FUSION_INFN_V°

FUsion StudIes of prOton boron Neutronless reaction in laser-generated plasma

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ABSTRACT

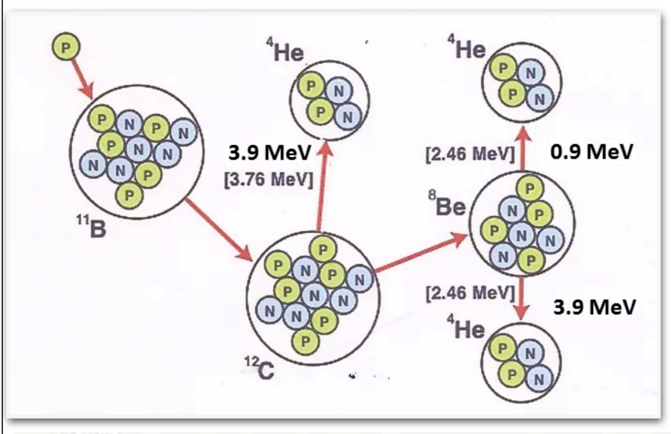
The conventional route of nuclear fusion for power generation is today mainly based on the reaction between deuterium and tritium nuclei, which yields one α-particle and one neutron. Formidable technological challenges, however, stem from the production and handling of tritium, as well as from the radiation damage and induced radioactivity by high-energy neutrons in the reactor. In this respect, the nuclear reaction between a proton and a^{11}B nucleus (p^{11}B fusion) yielding three energetic α-particles is very attractive, as it only involves abundant and stable isotopes in the reactants and no neutrons in the reaction products. The three α-particles generated from p^{11}B present, in the conventional nuclear scheme, a broad energy spectrum that peaks around 4 MeV.

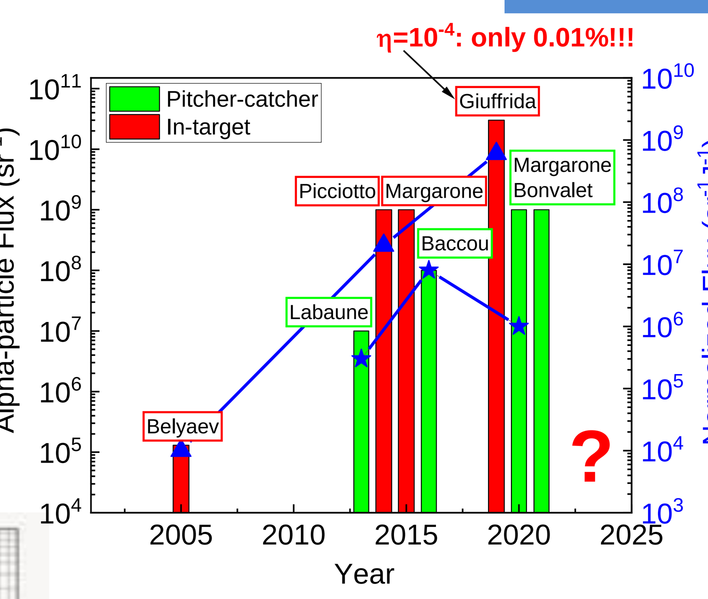
In the last 15 years, p^{11}B fusion has been effectively induced by means of high-power lasers. In this case, an impressive and not yet explained progression in the reaction yield has been observed to the extent that the reaction has become of interest to the energy sector, where it is being considered as an alternative approach to conventional inertial confinement fusion schemes. The chance to optimize the p^{11}B reaction producing intense α-particles streams in a compact, and potentially economic way, could also open the path for the realization of future table-top sources to be used in medical (i.e. radioisotopes production) and multidisciplinary applications. At present, an extensive systematic investigation of laser-based p^{11}B fusion, aimed at a better and deeper understanding of the underpinning physics of the nuclear reaction in plasma, is still missing. Parallel progresses in target optimization, in order to maximize the reaction rate and, hence, the generated alphas yield, as well as in reaction product diagnostic, are also essential. The FUSION project aims at realizing a new generation of solid targets, allowing for a more efficient in-plasma p^{11}B fusion reactions, to design new approaches and realize optimized detectors designed for a more accurate measure of the reaction products, to estimate alpha and proton cross-sections in the plasma environment to better understand the involved physics processes and, finally, to carry out a new class of in-plasma p11B fusion experiments based on nanosecond and femtosecond high repetition rate laser system. In FUSION, innovative targets will be developed (WP3) and simulated (WP4); new dedicated diagnostic systems will be realized (WP5) while N°3bspecific measurements of conventional proton beams interactions with Boron plasma state will be carried out to better understand the whole process (WP2). Three experimental campaigns dedicated to the study of the p^{11}B reaction in plasma with the developed targets and employing the implemented diagnostic will be coordinated by the WP1.

