THE DAΦNE BEAM TEST FACILITY: FROM 1 TO 10 MILLIARDS OF PARTICLES

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Abstract

The DAΦNE Beam Test Facility is operating since 2002, providing electrons, positrons and photons from the single particle up to 10^{10} particles per spill and from 25 to 750 MeV. During these years, the facility has hosted tens of high energy physics test and experiments from all over Europe, operating in very different conditions of multiplicity and energy. Operation performance and parameters, tools and diagnostics, as well as the main results obtained, are presented.

INTRODUCTION

The Beam Test Facility (BTF) started operation at the Frascati National Laboratory (LNF) of the INFN in October 2002; it is a part of the DAΦNE accelerator complex, a double ring electron-positron collider, optimised for the production of the Phi meson, at the centre of mass energy of 1019.2 MeV. Its injector, a high current electron/positron linear accelerator, can alternatively inject beams into the accumulator ring (and from there into the DAΦNE main rings), or provide beam to the BTF area [1]. 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. The beam line has been optimised in order to provide 49 pulses/sec of 1 or 10 ns duration and with a number of particles ranging from a single electron or positron per pulse up to DAΦNE LINAC maximum current, equivalent to 10^{10} particles/pulse. The energy can be adjusted between 25 MeV and 750 MeV.

Since the end of 2005 a photon tagging system has been installed and started operation with the first users.

THE FACILITY

The DAΦNE LINAC provides a beam with energy up to 800 MeV for the electrons, with a maximum current of 500 mA, and 550 MeV for the positrons, with a maximum current of 100 mA. The pulse time width can be 10 ns or 1 ns, while the maximum repetition frequency is tunable from fractions of Hz to 50 Hz [2].

The injector system provides beam both to the DAΦNE damping ring and to the test beam area. A 3 degree pulsed magnet injects all the available LINAC bunches in the BTF transfer line, where they are manipulated in order to tune multiplicity and energy required by users.

The minimum LINAC beam current that can be conveniently detected by the DAΦNE current monitors is $I \approx 1$ mA, and the corresponding number of electrons (positrons) is 10^7/pulse.

In order to tune the beam intensity down to a single electron per bunch, it is necessary to strongly reduce the number of particles. The reduction is obtained by strongly increasing the beam energy spread by means of a removable copper target intercepting the primary LINAC beam: three different thickness values can be selected corresponding to 1.7, 2.0, 2.3 radiation lengths. The emerging particles are then selected by a couple of collimators, which reduce the beam divergence at the entrance of the energy selector system, consisting of a bending magnet and a second slit system. This allows selecting the momentum with 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. The BTF transfer line includes a complete diagnostic set including: 2 beam wall current monitors, 2 fluorescent targets and 2 horizontal and vertical correctors, which can be used to optimally set the beam transport. 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.

Figure 1: The BTF experimental hall.

A 100m² area (shown if Fig. 1) is available for hosting experiment, fully equipped with diagnostic system [3,4], Data Acquisition system, High Voltage power supply, scope, network, crates, etc*. A dedicated control room (shown in Fig. 2) with consoles for beam controls, PCs, network and cabling of different type with the experimental hall is also available, within a meeting room and office dedicated to users.

Figure 2: The BTF control room.

* A complete and updated list of diagnostic tools, DAQ, and equipments of the DAΦNE Beam Test Facility is available at http://www.lnf.infn.it/acceleratori/btf/techdoc/

At the beginning of 2005, the AGILE team and the DAΦNE-BTF staff started a collaboration to design and realize a Photon Tagging Source in the BTF experimental hall. Photons in BTF are produced by Bremsstrahlung of electrons (with maximum momentum of 750 MeV/c) on an active targed made by four silicon micro-strip planes (two x and two y views) placed at the inlet of the 45 degrees bending magnet downstream in the BTF transfer line (see Fig. 3).

