Investigation of Secondary Particles Generation in Carbon Ion Beams for Cancer Radiotherapy

Shaikah Moslat Alsubayae

4th year PhD Student

Advisors: *Prof. Gianluigi Casse, Dr. Carlos Chavez and Dr. Jon Taylor*

Department of Physics – High Energy Physics

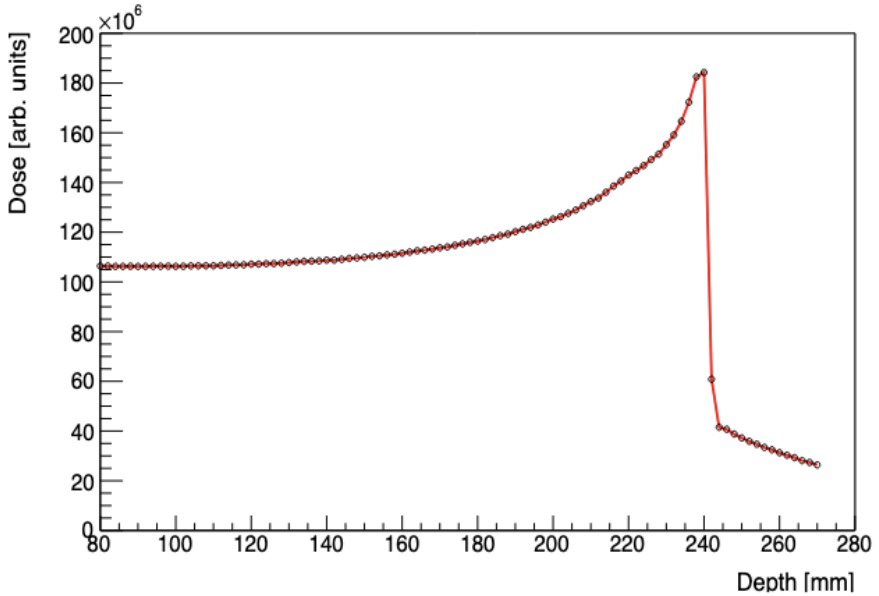
Introduction

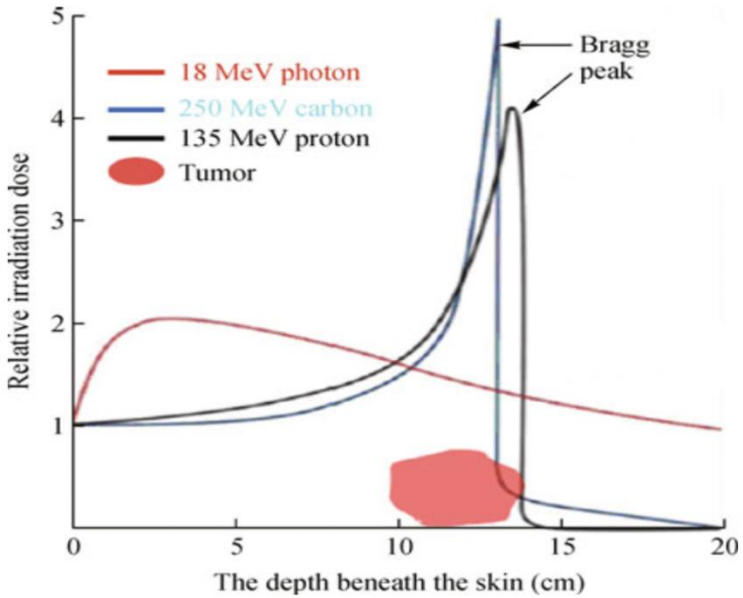
Research Aims:

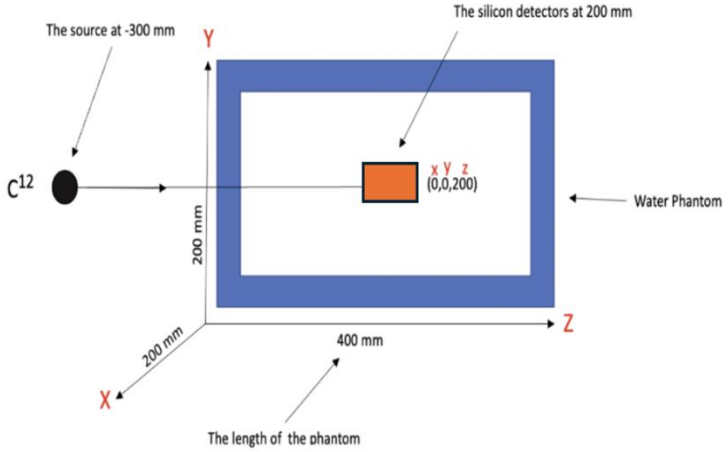
1- Simulation study → monitor the primary beam → produced secondary radiation of hadron therapy (Carbon therapy) with water phantom, using Geant4 Monte Carlo software.

