Construction of the Solenoid Spectrometer for Nuclear AstroPhysics (SSNAP) at Notre Dame

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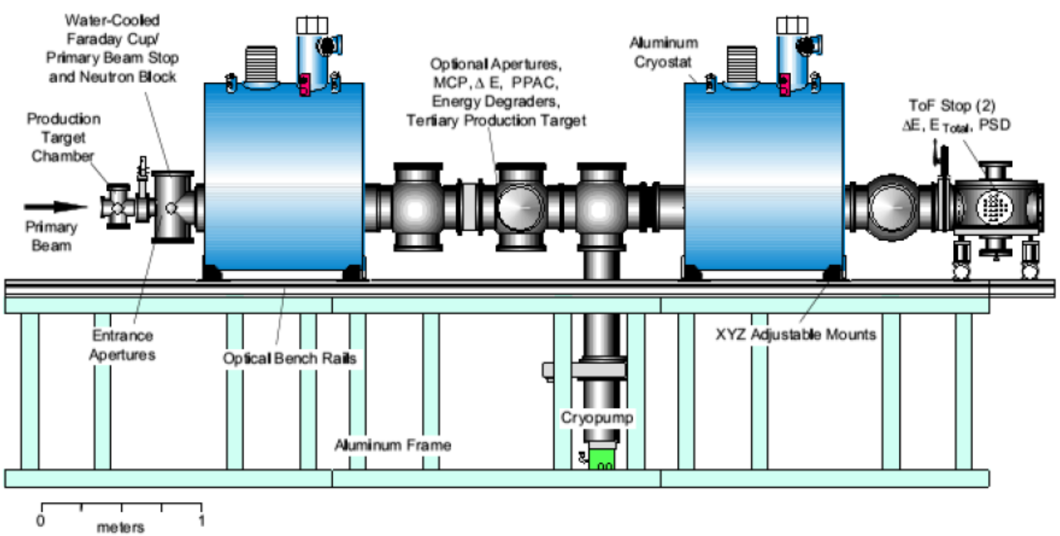
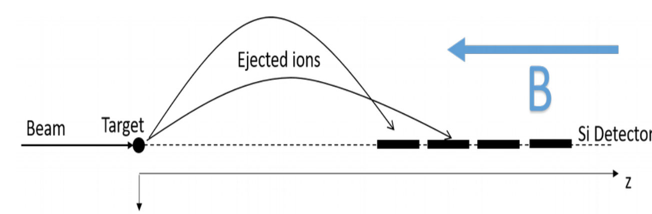
SSNAP Overview

- TwinSol, two paired superconducting-solenoids used for the creation of radioactive ion beams
  - Usually lighter beams (e.g. ^{7}Be, ^{17}F, ^{25}Al, etc)
- SSNAP: Solenoid Spectrometer similar to HELIOS
  - Instrumented with an array of position-sensitive silicon detectors
- Used to detect light-ion ejectiles from reactions important for astrophysics





Advantages

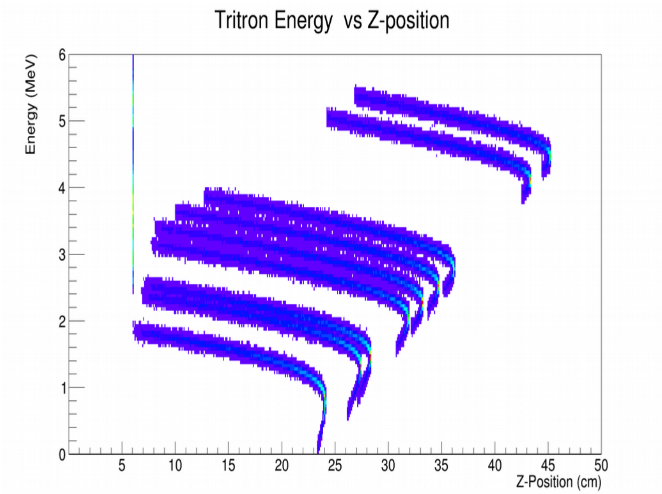
- In the presence of a magnetic field, ejected charged particles will orbit around the beam axis . The path the ion takes is dependent on its charge-to-mass ratio, energy, and ejected angle.
- Using SSNAP, three quantities can be measured from a reaction:
  1. Time-of-flight of the ejected particles, T_{cyc}
  2. Energy of ejected particle in laboratory frame, E_{lab}
  3. Detected position in the Z-direction, z
- These quantities can be used to reproduce the energy and emitted angle in the center of mass frame

