PROFILE MONITORS FOR WIDE MULTIPLICITY RANGE ELECTRON BEAMS

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Abstract

The DAFNE Beam Test Facility (BTF) provides electron and positron beams in a wide range of intensity, from single particle up to 10^{10} particles per pulse, and energy, from a few tens of MeV up to 800 MeV. The pulse time width can be 1 or 10 ns long, and the maximum repetition rate is 50 Hz.

The large range of operation of the facility requires the implementation of different beam profile and multiplicity monitors. In the single particle operation mode, and up to a few 10^3 particles/pulse, the beam spot profile and position are measured by a x-y scintillating fiber system with millimetric resolution and multi-anode PMT readout. From a few tens up to 10^{6-7} particles per pulse, a silicon chamber made of two 9.5x9.5 cm^2 wide 400um thick silicon strip detectors organized in a x-y configuration with a pitch of 121um has been developed. Once calibrated, the system can be used also as an intensity monitor. The description of the devices and the results obtained during the data taking periods of several experiments at the facility are presented.

INTRODUCTION

The DAFNE Beam Test Facility (BTF), operational in Frascati LNF since November 2002, is a beam transfer line optimized for the production of a pre-determined number of electrons or positrons. The main applications of the facility are: high energy detector calibration, low energy calorimetry, low energy electromagnetic interaction studies, detector efficiency and aging measurements, test of beam diagnostic devices, etc.

An attenuating target intercepting the primary Linac beam, together with a system of collimating slits (both along the horizontal and vertical coordinate) and an energy selecting dipole magnet, allows to fine-tune the beam intensity, momentum and spot size, according to the users requirements. The characterization of the beam thus requires several diagnostic devices, optimized in the full range of multiplicity and energy. The facility has been operating both in the single particle production scheme and the high multiplicity operation mode almost continuosly since November 2002.

The sensitivity of any standard beam diagnostics (beam current monitors, fluorescence flags, etc.) is not sufficient, especially in the single particle mode, so that several particle detectors have been used and developed to monitor the BTF beam characteristics during the users running periods. These detectors were mainly intended for the measurement of the number of particles in the beam pulses, in a typical momentum range of 20-800 MeV. However, a very important point for the operation of the facility is the measurement of the beam spot position and size. The typical beam spot at the end of the DAFNE Linac is fairly gaussian, with millimetric size in both the transverse (x-y) coordinates, and is efficiently transported by the BTF transfer line. The exit windows of the BTF beam line have been realized with a thin (500 um) Be alloy, so that the beam size is not spoiled by multiple scattering. The required accuracy for a beam profile detector is then of the order of 1 mm or better.

For this purpose, two different beam profile monitors, a scintillating fiber detector and silicon beam chamber, have been designed, built and tested during the last year. The detectors are described together with some details on the construction and the readout of the systems; and some experimental results with the BTF beam are also reported.

BEAM PROFILE MONITOR WITH SCINTILLATING FIBER DETECTOR

In order to have a measurement of the beam spot with millimeter accuracy, we have developed and realized a beam hodoscope, consisting of scintillating fibers coupled to multi-anode photomultipliers. This detector has been in fact designed to cope with the wide range of beam conditions, both in energy and multiplicity, and the typical beam spot characteristics[1].

A detector composed of few layers of 1 mm scintillating fibers should be at the same time fully efficient for single electrons and not saturated at intermediate intensities. We built a two views detector of 48×48 mm^2 active area. Each one of the two planes of the detector, arranged at 90 degrees with respect to each other, is composed of four layers of fibers staggered by a half-diameter (0.5 mm). Three fibers in width and four in depth are glued together with optical glue and are bundled. Each 12 fibers bundle, corresponding to an active width of 3 mm, is coupled to a pixel of two 16-channels multi-anode photomultipliers (Hamamatsu H6568). The analog signal of each pixel is fed into a channel of 0.1 pC/counts QDC (CAEN 792 V), measuring the collected charge for each fiber bundle [14]. The beam spot, in the transverse plane, can then be reconstructed from the charge-weighted distribution (for each of the two views)

An example of the beam profile transverse distribution, obtained with the fibers running along the horizontal and vertical directions is shown in Fig.1; this has been obtained for a well focused 493 MeV electron beam with an average of one-two particle per pulse.