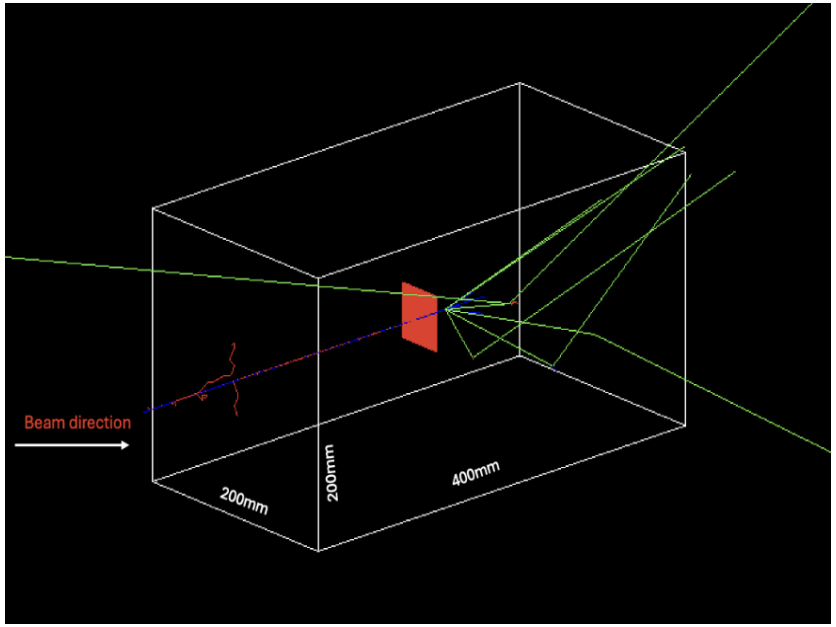
2- Secondary particle radiation → monitor the characteristics of the primary ion beam → measuring change particles coming out of the interactions between the ion beam and the molecules in the water.

3- Measurements → silicon pixel detectors such as Timepix3.



