UNIVERSITY OF LIVERPOOL

# A study of secondary particle production from carbon ion beam for radiotherapy

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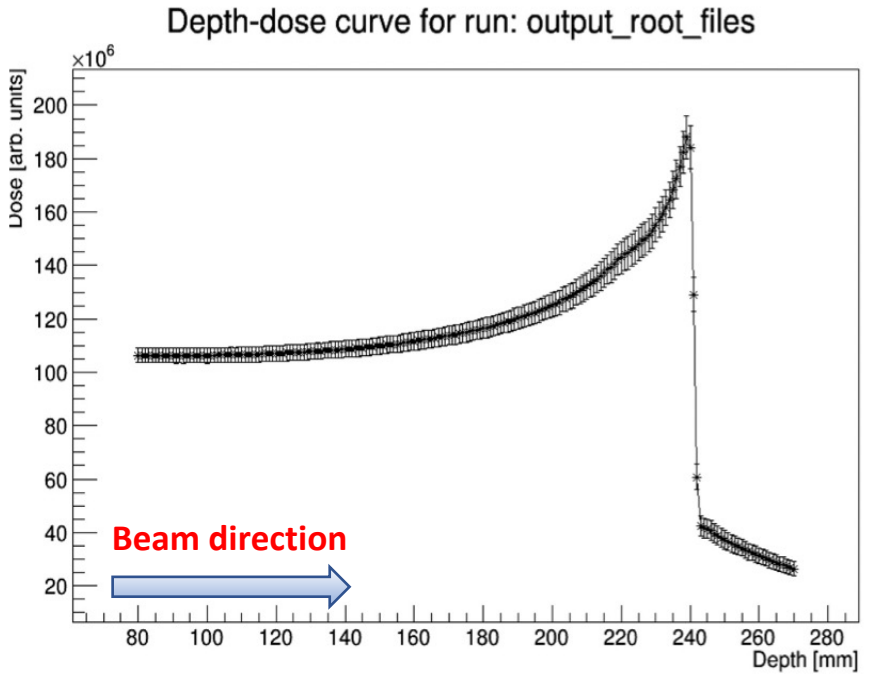
# Introduction

