

LINAC & BTF

L.Foggetta on the behalf of

LINAC/BTF Group

Researchers (5):

***B. Buonomo, F. Cardelli,
D. Di Giovenale, C. Di Giulio,
L. G. Foggetta
(Oct 2020)***

(From May 2021 up to Nov 2021)

Technicians (7):

***R. Ceccarelli, A. Cecchinelli,
M. Ceccarelli, G. Piermarini,
A.L. Rossi, S. Strabioli, R. Zarlenga
(Jun 2021)***

Retired: M. Belli, R. Clementi

BRIEF ACTIVITIES SUMMARY

What we got from last SciCom (Summer 2021)

LINAC (SIDDHARTA run)	12 Jan -> 04 Jul
LINAC (BTF2 commiss + user run)	04 Jul -> 26 Jul
BTF 2 installation and tech commissioning	08 Feb -> 18 Jun
BTF1 & BTFEH1 setup and checks (subservices, DAQ&detectors, safety checks)	01 Jun -> 21 Dec
BTF1 beam commissioning (BTF1 straight)	21 Jun -> 24 Jun
BTF USER run: KLEVER (2019, setup and preparation)	25 Jun -> 30 Jun
BTF2 Safety (final installation and commissioning)	24 Jun -> 10 Jul
BTF2 Beam commissioning (Phase 1 – 4d only with FISMELE present)	10 Jul -> 15 Jul
BTF USER run: ERAD (BTF1 straight, setup preparation and run)	15 Jul -> 23 Jul
BTF2 (power checks and detectors maintenance)	23 Jul -> 25 Jul
LINAC, BTF, DAFNE shutdown	26 Jul -> 15 Oct

BRIEF ACTIVITIES SUMMARY

What we got from last SciCom (Summer - Autumn 2021)

LINAC (Mob C HVPS installation, scheduled maintenance, PFN tune up, Thyratron box A,B,C,D)	26 Jul -> 18 Oct
LINAC Building upgrade (improving water seepage tightness linac build., LINAC OFF)	30 Jul -> 10 Oct
LINAC UFS upgrade (new power supply installation and test with magnets serv.)	02 Aug -> 10 Oct
LINAC diagnostic maintenance (slits and flags with vacuum serv.)	28 Aug -> 01 Sep
LINAC TEX duties (Kly installation and commissioning)	15 Sep -> UP to NOW
LINAC not scheduled maint. (Positron conv. vacuum bellow, quad fluids, primary pumps)	01 Oct -> 22 Oct
LINAC power up (checks, Beam on 700MeV, BTF2 test)	11 Oct -> UP TO NOW
DAFNE complex power up (partial part for LINAC and BTF)	18 Oct
LINAC and BTFEH1&2 safety checks	18 Oct -> 29 Oct
BTF2 Beam commissioning (Phase 2)	1 Nov -> UP TO NOW

BTF

EXPERIMENTAL ACTIVITIES

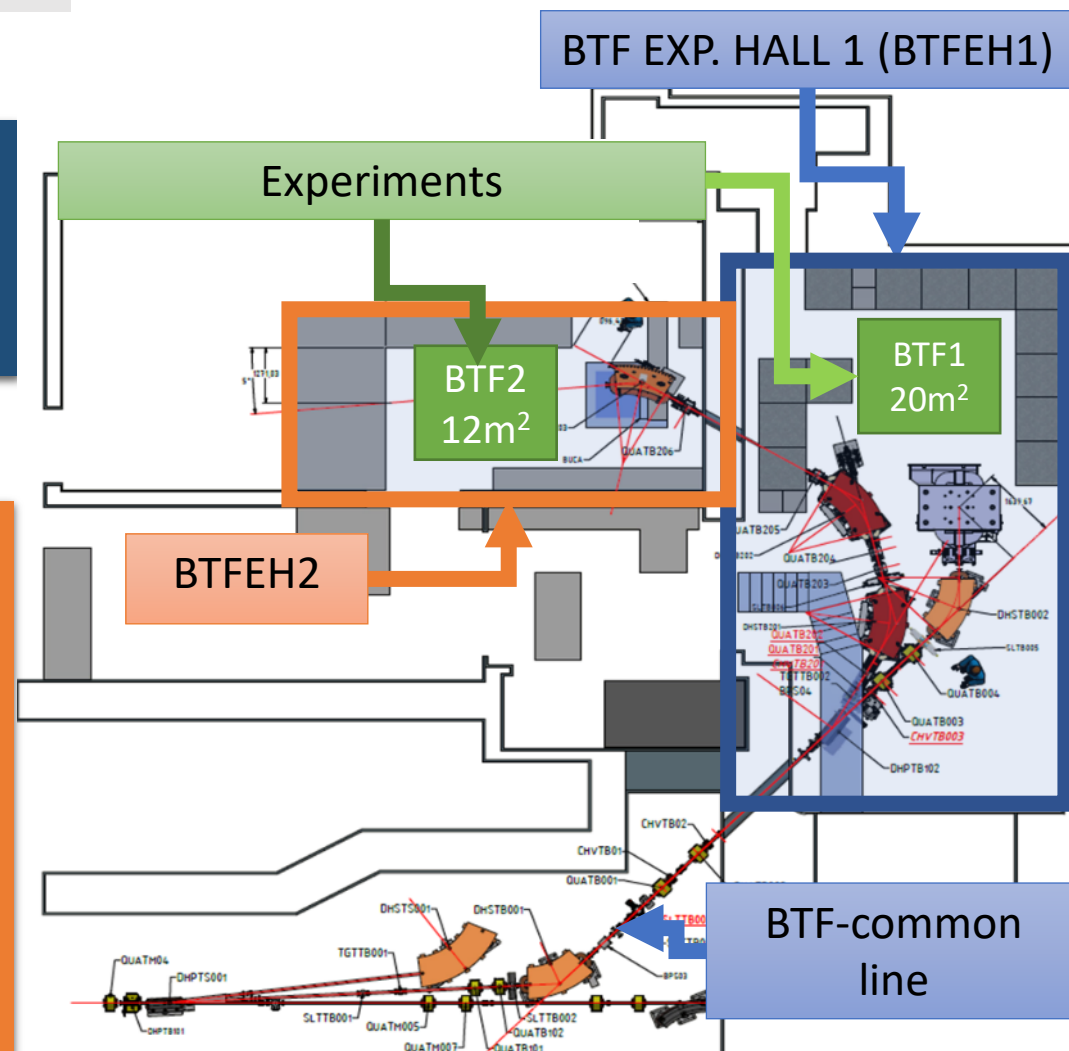
LNF – BTF LINES STATUS

BTFEH1 – BTF1

- **Operational** but now devoted to ERAD project and PADME experiment
- Involved in opportunistic INFN LNF user runs
- No other external users allowed for now, Next activities to be decided from Lab head.

BTFEH2 – BTF2

- **Hall operative, Beam commissioning on going**
 - Line mounting completed and tech commissioned
 - Safety commissioned
 - Beam Commissioning - First phase done (4-5days beam on)
- **Only BTF2 line to external users**
 - Intended for weekly based users
 - Only secondary beam, limited performances respect to BTF1
 - Have to understand facility interest
 - > in 2021-2022 will recover delayed users and sense the international user appreciation
- **Involved in EUROLABS Project**
- **Commissioning on going (today last measure)**



LNF – BEAM TEST FACILITY

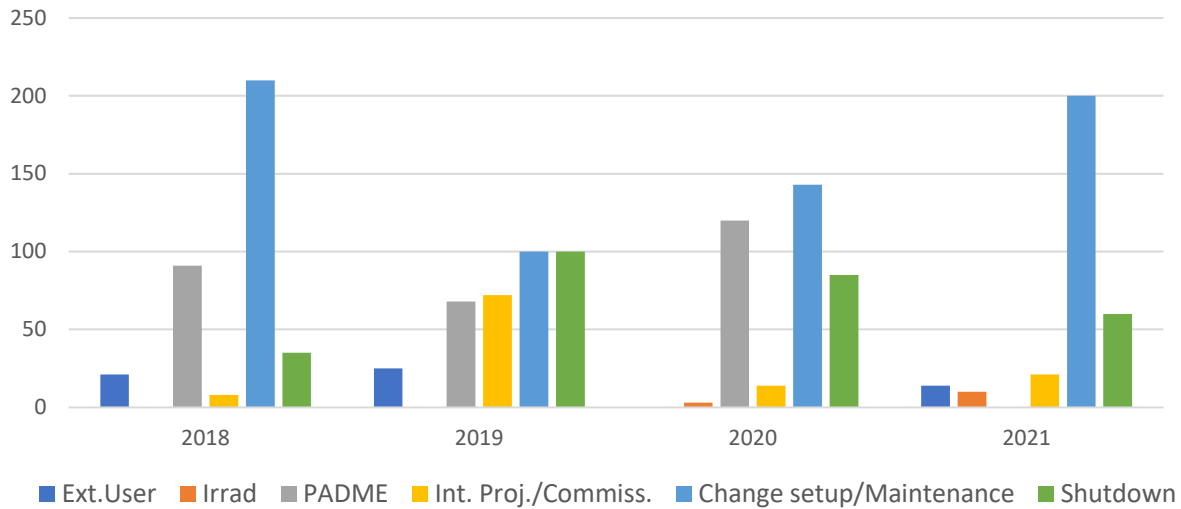
Parameters	BTF1 Time sharing		BTF1 Dedicated		BTF2 Time sharing	BTF2 Dedicated
	With Cu target	Without Cu target	With Cu target	Without Cu target	With Cu target	With Cu target
Particle	e^+ / e^- (User)	e^+ / e^- (DAΦNE status)	e^+ / e^- (User)		e^+ / e^- (User)	
Energy (MeV)	25–500	510	25–700 (e^-/e^+)	167–700 (e^-) 250–550 (e^+)	Expected 25–500 to be confirmed	Expected 25–700 to be confirmed
Best Energy Resolution at the experiment	0.5% at 500 MeV	0.5%/1%	0.5%	Energy dependent	Expected 1% at 500 MeV to be confirmed	
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)		Expected 10 To be confirmed	Expected 10-100 To be confirmed
Intensity (particle/bunch)	$1-10^5$ (Energy dependent)	1 to 10^7 / 1.5×10^{10}	$1-10^5$ (Energy dependent)	1 to 3×10^{10}	Expected $1-10^4$ (Energy dependent, To be confirmed)	
Max int flux	3.125×10^{10} part./s				1×10^6 part./s	
Beam waist size(mm)	0.5–55 X / 0.35–25 Y (vacuum window dependent)				1x1, To be confirmed	
Divergence (mrad)	Down to 0.5				Expected Down to 0.5, To be confirmed	

- 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 shutdown, exclusive BTF users
 - Time sharing: DAΦNE spare pulse injections mode via pulsed magnet
 - Beam top parameters defined by DAΦNE injections

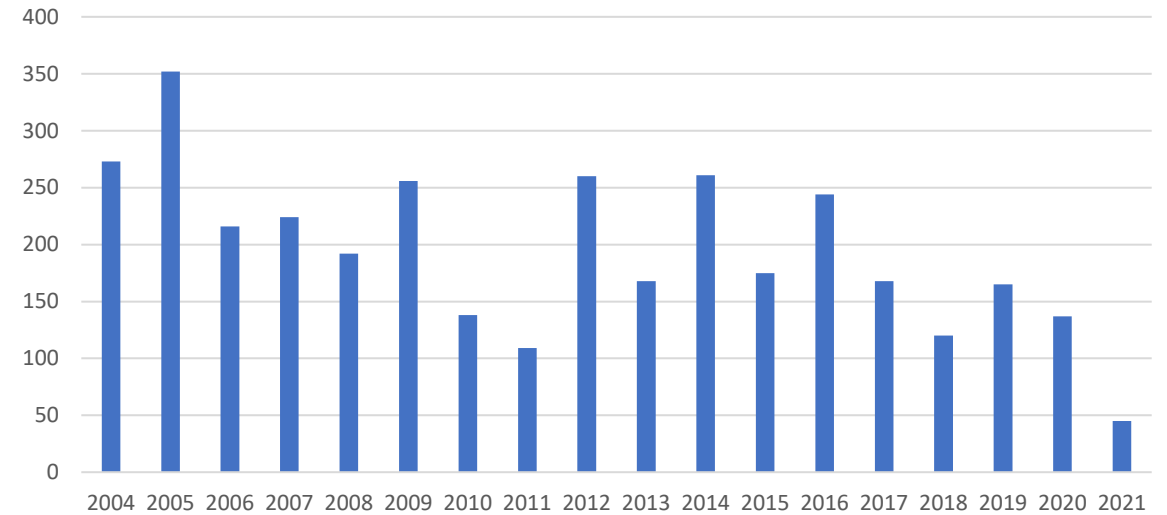
- Now BTFEH1 and BTF1 line are set up for dark matter searches PADME experiment, no external user
- **BTFEH2 and BTF2 line are recently equipped**
 - **under commissioning both safety and beam**
 - **beam parameters under study**

LNF – BTF NUMBERS

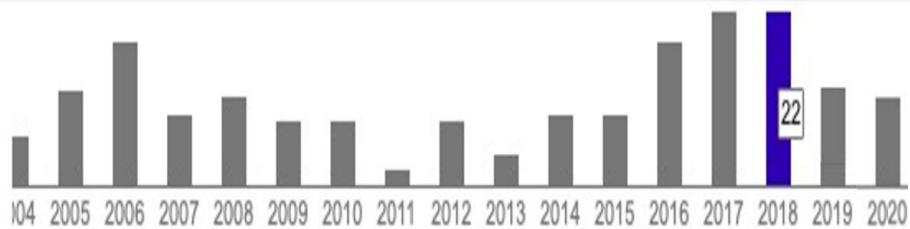
2018-2021 Activities



Beam On



Conferences: BTTB9, IPAC21, IBIC21, NanoIrrad



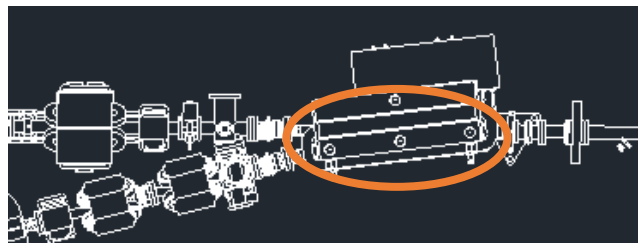
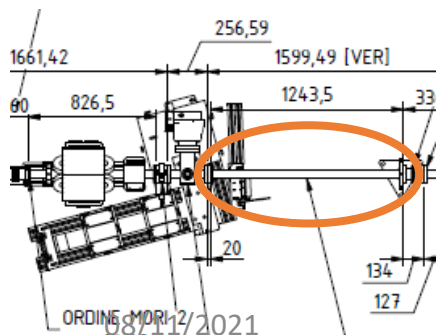
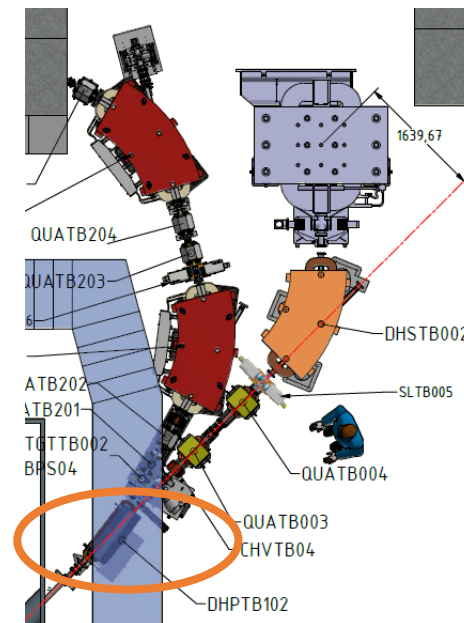
Citations of Nucl. Instrum. Meth. A515 (2003) 524

This year (not yet finished) in numbers:

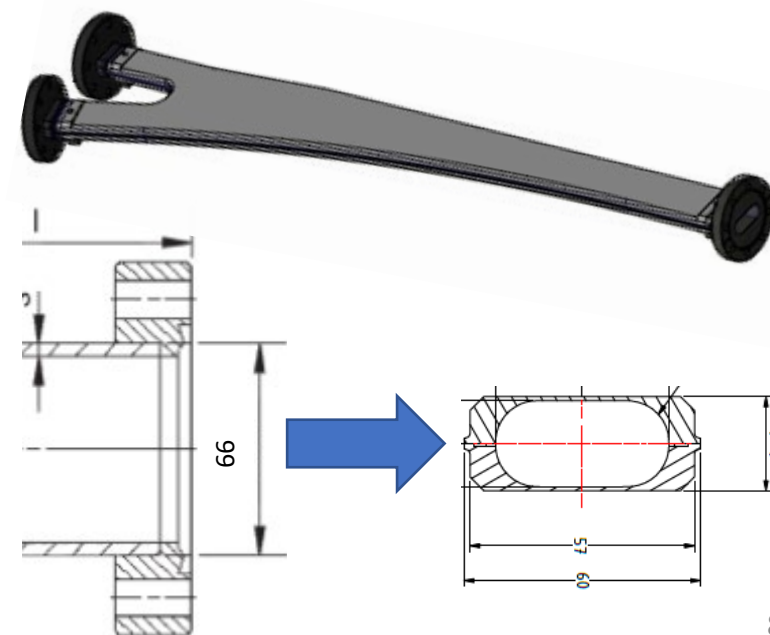
- Commissioning BTF2 Beam on = 8 [d](delay for LINAC tunnel civil work and TEX implementation)
- Shutdown = 60 [d] (see above)
- Beam on = 45 (users and LINAC trials, foreseen another 20)
- Hall commissioning and setup = almost the rest of the year