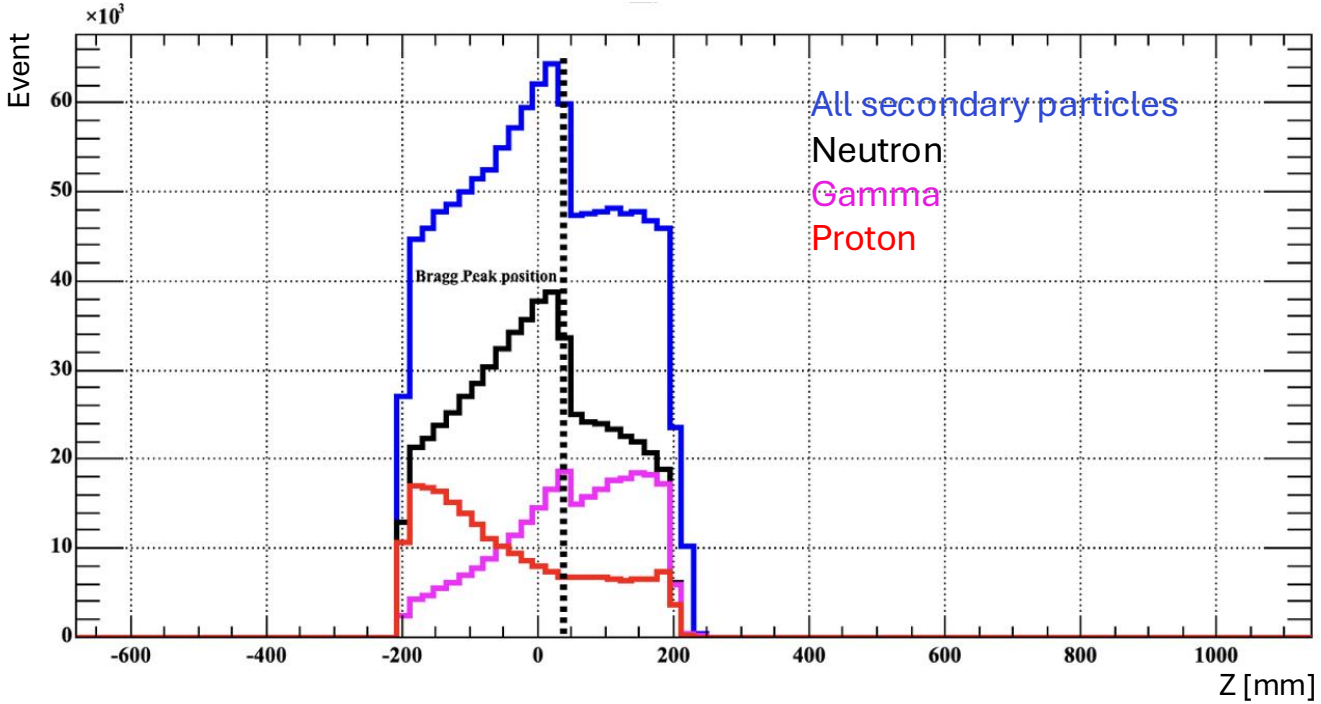


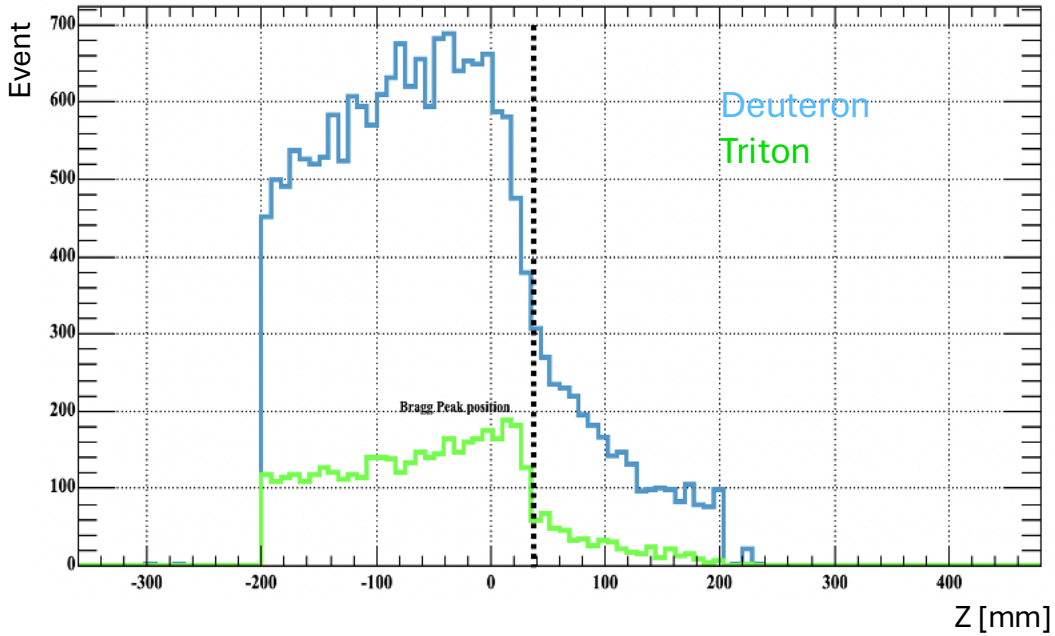




https://www.spiedigitallibrary.org/conference-proceedings-of-spie/12925/1292545/Reliability-evaluation-of-a-digital-pulse-driven-160kV-carbon-nanotube/10.1117/12.3008839.short

