EUROPEAN PLASMA RESEARCH ACCELERATOR WITH EXCELLENCE IN APPLICATIONS

EuPRAXIA

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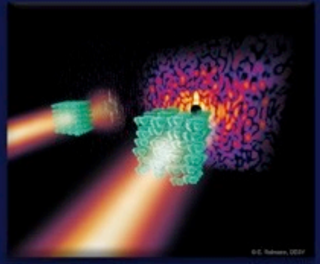
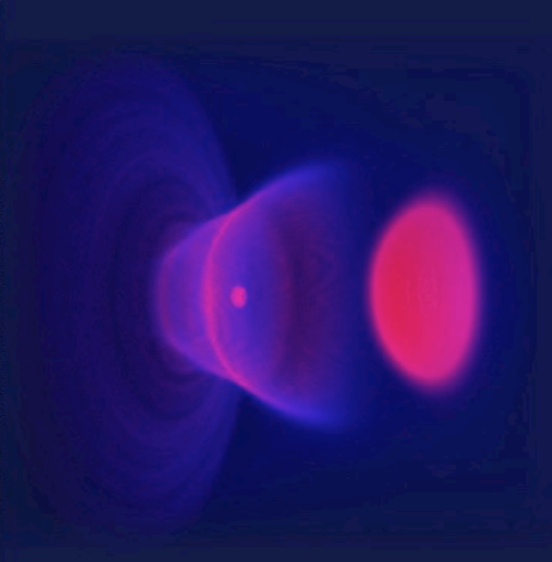
(INFN and DESY)

EuroNNAc Special Topics Workshop, Elba, Italy

21 September 2022





This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653782.

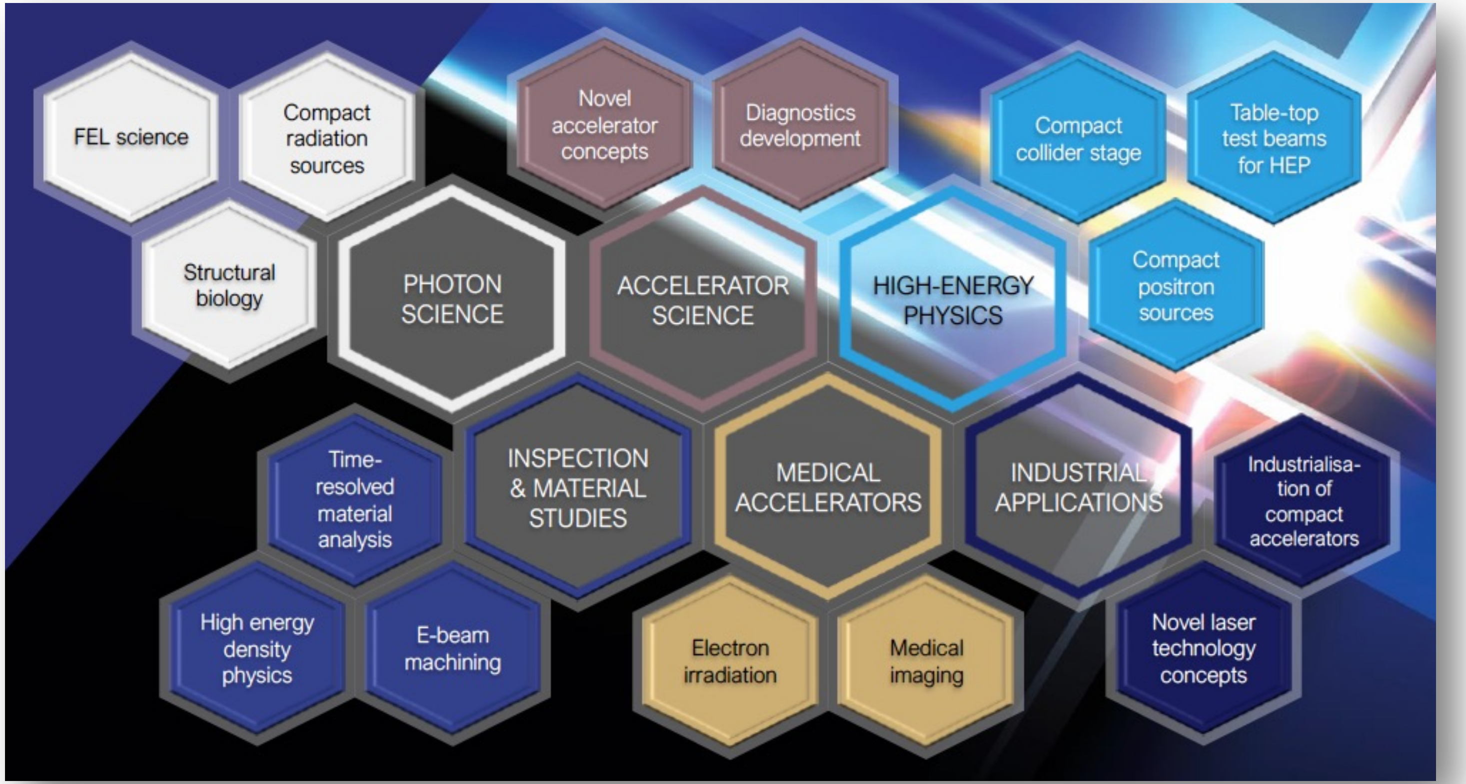
The EuPRAXIA Project

http://www.eupraxia-project.eu/

- First ever design of a **plasma accelerator facility**.
- **Conceptual Design Report for a distributed research infrastructure** funded by EU Horizon2020 program. Completed by 16+25 institutes.
- Challenges addressed by EuPRAXIA since 2015:
  - **Can plasma accelerators produce usable electron beams**?
  - **For what can we use those beams** while we increase the beam energy towards HEP and collider usages?
- Next phase consortium: **> 50 institutes**
- Preparatory Phase project: **1 Nov 2022 – 31 Oct 2026**
- Start of 1st operation: **2028**

600+ page CDR, 240 scientists contributed

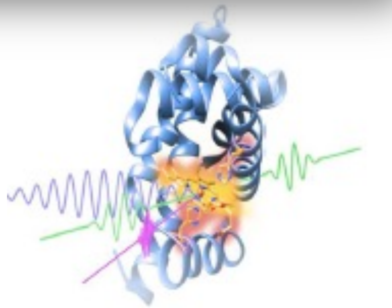
Versatile – Designed for Users in Multiple Science Fields



Delivers 10-100 Hz ultra-short pulses

- **Electrons** (0.1-5 GeV, 30 pC)
- **Positrons** (0.5-10 MeV, 10^6)
- **Positrons** (GeV source)
- **Lasers** (100 J, 50 fs, 10-100 Hz)
- **Betatron X rays** (1-110 keV, 10^{10})
- **FEL light** (0.2-36 nm, 10^9-10^{13})

Topics of research: proteins, viruses, bacteria, cells, metals, semiconductors, superconductors, magnetic materials, organic molecules



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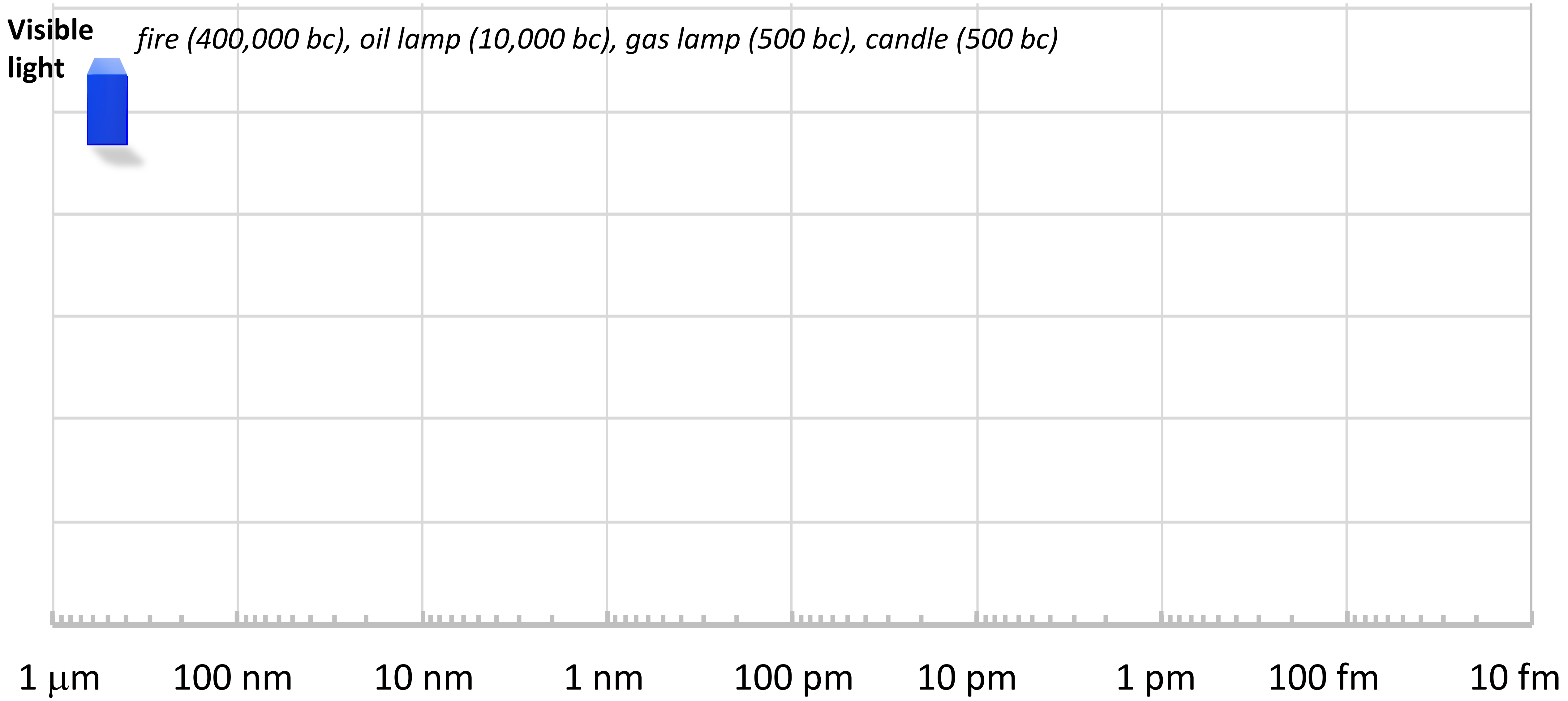
Human-made Sources of Light

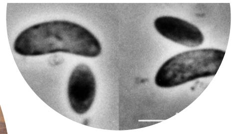


Human-made Sources of Light

Horizon Europe

Visible light

fire (400,000 bc), oil lamp (10,000 bc), gas lamp (500 bc), candle (500 bc)

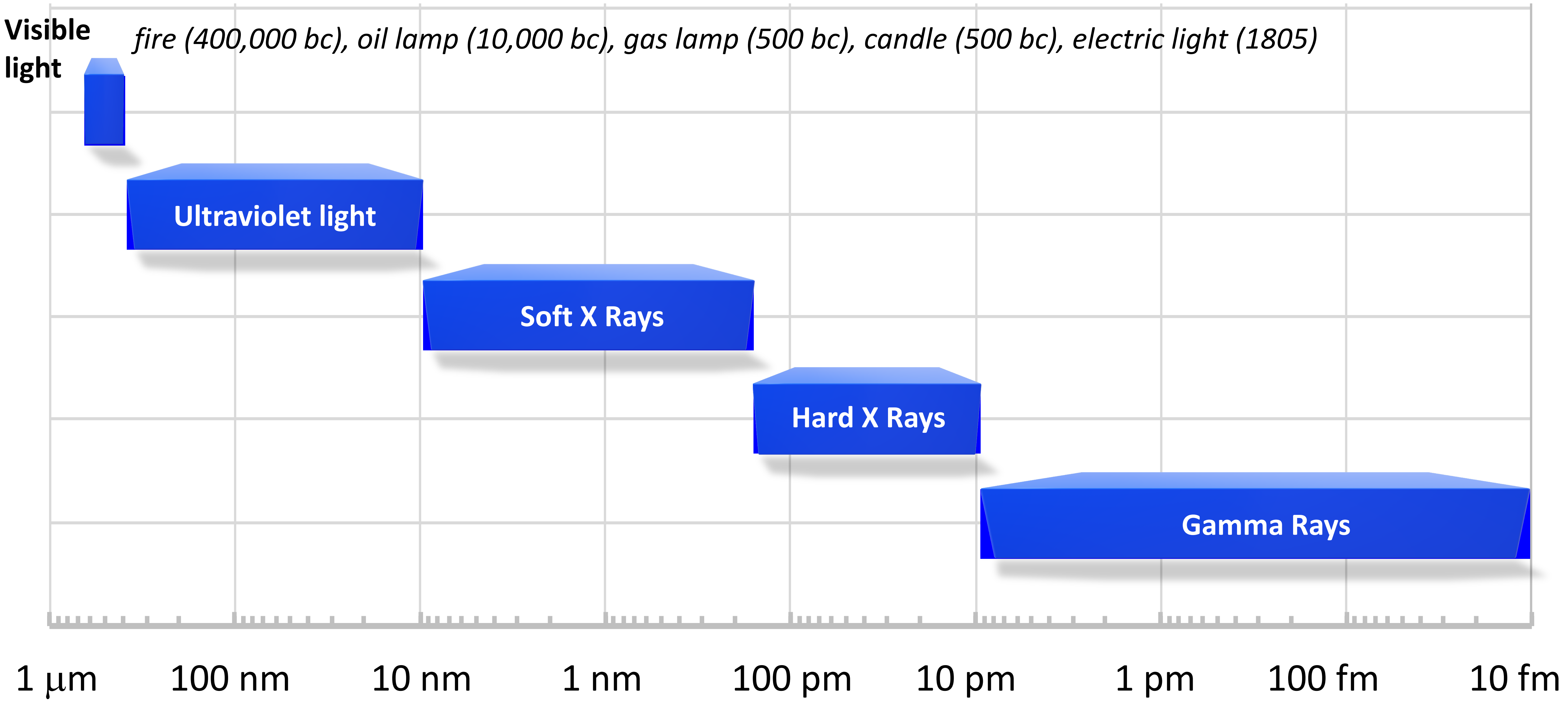


Anthonie van Leeuwenhoek (1632-1723)

