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G. Bendiscioli, P. Boccaccio, V. Filippini, U. Gastaldi, M. Lombardi,
E. Lodi Rizzini, C. Marciano, G. Maron, M. Morando, G. Pasquali, R.A. Ricci,
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The 4π cylindrical detector SPC/XDC for X-ray and charged particles detection in antiproton annihilations in the OBELIX experiment at LEAR

G. Bendiscioli[2)], P.Boccaccio[1)], V.Filippini[2)], U.Gastaldi[1)], M.Lombardi[1)], E.Lodi Rizzini[5)], C.Marciano[2)], G.Maron[1)], M.Morando[3)4)], G.Pasquali[3)], R.A.Ricci[1,4)], A.Rotondi[2)], P.Salvini[2)], L.Vannucci[1)], G.Vedovato[1)], A.Zenoni[2)]

1) INFN Laboratori Nazionali di Legnaro, Via Romea 4, 35020 Legnaro PD, Italy
2) Dipartimento di Fisica Nucleare e Teorica, and INFN Sezione di Pavia, Via Bassi 6, 27100 Pavia, Italy
3) INFN Sezione di Padova, Via Marzolo 8, 35131 Padova, Italy
4) Universita' di Padova, Via Marzolo 8, 35131 Padova, Italy
5) Dipartimento di Automazione Industriale, Università di Brescia, Via Europa 39, 25155 Brescia, Italy

Abstract

The central detector of the OBELIX experiment has been in operation during the 1990 runs with antiprotons at rest at LEAR. After a brief introduction, we illustrate its initial performances.

I. INTRODUCTION

The detector - called Spiral Projection Chamber (SPC)[1] or X-ray Drift Chamber (XDC)[2] depending whether its use for charged particles or for X-ray is emphasized - surrounds a cylindrical gas target at NTP, from which it is separated by a very thin mylar foil, and is positioned along the axis of the Open Axial Field Magnet[3] in the center of the Obelix experiment[4].

The SPC is similar to the Time Projection Chamber (TPC)[5], but has different geometry and accordingly different advantages.

The design[6] of the OBELIX SPC was based on the experience from ASTERIX SPC[7] and aimed at major improvements in the hardware capabilities, calibration procedures and event reconstruction software.

The SPC is used as X-ray drift chamber to identify and measure the energy of soft X-rays (0.5-15 Kev) emitted in the atomic cascade of pp atoms formed by antiprotons stopped in the H_2 target surrounded by the detector. The detection of X-rays from pp atomic transitions is necessary for performing a program of differential measurements proposed to observe broad states of glueballs, hybrids and quasi-nuclear baryonium, if they are produced in pp annihilition at rest with appreciable rates and with marked dependence from the quantum numbers of the initial state[8].

The SPC is used as charged particle detector to count the prong multiplicity in pp and p-nuclei annihilation, to measure the recoil proton in pn annihilation with D_2 gas in the target, to measure the direction and the specific ionization (dE/dx) of prongs, and to reconstruct accurately in three dimensions the annihilation vertex. Moreover it can be used to veto events with antiprotons scattered too far away from the beam axis and entering the SPC active volume.

II. DETECTOR CHARACTERISTICS

The detector (see Fig. 1 for the general scheme) is a 90-cell cylindrical projection chamber (L=60 cm, Φ_i=6 cm, Φ_e=29 cm) with radial drift field. The counter gas is separated from the target by a thin alluminated mylar tube (12 µm thickness) to allow good transmission for soft X-rays and low momentum prongs. The mylar tube also acts as internal cathode surface for the drift field. Charge division is applied to the 90 wires and 100 MHz FADC are used to sample and record the shape of the pulses generated by primary ionization. The read out and acquisition system are described in a separated paper[9].