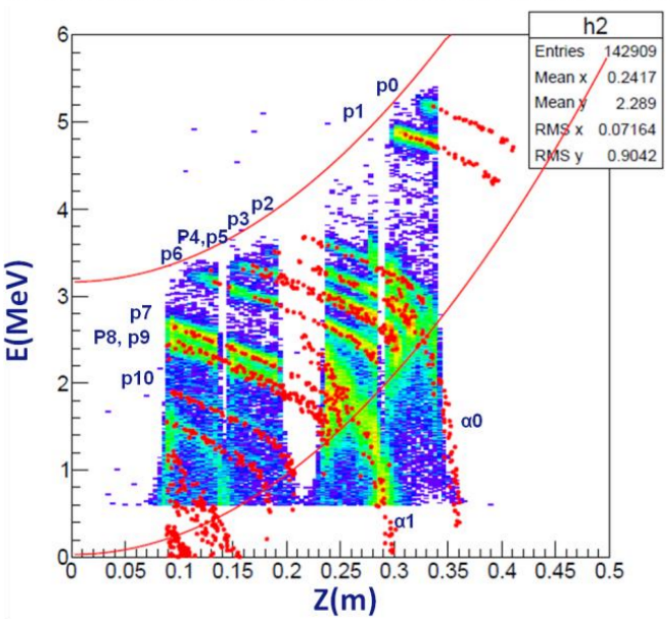
Ion	T_{cyc} (ns)		
	$\mathscr{B} = 1\mathrm{T}$	$\mathscr{B} = 3\mathrm{T}$	$\mathscr{B} = 6\mathrm{T}$
p	65.121	21.707	10.853
d	130.241	43.414	21.707
t	195.362	65.121	32.560
^{3}He	97.681	32.560	16.280
^{4}He	130.241	43.414	21.707

$$\theta_{CM} = \cos^{-1}\left(\frac{1}{2\pi}\frac{qeBz - 2\pi m V_{CM}}{\sqrt{2mE_{lab} + m^2 V_{CM}{}^2 - mV_{CM}qeBz/\pi}}\right)$$

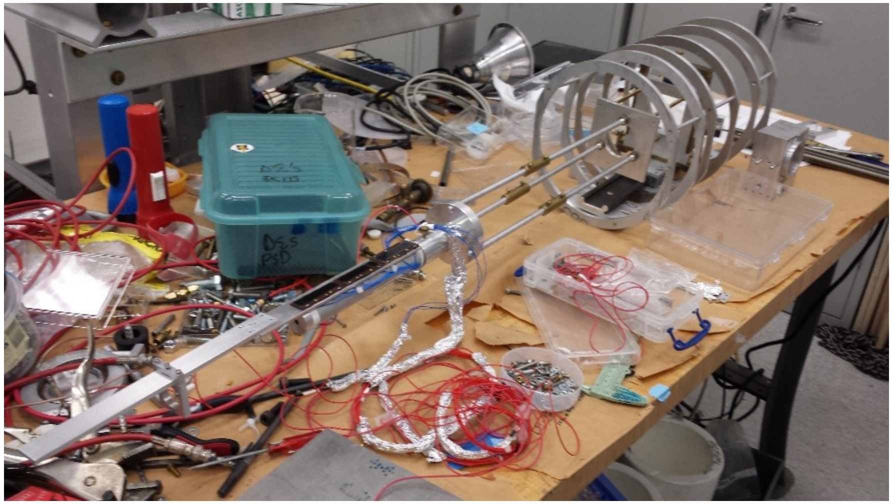
$$E_{cm} = E_{lab} + \frac{1}{2}mV_{CM}{}^2 - \frac{mV_{cm}z}{T_{cyc}}$$

