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Editorial: Proton boron nuclear fusion: from energy production to medical applications

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Editorial on the Research Topic
Proton boron nuclear fusion: from energy production to medical applications

The pB11 fusion reaction is highly appealing for controlled nuclear fusion in energy production. It produces no neutrons in its main reaction, only three charged alpha particles, and it has an almost unlimited supply of reactants available on Earth for fuel. The pB11 fusion reaction is also attractive for creating high-intensity high-energy alpha sources to produce radioisotopes for medical applications. In the last decade there has been a large increase of research in that field [1, 2].

The pB11 fusion research community has recently been strengthened by a European Union COST program, PROBONO (CA21128 - Proton-Boron Nuclear Fusion: From Energy Production to Medical Applications), which supports the development of this research field [3].

In this Research Topic, Frontiers is publishing seven articles about pB11 nuclear fusion that investigate both LTE and non-LTE fusion scenarios.

1) Kim et al. performed 2D particle-in-cell (PIC) simulations, supplemented with analytical calculations and estimations, to evaluate the fusion energy efficiency in the case of an ultrashort laser pulse guided by a plasma channel filled with carbon–hydrogen (CH2) clusters. The laser-plasma interaction produces MeV protons generated by the Coulomb explosion (CE) of the clusters, interacting with the surrounding boron to produce alpha particles. A Bayesian optimization (BO) algorithm was used to identify the optimal cluster and laser parameters that would have higher fusion energy efficiency.
2) Ghorbanpour et al. calculations for pB fusion shows that implosion-driven formation of a hot spot is hydrodynamically impossible, indicating that fast ignition is possibly the only scheme to ignite inertially confined pB fuel. It was found that isochoric self-heating conditions foster favourable preliminary conclusions on the utilization of proton fast ignition. In this case, they found a broad minimum in the ignition energy at $\rho R \simeq 8.5\ g/cm^2$ and $220 \lesssim T_i \lesssim 340$ keV ($80 \lesssim T_e \lesssim 95$ keV), for B/p ratio of 0.15.

3) Nissim et al. calculated the proton-boron fusion induced by an external proton beam in a homogenous plasma of density and temperature of interest for laser driven experiments. To decrease the effect of the thermalization of the protons, non-neutral plasma was also considered in the calculation. In this case the relaxation rate of the protons and alphas is much lower and secondary fusion reactions can occur, leading to the desired avalanche effect.
4) Daponta et al. presents the calculation results of a self-consistent multi-fluid global particle and energy balance code, that includes collisions between all medium species. The calculations are used for describing the temporal evolution of all fusion medium physical parameters and the evaluation of the optimum initial conditions for the obtainment of $Q \geq 1$ for a pB plasma with $n = 10^{20}$ m^{-3} and $n_p/n_B > 1$ with and without additional energetic protons. The calculations show that for the investigated initial conditions, ignition can be achieved at temperatures as low as $T < 100$ keV due to chain reactions and the related avalanche alpha heating effect.
5) Kurilenkov et al. present the results of PIC simulations in the full electromagnetic code of the processes leading to the pB reactions in a single device for plasma confinement, based on miniature nanosecond vacuum discharge (NVD) in a cylindrical geometry. The results of the PiC simulations show that the number of the proton-boron reactions at the anode space of the NVD increases with the anode volume, and that the α particles output turns out to be proportional to the value of anode radius in the range $R_A \approx 0.1$–0.5 cm. Furthermore, the formation of a more voluminous potential well with well–defined oscillations of protons and boron ions in it, provides a noticeable increase in the output of α particles.
6) Lavell et al. presents PIC simulations with Monte Carlo collisions of fusion burn waves in compressed deuterium–tritium and proton–boron plasmas. They simulate the expansion of a proton–boron hot-spot initialized at 200 keV and 1,000 g/cm^3, and found that energy radiated by the hot-spot is recaptured by the surrounding high-density opaque fuel reducing the expansion work done by the propagating burn wave, while the radiative heating of the cold fuel decreases the stopping of fusion alpha leading to non-local energy deposition. As a result, the net fusion energy produced over the course of 20 ~ ps is twice the initial hot-spot energy.
7) Lerner et al. discussed preparations for experiments with hydrogen-boron fuel in the megampere dense plasma focus (DPF) device, FF-2B. Isotopically pure decaborane ($B_{10}H_{14}$) is planned to be used as the fuel source, and measures were taken for safe handling and disposal of the toxic vapors. In these experiments it is expected to be able to measure the number of fusion reactions taking place as well as the mean ion energy density and confinement time of the plasma.

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