The LNF - Beam Test Facility from single particle to billions

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on the behalf of BTF Group

AMICI-I.FAST
Workshop on Facilities for beam test of accelerator components
October 12, 2023
IFJ PAN Kraków

BTF Where

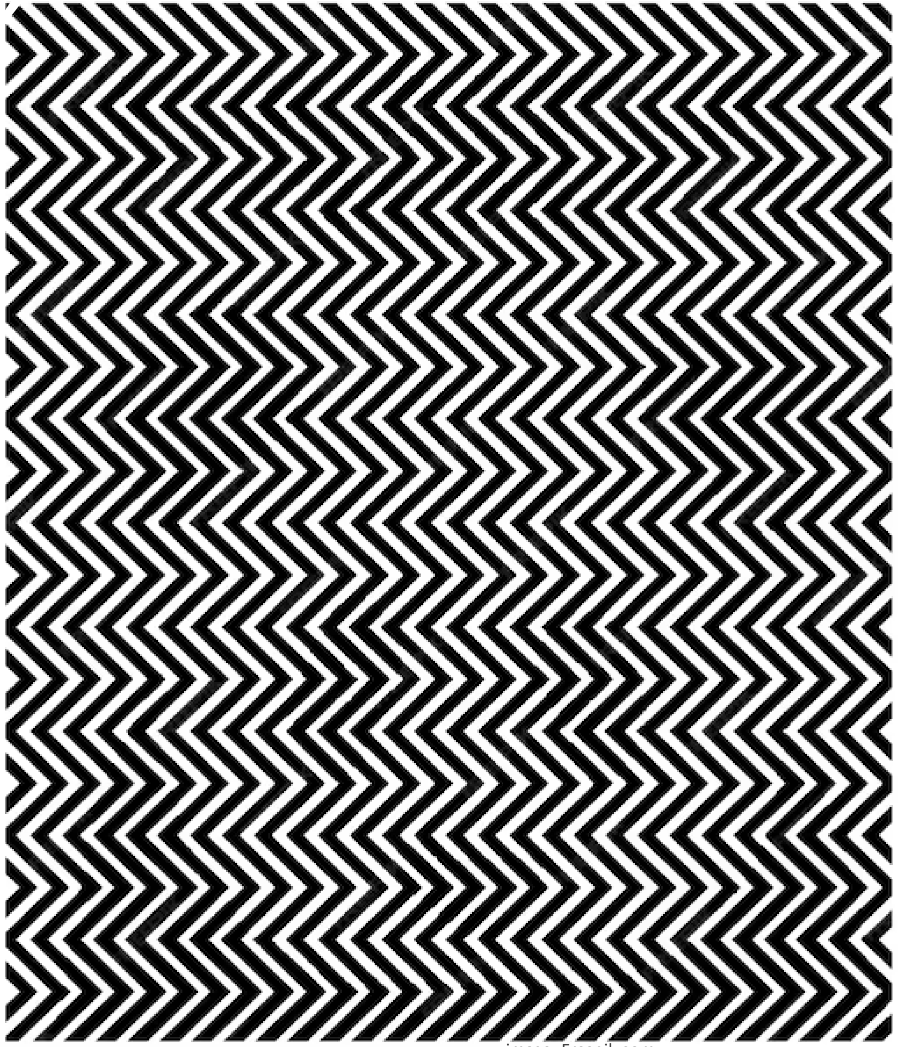
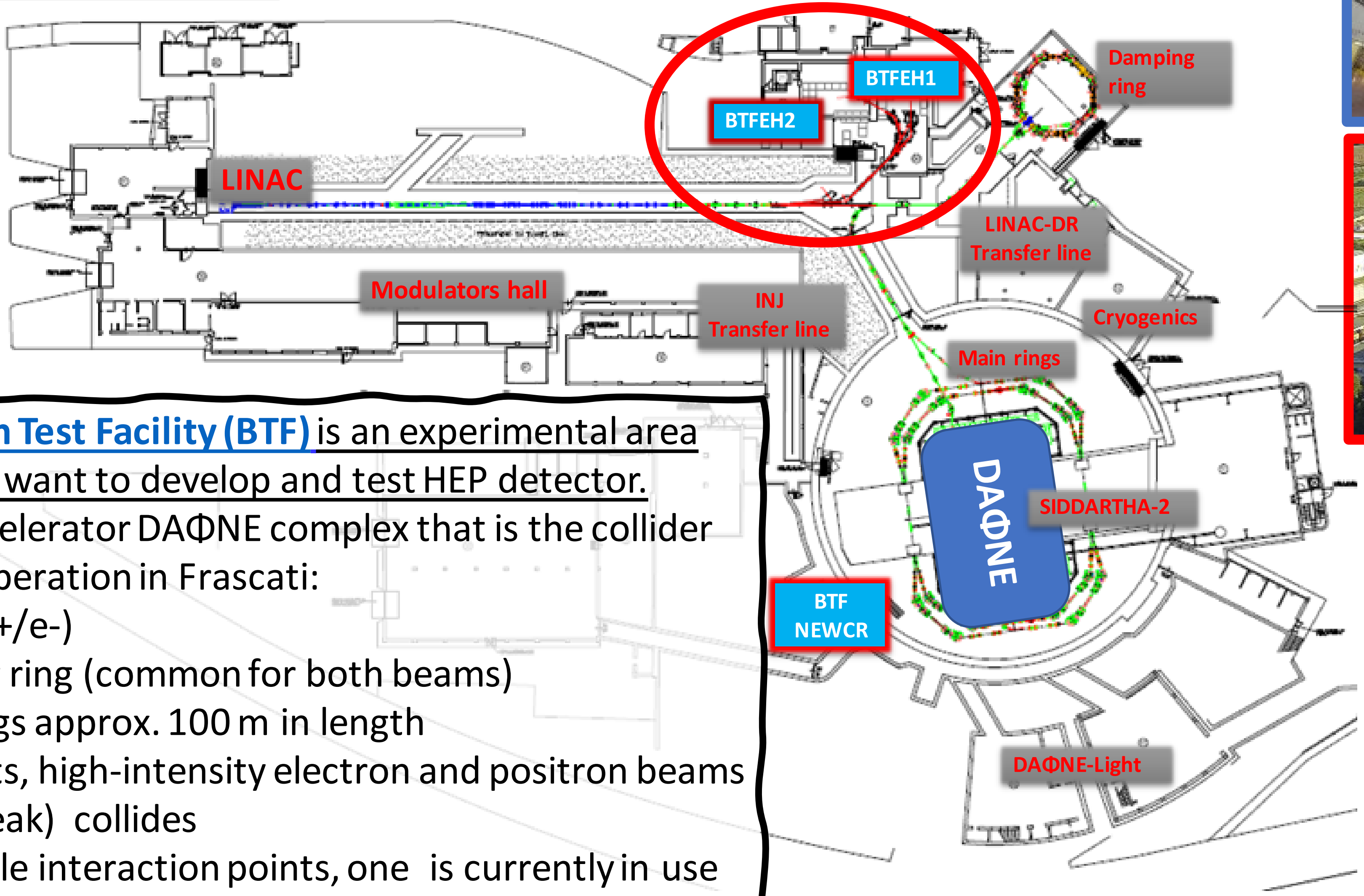


image: Freepik.com

The DAΦNE complex

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



The LNF Beam Test Facility (BTF) is an experimental area for users who want to develop and test HEP detector.
It's in the accelerator DAΦNE complex that is the collider currently in operation in Frascati:

- 1 **LINAC** (e+/e-)
- 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**

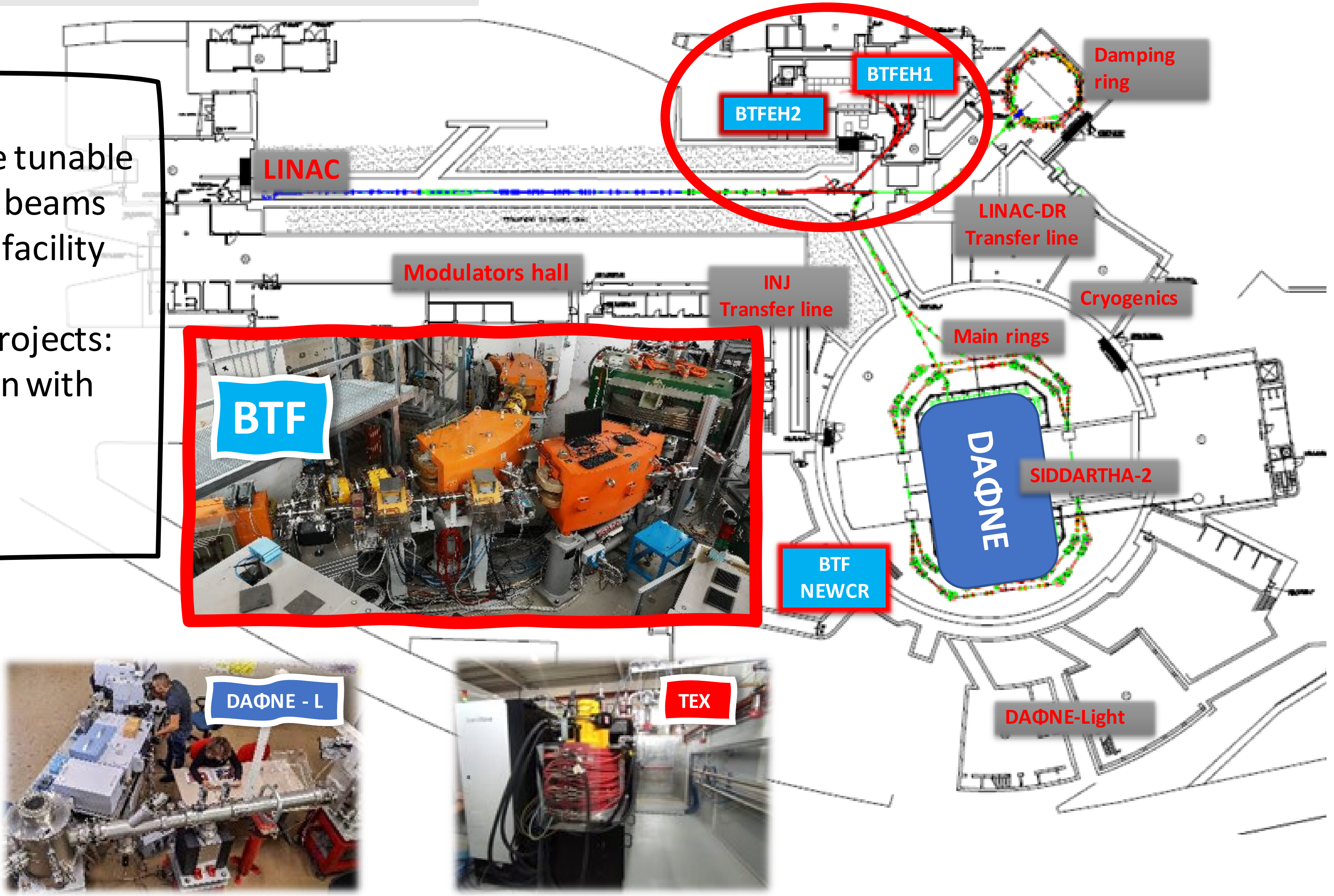
LNF LAB – USER FACILITIES

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 accelerator facilities/projects:

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



BTF
What and why

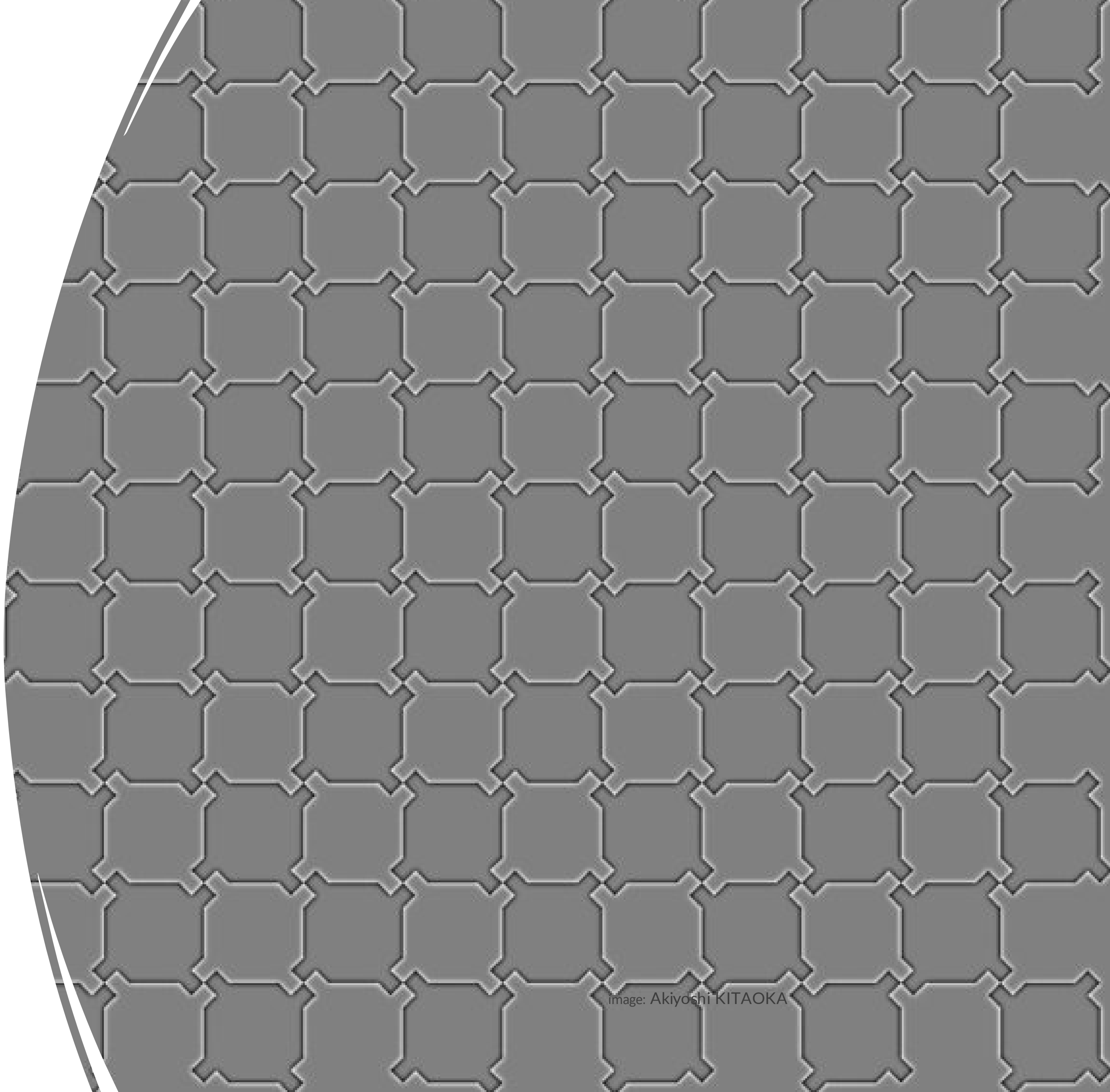


image: Akiyoshi KITAOKA

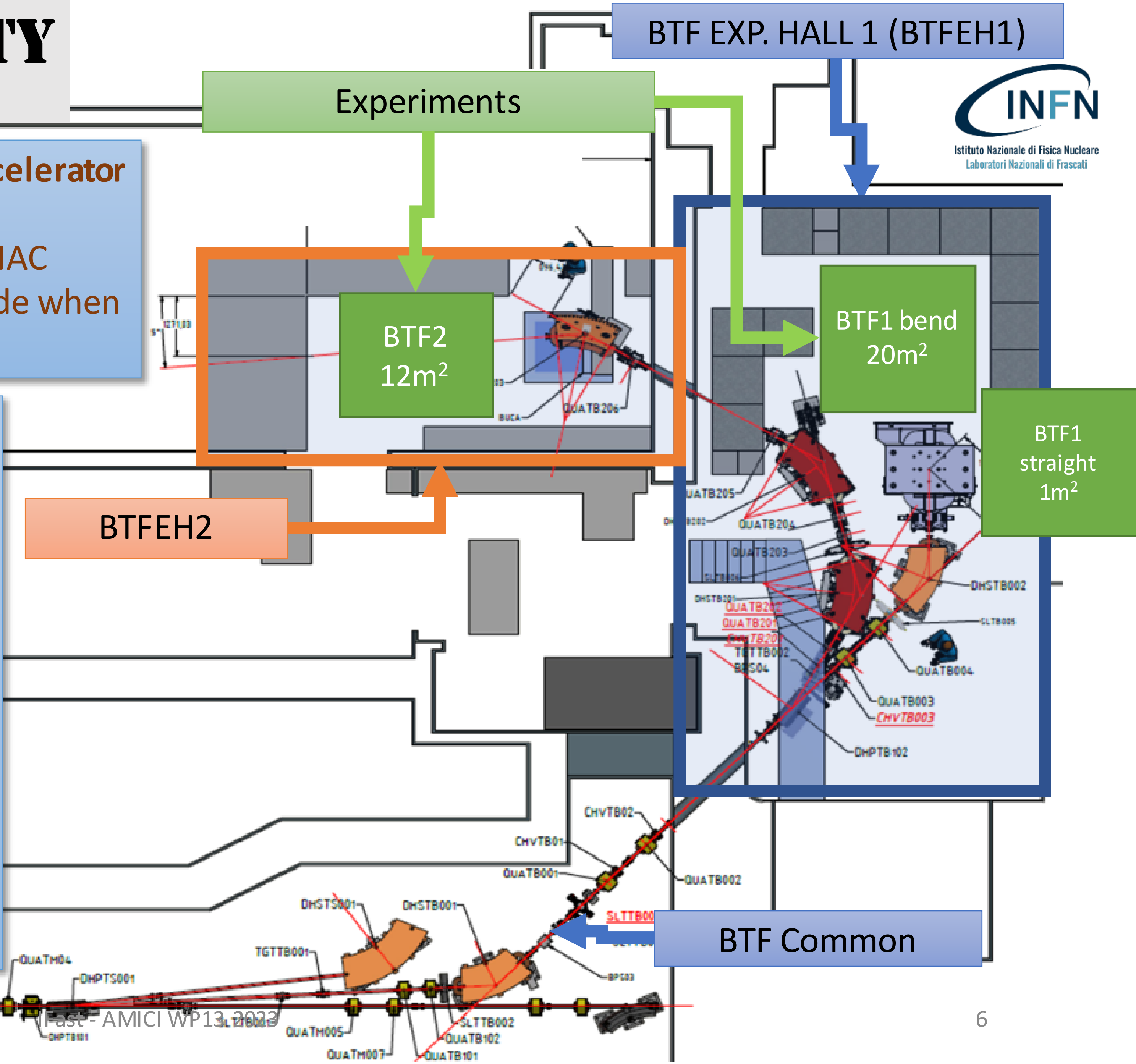
LNF – BTF FACILITY

The Beam Test Facility (BTF) is part of the DAΦNE accelerator complex in LNF (Frascati, Italy):

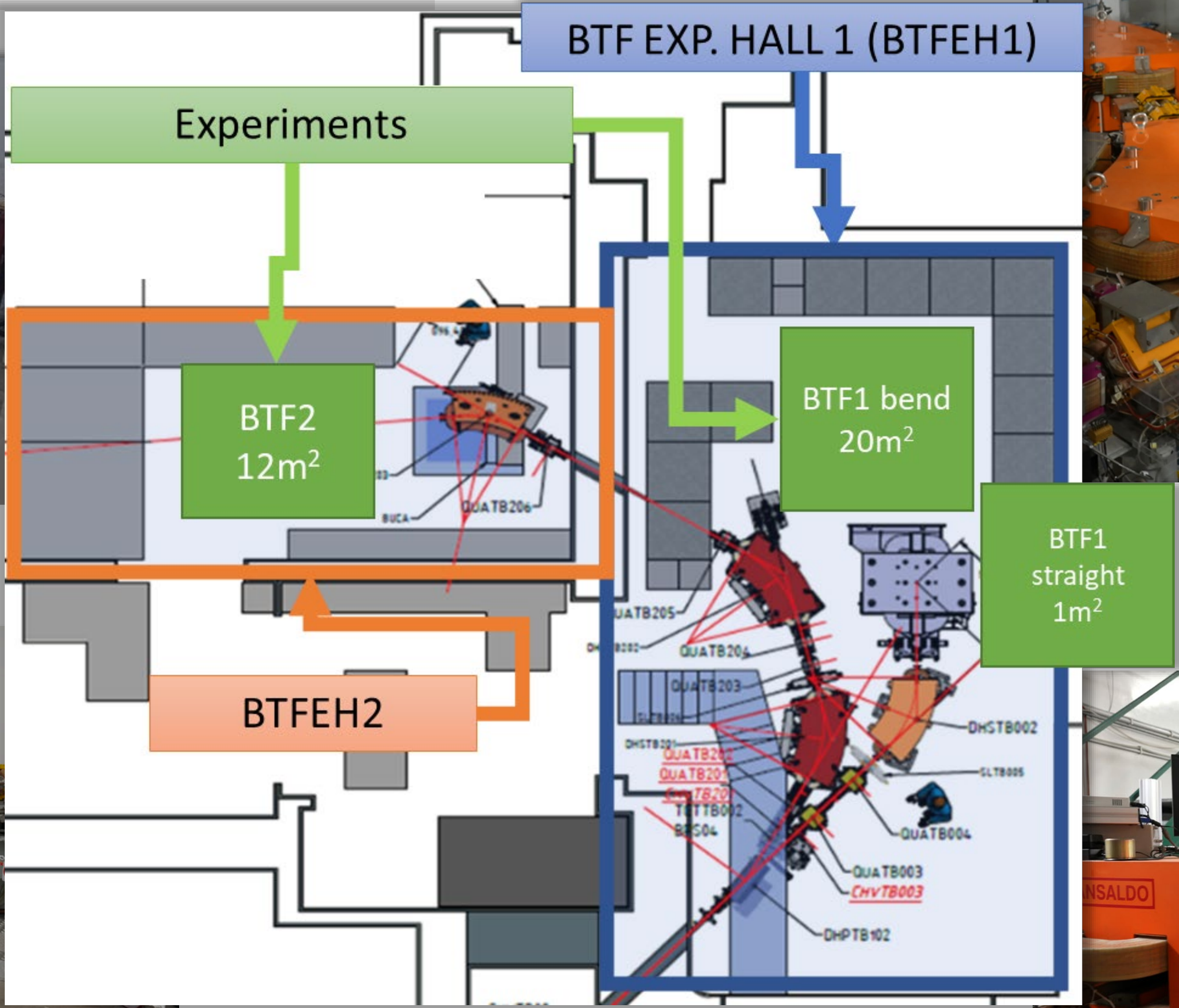
- it can extract and manipulate the high intensity LINAC e+/e- beam, in dedicated or beam spare-pulse mode when DAΦNE collider is operative since 20y

BTF is a facility:

- with a **pulsed** electron or positron beam, in a wide range of parameters
- optimized for detector **calibration, long time-based experiments and weekly test-beam in scientific coll.**
- with the possibility of **device e+/e- high flux irrad**
- with services at the user disposable
  - DAQ and DCS data,
  - Gas pipelines, dried compressed air
  - HV
  - Networking
  - Detectors
  - Dedicated Staff, Logistics
  - 24/7 operations

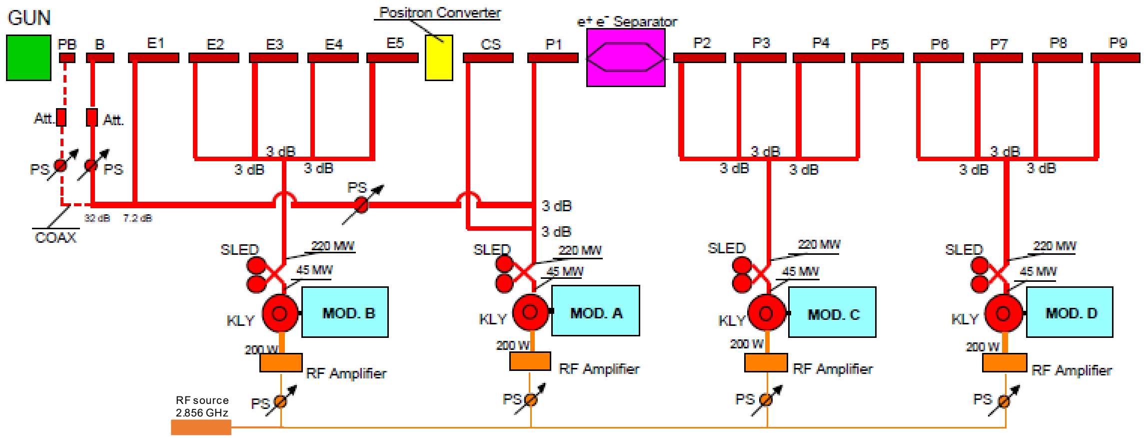


LNF – BTF FACILITY



LNF – LINAC FACILITY

	Design	Operational
Gun Type	120KV Thermoionic, Electron, Pulsed	
Accelerating structure	SLAC-type, CG, 2π/3	
RF source	4 x 45 MWp sled klystrons TH2128C	
Electron beam final energy	800 MeV	~780 MeV*
Positron beam final energy	550 MeV	~550 MeV*
RF frequency	2856 MHz	
Positron conversion energy	250 MeV	220 MeV
Beam pulse rep. rate	1 to 50 Hz	1 to 50 Hz
Beam macrobunch length	10 ns	1.4 to 320 ns (@0.01xcurrent)
Max Gun current (for positron production)	8 A	8 A
Beam spot on positron converter	1 mm	1 mm
norm. Emittance (mm. mrad)	1 (electron) 10 (positron)	< 1.5 <10
rms Energy spread	0.5% (electron) 1.0% (positron)	0.5% (electron) 1.0% (positron)
electron current on positron converter	5 A	5.2 A
Max output electron current	>150 mA	500 mA
Max output positron current	36 mA	85 mA



- Electron and positron beams from this pulsed LINAC
- Commissioning: 25 years ago
- When used for DAΦNE, BTF spare pulse injections
- Special beam test in BTF dedicated mode
- Developed for few uptime hours/day at 10ns pulse length
- **LINAC extended range:**
  - **Continuous Operation, 24/7, 50Hz**
  - **Now up to 320ns beam macrobunch length (tested on e+)**
  - **Now primary e- beam Energy span from (160,780)MeV**
  - **Now also conditioned primary single particle beam**

LNF – BTF THREE LINES STATUS

BTFEH1 – BTF1

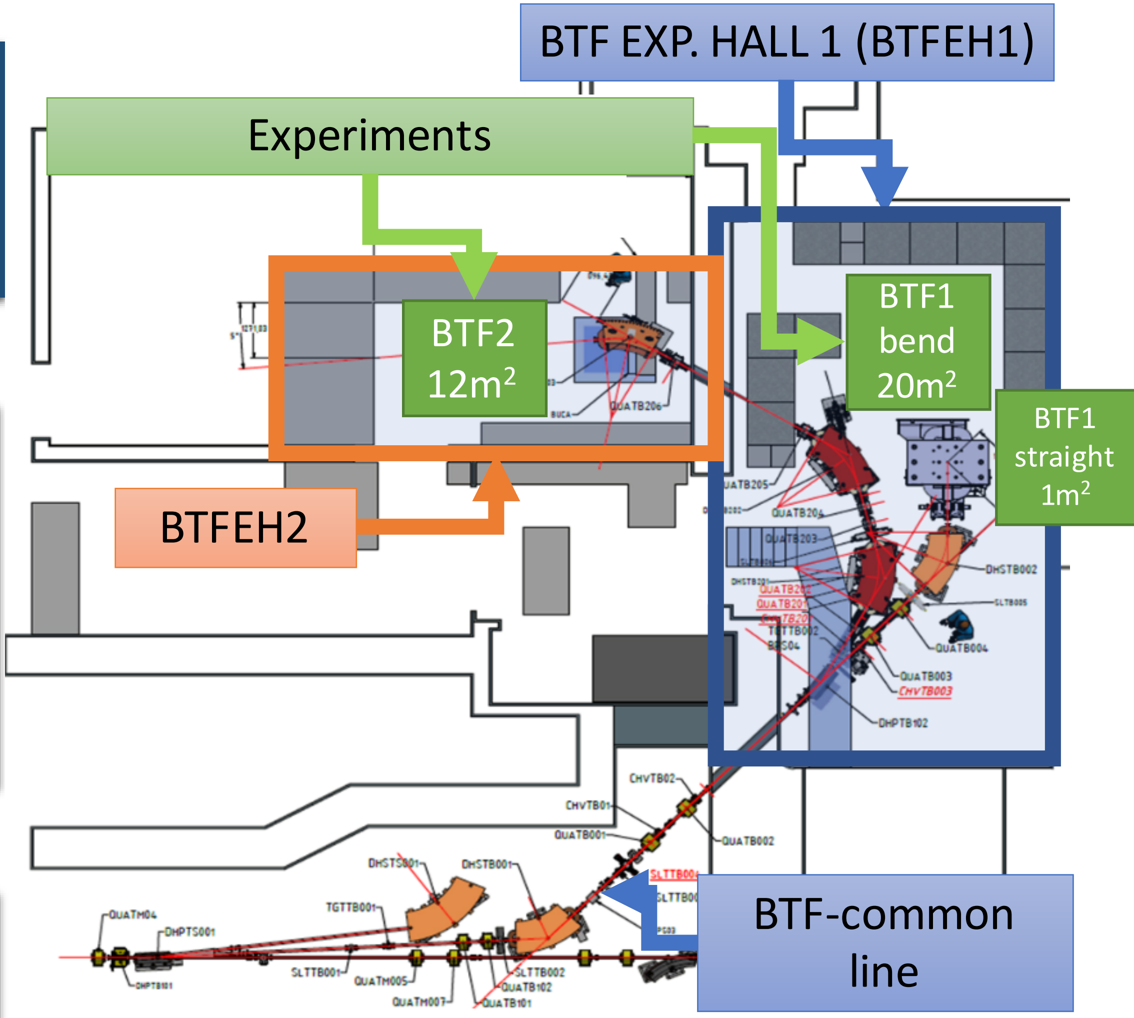
- Hall Operative, latest big setup change in 2017 for PADME installation
- Now mainly for long-time-based experiment (PADME-X17) - Opportunistic LNF runs
- Remarkable run FLASHMOB (99Tc production)
- 10^10 #/s current limit.

