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Single Plane Position Tracking Proton and Helium Radiography: Feasibility Study

Lukas Martin, Alexander Pryanichnikov, Jennifer Hardt, Ethan A. DeJongh,
Don F. DeJongh, Victor Rykalin, Stephan Brons, Oliver Jäkel, Niklas Wahl, Joao Seco

Contact: lukas.martin@dkfz-heidelberg.de

GERMAN CANCER RESEARCH CENTER IN THE HELMHOLTZ ASSOCIATION

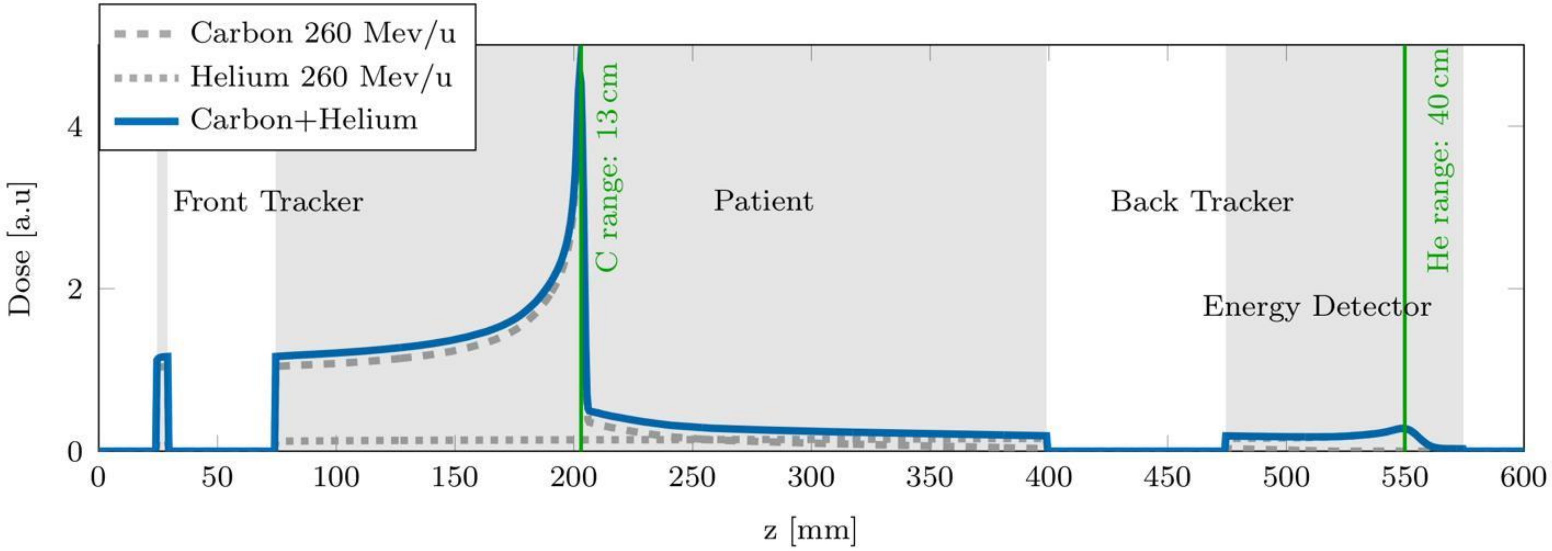
Research for a Life without Cancer

Agenda

1. Introduction
2. Materials & Methods
   - Operation with using only single position tracking plane
3. Results
   - Computational study of Head phantom at Chicago Northwestern Medicine
   - Calibration and Data acquisition at HIT facility
   - Spatial resolution measurement
   - WET value measurement of Gammex phantom
4. Conclusion
5. Future Work and Outlook

Introduction

- **HELIOS** (**HEL**ium **I**maging **O**ncology **S**canner)
- use $^{12}C^{6+}$ for treatment and $^{4}He^{2+}$ for imaging
- Simultanous acceleration due to similar charge/mass ratio

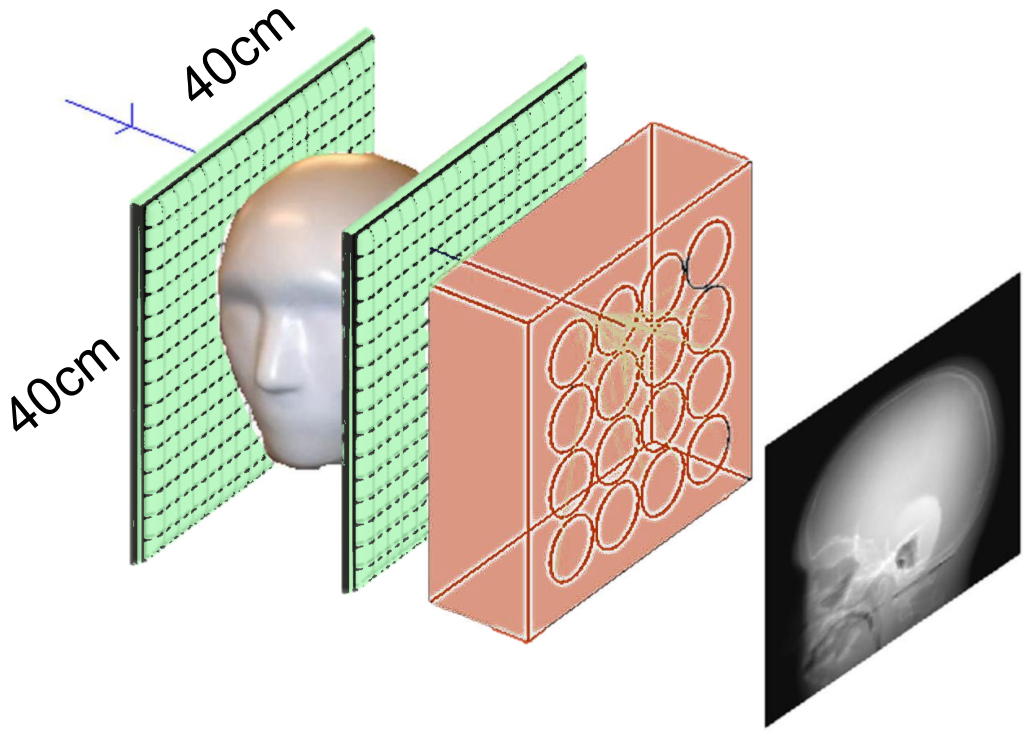


General Purpose of the Project:

1. Enhance particle therapy for lung and abdominal cancers
2. Develop helium radiography using existing proton imaging technologies
3. Improve treatment accuracy and patient outcomes

Materials and Methods

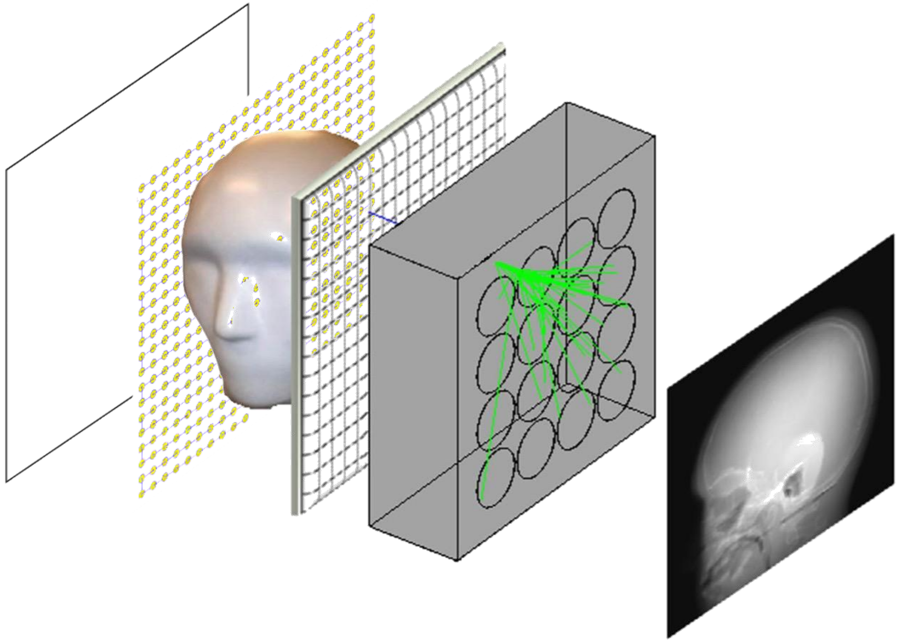
- Standard configuration uses upstream/ downstream tracker with scintillating fibers of 1 mm width
- physical hit resolution of 0.5 mm, spatial resolution of 1 mm
- Residual range detector with PMTs, signal is weighted
- At therapy-level intensity, the front tracker saturates due to the high-intensity carbon beam, making it unusable



→ Removing the front tracker prevents damage but raises concerns about the impact on image quality

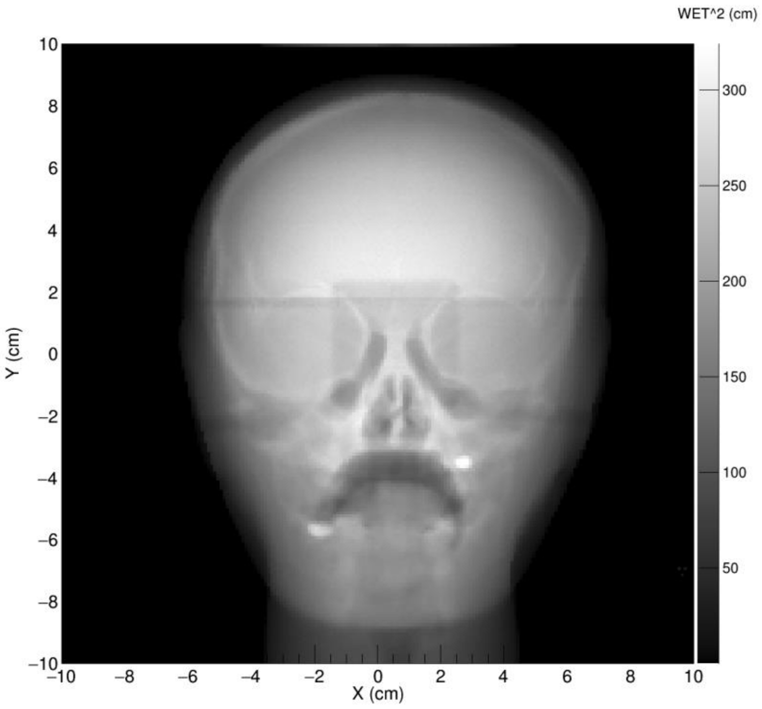
- With only back tracker, the software interpolates expected particle entry point from irradiation plan and source of pencil beam

