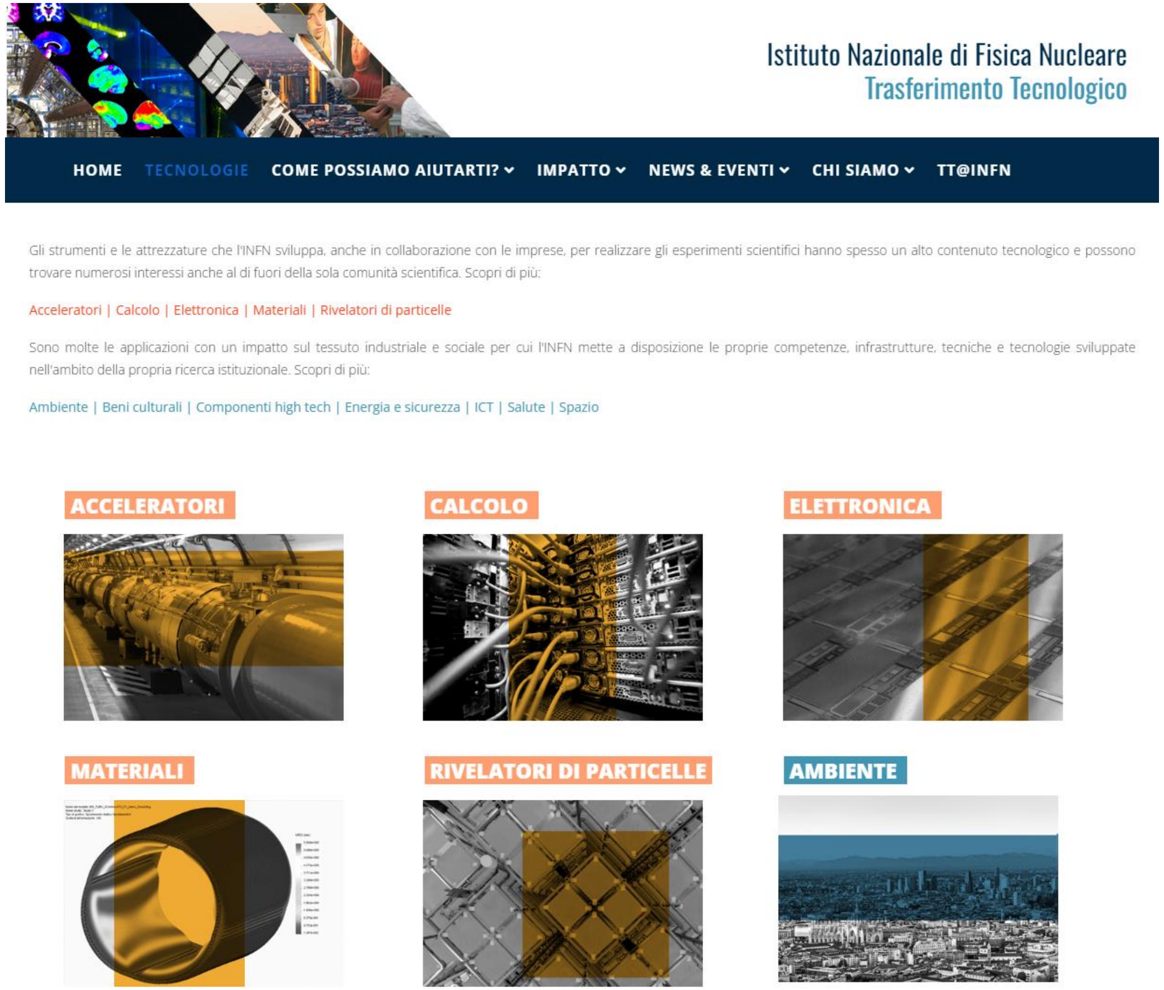
La rete ASIF e il contributo INFN

L.G Foggetta
INFN – LNF, LINAC-BTF Group

Convegno ENEA-INFN: collaborazioni in essere e sviluppi futuri
Frascati
05/11/2024

INFN and INFN Tech Transfer

INFN – Istituto Nazionale di Fisica Nucleare



More on https://web.infn.it/TechTransfer/

ASIF – ASI, ENEA, INFN, UniMiB project

Goal

- Create a national network to support customers and scientific research on radiation hardness assessment for space projects

Exploits

- Top-notch research labs and irradiation facilities
- Shared strategic vision from ASI, ENEA, INFN, UniMiB
- Dedicated professionals

ASIF – a coordinated approach for space applicaton

INFN Site	INFaN	Contact E-mail PAC (ask for beam)	Reference/Call Site
CURRENTLY INCLUDED (ASIF-2)			
INFN-LNF	Luca Foggetta	btf_sciresp@lists.lnf.infn.it https://booking.dsi.infn.it/	https://btf.lnf.infn.it
INFN-LNS	Vincenza Bonanno	vincenza.bonanno@lns.infn.it	https://www.lns.infn.it/it/user/come-chiedere-fascio.html
INFN-TIFPA	Enrico Verroi	enrico.verroi@tifpa.infn.it	https://www.tifpa.infn.it/sc-init/med-tech/p-beam-research/
Next Proposal			
INFN-LNL			
INFN-FI (LABEC)			

LNF – BTF THREE LINES STATUS

BTFEH1 – BTF1 (2 lines)

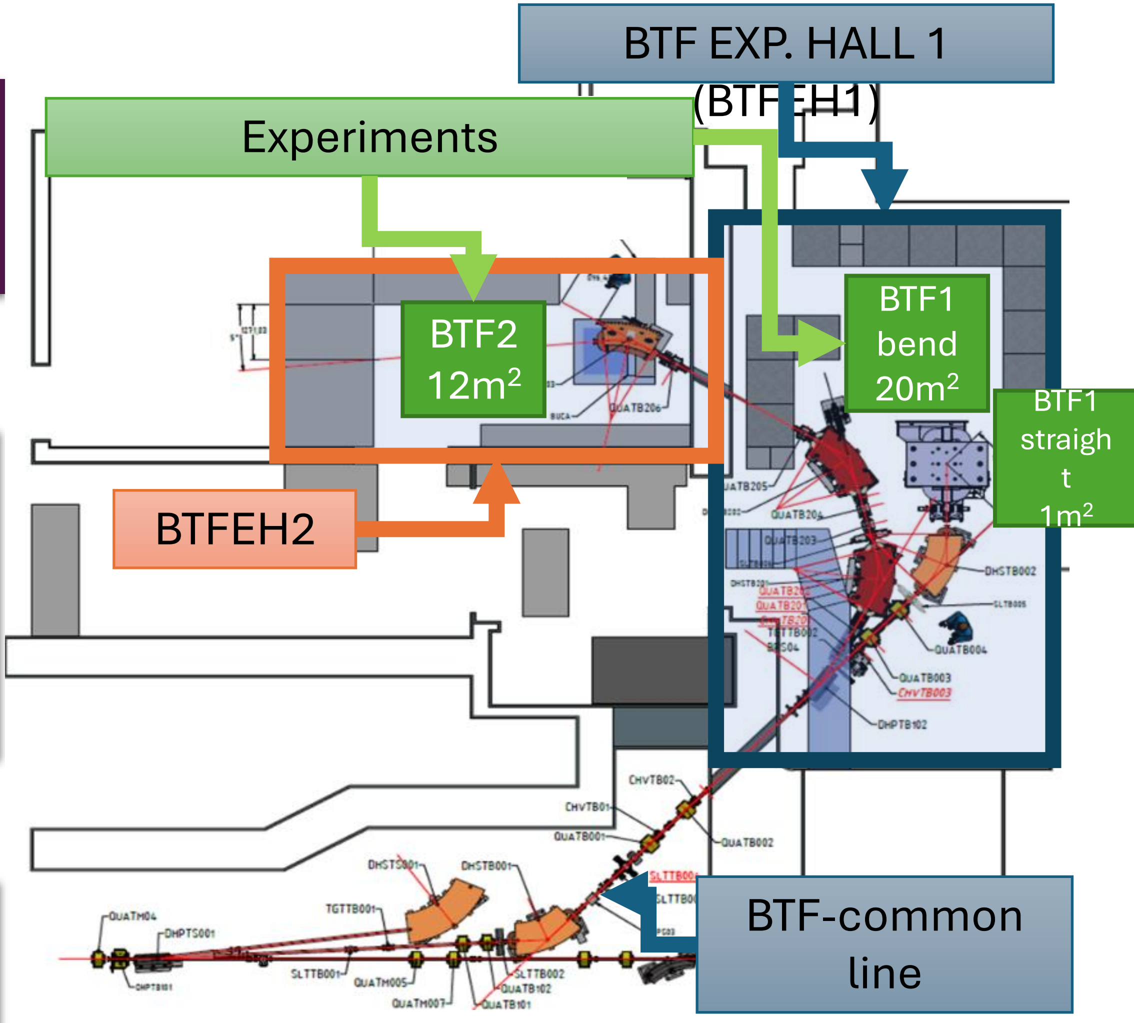
- 2025 Q1-2-3 Foreseen internal fixed target experiment run
- VHEE community interests – 3 runs both in primary and secondary beam
- HI Experimental area limitation due to fixed installation

