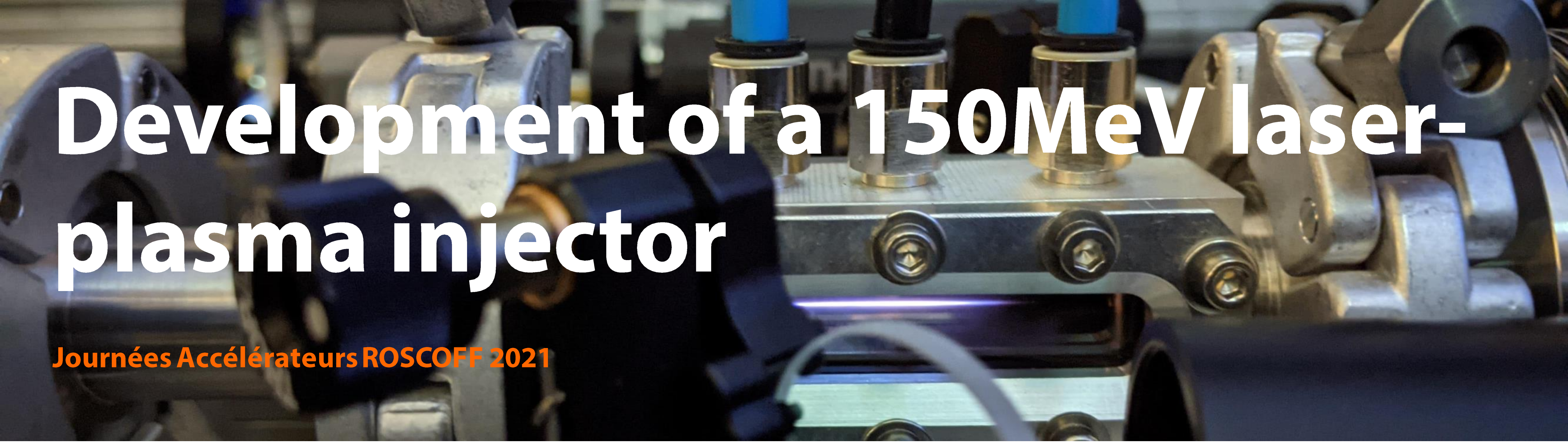


Development of a 150MeV laser-plasma injector

Journées Accélérateurs ROSCOFF 2021

Drobniak Pierre

October 13th 2021

1 –Project

The laboratory project

Stability at 10 Hz

Plasma Cell design

PALLAS

Beam transport -> multi-stage

high quality beam

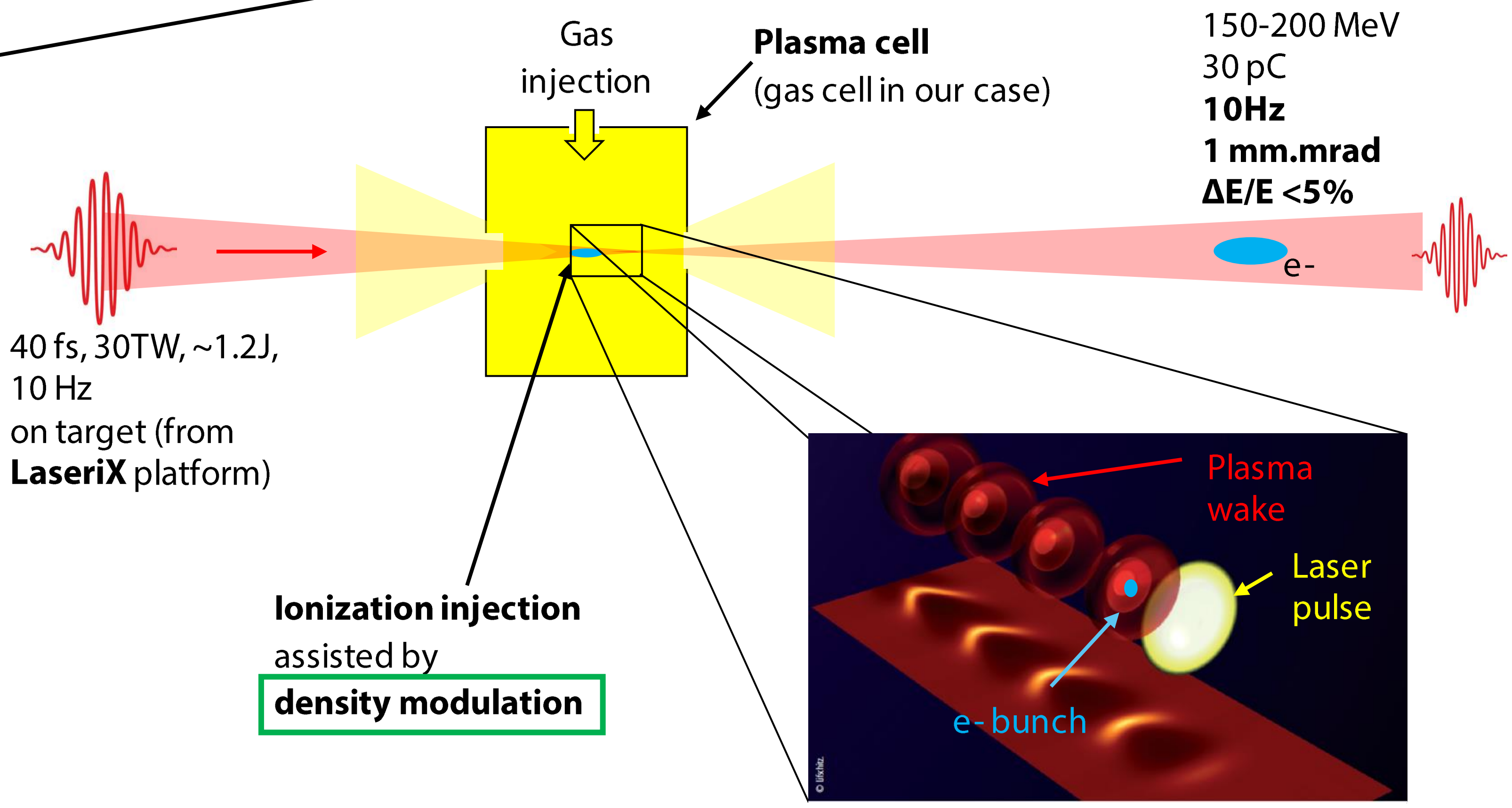
Prototyping **A**ccelerator based on **L**aser-p**LAS**ma technology