BTFEH2 – BTF2

- Installed in the old BTF control room, built in 2021 and operative
- BTF2 line devoted to external users, only secondary beam
    - 2023 Calls opened
        - Jan to July
        - Sept to Dec
- Upgrade beam performances respect to first runs (transverse param.)
- 10^6 #/s current limit.

BTFEHs

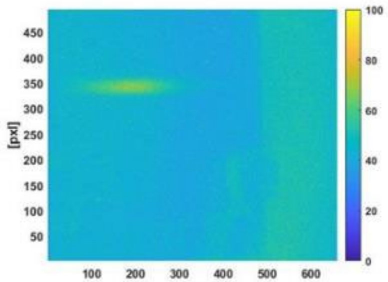
- **EUROLABS project, started in 2022**
- **Software for automated call and user management**
- **Involved in INFN-A,**



BTF PRIMARY AND SECONDARY BEAMS IN EH

LINAC Conditioned Primary Beam

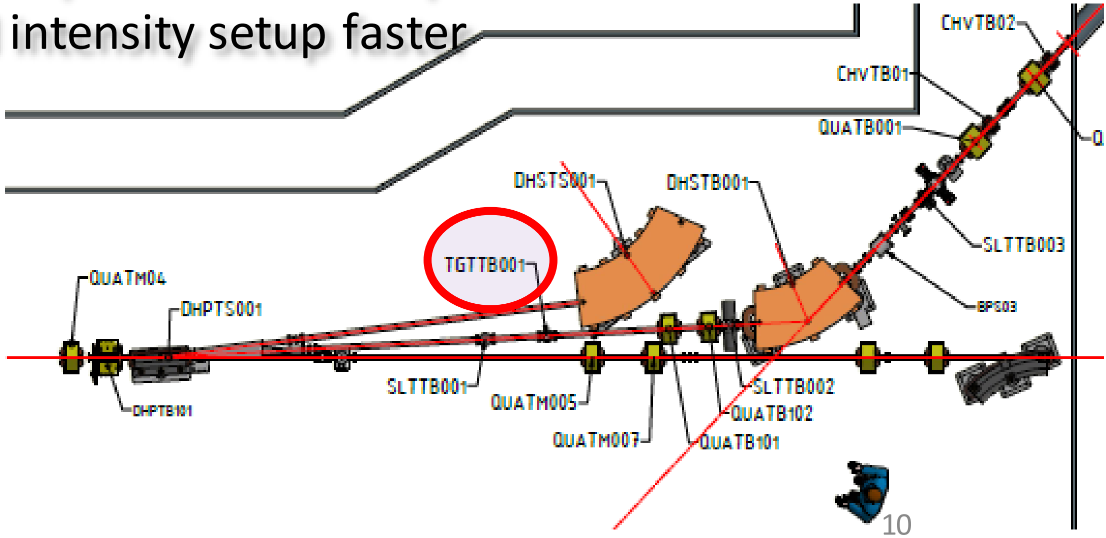
- Fixed energy
  - Steering and transverse tuning, energy setup longer implementation
- High current
  - from DAΦNE inj current
  - Tunable in 10 order of magnitude (dedicated mode)



510MeV, prim. e+ beam, OTR, BTFEH1

Cu-Target in the middle

- RUN time Tunable energy
  - All energies from $E_{primary}$ to ≈30 MeV
- RUN time Tunable multiplicity
  - From max(E) 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 taking

BTF PRIMARY BEAM

- Fixed Energy (Straigth forward from the LINAC)
- Multiplicity (current) selection (Scrapers)
- Spot transverse dimensions (Scrapers, Quad for final focus)
- Matching angle and position in the DUT (Dipoles and Correctors)
- Maximum allowed intensity ≈ 10^10 prim/sec in BTFEH1

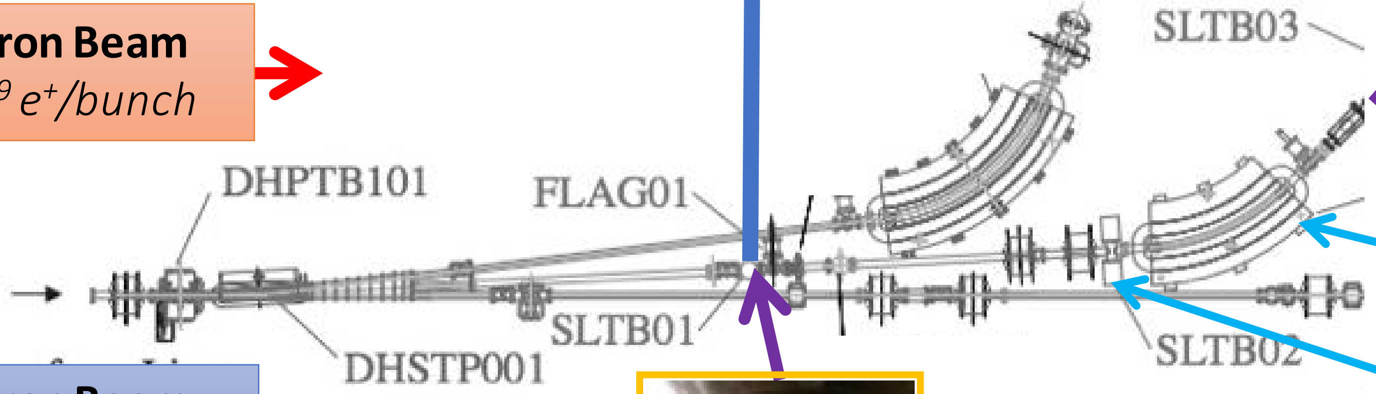
Normal way of thinking

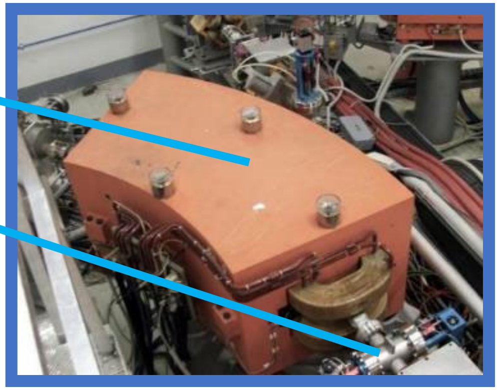
PRIMARY | **PRIM conditioned**

Positron Beam
6×10^{9} e^{+}/bunch

Electron Beam
3×10^{10} e^{-}/bunch

TO BTFEH1





DIAGNOSTICS: PRIMARY BEAM

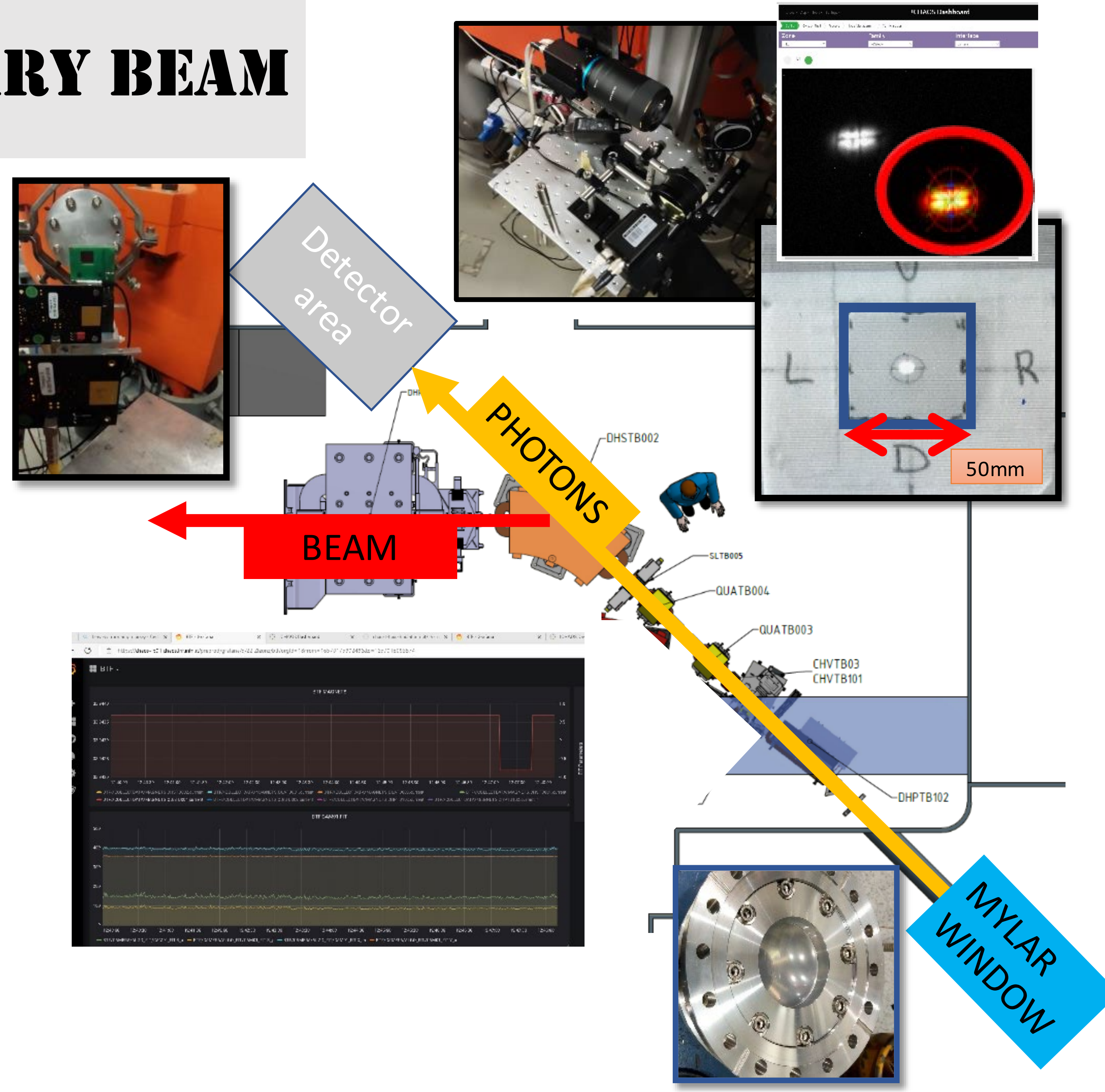
Primary beam diagnostics (some of)

Direct measurement
(test beam particles, partially destructive)

- Beam passing through the detectors
- Bergoz Integrating Current Transformer
  - (ICT-122-070-05:1)
- Flags and triggered fast cam, DAQ parameter shot by shot

Indirect measurement
(secondary photons, run quality monitor)

- 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%)

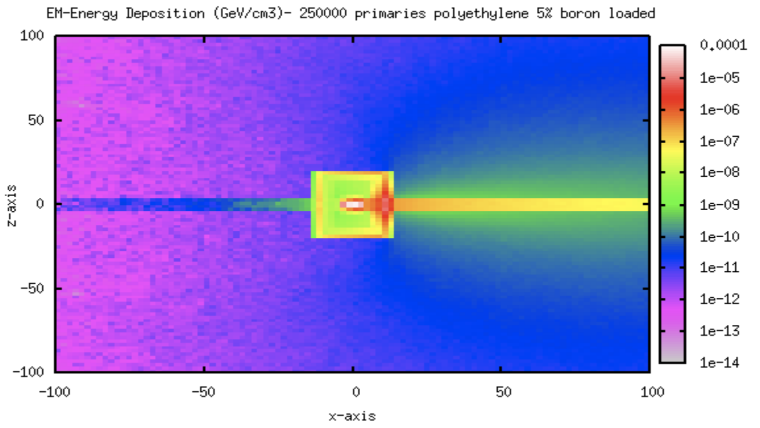


BTF TARGETS FOR SECONDARY BEAM

INFN Istituto Nazionale di Fisica Nucleare Laboratori Nazionali di Frascati

LINAC positron converter

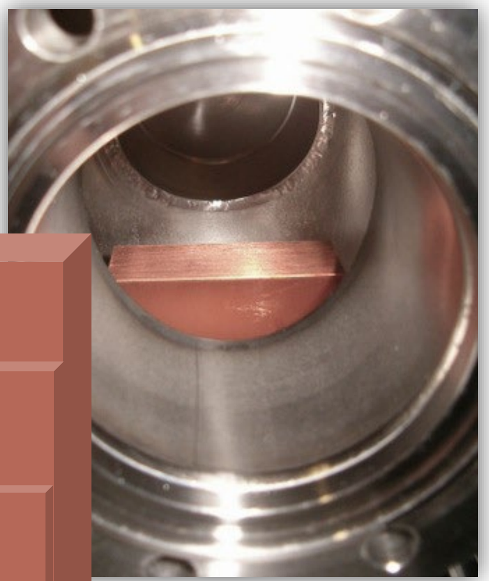
- Target: tungsten (Z=74)-rhenium(Z=75), L=2 x_0
- Positrons by pairs production
- Flux concentrator, jointly with DC solenoid magnets, generate a strong magnetic field (5 T peak) necessary for the positron capture.

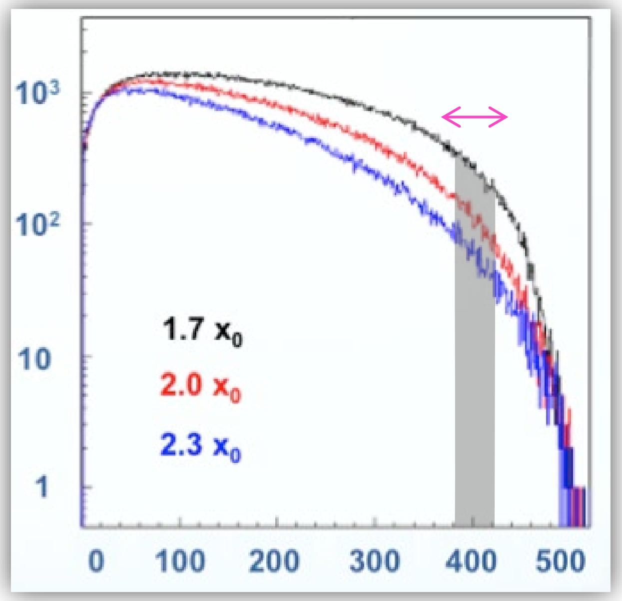


BTF target

- Copper (Z=29) variable depth (1.7, 2 or 2.3 radiation lengths)
- Positrons mainly by EM physics process
- Passive Capture (scrapers and quads)
- Selection in energy with (DHSTB001) and scrapers

- Copper critical energy ≈ **19 MeV** (≈ **46 MeV** for W/Re)
- Not so far from the less energetic BTF tuned beam (30MeV)





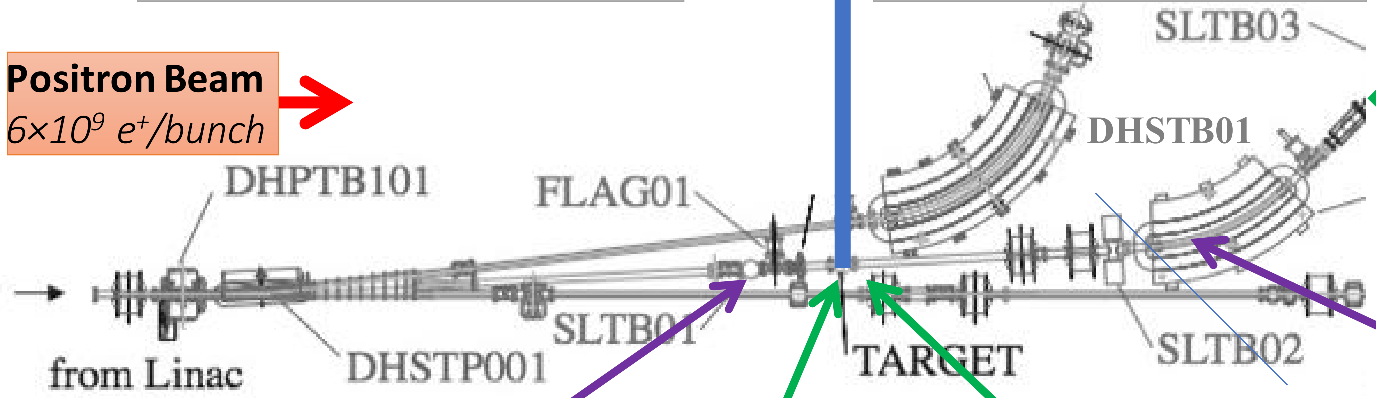
BTF SECONDARY BEAM

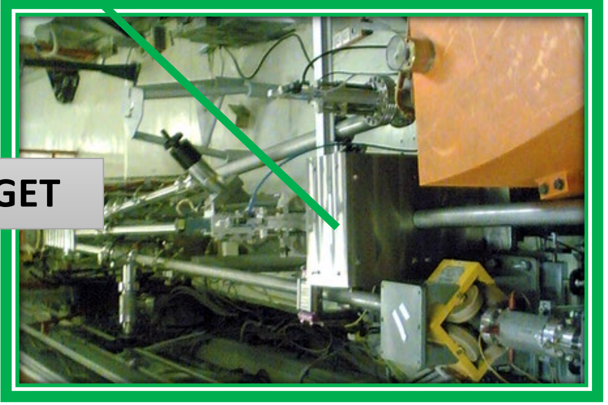
PRIMARY

SECONDARY

Positron Beam
6×10^9 e^+/bunch

Electron Beam
3×10^{10} e^-/bunch





- **6x single-axes SCRAPERS**
- **LINAC Energy is different to BTF energy**
- **TARGET!!!!**

DHSTB001
- **Selects energy**
- **Steers**

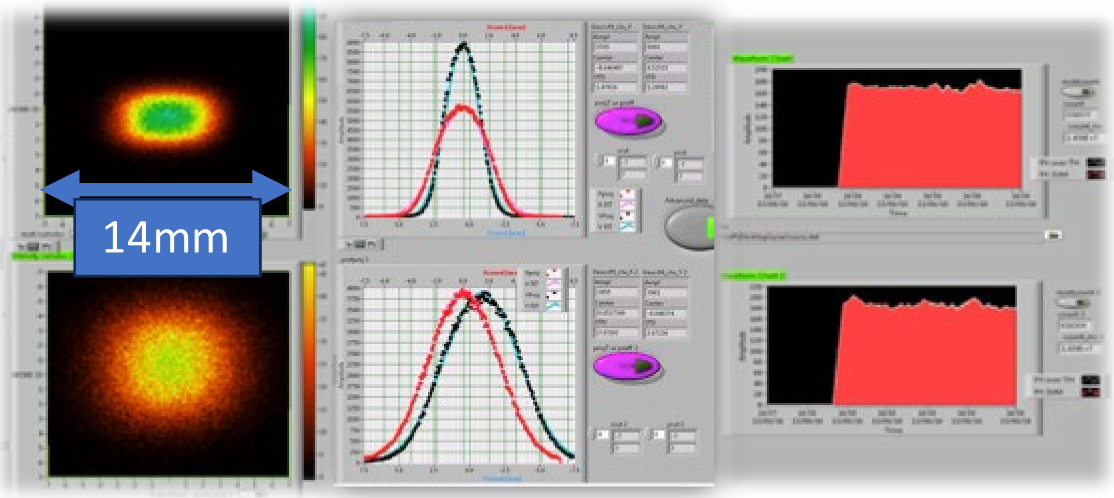
Is a spectrometer!

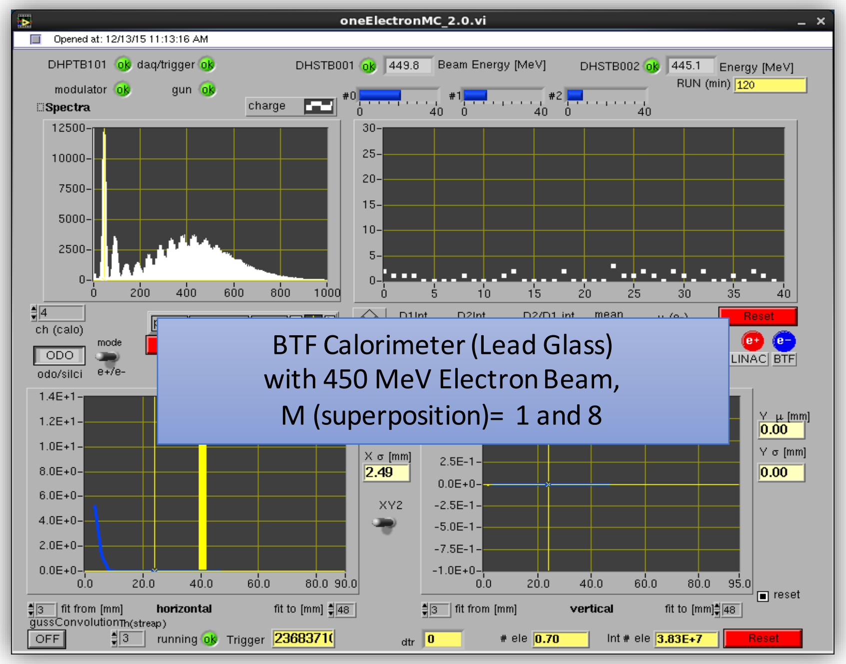
- Copper target in the middle
- ENERGY and its spread selection (Scrapers,Dipoles)
- Multiplicity selection (Scrapers,Dipoles)
- Transverse (Scrapers, Quad, Dipoles)
- Dipoles and Correctors to match angle and position in the DUT

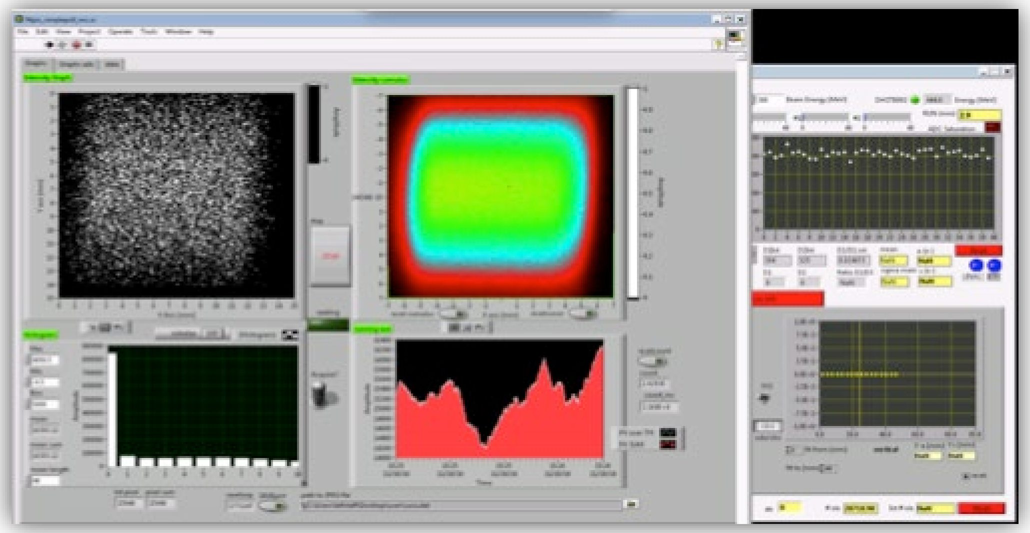
DIAGNOSTICS: SECONDARY BEAM

Typical secondary beam diagnostics (some of)

- **ADVACAM FITPIX/TIMEPIX detectors**
  - 256×256 pixels, 55 μm pitch, 14×14 mm^2 active area
  - 300 μm thickness sensor
  - Three FitPIX devices **operational**
- **LEAD GLASS Calorimeter: higher beam (charge*energy)**
- **BGO segmented Calorimeter**

