Laser-driven high repetition rate neutron sources at ELI-ALPS

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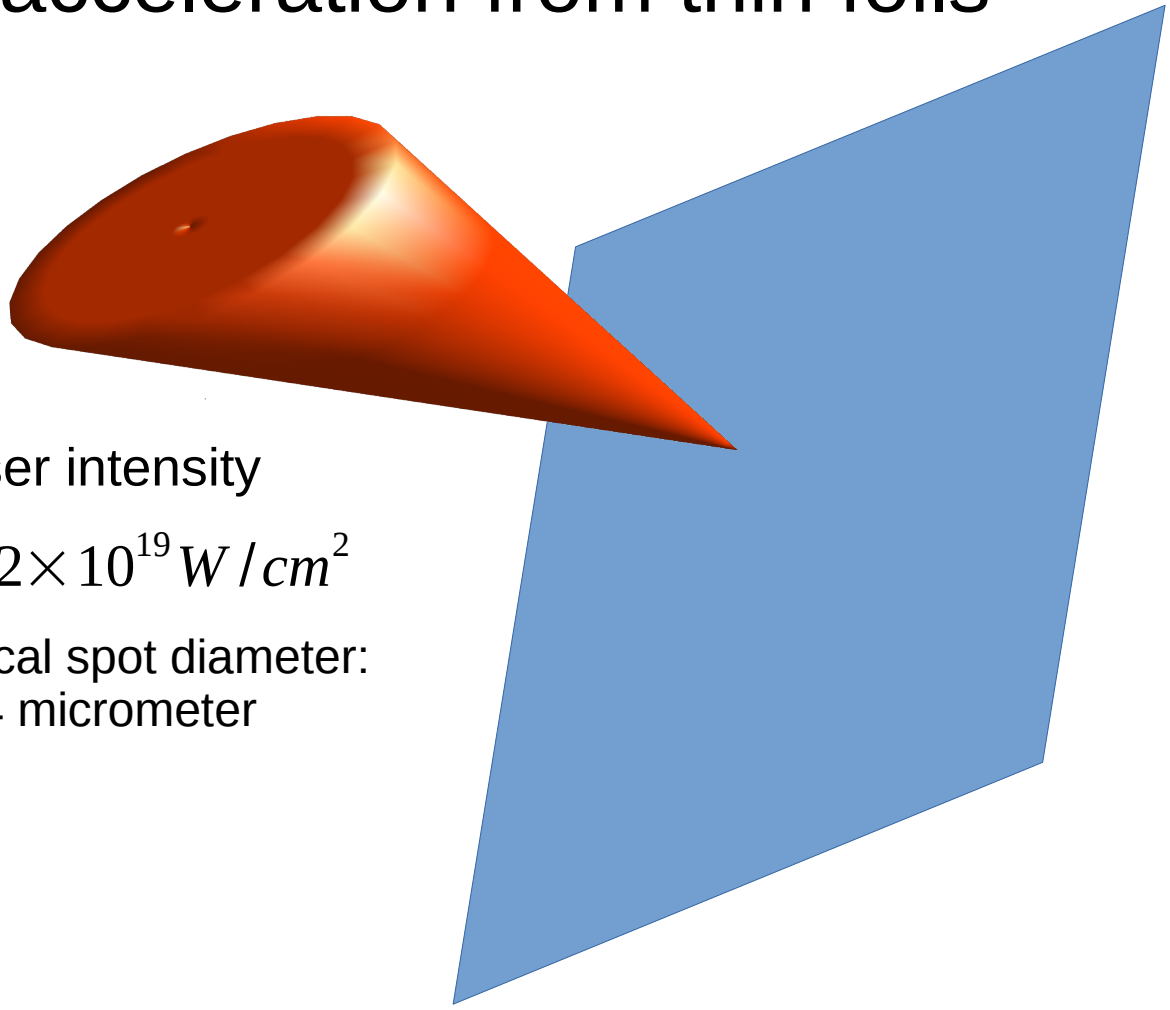
Institute: ELI-ALPS, Szeged, Hungary

