CERN/PS 88-73 (PA)
1 November 1988

A NEW TYPE OF A POSITION SENSITIVE ELECTRON MULTIPLIER

V. Agoritsas - PS Division, CERN, 1211 Geneva 23, Switzerland
K. Kuroda - Laboratoire d'Annecy-Le-Vieux de Physique des Particules,
BP 909, 74019 Annecy-Le-Vieux, France
Ch. Nemoz - PS Division, CERN, 1211 Geneva 23, Switzerland

A B S T R A C T

A new type of position sensitive electron multiplier is under development. The results of a first prototype are presented. The status and the construction of two other prototypes are described. A straightforward application of such a device is to monitor very low energy antiprotons ejected from LEAR under high vacuum conditions.

Paper presented at the
San Miniato 1988 Topical Seminar
on Perspectives for Experimental Apparatus
at Future High Energy Machines and Underground Laboratories
San Miniato (Pisa), Italy
6-12 March, 1988

1. INTRODUCTION

In order to meet the demands on the beam profile monitors for very low energy antiprotons (~ 20 MeV/c) of LEAR-extracted beams, under ultra-high vacuum conditions and without windows, a position sensitive electron multiplier with fine grid dynodes is under development since 1984 in a collaboration CERN-LAPP [1]. The electron multiplier is the main part of a charged particle detector of which a brief description is given in the following paragraphs. In addition to the capability of detecting very low energy charged particles, our detector is characterized by the following features:

- High gain ($\sim 10^7$) with good S/N ratio in particular withstanding under hot environment in electro-magnetic parasites.
- Extremely simple and reliable associated electronics capable of reproducing in real time the two-dimensional topology of the beam spot (i.e. toposcope).
- Covering a wide range of beam intensities.
- Excellent radiation hardness.
- No outgassing material under high vacuum conditions (essential for LEAR vacuum conditions).

The first step was successfully achieved in 1986 with encouraging results confirming the feasibility of such a position sensitive charged particle detector [2].

A number of improvements are presently under way, and we hope to achieve the final prototype operational under actual LEAR beam conditions by the end of 1988.

2. ANTERIOR WORK

2.1 The secondary emission phenomenon

The applications of the secondary emission phenomenon in the field of charged particle accelerator beam monitoring goes in parallel with the development of modern particle accelerating machines. As an example of such applications, Fig. 1 presents the principles of operation of a secondary emission chamber developped at CERN 25 years ago. Thanks to its unique performance and simple operation, giving a good linearity of DC response (over several orders of magnitude), the secondary emission phenomenon was the basis of a number of beam monitors, such as:

- SECs
- SEM grids
- Toposcopes or mini-toposcopes
- Flying wires
- Fork targets, etc.

These monitors have become the standard monitors of the slow extracted beams at CERN as well as in other laboratories.

Tests of the SEC confirmed also that the spectrum of secondary electrons does not depend on the energy of the incident charged particles (or photons) and has a pronounced peak around 2-3 electron volts (see Fig. 2).

2.2 First prototype

Figure 3 shows schematically the structure of a position sensitive detector based on the secondary emission phenomenon. The essential part is consisting of 14 stages of an electron multiplier, of grid-type dynodes 100 mm in useful diameter. To improve the multiplication efficiency, each stage has two layers of grids. They are made of CuBe, 98.2 % Cu and 1.8 % Be.

Figure 4 gives the geometrical parameters of the fine dynode structure prepared by Hamamatsu, following our specifications.

Figure 5 is a photograph of the electron multiplier. A thin aluminium foil, 50 mm thick, placed in front of the first dynode releases secondary electrons when traversed by charged particles. After multiplication of these secondary electrons by the dynodes system, the flux of the secondary electrons focused with the help of an axial magnetic field, falls onto an array of 20 anode strips, 3 mm wide, aligned in one direction, with a gap of 0.1 mm.

2.3 Results of the 1st prototype

We present two relevant and typical results obtained with the first prototype.

Figure 6 represents the linearity between the reconstructed position and the real position for two kinds of radiation sources. The solid circles represent data from collimated γ -rays and triangles those from 200 MeV/c π^- (pions). In both cases, the linearity is quite good in almost full range of the sensitive area (80x80 mm²).

Figure 7 shows a result obtained with 100 G axial magnetic field by moving the collimated π beam by a step of 30 mm. The FWHM is about 5 mm. Subtracting the geometrical size of the collimated beam $\sim$ 3 mm at the level of the aluminium foil (the secondary emission emitter or converter), the final resolution of the device is estimated to be $\sim$ 4 mm in FWHM.

It is worthwhile to mention that the resolution without magnetic field is kept in a range of 5-6 mm and does not decrease drastically as one could expect from the spread of the low energy (in a range of a few eV) secondary electrons along their multiplication. This implies a new approach of realizing a position sensitive electron multiplier without axial magnetic field.

3. PRESENT STATUS

During 1987 two approaches have been engaged with the aim of improving the performance of the detector especially in its spatial resolution and make it more compact so that it could work without axial magnetic field. For this purpose, a Monte-Carlo calculation has been performed to optimize the electric field across the new dynode fine structure.

3.1 Monte-Carlo calculations

The program simulates secondary electron trajectories across the static electric field determined by the boundary conditions; i.e. the dynode fine structure and geometry as well as the applied voltages.

