Particle acceleration and fusion reactions driven by ultrafast laser pulses

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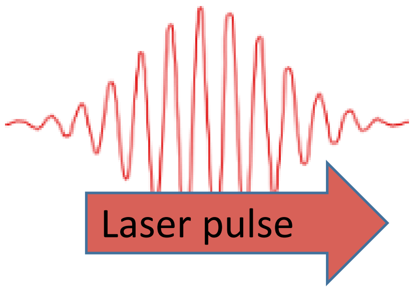
NAPLIFE

Nanoplasmonic Laser Fusion

Outline: an experiment with high intensity laser pulses..



Target

- particle acceleration
- fusion reaction

Detector 1

Detector 2

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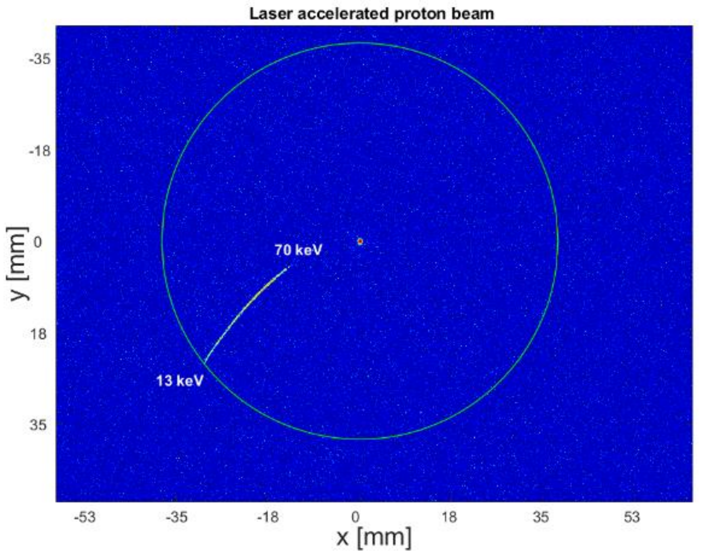
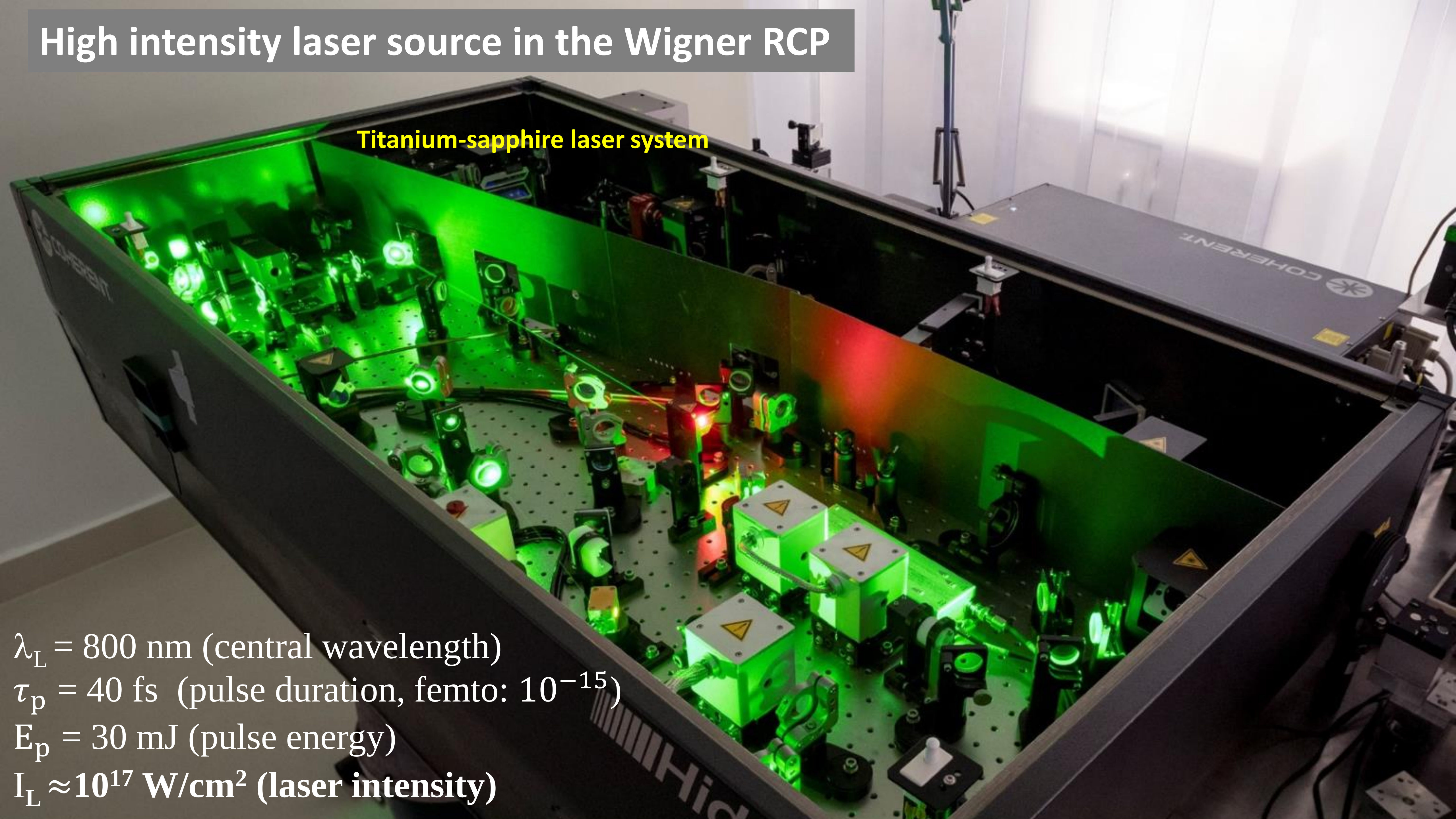
.
.

