Ongoing Efforts towards Coordination in Europe

R. Aßmann, DESY

ANAR2017: Advanced and Novel Accelerators for High Energy Physics Roadmap Workshop 2017

CERN, Switzerland

24th – 28th April 2017

EuroNNAc²

European Network for Novel Accelerators

EINDHOVEN University of Technology

University of Oxford
University of Strathclyde
Manchester University
Lancaster University
Cockcroft Institute
STFC Daresbury Laboratory
John Adams Institute
ASTeC
STFC Central Laser Facility
Liverpool University
University College London
Imperial College
Queen's University of Belfast

University Düsseldorf
LMU University Munich
Stiftung Deutscher Elektronen Synchrotron (DESY)
Gesellschaft für Schwerionenforschung (GSI)
Max-Planck-Institute for Quantum Optics
Max-Planck-Institute for Physics
Helmholtz Institute Jena
Helmholtz-Zentrum Dresden-Rossendorf (HZDR)
University Hamburg
University Erlangen
Universtity Darmstadt

Lund University

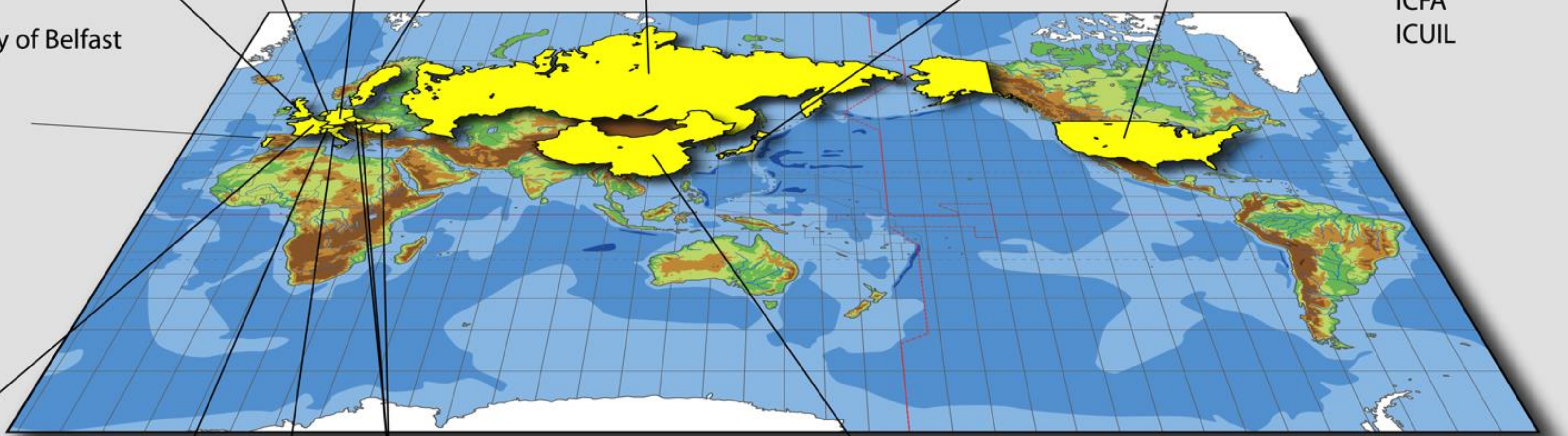
Budker INP
Institute of Applied Physics RAS

KEK

Fermi National Accelerator Laboratory
SLAC National Accelerator Laboratory
University of California Los Angeles
Lawrence Berkely National Laboratory
Brookhaven National Laboratory

ICFA
ICUIL

Instituto Superior
Tecnico de Lisboa



LULI
Soleil
LPGP
LOA
IRAMIS/CEA
IRFU/CEA
Laboratoire Leprince-Ringuet
(Ecole polytechnique - CNRS/IN2P3)
LAL

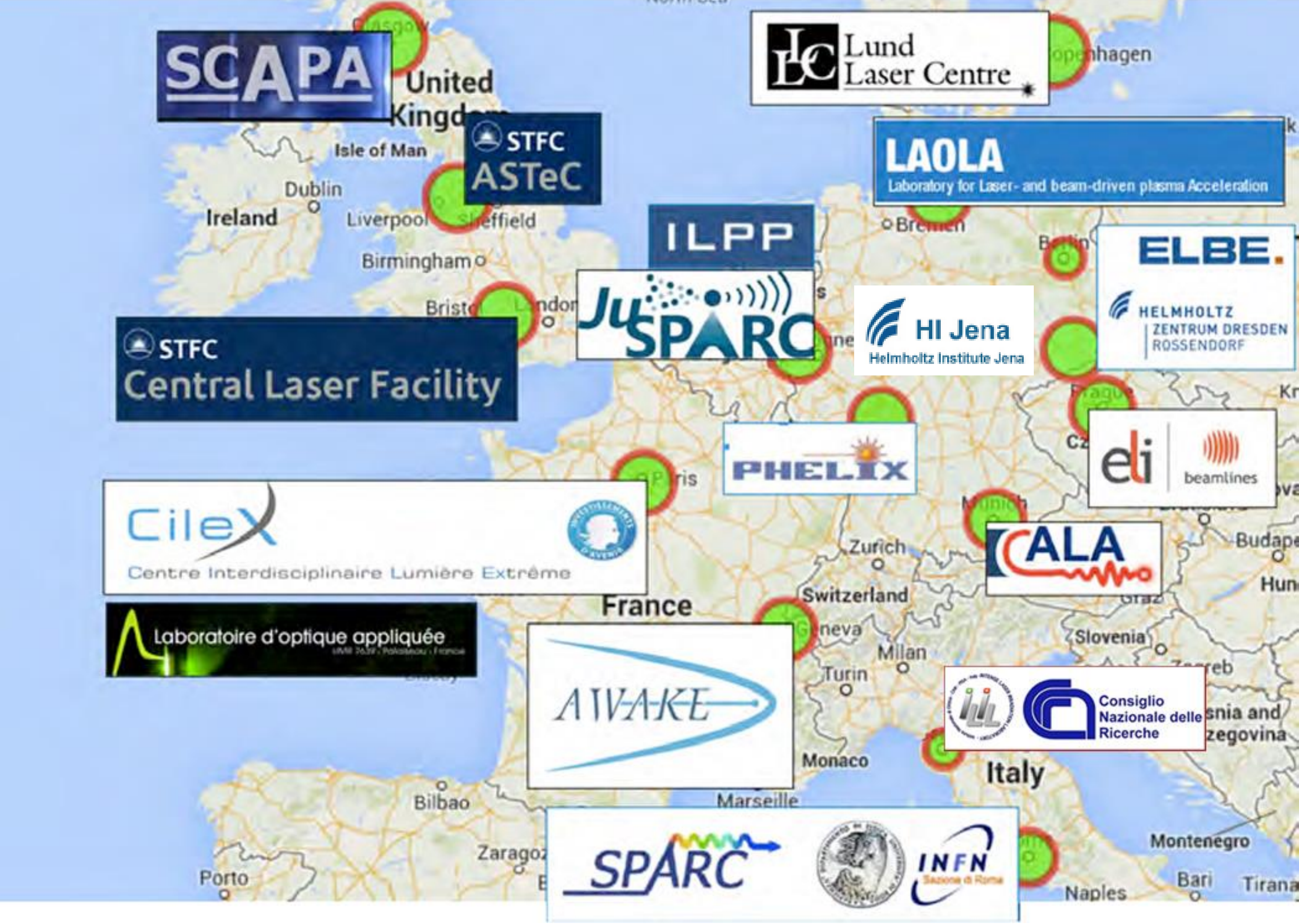
Extreme Light Infrastructures (ELI)
ELI Beams (Czech Republic)
Wigner Research Center (Hungary)

Inst. of Physics, Chinese Academy of Sciences
Tsinghua University, Beijing
Shanghai Jiao Tong University

European Organization for
Nuclear Research (CERN)
PSI

INFN-LNF
Pisa University and INFN
Consiglio Nazionale Delle Ricerche, INO
University of Rome LA SAPIENZA

EuCARD²


SCAPA
United Kingdom
Isle of Man
STFC
ASTeC
Dublin
Ireland
Liverpool
Sheffield
Birmingham
Bristol
London
STFC
Central Laser Facility
Lund Laser Centre
Copenhagen
LAOLA
Laboratory for Laser- and beam-driven plasma Acceleration
ILPP
JuSPARC
Bremen
Berlin
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HELMHOLTZ
ZENTRUM DRESDEN
ROSSENDORF
HI Jena
Helmholtz Institute Jena
Prague
PHELIX
eli
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Centre Interdisciplinaire Lumière Extrême
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CALA
Zurich
Budapest
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France
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Consiglio
Nazionale delle
Ricerche
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Herzegovina
Monaco
Italy
Bilbao
Marseille
Montenegro
Zaragoza
SPARC
INFN
Porto
Naples
Bari
Tirana

Scope : Novel High Gradient Accelerators

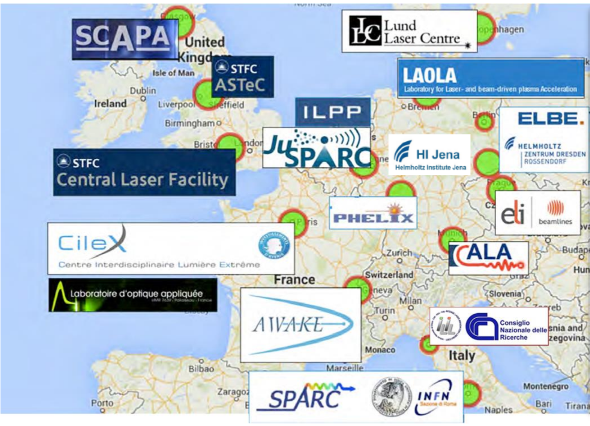
- Original focus: European **plasma acceleration** community
  - Plasma-based electron accelerators
  - Plasma-based hadron accelerators
  - Driven by lasers and/or particle beams (e- and p)
- Grown to include discussions and teams from **dielectric vacuum accelerator** R&D:
  - Dielectric vacuum accelerators driven by THz (more specifically 300 GHz) sources → **AXSIS ERC synergy grant** (DESY/UHH), **CLARA**, ...
  - Dielectric vacuum accelerators driven by optical lasers → **ACHIP international collaboration GBM grant** → Erlangen, PSI, DESY, GSI, TUD, ...

EuCARD²

Novel Acceleration R&D in Europe

European Network EuroNNAc for Novel Accelerators

National novel accelerator projects with European network



Independent national projects*, funded by national states. About 16 major facilities for novel plasma acceleration R&D.

Funded by EU FP7 through EuCARD2

European Network EuroNNAc for Novel Accelerators

European novel accelerator projects with international involvement

AWAKE

CERN experiment collaboration under leadership of MPI

AXSIS

ERC Synergy Grant

EuPRAXIA

Funded by EU Horizon2020 as EU Design Study

** See note on ELI*

EuroNNAc2 Mission I
Scientific Exchange

EAAC 2015

2nd EUROPEAN ADVANCED ACCELERATOR CONCEPTS WORKSHOP
13-19 SEPTEMBER 2015 *LA BIODOLA - ISOLA D'ELBA - ITALY*

- 258 registered participants
- 45 sponsored students.
- Participants from 23 countries in 4 continents (11 EU member states).
- Reached maximum capacity in 2^{nd} such workshop.

Scientific Work

- Working Groups + Summaries: 7
- Invited Talks: 30
- Special Science Talk: 1
- WG Talks: 138
- Posters: 76

  Thanks to Alban Mosnier + Program Committee

- Proceedings - Special Volume NIM → Published in 2016

  Lead editor: Ulrich Dorda

- **81 papers, peer reviewed** *(from 50 papers at EAAC2013)*
- Already generated **83 citations** → papers are read and used!

iNSPIRE HEP

Welcome to INSPIRE, the High Energy Physics infor[mation] system. Please direct questions, comments or conce[rns to] feedback@inspirehep.net

773__w:C15-09-12 or 773__w:C15/09 | Brief format | Search | Easy Search | Advanced Search

find j "Phys.Rev.Lett.,105*" :: more

Sort by: latest first | desc. | - or rank by - | Display results: 100 results | single list

HEP 81 records found Search took 1.74 seconds.

1. **Transverse oscillations in plasma wakefield experiments at FACET**
E. Adli *et al.*. 2016. 5 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 94-98
DOI: 10.1016/j.nima.2016.02.054
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record

2. **Production of quasi ellipsoidal laser pulses for next generation high brightne[ss] photoinjectors**
T. Rublack *et al.*. 2016. 4 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 438-441
DOI: 10.1016/j.nima.2015.12.004
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record

3. **Staging optics considerations for a plasma wakefield acceleration linear colli[der]**
C.A. Lindstrøm, E. Adli, J.M. Allen, J.P. Delahaye, M.J. Hogan, C. Joshi, P. Muggli, T.O. Raubenheime[r,] Yakimenko. 2016. 5 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 224-228
DOI: 10.1016/j.nima.2015.12.065
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record - Cited by 4 records

4. **Laser-plasma-based linear collider using hollow plasma channels**
C.B. Schroeder, C. Benedetti, E. Esarey, W.P. Leemans. 2016. 4 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 113-116
DOI: 10.1016/j.nima.2016.03.001
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record

5. **Recent advances in high-performance modeling of plasma-based acceleratio[n] using the full PIC method**
J.-L. Vay, R. Lehe, H. Vincenti, B.B. Godfrey, I. Haber, P. Lee. 2016. 5 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 353-357
DOI: 10.1016/j.nima.2015.12.033
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
OSTI Information Bridge Server
Detailed record - Cited by 1 record

6. **BESTIA – The next generation ultra-fast CO 2 laser for advanced accelerator research**
Igor V. Pogorelsky, Markus Babzien, Ilan Ben-Zvi, John Skaritka, Mikhail N. Polyanskiy. 2016. 6 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 432-437
DOI: 10.1016/j.nima.2015.11.126
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
OSTI Information Bridge Server
Detailed record - Cited by 3 records

7. **A “slingshot” laser-driven acceleration mechanism of plasma electrons**
Gaetano Fiore, Sergio De Nicola. 2016. 5 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 104-108
DOI: 10.1016/j.nima.2016.02.085
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record - Cited by 1 record

8. **Investigations of the concept of a multibunch dielectric wakefield accelerator**
I.N. Onishchenko, V.A. Kiselev, A.F. Linnik, V.I. Pristupa, G.V. Sotnikov. 2016. 7 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 199-205
DOI: 10.1016/j.nima.2016.02.080
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record

9. **Injection of electrons by colliding laser pulses in a laser wakefield accelerator**
M. Hansson, B. Aurand, H. Ekerfelt, A. Persson, O. Lundh. 2016. 5 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 99-103
DOI: 10.1016/j.nima.2016.02.070
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
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Detailed record

10. **A preliminary design of the collinear dielectric wakefield accelerator**
A. Zholents *et al.*. 2016. 4 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 190-193
DOI: 10.1016/j.nima.2016.02.003
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record - Cited by 4 records

11. **Numerical simulations of recent proton acceleration experiments with sub-100 TW laser systems**
Stefano Sinigardi. 2016. 5 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 167-171
DOI: 10.1016/j.nima.2016.04.001
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
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12. **The SPARC_LAB Thomson source**
C. Vaccarezza *et al.*. 2016. 6 pp.

