Gamma Ray Spectroscopy of ^{69}Ga

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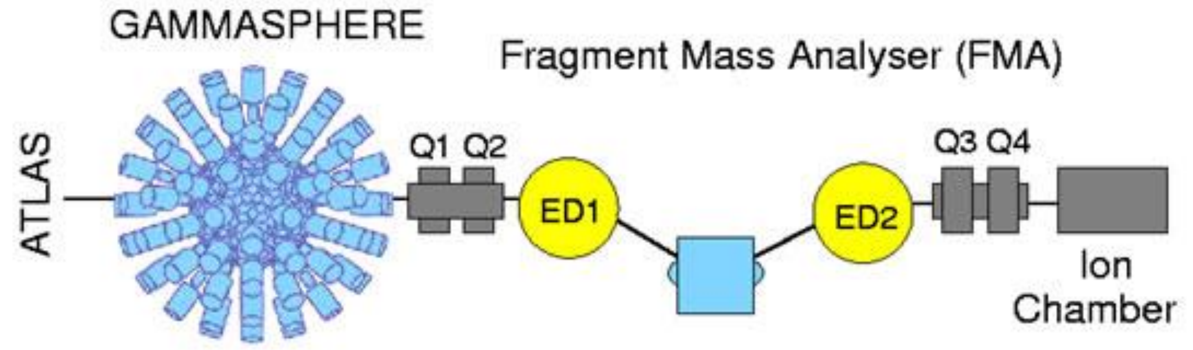
INTRODUCTION

The structure of neutron-rich nuclei beyond the doubly magic nucleus, ^{48}Ca, has been the subject of significant interest for both experimental and theoretical nuclear structure research. Over the last few years, studies of these nuclei have provided considerable insight into the evolution of shell structure, especially in regard to the disappearance of conventional shell gaps and the corresponding manifestation of new ones in nuclei far from the valley of stability [1, 2]. For example, a new subshell closure at N = 40 was recently established following the discovery of a 0^+ level as a first excited state and by the rather high energy of the first 2^+ state (2.033 MeV) and small $0^+ \rightarrow 2^+$ reduced transition probability in ^{68}Ni [3-5].

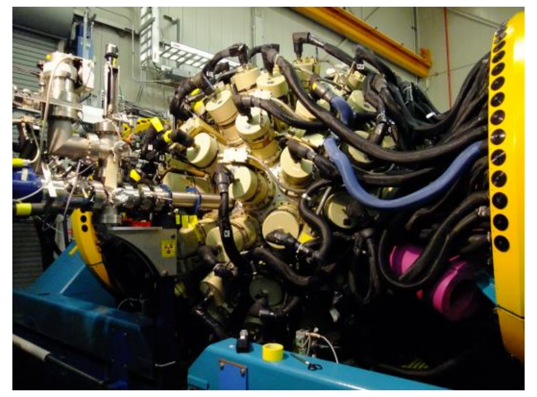
However, detailed experimental studies have shown that this subshell gap is rather fragile and that deformed, non-spherical structures become yrast as protons are removed from the $\pi f_{7/2}$ orbital. Indeed, prolate-deformed configurations, built upon single-particle excitations, have been observed at moderate to high spins in neutron-rich isotopes of Cr [6,7], Mn [8,9], and Fe [10,11], and interpreted using configurations involving the $\nu g_{9/2}$ orbital [12-14]. Similarly, rotational sequences have been reported at moderate and high spin in some of the lighter even-even Ni [15,16] and Co [17] isotopes: highly deformed and even super-deformed bands, built upon lower-lying single-particle excitations, have been observed. In contrast, no experimental evidence for collective excitations has been reported thus far for Ga isotopes closer to the N = 40 subshell closure. In this report, we present results of our ongoing study of the structure of ^{69}Ga.

