SATIF-16
May 28-31, 2024
Shielding aspects of Accelerators, Targets and Irradiation Facilities

INFN BTF

The Beam Test Facility of the Laboratori Nazionali di Frascati

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SATIF-16, May 28th 2024

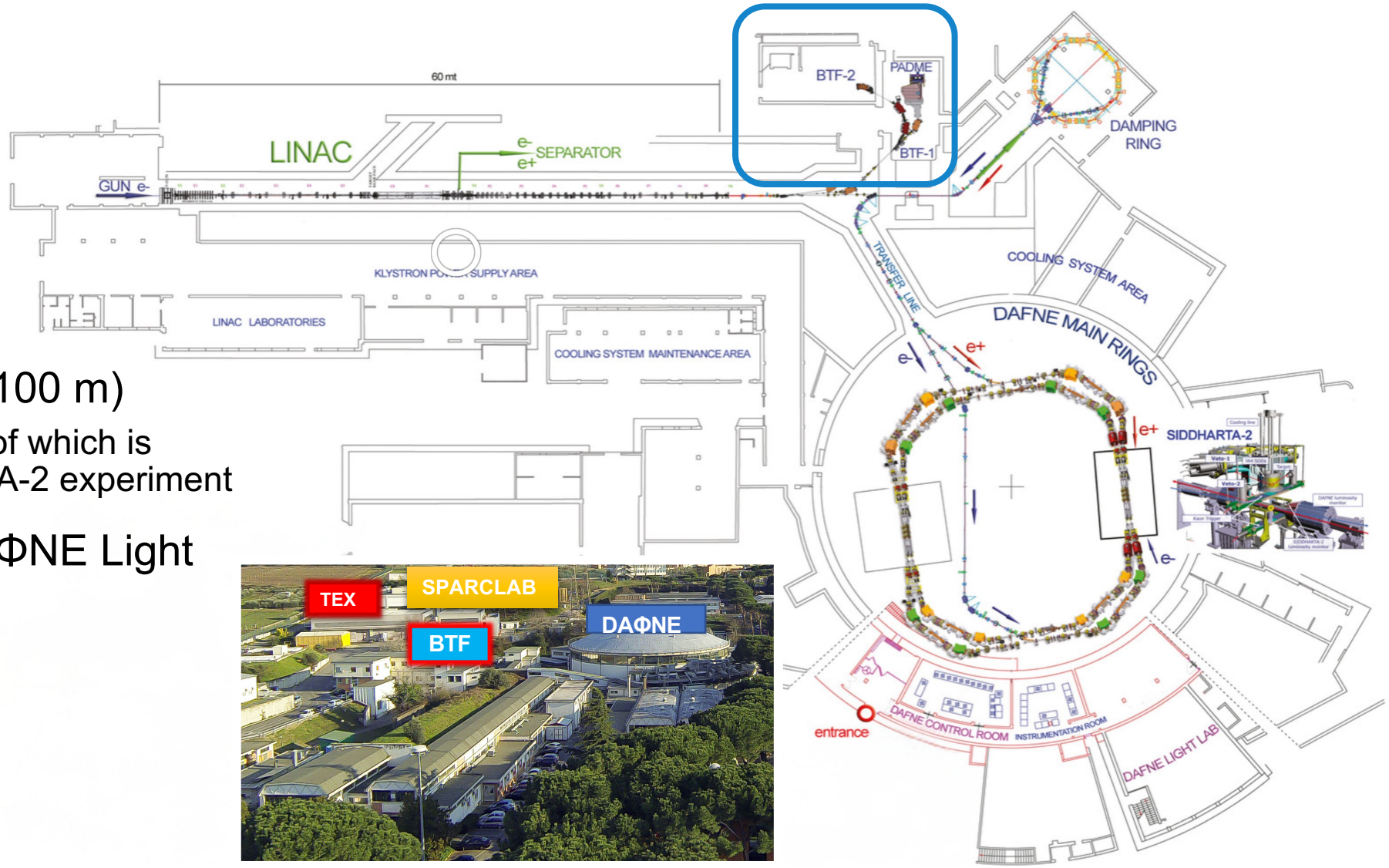
Outline

- The accelerator of the National Laboratories of Frascati
- The Beam Test Facility (BTF):
  - the LINAC
  - Experimental halls & beam lines
  - Beam production
  - Beam parameters
- Conclusions

The DAΦNE accelerator complex

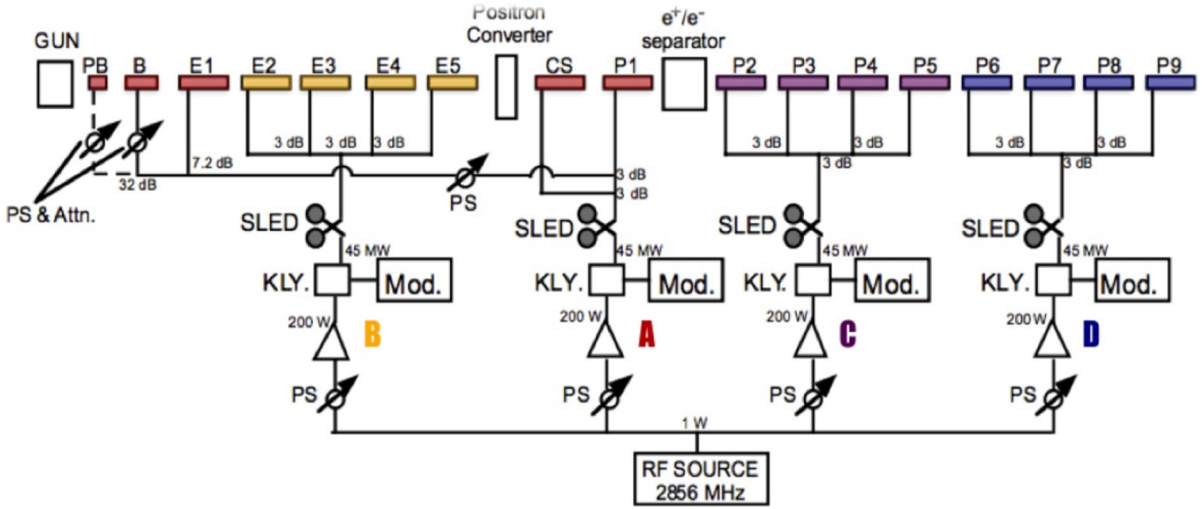
The activities of BTF are connected to those of the e^+/e^- collider DAΦNE, which consists of:

- A LINAC (e+/e-)
- A damping ring
- Two accumulation rings (~100 m)
  - Two interaction points, one of which is occupied by the SIDDARTHA-2 experiment
- Two facilities: BTF and DAΦNE Light



