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The Frascati LINAC beam test facility performances and upgrades

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Summary. — The Beam-Test Facility (BTF) of the $DA\Phi NE$ accelerator complex, in the Frascati National Laboratory of the INFN is in operation since 2004 for the high-energy particle and accelerator community. The performance of the BTF is discussed and the plans for the future upgrade of the facility are introduced.

1. – Introduction

The Beam-Test Facility (BTF) is an infrastracture mainly dedicated to the development and testing of particle detectors. The experimental hall available for the users is a shielded area of about 25 m^2 where the device under test is irradiated with electron or positron beams produced by the LINAC of the $DA\Phi NE$ accelerator complex, extracted before the injection into the damping ring to a dedicated transfer line.

During the test of their devices, the users have also access to various services available such as power supply, networking, gas system, DAQ, vacuum and cryogenics, alignment, magnetic fields.

2. – The LINAC

The main aim of the LINAC is to produce bunches with $\approx 10^{10}$ electrons /positrons with an energy of 510 MeV for the $DA\Phi NE$ collider. The injector of the $DA\Phi NE$ accelerator complex is an S band (2856 MHz) LINAC that alternately produces and accelerates the electron and positron beams up to the collider operation energy of 510 MeV. Before injection into the main rings the beams are stored into the accumulator ring for phase space damping. The LINAC has been designed, built, and installed by TITAN BETA (USA) [1, 2], and is operational since 1997. The Frascati LINAC consists mainly of two parts. The first part is the low-energy/high-current section made up of five SLAC-type

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Parameter	Parasitic mode		Dedicated mode	
	With target	Without target	With target	Without target
Particle species	e^+ or e^- Selectable by user	e^+ or e^- Depending on DAFNE mode	e^+ or e^- Selectable by user	
Energy (MeV)	25–500	510	25–700 (e^-/e^+)	250–730 (e^-) 250–530 (e^+)
Energy spread	1% at 500 MeV	0.5%	0.5%	
Rep. rate (Hz)	Variable between 10 and 49 Depending on DAFNE mode		1–49 Selectable by user	
Pulse duration (ns)	10		1.5–40 Selectable by user	
Intensity (particles/bunch)	1–10^5 Depending on the energy	10^7–1.5 10^{10}	1–10^5 Depending on the energy	10^3–3 10^{10}
Max. average flux	3.125 10^{10} particles/s			
Spot size (mm)	0.5–25 (y) × 0.6–55 (x)			
Divergence (mrad)	1–1.5			

Fig. 1. – Summary of the BTF parameters.

3 meters accelerating structures. The maximum achievable energy, on the Positron Converter (PC), is 250 MeV, and in operation, with 10 nsec, about 5 A of electron bunches at the PC, the energy conversion is 220 MeV. The second part is the high-energy/low-current section made up of ten SLAC-type accelerating structures. It can accelerate the positron bunches emerging by the PC, up to the maximum energy of 550 MeV. The SLAC-type structures are travelling wave, constant gradient units and are fed by RF pulses, compressed by means of SLED cavities. Four RF stations provide the power by means of 45 MW klystrons.

3. – The BTF

The BTF is composed of a transfer line driven by a pulsed magnet allowing the diversion of electron or positron bunches that are not injected into the $DA\Phi NE$ damping ring, with a duty cycle depending on the injection requirements: from a minimum of 20 up to 49 bunches/s [3] are available for users.

Two major modes of operations are possible, based on the user needs. The high-intensity mode is operated when the LINAC beam is directly steered in the BTF hall with a fixed energy (*i.e.* the LINAC one) and with a reduced capability in multiplicity selection (typically from 10^{10} down to 10^4 particles/bunch). The low intensity mode is operated when the LINAC beam is intercepted in the initial portion of the BTF line by a step Copper target. This produces a secondary beam with a continuous full-span energy (from LINAC energy down to 50 MeV) and multiplicity (down to single particle/bunch) selection range. In the so-called single-particle mode, the particle multiplicity delivered to the users follows a Poisson distribution.

