Joint Polish-Czech proposal at ELI-Beamlines

Scientific overview of the High energy Electron-acceleration by Laser Light (H.E.L.L.) and future potentialities;

Proposal for a Polish-Czech joint-upgrade: C.O.D.E.

ELI-Beamlines:
Tadzio Levato, Daniele Margarone, Georg Korn

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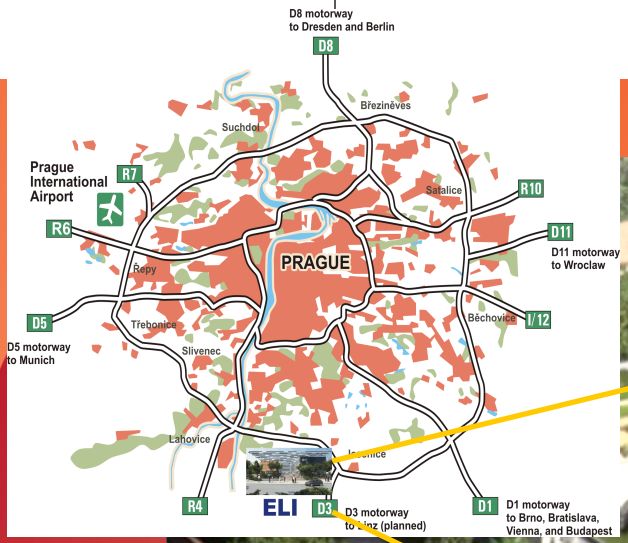
The ELI-Beamlines facility



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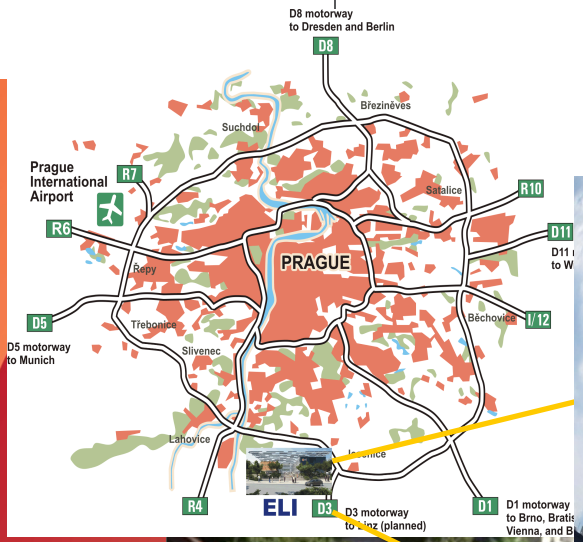

Opening Cerimony celebrated last year

The facilities is located in Dolní Břežany a very pleasant village surrounded by nature

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eli beamlines

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High energy ELectrons by Lasers - HELL

Scientific case from the ELI White Book

Electron acceleration

- exploring new acceleration regimes *(section 2.2.4)*
- compact XFEL *(section 6.4.2)*
- relativistic flying mirror *(section 2.2.4 and 6.4.3)*
- QED effects, inverse-Compton, particle physics (*section 2.1.1 and 2.1.2*)
- many others...

White Book

http://www.eli-beams.eu/wp-content/uploads/2011/08/ELI-Book_neues_Logo-edited-web.pdf

+ User requirements

HELL Conceptual Design

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ELI-Beamlines offer unique capabilities: Laser

LASER :

1 PW 10 Hz repetition rate beamline (L3)

All laser amplifiers pumped by DPSSL technology:

High pulse-to-pulse stability, robustness, low maintenance, high level of automation, scalability to higher peak power and rep rate

Supplier: LLNL

Collaborative effort of ELI-Beamlines on development of the PW compressor, PW diagnostics, control & timing systems

Planned to become PW workhorse of the ELI-Beamlines facility

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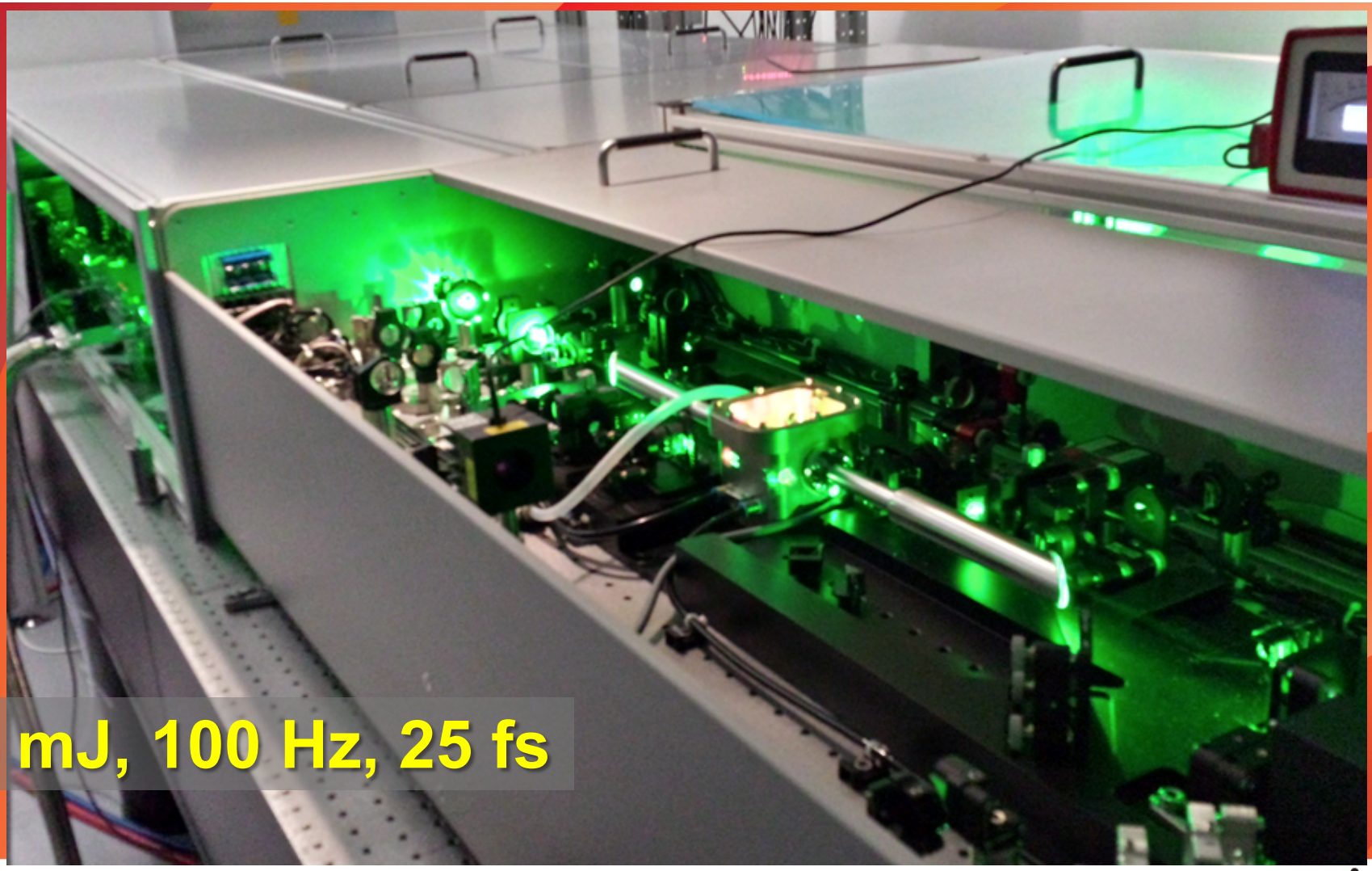
L3 Front end: Femtolasers GmbH

