Laboratori Nazionali di Frascati dell’INFN

Fabio Bossi, Frascati, June 20 2024

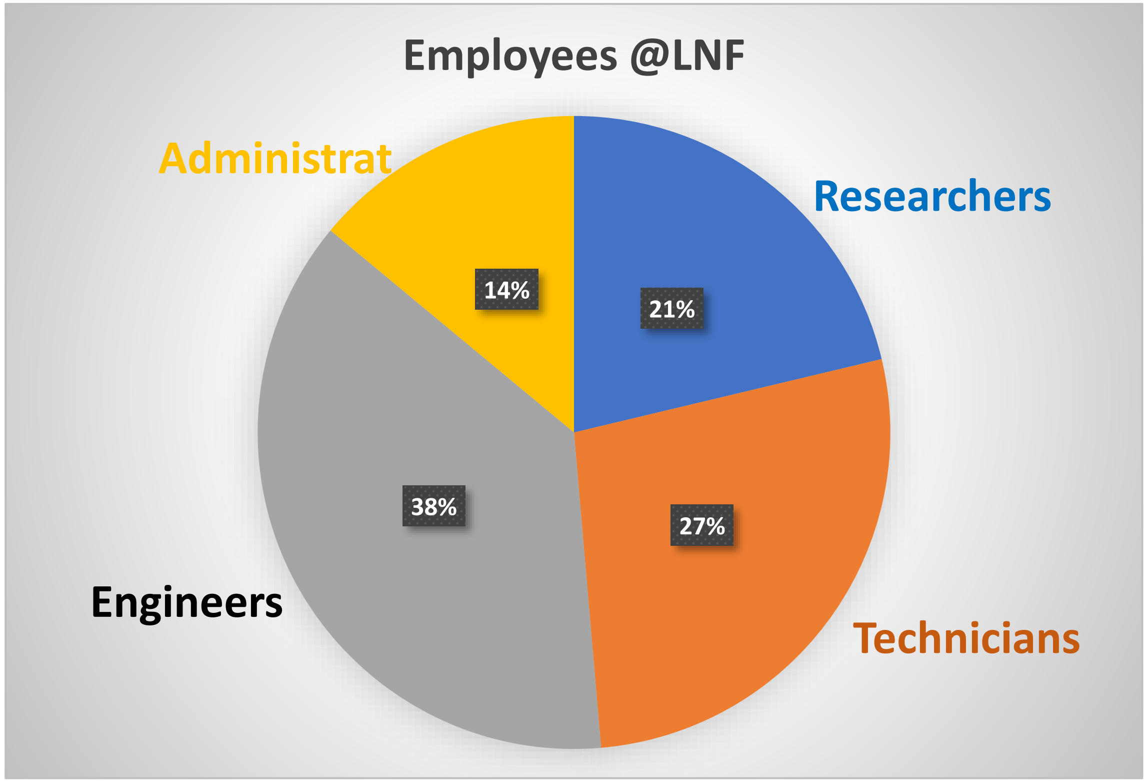
70 Years of LNF History

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

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

- 1957: 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

As of June 1, 2024 there are **331** 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 LNF has presently **two running accelerators**, DAΦNE and Sparc_Lab, and operate several **technical infrastructrures** devoted to accelerators or detector R&D and construction