Vertex of secondary particles

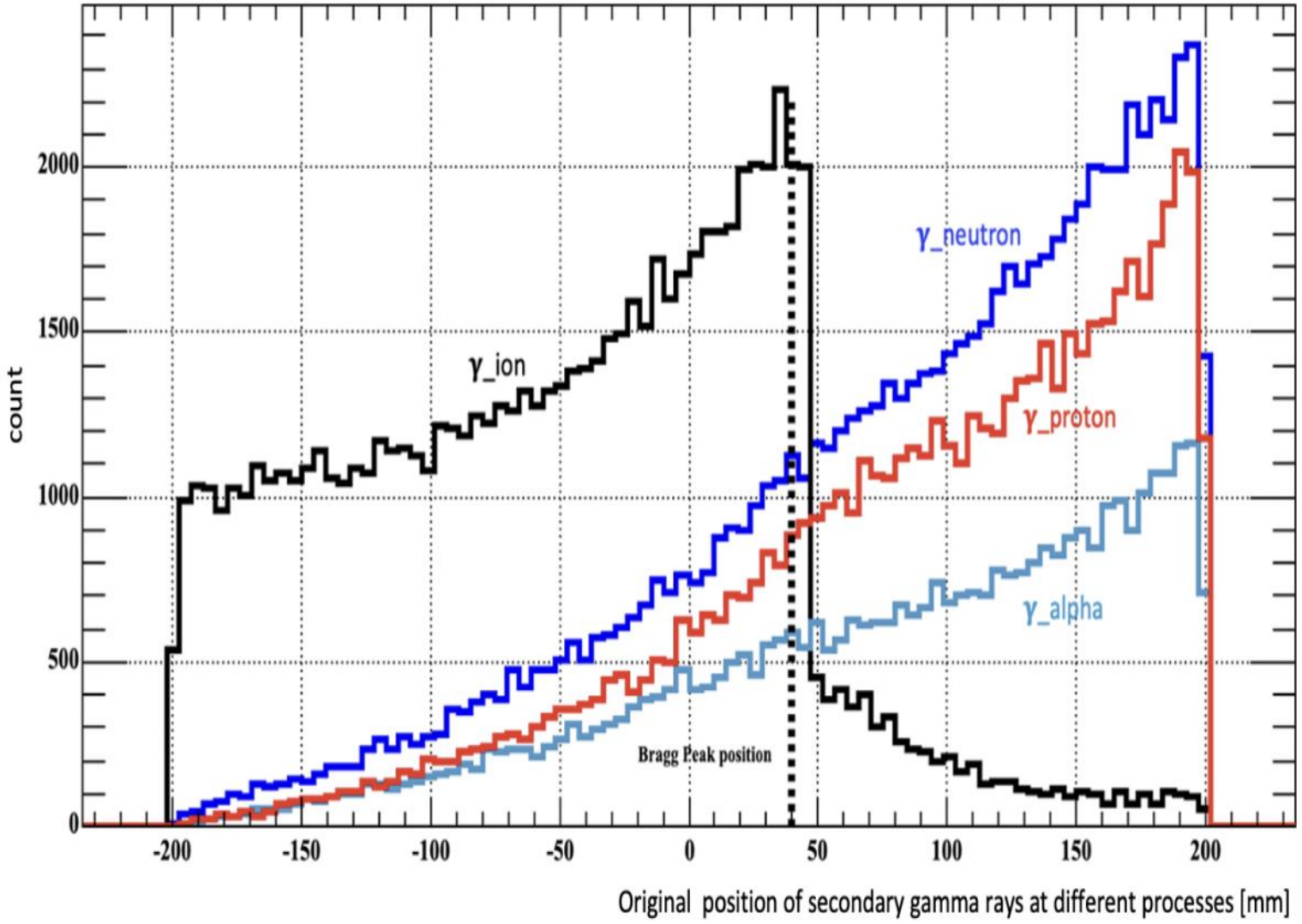




- The truth vertices of secondary particles corresponding to the Bragg Peak of 12C of 4.48 GeV with statistics 3M.

Vertex of secondary gamma rays

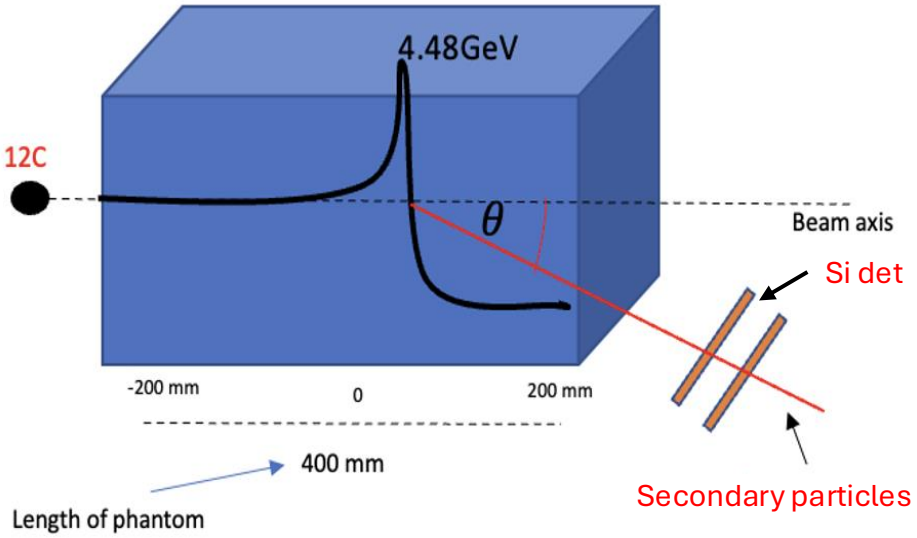
The original positions of gamma rays creating from different processes from 4.48 GeV carbon ion beam

