Neutron Production in a Laser Plasma Generated by a 200 mJ/160 fs CPA Laser System (MPQ ATLAS) ◇

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The rapid development of chirped-pulse-amplification (CPA) Ti:Sapphire lasers (pulse duration of about 100 fs) with energies in the range of several 100 mJ has just recently made the field of relativistic laser plasmas accessible to table top experiments. At focal intensities exceeding 10^{18}W/cm^2 electrons gain relativistic energies within one oscillation period of the light wave and are predominantly accelerated in forward direction by the $v \times B$ term, forming a jet of relativistic electrons stabilized by the self generated surrounding magnetic field of up to 100 MG. This effect strongly supports relativistic self-focusing of the laser beam in an underdense (optically transparent) plasma originating from the growth of the index of refraction with increasing electron mass and decreasing density. The key result then is the creation of a single narrow (1-2 wavelength λ) but elongated (several 10 λ) light propagation channel [1] accompanied by the relativistic electron jet. Since energies up to many MeV and currents of several 10 kA are predicted, this jet is an attractive source for nuclear physics like in the production of high energy Bremsstrahlung as well as a promising tool in inertial confinement fusion (ICF) as the so called fast igniter.

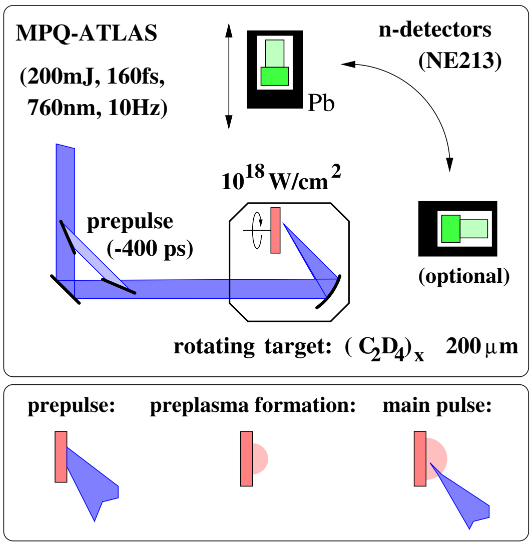

Fig. 1: Experimental setup used at the 1TW laser ATLAS (MPQ) for the production of fusion neutrons schematically also showing the crucial formation of an underdense preplasma.

Moreover since the vast majority of the fast electrons immediately leaves the channel region, it drives a flow of energetic ions outwards (100 keV region for d$^+$) mainly due to space charge repulsion, which can also be directly used to trigger nuclear reactions. The reported observation of fusion neutrons [2] produced in a non-thermal deuterium laser plasma via the reaction d(d,n)^{3}He therefore fortifies the above scenario gained from PIC simulations [1].

The experiment was performed at the 1TW CPA ATLAS system of the MPQ Garching, as depicted in fig. 1. The use of a well defined underdense preplasma, generated with a fraction of the original laser beam, allows the formation of the super channel and proved to be absolutely crucial for the neutron production. To clearly distinguish the 2.45 MeV neutron signal in the scintillation detector (20 cm lead shielding) from the omnipresent γ-background we simply used a time-of-flight method triggered by the laser pulse and varying the detector distance as shown in fig 2. The additional weak presence of low energy neutrons can be quantitatively understood including scattering in the surrounding material. The overall neutron yield amounted to about 140 neutrons per shot, being in reasonable agreement with estimations based on the d$^+$ energy distribution extracted from dedicated PIC simulations (VLPL3D) and the independently calculated (MULTI-fs) density of the preplasma [2].

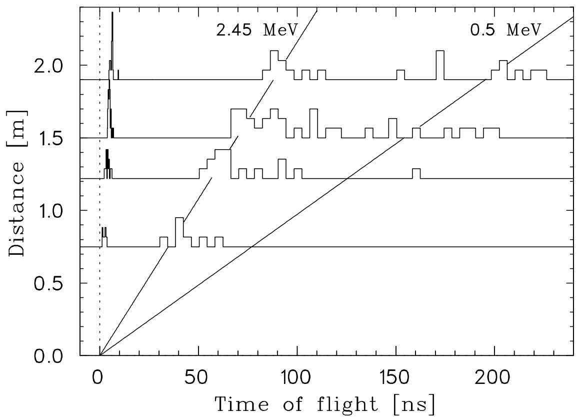

Fig. 2: Temporal distribution of γ- and n-events recorded at four different distances from the target. To discriminate against the strong γ-background (pile-up for each laser shot) only events containing a non γ-signal are evaluated (about one out of 40 shots at 1.9 m distance), clearly indicating the mono-energetic signature of the 2.45 MeV d(d,n)^{3}He fusion neutrons.

So far limited by the time resolution of our NE213 detectors (10 cm thick, therefore about 5 ns) we currently improve this fact to below 1 ns implementing several thin BC404 scintillators. Future objectives are the measurement of the angular distribution of the neutrons (in particular for higher laser power) and the determination of the original deuteron energy distribution inside the plasma. Furthermore we started to investigate the strong Bremsstrahlung γ-ray emission with NaJ scintillators as well as the supra-thermal electron distribution [3].

References

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