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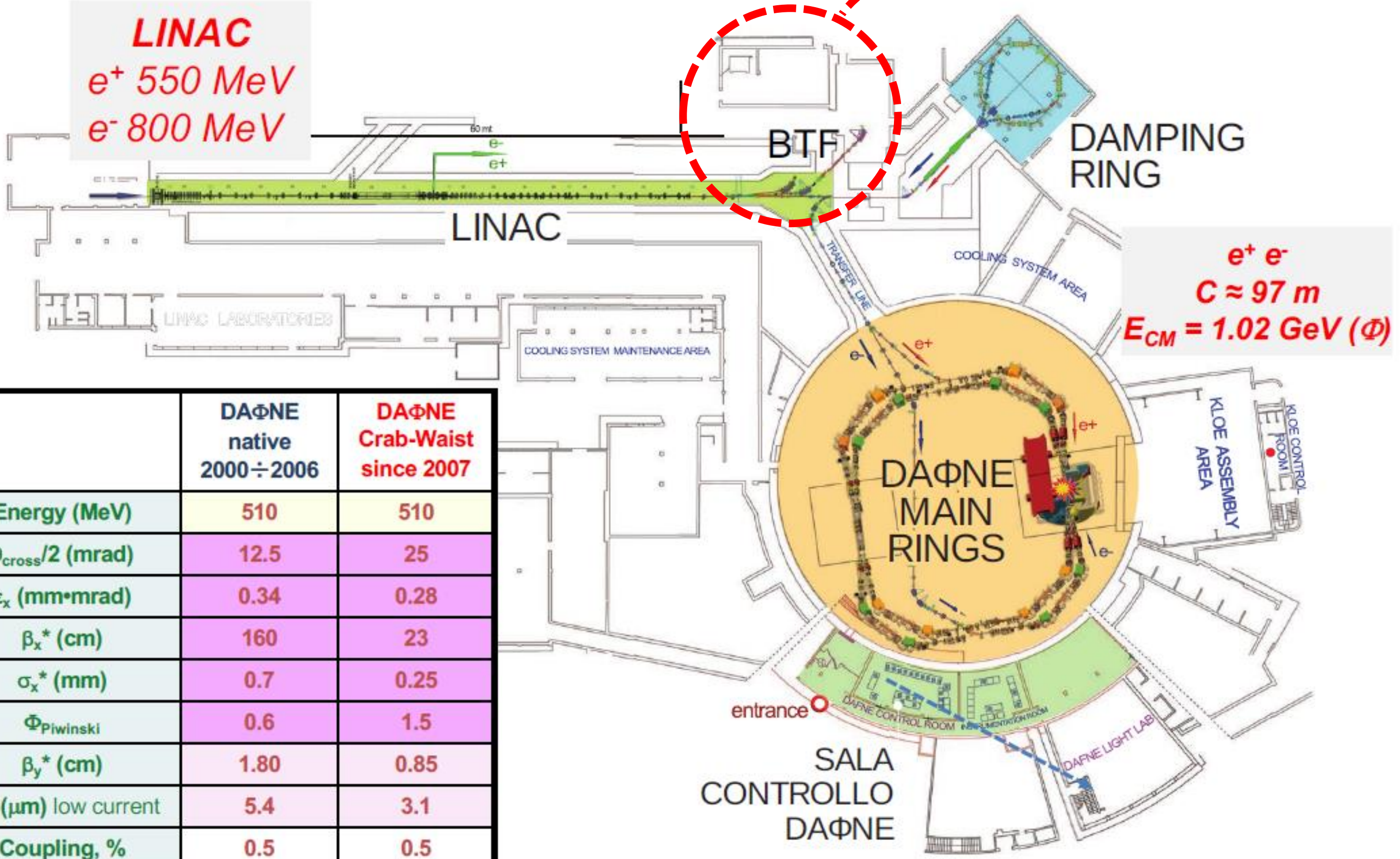
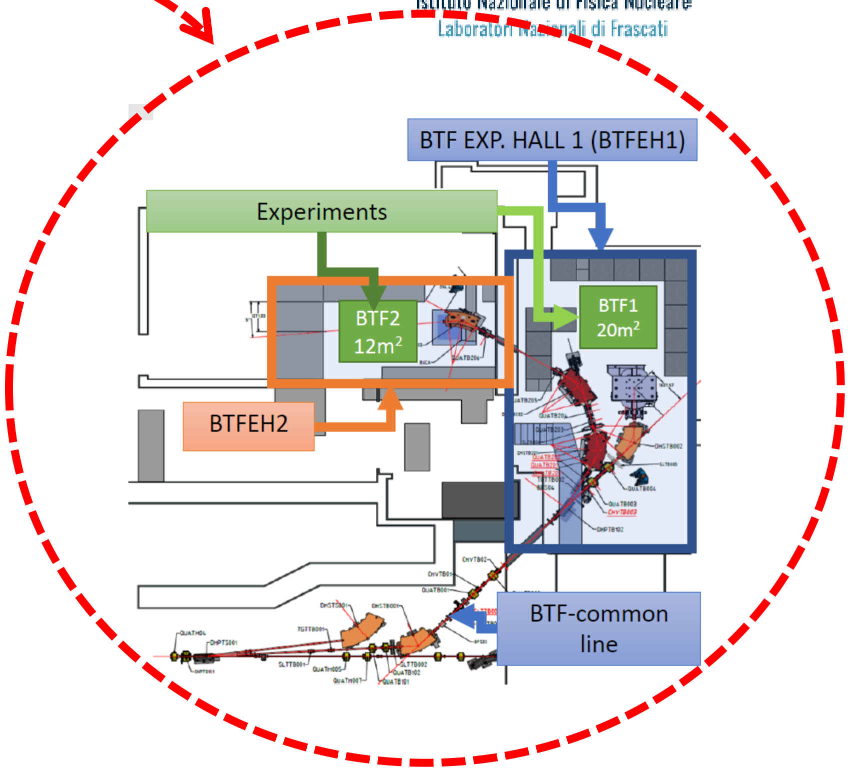
The DAΦNE Complex



	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**.