+ LLNL stretcher



5 mJ, 100 Hz, 25 fs

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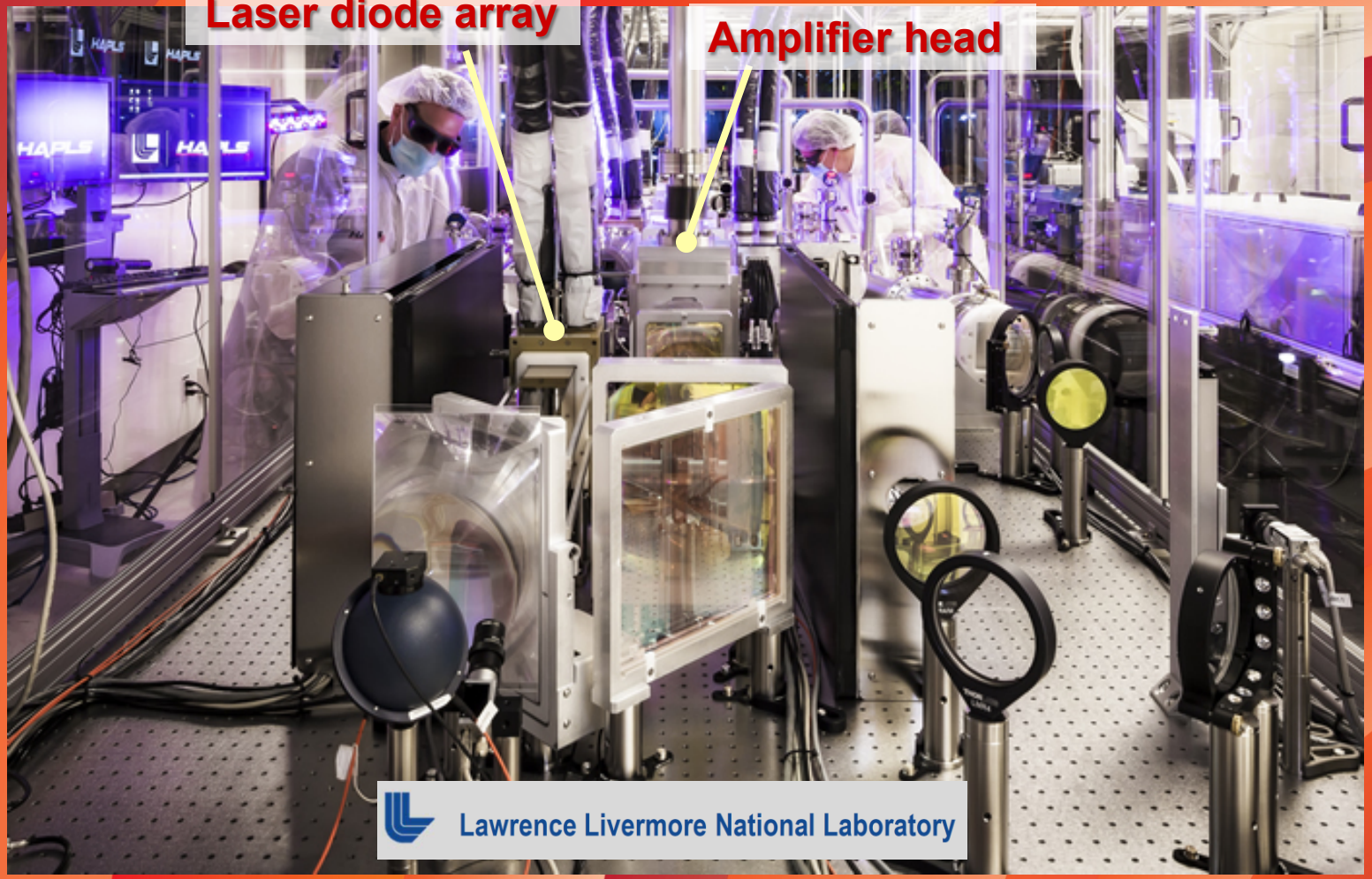
Gas cooled amplifiers assembled and integrated



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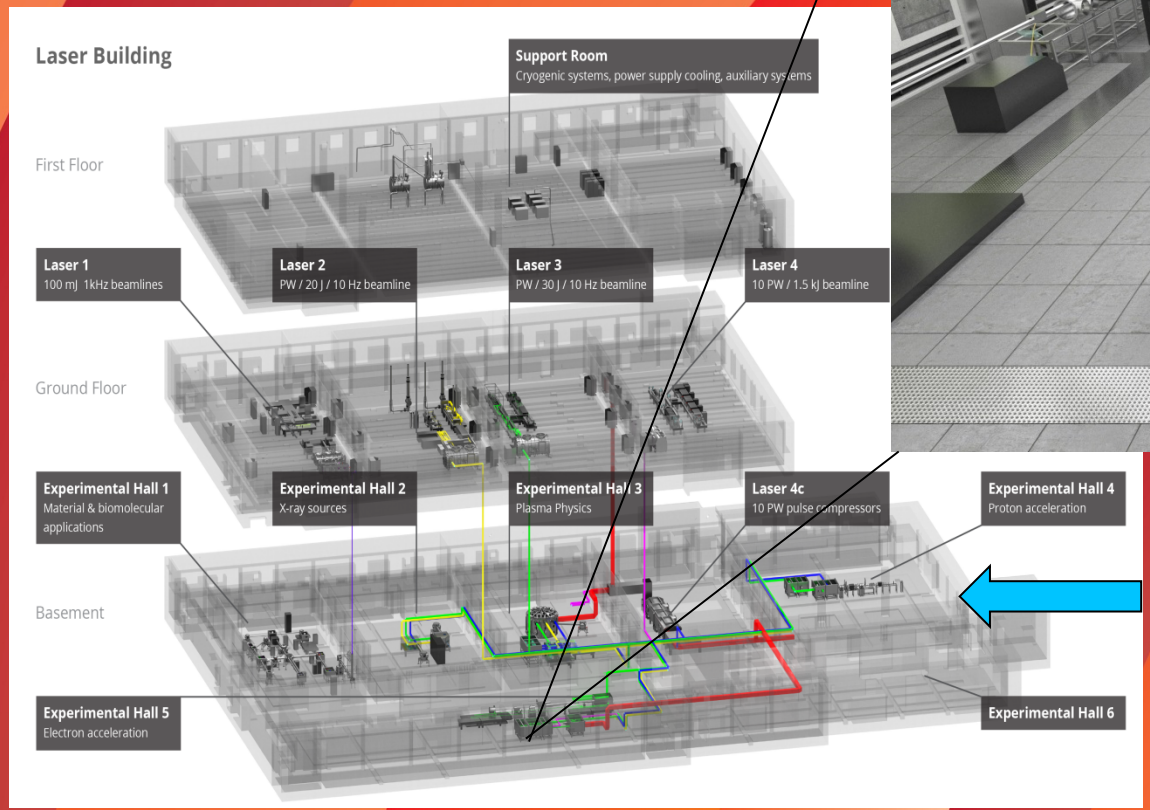
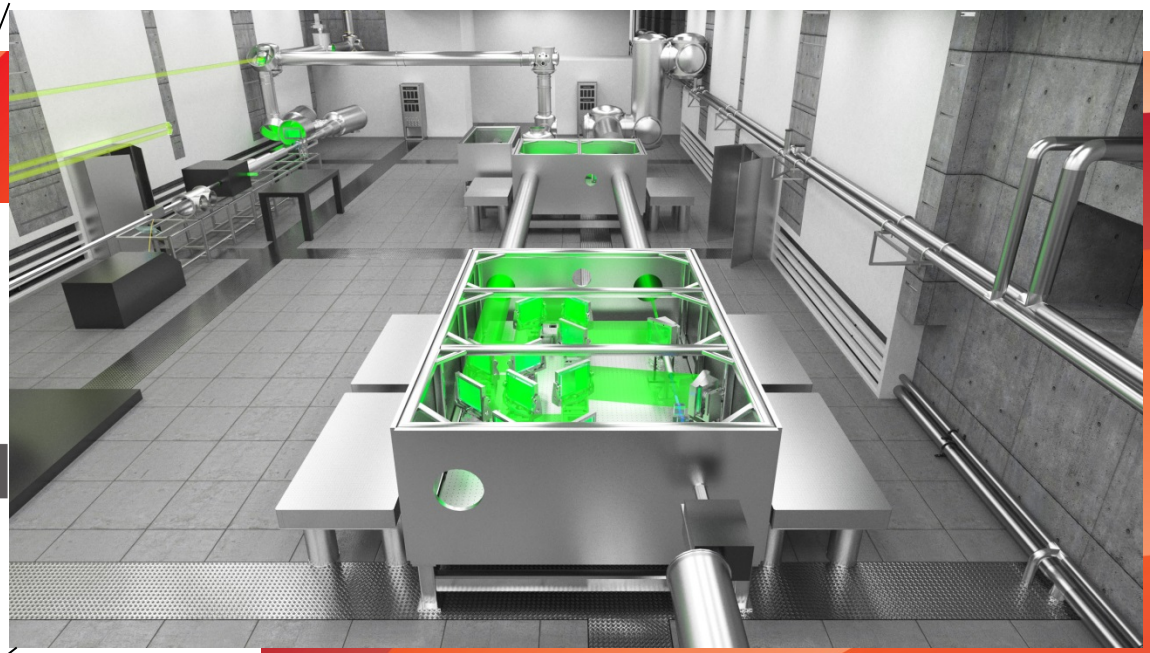
HELL platform in the experimental Hall (E5)





Experimental Halls Underground

The main function of this machine is already funded (H.E.L.L.) , here we propose to activate new functions in a joint-upgrade.

