GdR APPEL 2023

Characterization of proton and X-ray generation at the Apollon short-focal-area in the 1-2 PW range

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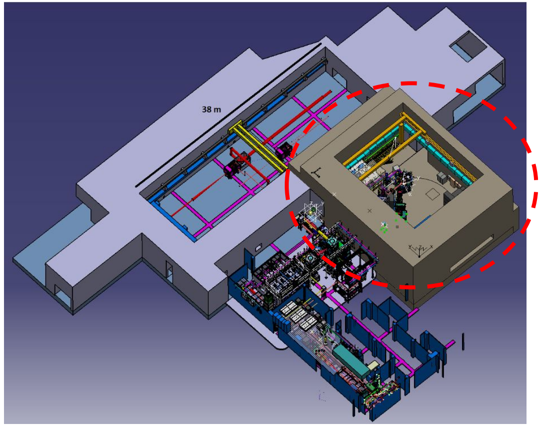
LULI, École Polytechnique, CNRS

Orme des Merisiers, 13-15/11/2023

Apollon laser facility, Short Focal Area (SFA) roadmap



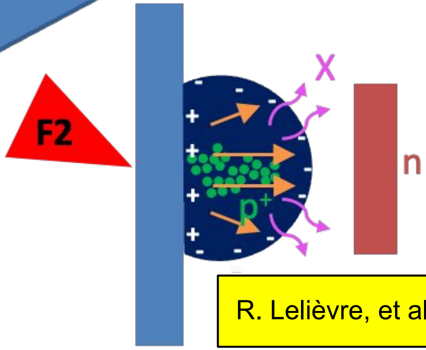
F1 @ 10 PW
& F3 (1 ns)
2024+

F1 (45 J, 22 fs) @ 2 PW
2023

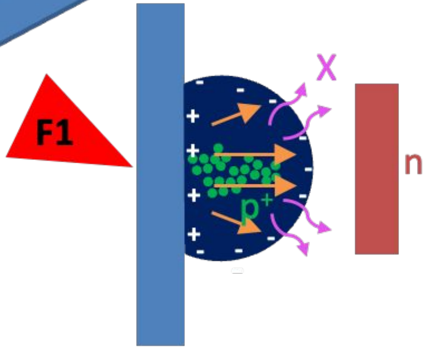
Pre-pulse optimization with DPM
2022

F2 (10 J, 24 fs) @ 0.5 PW
2021

K. Burdonov, et al., MRE (2021)

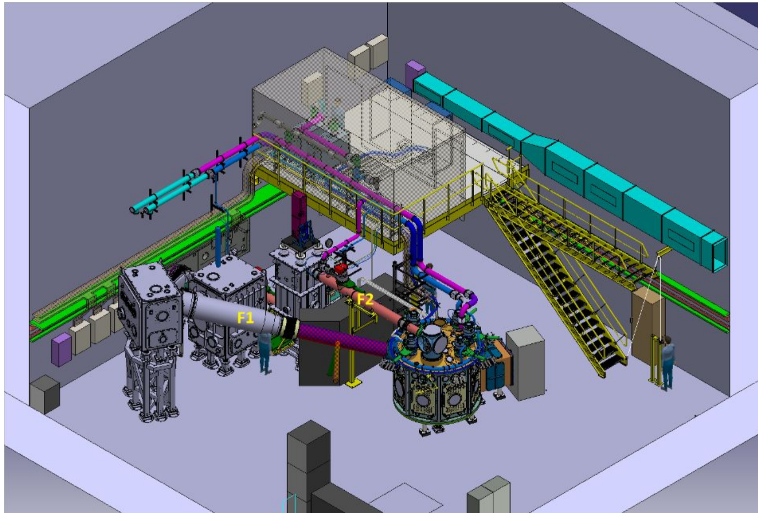


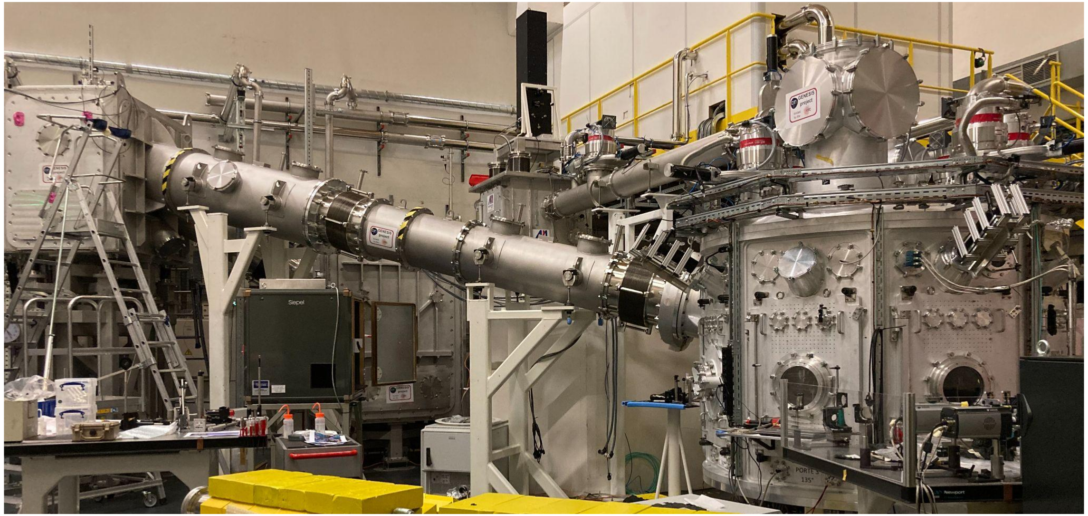
R. Lelièvre, et al., to be submitted



R. Lelièvre, et al., in preparation

