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May 3rd, 12:00 AM - 12:00 AM

Resonances of 25,26F Atomic Nuclei

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Augustana Digital Commons Citation

Tuttle-Timm, Matthew. "Resonances of 25,26F Atomic Nuclei" (2017). *Celebration of Learning.*
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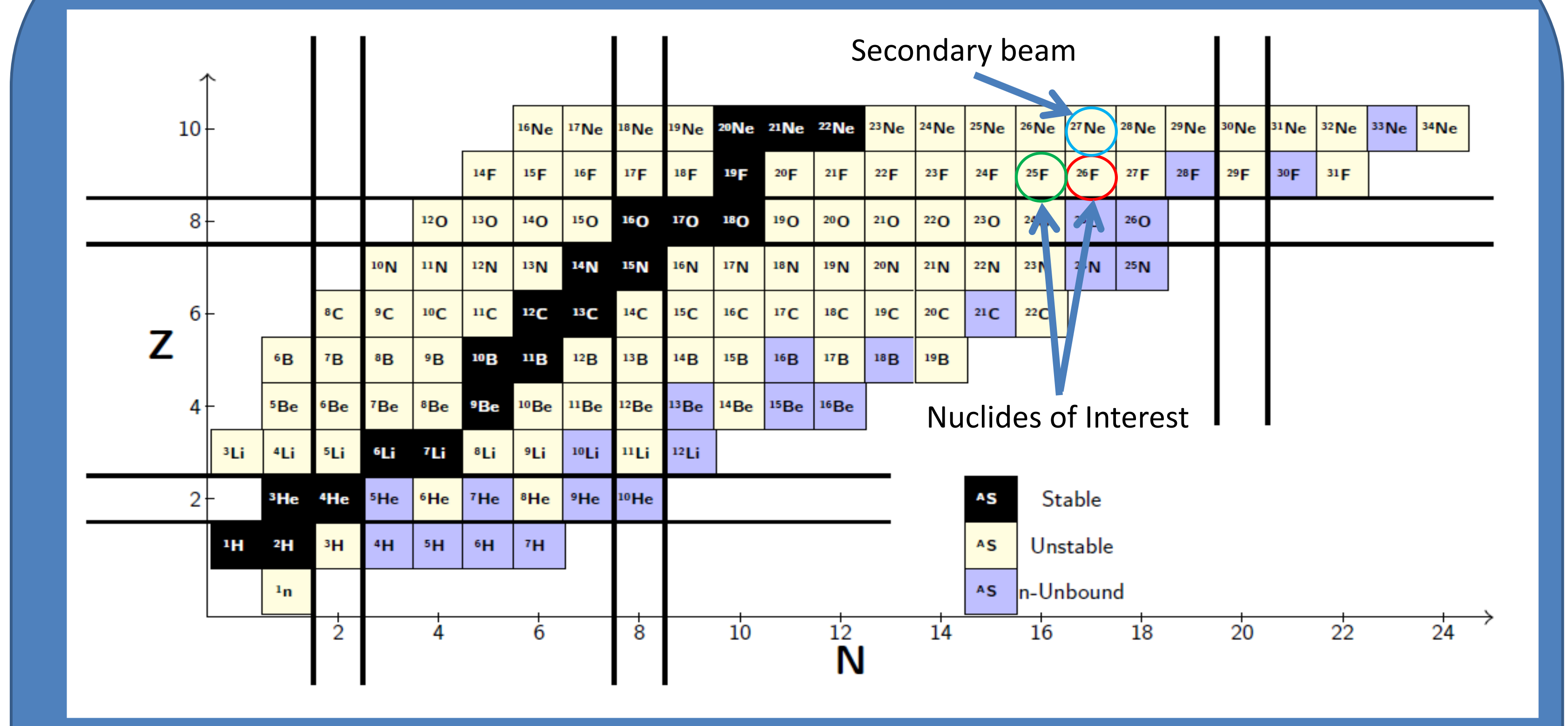
Resonances of ^{25,26}F Atomic Nuclei

M. Tuttle-Timm, N. Frank, Augustana College, MONA COLLABORATION

Overview



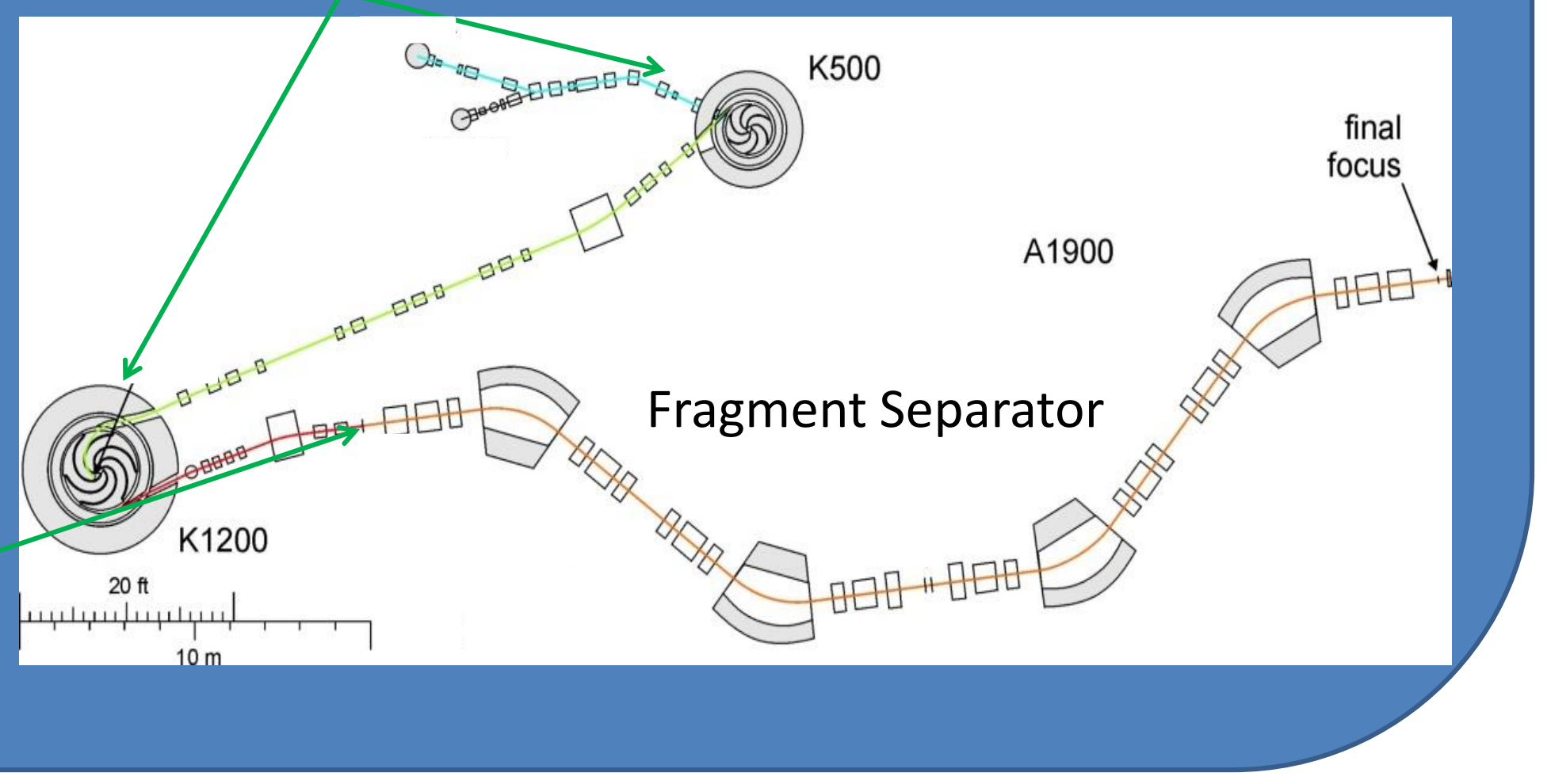
- Figure above shows a chart of nuclides in which the number of neutrons (N) is along the horizontal axis and the number of protons (Z) along the vertical axis
- Our analysis focuses on ^{26}F (red circle) and ^{25}F (green circle) produced from nuclear reactions between ^{27}Ne (blue circle) and a liquid Deuterium target

