Investigating the Isoscalar Giant Monopole Resonance in Ni-70 using the Active-Target Time-Projection Chamber and S800 Spectrometer

Tan Ahn

University of Notre Dame

ECT* Workshop on Giant Resonances

ECT*, Trento, Italy

July 12, 2022

Brief Outline

UNIVERSITY OF NOTRE DAME

- Motivation and Experiment
- Preliminary Analysis
- Challenges and Outlook
- Summary

Brief Outline

UNIVERSITY OF NOTRE DAME

- Motivation and Experiment
- Preliminary Analysis
- Challenges and Outlook
- Summary

Isoscalar Giant Monopole Resonance

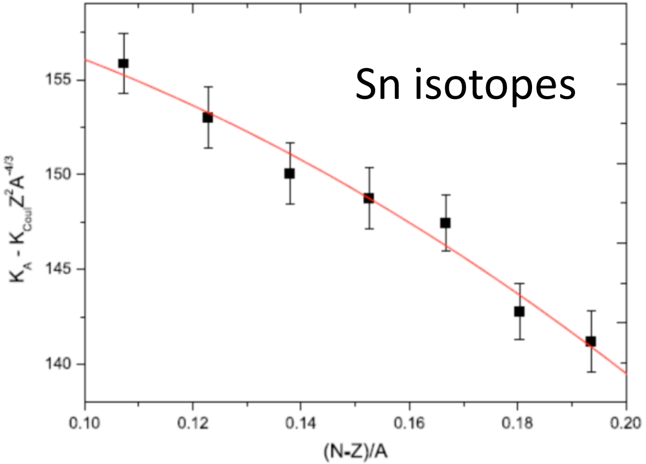
UNIVERSITY OF NOTRE DAME

- L=0, breathing mode
- Related to nuclear incompressibility of finite nuclear matter
- Symmetry energy; constrain nuclear equation-of-state; properties of neutron stars
- Evolution as a function of isospin; need ISGMR in very isospin asymmetric nuclei

Isoscalar Giant Monopole Resonance (ISGMR)

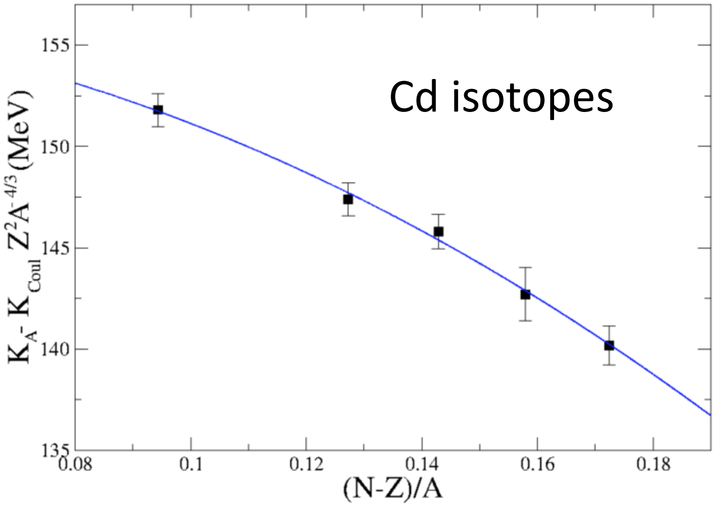
$$K_A \approx K_{\mathrm{vol}} + K_{\mathrm{surf}} A^{-1/3} + K_\tau \alpha^2 + K_{\mathrm{Coul}} \frac{Z^2}{A^{4/3}} + \ldots$$

$$E_{\mathrm{ISGMR}} = \hbar \sqrt{\frac{K_A}{m \langle r_0^2 \rangle}}$$



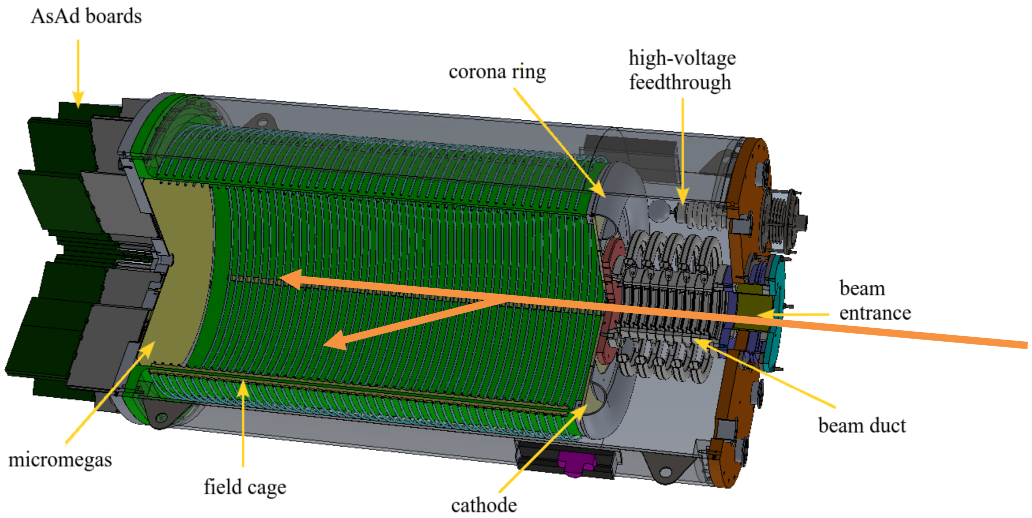
- K_A, finite nuclear incompressibility
- K_τ related to symmetry energy
- K_τ can be constrained by ISGMR measurements
- Measure curvature: most isospin asymmetric nuclei

Ni isotopic chain



- Medium-mass region; ^{70}Ni
  - Previous measurements
- Range of isospin
- Availability of neutron-rich Ni isotopes
- ^{70}Ni: (N-Z)/A = 0.2