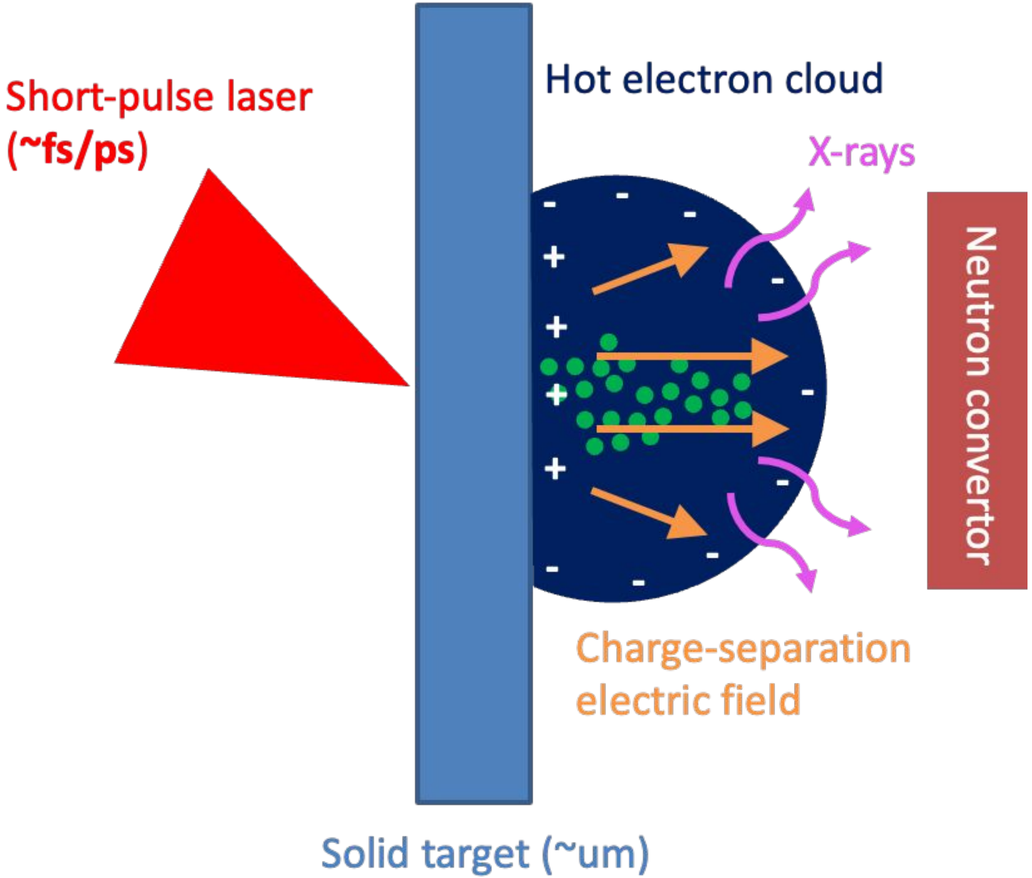
SFA current stage



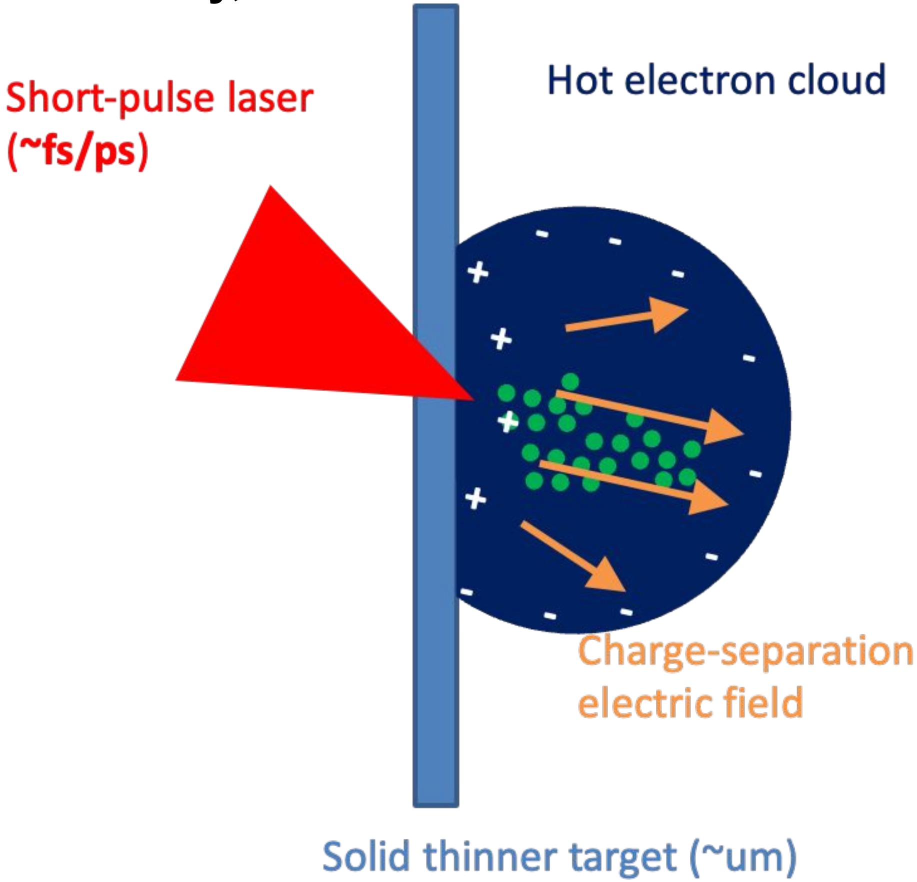


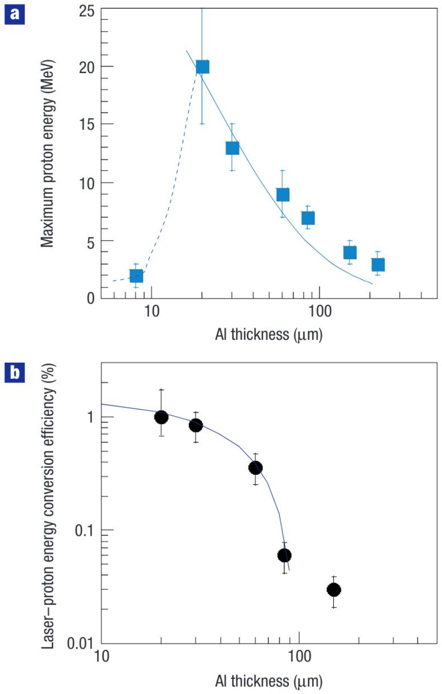
max. ~1 shot/min

Proton acceleration, X-ray emission, and neutron generation



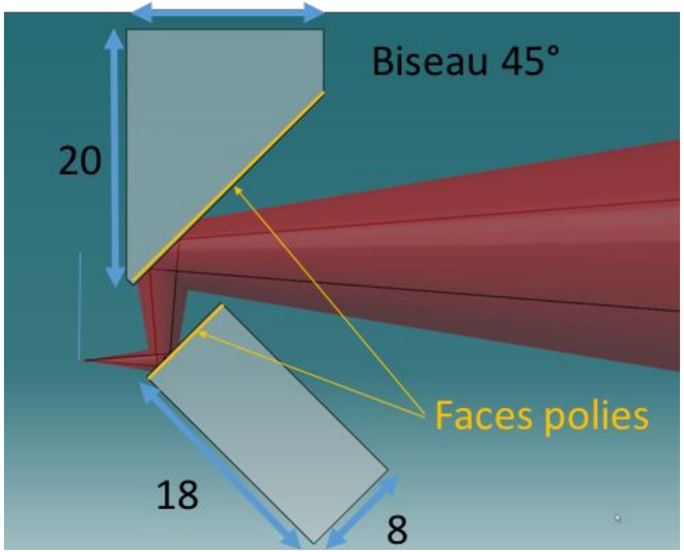
Thinner solid targets improve the maximum proton energy and its energy conversion efficiency, with risks.

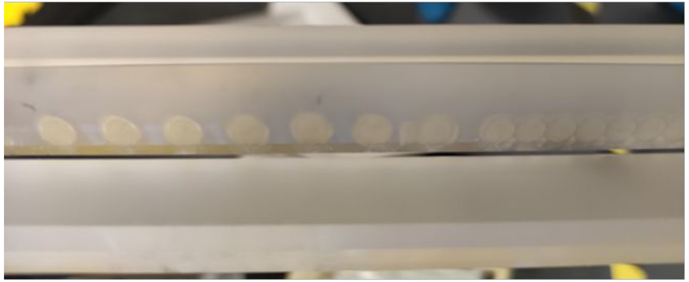


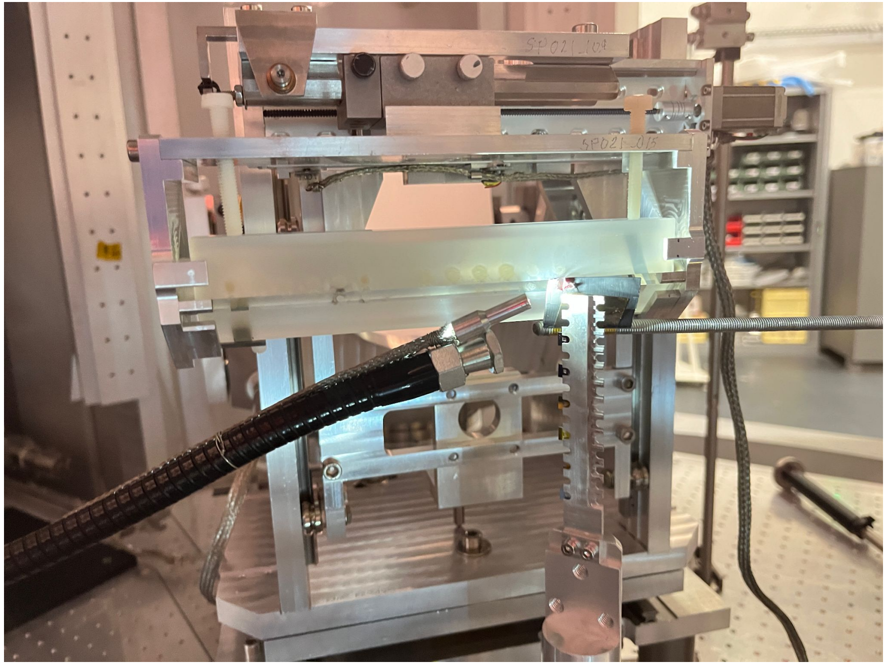


J. Fuchs, et al., Nat. Phys. (2006)

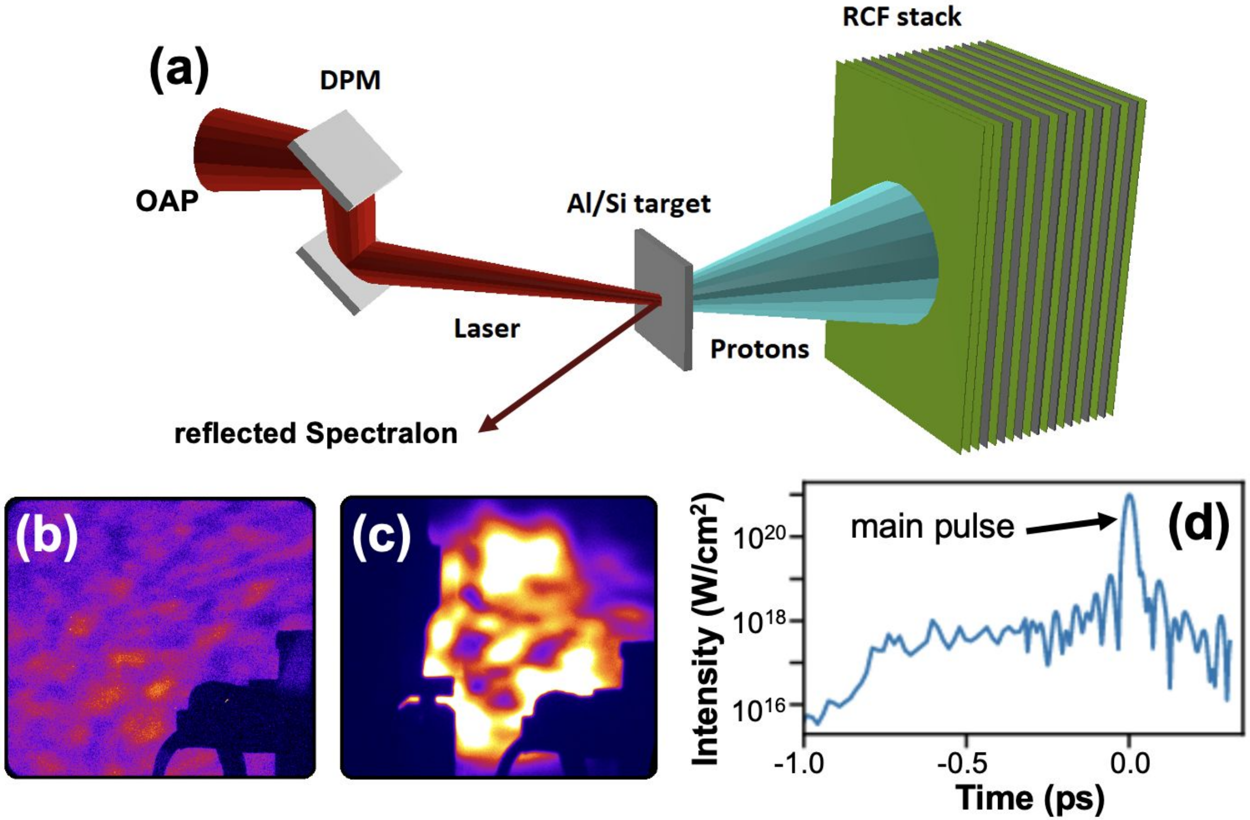
Double Plasma Mirrors (DPM) for contrast optimization using F2

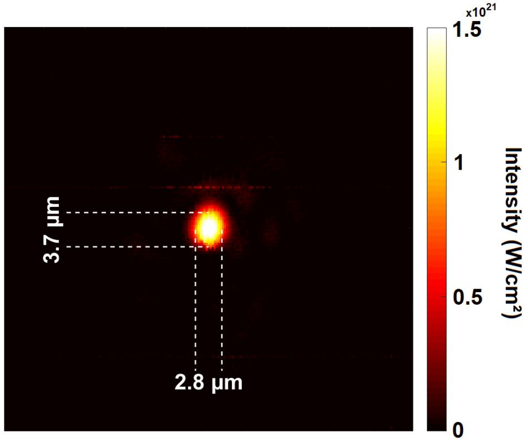






Double Plasma Mirrors (DPM) for pre-pulse optimization – using F2 (10 J, 24 fs)

