Time of Flight of Neutrons Produced in Reactions Driven by Laser-Target Interactions at Petawatt level

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Plasma

Plasma is often regarded as the fourth state of matter. In fact, over 99 % of the matter in the Universe is in this state. Plasma is described as a partially or fully ionized gas in which ions and free electrons are moving. The concentration of the ions and the free electrons is nearly equal ($n_i \approx n_e$). Because of this condition, plasma is regarded as quasi-neutral [1, 2].

The properties of plasmas provoke interest and a lot of applications are developed in order to use their specific characteristics. An important application is based on the use of the strong fields for acceleration of charged particles [3].

Target Normal Sheath Acceleration (TNSA)

The acceleration mechanisms based on the use of lasers and plasmas have different properties compared to the conventional acceleration systems.

An important laser-driven method is the Target Normal Sheath Acceleration (TNSA). In TNSA a laser beam with a high intensity is focused on a thin target. Protons from the rear side of the target are accelerated [3]. The Target Normal Sheath Acceleration allows the use of cheap and easy to produce targets.

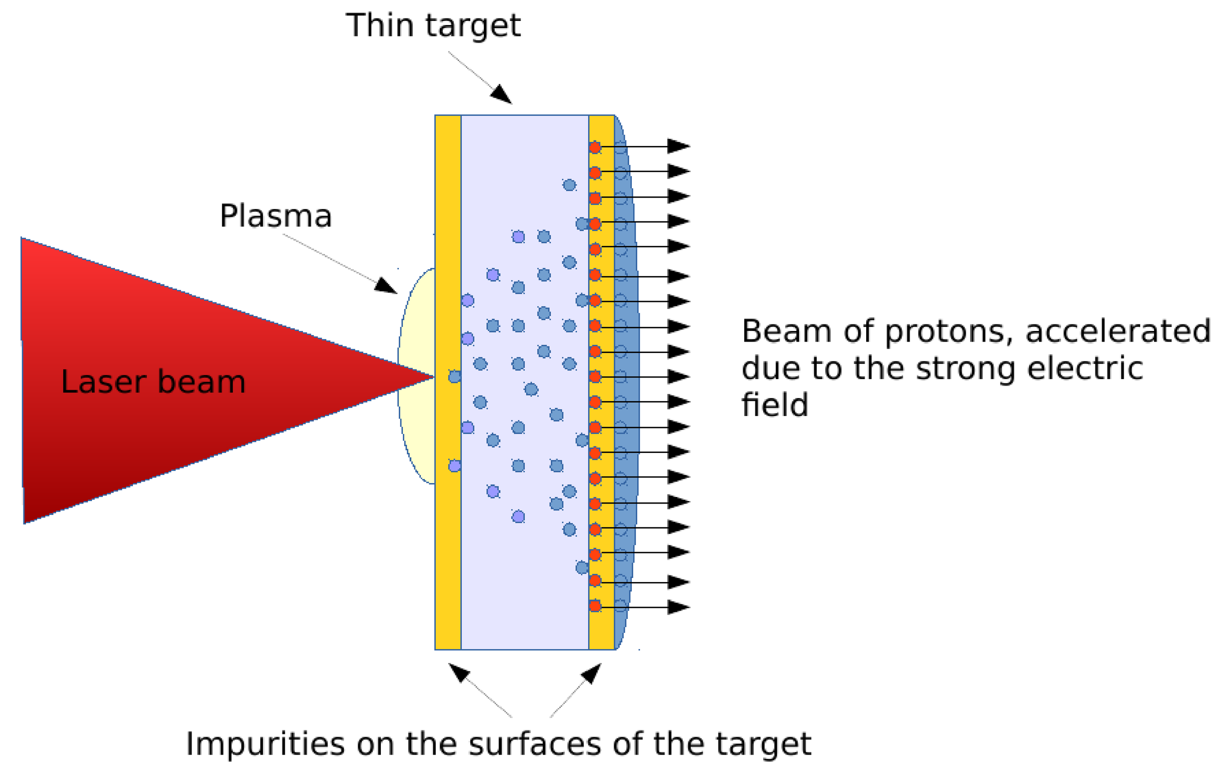

Figure 1: Schematic representation of the Target Normal Sheath Acceleration (TNSA).

Focusing of protons and generation of neutrons

An intense short pulse of protons ($\sim 10^{12}$ particles) with energies in the MeV region can be produced using the TNSA mechanism. Protons with a particular energy can be selected and focused using different methods. The microlens technique is presented on Fig. 2 [4].