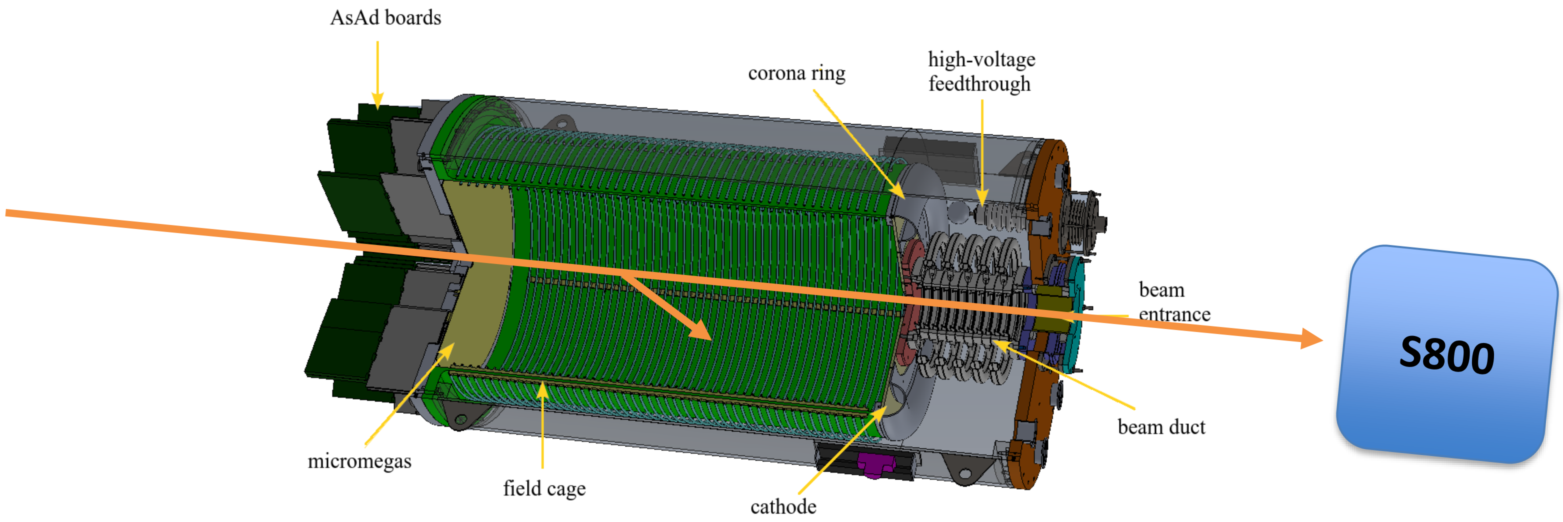
Inelastic alpha scattering with the AT-TPC



- GMR -> Small angles -> 90 deg in C.O.M. frame -> 0 energy
- Gas target; Active-target time-projection chamber
- Image tracks; Several cm alpha track length
- Thick target, high geometrical efficiency

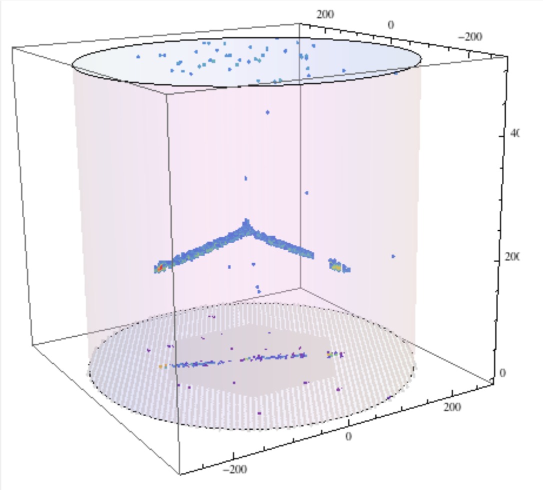
Tagging Ni recoils

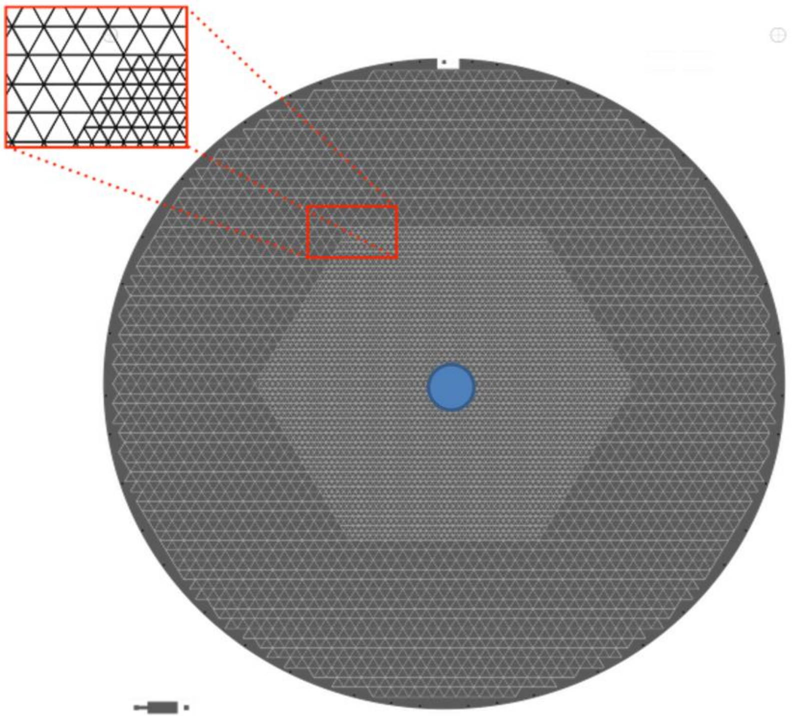
UNIVERSITY OF NOTRE DAME



- Inelastic cross section; elastic scattering background
- S800 spectrometer to tag Ni recoils
- Modification to AT-TPC
- Beam and reactants to pass through