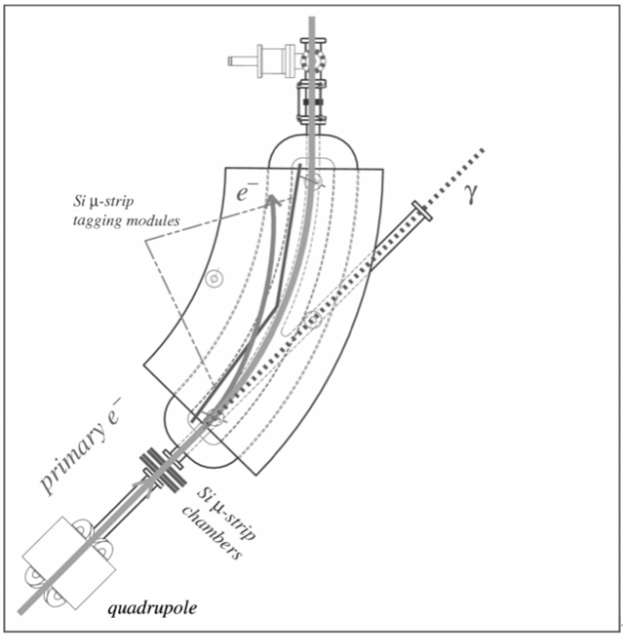

Figure 3: Schematic view of the tagged photon source showing the last part of the BTF line, the active target (silicon micro-strip chambers), and the tagging modules inside the bending magnet.

The four silicon planes, 8.9×8.9 cm^2 of active area, are 380 μm thick silicon detectors with a strip readout pitch of 242 μm. The energy of the radiated photon is obtained from the momentum lost by the emitting electron, measured in the magnetic field of the last bending magnet, by means of a set of tagging silicon micro-strip detectors arranged inside the magnet itself along the curved beam-pipe (on the left of the curved beam pipe in Figure 3): depending on the energy lost in the photon production, the emitting electron will hit different strips, once the dipole magnetic field is set to the nominal value of the electron beam, while non-irradiating electrons will be transported inside the curved pipe. The correlation between the direction of the electron, measured by the x-y micro-strip chambers, and the position where the electron impinges on the micro-strip module inside the magnet allows tagging the produced photons, with an energy resolution of 7% (A Bremsstrahlung spectrum is shown in Fig. 4).

The tagging detectors are divided in 12 modules of 2 cm active height and 384 strips each, with a readout pitch of 300 μm. Together with the four chamber planes, a total of 6144 micro-strip signals are read by TAA1 ASICs (IDEAS, Norway, 128 channels/chip), the analog signals are then multiplexed with a 5 MHz clock and acquired by sampling ADCs and C-RAMs (CAEN V550). The system is presently being integrated in the BTF data acquisition system in order to record on disk the reconstructed photon energy together with the electron beam parameters.

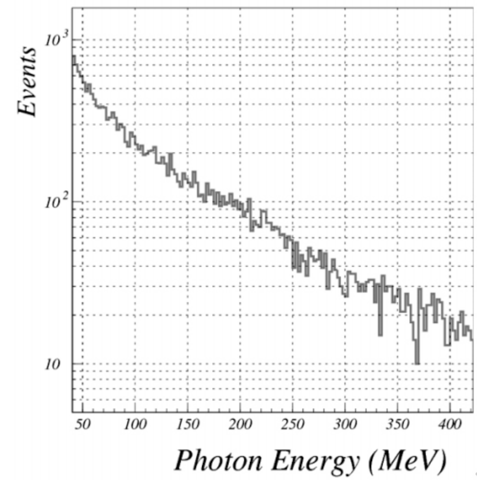

Figure 4: Photon spectrum obtained by Bremsstrahlung starting from a 450 MeV primary electron beam.

The beam spot size and divergence should be kept as small as possible in order not to spoil the photon energy resolution and in order to minimise mis-tagged events, mainly due to electrons scattered at large angles and hitting the tagging modules (see Fig. 5). These spurious events can be reduced offline by selecting single tracks in the active target silicon chambers, and by cutting on the primary electron angle, but this results in a reduction of useful tagged photon events. The contribution of the Coulomb scattering is minimised by using thin (0.5 mm) beryllium beam-pipe exit windows, and keeping a vacuum (at the level of 1 mbar or less) also in the last part of the beam-pipe inside the magnet.