- This can lead to inaccuracies when particles scatter within the object

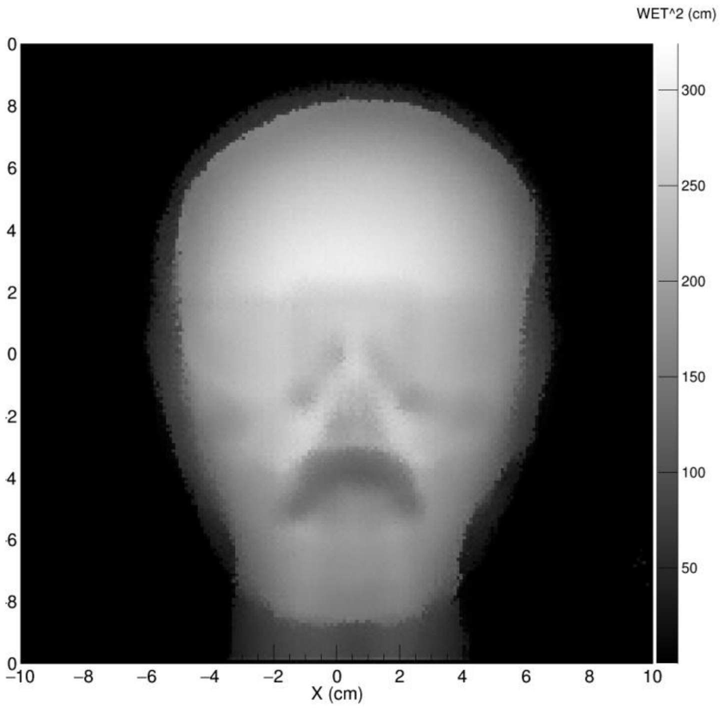


Results

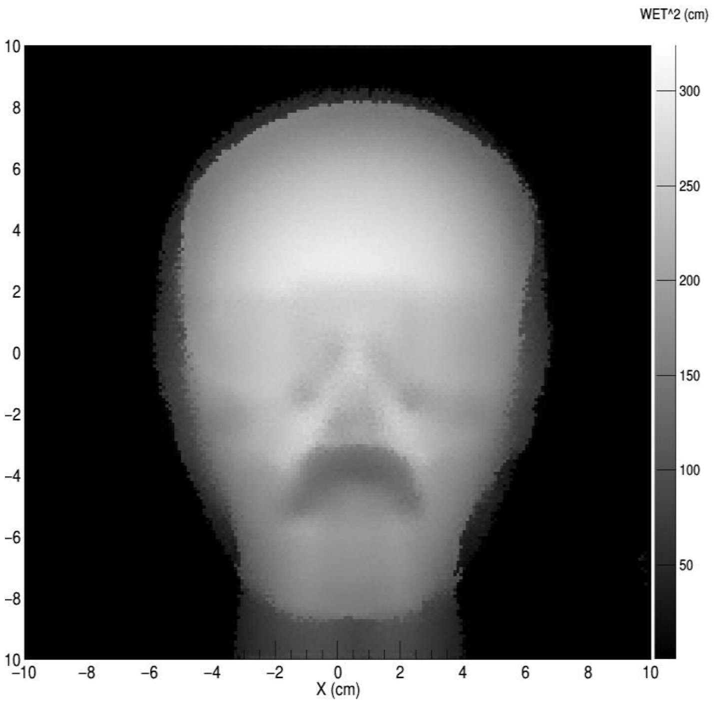
1. **Computational study of Head phantom at Chicago Northwestern Medicine**



2 Tracker

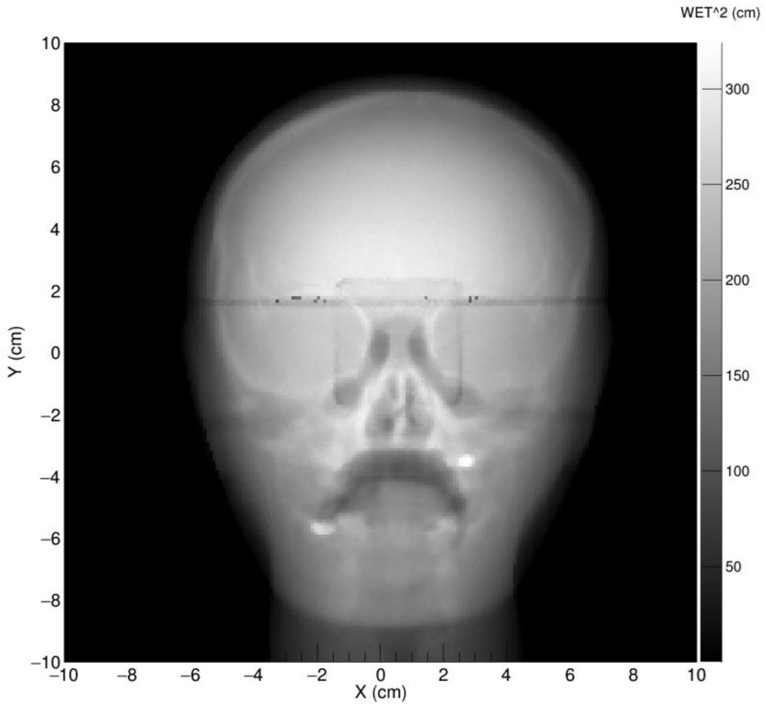


1 Tracker

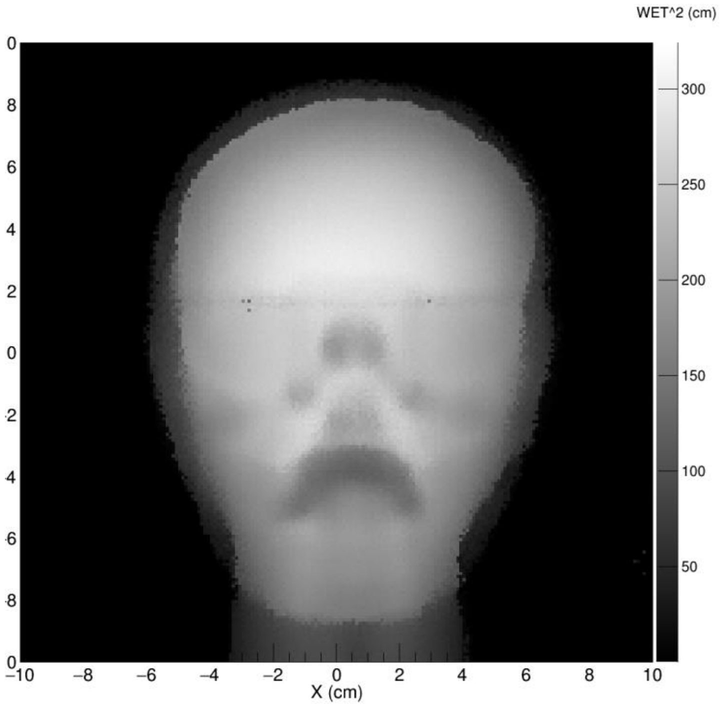


0 Tracker

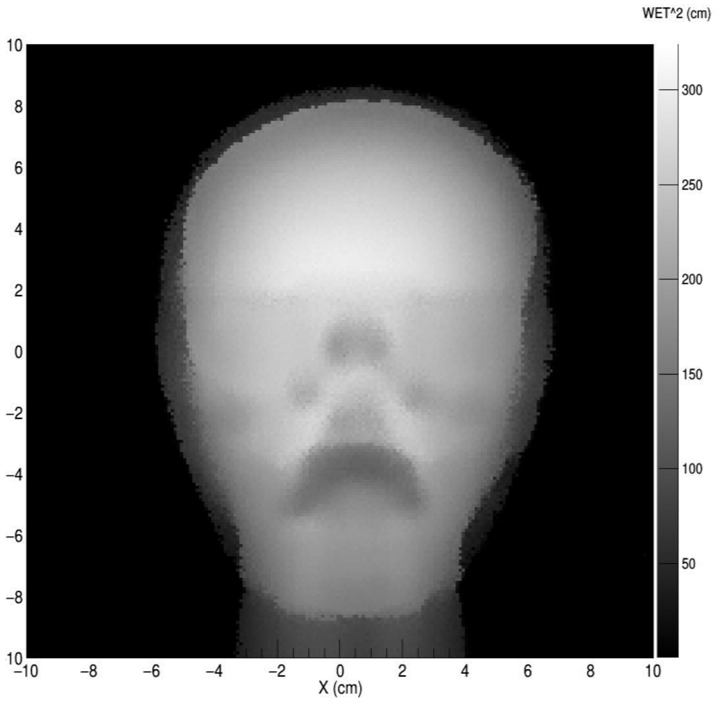
dkfz.



