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NEW EXPERIMENTAL RESULTS

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Abstract

A TPC-type RICH-counter with a $200 \times 200 \text{ mm}^2$ quartz window and a 1.27 mm wire pitch MWPC has been tested in a 10 GeV/c π^- beam. The MWPC is equipped with optical screens (called "cloisons") between the anode wires, with the purpose of absorbing the secondary UV-photons emitted from the charge avalanches around the wires. The test results show that the cloisons effectively suppress the noise caused by the photon reemission, without affecting the detection efficiency for single photoelectrons in the MWPC.

Introduction

In the present report we present results obtained with a new time-projection-type RICH counter in a 10 GeV π^- test beam at the CERN PS. These new tests were performed only two weeks ago and although the progress made can be clearly demonstrated the details of the results reported here are preliminary. The off-line analysis is under way and new measurements will resume in a week.

Before describing the measurements, let us shortly outline the ultimate purpose of the present investigation which is to provide RICH counters for use in colliding beam experiments. Unlike the situation in fixed target experiments a counter in a colliding beam experiment usually is required to cover the full solid angle and, also, to be very compact. It has furthermore become clear that it is difficult to keep the inherent concentric-sphere geometry of the Cherenkov ring imaging counter when constructing a general purpose colliding-beam detector that should comprise, in addition to the RICH counter, a magnetic spectrometer and calorimeters. The solution to this problem for the gaseous radiator counter has been to divide the counter into spherical sectors, here called cupolas, which can be inserted in the experimental layout in a way that is compatible with the space requirements of the other detector components.¹ How this division is done in principle is illustrated in Fig. 1. The basic consideration in the decomposition of the spherical counter into cupolas is that the aperture of each cupola must be made sufficiently small so that the optical aberrations (which occur if the particle tracks do not pass through the center of curvature of the mirror) do not exceed the irreducible, chromatic errors in the system.²

The DELPHI detector³ at LEP, shown in Fig. 2, is an example of how this decomposition can be done in practice (the heavy lines that delimit the cupolas in this figure are only drawn to indicate the apertures of the counters and do not correspond to physical walls between the gas volumes).

In Fig. 3 the UA2 experiment at the CERN proton-antiproton collider is shown equipped with a single RICH cupola in one of the endcap sectors.⁴ It is planned to install this counter in summer 1984 with the aim of improving the e/π separation capability in this sector for momenta up to about 10 GeV/c.

Fig. 1. (a) Ideal spherical ring imaging geometry and (b) RICH cupola geometry.

Fig. 2. Implementation of ring imaging detectors in the DELPHI spectrometer at LEP.

Fig. 3. Planned installation of RICH in the UA2 experiment at CERN.

The work reported here forms part of the development of RICH detectors to be used in these experiments. In particular the detector described in the present report corresponds to the short drift (20 cm), high spatial resolution detectors (wire pitch 1.27 mm) to be installed in the endcap sector in the UA2 detector and, later on, in the endcaps of the DELPHI detector.⁵

Earlier Experience

The basic principle of the TPC-type single UV-photon position-detector as proposed and developed^{6,7} by our group is illustrated in Fig. 4. The UV-photons are incident through a quartz window behind which they are absorbed, by a photoionizing vapor like TMAE (tetrakis dimethylamino-ethylene) mixed into a drift-chamber gas like CH_4 (80%)/iso- C_4H_{10} (20%). The absorption is followed by emission of single-photoelectrons which drift in an electric field, directed parallel to the quartz window, up to a MWPC where they are detected. The drift time gives the x-coordinate and the wire address the y-coordinate.

In Fig. 5 is shown the construction of an earlier detector of this type. This detector contains two MWPC's and two drift regions, with the electron drift in opposite directions and with an insensitive slot in the middle. The drift field cage is made up of two potential wire layers, one on either side of the 5 mm thick quartz window, and a single wire layer inside the gas

volume, 45 mm away from the quartz window and 100 mm away from the back wall of the drift-gas container. The maximum drift length in either of the two drift regions is about 120 mm and the MWPC has 224 wires, each with a pitch of 1.27 mm.

