Study of the Isovector Optical Potential from the Decay of ^{59}Mn Populated by the ^{11}B+^{48}Ca Reaction

ASHTON FALDUTO

CENTRAL MICHIGAN UNIVERSITY

Overview

Background

Motivation

Experiment

Analysis

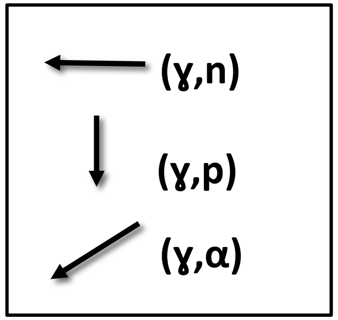
Summary

How are the Elements Created?

Explosive Nucleosynthesis:

*No longer formed through charged particle reactions

p-process
- 2-3x10^9K
- short time scale



Z

78 Sr	79 Sr	80 Sr	81 Sr	82 Sr	83 Sr	84 Sr
77 Rb	78 Rb	79 Rb	80 Rb	81 Rb	82 Rb	83 Rb
76 Kr	77 Kr	78 Kr	79 Kr	80 Kr	81 Kr	82 Kr
75 Br	76 Br	77 Br	78 Br	79 Br	80 Br	81 Br
74 Se	75 Se	76 Se	77 Se	78 Se	79 Se	80 Se
73 As	74 As	75 As	76 As	77 As	78 As	79 As
72 Ge	73 Ge	74 Ge	75 Ge	76 Ge	77 Ge	78 Ge
71 Ga	72 Ga	73 Ga	74 Ga	75 Ga	75 Ga	77 Ga
70 Zn	71 Zn	72 Zn	73 Zn	74 Zn	75 Zn	76 Zn

N

Other nucleosynthesis: Big Bang, Cosmic Ray Spallation, Stellar/ Burning

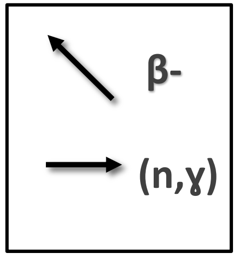
How are the Elements Created?

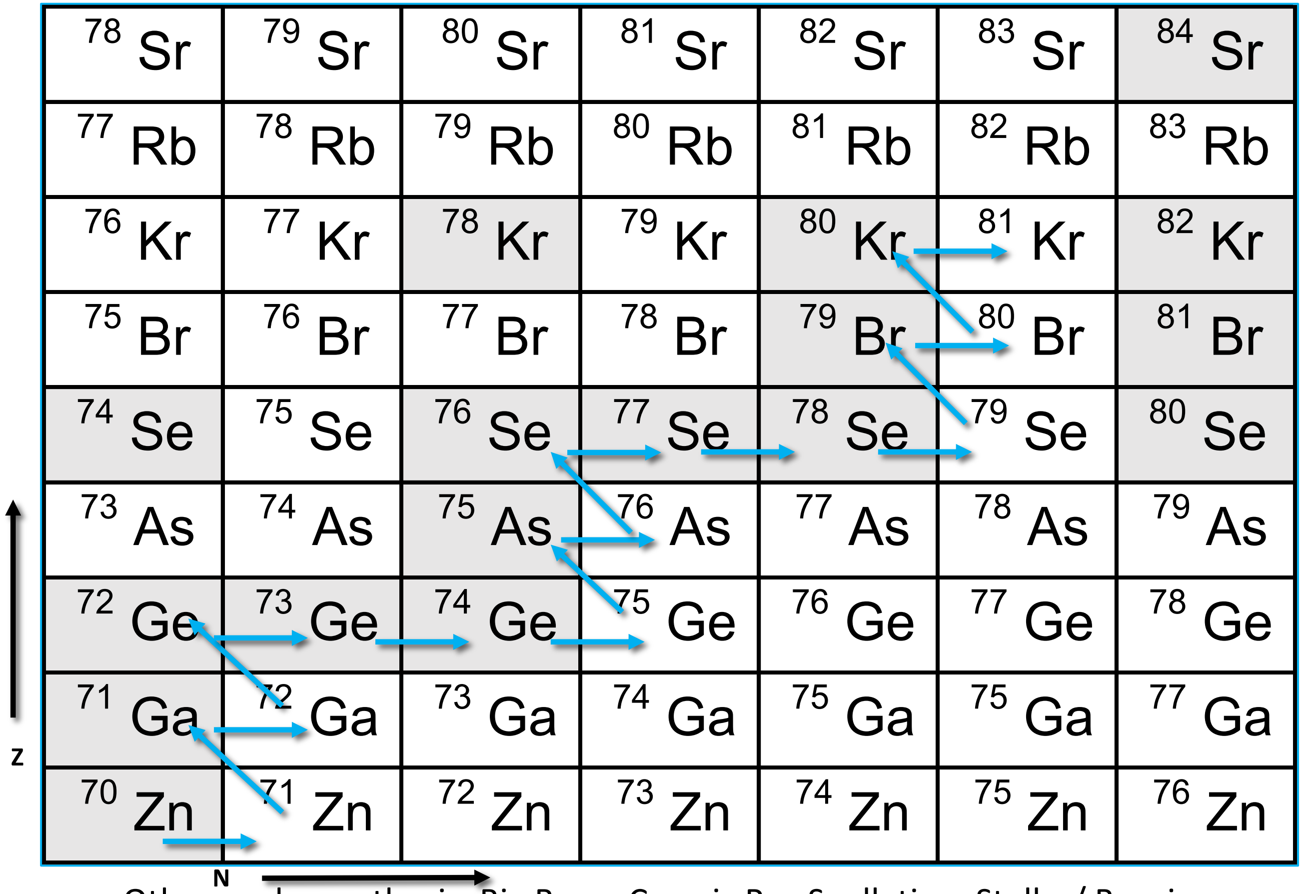
Explosive Nucleosynthesis:

*No longer formed through charged particle reactions

s-process

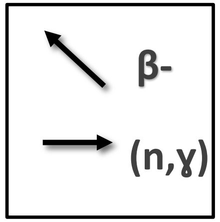
- 1-2x10^8K
- 1000's of years





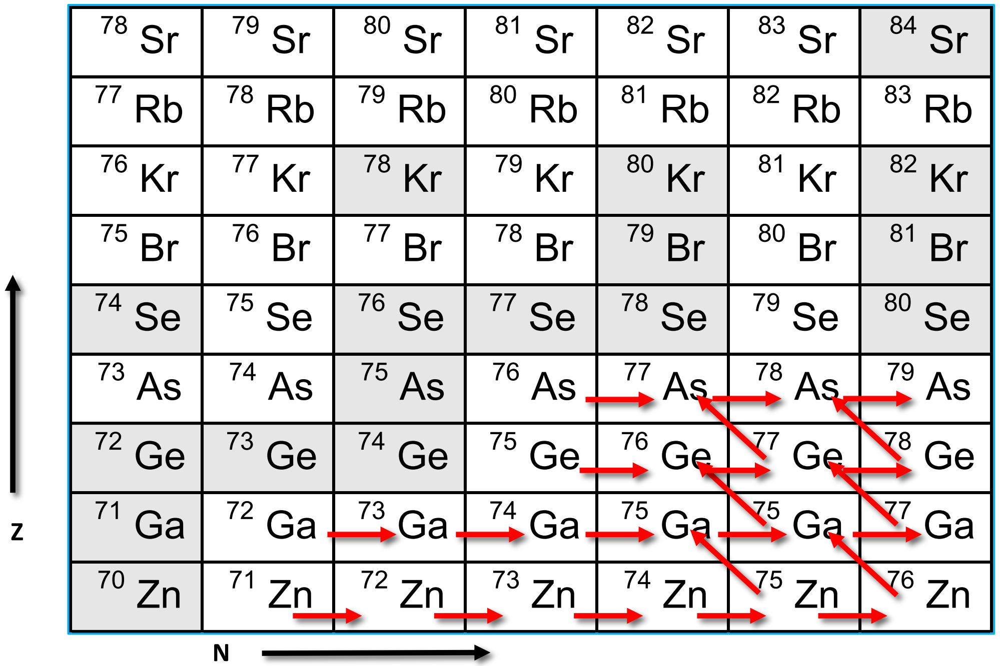
Other nucleosynthesis: Big Bang, Cosmic Ray Spallation, Stellar/ Burning

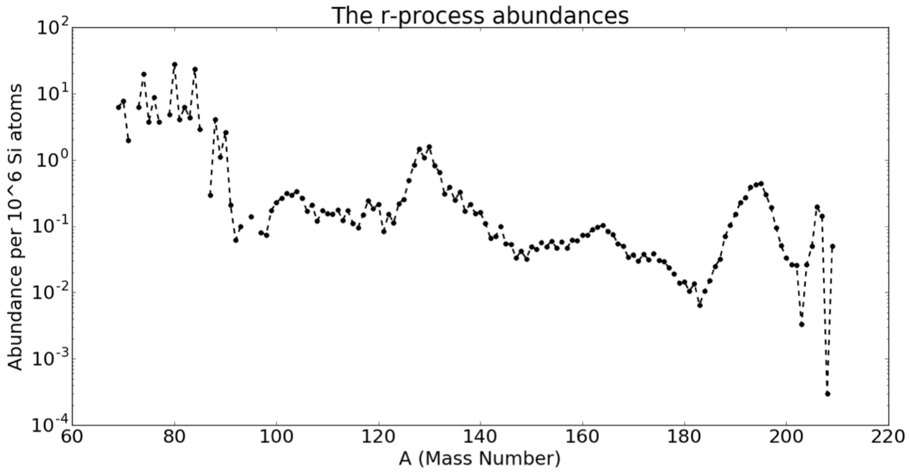
How are the Elements Created?



r-process

- $>10^9$K and 10^{20} neutrons/cm^3
- Takes seconds





Data from Goriely, S. (1999)

We need a reaction theory to calculate these reaction rates which can be put into astrophysical models to calculate abundances

We use the Hauser Feshbach Statistical Model

The Hauser Feshbach Model

The Hauser Feshbach theory is used to model compound nuclear reactions

Compound nuclei have many overlapping excited states

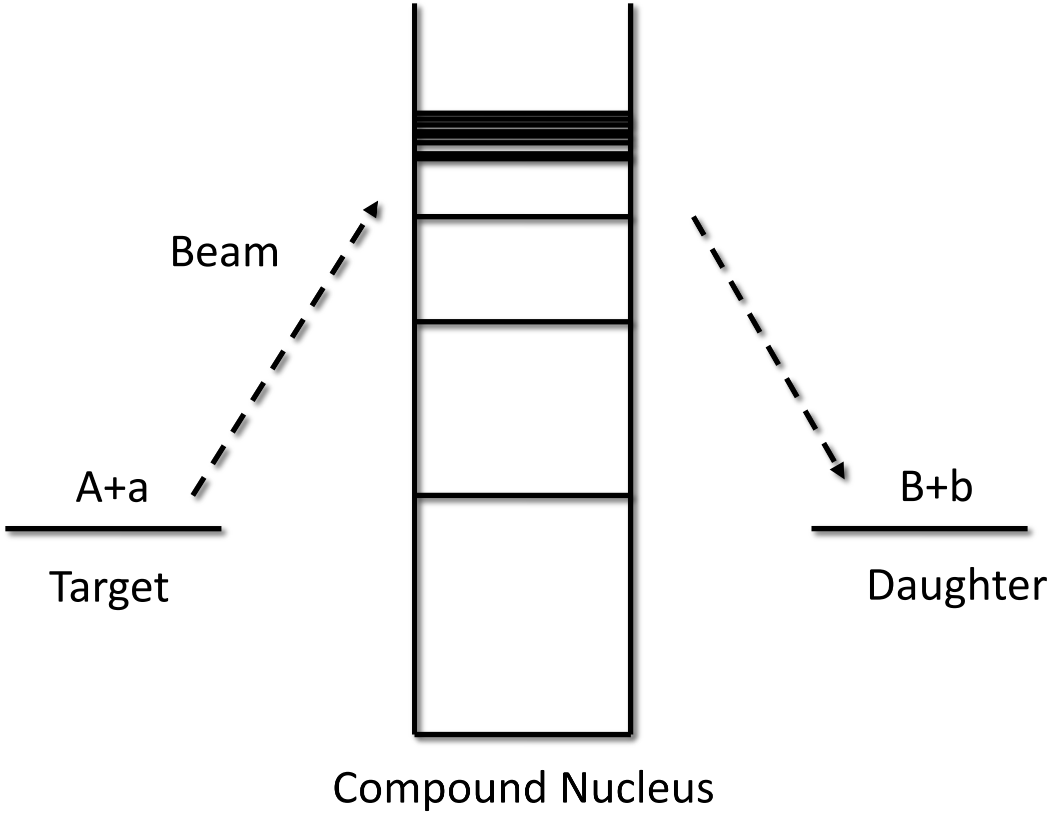
$$\sigma_{ab} \propto \frac{T_a T_b}{\sum_b T_b}$$