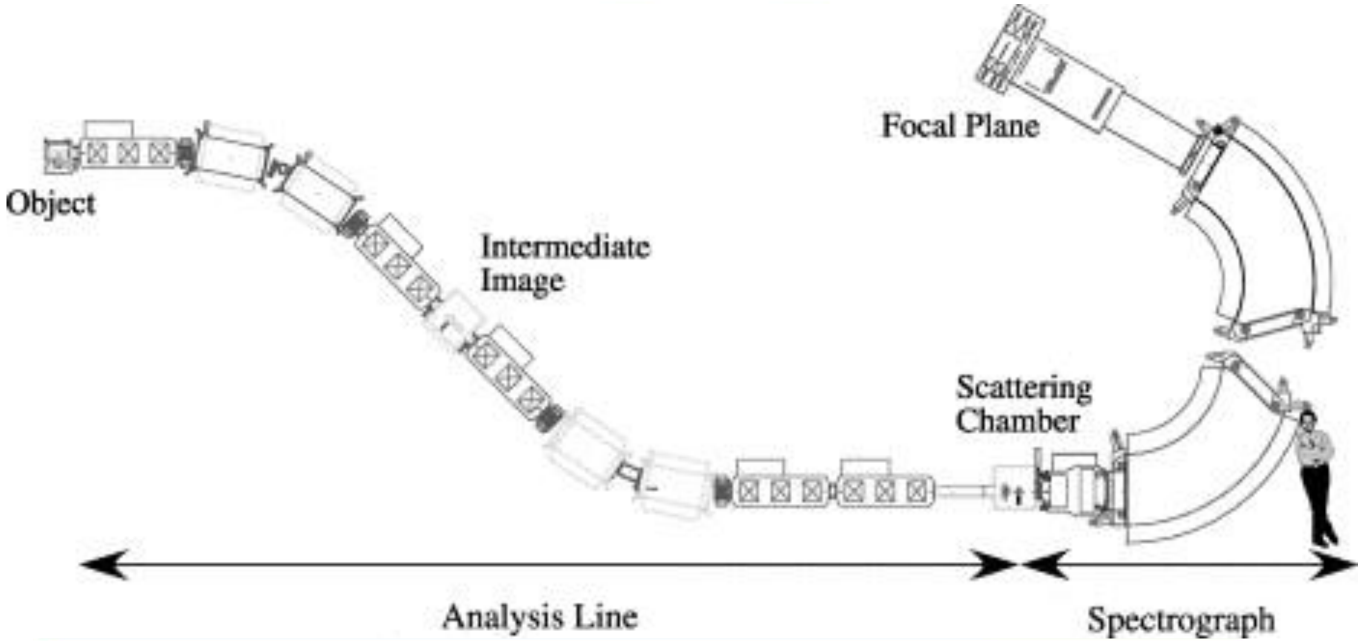
AT-TPC GEM/Micromegas





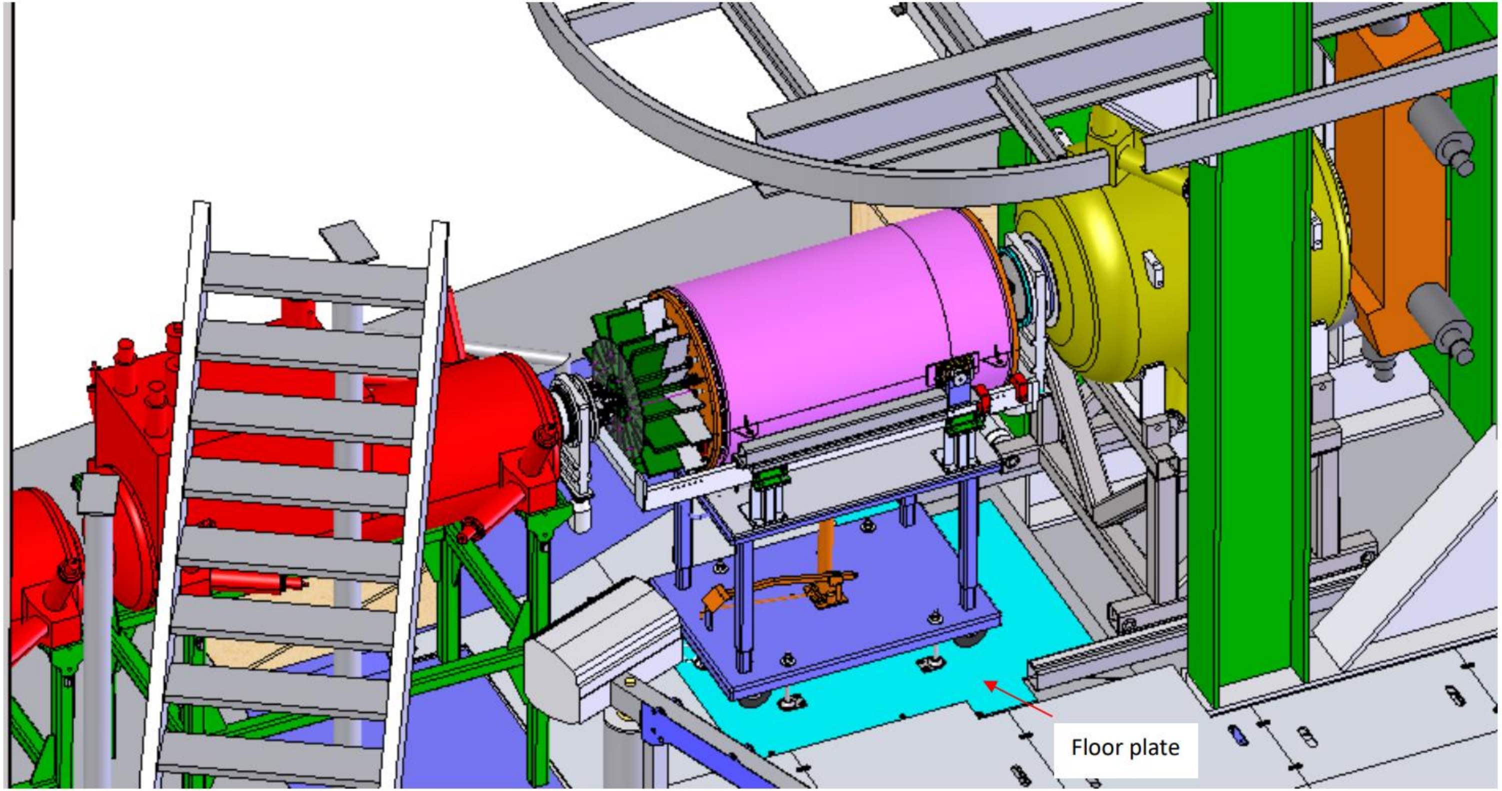
- 10,240 triangular pads
- GEM + Micromegas (gain 10^6)
- Use of pure He gas
  - Gas-recirculator, filter
- 3 cm diameter hole