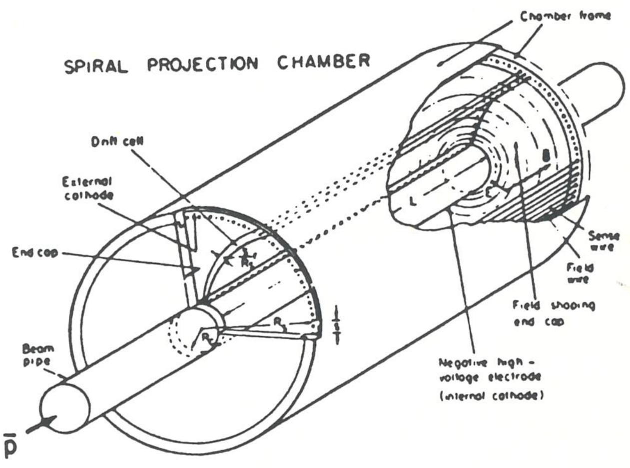

Fig.1 SPC schematics

90 cathode helicoidal strips are deposited on the inside of the external cathode surface so that each strip crosses 85 wires. The strips are equipped at one extremity with the same read out electronics of

the wires. The information of the strips extends the dynamic range of amplitude analysis, and improves the z resolution by the center of gravity technique.

Primary ionization clusters are localized in three dimensions: ϕ by wire number, ρ by drift time and z by charge division first and by wire/strip center of gravity crossing next. The absorbtion point of an X-ray and the generation point of a large cluster produced by an ionizing particle are localized inside one of the about 10^7 pixels into which the active volume of the detector can be electronically sliced. The form of the equidrift lines in the drift cell (see Fig. 2) gives the pixel a "gondoletta" shape. In the elongated part of the cell, away from the sense wire, the "gondoletta" have a radial extention of 500μm (determined by drift velocity and by the electronics samplig time), a z extension of 3 mm and an angular extension of 4^o .

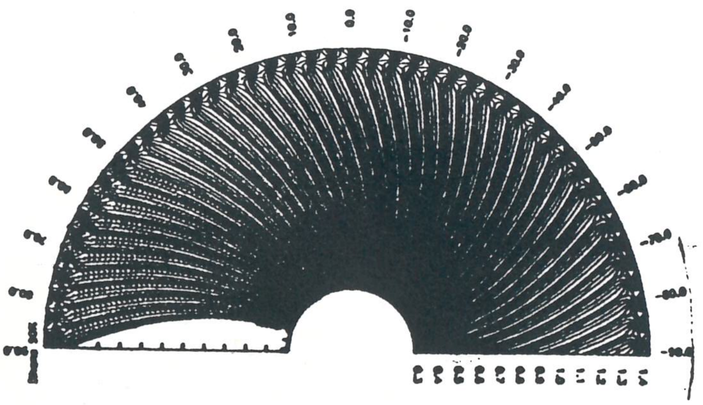

Fig.2 drift cell shape

The axial simmetry of the detector and the equality of all the drift cells permit to get from the SPC a trigger for the whole experiment. The triggers are based on the hit multiplicity at all radii in the active volume (X ray: an isolated hit in space; prong multiplicity: number of hits at the same drift time; neutral particle decay into two prongs: variation by two of the hit multiplicity).

III. INITIAL PERFORMANCES

The detector has been tested with X-ray sources and with cosmic rays, and operated in data acquisition run at LEAR during August '90 with Ar/C_2H_6 50/50 nominal gas mixture.

We used ^{54}Mn , ^{57}Co and ^{65}Zn X-ray sources to investigate the energy resolution, amplitude linearity and spatial resolution response.

These sources emit in coincidence with the X ray a gamma ray, which is used to trigger the data acquisition system and to give the zero time. The sources were point-like and positioned on the axis of the SPC.They were supported by the scintillator used for tagging the X-ray. The surface of the support shadowed one portion of the active volume from X-ray illumination, with a sharp cutoff in z or in ϕ[10].

