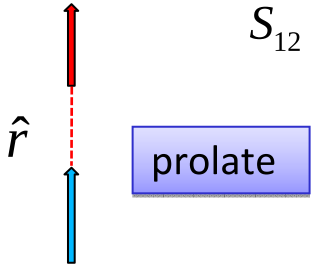
Effect of Tensor Correlations on Spin-Isospin mode

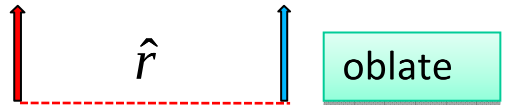
Second EMMI-EFES Workshop on
Neutron-Rich Exotic Nuclei
RIKEN June 16-18, 2010

H. Sagawa
Center for Mathematics and Physics, University of Aizu

Deformation of deuteron and Tensor Interaction

$$S_{12} = 3(\vec{\sigma}_1 \bullet \hat{r})(\vec{\sigma}_2 \bullet \hat{r}) - \vec{\sigma}_1 \bullet \vec{\sigma}_2$$





$$S_{12} = +2$$

$$S_{12} = -1$$

attractive

$$V_T = f(r) S_{12}$$

repulsive

Rarita-Schwinger, Phys.Rev.59, 436(1941)
Blatt-Weisskopf, Theoretical Nuclear Phys.(1952)

Tensor correlations on Spin-Orbit splitting

Skyrme-type tensor interactions

$$V^T = \frac{T}{2}\{[(\sigma_1\cdot k')(\sigma_2\cdot k') - \frac{1}{3}(\sigma_1\cdot\sigma_2)\, k'^2]\delta(r_1-r_2)$$
$$+\delta(r_1-r_2)\left[(\sigma_1\cdot k)(\sigma_2\cdot k) - \tfrac{1}{3}(\sigma_1\cdot\sigma_2)\, k^2\right]\}$$
$$+\frac{U}{2}\{(\sigma_1\cdot k')\,\delta(r_1-r_2)(\sigma_2\cdot k) + (\sigma_2\cdot k')\,\delta(r_1-r_2)(\sigma_1\cdot k)$$
$$-\tfrac{2}{3}[(\sigma_1\cdot\sigma_2)k'\cdot\delta(r_1-r_2)k]\}$$

T.H.R. Skyrme, Nucl.Phys. 9,615(1959).
F.L. Stancu, D. M. Brink and H. Flocard, PLB68,108 (1977).

T.Lesinski, M. Bender, K. Bennaceur, T. Duguet, J. Meyer, Phys. Rev.C76, 014312(2007).
G.Colo, H. Sagawa, S. Fracasso, P.F. Bortignon, Phys. Lett. B 646 (2007) 227.

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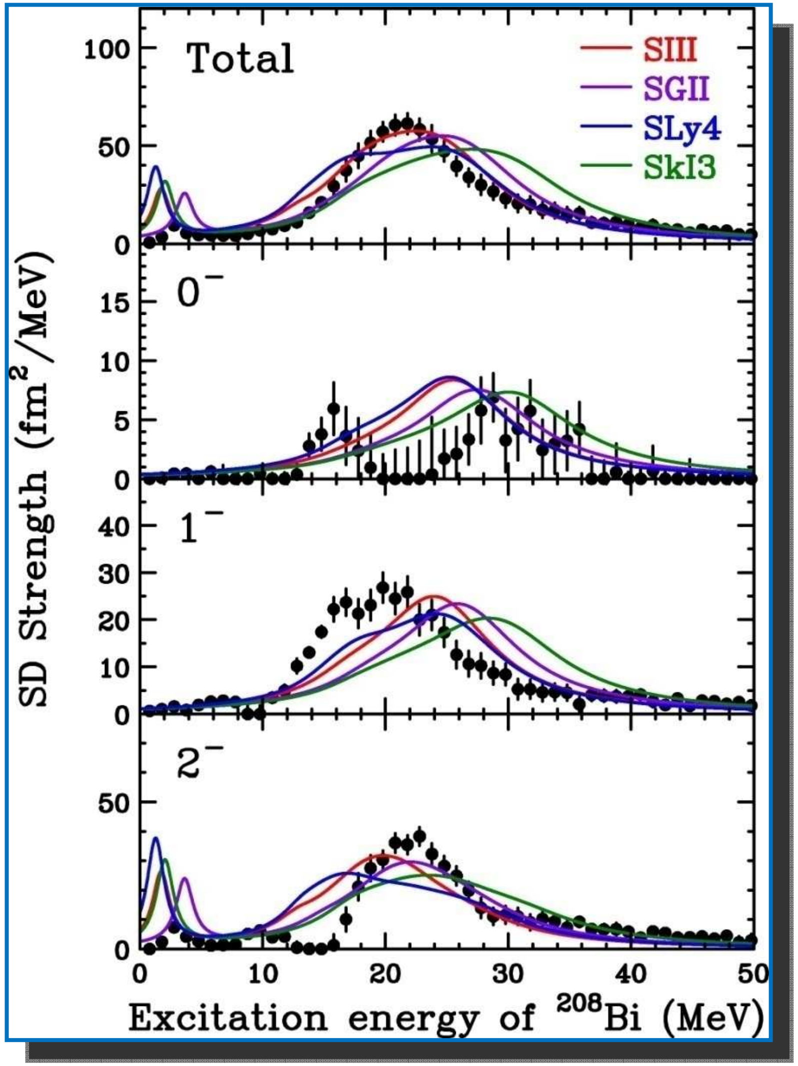
1. Introduction
2. Isotope and Isotone dependence of single particle energies
→ 3. Spin and Spin-Isospin excitations and tensor correlations
4. Spin Instability of Nuclear matter and Neutron Matter
5. Summary

SD Strength Distributions Wakasa, SIR2010,18-21 Feb.,2010)

H. Sagawa et al., PRC 76, 024301 (2007).

- Total strength
  - Asymmetric single bump
    - Extend up to 50 MeV
    - Same as ^{90}Zr(p,n)results
  - SIII provides better description
- 0^- strength
  - Quenched
    - Seems to be fragmented
- 1^- strength
  - Softened compared with theory
    - Peak shift to lower E_x
- 2^- strength
  - Hardened compared with theory
    - Peak shift to higher E_x



- No Skyrme int. which reproduces both total and separated strengths
- ΔJ^{π}-dependent correlation ? → Require further investigations

Multipole Expansion of Tensor Interactions

$$V^T = \frac{T}{2}\{[(\sigma_1 \cdot \mathbf{k}')(\sigma_2 \cdot \mathbf{k}') - \frac{1}{3}(\sigma_1 \cdot \sigma_2)\mathbf{k}'^2]\delta(\mathbf{r}_1 - \mathbf{r}_2)$$
$$+\delta(\mathbf{r}_1 - \mathbf{r}_2)[(\sigma_1 \cdot \mathbf{k})(\sigma_2 \cdot \mathbf{k}) - \tfrac{1}{3}(\sigma_1 \cdot \sigma_2)\mathbf{k}^2]\}$$
$$+\frac{U}{2}\{(\sigma_1 \cdot \mathbf{k}')\delta(\mathbf{r}_1 - \mathbf{r}_2)(\sigma_2 \cdot \mathbf{k}) + (\sigma_2 \cdot \mathbf{k}')\delta(\mathbf{r}_1 - \mathbf{r}_2)(\sigma_1 \cdot \mathbf{k})$$
$$-\tfrac{2}{3}[(\sigma_1 \cdot \sigma_2)\mathbf{k}' \cdot \delta(\mathbf{r}_1 - \mathbf{r}_2)\mathbf{k}]\}$$

$$\delta(\vec{r}_1 - \vec{r}_2) = \sum_{lm} Y_{lm}(\hat{r}_1) Y^*_{lm}(\hat{r}_2) \frac{\delta(r_1 - r_2)}{r_1 r_2}$$

$$V^T \propto T_{(\lambda,\kappa)}\{[\sigma_1 \times [\nabla_1 \times Y_{l=1}(\hat{r}_1)]^{(\lambda)}\}^{(\kappa)}[\sigma_2 \times [\nabla_2 \times Y_{l=1}(\hat{r}_2)]^{(\lambda')}\}^{(\kappa)}\}^{(0)}\delta(r_1 - r_2)$$

$1^+ \quad T_{(\lambda=\lambda'=2,\kappa=1)} \Rightarrow$ *repulsive*

$2^+ \quad T_{(\lambda=\lambda'=2,\kappa=2)} \Rightarrow$ *attractive*

$3^+ \quad T_{(\lambda=\lambda'=2,\kappa=3)} \Rightarrow$ *repulsive*

$1^+ \quad T_{(\lambda=2,\lambda'=0,\kappa=1)} \Rightarrow$ strong mixing between Gamow - Teller and spin - quadrupole excitations!

Diagonal p-h matrix element for SD excitations

$$\hat{O}^{\lambda}_{\pm} = \sum_i t^i_{\pm} r_i (Y^i_1 \sigma^i)_{\lambda}.$$

$$V^{(\lambda)}_{TE} = \frac{5T}{4} \sum_{\ell,k,k'} \frac{(-)^{k+k'+\lambda+\ell+1}\hat{k}\hat{k'}}{2\lambda+1} \left\{ \begin{array}{ccc} k & k' & 2 \\ 1 & 1 & \ell \end{array} \right\} \times \left\{ \begin{array}{ccc} 1 & 1 & 2 \\ k' & k & \lambda \end{array} \right\} \langle p||\hat{O}_{k',\lambda}||h\rangle \langle p||\hat{O}_{k,\lambda}||h\rangle^{*}, \quad (5)$$

$$V^{(\lambda)}_{TE} = -\frac{5}{12} T \left\{ \begin{array}{c} 1 \\ -1/6 \\ 1/50 \end{array} \right\} |\langle p||\hat{O}_{1,\lambda}||h\rangle|^2 \;\; for \;\; \lambda = \left\{ \begin{array}{c} 0^- \\ 1^- \\ 2^- \end{array} \right\}. \quad (6)$$

The TO tensor part is also expressed in a similar way as

$$V^{(\lambda)}_{TO} = \frac{5}{12} U \left\{ \begin{array}{c} 1 \\ -1/6 \\ 1/50 \end{array} \right\} |\langle p||\hat{O}_{1,\lambda}||h\rangle|^2 \;\; for \;\; \lambda = \left\{ \begin{array}{c} 0^- \\ 1^- \\ 2^- \end{array} \right\}. \quad (7)$$

Direct Diagonal Matrix Element

$$V^{(\lambda)}_{T} = V^{(\lambda)}_{TE} + V^{(\lambda)}_{TO} \equiv a_{\lambda} T + b_{\lambda} U.$$

Anti-symmetrized Matrix Element

$$V^{(\lambda)}_{T,AS} = [-\frac{1}{2} a_{\lambda} T + \frac{1}{2} b_{\lambda} U] \langle \tau_1 \cdot \tau_2 \rangle.$$

Tensor correlations on Spin-Dipole excitations

$$V^T \propto T_{(\lambda,\kappa)}\{[\sigma_1\times[\nabla_1\times Y_{l=1}(\hat{r}_1)]^{(\lambda)}\}^{(\kappa)}[\sigma_2\times[\nabla_2\times Y_{l=1}(\hat{r}_2)]^{(\lambda')}\}^{(\kappa)}\}^{(0)}\delta(r_1-r_2)$$

0^- $T_{(\lambda=\lambda'=1,\kappa=2)} \Rightarrow \textit{repulsive}$

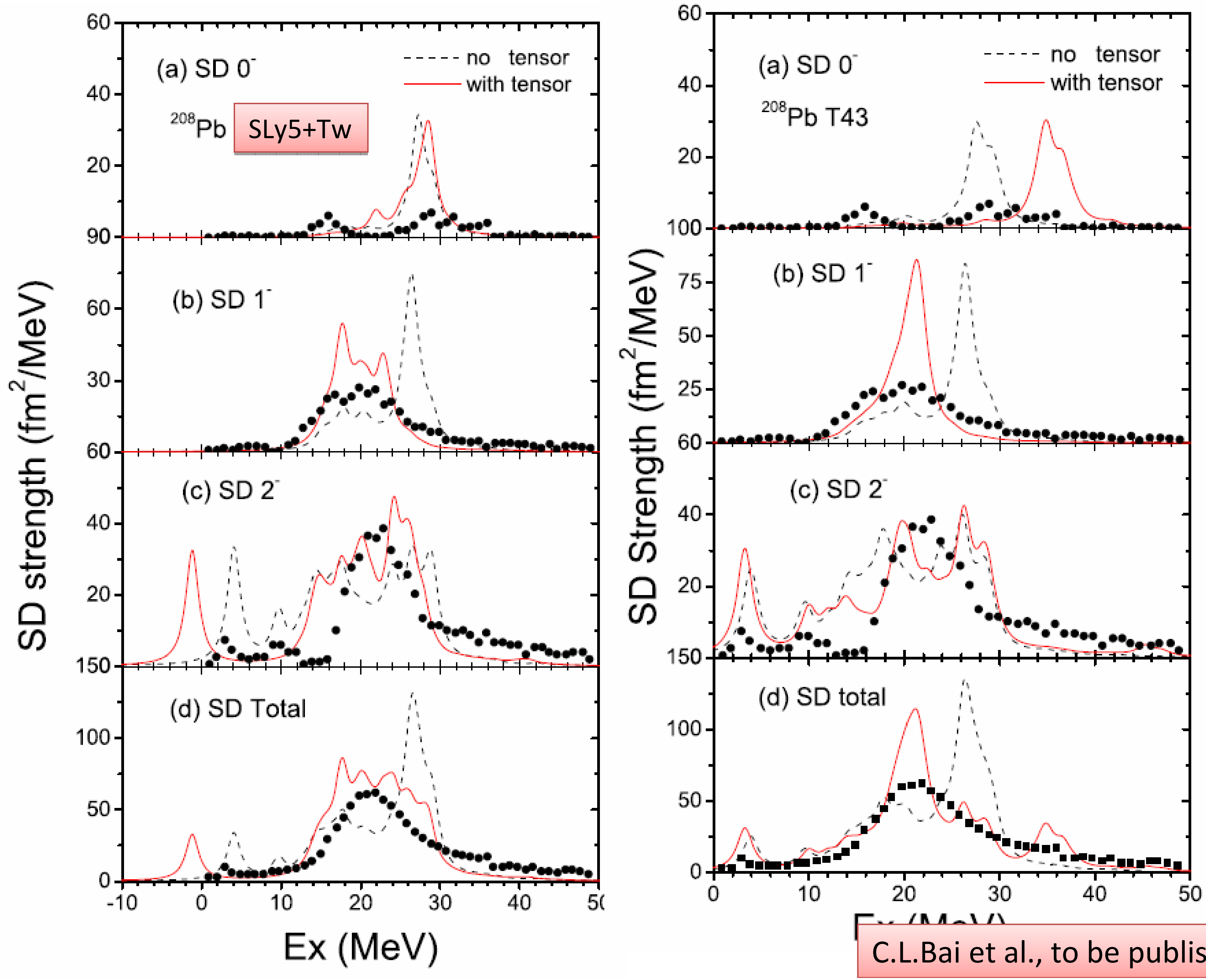
1^- $T_{(\lambda=\lambda'=1,\kappa=1)} \Rightarrow \textit{attractive}$