National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU)

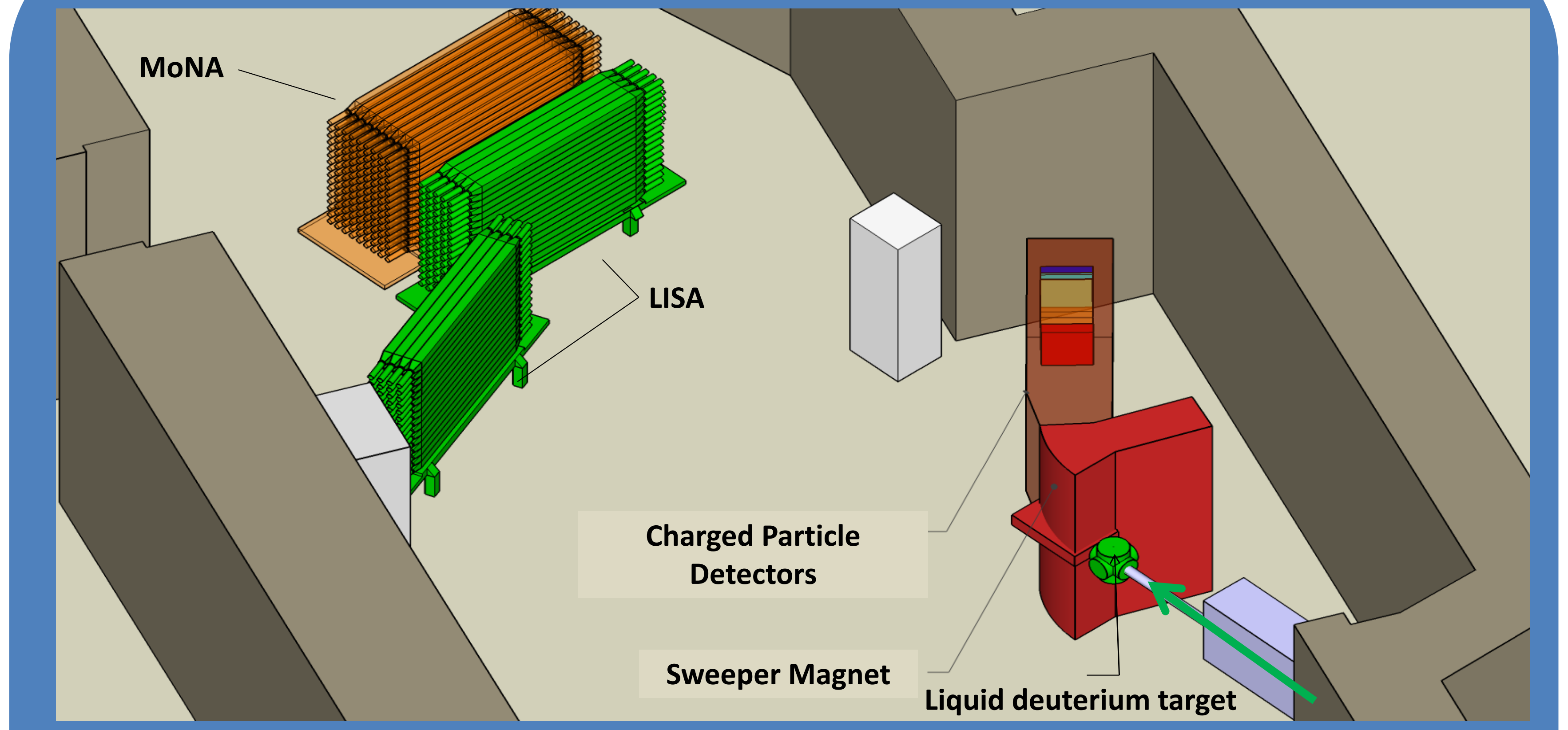
- *National Superconducting Cyclotron Laboratory* (NSCL) Lansing, Michigan
- Facility uses two particle accelerators called cyclotrons which produces many radioactive isotopes
- The isotopes are separated by a magnetic fragment separator
- The beam is then directed into a target where collisions cause reactions within the nucleus.