First test of SSNAP (oSSNAP)

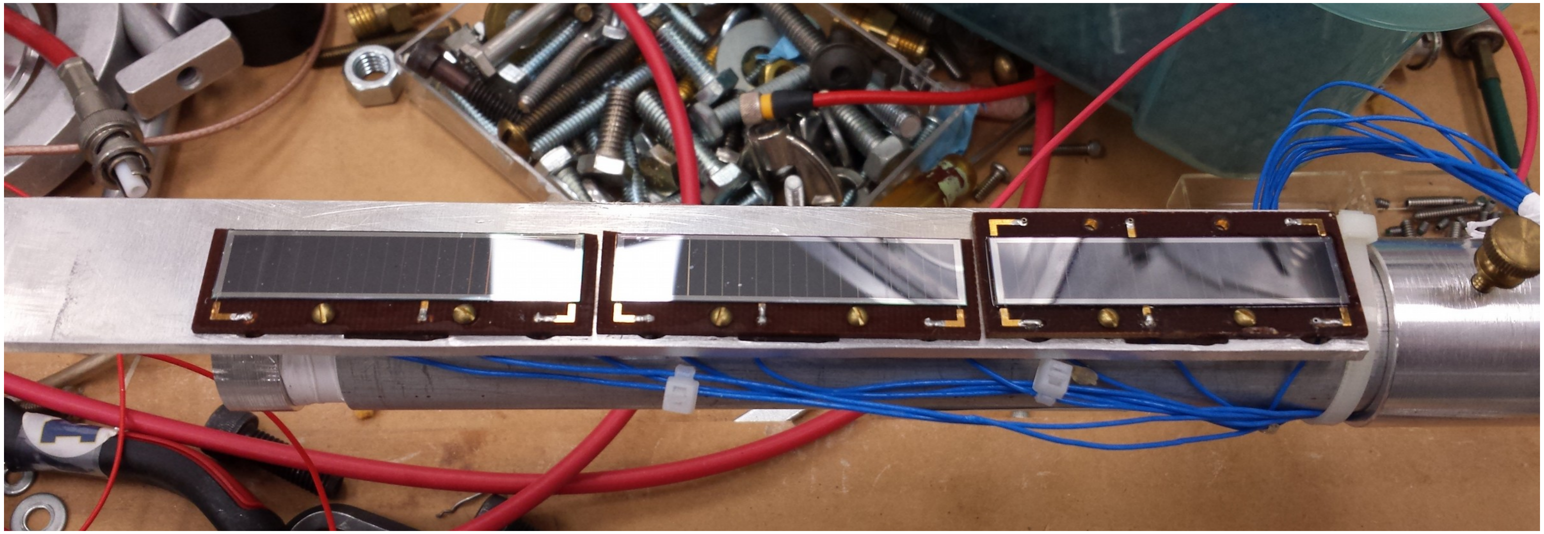




- $^{12}C(^{12}C,p)^{23}Na$
- E_{CoM} = 5 Mev
- 5.8μm aluminum degrader covering detectors
- Able to reproduce the positions of the detected states



oSSNAP to SSNAP



- Full array of Super-X3 detectors to replace older ones
  - Versatile array, can be used in other experimental setups
- Updated frame – Optimized for normal kinematics
- Updated electronics (multi-channel preamps, Mesytec shapers, etc)
- Stable beams
- Multi-target holder
- (d,p), (p,α), (^{3}He,t), …

