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CERN-PRE 90-043
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LNL INFN (REP) 034/90

3 SEP. 1990
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CM-P00052101

Presented at the 4th Course of the
International School of Physics with Low-Energy Antiprotons
Erice, Italy, 25-30 Jan. 1990

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(presented by V. Filippini)

INTRODUCTION

An X-ray detector for $p\bar{p}$ 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 $p\bar{p}$ annihilation at rest with appreciable rates and with marked dependence from the quantum numbers of the initial state¹.

The X-ray detector is requested to feature the following properties:

- High angular acceptance
- Low energy threshold
- Low mass
- High granularity
- High spatial resolution in three dimensions
- Fair energy resolution
- Good X-ray identification.

These properties, that are also an asset for a good annihilation vertex detector, are necessary not only to identify and measure efficiently protonium X-rays, but also to make the detection efficiency for a given exclusive final state of annihilation independent from the presence of the X-ray in the event. This last feature is very important in order to factorize efficiencies and acceptances in the differential measurements¹.

A program of meson spectroscopy differential measurements with two different distributions of angular momentum of the initial state of protonium is part of the scientific program of the OBELIX experiment², that includes also studies of interactions of antinucleons with nucleons and nuclei.

Our groups are commissioning the central detector of OBELIX, which is briefly presented in this contribution.

DETECTOR CHARACTERISTICS

The detector - called Spiral Projection Chamber (SPC)³ or X-ray Drift Chamber (XDC)⁴ depending whether its use for charged particles or for X-rays is emphasized - surrounds a cylindrical gas H_2 target at STP, and is positioned along the axis of the Open Axial Field Magnet⁵ in the center of the OBELIX experiment. The SPC is similar to the Time Projection Chamber (TPC) invented by Nygren and coworkers⁶, but has a different geometry and accordingly different advantages.

The design⁷ of the Obelix SPC was based on the operation experience from the ASTERIX SPC⁸ and aimed at major improvements in the hardware capabilities, calibration procedures, and event reconstruction software.

The detector will be 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 $p\bar{p}$ atoms formed by stopped antiprotons in the H_2 target surrounded by the SPC. The detection of the last X-ray transition of protonium permits to constrain or fix the angular momentum of the initial state of a $p\bar{p}$ annihilation reaction at rest. It is therefore foreseen to have a possibility of triggering the general data acquisition system on preselected X-ray patterns. The SPC will be used to count the multiplicity of charged particles emitted in $p\bar{p}$ and $\bar{p}A$ annihilations, to measure direction and ionization dE/dx of prongs, to reconstruct accurately in three dimensions the annihilation vertex, and also to veto events with antiprotons scattered too far away from the $\bar{p}$ beam axis and entering the SPC active volume.

The detector is a 90-cell cylindrical projection chamber ($L=60\text{cm}$, $\phi_1=6\text{cm}$, $\phi_2=29\text{cm}$) with radial drift field. The counter gas is separated from the H_2 target gas by a thin mylar tube ($\phi=6\text{cm}$, $\sim 6\text{mm}$ thickness) to allow good transmission for soft X-ray and low momentum prongs. The mylar tube also acts as the internal cathode surface for the drift chamber. Charge division is applied to the 90 wires and 100 MHz flash analog to digital converters (FADC) are used to sample and measure the shape of the pulses generated by primary ionization deposited in the active volume of the chamber by X-rays or by charged particles. 90 cathode strips are wound on the inside of the external cathode surface ($\phi_2=29\text{cm}$) of the chamber so that each strip crosses 85 sense wires. The strips are equipped on one side with the same front end and read out electronics as the anodes. The information of the strips extends the dynamic range of amplitude analysis of the anode wire pulses (8 bit linear, 10 bit non linear) and improves by the center of gravity technique⁹ the z resolution.

