Welcome to LNF

Fabio Bossi INFN-LNF

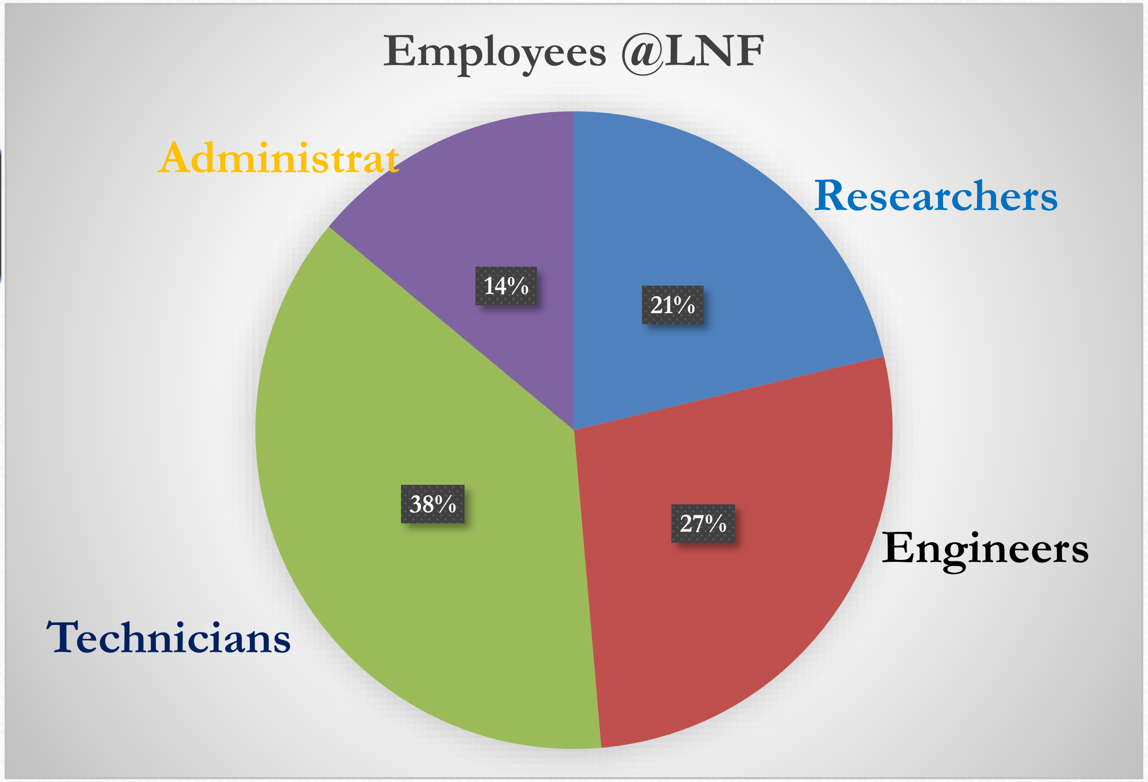
114° P-ECFA Meeting

Frascati, July 4 2024

The Laboratori Nazionali di Frascati (LNF) extends on a area of about 140000 sqm, 20 km south-east of Rome, 2 km away from the town of Frascati

The area hosts the largest concentration of scientific institutions of the country, mainly in physics, astrophysics, space science

As of July 1, 2024 there are **330** permanent or fixed-term employees (researchers, engineers, technicians, administratives) and about **50** doctoral and postdoctoral students



Year 2023 budget

Item	k€
General expenses (*)	13360.00
Ordinary Research	3884.00
External Funds	14542.00
PNRR (Next Gen. EU)	21005.00
Total	**52791.00**

(*) Electricity and salaries **NOT** included

The four pillars of LNF Activities

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The activity of the laboratory rests on four well defined pillars, the (short) description of which are also the outline of my talk

- Particle Accelerators Construction and Operation
- Particle Detectors Construction and Operation
- Fundamental and Applied Physics Experiments
- Public Engagement

70 Years of accelerators at LNF

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Since its foundation, the main mission of LNF has been the construction and operation of accelerators for nuclear and particle physics

- 1957: Official foundation of the Laboratori Nazionali di Frascati
  - 1959: First accelerator built: the Sincrotrone
    - 1961: First electron-positron collisions with Ada
      - 1969: Start of operations of ADONE
        - 2000: Start of operations of DAΦNE
          - 2004: Start of operations of SPARC
            - 2029: Start of operations of EuPRAXIA