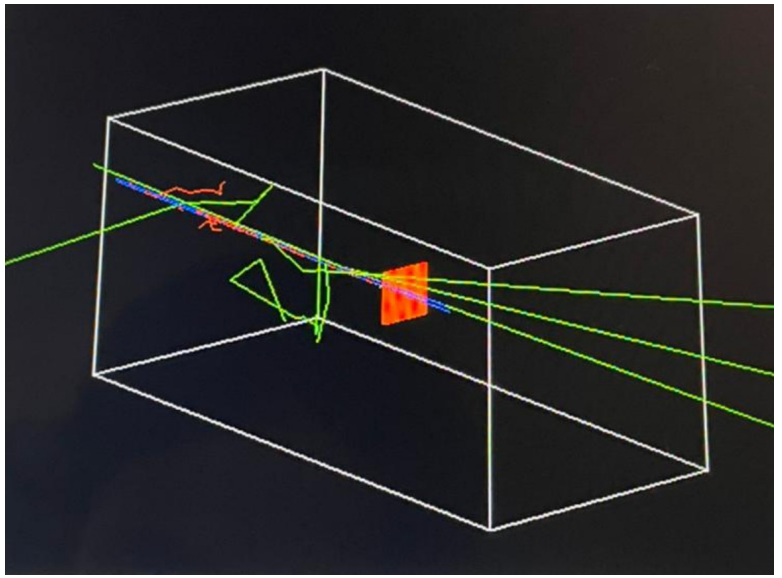



## Research Aims:

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

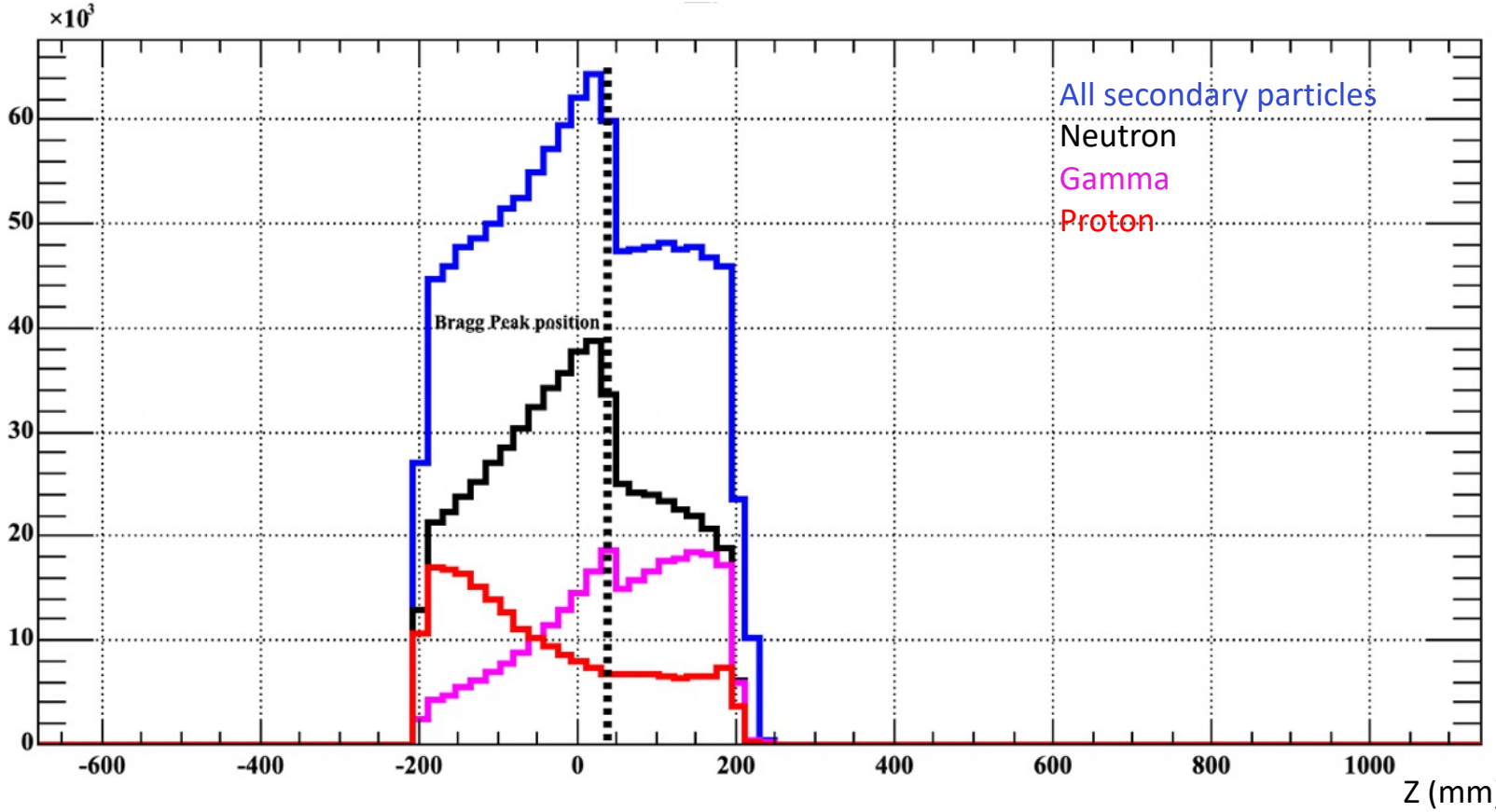
**2- Secondary particle radiation → monitor the characteristics of the primary ion beam → measuring change particles coming out of the interactions between the ion beam and the molecules in the water.**

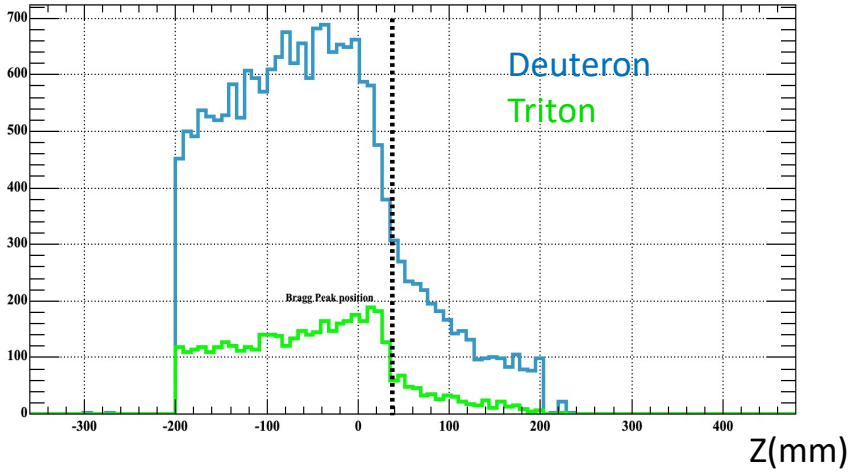
**3- Measurements → silicon pixel detectors such as a new HV-CMOS detector 'HVTrack' to compare with simulations.**