Participation to R&D Technical Design Report in preparatory phase on **high-quality laser-plasma injector (LPI)** for EUPRAXIA Horizon 2020 European project

EuPRAXIA

https://pallas.ijclab.in2p3.fr/
http://www.eupraxia-project.eu/

My PhD

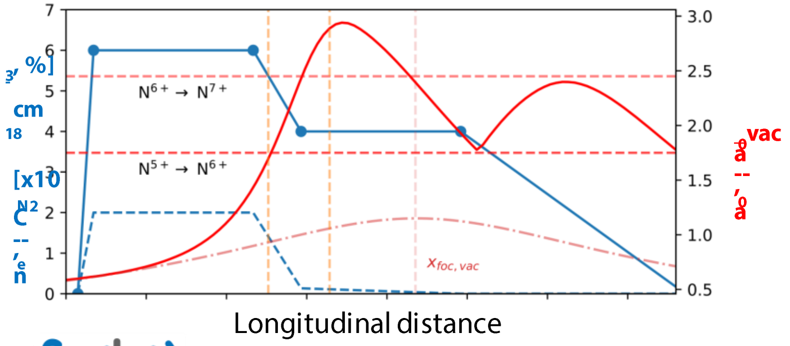


Laser **W**ake **F**ield **A**cceleration **(LWFA)** [1]