$L_{peak} = 4\times10^{32}\ cm^{-2}s^{-1}$



BTF #1/2

DAΦNE Collider Operations

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

SIDDHARTA-2

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The measurement of X-rays emitted by kaonic atoms allows the investigation the strong kaon-nucleon interaction at low energies to be performed

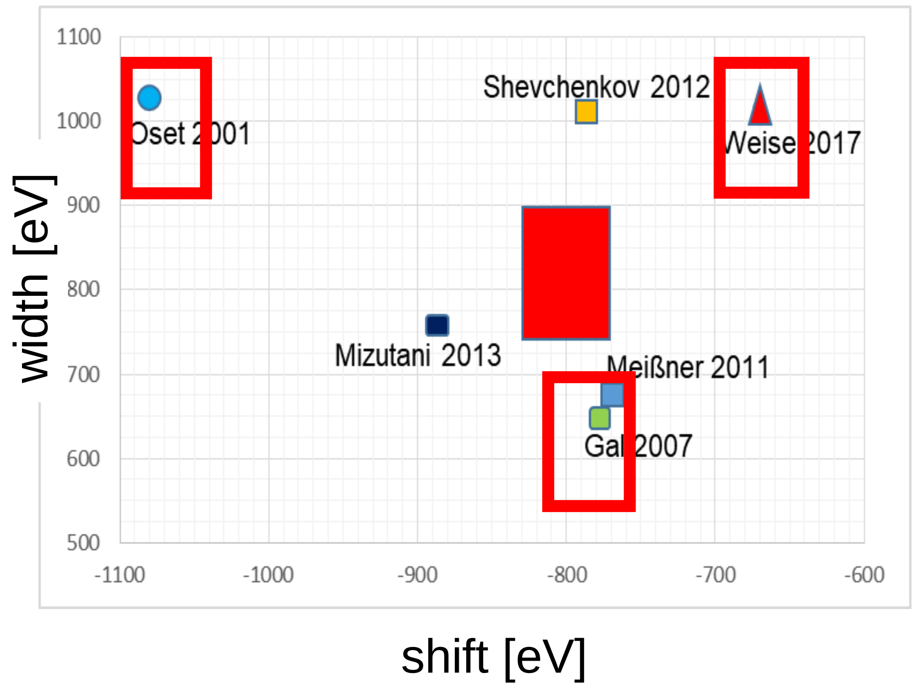
A crucial pioneering work in this respect was played in Frascati by the DEAR and SIDDHARTA experiments, which achieved the most precise measurement of kaonic hydrogen transition to ground level and the first measurement of kaonic helium transitions to 2p level.

Adding the measurement of kaonic-deuterium transition would allow us to extract the antikaon-nucleon ***isospin-dependent*** scattering lenghts

SIDDHARTA-2

The aim of the experiment is to perform a precision measurement of the shift and of the width of the 1s level of kaonic deuterium

- The requested luminosity is **800** pb^{-1}
- First successful run with reduced apparatus performed in Spring 2021
- First test run with full apparatus performed in Spring 2022
- Start of physics run in May 2023
- Luminosity integrated in 2023 **350** pb^{-1}
- **<u>Mission accomplished in May 2024</u>**
- Presently performing calibration runs
- End of the run July 2024