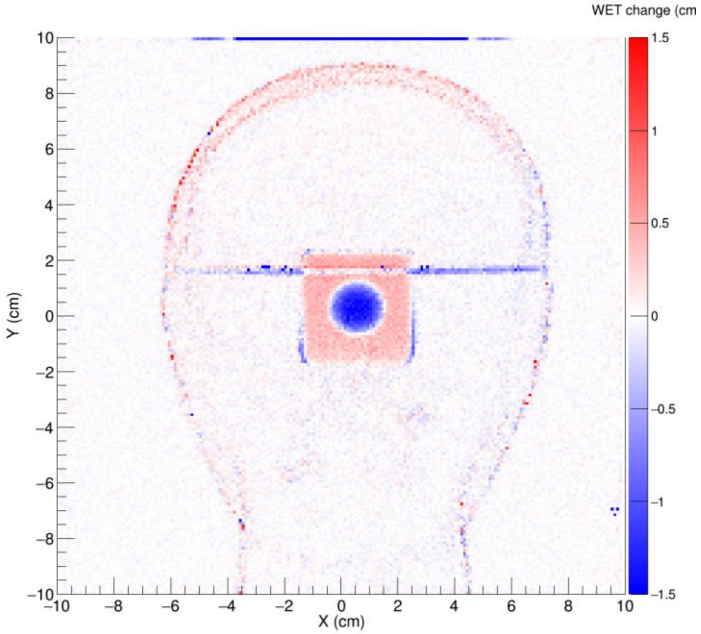
2 Tracker



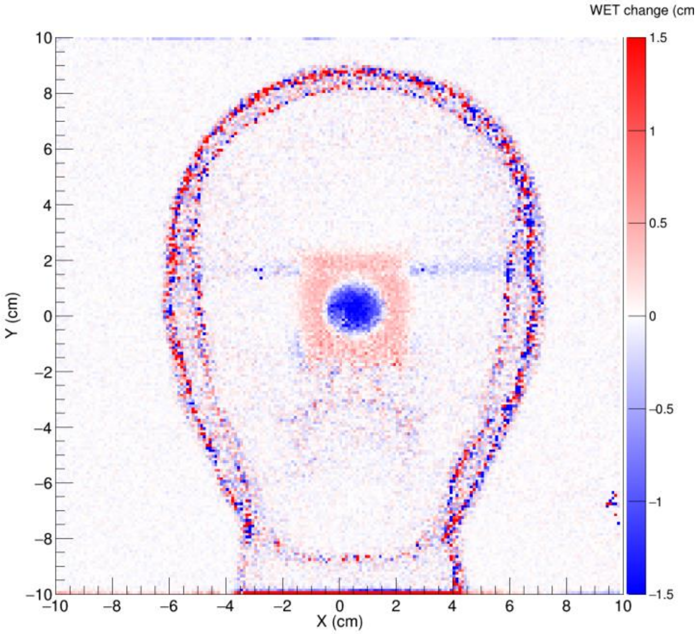
1 Tracker



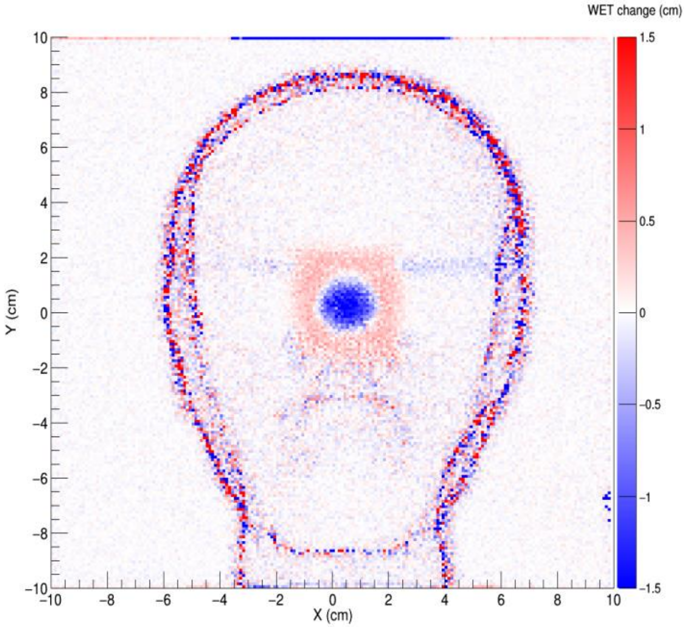
0 Tracker



2 Tracker



1 Tracker

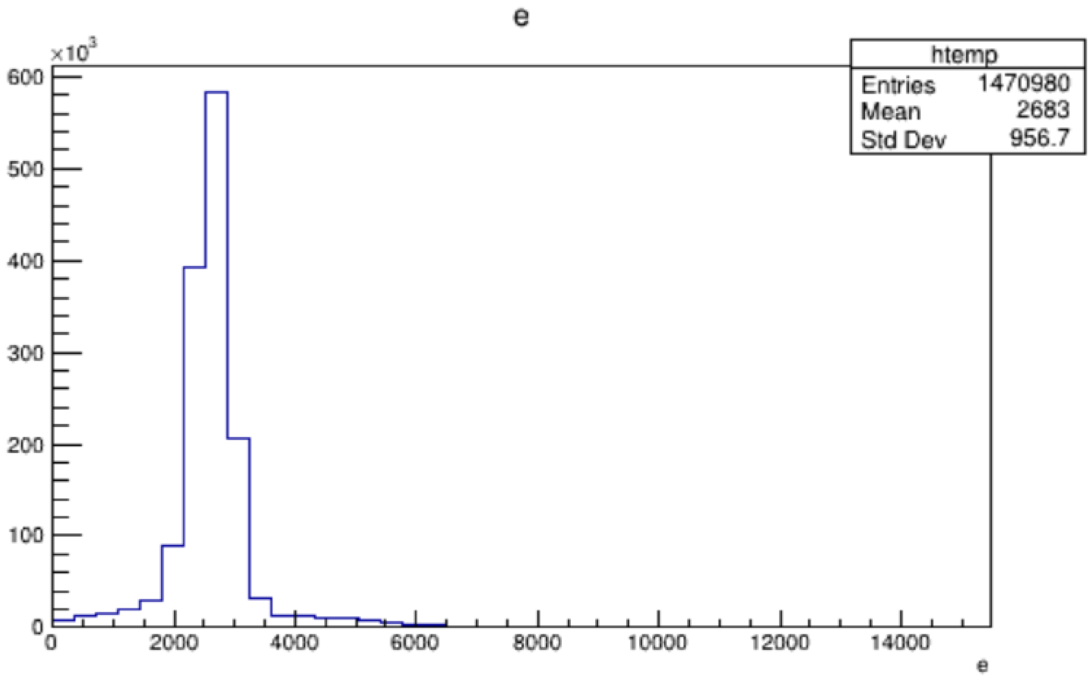


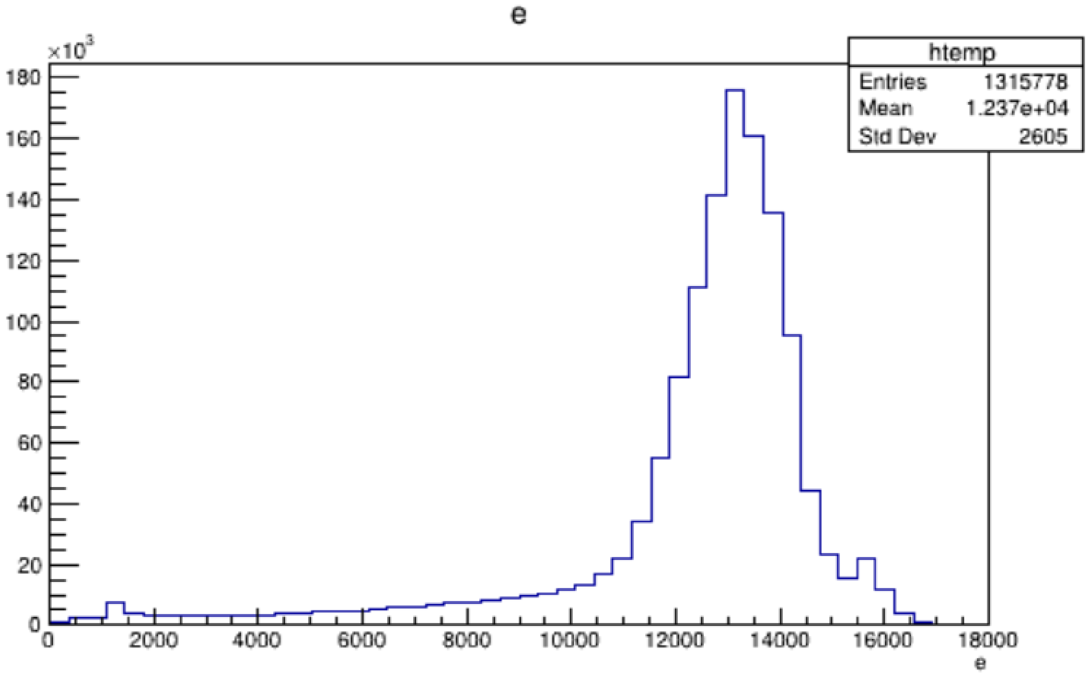
0 Tracker

2. Calibration & Dataset Acquisition