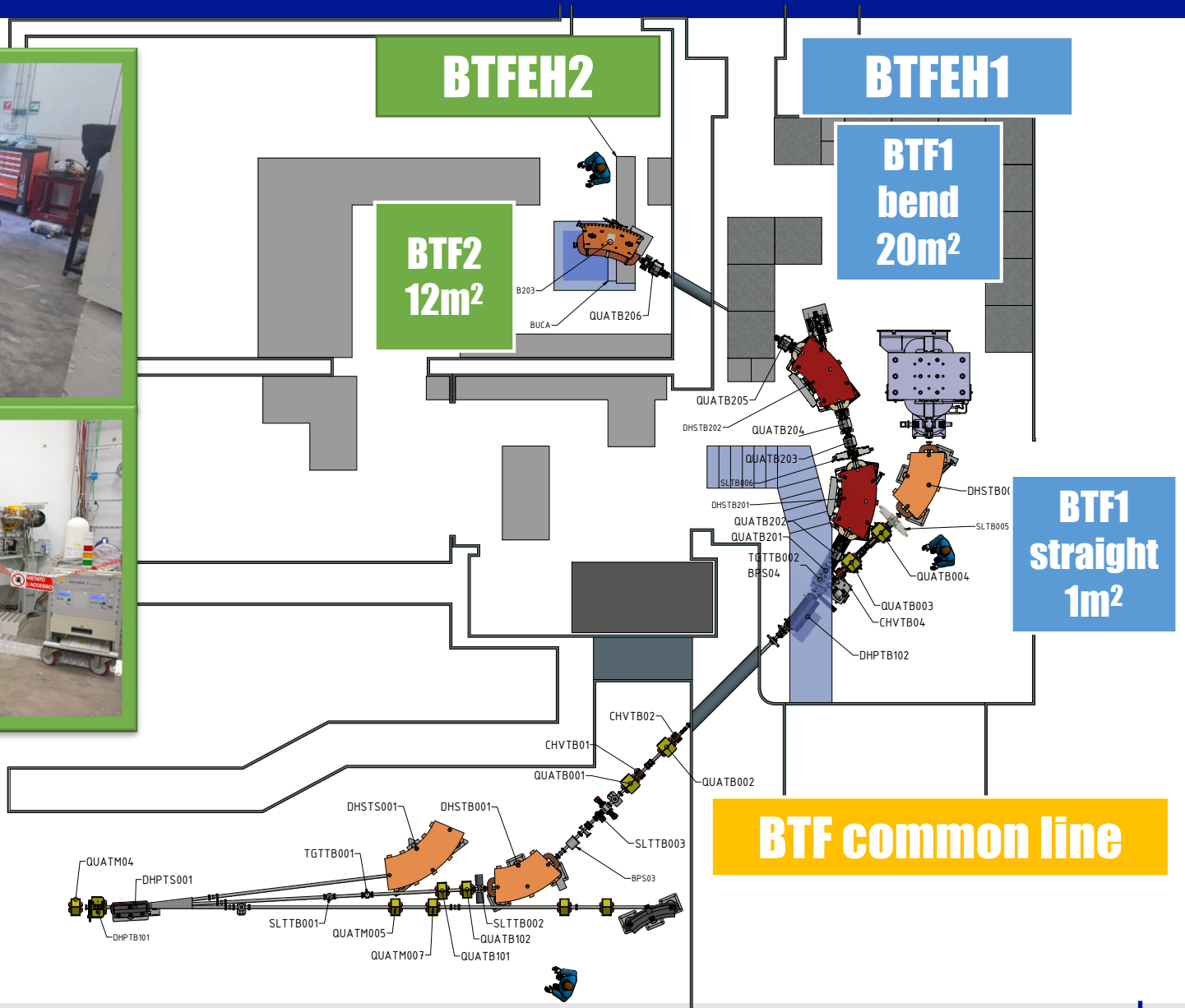
From the LINAC to DAΦNE

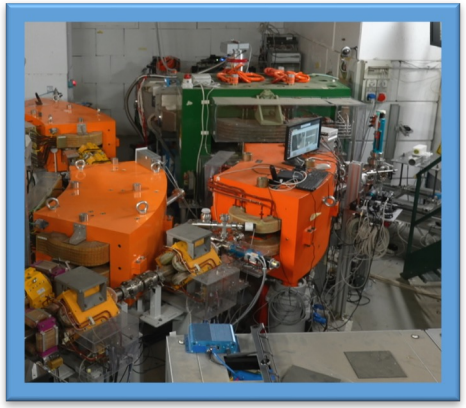
- Pulsed machine with **10ns** bunch envelope **repetition rate = 50/25 Hz.**
  - Initially developed for a few hours of uptime per day with a 10 ns pulse length.
  - When used for DAΦNE, BTF spare pulse injections
  - Special beam testing in BTF dedicated mode.
- Extended capabilities of the LINAC includes:
  - Continuous operation - 24/7,
  - tested macrobunch length of up to 320 ns (on positrons).
  - Primary electron beam energy spans from **160 MeV to 780 MeV.**



	Design	Operations (top)
Final energy e^-	800 MeV	510 MeV (780)
Conversion energy e^+	250 MeV	220 MeV
Final energy e^+	550 MeV	510 MeV (535)
Radiofrequency	2856 MHz	
Accelerating structure	SLAC-type, CG, $2\pi/3$	
RF amplifiers	4×45 MW klystron with TH2128C sleds	
Repetition frequency	1 Hz ÷ 50 Hz	1 Hz ÷ 50 Hz
Pulse duration	10 ns	1.4 ns ÷ 320 ns
Beam size on e+ converter	1 mm	1 mm
Normalized emittance (mm mrad)	1 (e^-) / 10 (e^+)	1 (e^-) / 10 (e^+)
Energy spread (RMS)	0.5% (e^-) / 1.0% (e^+)	0.5% (e^-) / 1.0% (e^+)
Output current e^- (510 MeV)	>150 mA	180 mA (>500)
Output current e^+ (510 MeV)	36 mA	50 mA (>85)

