STRUCTURE EFFECTS ON THE NUCLEAR REACTIONS WITH N-RICH Mg BEAMS

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A simple count rate idea

If efficiency is x% for singles measurement in a modern day stable beam experiment; and we maximise the detection setup for an RIB expt to efficiency of y% (100>y>>x).

Then a reduction of the beam flux by a factor of y/x for RIB expt can be taken care of. As y can be at best 100, the beam reduction factor can be at most 100/x. Further reduction of beam flux will move the experiment towards “not feasible”

For a 2 fold coincidence experiments, this flux reduction factor could be $10000/x^2$

For a 3 fold, it will be $1000000/x^3$

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ABSTRACT

COLLECTIVITY IN LIGHT NEUTRON-RICH NUCLEI NEAR N=20: INTERMEDIATE-ENERGY COULOMB EXCITATION OF ^{32,34}Mg, ^{35,36}Al AND ^{37}Si

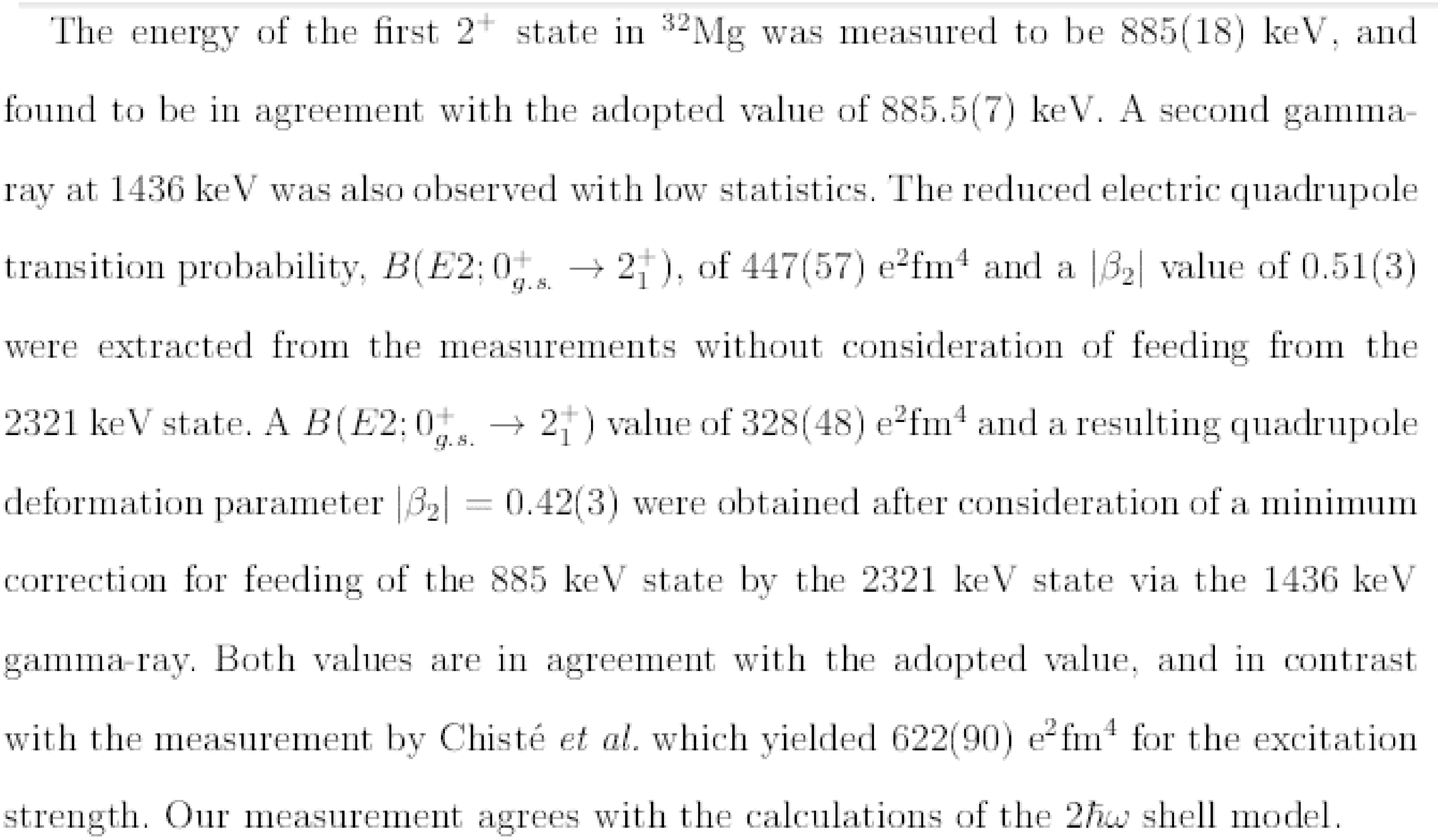
By

Jennifer Anne Church

Collectivity in the neutron-rich nuclei ^{32,34}Mg, ^{35,36}Al and ^{37}Si has been studied via intermediate-energy Coulomb excitation in an early experiment at the National Superconducting Cyclotron Laboratory's Coupled Cyclotron Facility. Reduced transition probabilities and quadrupole deformation parameters were extracted from the measurements.