**Geant4 snapshot shows the simulation where a carbon ion beam with energy 4.48 GeV is placed at 30 cm distance away from the water phantom. Silicon detectors are located inside the water.**

# Vertex of secondary particles



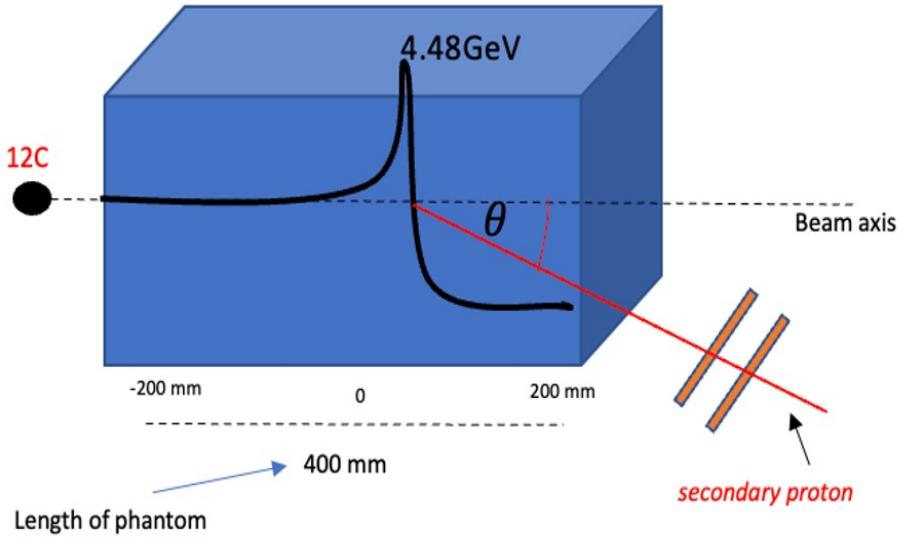



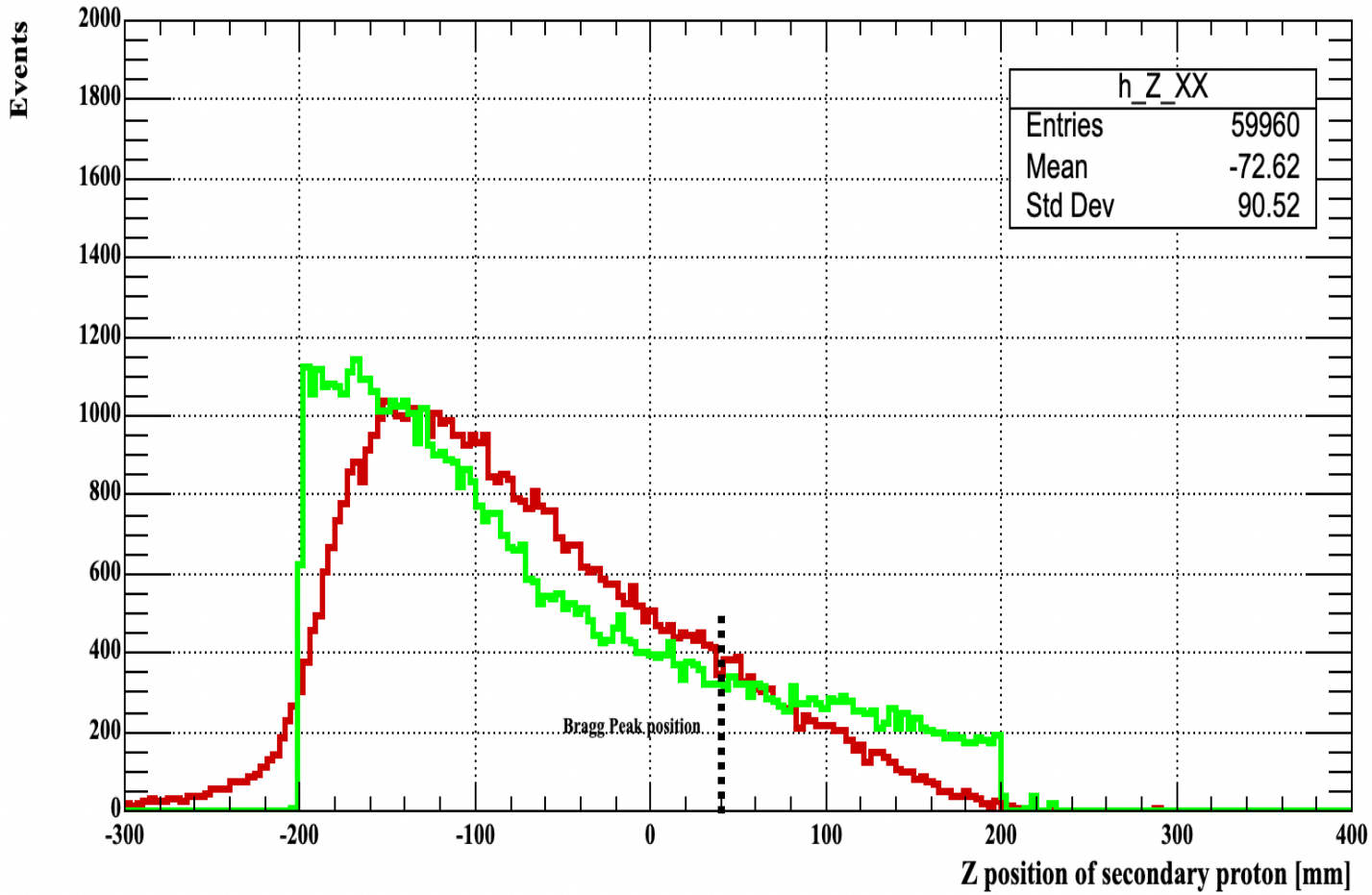

- **The truth vertices of secondary particles corresponding to the Bragg Peak of 12C of 4.48 GeV with statistics 3M.**