Published in Nucl.Instrum.Meth. A829 (2016) 237-242
DOI: 10.1016/j.nima.2016.01.089
Conference: C15-09-12 Proceedings
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13. **The electron accelerator for the AWAKE experiment at CERN**
K. Pepitone (CERN) et al.. 2016. 3 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 73-75
DOI: 10.1016/j.nima.2016.02.025
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
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Detailed record

14. **Matching sub-fs electron bunches for laser-driven plasma acceleration at**
J. Zhu, R.W. Assmann, U. Dorda, B. Marchetti. 2016. 4 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 229-232
DOI: 10.1016/j.nima.2016.01.066
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
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15. **Progress of plasma wakefield self-modulation experiments at FACET**
E. Adli et al.. 2016. 5 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 334-338
DOI: 10.1016/j.nima.2016.02.075
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
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16. **Role of laser contrast and foil thickness in target normal sheath accelerat**
L.A. Gizzi et al.. 2016. 5 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 144-148
DOI: 10.1016/j.nima.2016.01.036
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
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17. **Betatron radiation based diagnostics for plasma wakefield accelerated el beams at the SPARC_LAB test facility**
V. Shpakov et al.. 2016. 4 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 330-333
DOI: 10.1016/j.nima.2016.02.074
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record - Cited by 1 record

18. **Summary of working group 1: Electron beam from plasmas**
V. Malka, E. Gschwendtner (CERN). 2016. 3 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 30-32
DOI: 10.1016/j.nima.2016.01.006
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record

19. **The ELIMED transport and dosimetry beamline for laser-driven ion beams**
F. Romano et al.. 2016. 6 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 153-158
DOI: 10.1016/j.nima.2016.01.064
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record - Cited by 2 records

20. **Summary of Working Group 2: Ion beams from plasmas**
M. Borghesi, U. Schramm. 2016. 4 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 137-140
DOI: 10.1016/j.nima.2016.01.021
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record - Cited by 1 record

21. **High energy electron radiography system design and simulation study of beam angle-position correlation and aperture effect on the images**
Quantang Zhao et al.. 2016. 8 pp.
Published in Nucl.Instrum.Meth. A832 (2016) 144-151
DOI: 10.1016/j.nima.2016.06.103
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record

22. **Generation of attosecond electron bunches in a laser-plasma accelerator using a plasma density upramp**
M.K. Weikum, F.Y. Li, R.W. Assmann, Z.M. Sheng, D. Jaroszynski. 2016. 4 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 33-36
DOI: 10.1016/j.nima.2016.01.003
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record

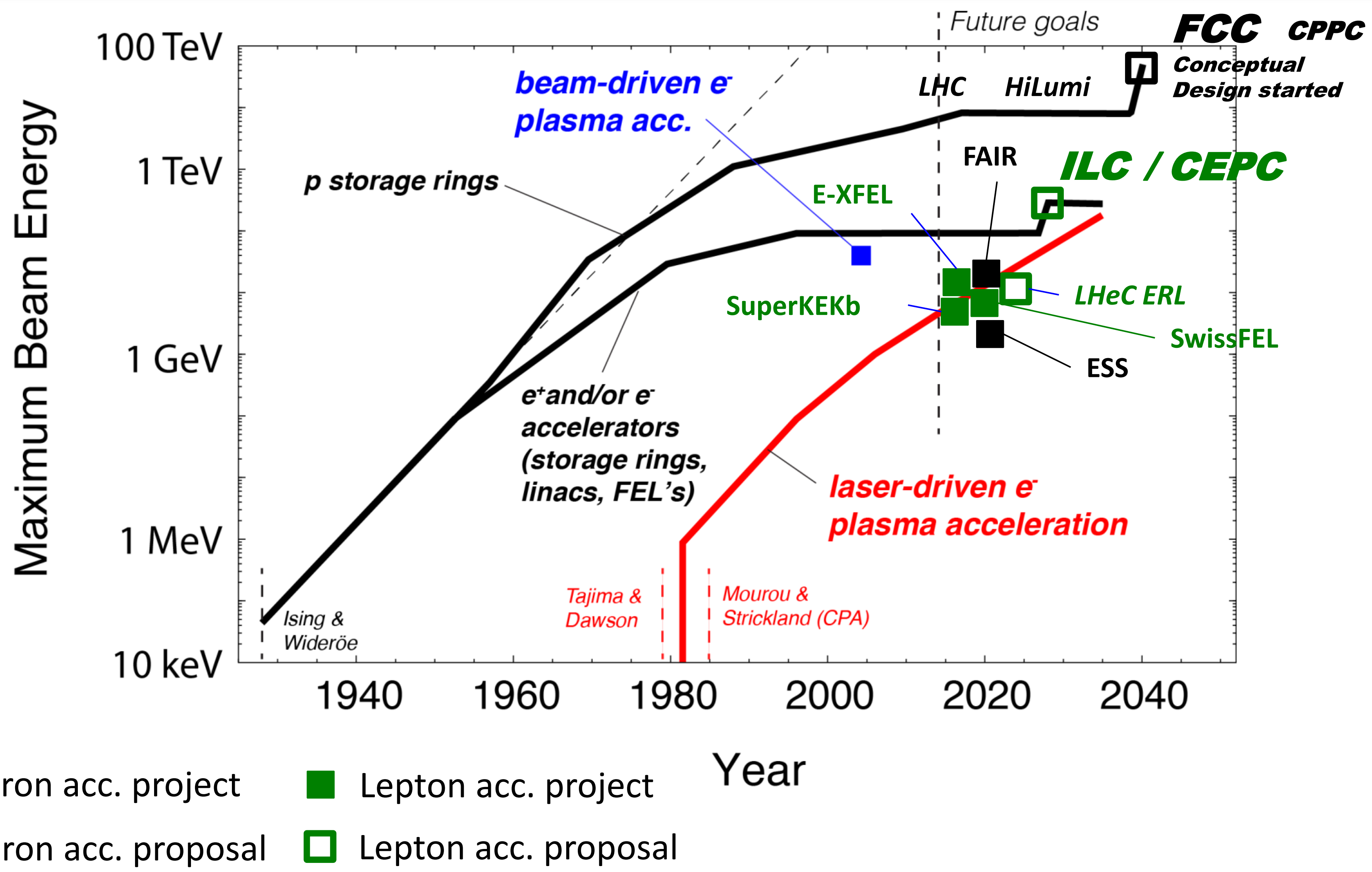
23. **High transformer ratio of multi-channel dielectric wakefield structures**
Sergey V. Shchelkunov, Thomas C. Marshall, Gennadij V. Sotnikov, Jay L. Hirshfield. 2016. 8 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 213-220
DOI: 10.1016/j.nima.2016.03.033
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
OSTI Information Bridge Server
Detailed record

24. **Comparison of self-injection thresholds in He and N 2 and role of self-focusing in LWFA**
D. Palla, F. Baffigi, F. Brandi, L. Fulgentini, P. Koester, L. Labate, P. Londrillo, L.A. Gizzi. 2016. 5 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 408-412
DOI: 10.1016/j.nima.2016.03.109
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record - Cited by 1 record

25. **Real-time diagnostic for charging and damage of dielectrics in accelerators**
S.V. Shchelkunov, T.C. Marshall, J.L. Hirshfield. 2016. 5 pp.
Published in Nucl.Instrum.Meth. A829 (2016) 194-198
DOI: 10.1016/j.nima.2016.02.014
Conference: C15-09-12 Proceedings
References | BibTeX | LaTeX(US) | LaTeX(EU) | Harvmac | EndNote
Detailed record - Cited by 1 record

26. **Observations and diagnostics in high brightness beams**
A. Cianchi, M.P. Anania, F. Bisesto, M. Castellano, E. Chiadroni, R. Pompili, V. Shpakov. 2016. 5 pp.

EuroNNAc2 Mission II Strategic Assessment



Fascinating Research Tasks for the 21st Century (selection)

Understand nature beyond the Higgs

Explain dark energy and dark matter

Understand & test quantum theory of gravity

High energy particle collider

Very large or high accelerating gradient

Control complex and dynamic matter

Investigate and understand transient states

Understand and manipulate non-equilibrium phenomena

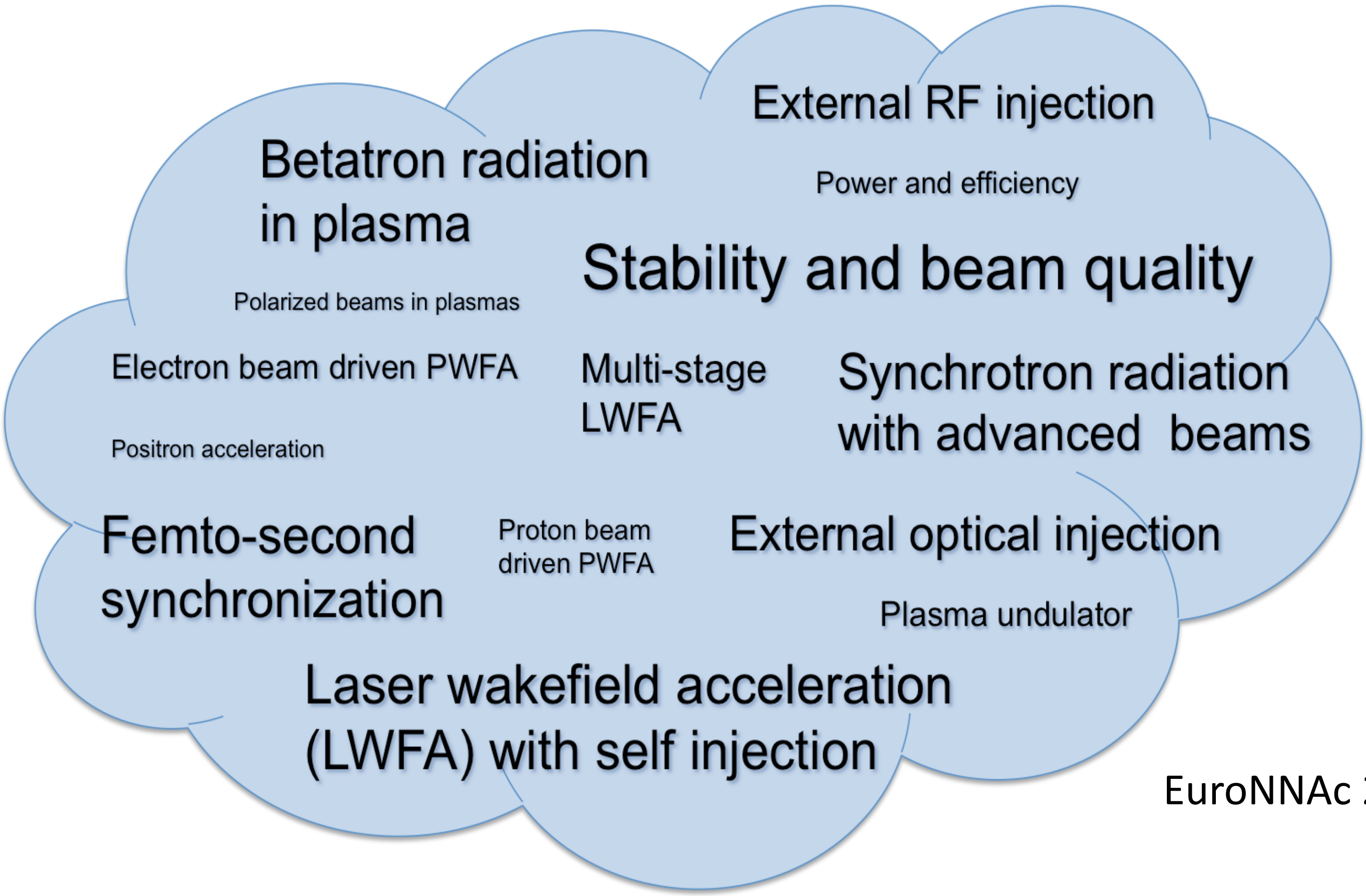
Accessible (compact) ultra-fast X ray FEL's university-based

Compact, high res & fast real time imaging of living organisms (humans)

Ultra-compact accel.-based X ray imaging

high resolution

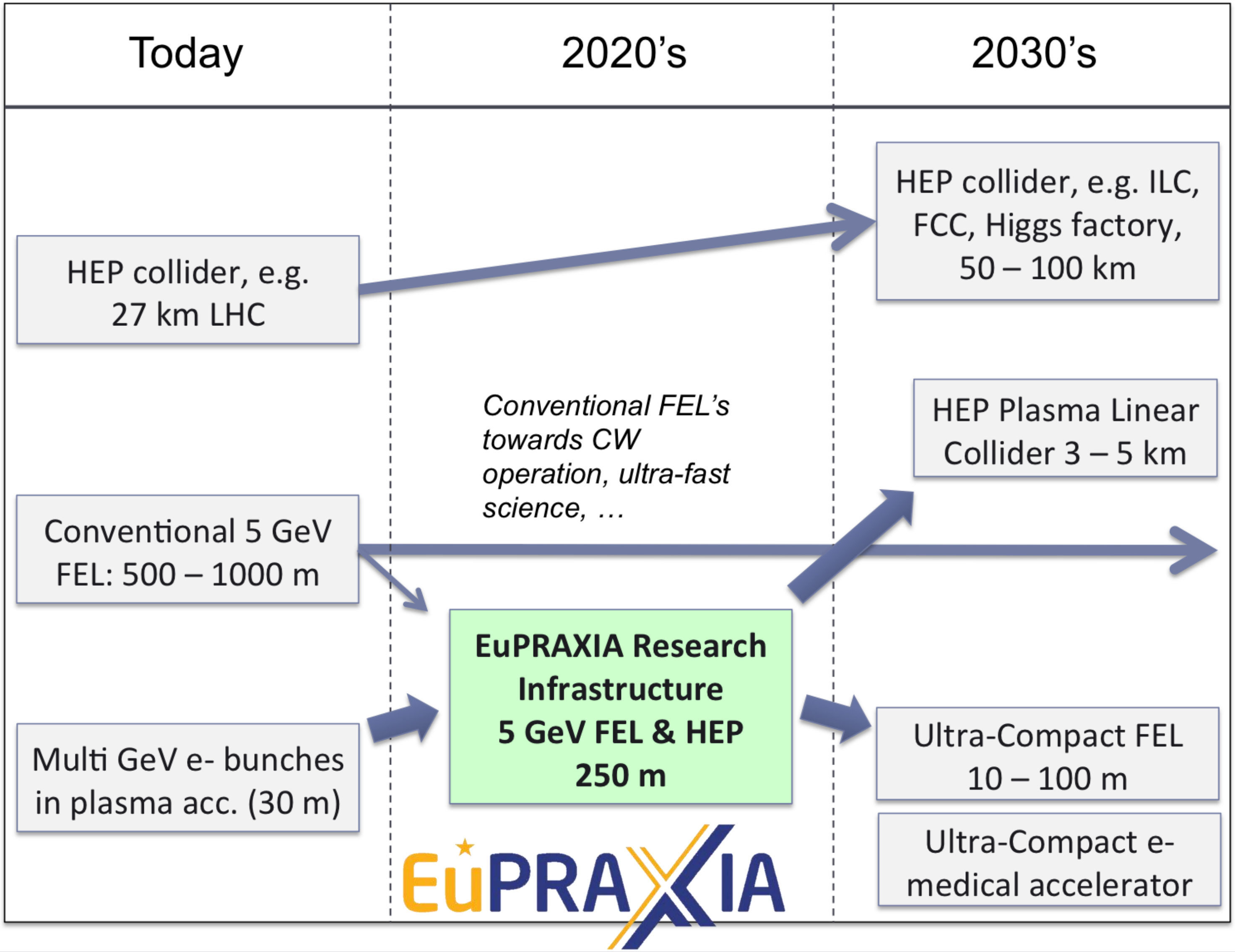
EuroNNAc2 Mission II Strategic Assessment



EuroNNAc 2013

Word cloud: Font size as indicator of invested effort. Based on community input.

EuroNNAc2 Mission III
Roadmap to the 2030's



EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA

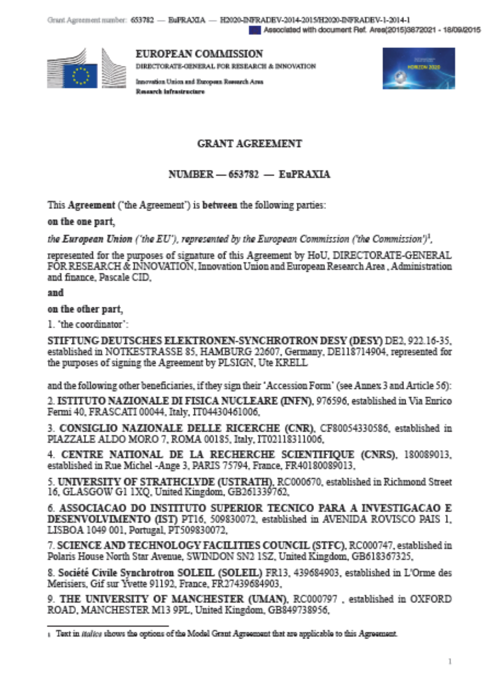
A **Horizon 2020 Design Study** for a future large Research Infrastructure

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

EuPRAXIA is a Horizon2020 Design Study

Horizon 2020

- EuPRAXIA is a so-called **EU design study**.
- On average in accelerator field only **one approved by EU every 2 years** since 2007.
- DESY is coordinating lab of EuPRAXIA.
- Study is legally governed by contracts:
  - ***grant agreement (269 pages)****, defining the work plan, milestones and deliverables.*
  - ***consortium agreement (48 pages)****, defining project rules.*
  - **Associated partners** have sent signed letters, accepting consortium rules (governance, IP, ...).