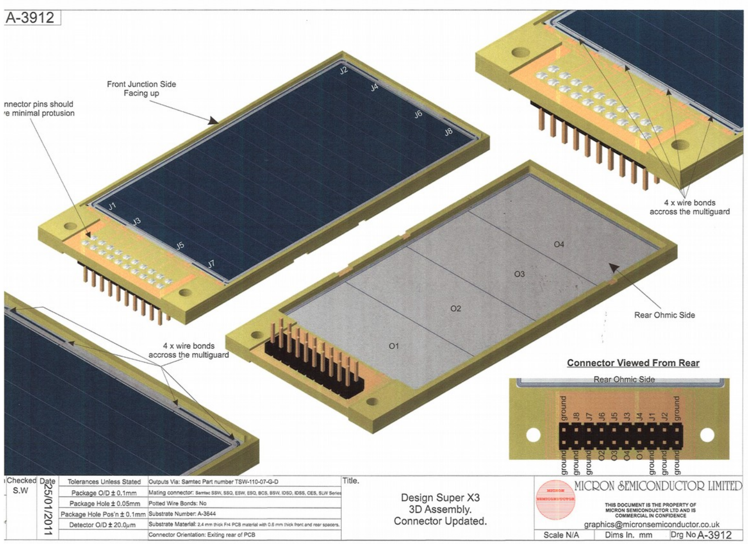
Super-X3 Detectors

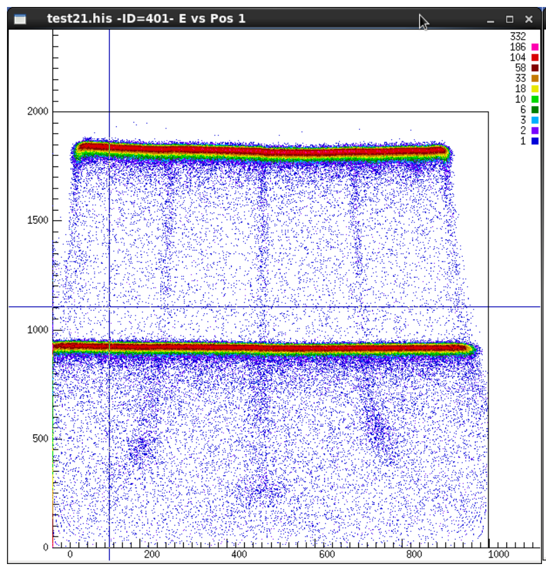
- 4 Resistive Front Strips
- 4 Back Segments
- 7.5 cm length

