A Study of Primary and Secondary Radiation During Proton Therapy

By

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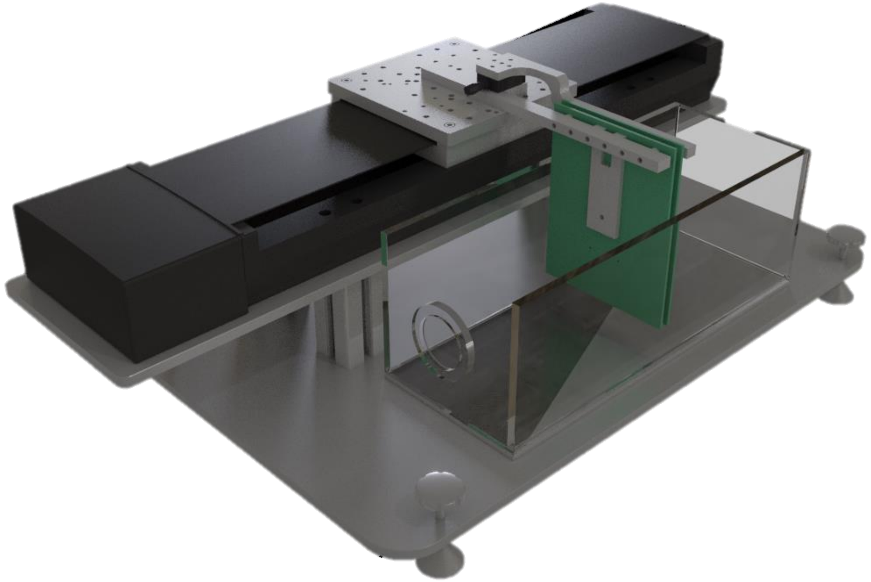

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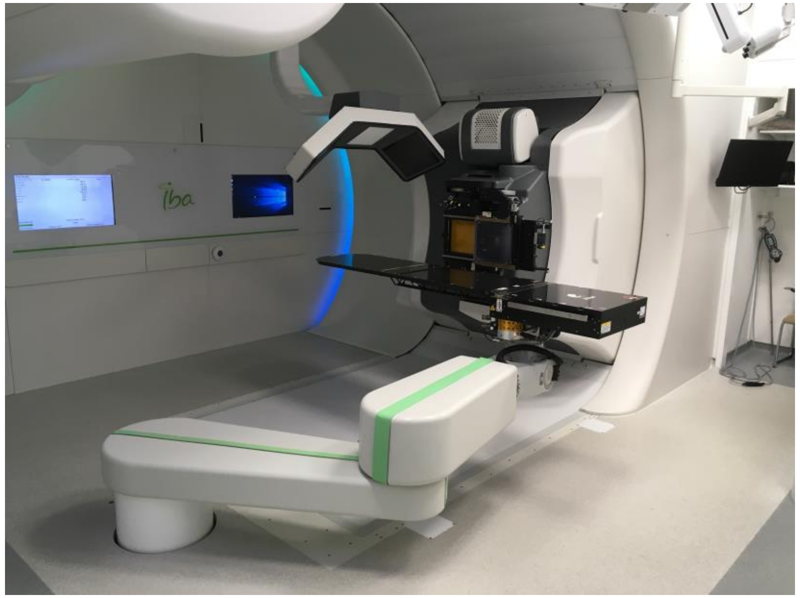
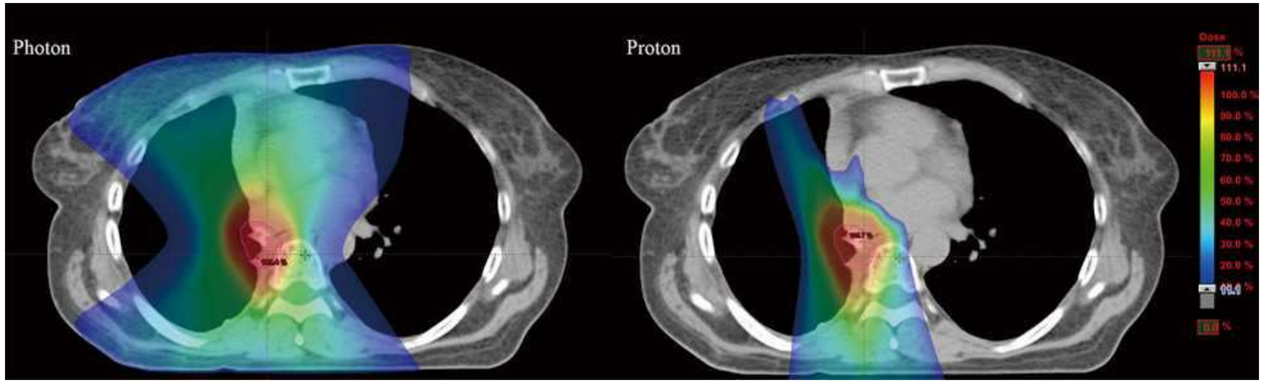
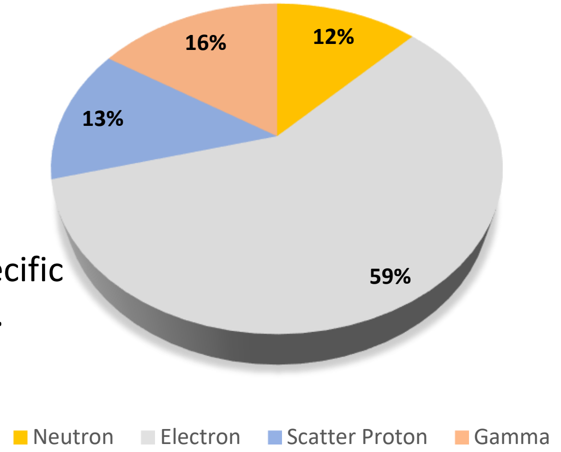


