

ISOSPIN MIXING IN THE N=Z NUCLEUS ^{80}Zr AT HIGH TEMPERATURE

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ABSTRACT

We propose to measure the isospin mixing in nuclei in the mass region $A = 80$ at temperatures in the interval $T=2-3$ MeV. So far this topic has been investigated mainly for $A < 60$ by comparing the statistical γ -decay of the giant resonance built on excited states in two compound nuclei, one corresponding to entrance channels with isospin $I = 0$ and the other to entrance channels with isospin $I \neq 0$. This is the first measurement of the isospin mixing in the mass region $A=80$ and we expect with these data a better understanding of the isospin mixing problem.

We propose to use the two symmetrical fusion evaporation reactions $^{40}\text{Ca} + ^{40}\text{Ca}$ and $^{39}\text{K} + ^{40}\text{Ca}$ to form the nuclei ^{80}Zr and ^{79}Y in order to extract the isospin mixing probability from the comparison of the high energy γ ray yields. The experiment will use the combined system GARFIELD plus HECTOR.

The request is for 16 days of beam time divided as follows

10 days for $^{40}\text{Ca} + ^{40}\text{Ca}$ with $E_{\text{beam}} = 200$ MeV

5 days for $^{39}\text{K} + ^{40}\text{Ca}$ with $E_{\text{beam}} = 190$ MeV

1 day for calibration of BaF_2 with 45 MeV $^{11}\text{B} + ^2\text{D}$

We ask the LNL beam development department to reserve a period of experimentation to develop and provide a ^{39}K beam.

1. Introduction

The problem of the mixing of states with isospin $I \neq I_0$ in $N \approx Z$ nuclei, related to the isospin symmetry and its breaking by Coulomb interaction, has attracted renewed interest both, at zero and finite temperature. In particular, at high excitation energy restoration of the isospin symmetry should occur. This is due to the fact, that the isospin mixing probability is related to the ratio of the spreading width of the Isobaric Analog States (IAS) with the statistical decay width of the compound nucleus. While the spreading width of IAS is expected not to depend on temperature [1], the decay width of the compound width is known to increase with temperature so that these two effects result in a decrease of the isospin mixing probability (see figure 1 right panel). So far the temperature dependence of the isospin mixing has been extensively investigated in light nuclei ($30 < A < 60$) [2] using the γ decay of the GDR in compound nuclei. The data in this mass region are consistent with the predicted restoration of the isospin symmetry [3]. Starting from this result and keeping in mind that the statistical decay width is a well known quantity one can infer from the measurements at finite temperature the isospin mixing probability at zero temperature. Therefore the investigation of the isospin mixing at finite temperature is a tool for the study of the isospin mixing problem particularly for several medium mass nuclei with $N=Z$ which are unstable nuclei and difficult to populate at zero temperature. Consequently, the study of the isospin mixing at finite temperature with the GDR decay for nuclei with increasing Z is expected to provide information on how the Coulomb interaction is affecting spreading width of the Isobaric Analog States.

The present proposal intends to measure for the first time isospin mixing on the nucleus ^{80}Zr for which (at zero temperature) the isospin mixing is expected to be of the order of 3-4 % (see figure 1, left panel). The aim is to obtain, together with the existing systematic, a A dependence of the isospin mixing at $T=2-3$ MeV, dependence which is presently not understood.