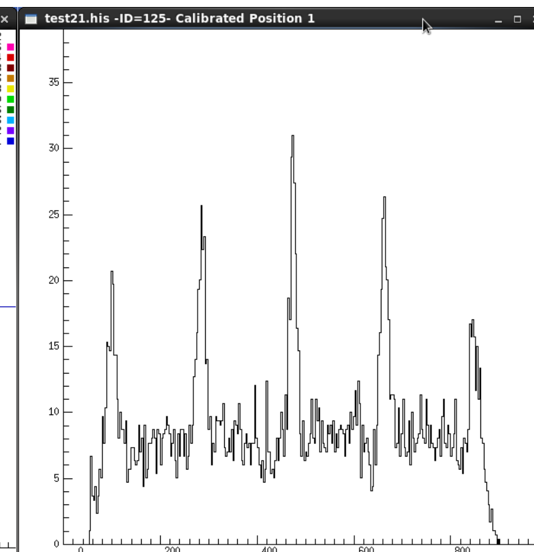
Energy Resolution: Back ~55 keV

Front ~75 keV

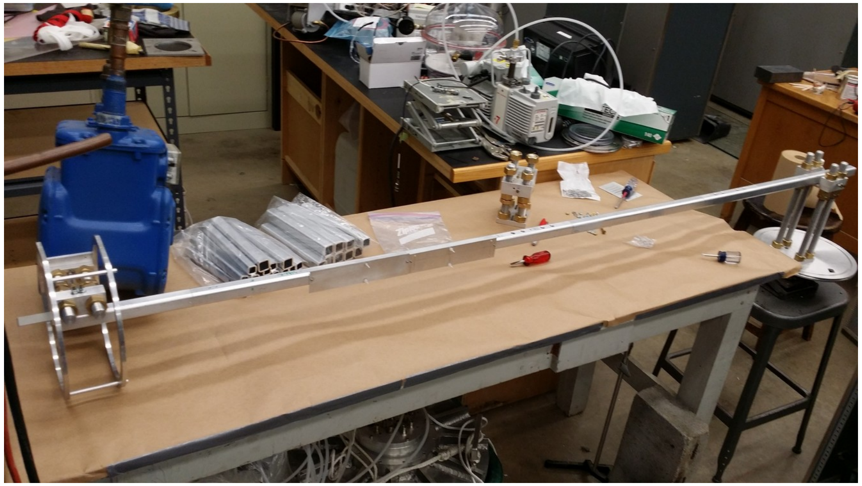
Position Resolution: ~1.2 mm

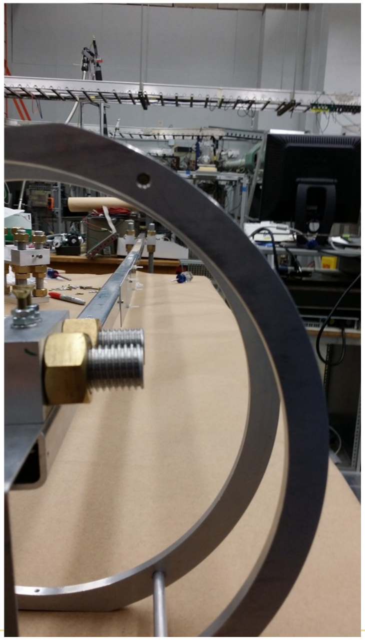


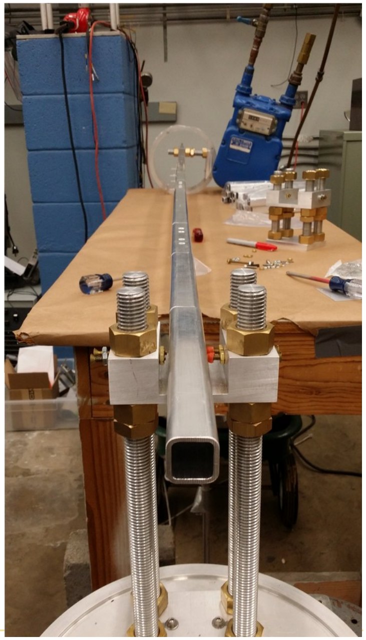


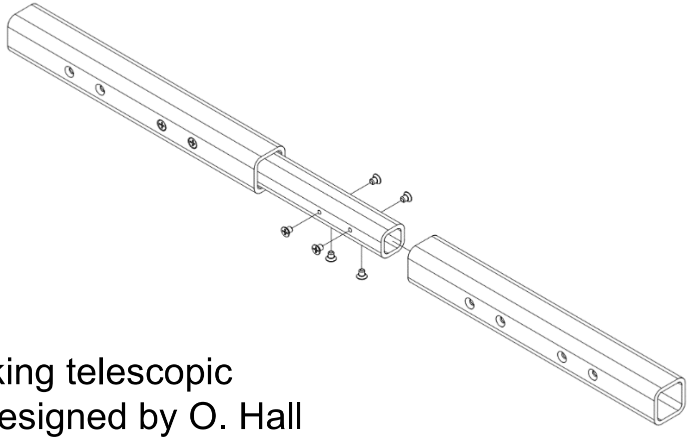