BTFEH2 – BTF2 (1 line)

- Hall operative, BTF2 line to external users
    - external users run foreseen now up to December ends
- Only secondary beam
- Improved stability (transverse param., single particle cumulative average position, timing scheme)
- Involved in ASIF2 and EUROLABS Project

BTFs latest

- **Software for automated call and user management operative, extended to other INFN labs**
- **New triggering scheme for users, Gas full feeding**
- **Currently BTF unique LINAC user (Dedicated mode)**

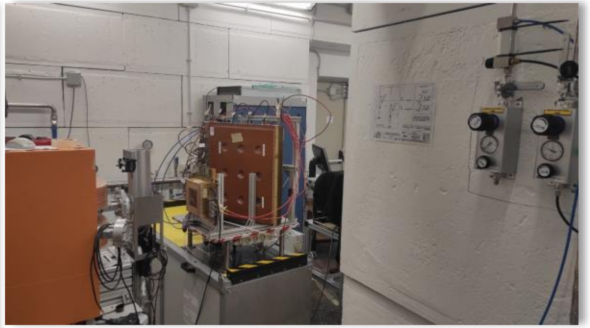


INFN LNF – BEAM TEST FACILITY

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

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Parameters	BTF1 Time sharing		BTF1 Dedicated		BTF2 Time sharing	BTF2 Dedicated
	With Cu target	Without Cu target	With Cu target	Without Cu target	With Cu target	With Cu target
Particle Type (Dependance)	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 dependent	1% at 500 MeV	
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	Expected 10-100
Intensity (particle/bunch)	1–10^5 (Energy dependent)	1 to 10^7 / 1x10^{10}	1–10^5 (Energy dependent)	1 to 10^{10}	1–10^4 (Energy dependent)	
Max int flux	1x10^{10} part./s				1x10^6 part./s	
Beam waist size(mm)	0.5–55 X / 0.35–25 Y (vacuum window dependent)				0.4x0.4	
Divergence (mrad)	Down to 0.5				Down to 0.5	



- Pulsed **electron** and **positron** beams (up to 49 pulses/second)
- Primary and secondary beam (w/o or with Cu target)
- Wide range: from 10^10 down to single particle per bunch, continuous energy selection

INFN – TIFPA - TRENTO PROTON BEAM LINE

Two beamlines available

- **Proton Pencil beam irradiation**
(≅1 cm beam diameter)
- Large field irradiation
(≅6 cm dose homogeneity)
- Large dynamic range: from 10 p/s to 10^12 p/s (dependence on beam energy)

Beam Production:

Isochronous Cyclotron IBA

Energy Range: 70-225 MeV

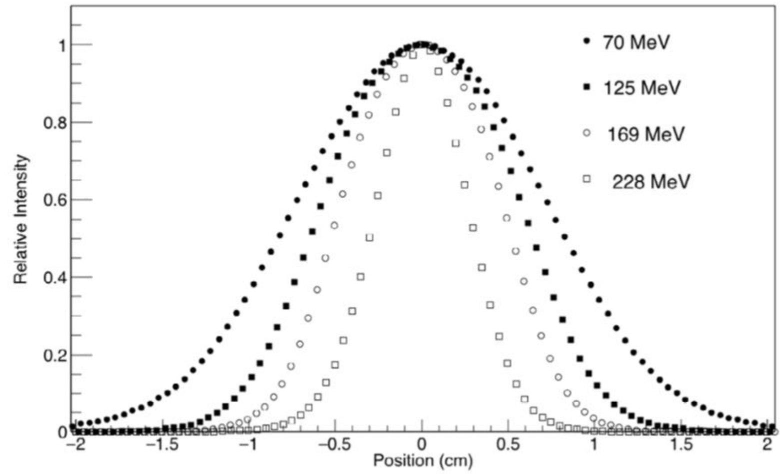
Beam Current: up to 320 nA

Average Time for Energy Change: 2 s

Energy selection and beam transport system

ESS = proton degrader + 'beam analyzer'

Beam spot profile at different energies



Experience for space: shielding materials for Rossini I (ESA funded) + radiation hardness

Availability of administrative procedure: yes

Availability of dosimetry and services: yes

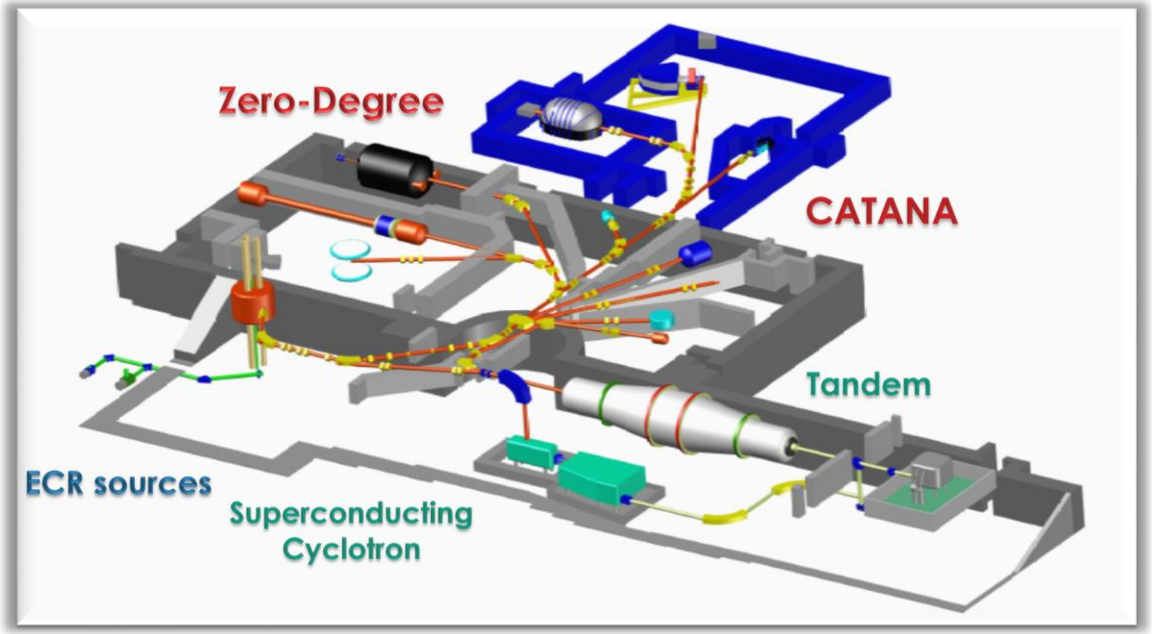
2018-2023: 108 proposals evaluated by the PAC

Beam available outside after clinical activities, approx. 19:30-22:30 Mon-Fri + Saturday Morning

More at https://www.tifpa.infn.it/sc-init/med-tech/p-beam-research/

INFN – LNS

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati



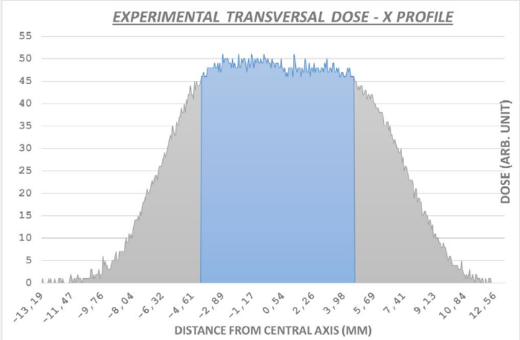
HEAVY IONS BEAMS			
Ion	Energy [MeVA]	LET^{SRIM} [MeV/mg/cm^2]	Range^{SRIM} [µm]
^{20}Ne	20	1.996	504.54
^{40}Ar	20	6.266	356.49
^{84}Kr	20	21.59	245.12
^{129}Xe	20	44.05	204.46