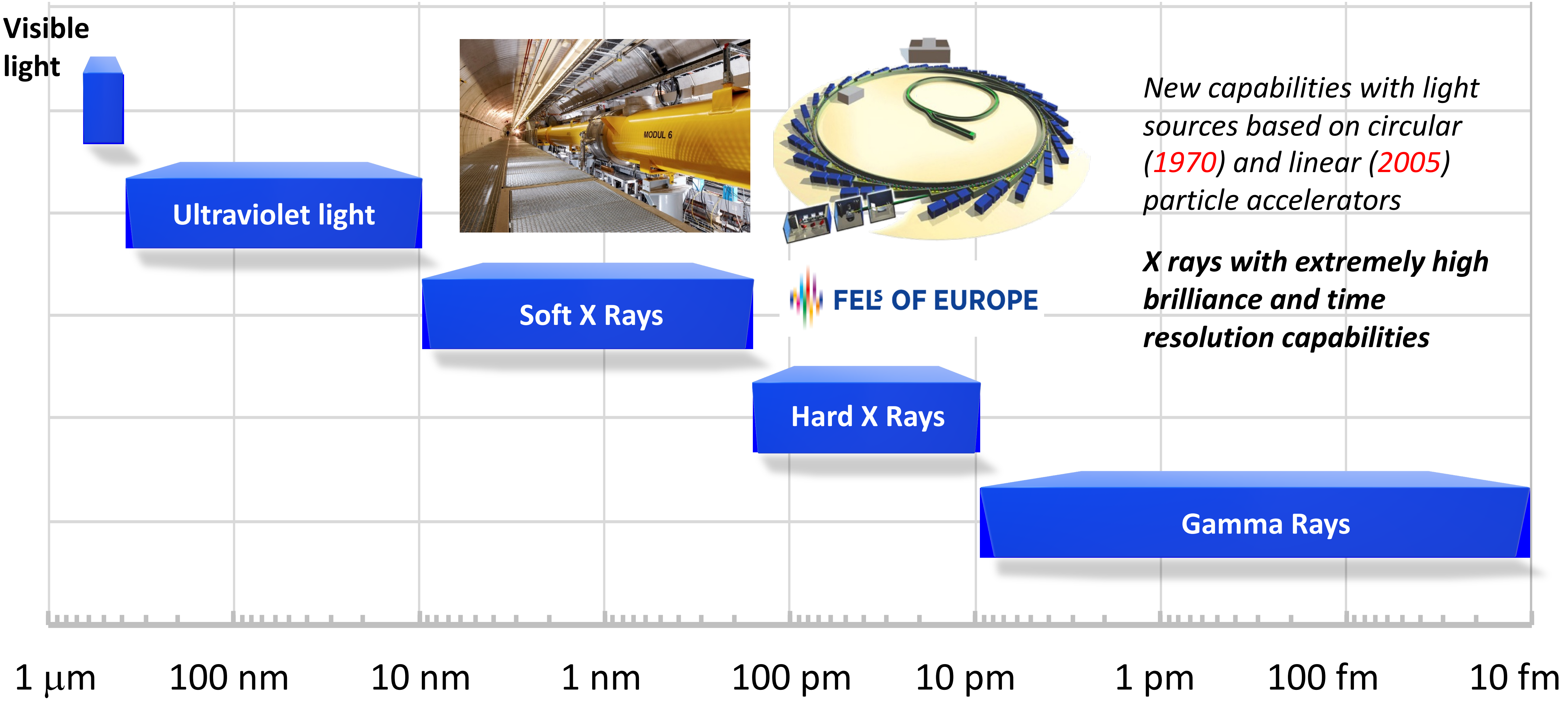
Candle light plus improved microscope → Leeuwenhoek discovered the **bacteria** (large Selenomonads from the human mouth) in 1683

1 μm   100 nm   10 nm   1 nm   100 pm   10 pm   1 pm   100 fm   10 fm

Human-made Sources of Light



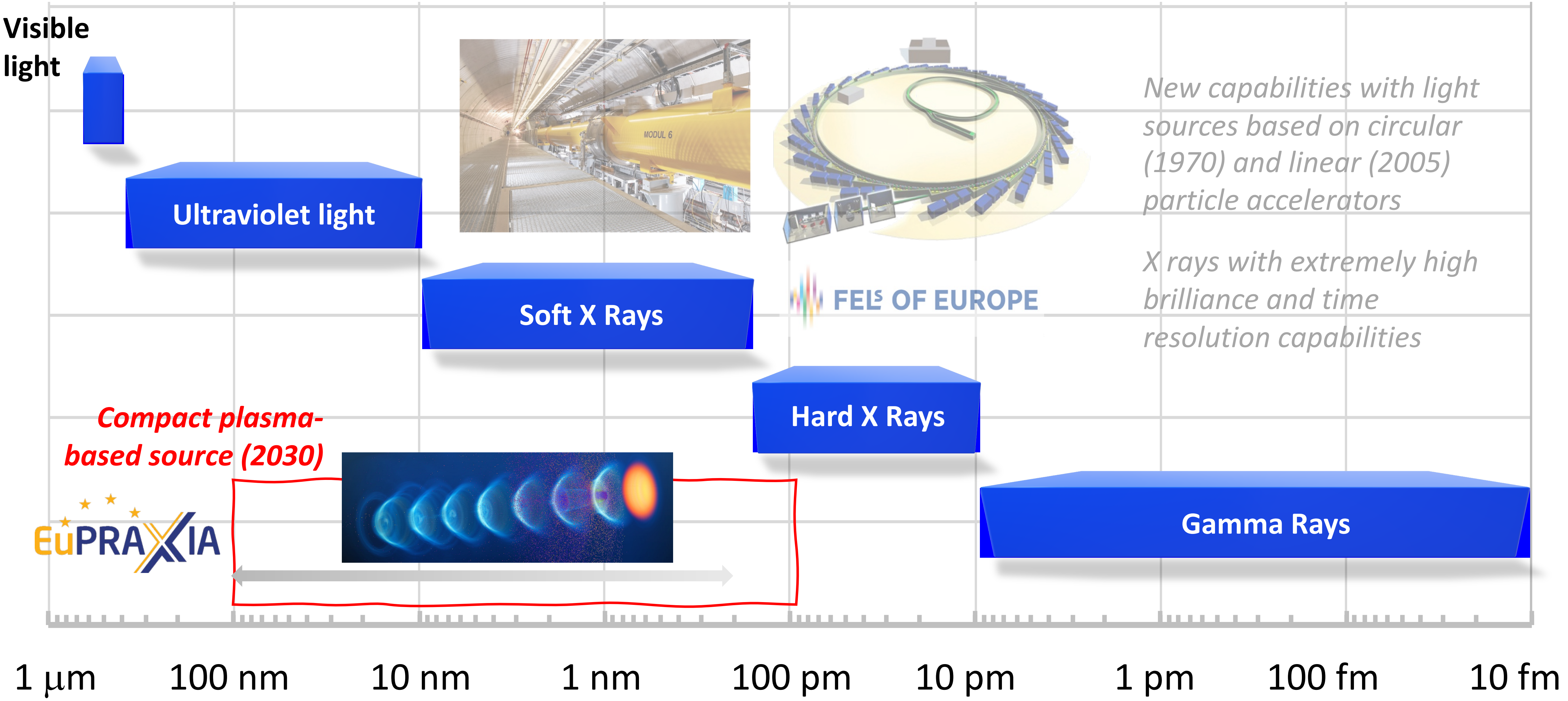
Human-made Sources of Light



New capabilities with light sources based on circular (1970) and linear (2005) particle accelerators

X rays with extremely high brilliance and time resolution capabilities

Human-made Sources of Light



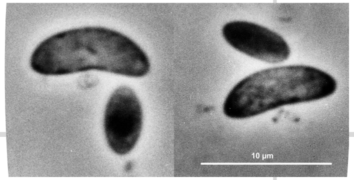
Why Additional Compact Light Sources?

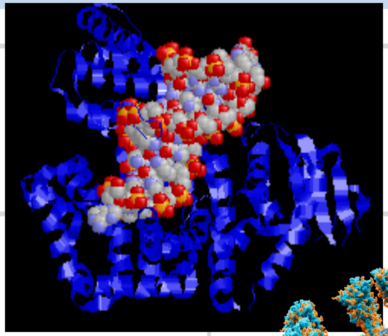
at the moment less powerful than the big machines

Horizon Europe

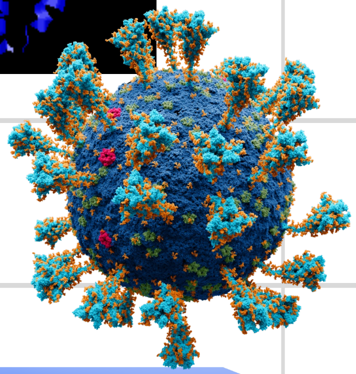
Visible light

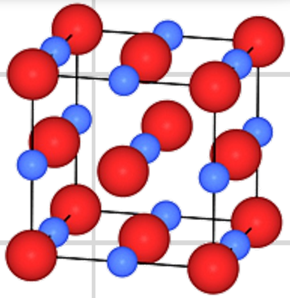
Ultraviolet light





Soft X Rays





Hard X Rays

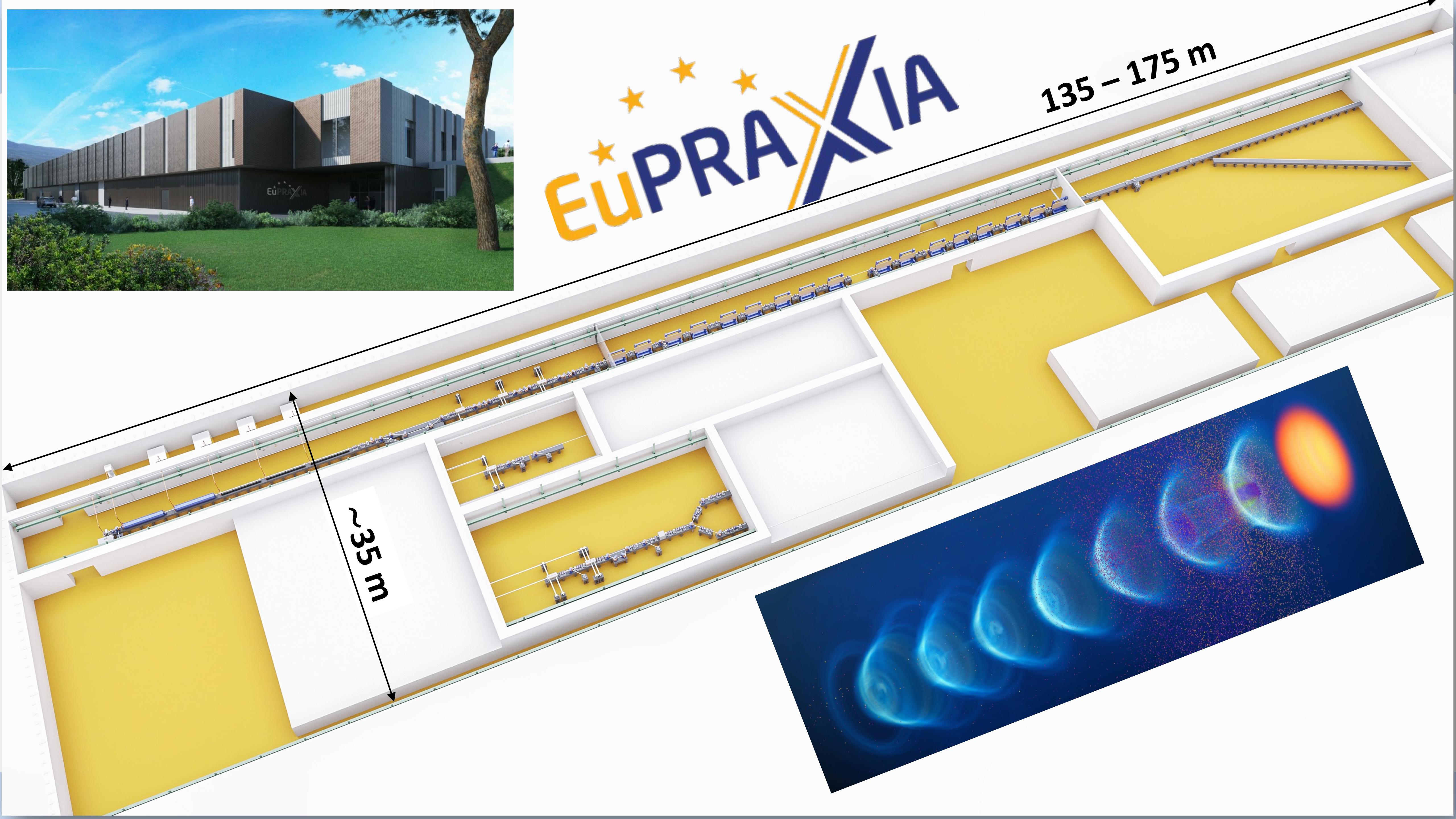
Gamma Rays

EuPRAXIA

1 µm | 100 nm | 10 nm | 1 nm | 100 pm | 10 pm | 1 pm | 100 fm | 10 fm

Practically unlimited number of study objects with potentially high impact on our lives:

- About **320,000 unknown viruses** that infect mammals
- There may be a **million bacterial species in 30 grams** of rich soil in Norway
- **Need for access** and screening time – work for students at many universities


EuPRAXIA
135 – 175 m
~35 m

EuPRAXIA Facility Size: C O M P A C T

Horizon Europe

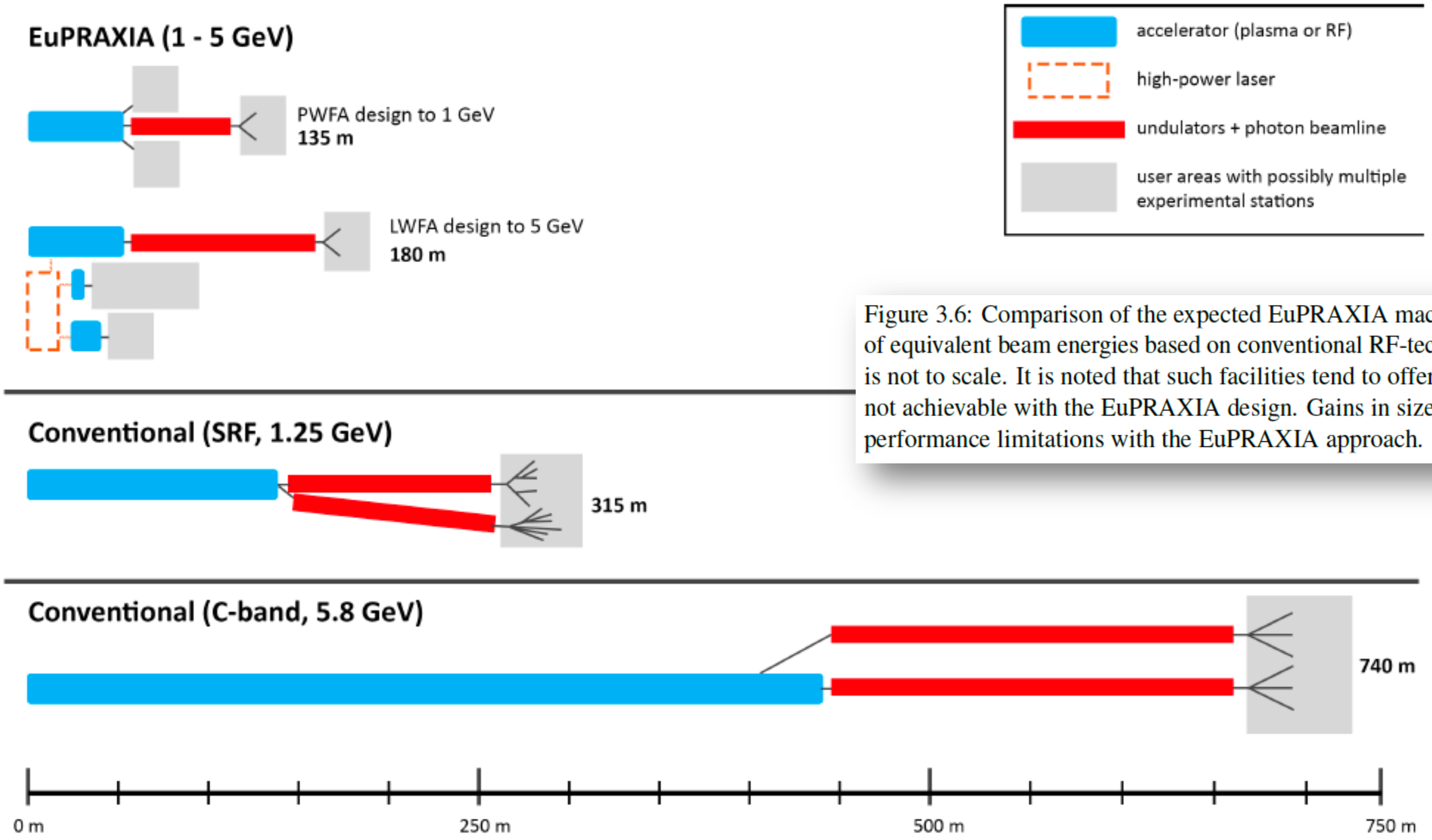


Figure 3.6: Comparison of the expected EuPRAXIA machine length with parameters for facilities of equivalent beam energies based on conventional RF-technologies [152, 153]. The transverse size is not to scale. It is noted that such facilities tend to offer FEL performance parameters which are not achievable with the EuPRAXIA design. Gains in size must therefore be put into the context of performance limitations with the EuPRAXIA approach.