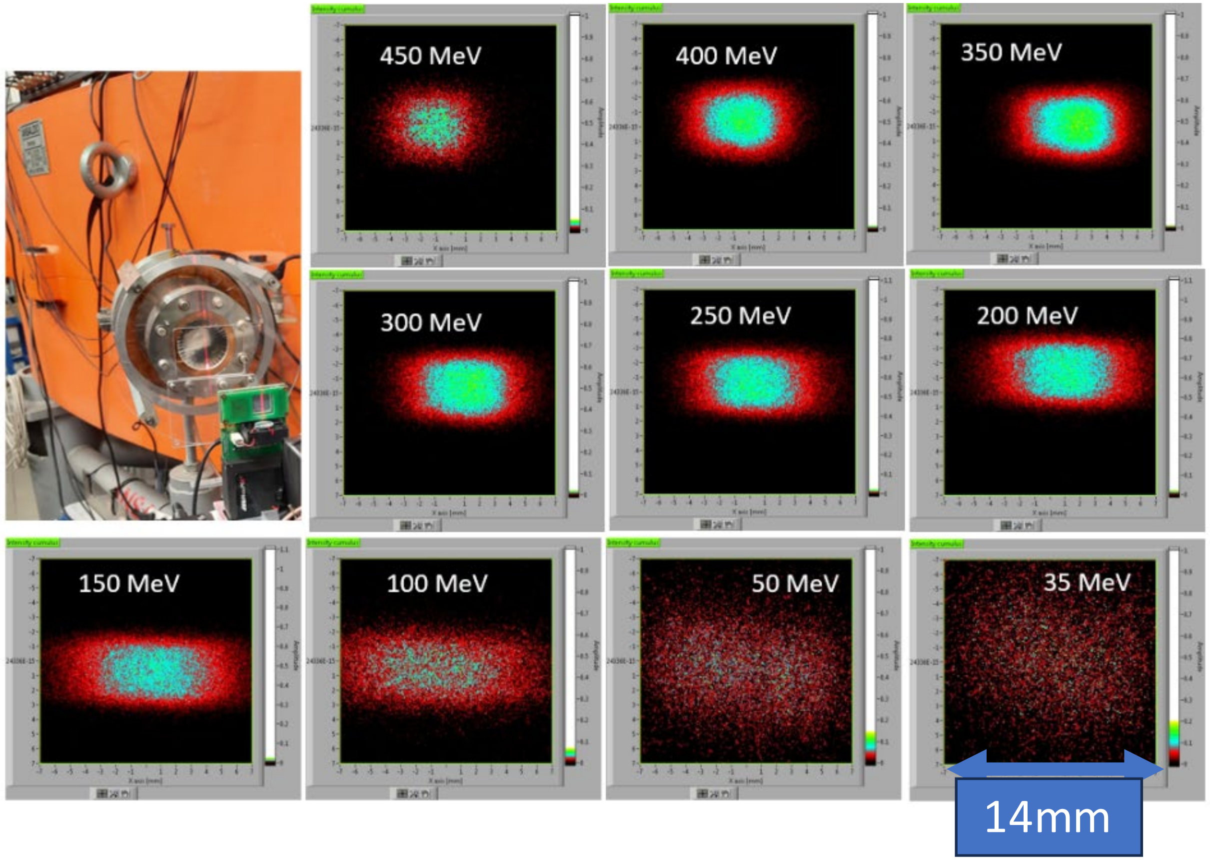






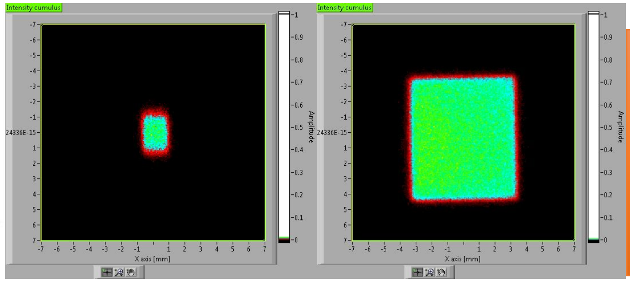
BTF BEAM – ENERGY/SHAPE TUNING

BTF-1 Hor. Beam example



- Improved energy scan of ~0,75 MeV (around 10 PS DAC digits-> 150KeV, effective where beam energy spread less than 0.5%)
- Fixed on Descending branch of the DHSTB001 hysteresis loop
- DHSTB001 -> -0,5A
- DHSTB002 -> -0,5A ± DAC digit (beam based alignment)
- DHRTB001 -> -1A in the tails of energy scan
- Scrapers ±0,01mm

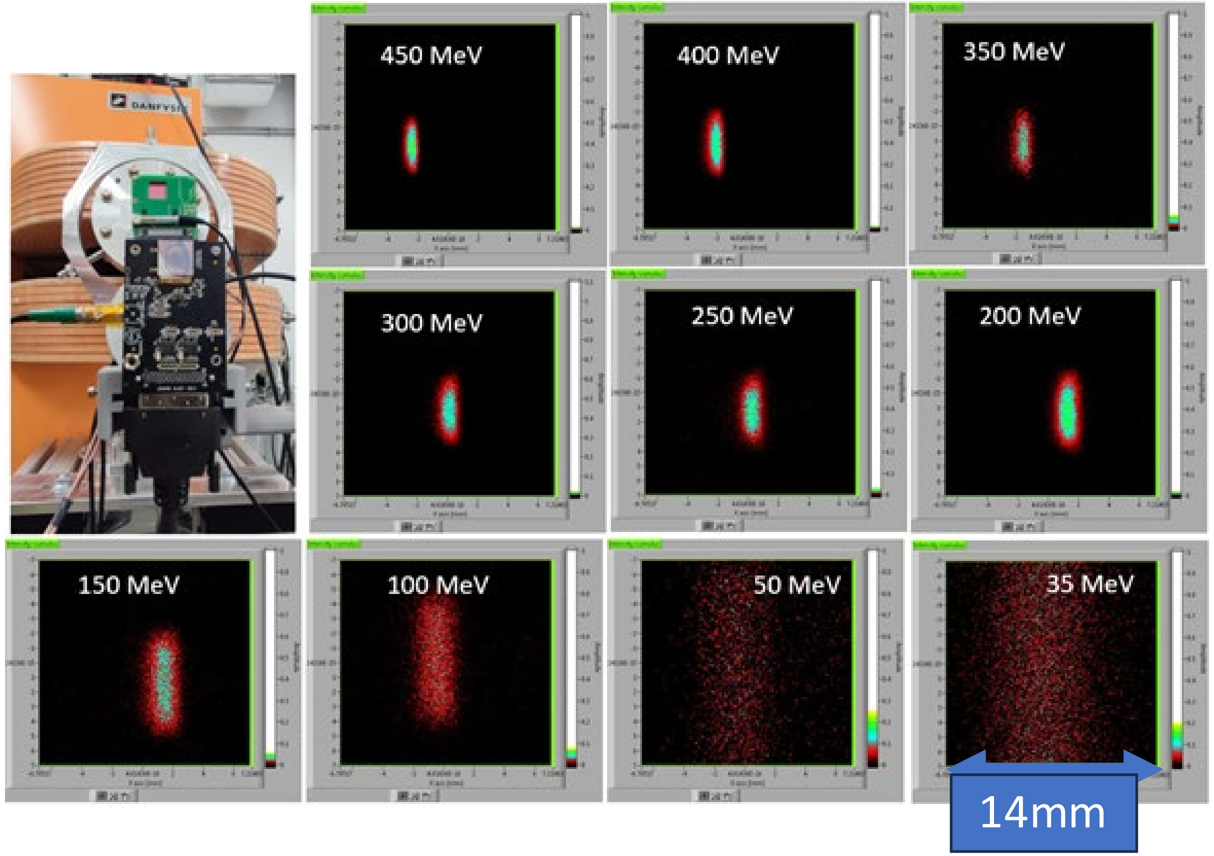
Stay clear checks via steering magnets (CHHVVTBXXX and DHPTB102)



SQUARE BEAM 450MeV, <10% FLATNESS, M=10 (L), M=1000(R)
SECONDARY ELECTRON BEAM BTF1 LINE
CUMULATIVE PLOT, REP RATE 50HZ, ~MINUTES EXPOSURE

BTF BEAM – ENERGY/SHAPE TUNING

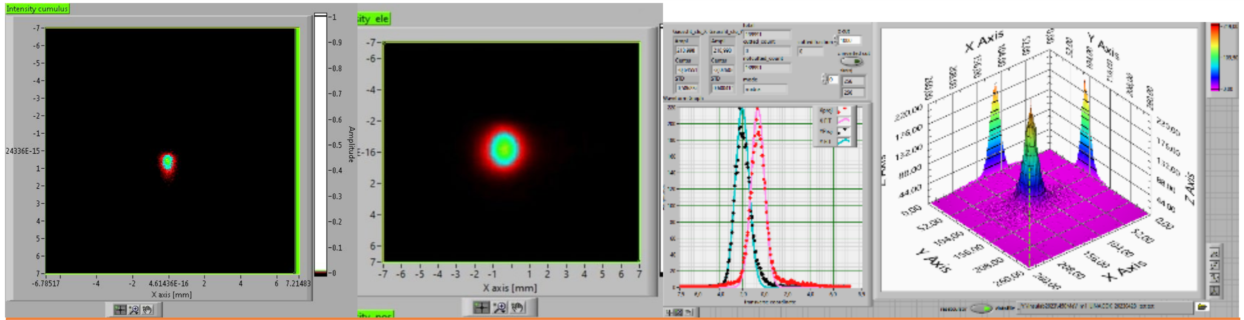
BTF-2 Vert. Beam example



Low Energy Secondary (<50MeV) beams experiences:

- DAC limits on magnets PS (on energy selection ε~100KeV)
- Exit windows:
  - BTFEH1-S 50um, Ti
  - BTFEH2 520um, Al
- Energy specific emittance from BTF target (secondary beam from positron primary ones affected too)
- Beam Profile Sigma => shot by shot precision

=> BTF minimum energy set around 30MeV, then no reasonable energy spread, multiplicity and



450MeV, 0.2x0.35mm^2, SINGLE PARTICLE ELECTRON (LEFT)
450MeV, 0.6x0.8mm^2 ELECTRON(R) BEAM BTF2 LINE
CUMULATIVE PLOT, REP RATE 20Hz, ~2H EXPOSURE

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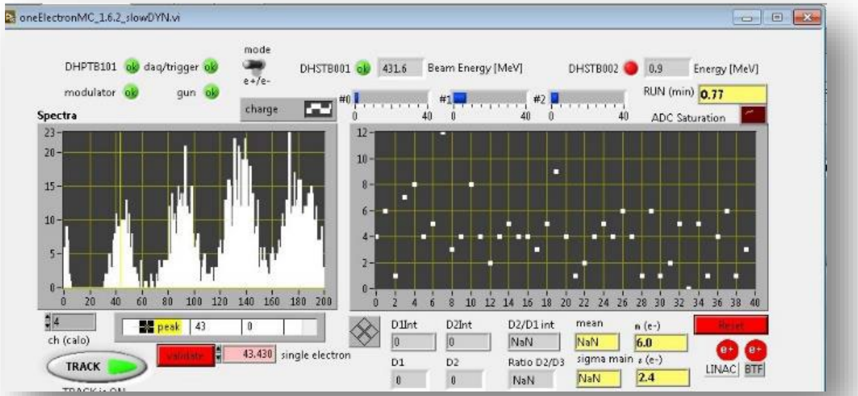
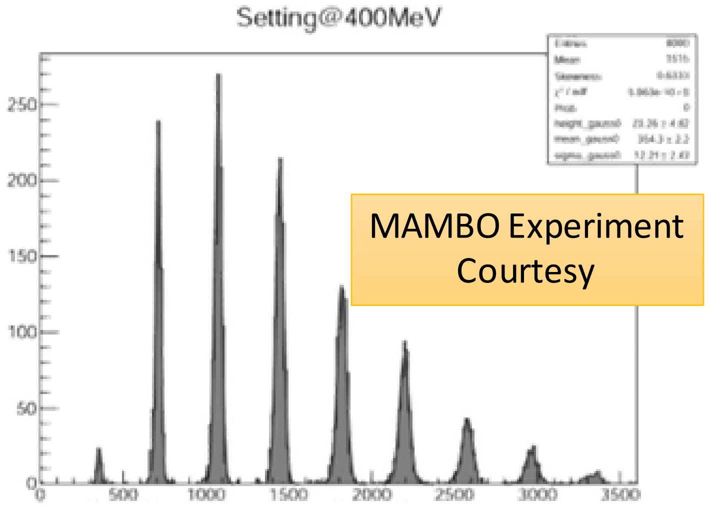
BTF BEAM – INTENSITY TUNING

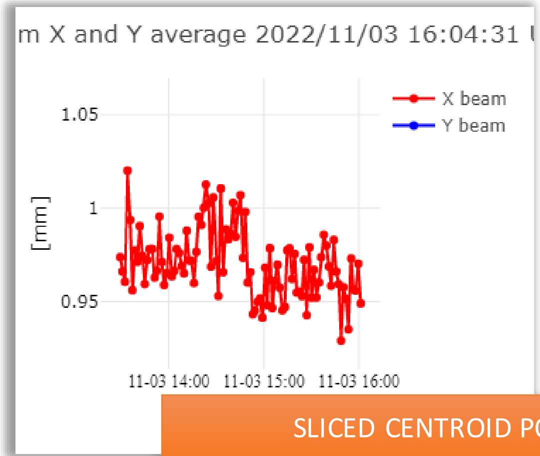


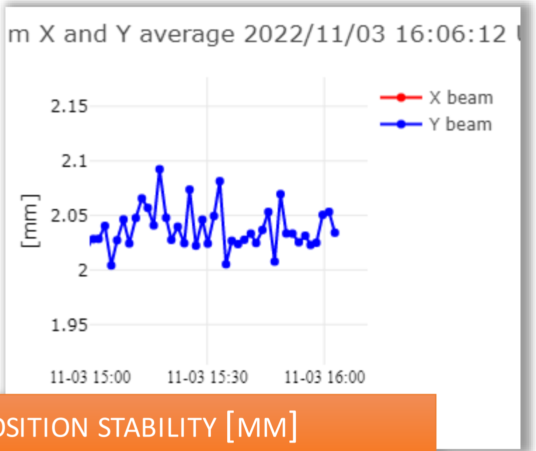
Secondary beam, single particle to 10^4 per shot, run-time selectable

- The primary beam is attenuated by the copper target
- Starting from primary beam energy down to 30 MeV
- **Multiplicity as Poissonian distribution with average multiplicity, selectable up to *the secondary energy spectrum accepted by the line (scrapers)***
- Selectable positrons or electrons , independently from LINAC phase

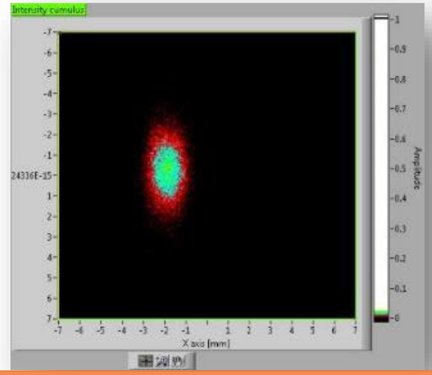


MAMBO Experiment Courtesy





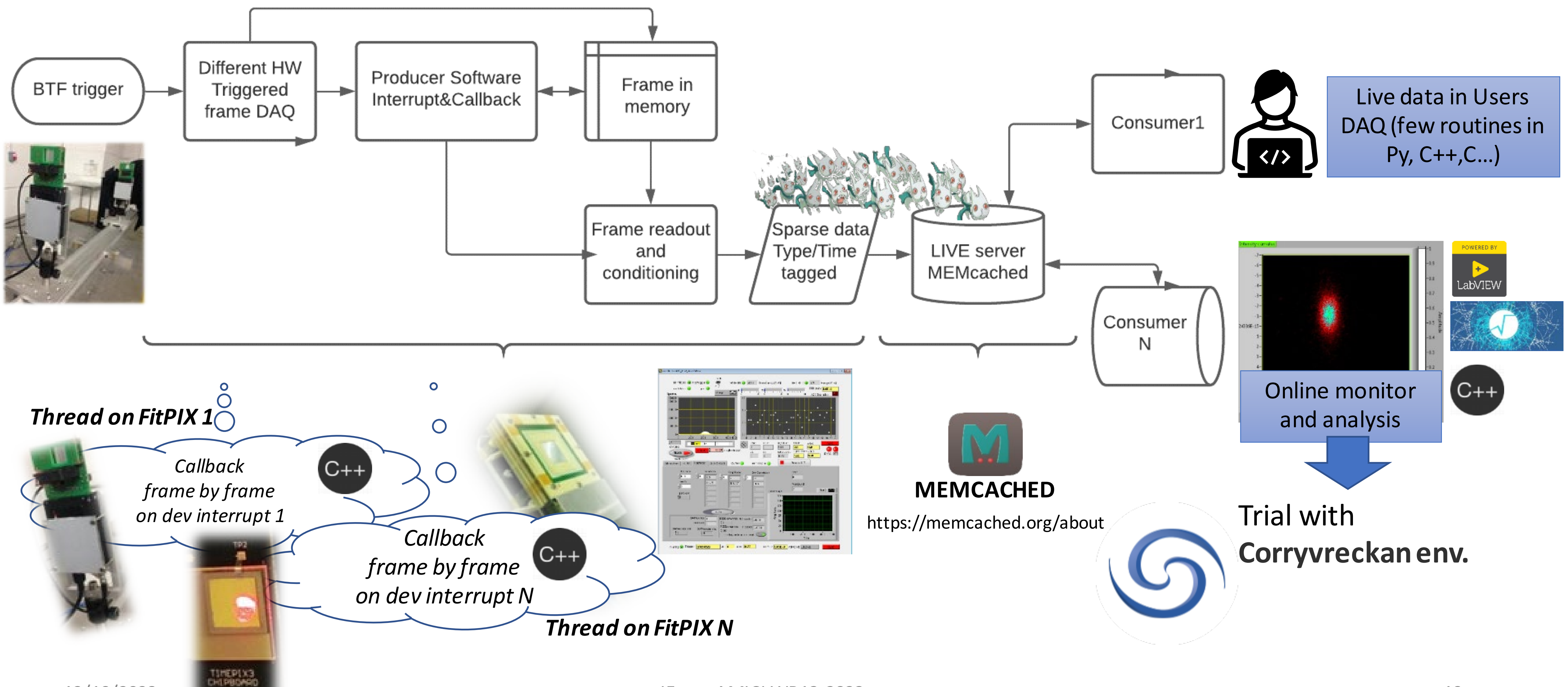
SLICED CENTROID POSITION STABILITY [MM]
230MEV BEAM, M=2.5K



450MeV, 0.4x0.9mm^2, SINGLE PARTICLE
PRIMARY POSITRON BEAM BTF1 LINE
CUMULATIVE PLOT, REP RATE 50HZ, ~1H EXPOSURE

→ thus allowing a very fine tuning of the beam intensity and energy in a matter of seconds

DIAGNOSTICS SOFTWARE LAYOUT

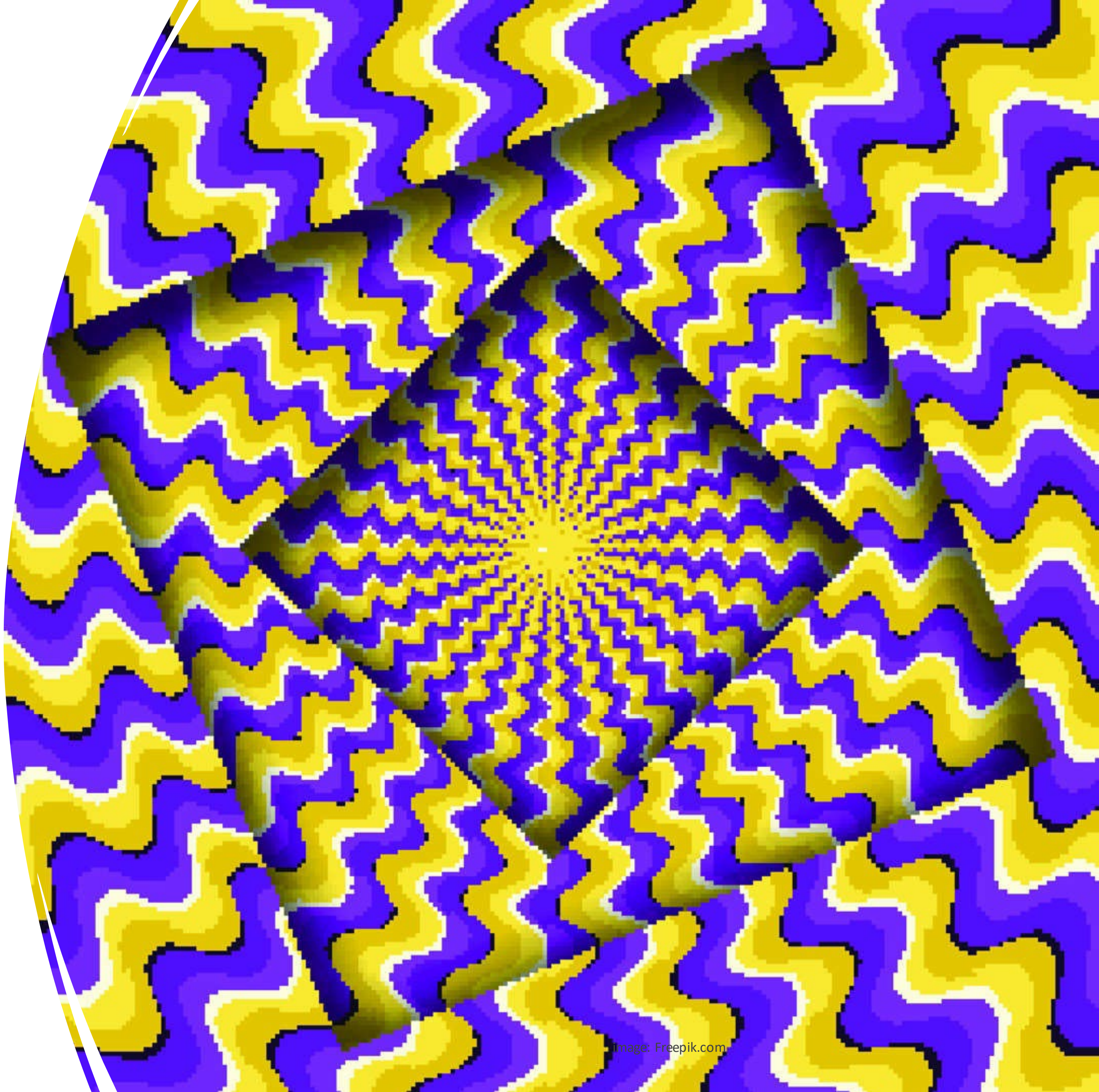


LNF – BEAM TEST FACILITY

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	3.125x10^{10} part./s				1x10^6 part./s	
Exit Beam waist size (m1, mm)	0.5–55 X / 0.35–25 Y (vacuum window dependent)				0.6x0.6(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