Beam Test Facility

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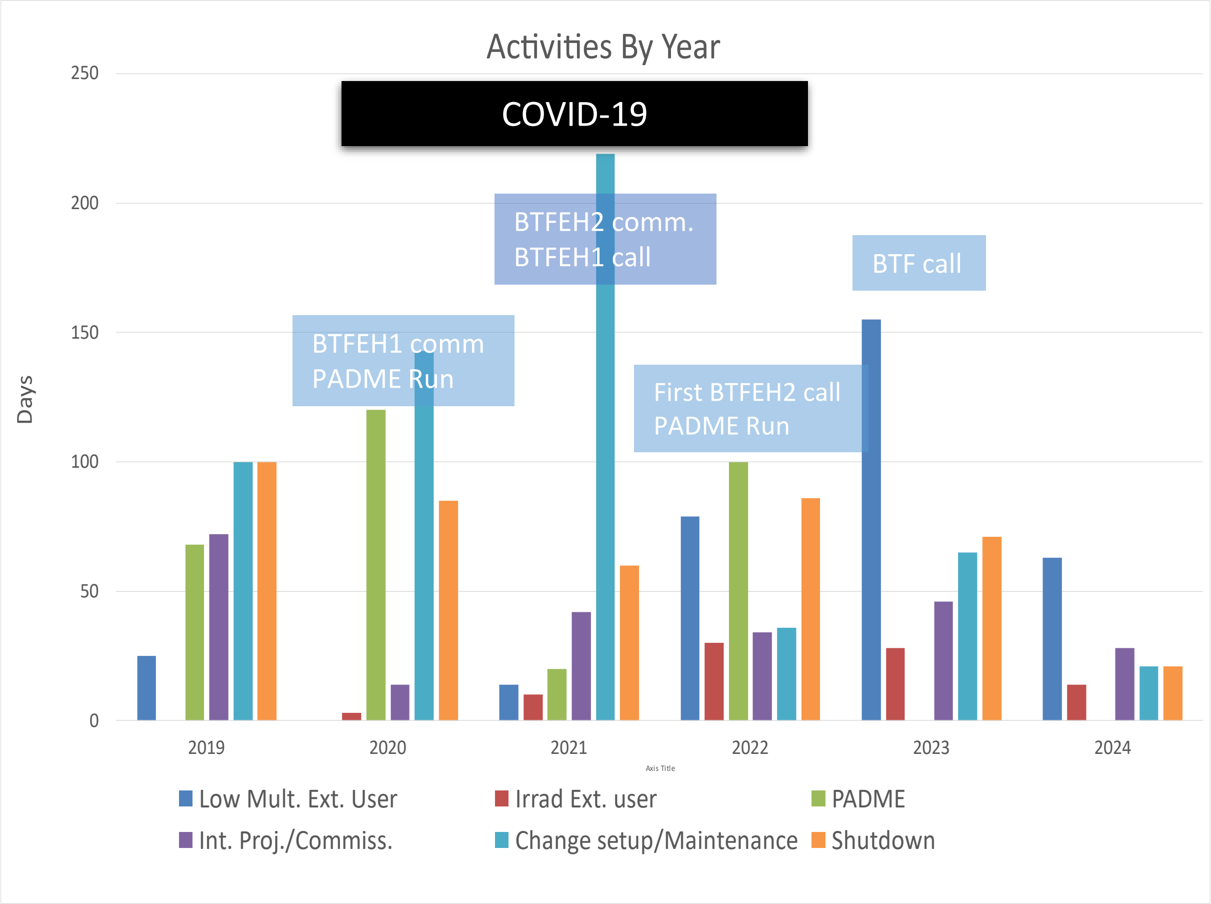
Parameters	BTF1 Time sharing		BTF1 Dedicated		BTF2 Time sharing	BTF2 Dedicated
	With Cu target	Without Cu target	With Cu target	Without Cu target	With Cu target	With Cu target
Particle	e^+ / e^- (User)	e^+ / e^- (DAΦNE status)	e^+ / e^- (User)		e^+ / e^- (User)	
Energy (MeV)	25–500	510	25–700 (e^-/e^+)	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 / $1.5x10^{10}$	$1–10^5$ (Energy dependent)	1 to $3x10^{10}$	Expected $1–10^4$ (Energy dependent, To be confirmed)	
Max int flux	$3.125x10^{10}$ part./s				$1x10^6$ 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	

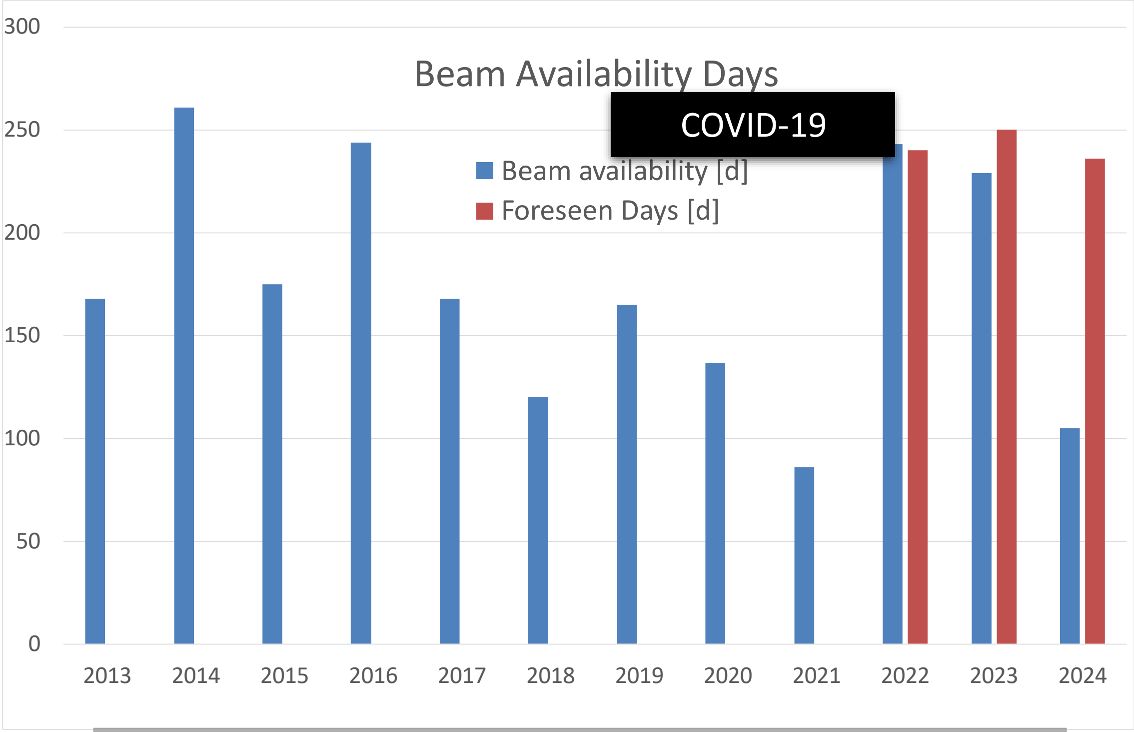
- Pulsed **electron** and **positron** beams (up to 49 pulses/second)
- Wide range: from 10^10 down to single particle per bunch, continuous energy selection
- Different ranges of parameters in the **two running modes**:
  - Dedicated: only when DAΦNE collider shutdown, exclusive BTF users
  - Time sharing: DAΦNE spare pulse injections mode via pulsed magnet
    - Beam top parameters defined by DAΦNE injections

