Proton Boron Capture Therapy
(UN) Effectiveness or not ?

Proof that things are not always as simple as they seem

G.A.P. Cirrone*

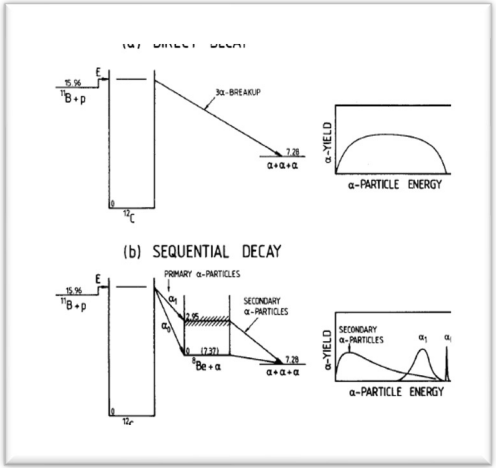
G.Cuttone, A.Attili, E. Scifoni, C.Voena, S.Bortolussi, S.Agosteo, L.Manti, G.Russo, F.P.Cammarata, R. Parenti, G.Petringa, L.Giuffrida, D.Margarone, A.Picciotto, F.Consoli

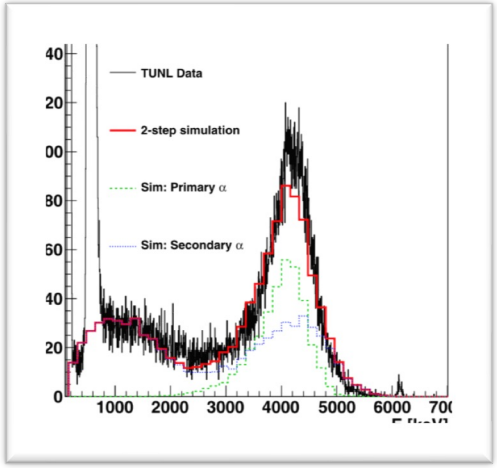
**Istituto Nazionale di Fisica Nucleare (INFN)- Laboratori Nazionali del Sud (LNS)*

The p-B fusion reaction

$$p + 11B \rightarrow \alpha_0 + {}^{8}Be + 8.59\ MeV \rightarrow \alpha_0 + \alpha_{01} + \alpha_{02}$$

$$p + 11B \rightarrow \alpha_1 + {}^{8}Be* + 5.65\ MeV \rightarrow \alpha_1 + \alpha_{11} + \alpha_{12}$$





H.W. Becker, "Low-Energy Cross Sections for 11B(p, 3a)", Z. Phys. A - Atomic Nuclei 327, 341-355 (1987)*

M. C. Spraker et al, "The 11B(p,a)8Be => a + a and the 11B(a,a)11B Reactions at Energies Below 5.4 MeV", J Fusion Energy (2012)

Neutronless fusion reactions

Two resonance at about **100 keV** and **600 keV** in the system center of mass

It is **not favourite in thermal equilibrium** conditions

It is considered as a **potential candidate** in inertial fusion scheme

Reagents **more abundant in nature** with respect to other fusion reactions of interest, and easier to handle (with respect to tritium, for example)

Interest for **astrophysical** processes

Interest for the realisation of intense α sources for applications

Long collaboration on the “Boron” studies

3

Collaboration with ENEA (I), FBK (I), ELI Beamlines (CZ)

PHYSICAL REVIEW X 4, 031030 (2014)

Boron-Proton Nuclear-Fusion Enhancement Induced in Boron-Doped Silicon Targets by Low-Contrast Pulsed Laser

A. Picciotto,[1,*] D. Margarone,[2,†] A. Velyhan,[2] P. Bellutti,[1] J. Krasa,[2] A. Szydlowsky,[3,4] G. Bertuccio,[5] Y. Shi,[5]

High-current stream of energetic α particles from laser-driven proton-boron fusion

Lorenzo Giuffrida, Fabio Belloni, Daniele Margarone, Giada Petringa, Giuliana Milluzzo, Valentina Scuderi, Andriy Velyhan, Marcin Rosinski, Antonino Picciotto, Milan Kucharik, Jan Dostal, Roman Dudzak, Josef Krasa, Valeria Istokskaia, Roberto Catalano, Salvatore Tudisco, Claudio Verona, Karel Jungwirth, Pierluigi Bellutti, Georg Korn, and G. A. P. Cirrone

Phys. Rev. E **101**, 013204 – Published 21 January 2020

Extended characterization of alpha particles via laser-induced p-^{11}B fusion reaction in silicon hydrogenated boron-doped thin targets

G. Milluzzo[1], F. Belloni[2], G. Petringa[3,4], V. Scuderi[3,4], L. Giuffrida[4,3], A. Velyhan[4], C. Verona[5,6], A. Picciotto[7], M. Rosinski[8], R. Catalano[3], M. Crivellari[7], J. Dostal[9], R. Dudzak[9,10], L. Juha[9], J. Krasa[9], M. Krupka[9,10], M. Krůs[10], G. Lanzalone[3], R. Leanza[3], C.G. Litrico[3], M. Pfeizer[9,10], F. Schillaci[4], G. Tudisco[3], D. Margarone[4,3,11] and G.A.P. Cirrone[3] ▲ Hide full author list

Published 31 July 2023 • © 2023 The Author(s)

Journal of Instrumentation, Volume 18, July 2023

Radioisotope production using lasers: From basic science to applications

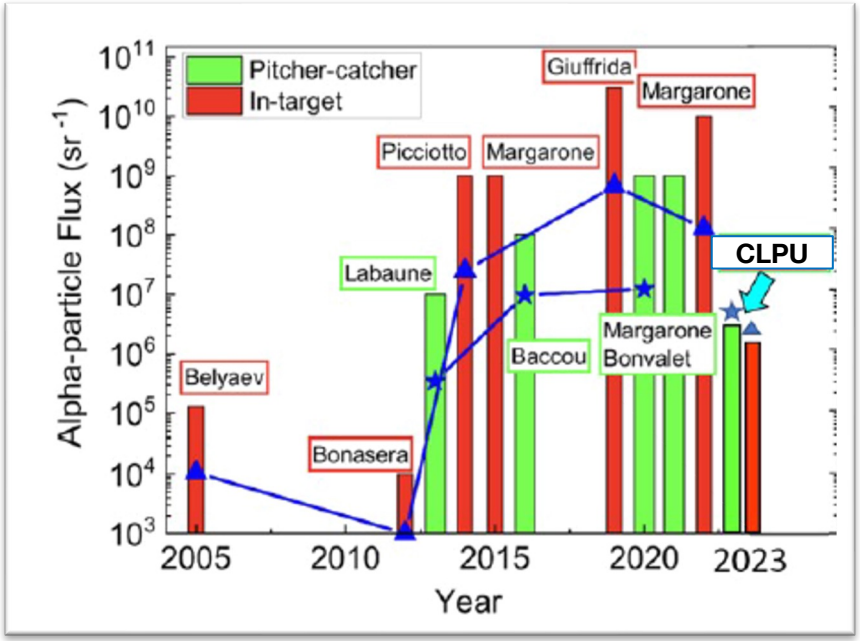
R. D. Rodrigues; A. Bonasera; M. Scisciò; J. A. Pérez-Hernández; M. Ehret; F. Filippi; L. Andreoli; M. Huault; H. Larreur; D. Singappuli; D. Molloy; D. Raffestin; M. Alonzo; G. G. Rapisarda; Lattuada; G. L. Guardo; C. Verona; Fe. Consoli; G. Petringa; A. McNamee; M. La Cognata; Palmerini; T. Carriere; M. Cipriani; G. Di Giorgio; G. Cristofari; R. De Angelis; G. A. P. Cirrone; Margarone; L. Giuffrida; D. Batani; P. Nicolai; K. Batani; R. Lera; L. Volpe; D. Giulietti; Agarwal; M. Krupka; S. Singh; Fa. Consoli

