Laboratori Nazionali di Frascati dell'INFN

Fabio Bossi, Frascati, June 17 2024

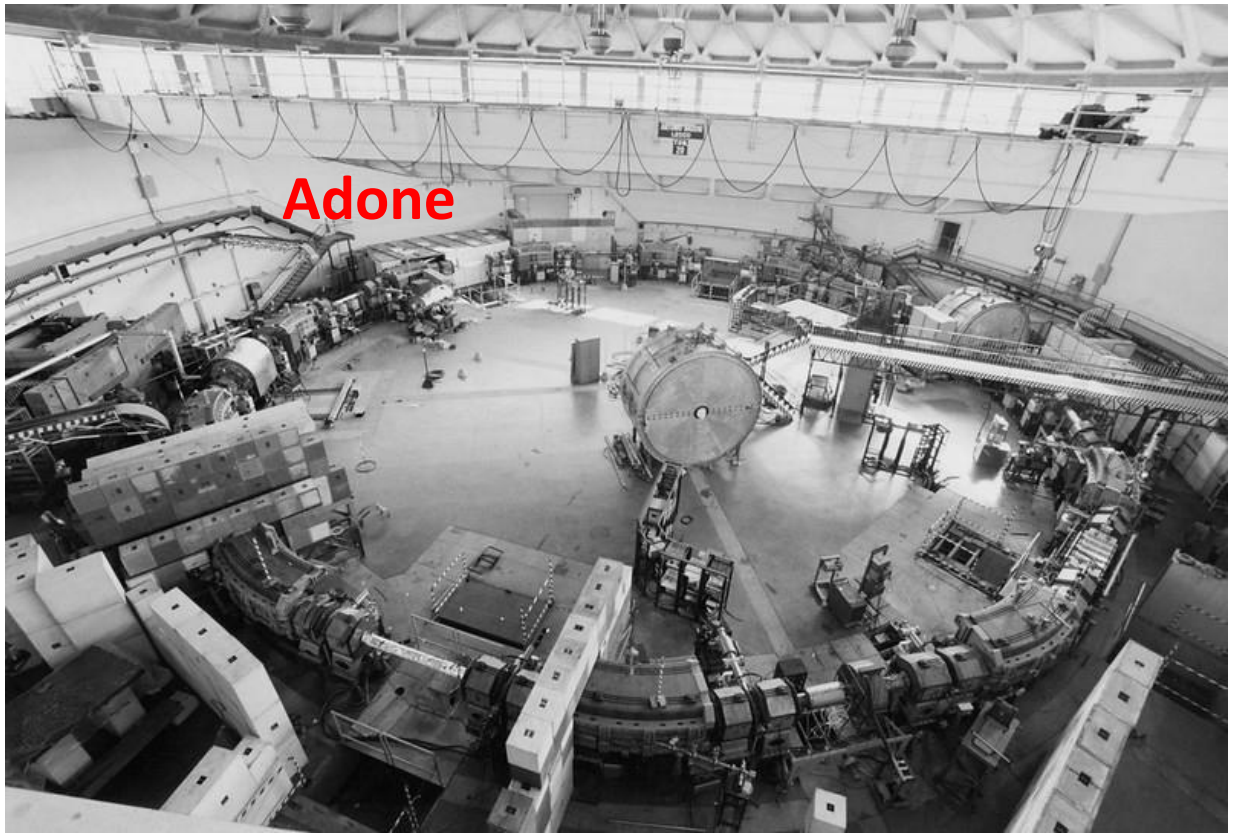
The Laboratori Nazionali di Frascati (LNF) is located about 20 km south-east of Rome, 2 km away from the town of Frascati

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

70 Years of LNF History

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



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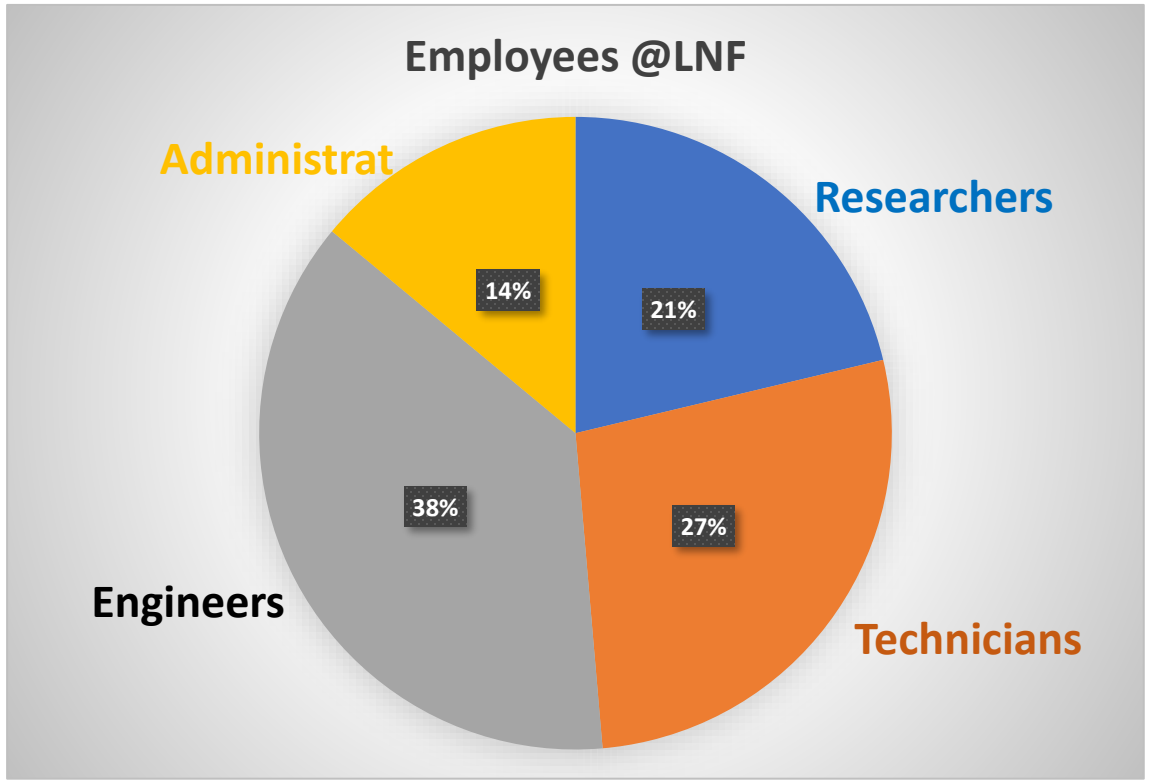
The LNF has presently **two running accelerators**, DAΦNE and Sparc_Lab, and operate several **technical infrastructrures** devoted to accelerators or detector R&D and construction

As of June 1, 2024 there are **331** permanent or fixed-term employees (researchers, engineers, technicians, administratives) and about **50** doctoral and postdoctoral students

