Rotational structure in nuclei near ^{66}Fe

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Abstract

Collective rotation structures of nuclei near N = 40 have been investigated previously, but the higher spin states of ^{66}Fe have not been studied. Here we analyze the data from an experiment conducted at the National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University (MSU) in a projectile fragmentation reaction. New transitions in ^{66}Fe were measured. One such transition was shown to be in coincidence with the adopted $J^{\pi} = 2^+ \rightarrow 0^+$ and $4^+ \rightarrow 2^+$ transitions. ^{65}Fe and ^{67}Co are also studied, with new transitions identified. The data gathered will help improve upon current models of nuclear structure; further analysis including comparison to such models is necessary.

Introduction and Motivation

- Nuclei with magic numbers of nucleons = more stable, spherical

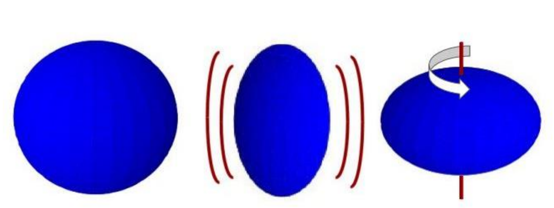

Fig. 1: A depiction of spherical, vibrational, and rotational nuclei.

- Shell model successful near stability, independent particle magic numbers ceases to work for unstable nuclei
- N = 40 expected to be semi-magic by shell model, but isn't

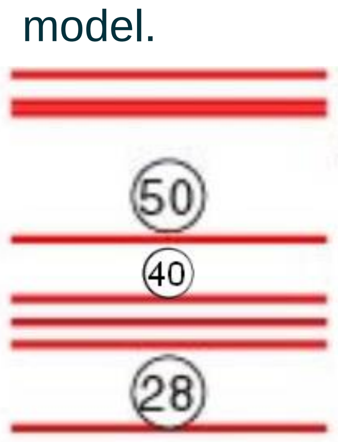

Fig. 2: Shell gaps from shell model.

- Collective rotation structures near N = 40 investigated
- No data for higher spin states of ^{66}Fe (angular momentum I > 4)
- Rotational model (below) can be good approximation for energy of deformed nuclei:

$$E_{rot}(I(I+1)) = AI(I+1) + BI^2(I+1)^2 +$$

Experiment

- National Superconducting Cyclotron Laboratory (NSCL) at Michigan State University using Gamma Ray Energy Tracking In-beam Nuclear Array (GRETINA) and S800 spectrometer

Fig. 3: The GRETINA detector.

- S800 was used to identify product nuclei based on energy loss (measured in ionization chamber), and time of flight (between two detectors)
- GRETINA used to measure energy of gamma-rays emitted from the product nuclei as they decayed
- Fragmentation: $^{82}Se \rightarrow {}^{80}Ge \rightarrow {}^{66}Fe$

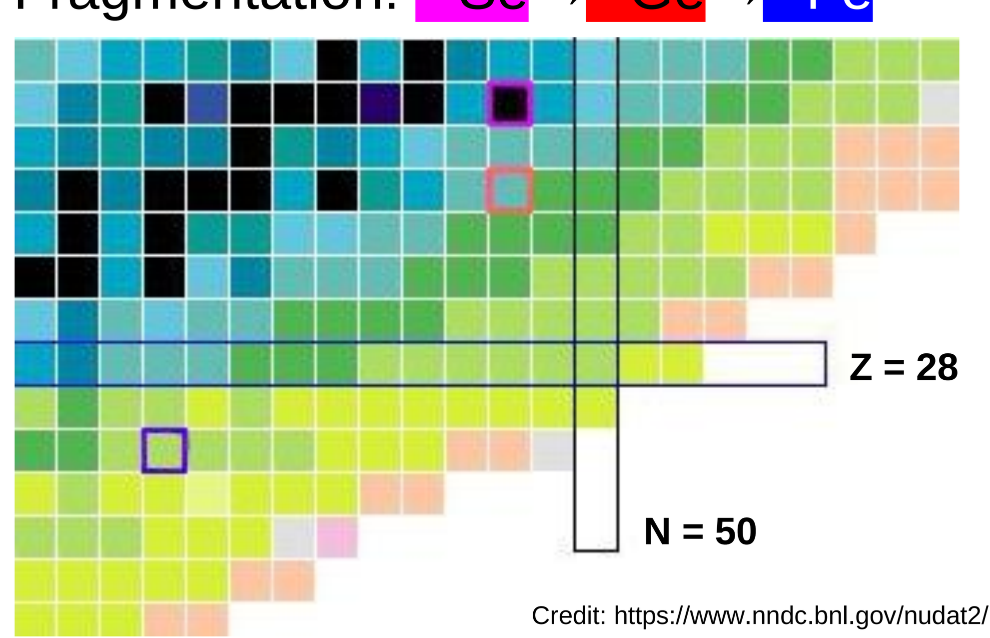

Fig. 4: The nuclei in the fragmentation reaction on the table of isotopes, boxed in magenta.

