EUROPEAN
PLASMA RESEARCH
ACCELERATOR WITH
EXCELLENCE IN
APPLICATIONS

EuPRAXIA

Layout considerations for EuPRAXIA

Paul Andreas Walker (DESY)
On behalf of the EuPRAXIA collaboration

3rd European Advanced Accelerator Conference

September 27th, 2017, Elba, Italy

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

Introduction

Horizon 2020

- EuPRAXIA is a **conceptual design study** for a **5 GeV electron plasma accelerator** as an European research infrastructure

- 125 scientists work in 38 international partners
  - 16 EU laboratories are beneficiaries
  - 22 associated partners contribute in-kind

- This talk focuses on layout plan for facility
  - Other throughout the week discuss RF & plasma injector, acc. stages, transport, …
  - **EuPRAXIA plenary session tomorrow at 11 am**
    - Ralph Assmann: EuPRAXIA overview
    - Leo Gizzi: Laser design and industry
    - Alban Mosnier: Simulations and performance

Considerations for layout design

- Facility layout design is driven by many aspects:
  - Simulations
  - Experimental results
  - Timeline, funding & commitment
  - Applications targeted and their requirements
  - Concepts ready/work on
  - Infrastructure requirements: water/cooling/power etc.
  - Available space at existing laboratories
  - …

- **Science & practical considerations** will determine final choice of configuration(s) and layout

- EuPRAXIA layout will be optimized for best synergy of lasers & RF technology

Timeline towards operating facility

Nov. 2015 — Start of EuPRAXIA project

2016/2017 — Hiring of dedicated personnel
19 workshops on EuPRAXIA/EuroNNAc
15 scientific reports published, 7 to come later in the year
→ ***Initial layout design (started 7/2016)***
Study parameters table for facility
Added 6 new institutes

2018/2019 — Work with refined parameters
Finalize laser and RF design
Decide on options/combination
→ ***Finalize layout design (summer 2019)***
Finalize Conceptual Design Report (CDR)
Application to ESFRI roadmap for 2020

Oct. 2019 — Final conceptual design report

2020 — *Construction decision*
2021 – 2025 — *Construction*
2025 – 2035 — *Operation*

More details tomorrow in Ralph's talk at 11 am

How to position user areas?

There will be **at least 2 user areas**:

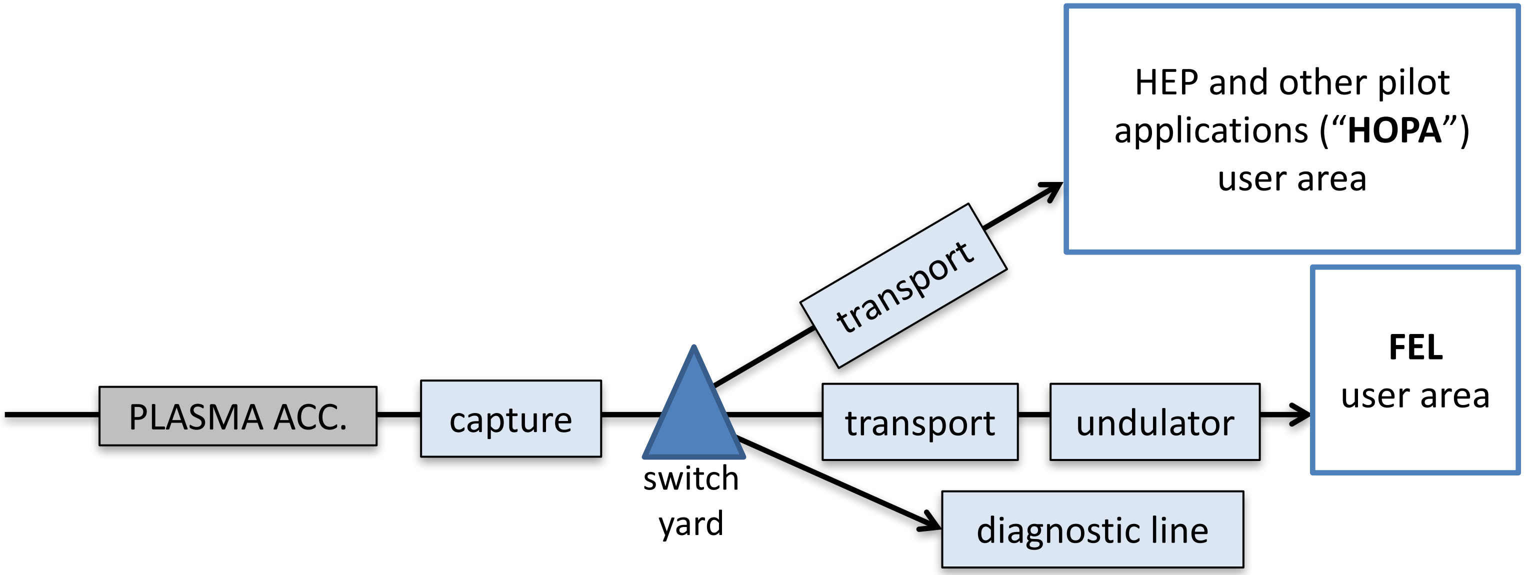
FEL user area:

- FEL's with new properties (complimentary to high power FEL's): *ultra-short pulses*, *pump-probe*, *excellent synchronization with low power (at least initially)*

HEP test beams & other pilot application ("HOPA" user area):

- Table-top test beams for HEP detector development
- Compact X-rays sources for e.g. medical imaging
- Proximity experiments (no transport needed)

There will be **at least 2 user areas:** FEL and HOPA



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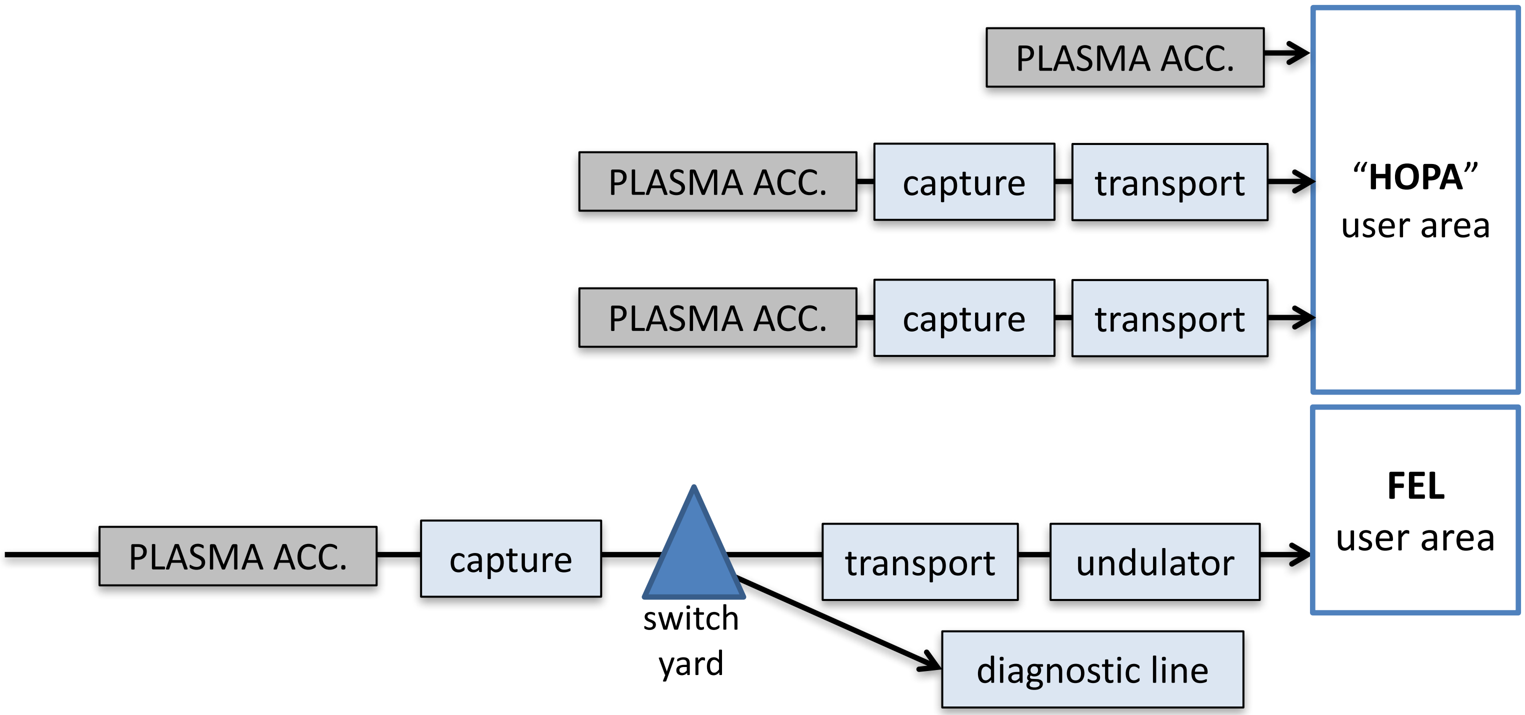
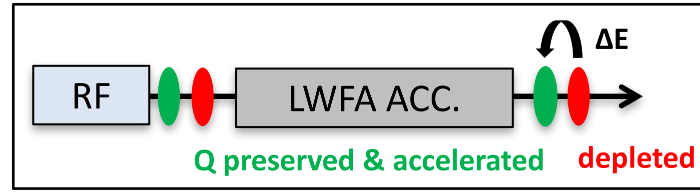