Experience: Particle in Cell simulations, Numerical methods, data analysis, laser-matter interaction at ultra-high intensities, strong field and attosecond science

Research areas: laser-driven ion and electron acceleration, surface high harmonic generation, high field phenomena in plasma

Ion acceleration from thin foils



Foil: 0.1-1 micron thick Aluminum

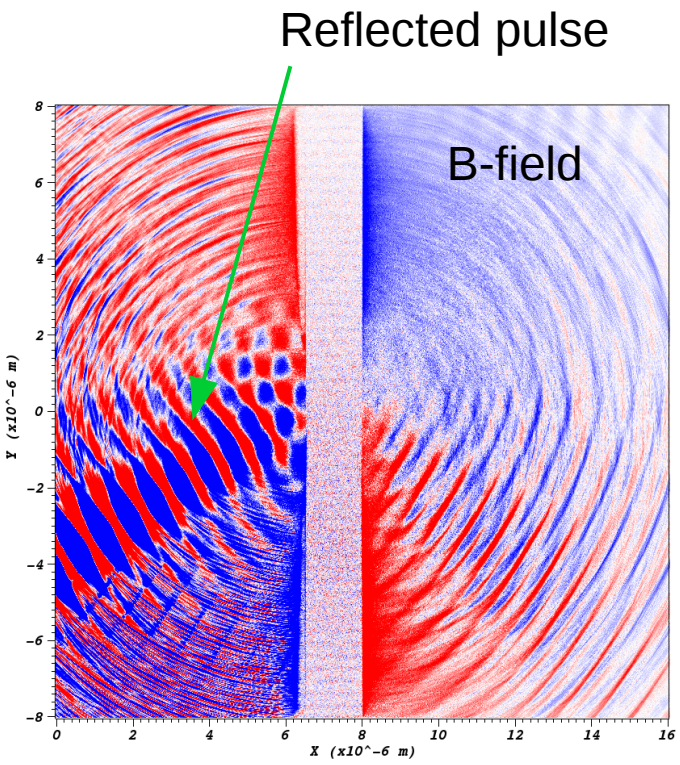
Laser intensity

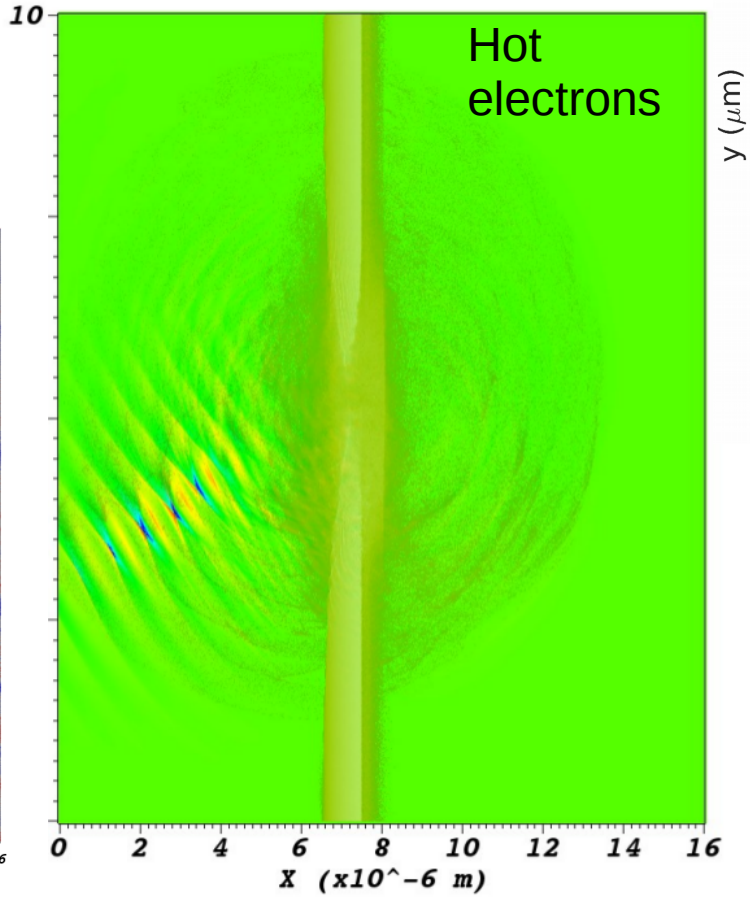
$$2\times 10^{19} W/cm^2$$

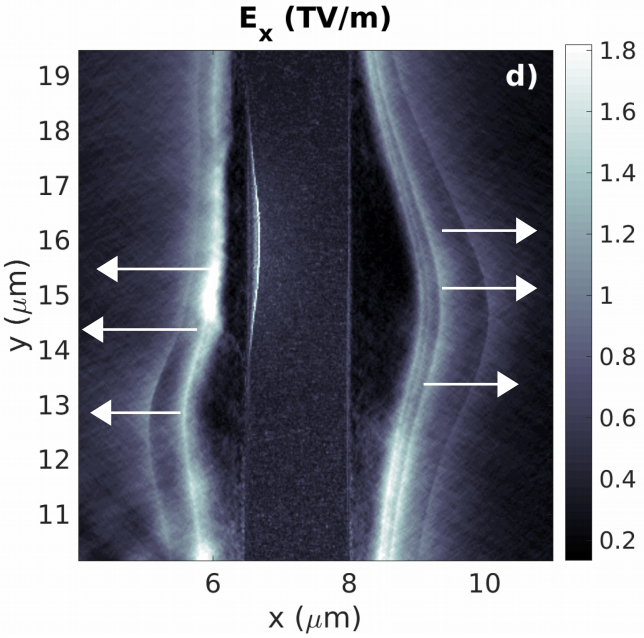
Focal spot diameter:
~ 4 micrometer

On the target surface there is always a thin (~ 5 nm) contaminant layer mainly consisting of carbon, oxygen and hydrogen

