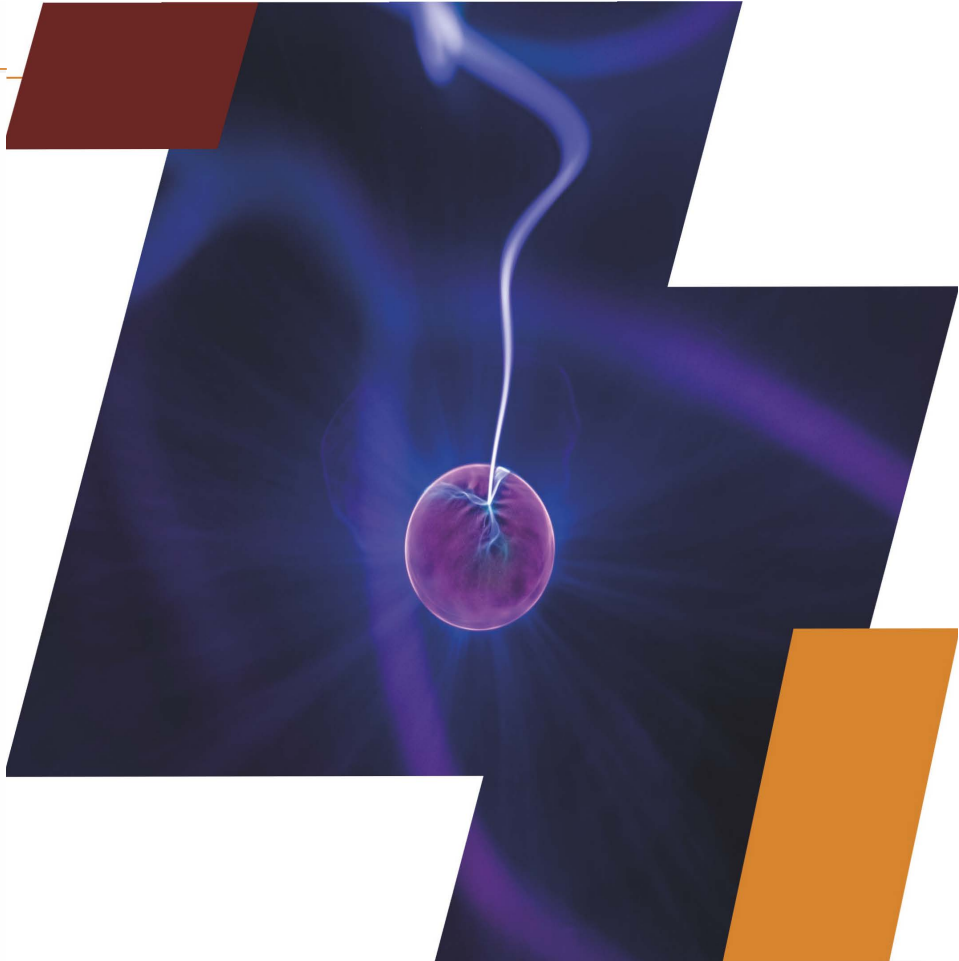
ANALYSIS OF ALPHA AND LITHIUM-7 PARTICLE ENERGY DEPOSITION IN BNCT USING GEANT4 SIMULATION

A Comprehensive Overview of Boron Neutron Capture Therapy (BNCT)

Khadija Charef



AGENDA

Exploring the Key Aspects of Boron Neutron Capture Therapy (BNCT)

1 Introduction : Brief Overview of BNCT

- BNCT Uncovered
- Clinical Applications of BNCT
- Mechanism

2 Importance of microdosimetry in BNCT

- Microdosimetry
- Critical for BNCT
- Enables
- Challenges

3 Research Objectives

- Research goals
- Specific aims

4 Methodology

- Geant4 Simulation Setup
- Physics lists evaluated
- Water models
- Cellular geometry
- Particles simulated

5 Single cell model results

- Alpha Particle Energy Deposition Patterns
- Lithium-7 Ion Energy Deposition Patterns

