Study of the octupole collectivity in ^{90}Zr

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Introduction and Motivation

One of the interesting themes of nuclear structure is the investigation of the effects of octupole correlations on the low lying excitations in nuclei [1, 2]. Magic and semi-magic nuclei exhibit low-energy excitations with angular momentum, $\Delta J = 3$ and negative parity. These low-lying excitations are associated with nuclear shapes that break reflection symmetry and, in particular, with pear-like or octupole shapes [3]. As a result, the reduced transition rate in low-lying excitations, $B(E3; 3_1^- \to 0^+_{\text{g.s.}})$ in closed shell nuclei (such as, ^{16}O, ^{40}Ca [4], ^{48}Ca [4], ^{132}Sn [5], ^{208}Pb [6] *etc.*) enhances.

For even-even Zr-isotopic chain, first excited 3^- state lies at a higher excitation energy than first excited 2^+ state. A number of experimental and theoretical efforts have been put to study the evolution of the 2_1^+ and 3_1^- level energies and reduced transition strengths in these nuclei. It has been frequently reported that the collectivity of 2_1^+ state is less compared to collectivity of 3_1^- state. Of particular interest is the semi-magic nucleus ^{90}Zr, with $Z = 40$ and $N = 50$, where the 2_1^+ and 3_1^- levels are located at the relatively high excitation energies of 2186 and 2748 keV, respectively (see fig-1), compared to the neighbouring isotopes. Although, several measurements employing light-ion as well as heavy-ion inelastic scattering have been performed to extract $B(E3)$ of ^{90}Zr, the values vary over a wide range. The corresponding results from scattering with e [7], p [8], d [9], t [10], ^{3}He [11], α [12, 13], ^{6}Li [14], ^{17}O [15] show discrepancies in measured $B(E3)$

ranging from 0.010 e^2b^3 to 0.086 e^2b^3.

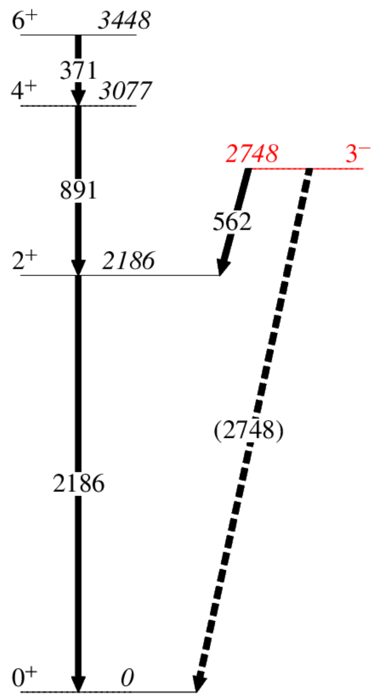

Figure 1: The partial level scheme of ^{90}Zr. The measurement of the excitation of the 2748 keV, 3^- level (marked in Red) can be used to determine the amount of octupole collectivity in ^{90}Zr.

In addition to inelastic scattering technique, Coulomb excitation (CoulEx) experiment is also an effective way to obtain the strengths of these γ-ray transitions. In this type of experiment, the beam energy is kept below a threshold value so that the excited states are populated by purely electromagnetic interaction between projectile and target with negligible contribution from nuclear interaction. Previous attempts of CoulEx on ^{90}Zr have not been successful in populating the 3^- level. The information is limited to the 2^+ level only. In our recent CoulEx measurement employing nat-Zr target, the population of 3^- level in ^{90}Zr could be confirmed by the presence of 562-keV, $E1; 3_1^- \rightarrow 2_1^+$ transition in coincidence with the 2186-keV, $E2; 2_1^+ \rightarrow 0_{\text{g.s.}}^+$ transition (as seen in fig-2). However, additional fusion reaction lines from light-mass nuclei present in the target give a lot of background. The region of interest (around 2-2.3 MeV) is shown to have a large background and the actual yield for the 2186-keV transition could not be extracted properly (see -3). In addition, another contamination from ^{92}Zr (561-keV, $E2; 4_1^+ \rightarrow 2_1^+$), which is a fairly abundant isotope in nat-Zr material, could be identified. To reduce the background and eliminate the contributions from the neighbouring isotopes, a fresh measurement using an enriched ^{90}Zr target is desirable