The three dimensional reconstruction of the absorbtion point of an X-ray is easy because the signals are well identified and have a large amplitude. The sharpness of the reconstructed boundary of the shadow gives a direct measure of the spatial resolution. The use of the center of gravity of the strips for the z measurements gives a z resulution of $\sigma_z = 1$mm, a result more than one order of magnitude better then the previous one of the ASTERIX XDC obtained by charge division only. Ref [12] illustrates some of the results that have yielded the z resolution of $\sigma_z = 1$mm.

The X-rays illuminating the active volume of the SPC not shadowed are used for calibrating the gains of all the electronic chain[11].

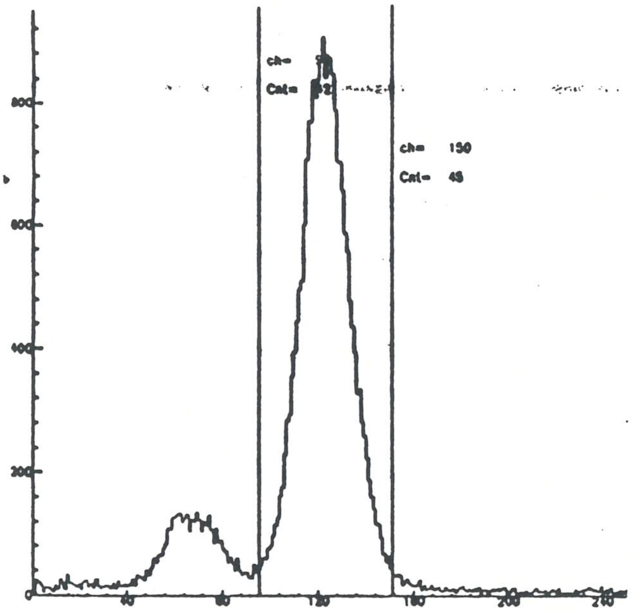

Fig.3 ^{54}Mn X ray spectrum

Fig. 3 shows the energy spectrum of the ^{54}Mn source, after the electronic calibration. This source emits an X ray of 5.5 Kev and the peak corrisponding to this energy is clearly visible in the spectrum. The escape peak coming from the Argon fluorescence (due to signal of 2.5 Kev and 3 Kev ionization) is visible at the left of the main peak.

The energy spectrum with the ^{57}Co source is plotted in Fig.4.The spectrum features the prominent 6.5 Kev signal and the associated escape peak at 3.5 Kev, and the 14.4 Kev small peak due to the soft γ ray line.

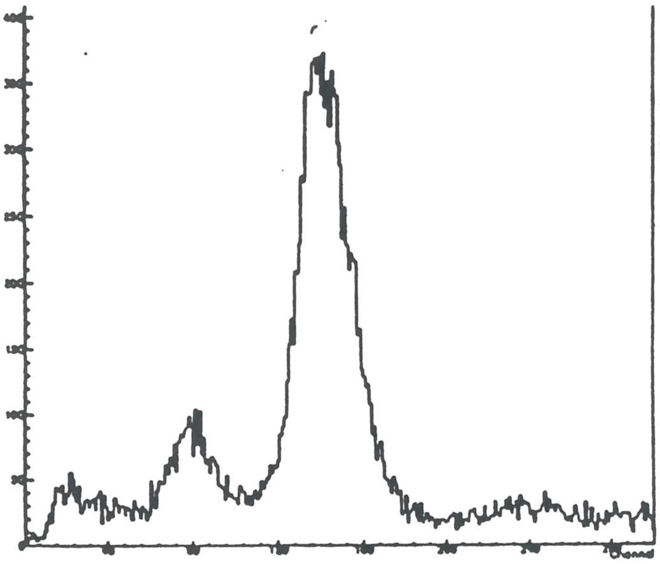

Fig.4 ^{57}Co X ray spectrum

The measured energy resolution is 18% FWHM at 5.5 Kev.

