

BEAM OPTIMIZATION OF THE DAΦNE BEAM TEST FACILITY*

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Abstract

The DAΦNE Beam Test Facility delivers electron and positron beam with a wide spread of parameters in charge, energy, transverse dimensions and time width. Thanks to the recent improvements of the diagnostics, all the beam parameters have been measured and optimized. In particular we report here some results on beam transverse size, divergence, and position stability for different energy and intensity configurations. After the upgrade of the electronic gun of the DAΦNE LINAC, the pulse time width and charge distribution have been also characterized.

DAΦNE BEAM TEST FACILITY (BTF)

The BTF (Beam Test Facility) is part of the DAΦNE accelerator complex: it is composed of a transfer line driven by a pulsed magnet allowing the diversion of electrons or positrons, usually injected into to the DAΦNE damping ring, from the high intensity LINAC [1] towards a 100 m² experimental hall. The facility can provide runtime tuneable electrons and positrons beams in a defined range of different parameters: energy (up to 750 MeV for e⁻ and 540 MeV for e⁺), charge (up to 10¹⁰ e⁻/bunch) and pulse length (1.4–40 ns). The bunch delivery rate is depending on the DAΦNE injection frequency (25 or 50 Hz) with a duty cycle also according to the DAΦNE injection requirements.

Two major modes of operations are possible, depending 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 10¹⁰ down to 10⁴ particles/bunch). In the low intensity mode of operation, a step copper target, allowing the selection of three different radiation lengths (1.7, 2 or 2.3 X₀), is inserted in the initial portion of the BTF line for intercepting the beam. 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 single particle mode, the multiplicity per bunch delivered to the users follows a Poisson distribution (Figure 1). A pulsed dipole magnet at the end of the LINAC allows alternating the beam between the DAΦNE damping ring and the test beam area, thus keeping a pretty high BTF duty cycle, assuring at least about 20 bunches per second during the positron injection in DAΦNE accumulator when BTF operates in low intensity regime, 28 on average for a complete e⁺/e⁻ injection cycle.

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GENERAL DAQ AND STANDALONE DIAGNOSTICS OVERVIEW

BTF DAQ

BTF DAQ is composed mainly of one data producer and two data consumers: one for online diagnostics and one for data storing. The DAQ hardware configuration is NIM/VME based and controlled by VMIC VMIVME 7750 (Intel PIII, 1.3Ghz, 0.5Gb RAM). The acquisition software, hosted in DAΦNE data control system environment (DAΦNE DCS), is written in LabVIEW® LV7.0 and a shared memory is provided for the system, based on MemCached protocol[2], in order to handle the new standalone USB/ETH/Serial based diagnostics elements. The BTF-DAQ is a dynamic composition of different modules, that can be switched on and off at run-time according to the user beam monitoring needs. A standard BTF configuration includes:

- Delay Programmable Unit
- Scaler, Peak sensing ADC, QDC, TDC
- BTF custom detectors electronics
- Digital I/O

The mostly used detectors, stably readout by the BTF DAQ front-end, are the fiber transverse beam profile hodoscope and a lead glass calorimeter[3]. The consumer software is also hosted in the DAΦNE DCS and it is normally used for online monitoring of the BTF beam and data storage.

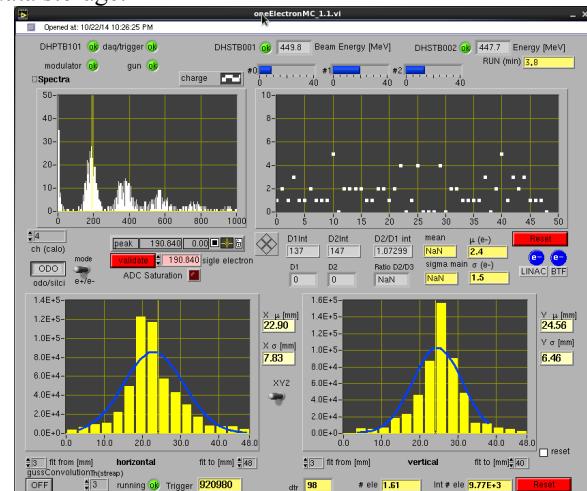


Figure 1: BTF DAQ data (Calorimeter on top and Hodoscope on the bottom) displayed in the BTF DCS diagnostics display software.

MEMCACHED

MemCached (MC) is an Ethernet based in-memory key-value store for arbitrary data (strings, objects). In the

BTF network environment, it is installed in native version on a virtual machine, running Linux (2.6.18-308.11.1.el5xen quad-cored), with 2GB RAM. Our custom MC APIs are exported in LabVIEW and the typical producer data are in the form of LabVIEW variant in flattened string values. This choice allows a clear coding and decoding strategy in the developing of further optimized diagnostics (integrated in the DCS or standalone).

MEDIPIX

In order to accomplish the user need for a fast transverse beam imaging, a MEDIPIX® silicon pixel detector with FITPIX® electronics has been made routinely available to the users: it is integrated in the BTF timing and virtual machine sub-systems. We acquire in Medipix mode the WIDEPPIX® with the PixelLite® software. The sensors have a square pixel of 55 μm side in a 256×256 pixels (overall side length 1.4 mm) layout for a square sensitive area of about 2 cm^2 and 300 μm of thickness. The timing feature of TIMEPIX detector fits well the BTF experimental needs. We are now working on the fetching the FITPIX delivered data in our caching system.