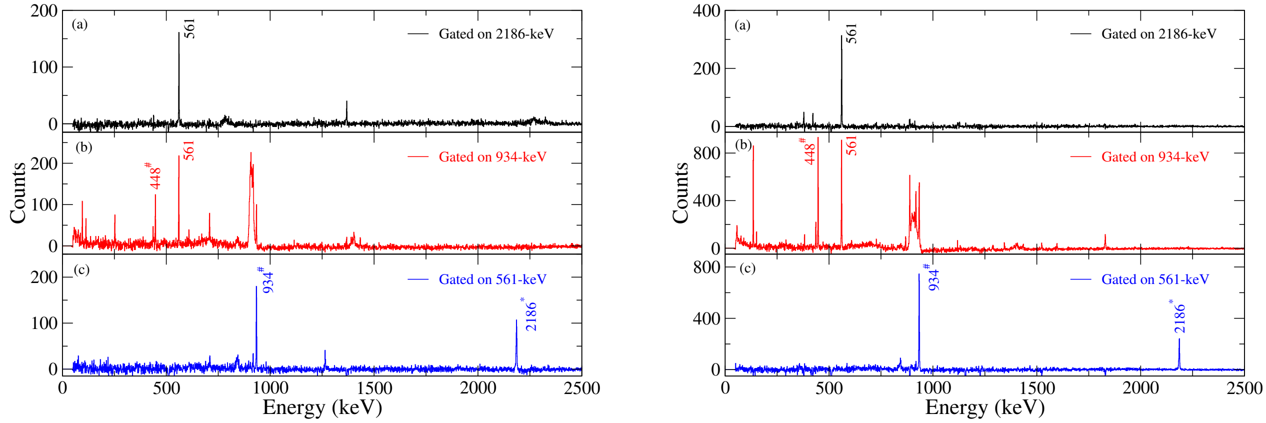

Figure 2: Excitations of both ^{90}Zr and ^{92}Zr nuclei with ^{16}O (left) and ^{32}S (right) beams.

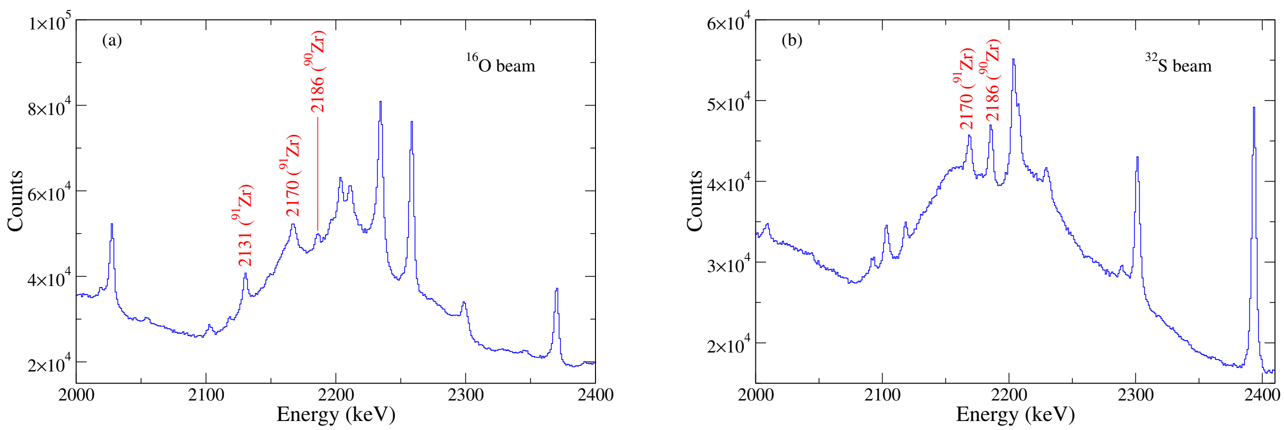

Figure 3: Total projection spectra with (a) ^{16}O and (b) ^{32}S beams showing large background in the vicinity of the γ-ray transitions of interest.

using particle-gamma coincidence technique.

Proposal

The CoulEx of the ^{90}Zr target with ^{32}S beam has the maximum safe bombarding energy 85.4 MeV. We have used this projectile-target combination and 85 MeV beam energy in the Coulomb excitation simulation code GOSIA [16], to simulate yields.

We propose to carry out the Coulomb excitation experiment using 80-90 MeV ^{32}S beam and a 1.0 mg/cm^2 thick ^{90}Zr target. The decay transitions will be detected by the INGA (array of clover HPGe detectors) and the complementary scattered projectile with an annular Si particle detector. The present proposal is a continuation of a program to study low-lying collectivity in Zr isotopes. In our last attempt, there were some unexpected technical issues with the DAQ and Si detector during the beam time. We propose to repeat the experiment.

Experimental setup

Gamma-ray detectors : 16 Compton suppressed HPGe Clover detectors of INGA.

Particle detector : Annular Si particle detector kept at a distance of 52 mm from the target.

Beam requirements

Type of the projectile : ^{32}S

Beam energy : 80-90 MeV

Beam intensity : 1 pnA

Target details : 1.0 mg/cm^2 thick ^{90}Zr (of 97.6% enrichment)

Yield calculations

As per integrated yield calculations predicted by GOSIA, over laboratory scattering angles of the projectile in the range $146^o - 168^o$, the estimated count rates for the 2186- and 562-keV γ-lines of ^{90}Zr are ∼3000 and ∼8000 counts/day, respectively. Thus, we propose 6 days of beam-time for the substantial population of 3^- state in ^{90}Zr.

Beam-time required : 6 days (18 shifts).

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