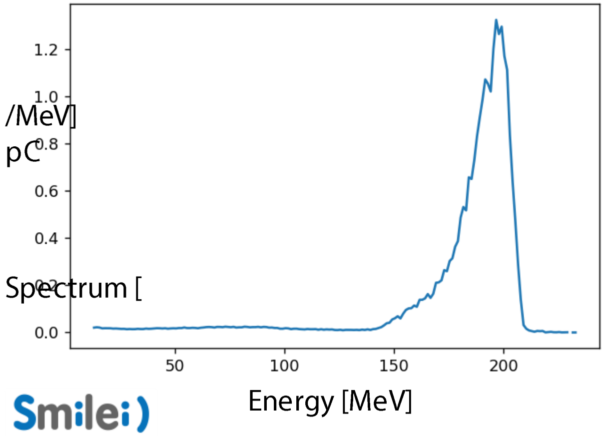
[1] Malka, V., Thaury, C., Corde, S., Phuoc, K. T., & Rousse, A. (2013). Accélérateurs à plasma laser: principes et applications. *Reflets de la physique*, (33), 23-26.

2 – Optimization principle

Theoretical profile and PIC simulated laser variation

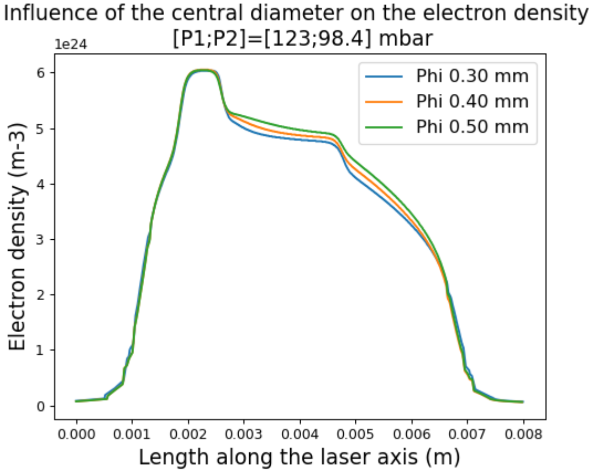


Smilei



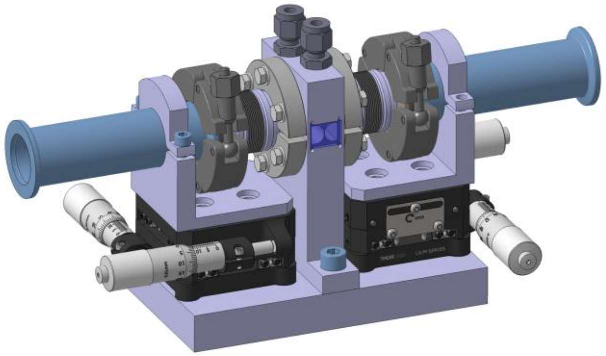
Smilei

Experimental qualification on test bench



OpenFOAM-simulated electronic density

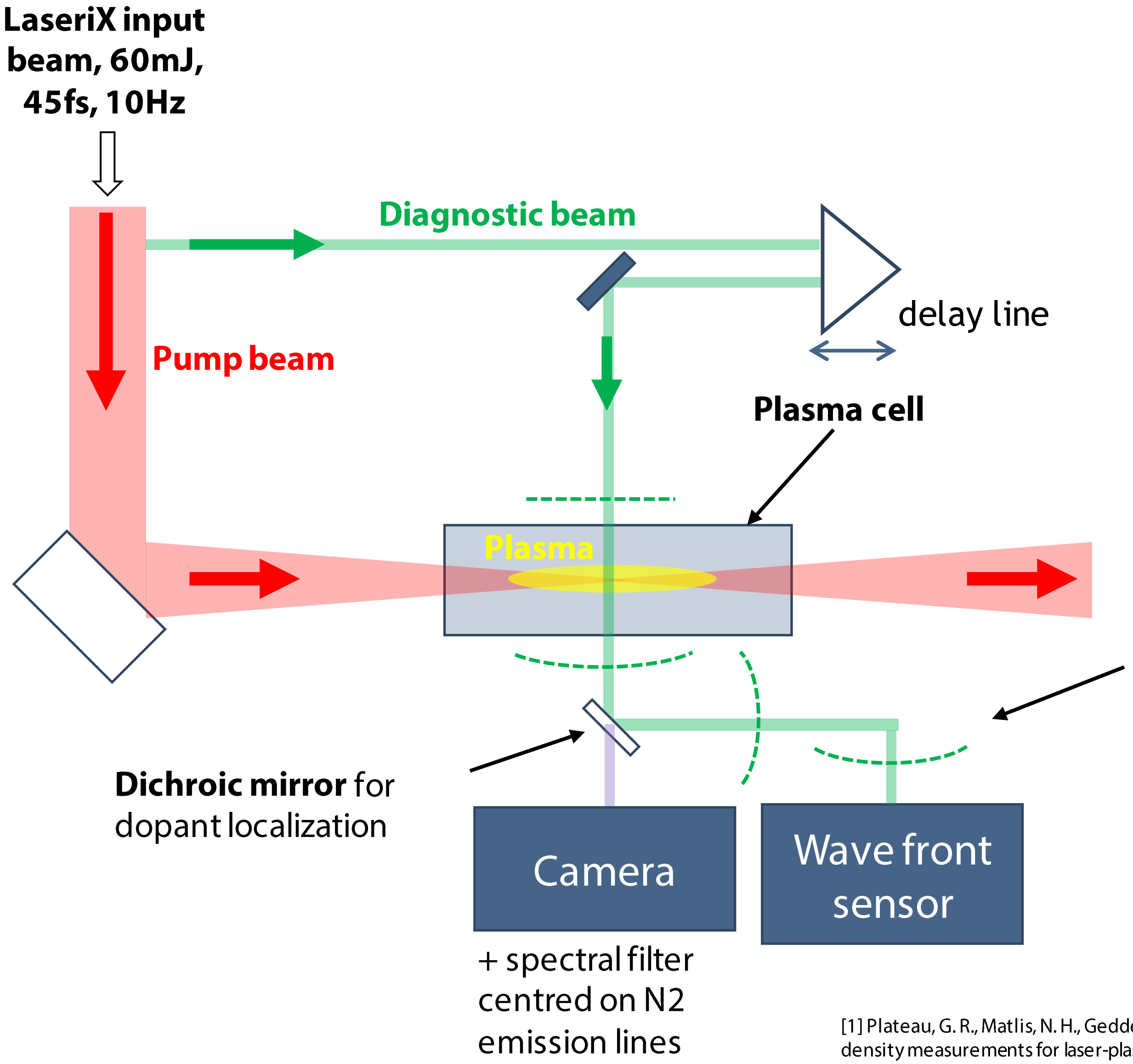
OpenFOAM®



Cell design

[1] Audet et Al. (2018). Gas cell density characterization for laser wakefield acceleration. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, *909*, 383-386.
[2] Kononenko, et Al. (2016). 2D hydrodynamic simulations of a variable length gas target for density down-ramp injection of electrons into a laser wakefield accelerator. *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment*, *829*, 125-129.
[3] Kirchen et Al. (2021). Optimal Beam Loading in a Laser-Plasma Accelerator. *Physical review letters*, *126*(17), 174801.
[4] Couperus, J. P., Pausch, R., Köhler, A., Zarini, O., Krämer, J. M., Garten, M., ... & Irman, A. (2017). Demonstration of a beam loaded nanocoulomb-class laser wakefield accelerator. *Nature communications*, *8*(1), 1-7.
[5] Jalas et Al. (2021). Bayesian Optimization of a Laser-Plasma Accelerator. *Physical review letters*, *126*(10), 104801.