# Secondary proton

***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*

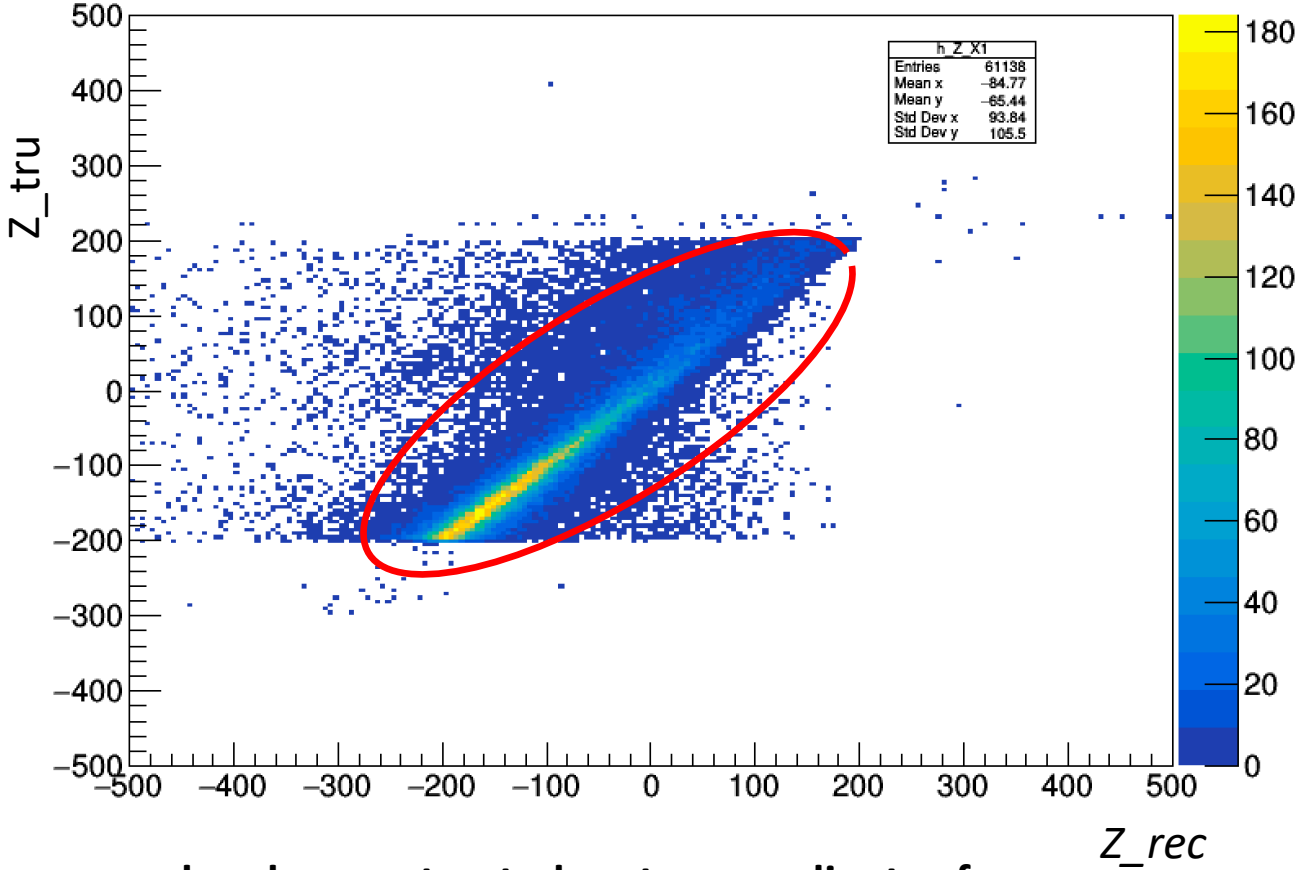



**Z position of secondary proton as calculated from the positions in Si det**