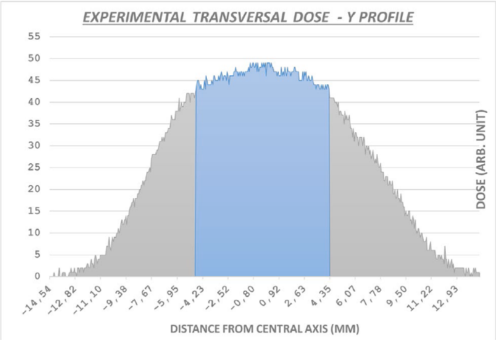
Integrated dose test

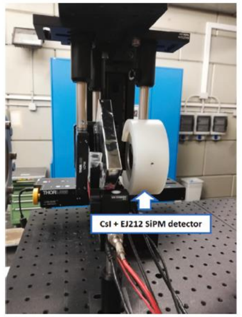
PROTONS	
Energy [MeV]	Flux [ions/cm^2/s]
10-23 from Tandem 60, 80 from CS*	10^7

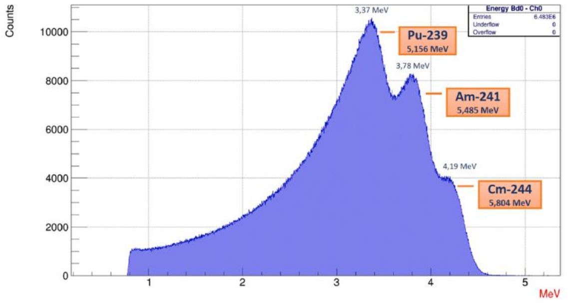
*Energy can be reduced by means of a stack of plastic degraders

- ✓ LET values and range in Silicon are calculated with SRIM2008, accordingly to ESA specifications;
- ✓ For in-air irradiation, air is used to reduce beam energy → Several LET points up to 60 *MeV/(mg/cm²)*;
- ✓ During the latest SEE test, a bottle containing a cocktail of ^{20}Ne, ^{40}Ar and ^{84}Kr has been set-up.









More at https://doi.org/10.1016/j.nimb.2019.09.015

INFN LNL - An2000+CN Irradiation Facility

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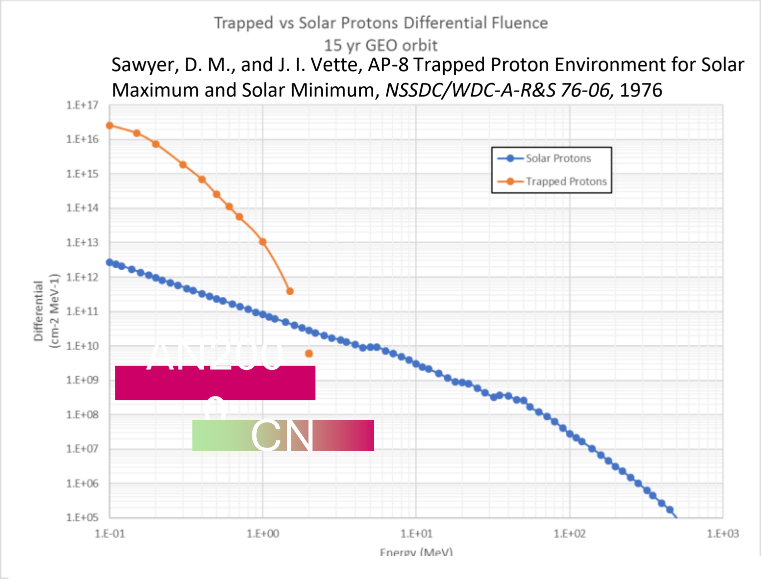


Graphic Rendering

- **BEAM FEATURES:**
  - Monochromatic Beams: ^{1}H+, ^{4}He+
  - Energy: 0.2÷5.5 MeV
  - Standard Beam Size: 2÷8 mm (FWHM)
  - Beam Current: 1-400nA (typical)- (>400nA, <2μA energy dependent)

- **IRRADIATION SPECIFICATIONS OF THE NEW FACILITY**
  - Large area uniform irradiation of spacecraft materials and components in a wide range of energies and fluences
    - Fluence: $1x10^{9} \div 10^{16}$ cm^{-2}
    - Energy: 0.2÷5.5 MeV
  - Large area
    - ΔX·ΔY=20x20cm^{2} @ 2 MeV, ΔX·ΔY=8·8cm^{2} a 5.5 MeV
    - XY beam scanning
  - Uniformity
    - Spatial uniformity: target ≤ ±1%
  - Accuracy
    - Accuracy: base ≤ ±5% - target to ≤ ±3% (multiple Faraday cups)
  - No Carbon build-up (cryogenic LN2 trap)
  - Time for full irradiation
    - From 30s to several hours
  - Certification of irradiation: ESA/ASI ongoing

Courtesy of V. rigato

INFN – LABEC

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Laboratorio di tecniche nucleari per l'**A**mbiente e i **Be**ni **C**ulturali
INFN e Dipartimento di Fisica e Astronomia dell'Università di Firenze

INFN LABEC
Istituto Nazionale di Fisica Nucleare
Laboratorio di tecniche nucleari per l'Ambiente e i Beni Culturali

LABEC, the Laboratory of nuclear techniques for Environment and Cultural Heritage, is a high-qualified centre for the development of new technologies based on small particle accelerators and ionizing radiations, and for their applications in environmental contexts and in heritage science. The laboratory is hosted at the Florence unit of INFN (National Institute of Nuclear Physics) and it is jointly managed by INFN and the Department of Physics and Astronomy of the University of Florence.

ENVIRONMENT

The investigation of particulate matter (i.e. aerosol) allows us to get information that are useful for researches about climate changes, pollution processes and health.

CULTURAL HERITAGE

The studies on the composition of artworks and on radiocarbon dating represent fundamental ways to enhance our knowledge about cultural heritage to better understand and preserve it for the future.

MATERIALS

Advanced and innovative materials are the keys for future applications to sensors and quantum technologies, such as data storage and communication.

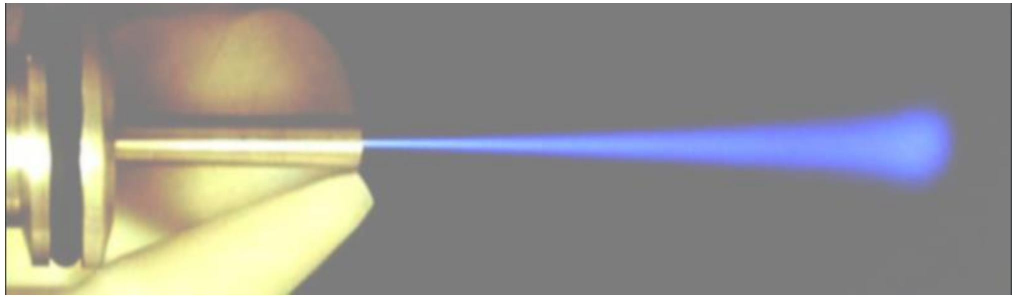
ACCELERATORS

Particle accelerators, such as the 3 MV tandem electrostatic accelerator and the new MACHINA accelerator, which is at present under development, represent the core of the laboratory activities.

DIGITAL LABS

Innovative digital services, both desktop and/or web-based, are developed to support researchers in their work.

6	3	8
Beam lines at the 3 MV tandem accelerator	Portable XRF scanners for in-situ analyses in Cultural Heritage contexts	Particulate matter samplers characterized by different temporal resolutions



Since 2018, LABEC has been part of ACTRIS-IT, the Italian node of ACTRIS (Aerosols, Clouds and Trace Gases Research Infrastructure), which is the European infrastructure coordinating the observations and the scientific research on aerosol, clouds and gases in atmosphere. ACTRIS has been inserted in the ESFRI roadmap since 2016.

ACTRiS
Exploring the Atmosphere

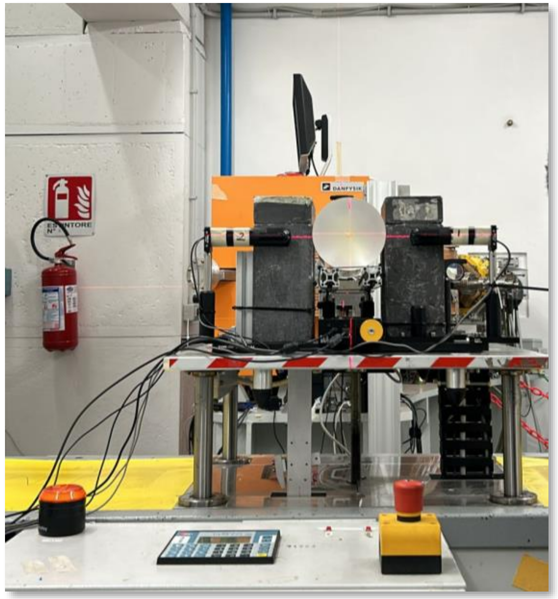
INFN CHNet
Istituto Nazionale di Fisica Nucleare
Cultural Heritage Network

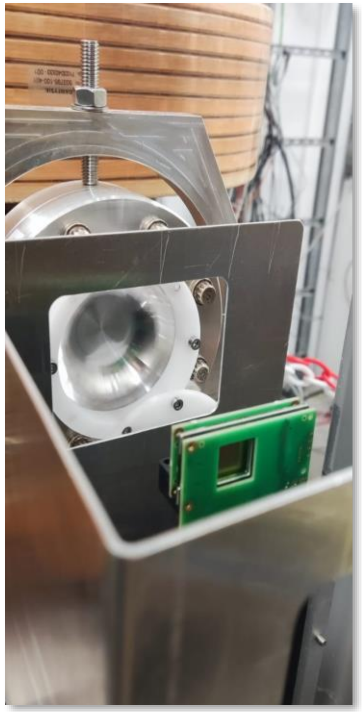
CHNet (Cultural Heritage Network) is the first network of INFN in the framework of technology transfer and it is dedicated to the study of Cultural Heritage.