H_2, D_2 and ^4He gas targets at NTP have been used with the Ar/C_2H_6 50/50 nominal gas mixture in the chamber during the August '90 antiprotons runs. Correspondingly more than 100.000, 50.000 and 20.000 events with stopping antiprotons have been collected.

The quantitative study of the detector performances with charged particles is in progress, and it requires substantial software development in particular to exploit the informations obtainable from the strips. This software work is in progress, however several essential features and performances of the detector are already evidentiated from the display of some events that have been recorded. The displays are given with the default settings of the calibration costants and are bound to improve when calibration values will be extracted from the data themselves (in all the event displays the signal amplitudes integrated over 50 ns are represented by vertical bars (wires) and horizontal bars (strips)).

Fig. 5 shows a pp annihilation with six prongs.

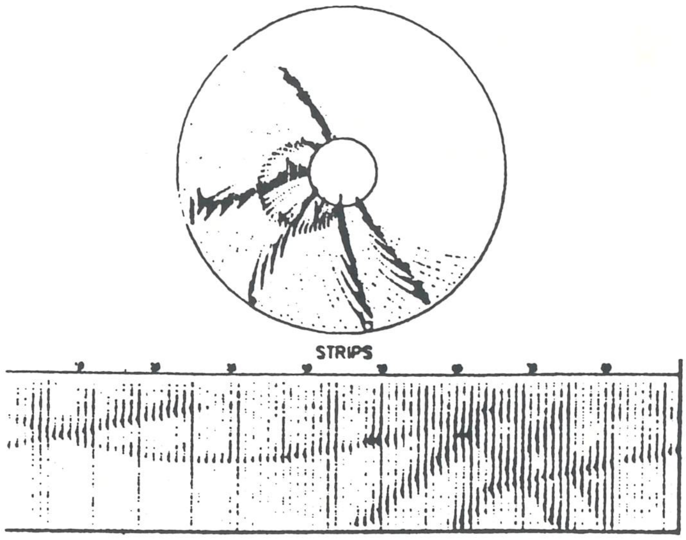

Fig.5 pp event

The upper part shows the raw sampled pulses from anode wires, while the lower parts shows the sampled pulses coming from strips.

In the upper (wires) part the ρ coordinate is computed using the drift time and the computed shape of the drift cell, while the ϕ coordinate is directly related to the wire number.

The lower part of the figure shows the signal from strips: from left to right the strip number, from bottom to top the drift time.

One of the tracks is due to a very low momentum particle. Along the track we can easily identify the clusters of large deposited energy, contributing to the tail of Landau distribution. One track exits the chamber from the field shaping end cap.

In both the wires and strips display, one notes six bands associated with prongs coming from the target. One can connect the low momentum and the end cap exiting particles with two tracks in the strip plane. The wire/strip connection in the remaining four tracks requires the solution of an ambiguity. This operation can be carried out with the help of charge division, which gives a z point with lower precision, but useful to exclude uncorrect connection.

This event illustrates another feature of SPC: due to the very low quantity of material between the target and the chamber, also very low momentum or highly ionizing particles (i.e. proton or nuclear fragment) can be detected.

Fig. 6 shows a cosmic ray crossing the chamber without magnetic field.

In the bottom of Fig. 6 the long signal of the one cell traversed by the cosmic ray is displayed. Again an "high energy" isolated cluster is visible.