AT-TPC coupled to S800



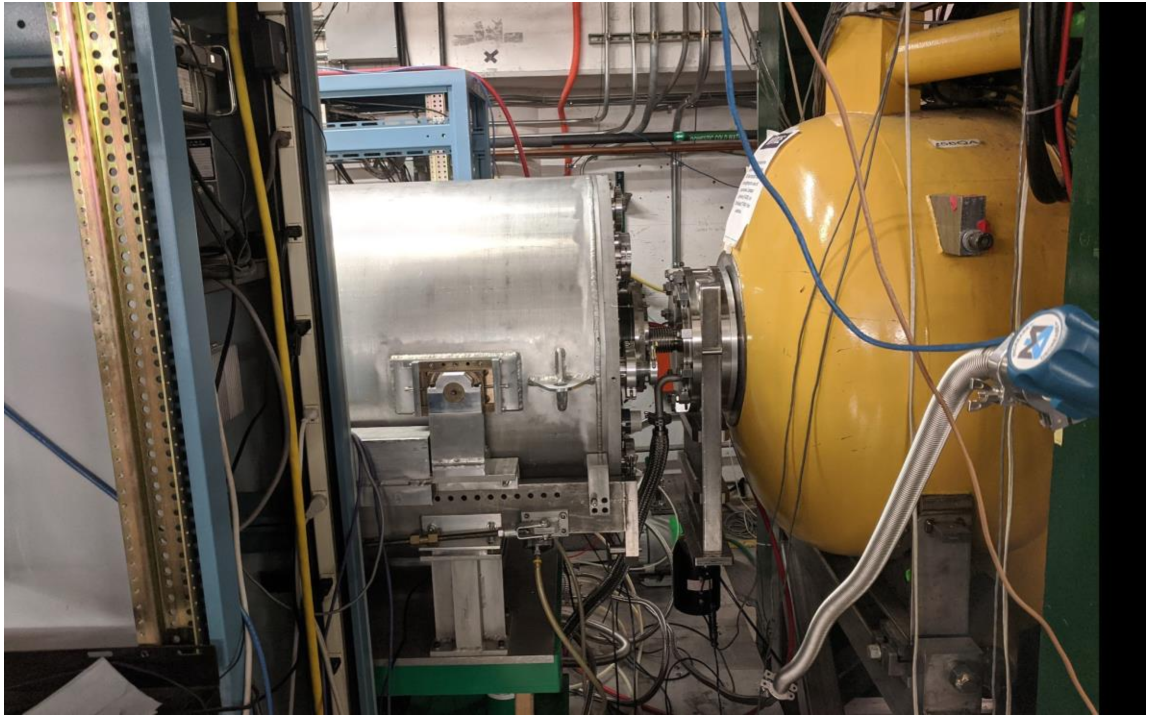
S800 Target Position

University of Notre Dame

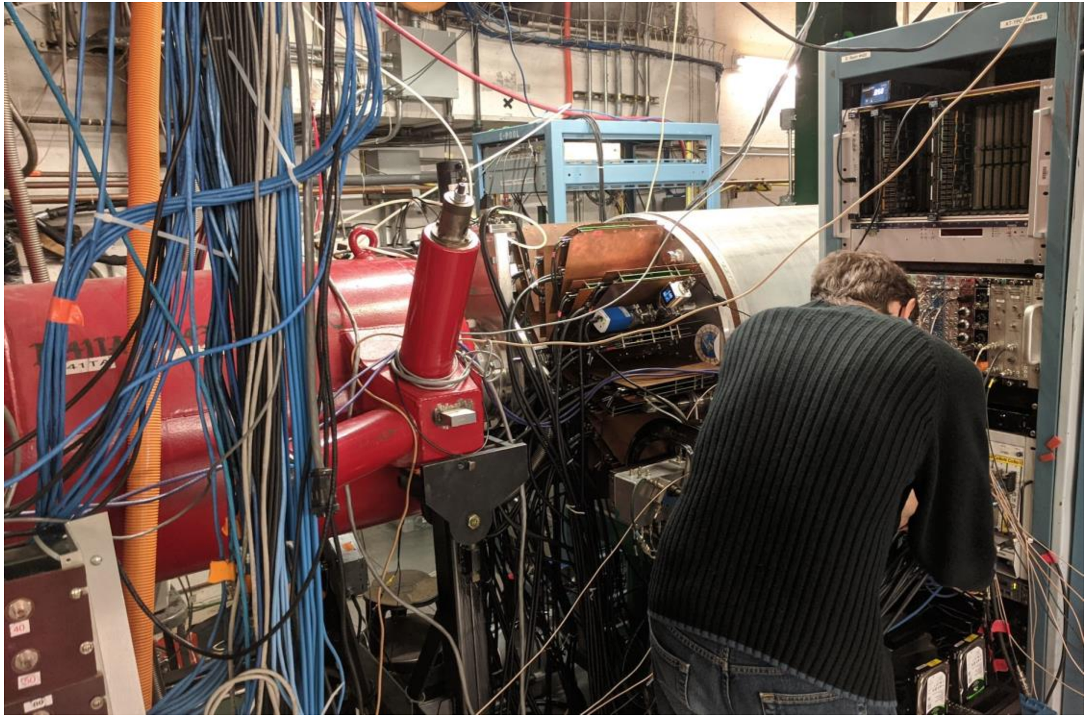


18008 – Zamora & 18027 – Ahn (shown without raised floor)

AT-TPC (upstream side)

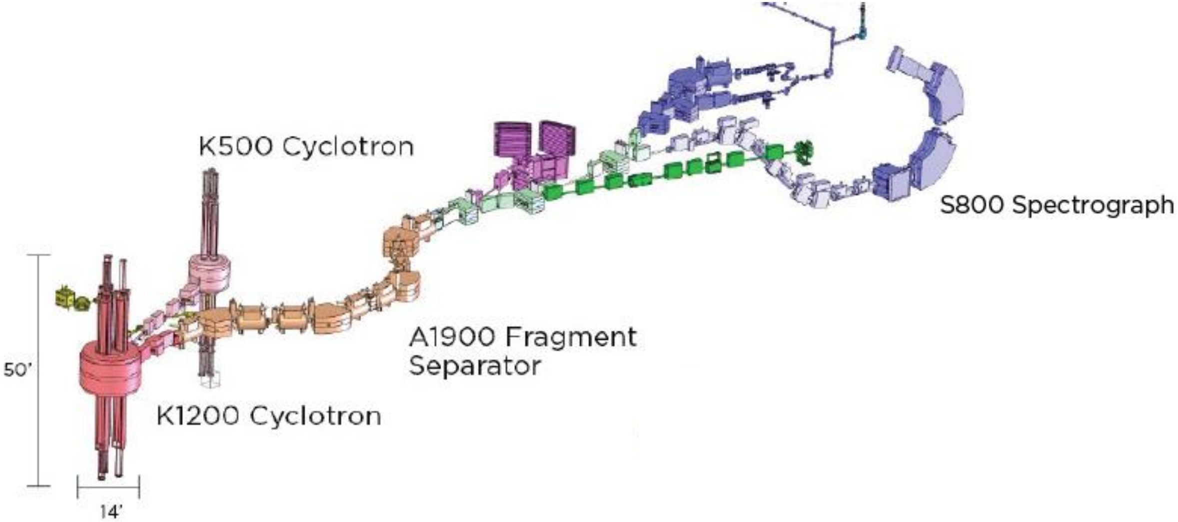


AT-TPC (Downstream Side)



Experiment e18027 @ NSCL

UNIVERSITY OF NOTRE DAME



- October 2020
- ^{76}Ge, primary beam, ^{70}Ni Beam ~ 82 MeV/u
- Pure He gas at 150 torr
- $^{70}Ni(\alpha,\alpha')^{70}Ni^*$
- Decay via 1n, 2n, 3n, 4n channels
- 2 B-rho settings to maximize the acceptance for $^{68,69}Ni$ & $^{66,67}Ni$

Brief Outline

UNIVERSITY OF NOTRE DAME

- Motivation and Experiment
- Preliminary Analysis
- Challenges and Outlook
- Summary

