MUSE and becoming a physicist

Advisor: Steffen Strauch

Anne Flannery

UNIVERSITY OF
South Carolina

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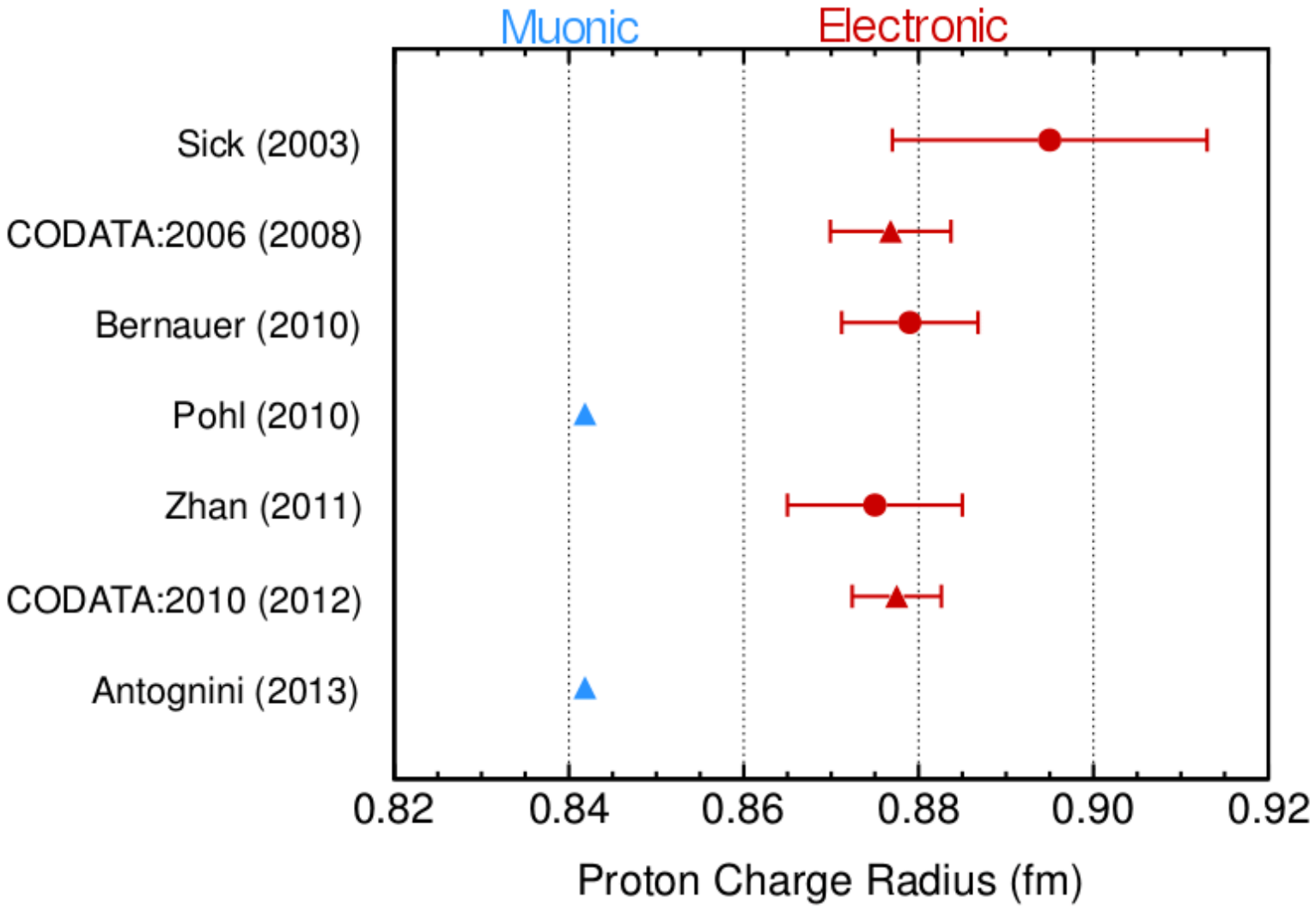
Outline

