NEXT-STEP: a proposal for a European Research Infrastructure

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on behalf of the NEXT-STEP partners

RAIN15 - Frascati, 12 - 13 Ottobre 2015

Introduction

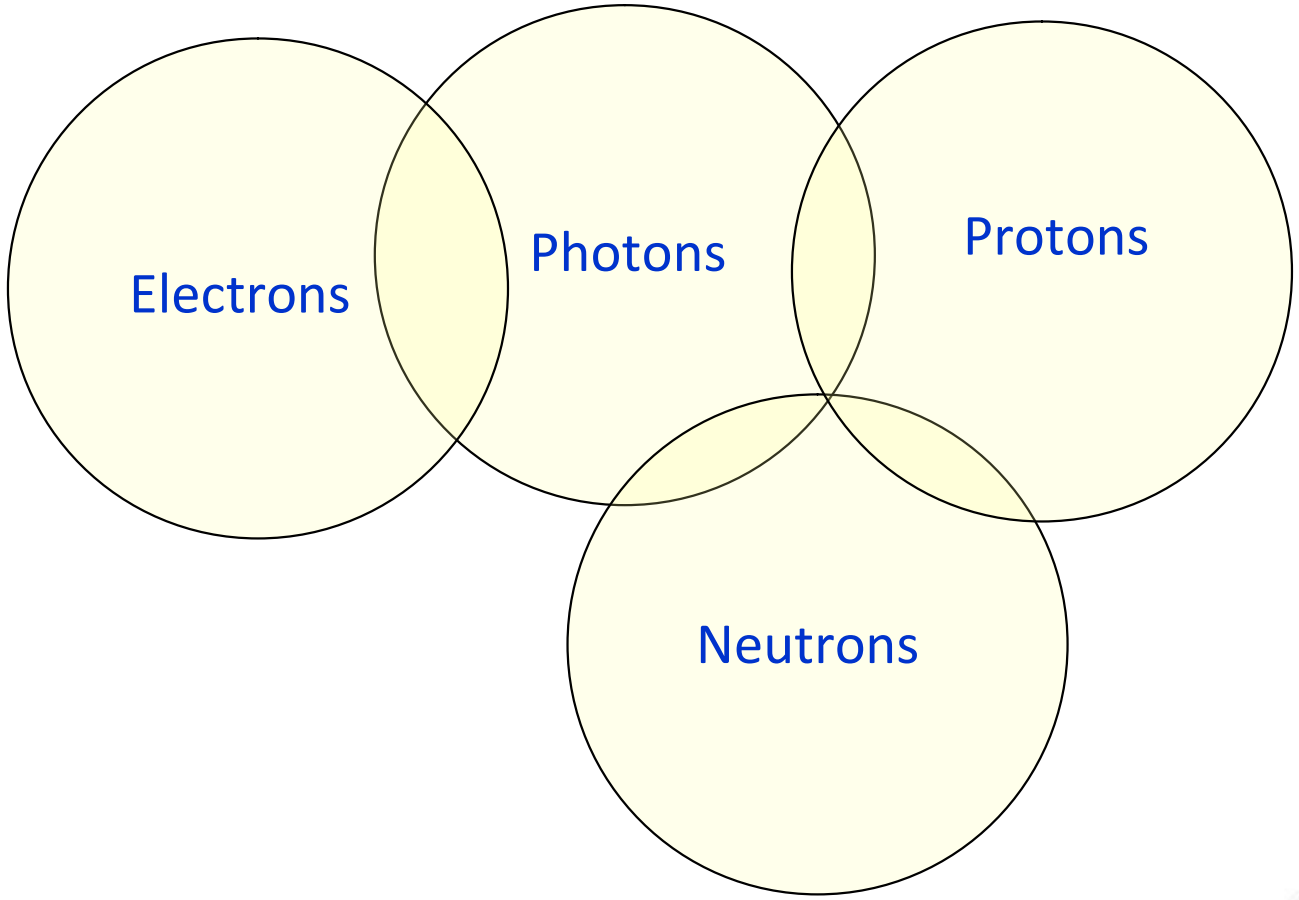
- NEXT-STEP (Neutron, Electron, X-ray, THz, Sources, Techniques & Experiments with Protons) is research infrastructure that ENEA and its partners are proposing with its unique characteristics to make particle accelerator sources and a variety of radiation sources in the wide spectral range from EUV/Soft X-rays to Terahertz available at the same site.
- NEXT-STEP proposal has been submitted for inclusion in the 2016 ESFRI Roadmap update to integrate existing photon and particle facilities in a new Research Infrastructure that provides open access to international users.
- Being mostly based on existing facilities, NEXT-STEP can become operational after a short Preparatory Phase (2016-2017).
- A two-year (2018-2019) upgrade phase is also foreseen to significantly increase the NEXT-STEP variety of instrumentation available to users and become fully operational by the beginning of 2020.

NEXT-STEP site @ Frascati

- Plasma heating & diagnostics
- Particle accelerators (protons, neutrons, electrons) for industrial and medical applications
- THz and mm-wave Free Electron Lasers (FEL)
- ABC Laser for inertial confinement fusion
- Excimer Lasers
- EUV/ Soft X-ray sources
- X-ray Microscopy
- Metrology