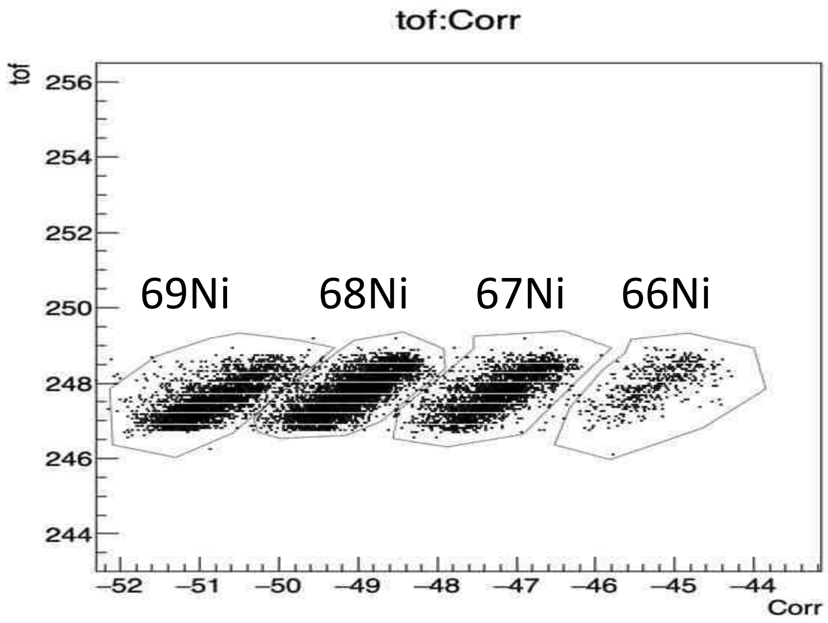
Disclaimer

UNIVERSITY OF NOTRE DAME

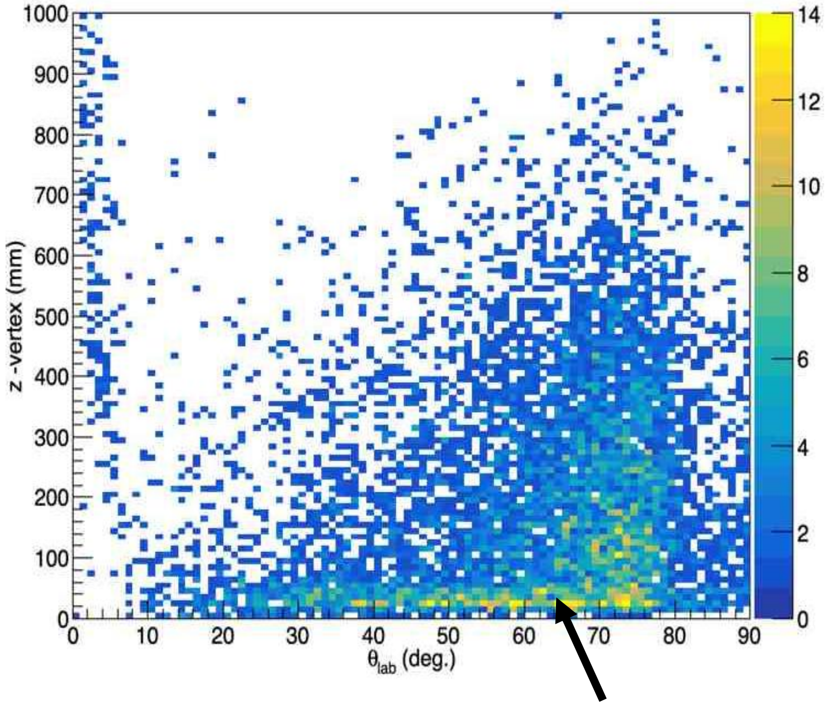
- Preliminary results
- Analysis: Jaspreet Randhawa
- More thorough analysis planned

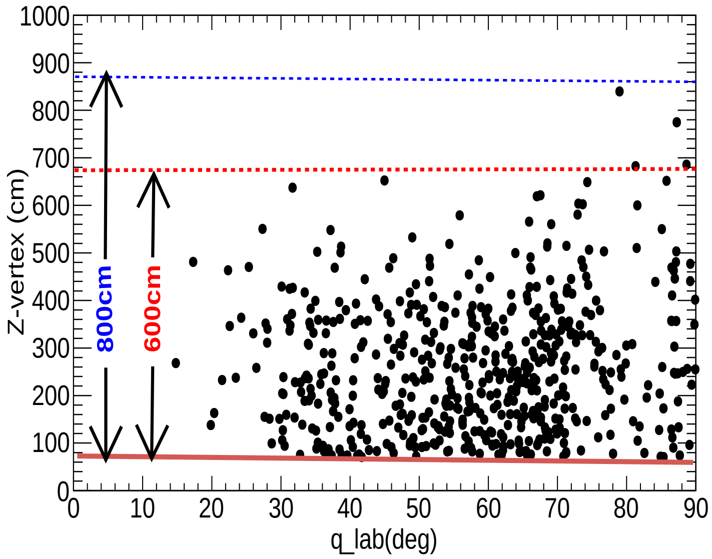
AT-TPC coupled to S800

- 70Ni decay via 1n, 2n, 3n, 4n channels
- B-Rho settings to maximize the acceptance for ^{68,69}Ni & ^{66,67}Ni
- α-particles tracked using RANSAC
- Obtained → Range, Vertex and angle