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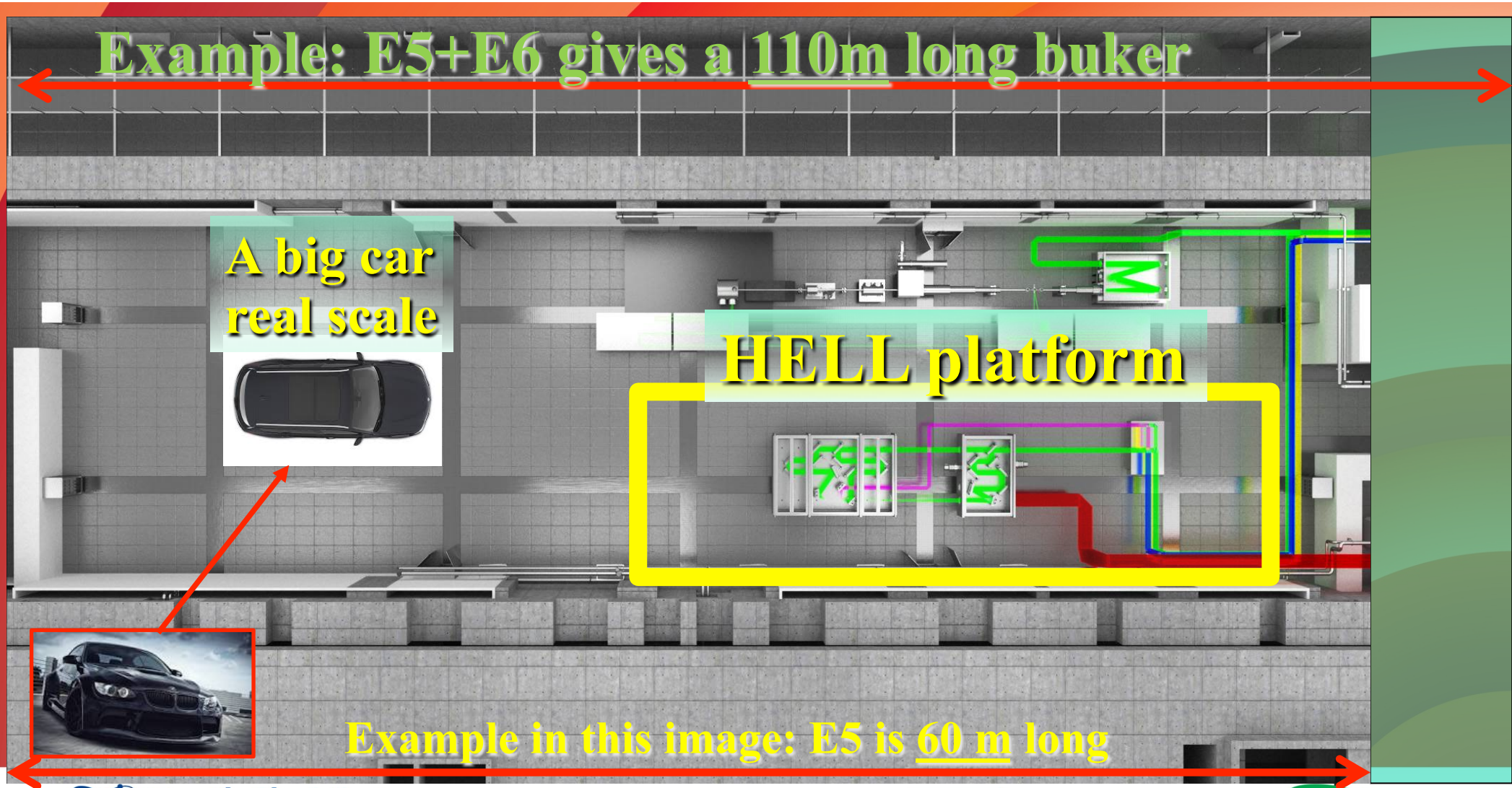
ELI-Beamlines: Huge experimental halls.



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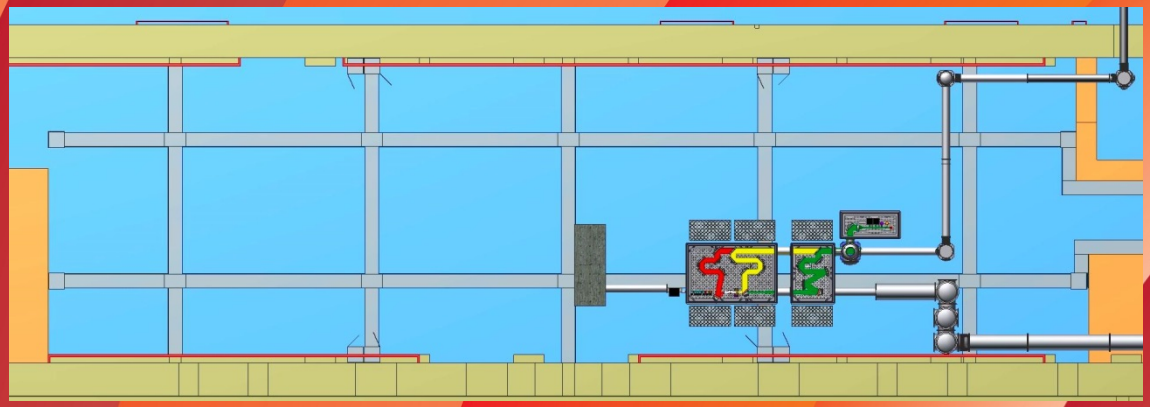
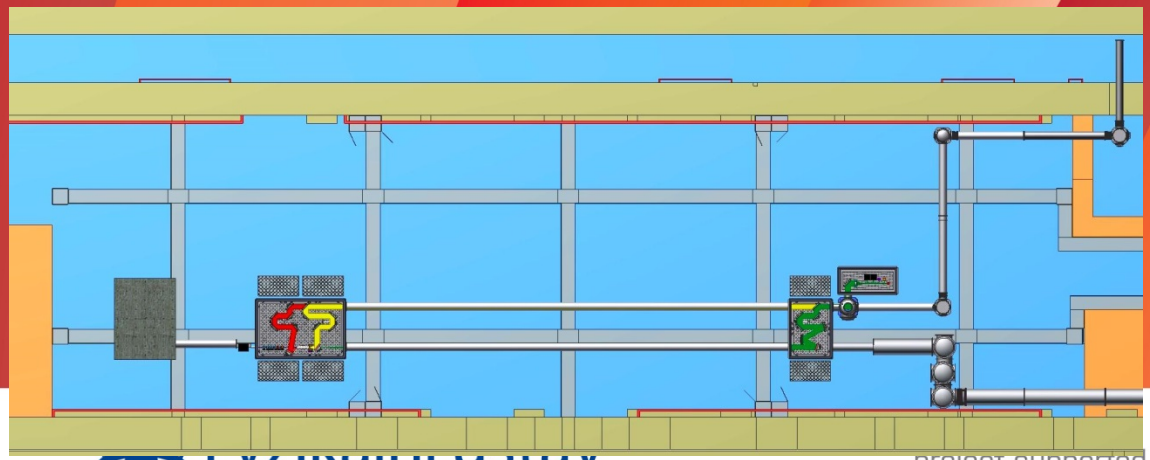
ELI-Beamlines: short and long focusing.

