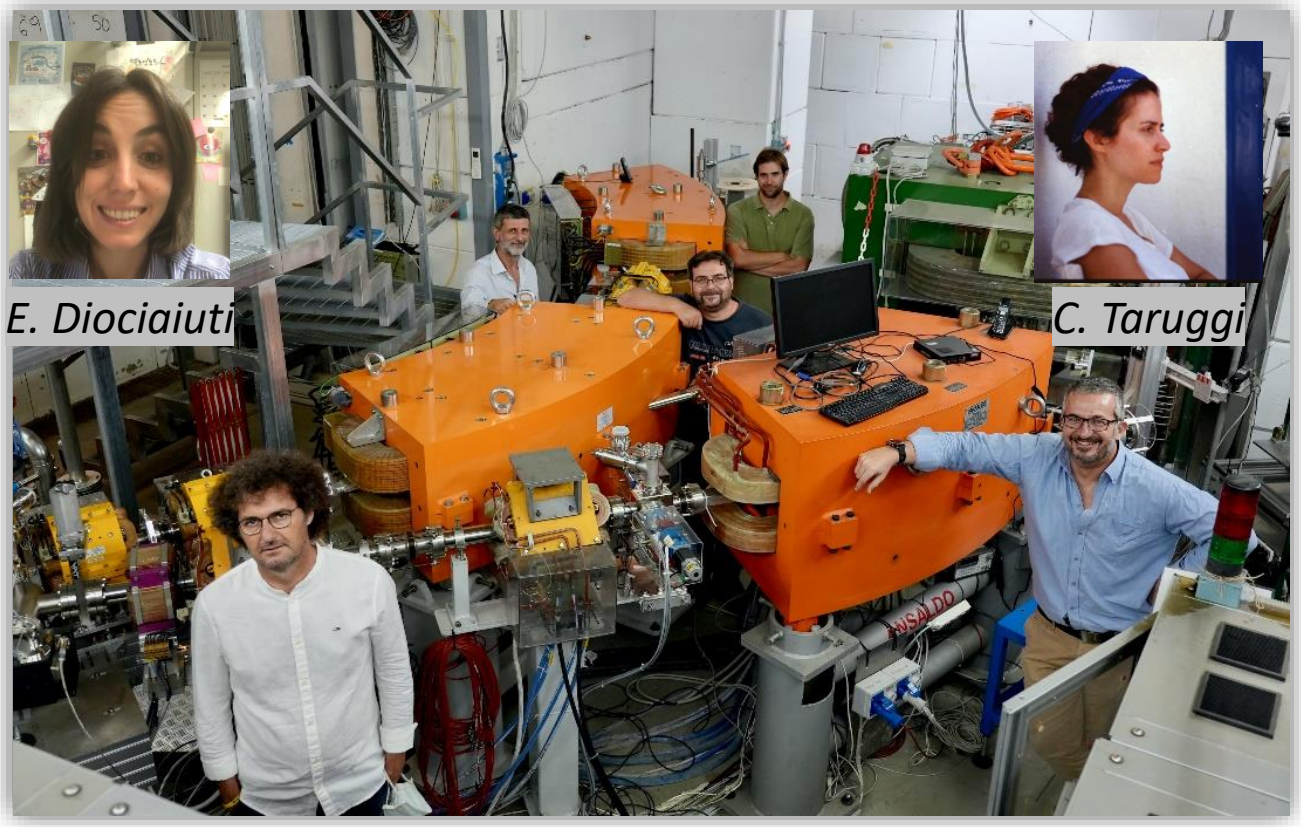
12th Beam Telescopes and Test Beams Workshop
15-19 April 2024 Edinburgh, Scotland, United Kingdom

The Frascati Beam Test Facility: Status and Prospective

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati



Claudio Di Giulio

On behalf of the LINAC-BTF team:
L.G. Foggetta (Scientific Resp.)
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Accelerators and Facilities | INFN-LNF

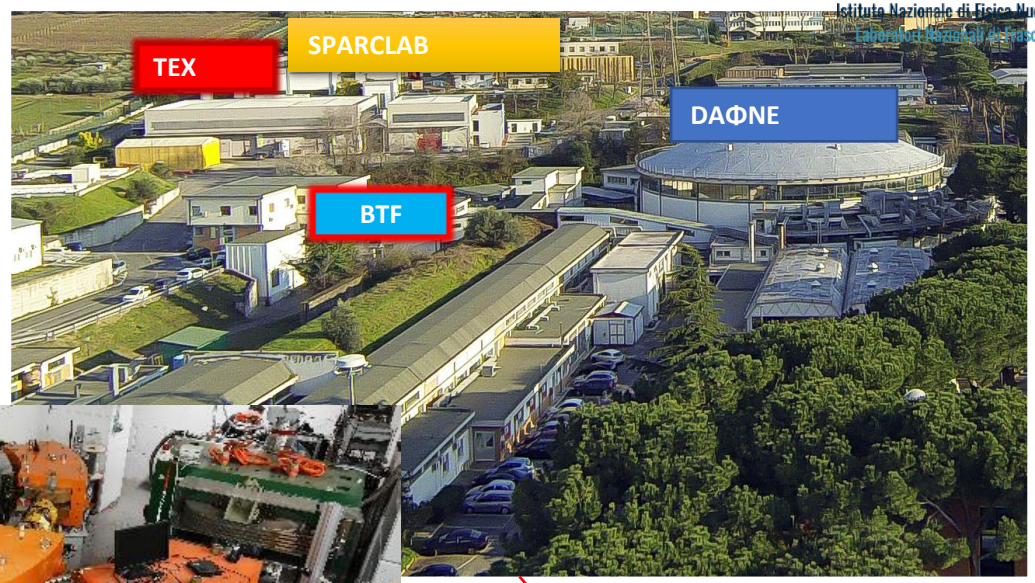
Laboratori Nazionali di Frascati (LNF)
Frascati (Rome, IT)

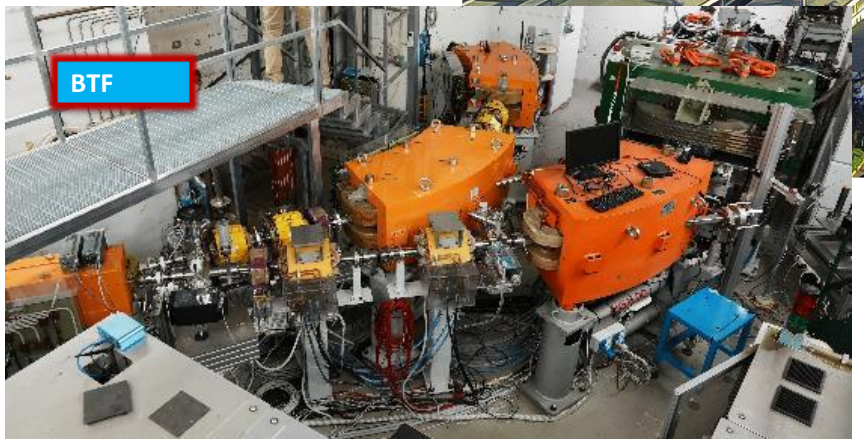
DAΦNE is a e+/e- collider @ LNF
Two test facilities in the DAΦNE complex:

- **BTF** (e-/e+) -> high dynamic range tunable beams sub-mm charged particles beams
- DAΦNE Light -> synchrotron light facility

In LNF are present other accelerator facilities and projects:

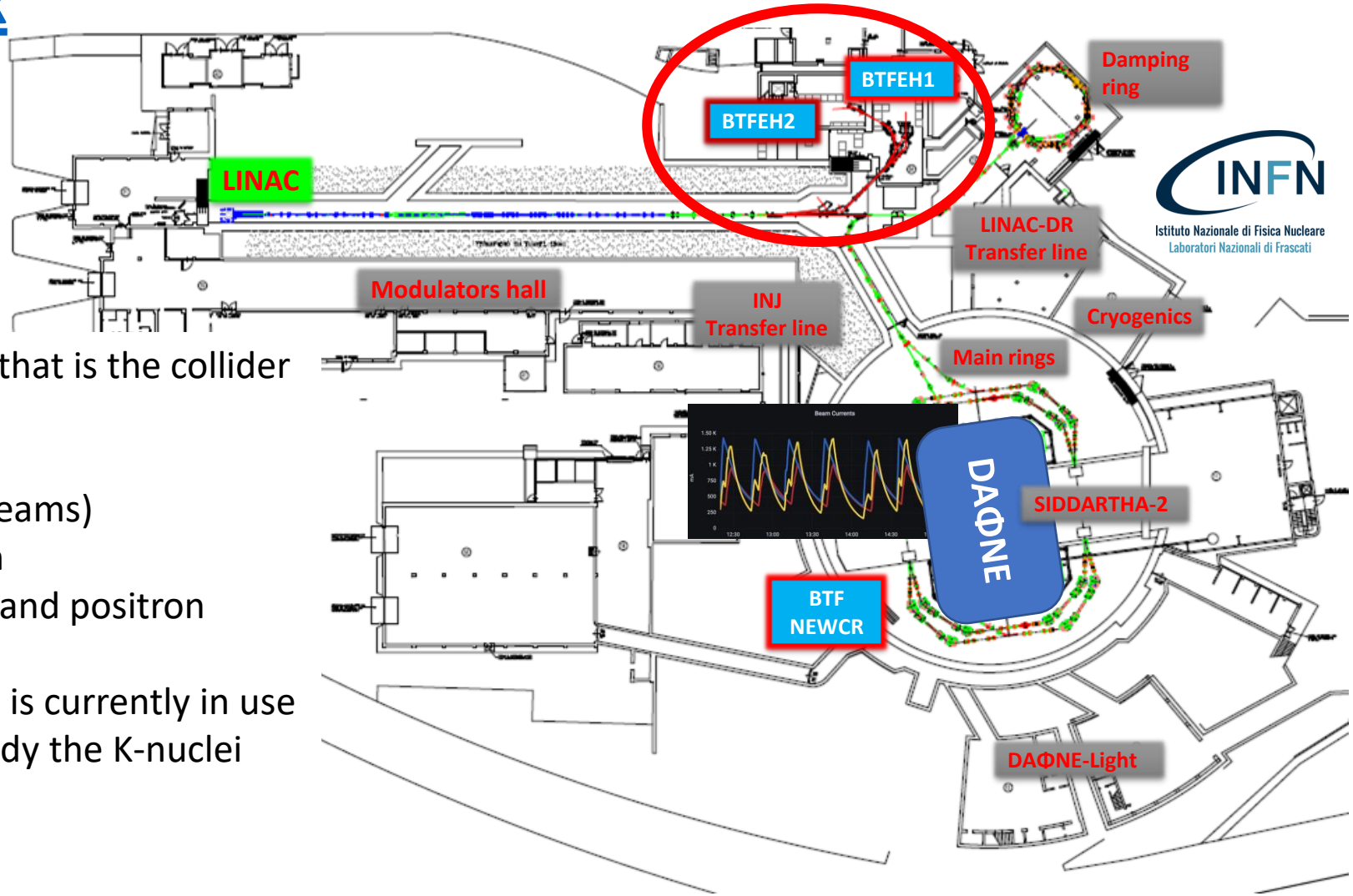
- SPARC Lab -> high gradient acceleration with plasma, EUPRAXIA project
- TEX -> X-Band develop lab
- Many other, in develop





