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BEAM PROFILE MONITOR FOR VERY LOW ENERGY ANTIPROTONS
USING POSITION SENSITIVE PHOTOMULTIPLIER

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1. ABSTRACT

A new type of beam profile monitor for low and very low energy antiproton and proton beams has been developed. It is based on a position sensitive photomultiplier coupled to an adequate inorganic scintillator. The device presented at this conference is characterized essentially by the possibility of detecting low energy protons or antiprotons (and even stopped antiprotons) inside or in front of a scintillator, operating under Ultra High Vacuum conditions. The beam is displayed in real time, and the beam intensity can be measured.

We present recent results obtained with 200 MeV/c and 105 MeV/c antiproton beams extracted from the CERN low energy Antiproton Ring (LEAR), and also the results obtained with a 80-200 KeV H^- beam from the pbar mass (PS189) H^- source experiment.

2. INTRODUCTION

The CERN proton synchrotron complex feeds with protons, antiprotons, heavy ions, electrons and positrons two physics experimental areas, the SPS and LEP. Fig. 1 illustrates very schematically this PS complex⁽¹⁾.

Fig. 1 : schematic diagram of the PS complex

The Low Energy Antiproton Ring (LEAR) is a part of the PS complex and feeds with low energy antiprotons (sometimes protons for calibration and setting up purposes) several antiproton physics experiments⁽²⁾. Fig. 2 shows a layout of LEAR and its extracted beams (see next page).

In order to control these beams, a number of diagnostic devices or detectors are installed in predetermined positions. These detectors must operate under the ultra high vacuum condition of LEAR, be radiation resistant, and have also to be retractable⁽³⁾. It is desired to monitor beam position, profiles and intensity. The main type of detector in use, up to now, is a home made Multi Wire Proportional Chamber (MWPC) which is insensitive to beams with less

FIGURE 2 : SIMPLIFIED LAYOUT OF EXTRACTED ANTIPROTON BEAMS FROM LEAR

than 100 MeV/c antiproton or proton momenta. However, the PSCC (the LEAR experiments committee) has approved antiproton physics experiments with less than 100 MeV/c antiproton momenta (~ 20 MeV/c i.e. 200 KeV Kinetic energy). The range of antiprotons or protons is only a few micrometers in Aluminium for 20 MeV/c momenta. At the end of their range, the protons are stopped, but the antiprotons are annihilated and produce a number of pions and other particles.

In order to meet these real time monitoring requirements, new types of beam monitors, operating under the above constraints are being developed to study the profile and the intensity of very low energy antiproton beams ejected from LEAR.

We will present one of the detectors which has been developed, consisting of a non outgassing inorganic scintillator coupled to a Position Sensitive PhotoMultiplier (PSPM)^(4,5,6,7,8). The experimental results obtained with 200 MeV/c and 105 MeV/c antiproton beams and with 200-80 KeV H^- beams provided by the pbar mass (PS189) experiment are also presented. A brief presentation of the electronic chains to obtain beam profile in real time is also given.

3. THE DETECTOR

The detector consists of the following commercially available components :

3.1 A position sensitive photomultiplier (PSPM)

Recently commercialized by Hamamatsu⁽⁹⁾, the R2486 tube has a 12-stage fine grid dynode and 16x16 cross-wire anodes. The useful area is 60 mm in diameter. Fig. 3 is an outline of the R2486 PSPM as advertised by Hamamatsu.

• Schematic Presentation of Crossed Wire Anode Type

Fig. 3 : An outline of Hamamatsu R-2486 position sensitive photomultiplier (PSPM).

3.2 An inorganic scintillator coupled to the tube

Two types of inorganic scintillators were used for performance tests of the detector in vacuum. The NE901 (Nuclear Enterprises) glass scintillator and a P11 type phosphor mounted on a glass optical fibre disk. These scintillators are considered to be non-outgassing and resistant to radiation.

The localisation of photoelectrons and the secondary electrons during the process of multiplication inside the electron multiplier of the tube is assured by a new type of fine grid dynode^(4,5,6,8). In order to describe briefly how the localisation of the secondary electrons takes place during the multiplication, we present in Fig. 4

a fine grid dynodes prepared at CERN for PSEM⁽¹⁰⁾.

Details of the grid type dynodes of a position sensitive electron multiplier

Fig. 4 : Position sensitive electron multiplier using home made grid dynodes

A photoelectron or single electron hits the triangular cross-section grid of the first dynode, then a number of secondary electrons will be emitted by the grid, some of them guided by the electric field between the dynodes will hit one or two grids of the next dynode. Because of the fine structure of the grid dynodes, the electric field is almost uniform so that the dispersion of the secondary electrons is limited. However, the dispersion is directly related to the geometric dimensions of the fine grid structure. The secondary electrons emitted by the last dynode will be collected by the corresponding cross-wire anodes. The measurement of the charge collected by the anodes, event by event, allows to reconstruct the impact position of the photons produced inside the scintillator, by using one of the standard centroid methods.