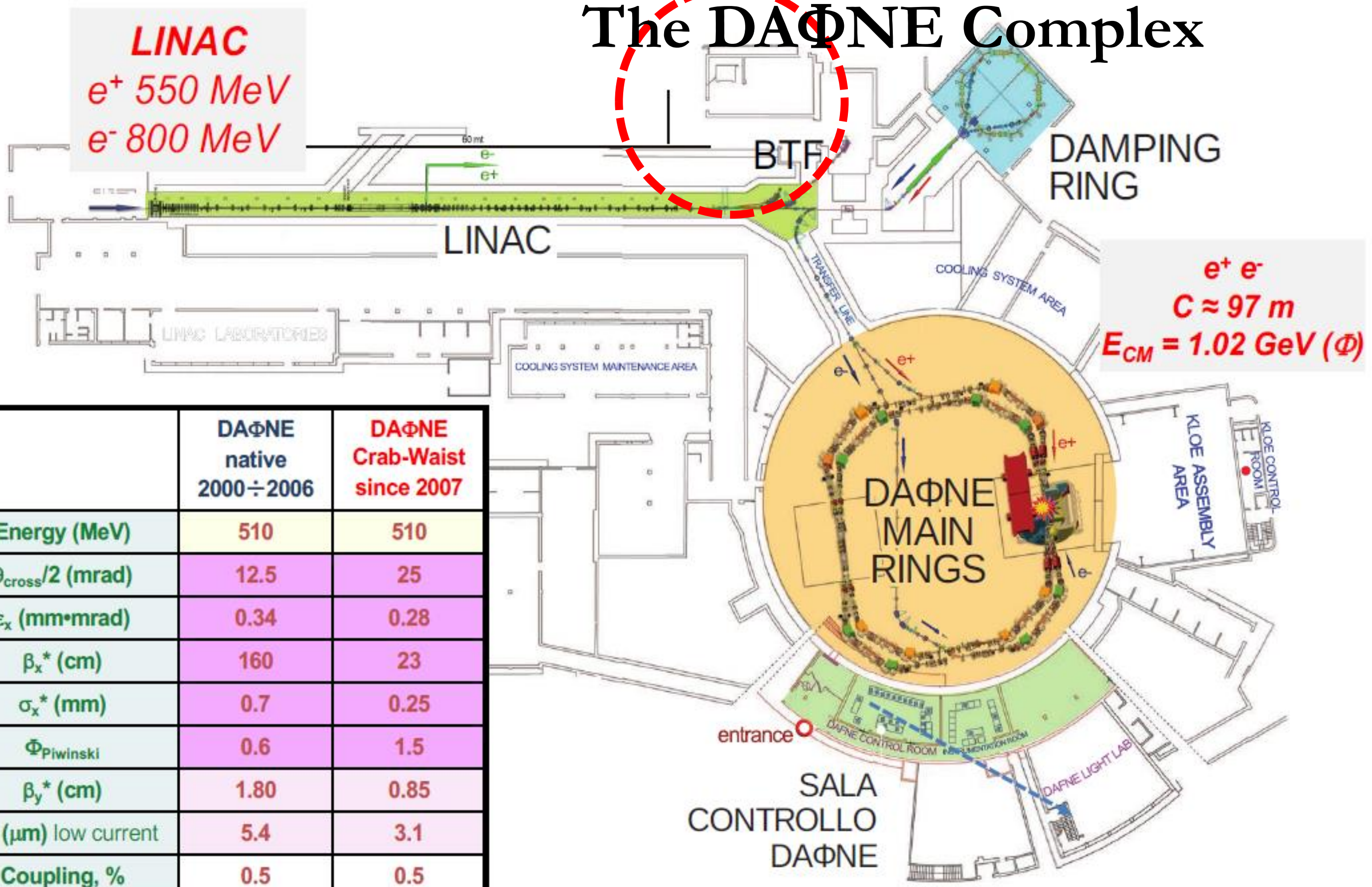
Present accelerator facilities

At present we are running two accelerator facilities:

- The **DAΦNE** e^+e^- collider (1 GeV c.m.) with the annex Beam Test Facility (BTF)
- The **SPARC_LAB** linear accelerator complex devoted mainly to PWFA studies

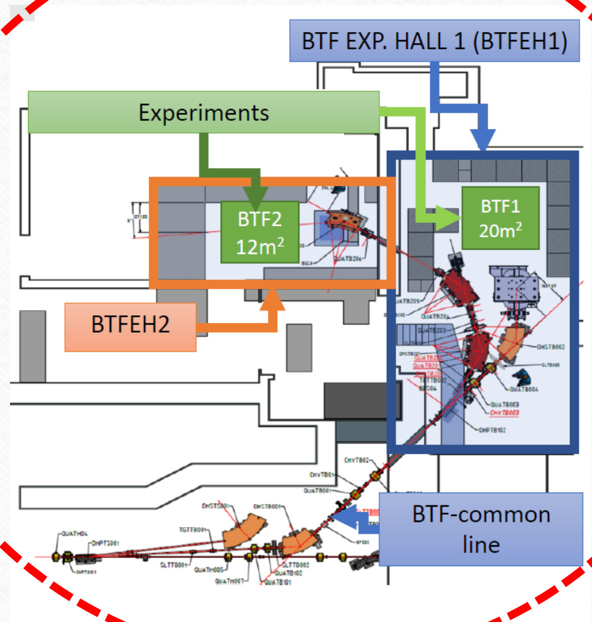
We do run also a series of laboratories dedicated to R&D of specific accelerator related technologies (magnets, RF, plasma, vacuum ecc…)

The DAΦNE Complex

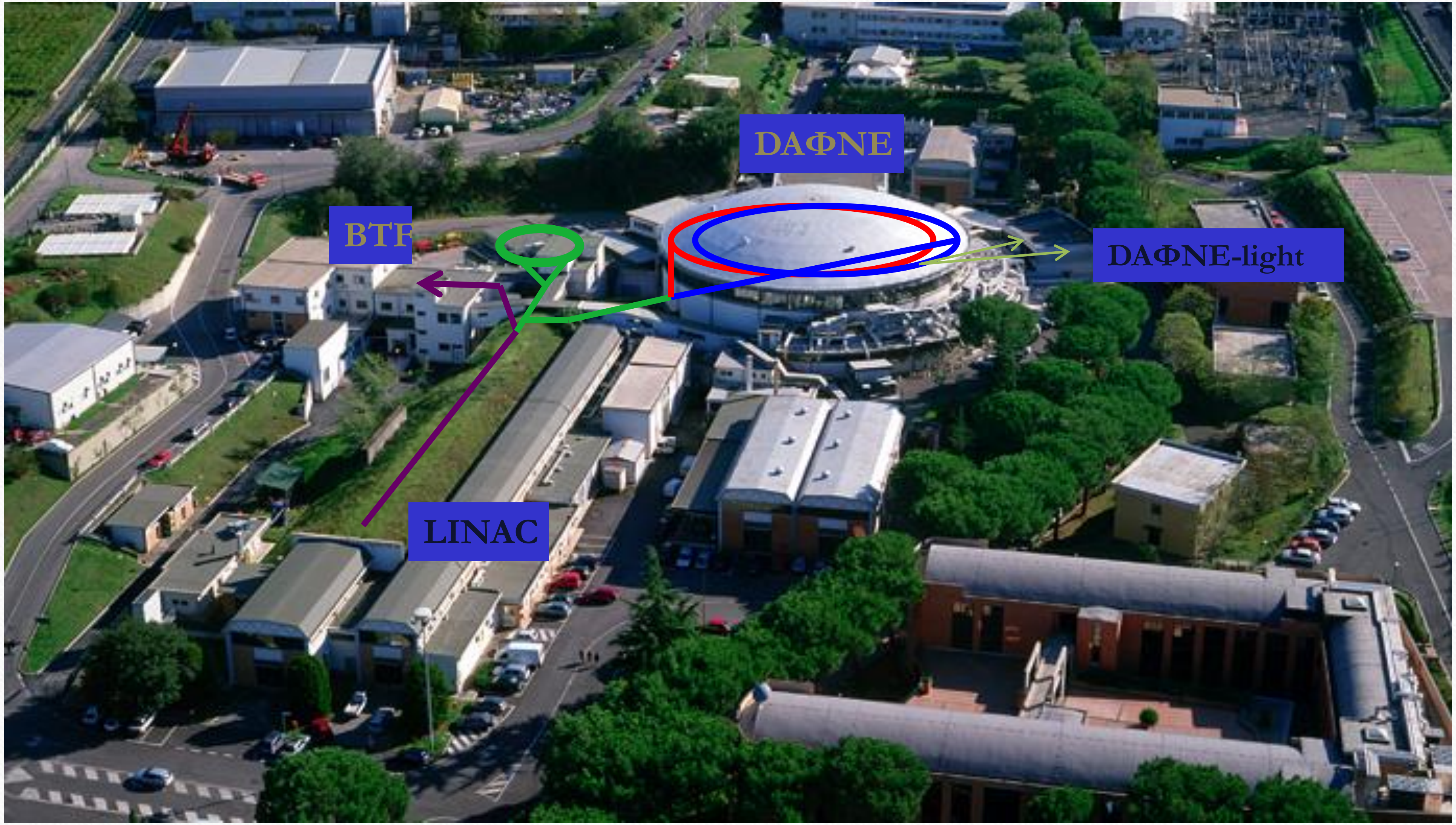


	DAΦNE native 2000÷2006	DAΦNE Crab-Waist since 2007
Energy (MeV)	510	510
$\theta_{cross}/2$ (mrad)	12.5	25
ε_x (mm•mrad)	0.34	0.28
β_x^* (cm)	160	23
σ_x^* (mm)	0.7	0.25
$\Phi_{Piwinski}$	0.6	1.5
β_y^* (cm)	1.80	0.85
σ_y^* (μm) low current	5.4	3.1
Coupling, %	0.5	0.5
Bunch spacing (ns)	2.7	2.7
I_{bunch} (mA)	13	13
σ_z (mm)	25	15
N_b	120	120

