LINAC-BTF ACTIVITY REPORT 2021

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1 Experimental activities, beam time and outreach

The pandemic emergency had minimal impact on the scheduled activities since we were up for all the year long. The LINAC-BTF group, during 2021, was mainly involved in this chapters:

- BTF detector and services upgrade
- BTF 2021 users run
- E-rad project and related LINAC activities (2021 run)
- Dismantling part of BTF1 line, BTFEH preparing for BTF2 installation
- BTF2 installation and commissioning
- SIDDHARTA run and related LINAC activities
- Maintenance and consolidation of the LINAC

Focusing on LINAC activities:

- Mod A klystron replacement;
- Online diagnostics;
- LINAC vs Singularity preparation;
- Maintenance and upgrade, especially Mod. A&C HVPS;
- TEX/SABINA/SPARC related activities.

As shown in Fig.1 we used most of the beam on days for user, irradiation and PADME testbeam in 2021. A significant part of the working days were oriented toward the BTF2 installation, technical commissioning and beam commissioning. Another strong activities was the offline maintenance, test and upgrade of BTF subsystems.

2 BTF detector and services upgrade

Since a new experimental hall (BTFEH2) was planned to get operative in 2022, during the late 2020 and the initial part of 2021 were developed many upgrades of BTF services and software thus doubling the fundamental parts, thus providing almost the same quality level and services in both of the experimental halls.

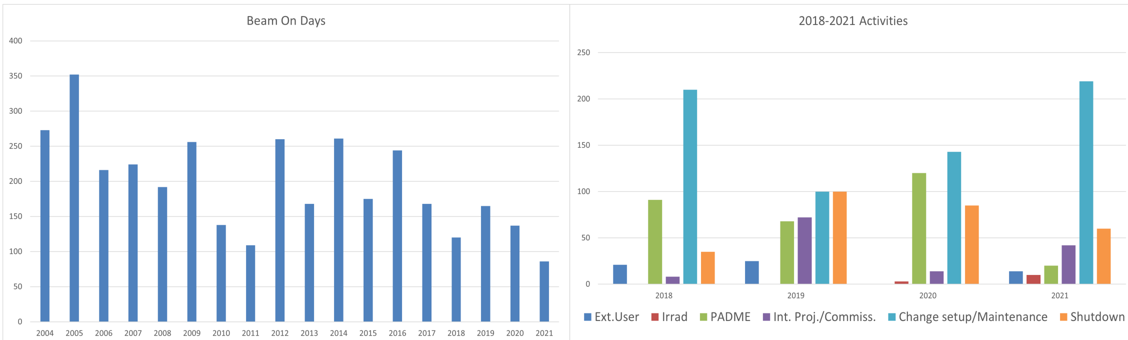

Figure 1: On the top, the 2018-2021 the number of beam on day during years. On the bottom: graph showing different kind of activities in the last 4 years.

2.1 Remote controlled trolley tables

Utilizing the SHIP collaboration beam time, we developed a new remotely controlled trolley table in the BTFEH1 in order to have a movable surface since the old table did not fit due to PADME's floor occupancy This new trolley table in BTFEH1 is a DMX-ETH integrated stepper controller + driver + motor product in a Bosch profile frame with a placing precision of 20µm per step (100µm accuracy overall), where was implemented from scratch a new communication and control protocol established over TCPIP/ETH using software newly developed in LabView, successfully tested in the all the year beam times. The old remote-controlled trolley table was remodeled to fit in the new BTFEH2 hall thanks to the collaboration of LINAC and Research Division technicians (R. Ceccarelli and R. Tesauro), to overcome again less space for placing DUT, and has been used intensively in the commissioning runs.

2.2 DAQ and detector upgrade and trials

During Commissioning and user-run preparation, a part of the time was devoted to doubling the DAQ and the subsystems for getting prepared for the second hall-related services installation. The time at our disposable was so strict for different reasons (i.e. hall and beam availability) however, in synergic operations, we also tested a new configuration of a high-intensity detector and a tracking one. These developments continue in the trajectory to remove fixed installation changing them in ethernet communication-based standard, to permit an easier (from the installation point of view), modular and interchangeable way of thinking of BTF subsystems.

2.2.1 !CHAOS trials for DAQ and triggered camera

Since in the second, new experimental hall (BTFEH2) we want to offer almost all the standard services (see related chapter) we took the opportunity to make some trials for a future upgrade. In the past, we tested a new VME arbiter based on ETH communication, the STRUC Innovative Systeme SIS3153. This hardware, with low latency ETH 1Gbit comms, holds a programmable FPGA for automated W/R routines; it was integrated as a driver by A. Michelotti on !CHAOS environment. Thanks to these fully wrapped SIS3153 APIs in a C++-written ControlUnit (CU), which is the main process that polls and interrupts the SIS3153, we were able to get triggered events up to 100Hz with synchronous data download in BTF standard configuration (SCALER+QDCs+PIO+TDCs+TU) in !CHAOS data structure. The single data package is a few kB per shot with actual data push jitter around 3 ± 0.5ms on CU virtual machine host in

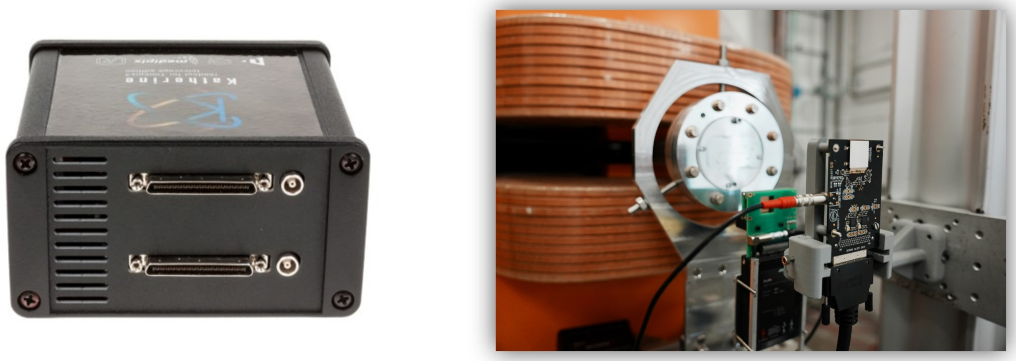

Figure 2: On the left, the dual Katherine. On the right an assemply at BTF2 exit window, with FitPIX Kit (upstream) and TPX3 sensor mounted on the SPCM holder, on 2.5m cable connection toward dual Katherine channel.

non-local subnet. The data displaying is embedded in the GRAFANA environment with both live and historical DB, just been tested from !CHAOS collaboration.

Regarding another application developed in !CHAOS environment is our triggered camera, BASLER based, whose aim is to get triggered image from a fluorescence flag in high-intensity regime of our facility. This development is customization of SPARC one for almost the same finality where we pushed up camera background pedestal removal and operating stability. For each shot is been performed a Gaussian fitting whose parameter we are trying to correlate with beam intensity and spatial parameters (centroid position and transverse dimension). The trial run was operated during ERAD beam time and the SPARC-ULENS trial run. The integration has to be continued due to some big uncertainty in detecting some of these parameters.

2.2.2 BTF silicon detectors: Dual Katherine tests

In the area of UA9-LNF collaboration with CERN, we gain the opportunity to get some new frontend electronics able to be interfaced with CERN standard TPX3 pixellated silicon detector. This Ethernet Embedded Readout Interface is called "Katherine" and its related software comes from a collaborative development with CERN, IEAP Institute (Prague, Czech Republic), and the University of West Bohemia (Pilsen, Czech Republic). Easy included in BTF virtual machine environment with a native software and API's, we are trying to debug a BTF solution for compact and portable tracker replacing our actual one, composed of Advacam FITPIX KIT, mostly used from user to get double passage information (i.e. from the front to the back of DUT). We tested a new version of Katherine, a dual mini tracker, hosting two synced frontends for 2x TPX3 sensors (installed 300um and 600um thickness) in a 450MeV, single-particle regime. Thus we got to explore the goodness of the two module synchronization both in time and cluster detection efficiency. Another key point of Katherine is the possibility to connect TPX3 hybrid via TPX3 connection tested with 2.5m + ETH. The best synchronization error (with rejection) between k8 and is around $\pm$10ns independence of the used clusterization model.

