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Test of full size Cherenkov detector for proton Flux Measurements

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ABSTRACT

The device called Cherenkov detector for proton Flux Measurement is going to be installed inside of the primary vacuum of the Super Proton Synchrotron to monitor a secondary beam produced by the bent crystal inserted in the proton halo. Test of this detector with 449 MeV electrons was performed at beam test facility at Frascati. We measure 0.62 p.e. per incoming electron and a resolution of 15% for 100 incoming electrons.

1. Introduction

The first idea of using bent crystal for charge particle steering belongs to Tsyganov [1] in 1976. This phenomenon was observed at the Laboratory of High Energies, JINR [2] in 1979 where a 8.4 GeV proton beam was deflected up to 26 mrad.

The use of a small object (bent crystal) to direct halo into a secondary collimator-absorber will permit one to decrease the impedance of the machine, losses in sensitive areas of the accelerator and to simplify the collimation system.

Since 2009, the UA9 collaboration is investigating the possibility of using bent crystals for beam collimation at LHC [3–5]. In this framework, the Cherenkov detector for proton Flux Measurements (CpFM) is a invacuum device conceived to monitor protons deflected by a bent crystal.

2. The CpFM detector geometry

The CpFM detection chain components are shown in Fig. 1. It has been significantly changed with respect to the previous one described here [6]. Present geometry is composed of

- The two radiation hard fused silica (quartz) radiators of rectangular shape. One bar to measure signal from the secondary beam and the other one to monitor the background. Due to the total internal reflection, the Cherenkov light is kept inside of the fused silica radiator and propagates towards PMT via fibers bundle. Number of outgoing light injected into the fibers bundle reach its maximum at 47° bevelled end of the radiator which is equal to the Cherenkov angle (for ultra relativistic particle) in fused silica.
- A movable bellow which permits the insertion and extraction of the bars into the secondary beam.
- A flange inclined by 47° angle with respect to the beampipe.
- A radiation hard fused silica viewport with 3 mm thick window mounted into the flange. It provides optical contact between radiators placed in vacuum and the bundle of fibers.
- Two radiation hard bundles composed of fused silica/fused silica (core/cladding) fibers to bring out the Cherenkov light from radiators to photomultipliers (PMTs). Properties details are given in Table 1. The bundles permit one to place the PMTs around 5–10 m away from the beam pipe where the radiation level is significantly smaller.
- Two R7378A radiation resistant HAMAMATSU PMTs.
- Two 300 m long low attenuation CKB50 cables.
- The USB-Wavecatcher module [7,8] for data acquisition situated 300 m away in an area safe in term of radiation.

3. PMT characterization

To characterize the PMT R7378A (gain and output linearity), we used the optical test bunch composed of a $\sim$1 m^3 light tight chamber which temperature is maintained at $\pm 0.1\,^{\circ}$C, inside which the detector under test, the calibrated PMT (R7400U-01) and PIN photodiode (S3902-19) are fixed to a 3-D translation stage driven by a LabView program that permits one to place with an accuracy of μm the detectors in front of the light sources. The

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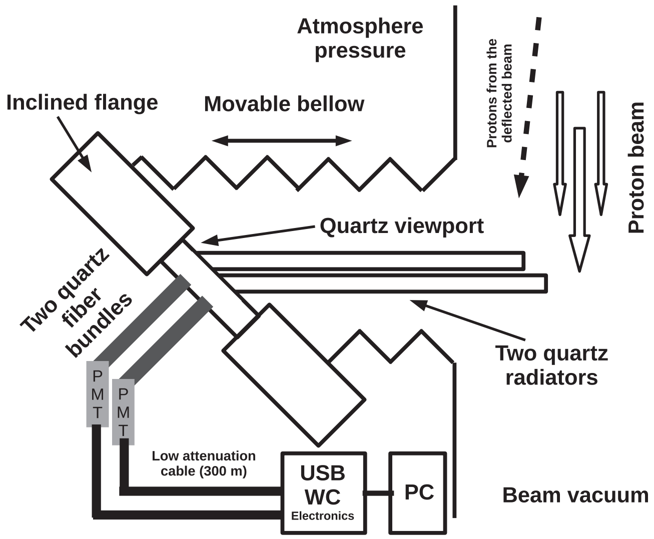

Fig. 1. CpFM detection chain components.