EMERGENCY
OFF
EuPRAXIA
IMPORTANT: EuPRAXIA design includes
lab space, RF injectors, transfer lines, undulator lines, shielding, ...

Schemes and their Building Blocks

Laser Plasma Injector

Figure 23.4: Scheme 1 using a single-stage injector / accelerator generating an FEL-quality 5 GeV beam.

Laser-driven Plasma Accelerator Section

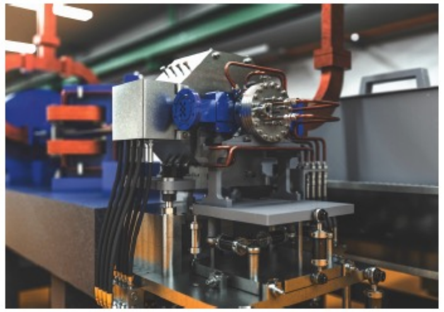
Figure 23.14: Scheme 2 combining a 150 MeV laser-plasma injector with an LPAS to 5 GeV.

RF Injector

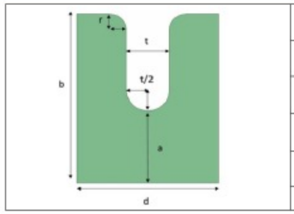
Figure 23.24: Scheme 3 combining a 500 MeV RF injector with an LPAS to 5 GeV.

Particle-driven Plasma Accelerator Section

Figure 23.40: Scheme 5 combining a 500 MeV RF injector with a PPAS to 1 GeV.



Electron Driver: X Band RF Linac



Geometrical parameters	
a[mm]	2 ÷ 5
b [mm]	9.828 ÷ 10.917
d [mm]	8,332 (2π/3 mode)
r [mm]	1
t [mm]	2.5

Figure 12.7: Basic EuPRAXIA X-band accelerating cell.

Accelerating section parameter	Symbol	Unit	Value
Average iris radius	$\langle a \rangle$	mm	3.2
Structure length	L_s	mm	500
Quality factor	Q		6400
Normalised group velocity	v_g/c	%	2.5 – 0.77
Filling time	τ_F	ns	121
Number of cells	N_c	-	60
Average shunt impedance per unit length	$\langle R \rangle$	MΩ m^{-1}	90
Effective shunt impedance per unit length	R_s	MΩ m^{-1}	330

Table 12.6: Characteristics of the EuPRAXIA constant gradient accelerating section.

	Parameter	Unit	Value	
N_s	Number of sections		16 (2 modules x 8 sections)	
P_k	RF power available per klystron	MW	50 (at klystron output couplers) 40 (at section input couplers)	
			PWFA – LWFA	Ultimate
$\langle E_{acc} \rangle$	Max. average gradient	MV/m	57	80
P_{RF}	Total RF power required	MW	79	155
N_k	Number of klystrons		2 (reduced power)	4 (full power)

Table 12.7: Main parameters of the X-band linac RF system for different scenarios: injection in the plasma (LPWA – PWFA) and ultimate performance.

Laser-Driver Chain

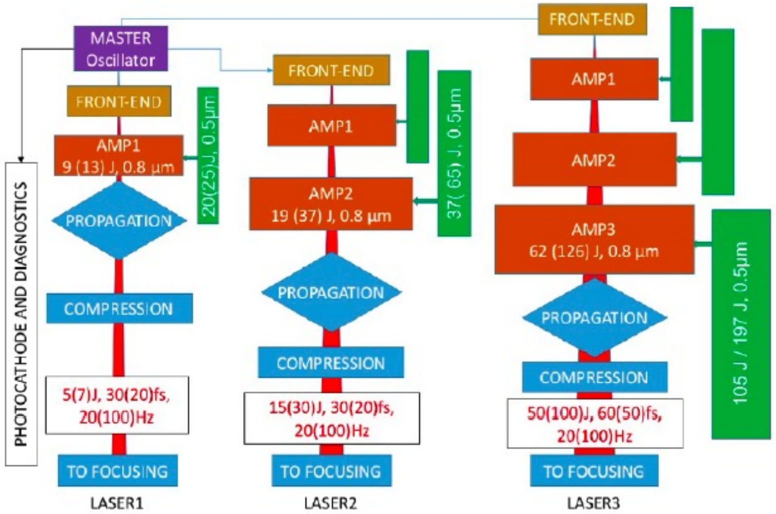


Figure 10.1: Block diagram of the three laser driver chains.

LASER1 - Injector 150 MeV			
Parameter	Unit	P0	P1
Wavelength	nm	800	800
Max Energy on Target	J	5	7
Max Total Output Energy	J	8.8	12.5
Shortest Pulse Duration	fs	30	20
Repetition Rate	Hz	20	100
Energy Stability RMS	%	1	0.6
LASER2 - Injector 1 GeV			
Parameter	Unit	P0	P1
Wavelength	nm	800	800
Max Energy on Target	J	15	30
Max Total Output Energy	J	18.8	37.5
Shortest Pulse Duration	fs	30	20
Repetition Rate	Hz	20	100
Energy Stability RMS	%	1	0.6
LASER3 - Accelerator 5 GeV			
Parameter	Unit	P0	P1
Wavelength	nm	800	800
Max Energy on Target	J	50	100
Max Total Output Energy	J	62.5	125
Shortest Pulse Duration	fs	60	50
Repetition Rate	Hz	20	100
Energy Stability RMS	%	1	0.6

Laser Transport Lines: In- and Outcoupling

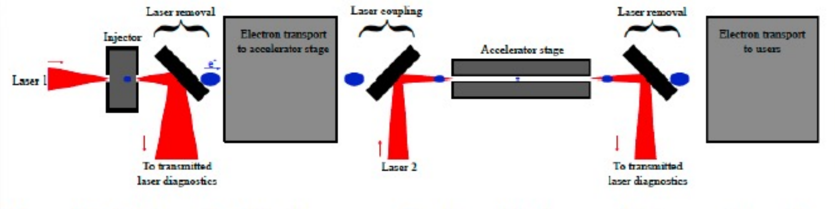
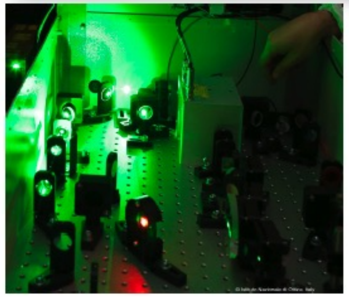
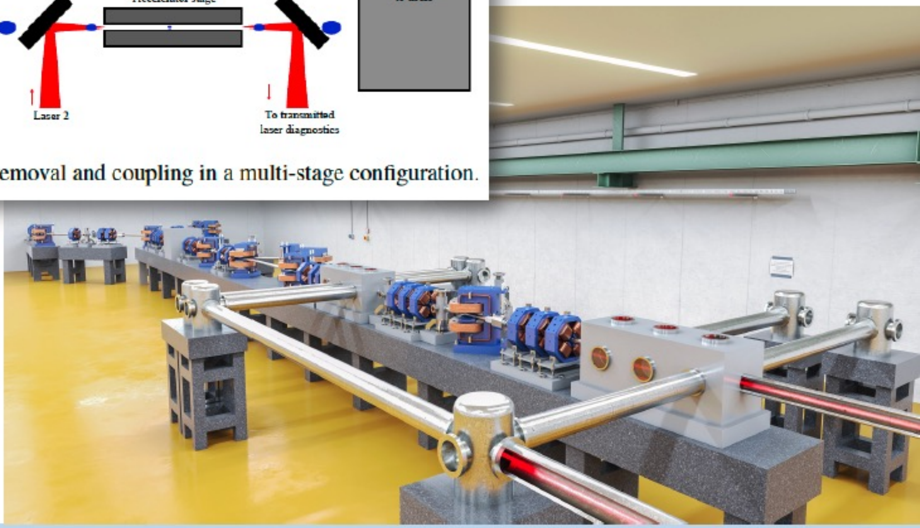
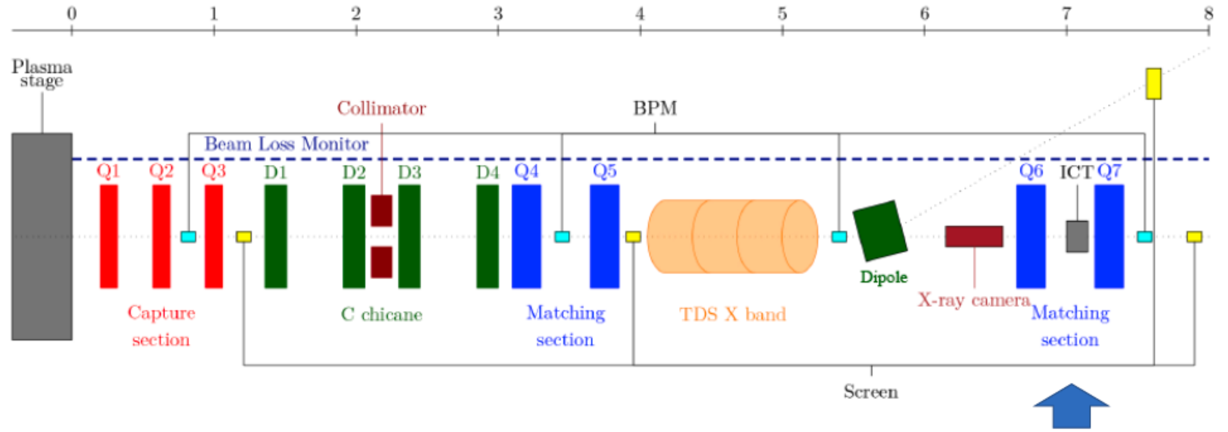


Figure 16.3: Schematic of the laser removal and coupling in a multi-stage configuration.





Electron Beam Transport Lines



Matching to Entrance of Undulator Section

	$\langle\beta_{x,y}\rangle$ [m]	β_x [m]	β_y [m]	α_x	α_y
Scheme 1: LPI-5 GeV	5	3.16	7.31	-0.697	1.556
Scheme 2: LPI-150 MeV + LPAS-5 GeV	5	3.16	7.31	-0.698	1.556
Scheme 3: RFI-500 MeV + LPAS-1 GeV	5	3.39	6.89	-0.613	1.174
Scheme 3: RFI-500 MeV + LPAS-5 GeV	5	3.16	7.31	-0.698	1.556
Scheme 5: RFI-500 MeV + PPAS-1 GeV	5	3.40	6.87	-0.608	1.155

Table 19.5: Electron beam matching parameters at the entrance of the undulator section in the case of a short-wavelength design (undulator period: $\lambda_u = 20$ mm, module length: $L_u = 2$ m, distance between modules: 360 mm).

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Beam Transport Solutions

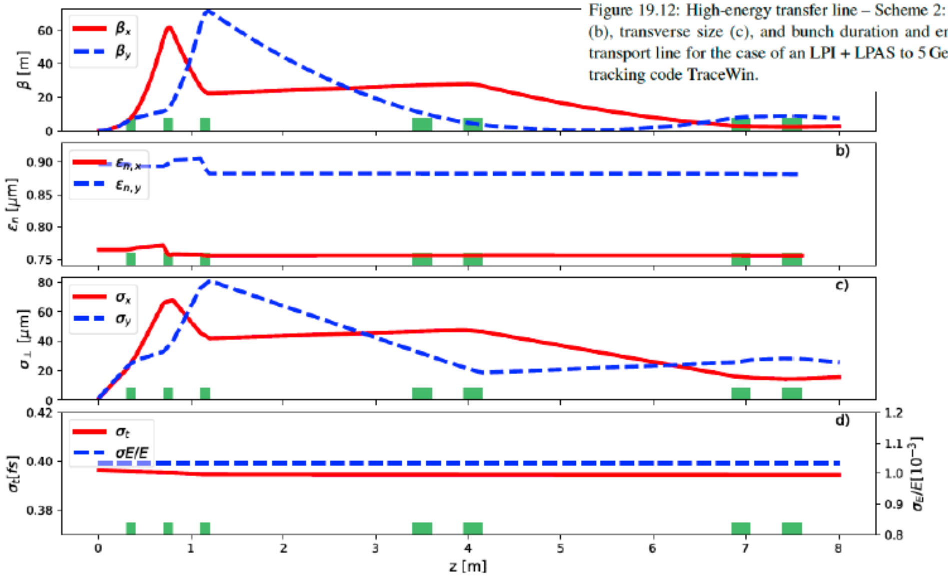

Figure 19.12: High-energy transfer line – Scheme 2: Beam beta function (a), normalised emittance (b), transverse size (c), and bunch duration and energy spread (d) of the core beam along the transport line for the case of an LPI + LPAS to 5 GeV. The calculations were performed with the tracking code TraceWin.

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Performance Simulations *(end of transport)*

Start-to-end into undulator section, then semi-analytical

Name	E [GeV]	I_{peak} [kA]	σ_E/E [%]	$\langle\varepsilon_n\rangle$ [μm]	$\langle\beta\rangle$ [m]	L_c^{2cm} [nm]	L_c^{3cm} [nm]
Scheme 2-5 GeV	4.96	2.63	0.052	0.58	5	20	61
Scheme 3-5 GeV	5.41	2.74	0.052	0.34	5	14	42
Scheme 3-1 GeV	1.09	1.75	0.103	0.44	4	140	430
Scheme 5-1 GeV	1.07	1.06	0.047	0.55	4	320	990

Table 24.3: Best slice values of the relevant parameters at the **undulator** entrance and expected cooperation lengths.

Name	E [GeV]	I_{peak} [kA]	σ_E/E [%]	$\varepsilon_{n,x}$ [μm]	$\varepsilon_{n,y}$ [μm]	σ_x [μm]	σ_y [μm]	ℓ_s [μm]
Scheme 2-5 GeV	4.98	2.93	0.108	0.53	0.59	0.87	0.92	0.11
Scheme 3-5 GeV	5.41	2.85	0.046	0.38	0.32	1.06	0.98	1.3
Scheme 5-1 GeV	1.07	1.95	0.098	0.67	0.59	0.83	0.98	0.9
Scheme 3-1 GeV	1.09	1.88	0.923	0.4	0.41	2.2	2.2	1.2

Table 24.1: Best slice values of the relevant parameters at the plasma exit.

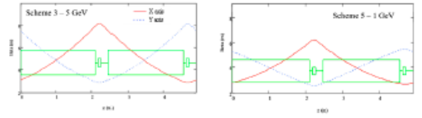

Figure 24.1: Magnetic unit cell of a system made up of an undulator as well as focussing and defocusing quadrupoles for the $\lambda_u = 3$ cm configuration, associated with the specified electron beams and superimposed with the longitudinal profiles of their Twiss β_x (solid red line) and β_y (dotted blue line) functions.