6 Conclusion

- Summary of Key Findings
- Future Perspectives

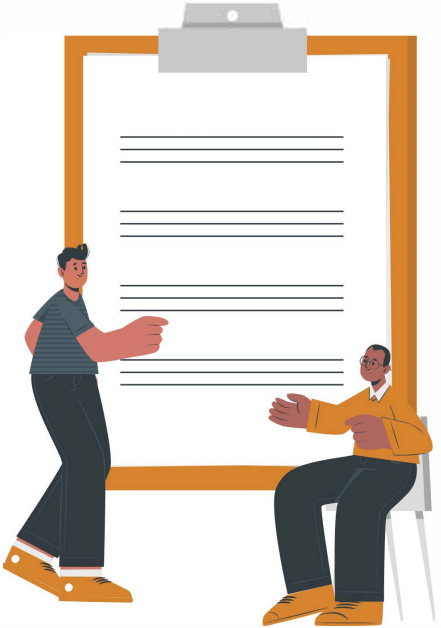
BNCT UNCOVERED

1. What is BNCT ?

Boron Neutron Capture Therapy (BNCT) is a targeted radiation therapy designed for treating cancer. It utilizes boron-10 isotope to differentiate between cancerous and healthy cells.

2. How It Works ?

BNCT involves two main steps: first, boron-10 is administered to the patient, and then a neutron beam is directed toward the tumor. This interaction produces high-energy alpha particles and lithium-7 nuclei



3. Benefits of BNCT

The advantages of BNCT include minimal damage to surrounding healthy tissues, the potential for treating a variety of cancer types, and effectiveness against tumors

4. Future Prospects

The future of BNCT looks promising with ongoing research to enhance its effectiveness, improve delivery methods, and expand its application in oncology.

CLINICAL APPLICATIONS OF BNCT

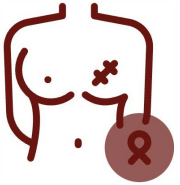
A promising treatment for various cancers through targeted therapy

Targeting Glioblastoma Multiforme

BNCT effectively targets glioblastoma multiforme, a highly aggressive brain tumor, offering hope for improved outcomes.

Melanoma Treatment

The therapy shows promise for treating melanoma, known for its resistance to conventional therapies, enhancing patient survival.



Head and Neck Cancers

BNCT is utilized in addressing head and neck cancers, aiming to minimize damage to surrounding healthy tissues during treatment.

Selective Tumor Cell Destruction

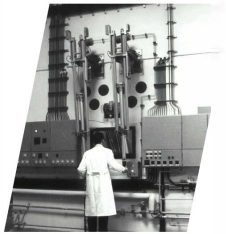
The modality's precision allows for selective destruction of tumor cells while preserving the integrity of healthy tissues.

Advancing Treatment Modalities

BNCT represents a significant advancement in cancer treatment, particularly for cases resistant to standard therapies.

UNDERSTANDING BNCT MECHANISM

A Comprehensive Overview of Boron Neutron Capture Therapy (BNCT)



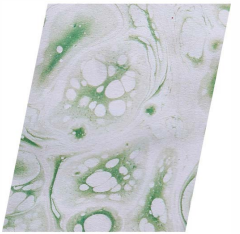
1 Targeting Tumor Cells

BNCT uses boron-10-loaded agents that are specifically designed to attach to tumor cells, allowing for targeted treatment

2 Nuclear Reaction Mechanism

When neutrons are captured by boron-10, a nuclear reaction occurs, releasing alpha particles and lithium-7 nuclei, which leads to the destruction of tumor cells

^{10}B + neutron → α particle (^{4}He) + ^{7}Li nucleus



3 Cytotoxic Effects

The alpha particles generated have a limited range, ensuring that their cytotoxic effects are confined to tumor cells

4 Sparing Healthy Tissues

The localized nature of BNCT minimizes damage to healthy tissues by targeting only the affected cells.

MICRODOSIMETRY IN BNCT :

Microdosimetry :

Focuses on measuring and analyzing the energy deposition patterns from neutron capture reactions at the microscopic level.

Critical for BNCT :

- Precision - Treatment planning - Safety

Enables :

Dose quantification - Treatment optimization - Biological effect estimation - Quality assurance

Challenges :

Technical complexity - Biological variability - Data interpretation - Standardization

RESEARCH OBJECTIVES :

Research goals :

Advance understanding of BNCT microdosimetry

Optimize BNCT treatment planning

Investigate biological effects of high radiation

Specific aims :

Develop and validate a Geant4-based simulation model

Compare different physics lists and water representations for BNCT simulations

Analyze energy deposition patterns

Methodology :

1

Geant 4

A toolkit for simulating particle interactions in matter
Geometry used

2

Physics Lists

Comparison of different physics lists : Geant4-DNA, QGSP_BIC_HP

3

Water Models

Implementation of various water models : predefined water (G4_Water) and structured water