Background

- Proton therapy delivers a precise, concentrated dose to the tumour, a low dose to the surrounding tissues, and no dose beyond the tumour.
- Various of secondary radiation is created during the treatment when protons are interacting with the tissues and the beam-line.
- Depends on the target material, beam delivery and the beam energy.
- This research is aiming to monitor the dose distribution of protons and associated secondary neutrons inside a water phantom.



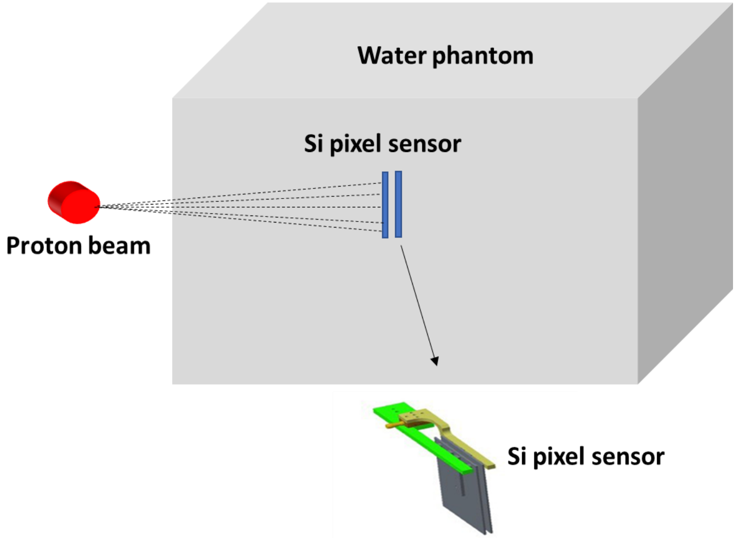
Proton therapy delivered less radiation to the heart, lungs and healthy tissues than conventional photon therapy.



Share of secondary radiation at specific depth with 229 MeV in Geant4.