In Fig. 6 is shown the TPC-image, obtained from the on-line computer-display for 200 accumulated events, when operating the detector without TMAE, having the 10 GeV/c π^- beam running through one of the two drift volumes in a direction perpendicular to the quartz window. The width of the beam spot is determined by the width of the triggered beam (5 mm diameter). The spurious tracks emerging sideways from the beam spot correspond to δ -rays.

Fig. 5. Earlier TPC detector.

Fig. 4. The principle of TPC type photon detector.

Fig. 6. Beam spot without TMAE in detector without cloisons.

In Fig. 7 the same type of data are shown, with the only difference that in this case the detector gas contained about 0.7 torr partial pressure of TMAE. A dramatic blow-up of the beam spot can be seen with a tendency of forming a halo towards later arrival times. The explanation for this phenomenon is that when the ionization created by the passage of the charged particle reaches the anode wires UV-photons are emitted from the charge avalanche around the wires. These secondary UV-photons are then converted to electrons in case TMAE is present. The mean free path for UV-photon absorption in 0.7 torr of TMAE is about 12 mm and the background photoelectrons are therefore spread around, on average, by this distance and tend to arrive to the MWPC at a later time than the primary beam track ionization. On average there were about 20 background points per beam track created in this way. The beam track produced a dE/dx -charge of about 250 electrons over the 45 mm track length in the drift volume, and the probability for obtaining a background point through this mechanism is thus of the order of 8% per electron.

Fig. 7. Beam spot with TMAE in detector without cloisons.

In order to verify the understanding of this background and to seek for a solution how to suppress it, small UV-light-absorbing walls were installed between the anode wires in a small 2.54 mm wire pitch detector. In a first approach, in which the walls were made of insulating material, the detection efficiency of the chamber was drastically reduced, owing to field distortions around the anode wire. It was concluded that these distortions were due to charges being accumulated on the separating walls. Making the separating walls conductive by deposition of a thin layer of carbon did not solve the problem. The conclusion was that having insulating or equipotential separating walls did not lead to an efficient collection field around the anode wire, at least not in the particular geometry chosen which had a comparatively small angular opening ($\pm 23^\circ$) between the endpoints of the walls, as viewed from the anode wire (this angle should be small in order to minimize the solid angle over which reemitted photons are not absorbed by the walls).

The final solution tried was to use separating walls (cloisons), made of thin printed circuit boards with thin conductive lines running parallel to the anode wires along the two surfaces of the board. Equipping a limited region of the 2.54 mm pitch MWPC, it was found that the voltages on these lines could be tuned so to obtain a fully efficient charge collection in the MWPC from beam tracks.

The New Detector

On the basis of this experience the detector shown in Fig. 8 was constructed. In this case the 5 mm thick quartz window is $200 \times 200 \text{ mm}^2$. The thin back wall of the drift-gas container is mounted only 40 mm away from the quartz window and supports a layer of parallel printed circuit lines on either side of the wall. In Fig. 9 the drift box with flanges for the radiator container (down) and for the MWPC (front) is shown in perspective.

Fig. 8. The new detector with cloisons.

Fig. 9. Perspective view of drift box.

The MWPC has an anode wire pitch of 1.27 mm and is equipped with cloisons. Figure 10 shows in three views the construction of the support for the wires and the cloisons in the MWPC. The 10 μm diameter anode wires are soldered on 0.6 mm wide holders, consisting of copper-wire hooks, surrounded by plastic insulator. The signals are led through these hooks to the backside of the cathode plane on which the preamplifiers are mounted on small IC-sockets.

Fig. 10. Details of the cloison (blind) picket fence.

The cloisons consists of 5 mm wide and 30 μm thick Kapton strip, mounted between the anode wires. The potential on the surface of the Kapton strip is controlled by eight 35 μm diameter stainless-steel wires, running along the surface of each strip, four wires on either side, with a distance between adjacent wires on one side of 7 mm (see Fig. 10). The wires are stretched around small ceramic pylons and are kept in place by small washers. The pylons are mounted between two metallic frames outside the anode-wire holders with one pylon behind every second such holder allowing eight single potential wires of about 10 m length to be wound around the endpoints of the anode wires in a serpentine-like manner. The high voltages applied at the endpoints of these wires thus simultaneously control the electrostatic field around all anode wires in the MWPC. Mechanically the cloison strips are kept in place by the potential wires. Finally, a single wire grid is mounted on top of the MWPC, adding a 70 μm diameter wire

on the top-edge of each cloison. The "cell" around one anode wire thus consists of five potential wires at a height of -1, 0, +1, +2 and +3 mm with regard to the anode and at a lateral distance of ± 0.6 mm. A cathode plate is mounted at -2 mm, below the anode wire. The opening angle between the upper borders of the cloisons, as viewed from the anode wire, is $\pm 13^\circ$, leaving only a very small solid angle over which the photons are not absorbed by the cloisons ($\sim 7\%$).