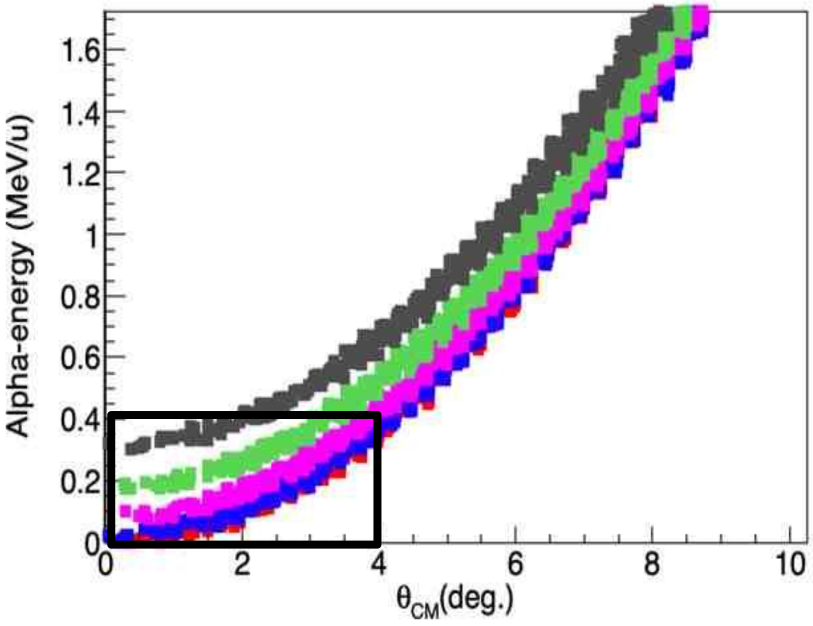
Angle vs. reaction vertex

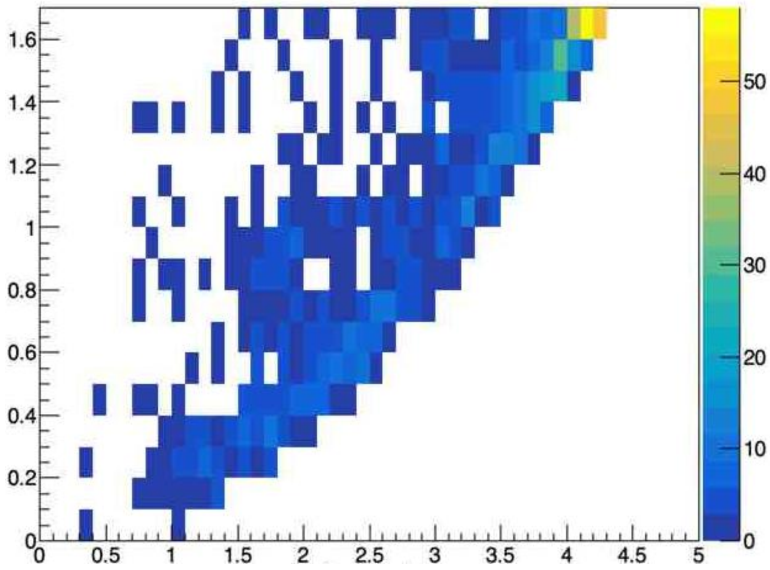




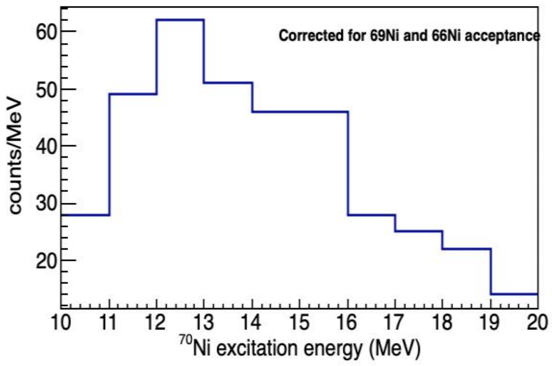
Scattering from window and foil

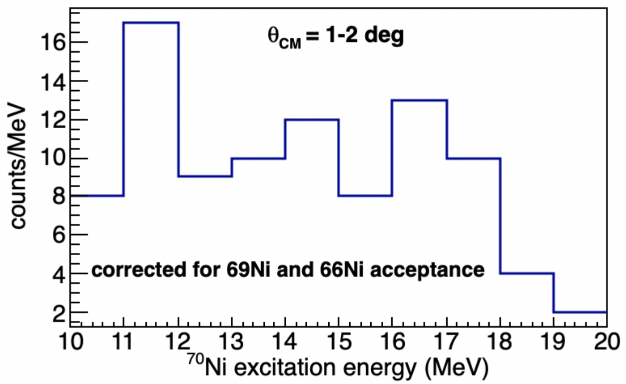
Coverage in C.O.M. Frame

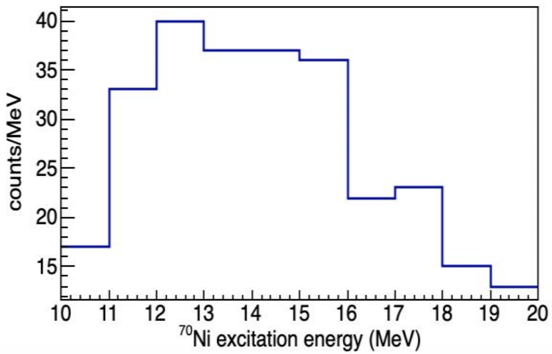


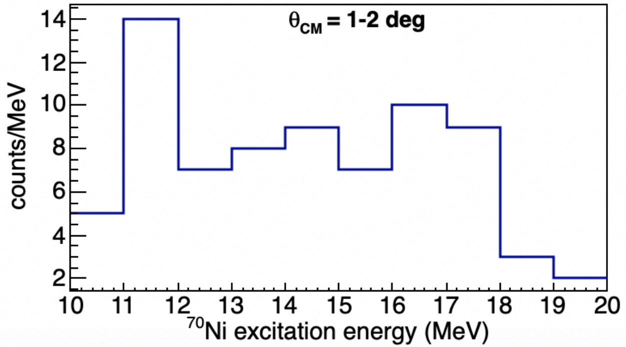


Rough correction for ^{69}Ni and ^{66}Ni acceptance

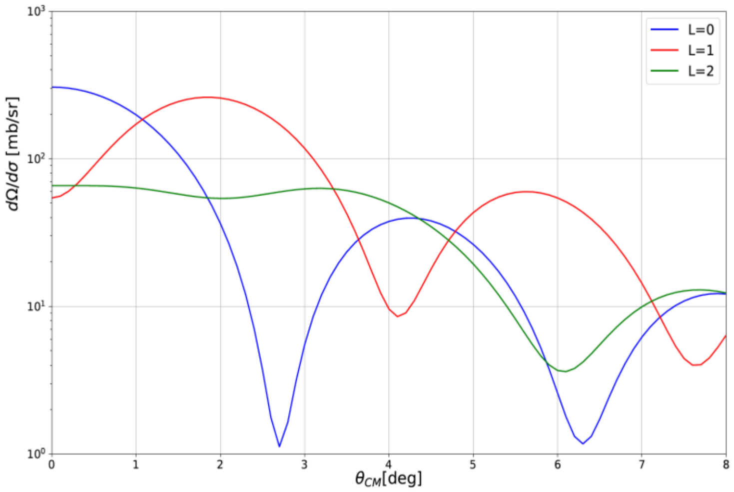








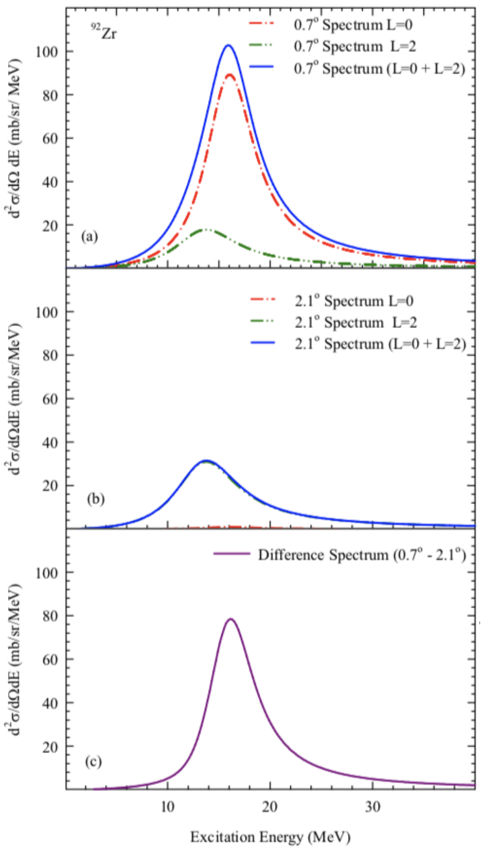
Difference of Spectra Procedure



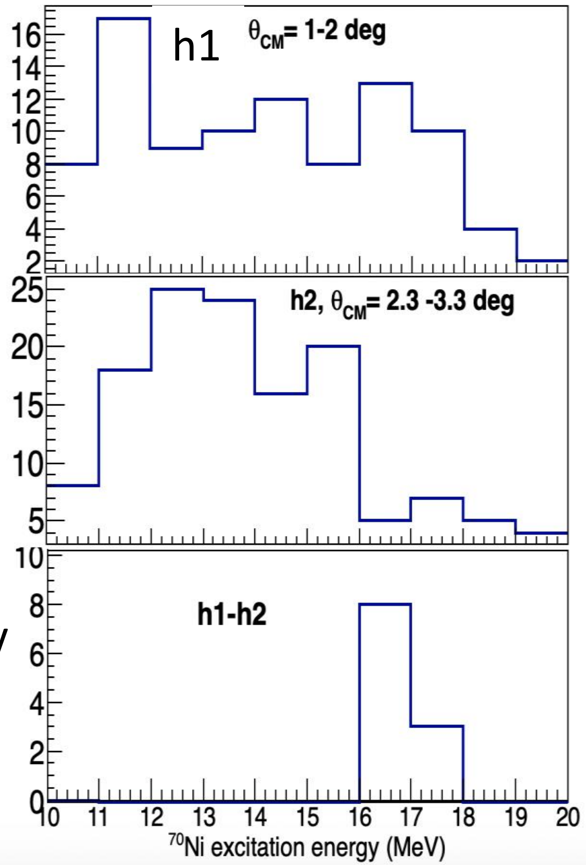
- ISGMR has maximum at 0 degrees in C.O.M. frame and declines sharply
- Competing ISGQR remains essentially flat over this range
- Subtract the inelastic scattering spectrum at the minimum of the expected ISGMR angular distribution from that at 0 deg. (or close to zero degrees)