Interaction







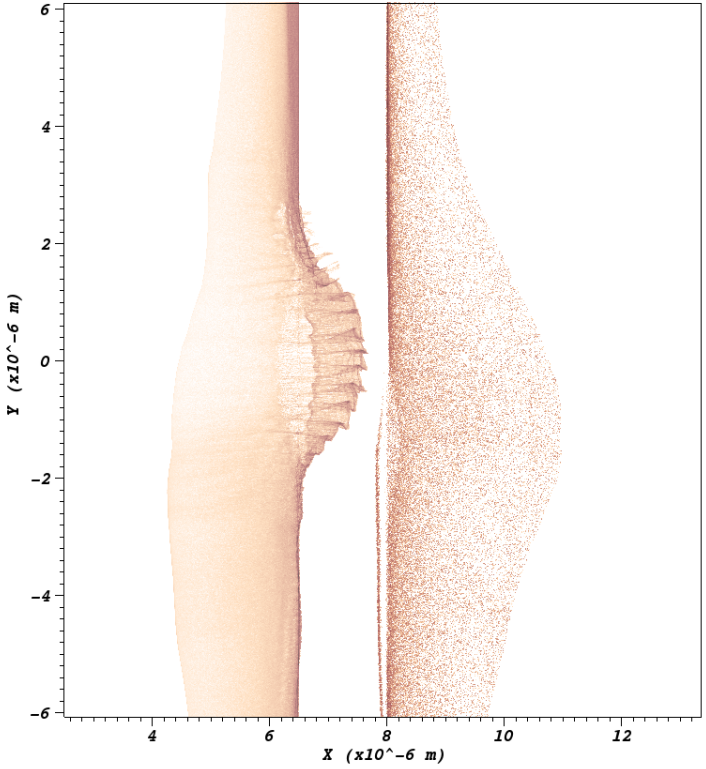
Accelerating field

Ion distributions

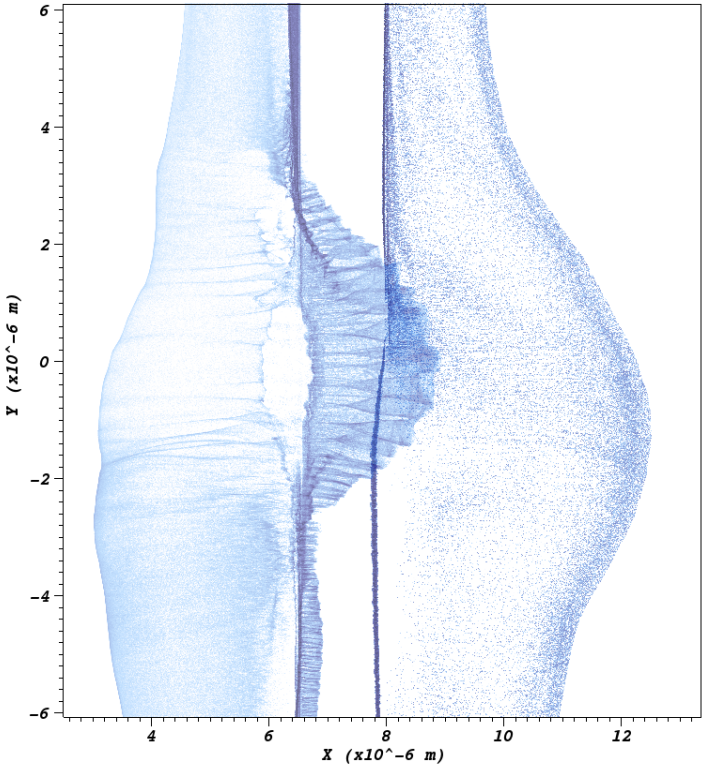
t=165 fs

Maximum energy ~MeV

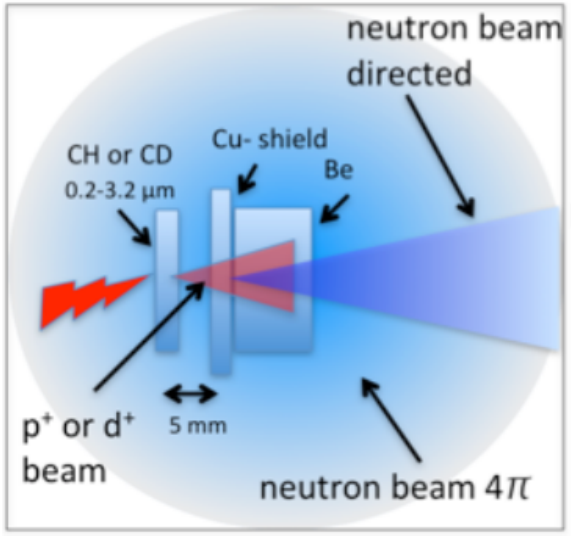
Carbons (6+)