Compound Cross Section

Transmission coefficients

Sum over all possible decay channels

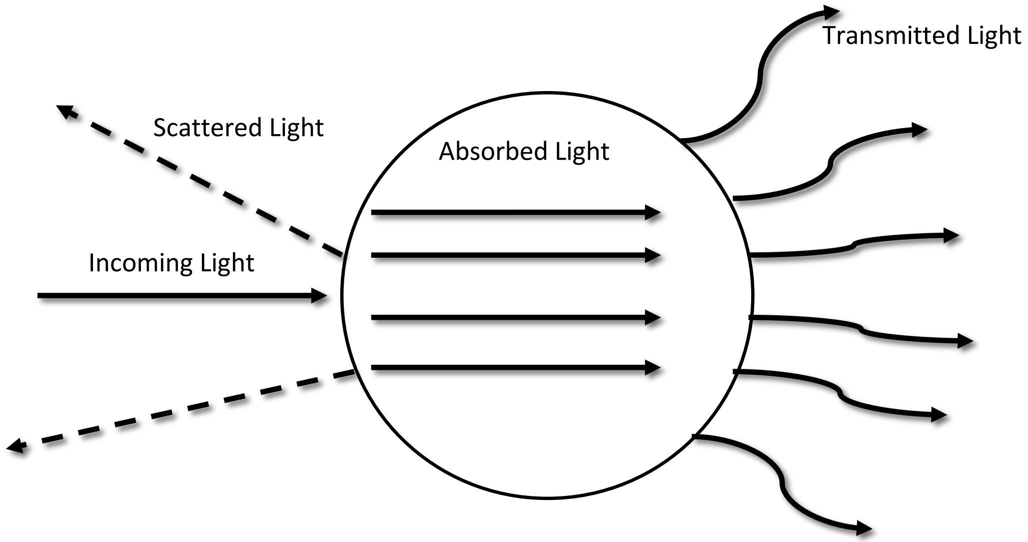
Transmission coefficients depend on the level densities and the optical potential



The Optical Potential Model

Nuclear reactions are modeled like light hitting a cloudy sphere

Particles can be scattered, transmitted, or absorbed



The optical potential can be expressed as:

$$U = V + iW$$

Real, Scattered — Imaginary, Absorbed

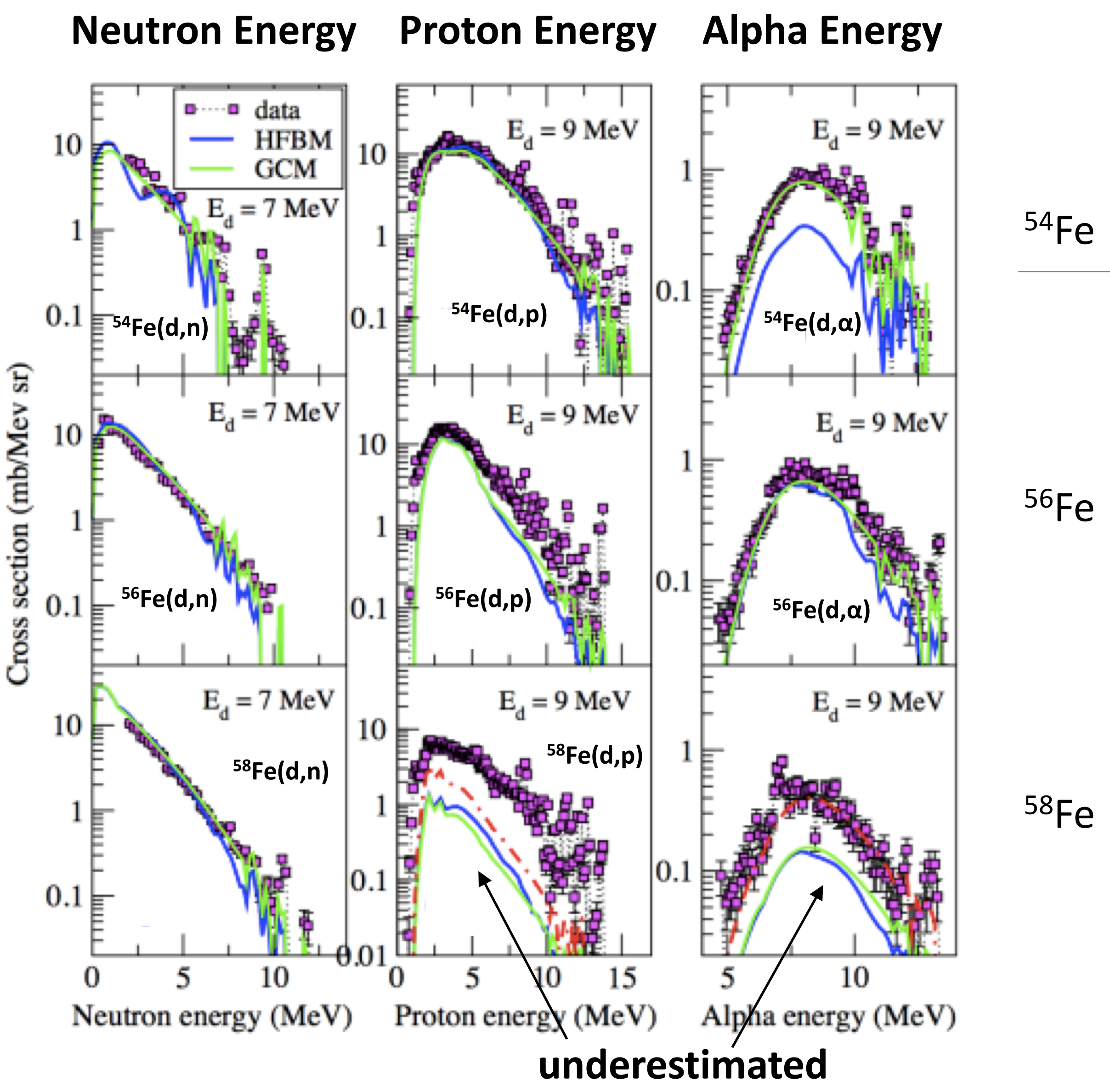
The imaginary term determines the absorption of neutrons to form a compound nucleus

$$W = i(W_{scalar} + W_{vector})$$

No n/p ratio dependence — Has n/p ratio dependence

We care about the ratio because as neutron number increases we think the model will have less agreement