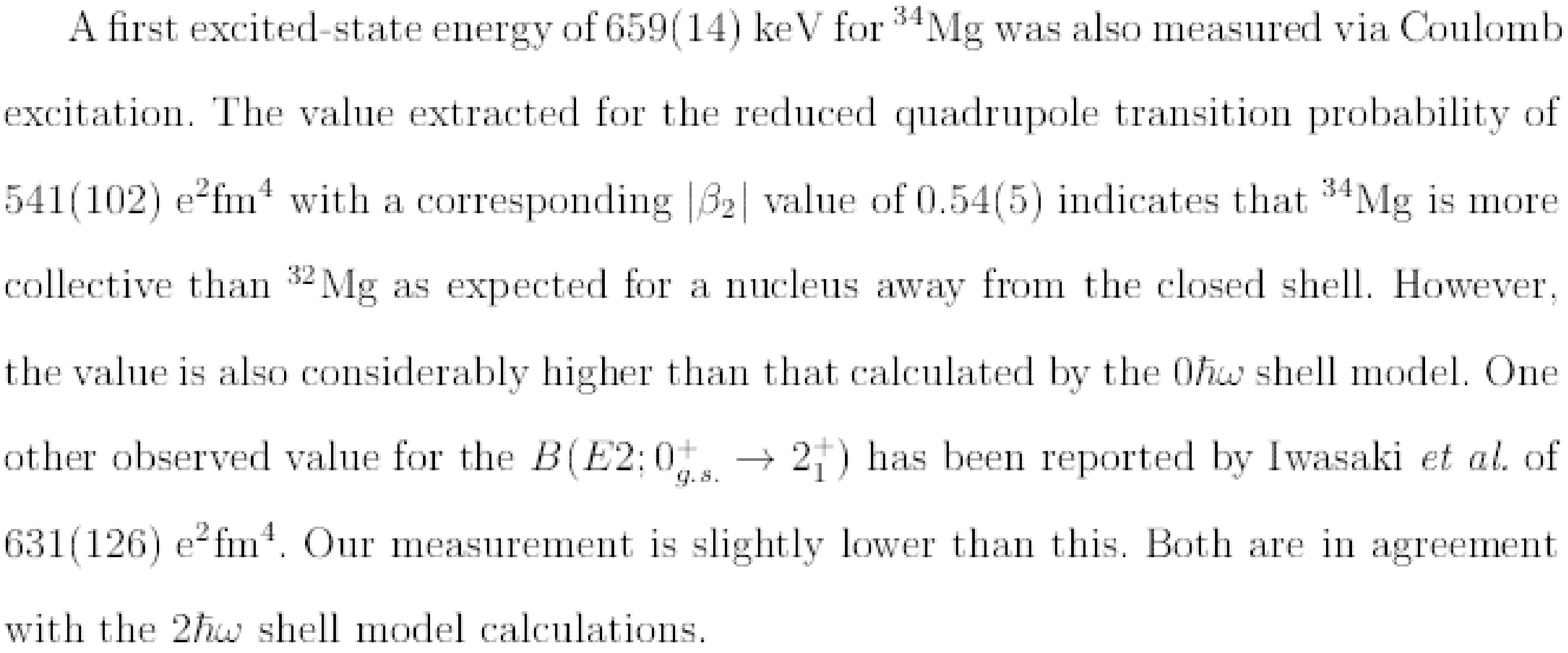
^{32,34}Mg are members of a group of nuclei near $N = 20$ which exhibit collective characteristics unexpected for nuclei at or near a shell closure. The observations are successfully reproduced by shell model calculations that allow a $2\hbar\omega$ intruder configuration as the ground state, in which 2 neutrons are promoted from the $\nu 1d_{3/2}$ level to the $\nu 1f_{7/2}$ level. Models based on valence spaces limited to the $0\hbar\omega$ configuration which describe the stable nuclei well are unsuccessful in calculating observables for these nuclei. Because of this inversion of the $0\hbar\omega$ and $2\hbar\omega$ configurations in energy, the group has been named the "Island of Inversion," and is predicted by the $2\hbar\omega$ shell model to extend to $10 \leq Z \leq 12$ and $20 \leq N \leq 22$. The possibility for static shape deformation has also been considered, and models utilizing a deformed potential are successful in calculating excited state energies and reduced quadrupole transition probabilities for this group. Recently, the neutron boundary has been predicted to extend to $N = 24$ by the $sd - pf$ Monte Carlo Shell Model, and several mean-field calculations predict shape coexistence for ^{32}Mg.