The extraction factor g is obtained by summing up all the n electrons arriving onto the next dynode d_{i+1} stage and dividing it by the number N secondary electrons initially generated on the dynode d_i , i.e.

$$g = n/N, \quad g \leq 1$$

The gain per stage is therefore

$$G = g\delta.$$

where δ is the secondary emission coefficient of the activated CuBe dynodes. This secondary emission coefficient, however, varies as a function of the interdynode voltage V .

The voltage V was fixed at 300 V, a compromise between a sufficiently high δ and the loss of secondary electrons due to repulsive electric field over the emissive surface (which increases as a function of V). Under this condition, the voltage V between the grids of the same dynode stage i has been varied as a parameter so as to optimize the extraction factor g . The result is given in Fig. 8.

The bias factor K represents a deviation of V from the uniform electric field distribution between the dynodes ($K=1$) space. The optimum voltage V_1 is found to be ~ 45 V: i.e. $K=0.5$ bias, so that the upper layer would play the role of attenuating the repulsive electric field on the emissive surface of the lower grid.

From these results we can expect a g factor as high as ~ 0.55 giving a total gain of 1.8×10^7 for 14 stages of our electron multiplier. In the following sections we describe expected performances from the above calculation under some practical conditions.

3.2 Compact electron multiplier based on Hamamatsu grids

The Hamamatsu prototype described in section 2 has been modified by reducing the space between dynode stage (i.e. D_1 and D_2 on Fig. 4) and the possibility to optimize the interdynode voltage has been added. The copper Beryllium grids have been recently reactivated by the EMI Electron Tubes Laboratory in G.B.

The Monte-Carlo calculations mentioned above indicated that under those conditions, this compact electron multiplier will work without axial magnetic field and will provide a better performance not only in gain but also in spatial resolution compared to the original set-up (1st prototype). For this prototype, the spatial resolution is, expected to be 2-3 mm due to the Hamamatsu dynode grids with fine structure of 0.5 mm intergrid bar gap. Some tests are presently under way at CERN with this set-up.

3.3 New compact electron multiplier based on CERN grids

Figures 9 and 10 show schematically the new grids of our new compact electron multiplier of useful diameter 58 mm. The CuBe grids were fabricated entirely at CERN by photolithographic techniques. They are made of 100 μ m CuBe sheets with a 0.2 mm intergrid bar gap. The spatial resolution of this new compact electron multiplier is expected to be ~ 1 mm in FWHM.

The activation of the copper beryllium grids was done also by EMI Electron Tubes Laboratory in G.B.

The assembly of the detector is actually under way in TS/TE workshop of CERN. To start with, 2 mm wide anode strips will be mounted and interconnected through vacuum feed-throughs to a suitable delay line readout system [3].

4. CONCLUSION

We presented, in this paper, a short summary of anterior work on secondary emission beam monitors and outlined the actual status of new position sensitive electron multiplier which are under development in a collaboration CERN-LAPP.

The new dynodes recently realized at CERN will be of great interest, not only for application of beam monitoring purposes of very low antiproton beams extracted from LEAR, but also for new position sensitive photomultipliers which will potentially have great importance for future collider experiments [4].

ACKNOWLEDGEMENTS

We thank Dr. D.J. Simon for his constant encouragement which enabled us to efficiently pursue our work since 1984. We acknowledge also Dr. D. Sillou who has actively participated in the Monte-Carlo calculations which permitted us to design the new prototypes. We are much indebted to Messrs. A. Gandi, L. Mastrostefano, N. Mezin and J. Gabardo who brought their high technical competences to this project.

It is a pleasure to express our thanks also to Messrs J.P. Bovigny, J. Haffner and J. Ditta for their efficient technical assistance.

REFERENCES

- [1] V. Agoritsas, Proc. IV LEAR Workshop, Villars 6-13 Sept. 1987.
- [2] V. Agoritsas et al., Nucl. Instr. and Meth. A255 (1987) 437.
- [3] J. Ditta et al., Nucl. Instr. et Meth. A 250 (1986) 539.
- [4] K. Kuroda et al., Proposal to the LAA, upgraded position sensitive photomultiplier and its applications to an ultrafast scintillating-fibre detector, Jan. 19, 1988.

FIGURE CAPTIONS

- Fig. 1 Principle of secondary emission chamber.
- Fig. 2 Energy distribution of secondary electrons emitted by Al foils for several kinds of incident particles.
- Fig. 3 The prototype of a new type position sensitive detector working under ultra-high vacuum conditions.
- Fig. 4 Position sensitive electron multiplier dynode structure.
- Fig. 5 Photograph of the electron multiplier.
- Fig. 6 Linearity of position reconstruction.
- Fig. 7 Measurement of the spatial resolution.
- Fig. 8 Effect of bias voltage on the extraction factor g .
- Fig. 9 New dynode realized at CERN; detailed geometry of grid-bars.
- Fig. 10 Upper view and side-view of the compact electron multiplier.

Fig. 1 Principle of secondary emission chamber.

Fig. 2 Energy distribution of secondary electrons emitted by Al foils for several kinds of incident particles.

Fig. 3 The prototype of a new type position sensitive detector working under ultra-high vacuum conditions.

Fig. 4 Position sensitive electron multiplier dynode structure.

Fig. 5 Photograph of the electron multiplier.

Fig. 6 Linearity of position reconstruction.

Fig. 7 Measurement of the spatial resolution.

Fig. 8 Effect of bias voltage on the extraction factor g .

Coupe A-A'
Echelle: 100/1

Fig. 9 New dynode realized at CERN; detailed geometry of grid-bars.

Fig. 10 Upper view and side-view of the compact electron multiplier.