Mounting Frame



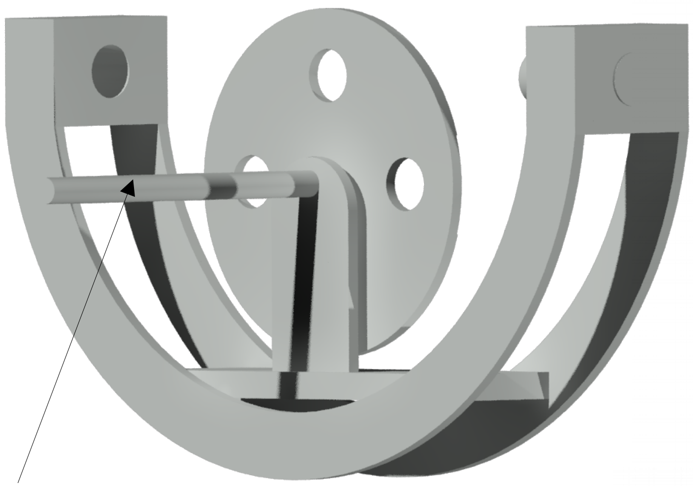




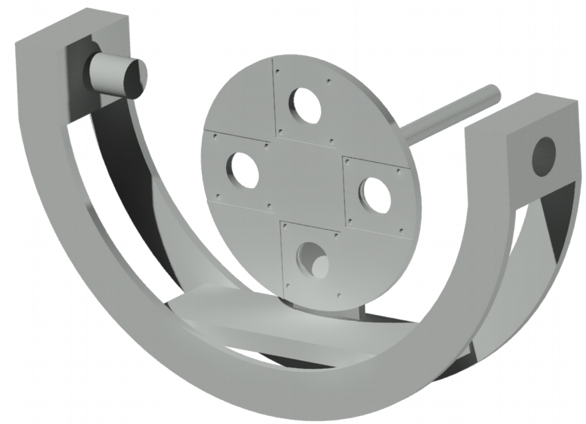


Interlocking telescopic
tubing designed by O. Hall

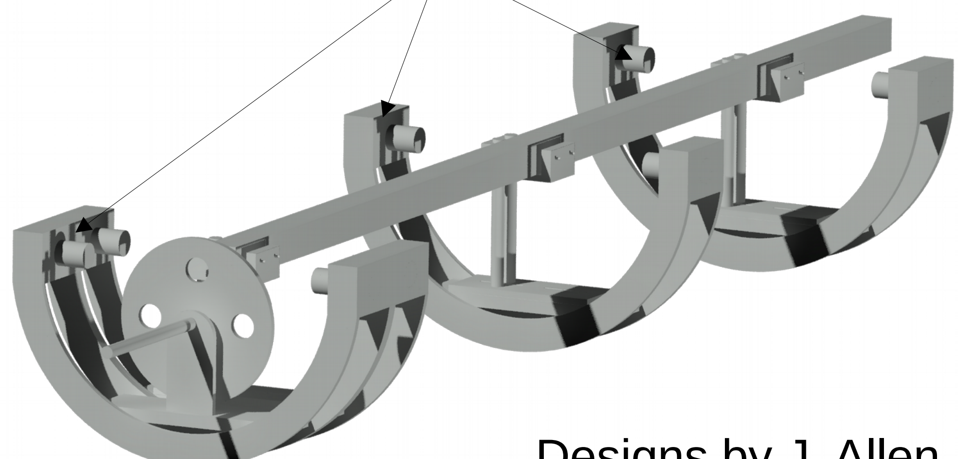
Mounting Frame - target ladder



Attaches to rotatable feedthrough