Evidence Near Stability



A.P.D. Ramirez, *Phys.Rev.,C,*2015

Optical Potential Model is constrained by data near stability

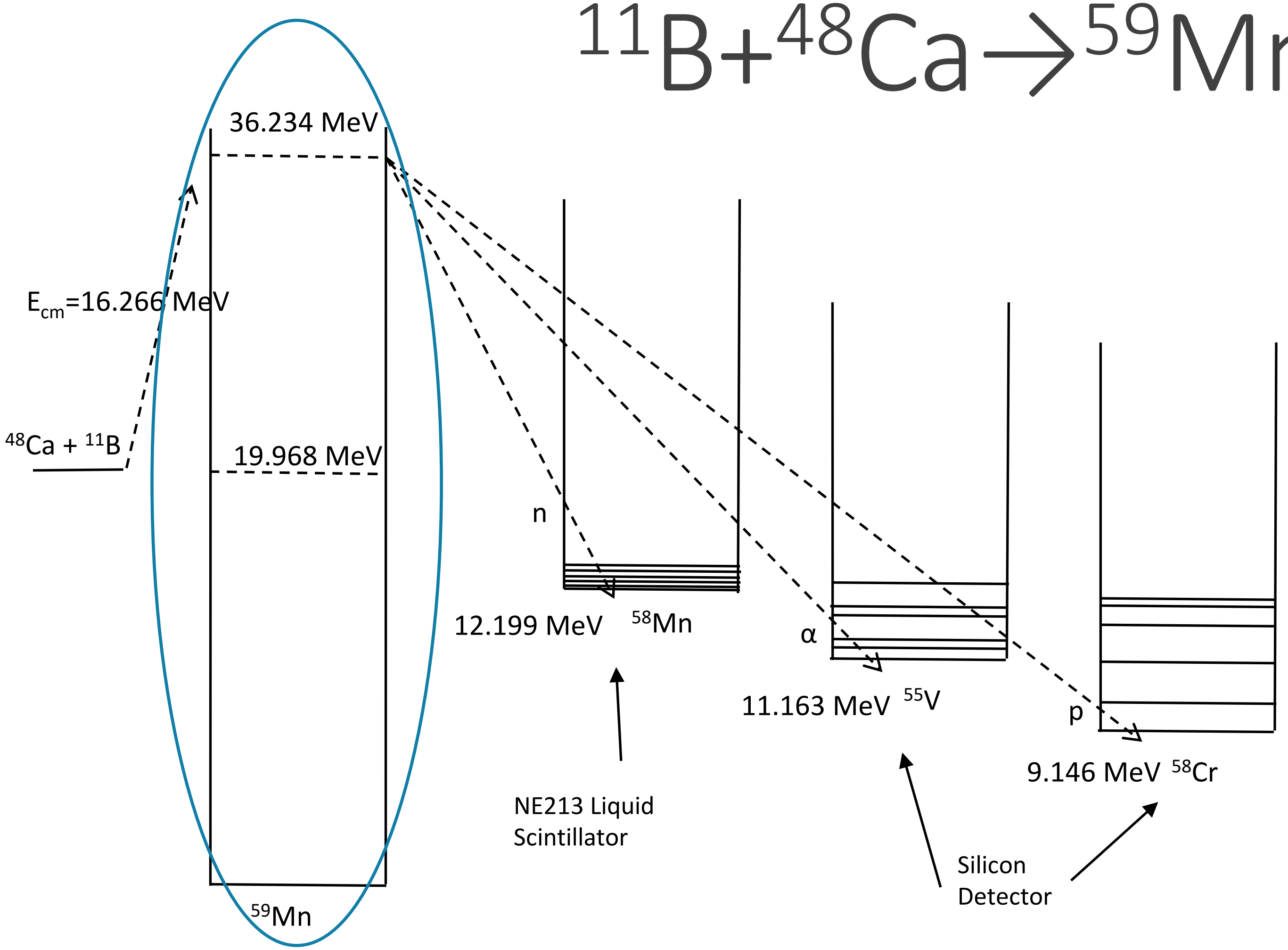
A.P.D. Ramirez et al experiment

Deuteron beam on ^{54}Fe, ^{56}Fe, and ^{58}Fe

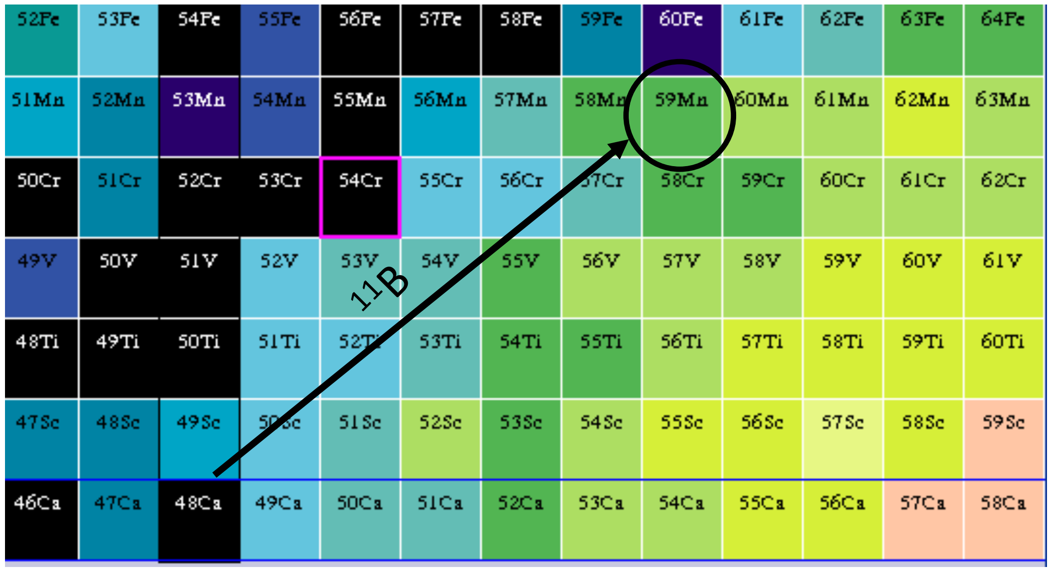
As neutron number increases, value was more underestimated

What happens as we move out of stability?

$^{11}B + ^{48}Ca \rightarrow ^{59}Mn$



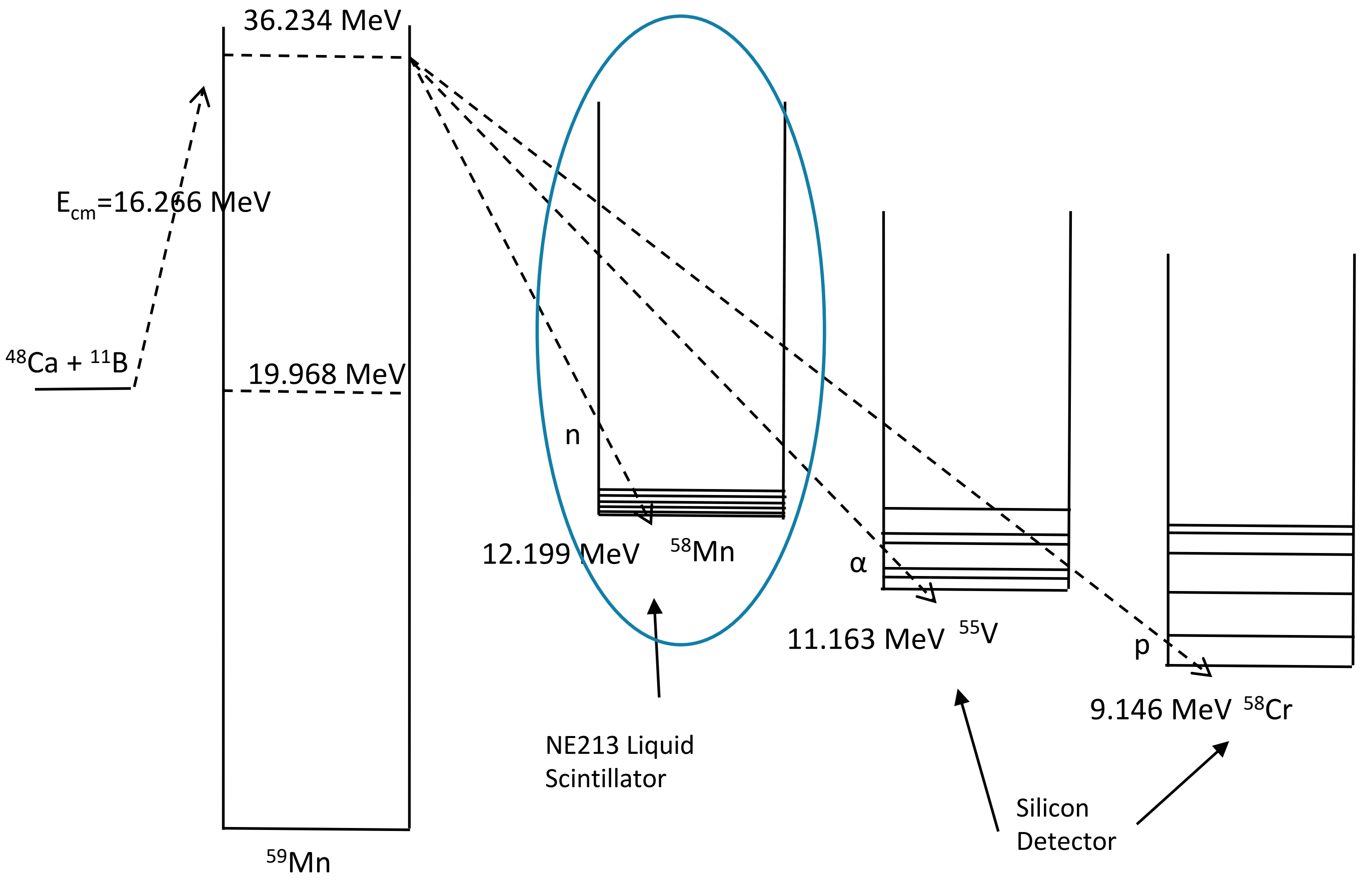
^{59}Mn was chosen because it is neutron rich, but near stability so it could be made with a stable beam and target.



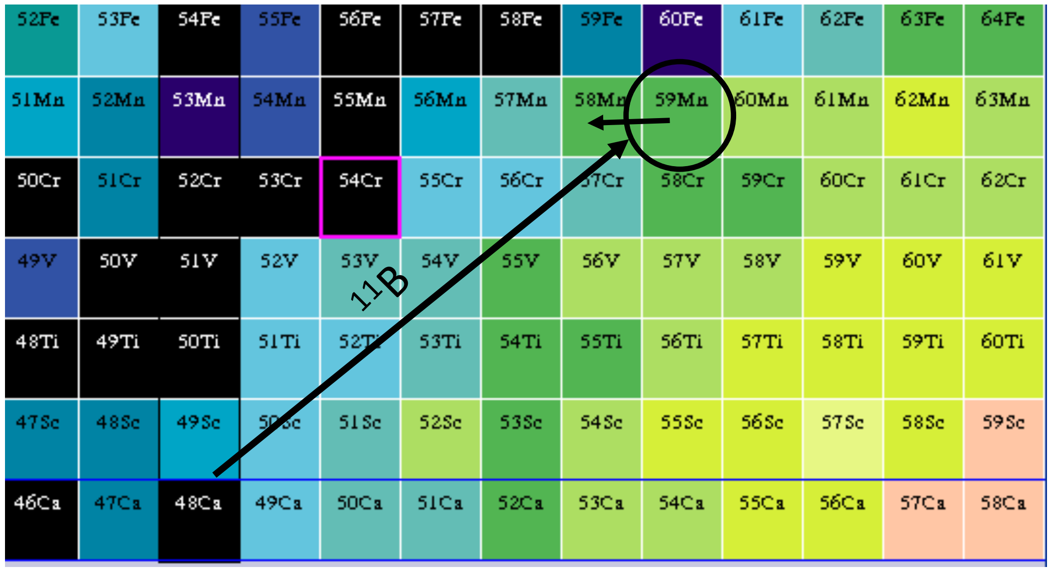
The yields of protons, alphas, and neutrons will tell us if a modification to the isovector potential is needed.

Level densities are well defined in this area, so any difference we see is expected to come from the optical model

$^{11}B + ^{48}Ca \rightarrow ^{59}Mn$



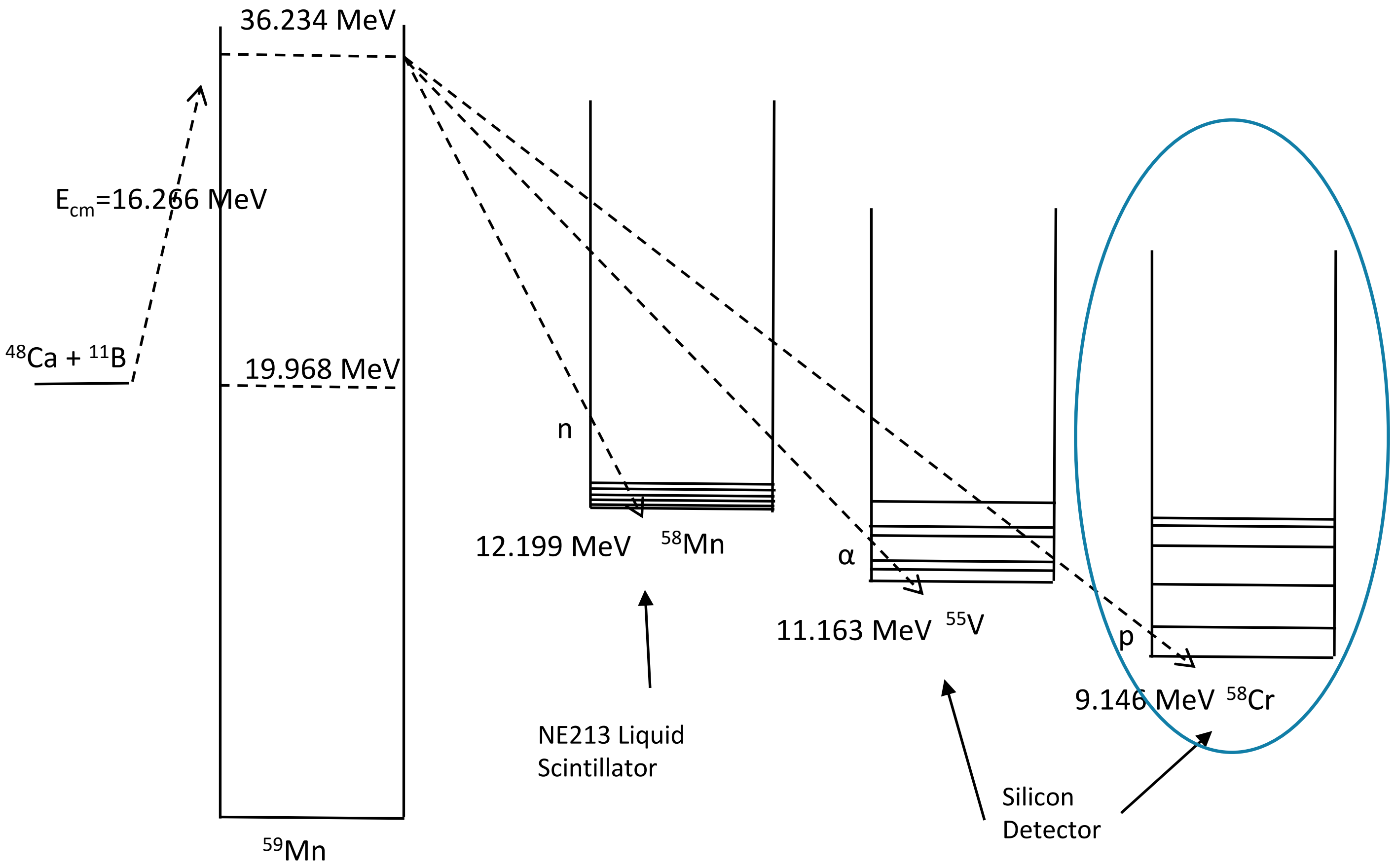
^{59}Mn was chosen because it is neutron rich, but near stability so it could be made with a stable beam and target.