TPC - GEM

It is essentially a compact TPC with a 4 cm drift and readout with triple GEM. The front-end and readout electronics has been completely developed in the LNF Lab [4]. The material budget crossed by a particle is only two Kapton foils ($<0.2\% X_0$) in addition to the 10 cm gas volume. With a layout of 16×8 pads matrix, in bunched beam it is possible a 3D track reconstruction: a resolution of 90 μm in the drift coordinate (Z) has been measured in single particle mode, in a dedicated run using a Medipix telescope.

Starting from 2012, the tracker system has been tested at BTF in various conditions of beam multiplicity, from single particle, up to a thousand electrons per bunch, and it has also demonstrated the possibility of monitoring the beam intensity using the current measurement. This technique needs to be further developed: a pressure/flow stabilization system is needed to improve the HVGEM 2.0 native current measurement, in particular for covering the intermediate current range.

The final system of TPC GEM, readout with a custom data acquisition card based on FPGA and CARIOCA chips[5], and powered with the dedicated HVGEM module, has been installed in late 2013. Both the GEM FPGA readout and the HV CANBUS-USB KVASER adapter for HVGEM control have been integrated in the Ethernet BTF virtualization system and are now operated without standalone control PC. For the assembly and commissioning of the GEM trackers the developing of some ancillary elements has been necessary, such as gas system, electronics, mechanical and support system, as well as the implementation, installation and test of the new software, in the BTF DAQ environment. A user-

friendly automated calibration software has been also developed for improving detectors reliability.

BEAM Transverse Diagnostics - Examples

The new diagnostics improved a lot the characterization and optimization of the BTF beam[6]. We report a sample of beam diagnostics acquired during the user shifts: as one can easily notice, very different setups are selected. The plots are relative to Medipix data with a square sensor of 1.4 mm side (0 to 255 pixels per column/row, 55 μm pixels).

Beam runtime configuration - The user requirements span a variety of beam energy, transverse parameters, multiplicity and bunch length. Most of these parameters could be easily implemented by the users themselves, using the collimators and the magnetic optics. The beam setup files are either made available in advance (for standard or frequently asked configurations) or just prepared with test runs by BTF staff at run-time.

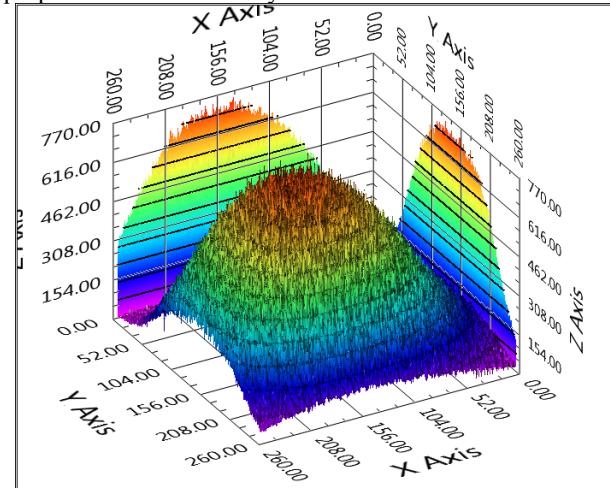


Figure 2: Beam spot for 447 MeV electrons at 50 particles/bunch and wide beam: it's a 2-D Gaussian shaped beam with $\sigma_x=4.8 \text{ mm}$, $\sigma_y=3.7 \text{ mm}$.

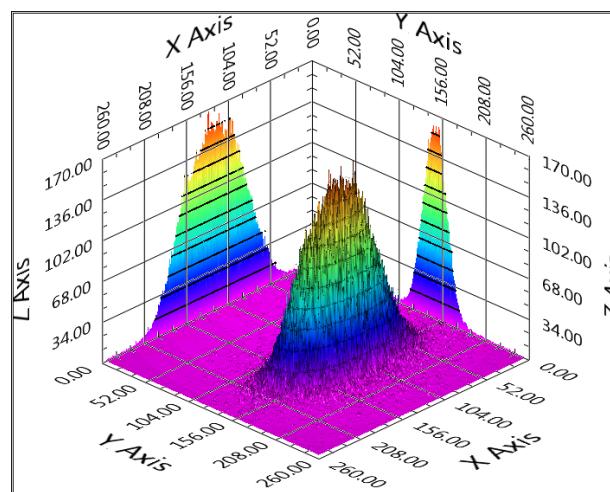


Figure 3: Transverse spot in single particle and vertically collimated beam: $\sigma_x=2.1 \text{ mm}$, $\sigma_y=0.8 \text{ mm}$.

Beam transverse parameters stability vs multiplicity and energy - In the following figures we show the stability, within the errors, of the transverse beam parameter (centroid position, σ of both axes) changing the beam intensity with the collimators and the energy selected on the BTF line.