Grant Agreement number: 653782 — EuPRAXIA — H2020-INFRADEV-2014-2015/H2020-INFRADEV-1-2014-1
Associated with document Ref. Ares(2015)3872021 - 18/09/2015

EUROPEAN COMMISSION
DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION
Innovation Union and European Research Area
Research infrastructure

GRANT AGREEMENT

NUMBER — 653782 — EuPRAXIA

This **Agreement** ('the Agreement') is **between** the following parties:

on the one part,

the European Union ('the EU'), represented by the European Commission ('the Commission')[1],

represented for the purposes of signature of this Agreement by HoU, DIRECTORATE-GENERAL FOR RESEARCH & INNOVATION, Innovation Union and European Research Area , Administration and finance, Pascale CID,

and

on the other part,

1. 'the coordinator':

STIFTUNG DEUTSCHES ELEKTRONEN-SYNCHROTRON DESY (DESY) DE2, 922.16-35, established in NOTKESTRASSE 85, HAMBURG 22607, Germany, DE118714904, represented for the purposes of signing the Agreement by PLSIGN, Ute KRELL

and the following other beneficiaries, if they sign their 'Accession Form' (see Annex 3 and Article 56):

2. **ISTITUTO NAZIONALE DI FISICA NUCLEARE (INFN)**, 976596, established in Via Enrico Fermi 40, FRASCATI 00044, Italy, IT04430461006,

3. **CONSIGLIO NAZIONALE DELLE RICERCHE (CNR)**, CF80054330586, established in PIAZZALE ALDO MORO 7, ROMA 00185, Italy, IT02118311006,

4. **CENTRE NATIONAL DE LA RECHERCHE SCIENTIFIQUE (CNRS)**, 180089013, established in Rue Michel -Ange 3, PARIS 75794, France, FR40180089013,

5. **UNIVERSITY OF STRATHCLYDE (USTRATH)**, RC000670, established in Richmond Street 16, GLASGOW G1 1XQ, United Kingdom, GB261339762,

6. **ASSOCIACAO DO INSTITUTO SUPERIOR TECNICO PARA A INVESTIGACAO E DESENVOLVIMENTO (IST)** PT16, 509830072, established in AVENIDA ROVISCO PAIS 1, LISBOA 1049 001, Portugal, PT509830072,

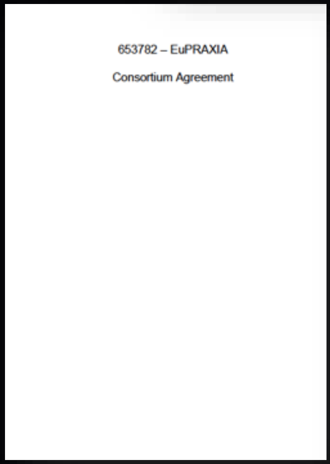
7. **SCIENCE AND TECHNOLOGY FACILITIES COUNCIL (STFC)**, RC000747, established in Polaris House North Star Avenue, SWINDON SN2 1SZ, United Kingdom, GB618367325,

8. **Société Civile Synchrotron SOLEIL (SOLEIL)** FR13, 439684903, established in L'Orme des Merisiers, Gif sur Yvette 91192, France, FR27439684903,

9. **THE UNIVERSITY OF MANCHESTER (UMAN)**, RC000797 , established in OXFORD ROAD, MANCHESTER M13 9PL, United Kingdom, GB849738956,

[1] Text in *italics* shows the options of the Model Grant Agreement that are applicable to this Agreement.

1


653782 – EuPRAXIA

Consortium Agreement

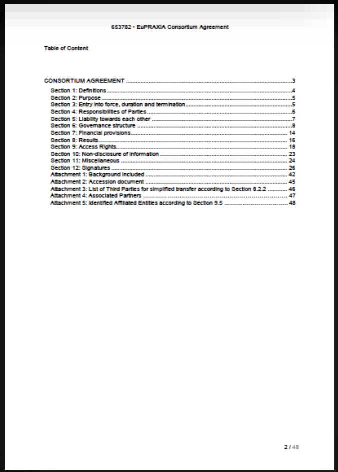

653782 - EuPRAXIA Consortium Agreement

Table of Content

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Participating Institutions

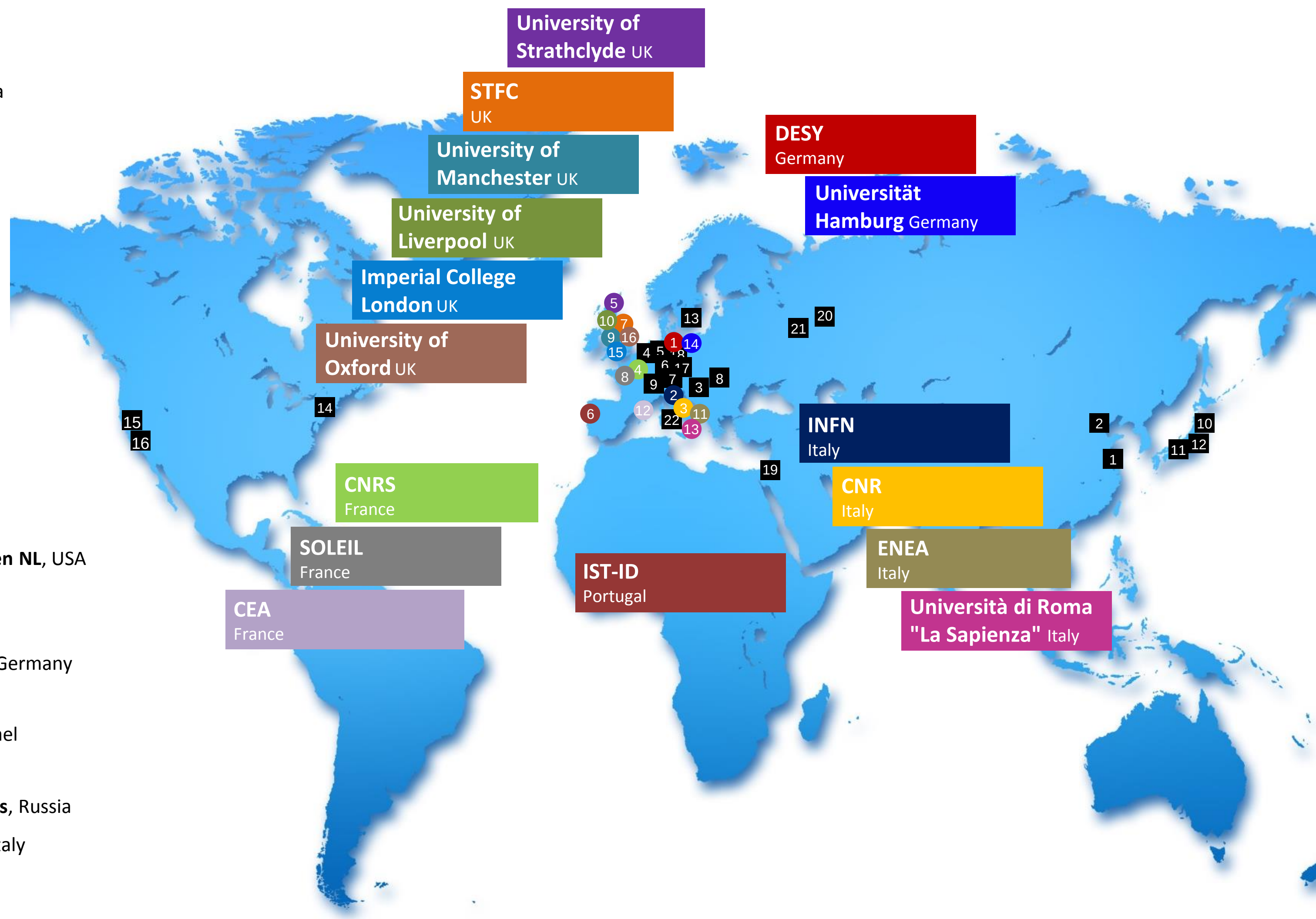
16 beneficiaries, 22 associated partners

Horizon 2020

Associated Partners

(as of October 2016)

1 **Shanghai Jiao Tong-University**, China
2 **Tsinghua University Beijing**, China
3 **ELI Beamlines**, International
4 **PHLAM, Université de Lille,** France
5 **Helmholtz-Institut Jena**, Germany
6 **HZDR (Helmholtz)**, Germany
7 **LMU München**, Germany
8 **Wigner Fizikai Kutatóközpont**, Hungary
9 **CERN**, International
10 **Kansai Photon Science Institute**, Japan
11 **Osaka University**, Japan
12 **RIKEN SPring-8**, Japan
13 **Lunds Universitet**, Sweden
14 **Stony Brook University & Brookhaven NL**, USA
15 **LBNL**, USA
16 **UCLA**, USA
17 **Karlsruher Institut für Technologie**, Germany
18 **Forschungszentrum Jülich**, Germany
19 **Hebrew University of Jerusalem**, Israel
20 **Institute of Applied Physics**, Russia
21 **Joint Institute for High Temperatures**, Russia
22 **Università di Roma "Tor Vergata«**, Italy



HORIZON 2020 EuPRAXIA Design Study

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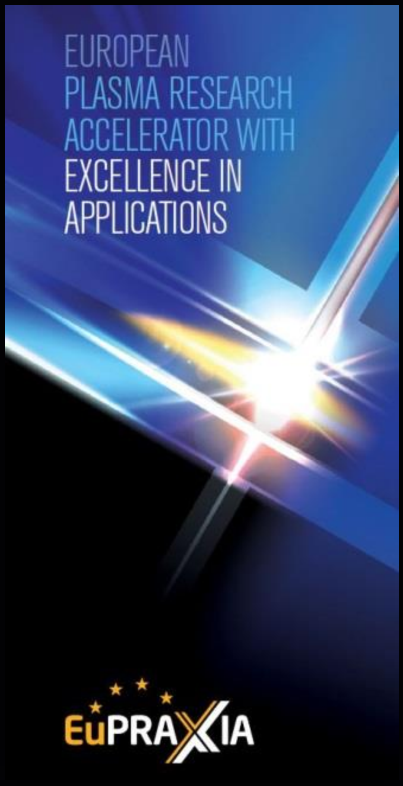
Outreach

→ PR Material available

Horizon 2020



www.eupraxia-project.eu

#EuPRAXIA
#plasma
#accelerator

The Decisive Goal

Plasma Acceleration

proven

Build a plasma accelerator with usable beam quality!

to be done

Plasma Accelerator

(goal: high beam quality, lower cost, lower size)

Project Timeline

Horizon 2020

09.2014	Proposal submission
07.2015	Approval
11.2015	**Start of EuPRAXIA project**
2016	Organization (collaboration agreements, ...). Hiring dedicated personnel. Ten workshops on EuPRAXIA/EuroNNAc matters. Decision parameters for first study versions.
08.2019	Application to **ESFRI roadmap** for 2020 update
10.2019	Final **conceptual design report** and end design study
2020	*Construction decision*
2021 – 2025	*Construction*
2025 – 2035	*Operation*

ESFRI = European Strategy for Future Research Infrastructures

Industrial Participation

Horizon 2020

Industry: involved through workshops and Scientific Advisory Board

Contacts still evolving, several cooperations under discussion

Thales group (France): Number of employees: 62,194 (2015)
Sales 14.06 B€ (2015)

Amplitude (France): Number of employees: 80 (2015)
Sales 17.4 M€ (2015)

Trumpf group (Germany): Number of employees: 11,181 (2016)
Sales 2.81 B€ (2016)

Reminder: Linear Collider Design Constraints

1) High energy E
Low cost → Efficient acceleration with high accelerating gradients (small length)

---

2) High luminosity L
Low cost → Limited beam power P_b *(14 MW x 2, 6% efficiency → 500 MW wall plug)*
Very small beam sizes (no beam-beam limit)

LC → P_b ≈ 14 MW

limit

$$P_b = E \cdot \left[N_e \cdot N_b \cdot f_{rep} \right] e$$

Aim for maximum energy reach

$$L = \frac{N_e^2 \cdot N_b \cdot f_{rep}}{4\pi \; \sigma_x^* \cdot \sigma_y^*} \cdot H_D$$

Decrease beam sizes

Practical limit on IP beam sizes: Imperfections Errors
static + time dependent (= stability)

European Network EuroNNAc for Novel Accelerators

EuPRAXIA

Typical IP Spot Size Goals LC's

Horizon2020

Machine	σ_x^* [nm]	σ_y^* [nm]	$\sigma_x^* \cdot \sigma_y^*$ [cm^2]
LEP	300000	3000	$9.0 \cdot 10^{-6}$
SLC	1700	900	$1.5 \cdot 10^{-8}$
TESLA	553	**5**	$2.8 \cdot 10^{-11}$
JLC/NLC	235	**3**	$7.5 \cdot 10^{-12}$
CLIC	43	**1**	$4.3 \cdot 10^{-13}$

Like a human hair…

Achieved

1 nm = size of water molecule

Emittance growth inside a stage and from stage to stage

Where is the feasibility limit with plasma accelerators?

(collide nm-size beams – no collider if beams miss each other)

Tolerances from Emittance Growth

Nuclear Instruments and Methods in Physics Research A 410 (1998) 544–548

Transverse beam dynamics in plasma-based linacs

Ralph Assmann[1a,*], Kaoru Yokoya[b]

[a] Stanford Linear Accelerator Center, Stanford University, Stanford, CA 94309, USA
[b] High Energy Accelerator Research Organization (KEK), Tsukuba, Ibaraki 305, Japan

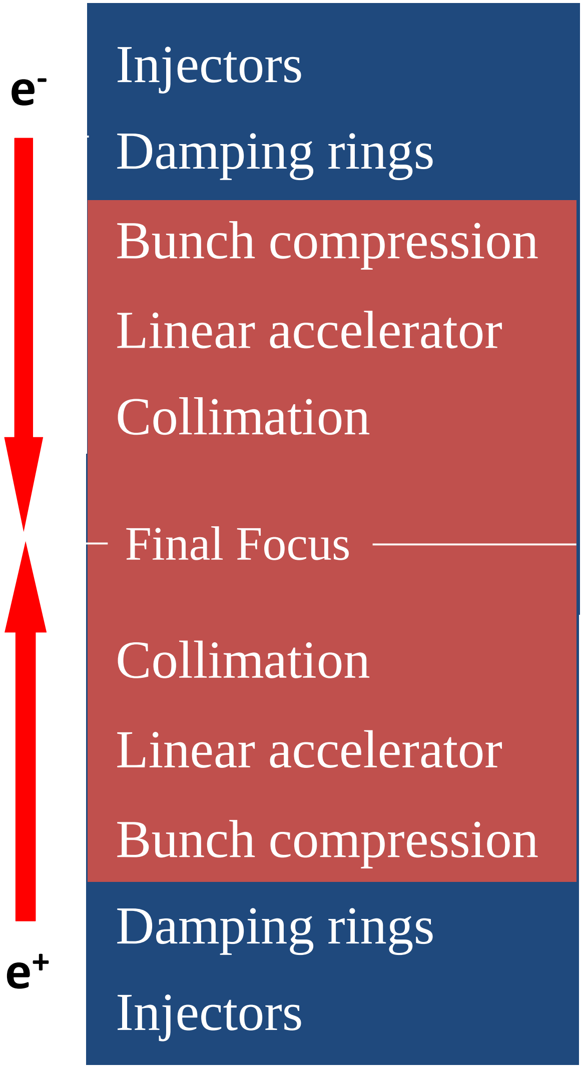
Single stage approaches avoid this problem (→ AWAKE) but can develop other problems.