***truth Z positions of secondary proton***

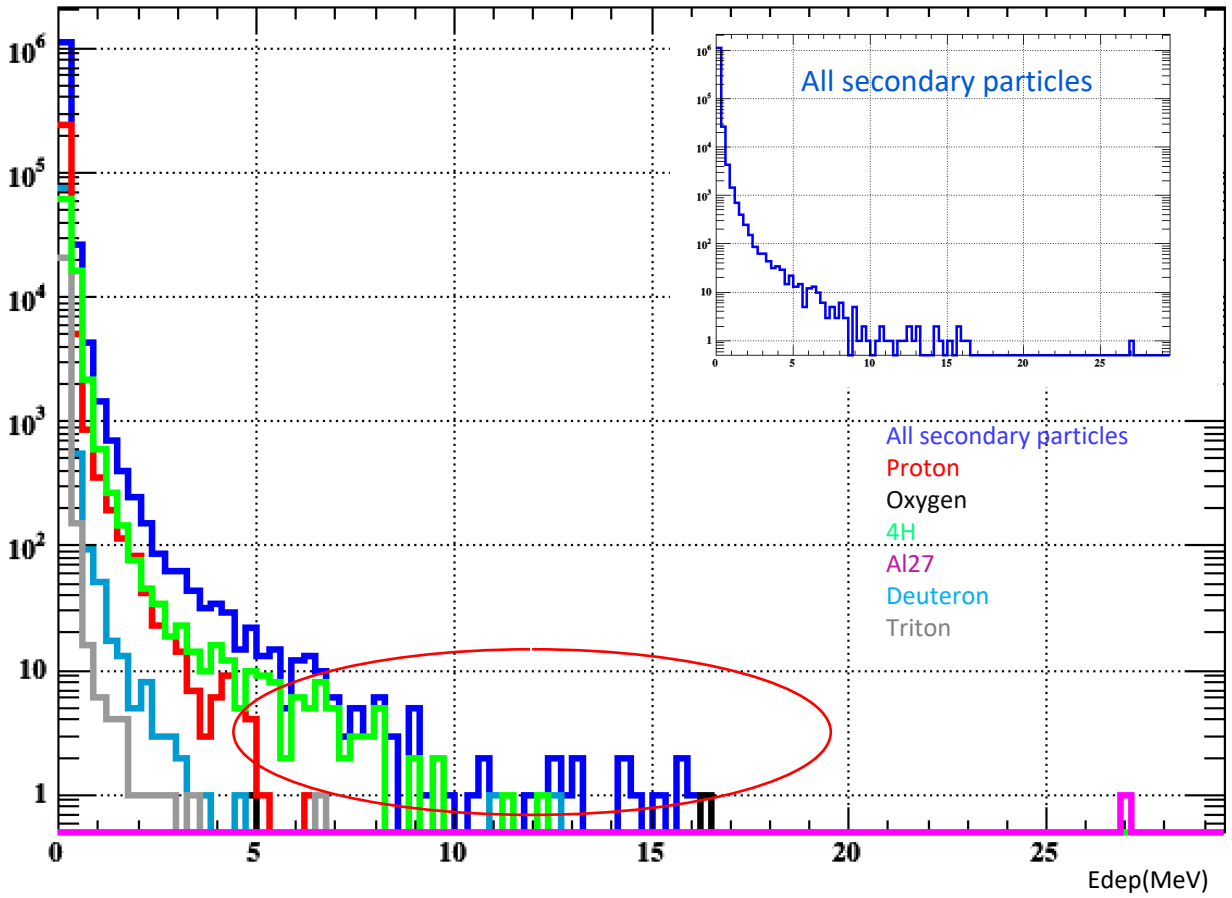
# Correlation plot between real and reconstructed vertex coordinates for secondary protons along the beam direction