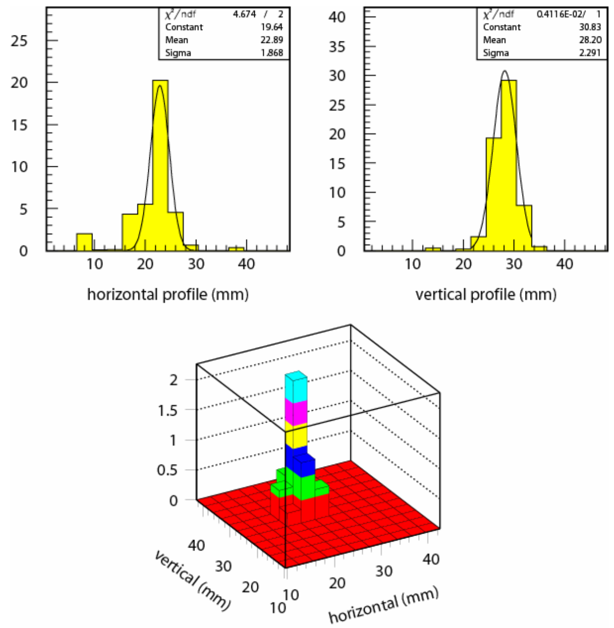

Figure 1: Charge-weighted distribution for horizontal and vertical planes of the scintillating fibers detector (top),and the corresponding two-dimensional beam spot (bottom); focused beam, 493 MeV electrons.

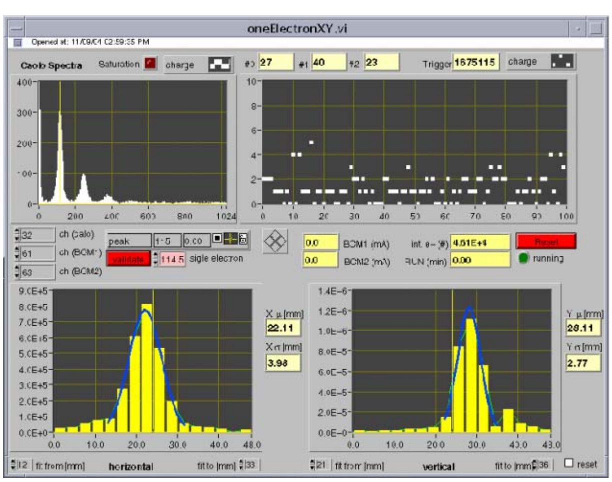

Figure 2: LabVIEW panel showing the calorimeter charge spectrum (up left) and the relative average multiplicity (up right) and the horizontal and vertical profile (down) in a typical BTF run. Each beam profile is obtained by accumulating 2 s of beam (100 hits).

A good accuracy in the beam spot determination can be achieved already with a few hundreds of hits, so that a few seconds of data taking are required at the maximum repetition rate of 50 Hz.

This allows a very useful online monitoring of the beam position and shape, since the measured horizontal and vertical profiles are available in real-time in the control system of the facility, together with the calorimetric measurement of the beam intensity (Fig. 2).

BEAM PROFILE MONITOR WITH SILICON BEAM CHAMBER

Two different silicon based systems have been used for the measurement of the beam profile in low and high multiplicity situations:

-Two x-y silicon chambers each consisting of two 8.9x8.9cm^2 silicon strip detectors (Micron Semiconductor ltd) 400 µm thick and with a pitch of 228µm. Each detector is AC-coupled and readout by 3 TAA1 ASICs (ideas) characterized by low noise, analog readout and self triggering capabilities. The chambers are able to measure the beam profile with a spatial resolution of ~40µm in low multiplicity conditions[2].

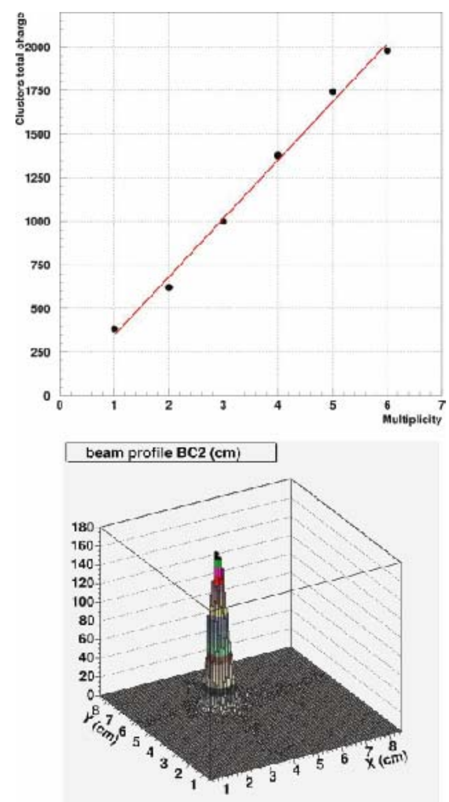

Fig 3: Silicon Beam Chamber: Calibration tests. Top: the beam multiplicity, computed with the number of clusters, is compared with the number of electrons estimated by the NaI calorimeter total energy. Bottom: beam profile for 433 MeV electrons.

Figure 3 shows the results in terms of beam profile, dimensions as a function of energy and linearity with respect to the number of particles impinging on the detector.