5 configurations currently considered for layout

Horizon 2020

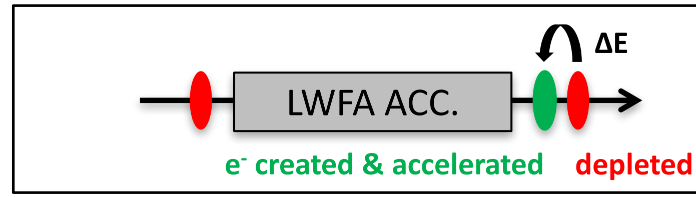
1) RF electron injector + laser plasma accelerator (LPA)

(LWFA with external injection from an RF accelerator)



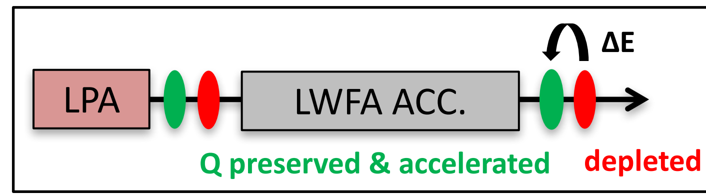
2) LPA with electron bunch created in plasma directly

(LWFA with internal injection)



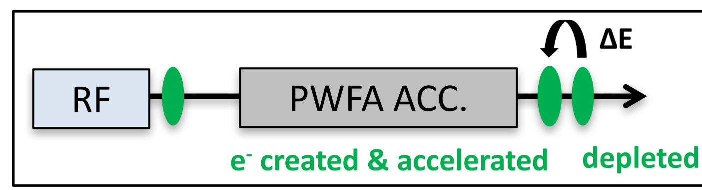
3) LPA electron injector + LPA

(LWFA with external injection from a LPA)



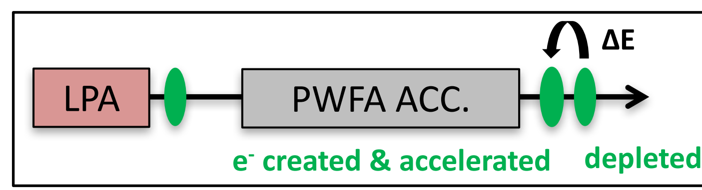
4) RF electron bunch as beam driver in LPA

(PWFA with an RF electron beam)



5) RF electron bunch as driver in a hybrid stage

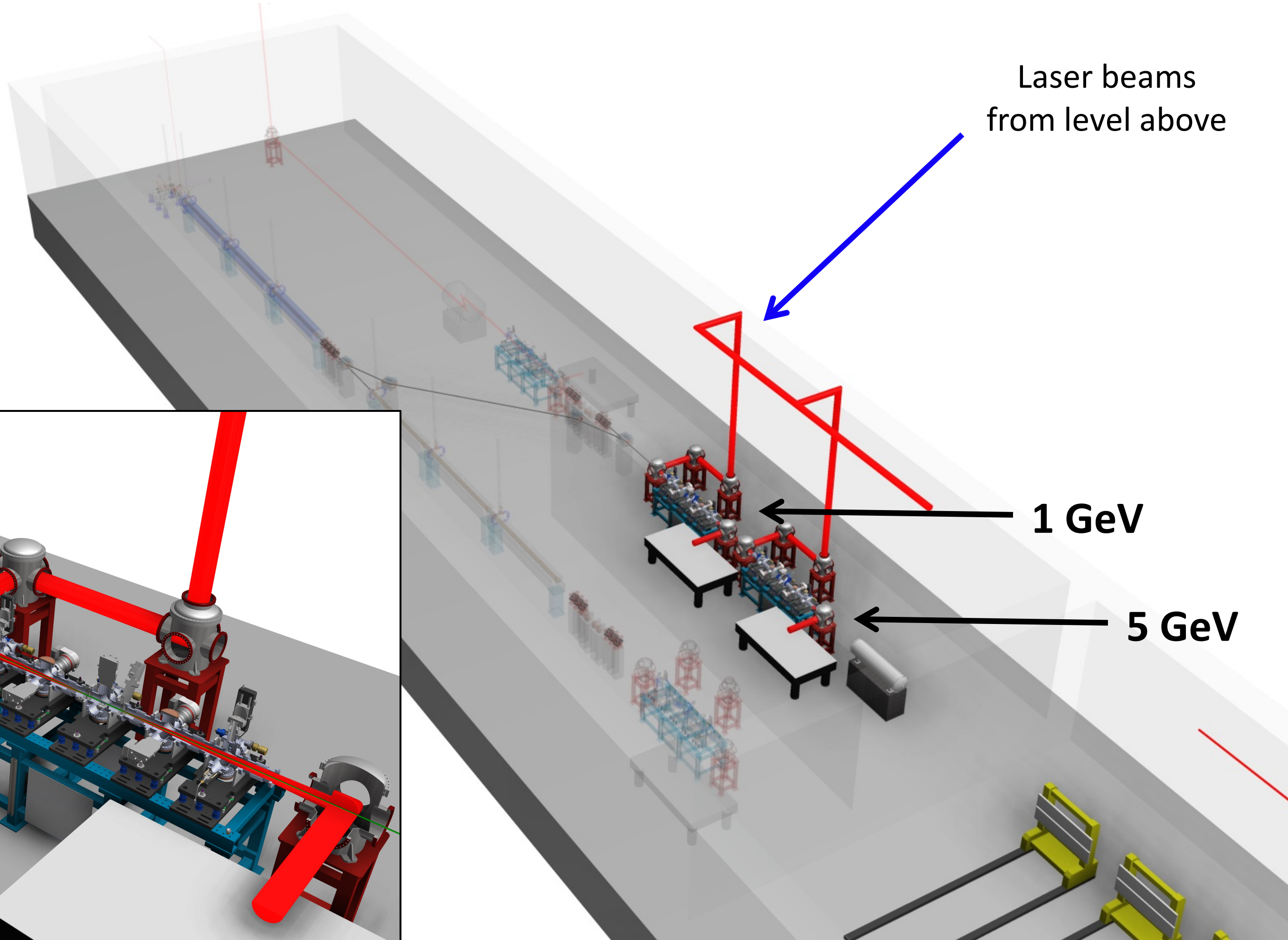
(PWFA with LWFA produced electron beam or Trojan Horse scheme)