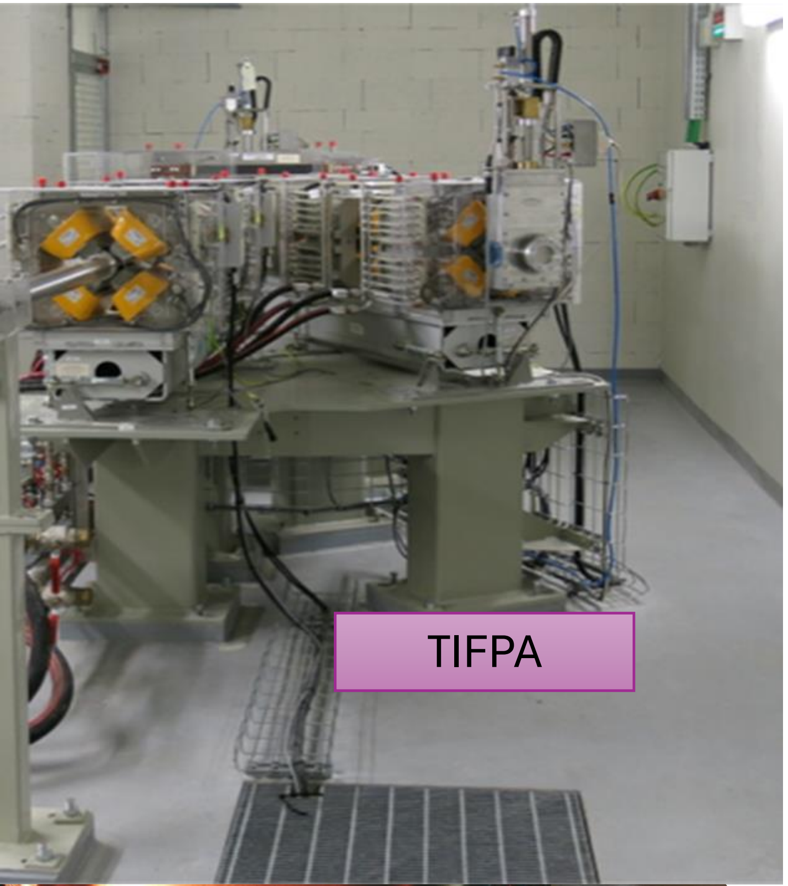
http://chnet.infn.it/

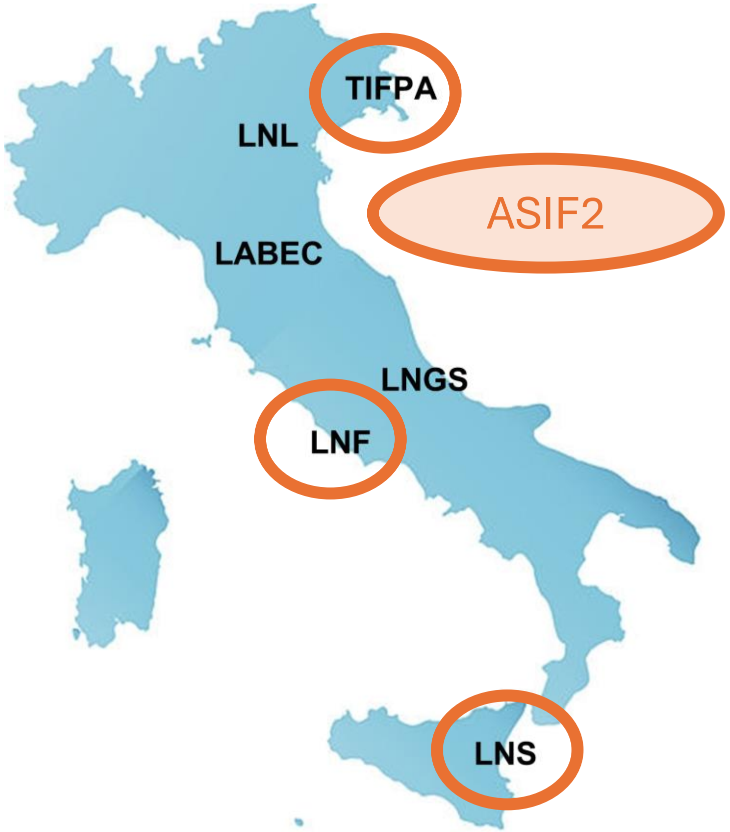
ASIF Implementation of ESA test requirements – coarse overview

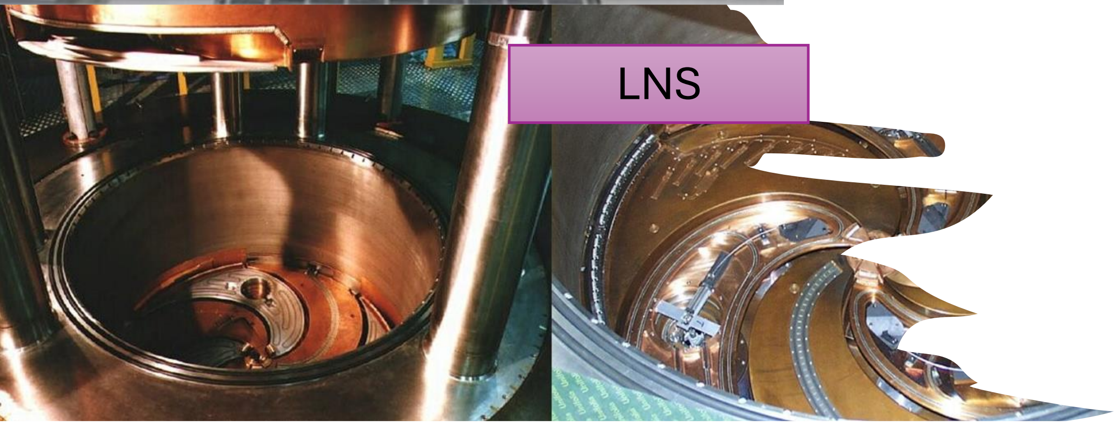
Parameter	Requirement
Dosimetry	~10%
Temperature stability	+/- 3C
Beam size	Variable, from ~mm (chip) to ~10cm (solar panels)
DUT positioning	Remote, automatic
Beam time availability	Flexible, with short notice
Access to service	Single web portal
Access to facility	Lab-specific safety and dosimetry procedures, Local staff support











INFAN
Accelerators network at INFN – A

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Laboratori Nazionali di Frascati

INFN-A Generalized common infrastructure

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

National Level

- INFN main site
- Light web DB facility
- Calls Newsletter (now performed by hand replies)
- Local level object linking
- Guided path to best beam needed
- Dissemination

BTF way of operation could explore a new paradigm of working for easy develop and integration from external project and internal collaboration

Distributed IT facility for INFAN

National service

- **fully mantained**
- **more reliable**

wiki.infn.it
@lists.*.it
GODIVA
AAII
Userportal
Booking
DB
Backup
Territorial access

Local Level (Customizable)

- Facility web site
- Wiki.infn
- Mailing list
- Booking app
- Own call DB
- Repository Software
- Data Logging

LNF Booking DSI SW

Booking DSI: Facility beam time and users management software based on an automated approval workflow.

Call for users and calendar management. Users' territorial and lab access. Auth Process and ticketing traceability.