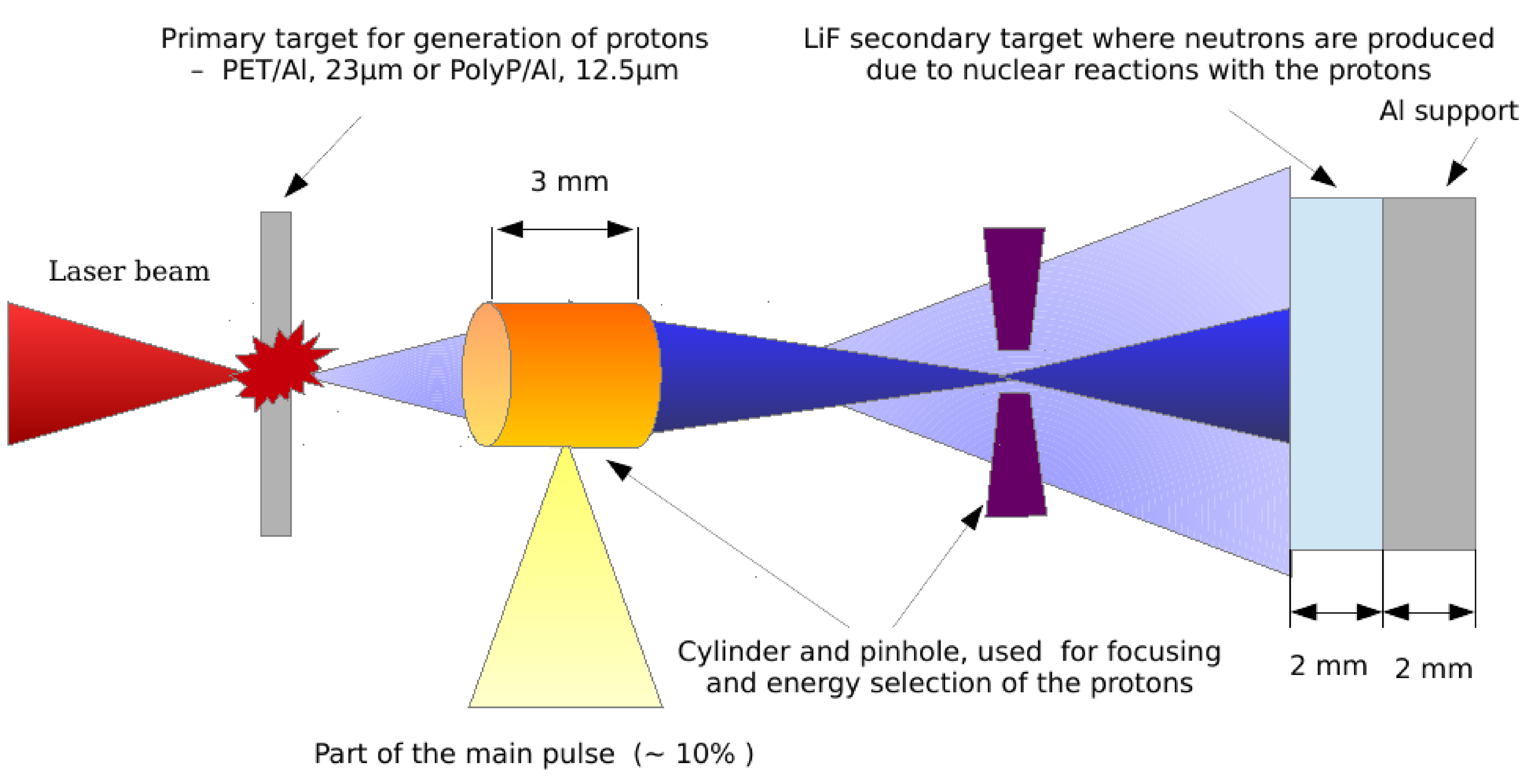

Figure 2: The microlens technique for focusing and selecting protons with particular energy.

The protons can be further directed to a secondary target where neutrons are produced due to nuclear reactions.

Experimental setup

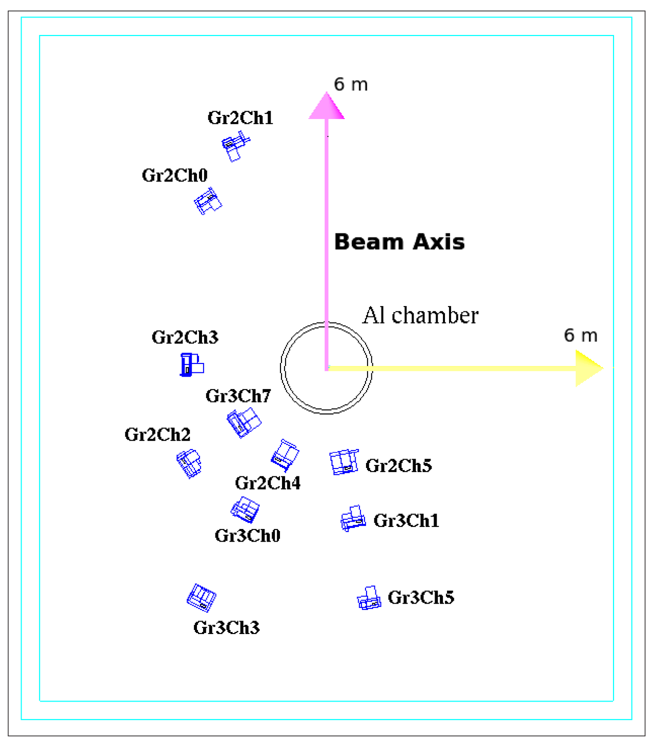

Figure 3: Configuration of the neutron detection setup including plastic scintillators BC-400 and their Pb shielding.