2^- $T_{(\lambda=\lambda'=1,\kappa=2)} \Rightarrow \textit{replusive}$

2^- $T_{(\lambda=3,\lambda'=1,\kappa=2)} \Rightarrow$ strong mixing between SD and Spin - octupole

mode	T term (>0)	U term (<0)
0- IS	attractive	attractive
IV	repulsive	repulsive
1- IS	repulsive	repulsive
IV	attractive	attractive
2- IS	attractive	attractive
IV	repulsive	repulsive

For charge exchange mode,
- 0- repulsive (hardening)
- 1- attractive (softening)
- 2- repulsive (hardening)



C.L.Bai et al., to be published

Tensor Force on Multipole Response in Finite Nuclei

Li-Gang Cao, G. Colo, H. Sagawa, P.F.Bortignon and L. Sciacchitano
Phys. Rev.C80, 064304(2009)

SLy5 +Tensor [G. Colo et al., PLB646, 227 (2007)]
T44 [T. Lesinski et al., PRC76, 014312 (2007)]

$$\Delta E_{RPA} \approx \Delta E_{HF} + < V_{tensor} >$$

SLy5+tensor	T=888.0	U=-408.
T44	T=520.983	U=21.522

^{208}Pb

$\pi h_{11/2} \rightarrow \pi h_{9/2}$ HF 5.85MeV 6.45MeV(+tensor)

$\nu i_{13/2} \rightarrow \nu i_{11/2}$ HF 7.49MeV 9.17MeV(+tensor)

[SLy5] RPA 7.39MeV 7.79MeV(+tensor)

[SLy5] RPA 9.14MeV 10.57MeV(+tensor)

$$\Delta\overline{E}_{HF} = 1.14\text{MeV} \quad <\overline{V}_T> = -0.23\text{MeV}$$

$\pi h_{11/2} \rightarrow \pi h_{9/2}$ HF 6.4MeV 4.6MeV(+tensor)

$\nu i_{13/2} \rightarrow \nu i_{11/2}$ HF 8.7MeV 6.9MeV(+tensor)

[T44] RPA 8.0MeV 6.1MeV(+tensor)

[T44] RPA 10.1MeV 8.3MeV(+tensor)

$$\Delta\overline{E}_{HF} = -1.8\text{MeV} \quad <\overline{V}_T> = -0.05\text{MeV}$$

Exp. T. Shizuma et al., PRC78, 061303(2008)

A. Tamii (this symposium)

5.85MeV

7.30MeV

Stability condition with tensor interaction

Li-Gang Cao, G. Colo and H.S.,PRC(2010)

$$V_{\rm ph} = \sum_{\ell}(F_\ell + F'_\ell \tau_1 \cdot \tau_2 + G_\ell \sigma_1 \cdot \sigma_2$$

$$+G'_\ell(\tau_1 \cdot \tau_2)(\sigma_1 \cdot \sigma_2))P_l(cos\theta) \ ,$$

$$+\frac{q^2}{k_F^2} H(\cos\vartheta) S_{12}(\hat{q}) + \frac{q^2}{k_F^2} H'(\cos\vartheta) S_{12}(\hat{q}) \tau \cdot \tau)$$

$$H_0 = N_0 k_F^2 \frac{1}{4}(\frac{1}{2}T + \frac{3}{2}U) \qquad H'_0 = N_0 k_F^2 \frac{1}{4}(-\frac{1}{2}T + \frac{1}{2}U)$$

Stability conditions

no tensor

IS $l = 0$ $\quad 1 + G_0 > 0$

IS $l = 1$ $\quad 1 + \frac{1}{3} G_1 > 0$

with tensor

IS $l = 1, J = 0$ $\quad 1 + \frac{1}{3} G_1 - \frac{10}{3} H_0 > 0$

IS $l = 1, J = 1$ $\quad 1 + \frac{1}{3} G_1 + \frac{5}{3} H_0 > 0$

Summary

1. Skyrme Tensor is introduced in HF calculations. Triplet-Even and Triplet-Odd components

2.The isotope dependence of energy splitting (*ε(h11/2) − ε(g7/2)) of Z=50 isotopes is well reproduced by a parameter set of tensor interactions.* The same parameter set gives fairly good description of energy difference *ε(i13/2) − ε(h9/2) of N=82 isotones .*

3. HF+RPA calculations are performed for Gamow-Teller and Spin Quadrupole excitations. We found that the sum rule strength of GT transitions are increased, while the main peak energies are slightly shifted to lower energy side. This is due to the coupling between GT and SQR with the tensor interactions.

4. 10% of sum rule strength is removed from the main peak to higher energy region of SQR.

5. Softening and hardening of Spin-Dipole excitations are found in experimentally and RPA with tensor interactions .

Collaborators

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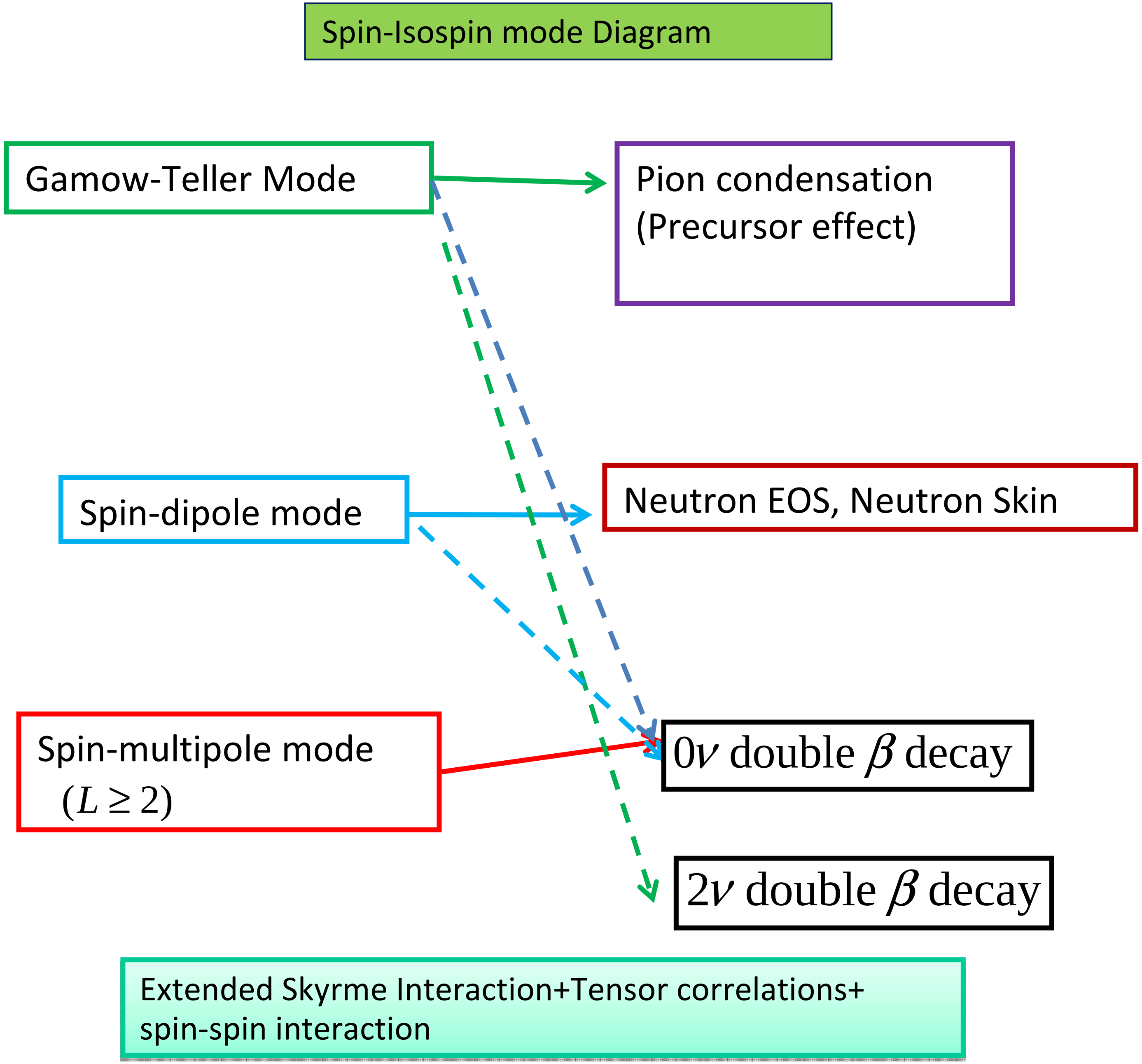
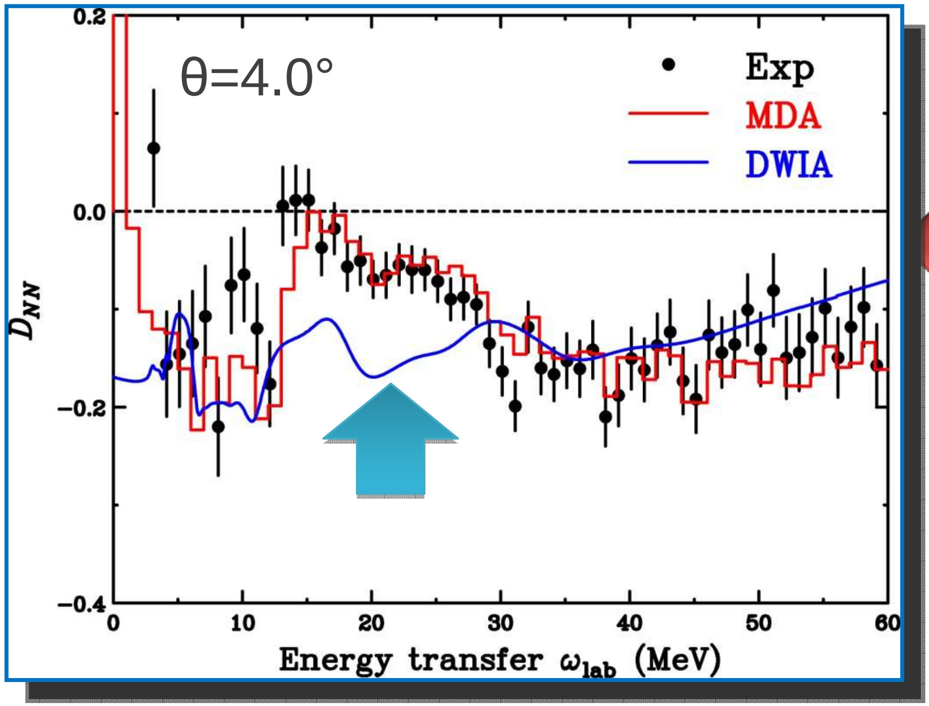
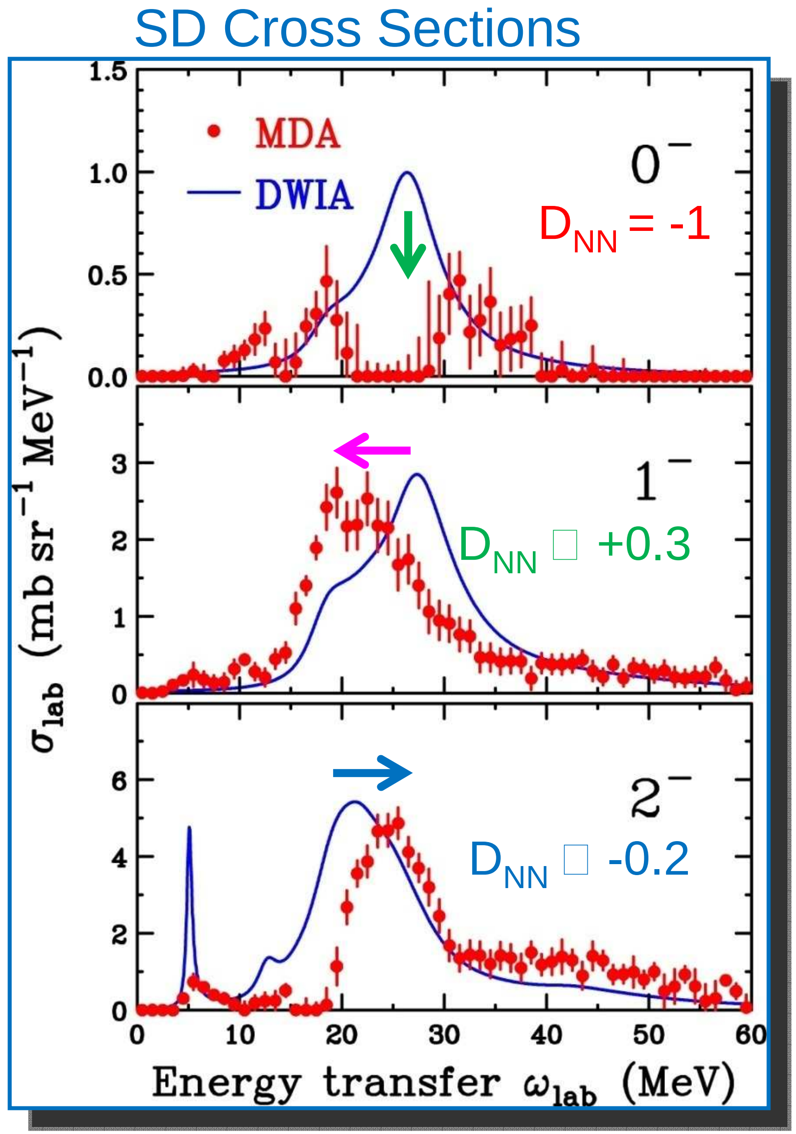
P.F. Bortignon, University of Milano,Italy

