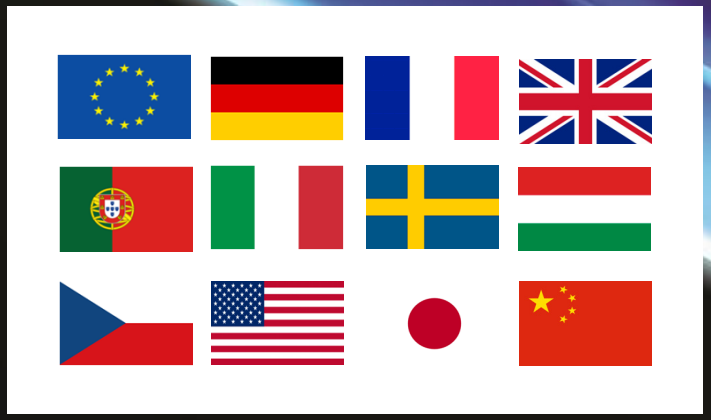
EUROPEAN PLASMA RESEARCH ACCELERATOR WITH EXCELLENCE IN APPLICATIONS

Ulrich Dorda, R. Assmann, P.A. Walker

11.10.2016

NAPAC2016



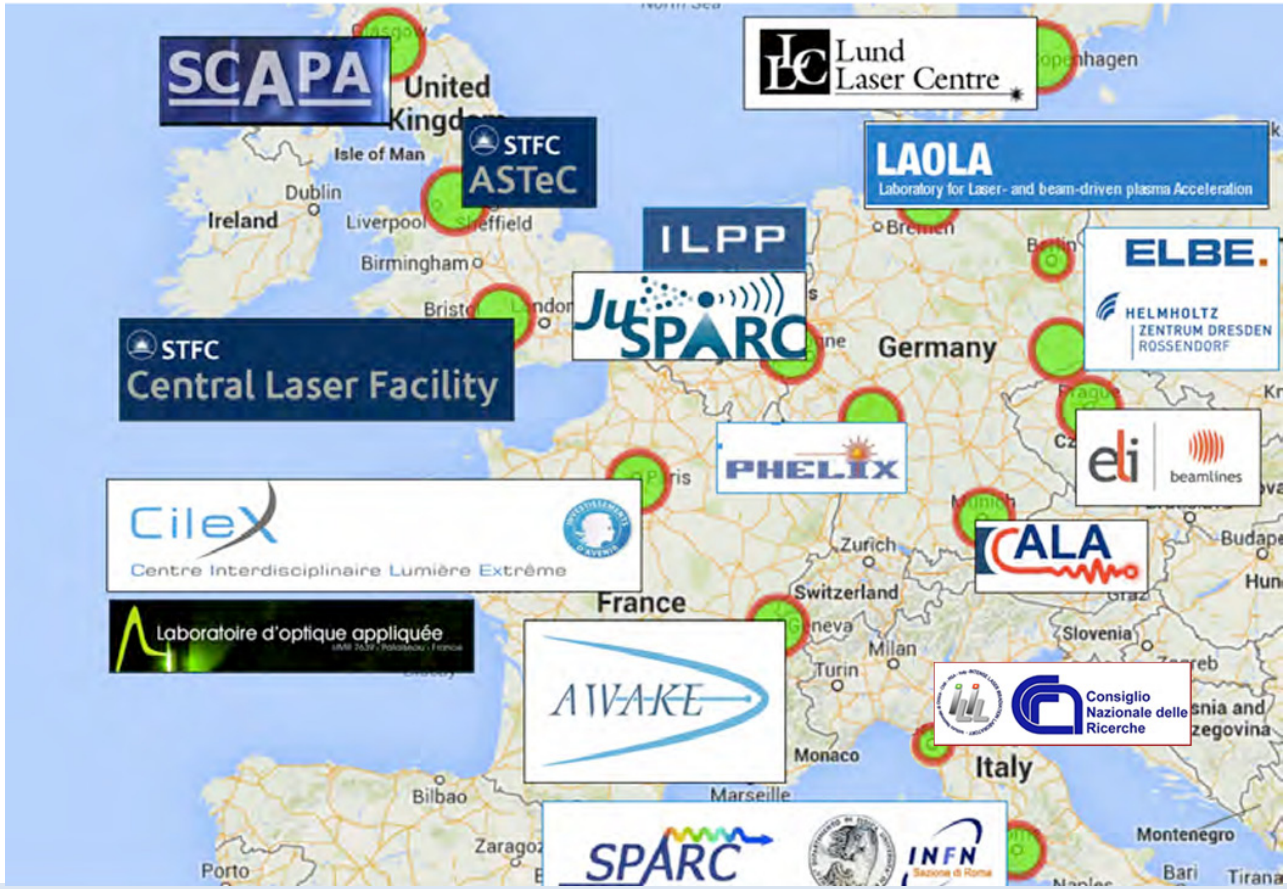
This project has received funding from the European Union's Horizon 2020 research and innovation programme under grant agreement No 653782.

What is EuPRAXIA?

- **Collaboration** between 16 European partners and 16 associated international partners
  - Study-leader R. Assmann (DESY), deputy: A. Specka(CNRS)
  - Scientific secretary: P.A. Walker (DESY)
- **Design study** for an accelerator facility for a
  - **5GeV electron plasma accelerator**
  - **with user areas**: FEL & HEP test site
  - using laser or electron beam drivers
- With “industrial beam quality”
  - sufficient beam quality for user applications
  - ready for 24/7 user operation
  - **“from acceleration to accelerators”**
- Including site-studies and financial planning