Check for updates

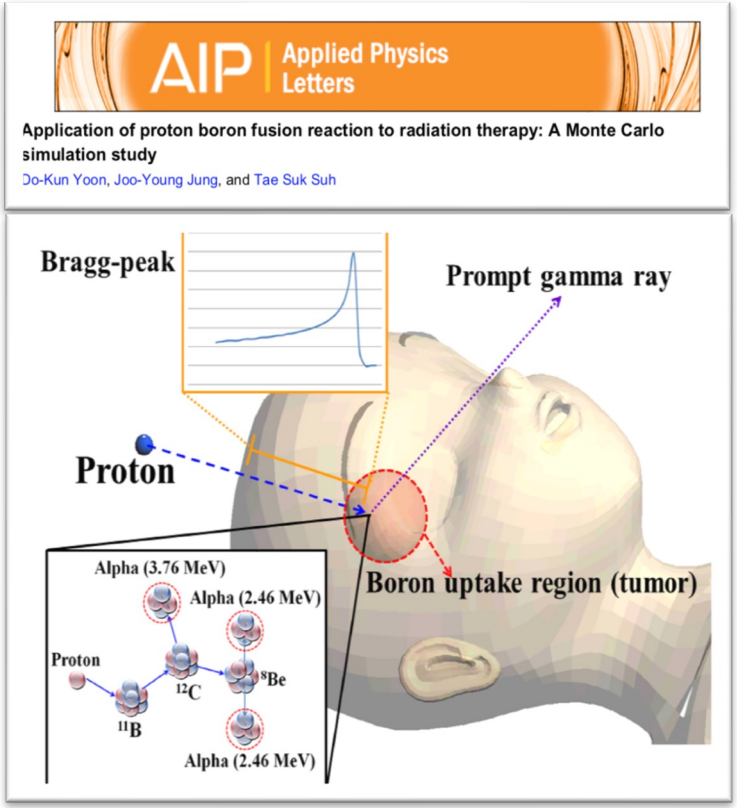
Matter Radiat. Extremes 9, 037203 (2024)

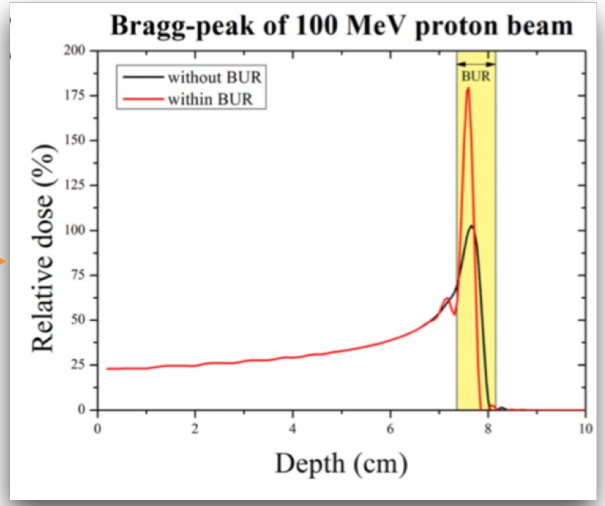
Patent n.E16002 and n.EP16178280, INFN-LNS (Italy), FBK (Italy) and ELI-Beamlines (Czech Republic)

Activity on the study of the proton-Boron reaction in plasma



Back to 2015



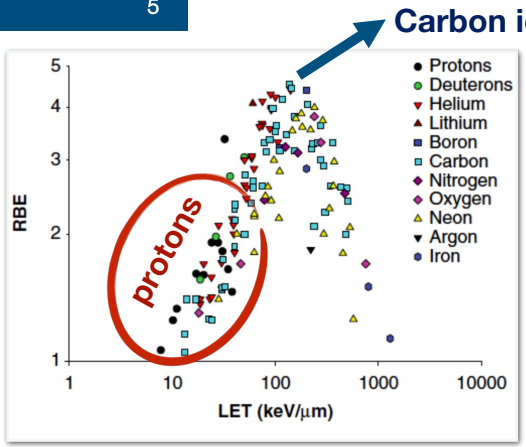


Errors in the interpretation of Korean colleagues were immediately evident

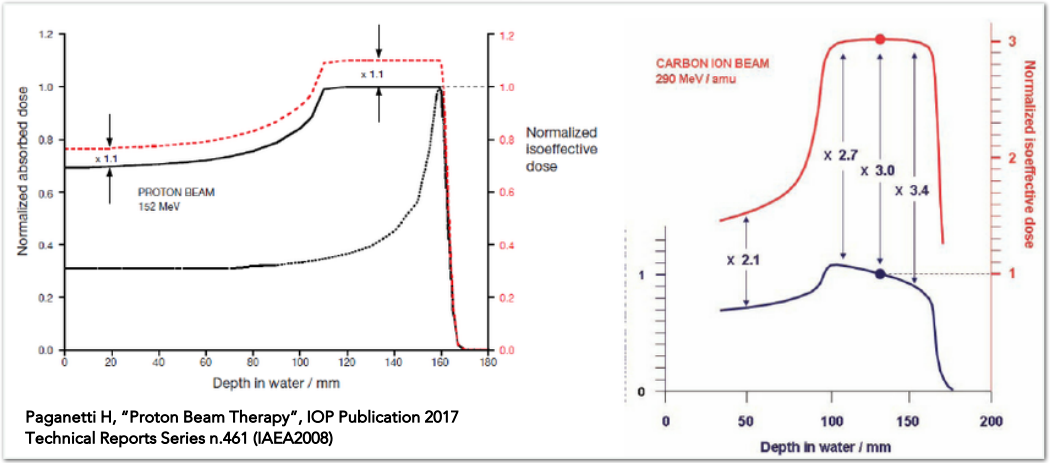
L. Giuffrida et al., "Prompt gamma ray diagnostics and enhanced hadron-therapy using neutron-free nuclear reactions', AIP Advances (2016)

G. Petringa et al., "Prompt gamma-ray emission for future imaging applications in proton-boron fusion therapy", Journal of Instrumentation 12(03):C03059-C03059, (2017)

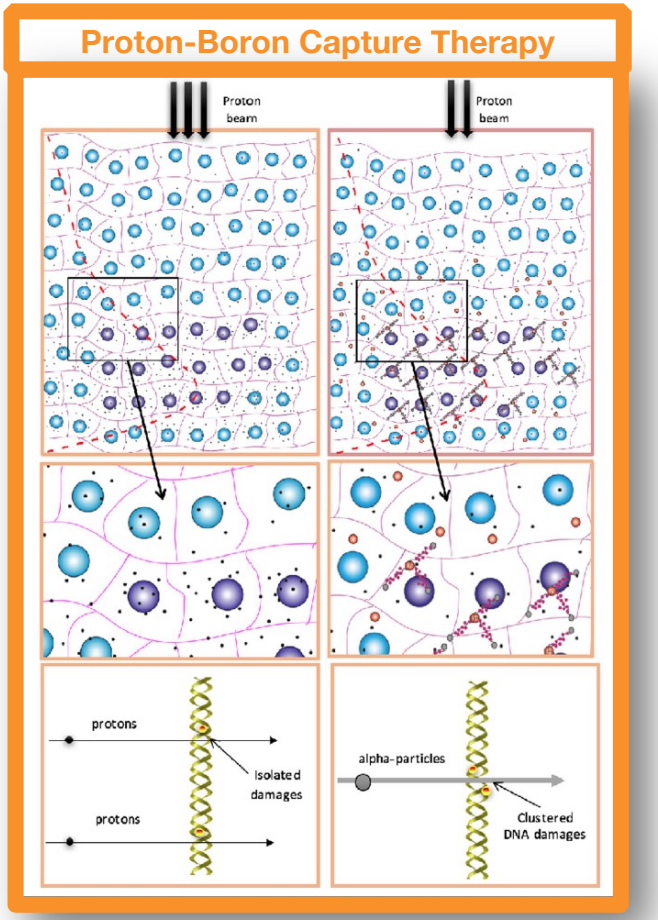
Hadrontherapy: treatments with H and 12C