The DAΦNE complex

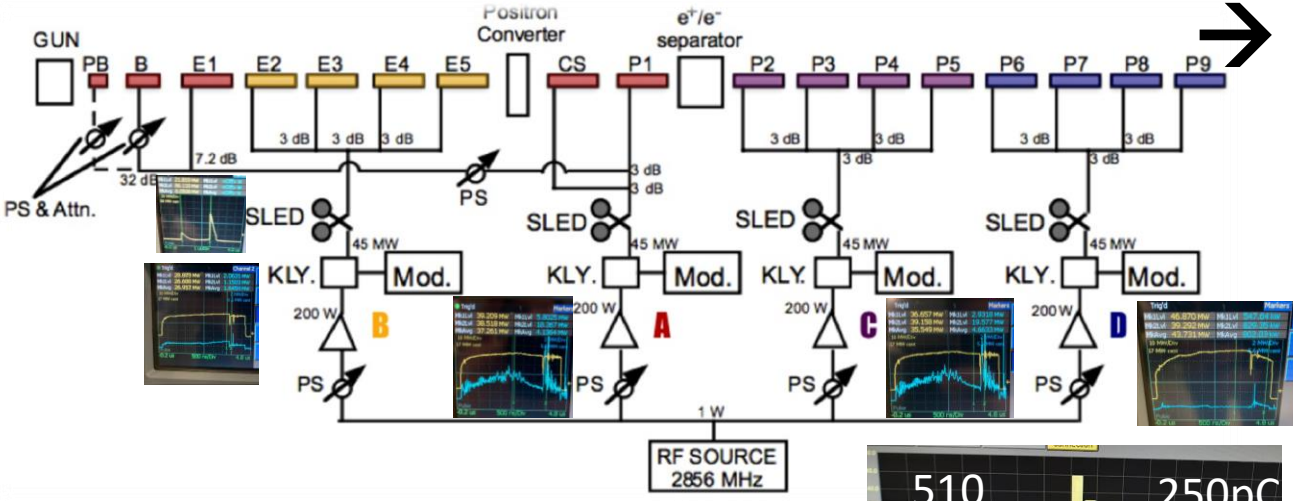
The **Beam Test Facility (BTF)** is an experimental area for users to develop and test particle detector.

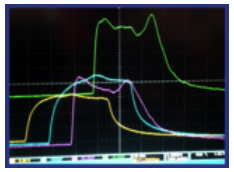


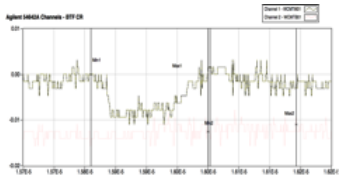
It's in the accelerator DAΦNE complex that is the collider currently in operation in Frascati:

- 1 LINAC (e+/e-) 24 h 7/7
- 1 Damping ring (common for both beams)
- 2 Main rings approx. 100 m in length
- 120 buckets, high-intensity electron and positron beams (1,5/1 A peak) collides
- two possible interaction points, one is currently in use for the detector SIDDARTHA-2 to study the K-nuclei
- Two USERS test facilities:
  - BTF (e-/e+)
  - DAΦNE Light

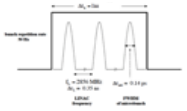
LINAC → BTF
→ DAΦNE

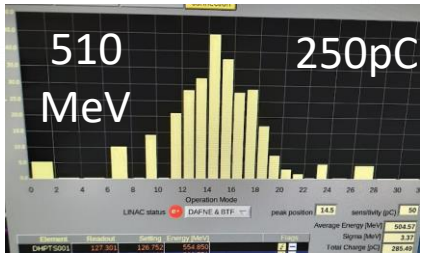


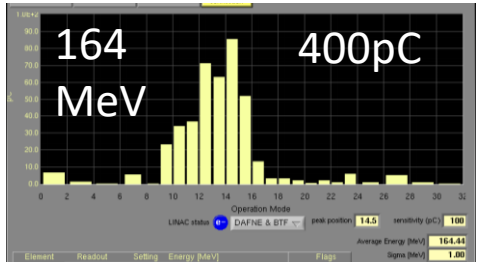




- SLAC Type Traveling wave S-band accelerator (2.856 GHz)
- Driven by
  - Traditional Cathode
  - 120KV electrostatic gun
  - four 45 MW klystrons
  - four SLED peak power doubling
  - 780MeV electron final energy
- Pulsed Machine
  - 10ns bunch envelope
  - repetition rate = 50 Hz.