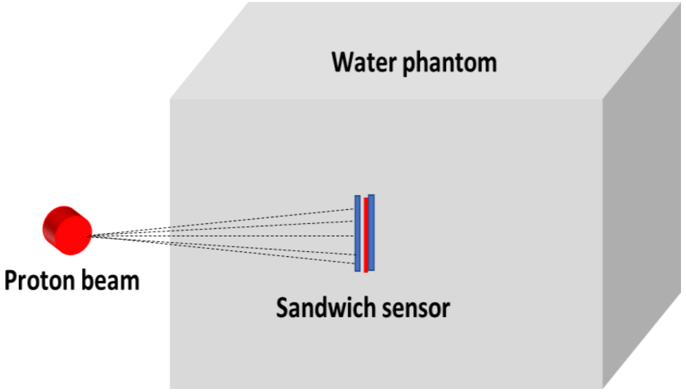
Methodology

The 1st Experiment



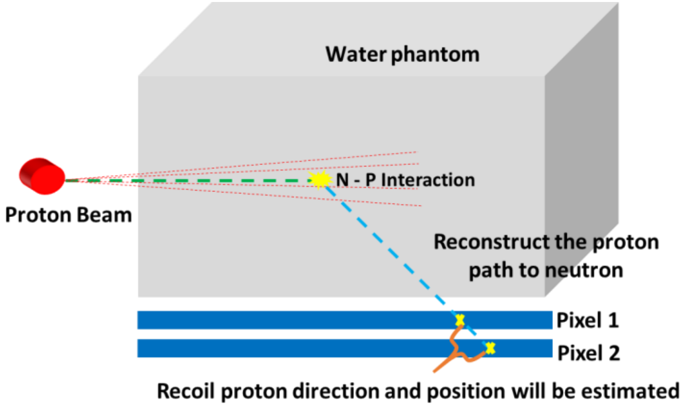
Simulate the Si pixel detector for monitoring the primary proton beam and created secondary radiation.

The 2nd Experiment



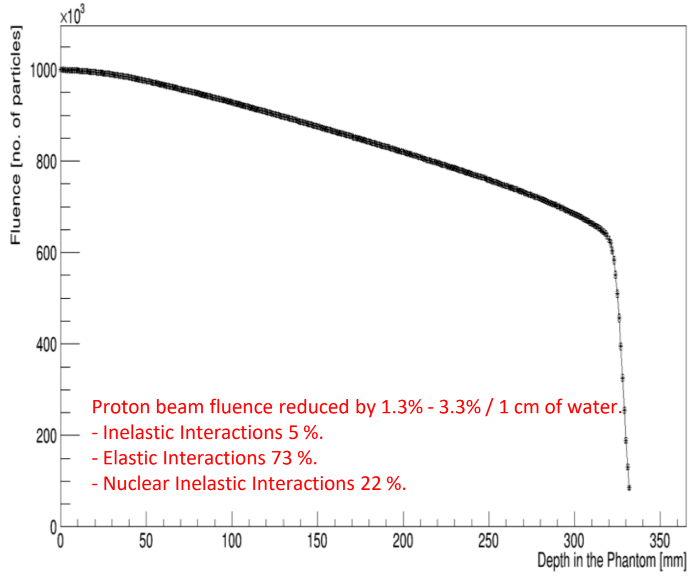
Simulate the Si sandwich detector for monitoring the produced secondary thermal neutrons.

The 3rd Experiment

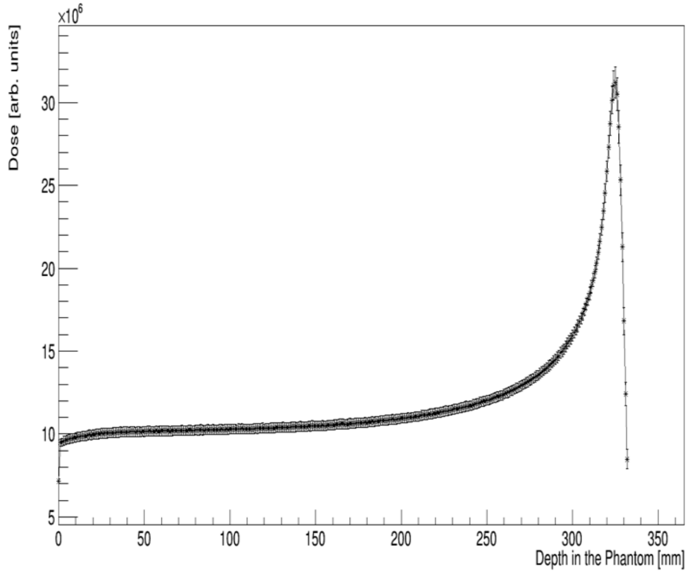


Simulate the Si pixel detectors for monitoring the produced secondary fast neutrons.