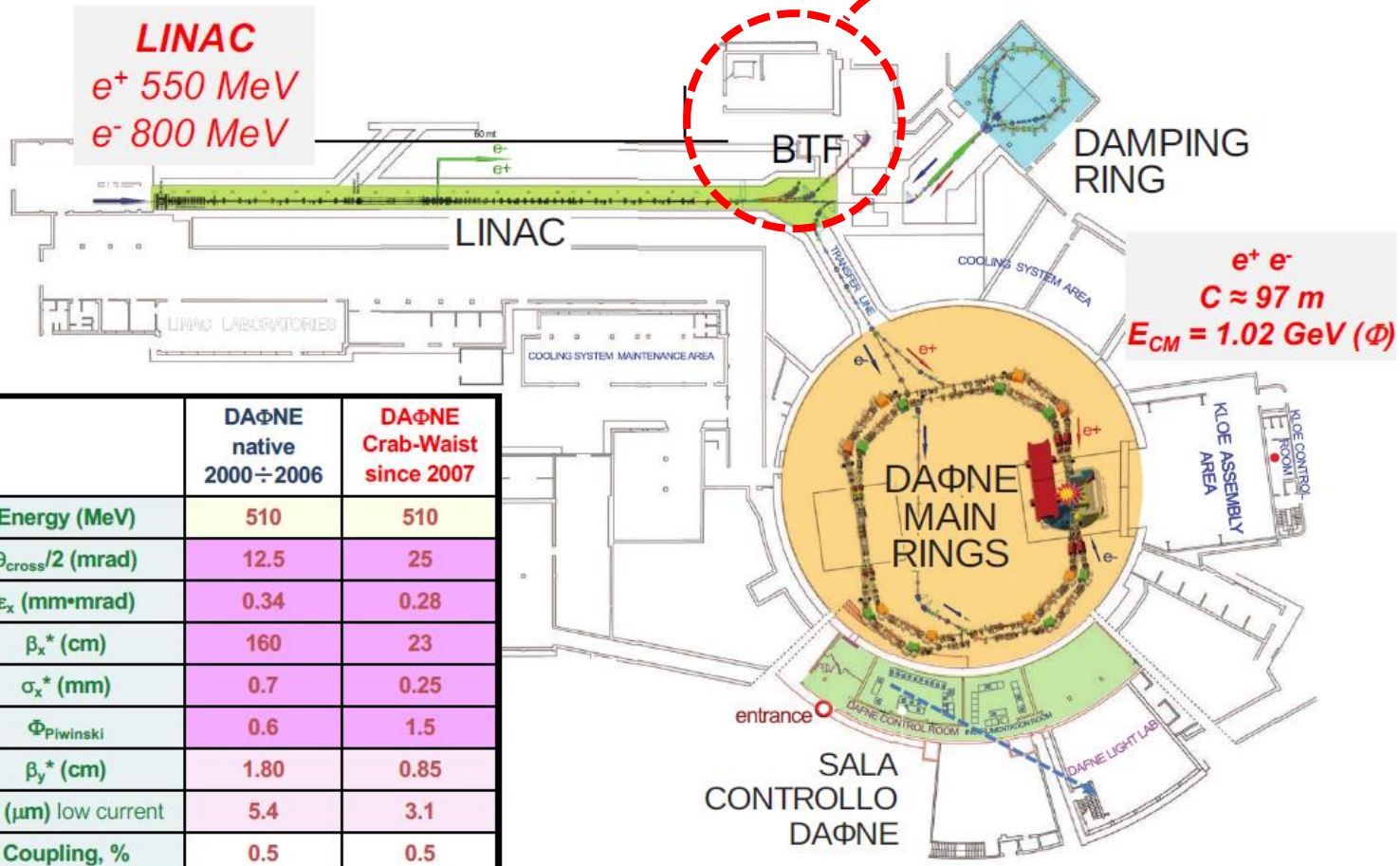


Year 2023 budget

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

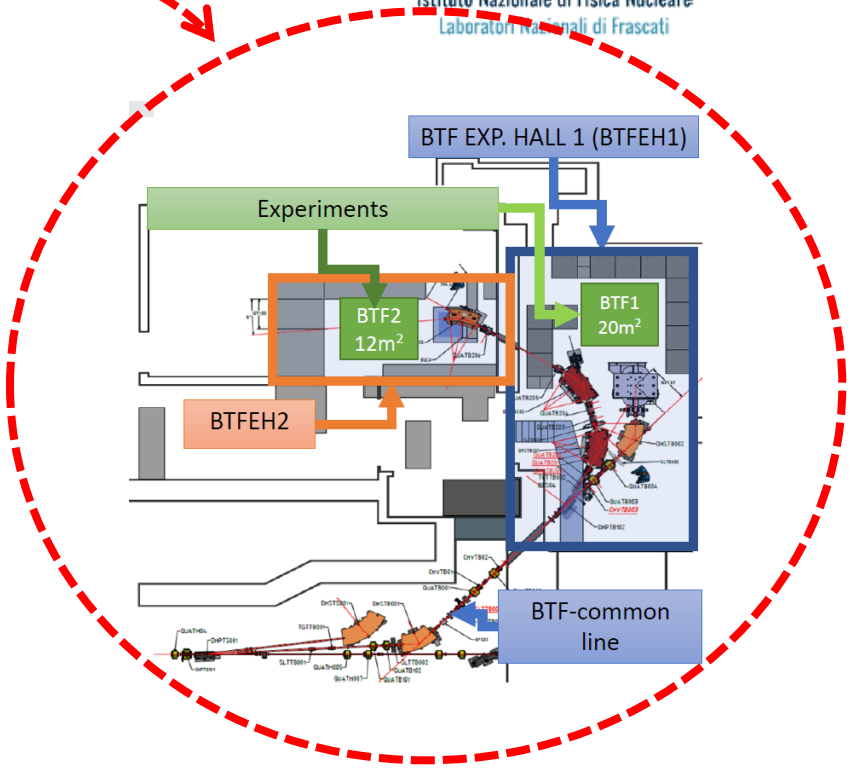
The DAΦNE Complex



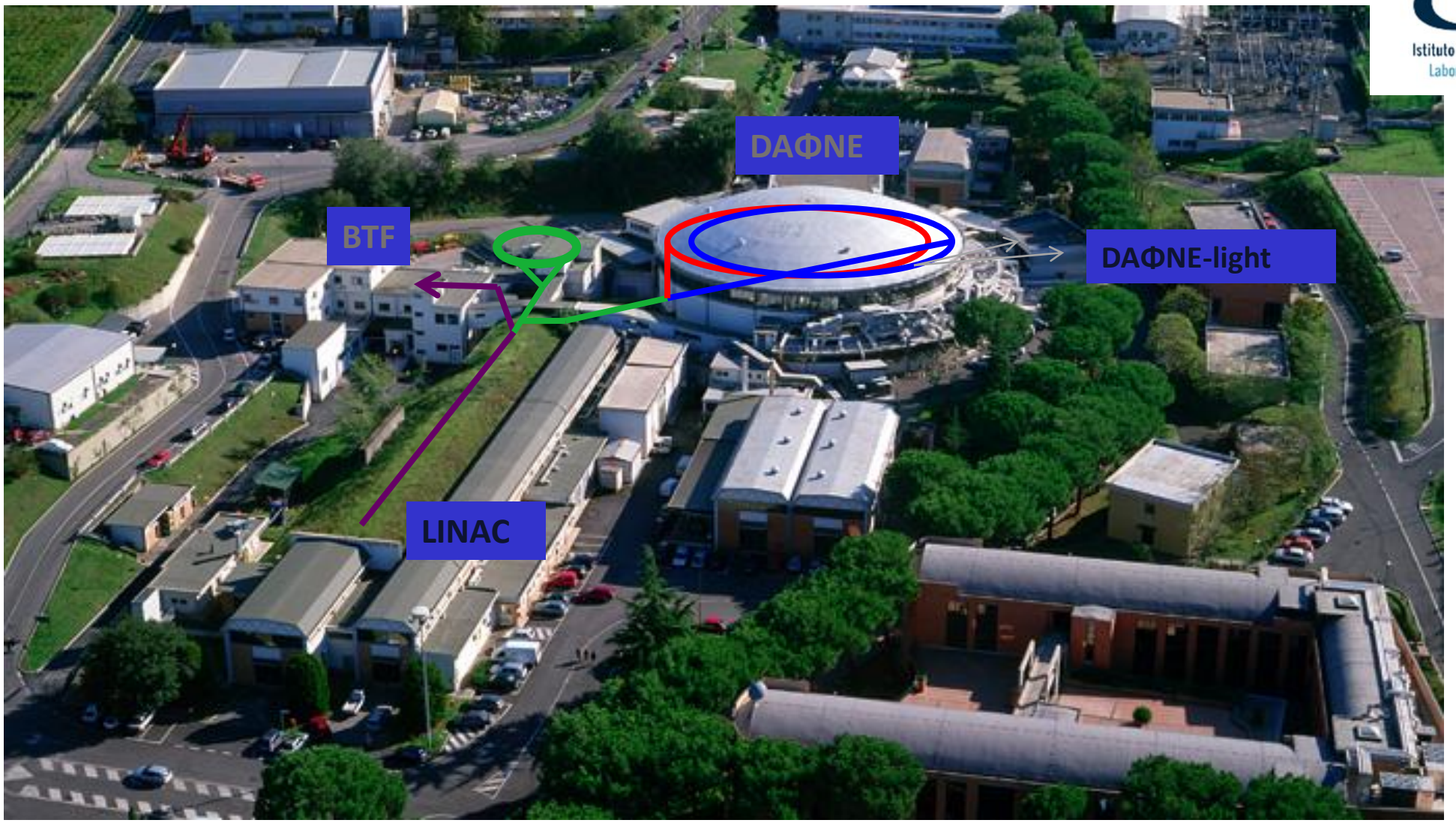
	DAΦNE native 2000÷2006	DAΦNE Crab-Waist since 2007
Energy (MeV)	510	510
$\theta_{cross}/2$ (mrad)	12.5	25
ε_x (mm•mrad)	0.34	0.28
β_x^* (cm)	160	23
σ_x^* (mm)	0.7	0.25
$\Phi_{Piwinski}$	0.6	1.5
β_y^* (cm)	1.80	0.85
σ_y^* (μm) low current	5.4	3.1
Coupling, %	0.5	0.5
Bunch spacing (ns)	2.7	2.7
I_{bunch}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