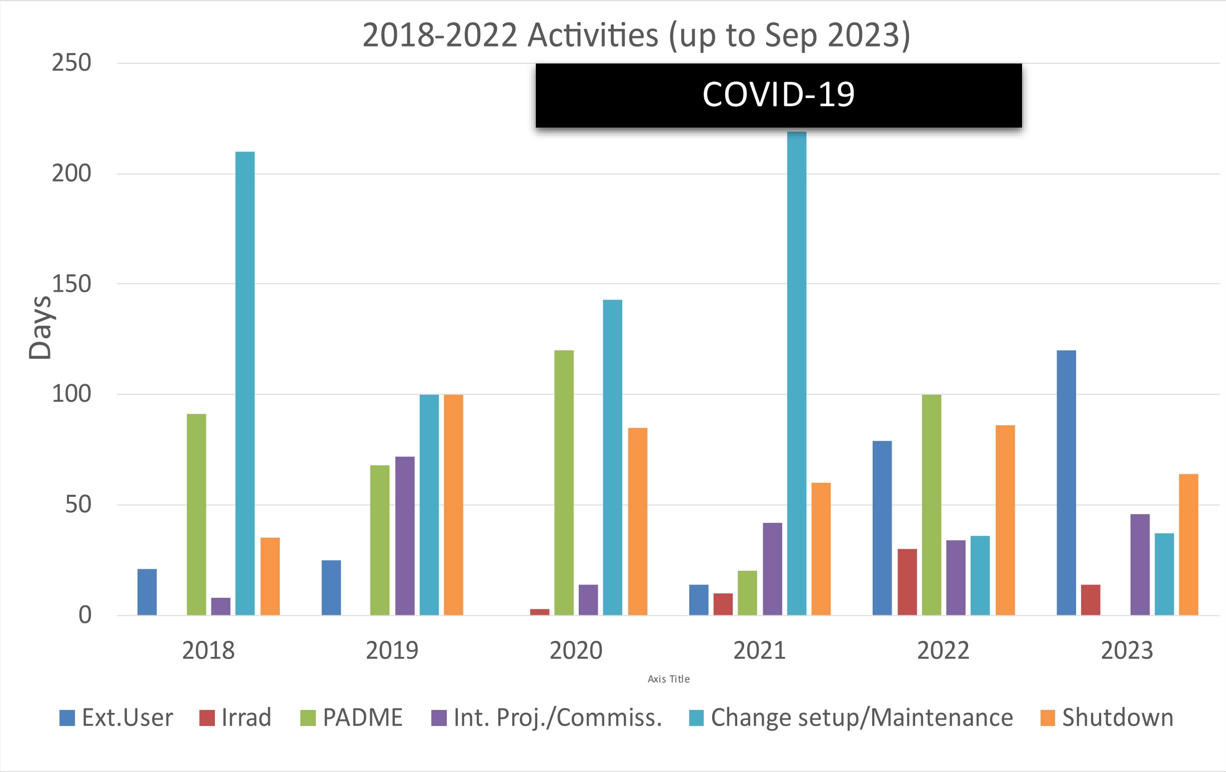
BTF
Who and When



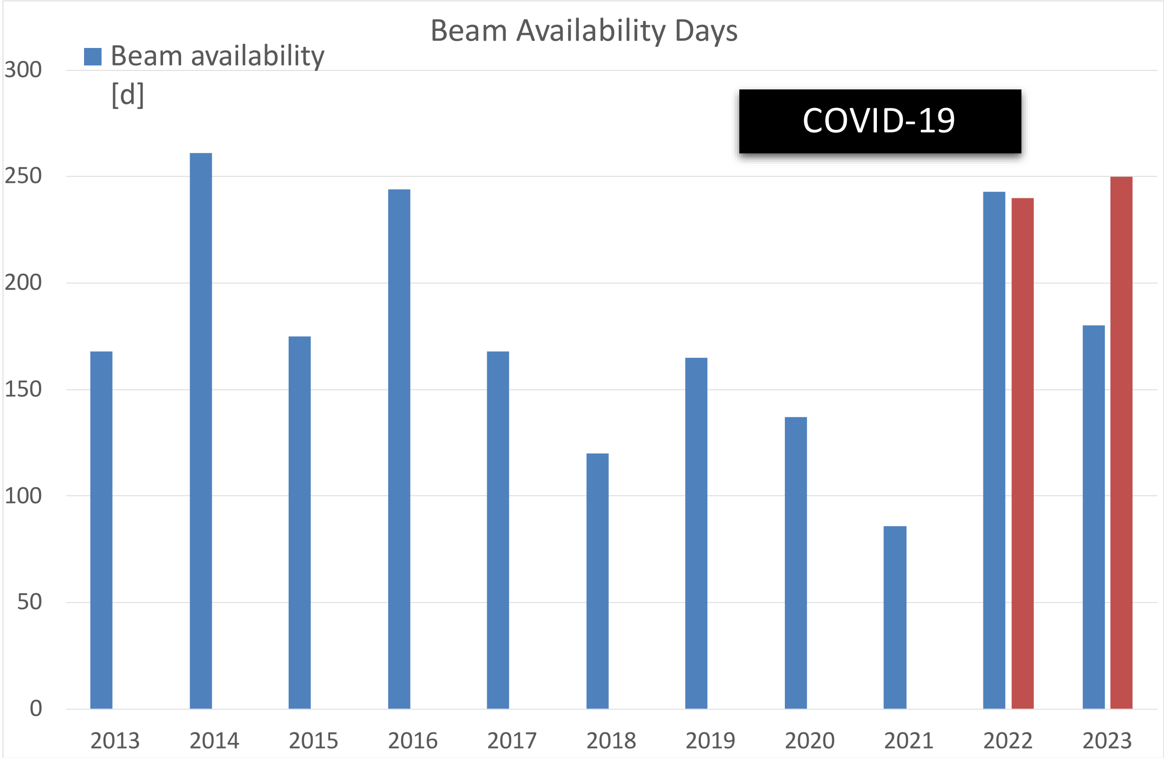
LNF – BTF NUMBERS

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

2018-2023 Activities

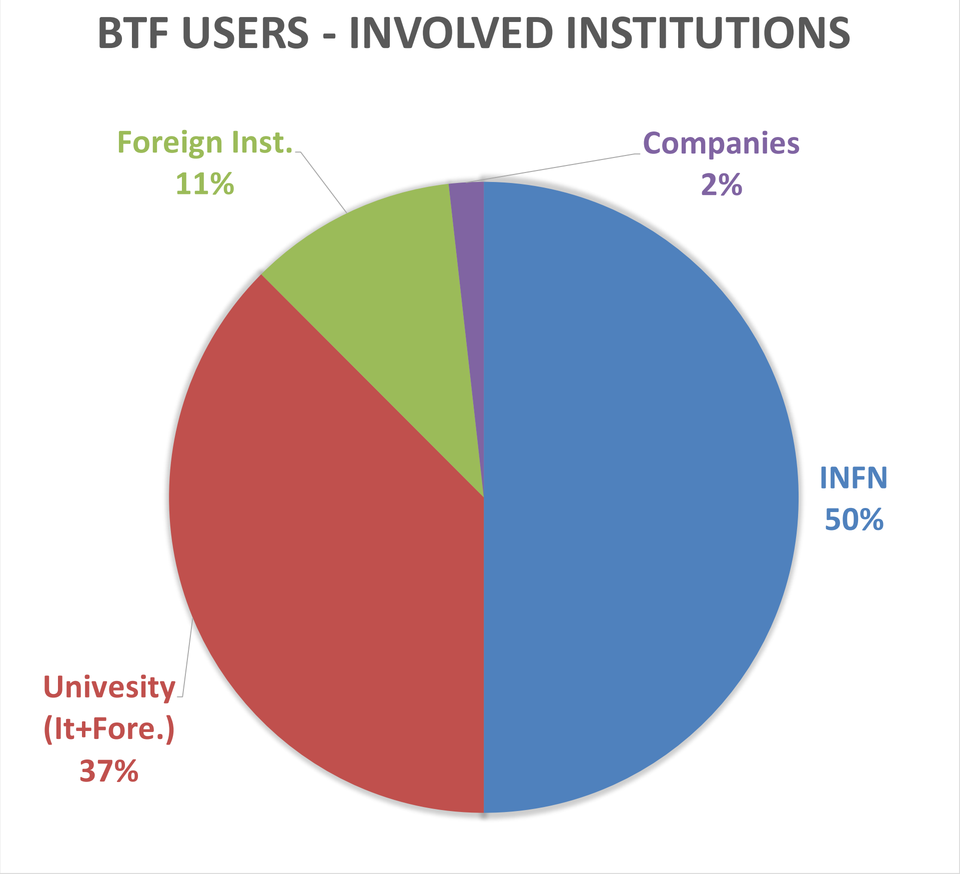


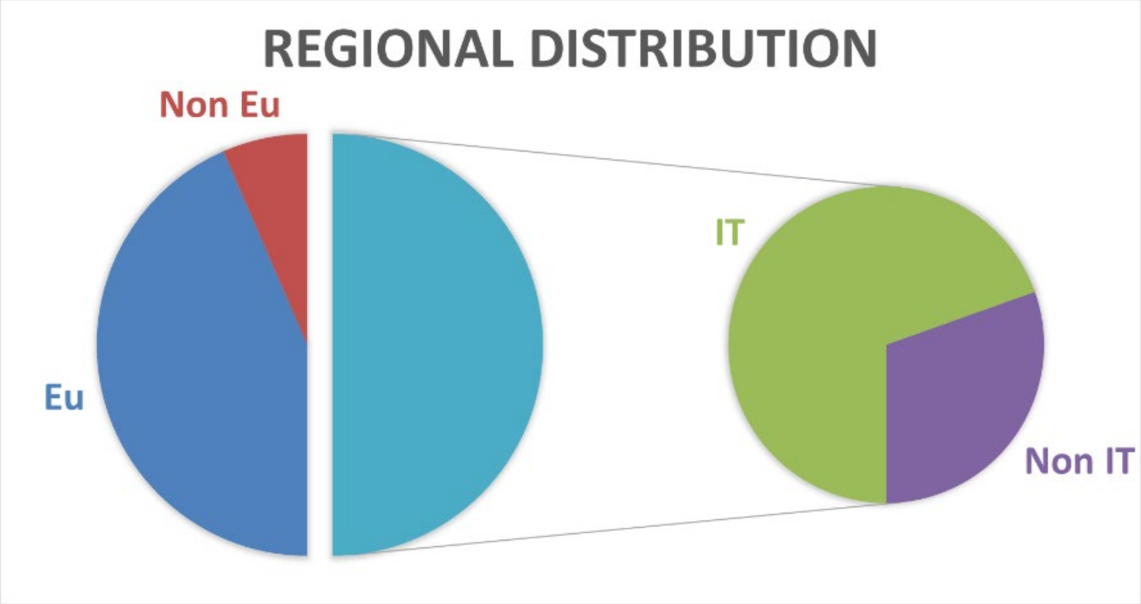
Beam Availability Days (up to Sep 2023)



LNF – BTF NUMBERS

2022-2023 Involved Institutions



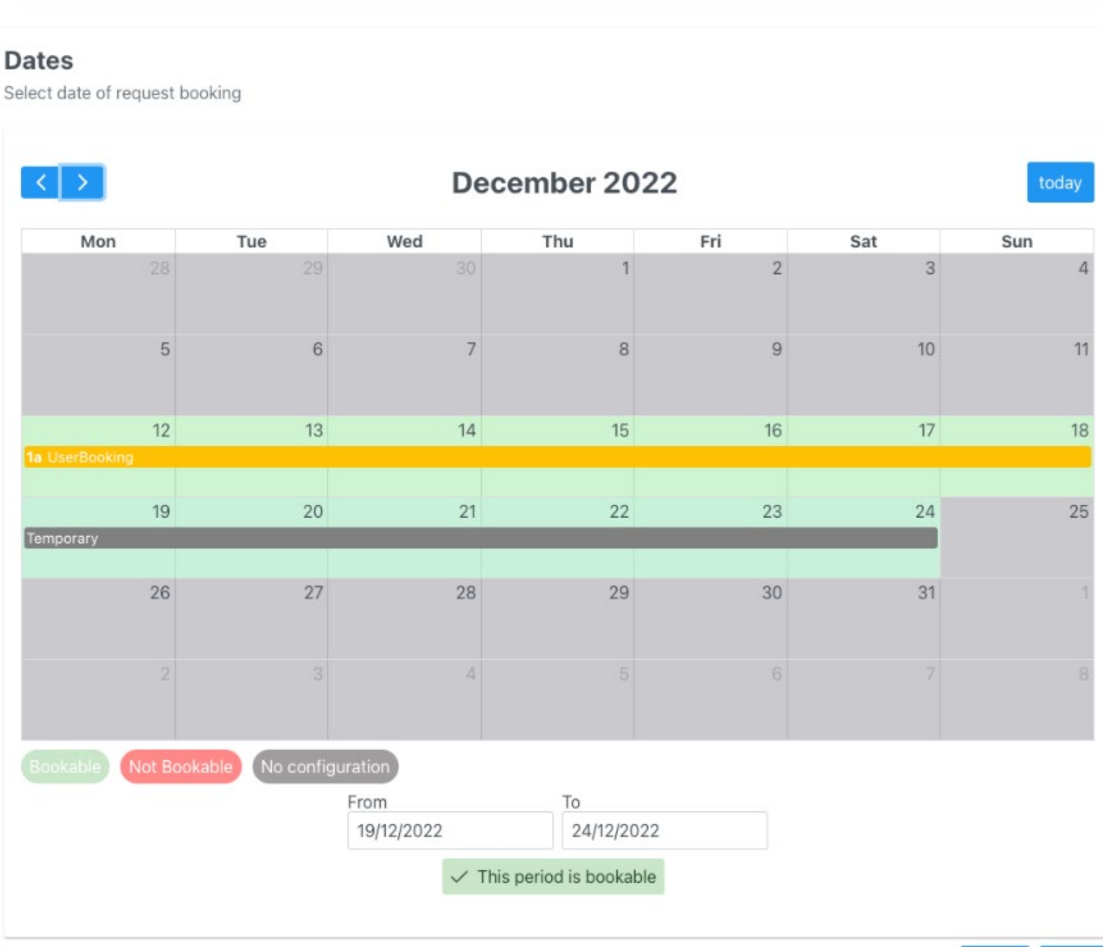


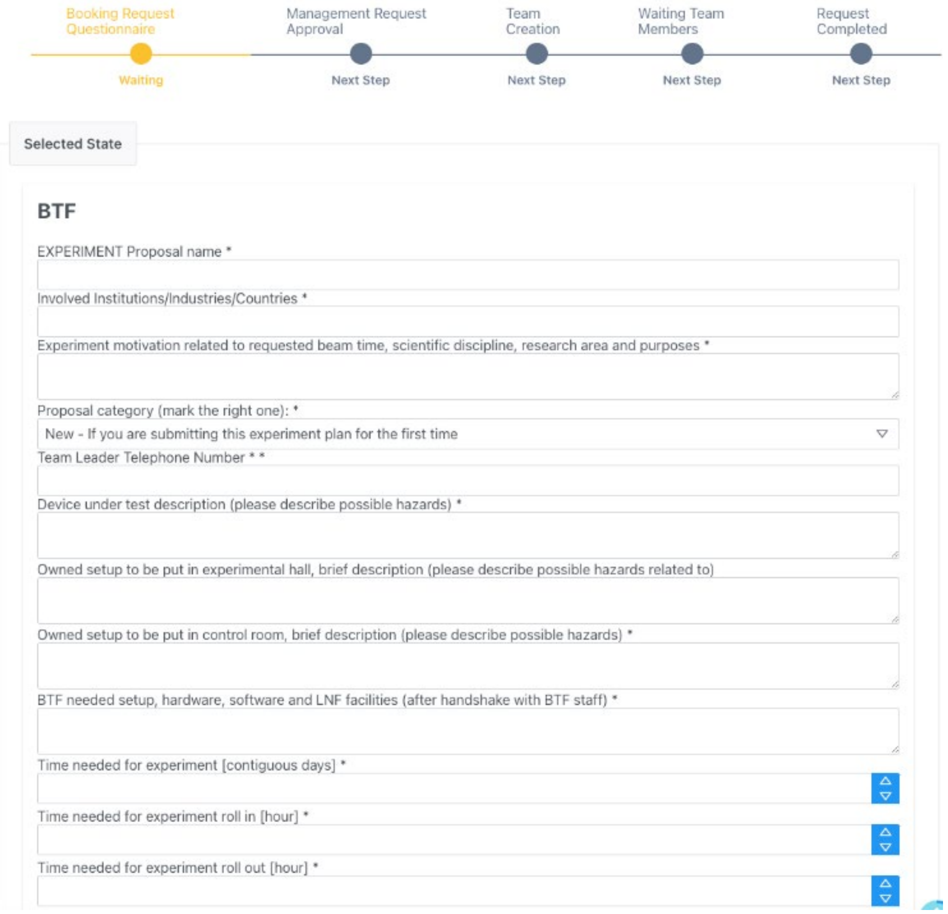
Beam availability days = ~200d/y
Shift average time = 7d
Average team member number = 7.5

BOOKING SW

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

Once the call for BTF is open, team leader can submit new booking request choosing the available dates on calendar.





- Team leader fill the BTF questionnaire in order to proceed with request.
- The facility management and facility user committee will approve or deny via tech. and scient. reasons the submitted questionnaire.

BOOKING SW

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

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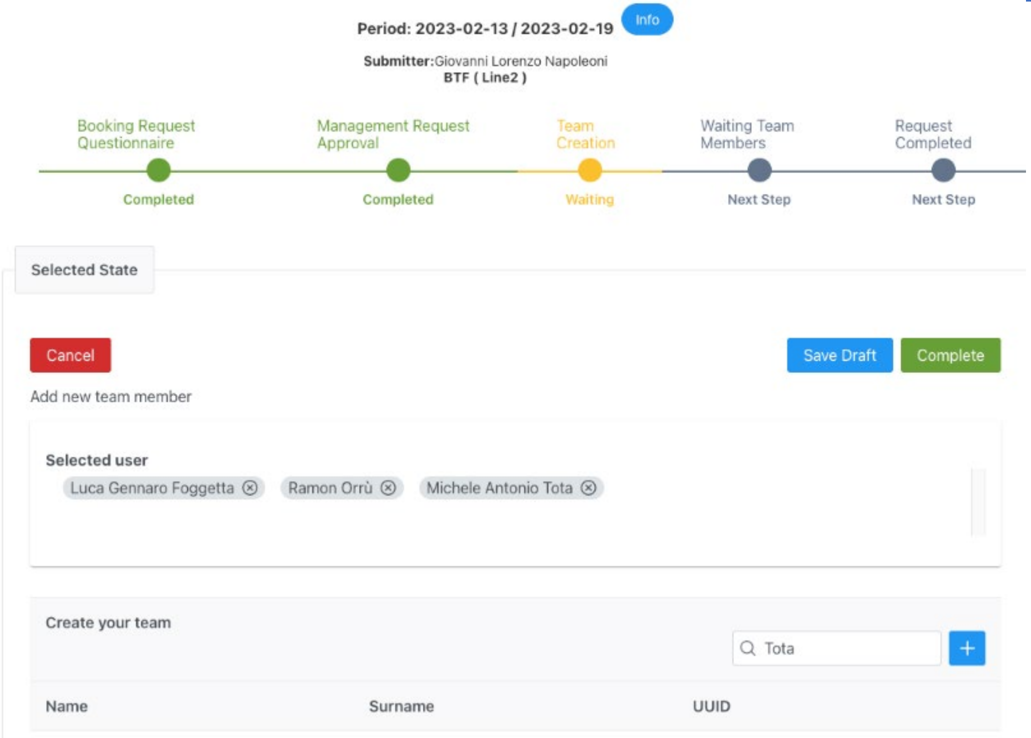
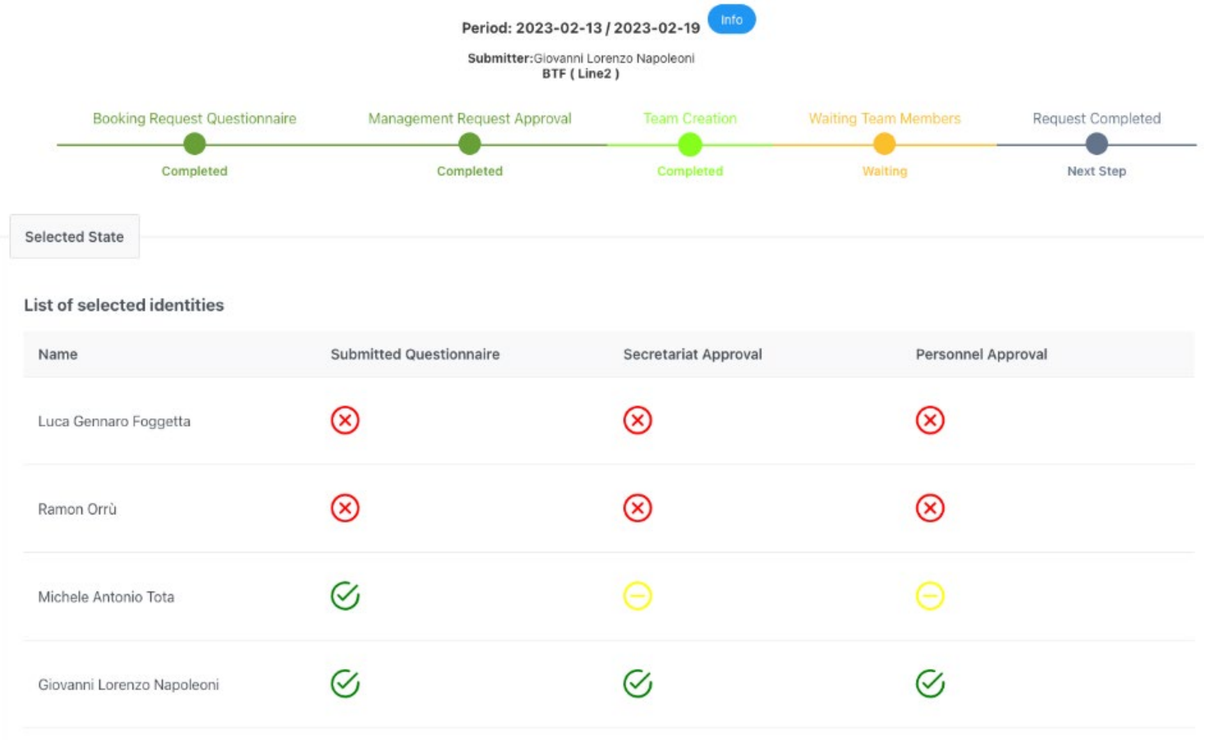
After facility management approval, the team leader can create the team by adding INFN identities hosted in INFN identity management system.



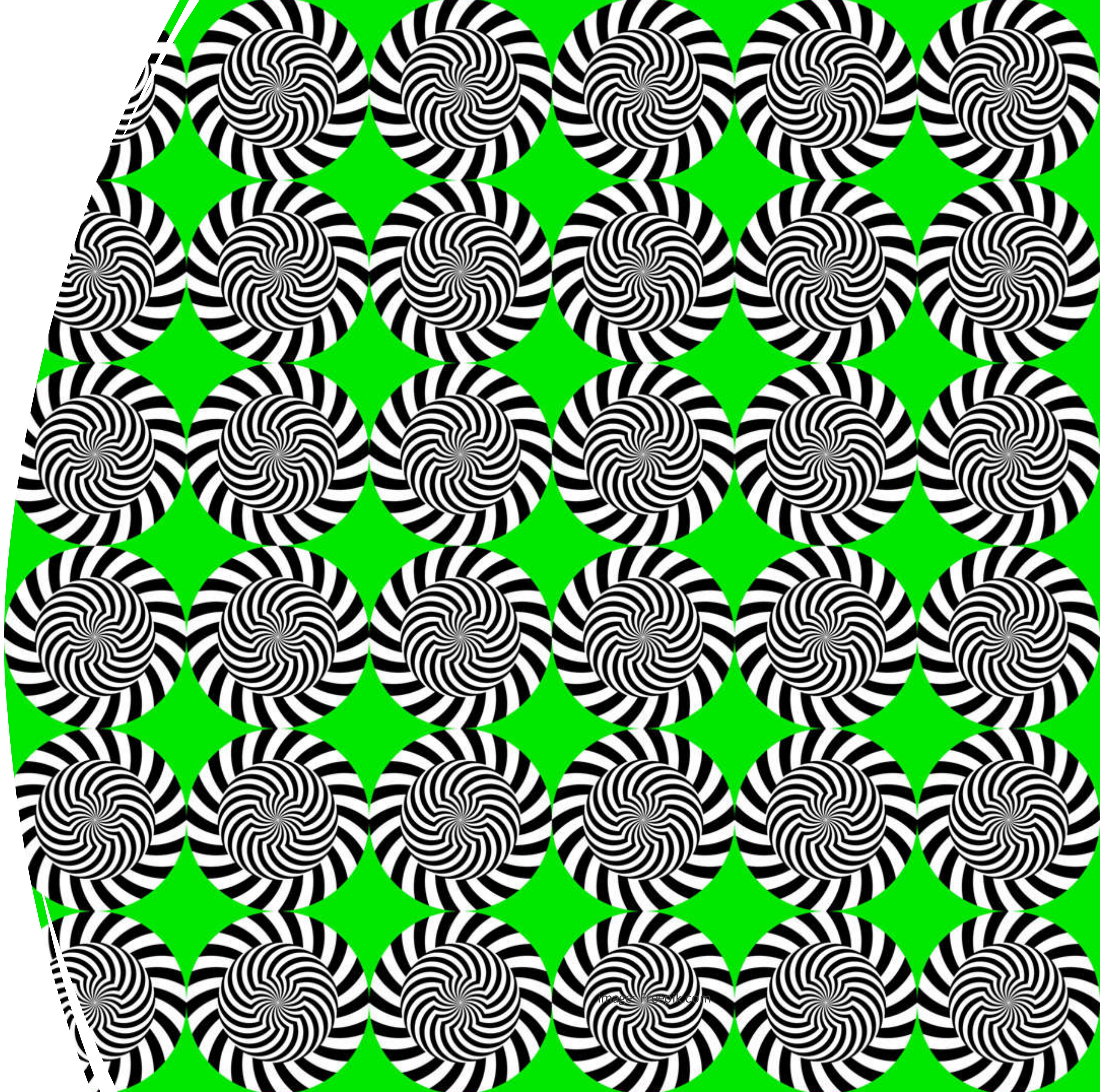


- **Huge reduction** factor of overall secretariat time
- Users report **easier access** from user side,
- **Easy management** by the Team Leader
- **Easier admin** from beamline manager personnel
- **Process traceability** from submission to territorial access

- Each team member must fill single web personal form.
- Workflow approval by secretariats, beamline manager...
- Team leader can overview its team members approval state in each moment.
- This software manage call period, documentation and the territorial QR-code.
- All the communications via automated email and web site

BTF WEEKLY USERS

and few examples



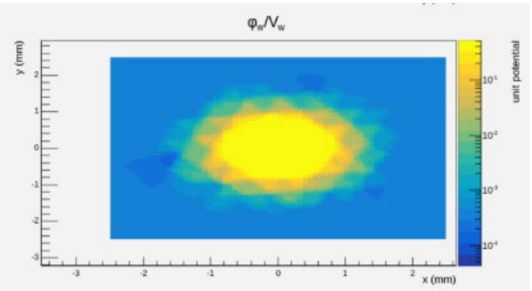
LUXE

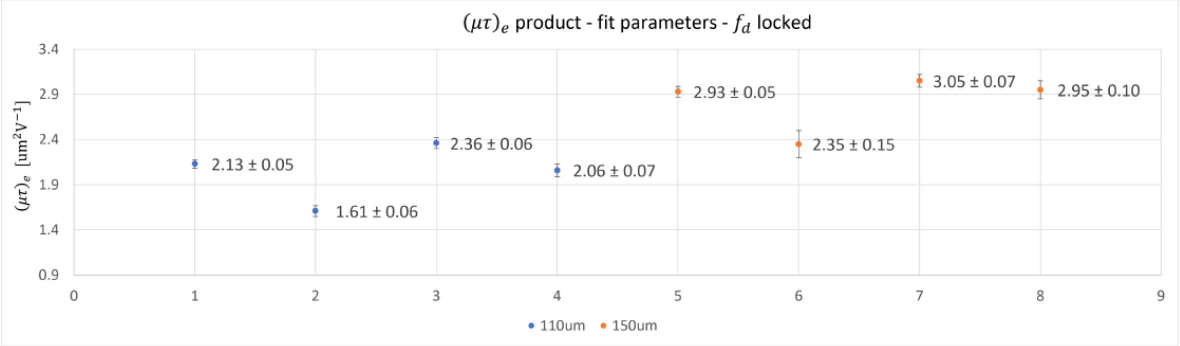
(Laser Und XFEL Experiment) is a new experiment proposed at DESY and the European XFEL to study QED in the strong-field regime where QED becomes non-perturbative

BTF USER run (New Detector dev.)