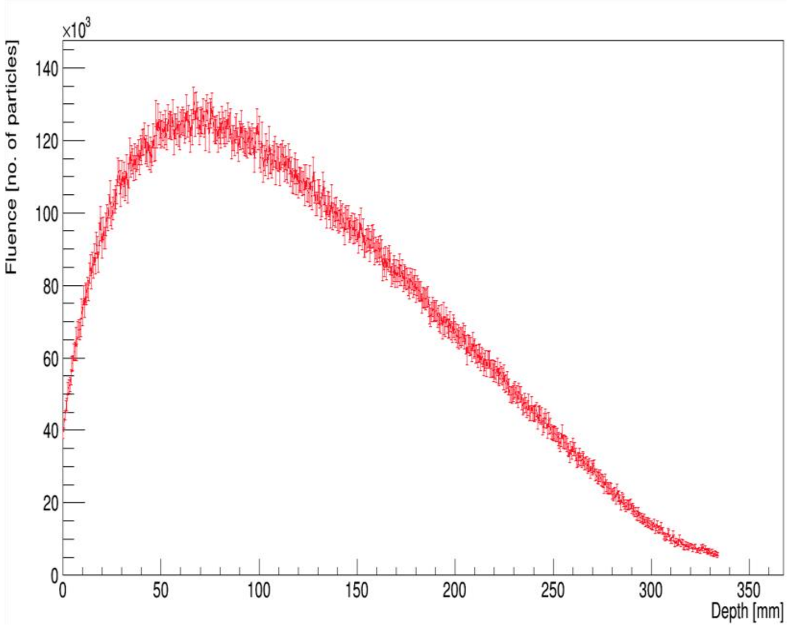
The 1st Experiment: Si detector for monitoring Proton Beam



Proton beam fluence VS depth.



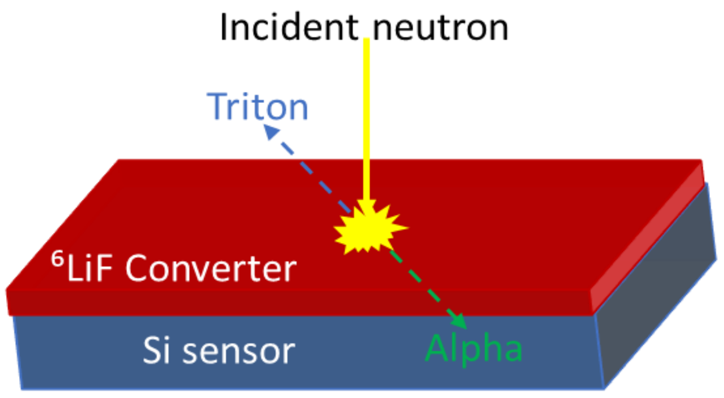
Proton beam dose VS depth curve.



Neutron fluence VS depth generated inside the water phantom as a result of p-n interactions.

The 2nd Experiment: Sandwich Detector Theory & Design

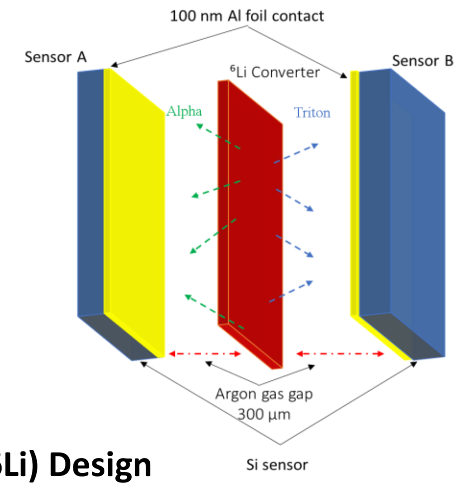
$$ {}^{6}_{3}Li + {}^{1}_{0}n \rightarrow {}^{3}_{1}H\ (2.73\ MeV) + {}^{4}_{2}\alpha\ (2.05\ MeV) $$



