DAΦNE BEAM TEST FACILITY COMMISSIONING

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Abstract

The DAΦNE Beam Test Facility (BTF) is a beam transfer line optimized to produce single electrons and positrons mainly for high-energy detectors calibration in the energy range between 20 and 800 MeV. The BTF has been successfully commissioned in February 2002, and started operation in November. The scheme of operation, the commissioning results, as well as the first users' experience are presented.

DESCRIPTION OF THE DAΦNE BTF

The Beam Test Facility (BTF) has been designed [1] to provide a defined number of particles in a wide range of multiplicities and energies, mainly for detector calibration purposes, such as energy calibration and efficiency measurements (in single electron mode), and also for beam diagnostics devices and detector aging (at higher intensities).

The BTF is part of the DAΦNE accelerator complex, consisting of a double ring electron-positron collider, a high current linear accelerator (LINAC), an intermediate damping ring (Accumulator) and a system of 180 m transfer lines connecting the four machines. The LINAC delivers electrons with energy up to 800 MeV, with a typical current of 500 mA/pulse, or positrons with energy up to 550 MeV, with a typical current of 150 mA/pulse; the pulse duration can be adjusted in the range 1÷25 ns with a maximum repetition rate of 50 Hz. When injecting for operation of the main rings at the ϕ resonance, the beam energy is 510 MeV.

The minimum LINAC beam current that can be conveniently measured by the DAΦNE current monitors is $I \approx 1$ mA, corresponding to $\approx 10^8$ electrons/pulse, so that 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[2]: first the LINAC beam is intercepted by a (variable depth) target in order to strongly increase the energy spread of the primary beam; then the outcoming particles are energy selected by means of a bending magnet and slit system. The energy selector only accepts a small fraction of the resulting energy distribution, thus reducing of the number of electrons by a large and tunable factor. The target is shaped in such a way that three different values of depth can be selected by inserting it into the beam-pipe, corresponding to $1.7, 2.0, 2.3\ X_0$.

The attenuated beam is transported by a ≈ 12 m transfer line to the BTF hall, where the experimental set-ups can be installed; at the end of the BTF line a second bending magnet allows to use two separate test lines: one directly from the straight section, the other from the magnet at 45°. A schematic view of the BTF layout is shown in Fig. 1.

Due to the momentum dispersion introduced by the bending magnet, the relative energy spread $\Delta E_{\rm sel}/E_{\rm sel}$ is essentialy determined by the magnet/collimators configuration[1]; in the standard BTF operation for a wide range of slit apertures a resolution better than 1% can be obtained.

The number of transported electrons (or positrons) can be adjusted in a wide range, down to single particle, and is well below the sensitivity of any standard beam diagnostics device, so that many different particle detectors have been used to monitor the beam characteristics.

The experimental area extendes over a 100 m^2 area hall, surrounded by shielding walls of (movable) concrete blocks; a 20 ton crane and a remotely controlled, motorized trolley are available. A number of coaxial cables are stretched between the experimental hall and a dedicated control room, where the BTF beam (and user apparata) can be fully steered. The facility is fully equipped with a complete DAQ, both VME and CAMAC, with NIM electronics and HV modules available for the users.

BEAM COMMISSIONING

During 2002 the BTF has been successfully commissioned and started operation, delivering beam to the first user experiments, from Nov. 2002 to May 2003[3]. Two different operation modes of the facility have been successfully implemented:

- "parasitic": when the DAΦNE collider is working for the main experiments, the LINAC can deliver electron/positron beams to the BTF only between two injection cycles for the main rings. The LINAC setting was optimized to provide a 510 MeV energy, 4÷5 mA intensity beam, with a repetition rate of 24 Hz (+1 shot to the spectrometer line for LINAC energy measurement), and the pulse duration was the same as for injection in the accumulator, ≈ 10 ns. With a typical collimator setting of 2 mm total aperture, both for the upstream and downstream slits and with the target depth set to 1.7 X_0, only a few electrons reach the diagnostic detectors.