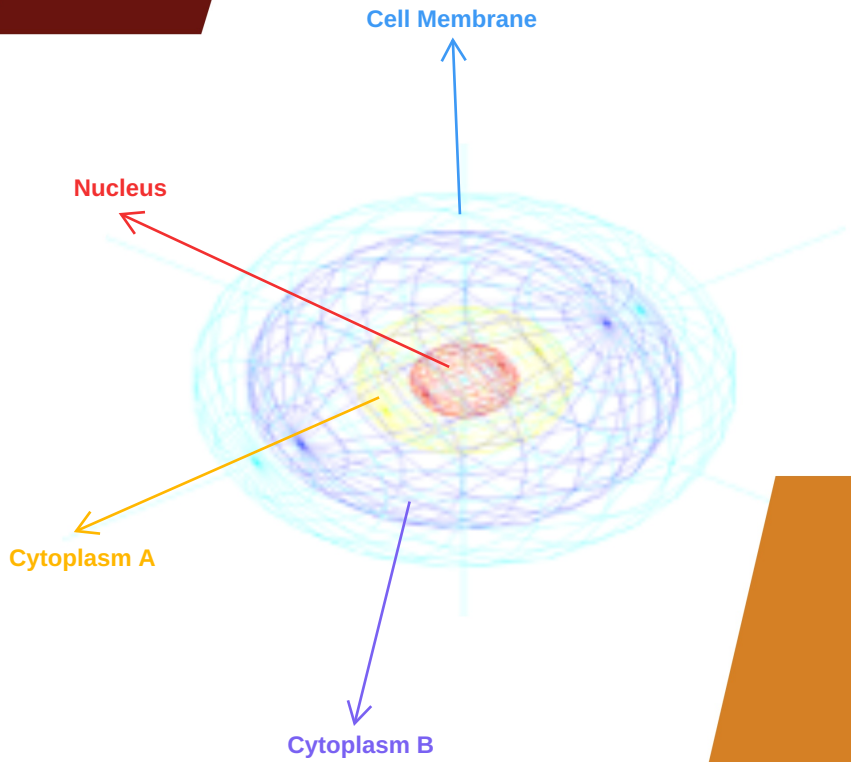
4

Particles simulated

Alpha particles and Lithium ions from 10B(n,α)7Li reaction

a simplifed single cell model was utilized to calculate the behavior of alpha and lithium-7 particles generated through boron neutron capture reactions. the cell was modeled with distinct compartments representing the nucleus, cytoplasm a, cytoplasm b, and cell membrane, with dimensions set based on typical cellular anatomy.

Single Cell Model



G4QGSP_BIC_HP Model

an extension of G4QGSP_BIC that includes high-precision (HP) models for low-energy neutrons. The HP component uses evaluated cross-section data to improve the accuracy of neutron interaction simulations, which is particularly important in applications such as BNCT (Boron Neutron Capture Therapy) where low-energy neutrons play a crucial role.

Vs

Geant4-DNA Model

an extension of the Geant4 toolkit specifically designed to simulate particle interactions with biological matter at the molecular and cellular scale. This model implements detailed physical, chemical, and biological processes to simulate direct and indirect damage to DNA caused by ionizing radiation. It is particularly useful for applications in radiobiology, radiotherapy, and radiation protection.

PHYSICS LISTS

Exploring G4QGSP_BIC_HP vs Geant4-DNA for BNCT Microdosimetry

WATER MODEL :

H_2O

"Manual" declaration of water in Geant4, where the user defines the chemical composition of the molecule themselves.

2

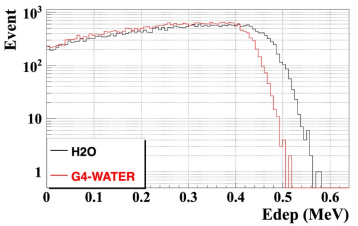
1

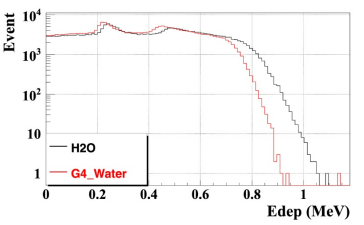
G4_WATER

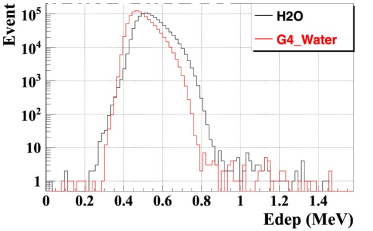
Predefined declaration in Geant4, part of the NIST (National Institute of Standards and Technology) predefined materials