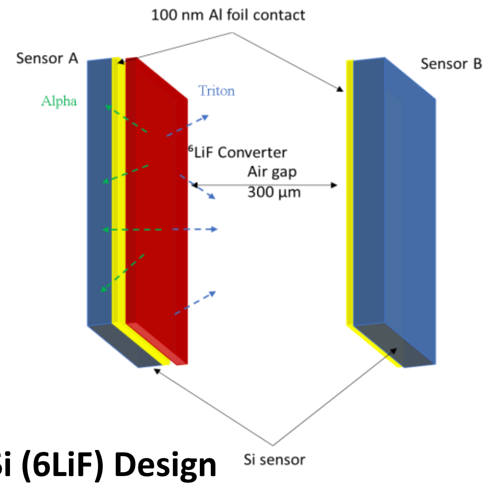
❖ **Increasing the neutron converter thickness leads to:**

- ***Increased*** *neutron capture probability.*
- ***Decreased*** *number of reaction products that reach the Si sensors.*
- ***A reduction*** *in detector efficiency.*

An isotropic source that emits alpha and triton particles as thermal neutron interactions has been generated from the converter itself.



Si (6Li) Design



Si (6LiF) Design

Total and coincidence detections efficiency calculation formula

$$ \varepsilon_n = \frac{n}{N} \times \{\, 1 - \exp(-\frac{N_A}{\omega_A} \times \rho\, \sigma\, x) \,\} $$

Where: n the number of particles detected by the detector.

N the total number generated inside the converter.

N_A the Avogadro number which is equal to 6.022×10^{23} /mol.

ω_A the atomic or the molecular weight of the converter [ω_A for ^{6}LiF = 25 g/mole and ω_A for ^{6}Li = 6 g/mole].

ρ the density of the converter which is [2.539 g/cm³ for ^{6}LiF and 0.462 g/cm³ for ^{6}Li].

σ the cross section which is 940 barn for ^{6}Li.

x the converter thickness.

The 2nd Experiment: Sandwich Detector Efficiency Results

^{6}Li Converter

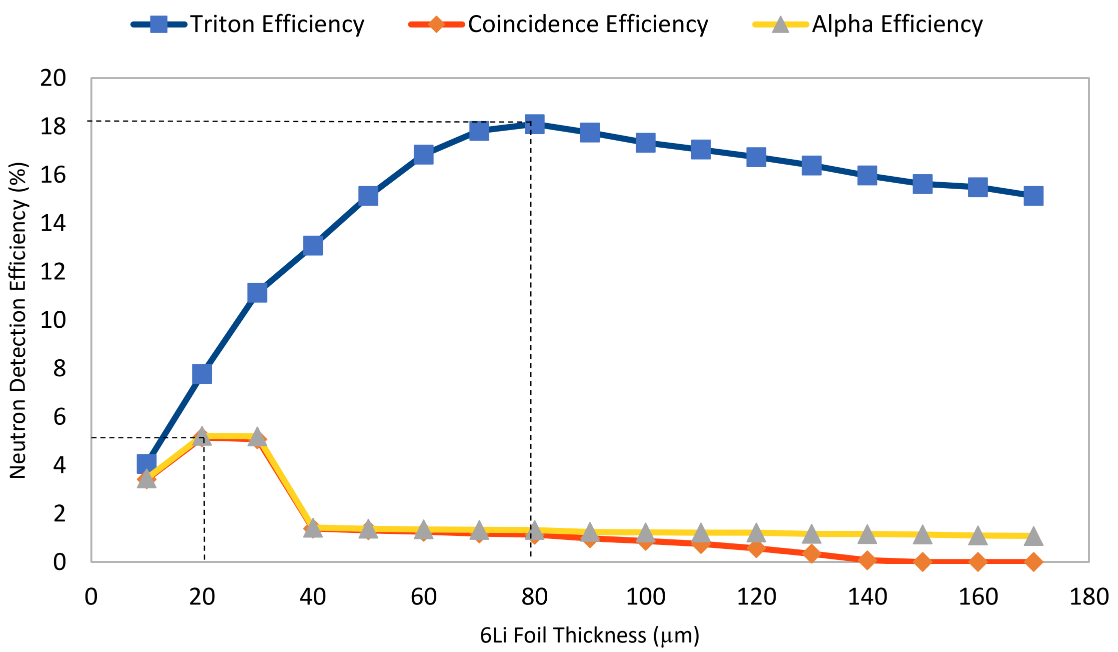
The coincidence efficiency 5.15% @ 20 μm.