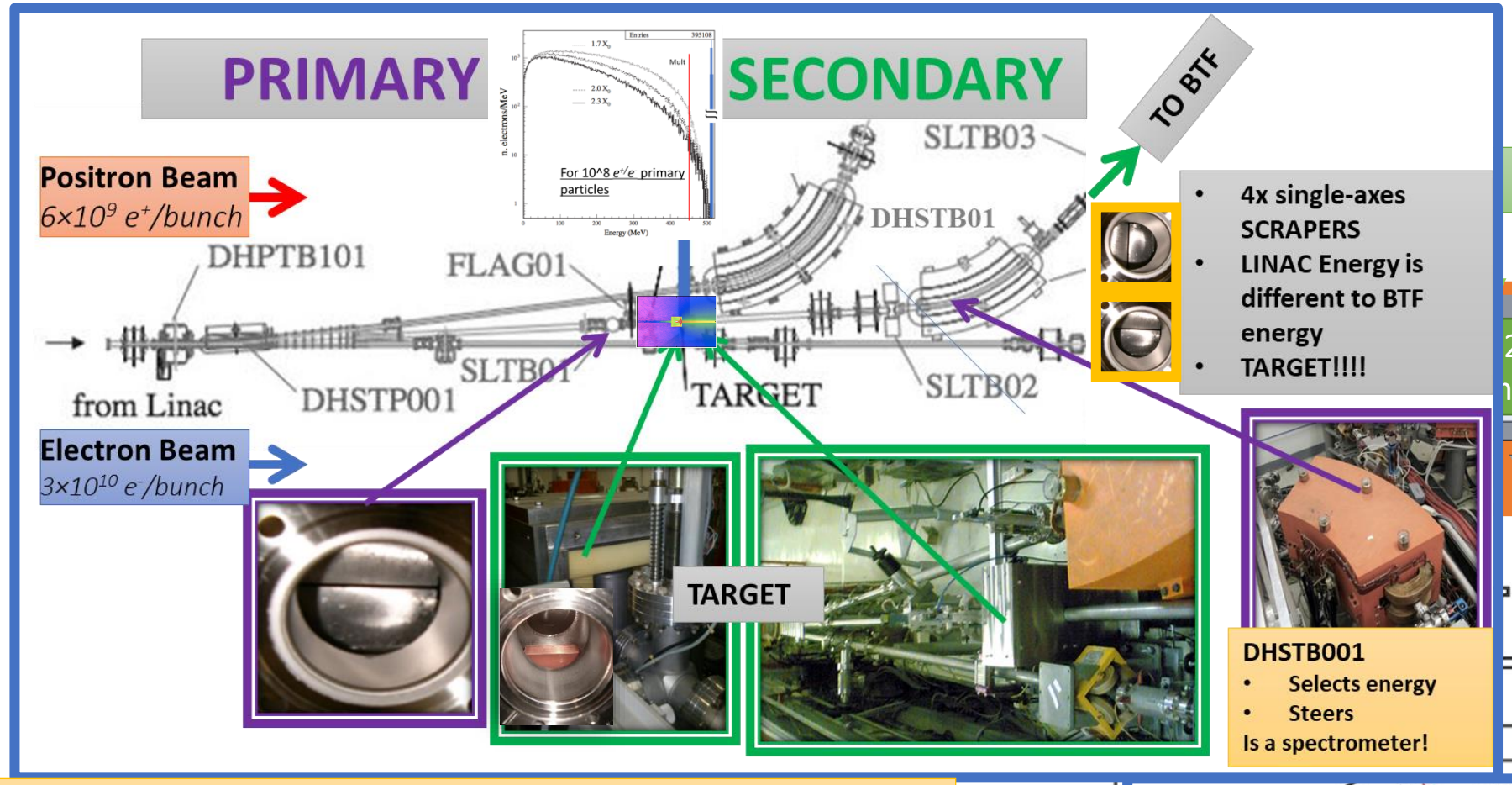


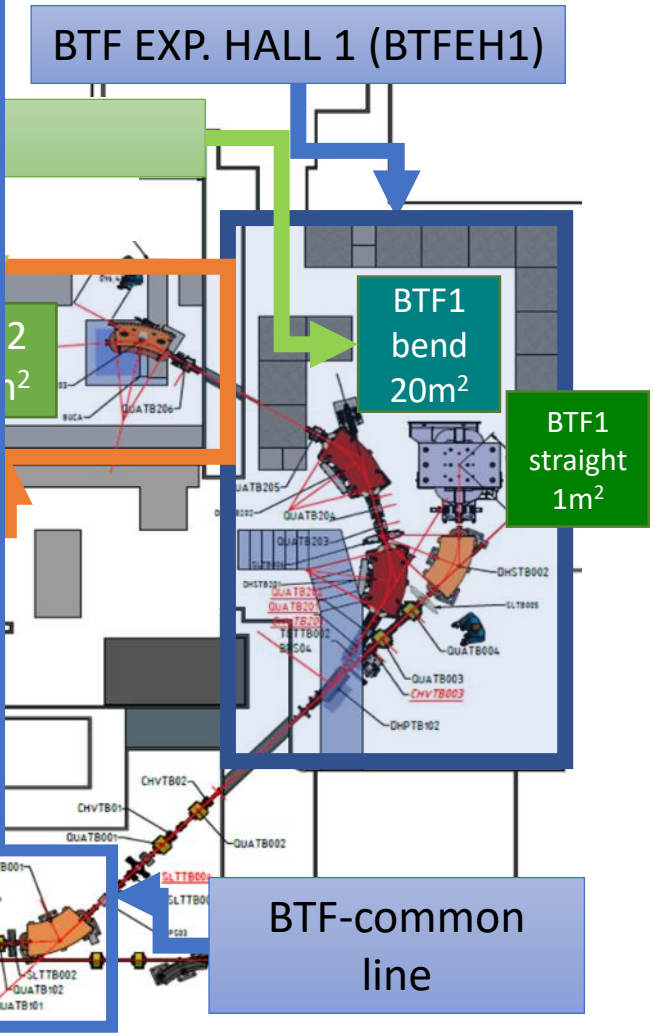




	Design	Operational (top)
Electron beam final energy	800 MeV	510 MeV (750)
Positron conversion energy	250 MeV	220 MeV
Positron beam final energy	550 MeV	510 MeV (535)
RF frequency	2856 MHz	
Accelerating structure	SLAC-type, CG, 2π/3	
RF Amplifiers	4 x 45 MW sledded klystrons TH2128C	
Beam pulse rep. rate	1 to 50 Hz	1 to 50 Hz
Beam macropulse length	10 nsec	1.4 ns to 300 ns
Beam spot on positron converter	1 mm	1 mm
Normalized Emittance (mm mrad)	1 (electron) 10 (positron)	1 (electron) 10 (positron)
RMS Energy spread	0.5% (electron) 1.0% (positron)	0.5% (electron) 1.0% (positron)
Output electron current (510MeV)	>150 mA	180 mA (>500)
Output positron current (510MeV)	36 mA	50 mA (>85)

Beam Test Facility secondary particles beam production:





- Copper target in the middle
- ENERGY and its spread selection! (Scrapers,Dipoles)
- Multiplicity selection! (Scrapers,Dipoles)
- Transverse Scrapers, Quad, Dipoles
- Dipoles and Steerings to match angle and position in the DUT

Beam Test Facility Experimental Hall and lines:

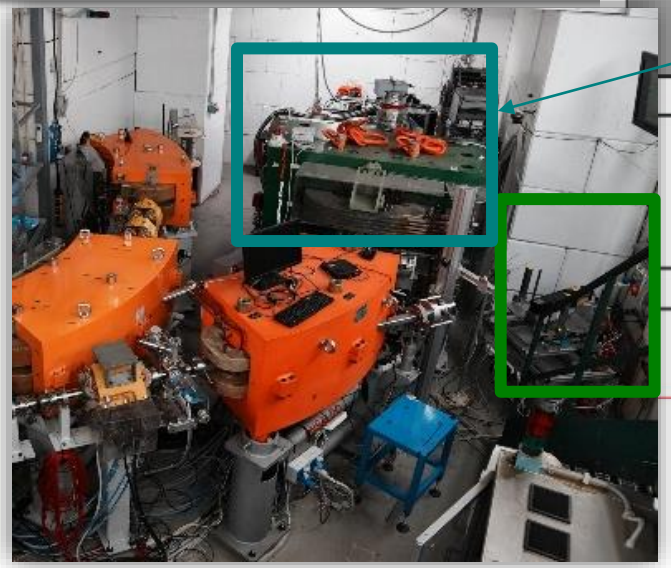
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

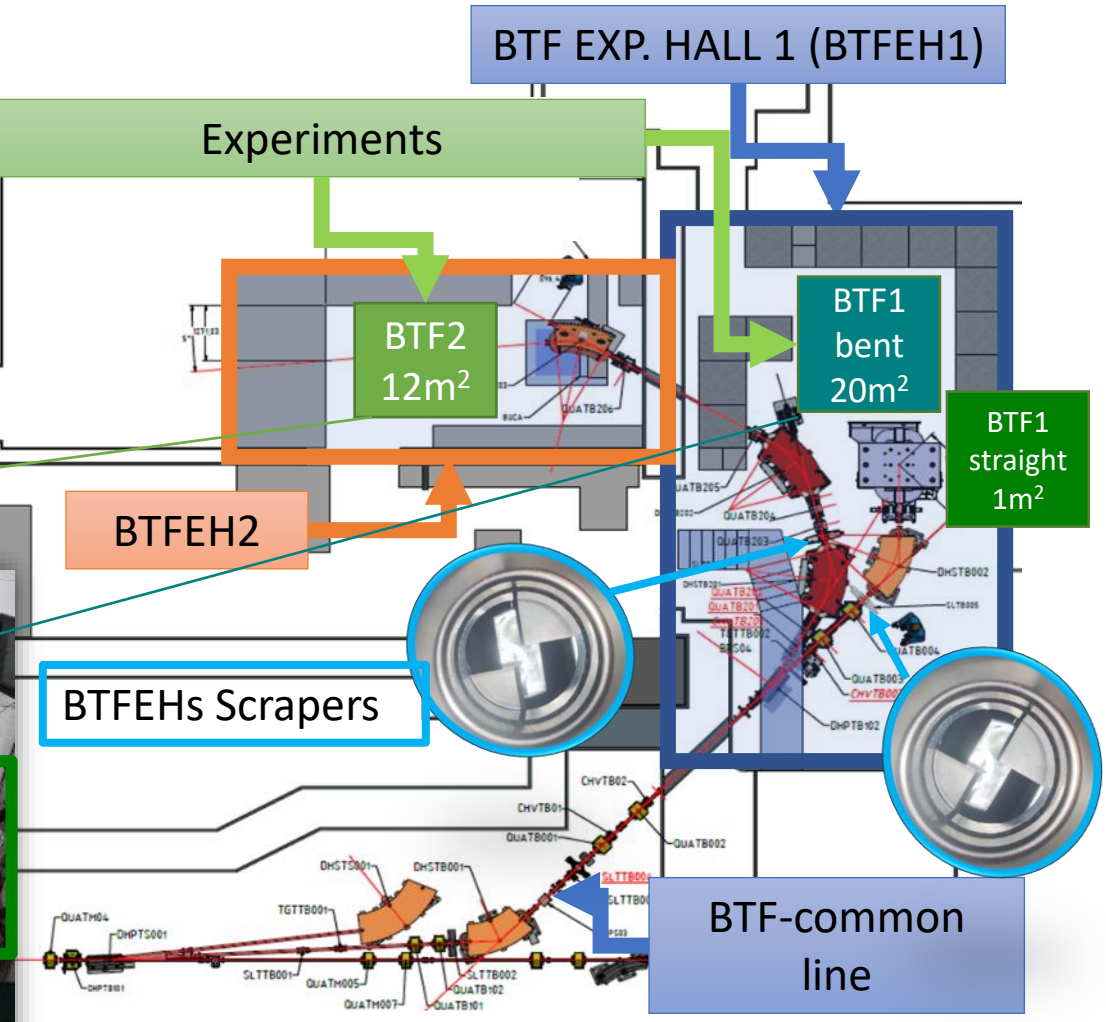
BTFEH1 – BTF1 (2 lines)

- A straight line where an area of 1m^2 with remote controlled table and beam diagnostics for the users. Dedicated at High intensity beam experiment (VHEE users request).
- A bended line where an area of 20m^2 is actually used by the PADME experiment (Dark matter search experiment)

BTFEH2 – BTF2 (1 line) from 2020

- A 12m^2 Hall operative, with line to external users
- Only secondary beam is used.