- What is MUSE?
  - Proton Radius puzzle introduction
  - Goal of MUSE
  - MUSE setup, and SPS bars
- Calibration of the MUSE SPS
  - Types of light-matter interaction
  - Compton scattering
  - QDC histogram and the Compton edge
  - Decay scheme for Na-22
  - Na-22 Calibration and results
- Concluding statements

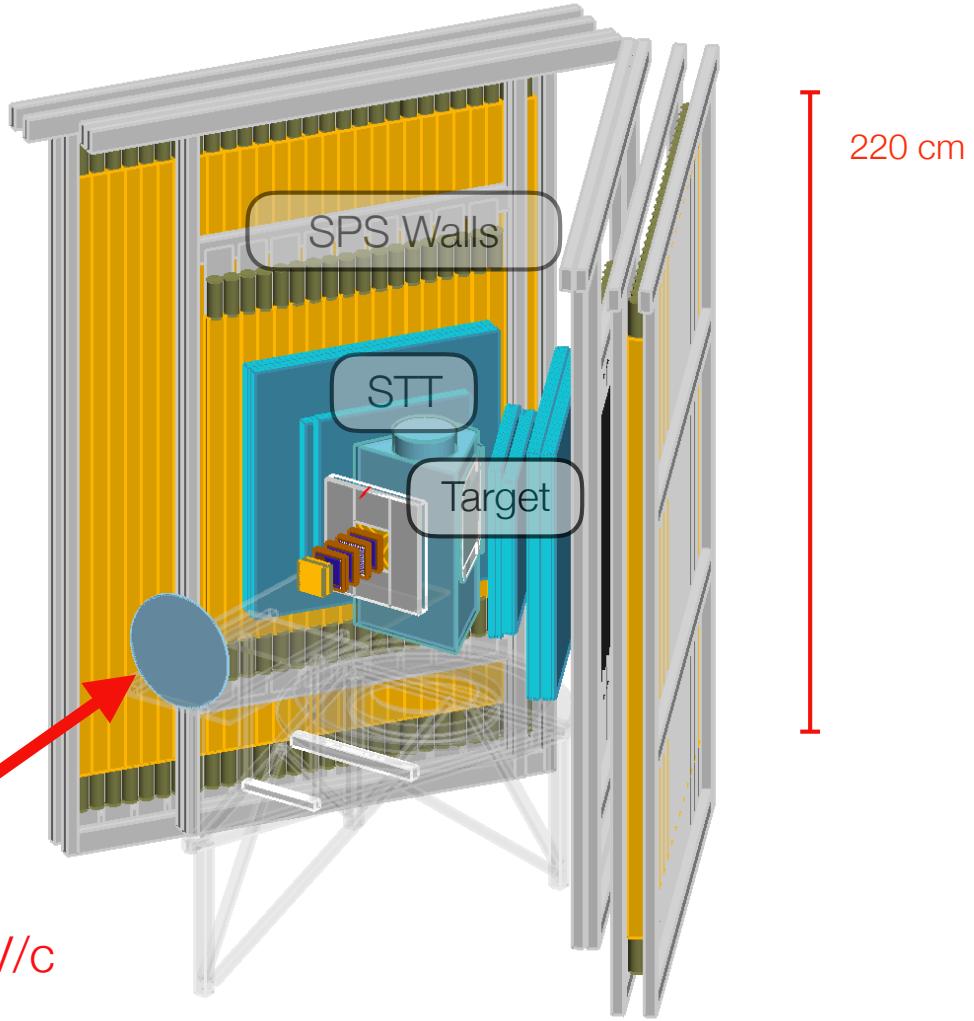
What is the radius of the proton?



Mesick, Katherine. (2015). The MUSE Experiment: Studying the Proton Radius Puzzle with muon-proton Elastic Scattering. 091. 10.22323/1.226.0091.