BTF1 COMMISSIONING

- BTF1 in respect of BTF1 temp. installation (due to get PADME run) **has new element installed in**
 - DHPTB102 pulsed dipole and a improved thickness and internal section steel pipe in (round 60 mm-> oval 22mm)
 - > **could be a background issue for PADME (see PADME RUN1)**
 - > **New ab initio transport has been studied**
- From the end of BTF2 Tech Commissioning, **BTF1 commissioning starts on 17/06**
 - time sharing with BTF2 safety system installation
- Test and debug of all the BTF1 subsystem
 - some develops/improvements in software due to BTF2 integration
- Fundamental study for BTF2 steering

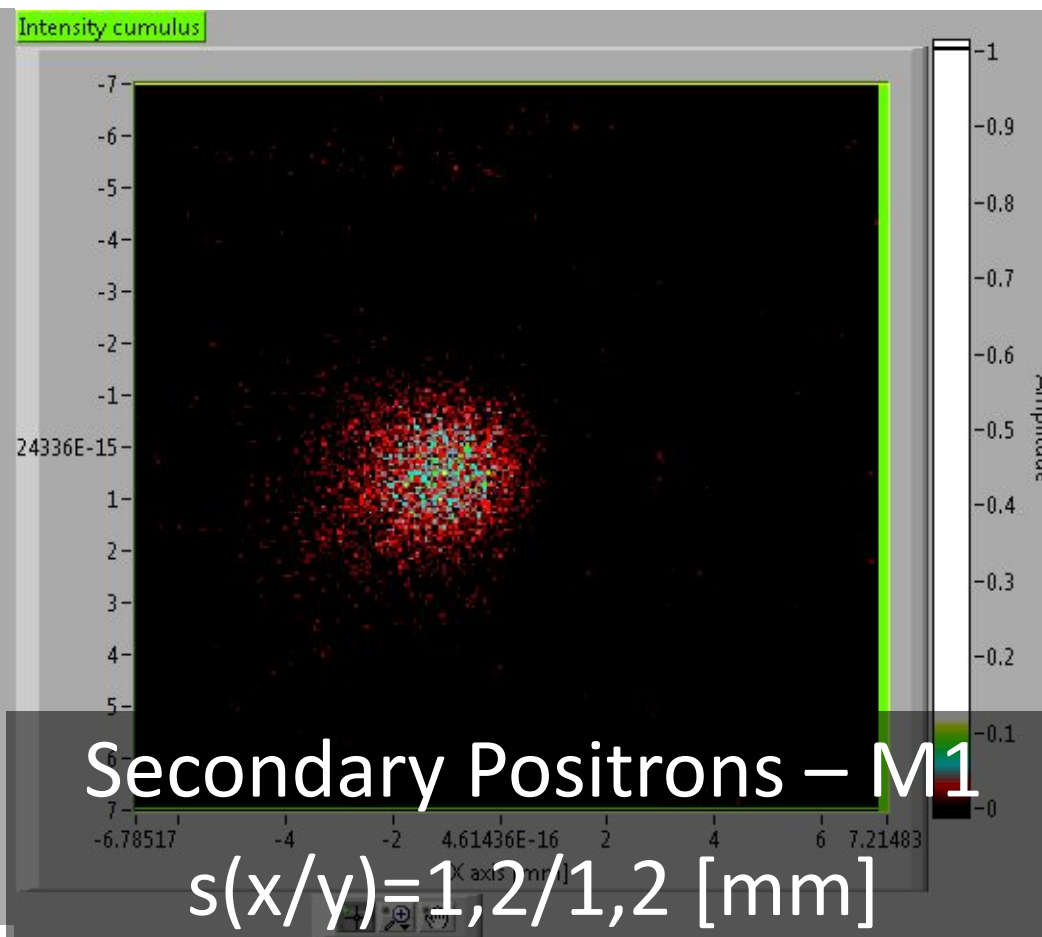
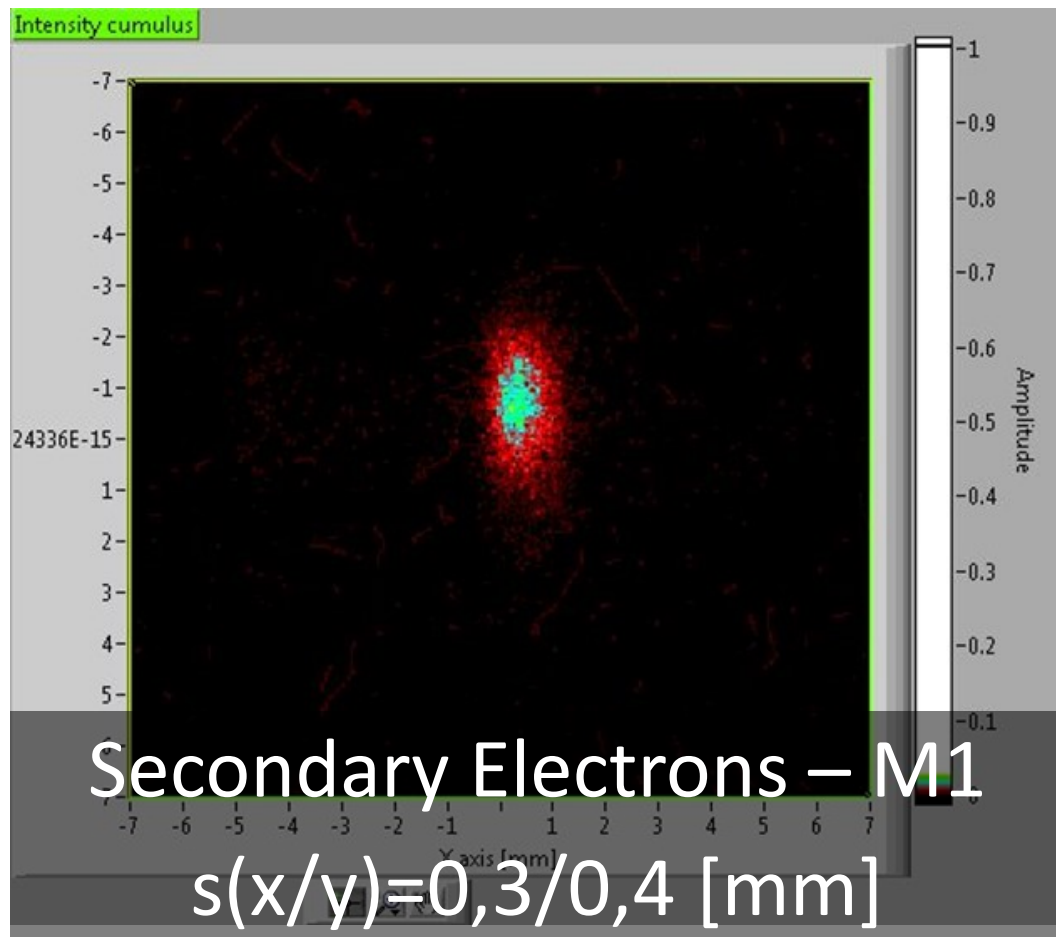


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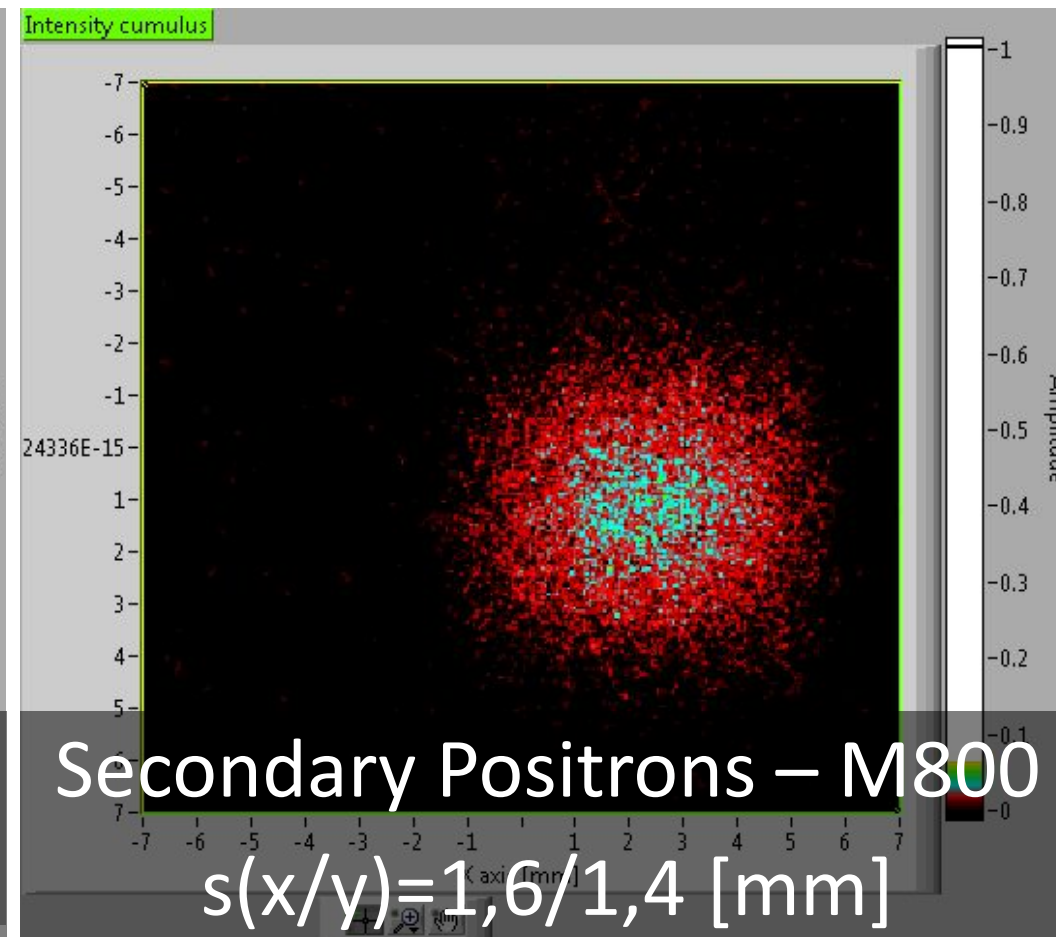
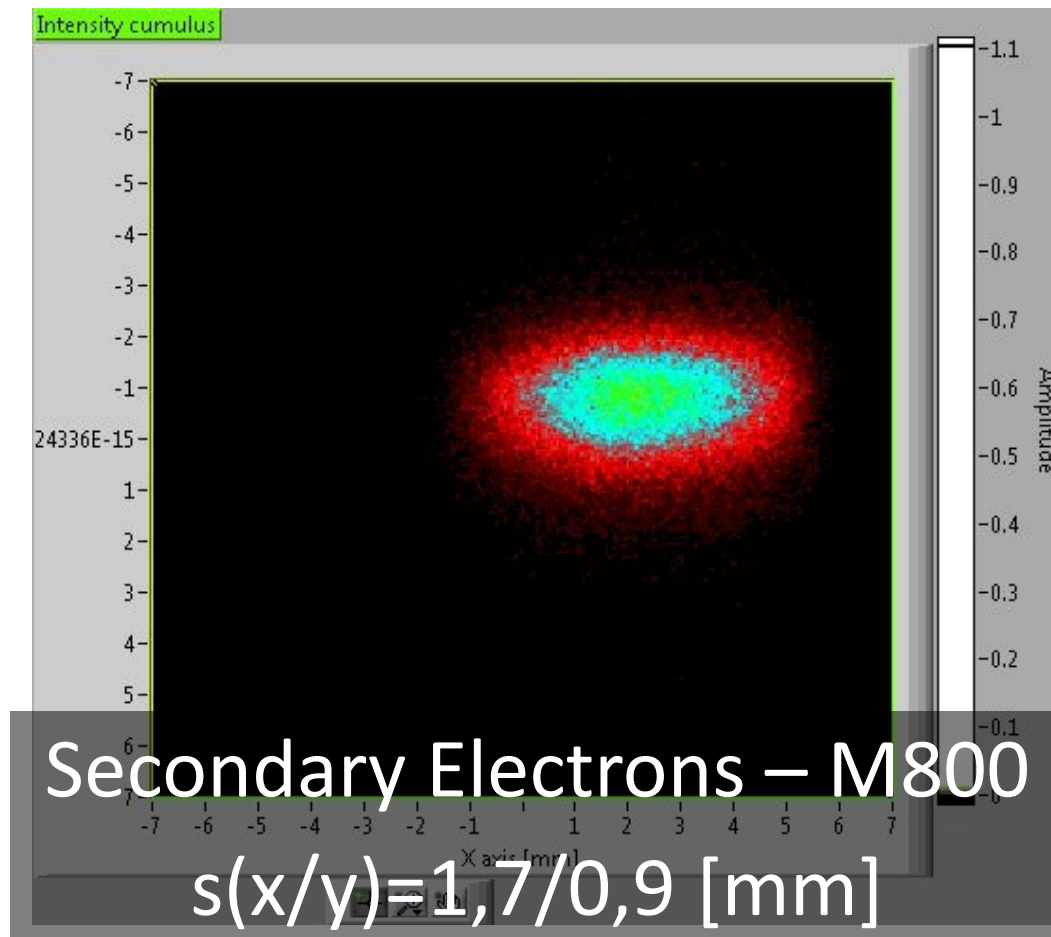
Best Beam BTF1 straight – 450MeV

~14mm



Best Beam BTF1 straight – 450MeV

~14mm

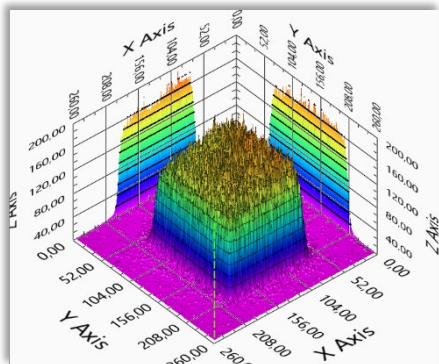


BTF1 COMMISSIONING

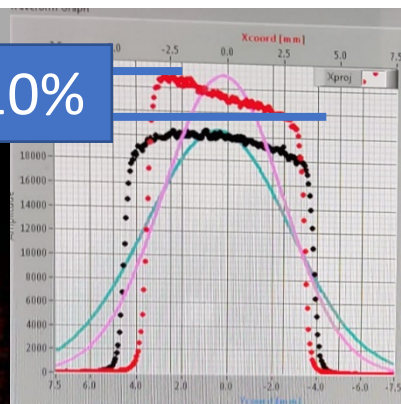
Timepix Detector
Pixels = 256x256
Pixel = 0,055um

BOX Beam BTF1 straight

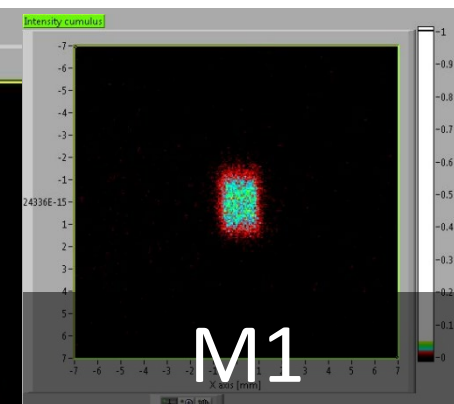
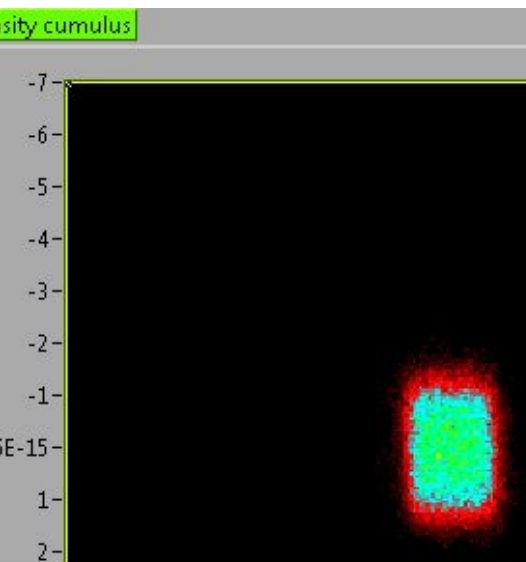
~14mm



>10%



Intensity cumulus



M1

450MeV electrons in linear scraping

- Very sharp edges
- >10% error on uniformity (to be improved)
- Useful a secondary beam irradiation