- Performed calibrations for protons and helium across 22 different energies ~ 95 – 125 MeV/u to see how photons inside energy detector are distributed

<u>Setup 1</u>: Helium calibration with PMMA Block

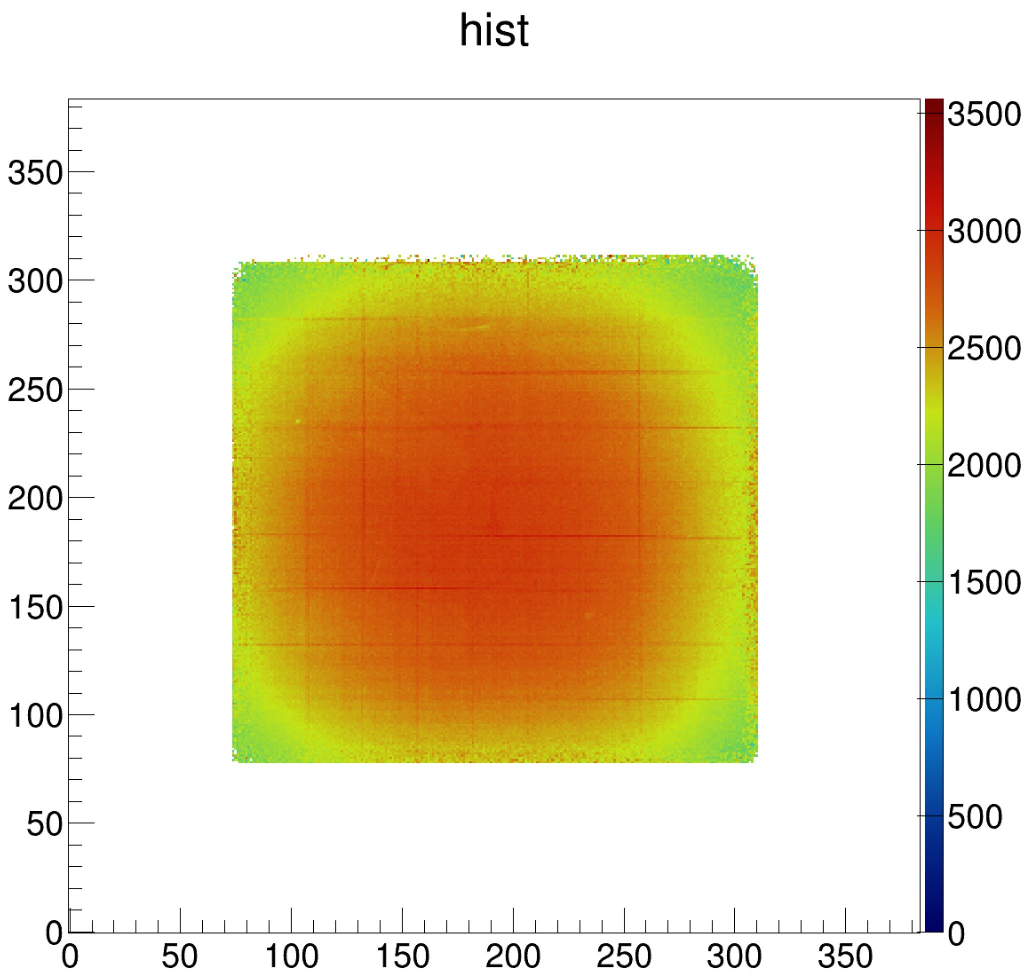




<u>Setup 2</u>: Proton calibration without PMMA block

- Ideally would like to use setup without PMMA because it will generate even more fragments when particles traverse it