Case of ^{32}Mg



The energy of the first 2^+ state in ^{32}Mg was measured to be 885(18) keV, and found to be in agreement with the adopted value of 885.5(7) keV. A second gamma-ray at 1436 keV was also observed with low statistics. The reduced electric quadrupole transition probability, $B(E2; 0^+_{g.s.} \to 2^+_1)$, of 447(57) e^2fm^4 and a $|\beta_2|$ value of 0.51(3) were extracted from the measurements without consideration of feeding from the 2321 keV state. A $B(E2; 0^+_{g.s.} \to 2^+_1)$ value of 328(48) e^2fm^4 and a resulting quadrupole deformation parameter $|\beta_2| = 0.42(3)$ were obtained after consideration of a minimum correction for feeding of the 885 keV state by the 2321 keV state via the 1436 keV gamma-ray. Both values are in agreement with the adopted value, and in contrast with the measurement by Chisté *et al.* which yielded 622(90) e^2fm^4 for the excitation strength. Our measurement agrees with the calculations of the $2\hbar\omega$ shell model.

Case of ^{34}Mg



A first excited-state energy of 659(14) keV for ^{34}Mg was also measured via Coulomb excitation. The value extracted for the reduced quadrupole transition probability of 541(102) e^{2}fm^4 with a corresponding $|\beta_2|$ value of 0.54(5) indicates that ^{34}Mg is more collective than ^{32}Mg as expected for a nucleus away from the closed shell. However, the value is also considerably higher than that calculated by the $0\hbar\omega$ shell model. One other observed value for the $B(E2; 0^+_{g.s.} \rightarrow 2^+_1)$ has been reported by Iwasaki *et al.* of 631(126) e^{2}fm^4. Our measurement is slightly lower than this. Both are in agreement with the $2\hbar\omega$ shell model calculations.

The puzzle of ^{32}Mg

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An analysis of results of the ^{30}Mg(t,p) ^{32}Mg reaction demonstrates that the ground state is the normal state and the excited 0^+ state is the intruder, contrary to popular belief. Additional experiments are suggested.

Several experiments have suggested that the gs of ^{32}Mg has a neutron configuration that is predominantly $(fp)^2(sd)^{-2}$, even though much of the data [e.g., the $B(E2)$] do not seem to require that conclusion. A straightforward analysis of the ^{30}Mg(t,p) reaction results leading to the gs and the excited 0^+ state demonstrates that the gs is predominantly 0p-0h and the excited state is 2p-2h. If nothing is wrong with the (t,p) experiment, the only reasonable resolution that I see to this dilemma is that the ^{32}Mg nuclei in the knockout experiments were primarily in the excited 0^+ state rather than in the gs. It would be interesting to measure the lifetime of the excited 0^+ state, which is estimated here to be in the range of 50 to 100 ns. Finally, if the neutrons in ^{30}Ne(gs) are predominantly $(fp)^2$ $(sd)^{-2}$, then I expect the excited 0^+ state to be very weak in the reaction ^{28}Ne(t,p)^{30}Ne.