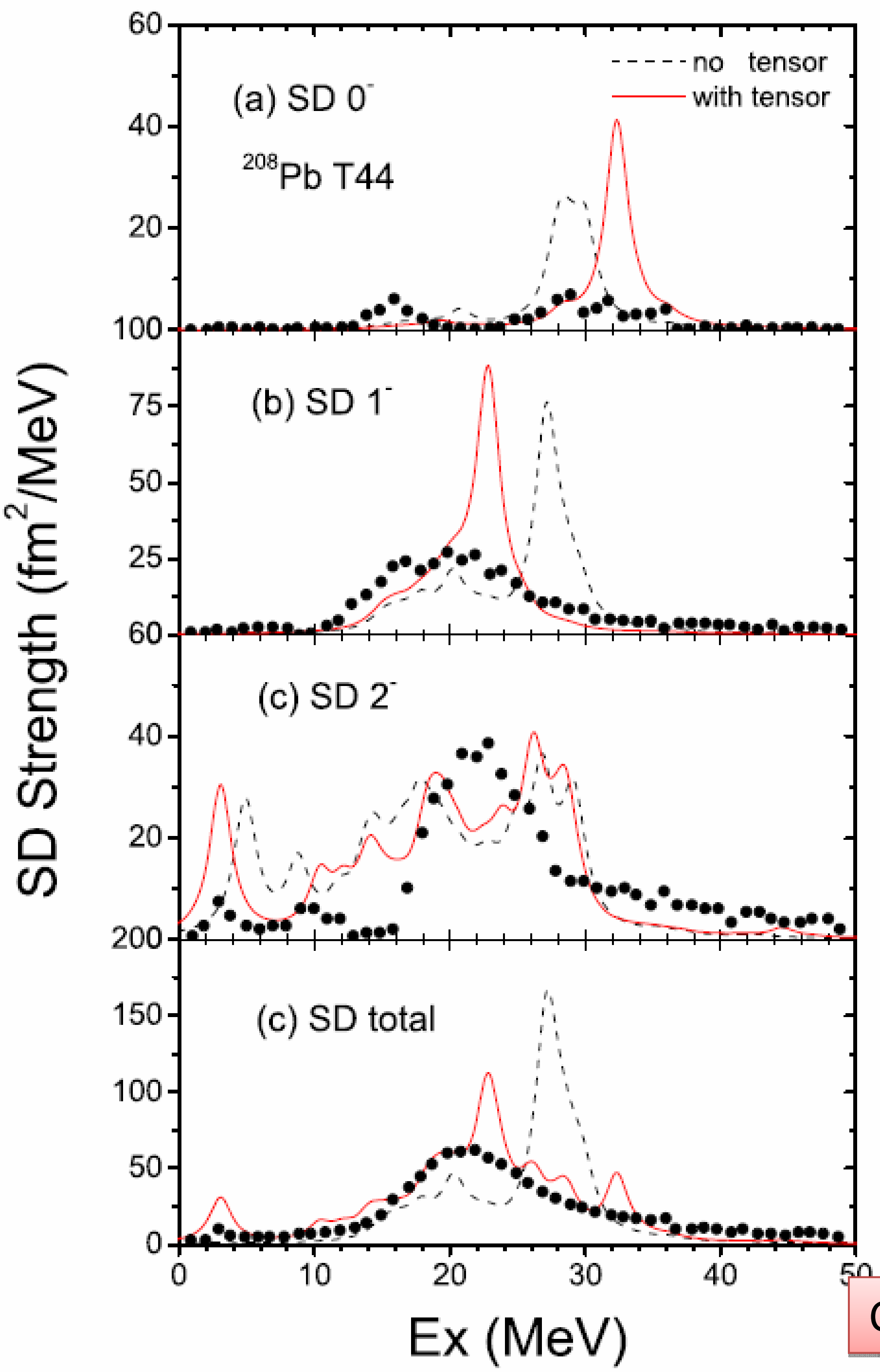

Spin-Isospin mode Diagram
Gamow-Teller Mode
Pion condensation
(Precursor effect)
Spin-dipole mode
Neutron EOS, Neutron Skin
Spin-multipole mode
$(L \geq 2)$
0ν double β decay
2ν double β decay
Extended Skyrme Interaction+Tensor correlations+
spin-spin interaction

Comparison between DWIA and MDA

ΔJ$^\pi$	MDA (compared with theory)
0^-	Quenching
1^-	Softening (shift to lower ω)
2^-	Hardening (shift to higher ω)







SLy5+T’

C.L.Bai, 17 March 2010

Spin-orbit splitting

The contribution of the tensor to the <u>total energy</u> is not very large and does not improve mass systematics.(Thomas Duguet)

$$\delta H = \frac{1}{2}\alpha(J_n^2 + J_p^2) + \beta J_n J_p.$$

however, it may play important role for the **<u>spin-orbit splittings.</u>**

$$U_{s.o.}^{(q)} = \frac{W_0}{2r}\left(2\frac{d\rho_q}{dr} + \frac{d\rho_{q'}}{dr}\right) + \left(\alpha\frac{J_q}{r} + \beta\frac{J_{q'}}{r}\right),$$

$q\ (n=0,\ p=1) \qquad q' = 1-q$

$$J_q(r) = \frac{1}{4\pi r^3}\sum_i v_i^2(2j_i+1)\left[j_i(j_i+1) - l_i(l_i+1) - \frac{3}{4}\right] R_i^2(r).$$

SLy5+T

$$\alpha_C = \frac{1}{8}(t_1 - t_2) - \frac{1}{8}(t_1x_1 + t_2x_2) = 80.7\,\text{MeV.fm}^5$$

$$\beta_C = -\frac{1}{8}(t_1x_1 + t_2x_2) = -48.9\,\text{MeV.fm}^5$$

$$\alpha_T = \frac{5}{12}U = -170\,\text{MeV.fm}^5$$

$$\beta_T = \frac{5}{24}(T+U) = 100\,\text{MeV.fm}^5$$

TIJ family

$$\alpha = \alpha_C + \alpha_T = 60(J-2)\,\text{MeV.fm}^5$$

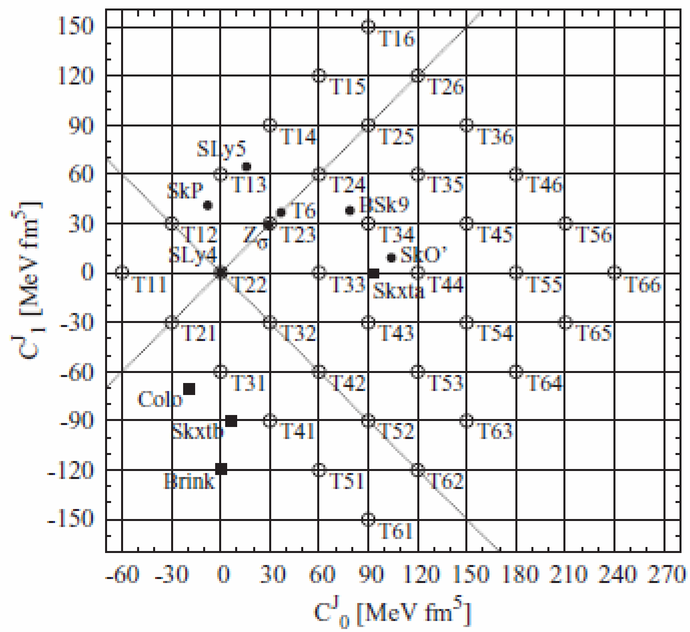
$$\beta = \beta_C + \beta_T = 60(I-2)\,\text{MeV.fm}^5$$

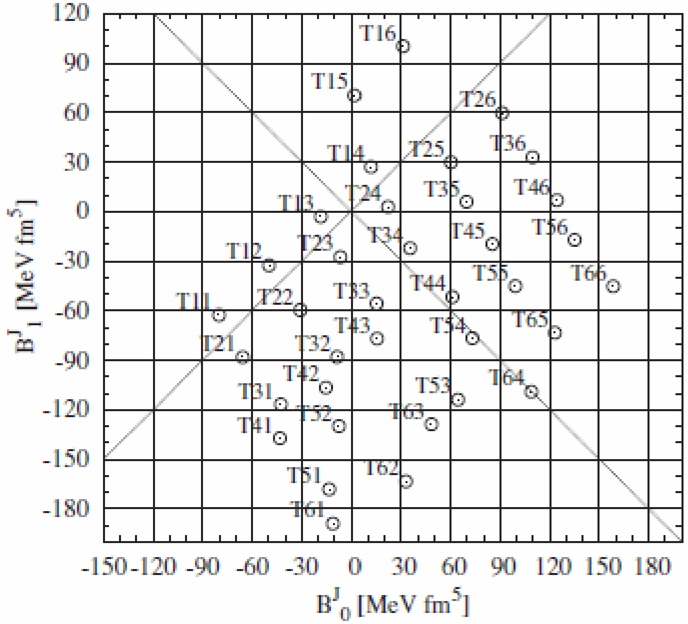
	sign	spin-orbit splitting
α, β	negative	larger
	positive	smaller

PHYSICAL REVIEW C **76**, 014312 (2007)

Tensor part of the Skyrme energy density functional: Spherical nuclei

T. Lesinski,[1,*] M. Bender,[2,3,†] K. Bennaceur,[1,2] T. Duguet,[4] and J. Meyer[1]





$$\alpha = C^J_0 + C^J_1, \quad \beta = C^J_0 - C^J_1,$$

$$C^J_0 = \tfrac{1}{2}(\alpha + \beta), \quad C^J_1 = \tfrac{1}{2}(\alpha - \beta).$$

$$B^J_0 = \tfrac{5}{16}(t_e + 3t_o) = \tfrac{5}{48}(T + 3U),$$

$$B^J_1 = \tfrac{5}{16}(t_o - t_e) = \tfrac{5}{48}(U - T),$$

TIJ family

$$\alpha = 60(J-2)\,\mathrm{MeV\,fm}^5,$$

$$\beta = 60(I-2)\,\mathrm{MeV\,fm}^5.$$

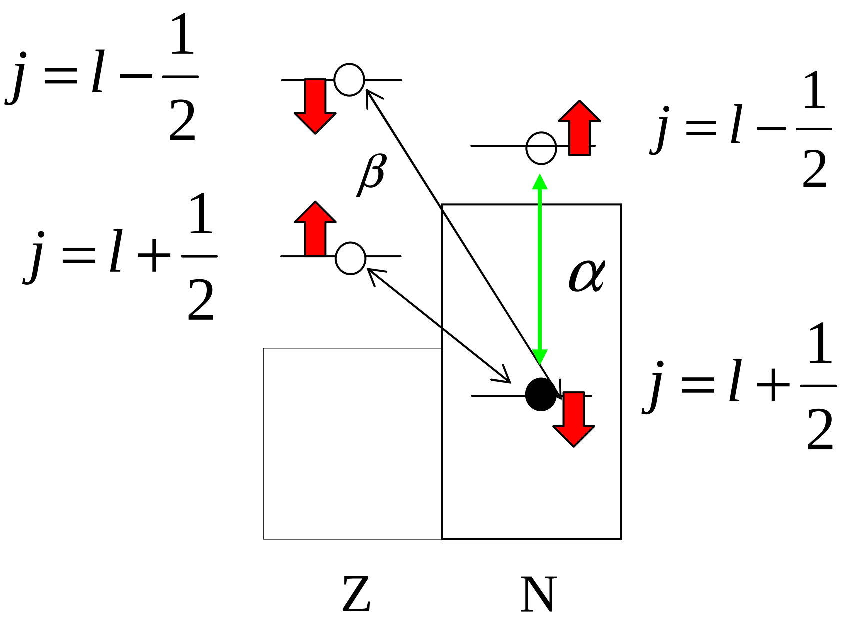
$$\alpha_C = \tfrac{1}{8}(t_1 - t_2) - \tfrac{1}{8}(t_1 x_1 + t_2 x_2),$$

$$\beta_C = -\tfrac{1}{8}(t_1 x_1 + t_2 x_2),$$

$$\alpha_T = \tfrac{5}{4} t_o = \tfrac{5}{12} U,$$

$$\beta_T = \tfrac{5}{8}(t_e + t_o) = \tfrac{5}{24}(T + U).$$

Effect of tensor interaction on spin-orbit splitting



SLy5+T

$$\alpha = \alpha_C + \alpha_T = -89.3\text{MeV.fm}^5$$

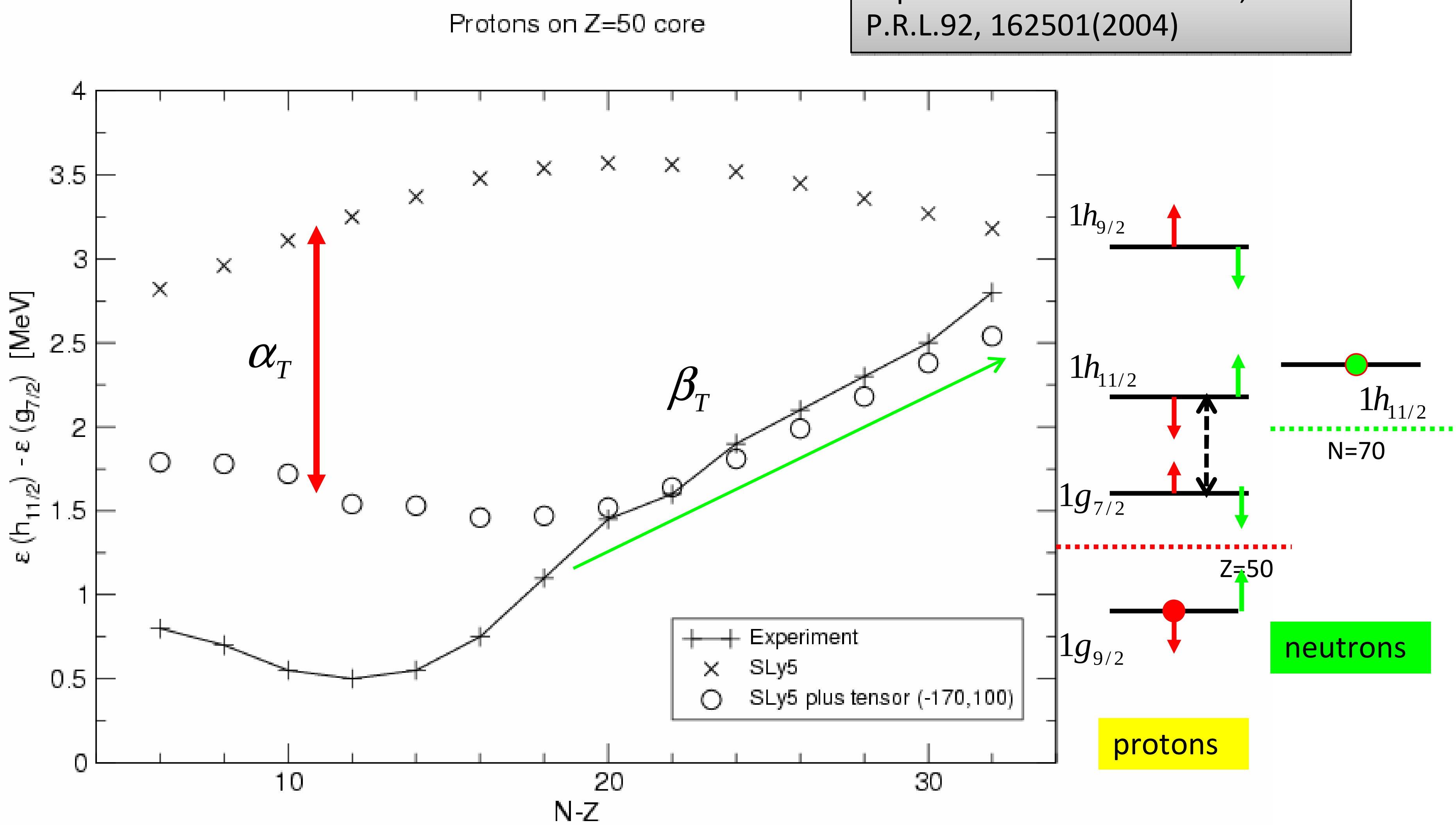
$$\beta = \beta_C + \beta_T = 51.1\text{MeV.fm}^5$$