Detector n



High intensity laser source in the Wigner RCP

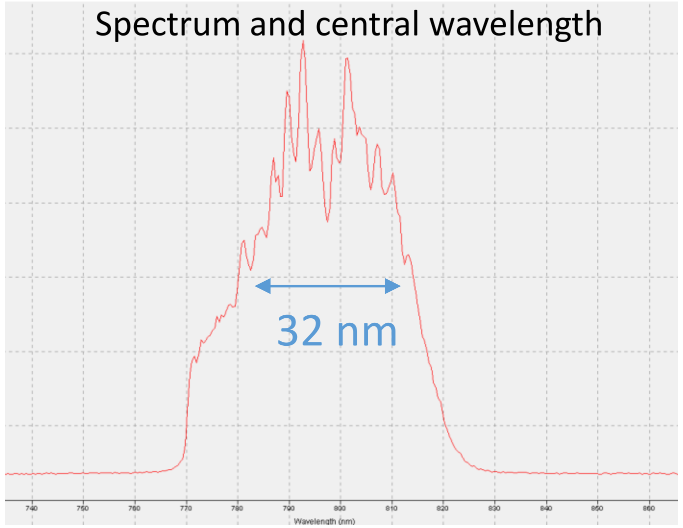


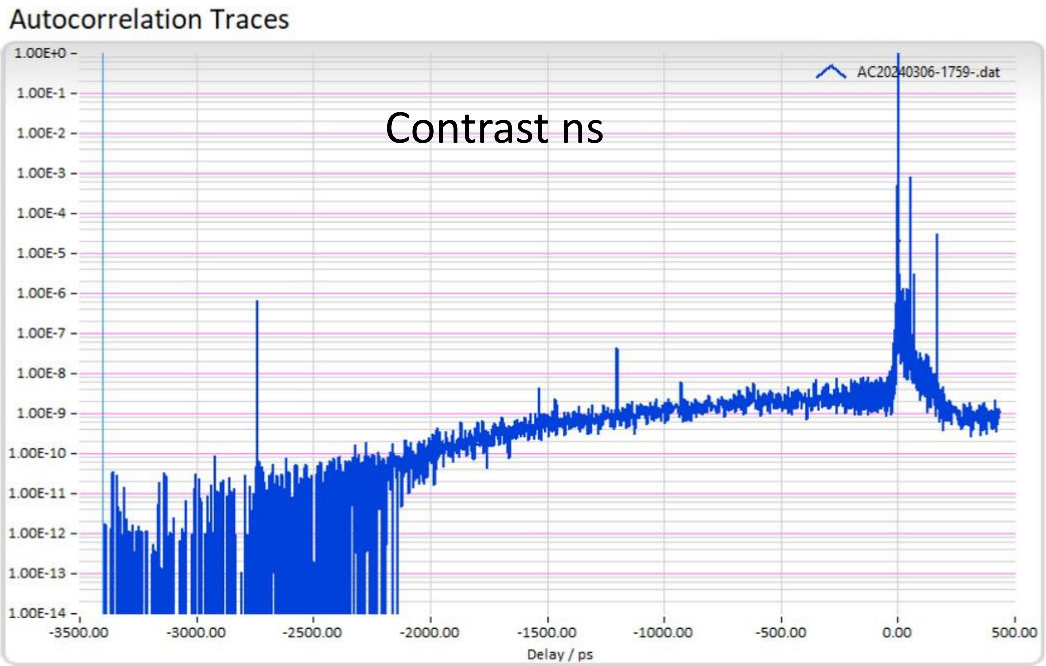
λ_L = 800 nm (central wavelength)
τ_p = 40 fs (pulse duration, femto: 10^{-15})
E_p = 30 mJ (pulse energy)
$I_L \approx 10^{17}$ W/cm^2 (laser intensity)

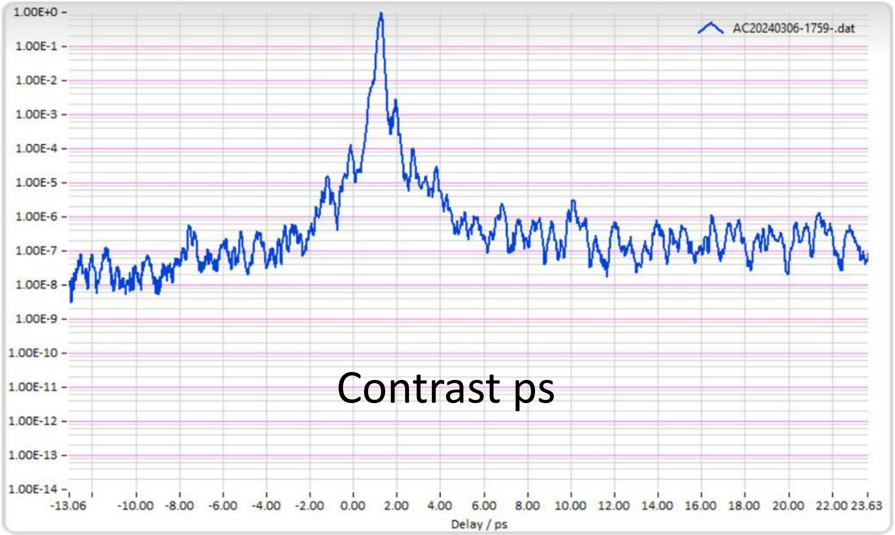
A laser pulse

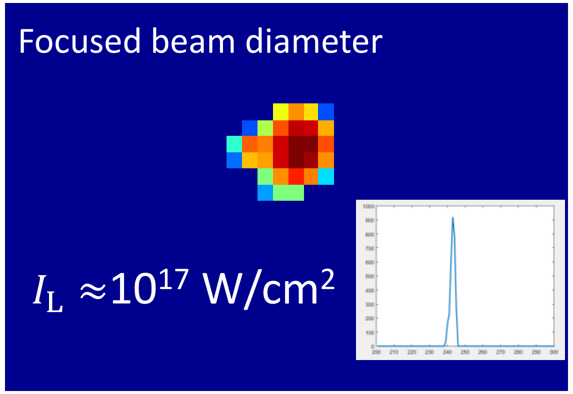
Many parameters for the characterization of a laser pulse:

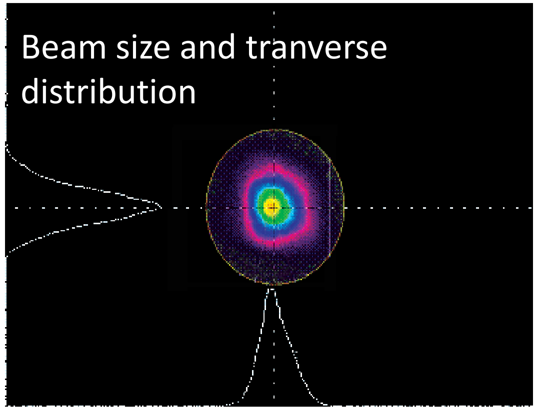
- Repetition rate
- Pulse duration
- Pulse energy
- Chirp
- Polarization