- **Correlation plot between real and reconstructed vertex coordinates for secondary protons along the beam direction**
- **The correlation is linear**
- **One major factor which reduces the accuracy of the overall vertex distribution is straggling, where the trajectory of a secondary particle changes as it passes through the target before reaching the detector. This effect is more prominent for secondary particles of lower kinetic energy**
- **increasing linearly**

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

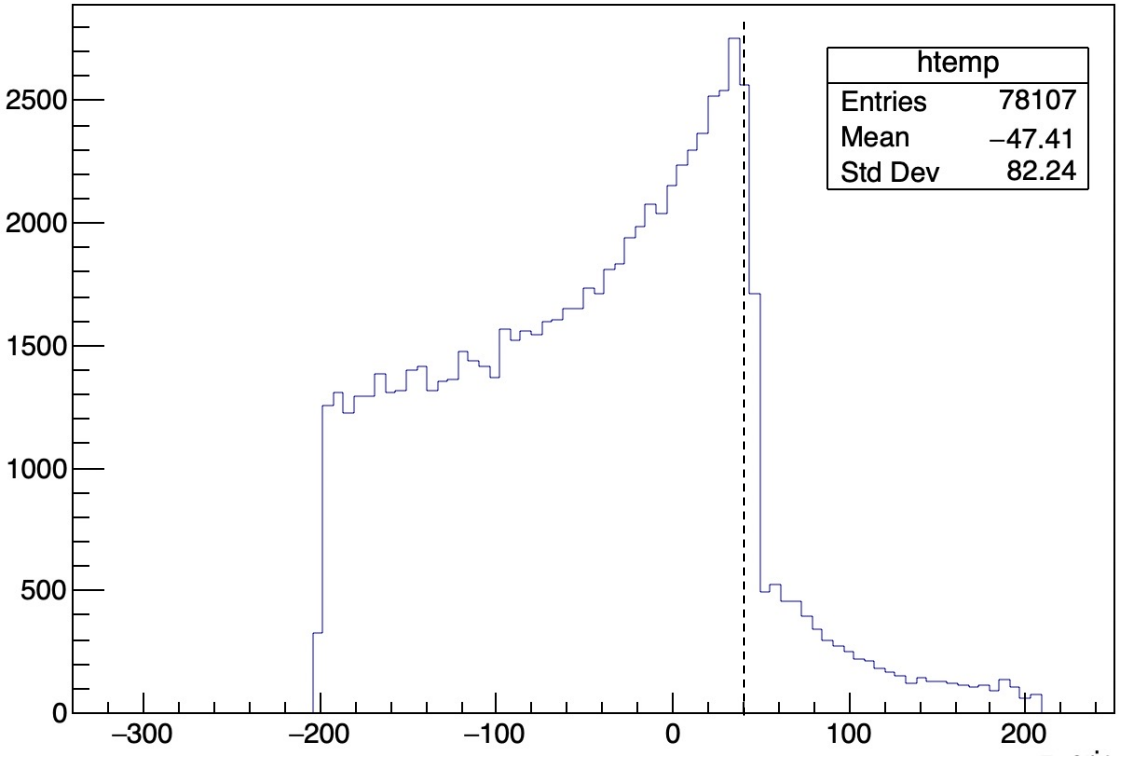
***Geant4 toolkit version 10.03.***
***Physics list: QGSP_BIC_HP.***
***Beams: Carbon ion***
***Energy: 4.48 GeV***
***Event. no: 1M***
***Medium: Water***