Results of Beam Tests

In a first series of runs at the CERN PS, performed in the t_0 beam line in the East Area with 10 GeV/c negative particles, the homogeneity of the drift field inside the field-cage was investigated by recording straight beam tracks traversing the drift volume parallel to the quartz window. A single straight beam track is shown as recorded in Fig. 11. By placing the detector in a series of different positions in the beam, thus scanning the drift volume, it was found that the collection of the beam ionization was complete also in case when the beam was running close to the quartz window or near the back wall at the drift volume. This is illustrated in Fig. 12 in which it can be seen the number of wires hit per beam track is independent of beam position as long as the whole beam is inside the drift region. (The successive drop-off at the end of the distribution are due to the finite size, 5 mm diameter, of the beam. The small slope of a few percent seen in the drift direction scan is probably due to the electric field being directed slightly away from the side walls of the drift cage when approaching the MWPC.)

The square of the average residue distance of a point from the fitted straight line (Fig. 11) is shown in Fig. 13 as function of longitudinal drift distance from the MWPC. The residue is expressed in units of nanoseconds. With a drift velocity of 65 mm/ μsec one may conclude that the residue per point increases from about 0.45 mm to about 0.6 mm when scanning over the drift region. This increase is compatible with being due to diffusion.

In a second series of runs the photon detector was mounted on the radiator gas vessel which was filled with isobutane (containing less than 5×10^{-4} impurities, further purified through Oxisorb). The focussing mirror is a polished spherical glass mirror with a focal length of $f = 500$ mm, coated in vacuum with 90 nm Al and 35 nm MgF_2 . The detector gas (80% CH_4 , 20% iso C_4H_{10}) was bubbled through TMAE at 28°C . The

Fig. 11. Event with a single straight beam track.

Fig. 12. Number of wires hit per beam track versus position.

Fig. 13. Residual squared from straight line versus drift distance from MWPC.

beam was incident slightly off the optical axis of the system (impact parameter $x = 0.05$).

In Fig. 14 the on-line display of the first 300 events recorded is shown. The Cherenkov ring and the beam spot, limited to the size of the triggered beam (5 mm diameter), are clearly distinguished. Also seen are the δ -ray background and some remaining ionization from early beam-tracks (vertical line down from the beam spot - the two circular lines are fiducial limits drawn by the computer).

In Fig. 15 three individual event-displays from the first run are shown. The beam spot is limited to about four adjacent wires. Moving the beam spot to the other side of the ring, close to the MWPC, reduced the size to about two wires. The number of photons per event was about six in this first run. After some further optimization of the MWPC high voltages an average of about 10 photons per event was obtained.

Fig. 14. Online display of first 300 events.

Fig. 15. Three individual events with the beam in the detector.

Figure 16 shows three individual events recorded under these conditions (in this case the beam had the same direction as in the first run but it had been moved out of the photon detector). With an effective radiator length of 47.5 cm and a Cherenkov angle of 54 mrad this corresponds to a N_0 value of about 72

cm^{-1} . Further optimization of N_0 , as well as a detailed study of the Cherenkov angular resolution, will be carried out in future runs.

Fig. 16. Three events with the beam out of photon detector and a mean number of detected photons of 10 per event.

Conclusions

The first test results obtained with the new TPC-type single-photon position-detector show that using thin dielectric walls (cloisons) with field-defining wires running along the surface to screen optically the anode wires from each other makes it possible to detect the charged particle ionization (~ 250 electrons) and the single photoelectrons simultaneously side by side. The measurements indicate no loss in the single-photoelectron detection efficiency. Furthermore, the drift cage consisting on all sides of thin dielectric walls with narrow field-defining strips or wires (the ratio of the strip or wire width to the pitch is smaller than 1:10) is found to produce a drift-field of satisfactory uniformity inside the whole volume.

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