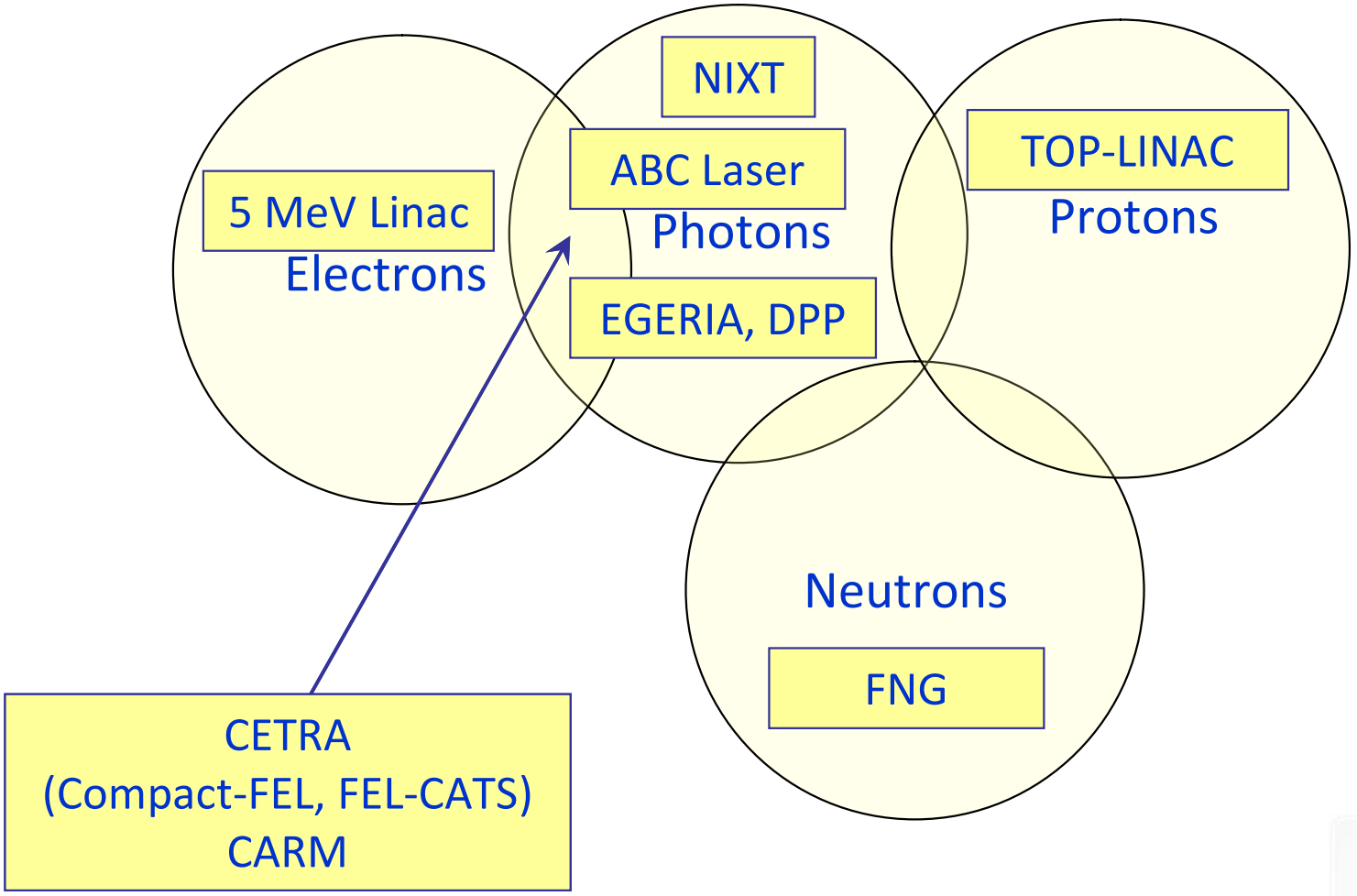
NEXT-STEP Building blocks

NEXT-STEP is conceptually based on five building blocks. These imply different analytical techniques different research areas, which overlap to provide new research tools.

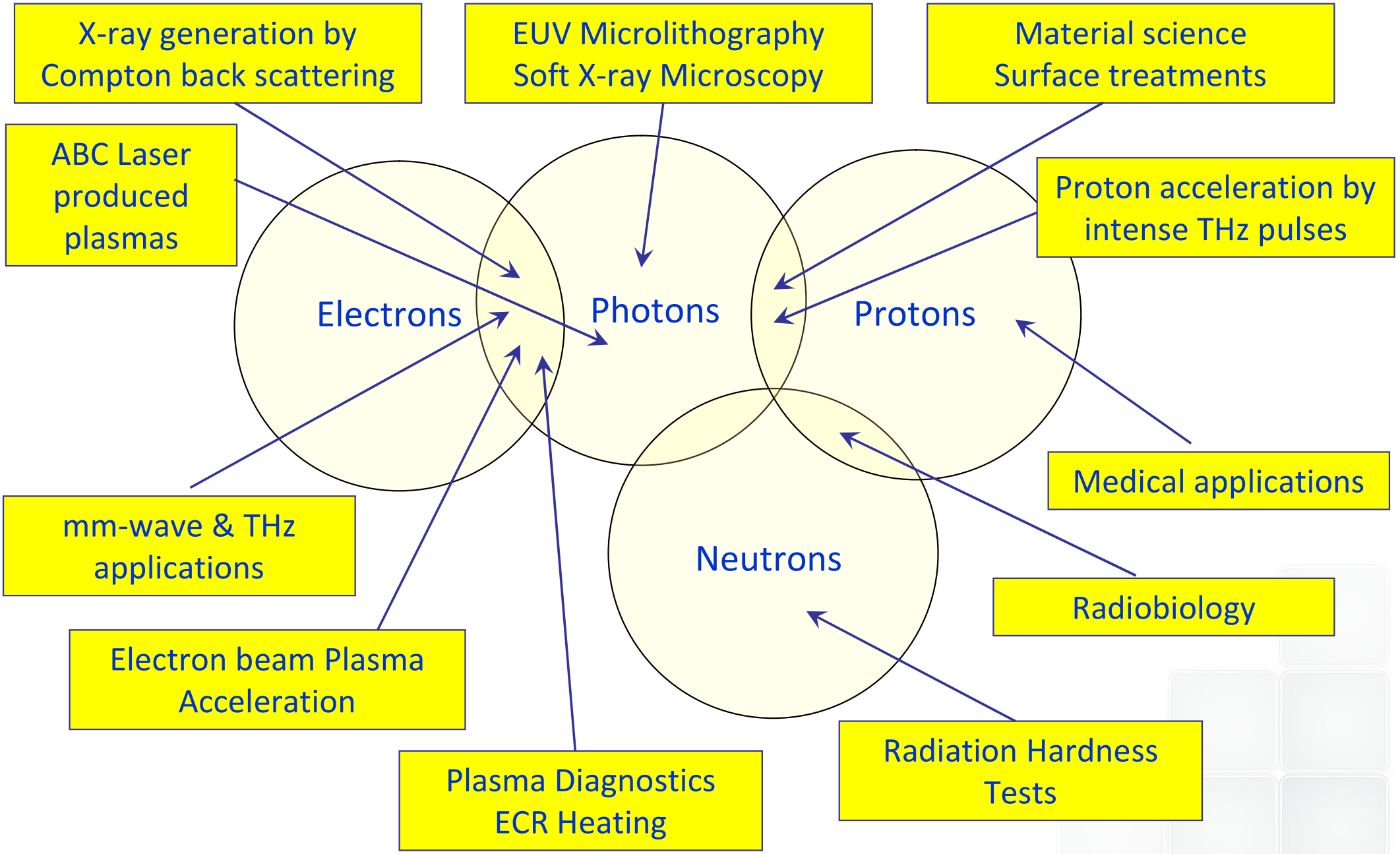


NEXT-STEP Facilities

NEXT-STEP can be seen as a series of clusters of subfacilities.