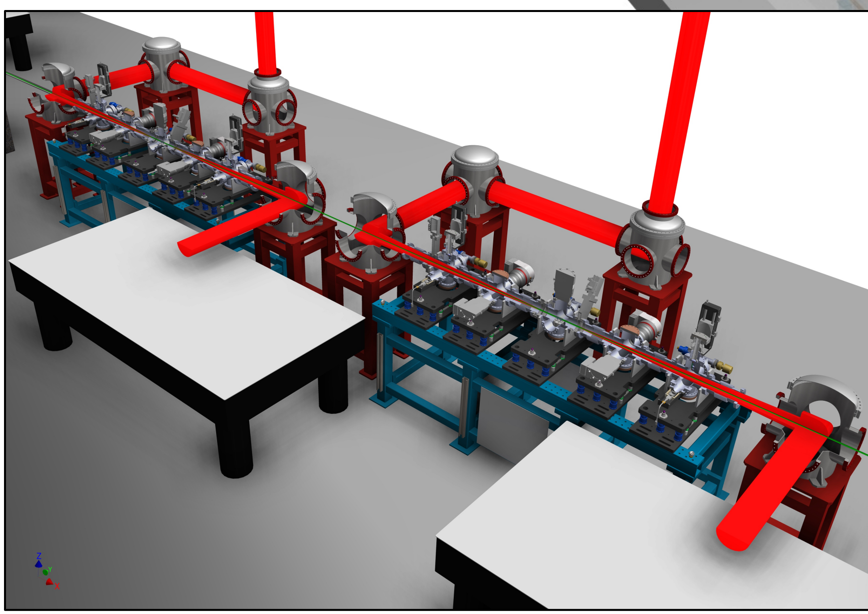
P. A. Walker *et al.*, Horizon 2020 EuPRAXIA design study, *J. Phys.: Conf. Ser.* **874**, 012029 (2017)

Laser beam Electron beam

Layout proposal: LWFA with internal injection

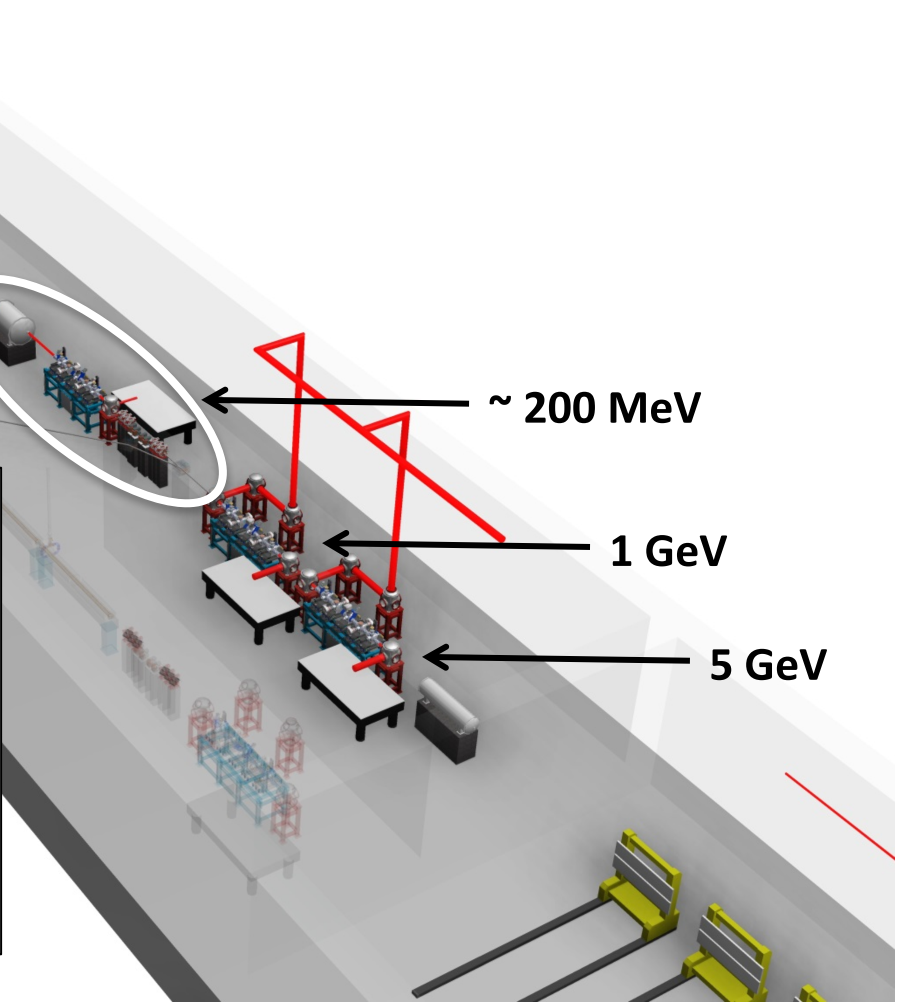


LWFA accelerator
1 or 2 stages

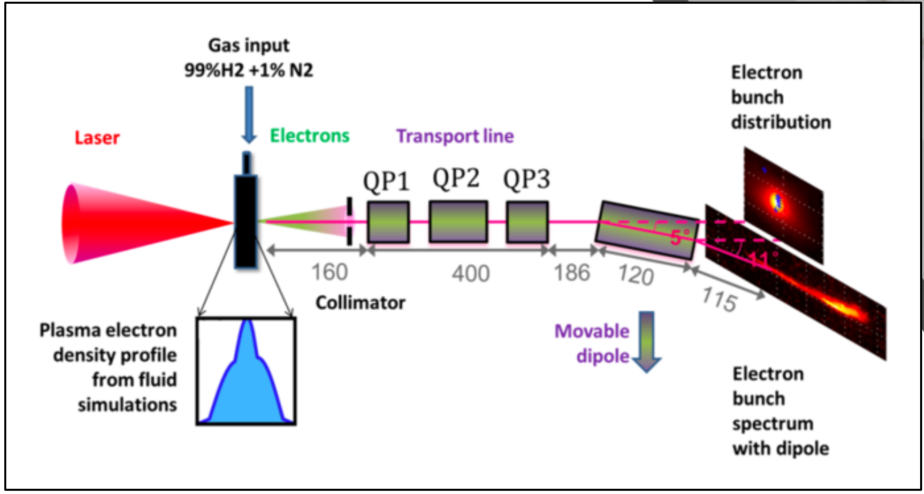


3D design by Dariusz Kocoń (ELI-Beams)