DAΦNE implemented and tested succesfully a new approach to beam-beam interaction: the ***Crab-Waist* collision scheme.** $L_{peak} = 4x10^{32}\ cm^{-2}s^{-1}$



Pulsed e^-/e^+ beams (50 Hz)
From 10^{10} to 1 p/pulse
Continuous energy 200-500 MeV


DAΦNE
BTF
DAΦNE-light
LINAC

DAΦNE Collider Operations

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The **DAΦNE** collider has entered into operations in year 2000, and has provided luminosity since then to 6 different particle and nuclear physics experiments

Experiment	Data Taking period	Int. Luminosity (pb-1)
KLOE	2000-2006	2500
DEAR	2003	60
FINUDA	2003-2007	1200
SIDDHARTA	2008-2009	600
KLOE-2	2012-2018	5000
SIDDHARTA-2	running	>800

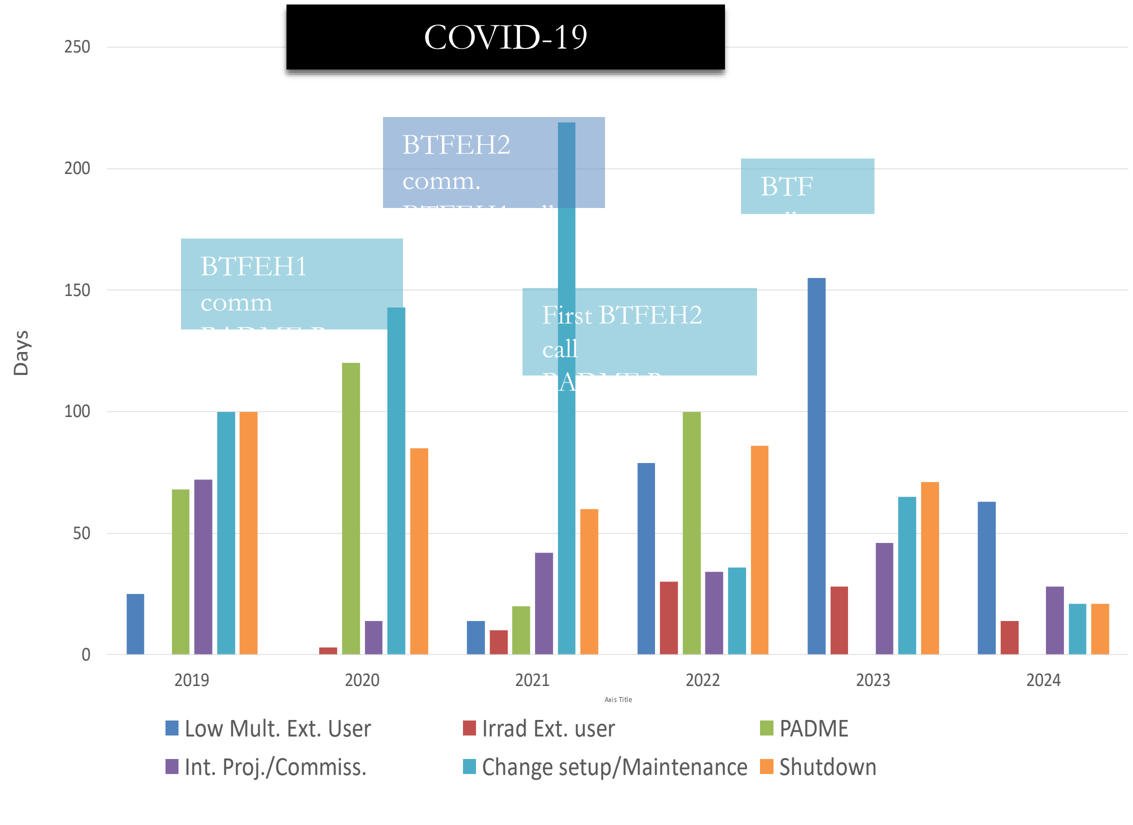
Flavour, CKM

Hypernuclei

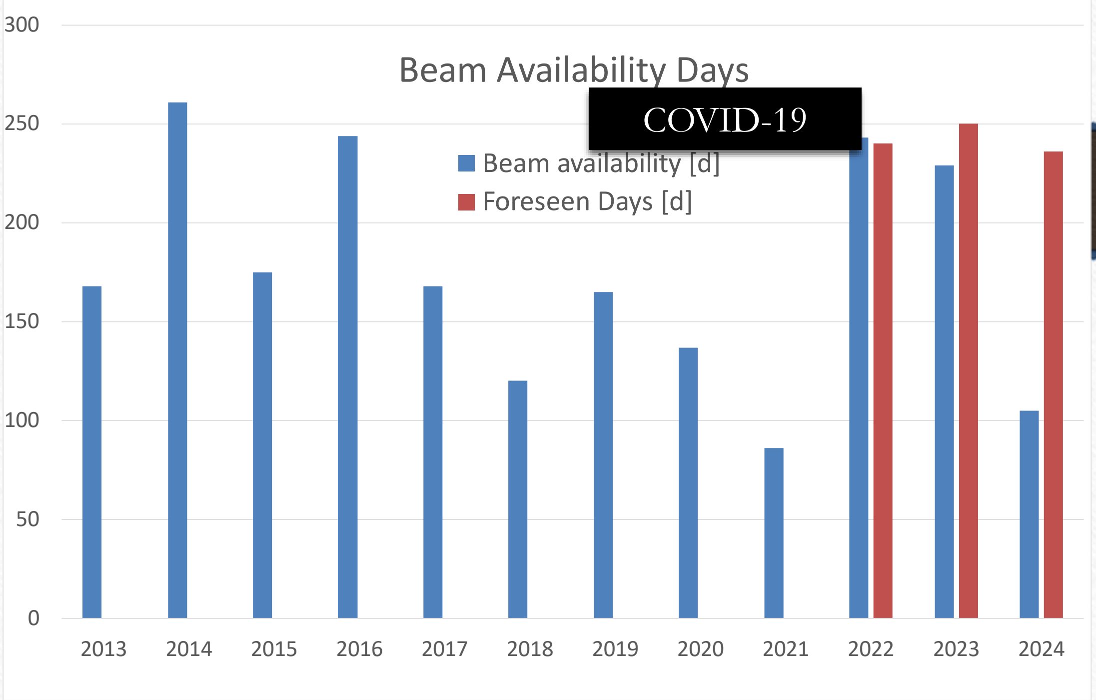
Kaonic Atoms

BTF Operations

2019-2024 Activities



Beam Availability Days (up to May 2024)



