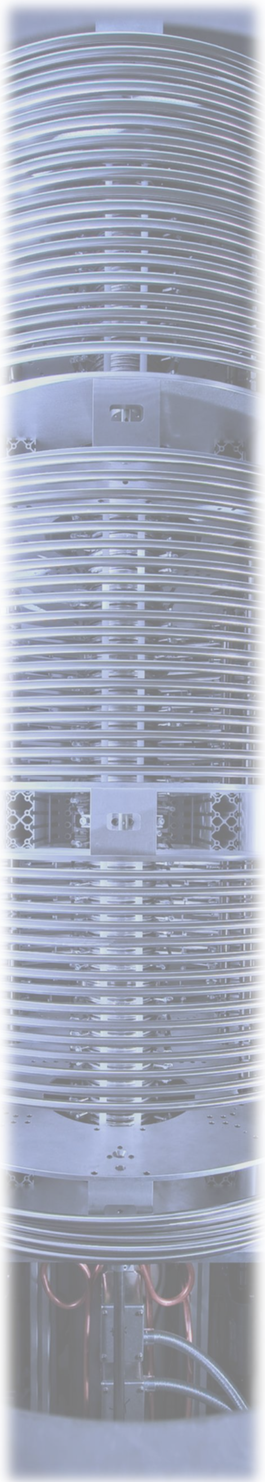
A Method to Account for Hydroxide Contamination in Characterizing the Giant Monopole Resonance to Determine an Accurate K_τ

Sierra Weyhmiller, Kevin Howard, Umesh Garg, Joe Arroyo (University of Notre Dame)
and the collaborators from RCNP, Osaka University, Konan University, Saint Mary's College, Kyoto University, University of Groningen, Tohoku University, and University of Tokyo.



Background

K_τ and the ISGMR

K_τ, the nuclear incompressibility asymmetry term, can be used to understand several interesting phenomena, including supernovae and neutron stars [1]. A K_τ value can be extracted from measurements on the isoscalar giant monopole resonance (ISGMR) in finite nuclei over a range of isotopes.

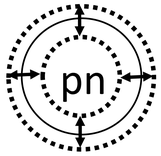


Figure 1: ISGMR illustration.

A Surprising Finding in Calcium Isotopes

The goal of this experiment is to investigate a controversial K_τ value proposed by a contemporary group at Texas A&M. This group published data on calcium isotopes indicating a positive K_τ value, in contrast to the negative value that has been previously measured [2].

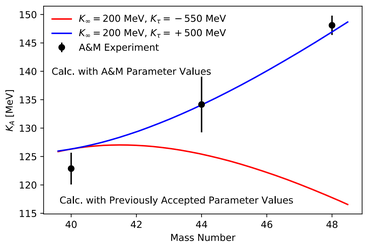


Figure 2: Experimental results for ^{40,44,48}Ca. Data adapted from Ref [2].

Methodology

Experimental Setup

A simultaneous study of the ISGMR of the ^{40,42,44,48}Ca nuclei was conducted at the Research Center for Nuclear Physics, Osaka University. α-particles bombarded the calcium nuclei and then scattered into the spectrometer, Grand Raiden, which separated the α-particles according to their momentum.

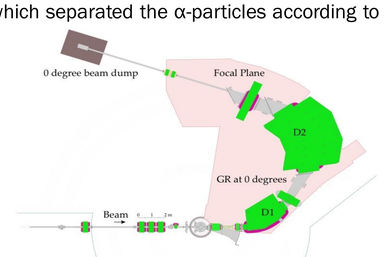
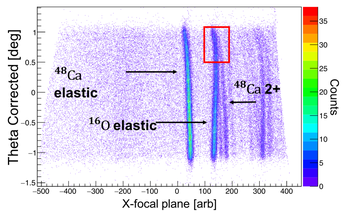


Figure 3: Schematic of Grand Raiden. Figure courtesy of Atsushi Tamii.

Evidence of Hydroxide Contaminant

At some angles, a slanted line crossed the excited state of ^{48}Ca, implying that this was a contaminant elastic state. This contaminant was calculated as ^{16}O. The amount of oxygen contaminant must be calculated and accounted for to determine an accurate K_τ because the contaminant's presence in the energy spectrum contributes to the extracted cross sections, which are used to isolate the ISGMR strength.

Figure 4: Theta Corrected vs. x-focal plane for the 12.8° elastic ^{48}Ca run.



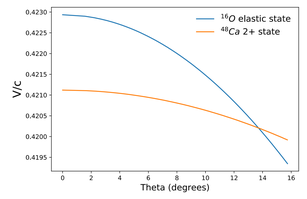


Figure 5: Velocity of ejectile vs. scattering angle of ^{16}O (α, α) elastic scattering and ^{48}Ca 2+ inelastic scattering.