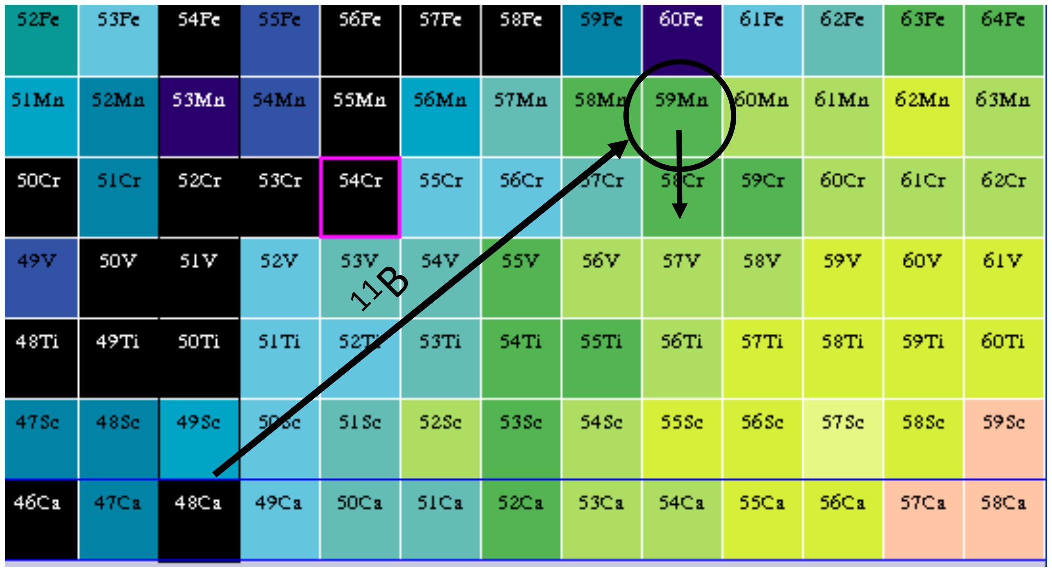
The yields of protons, alphas, and neutrons will tell us if a modification to the isovector potential is needed.

Level densities are well defined in this area, so any difference we see is expected to come from the optical model

$^{11}B+^{48}Ca \rightarrow ^{59}Mn$



^{59}Mn was chosen because it is neutron rich, but near stability so it could be made with a stable beam and target.

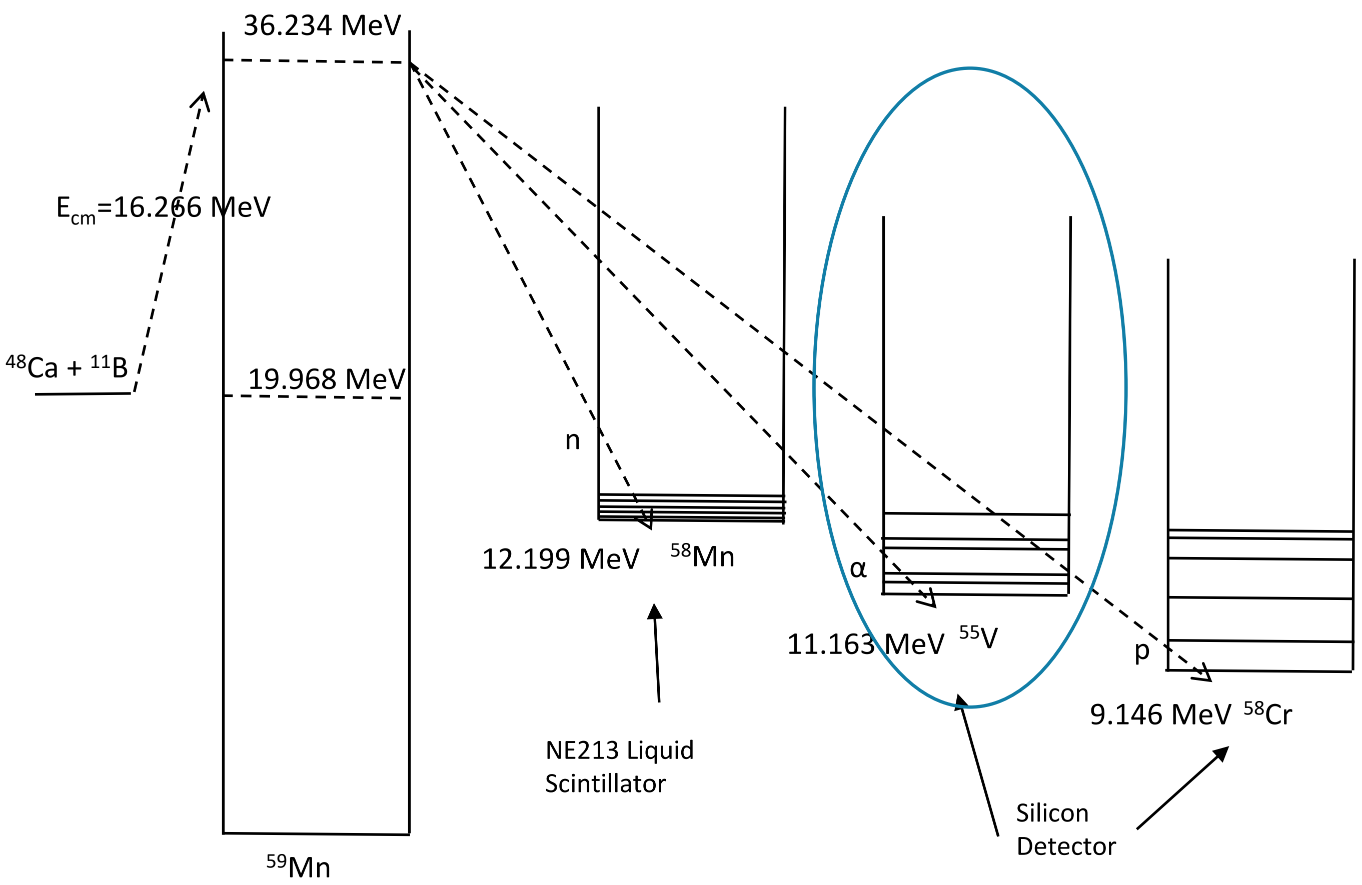


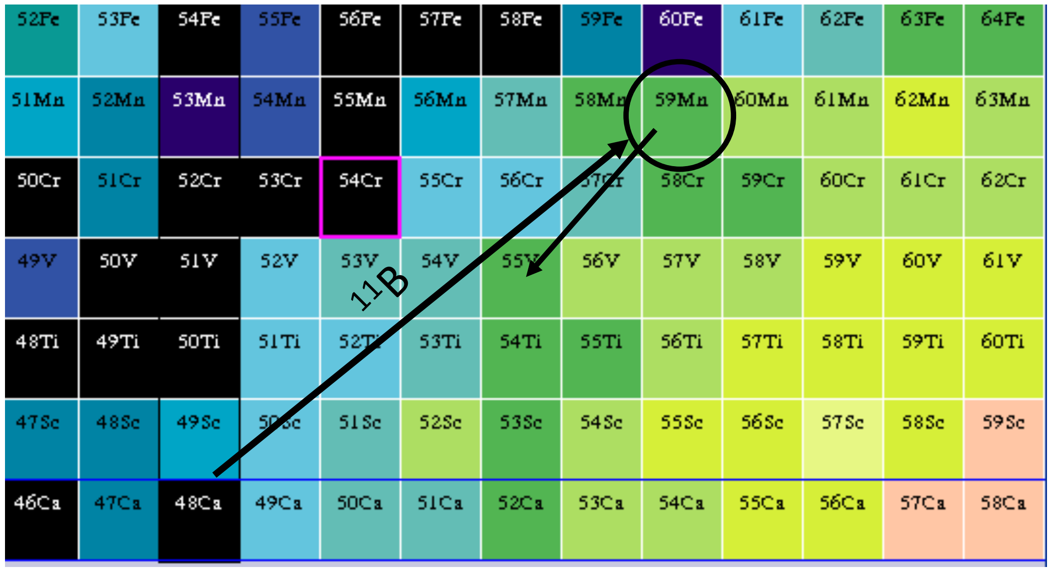
The yields of protons, alphas, and neutrons will tell us if a modification to the isovector potential is needed.

Level densities are well defined in this area, so any difference we see is expected to come from the optical model

$^{11}B+^{48}Ca \rightarrow ^{59}Mn$

^{59}Mn was chosen because it is neutron rich, but near stability so it could be made with a stable beam and target.