3 –Setup of the gas cell test bench



Plasma induced **phase shift** in the diagnostic beam wave front

$$\phi(x,y)=\omega/c\int(1-\sqrt{1-n_e(x,y)/n_c(\omega)})dl$$

Reconstruction of the **absolute phase shift** (Abel inversion)

$$\Phi(x,r)=-1/\pi\int_r^R\partial\phi(x,y)/\partial y\cdot(y^2-r^2)^{-1/2}dy$$

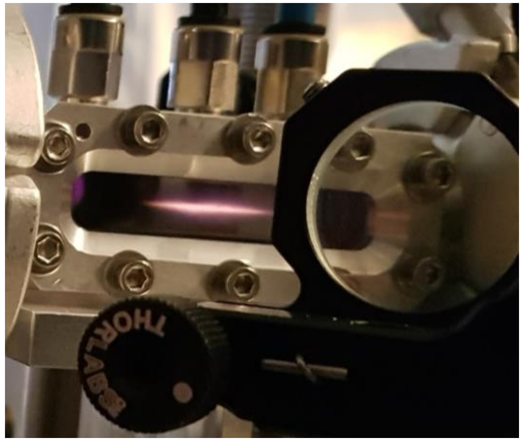
Reconstruction of the **plasma density**

$$n_e(x,r)=n_c(\omega)\{1-[1-c/\omega\cdot\Phi(x,r)]^2\}$$

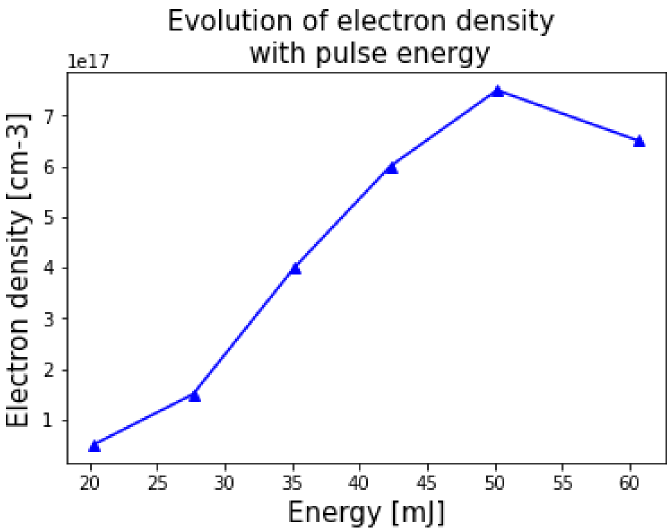
[1]

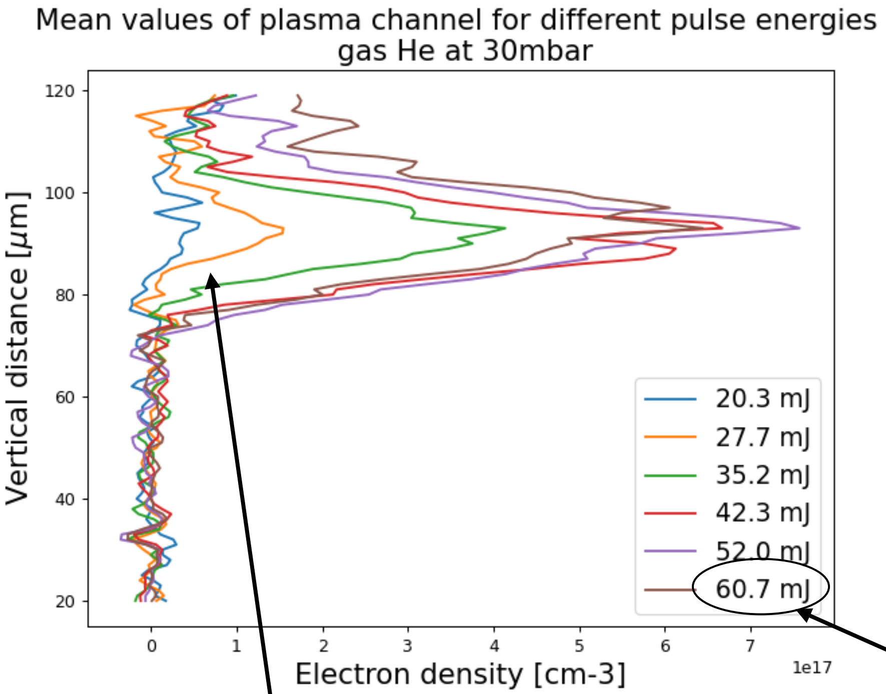
[1] Plateau, G. R., Matlis, N. H., Geddes, C. G. R., Gonsalves, A. J., Shiraishi, S., Lin, C., ... & Leemans, W. P. (2010). Wavefront-sensor-based electron density measurements for laser-plasma accelerators. *Review of Scientific Instruments*, *81*(3), 033108.