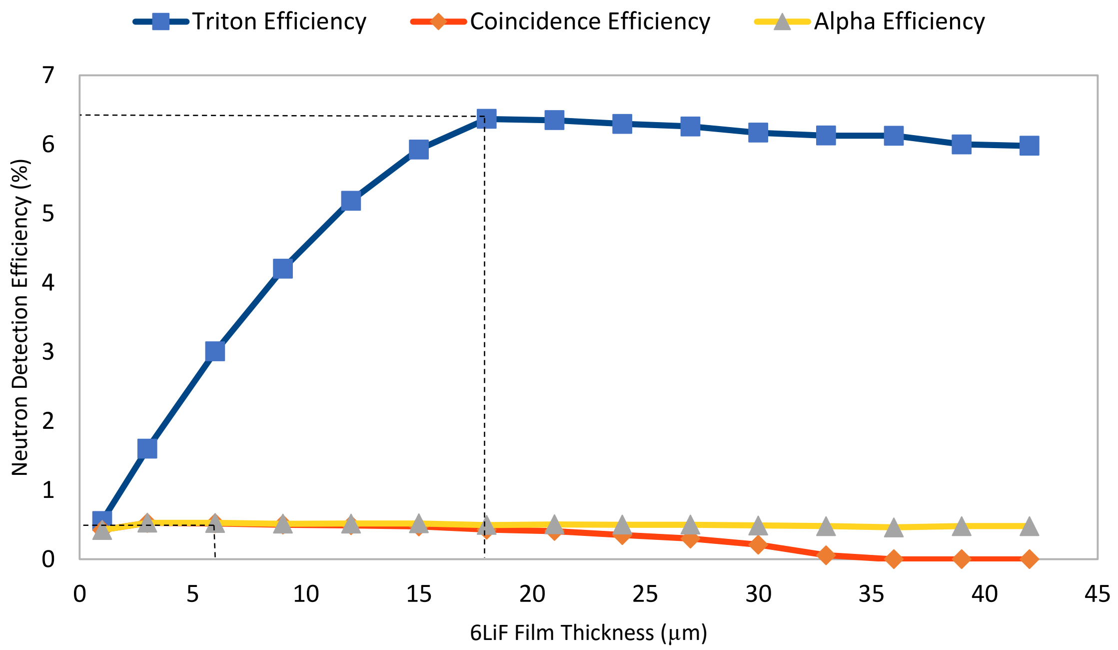
The Triton (maximum) efficiency 18% @ 80 μm.

^{6}LiF Converter

The coincidence efficiency 0.53% @ 3 μm.

The Triton (maximum) efficiency 6.37% @ 18 μm.