DAΦNE implemented and tested succesfully a new approach to beam-beam interaction: the ***Crab-Waist*** **collision scheme.**

$L_{peak} = 4x10^{32}\ cm^{-2}s^{-1}$



BTF #1/2



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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

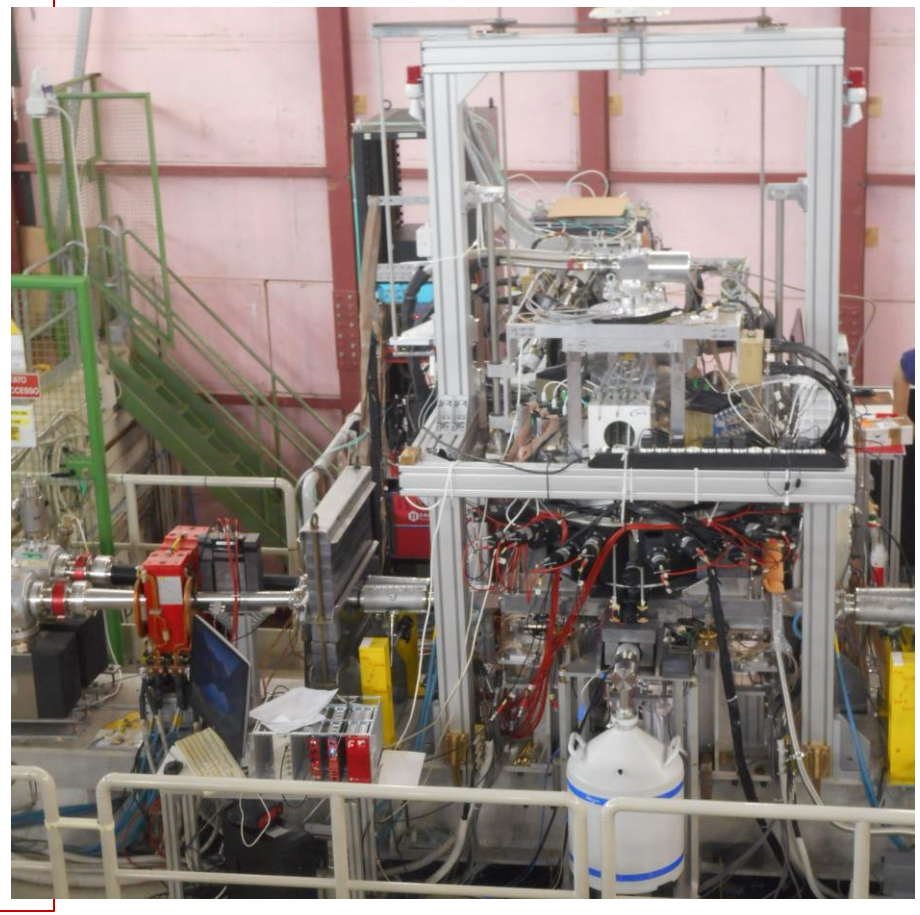
SIDDHARTA-2 experiment at DAΦNE

Aim: **precision measurements of kaonic atoms X-ray transitions using kaons produced by DAΦNE** (first ever Kd in particular) -> QCD with strangeness in non-perturbative regime (antikaon-nucleon scattering lengths; kaon mass, K-NN interactions…)

Main activities in 2022-2024:

- **SIDDHARTA-2 full setup on DAΦNE: autumn 2021**
- **2022: SIDDHARTA-2 setup in test run at DAΦNE (till July 2022) with KHe (50 pb^{-1}) and Kd (35 pb^{-1}; test run);**
- **Autumn 2022: further optimization of the setup**
- **April 2023: SIDDHARTA-2 run with kaonic neon for first measurement and degrader optimization (125 pb^{-1});**
- **May 2023-today: Kaonic deuterium run (800 pb^{-1});**

In parallel kaonic atoms with CdZnTe and HPGe setups



Beam Test Facility

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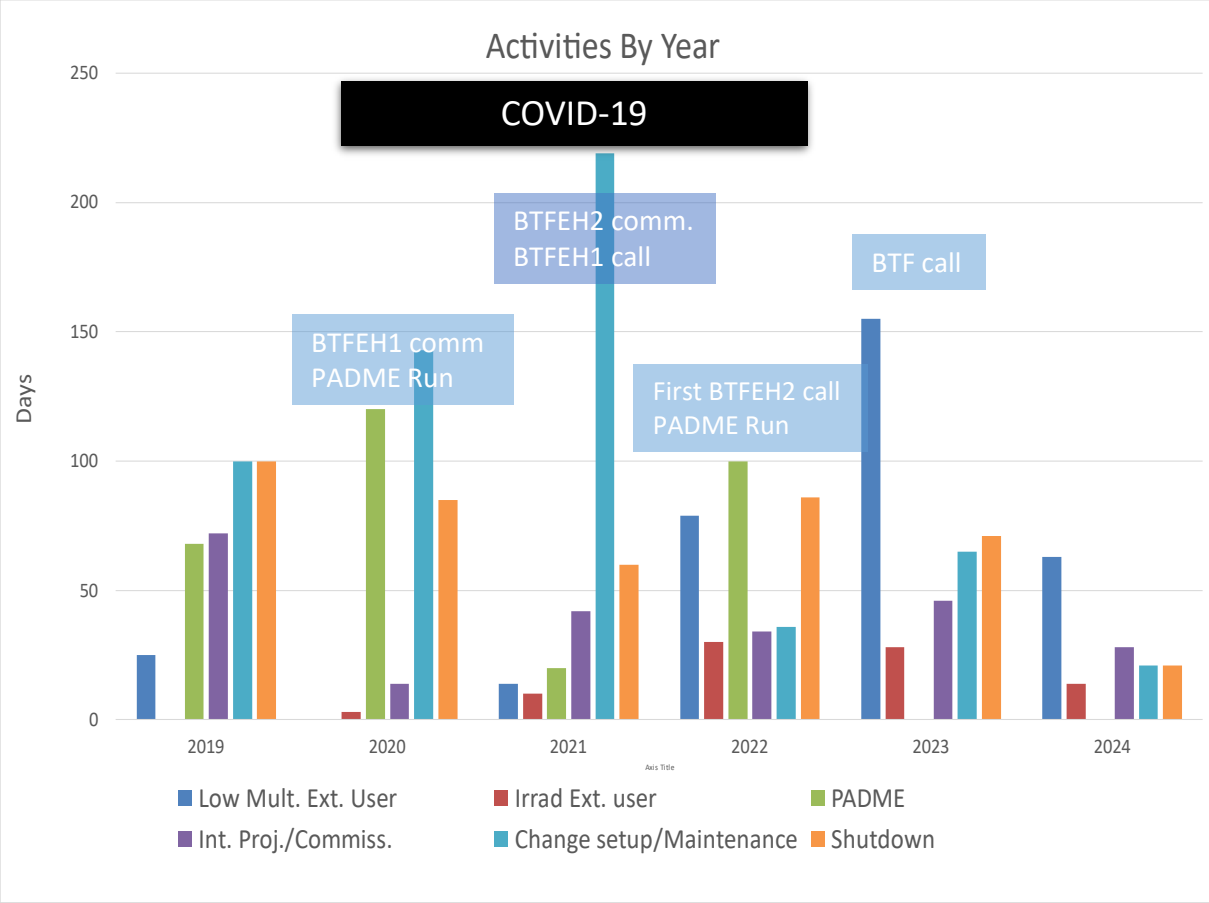
Parameters	BTF1 Time sharing		BTF1 Dedicated		BTF2 Time sharing	BTF2 Dedicated
	With Cu target	Without Cu target	With Cu target	Without Cu target	With Cu target	With Cu target
Particle	e^+ / e^- (User)	e^+ / e^- (DAΦNE status)	e^+ / e^- (User)		e^+ / e^- (User)	
Energy (MeV)	25–500	510	25–700 (e^-/e^+)	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	