T44

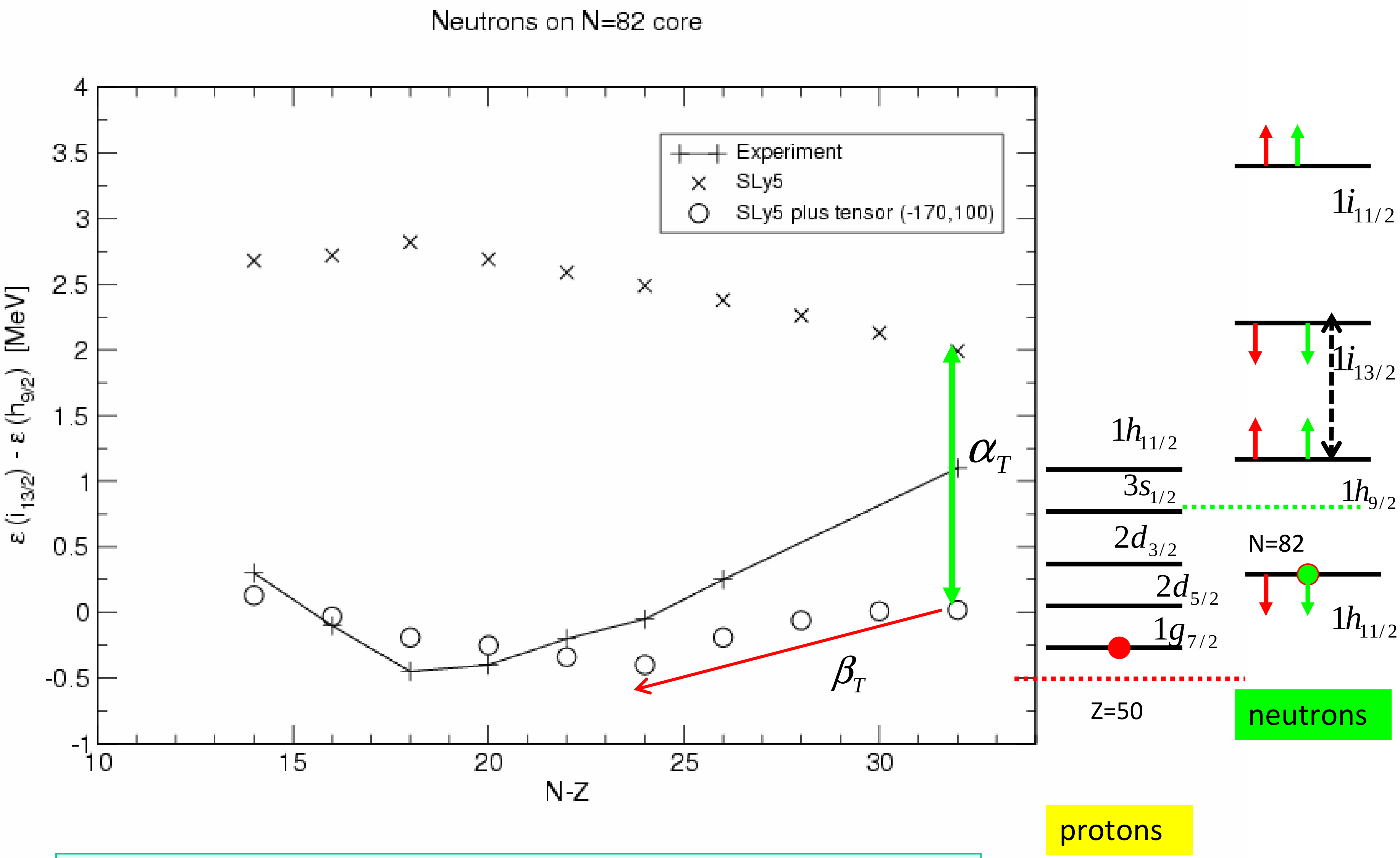
$$\alpha = \alpha_C + \alpha_T = 120\text{MeV.fm}^5$$

$$\beta = \beta_C + \beta_T = 120\text{MeV.fm}^5$$

Exp. Data : J.P.Schiffer et al., P.R.L.92, 162501(2004)

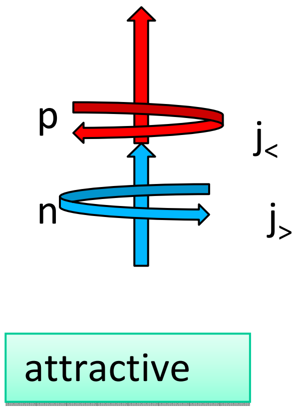


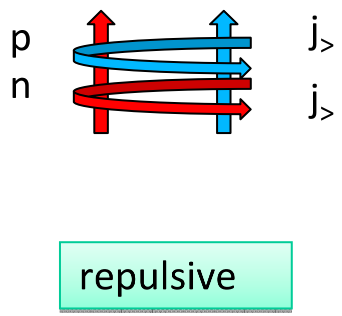
G.Colo, H. Sagawa, S. Fracasso, P.F. Bortignon, Phys. Lett. B 646 (2007) 227.



Effect of tensor correlations are shown on both p and n spin-orbit splittings.

Tensor effect of pion and rho meson exchange potentials on Spin-orbit interaction





T. Otsuka et al., PRL95,232502 (2005)

Tensor correlations on Spin-Isospin mode

Effect of Tensor Correlations on Gamow-Teller States in ^{90}Zr and ^{208}Pb

C.L. Bai[1,2], H. Sagawa[3], H.Q. Zhang[1,2], X.Z. Zhang [2], G. Colò[4] and F.R. Xu[1]

$$
\begin{aligned}
V^T = & \frac{T}{2}\{[(\sigma_1\cdot\mathbf{k}')(\sigma_2\cdot\mathbf{k}') - \frac{1}{3}(\sigma_1\cdot\sigma_2)\mathbf{k}'^2]\delta(\mathbf{r}_1-\mathbf{r}_2) \\
& +\delta(\mathbf{r}_1-\mathbf{r}_2)\left[(\sigma_1\cdot\mathbf{k})(\sigma_2\cdot\mathbf{k}) - \tfrac{1}{3}(\sigma_1\cdot\sigma_2)\mathbf{k}^2\right]\} \\
& +\frac{U}{2}\{(\sigma_1\cdot\mathbf{k}')\,\delta(\mathbf{r}_1-\mathbf{r}_2)(\sigma_2\cdot\mathbf{k}) + (\sigma_2\cdot\mathbf{k}')\,\delta(\mathbf{r}_1-\mathbf{r}_2)(\sigma_1\cdot\mathbf{k}) \\
& -\tfrac{2}{3}\left[(\sigma_1\cdot\sigma_2)\mathbf{k}'\cdot\delta(\mathbf{r}_1-\mathbf{r}_2)\mathbf{k}\right]\}
\end{aligned}
$$

$$
\begin{aligned}
m_-(0) - m_+(0) &= \sum_\nu \left(|\langle\nu|O_-|0\rangle|^2 - |\langle\nu|O_+|0\rangle|^2\right) \\
&= \langle 0|\,[O_-, O_+]\,|0\rangle,
\end{aligned}
$$

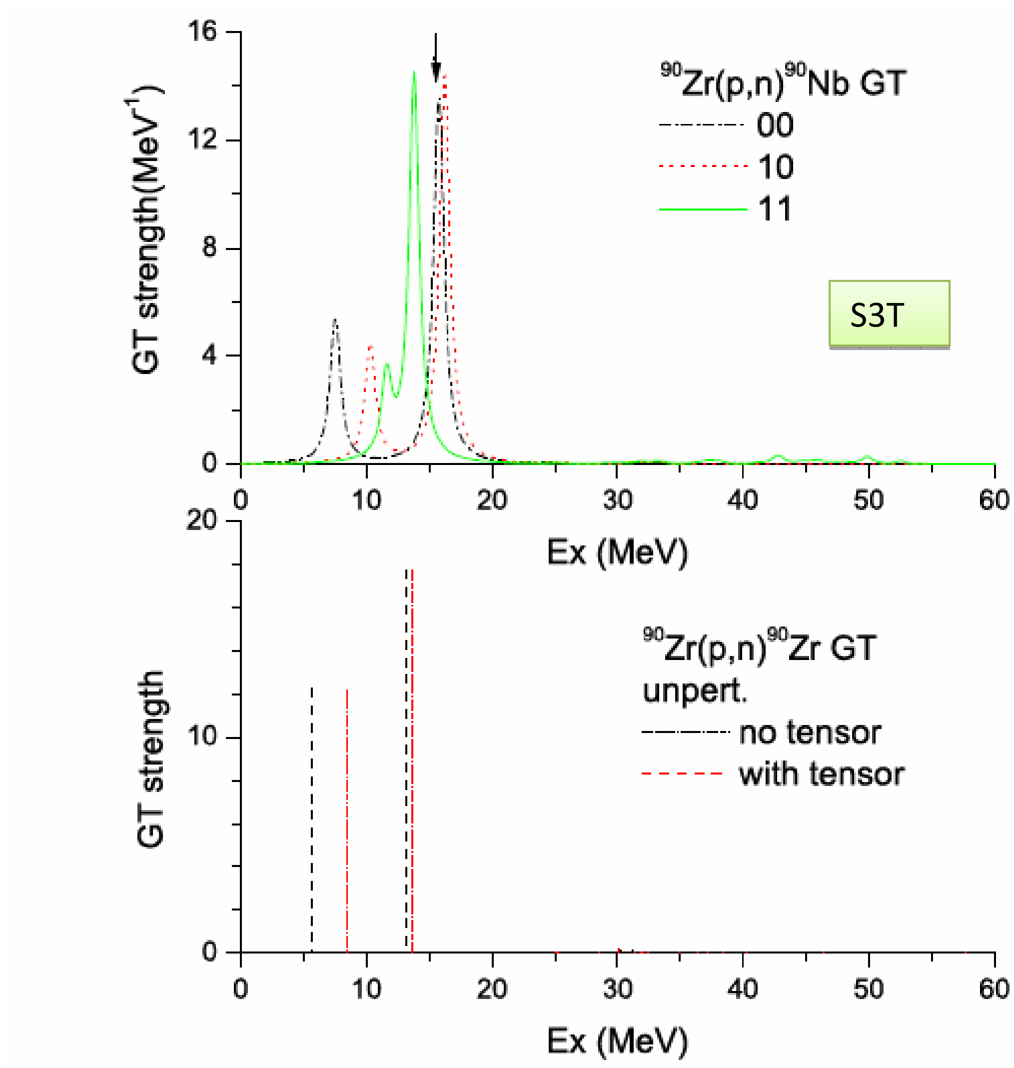
$$
\begin{aligned}
m_-(1) + m_+(1) &= \sum_\nu \left(|\langle\nu|O_-|0\rangle| + |\langle\nu|O_+|0\rangle|^2\right) E_\nu \\
&= \langle 0|\,[O_+, [H, O_-]]\,|0\rangle,
\end{aligned}
$$

$$
\begin{aligned}
\Delta E_{GT} &= \frac{m_-(1)}{m_-(0)} \\
&\sim \frac{m_-(1)+m_+(1)}{m_-(0)-m_+(0)} \\
&= \frac{4\pi}{3(N-Z)}\int drr^2[-(\tfrac{5}{2}U + \tfrac{5}{2}T)J_nJ_p - \tfrac{5}{3}U(J_n^2 + J_p^2)]
\end{aligned}
$$

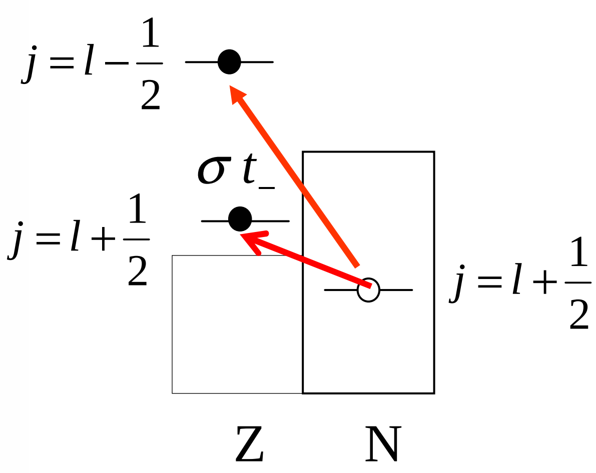
S3T

	$m_-(1;\text{no tensor})$ MeV	$m_-(1;\text{with tensor})$ MeV	δE_{RPA} MeV	δE_{DC} MeV
^{90}Zr	271.45	338.68	2.241	2.276
^{208}Pb	1854.12	2000.76	1.111	1.118