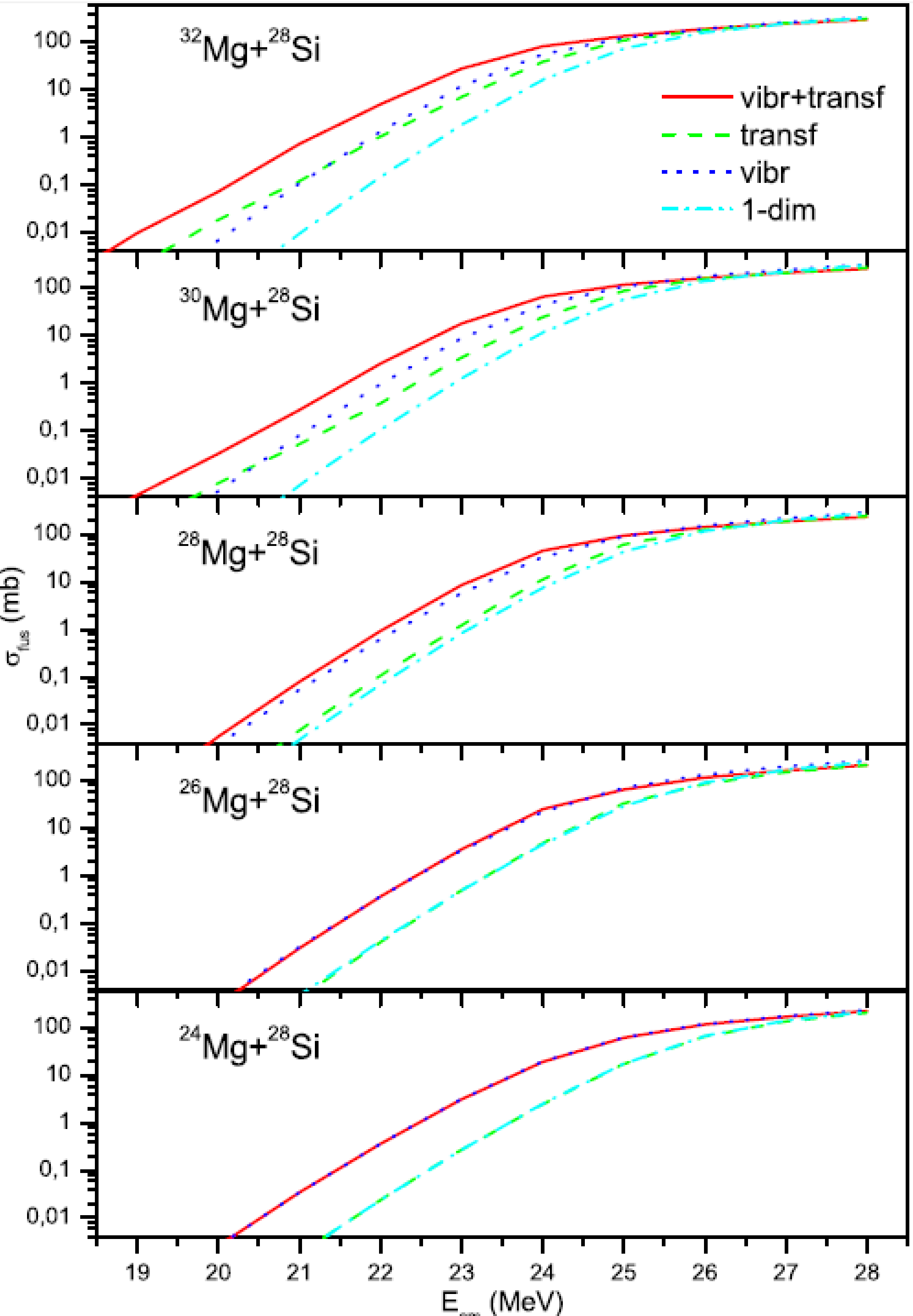
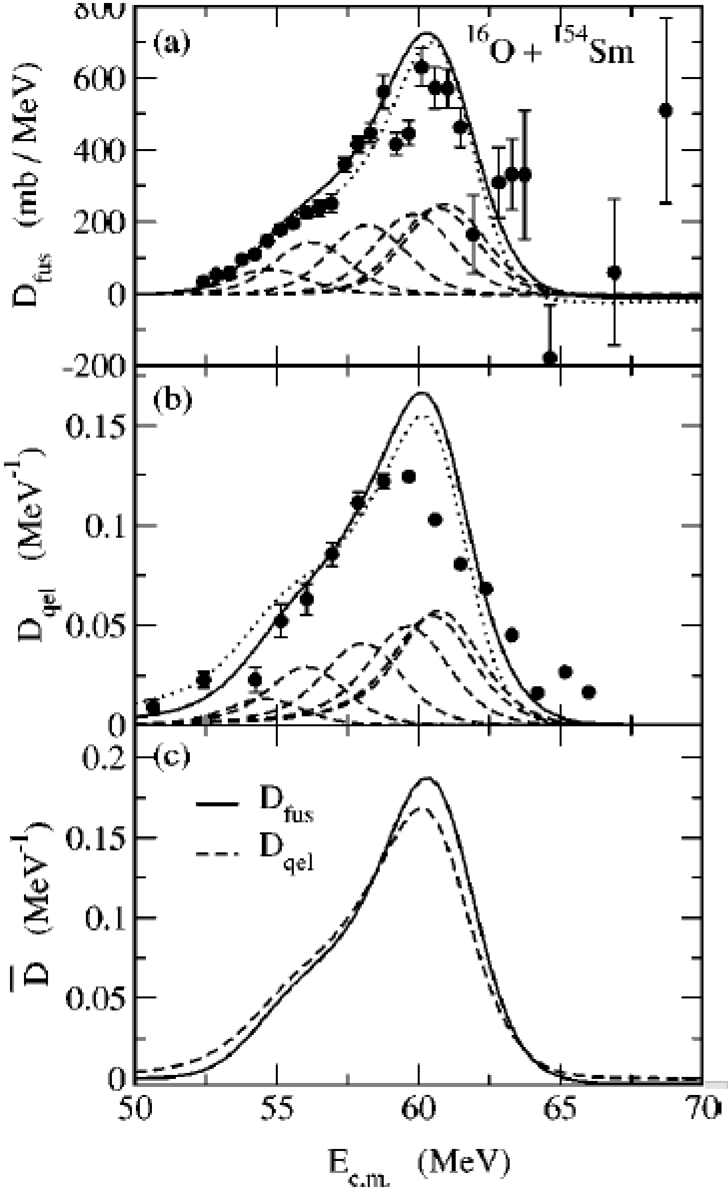