Table 1
Parameters of the two 1 TeV linac designs and the accelerated beam. We only list parameters that are important for the discussion of the transverse beam dynamics. The focusing field for the LWFA case is a simplified estimate

Parameter	PWFA	LWFA
Plasma density	2×10^{14} cm^{-3}	10^{17} cm^{-3}
Accelerating gradient	1 GeV/m	30 GeV/m
Acc. wavelength	2 mm	100 µm
Focusing field	6000 T/m	600000 T/m
Module length	6 m	1 m
Injection energy	1 GeV	1 GeV
Final energy	1 TeV	1 TeV
Number of modules	167	33

In this case we can calculate the tolerances on the offsets Δx for a total emittance growth of 200%. We find tolerances on σ_x/σ_0 of 0.08 (PWFA) and 0.18 (LWFA).

Linear Collider → Not without stability!



Provide the beam

Provide small emittance

Provide short bunch length

Provide beam energy

Provide small background

Provide demagnification

Collide beams

Exponential loss in luminosity with shot-to-shot jitter:

$$L \approx L_0 \cdot e^{-\left(\Delta_y^2 / 4\sigma_y^2\right)}$$

LEP: beam overlap alignment (Δ_y ~ 300 nm)

SLC: beam overlap alignment (Δ_y ~ 50 nm)

Stability – A Multi Facetted Problem

- **Errors**:
  pointing stability of driver (laser/e-beam/p-beam), driver fluctuations, plasma inhomogeneities versus length, plasma relaxation issues shot to shot, plasma heating from driver, driver instabilities, ground motion, support resonances, ...
- **Measurement, correction and feedback**:
  measurement of driver and accelerated beam, correcting accelerated beam, feedback against errors, plasma energy extraction, structural engineering, compensating schemes, ...
- **Shaping of accelerated beam**:
  collimation, correction of correlated energy spread, ...

Bringing standard accelerator technology & methods to plasma accelerators

HEP Roadmap from EuroNNAc2 → for discussion

- **OPTION A:**
  - LHC program — until 2035
  - A linear collider built — in 2020's
  - Linear collider physics program — 2030 – 2045
- **OPTION B:**
  - LHC program — until 2035
  - No linear collider constructed — in 2020's
  - FCC built — in 2030's
  - FCC physics program — 2040 – 2055
- **OPTION C:**
  - LHC program — until 2035
  - No large collider project approved.

HEP Roadmap from EuroNNAc2 → for discussion

- **OPTION A:**
  - LHC program — until 2035
  - A linear collider built — in 2020's
  - Linear collider physics program — 2030 – 2045
- **OPTION B:**
  - LHC
  - No li
  - FCC
  - FCC
- **OPTIO**
  - LHC — until 2035
  - No large collider project approved.

- **Plasma accelerator technology as linear collider upgrade to higher energies**
- **Required in 2040's**

HEP Roadmap from EuroNNAc2 → for discussion

- **OPTION A:**
  - LHC program — until 2035
  - A linear collider built — in 2020's
  - Linear collider physics program — 2030 – 2045
- **OPTION B:**
  - LHC program — until 2035
  - No linear collider constructed — in 2020's
  - FCC built — in 2030's
  - FCC physics program — 2040 – 2055
- **OPTION C:**
  - LHC p
  - No lar

- **Plasma accelerator technology not needed for HEP**

HEP Roadmap from EuroNNAc2 → for discussion

- **OPTION A:**
  - LHC pro
  - A
  - L
- **OPT**
  - LH
  - No
  - FC
  - FC … program — 2040 – 2055

Plasma accelerator technology for a plasma linear collider for high energies

Required in 2030's

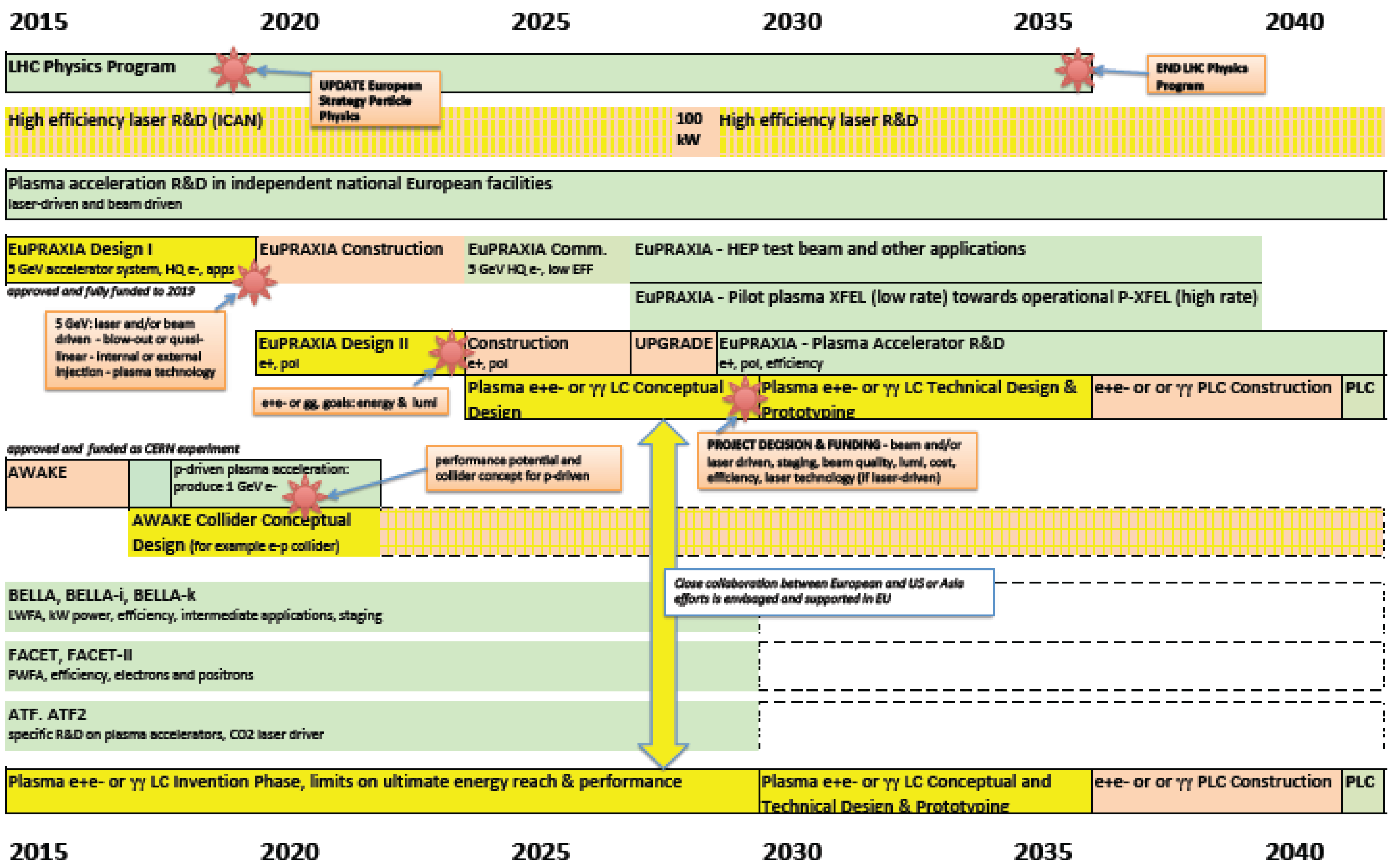
- **OPTION C:**
  - LHC program — until 2035
  - No large collider project approved.

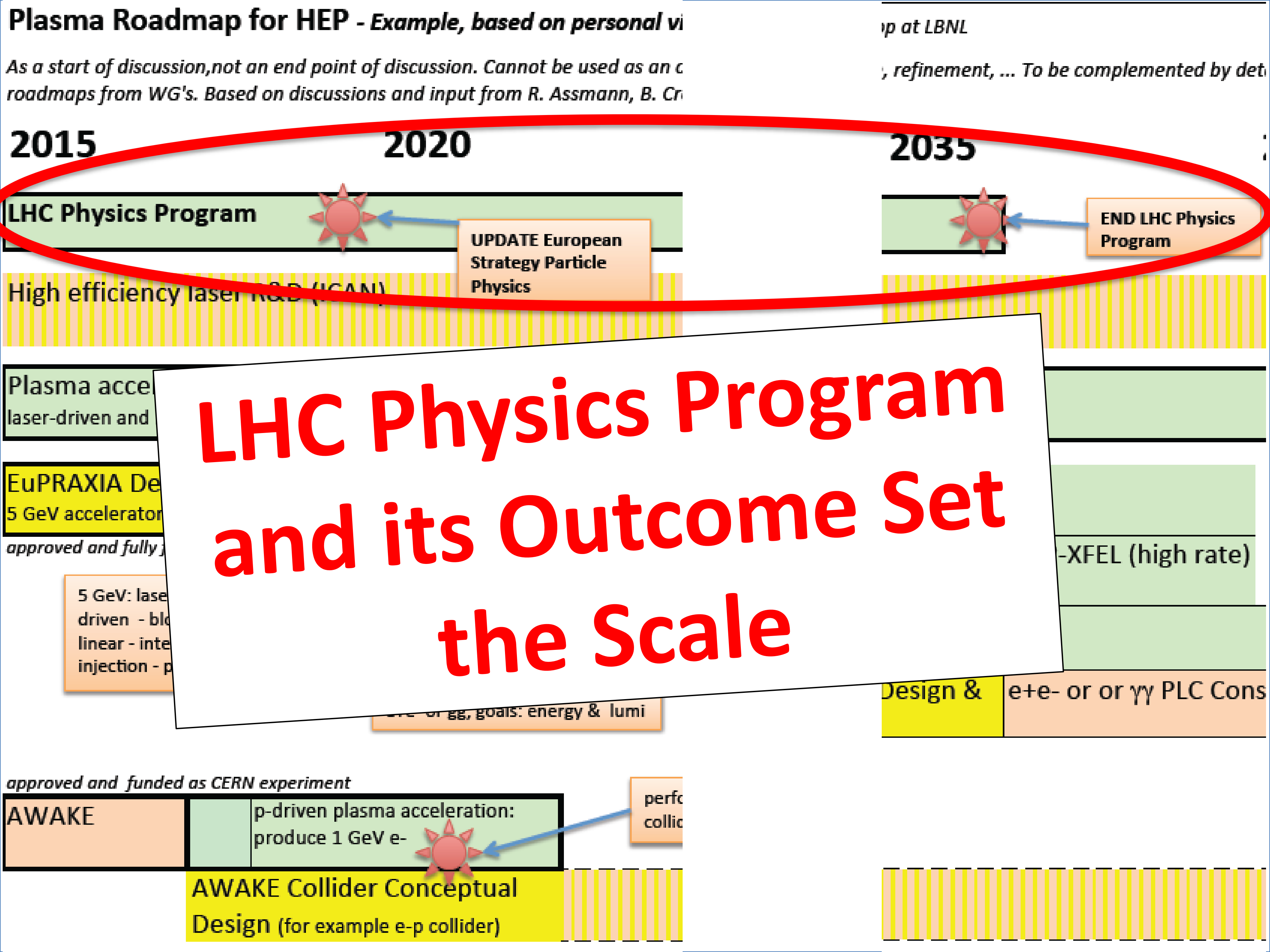
HEP Roadmap from EuroNNAc2
OPTION C → for discussion

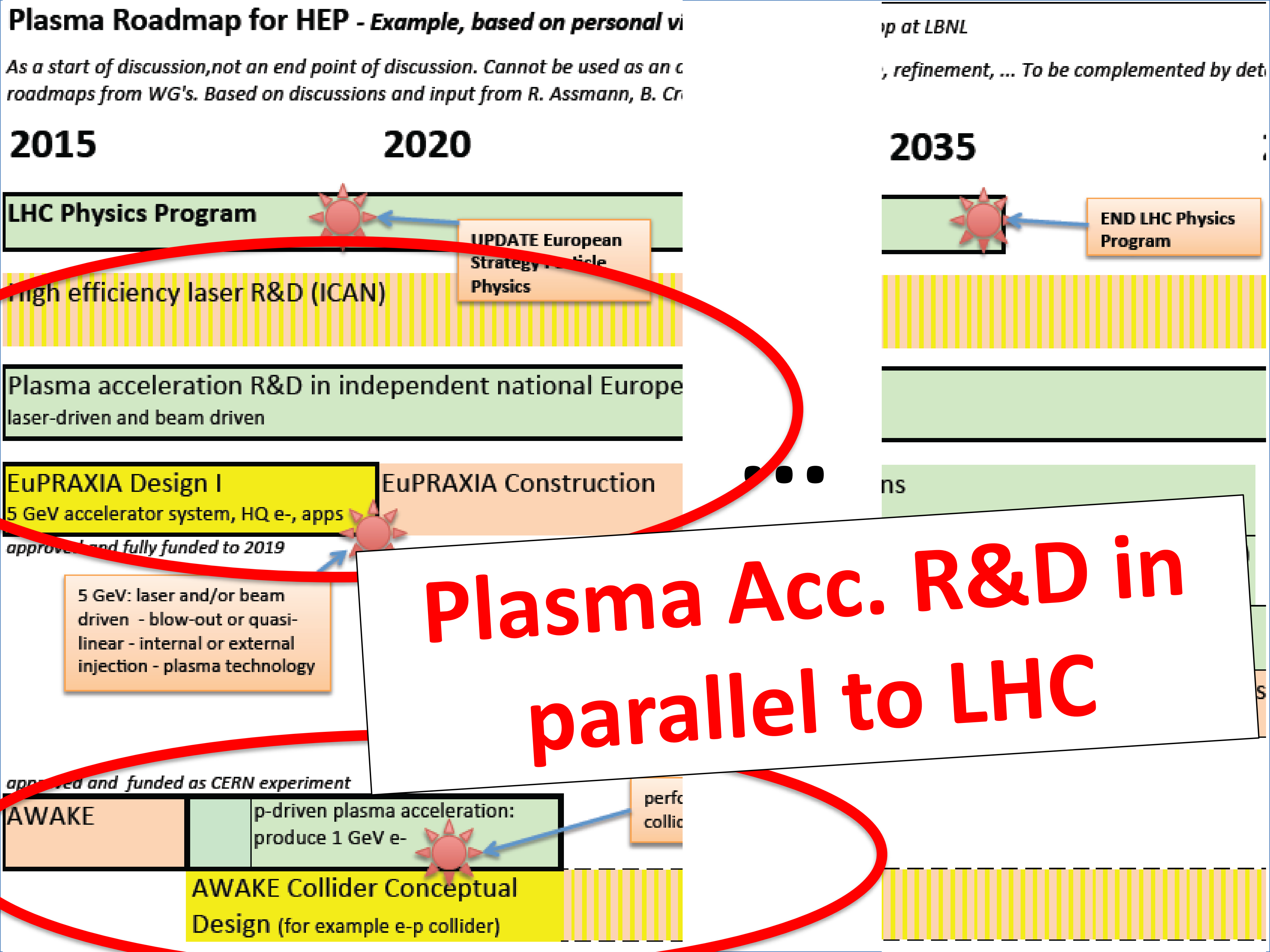
European Network EuroNNAc for Novel Accelerators — EuPRAXIA — Horizon2020

European Plasma Roadmap for HEP - *Example, based on personal view of a few persons* *Drafted January 2016, Plasma LC Workshop at LBNL*

As a start of discussion,not an end point of discussion. Cannot be used as an official roadmap, should trigger discssuions and thoughts. Requires input, discussion, iteration, refinement, ... To be complemented by detailed R&D roadmaps from WG's.