INFN LNF developing

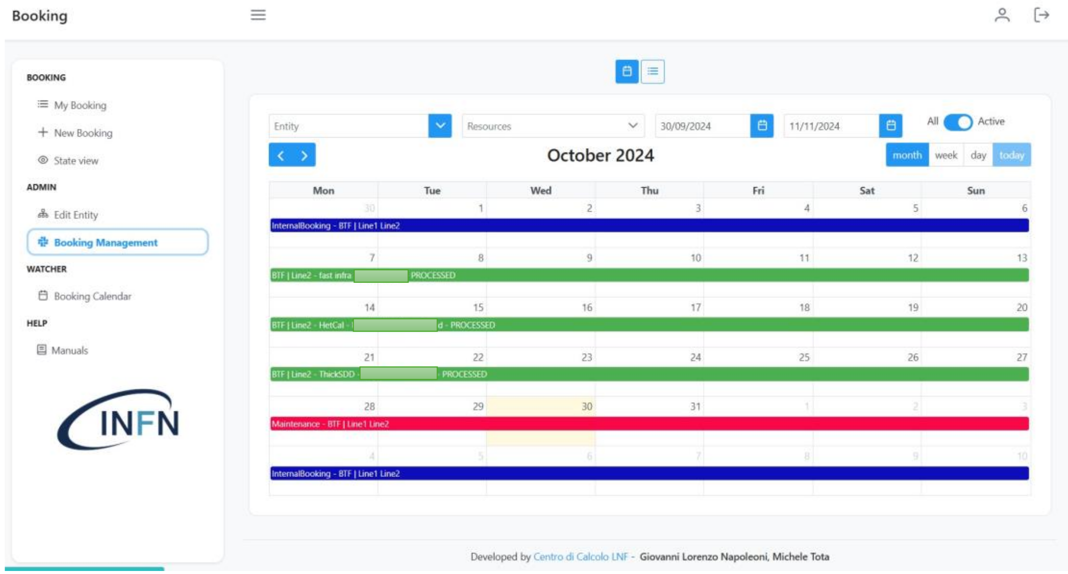
Beam Test Facility(BTF)

- **More than two year of continuous operation**
- Weekly, last-minute shift, renunciation or rebooking
- New GUI
- 400 users in automated managed shift (weekly based) up from first release

DAϕNE-L Facility

INFN-LABEC developing

- **Released** few month ago
- Collaboration born on INFN-A
- Similar aim (internal or users management)
- Many lines: 5 for TANDEM facility



Will meet ESA test requirement (Next)

Tech note

https://www.openaccessrepository.it/record/143679

Developed by L.G. Foggetta, **G. L. Napoleoni** (LNF Computing Center, main dev.), R. Orrú, M. Tota. BTF group, LNF AD-Secretariats and Personnel-Secretariats

Latest LNF-BTF Space appl experiences

LIMADOU

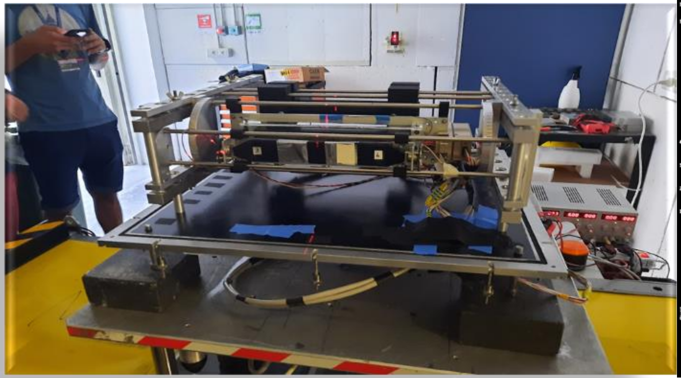
LIMADOU is part of a scientific program that studies natural and anthropogenic electromagnetic fields, their emissions and possible correlations with seismic events.
https://w3.lnf.infn.it/experiments-in-btf-orbit/?lang=en

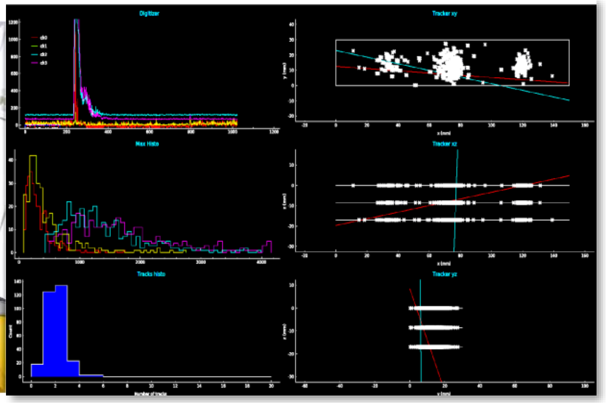
HEPD CSES LIMADOU – (SPACE Appl) 2023

Prototype: 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/experiments-in-btf-orbit/?lang=en

Run with dedicated 30MeV- single particle beam

The main purpose of the test: check tracker efficiency in track reconstruction with single-particle electron beams at different energies (from 30 to 120MeV) were produced to characterize the response of the apparatus to natural events, similar events that will occur along the satellite's orbit



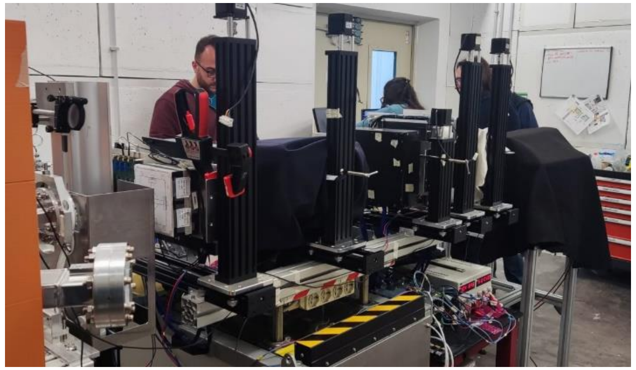


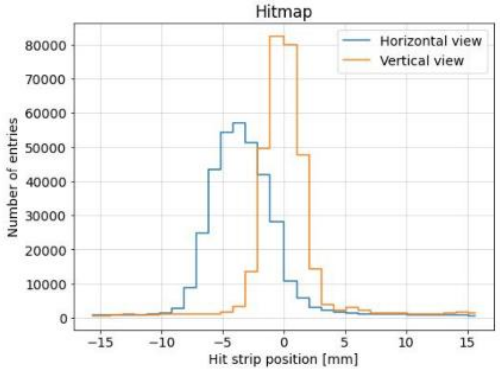
ZIRETTINO – (Space Appl) 2024

Zirettino is a prototype of Ziré which is parte of the NUSES space mission and will detect Cosmic Rays with energies from few up to hundreds of MeVs

BTF Beam from 450 to 50 MeV few particles regime in a impressively dense setup

Firsts operative test with FTK+LYSO cubic crystals @ lower energies (different energies, m1, electrons), multiple apparatus test, developed directly in the BTF EH, fiber tracking calibration and test.





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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

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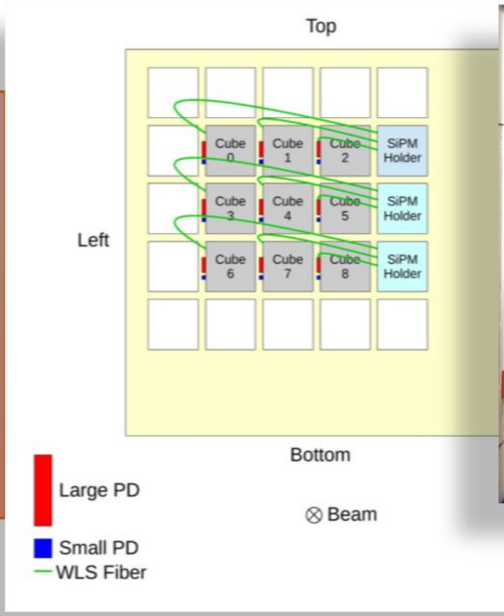
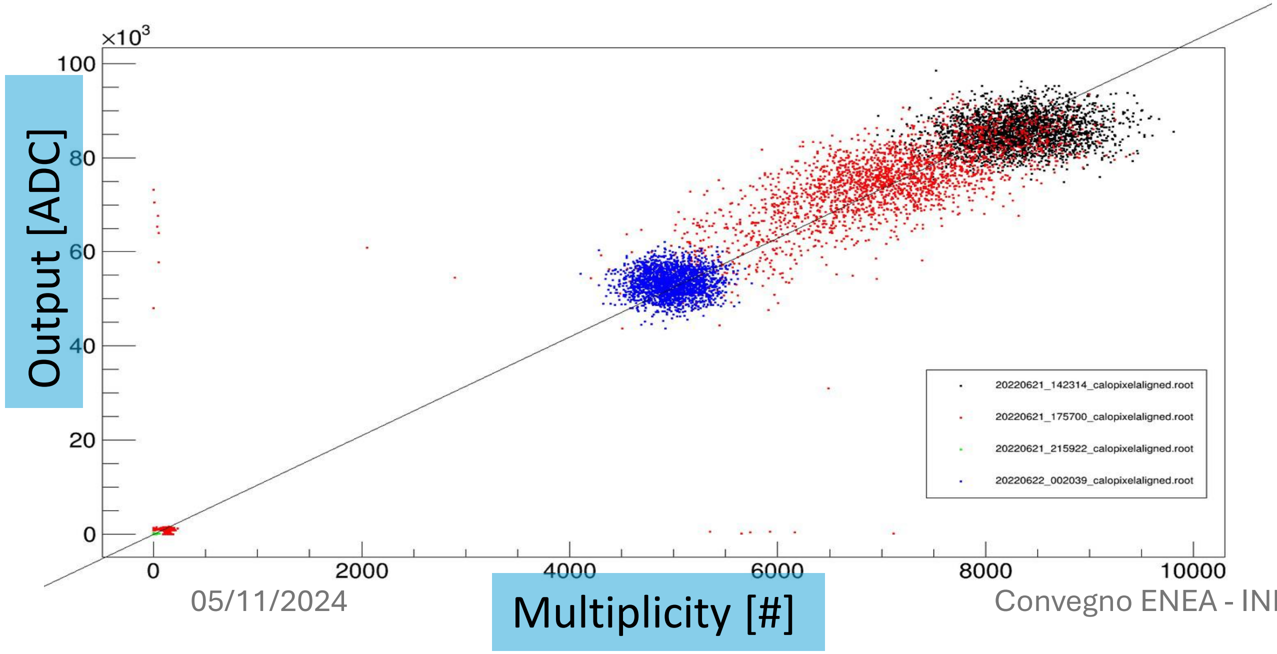
BTF USER run (SPACE Appl) 2021-2023