- "dedicated": when there are no collisions in the DAΦNE main rings the LINAC beam can be continuously delivered to the BTF. In this case is possible to change the LINAC energy in order to optimize the

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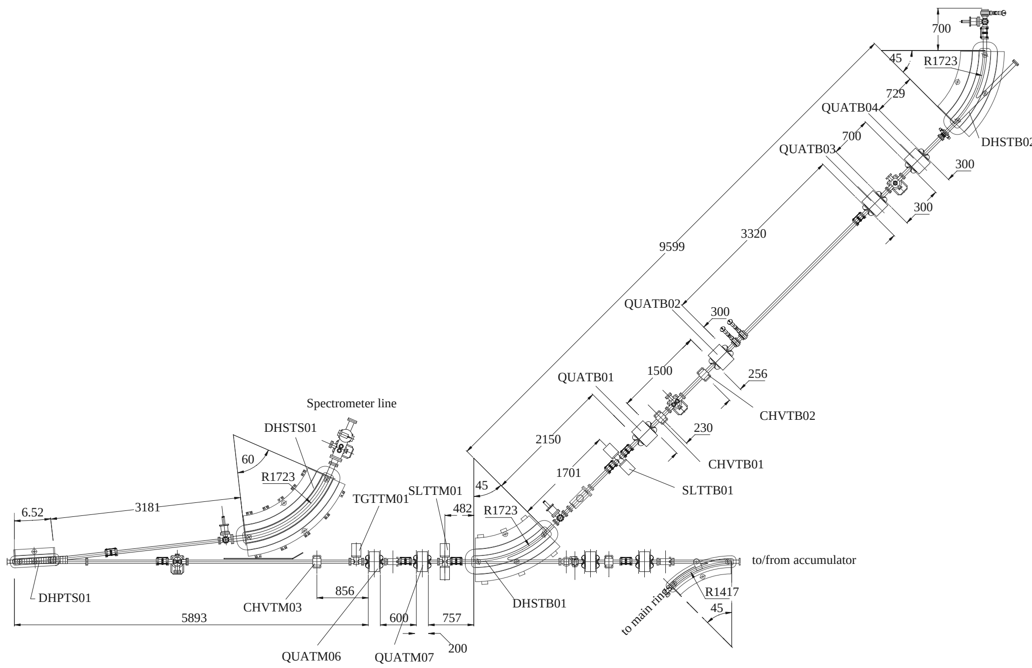

Figure 1: Layout of the Beam Test Facility.

energy/multiplicity of the BTF beam; moreover, the pulse duration can be also changed.

The facility has been operating both in the single electron production scheme and in the high multiplicity operation mode, according to the different user requirements. At low multiplicity a calorimeter has been used as main diagnostic device. The detector is a lead/scintillating fibers calorimeter (developed for the KLOE experiment[4]), with single side photomultiplier readout, with good energy resolution (7% at 500 MeV).

Due to the good energy resolution of the calorimeter (anyhow still worse than the intrinsic beam-line energy acceptance) the number of produced electrons can be counted simply by measuring the total deposited energy E: $n = E/E_1$, where E_1 is the energy deposited by a single electron. An example of ADC spectrum (pedestal subtracted) is shown in Fig. 2, for a selected energy of $E_{\rm sel} = 442$ MeV: the individual peaks corresponding to $0, 1, \ldots, n$ electrons can be easily identified.

The most effective way to change the average number of particles in the beam is to change the selected energy $E_{\rm sel}$; in particular, at the **same** LINAC energy and intensity and with the **same** collimator settings, the multiplicity increases by decreasing the chosen $E_{\rm sel}$. In addition, the multiplicity can be tuned by changing the aperture of the upstream and/or downstream collimators. In this case the energy resolution of the selector will be also affected by a relatively small amount, in any case well below the intrinsic resolution of our calorimeters. In particular, the measured multiplicity increases by increasing the slits aperture until the intrinsic beam spot size is exceeded.

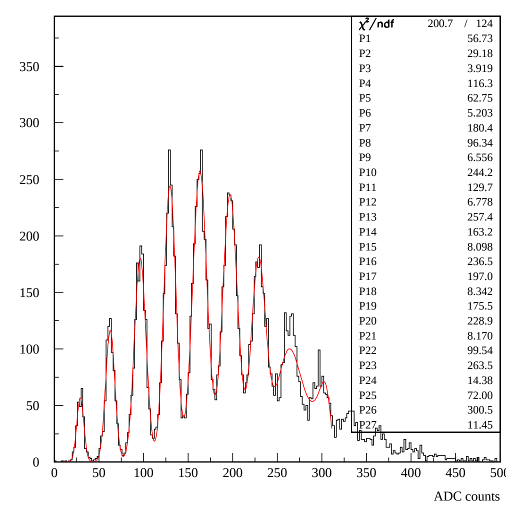

Figure 2: Counting electrons in the calorimeter: charge spectrum for $E_{\rm sel} = 442$ MeV.

Above ≈ 20 particles the calorimeters are no longer effective due to saturation effects. In order to have a diagnostics device in the $\overline{n} = 100$-1000 range (and higher), a detector has been developed and tested in collaboration with the AIRFLY group [5, 6], based on the Cerenkov radiation emission.