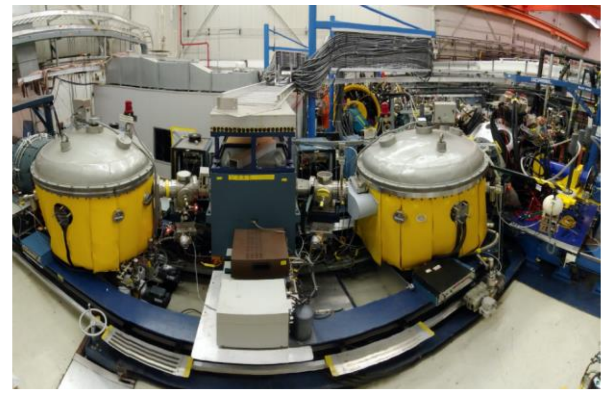
EXPERIMENTAL METHOD

Excited states in ^{69}Ga were populated in the multinucleon transfer reaction, ^{26}Mg(^{48}Ca,α4npγ)^{69}Ga, in inverse kinematics. A self-supporting 0.973-mg/cm^2 -thick ^{26}Mg target was bombarded by a 145-MeV ^{48}Ca beam supplied by the Argonne Tandem Linear Accelerator System (ATLAS). Gamma rays emitted in the deexcitation process were detected with Gammasphere, a 4π array of 101 Compton-Suppressed high-purity germanium (HPGe) detectors. The reaction residues were transported to the focal plane of the Fragment Mass Analyzer (FMA), where they were dispersed according to their mass-to-charge ratios, M/q. The recoils were identified on an event-by-event basis from the position and time-of-flight measured in a microchannel plate detector (MCP) placed at the focal plane and the energy loss measured with a threefold segmented ionization chamber positioned behind the focal plane.



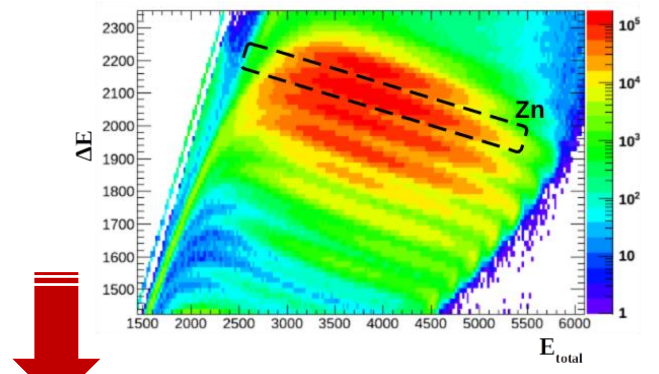
Schematic view of the experimental setup





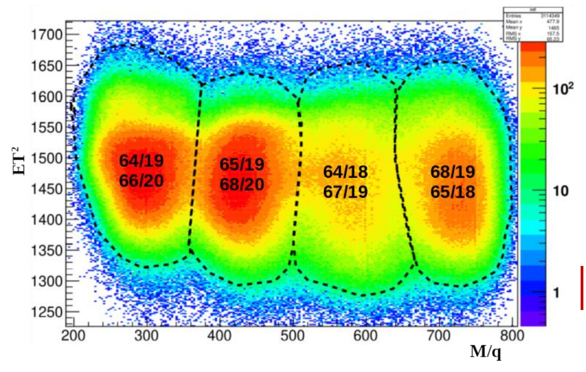
ANALYSIS

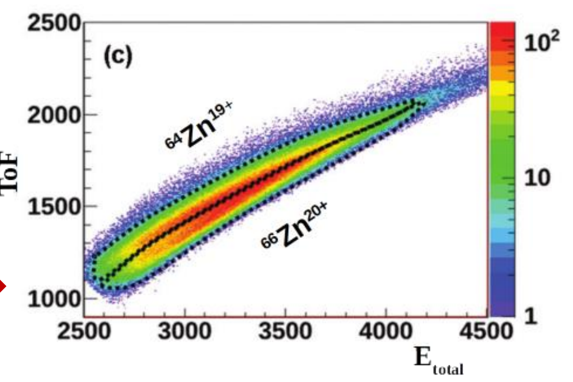
The emitted γ rays were detected in kinematic coincidence with particle recoils identified in the focal plane ionization chamber.