Layout proposal: LWFA with external injection from a LPA



plasma injector



T. Audet et al., 'Laser wakefield injector in the frame of EuPRAXIA', EAAC17, **WP4 Thursday 18:15**

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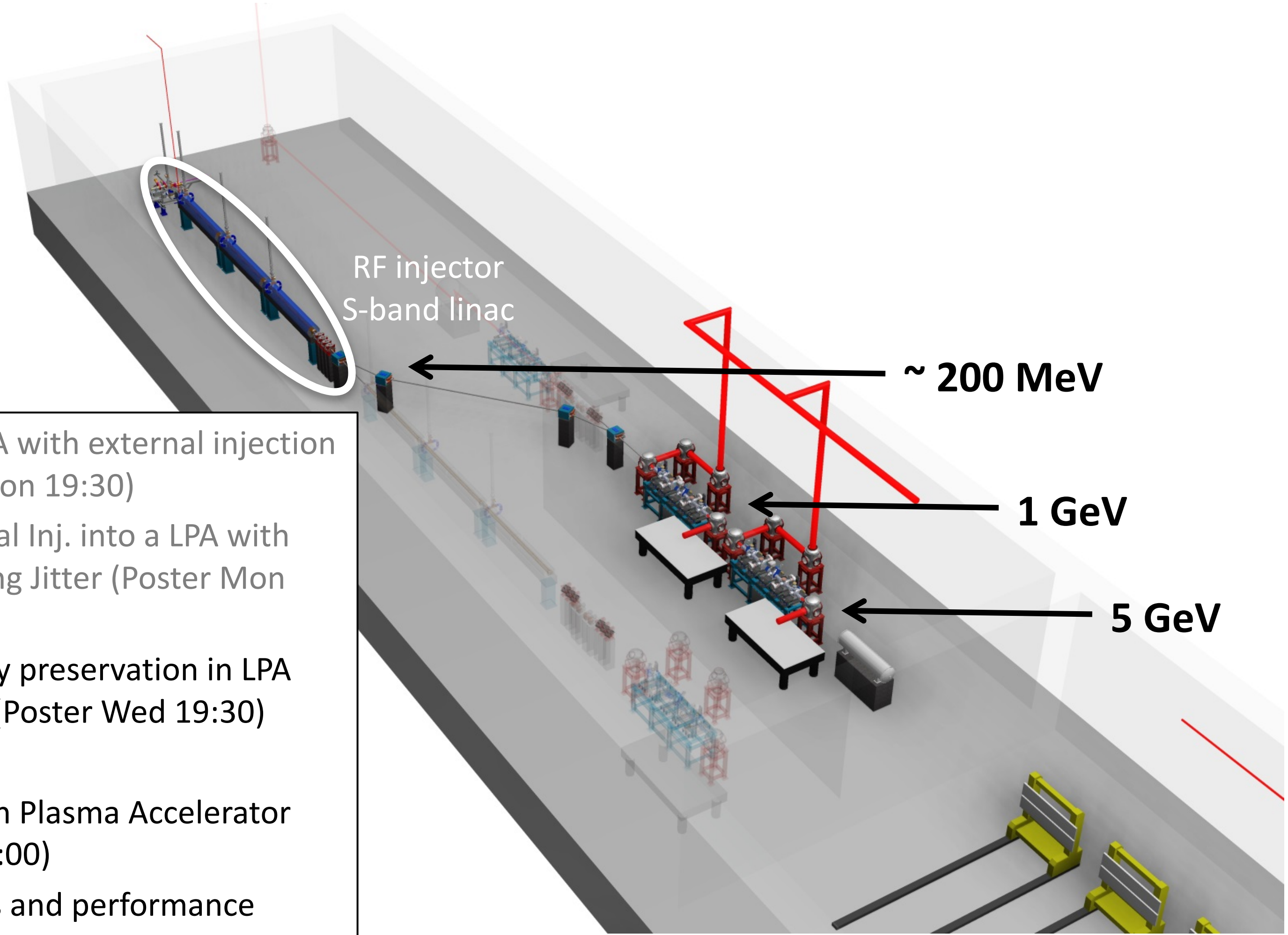
Layout proposal: LWFA with external injection from an RF accelerator



- Svystun:Single stage LPA with external injection for EuPRAXIA (Poster Mon 19:30)
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- E. Svystun: Beam quality preservation in LPA with external injection (Poster Wed 19:30)
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- A. Mosnier: Simulations and performance (Plenary Thu 11:50)

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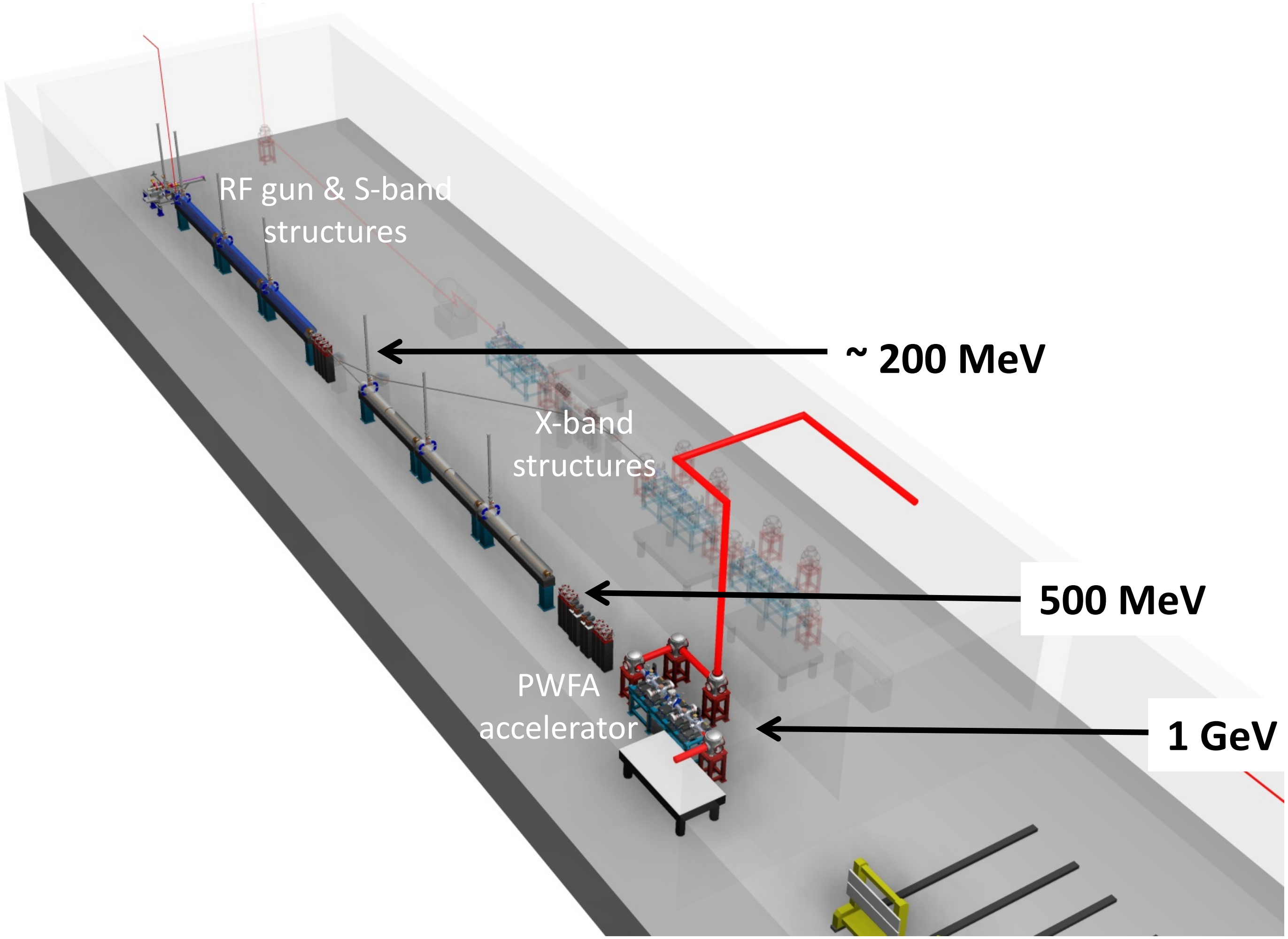
Layout proposal: PWFA with an RF electron beam



3D design by Dariusz Kocoń (ELI-Beams)