M1000

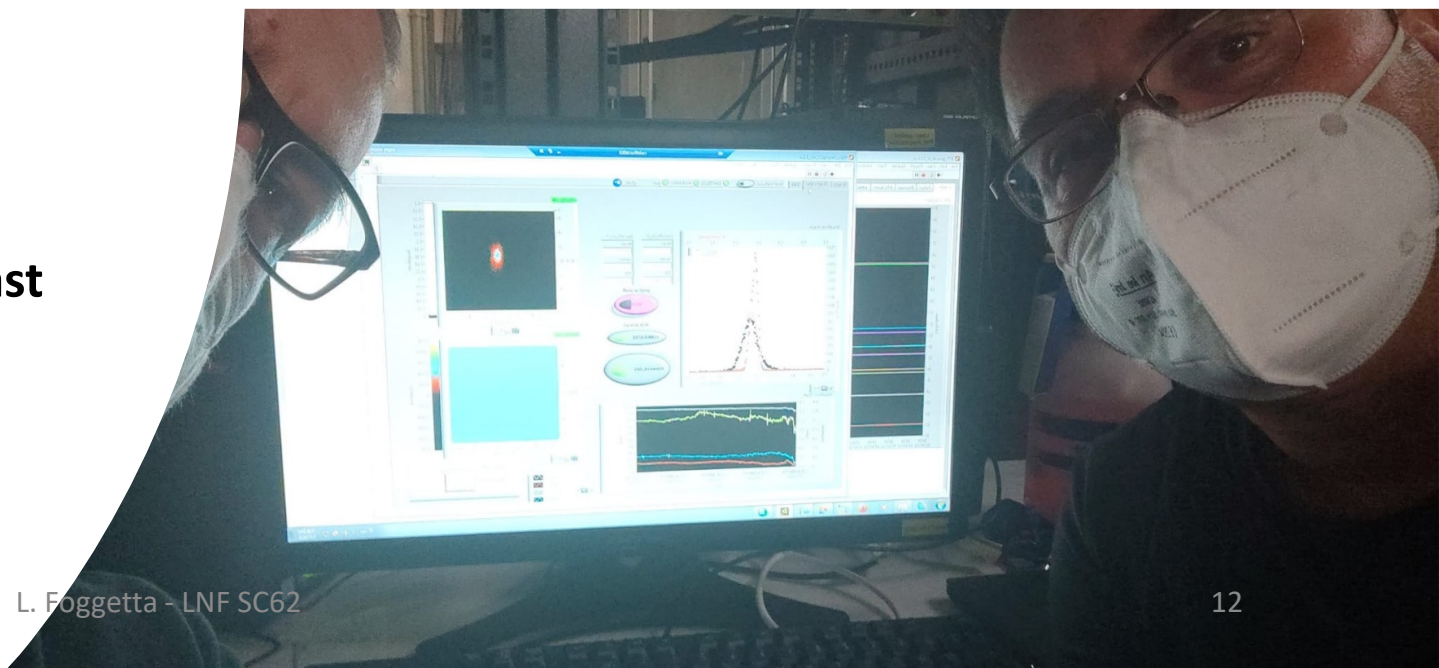
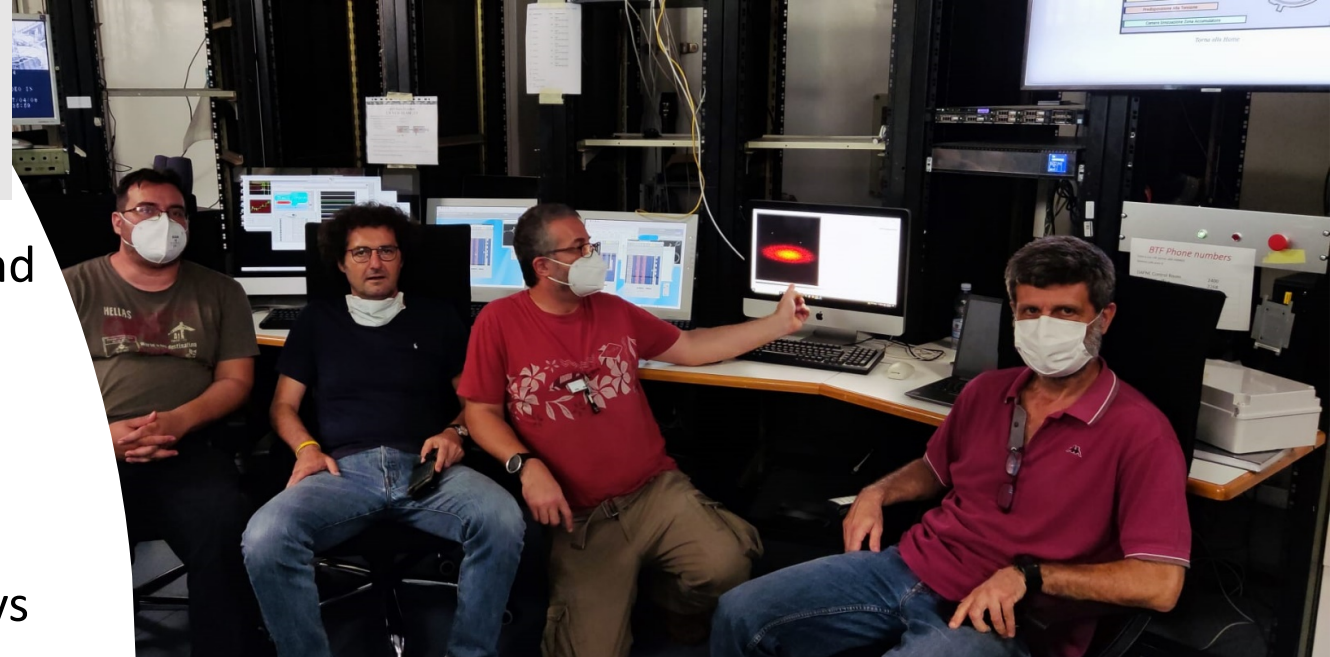
M10

BTF2 COMMISSIONING

- **BTF2 Commissioning phase 1 started 06/07** at the end of BTF2 safety installation
- Only with FISMEL surveillance
- **In few hour first beam transported**
 - 450MeV,e-, m1 w Katherine, TPX3, Si, t=1mm
- Optimization substantially on electrons until for 4 days of beam on
- **On 15/07 switched to ERAD installation**
- Debugging of BTF2 software and detectors:
 - Katherine single and dual
 - !CHAOS on BTF2 DAQ
 - Subsystem (HV, remotely controlled motorized table..)
- **The BTF2 commissioning restarted in Phase 2 last week**
 - 1,5month delayed restart in order to accomplish:
 - LINAC tunnel building restore
 - TEX installation
 - Unexpected faults

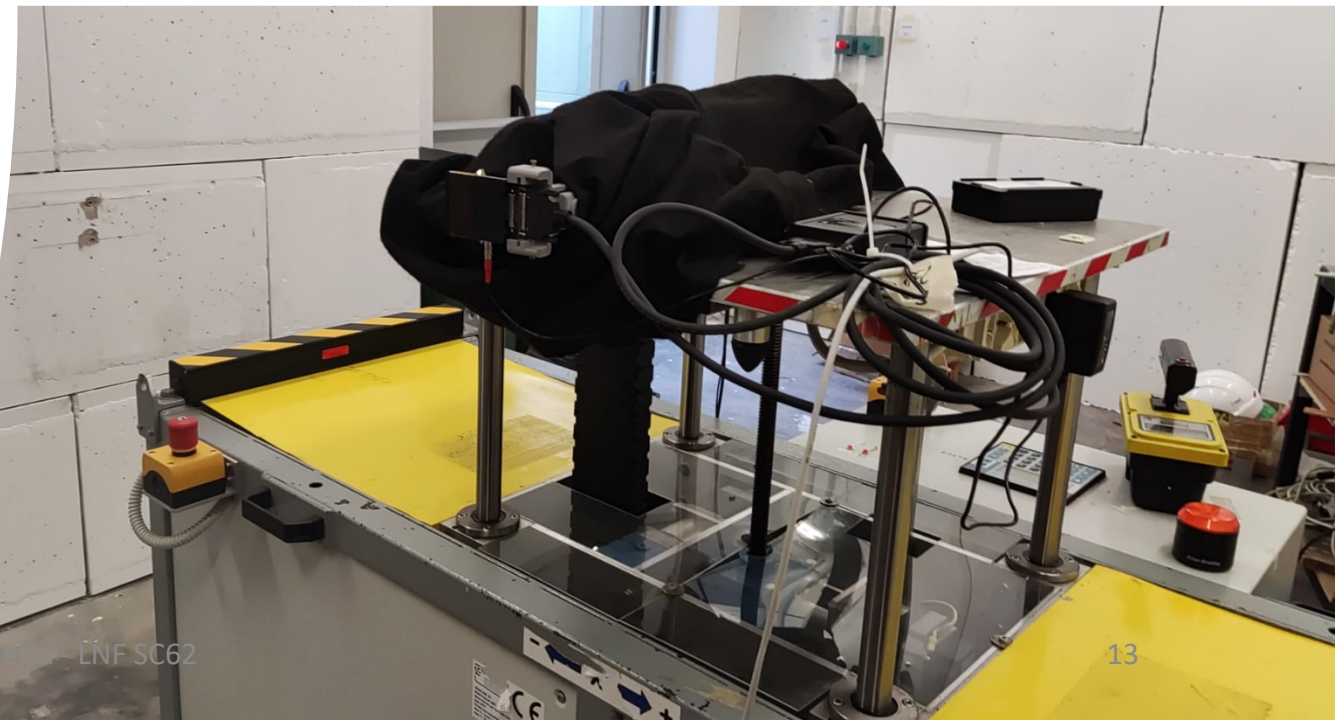
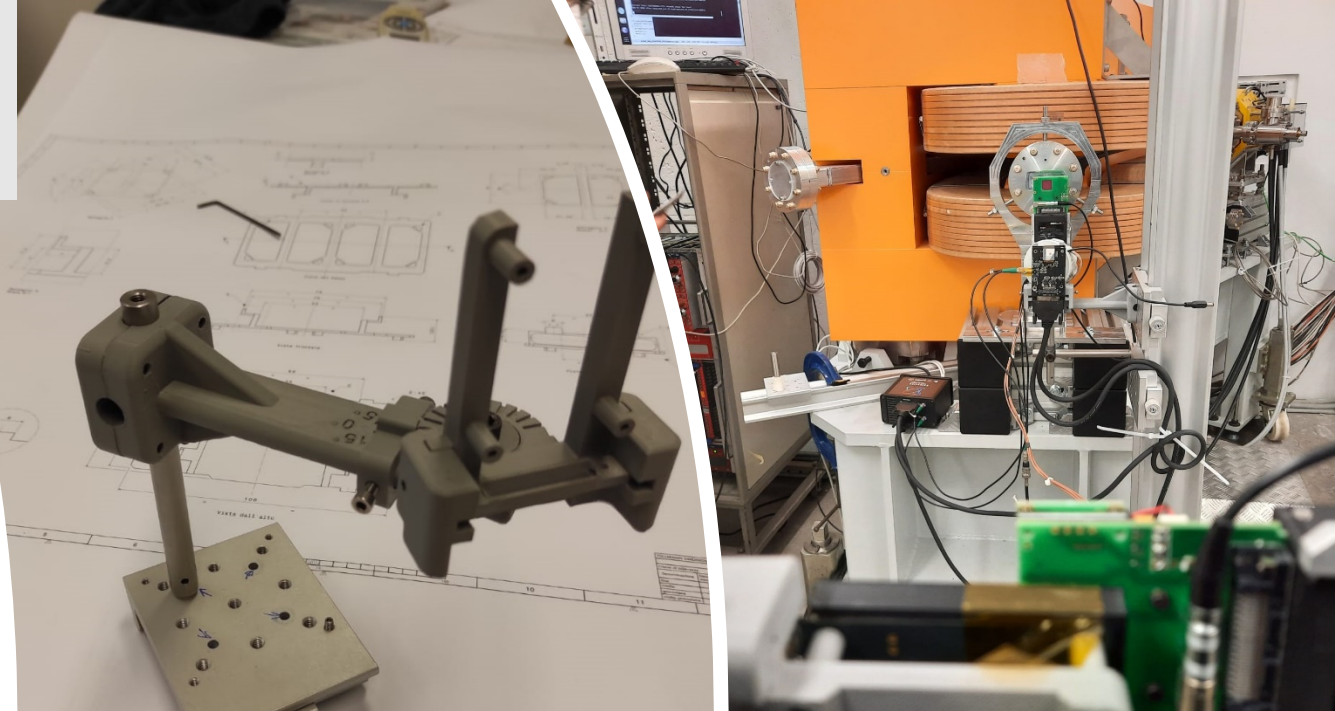
08/11/2021

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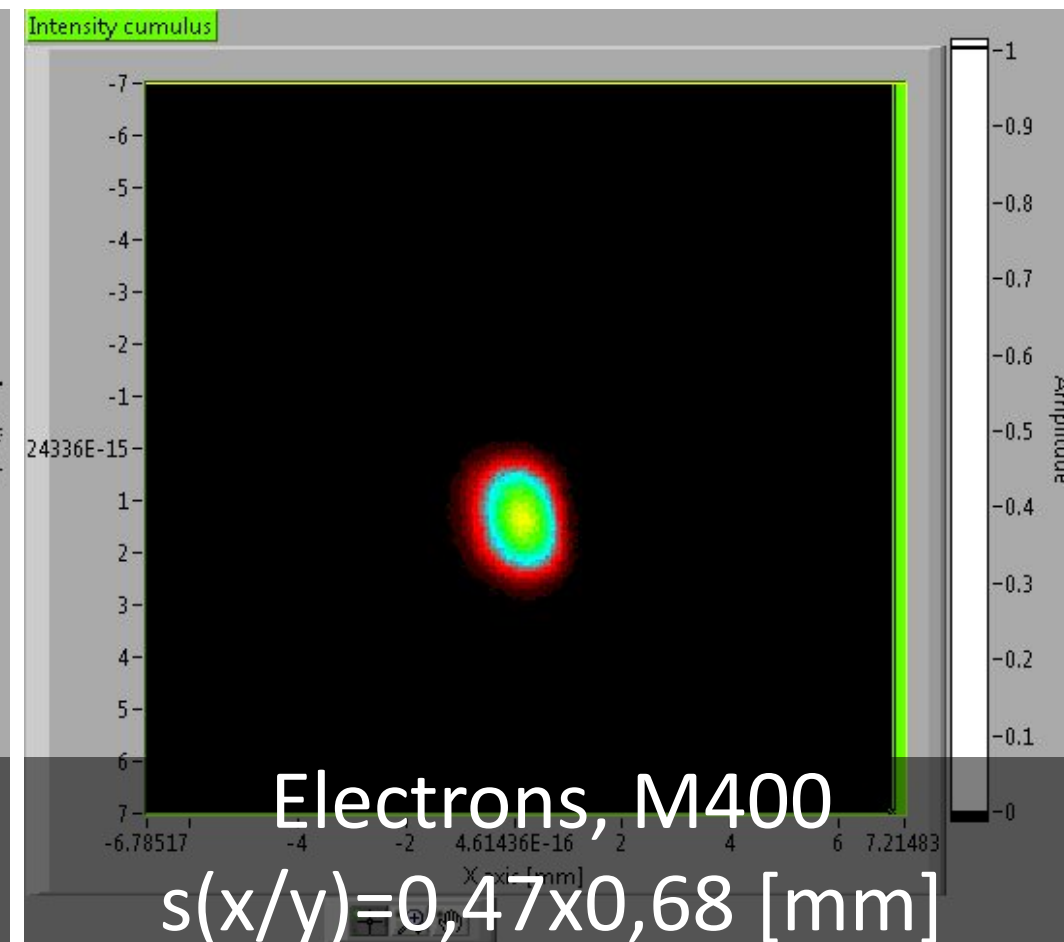
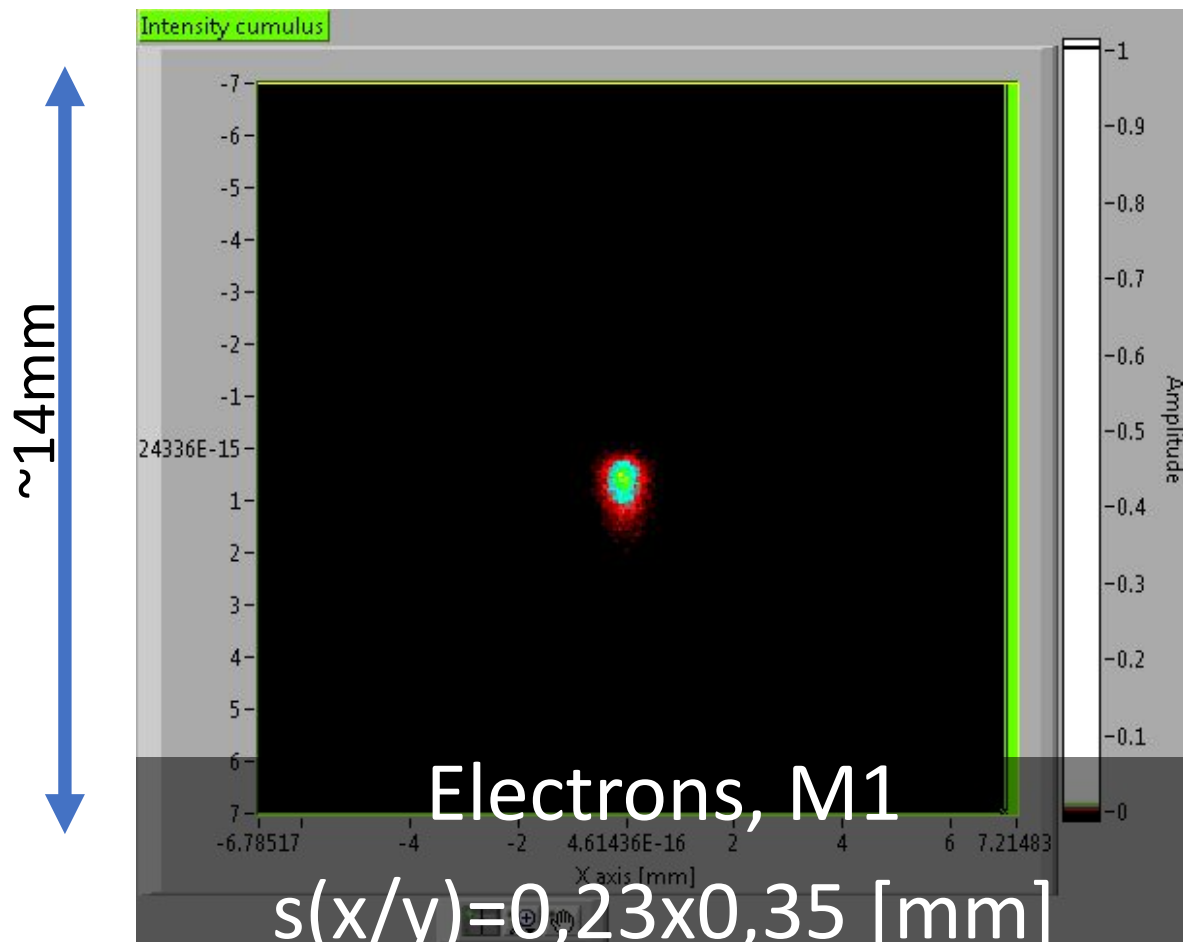