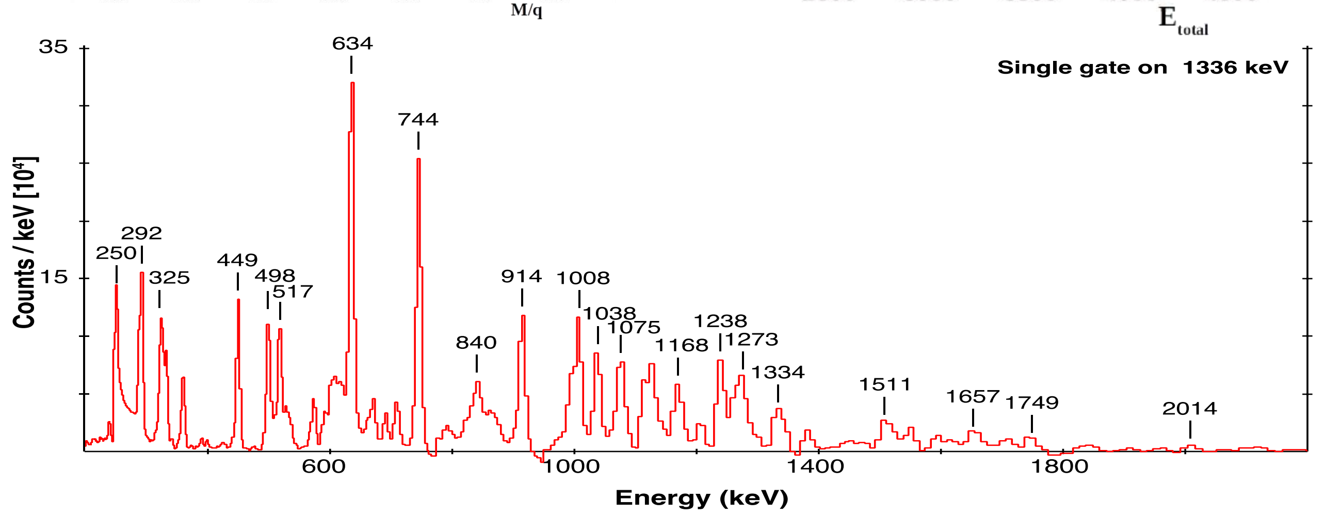


Fragment Mass Analyzer used for particle identification

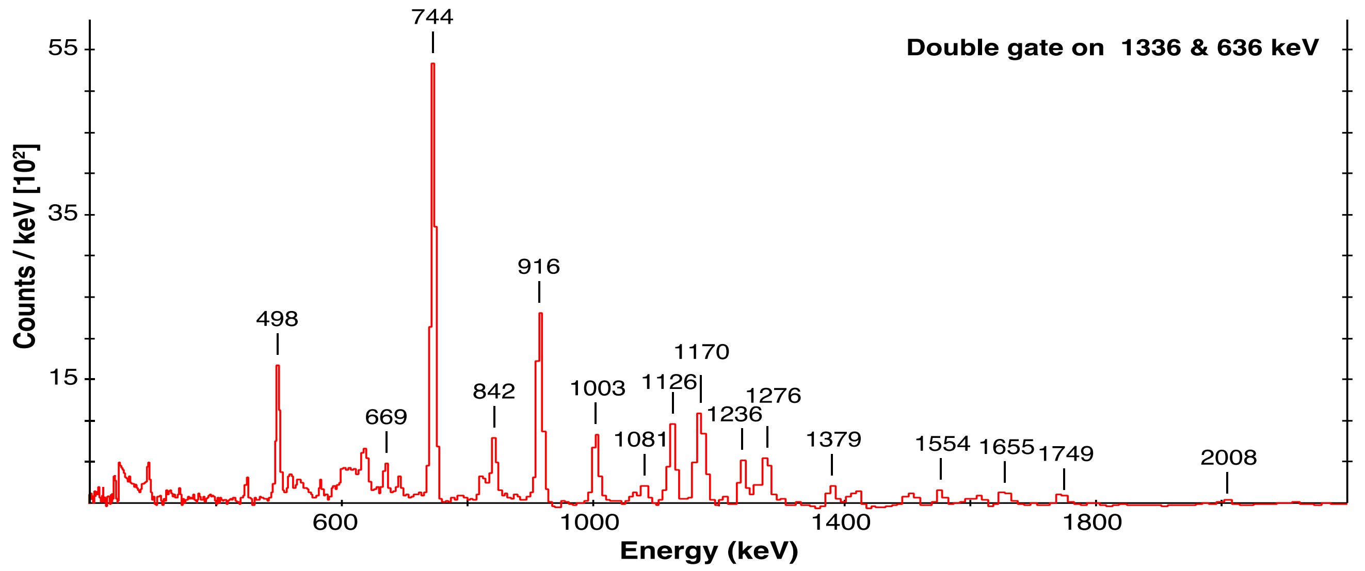
- Information from ion chamber (ΔE-E telescope) used for Z determination
- TOF between γ-ray and residue in MCP used for M/Q determination