Figure 2: Fusion cross sections for ^{24,26,28,30,32}Mg + ^{28}Si reactions. Subbarrier contributions are enhanced with increasing neutron number in Mg. Red: enhancement due to neutron transfer (until 1n, 2n, 3n and 4n with positive Q-value, negative Q-values for transfer channel are ignored.) and 2+ and 3- vibrational excitations in target and projectile. Green: only neutron transfer contribution. Blue: only 2+ and 3- vibrations in both nuclei. Cyan: 1-dimensional WKB result.



(a) The fusion barrier distribution $D_{\rm fus}(E) = d^2(E\sigma_{\rm fus})/dE^2$ for the ^{16}O+^{154}Sm reaction. The solid line is obtained with the orientation-integrated formula with β_2=0.306 and β_4=0.05. The dashed lines indicate the contributions from the six individual eigenbarriers. These lines are obtained by using a Woods-Saxon potential with a surface diffuseness parameter a of 0.65 fm. The dotted line is the fusion barrier distribution calculated with a potential which has a=1.05 fm. Experimental data are taken from Ref. [5]. (b) Same as Fig. (a), but for the quasielastic barrier distribution $D_{\rm qel}(E) = -d[\sigma_{\rm qel}(E,\pi)/\sigma_R(E,\pi)]/dE$. Experimental data are from Ref. [8]. (c) Comparison between the barrier distri-