Actual results

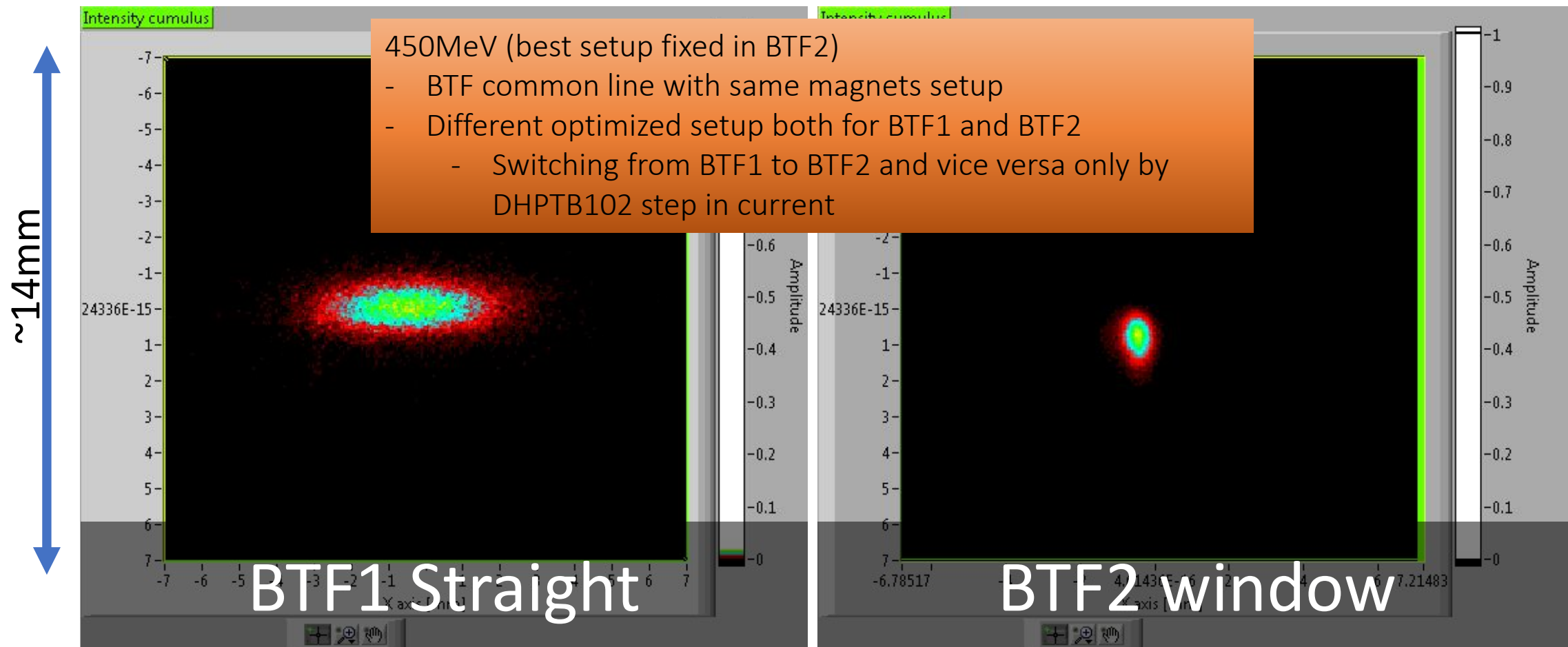
- **Secondary electrons beam of different energies:**
 - from 650 MeV to 30 MeV
 - From single particle ($m=1$) to $m=2 \times 10^5$
- **Dual transport both in BTF1 and BTF2 lines**
 - efficiency 0.7, emittance to be improved
- **BTF1 best performances in m1: $s(x/y) = 0.2/0.4$ [mm]**
- **BTF2 best performances in m1:**
 - At vacuum window: $s(x/y) = 0.23/0.35$ [mm]
 - At DUT: $s(x/y) = 1.9/2.0$ [mm]
- **BTF2 positron beam ok in multiplicity and lower energy**
- **Performed some performance tests for specific users**
 - BTF2 Vacuum windows has to be thinner
 - Lowering energy vs divergence still contained
- **For BTF2 commissioning:**
 - To get ministry-released authorization needs study radiative background outside shielding
 - just prepared a 650MeV, $m=25k$, 50Hz pulsing rate secondary electron beam close to ministry requirements
 - LINAC at 700 MeV in dedicated mode



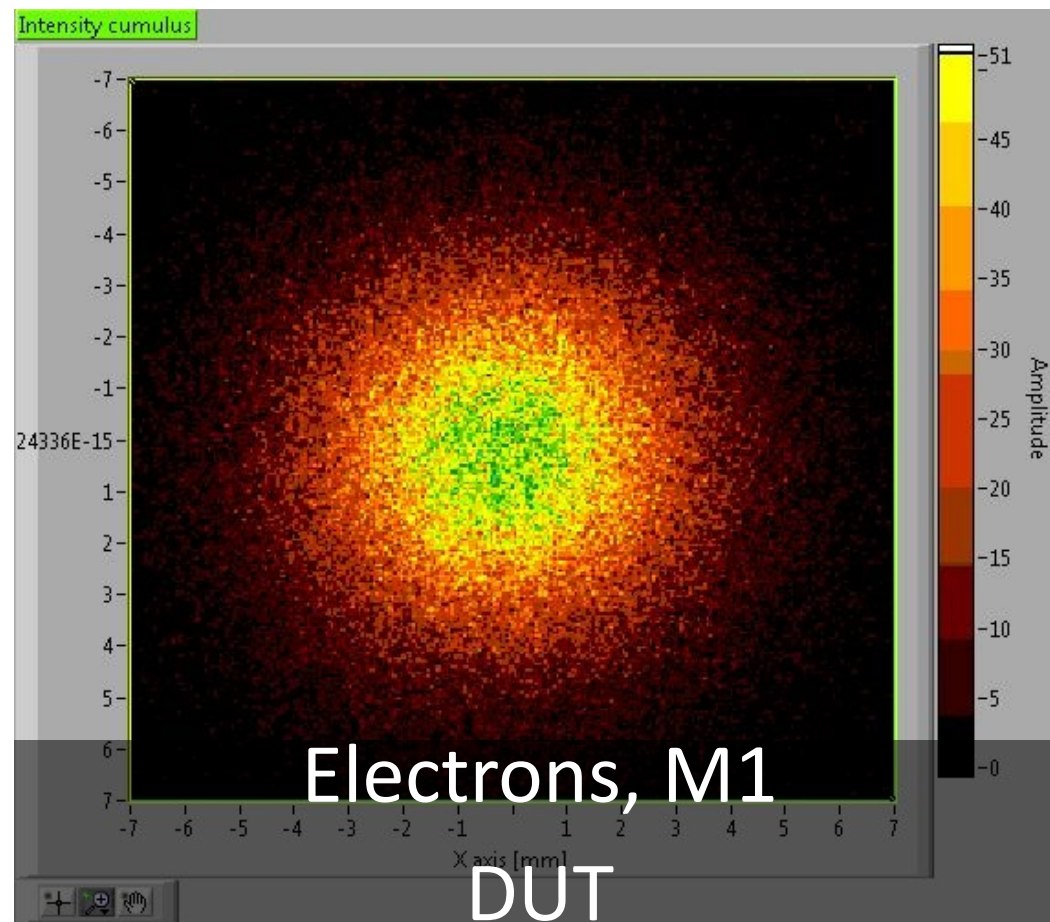
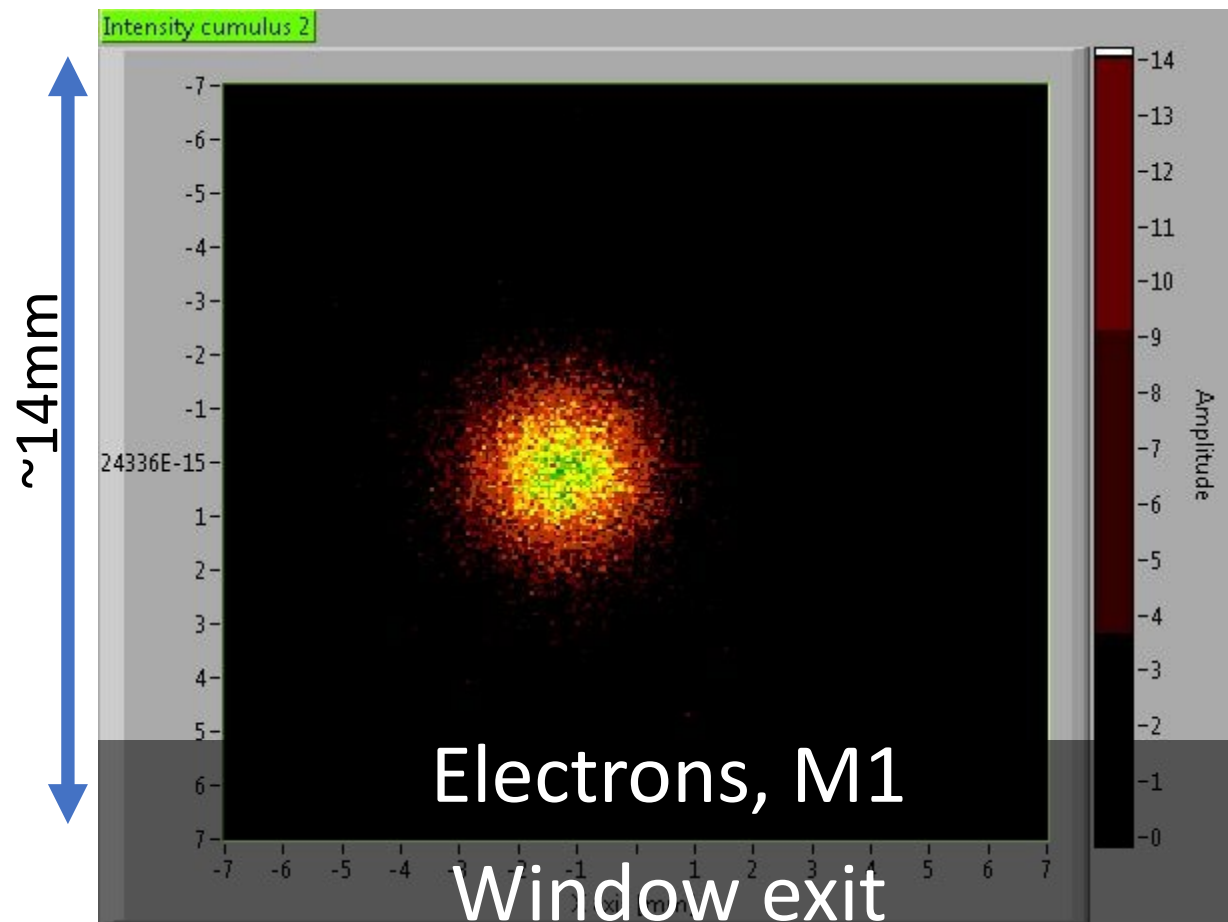
Best Beam BTF2 – 450MeV Window exit



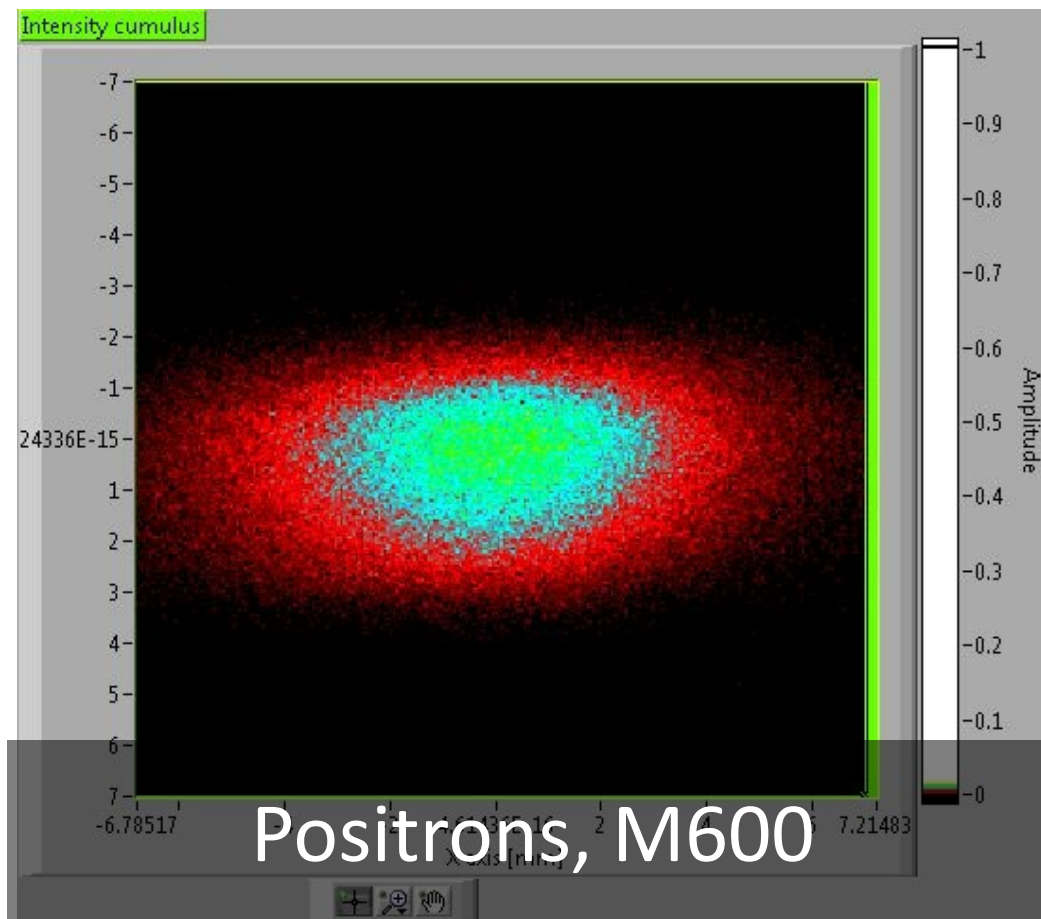
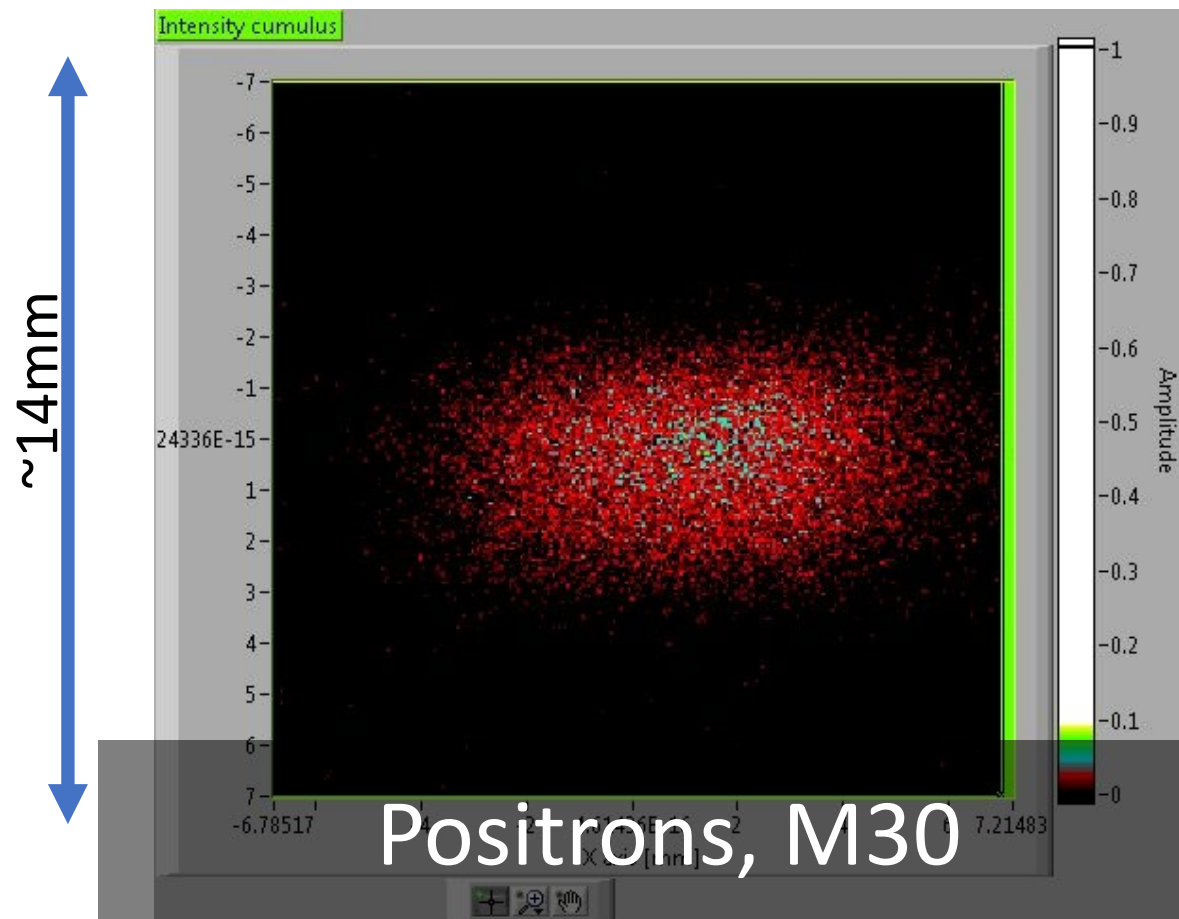
Best Beam Common transport BTF1/BTF2