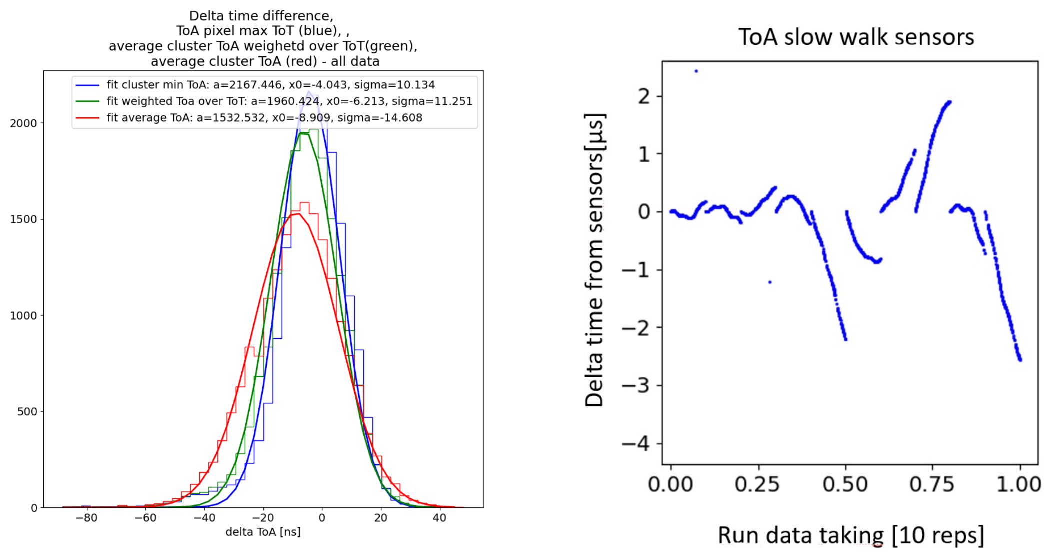

Figure 3: On the left, the dual Katherine. On the right an assemply at BTF2 exit window, with FitPIX Kit (upstream) and TPX3 sensor mounted on the SPCM holder, on 2.5m cable connection toward dual Katherine channel.

2.3 Software for user management and related call

This development has been raised after the searching of best user access-related solutions in experimental areas and some discussion with Elettra, SLAC, and some other user facilities that experience high flux and short time-based user beam time. This particular activity commonly involves a high load of exchanged emails and signed documents, in different channels/media to get a fail-proof experience from the user side. These aspects usually overload the divisions' secretary office for getting users in an experimental area with all the required (and verified) permissions. So our idea is to move the redundant, human-based actions toward a web-based frontend interface and a backend automated workflow control and database. This choice permits to log all the exchanged documents, automates some basic administrative actions and simplifies in some way the user experience by putting the status and the errors that could occur during the access procedures clearly on a web page. Hence, this "software" way is expected to lower administrative load, focusing only on supervising exceptions and taking verification procedures (i.e. implementing automated mail dispatching, permission tracking, automated, personalized timed data input alarms sending...). This software is intended to manage the access path from user call application to team building and related authorization, finally to the territorial access. The chosen programming method is abstraction-based thus leading the software to include the managing of different types of booking with different application rules, such as lab and guesthouse. To gain full automation, the link to the INFN main registration DB has been established in custom internal language, the workflow is developed under CAMUNDA(Java) engine, the User Interface (UI) is composed using Angular, whose backend is Java Spring Boot. The UI hosts the user call questionnaires and information, written and saved respectively in JSON and base64 code, useful for future facilities customization hence the same possibility is leaving also to work-flow upgrade. This work is actually driven by C. Bisegni and M. Tota, belonging to IT group of the lab, where the UI is made by external IT company.

3 BTF 2021 user run

The pandemic restrictions for transfers had led to a more internal user beam time despite a less external one. The improved rules for experimental hall and BTF/DAFNE control room occupancy, arranged with RSPP and Director, have gained an optimal level of efficacy in preventing any infection cluster, even if few cases were detected in the people involved.

3.1 ERAD: RUN-I and RUN-II

The principal experiment that took place was ERAD with almost one month of beam time allocation with the partnership of IMT lab and ASI in the LAerospaZIO (Lazio) regional funding program. It was taken in account two runs including LINAC warmup, beam preparation, BTF/user setup installation with a remote connection, and the possible contingency for the pandemic at the highest peak in the last winter. The first one took place in July'21 with an electrons beam delivered on IMT DUT (mostly optoisolator and memories) with an irradiation profile as a short delivered dose and fast functional DUT test: an optimal sampling to detect variation on both main operative parameter and related tolerance goodness (load curve, noise, junction currents...) relatively to an overall DUT behavior (SEE or cumulative effects). In the July run, we push on ERAD team to have a totally remote configuration/operation of their setup, putting it in the BTF software environment with very good stability: no faults or down of service were detected in the internal BTF VLAN, along with the full data taking. Moreover, during this run, we prepared some of the features referred to 2.2.1. Having set with FISMEL the optimal dose profile, the users explored all the DUTs and finally had a fully referenced profile dose with the effects under study. A second run, with the purposes of testing both BTF irradiation's repeatability (with the same type of DUTs) and different package type exploring, has been concluded in January 2022 conserving the irradiation profile features and total/partial dose. Since we were exactly in the middle of the COVID-19 pandemic peak, we explore with success the possibility to give full remote access to the working site of the user involved. As a general way of attitude, also BTF setups and apparatus are totally remotely controlled as their status data, all fetched and displayed in BTF slow control applications: linking the BTF data display with the previously described user setup, IMT people has been able to follow the run from their office. Following a low proximity activity, all the user's apparatus setup and dismount, the DUT changing and all the related irradiation procedures, were totally in charge of BTF staff in accordance with user's practices and manuals. The data analysis is actually ongoing.

3.2 Other user runs

In the earlier 2021, after the PADME RUNII ending, we started to prepare the SHIP[9] experiment with some needed upgrades of the facility 2.1. The SHIP beam time was intended also for a future experimental search as SHADOWS[11], a proposed beam dump experiment to be installed off-axis in the ECN3 experimental hall of the CERN North Area complex. The SHIP beam time was a standard single particles test where four $(150 \times 150 \times 10)$ mm^3 scintillating tiles, each read out by four SiPMs Hamamatsu S14160-6050HS with (6×6) mm^2 active area, had been investigated in terms of light yield, time resolution, and efficiency. Even though the four tiles were prepared with different construction techniques, they showed similar performance in terms of time resolution. The SHIP group referred that this technology is therefore proven to be suitable for large area scintillating detectors when time resolution of 200-300 ps and very high efficiency are required.