Protons



Neutron production



M. Roth et al., Phys Rev Lett **110**, 044802 (2013)

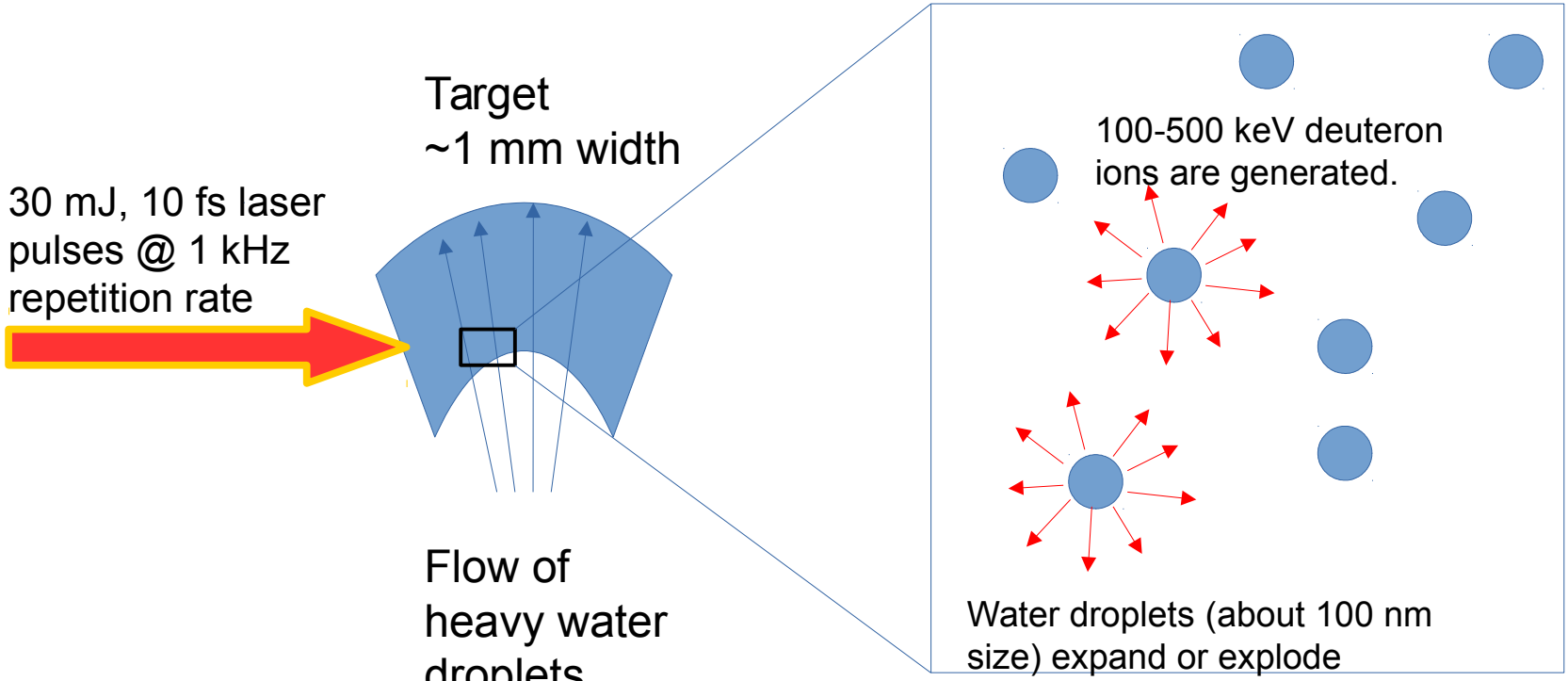
This is a two stage process:

1. Accelerate ions (deuterium)
2. Collide them with another target containing neutron-rich atoms

We would like to do it in one stage...

<u>First step:</u> understand what are the capabilities of SYLOS 2 laser at ELI-ALPS. Now we use Aluminum foils to accelerate protons.