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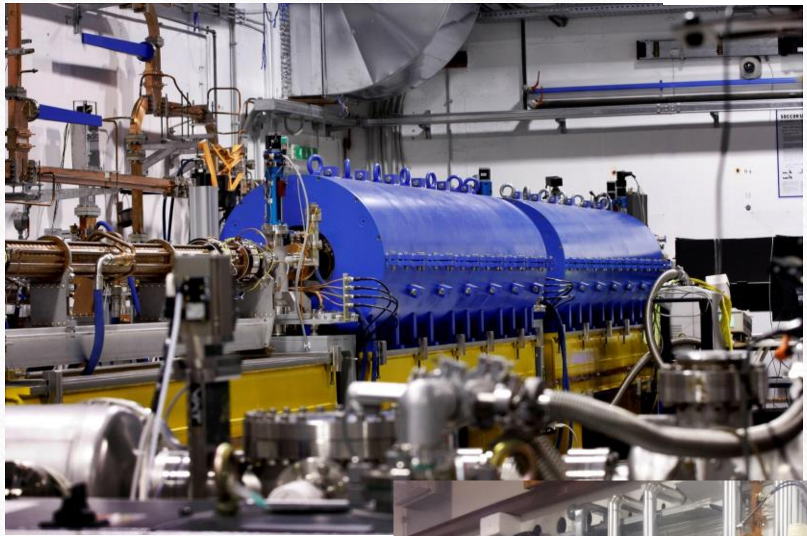
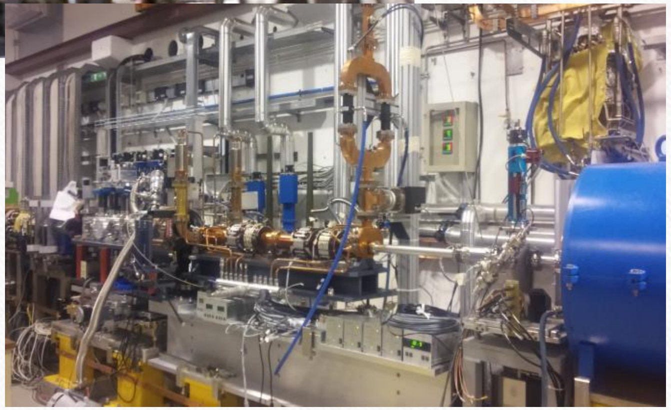
SPARC_LAB

SPARC_LAB consists of a high-brightness RF photoinjector, **SPARC**, and a multi-hundred terawatt laser, **FLAME**, and was initially focussed on performing FEL experiments and in general on the production of new radiation sources

In recent years a dedicated effort has been put in the research on very high acceleration gradients with the plasma wake field technique



Photoinjector



Plasma Vacuum Chamber

Recent SPARC_LAB achievements

- **Guiding of Charged Particle Beams in Curved Plasma-Discharge Capillaries**
  Pompili, R., et al., Physical Review Letters 132.21 (2024): 215001.
- **Acceleration and focusing of relativistic electron beams in a compact plasma device**
  Pompili, R., et al., Physical Review E 109.5 (2024): 055202.
- **Stable operation of a free-electron laser driven by a plasma**
  Galletti, M., et al., Physical review letters 129.23 (2022): 234801.
- **Free-electron lasing with compact beam-driven plasma wakefield accelerator**
  Pompili, R., et al., Nature 605.7911 (2022): 659-662.
- **First emittance measurement of the beam-driven plasma wakefield accelerated electron beam**
  Shpakov V., et al. Physical Review Accelerators and Beams 24.5 (2021): 051301.
- **Energy spread minimization in a beam-driven plasma wakefield accelerator**
  Pompili R. et al., Nature Physics 17.4 (2021): 499-503.

International Collaborations on Accelerators

- **CERN**
  - FCC
  - High Gradient (CLIC)
- **PSI** development and testing of C-band RF guns
- **KEK** SuperKEK_B luminosity optimization
- **EIC** Vacuum chamber Secondary Electron Yield (SEY) characterization for Electron Cloud effects study and mitigation
- **EU** programs:
  - iFAST
  - EUROLABS
  - EAJADE

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EuPRAXIA

Experiments at SPARC_LAB are precursory to the construction of our next accelerator facility: **EuPRAXIA**

It is a multi-national project aimed at building two plasma-based accelerator facilities to drive a FEL for photon-science users

The project has headquarter at LNF, where one of the two facilities will be built

We are now in the phase of the executive design of the building and finalising the project of the machine, which should start operations by the end of this decade

The machine will be located in the sothern part of the Laboratory

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Overall cost is estimated to be **~130** M€, we have at present granted 110 M€. Actions are being taken to fill the gap

Detector development and construction

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Since its foundation in the laboratory an intense activity of particles detector development and construction has been carried out. Among the various achievements it is worth mentioning

- The invention of the plastic streamer tubes (Iarocci's tubes) circa 1980
- The construction of the largest drift chamber to date for the KLOE experiment, circa 1998
- The construction of the first lead-scintillating fibre «curved» calorimeter for the KLOE experiment, circa 1998
- The realization of the first cylindrical GEM detector, circa 2014

Detector construction for outside experiments

In the course of the last couple of years important detector installation have been completed or are being completed by LNF personnel

- The New Small Wheels Muon detectors of the ATLAS experiment at CERN
- The RICH detector of the CLAS12 experiment at TJNAF
- The Crystal Calorimeter of the Mu2E detector at FERMILAB

Other big detector construction and/or installation have started and will be use a relevant fraction of manpower of the RD, among which the most ambitious one are

- Buiding part of the **ITK** internal tracker for **ATLAS** Phase II
- Shipping the KLOE detector to FERMILAB as a part of the **DUNE** near detector

Fundamental physics experiments: PADME

Small in situ experiments are being carried out and planned in the field of light dark matter searches

The PADME detector, installed on BTF line 1, aims at searching light (< 100 MeV) exotic bosons (γ') in the process

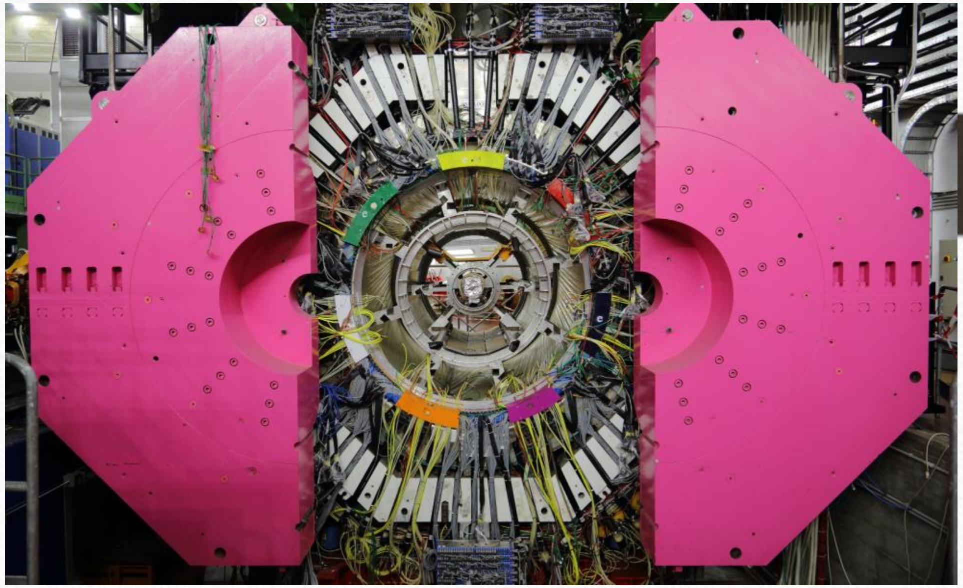
$$e^+e^- \rightarrow \gamma'\gamma$$

In particular, in the 2022 run, a search has been carried out for the resonant production of the **X17** particle, whose existence is suggested by several nuclear physics experiments. Results are expected at the forthcoming conferences