Cyclotrons

Production Target

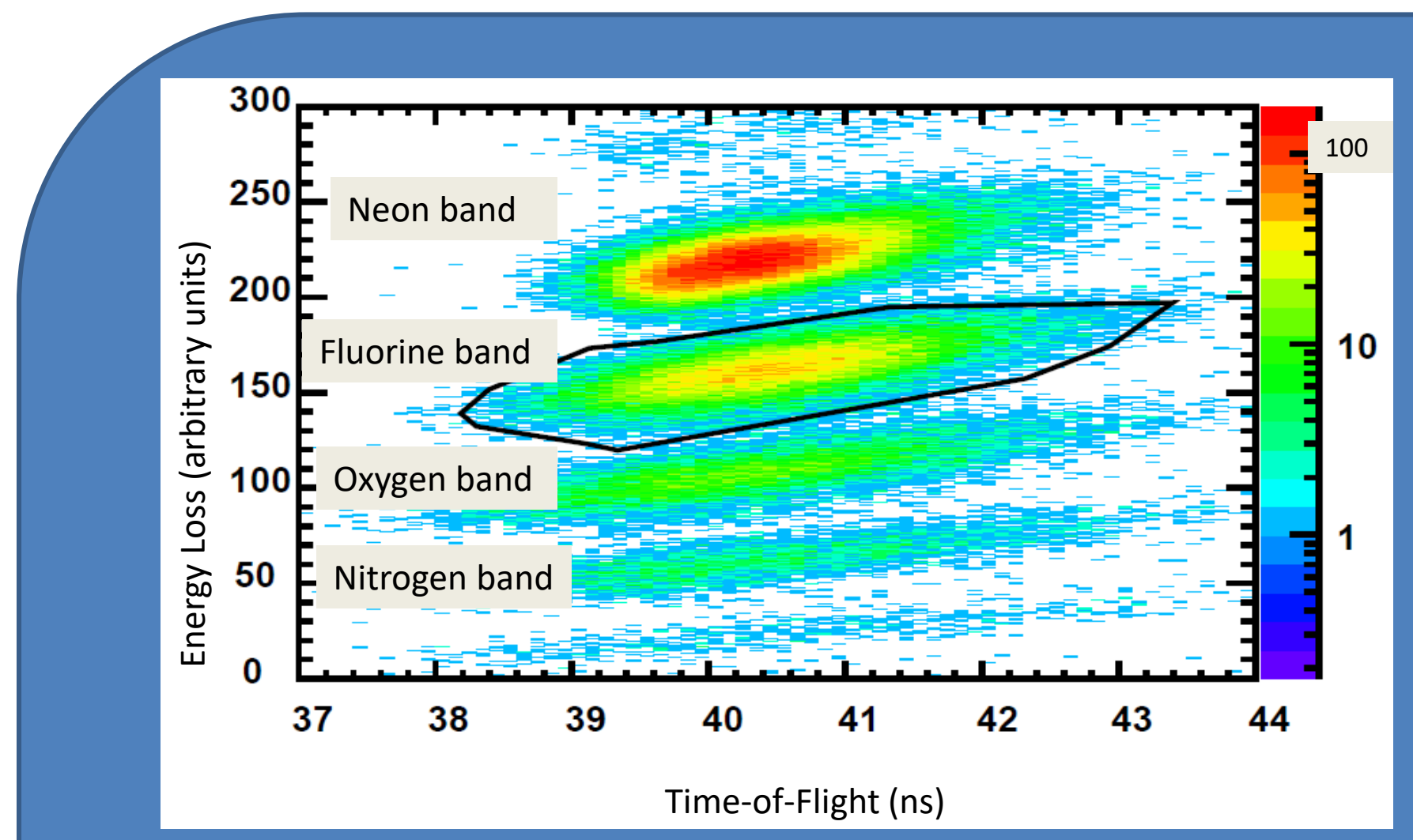


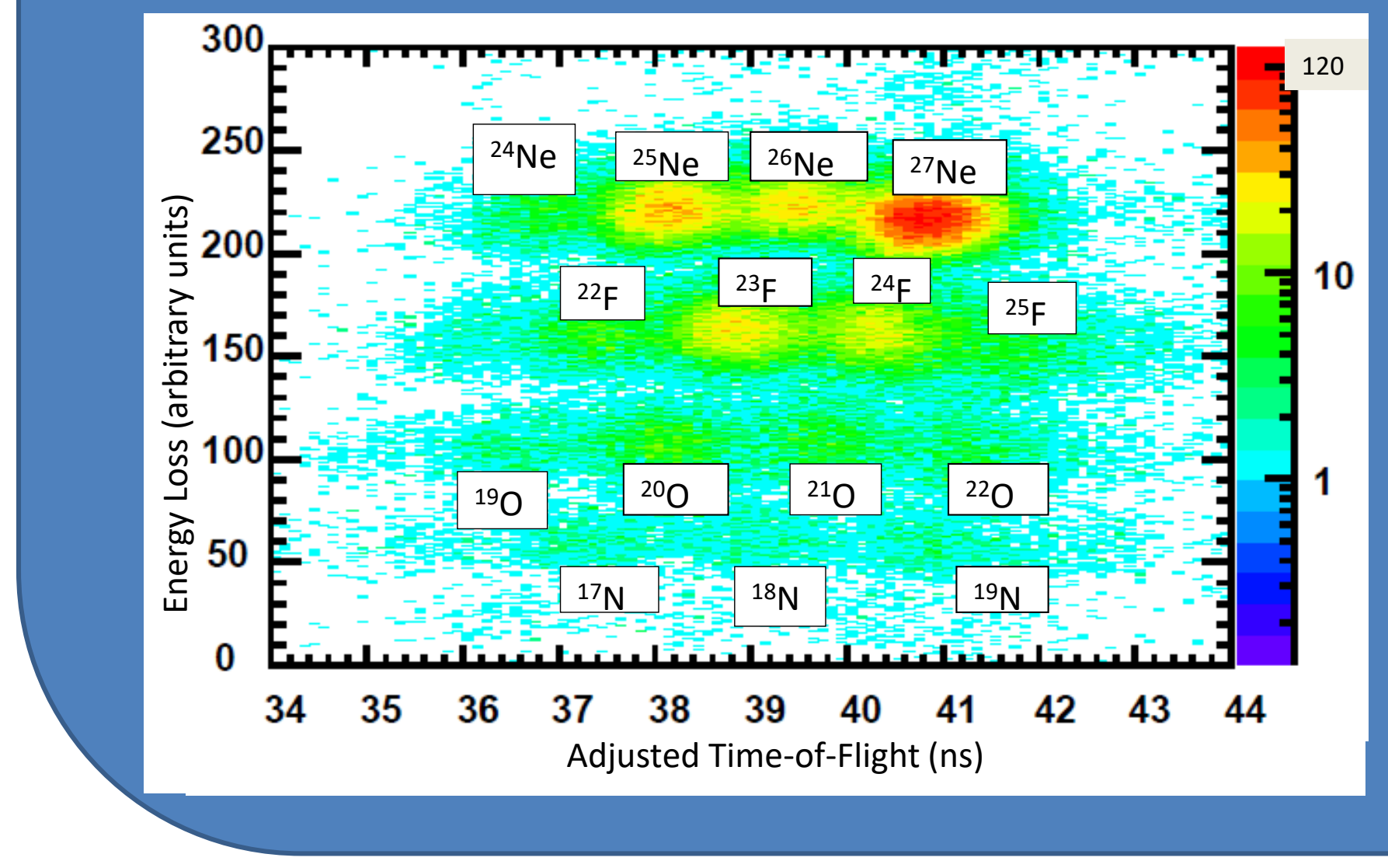
Experiment Setup



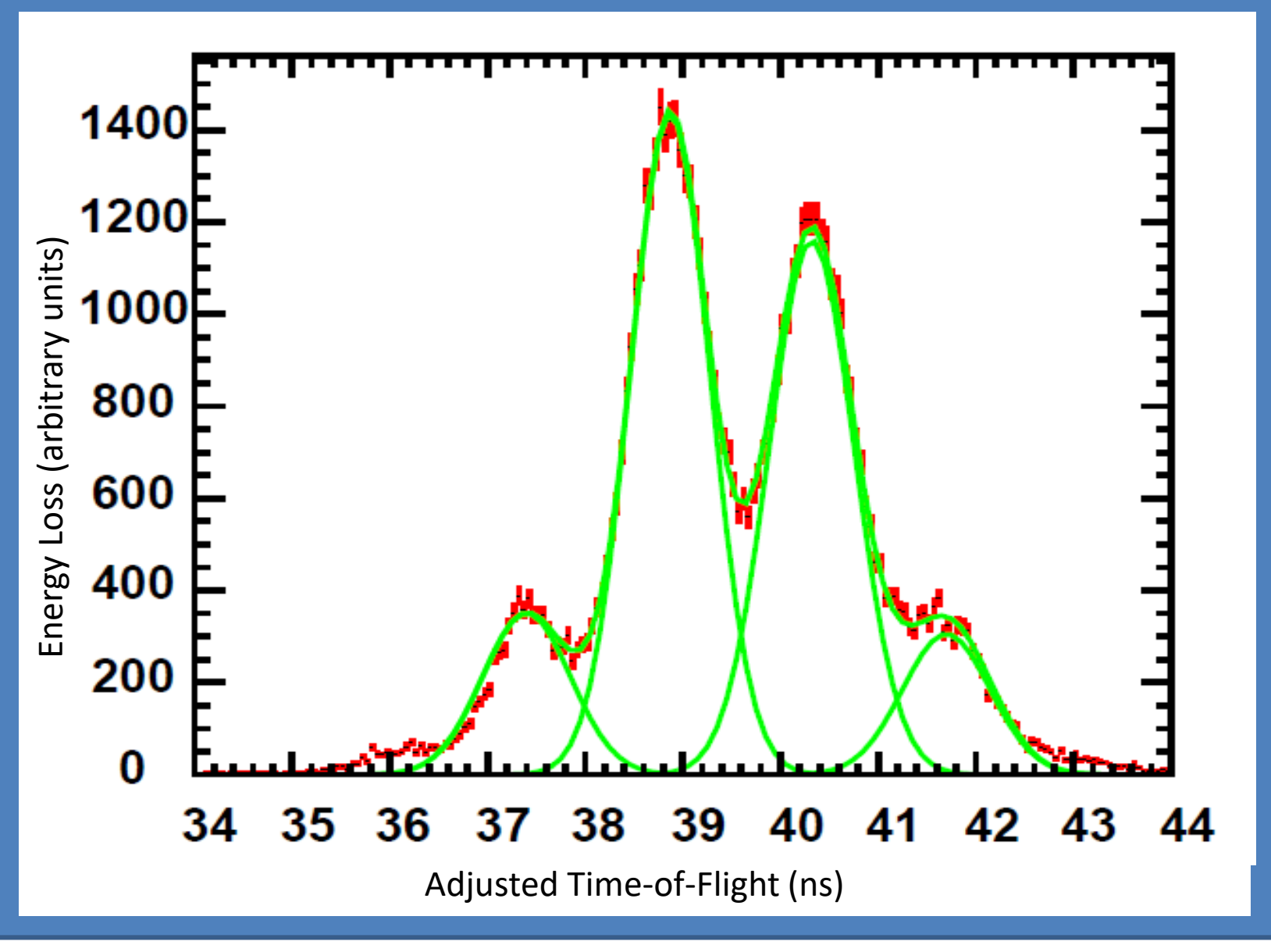
- The ^{27}Ne secondary beam reacts with the liquid deuterium target resulting in ^{26,25}F .
- ^{26,25}F emits a neutron shortly after being formed giving us ^{25}F + n or ^{24}F + n.
- The Sweeper magnet bends the charged particles into the charged particle detectors while neutrons continue straight to the MoNA-LISA detectors.