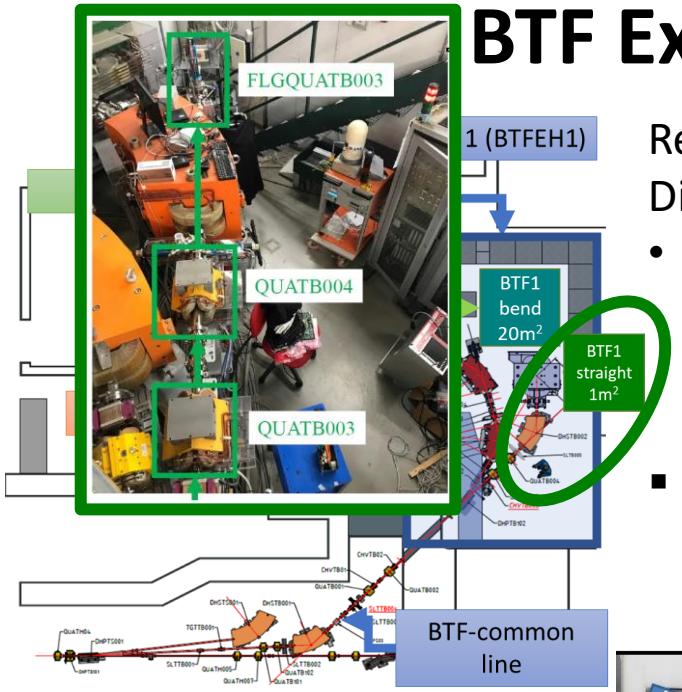
BTF Beam Parameters

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Parameters	BTF1 Time sharing		BTF1 Dedicated		BTF2 Time sharing	BTF2 Dedicated
	With Cu target	Without Cu target	With Cu target	Without Cu target	With Cu target	With Cu target
Particle	e^+ / e^- (User)	e^+ / e^- (DAΦNE status)	e^+ / e^- (User)		e^+ / e^- (User)	
Energy (MeV)	25–500	510	25–700 (e^-/e^+)	167–700 (e^-) 250–550 (e^+)	25–500	25–700
Best Energy Resolution at the experiment	0.5% at 500 MeV	0.5%/1%	0.5%(Energy/mult dependent)		1% at 500 MeV(Energy/mult dependent)	
Repetition rate (Hz)	Variable from 1 to 49 (DAΦNE status)		1–49 (User)		Variable from 1 to 49 (DAΦNE status)	1–49 (User)
Pulse length (ns)	10		1.5–320 (User)		10	10
Intensity (particle/bunch)	1–10^5 (Energy dependent)	10^3 to 1.5x10^{10}	1–10^5 (Energy dependent)	1 to 3x10^{10}	1–10^4 (Energy dependent)	
Max int flux	3x10^{10} part./s				1x10^6 part./s	
Exit Beam waist size (m1, mm)	0.5–55 X / 0.35–25 Y (vacuum window dependent)				0.4x0.4(Energy/mult dependent)	
Divergence (mrad)	Down to 0.5				Down to 0.5	

- Pulsed **electron** and **positron** beams (up to 49 pulses/second)
- Wide range: from 10^10 down to single particle per bunch, continuous energy selection
- Different ranges of parameters in the **two running modes**:
  - Dedicated: only when DAΦNE collider in shutdown, exclusive BTF users
  - Time sharing:
    - DAΦNE spare pulse injections mode via DHPTB101 pulsed magnet
    - Beam top parameters defined by DAΦNE injections

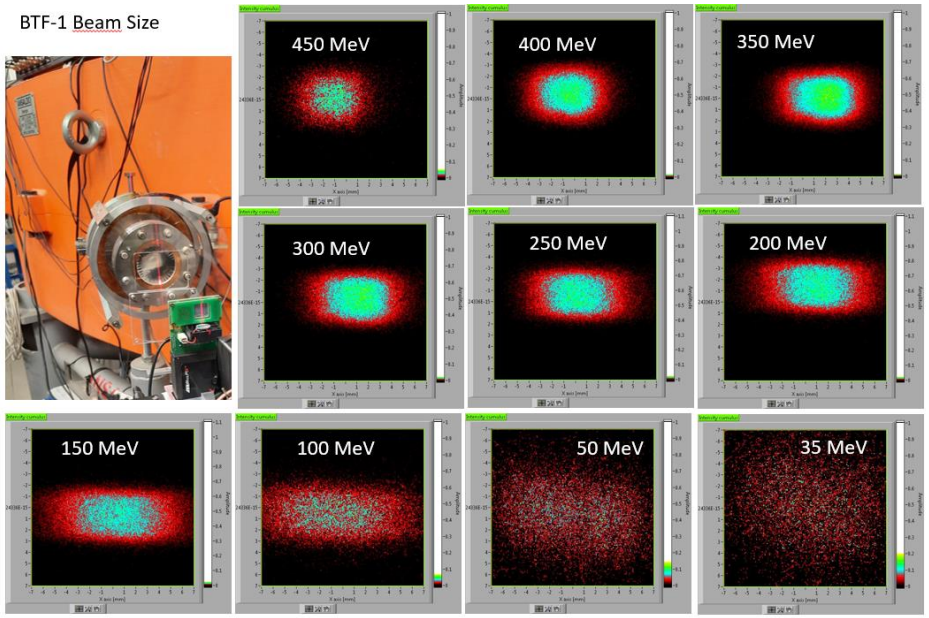
BTF Experimental Hall 1 Straight Line (BTF1-S)



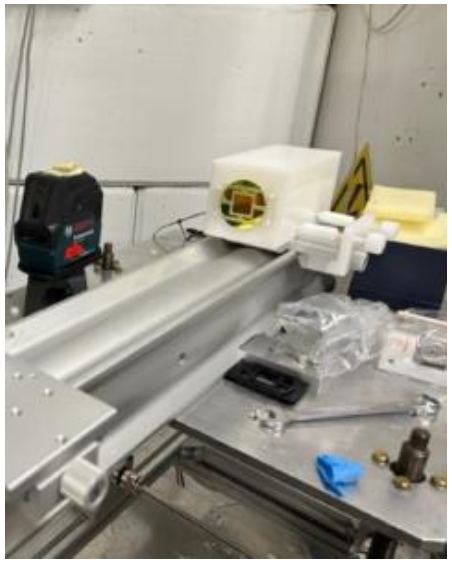
Remote controller table X,Y

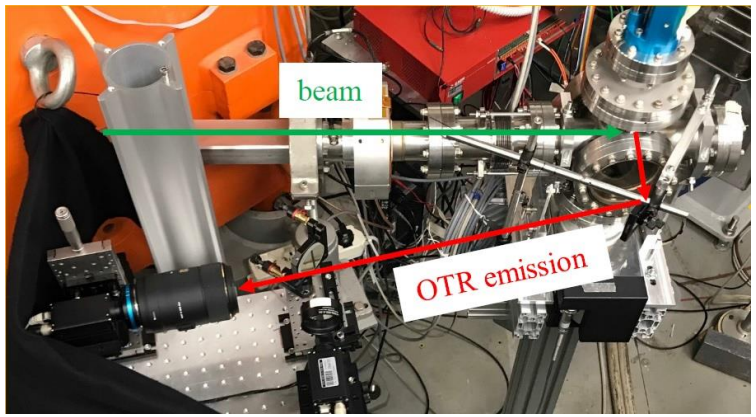
Diagnostics:

- For high charge beam:
  - ICT as charge monitor
  - OTR as size monitor
  - Flags
- For low charge beam:
  - FitPiX
  - Calorimeter PbWO3

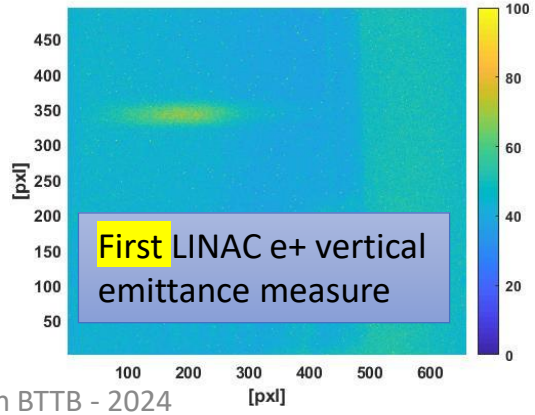


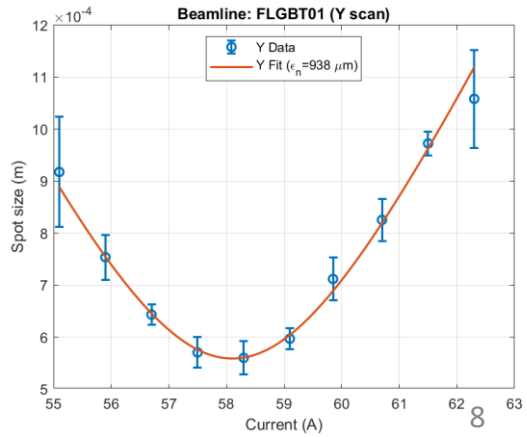
~49 bunches per second with maximum of 1E10 particles per second.