Laser-based neutron source: concept 1



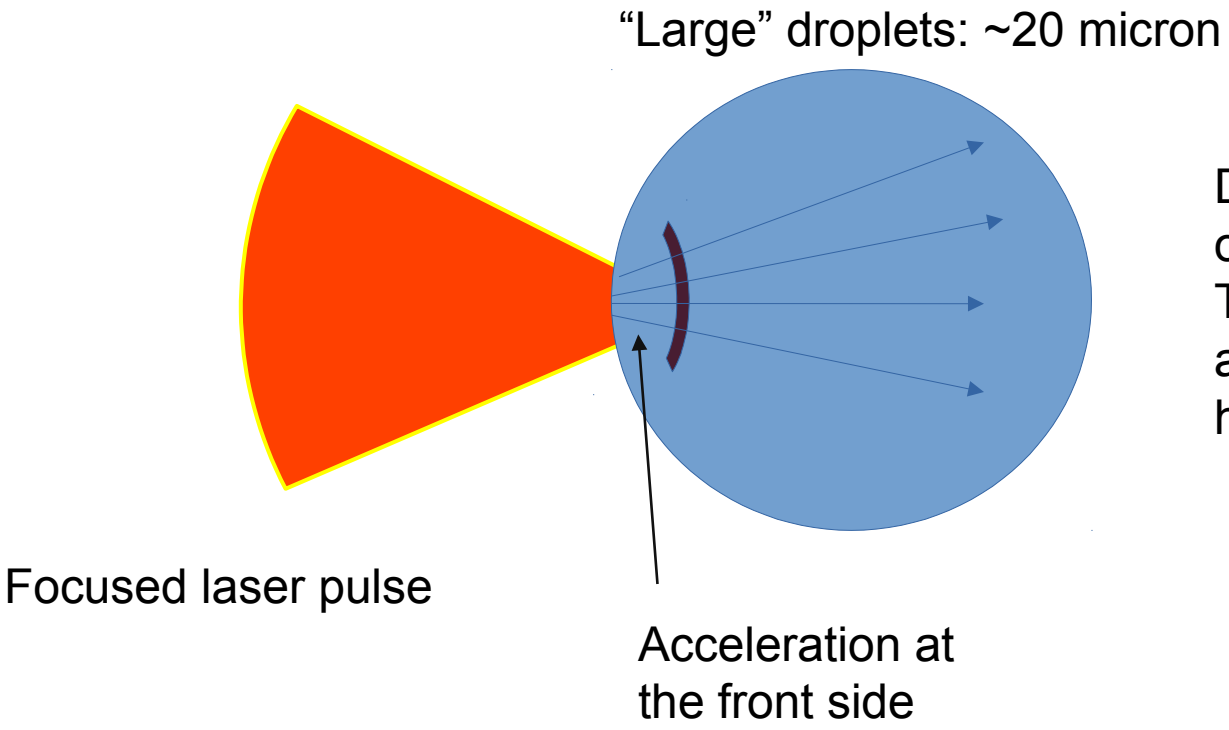
Expectation:
10-100 neutrons/shot

10^6-10^7 neutrons/sec

Isotropic, spherical emission at 2.45 MeV energy

Reaction: D(1,2)+D(1,2)=He(2,3)+n

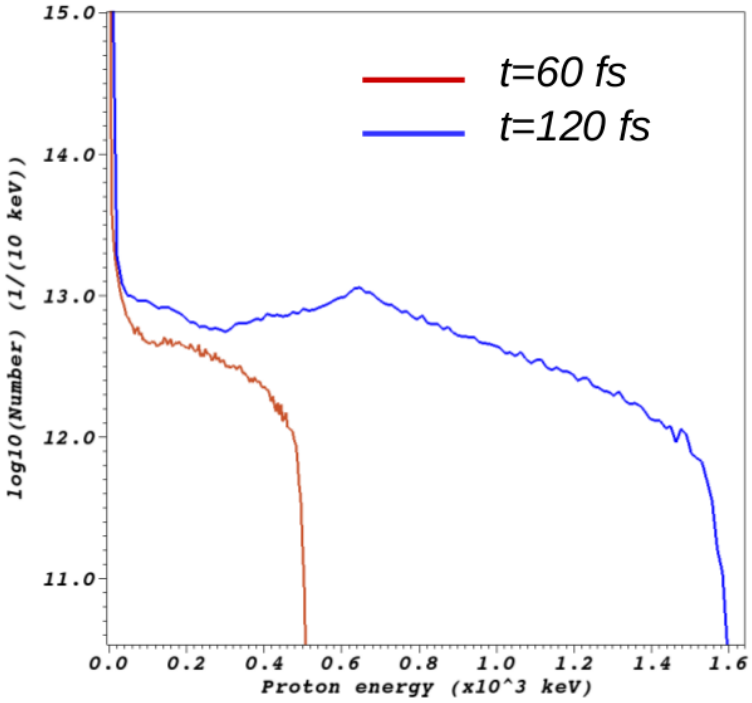
Laser-based neutron source: concept 2



