

EVOLUTION OF DIAGNOSTICS AND SERVICES OF THE DAΦNE BEAM TEST FACILITY

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Abstract

The DAΦNE Beam Test Facility (BTF) is operational in Frascati since 2003. In the last years the beam diagnostics tools have been completely renewed and the services for users have been largely improved. We describe here the new transverse beam diagnostics based on new GEM TPC detectors and MEDIPIX, the new BTF network layout, the renewed DAQ system including the BCM detectors, the data caching system based on MEMCACHED and the integration of the new sub-systems in the new data-logging. All other services, such as the environmental monitoring system, vacuum system, payload remote handling, and gas distribution have been also improved.

THE 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 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) [2]. 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. 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 injection in DAΦNE accumulator when BTF operates in low intensity regime. A large fraction of the tests required electron or positron beam, with a 10% of allocation for the tagged-photon beam and a few shifts dedicated to neutron production.

BTF TOWARD USERS' NEEDS

Some Classes of Users

Such a kind of versatility is very interesting for a wide community of experimental HEP groups: at least one half of the users have used the facility for detector-testing purposes, covering almost all the possible detection techniques:

- Calorimeters: homogenous (NaI, CsI, PbWO, LYSO, YAP: Belle-II, CMS, KLOE-2, Linear collider, Mu2e, BGO-OD); sampling (KLOE, AMS, LUMI, Linear collider, NA62, MICE, etc.);
- Gas detectors: GEM/Micromegas (LHCb, ATLAS, UA9, Siddharta, KLOE-2), drift chamber/tubes (Super-B, MEG, TPS), RPC (Linear collider);
- Silicon detectors: micro-strip (AGILE, Insulab), pixel (ALICE, MIMOSA, Linear collider);
- Scintillating/Fluorescence detectors: MEG, neutron detection, fiber-trackers (MEG, BES-III, Plasmon-X), AIRFLY (Auger);
- Cerenkov detectors: RICH (LHCb, JLAB12), threshold (UA9)
- Nuclear emulsion: OPERA.

In addition, experiments looking at specific beam-induced effects were carried on:

- Beam diagnostics: fluorescence flag, WCM diagnostics calibration, emittance measurement
- Thermo-acoustic effect: RAP (gravitational wave detection)
- Beam-induced radiation: C-SPEED, AMY
- Crystal channelling and parametric radiation emission.

In the last 10 years of operation, the DAΦNE Beam-Test Facility has delivered an average of 220 beam-days/year. The facility usually allocates slots of 1 week, Monday to Monday, and operates 24/7. More complex experimental setups of course required much longer beam-periods (i.e. up to five months of total allocation for the AGILE satellite pay-load in 2005; the beam was not delivered 100% of this period, however). Occasionally, two teams were present together, profiting of the possibility of parasitizing each other.

DETECTOR, DIAGNOSTIC, SCIENTIFIC INSTRUMENTATION AND DAQ IMPROVEMENTS

BTF Computing and Control Service

A complete new design of the BTF networking service offered to the users has been deployed, in accordance to

the recent developing of the DAΦNE network service architecture. The number of network switch and wireless beacons has been improved and a dedicated VLAN has been prepared for the access of non-LNF/INFN users. The topological distribution of the Ethernet cables, plugs and access point in the BTF-LNF internal network was improved in order to be prepared in hosting long term local experiments: the overall number of cables/plugs is over 50 unities.

A BTF-dedicated DHCP server has been implemented: the BTF DHCP server is extremely efficient is extremely efficient, indeed the setup time: the nominal integration time of any users computing machine in the BTF private subnet is now just the time to plug the Ethernet cable. We are now able to offer 100Mbit/s DHCP network as well as 1Gbit/s point to point private links.

These hardware consolidation work was also fundamental for allowing us the migration of the overall diagnostic software in a virtual machine environment in order to strengthen the reliability of the software services needed by the facility itself and the ones given to the users for BTF beam run-time control.