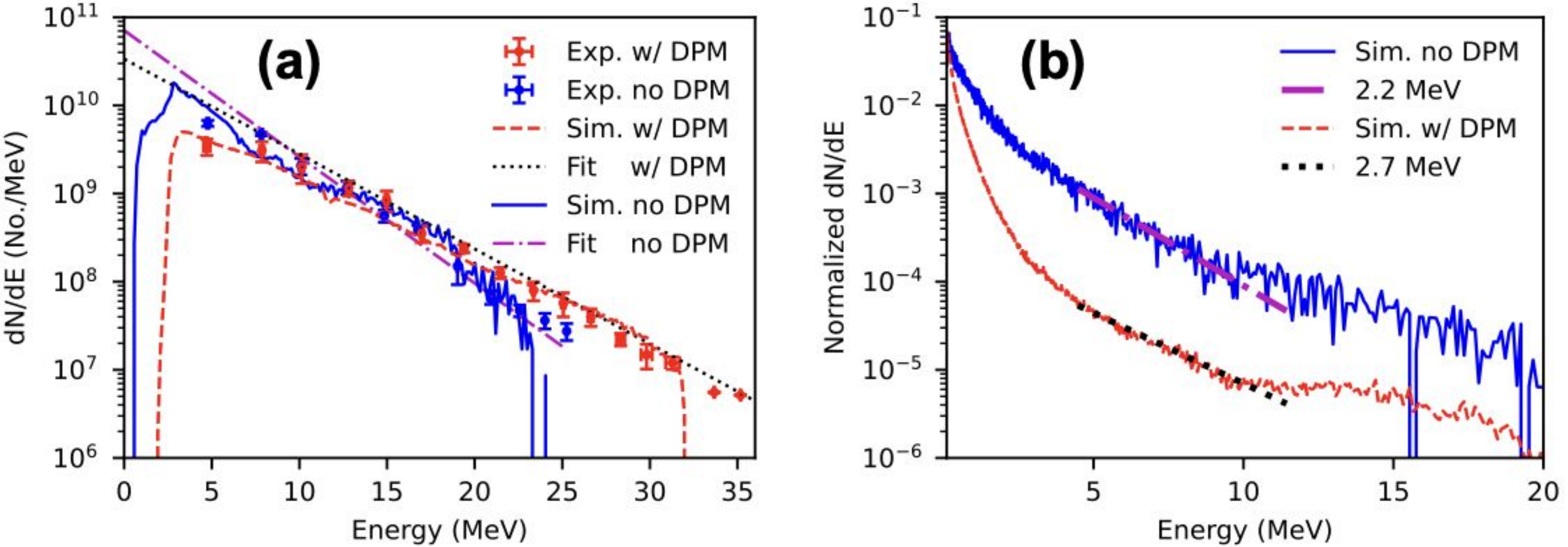




Pulse duration: 24 fs
On-target laser energy: ~ 10 J
~ 2.8 um x 3.7 um FWHM spot
-> ~ **1.1x10^{21} W/cm^{2}**

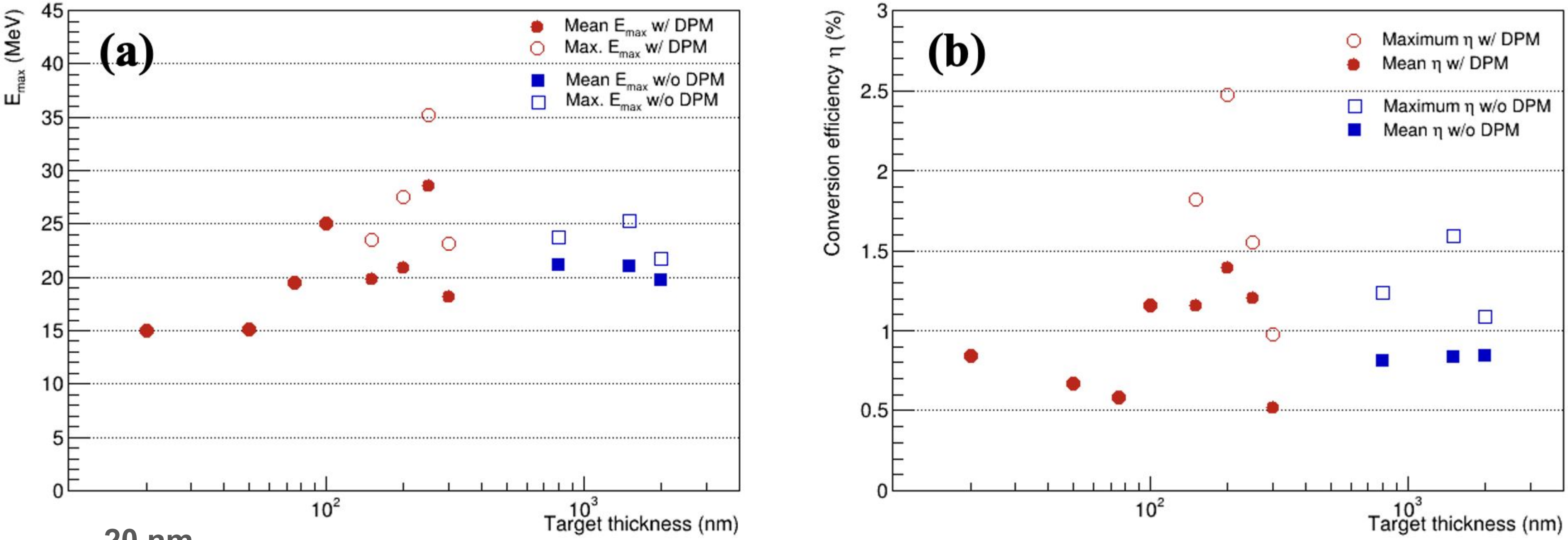
R. Lelièvre, et al., to be submitted

DPM for pre-pulse optimization using F2 – enhanced proton acceleration



With DPM: 200 nm Si + 50 nm Al
w/o DPM: 1500 nm Al

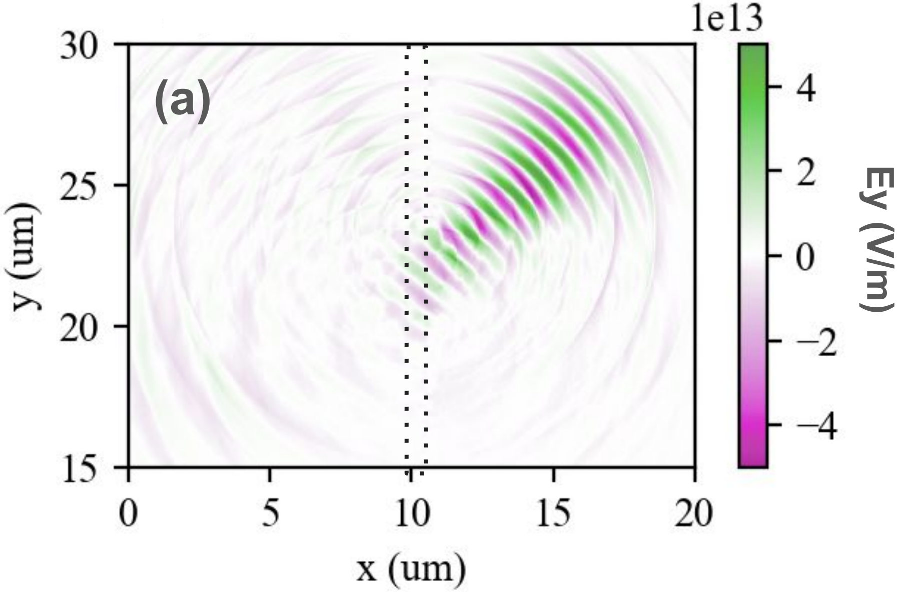
DPM using F2 – enhanced laser-proton energy conversion efficiency



20 nm

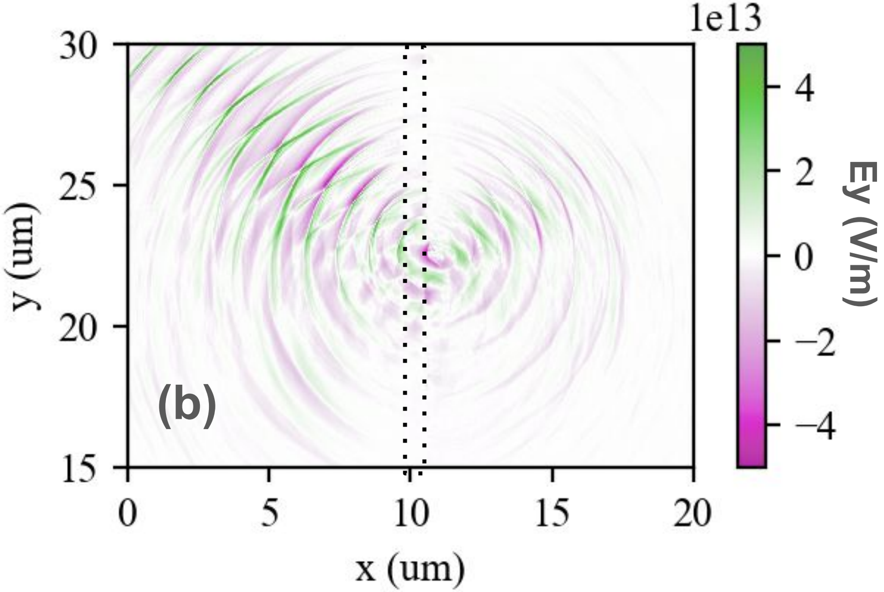
DPM using F2 – simulations confirm target under 20 nm is totally transparent.