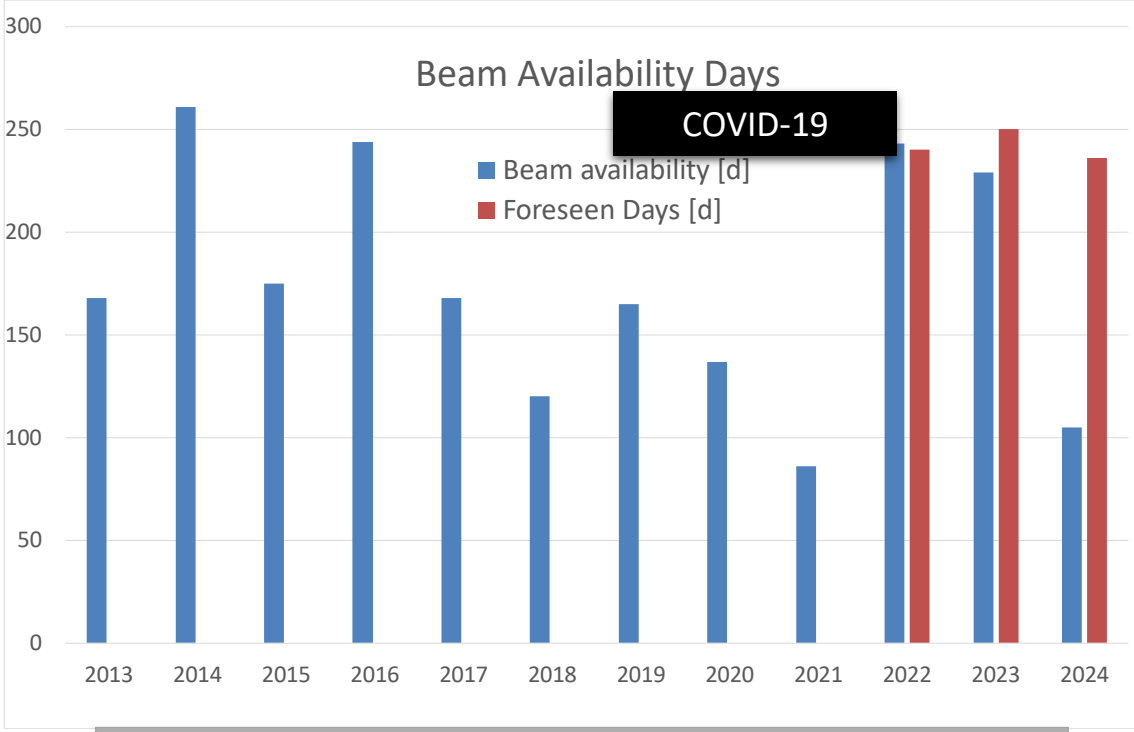
- Pulsed **electron** and **positron** beams (up to 49 pulses/second)
- Wide range: from 10^10 down to single particle per bunch, continuous energy selection
- Different ranges of parameters in the **two running modes**:
  - Dedicated: only when DAΦNE collider shutdown, exclusive BTF users
  - Time sharing: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

LNF – BTF NUMBERS

2019-2024 Activities

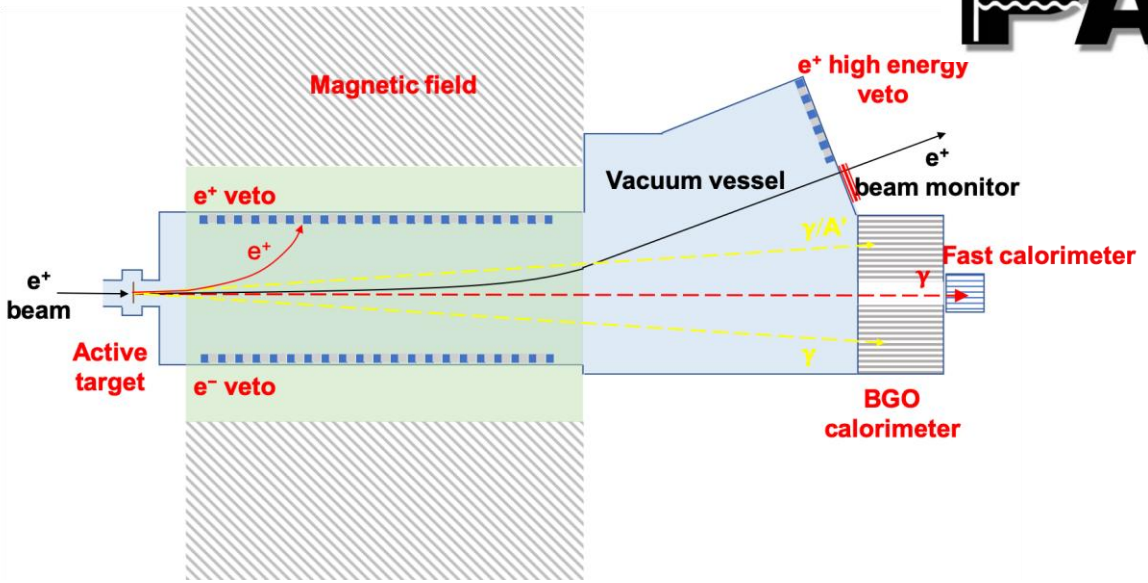


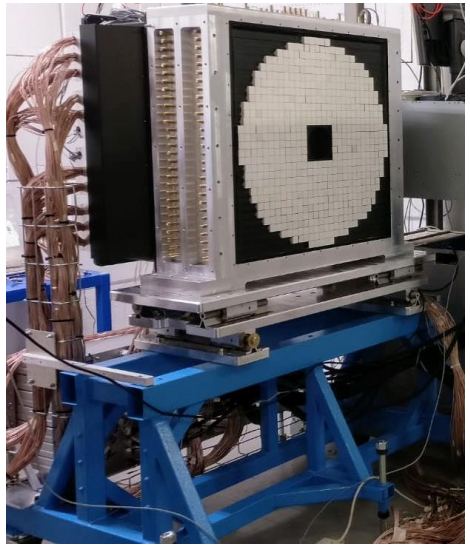
Beam Availability Days (up to May 2024)



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





A particle physics experiment (**PADME**) is presently installed in HALL 1 of BTF

The aim of the experiment is to find evidence for the existence of a Dark Photon (A') in the process

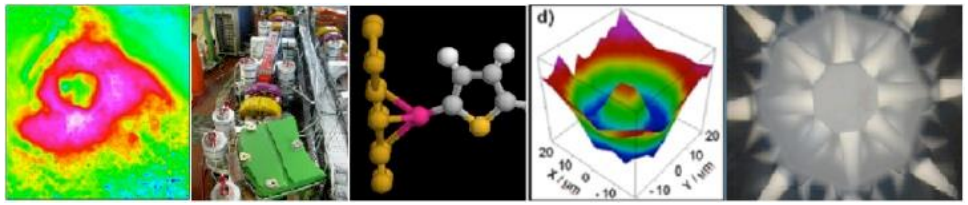
$$e^+ e^- \rightarrow \gamma A'$$

..or other exotic particles with mass 10-100 MeV

In particular in the fall of 2022 a dedicated run has been performed tuning the positron beam at energies proper to produce resonantly the hypothetical X17 particle, whose existence is suggested by nuclear physics experiments