- Many-nucleon knockout lends higher angular momentum to final nuclei
- Many different nuclei produced in reaction

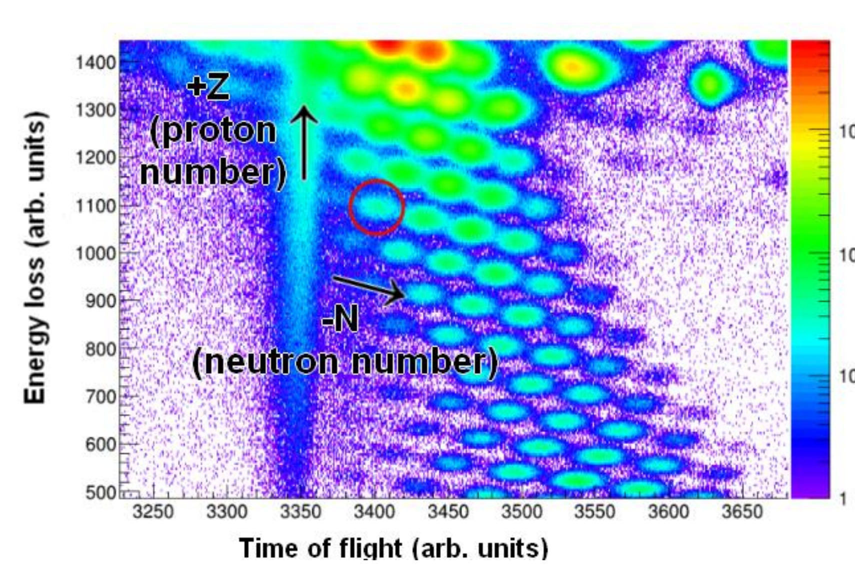

Fig. 5: Particle ID plot. Each circle is a different nucleus. ^{66}Fe is indicated with a red circle.

Results

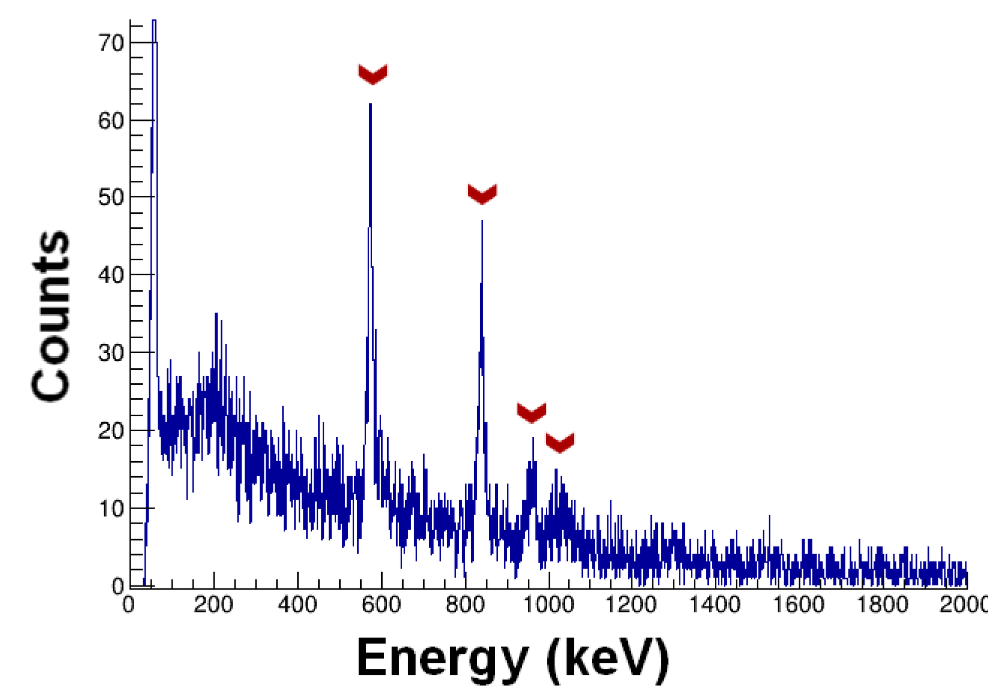

Fig. 6: ^{66}Fe: Transitions at energies of **573** keV ($2^+ \rightarrow 0^+$), **838** keV ($4^+ \rightarrow 2^+$), 958 keV, and **1026** keV. Coincidences in bold.

