# Simulation the interaction range of Alpha and 7Li particle in human tissues on BNCT therapy

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**Abstract.** This paper examines the function of particle therapy, a novel form of radiation therapy (RT) that has gained popularity and quick advancement in recent years, in interdisciplinary care. Proton beam therapy (PBT), carbon-ion beam therapy (CIBT), and boron neutron capture therapy (BNCT) are the three particle therapies that are currently used to treat cancer. One special feature of boron neutron capture therapy (BNCT) is its ability to selectively irradiate tumor cells with heavy particles. Even when cancer and normal cells are mixed together at the tumor edge, BNCT can still create significant dose gradients between the two types of cells. This characteristic allows pre-irradiated locally recurrent cancers to be treated with BNCT. It is yet unclear, though, whether thermal neutron irradiation of the region will cause the two heavy particles that result from the BNCT reaction to target the malignant cells more specifically. This paper's second section describes the simulation that SRIM utilized to determine the interaction range between two heavy particles, alpha and 7Li particles, in human tissues during BNCT treatment. Based on this simulation, we discovered that the energy generated by BNCT therapy can be largely absorbed by the pathogen, leading to successful treatment outcomes and avoiding harm to other healthy tissues in the human body. This effectively shows that BNCT therapy is stable and feasible.

**Keywords:** BNCT, Particle Physics, Simulation.

## 1. Introduction

One kind of radiotherapy (RT) is particle beam therapy. In addition to administering a high radiation dose to malignancies, particle beam therapy now offers anticancer effects because to advancements in technology. The use of medication therapy is essential to development. In terms of medication therapy, common particle beam therapies include Heavy Ion Therapy such as C-ion beam therapy (CIBT) and proton beam therapy (PBT) [1].

Compared to photons, which are employed in traditional RT, protons and C-ions have dose distributions that are very different. The most notable physical characteristic difference is the presence of a depth-dose distribution, also known as the Bragg peak. Because of this feature, particle beam therapy can provide the highest amount of energy to the area close to the stop (the cancer portion) (Figure 1) [2]. While protons and C-ions have extremely similar dose distributions, C-ion beams differ from proton beams in that they have longer fragmentation tails and a narrower penumbra [3].

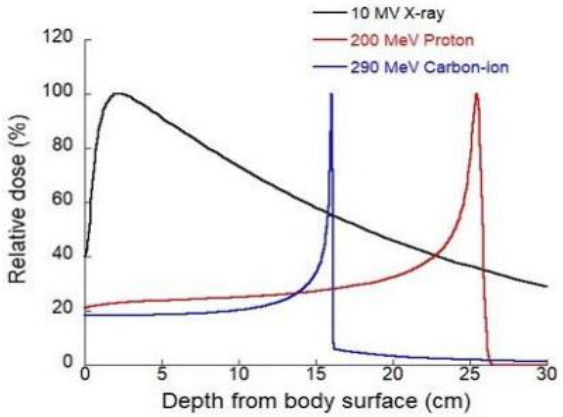


**Fig 1.** Depth-dose distributions of clinical X-ray, proton, and carbon-ion beams.

Boron neutron capture therapy (BNCT) is a new type of particle therapy which has a unique property of tumor-cell-selective heavy-particle irradiation. BNCT can form large dose gradients between cancer cells and normal cells, even if the two types of cells are mingled at the tumor margin. This property makes it possible for BNCT to be used for pre-irradiated locally recurrent tumors. Subsequent paragraphs, however, are indented.

Four years after Chadwick's 1932 discovery of neutrons, the concept of boron neutron capture therapy was put out. It makes use of 10B, which has a high thermal neutron absorbable cross section. It falls under the category of radiation therapy (RT) known as particle beam RT and is distinguished by the use of high-LET particle beams (alpha rays and lithium nuclei) generated by the reaction of neutrons with 10B in the body for cellular damage (treatment of malignant tumors) and external irradiation of thermal neutrons, which have no electric charge. At theory, the reaction will only happen at the targeted area and have a cell-killing impact if boron can be directed there.

High-power neutron sources, like the Japan Proton Accelerator Research Complex (J-PARK, Tokai, Japan), have been developed in the field of physics in recent years as the use of nuclear reactors for both commercial and research purposes has grown more challenging. As a spin-out of these sources, research on thermal neutron sources for therapeutic use without using nuclear reactors has become popular. Because they are not bound by the same stringent rules as nuclear reactors, accelerator neutron sources have a greater potential for medical uses than nuclear reactors. They can be deployed in hospitals for medical purposes.

