TRS calculation for light nuclei formed in heavy-ion reactions

*Aparajita Dey[1], #Sourav Ganguly[2]
[1]*Saha Institute of Nuclear Physics, 1/AF, Bidhan Nagar, Kolkata - 700064, INDIA*
[2]*Deptartment of Physics, Chandernagore College, Chandernagore, Hoogly - 712136, INDIA*
*email: * aparajita.dey@saha.ac.in, #sgpresi78@gmail.com*

Several experimental studies have been done to estimate the deformed configuration of the hot composites formed in the light-heavy-ion reactions. In light-ion-induced reaction the composite system gains low excitation and low angular momentum, while in heavy-ion-induced reaction the associated angular momentum value is high enough. The statistical model is used to describe the decay of a highly excited composite. The energy spectra of light charged particles emitted in light-ion-induced reaction are explained satisfactorily by the statistical model predictions [1,2]. However, in heavy-ion-induced reaction, the energy spectra of LCPs are inconsistent with the respective theoretical predictions of statistical model because of the angular-momentum-induced deformation of the hot composite [3]. In addition, specific structure effects (*i.e.*, α-clustering in α-like nuclei) are also known to influence the reaction process and thus contribute to the deformation of the composite. In most of the cases, the deformed configuration of the hot composite has been estimated from the emitted light charged particle spectra, particularly, the α-particle spectra, and it was incorporated by varying the radius parameter r_0 as well as the deformation parameters δ_1, δ_2 of the spin-dependent moment of inertia [1-5]. The optimum values of the parameters for different light heavy-ion reactions are given in Table 3 of Ref. [5]. In some cases, the GDR lineshape was used to study the deformation [6].

Theoretically the deformation of a nucleus has been estimated using the Total Routhian Surface (TRS) calculation. The present TRS calculation has been studied for ^{31}P, ^{32}S and ^{40}Ca nuclei with a ground state configuration as well as the excited state configuration. These calculations were performed using a deformed Wood-Saxon potential with monopole pairing [7]. The total Routhian was minimized on a lattice in the (β_2,γ) space with respect to the hexadecapole deformation β_4 and displayed in Figs.1 – 5.

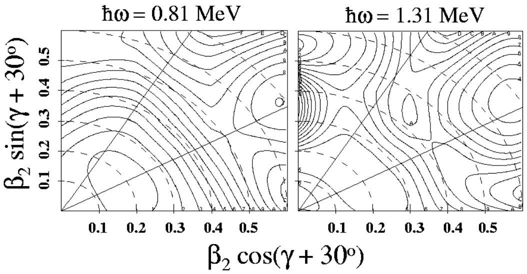

Fig. 1 TRS calculation for ^{32}S nucleus with ground state configuration.

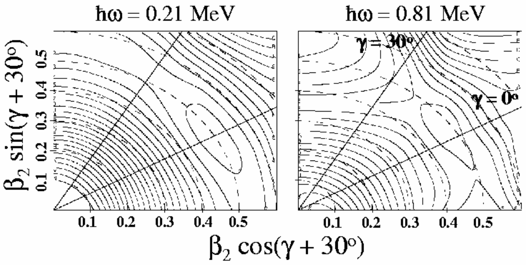

Fig. 2 TRS calculation for ^{32}S nucleus with $\pi(f\,p)^2\,\nu(f\,p)^2$ configuration (SD band).

Light charged particle spectroscopy and GDR lineshpae show that ^{32}S nucleus has a very deformed shape (super-deformation). It was also found from GDR lineshpae that ^{32}S has a prolate shape. TRS calculation shows that with ground sate configuration it has a nearly prolate shape with small deformation at $\hbar\omega < 1$ MeV but the deformation is large ($\beta_2 \sim 0.6$) at $\hbar\omega > 1$ MeV with nearly oblate shape (Fig. 1). With $\pi(fp)^2\,\nu(fp)^2$ configuration, $\beta_2 \sim 0.6$, however the shape changes from prolate to near-oblate shape with increasing rotational frequency (Fig. 2). On the other hand, the nearby nucleus ^{31}P has small deformation ($\beta_2 = 0.27$, estimated from LCP spectra). TRS calculation also confirms that $\beta_2 \sim 0.34$ and the shape is triaxial. However, at higher rotational frequency ($\hbar\omega > 1$ MeV) the value of deformation increases to $\beta_2 \sim 0.6$. The TRS results are compared with experimental results in Table 1.