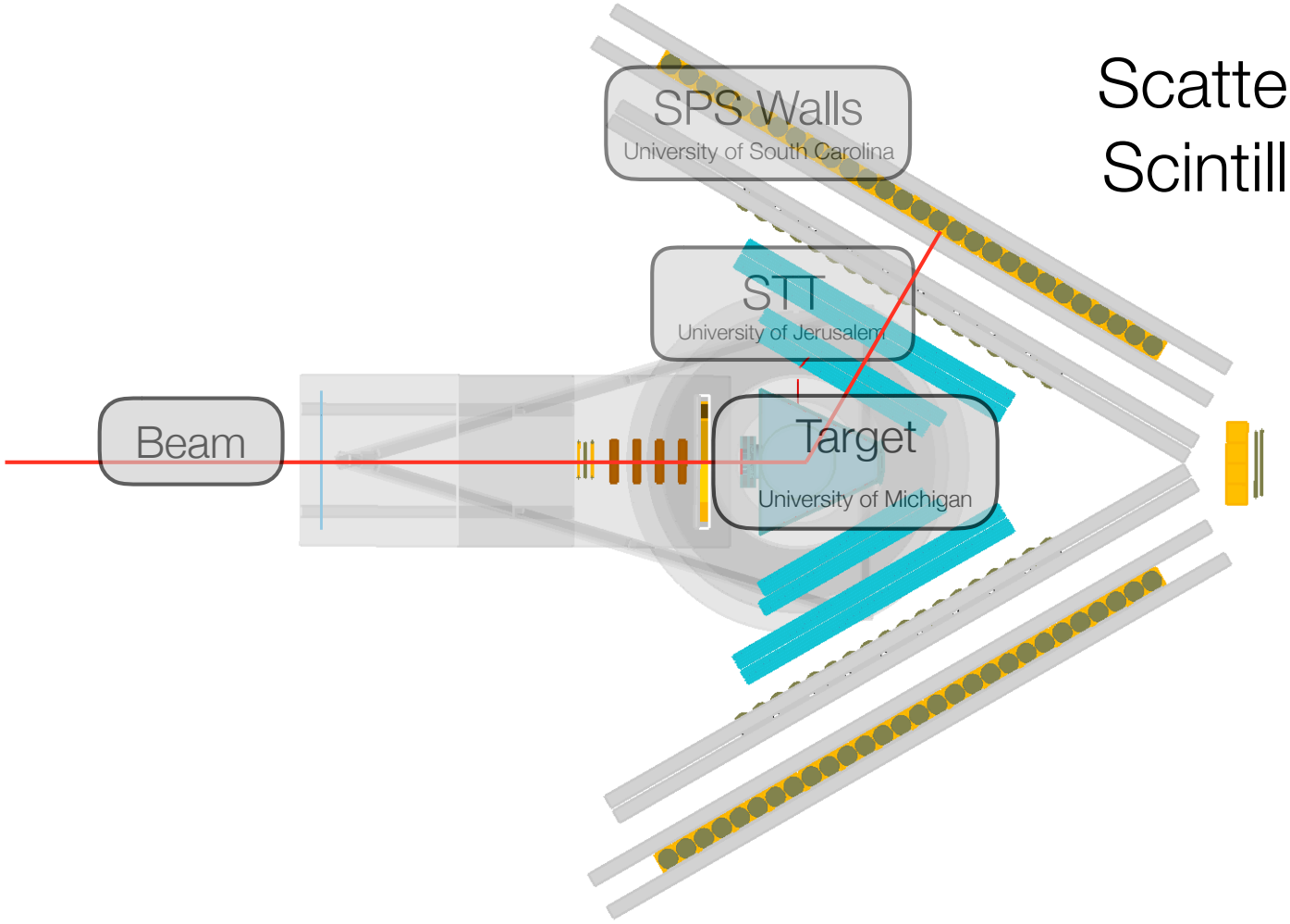
MUon Proton Scattering experiment

- an experiment which attempts to address the proton radius puzzle through muon-proton and electron-proton scattering measurements in the same experiment



Muse Setup

Path of the scattered particle



Scattered-Particle Scintillators (SPS)

The SPS bars are fast timing detectors for the experiment

What happens when a charged particle passes through a scintillator?