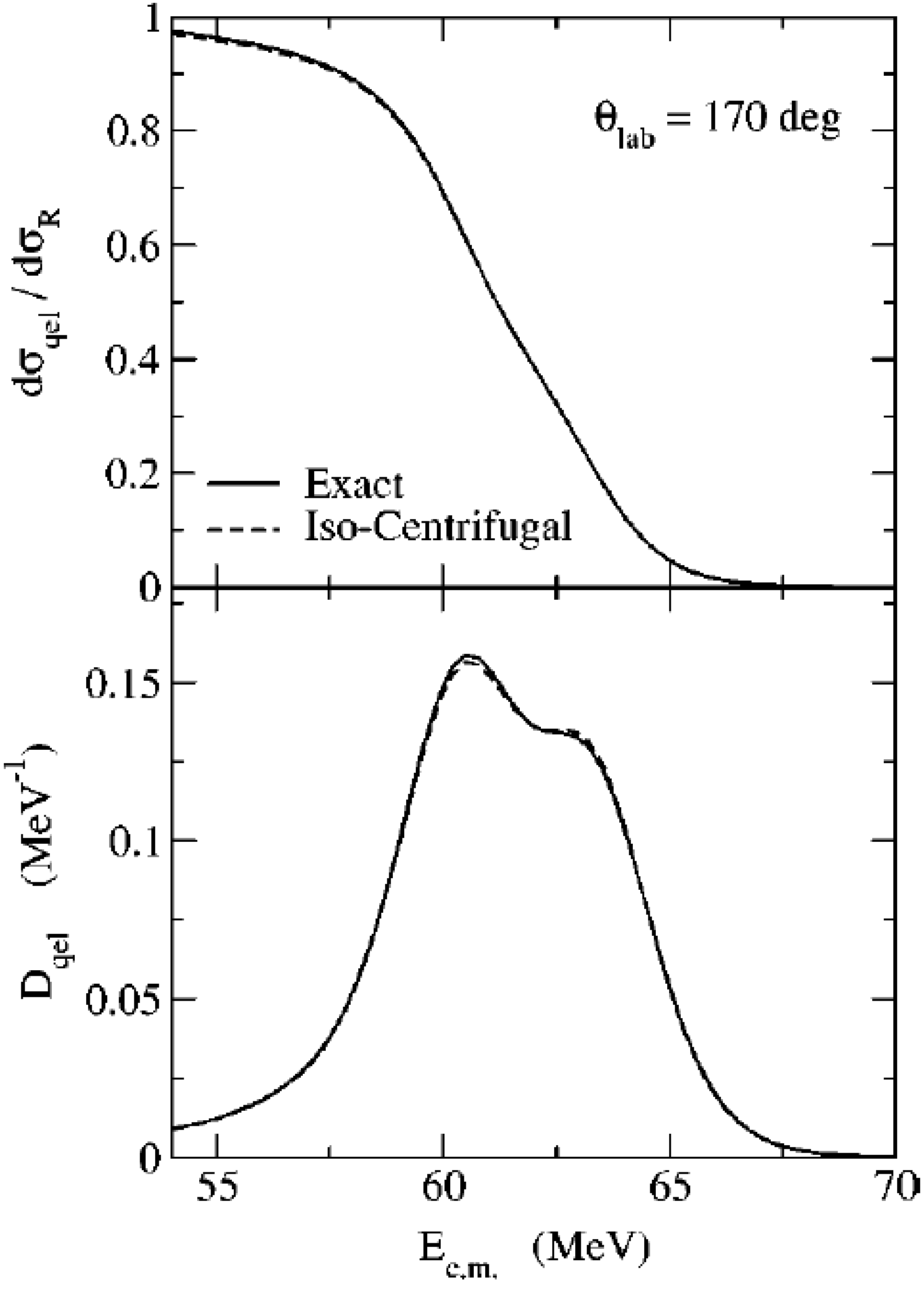


FIG. 8. The excitation function for quasielastic scattering (upper panel) and the quasielastic barrier distribution (lower panel) for the ^{16}O+^{144}Sm reaction calculated at θ=170° in the laboratory frame. The significance of each line is the same as in Fig. 5.