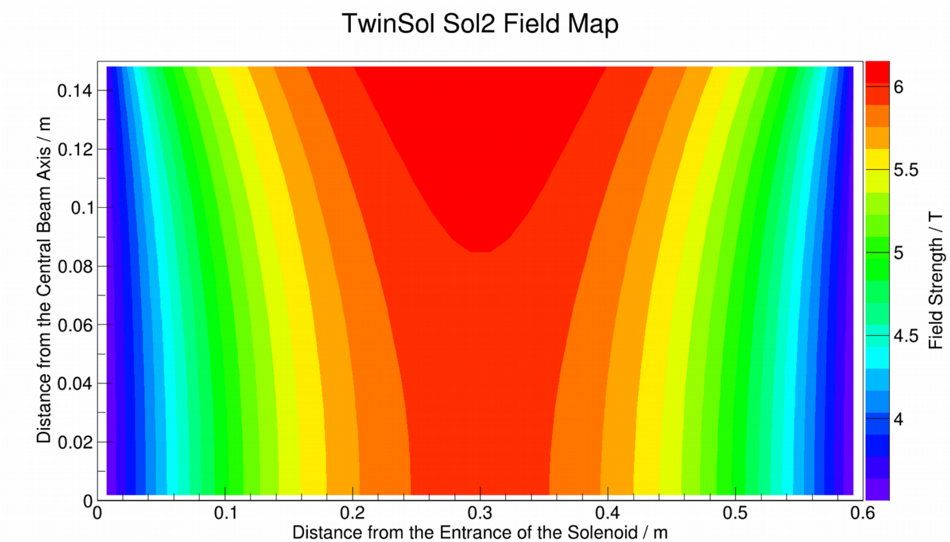
Alignment bolts

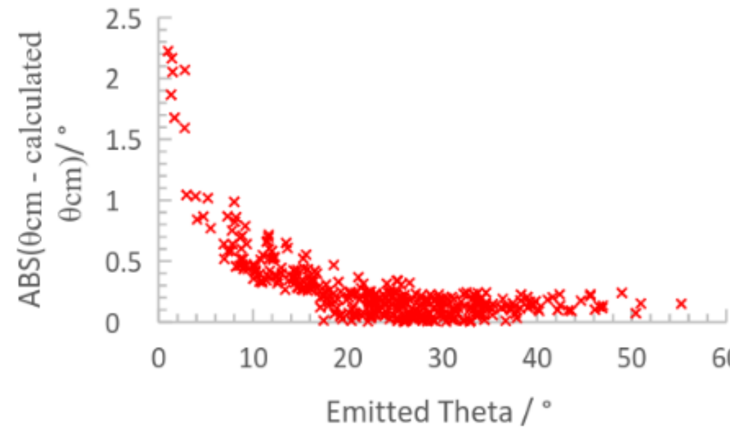


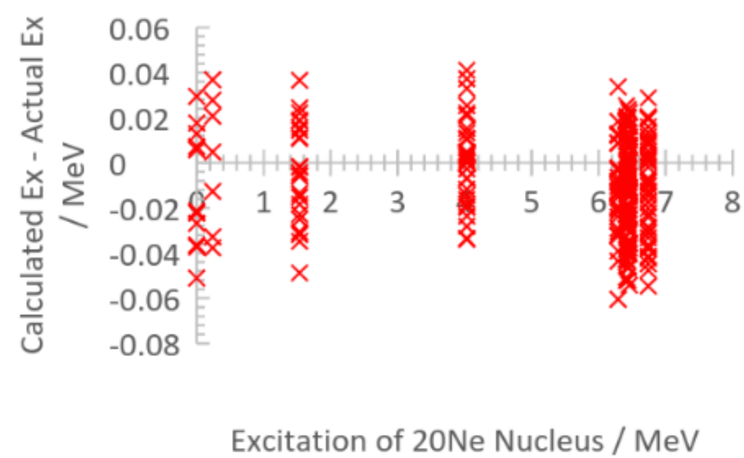
- Target ladder currently optimized for existing targets
  - Plan is also to have one designed for smaller target frames to allow for more targets