Isotope Separation

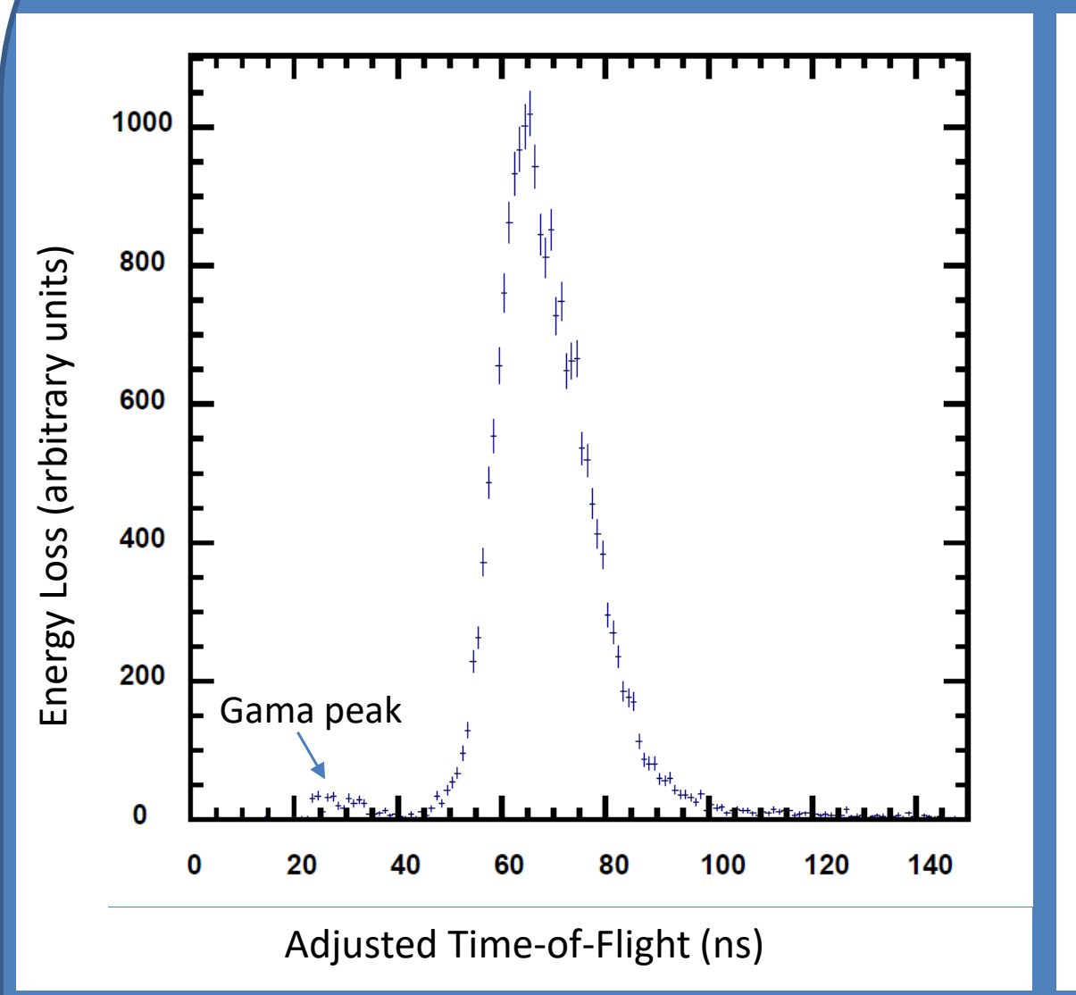




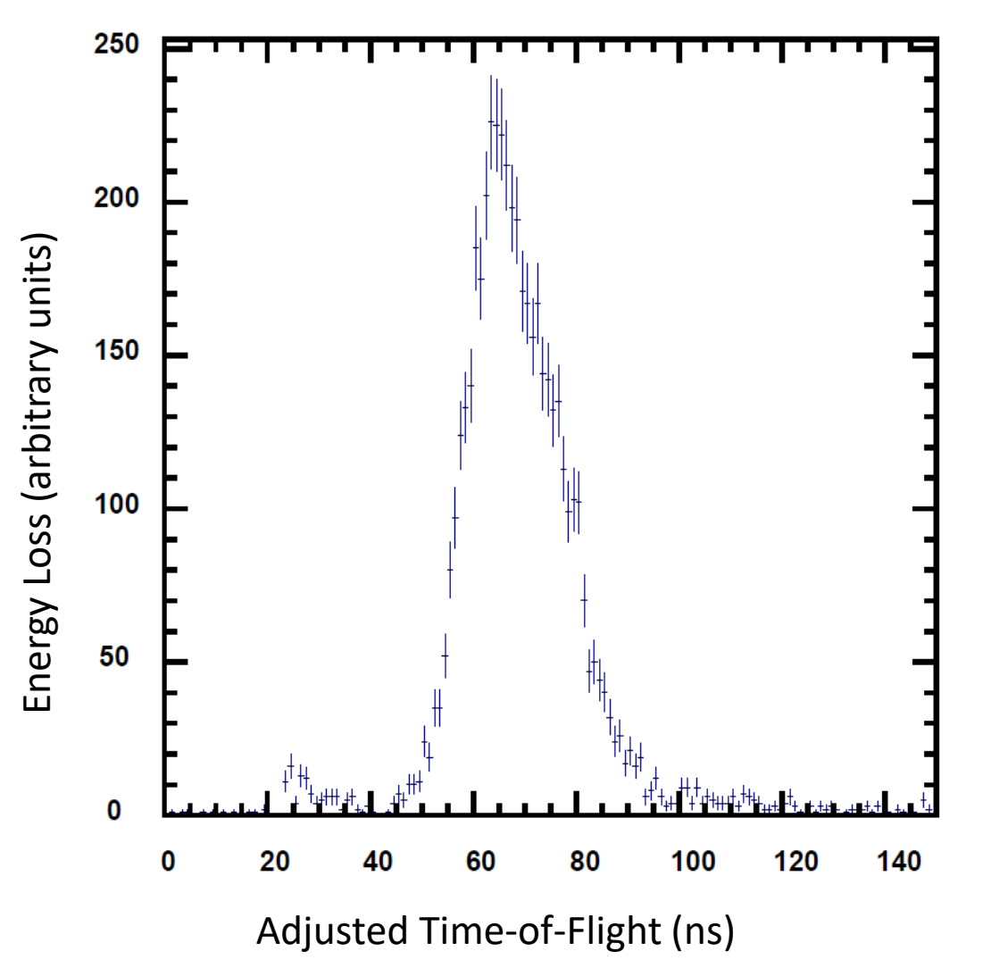
- Time-of-Flight (ToF) is the time it takes the charged fragment to get from the target to the fragment detectors.
- The energy loss separates the elements and is proportional to Z^2 where Z is the number of protons in the nucleus
- Adjusting the ToF based on charged particle trajectories results in isotope separation
- Nuclides generated from our secondary beam based on their adjusted ToF and energy loss is shown below.



Neutron Detection



Neutron Time-of-Flight ^{24}F



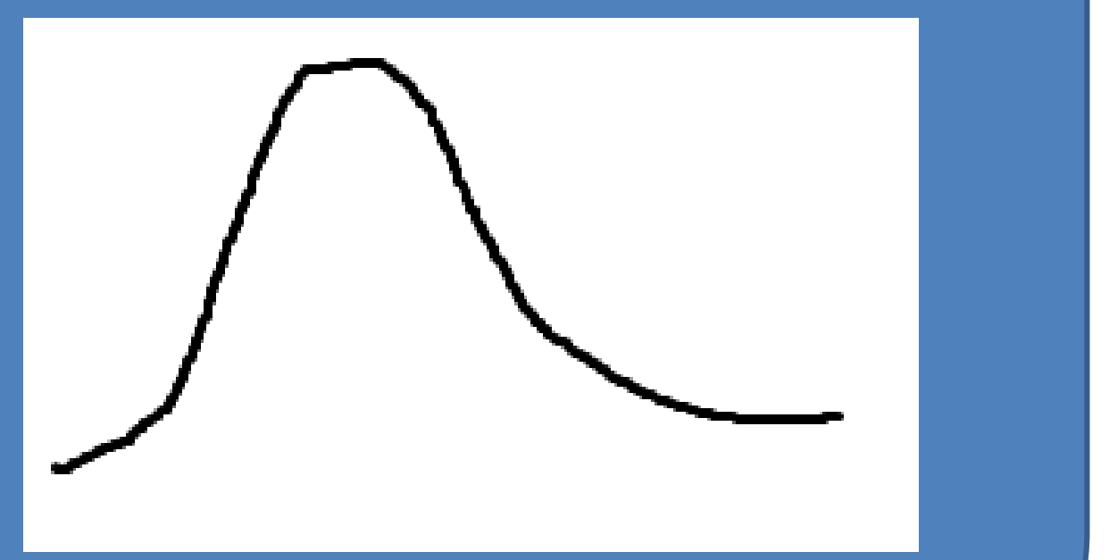
Neutron Time-of-Flight ^{25}F

- Neutron Time-of-Flight is the time it takes the neutron to get from the target to MONA and LISA.
- The is timed right before the liquid deuterium target to the MONA-LISA detectors.
- First peak is an interaction with the detectors and Gamma-rays.

