Exploring High-Spin States in ^{39}Ar using a Fusion-Evaporation Reaction

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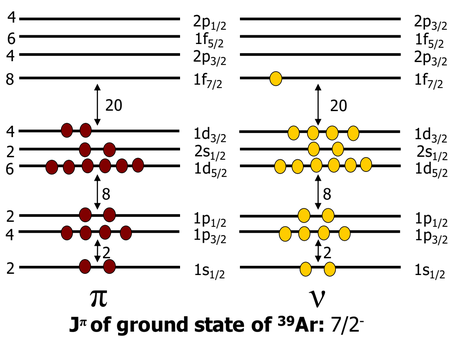
Motivation

Intruder States: Excited states that arise when particles cross a shell gap

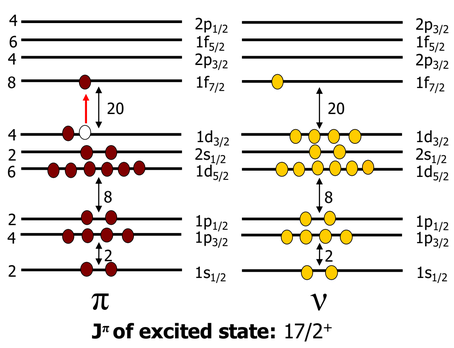
Standard shell model of ^{39}Ar in ground state



Jπ of ground state of ^{39}Ar: 7/2$^-$

- To the **left** is the standard configuration of protons and neutrons in the ground state of ^{39}Ar.
- A state's spin parity, J^π, is determined by the coupling of protons, π, and neutrons, ν, in the various particle shells.
- Ground state comes from uncoupled neutron in $1f_{7/2}$ shell

Standard shell model of ^{39}Ar in an excited state



Jπ of excited state: 17/2$^+$

- The new state created by promoting a $1d_{3/2}$ proton into the $1f_{7/2}$ shell gives a new energy level with a J^π of $17/2^+$.
- **Importance:** this state is an ***intruder state***, which are useful when helping to adjust/create theory models that are applicable for *all* isotopes

John D. Fox Superconducting Linear Accelerator Laboratory

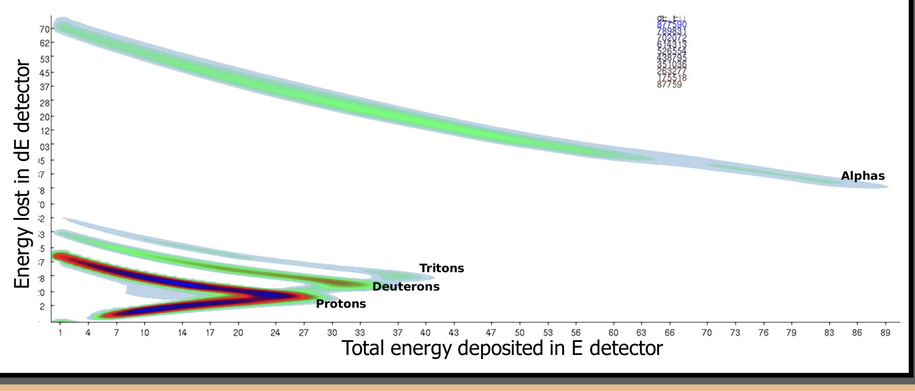
- Compound nucleus: ^{41}K
- Decay channel selected: proton-neutron

A particle ID chart was created, as seen to the **right**, by taking the energy relationship between the E detector and dE detector in the particle telescope

- PID allows to select all events that occur with the decay through proton-neutron channel

Experimental Details: Ran for approximately 7 days using a Tandem Van de Graaff accelerator

- Used ^{14}C beam with an energy of 25.6 MeV
- Used self-supporting, 100 μg/cm^2 ^{27}Al target
- Gamma Spectroscopy Array: Consisting of 3 Compton-suppressed HpGe clover detectors and 7 HpGe single crystal detectors at angles 90°, 35°, and 145°
- Utilized a particle telescope, made from two silicon detectors (100μm and 1000μm thicknesses), placed at 0° [1]

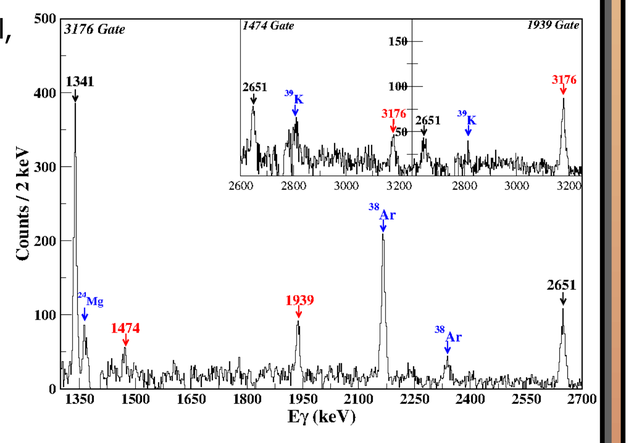


Preliminary Analysis and Results

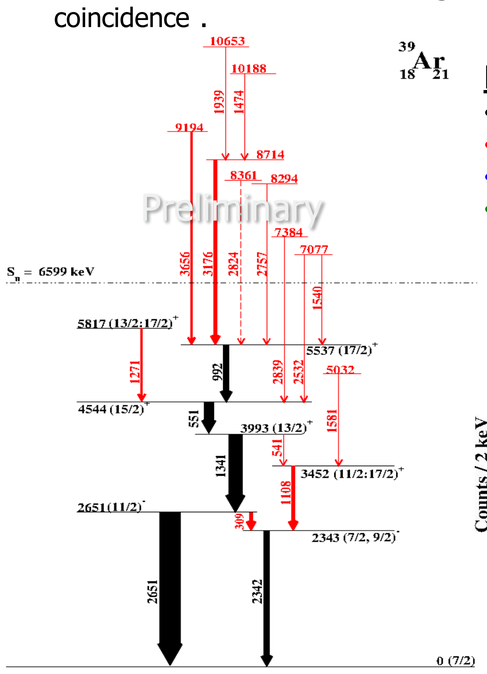
After selecting events that occur in coincidence with the proton-neutron decay channel, a partial level scheme for ^{39}Ar could be created using gamma-gamma coincidences.