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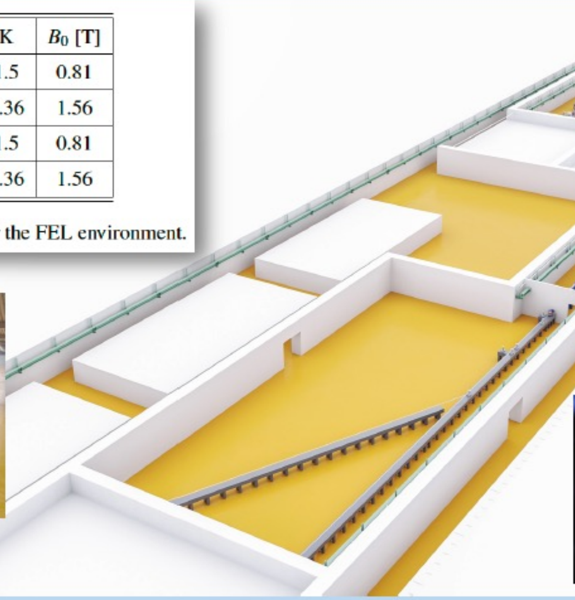
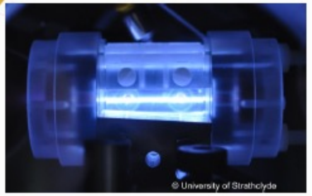
Undulator Parameters

E [GeV]	λ_R [nm]	λ_u [mm]	K	B_0 [T]
5	0.22	20	1.5	0.81
5	1.65	30	4.36	1.56
1	5.5	20	1.5	0.81
1	41	30	4.36	1.56

Table 24.2: Undulator configurations used for the FEL environment.





Performance Simulations *(short period)*

Start-to-end into undulator section, then semi-analytical

Name	λ_R [nm]	Pierce ρ [%]	$L_{G,3d}$ [m]	P_{sat} [GW]
Scheme 3-5 GeV	0.19	0.099	1.7	4.39
Scheme 2-5 GeV	0.3	0.084	2.74	1.75
Scheme 3-1 GeV	4.67	0.236	0.59	1.94
Scheme 5-1 GeV	4.86	0.188	0.63	1.29

Table 24.4: FEL semi-analytical results for the short-undulator-period configuration based on the best slice parameters of Table 24.3.

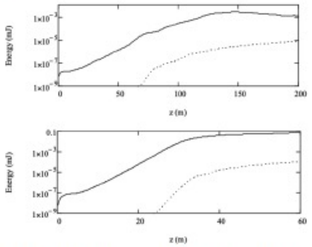


Figure 24.4: Growth of the SASE FEL energy per pulse of Scheme 2-5 GeV (top) and Scheme 3-5 GeV (bottom) beam distributions with the short-undulator-period configuration. The fundamental (solid line) and third (dotted line) harmonics are shown.

Name	Saturation length [m]	Linewidth [%]	Pulse duration [fs]	Photons per pulse [10^{10}]	Brightness [$\times 10^{30}$ s^{-1} (mm mrad)$^{-2}$ (0.1%bw)$^{-1}$]
Scheme 2-5 GeV	126	0.18	0.4	0.19	3.7
Scheme 3-5 GeV	38	0.23	2.0	3.2	40
Scheme 3-1 GeV	28	0.25	2.4	2.3	0.5
Scheme 5-1 GeV	16	0.59	2.0	1.3	0.08

Table 24.5: Results of the time-dependent simulations with longitudinal dynamics, obtained with PERSEO, for the short-undulator-period configuration.

Performance Simulations *(long period)*

Start-to-end into undulator section, then semi-analytical

Name	λ_R [nm]	Pierce ρ [%]	$L_{G,3d}$ [m]	P_{sat} [GW]
Scheme 3-5 GeV	1.4	0.23	0.83	17.8
Scheme 2-5 GeV	1.67	0.2	0.94	14
Scheme 3-1 GeV	34.5	0.57	0.36	4.94
Scheme 5-1 GeV	35.9	0.45	0.44	2.51

Table 24.6: FEL semi-analytical results for the long-undulator-period configuration based on the best slice parameters of Table 24.3.

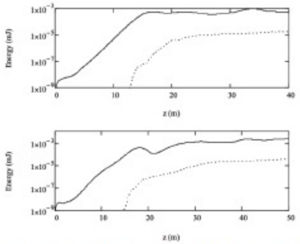


Figure 24.5: Growth of the SASE FEL energy per pulse of Scheme 5-1 GeV (top) and Scheme 3-1 GeV (bottom) beam distributions for the short-undulator-period configuration. The fundamental (solid line) and third (dotted line) harmonics are shown.

Name	Saturation length [m]	Linewidth [%]	Pulse duration [fs]	Photons per pulse [10^{10}]	Brightness [$\times 10^{30}$ s^{-1}(mm mrad)$^{-2}$ (0.1%bw)$^{-1}$]
Scheme 2-5 GeV	26	0.3	0.71	4.2	27.6
Scheme 3-5 GeV	20	0.3	2.2	72	475
Scheme 3-1 GeV	16	0.54	7.8	31	0.86
Scheme 5-1 GeV	23	3.6	15	16	0.02

Table 24.7: Results of the time-dependent simulations with longitudinal dynamics, obtained with PERSEO, for the long-undulator-period configuration.

FEL Brilliance Compared

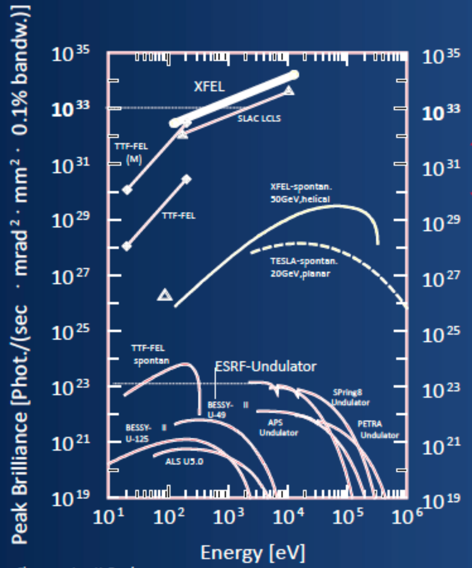
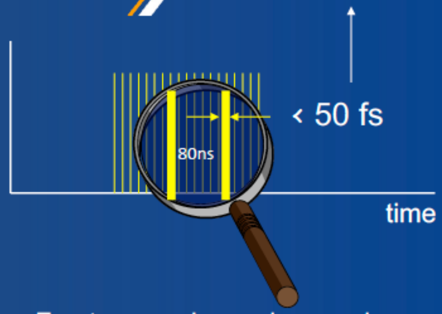


Figure courtesy H. Dosch

EuPRAXIA range in peak brilliance

naturally ultra-short pulses to fit into plasma bucket

Up to 100 Hz single bunches



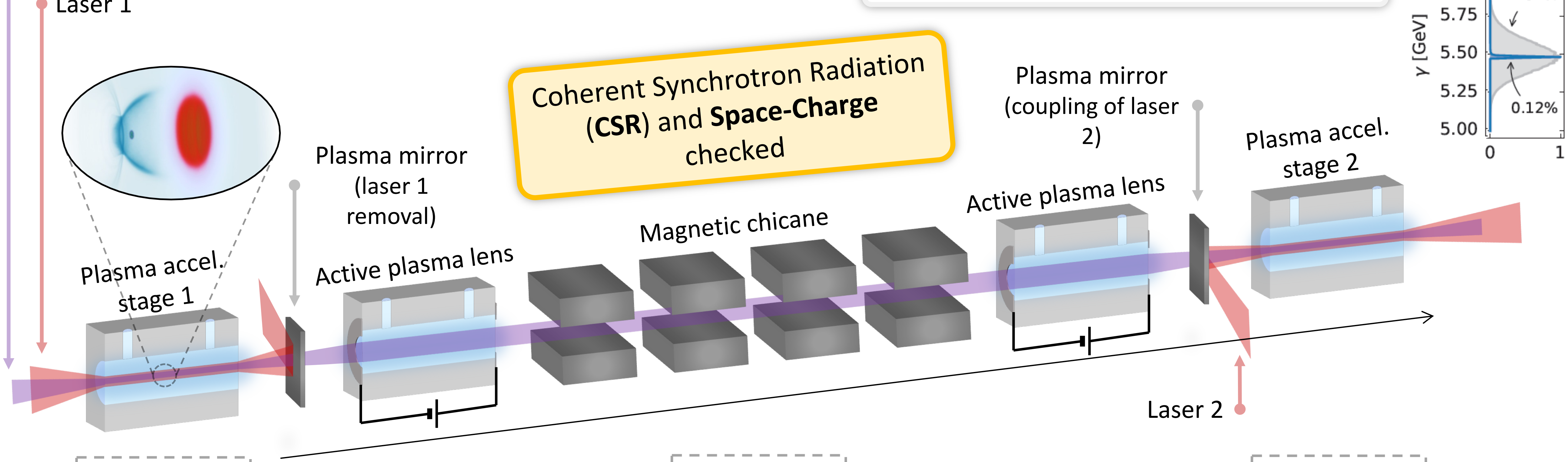
Femtosecond x-ray laser pulses

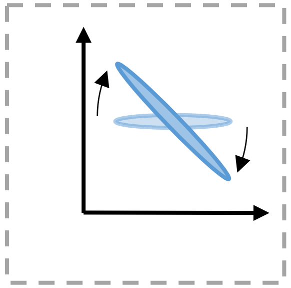
Solving Energy Spread (Touschek Prize 2020)

Ref.: Ferran Pousa, Martinez de la Ossa, Brinkmann, Assmann
PRL 123, 054801 (2019)

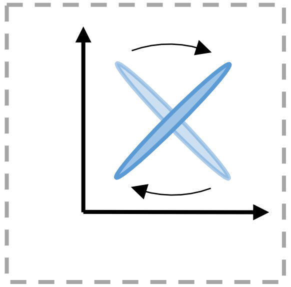
Not to scale. **Compact setup 1.5 m.**

Coherent Synchrotron Radiation (**CSR**) and **Space-Charge** checked

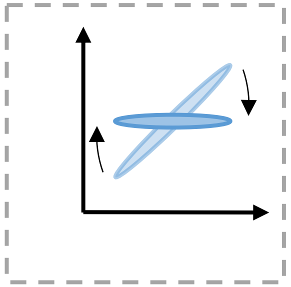




Accelerating in a plasma stage and...



... flipping phase space in the middle before second plasma stage



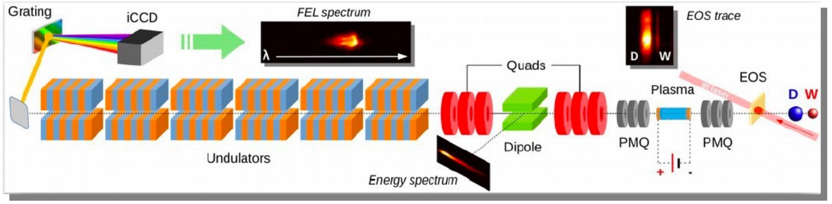
EuPRAXIA FEL: Feasibility Proof Achieved

Horizon Europe

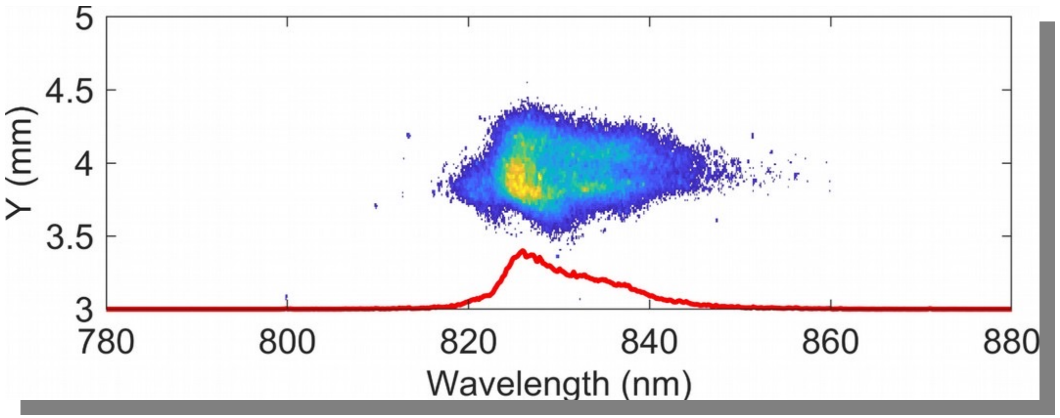
Recent ground-breaking results in Frascati:

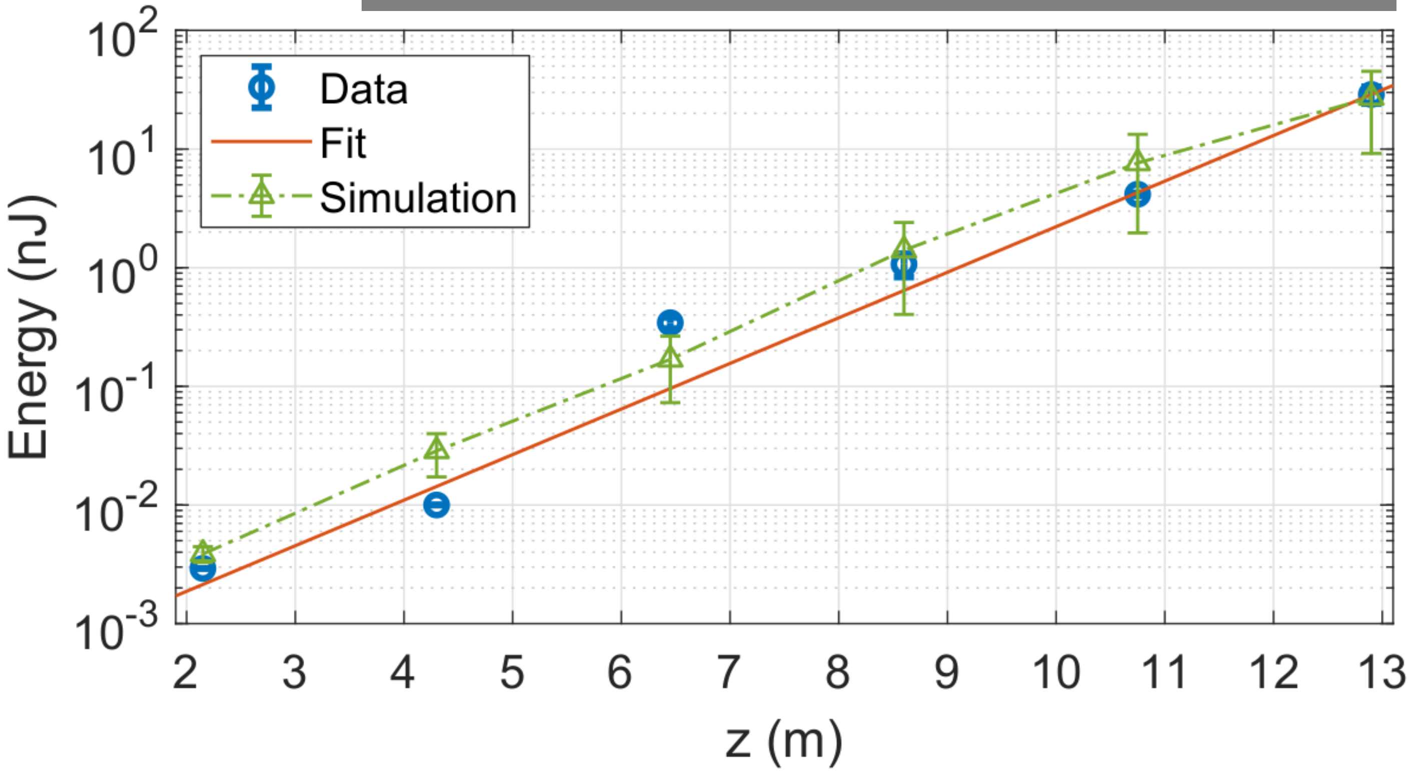
First FEL lasing from a beam-driven plasma accelerator

Nature **605**, 659–662 (2022)