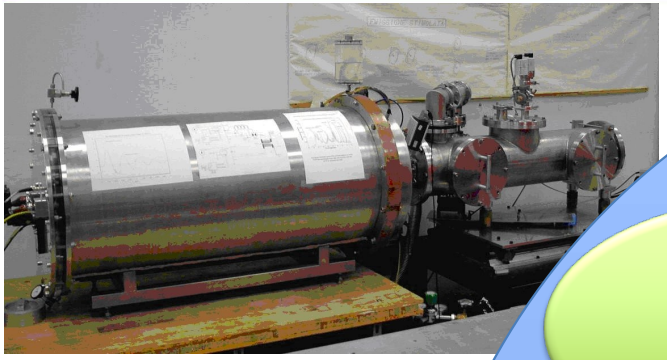


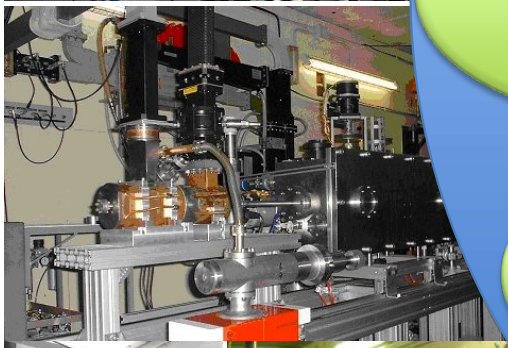
NEXT-STEP Research Areas



NEXT-STEP Facilities

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE





DPP

NIXT

ABC

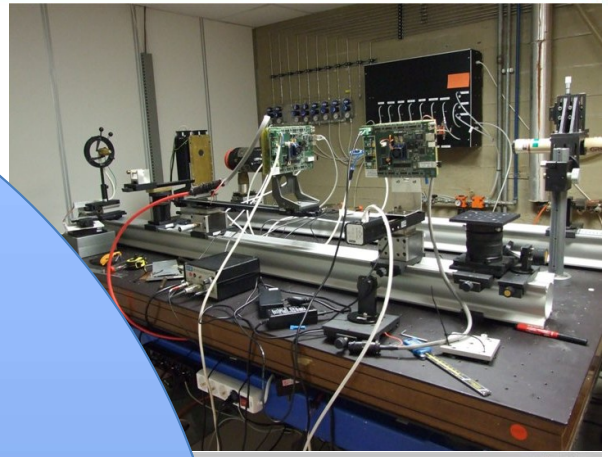
CETRA

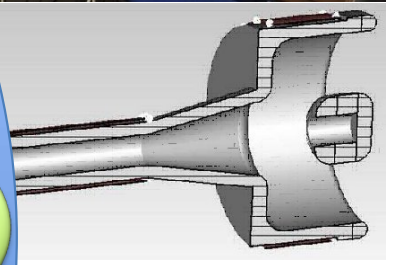
CARM

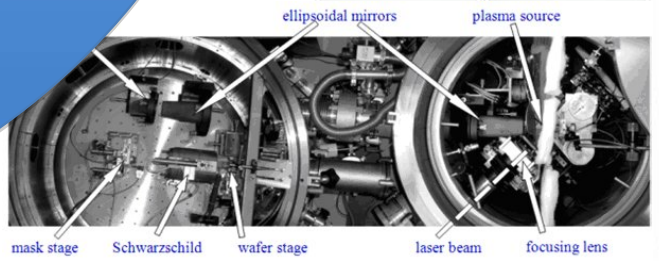
TOP

FNG

EGERIA







General description

Each existing facility and their upgrades are well positioned in the scenario of “Photon and Particle Sources” in Europe and worldwide.

They have been described in detail during the first day of RAIN15.

A few examples are given in the following slides, specifically for the neutron sources, the EUV/Soft X-ray sources, THz sources and applications.

The application areas in which NEXT-STEP considers itself unique are:

- Material science (including materials for Fusion)
- Biology and biomedical studies
- Novel imaging techniques
- Art conservation and diagnostics

Example of relative merit: the FNG facility

FNG neutron accelerator unique areas: validation of nuclear cross section database and the test and development of neutron detectors.

Fall-outs in different fields:

- ✓ Radiation hardness tests on detectors and electronics for high energy physics.
- ✓ Studies of detectors response under intense pulsed operation
- ✓ Tests of radiation hardening for fiber optics and insulators.
- ✓ Radiobiology studies.

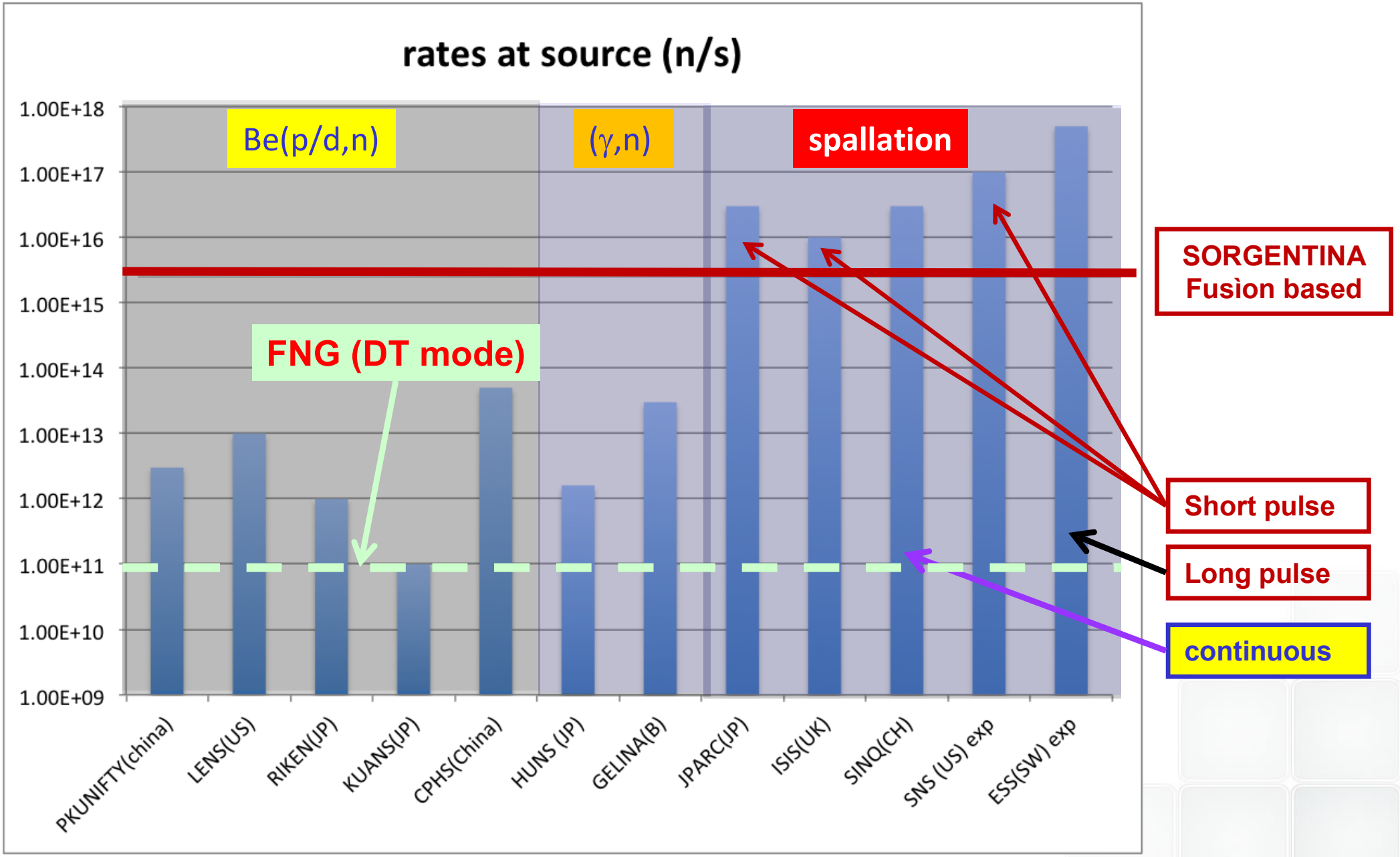
New potential users are expected from the Agenzia Spaziale Italiana (ASI) and European Space Agency (ESA -Component Space Evaluation and Radiation Effects Section)

The ESA interest pushes the full characterization of the neutron field around the neutron target. The FNG neutron energy changes with the angle, with respect to the deuteron beam direction, where the component under test is placed.

ESA is very interested in studying the response of electronics components vs. small variation of the neutron energy.