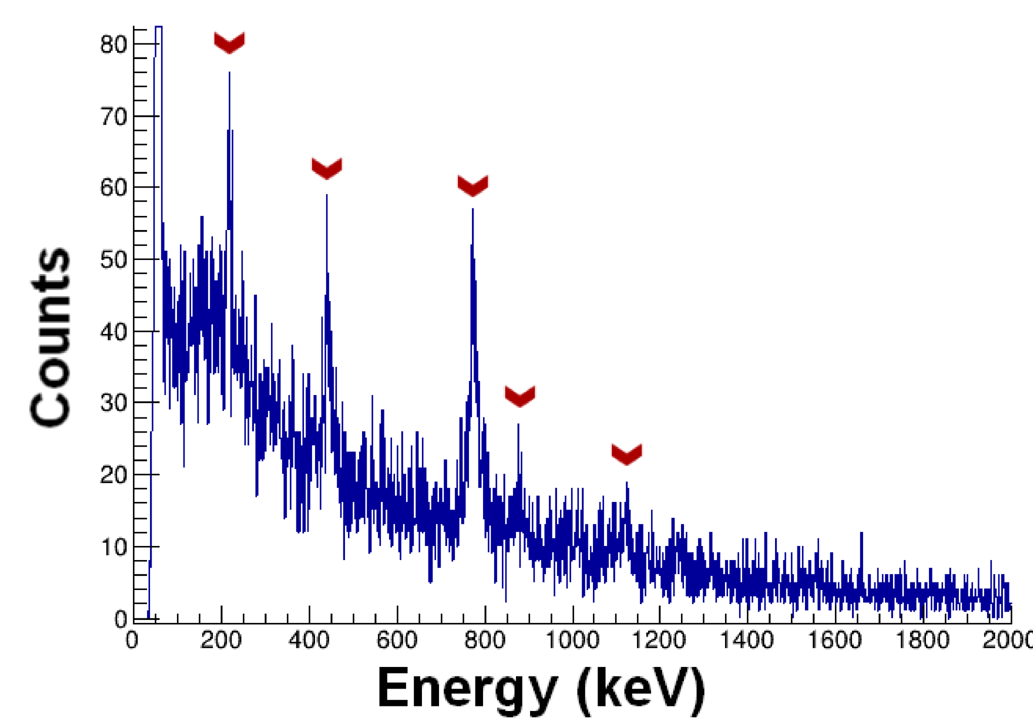

Fig. 7: ^{65}Fe: Transitions at energies of 215, **442**, **776**, 878, **1112** keV.

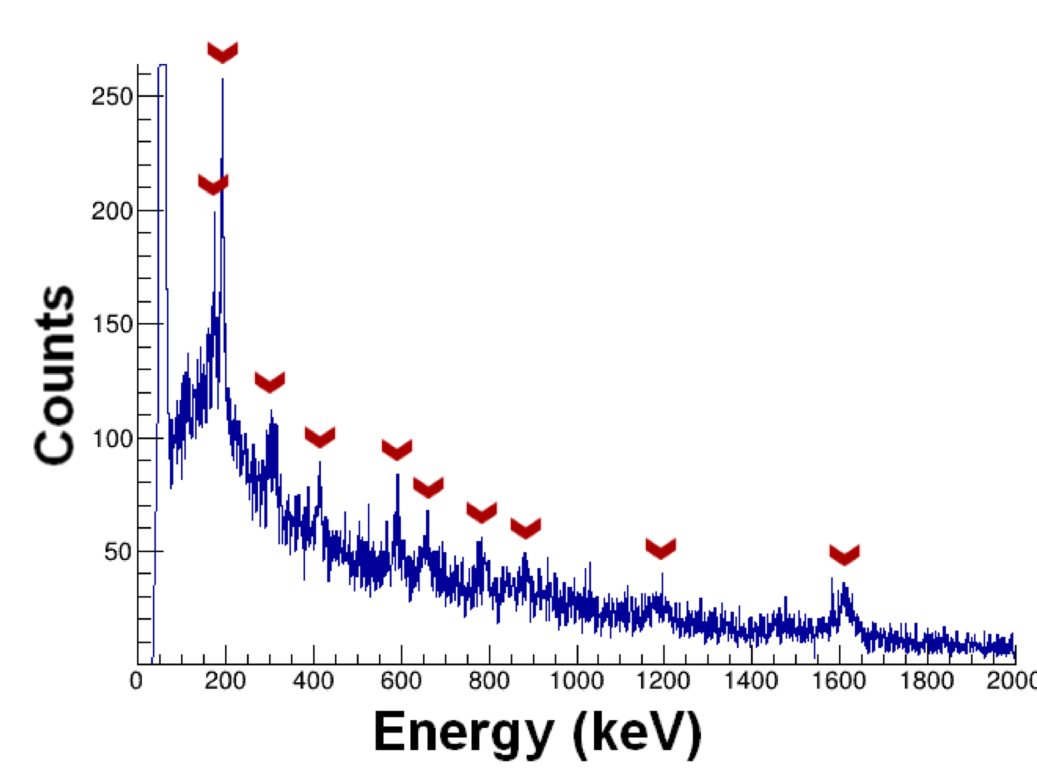

Fig. 8: ^{67}Co: Transitions at energies of 174, 192, **307**, 411, 593, 657, 789, **881**, 1187, and **1609** keV.