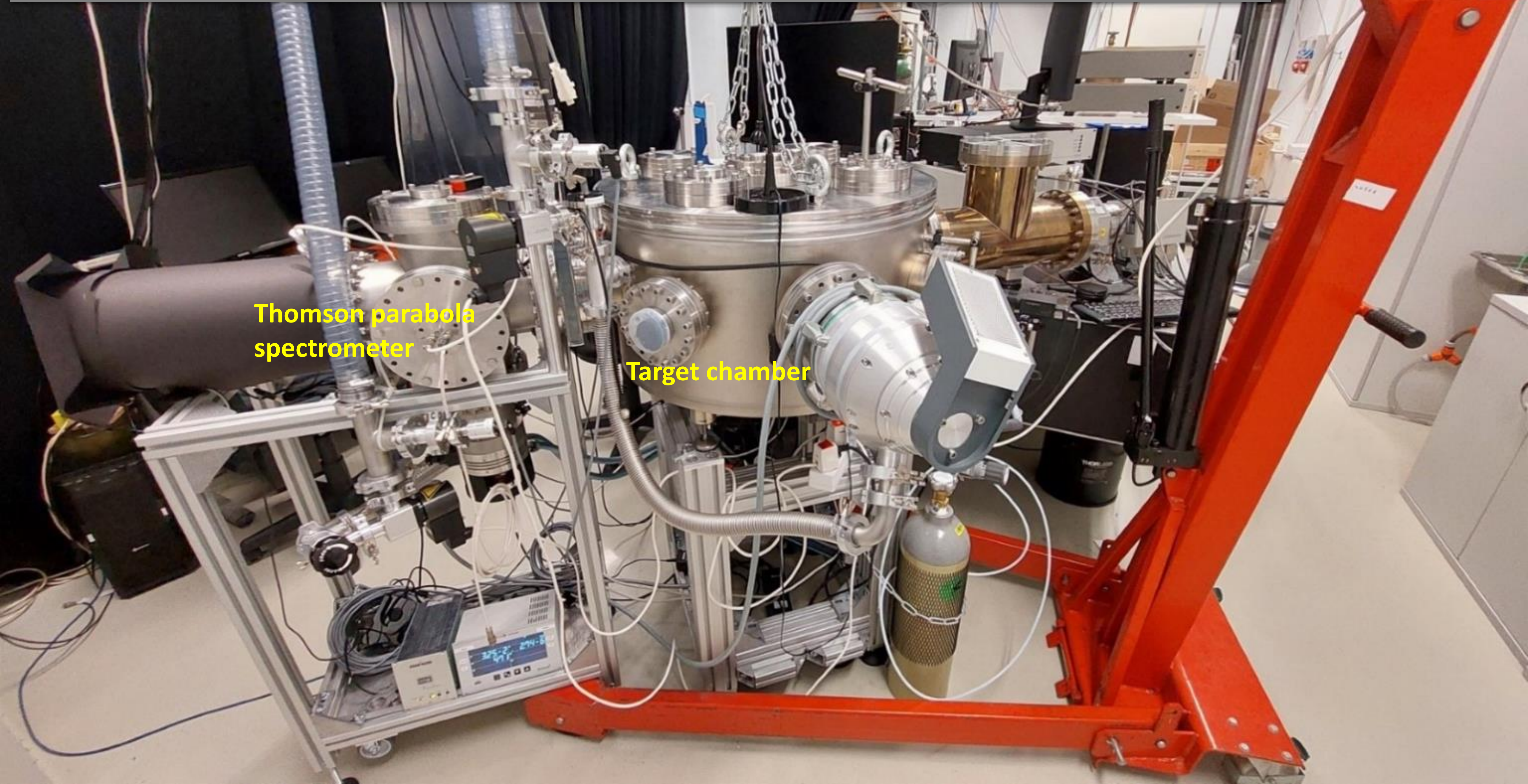






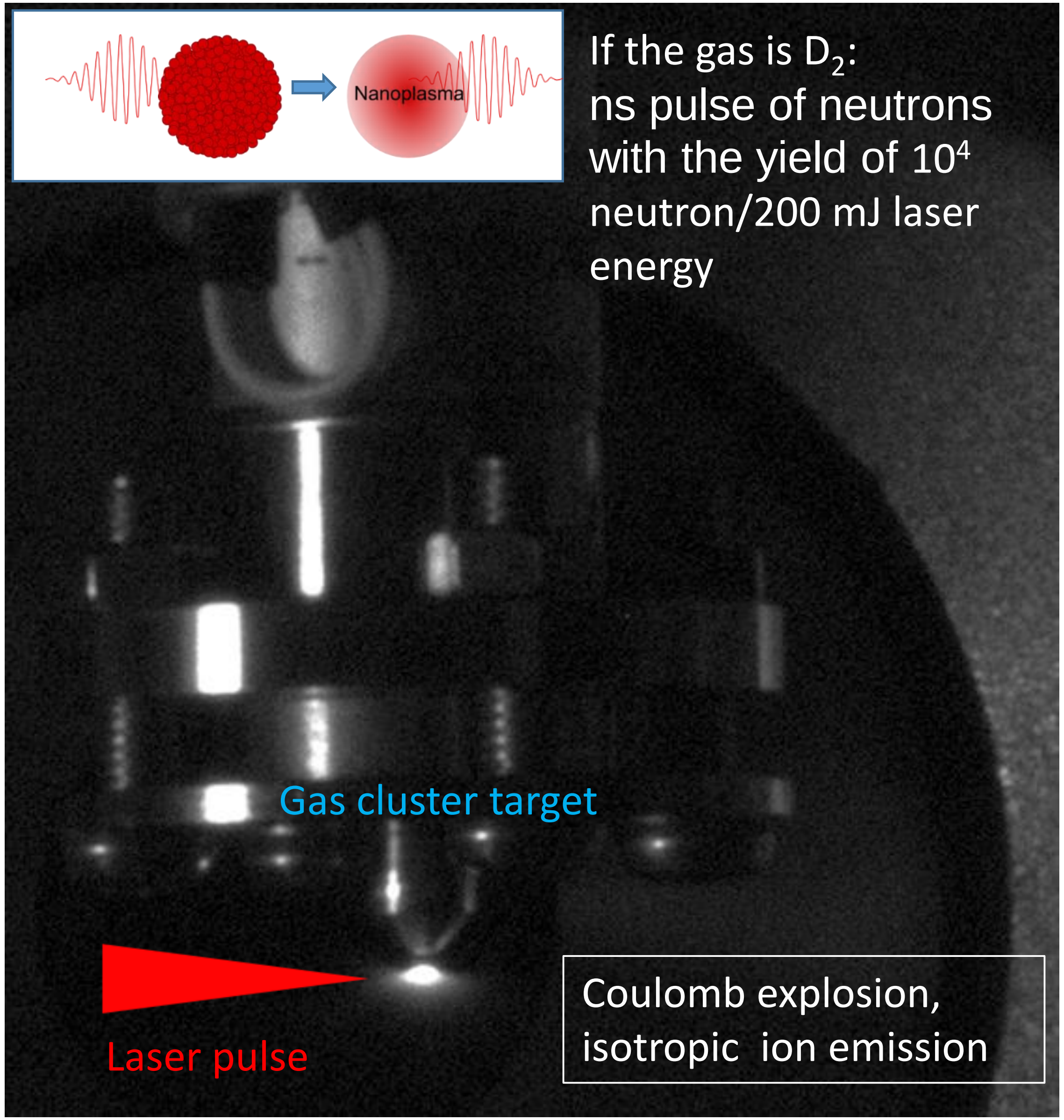


Experimental setup for acceleration and fusion in the Wigner RCP

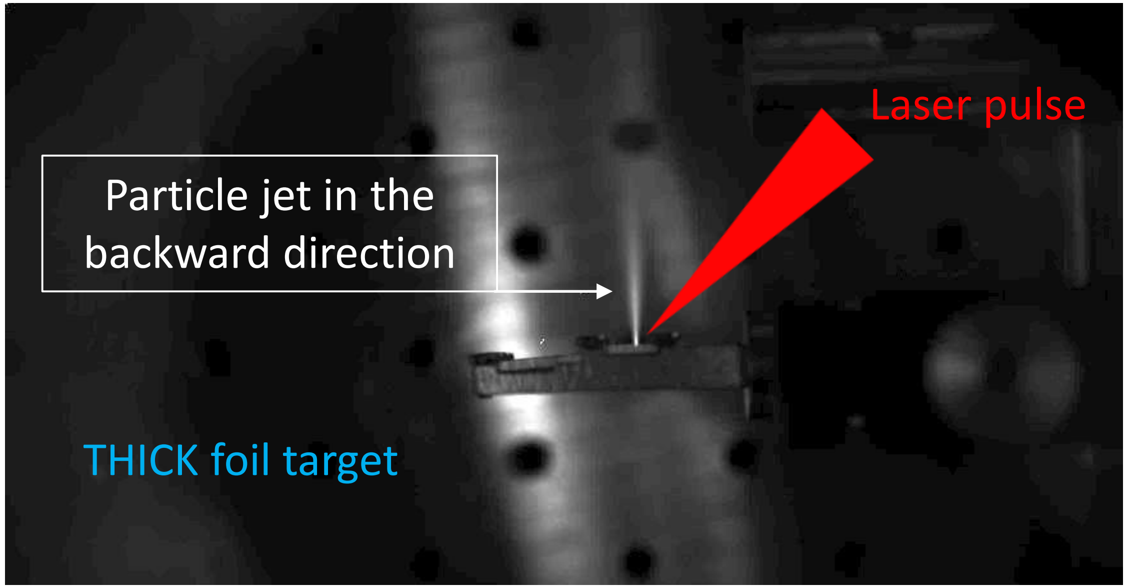


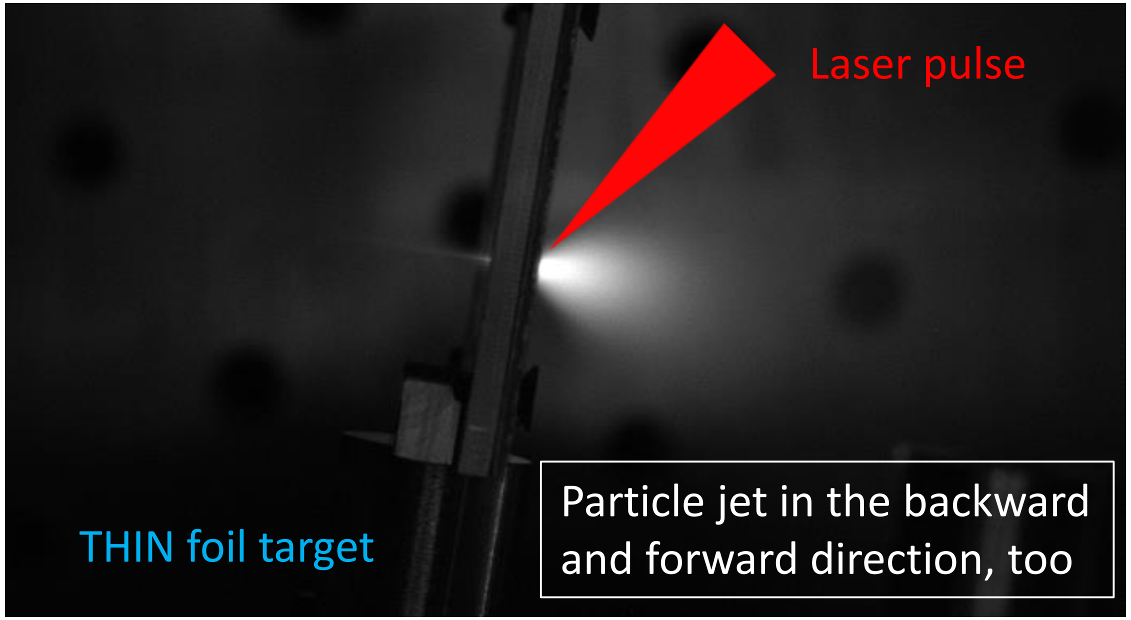
Target

Gas/fluid target

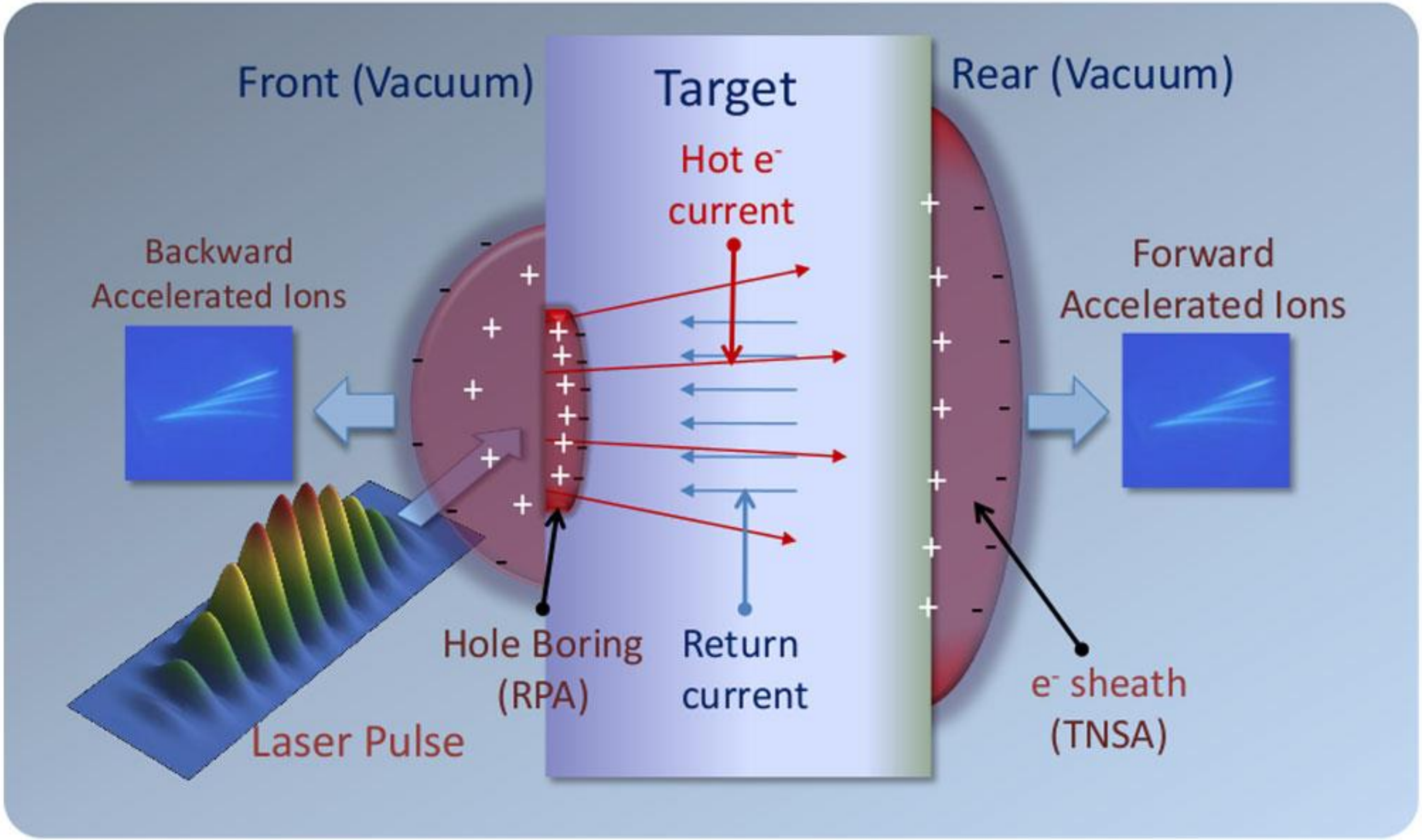