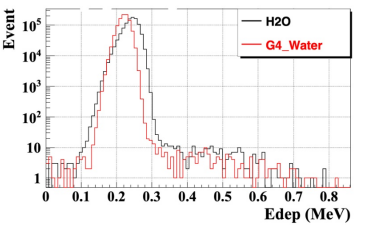
ALPHA PARTICLE ENERGY DEPOSITION PATTERNS

Geant4-DNA

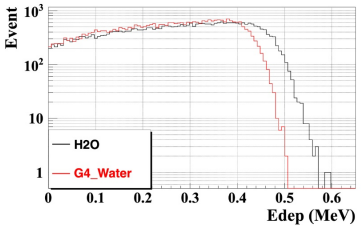


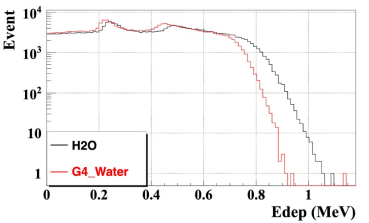


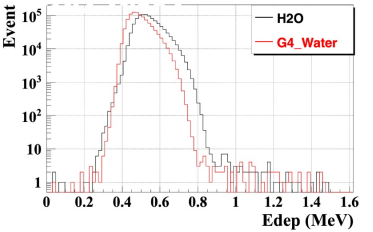


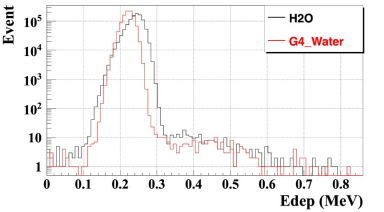


G4QGSP_BIC_HP



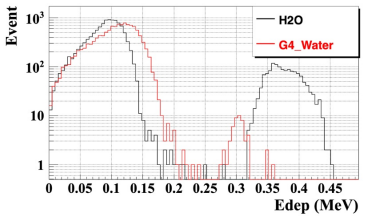


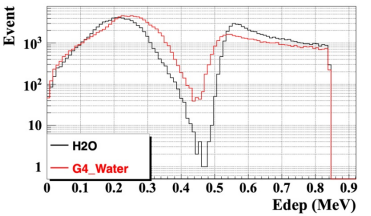


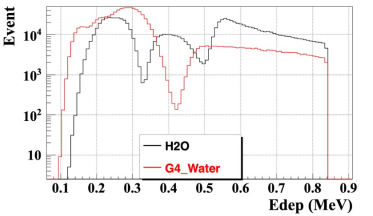


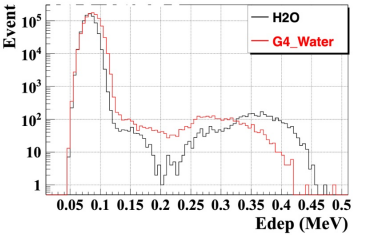
LITHIUM-7 ION ENERGY DEPOSITION PATTERNS

Geant4-DNA

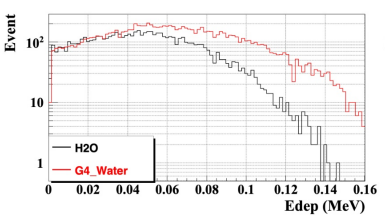


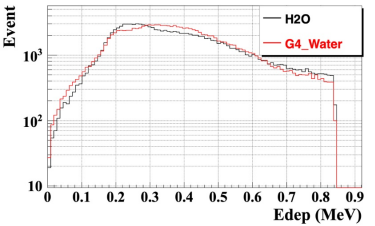


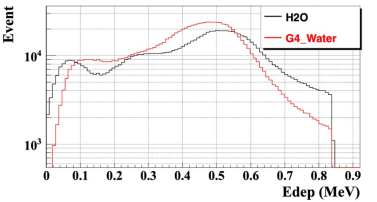


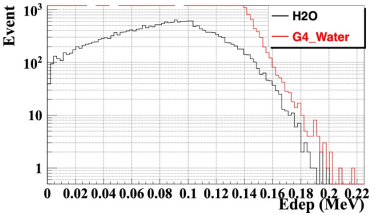


G4QGSP_BIC_HP









CONCLUSION AND CALL TO ACTION

Advancing BNCT for Selective Cancer Treatment Requires Ongoing Research