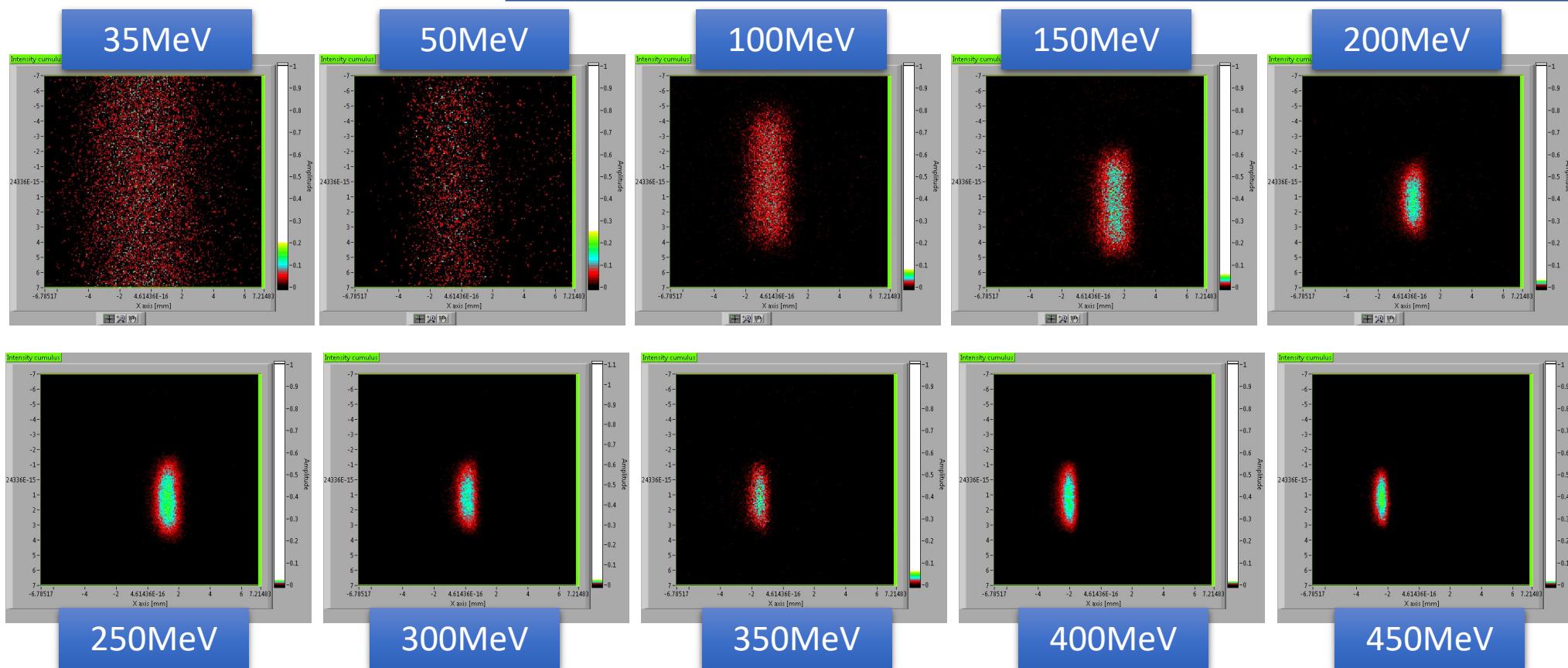
Best Beam BTF2 – 450MeV different focus



Best Beam BTF2 – 450MeV Positrons



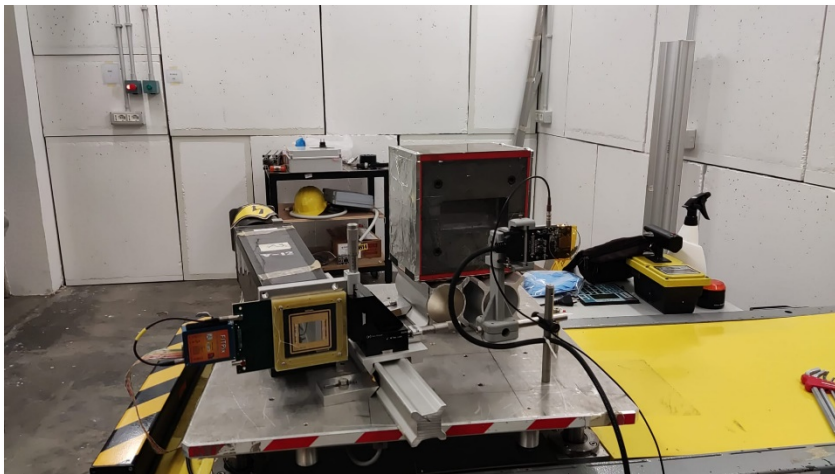
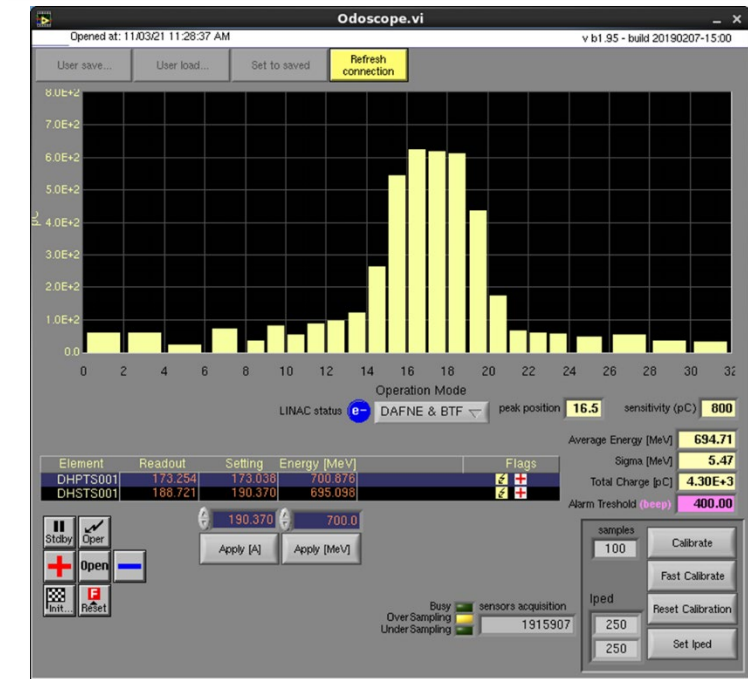
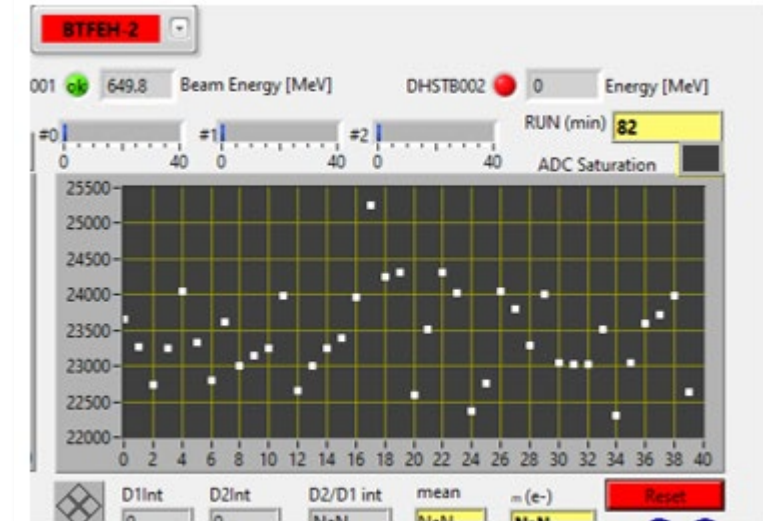
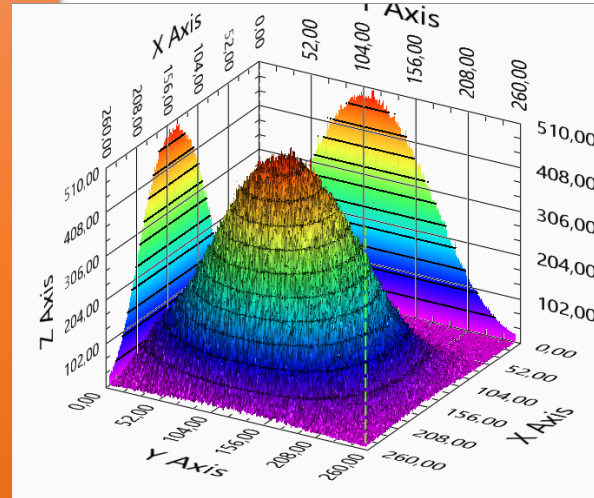
Beam BTF2 – Electron Beam energy set



LNF – BTF2 COMM. BEAM

BTF test beam for commissioning shielding
Developed (two days on):

- Secondary beam
 - $E = 650\text{MeV}$
 - $m=24\text{k}[e^-]$ (measured by CALOBTF1)
 - $\sigma(x/y)=2,8/3,3 [\text{mm}]$
- Slightly charged 700MeV LINAC, 10ns pulse, 50 Hz
- Different focusing set usable from FISMEL to check shielding



08/11/2021

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What we have to improve/get in BTF2

- 550um thickness Al windows -> new design just put in place
- Continuing in beam developing but in a good status
- Minor issues appears during this commissioning in magnets control system, DHPTB102 ramp up and fluids -> fixing in next days
- Developing analysis and software

What we need to get users (2022)

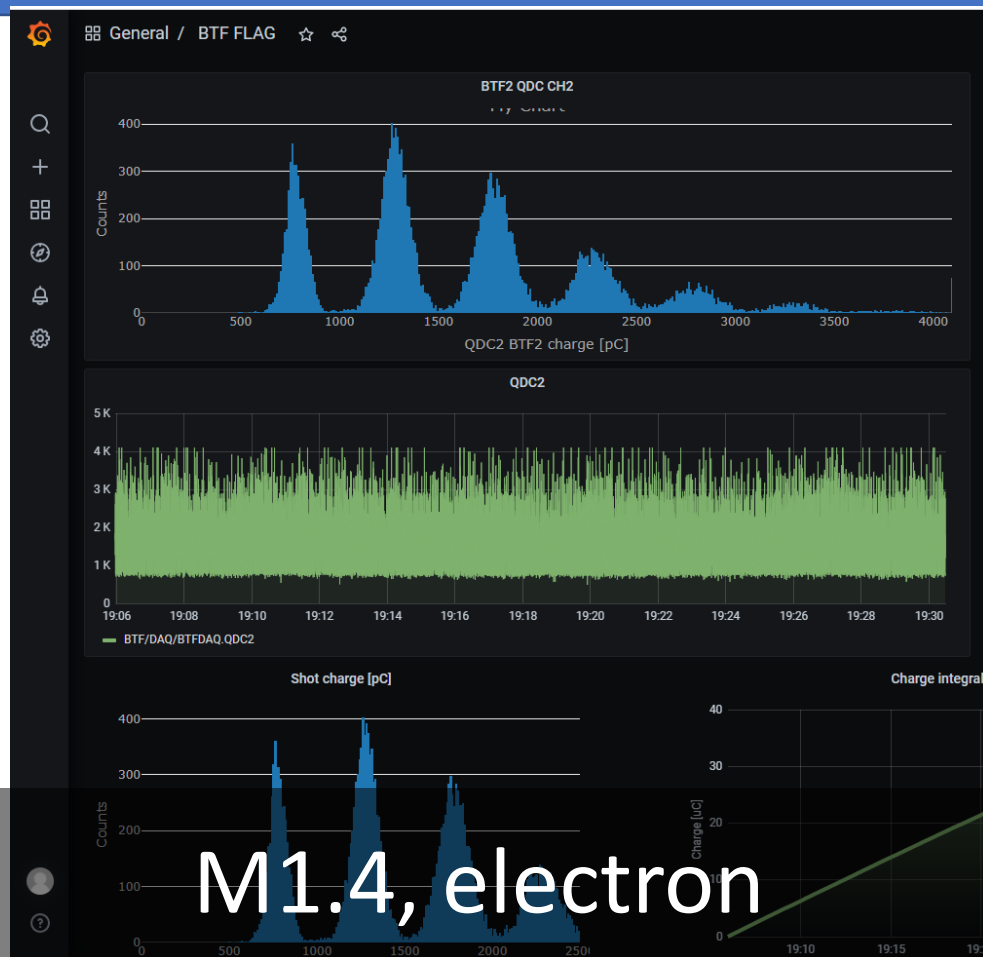
- **Today afternoon** is the final day for FISMELE background checks
- If ok, **one month and a half** to prepare authorization documents and reports at ministry
- Then **few week** to get the authorization reply from Italian government
- **Then** free to get external users
- COVID upgraded protocol for halls and CR

Other Development achievement under commissioning

- BTF DAQ under !CHAOS
 - BTF DAQ prototype with Struck SIS3513 (important for DAFNE DCS development)
 - displaying in GRAFANA – live and historical DB tested
 - Achieved 100Hz rep rate
- Dual Katherine first tests and analysis
- Fluids, magnets, controls stable and reliable @ 700 MeV
- FISMEL super visoring check -> up to now no issues on
- BTF subsystem user oriented are ok – debug on doubled systems (BTF1+BTF2) on going

BTF2 COMMISSIONING

450MeV on BTFDAQ under !CHAOS



BTF2 COMMISSIONING – KATHERINE TRACKER

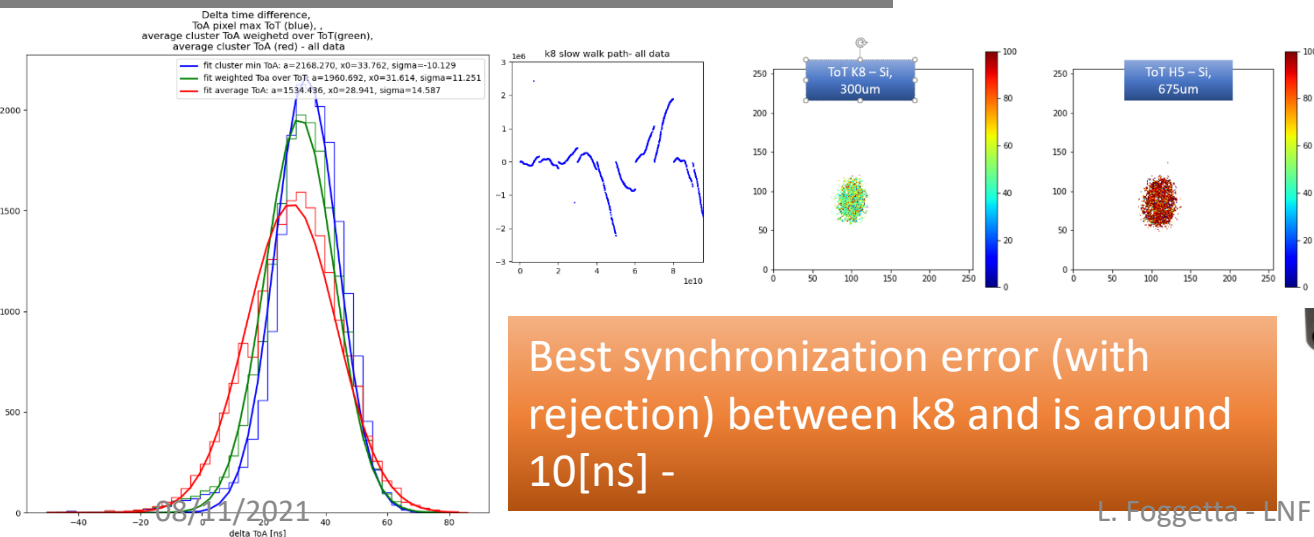
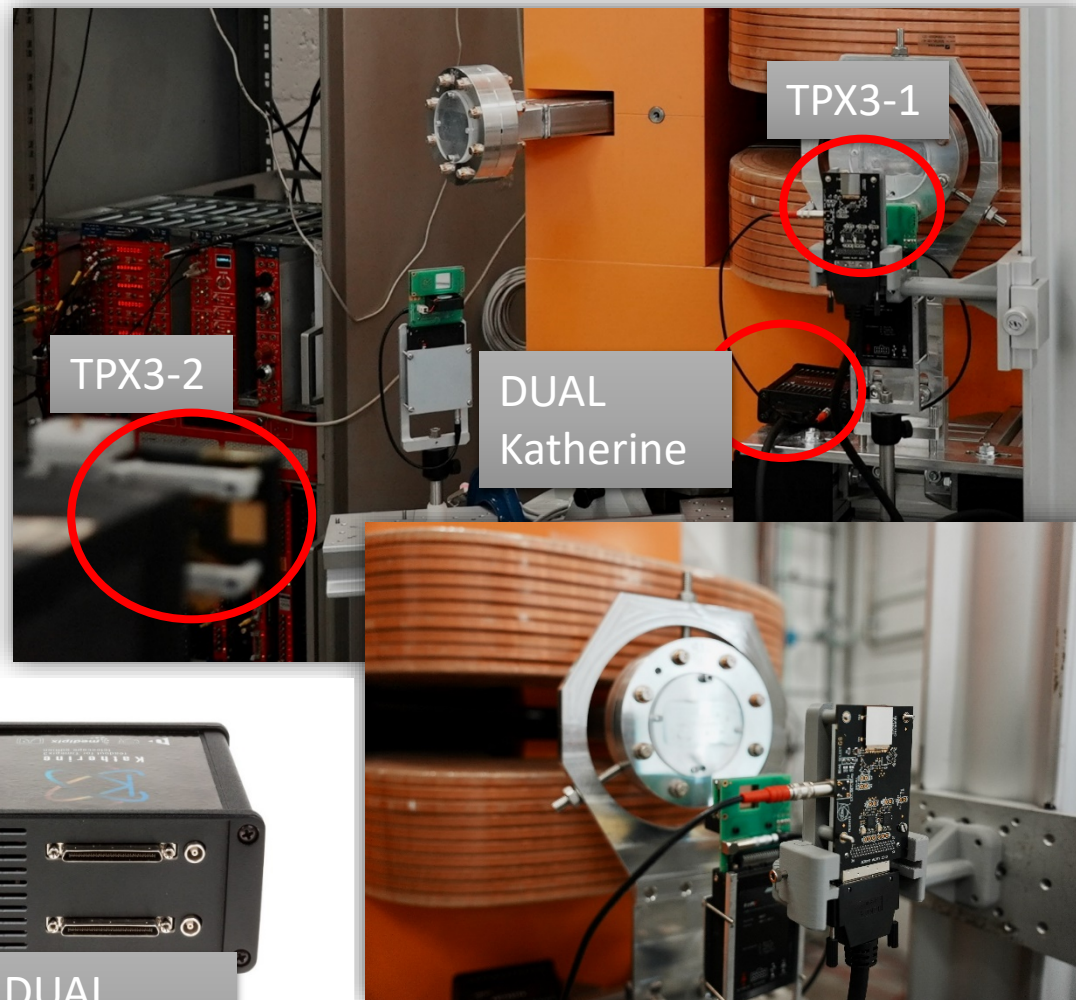
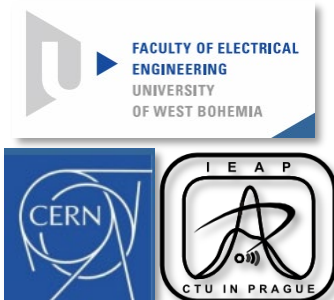
KATHERINE = Ethernet Embedded Readout Interface for Timepix3

Dual Version is a mini tracker, hosting two synced frontend for 2x TPX3 sensors (300um and 600um thickness).