Plasma Roadmap for HEP - Example, based on personal vi
p at LBNL
As a start of discussion,not an end point of discussion. Cannot be used as an c
, refinement, ... To be complemented by det
roadmaps from WG's. Based on discussions and input from R. Assmann, B. Cr
2015
2020
2035
LHC Physics Program
UPDATE European Strategy Particle Physics
END LHC Physics Program
High efficiency laser R&D (ICAN)
Plasma acce
laser-driven and
EuPRAXIA De
5 GeV accelerator
approved and fully f
5 GeV: lase
driven - blo
linear - inte
injection - p
-XFEL (high rate)
Design &
e+e- or or γγ PLC Cons
goals: energy & lumi
approved and funded as CERN experiment
AWAKE
p-driven plasma acceleration: produce 1 GeV e-
perfo
collid
AWAKE Collider Conceptual Design (for example e-p collider)
LHC Physics Program and its Outcome Set the Scale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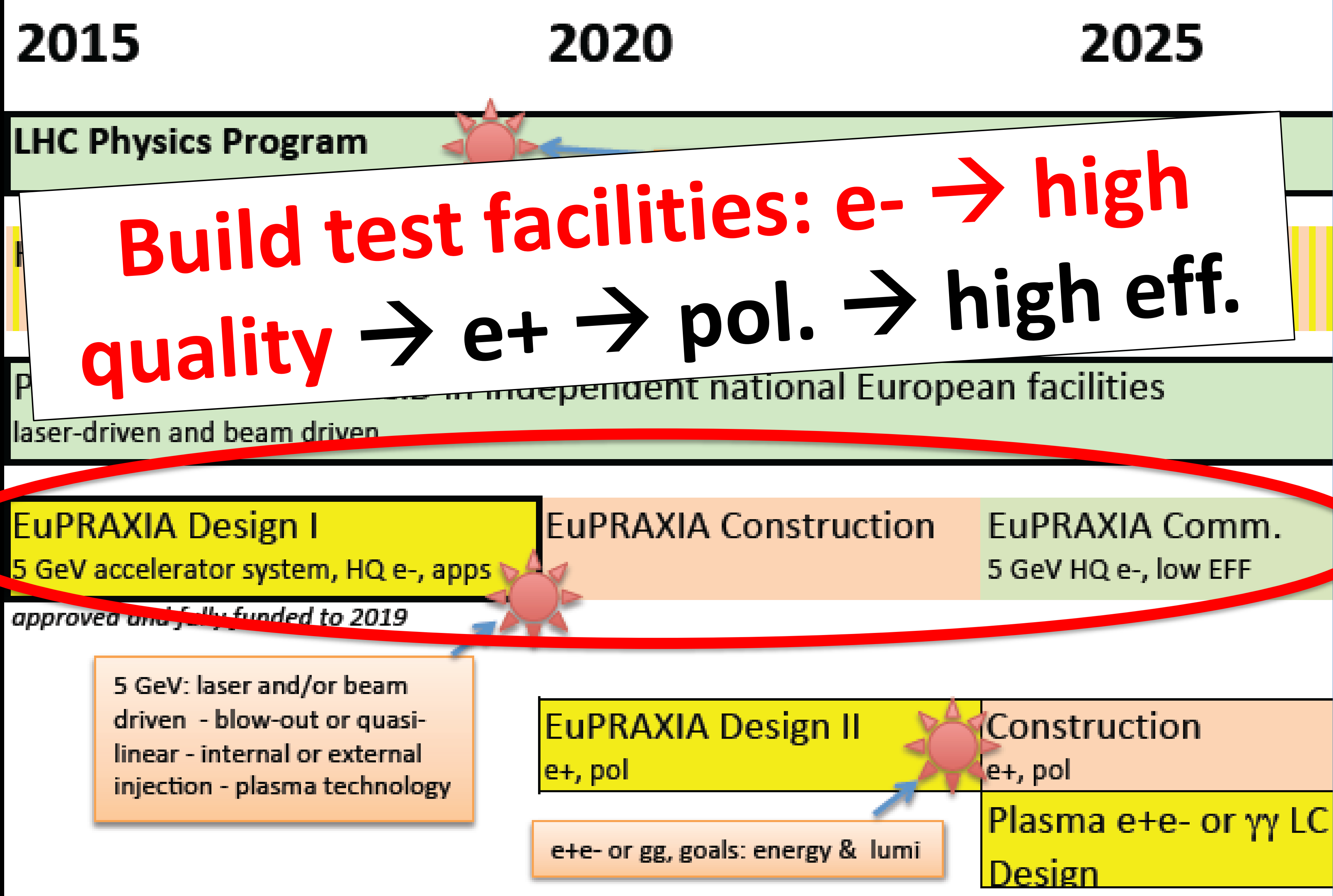
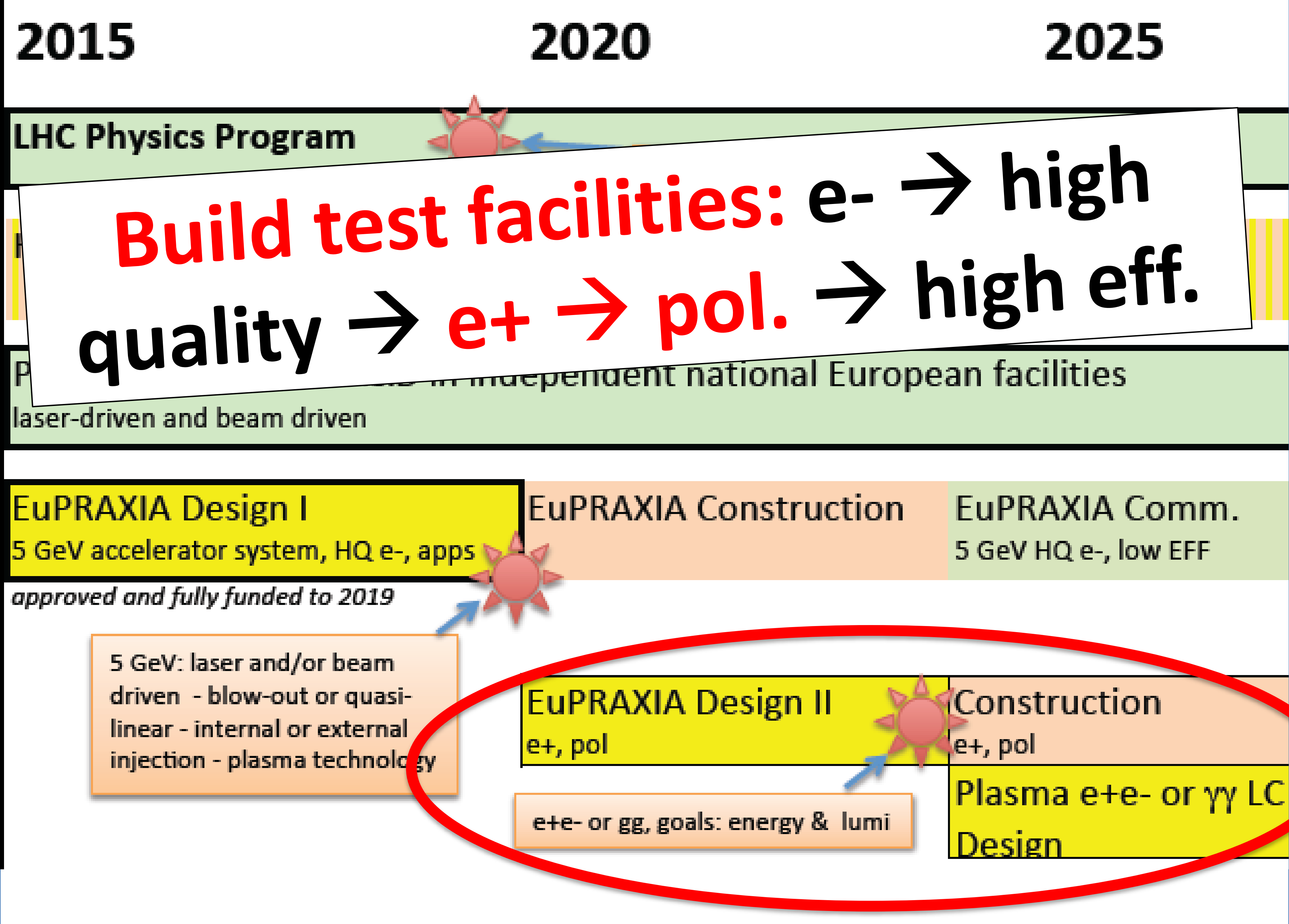
2015
2020
2035
LHC Physics Program
UPDATE European Strategy Particle Physics
END LHC Physics Program
High efficiency laser R&D (ICAN)
Plasma acceleration R&D in independent national Europe
laser-driven and beam driven
EuPRAXIA Design I
5 GeV accelerator system, HQ e-, apps
approved and fully funded to 2019
EuPRAXIA Construction
ns
5 GeV: laser and/or beam driven - blow-out or quasi-linear - internal or external injection - plasma technology
Plasma Acc. R&D in parallel to LHC
approved and funded as CERN experiment
AWAKE
p-driven plasma acceleration: produce 1 GeV e-
perfo
collic
AWAKE Collider Conceptual Design (for example e-p collider)



2015
2020
2025
LHC Physics Program
Build test facilities: e- → high quality → e+ → pol. → high eff.
independent national European facilities
laser-driven and beam driven
EuPRAXIA Design I
5 GeV accelerator system, HQ e-, apps
approved and fully funded to 2019
EuPRAXIA Construction
EuPRAXIA Comm.
5 GeV HQ e-, low EFF
5 GeV: laser and/or beam driven - blow-out or quasi-linear - internal or external injection - plasma technology
EuPRAXIA Design II
e+, pol
Construction
e+, pol
Plasma e+e- or γγ LC Design
e+e- or gg, goals: energy & lumi


2015
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2025
LHC Physics Program
Build test facilities: e- → high quality → e+ → pol. → high eff.
national European facilities
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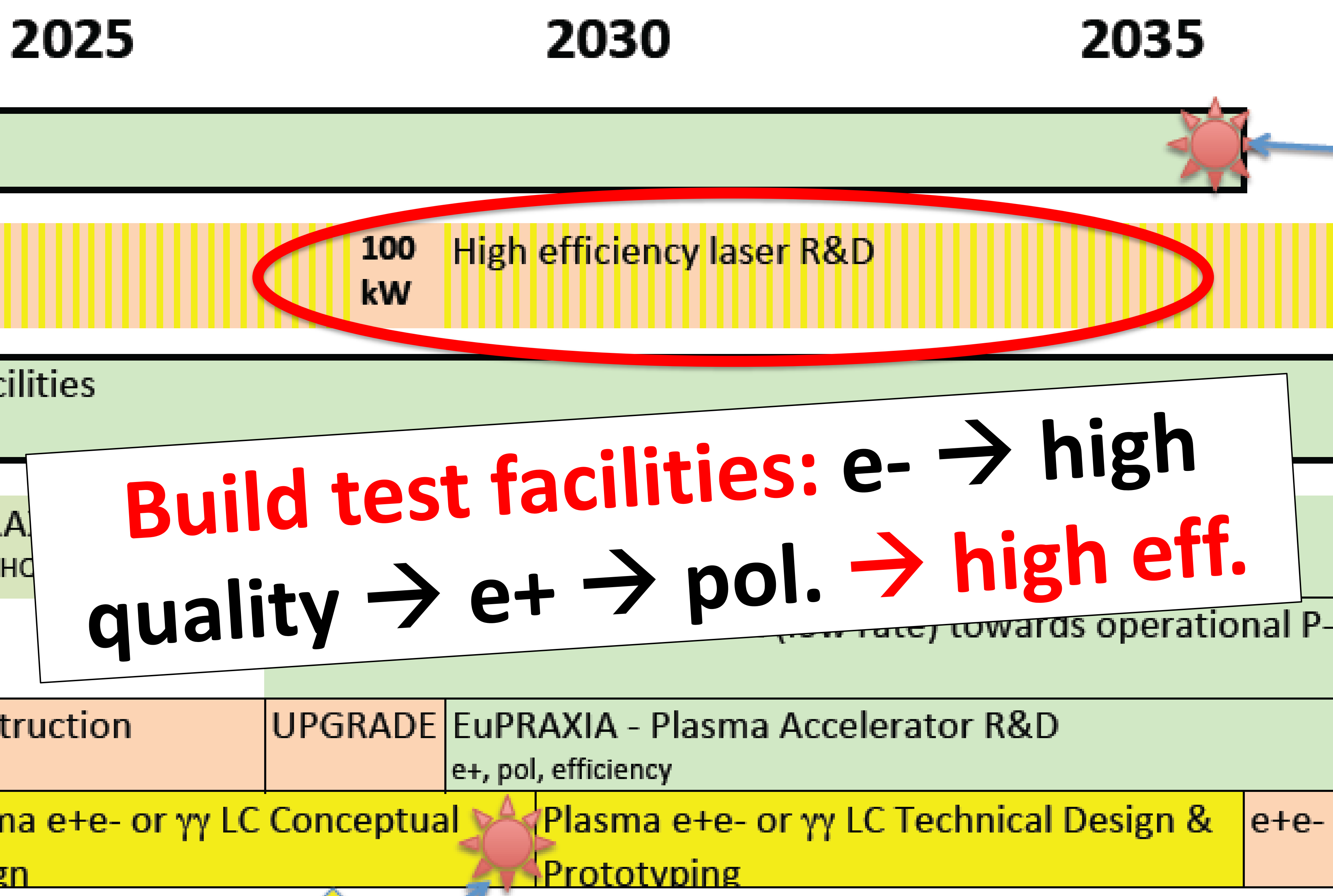
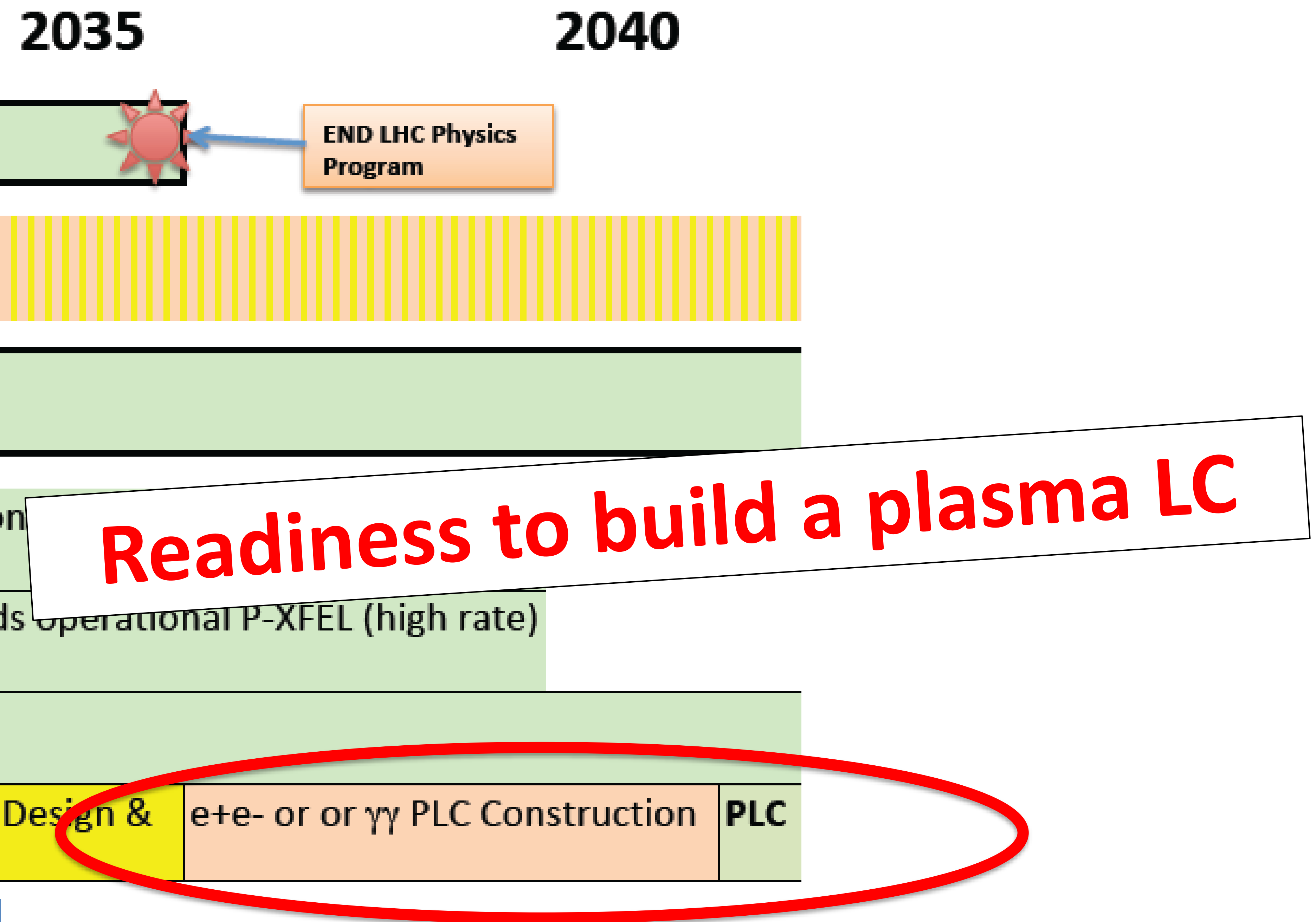
5 GeV HQ e-, low EFF
5 GeV: laser and/or beam driven - blow-out or quasi-linear - internal or external injection - plasma technology
EuPRAXIA Design II
e+, pol
Construction
e+, pol
e+e- or gg, goals: energy & lumi
Plasma e+e- or γγ LC Design



2025
2030
2035
100 kW
High efficiency laser R&D
cilities
Build test facilities: e- → high quality → e+ → pol. → high eff.
towards operational P-
truction
UPGRADE
EuPRAXIA - Plasma Accelerator R&D
e+, pol, efficiency
ma e+e- or γγ LC Conceptual
gn
Plasma e+e- or γγ LC Technical Design & Prototyping
e+e-


2035
2040
END LHC Physics Program
Readiness to build a plasma LC
ds operational P-XFEL (high rate)
Design &
e+e- or or γγ PLC Construction
PLC

Notes on a PLC

- These are success oriented thoughts on a possible route to a plasma linear collider for the end of the 2030's.
- Many very important issues but no showstopper.
  - Some showstoppers claimed are not fundamental (e.g. fixable with hollow plasmas, lower plasma densities, ...).
- Many challenges arise only for HEP, not for other applications. HEP must drive solutions for these issues!
- Only achievable if there is a SERIOUS R&D line with sufficient funding for plasma accelerator technology with HEP applications.
- Plasma accelerator technology as upgrade for a conventional LC is a very interesting option and easier to achieve!

