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THE FRASCATI BEAM TEST FACILITY NEW LINE: FROM DESIGN TO BEAM COMMISSIONING.

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INTRODUCTION

The request of beam time for long-time experiments and contemporary the need to provide beam time to the detector developers community, drive the INFN to invest in the commissioning of a new beam line test facility. In this work we describe the necessary steps followed from the design to the commissioning of the new beam line in the Frascati Beam Test Facility.

From 2005 the Beam-Test Facility (BTF) of the DAΦINE accelerator complex in the Frascati laboratory of the Italian National Institute of Nuclear Physics (INFN) has gained an important role in the European infrastructures devoted to the development and testing of particle detectors [1–3].

The presented proposal in 2016 aimed at improving the performance of the facility extending the range of application for the LINAC beam extracted to the BTF lines, in the directions of hosting fundamental physics long term experiments [4] and providing electron irradiation also for industrial users. The original BTF line is in operation since 2002 [5, 6], and from 2004 operates in opportunistic mode [7] during the running of the Frascati electron-positron collider.

In the next paragraphs the steps from the Conceptual Design Report (CDR) presented in 2016 [8] to the commissioning of the new line are described. The issues necessary [9,10] to be discussed for the reconstruction of the first line of the BTF (BTF1) for a long-term experiment and the processing difficulties of the commissioning of the second line of BTF (BTF2) are described.

Figure 1: The BTF layout until 2017.

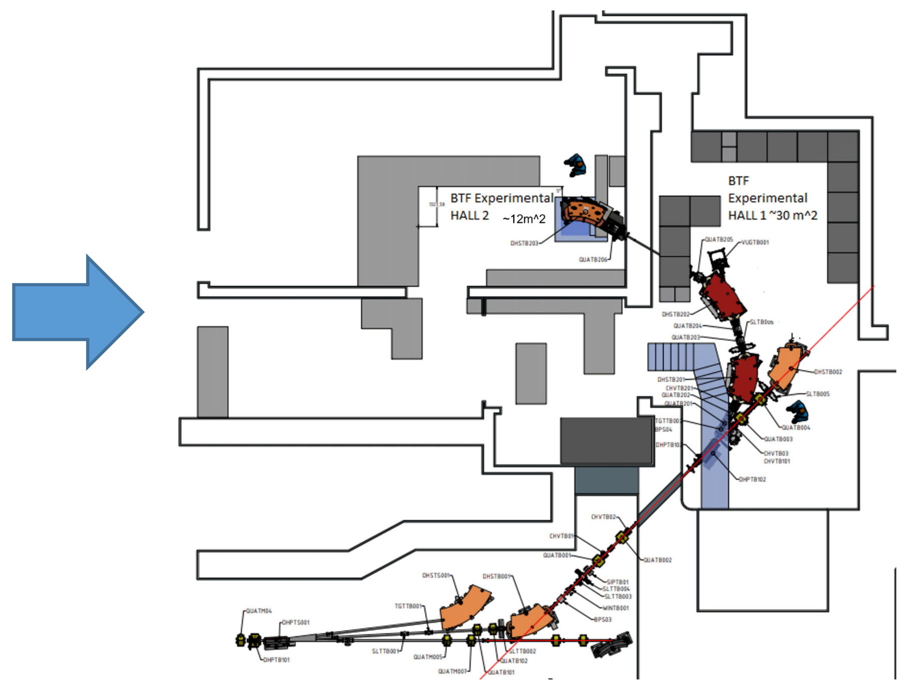

Figure 2: The BTF2 new layout.

THE NECESSARY STEPS FROM THE DESIGN TO THE COMMISSIONING

The budget. From the CDR and after review of the INFN Machine Advisory Committee the budget for all the project was available from March 2018.

The law authorizations. All the requested legislation steps for start a new activity in the building 54 of the laboratory was submitted to the relative authorities and government agencies to obtain the permission.

The civil engineering activities. The building 54 of the laboratory was modified for adding the new radioprotection shielding for the BTF2, a new entrance was realized, and the building was modified to receive all the auxiliary systems as the new electric distribution and the required cooling system distribution for the magnets elements with their interlocks and for the experimental area. A new room on the roof of the BTF2 for the power supplies was prepared considering all the necessary auxiliary systems (network, cooling, controls). The new control room of BTF, far away 60 m from the experimental hall, was prepared in 2018 with all the auxiliary systems to accommodate the users.

The design and commissioning of the magnetic elements. During the design phase was evident that the main constrain for the installation of the new BTF line was the space limitation. The Magnetic Service of the Accelerator Division has collected the requirement for a 20 T/m magnetic fields for the six quadrupoles and the requirements for the different dipoles, the fast pulse dipoles, the 2 H-type bending dipoles and the last 35 degree C-type bending dipoles. All the magnets delivered are characterized with their power supplies by the Magnet Service in the new measurement magnet area. More details on the magnetic elements are in [11].