4 – First experimental results

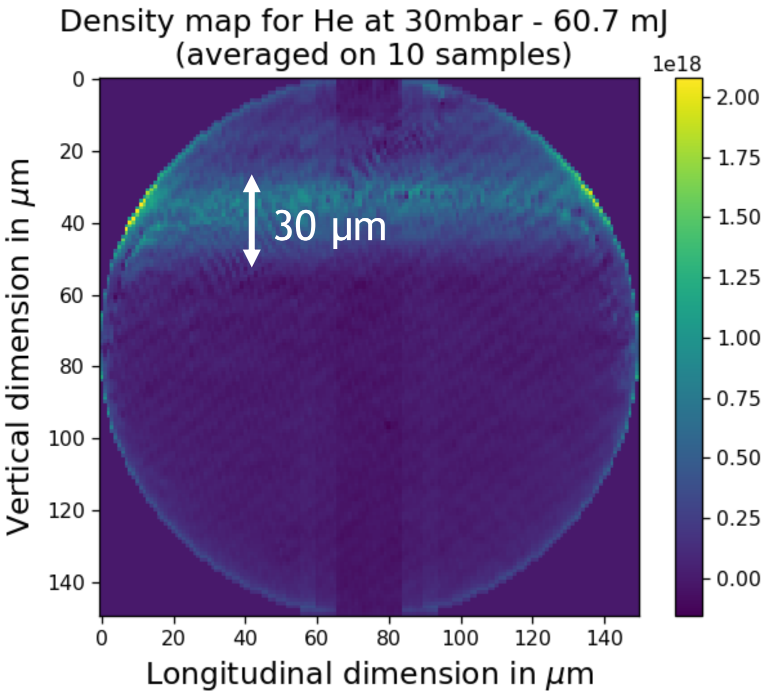


Test cell [1]





Sensitivity ~ 10^{17}cm^{-3}



Max. pulse energy

[1] developped in the frame of the ESCULAP project (N.Delerue, K. Wang, J.Jenzer et al.), used as a test cell [1]

[1] Baynard, E. *et al.* Status report of the ESCULAP project at Orsay: External injection of low energy electrons in a Plasma *Nuclear Instruments and Methods in Physics Research Section A: Accelerators, Spectrometers, Detectors and Associated Equipment* **909**, 46–48 (2018).

5 – Next steps

SHORT TERM

1 – Implementation **first prototype** on **test bench**

2 – **Plasma** ignition and measurements (using a **mixture**)

3 – **Optimization** of gas density (and **mixture**)