The users' runs had been stopped since we started BTF2 installation 4, which ended in June 2021. Accordingly to the foreseen time schedule for the new BTF1 commissioning, we got enough beam time before the BTF2 commissioning phase 1, using a week for the KLEVER trial

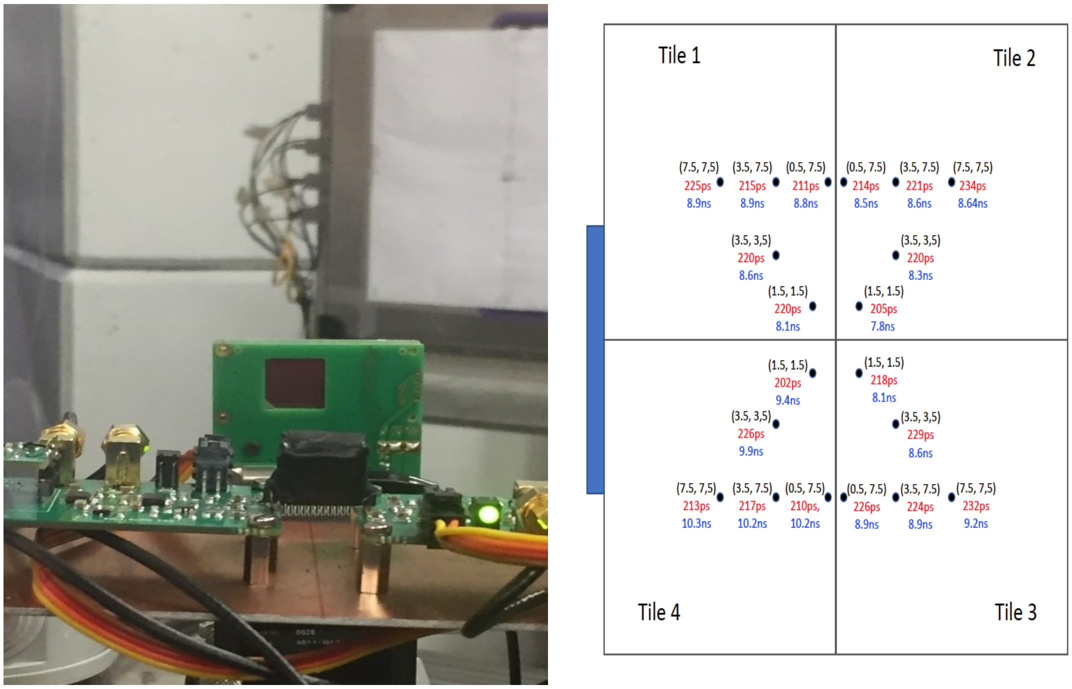

Figure 4: On the left: test beam setup with the four tiles hosted in the box (backmost detector), BTF timepix device and the small scintillating cube used as trigger and time reference (foremost detector). On the right: the hit points acquired during the test beam within 100µm

run (delayed since 2019). The next slot was for ERAD RUN-I 3.1 successfully ended just before the summer shutdown, after a short period of test and maintenance of BTFEH detectors. Due to an LNF stop until November for TEX installation and LINAC/BTFEH1/BTFEH2 safety checks, we restarted user operation after BTF2 commissioning phase 2. Two weeks were booked from PADME collaboration for single-particle beamline test on the SAC calorimeter and vacuum line test on PADME chamber, actually again detached from BTF vacuum due to detectors operations on the PADME vacuum cross, left axis, asked from the group. During these two weeks we, unfortunately, found a leak on the PADME vacuum cross connector flange, right axis, and a leak on 250µm Ti exit windows.

After the PADME SAC test conclusion then we switch to providing a line ending modification for embedding the SPARC-ULENS setup in the BTF1 line. This run has been taken into account due to a synergistic emittance measurement system both for SPARC and BTF. The installation requirements were to put on line a movable Aluminium OTR flag and the related in-air optics, that will collect the OTR radiation in the visible spectrum. The proposal aims to measure in single-shot the beam emittance via a pepper-pot-like method using a microlens array of the beam OTR radiation produced thru the OTR radiator. The synchronous image reconstruction extracts the phase space parameters instead of the direct beam measurement of thick collimator-scraped beamlets in the standard pepper-pot method. The BTF microlensing measure setup in a vacuum is composed of a movable Aluminium thin mirror (≈300µm) mounted on a motorized axis in a vacuum cross with a Quartz exit window, an ionic-pump and a 50µm Ti exit window, the end of BTF1 line. Such a kind of installation had to be pursued to get the Al mirror free to be put off-axis, thus maintaining the line multiple scattering as minimum as possible and letting the beamline compatibility with any other further experiment (i.e. ERAD); the setup didn't change vacuum limit that was stable around 1×10^{-9} mbar, good enough for such a kind of measure. The Al-mirror axis is perpendicular to the Quartz window: the OTR radiation is then caught by an optical mirror in the air that reflects the OTR light along a quasi-parallel line to a very compact optical table, where different optical lines are selected by a remotely movable mirror. Both at the end of these lines, two Ethernet triggered cameras (BASLER scA1300-32gm) are placed whose optics setup are optimized to measure respectively OTR transverse dimension and divergence. The alignment of all the mirrors and camera is performed via the centering of different checkpoints using beamline elements focused at the center of the AL-mirror itself, in order to get fixed beam passing-thru points, from 2 to 6 meters away from the cameras, thus achieving prealignment error less than 1mrad. All the mirrors rotations/offset, camera setup, and operations are fully ethernet-based which improves a lot the beam time efficiency. The setup was not so easy to be implemented since the elements density of the line but in the last part of December 2021 some beam hours were devoted to getting the proof of the correctness and the run has to be continued in 2022 with the final microlens installation.

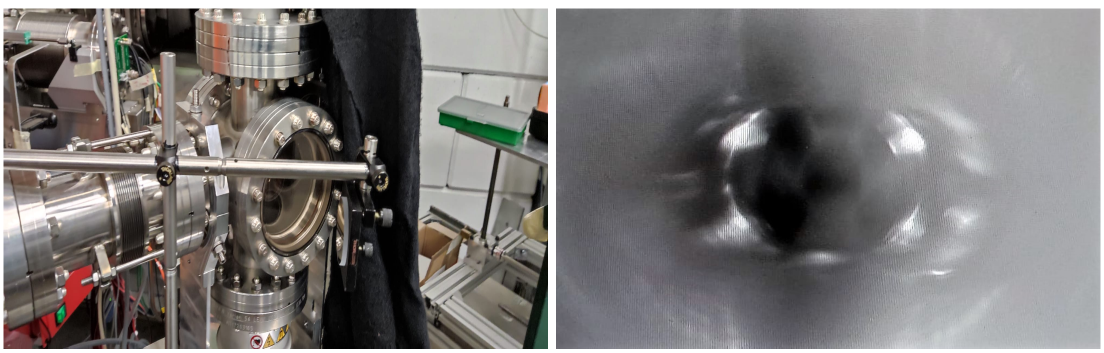

Figure 5: On the left: final part of the SPARC-ULENS line with the external mirros. On the right: the collimation image of BTF VALTB002 got from camera on the same mirror.

The first part of 2022 was devoted to ERAD RUN2 (sect. 3.1) and we filled the remaining free beam time for PEROV experimental run and other tests we some first-use detectors useful for BTF internal development. The PEROV experiment will pursue the investigation of Organo Metal-Halide Perovskites, a class of hybrid organic-inorganic semiconductor materials with a perovskite unit-cell structure CH3NH3, metallic cation (Pb2+), and different halide anions (Cl-, Br-,I-). In the provided beam time, the group with BTF team technical and scientific support explored different perovskite setups as a light converter (behind LYSO adsorber) and as well as main bulk adsorber (and signal converter). In both the trials the group found good linearity response with different bias configuration, data analysis ongoing [12].

The LNF programs wanted user activities to stop due to improving the BTFEH2 rooftop shieldings thickness and LINAC KLYA replacement, so BTF beam time ends on the 14th of February 2022.