- L=0 : Minima at ~ 2.7 degrees
- L=2 : nearly flat in 1-4 degrees

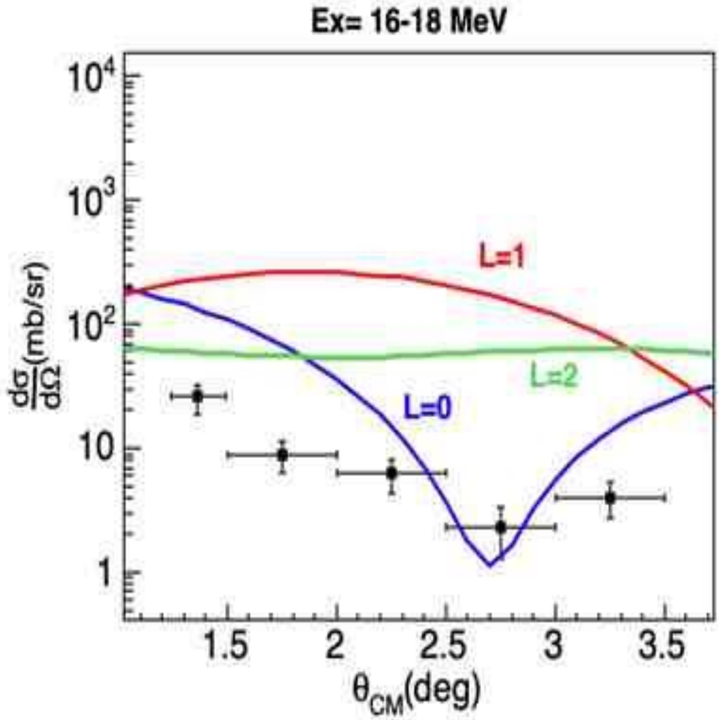
Difference Spectrum for ^{70}Ni Data

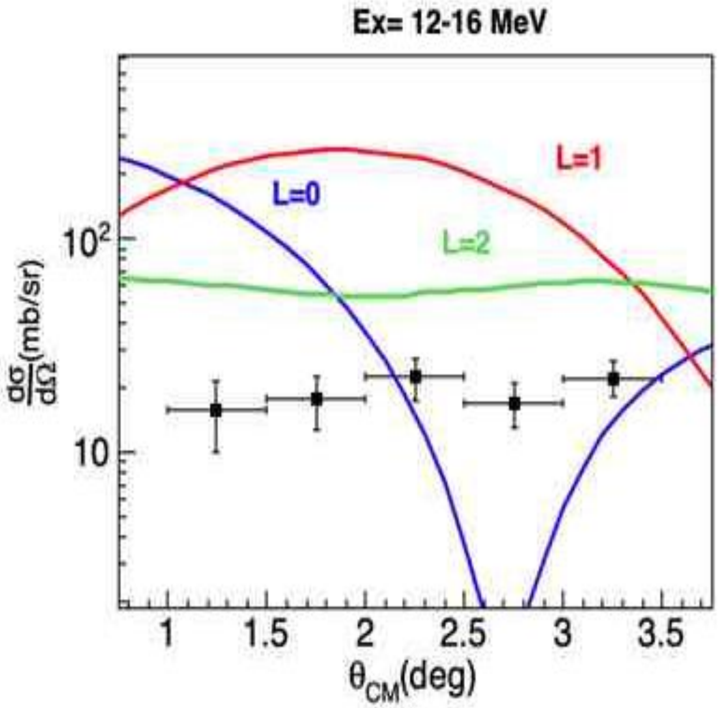


GMR expected at ~17 MeV

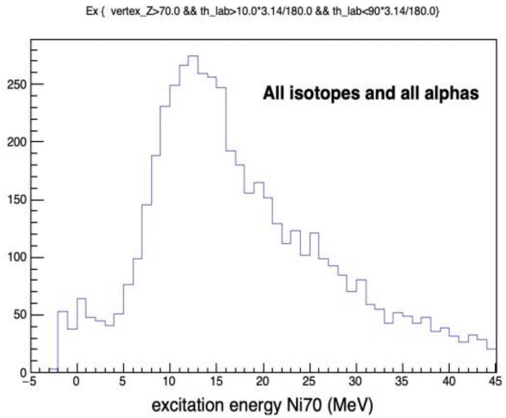


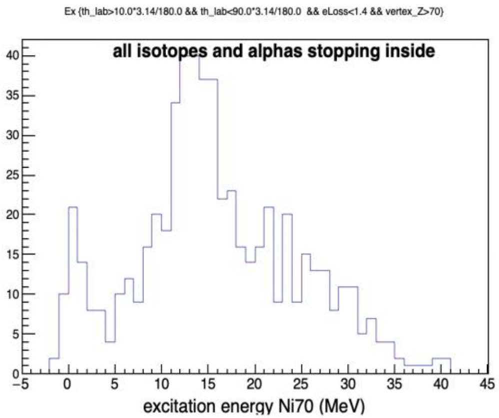
Angular Distribution Energy Cuts

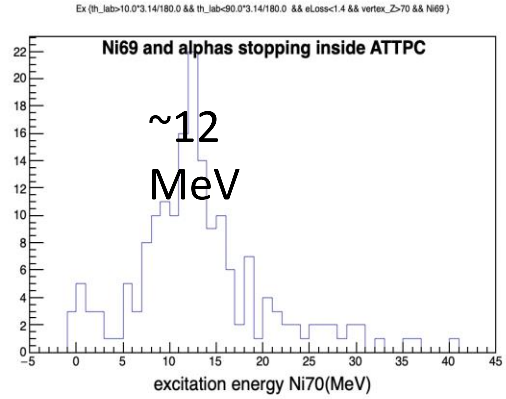


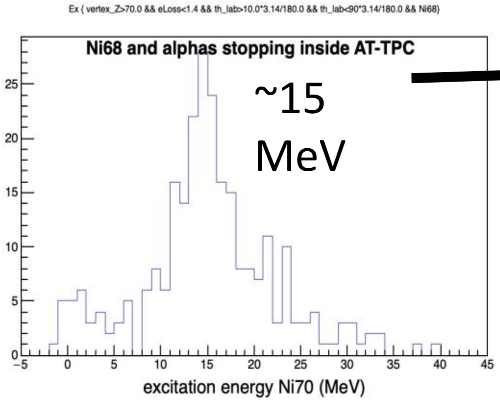


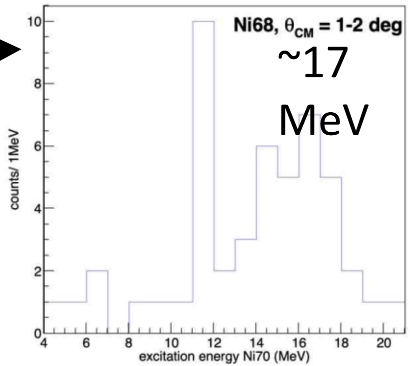
Gating on Isotopes











Brief Outline

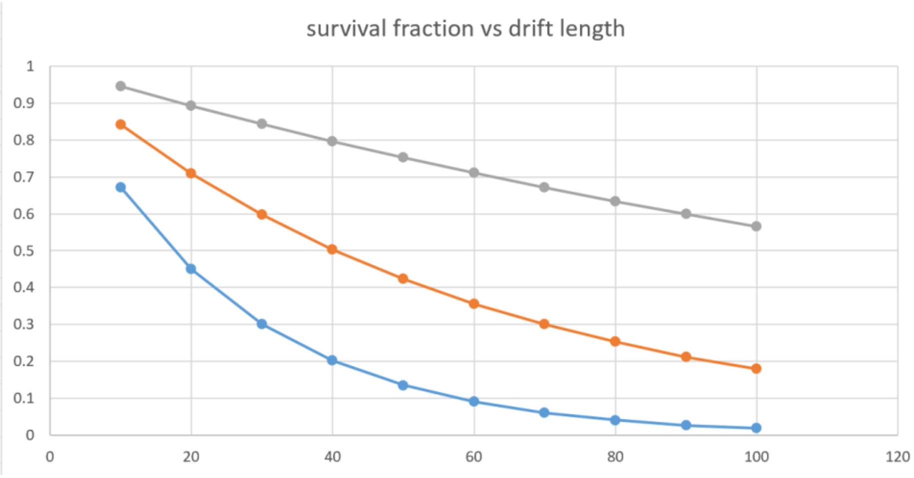
UNIVERSITY OF NOTRE DAME

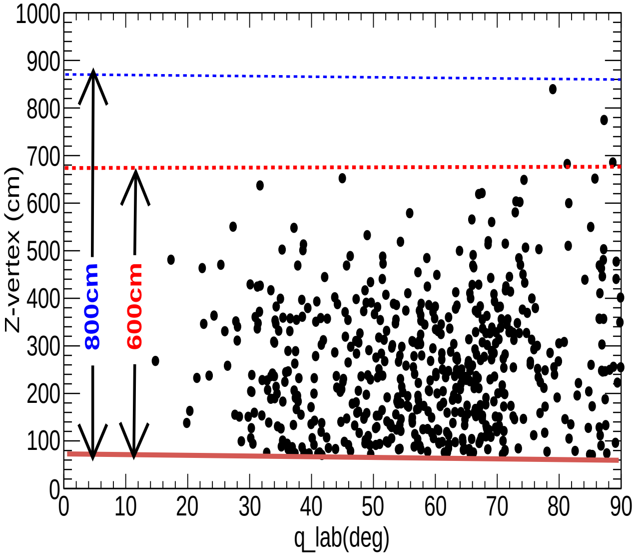
- Motivation and Experiment
- Preliminary Analysis
- Challenges and Outlook
- Summary

Experimental Challenges

- Circumstantial; Solution straight forward
- Failure of Cyclotron power supply
  - Premature end to beamtime
  - Somewhat limited statistics

Experimental Challenges





- Contamination of detector gas
- Use of different gases for gas filter
  - Prior experiment, use of H_2 gas
  - Magboltz calculations

Intrinsic Experimental Challenges

UNIVERSITY OF NOTRE DAME

- More sophisticated solutions needed
- Space charge issues
  - Local electric field distortions
  - Geometric limitations due to hole in Micromegas/GEMS
    - Limitations in energy and angle measurements