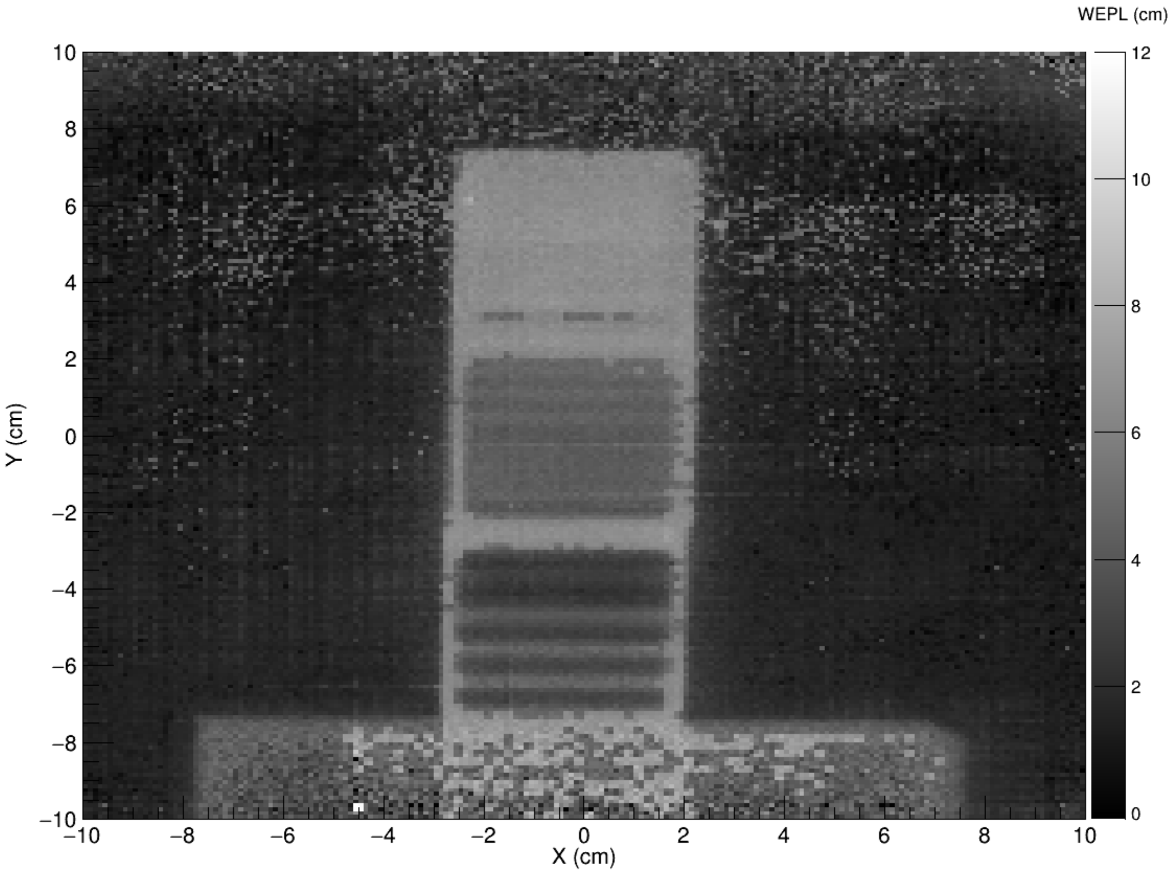
- For protons its not necessary to put PMMA block in front



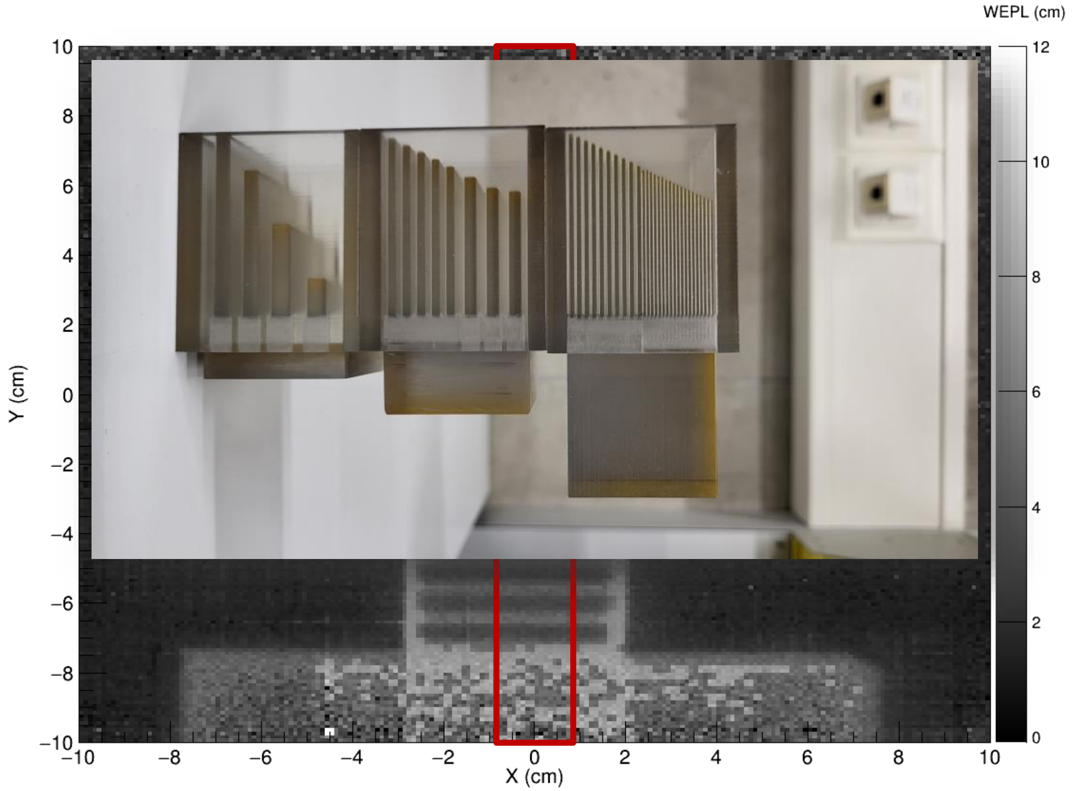
Helium calibration histogram with PMMA block