Proton therapy relies on the inverted dose-depth profile of charged particles, though its low LET limits radiobiological benefits over conventional radiotherapy, while 12C ion beams provide higher RBE for treating radioresistant tumors but are challenged by dose deposition beyond the SOBP and high costs



Paganetti H, "Proton Beam Therapy", IOP Publication 2017
Technical Reports Series n.461 (IAEA2008)



First experimental results (2018)

nature.com > scientific reports > articles > article

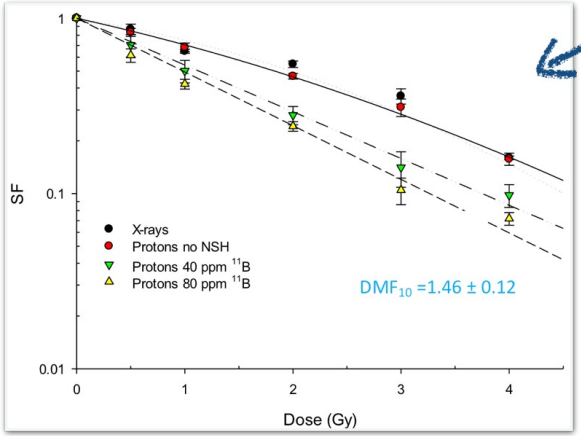
SCIENTIFIC REPORTS

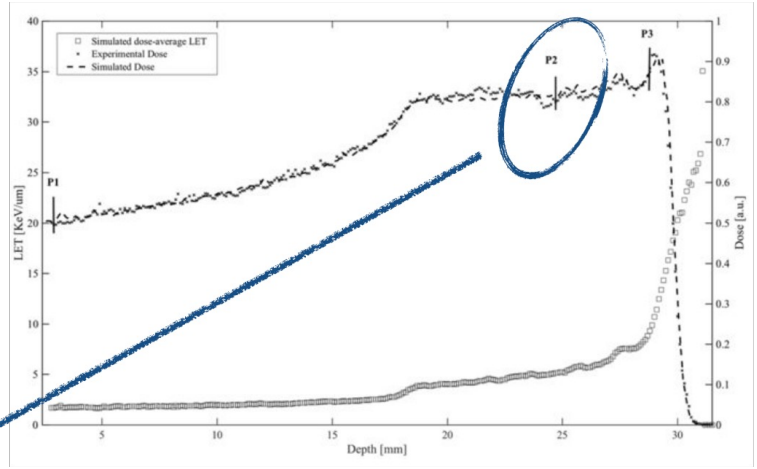
Article | OPEN | Published: 18 January 2018

First experimental proof of Proton Boron Capture Therapy (PBCT) to enhance protontherapy effectiveness

G. A. P. Cirrone, L. Manti, D. Margarone, G. Petringa, L. Giuffrida, A. Minopoli, A. Picciotto, G. Russo, F. Cammarata, P. Pisciotta, F. M. Perozziello, F. Romano, V. Marchese, G. Milluzzo, V. Scuderi, G. Cuttone & G. Korn

Scientific Reports **8**, Article number: 1141 (2018) | Download Citation

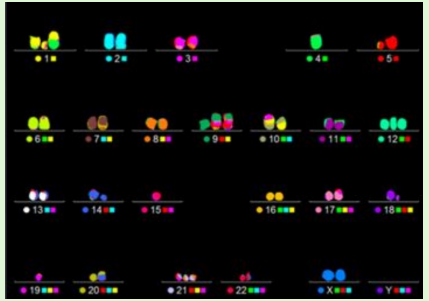


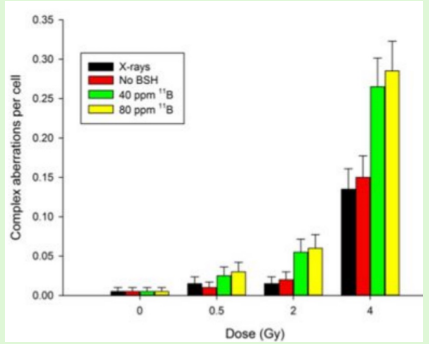


DMF$_{10}$ (RBE$_{10}$)= 1.46 ± 0.12

	α (Gy^{-1})	β (Gy^{-2})
X ray irradiation	0.222 ± 0.062	0.064 ± 0.014
Proton irradiation in the absence of BSH	0.314 ± 0.022	0.035 ± 0.007
Proton irradiation with 40 ppm ^{11}B	0.614 ± 0.069	—
Proton irradiation with 80 ppm ^{11}B	0.705 ± 0.033	—

Complex type chromosomal aberrations





arXiv:1802.09482 (26 Feb 2018)

Eur. Phys. J. Plus (2019) 134: 361
DOI 10.1140/epjp/i2019-12725-8

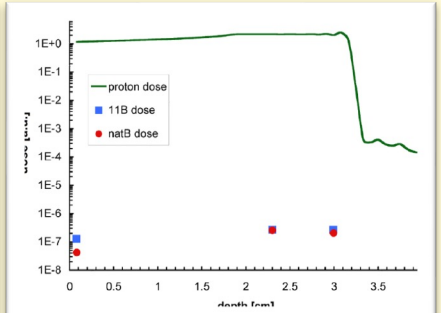
THE EUROPEAN PHYSICAL JOURNAL PLUS

Regular Article

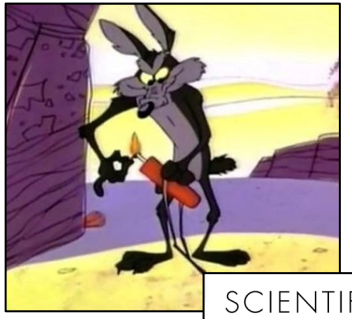
On the (un)effectiveness of proton boron capture in proton therapy

Annamaria Mazzone[1], Paolo Finocchiaro[2], Sergio Lo Meo[3], and Nicola Colonna[4,a]

[1] Consiglio Nazionale delle Ricerche - Istituto di Cristallografia (CNR - IC), Bari, Italy
[2] Istituto Nazionale Fisica Nucleare, Laboratori Nazionali del Sud (INFN - LNS), Catania, Italy
[3] ENEA, Centro Ricerche "E. Clementel", Bologna, Italy
[4] Istituto Nazionale Fisica Nucleare (INFN), Sezione di Bari, Bari, Italy



«While the experimental evidences of an effect of BSH on the cell survival probability is mostly clear (although it does not seem to scale with the BSH concentration), the statement that such effect could be related to the p + 11B reactions is mostly speculative. In particular, the article does not report calculations of the reaction rate nor simulations of the dose related to this reaction to support with solid arguments the claim of an important effect of Proton Boron Capture on Proton Therapy.»



