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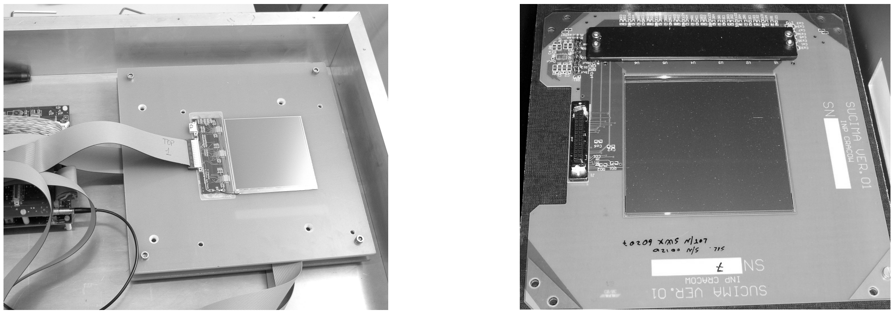
High Granularity Silicon Beam Monitors for Wide Range Multiplicity Beams

A. Mozzanica, F. Risigo
Università degli Studi di Milano and INFN Milano
A. Bulgheroni, M. Caccia, C. Cappellini, M. Prest
Università degli Studi dell'Insubria and INFN Milano
L. Foggetta
CIFS, Consorzio Interuniversitario per la Fisica Spaziale, Torino
B. Buonomo, G. Mazzitelli
INFN, Laboratori Nazionali di Frascati
P. Valente
INFN, Roma
E. Vallazza
INFN Trieste

Abstract

The DAFNE BeamTest Facility (BTF) at the INFN Laboratories in Frascati provides electron and positron beams in the energy range tens of MeV-750 MeV in a wide range of intensity, from 1 up to 10^{10} particles per pulse. The pulse rate is 50 Hz.
This paper describes the implementation of two types of high granularity silicon beam monitors: two pairs of silicon strip detectors readout by single particle ASICs for the low multiplicity range (1-100 particles) and a silicon strip detector with charge integrating electronics to cover the remaining range (100-10^{10}). Both the silicon detectors are characterized by large dimensions (up to 9.5×9.5 cm^2) and a granularity in the 100 μm range. The paper describes the two systems and the results obtained during several dedicated runs.



(a) (b)

Figure 1: (a) The silicon beam chambers inside the aluminum box. (b) The SUCIMA hybrid.

1 Introduction

The DAFNE Beam Test Facility[1] (BTF) at the INFN Laboratories in Frascati provides electron and positron beams in the energy range tens of MeV-750 MeV in a wide range of intensity, from 1 up to 10^{10} particles per pulse. The high current LINAC beam can be extracted directly to the BTF or to a 1.7 X_0 W target to produce a shower. The development of a silicon on-line monitor covering all the energy and multiplicity range can be a true improvement of the Test Facility capabilities.
Section 2 will describe the silicon monitors, Section 3 the multiplicity reference calorimeter, section 4 and 5 low and high multiplicity results.

2 Silicon monitors description

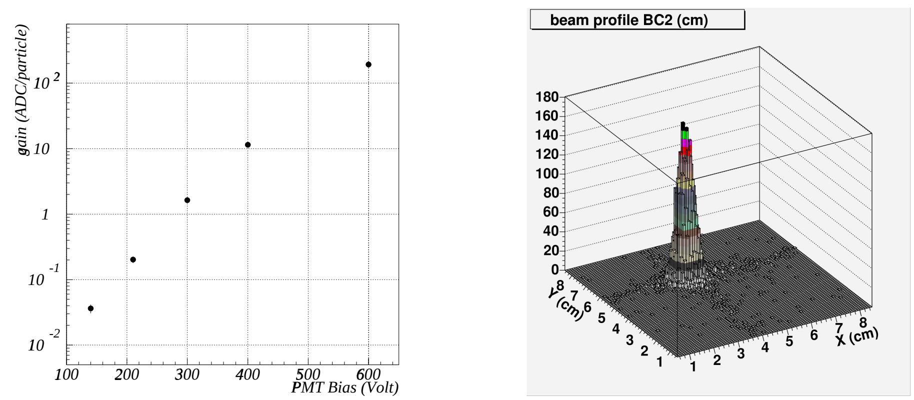
Two different silicon based systems have been assembled and used:

- The low multiplicity monitor, made of four 8.9×8.9 cm^2 228 μm pitch silicon strip detectors (Micron Semiconductor ltd) 380 μm thick (Fig. 1a). Each detector is AC-coupled and readout by 3 TAA1 ASICs[2] characterized by low noise, analog readout and self triggering capabilities. The chambers are able to measure the beam profile with an expected spatial resolution of $\sim$50 μm in low multiplicity conditions. The 4 detectors are organized in a double x-y configuration, with a 15 mm gap between the planes.