The tensor force in RPA



Gamow-Teller

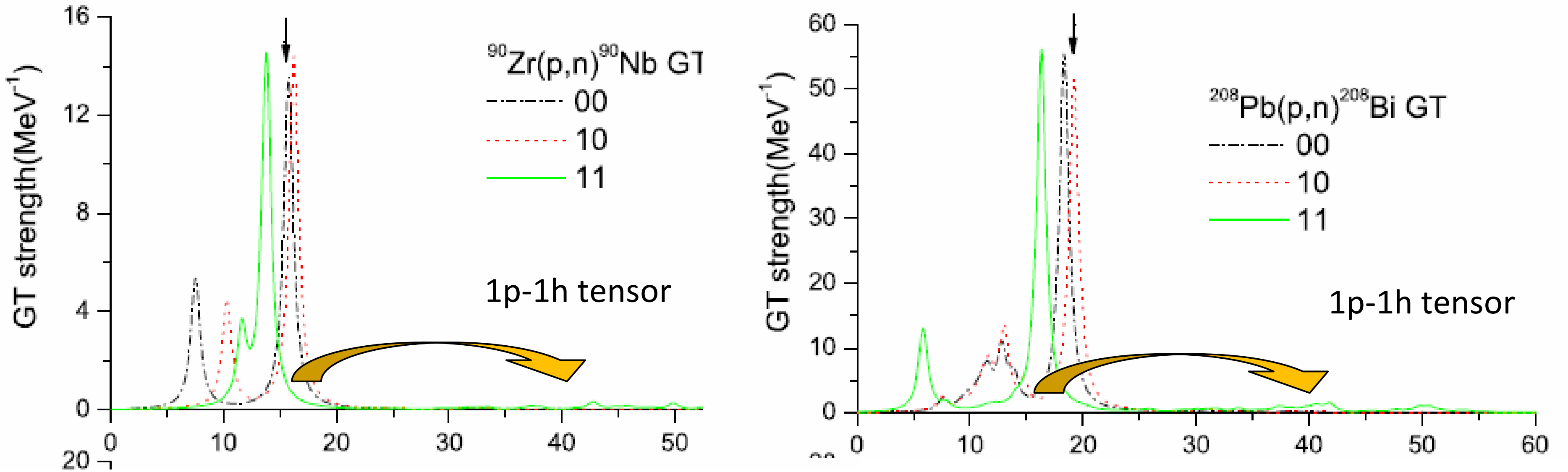


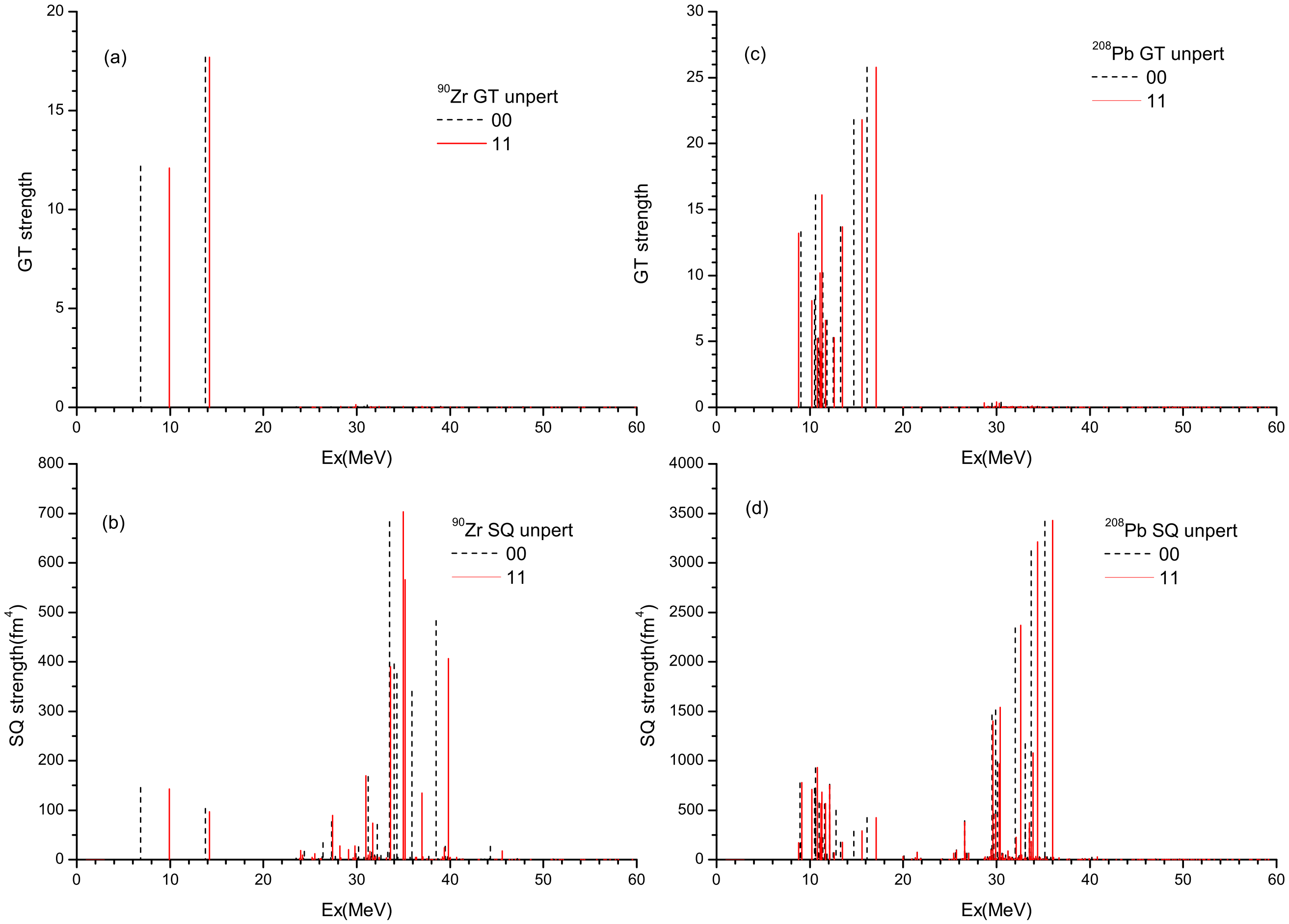
The main peak is moved downward by the tensor force but the centroid is moved upwards !

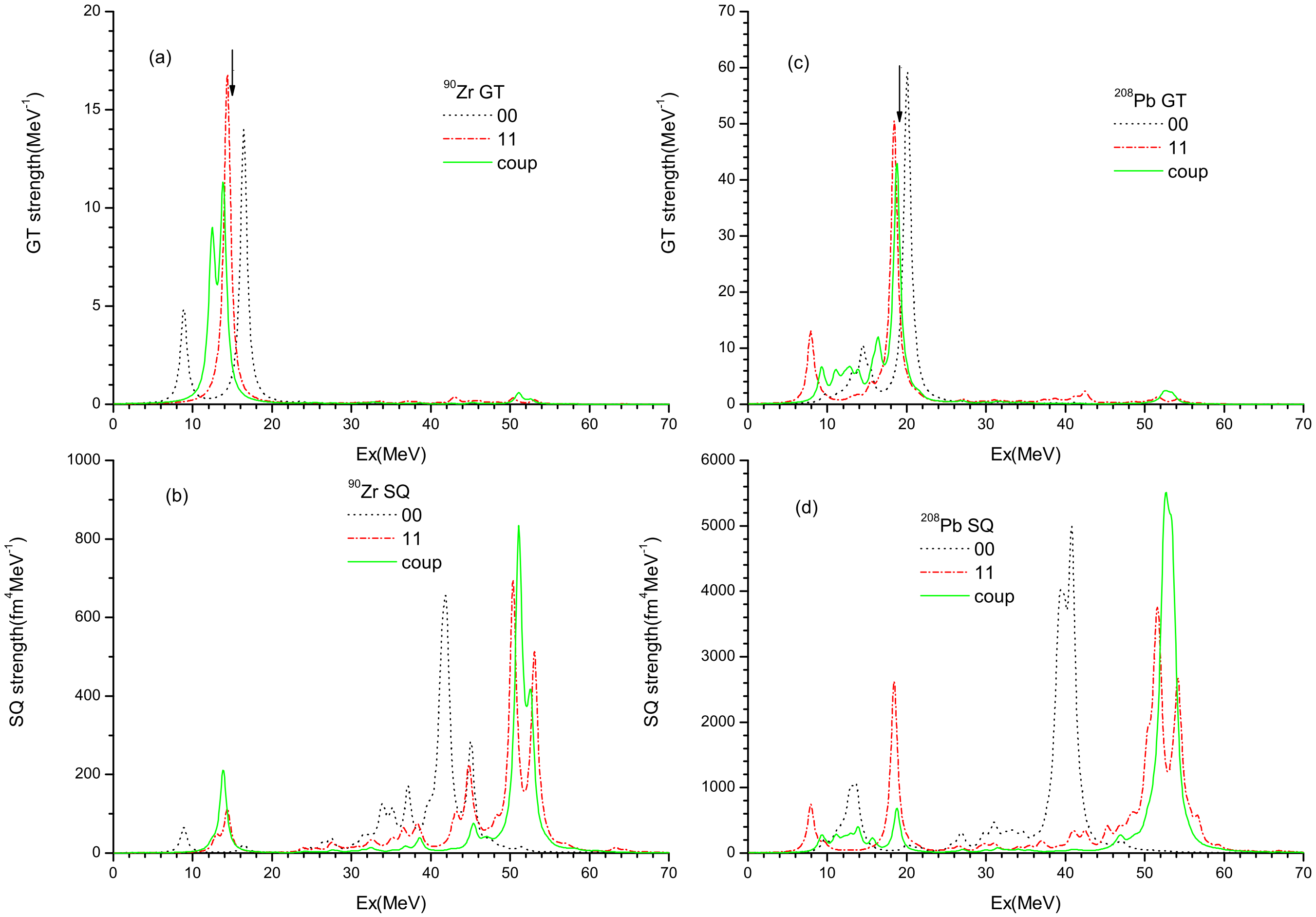
C.L.Bai, HS, H.Q.Zhang, X.Z.Zhang, G.Colo and F.R.Xu, P.L.B675,28 (2009).
C.L.Bai, H.Q. Zhang, X.Z.Zhang, F,R,Xu, HS and G.Colo, PRC79, 041301(R) (2009).

	type of calculation	$m_-(0)$ 0-30MeV	$m_-(0)$ 30-60MeV	$m_-(1)$ 0-30 MeV	$m_-(1)$ 30-60 MeV	$m_-(1)$ total	$m_+(1)$ total
^{90}Zr	00	29.16	0.71	395	26.2	421.8	10.1
	10	29.16	0.79	444	22	466	11.1
	11	27.00	2.89	366.9	122	493.2	10.3
^{208}Pb	00	127.54	3.43	2080	124.5	2212.8	18.8
	10	127.38	3.68	2176	93	2269	21
	11	114.10	16.58	1658	694	2370	19.3

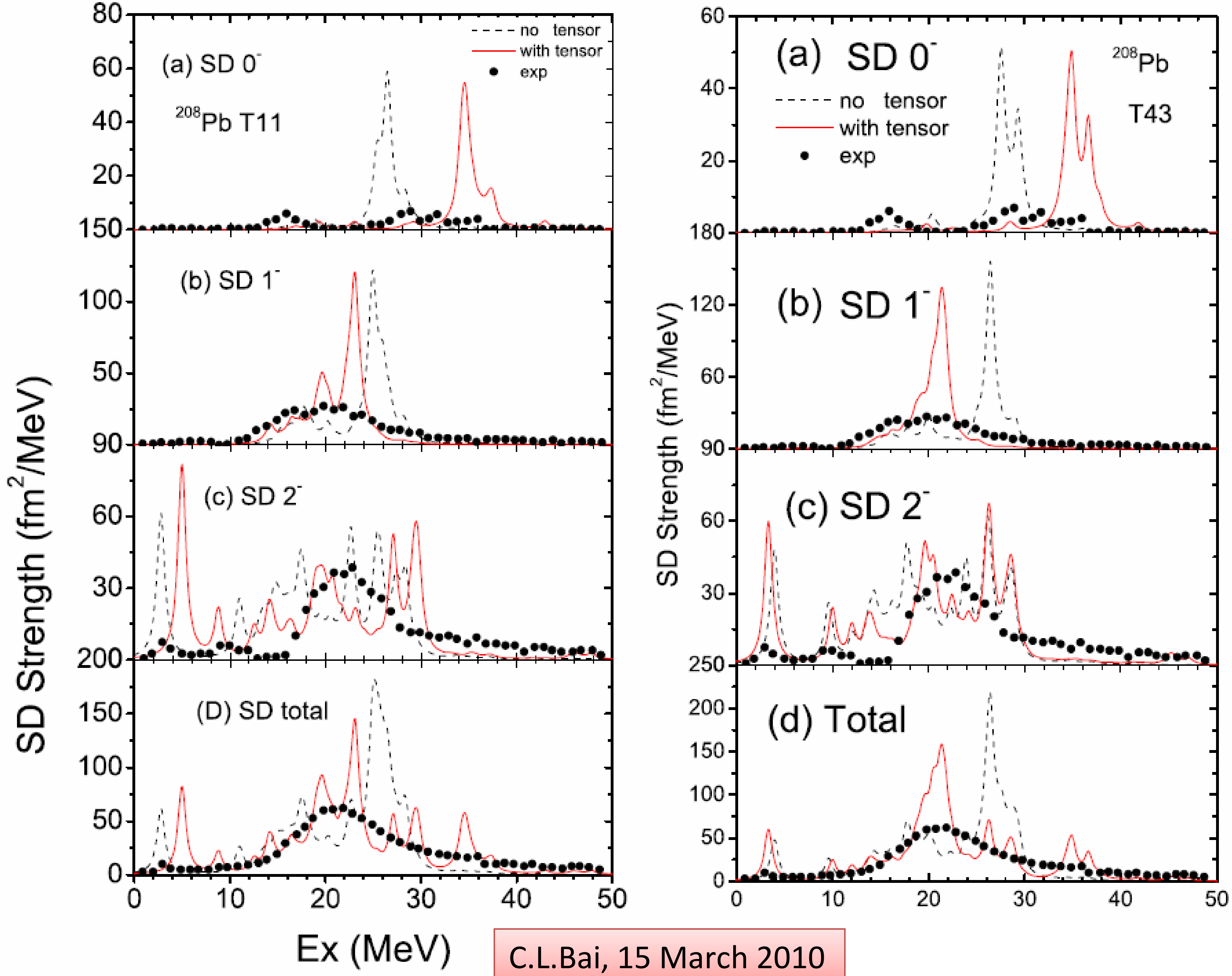
About 10% of strength is moved by the tensor correlations to the energy region above 30 MeV.
Relevance for the GT quenching problem.