Layout proposal: PWFA with an RF electron beam

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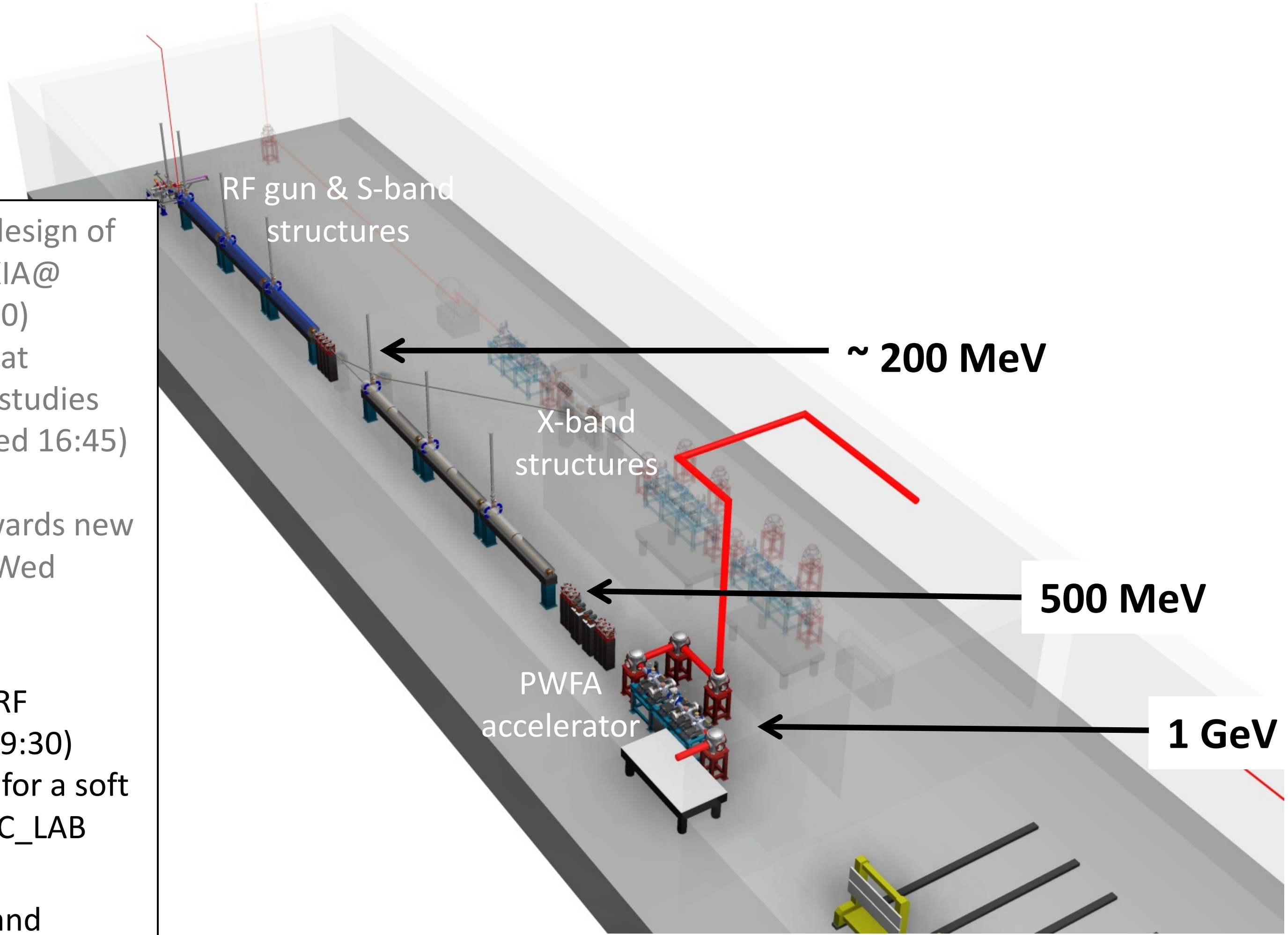
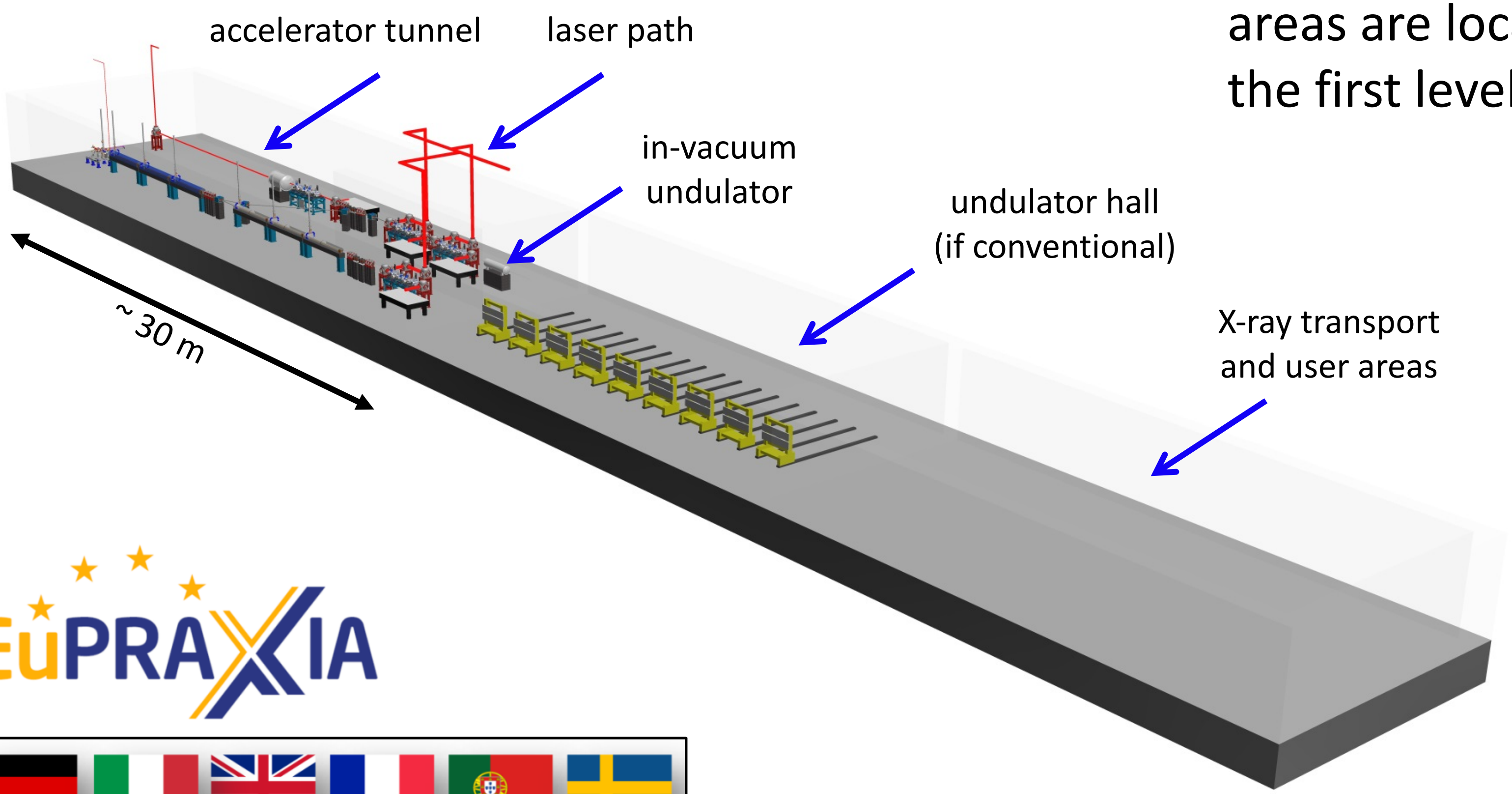


3D design by Dariusz Kocoń (ELI-Beams)