TPX3 connection tested with 2.5m + ETH.

Very ductile tracker for different ex. setups

- E = electron, 650MeV
- m=20k[e-] (measured by CALOBTF1)
- $\sigma(x/y)=2,8/3,3$ [mm]



BTF2 COMMISSIONING –USER CALL SOFTWARE

New managing tool for:

- user call, facility booking and team access, run time assistance
- Fully automated + human verification

Intended as generic tool for all LNF (and more) facilities

- Access LNF-INFN software and rules acquired
- Implementation with different level of abstraction
- Facility types and template
- Automated dispatching, lowering secretary load

Status

UI => starting this week

Backend => 40%

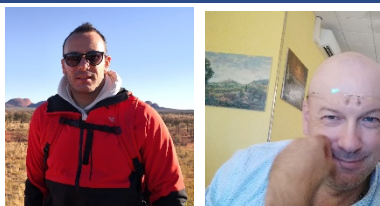
Workflow => 10%

AGILE development
2w - based SCRUM meeting

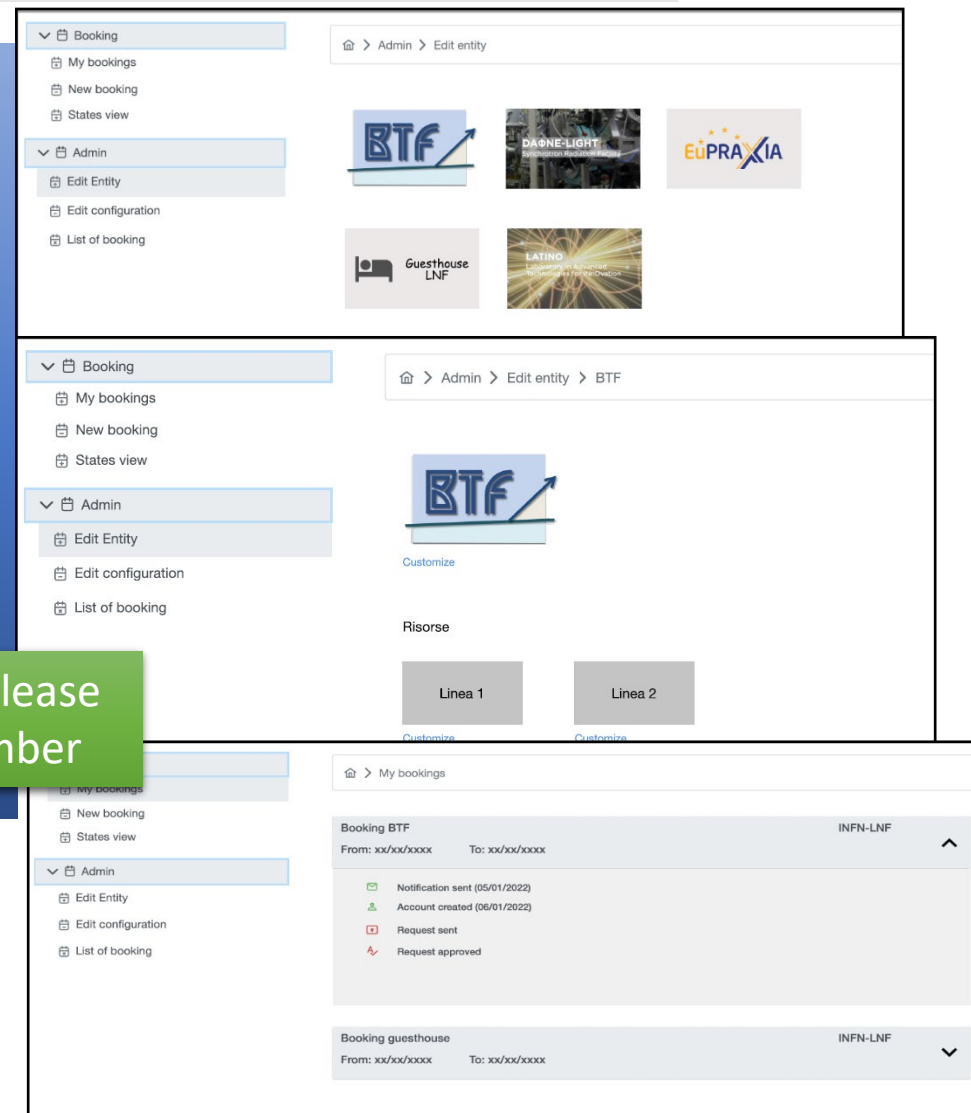
Foreseen pre-release
on end of December

APULIASOFT
Digital Roots

UI and data logging



Back end, workflow & integration
by BTF & Computing Service

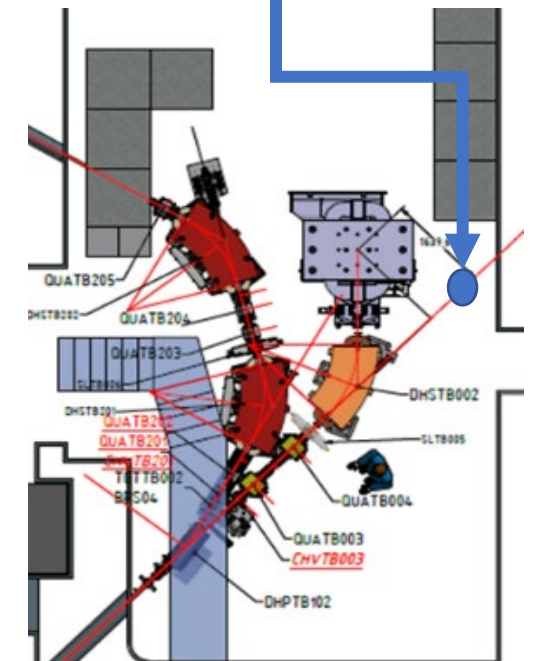


- SHIP (Jan, before BTF installation, more publications)
- **KLEVER** (July, after BTF install., usable 1w before BTF2 Phase1)
 - Opportunistic run and test (passed) of user BTF1 subsystem
- **ERAD** (July, after BTF2 Phase1)
 - Scheduled with dedicated LINAC&BTF beamtime

- Selected users foreseen in Nov-Dec for a total of 1 month run
- Call 2022 with a new user call booking software ongoing,
- EUROLABS call submitted, projects starts in 2022
 - 7w in 4 year (1+2+2+2) submitted on September



BTF1 straight,

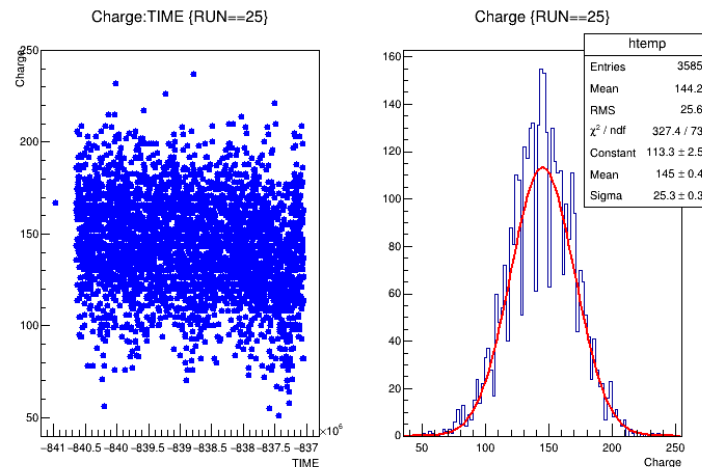


ERAD RUN - OUTPUTS

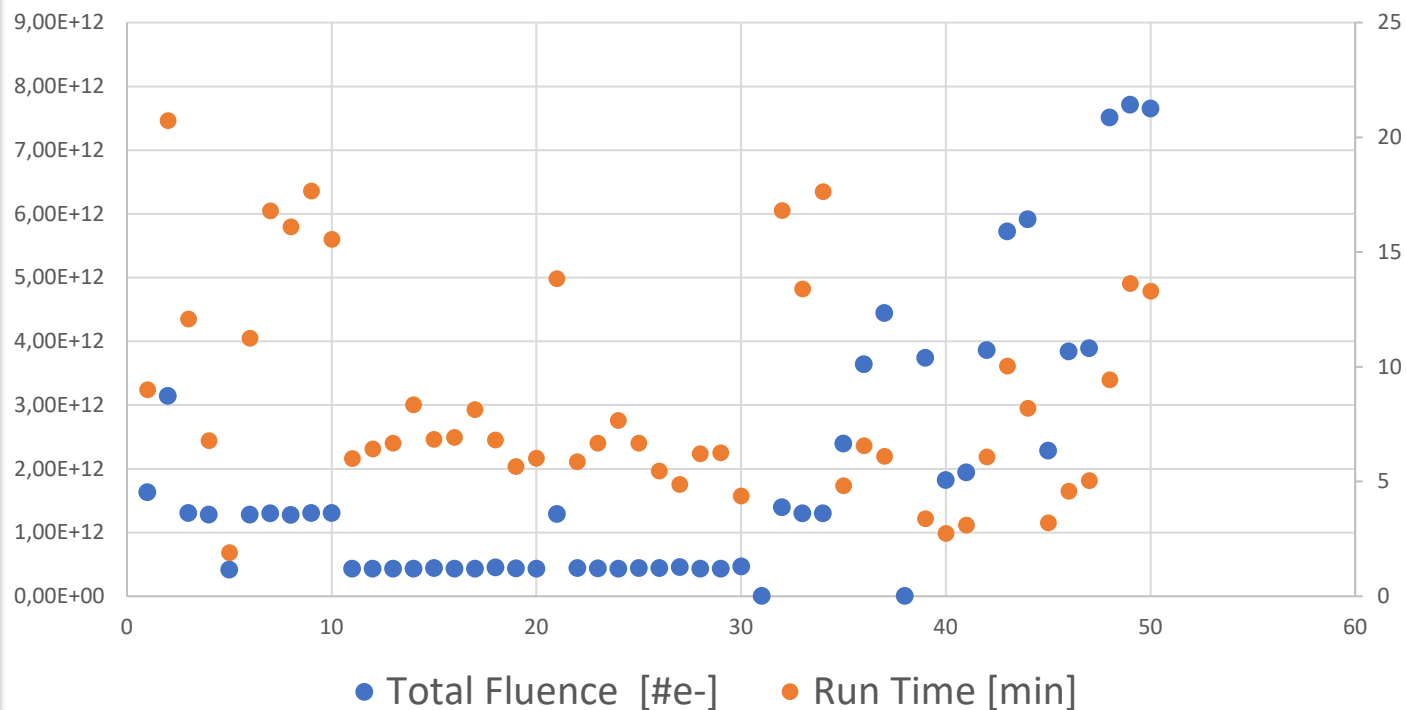
BTF USER run: ERAD (BTF1 straight, setup, preparation and run) **15 Jul -> 23 Jul**

High charge irradiation run for Lazio region funded,

- Users (IMT) very happy
- Different DUTs (memories, photocouplers)
- Different Irradiation profile:
 - Few issues on stability irradi profile to be improved on low charge
- Different searched
 - SEE on SRAM ($\sim 6 \cdot 10^{12}$ e-, TID = 193krad)
 - Optocoupler stability ($\sim 2.5 \cdot 10^{13}$)
- Run time control of irradiation from BTF and Users side, shot by shot
 - BTF remotely adapt all the users instrumentation
 - Users decide run time how to explore DUT functionality



ERAD RUN IRRAD profile



ERAD @ BTF

Lucia Sabbatini, Bruno Buonomo

INFN TEAM : Bruno Buonomo, Luca Foggetta, Claudio Di Giulio, Domenico Di Giovenale, Fabio Cardelli

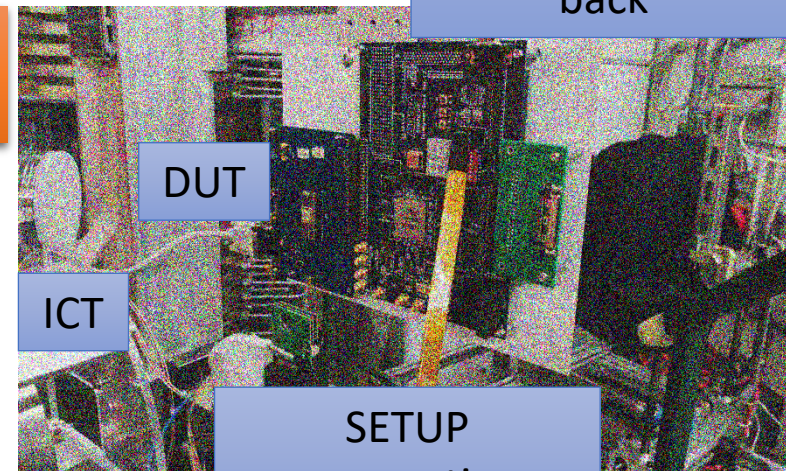
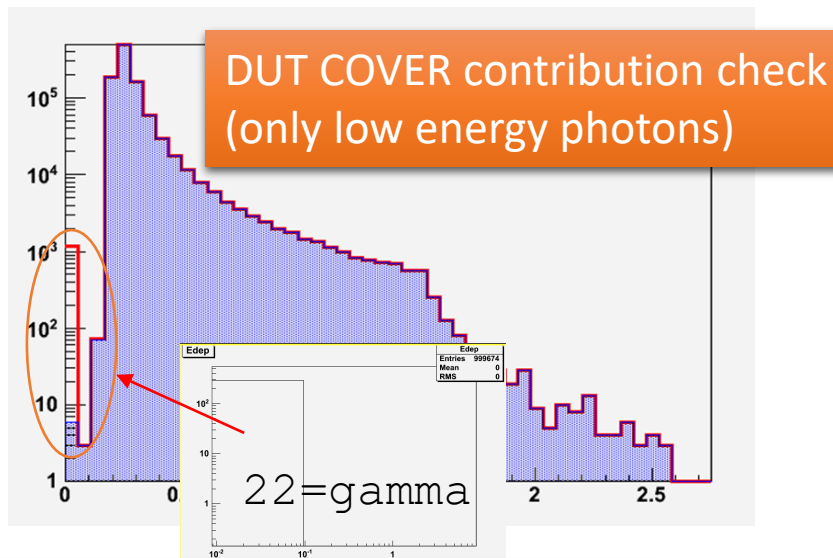
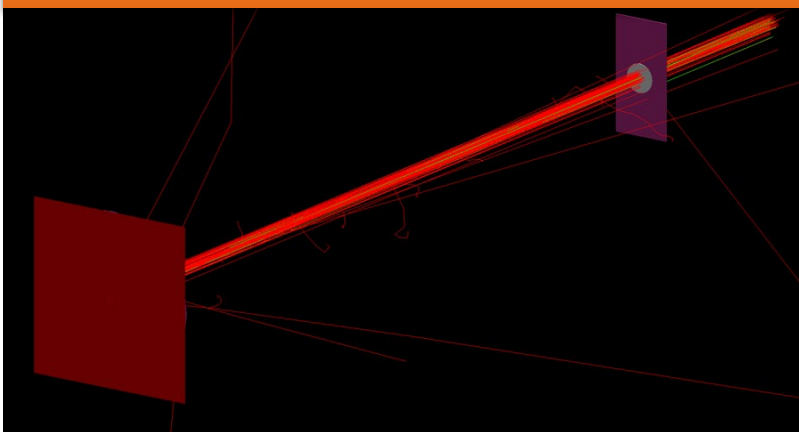


eRAD
Test di resistenza alle radiazioni per componenti aerospaziali



ERAD RUN - OUTPUTS

Simulation G4 Beam Line



Residual radiation will be studied using FLUKA in a separate work package.