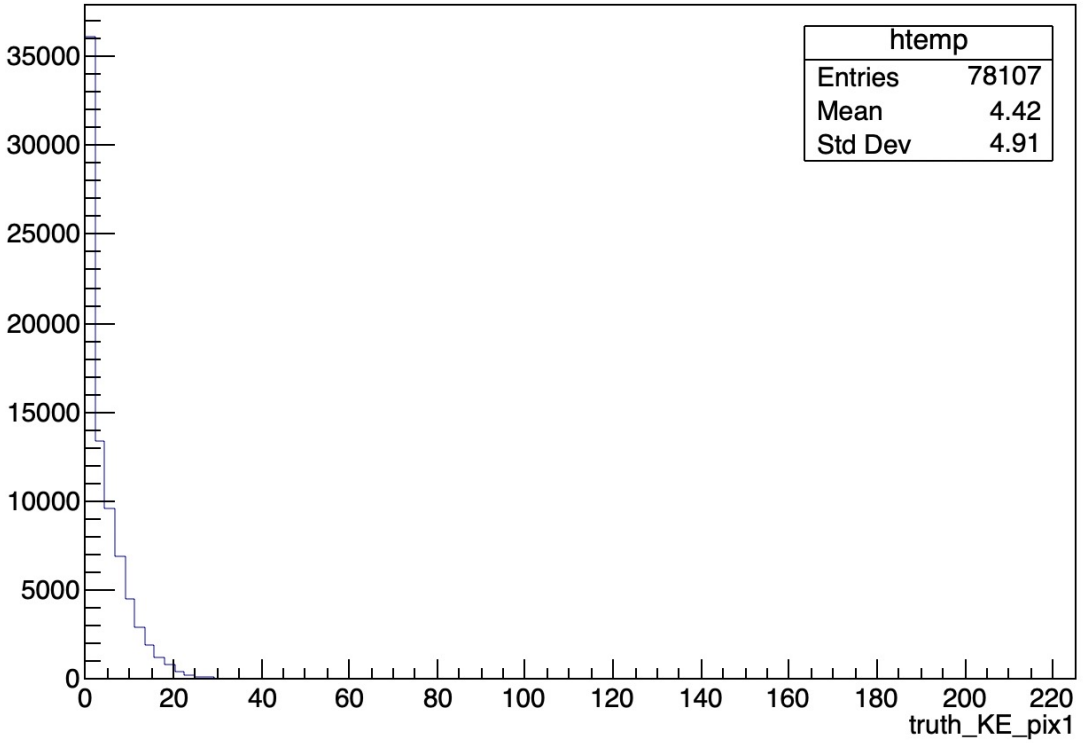

- ***Energy deposition of secondary particles*~1-27 MeV**
- **Secondary ions produced during nuclear fragmentation processes**
- **The high energies deposition are generated by secondary ions**

# Study the original positions and KE of gamma rays

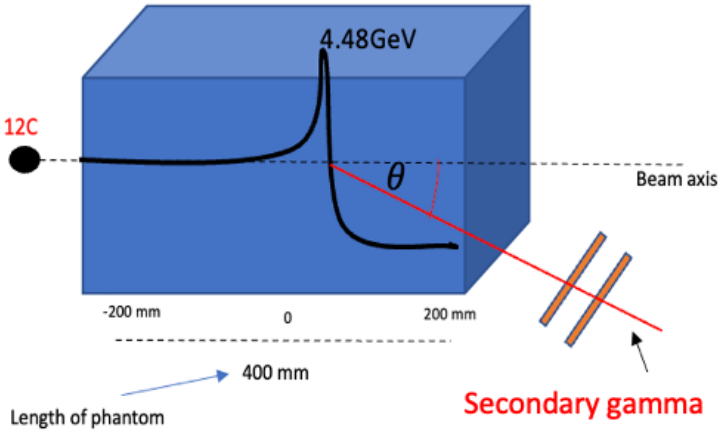
***Geant4 toolkit version 10.03.***
***Physics list: QGSP_BIC_HP.***
***Beams: 12C***
***Energy: 4.48 GeV***
***Event. no: 800k***
***Medium: Water***
***Thickness: 200 um***