-A 9.5x9.5cm2, 400 μm thick silicon strip detector (HAMAMATSU Photonics) developed for the AGILE satellite and used in the SUCIMA configuration[3]. The 121um pitch 768 DC-coupled strips are readout by 6x128 channel charge integrating VA_SCM2 ASICs {ideas} characterized by 4 possible gains (corresponding to a charge range of 400-41000fC/channel) and a double sample & hold circuit enabling deadtime-less data acquisition. This detector can at the same time measure a beam profile and extract from the integral of the profile the beam multiplicity up to very high values.

Figure 4 shows the beam profile obtained in a high multiplicity configuration, and the linearity of the detector response to increasing multiplicity as measured by a NaI calorimeter. All the measurements have been taken using the last but one lower gain. A second set of data taking is foreseen to explore higher multiplicity ranges.

CONCLUSIONS

The Beam Test Facility has showed very good performance operating with very high reliability in the energy range from a few tens of MeV up to 800 MeV, in single electron/positron mode as well as in the high intensity beam.

In order to improve the characterization of the beam quality, we have developed and tested two different beam profile monitors in a wide range of beam conditions, both in energy and in multiplicity. This detectors will be used to monitor the beam conditions and to adjust them to the experimental requests.

REFERENCES

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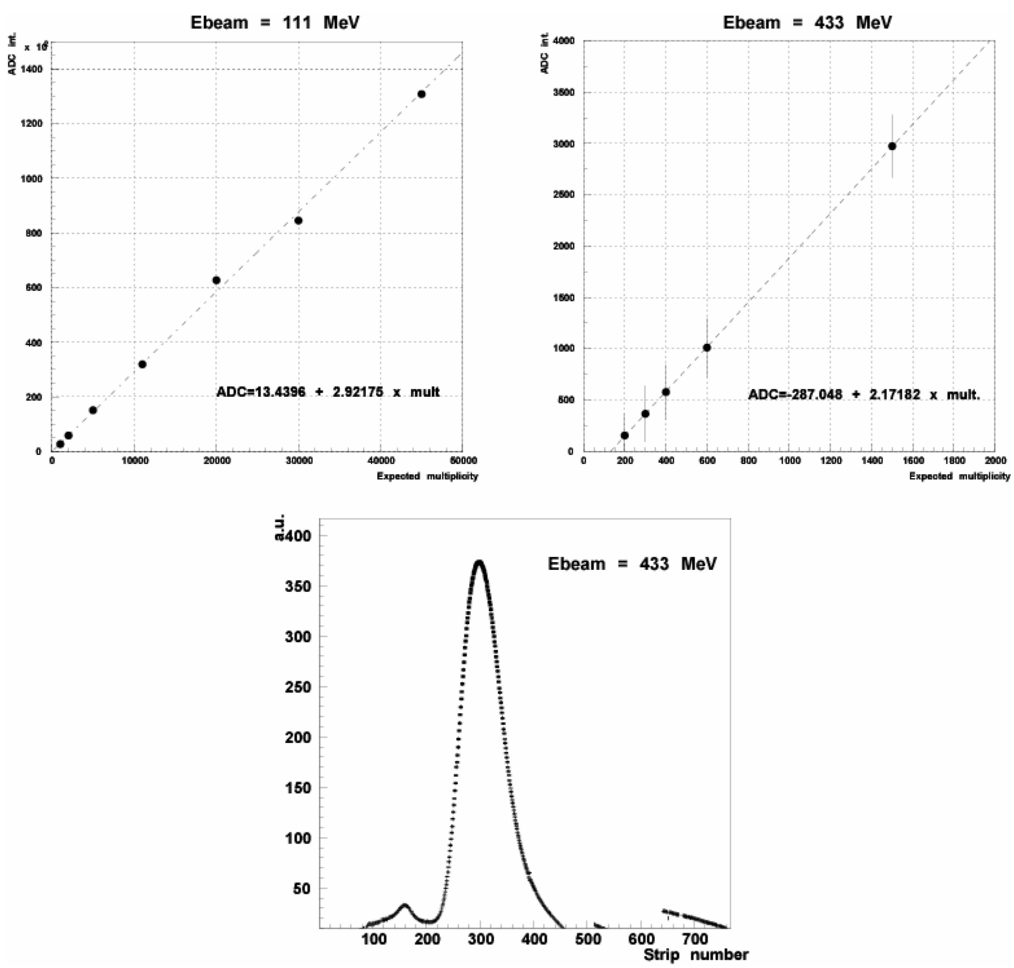

Fig 4: Linearity at two different energies of the detector response with respect to increasing multiplicity (top). The expected multiplicity has been measured with a NaI calorimeter. The y axis units are ADC counts. Beam profile in a high multiplicity configuration (bottom).