10 nm Si



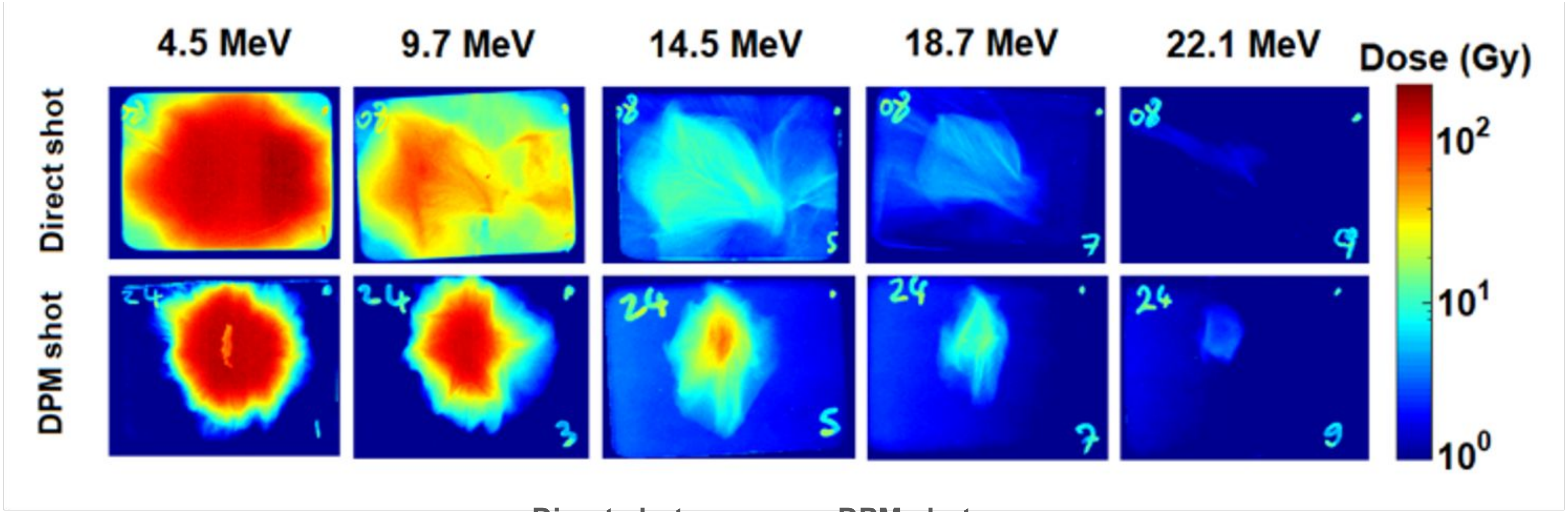
Laser penetrate through the target

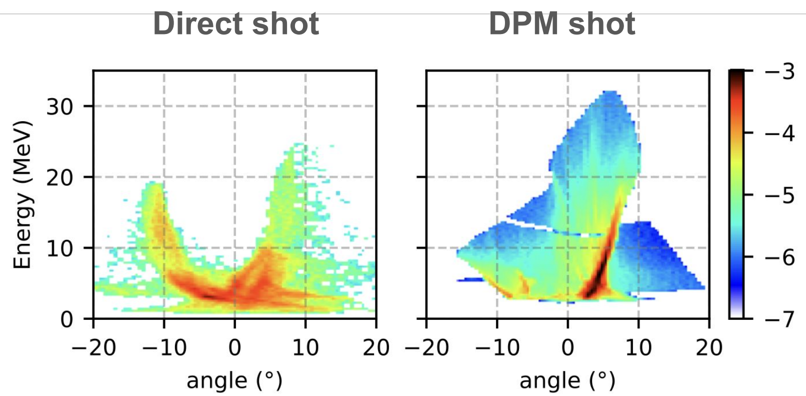
20 nm Si



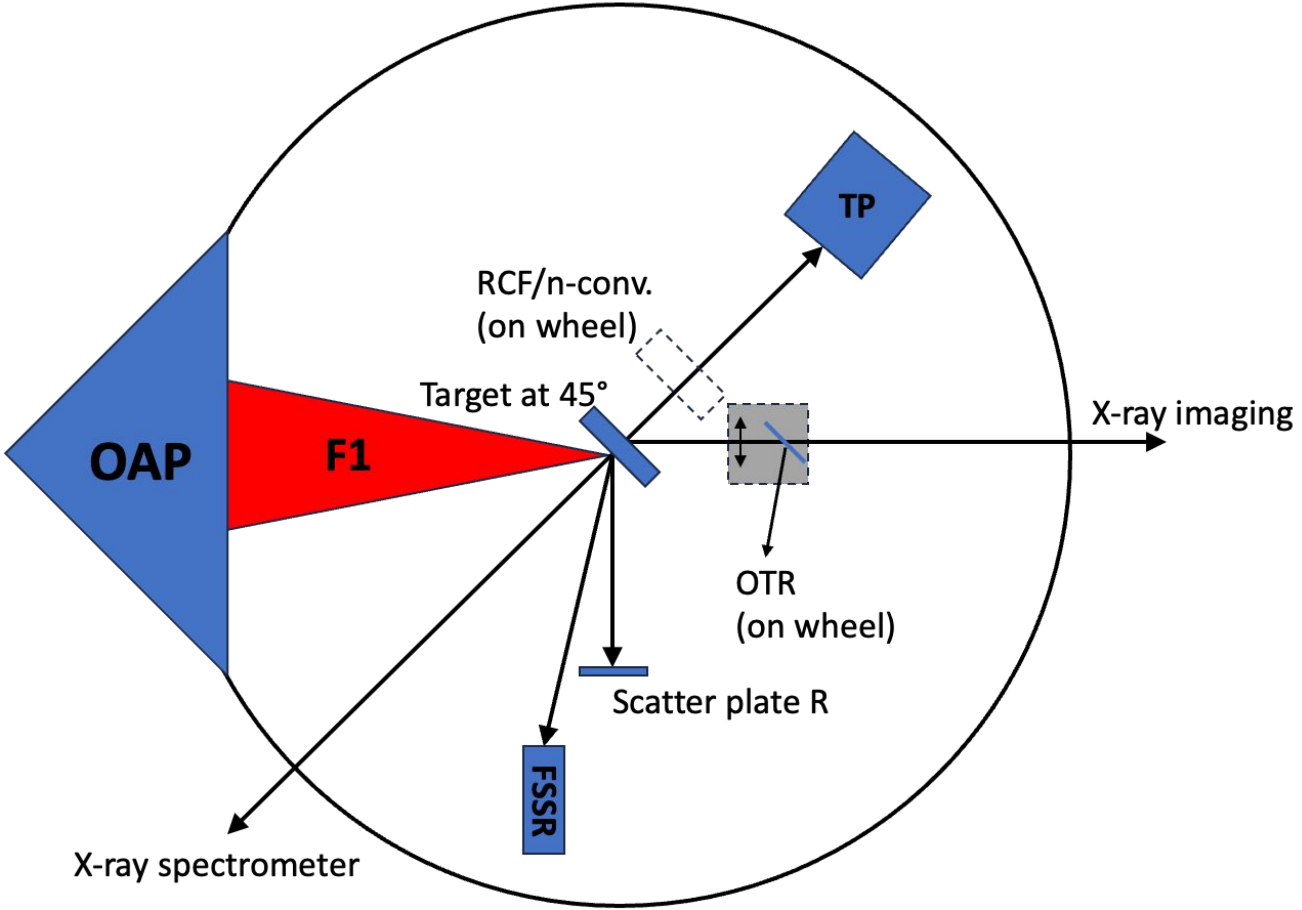
Laser reflected by the target

DPM using F2 – improved beam profile

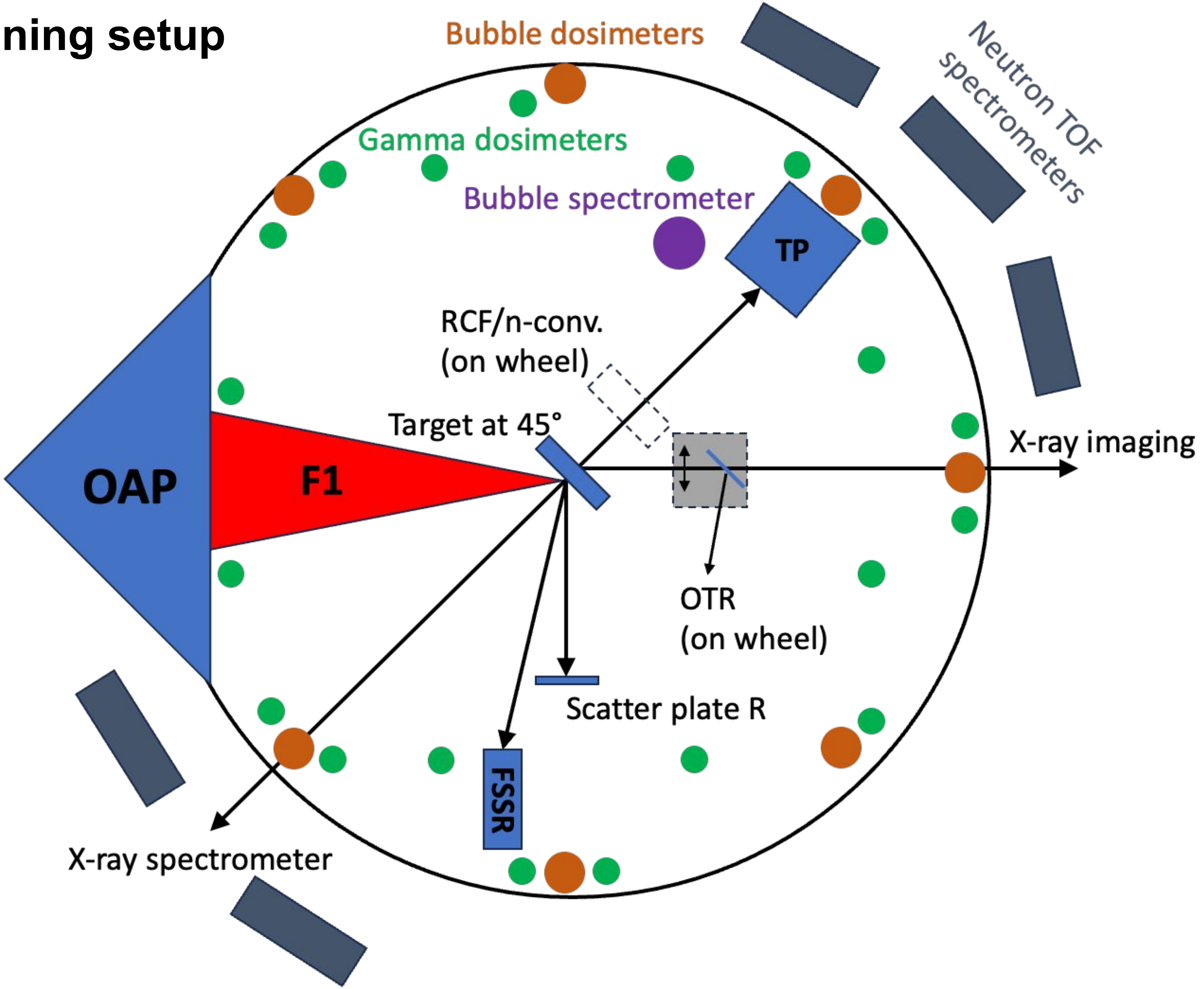




F1 commissioning setup

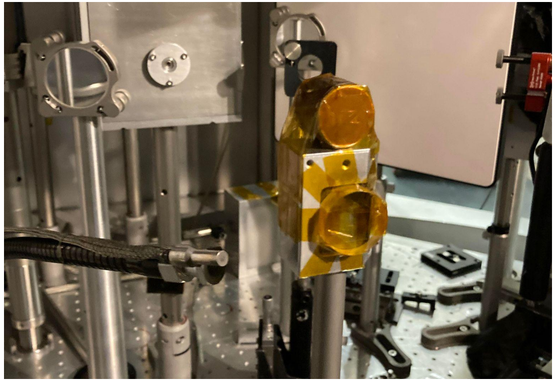


F1 commissioning setup



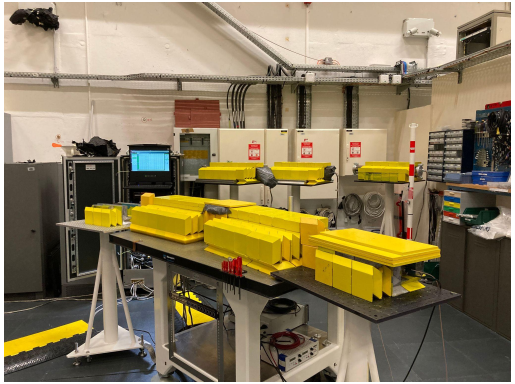
Neutrons – more detail see Ronan's talk

Activation samples



