# BEAM DIAGNOSTIC FOR A WIDE RANGE BEAM TEST FACILITY

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*Abstract*

The DAFNE Beam Test Facility (BTF), initially optimized to produce single electrons and positrons in the 25-750 MeV energy range, can now provide beam in a wider range of intensity up to $10^{10}$ electrons/pulse. The facility has been also equipped with a system for the production of tagged photons, and the possibility of photo-production of neutrons is under study. Different diagnostic tools have been developed and are available for high-energy physics and accelerator communities for testing beam monitor devices and for all studies of particles detectors performances. The facility diagnostic devices are here presented: the main characteristics and operation are described, as well as the performances and the experience of the experimental groups collected during these years.

## INTRODUCTION

The Beam Test Facility (BTF) is part of the DAFNE collider, which includes a high current electron-positron LINAC and 510 MeV storage rings (Main Rings).

The e+/e- beam from the LINAC is stacked and damped in the accumulator ring for being subsequently extracted and injected into the Main Rings. When the injector is not delivering beam to the accumulator, the LINAC beam can be transported into the Beam Test area by a dedicated transfer line (BTF line). The main components of the line are described in the following[1].

The main parameters of the S-band LINAC (length 60 m ) are listed in the table below:

Table 1. LINAC parameters

| Particle | Electron | Positron |
|---|---|---|
| Energy | 800 MeV | 510 MeV |
| Max. Current | 500 mA/pulse | 100 mA /pulse |
| Transverse Emmittance | ≤ 1 mm mrad at 510 MeV | ≤ 10 mm mrad at 510 MeV |
| Energy spread | 1% at 510 MeV | 2.5 % at 510 MeV |
| Pulse duration | 1 or 10 ns | |
| Repetition rate | 1-50 Hz | |

Electron (positron) beams in that energy range are suitable for many purposes: high energy detector calibration, low energy calorimetry, low energy electromagnetic interaction studies, detector efficiency and aging measurements, test of beam diagnostic devices etc. Since the end of 2005 a photon tagging system has been installed and started operation with the first users.

## THE BTF TRANSFER LINE

The layout of the BTF transfer line is shown in Fig.1. The transfer line is about 21 m long, from the outlet of DHPTB101 (the pulsed dipole extracting the beam to the BTF line) to the bending magnet DHSTB002 in the BTF hall that is one of the two beam exits, and has an inner diameter of about 5 cm. All the line is kept under high vacuum ($10^{-10}$ bar) with the exception of the final part (from the DHSTB002 inlet to the 2 beam exits in the experimental hall), that is working, at present time, at $10^{-4}$ bar. The part under high vacuum ends with a Be window of 0.5 mm thick. The 10 cm air gap between the Be window and the inlet of the DHSTB002 bending allows the insertion of the silicon micro-strip chambers needed for tagged photon production.

The injector system provides beam both to the DAFNE damping ring and to the test beam area. The DHPTB101 allows to drive each of 49 pulses per second either to accumulator or to the BTF line, thus allowing a quasi-continuous operation of the facility. Indeed, even when beams are injected into the DAFNE main rings, not all the bunches are used for machine filling, so that beam can still be delivered to the BTF, but with a lower repetition rate [2]. Obviously, in this operation scheme the pulse duration and the primary beam energy must be the same of DAFNE. This is not a strong limitation, since the facility is mainly operated in single particle mode (electrons/positrons), which is the ideal configuration for detectors calibration and testing. Once per second, one of the 50 LINAC pulses is bent by 6 degrees to the spectrometer line by another pulsed dipole magnet (DHSTP001), in order to measure the LINAC beam momentum with an accuracy of ≈ 0.1%.

The intensity and the spot of the beam inside the BTF line can be measured by a beam current monitor (BCM1 beam charge to charge output ratio 50:1) and a fluorescent screen of beryllium-oxide type (FLAG01).

The intensity of the beam can be tuned by means of a vertical collimator (SLTB01), located upstream respect to FLAG01 in the BTF transfer line. In the high multiplicity ($10^7$ up to $10^{10}$ particles/bunches) range, the diagnostic elements of the line are completed by another beam charge monitor BCM2 (high sensivity, beam charge to output charge ratio 5:1) and two fluorescent screens FLAG02 (beryllium oxide), FLAG03(YAG:CE) mounted at the two exits of the line. In the following, the number of particles per bunch is also referred as “multiplicity of the beam”.