Solid target



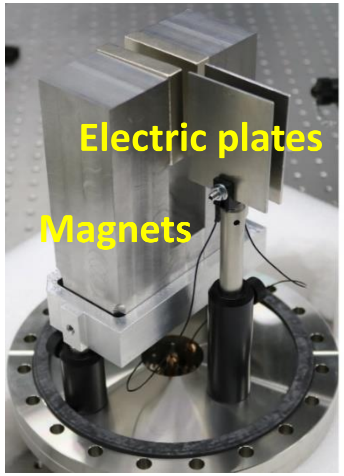


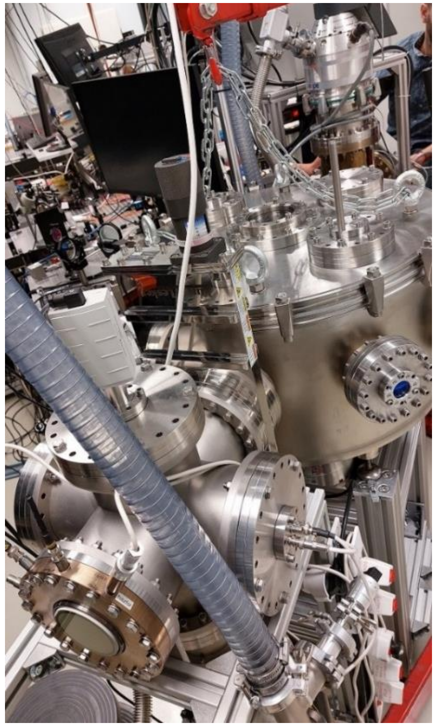
Particle acceleration: some of the possible acceleration mechanisms

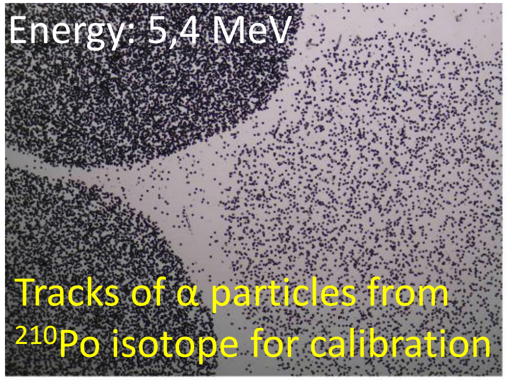


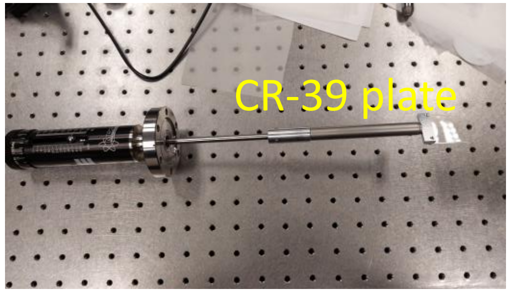
Andrea Macchi et al. Rev. Mod. Phys., Vol. 85, No. 2, 2013.