- The high multiplicity monitor consisting of a 9.5×9.5 cm^2, 410 μm thick silicon strip detector (HAMAMATSU Photonics) developed for the AGILE satellite[3] and used in the SUCIMA[4] configuration (Fig. 1b). The 121 μm pitch 768 DC-coupled strips are readout by 6 128 channel charge integrating VA_SCM2 ASICs[2], characterized by 4 possible gains (gain 1-4 from lowest to highest) and a maximum charge range of 41 pC/channel.

3 NaI calorimeter at low voltage

Testing the silicon beam monitor multiplicity response needs an indipendent method for measuring the number of arriving particles. A 15 X_0 NaI(Tl) calorimeter has been used with photomultiplier, shaping amplifier and peak sensing ADC readout. Since the expected multiplicity range extends up to 10^5 particles, the PMT bias voltages had to be reduced to very low values. Starting from a single particle calibration point at 600 V the gain ratio is computed for each bias step down to 140 V (Fig. 2a).

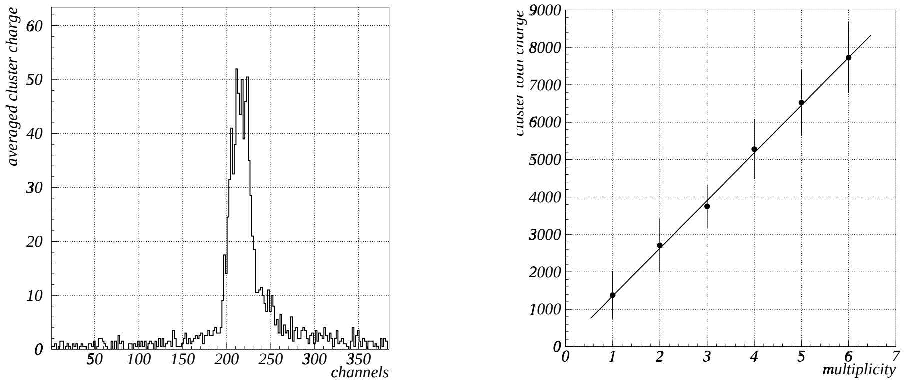


(a) (b)

Figure 2: (a) Calorimeter gain vs. bias curve. At 140 V a range of 10^5 particles is reached. (b) Example of a 2d profile obained in single electron mode on chamber 2.

4 Low multiplicity beam chamber results

Fig. 2b shows the beam profile measured by the beam chambers in single electron mode. The tracks are fully reconstructed and the angular resolution is limited to a mrad level by the low distance between tracker planes. If more than one electron per bunch is crossing the chambers, no tracking is possible due to the presence of ghosts, but a profile can still be extracted, using a charge weighted clusters (Fig. 3a). The total charge of the detector clusters is proportional to the number of incoming particles, so this value can be used for an event by event estimation of the particle crossing with a ± 1 uncertainy (Fig. 3b).



(a) (b)

Figure 3: (a) 1d profile with silicon chambers at an average multiplicity of $\sim$10 (b) Total cluster charge in silicon vs. multiplicity as given by the NaI calorimeter.