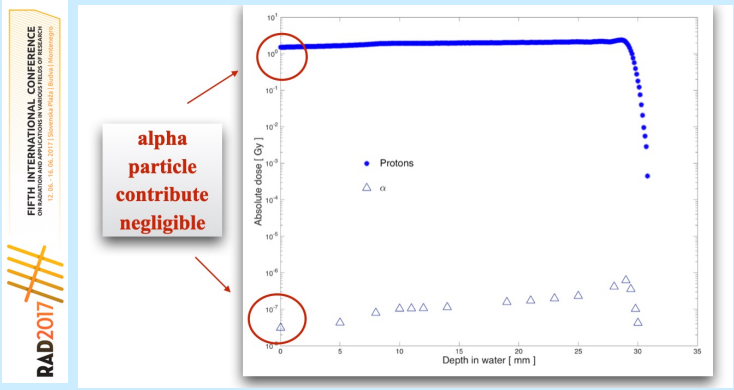
SCIENTIFIC REPORTS

OPEN

First experimental proof of Proton Boron Capture Therapy (PBCT) to enhance protontherapy effectiveness

Received: 28 January 2017
Accepted: 27 December 2017
Published online: 18 January 2018

G. A. P. Cirrone[1], L. Manti[1,2], D. Margarone[1], G. Petringa[1,3], L. Giuffrida[1], A. Minopoli[1], A. Picciotto[1], G. Russo[1,3], F. Cammarata[1,3], P. Pisciotta[1,3], F. M. Perozziello[1,3], F. Romano[1,3], V. Marchese[1], G. Milluzzo[1,4], V. Scuderi[1,4], G. Cuttone[1] & G. Korn[1]



RADIATION & APPLICATIONS
ISSN 2466-4294 (online) | rad-journal.org
Vol. 3 | Issue 3 | pp. 147–151, 2018
doi: 10.21175/RadJ.2018.03.025
Case study

STUDY OF THE DISCREPANCY BETWEEN ANALYTICAL CALCULATIONS AND THE OBSERVED BIOLOGICAL EFFECTIVENESS IN PROTON BORON CAPTURE THERAPY (PBCT)

G.A.P. Cirrone[1,2], G. Petringa[1*], A. Attili[3], D. Chiappara[1,6], L. Manti[4,5], V. Bravatà[7], D. Margarone[2], M. Mazzocco[6,8], G. Cuttone[1]

[1]Laboratori Nazionali del Sud, Istituto Nazionale di Fisica Nucleare, Catania, Italy
[2]Institute of Physics, Czech Academy of Science ELI-Beamlines, Dolní Břežany, Czech Republic
[3]INFN Section of Roma "Roma Tre", Rome, Italy
[4]Physics Department, University of Naples Federico II, Naples, Italy

The total number of alpha particles generated and estimated on the basis of the well-known total production cross-section of the p-B reaction, does not explain the experimental results in terms of an average LET increase and, hence, with a corresponding RBE enhancement. On the other hand, if classical radiobiological models are applied, in order to reach the observed DMF values, one would require a number of alpha particles larger by a factor of 10^5 with respect to the calculated yield.

G. Petringa and G.A.P. Cirrone, «The proton-Boron fusion therapy: a new clinical treatment and a powerful online imaging technique»

L. Giuffrida et al., "Prompt gamma ray diagnostics and enhanced hadron-therapy using neutron-free nuclear reactions', AIP Advances (2016)

National and International initiatives

to better understand the observed biological effect

NEPTUNE
Nuclear process driven Enhancement of Proton Therapy UNravEled

INFN Call CSNV
2019-2022

PBCT

Proton Boron Capture Therapy

PRIN-MIUR Project
2020-2023

Italian-Serbia MAECI project - MAE00643202020-06-16 (2019-2021) - "Studio dell'aumento dell'efficacia biologica di un fascio di protoni dalla reazione p+ nB -> 3alfa"

GAMA2 project - TP01010035 - "Proton Boron Capture Therapy (PBCT): in-vivo validation for clinical application".

BAFOMET (proton Boron cApture and FLASH apprOach coMbination to Enhance protonTherapy efficiency) INFN CSNV (2021-2022) young researcher grant Dr Pavel Blaha, INFN Naples Section

~ 2 M€

Radiobiological studies to support the observed effect

A large number of radiobiological studies have been conducted.

Facility	Cell line	^{11}B Carrier & concentration	Position	DMF_{10}
CNAO	DU-145	BPA-120 ppm	Mid-SOBP	1.10 ± 0.10
CNAO	DU-145	F-BPA-120 ppm	Mid-SOBP	1.35 ± 0.13
CNAO	DU-145	BPA-120 ppm	Distal	1.28 ± 0.16
CNAO	DU-145	F-BPA-120 ppm	Distal	1.56 ± 0.11
CIRCE	DU-145	F-BPA-120 ppm	Pristine (~700 keV)	1.58 ± 0.11
CIRCE	DU-145	F-BPA-120 ppm	Pristine (~ 2 MeV)	1.94 ± 0.18
CNAO	PANC-1	BPA-120 ppm	Mid-SOBP	1.15 ± 0.13
CNAO	PANC-1	F-BPA-120 ppm	Mid-SOBP	1.22 ± 0.18
CNAO	PANC-1	BPA-120 ppm	Distal	1.32 ± 0.18
CNAO	PANC-1	F-BPA-120 ppm	Distal	1.47 ± 0.11
CIRCE	PANC-1	F-BPA-120 ppm	Pristine (~700 keV)	1.51 ± 0.14
CIRCE	PANC-1	F-BPA-120 ppm	Pristine (~ 2 MeV)	1.80 ± 0.19
CIRCE	DU-145	BSH-80 ppm	Pristine (~700 keV)	1.85 ± 0.19
CIRCE	PANC-1	BSH-80 ppm	Pristine (~700 keV)	1.56 ± 0.08

More than 15 experimental shifts were conducted at the CATANA facility (in-vitro and in-vivo irradiations)

Approximately ten biological endpoints were investigated through both in vitro and in vivo studies, using various cell lines (both healthy and tumor cells).

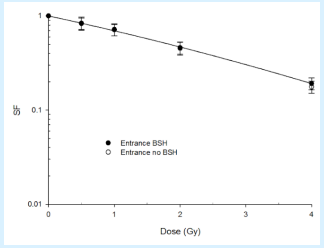
Radiobiological studies to support the observed effect

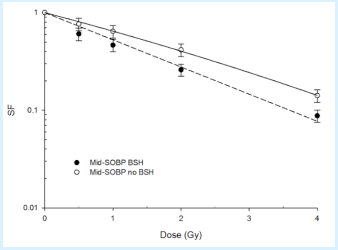
10 A large number of radiobiological studies have been conducted.