Comparing data in accordance on what IMT expected as DUT behavior

Test also with DUT with and without cover

DUT Cover = COVAR - 0,25mm

DUT Volume=0.05cmx1cmx1cm

DUT density= 2,33 g/cm³

DUT Weight=0.1165 g

Total Inj Dose = 2,56x10⁵ RAD (Overall runs)

Data presented at NanoInnovation Exhi.21



Electron Beam Radiation Tests - The eRAD Project experience

Giovanni Cucinella ⁽¹⁾, Fabiano Boccolini ⁽¹⁾, Gabriele Germani ⁽¹⁾, Claudio Di Giulio ⁽²⁾

⁽¹⁾IMT srl - Via Carlo Bartolomeo Piazza, 30 - 00161 Roma - Italy

⁽²⁾INFN-LNF -
Author Emails:

a) giovanni.cucinella@imtsrl.it - b) fabiano.boccolini@imtsrl.it - c) gabriele.germani@imtsrl.it
d) Claudio.DiGiulio@inf.infn.it

Testing of radiation hardness of electronic components - WS.VI.2 - TT.II.I

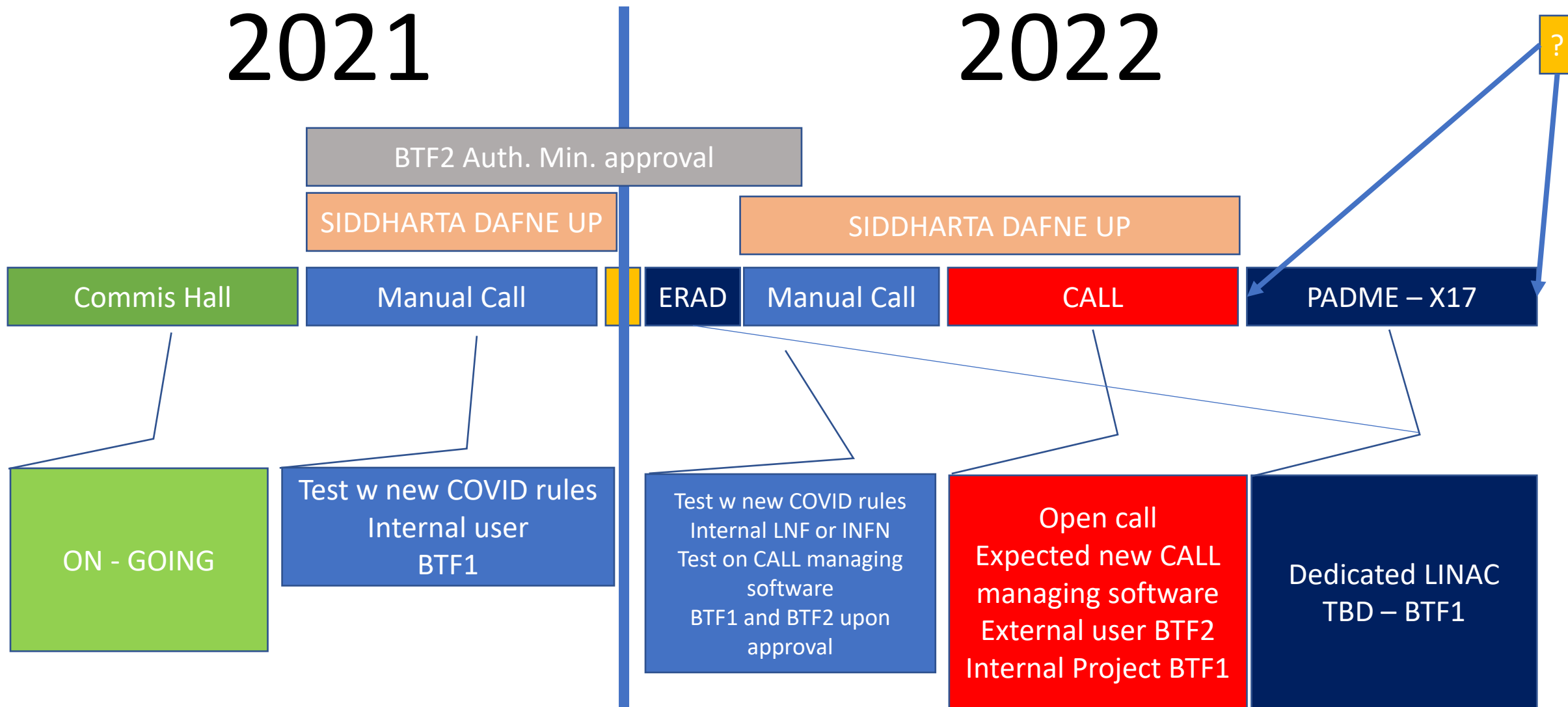
22/09/2021

Giovanni Cucinella - IMT srl

INTENDED TASKS


2021

2022



X17 EXPERIMENT – SECONDARY BEAM

Summary X17 beam needs for background validation

 (Secondary beam case)

Beam **energy** = tunable, ranging (260-290)[MeV]

Beam **pulse length** = ~200 [ns],

Particle **type** = Positrons

Multiplicity = around 10 [# / ns]

- Pulse length and Multiplicity in dependence with build time optimization

Estimation for build and test a secondary beam:

-
- more robust to energy fluctuations (secondary slow increment in multiplicity)
 - Lower current and primary energy in respect to PADME RUN 1
 - expected 350MeV (or 510MeV with 1/10 current) -> expected less than usual BTF test beam background
 - and easy to tune with only line tools, LINAC primary untouched
 - longitudinal couplings (i.e. time vs energy)
-


Beam first setup and optimization trials = +7 [d]? (never tried)

Plus beam background validation time from experiment

Eventually Switch to primary beam = 1-2 [d]

X17 EXPERIMENT – PRIMARY BEAM

Summary X17 beam needs for background validation

 (Primary beam case)

Beam **energy** = tunable, ranging (260-290)[MeV]

Beam **pulse length** = 200 [ns] or less ,

Particle **type** = Positrons

Multiplicity = around 10 [# / ns]

- Pulse length and Multiplicity in dependance with build time optimization

Estimation for build and test a primary beam:

-
- Huge Lower current and primary energy in respect to PADME RUN 1
 - More LINAC studies to maintain the long coupling also for the intermediate steps
 - Seems harder to maintains exact specs
 - From scratch surely low background expected 350MeV
 - Expected more time needs for tuning and timing validation
-

Beam first setup and optimization trials = +7 [d]? (never tried)

- Plus beam background validation time from experiment

LINAC

LINAC STAFF SCHEDULED ACTIVITIES

• LINAC-DAFNE-BTF

□ LINAC

- RUN DAFNE
 - DAFNE Run coordinators:
 - Buonomo, Foggetta, Di Giulio
- Ordinary Maintenance:
 - Modulators
 - LINAC auxiliary
- Extraordinary Maintenance and consolidation
- Modulator Consolidation:
 - Solid State Power supplies
- Upgrade
 - Building and install of new modulator
 - Test Solid CERN state Switch on new Modulator

□ BTF

- BTF2 Safety
- BTF2 Installation and commissioning
- ERAD project

• SPARC

- Modulator Maintenance
- Safety Check

• SABINA

- New C band Modulator at SPARC
- New directional couplers

• TEX

- Safety Check
- Klystron commissioning and TEST
- Modulator SAT

• SINGULARITY

- LINAC CONTROL Memcached DATA and AI feedback test

■ EUPRAXIA

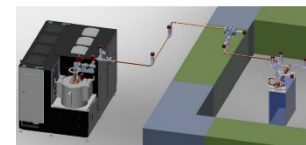
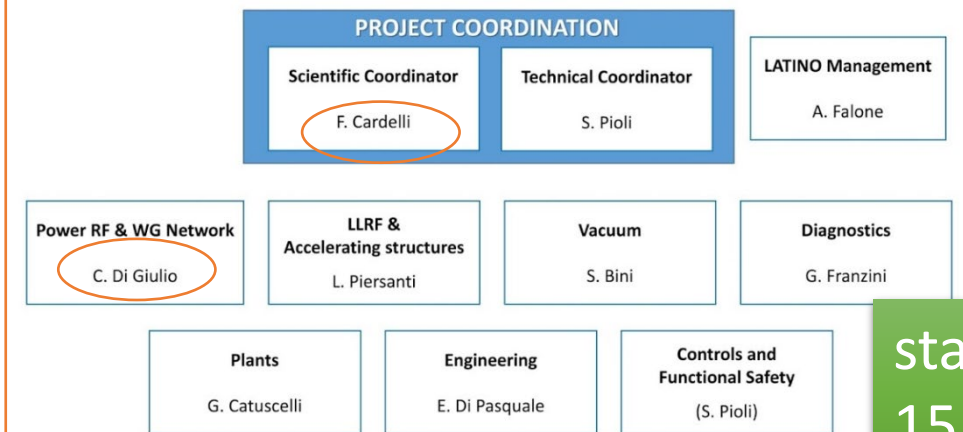
- WP12 RF Power and distribution

Modulator SAT with Scandinova
Klystron from CERN

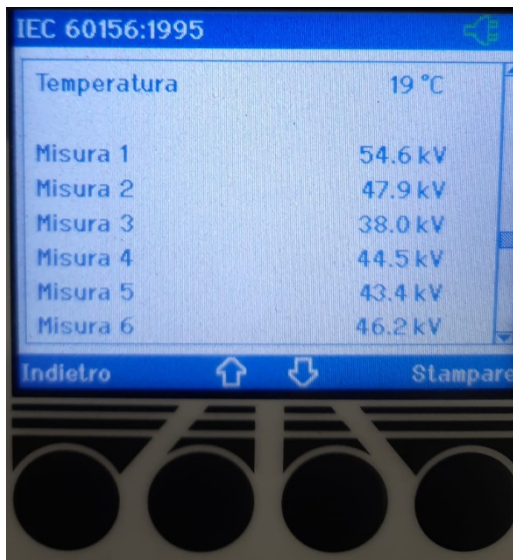
LINAC service starting from 15/09/21

- > Klystron installation
- > Modulator integration with subsystem
- > Technical support also to Scandinova
- > Power and qualification measurements

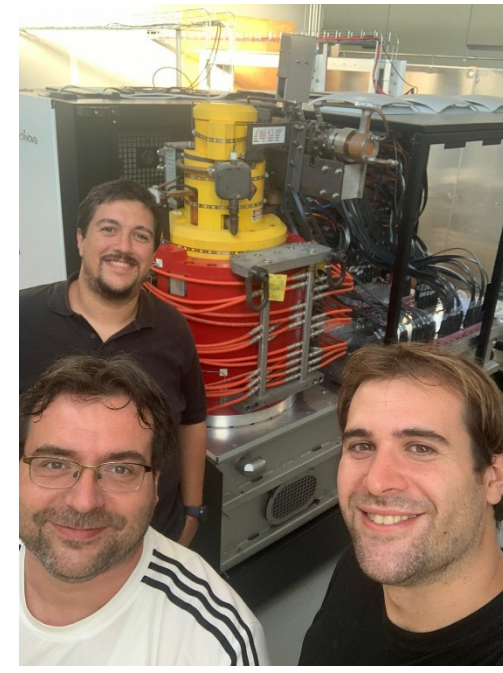
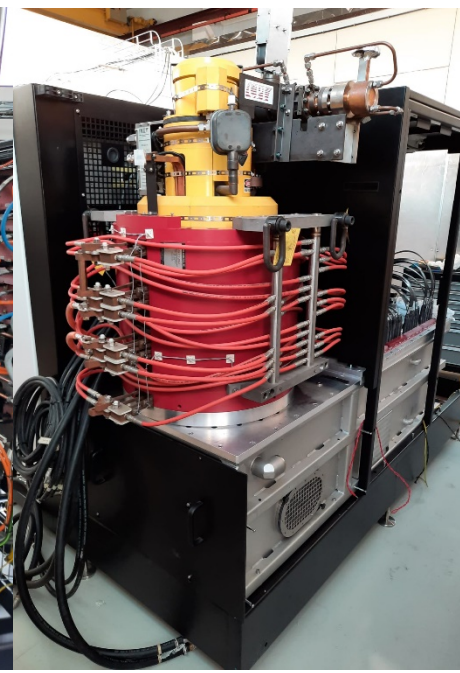
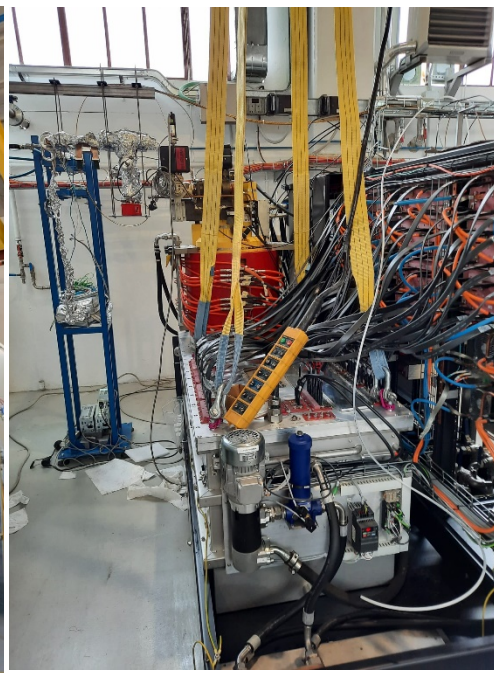
TEX Organization Chart



starting from
15/09/21 -> NOW



08/11/2021

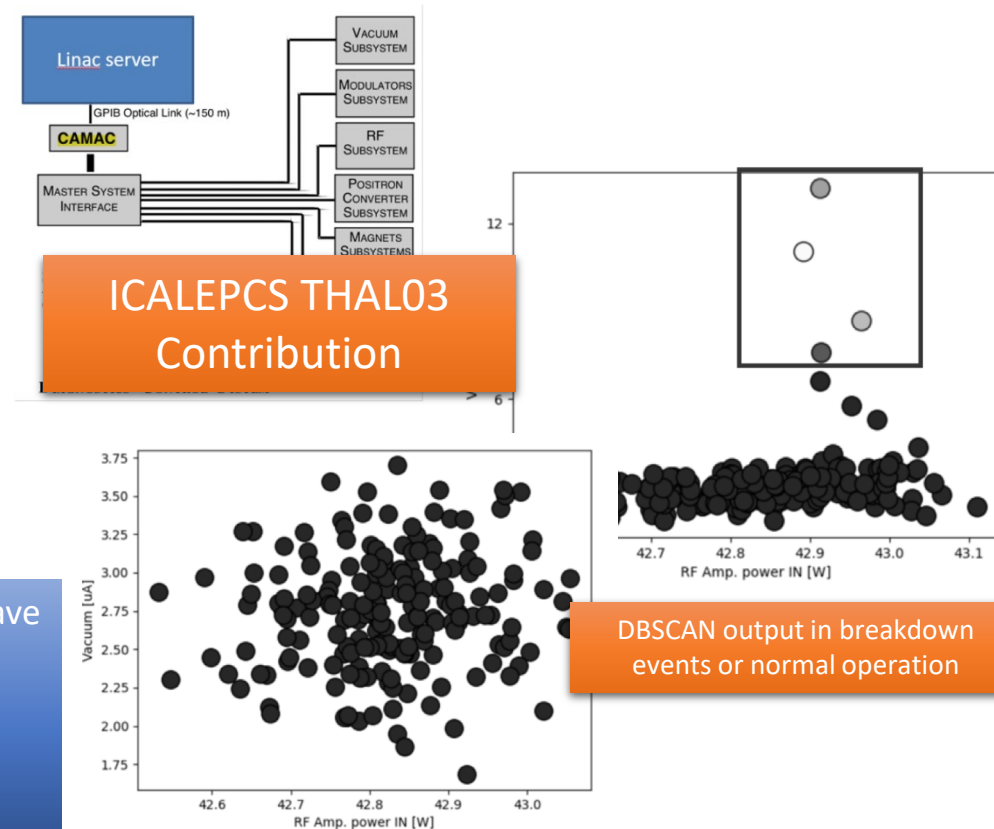
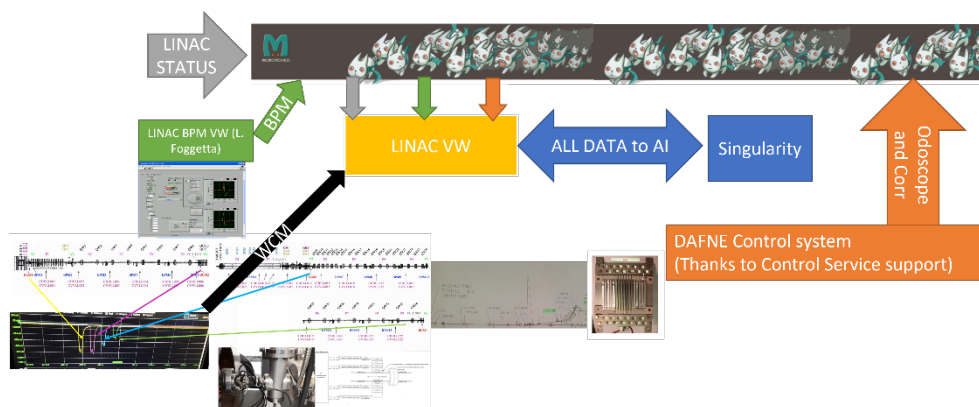


L. Foggetta - LNF SC62

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- Send LINAC CONTROL DATA to **Artificial Intelligence** for learning&process (Leader S. Pioli)
 - (WCM, Energy Charge BPM → Linac Magnet elements Linac Correctors RF V_k)
- Data collector **done** (C.Di Giulio)
- AI response trials -> Simulation and test offline (Summer 2021, S. Pioli)
- Oral in ICALEPCS21
- **Intended specific LINAC/BTF run for operative tests**



RF Energy tuning tool

BPM feedback and Quadrupole Magnet optimization tools

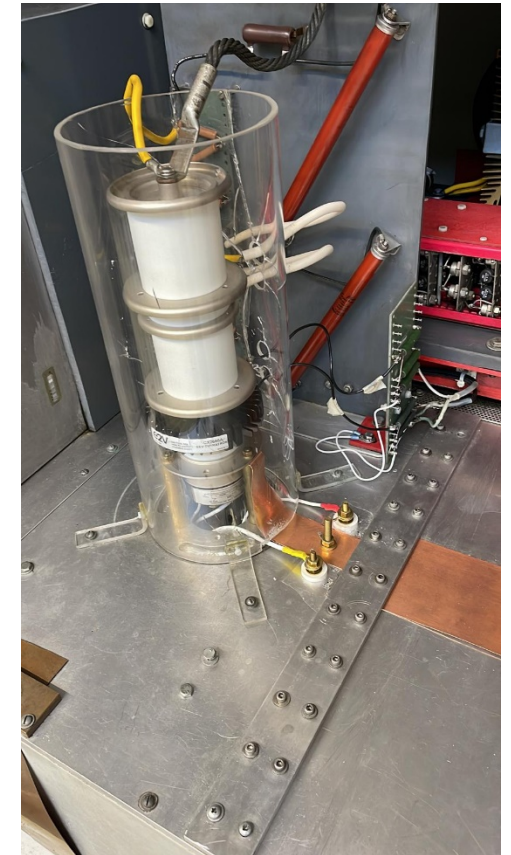
08/11/2021

Two autonomous operation tools have been developed:

- Reduced operators intervention time consuming task
- Optimizing performances for the DAFNE complex and the BTF.

