BARC–TIFR Pelletron Linac Facility Beam Time Request @2024

Title of the Experiment: Investigation of octupole correlation in Zn and Ge isotopes, near N~Z=34, A~60-70 region

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Local Collaborator / Spokesperson: Prof. Rudrajyoti Palit
Note: Local collaborator is mandatory for non BARC (NPD) / TIFR (DNAP) user

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Motivation of the experiment:

This PhD thesis proposal aims to undertake experimental investigation on octupole correlation of the nucleus of mass number A~60-70 region. For this purpose, We select ^{68}Zn and ^{70}Ge and their close by neighbors. The systematic study of some parameters will help to explore the collective behavior of the proposed nuclei and its neighbour.

Beam Details:

No. of runs	Energy(MeV)		Ion species	Current (pnA)	
	Min.	Max.		Min.	Max.
1.	20	50	^{7}Li	2	3
2.	35	75	^{18}O	2	3

Buncher requirement: No

Number of shifts (1 shifts=8 hr.) required: 24 Shifts

Experiment details:

1. **Objective of Experiment:**

The main two pillars to understand nuclear structure are shell model and deformation, rotation and vibration of nuclear shapes etc., which we obtain from collective model. Symmetries of nuclear shapes have long been of great interest in nuclear structure physics. Most of the nuclei in nuclear chart have reflection symmetry. We can use spontaneous symmetry breaking as a lens to study more about nuclear structure. With breaking reflection symmetry, some nuclei appear to have an octupole deformation, i.e. pear-like shapes. If we look for permanent octupole deformation i.e. those nuclei that show minima in the binding energy as a function of octuplet deformation, we get some nuclei in actinide region, some rare earth region and very neutron rich region. Octupole magic number configurations occure in the single particle spectrum where nearby opposite parity levels are very close to Fermi level. This situation happens around particle number 34, 56, 88, 134, 196 and these correspond to angular momentum difference 3 units. This is governed by multipole-multipole term in Hamiltonian which depends on Y_3 for octupole case. It came out that differences of three units in angular momentum quantum number can be found just above each of the closed shell. There is a prediction that with proton or neutron numbers close to 34 and close to N=Z line will show the octupole correlation effects. In ^{114}Xe, the experimental B(E3) value is of the order of 77(27)W.u, having almost twice the octupole strength deduced for the 3^- state in the ^{146}Gd region. This enhancement was interpreted as the coherent contribution of protons and neutrons to the octupole collectivity. This is introduced as new mechanism, which is expected to appear close to N~Z ~28 line. One of the most common and strong evidences of reflection asymmetry in nuclei is the occurrence of low lying negative parity collective states. These types of properties were first identified in and the isotopes with neutron number approximately 136 by Berkeley group (Asaroetal., 1953; Stephens et al., 1954, 1955) using alpha spectroscopy. In this mass region the 1^- and 3^- states remain energetically higher than 2^+ and 4^+ states respectively, which rules out a simple interpretation in terms of octupole deformation. Another common property of nuclei exhibiting the features of reflection asymmetry is occurrence of relatively large E1 transition probabilities between yearst positive and negative parity bands. Low energy B(E3) values are also good measures of octupole collectivity. The spectroscopy of ^{71}Ge has been investigated via the fusion-evaporation reaction ^{74}Ge (α, α3n)^{71}Ge. Collective structures including a rotational band built on the $15/2^-$ octupole state in ^{71}Ge have been established. The observation of strong E1 transitions and the well-behaved rotational sequence built on the $15/2^-$ octupole state provide the first experimental evidence of an octupole rotational band in Ge isotopes, suggesting an enhanced octupole correlation around N=40 in the A≈70 region. A newly developed semi microscopic cluster model provides a good description of the octupole characteristics of ^{71}Ge.In this proposed work we want to study and explore the octupole correlation and collective behavior in a region near about proton and neutron number 34. In ^{66}Zn good amount of E1 transition have been observed (Fig. 1) and this indicates the probability of getting E3 transition. Characterization of the low-lying states of