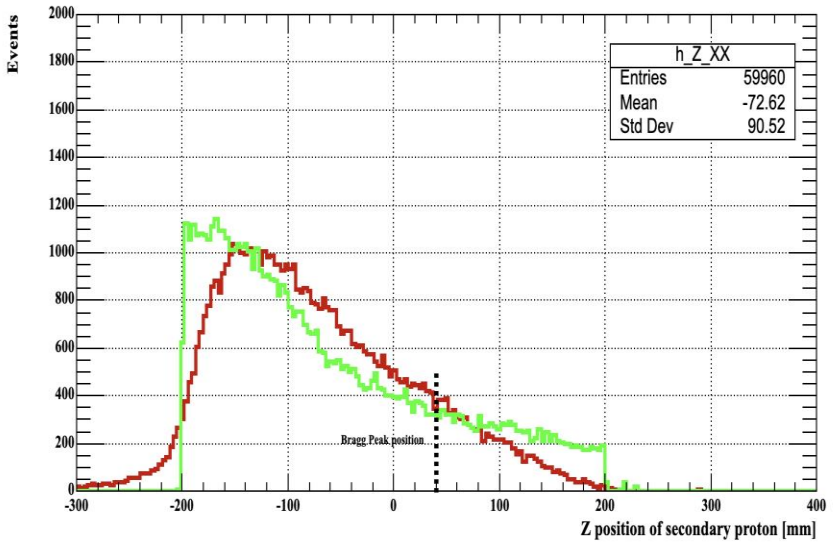


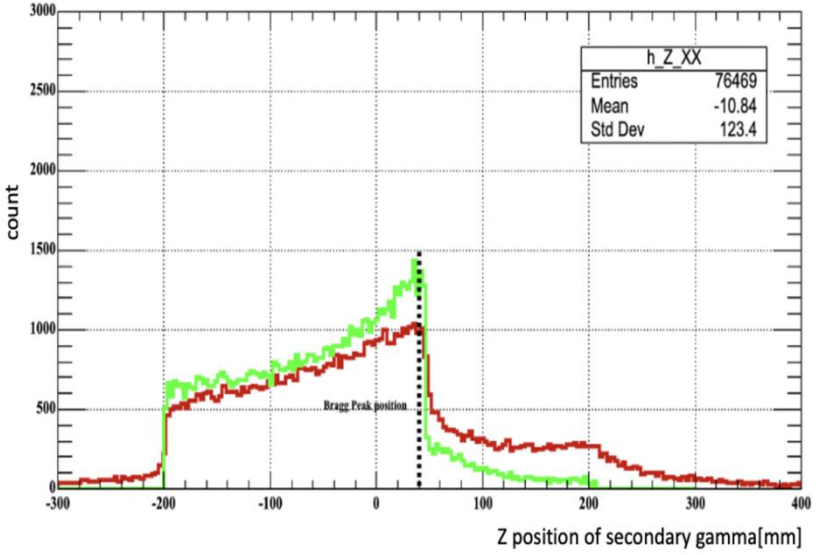
Secondary particles

Geant4 toolkit version 10.03.
Physics list: QGSP_BIC_HP.
Beams: Carbon ion
Energy: 4.48 GeV
Event. no: 3M
Medium: Water