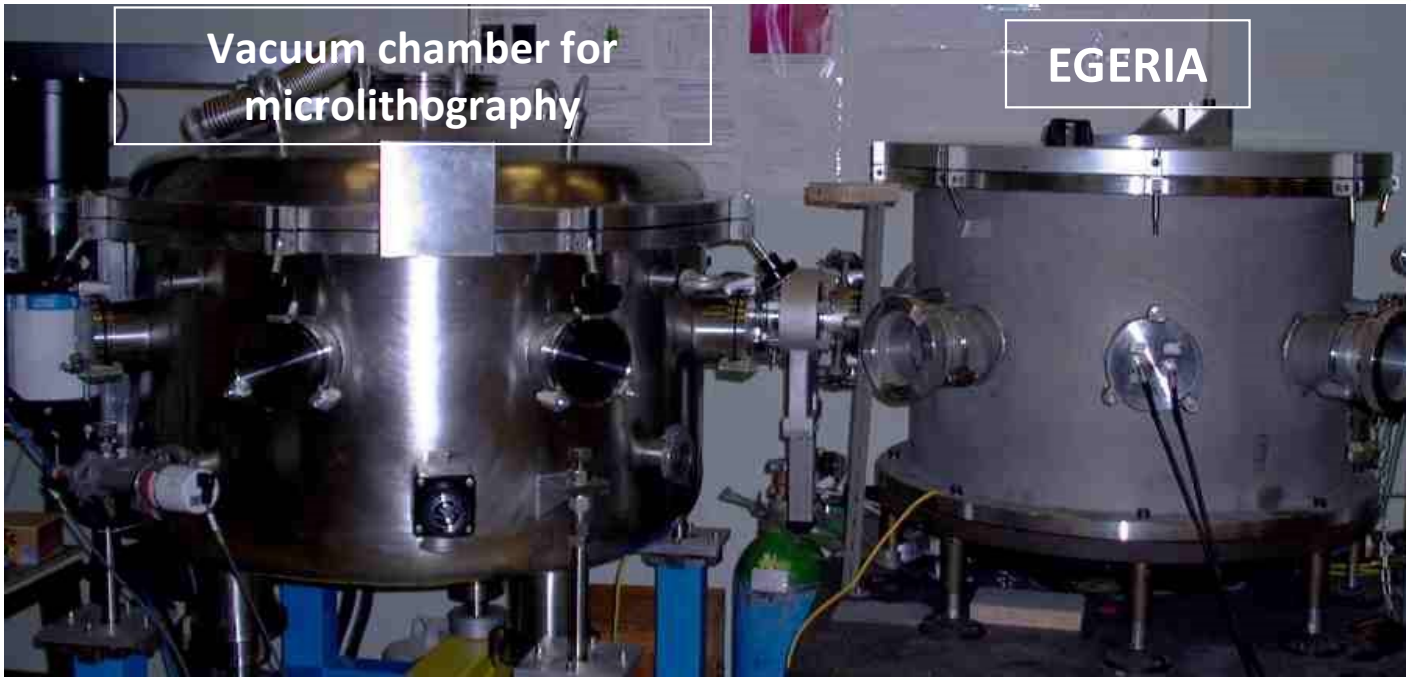
Further upgrade: possibility to operate FNG in the pulsed mode at the maximum beam intensity (300 KeV, 1mA). This requires the installation of an RF deuteron source. Potential users in high energy physics (CERN, Fermi LAB, INFN, etc.).

International scenario of neutron sources

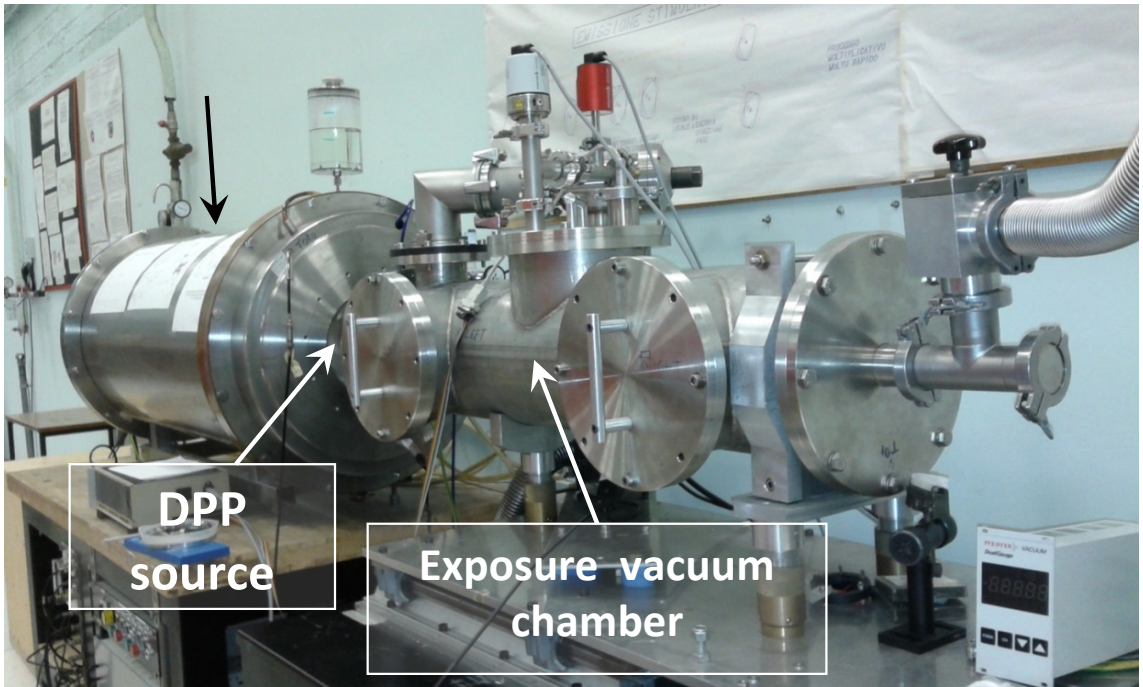


Example of relative merit:

EGERIA and DPP facilities



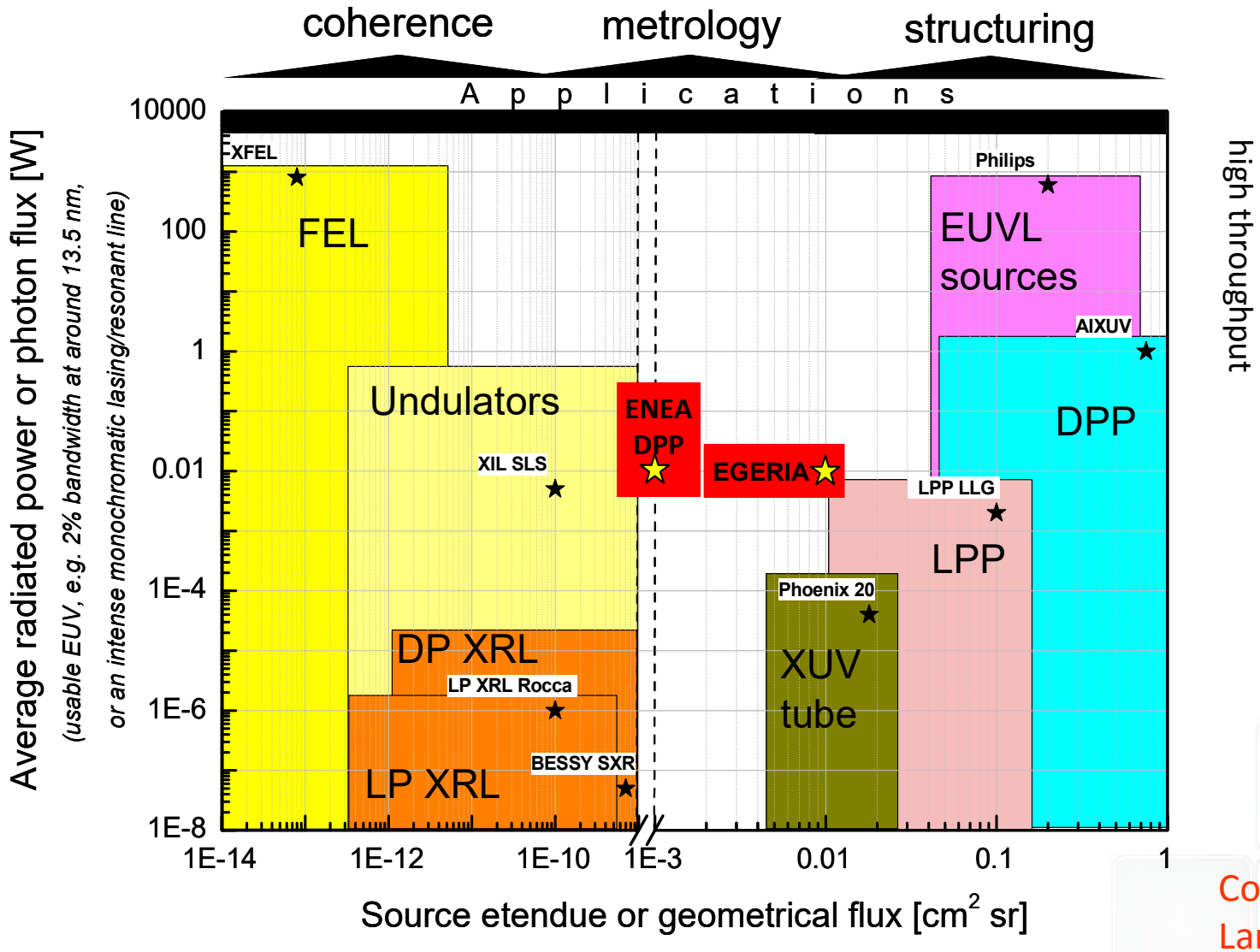
XeCl laser pulses are focused on a moving tape, where a point-like plasma is generated, emitting tunable radiation from the EUV (≈20÷250 eV) to the soft-Xrays (≈ 250÷1000 eV), depending on the laser intensity and on the target material.