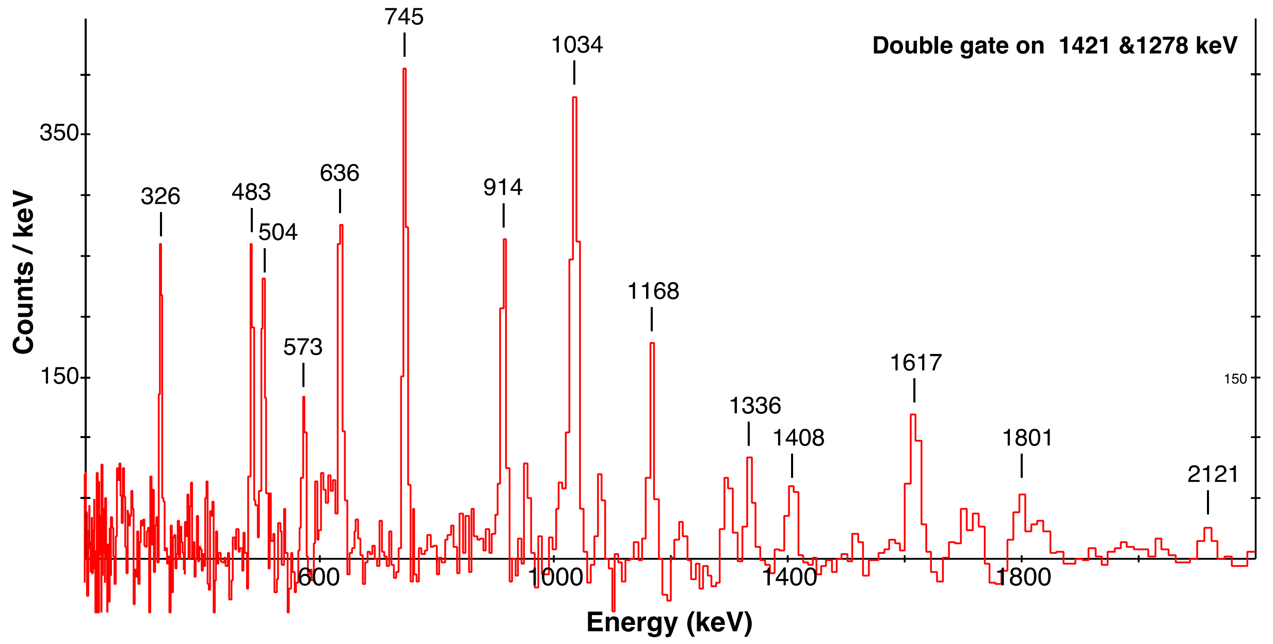


About the 1336 gate: This gate was a good starting point, because it shows almost all of the transitions that we added to this level scheme. The data also contains peaks from other level schemes, so many of the peaks are not from ^{69}Ga. This presents a problem. However, we can use double gates (only showing transitions that appear in coincidence with two others) to figure out which peaks are actually in the ^{69}Ga level scheme.