Overview of the experimental hall

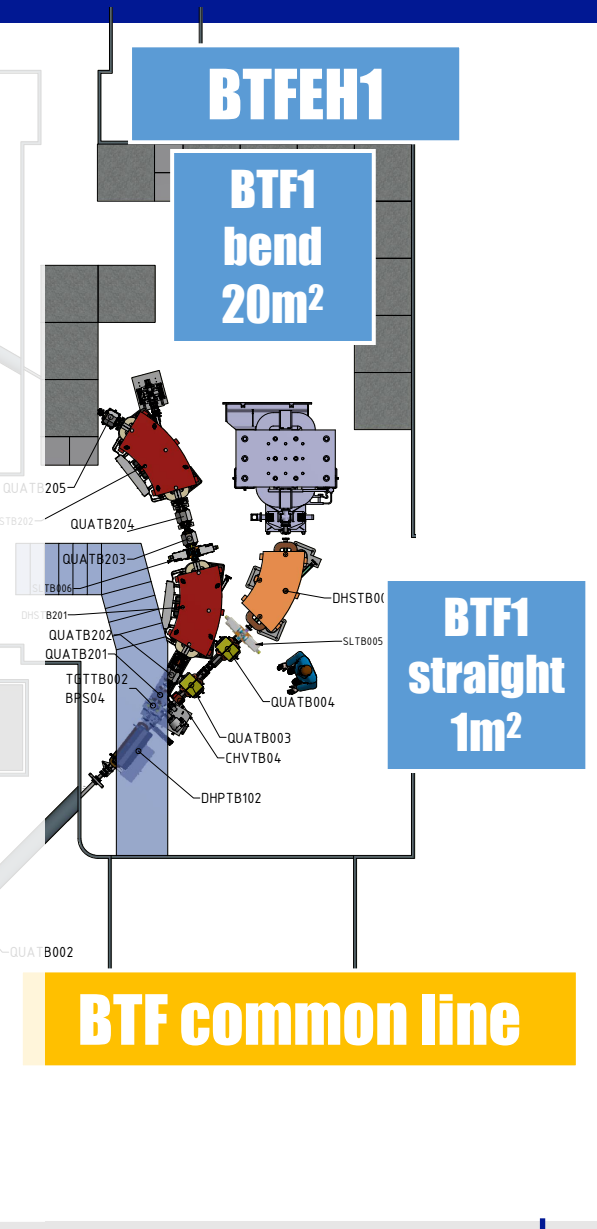


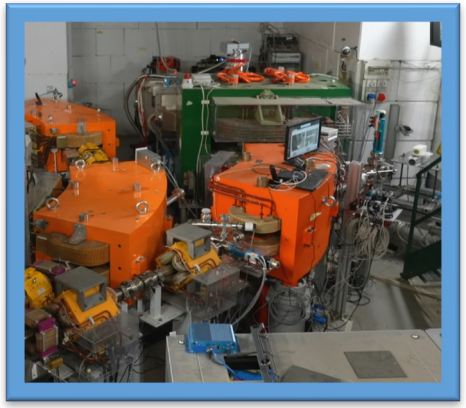


Overview of the experimental hall

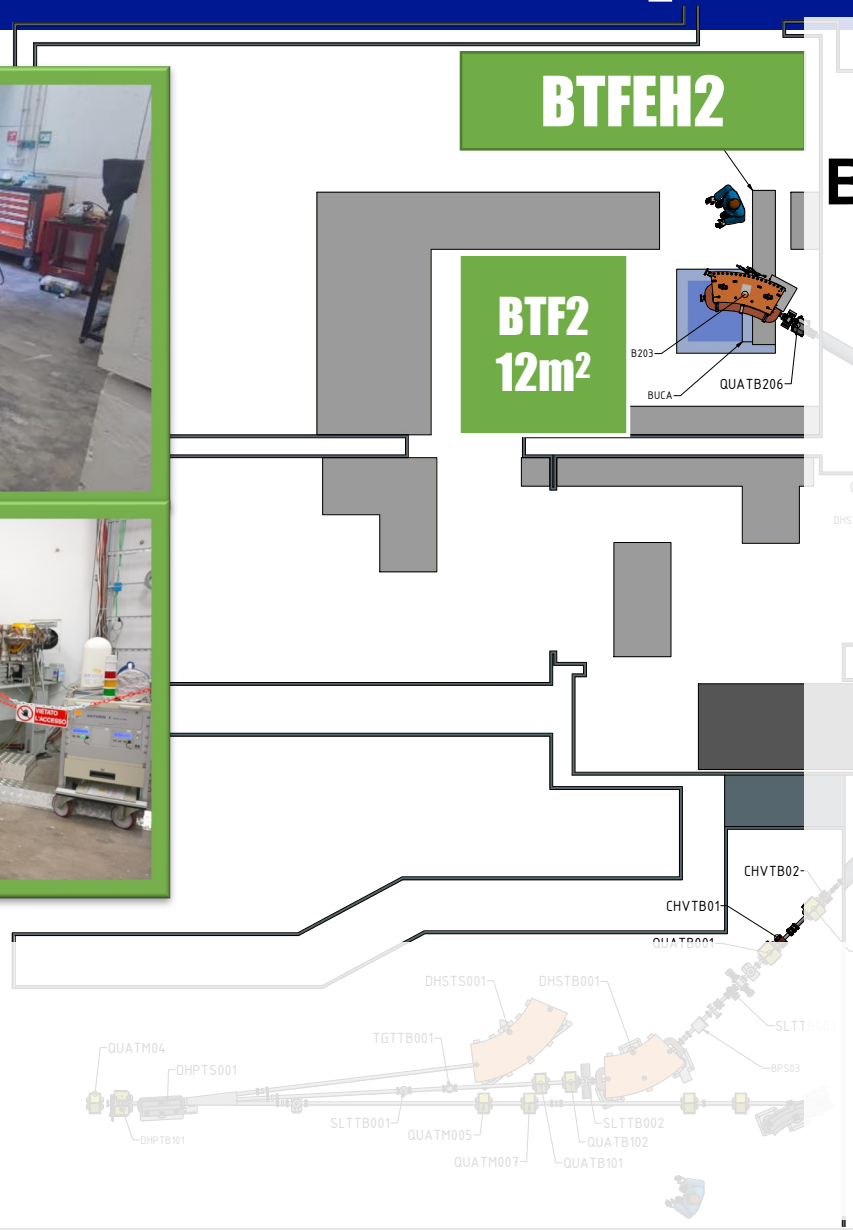
BTFEH1 – BTF1 (2 lines)

- Foreseen activity for PADME/X17 in 2025 Q1 at least
- Involved in internal/opportunistic INFN runs
- FLASH VHEE community interests – 3 runs both in primary and secondary beam





Overview of the experimental hall



BTFEH2 – BTF2 (1 line)

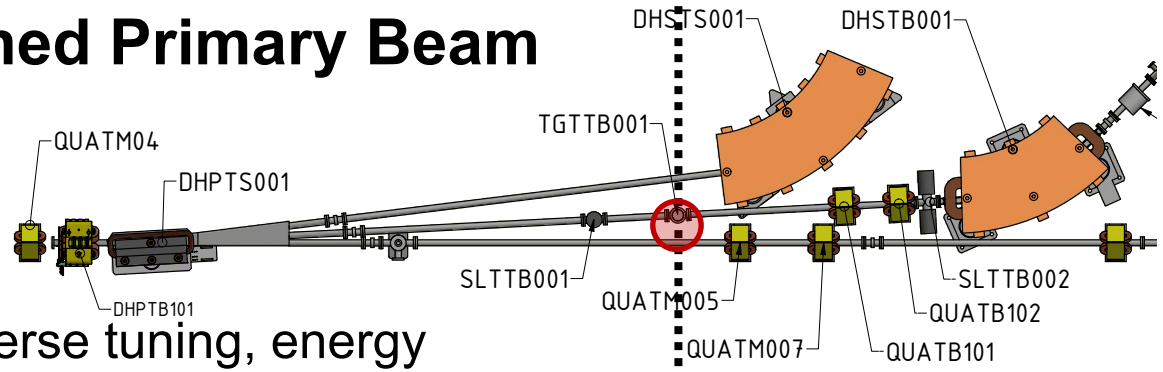
- Hall operative from 2022
- Currently BTF2 line to external users
- Intended for weekly based users
- **Only secondary beam**
- Upgraded performances – 0.4x0.4mm² at BTF2 Exit window
- Beam time foreseen up to mid-July 2024
- Programmed user call for 2024 Q4

The BTF beam parameters

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 10^{10}	1–10^5 (Energy dependent)	1 to 10^{10}	1–10^4 (Energy dependent)	
Max int flux	3x10^{10} part./s				1x10^6part./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	

Primary and secondary beam in EH

LINAC Conditioned Primary Beam

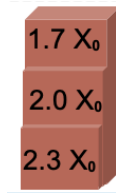


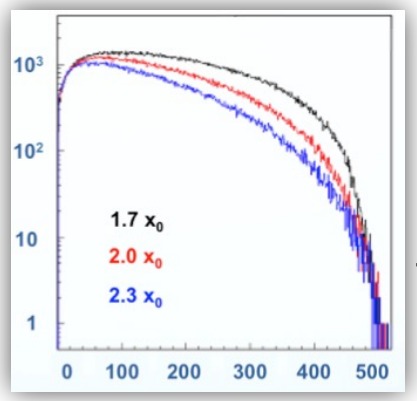
Fixed energy:

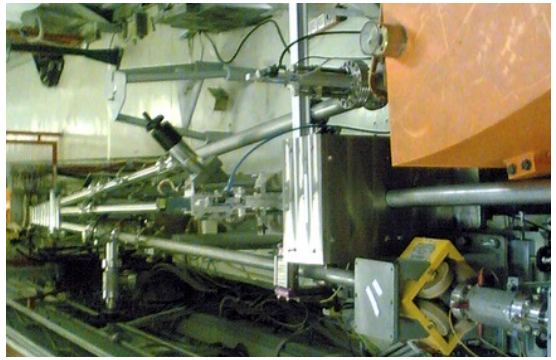
- Steering and transverse tuning, energy setup longer implementation