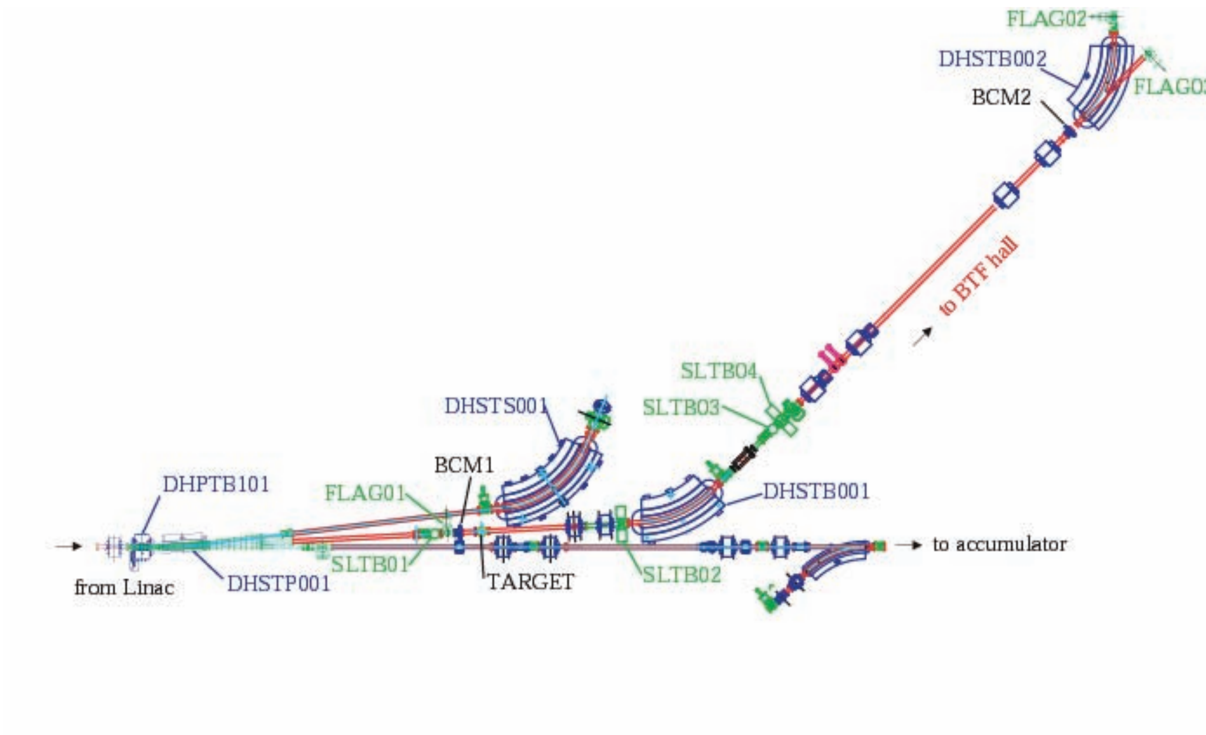


Figure 1. The BTF transfer line. In figure are shown the diagnostic elements mounting on the line, and the position of the target and the four collimator which is necessary to produce a beam with a variable number of particles

When the facility operates in low multiplicity range, it is necessary to strongly reduce the primary beam of the LINAC. The minimum beam current that can be detected by the BCM2 current monitors is $I \approx 1$ mA, and the corresponding number of electrons(positrons) is $10^7$/pulse. It is thus necessary to strongly reduce the number of particles to reach the few particles range. The reduction of the particle multiplicity can be achieved with different methods; the one chosen for the BTF operation is the following: first the LINAC beam is intercepted by a variable thickness TARGET, in order to strongly increase the energy spread of the primary beam; then the out coming particles are energy selected by means of a bending magnet DHSTB001 and two horizontal collimators (SLTB02 and SLTB04).
This energy selector accepts a small fraction of the resulting energy distribution of particles, thus reducing the number of electron/positron by a large and tunable factor. The TARGET is shaped in such way that three different values of radiation length can be selected (1.7, 2.0, 2.3 $X_0$) by inserting it at different depths into the beam-pipe. The momentum of the selected particles has a resolution better than 1%.
After the energy selector, the beam is driven by a 12 m transfer line into the experimental hall by means of a focusing system of four quadrupoles. At the end of the BTF line a second bending magnet allows to use two separate beam-lines alternatively: a straight line is used when the magnet is off, while particles exit from a 45 degrees curved line when the magnetic field is properly set. In table 2 the beam parameters of the facility operated at different multiplicity are reported.