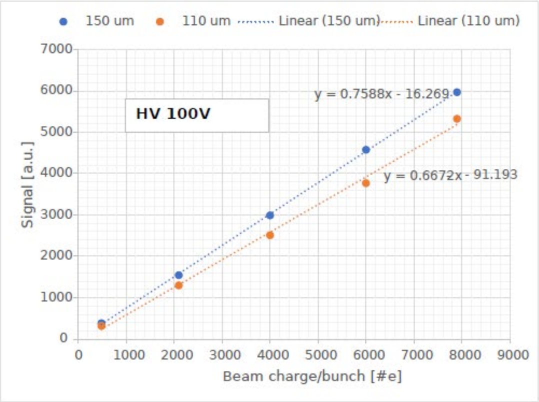
BTF beam 300MeV, m=10K scan,
Highly focused, completely contained

(**L**aser **U**nd **X**FEL **E**xperiment) is a new experiment proposed at DESY and the European XFEL to study QED in the strong-field regime where QED becomes non-perturbative
2 x Sapphire wafer(2in) Thick d2=0.15 mm
2 x Circular Pads R1= 0.8 mm and R2=2.75 mm

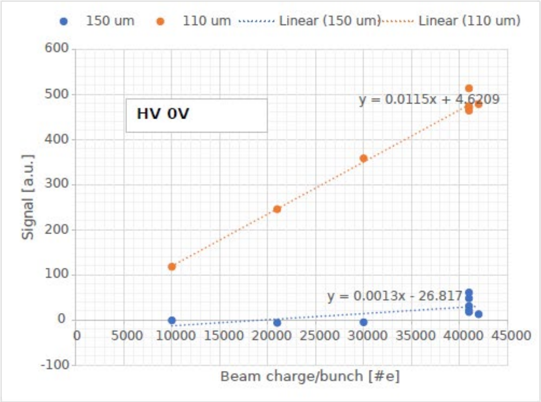




		Forward LargePad	SmallPad	Reverse LargePad	SmallPad	Forward LargePad	SmallPad	Reverse LargePad	SmallPad	
110	\mu\tau	2.13	1.61	2.36	2.06	2.93	2.35	3.05	2.95	150
	err	0.05	0.06	0.06	0.07	0.06	0.15	0.07	0.1	
		1	2	3	4	5	6	7	8	



(a) $V_{\text{bias}} = 100\text{V}$



(b) $V_{\text{bias}} = 0\text{V}$

- **First test as Sapphire photon current integrator for LUXE experiment**
- As a preliminary response, impressive linearity in wide range in multiplicity and voltage scan
- Team reached the goal to be first in detect such Sapphire Charge Collection Efficiency

Courtesy of P. Grutta and M. Morandin (CERN, INFN-Pd)

HERD

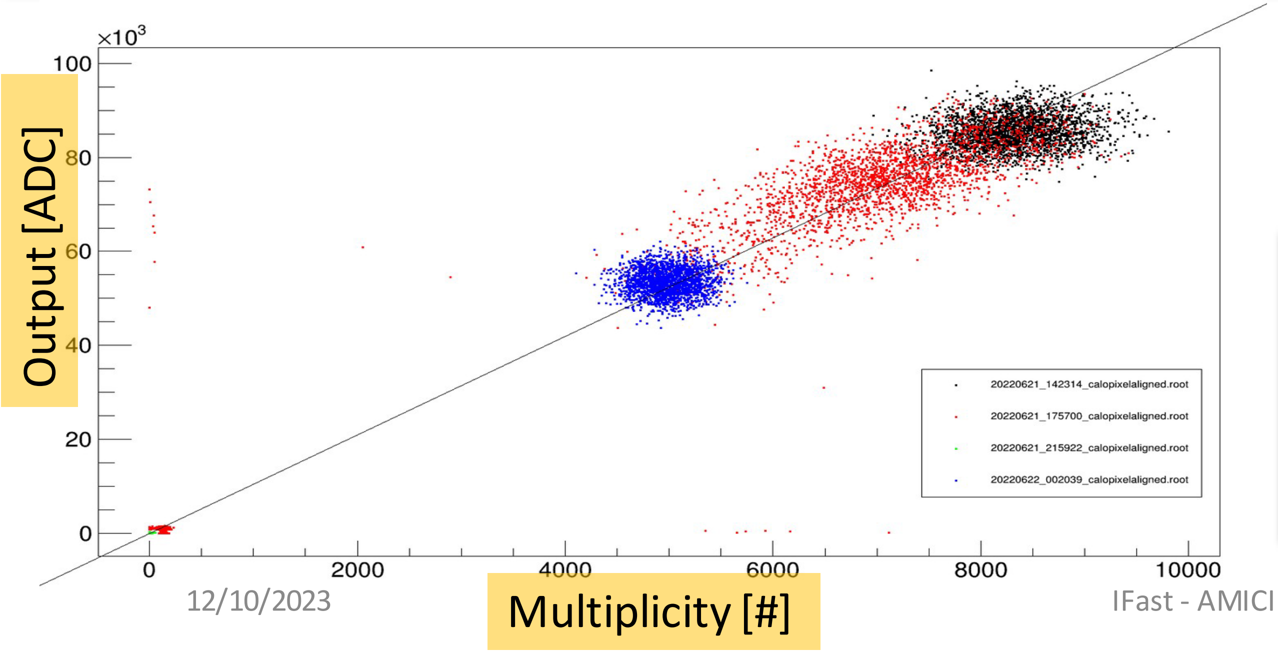
The HERD mission: will be installed on the **Chinese Space station** in 2027.
It will extend direct measurements of cosmic-rays up to the knee region.
https://w3.lnf.infn.it/experiments-in-btf-orbit/?lang=en

BTF USER run (SPACE Appl)

BTF beam 300MeV, m=10K scan, few mm^2 beam size

Prototype: small calorimeter made of 4 layers of 3x3 LYSO crystals. Each crystal is 3x3x3 cm^3
Crystals read-out: two PDs with different active areas and a wave length shifter fiber + SiPM.
The HERD (High Energy Cosmic Radiation Detection) collaboration, on the other hand, aims to install its detector in the Chinese space station

Courtesy of
Nicola Mori (INFN-Fi)



The main purpose of the test: check the linearity of the read-out system up to the saturation (very wide energy range!!!).
Preliminary results show a good linearity.
Additional goals: test different hardware and firmware configurations, measure the direct ionization of PDs.

LIMADOU

CSES - LIMADOU is part of a scientific program that studies natural and anthropogenic electromagnetic fields, their emissions and possible correlations with seismic events.
https://w3.lnf.infn.it/una-pioggia-di-elettroni-per-lhigh-energy-particle-detector-di-cses-limadou/

BTF USER run (SPACE Appl)

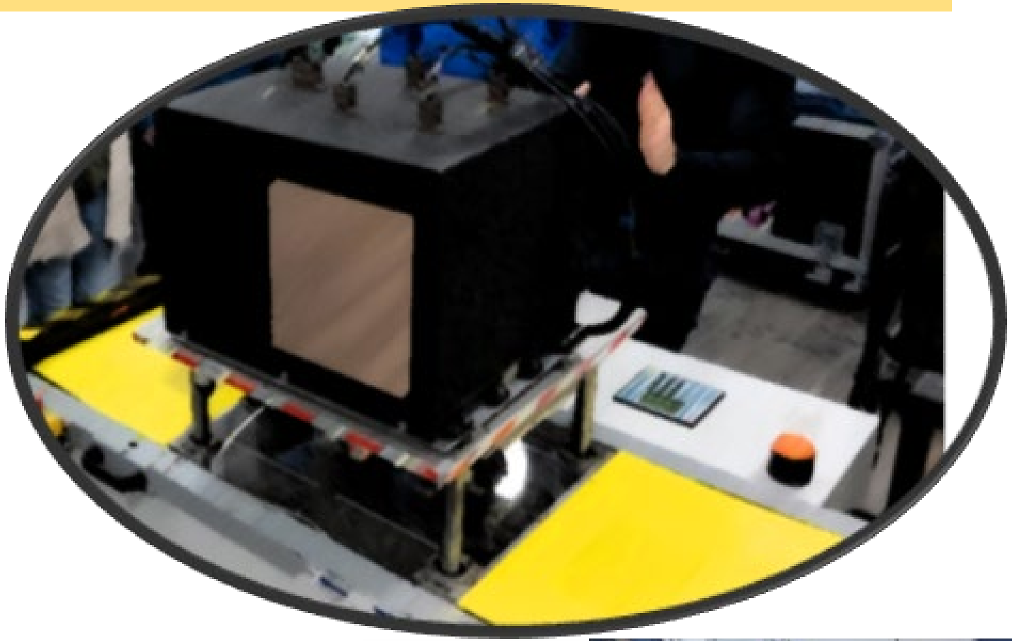
The main purpose of the test:
Check before flight HEPD with different BTF configuration set:

- Electrons, M=Poissonian Single Particle
- from 30MeV to 120MeV in 15MeV steps,
- different multiplicity (mostly single particle for all energy sets)
- Large spot area up to 30 cm^2

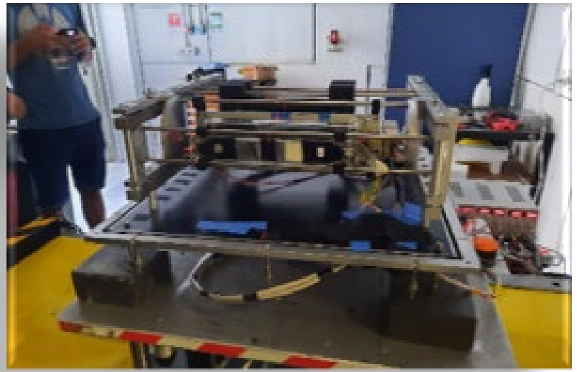
Flight model High-Energy Particle Detector (HEPD-02)

HEPD-02 comprises a tracker made of CMOS Monolithic Active Pixel Sensors (MAPS), a double layer of crossed plastic scintillators for trigger and a calorimeter, made of a tower of plastic scintillators and a matrix of inorganic crystals, surrounded by plastic scintillator planes for containment tagging.

All the HEPD subsystem was tested as programmed



Courtesy of
R. Iuppa (Trento Univ.)



Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

FISMEL

Dose evaluation from electrons impinging on a Pb target due to: i) Bremsstrahlung **photon** production; ii) photo-**neutrons** production.
TLD passive dosimeters used to measure dose at several charge intervals.

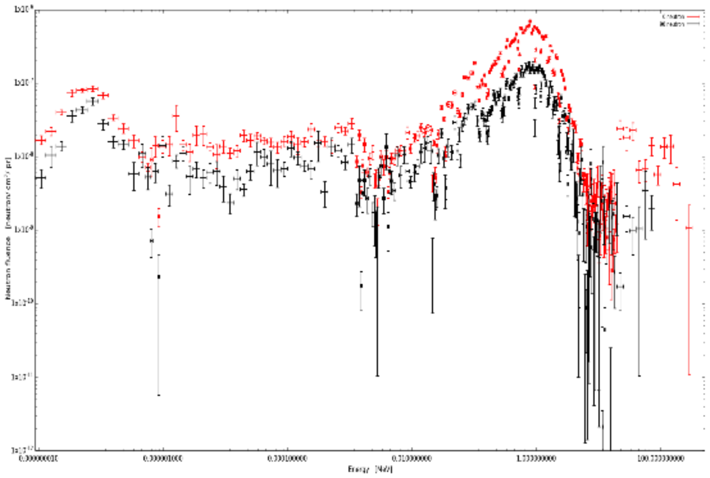
LNF Internal run (Irrad Device Calibration and test)

BTF beam 503 MeV, 1 Hz, 10^9 e-/s, spot diameter around 1 cm

Beam on a ~ 16 cm Pb target → mixed radiation field

1° run: photon Air KERMA evaluation at 0 ° (TLD700)
2° and 3° run: photon Air KERMA and neutron ambient dose equivalent evaluation at 0 ° and 90 ° (TLD700 + TLD600)
Calibration at Cs-137 and Am-Be → Data-MC comparison needed to validate the results at higher energies and benchmark the simulation (FLUKA) itself

Neutron spectra - Fluka



Photon air kerma at 0 °

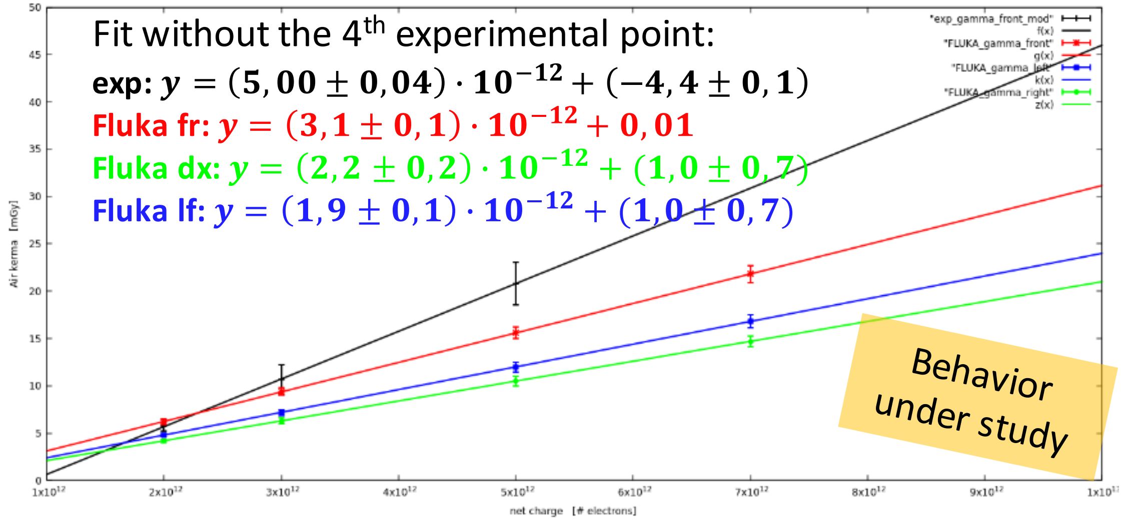
Fit without the 4th experimental point:

exp: $y = (5,00 \pm 0,04) \cdot 10^{-12} + (-4,4 \pm 0,1)$

Fluka fr: $y = (3,1 \pm 0,1) \cdot 10^{-12} + 0,01$

Fluka dx: $y = (2,2 \pm 0,2) \cdot 10^{-12} + (1,0 \pm 0,7)$

Fluka lf: $y = (1,9 \pm 0,1) \cdot 10^{-12} + (1,0 \pm 0,7)$



Courtesy of F. Chiarelli and R. Donghia on behalf of the LNF FISMEL Group

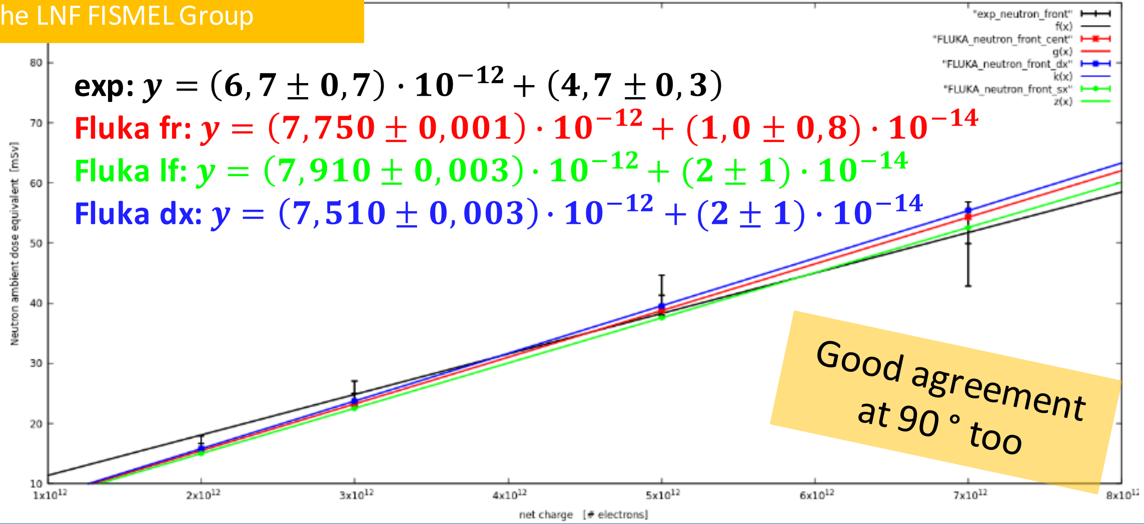
Neutron ambient dose equivalent at 0 °

exp: $y = (6,7 \pm 0,7) \cdot 10^{-12} + (4,7 \pm 0,3)$

Fluka fr: $y = (7,750 \pm 0,001) \cdot 10^{-12} + (1,0 \pm 0,8) \cdot 10^{-14}$

Fluka lf: $y = (7,910 \pm 0,003) \cdot 10^{-12} + (2 \pm 1) \cdot 10^{-14}$

Fluka dx: $y = (7,510 \pm 0,003) \cdot 10^{-12} + (2 \pm 1) \cdot 10^{-14}$



Run provided updates useful to estimate the mixed radiation field doses in BTF produced by HE e-beam on target

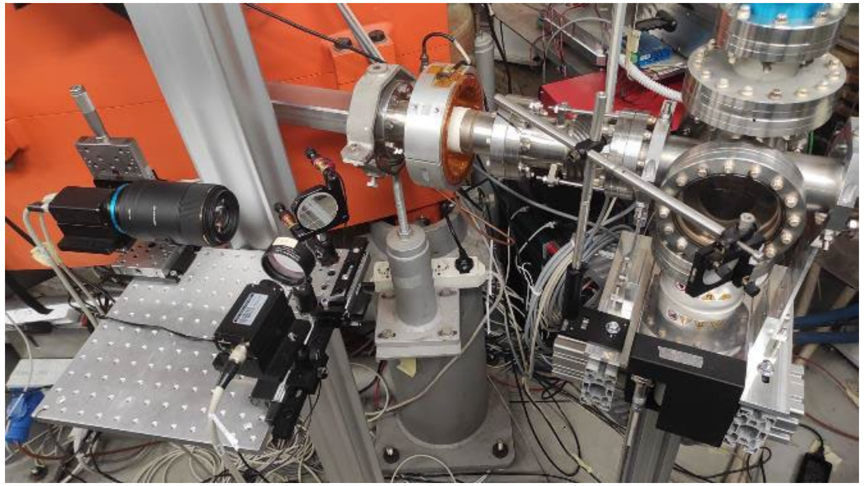
SPARC-ULENS

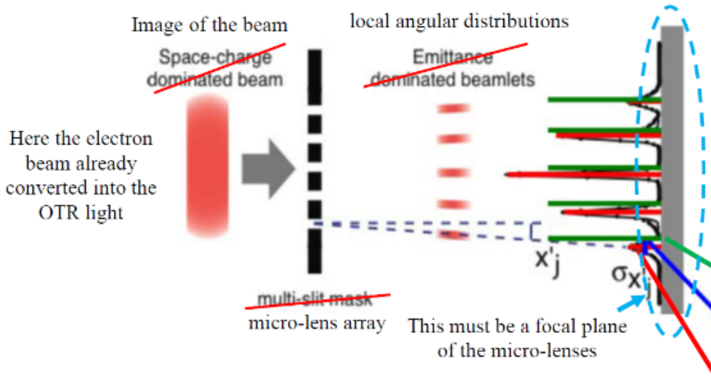
BTF USER run (New Diagn.)

Synergistic emittance measurement system both for SPARC **Vladimir Shpakov** and BTF team.

Single-shot beam emittance via a pepper-pot-like method:

-> microlens array beamlets from the beam OTR radiation produced by the OTR radiator. Single shot measurement of **beam size (OTR beam image), beam divergence (from OTR ang. distr. image), beam correlation (from microlens)**



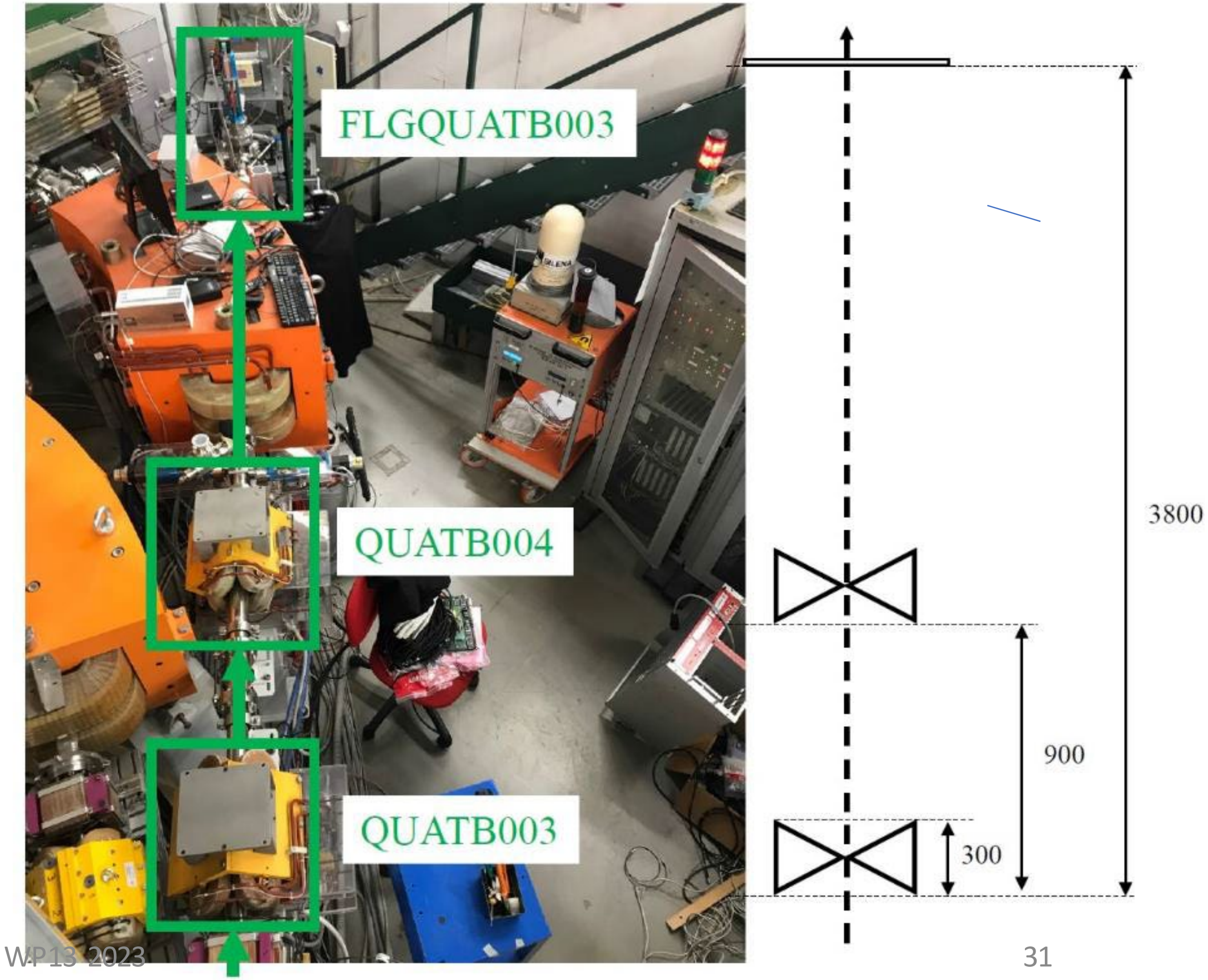


In **optical pepper pot** the necessary parameters are extracted in following way:

- beam size is determent in similar way – by the number of micro-lenses "covered" by the beam
- beam divergence a bit more complicated. Each of the micro-lenses will create an angular distribution for the corresponding beamlet. Since we are working with OTR the beamlets divergence can be extracted from OTR angular distribution
- the correlation is determent also in a similar fashion to a classical pepper pot. The sift is measured between the center of angular distribution and optical axis of the corresponding micro-lens.

$$\varepsilon = \sqrt{\langle x^2 \rangle \langle x'^2 \rangle - \langle xx' \rangle^2}$$

Courtesy of SPARC-LNF



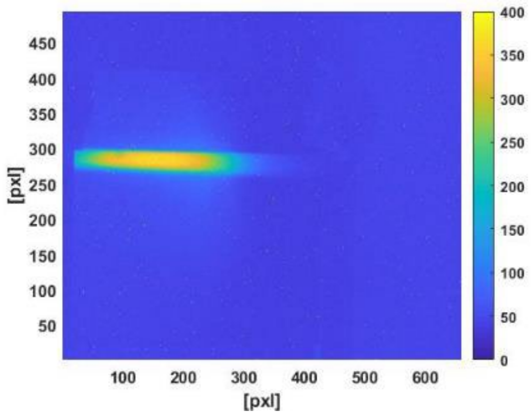
SPARC-ULENS

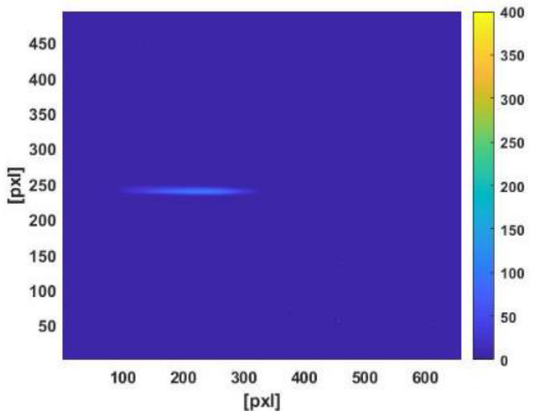
BTF USER run (New Diagn.)

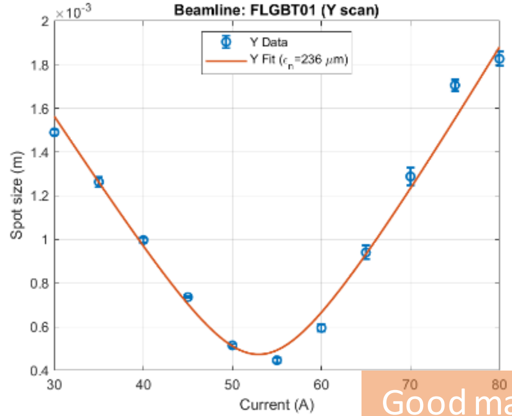
BTF beam 503 MeV, 1 Hz, ~10^7 e+/s, ~10^9 e-/s, optimized
Sub mm beam size

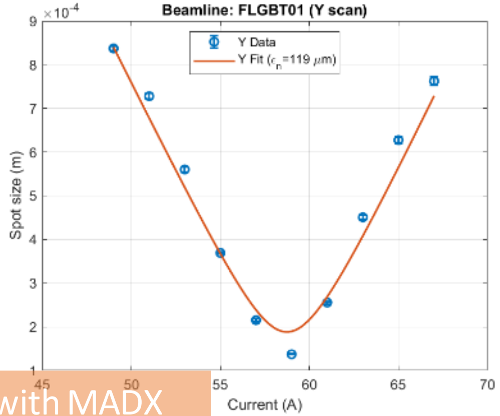
Synergistic emittance measurement system both for SPARC **Vladimir Shpakov** (leave) and BTF team.
Single-shot beam emittance via a pepper-pot-like method:
-> microlens array beamlets from the beam OTR radiation produced by the OTR radiator. Single shot measurement of **beam size (OTR beam image), beam divergence (from OTR ang. distr. image), beam correlation (from microlens)**

ELECTRON Beam = 503 MeV/10ns/300pC
Vertical emittance (rms) 0,2±0,05 mm x mrad



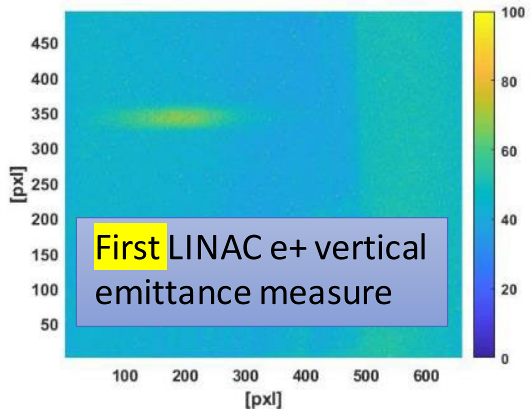




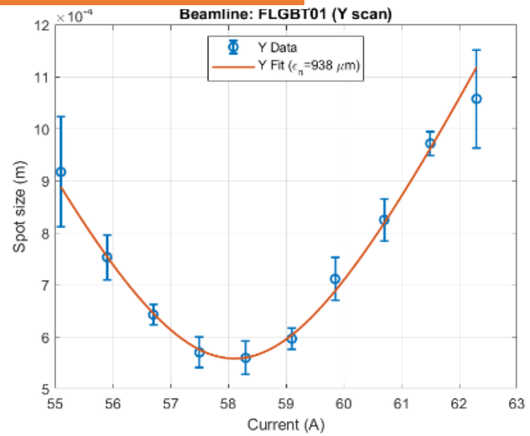


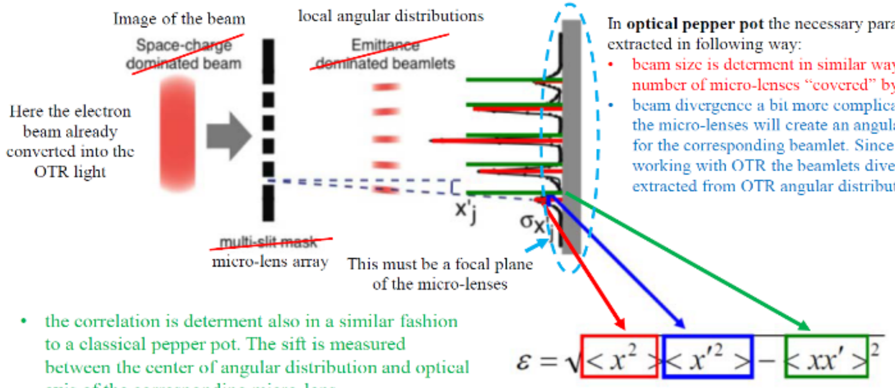
Good match with MADX sims (C. Di Giulio)

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



First LINAC e+ vertical emittance measure





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$$\varepsilon = \sqrt{\langle x^2 \rangle \langle x'^2 \rangle - \langle xx' \rangle^2}$$

FLASHMOB

FLASHMo6

- **BTF SCI Coll run: (New Mat. Prod. and Dosy.)**

BTF beam 504 MeV, 1 Hz, 10^9 e-/s, spot diameter around 2mm
Beam on a ~ thin foil Mo target

Explored an alternative approach to produce Tc-99m radiopharmaceutical, a crucial diagnostic tool in medical imaging, without relying on nuclear reactors.