The facility can thus provide tunable electrons and positrons beams in a defined range of the different parameters: energy (up to 730 MeV for e^- and 530 MeV for e^+), charge (up to 10^{10} e^-/ bunch) and pulse length (1.4–40 ns), as summarized in fig. 1.

A scheme of the beam transfer line with some pictures of the elements is shown in fig. 2.

Users of the BTF are provided with diagnostics tools to control the beam parameters. An example is the monitoring of the beam size by means of a pixelized Silicon detector (FitPIX) installed at the exit of the beamline, as shown in fig. 3 for 450 MeV electrons in single-particle mode.

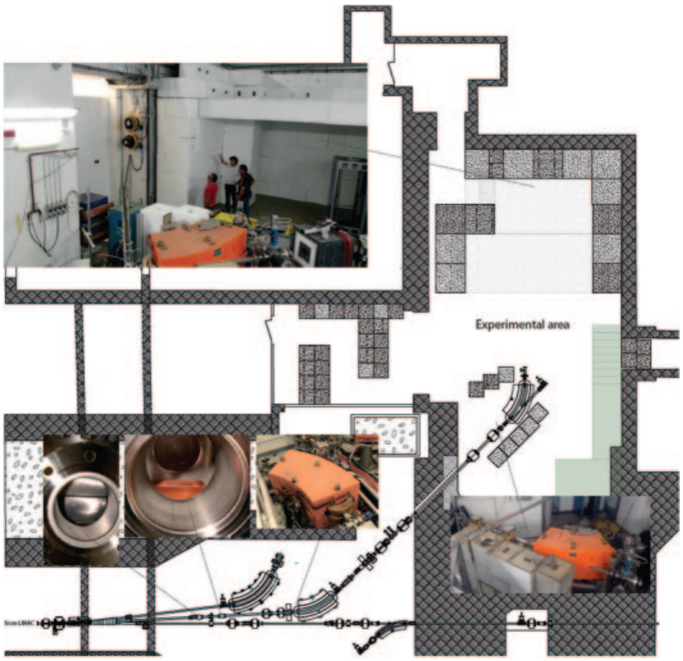

Fig. 2. – The layout of the trasfer line from the LINAC to the BTF experimental hall with photos of the two dipoles, one of the scrapers and one the copper target.

Other particles species available for the user are the neutrons and the energy-tagged photons.

The photo-production neutrons source is obtained by the LINAC primary beam on an optimized tungsten target located in a polyethylenelead shielding assembly. The neutron spectrum emerging from the target has been characterized, showing the expected evaporation peak at about 1 MeV [5, 6]. The huge prompt photon background is only

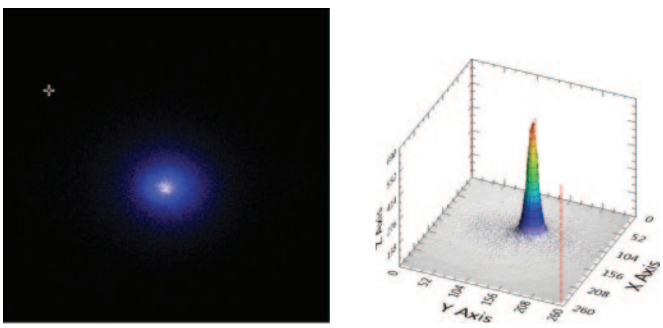

Fig. 3. – On the left the BTF beam spot image acquired with a FitPIX detector (by WidePix). The Silicon sensor size is of 14 mm × 14 mm and consists of a 255 × 255 pixels matrix, with a pixel dimension of 55 μm. On the right side, the 3D image is shown. The best beam obtained was $\sigma_x = 420\,\mu$m and $\sigma_y = 440\,\mu$m operating in single-particle mode.

partially reduced by the choice of the 90° extraction channel from the lead/polyethylene shielding.