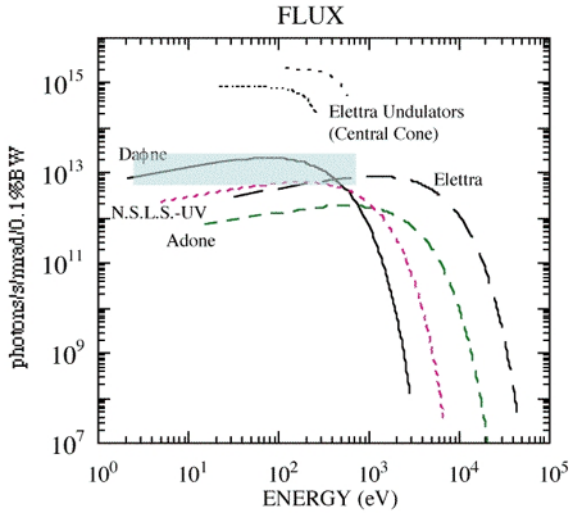
An accurate analysis of these data is ongoing. We expect to «open the box» before the summer conferences

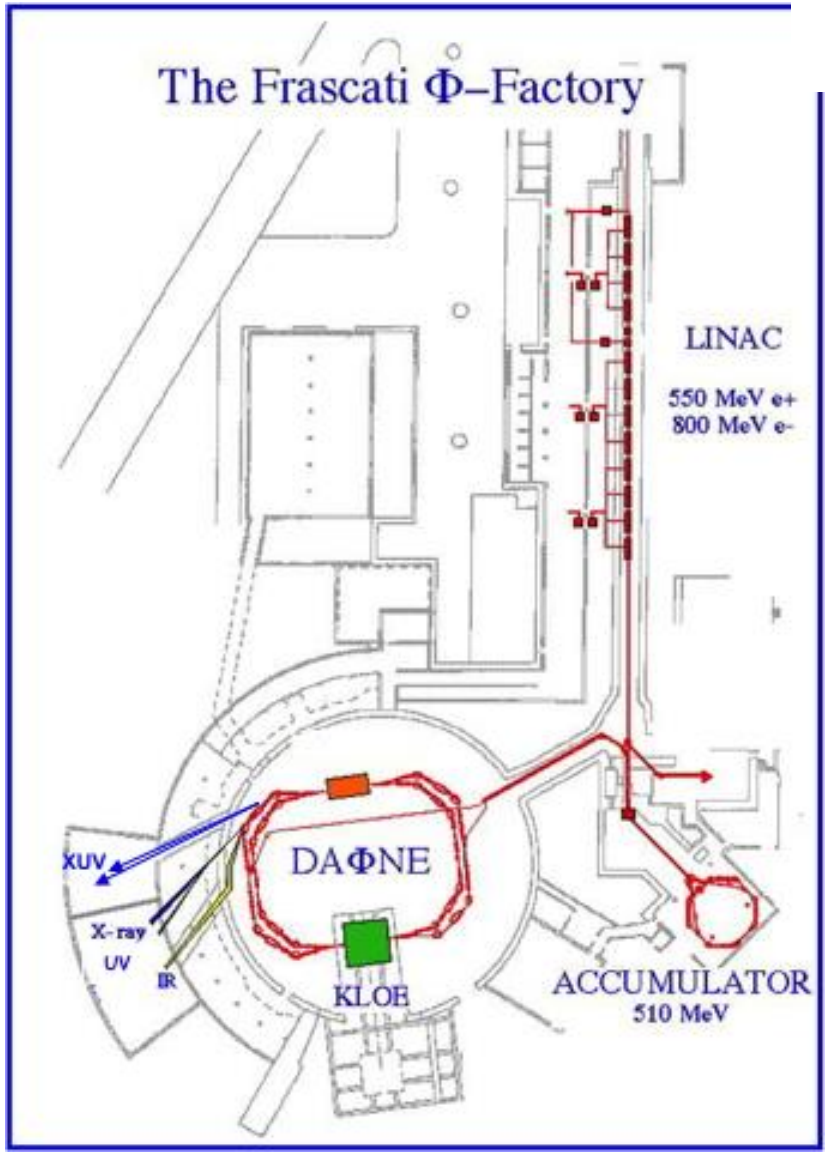
Beamlines @ DAΦNE-Light



DXR1 Soft X-ray beamline
DXR2 UV beamline
SINBAD InfraRed beamline
DXUV XUV beamlines

LNF are part of the European synchrotron light Infrastructures





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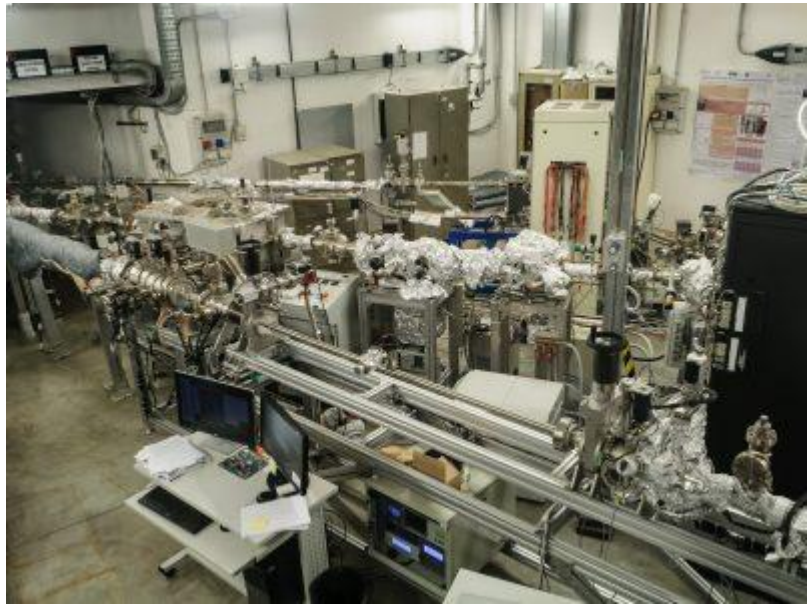
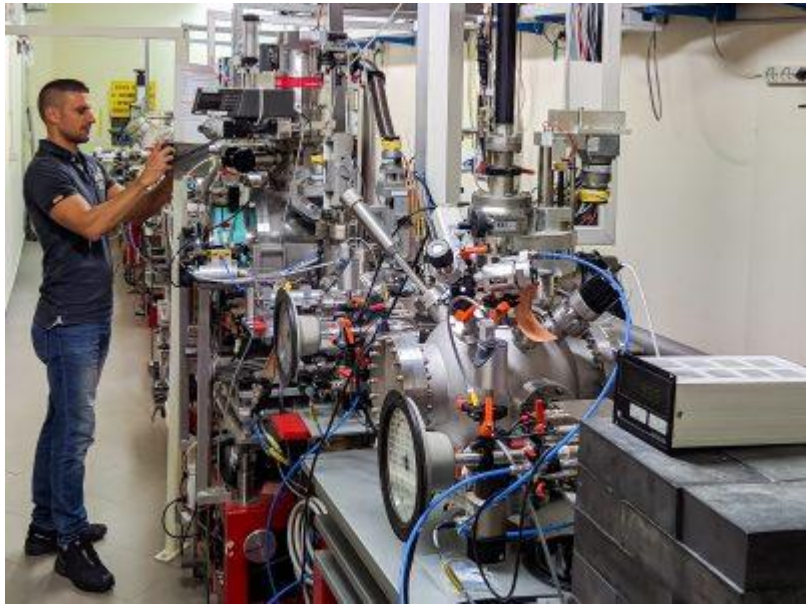
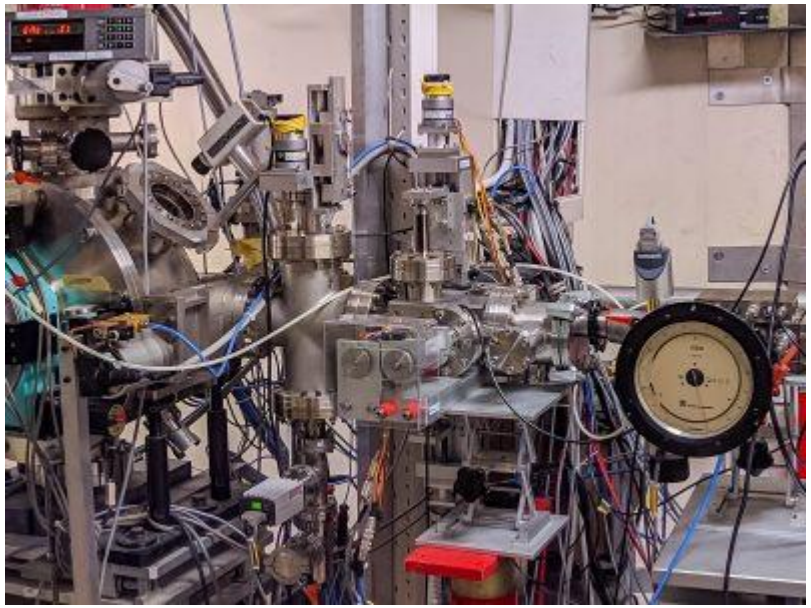
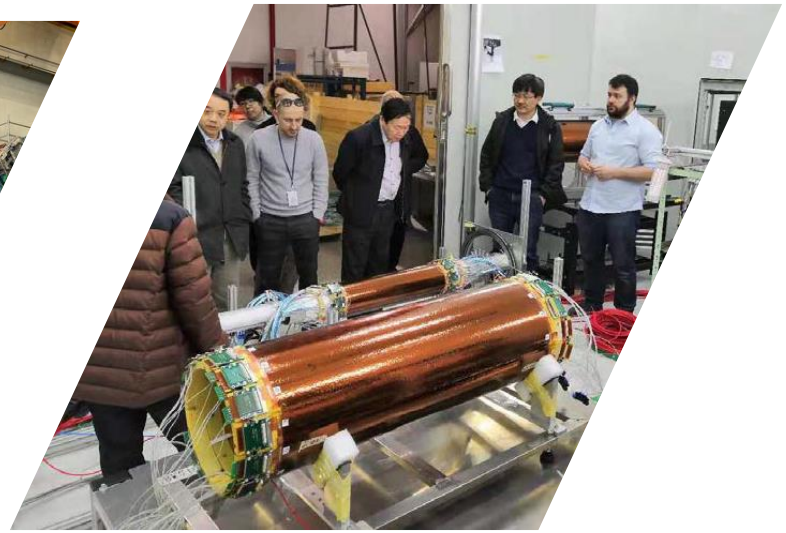
Details on the available beamlines and on their access can be found in https://dafne-light.lnf.infn.it/