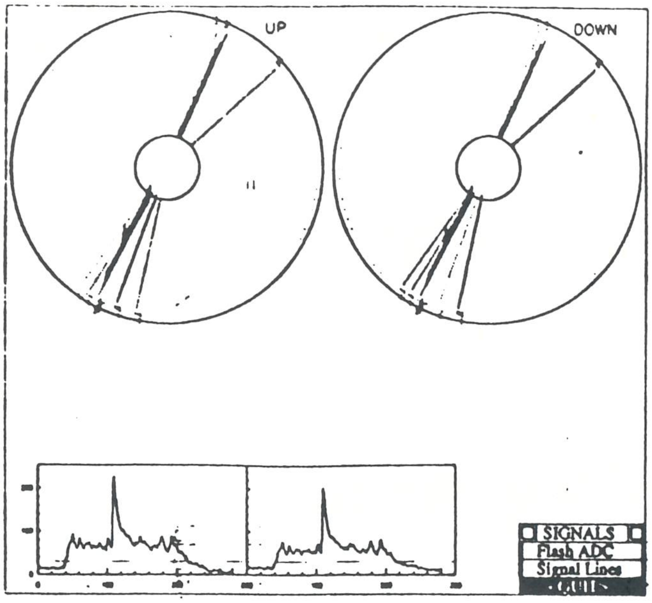

Fig.6 cosmic ray

Fig. 7 shows a K^0_S decay into two π. Due to short distance between the vertex and the active part of the chamber, also short life neutral particles can be identified.

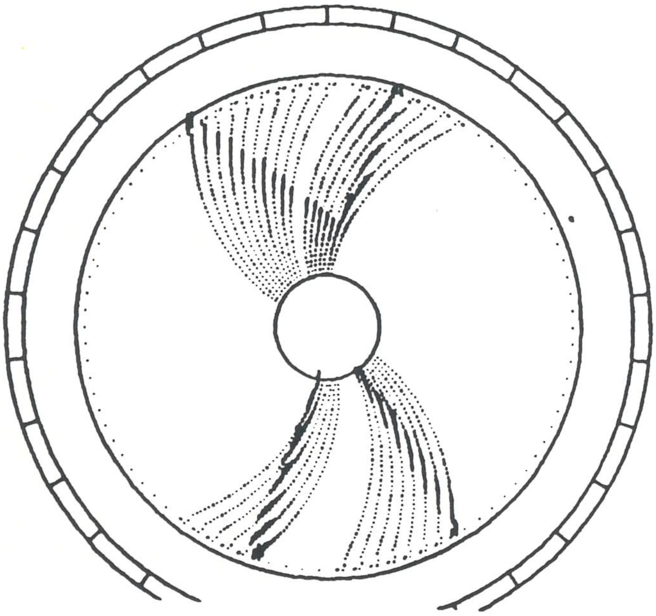

Fig.7 K^0_s decay

Fig. 8 shows a pd annihilation event. The recoiling proton is clearly identified due to its highly ionizing track, that saturates the FADC on the wire.

The same is not true for the proton track on the strips. This is due to the fact that only a fraction of the signal on the wires is induced on the cathode strips.

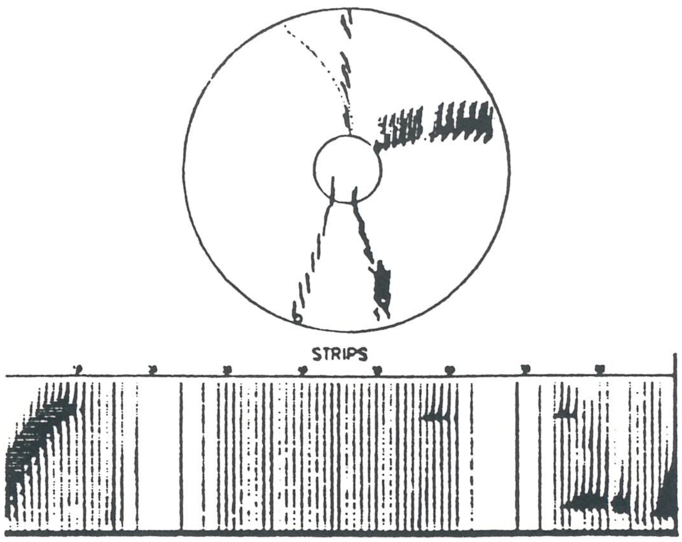

Fig.8 pd event with an outgoing proton

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