In order to study neutrons generated by the presented mechanism an experiment was performed at the Lawrence Livermore National Laboratory (LLNL), USA [5]. The properties of the laser that was used are:

- λ=1054 nm;
- 0.65 ps duration of the laser pulse;
- maximum power up to 1 PW;
- intensity of order of $\sim 10^{19}$-10^{20} W/cm^2.

Plastic scintillators BC-400 were used for detection of the neutrons. Pb bricks were placed around the detectors because of the sensitivity of the scintillators to X-rays and γ-rays.

Experimental results for the nTOF

The time of flight of the neutrons produced in the secondary target (nTOF) was measured. The waveforms of the signals corresponding to the neutron detection events were digitized and recorded.

Procedures for aligning the different detectors in time were performed.

A background subtraction was applied using data from shots in which the secondary target was removed (Fig. 4) [6].

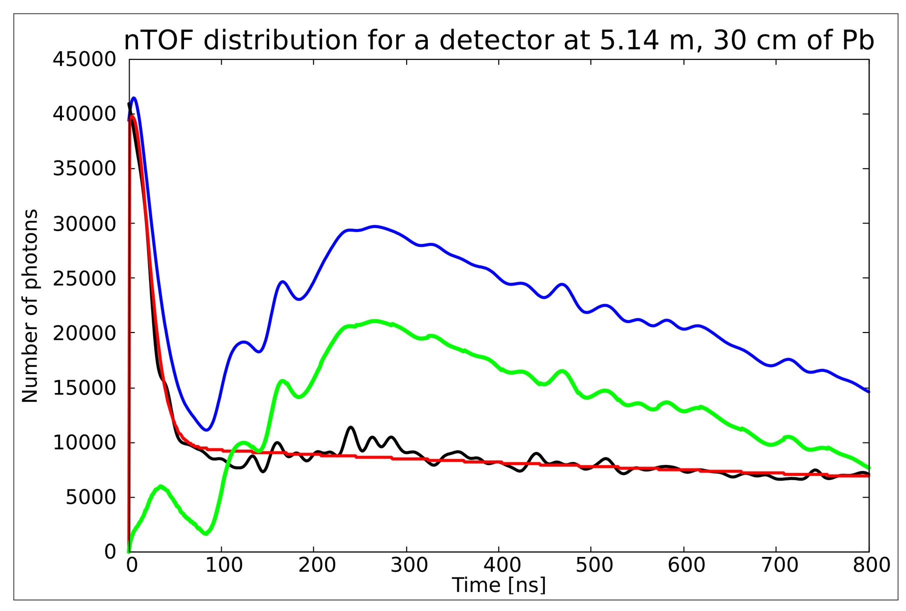

Figure 4: Time of flight of the detected neutrons in detector Gr3Ch5.

Simulations of the experimental conditions

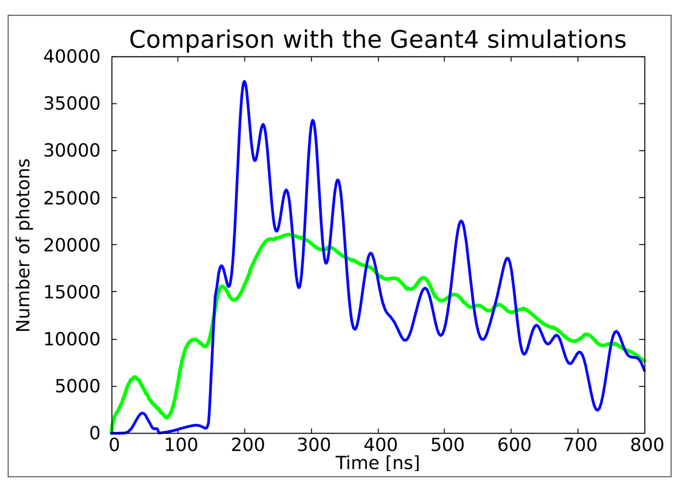

Figure 5: Comparison of the experimental and simulated nTOF for detector Gr3Ch5.

The experimental conditions were simulated using the Geant4 toolkit [7]. The nTOF was studied in different configurations of the experimental setup and neutron energy distributions (Fig. 5) [6]. The different components of the setup were successively added and their impact on the nTOF was studied. The scattering of neutrons from the Pb shielding was found to have a significant effect on the nTOF.

Conclusion

The preliminary results show a good agreement between the experimental and the simulated nTOF for detectors at large distances from the laser interaction chamber.

Acknowledgments

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