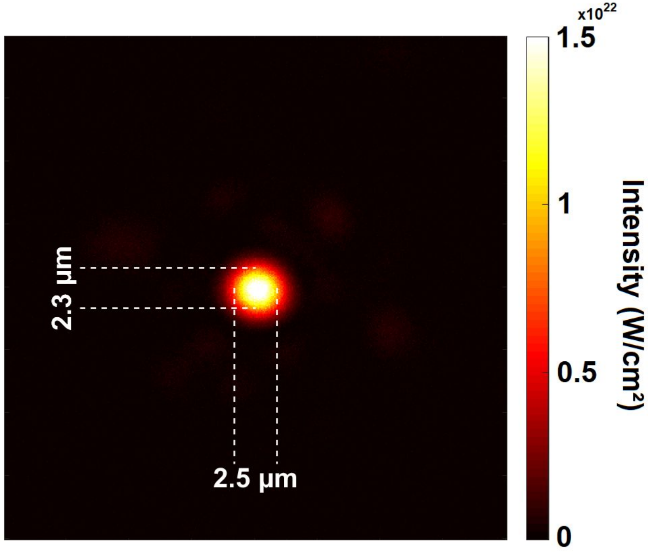
Bubble spectrometer & dosimeters

neutron Time-of-Flight detectors

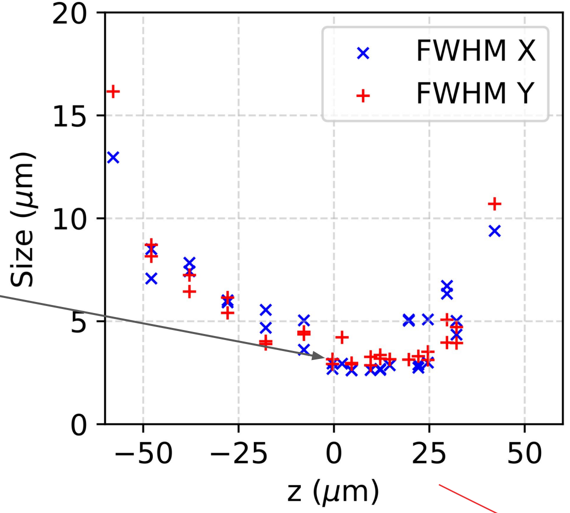


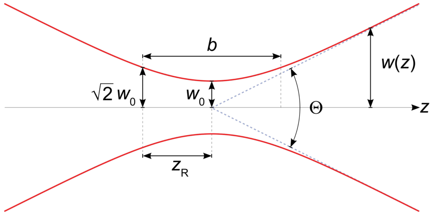
F1 beam characterization – I

Intensity distribution at z~0



Focal spot sizes scan along the laser axis





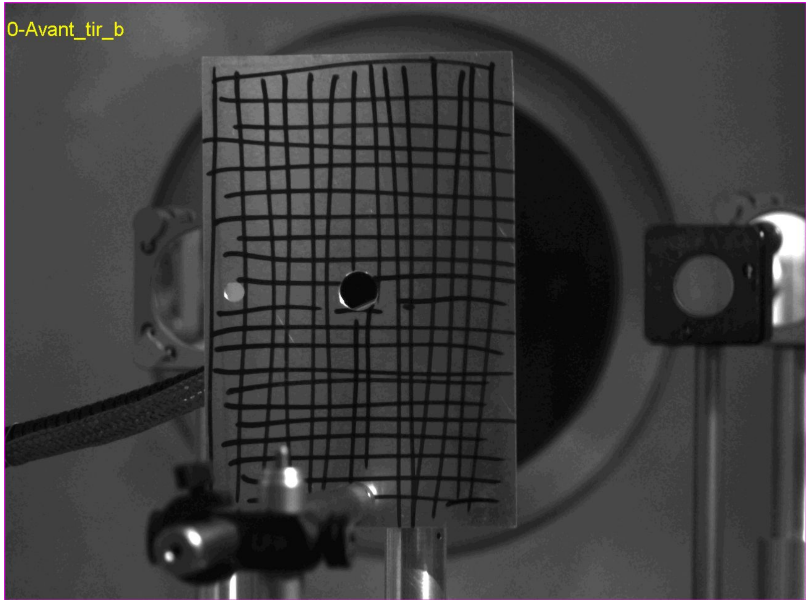
$$w(z) = w_0\sqrt{1+\left(\frac{z}{z_R}\right)^2}$$

Pulse duration: 22 fs
On-target laser energy: ~ 45 J
~ 2.3 um x 2.5 um FWHM spot
-> ~ 1.5x10^{22} W/cm^2