Scientific collaboration with:

- Researchers from Rutherford Appleton Laboratory and (RAL, UK) and ENEA (target, idea)
- INFN-LNF (BTF, FISMEL, and SPCM teams) (target setup, testbeam and measure)
- Based on Nature | Vol 603 | 17 March 2022 | **393**
- **Two months from measure idea to install the 3D printed setup**

Run Aims:

- ^{99}Tc Production
- Tc buffer (based Mo precursor)
- assessment of the physical model used in the Monte Carlo code (cross section measurement). First measure at these energy

Courtesy of L.Quintieri (RAL, UK)

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, paper ongoing

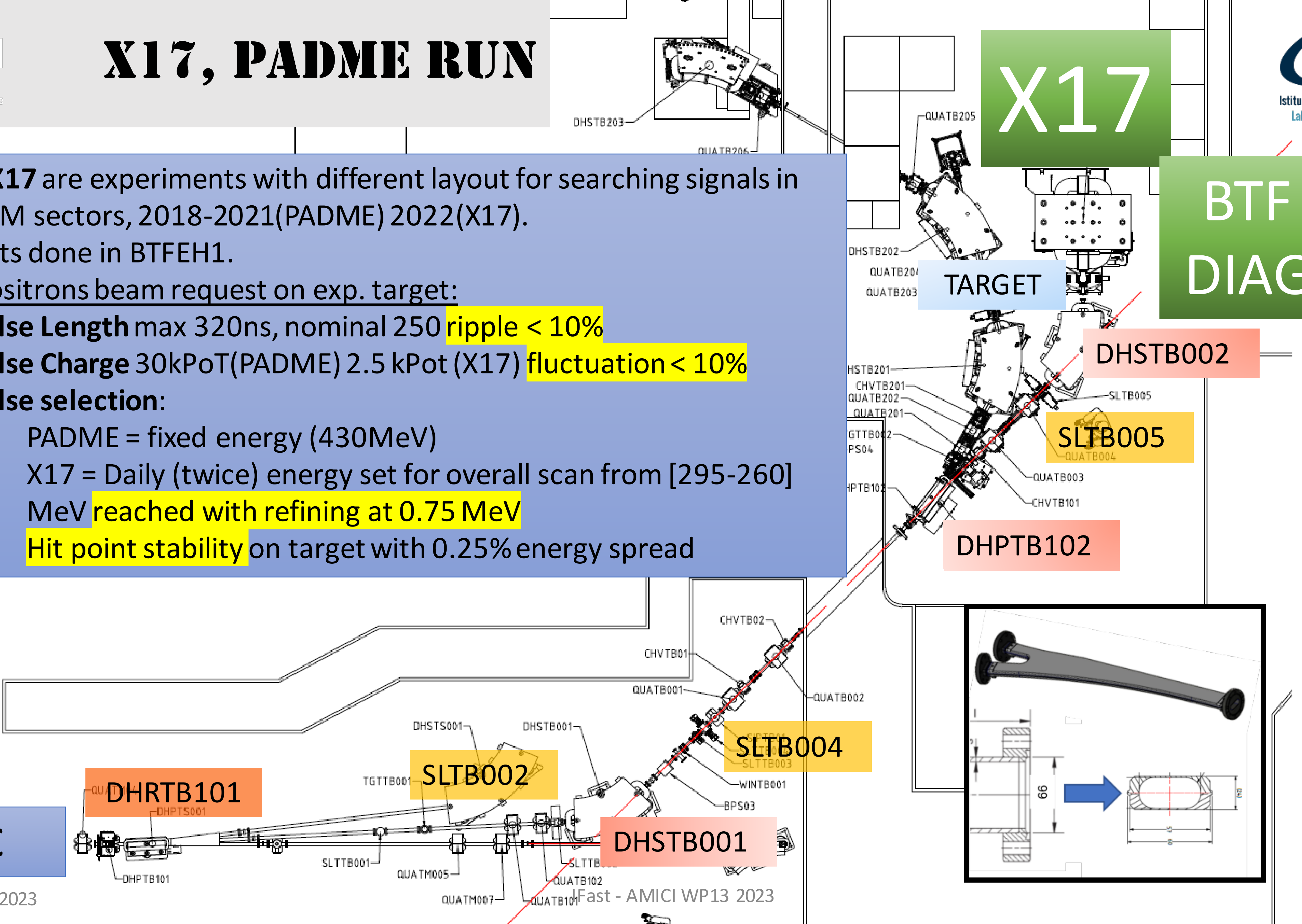
BTF

LONG TERM BASED EXP

X17, PADME RUN

PADME / X17 are experiments with different layout for searching signals in different DM sectors, 2018-2021(PADME) 2022(X17).
Experiments done in BTFEH1.
Primary Positrons beam request on exp. target:

- **Pulse Length** max 320ns, nominal 250 ripple < 10%
- **Pulse Charge** 30kPoT(PADME) 2.5 kPot (X17) fluctuation < 10%
- **Pulse selection**:
  - PADME = fixed energy (430MeV)
  - X17 = Daily (twice) energy set for overall scan from [295-260] MeV reached with refining at 0.75 MeV
  - Hit point stability on target with 0.25% energy spread

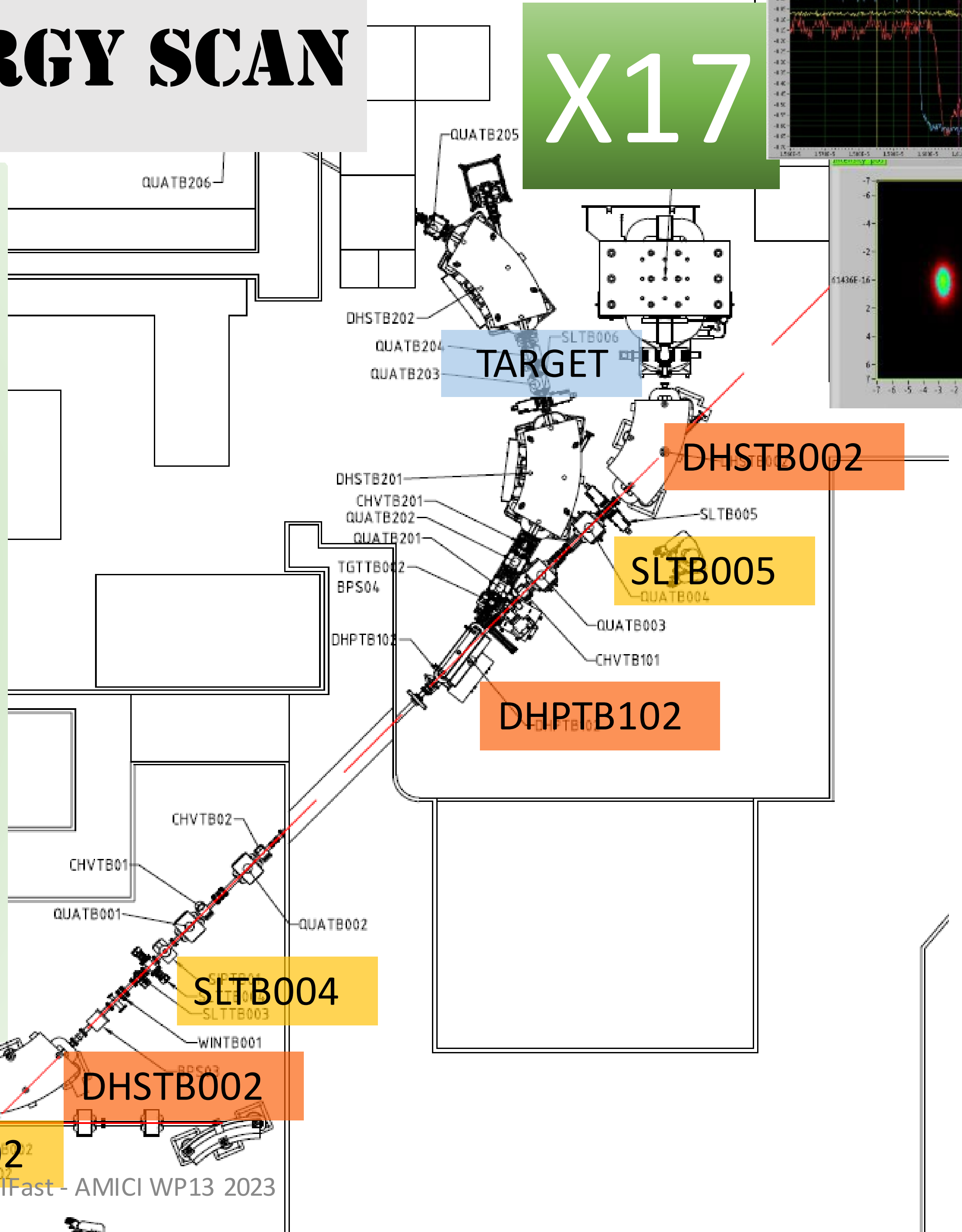


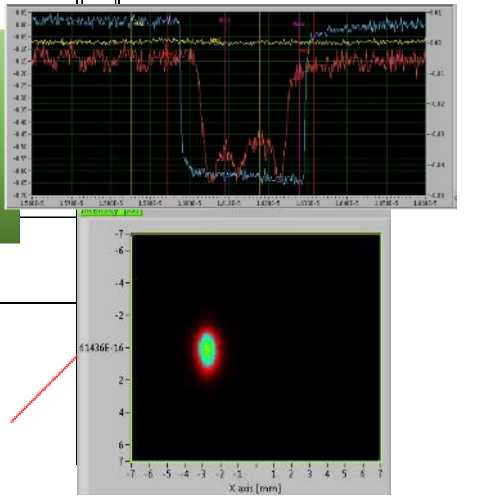
BTF FOR X17 ENERGY SCAN

Measure type:

- Improved energy scan of ~0,75 MeV (around 10 PS DAC digits-> 150KeV)
- Descending branch of the DHSTB001 hysteresis loop
- DHSTB001 ->-0,5A
- DHSTB002 ->-0,5A ± DAC digit (beam based alignment)
- DHRTB001 -> -1A in the tails of energy scan
- SLTB002 Scrapers ±0,1mm (±500PoT)
- REMAINING SCRAPERS
  - Halo removal
  - Beam transverse reference point
  - Untouched for overall data taking

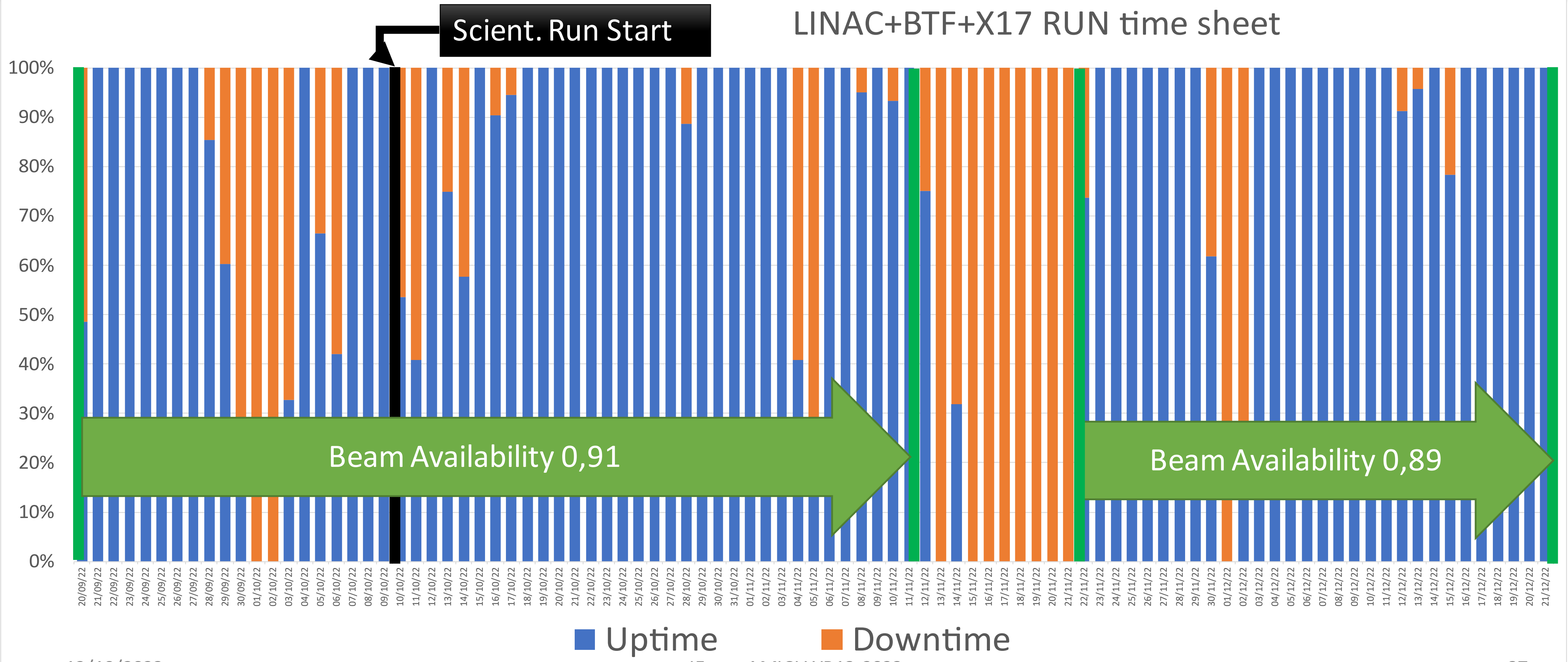
Stay clear checks via steering magnets (CHHVVTBXXX and DHPTB102)



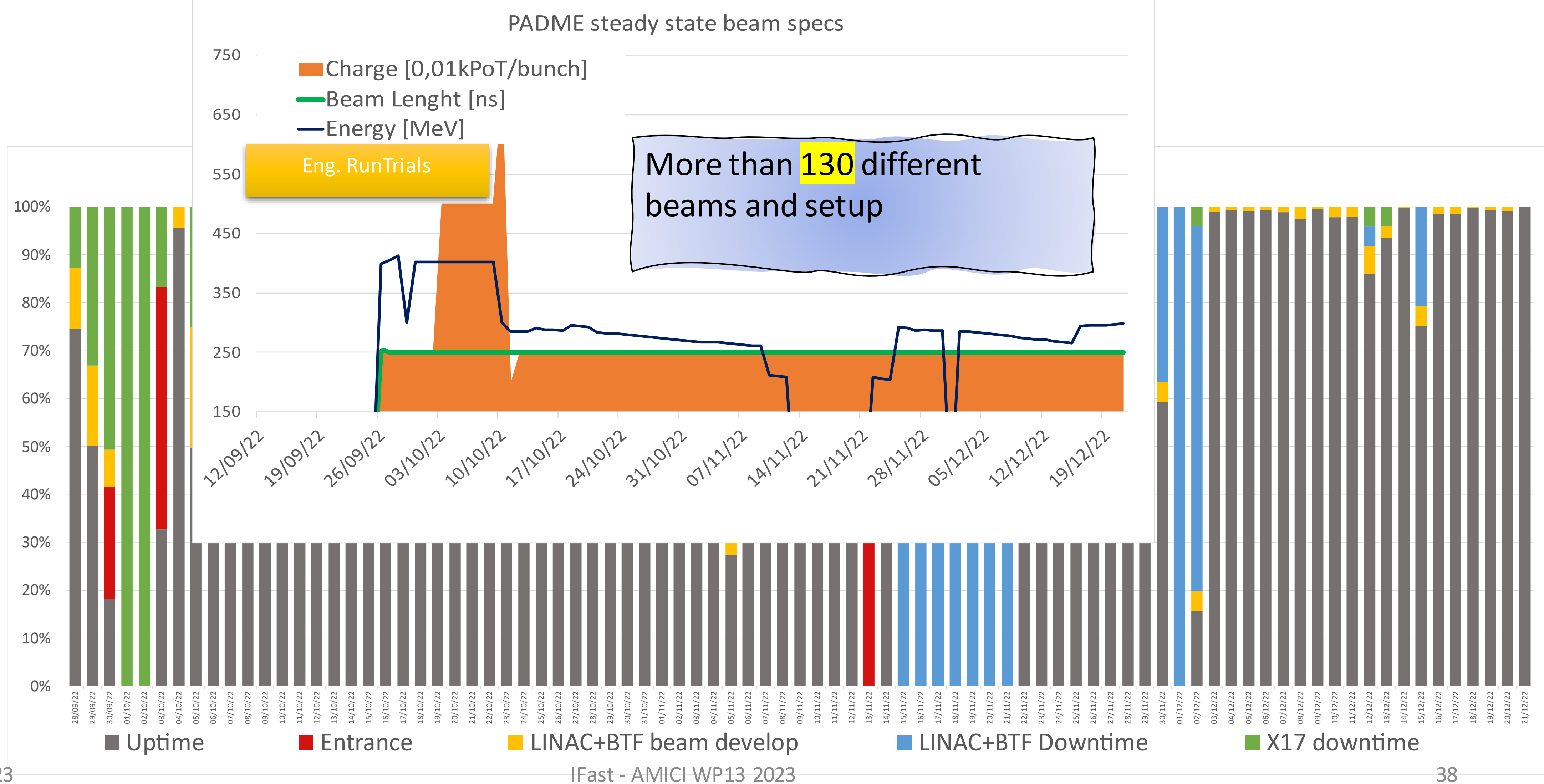


BTF X17 RUN STATISTICS

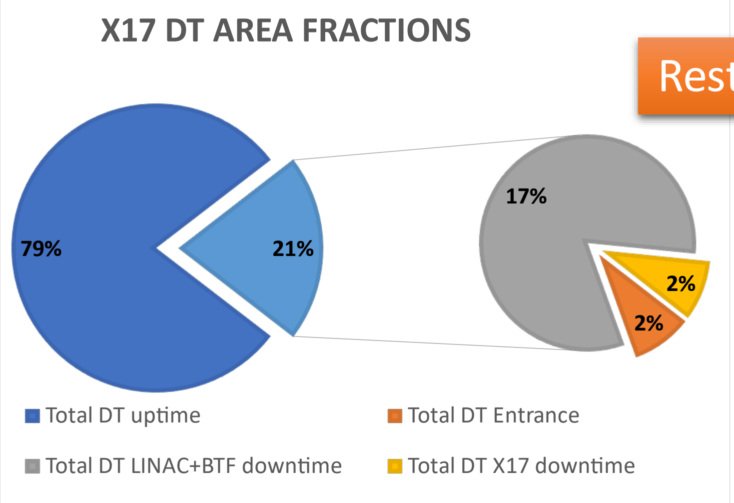
- 50Hz, continuos BTF dedicated injections, 24/7 operation for more than three months
- In respect to PADME RUN, the X17 injection efficiency moves from 0.77 to 0.9 average (counting restored days at December)
- Main stop due to maintenance on this **National Main Power Line branch and a fault on SLED B Vacuum Windows**



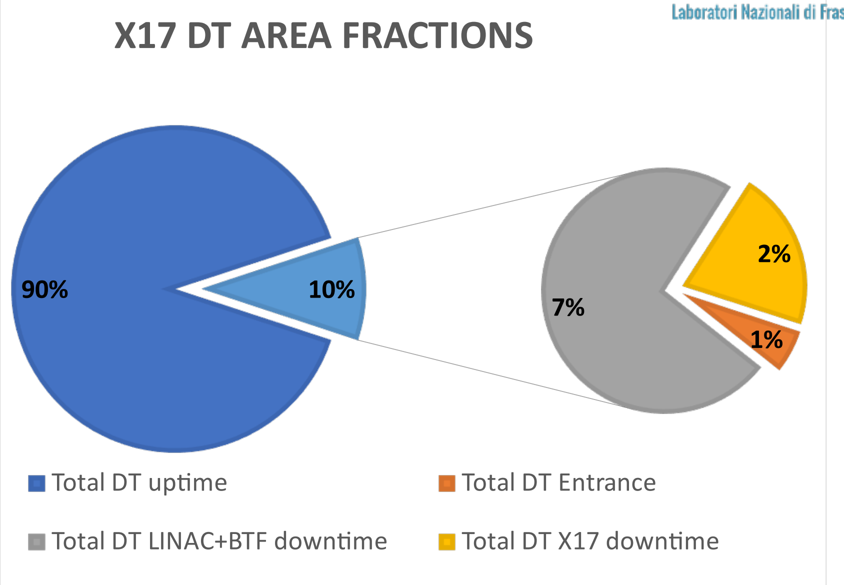
BTF X17 RUN STATISTICS

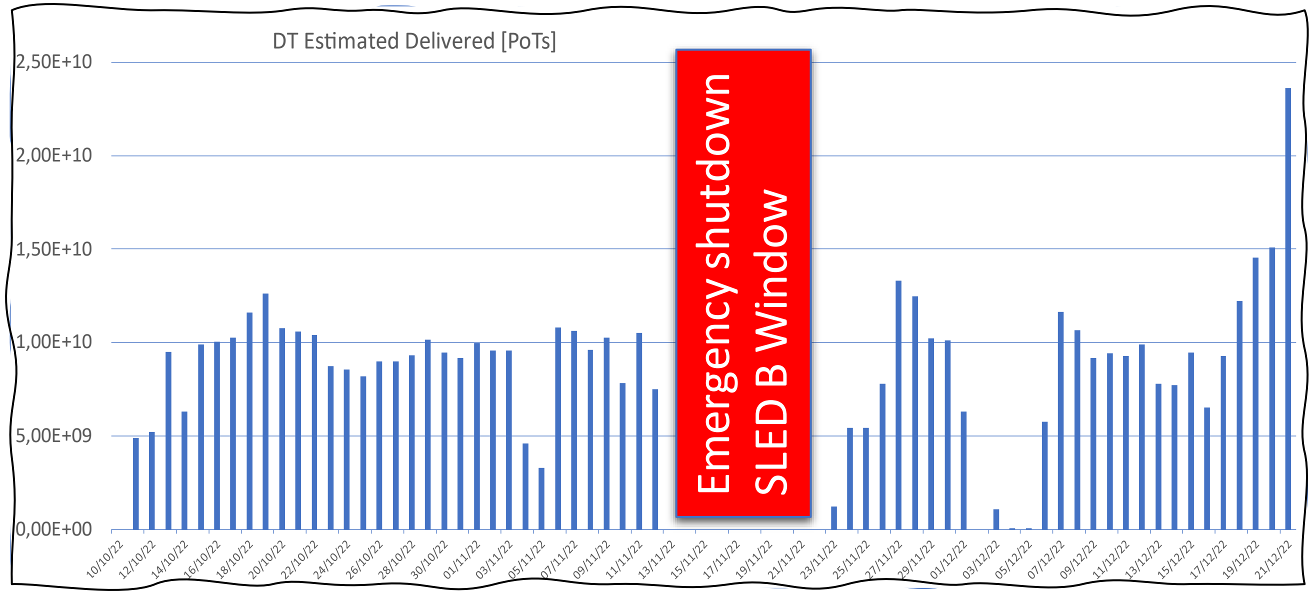


X17 RUN STATISTICS



Restored Days from 15° -> 21° Dec





- Delivered suffers huge variance due to very low current (and related photons from Mylar window, see previous slides)
  - **Delivered** PoTs (from BTF secondaries Diagn)
    - Average $(0{,}9\pm0{,}2)\times10^{10}$ [PoTs/day]
    - Gross total $6{,}51\times10^{11}$ [PoTs]
  - We were out of total 3+2+8 overall day in data taking
  - Restored 8 days
  - 72 days on Scientific Run, 100 Tech+Scient