4. ELECTRONIC CHAINS OF THE DETECTOR

Three different types of electronic chains have been used for the reconstruction of impact points as well as the display of the beam profile :

- 1) The "moment" method,
- 2) The "delay line" method⁽¹¹⁾,
- 3) The "charge division" method.

The latter two methods allow to reconstruct in real time the x and y coordinates of the antiproton impact point on the scintillator, and display the corresponding spot point on oscilloscope screen. Fig. 5 illustrates schematically the "charge division" method.

Fig. 5 :
Electronic chain for the "charge division" method

The cross-wire anodes of both x and y planes are connected respectively to a resistance chain with 1 K Ω intervals. This chain divides the total electron charge collected by the anode wires, for each event, into one end (X_A, Y_A) of the chain with respect to the other end (X_B, Y_B). The electronic modules "sum" up the charges of both ends and divide one of them over the "sum" giving the impact coordinates in pulse amplitude

$$\bar{x} = \frac{X_A}{X_A + X_B} \quad \text{and} \quad \bar{y} = \frac{Y_A}{Y_A + Y_B}$$

which feed the display oscilloscope. Therefore, a point spot is displayed on the oscilloscope screen. The display of x or y plane projections are obtained by a PHA (Pulse Height Analyser) fed by the corresponding charge divider output. Fig. 6 shows the two displays (profiles and projections) as seen on the oscilloscope screens. The event rate capacity of the "charge division" electronic chain is up to $(2-3) \times 10^4$ per second which is considered big enough to display the beam spot or projection on oscilloscope screen with good statistics of events in short lapse of time.

a) Profiles in real time b) Projections by accumulating events

Fig. 6 : Signal displays of the "charge division" method

5. EXPERIMENTAL LAYOUTS AND RESULTS

5.1 105 MeV/c antiprotons, detector in air (Nov. 1988)

The first prototype of our detector and associated electronics, after having been extensively tested in the laboratory using radioactive sources and in the PS T11 beam with 2 GeV/c hadrons, has been installed and tested in the M1 LEAR antiproton beam. The experimental layout of the detector is shown in Fig. 7.

Fig. 7 : Experimental layout of the detector (first prototype)

The 105 MeV/c antiprotons were stopped and annihilated inside the light tight PVC (window of the detector). The detector and the associated electronics ("moment" method), gave two dimensional tomographic images of stopped antiproton through the radiation coming from their annihilations. To our knowledge, this is the first time that such displays have been obtained.

Fig. 8 presents the x projection of the 105 MeV/c antiproton beam, obtained

- a) by the standard detector (MWPC), and
- b) by our PSPM detector, which gave also the corresponding profile as shown on the up-right

Fig. 8 : First prototype experimental results with 105 MeV/c antiproton beam

With reference to these results, the spatial resolution of our device was estimated to be ± 0.8 mm.

5.2 105 MeV/c antiprotons, detector in air (April 1989)

We repeated the test of the detector in a similar layout again with 105 MeV/c at the end of the E5 LEAR test beam (April 1989). The vacuum window was 100 μ m Aluminium and attention was paid that the annihilation of the antiprotons took place inside the 1mm thick glass scintillator. The electronic chain for this test was based on the delay line method⁽¹¹⁾.

Fig. 9 shows representative beam profile displays on the oscilloscope screen obtained during this test :

- a) by moving the detector of 15 mm in the horizontal plane,
- b) by moving the detector of 15 mm in the vertical plane.

Fig. 9 : 105 MeV/c antiproton beam profiles displayed in real time using the delay line method

Although the intrinsic resolution of the device remains to be studied in detail, these results confirmed the possibility of monitoring the LEAR antiproton beam profile in real time as well as the mean intensity.

5.3 200 MeV/c antiproton beam

Compared to the previous set-up, the detector used here is characterized by :

- a 4 mm thick glass scintillator in vacuum
- a quartz window
- a large aperture optical lens system with adjustable image magnification
- a PSPM in air

Fig. 10 shows schematically the experimental layout.

Fig. 10 : Simplified schema of the experimental layout of the detector for monitoring the 200 MeV/c antiproton beam

The detector was calibrated in the lab with collimated particles of a Am^{241} radioactive source. The spatial resolution obtained with threefold optical magnification was of the order of 0.4 mm compared to 1.1 mm (FWHM) without optical amplification (see Fig. 11).

Fig. 11 : Calibration of the detector using collimated α particles of Am^{241} radioactive source and the "charge division" method. The 0.2 mm wide slit was displaced 2.5 mm in the x plane and threefold optical magnification spatial resolution obtained 0.4 mm FWHM

Fig. 12 shows typical examples of beam profile displays

- a) beam not focused
- b) beam focused in the x plane and detector moved in x direction by 20 mm
- c) beam focused in both planes and detector moved by 10 mm respectively

- a) Beam not focused
- b) Beam focused in x plane and detector moved in x direction by 20 mm
- c) Beam focused in both planes and detector moved by 10 mm*

Fig. 12 : 200 MeV/c antiproton beam profiles

* N.B. : inclined beam profiles are undetectable with projections

The last display of inclined beam profiles demonstrates an evident merit of two dimensional display over simple projections ignoring the orientation of the shape of the profile.