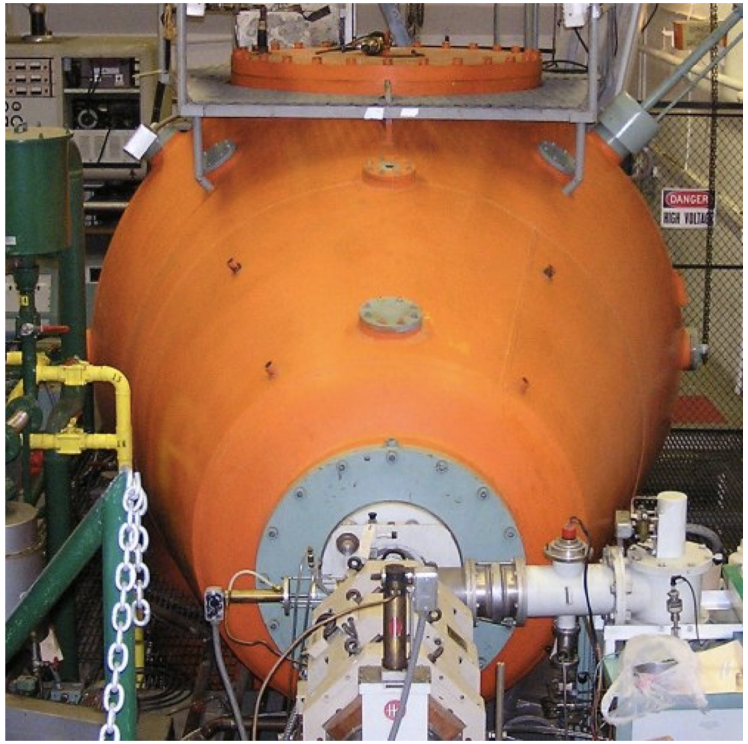




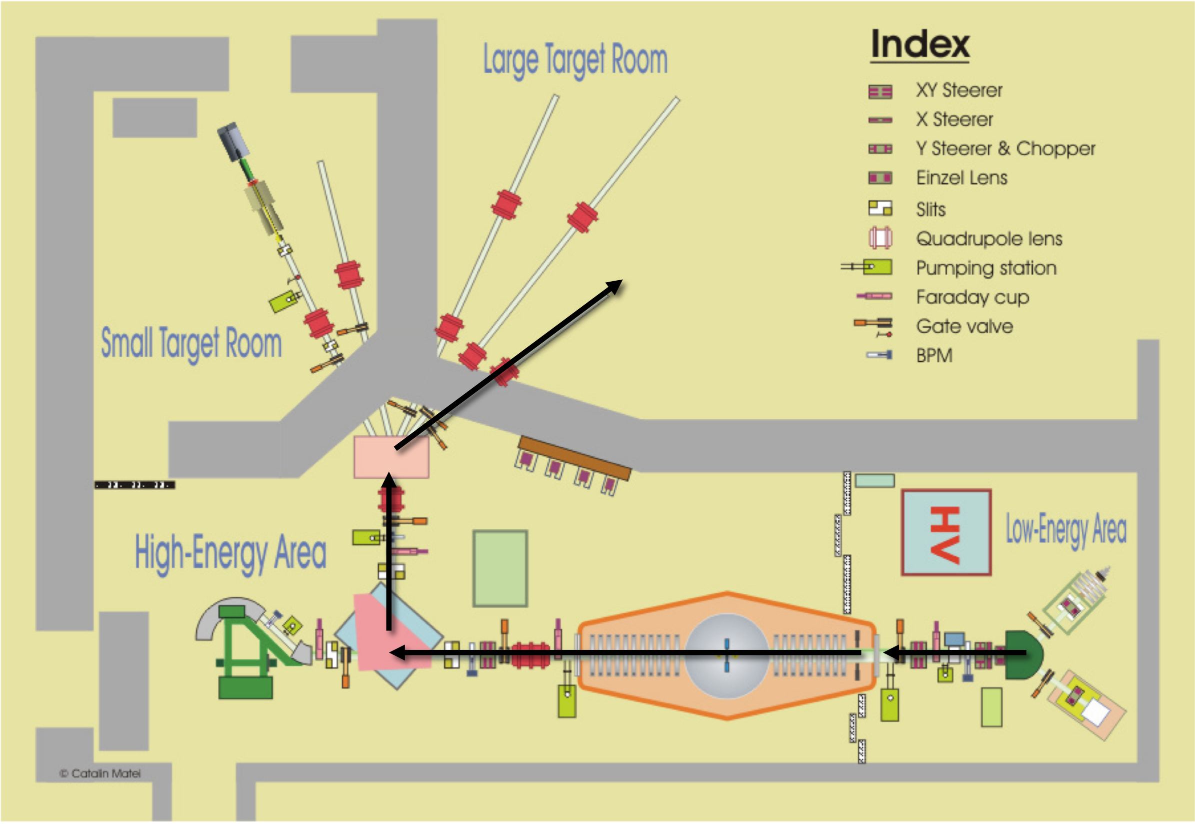
The yields of protons, alphas, and neutrons will tell us if a modification to the isovector potential is needed.

Level densities are well defined in this area, so any difference we see is expected to come from the optical model

Experiment Setup

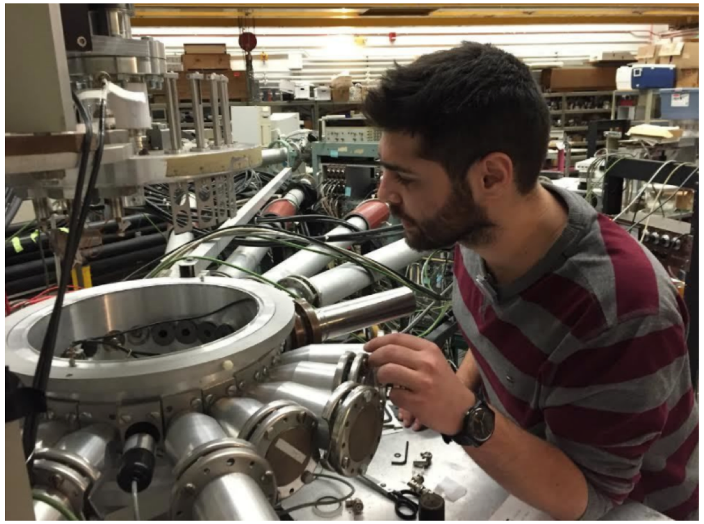


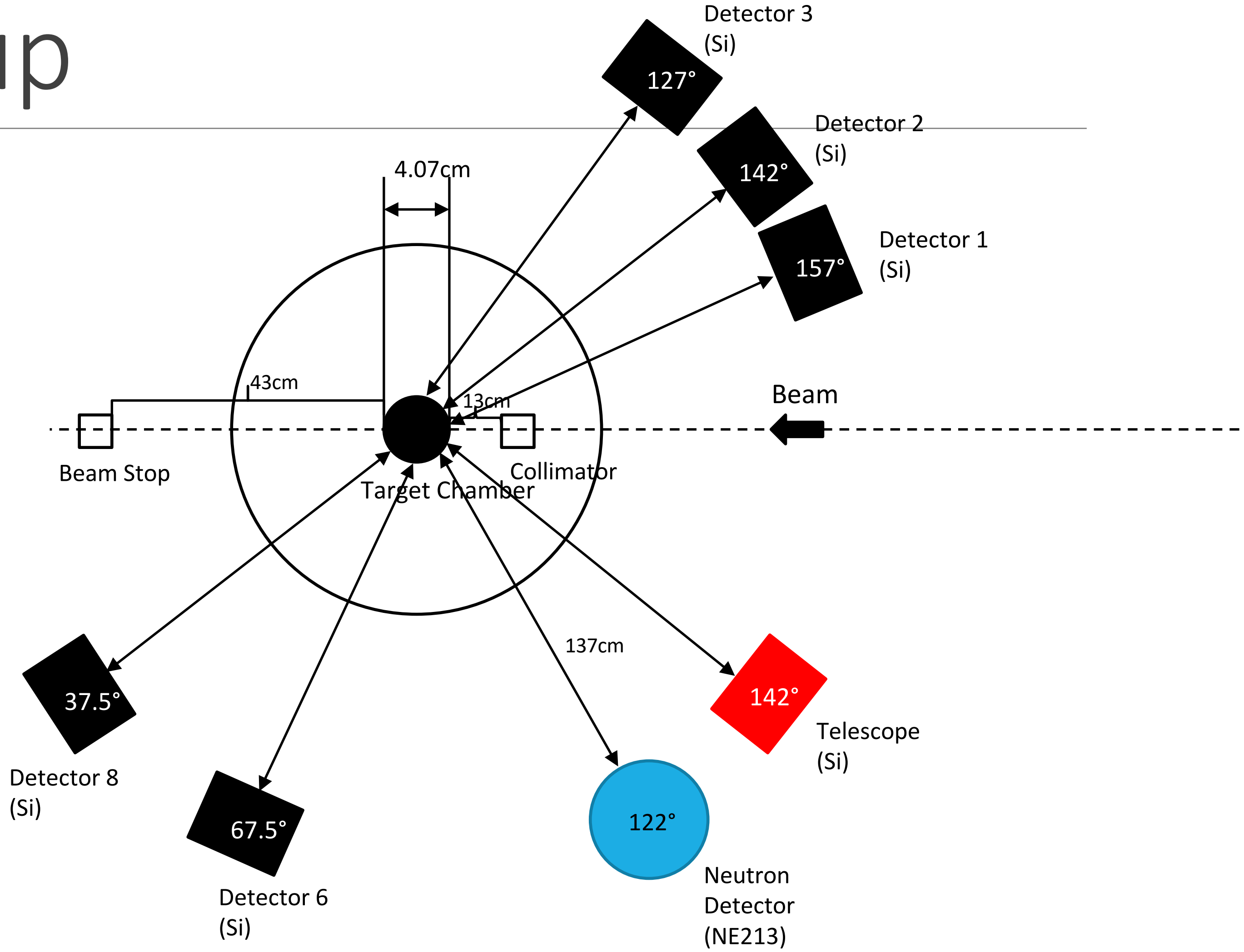
Tandem accelerator at Edward's Accelerator Laboratory at Ohio University



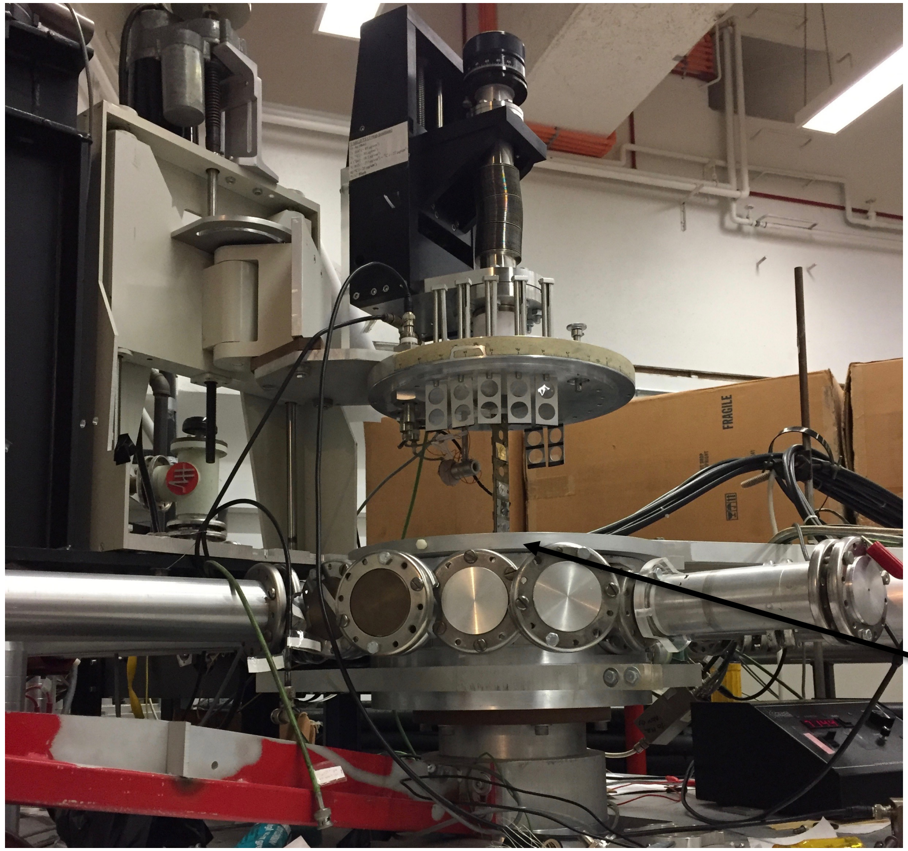
Experimental Setup

- NE213 detector for neutrons and gammas
  - Pulse Shape Discrimination- (n,ɣ) separation
  - Time of Flight- Total Energy
- Si detectors for alphas and protons
  - Energy
  - Time of Flight- Total Energy