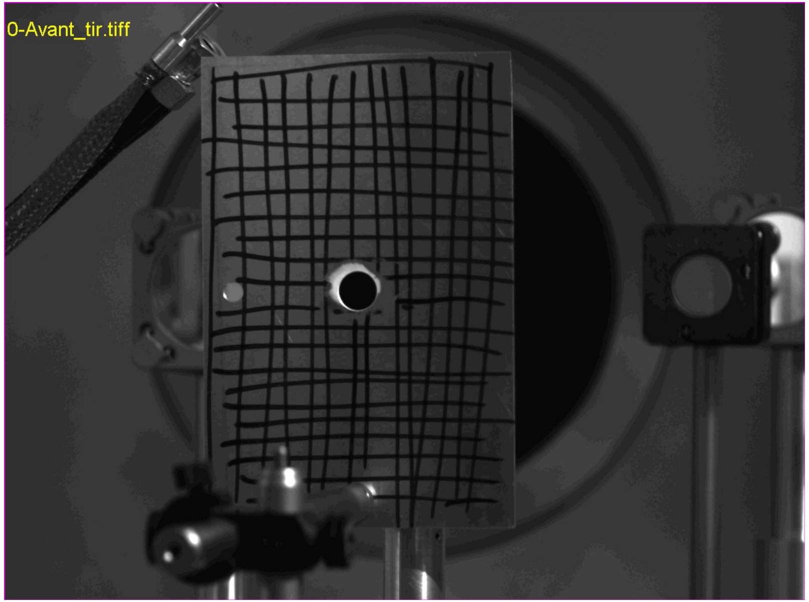
F1 beam characterization – II

No direct contrast measurement -> 2024

w/o membrane



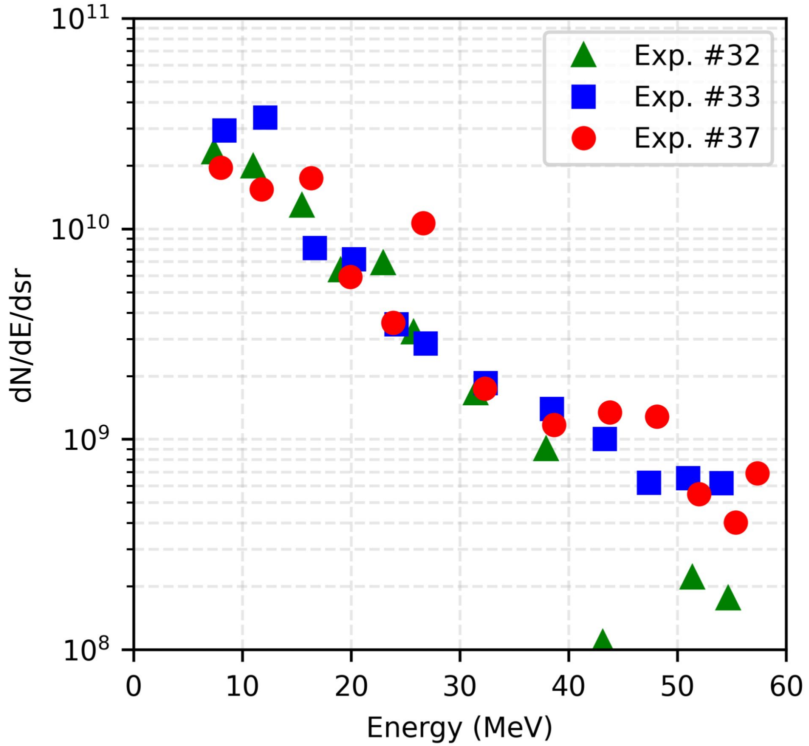
with membrane



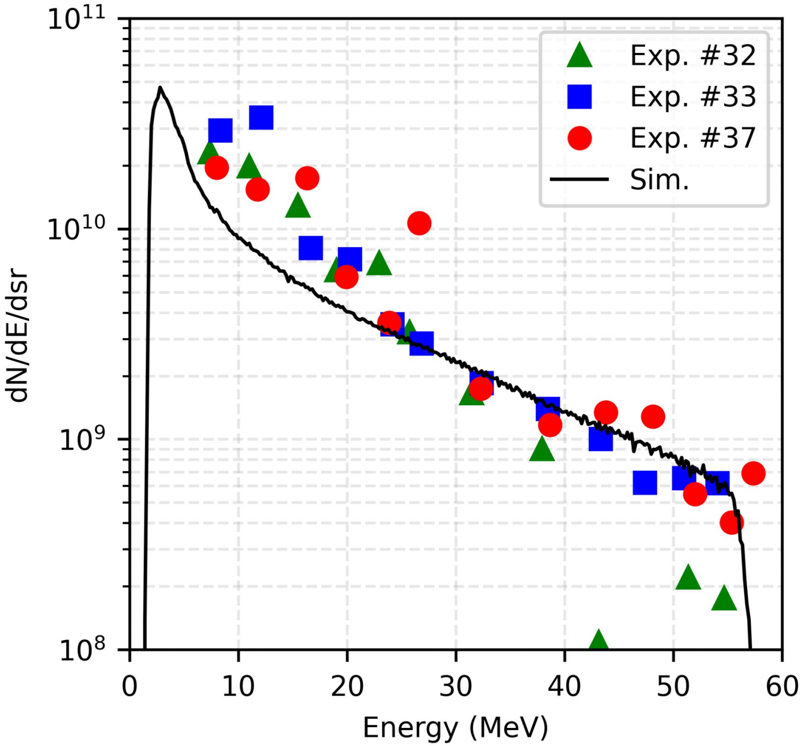
67% energy in the main pulse, caused by the membrane
(who protect the OAP) itself.

Proton acceleration – diagnostics (TP / RCF)

Total number of shots : 180
Mean proton energy : 42 MeV

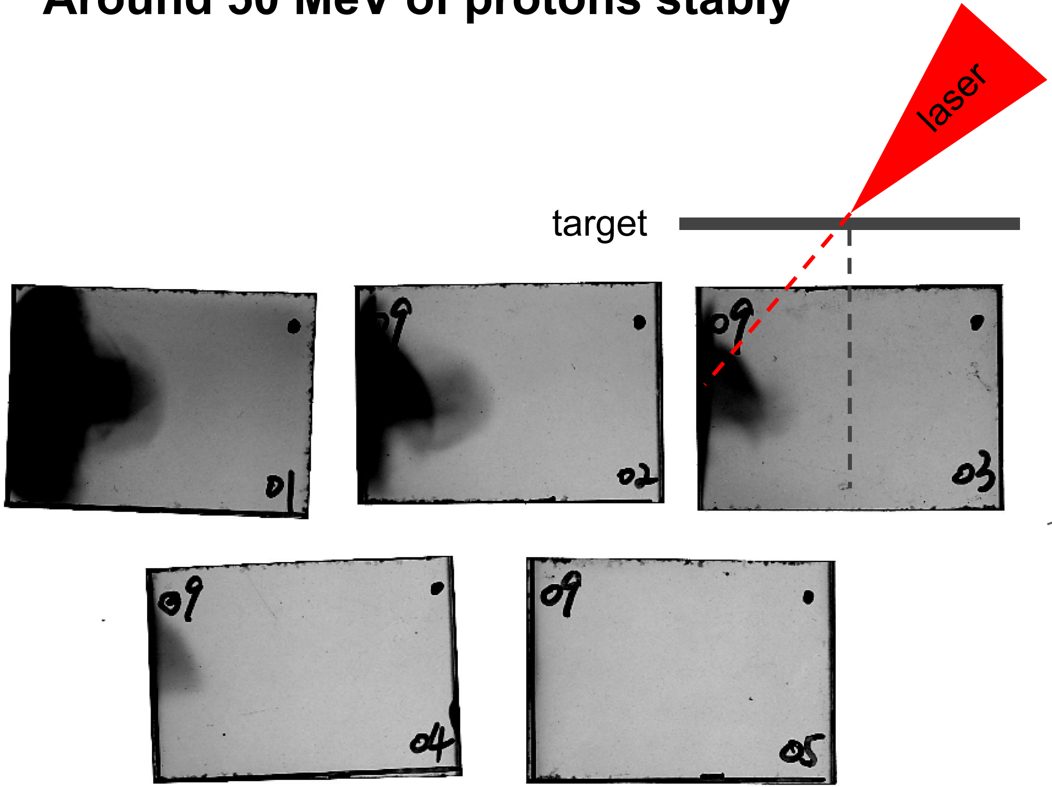


Proton acceleration – started to run PIC simulations



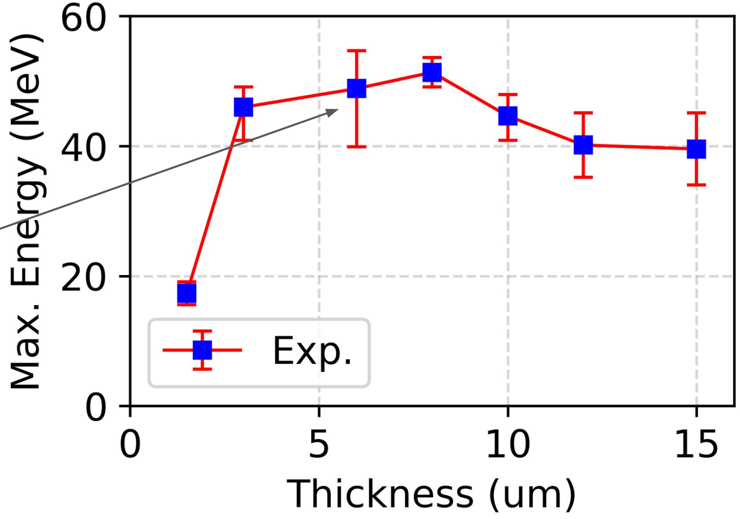
*35% of laser energy (a_0 ~ 90)
***No pre-pulse yet**, but we lower the solid target density (60 nc) so that the thinner target will be partially transparent to the laser.

Around 50 MeV of protons stably



Shot 10, ~ 52 MeV

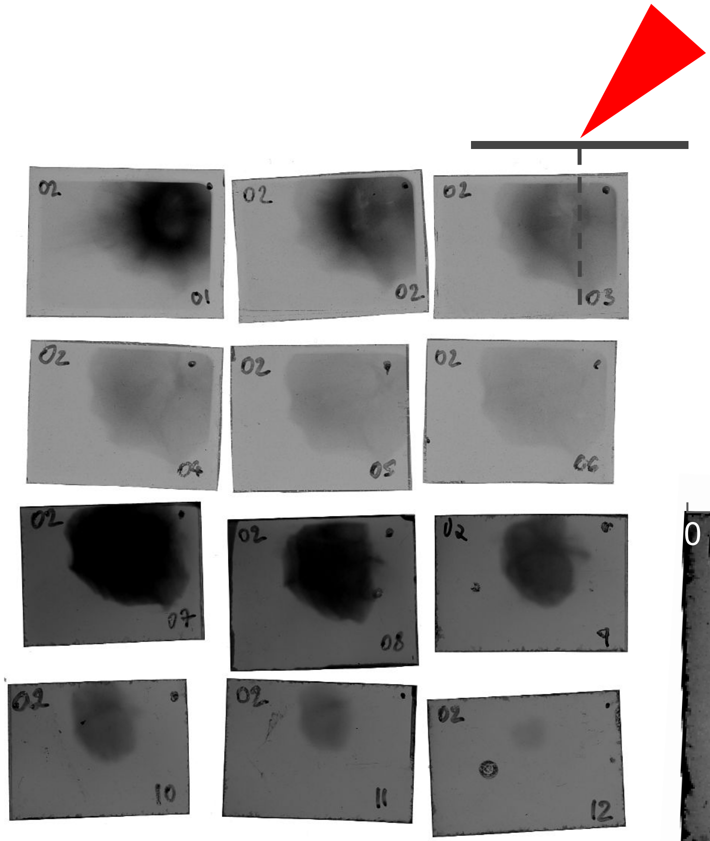
Target (Al) thickness scan for proton acceleration



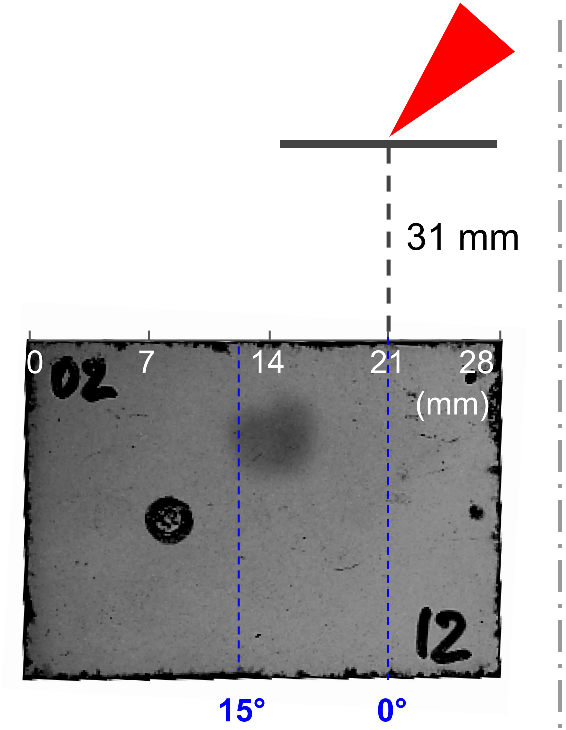
The high-energy protons are along the laser-axis,
indicating a large pre-pulse issue.