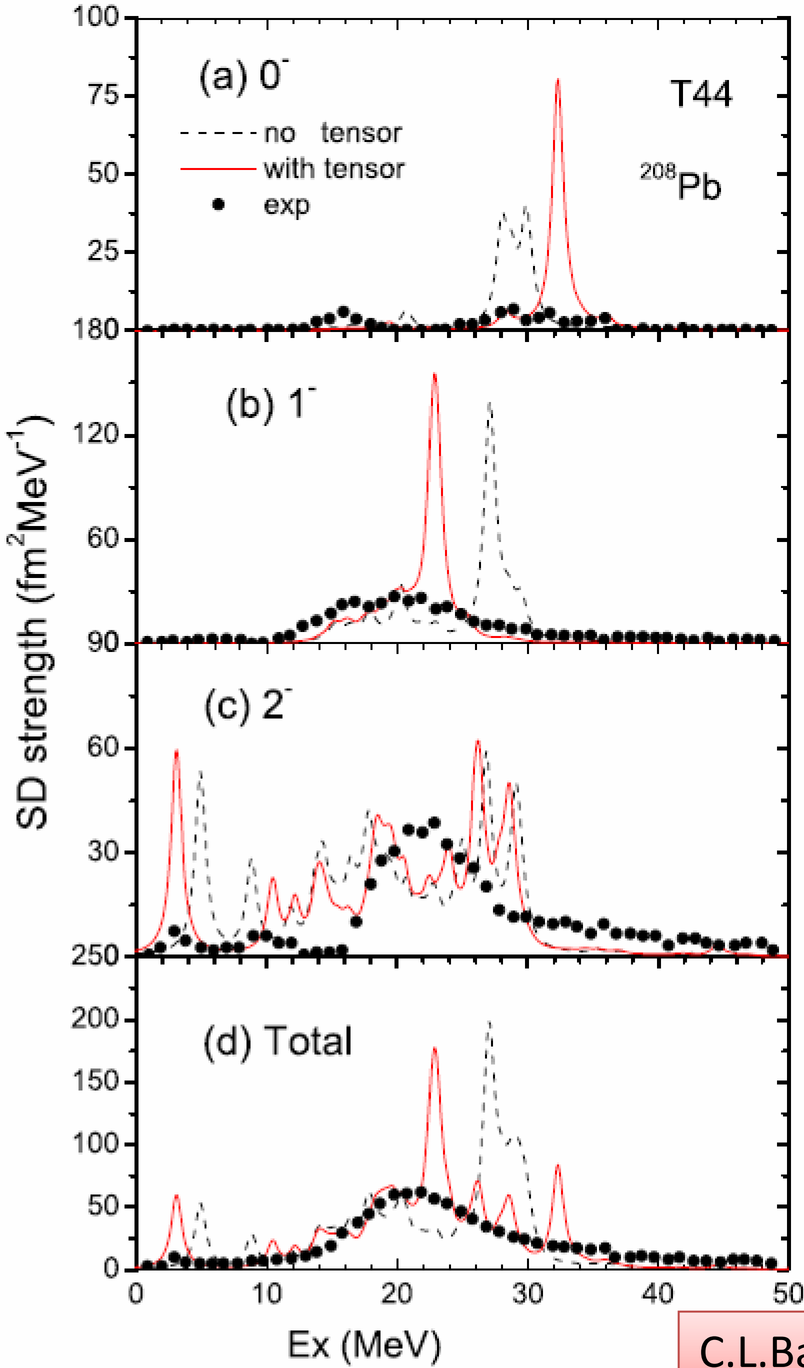

(a)
90Zr GT unpert
00
11
GT strength
Ex(MeV)
(b)
90Zr SQ unpert
00
11
SQ strength(fm4)
Ex(MeV)
(c)
208Pb GT unpert
00
11
GT strength
Ex(MeV)
(d)
208Pb SQ unpert
00
11
SQ strength(fm4)
Ex(MeV)

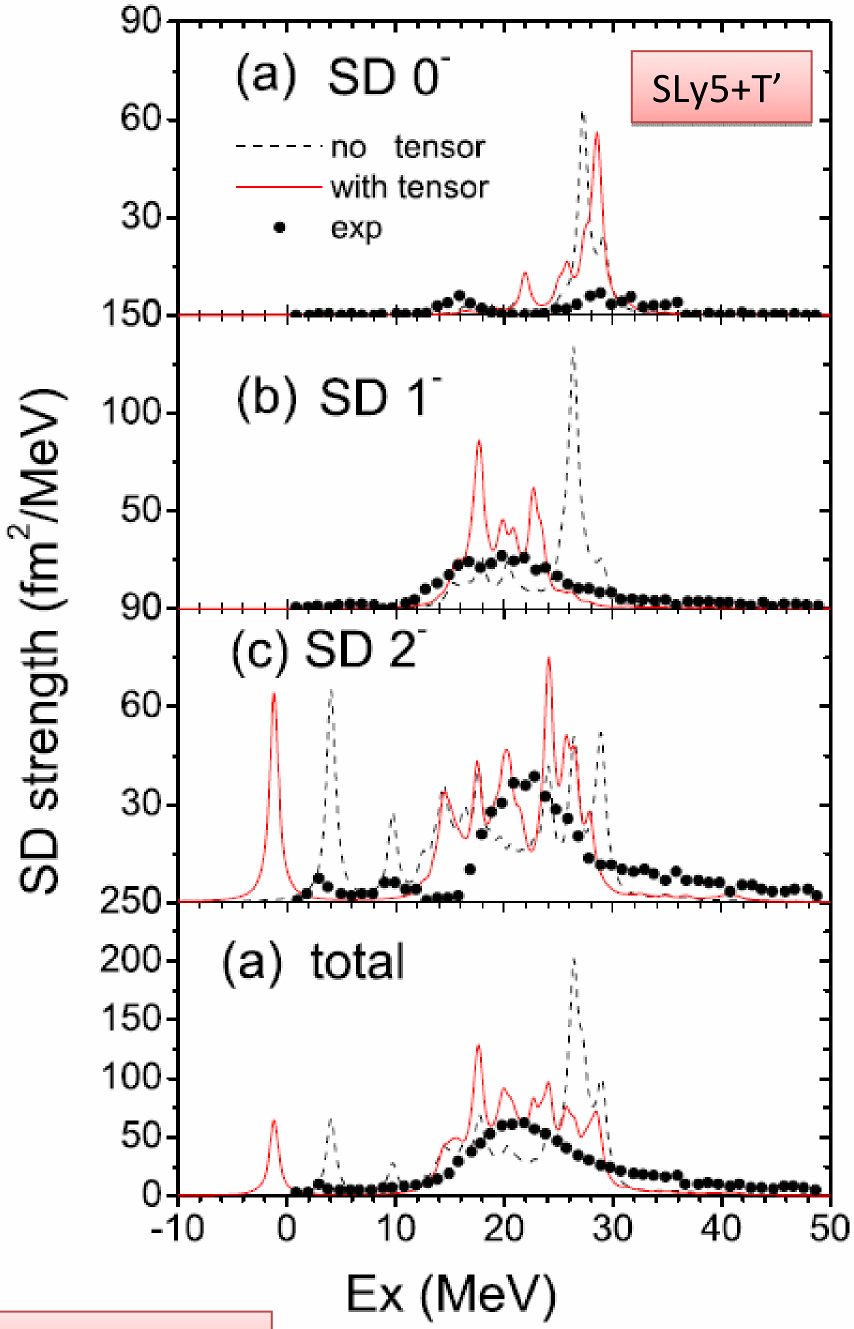


(a)
^{90}Zr GT
00
11
coup
GT strength(MeV^{-1})
Ex(MeV)
(b)
^{90}Zr SQ
00
11
coup
SQ strength(fm^{4}MeV^{-1})
Ex(MeV)
(c)
^{208}Pb GT
00
11
coup
GT strength(MeV^{-1})
Ex(MeV)
(d)
^{208}Pb SQ
00
11
coup
SQ strength(fm^{4}MeV^{-1})
Ex(MeV)

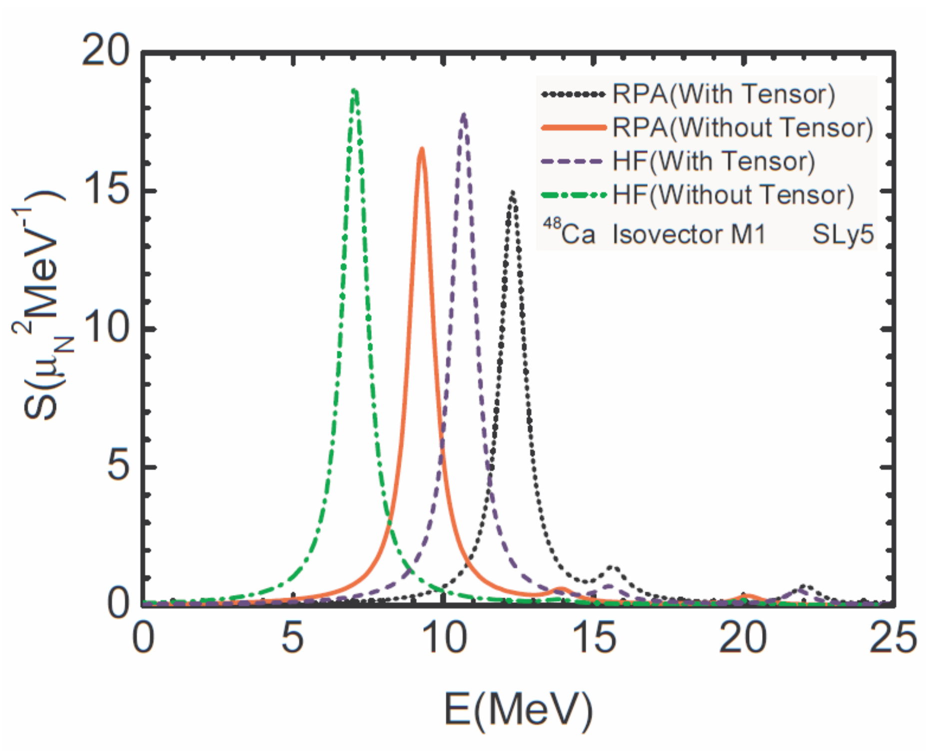


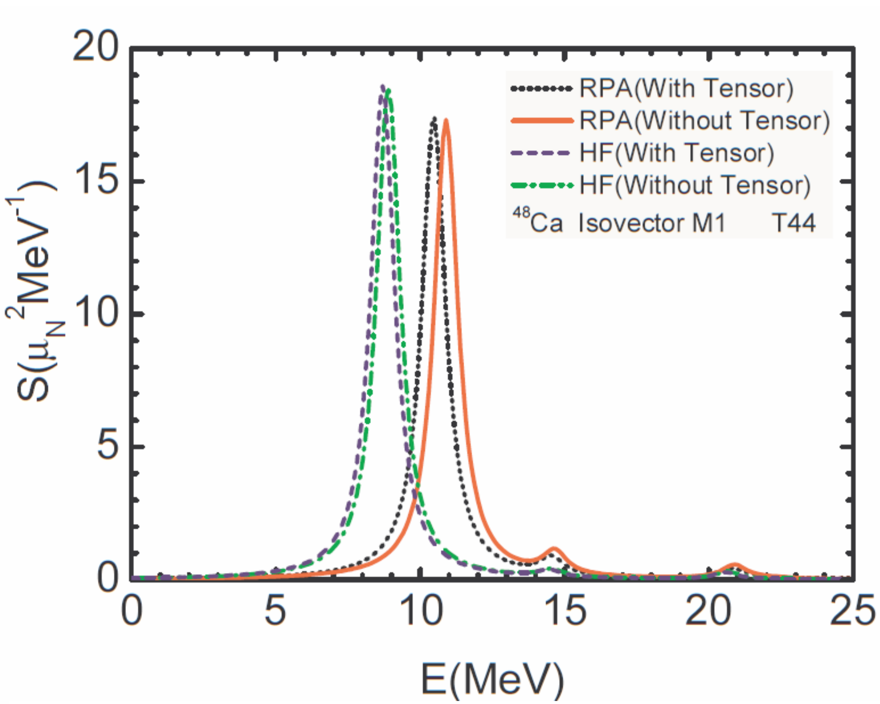
C.L.Bai, 15 March 2010





C.L.Bai, 15 March 2010





$f_{7/2} \rightarrow f_{5/2}$ HF 7.06MeV 10.68MeV(+tensor)

[SLy5] RPA 9.28MeV 12.31MeV(+tensor)