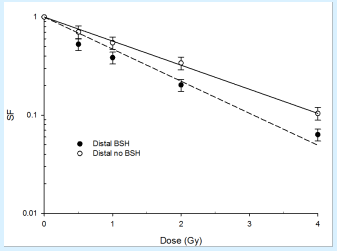
Front Oncol. 2021 Jun 28;11:682647. doi: 10.3389/fonc.2021.682647

The Proton-Boron Reaction Increases the Radiobiological Effectiveness of Clinical Low- and High-Energy Proton Beams: Novel Experimental Evidence and Perspectives

Pavel Bláha [1,‡], Chiara Feoli [1,‡], Stefano Agosteo [2], Marco Calvaruso [3,4], Francesco Paolo Cammarata [3,4], Roberto Catalano [4], Mario Ciocca [5], Giuseppe Antonio Pablo Cirrone [4], Valeria Conte [6], Giacomo Cuttone [4], Angelica Facoetti [5], Giusi Irma Forte [3,4], Lorenzo Giuffrida [7,†], Giuseppe Magro [5], Daniele Margarone [7,†], Luigi Minafra [3,4], Giada Petringa [4,7], Gaia Pucci [3,8], Valerio Ricciardi [1,9], Enrico Rosa [10], Giorgio Russo [3,4,11], Lorenzo Manti [1,10,*]







DMF increases with position along the SOBP (CNAO,I)

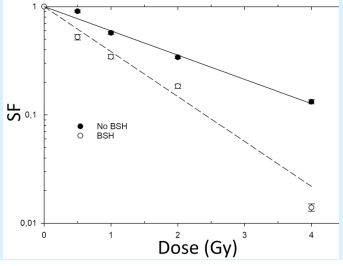
applied sciences
MDPI
Article

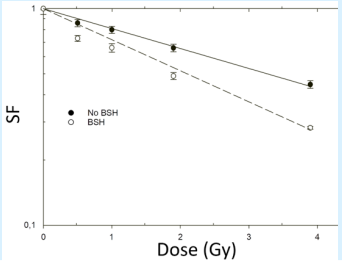
A New Low-Energy Proton Irradiation Facility to Unveil the Mechanistic Basis of the Proton-Boron Capture Therapy Approach

Valerio Ricciardi [1,2,†], Pavel Bláha [1], Raffaele Buompane [1,2], Giuseppina Crescente [3,4], Giacomo Cuttone [5], Lucio Gialanella [1,2], Katarina Michaličková [1,6], Severina Pacifico [1,3], Giuseppe Porzio [1,2]

DU 145	a (Gy^{-1})	DMF_{10}
NO BSH	0.52 ± 0.03	
BSH	0.96 ± 0.08	1.85±0.19

PANC-1	a (Gy^{-1})	DMF_{10}
NO BSH	0.212± 0.006	
BSH	0.330± 0.012	1.56±0.08

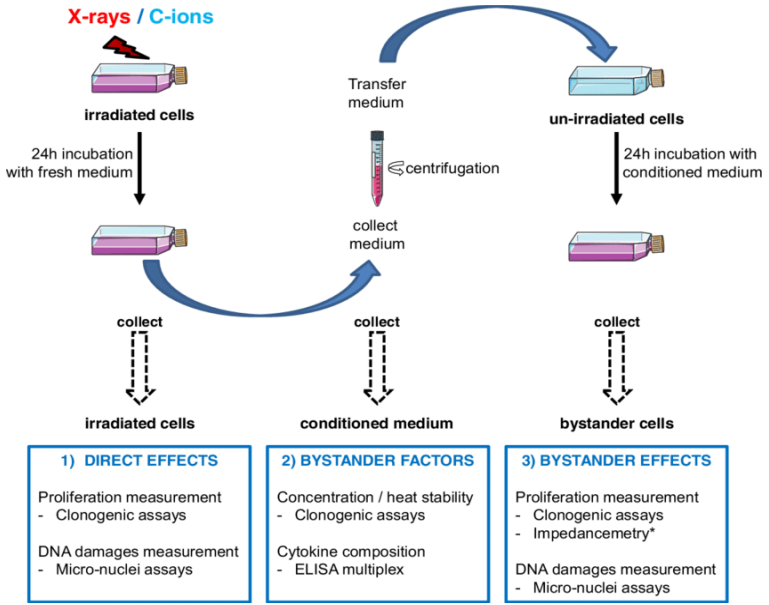


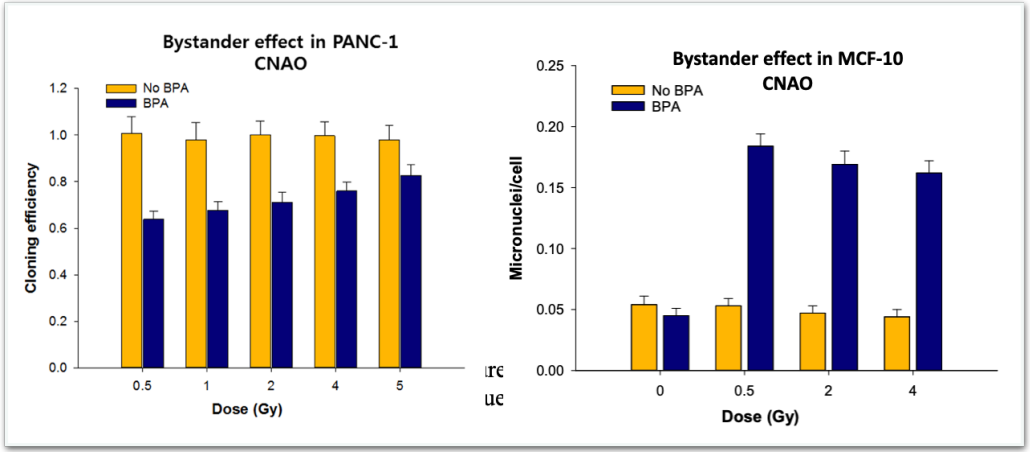


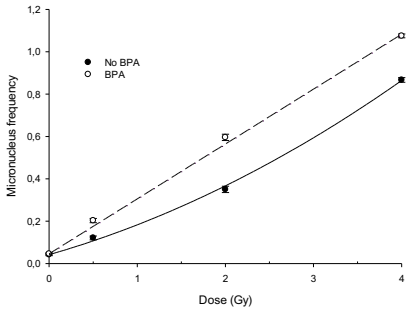
Radiobiological studies to support the observed effect

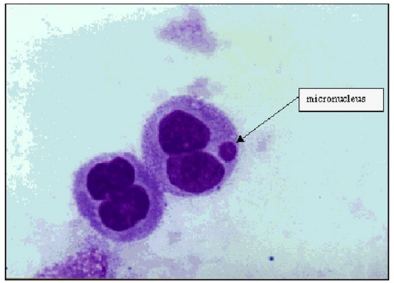
11

Evidence on bystander effect









Radiobiological studies to support the observed effect

12

In-vivo studies

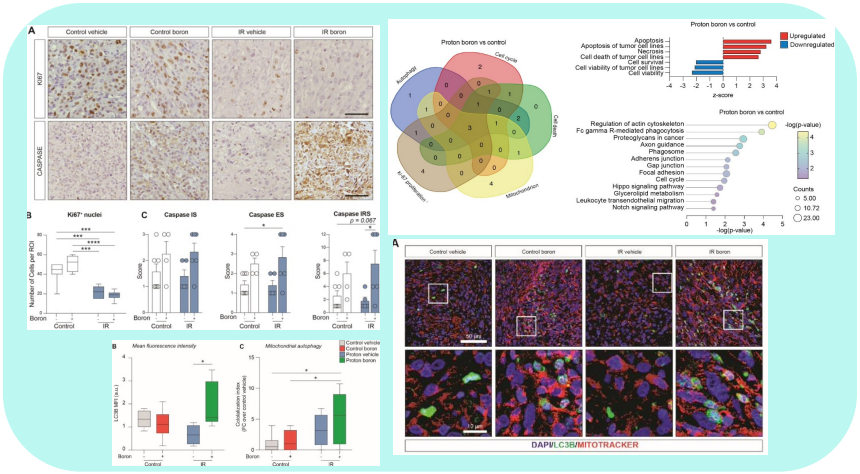
communications biology

ARTICLE

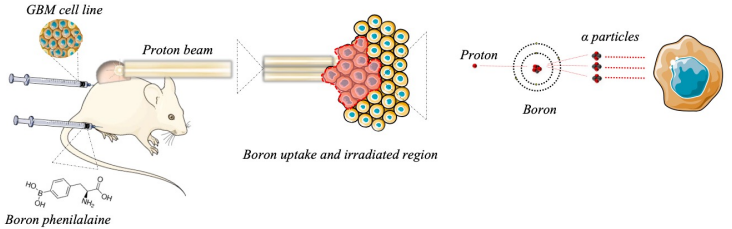
https://doi.org/10.1038/s42003-023-04770-w OPEN