High current up to ~10^{10} particle/shot:

- from DAΦNE injection current
- Tunable in 10 order of magnitude







Secondary beam

- RUN time **Tunable energy**
  - All energies from $E_{primary}$ to ≈25 MeV
- RUN time Tunable multiplicity
  - From **~10^4 to single particle per shot**
- Particle type decoupled from LINAC production

Both energy and intensity setup faster implementation

- Parameters setup via LINAC and BTF scrapers/magnets
- Final focus user dependent
- All parameters manageable during data

Diagnostics: Primary beams

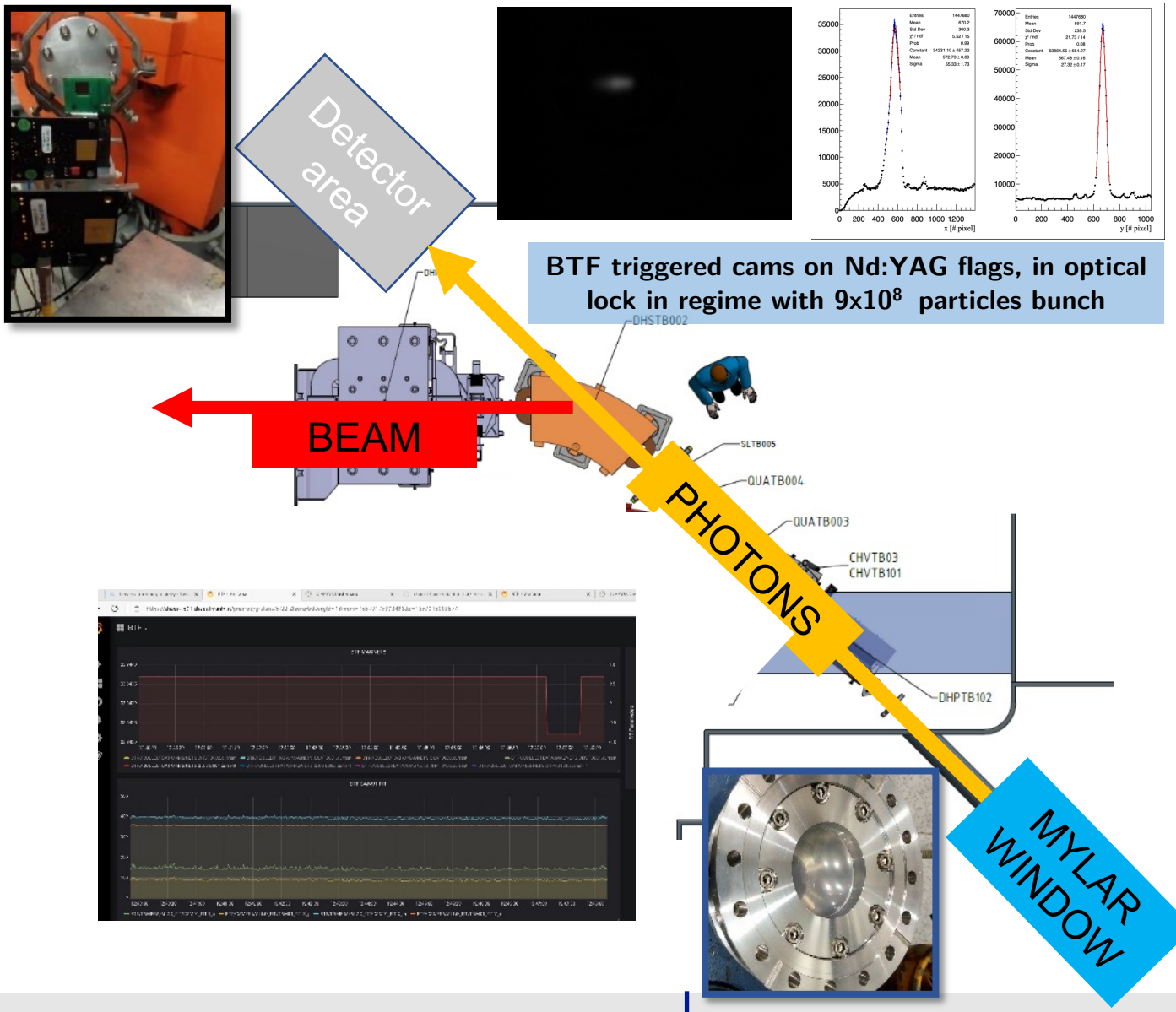
Direct measurement

- Beam passing through the detectors
- Bergoz Integrating Current Transformer

- Flags and triggered fast cam, DAQ parameter shot by shot
- Faraday cup

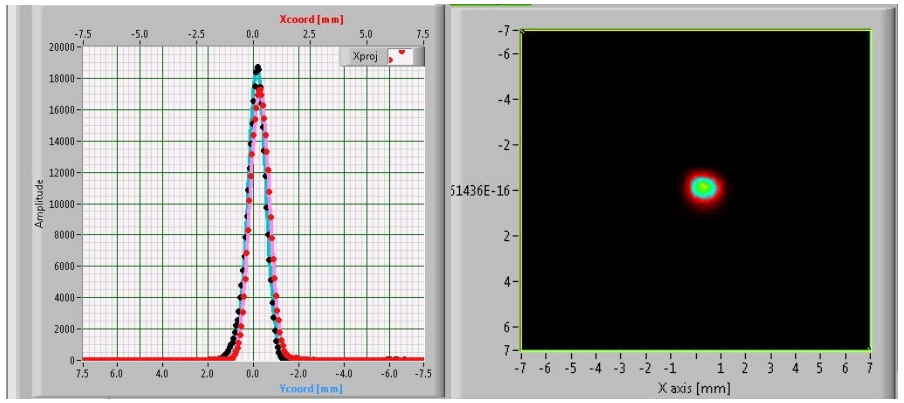
Indirect measurement (secondary γ)

- Beam steered to experiment, detectors get secondaries
- Lead Glass Calo and FITPix get Bremsstrahlung photon from mylar window (vacuum decoupler for static-ionic to dyn-TMP vacuum types)
- Energy collected is less a factor of 0,001 of the total steered charge (12m away)
- Used to calculate approx. delivered charge, beam length, uptime
- Higher measurement errors (~10%)

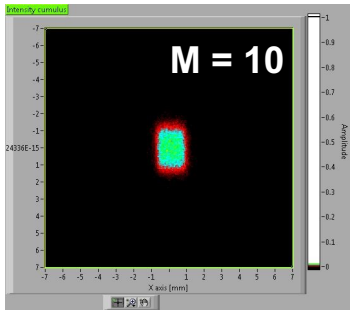


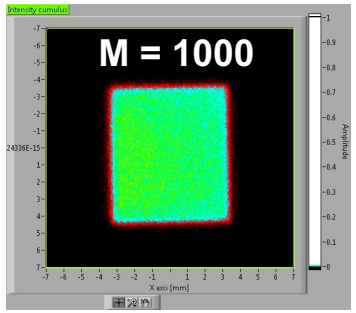
Diagnostic for Secondary beams

- **ADVACAM FITPIX/TIMEPIX detectors**
  - 256×256 pixels, 55 μm pitch, 14×14 mm² active area
  - 300 μm thickness sensor
  - Three FitPIX devices operational
- **LEAD GLASS Calorimeter: higher beam**
- **BGO segmented Calorimeter under test rn**