The first nation to start using it in clinical settings was Japan. Based on the earlier BNCT treatment in nuclear reactors, which prioritized head and neck cancers and malignant brain tumors, a clinical research utilizing accelerator-based BNCT was created in Japan. The first BNCT medications and equipment to be approved by health insurance in Japan were NeuCure from Sumitomo Heavy Industries and L-p-boronophenylalanine (BPA) agents from Stella Pharma, which were released in June 2020. Consequently, BNCT has evolved into a medication-assisted medical therapy option, and it is now being used as a full-fledged treatment for a select few indications.

When low energy (<0.5 eV) neutrons, also known as thermal neutrons, are absorbed by nonradioactive isotope 10B atoms, they break down into an alpha (4He) particle and a recoiled lithium nucleus (7Li). High energy is left behind by these particles on their brief (<10 μm) journey. Since a single cell is only 10 μm in size, the BNC reaction takes place inside of it (Figure 2) [4]. Thermal neutron irradiation to the area can preferentially destroy the cancerous cells by two heavy particles, 4He and 7Li, yielded following BNCT reaction, provided that 10B atoms selectively collect in the malignant cells surrounded by normal cells.

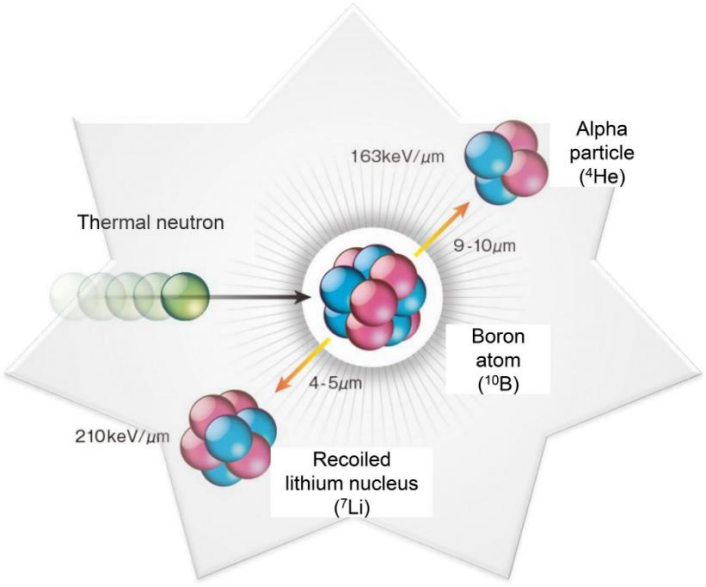


**Fig 2.** Boron neutron capture reaction.

## 2. Simulation

### 2.1. Heavy Ion simulation software SRIM

SRIM (Simulation of Rdition Induced Mterils Effects) is a collection of software packages which calculate many features of the transport of ions in matter. SRIM includes quick calculations which produce tables of stopping powers, range and straggling distributions for any ion at any energy in any elemental target. More elaborate calculations include targets with complex multi-layer configurations [5]**.**

Ion Stopping and Range in Targets: SRIM, the Stopping and Range of Ions in Matter, calculates the majority of the energy loss of ions in matter. For any ion at any energy in any elemental target, SRIM's fast computations yield tables of stopping powers, range, and straggling distributions. Targets with intricate multi-layer arrangements are included in more complicated calculations.

Ion Implantation: Ion beams are used to modify samples by inserting atoms to affect the intended chemical and electrical properties. By moving atoms, the ion beam damages solid targets as well. The SRIM package contains the majority of the kinetic effects related to the physics of these kinds of interactions.

Sputtering: Ion sputtering is the method by which the ion beam may eliminate target atoms. The SRIM program includes the calculation of sputtering by any ion at any energy.

Ion Transmission: In ionization chambers or energy degrader blocks, which lower the energy of ion beams, ions can pass through layers of mixed gas and solid target material.

Ion Beam Therapy: In radiation oncology in particular, ion beams are frequently utilized in medical therapy. Included are common applications.

Based on the capabilities of SRIM and the principle of BNCT treatment response (Figure 3), it can be concluded that SRIM can be used to simulate the interaction range of alpha and 7Li particles in human tissues with high accuracy during BNCT treatment.