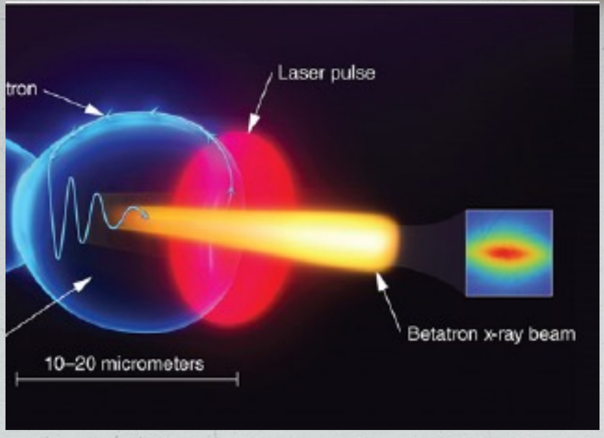


Single Spike SASE spectrum

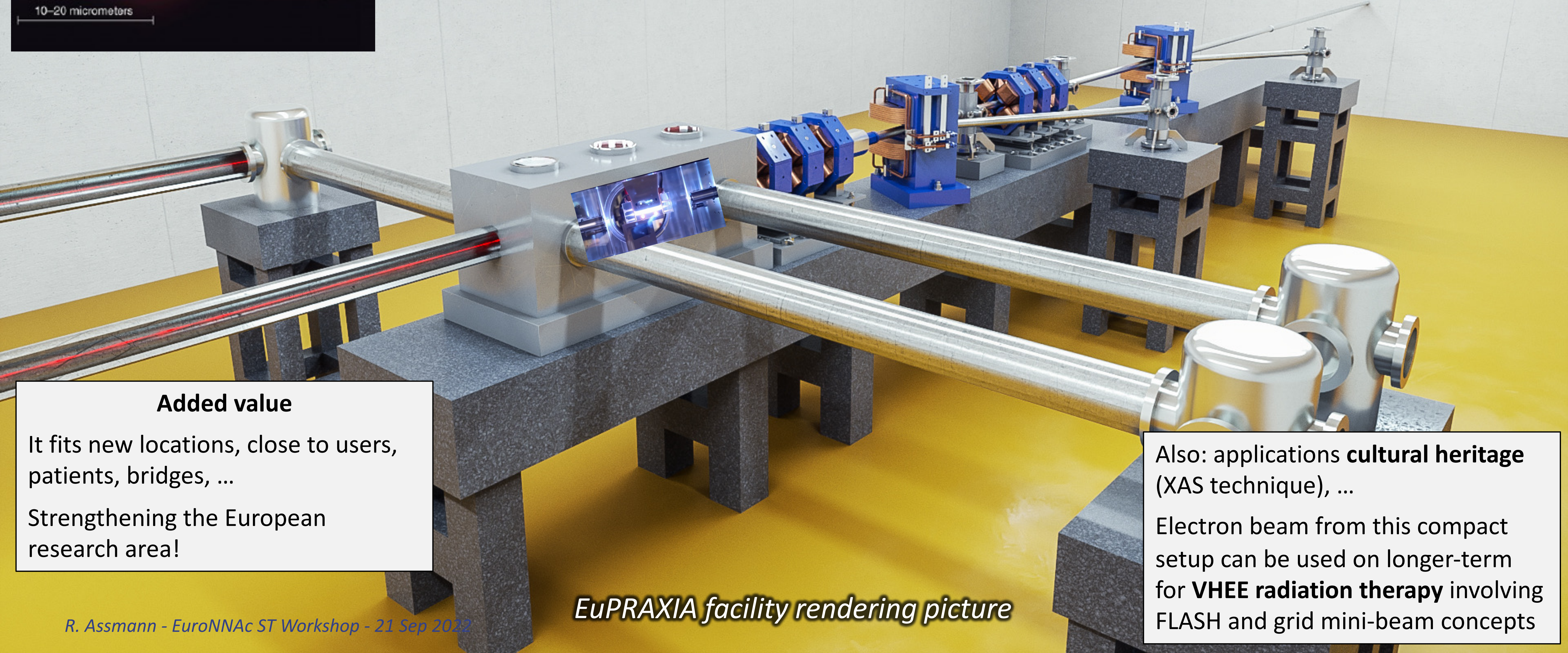




Betatron X Rays: Design Compact Medical Imaging Line



*Fully plasma-based beamline for generating betatron radiation as a **compact X-ray source for medical imaging and material analysis**. The user area is behind the wall on the right.*



EuPRAXIA facility rendering picture

Added value

It fits new locations, close to users, patients, bridges, …

Strengthening the European research area!

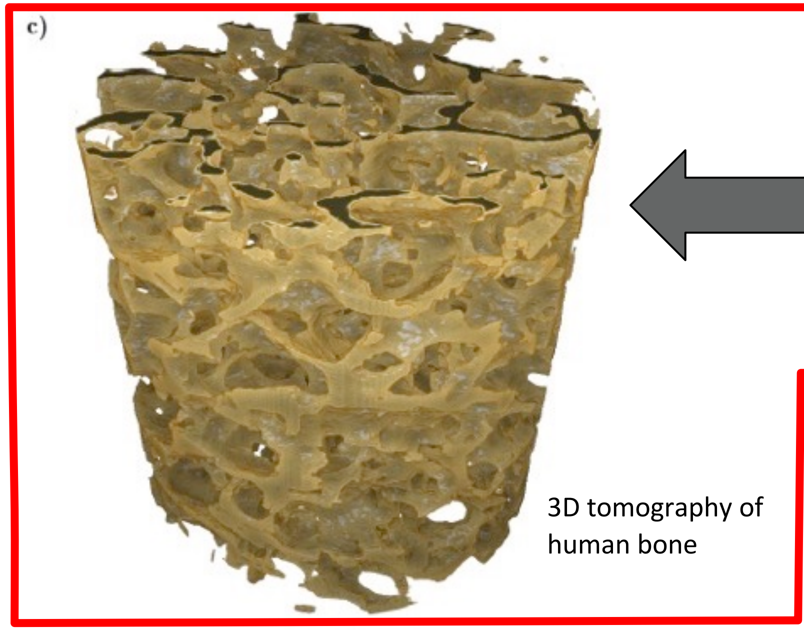
Also: applications **cultural heritage** (XAS technique), …

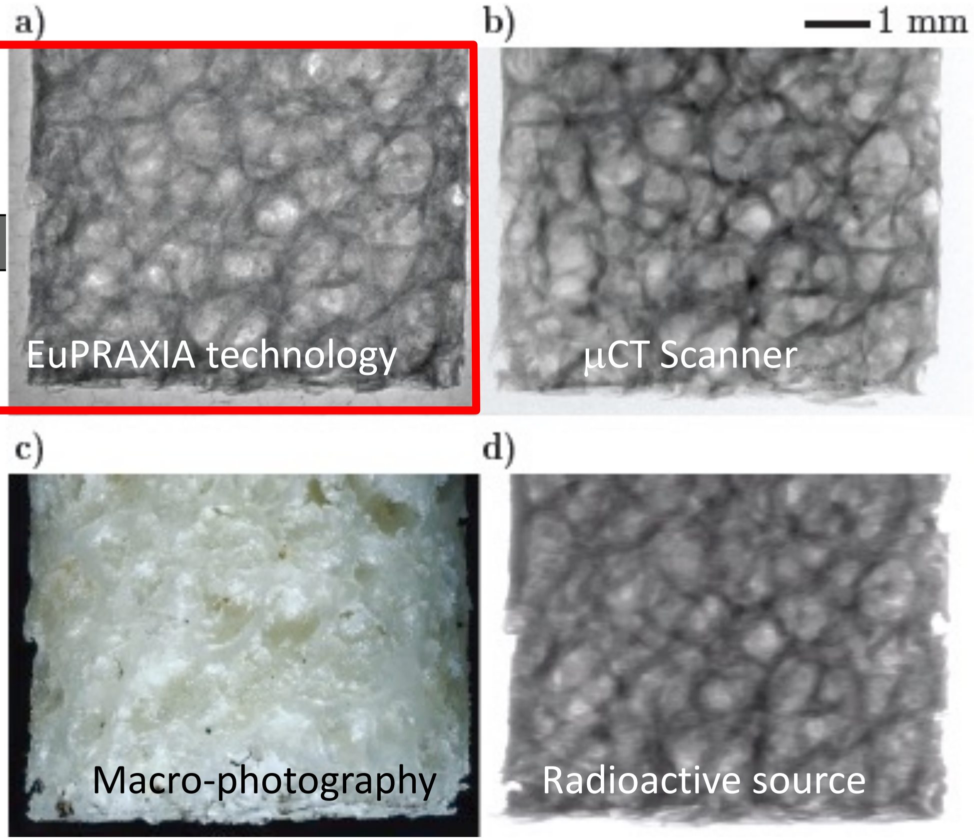
Electron beam from this compact setup can be used on longer-term for **VHEE radiation therapy** involving FLASH and grid mini-beam concepts

Betatron X Rays: Compact Medical Imaging

Horizon Europe

J.M. Cole et al, "Laser-wakefield accelerators as hard x-ray sources for 3D medical imaging of human bone". Nature Scientific Reports 5, 13244 (2015)





- EuPRAXIA laser advance (industry) will push rate from 1/min to 100 Hz.
- **Ultra-compact source of hard X rays → exposing from various directions simultaneously is possible in upgrades**

FOOD & HEALTH

Physics & Technology Background:

- Small EuPRAXIA accelerator → small emission volume for betatron X rays.
- **Quasi-pointlike** emission of X rays.
- **Sharper image from base optical principle.**
- Quality demonstrated and published, but takes a few hours for one image.
- Advancing flux rate with EuPRAXIA laser by factor > 1,000!

Added value

Sharper images with outstanding **contrast**

Identify smaller features (e.g. early detection of cancer at micron-scale – calcification)

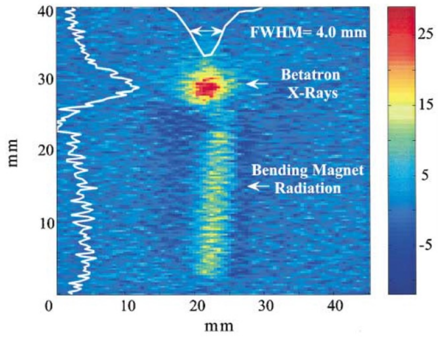
Laser advance in EuPRAXIA → **fast imaging** (e.g. following moving organs during surgery)

Horizon Europe

Betatron X Ray Source in Numbers

Property	Symbol	Characteristic Value	Implication
Hard photon energy	E_{crit}	$> 25\,\mathrm{keV}$	deeply penetrating
Small source size	r_β	$\sim \mu\mathrm{m}$	exhibits high spatial resolution
Small divergence	θ	$\sim 10\,\mathrm{mRad}$	makes beamline
Short pulse	τ	$\sim 10\,\mathrm{fs}$	ultra-fast dynamics
Bright	N_{ph}	$> 10^9$ (photons per shot)	single-shot imaging

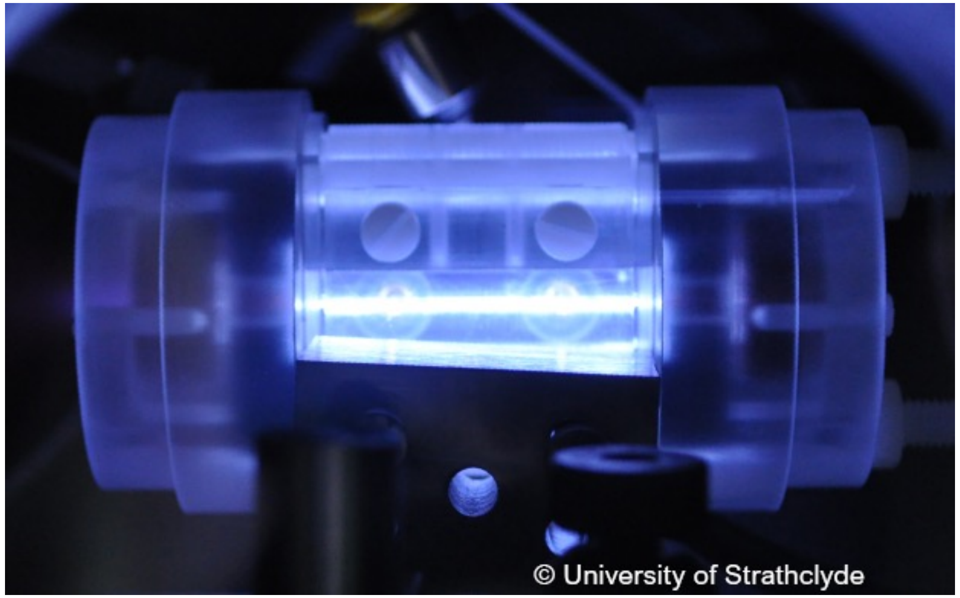
Table 24.8: Important properties of a plasma betatron-radiation source and their implications.




VOLUME 88, NUMBER 13 PHYSICAL REVIEW LETTERS 1 APRIL 2002

X-Ray Emission from Betatron Motion in a Plasma Wiggler

Shuoqin Wang,[1] C. E. Clayton,[1] B. E. Blue,[1] E. S. Dodd,[1] K. A. Marsh,[1] W. B. Mori,[1] C. Joshi,[1] S. Lee,[2] P. Muggli,[2] T. Katsouleas,[2] F. J. Decker,[3] M. J. Hogan,[3] R. H. Iverson,[3] P. Raimondi,[3] D. Walz,[3] R. Siemann,[3] and R. Assmann[4]
[1]*University of California, Los Angeles, California 90095*
[2]*University of Southern California, Los Angeles, California 90089*
[3]*Stanford Linear Accelerator Center, Stanford, California 94309*
[4]*CERN, Switzerland*
(Received 8 October 2001; published 19 March 2002)