Θ= 35 deg





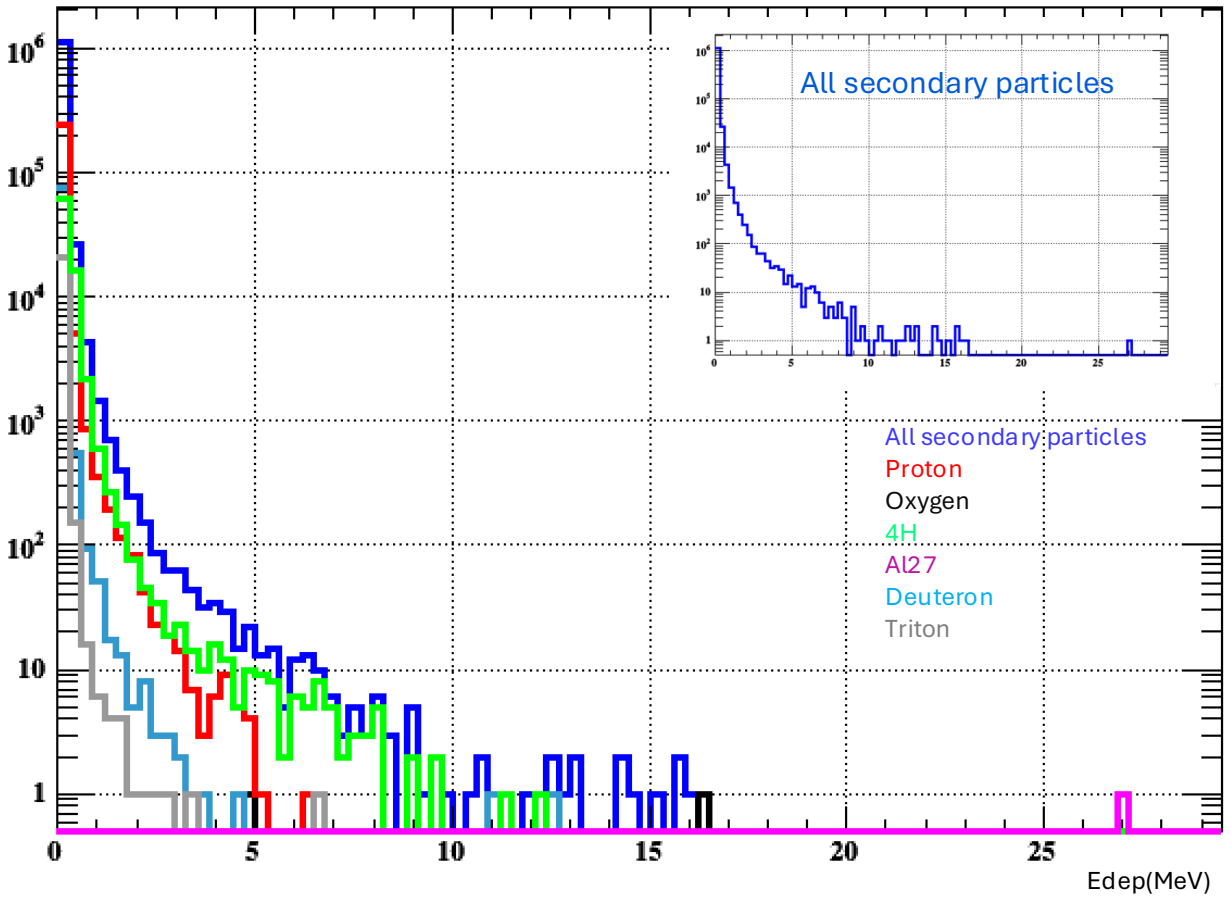


Z position of secondary particles as calculated from the positions in Si det

truth Z positions of secondary particle

Deposited Energy of secondary charged particles that is measured by using Si det

Geant4 toolkit version 10.03.
Physics list: QGSP_BIC_HP.
Beams: Carbon ion
Energy: 4.48 GeV
Event. no: 1M
Medium: Water



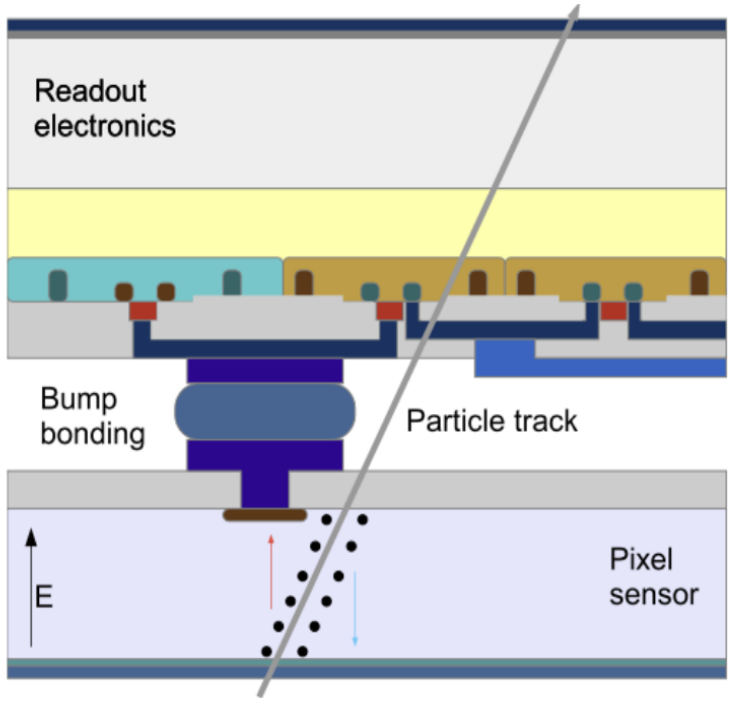
- *Energy deposition of secondary particles* ~**1-27 MeV**
- Secondary ions produced during nuclear fragmentation processes
- The high energies deposition are generated by secondary ions