EUV emission band	60 -120 eV
In-band pulse energy	20 mJ/shot/sr
EUV pulse duration	100 ns
EUV source transverse size	0.3 mm
Repetition rate	10 Hz
Energy stability	≈ 4% rms
Usable emission cone aperture	≈ 1 sr

Example of relative merit:
EGERIA and DPP facilities

State of the art of EUV different source concepts and existing sources



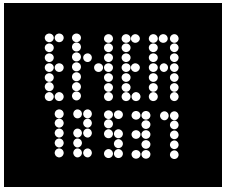
Courtesy of
Larissa Juskchin

Example: EUV applications

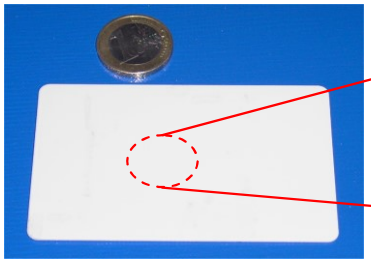
Microlithography for anticounterfeiting

La ricopertura di etichette/oggetti con film di LiF trasparenti ed il successivo irraggiamento tramite maschera con opportune dosi di radiazione EUV creano marcature invisibili che sono rivelabili solo tramite opportuna illuminazione.

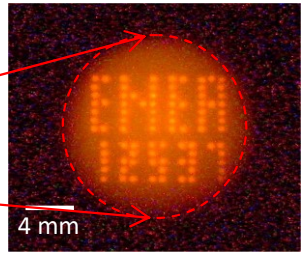
Oggetti/Documenti per l'identificazione



Mask



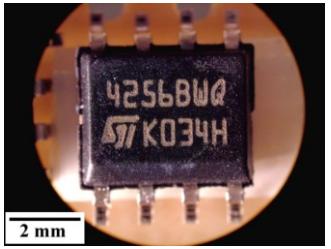
Visible light image



Fluorescent image

Componenti per microelettronica

Mask



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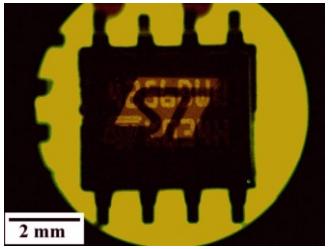


Fluorescent image

Prodotti farmaceutici

Beni di lusso

Rifiuti pericolosi

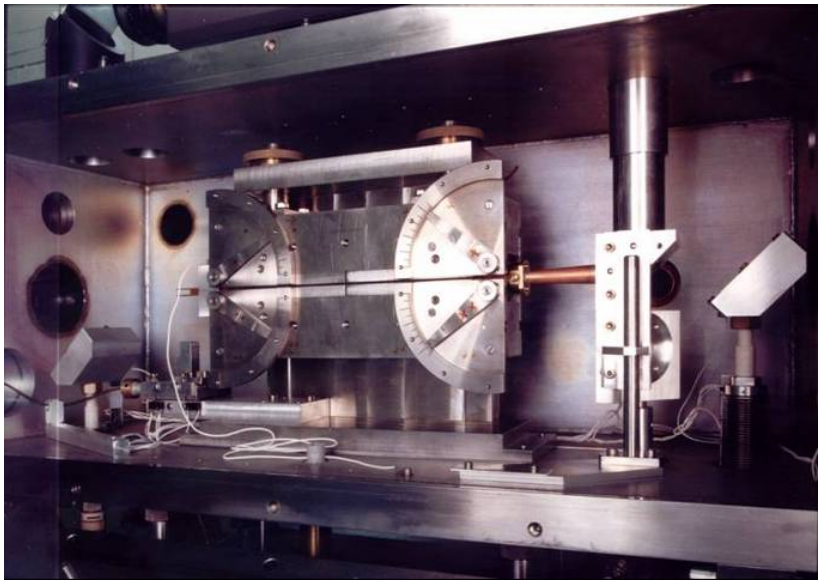
Example of relative merit:

CETRA *(Center of Excellence on THz Radiation and Applications)*

AGENZIA NAZIONALE PER LE NUOVE TECNOLOGIE, L'ENERGIA E LO SVILUPPO ECONOMICO SOSTENIBILE

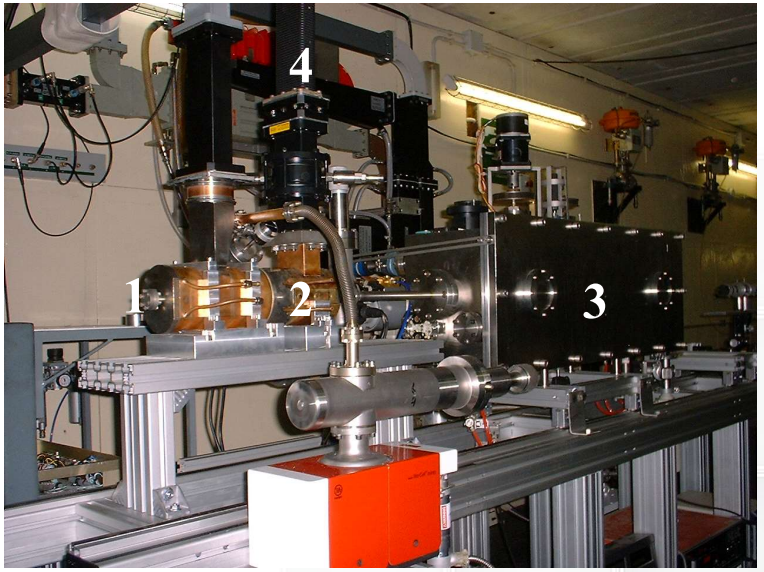
THz Compact FEL based on a Microtron accelerator

- Spectral tunability from 90 to 150 GHz changing the resonator length.
- Broad bandwidth operation
  ($\Delta\nu/\nu$=8% P = 10 kW in 60 ps,
  P = 1.5 kW in 4 μs)
- Single frequency operation
  (P= 300 W in 4 μs)