Beam profile

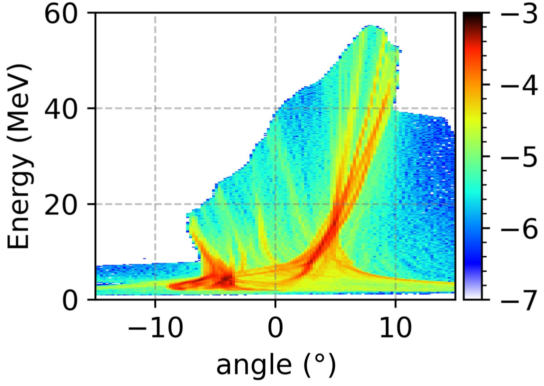
Moved the RCF box towards the laser axis to see more signal of high-energy protons



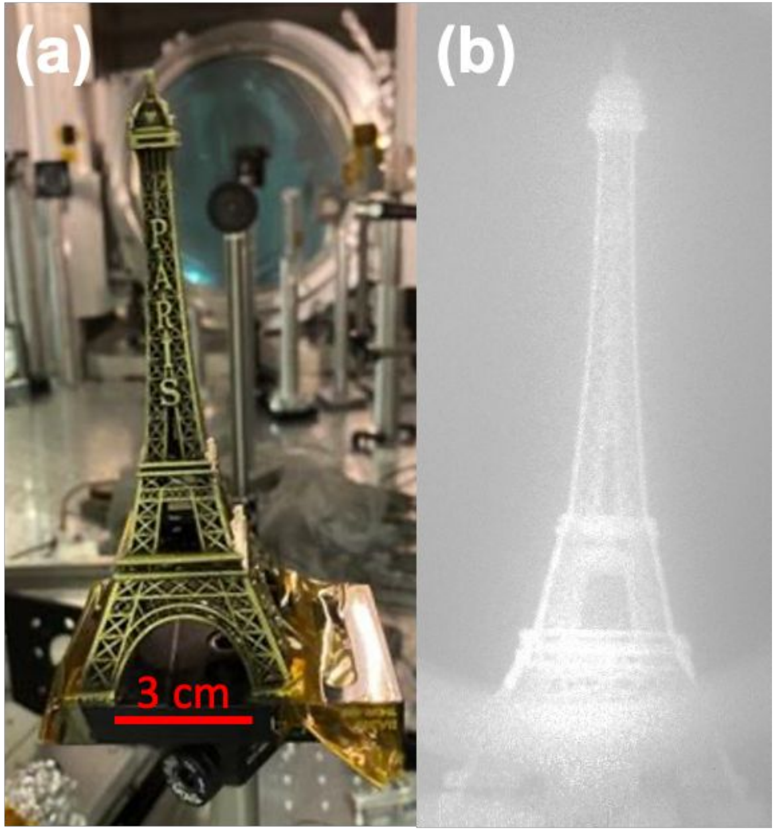
Shot 33, ~ 54 MeV



The same 2D PIC simulation results



Exquisite resolution of X-ray radiograph



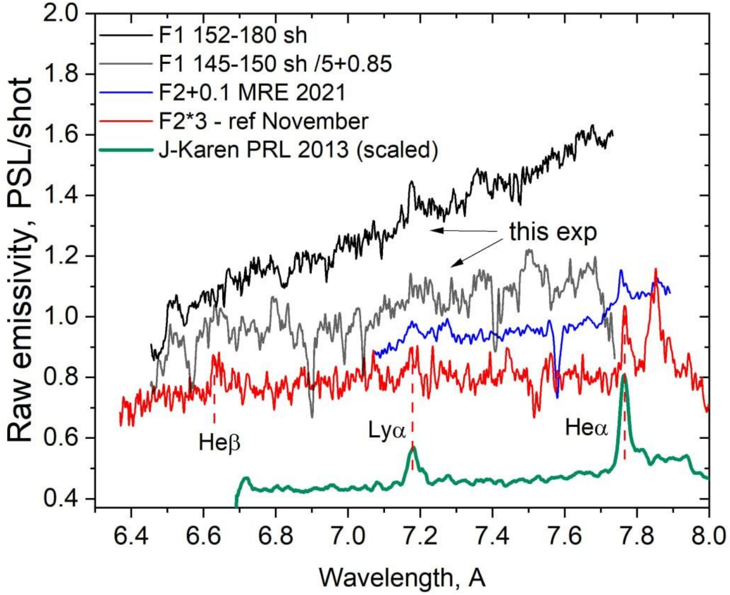
Detector resolution:
125 um

Magnification ~ 2

For X-ray around MeV

More analysis ongoing

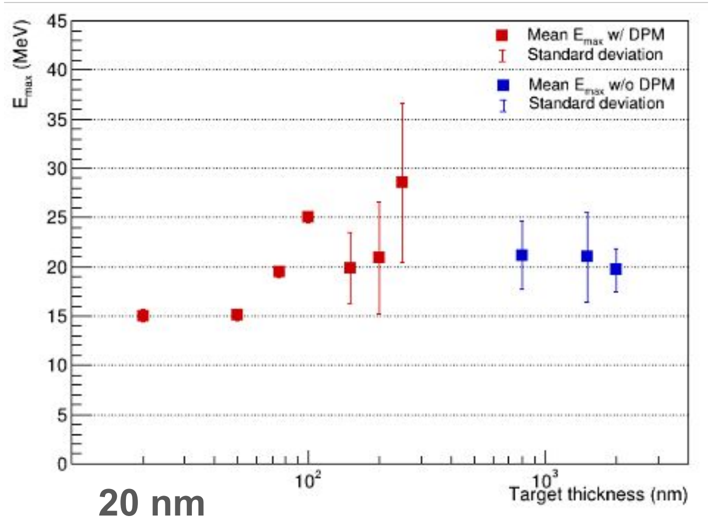
FSSR for characterizing the plasma condition (density and temperature)



Al Ly_{α} line is measured (high electron Te is supposed to be achieved), however, we observe that the ratio between X-ray resonance lines/ bremsstrahlung is much lower (vs other experiments or F2) indicating a more extended plasma source due to the *lower laser contrast*.

DPM for pre-pulse optimization – not good enough using F1

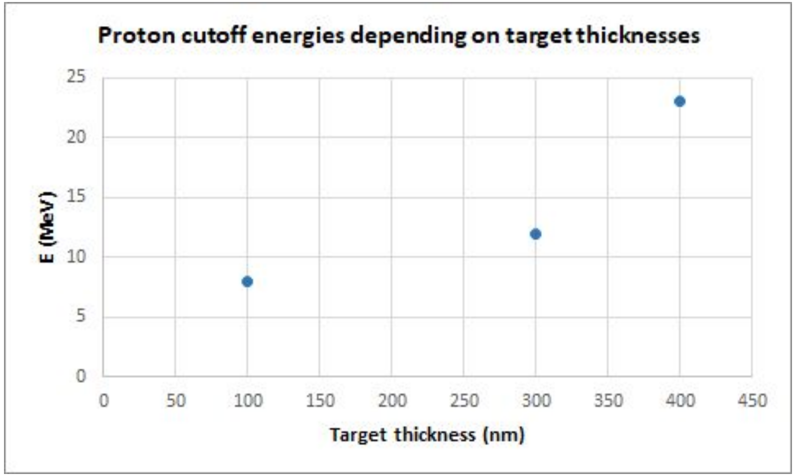
With F2 (10 J, 24 fs), DPM works well.