EuPRAXIA Laser Specifications

Horizon 2020

- On **May 18, 2016** at SOLEIL - France.
- **Leading international laboratories were represented** including:
  - Intense Laser Irradiation Laboratoy (INO - Italy),
  - the Laboratoire d'Utilisations des Lasers Intenses (CNRS - France),
  - the Lawrence Livermore National Laboratory (USA),
  - the Centro de Láseres Pulsados Ultracortos Ultraintensos (University of Salamanca, Spain),
  - the Central Laser Facility (Science and Technology Facilities Council, UK),
  - The Petawatt Laser Facility (University of Texas at Austin, USA)
- and **international laser manufacturers** such as
  - Thales (France),
  - National Energetics (USA),
  - Amplitude Technologies (France),
  - Amplitude Systèmes (France) and
  - Proton Laser (Spain).

100cube Laser Challenge

- "Brainstorming" session starting basic specifications of the EUPRAXIA laser from EUPRAXIA steering committee, the so-called "**100 cube**":

100 J, 100 fs, 100 Hz, contrast 10^{10} at 10ps → 1PW @ 100Hz

From L. Gizzi and F. Mathieu

Example: e- Beam Parameters at Entrance of Undulator Section

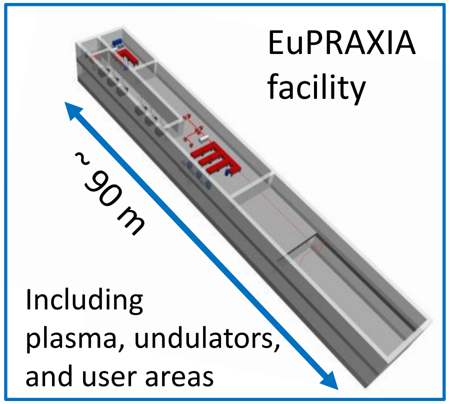
EuPRAXIA

Horizon 2020

Quantity	Symbol	Baseline value	Range of exploration	
			Lower limit	Upper limit
Particle type	-	e-	e-	
Energy	E	5 GeV	5 GeV	
Charge	Q	30 pC	15 pC	100 pC
Bunch length (FWHM)	τ	10 fs	3 fs	30 fs
Peak current	I	3 kA	3-5 kA	
Repetition rate	f	10 Hz	1 Hz	100 Hz
Number of bunches	N	1	1	
Total energy spread (RMS)	σ_E/E	1%	1 %	
Slice energy spread (RMS)	$\sigma_{E,S}/E$	0.1 %	0.1 %	
Transverse normalized emittance	$\varepsilon_{N,x}$, $\varepsilon_{N,y}$	1 mm mrad	1 mm mrad	
Alpha function	α_x, α_y	0	0	
Beta function	β_x, β_y	5 m	5 m	
Transverse beam size (RMS)	σ_x , σ_y	22 µm	22 µm	
Transverse divergence (RMS)	$\sigma_{x'}$, $\sigma_{y'}$	4.5 µrad	4.5 µrad	

Configuration A: LWFA with internal injection

Horizon 2020

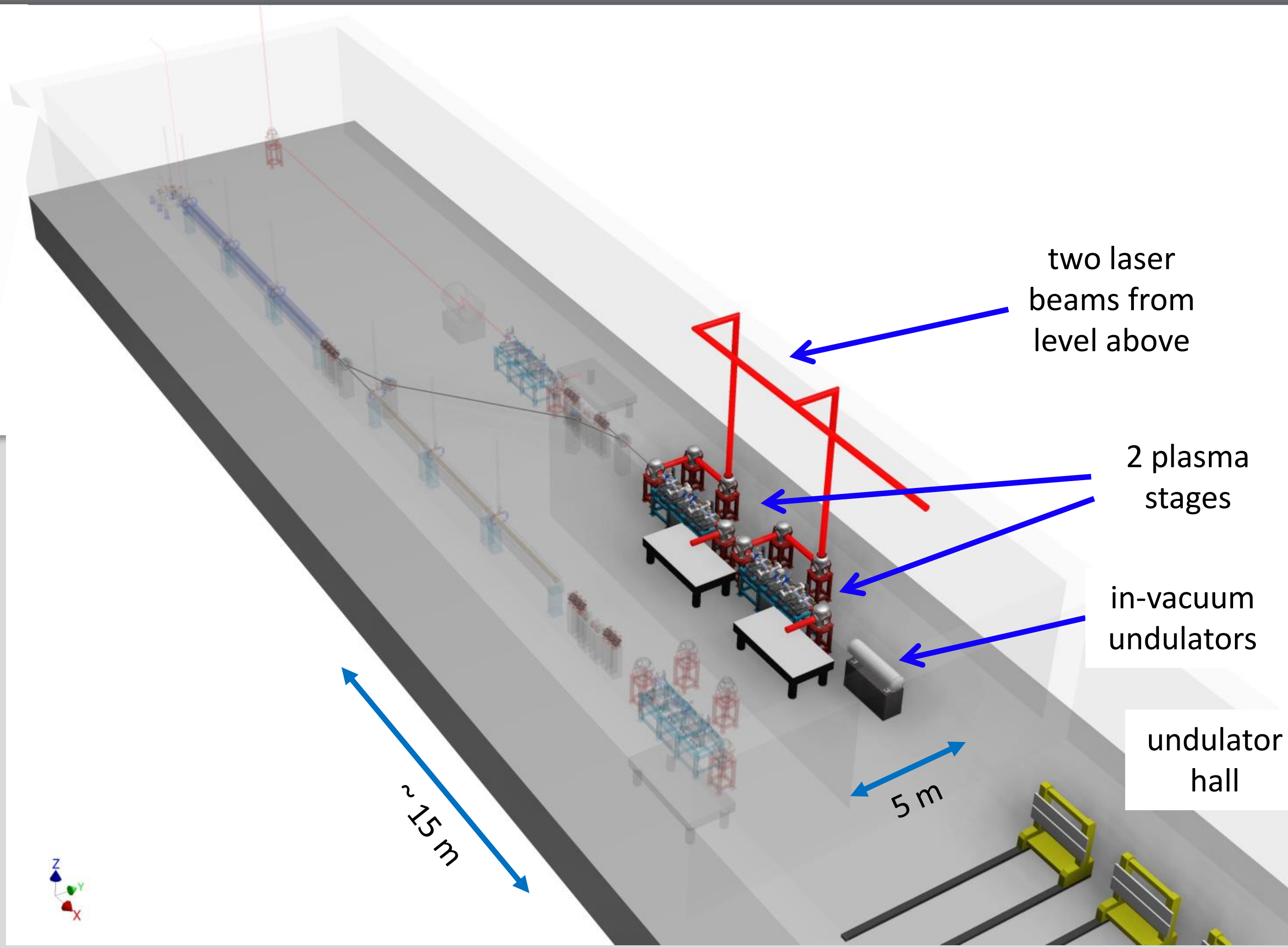


LWFA with 2 stages sufficient to produce 5 GeV electron beam

In-vacuum undulators used for FEL radiation

A = 75 m^2 needed on accelerator floor

Similar footprint for laser laboratory

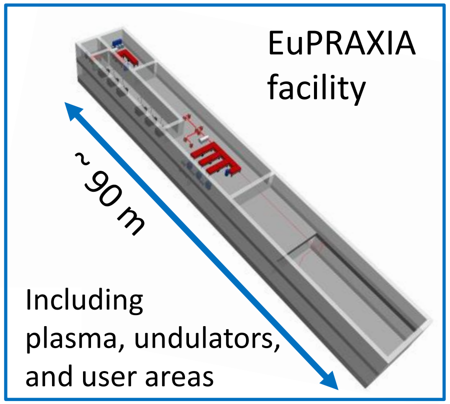


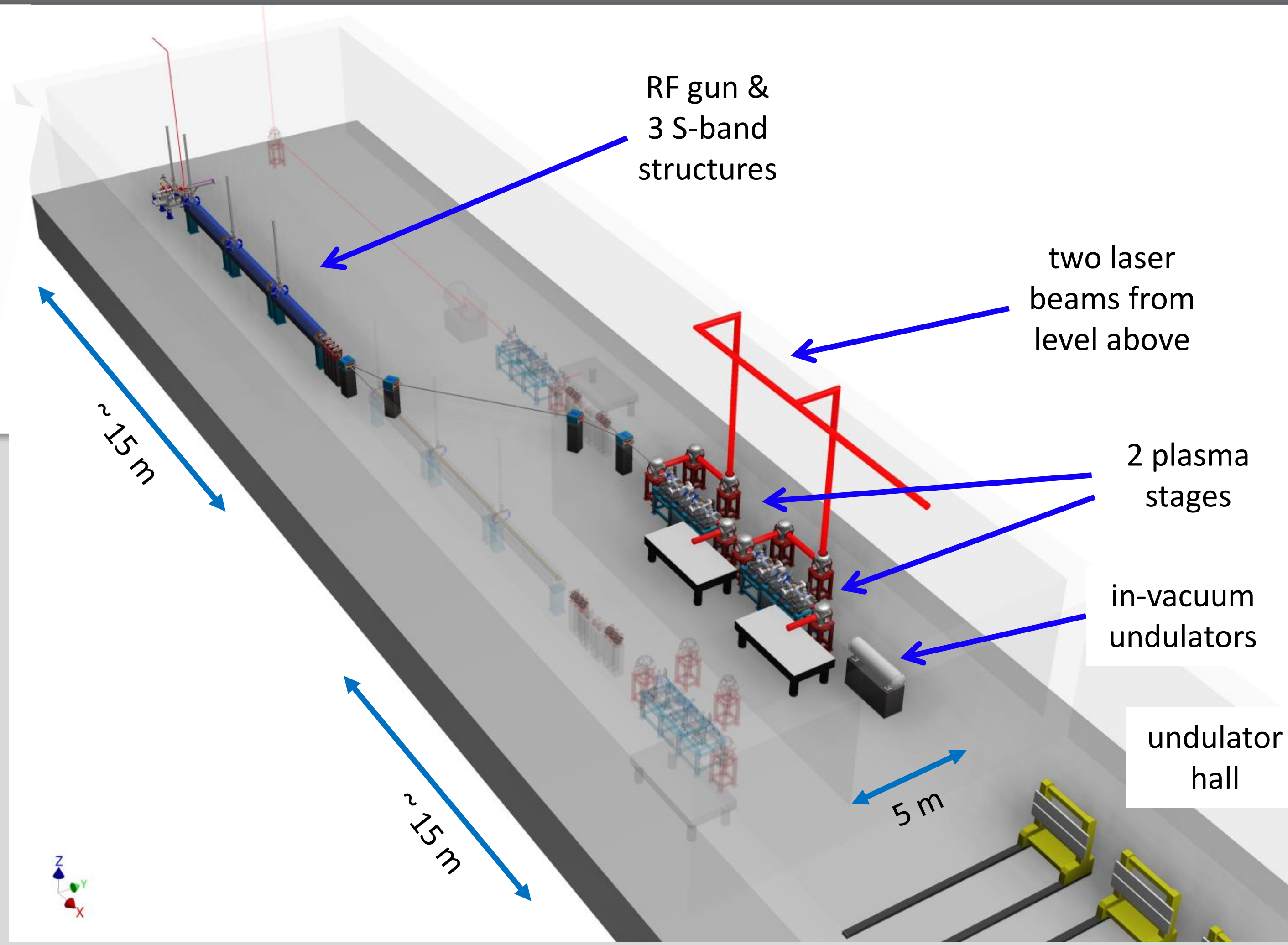
A = 15 x 5 m^2 = 75 m^2

3D layout by Dariusz Kocoń and Paul Andreas Walker

Configuration B: LWFA with external RF injector

Horizon 2020





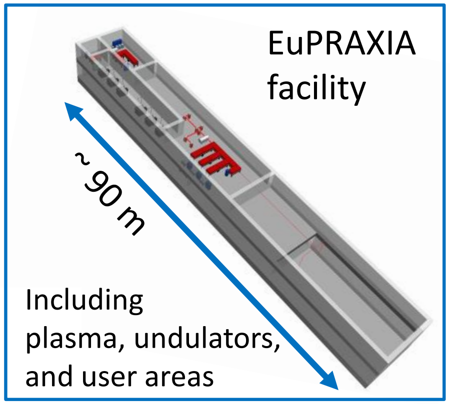
- LWFA with external injection of RF accelerated electron beam
- RF gun and S-band structures added
- Results in more control and better beam quality

A = 2 x 15 x 5 m^2 = 150 m^2

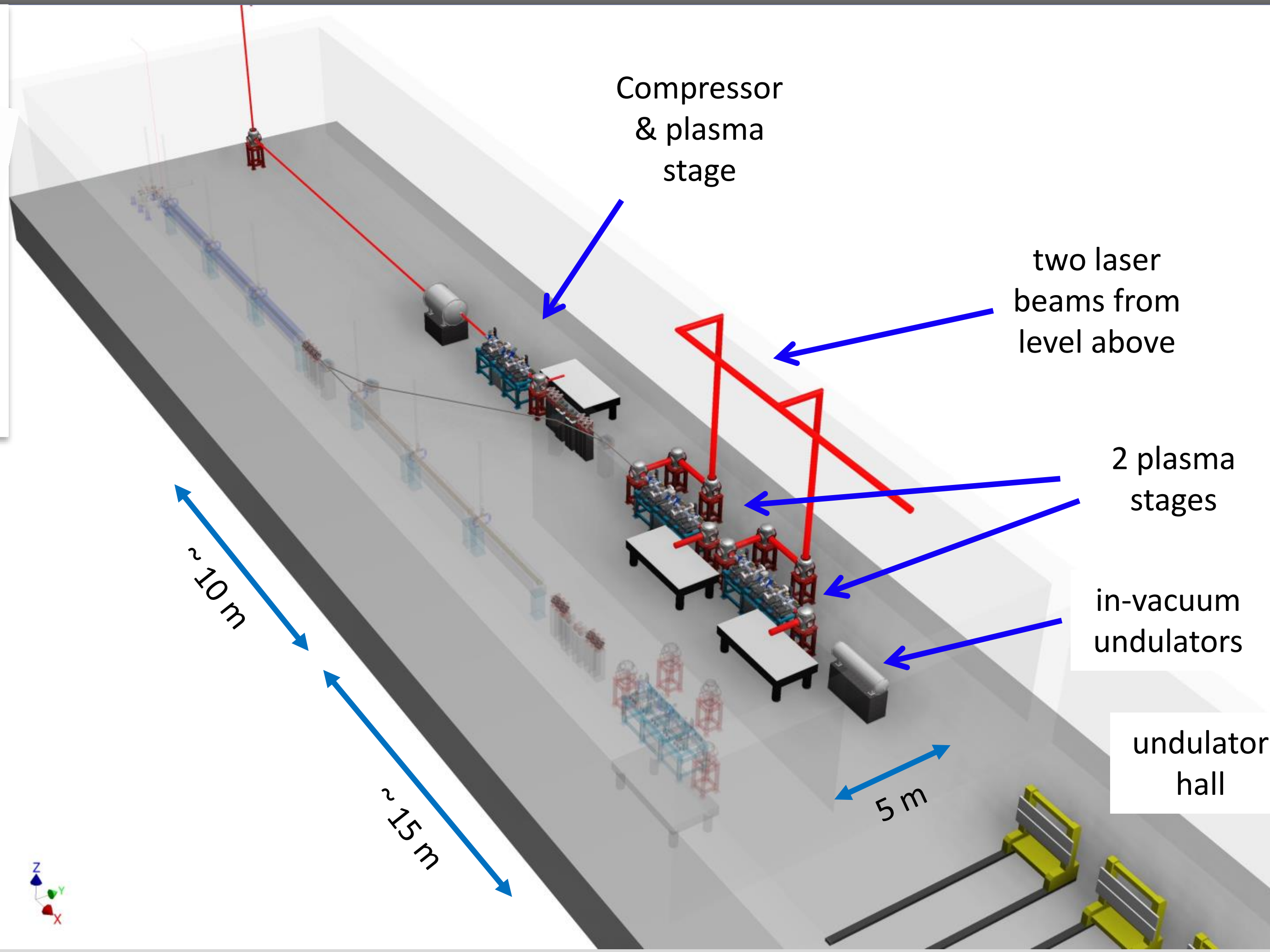
3D layout by Dariusz Kocoń and Paul Andreas Walker