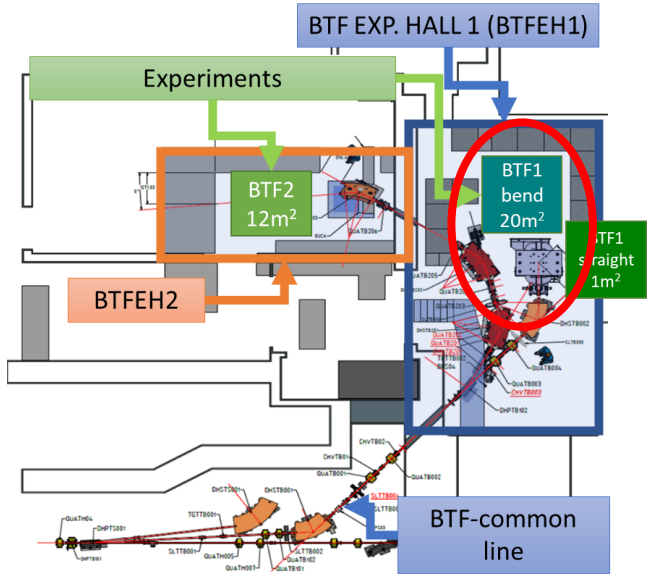


POSITRON Beam = 497 MeV/10ns/4,7pC
Vertical emittance (rms) 0,93±0,32 mm x mrad





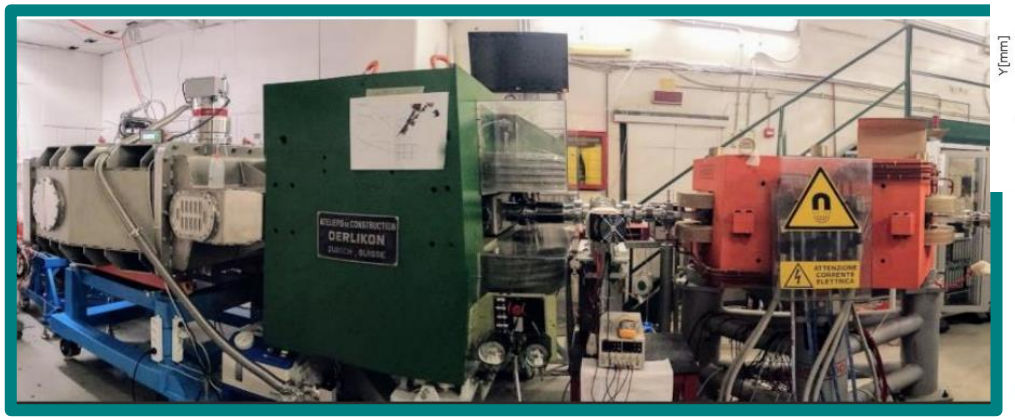
BTF Experimental Hall 1 Bent line (BTF1-B)



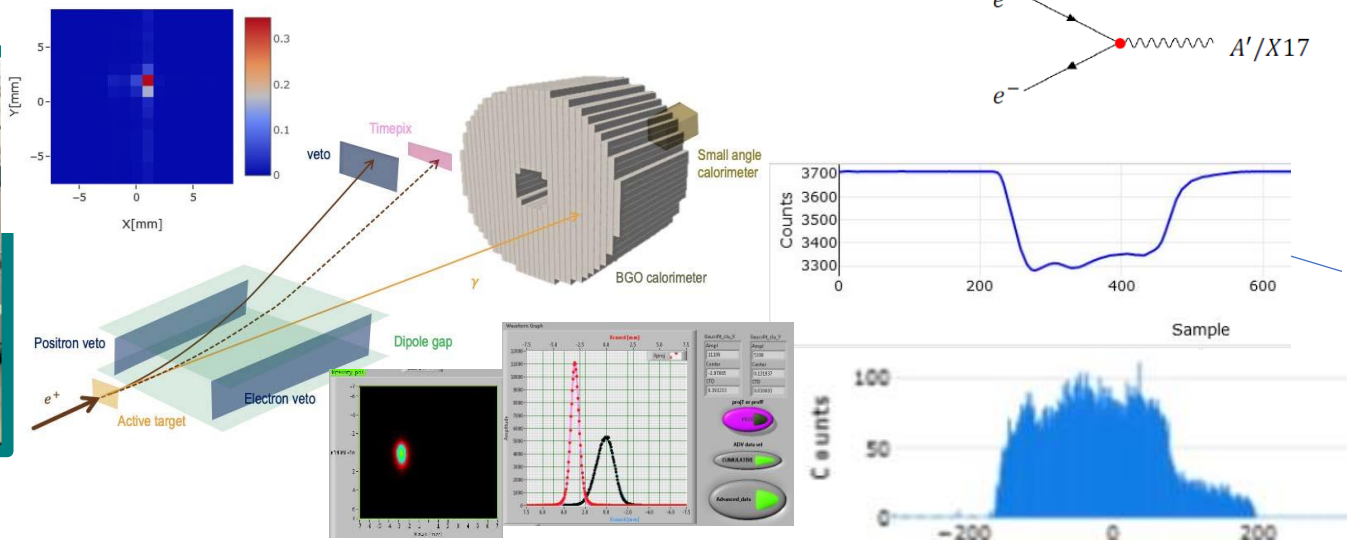
Devoted to PADME(X17) experiment.

The PADME experiment (Positron Annihilation into Dark Matter Experiment) at Laboratori Nazionali di Frascati of INFN aims to search for a “Dark Photon” using **positron on target collision** at the DAΦNE Beam Test Facility.
PADME use the missing-mass technique to be:

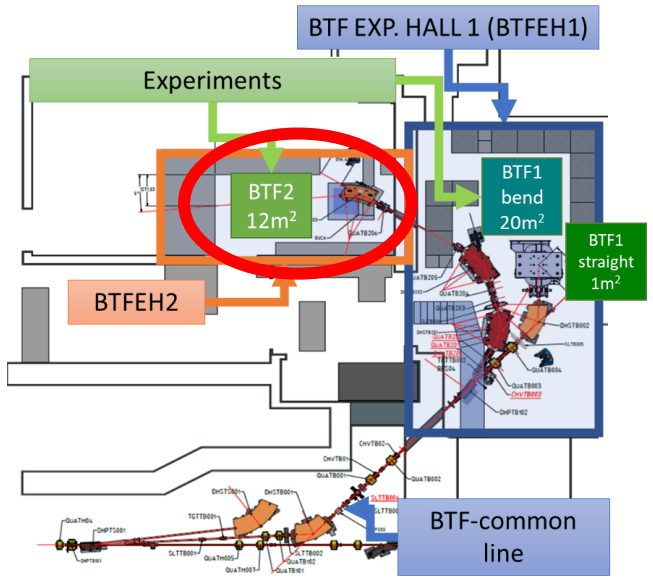
- Sensitive to low-mass dark photons in the range ~ 20 MeV, with a positron beam energy of ~ 500 MeV.
- A dedicated scan to X17 was recently concluded with Energy Scan around of **282MeV pulse length >300 ns about 3000 positron per shots**



For details: F. Bossi *et al.*
Phys. Rev. D **107**, 012008 – Published 30 January 2023



BTF Experimental Hall 2 Bent Line (BTF2-B)

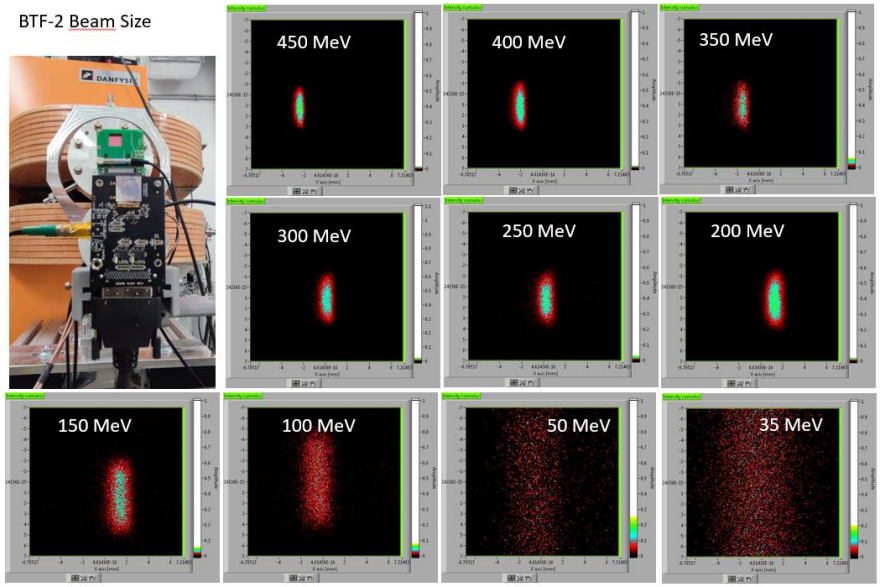


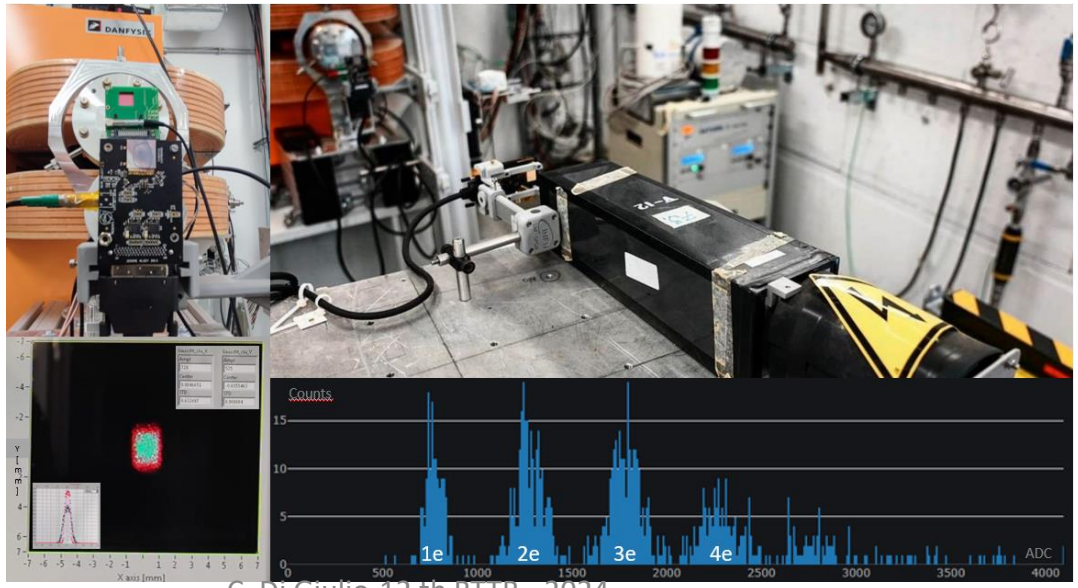
- Remote controller table X,Y

Diagnostics:

- For high charge beam (1E6 max):
  - Calorimeter
- For low charge beam:
  - FitPiX
  - TimePix3 read by Kat.
  - Calorimeter PbWO3

All the data provided to the user by a Memcached server





~20 bunches per second with maximum of 1E6 particles per second.