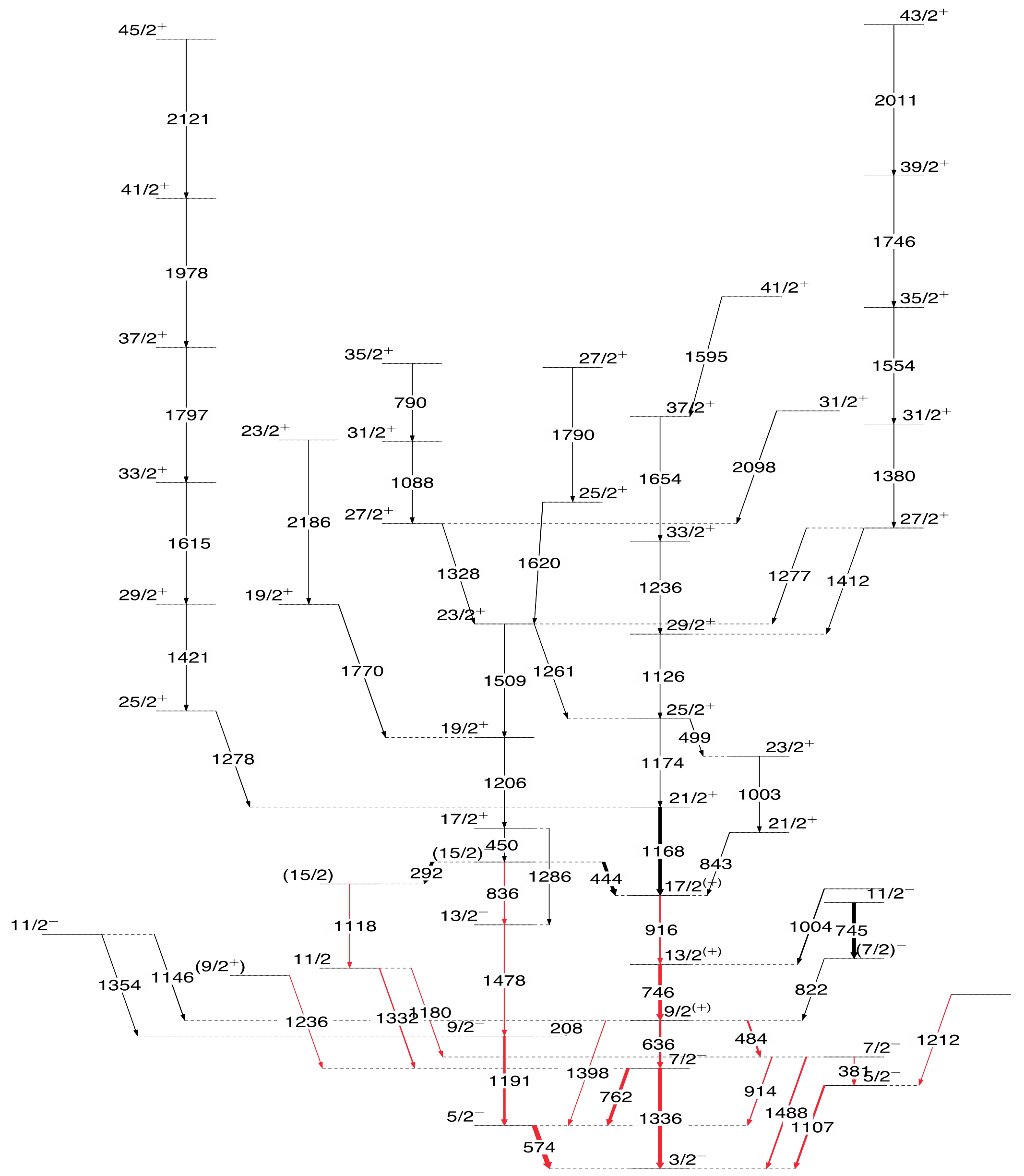


About the 1336/636 gate: After realizing that using a single gate showed some peaks that were not in ^{69}Ga, I tried this double gate to verify my results. I used this gate to confirm that certain transitions were definitely in this level scheme. Among the transitions that I discovered were the 1278, 1379, and 1421 keV transitions, which eventually connected several new bands to the main band.

RESULTS

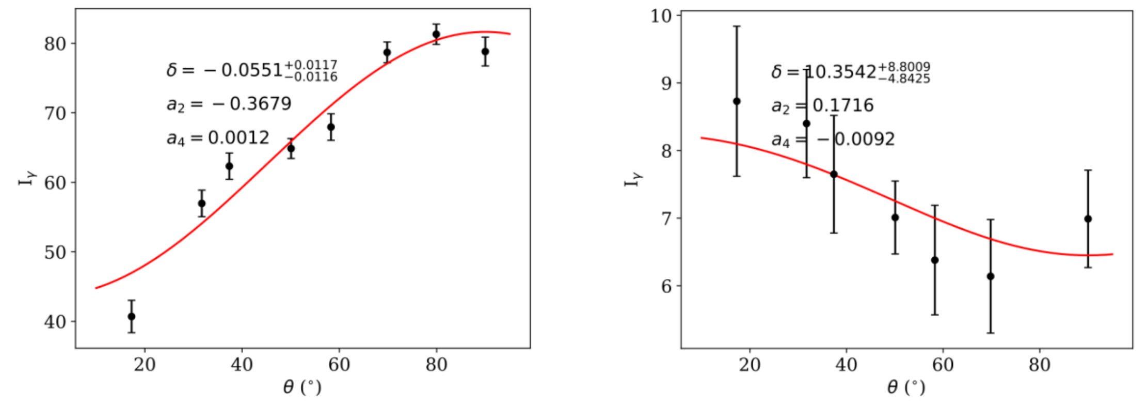


About the 1421/1278 gate: When I tried this gate, I saw many of the transitions in the main band, but I did not see the 449 keV transition, and the 574 keV transition was not as prominent as it was when I used the 1278/1379 gate. Therefore, I knew that this new 1278/1421 band only connects to the main band, not the band on the left side, which allowed me to place this band to above the 1168 transition. I also placed the 1615, 1797, 1978, and 2121 keV transitions in the new band, which correspond to the 1617, 1801, and 2121 peaks in this spectrum.



NEXT STEP

Spin quantum numbers for newly-identified and previously known transitions in ^{69}Ga will be assigned based on angular distributions analyzed by means of Markov Chain Monte Carlo technique. DCO-like ratios were used for weak transitions.



The left figure exemplifies a high statistics *M1* transition, from the 8^+ to 7^+ excited states. The right figure is the base of the quasi-rotational-like branch and demonstrates clear *E2* behavior.

CONCLUSIONS

Medium and high-spin states in ^{69}Ga were investigated by means of the complex multinucleon transfer reaction ^{26}Mg(^{48}Ca, α4nγ) at beam energies of 275, 290 and 320 MeV. The experiment was performed in inverse kinematic at the ATLAS facility at Argonne National Laboratory using the Gammasphere spectrometer and the fragment mass analyzer (FMA). A high-spin, quasi-rotational-like band consisting of stretched-*E2* transitions was observed in coincidence with the known low-spin structure of mostly single-particle character. The band has been assigned deformed configuration based on $\pi(1g_{9/2})^2$ from the adiabatic and configuration-fixed constrained covariant density functional theory calculations. This configuration is somewhat different from the $\nu(1g_{9/2})^2$ observed in the Ni and Co isotopes populated in this experiment.

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