- A charged particle passing through the bar deposits a certain amount of energy (minimum 2MeV/gcm^2 for scattered particles), causing photon emission. A photodectector receives a signal whose strength is determined by the amount of energy deposited.

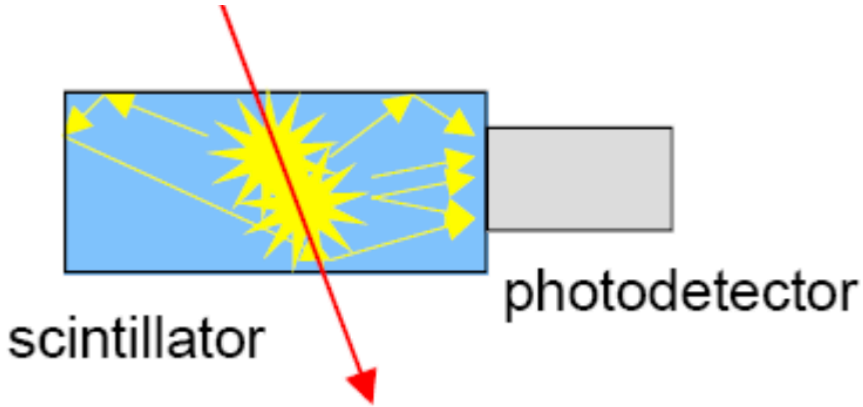
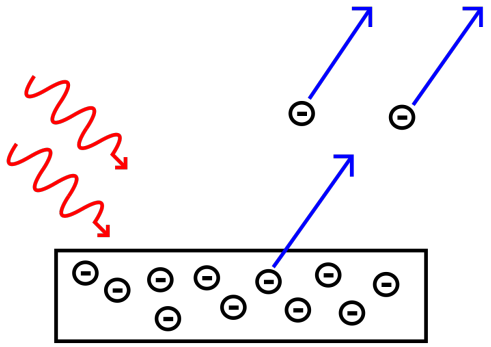


Diagram of a simple scintillator

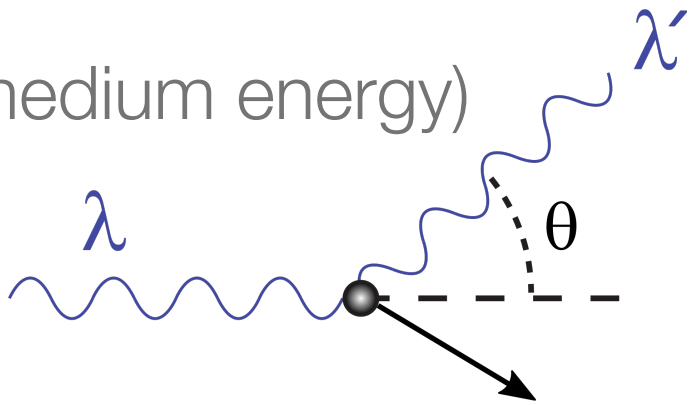
http://crd.yerphi.am/files/Detectors_WS2014-15_A2.pdf

Three kinds of light-matter interaction

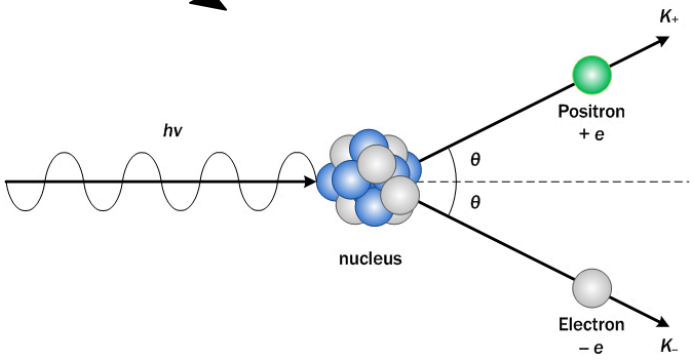
- Photoelectric effect (lowest energy)



- Compton scattering (medium energy)