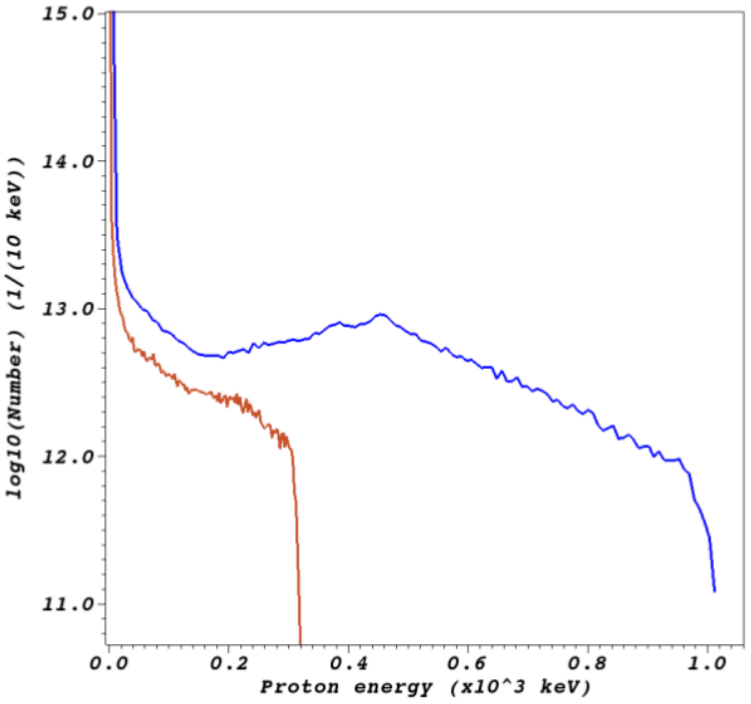
Deuteron ions collide with other ions inside the droplet. The fast ions have smaller angular spread, therefore higher density.

Typical ion spectrum (aluminum foil)

Longer preplasma (400 nm)



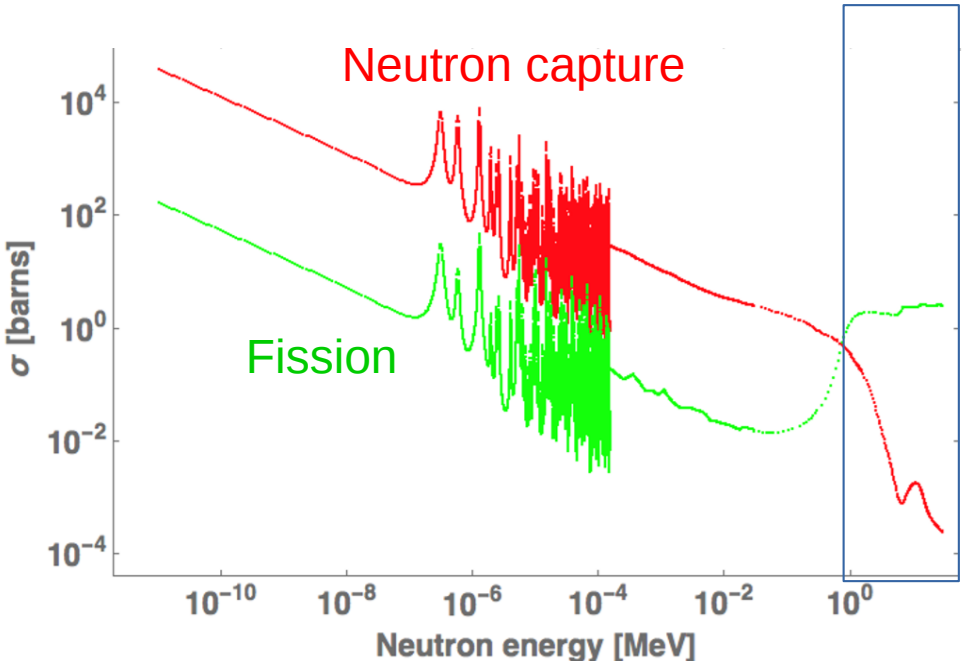
shorter preplasma (200 nm)