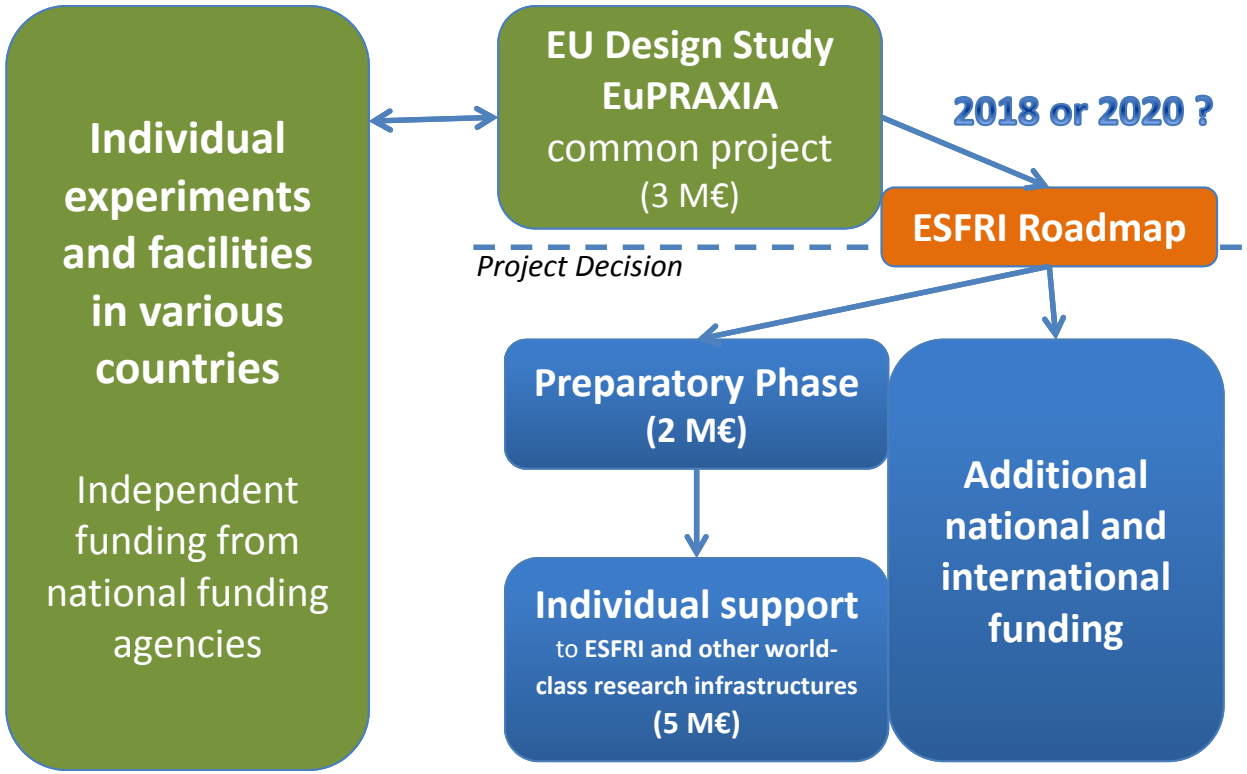
European facilities & background

- Plasma acceleration is studied at many sites in Europe.
- EuCARD^2 = a EU funded “integrating activity project for coordinated Research and Development on Particle Accelerators” in Europe.
- Work-package EuroNNAc (European Network for Novel Accelerators) submitted in 2014 a Horizon 2020 proposal for the design study “EuPRAXIA”.

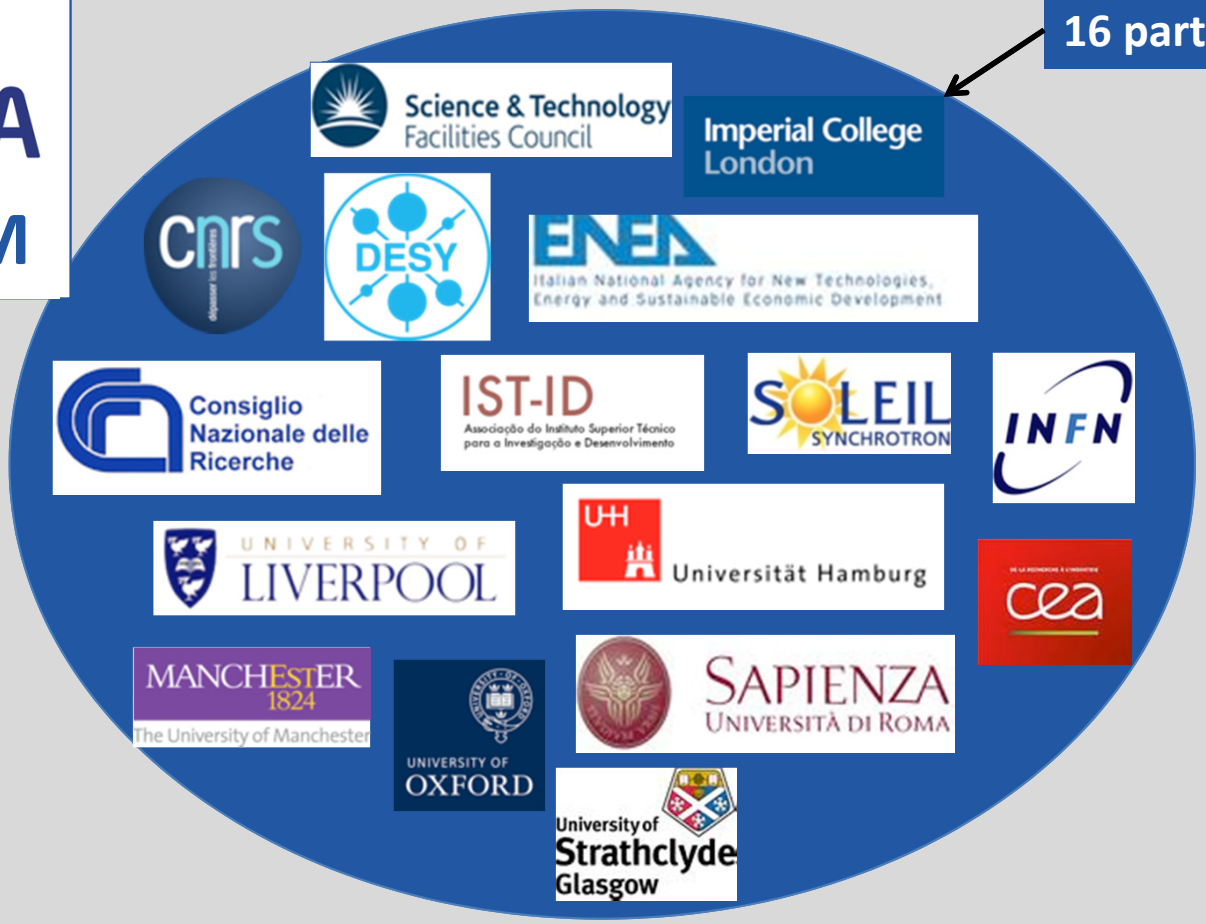


European Strategy for Research Infrastructures (ESFRI)

- EuPRAXIA is a Horizon2020 design study funded by 3ME
- Horizon2020 = 8th iteration of the EU Framework for Research and Technological Development (former FP1-FP7)
- This is one important step towards the goal of becoming part of the ESFRI roadmap, which "… identifies the new Research Infrastructures (RI) of pan-European interest …."