Usually secondary beam.

BTF Services for users:

Accelerator Division Services are available for user in Experimental Halls/Control Room

Networking
- BTF dedicated VLAN
- DHCP Server (on DHCP auto endpoint)
- Proxy for getting web access
- LNF INFN VPN External connection (for registered users)
- BTF Diagnostics on MemCached

GAS pipeline
- BTFEH1, standby, 4 lines
- BTFEH2, will be implemented, 2 lines

Power supply, crates, boards
- CAEN5527 crates and multiple HV boards
- VME/NIM crates and commonly used boards on pool

Logistics
- Trolley tables (100um rep., 200kg max load)
- Sliders, mounting kits

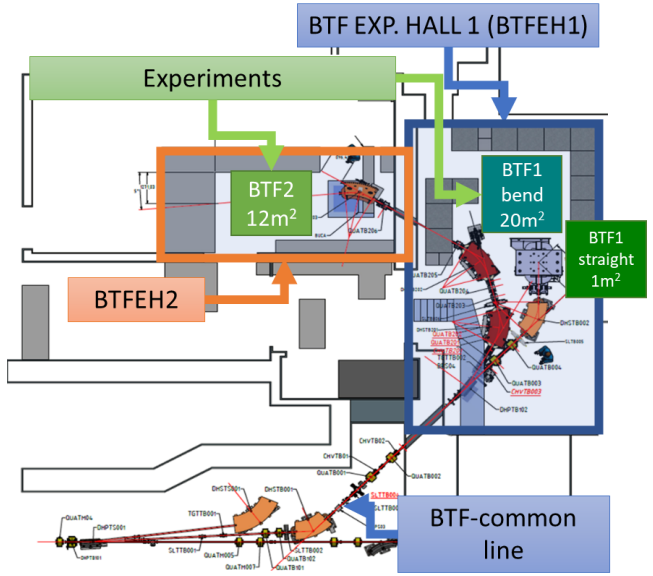
DAQ, Data delivery, Triggering
- VME based (QDC, TDC, Scalers…)
- LC8108 scope (8Ch's,5Gsam/s, 1GHz BP)
- !CHAOS triggered cams online data analysis

- Digital delay, particle type latching

Fluids, Compressed Air

24/7 Beam line scientist on call

BTF external projects

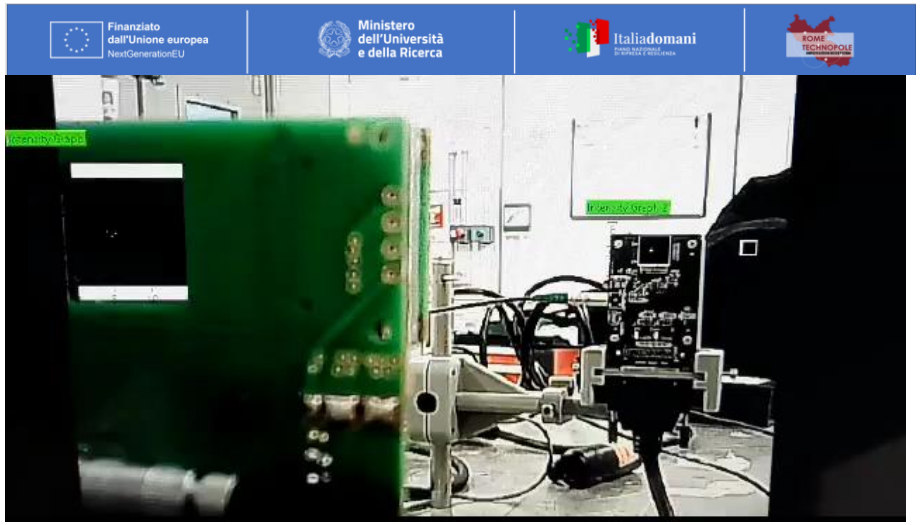


Different projects from EU and Regional funds provides us the possibility to hiring human resources.

Thanks to the ERAD (Regional) project a proposal for a protocol for irradiation of electronic device for space was developed. (1TFE x 2 years)

Thanks to Rome Technopole (EU) an AI with augmented reality project is ongoing (1FTEx2 years).

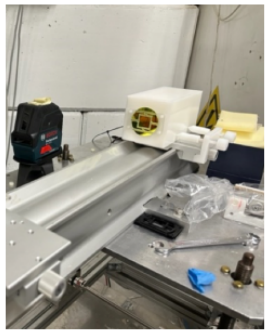
Robot usability test in experimental facility.



BTF news 2023:

DIRECT ELECTRONUCLEAR PRODUCTION OF TC-99M PRECURSOR AT THE BTF

3 May 2023 Featured, News



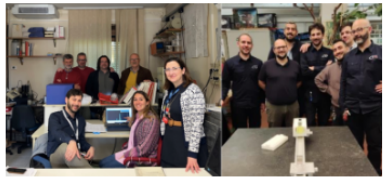
The experimental setup used at the BTF that contains the Molybdenum target

In the framework of a scientific collaboration with INFN-LNF (BTF, FISMEL, and SPCM teams), researchers from the Rutherford Appleton Laboratory (RAL, UK) and ENEA explored an alternative approach to produce Tc-99m radiopharmaceutical, a crucial diagnostic tool in medical imaging, without relying on nuclear reactors.

The team has successfully used a dedicated high energy electrons beam from BTF (E=504 MeV) on a specially designed target by RAL and setup by BTF and SPCM, to investigate the feasibility of direct electronuclear production. A preliminary target solution, consisting of a cascade of very thin foils made of natural Molybdenum, was irradiated in the BTF on March 27-28, 2023 by FISMEL direct supervision, and measured by FISMEL itself in the days after. Gamma spectroscopy was used to measure the radionuclides produced and their activity, which are currently compared to the updated MC predictions, using the real exposure data acquired during the beamtime.

The preliminary results confirm the success of the feasibility study. Moving forward, the team will focus on designing a well-optimized target made of Mo-100 enriched to maximize the Mo-99 activity, building upon the positive outcomes of this study.

Furthermore, the experimental setup enabled the measurement of the Mo-100(e, e'n)Mo99 cross section at 504 MeV, providing valuable input to the assessment of the physical model used in the Monte Carlo code.



Compared to the photonuclear method, where electrons are used to produce bremsstrahlung photons, this direct electronuclear production method should offer several advantages, including reduced harsh environmental dose and reduced spurious secondary RN produced. Furthermore, this method promises to be more suitable to match a new paradigm proposed to produce Mo-99 in a post-pandemic scenario, as reported in the correspondence of Nature | Vol 603 | 17 March 2022 | **393.** In particular, the investigated method can potentially improve the post-process of extraction of Mo-99 from thin irradiated according to the specific needs of a hospital, matching the modularity and proximity criteria of the new paradigm. These results provide promising evidence for the potential of direct electronuclear production as a viable alternative for the production of the Tc-99m radiopharmaceutical.

The recent results obtained in BTF could have the potentiality of a critical development for modern medical imaging for a worldwide benefit.

EXPERIMENTS IN BTF ORBIT

13 July 2022 Featured, News

The HERD team, Florence unit, with the LYSO calorimeter's prototype.

The activity of the Beam Test Facility (BTF) of the Frascati National Laboratory included two operating slots (test beams) to test, for the first time, as many experimental apparatuses born in two distinct INFN collaborations and Chinese scientific and government institutes.

Both dedicated to investigations in the orbital environment, the second satellite of CSES-LIMADOU and the calorimeter of HERD have been designed for totally different measurements tested in BTF, thanks to the great potential that the infrastructure offers.

LIMADOU is part of a scientific program that studies natural and anthropogenic electromagnetic fields, their emissions and possible correlations with seismic events. The first satellite of the collaboration (CSES-01) has already been tested in BTF in 2016: the second element of the constellation (CSES-02) will mount an innovative particle tracker, which has just concluded its tests with an electron beam in the new BTF experimental room, the BTFEH2.

So, the LIMADOU team, made up of INFN and the University of Trento, used the corresponding BTF2 line: single-particle electron beams at different energies (from 30 to 120MeV) were produced to characterize the response of the apparatus to natural events, similar events that will occur along the satellite's orbit. A delegation from the Italian Space Agency was received in the same experimental room where the LNF director and the head of the Accelerator Division of the Frascati National Laboratory illustrated the potential of the line.