4 BTF2 upgrade

The project entailed a new design on the final part of the previous beamline by splitting the existing Frascati beam-test facility line (BTF) into two branches (so-called BTF1 and BTF2), allowing to run two different beam-lines for different purposes and for serving two different experimental areas

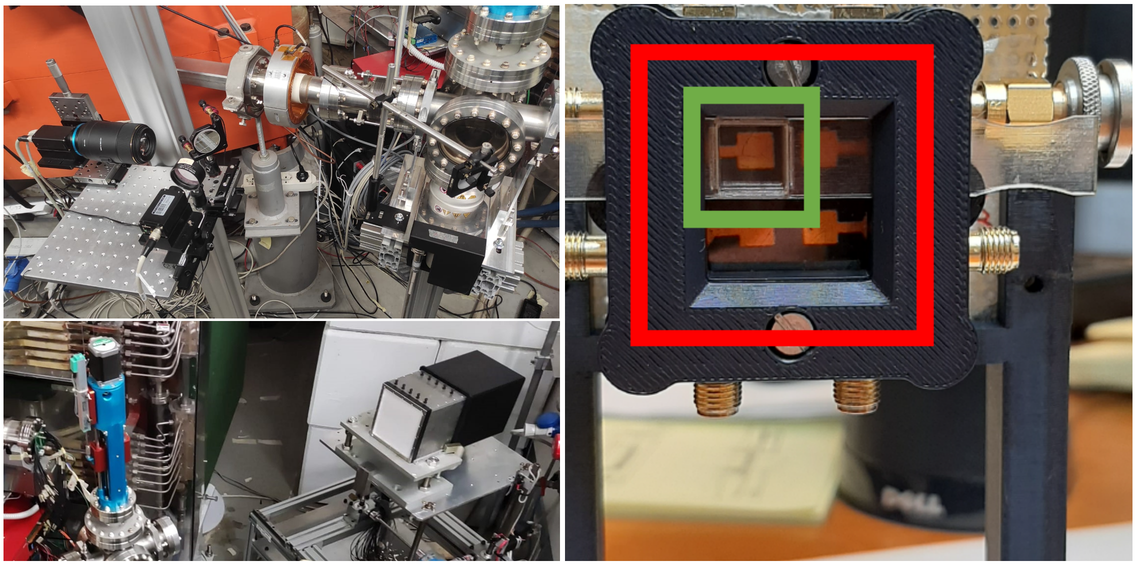

Figure 6: On top left: SPARC-ULENS compact optics line. On bottom left: PADME SAC test beam setup. On the right: a close up photo of MAPbBr3 film (multiple pads 4x4 mm^2)

(further called BTFEH1, the existing area, and BTFEH2, the newer one). These aims led the creation of a new experimental hall, the related shielding, a new control room, a new power supply hall, and the improving principal LNF-LINAC features, extending LINAC lifetime.

The splitting is realized by sharing the beam from the LINAC employing a pulsed 15° dipole (<100 ms ramp, DHPTB102) and a two-way vacuum pipe, on two new beamlines, with a second set of beam diagnostics for the monitoring of the beam intensity, of the spot size and position. The design of the two beamlines, the project of all-new elements, the improvement of the vacuum, power, cooling, and conditioning systems, as well as the modifications to the building has been completed in-house by the Frascati staff. In 2020, to permit PADME to run II in accordance with this project requirements, the BTF1 line was prepared for the 2021 upgrade with a drift in the area of DHPTB102 placing position. At the end of the PADME and user-run, starting from February 2021 the BTF2 line started to be mounted without any further intervention on the BTF1 line and PADME installation.

In the new configuration, the beam-line is split into two branches immediately after entering the BTFEH1, in order to share the available beam pulses between two different experimental setups; the final part of the existing beam-line is also slightly modified:

- The BTF-1 is dedicated to short, medium, and long-term (more than a few weeks, up to several months) experimental installations or high-intensity applications requiring the extraction of the LINAC primary beam. It almost replicates the previous beamline, downstream of the splitting magnet fast-ramp pulsed dipole DHPTB102, the first magnet at the head of the two lines. Today BTF-1 is essentially devoted to the PADME experiment, a fixed target experiment for Dark Photon and dark matter-related research.

- The BTF-2 is intended instead for short-term (from one to a few weeks) beam tests, mainly at medium and low secondary beam intensity. It also stems from the DHPTB102.

The final design of the new beamlines has been carefully optimized to get the required beam parameters on both branches, in particular, around millimetric beam spot size and less than 1 mrad beam divergence at 500MeV. The main characteristics of the new beam lines are fully described in [3]. The upgrade activities in 2020 were continued following pandemic restrictions, getting all the needed items at the end of June, and preparing halls and services to be ready for the BTF2 installation, immediately started at the end of the PADME run after an experimental run with a 2019 delayed user.

5 The necessary steps from the design to the commissioning

The BTF2 commissioning has been realized involving all the LNF services in different areas: the design of the two beamlines, the project of all-new elements, the improvement of the vacuum, power, cooling, and conditioning systems, as well as the modifications to the building, has been completed in-house by the Frascati Technical and Accelerator Division staff. The BTF2 deployment was prepared in the previous years with the acceptance tests of the involved elements and the development of the related software, hardware, and civil infrastructure. Most of the building layout redesign and bunker shielding preparation have been executed by the Civil Engineer service. This led to a DANE cabling re-routing since a significant part of it passed thru the involved areas: these threatening tasks were ready in time to accept the BTF2 installation and technical commissioning, which started in February 2021 and ended in next July. This work has been executed by the Electronics and Diagnostics Service, the deployment of the power and interlock cables by the Electric Service. In 2020, to permit PADME RUN-II following the upgrade project requirements, the BTF1 line was prepared for the 2021 installation with a drift in the area of DHPTB102 placing position. At the end of the PADME and user-run, the BTF2 line started to be mounted without any further intervention on the BTF1 line and PADME environment.

5.0.1 The budget.

The financial aspect of the project was shown as a conceptual design report in 2016: the INFN Machine Advisory Committee approved the budget for the project, available from March 2018 with a partial founding from AIDA-2020 Grant Agreement 654168. The related financial issues were managed by INFN and LNF Administrative Departments.

5.0.2 The law authorizations.

All the requested legislation steps for starting a new activity in building 54 of the laboratory were submitted to the relative authorities and government agencies to obtain the permission. The agencies that request clarification on the environmental aspect of the activity receive the answers in the requested time thanks to the effort coordinated effort of the Safety Division, Technical Division, Radio-Protection Division, Administrative Division, and Accelerator Division of the Laboratory.

5.0.3 The civil engineering activities.

After a first step where the general requirements from the Technical Division were collected related to the building, cooling systems, power supplies, electrical and interlock systems, a continued feedback loop with the designer of the Accelerator Division was necessary, to produce the right actions to mitigate the risks that could present this upgrade project in a 50-year-old building with a lack of documentation of the status of the building and auxiliary system.

Building 54 of the laboratory was modified for adding the new radio-protection 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 halls, was prepared in 2018 with all the auxiliary systems to accommodate the users.

5.0.4 The design and commissioning of the magnetic elements.

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 dipole. The Magnetic Service has provided the Magnetic design to the Mechanical Engineering Service of the Accelerator Division that has produced the mechanical design for the bids. All the magnets delivered are characterized with their power supplies by the Magnet Service in the new measurement magnet area. The magnets performances were reached within the project field tolerances both from the integrated field and multipole amplitude point of view. The magnets project and their commissioning measures were performed by the Electrotechnics Engineer Service with the related power supply commissioning: all the plants reach the 200ppm max admitted ripple and in most cases were under half of it. More details on the magnetic elements are in [8]. During the same test duration, the LNF Control System Service verified respectively the stability of the magnet controls whose drivers, fully nested in the main DANE slow control system, were developed during the power supply construction in a strong link of development with the industry. We also successfully checked the splitting magnet, DHPTB102, a special dipole whose ramp-up to 330 A is reached stable in less than 100 ms.

5.0.5 The design and commissioning of the vacuum elements.

The Vacuum Service was in charge of some BTF vacuum items design, production and line operation: motorized vacuum elements (scrapers, beam stopper, and target), vacuum pumps, gauges, and beam exit windows have been part of the work. The new tentative design of scrapers and especially for titanium-foil vacuum windows (thickness down to 25μm) was a good choice: all the pumps put both the lines stable down to 1×10^{-9} mbar. The worst vacuum leak is less than $6.2 \times 10^{-10}\,\mathrm{mbar\,L\,s^{-1}}$.