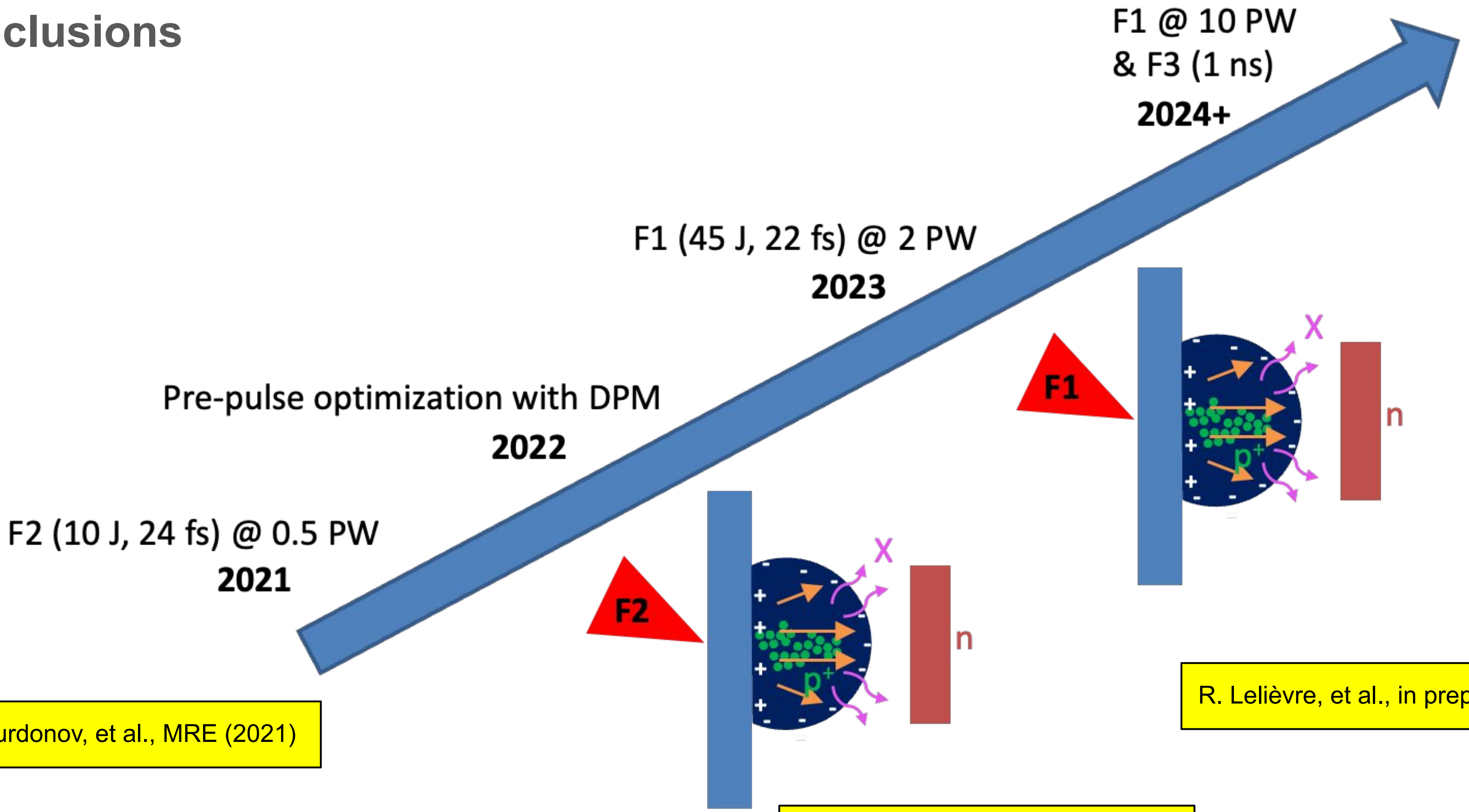
20 nm

R. Lelièvre, et al., to be submitted

But using F1 with the current contrast, the DPM didn't allow us to shoot on a thinner target.



Conclusions



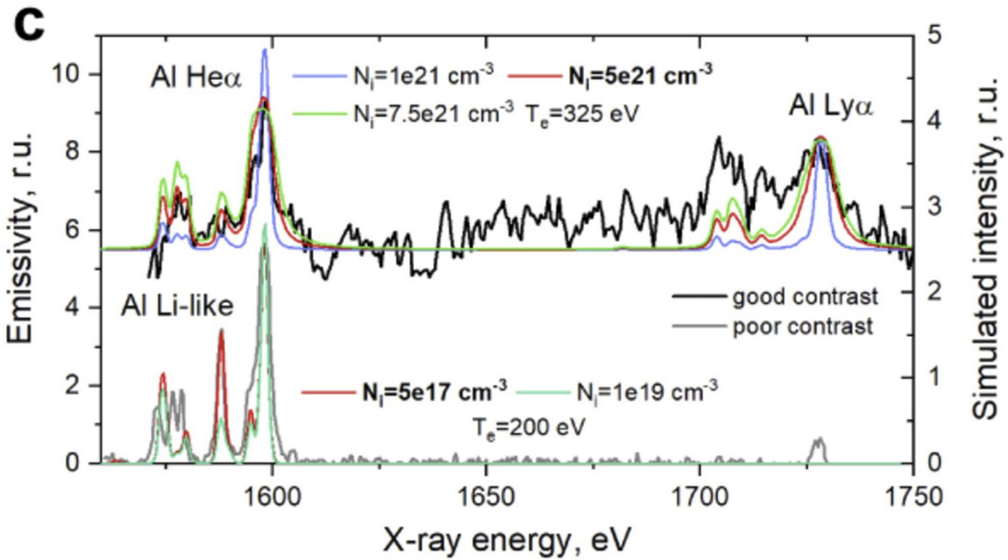
K. Burdonov, et al., MRE (2021)

R. Lelièvre, et al., to be submitted

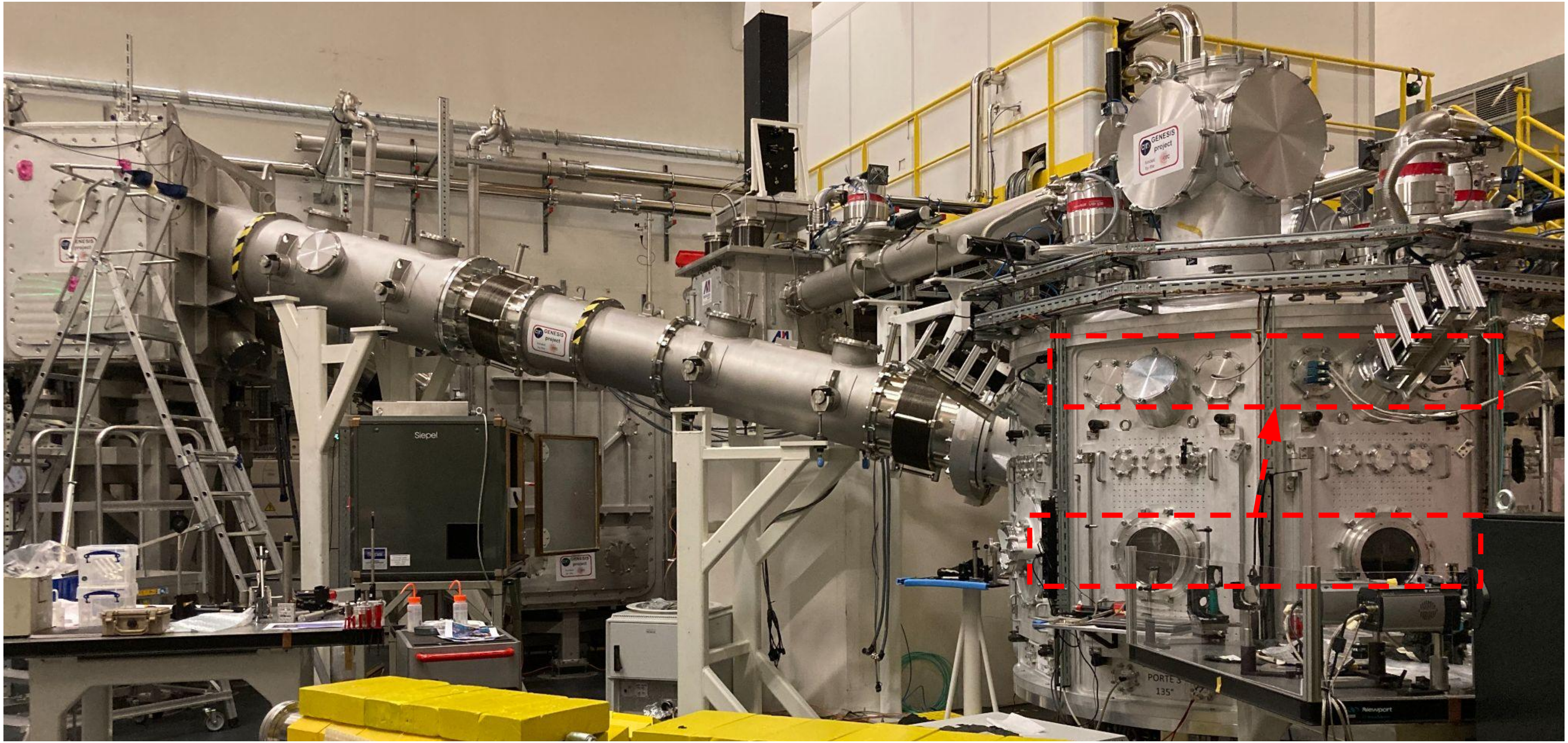
R. Lelièvre, et al., in preparation

Thanks for your attention

FSSR for characterizing the plasma condition (density and temperature)

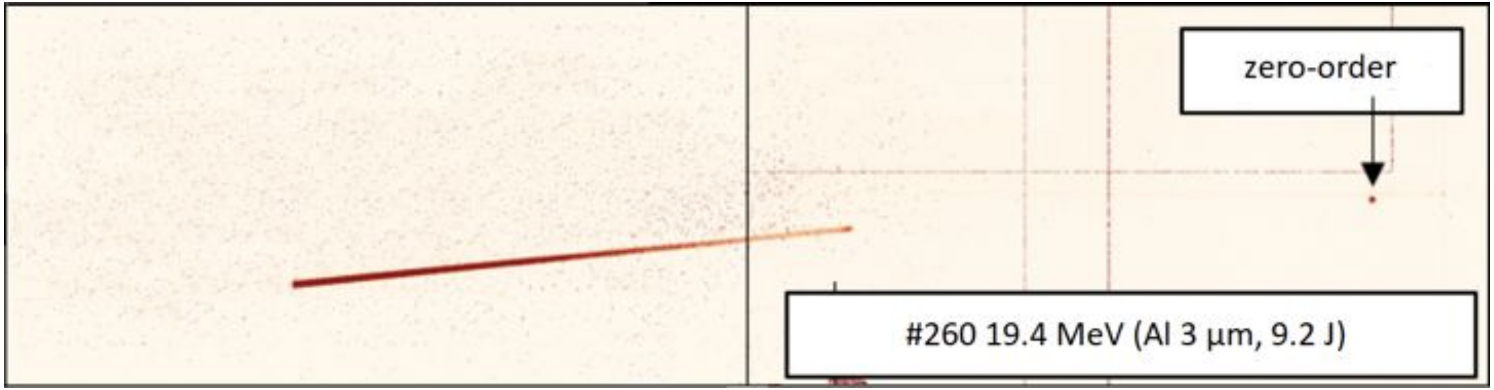


K. Burdonov, et al., MRE (2021)


GENESIS
project
Siepel
PORTE 3
135°
Newport

Proton acceleration – diagnostics (TP / RCF)

Real-time proton spectra acquisition using Thomson Parabola



Radeye detectors (along with other cameras outside the target chamber at the **equatorial plane**) are killed by the EMPs, so we have to replace it with Image Plate.

The IP data -> to be analyzed

K. Burdonov, et al., RSI (2023)