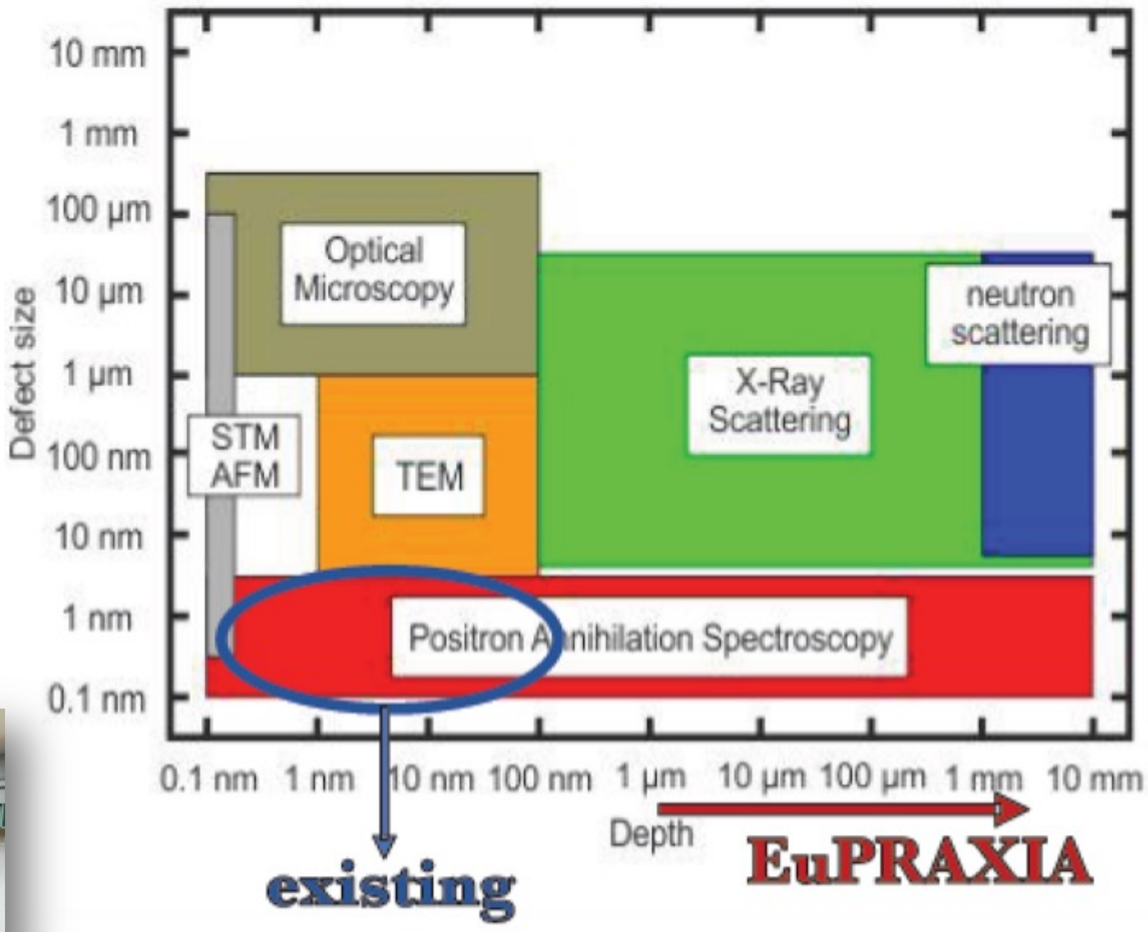
Laser power	10 TW	100 TW	1 PW
Pulse duration τ (fs)	12	37	120
Spot size w_0 (μm)	4	10	35
Plasma density n_e (cm^{-3})	5×10^{19}	5×10^{18}	5×10^{17}
Plasma length (mm)	90×10^{-3}	3	90
Peak electron energy $\gamma m_e c^2$ (MeV)	60	600	6×10^3
Beam charge (nC)	0.1	0.4	1
X-ray energy (keV)	0.6	8	110
Source size (μm)	1.4	1.8	2.4
Divergence θ (mrad)	70	7	0.7
Undulator parameter α_β	7	9	12
Peak X-ray brightness *	2×10^{21}	3×10^{23}	1×10^{26}
Photon number	2×10^8	3×10^9	4×10^{10}

Table 24.9: Scalings for betatron radiation from established scaling laws ([427]). The figures for 10 and 100 TW systems agree well with reported measurements.
* Units for peak X-ray brightness are photons/($\mathrm{mm}^2\mathrm{mrad}^2\mathrm{s}^1$ 0 1%BW).

EuPRAXIA Positron Annihilation Spectroscopy

Horizon Europe

- Electron beams from EuPRAXIA (also lower quality) can be used to produce positrons from a beam target.
- Relevant here are lower energy positrons. EuPRAXIA:
  - Energy: 0.5-10 MeV
  - Intensity per pulse: 10^6 e^+
- Those positrons penetrate deeper → new performance reach material science
- Detection of nano and sub-nano scale defects.



Distributed RI Concept

Advisory & Oversight Boards
- Open Innovation Forum
- Scientific & Technical Advisory Committee
- User Meetings & Program Committees
- Resource Review Board
- Quality Assurance Panel
- Ethical Advisory Board

Collaboration Board
1 representative per Member & Observer
1 Chair and 1 Deputy Chair

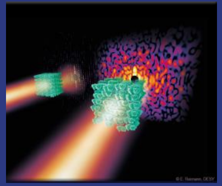
Co-funded by the European Union

Project Coordinator + Management Team

Steering Committee

Central EuPRAXIA Management

Construction Site Frascati
Local Project Team
Beam-driven plasma accelerator
Delivers FEL light, X rays, electrons, positrons
Life sciences, particle physics, medicine, materials



Location: metropolitan area Rome, Italy

Construction Site
(tbd in 2023)
Local Project Team
Laser-driven plasma accelerator
Delivers FEL light, X rays, electrons, positrons
Life sciences, medicine, materials

Four candidate sites described in conceptual design report

Excellence Centres
Local Project Teams
- *Plasma Simulations & Theory*
- *Laser-Plasma Acceleration & FEL Developments*
- *Plasma Acceleration & High-Rep-Rate Developments*
- *Advanced Application Beamlines*
- *Technology Incubator to Laser Science Users*
- *EuPRAXIA user e-needs infrastructure*

Technical design tests, prototyping, production

Project Clusters (WPs)
- *Theory & Simulation*
- *Laser Technology*
- *Plasma Components & Systems*
- *RF Technology*
- *Magnets & Other Beamline Components*
- *Diagnostics*
- *Applications*
- *Transfor-mative Innovation Paths*
- *Training, Outreach & Dissemi-nation*
- *Implemen-tation & Layout*

Technical Design Report

National projects and facilities

Individual groups at universities and laboratories

Organization for initial Preparatory Phase in dark blue

Features to be added with decision on second site or in later phases are indicated in lighter shades

Sorry for the very fast run through.

For more details on our innovative concepts, applications and new solutions please refer to our 2020 Conceptual Design Report.

Can we move our idea and our dream into reality?

Can we build this new European Research Infrastructure?

600+ page CDR, 240 scientists contributed

The Next Level: ESFRI Roadmap Update 2021

Horizon Europe

E uropean
S trategy
F orum on
R esearch
I nfrastructures

https://roadmap2021.esfri.eu

Roadmap projects selected after thorough review by ESFRI committee and approved by **EU governments** every few years

2006 – 2008 – 2012 – 2016 – 2018 – **2021**

EuPRAXIA facility rendering picture

ESFRI Projects Roadmap 2021

Horizon Europe

https://roadmap2021.esfri.eu

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ESFRI PROJECTS

PHYSICAL SCIENCES & ENGINEERING

NAME	FULL NAME	TYPE	LEGAL STATUS (Y)	ROADMAP ENTRY (Y)	OPERATION START (Y)	INVESTMENT COST (M€)	OPERATION COST (M€/Y)
EST	European Solar Telescope	single-sited		2016	2029*	200.0	12.0
ET	Einstein Telescope	single-sited		2021	2035*	1,912.0	37.0
EuPRAXIA	European Plasma Research Accelerator with Excellence in Applications	distributed		2021	2028*	569.0	30.0
KM3NeT 2.0	KM3 Neutrino Telescope 2.0	distributed		2016	2020	196.0	3.0

- Two new entries in 2021: **Einstein Telescope (ET)** and **EuPRAXIA**
- EuPRAXIA is the only accelerator facility selected in the last 5 years
- EuPRAXIA is the first plasma accelerator facility ever included

PHYSICAL SCIENCES & ENGINEERING

EuPRAXIA-PP (Preparatory Phase) Approved

Horizon Europe

Von: European Commission <EC-NO-REPLY-GRANT-MANAGEMENT@nomail.ec.europa.eu>
Betreff: For Action - EuPRAXIA - 101079773 - GAP-101079773 - Evaluation results and start of grant preparation
Datum: 12. April 2022 um 16:13:44 MESZ
An: Ralph Assmann <ralph.assmann@lnf.infn.it>

Europa / Funding & Tenders Portal notification

Dear Madam/Sir,

Congratulations. Your proposal has reached the stage of Grant Agreement preparation.
To view the evaluation results and the instructions on how to provide additional information and data required for the preparation of your Grant Agreement, log on to the Funding & Tenders Portal > My Proposal(s) (https://ec.europa.eu/info/funding-tenders/opportunities/portal/screen/myarea/proposals) and click on Action > Follow-up.

Regards,
Grant Management Services

Please do not reply to this message
This message has been automatically generated by the Grant Management Services of the European Commission with the following configuration:
To:
Coordinator Contact
Cc:
Account Administrator, LEAR, Participant Contact and Coordinator Contact
Priority:*High*
You can change your preferences on email alerts in the "Notifications" area of your Funding & Tenders Portal

Complemented by other projects:

<u>EuPRAXIA Doctoral Network (approved)</u>
(2023 – 2027)

<u>2.6 M€ EU funding, 10 MSCA Fellows</u>
Coordinated by U Liverpool (C. Welsch)
Start date: 1 Jan 2023

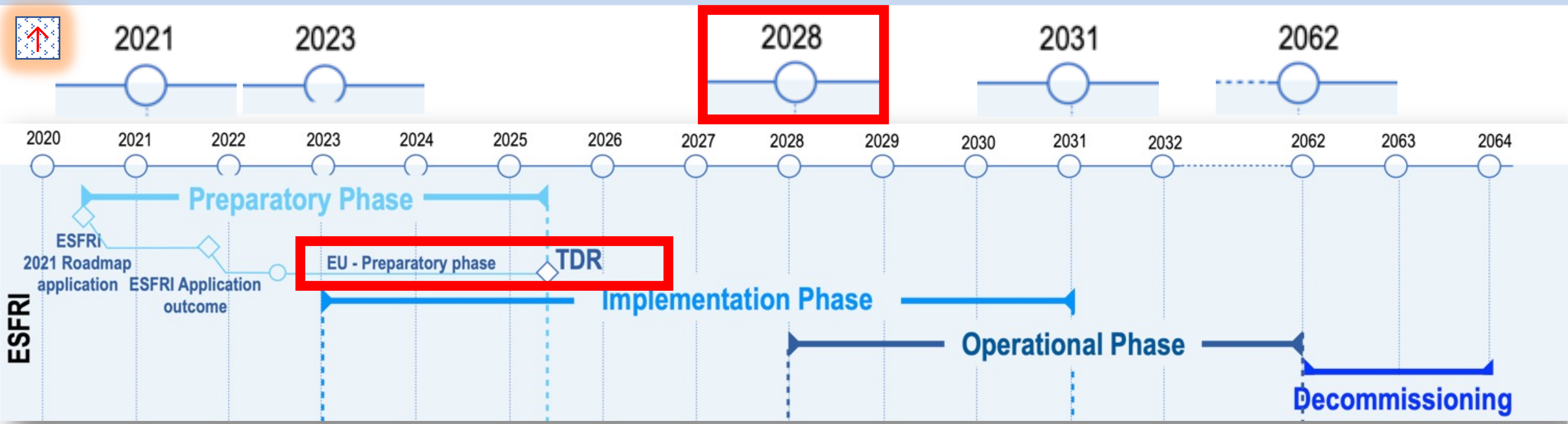
Others coming (miss no opportunity)

EuPRAXIA-PP (Preparatory Phase) Key Facts

Horizon Europe

- Prepares the implementation of the full RI in Europe
- Total project volume (including in-kind): **8.3 M€**
  - EU funding: 2.49 M€ (plus in-kind)
  - Additional funding Switzerland: 0.69 M€
    UK: 0.51 M€
- Work organized in 16 Work Packages
- **Project dates: 1 Nov 2022 – 31 Oct 2026**
- Coordinator and location of headquarters: INFN
- **34 participating organizations from 12 countries**
- Establish, amongst others, "Board of Financial Sponsors" with representatives of funding agencies.
  So far ~ 25% of total M&P funding (569 M€) secured. Site 1 financed.

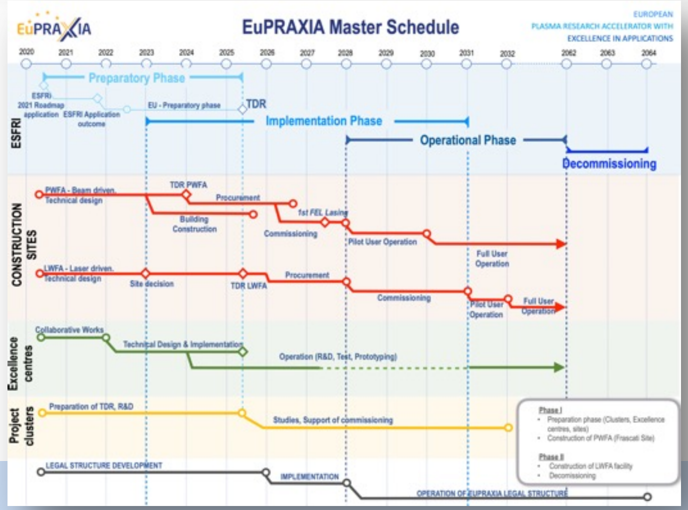
EuPRAXIA Schedule



SUCCESS – ON TRACK

European World-Class RI on compact accelerators for the end of the 2020‘s to the beginning of the 2060‘s

More detail in Master Schedule



EuPRAXIA-PP Consortium I

Horizon Europe

Coordinator

Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Frascati

Università di Roma Tor Vergata

Consiglio Nazionale delle Ricerche

SAPIENZA UNIVERSITÀ DI ROMA

ENEA
Agenzia nazionale per le nuove tecnologie, l'energia e lo sviluppo economico sostenibile

Elettra Sincrotrone Trieste

FBH Leibniz Ferdinand Braun Institut

Fraunhofer ILT

DESY.

HZDR
HELMHOLTZ ZENTRUM DRESDEN ROSSENDORF

JÜLICH Forschungszentrum

LMU LUDWIG-MAXIMILIANS-UNIVERSITÄT MÜNCHEN

EuPRAXIA-PP Consortium II

Horizon Europe

UK Research and Innovation

University of Liverpool

University of Oxford

Queen's University Belfast

University of Strathclyde Glasgow

Imperial College London

eli beamlines

cnrs

cea

THALES

CERN

EuPRAXIA-PP Consortium III

TÉCNICO LISBOA

WIGNER

SZTE UNIVERSITY OF SZEGED

PÉCSI TUDOMÁNYEGYETEM
UNIVERSITY OF PÉCS

ALBA

CLPU CENTRO DE LÁSERES PULSADOS

EuPRAXIA-PP Consortium IV

Complemented by institutes in EuPRAXIA ESFRI consortium: **additional 17 institutes** from France, Germany, Poland, Sweden, United Kingdom, China, Japan, United States . Russian institutes presently suspended.