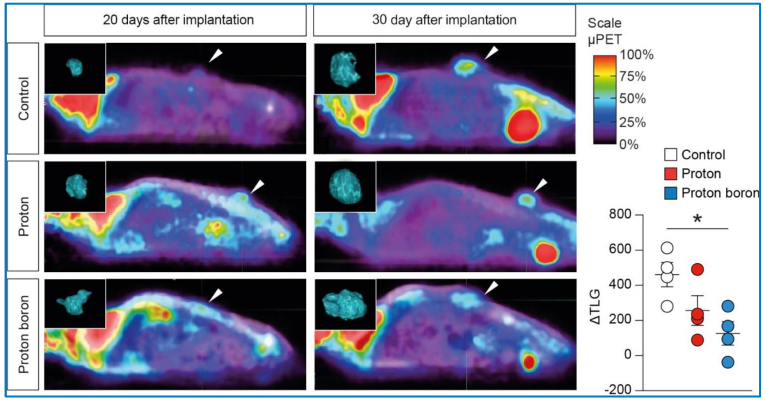
Proton boron capture therapy (PBCT) induces cell death and mitophagy in a heterotopic glioblastoma model

Francesco Paolo Cammarata[1,2,8], Filippo Torrisi[3,8], Nunzio Vicario[3,4,8], Valentina Bravatà[1], Alessandro Stefano[1], Lucia Salvatorelli[5], Simona D'Aprile[3], Pierangela Giustetto[3], Giusi Irma Forte[1], Luigi Minafra[1], Marco Calvaruso[1], Selene Richiusa[1], Giuseppe Antonio Pablo Cirrone[2], Giada Petringa[2], Giuseppe Broggi[5], Sebastiano Cosentino[6], Fabrizio Scopelliti[7], Gaetano Magro[5], Danilo Porro[1], Massimo Libra[3], Massimo Ippolito[6], Giorgio Russo[1,2✉], Rosalba Parenti[3,4✉] & Giacomo Cuttone[2]



Multimodal imaging techniques and Radiomics





Studies on the quantification of boron internalization

Physica Medica 94 (2022) 75–84

Contents lists available at ScienceDirect

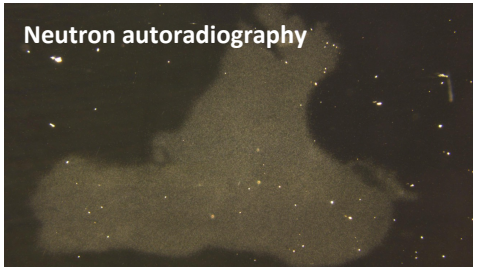
Physica Medica

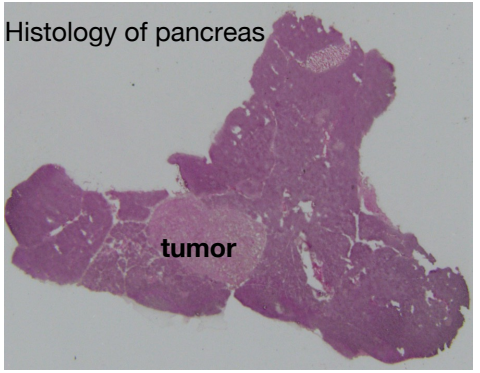
journal homepage: www.elsevier.com/locate/ejmp

Multimodal evaluation of ^{19}F-BPA internalization in pancreatic cancer cells for boron capture and proton therapy potential applications

Andrea Ciardiello [a,d], Saverio Altieri [b,c], Francesca Ballarini [b,c], Valerio Bocci [d], Silva Bortolussi [b,c], Laura Cansolino [c,e], Daniele Carlotti [d,f], Mario Ciocca [c,g], Riccardo Faccini [a,d], Angelica Facoetti [c,g], Cinzia Ferrari [c,e], Luca Ficcadenti [d], Emiliano Furfaro [a], Stefano Giagu [a,d], Francesco Iacoangeli [d], Giampiero Macioce [f], Carlo Mancini-Terracciano [a,d], Andrea Messina [a,d], Luisa Milazzo [f], Severina Pacifico [h,i], Simona Piccolella [h,i], Ian Postuma [c], Dante Rotili [j], Valerio Vercesi [c], Cecilia Voena [d,*], Francesca Vulcano [f], Silvia Capuani [d,k,l]

BPA was identified as best molecula in terms of toxicity and 11B concentration



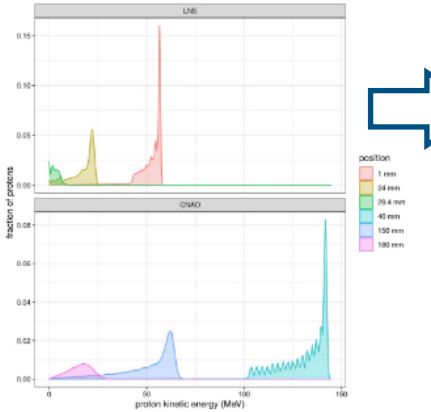


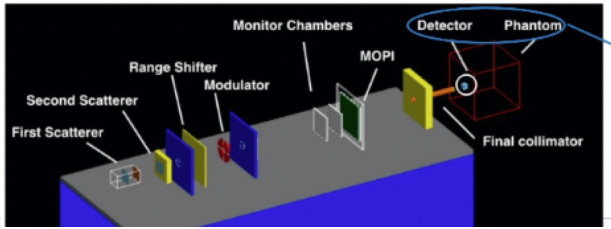
3 techniques:

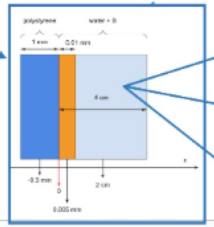
1) Neutron autoradiography, used to quantify boron
2) Liquid chromatography coupled with tandem mass spectrometry and UV-Diode Array Detection, for quantifying the 119F-BPA molecule
3) 19F NMR spectroscopy, used to detect fluorine nuclei

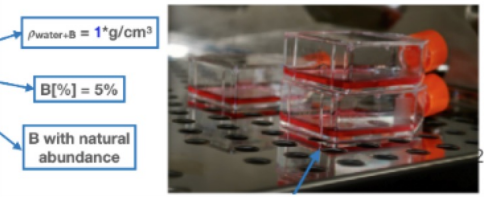
Cell lines	Molecula
PANC-1 DU-145 MCF-10	BPA F-BPA

