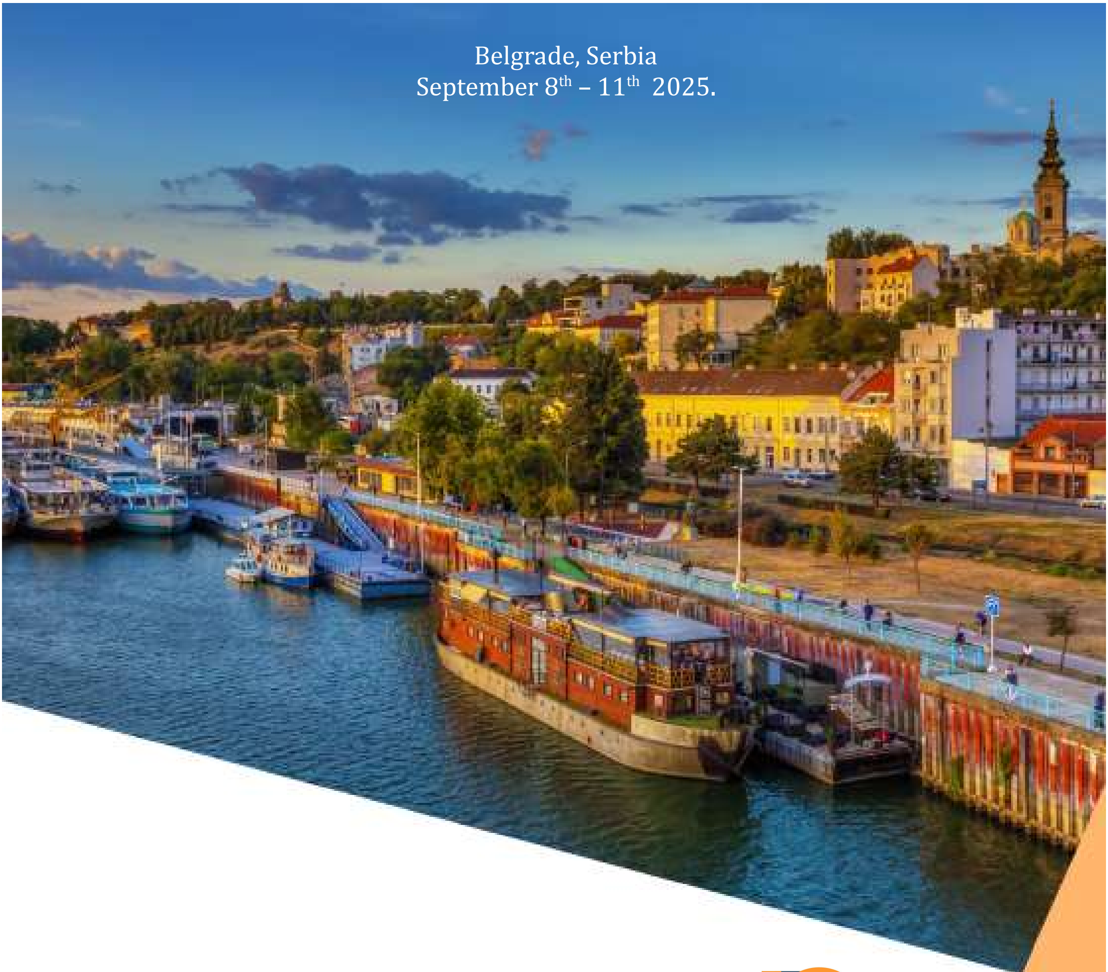
Belgrade, Serbia
September 8th – 11th 2025.



BOOK OF ABSTRACTS

5th International Workshop on Proton-Boron Fusion

Institute of General and Physical Chemistry

cost EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

Funded by the European Union

CA 21128 PROBONO

BOOK OF ABSTRACTS

5th International Workshop on
Proton-Boron Fusion

Belgrade, September 8th – 11th 2025.

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ORGANIZERS

Organizer: Institute of General and Physical Chemistry, Belgrade, Serbia (IGPC) www.iofh.bg.ac.rs
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WORKSHOP TOPICS

New experimental results
Advanced fusion approaches
Diagnostics
Materials for targetry and nuclear reactors
Theory and simulations
Applications0

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5th International Workshop on Proton-Boron Fusion
Belgrade, September 8th – 11th 2025.

Institute of General and Physical Chemistry

This book contains abstracts of
six invited lectures,
twenty-four oral contributions,
seven poster contributions,
accepted for presentation at
the 5th International Workshop on Proton-Boron Fusion.

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Commitment to quality and investments in production and people have strengthened and put us in the leading position in the country and the region and made us an additional member of every household and, a stable system based on strong links: a liquid detergent factory, a powder detergent and household cleaning products factory and a PET packaging production plant.

https://www.beohemija.com/

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WORKSHOP INFORMATION

Workshop location

Belgrade (Beograd) the capital of the Republic of Serbia, Serbian culture, education, science and economy, having estimated 2.5 million habitants, is situated in the South-Eastern Europe, on the Balkan Peninsula, at the confluence of the Sava and Danube rivers in north-central Serbia. The official language is Serbian.

Workshop venue

Institute of General and Physical Chemistry, Studentski trg 12, Stari Grad, 11158 Beograd (see location on our page) (III floor, amphitheatre No. 661, V floor, Library No.29)

Registration fee payment options

Bank transfer, online card payment and on-site payment.
Early registration fee: 250 € until 2025/08/15
Late registration fee: 350 €
Student fee: 150 €

Posters installation

09/09/2025 (12:40 – 14:00, III floor, Hall of the amphitheatre No. 661)
After the poster session, participants should remove their posters.

Abstracts publication

The official language of the conference is English. Conference abstracts are published in the Book of Abstracts.

Type of presentations

Visuals for invited lectures and oral presentations should be in Microsoft PowerPoint (*.ppt or *.pptx) or Adobe Acrobat Reader (*.pdf). Participants are advised to send the presentations by e-mail to or copy them to the dedicated PC from the storage unit 15 minutes before the session in which the presentation is scheduled starts.
Invited contributions duration: 40 min (35+5).
Oral contributions duration: 25 min (20+5).
Posters should be prepared in maximum dimensions: 70x100 cm.
The official language of the workshop is English.

Additional Workshop information

https://www.iofh.bg.ac.rs/en/about-institute/scientific-professional-events/5th-international-workshop-on-proton-boron-fusion

Useful telephone numbers

Police:192
Firemen:193
Ambulance:194

Taxi services
For the taxi services from Belgrade Nikola Tesla Airport to any destination in Belgrade area and further, please contact TAXI INFO desk, located in the baggage area.

Time zone
Belgrade and Serbia are located in the Central European time zone region GMT + 1

Electricity
The electricity voltage in Belgrade is 220V. Electrical outlets are standard EU.

Currency
The official currency in Serbia is dinar, abbreviated RSD. Money may be exchanged in all banks and authorized exchange offices. Exchange rate for 1 EUR is around 117.2 RSD. Cash may be taken from ATMs 24 hours a day. Credit cards are accepted in shops, hotels and restaurants.

Water
Tap water in Belgrade is safe to drink.

Tourist Information Centre
Kneza Mihaila 5, Belgrade
http://www.tob.rs/en

PROGRAMME OVERVIEW

5th INTERNATIONAL WORKSHOP ON PROTON-BORON FUSION, Belgrade 8th – 11th September 2025

PROGRAMME OVERVIEW

	Monday		Tuesday		Wednesday		Thursday
	08/09/2025		**09/09/2025**		**10/09/2025**		**11/09/2025**
08:00 – 09:00	*Registration on site*						
Opening Session I **Chairs: Daniele Margarone and Dimitri Batani**		**Session III** **Chairs: Dieter Hoffman and Daniele Margarone**		**Session V** **Chairs: Fabrizio Consoli and Michael Tatarakis**		**Session VI** **Chair: Giuseppe A.P. Cirrone**	
09:00 – 09:10	Welcome from the IGPC general manager and LOC	09:00 – 09:40	**Yueng-Kay Martin Peng** *(INV6)*	**09:00 – 09:40**	**Igor Morozov** *(INV5)*	**09:00 – 09:40**	**Lorenzo Manti** *(INV4)*
09:10 – 09:15	Welcome from the SC Chair and ProBono Chair						
09:20 – 09:30	Presenting the outline of the workshop programme						
09:30 – 10:10	**Dieter Hoffmann** *(INV2)*	09:40 – 10:05	Bing Liu *(O9)*	09:40 – 10:05	Lars Reichwein *(O19)*	09:40 – 10:05	Masakatsu Murakami *(O17)*
10:10 – 10:35	I. C. Edmond Turcu *(O23)*	10:05 – 10:30	Gerard Malka *(O12)*	10:05 – 10:30	Vittorio Ciardiello *(O3)*	10:05 – 10:30	Marcia Dias Rodrigues *(O20)*
10:35 – 11:00	*Coffee Break*	10:30 – 11:00	*Coffee Break*	10:30 – 11:00	*Coffee Break*	10:30 – 11:00	
11:00 – 11:25	Nikolaus Metzger *(O14)*	11:00 – 11:25	Farmesk Abubaker *(O4)*	11:00 – 11:25	Esmat Ghorbanpour *(O5)*	11:00 – 11:25	Violeta Lazic *(O8)*
11:25 – 11:50	M.G.S. Londesborough *(O10)*	11:25 – 11:50	Massimiliano Scisciò *(O21)*	11:25 – 11:50	Nicolò Macaluso *(O11)*	11:25 – 12:00	PROBONO wrap-up
11:50 – 12:15	Marcus Borscz *(O2)*	11:50 – 12:15	Dimitri Batani *(O1)*	11:50 – 12:15	Gordana Lastovicka-Medin *(O7)*	**Closing Session** **(Chairs: K. Batani and D. Milovanović)**	
12:15 – 12:40	Stavros Moustaizis *(O16)*	12:15 – 12:40	Przemysław Tchorz *(O22)*			12:00 – 12:15	**Closing session**
12:40 – 14:00	*Lunch Break*	12:40 – 14:00	*Lunch Break*	12:15 – 13:30	*Lunch Break*	12:15 – 13:30	*Lunch*
Session II Chair: **I. C. Edmond Turcu**		**Session IV** **Chair: Katarzyna Batani**		13:00-13:30	PROBONO / Core Group Meeting (closed)		
14:00 – 14:40	**Umit Demirci** *(INV1)*	14:00 – 14:40	**Eric .J. Lerner** *(INV3)*	**MC meeting** **Chair: Katarzyna Batani**			
14:40 – 15:05	Dubravka Milovanovic *(O15)*	14:40 – 15:05	Milos Manojlovic *(O13)*	13:30 – 15:30	**PROBONO / MC meeting (closed)**		
15:05 – 15:30	Nicolina Pop *(O18)*	15:05 – 17:00	***Poster Session*** */ Coffee Break*				
15:30-15:55	Mirac Kamislioglu *(O6)*			15:40-17:00	**Nikola Tesla Museum visit Group I**		
17:00 – 18:00	**Welcome cocktail**	17:00 –	**Guided tour to Belgrade fortress and Kalemegdan**	16:40-18:00	**Nikola Tesla Museum visit Group II**		
				19:00	**Conference dinner**		

Invited contributions 40 min (35+5)

Oral contributions 25 min (20+5)

5th International Workshop on Proton-Boron Fusion

DETAILED PROGRAMME

Monday 08/09/25	
08:00 – 09:00	**Registration on site** *(III floor, Amphitheatre No. 661)*
Opening Session / Chairs: D. Margarone and D. Batani *(III floor, Amphitheatre No. 661)*	
09:00 – 09:10	Welcome from the IGPC general manager and LOC
09:10 – 09:15	Welcome from the SC Chair and ProBono Chair
09:20 – 09:30	Presenting the outline of the workshop programme
09:30 – 10:10	**Fusion Energy at the Cross Roads (INV2)** *D.H.H. Hoffmann*
10:10 – 10:35	**Nuclear Fusion Power Reactor Concept Proposed for Laser-Driven Proton-Boron (HB11) Fusion (O23)** *I.C.E. Turcu*
10:35 – 11:00	*Coffee Break*
11:00 – 11:25	**A Commercially Viable High-Efficiency Thulium-Based Laser System for Proton Boron Fusion Power Plants (O14)** *S. Saha, C. Pflaum. W. M. Lee, N. Metzger*
11:25 – 11:50	**Boron Hydrides: A Fuel of Choice for p-B Fusion? Part II (O10)** *M. G. S. Londesborough, M. Ehn, J. Bould, M. Krůs*
11:50 – 12:15	***Monte Carlo Simulations of Suprathermal Enhancement in Advanced Nuclear Fusion Fuels (O2)*** *M. Borscz, P. Burr, I. Morozov, S. Pikuz*
12:15 – 12:40	**Hydrogen Boron ignition using specific fusion fuel composition in MIF configuration (O16)** *S. Moustaizis, C. Daponta, N. Nissim, S. Eliezer, Z. Henis, P. Lalousis, Y. Schweitzer and É. Berthoumieux*
12:40 – 14:00	*Lunch Break (V floor/29)*
Session I / Chair: E. Turcu *(III floor, Amphitheatre No. 661)*	
14:00 – 14:40	**Designing hydrogen (deuterium)- and boron-rich targets for laser-driven proton-boron fusion (INV1)** *U.B. Demirci*
14:40 – 15:05	**Laser structuring of titanium-based alloy and metallic thin films under controlled atmospheric conditions (O15)** *D. Milovanović, B. Rajčić, A. Kovačević, B. Gaković, B. Stankov, S. Dimitrijević, S. Petronić*
15:05 – 15:30	**Electron driven reactive processes involving H2+, BeH+ and their isotopologues in plasma fusion (O18)** *N. Pop, E. Djuissi, J. Boffelli, R. Hassaine, J. Zs Mezei, K. Chakrabarti, I. F. Schneider*
15:30-15:55	**Production and Characterization of Boron-doped foams for Proton-Boron Fusion Applications (O6)** *M. Kamislioglu, F. Consoli, K. Batani, D. Batani, M. Ciprian, S. Ipek Karaaslan, B. Buyuk*
17:00 – 18:00	**Welcome cocktail** *(III floor / Blue hall)*