Accelerator tunnel, undulator hall, X-ray transport and user areas

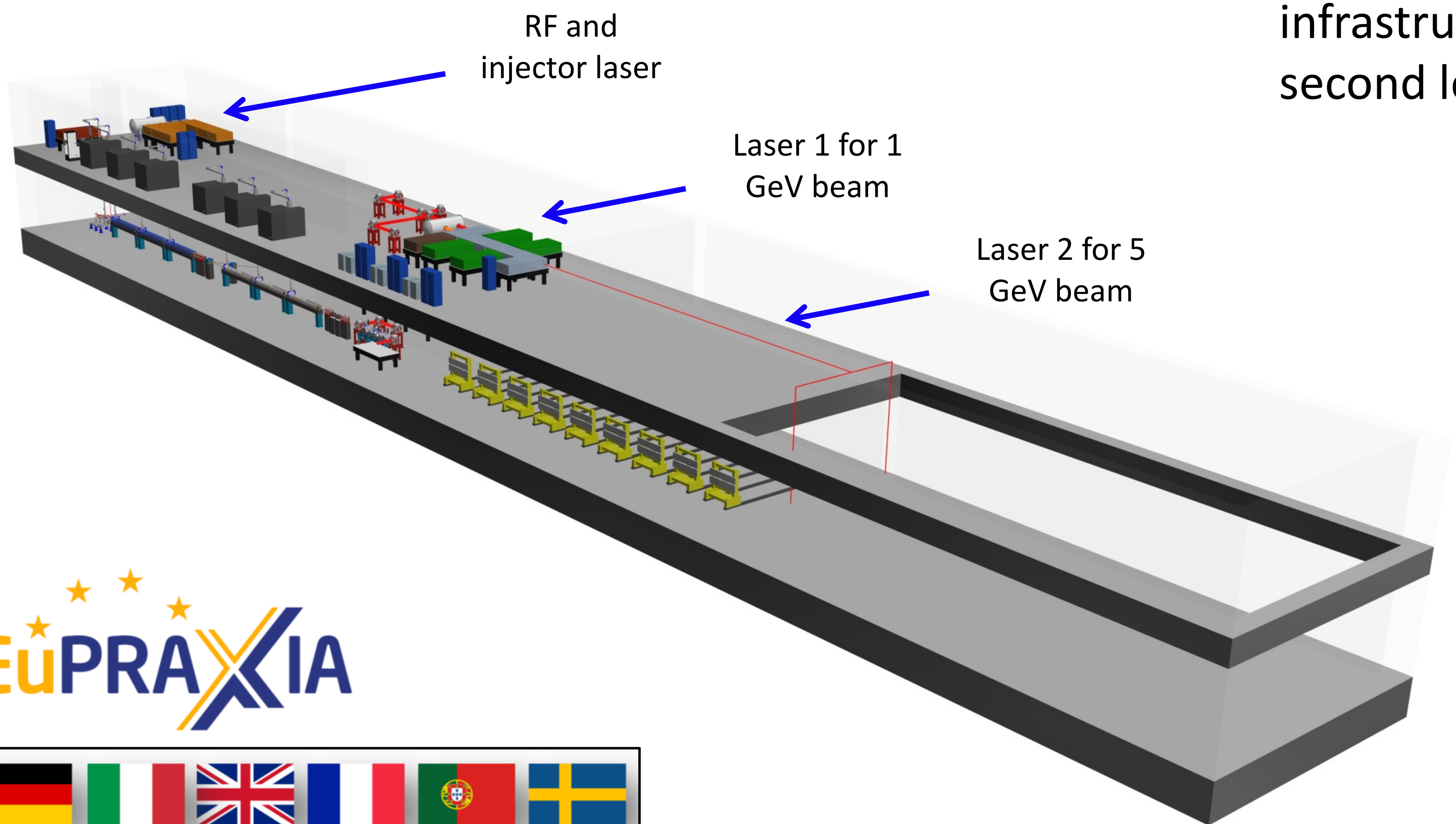
Horizon 2020

Accelerator research, undulators and user areas are located on the first level

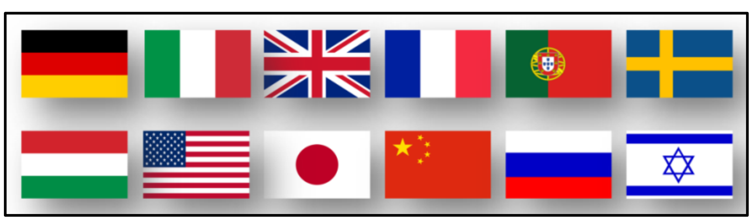


3D design by Dariusz Kocoń (ELI-Beams)

… with 1st floor for laser/RF infrastructure



RF and laser infrastructure on second level



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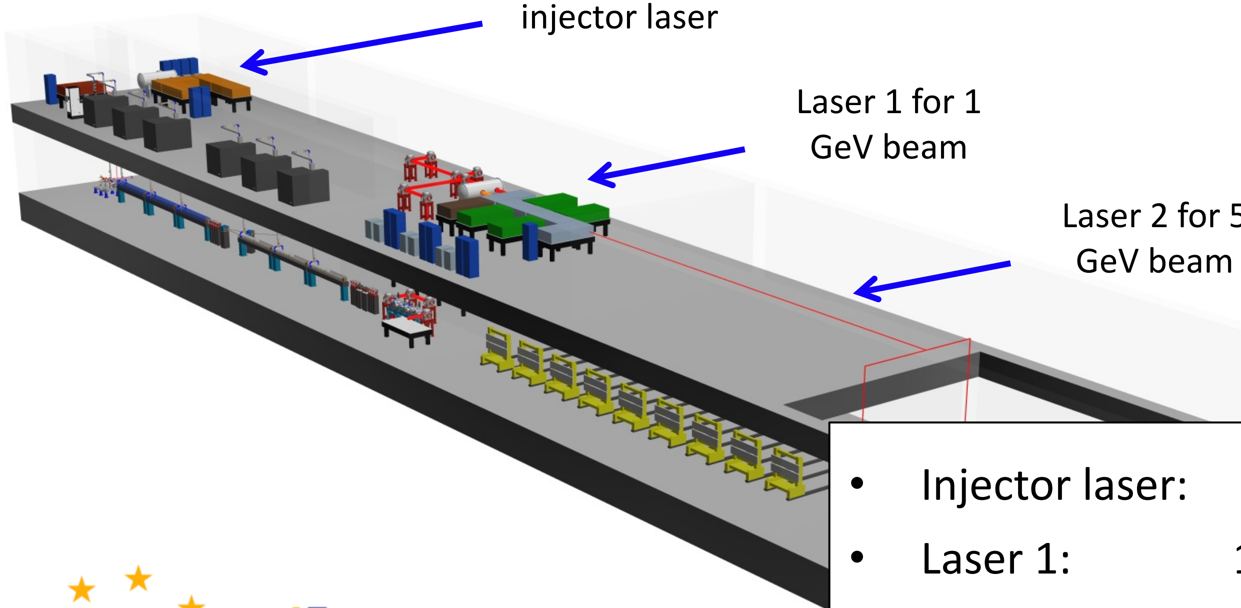
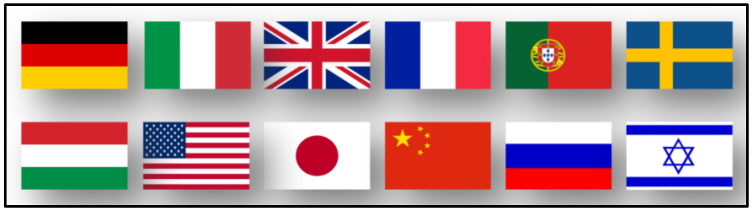


- Injector laser: 5 J, 30 fs, 20 Hz
- Laser 1: 15 J, 30 fs, 20 Hz
- Laser 2: 50 J, 60 fs, 20 Hz
    - Ti:Sa based architecture
    - Diode-pumped solid-state laser technology for high energy pump lasers
    - Option at higher repetition rate being worked out currently

EuPRAXIA



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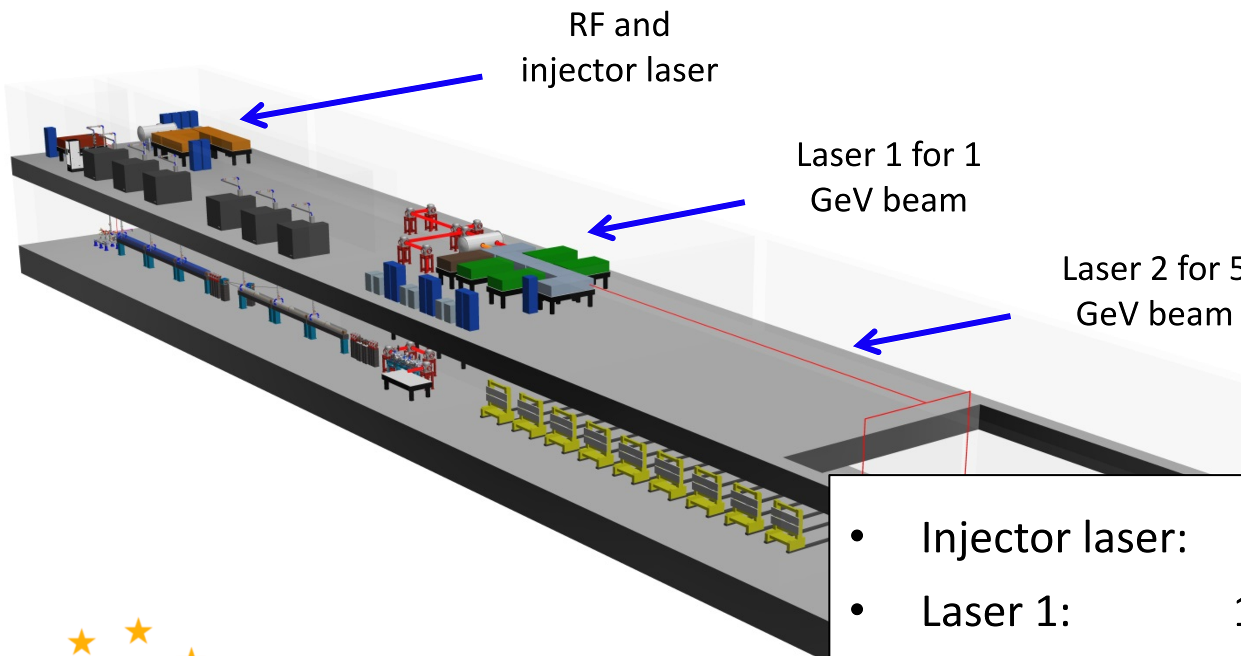