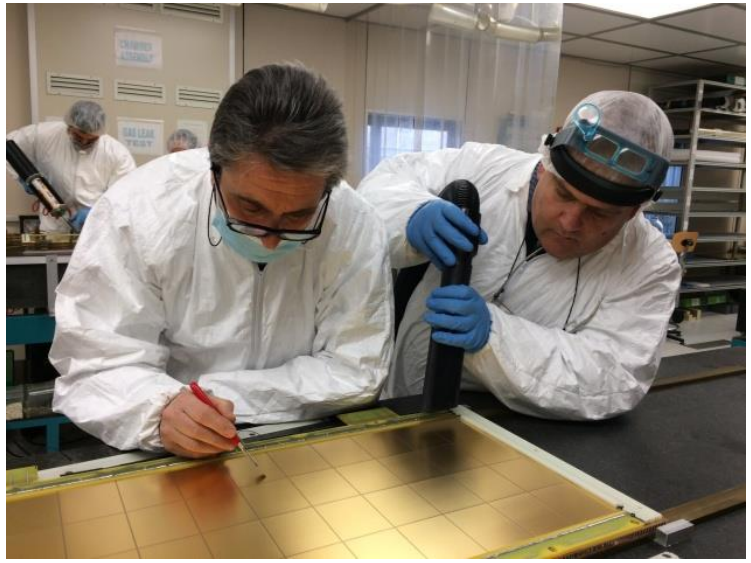




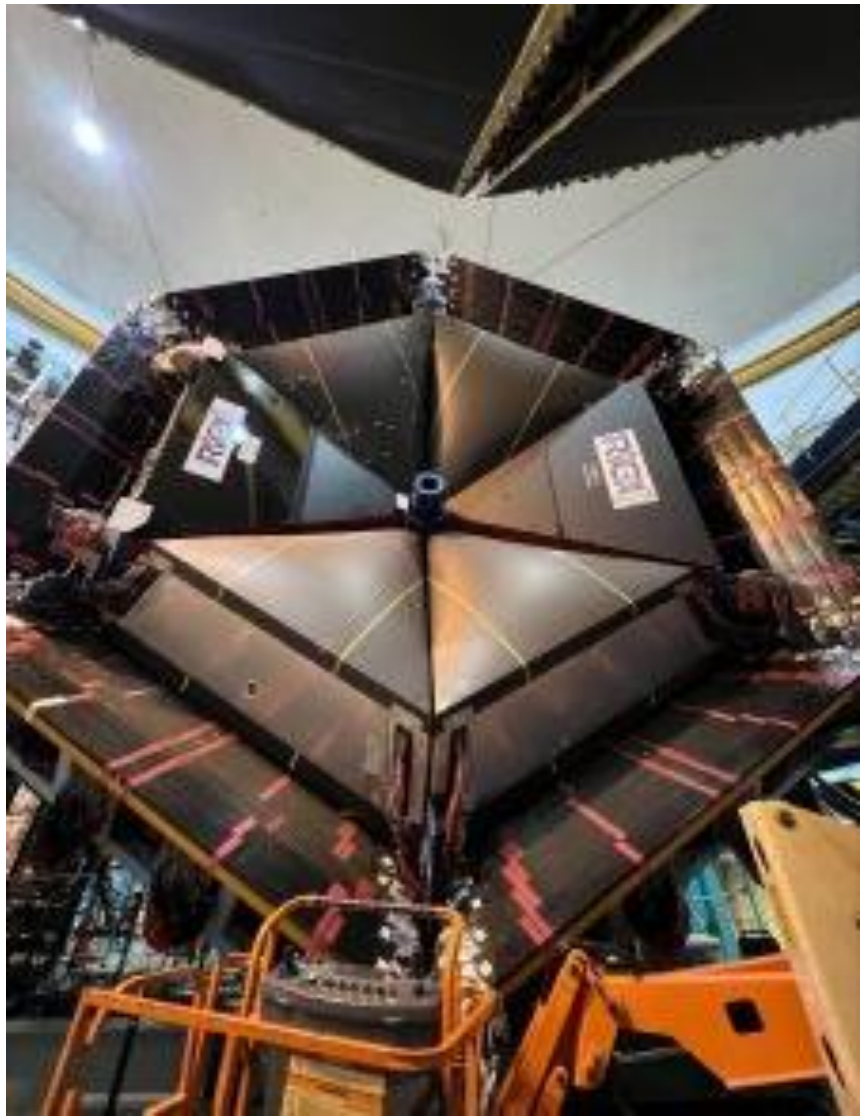


The laboratory has strong experience also in the development and construction of particle's detectors in particular in the fields of gaseous detectors and of scintillating materials