Tuesday 09/09/2025	
Session II / Chairs: D. Hoffman and D. Margarone *(III floor, Amphitheatre No. 661)*	
09:00 – 09:40	**Physics model of spherical torus p-^{11}B plasma with superior confinement and fusion reaction rates (INV6)** *Y.-K.M. Peng, B. Liu, Y. Shi, A. Ishida, W. Liu, T. Sun, D. Guo, Z. Li, D. Luo, X. Xiao, H. Huang, G. Zhao, J. Dong, M. Liu, and the ENN Fusion Team*
09:40 – 10:05	**Progress of p-^{11}B Research for Fusion Energy at ENN (O9)** *B. Liu, Z. Li, D. Luo, X. Xiao, H.R. Huang, G.C. Zhao, Y.S. Zhang, R. Cheng, Y.T. Zhao, Y.J. Shi, D.K. Yang, Y.C. Li, W. Yang, H.S. Xie, T.T. Sun, W.J. Liu, H.Z. Kong, Y.Y. Li, H.Y. Wu, Z.H. Li, T.S. Fan, D. Wu, S.J. Liu, Y.C. Liu, D. H.H. Hoffmann, J.Q. Dong, Y.-K.M. Peng, M.S. Liu*
10:05 – 10:30	**Investigation of advanced laser-driven proton sources produced by the interaction of relativistic laser pulse with low density foams and their applications to proton-boron fusion (O12)** *G. Malka, D. Batani, J. Commenge, H. Larreur, L. Giuditta Pavan, A. Milani, A. Moroz, D. Raffestin, S. Busch, A. Martynenko, O. Rosmej, P. Tavana, K. Zarouk, D. Hoffman, E. Filippov, A. Huerta, L. Volpe, Y. Ferber, N. Nissim, M. Alonzo, F. Consoli, C. Verona, B. Grau, M. Sciscio, K. Batani, W. Kang, D. Margarone, M. Tosca, S. Pikuz, A. Raso, B. Liu*
10:30 – 11:00	*Coffee Break*
11:00 – 11:25	**High-yield and high energy protons in proton–boron reactions with pitcher–catcher configuration in nanosecond laser systems (O4)** *F. Abubaker, G. Petringa, C. Verona, M. Alonzo, S. Arjmand, E. Domenicone, B. Grau, N. Macaluso, A.M. Raso, M. Sciscìò3,5, G. Cantone, L. Guardo, G. Messina, C. Altana, La. Cognata, E. Pagano, G. Rapisarda, D. Santonocito, S. Agarwal, M. Cervenak, D. Bortot, R. Catalano, C. Ciampi, M. Cipriani, P. Devi, R. Dudzak, D. Ettel, P. Gajdos, L. Giuffrida, L. Juha, J. Krasa, M. Krupka, M. Krus, L. Malferrari, D. Margarone, S. Mirabella, G. Morello, A. D. Pappalardo, A. Picciotto, R. Rinaldi, M. Rosinski, A. Scandurra, S. Singh, P. Tchórz, A. Trifirò, F. Consoli and G. A. P. Cirrone*
11:25 – 11:50	**Laser-driven high-repetition-rate fusion reactions at the ELI-Beamlines laser facility (O21)** *M. Sciscìò, M. Alonzo, E. Domenicone, B. Grau, M. R. D. Rodrigues, G. Petringa, A. Bonasera, R. Catalano, S. Agarwal, P. L. Andreoli, D. Batani, K. Batani, J. Cikhardt, M. Cipriani, G. A. P. Cirrone, G. Claps, F. Cordella, G. Cristofari, V. De Leo, E. Di Ferdinando, D. Dubresson, L. Giuffrida, F. Grepl, A. Hadjikyriacou, V. Istokskaia, V. Kantarelou, D. Klir, M. Krupka, M. D. Lattuada, D. Margarone, S. Moustaizis, M. Nocente, D. Pacella, A. Růžička, F. Schillaci, M. Sestak, S. Singh, T. Slavicek, M. Tryus, A. Velyhan, C. Verona, M. Veselsky, F. Consoli*
11:50 – 12:15	**Hydrogen boron fusion in confined geometries (O1)** *D. Batani, M. Tosca, L. Giuffrida, P. Nicolai, C. Caizergues, D. Margarone, D. Raffestin, E. Filippov, S. Pikuz, K. Batani, Q. Cai, S. Mateti, Y. (I.) Chen, K. Yamanoi, A. Morace*
12:15 – 12:40	**Cavity Pressure Acceleration in laser-induced, mixed-fuel fusion reactions (O22)** *P. Tchórz, T. Chodukowski, S. Borodziuk, M. Rosinski, M. Cipriani, Z. Rusiniak, R. Dudzak, M. Krupka, J. Cikhardt, T. Burian, S.Singh, M. Szymanski, A. Marchenko, M. Kustosz, S. Agarwal, J. Krasa, R. Swierczynski, J. Pokorska, T. Pisarczyk, D. Klir, J. Skala, J. Dostal, M. Krus and L. Juha*
12:40 – 14:00	*Lunch Break (V floor/29)*

Tuesday 09/09/2025	
	Session III / Chair: K. Batani *(III floor, Amphitheatre No. 661)*
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14:40 – 15:05	**Potential of Low Gain Avalanche and SiC Detectors for Plasma Diagnostics in p–^{11}B Fusion Experiments (O13)** *M. Manojlovic, N. Moffat, P. Fernández-Martínez, E. Cabruja, C. Fleta, M. Perez, G. Laštovička-Medin, G. Pellegrini, S. Hidalgo*
15:05 – 17:00	**Poster Session** / ***Coffee Break*** *(III floor, Hall of the Amphitheatre No. 661)*
17:00 –	**Guided walking tour to Belgrade fortress and Kalemegdan** *(starting at the Workshop venue)*

Wednesday 10/09/2025	
Session IV / Chairs: F. Consoli and M. Tatarakis *(III floor, Amphitheatre No. 661)*	
09:00 – 09:40	**Numerical simulations of ignition and fusion burn wave propagation in proton-boron fuel (INV5)** *I. Morozov*
09:40 – 10:05	**Interaction of Laguerre-Gaussian laser pulses with borane targets for axial magnetic field generation (O19)** *L. Reichwein, A. Pukhov, and M. Büscher*
10:05 – 10:30	**Numerical simulation of proton-boron fusion via Micro Bubble Implosion (O3)** *V. Ciardiello, D. Davino,V.P. Loschiavo*
10:30 – 11:00	*Coffee Break*
11:00 – 11:25	***Optimizing proton–boron-11 fuel for fast ignition inertial fusion applications (O5)*** *E. Ghorbanpour, I. Morozov, S. Pikuz, F. Ladouceur*
11:25 – 11:50	**Investigation of Laser driven proton-boron reaction in Pitcher-Catcher configuration: CR39 and activation measurements with Monte Carlo validation (O11)** *N. Macaluso, G. Petringa, F. Abubaker, L. Guardo, M. La Cognata, E. Pagano, G. Rapisarda, D. Santonocito, S. Agarwal, M. Alonzo, C. Altana, S. Arjmand, D. Bortot, G. Cantone, R. Catalano, M. Cervenak, C. Ciampi, M. Cipriani, G. A. P. Cirrone, F. Consoli, P. Devi, E. Domenicone, R. Dudzak, D. Ettel, P. Gajdos, B. Grau, L. Giuffrida, J. Krasa, M. Krupka, M. Krus, L. Juha, L. Malferrari, D. Margarone, G. Messina, S. Mirabella, G. Morello, A. D. Pappalardo, A. Picciotto, A.M. Raso, R. Rinaldi, M. Rosinski, M. Scisciò, A. Scandurra, S. Singh, P. Tchórz, A. Trifirò and C. Verona*
11:50 – 12:15	**Characterization of Charge Collection, Signal Timing and Radiation Defects in 3D Silicon Sensors Using Two-Photon (2PA) and Three-Photon (3PA) Transient Current Technique (TCT) for Advanced Timing Applications in Laser-Driven pB Fusion (O7)** *G. Lastovicka-Medin, M. Rebarz*
12:15 – 13:30	*Lunch Break (V floor/29)*
13:00-13:30	**PROBONO / Core Group Meeting (closed)** *(III floor, Amphitheatre No. 661)*
MC meeting (Chair: Katarzyna Batani)	
13:30 – 15:30	**PROBONO / Management Committee Meeting (closed)** *(III floor, Amphitheatre No. 661)*
15:40-17:00	**Nikola Tesla Museum visit Group I** *(Krunska 51, Belgrade)*
16:40-18:00	**Nikola Tesla Museum visit Group II** *(Krunska 51, Belgrade)*
19:00	**Conference dinner** *(Caruso Restaurant, Terazije 23/8, Belgrade)*

Thursday 11/09/2025	
Session V / Chair: G.A.P. Cirrone *(III floor, Amphitheatre No. 661)*	
09:00 – 09:40	**The proton-boron fusion reaction enhances *in-vitro* cancer cell death (INV4)** *L. Manti*
09:40 – 10:05	**Laser-Driven Ultrahigh Compression of Matter and Application to Proton-Boron Fusion (O17)** *M. Murakami*
10:05 – 10:30	**Radioisotopes production using lasers: from basic science to applications (O20)** *M. R. D. Rodrigues, A. Bonasera, M. Scisciò, J. A. Pérez-Hernández, M. Ehret, F. Filippi, P. L. Andreoli, M. Huault, H. Larreur, D. Singappuli, D. Molloy, D. Raffestin, M. Alonzo, G. G. Rapisarda, D. Lattuada, G. L. Guardo, C. Verona, Fe. Consoli, G. Petringa, A. McNamee, M. La Cognata, S. Palmerini,T. Carriere, M. Cipriani, G. Di Giorgio, G. Cristofari, R. De Angelis, G. A. P. Cirrone, D. Margarone, L. Giuffrida, D. Batani, P.Nicolai, K. Batani, R. Lera, L. Volpe, D. Giulietti, A. Alejo, S. Agarwal, M. Krupka, S. Singh, F. Schillaci, M. Tryus, S. Stancek, V. Kantarelou, B. Grau', D. Dubresson, E. Domenicone, M. Nocente, T. Slavicek, M. Veselsky, F. Consoli*
10:30 – 11:00	
11:00 – 11:25	**Characterization of boron irradiated by laser-driven protons in high-repetition-rate petawatt-range experiments by laser induced breakdown spectroscopy (O8)** *V. Lazic, S. Almaviva, M. Scisciò, M. Alonzo, B. Grau, M. R. D. Rodrigues, G. Petringa, A. Bonasera, R. Catalano, E. Domenicone, P. L. Andreoli, D. Batani, K. Batani, M. Cipriani, G. A. P. Cirrone, G. Cristofari, E. Di Ferdinando, D. Dubresson, L. Giuffrida, D. Margarone, M. Nocente, F. Schillaci, M. Tryus, C. Verona, and F. Consoli*
11:25 – 12:00	PROBONO wrap-up
Closing Session ***Chairs: K. Batani and D. Milovanović*** *(III floor, Amphitheatre No. 661)*	
12:00 – 12:15	**Closing session**
12:15 – 13:30	***Lunch*** *(V floor/29)*

INVITED LECTURES

We are honored to present

The 5th IWPBF 2025 INVITED SPEAKER

Prof. Umit B. DEMIRCI
University of Montpellier, France

INVITED TALK: ***Designing hydrogen(deuterium)- and boron-rich targets for laser-driven proton-boron fusion***

A 2002 graduate of the University of Strasbourg, Umit B. Demirci began his academic career as an associate professor at the University of Lyon 1 in 2007. He moved to the University of Montpellier in 2011, earning a promotion to professor in 2015. His research expertise lies in materials chemistry, with a focus on boron-nitrogen-hydrogen based compounds (e.g. ammonia borane and amine borane adducts) for applications like hydrogen storage and production, BCN ceramics and gas separation membranes. Currently, his work explores also ammonia and aluminum-based materials. His extensive publication record includes over 180 in international journals. He has successfully supervised 17 PhD students to completion (+ 6 in progress) and managed 20 research projects as PI. He also serves on the editorial boards of the *International Journal of Hydrogen Energy* (Elsevier) and, since recently, *Scientific Reports* (SpringerNature).