The LIMADOU team, Trento unit, with the future satellite's tracker.

The HERD (High Energy Cosmic Radiation Detection) collaboration, on the other hand, aims to install its detector in the Chinese space station, to study the composition of cosmic rays, to monitor gamma emission and indirect search for dark matter.

The team of the INFN and the University of Florence performed a fixed energy with variable charge test beam with BTF2, from a single particle to about ten thousand per shot, to explore the extremely extended dynamic range of the electronics associated with the LYSO calorimeter, designed to detect the energy released by both penetrating particles and high energy showers up to (and beyond) the impressive PeV scale.

DEFLECTING PARTICLES USING CURVED CRYSTALS

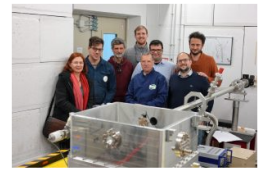
20 December 2023 Featured, News

During the week between December 11th and 17th, the SHERPA collaboration conducted a significant experiment in hall 2 of the BTF at LNF. It was a test to explore the possibility of deflecting the trajectory of positrons, the anti-particles of electrons with a positive electric charge, using curved silicon crystals. The phenomenon, known as *"channeling"*, is well-known and has been used, for example, with high-energy protons at CERN.

The possibility to extend this technique to lighter particles at lower energies will simplify and reduce the cost of extraction and manipulation of beams of this kind. This will open up new opportunities not only for fundamental physics experiments but also for applications in technology and medical physics.

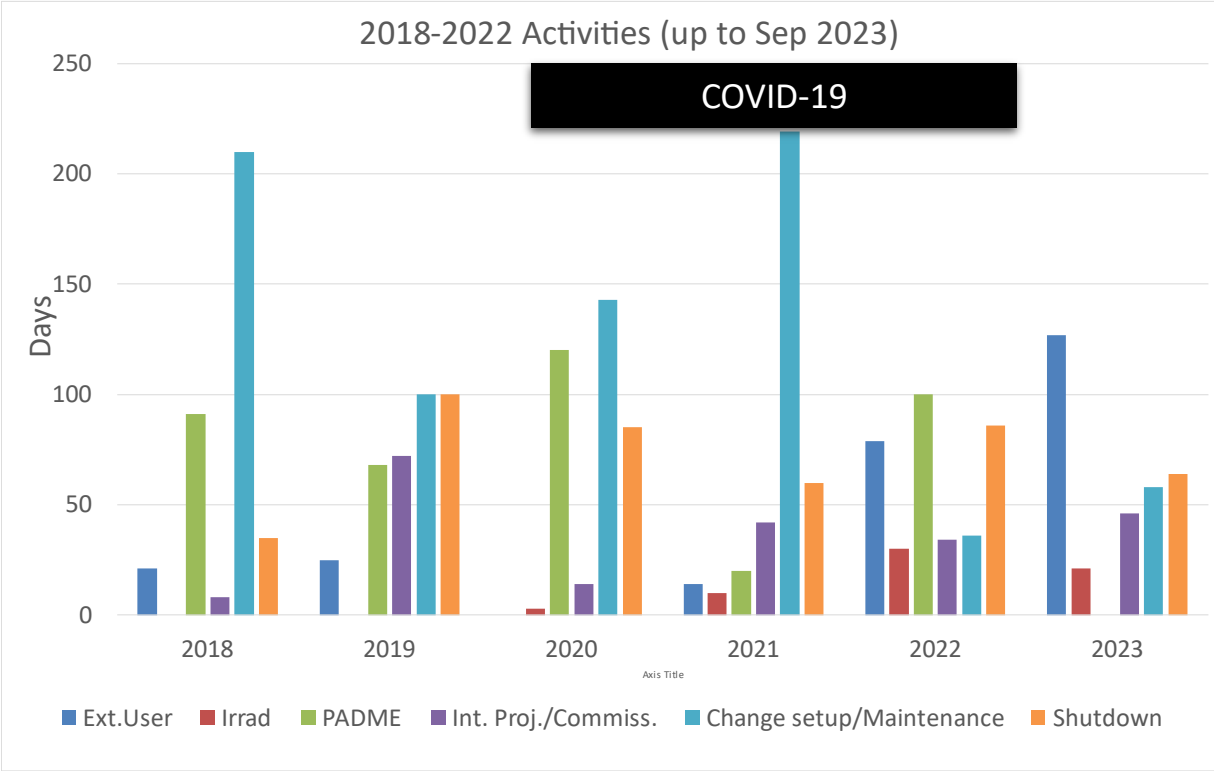
SHERPA (Slow High-efficiency Extraction from Ring Positron Accelerator) is a collaboration between researchers from LNF and the INFN section of Rome 1, funded by the INFN's Fifth Scientific Commission from 2020 to 2022, to conduct an initial feasibility study. Due to the COVID pandemic, the planned activities faced various delays, and only this year was it possible to complete the measurement program.

Marco Garattini, the project's P.I., is very proud of the work done: "The channeling of positrons at this energy level had not been observed before. I believe these results represent a significant step forward in the field of accelerator physics. Another source of pride is having achieved this in Frascati, with a group of young and passionate researchers, strongly supported by senior experts of proven value. An important technological aspect was the precision mechanical support to curve the 15 μm thick silicon crystals, produced by the INFN section of Ferrara, controlling their curvature without damaging them. To understand the technical challenge but also the fragility of such crystals, consider that they are less than one-fifth the thickness of a normal photocopy paper!".