Designs by J. Allen

Effect of non-uniform field



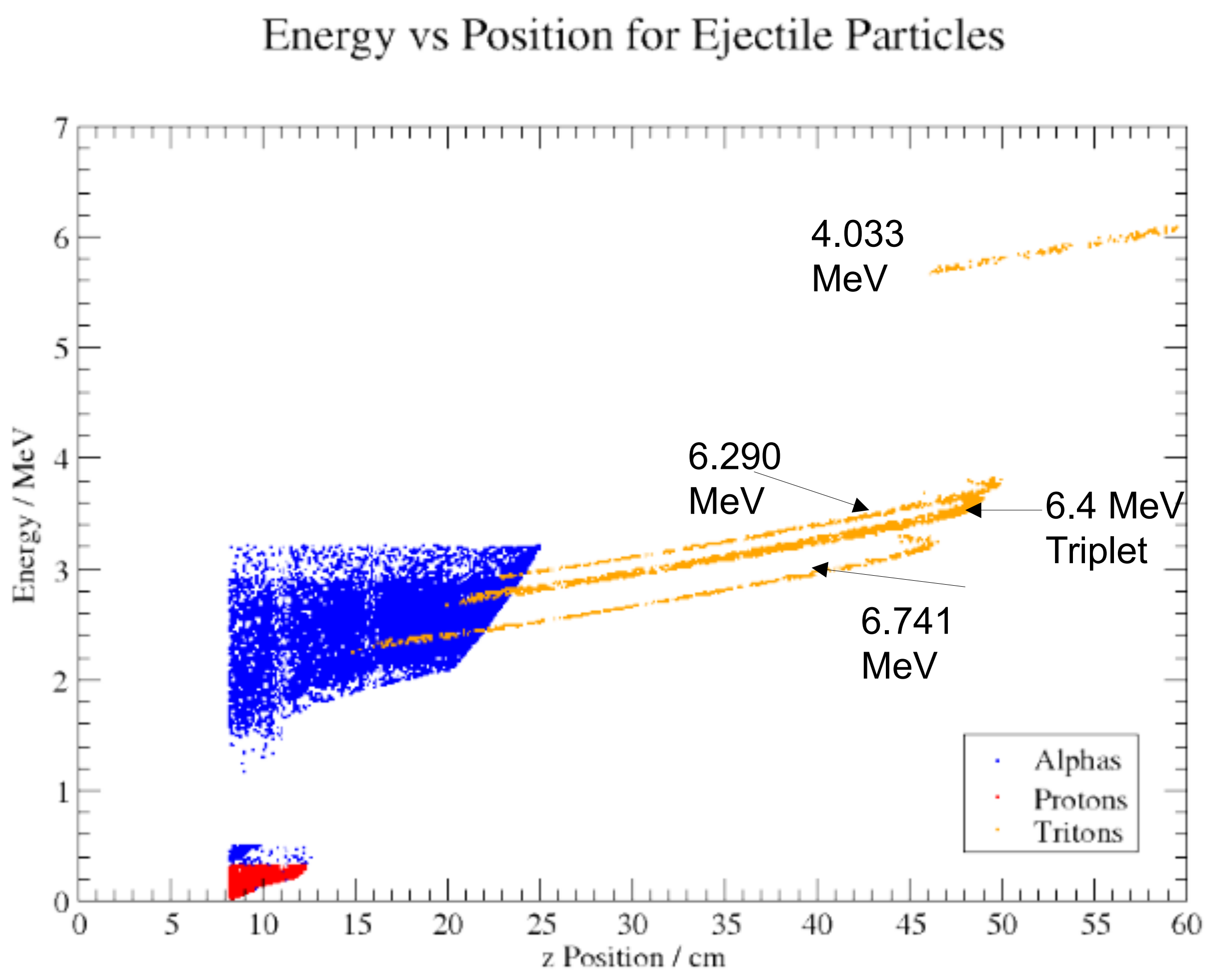




- TwinSol fields non-uniform
- May have larger uncertainties in position-to-angle conversions
- Simulations done using TwinSol mapping to characterize the precision of angular determination
- Find that above 20º, the angle is accurately determined to within 0.5º

Simulated $^{19}F(^{3}He,t)^{19}Ne$ at E_{beam} = 14 MeV

- States near proton threshold in ^{19}Ne important for understanding gamma ray emission from novae
- Possible triplet at ~E=6.4 MeV could interfere with strong, higher-lying resonance
- Attempted to measure energies and spins of this possible triplet with GODDESS
- Would also be nice to understand particle emission branchings
  - States are above the proton and alpha emission thresholds



ReA6 Solenoid Spectrometer

- Optimized for inverse kinematic
  - Allow for possible normal kinematic experiments?
- Possible gas cell target for use with ^{3}He gas
  - (^{3}He,t) and (^{3}He,d) are nice probes of proton-rich nuclei
- High detector efficiency – instrument all sides of detector mount
- Resistive-strips for position and segmented backsides for energy
- Recoil detector with position-sensitive initial grids
  - Allows for full kinematic reconstruction

Acknowledgements

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F. D. Becchetti (U.Michigan), J. C. Blackmon (LSU), S. D. Pain (ORNL)

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