A complex prediction study was carried on

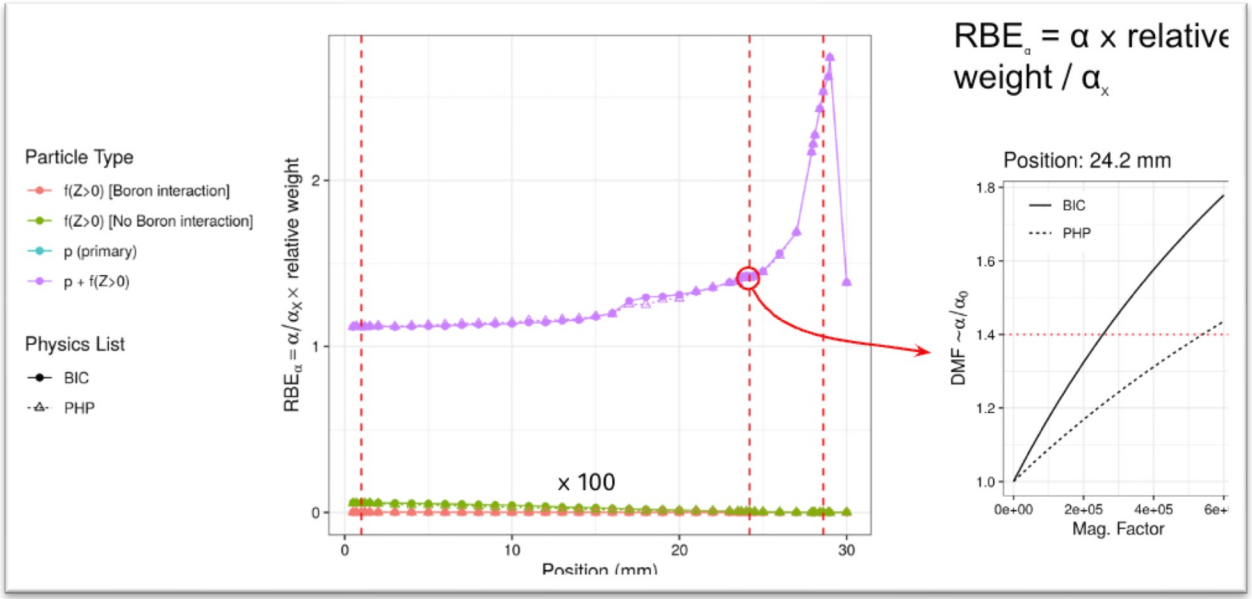






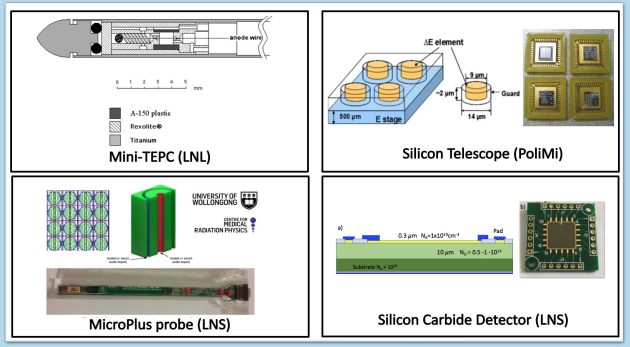


The experimentally observed DMF could only be replicated by introducing a factor of 10^5 of generated fragments /alpha particles

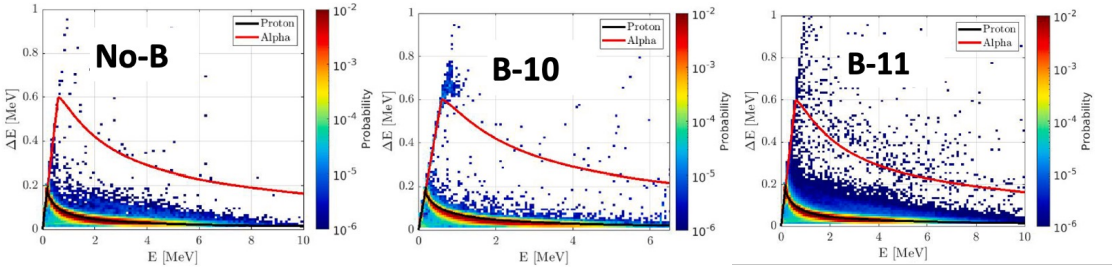


Microdosimetric studies to quantify the alpha

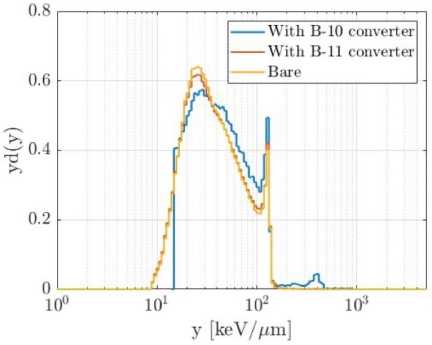
Four microdosimetric detectors coupled with boron targets were utilized to measure the alpha particles produced in a clinical configuration



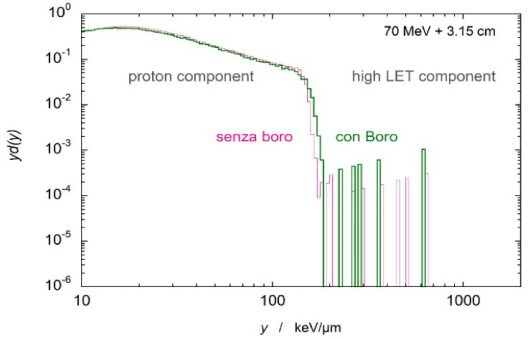
Silicon telescope detector



Silicon detector



TEPC



Do-Kun Yoon, Joo-Young Jung, Tae Suk Suh;
Application of proton boron fusion reaction to radiation therapy: A Monte Carlo simulation study.
Appl. Phys. Lett. 1 December **2014**; 105 (22): 223507. https://doi.org/10.1063/1.4903345

P.Kundràat, K.P.Brabcova et al,
BORON-ENHANCED BIOLOGICAL EFFECTIVENESS OF PROTON IRRADIATION: STRATEGY TO ASSESS THE UNDERPINNING MECHANISM
Radiat Prot Dosimetry, **2022** Aug 22;198(9-11):527-531. doi: 10.1093/rpd/ncac093

A.J.Michaelidesova, P.Kundrat et al.
First independent validation of the proton-boron capture therapy concept
Sci Rep. **2024** Aug 20;14(1):19264. doi: 10.1038/s41598-024-69370-y.

M Nuez-Martinez et al.
Boron clusters (ferrabisdicarbollides) shaping the future as radiosensitizers for multimo
J. Mater

M. Shah
On the
Scientific Reports volume 12, Article number: 18098 (2022)

> Radiat Prot Dosimetry. 2022 Aug 22;198(9-11):527-531. doi: 10.1093/rpd/ncac093.

BORON–ENHANCED BIOLOGICAL EFFECTIVENESS OF PROTON IRRAD TION: STRATEGY TO ASSESS THE UNDERPIN ECHANISM

Pavel Kundrát [1], Kater
Oldřich Zahradníček [1], Ir
Marie Da
[1], Anna Jelínek Michaelidesová [1,2],
těpán [1,2], Zuzana Jamborová [1,2],

scientif

OPEN First validation of the p capture therapy c

Anna Jelínek Michaelidesová
Kateřina Pachnerová Brabcová
Vladimír Vondráček[3,4] & Marie Da
hradníček[1], Irina Danilová[1,2],
[3], Miroslav David[4],

p11B publication in medical applications

We believe that the relative biological effectiveness (RBE) weighted doses by attributing maximum potential RBEs to the dose of alphas would be incapable of explaining the significance of the biological effect observed in PBFT, therefore more investigations would be needed in this regard

The fraction of deposited energy from alpha particles compared to incident protons is not entirely negligible, despite the previously reported results

scientific repo

OPEN **First independent validation of the proton-boron capture therapy concept**