Determining γ-γ Coincidences:

- Observe the gamma rays that are in coincidence with another gamma ray(s), taken from a specific cut on the data
- If in true coincidence, making a "reverse" cut on the new gamma ray will show the original gamma ray and possibly other gamma rays.
- If there is no evidence of the original gamma ray, the coincidence is a random coincidence .



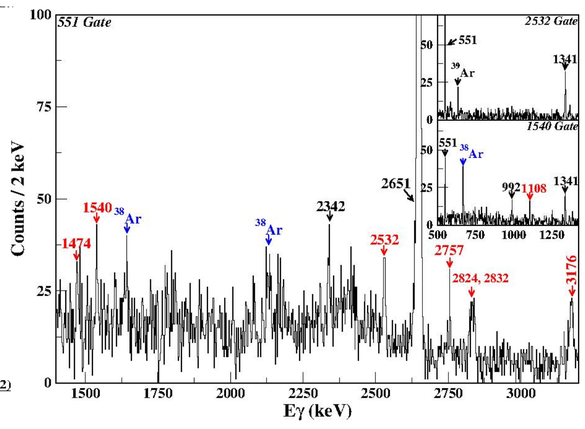
Below and **above** are a few examples of γ-γ coincidences that were used to build the level scheme

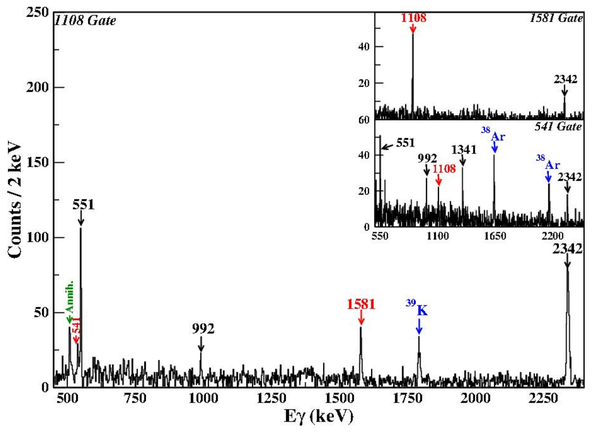


Partial level scheme of ^{39}Ar, depicting high-spin states [1-11]

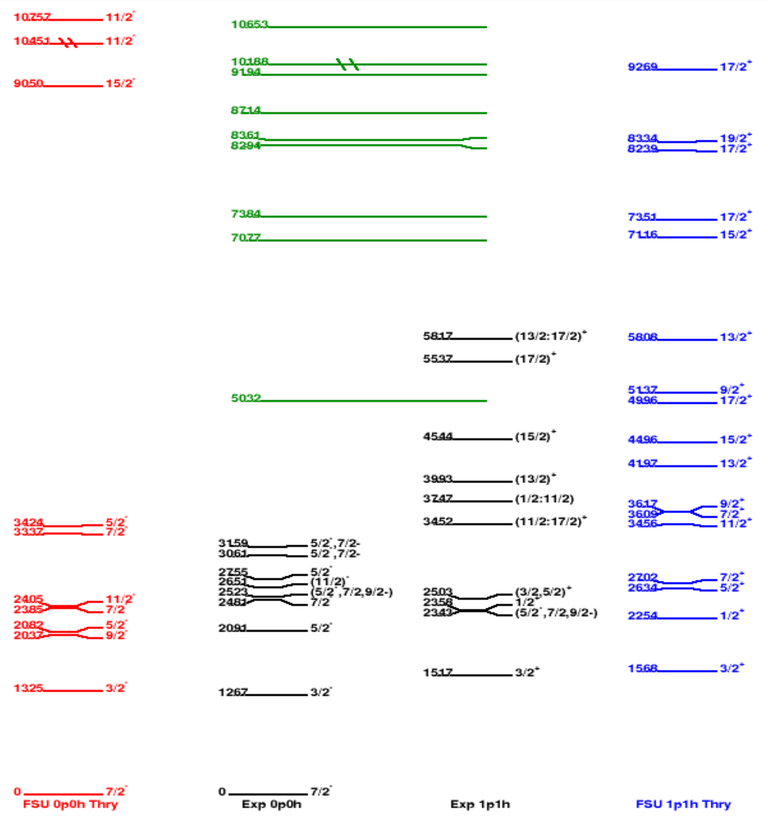
Legend:

- **Black:** Previously measured gamma transition
- **Red:** New gamma transition
- **Blue:** Contaminant
- **Green:** electron annihilation





Theory



At FSU, we are in the process of developing a new interaction that will better predict intruder states for excitations across the n = 20 shell gap [12]. **Above** is the comparison of the FSU interaction predictions to the experimental results for ^{39}Ar.

Legend:

- Red: negative parity theory states
- Blue: positive parity theory states

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The Future

Further comparison and development of the FSU shell model interaction will be conducted in order to help predict the J^π of the newly discovered states. Because of the nature of the reaction and the J^π of the previously known transitions, it is suspected that these new states will have high spin. Fitting an interaction to these new states will help build an interaction that is applicable for other isotopes that might also have intruder states.

Acknowledgements

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