The design and commissioning of the vacuum elements. The vacuum system has been designed by the Vacuum Service of the Accelerator division in order to allow the installation of elements in the transfer line without exposing the LINAC vacuum to risks. It is composed by fast valves, vacuum measurement systems, pumping devices, collimators for beam manipulation, beam stopper for safety procedure, thin Mylar windows for vacuum LINAC separation and thin Titanium (25 um) and Aluminum windows at the end of the lines as shown in Fig. 3..

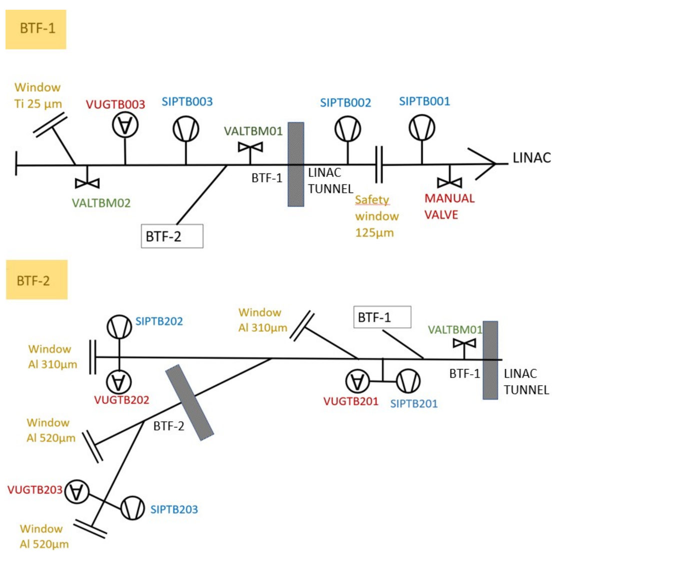

Figure 3: The BTF Vacuum system layout.

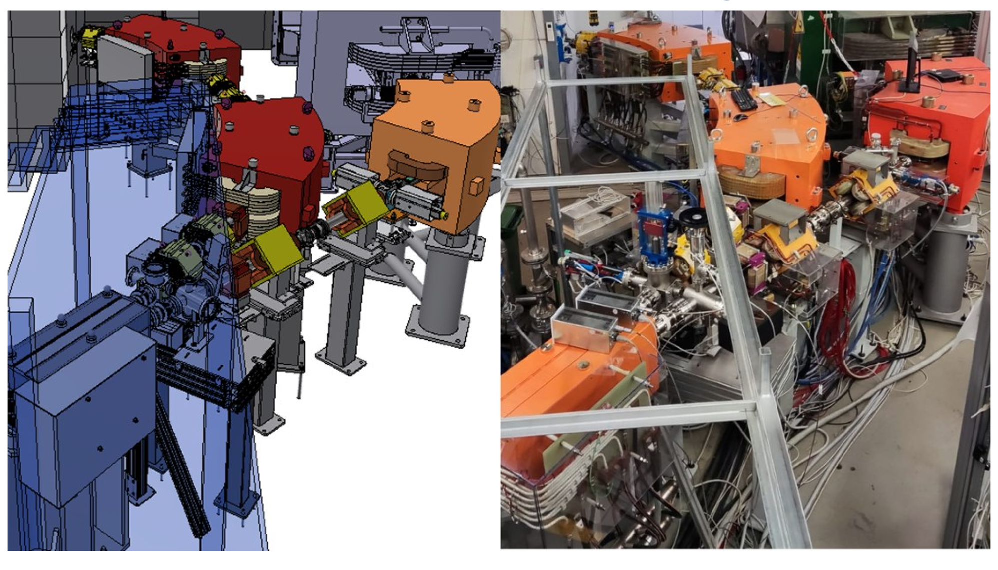

Figure 4: On the left the 3D design and on the right the commissioned BTF line.

The design and commissioning of the mechanics elements. Most of the magnets and auxiliary mechanics system drawings are produced by the Mechanical Service of the Accelerator Division. They produce different 3D mapping of the BTF areas to reduce the installation time and the risk of the interference during the installation of all the elements as shown in in Fig. 4. Thanks to this method a detailed schedule of the activities has provided the tools to optimize the resources.

The radio protection system. The radioprotection Service has followed all the procedure for the authorizations and provides the guidelines for the search procedure of the BTF2 area. The installation of the safety system for the BTF2 is shown in Fig 5. Thanks to their support the beam commissioning of the new line is ongoing. The actual radioprotection limit for BTF2 is 10^6 particle/s with an energy of 730 MeV.