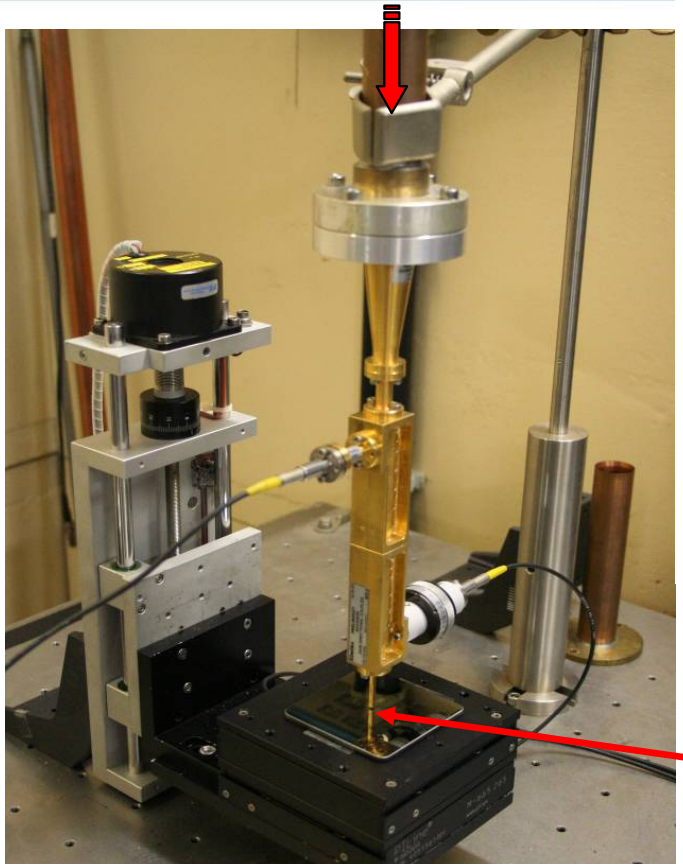


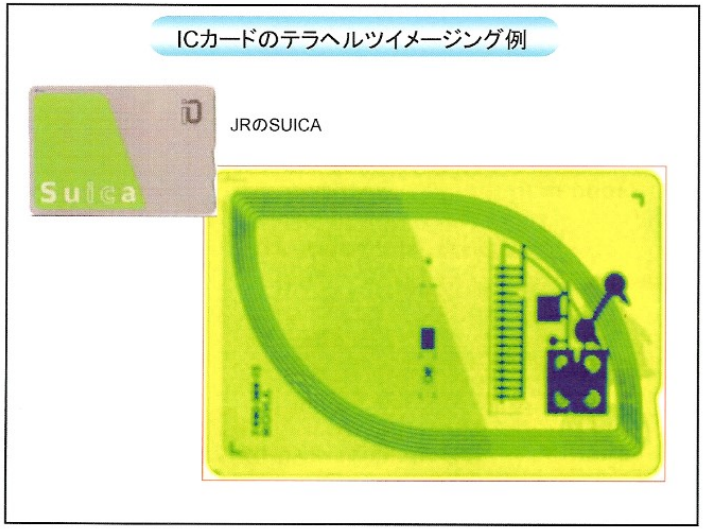
FEL-CATS (Compact Advanced THz Source)

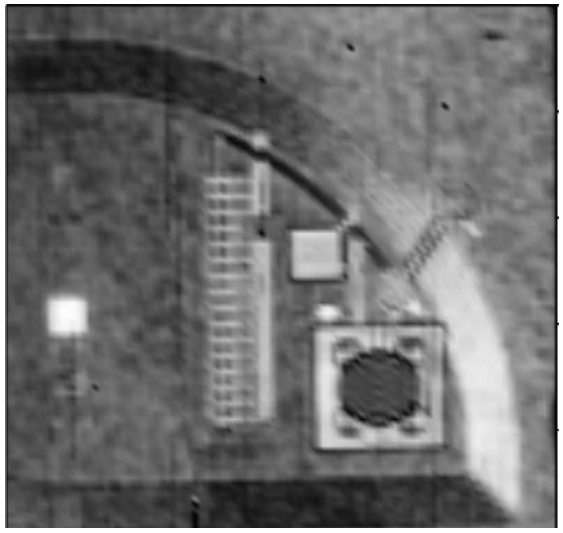
FEL-CATS exploits a new generation scheme based on coherent spontaneous emission in an undulator with a proper "energy-phase correlation" in the electron bunch.
Spectral tunability 0.7-0.4 THz (450-800 μm)
$\Delta\nu/\nu$=20% P > 10 kW in 15 ps
The device reaches saturation levels in a single passage without the use of any optical resonator.