Configuration C: LWFA with external plasma injector

Horizon 2020



- LWFA with external injection with a plasma injector
- All optical approach with laser beams as driver only
- One plasma stage added in front of existing plasma stages

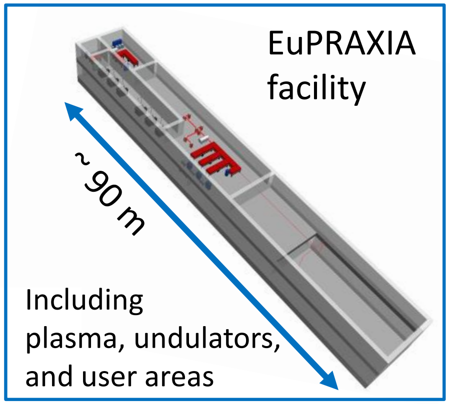


A = 25 x 5 m² = 125 m²

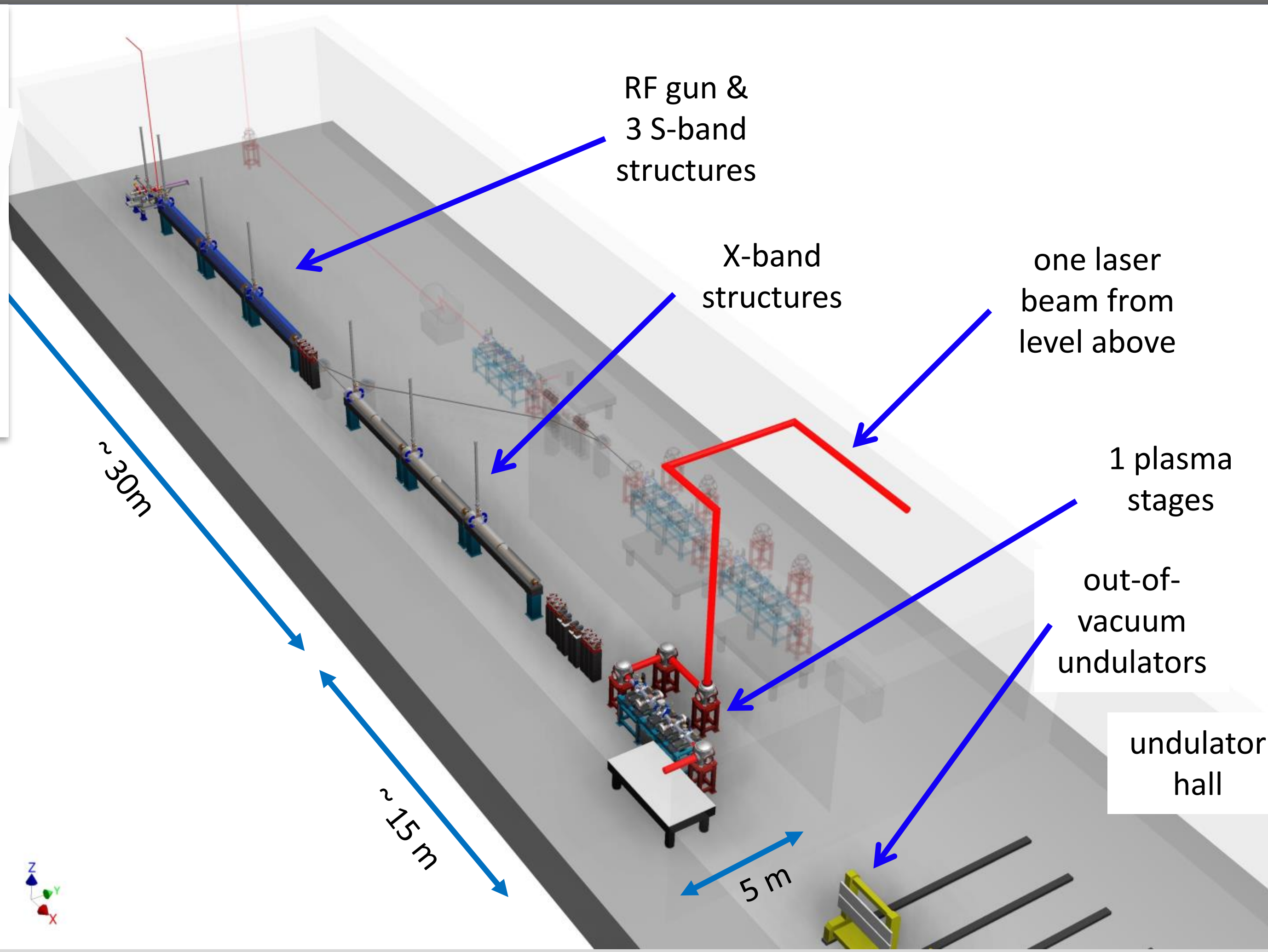
3D layout by Dariusz Kocoń and Paul Andreas Walker

Configuration D: PWFA with external RF beam driver

Horizon 2020



PWFA uses electron beam as driver in one plasma stage
RF structures consist of S-band and X-band
Laser needed for pre-ionization of plasma

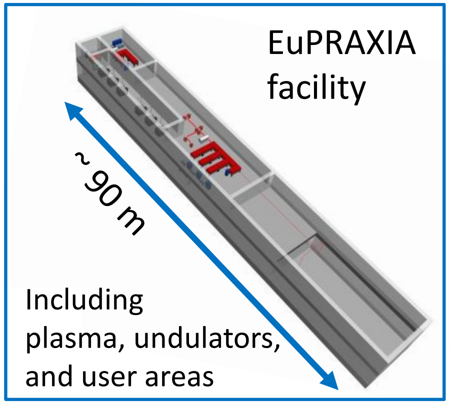


A = 45 x 5 m² = 225 m²

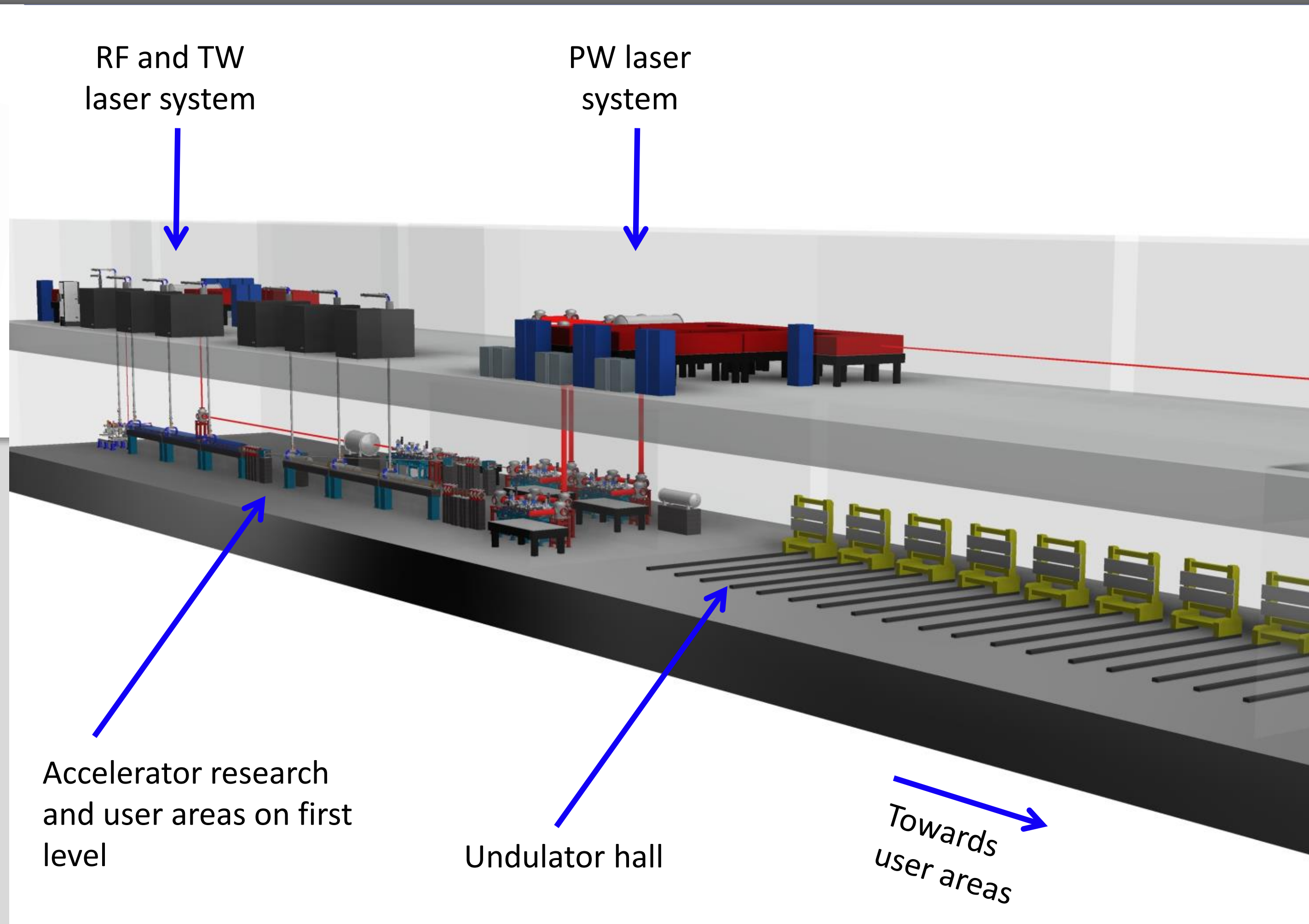
3D layout by Dariusz Kocoń and Paul Andreas Walker

Laser and RF Infrastructure

Horizon 2020



Laser and RF infrastructure on top level
Accelerator level below
TW lasers available in user areas of plasma

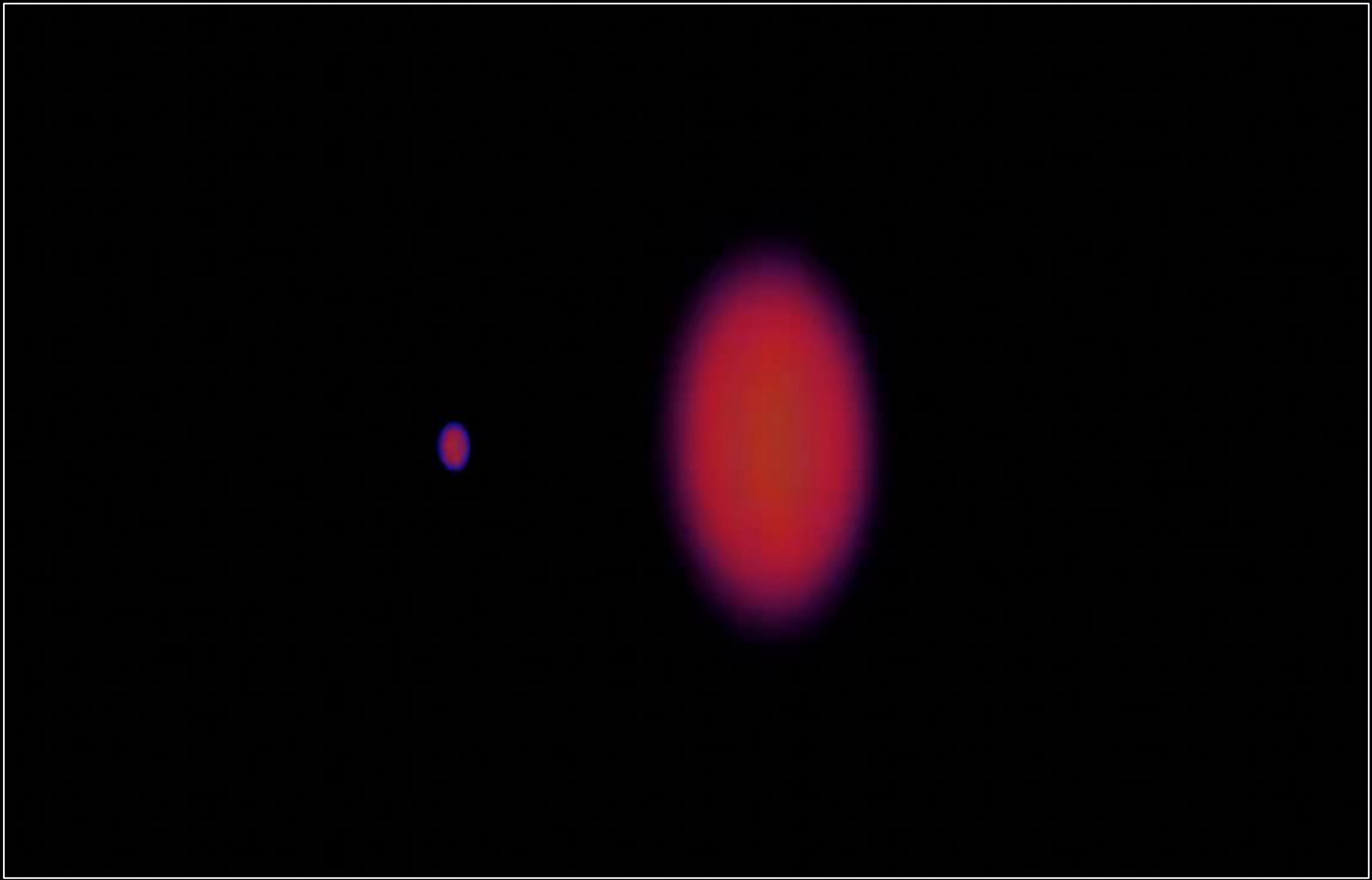


3D layout by Dariusz Kocoń and Paul Andreas Walker

EuPRAXIA
Plasma & Beam Movie

Horizon 2020

A. Ferran Pousa et al: “**Visualpic** Data Visualizer and Post-Processor for PIC Codes”

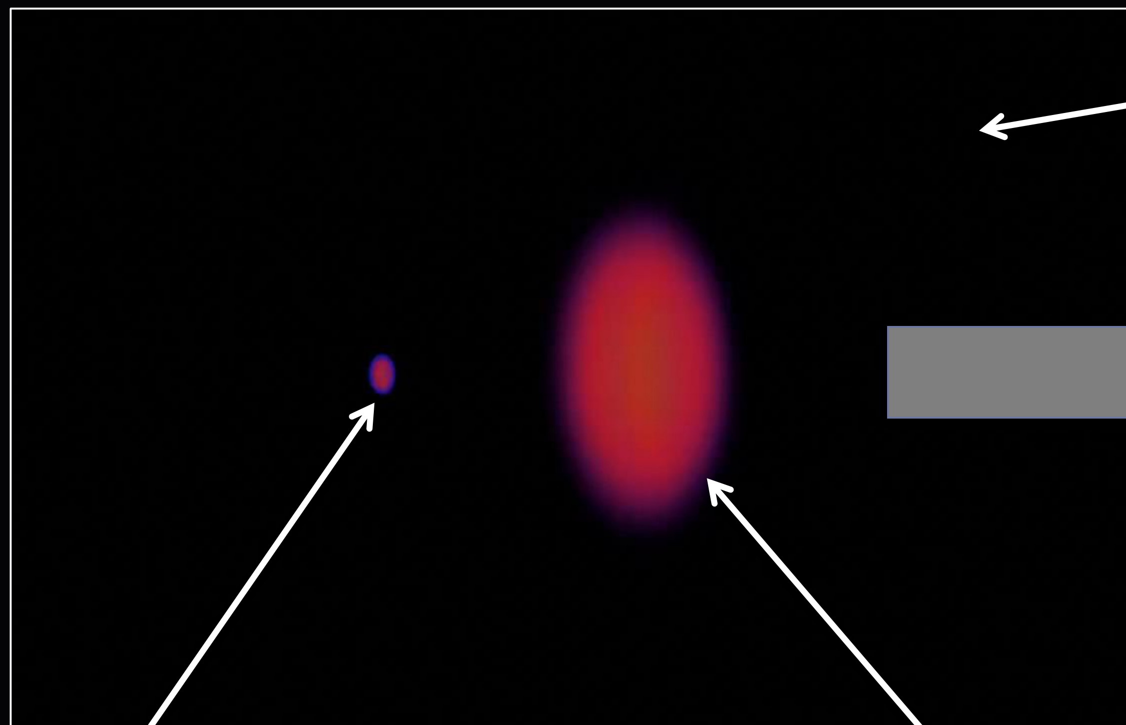


Á. Ferran Pousa, A. Aschikhin, R. Assmann ,A. Martinez de la Ossa. IPAC17 paper TUPIK007.