Semiconductor Tracking Detectors

Sensor Layer: This is the active part of the detector where radiation or particles interact with the material, typically silicon. When radiation passes through the sensor, it ionizes atoms, creating electron-hole pairs that generate electrical signals. These signals are proportional to the energy of the radiation

Readout Electronics: This component processes the electrical signals generated by the sensor. It amplifies, digitizes, and records the signals to extract information about the detected radiation, such as its energy and position.

Bump-bonding connects the sensor and readout electronics in hybrid pixel detectors by using small conductive bumps to ensure precise electrical contact.



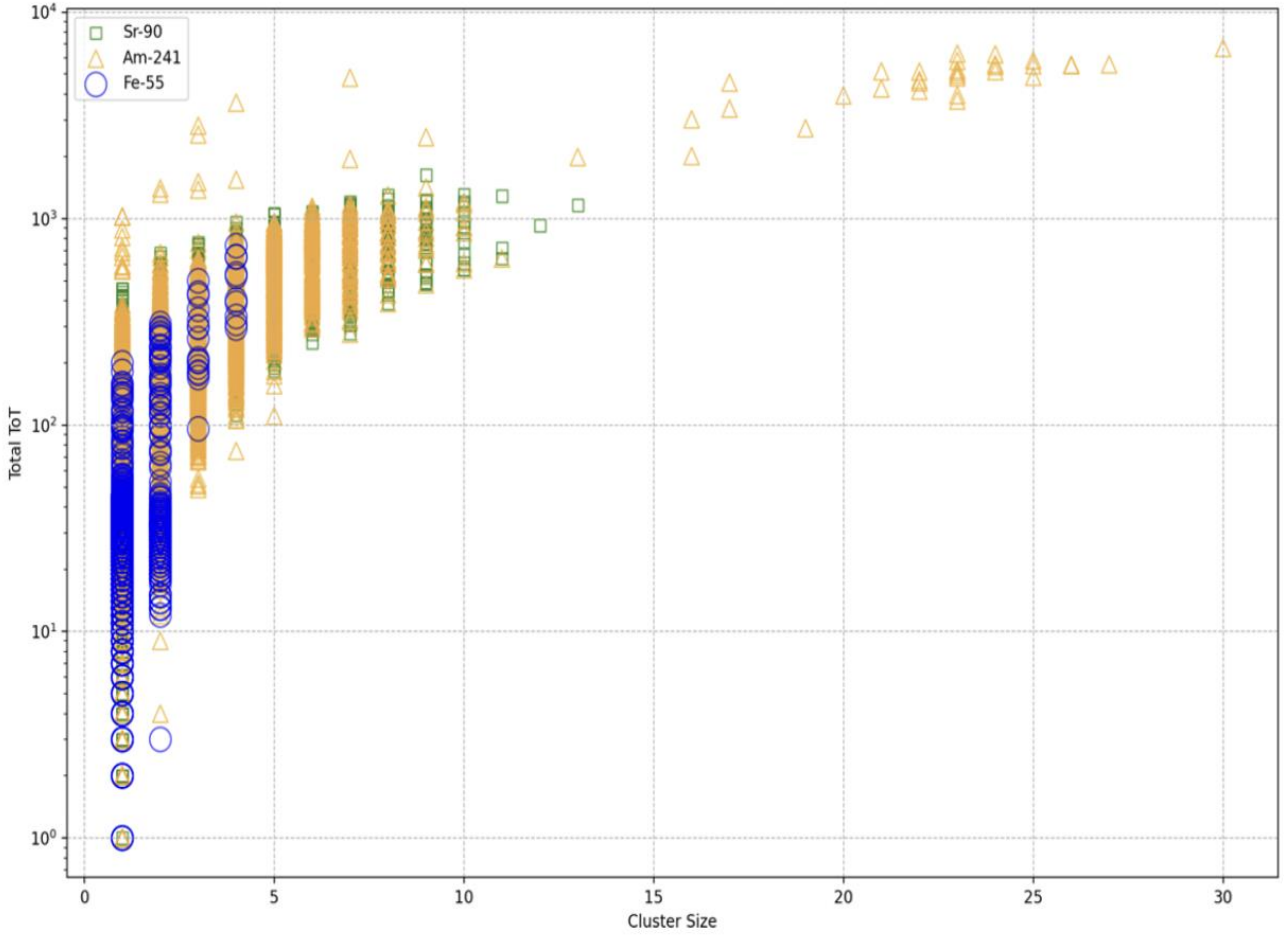
Semiconductor Tracking Detectors

The correlation between total Time over Threshold (ToT) and cluster size for 30,000 hits from three radioactive sources:

Fe-55 (low-energy X-rays) → smaller clusters and lower ToT values.

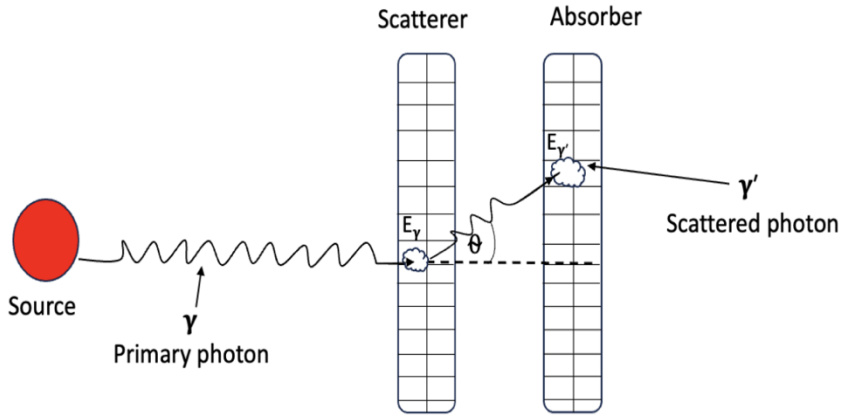
Sr-90 (higher-energy beta particles) → in larger clusters and higher ToT values.

Am-241 (emits alpha particles) → largest clusters and greatest ToT values.

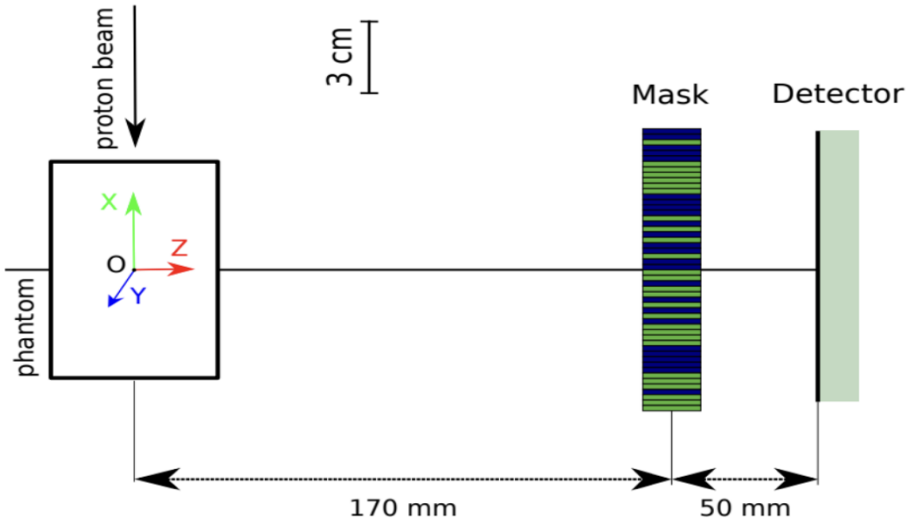


Next Steps and Outook

Using double layered Si detector and the coded mask technique for identifying the origins of secondary gamma emissions in the monitoring of particle therapy as an alternative to the Compton camera technique. This advanced imaging method will potentially enable precise determination of the origin of the secondary gammas, allowing for real-time verification of the beam path to ensure accurate targeting of tumors while minimizing exposure to surrounding healthy tissues.



Principle of Compton camera.



Geometry with a Coded Mask and Gamma Detection System for Proton Therapy Monitoring.

Thank you!

Any questions?