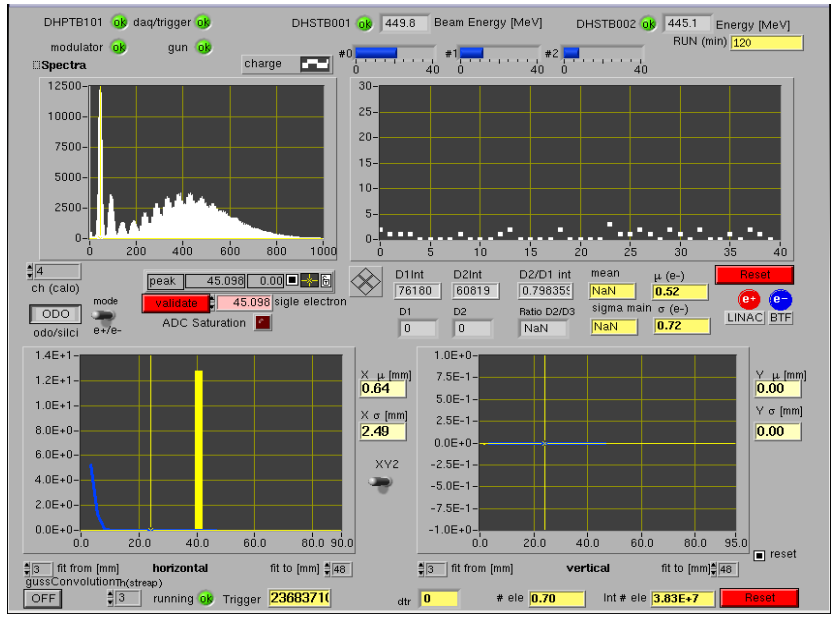


5 days long measure in BTFEH2
- 450MeV, 0.4x0.4mm², >600k events single particle (l poiss=0.8)
- **3x10⁶ TOTAL EVENTS**





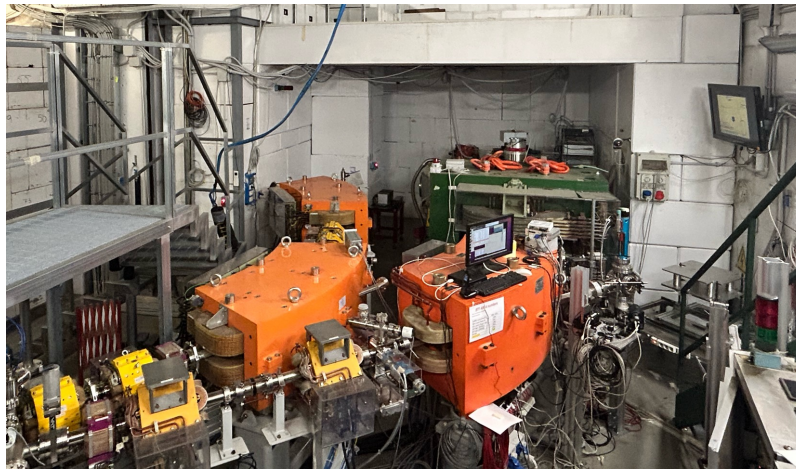
Square beam 450 MeV
- **<10% Flatness**
- **Secondary electron beam in BTF1 Line**
- **Few minutes of exposure**



BTF Users

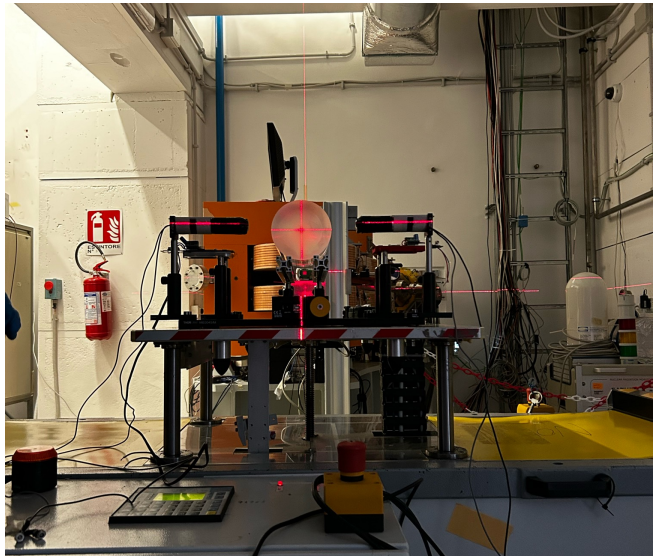
BTFEH1:

- Fixed target experiment: PADME/X17
- High intensity beam:
  - Dosimetry calibration
  - RadHard
  - VHEE related instrumentation (this year)
  - Machine diagnostic/detector development
  - Nuclear Physics



BTFEH2:

- New detector development (HEP Physics)
- Single particle diagnostic calibration (HEP, Medical physics)
- Payload calibration (Space applications)
- New materials characterization



BTF runs FLASH VHEE regime

FLASH: New strategy for tumor treatment involves using **an ultra-high dose rate exceeding 40 Gy/s**.

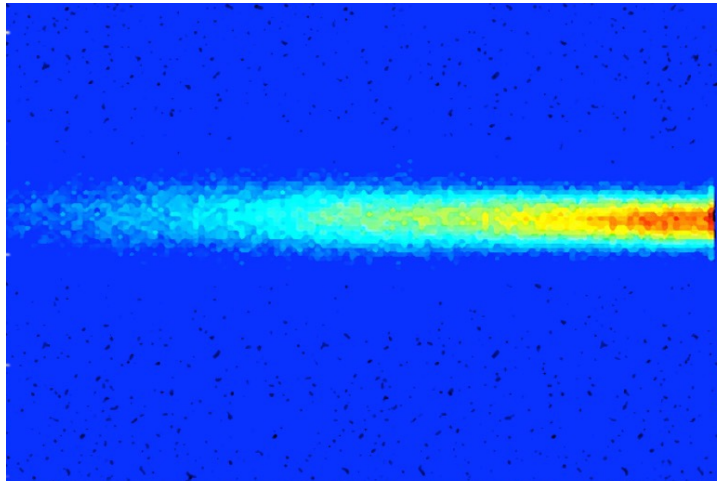
- Compared to conventional radiotherapy, FLASH exhibits similar tumor inhibitory effects while causing less harm to normal tissues, a phenomenon known as the "spare" effect
- Experimented with low energy (4-7 MeV) electrons

EH1: Longitudinal and transverse shower profile in PMMA from gafchromic film. 510 MeV, 10^{10} particle/bunch

- **VHEE FLASH LINAC:** Aiming to treat deep-seated tumors with Very High Energy Electrons (50-200 MeV).