Designing hydrogen(deuterium)- and boron-rich targets for laser-driven proton-boron fusion

U.B. Demirci

Institut Européen des Membranes, IEM – UMR 5635, ENSCM, CNRS, Univ Montpellier, Montpellier, France

Abstract

Boron-based molecular and solid-state compounds, such as ammonia borane (NH_3BH_3), metal borohydrides (MBH_4), and metal decaborates ($M(B_{12}H_{12})_n$), have been extensively studied in recent years, primarily in the fields of hydrogen storage and solid-state electrolytes for batteries. Their high hydrogen content, thermal tunability, and rich structural chemistry make them attractive for energy-related applications. However, their potential in nuclear fusion, particularly in the context of laser-driven proton–boron fusion, as recently revisited (see e.g. ref. [1]), remains underexplored.

Our work, recently initiated and currently under development, aim to investigates the use of hydrogen- and boron-rich compounds as target materials for proton-boron fusion. We focus on ammonia borane (including the deuterated counterpart) as a prototypical compound due to its favorable hydrogen content, decomposition characteristics, high purity, and solid-state stability. Additionally, metal borohydrides and metal decaborates are being kept in mind as promising alternatives, offering diverse thermal behaviors and compositional flexibility, particularly with respect to the incorporated metal cations. A key focus of our work is on the synthesis and processing of these compounds into low-density target architectures suitable for laser interaction. Achieving such porous structures while preserving chemical integrity is non-trivial, given their tendency to form dense crystalline phases and their sensitivity to processing conditions, and requires strategies such as templated synthesis and, nanostructuring, among other ones.

The synthesis-related aspects of our work will be presented during the 5th IWPBF meeting, with the objective of stimulating discussion and collaboration within the community toward advanced boron-hydrogen targets for laser fusion applications.

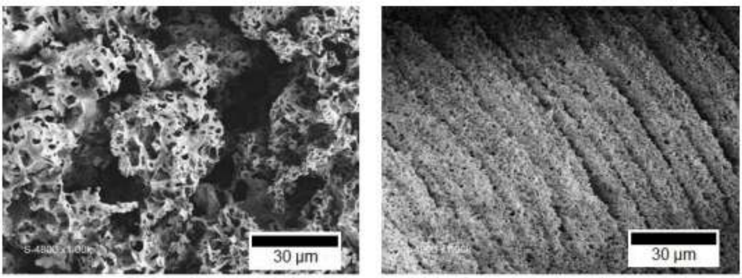

Figure 1. Amine-borane adduct driven synthesis of porous ammonia borane.

Reference
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We are honored to present

The 5th IWPBF 2025 INVITED SPEAKER

Prof. Dieter H.H. HOFFMANN
Xi'An Jiaotong University, Xi'An, Shaanxi, P.R. China
E-mail: hoffmann@physik.tu-darmstadt.de

INVITED TALK: *Fusion Energy at the Cross Roads*

Professor Hoffmann earned his degree in physics from Ruhr-Universität Bochum, Germany, in 1975. He completed his doctoral studies at the Technical University of Darmstadt in 1979, followed by a research stay at Stanford University, California, USA, as an Alexander von Humboldt Fellow. After returning to the Technical University of Darmstadt in 1982, he worked at the Max Planck Institute for Quantum Optics in Garching near Munich and later at the Gesellschaft für Schwerionenforschung in Darmstadt.

He obtained his habilitation at TU Darmstadt in 1993 and subsequently accepted a professorship in experimental nuclear physics at the University of Erlangen. In 1998, he returned to Darmstadt as a professor of nuclear and radiation physics. In 2018, he joined China's *Thousand Talents Program* as a specially appointed professor at Xian Jiaotong University.

SCIENTIFIC WORK

Professor Hoffmann has authored or co-authored about 500 peer-reviewed scientific publications spanning nuclear physics, plasma physics, and astro-particle physics. His primary research focus is high-energy-density physics, particularly in the context of fusion science.

Scientific positions:

1996–1997:Director of the Physics Institute of the Friedrich-Alexander-University, Erlangen
1998–1999:Director of the Institute of Nuclear Physics, TU Darmstadt
2002- 2021:Editor of the journal Laser and Particle Beams, Cambridge University Press
2003-2015:Spokesperson of the HEDgeHOB collaboration of the FAIR/GSI
2002-2021:editor-in-chief of Laser and Particle Beams, Cambridge University Press
Since 2017:International Guest Editor of Matter and Radiation at Extremes, publ. by CAEP and AIP

Fusion Energy at the Cross Roads

Dieter H.H. Hoffmann[1,2,3]

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[2] Hebei Key Laboratory of Compact Fusion, Langfang 065001, China
[3] ENN Science and Technology Development Co., Ltd., Langfang 065001, China
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Abstract

Recent progress in inertial fusion as well as magnetic confinement experiments have initiated new research efforts for Fusion Energy. While we do see a remarkable progress in understanding the basic physics details of fusion ignition and burn on the laboratory scale, there is – in my eyes- a considerable technology gap to prepare for fusion generated power on the grid. Some of the issues concerning the main path based on the Deuterium Tritium Reaction will be discussed. These include the technological problems associated with Tritium breeding and material problems due to the high neutron flux. Since these problems will take time to find not only solutions, but economically competitive solutions, we have time to also look for alternatives. Therefore, some alternative pathways will be addressed. Among them the quasi-neutron free fusion reaction ${}^{11}_{5}B\ (p,\ \alpha)2\alpha$ reaction. We report on experiments using conventional accelerator beams and intense laser generated proton beams to investigate the details of this reaction. We performed experiments at the 320 kV high voltage platform at the Institute of modern Physics in Lanzhou and the Laser Fusion Research Center at Mianyang. There are different reaction channels, but in no case three alpha particles are emitted with each 2.7MeV energy. In the experiments at IMP-Lanzhou we also used hydrogen doped boron targets and the alpha yield in this case is increased by approximately 30%. In experiments with intense proton beams at the Laser Fusion Research Center in Mianyang we observed up to 10^{10}/sr/ alpha particles per laser-shot. This presently constitutes the highest yield normalized to the laser energy on target.

We are honored to present

The 5th IWPBF 2025 INVITED SPEAKER

Dr. Eric LERNER

President and chief scientist, LPP Fusion Inc., USA

INVITED TALK: ***Initial Experiments with Decaborane in a Dense Plasma Focus Device***

Dr. Eric Lerner has been active in dense plasma focus (DPF) research for 40 years. Beginning in 1984, he developed a detailed quantitative theory of the functioning of DPF, based on his work using the DPF-produced plasmoids as models for quasars. Using this theory, he proposed that the DPF could achieve high ion and electron energies at high densities, suitable for advanced fuel fusion and space propulsion. After a series of contracts with NASA's Jet Propulsion Laboratory, which gave preliminary confirmation to the theories, he founded LPPFusion in 2003, the fourth fusion company to be founded, to develop these ideas into a working fusion generator. In 2005, he developed an original model of the role of the quantum magnetic field effect on DPF functioning, showing that this effect could have a large effect on increasing ion temperature and decreasing electron temperature, which would make possible hydrogen-boron fusion. He has also been a leader in cosmological research as a developer of a non-expanding, non-Big Bang theory of the evolution of the universe, proposing new theories of large scale structure, the origin of light elements, the CMB and the surface brightens of galaxies . He is the author of the popular book, The Big Bang Never Happened. Eric can be reached at eric@lppfusion.com.

Initial Experiments With Decaborane in a Dense Plasma Focus

E. J. Lerner[1], S. Hassan[1], I. Karamitsos[1], and R. Fritsch[1]

[1] LPPFusion, 128 Lincoln Blvd., Middlesex NJ, USA

Abstract

Beginning in November, 2024, LPPFusion has initiated experiments with pB11 fuel, using decaborane ($B_{10}H_{14}$) and gas mixes with decaborane in our dense plasma focus device, FF-2B. We were able to overcome initial difficulties in evenly heating the vacuum chamber and succeeded in filling the chamber with up to 1.6 torr decaborane. We achieved the first pinches (plasmoid formation) with a hydrogen-decaborane mix on March 7. However, we found that the breakdown was too difficult with both pure decaborane and decaborane - hydrogen mixes. Difficult breakdown, measured by the peak anode potential at the start of the pulse, leads to asymmetric breakdown and low-density plasmoids, thus drastically reducing fusion yield. We instead switched to deuterium-decaborane mixes, which reduced the pressure for a given density of gas, thus improving breakdown. While deuterium produces fusion neutrons , the secondary neutrons produced by pB11-generated alpha particles reacting with ^{11}B are expected to peak at energies of 4 MeV, thus separating them by time-of -flight measurements from the 2.45 MeV DD neutrons. We report here on our efforts to improve breakdown with enhanced preionization. In addition, we observed the production of a beryllium-boride coating during boron shots. The partial removal of this coating with cleaning shots greatly enhanced the yield of subsequent deuterium shots, leading to record deuterium fusion yields. We also report here on our efforts to improve cleaning which, together with improved preionization, is expected to lead to measurable pB11 fusion yield.

Acknowledgements
This work is funded by LPPFusion, Inc. We thank our investors and donors.

We are honored to present

The 5th IWPBF 2025 INVITED SPEAKER

Prof. Lorenzo MANTI
University of Campania, Caserta (Italy) &
INFN Naples Section, Italy

INVITED TALK: ***The proton-boron fusion reaction enhances in-vitro cancer cell death***

Lorenzo Manti is Full Professor of Applied Physics at the Mathematics and Physics Department, University of Campania "L. Vanvitelli", Italy. After graduating in Physics, he moved to the UK where he was awarded an MSc and a PhD, both in experimental radiobiology. He has thereafter continued working in this field at the University of Naples Federico II, Italy, with a focus on the radiobiology of charged particle beams. Other research interests include radiosensitizing and radioprotecting strategies based on natural compounds, spectroscopic vibrational techniques and medical applications of boron-based nuclear physics reactions such as Proton-Boron Capture Therapy and BNCT. Most recently, he had been studying the potential use of accelerated helium beams in hadrontherapy. He has been President of the Italian Radiation Research Society (SIRR) and of the European Radiation Research Society (ERRS). As part of his academic duties, he has supervised almost 100 BSc and MSc students, tutoring several PhD candidates. He is the author of 90 peer-reviewed papers.

The proton-boron fusion reaction enhances *in-vitro* cancer cell death

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Abstract

Arguably one of the most exciting clinical applications of the proton-boron (pB) fusion reaction, Proton-Boron Capture Therapy (PBCT) marries nuclear physics and radiobiology by using the pB reaction products to enhance the biological effectiveness of protontherapy (PT) at killing cancer cells. PT is a fast-growing modality in precision radiotherapy (RT) that exploits the inverse dose-depth profile (Bragg curve) of conventionally accelerated proton beams to reduce normal-tissue radiotoxicity compared to photon-based RT. This makes PT particularly attractive for pediatric patients or for those affected by cancers close to radiosensitive organs, for whom the abatement of unwanted dose is imperative. Despite its superior ballistics, the better dose conformity to the tumour volume ensured by PT, however, is not accompanied by a radiobiological advantage since, at clinically relevant energies (~ 200 MeV), protons kill basically the same amount of cancer cells as photons at any given dose. Therefore, PT is of no avail against radioresistant cancers. The PBCT approach was thus proposed to augment tumour local control by PT [1], based on the notion that the α-particles yielded by the pB reaction are known to be radiobiologically highly effective at causing lethal cellular damage. In fact, PBCT has been successfully verified *in vitro* [2, 3] by work carried out at INFN-LNS in Catania and at CNAO (Centro Nazionale di Adroterapia Oncologica) in Pavia, Italy (Fig. 1).

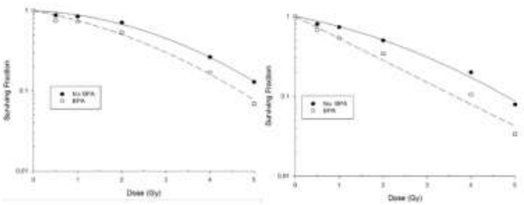

Figure 1. Enhancement of clonogenic cell death by pB in a radioresistant pancreatic cell line at the mid-(left) and distal (right) positions of the CNAO clinical proton Spread-Out Bragg Peak (SOBP) using the BPA compound as ^{11}B carrier (unpublished data).

This talk will illustrate the radiobiological rationale behind PBCT, providing an overview of the main results obtained thus far and of the clinical prospects for the pB reaction. Additionally, the idea of using extremely ultra-high dose rates (~ 10^9 Gy/s) from laser-driven protons to trigger the pB reaction will be discussed as to couple PBCT with the FLASH phenomenon, whereby normal-tissue toxicity appears to decrease normal-tissue damage at higher-than-conventional dose delivery temporal regimes. This may further widen the adoption of PT, which in turn holds important societal impact.