Fig. 13 shows profiles and projections for x plane by moving the detector by 20 mm.

Moving the detector 20 mm in x direction

Fig. 13 : 200 MeV/c antiproton beam

5.4 105 MeV/c protons, detector in vacuum at the end of S3 LEAR beam, 1 mm thick glass scintillator

Fig. 14 shows schematically the detector mounted entirely in vacuum on a retractable mechanism. The interconnections of the PSPM are achieved by using a multiple ultra high vacuum feedthrough. Because of a lack of available connector pins, only 12x12 central anode wires are connected to the charge division circuits.

Fig. 14 : simplified schema of the detector mounted on a retractable mechanism in order to function under the Lear UHV conditions

Fig. 15 shows four successive projections in the horizontal plane of the same beam moved magnetically by feeding the horizontal dipole DVHNOZ of the S3 LEAR beam with 0, -1, -2 and -3 amperes current. The linearity of the reconstructed position is very good over ~ 20 mm. From the characteristics of the dipole we have calculated that peak to peak distance is ~ 5.0 mm and thus the horizontal size of the beam profile is ~ 2.0 mm FWHM.

Fig. 15 : 105 MeV/c antiproton beam - Four successive x plane projections of the same beam displaced magnetically by feeding the horizontal dipole DVHNOZ of the S₃ Lear beam with 0, -1, -2 and -3 amperes respectively

Beam size : ~ 2 mm FWHM in x direction very good linearity over 20 mm

5.5 200 KeV H⁻ beam of the pbar experiment, H⁻ source, detector in vacuum as in previous tests but P11 phosphor as scintillator

The beam was at our disposal for a few hours, and allowed us to study in detail the performance of the detector.

Fig. 16 shows a H⁻ beam perfectly focused in the x plane but defocused in y plane for :

- a) 200 KeV H⁻
- b) 100 KeV H⁻
- c) 80 KeV H⁻

a) H⁻ beam
200 KeV

b) H⁻ beam
100 KeV

c) H⁻ beam
80 KeV

Fig. 16 : H⁻ beam profiles focused in x plane (scintillator : P11 phosphor)

In order to study the intrinsic spatial resolution of the detector, an opaque plate with two parallel fine slits 0.2 mm wide separated by 10 mm were installed in front of the P11 phosphor.

Fig. 17 shows a resolution of $\Delta x \sim 0.7$ mm FWHM obtained with 200 KeV H⁻ beam using the charge division method .

a) Reconstructed x plane projections

b) Direct displayed x plane projections on the PHA oscilloscope screen

Fig. 17 : The intrinsic spatial resolution of the detector obtained with 200 KeV H^- beam defined by fine slits (0.2 mm wide, spaced 10 mm)

6. CONCLUSION

We consider that the detector is ready for operational use with LEAR extracted beams of very low energy protons, H^- , antiprotons and even stopped antiprotons inside or in front of the scintillator and under UHV conditions. It goes without saying that the detector can also work for antiproton (proton) beams at higher momenta than 100 MeV/c, using commercially available adequate inorganic scintillator.

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8. REFERENCES

- [1] R. Billinge and al., The CERN PS complex Annibipurpose particle source, proc. XII Int. Conf. of H. E. Accel., FNAL Bat 11-16 August 1983 or CERN PS 83-26.
- [2] P. Lefèvre, LEAR in the nineties, Proc. Int. School of Physics with low energy antiprotons, Erice, 10-18 June 1988 or CERN/PS 89-59.

- [3] V. Agoritsas, proc. of the 4th LEAR workshop, Villars-sur-Ollon, Switzerland, September 6-13th, 1987, p 75.
- [4] K. Kuroda, D. Sillou and F. Takeutchi, French patent nr 7836148 applied by ANVAR-France (Dec. 22nd, 1978).
- [5] K. Kuroda, D. Sillou and F. Takeutchi, Rev. Sci Instr. 52 (1981) 539.
- [6] H. Kume, S. Suzuki, J. Tanaka and K. Oba, IEEE Trans. NS32 (1985) 448.
- [7] V. Agoritsas, K. Kuroda, C. Nemoz and D. Sillou, Nucl. Inst. and Method A250 (1986) 539.
- [8] K. Kuroda et al., An upgraded position-sensitive photomultiplier and its applications to an ultrafast scintillating fibre detector proposal to the LAA, Jan. 19th, 1988.
- [9] Photonic devices for scientific instruments, published by Hamamatsu (Feb. 1989).
- [10] V. Agoritsas, K. Kuroda and C. Nemoz, Nucl. Inst. and Meth. A277 (1989) 237-24.
- [11] J. Ditta, K.I. Kuroda, C. Nemoz and D. Sillou, Nucl. Inst. and Meth. A250 (1984) 539.