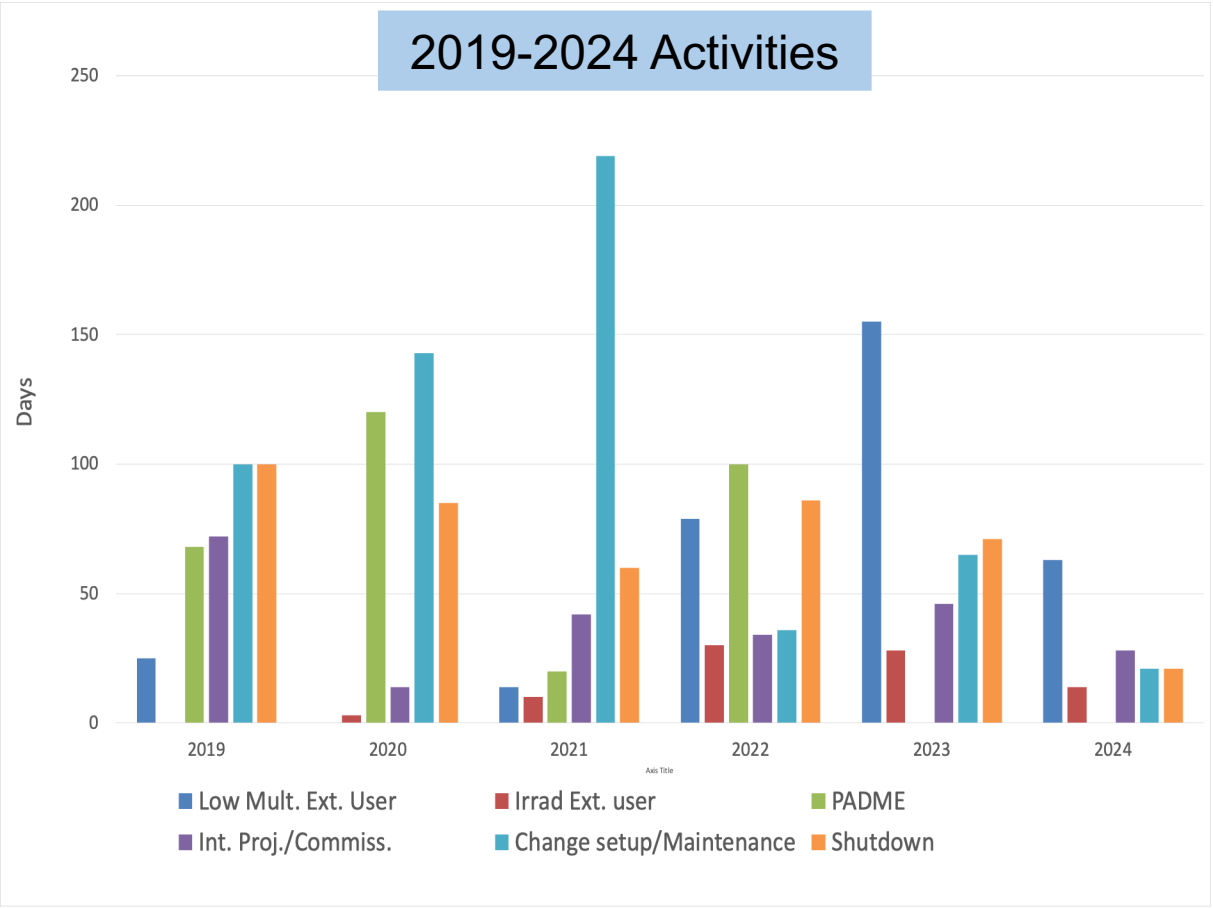
Scientific Needs explored in BTF (EH1 and EH2)

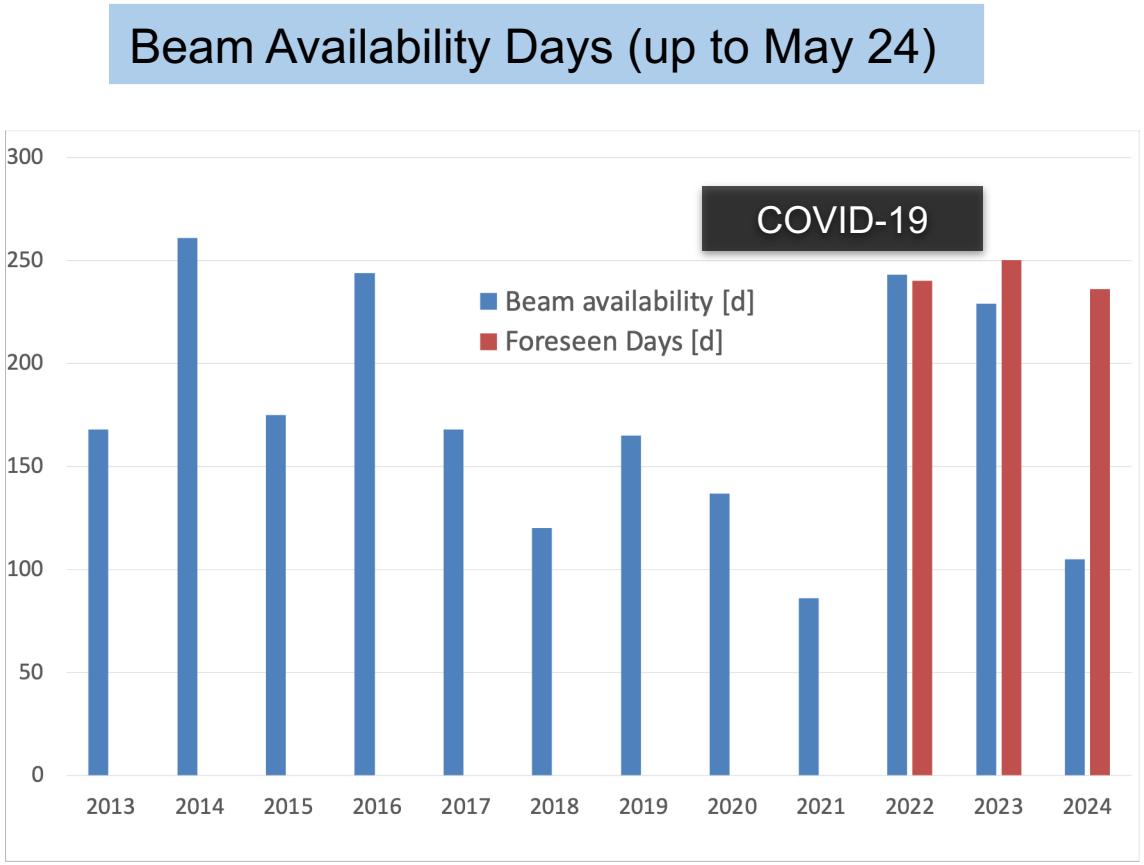
- **Control Imaging Systems - MORSEPET**
- **Certified dosimetry in FLASH regime – DIAMONDS for VHEE**
- **New beam fluorescence measurement in air – FLASHDC**



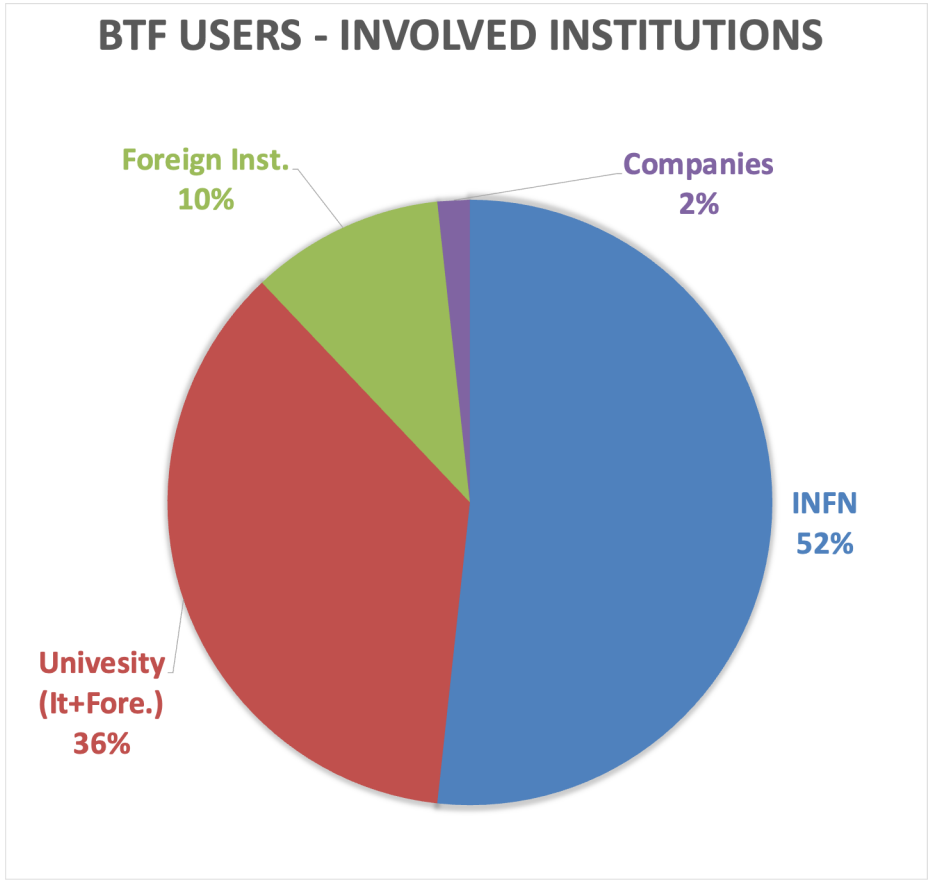
EH2: 150MeV electrons secondary beam, m=1k, single shot EJ212 plastic scintillator foil parallel to the beam direction