Simulation Description

- The Monte Carlo simulation that we use to simulate our experiment requires a number of inputs
- ^{27}Ne beam energy (101.305 MeV/amu) along with position and angle distributions at the target
- Liquid deuterium target thickness (cylinder of diameter of 38 mm and a length of 30 mm) → in the simulation we use an equivalent energy loss with ^{9}Be instead of deuterium
- Identify the reaction product → ^{26}F* resulting from removing 1p or ^{25}F* resulting form removing 1p and 1n
- Reaction model[1] → momentum kick given to the product after reaction

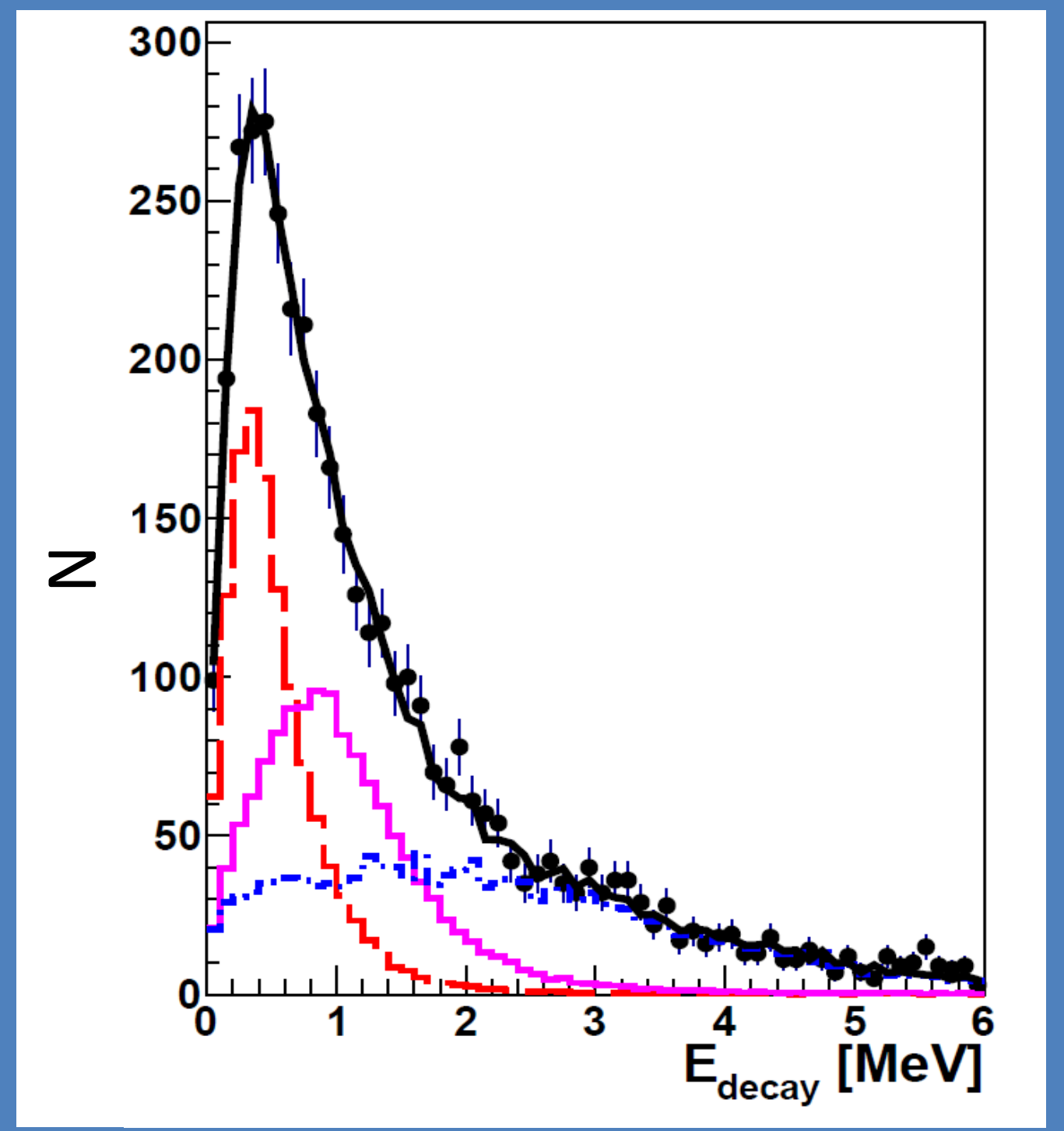
- Breit-Wigner distribution[2] for states that requires a centroid energy (E_r) and the width (Γ) of the peak used in the equation to the right
- Detector sizes, Sweeper magnet neutron window, charged particle and neutron detector dimensions, detector resolutions, and complete detector setup



[1] R.J. Glauber, in: W.E.. Brittin (Ed.). Lectures in Theoretical Physics, Vol 1, Interscience, New York, 1959, p. 35

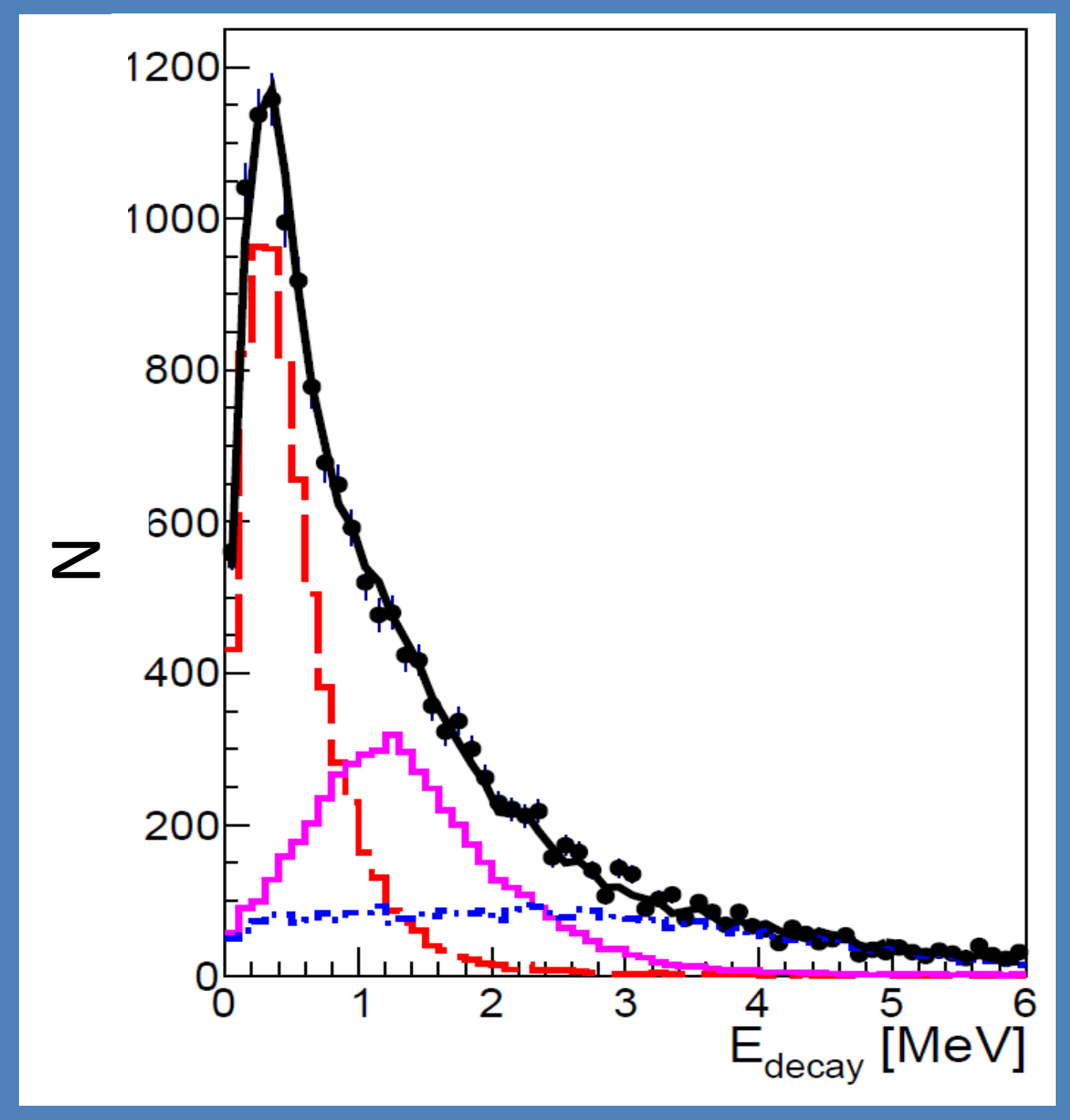
[2] A.M. Lane and R.G. Thomas. R-Matrix Theory of Nuclear Reactions. *Rev. of Mod. Phys.*, 30:257, 1958.