EuPRAXIA CONSORTIUM



Coordinator:
DESY/Helmholtz Association
R. Assmann, deputy: A. Specka
Scientific secretary: P.A. Walker (DESY)

EuPRAXIA CONSORTIUM

EuPRAXIA CONSORTIUM

32 Public Research Institutions

**Associated membership of SLAC being finalized, documents at DOE*

***Possibility for additional associated partners: Discussions with Univ. Jersualem, FZJ, Moscow Univ., KIT, …*

Private Industry

Companies which have joined EuPRAXIA meetings

THALES

Amplitude SYSTEMES Nothing but ultrafast.

protonlaser

NATIONAL ENERGETICS

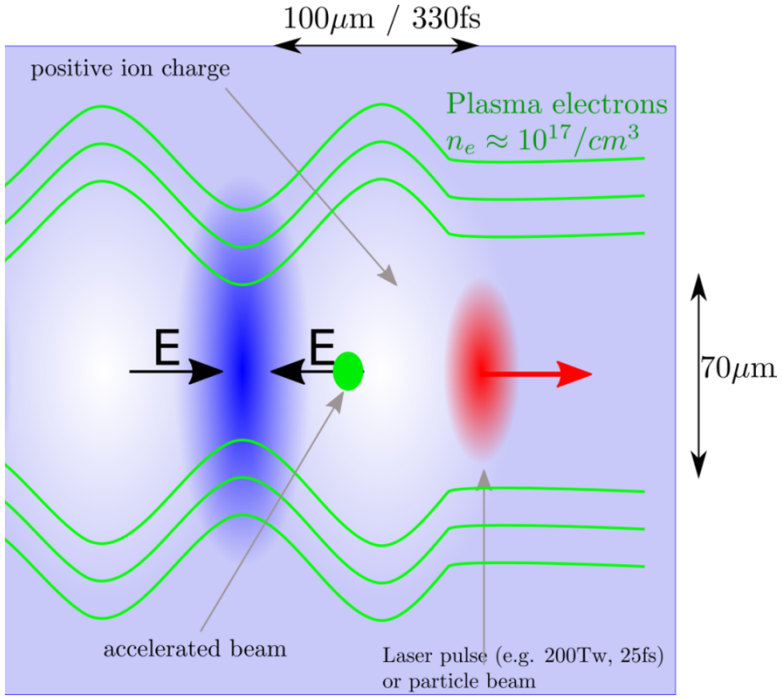
Timeline

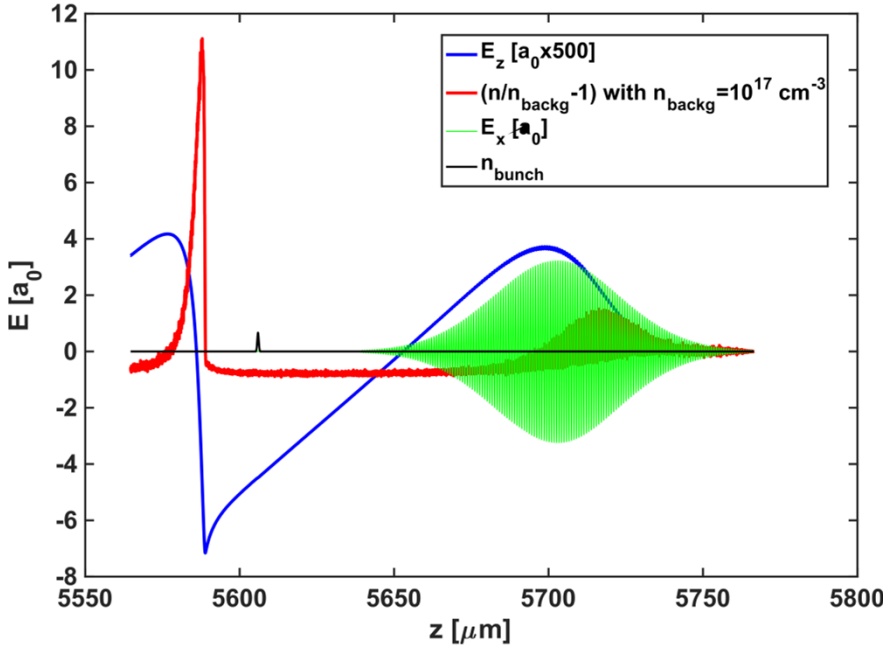
- Proposal submission: 09.2014
- Approval: 07.2015
- Start: 11.2015
- 1st year:
  - Organization (collaboration agreements, …)
  - Hiring of dedicated personnel
  - 1st yearly meeting Oct. 2016: Decision on set of parameters for first study versions.
- Final report & project end: 11.2019

- Future Targets:
  - ESFRI roadmap in 2018 or 2020
  - CDR for 2020
  - Operation 2025 to 2035

Plasma 101

- The wake can be created using a particle beam or a laser pulse.
- The plasma is used to convert the transverse beam/laser fields (TV/m) into longitudinal, accelerating fields (GV/m)
- The accelerated electrons can be taken from the plasma (internal injection) or externally injected
- There are also huge transverse forces
  - Proper matching into/out of plasma is critical!