Fundamental physics experiments: FLASH

A proposal for searching galactic axions in the mass range **0.49-1.49 μeV** using the magnet of the FINUDA experiment has been recently put forward

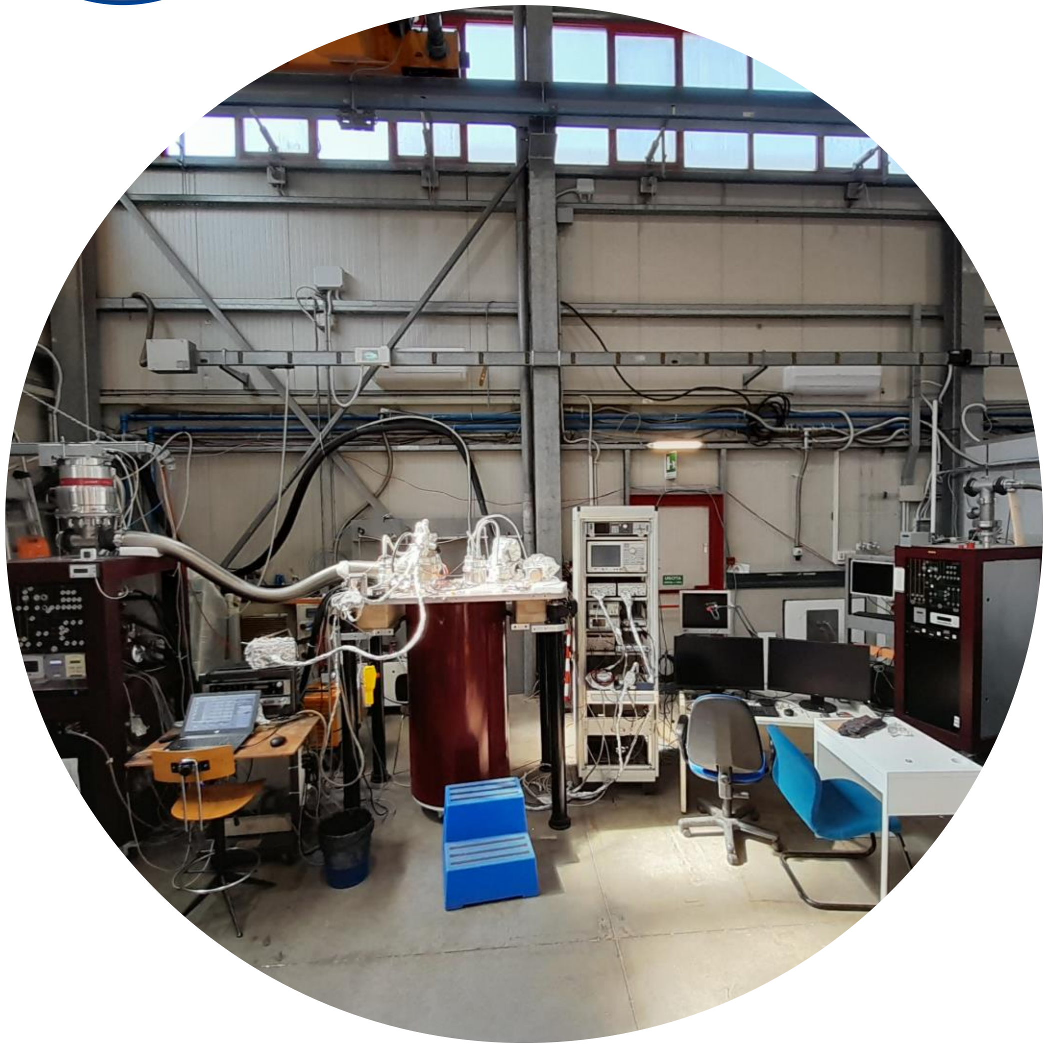
The magnet, of 1.1 T, has not been in use for more than 15 years. Therefore a campaign of refurbishing old/repairing broken components, has been carried out during the fall of 2023. The magnet has been succesfully powered in January this year



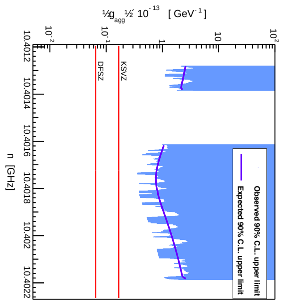
Besides the magnet, the other big component of the apparatus will be a large, 4.15 m^3, copper resonant cavity, for which expertise is already present in the laboratory

COLD - Cryogenic Laboratory for Detectors

- Axion Experiments
- Superconducting Quantum Devices
- Superconducting Cavities
- Magnetic Measurements

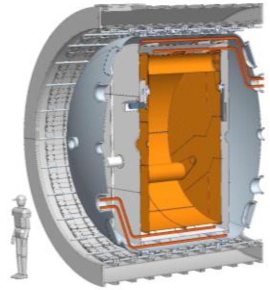


EXPERIMENTS



QUAX – QUest for AXions

Search for galactic axions with Sikivie's Haloscopes at 10 GHz (Ongoing sxperiments at LNL and LNF).



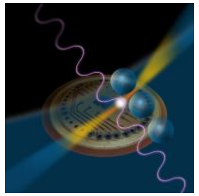
(K)FLASH

Search for galactic axions with a Sikivie's Haloscope at 100 MHz (Design Study).

Superconducting Devices

DART WARS (Detector Array Readout with Travelling Wave AmplifieRS)

Development of wide band quantum amplifiers for multi-channel detector readout (Ongoing).



SIMP (Single Microwave Photon detectors)

Development of single-microwave photon detector (Ends 2021)

Qub-IT Quantum Sensing with superconducting qubits (Starts 2022).

Supergalax FET H2020 Project

SC-qubits array photon-detector for axion experiments

Applied physics experiments

Applied physics research is carried out, in several field of research including:

- Space Science
- New materials
- Life sciences
- Cultural Heritage
- …

Recent study on a XVIII century copy of a Raffaello painting, performed at our synchrtron light facility

Outreach Activities in 2023

Public events [OpenLab PintOfScience ERN PS]	Student's Events [from primary to Uni]	Course for teachers [HOP Aggiornamenti IdF]	Scientific Conferences/ Workshops
~17.000	~5300	264	33

Thank you for your attention!