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Acknowledgements

The work herein described was funded by INFN Call NEPTUNE and MIUR PRIN PBCT-Proton Boron Capture Therapy

We are honored to present

The 5th IWPBF 2025 INVITED SPEAKER

Dr. Igor MOROZOV

Head of simulations, HB11 Energy Holdings Pty Ltd, Manly, Australia

Research fellow, School of Mathematical and Physical Sciences, Macquarie University, Australia

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igor.morozov@mq.edu.au

INVITED TALK: ***Numerical simulations of ignition and fusion burn wave propagation in proton-boron fuel***

Dr. Igor Morozov graduated from Moscow State University and received his PhD degree in 2004 in plasma physics in Russia. Since 2001 he has worked in the Joint Institute for High Temperatures of the Russian Academy of Sciences as a researcher and the head of laboratory. From 2004 to 2018, he also gave lectures at Moscow Institute of Physics and Technology and Higher School of Economics, Moscow; worked closely with the Institute of Physics, Rostock University, Germany; and visited Argonne National Lab, USA. Igor's area of competence is computer simulations of different plasmas, including nonideal plasma and warm dense matter. He is a co-author of a new computational algorithm based on the wave packet molecular dynamics. Since 2023, he has started his collaboration with HB11 Energy, an Australia-based startup aimed at facilitating green fusion technologies. In September 2004, he joined Macquarie University as a research fellow under the linkage project, still working at HB11 Energy as a consultant. At present, he conducts theoretical and computational studies of the potentiality of proton-boron fusion, working in close collaboration with researchers from Europe and the USA.

Numerical simulations of ignition and fusion burn wave propagation in proton-boron fuel

Igor Morozov[1,2]

[1] HB11 Energy Holdings Pty Ltd, Sydney, Australia
[2] School of Mathematical and Physical Sciences, Macquarie University, Sydney, Australia

Abstract

The interest in the proton-boron ($p^{11}B$) fusion is renewed after publication of updated cross-section data [1]. This reaction is aneutronic and relies on the elements that are abundant in nature, safe to transport, and do not require low-temperature cryogenics to create a target [2]. The ignition of the proton-boron fuel, however, remains challenging as it requires plasma temperatures over 150 keV and densities up to 4000 g/cc, where the radiative losses become critical [3]. Preliminary studies also show the significance of suprathermal effects such as upscattering of protons by fusion-born alpha-particles [4] and reabsorption of the hot spot bremsstrahlung radiation in the cold fuel.

In this report, different simulation techniques are overviewed that allow one to study ignition and burn propagation in proton-boron ($p^{11}B$) fuel. In particular, the results of two-temperature 1D hydrodynamics simulations are presented for initially isochoric configurations related to the proton fast ignition scheme. The results are obtained for a wide range of hot spot temperatures and densities. The role of kinetic effects, bremsstrahlung reabsorption, alpha-particle transport, and fuel depletion is analyzed. The other methods under review include the 0D dynamical model, kinetic (particle-in-cell) codes, and Monte Carlo collision simulations (Figure 1).

<table>
<tr><th colspan="2">Analytical model</th><th colspan="2">Fokker-Planck/ Monte-Carlo</th><th colspan="2">Hydrodynamics</th><th>Particle-in-cell/hybrid kinetic methods</th></tr>
<tr><td colspan="4">Spatially uniform (0D)</td><td colspan="2">1D/2D/3D distributions</td><td>1D/2D/3D distributions</td></tr>
<tr><td colspan="2">Equilibrium velocity distributions for electrons and ions</td><td colspan="2">Non-equilibrium velocity distributions</td><td colspan="2">Equilibrium velocity distributions</td><td>Non-equilibrium and spatially resolved velocity distributions</td></tr>
<tr><td colspan="2">Average energy transfer rates between species</td><td colspan="2">Calculations of collision integrals</td><td colspan="2">Average energy transfer rates between species</td><td>Monte-Carlo collisions</td></tr>
<tr><td colspan="2">Variables: R, T_i, T_e, ρ</td><td colspan="2">Variables: $f_s(v)$</td><td colspan="2">Variables: $T_i(\mathbf{r})$, $T_e(\mathbf{r})$, $\rho(\mathbf{r})$, $v(\mathbf{r})$</td><td>Variables: $f_s(\mathbf{v},\mathbf{r})$</td></tr>
<tr><td>static</td><td>dynamic</td><td>static</td><td colspan="4">dynamic</td></tr>
<tr><td colspan="5">Suitable for personal computers</td><td colspan="2">Require supercomputers</td></tr>
</table>

Figure 1. Numerical simulation algorithms to study ignition and fusion burn wave propagation in proton-boron fuel.

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Acknowledgements
This work is funded by ARC Linkage Grant No LP220100061, project title: Towards non-thermal hydrogen-boron fusion.

We are honored to present

The 5th IWPBF 2025 INVITED SPEAKER

Dr. Yueng-Kay Martin PENG
ENN Science and Technology Development Co., Ltd.
Langfang 065001 China

INVITED TALK: ***Physics model for spherical torus proton-boron fusion plasmas with superior ion energy confinement and reaction rates***

Yueng-Kay Martin Peng is the Chief Scientist of Fusion at ENN Energy Research Institute. He holds a master's degree and a Ph.D. in Applied Physics from Stanford University. With 40 years of experience in fusion research and development at Oak Ridge National Laboratory, he has pioneered the field of spherical torus (spherical tokamak) fusion research. He served for more than a decade as the R&D Director for the National Spherical Torus Experiment (NSTX) at Princeton Plasma Physics Laboratory. Since retiring, he has been an adjunct visiting professor at the School of Nuclear Science and Technology at the University of Science and Technology of China and a distinguished researcher at the Institute of Plasma Physics of the Chinese Academy of Sciences.

Physics model of spherical torus p-^{11}B plasma with superior confinement and fusion reaction rates

Y.-K.M. Peng, B. Liu, Y. Shi, A. Ishida, W. Liu, T. Sun, D. Guo, Z. Li, D. Luo, X. Xiao, H. Huang, G. Zhao, J. Dong, M. Liu, and the ENN Fusion Team

ENN Science and Technology Development Co., Ltd, Langfang 065001, China

Abstract

Spherical torus (ST) p-boron plasma research results at 0.5-1.0MA on EXL-50 and EXL-50U [1,2,3] has been extended [4] to an ST p-^{11}B plasma near the fusion burn parameters. These are, in units of m, MA, T, $10^{20}/m^3$, and keV: $R = 1.4$, $a = 0.74$, $I_p = 13.6$, $B_T = 3.5$, $\beta_T = 0.27$, $\beta_p = 1.4$, $\beta_N = 5.1$, $q_0 = 1.5$, $q_{LCFS} = 5.3$, for thermalized components $n_{e0} = 1.04$, $n_{p0} = 0.34$, $n_{B0} = 0.14$, $T_{p0} = T_{B0} = 130$, $T_{e0} = 29$, and for supra-thermal components $n_{ph0} = 0.004$, $n_{Bh0} = 0.0018$, $n_{eh0} = 0.036$, $T_{ph0} = T_{Bh0} = 620$, and $T_{eh0} = 2050$. These parameters leverage the sharp peak at 160 keV and the broad peak at 675 keV of the p-^{11}B reaction cross section. Some of the calculated plasma profiles in the poloidal cross-section are shown in the Figure. The supra-thermal components exhibit substantial current, pressure, and rotation beyond the last closed flux surface (LCFS), while the thermalized components remain within the LCFS. A positive potential of up to 10 kV relative to the wall around the plasma helps expel the escaping cold ions. The plasma forms a magnetic well and hill combination in the outboard region, suppressing ion microturbulence and causing "orbit squeezing" and axisymmetric omnigeneity. These are expected to lessen neoclassical ion transport and lead to superior confinement $\tau_{Ei} \sim T_i^2$.

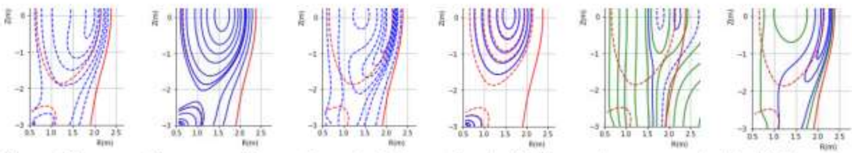

Figure. Plasma profile contours (blue and green) relative to the poloidal flux surface contours (red) with the potential to achieve substantial p-11B fusion burn, from left to right: (1) toroidal current density (-0.1 ~ -4.0 MA/m²), (2) plasma pressure (0.01 ~ 2.5 MPa), (3) supra-thermal electron current density (-0.01 ~ -1.45 MA/m²), (4) electrostatic potential (1.8 ~ 11.5 kV), (5) magnetic well (= 2.82 T) and hill (= 3.14 T) in the omnigenous region, and (6) velocity difference between the supra-thermal proton and the thermal boron (0.6 ~ 1.75 Mm/s).

The supra-thermal proton rotation peaks near the LCFS outboard, with velocities of up to 1900 km/s over the thermal boron, thereby increasing the plasma fusion reaction rate. The intermixing of these components in space improves the microturbulence and transport properties beyond the standard tokamak. The orbit confinement of the supra-thermal components sets their maximum energies in the pitch-angle-energy space and substantially increases the p-^{11}B fusion reaction rates. These new plasma features are important to ST p-^{11}B fusion, will be tested and updated in EXL-50U, and will support the physics design of the upcoming larger experiment, EHL-2 at the level of $I_p \sim$ 3 MA [5].

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Acknowledgements
Helpful discussion with Drs. Yunfeng Liang, Huasheng Xie, and Yuanming Yang are gratefully acknowledged.

ORAL CONTRIBUTIONS

Hydrogen boron fusion in confined geometries

Dimitri Batani[1], Marco Tosca[2,3], Lorenzo Giuffrida[2], Philippe Nicolai[1], Clement Caizergues[1], Daniele Margarone[3], Didier Raffestin[1], Evgenij Filippov[4], Sergey Pikuz[4], Katarzyna Batani[5], Qiran Cai[6], Srikanth Mateti[6], Ying (Ian) Chen[6], Kohei Yamanoi[7], Alessio Morace[7]

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Abstract

High-energy, short-pulse laser-driven proton-boron pB fusion has garnered increasing interest due to its neutronless nature and potential for clean energy production. In our study, two experimental campaigns were conducted at the LFEX laser facility using PW-class laser systems (energy 1.2 – 1.4 kJ, duration 2.7 ps, intensity 2-3 × 10^{19} W/cm^2) to investigate the impact of complex target geometries including spheres, cylinders, and wedges targets on α-particle yield. Our findings reveal that spherical targets produce an increase in α-particle yield up to two orders of magnitude that of flat targets of the same composition, with a notable shift in the α-particle spectrum towards higher energy values. Additionally, we successfully implemented a novel method for unambiguous α-particle detection using CR-39 detector within a Thomson Parabola spectrometer. Particle-in-cell (PIC) simulations with the Smilei code further elucidate the influence of self-generated magnetic fields on particle dynamics, highlighting the intricate relationship between target confinement and fusion efficiency. These results provide valuable insights into the possibility of optimizing target designs for enhancing fusion yield and a-particle generation in pB fusion with possible application to developing laser-driven a-particle sources and a broader relevance to clean energy production.

Key words
Hydrogen boron fusion; a-particles; Thomson parabola; CR-39; boron nitride; high-intensity lasers; laser-induced nuclear reactions

Monte Carlo Simulations of Suprathermal Enhancement in Advanced Nuclear Fusion Fuels

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Abstract

Recently developed particle-in-cell (PIC) codes [1,2] have established the importance of large-angle Coulomb collisions for explaining the surprising observation of non-Maxwellian behaviour in burning plasmas at the National Ignition Facility [3]. These collisions facilitate large transfers of energy from fast alpha particles to fuel ions which enhances the high-energy tail of the distribution function and increases fuel reactivity. A Landau-Fokker-Planck treatment of α-p scattering in low-density pB11 [4] has estimated a reactivity increase of 10% due to kinetic modification of the proton tail, which has been shown to be critical for providing the necessary conditions for self-heating. This is likely a lower bound for moderately coupled ICF plasmas where the effects of large-angle Coulomb collisions and nuclear elastic scattering must be considered [5]. To ascertain the extent of suprathermal enhancement as a function of fuel conditions, we have developed a Monte Carlo code that tracks collisions between fast particles and an infinite and homogenous thermal background plasma. This method is inspired by recent studies of suprathermal ion-driven chain reactions in pure deuterium [6]. At each timestep, charged particles are slowed down using the Li-Petrasso stopping power [7] and collisions are sampled. The cutoff for large-angle Coulomb scattering is determined from the collective screened potential and the cross sections for nuclear elastic scattering and nuclear reactions are taken from the ENDF database. The energy and generation of each particle are used to compute the suprathermal gain and multiplication factor of the fuel. We present preliminary results of the code in the context of a fast proton in a cold pB11 target and a 2.9 MeV alpha particle in a burning plasma, which are both essential processes in the proton fast ignition target concept.