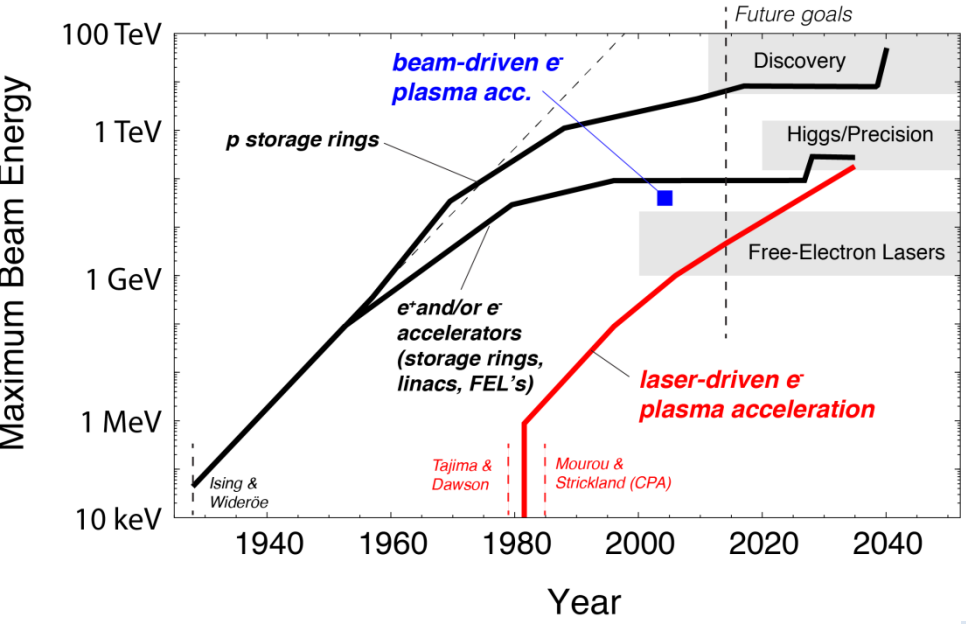
Accelerator Builder's Challenge

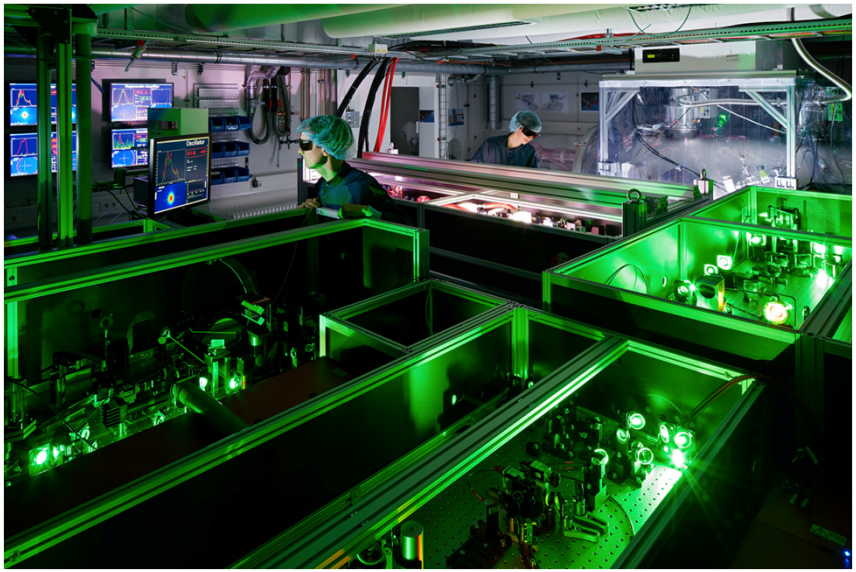
(simplified to typical values)

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.

Why now?

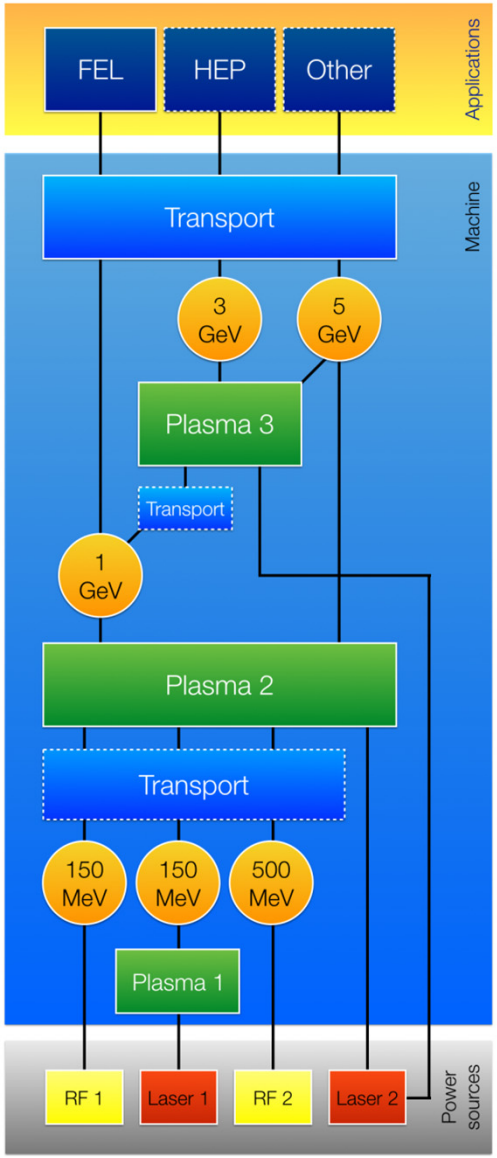
- FEL energies have been reached experimentally
- Required laser power available “off-the shelve”
  - Currently still under heavy development: Repetition rate, reliability & reproducibility (“klystron equivalent”), power-efficiency
- Worldwide steady progress on beam quality





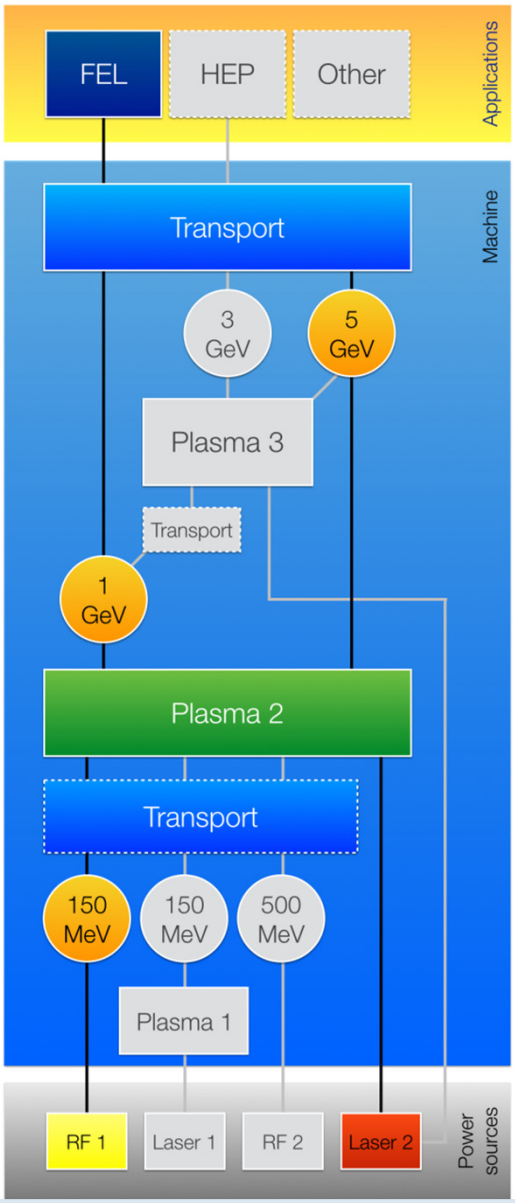
ANGUS laser lab (R. Maier; U. Hamburg/DESY)