Vacuum Windows set:

- SAFETY (BTF common - internal) = My (press foil) – 125μm
- DHSTB002 Straight line = Ti (brazed foil) – 25μm
- DHSTB201(202) Straight line = Al (machined from solid) – 310μm
- DHSTB203 Bend(Straight) line = Al (machined from solid) – 520um

In order to be able to run PADME, whose vacuum is dynamically reached by a turbomolecular pump and (in principle) not compatible with the BTF sealed ionic one, we had to take care of this last vacuum arrangement. Furthermore, to strengthen the protection in case of an unexpected vacuum vent, we put a static and fast-reaction valve (less than 14ms) safety system that will interlock and stop a possible pressure increase in BTF lines. This vacuum structure revealed itself robust in combining the two different vacuums with a slightly degraded vacuum limit in the last BTF1 section, verified finally in a 2021 PADME test run. All the vacuum subsystems and gauges sensor readout are implemented in LabVIEW®, on BTF Slow control where interlocks and valve readout are managed by DAFNE supervisor (within 1 month)

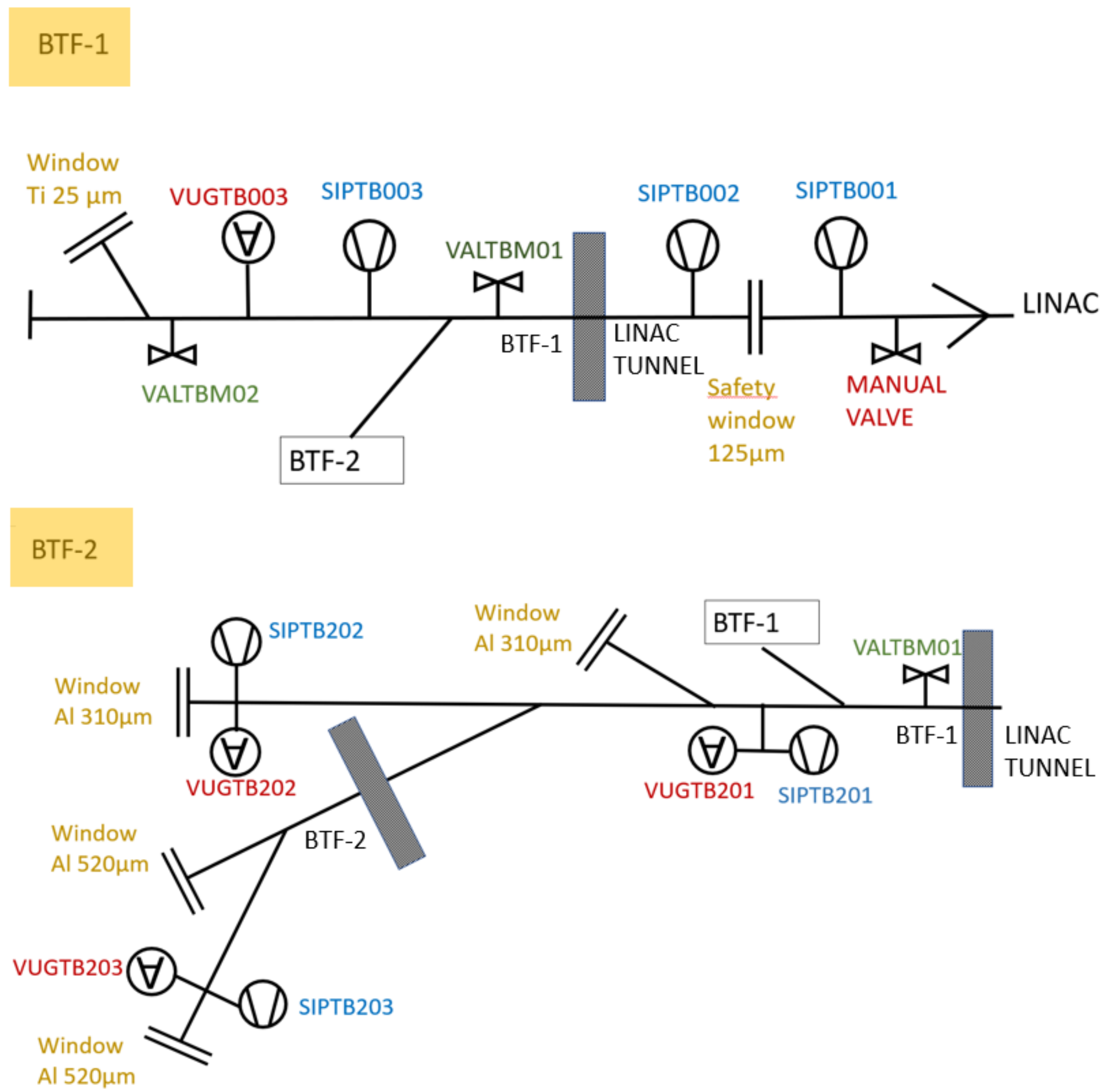

Figure 7: The BTF Vacuum system layout.

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 compose 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 Aluminium windows at the end of the lines as shown in Fig. 7.

5.0.6 The design and commissioning of the mechanics elements.

During the design phase was evident that the main constraint for the installation of the new BTF line was the space limitation. The mechanics of all the BTF2 installations suited the highly constrained space for both the experimental halls, at some positions the BTF1 and BTF2 elements

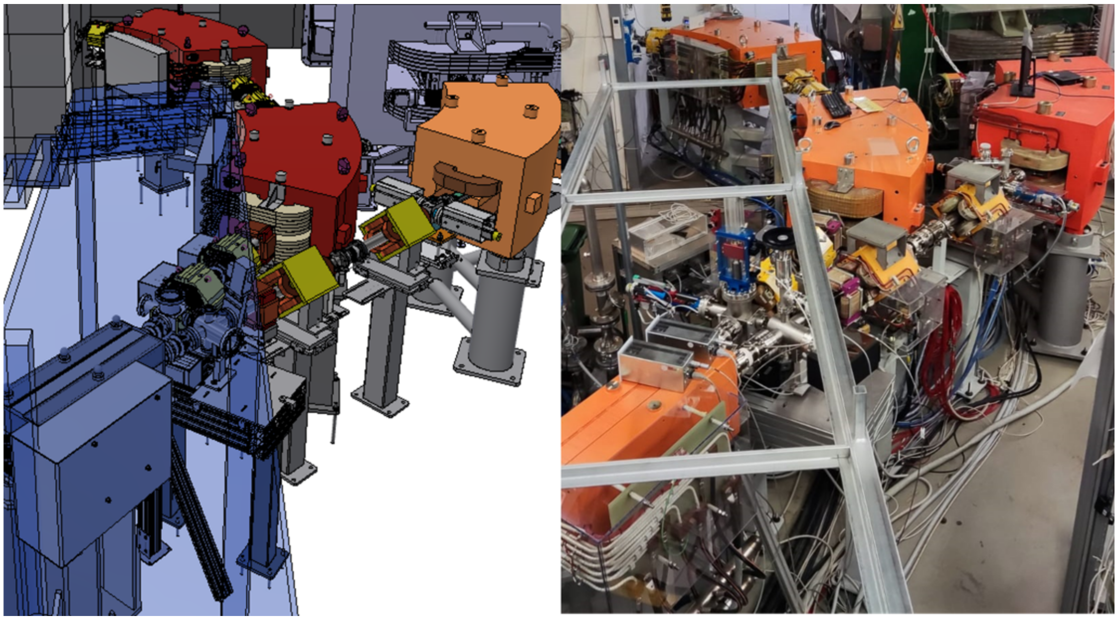

Figure 8: On the left the 3D design and on the right the commissioned BTF line.

are less than a few centimeters far away from each other and other hall components. A tight tolerance calculation avoided placing problems, a task executed by the Mechanical Engineering Service that put in place and aligned all the magnets and the vacuum chambers in both the experimental hall. After having renewed the BTF common line placing positions in the LINAC tunnel elements, amidst the 2021 winter pandemic peak, we were able to set up the BTF2 line in less than 0.1mm placing error for all of the main components. Most of the magnets and auxiliary mechanics system drawings are produced by the Mechanical Service of the Accelerator Division. They produce many 3D mappings of the BTF areas to reduce the installation time and the risk of interference during the installation of all the elements as shown in Fig. 8. Thanks to this method a detailed schedule of the activities has provided the tools to optimize the resources.