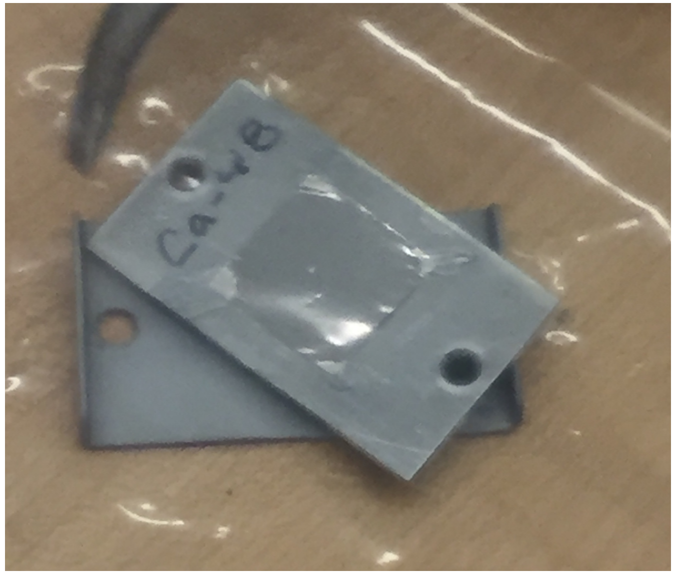


Experimental Setup



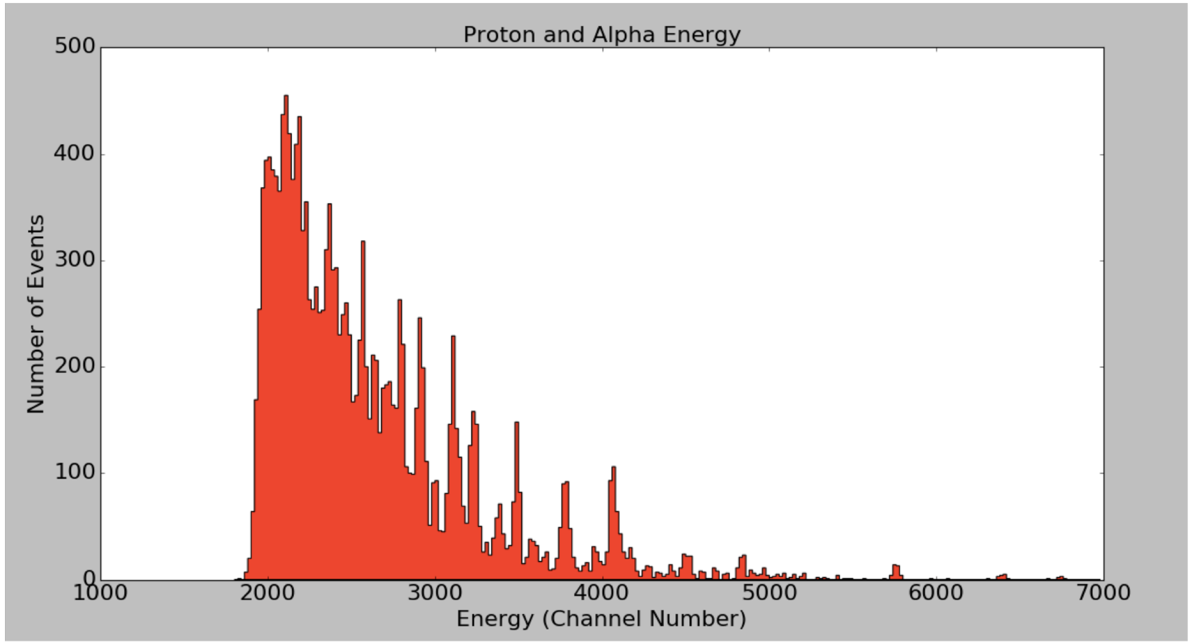
- Experiment: $^{48}Ca+^{11}B \rightarrow ^{59}Mn$ at 20 MeV
- Energy Calibration Run: $^{12}C+^{11}B \rightarrow ^{23}Na$ at 20 MeV
- Other Targets: ^{27}Al, ^{197}Au, Empty

