Nuclear symmetry energy in relativistic meanfield model constrained by collective excitations

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Our aim

- ✓ Investigate the relation between the nuclear symmetry energy (J) and collective excitations in the framework of relativistic nuclear energy-density functional (RNEDF);
- ✓ Optimize the RNEDF parameters to existing data, and thus, examine the appropriate value of symmetry energy, equation of state (EOS), etc.

RNEDF Lagrangian and symmetry energy

We use the density-dependent point-coupling (DD-PC) Lagrangian for relativistic meanfield calculation.

$$\mathcal{L} = \bar{\psi}(i\gamma\cdot\partial - m)\psi - \frac{1}{2}a_S(\hat{\rho})(\bar{\psi}\psi)(\bar{\psi}\psi) - \frac{1}{2}a_V(\hat{\rho})(\bar{\psi}\gamma^\mu\psi)(\bar{\psi}\gamma_\mu\psi) - \frac{1}{2}a_{TV}(\hat{\rho})(\bar{\psi}\vec{\tau}\gamma^\mu\psi)(\bar{\psi}\vec{\tau}\gamma_\mu\psi) - \frac{1}{2}\delta_S(\partial_\nu\bar{\psi}\psi)(\partial^\nu\bar{\psi}\psi) - e\bar{\psi}\gamma\cdot A\frac{(1-\tau_3)}{2}\psi\,.$$

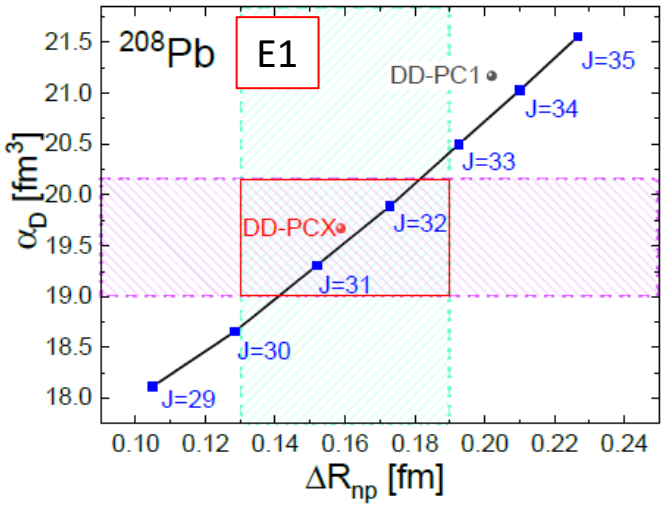
Parameters in DD-PC Lagrangian ⇔ J at saturation density.

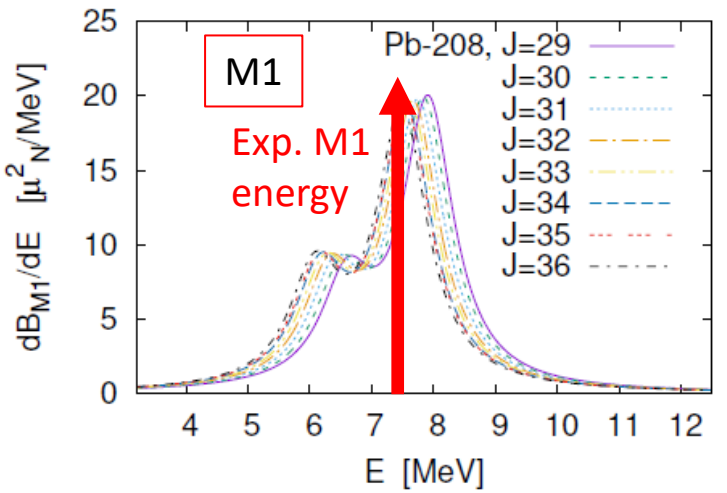
$$\boxed{J \equiv S(\rho_0)} \quad \text{where} \quad \frac{E}{A}(\rho,\delta) = \frac{E}{A}(\rho,0) + S(\rho)\delta^2 + \mathcal{O}[\delta^4]$$

$$S(\rho) = J + L\left(\frac{\rho-\rho_0}{3\rho_0}\right) + \frac{1}{2}K_{sym}\left(\frac{\rho-\rho_0}{3\rho_0}\right)^2 + \mathcal{O}[(\rho-\rho_0)^3],$$

E1 and M1 responses with relativistic QRPA:

$$\begin{pmatrix} A & B \\ B^* & A^* \end{pmatrix}\begin{pmatrix} X(\omega) \\ Y^*(\omega) \end{pmatrix} = \hbar\omega \begin{pmatrix} I & 0 \\ 0 & -I \end{pmatrix}\begin{pmatrix} X(\omega) \\ Y^*(\omega) \end{pmatrix},$$





By comparing with E1 and M1 data, J=31-32 MeV is found as appropriate.

Summary

The nuclear E1 and M1 excitations are investigated as functions of nuclear symmetry energy J in the RNEDF framework. The J=31-32 MeV and its corresponding DD-PC Lagrangian are found as the best option with respect to the experimental data.

For more details, please see [1] G. Kruzic et al, Phys, Rev, C 102, 044315 (2020); [2] E. Yuksel et al, Universe Vol. 7(3), 71 (2021).

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