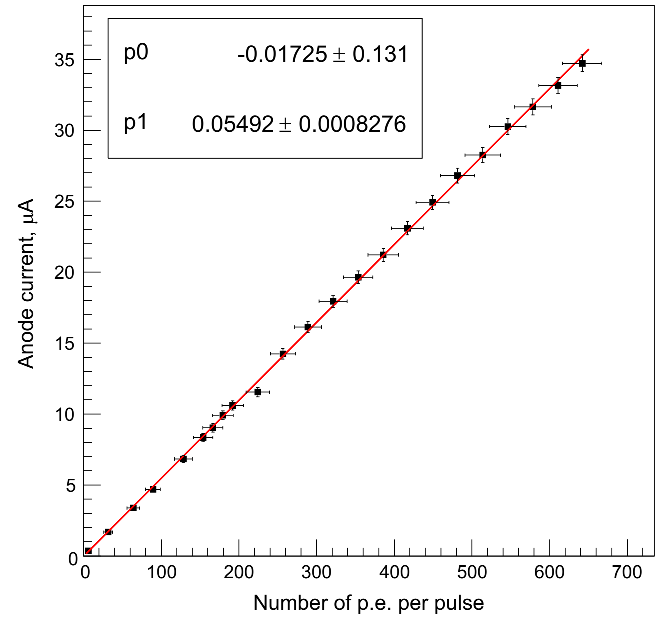

Fig. 2. Output anode current of the PMT (R7378A - BA1511) for different photon fluxes under 1000 V operation.

Table 1
Properties of one bundle.

Parameter	Value
Fiber core diameter	0.6 mm
Fiber cladding diameter	0.66 mm
Fiber coating diameter	0.77 mm
Fiber buffer diameter	0.92 mm
Fiber numerical aperture	0.22
Operating wavelength	200–1100 nm
Number of fibers	100
Length	4 m
Total covered surface	40.5 mm^2
Effective surface	28.3 mm^2

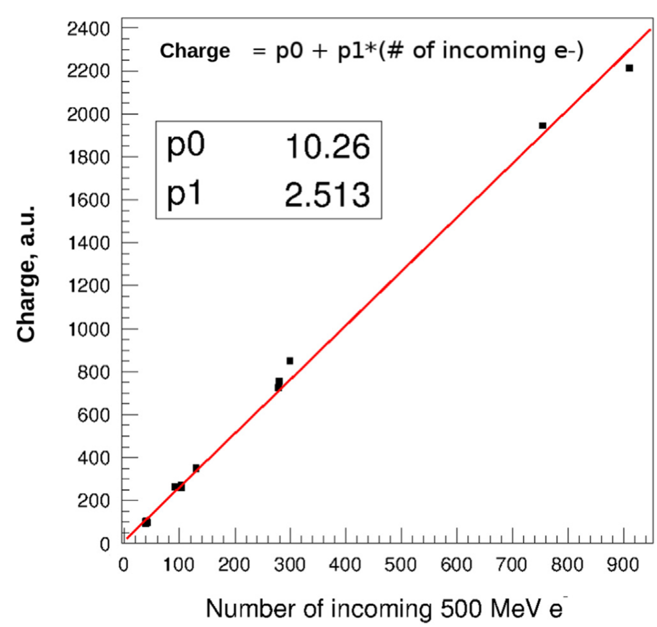

Fig. 3. CpFM measured charge versus number of incoming 449 MeV electrons.

measurements of the detectors coordinates are performed with a CCD camera.

The measurement of the PMT gain is performed with a pulsed Pilas laser diode (467 nm, pulse duration around 50 ps FWHM) with the unique photo-electron method [10].

For the linearity measurements (Fig. 2) we used a blue LED diode emitting at 460 ± 10 nm with a pulse duration of 10 ns. The R7378A shows a good linearity up to 650 p.e. per pulse for an operation at 1000 V (corresponding to a gain of 4×10^6). This PMT shows a much better linearity with respect to the R762 that was used in the previous CpFM configuration [6].

4. Test at BTF

The DA Φ NE Beam-Test Facility (BTF) [9] is a beam line designed for detector calibration purposes with single or multiple electrons up to 800 MeV energy. The flux of outgoing electrons can be monitored with a lead glass calorimeter capable to separate single incoming electron.

To count scattered electrons in the CpFM detector, we installed it as close as possible to the calorimeter placed downstream. CpFM shows good signal linearity with number of incoming electrons as shown in Fig. 3.

We adjusted the beam to get on average 200 electrons and performed resolution measurements of the CpFM. Fig. 4 shows the number of p.e. detected by the CpFM as a function of the measured charge by the calorimeter. The correlation due to statistic variation of the incoming electrons is observed. Using a linear fit of this dependency, one can perform correction on incoming numbers of electrons and measure the CpFM resolution (see Fig. 5) which gives 15% for 100 electrons. The fit with the Gaussian function of this histogram gives 0.62 p.e. per incoming electron.

To estimate the effect of the viewport between the vacuum inside the beam pipe and atmosphere, where is the fibers bundle, we performed sets where a glass plate of 3.8 mm thickness simulates the viewport. The signal at the PMT output is divided into 2 in comparison with direct coupling.