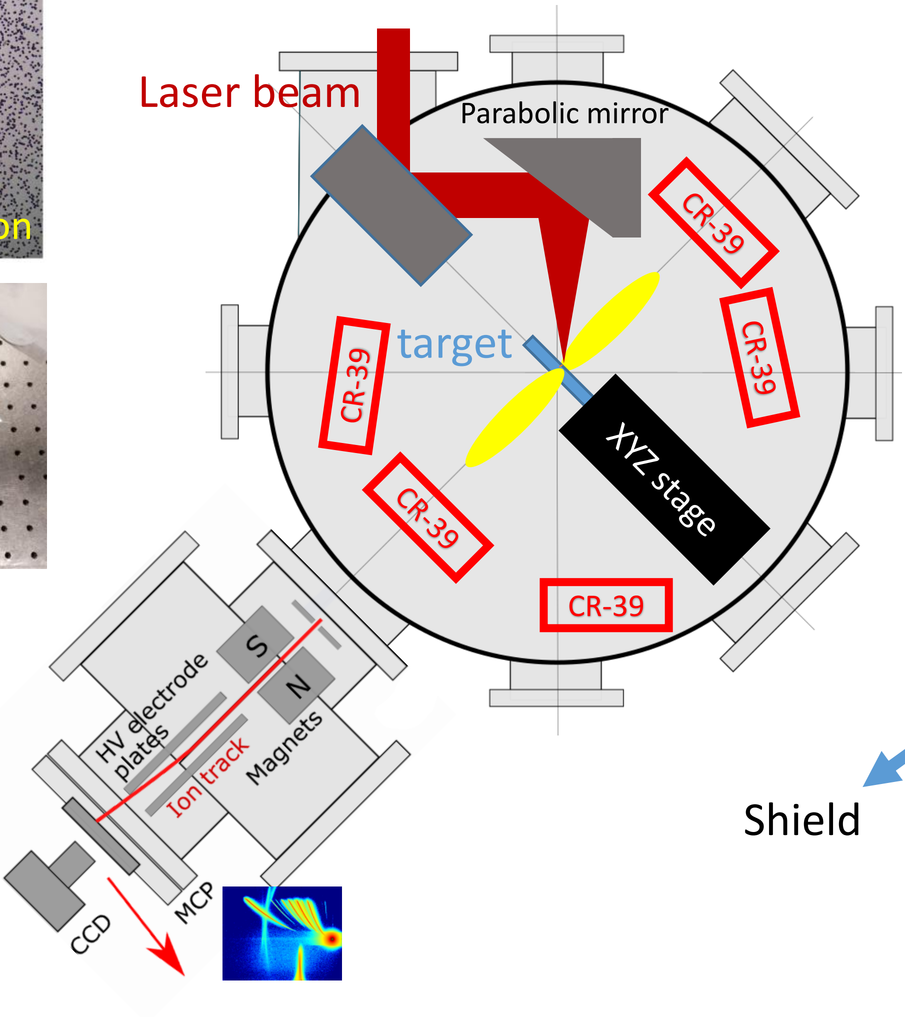
Detectors: Thomson parabola spectrometer and CR-39 track detector