Targets are loaded into the detector

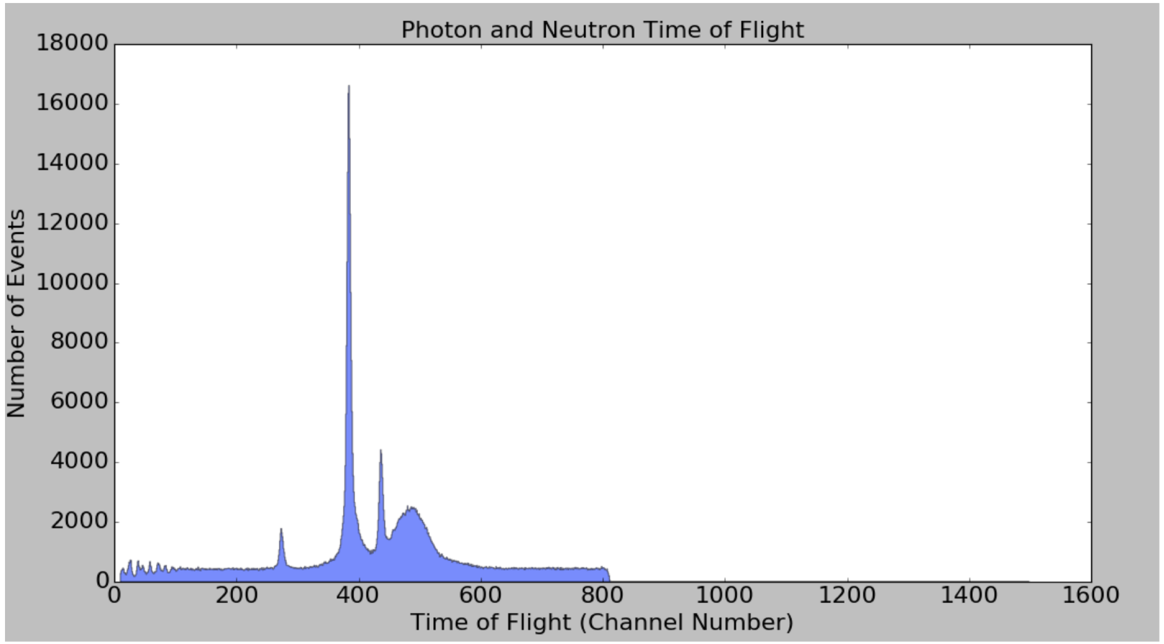


Particle Spectra

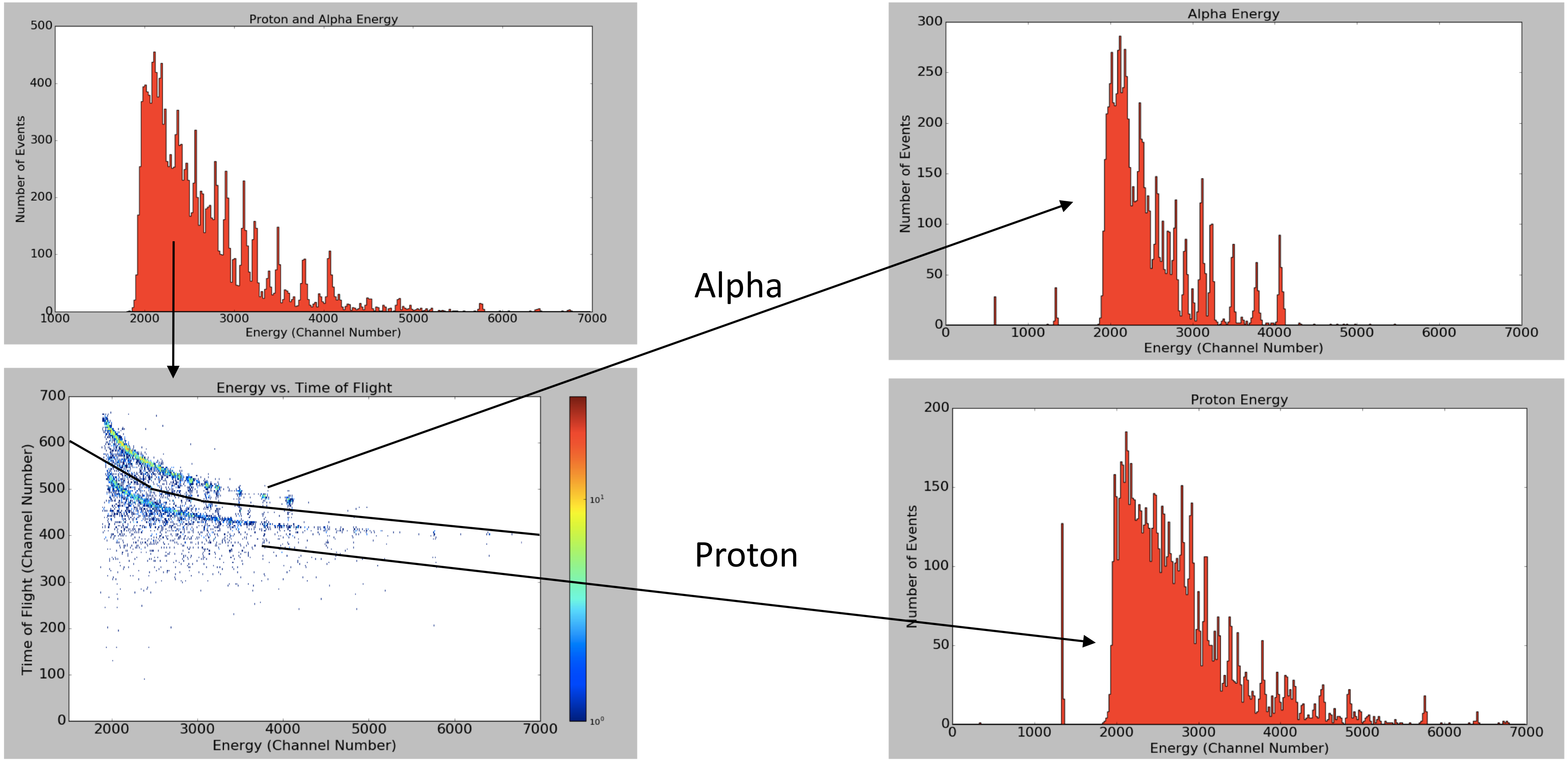
Alpha and Proton Spectra



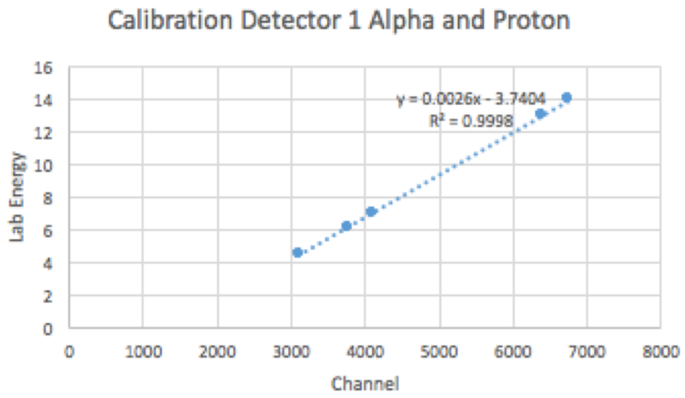
Gamma and Neutron Spectra



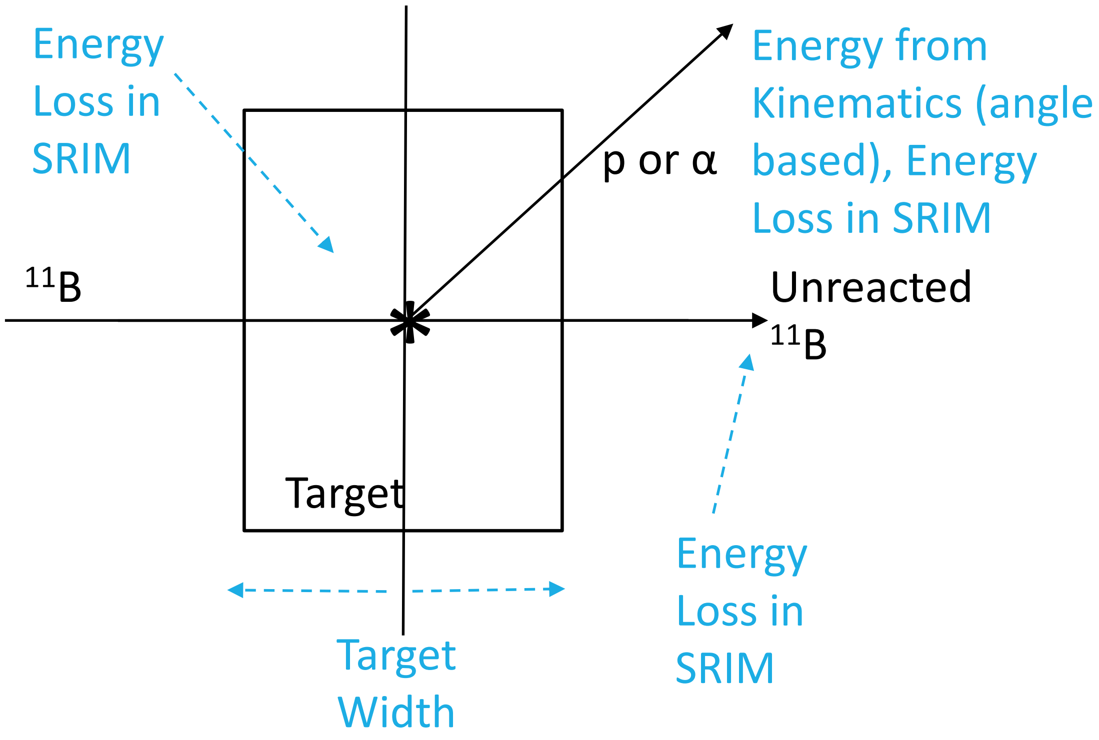
Separation of Alphas and Protons

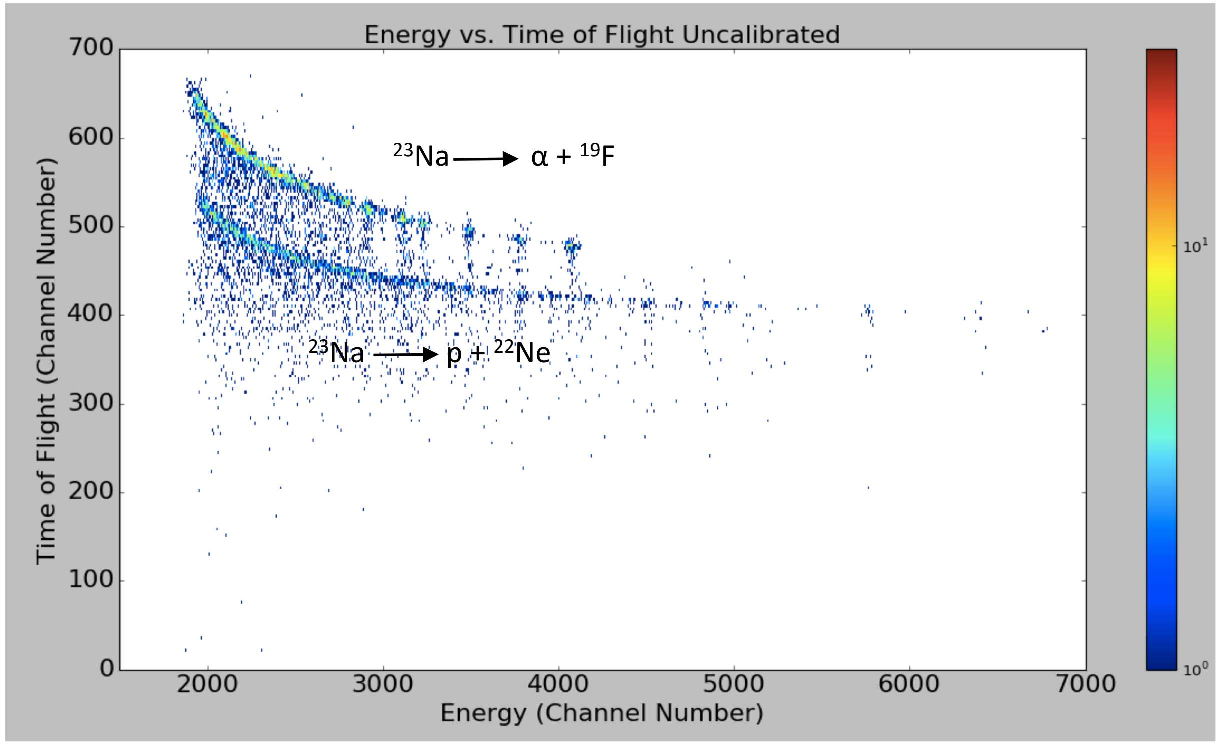


Energy Calibration Si Detector

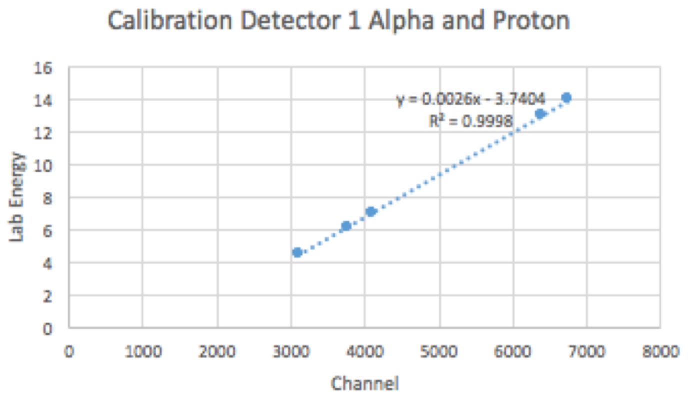


Calibration Data: $^{11}B + ^{12}C \rightarrow ^{23}Na$ at 20 MeV

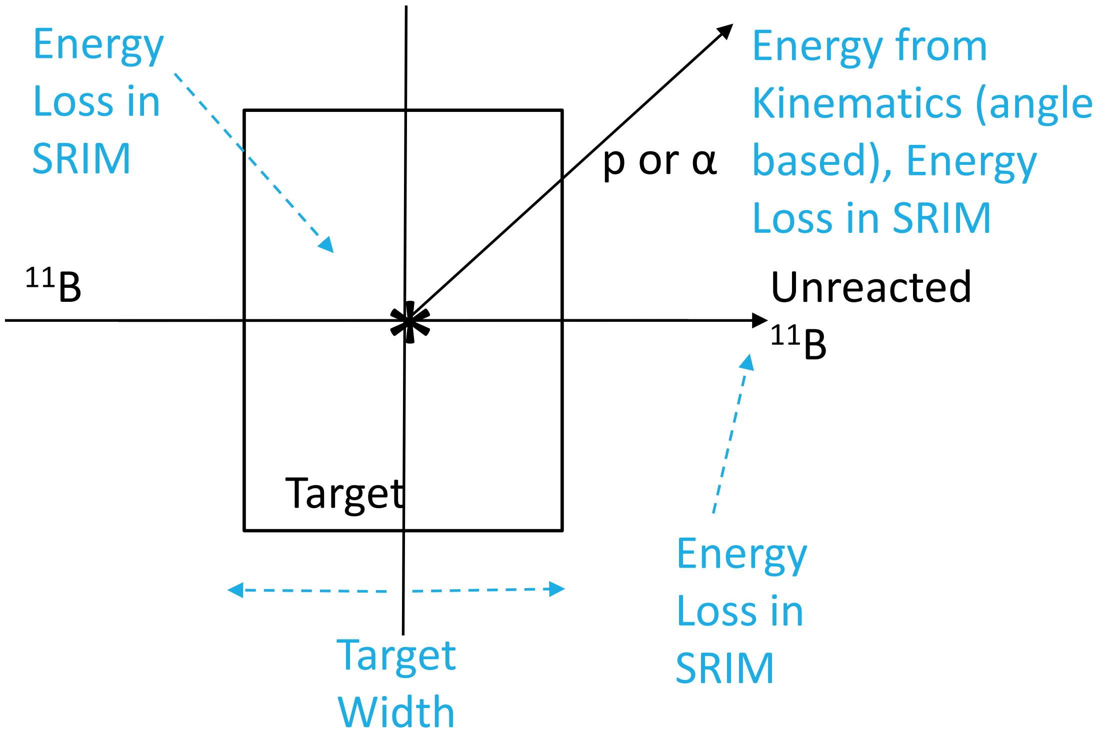


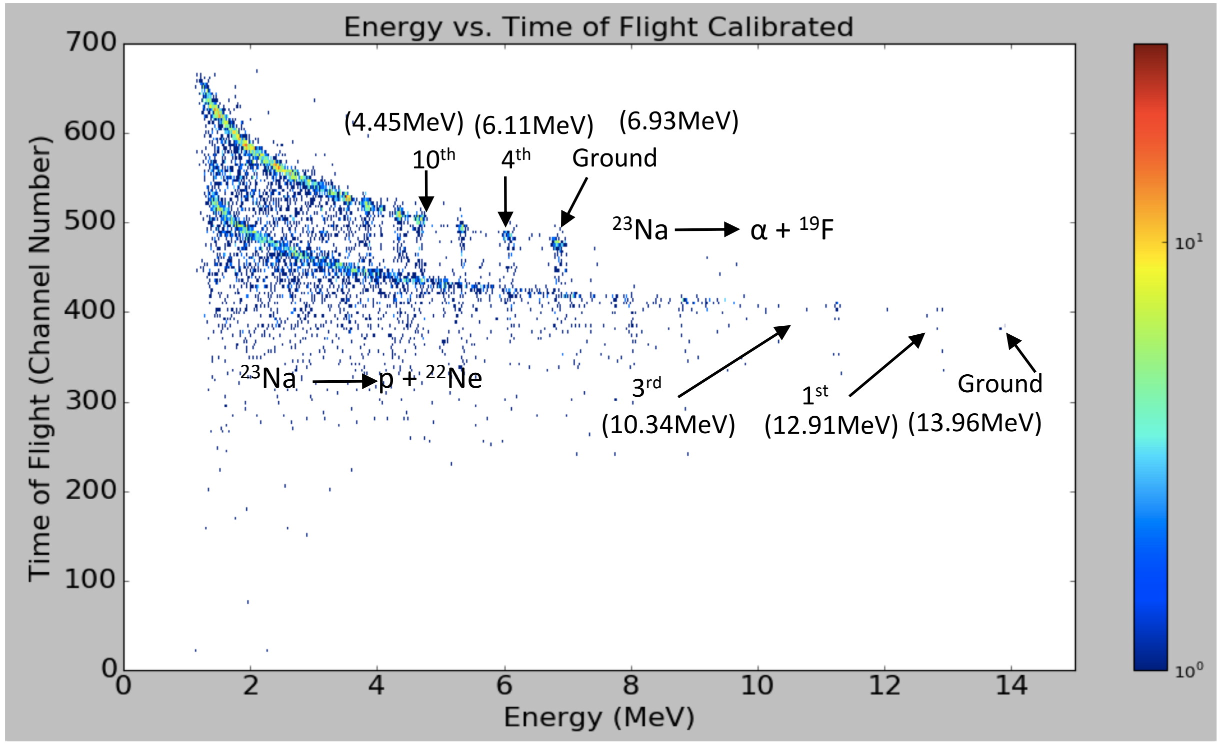


Energy Calibration Si Detector



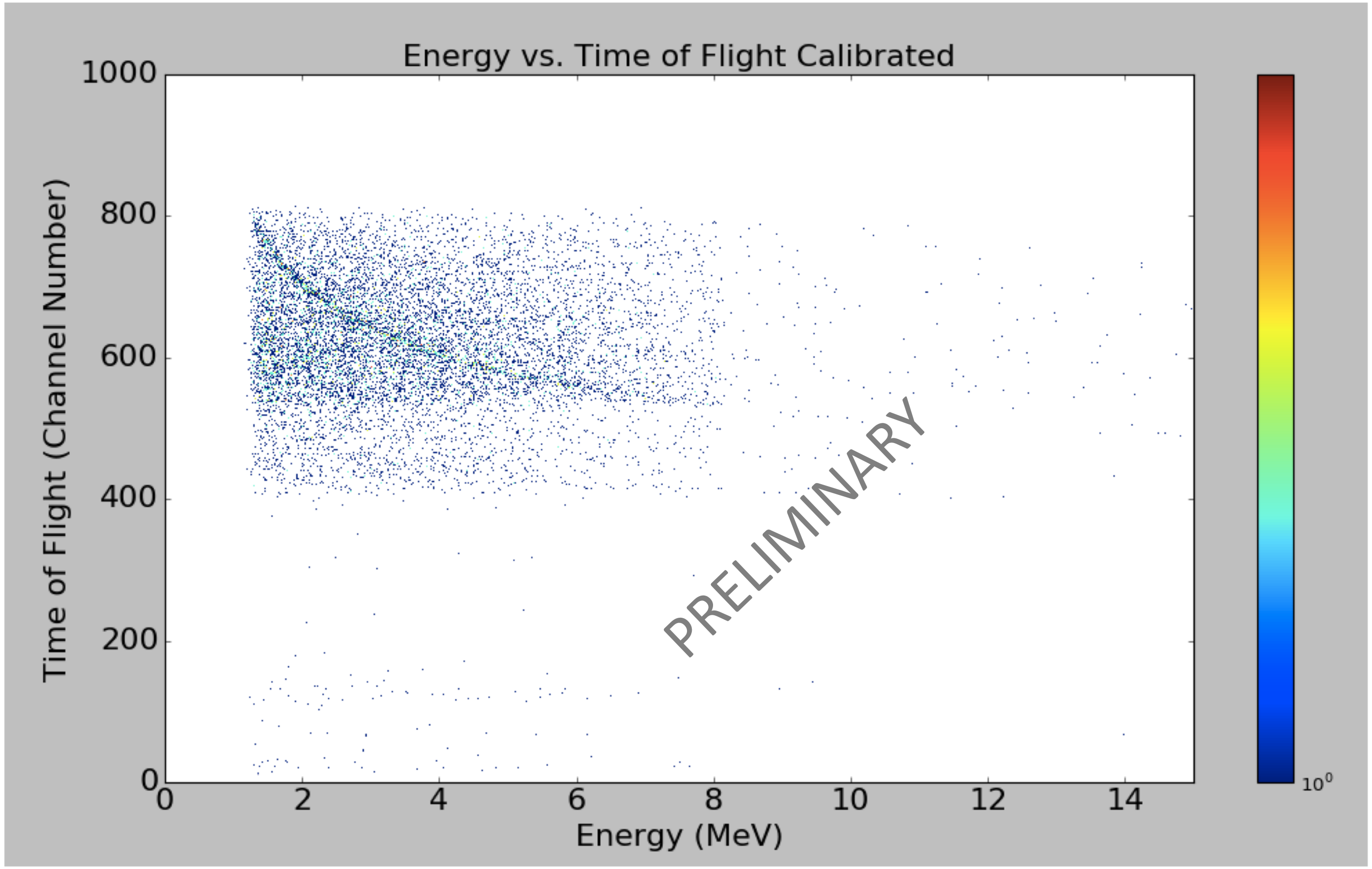
Calibration Data: $^{11}B+^{12}C \rightarrow ^{23}Na$ at 20 MeV



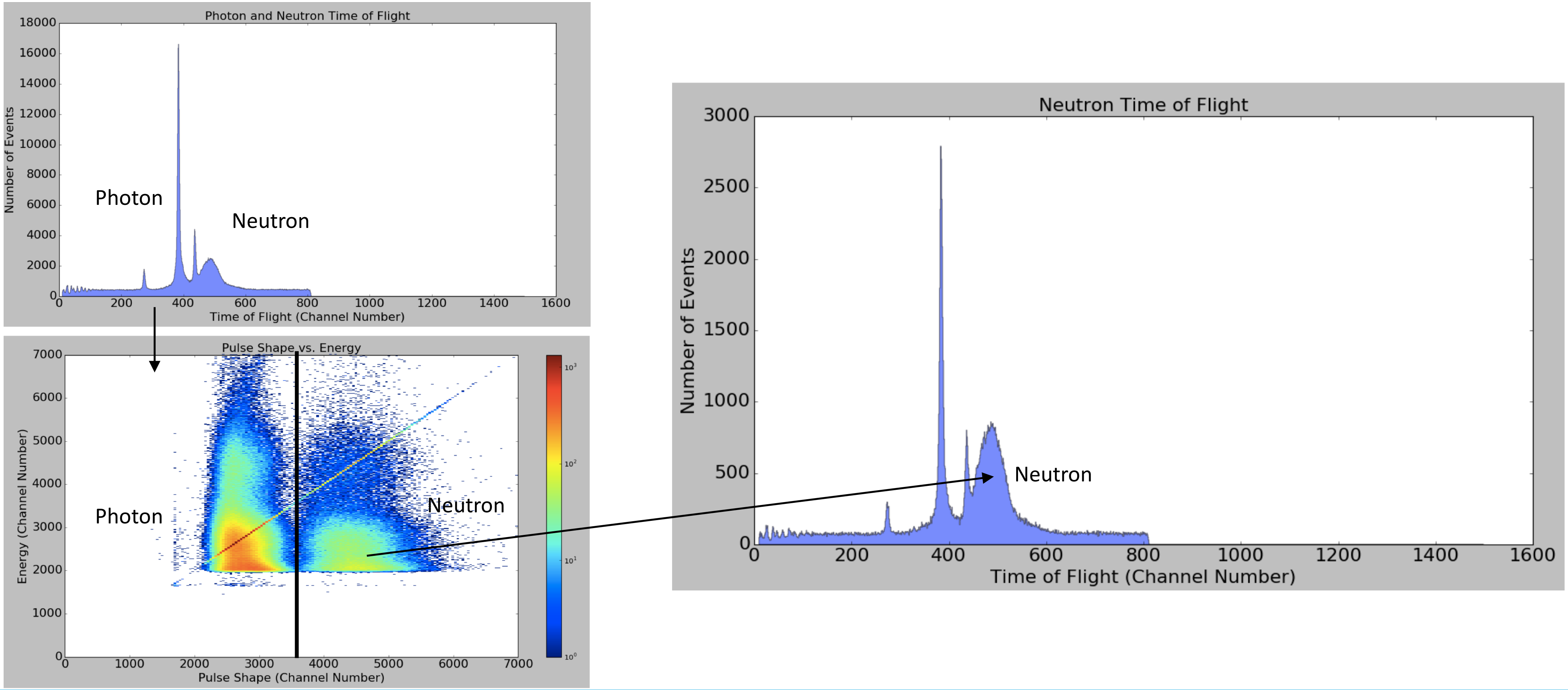


Alpha and Proton Decay

Calibrated ^{11}B+$^{48}Ca \rightarrow ^{59}Mn$ alpha and proton spectra



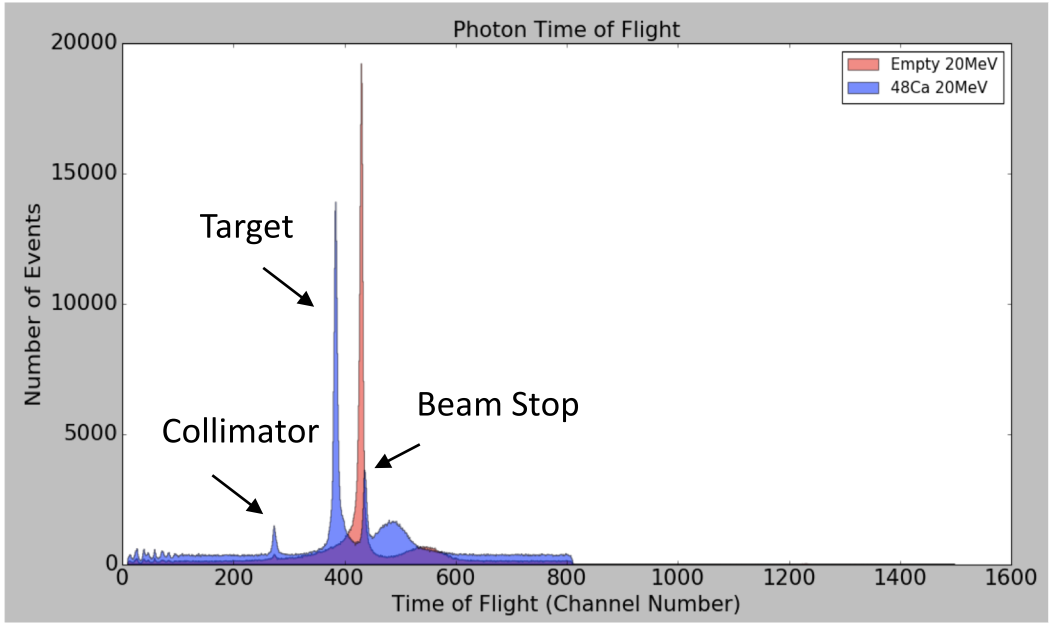
Separation of Photons and Neutrons

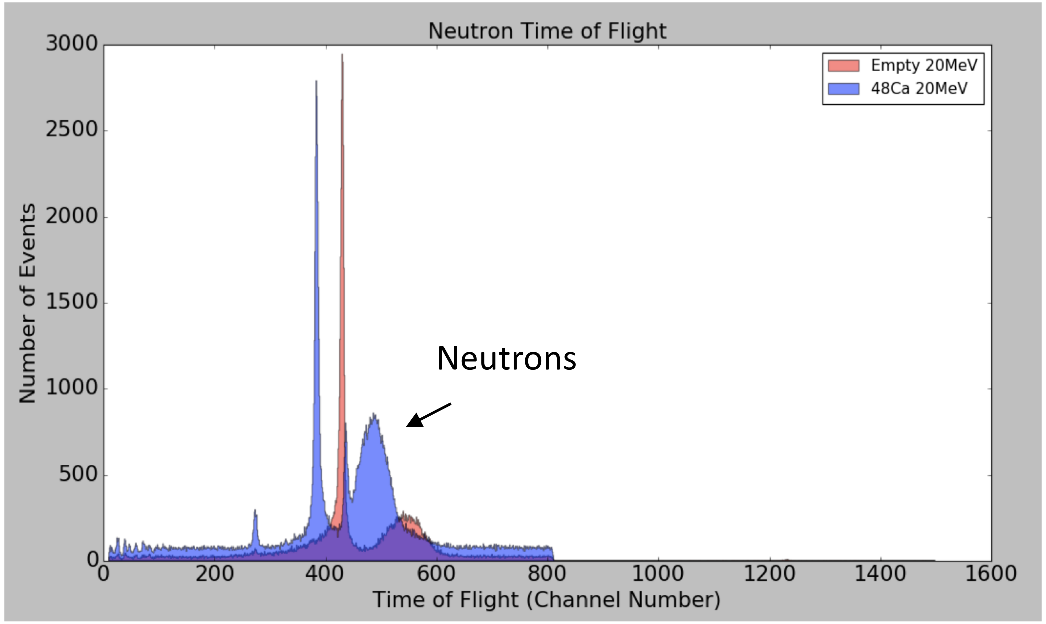


Neutron Detector Background Spectra

Eliminate the background spectra

- Use empty targets to identify collimator, target, and beam stop peaks
- Identify peaks using photon spectra
- Calculated time from each location to neutron detector





Summary and Outlook

Measured the reaction $^{11}B + ^{48}Ca \rightarrow ^{59}Mn$

Performed Particle Identification using Time of Flight for protons and alphas

Performed Particle Identification using Pulse Shape for neutrons and gammas

Identified background sources

In Progress/ To Be Completed:

- Absolute Time of Flight
- Integration of yields for protons, alphas, and neutrons
- Efficiency calibrations
- Theoretical analysis to determine if a correction is needed for imaginary isovector term

Thank You!

Collaborators:

CMU CENTRAL MICHIGAN UNIVERSITY

George Perdikakis

OHIO UNIVERSITY 1804

Alexander Voinov
Steven Grimes

Questions??

Support:
Central Michigan University College of Graduate Studies