The control system. As shown in Fig 6, all the new magnetic elements power supplies controls are implemented into the DAΦINE Control System (DCS) [12] thanks to the support of the Control Service of the Accelerator Division, and a BTF2 Data Acquisition System based on SIS3153 Ethernet-VMEbus interface was developed, installed and tested as shown in Fig. 6 during the test phase, where the SCALER, QDCs, PIO, TDCs and the Timing Unit are visible on the left.

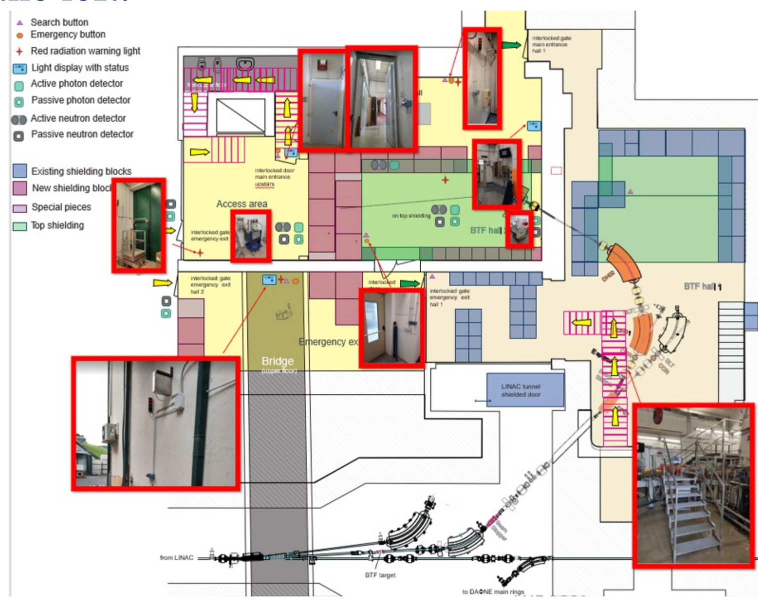

Figure 5: The layout of the BTF2 safety system.

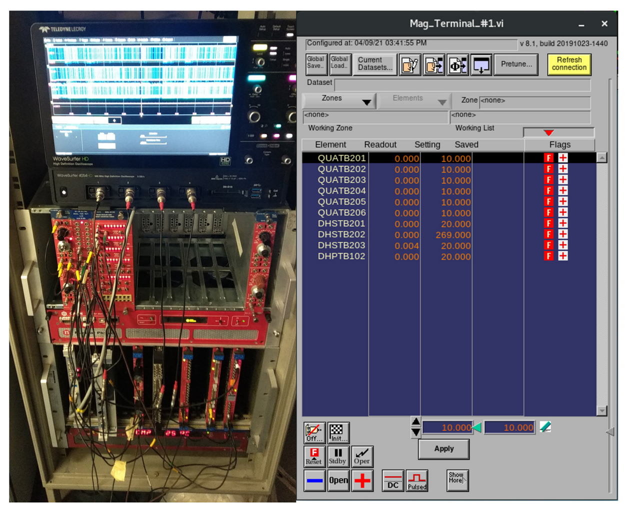

Figure 6: On the left the new BTF2 DAQ system under test, on the right the controls of the new magnets implemented in DCS.

THE FIRST BEAM COMMISSIONING IN BTF2

Driven by simulations and thanks to the possibility to check the beam at the straight exit of each dipole in the new transfer line, the first beam was transported at the exit of the new line in few working hours. The diagnostic used for this test is a silicon pixel detector for details see [14–18] and a lead glass calorimeter as shown in Fig 7.

After few days we obtain the best focused beam at the exit of the BTF2 for a 450 MeV electron beam bunch with single particle for bunch is shown in Fig 8.

The measurements of the beam spot with silicon pixel detector are shown for an energy range from 450 MeV to 35 MeV in Fig. 9 for BTF1 and Fig. 10 for BTF2.

For the BTF2 a pre-tune of the magnet provide the possibility to check the beam quality for different energies of electron, as shown in Fig. 11.

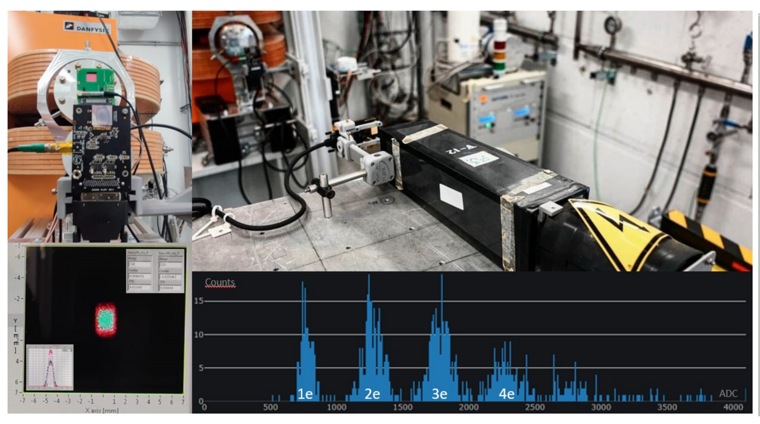

Figure 7: On the left high the pixel detectors low the cumulative distribution, on the right the lead glass calorimeter and low the particle count identification by the ADC counts (thanks to !CHAOS [13] integration of BTF DAQ).