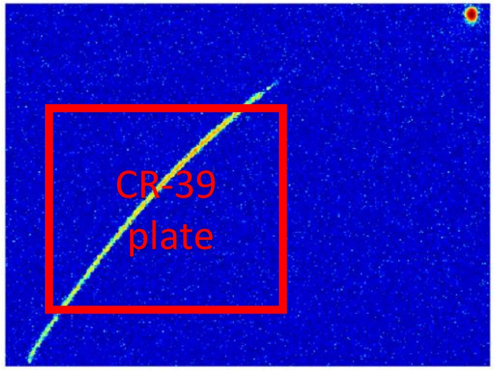




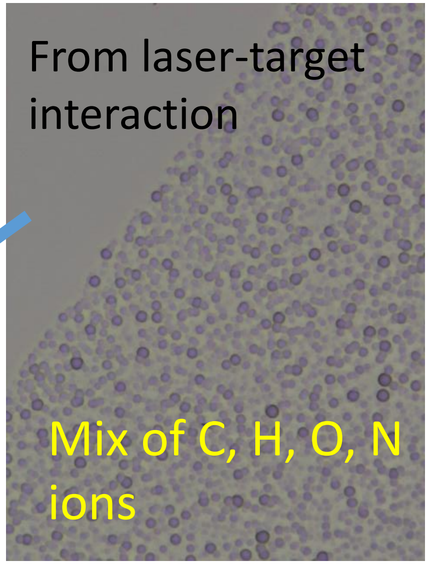




2 µm Al foil blocks the low energy plasma ions

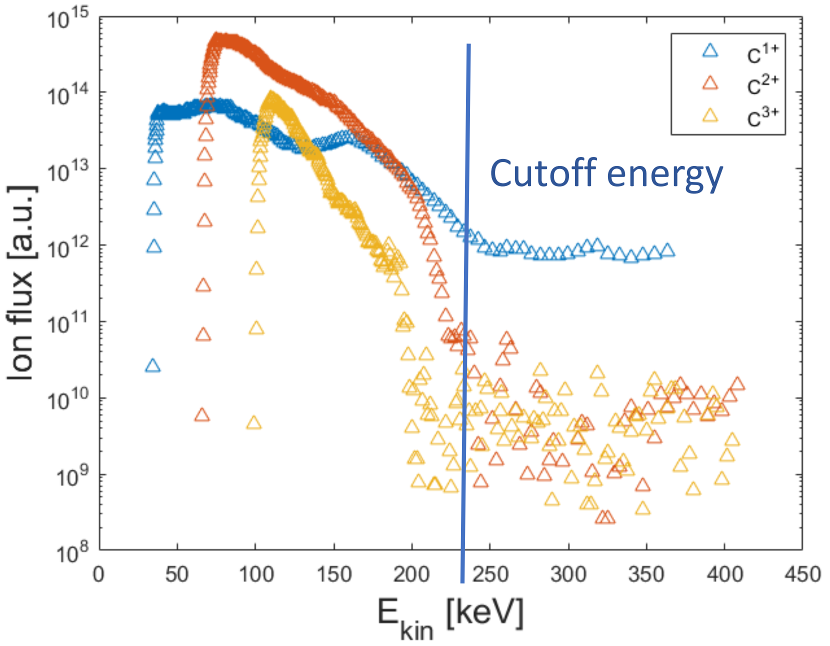


Better way

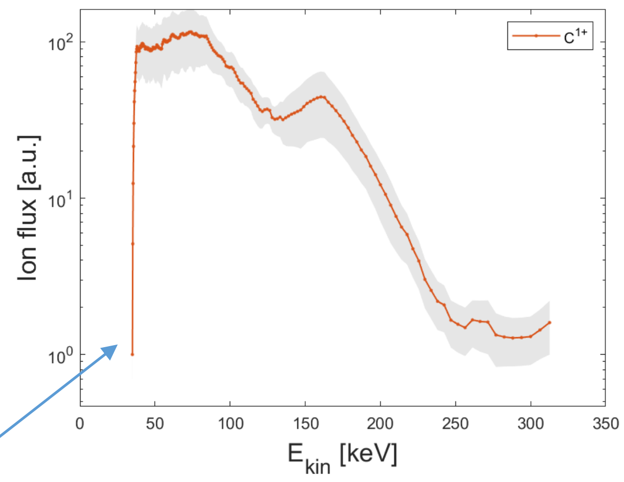


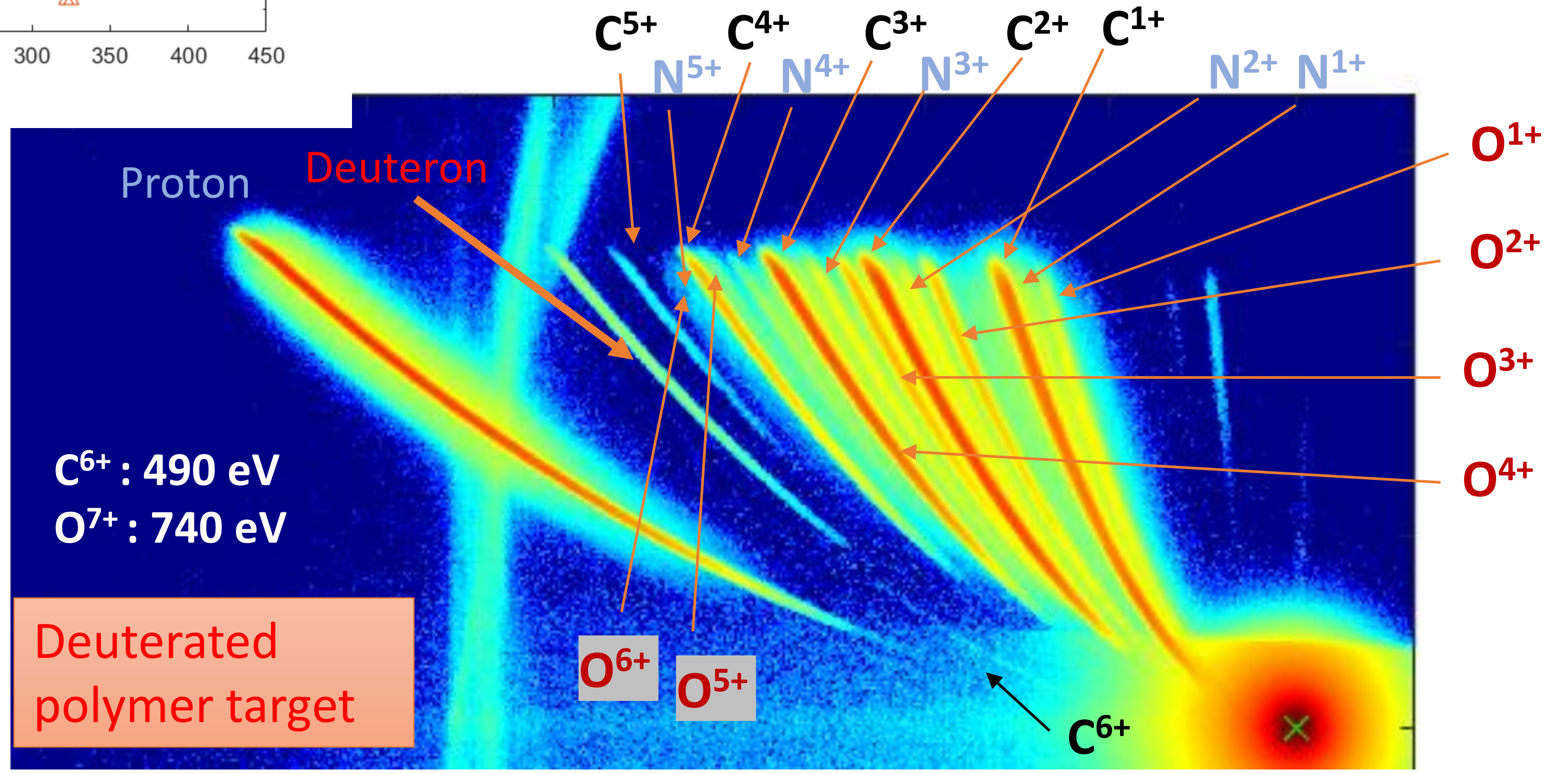
Shield

Experiment at ELI-ALPS with the setup of National Laser-Initiated Transmutation Laboratory



Polymer film with
resonant gold nanorods





Fusion fuels as laser targets: DD and pB reaction

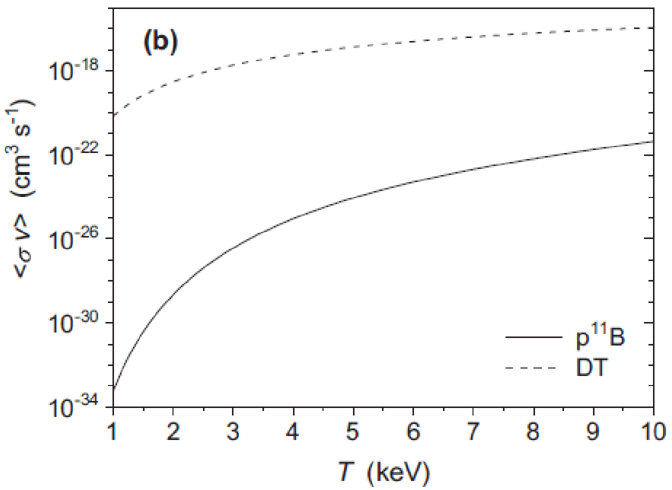
- Deuterium (not very rare: 0.0184–0.0026 %)
- Tritium (radioactive and very rare!)
- ^{3}Helium (rare, 0.0002 %)
- ^{6}Lithium and ^{7}Lithium (7.5/92.5 %)
- ^{11}Boron (80 %)

$$D + D \rightarrow \mathrm{T}(1\,\mathrm{MeV}) + p(3\,\mathrm{MeV})$$

$$D + D \rightarrow {}^{3}_{2}\mathrm{He}(0.8\,\mathrm{MeV}) + n(2.4\,\mathrm{MeV})$$

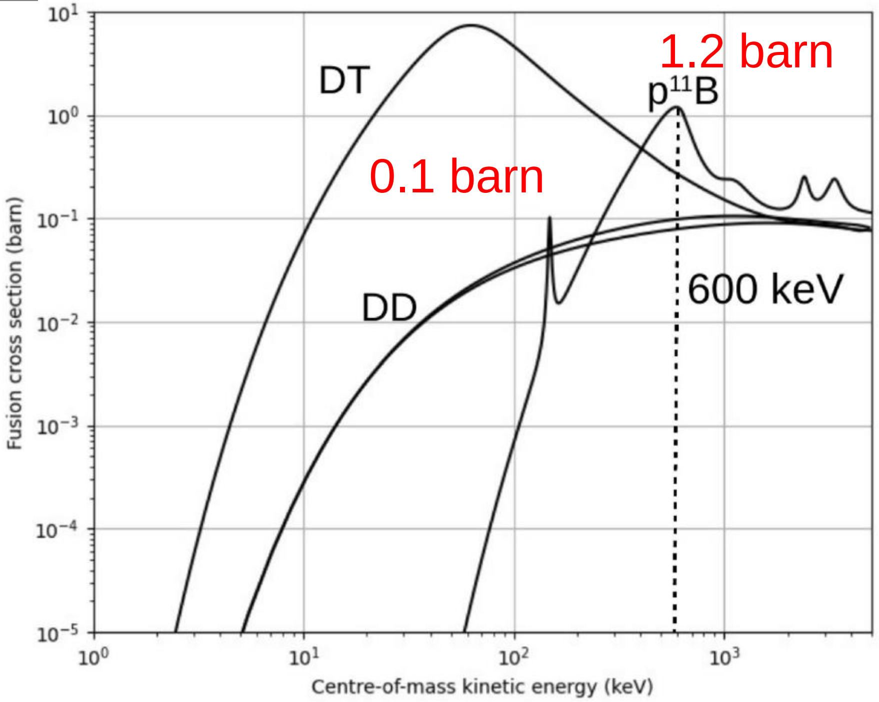
$$p + {}^{11}_{5}\mathrm{B} \rightarrow 3\alpha(8.68\,\mathrm{MeV})$$

LORENZO GIUFFRIDA *et al.* PHYSICAL REVIEW E **101**, 013204 (2020).

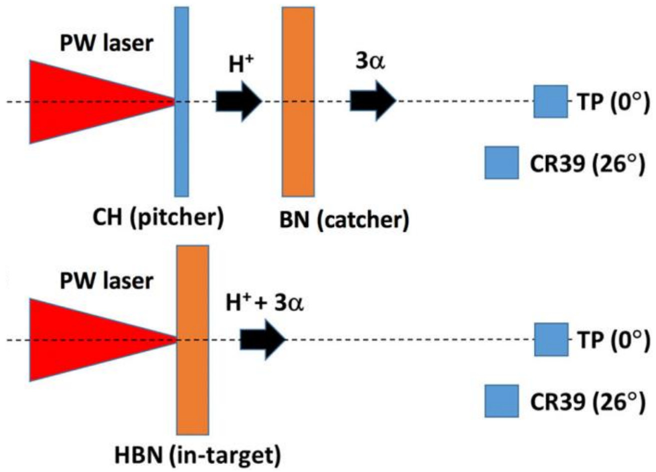


Low-temperature reactivity for pB and DT fusion.