Primary ionization clusters are localized in three dimension: ϕ by wire number, r by the drift time (delay of the leading edge of the associated pulse), and z by charge division first and by anode-strip center of gravity crossing next. The absorption point of an X-ray (and the generation point of a large cluster produced by the passage of a ionizing particle) are localized inside one of the about 10^7 pixels into which the active volume of the detector is sliced electronically. The form of the equidrift lines in the drift cells give the pixels a

"gondoledda" shape with radial extension 500 μm (determined by the drift velocity and the electronic sampling time), a z extension of 3 mm and an angular extension of 4° .

The axial symmetry of the detector and the equality of all the drift cells permits to realize simple triggers based on the hit multiplicity at all radii in the active volume (X-ray: isolated hit in space, prong multiplicity: number of hits at the same drift time, neutral particle decay vertex - e.g. $K^0 \rightarrow \pi^+\pi^-$: variation by two of the hit multiplicity as a function of the drift time). Commercial electronics exploiting the analog signals of the wires is employed for producing triggers on X-ray, K^0 or Λ , and prong multiplicities.

INITIAL PERFORMANCES

Initial measurements outside the OAFM magnet with tagged X-ray sources and cosmoics indicate that the design performances can be reached. In particular a resolution better than $\sigma_z = 2\text{mm}$ has been measured for 5.5 Kev X-ray by use of crossing of the center of gravity of the strips signal and the hit anode wire.

Fig. 1 shows the event display of one event containing a 5.5 Kev X-ray from a Mn^{54} source deposited on the axis of the SPC onto the flat surface of a plastic scintillator, that provides the trigger and the timing of the data acquisition via the 0.8 Mev gamma ray emitted in coincidence.

Fig. 1. Display of one event with a 5.5 KeV Mn^{54} X-ray in the SPC.

For test and calibration purposes we had two such sources and scintillators positioned upstream and downstream of the SPC on its axis at distances of 248 mm from the target center. The support of the sources screened all the X-rays emitted in the half emisperes not facing the target center. By this mean the distribution of the absortion points of X-rays inside the active volume of the SPC was expected to feature a sharp cutoff at values $z = \pm 248$ mm, and in correspondence of the separation mylar tube ($r = 3$ cm). Fig 2 shows a scatter plot for a run without magnetic field of the absortion points of X-rays (z versus drift time - corresponding in first approximation to a z versus radius plot), that features the expected sharp cutoffs. Fig. 3 shows the z distribution of the points of Fig.2 illustrating the two sharp cutoffs in z , that reflect the localization of the two sources and the good z resolution obtained with the anode crossing the strips center of gravity for all drift times. Fig. 4 shows the distribution of the absortion points in the radial direction with a z cut selecting X-rays emitted in directions nearly ortogonal to the SPC axis. This distribution features an exponential slope that gives the mean free paths of 5.5 Kev X-rays in the SPC gas ($\text{Ar-C}_2\text{H}_6$). This curve permits to measure the minimum and maximum drift times, and indicates a signal to noise ratio better then 200 near to the mylar membrane.

Fig 2. (r, z) scatterplot of absorption points of X-rays emitted by the two Mn^{54} sources positioned on the SPC axis.

Fig. 3. Z distribution of all the points of the scatterplot of fig.2.

Fig. 4. Radial distribution of the absorption points of X-rays emitted by one source in directions nearly orthogonal to the SPC axis.

The continuum line in fig. 5 shows the amplitude distribution of X-rays from events where only one cell of the SPC had fired. This selection rejects nearly completely the escape peak at 2.5 Kev. The dashed line in Fig. 5 shows the amplitude of the events in which two and only two non adjacent cells of the SPC had fired. This selection picks up events with a 2.5 Kev energy deposition in one cell, and a 3 Kev Ar fluorescence X-ray absorbed in another one.

Fig. 5. Mn^{54} X-ray amplitude spectra.

Fig. 6 shows the event display of one event with a cosmic ray crossing the detector. The upper part of the figure is self-explanatory, taking into account that amplitudes integrated over 50 ns sampling time are displayed in the vertical direction. The lower part of the figure displays the signals of the strips.

The detector has been exposed to a 105 MeV/c antiproton beam at LEAR in November 1989.

Fig. 6. Display of an event with a cosmic ray crossing the SPC and an external scintillator used for triggering and timing.

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