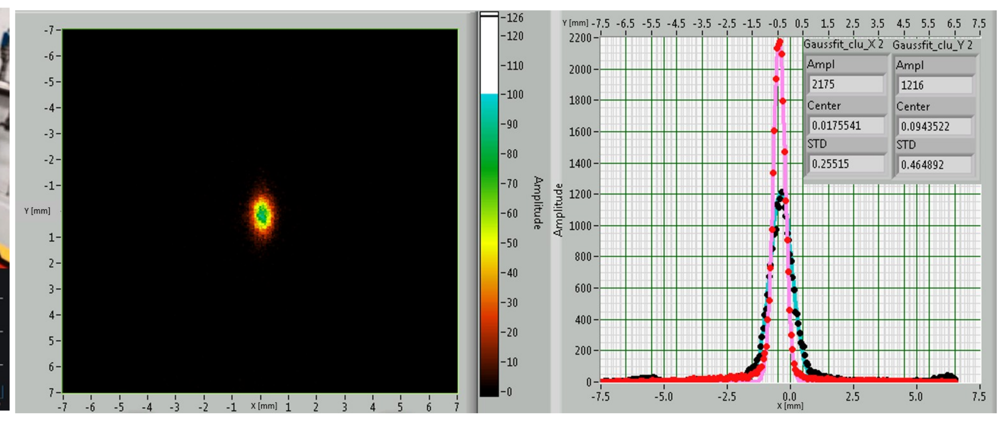

Figure 8: : On the left the beam spot accumulated for about 2000 bunches with single particle detected by silicon pixel detector, on the right the Gaussian fit of the cumulative distribution (σ_X = 0.25 mm, σ_Y = 0.46 mm).

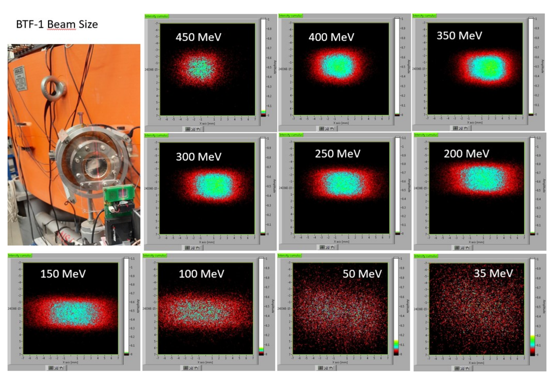

Figure 9: The BTF1 exit windows and the measured beam spot at different energies.

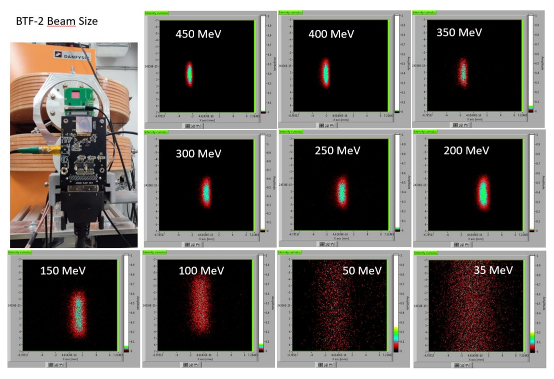

Figure 10: The BTF2 exit windows and the measured beam spot at different energies.

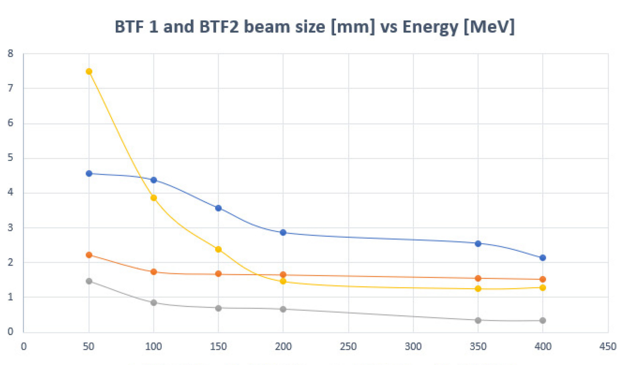

Figure 11: The plot of the measured BTF2 and BTF1 beam spot size vs Energy.

The commissioning of the BTF2 line will continue in the next months to scan all the possibility and to provides to the users the parameters of the facility. The call for the users is scheduled to be published at the begin of 2022.

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