LNF – BTF NUMBERS

2019-2024 Activities



Beam Availability Days (up to May 2024)



Minor fault to be reported, 2w withdrawal converted:
- in crane maintenance (stuck on 2022)
- BTFEH2 gas installation
- BTF particle type masked trigger for users
- Detector devel

The ATOMKI anomaly

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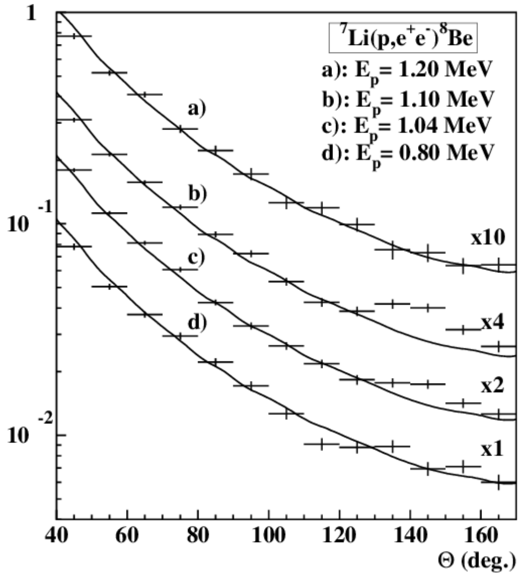
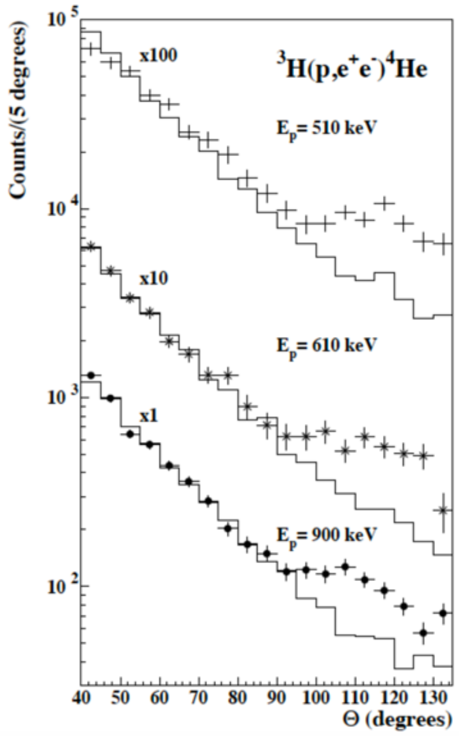
Experiments at the ATOMKI laboratory in Debrecen, Hungary, have reported evidence of an anomalous peak in the angular distribution of internal pair creation in ^{7}Li(p)^{8}BE, ^{3}H(p)^{4}He, ^{11}Be(p)^{12}C transitions





Prl 116, 042501 (2016)
Phys.Rev. C 104, 044003 (2021)
Phys.Rev. C 106, L061601 (2022)

Feng and coll., and then Denton and Gehrlein have suggested that these anomalies can be explained by the existence of a new vector or axial vector boson of mass around 17 MeV, therefore dubbed as «X17»

Phys.Rev. D 102, 036016 (2020)
Phys.Rev. D 108, 015009 (2023)

PADME X17 run

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It has been shown that this new particle can be produced resonantly by properly tuning the energy of the positron beam of BTF on PADME (Darmé et al., *Phys.Rev. D 106, 115036 (2022)*)

Thousands of events can be produced with just 10^{10} PoT

During fall 2022 PADME has collected 47 different points to cover a 1.1 MeV mass range around the region predicted by ATOMKI