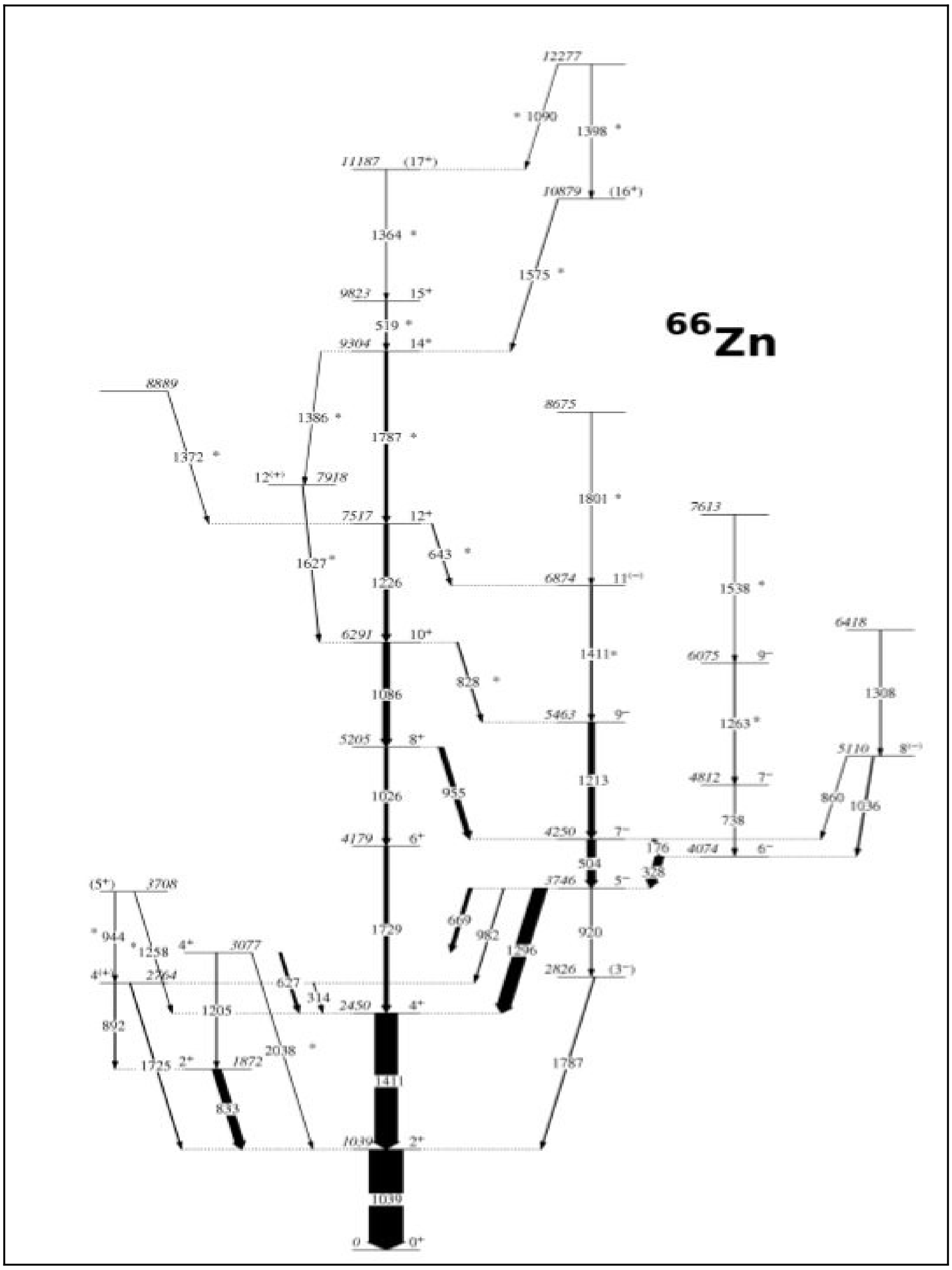

Fig. 1 Level scheme (partial) of ^{66}Zn, as obtained from the work of S. Rai et al.

Zn and Ge isotopes is another aim of this work. We want to map the characterization of octupole states in ^{68}Zn and its isotopes and isotone of ^{68}Zn i.e., ^{70}Ge and it will help give

the clear pattern how octupole collective nature changes with changing proton and neutron number in this region. We want to investigate variation of B(E1)/B(E2), systematic variation of excitation energy, systematic changes of the position of $2^+$and 3^- with increasing neutron number in this mass region. We can also explore the variation of aligned spin with quantum mechanical rotational frequency.

2. **Description of Experiment:**

The experiment we would like to perform at TIFR aims mainly at measuring the B(E3) values of ^{68}Zn and ^{70}Ge. It is seen that there are many E1 transitions [$12^+ \rightarrow 11^-$,$10^+ \rightarrow 9^-$,$8^+ \rightarrow 7^-$(935MeV), $5^- \rightarrow 4^+$(1296MeV)] in ^{66} Zn (Fig 1.) and this motivates us to explore about octupole correlation and collectivity of isotopes and isotone of ^{66}Zn. Here, we select ^{68}Zn as main nucleus and ^{70}Ge as its isotone.