5.0.7 Cooling and power plant.

In the last part of the installation the Fluid Plants and the Electrical Plants Services, after having finished to set up in 2020 the arrangement of a new secondary cooling pumping station and the new related routing of water pipelines with sensors and interlocks, powered up the plant for technical commissioning to full power the magnets and services at about 160kW. The new installed 50m-long secondary pipeline starts from LINAC cooling tower downstream to BTF power supply and experimental halls. It was partially dismantled to permit the maintenance of LINAC tunnel performed in autumn 2021.

5.0.8 The radio protection system.

In the last part of the technical commissioning phase, took place the LINAC and FISMEL (radioprotection) Services conventional safety system tests for both the experimental halls. The BTFEH1 was subjected to redesigned hall preparation actions (search procedures) before getting the beam while BTFEH2 has a new safety system, both implemented by LINAC Service: the related checks

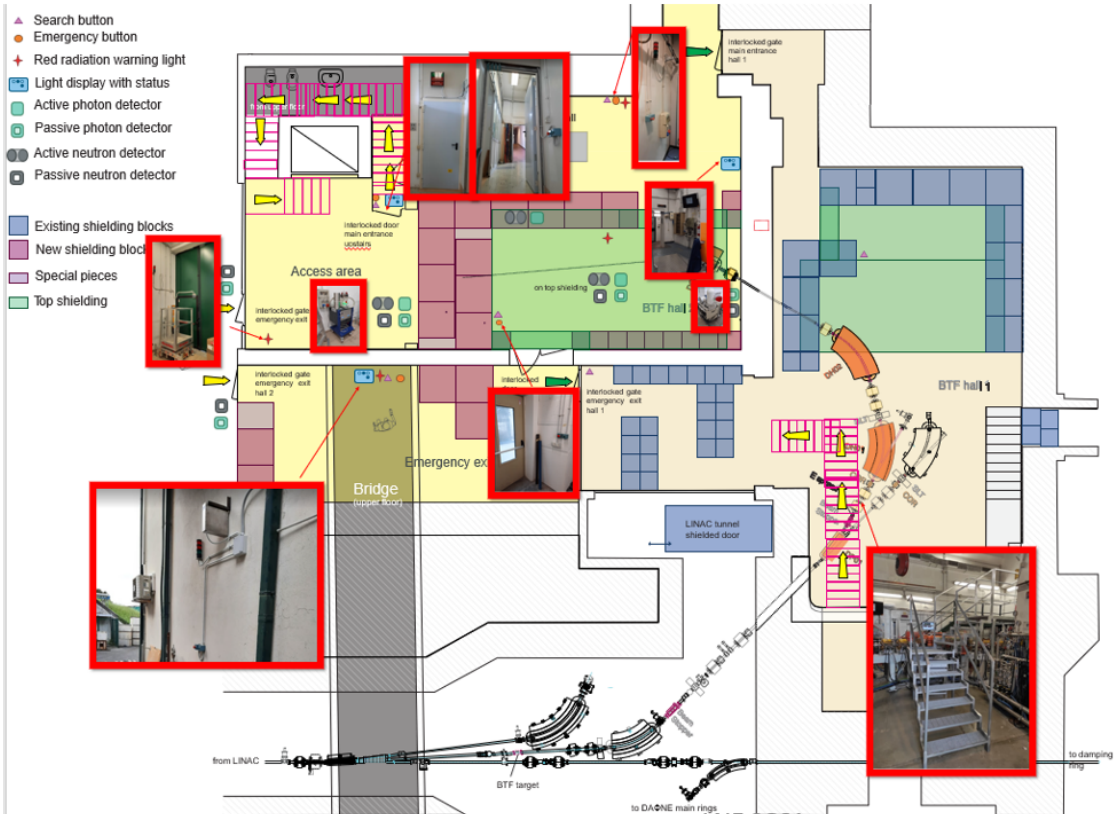

Figure 9: The layout of the BTF2 safety system.

constituted a milestone before preparing the BTF2 beam commissioning tests. This last is an event where we had to deliver a beam with the needed flux in both the areas towards a dump: the outside-wall radiation background has to be checked by FISMEL. The radio-protection Service has followed all the procedures 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 9. Thanks to their support the beam commissioning of the new line is ongoing. The radio-protection limit for BTF2 is 10^6 particle/s with an energy of 700 MeV.

5.0.9 The control system.

As shown in Fig 10, all the new magnetic elements power supplies controls are implemented into the DAΦNE Control System (DCS) [1] 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. 10 during the test phase, where the SCALER, QDCs, PIO, TDCs and the Timing Unit are visible on the left.

6 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. During the trial period before the beam commissioning initial phase, we

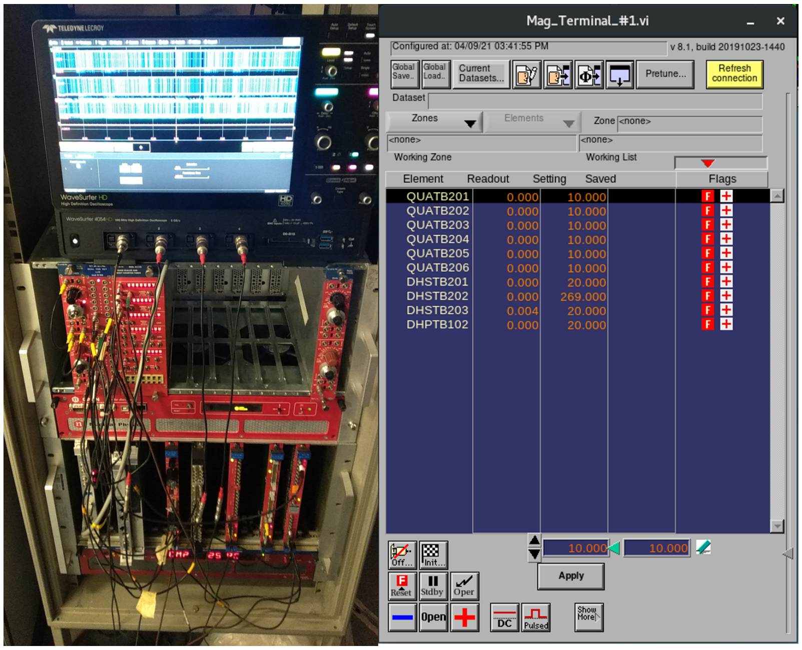

Figure 10: On the left the new BTF2 DAQ system under test, on the right the controls of the new magnets implemented in DCS.

