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Observation of the hot GDR in neutron-deficient thorium evaporation residues

J.P. Seitz [a,b,1], B.B. Back [c], M.P. Carpenter [c], I. Diószegi [d,2], K. Eisenman [b], P. Heckman [a,b,3], D.J. Hofman [e], M.P. Kelly [c], T.L. Khoo [c], S. Mitsuoka [c,4], V. Nanal [f], T. Pennington [c,✠], R.H. Siemssen [c,5], M. Thoennessen [a,b,*], R.L. Varner [g]

[a] *Department of Physics and Astronomy, Michigan State University, East Lansing, MI 48824, USA*
[b] *National Superconducting Cyclotron Laboratory, Michigan State University, East Lansing, MI 48824, USA*
[c] *Argonne National Laboratory, Argonne, IL 60439, USA*
[d] *Department of Physics and Astronomy, State University of New York at Stony Brook, Stony Brook, NY 11794, USA*
[e] *Department of Physics, University of Illinois at Chicago, Chicago, IL 60607, USA*
[f] *Tata Institute of Fundamental Research, Mumbai 400 005, India*
[g] *Oak Ridge National Laboratory, P.O. Box 2008, Oak Ridge, TN 37831, USA*

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Abstract

The giant dipole resonance built on excited states was observed in very fissile nuclei in coincidence with evaporation residues. The reaction $^{48}Ca + {}^{176}Yb$ populated evaporation residues of mass

* Corresponding author.
E-mail address: thoennessen@nscl.msu.edu (M. Thoennessen).
1 Present address: Theragenics Corporation, 5203 Bristol Industrial Way, Buford, GA 30518, USA.
2 Present address: Brookhaven National Laboratory, Upton, NY 11973-5000, USA.
3 Present address: Department of Radiation Oncology, University of Michigan Hospitals and Health System, 1500 East Medical Center Drive, Box 0010, Ann Arbor, MI 48109, USA.
4 Present address: JAERI Advanced Science Research Center, Japan.
5 Permanent address: Kernfysisch Versneller Instituut, 9747 AA Groningen, The Netherlands.
✠ Deceased.

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$A = 213$–220 with a cross section of $\sim$200 µb at 259 MeV. The extracted giant dipole resonance parameters are in agreement with theoretical predictions for this mass region.

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1. Introduction

The giant dipole resonance (GDR) built on highly excited states has been used extensively to study nuclear structure at finite temperatures and angular momenta [1]. In recent years it has also been useful for the investigation of reaction mechanisms in fusion-fission reactions [2]. The observation of excess high-energy γ-ray emission prior to fission [3,4] confirmed results from earlier pre-fission neutron measurements [5,6] that fission in hot systems is slower than expected from standard statistical model calculations.

The difficulty in these high-energy γ-ray experiments, in contrast to the neutron measurements, is the fact that it is not possible to distinguish experimentally the pre-fission γ-rays from γ-rays emitted from highly excited fission fragments. Measuring high-energy γ-rays in coincidence with evaporation residues eliminates this problem and would potentially give more detailed information about the dependence of the structure of these heavy nuclei as a function of temperature and angular momentum.

It also has been speculated that the spin distribution of the evaporation residues is an observable that can distinguish between the different possible causes of fission hindrance [7]. If the extra neutrons and high-energy γ-rays are emitted after the system has committed itself to fission, i.e., after the saddle point, the evaporation residue distribution will not be affected. However, if these particles are emitted earlier, the competition between particle emission and fission is altered and it could change the final spin distribution of the evaporation residues. A first measurement of the spin distribution following the decay of ^{194}Hg formed in the reaction ^{19}F + ^{175}Lu showed no deviation from standard statistical model predictions, indicating that the fission hindrance does not occur in the presaddle region [8–10].

We chose the neutron deficient ^{224}Th for our studies because it is one of the most completely explored nuclei in terms of cross section and pre-fission γ-ray and light particle emission measurements. Fission [11–15] and evaporation residue cross section [14–17], as well as pre-fission neutron [18], charged particle [19] and γ-ray [3,20–23] measurements have been performed. Most of these studies utilized the reaction ^{16}O + ^{208}Pb to populate the compound nucleus ^{224}Th. However, the detection efficiency of the evaporation residues with the light oxygen projectiles is rather small due to their small recoil energy. Thus we chose the reaction ^{48}Ca + ^{176}Yb to form ^{224}Th.