The potential losses of photons due to the contact of material (for example an holder made of metal) and the quartz surface was simulated by putting around the bar different kinds of rings made of copper or black tape with a width of 0.5–1 cm. No degradation of the output signal was observed.

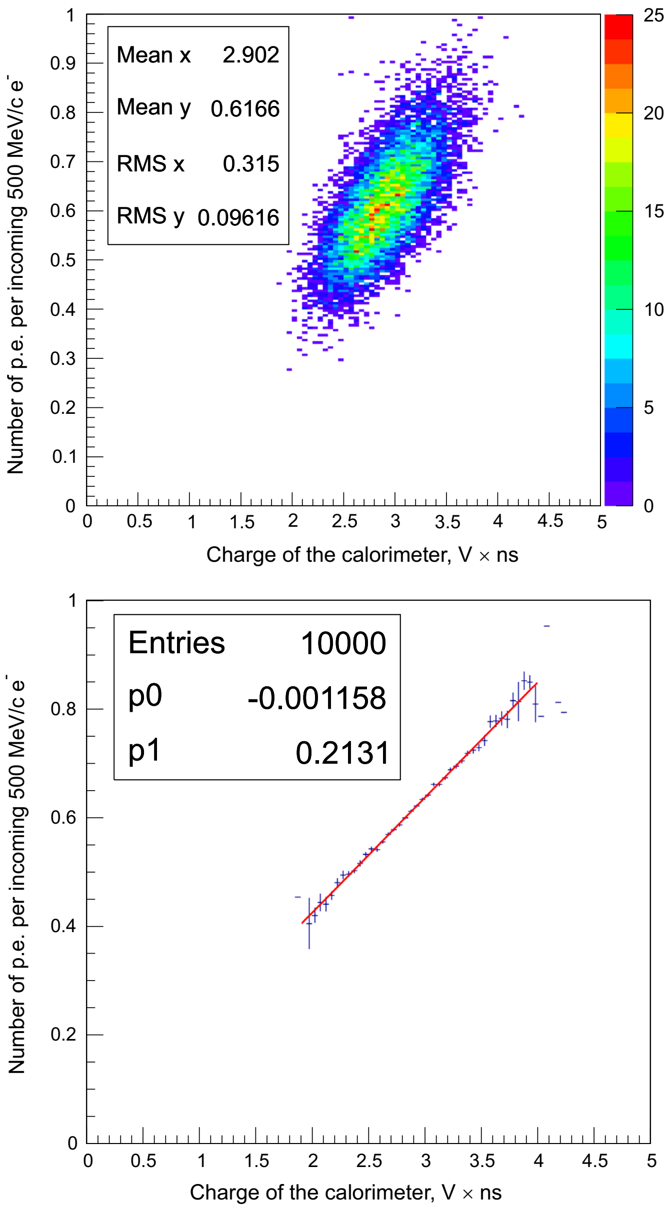

Fig. 4. *Top:* 2-dimensional histogram of the number of detected p.e. per incoming 500 MeV electron versus charge measured by the calorimeter. *Bottom:* Its profile fitted with a first order polynomial function.

5. Conclusions

CpFM detector has been successfully tested at the Beam Test Facility at Frascati with electrons of 449 MeV. Measured resolution of about 15% can be significantly improved by changing the I-like geometry of the radiator by a L-like. Particle will penetrate thicker radiator hence will produce more light. Potential problem of this geometry is its polishing quality.

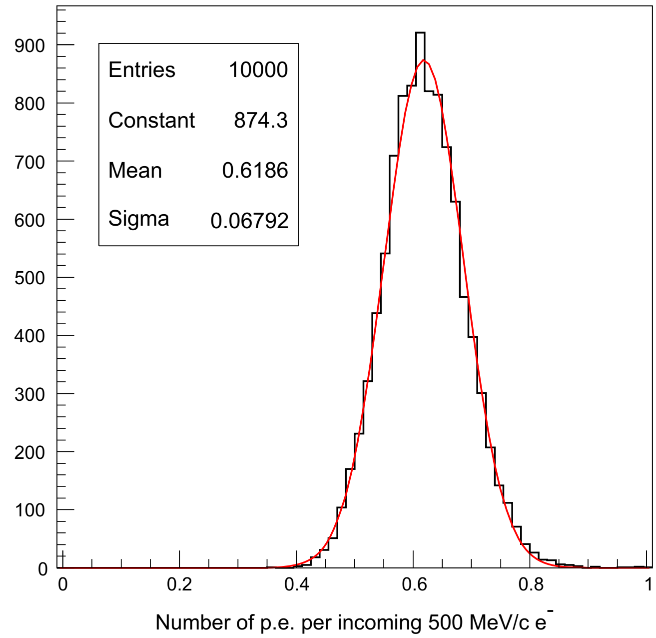

Fig. 5. Number of p.e. measured by the CpFM normalized by the number of incoming electrons.

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