- Pair-production (highest energy)



http://electrons.wikidot.com/pair-production-and-annihilation

Compton scattering on an MQDC histogram

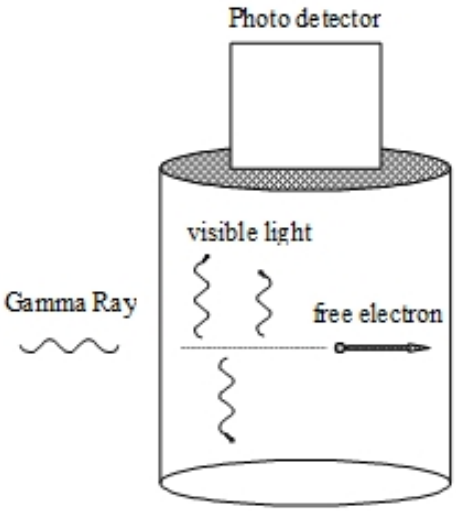


Figure 1 *The NaI crystal converts a gamma ray into visible light. The photo detector converts the visible light into a voltage pulse.*

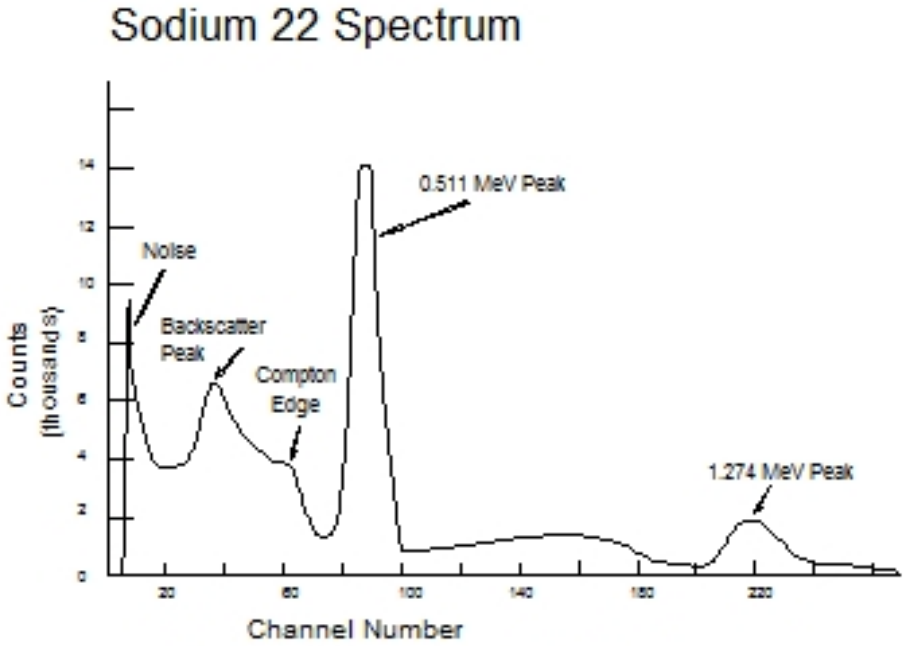


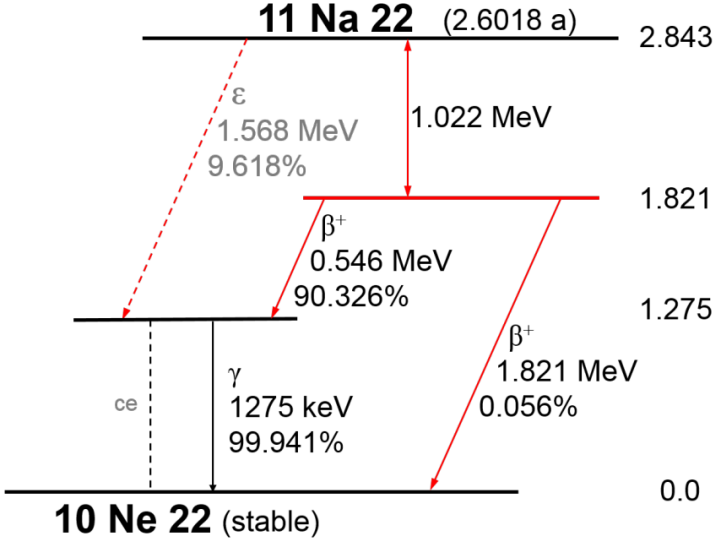
Figure 2 *Gamma ray spectrum*

- The Compton edge is the shoulder of a peak, which corresponds to the maximum energy deposition in the material