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



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.

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ERAD – SPACE APPL

2022 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.

Last Test Beam in July 2022
Project ended with great success!

ERAD @ BTF

INFN TEAM :
Project leader: B. Buonomo

Project TEAM: LINAC BTF Staff and LNF Services

eRAD
Test di resistenza alle radiazioni per com[ponenti]
aerospaziali

eRAD Protocol N. 001/2022

eRAD

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.

LAerospazio IMT Ingegneria Marketing Tecnologia INFN ASI Agenzia Spaziale Italiana

Bando Regione Lazio n: POR FESR LAZIO 2014-2020 "Progetti Strategici"
eRAD
Test di resistenza alle radiazioni per component aerospaziali
DELIVERABLE REPORT
MANUALE DEI REQUISITI OPERATIVI
D1.1

Documento N.:	ERAD-2020-D1.1
Data di consegna:	Da Mese 5 (Nov 2020) a Mese 8 (Feb, 2021)
Data:	12/01/2021
Work package:	WP1: Studio requisiti di prova e definizione protocolli
Lead beneficiary:	eRAD Teams
Document status:	12/01/2021

Bando Regione Lazio n: POR FESR LAZIO 2014-2020 "Progetti Strategici"
eRAD
Test di resistenza alle radiazioni per component aerospaziali
DELIVERABLE REPORT
RAPPORTO DI PROVA :
HIGH ENERGY ELECTRONS RADIATION TESTS IN COMPARISON WITH TID TESTS
D2.1

Documento N.:	ERAD-D2.1
Data di consegna:	(Agosto, 2022)
Data:	12/08/2022
Work package:	WP2: Rapporto di prova
Lead beneficiary:	eRAD Teams
Document status:	11/02/2022

Bando Regione Lazio n: POR FESR LAZIO 2014-2020 "Progetti Strategici"
eRAD
Test di resistenza alle radiazioni per component aerospaziali
DELIVERABLE REPORT
RAPPORTO DI PROVA
D3.1

Documento N.:	ERAD-D3.1
Data di consegna:	(Feb, 2022)
Data:	12/08/2022
Work package:	WP3: Rapporto di prova
Lead beneficiary:	eRAD Teams
Document status:	11/01/2022

Bando Regione Lazio n: POR FESR LAZIO 2014-2020 "Progetti Strategici"
eRAD
Test di resistenza alle radiazioni per component aerospaziali
DELIVERABLE REPORT
RAPPORTO DI PROVA LINAC-BTF
D4.1

Documento N.:	ERAD-2020-D4.1
Data di consegna:	A Mese 8 (Feb, 2021)
Data:	26/02/2021
Work package:	WP1: Rapporto di prova LINAC-BTF
Lead beneficiary:	eRAD Teams
Document status:	12/01/2021

INFN LNF **FISMEL**

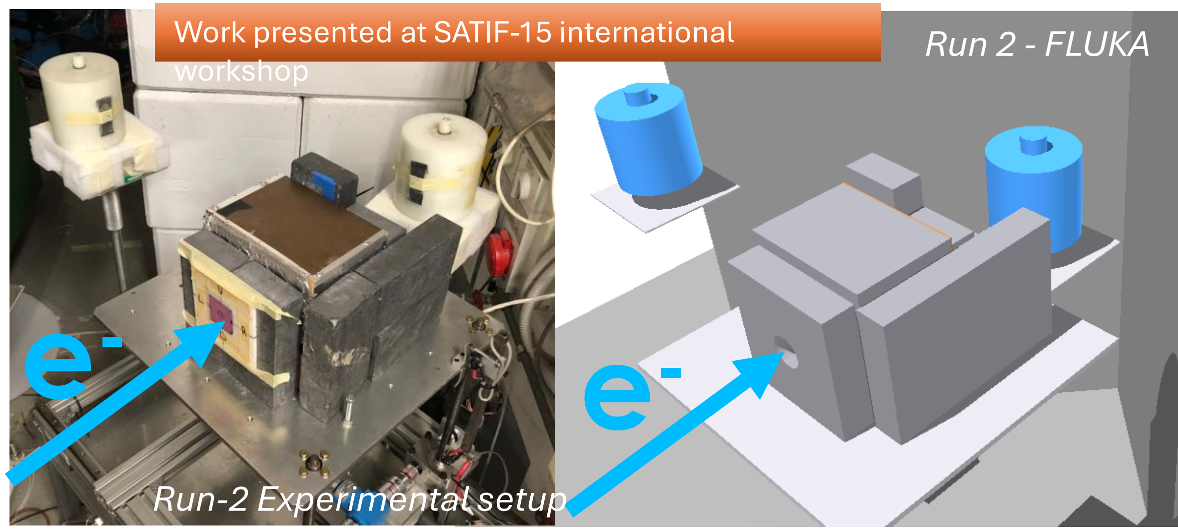
Dose evaluation from electrons impinging on a Pb target due to: i) Bremsstrahlung photon production; ii) photo-production of neutrons.
Thermoluminescent dosimeters used to measure doses at several charge intervals.

BTF USER run: (New Rad Dosy.) 2024

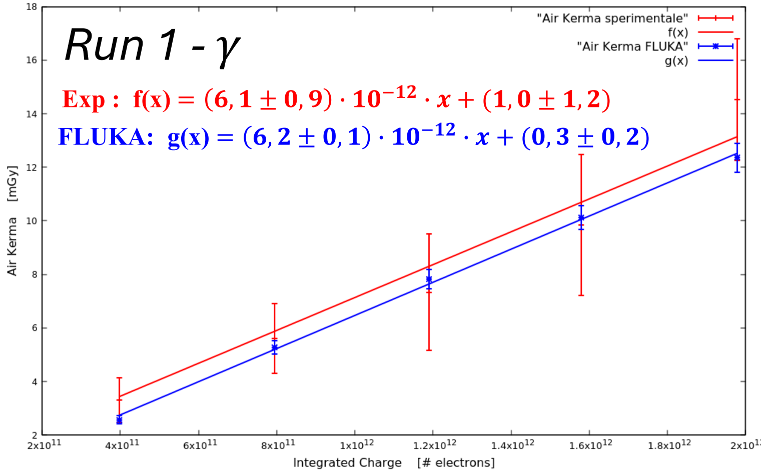
BTF beam 503 MeV, 1 Hz, 10^9 e-/s, spot diameter around 1 cm
Beam on a ~ 16 cm Pb target → mixed radiation field

1° run: photon Air KERMA evaluation at 0 ° (TLD700)
2° 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

Work presented at SATIF-15 international workshop



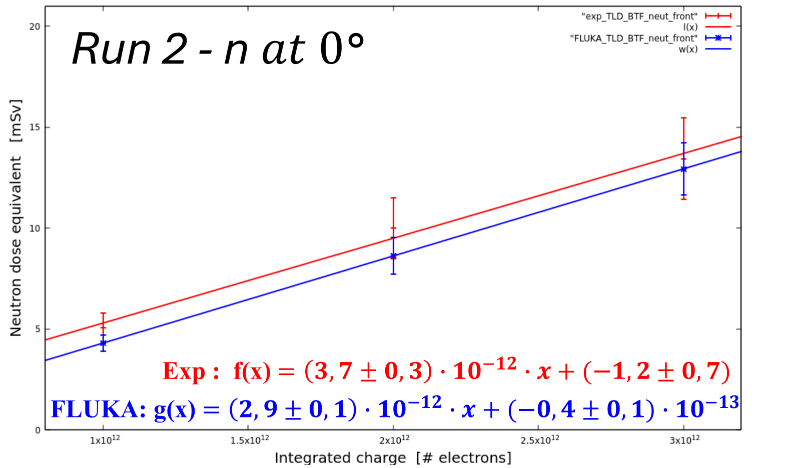
Good MC-Data agreement for the Dose-electrons conversion factor:



TLDs placed inside the cylinders

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

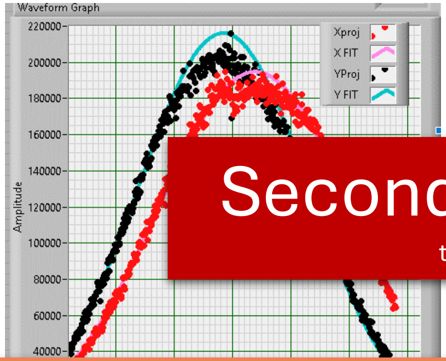
Important results useful to estimate the mixed radiation field doses in BTF produced from HE e-beam on target

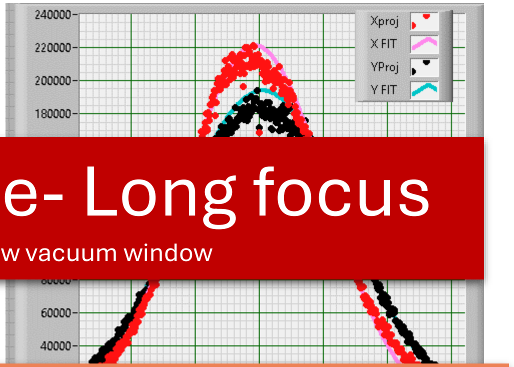


BTF AND ENEA NTOF

- Used New QUAD TPX3 Hybrid with 100um thickness w Katherine readout (developed with ENEA N-TOF group)

Test Beam for FCC – PCUBE injector (P. Craievich, G.L. Orlandi, R. Zennaro – PSI) and N – TOF (G. Claps et al. ENEA)



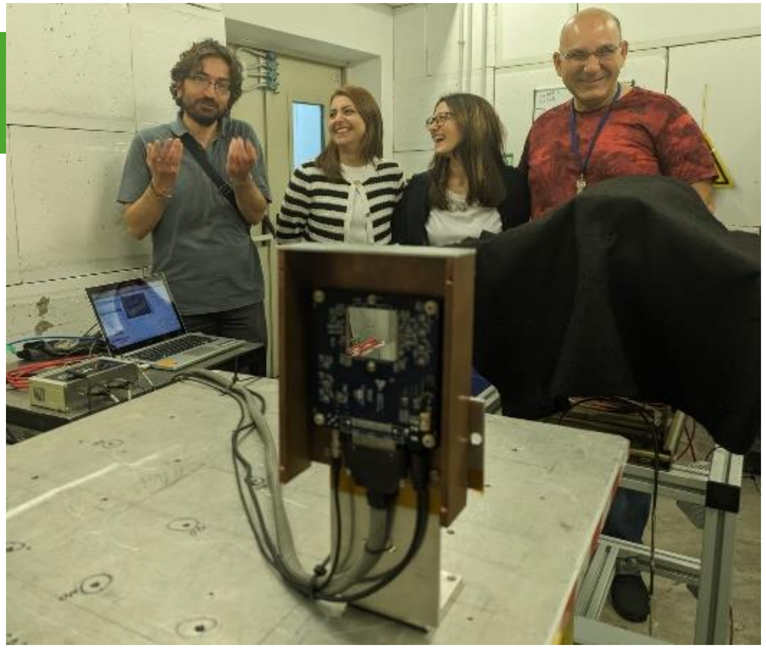


Secondary e- Long focus

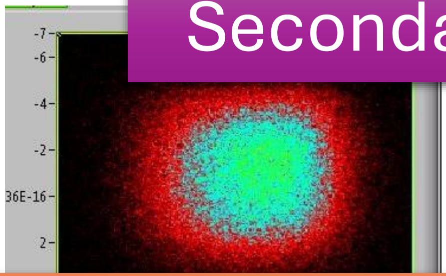
thanks to new vacuum window

40MeV – m=2,5K
σx/σy=8,4/7,3[mm]

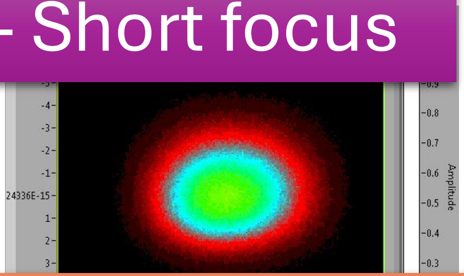
50MeV – m=5K
σx/σy=5,5/6,5[mm]



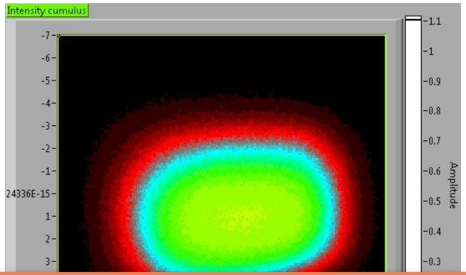
Secondary e- Short focus



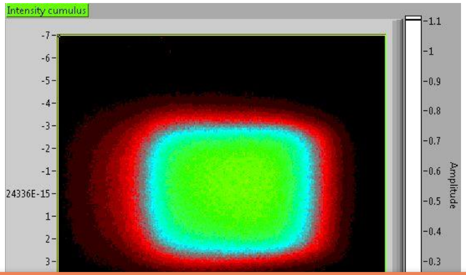
40MeV – m=1K
σx/σy=2,5/2,4[mm]



50MeV – m=5K
σx/σy=2,3/1,7[mm]



75MeV – m=18K
σx/σy=3,2/2,3[mm]



100MeV – m=30K
σx/σy=3,2/2,3[mm]

Conclusion

- The new space economy leads to a huge increase in space applications.
- The radiation hardness protocol needs to match the typical radiation types encountered by these applications.

- INFN and ENEA have a long history of successful collaboration
- Their similar activities and different capabilities in particle beam production have converged in the ASIF2 project.

Spare Slide

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/

New Space Economy - NSE

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Upcoming opportunities from well-known needs

PROFESSIONAL EDUCATION

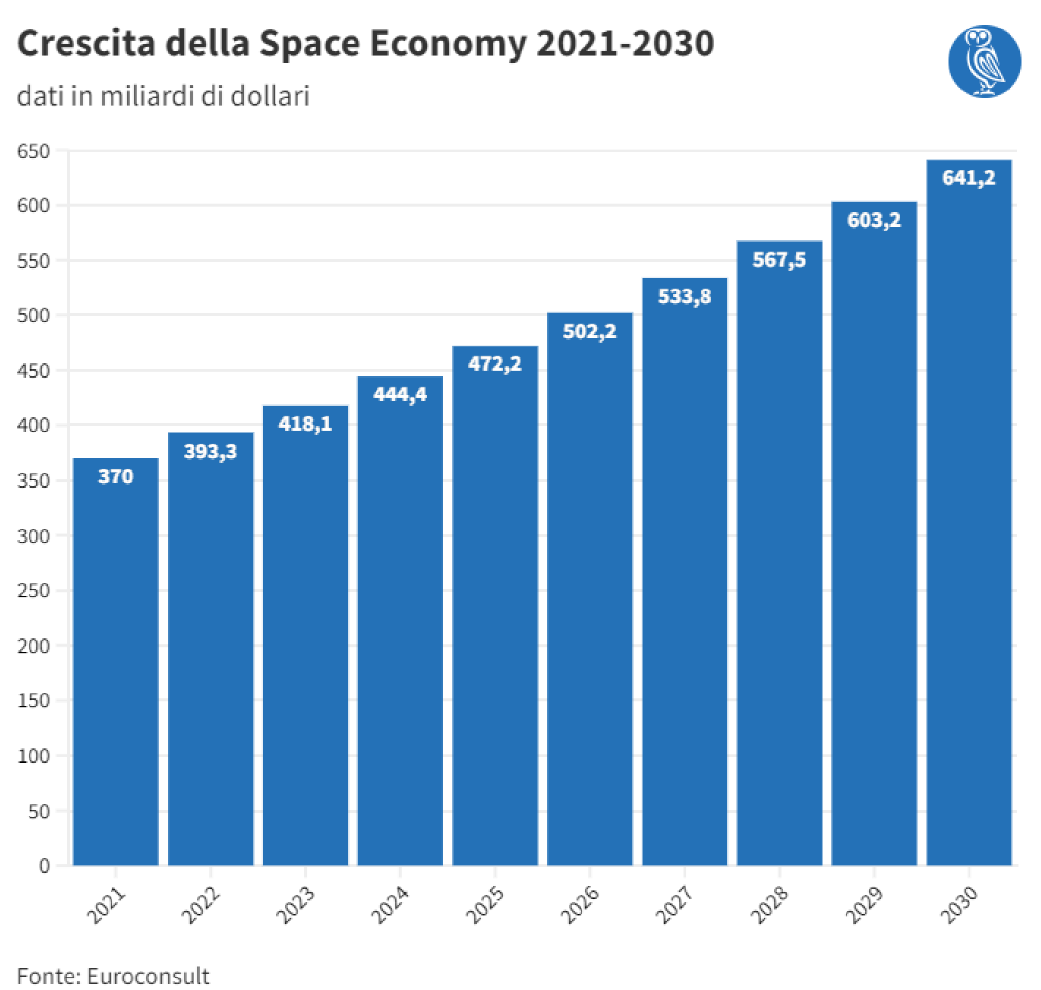
What is the New Space Economy?