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Acknowledgements
Funding provided by HB11 Energy Holdings Pty Ltd, Australia.

Numerical simulation of proton-boron fusion via Micro Bubble Implosion

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Abstract

The development of ultra-high-intensity lasers (UHIL) facilities, thanks to the Chirp-Pulse-Amplification (CPA), allows to think about a lot of new different applications.

Micro-Bubble-Implosion is a novel proposition introduced in [1], which consists in the possibility of having an implosion of a spherical cavity target due to the redistribution, within the cavity, of the hot electrons due to the interaction of the target with a UHIL ($10^{18} - 10^{22} W/cm^2$). This charge separation may lead to the generation of a very intense electric field which will lead to the implosion of the ions. By considering very light ions, i.e., hydrogen and eventually its isotopes, numerical and analytical models show that when the ions are fully compressed, they can reach densities in the order of about 10^5 times the ordinary solid state, i.e. like in a white dwarf. At the maximum compression, the so-called stagnation phase, an electric field which can be as high as two orders of magnitude lower than the so-called Schwinger limit ($10^{18}\ V/m$) is established.

The main applications are related to ions acceleration up to relativistic regime and ultra-intense coulomb field generation [1,2].

In this work we are going to show several new numerical results concerning laser-matter interaction. Both FLASH and EPOCH simulations are carried out. This analysis improves our understanding of how in a more realistic scenario it would be possible to ignite p-B fusion via Microbubble implosion. We considered a submicrometric target constituted by an external gold layer and two internal layers made of boron and hydrogen. We simulated the evolution in time of these layers and as consequence we defined a procedure to evaluate the reactivity $< \sigma v >$.

Moreover, the evaluation of the alpha particle yields is calculated in different configurations.

All these results are useful to determine whether the breakeven may be feasible.

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High-yield and high energy protons in proton–boron reactions with pitcher–catcher configuration in nanosecond laser systems

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Abstract

This experiment was designed to measure the maximal energy of protons and the high fusion yield when they were released from the front side of various target materials which had been exposed to high-intensity laser pulses. Fusion reactions are initiated in a plasma generated by using the Prague

Asterix Laser System (PALS) facility with a long-pulse laser (300 ps) and 600 J energy on target. In this work two schemes are employed: the In-Target and the Pitcher-Catcher configurations to characterise proton energy and fusion yield. For the purpose of studying p-^{11}B nuclear reaction, protons are directly generated by the laser's interactions with the primary target (pitcher) and generated protons are accelerated from the primary target impinging on a secondary target (catcher). Various target materials and geometries were used in both setups to explore the influence of target composition on the acceleration process and the yield. To evaluate the charged particle emission characteristics, a combination of diagnostic tools was utilised. The solid-state nuclear track detectors (CR-39) were positioned at various angles with respect to the primary target's normal axis, with one CR39 facing the catcher target at the distante of 4 cm. The CR39 detectors were covered with thin aluminium foils of varying thicknesses supposed to distinguish particles with distinct linear energy transfers (LETs) to enable them to reconstruct the charged particle spectra to identify the contributions of the charged particles at different energies.
Furthermore, a series of Time-of-Flight (TOF) detectors were installed at the similar angle of CR39 to monitor the energy and timing characteristics of the protons with angular resolution. On top of that, three Thomson Parabola (TP) spectrometers, positioned at certain positions, delivered charge and energy-resolved measurements of the emitted particles, providing a comprehensive measurement picture of the proton spectra.
To estimate the number of protons that reached the catcher, the activation methodology was additionally implemented as an independent approach. This was achieved by detecting gamma emissions from activation products using a high-purity germanium (HPGe) detector.
Remarkably, the highest proton energy, up to around 5.5 and 6 MeV, were reliably detected by the TP and TOF detectors orientated along the primary target normal (0°) respectively. All diagnostic results showed an outstanding level of agreement. It's interesting to note that the maximal proton energy measured was not significantly impacted by the target's boron content. However, the proton yield of boron-containing targets was higher than that of boron-free targets. It therefore suggests that boron might contribute to making the acceleration process more efficient, either through changing the sheath field that drives proton acceleration, modifying the manner in which the laser energy is absorbed, or altering hot electron transport

Overall, the highest proton energy was successfully recorded for TOF and TP diagnostics across all target types . In the pitcher–catcher configuration, the number of charged particles produced by the secondary target and those emitted straight from the primary target were compared. Besides, an innovative approach for evaluating secondary reactions like proton–boron fusion has been demonstrated by the incorporation of the pitcher–catcher method with CR-39 detectors and gamma-based activation diagnostics through HPGe spectroscopy. These results highlight the significance of formulation of materials and cutting-edge diagnostics are to maximising laser–plasma interactions for future applications in ion beam technologies and nuclear physics.

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Optimizing proton–boron-11 fuel for fast ignition inertial fusion applications

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Abstract

Proton fast ignition approach in inertial confinement can take advantage of proton-boron (p-^{11}B) fusion in terms of safety, abundance, clean reaction products, and the absence of cryogenic requirements. Moreover, recent re-evaluation of cross-section data for p-^{11}B [1,2] and general progress in laser technologies improve its potential for reduction in electricity production costs.
For p-^{11}B fusion to be commercially viable, a high hydrogen concentration is required to overcome the challenge of driving burn propagation via fast proton production from elastic scattering. Therefore, a crucial factor in energy generation is the optimisation of H:B ratio to higher values, which enhances proton-boron collision rates, leading to a higher yield of alpha particles and improving fusion efficiency.
Furthermore, one of the main material-related obstacles is that available synthesized, stable compounds are either heavily boron-rich, as in boranes [3], or contain heteroelements such as nitrogen (N) and carbon (C); the impurities enhancing Bremsstrahlung radiation, which in turn cools the plasma down and makes ignition more difficult. As such, the ideal fuel compound would be composed of minimal contamination from elements other than hydrogen and boron.
This study focuses on evaluating the potential of boron-based compounds, with regards to suprathermal effects due to the non-Maxwellian tail in reactivity [4] and significant Bremsstrahlung reabsorption. The latter has been evaluated using HELIOS (a two-temperature 1D hydrodynamics code) with PROPACEOS opacity models [5]. Ignition temperatures depending on a set of fast ignition IFE-relevant plasma parameters are determined based on various compounds and structural assemblies ranging from theoretically ideal to naturally existing or recently manufactured ones. This approach highlights material configurations that could lead to more efficient proton–boron fusion fuel designs.

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Production and Characterization of Boron-doped foams for Proton-Boron Fusion Applications

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Abstract

Proton-Boron (p-^{11}B) fusion represents an advanced nuclear fusion reaction that offers a cleaner and more sustainable alternative to conventional fusion methods employing DT fuels, although at this moment of more difficult realization with respect to the latter. This reaction holds significant promise for a range of high-tech applications, including both medicine and energy production. Given that the pB fusion process utilizes Boron-11, boron-containing materials are considered potential fuel candidates for pB fusion technology. Usually, boron nitride (BN), ammonium borane (NH_3BH_3), brophene, decaborane, and diborane materials were used or planned to be used in pB fusion schemes such as laser driven inertial confinement and magnetic confinement. Boron-doped foams are gaining significant attention in the field of pB fusion due to their potential to enhance reaction yields and overcome some of the challenges associated with this promising aneutronic fusion reaction (Hu et al., 2015; Wei et al., 2023; Peddock et al., 2023). In this study, B_4C-doped foams, elemental boron-doped foams, and ulexite-doped foams were produced. The samples were characterized to be potentially used for laser-driven inertial confinement pB fusion schemes. The figure of produced samples is given in Figure 1.

SAMPLES CODE	SAMPLES
B4C-doped foams	
Elemental boron-doped foams	
Ulexite-doped foams	

Figure 1. B_4C-doped foams, Elemental boron-doped foams, and ulexite-doped foams

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Characterization of Charge Collection, Signal Timing and Radiation Defects in 3D Silicon Sensors Using Two-Photon (2PA) and Three-Photon (3PA) Transient Current Technique (TCT) for Advanced Timing Applications in Laser-Driven pB Fusion

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Abstract

Laser-driven proton–boron (pB) fusion is a highly promising pathway for clean, aneutronic energy production. However, the extreme complexity and nature of these interactions—often involving overlapping emissions from multiple reaction zones—require state-of-the-art timing detectors capable of resolving events on picosecond timescales. Precise timing is essential to disentangle the spatial and temporal dynamics of fusion products, making detector performance a critical factor in both diagnostics and fundamental studies. At the same time, the harsh radiation environment leads to the formation of defects and damage within the detector material, which can degrade signal fidelity and timing accuracy. Understanding and mapping these defects in three dimensions is crucial for developing robust, radiation-hard sensor technologies suitable for fusion and high-flux applications. In this study, we apply advanced femtosecond-laser-based multiphoton absorption Transient Current Techniques (TCT)—namely Two-Photon (2PA) and Three-Photon Absorption (3PA)—as precision tools for characterizing both timing performance and defect distribution in 3D silicon sensors. These techniques enable high-resolution 3D scanning of the detector volume, allowing for localized analysis of charge collection, rise time, and Time-of-Arrival (ToA). Our results highlight spatial variations in charge collection efficiency and timing resolution, revealing structure-related performance differences. Notably, we demonstrate for the first time the application of Three-Photon Absorption TCT to detect and study radiation-induced defects deep within the sensor volume. 3PA offers improved spatial confinement and sensitivity compared to 2PA, making it a powerful tool for defect diagnostics.

Together, these findings emphasize the dual importance of ultrafast timing and defect characterization in the development of next-generation detectors for laser-driven fusion experiments. The combined use of 2PA and 3PA-TCT provides a comprehensive approach to optimizing sensor performance under extreme conditions, directly supporting R&D on ToF diagnostic tools and device design for advanced pB fusion research.

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Characterization of boron irradiated by laser-driven protons in high-repetition-rate petawatt-range experiments by laser induced breakdown spectroscopy

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Abstract

In the 'pitcher-catcher' scheme for triggering H-^{11}B nuclear fusion reactions by laser with high power and energy, a laser-accelerated proton beam interacts with solid B target. Laser-plasma acceleration involves also a wide set of particles that can interact and deposit within the B target, and this is of particular interest in high-repetition-rate experiments with a single B sample [1]. For this reason, we used the Laser Induced Breakdown Spectroscopy (LIBS) technique in ENEA C. R. Frascati laboratories to analyze a B sample irradiated in a pitcher-catcher experiment of H-^{11}B conducted at ELIMAIA-L3 in ELI-Beamlines (4 J, 30 fs, 3×10^{19} W/cm^2). The depth profiling by LIBS [2] was performed in four sample areas: at the front and back side, both at the sample's center and its edge. The measurements were performed by applying 1000 laser pulses with ns duration and energy of 160 mJ; the laser spot diameter on sample was of 0.3 mm and the average ablation rate was of about 0.1 µm/pulse. From the element distributions in depth, it was possible to distinguish a top sample layer (thick ~10 µm) rich in C, and to observe other elements, potentially present in the used Al target. The implanted Al is for an order of magnitude higher at the frontal central part compared to its back while Al presence at the edges is further reduced by a factor of 10. The relative content of hydrogen is maximum at the sample center starting from the depth of about 50 µm and 20 µm for the front and back sample side, respectively. The other details of the experiment and the reconstructed in-depth profiles of various elements detected in the irradiated B target will be discussed.

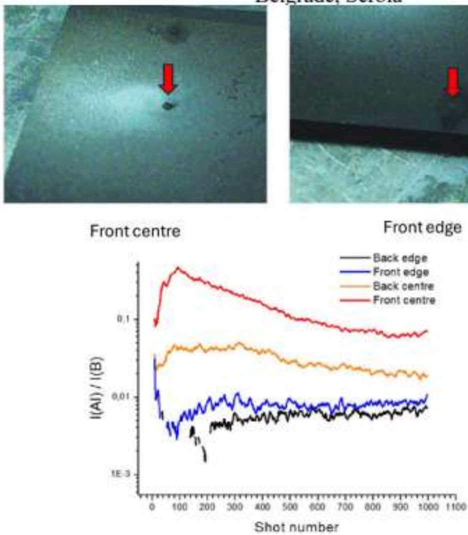

Figure 1. Photos of the frontal sample side where the laser spot is indicated by the arrow, and in-depth distribution of the analytical Al peak normalized on the B peak.

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Progress of p-^{11}B Research for Fusion Energy at ENN

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Abstract

Proton-boron (p-11B) fusion, an aneutronic pathway to clean energy, faces challenges including extreme plasma conditions, cross-section uncertainties, and unthermalized plasma physics. This work highlights ENN's advancements in three areas: p-^{11}B reaction physics, fusion rate enhancement, and magnetic confinement integration.