LINAC STATUS

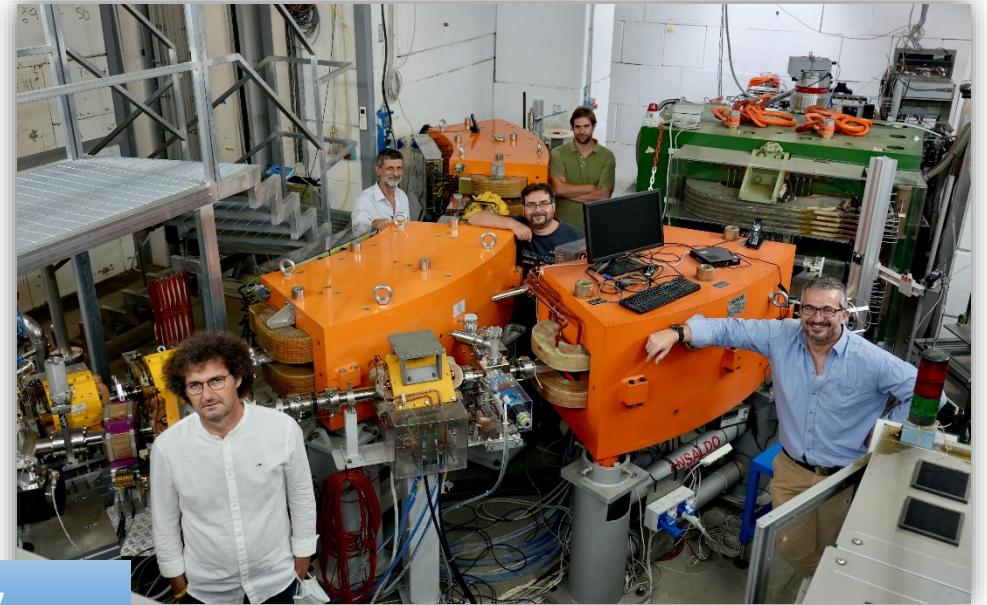
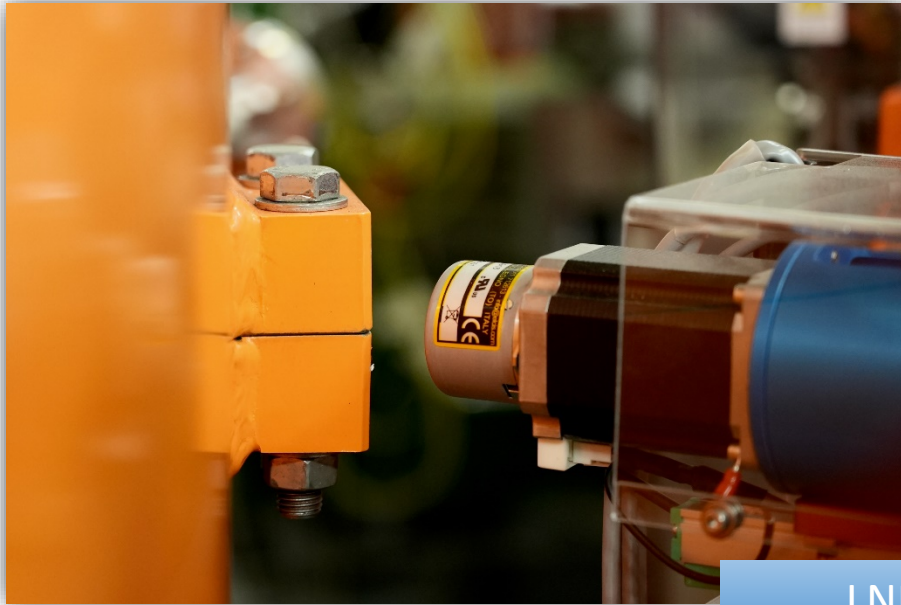
- **Finally**
- **KlyC has still a faulty vacuum window that led lower output power: now fixed 50 Hz operation**
- **Fault still less than 5% of availability time**
- **UPGRADE&CONSOLIDATION ongoing:**
 - Mod C HVPS installation -> **remains only one** modulator,
 - scheduled maintenance improved
 - New PFN tune up at lower voltage (with Spice model TBC)
 - Thyratron box A,B,C,D to new standard (improving vent and parts)
 - All the new UFS power supply have been installed with Magnet service
 - Replaced some slits parts and relative flags with vacuum service



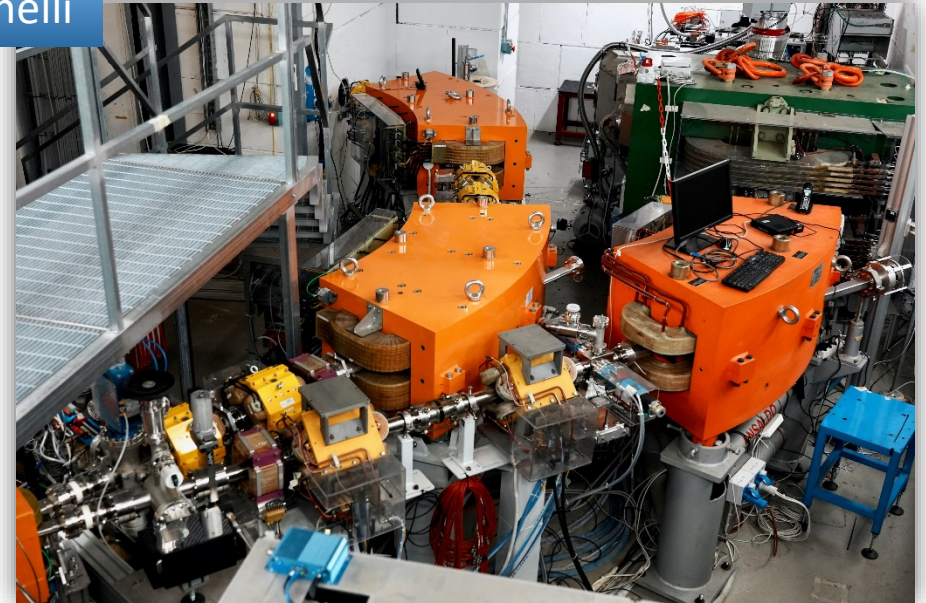
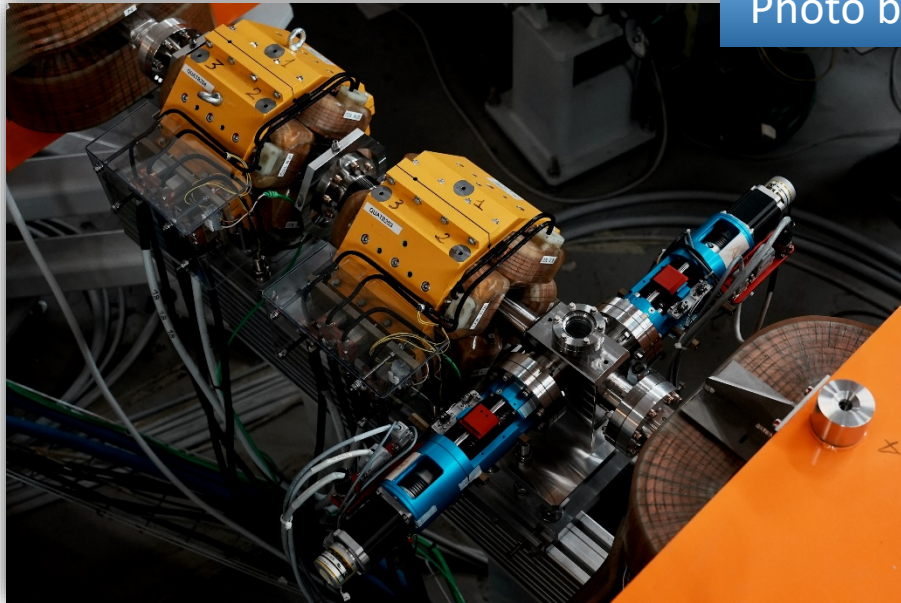
LINAC STATUS

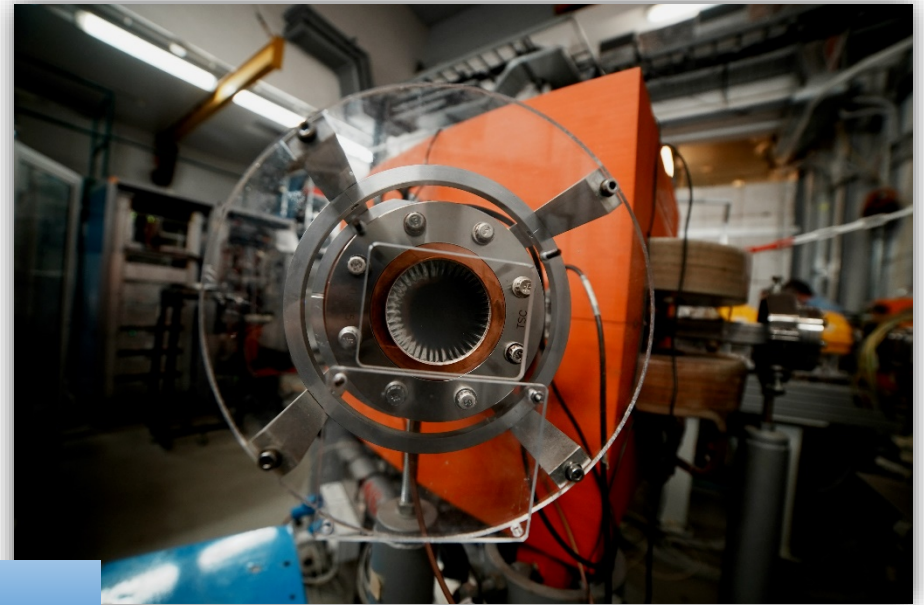
- **LINAC tunnel water seepage tightness improved**
 - Long shutdown period 30 Jul -> 10 Oct to remove tons of terrain
 - Cut BTF cooling pipes
 - Restore LINAC tunnel building
 - Put again the shield terrain and restore BTF coolant circuit
- **Difficult restart due to unexpected events**
 - Positron converter vacuum bellow
 - Difficult position
 - Design and production in few days and reinstalled in by Vacuum service
 - One Quads Triplet in low energy region had a faulty fluids connections - restored
 - LINAC Water tower with a faulty primary pump on startup
 - Restored by Fluid service in few days
 - One Helmholtz solenoid near gun in short
 - To be fixed, now bypassed



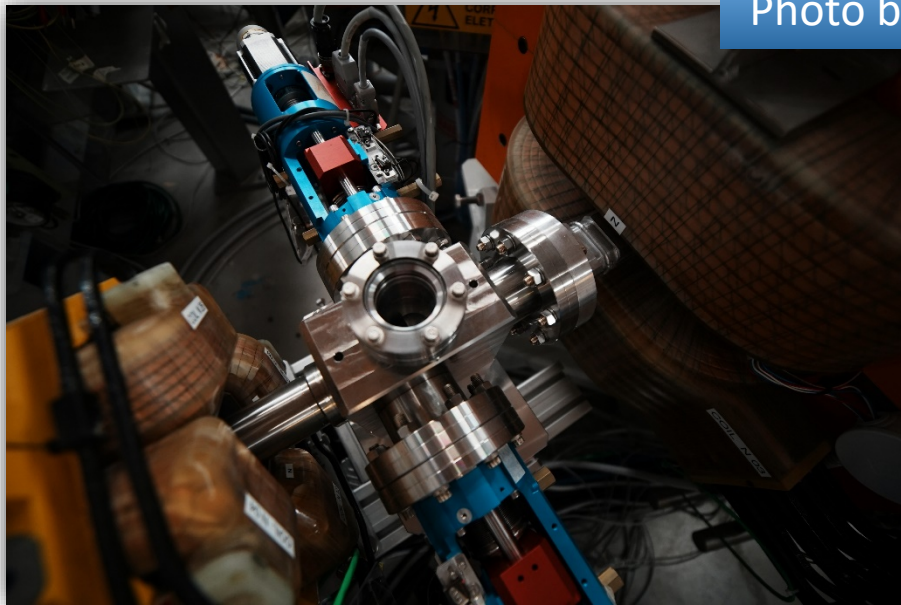


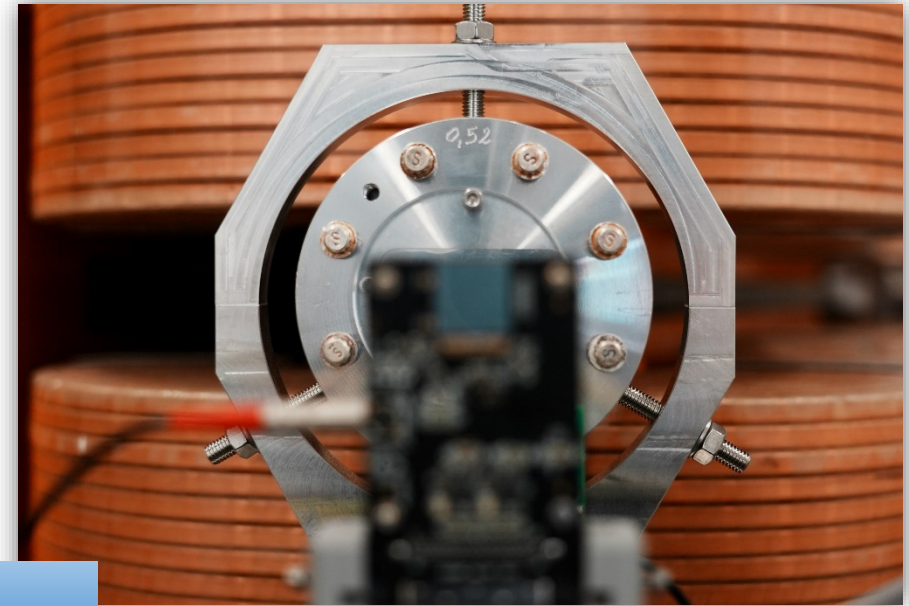
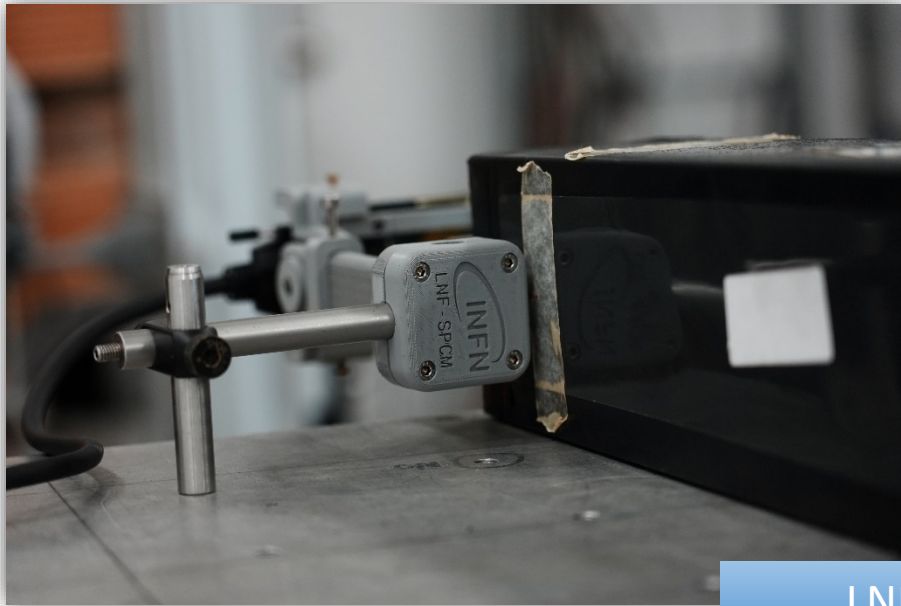
LNF SIDS Courtesy
Photo by Elena Patrignanelli



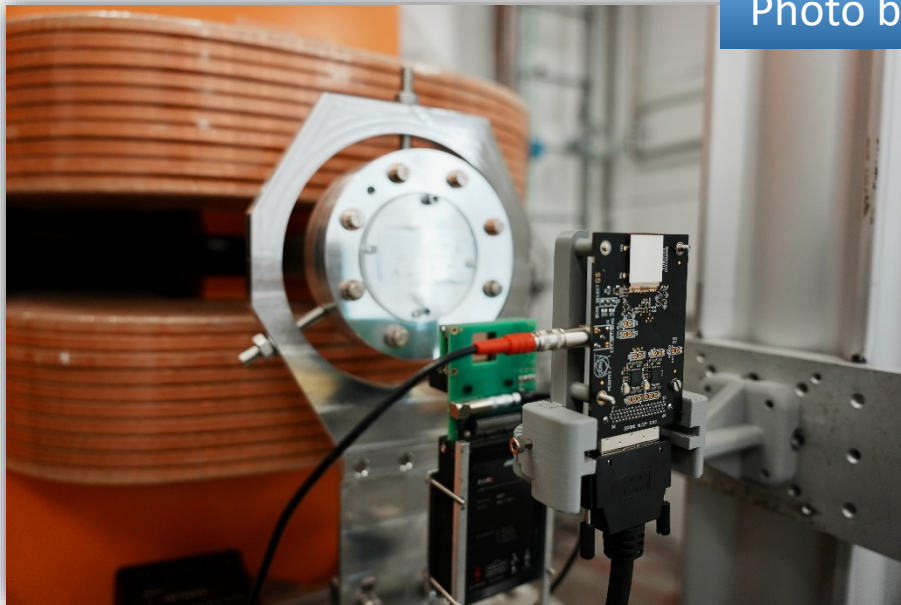


LNF SIDS Courtesy
Photo by Elena Patrignanelli





LNF SIDS Courtesy
Photo by Elena Patrignanelli





CONCLUSIONS