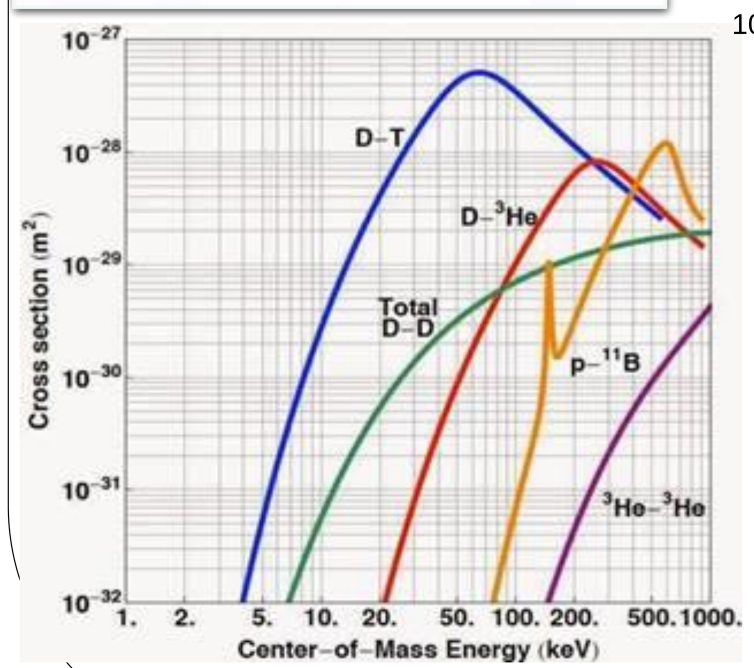
A better understanding of the p^{11}B reaction and its optimization, in terms of alpha yield maximization, also with the new generation of high-repetition-rate laser systems, are the main goals of FUSION project.

Why the p-^{11}B fusion reaction?

M.Oliphant, L.Rutherford, Proc. R. Soc. London A 141 259 (1933)





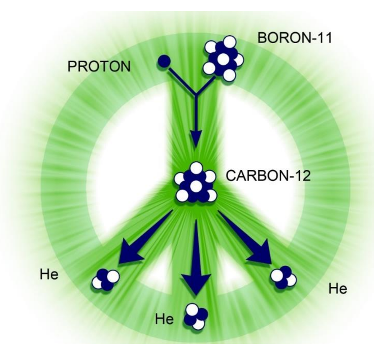


$$\mathrm{p}(^{11}\mathrm{B},\alpha)^8\mathrm{Be}$$

$$^{11}\mathrm{B} + p \rightarrow \alpha_0 + {}^8\mathrm{Be} + 8.586\ \mathrm{MeV},$$

$$^{11}\mathrm{B} + p \rightarrow \alpha_1 + {}^8\mathrm{Be}^* + 5.65\ \mathrm{MeV},$$

$$^8\mathrm{Be}^* \rightarrow \alpha_{12} + \alpha_{12} + 3.028\ \mathrm{MeV}.$$



- **Neutronless** fusion reactions
- Two resonance at **148 keV** and **580 keV** in the system center of mass
- It is considered as a **potential candidate** in inertial fusion scheme
- Reagents **more abundant in nature** with respect to other fusion reactions of interest, and easier to handle (with respect to tritium, for example)
- Interest for the realisation of intense **α sources** for applications