Options



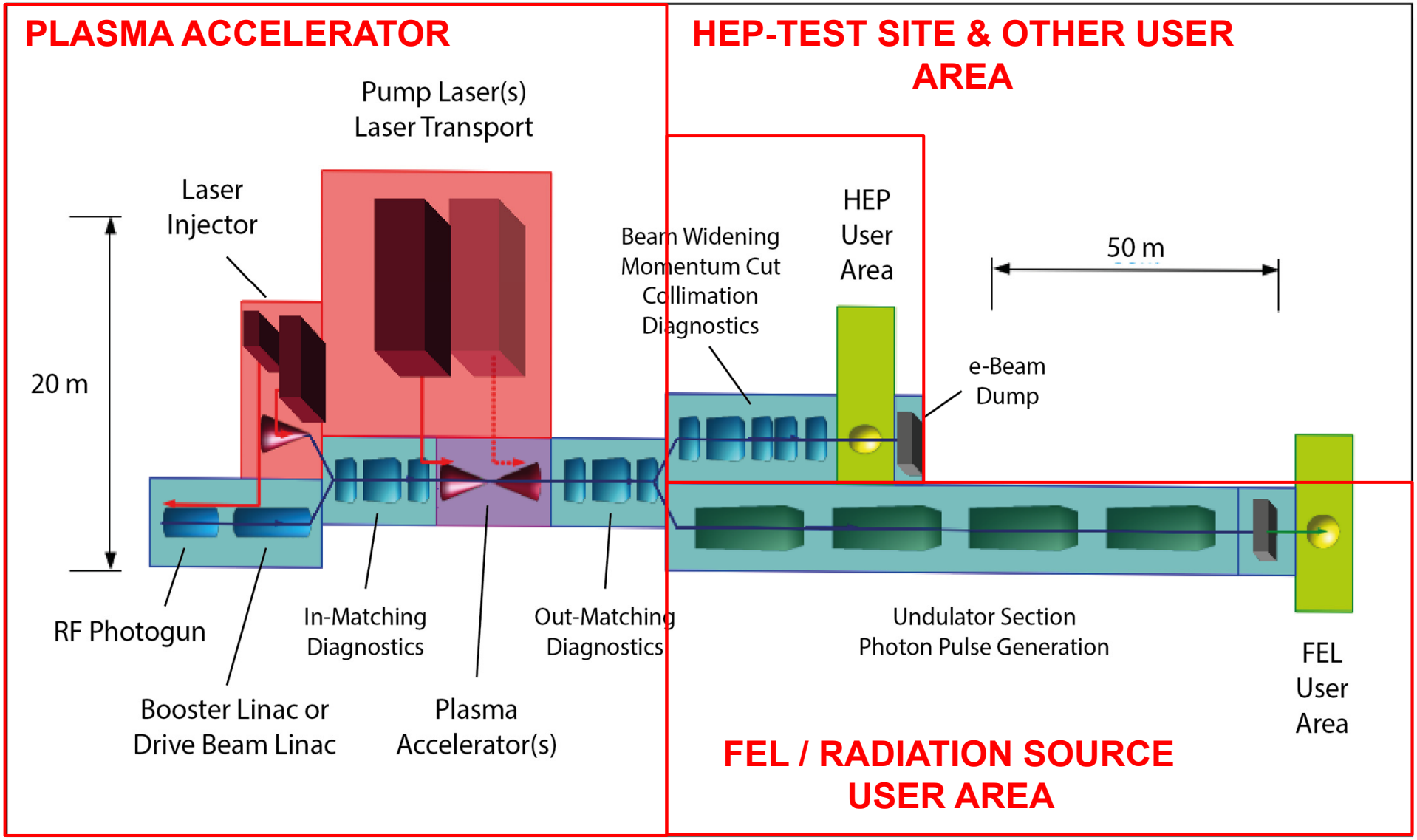
- EuPRAXIA currently still contains several options to reach this goal.
- With the manpower starting these days and the knowhow of all collaborators, the next years will be used to compare all options and identify the best one.

Example: Option RF-injector



- 150 MeV conventional (S-band) photo-injector
- Laser: ("100 cube challenge")
  - 100J, 100Hz, 100fs
- Plasma density: $n \approx 10^{17}/cm^3$
- Target beam parameters at FEL
  - ε_n: 1mm mrad
  - τ (FWHM) = 10fs
  - Q: 25pC
- Document with the targeted parameter for all options being finalized. To be used as common starting point for all future studies

Layout from proposal



"Industrial Beam Quality"