We will use following two reactions to populate both the nuclei of interest

- **^{7}Li+ ^{64}Ni at lab energy of 33 MeV**
- **^{18}O + ^{55}Mn at lab energy of 60 MeV**

Material	**Backing**		**Thickness (µg/cm^2)**
	Material	**Thickness(µg /cm^2)**	
^{64}Ni	**^{197}Au**	**10mg/cm^2**	**700**
^{55}Mn	**^{197}Au**	**10mg/cm^2**	**700**

In our research, we utilized the powerful statistical model code PACE4(24) to get the cross-section of residual nuclei generated during a specific reaction, selecting the appropriate energy of he projectiles for our study. Our calculations showed that the nuclei we were interested were well populated at the proposed energies. For our experiment, we have planned two runs. In the first run, we aim to populate ^{68}Zn by target projectile combination ^{7}Li +^{64}Ni at 33 MeV lab energy. In the second run, we aim to populate ^{70}Ge by target projectile combination ^{18}O + ^{55}Mn at 60 MeV lab energy. The

value of cross-section(predicted by PACE4) for ^{68}Zn is 223mb at 33 MeV lab energy and 111mb for ^{70}Ge at 60 MeV lab energy.

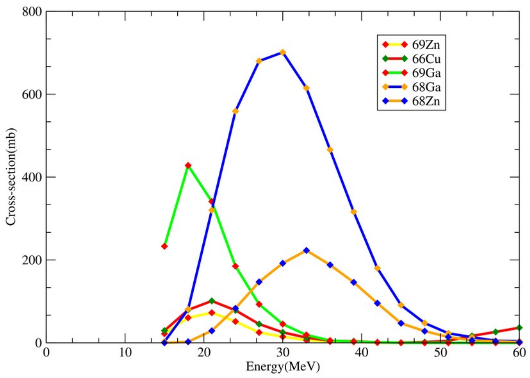

Fig. 2 Production cross-section of some yields by target-projectile combination ^{7}Li +^{64}Ni at various energies

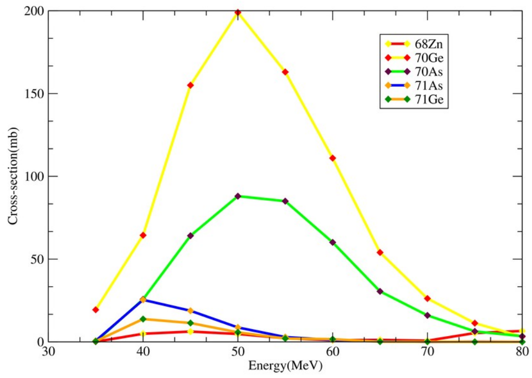

Fig. 3 Production cross-section of some yields by target-projectile combination ^{18}O +^{55}Mn at various energies

Beam Time Calculation

Yield=3.76/A * σ_{total} * I * t **Where, A = 64 I = 3 pnA, t = 700 μg/cm^2, σ_{tot} = 223 mb (following PACE4 calculations).**

The production of ^{68}Zn per sec is given by = 27.51*10^{3}counts/sec Considering INGA at TIFR comprising of 16 numbers of clover detectors, we have:

The efficiency of each clover detector w.r.to NaI(Tl) is 23% placed at 25cm from target, the efficiency of NaI(Tl) detectors is 1.2 * 10^{-3}.

INGA efficiency (placed at 18cm from target position)

$€=16*4*23*1.2*10^{-3}*25^2/18^2=3.40\%$

Average gamma multiplicity=12

Thus the no. of gammas detected by INGA per sec is given by:

$N_{\gamma\ per\text{-}sec}=12.09 * 10^3 * 12 * 3.40 * 10^{-2} = 4932$

$N_{\gamma\text{-}\gamma per\text{-}sec}=4923 * (13 * 23 * 1.2 * 10^{-3}\ \%) * 13 * 25^2/18^2 = 444$

Thus, for the 24-shift beam time counts are

- **$4932 * 24 * 8 * 60 * 60 = 3.40 * 10^9$**
- **$444 * 24 * 8 * 60 * 60 = 0.30 * 10^9$**

Similarly, for ^{70}Ge:

The no. of gammas detected by INGA per sec is given by:

$N_{\gamma per\text{-}sec} = 15.93 * 10^{3} * 12 * 2.98 * 10^{-2} = 5697$

$N_{\gamma\text{-}\gamma\ per\text{-}sec} = 5697 * (13 * 23 * 1.2 * 10^{-3}\%) * 25^{2}/18^{2} * 13 = 512$

Thus, for the 24–shift beam time:

- **$5697 * 24 * 8 * 60 * 60 = 3.9 * 10^{9}$**
- **$512 * 24 * 8 * 60 * 60 = 0.35 * 10^{9}$**

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