All these possibilities are self-synchronized when using different focal lenghts from few meters up to 30m (max available at the moment in E5)





1 PW - 10Hz

Not-guided regime //
short focal lenght OAP of 4m

Guided regime //
long focal lenght OAP of 30m

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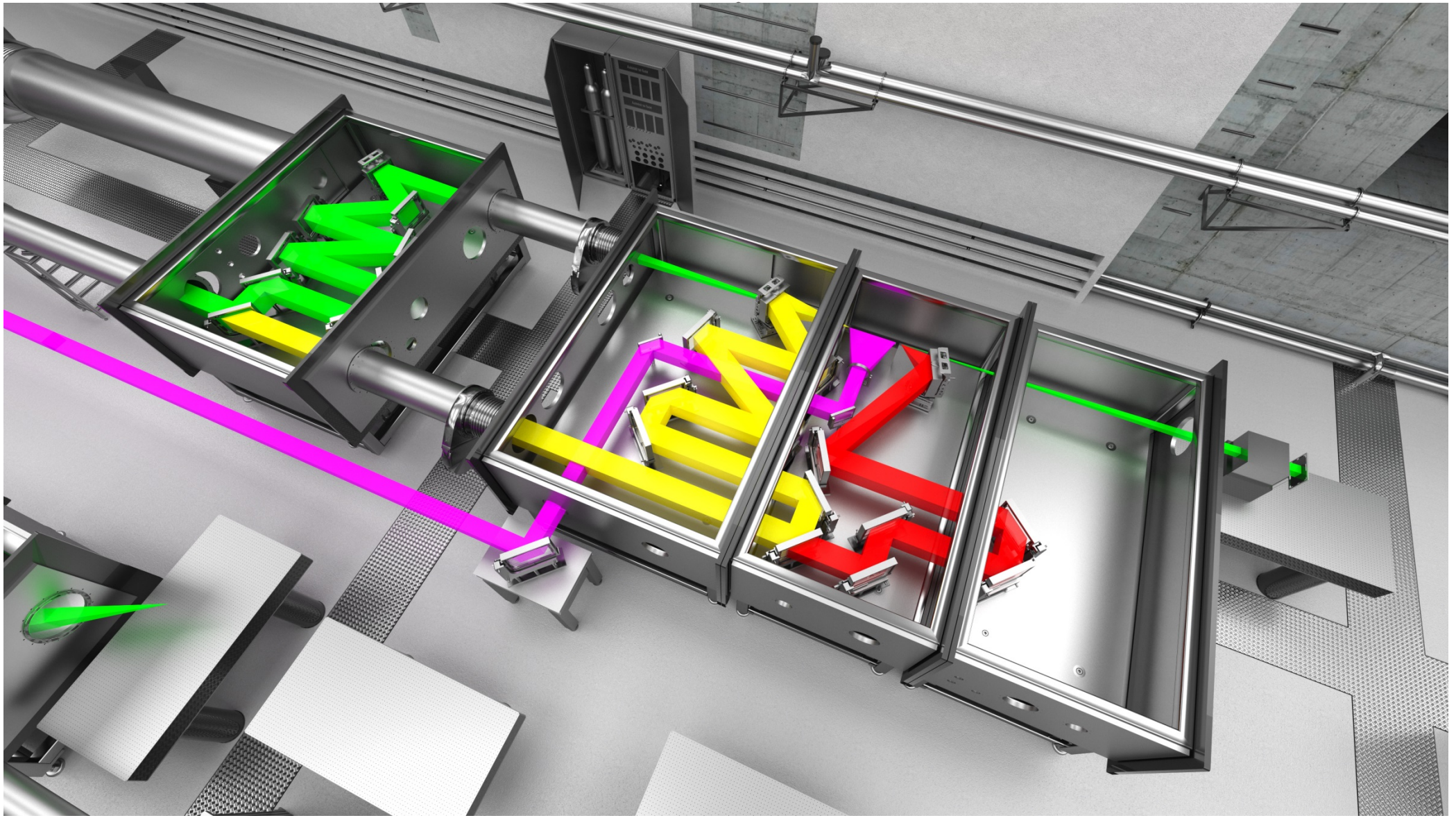
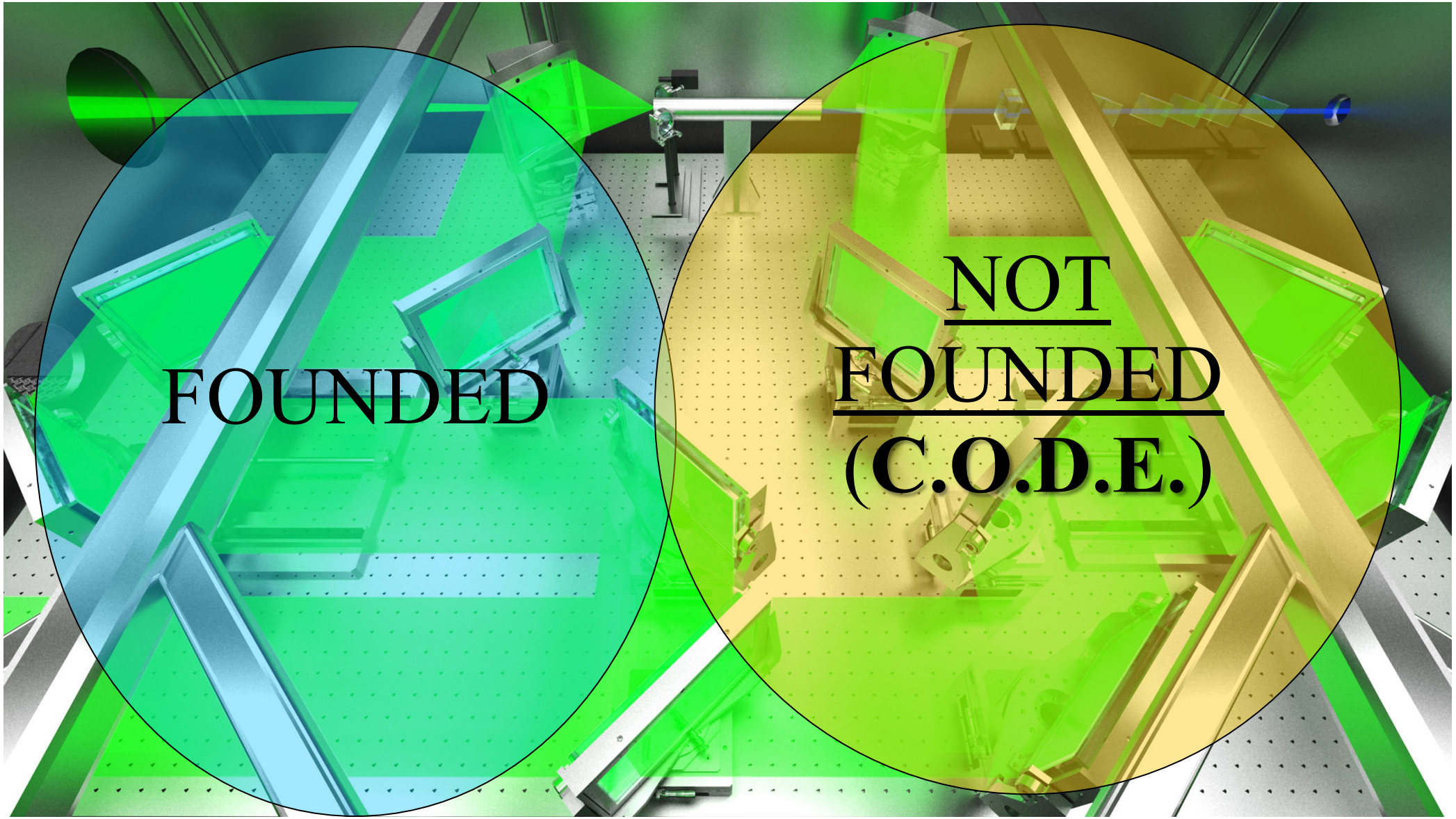
HELL experimental platform
3D overview



The Joint-Proposal



Invitation for a joint project CODE

Institute of Physics ASCR, v. v. i., Na Slovance 2, 182 21 Praha 8

info@eli-beams.eu | www.eli-beams.eu

Dear Friends and Colleagues in Poland.