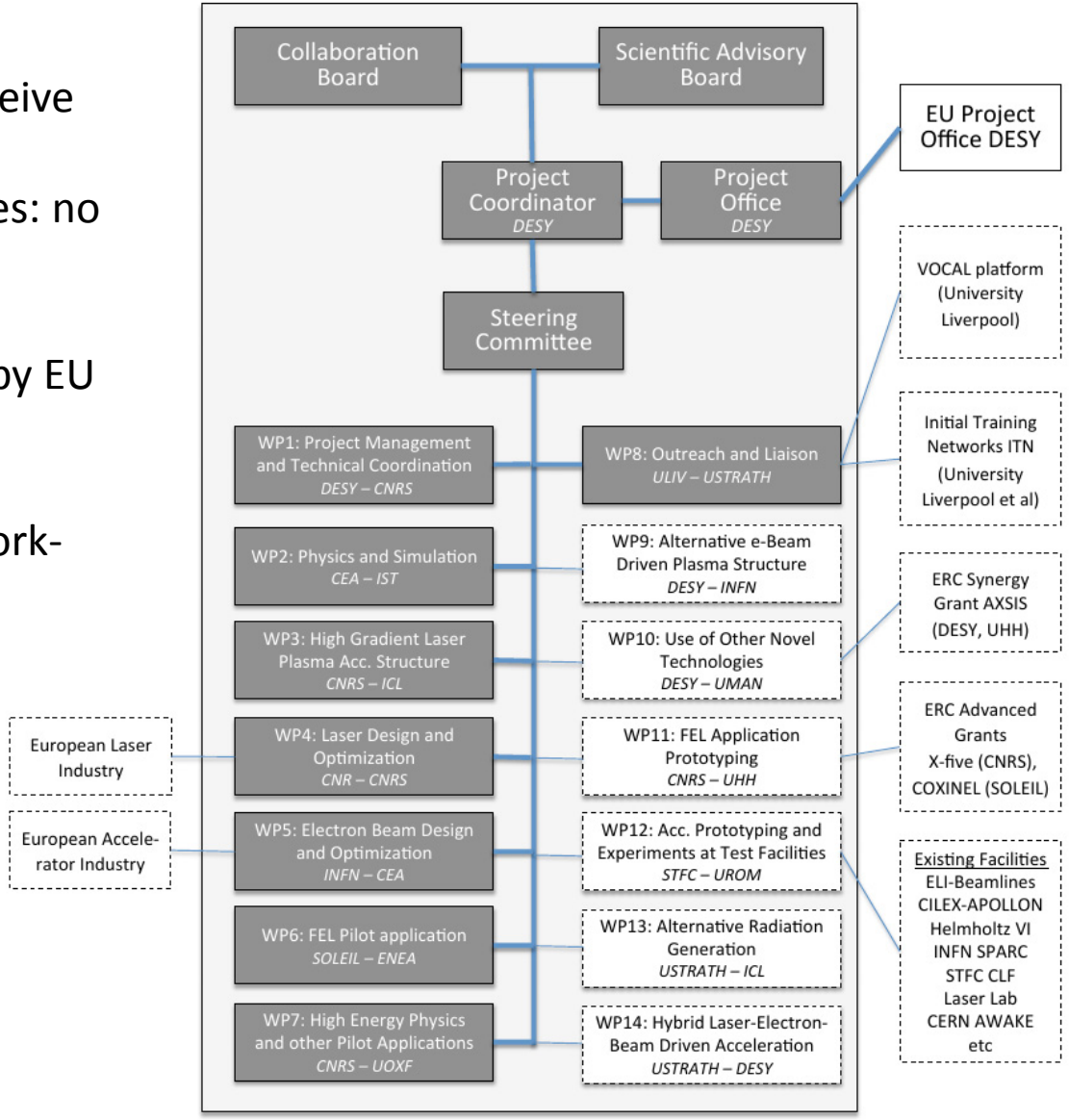
1. **Criterion:**
   Transport 99% of pulses after plasma accelerator through a transport channel of π phase advance with 99% transmission at +- 10 σ aperture.

2. **Criterion:**
   Have a compact and cost-efficient accelerator that can finally be operated by a small team (2-3 persons).

Such an accelerator is useable for many applications and would be suited for the foreseen application range (hospitals, universities, industry, ...).

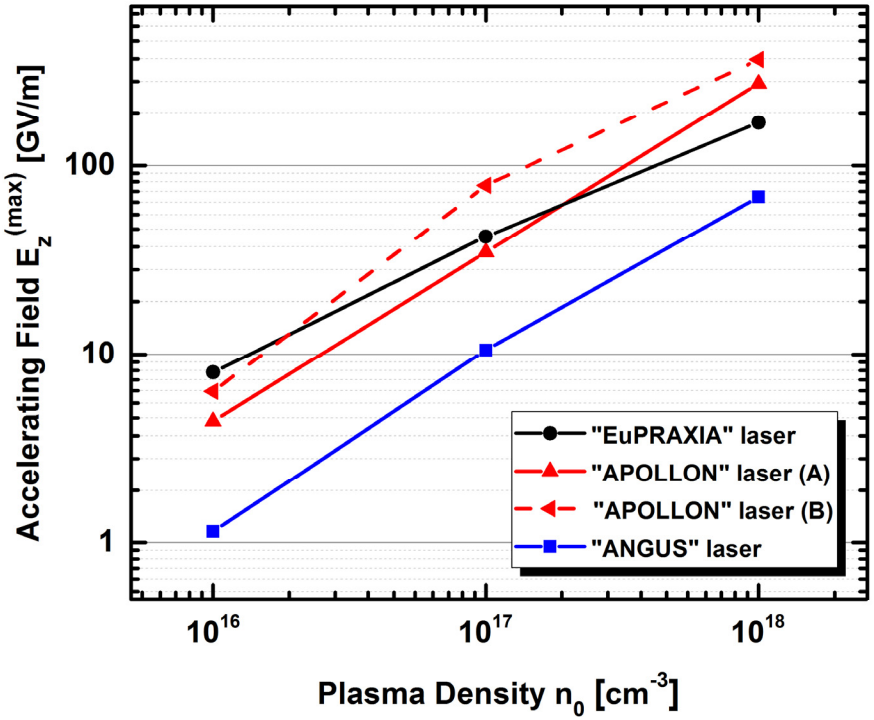
Work Breakdown Structure

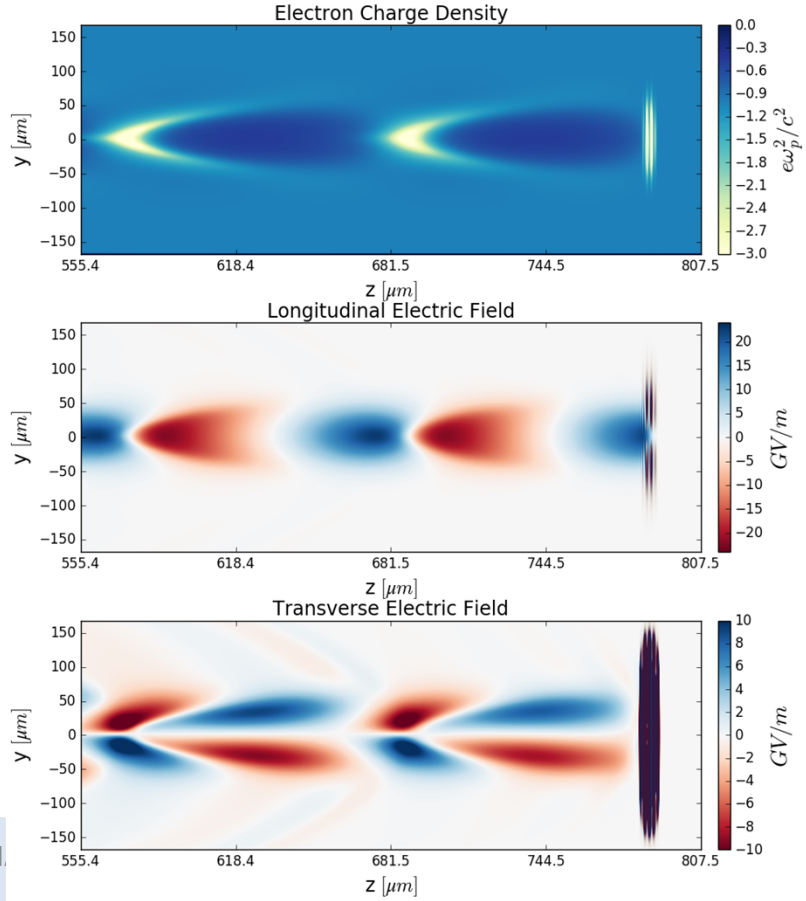
- WP1 – WP8: EU work packages: receive funding
- WP 9 – WP14: In-kind work packages: no EU funding
- Available manpower over 4 years:
  - 42 man-years new hires, paid by EU budget
  - 81 man-years (in-kind)
- http://www.eupraxia-project.eu/work-packages.html