Table 1 Deformation estimated using different techniques for light nuclei.

Nucleus	LCP β_2	GDR β_2 shape	TRS ħω β_2 γ (MeV)
^{31}P	0.27	… …	$\pi\ s_{1/2}$ 0.21 0.34 -30° 1.31 0.57 72°
^{32}S	0.55	0.68 prolate [8]	Ground state 0.21 0.13 125° 0.81 0.20 -8° 1.31 0.57 72° $\pi(fp)^2\ \nu(fp)^2$ 0.21 0.50 5° 0.81 0.61 71°
^{40}Ca	0.08	… …	Ground state 0.51 0.04 33° 0.71 0.32 55° $\pi(fp)^2\ \nu(fp)^2$ 0.51 0.29 54° 0.81 0.09 22° 1.51 0.50 37°

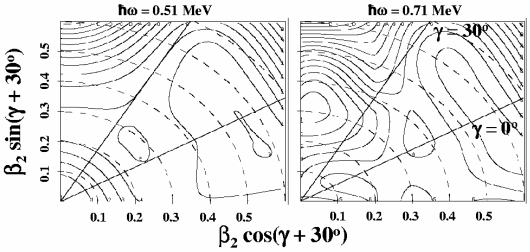

Fig. 3 TRS calculation for ^{40}Ca nucleus with ground state configuration.

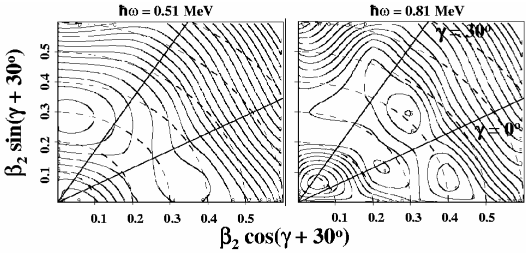

Fig. 4 TRS calculation for ^{40}Ca nucleus with $\pi(fp)^2\ \nu(fp)^2$ configuration at ħω < 1 MeV.

Figs. 3 – 5 show the TRS plot for ^{40}Ca nucleus. LCP spectroscopy gives very low deformation for this nucleus while the TRS calculation shows that the deformation increases with increasing rotational frequency and the shape changes from triaxial to near-oblate for ground state configuration. For excited states [$\pi(fp)^2\ \nu(fp)^2$ configuration] the β_2 value decreases with rotational frequency for ħω < 1 MeV and the shape is triaxial. Above ħω = 1 MeV, β_2 is large (~ 0.5).

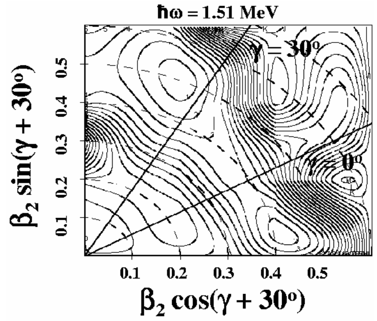

Fig. 5 TRS calculation for ^{40}Ca nucleus with $\pi(fp)^2\ \nu(fp)^2$ configuration at ħω > 1 MeV.

TRS calculation shows that for light mass nuclei the value of deformation β_2 increases with rotational frequency and reaches a value which is > 0.5, *i.e.*, according to TRS calculation these light mass nuclei, at higher excitation, have a superdeformed configuration. More experiments have to be performed to establish this feature.

References

[1] J. R. Huizenga, *et al.*, Phys. Rev. C **40** (1989) 668.
[2] G. Viesti, *et al.*, Phys. Rev. C **38** (1988) 2640.
[3] T. C. Awes, *et al.*, Phys. Rev. C **24** (1981) 89.
[4] Aparajita Dey, *et al.*, Phys. Rev. C **74** (2006) 044605 and references therein.
[5] Aparajita Dey, *et al.*, Eur. Phys. Jour. A **41** (2009) 39 and references therein.
[6] M. Kmiecik, *et al.*, Acta Phys. Pol. **B 38** (2007) 1437.
[7] W. Nazarewicz, R. Wyss and A. Johnson, Nucl. Phys. **A 503** (1989) 285.
[8] Deepak Pandit, *et al.*, Proc. DAE Symp Nucl. Phys. **53** (2008) 269.