Preparation for ATLAS ITK construction

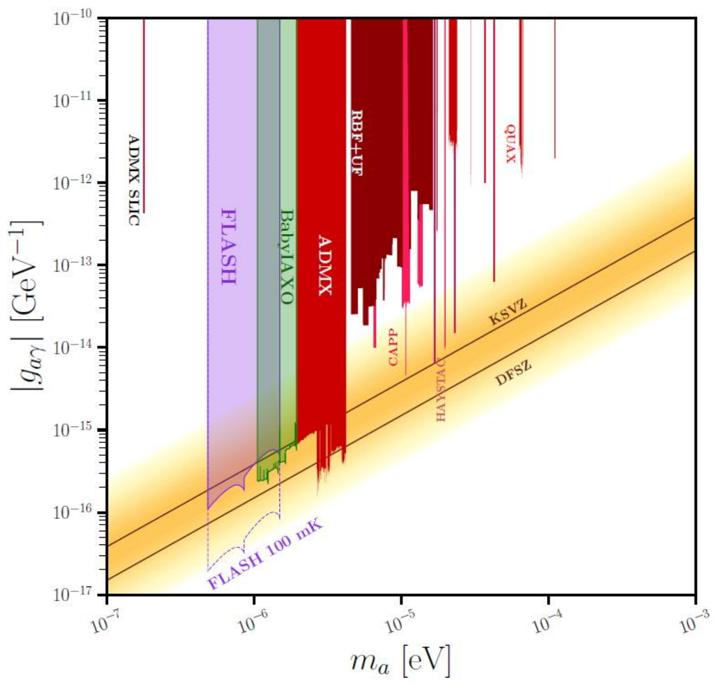
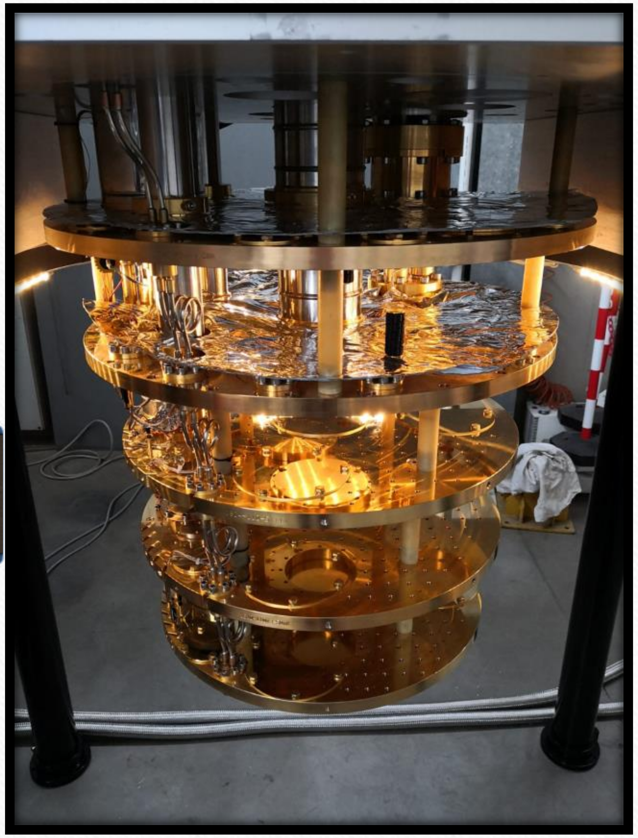


Figure 2: The FLASH discovery potential (90% confidence level or c.l.) compared to existing experimental limits. The brown lines with yellow error-band show the theoretical predictions for the KSVZ and DFSZ axions [25, 26, 28, 27]. The forecast reach of FLASH is compared with experimental limits from other haloscopes [32, 33, 40, 41, 45, 46, 118, 119, 120] as well as a projection from [48] labled 'babyIAXO' in green, which is expected to be realized somewhat later than FLASH. Image realized with [121].

QUAX haloscope at LNF

Probe KSVZ axions in 1 GHz band at 9 GHz

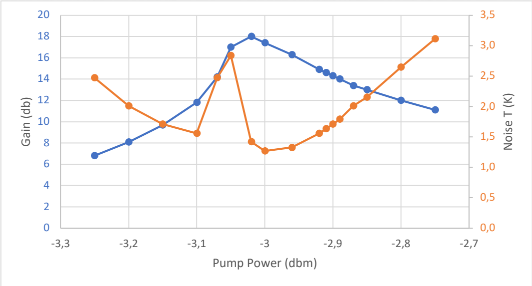
- Multi cavity for fast scanning rate
- Wide band TWJPA quantum amplifier
- Superconducting cavities

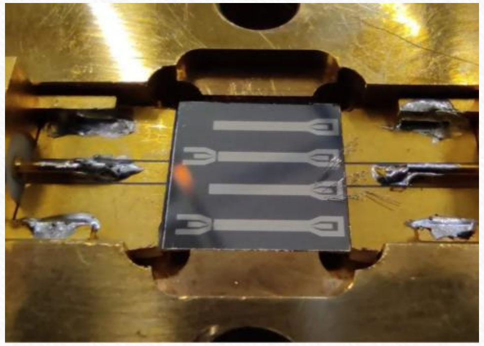


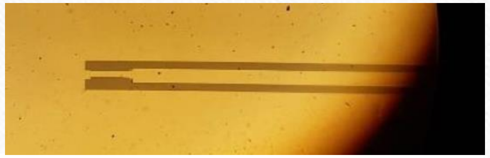
Operate at 10 mK inside LNF dilution refrigerator to reduce thermal noise.