BTF PROJECTS

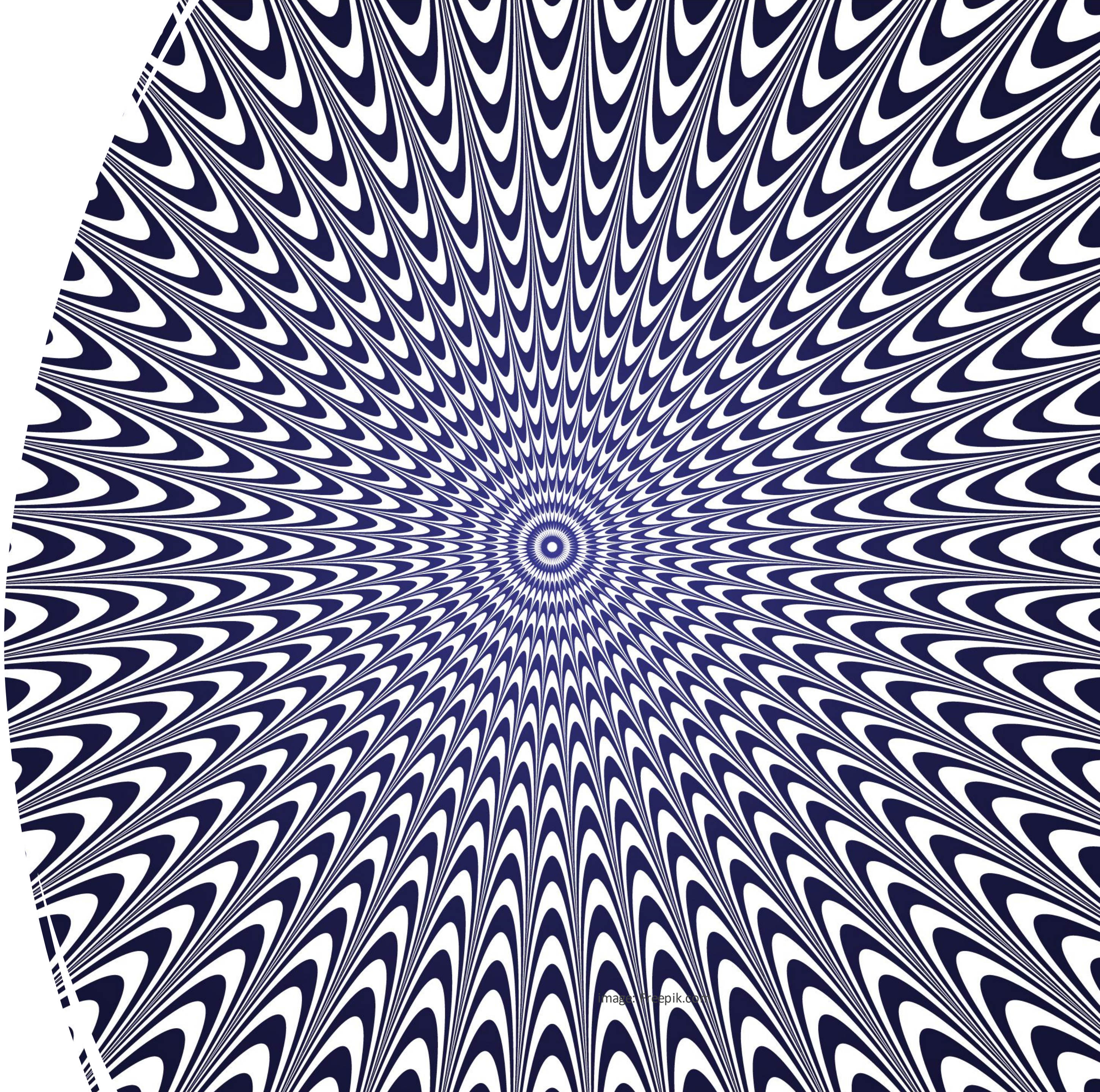
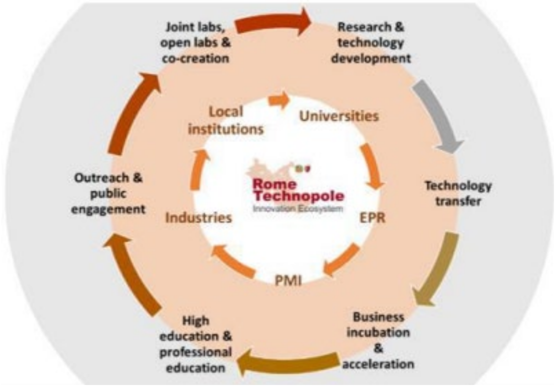


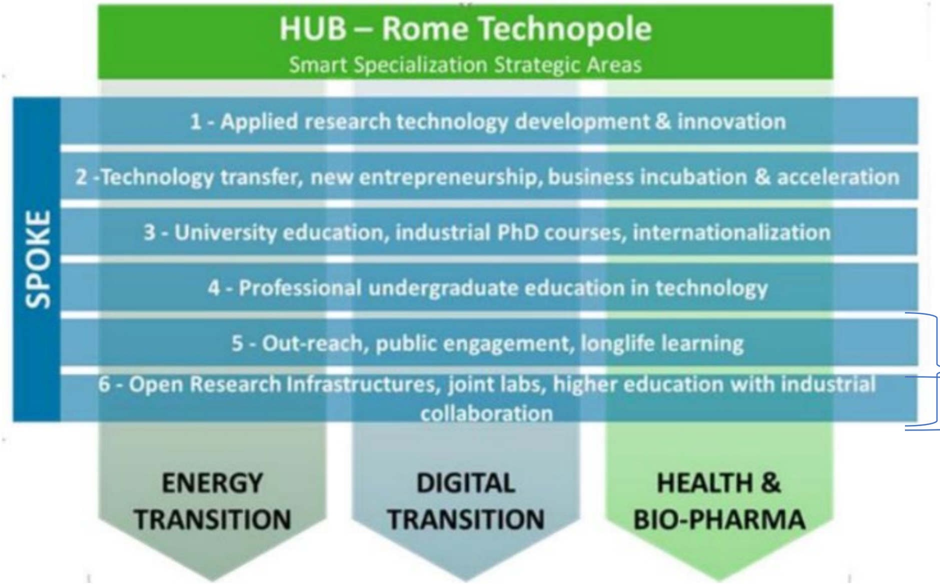
image: Freepik.com

Avviso pubblico: Proposte per la creazione e il rafforzamento di "Ecosistemi dell'Innovazione»
PNRR, Missione 4 Istruzione e ricerca
Componente 2 Dalla ricerca all'impresa, Investimento 1.5



Rome Technopole
Innovation Ecosystem

AIM:
Equip the region with an open research infrastructure to provide support for competitive innovation and growth for companies and stakeholders.



LINAC SERVICE involved with total 1.2 FTE/YEAR
(B. Buonomo, F. Cardelli, C. Di Giulio)

Flagship projects

Joint Open Labs:
o FP4 (Health & Bio-Pharma) – **F. Cardelli** (Resp. BvTech) – Measurements and RF conditioning of acc. structures for medical application
o FP6 (Digital Transition) – **C. Di Giulio** (Resp. Thales) – Development of algorithms based on Machine learning for big-data analytics, Virtual and augmented reality and Digital Twin.

ERAD PROJECT

Last Test Beam in July 2022

Project ended with great success!

REGIONAL FUND ~ 690kE (FTE+Consumables)

AIMS:
The general aim of the project is the use of electron sources, available at the INFN-LNF to measure the behavior and resistance of electronic components intended to be subjected to radiation in the aerospace environment.

The values and results acquired with these measurements will be compared with homologous measurements performed with photons in order to define comparative resistance thresholds and related indicators.

ERAD @ BTF

INFN TEAM :
Project leader: B. Buonomo

Project TEAM: **LINAC BTF Staff and LNF Services**

eRAD
Test di resistenza alle radiazioni per componenti aerospaziali

eRAD Protocol N. 001/2022

Electron beam irradiation protocol proposal for electronic components in the aerospace environment

This document is a proposal for a irradiation protocol for electronic components in the Space environment. It is the result of the eRAD project where the difference competencies by the Italian Space Agency (ASI), the National Institute of Nuclear Physics (INFN) and IMT s.r.l. in the contest of the LAEROSPAZIO main project coordinated by the ENEA synergic propose this protocol.

eRAD – DELIVERABLE REPORT – MANUALE DEI REQUISITI OPERATIVI D1.1

eRAD – DELIVERABLE REPORT – RAPPORTO DI PROVA : HIGH ENERGY ELECTRONS RADIATION TESTS IN COMPARISON WITH TID TESTS D2.1

eRAD – DELIVERABLE REPORT – RAPPORTO DI PROVA D3.1

eRAD – DELIVERABLE REPORT – RAPPORTO DI PROVA LINAC-BTF D4.1

BTF offers EUROLABS support

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

Access

To provide efficient access to the available resources at a major fraction of **EUROpean Laboratories for Accelerator Based Sciences** (**EURO-LABS**).

Infrastructure

Large and diverse community of users to choose the most appropriate state-of-the-art Research Infrastructures RI(s).
For conducting high impact research, fostering the sharing of knowledge and technologies across scientific fields.

Data Management & Service Improvements

Implementation of good practices for data management and activities relating to targeted service improvement to enhance capabilities and performance of the RIs.

RIs

Provide broad and focused joint training activities with hands-on experience at the RI's to develop diverse skills of the next generation researchers, for the optimal use of the large number of RIs potential for scientific and technological discoveries.

Community

Build a super community of sub-atomic researchers and the associated technical staff.

Physics

This proposal brings together for the first time in Europe the three communities engaged in Nuclear Physics and Accelerator/ Detector technology for High Energy Physics.

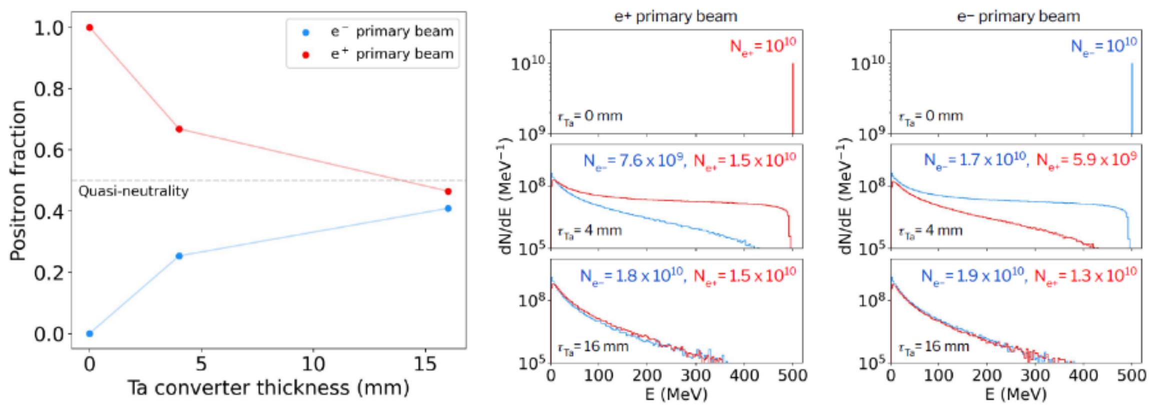
BTF Remarks and Future develops

- LINAC is in permanent upgrade: GUN, HVPS, Modulator setup are the latest, to provide very high uptime
- BTFEH2 recently installed and commissioned: huge effort in COVID period but we got it
- Recent interest in neutral beam for Astroparticle and Plasma accelerator
    - i.e. Blazar Jets and Gamma Ray Burst (G. Gregori)
    - Syntactic Isomorphism especially for plasma acceleration studies
    - Lab Astrophysics as new way to study astrophysical object, complementary to both observation and simulation
- FLASH therapy needs huge contribution from low energy electron LINACs
    - short pulse
    - highly charged
    - medical application

=> LINAC+BTF@1GeV could be a good improvement idea

Courtesy of
C. Arrowsmith (Oxford Univ.)

FLUKA simulations input: Beam intensity = 10^{10}, Particle energy = 500 MeV (mono-energetic), Tantalum converter thickness = 0, 4, 16 mm.



Approximate beam densities = 10^8–10^9 cm^{-3} (assuming 1 cm^2 beam size and 1.5 ns pulse duration).

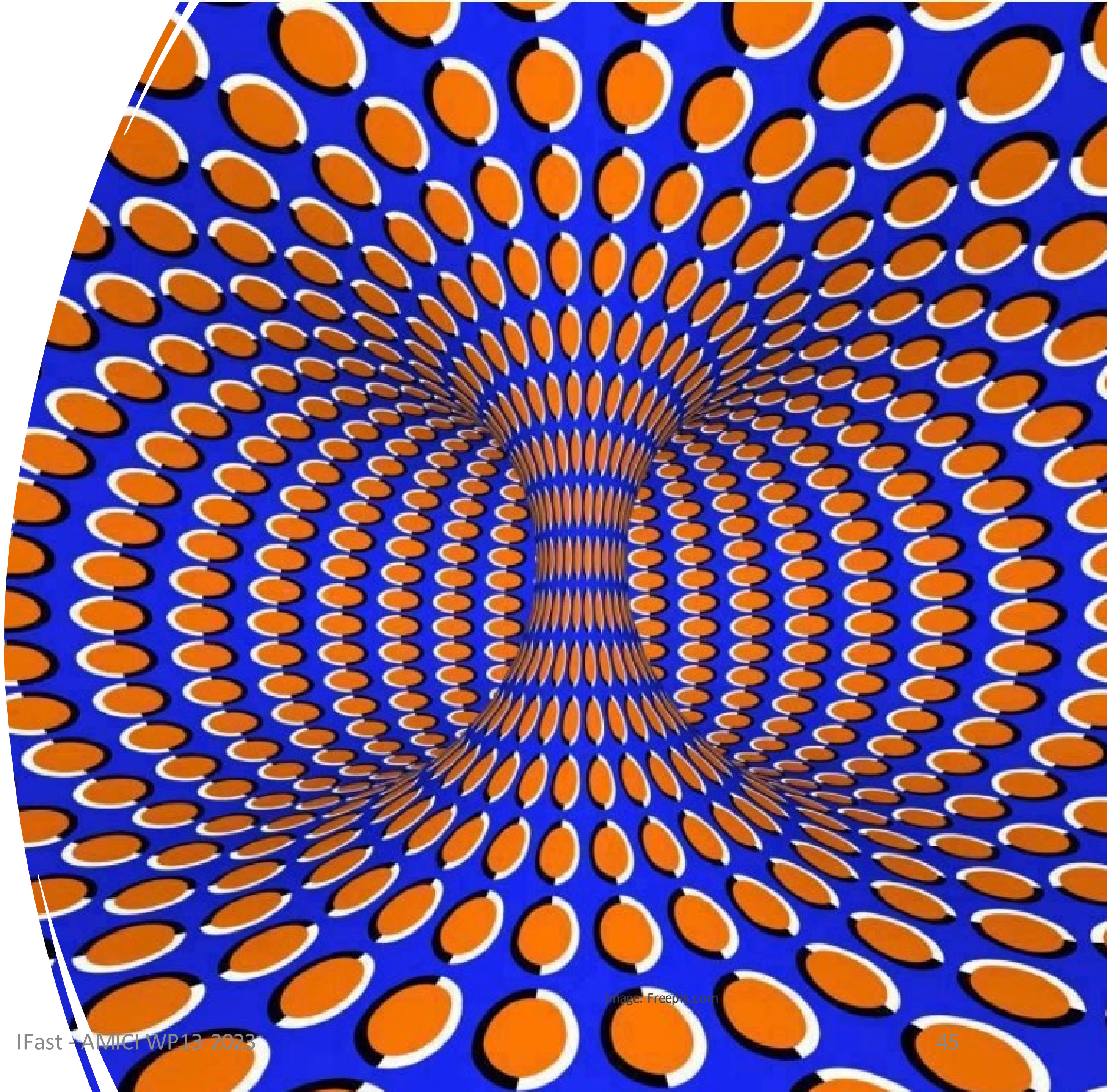
SUMMARY

Strengths of BTF:

- The facility can be easily reconfigured logistically to adapt to experimental needs.
- The ability to change parameters during data collection, well adapting beam to needs.
- After a brief training course, users are equipped to understand beam production mechanisms and operate on certain parameters.
- The user interface for parameter modification is intuitive and user-friendly (with manuals and wiki available).
- 24/7 support from beam operators.
- Everyone wants running in BTF for creating his own beam

Detailed information and contacts

- Main web site: https://btf.lnf.infn.it/
- Technical information and documentation: http://wiki.infn.it/strutture/lnf/da/btf/home
- Contact: btf@lists.lnf.infn.it



SWITCHING TO LONGER PULSE PRIMARY BEAM

BTF could be tuned for wide range of user requests (both primary and secondary beams)

Long term Experiments have led us to push forward functional limitation of LINAC-BTF

- Bunch length up to 300ns, pulse flatness in few percent
- Charge at user needs (down to single particle)
- High beam stability (bunch charge, position, transverse dimension, transport…)
- Very very low background (externals, pipe internal, dark current included)

Trials with longer pulse with secondary beam -> more background issues -> we switched to conditioned primary one:

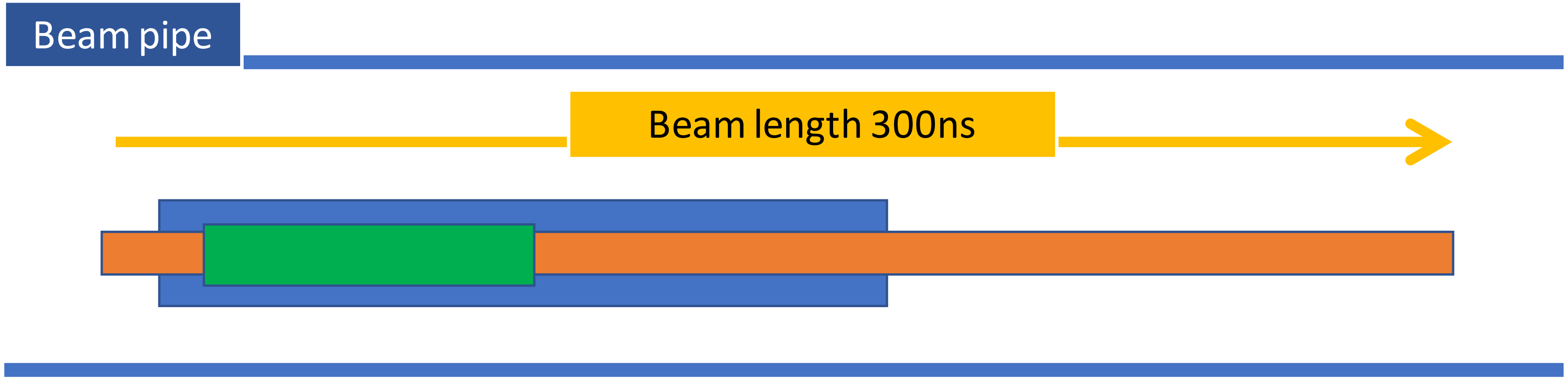
- **Lowering two order of magnitude the GUN emitted current**
  - Under the dynamic range for the most LINAC diagnostic, after positron converter (BCM, BPM, ICT)
  - Setup done at higher current, then increase GUN cathode control grid voltage (in linear range)

- **Reducing background** in BTF1 experimental hall and PADME
  - Increased stay-clear factor in BTFEH1 pipes, avoiding bottleneck
  - **Low beam loading and primary energy**=> Final beam energy spread around 5% (before BTF line selection)
  - Energy spread @ PADME target less than 1%

- **LINAC is in quasi-continuous mode** => Pulse time over 300ns => Beam length ~90m
    - The head of the pulse already converted in shower at the experiment, the tail yet to be born

LINAC BEAM – HODOSCOPE MEASUREMENT

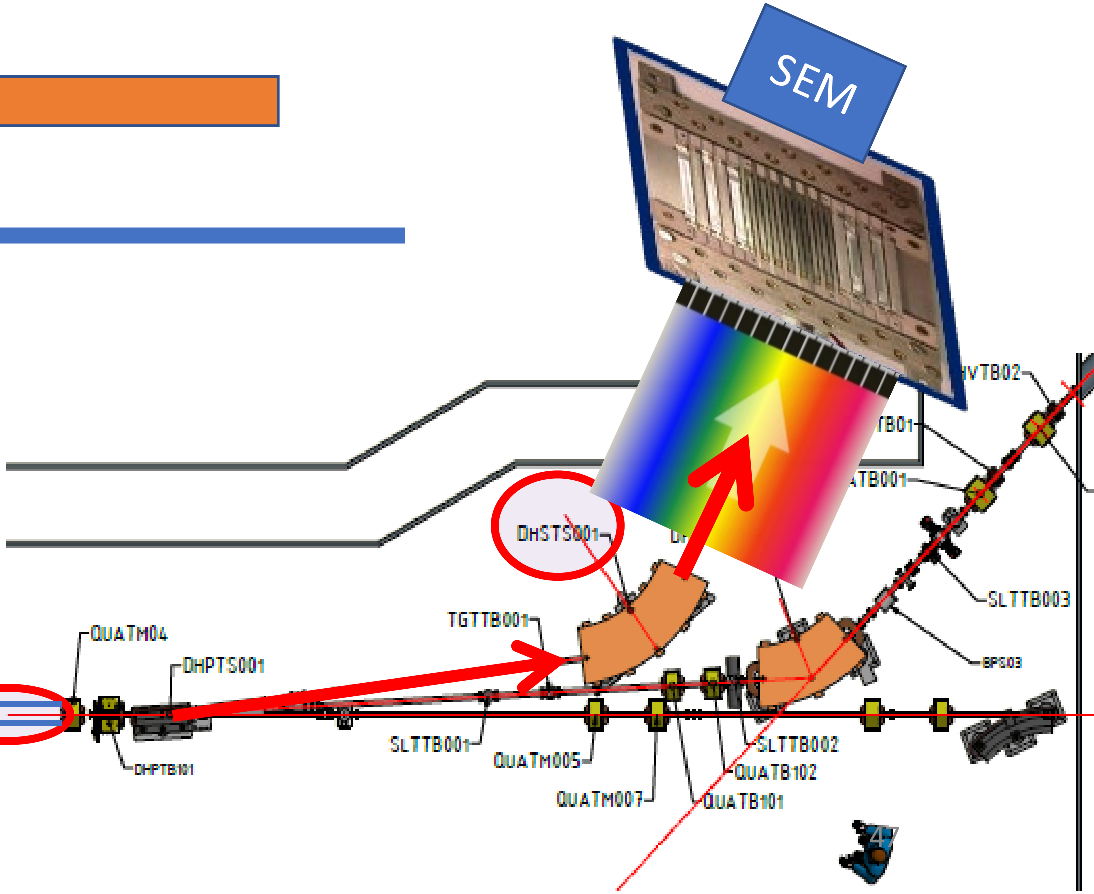
Naive model of LINAC 300ns beam pulse



+10MeV, 80ns, 10x charge

Beam energy centroid, 150ns, 2x charge

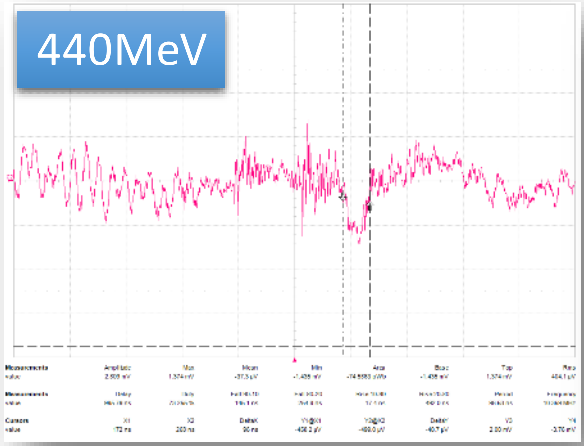
-10MeV, 300ns, 1x charge Good for Exp.

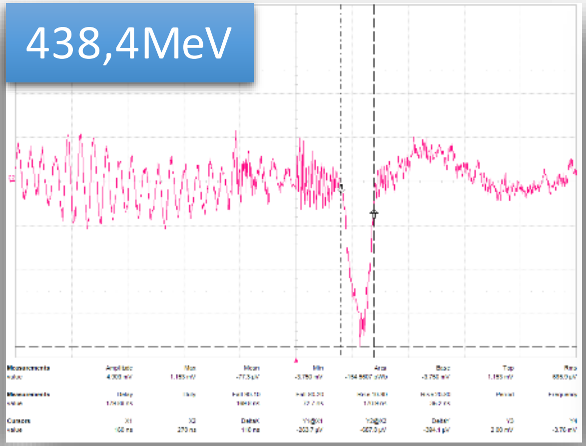


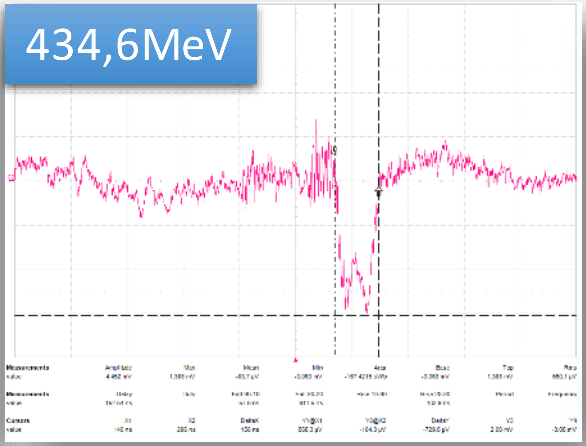
Hodoscope Seconday Emission strip Monitor (SEM)
used for LINAC pulse energy spread and charge diagnostic:

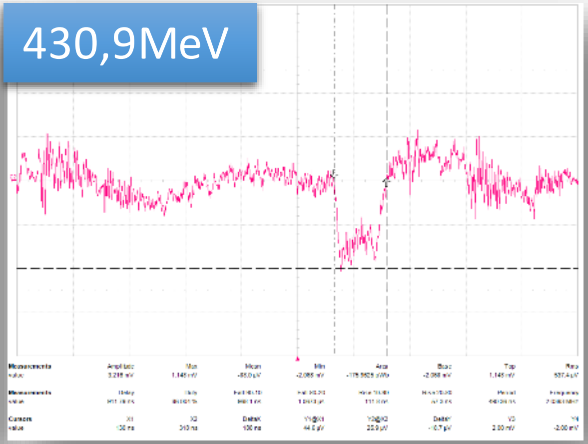
- **Downstream of DHSTS001 60° magnet (high dispersion)**
- Typically in charge readout (**QDC**)
- **Each strip senses a different beam energy bin**
  - **(~2MeV/strip at 432MeV energy)**
- Hodoscope time measurements with high band pass scope
  - Pulse delay
  - Pulse width
  - Pulse charge