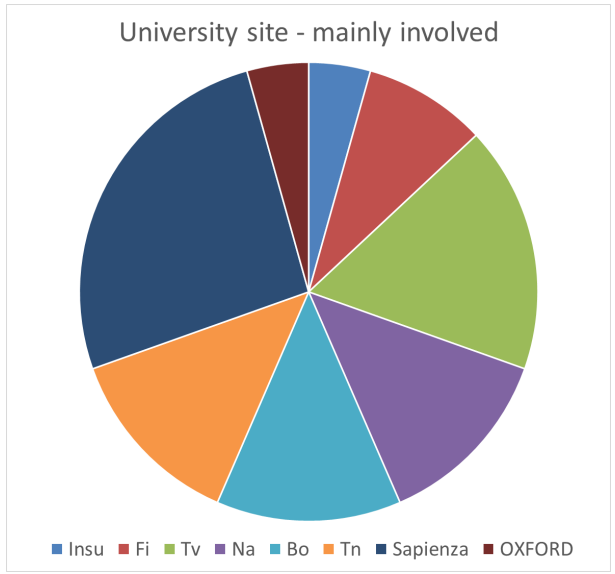
BTF- Activities

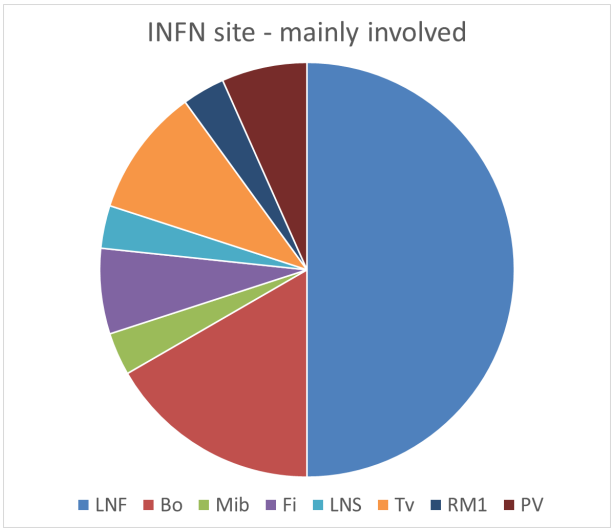


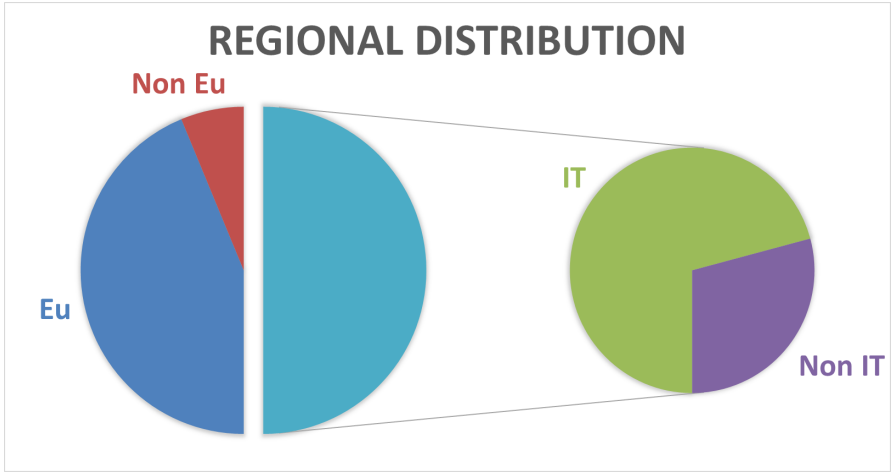


2022-2024 Involved Institutions









Services to users

BTF Services available to 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, 2 lines just implemented

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, optical mounting kits

DAQ, Data delivery

•VME based (QDC, TDC, Scalers…)
•LC8108 scope (8Ch's,5Gsam/s, 1GHz BP)
•!CHAOS triggered cams online data analysis
•Grafana online data monitoring

Triggering:

•Digital delay, particle type latching

Ancillary services

•Fluids, Compressed Air, Lab service

BTF-INFO

- To get informed about BTF experimental call opening, please check:
  - BTF site
  - Subscribe to BTF Newsletter
  - If you need more information or help, please contact btf@lists.lnf.infn.it

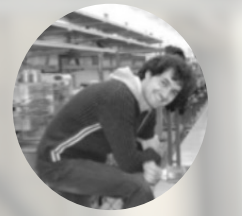
BTF - Transnational Access

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/

Conclusions

- The Beam Test Facility at the National Laboratories of Frascati provide external users with **e^+/e^- beams in various configurations** for the development and characterization of detectors.
- The BTF can produce e^+/e^- beams with a variable multiplicity ranging from **1 particle/bunch to 10^{10} particles/bunch**, with a maximum energy of **700 MeV (e^-) and 500 MeV (e^+).**
- The strength of the BTF lies in a **wide variability of beam parameters that can be changed even during data acquisition**, even by the users themselves.
- The facility is organized into **two experimental halls and three beam lines.**
- Currently, of the three beam lines, one is available to users and is equipped with a remotely controlled table for user use, beam diagnostics, and ancillary services.



