Isovector Giant Dipole Resonance energy constant using finite range effective interaction

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Introduction

The density-dependent symmetry energy is a key ingredient for the study of many aspects of astrophysics as well as nuclear physics in both theoretical and experimental fields [1- 3]. But we cannot measure fundamental quantities like nuclear symmetry energy directly. So it is very essential to gather some measurable observables to extract information about the fundamental quantity. The isovector giant dipole resonance (IVGDR), dipole polarizability & neutron skin thickness (S) are supposed to be very strong isovector observables .

The isovector giant dipole resonance (IVGDR) is one type of oscillation mode in which neutrons and protons move collectively relative to each other [4].

D. Behra et.al. [5] showed that the IVGDR energy constant D can be expressed as D=73.833+0.538[$a_{sym}(A)$/t]$^{1/2}$ where a_{sym} is the symmetry energy coefficient and using this relation they calculate the quantity t=0.202fm which is an important parameter of skin thickness S. Therefore, it is very important to study the IVDGR energy constant through our splitting channel and find a relation between skin thickness and D. Using finite range effective interaction, we have calculated D and find the relation with neutron skin thickness.

Correlation of neutron skin "S" with dipole resonance.

The dipole response of a heavy nucleus to an externally applied electric field is mostly dominated by the giant dipole resonance (GDR) of width 2−4 MeV [5-6]. Due to excess neutrons in heavy nuclei like ^{208}Pb, the E_1 value is in the range between 9 to 11 MeV. It is well known that nuclear symmetry energy dominates the properties of IVGDR to a great extent.

There are some correlations of nuclear symmetry energy parameters with pygmy dipole resonance [7], giant dipole resonance and dipole polarizability [8] as seen in this paper also.

The IVGDR energy constant, D can be written as [9]

$$D=\sqrt{\frac{8\hbar^2}{mr_0^2}\left[\frac{E_{sym}(\rho_0)}{1+3\frac{E_{sym}(\rho_0)}{Q}A^{-1/3}}\right]}. \qquad (1)$$

As the E_{sym}/Q depends on neutron skin thickness S [10] we can find out a relation between the IVGDR energy constant D with S.

We can rewrite Eq. (1) as

$$D=\sqrt{\frac{8\hbar^2}{mr_0^2}\left(\frac{3}{A^{1/3}Q}\right)^{-1/2}\left[1+\frac{A^{1/3}Q}{1+3E_{sym}(\rho_0)}\right]}. \qquad (2)$$

Expanding the square-bracketed term in powers of $\frac{A^{1/3}Q}{3E_{sym}(\rho_0)}$ and retaining up to the 1st order we get:

$$D\approx\sqrt{\frac{8\hbar^2}{mr_0^2}\left(\frac{3}{A^{1/3}Q}\right)^{-1/2}\left[1-\frac{A^{1/3}Q}{6E_{sym}(\rho_0)}\right]}. \qquad (3)$$

$$D=B_A\left(\frac{a_{sym}(A)}{t}\right)^{-1/2}\left[1-\frac{A^{1/3}Q}{6E_{sym}(\rho_0)}\right]. \qquad (4)$$

$$D=B_A\left(\frac{a_{sym}(A)}{t}\right)^{-1/2}\left[1-\frac{3}{8}\frac{A^{1/3}E_{sym}(\rho_0)}{\left(L-\frac{K_{sym}}{12}\right)}\right]. \qquad (5)$$

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We substitute Q in terms of t and define a constant $B_A = \sqrt{\frac{4\hbar^2}{mr_0^2} A^{1/3} (I - I_c)}$ for a given nucleus. In eq. (5), the leading term is proportional to $\left(\frac{a_{sym}(A)}{t}\right)^{1/2}$.

We plot IVGDR energy constant D as a function of L for ^{208}Pb by using the like and unlike part of finite range effective interaction in Fig. 1 and D as a function of "S" in Fig. 2. In both cases, we used $E_{sym}(\rho_0)$=30 MeV and ρ_0=0.161 fm^{-3}.

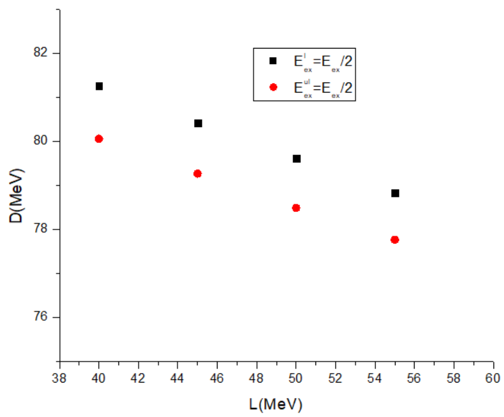

Fig.1. The variation of IVGDR energy constant D of ^{208}Pb is shown as a function of the density slope parameter L for both $E_{ex}{}^{l}$ & $E_{ex}{}^{ul}$.

From Fig. 1 we saw a decreasing nature of D with the increased value of slope parameter for both like and unlike interaction. We obtained the IVGDR energy constant for ^{208}Pb in the range 77.6 MeV− 80.6 MeV by using the Q values calculated in the present work, which is in close agreement with the experimental value Dexp ≈ 80 MeV for heavy nuclei.

We varied S in between 0.16 fm to 0.24 fm and calculate the D values for both cases and we observe that decreasing nature of D with the increase of S for both $E_{ex}{}^{l}$ & $E_{ex}{}^{ul}$ and these results were also consistent with another study [5]. From the experimental result of IVGDR energy constant D we see from figure 2, the skin thickness is 0.16 fm for like & 0.18 fm for unlike interaction. Here we see that the deviation of skin thickness in two different splitting is minimum.

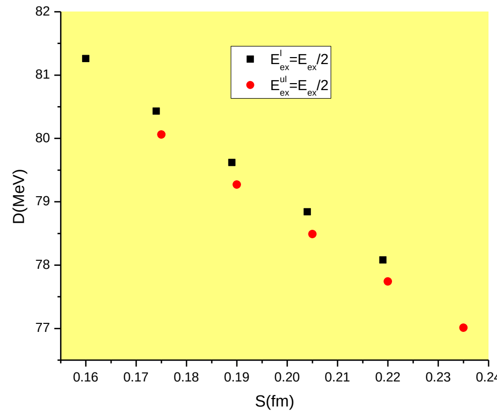

Fig. 2. the plot of IVGDR energy constant D of ^{208}Pb is as a function of neutron skin thickness S for both $E_{ex}{}^{l}$ & $E_{ex}{}^{ul}$.

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