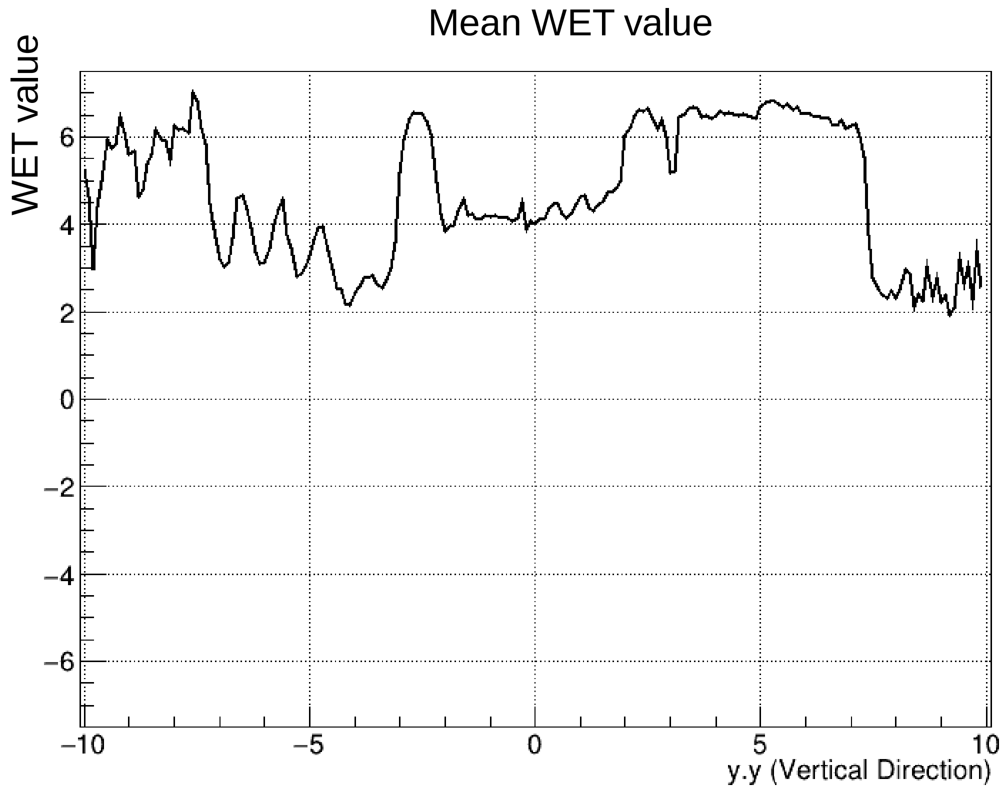
3. Spatial Resolution measurements for Helium

- 3D printed cubes (VeroClear-RGD810)
- $\rho = 1.18 - 1.19\ \mathrm{g/cm^3}$
- Different spacing and depth of lines from 5 mm to 0.5 mm



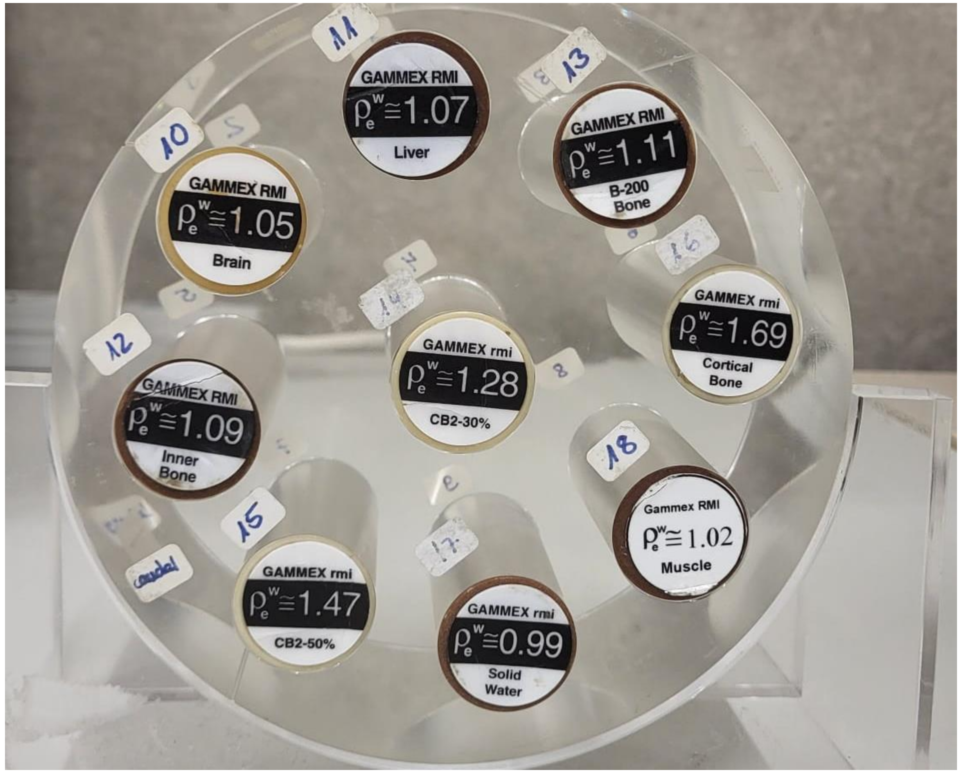
- Reconstructed multi-energy helium Radiograph (HeRad) within root framework (100 MeV/u, 125 MeV/u, 145 MeV/u)
- Determination of WEPL value from MLP binning