Recent p-11B cross-section measurements validate historical data while extending Rider's model [1] to high temperatures (hundreds of keV) and alpha-heating effects. Simulations [2] reveal a net energy gain window at electron temperatures >130 keV, with recirculating power loss minimized at Te/Ti ≈ 0.5, enabling Q-fusion >10. Fusion rate enhancement experiments [3] demonstrate a 30% increase in alpha yield using mixed hydrogen-boron targets under 120–260 keV proton beams.
In magnetic confinement systems, projections for the EHL-2 spherical torus [4] predict 1.5×10^{15} and 5×10^{14} alpha particles/s for thermal-thermal and beam-thermal reactions under 200 keV neutral beam injection. EXL-50U experiments [5] explore ICRH-NBI synergy, achieving 5×10^{8} alpha particles/s with 20 keV NBI and 1.5 MW ICRH. Diagnostics for alpha and gamma-ray detection are under development to support reactor control.

Collaborative efforts across accelerators, lasers, and magnetic devices underscore ENN's progress in addressing p-11B fusion challenges. Key milestones include validating cross-sections, demonstrating nonlinear yield enhancements, and advancing reactor-relevant scenarios.

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Boron Hydrides: A Fuel of Choice for p-B Fusion? Part II

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Abstract

At the previous conference in Frascati, we outlined the case for using molecular boranes as potentially optimal fuel targets for proton–boron (p–B) fusion (using octadecaborane, $B_{18}H_{22}$, as a case study[1]), emphasizing their favourable chemical structure, boron density, and manipulable physical properties. We also proposed a roadmap for evaluating key fuel parameters for the boranes—such as energy yield, target stability, boron-hydrogen ratio, molecular charge, etc.

In this year's presentation, we will share preliminary experimental results from a significant series of tests—comprising hundreds of laser shots—conducted on a range of borane-based targets using the high-power PALS (Prague Asterix Laser System) facility. These early findings offer new insight into the response of borane compounds under high-energy laser irradiation and their viability as p–B fusion fuel. The talk will provide an update on target performance, diagnostic observations, and future directions for optimizing borane materials in fusion applications.

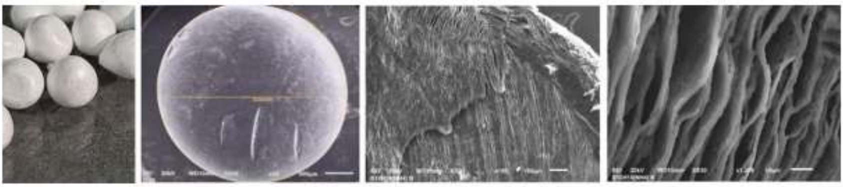

Figure 1. An example of 'foam' borane targets and their inner macrostructure.

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Investigation of Laser driven proton-boron reaction in Pitcher-Catcher configuration: CR39 and activation measurements with Monte Carlo validation

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Abstract

The proton–boron-11 fusion reaction is gaining interest as an aneutronic alternative to conventional fusion approaches, due to its ability to produce three alpha particles without neutron emission. This feature makes it attractive for clean energy production with reduced radiological impact. In this context, an experimental campaign was conducted at the PALS facility in 2024 to investigate alpha particle production from boron-enriched targets irradiated with a high-intensity laser. The study employed a mixed setup combining both "in-target" and "pitcher–catcher" configurations. Figure 1 shows a CAD rendering of the dual-target system used: the main laser pulse interacts with a primary target, initiating both in-target fusion reactions and the emission of energetic particles (mainly protons). These particles then strike a secondary target composed of natural boron, where further $p - {}^{11}B$ reactions occur in the pitcher–catcher configuration.

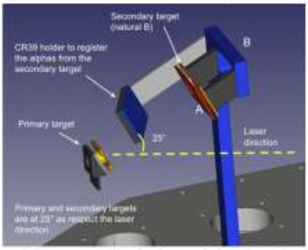

Fig.1 CAD rendering of the double target configuration.

Various diagnostics were employed during the experiment, including Time-of-Flight (TOF) systems for real-time monitoring, Thomson Parabola (TP) spectrometers for ion characterization, and CR39 nuclear track detectors for particle identification. This work focuses on the fusion reactions occurring in the secondary target. Alpha particles emitted from the boron target were detected using CR39 detectors positioned in front of the target and shielded with aluminum filters of varying thicknesses to suppress low-energy background contributions. Preliminary analysis of the CR39 detectors indicates an estimated alpha yield in the range of **10^7 to 10^8 α/str** per shot.

A key aspect of the experiment was the successful activation of the boron target by the ion beam produced via the Target Normal Sheath Acceleration (TNSA) mechanism in the primary target. The proton spectra associated with this beam, as measured using the Thomson Parabola diagnostic, showed energies up to **5 MeV**, consistent with the conditions required to trigger the $p–{}^{11}B$ fusion reaction. Activation was quantified using an HPGe detector, leading to an estimate of approximately **10^7 to 10^8 $p - {}^{11}B$ fusion reactions** occurring within the secondary target per laser shot. To support and interpret the experimental results, Monte Carlo simulations were carried out. These simulations incorporated the experimentally measured proton spectra from the TP diagnostic, computed the geometric efficiency of the CR39 detectors, and evaluated the impact of backscattered protons. The simulations provided a numerical estimate of alpha emission from the secondary target, which was then compared with both CR39 measurements and activation data.

In summary, this study combines CR39 diagnostics, activation analysis, and numerical modeling to confirm the occurrence of proton–boron fusion reactions in a pitcher–catcher configuration and to provide a comprehensive assessment of the alpha particle yield.

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Investigation of advanced laser-driven proton sources produced by the interaction of relativistic laser pulse with low density foams and their applications to proton-boron fusion

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Abstract

In recent years, laser-driven generation of energetic protons, and their applications to several fields of science, have been hot topics in physics. One interesting application is the study of proton-boron fusion induced by laser driven protons. In this context, the experiment that we have done recently on PHELIX laser facility at GSI has two goals: (i) Study the process of super-ponderomotive acceleration of electrons in plasmas with very-long scale-length and the effect they have on proton acceleration in laser-produced plasmas. (ii) Use the improved proton source for the generation of α particles from proton boron fusion reaction in a confined cylindrical geometry. We expect an increased number of protons generated in foam and increased generation of α-particles which will indeed be interesting in the framework of proton-boron fusion studies (for future production of energy), for the possible development of high-brightness α-particles sources, but also to allow a precise characterization of proton emission.

We will present results of this experiment using several diagnostics to estimate the proton spectrum and the absolute conversion laser energy into the proton beam; we have shown unfortunately that the foam target induced a proton beam pointing instability which induced that the proton beam has a chaotic direction around the backside of the target normal.

Acknowledgements

This work has been carried out within the framework of the COST Action CA21128- PROBONO "PROton BOron Nuclear fusion: from energy production to medical applications", supported by COST (European Cooperation in Science and Technology - www.cost.eu).

Potential of Low Gain Avalanche and SiC Detectors for Plasma Diagnostics in p–^{11}B Fusion Experiments

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Abstract

Proton–boron (p–^{11}B) fusion presents a very promising aneutronic alternative to standard deuterium–tritium (D–T) fusion. It has the potential to provide a cleaner energy with minimal neutron yield. While D–T fusion presents extreme challenges due to its intense neutron flux, p–^{11}B introduces a different but equally demanding challenge to diagnostics: necessity to directly detect and resolve high-energy charged particles — mainly alpha particles — in real time and at fluxes exceeding 10^{10} particles/sr/shot.

In this context, we explore the potential application of Low Gain Avalanche Detectors (LGADs) and radiation-hard silicon carbide (SiC) devices for real-time plasma diagnostics in p–^{11}B fusion experiments. These technologies, developed at IMB-CNM (CSIC)[1], offer a combination of high temporal resolution, radiation tolerance, and spatial resolution necessary for measuring key features of fusion plasmas, such as alpha particle yield and protons. Additionally, we discuss the LGAD and SiC technology equipped with conversion layer for indirect neutron flux measurement.

We introduce the technology and present experimental results obtained under fusion-like conditions (proton, alpha particle and neutron detection) and discuss the advantages and limitations of each detector type, including considerations of thermal exposure and radiation damage.

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A Commercially Viable High-Efficiency Thulium-Based Laser System for Proton Boron Fusion Power Plants

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Abstract

The realization of laser-driven proton boron (p-B) fusion as a practical energy source hinges on the development of laser systems that are not only capable of delivering the required pulse energies and durations, but are also efficient and economically scalable. We present experimental and simulation data on a complete Thulium-based laser amplifier system designed specifically to meet the needs of a p-B fusion power plant, demonstrating a path to commercial viability that dramatically outperforms conventional glass amplifier systems.

Our approach leverages the unique gain dynamics of the Thulium-based gain material, enabling high system wall-plug efficiency while requiring only a fraction of the pump power compared to traditional laser systems. This efficient delivery mechanism allows for up to a 40-fold reduction in system cost under typical scaling assumptions, representing a transformative advantage for power plant-scale deployment when compared to Nd:glass or Yb:glass architectures. The system delivers nanosecond to picosecond pulses at 2 µm, which are ideally suited for p-B fusion ignition. Unlike deuterium-tritium (DT) fusion, p-B fusion does not inherently require UV ultrafast pulses for ignition; nanosecond and picosecond pulses at 2 µm have been shown to reach the necessary conditions in advanced theoretical and experimental models.

To power a 100 MW-class proton-boron (p-^{11}B) fusion plant, our calculations suggest that the laser driver system must collectively deliver pulse energies equivalent to the multi-megajoule range (e.g., 1–2 MJ per shot), with each pulse focused to achieve intensities on the order of 10^{16} to 10^{18} W/cm². Rather than relying on a single high-energy beamline, our architecture employs an array of synchronized, kilojoule-class Thulium-laser modules (see figure 1). This modular approach enables improved thermal management, higher average power scalability, and fault tolerance. While current technology does not yet support megajoule-class pulses at multi-hertz repetition rates, our system is designed to bridge this gap by distributing the energy delivery across many efficient, time-multiplexed laser channels.

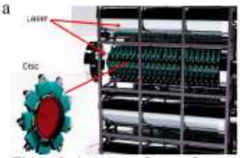

Figure 1: *Artist's rendering of a single disk laser module and its replication to form a complete high-energy laser system. Multiple such lasers are combined to provide redundancy and scalable output for a fusion power plant.*

Our system, based on stacked, edge-pumped Thulium disks, is designed to meet these requirements with high wall-plug efficiency and robust thermal management, made possible by cryogenic cooling and optimized coupling optics. The modular architecture allows for rapid scaling and redundancy, critical for continuous power plant operation.

This work is directly relevant to the commercial ambitions of companies such as HB11 and Blue Laser Fusion, who are pioneering p-B fusion as well as many research institutes using advanced laser technologies. Our system addresses the key bottleneck of laser cost and efficiency, offering a practical solution for scaling p-B fusion to grid-level power. At the conference, we will present detailed data on system performance, diode utilization, and power plant-level calculations, demonstrating how this technology can achieve competitive levelized cost of electricity (LCOE) and enable the first generation of commercially viable p-B fusion power plants.

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Laser structuring of titanium-based alloy and metallic thin films under controlled atmospheric conditions

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Abstract

Titanium and its alloys are extensively used in aerospace, nuclear, marine and biomedical applications due to their superior physicochemical properties, such as excellent corrosion resistance and biocompatibility, high specific strength, good ductility, and deformability. The surface of the material is significant in terms of the response of the environment to titanium and titanium-based materials. This is the reason for continuous research interest focused on enabling prolonged usage of Ti-based materials, specifically Ti6Al4V alloy, by improving their wear resistance and hardness and increasing the active surface, for instance, by patterning the surface with laser induced periodic surface structures by direct laser action, in nitrogen and argon atmosphere, or improving the mechanical properties by laser shock peening. Beside the modification of bulk materials, the thin films deposition also enables surface functionalization and improvement of materials. The significance of metallic thin films with nanometer-scale thicknesses is recognized for various applications, including microelectronics, biosensors, solar engineering, optical components, etc. Laser patterning/microstructuring of the thin films surface conducted by the fast and ultrafast lasers is a powerful technique for altering/modifying metallic surface and, also inducing some functional changes in sample properties, aiming to heighten or unlock their potential for diverse applications – optical, chemical, sensing, protective.