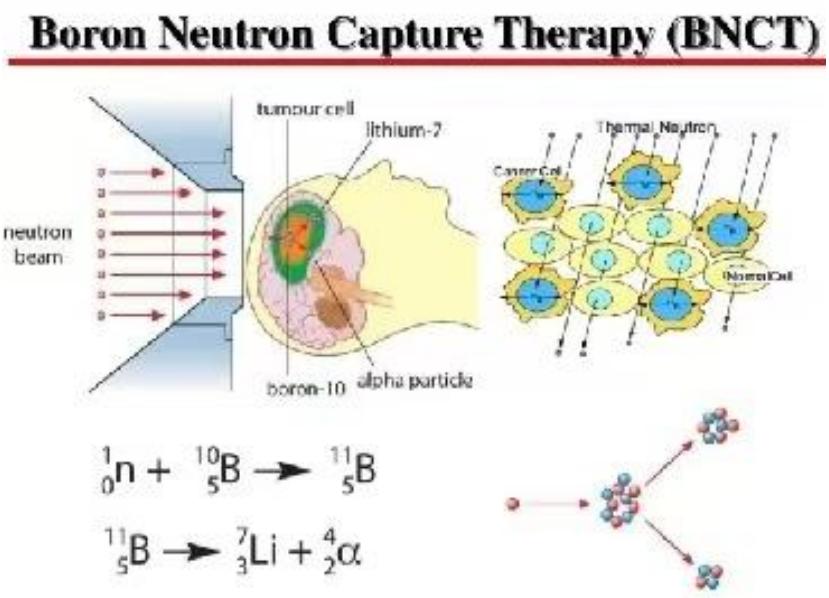


**Fig 3.** The principle of BNCT treatment response.

### 2.2. Simulation of alpha particles

The impact range of alpha particles during BNCT treatment was simulated using SRIM in three distinct human body regions (blood, skin and bone simulations).

The figure (Figure 4)'s vertical axis represents the total number of elements (unit: Atoms) in human tissue at various depths, while the figure's horizontal axis represents the depth (unit: ANG) of the tissue.

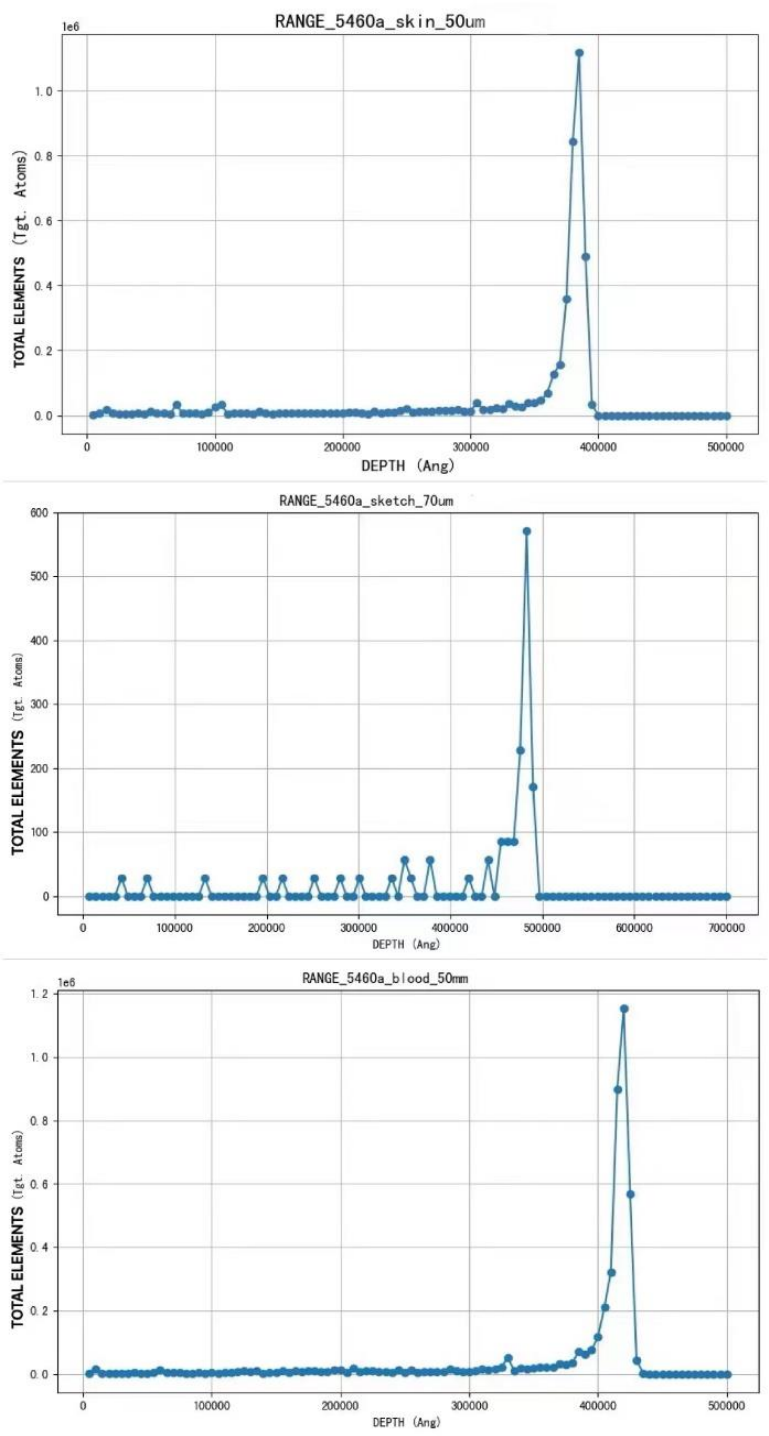


**Fig 4.** The total number of elements in human tissue at various depths during the simulation of alpha particles.

According to the figure (Figure 4), the total number of elements in human skin and blood is highest at a depth of approximately 0.04mm in human tissue; in bones, the highest point is reached at a depth of approximately 0.05mm in human tissue.