Table 2. BTF parameters for electron/positron beam; A) time-sharing with the DAFNE collider operation, B) continuous operation.

| Operation mode | Time sharing | Dedicated |
|---|---|---|
| Energy range | 25-500 MeV | 25 – 750 MeV |
| Repetition rate | 20-49 Hz | 49 Hz |
| Pulse duration | 10 ns | 1 or 10 ns |
| Multiplicity | 1 up to $10^5$ | 1 up to $10^{10}$ |
| Duty cycle | 80% | 96 % |
| Spot size ($\sigma_x*\sigma_y$) | ~ 2×2 mm (low multliplicity)<br>~ 10x10 mm (high multiplicity) | |
| Divergence | ~2mrad- 10 mrad | |
| Energy resolution | < 1% | |

## BTF PHOTON TAGGED SOURCE.

During 2005, the tagged photon source has been designed, built and tested. The photons are produced by bremsstrahlung of electrons, on a pair of x-y silicon micro-strip chambers, placed at the inlet of the last bending magnet DHSTB002. The photons are tagged in energy using the same bending dipole: the walls of the curved beam-pipe inside the magnet are covered by 10 modules of silicon micro-strip detectors (Fig 2.)

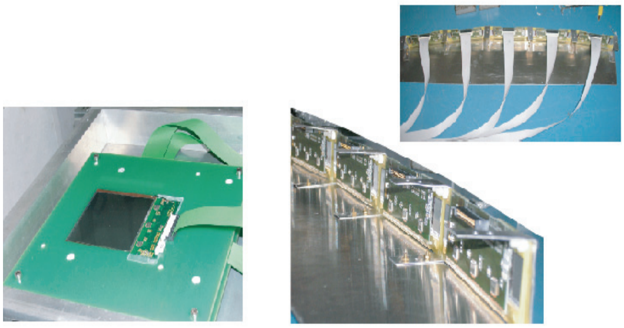

Figure 2. Hardware configuration of the photon tagging system. Left: the silicon microstrip chamber (active target). Right: one of the two supermodules of micro-strips (5x384) mounted on the internal wall of the DHSTB002.

Depending on the energy loss in the photon production, the electrons impinge on a different strip once the dipole current has been set to the nominal value. The correlation between the direction of the electron momentum measured by silicon chambers and the impinging position on the tagging module inside the magnet allows the tagging on the photons. Further details on this system can be found in Ref. [3].

## BTF PERFORMANCE AND DIAGNOSTIC TOOLS.

Since November 2002, the facility has hosted many users that have worked in different conditions of beam parameters (wide range of energy and multiplicity). The following table shows the test beam allocated in the last 4 years.

Table 3. Test beam request in the last years.

| Year | Days |
|---|---|
| 2007 | 224 |
| 2006 | 244 |
| 2005 | 364 |
| 2004 | 282 |

The large range of operation of the facility requires the implementation of different diagnostic devices by mean of which it is possible to measure the beam characteristics (spot size, position, multiplicity). In the low multiplicity operation mode, the standard diagnostic beam devices do not reach the necessary sensivity for monitoring the beam. We have then employed a number of particle detectors (already existing or developed and built for this purpose) optimized for the measurement of the BTF beam. To define the multiplicity (1-100 particles/pulse) we have used different type of calorimeters: lead glass, PbWO4 crystal lead/scintillator fibers (KLOE type), NaI high resolution.

An example of calorimeter spectrum acquired with charge ADC is shown in Fig3. The individual peaks corresponding to the number of electrons can be easily identified. The total number of events in each peak should represent the probability of producing n particles: by fitting the distribution of the number of events in each peak with the Poisson function, the average number of particles can be determinated.

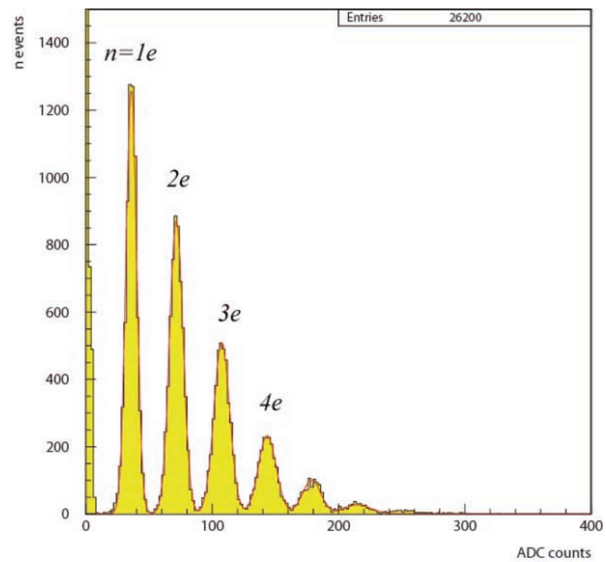


Figure 3. Calorimeter spectrum of BTF beam at low multiplicity

The beam spot profile and position are measured by a x-y scintillating fiber system with millimetric resolution and multi-anode PMT readout, in the range from single particle up to $10^3$ particles/pulse[4].