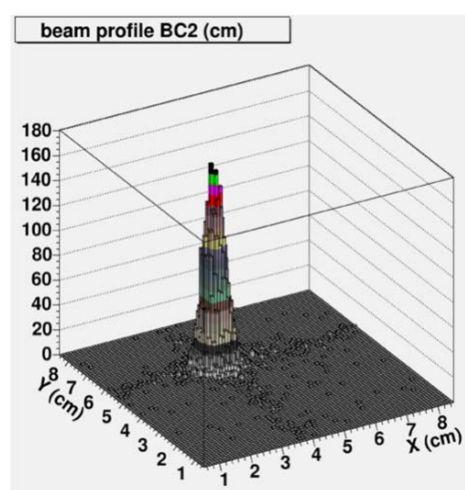

Figure 5: Beam spot size measured on the silicon micro-strip chambers at the entrance of the last dipole magnet.

A dedicated study investigating the possibility of producing low momentum neutrons with the BTF electron beam on a dedicated target has also started; simulations using hadronic interactions simulation packages like FLUKA are presently under way.

OPERATION AND PERFORMANCE

The operation parameters for the DAΦNE Beam Test Facility are listed in Table 1. Up to now the facility essentially worked in time-sharing with injection into the rings of DAΦNE. The duty cycle was then limited to about 40% due to the continuous topping-up during the operation of DAΦNE collider experiments.

Table 1: BTF parameters for electron/positron beam; 1) left time-sharing with the DAΦNE collider operation, right continuous operation; 2) left single particle value, right high multiplicity value.

Energy range	25-500 MeV / 25 – 750 MeV$^{(1)}$
Repetition rate	20-50 Hz / 50 Hz$^{(1)}$
Pulse duration	10 ns / 1 or 10 ns$^{(1)}$
Duty cycle	40 / 80 %$^{(1)}$
Multiplicity	1 – 10^3 (allowed) up to 10^{10} (waiting for approval)
Spot size (σ_x*σ_y)	~ 2×2 – 10 mm$^{(2)}$
Divergence	~ 2 – 15 mrad$^{(2)}$
Energy resolution	< 1%

During the last DAΦNE shutdown in 2006 a pulsed dipole magnet has been inserted at the end of the LINAC, allowing to continuously deliver beam in the BTF experimental area. Even when beams are injected into the DAΦNE rings, the BTF beam can still be delivered, with a lower repetition rate, since not all the LINAC bunches are needed for the filling the accumulator ring. Obviously, in this operation scheme the pulse duration and the primary beam energy must be the same of DAΦNE. 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; in this case the beam characteristics (see Table 1) are largely determined by the energy selector magnetic field and by the positioning of the slits.

The values listed in Table 1 are average values: the beam parameters can be further tuned depending on the needs of the user group, from the point of view of beam intensity, energy and beam spot size.

Concerning the beam multiplicity the limit of thousands of particles can be overcome as soon as radio-protection safety permissions will be granted by the Regional Environment Protection Agency, in order to bring all the LINAC current in the area, equivalent to 10^{10} electrons.

CONCLUSIONS

In almost four years of operation the DAΦNE Beam Test Facility hosted tens of international research groups testing devices and detectors in many different conditions.

The BTF demonstrated very good flexibility and optimal performances in a wide range of different applications and conditions. More technical and detailed information are available on the facility web site: http://www.lnf.infn.it/acceleratori/btf/

ACKNOWLEDGMENTS

We are deeply grateful to all the DAΦNE operators who ensured a steady and effective operation of the LINAC and BTF beams from the beginning, and to all our colleagues of the Accelerator Division for their efforts in minimising the BTF dead times.

One of us (P. V.) wants to the dedicate this paper to the memory of Sabrina Picucci.

REFERENCES

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