The eight virtual machine subsystem (VMS, both Linux and Windows) is hosted by 8x2.80Ghz Intel Xeon E5 processors, 16GByte RAM DELL PowerEdge R320 with CentOS6 distribution in KVM based environment offering a very good redundancy in terms of users services and development environment. This was essential improvement, enabling us to perform software development during the users' run-time in a common well defined software infrastructure. The VMS is used as computational node both for the users and the BTF staff even if it is mostly used for BTF setup and diagnostics display during users run-time. The serial bus-controlled apparatus (i.e. BTF scrapers, remote translation and rotation devices, remote trolley table and others) have been migrated to a MOXA serial to Ethernet switches in order to standardize, via serial virtualization, the basic BTF slow control low level communications.

The MOXA apparatus are controlled via Ethernet drivers; USB devices, as MEDIPIX and HVGEM-CANBUS, are directly attached to the VMS via virtual USB probes.

These different sources of data need an abstraction layer like net-based shared memory for data collection: this system has been developed in conjunction with the DAΦNE DCS upgrades. It is based in MEMCACHED technology whose dead time is completely negligible in comparison with loop time of BTF subsystem asynchronous data chunk repetition rate. Both the producer and consumer software instances use this layer. The BTF-MEMCACHED subsystem has been under stress, without failures, for more than three years.

It has been reached the complete redundancy on BTF DAQ boards, VMIC control machine and crates. Recently, a twin BTF DAQ system has been controlled by !CHAOS DCS environment successfully.

The BTF pool services accounts the basic NIM, VME, HV crates/boards and power supplies unities, available to

be provided to the users. Moreover, user-friendly BTF PTU environmental sensors have been implemented, whose data is used by the users to gain a net calibration of their detectors in temperature, humidity and pressure in real time. This service is devoted to the fine tuning and calibration of the experimentalist community which operate with temperature and sensitive devices like gas detector and SiPM ones

For the DAQ topics we have resolved problems related to the data format, maintaining the DAQ modular flexibility and we have performed a good improving in timing issues. The BTF data acquisition is working as usual in a very straightforward way, collecting and displaying data to the users via the DAΦNE slow control environment. The data caching of BTF-DAQ has been doubled also on the BTF MEMCACHED server in order to permit a full collection of BTF data sources. Some improvement to the BTF-DAQ code and bug fixing allowed to stably running the system at the full LINAC repetition rate. The overall system stability is assured by the BTF internal network, capable of reaching a very stable configuration even if the weekly stress due to different users requirements.

Some recent upgrades in acquiring and integration of scientific instrumentation follow:

A CAEN® based high voltage distributing infrastructure capable to control six CAEN HV board for a total amount of 64 channels, remotely controlled: the SY2527 crate hosts positive and negative boards ranging from 0-4KV up to 0-15KV with, respectively, maximum delivered current of 3mA down to 1mA(CAEN A1833P, A1733N, A1526P).

A remote motorized linear stage, 5 Kg of payload, PI® VT-75 was implemented with a resolution 0.4 μm in a maximum range of 100 mm; this stage has been also integrated in the BTF data caching and virtual machine subsystem.

A remote motorized rotary stage system, 65 Kg of payload, PI® M-062.2S is equipped with heavy-duty stepper motor and was implemented with an accuracy of 20 μrad, mostly used by users to precisely control the angular positioning of detectors (e.g. Cherenkov effect or channelling precise measurements).

A remote trolley table [3] with a 200 kg of maximum payload, capable of 984 mm/380 mm X/Y range. In case of light payload (under few kilograms), we pushed up the single axis step resolution, lowering it down to 0.1 mm in same step direction of movement; in case of heavier payloads 0.5 mm step is possible. It has been performed on the both axes and a complete software bug correction has been implemented.