Another important parameter is the beam energy, that can be chosen by changing the current of the energy selector dipole magnet. The average measured energy of the single electron signal in the calorimeter is proportional to the incoming beam energy $E_{\rm sel}$ as shown in Fig. 3.

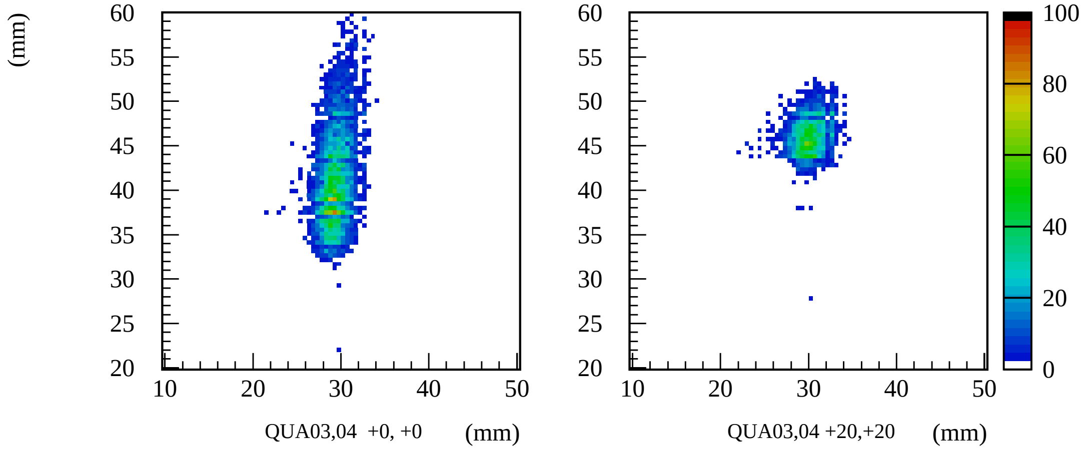

Figure 4: Beam spot measured by the AGILE silicon tracker: on the left for defocussed beam (last vertical and horizontal quadrupoles off); on the right for optimized optics ($\sigma_x \approx \sigma_y \approx 2$ mm).

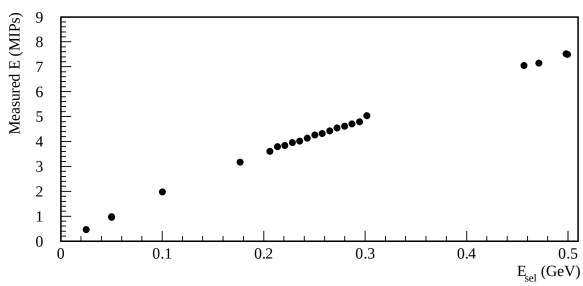

Figure 3: Total energy deposited in the calorimeter by a single electron as a function of the selected beam energy E_{sel}.

The single electron beam spot size has been measured profiting of the high spatial resolution of the silicon microstrip tracker of the AGILE gamma-ray experiment [7]. An example of the beam spot measured by the silicon microstrip monitor is shown in Fig. 4: a $\sigma_x \approx \sigma_y \approx 2$ mm spot has been measured with an optimized optics, defocussed optics have been also studied for detector efficiency testing purposes.

Many user experiments were carried out since Nov. 2002, both in single electron mode and at high multiplicity. The single electron mode has been mainly used for testing particle detectors, while the AIRFLY experiment (measuring the air fluorescence yield) has been the main user of the high multiplicity beam: a wide range of particle multiplicity has been exploited, spanning from 10 to more than 1000 electrons/pulse. In both cases the full energy range of the BTF beam has been spanned, up to the maximum LINAC energy ($\approx$ 800 MeV), and also at very low energy (as low as 25 MeV).

Many different settings for BTF beam, for various energy/multiplicity/beam-size configurations have been optimized. The desired beam characteristics were in general easily tunable and the settings showed a very good reliability. Moreover, some diagnostic devices have been integrated in the DAΦNE control system in order to provide an easy user interface.

CONCLUSIONS

The BTF has been operational during the second half of year 2003, both in parasitic and dedicated mode, giving beam to a number of experimental users in a wide range of energy and particle multiplicity. It demonstrated to be easily tunable and very reliable both from the point of view of the desired particle number (from single electron mode to ≈ 1000) and energy setting. In order to overcome the present limitations imposed by the DAΦNE collider experiments operation and to largely improve the duty-cycle, we plan to upgrade the facility [8]; a complete separation between the DAΦNE transfer lines to the Main Rings and the BTF channel will allow to operate in the BTF mode with the only limitations of the LINAC switching time and the time spent for filling the Main Rings. An upgrade of allowed dose, up to 10^{10} particles/s, will also permit to use the BTF for testing of standard beam diagnostic devices.

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