- Systematic effects studies performed on the sidebands data and MC
- Energy resolution found to be worst by a factor 2 wrt initial expectation
- Box opening and physics results announcement expected for the next summer conferences
- It is for sure needed a second run with an improved detector, presently planned for the first half of 2025

The FLASH Proposal

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 fully powered in January this year

The future search for low-frequency axions and new physics with the FLASH resonant cavity experiment at Frascati National Laboratories

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[f]*Centro de Astropartículas y Física de Altas Energías (CAPA), Universidad de Zaragoza, Zaragoza, 50009, Spain*
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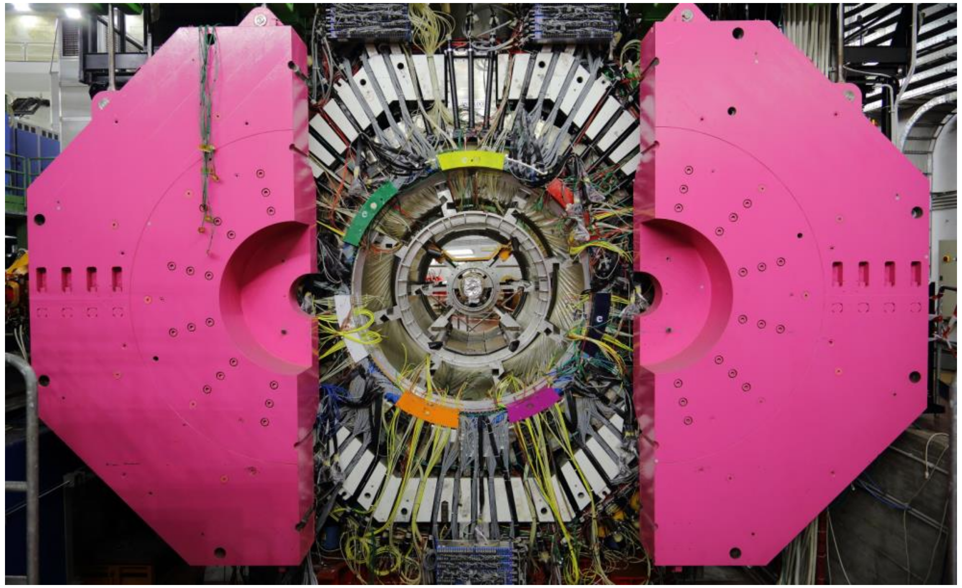
Email address: alessandro.delia@lnf.infn.it (Alessandro D'Elia)

The FLASH Proposal

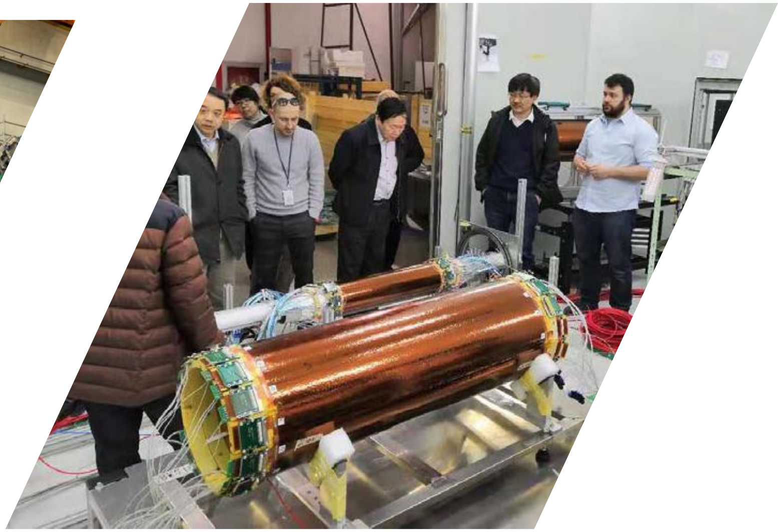
We have started the process of consolidation of the project in terms of both manpower and financial resources (INFN CSN2 alerted)

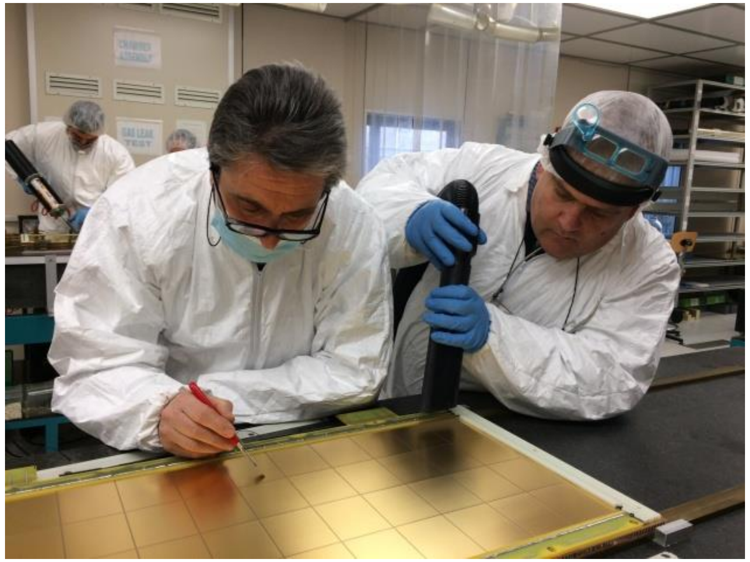
Besides the magnet, the other big component of the apparatus will be a large, 4.15 m^3, copper resonant cavity, for which expertise is already present in the laboratory