X. Ribeyre et al. Scientific Reports 12:4665 (2022).



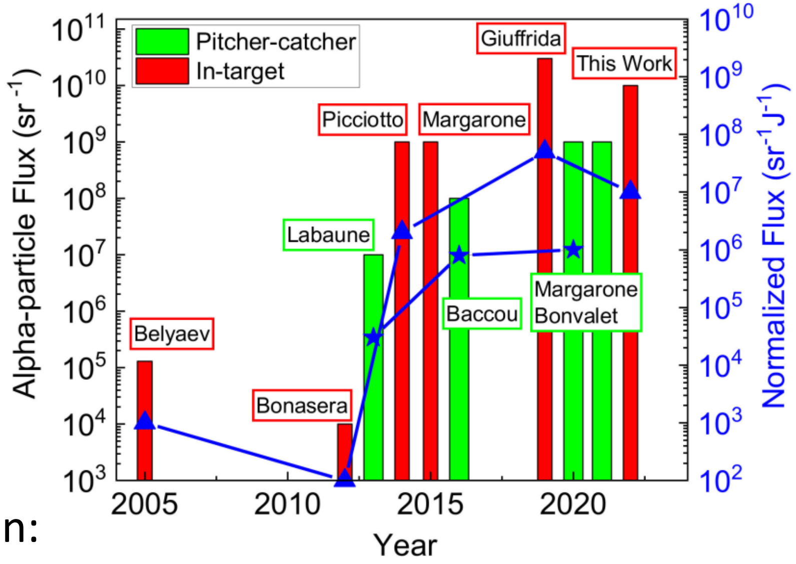
Two experimental geometries:



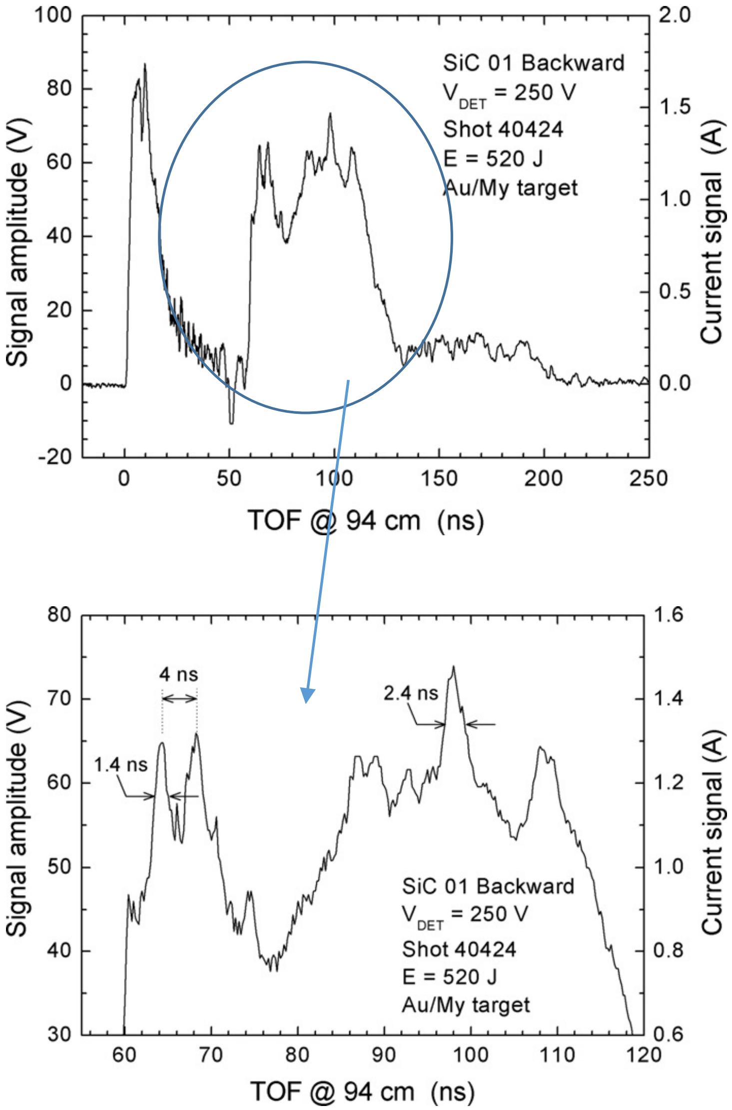
D. Margarone et al. Front. Phys. 8:343 (2020).

D. Margarone et al. Appl. Sci. 2022, 12, 1444.

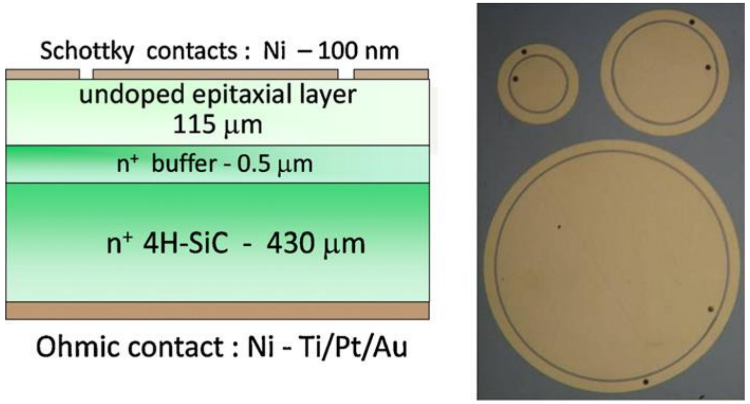
Progress in pB fusion:



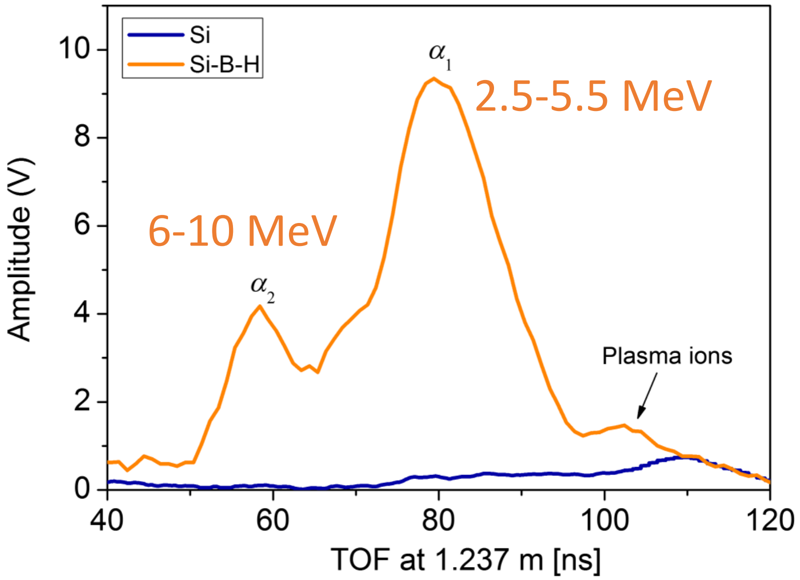
Time-of-flight detector: alpha particle spectra in pB fusion



Giuseppe Bertuccioa et al. Applied Surface Science 272 (2013) 128– 131



Section of the SiC detectors.