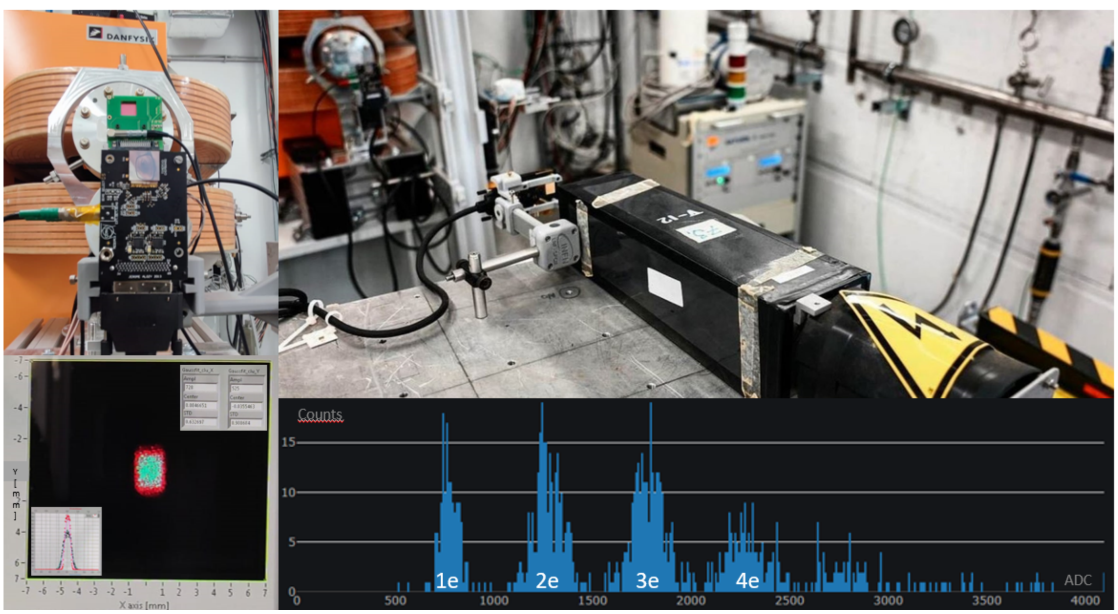

Figure 11: On the left high the pixel detectors low the cumulative distribution, on the right the lead glass calorimeter and low the particle count identification by the ADC counts (thanks to !CHAOS [10] integration of BTF DAQ).

took part of the time to set up the new BTF1 beam optics, and then, in a few hours, we got the first transported BTF2 beam in a Timepix detector, whose new holders have been designed and produced by SPCM Service. It was hard but three days after we were capable to get the first full display of secondary beam in different energies, multiplicity per bunch, and particle type (electron or positron). The diagnostic used for this test is a silicon pixel detector for details see [2, 4, 7, 5, 6] and a lead glass calorimiter as shown in Fig 11.

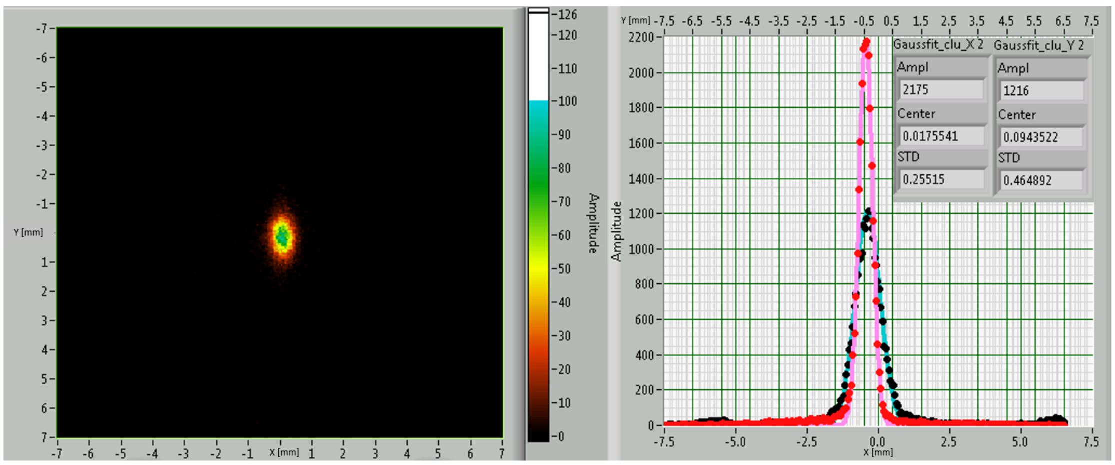

Figure 12: On the left the beam spot accumulated for about 2000 bunches with single particle detected by silicon pixel detector, on the right the Gaussian fit of the cumulative distribution ($\sigma_x = 0.25\ mm, \sigma_y = 0.46\ mm$).

After few days of optimization of the line parameters 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 12.

We test the possibility to transfer the beam between the two lines simply turning on and off the 15 degree pulsed magnet to find the best beam possible for the two lines. The measurements of the beam spot with silicon pixel detector are shown for an energy range from 450 MeV to 35 MeV in Fig. 13 for BTF1 and Fig. 14 for BTF2.

For the BTF2 a pretune of the magnet provide the possibility to check the beam quality for different energy of electron, as shown in Fig. 15.

During the first commissioning phase, the FISMEL survey found a gap of 20cm on the BTF2 bunker roof that has planned to be covered in 2022, thus delaying BTF2 commissioning ending.

7 LINAC Activities

The S-band linear accelerator was built to be the electron and positron source is now also being used to support the DAFNE accelerator complex and the Beam Test Facility (BTF) out of the standard way of operations. The existing klystron modulator in the Linac uses a 50 Hz high voltage power supply and adopts a traditional L-C resonant charging scheme. The original design of the TITAN BETA system for the FRASCATI linac employed a conventional DC high-voltage power supply based on a full-wave bridge diode assembly and a resonant charging circuit. The main component of high voltage charging power consists of a 3- phase variable phase control (SCR), a high voltage step-up transformer, a rectifier assembly and a charging inductance. After more than twenty years' operation, some components are no longer in good condition and circuit failure

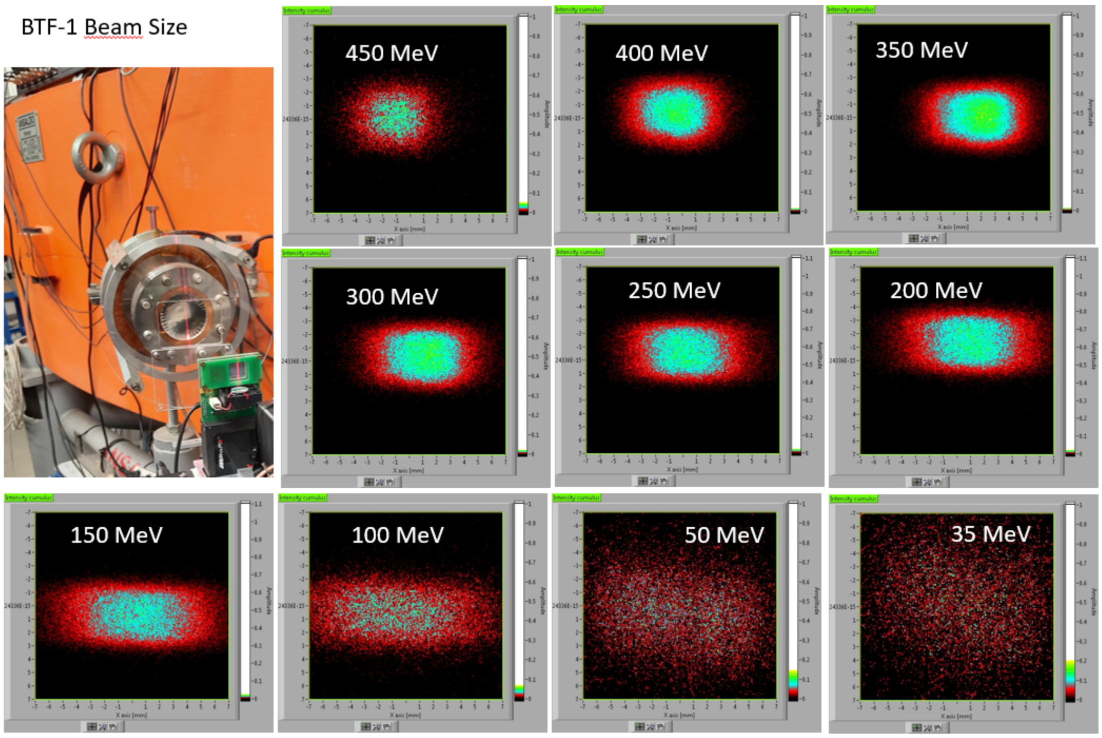

Figure 13: The BTF1 straight exit windows and the measured beam spot at various energy.