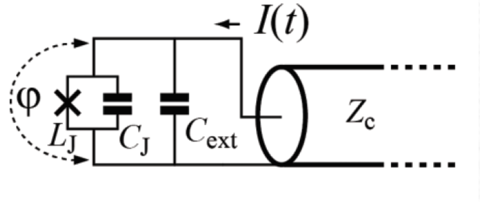
First 8.5 GHz cavity for LNF pilot run

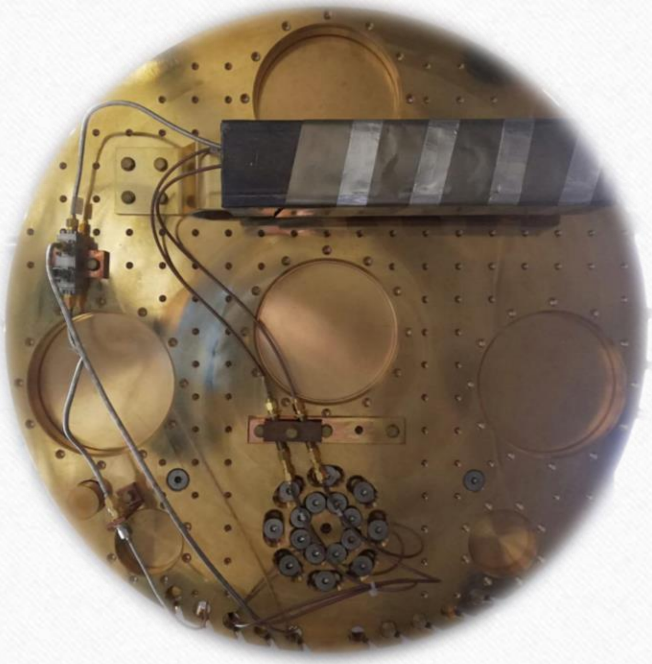
Superconducting Quantum Devices



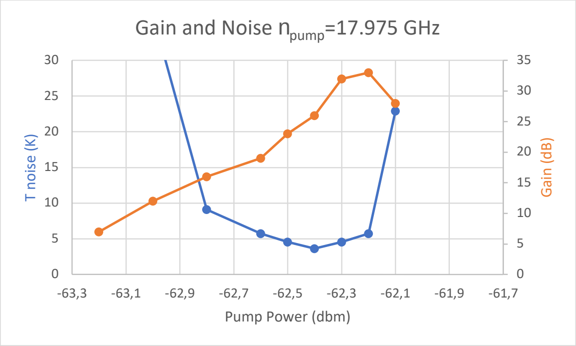


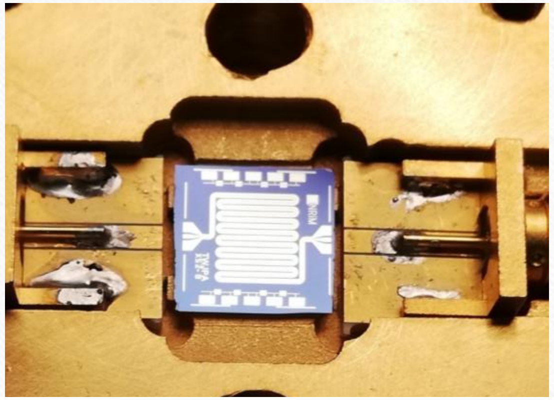




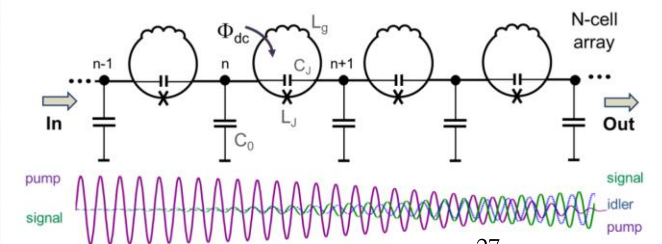


First LNF results of a JJ coupled to a transmission line operated as a Josephson parametric amplifier and as a microwave photon detector (SIMP collaboration with CNR-IFN)





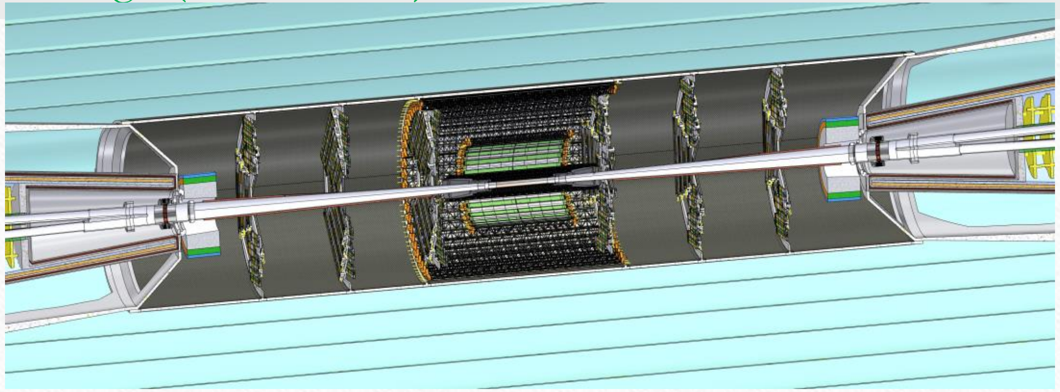
Characterization at LNF of first production of TWJPA from INRiM (Dart Wars)



LNF oversees the INFN FCC-related accelerator activities in the context of a dedicated INFN project (RD_FCC).
Two main activities in Frascati: design of the Interaction Region design and of the e+ Damping Ring

FCC-ee Interaction Region Design

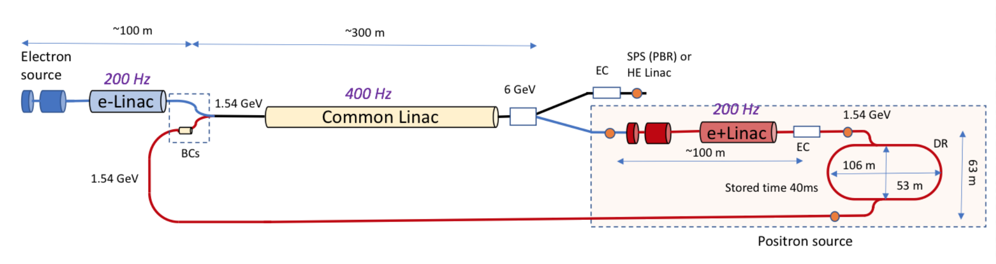
- The LNF leads the Feasibility Study WP **MDI** to design the IR including its mechanical model. The team is involved on the mechanical model, background simulations, IR optics, bellows, vacuum connection, IR impedance, etc.
- IR and MDI full-scale mockup at Frascati – co-funded project by CERN & INFN (~700 kEuro) 2023-25
- LNF (solely in INFN) in **FCCIS** EU-H2020, Task Leader in MDI design (~280 kEuro) 2020-24



Positron Damping Ring and transfer lines

LNF leads this design within the **CHART** program
Task of the Feasibility Study WP Injector

- 1.54 GeV & 240 m circumference ring
- TL from the DR to the common linac



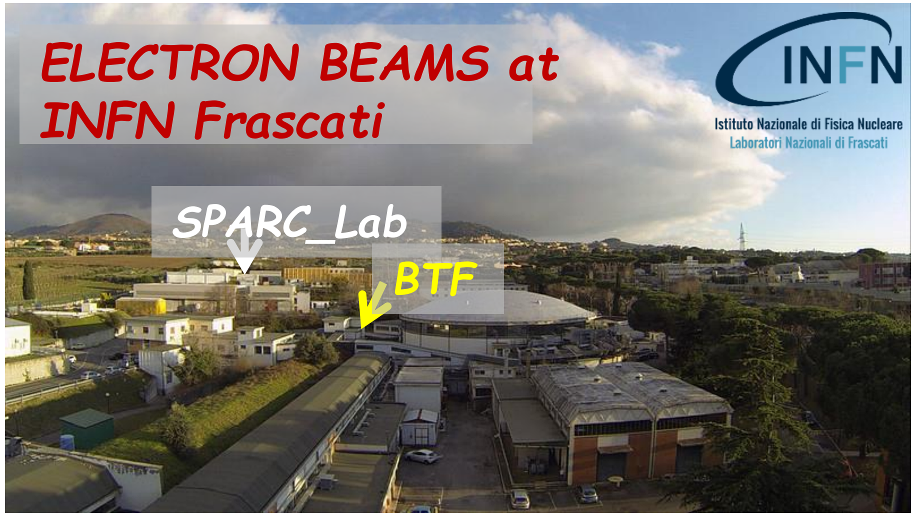
Courtesy of M. Boscolo

LNF participation to EUROLABS

The Euro-Labs Horizon EU project provides support for transnational access to a network of 45 Research Infrastructures (including 3 RIs with Virtual Access) from 18 countries

EUROLABS Task 3.3 - ELECTRON BEAMS at INFN Frascati

Within the EURO-LABS project the beams of BTF and SPARC_Lab facilities are offered to transnational users. LNF is also the project administrative headquarter



SPARC_Lab (high brightness e^-)
11 weeks offered in 4 years

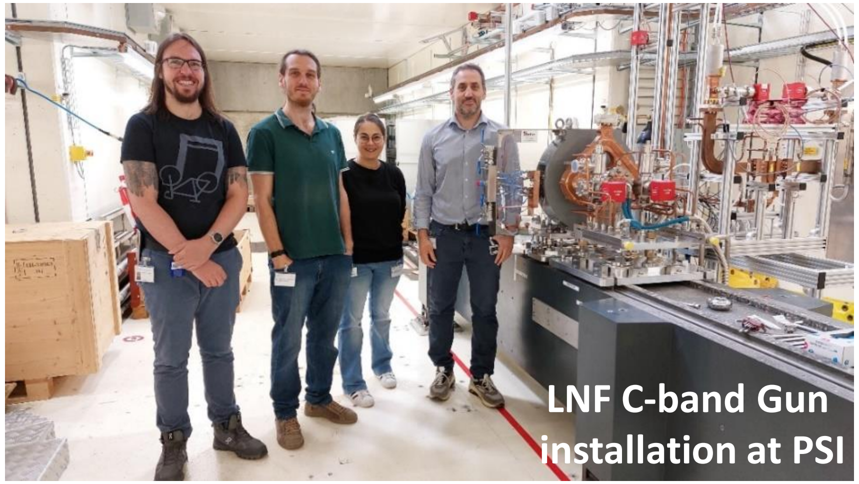
Beam Test Facility (e^+/e^-)
9 weeks offered in 4 years