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Hydrogen Boron ignition using specific fusion fuel composition in MIF configuration

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Abstract

Magnetic Inertial Fusion (MIF) [1] is a promising configuration for the fusion ignition of the p-^{11}B medium [2]. Interesting results of MIF activities are presented in [3, 4] and especially for the case of a laser preheated target [5], compressed to high temperatures, by the intense magnetic field, that is generated by a pulsed z-pinch [4, 6, 7]. In this work, a new alternative approach to p-^{11}B MIF is presented, which could be considered as less complex, compared to the compression configuration, of the z-pinch. Laser-induced acceleration [8-12] of a metallic cylindrical structure ["target-liner"] [13], charged with specific fusion material, will enable the achievement of high speeds (15 km/sec – 100 km/sec), through the use of high-power laser pulses. In this context, the laser accelerated target-liner of high velocity, will interact axially with a high gradient magnetic field. The laser beam may also enable the potential preheating of the target-liner with significant contribution [3] to the finally reached high fuel temperature. The inductively driven compressed fields will implode the target and lead to relatively high fuel density and high temperature, thus enabling the buildup of an important number of fusion reactions. The development of a code describing the compression process and the high fuel temperature in the high velocity target-liner, is coupled with a multi-fluid code [14, 15], describing the temporal evolution of the physical parameters and the ignition process of a p-^{11}B medium, arising from a [d-t-p-^{11}B] fuel mixture. In a previous work of ours [16], it is shown that the p-^{11}B component of a [d-t-p-^{11}B] fuel mixture can be ignited at relatively low initial temperatures (~10 keV), as a consequence of the alpha heating, generated by the d-t fusion reactions. The coupled code [MIF + multi-fluid], describing the aforementioned configuration, can simulate cases with appropriate initial parameters and conditions, in order to test the efficiency of the p-^{11}B medium fusion ignition, resulting from various new specific fuels compositions [17-19], such as *ammonia –borane- d6, ammonia-borane-d3-t3 or Diborane with d-t gas*, at currently existing laser facilities [e.g. ELI] . The present work could be considered as the starting point for a series of investigations on challenging technical achievements, which may lead to a novel p-^{11}B fusion experiment.

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Laser-Driven Ultrahigh Compression of Matter and Application to Proton-Boron Fusion

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Abstract

To compress matter to a density higher than a few thousands of times solid density, two different schemes, microbubble implosion (MBI)[1,2] and multi-stacked shocks (MSS), are discussed, as fundamental physical approach rather than as energy application.

In the MBI scheme, a micron-sized target with a hollow sphere (bubble) embedded inside is irradiated by PW-laser to produce MeV-electrons, which fill in the bubble. Ions on the inner surface of the bubble are then subject to a strong spherically symmetric electrostatic fields to be accelerated to the center.

Meanwhile, in the MSS scheme, a spherically uniform matter is compressed by multi-stacked shocks to asymptotically form a self-similar stacked-converging shock, which is substantially different from the Guderley[3] solution for a single converging shock wave.

Both schemes can be applied to proton-boron fusion, the detail of which will be provided in the conference.

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ELECTRON DRIVEN REACTIVE PROCESSES INVOLVING H2+, BeH+ AND THEIR ISOTOPOLOGUES IN PLASMA FUSION

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Abstract

The Multichannel Quantum Defect Theory (MQDT) has been employed in computing cross sections and Maxwell rate coefficients for electron-driven reactions involving molecular cations. These data are usefully in the modelling of the kinetics of various cold ionized media of fundamental and applied interest. Rotational and vibrational transitions (RVT) and dissociative recombination (DR) rate coefficients, an extension of our previous studies [1-2] and outline several important features, like isotopic and resonant effects are presented for H2+ , HD+ and D2+.

For the fusion plasma edge, Cross sections and rate coefficients have been produced for BeH+ [4], BeD+ [5] and BeT+ [6] cations suitable for the modeling of the kinetics in fusion plasmas, in devices with beryllium based main chamber materials, such as ITER and JET. The isotopic effects demonstrates the quasi-independence of the rate coefficients on the isotopologues, if they are represented with respect to the vibrational energy of the target, at a given electron temperature. The energy of the incident electron is below and above the dissociative threshold, 2.7eV.

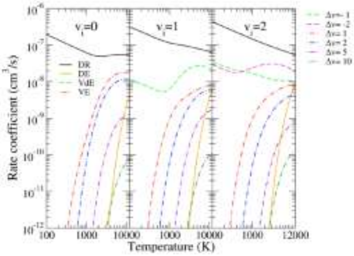

Figure 1. DR, DE, VdE, and VE rate coefficients of BeH^+ in its ground electronic states for the lowest three vibrational levels of the target (vi = 0–2).

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Interaction of Laguerre-Gaussian laser pulses with borane targets for axial magnetic field generation

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Abstract

Boron hydrides (boranes) have gained interest as possible targets for proton-boron fusion as they provide an option for in-target approaches instead of pitcher-catcher setups. Such borane targets like $B_{18}H_{22}$ have recently been investigated by Krůs *et al.* in [1], showing an alpha-particle yield in the range of 10^9 per steradian using the PALS laser system.
Moreover, boranes allow to effectively tune the ratio of hydrogen to boron depending on the utilized molecules, giving more control over several aspects during laser-plasma interaction like the generation of electromagnetic fields.
It is known that laser pulses carrying orbital angular momentum, like Laguerre-Gaussian modes, can excite strong axial magnetic fields using the Inverse Faraday Effect [2], which can in turn be used for plasma confinement.
In this talk, we present the results of 3D particle-in-cell simulations for the interaction of Laguerre-Gaussian laser pulses with different borane targets. We show that – depending on the ratio of hydrogen to boron – the strength of the axial magnetic field can be increased [3].

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Radioisotopes production using lasers: from basic science to applications.

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Abstract

Laser technologies have advanced significantly with the understanding of Chirped Pulse Amplification (CPA), which allows energetic laser beams to be compressed to tens of femtoseconds (fs) pulse durations and focused to a few micrometers (μm). Protons with energies of tens of MeV can be accelerated using methods such as Target Normal Sheath Acceleration (TNSA) and focused on secondary targets. Under these conditions, nuclear reactions can occur, producing radioisotopes relevant for medical purposes. High repetition lasers can produce sufficient isotopes for medical applications, making this approach competitive with conventional methods that rely on accelerators. The production of the ^{67}Cu, ^{63}Zn, ^{18}F, and ^{11}C were investigated [1-2] at the 1-petawatt (PW) laser facility at Vega III in Salamanca, Spain. These radionuclides are used in positron emission tomography (PET) and other applications. The reactions ^{10}B(p,α)^{7}Be and ^{70}Zn(p,4n)^{67}Ga were also

measured to further constrain proton distributions at different angles. The nuclear reaction products were investigated using the pitcher-catcher method, with protons produced by an aluminum target and impinging on various targets in both the forward and backward directions relative to the laser. Angular distributions of radioisotopes were measured using a High Purity Germanium Detector (HPGE). Our results, presented in detail in Rodrigues et al. [1], are reasonably reproduced by numerical estimates following the approach of Kimura et al. [3]. In the last campaign at Vega III [4-5], the radioisotopes ^{52m}Mn and ^{55,56,57}Co were produced with proton-induced reactions on natural iron. The positron emitters ^{52m}Mn and ^{55}Co are of interest in PET imaging and in particular the ^{55}Co is a potential theranostic pair with ^{58m}Co. Preliminary results in the ^{11}C production, tests looking for the feasibility of ^{211}At production and the use of silicon detectors to measure the β^+ decay from ^{11}C as alternative from HPGe detectors, in the L3-HAPLS laser experiment at ELI facility at Czech Republic, will be presented.

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Laser-driven high-repetition-rate fusion reactions at the ELI-Beamlines laser facility

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Abstract

The deuterium tritium (DT) fusion reaction represents today the best candidate for future nuclear fusion plants. However, supply and management of radioactive tritium involves several serious issues for a future reactor. Thus, the investigation of alternative fuels is a trending topic of research. In particular, the $p+{}^{11}B \rightarrow 3\alpha + 8.7$ MeV fusion reaction represents a potential alternative to DT, due to comparable cross-sections but at much higher energy, and is attracting also for many applications such as fusion energy production [1,2], astrophysics [3] and alpha-particle generation for medical treatments [4]. One possible scheme for laser-driven $p+{}^{11}B$ reactions is to direct a beam of laser-accelerated protons onto a boron sample (the so-called "pitcher-catcher" scheme). This technique was successfully implemented with energetic lasers yielding hundreds to thousands of joules per shot [5-7]. This is possible on a few large installations and for a limited number of shots. An alternative approach is to exploit high-repetition rate laser-systems at PW-power scale [8], allowing to explore

the laser-driven fusion process with hundreds (up to thousands) of laser shots (at more moderate energy), leading to an improved optimization of the diagnostic techniques and an enhanced statistics of the obtained results. In this work we describe the experiments recently performed at the L3 ELIMAIA laser system at ELI-Beamlines, with an intensity of about 10^{21} W/cm^2. Moreover, we exploited the potential of the in-target scheme (i.e. directly triggering the fusion reactions in the laser-irradiated target) with the same laser. We used deuterated targets aiming to achieve deuterium-deuterium (DD) nuclear reactions. Both schemes were successfully implemented and triggered the related reactions and, in this presentation, we are going to give details of them and of the preliminary results achieved.

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Cavity Pressure Acceleration in laser-induced, mixed-fuel fusion reactions

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Abstract

The majority of current research related to driving nuclear fusion reactions using lasers employ hundreds of TW and PW-class laser systems to increase the reaction yield, effectively taking advantage of increasing the intensity of laser pulse. In this work we report highly efficient generation of both 2.45 MeV neutrons and energetic ¿), intense proton beam during Cavity Pressure Acceleration (CPA) scenario of laser-matter interaction using PALS laser system [1], where either CD_2 foils or CD_2 powder were used inside the target cavity [2,3]. In this approach, the target geometry plays a crucial role in controlling the plasma parameters such as density, electron temperature and pressure which are directly affecting the number of fusion reactions during laser-matter interaction. On the basis of experimental data and numerical results of radiation-hydrodynamics simulations, a new two-step fusion reaction is proposed, in which protons arising from DD reactions are driving proton-boron fusion upon interaction with a boron-based catcher target. The experimental measurements of proton energy spectra carried out during the mentioned experiments [2,3] served as an input for preliminary FLUKA [4] simulations of proton beam colliding with boron targets of different thickness, which suggest potential for few-TW, ns laser systems to generate alpha particle flux comparable to these achieved using the most powerful laser beamlines.

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Nuclear Fusion Power Reactor Concept Proposed for Laser-Driven Proton-Boron (HB11) Fusion

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Abstract

Proton-Boron or HB11, fusion reaction energy is carried by energetic, positive charged He ions: ${}_1^1H + {}_5^{11}B = 3 \times {}_2^4He + 8.7$ MeV. An early reactor design applied a strong Electric field to stop the ions and convert their radiation power into electric power [1]

In our proposed conceptual HB11 fusion reactor, Fig. 1., the fusion power is converted into useful power by two channels:

i. Power carried by the ions heats up the buffer gas. The heat is extracted by a heat exchanger and transmitted to the turbine for conversion into electric power. The reactor is filled with 10mBar of He buffer gas. The ions will be stopped efficiently by the 'snow-plough' effect [2.1].

ii. The Bremsstrahlung X-rays will propagate through the buffer-gas and will irradiate 'X-ray Converter Panels' surrounding the Laser-Plasma-Fusion Source. Such X-ray Converter Panels would be made of solid-state P-I-N X-ray diode [2.2] chips which would convert the X-rays directly into electric current/power.

The reactor core components and the 'vacuum wall' are protected from the Fusion Radiation Source: buffer gas stops the ions, and the X-ray Panels stop the energetic X-rays. Residual Neutron radiation is stopped by Water blanket.

Figure 1. Schematic of the proposed HB11 (Proton-Boron) Laser Driven Fusion Reactor. The HB11 fusion power is converted into (i) He Buffer-Gas heating by ion radiation power and (ii) electric current/power in the X-Ray Converter Panels irradiated by Bremsstrahlung X-Ray power. Buffer gas also protects all the reactor-core components.

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Equation of State of Shock Compressed BN in the Megabar Pressure Range

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Abstract

The interest in the behavior of boron nitride (BN) in extreme conditions is largely justified by recent renaissance in hydrogen boron fusion studies and by the perspective of application of this material as ablator in ICF in alternative to diamond (high density carbon, HDC). In particular, hydro simulations related to hydrogen boron fusion will need information on the Equation of State of boron and boron compounds.

The database of experimental Equation of State (EoS) points for BN is very limited. Only a few points are available on boron nitride in extreme conditions between 12 and 27 Mbars [1] while for pure boron there is one point at 56 Mbars [2] and extended recently by a few points in a range 5–16 Mbar, using hohlraum-driven shock waves at the SGIII-P laser facility in China [3].

Most of presently kilojoule-class laser systems, which were used as a standard tool in creation of the high-density states, operate at low repetition rates, limiting the amount of data. The L4n beamline, which was used in this experiment overcomes this limitation by deliverig hundreds joule-scale energy at high repetition rate (HRR) in principle up to 1 shot/minute.

Therefore, we have conducted studies on the hexagonal BN EoS at the ELI beamlines / ELI ERIC installation in Prague, Czech Republic. High compression of *h*-BN was achieved with the L4n laser of ELI beamlines operating at 2ω (526.5 nm) with pulse length of $\tau_L \sim 1.92$ ns delivering energy up to 200 J. A flat-top intensity profile within a focal spot of ~300 μm diameter was produced by using a phase plate.