PP Steering Committee: Leaders Behind EuPRAXIA

Governing Board (Decision-making body)

Steering Committee

Scientific Advisory Board

Technical & Industrial Advisory Board

Board of Financial Sponsors

WP1 - Coordination & Project Management
R. Assmann, INFN & DESY
M. Ferrario, INFN

WP2 - Dissemination and Public Relations
C. Welsch, U Liverpool
S. Bertellii, INFN

WP3 - Organization and Rules
A. Specka, CNRS
A. Ghigo, INFN

WP4 - Financial & Legal Model. Economic Impact
A. Falone, INFN

WP5 - User Strategy and Services
F. Stellato, U Tor Vergata
E. Principi, ELETTRA

WP6 - Membership Extension Strategy
B. Cros, CNRS
A. Mostacci, U Sapienza

WP's on coordination & implementation as ESFRI RI (organization, legal model, financing, users)

WP7 - E-Needs and Data Policy
R. Fonseca, IST
S. Pioli, INFN

WP8 - Theory & Simulation
J. Vieria, IST
H. Vincenti, CEA

WP9 - RF, Magnets & Beamline Components
S. Antipov, DESY
F. Nguyen, ENEA

WP10 - Plasma Components & Systems
K. Cassou, CNRS
J. Osterhoff, DESY

WP11 - Applications
G. Sarri, U Belfast
E. Chiadroni,U Sapienza

WP12 - Laser Technology, Liaison to Industry
L. Gizzi, CNR
P. Crump, FBH

WP13 - Diagnostics
A. Cianchi, U Tor Vergata
R. Ischebeck, EPFL

WP14 - Transformative Innovation Paths
B. Hidding, U Strathclyde
S. Karsch, LMU

WP15 - TDR EuPRAXIA @SPARC-lab
C. Vaccarezza, INFN
R. Pompili, INFN

WP16 - TDR EuPRAXIA Site 2
A. Molodozhentsev, ELI-Beamlines
R. Pattahil, STFC

WPs on technical implementation and sites

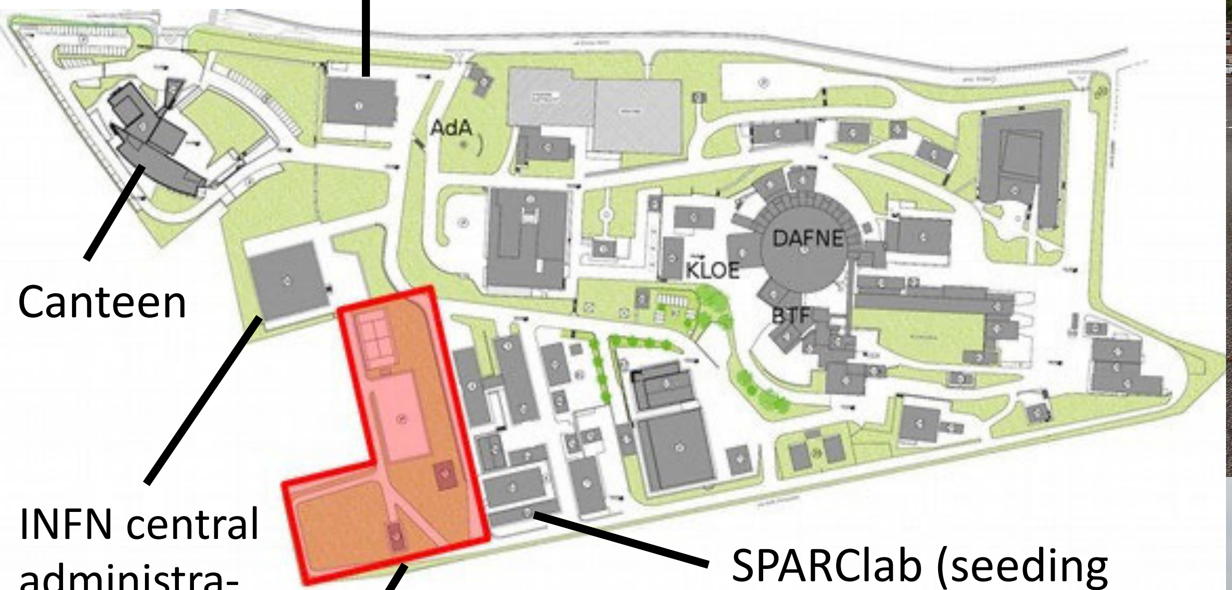
Headquarter and Site 1: EuPRAXIA@SPARClab

- Frascati`s future facility
- > 130 M€ invest funding
- Beam-driven plasma accelerator
- Europe`s most compact and most southern FEL
- The world`s most compact RF accelerator (X band with CERN)

It Fits the Frascati Site

(also fits sites at a large university, hospital, company, …)

Directorate building



Canteen

INFN central administra-tion

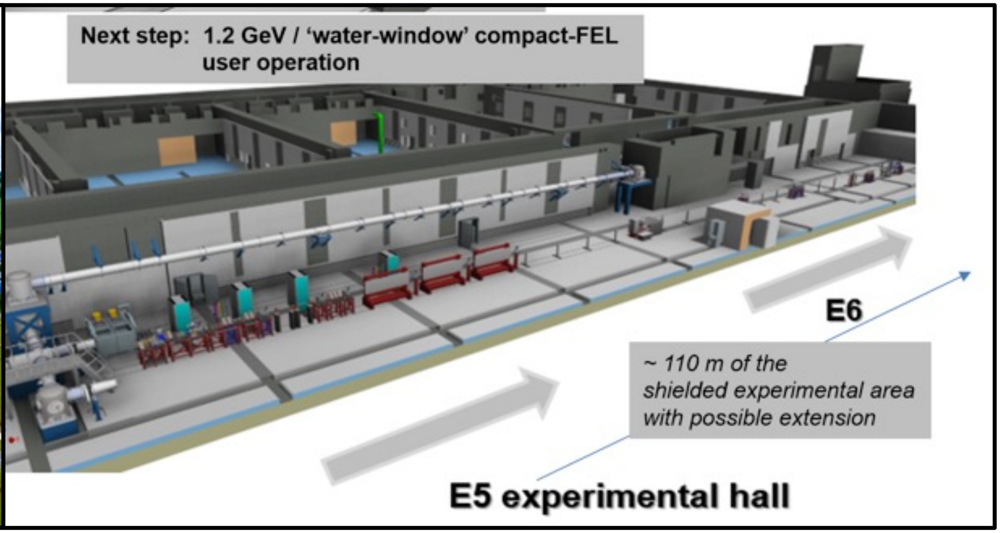
SPARClab (seeding with plasma acc.)

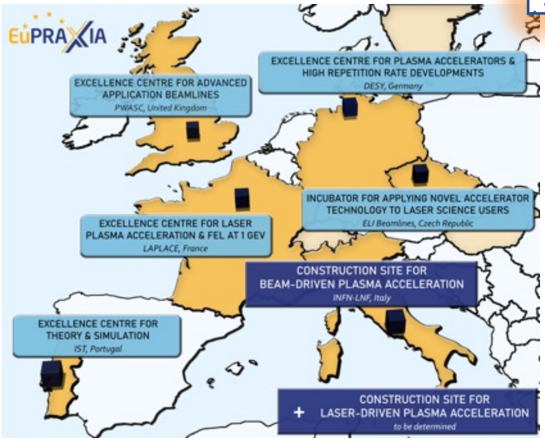
@ SPARClab

(European site 1)

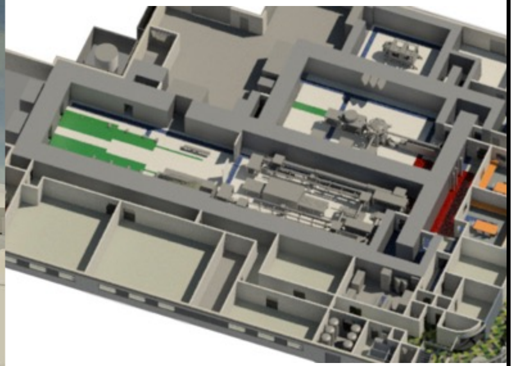
Candidate 2nd Sites from CDR

Prague, Czech Republic





@ EPAC
Rutherford, STFC, UK



CNR-INO
ISTITUTO NAZIONALE DI OTTICA
CONSIGLIO NAZIONALE DELLE RICERCHE

CNR Campus Pisa

Selection Criteria 2nd EuPRAXIA Site

(from CDR, fulfilled by 1st Site LNF/INFN)

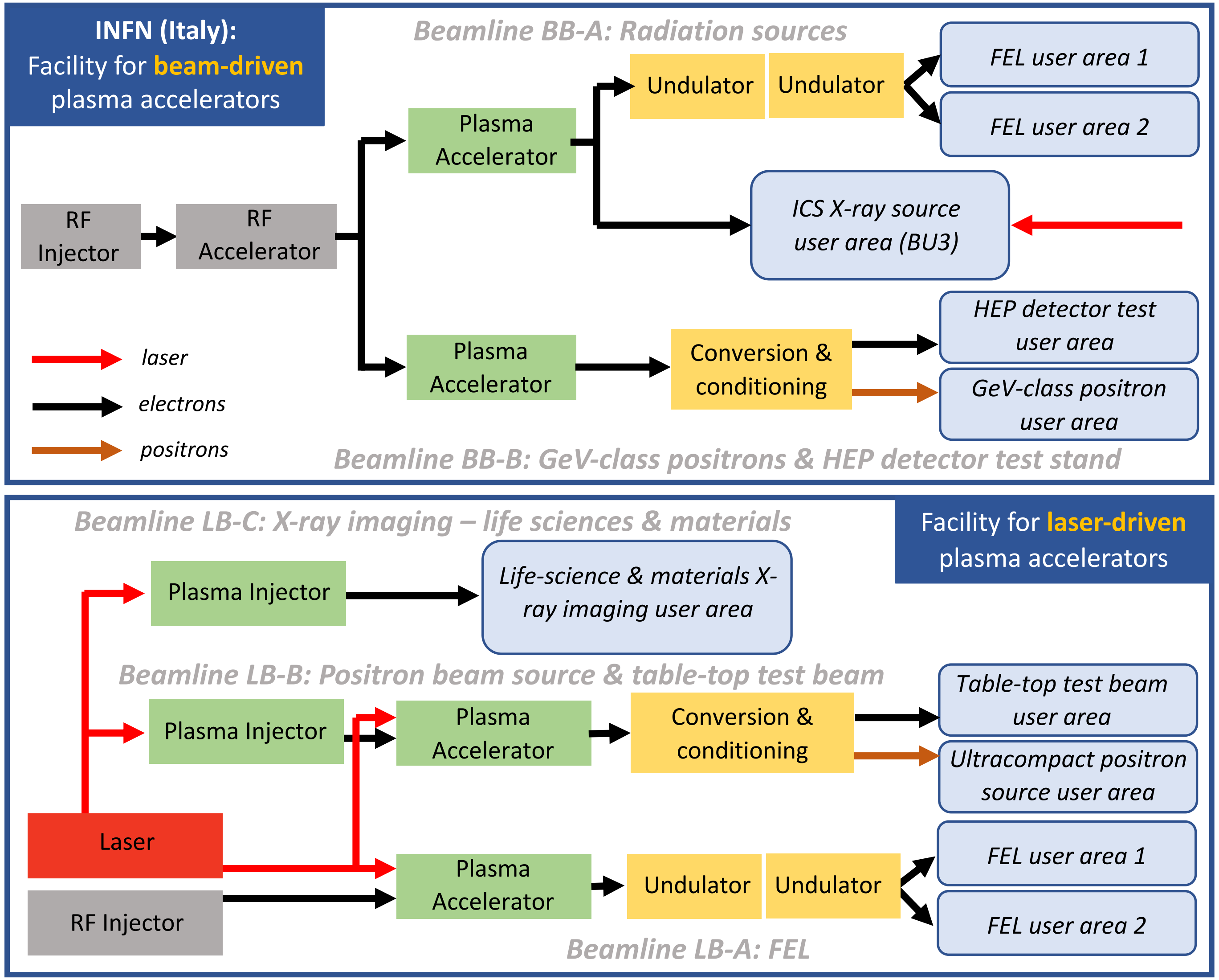
Legal/Political	Technical	Financial
Compliance of host institution with **EuPRAXIA Access** Policy	Site provides sufficient **space** (about 175 m x 35 m)	Commitment to **sustainability** of EuPRAXIA (host lab covers site operation costs)
Compliance of host institution with **EuPRAXIA Open Innovation** and **Open Science** Policy	Laboratory has **infrastructures** in one or several of RF accelerators, laser installations, user access.	**Previous investments** into local infrastructures of relevance for EuPRAXIA (leverage effect)
Agreement of host institution with the **long-term scientific agenda** of EuPRAXIA	Site provides required **services** and facilities for support of external users, including E infrastructure	Existence of one or a mix of **funding sources** able to finance implementation of the site
Laboratory has existing groups in place to guarantee **safety** requirements (laser, radio-protection, access control) and rules		*Note: approach reduces cost (pre-invest) and risks of cost-overun.*

Phased Implementation of Construction Sites

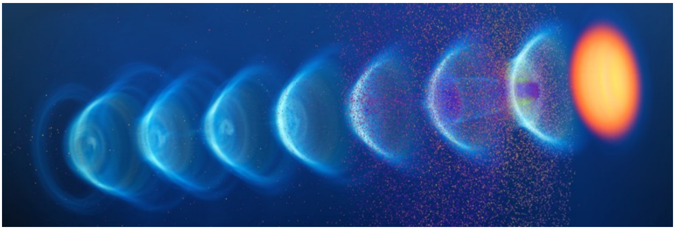
	Laser-driven	Beam-driven
Phase 1	✓ FEL beamline to 1 GeV + user area 1 ✓ Ultracompact positron source beamline + positron user area	✓ FEL beamline to 1 GeV + user area 1 (1) ✓ GeV-class positrons beamline + positron user area
Phase 2	✓ X-ray imaging beamline + user area (2) ✓ Table-top test beams user area ✓ FEL user area 2 ✓ FEL to 5 GeV	✓ ICS source beamline + user area ✓ HEP detector tests user area ✓ FEL user area 2 ✓ FEL to 5 GeV
Phase 3	✓ High-field physics beamline / user area ✓ Other future developments	✓ Medical imaging beamline / user area ✓ Other future developments

1: INFN-LNF construction funding 108 M€

2: INFN/CNR/TorVer demo facility 22 M€ (PNRR)



Conclusion



- We consider it a major success that EuPRAXIA was selected for the 2021 update of the ESFRI Roadmap (besides Einstein Telescope the only project from physical sciences). We think it reflects on **quality and readiness** of our work and technology.
- EuPRAXIA is the **first ever plasma accelerator project with a Conceptual Design Report**.
- EuPRAXIA is the **first ever plasma accelerator project on the ESFRI roadmap**.
- Being on the ESFRI roadmap: Just approved EuPRAXIA-PP project will establish a **fully European project**, with European shareholders.
- Significant funding secured already (160 M€), ca. 25% of full implementation.
- We hope to make it an **example of European innovation**, bringing science to new applications and new areas. Following inspiration of particle physics detectors.
- Start-up mode for preparatory phase with 1,550 person months … Two more countries joined: Spain and Greece. Important: Decision 2nd site.

Thank You for Your Kind Attention

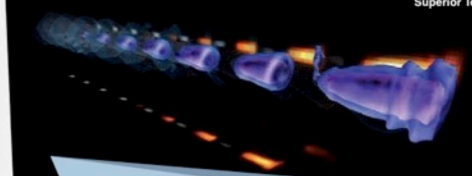
DESIGNING THE FUTURE

The EuPRAXIA Consortium is preparing a conceptual design for the world's first multi-GeV plasma-based accelerator with industrial beam quality and dedicated user areas.

INTERNATIONAL COLLABORATION

EuPRAXIA brings together a consortium of 16 laboratories and universities from 5 EU member states. The project, coordinated by DESY, is funded by the EU's Horizon 2020 programme. The consortium has been joined by 18 associated partners to make additional in-kind contributions.

The consortium holds open international events to strengthen collaborations, to connect to interested users from FEL's, high-energy physics, medicine and industry, and to assess the development of the project.



Computer simulation of a laser wakefield

© Dr Jorge Vieira, Instituto Superior Tecnico, Lisbon

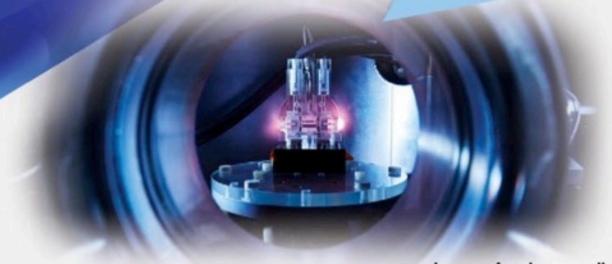


Image of a plasma cell.

© DESY, Heiner Müller-Elsner

Particle accelerators have become powerful and widely used tools for industry, medicine and science. Today there are some 30,000 particle accelerators worldwide, all of them relying on well-established technologies.

The achievable energy of particles is often limited by practical boundaries on size and cost, for example, in hospitals and university laboratories, or available funding for very large scientific instruments at the energy frontier.

A new type of accelerator that uses plasma wakefields promises accelerating gradients as much as 1,000 times higher than conventional accelerators! This would allow much smaller machines for fundamental and applied research.

The goal of this project is to produce a conceptual design for the world's first multi-GeV plasma-based accelerator that can provide industrial beam quality into dedicated user areas.

OPENING NEW HORIZONS

The project will bridge the gap between successful proof-of-principle experiments and ground-breaking, ultra-compact accelerators.