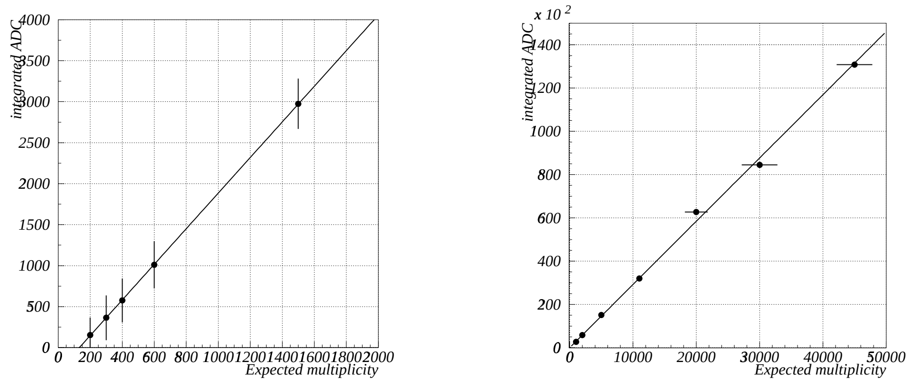
5 High multiplicity SUCIMA hybrid results

In case of high multiplicity the integrated profile of the SUCIMA detector is computed event by event, after pedestal subtraction, to obtain the total charge (in ADC units) collected by the detector. This charge is proportional to the number of particles. At the maximum gain the detector starts to be sensitive to a few hundreds of electrons (Fig. 4a) and is still linear up to $5 \cdot 10^4$ particles (Fig. 4b). This is the maximum allowed multiplicity at the BTF with the W target in place. The maximum number of particles before electronic saturation can be extimated measuring the ASIC gain ratio (Fig. 5a); being 36 the ratio between the lowest and the highest gains the maximum multiplicity is $36 \cdot 5 \cdot 10^4 = 1.8 \cdot 10^6$. This result refers to a 2.35 cm sigma gaussian beam and has to be scaled down for narrower beams. The multiplicity response of the detector was checked to be indipendent from both the beam size and the particle energy.

Tests have been done removing the W target so that the whole LINAC beam could reach the detector. The calorimeter has to be removed, thus no indipedent multiplicity measurement was provided. With the slits full opened the detector shows saturation at any gain (Fig. 5b), but the system is still able to return useful information on size, position and tail structures.

6 Conclusions

Silicon beam chambers have proven to be a very useful tool for the BTF operation in both single electron and low multiplicity mode. Silicon detectors with charge integrat-



(a) (b)

Figure 4: (a) Mean integrated signal for multiplicities up to 2000 particles, with gain 4 and a beam energy of 433 MeV (b) The integrated signal in the 2000-5000 multiplicity range, with gain 4 and electrons of 112 MeV . The uncertaines on the calorimeter data become relevant since the errors due to the bias lowering procedure sum up.

ing ASICs show a linear behavior in measuring the multiplicity from some hundreds to $5{\cdot}10^4$ particles per bunch, covering the whole BTF range when the W target is in place. Futhermore, the high multiplicity monitor is able to provide position, size and tail structure information in a much wider range (up to 10^{8-9} particles per bunch). A future beam monitor dedicated detector is foreseen; it will feature a smaller size, to match the beam pipe dimensions, a finer pitch, to decrease the number of particles per strip thus increasing the range and an AC coupling of the strip with the frontend to avoid pedestal contributions.

References

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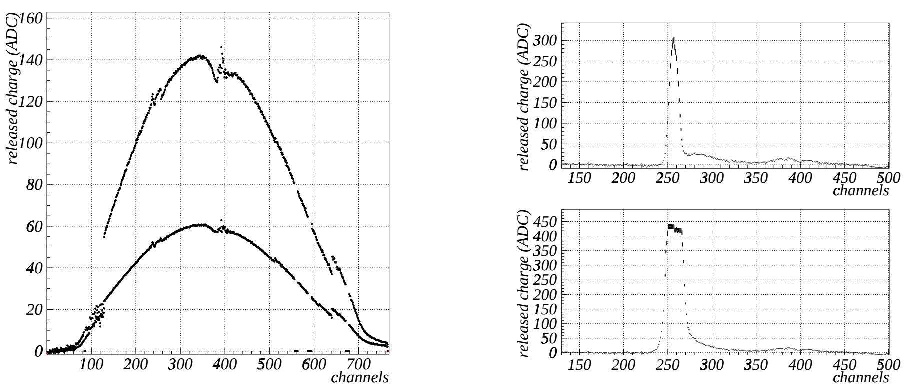

(a) (b)

Figure 5: (a) Profile of the beam at 2 different gains. (b) Beam profiles without W target, during slits opening (up) and with full opened slits (down), with the lowest gain.