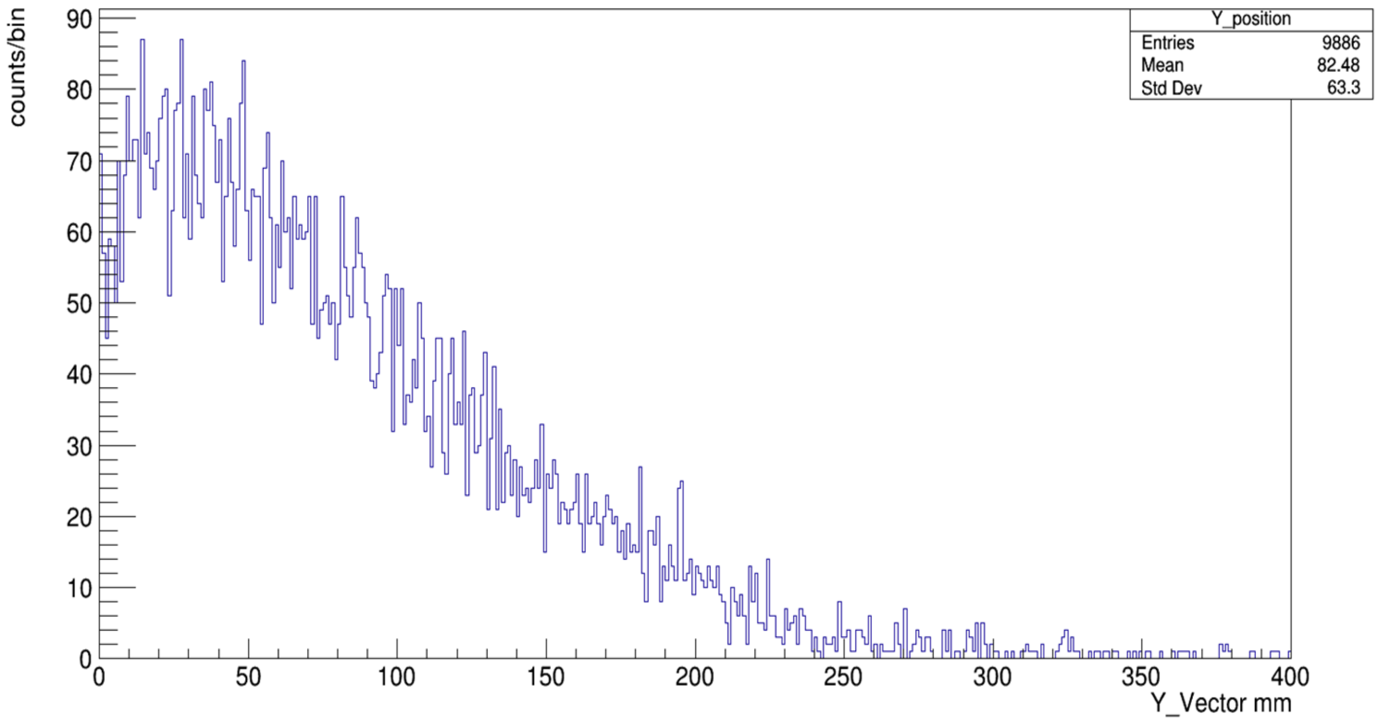


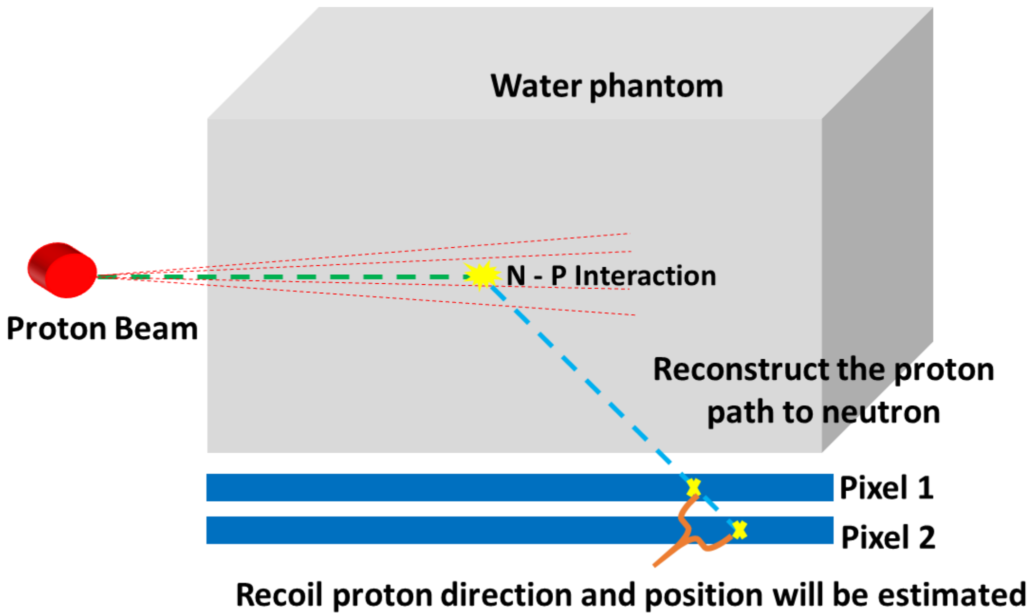


The detection efficiency of triton, alpha and the coincidence efficiency regarding the changing in the converter thickness.

The 3rd Experiment: Fast Neutron Measurement Results

System design for monitoring the fast neutron and the recoil proton, allowing the interaction point to be determined.





Reconstruct the position of the fast neutrons inside the water phantom using Intersection formula.

The PhD Research Journey

Done:

- ✓ A simulation of proton pencil beam and its interactions within water phantom.
- ✓ A simulation of sandwich detector design to measure the produced neutrons in proton therapy.