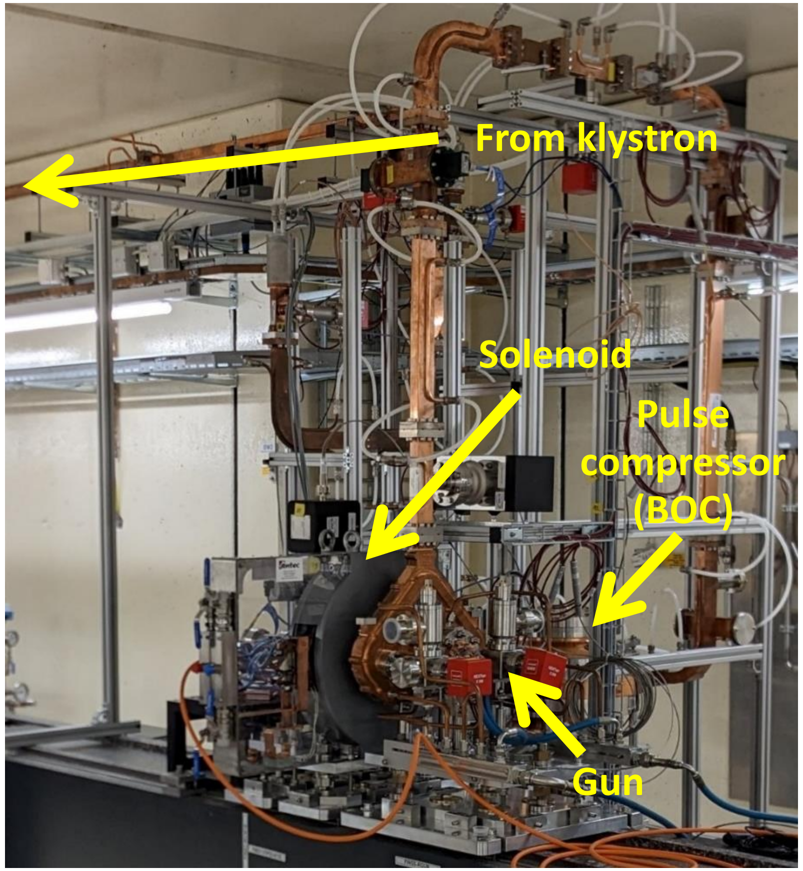
LNF Accelerator Collaboration with PSI

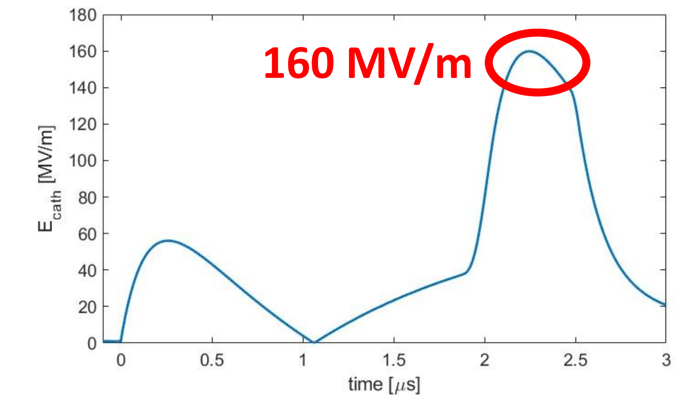
INFN-LNF and **Paul Scherrer Institute** (**PSI**) are collaborating in developing new **high-performances photo-injectors** also joined within the EU R&D program **iFAST**.

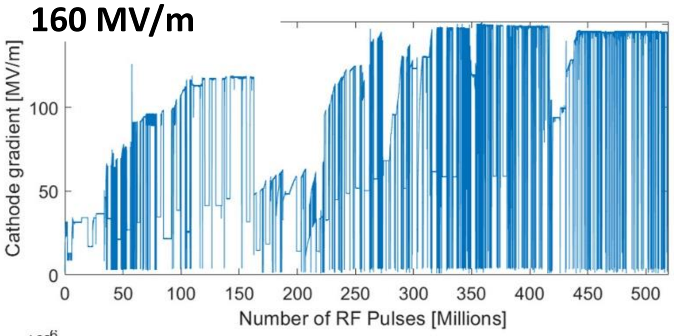
The Standing Wave C-band (*f=5712 MHz*) brazing-free photo-injector designed and realized by INFN-LNF is now **under RF power test and conditioning at PSI** test stand and it has reached the noticeable **cathode gradient** of **160 MV/m** at 100 Hz rep rate.

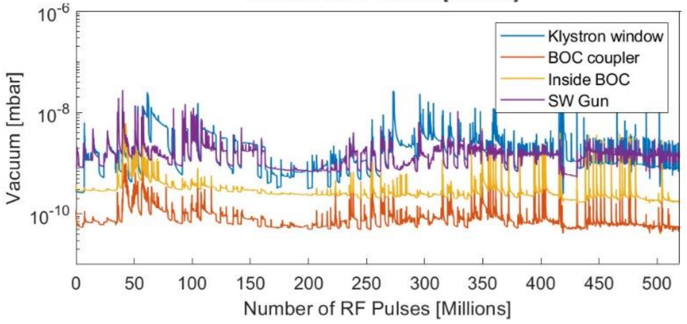
The ultimate goal for the near future is reaching ≈200 MV/m at 400 Hz rep rate in the LNF test stand TEX equipped with a high rep rate C-band RF station.











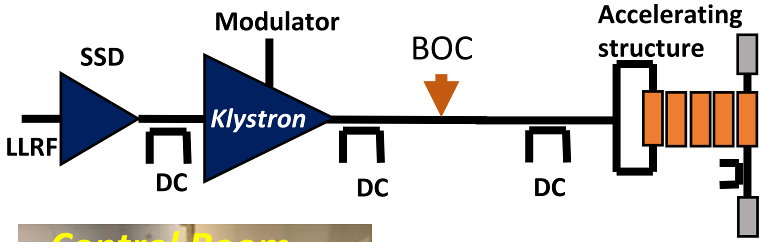
LNF Accelerator Collaboration with CERN: High Gradient

The expired Mou KE3894_CLIC has been the framework of the HG collaboration between CERN and INFN-LNF.

***TEX** - the LNF X-band test facility*

VKX8311A X-band Klystron (on loan from CERN to LNF)

RF Modulator (purchased by LNF)



CERN CLIC group supported the realization of the LNF X-band test facility TEX

INFN-LNF designed, built, tested and delivered a high-performance S-band photo injector for the CERN facility CLEAR