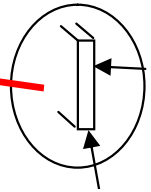


THz Imaging Applications: Environment, Cultural Heritage

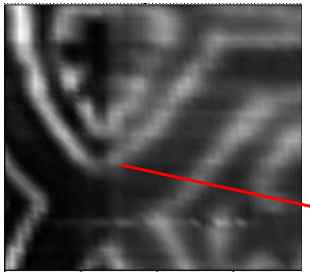


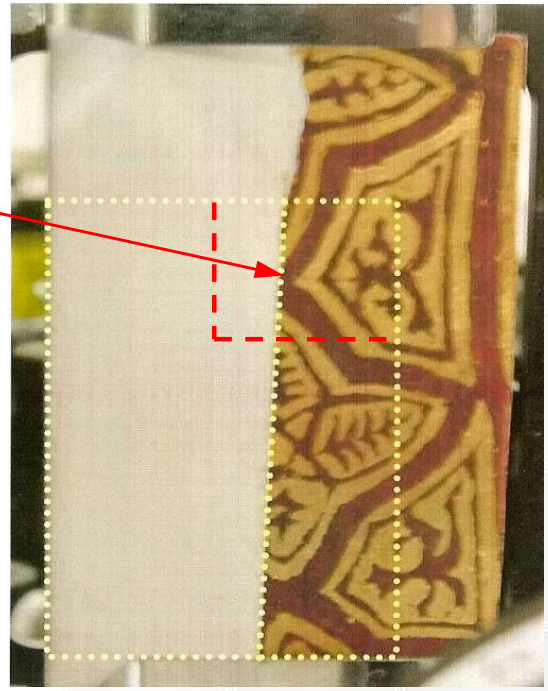


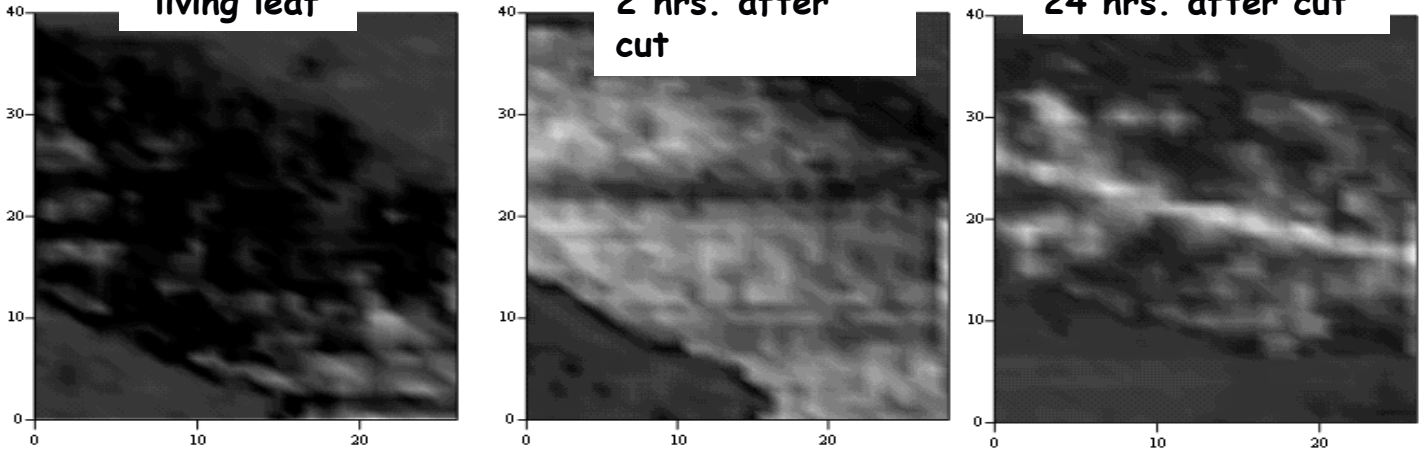




1.3 mm

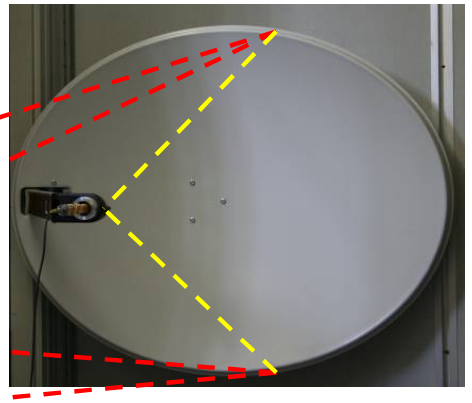


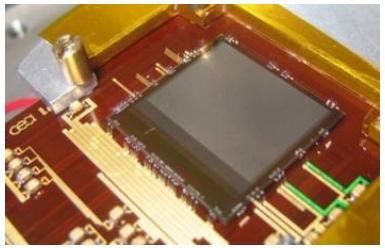


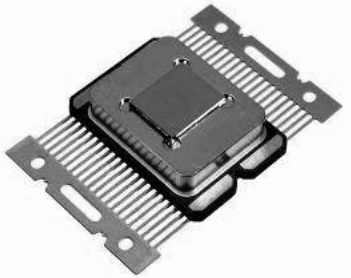


Perspective application: Active THz Imaging

High peak power source (ENEA) Multispectral sensors & cameras (CEA-LETI)







In the frame of a collaboration between ENEA-Frascati and CEA-LETI there is a strong interest in carrying on on the development of active THz imaging techniques to be applied to the surveillance of large areas exploiting the relevant expertise on:

- ✓ High power sources of THz radiation (ENEA, SAD Laboratory)
- ✓ Array of room temperature microbolometers (CEA-LETI)

Priorities & developments of THz applications

Necessità di studi sui meccanismi d'interazione con i sistemi biologici:

- ✓ Effetti di campi elettrici elevati sulle membrane cellulari
- ✓ Confronto degli effetti di campi elettrici impulsati ed impulsi elettromagnetici su membrane e cellule
- ✓ Ruolo della frequenza portante e della modulazione

Integrazione & confronto delle tecniche di THz imaging in campi interdisciplinari

Lo sviluppo di applicazioni emergenti quali:

Wireless THz

Active THz imaging

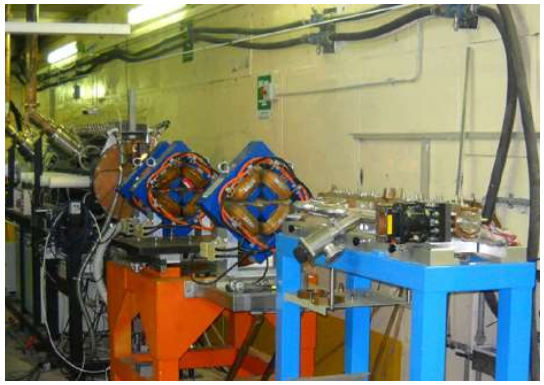
richiederano una migliore definizione delle condizioni di esposizione della popolazione

Scientific impact

- ✓ The large variety of radiation and particle sources available makes possible almost simultaneous, **multiple-source irradiation of the samples of interest** and their in-loco analysis.
- ✓ This is of particular relevance for the **test of electronic components under electron, neutron and proton irradation**. Such an interest has been expressed by the Component Space Evaluation and Radiation Effects Section of ESA.
- ✓ NEXT-STEP will encourage performing irradiation experiments at its diverse radiation sources.
- ✓ The upgrades to be performed on the individual facilities will significantly enlarge NEXT-STEP users base, giving to the scientific communities active in Physics, Biology and Material Sciences unique research opportunities.
- ✓ Users' needs are expected to be addressed during RAIN15

Socio-economic impact

- Some of the individual facilities that are part of NEXT-STEP have already paved the way for a close collaboration with the biomedical or fusion energy community and end users:



- **The Proton Source TOP-IMPLART is funded by and dedicated to hadrontherapy programs**, radiobiology studies and to the treatment of materials for specific industrial applications.
- Irradiation studies to investigate the biological effects and test plant radio-resistance are already in progress in the framework of a project funded by the Italian Spatial Agency (ASI).
- **The ABC Laser source and the Neutron source FNG already play an important role in the fusion energy community.**

Access issues

- ✓ NEXT-STEP plans to provide multidisciplinary open access to its wide-range facilities in ionizing particles and radiation sources as diagnostic tools.
- ✓ At present each of the NEXT-STEP facilities approximately provides an average of **250 hours/year** for external collaboration experiments for a total of over **1500 hours/year** for the whole infrastructure.
- ✓ It is expected that the recognition by ESFRI of NEXT-STEP as European RI and the developments to be undertaken during the Preparatory Phase and the Implementation & Upgrade Phase will increase this number by a factor 3-4 leading to a a total of over **6000 hours/year** .
- ✓ For some applications NEXT-STEP will also offer more realistic **'production-like'** sample environment, like many companies wish. As an example, in the case of the DPP source, prototyping environments for anti-counterfeiting tags have been designed as well as set up after a company interest.
- ✓ Collaboration Agreements and Non Disclosure Agreement will be implemented with private enterprises interested in the exploitation of techniques for specific industrial applications

From a national toward a pan-European Research Infrastructure

The individual facilities that are part of NEXT-STEP already operate in the frame of international collaborations. These links will increase the scientific potential of NEXT-STEP and expand its collaborations network:

- ✓ ABC Laser and the EUV/Soft X-ray sources link to INFN-LNF Frascati, Sapienza University of Rome the University of Pisa, University of Catania on the ELI-NP initiative;
- ✓ The link to to the project HILASE on high power diode pumped lasers;
- ✓ CETRA link to INFN-LNF Frascati, FERMI @ Elettra and more generally to the FELs of Europe;
- ✓ Partnership with the Clarendon Laboratory, Oxford University (UK), MoU on THz Spectroscopy with a focus on fusion plasma diagnostics;
- ✓ The link to ESA, ASI and INAF for the characterization of space materials;
- ✓ The presence of the FNG neutron source on the NEA Research and Test Facilities DataBase (RTFDB) http://www.nea.fr/rtfdb/

Partnership strategy

- ✓ NEXT-STEP intends to take on board other national and international partners besides the founding partners.
- ✓ An analysis of Governance and Partnership Extension Rules will be one of the task of the Preparatory Phase (PP) of the project to be conducted during 2016-2017.
- ✓ Starting points will be the existing international collaborations of the various facilities and the expressions of interest we already received in setting up the proposal for the ESFRI Roadmap:

  Clarendon Lab Oxford UK, SNU Korea

  EOI by: **IAP Nizhny Novgorod, CEA-LETI**

- ✓ Definition and Approval of Staff Exchange programs between the NEXT-STEP partners will also be defined during the PP.
- ✓ The input and feedback by the NEXT-STEP partners and by the Scientific Advisory Board will significantly contribute to internationalize the user community.