- ✓ Present promising results for proton range verification studies.

To Do:

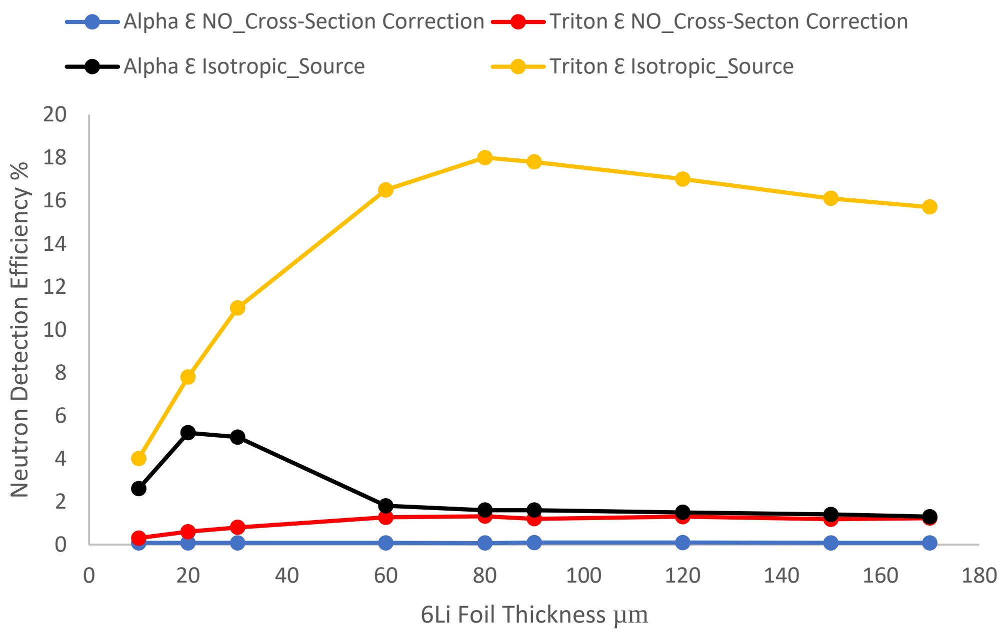
- ➢ Test the sandwich detector response with different neutron energy.
- ➢ Fabrication and calibration of the prototype detector in Liverpool Semiconductor Detector Centre **LSDC**.
- ➢ Test beams with the prototype system at clinical proton beam facilities within different energies.

Sandwich detector efficiency comparison between Isotropic source and direct thermal neutron

There are only three Physics Lists can simulate the thermal Neutrons in Geant4 due to contain thermal neutron packages.

QGSP_BIC_HP, QGSP_BERT_HP and **Shielding**.

Without a cross-section correction



With a cross-section correction