Both of the two linear and rotary stages, the BTF scrapers control, some vacuum probes, the remote trolley table, the environmental dose detectors and some other BTF diagnostic tools are controlled and collected in the MOXA serial-to-Ethernet BTF subsystem. This system is also used by the users, thus permitting the integration in the BTF private VLAN, removing the necessity of any standalone PC.

Large Covering of Users' Needs

The large variety of experimental needs requires a very flexible and quick setup of all the services [4], especially for foreign users, to be made available as quickly as possible, in order to use efficiently the allocated beam time:

Gas system: the gas lines in the BTF area have been upgraded and fully tested. Now four different gas lines are fully operational: low pressure hydrocarbons, high pressure hydrocarbons, two lines for CO₂/Ar/N/He and similar gases. The four second stages, located in BTF area, give controlled pressure up to 1.5bar. We have developed a dried compressed air pipes to manage actuator from BTF control room.

BTF beam conditioning/magnet system: The DHPTB101 pulsed magnet and the BTF scrapers were subject to a thorough maintenance due to aging of the electronics and power supply apparatus. The last scrapers software was perfectly integrated in a very stable configuration in the virtual machine BTF subsystem and the MEMCACHED environment. In the first part of the 2014 a new 1.5T C-shaped magnet has been installed in the N@BTF neutron beam exit in order to achieve a neutron to charged particles spatial separation. It is logistically manageable in the BTF experimental area to satisfy future experimental needs. The other little 0.8T H-shaped magnet is still available to users.

BTF Cooling system: The BTF cooling sub-system was linked with the LINAC one, thus allowing a continuous operation even in case of DAΦNE shut-down. This strategy was extremely important in assuring beam time in 2014, since the DAΦNE complex suffered a lot due to some emergency situations, mainly due to exceptionally bad weather conditions, in particular several long stoppages of the main water supply from the local aqueduct.

Vacuum system: The BTF vacuum line is operated at LINAC-TL vacuum, meanly down to $\sim 10^{-10}$ mbar, with the vacuum breaks at the level of 500 μ m-thick Be window and the overall BTF vacuum is provided via 60-120 L/s ion pumps. The choice to implement this design, although it is slightly difficult to interface with user's setup, is due to the necessity to work with the less internal multiple scattering and, in the meantime, to protect the LINAC TL in occurrence of PS mains failure: vacuum is still maintained closed. In order to reduce vacuum restoring time in a vent failure, a new fast and gate vacuum interlocking valve system has been implemented. The vacuum gauge measuring system, the fast and the gating valves now are under the DAΦNE vacuum supervisor program to manage and restore from protection the BTF vacuum lines.

The users experimental vacuum joining was designed and implemented at the end pipe level with internal gating valves equipped with pre-vacuum service for different line extensions. Both of the section ends are equipped with a KF flange for pre-vacuum operations, an independent pressure gauge, an ionic pump, a flag (YAG

and BeO₂) with their remote controlled pneumatic movement. A new passive protection system for the Beryllium vacuum exit window of the bent line has been designed in order to house the wall current monitor (WCM) detector as well as protecting the ceramic pipe and window with a removable polycarbonate window spacer; we also built some Mylar-based windows to match pre-vacuum needs down to 10⁻⁶ mbar.

BTF General Services and Safety

Air ducts and conditioning: The conditioning system has been improved to reach thermal stability for a maximum 0.3 Celsius range during summer period, reducing the systematic error on user thermal-sensitive device under test.

Logistics: In order to setup the radio-protection upgrades, a huge work on the BTF services layout, walls and infrastructures has been performed. We operate with 20ton crane and the BTF area is widely covered in its operational range. The main entrance is a modular chicane built by removable concrete blocks that are completely movable to permit the entrance of wide area experimental apparatus.

Radioprotection: A new passive shielding design for improving the neutron attenuation in the surrounding area in some high intensity experiments has been designed and will be implemented in the next months. The acquiring of new dosimeter and environmental instrumentation helped in a better adapting to the users' needs, while respecting the operational limit foreseen by the radio-protection rules of the laboratory.

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