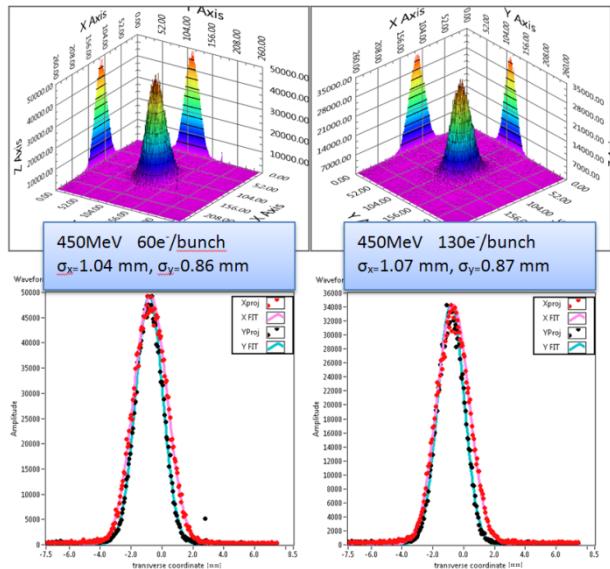


Figure 4: Different setups for beam multiplicity at 450 MeV: no significant variation in position (less than 10 μm) and in transverse parameters.

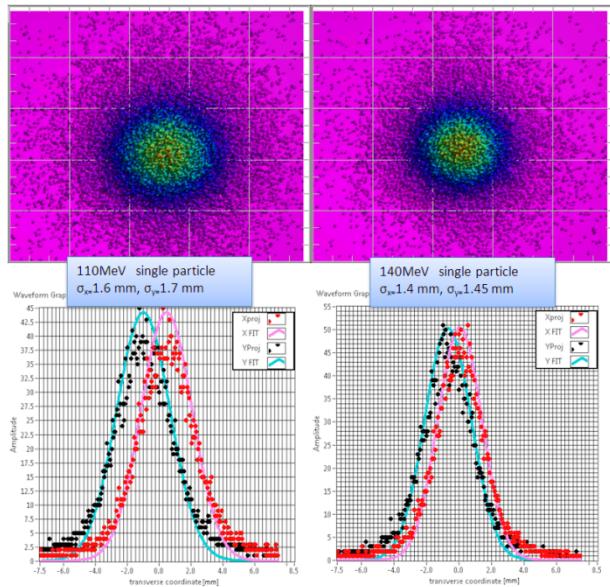


Figure 5: Run-time beam stability for different energy settings, maintaining the single particle multiplicity (with some tuning to match users' needs).

Beam centroid bunch by bunch - runtime stability - The measurement of beam centroid has been performed in low intensity mode with 450 MeV electrons, at 25 e $^-$ /bunch (3500 bunches). The uncertainty in position is a 1/4 of the beam transverse dimension (typically 1 mm), mainly due to the Poisson fluctuation in multiplicity.

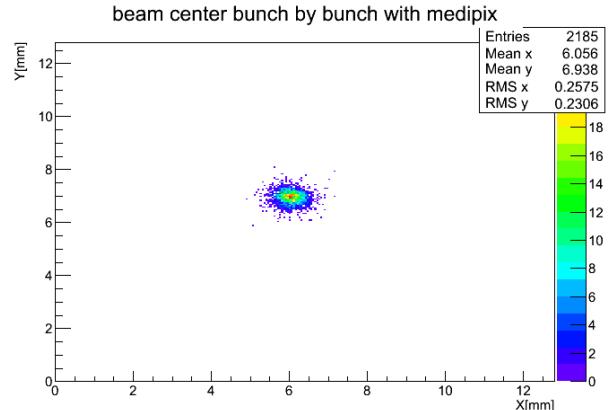


Figure 6: XY plot of the beam centroid position for 3500 bunches of 450 MeV electrons.

GEM Diagnostics

The GEM MC consumer software shows both the single event track projections and the run cumulative ones. In GEM TPC mode it is possible to note the high degree of resolution in the Z direction (90 μm). This real time tracking offers many degrees of possible utilizations by the users.

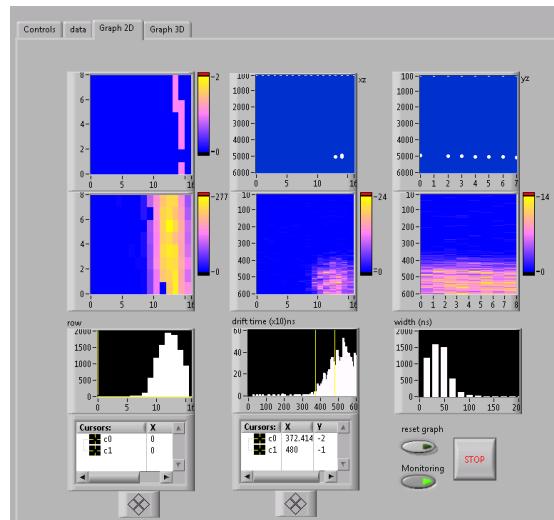


Figure 7: Typical layout of GEM MC consumer program. First row displays single particle track projection and the second row the run cumulative data.

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