Please find in the following our elaboration of the possible path for the Polish Scientific community to participate and help in development of the new International Research Facility, the ELI-BL in Prague. We are looking forward to engage in further discussions and to respond to your concerns and program inquiries. We believe that together we can develop a research program unique in the world taking us to the edge of the unknown in foundational and applied research.

Yours

Tadzio Levato
Daniele Margarone
Jan Rafelski
Georg Korn

Invitation for a joint project CODE

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COmpact ultra-stable laser Driven Electron accelerators and their applications (CODE)

The Physics and Technology Scope

We invite the Polish Scientific Community to a joint effort to design, develop and build a femto-second (fs)-laser driven particle beam line at the ELI-Beamlines (ELI-BL) infrastructure facility in Dolny Brezany near Prague. New concepts and techniques will be developed which will allow tuning of the physical parameters of the particle beam to the research objectives. Through this beam line development we expect to enable and carry out ground-breaking fundamental research at the frontier of the known:

a) by conducting experiments involving laser pulse-ultra-relativistic electron collisions;
b) technology developments serving future particle collider concepts where of particular relevance in consideration of the fs character of the laser pulse is the facilitation of the muon-muon collider technology;
c) advance the understanding of the ultra-intense, high contrast light pulse itself;
d) control of the EMP formation in consideration of the necessary exploration of fs-pulse interaction with matter;
f) development of compact free electron laser technology.

Proposal form for research infrastructure project to be included in the Polish Roadmap for Research Infrastructures

(Please fill your answers in the blank areas; max 6000 characters without spaces per each item; max 25 pages in total)

Title (name) of the proposed Research Infrastructure:	**Extreme Light Infrastructure (ELI)**
Name and affiliation of the coordinator; the consortium members; name of the consortium:	Proposal is submitted by Military University of Technology in Warsaw on behalf of the "ELI – PL" national scientific/industrial consortium which was informally created by Polish research institutions and enterprises that were interested in participation in construction and exploitation of the ELI research infrastructure.

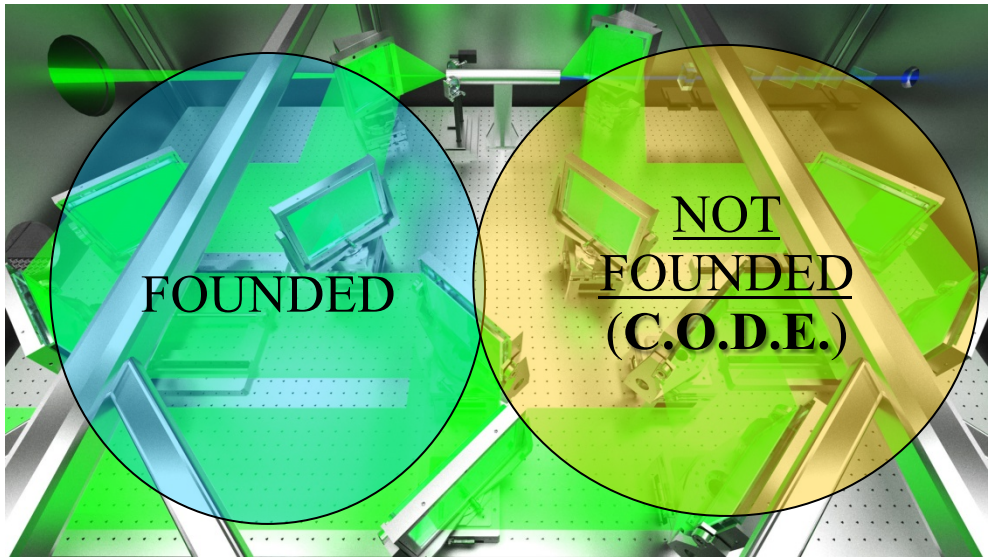
14: Any additional comments:

Majority of the scientific equipment and apparatus in the planned facility will be commissioned in 2015 and 2016 with full commitment of the budget. However, some equipment in the experimental halls that is considered in the Research Programs needs further evaluation and commitment and should be realized in the 2nd Phase of the project.

The **High-energy Electron-acceleration beamline (HELL)** located in the experimental hall E5 can be one of such example. The **HELL** beamline, placed in the Southern area of E5, will use the 1PW-L3 and 10PW-L4 laser beams and will be mainly focused on high energy laser plasma electron acceleration investigations. It will be a tool for the optimization of a laser-plasma accelerator (using gas-jet targets, gas-filled capillary, etc.) by using laser wakefield acceleration schemes and implementation of a multi-staged (two stages, the first with 1PW and the second with 10PW laser) acceleration up to a few tens of GeV. It will be one order of magnitude higher value that is it achievable now. The results of these studies will open the way for the development of a new class of high-energy electron accelerators based on lasers.

Participation of the research group from MUT in the development and implementation of the **HELL** beamline has been considered and suggested by the **ELI - Beamlines** management team. The subject is highly challenging and interesting for the MUT group as it is recognized as the leading group specializing in development and optimization of various targetry systems to be used in the laser-matter interaction experiments, including laser wakefield electron acceleration.

H.E.L.L. upgrade C.O.D.E.,



Compact ultra-stable laser driven electron accelerators and their applications (CODE):

Abstract: Within the joint project we propose to design, develop and build a **very compact fs-laser driven electron beamline** based on new concepts and techniques which will allow to tune the energy range of the beam, its charge and energy spread to hitherto unknown values.

A major emphasis will be given to enhance the stability of the generated electron beam with repetition rates up to 10 Hz.

The electron beamline will be used for different experiments like **short pulse x/ray and gamma generation** as well as for fundamental physics investigation of **collision of high intensity laser pulses with energetic electron bunches** entering new interaction regimes.

The Beamline will be based within the shielded experimental area E5 of ELI Beamlines whereas as the laser driver will be the most advanced diode pumped **high repetition rate 10 Hz PW laser** system HAPLS developed within the ELI Beamlines project.

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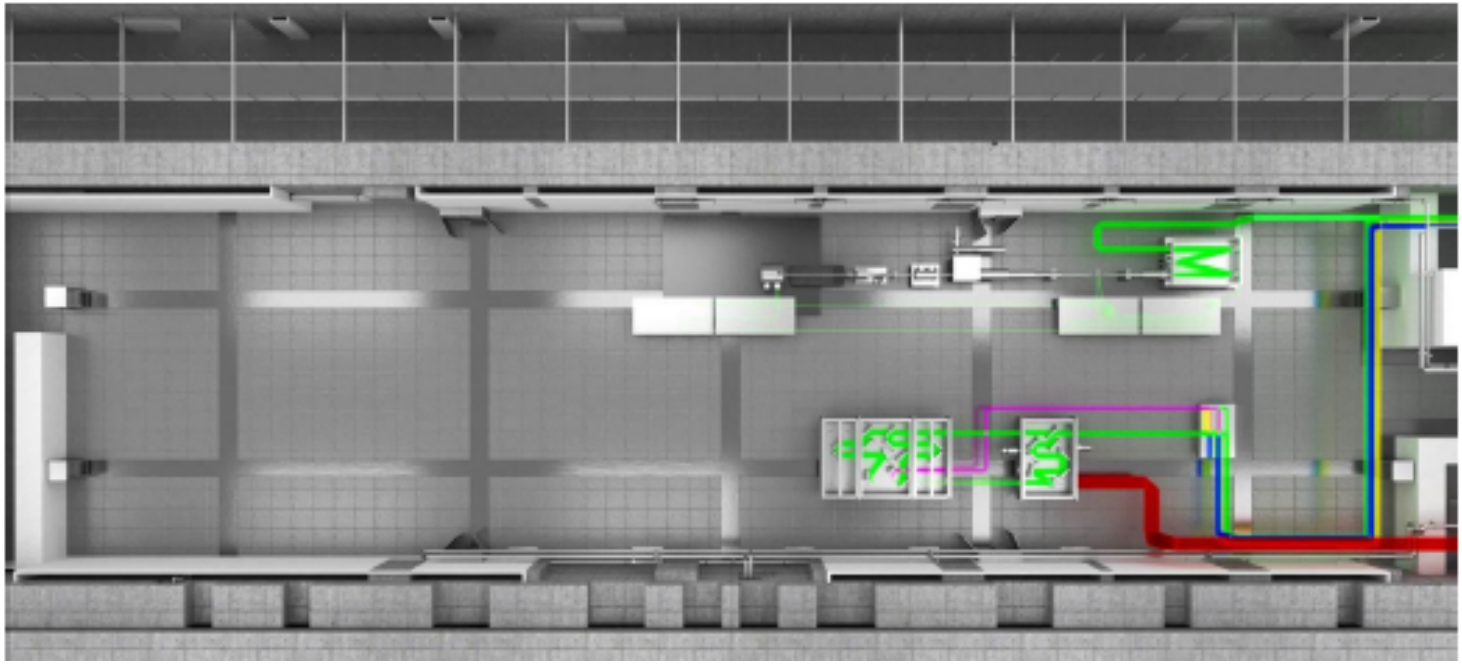
A dedicated Polish high energy electrons experimental area (E5)