EU - work packages

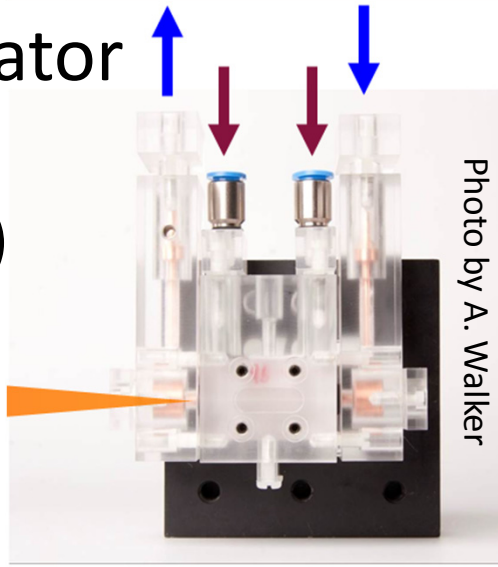
- WP1: Project Management and Technical Coordination
  - WP Leaders: R. Assmann (DESY), A. Specka (CNRS)
  - Management & definition of common parameters, overall layout
- WP2: Physics and Simulation
  - WP Leaders: A. Mosnier (CEA), L. Silva (IST)
  - Tasks: S2E simulations of plasma injector & accelerating modules. External injection & self-injection from a laser-driven plasma cell.





EU - work packages

- WP3: High Gradient Laser Plasma Accelerator Structure
  - WP Leaders: B. Cros (CNRS), Z. Najmudin (ICL)
  - Tasks: Design injector and accelerator stage
  - Workshop end Oct. in Paris
- WP4: Laser Design and Optimization
  - WP Leaders: L. Gizzi (CNR), F. Mathieu (CNRS)
  - First WP meeting resulted in the 100cube challenge
    - **100 J, 100 fs, 100 Hz**
    - contrast 10^{10} at 10ps
    - → 1PW @ 100Hz



EU - work packages

- WP5: Electron Beam Design and Optimization
  - WP Leaders: E. Chiadroni (INFN), A. Chance (CEA)
  - External RF injector incl. long. Compression to fs bunches
  - Matching to/from plasma
  - Workshop held last week (5.-6. Oct.)
- WP6: FEL pilot application
  - WP leaders: M-E. Couprie (SOLEIL), G. Dattoli (ENEA)
  - Provide requirements
  - Study the beam manipulation techniques:
    - transverse gradient undulator
    - decompression chicane to sort the electrons by their energy
  - Study innovative undulator magnets
    - RF-type or laser-type undulators

EU - work packages

- WP 7: High Energy Physics and other Pilot Applications
  - WP Leaders: A. Specka (CNRS), R. Walczak (UOXF)
  - Survey the needs and requirements of test beam users that are not covered at existing facilities
  - Identify users that may actually profit from “non-standard beam parameters”
    - HE EM shower “simulation” in the lab
    - Big detector calibration
    - test facility for bunch length diagnostics
  - Workshop “PAEPA” this week (11.-13. Oct.) in Paris
- WP8 : Outreach and Liaison
  - WP Leaders: C. Welsch (ULIV), B. Hidding (USTRATH)
  - www.eupraxia-project.eu, #EuPRAXIA


THE EuPRAXIA FILES

ISSUE I – May 2016

Foreword

Novel accelerators have seen strong advances not only in achievable beam energy but also in beam quality. This success story is still developing, as you can see from the publications that we collect in this first edition of “The EuPRAXIA Files”. As many of you are aware, the Horizon2020 Design Study EuPRAXIA aims at a conceptual design for a European plasma accelerator with usable beams. Instead of another newsletter we will regularly provide you with summaries of recent publications, letting the science speak for itself. EuPRAXIA has meanwhile had an excellent project start and is gearing up to a workshop in Pisa at the end of June, organized together with the European Network for Novel Accelerators EuroNNAc2 and EuCARD2. For further news on EuPRAXIA please visit our website or read regular updates in “Accelerating news”. We wish you some inspirational science readings in this edition of “The EuPRAXIA Files”, prepared by the EuPRAXIA outreach team in Liverpool with Ricardo Torres as lead editor.

Dr Ralph Assmann
EuPRAXIA Coordinator

Research Highlights

Berkeley Lab Scientists Create the First-ever, 2-stage Laser-plasma Accelerator Powered by Independent Laser Pulses

Researchers from the Lawrence Berkeley National Laboratory in the US have made an important breakthrough in the development of ultra-compact high-energy plasma-based accelerators.

In a paper recently published in Nature, they demonstrate for the first time the technique of staging, or sequencing multiple plasma accelerators independently powered. Staging is critical for high-energy physics applications of laser-plasma accelerators, as it enables to achieve higher beam energies, while maintaining accelerating gradients orders of magnitude above conventional technology.

Members of the BELLA Center staging experiment team, from left, are Eric Esarey, Wim Leemans, Jeroen van Tilborg, Carlo Benedetti, Kelly Swanson, Anthony Gonsalves, Joost Daniels, Sven Steinke, and Kei Nakamura. Not pictured are Cameron Geddes, Carl Schroeder, Nicholas Matlis, and Brian Shaw. (Photo credit: Roy Kaltschmidt/Berkeley Lab)

In these experiments, electrons from one laser-plasma accelerator were transported into a second laser-plasma accelerator, powered by a second laser pulse, and accelerated. What was particularly novel about this experiment is that a plasma-based lens was employed to transport the beam between stages and a plasma mirror was used to couple in the second laser pulse. These plasma-based components allowed the system to remain extremely compact.