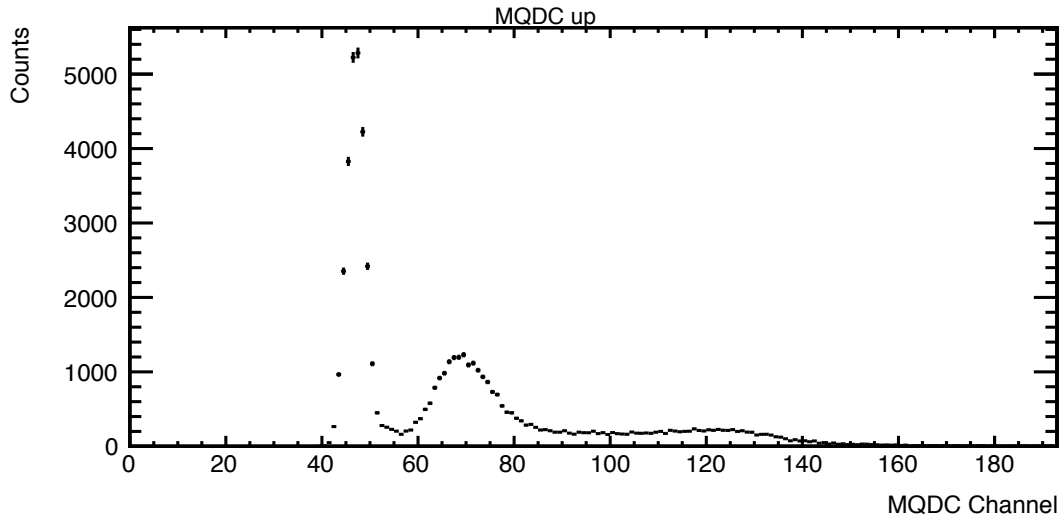
https://www.andrews.edu/phys/wiki/PhysLab/doku.php?id=272s11l12

Where does the signal go, and what does it mean?

- The PMT outputs the signal to a QDC (Charge to Digital Converter), so computer analysis can be done. A QDC histogram is made, which simply plots number of counts over an energy distribution. Understanding these distributions is a crucial part of the experiment.