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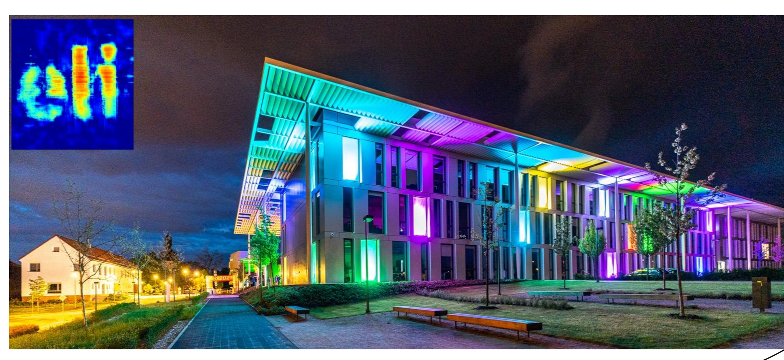
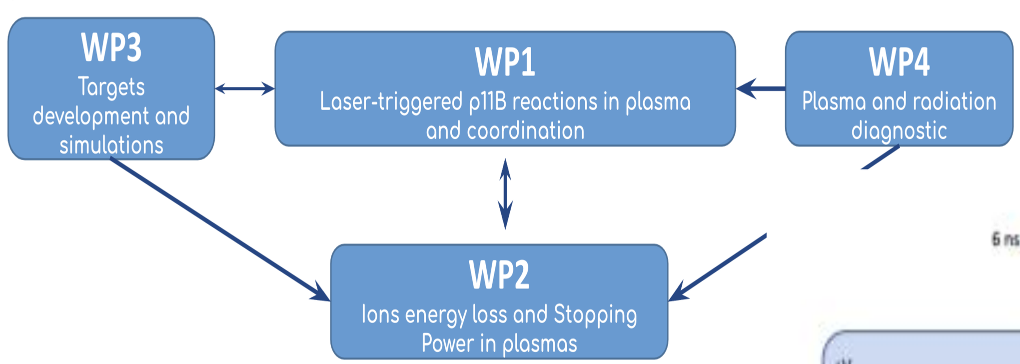
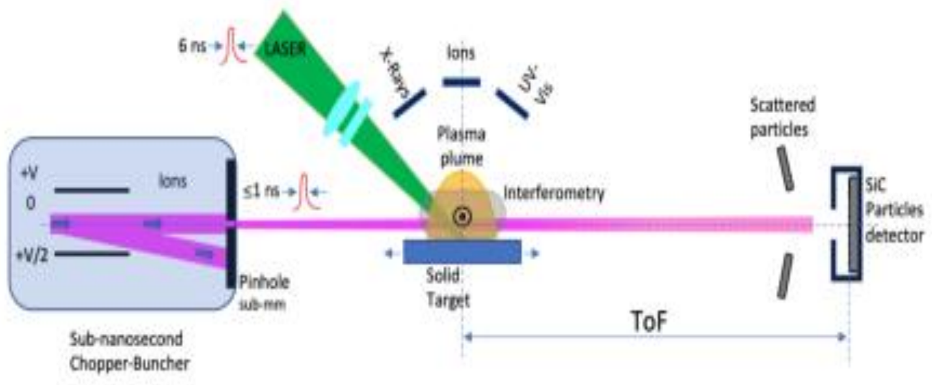
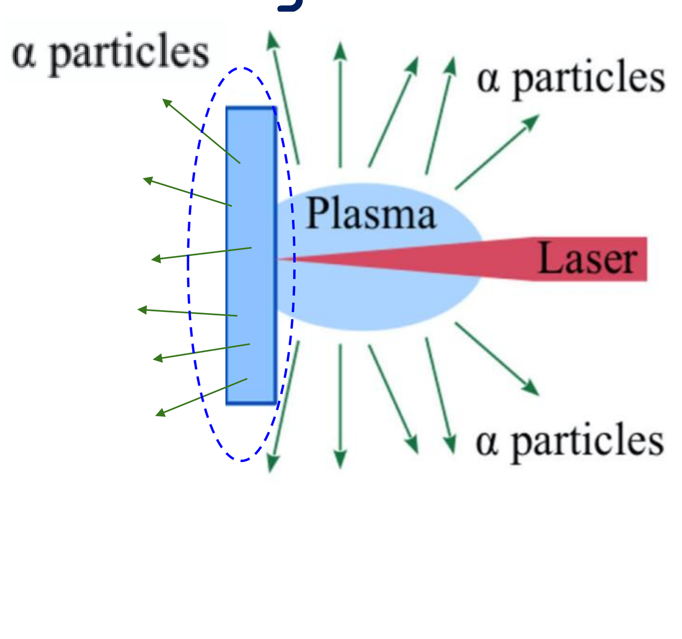


FUSION: an INFN project to study the p-^{11}B fusion reaction

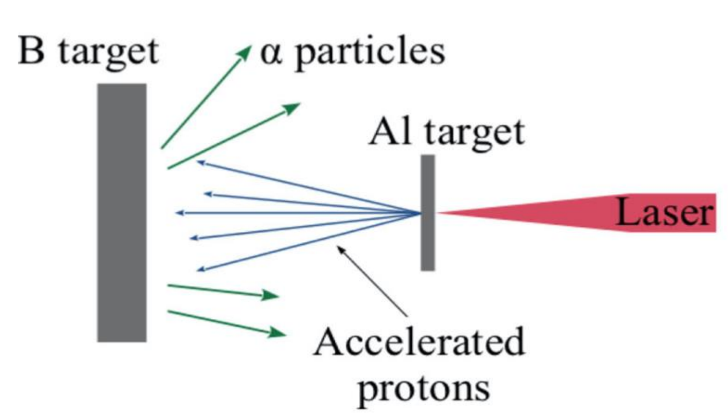




In-target scheme



Pitcher-catcher



FUSION Project Objectives:

- New targets, diagnostics and irradiation schemes for p11B fusion reaction in plasma and in catcher configuration
- Protons and alphas stopping powers measurements in plasma
- PIC and hydrodynamic simulation to predict the emission

MNF MICRO NANO FACILITY

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- *Extended characterization of alpha particles via laser-induced p-11B fusion reaction in silicon hydrogenated boron-doped thin targets* Milluzzo, G ,Cirrone, G. Journal of Instrumentation, 2023, 18(7), C07022