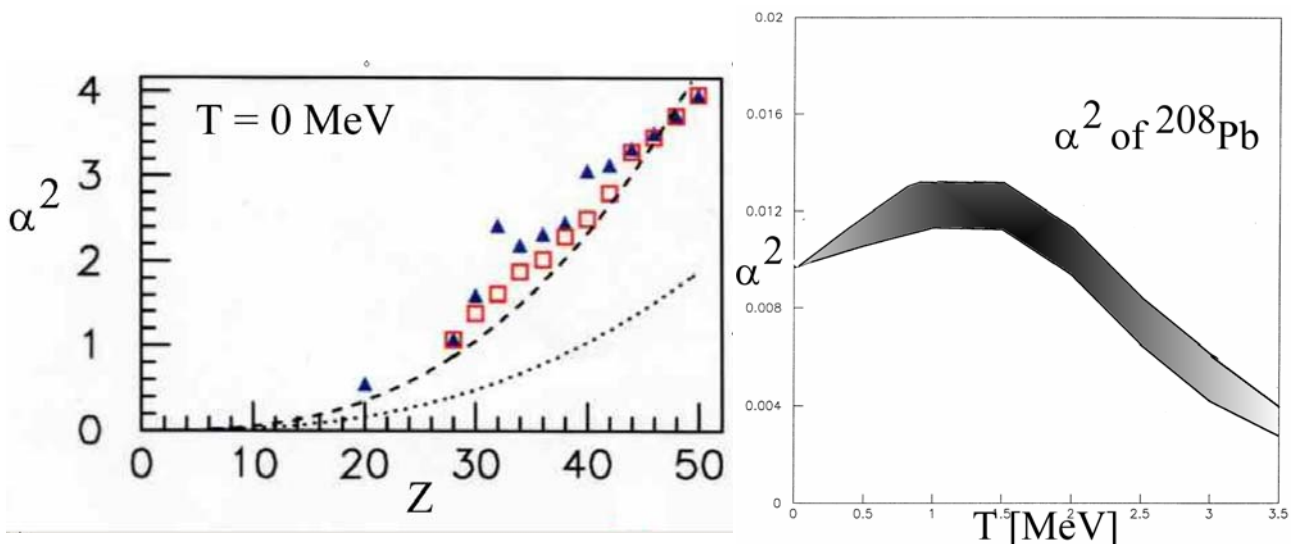


Figure 1: Left panel: plot of different isospin mixing α^2 calculations, shown as a function of Z in $N=Z$ nuclei, which predicts an isospin mixture of $\alpha^2 \sim 3-4\%$ in ^{80}Zr [6]. Right panel: plot of the mixing parameter α^2 as a function of temperature for $A=208$ [7].

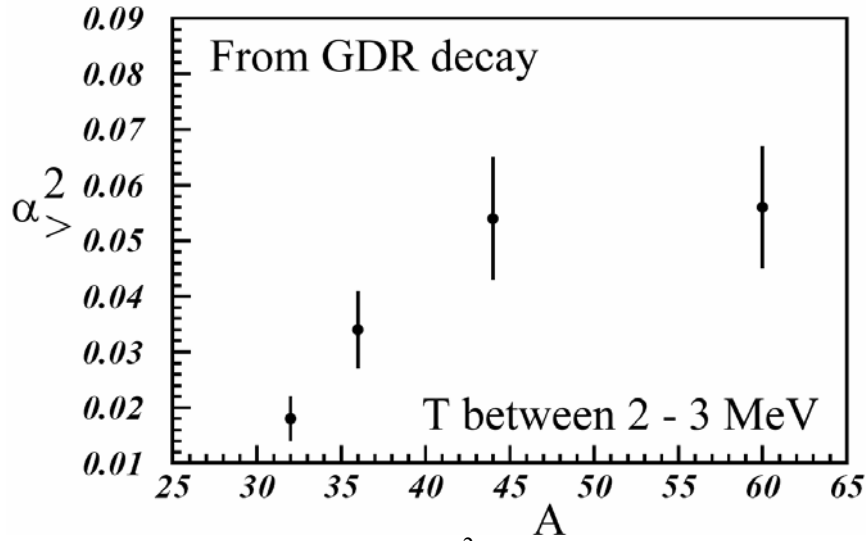


Figure 2: Isospin mixing dependence $\alpha^2_{>}$ on atomic mass extracted from presently available experimental data [5,8] in the temperature range between 2 and 3 MeV.

The values of isospin mixing parameter $\alpha^2_{>}$ are known only in a limited mass region. The mixing at finite temperature generally increases with increasing nuclear mass as can be seen in figure 2 where the observed experimental mixing parameter $\alpha^2_{>}$ [4] defined as:

$$\alpha^2_{>} = \frac{\Gamma^{\downarrow}_{>}/\Gamma_{>}}{1 + \Gamma^{\downarrow}_{<}/\Gamma_{<} + \Gamma^{\downarrow}_{>}/\Gamma_{>}}$$

is plotted. “<” and “>” indicate the states with isospin $I_{<} = I$ and $I_{>} = I + 1$, Γ^{\downarrow} the Coulomb spreading width and Γ the CN decay width.