Laser plasma acceleration of ultrashort electron bunches is an experimental approach well established in the scientific community which has reached large visibility thanks to several high relevance experimental results and also to its great potential for scientific and societal applications. Currently the energy record for the accelerated electrons is around 5 GeV, demonstrated by a 300TW laser [*Leemans et al. PRL 113, 50, 2014*]. The laser peak power available at ELI-Beamlines for electron acceleration experiments will be more than 3-times higher (1PW), and the average power more than 10-times higher, thanks to the available diode-pumped HAPLS laser system. The specific nature of the laser-matter interaction needed for such plasma acceleration regime requires long geometries of the focusing optics. The 70-m long E5 bunker shown in **Fig. 4**, which is part of the ELI-Beamlines experimental area, is fully available to be dedicated to this acceleration concept due to the importance of laser driven electron acceleration both for societal applications and for fundamental science (so-called "exotic physics") as envisioned into the ELI-White-Book [http://www.eli-beams.eu/wp-content/uploads/2011/08/ELI-Book_neues_Logo-edited-web.pdf]. Furthermore, the E5 clean-room bunker is adjacent to another bunker (E6) that can be used to easily extend E5 into a larger experimental hall with a total length of about 110m (E5+E6).



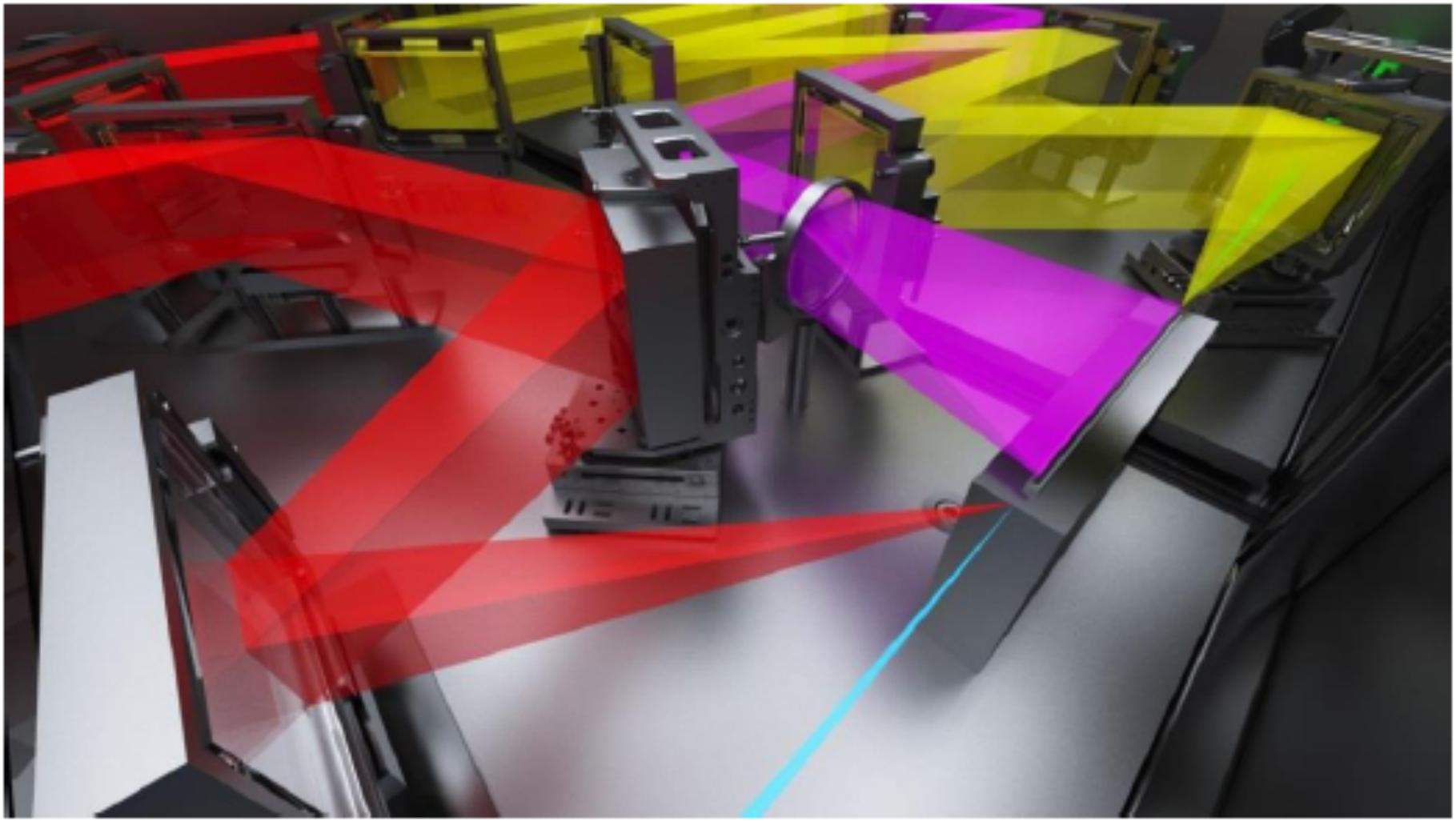
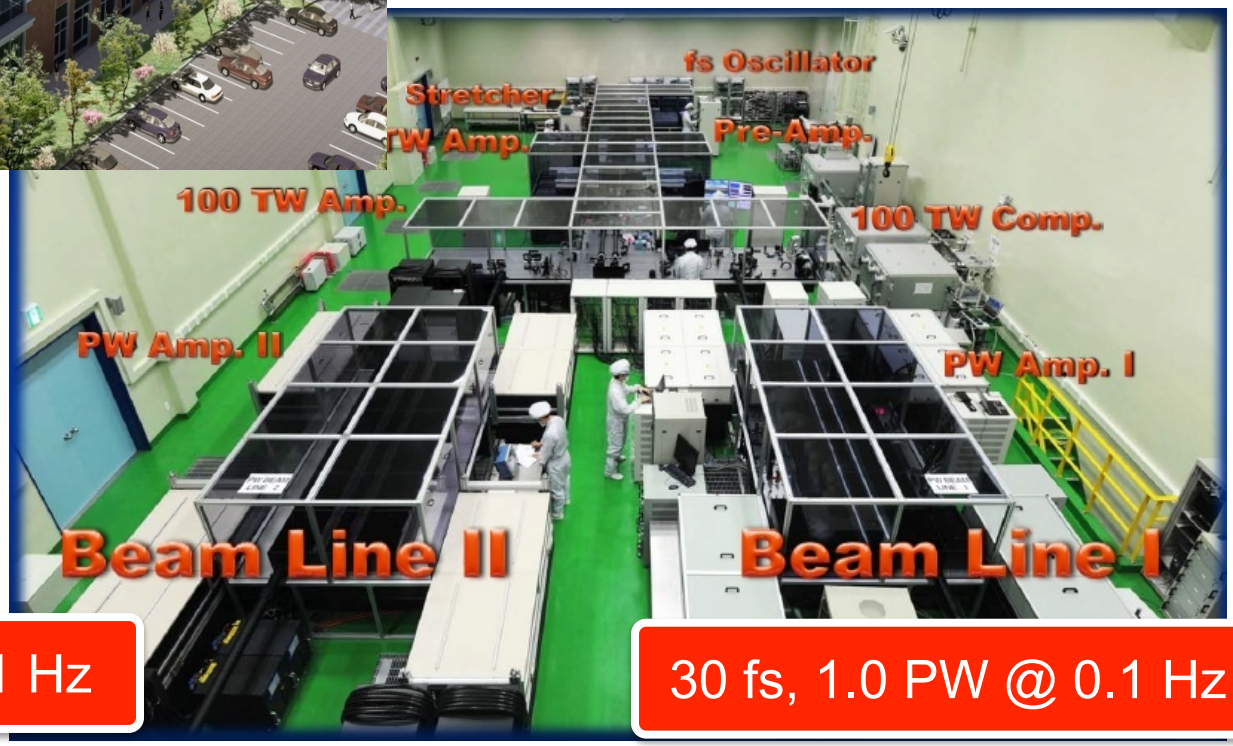


Figure 7: The Laser-pulse--Electron collider interaction region; the gas-target is shown in grey-color, the auxiliary nanosecond beam for the production of the plasma-channel used for "guiding" is depicted in purple-color, the accelerating laser pulses are yellow and green, the electron beam is blue, and the counter-propagating laser pulse is red.