Configuration B: Simulation I

Horizon 2020

From
A. Ferran-Pousa



Vacuum

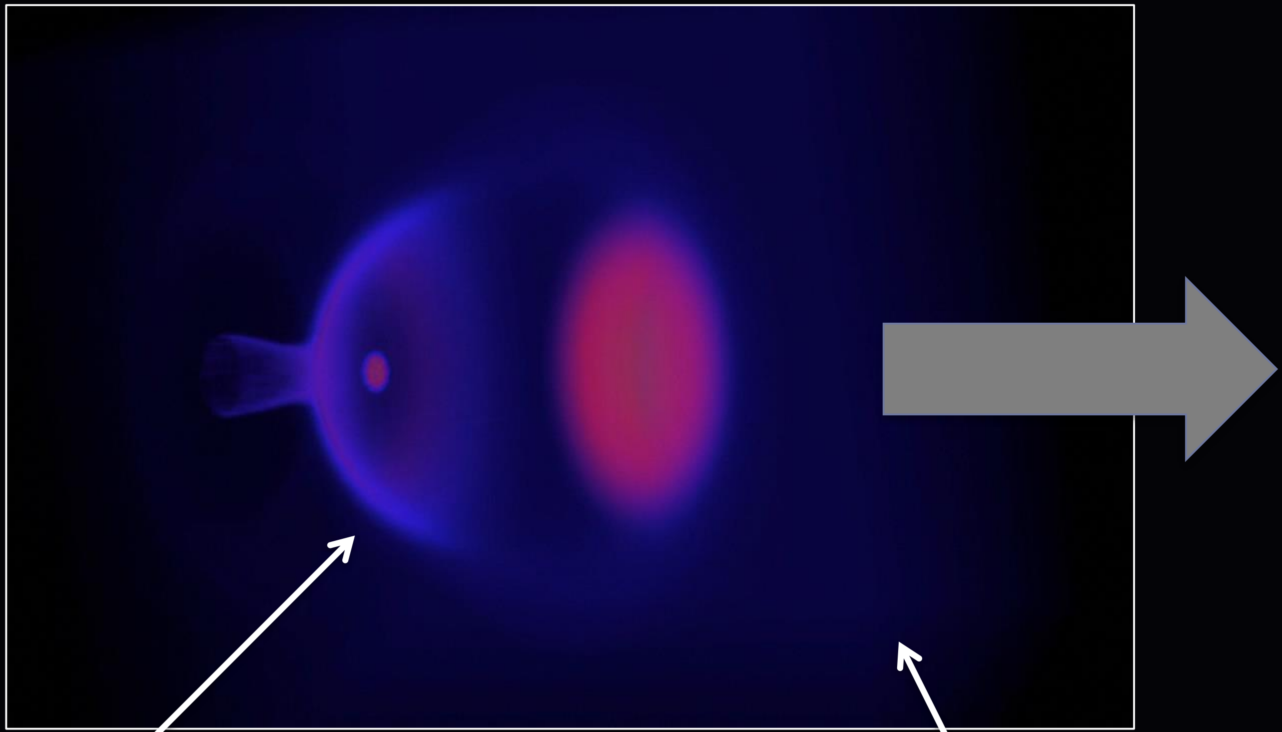
Electron pulse:
Gaussian beam, 1 pC, 100 MeV, relative energy spread = 0.1%, 3.3 fs length (rms), 1.26 micron transv. size (rms),norm. emittance 0.99 mm mrad

Laser pulse:
a_0 = 3.1, λ = 800 nm, 100 fs (FWHM in intensity), w_0 = 54 μm, 100 J energy, 1 PW peak power, laser and plasma parameters adjusted for self guiding.

Configuration B: Simulation II

Horizon 2020

From
A. Ferran-Pousa

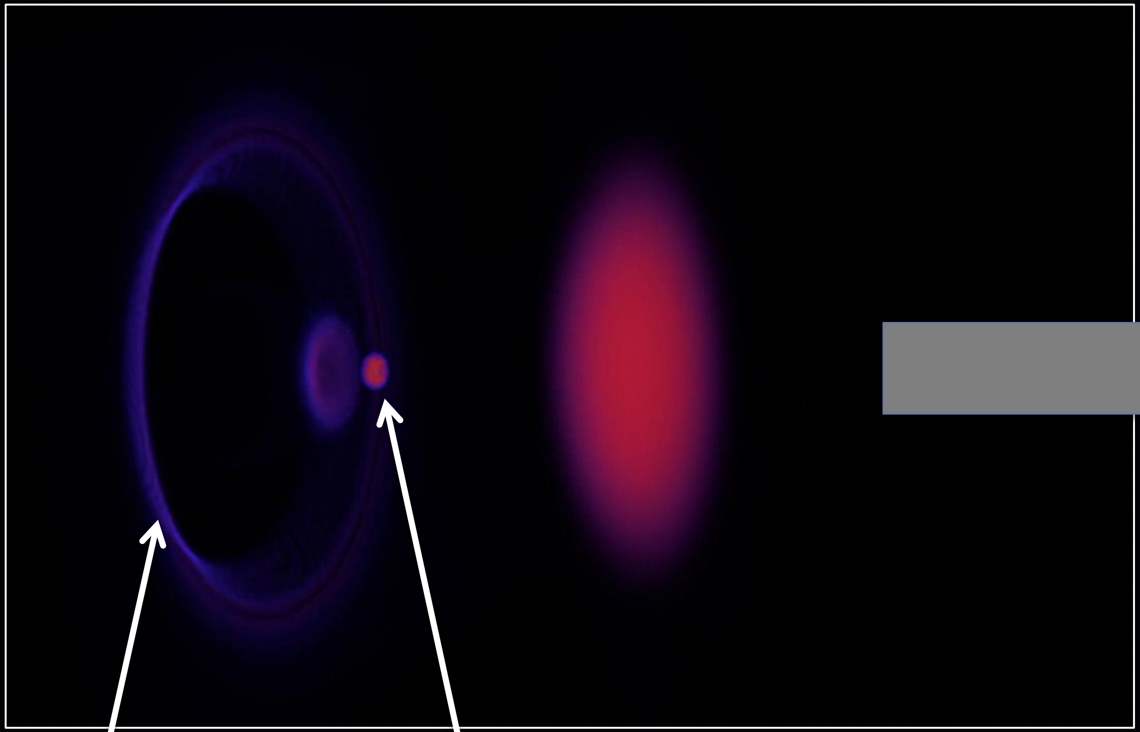


The acceleration regime:
close to blowout. 2D simulation: the 3D animation was made assuming cylindrical symmetry and reconstructing a 3D field.

Plasma:
Density = 1.2×10^{17} cm^{-3}
Length = 2.5 cm

Configuration B: Simulation III

From
A. Ferran-Pousa



Just after exiting plasma:
Back in vacuum.

Electron beam:
Energy = 1 GeV
Relative energy spread = 1.5%
Normalized emittance = 0.995 mm mrad

A Low Energy Spread Solution
(beam-driven case CONFIG D)

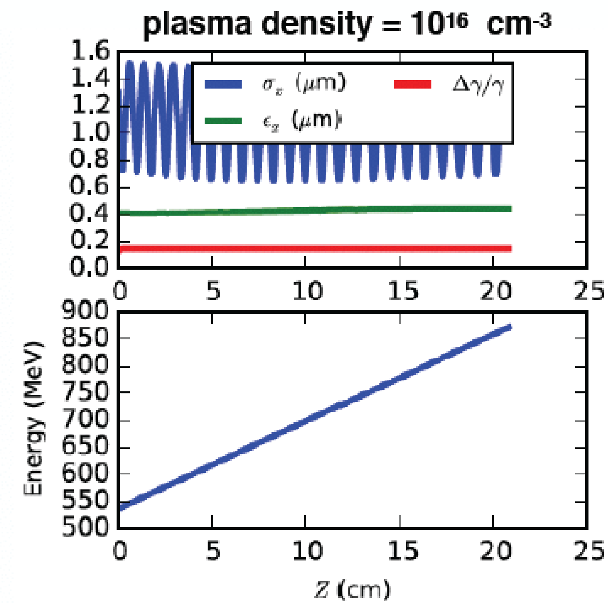
Horizon 2020

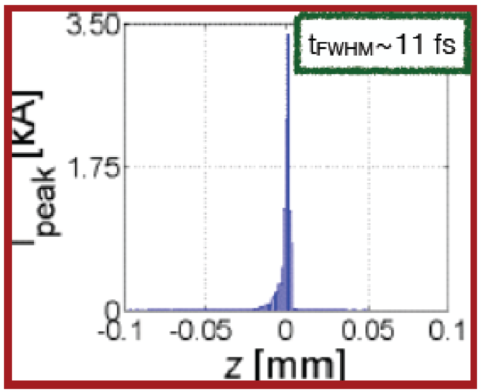
Witness Interaction in the Plasma

by Alberto Marocchino (INFN-LNF)

- Input witness beam from TSTEP-Elegant simulation
- Driver beam modeled in Architect*
- Witness interaction simulated in Architect

	Witness
E [MeV]	548.3
ΔE/E [%]	0.07
$I_{peak-FWHM}$ [kA]	~ 2.7
Q [pC]	30
$\sigma_{z\text{-}rms}$ [μm]	6.6
$\sigma_{z\text{-}FWHM}$ [μm]	~ 3.3
$\varepsilon_{x,y}$ [mm mrad]	0.6 – 1.0
$I_{peak-Slice}$ [kA]	3.5





*A. Marocchino, F. Massimo, Architect: first release (Apr. 2016). doi:10.5281/zenodo.49572.

From
E. Chiadroni

Accelerator Builder’s Challenge

(simplified to typical values)

Horizon 2020

1) Match (into &) out of plasma with **beam size ≈ 1 μm** (about 1 mm beta function). Adiabatic matching (Whittum, 1989 – also more recent LAOLA work).

2) Control **offsets** between the wakefield driver (laser or beam) and the accelerated electron bunch at **1 μm level.**

3) Use **short bunches (few fs)** to minimize energy spread.

4) Achieve **synchronization stability of few fs** from injected electron bunch to wakefield (energy stability and spread).

5) Control the **charge and beam loading** to compensate energy spread (idea Simon van der Meer).

6) Demonstrate “**industrial beam quality**”.

7) Develop and demonstrate **user readiness of a 1 – 5 GeV plasma accelerated beam.**

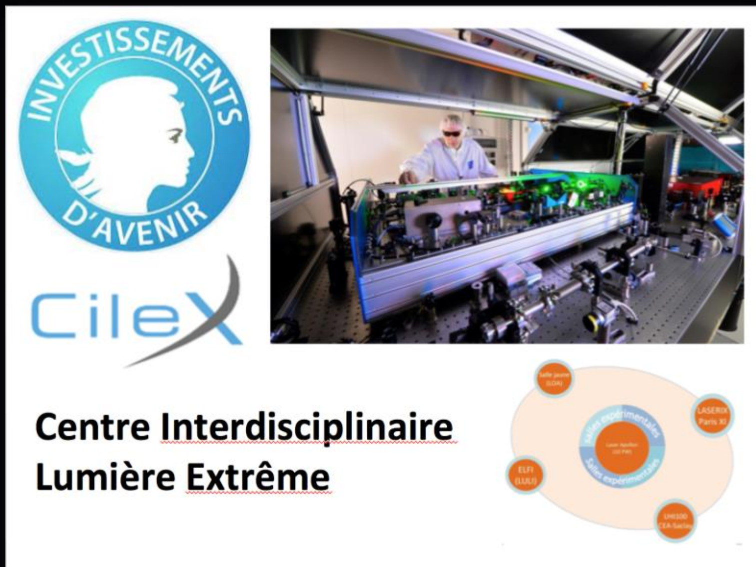
Work in Progress

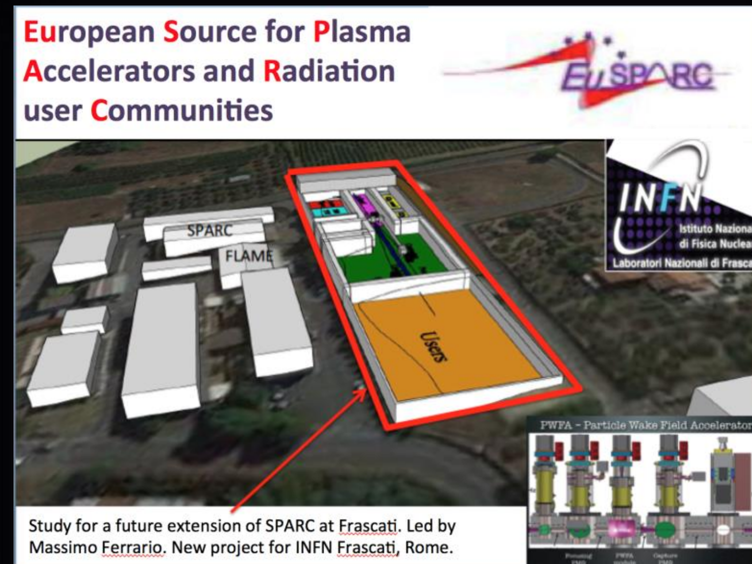
Horizon 2020

- Add user areas for:
  - **Table-top test beam accelerator** for HEP detectors and/or industry
  - Compact and real-time **medical imaging** with high resolution
- Detailed estimates on required **real-estate footprint**
  - Looks very hopeful compared to conventional RF facility
- Overview on **investment cost** for various options and configuration
- Overview on **operational cost** for various options and configuration
- Last not least: Beam and light **quality, science reach**

Site Selection

Horizon 2020





Exciting developments in various partner and associate partner labs. Some discussed at EuPRAXIA's first yearly meeting (more to come?).

The EuPRAXIA design study is site-independent. It's final report will include various European site options. This is the basis for EuPRAXIA...

Conclusion

- In Europe **progress in bringing diverse efforts together**.
- Issues in plasma accelerators exist but no fundamental showstopper identified by us. **Solutions cost effort & funds**!
- Community must work together towards the ambitious goals. **Common roadmaps** must be supported by **common funding**. Grateful for EU funding for network and DS.
- EU efforts focus on **beam quality** (EuPRAXIA, ...) and **high efficiency / high power drivers** (AWAKE, ICAN, ...).
- High beam quality required for LC. Also opens **applications for photon science, medicine, ...** This synergy is central component of our EU strategy.
- Near term steps in Europe can be seen as **required intermediate steps, similar to RF unit tests** in conv. LC's.

3rd European Advanced Accelerator Concepts Workshop

Pre-registration open at web site (deadline May 26):

https://agenda.infn.it/confRegistrationFormDisplay.py?confId=12611

Go to link "EAAC2017 Application Form".

Also: offering student grants. Please apply!

Thank you for your attention