Simulation Overlay



Edecay of ^{26}F with simulation overlay

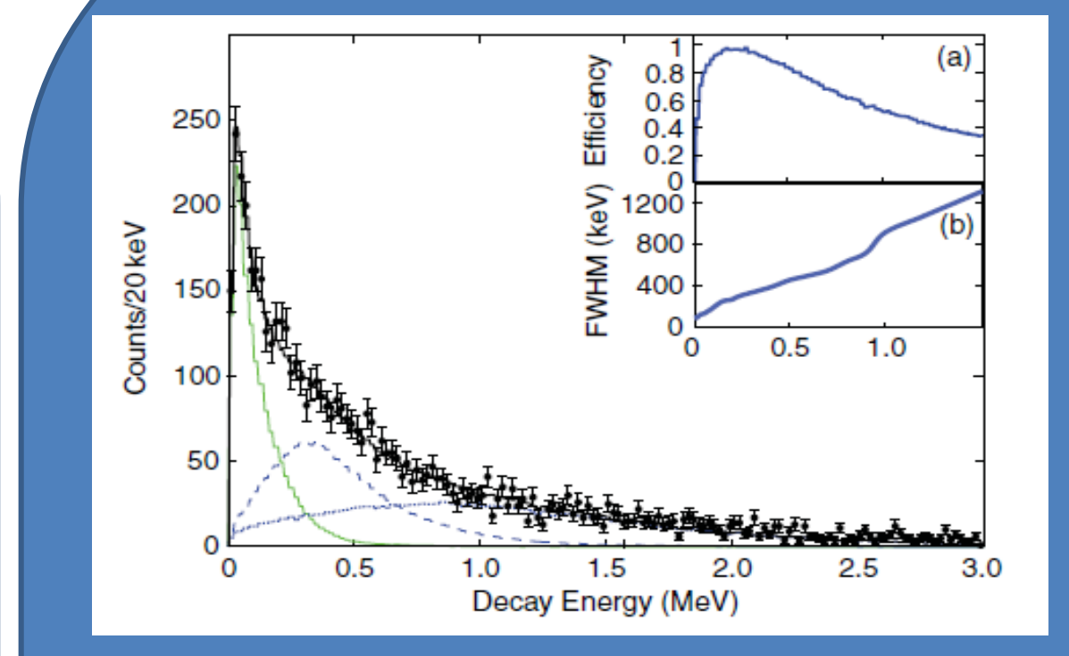
The three simulation peaks are (red line) .375 MeV peak with a .2 MeV width, (pink line) 1.0 MeV peak with a .6 MeV width, and (blue line) 3.0 MeV peak with a 2.0 MeV width.



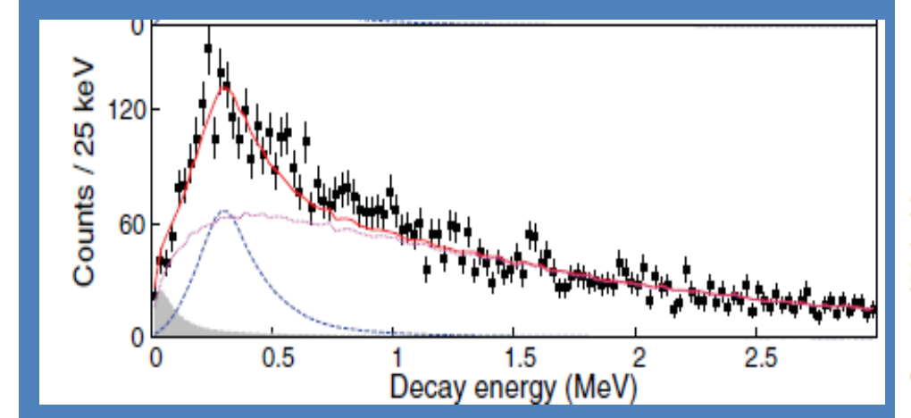
Edecay of ^{25}F with simulation overlay:

The three simulation peaks are (red line) .35 MeV peak with a .3 MeV width, (pink line) 1.45 MeV peak with a .6 MeV width, and (blue line) 3.5 MeV peak with a 2.0 MeV width.

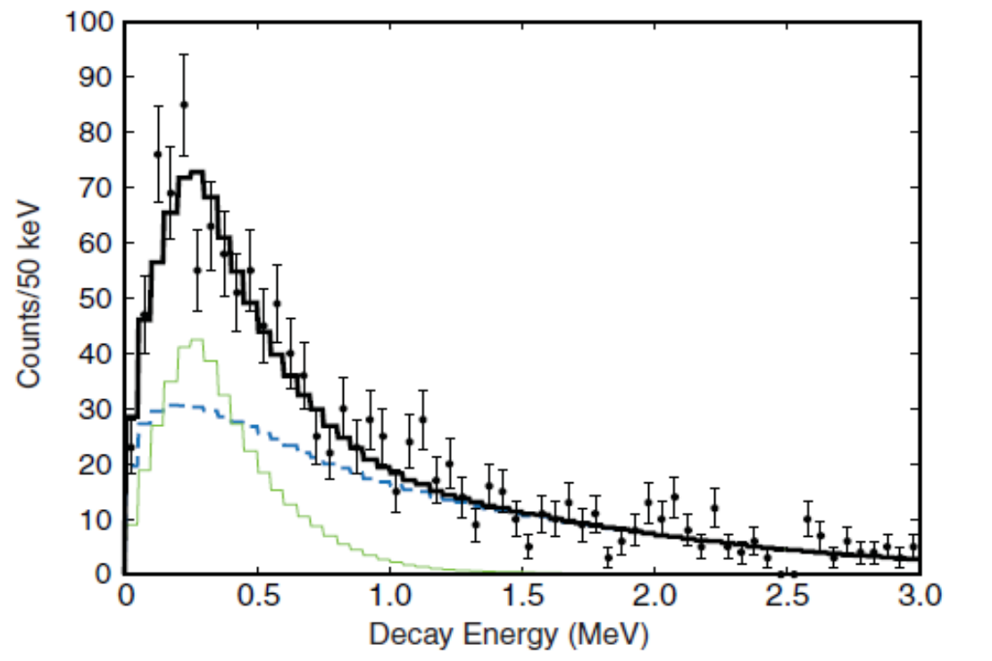
Prior Results



This figure (taken from Reference 1) shows the decay energy of ^{25}F with resonances at (green line) 28 KeV, (thin line) 350 KeV, and (dotted line) 1200 KeV.