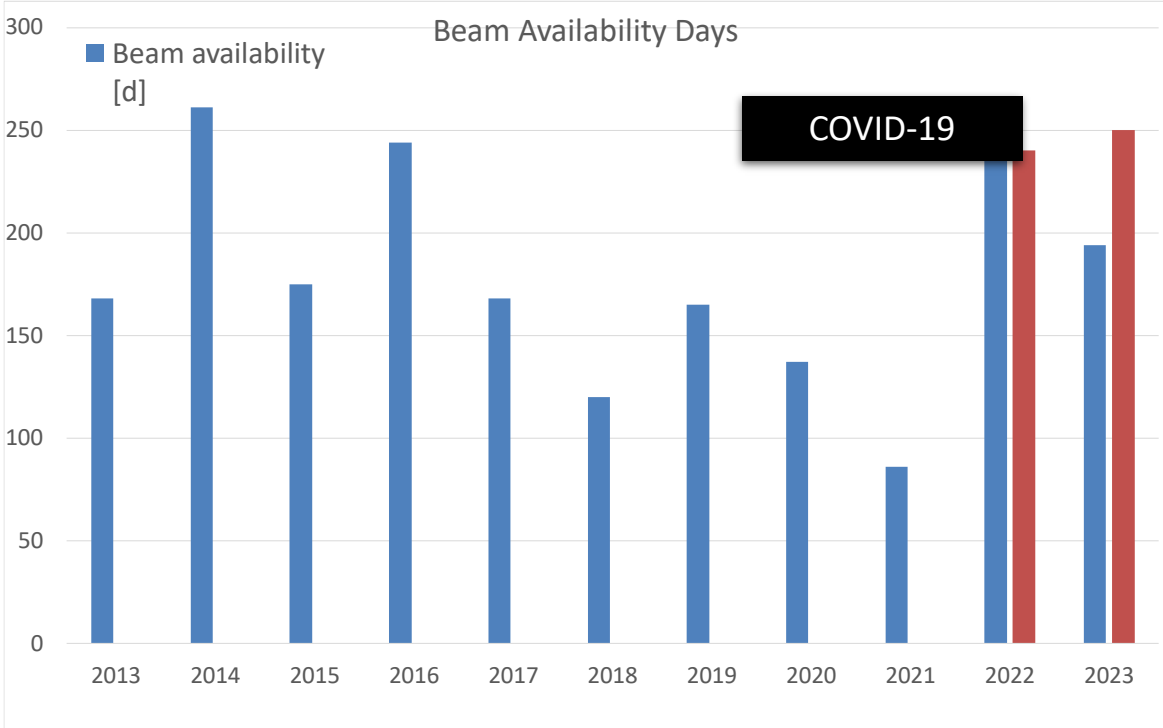


BTF Activities and beam avaiability

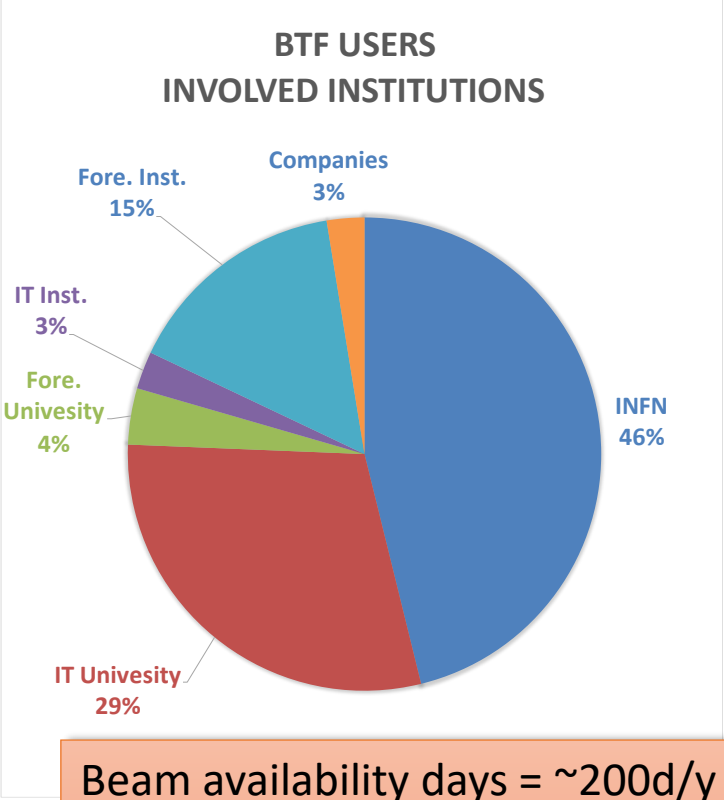
2018-2023 Activities

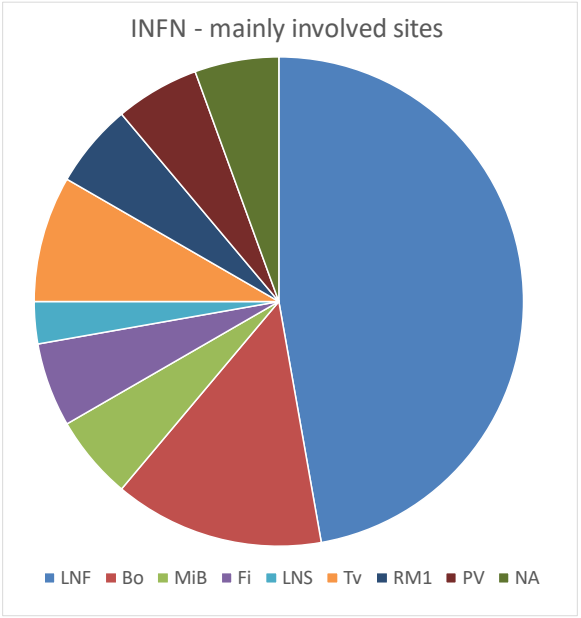


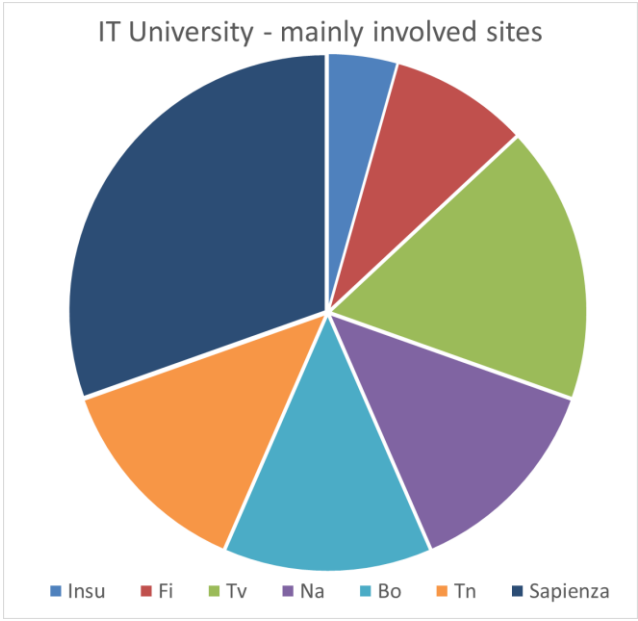
Beam Availability Days (up to Nov 2023)



BTF 2022-2023 users:



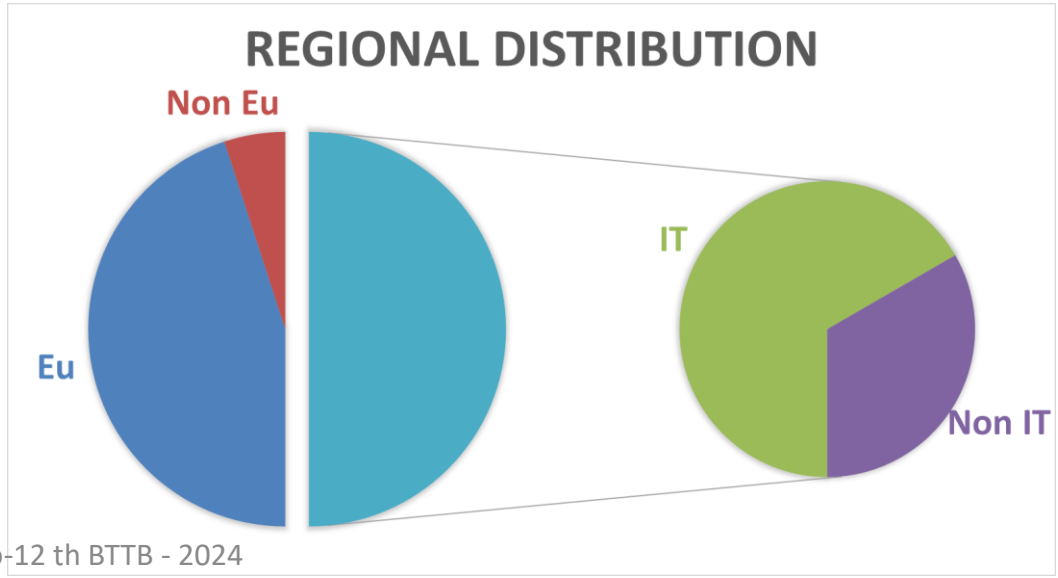




Beam availability days = ~200d/y
Shift average time = 7d
Average team member number = 8

2023 BTF mostly used for:

- New Solid-state detector developing
- Space detectors test and calibration
- HEP detector developing

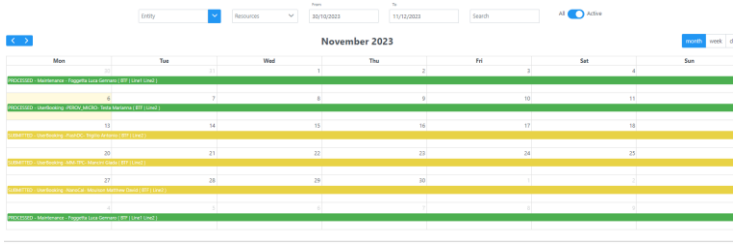


BTF Booking software

Booking BTF: BTF booking management software based on an automated approval workflow software. Call management.

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

- First **operative use on March 2023**
- **Few bugs** in the first two months (only losing some user shifts display on UI but the automation worked well)
- Acquired some **other features** especially in the Admin section to ease calendar management in case of last-minute shift renunciation or rebooking.



Hard to reach but could be a widely use new standard.
Around than 300 users has been managed (by this LNF app and staff)

Simple to use, as reported by users
Up to now, **the IT infrastructure has no detectable fault**
Many thanks to our scientific groups that acted as beta-tester user!

Designed by L. G. Foggetta
Developed G. L. Napoleoni (LNF Computing Center, main dev.), R. Orrú, M. Tota
BTF group and LNF Secretariats (and bug-finder group):

- AD-Secretariats (M.R. Ferrazza, G. Vinicola, V. Rosicarelli)
- Personnel-Secretariats (G. Dalla Vecchia, F. Triolo, L. Occidente, A. Mininni)

BTF - INFO

To get informed about BTF experimental call opening, please check:

- BTF site https://mediawall.infn.it/v/1030

and/or

- Subscribe to BTF Newsletter

If you need more information or help, please contact btf@lists.lnf.infn.it

BTF - Transnational Access

BTF is part of the EURO-LABS (EUROpean Laboratories for Accelerator Based Science) project that has received funding from the European Union's Horizon Europe Research and Innovation programme under Grant Agreement no. 101057511.

https://web.infn.it/EURO-LABS/
https://web.infn.it/EURO-LABS/transnational-access/

[BTF site](https://btf.lnf.infn.it/)

https://btf.lnf.infn.it/

https://btf.lnf.infn.it/schedule-beam-request/

[BTF wiki](https://wiki.infn.it/strutture/lnf/da/btf/home/)

https://wiki.infn.it/strutture/lnf/da/btf/home/

Technical, Call for submission information and documentation

[INFN User Portal guide](http://btf.lnf.infn.it/wp-content/uploads/sites/75/2023/03/Instruction_INFN_USER_Portal.pdf)

http://btf.lnf.infn.it/wp-content/uploads/sites/75/2023/03/Instruction_INFN_USER_Portal.pdf

INFN Identity management guide
(for getting BTF beamtime and access)

[Booking Call for beam time guide](https://btf.lnf.infn.it/wp-content/uploads/sites/75/2023/03/Booking_BTF_Call_Guide.pdf)

https://btf.lnf.infn.it/wp-content/uploads/sites/75/2023/03/Booking_BTF_Call_Guide.pdf

[Booking guide for Team Leader](http://btf.lnf.infn.it/wp-content/uploads/sites/75/2023/03/Booking_guide_team_LEADER.pdf)

http://btf.lnf.infn.it/wp-content/uploads/sites/75/2023/03/Booking_guide_team_LEADER.pdf

[Booking guide for Team Members](http://btf.lnf.infn.it/wp-content/uploads/sites/75/2023/03/Booking_guide_team_MEMBER.pdf)

http://btf.lnf.infn.it/wp-content/uploads/sites/75/2023/03/Booking_guide_team_MEMBER.pdf

Call for proposal submission guide

[BTF submit proposal software](https://booking.dsi.infn.it/)

https://booking.dsi.infn.it/

INFN Identity management guide
(for getting BTF beamtime and access)

Conclusions:

- The BTF of INFN @Frascati labs, near Rome in Italy is an opportunity for the developers of particles detector to test their device electron and positron beam without cost if it is for scientific purpose.

- Next Users call will be open waiting the PADME results.