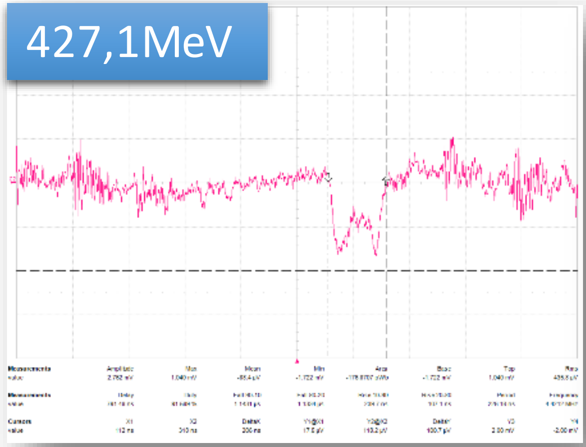
LINAC BEAM – PRIMARY LONG PULSE

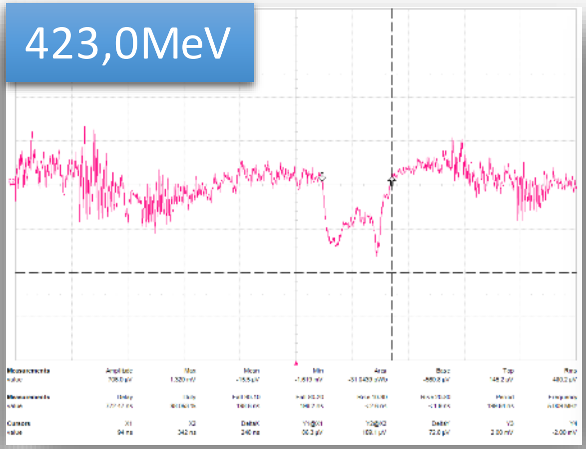


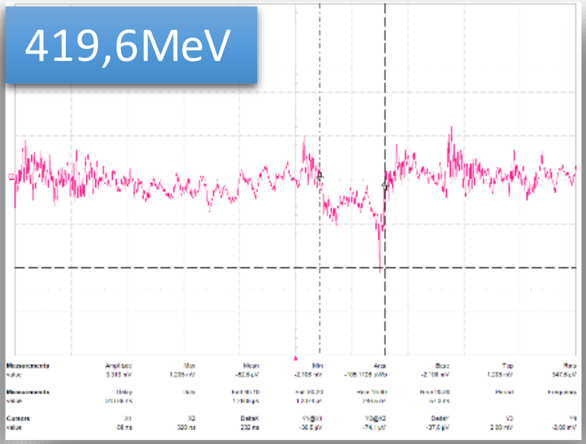


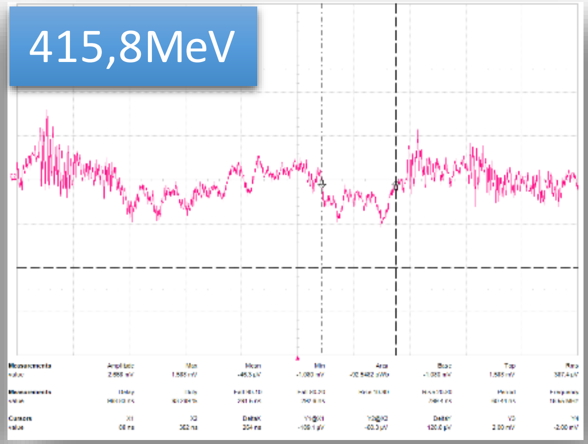




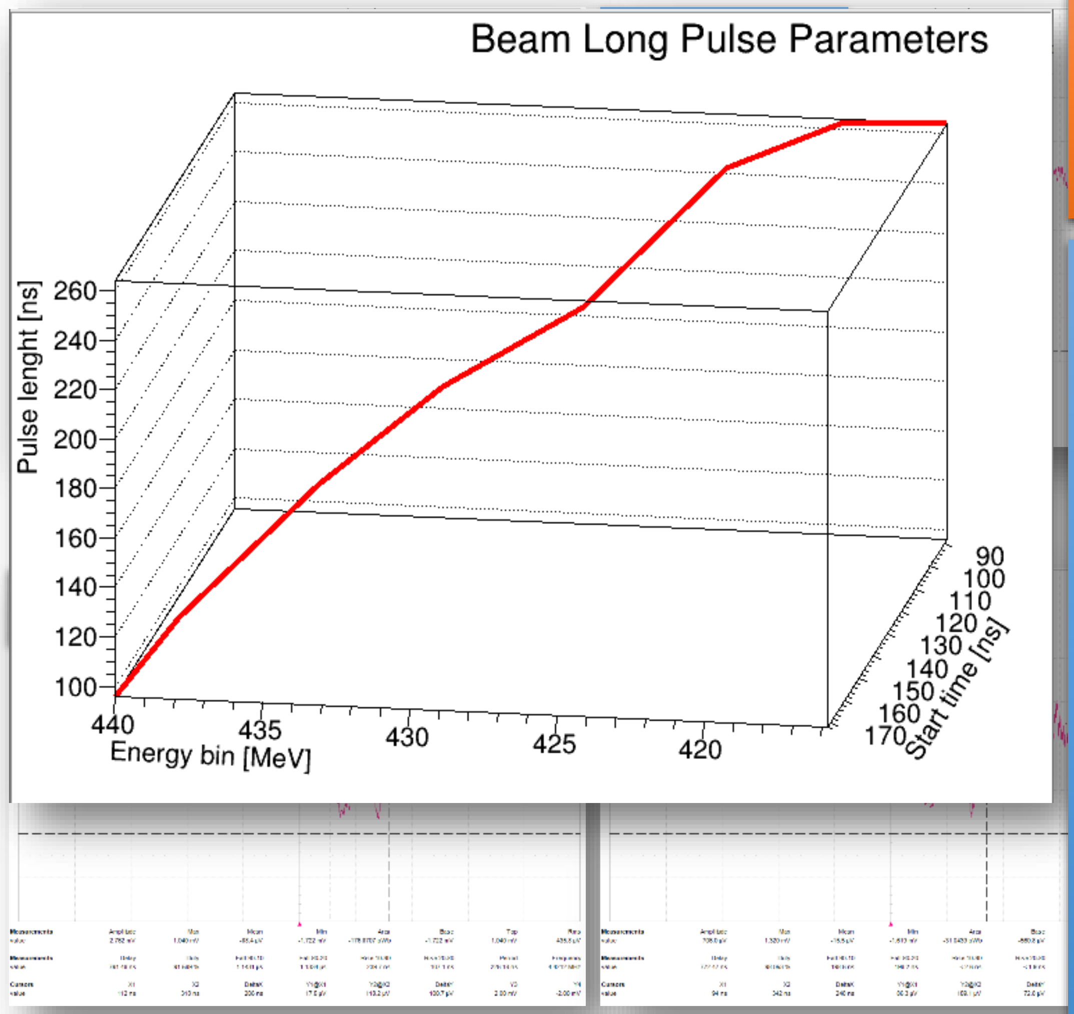








LINAC BEAM - HODOSCOPE



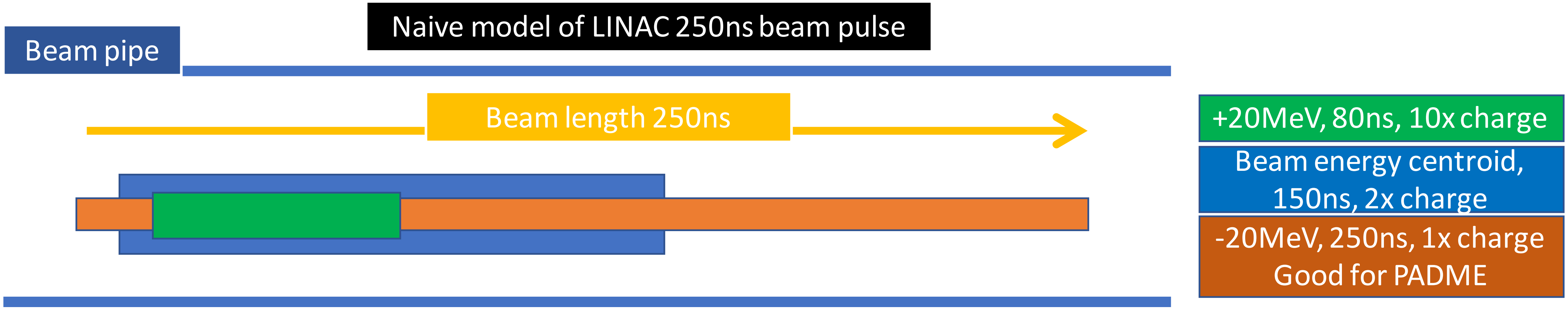
- Starting from end point energy, a monotonic increase on all the parameters (flux, energy bin, pulse width)
- A tool for selecting wide energy spread beams downstream scrapers and spectrometer

Beam structure strongly dependent on:

- Gun time advance in respect to the best injection point (as in DAΦNE mode, 10ns as DIRAC δ, -200ns)
- GUN control grid and HV
- LINAC RF main frequency then prebuncher&buncher power/phases
- Modulator phase, obviously, for the beam energy centroid I(t) (i.e. pulse flatness) controlled via first two mod's
- Modulator reciprocal timing

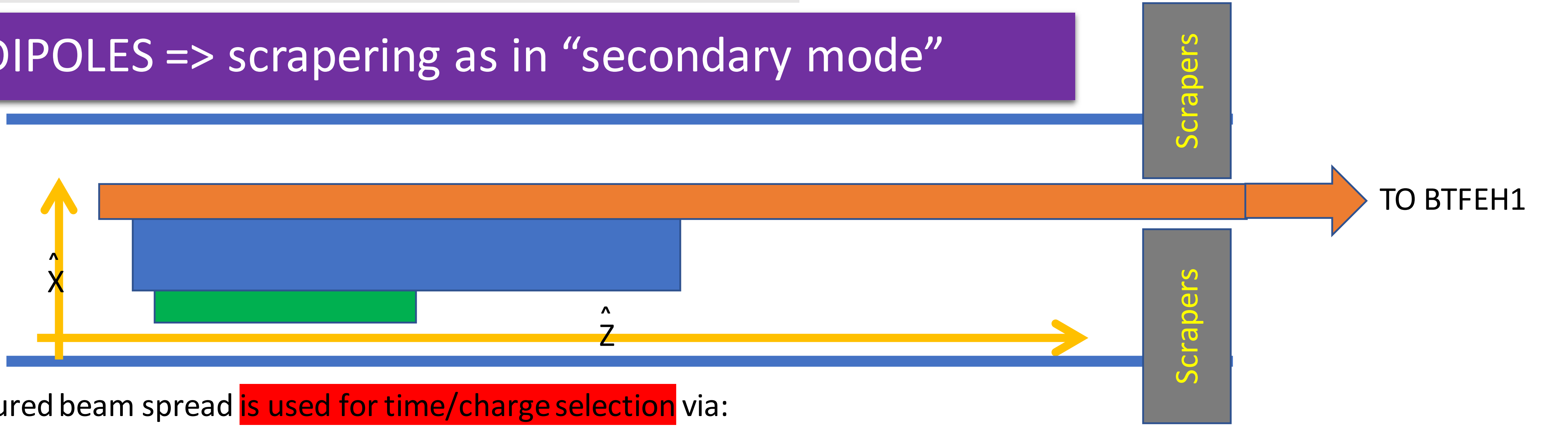
X17 LINAC BEAM

For X17 run:
- LINAC pulses 50 shots/s
- Primary positrons
- 250ns pulse for all the energy involved (400MeV and continuously 300MeV down to 200MeV)
- Lower current on target



BTF BEAM - SELECTION

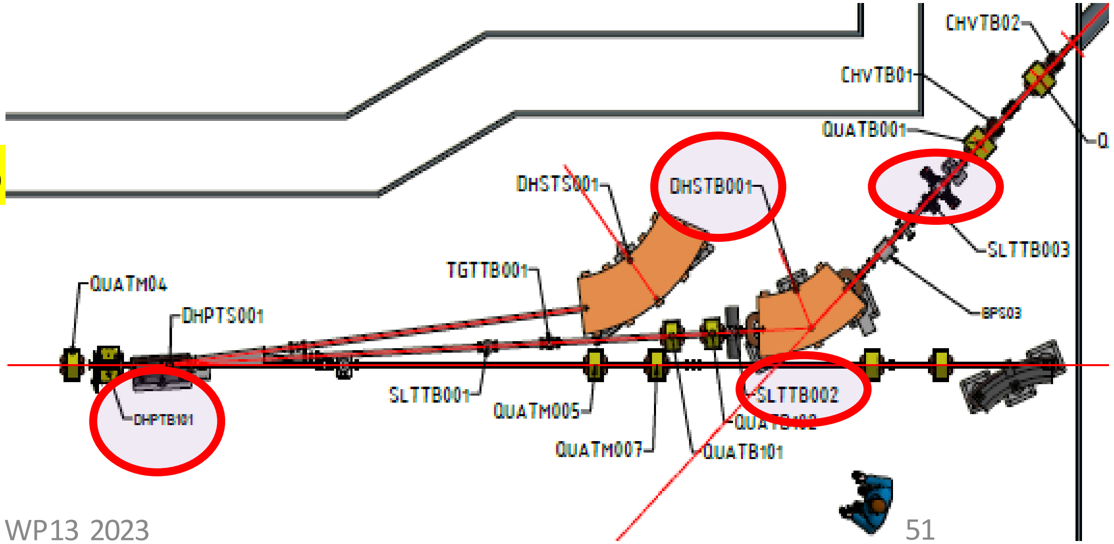
After DIPOLES => scrapering as in “secondary mode”



The structured beam spread is used for time/charge selection via:

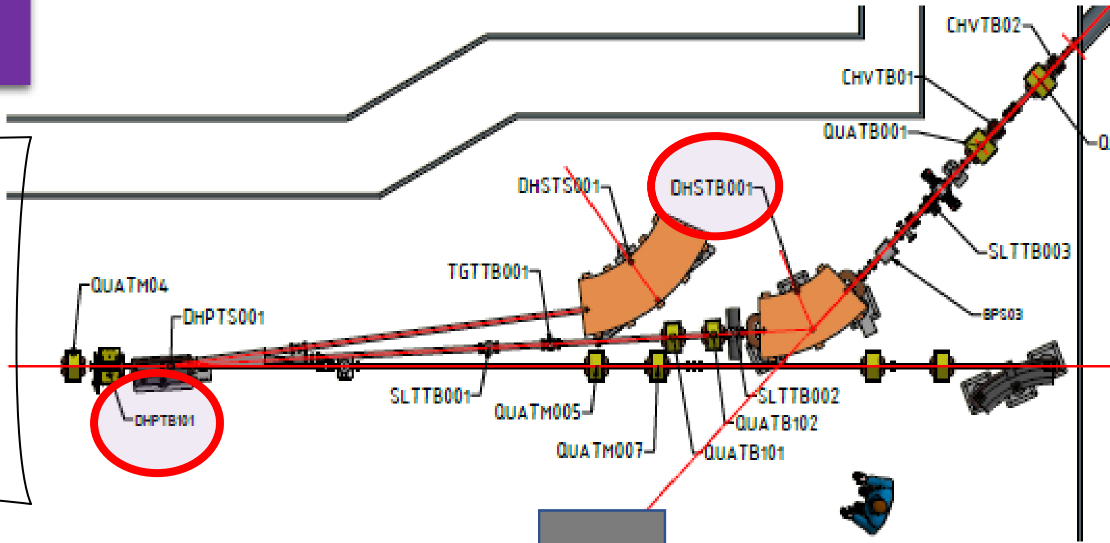
- Injection angle in BTF channel
- Horizontals scrapering, then get final energy spread

- Charge control via LINAC current with GUN grid fine tuning (down to single particle multiplicity !!!!) **-> no needs of target**
- SLTB004 scrapering downstream enhances final beam spread (< 1%)
  - Limited use of downstream scrapers => lower BTFEH1 background and beam halo effects
- **Reduced coupling of final focus from injected beam** (transverse shape are huge compared to SLTB003-004 scraper equivalent pin hole)



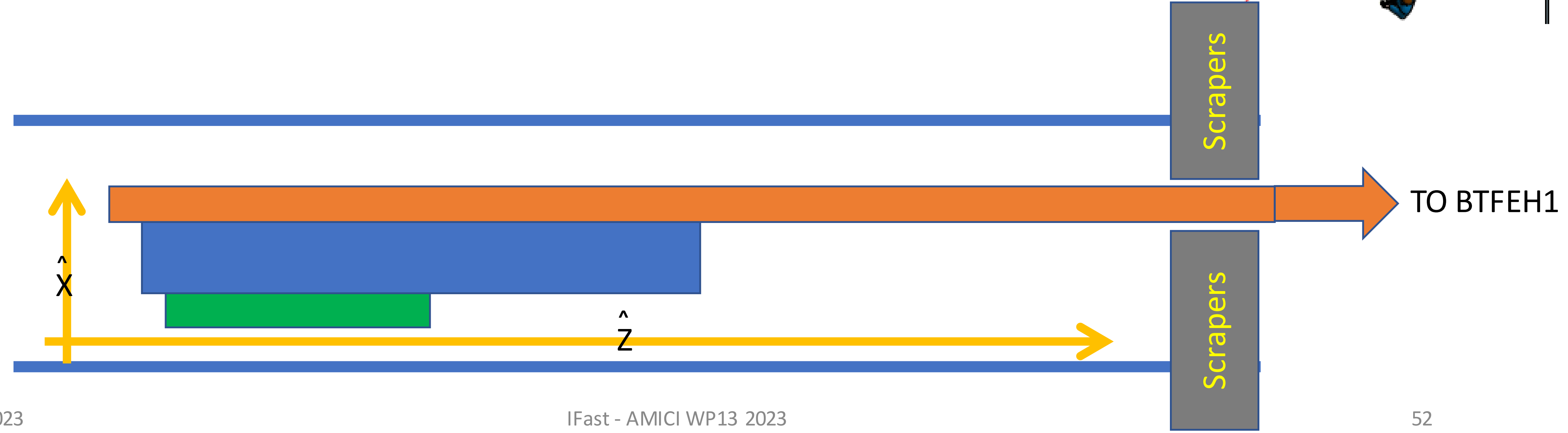
BTF BEAM - SELECTION

After DHSTB001 e DHRTB101, TB2 scrapering



The structured beam spread is used for time/charge selection via:

- Injection angle in BTF channel
  Horizontals scrapering , get final energy spread at SLTB002 level
- Refining as secondary beam the SLTB004
- Charge control via LINAC current is great(down to single particle multiplicity !!!!) **-> no needs of target**

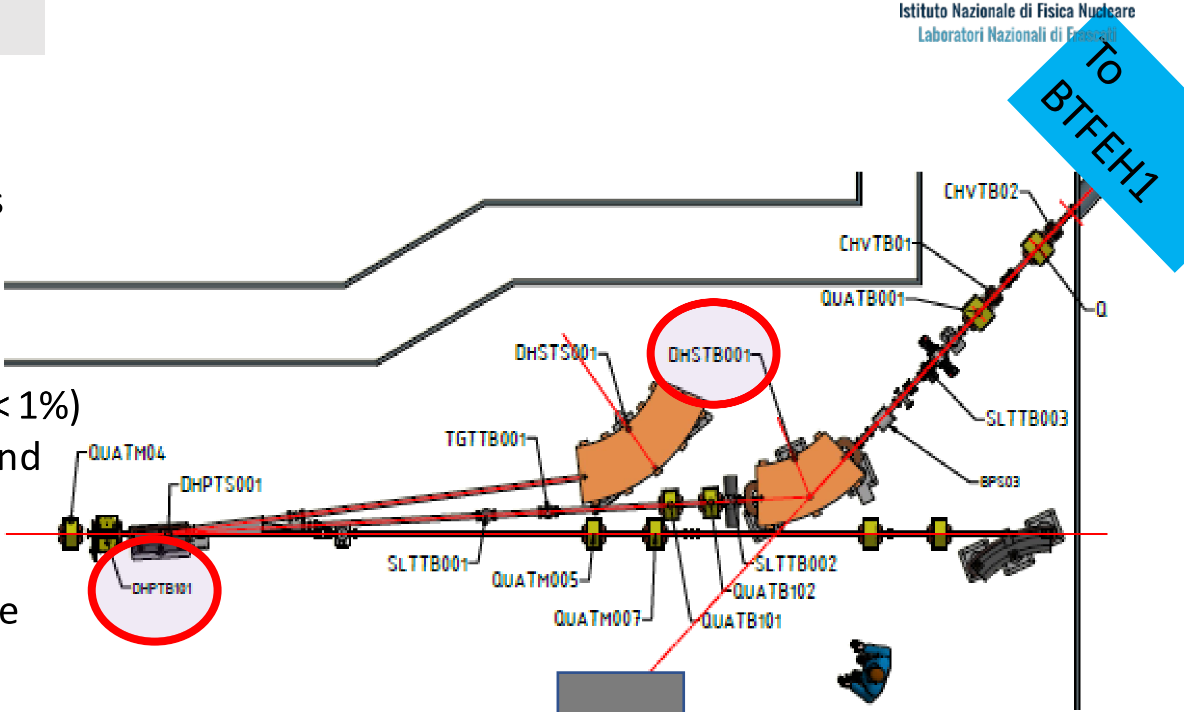


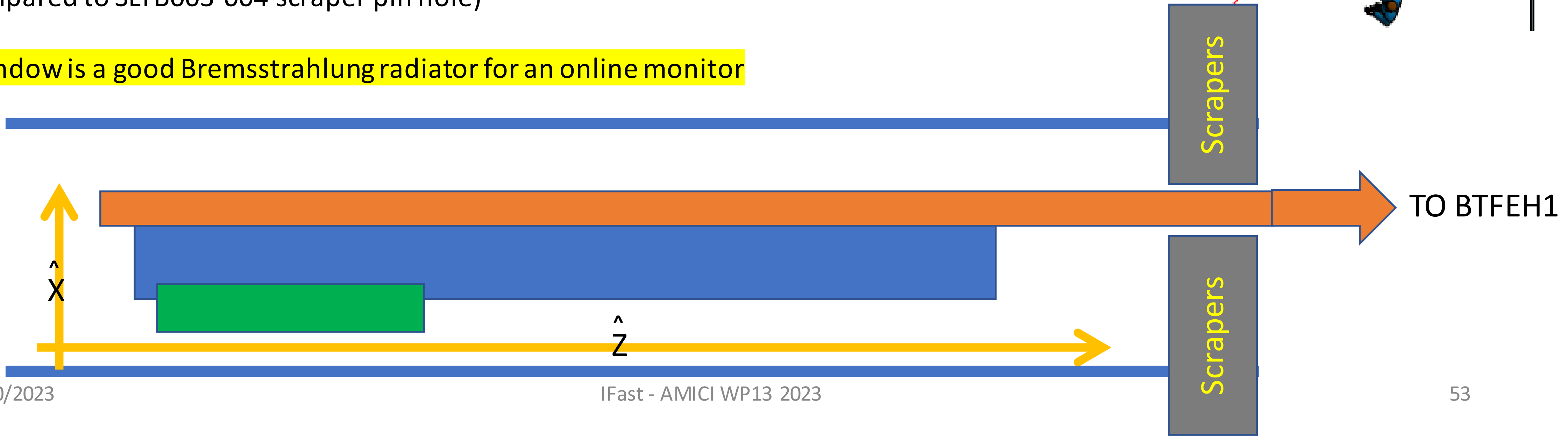
BTF BEAM - SELECTION

These way of beam structure leads to:

- DHRTB101 - DHSTB001 act as second beam pulse flattening tool (removes head-tail peaks)
- DHSTB001 sector magnet => -X sees more focusing, higher energy
  - Treat this beam as secondary beam (as BTF usually do)
- SLTB004 – SLTB005 scrapering downstream enhances final beam spread (< 1%)
  - Limited use of downstream scrapers => lower BTFEH1 background and beam side effects
- More degree of freedom to get desired beam parameters
- **Reduced coupling of final focus from injected beam** (transverse shape are huge compared to SLTB003-004 scraper pin hole)

- Mylar window is a good Bremsstrahlung radiator for an online monitor



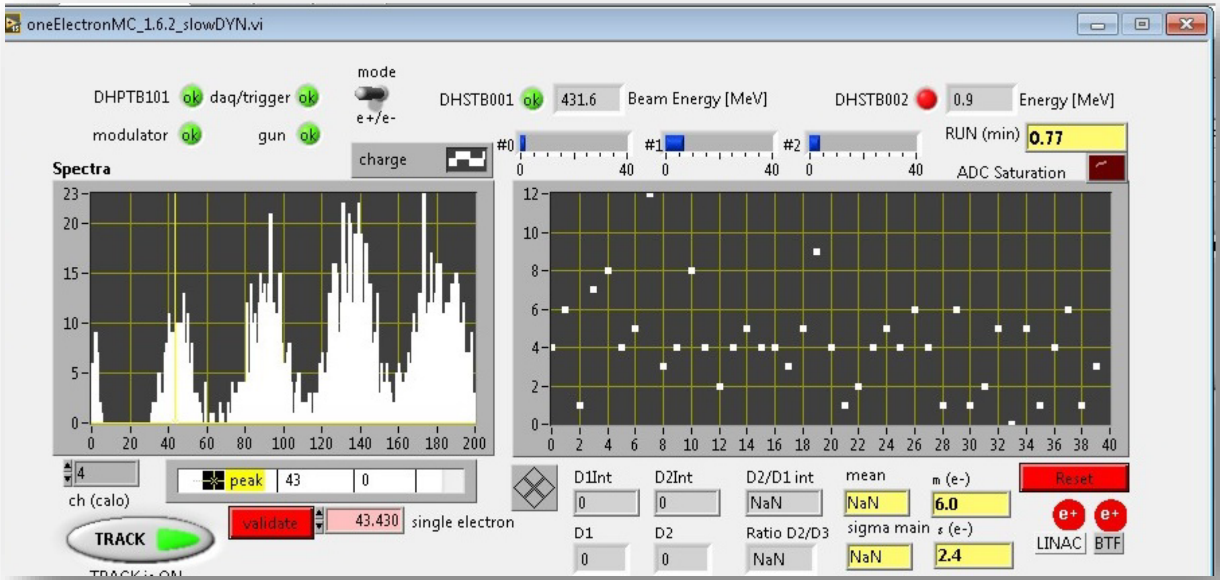


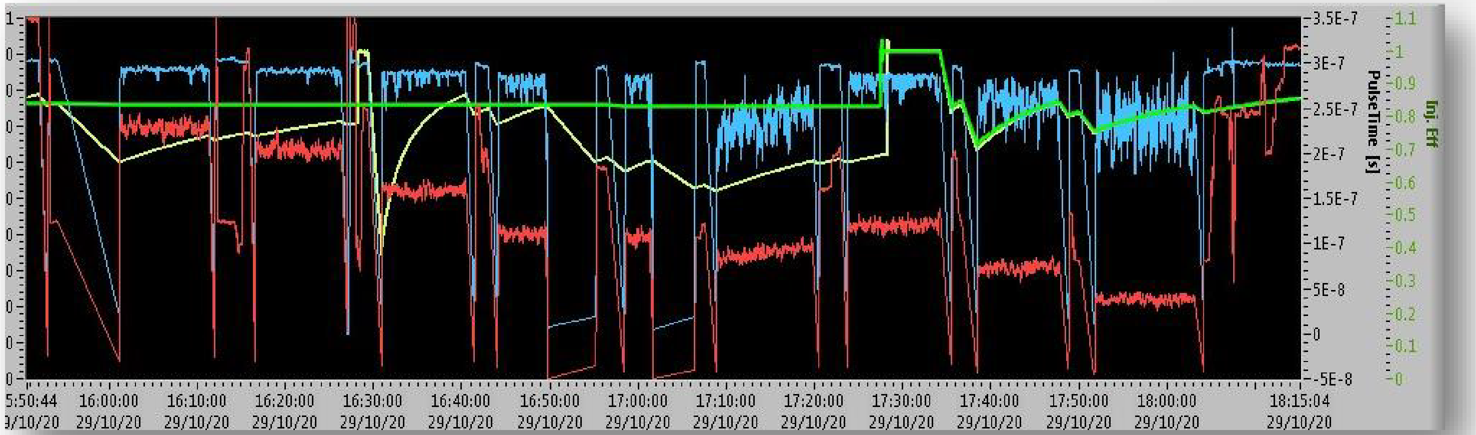
BTF1 BEAM – PRIMARY SINGLE PARTICLE

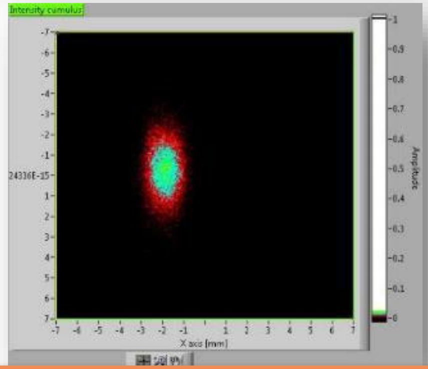
A tough feature gained is the delivery of a single particle beam by only means of GUN grid control:

- Scrapers setpoint unchanged from nominal position
- Apart GUN grid, LINAC set not changed
- Beam pulse width conserved (distortion on flatness)
- Linear control
- Standard transport unchanged

AGAIN another very good result for a LINAC intended for high charge, 10ns pulse!!!







Standard transport maintained in single particle range