This figure (taken from Reference 4) shows the decay energy of ^{25}F with a resonance at (blue line) 300 KeV and (purple line) a non-resonant background



This figure (taken from Reference 1) shows the decay energy of ^{26}F with a resonance (green line) at 270 KeV on top of a non-resonant background (blue line).

- Neutron-unbound and bound states of ^{26}F have been observed in prior experiments[1,2,3]
- The MoNA Collaboration found a resonance[1] produced from a nucleon-exchange reaction between a secondary beam of ^{26}Ne and a target of ^{9}Be
- The state was difficult to determine due to the type of reaction in that experiment.
- The data presented in this poster looks different from this prior result possibly due to the different reactions or some additional background

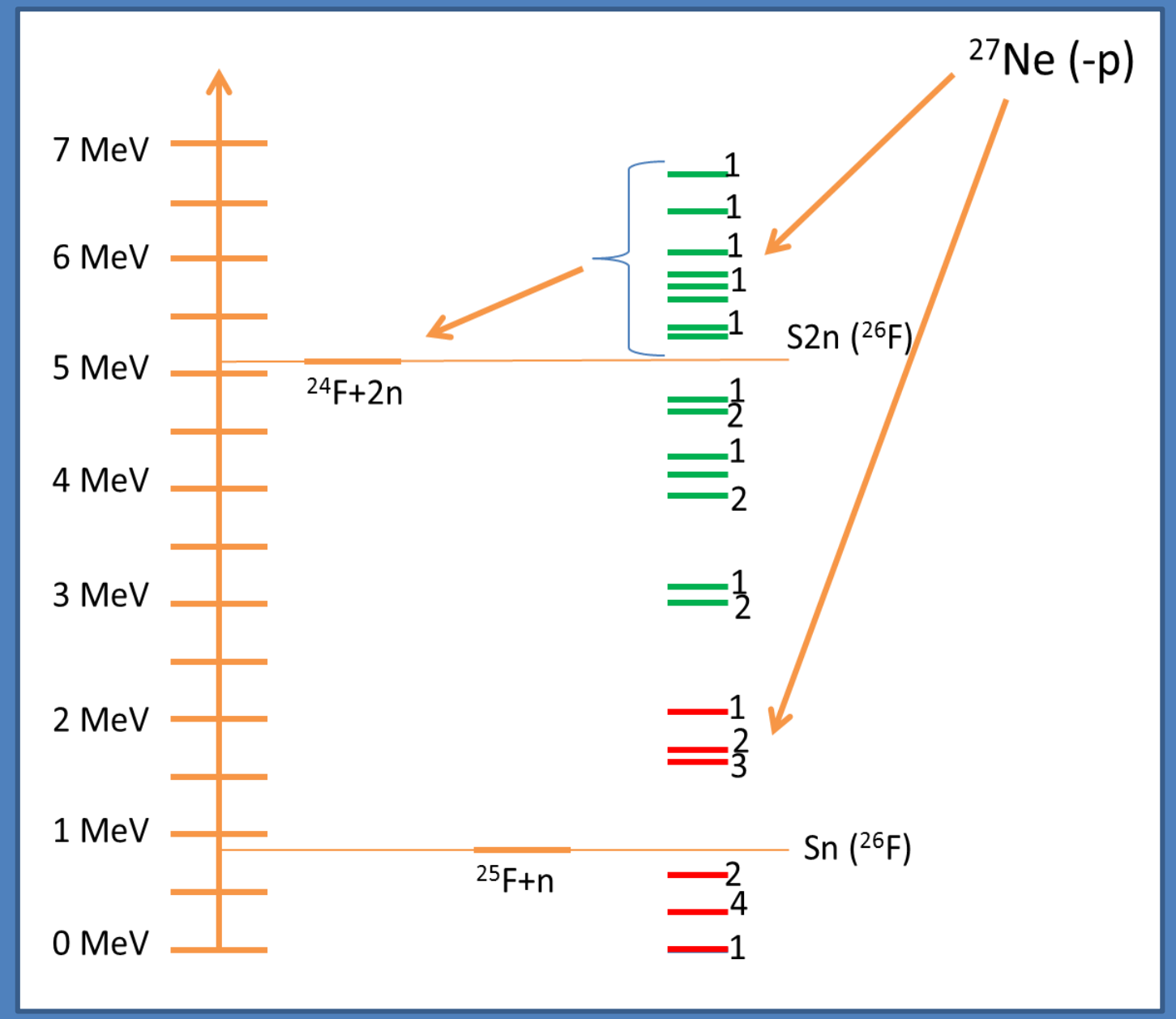
[1] N, Frank, *et.al, PRC 84, 037302 (2011)*

[2] M., Stanoiu, *et.al*, PRC 85, 017303 (2012)

[3] A. Lepailleur, *et.al*, PRL 110, 082502 (2013)

[4] J.K. Smith, *et.al*, PRC 86, 057302 (2012)

Interpretation



- The states above the S_{2n} line have enough energy to emit a neutron and are still unstable and emit another neutron and ends at a stable ^{24}F with two emitted neutrons
- The three positive states (red lines) above the s_n line have enough energy to emit a neutron and end a stable ^{25}F with one emitted neutron
- Theoretical calculations for the different ways ^{27}Ne produces ^{25}F or ^{26}F.
- Green lines are for negative parity and red lines are for positive parity.
- A parity is how the state is mathematically represented with a positive parity being a cosine function and a negative parity is a sine function.
- Theory calculation using NuShell[1]

[1] B. A. Brown and W. D. M. Rae; Nuclear Data Sheets **120**, 115 (2014)

Outlook

- The difference between the prior results and our data will be explored.
- Publish a journal article on the unbound states of ^{25}F and ^{26}F.
- We plan to reconstruct a 3-body decay energy spectrum

Acknowledgements

We thank our MoNA Collaboration colleagues, especially Jaclyn Brett and Dr. Paul DeYoung from the Hope College Nuclear Group. We would like to acknowledge support from NSF grant #1404236 and Augustana College.