In the experiment, we used multilayer stepped targets produced at Scitech Precision, UK, with either aluminum or quartz as reference material. We then simultaneously measured the shock velocities in the reference material and in BN, using Streaked Optical Pyrometry (SOP) and Velocity Interferometer System for Any Reflector (VISAR) diagnostics, and we applied the impedance mismatch technique to obtain the experimental points on the equation of state (EoS) of BN achieving pressures between 1 and 9 Mbars.

This first EoS shock compression experiment at L4n demonstrates the potential of this platform to significantly reduce statistical uncertainties and enhance model discrimination in WDM research.

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POSTER CONTRIBUTIONS

Defect Formation in Time-of-Flight Detector Applications for Fusion Environments

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Abstract

Within the framework of COST Action CA21128 PROBONO, the Institute of Solid State Physics, University of Latvia, proposes a targeted investigation into defect formation and material resilience under realistic fusion conditions. The primary objective is to evaluate candidate materials for Time-of-Flight (TOF) detector applications, with a specific focus on their radiation tolerance before and after exposure to fusion-relevant environments.

This study presents experimental benchmarks for radiation-induced damage in CVD diamond detectors, referencing literature data [1,2]. Various irradiation types - including neutrons, particles and X-rays - have been investigated to determine threshold and damage doses. Notable observations include a decline in charge collection efficiency, which is dependent on dose and radiation type.

To date, material testing was conducted using surrogate radiation sources under extreme but non-fusion conditions. To bridge this gap, we aim to evaluate radiation-induced defect evolution during direct exposure to laser-plasma interactions. To this respect, CVD diamond samples, prepared at the University of Rome Tor Vergata, and which interacted with laser-plasma radiation produced in different experimental conditions, were analyzed and we show here the comparison of these defects with respect to those coming from ordinary sources. Characterization will be conducted in Riga using advanced spectroscopic and analytical tools recently acquired through the CAMART[2] project.

The research investigates the formation and evolution of defect structures such as point defects, color centers, trapped charge sites, and amorphous regions. It also aims to identify any novel or unexpected damage mechanisms arising from authentic fusion plasma interactions. This collaborative effort invites contributions from the broader fusion diagnostics community to validate and co-develop robust, radiation-hardened materials for future diagnostic platforms. The outcomes will directly inform the selection and optimization of materials for next-generation fusion experiments.

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Photomechanical spallation of nanolayer bimetallic thin films with single femtosecond laser pulses

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Abstract

Composite materials in the form of nanolayer thin films (NLTF), consisting of alternating metallic layers, are widely used in modern technology because of their unique properties that cannot be found in the bulk material's constituents [1]. Among NLTFs, NLTFs composed of Ti with other metals form a broad group. They have found applications in microelectronics, catalysis, sensing, neutron and soft X-ray optics, micro-junction solutions, biotechnology, etc. Laser processing of NLTFs is a non-contact, widespread method for their modification. Ultra-fast laser (UFL) irradiation (pulse duration from tens of fs to 10 ps) can be used for their processing without photomasks and special environments. Irradiation with these pulses enables ultrafast transfer of photon energy into the material. This is important because of reduced heat diffusion into the surrounding regions of the treated surface area [2]. Using UFL, it is possible to achieve a special type of ablation of the target surface with a single UFL pulse - selective ablation, also known as photomechanical spallation. It can be used to remove one or more layers from the surface of the NLTF, but photomechanical spallation can only be achieved for a given material at certain laser beam parameters. We present the results of our research of Ti-based composite NLTFs (Ti/Ni, Ti/Al, Al/Ti and Ti/Nb) deposited on silicon wafers [3-5]. Irradiations were performed in air under standard laboratory conditions using single femtosecond pulses. Depending on the laser radiation parameters, partial ablation of the first layer, several layers, or complete ablation of NLTF was registered. Microscopy, scanning electron microscopy (SEM), energy dispersive X-ray spectroscopy, and optical profilometry were used to examine the surface morphology, the depth of the ablated areas, and the changes in elemental composition altered by the incident laser pulse. The presence of an interface between two metal nanolayers affected the ablation process.

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Copper Borophene: Mechanochemical Synthesis for P-B^{11} Fusion Reaction Target material

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Abstract

Borophene, a two-dimensional allotrope of boron, possesses exceptional mechanical strength, electrical conductivity, and electrochemical activity, making it a compelling candidate for next-generation energy storage and advanced fusion applications. However, scalable synthesis remains a major bottleneck[1]. In this study, we demonstrate a simple and scalable ball milling approach to produce borophene nanosheets and copper-intercalated borophene composites in a single step. The high-energy milling facilitates both the exfoliation of bulk boron into thin sheets and the in situ incorporation of copper, resulting in significant structural and electronic modifications. Comprehensive characterization—including X-ray diffraction (XRD), high-resolution transmission electron microscopy (HR-TEM), X-ray photoelectron spectroscopy (XPS), Raman spectroscopy, and Fourier-transform infrared (FTIR) spectroscopy—confirms successful exfoliation and copper intercalation. HR-TEM imaging reveals the formation of a novel structure with β^{12} and χ^3 phases in a 2D planar structure, where β^{12} ring offers potential sites for hydrogen confinement. These copper-intercalated borophene materials show promise as target materials in proton–boron (p–^{11}B) fusion reactions, potentially supporting avalanche fusion mechanisms through their unique structural and electronic features[2].

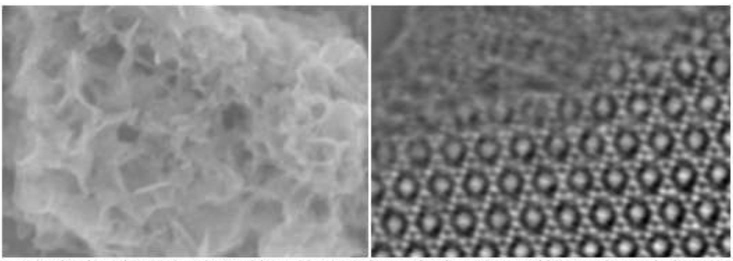

Figure 1. As-synthesized Cu intercalated Borophene sheets a) imaged using SEM and b) atomic resolution HRTEM image displaying the β^{12} ring and χ^3 traingles.

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Nonlinear Heating Mechanism Driven by High-Energy Ion Beam in Hydrogen-Boron Plasma

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Abstract

Proton-boron ($p\text{-}B^{11}$) fusion is acclaimed as an ultimate energy solution due to its abundant fuel resources and neutron-free reactions. However it needs temperature over 10 times higher than deuterium-tritium fusion, presenting great challenges in plasma ion heating efficiency. To address this, recent research has focused on collisionless mechanisms, such as exciting Ion Bernstein Waves (IBW) via neutral beam injection (NBI) ions. IBW with high phase velocities can generate substantial supra-thermal ions that enhance p-B11 fusion yield [1,2].

This study investigates the characteristics of supra-thermal ion generation by high-energy proton beams in hydrogen-boron plasmas using full-kinetic Particle-in-Cell (PIC) simulations of the EPOCH code [3]. Results show that, under appropriate conditions, the NBI ions can excite IBW in hydrogen-boron plasmas and transfer energy to copious supra-thermal ions. For example, in background plasma temperature of 5 keV, ion density n_i of 5×10^{18} m^{-3}, and magnetic field B of 1 T, or n_i of $1\times10^{20}\,m^{-3}$ and B of 4.484 T, the maximum energy of the supra-thermal ions can exceed the energy of first resonance peak (162 keV) of the $p\text{-}B^{11}$ reaction cross-section (see Figure), leading to an enhancement of several orders of magnitude in the fusion yield. Details of this research will be presented.

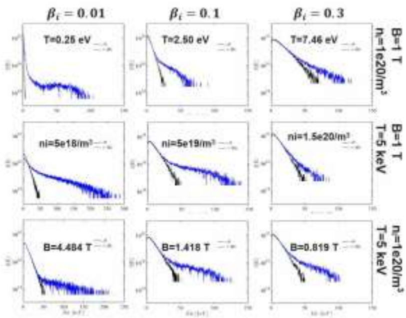

Figure. Under different β values, temperatures, densities and magnetic fields, Energy spectra of background hydrogen ion at the initial and final times of simulstion.

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kJ-Class Attosecond X-Ray Drivers via Coherent Diamond Bragg Cavity Stacking

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Abstract

Aneutronic proton–^{11}B fusion promises clean, neutron-free energy but hinges on the availability of kJ-class, 10 keV, single-cycle X-ray drivers – technology that today's XFELs cannot deliver. Here we propose a practical, optics-driven pathway to bridge the gap between theoretical ignition schemes (Wenjuan Lv et al. 2022 [1]; Ribeyre et al. 2021 [2]) and experimental reality, by coherently stacking thousands of XFEL seed pulses in ultra-high-quality diamond Bragg cavities [3]. Diamond Bragg mirrors employ zero-dislocation-density, isotopically pure ^{12}C crystals, cryogenically cooled to suppress thermal dephasing, and cut for 45° incidence at 10 keV. Projected reflectivities exceed 99.968%, corresponding to a round-trip loss of 1,279 ppm per bounce. By coupling an XFEL's attosecond pulse train into a multi-meter, multi-mirror coherent stacking diamond cavity, and phasing each burst to within <10 as, one can accumulate more than 1,000 passes before significant loss, enabling the access to Joule-scale X Ray laser regime. Focusing to 15 µm diameter yields intensities 5×10^{27} W/cm^2, satisfying the resonant KH-enhancement condition ($n_D = 9$) for a 26× Coulomb-barrier suppression [1]. When directed into a 38 µm-diameter, 500 g/cm^3 p–^{11}B sphere, this driver can launch MeV-scale protons via radiation-pressure acceleration and seed a self-propagating α-burn throughout ~1 mg of fuel, producing 1 MJ of fusion energy. This concept provides a potential experimental roadmap: demonstrate 10–50 J stacking in existing XFEL beamlines; phase-lock and compress to attoseconds; ignite micro-targets to validate the 26× barrier enhancement and single-cycle acceleration. By uniting advanced X-ray optics with state-of-the-art fast-ignition physics, our scheme offers the path from current XFEL sources to aneutronic fusion ignition.

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Estimation of Proton–Boron Fusion Reactions from Laser-Driven Proton Sources Using Low-Density Foam Targets

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Abstract

In a recent experiment at the PHELIX facility (GSI), we investigated proton generation via the interaction of high-intensity picosecond laser pulses with low-density foam targets. A primary objective was to study the process of super-ponderomotive acceleration of electrons in plasmas with very long scale length and the effect they have on proton acceleration in laser-produced plasmas. This talk presents preliminary results on the evaluation of fusion yields based on the measured energy spectrum of laser-accelerated protons and boron nitride target activation spectra. We discuss the estimated reaction rates based on data from multiple diagnostics, taking into account the interaction probabilities and target parameters. Our findings suggest that cold foams near the critical density regime enable increase the generation of proton beams in the low-energy range which is well-suited for triggering p–B fusion reactions. These results highlight the potential of this approach for producing high-brightness α-particle sources and advancing aneutronic fusion research.

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Femtosecond Laser Surface Engineering of Nickel-Based Superalloy Under Controlled Atmospheres

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Abstract

This study investigates the surface modification of Nimonic 263, a nickel-based superalloy, using femtosecond (fs) laser pulses under different atmospheric conditions. With its high strength and corrosion resistance, Nimonic 263 is widely used in aerospace and high-temperature applications [1-2]. Femtosecond laser processing offers a precise, non-thermal method for enhancing surface properties without altering the bulk material [3].

Experiments were conducted using a Ti:Sapphire fs laser (200 fs, 775 nm) with pulse energies ranging from 2.5 μJ to 250 μJ. Samples were irradiated in air, nitrogen-rich, and argon-rich environments. The impact of atmosphere and pulse count (1–400) on surface morphology and properties was systematically examined using SEM, XRF, profilometry, and microhardness testing.

With SEM micrographs obtained from the target surface of the Nimonic 263 superalloy irradiated with a fs laser in air and nitrogen atmospheres, it is evident that surface damage becomes more pronounced with increasing pulse energy and number of pulses. To facilitate a clearer and more effective analysis of the morphological changes on the surface of the Nimonic 263 superalloy, two energy density regimes are studied: the low and the high energy density regime.

Results demonstrated that fs laser pulses produced fine laser-induced periodic surface structures (LIPSS) with minimal thermal diffusion. Nitrogen-rich atmospheres enhanced ripple definition and promoted localized compositional changes. Argon atmospheres yielded smoother, more uniform modifications. Up to 200 pulses, surface roughness and crater depth increased, after which saturation occurred. XRF analysis revealed minor redistribution of surface elements, including slight variations in Co, Cr, and Mo levels depending on atmosphere. Microhardness measurements showed a notable increase in hardness in fs-treated regions, especially in nitrogen environments. This is attributed to rapid cooling rates, refined surface structuring, and potential nitride formation [4].

In summary, femtosecond laser irradiation enables controlled nanostructuring of nickel superalloys, especially Nimonic 263 alloy. By tailoring ambient gas conditions, surface features and mechanical properties can be optimized for high-performance applications in extreme environments.

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