**Original position of gamma rays that are produced from ion inelastic scattring (mm)**




**Mean KE of gamma rays that is produced from ion inelastic scattring (MeV)**

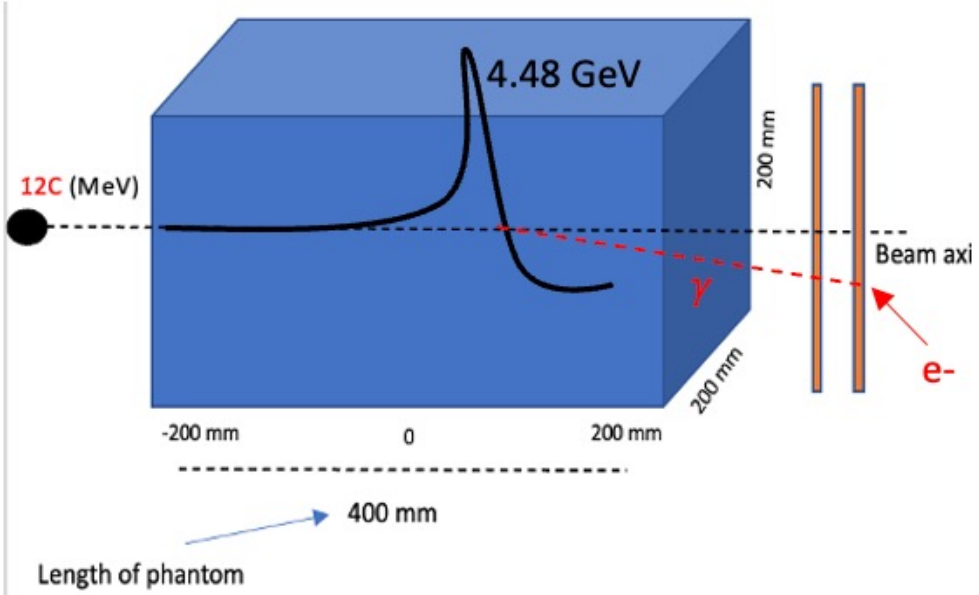



****dotted line represents bragg peak position***

***All original position of gamma rays that are produced from ion inelastic scattring are correlated to the beam range.**

# Compton camera

**A Compton camera is a promising γ-ray detector that operates in the wide energy range of a few tens of keV to MeV. The γ-ray detection method of a Compton camera is based on Compton scattering kinematics.**



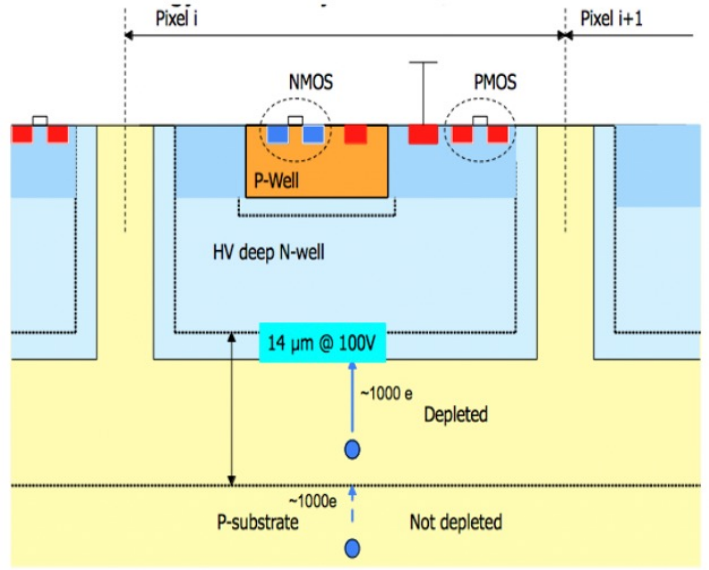

$$cos(\theta) = 1 - m_e c^2 \left( \frac{1}{E_F} - \frac{1}{E_0} \right) \qquad E_0 = E_F + E_e$$

- **We are aiming to simulate and measure gamma ray and subsequent scattered electron to track gamma or to identify where gamma was generated.**
- **we are looking into kinematic cuts that will allow us to predict the origins of the gamma ray hitting the first detector , by looking at the energy and position of the Compton scattered electron in the second detector.**
- **We will use a large area strip detector to measure scatter gamma ray in first detector and scattered electron in second detector.**
- **Measuring the scattered electron in the second detector is because the efficiency of measuring a double Compton scatter in 300um silicon is low and also because the Compton camera formula requires an energy measurement and the silicon will only give an energy loss measurement.**

# Semiconductor Tracking Detectors

## HV-CMOS detector

- Readout and digitization electronics can be integrated on the same chip with the pixel array
- Very small pixel sizes are possible → high granularity
- Low mass detector giving less scattering
- Good speed and good radiation tolerance (HV-CMOS)




CMOS electronics placed inside the diode (inside the n-well)

V-CMOS

## Large area strip detector

- Large area strip detector (10x10cm) developed for the Dark Matter Particle Explorer (DAMPE)experiment
- 300um thick sensors with a strip pitch of 242um readout with VIKING Asic.

~10x10cm DAMPE sensor with VIKING ASIC

# Next Steps and Outook

- **Doing measurements with silicon pixel detectors such as a new HV-CMOS detector ‘HVTrack’.**
- **10x10cm thick silicon strip detector with 300um thick will be used as Compton Camera.**
- **Working on calculating the reconstruction of secondary gamma rays from Si (Compton Camera).**

# Thank you!

*Any questions?*