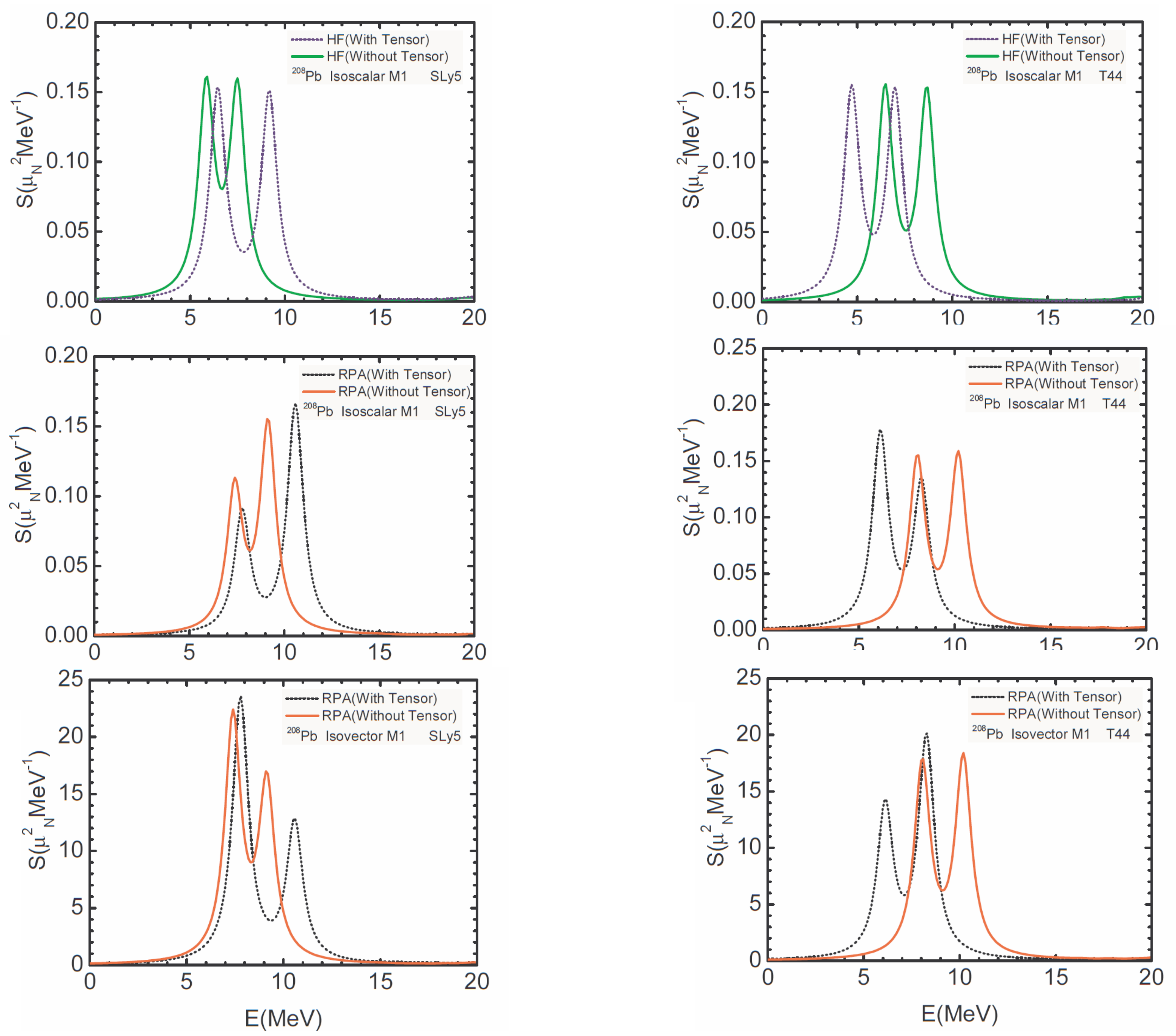
$\Delta E_{HF} = 2.22\text{MeV} \quad < V_T > = -0.59\text{MeV}$

$f_{7/2} \rightarrow f_{5/2}$ HF 8.90MeV 8.60MeV(+tensor)

[T44] RPA 10.9MeV 10.47MeV(+tensor)

$\Delta E_{HF} = 0.30\text{MeV} \quad < V_T > = -0.13\text{MeV}$

Exp. 10.23MeV


HF(With Tensor)
HF(Without Tensor)
208Pb Isoscalar M1 SLy5
HF(With Tensor)
HF(Without Tensor)
208Pb Isoscalar M1 T44
RPA(With Tensor)
RPA(Without Tensor)
208Pb Isoscalar M1 SLy5
RPA(With Tensor)
RPA(Without Tensor)
208Pb Isoscalar M1 T44
RPA(With Tensor)
RPA(Without Tensor)
208Pb Isovector M1 SLy5
RPA(With Tensor)
RPA(Without Tensor)
208Pb Isovector M1 T44
S(μN2MeV-1)
E(MeV)

Stability under extreme conditions

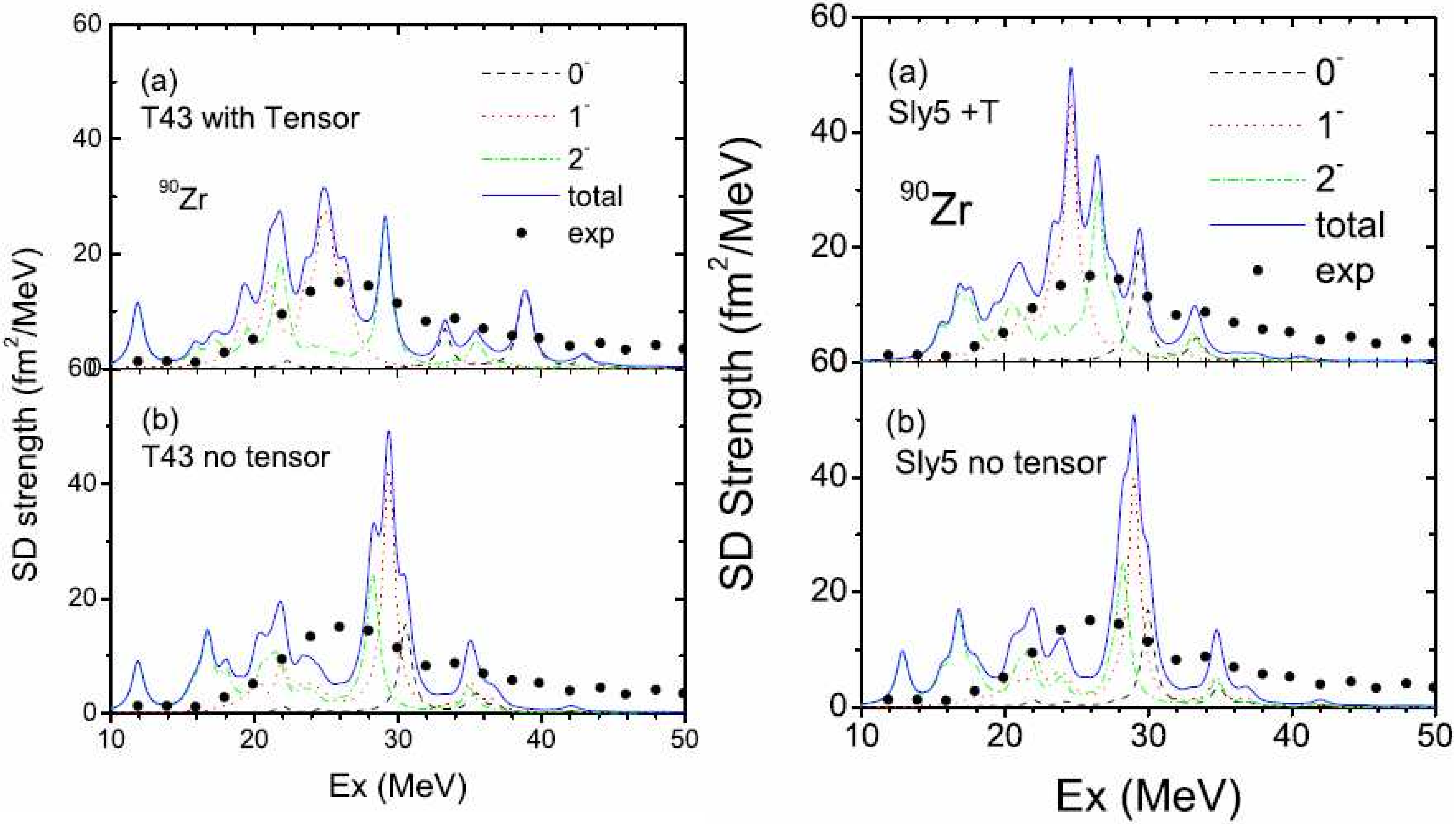
Large asymmetries, high densities, finite T, ...

RPA framework: probe the fluctuations around the ground-state
$\rightarrow$ local stability criterium

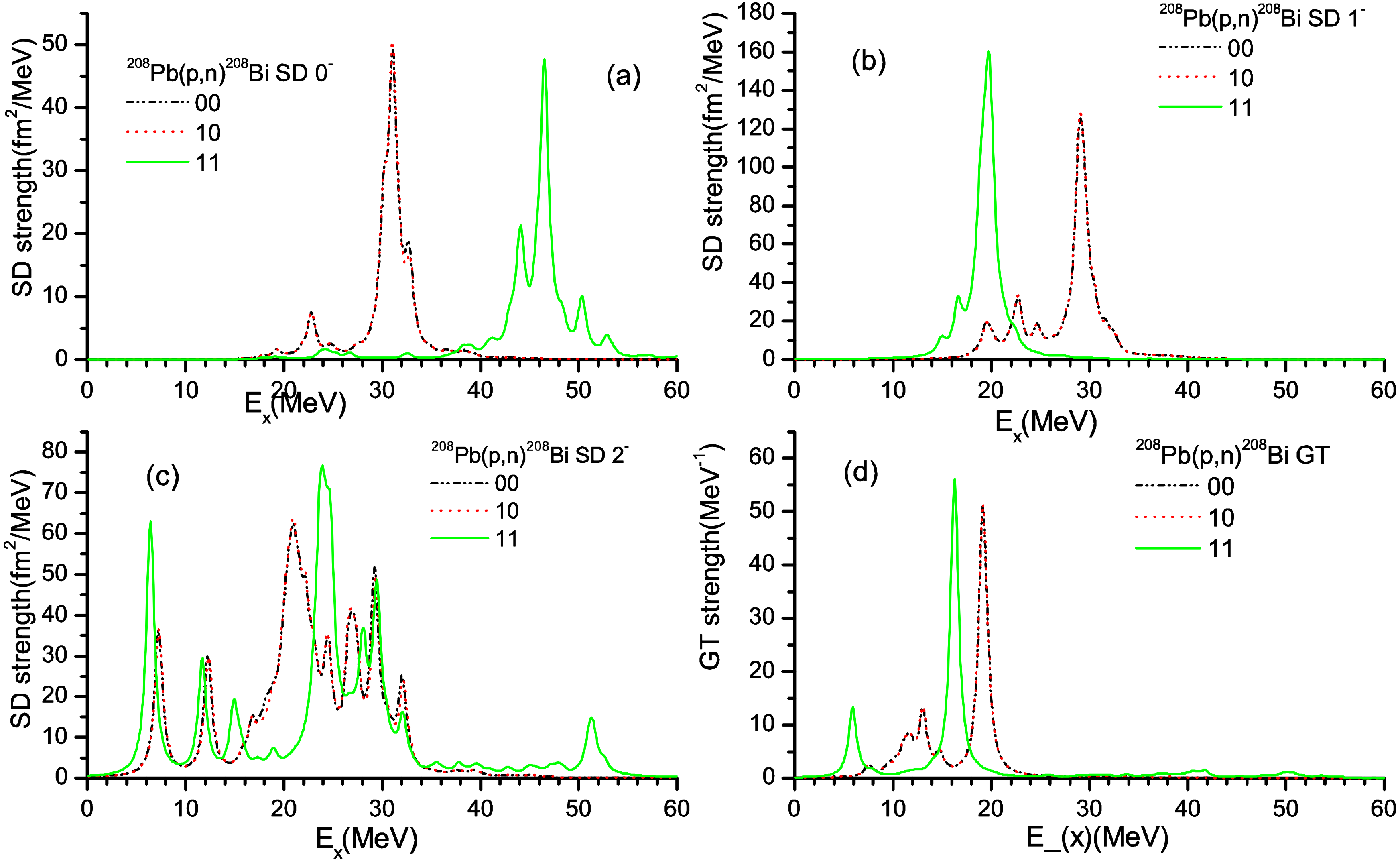
Validity check of residual interaction $\rightarrow$ **Landau parameters**

$$V_{\rm ph} = \sum_\ell (F_\ell + F'_\ell \tau_1 \cdot \tau_2 + G_\ell \sigma_1 \cdot \sigma_2 + G'_\ell (\tau_1 \cdot \tau_2)(\sigma_1 \cdot \sigma_2)) P_l(cos\theta) \ ,$$