Note that the magnet and its cryogenic plant reside inside the DAΦNE hall. Operation of FLASH could therefore be conflicting with the usage of DAΦNE as at present

The laboratory has strong experience also in the development and construction of particle's detectors in particular in the fields of gaseous detectors and of scintillating materials





This translates in the participation of LNF scientists in HEP experiments in most of the largest laboratories in the world (CERN, FERMILAB, IEHP, KEK…)

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

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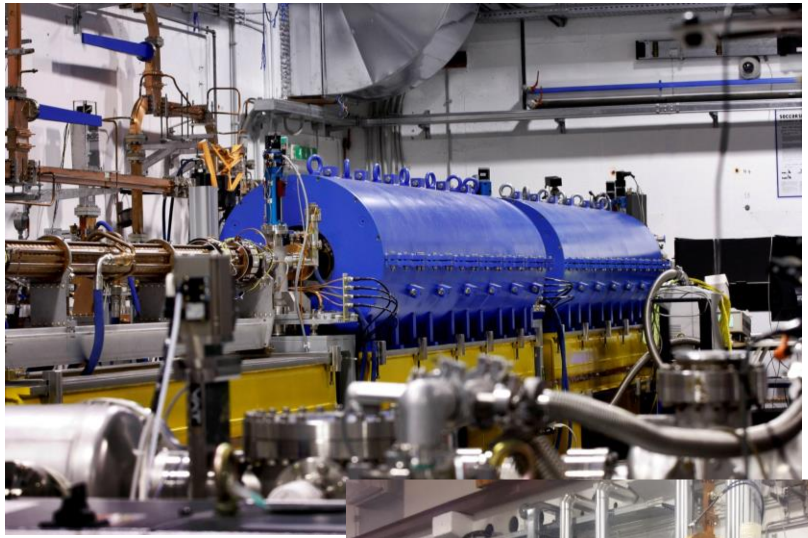
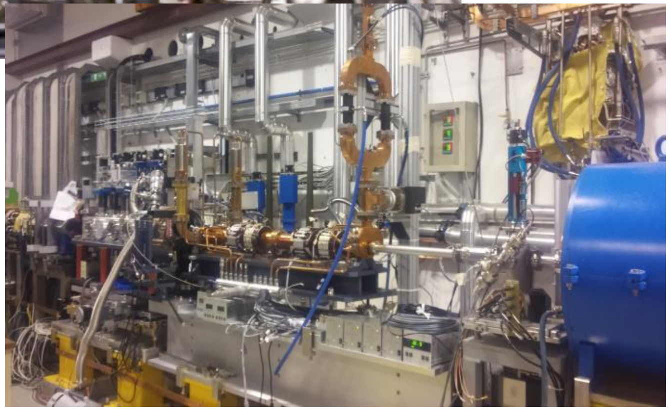
In 2005 the facility **SPARC_LAB** was put into operation as a test and training facility for advanced accelerator developments

It 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

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The most important result obtained so far has been the first demonstration of FEL light production induced by a beam-driven plasma wakefield accelerator (*Nature Physics 17 (2021) 4, 499-503*; *Nature 605 (2022) 7911, 659-662*)

These results are fundamental demonstrator of the feasibility of the next big enterprise of the Laboratory: the EuPRAXIA project

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

Eupraxia@Sparc_Lab: the Italian branch of the enterprise with the aim of building at LNF one of these two facilities, using the beam-driven technique