Laser acceleration of electrons

Advanced Photonics Research Institute, Gwangju Institute of Science and Technology



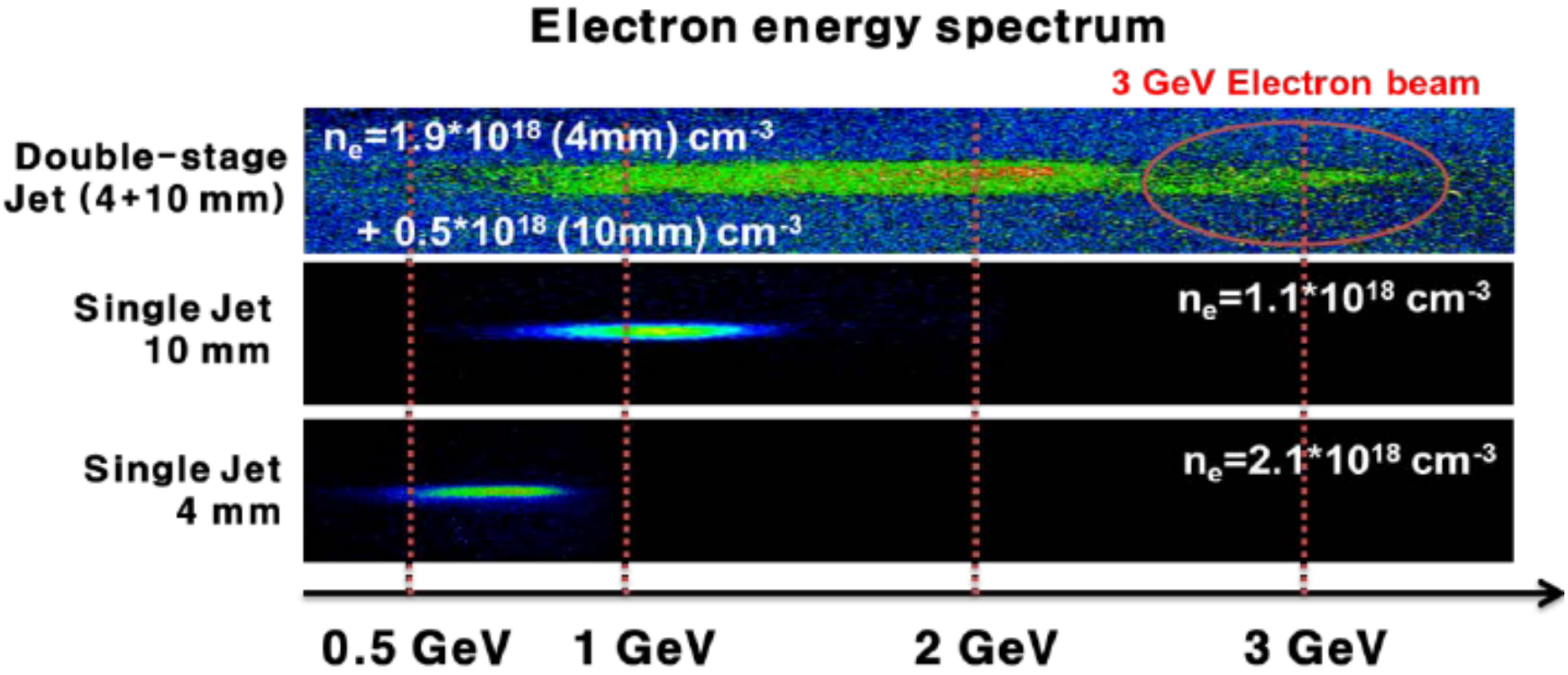
30 fs, 1.5 PW @ 0.1 Hz

30 fs, 1.0 PW @ 0.1 Hz

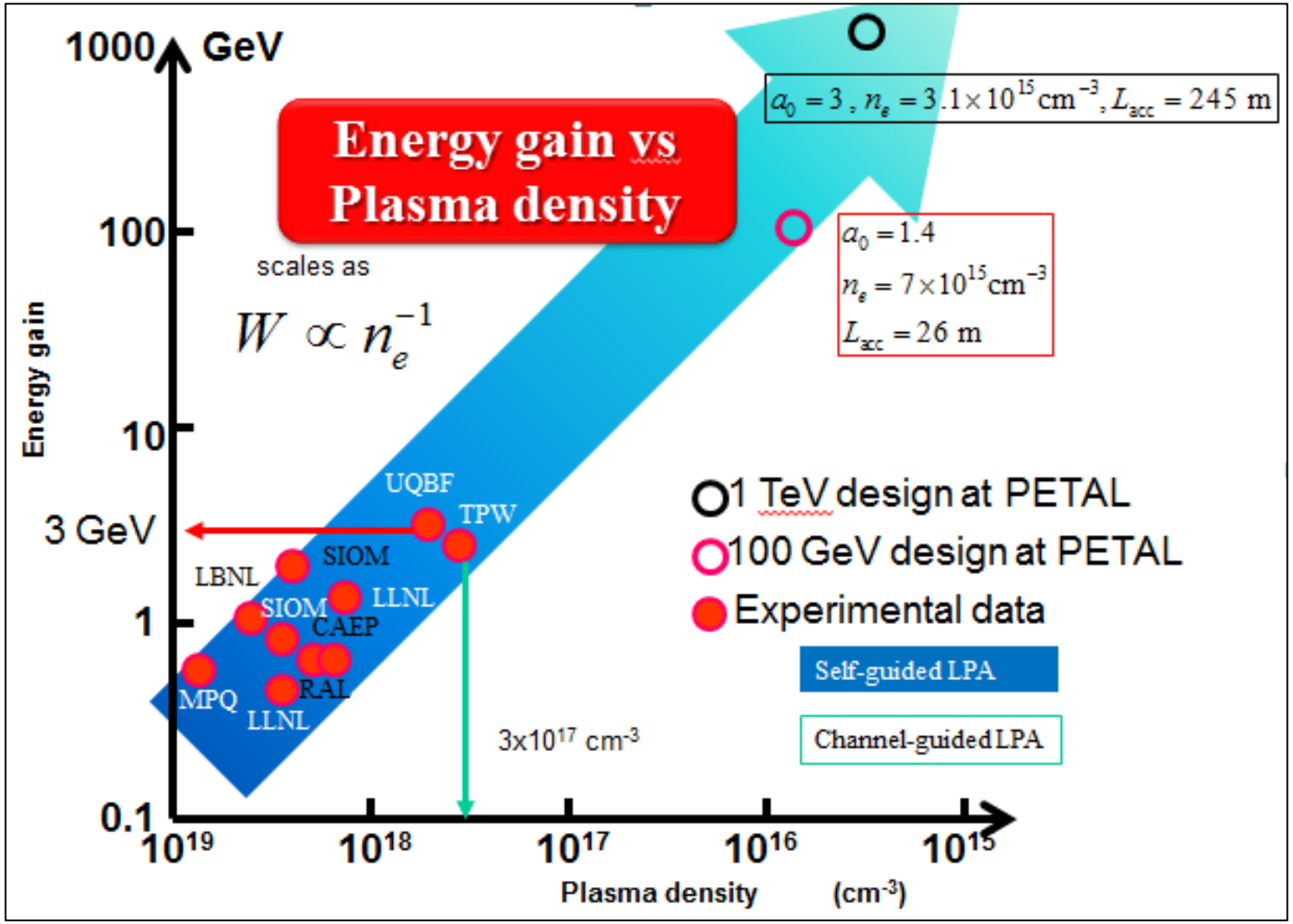
Breaking 3 GeV barrier using two stage LWFA driven by PW-class laser