The proposed experiment intends to measure for the first time the isospin mixing in the nucleus ^{80}Zr for which (at zero temperature) the isospin mixing is expected to be of the order of ~3 - 4 % (see figure 1, left panel and [6,8]). The aim is to obtain, together with the existing systematic, an A dependence of the isospin mixing at $T = 2 - 3$ MeV, dependence which is presently not understood.

2. Experiment

The proposed study of the isospin mixing in ^{80}Zr needs the measurement of the γ decay of the GDR formed with two reactions leading to a very similar CN. The first is $^{40}\text{Ca} + ^{40}\text{Ca}$ forming ^{80}Zr , the second leading to ^{79}Y at the same E^* through the reaction $^{39}\text{K} + ^{40}\text{Ca}$. In fact, the present work will use the well-established method [1,10] of comparing the γ decay of the same compound nucleus formed in 2 different situations, one with isospin $I = 0$ and the other one with $I \neq 0$. In fact, E1 transitions from the GDR-decay in a system with $I = 0$ is strongly inhibited because of the isovector nature of the E1 dipole, which requires a $I=1$ final state and such states have low density. To extract the information on the isospin mixing, the comparison of two reactions is essential to eliminate uncertainties in the determination of width and position of the GDR. This is particularly important due to the small size of the yield difference associated to the isospin mixing effect.

The proposed setup consists of the GARFIELD array, for light charged particle (LCP) detection from 60 to 90 degrees and for the evaporated residues selection under forward angles, combined with 8 large volume BaF₂ crystals of the HECTOR setup for high energy γ ray detection. The GARFIELD array is important for the coincidence selection of the residues and to eliminate all non evaporative contributions to the reaction. Additionally it is crucial to measure the conjunction of the LCP spectra, which in contrast with the γ -ray spectra are expected to be the same in both reactions. It is also of interest to measure high-energy γ spectra in coincidence with alpha particles, because the alpha emission conserves the isospin initial state and therefore the comparison of such spectra should enhance the isospin mixing effect. The investigation of such spectra could play an essential role if the isospin mixing parameter is found to be small.

We have calculated the γ -ray yield of the proposed reaction with the statistical model including isospin effects. The calculated γ ray spectra and the expected ratio between the γ ray yield with full mixing and with an estimated mixing around 4% are shown in figure3.