Anna Jelínek Michaelidesová[1,2,5], Pavel Kundrát[1,5], Oldřich Zahradníček[1], Irina Danilová[1,2], Kateřina Pachnerová Brabcová[1], Jana Vachelová[1], Jan Vilimovský[3], Miroslav David[4], Vladimír Vondráček[3,4] & Marie Davídková[1]

Journal of Materials Chemistry B

PAPER

Boron clusters (ferrabisdicarbollides) shap the future as radiosensitizers for multimoda (chemo/radio/PBFR) therapy of glioblastoma

Miquel Nuez-Martinez,[a] Maria Queralt-Martin,[b] Amanda Muñoz-Juan,[a] Vicente M. Aguilella,[b] Anna Laromaine,[a] Francesc Teixidor,[a] Clara Viñas,[a] Catarina G. Pinto,[c] Teresa Pinheiro,[d] Joana F. Guerreiro,[c] Filipa Mendes,[c] Catarina Roma-Rodrigues,[e] Pedro V. Baptista,[e] Alexandra R. Fernandes,[e] Srecko Valic[g] and Fernanda Marques[c]

Glioblastoma multiforme (GBM) is the most common and fatal primary brain tumor, and is highly resistant to conventional radiotherapy and chemotherapy. Therefore, the development of multidrug resistance and tumor recurrence are frequent. Given the poor survival with the current treatments, new therapeutic strategies are urgently needed. Radiotherapy (RT) is a common cancer treatment modality for GBM. However, there is still a need to improve RT efficiency, while reducing the severe side effects. Radiosensitizers can enhance the killing effect on tumor cells with less side effects on healthy tissues. Herein, we present our pioneering study on the highly stable and amphiphilic metallacarboranes, ferrabis(dicarbollides) ([o-FESAN]$^-$ and [8,8′-i2-o-FESAN]$^-$), as potential radiosensitizers for GBM radiotherapy. We propose radiation methodologies that utilize secondary radiation emissions from iodine and iron, using ferrabis(dicarbollides) as iodine/iron donors, aiming to achieve a greater therapeutic

The results obtained for the cellular damage suggest that proton boron fusion radiation therapy, when combined with boron-rich compounds, is a promising modality to fight against resistant tumors.

Long standing collaboration beyond the clinical applications

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

M. Tosca et al,
Plasma polymers as targets for laser-driven proton-boron fusion
Frontiers in Physics, 2023, 11, 1227140

Kantarelou V et al,
A Methodology for the Discrimination of Alpha Particles from Other Ions in Laser-Driven Proton-Boron Reactions Using CR-39 Detectors Coupled in a Thomson Parabola Spectrometer
Laser and Particle Beams, 2023, 2023, 3125787

Margarone D, et al
In-Target Proton–Boron Nuclear Fusion Using a PW-Class Laser
Applied Sciences (Switzerland), 2022, 12(3), 1444

Bonvalet J, et al
Energetic α -particle sources produced through proton-boron reactions by high-energy high-intensity laser beams
Physical Review E, 2021,103(5), 053202

Margarone D, et al
Generation of alpha particle beams with a multi-kJ, Peta Watt Class Laser System
Frontiers in Physics 2020, 8, 343

Giuffrida, L et al,
High-current stream of energetic alpha particles from laser-driven proton-boron fusion
Physical Review E, 2020, 10(1), 013204

Belloni. F, et al
On the enhancement of p-11B fusion reaction rate in laser-driven plasma by alpha – proton collisional energy transfer
Physics of Plasmas, 2018, 25(2), 020701

Picciotto, A et al
Fabrication of advanced targets for laser driven nuclear fusion reactions through standard microelectronics technology approaches
Journal of Instrumentation 2017, 12(10),P10001

A Picciotto et al.,
Boron-Proton Nuclear-Fusion Enhancement Induced in Boron-Doped Silicon Targets by Low-Contrast Pulsed Laser"
Phys. Rev. X 4, 031030 (2014)

A .Picciotto et al. Ammonia borane-based targets for new developments in laser-driven proton boron fusion
Applied Surface Science 672, 01/11/2024, 160797

I.C.E Turcu et al, Borane (B_mH_n), Hydrogen rich, Proton Boron fusion fuel materials for high yield laser-driven Alpha sources,
Journal of Instrumentation, 2nd International Workshop on Proton-Boron Fusion, Catania, Italy 5–8 September 2022, published 2024.

Istokskaia, V et al. A multi-MeV alpha particle source via proton-boron fusion driven by a 10-GW tabletop laser
Communications Physics, 2023, 6(1), 27

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

M. Tosca et al,
Plasma polymers as targets for laser-driven proton-boron fusion
Frontiers in Physics, 2023, 11, 1227140

Kantarelou V et al,
A Methodology for the Discrimination of Alpha Particles from Other Ions in Laser-Driven Proton-Boron Reactions Using CR-39 Detectors Coupled in a Thomson Parabola Spectrometer
Laser and Particle Beams, 2023, 2023, 3125787

Margarone D, et al
In-Target Proton–Boron Nuclear Fusion Using a PW-Class Laser
Applied Sciences (Switzerland), 2022, 12(3), 1444

Bonvalet J, et al
Energetic α -particle sources produced through proton-boron reactions by high-energy high-intensity laser beams
Physical Review E, 2021,103(5), 053202

Margarone D, et al
Generation of alpha particle beams with a multi-kJ, Peta Watt Class Laser System
Frontiers in Physics 2020, 8, 343

Giuffrida, L et al,
High-current stream of energetic alpha particles from laser-driven proton-boron fusion
Physical Review E, 2020, 10(1), 013204

Belloni. F, et al
On the enhancement of p-11B fusion reaction rate in laser-driven plasma by alpha – proton collisional energy transfer
Physics of Plasmas, 2018, 25(2), 020701

Picciotto, A et al
Fabrication of advanced targets for laser driven nuclear fusion reactions through standard microelectronics technology approaches
Journal of Instrumentation 2017, 12(10),P10001

A Picciotto et al.,
Boron-Proton Nuclear-Fusion Enhancement Induced in Boron-Doped Silicon Targets by Low-Contrast Pulsed Laser"
Phys. Rev. X 4, 031030 (2014)

A .Picciotto et al. Ammonia borane-based targets for new developments in laser-driven proton boron fusion
Applied Surface Science 672, 01/11/2024, 160797

I.C.E Turcu et al, Borane (B_mH_n), Hydrogen rich, Proton Boron fusion fuel materials for high yield laser-driven Alpha sources,
Journal of Instrumentation, 2nd International Workshop on Proton-Boron Fusion, Catania, Italy 5–8 September 2022, published 2024.

Istokskaia, V et al. A multi-MeV alpha particle source via proton-boron fusion driven by a 10-GW tabletop laser
Communications Physics, 2023, 6(1), 27

Long standing collaboration beyond the clinical applications

CA 21128

PROBONO

cost

EUROPEAN COOPERATION IN SCIENCE & TECHNOLOGY

F Consoli (ENEA) and GAP Cirrone INFN, Italian representatives and spokespersons

Comments/conclusions

The effect of the p-B fusion reaction on biological samples, both in vitro and in vivo, is evident: a significant and quantifiable biological impact has been observed, assessed across multiple biological endpoints, cell lines, and experimental models.

This biological effect has proven reproducible, with several radiobiological experiments conducted by different research groups yielding consistent findings.

It has become clear that the observed biological impact is not merely a consequence of the alpha particles produced but is instead related to how these alphas interact at the cellular level.

The bystander effect is distinctly associated with an increased Dose Modification Factor (DMF).

The in-vivo biological effect is exceptionally promising, as evidenced by a publication in Nature Communications. These results strongly support further studies and potential clinical trials.

Thanks for listening