Conclusions

- ^{66}Fe: Can conclude that $6^+ \rightarrow 4^+$ transition occurs at 1026 keV, placing 6^+ state at 2432 keV
- Based on moment of inertia from updated level scheme, estimated deformation of ^{66}Fe is $\varepsilon \sim 0.29$

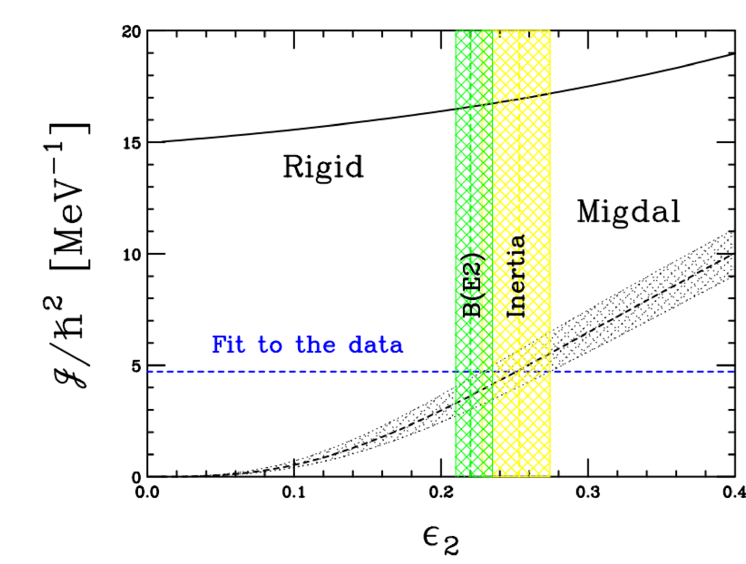

Fig. 9: Moment of inertia of ^{66}Fe as estimated by the rigid rotor and Migdal models.

Future Directions

-More analysis to be done, such as:

- Fit peaks with simulated data
- Compare structure of 65Fe, 67Co to particle-rotor model calculations
- Examine other isotopes in PID

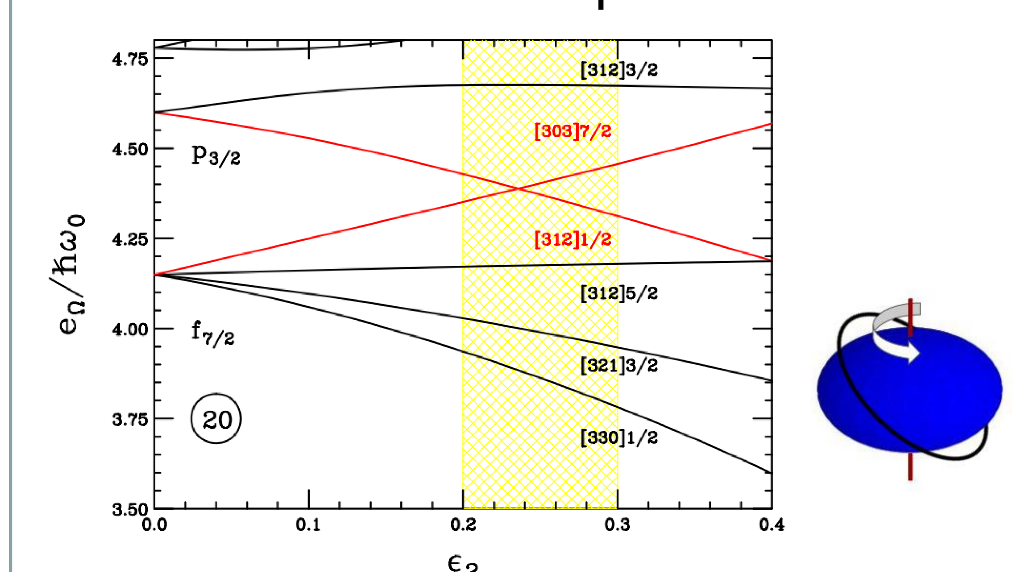

Fig. 10: Nilsson diagram. Single particle level information for protons needed for particle-rotor calculations for ^{67}Co. Artistic depiction of single-particle alignment that occurs in this nucleus.

Acknowledgments

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