### 2.3. Simulation of 7Li particles

To confirm the overall effectiveness of BNCT treatment, SRIM was used again to simulate the influence range of 7Li particles during BNCT treatment in four different human regions (blood and skin).

The figure (Figure 4) represents the depth to which 7Li particles are able to reach across the surface of human cells in the simulation of different human tissues (blood situation above).

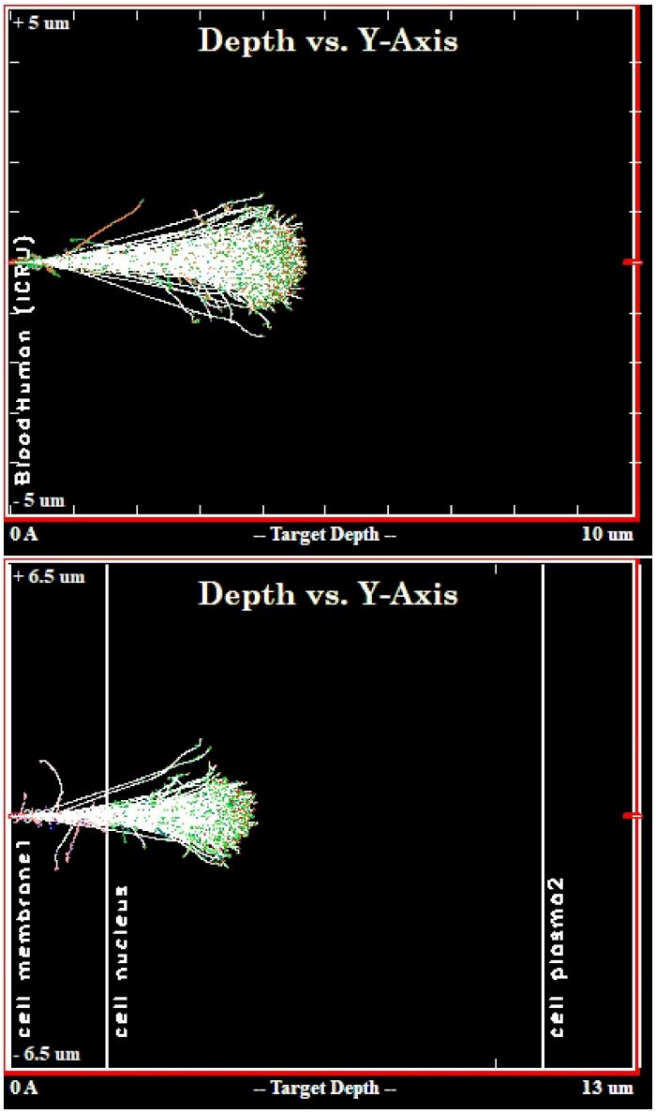


**Fig 5.** The depth to which 7Li particles are able to reach across the surface of human cells.

According to the figure (Figure 5), in the blood simulation, the energy of 7Li particles disappears roughly 2um after entering the surface of human cells; in the skin simulation, the energy of 7Li particles decreases significantly after passing through the nucleus of the cell, and finally disappears at around 4-5um.

## 3. Conclusion

The maximum value of the total number of elements in the SRIM experiment to simulate alpha particles is roughly 0.04 mm~0.05 mm in human tissue. As a result, during BNCT therapy, the energy effect range of alpha particles is likewise roughly discharged inside 0.01mm inside human tissue.

The effect range of these particles will likewise release energy in a small range in human tissues during the treatment of BNCT since both alpha and 7Li particles have an interaction range of approximately 0.01 millimeters. This shows that BNCT therapy can successfully regulate the reaction energy concentration close to the pathogen and, thanks to its reduced impact range, guarantee that high energy does not surpass the skeletal portion of human tissue.

The energy released during BNCT therapy can be mostly lost to the pathogen, achieving effective treatment results and preventing damage to other healthy tissues around the human body, according to the influence range of alpha and 7Li particles. This essentially demonstrates the stability and practicability of BNCT therapy.

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