RF and laser infrastructure on second level

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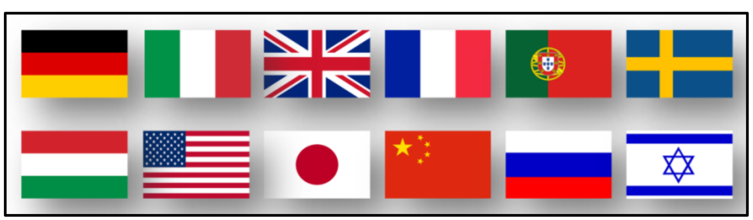
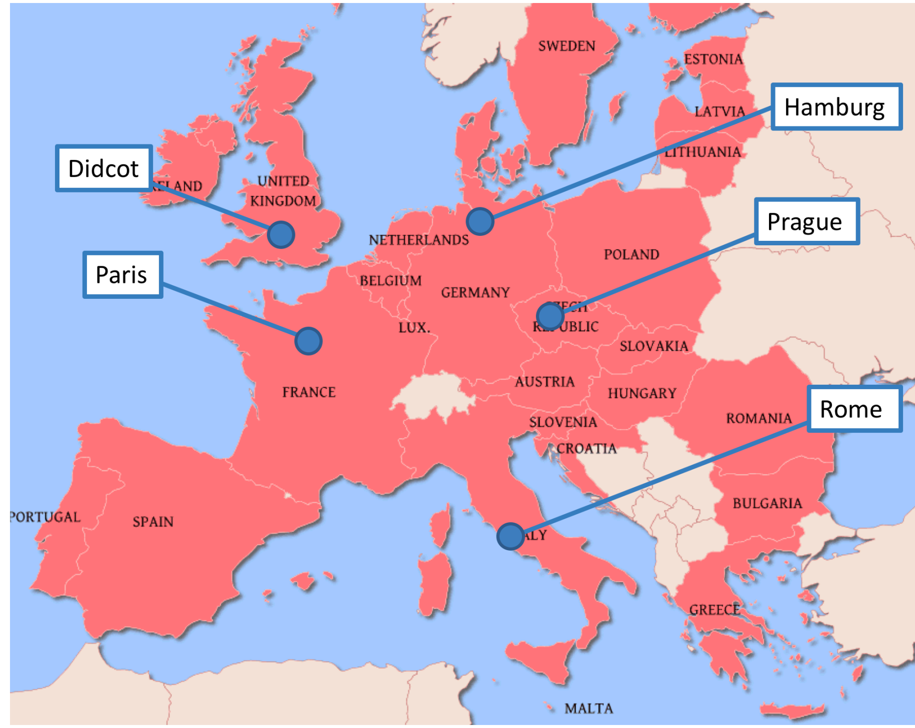
More details tomorrow in Leo 's talk (Thu 11:25)

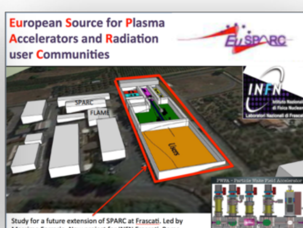


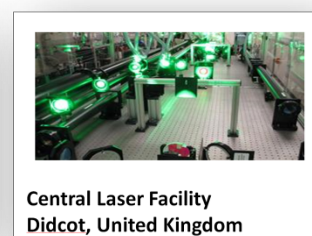
Location of possible sites within EU

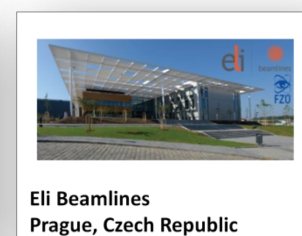
EuPRAXIA site studies:

- Design study is site independent
- Five possible sites have been discussed so far
- We invite the suggestions of additional sites









Next steps

- Include realistic space for:
  - diagnostics
  - beam transport
  - feedbacks systems
  - collimation
  - in/out-coupling of lasers/beams
- Estimate cost for individual configurations
- Decide for switch-yard or several plasma accelerators
- Work out individual site studies
- Refine parameter table: 2nd iteration will be published November 2017

EuPRAXIA Yearly & Collaboration Meeting 2017
20th – 24th November in Lisbon, Portugal

Possible footprint

3D design by Dariusz Kocoń (ELI-Beams). Photo credit: google.

Possible footprint

3D design by Dariusz Kocoń (ELI-Beams). Photo credit: google.

Conclusion

- Current layout consideration for **European 5 GeV electron beam accelerator facility** presented
- Design includes user areas for **FEL radiation**, **test beams for HEP detectors tests**, and **compact X-ray source** for medical imaging, and other applications
- Five facilities in European Union consider local design study for final CDR in October 2019

- This is a Horizon 2020 project and we acknowledge the support from the EU under grant agreement No. 653782.

This is EuPRAXIA:

The EuPRAXIA team

P. D. Alesini, A. S. Alexandrova, M. P. Anania, N. E. Andreev, R. W. Assmann, T. Audet, A. Bacci, I. F. Barna, A. Beaton, A. Beck, A. Beluze, A. Bernhard, S. Bielawski, F. G. Bisesto, J. Boedewadt, F. Brandi, O. Bringer, R. Brinkmann, E. Bründermann, M. Büscher, G. C. Bussolino, A. Chance, M. Chen, E. Chiadroni, A. Cianchi, J. Clarke, M. Croia, M. E. Couprie, B. Cros, J. Dale, G. Dattoli, N. Delerue, O. Delferriere, P. Delinikolas, J. Dias, U. Dorda, K. Ertel, Á. Ferran Pousa, M. Ferrario, F. Filippi, J. Fils, R. Fiorito, R. A. Fonseca, M. Galimberti, A. Gallo, D. Garzella, P. Gastinel, D. Giove, A. Giribono, L. A. Gizzi, F. J. Grüner, A. F. Habib, L. C. Haefner, T. Heinemann, B. Hidding, B. J. Holzer, S. M. Hooker, T. Hosokai, B. Imre, D. A. Jaroszynski, C. Joshi, M. Kaluza, O. S. Karger, S. Karsch, E. Khazanov, D. Khikhlukha, A. Knetsch, D. Kocon, P. Koester, O. Kononenko, G. Korn, I. Kostyukov, L. Labate, C. Lechner, W. P. Leemans, A. Lehrach, F. Y. Li, X. Li, A. Lifschitz, V. Litvinenko, W. Lu, A. R. Maier, V. Malka, G. G. Manahan, S. P. D. Mangles, B. Marchetti, A. Marocchino, A. Martinez de la Ossa, J. L. Martins, K. Masaki, F. Massimo, F. Mathieu, G. Maynard, T. J. Mehrling, A. Y. Molodozhentsev, A. Mosnier, A. Mostacci, A. S. Müller, Z. Najmudin, P. A. P. Nghiem, F. Nguyen, P. Niknejadi, J. Osterhoff, D. Papadopoulos, B. Patrizi, R. Pattathil, V. Petrillo, M. A. Pocsai, K. Poder, R. Pompili, L. Pribyl, D. Pugacheva, S. Romeo, A. R. Rossi, A. A. Sahai, Y. Sano, L. Schaper, P. Scherkl, U. Schramm, C. B. Schroeder, J. Schwindling, J. Scifo, L. Serafini, Z. M. Sheng, L. O. Silva, C. Simon, U. Sinha, A. Specka, M. J. V. Streeter, E. N. Svystun, D. Symes, C. Szwaj, G. Tauscher, A. G. R. Thomas, N. Thompson, G. Toci, P. Tomassini, C. Vaccarezza, M. Vannini, J. M. Vieira, F. Villa, C.-G. Wahlström, R. Walczak, P. A. Walker, M. K. Weikum, C. P. Welsch, J. Wolfenden, G. Xia, M. Yabashi, L. Yu, J. Zhu, A. Zigler