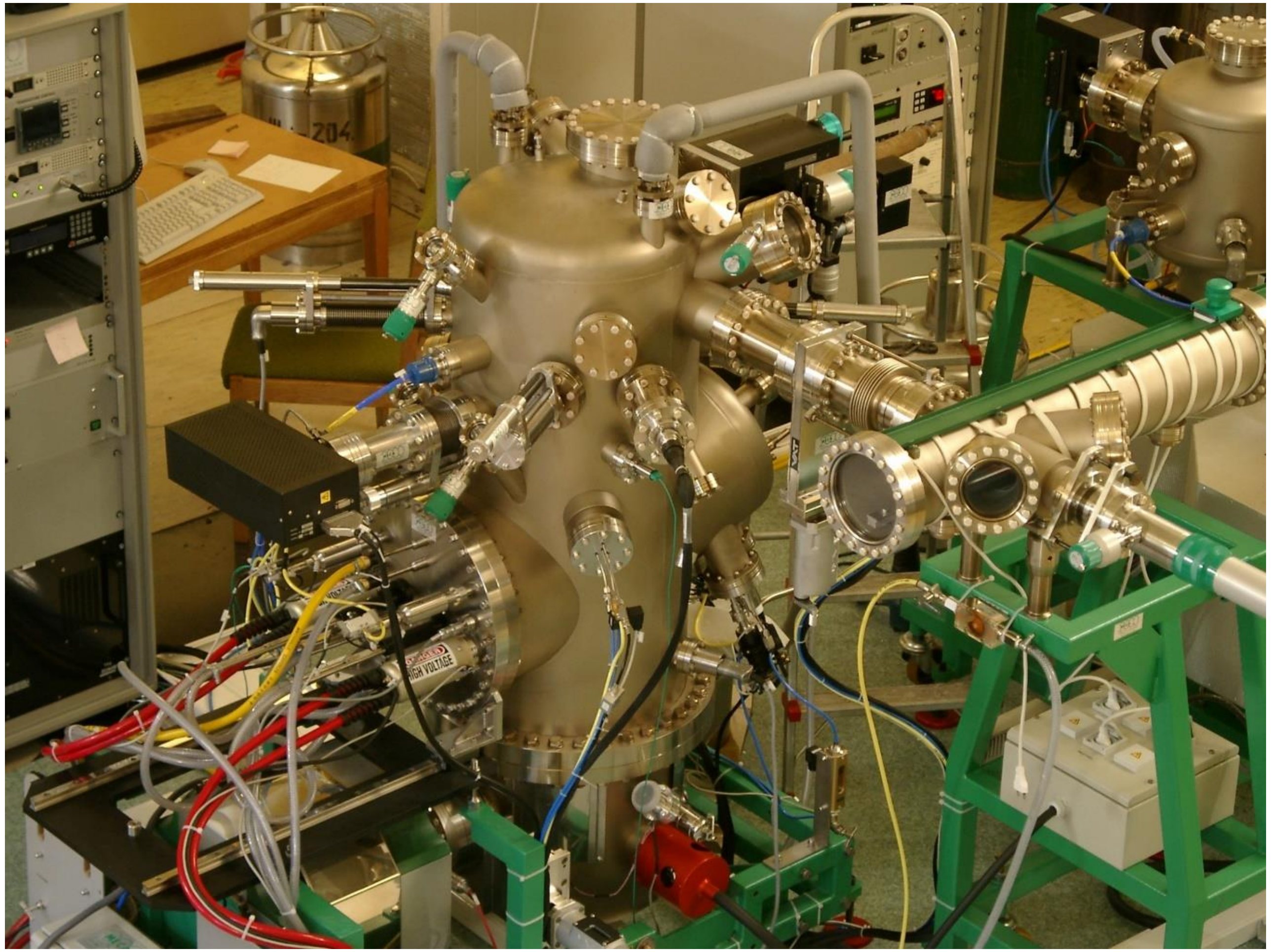
Ion TOF distribution for the Si-H-B target (orange curve) with the alpha-particle signal (α1 and α2) and plasma ions measured by the SiC detector covered by a 8-µm aluminum foil.

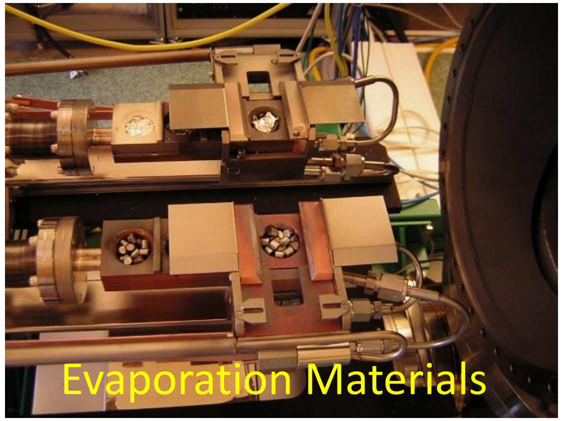
A. Picciotto et al. PHYSICAL REVIEW X 4, 031030 (2014).

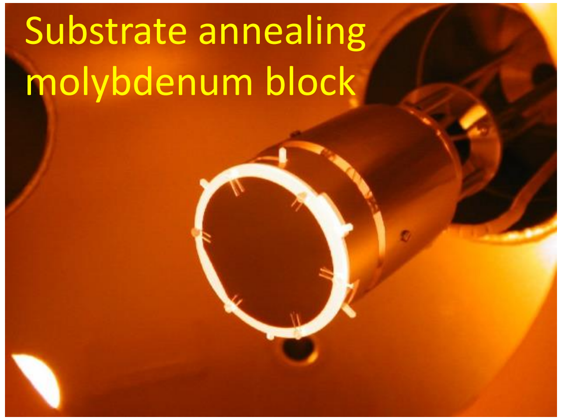
Our TOF detector system is under construction.

Metallic MBE (molecular beam epitaxy)

By Gergő Hegedűs, Dániel Merkel

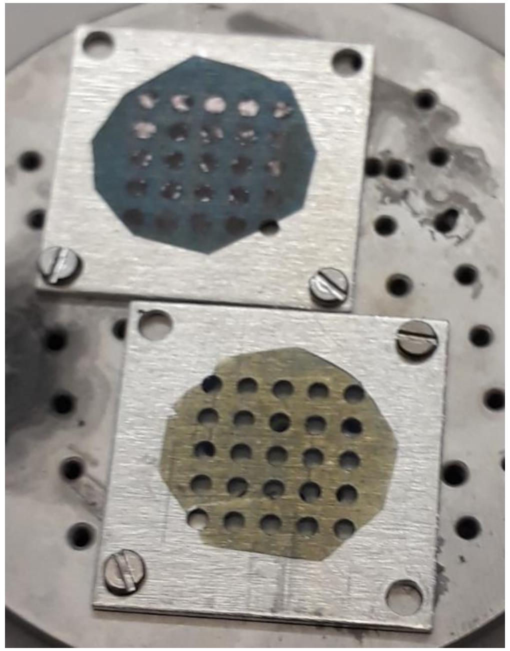


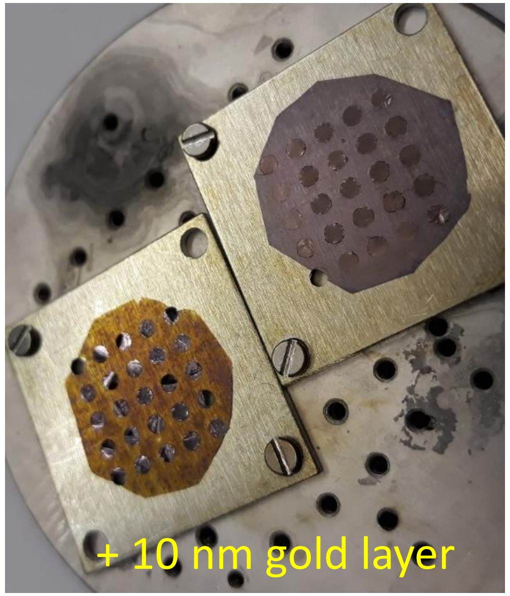




Carbon nanotube foil (~100 nm)

By Gergely Németh





Goals:

- boron layer evaporation to polymer foil
- Boron-polymer multilayers

Few 100 nm thickness of 1 layer

Thank you!