With this result, one can envision scaling to beam energies of interest for high-energy physics applications in a compact footprint. However, these results are a first step toward that vision—experiments at higher beam energy, with higher efficiency and improved beam quality, will need to be performed to further develop plasma-based technology for next-generation colliders.

Read more at: http://newscenter.lbl.gov/2016/02/01/2-stage-laser-plasma-accelerator/

EuPRAXIA

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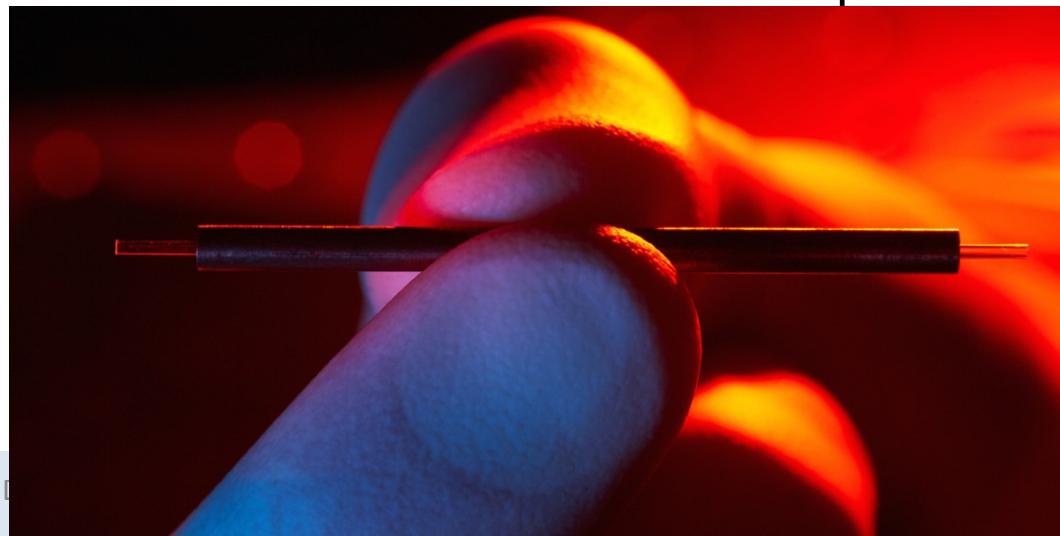
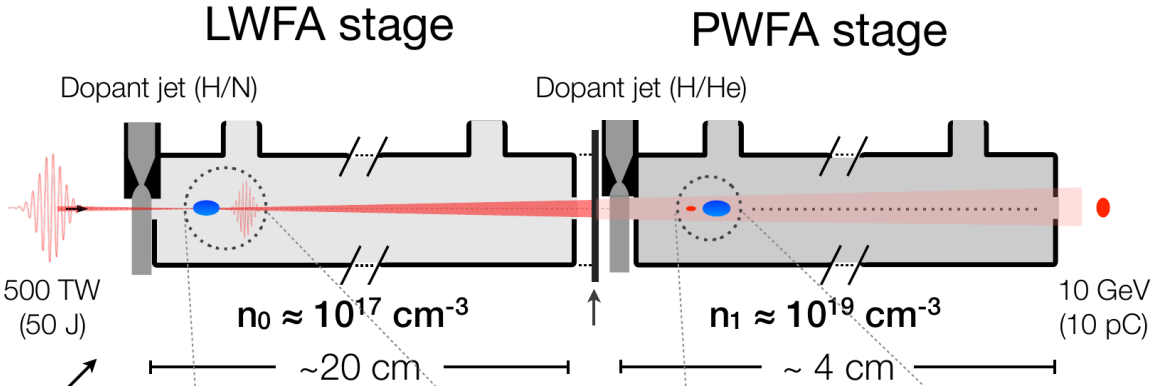
In kind - work packages

- WP9: Alternative e-Beam Driven Plasma Structure
  - WP Leaders: J. Osterhoff (DESY), M. Ferrario (INFN)
  - Electron beam-driven plasma wakefield stages
  - Study the electron beam-driver options and beam preparation schemes, studies into the plasma target and vacuum system, plasma diagnostics , staging of acceleration modules, as well as general engineering issues and stability studies.
  - Workshop held last week (3-4. Oct.)
- WP10: Use of Other Novel Technologies
  - WP Leaders: U. Dorda (DESY), Guoxing Xia (UMAN)
  - Study/monitor the potential of other ‘novel’ acceleration techniques & fiber lasers



In kind - work packages

- WP11: FEL Application Prototyping
  - WP Leaders: V. Malka (CNRS), A. Lifschitz (CNRS), A. Maier (UHH)
  - Address technical issues in real experiments
  - Simulations and comparative studies between experiments and theory
- WP12: Accelerator Prototyping and Experiments at Test Facilities
  - WP Leaders: R. Pattathil (STFC), A. Mostacci (UROM)
  - Coordinate access to various test facilities for proof-of-principle tests
- WP13: Alternative Radiation Generation
  - WP Leaders: D. Jaroszinsky (USTRATH), Z-M. Sheng (ICL)
  - E.g. betatron & synchrotron radiation, nonlinear Thomson scattering
- WP14: Hybrid Laser-Electron-Beam Driven Acceleration
  - WP Leaders: B. Hidding (USTRATH), A. Ossa (DESY)



A. Ossa, 2016
EuPRAXIA Pisa meeting

Conclusion/ Summary/ further info

- EuPRAXIA is a **design study** for a plasma accelerator based facility in the Horizon2020 research program of EU.
- **32 partners and associated partners** presently.
- Collaboration is set up and personnel hiring started
- Technical approaches being followed towards 2019 proposal:
  100cube challenge for lasers, compact accelerator, cost-effectiveness a must, modular approach, stages with intermediate “conventional” beam forming, RF vs novel injectors for controlled beam shaping, best solution approach (laser vs beam vs hybrid driver), short bunches, feedbacks, advanced controls
- Project started Nov 2015. **Next steps**:
  - Finalize set of parameters for first study version end October 2016.
  - 1st yearly meeting in October in Paris.

EuPRAXIA workshop in June 2016 in Pisa