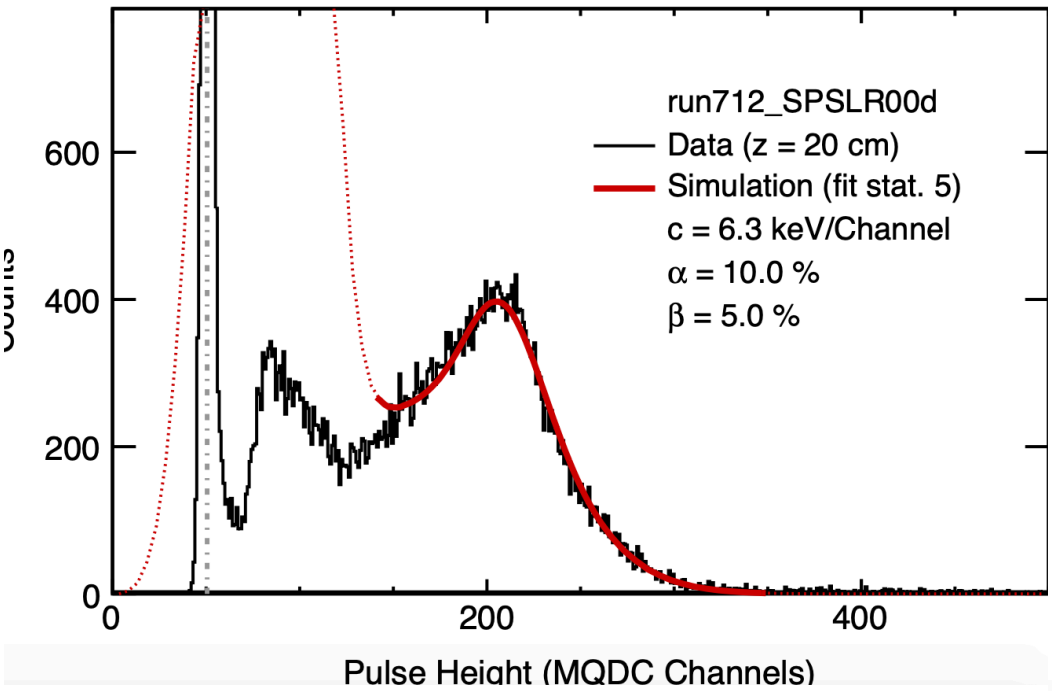
Na-22 Decay scheme



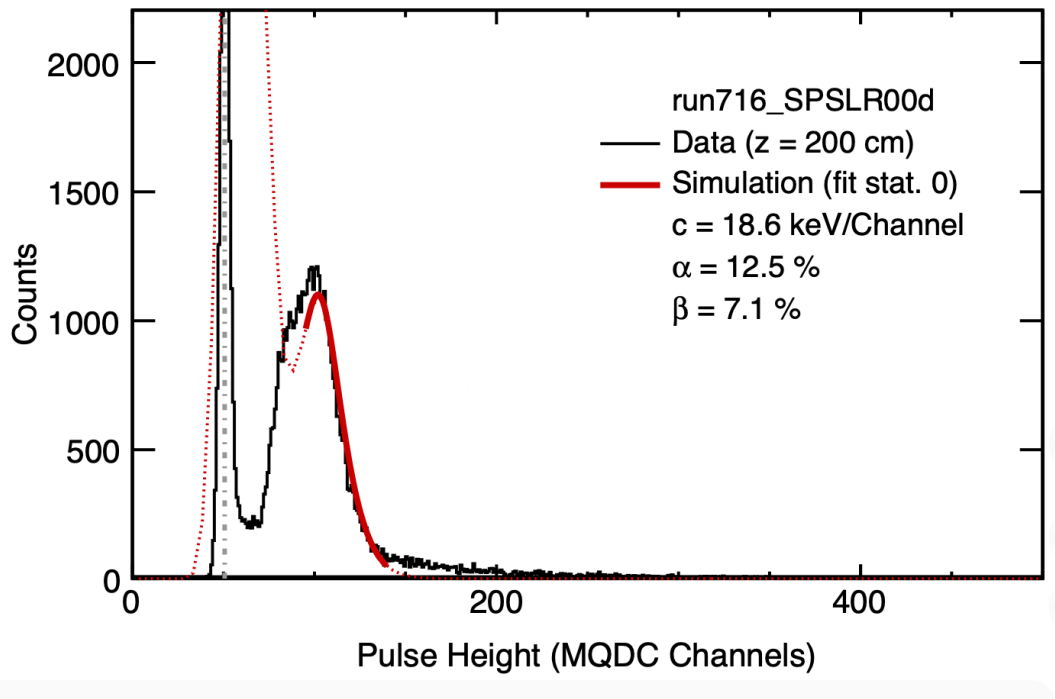
MQDC Histogram for Na-22 in one of our bars, which has a decay scheme of 1275keV and 511 keV

Na-22 Calibration for the SPS Bars

- A Na-22 source was placed at varying heights along the bar, in 20cm increments. Since the PMTs were on both the top and bottom of the bar, signal strength lowered as Na-22 source became further from either the up or the down PMT.



Closer Na-22 source



Further Na-22 Source

Concluding Statements

- Calibration of the SPS bars through Na-22 is effective yet inefficient.

- Future calibration methods will include room background source, especially focusing on the Compton edge for Thalium 208, which is ever-present for all bars.