In the low multiplicity range a silicon micro-strip chamber ( the active target of the photon tagged source) can be used to measure the beam spot profile and position with ≈ 200 micron resolution (Fig 4).

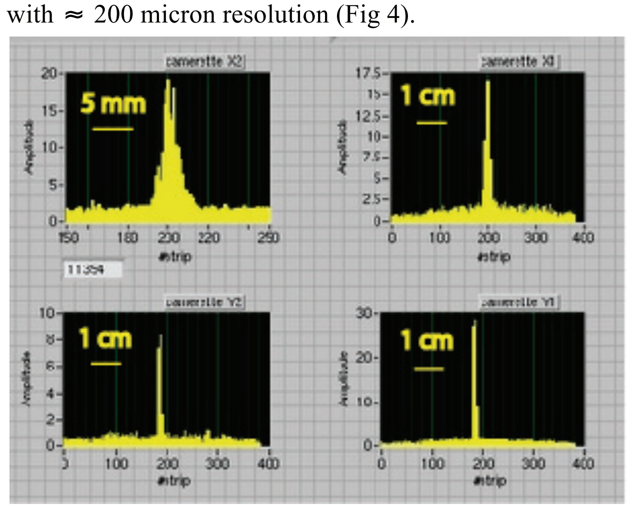


Figure 4. beam spot profile acquisited with a silicon microstrip chamber.

In the range of medium multiplicity (100-$10^8$ particles/pulse) we have used Cerenkov light emission counter to define the number of particles. This device has been cross-calibrated with the calorimeter at low multiplicity.

In order to have a high resolution beam position and size monitor in the intermediate multiplicity range another silicon microstrip detector, having a readout by front-end eletronics with tunable gain, has been developed and tested [5]. The dimension of this diagnostic device are 9.5x9.5cm$^2$, 400 µm thick silicon strip detector (HAMAMATSU Photonics). The 121µm pitch 768 DC-coupled strips are readout by 6x128 channels, 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 the beam profile and extract from the integral of the profile the beam multiplicity up to very high values (i.e.$10^8$ particles /pulse) (Fig5).

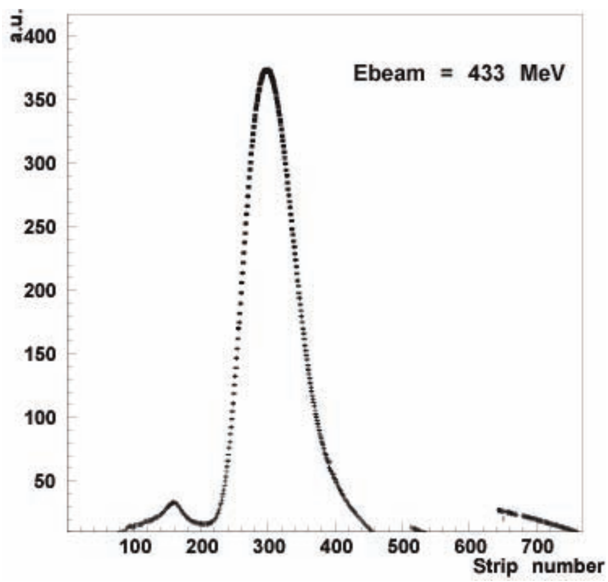


Figure 5. Beam profile with a $10^8$ particles/pulse

## CONCLUSIONS

The DAFNE Beam Test Facility showed very good performance, both from the point of view of operation reliability and the flexibility in order to cope with very different experimental needs. The diagnostic devices, data acquisition system and tools available for experiments are continuously improving.

In the last upgrade, the duty-factor of the facility has been greatly improved (up to 90%) thanks to the installation of a new dedicated pulsed dipole magnet (DHPTB101), capable of driving any of the 50 Linac pulses either to the accumulator ring or to the BTF transfer line.

First preliminary study has been done in order to develop a neutron source at the Beam Test Facility.

## ACKNOWLEDGEMENTS

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