4 – Characterization of **dopant migration**

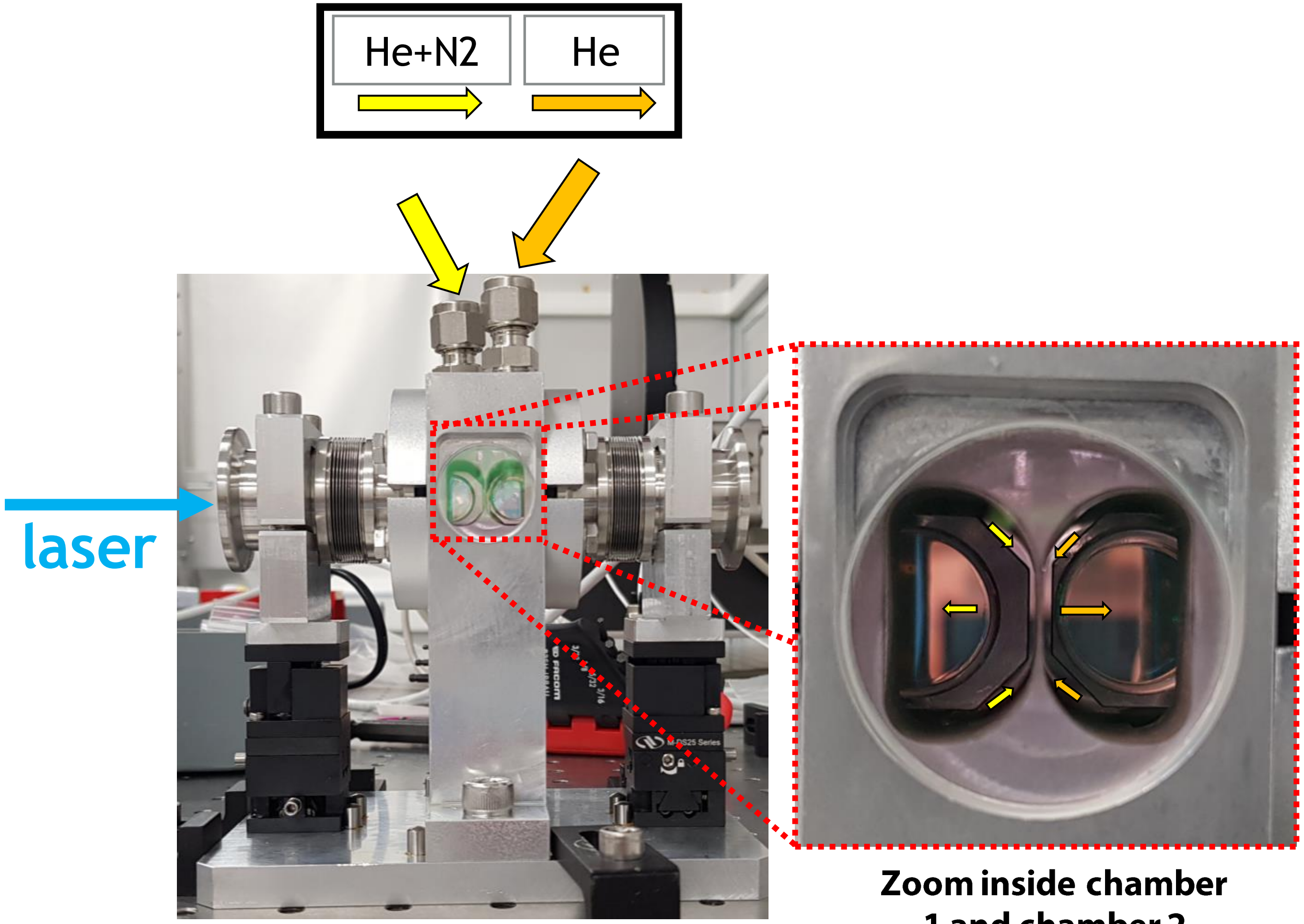
LONG TERM

1 – Plasma cell **lifetime**

2 – Integration of the plasma cell on the beam line (~ late 2022)

-> first electron bunches!

3 – Characterization of the **electron bunch**



First prototype

Zoom inside chamber 1 and chamber 2

Thank you

Many thanks to: Kevin CASSOU, Sophie KAZAMIAS, Bruno LUCAS, Viacheslav KUBYTSKYI, Yann PEINAUD, Moana PITTMAN, Elsa BAYNARD, Julien DEMAILLY, Alexandre GONNIN, Stéphane JENZER

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