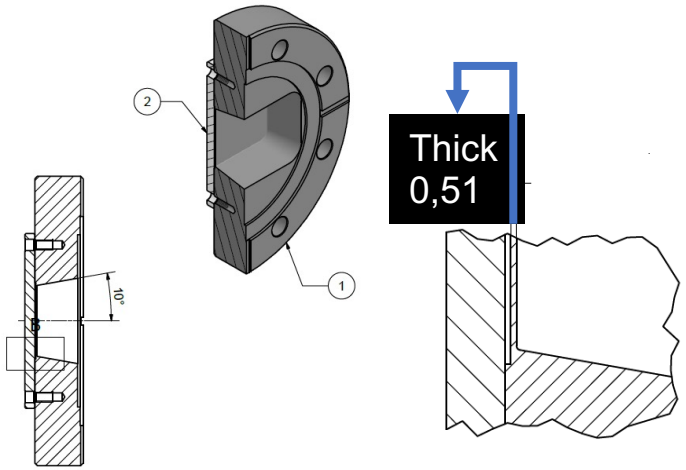




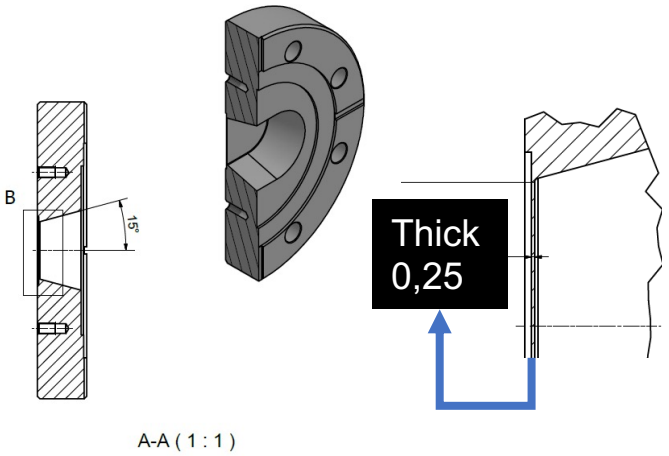
Thank you!

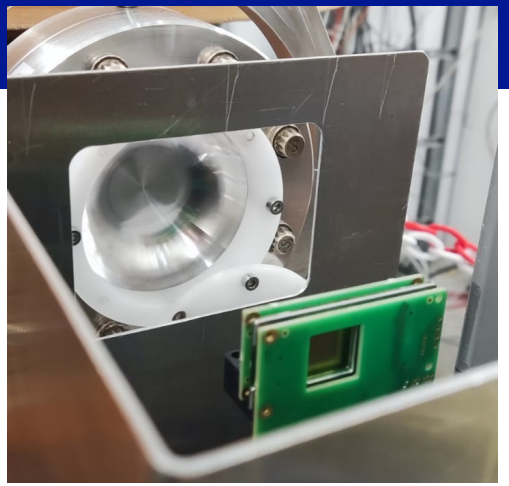
BTF2 vacuum windows

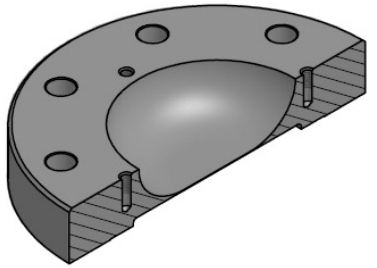
DHSTB203 – BTF2



DHSTB201-202







Easier beam setup operation

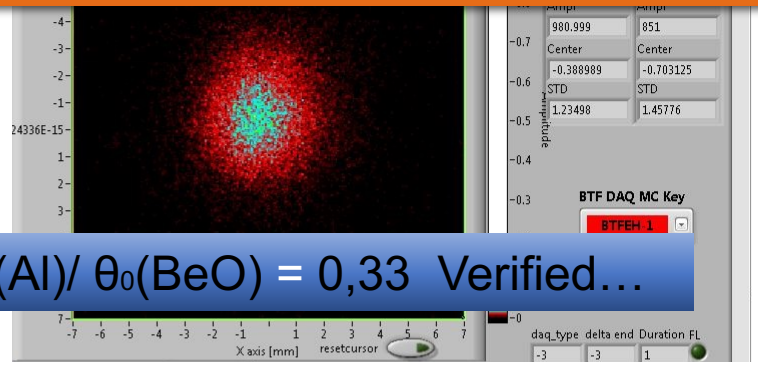
Developed specific tool and machining procedure to reach 100um at flat (one inch)

Trials with 80um -> ok but…you know

Cycle Test:
20 cycle bar abrupt vent _> leak <1.8x10^-8mb*l/s

Low energy beam transverse improvement!
50MeV m1, electrons -> σx/σy=1,21/1,45 [mm]

	BeO	~Al	
Radiation length	13,72	24.01	cm
Critical energy	74,86	42,7	MeV (for e^-)
X/X0 in use	3,6E-3	5E-4	

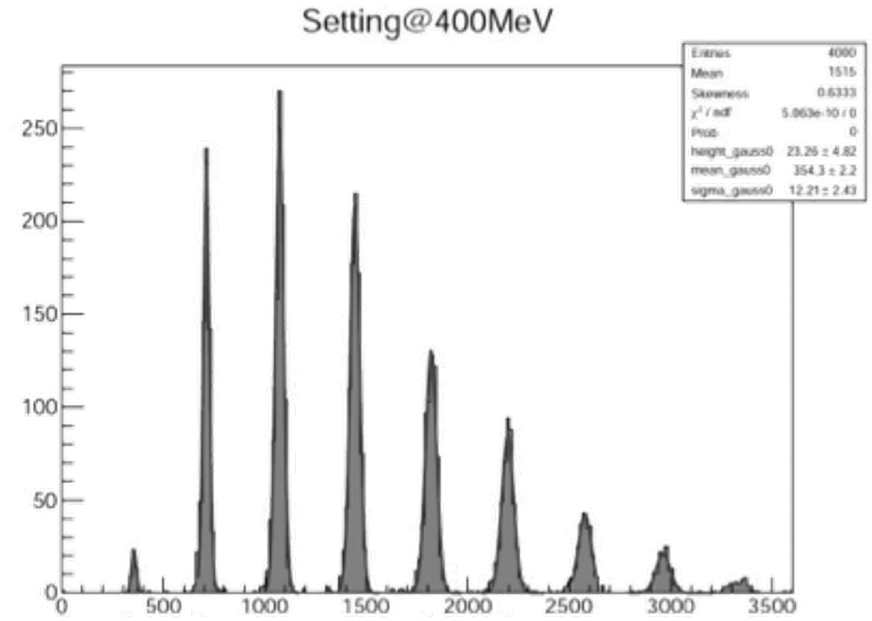


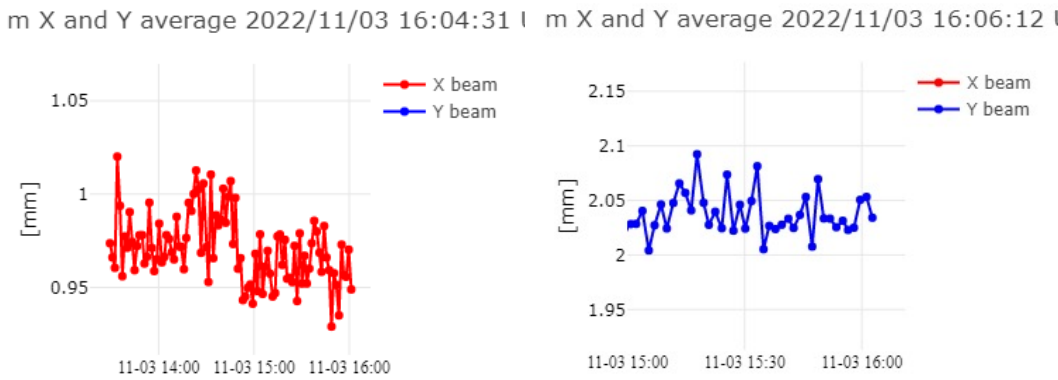
θ_0(Al)/ θ_0(BeO) = 0,33 Verified…

BTF beam intensity tuning

Adjustment of the number of particles can be achieved:

- Without changing the momentum resolution:
  - Modulating the LINAC current : Act on transport optics or modulators power/phase
  - Choosing another target depth →Secondary beam
  - Closing/Opening the down-stream vertical collimators
  - Closing/Opening the up-stream vertical collimators
- Changing the momentum resolution:
  - Closing/Opening the horizontal collimators





Sliced centroid position stability[mm]
230 MeV beam, M = 2.3k