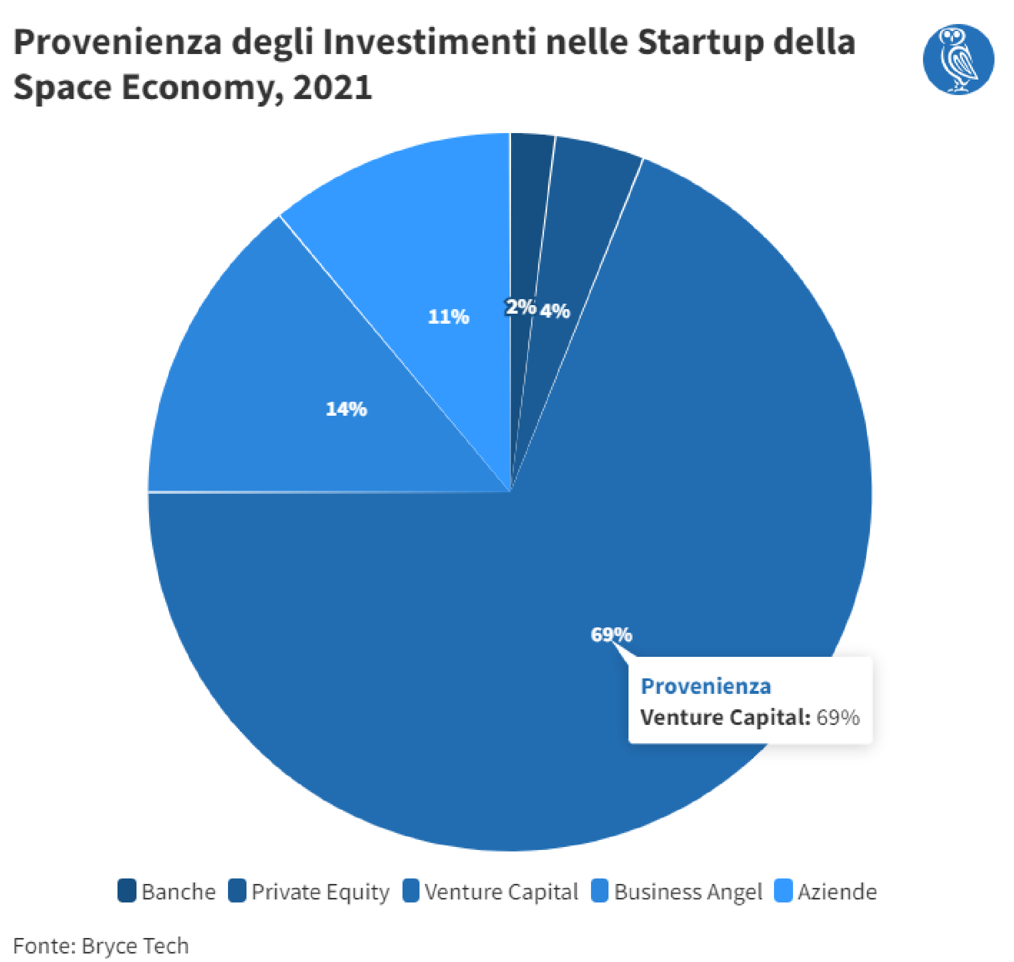
The new space economy is the rising commercialization of space exploration. Private investors, companies, and start-ups are investing and contributing to space exploration. The difference between traditional space exploration and the current one—sometimes referred to as NewSpace— is that the government no longer has to intervene entirely.

> *“We expect that the global space economy will rapidly expand in the coming decade and beyond. Investments in the space sector have been made since the 1950s, but what’s changing is who these investors are and what form those investments really take.”*
>
> **Professor Olivier de Weck – Professor of Astronautics and Engineering Systems at MIT**

It’s becoming increasingly accessible to launch products into space. Today, private launch companies can send small 10x10x10-sized satellites to space for research and business. They wouldn’t send just one, of course. Launch companies gather satellites from different companies to send them together, sometimes with more than 49 satellites in a single launch. The number of satellites can quadruple in the next decade (Pultarova & Howell, 2022). With over 2,000 up in space now, this number will increase exponentially.

NSE figures - globally





Towards 1T$ in the 30s

130+ agencies, 150+ research centres, 10k+ companies

Radiation effects on electronic components

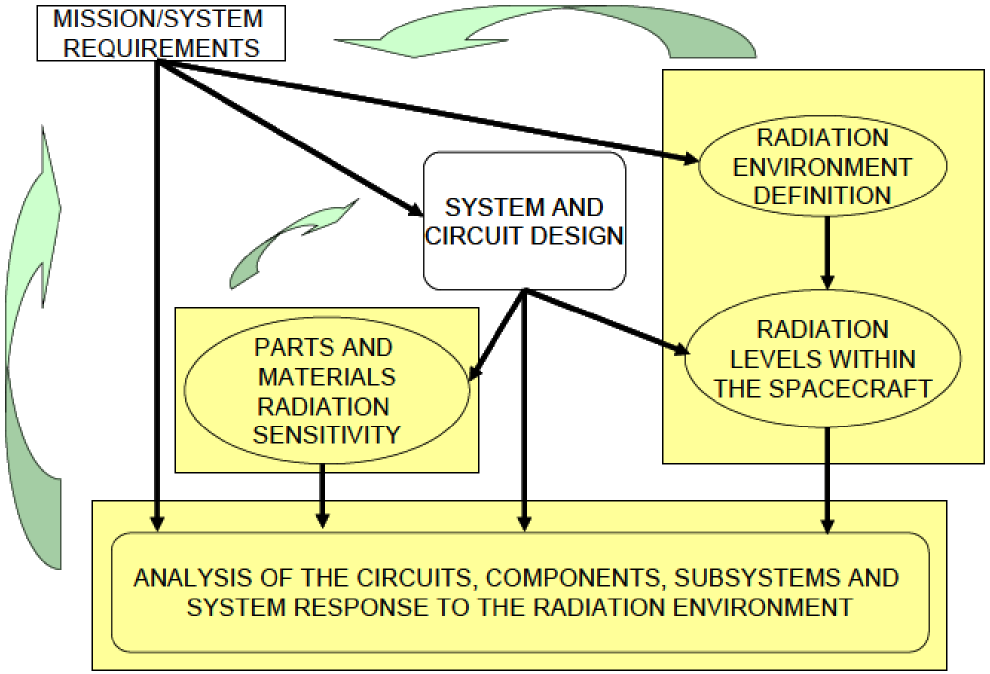
Why that test requirement are needed?

	TID ***Total Ionizing Dose***	**TNID / NIEL / DD** ***Total Non-Ionizing Dose*** ***Non-Ionizing Energy Loss*** ***Displacement Damage***	**SEE** ***Single Event Effect***
Effect	Cumulative long-term degradation	Cumulative long-term non-ionizing damage	Bit flips from single energetic particles From harmless (eg SE-Upset) to severe (eg SE-Latchup or SE-GateRupture)
Caused by	Proton, electron	p, e, n, ions	p, ions
Unit	dose (Krad/gray)	fluence (part/cm2)	Linear Energy Transfer (LET, MeV*cm2/mg

Radiation effects countermeasures

Output of the beam tests, why we use them:

- Shielding (expensive)
  - requires tradeoff with system requirement
  - Not applicable to SEE (ions are penetrating
- Specific Rad-Hard design
  - Single components, eg Silicon On Insulato
  - Circuit design, eg redundancy
- Radiation Hardness Assurance (RHA)
  - Iterative design and test methodology



→ **ground irradiation tests in representative environments are needed**