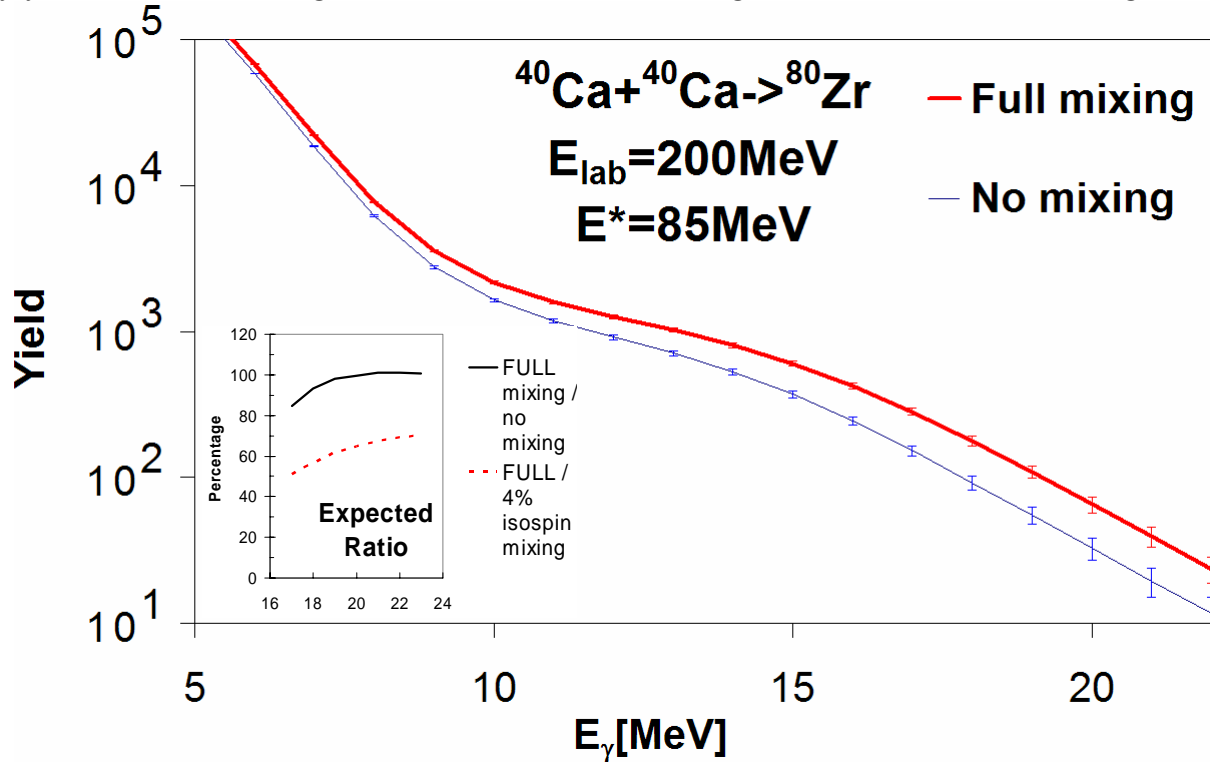


Figure 3: Statistical model calculations of the expected γ ray yield of the symmetrical $^{40}\text{Ca} + ^{40}\text{Ca}$ reaction leading to ^{80}Zr at $E^* = 85 \text{ MeV}$. The upper thick red line is calculated with the assumption of completely mixed isospin (Coulomb spreading width $\Gamma_{>}^{\downarrow} = 100 \text{ MeV}$). The lower thin blue curve is for no isospin mixing ($\Gamma_{>}^{\downarrow} = 0$). In the inset the expected yield ratio for full vs. no mixing and full vs. 4% isospin mixing is shown.

In order to obtain a good determination of the mixing parameter $\alpha_{>}^2$, it is crucial to have sufficient statistics to compare the experimental spectra which could differ by small amount (up to 10-20%). We expect a typical isospin mixing effect of around 20% in the γ -ray yield in the high energy region, with respect to the yield with no isospin mixing [1]. We need a minimum of 300 counts at $E_{\gamma} = 15 \text{ MeV}$ per 1 MeV bin, in order to obtain $\alpha_{>}^2$ with an error of 10%-20% and be able to distinguish the isospin mixing values of $\alpha_{>}^2 = 2\%$ and 4%

Beam time request

For the isospin $^{40}\text{Ca}+^{40}\text{Ca}$ reaction we expect a beam current of 0.25 p_nA on Target (0.5 mg/cm² thick) and 1% efficiency of the BaF₂ detection system, 11% ppac efficiency (the numbers are verified in a former experimental campaign [11] with the Garfield+Hector setup under similar kinematical conditions).

At E_{lab} of 200 MeV (corresponding to a nuclear temperature of approx $T^*=2.2\text{MeV}$) we expect in one MeV bin at $E_{\gamma}=15$ MeV a count rate of 1.42E-04 cts/s.

To arrive to a necessary minimum of statistics to be able to observe isospin effects we need 300cts at 15 MeV, this means 10 days of 24/24h beam on Target.

Additionally we need 1 day of calibration beam to produce high energy γ rays of 15.1 MeV. For the second reaction $^{39}\text{K} + ^{40}\text{Ca}$ the expected count rates are more or less the same as for the $^{40}\text{Ca}+^{40}\text{Ca}$ reaction, and we need to determine the GDR parameters (as seen also in the Ce reaction) a minimum of 150cts per 1MeV bin at $E_{\gamma}=15$ MeV, which corresponds to 5 days of Beam time.

The total request of Beam time is 16 days (not including tuning of ALPI) divided as follows:

10 days for $^{40}\text{Ca} + ^{40}\text{Ca}$ with $E_{\text{beam}} = 200$ MeV

5 days for $^{39}\text{K} + ^{40}\text{Ca}$ with $E_{\text{beam}} = 190$ MeV

1 day for calibration of BaF₂ with 45 MeV $^{11}\text{B} + ^2\text{D}$ (with a gold foil).

Additionally we ask the LNL beam development department to reserve a period of experimentation to develop and provide a ^{39}K beam.

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