EuPRAXIA International Collaboration

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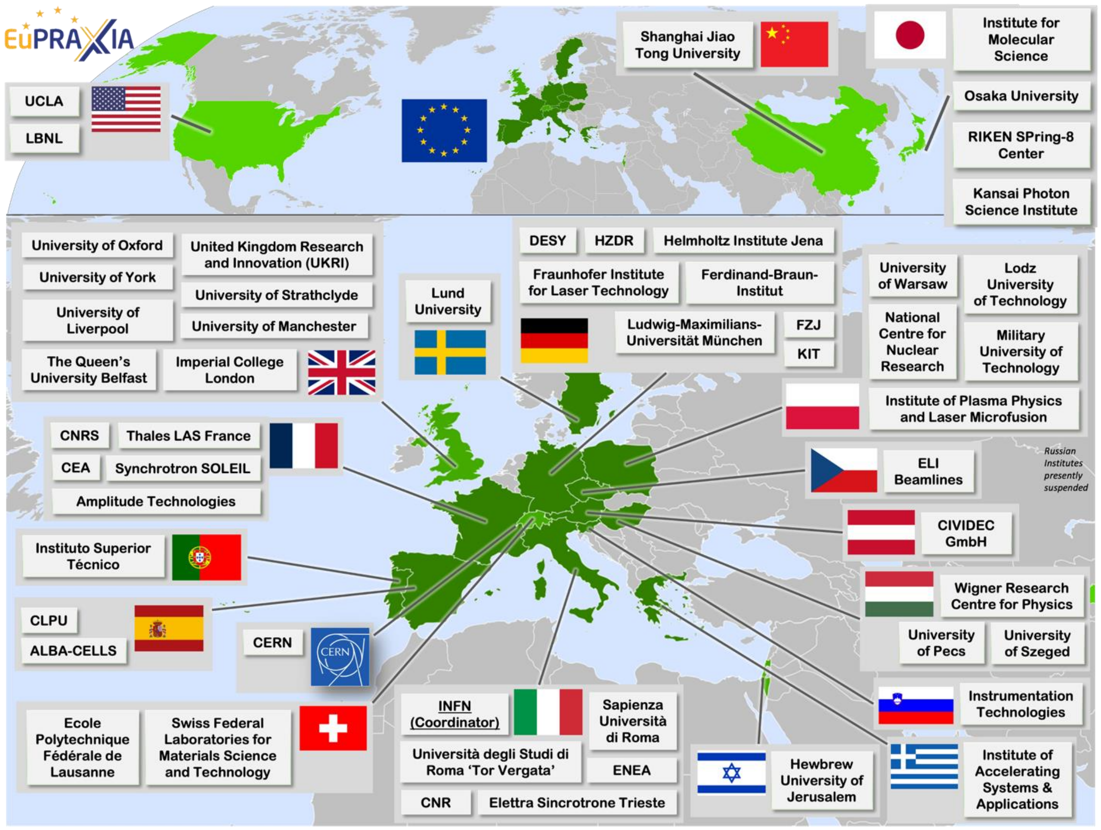
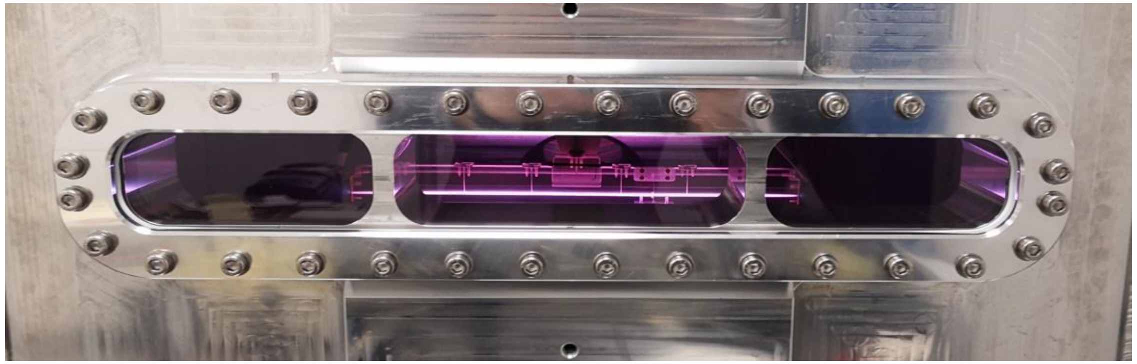
- The EuPRAXIA Consortium today: **54 institutes** from **18 countries** plus CERN
- Included in the **ESFRI** Road Map
- Efficient fund raising:
  - –**Preparatory Phase** consortium (funding EU, UK, Switzerland, in-kind)
  - –**Doctoral Network** (funding EU, UK, in-kind)
  - –**EuPRAXIA@SPARC_LAB** (Italy, in-kind)
  - –**EuAPS Project** (PNRR)



Besides SPARC_LAB, experiments and tests on specific technical items relevant for the project are under way in several other facilities of the laboratory



Plasma_Lab: First EuPRAXIA plasma source to reach 1.1 GeV (1.5 GV/m) - **40 cm long**

TEX: Tests on high-gradient X-band accelerating structures. First test accomplished succesfully last month

EuPRAXIA@SPARC_LAB

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- The Italian pillar of the Project **EuPRAXIA@SPARC_LAB** has been granted 108 M€ from the Italian Government
- The design of the building is over and that of the machine is under way. The facility is expected to start operations in 2029
- It will be the world first user facility based on the technique of plasma acceleration