With a smaller size and improved efficiency, plasma-based technologies have the potential to revolutionize the world of particle accelerators multiplying their applications to medicine, industry and fundamental science.

Participants in the EuPRAXIA Steering Committee Meeting. Paris, February 2016

© Sylvaine Pieyre, LLR

ADVANCED TECHNOLOGIES

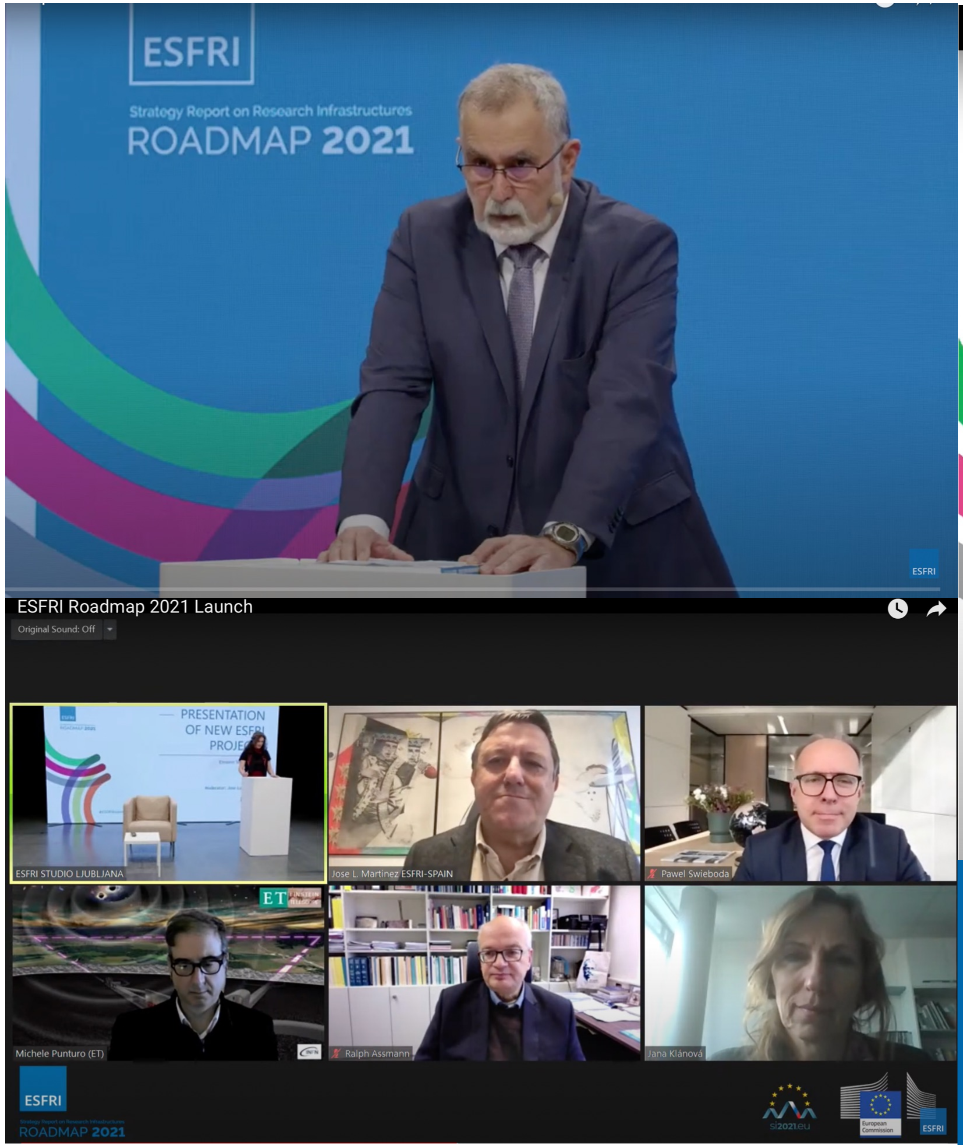
The project is structured into 14 working groups dealing with simulations of high gradient laser plasma accelerator structures, design and optimization of lasers and electron beams, research into alternative and hybrid techniques, Free Electron Lasers (FEL), high-energy physics, and radiation source applications.

EuPRAXIA joins novel acceleration schemes with modern lasers, the latest correction technologies and large-scale user areas. The consortium offers unique training opportunities for researchers in a multidisciplinary field.

EuPRAXIA

Additional Slides

EuPRAXIA is Europe`s Most Recent and Most Innovative Particle Accelerator Project on ESFRI



https://www.esfri.eu/latest-esfri-news/new-ris-roadmap-2021

The ESFRI Roadmap

E uropean
S trategy
F orum on
R esearch
I nfrastructures

https://roadmap2021.esfri.eu

NEW PROJECTS FILLING GAPS IN EUROPEAN RI CAPACITIES

The new entries in the Roadmap 2021 reinforce important areas of research in which insufficient capacities exist in Europe. They will also make essential contributions to fostering research relevant for some of the key EU priorities, such as health, the Green Deal, digital transition or strengthening the EU social pillar.

ESFRI

CHALLENGES AND STRATEGY FOR THE FUTURE

Why do we care? Projects selected after very **thorough review** of technical readiness, feasibility, user needs, strategic impact, **alignment with EU`s grand societal goals**. ESFRI delegates from **governments**. Final roadmap approved by science ministers.

ESFRI Projects Roadmap 2021

https://roadmap2021.esfri.eu

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ESFRI PROJECTS

	NAME	FULL NAME	TYPE	LEGAL STATUS (Y)	ROADMAP ENTRY (Y)	OPERATION START (Y)	INVESTMENT COST (M€)	OPERATION COST (M€/Y)
DIGIT	EBRAINS	European Brain ReseArch INfrastructureS	distributed	AISBL, 2019	2021	2026*	323.8	19.8
	SLICES	Scientific Large-scale Infrastructure for Computing/ Communication Experimental Studies	distributed		2021	2024*	137.7	6.5
	SoBigData++	European Integrated Infrastructure for Social Mining and Big Data Analytics	distributed		2021	2030*	130.5	5.0
ENERGY	IFMIF-DONES	International Fusion Materials Irradiation Facility - DEMO Oriented NEutron Source	single-sited		2018	2033*	884.0	56.0
	MARINERG-i	Marine Renewable Energy Research Infrastructure	distributed		2021	2030*	8.9	0.9
ENVIRONMENT	DANUBIUS-RI	International Centre for Advanced Studies on River-Sea Systems	distributed	ERIC Step1	2016	2024*	202.5	23.9
	DiSSCo	Distributed System of Scientific Collections	distributed		2018	2025*	420.3	12.1
	eLTER RI	Integrated European Long-Term Ecosystem, critical zone and socio-ecological system Research Infrastructure	distributed		2018	2026*	150.0	50.0

ESFRI Projects Roadmap 2021

https://roadmap2021.esfri.eu

ESFRI PROJECTS

	NAME	FULL NAME	TYPE	LEGAL STATUS (Y)	ROADMAP ENTRY (Y)	OPERATION START (Y)	INVESTMENT COST (M€)	OPERATION COST (M€/Y)
HEALTH & FOOD	EIRENE RI	Research Infrastructure for EnvIRonmental Exposure assessmeNt in Europe	distributed		2021	2031*	202.0	42.2
	EMPHASIS	European Infrastructure for Multi-scale Plant Phenomics and Simulation	distributed		2016	2021	160.0	3.6
	EU-IBISBA	European Industrial Biotechnology Innovation and Synthetic Biology Accelerator	distributed		2018	2025*	52.6	65.1
	METROFOOD-RI	Infrastructure for promoting Metrology in Food and Nutrition	distributed		2018	2020	102.4	31.0
SOCIAL & CULTURAL INNOVATION	E-RIHS	European Research Infrastructure for Heritage Science	distributed		2016	2025*	54.0	5.0
	EHRI	European Holocaust Research Infrastructure	distributed		2018	2025*	15.0	2.0
	GGP	The Generations and Gender Programme	distributed		2021	2028*	18.2	1.1
	GUIDE	Growing Up in Digital Europe: EuroCohort	distributed		2021	2032*	580.6	17.8
	OPERAS	OPen scholarly communication in the European Research Area for Social Sciences and Humanities	distributed	AISBL, 2019	2021	2029*	15.0	0.9
	RESILIENCE	REligious Studies Infrastructure: tooLs, Innovation, Experts, conNections and Centres in Europe	distributed		2021	2034*	318.4	9.5

ESFRI Projects Roadmap 2021

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ESFRI PROJECTS

PHYSICAL SCIENCES & ENGINEERING

NAME	FULL NAME	TYPE	LEGAL STATUS (Y)	ROADMAP ENTRY (Y)	OPERATION START (Y)	INVESTMENT COST (M€)	OPERATION COST (M€/Y)
EST	European Solar Telescope	single-sited		2016	2029*	200.0	12.0
ET	Einstein Telescope	single-sited		2021	2035*	1,912.0	37.0
EuPRAXIA	European Plasma Research Accelerator with Excellence in Applications	distributed		2021	2028*	569.0	30.0
KM3NeT 2.0	KM3 Neutrino Telescope 2.0	distributed		2016	2020	196.0	3.0

- Two new entries in 2021: **Einstein Telescope (ET)** and **EuPRAXIA**
- EuPRAXIA is the only accelerator facility selected in the last 5 years
- EuPRAXIA is the first plasma accelerator facility ever included

PHYSICAL SCIENCES & ENGINEERING

EuPRAXIA surrounded by three telescopes…

ESFRI Landmarks Roadmap 2021
(Physical Sciences & Engineering)

PHYSICAL SCIENCES & ENGINEERING

ESFRI LANDMARKS

NAME	FULL NAME	TYPE	LEGAL STATUS (Y)	ROADMAP ENTRY (Y)	OPERATION START (Y)	INVESTMENT COST (M€)	OPERATION COST (M€/Y)
CTA	Cherenkov Telescope Array	single-sited	gGmbH, 2014	2008	2024*	400.0	20.0
ELI ERIC	Extreme Light Infrastructure	single-sited	ERIC, 2021	2006	2018	850.0	80.0
ELT	Extremely Large Telescope	single-sited	ESO#	2006	2027*	1,309.0	48.0
EMFL	European Magnetic Field Laboratory	distributed	AISBL, 2015	2008	2014	170.0	20.0
ESRF EBS	European Synchrotron Radiation Facility Extremely Brilliant Source	single-sited	ESRF#	2016	2020	128.0	82.0
European Spallation Source ERIC	European Spallation Source	single-sited	ERIC, 2015	2006	2026*	3,009.0	140.0
European XFEL	European X-Ray Free-Electron Laser Facility	single-sited	European XFEL#	2006	2017	1,540.0	137.0
FAIR	Facility for Antiproton and Ion Research	single-sited	GmbH, 2010	2006	2025*	NA	NA
HL-LHC	High-Luminosity Large Hadron Collider	single-sited	CERN#	2016	2027*	1,408.0	136.0
ILL	Institut Max von Laue - Paul Langevin	single-sited	ILL#	2006	2012	188.0	100.0
SKAO	Square Kilometre Array Observatory	single-sited	SKAO, 2011	2006	2027*	1,986.0	77.0
SPIRAL2	Système de Production d'Ions Radioactifs en Ligne de 2e génération	single-sited	GANIL	2006	2019	307.3	5.2

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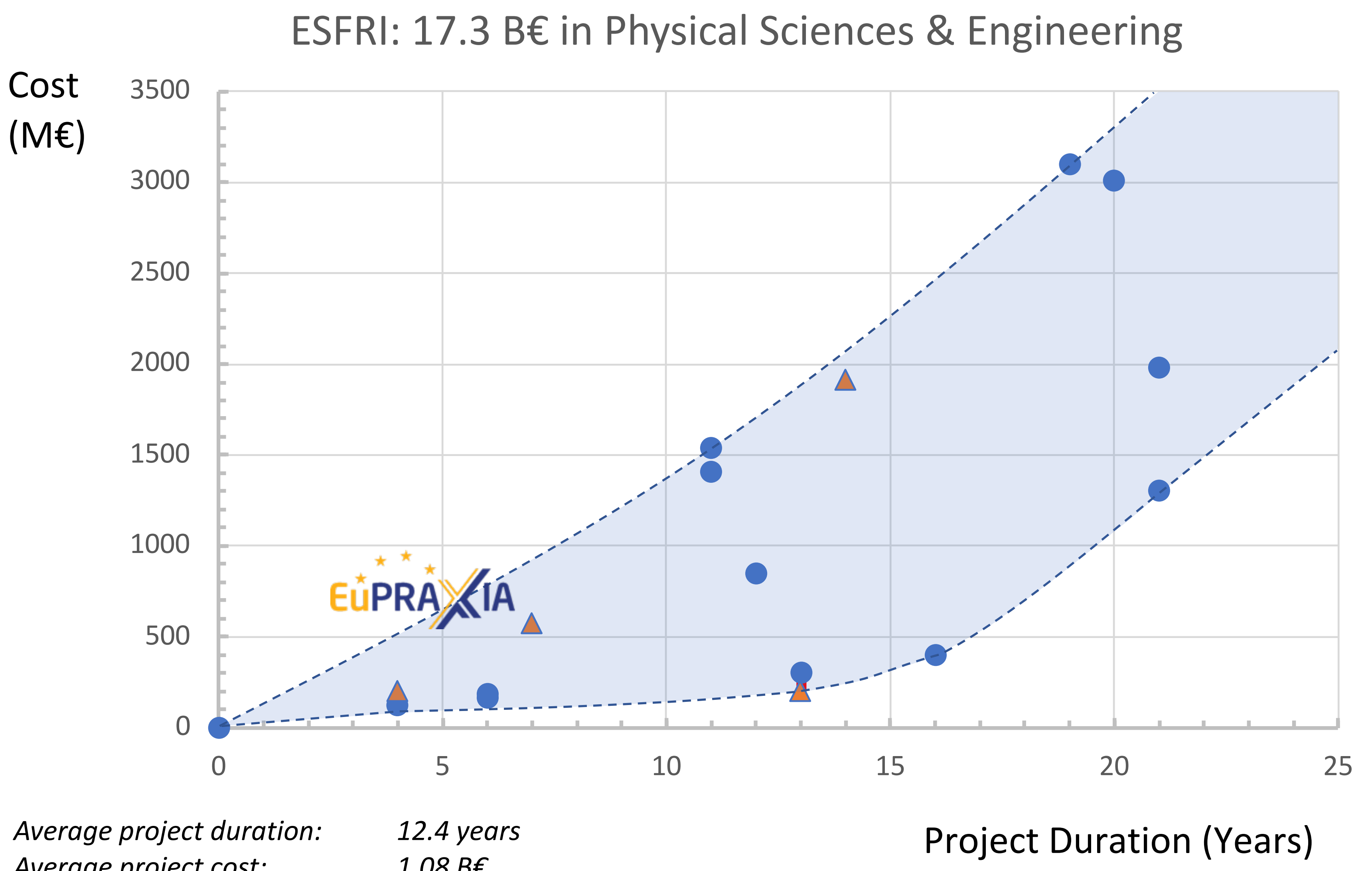
ESFRI Roadmap 2021

(Physical Sciences & Engineering – Projects Red Triangles)



Average project duration: *12.4 years*
Average project cost: *1.08 B€*

Accelerator Facilities	• 10.1 B€ invest • 730 M€ OP / year
Telescopes	• 6.0 B€ invest • 197 M€ OP / year
Laser Facilities (ELI)	• 0.85 B€ invest • 80 M€ OP / year
Reactor neutrons (ILL)	• 0.19 B€ invest • 100 M€ OP / year
Magnet lab (EMFL)	• 0.17 B€ invest • 20 M€ OP / year