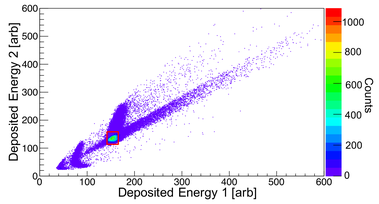
Analysis

Determining the Oxygen Counts

To determine the amount of oxygen in the target, one must find the counts arising solely from ^{16}O (α, α) elastic scattering. To do so:

1. Perform Particle Identification – Identify which events correspond to α-particle scattering. The rate of energy loss of any charged particle as it travels through the target is dependent on that particle's velocity and charge [2]. Thus, one can measure the energy a particle deposits into the scintillator to identify which particle it is.

Figure 6: Particle Identification histogram for the 8° elastic ^{48}Ca run.



2. Perform Background Subtraction - Subtract a normalized amount of background events from the true + background region.

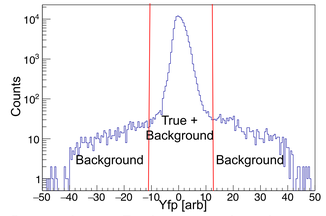


Figure 7: Background Subtraction histogram for the 8° elastic ^{48}Ca run.

3. Perform Shape Correction – Reduce overlap between oxygen and calcium states by straightening the spectrum.

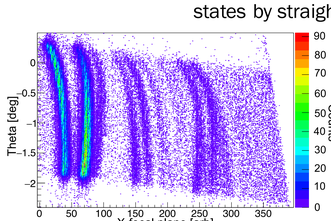


Figure 8: Theta Scattered vs. x-focal plane for the 8° elastic ^{48}Ca run before shape correction.

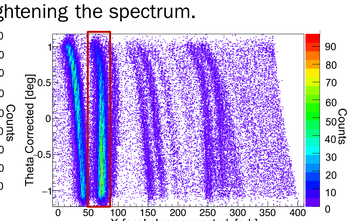


Figure 8: Theta Scattered vs. x-focal plane for the 8° elastic ^{48}Ca run after shape correction.

4. Obtain Oxygen Counts – Integrate oxygen state region.

Results

Oxygen Thickness Calculation

The thickness of the oxygen contaminant can be determined from:

$$\frac{d\sigma}{d\Omega} = \frac{YA}{kQ\Delta x\Delta\Omega\epsilon_{VDC}}$$

Y, the oxygen counts, was obtained from the analysis, A and k are physical quantities, and Q, $\Delta\Omega$, and ϵ_{VDC} are known experimental parameters.

Published ^{16}O (α, α) elastic scattering cross sections in the center of momentum frame were converted to the lab frame for use in this analysis [3]. However, these cross sections correspond to different angles than those used in the present experiment. Thus, the published cross sections were interpolated using a cubic spline.

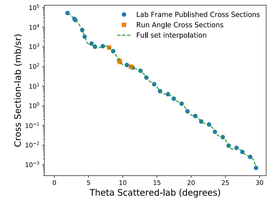


Figure 9: Cross Section interpolation. Data adapted from Ref. [3].

Oxygen thicknesses were calculated from five runs with ΔΩ=12msr and a constant line of best fit was determined. The thickness of the ^{16}O contaminant was found to be 0.44 ± 0.02 mg/cm^2.

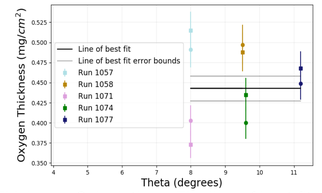


Figure 10: Oxygen Thickness Calculations. The line of best fit is 0.44 ± 0.02 mg/cm^2.

Discussion

Using this thickness and the published ^{16}O cross sections, the contribution of ^{16}O to the experimental excitation energy spectrum was calculated. The analysis of this spectra and the extraction of a K_τ value is ongoing.

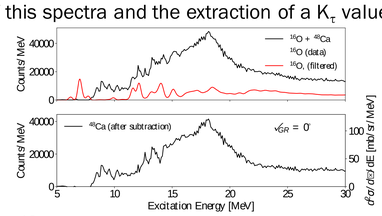


Figure 11: ^{48}Ca experimental spectrum for 0° before and after subtraction of ^{16}O contaminant.

References and Acknowledgments

(1) J. Piekarewicz. Unmasking the nuclear matter equation of state Phys. Rev. C 69, 041301(R), 2004.
(2) J. Button, Y.-W. Lui, D. H. Youngblood et al. 2017. Physical Review C 96, 054330.
(3) T. Wakasa, E. Ihara, K. Fujita et al. 2007. Physics Letters B Volume 653 Issues 2-4 Pages 173-177

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