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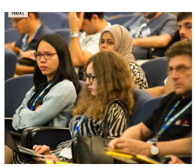
This is EuPRAXIA:

www.eupraxia-project.eu



Related posters/talks

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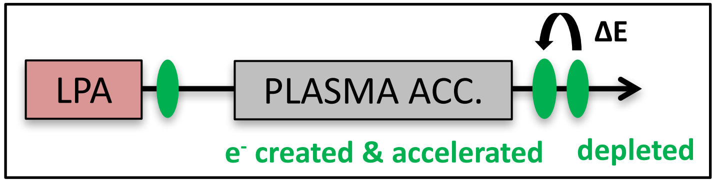
Backup Slides

Horizon 2020

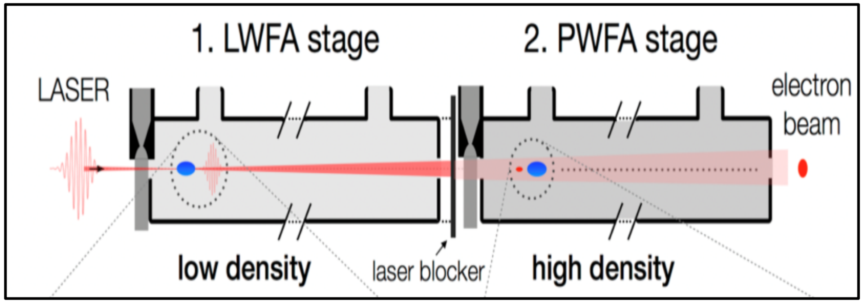
EuPRAXIA hybrid plasma acceleration ("Trojan Horse" and "L_2PWFA" schemes)

RF electron bunch as the driver in a hybrid stage:

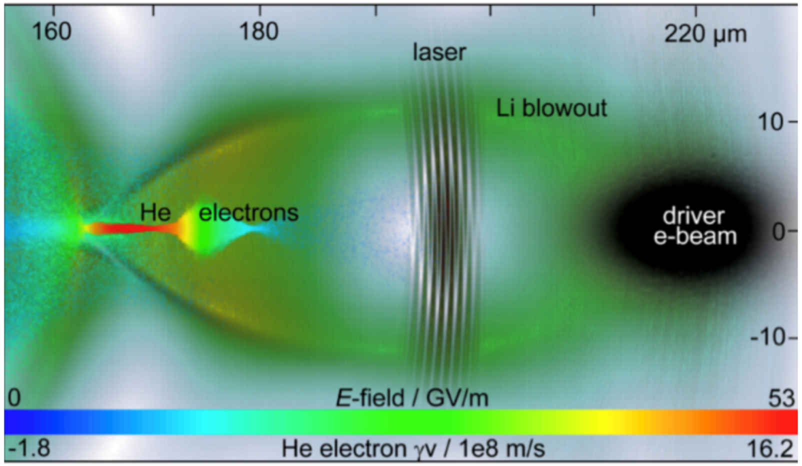
- 1st stage uses laser driver to accelerate electron beam
- 2nd stage uses electron beam as beam driver to accelerate high quality electron beam



Laser beam Electron beam



L_2PWFA scheme (pictured above): A. Martinez de la Ossa *et al.*, Phys. Rev. Lett. **111**, 245003 (2013)



Trojan Horse scheme (pictured above): B. Hidding *et al.*, Phys. Rev. Lett.**108**, 035001 (2012)

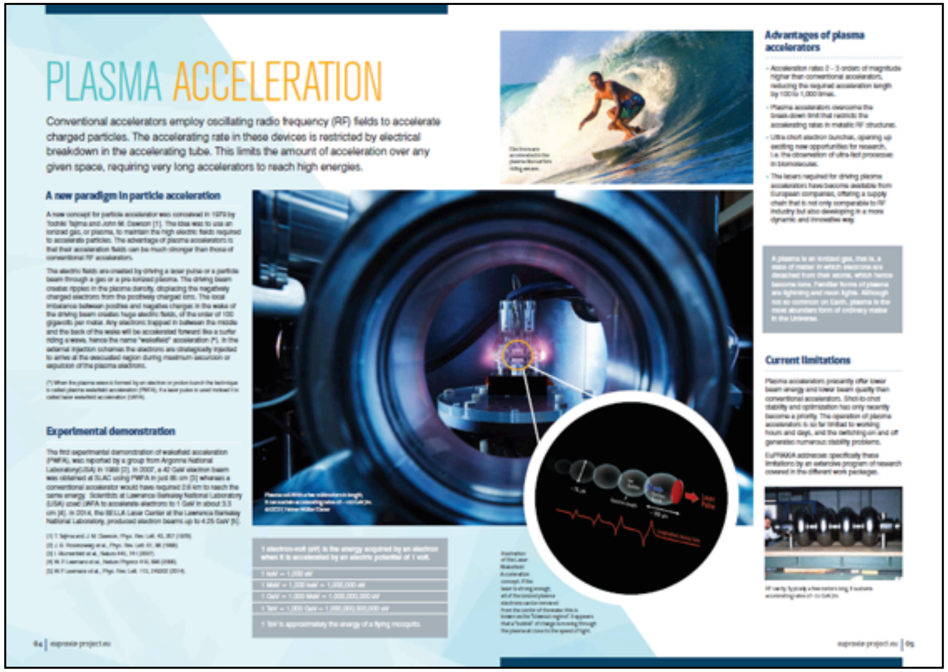
Is EuPRAXIA Accelerator Really Compact?

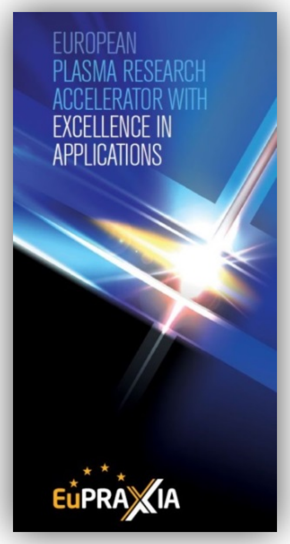
Horizon 2020

- Detailed estimates of required space are ongoing:
  - Acc. tunnel **+** infrastructure **about 300 – 600 m^2 for 5 GeV** (depending on conf.)
  - Potential **factor of 5-10 footprint reduction** compared to RF based electron linac
  - Reduced footprint has potential to open many additional applications
- **Sufficient beam quality** required which is **central goal of EuPRAXIA**
  - Improve energy spread (“beam loading” [3] or “modulated plasma density” [4])
- EuPRAXIA will initially be **low power and low wall-plug power efficiency**
  - Efforts with industry and laser institutes to improve rep. rate & efficiency of currently used laser systems (also incorporate fiber-based lasers with 30 % eff.)
- EuPRAXIA report will be technical design report and project proposal:
  - Performance, required tolerances, footprint and cost will be assessed
  - We **hope for significant cost benefit** from this new technology

[3] S. Van der Meer, CLIC Note No. 3, CERN; PS, ‘85-65
[4] R. Brinkmann et al., arXiv:1603.08489, accepted for publication in PRL

Dissemination





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#EuPRAXIA
#plasma
#accelerator