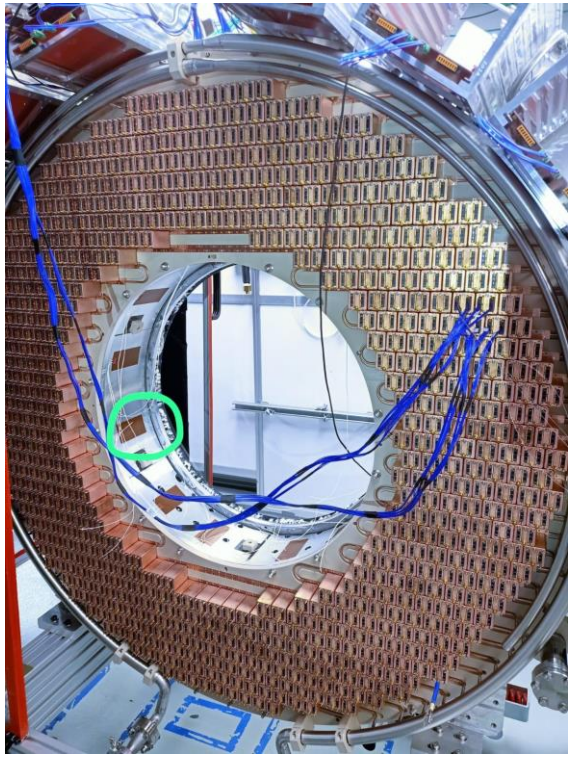
This translates in the participation of LNF scientists in HEP experiments in most of the largest laboratories in the world (CERN, FERMILAB, IEHP, KEK…)



The most recent achievements in this field are

RICH detector of **CLAS12** experiment at **TJNAF**, installation completed on June 2022

Crystal Calorimeter detector of **MU2E** experiment at **FERMILAB**, currently being installed and tested



The KLOE detector

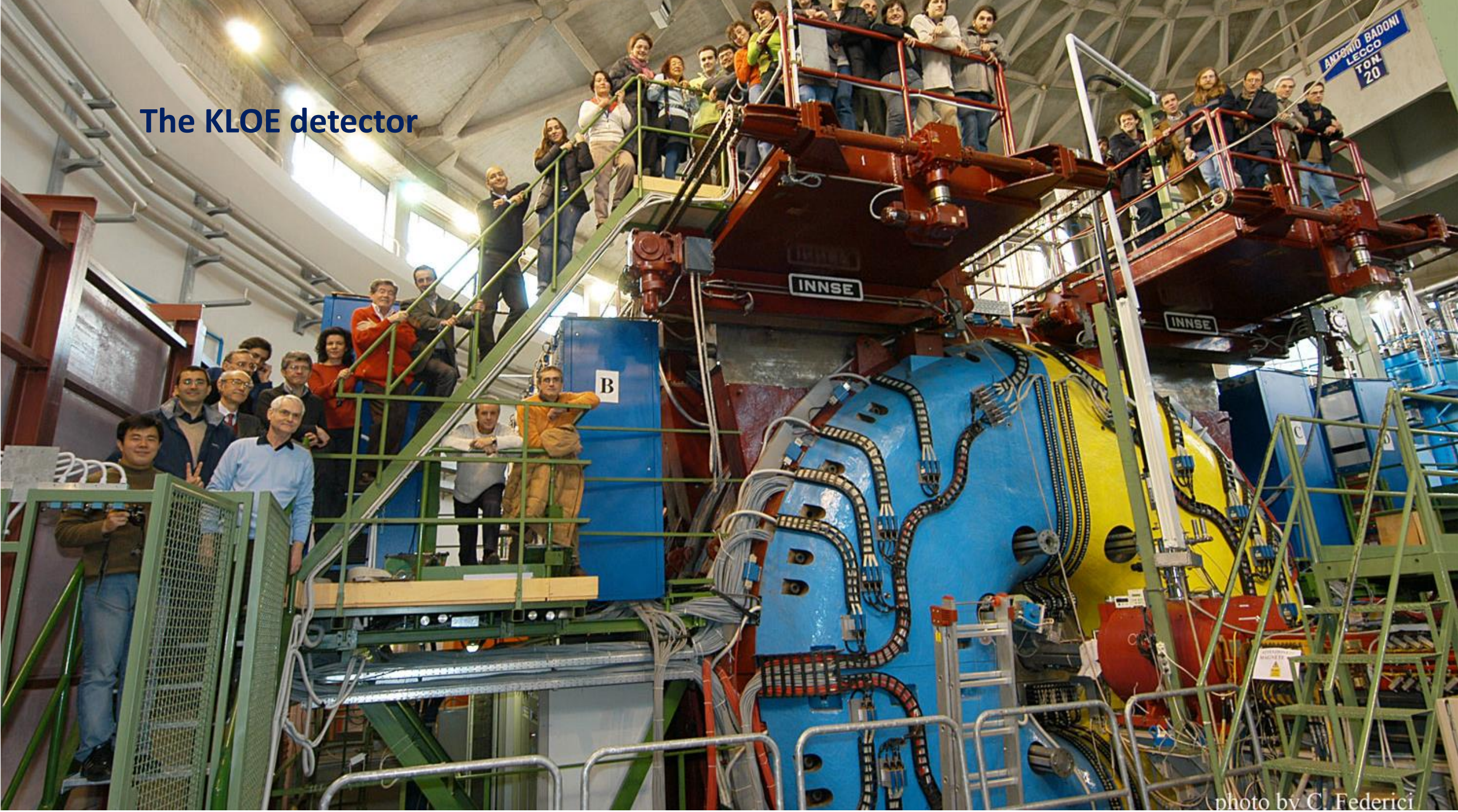
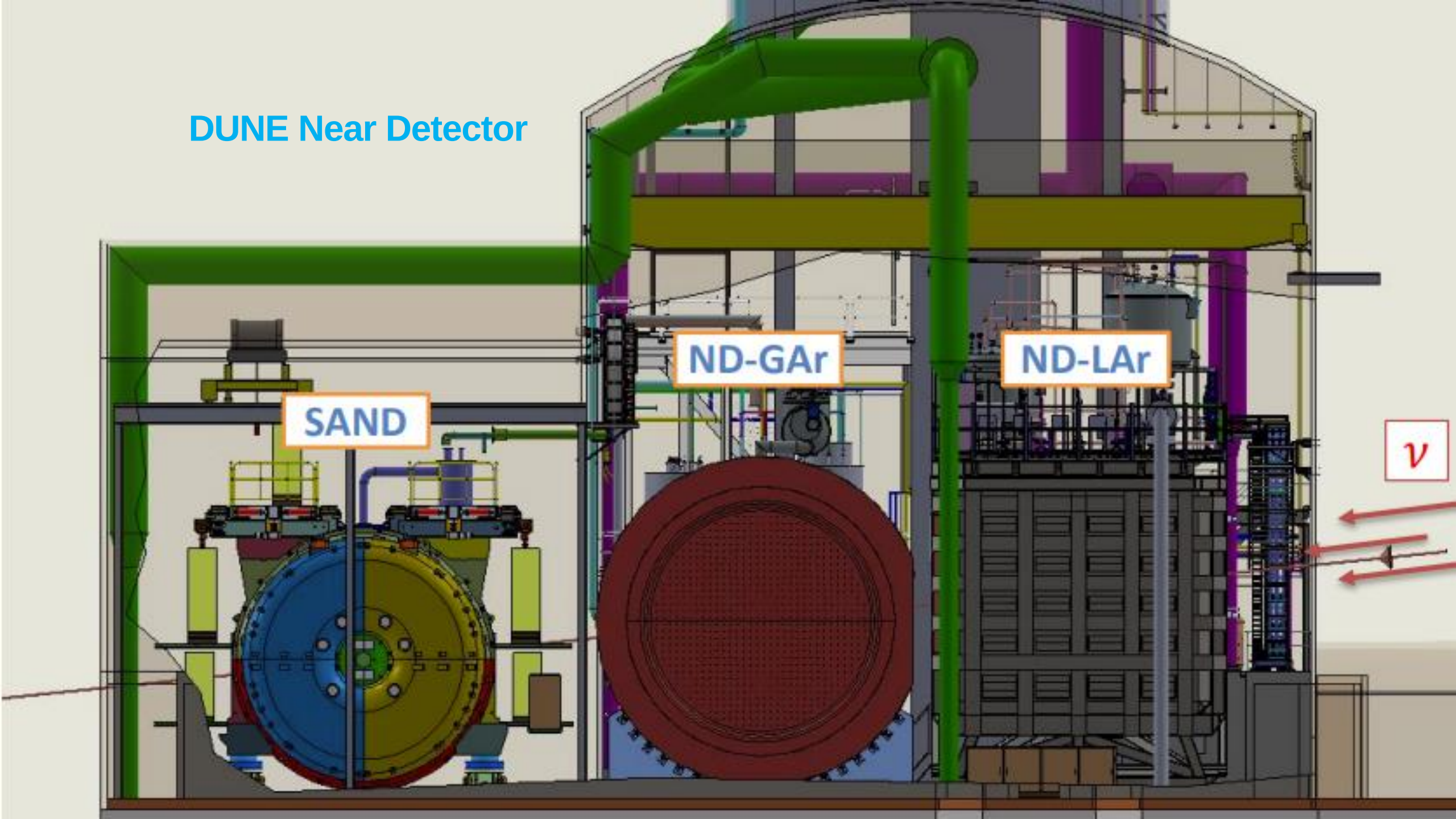