The BTF energy-tagged photons source is an active Bremsstrahlung target. It consists of two pairs of Silicon single-sided micro-strip detectors to measure the coordinates and the direction of the electrons beam and to cause the emission of bremsstrahlung photons before last dipole in the BTF hall. A series of modules of Silicon micro-strip detectors, placed in the final dipole pole gap, is used for the measurement of the radiating electron energy loss and tag the photon energy. The system has been designed in collaboration with the AGILE [7] (gamma astronomy satellite) team, with the aim of calibrating with a well defined energy and impact point photon beam the scientific payload before the launch.

4. – The upgrade of LINAC BTF

An important upgrade program of the facility is under evaluation, along three main lines [8]: consolidation of the LINAC infrastructure, in order to guarantee a stable operation on the long term; upgrade of the LINAC energy, in order to increase the facility capability (especially for the almost unique extracted positron beam); doubling of the BTF beam-lines, in order to cope with the significant increase of users due to the much wider range of applications.

Consolidation of the LINAC. A LINAC modulators consolidation and the realization of a complete test of a new RF station is in program. These two different activities are strongly related, since the additional RF power station is a fundamental element for preparation and testing of the components for the consolidation of the existing modulators, thus avoiding a very long shut-down of the LINAC.

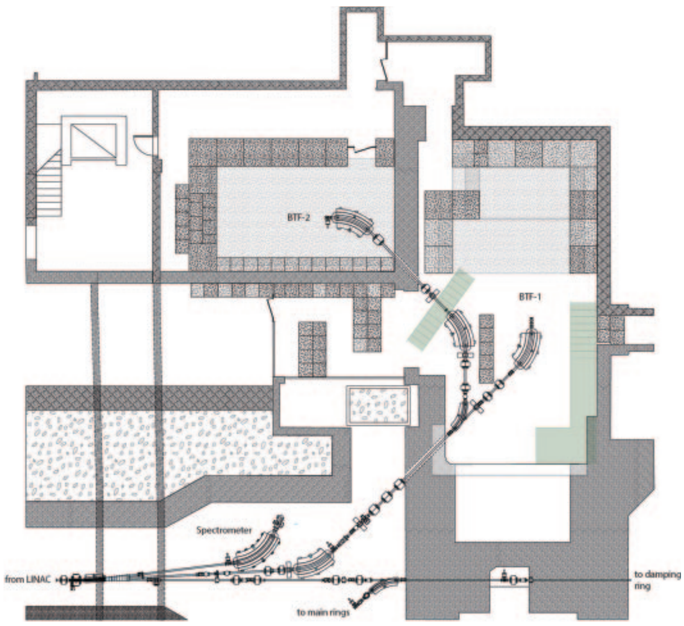

Fig. 4. – The project of the new BTF layout with the doubling of the line.

Upgrade of LINAC energy. The energy of the LINAC will be upgraded to 1 GeV, by adding four more accelerating sections which will be supplied by a fifth RF station. A simpler scheme is in project which exploits the extra-length in the LINAC tunnel, of about 15 m, between the last accelerating section at the end of the LINAC and the three-way switch-yard (towards the damping ring, the BTF and the spectrometer line) as shown in fig. 1, presently used as a drift space, with four quadrupoles to preserve the beam optics.

Doubling BTF line. The possibility to have a second beam-line for the BTF has been studied. With the current infrastructure an average of 200 beam-days are delivered to about 20 experiments in a year. Having a second line will allow to work in parallel and it will be particularly useful in case of long-exposure experiments. A first application will be the PADME experiment for dark photon searches [9]. The INFN has approved PADME for running at the BTF in late 2017/beginning of 2018, for reaching an exclusion of $\epsilon = 10^{-3}$ for invisible decays, up to 26 MeV/c^2 dark photon masses [10]. Simulations of the new transfer line with MAD-X and G4-beamline confirm that the new layout provided in fig. 4 is compliant to the beam requirements [11, 12].

5. – Conclusions

The BTF is continuosly improving and the upgrade program is in progress in order to take into account the increasing user requirements. This ensures that the BTF continues playing a key role within the European infrastructures dedicated to development and test of particle detectors.

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