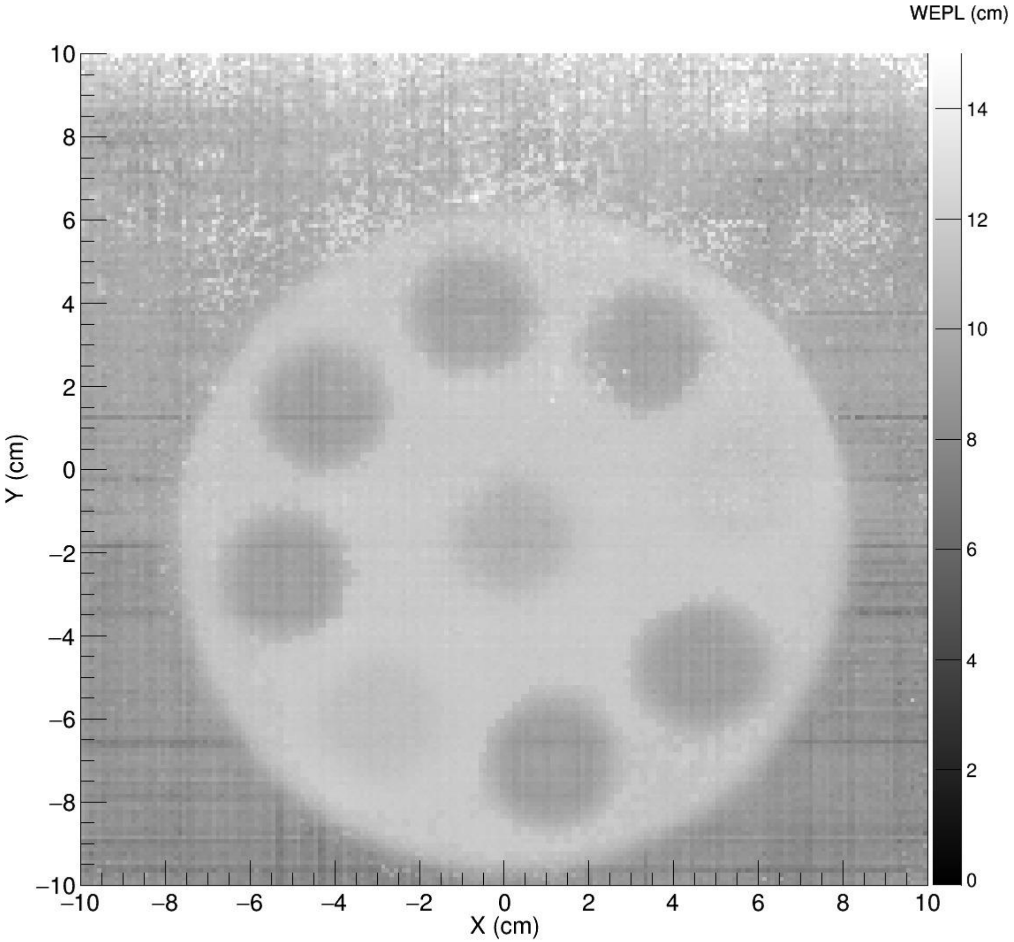




- WET values evaluated over the y-range of x = 0 ± 10 mm
- Mean WET computed from 21 measurements at each y-coordinate
- Resolution assessed at cube line spacings of 5 mm, 4 mm, 3 mm, 2 mm, 1 mm and 0.5 mm

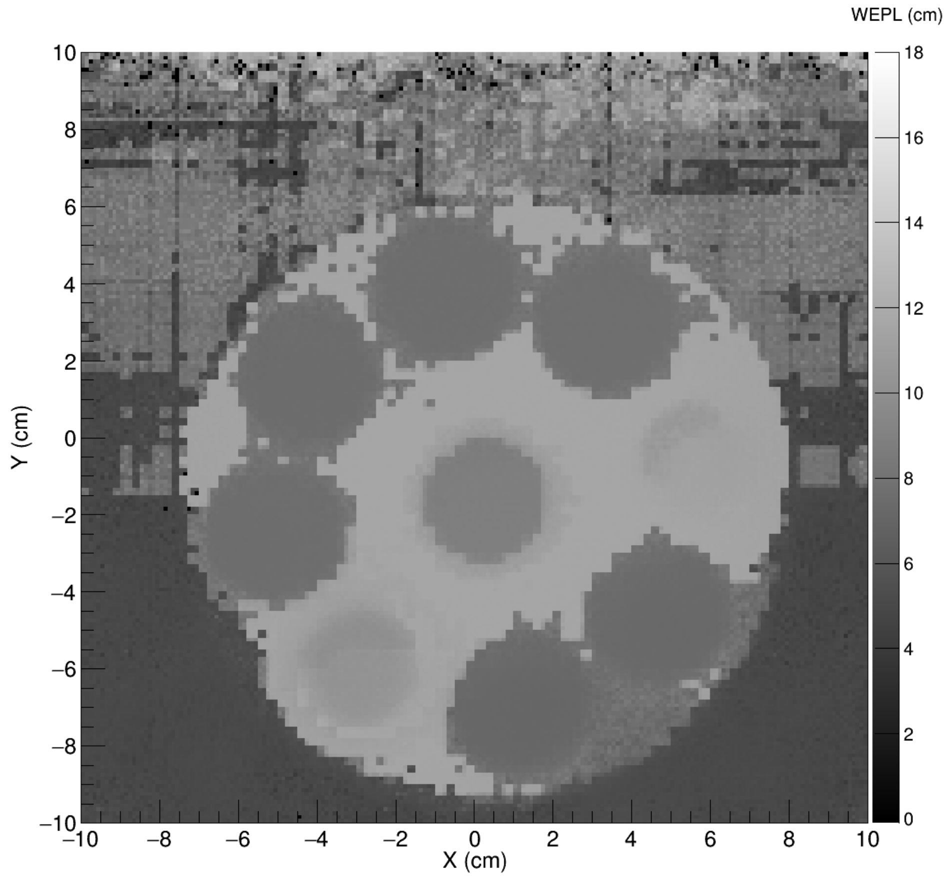
4. Measurement on WET accuracy





Gammex phantom with tissue-equivalent inserts

Multi-energy HeRad (125 MeV/u, 140 MeV/u, 160 MeV/u)



Multi energy HeRad (125 MeV/u, 140 MeV/u, 160 MeV/u)

Material	Ground truth [cm]	WET measured [cm]
PMMA cylinder	11.6	(11.58±0.02)
CB2-30%	8.96	(8.80±0.02)
Liver	7.49	(7.60±0.02)
Brain	7.35	(7.51±0.02)
Inner Bone	7.63	(7.60±0.02)
CB2-50%	10.29	(10.25±0.05)
Solid Water	6.93	(7.11±0.03)
Muscle	7.14	(7.29±0.02)
Cortical Bone	11.83	(11.26±0.03)
B-200 Bone	7.77	(7.70±0.02)

Conclusion

- Computational study of Northwestern Medicine shows clear change in WET values despite the fact of not using data for 2 tracking planes
- Achieved spatial resolution of currently 3 mm
- Achieved WET value accuracy for gammex phantom in the order of mostly 1 – 2 %
- Next iterations and implementation of better statistical cuts will improve current results

Outlook

1

Detector alignment and calibration

- Alignment of the detector for proton and helium pencil beam scanning and calibration for different ion energies

2

Measurement with 2 tracking planes for protons and helium

- pRad, HeRad
- pRad in time
- Proton/helium CT

3

Operation with single tracking plane

- Resolution and WET measurements
- Abdominal phantom measurements

4

Enhancement of image quality

- Implement better statistical cuts
- Increase number of measurements

Thank you for your attention!

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