photo by C. Federici

DUNE Near Detector



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

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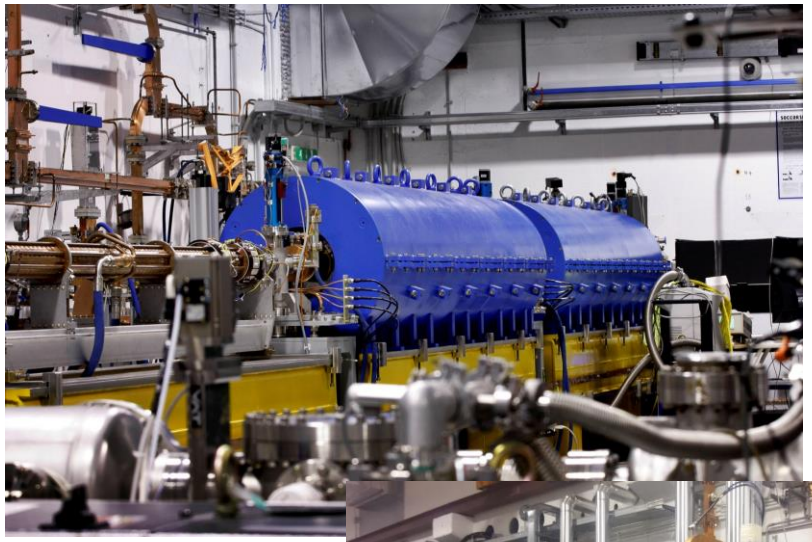
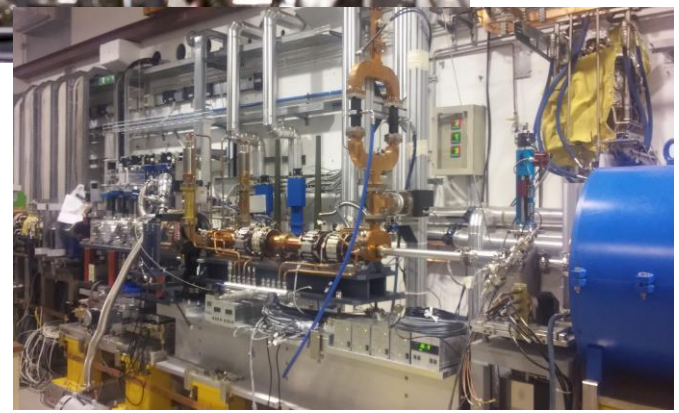
It consists of a high-brightness RF photoinjector, **SPARC**, and a multi-hundred terawatt laser, **FLAME**, and was initially focussed on performing FEL experiments and in general on the production of new radiation sources



Photoinjector



Plasma Vacuum Chamber

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

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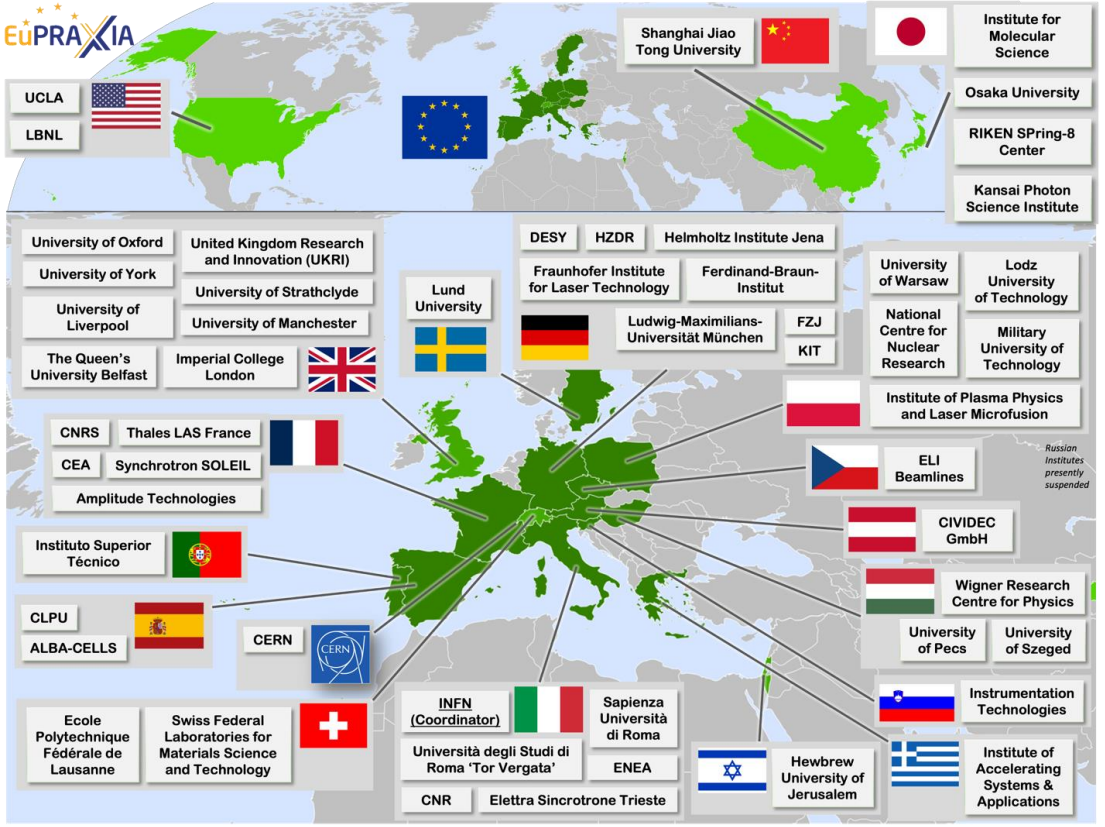
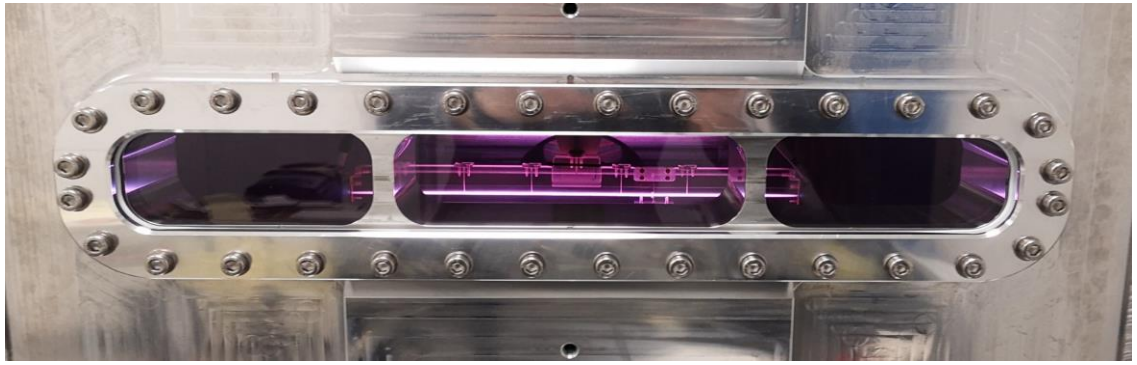
- The EuPRAXIA Consortium today: **54 institutes** from **18 countries** plus CERN
- Included in the **ESFRI** Road Map
- Efficient fund raising:
  - **Preparatory Phase** consortium (funding EU, UK, Switzerland, in-kind)
  - **Doctoral Network** (funding EU, UK, in-kind)
  - **EuPRAXIA@SPARC_LAB** (Italy,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