  - Map field distortions due to positive ion buildup
- Delta electrons present challenge for tracking algorithms
- Competition with neutron knockout reactions

Analysis Outlook

UNIVERSITY OF NOTRE DAME

- Basic tracking using Random Sample Consensus (RANSAC)
- ATTPCROOT analysis framework
  - GENFIT (Kalman filter)
  - Goal: Robust and precise track fitting
- Ray-tracing for S800
  - S800 acceptance
  - Needed for getting accurate GMR peak
- https://github.com/ATTPC/ATTPCROOTv2

Summary

UNIVERSITY OF NOTRE DAME

- Performed first experiment using AT-TPC coupled to S800 spectrometer to study ISGMR in neutron-rich nucleus ^{70}Ni
- Preliminary analysis; Detailed analysis commencing this summer
- Technical feasibility of active-target + spectrometer method
- Future measurement of ISGMR in ^{132}Sn at FRIB
- Program of measuring highly-excited unbound structures in nuclei

Acknowledgements

- Jaspreet Randhawa (ND)
- Samuel Henderson (ND)
- Umesh Garg (ND)
- Joseph Arroyo (ND)
- Lihao Yan (ND)
- Wolfgang Mittig (MSU)
- Daniel Bazin (MSU)
- P. Gueye (MSU)
- N. Watwood (MSU)
- Zach Serikow (MSU)
- Remco Zegers (MSU)
- Felix Ndayisabye (MSU)
- Jason Surbrook (MSU)
- Tom Ginter (MSU)
- Chandana (MSU)
- Mallory Smith (MSU)
- Shumpei Noji (MSU)
- Jorge Pereira (MSU)

Thank you for your attention!