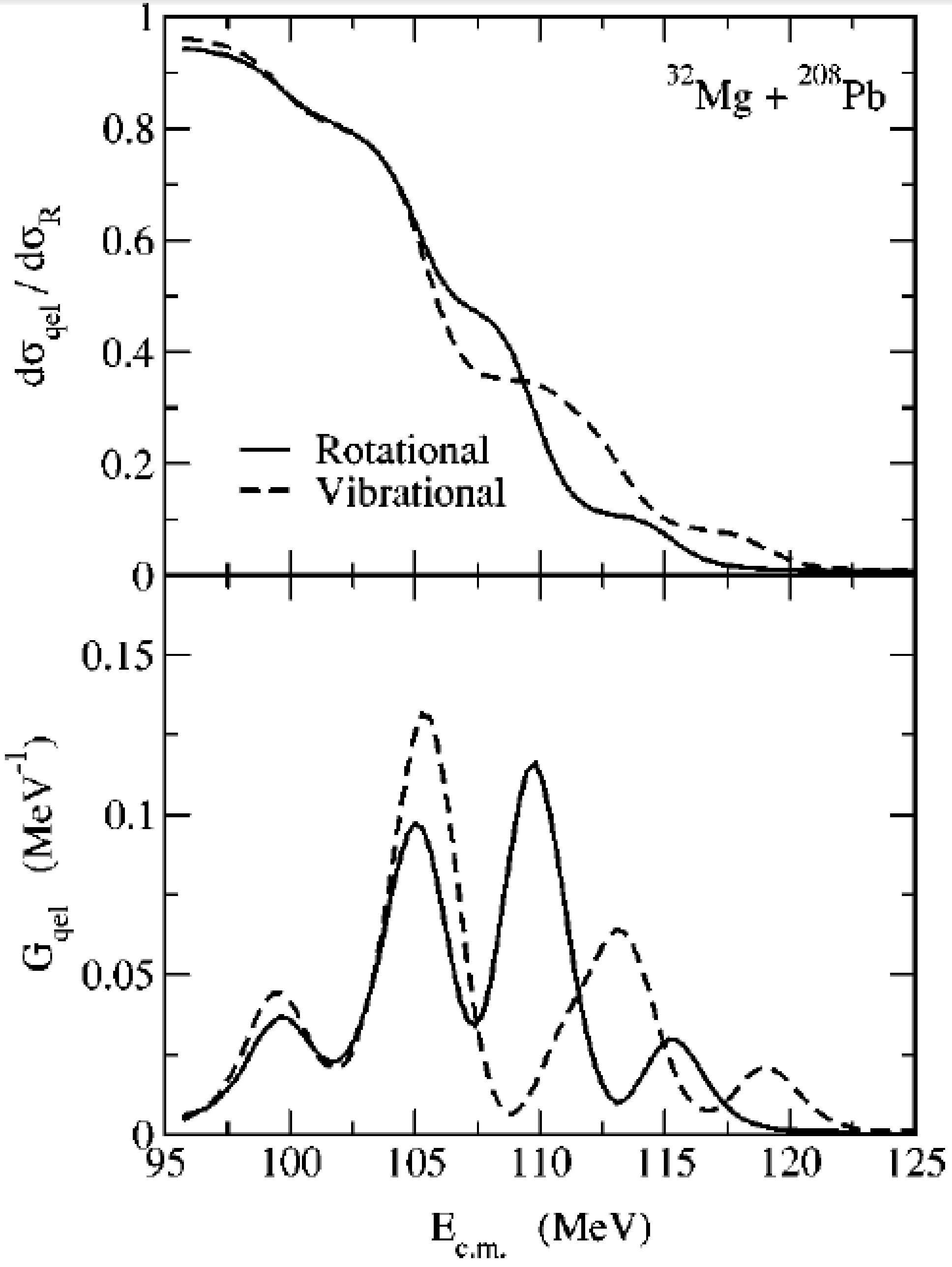


FIG. 9. The excitation function for quasielastic scattering (upper panel) and the quasielastic barrier distribution (lower panel) for the ^{32}Mg+^{208}Pb reaction around the Coulomb barrier. The solid and the dashed lines are the results of coupled-channels calculations which assume that ^{32}Mg is a rotational and a vibrational nucleus, respectively. The single octupole-phonon excitation in ^{208}Pb is also included in the calculations.

Quasi elastic scattering cross sections are to be measured .

Need to carry out cross section measurements across the barrier energy in steps of 1 MeV with accuracy of few percent.

A closed shell but relatively light target ^{40}Ca will be ideal.

The detector should cover a large solid angle (full 2pi coverage of the phi is ideal). A CD type detector with a hole will be fine.

We propose a detailed experimental plan at CERN ISOLDE for a series of experiments for nuclei in and around the Island of Inversion.

~~Thank you for your patience~~