How to proceed

If included in the ESFRI Roadmap update NEXT-STEP would be ready to apply to the Preparatory Phase call for proposal INFRADEV-2-2016 with a project total cost of about 7 M€ (of which 3 M€ requested EU contribution)

Type of Call	Call ID	Opening date (provisional)	Closing date (provisional)	Budget 2016 M€	Budget 2017 M€
Design Studies	INFRADEV-1-2017	01/12/2016	29/03/2017		20.00
Preparatory Phase of ESFRI Projects	INFRADEV-2-2016	10/12/2015	30/03/2016	40.00	
Individual support to ESFRI projects	INFRADEV-3-2016/2017	10/12/2015	30/03/2016	30.00	40.00
Towards a European Research and Science Cloud	INFRADEV-4-2016	22/03/2016	22/06/2016	10.00	

The Design Study of the NEXT-STEP infrastructure will be delivered by the end of 2015 to be included as an Annex to the Preparatory Phase proposal

Implementation aspects

- ✓ Two Italian Ministries (University and Scientific Research, Economic Development) already expressed their support to the NEXT-STEP proposal and their commitment in an investment plan to fund the proposed upgrade and contribute to the running costs.
- ✓ The TOP-IMPLART project, is currently funded by the Regione Lazio (**4.5 M€ already assigned + 6.5M€ expected to be allocated in 2016**). The collaboration involves a validation institution (the Italian National Health Institute - ISS) and Rome oncology main hospital - IFO-IRE as stakeholders.
- ✓ Stakeholders from large industries and SMEs are expected to be interested in specific applications of the diagnostic techniques developed at NEXT-STEP for material characterization and processing.
- ✓ the activities to be carried out at NEXT-STEP are included in the **Smart Strategy specialisation of the Regione Lazio**. In particular **applications in Life Sciences and in Cultural Heritage are included in S3 Priorities** as Encoded in the "Eye@RIS3" Tool
- ✓ Is it planned to use the **EFSI funds** for the construction of the infrastructure. **On July 17, 2015 ENEA has confirmed such intention to the Italian Ministry of University and Scientific Research** in reply to a request for inclusion of the NEXT-STEP initiative in an investment plan to be covered through EFSI funds.
- ✓ The requested amount for is 2 M€ in 2016-2017 and 7 M€ in 2018-2019

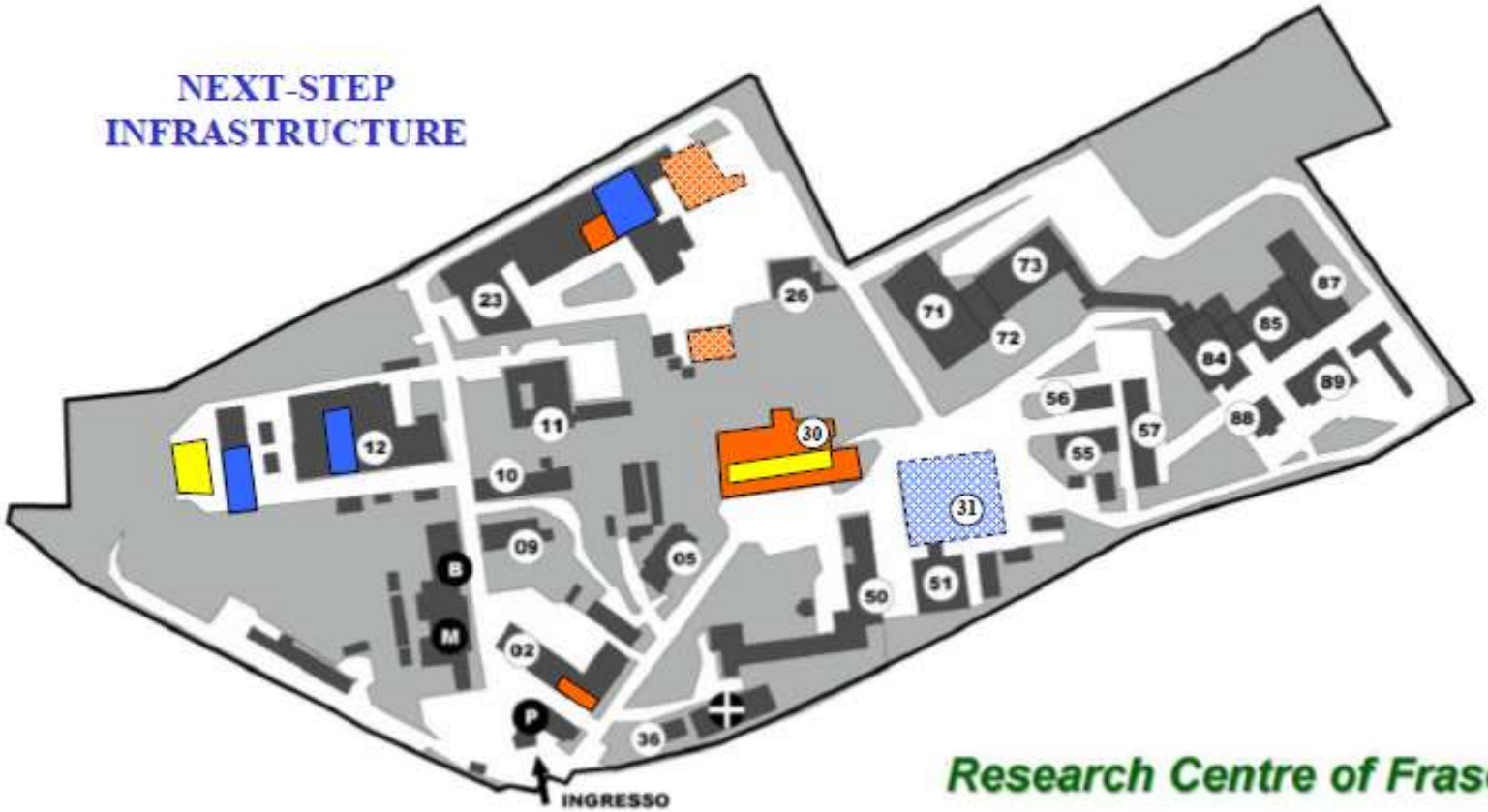
NEXT-STEP Upgrade costs

	NEXT-STEP Current Status (existing equipment M€)	Budgetary information: Preparatory Phase (M€)	Implementation & Upgrade Phase (M€)	TOTAL COST NEXT-STEP (M€)	Operation cost (M€/yr)	Decommissioning cost (total in M€)
ABC Laser	7,50	0,10	3,50	3,60	0,40	
EGERIA	2,00	0,80	3,80	4,60	0,20	
DPP	0,50	0,50	1,50	2,00	0,10	
NIXT	0,50	0,10	0,20	0,30	0,05	
CETRA	2,00	1,00	3,00	4,00	0,20	
FELs-CARM	2,00	0,20	5,00	5,20	0,20	
FNG	3,00	0,10	0,50	0,60	0,20	
TOP-IMPLART	4,50	0,50	7,00	7,50	0,15	
Buildings	10,00	1,00	5,00	6,00	0,20	
TOTAL	**32,00**	**4,30**	**29,50**	**65,80**	**1,70**	
Access to NEXT-STEP		0,10	0,50	0,60	0,30	
Support to users		0,10	0,50	0,60	0,50	
Personnel costs*		2,00	5,00	7,00	2,00	
Management		0,50	0,50	1,00	0,20	
	TOTAL	**7,00**	**36,00**	**75,00**	**4,70**	
		(of which likely to be obtained by possible stakeholders): M€	(of which likely to be obtained by possible stakeholders): M€	(of which likely to be obtained by possible stakeholders): M€	(of which likely to be obtained by possible stakeholders): M€	Long term facilities services. Decommisioning not yet foreseen.
		4,00	14,50	18,50		
		2 M€ of personnel costs covered by the project partners and 2 M€ to be obtained by national funds	2 M€ of personnel costs covered by the project partners, 6.5 M€ allocated by Regional Funds and 3 M€ to be allocated by ENEA			

* Allocated by NEXT-STEP partners

Timetable until operation				
Preparatory Phase	Upgrade Phase		Operation	Decommissioning
2016- 2017	**2018-2019**		**2020**	N/A

NEXT-STEP Site details



Infrared and Terahertz Facilities (CETRA)

EUV/Soft X-ray Facilities (ABC, EGERIA, DPP, NIXT)

Hadron Facilities (FNG, TOP-IMPLART)

Expansion area (CETRA, 250 GHz CARM)

Expansion area (Tech. Support & SMEs floor space)

Further partnership

Acknowledgements & Contributors

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