device the magnification will reach 1000. The cell transverse size at the surface of the central cathode will be $0.2\text{ }\mu\text{m}$, whilst it will be $< 20\text{ }\mu\text{m}$ for radii < 1 mm; the radial depth of the equidrift curves will be $100\text{ }\mu\text{m}$, well below the $500\text{ }\mu\text{m}$ distance between two contiguous equidrift curves for the 10 ns sampling-time FADC electronics. A minimum-ionizing particle, traversing the detector at a distance from the axis < 1 mm, will cross about 150 cells. The length of the dx intercept of a track with a cell increases with decreasing angle α between the cell and the track in the transverse plane. The cells at low α allow the track parameters to be measured accurately. Resolutions of better than $40\text{ }\mu\text{m}$ have been reported in planar structures. At high α , the ionization

(generated every $\approx 300 \mu\text{m}$) will give signals typically in one of ten contiguous cells. The transverse diffusion is minimized by the reduced size of the detector.

A series of measurements varying the mass, charge, and momentum of the ionizing agent, and the density and composition of the gas, can be envisaged. Measurements are foreseen to start in 1992 with the conventional RPC and in 1993 with the first μSPC prototype.

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Amplification region with μ -STRIPS

Figure 1: Scheme of μ SPC