occurred often. The stability of the output high voltage is not satisfying especially when the AC line voltage fluctuations: one of the possible ends of this class of events is the circuit breaker trips caused by arcing at the load side during the 'On' state (before the recovery) of the thyratron. This problem is attributable to the DC high-voltage power supply, which sees the arcing as a short circuit. If an inverter power supply is used as an HV generator, it will just meet the demands and makes the overall system size smaller with a new generation modular implementation, improving the reliability of the highly demanded LINAC switching power scheme for the repeated production of positrons and electrons. With extensive field-tests, the modulator's high-voltage charging system has been redesigned to use a constant-current, high-frequency inverter power supply (EMI-303), which has 30 kJ/sec charging capability. From July 2020 the modulators B,C and D are all upgraded in the final configuration with the power supply in the modulator cabinet.

7.1 LINAC in 2021

From January 2021 up to begin of July 2021 the LINAC provides electrons and positrons for the DAFNE collider for the SIDDHARTA experiment. The operation was not regular due to the faults on the klystron installed in modulator C.

In July 2021 the activities were dedicated to the first test of the commissioning of BTF2 shielding and for users in BTF1 ad the ERAD project.

From July up to Oct 2021, a long shutdown due to the LINAC building consolidation provide the opportunity to execute a few upgrades and consolidation on the LINAC machine itself.

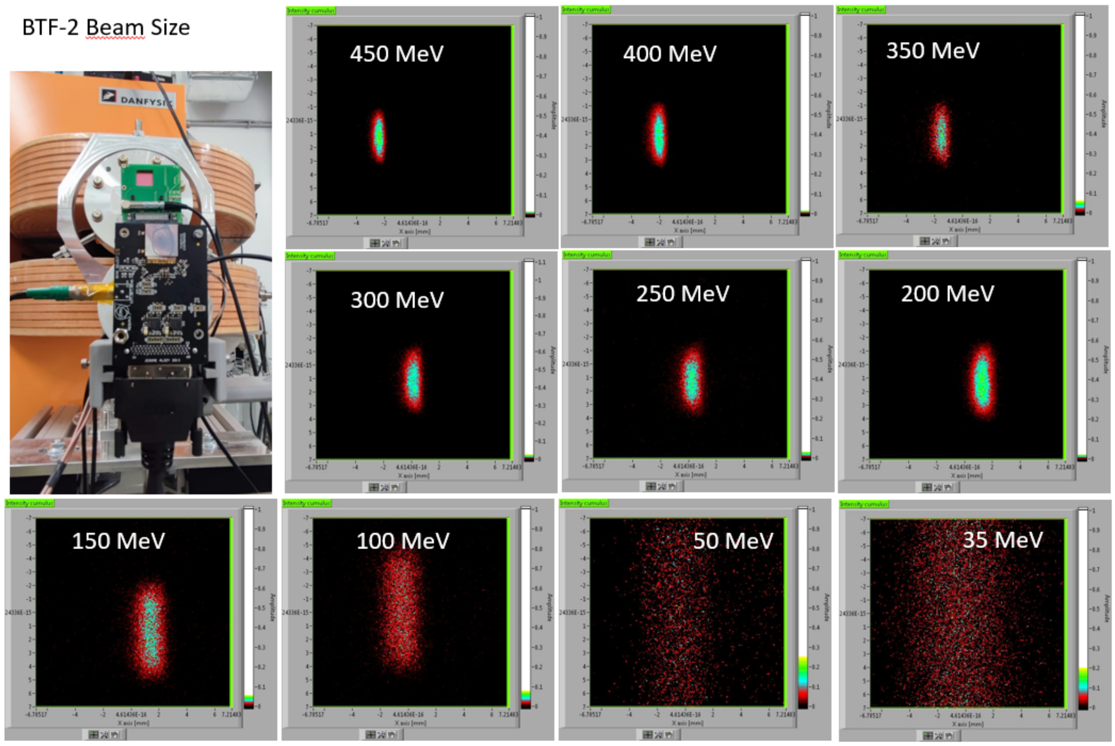

Figure 14: The BTF2 exit windows and the measured beam spot at various energy.

- All the Uniform Fields Solenoids (UFS) power supply are substituted with the support of the Magnetic Service;
- New EMI-303 power supplies for the C modulator.
- The upgrade configuration for the thyratron box airflow is installed in all the modulators.
- Unfortunately during the start-up procedure in October 2021 a vacuum leak on the pipe in the quadrupoles triplet before the positron converter required the pipe substitution.
- The water distribution system in the triplet was substituted due to the radiation damage of the o-ring.

Another minor issue on the LINAC water tower primary pump was recovered in a few days but one Helmholtz solenoid short circuit near the LINAC GUN was bypassed.

In September 2021 the commissioning of the TEX facility requires the support of the LINAC staff.

8 CONCLUSION

The commissioning of the BTF2 line will continue in 2022 to scan all the possibilities and provide the users facility beam parameters, releasing the experimental area after the final test following FISMEL service directives.

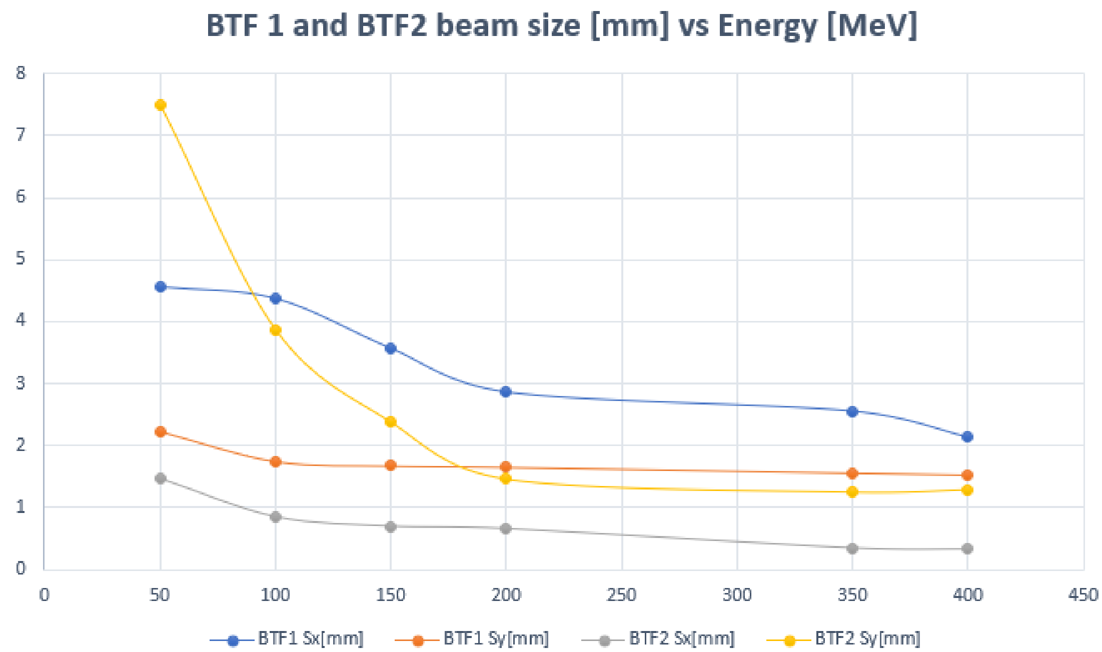

Figure 15: The plot of the measured BTF2 and BTF1 beam size vs Energy.

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