Gas target developed at MUT-IOE

- Pumping energy 22–25 J on target with 60 fs pulse duration
- 4 mm, 10 mm, elongated supersonic He gas jet
- Laser Intensity = 2.5 x 10^{18} W/cm^2 (a_0 = 3.5)

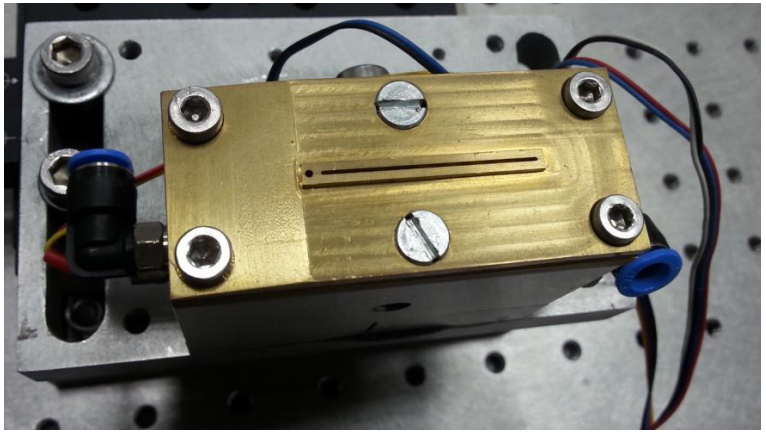


Route to 100 GeV and 1 TeV

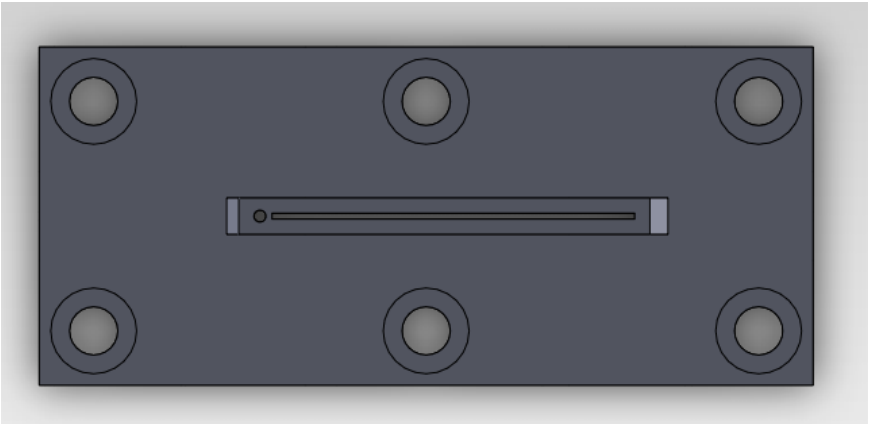


Double-stream gas puff target for laser-driven electron acceleration

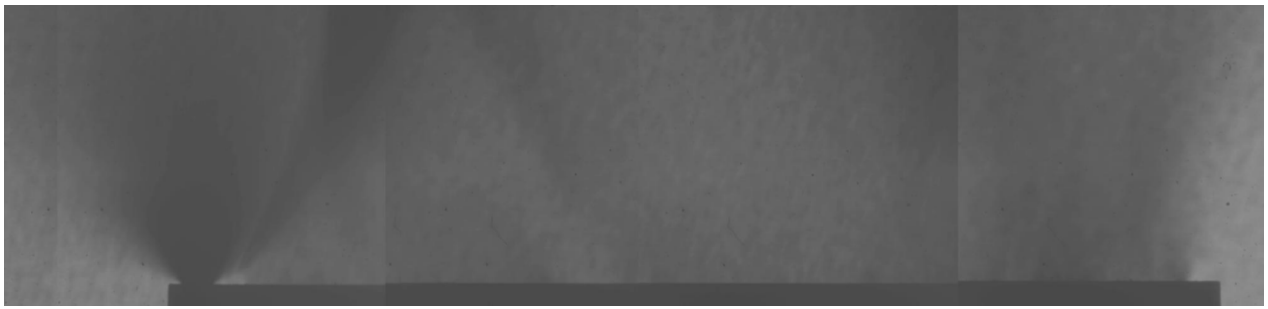
Valve system



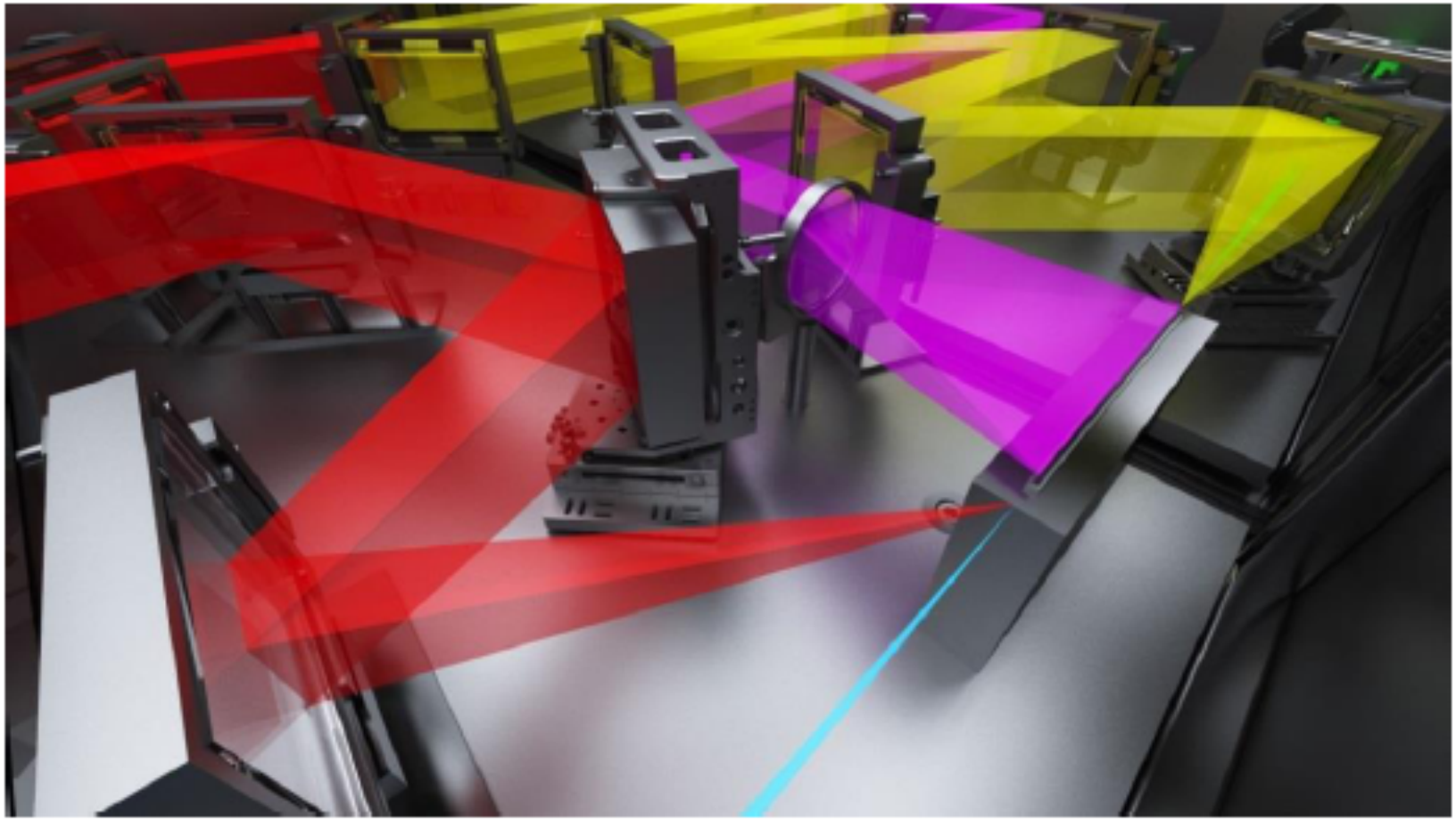
Dual nozzle



EUV radiography



Conclusion



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