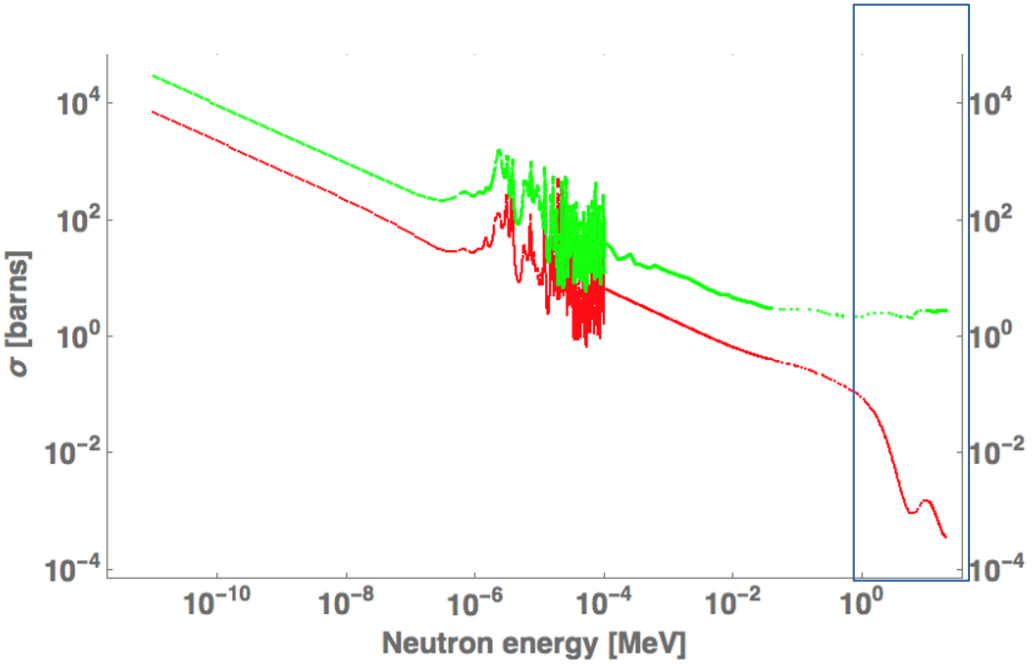
In experiments similar spectra are obtained, cut-off at ~1 MeV

Transmutation:

Americium

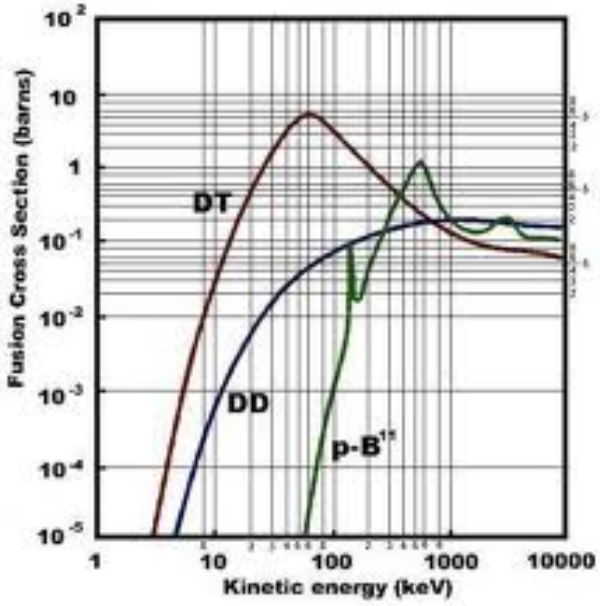


Curium



Many nuclear waste materials undergo fission if the neutron energy is higher than MeV, thus the long lifetime radioactive species transform into something more safe!

Deuterium reactivity



$$1\,barn = 10^{-28}\,m^2$$

$$\frac{df}{dt} = N_i\, n_t\, \sigma\, v$$

N_i – number of accelerated ions

n_t – atomic density of the target

$v = \sqrt{2E/m_i}$

$$n_t = 6 \cdot 10^{28}\,m^{-3}$$

$$N_i = 10^9$$

$$\sigma = 10^{-29}$$

$$v \approx 7 \cdot 10^6\,m/s$$

→ 4000 neutrons/picosecond
OR
Neutrons/10 micron

Several million neutrons can be produced with 1 cm thick target / shot
<u>10^10 neutrons per second</u>