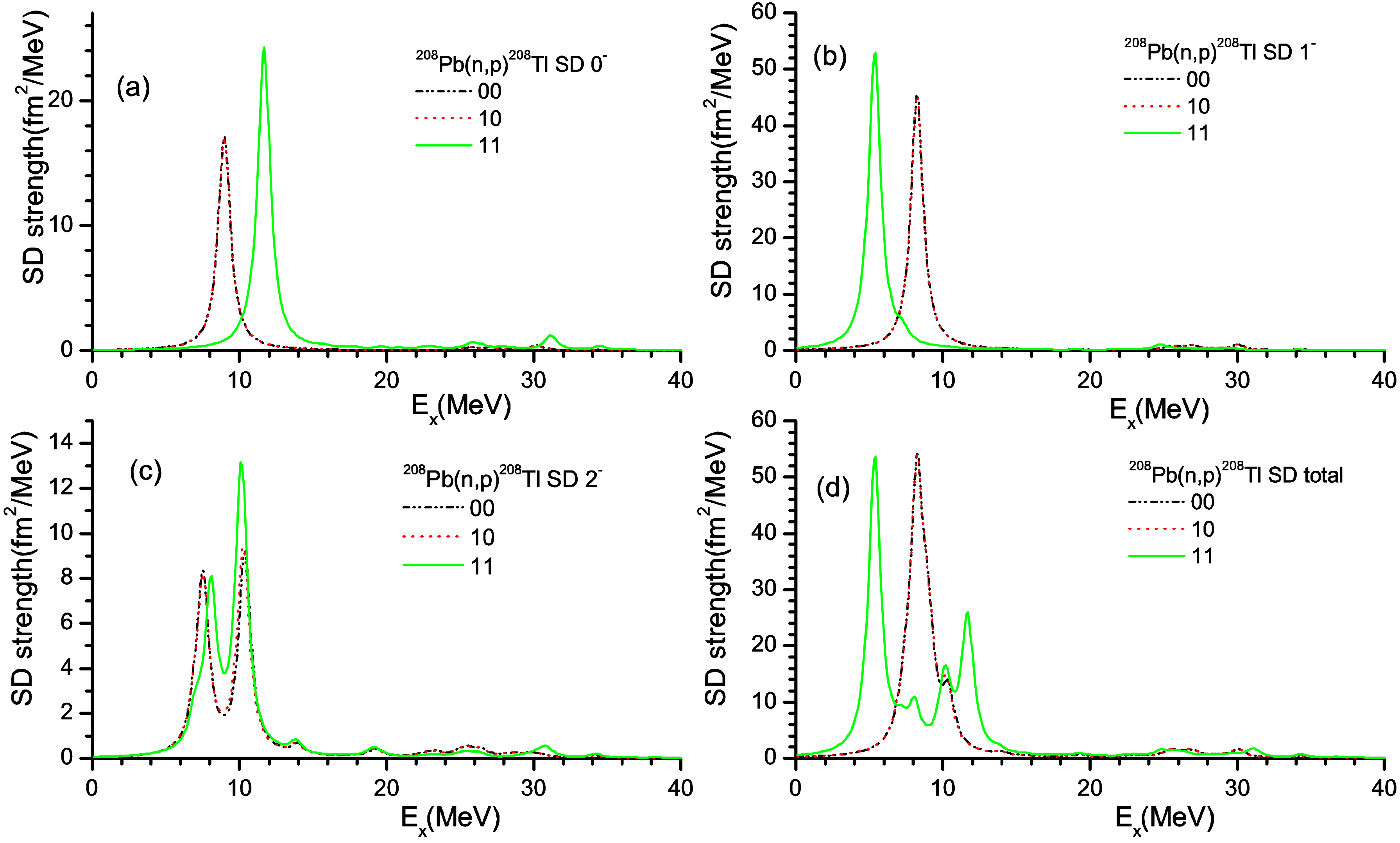
Matter is stable if $F_l > -2l - 1$



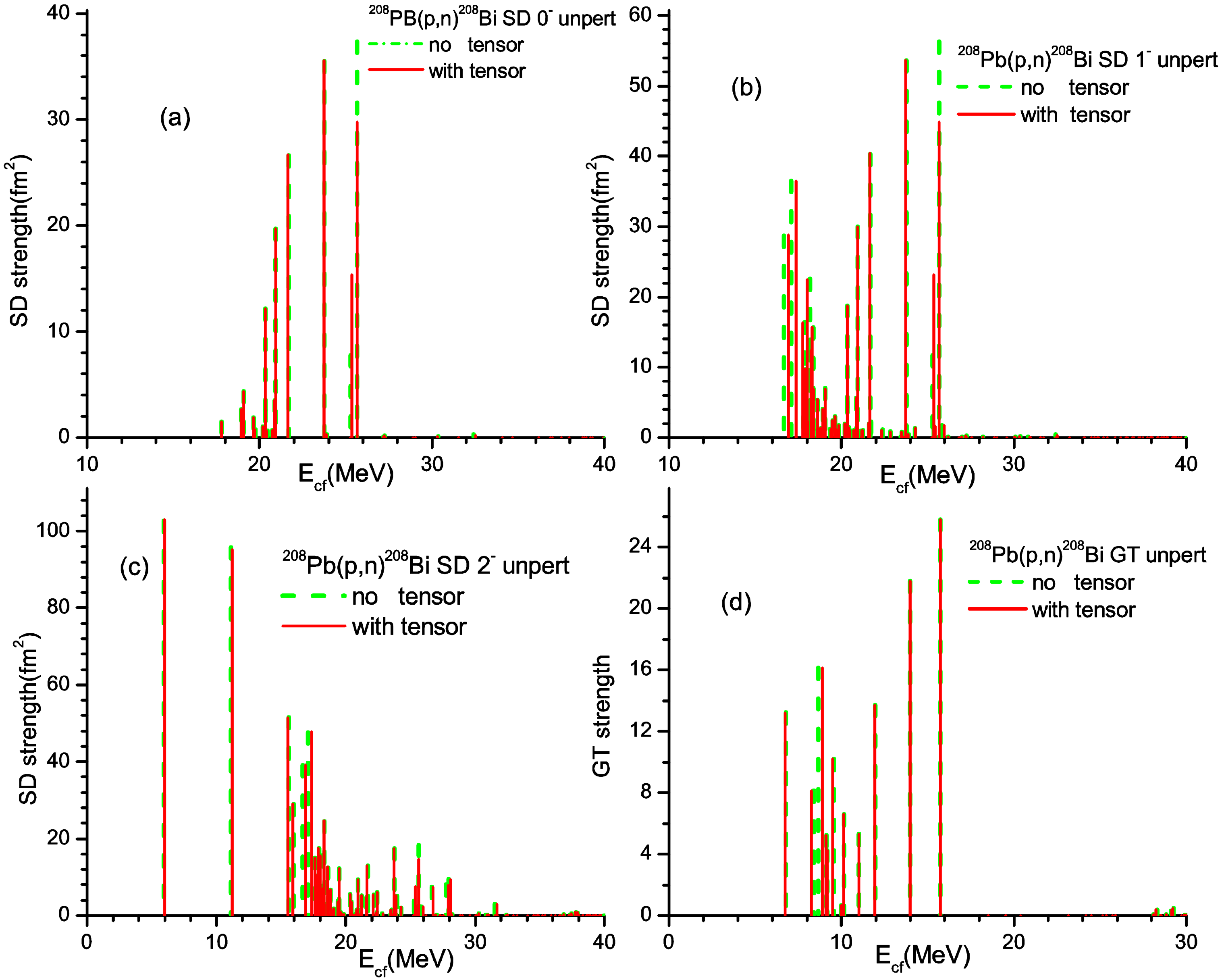
(a)
T43 with Tensor
^{90}Zr
0$^-$
1$^-$
2$^-$
total
exp
(b)
T43 no tensor
SD strength (fm^2/MeV)
Ex (MeV)
(a)
Sly5 +T
^{90}Zr
0$^-$
1$^-$
2$^-$
total
exp
(b)
Sly5 no tensor
SD Strength (fm^2/MeV)
Ex (MeV)



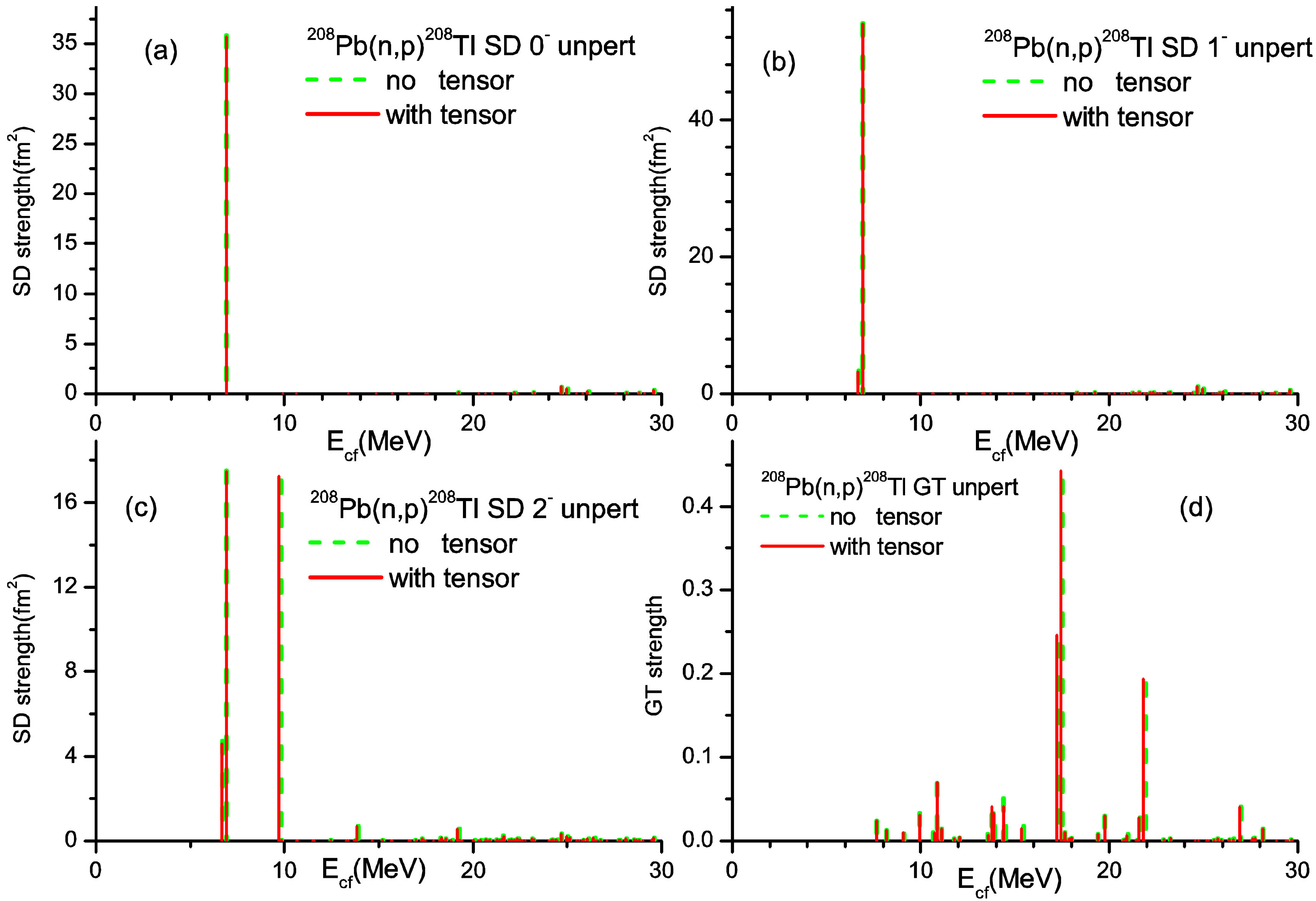
(a)
208Pb(p,n)208Bi SD 0-
00
10
11
SD strength(fm2/MeV)
Ex(MeV)
(b)
208Pb(p,n)208Bi SD 1-
00
10
11
SD strength(fm2/MeV)
Ex(MeV)
(c)
208Pb(p,n)208Bi SD 2-
00
10
11
SD strength(fm2/MeV)
Ex(MeV)
(d)
208Pb(p,n)208Bi GT
00
10
11
GT strength(MeV-1)
E_(x)(MeV)



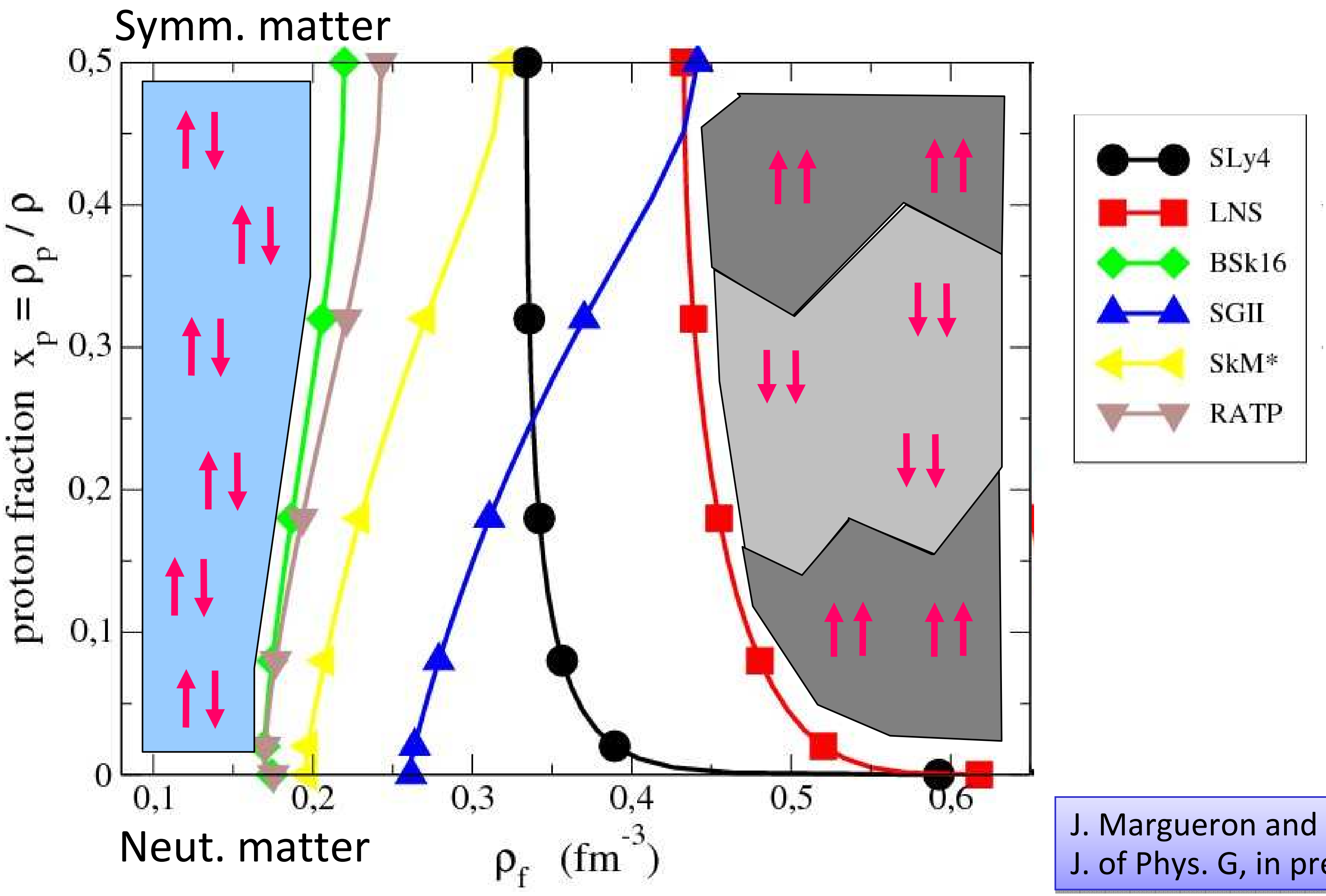
(a)
^{208}Pb(n,p)^{208}Tl SD 0$^-$
00
10
11
SD strength(fm^2/MeV)
E$_x$(MeV)
(b)
^{208}Pb(n,p)^{208}Tl SD 1$^-$
00
10
11
SD strength(fm^2/MeV)
E$_x$(MeV)
(c)
^{208}Pb(n,p)^{208}Tl SD 2$^-$
00
10
11
SD strength(fm^2/MeV)
E$_x$(MeV)
(d)
^{208}Pb(n,p)^{208}Tl SD total
00
10
11
SD strength(fm^2/MeV)
E$_x$(MeV)



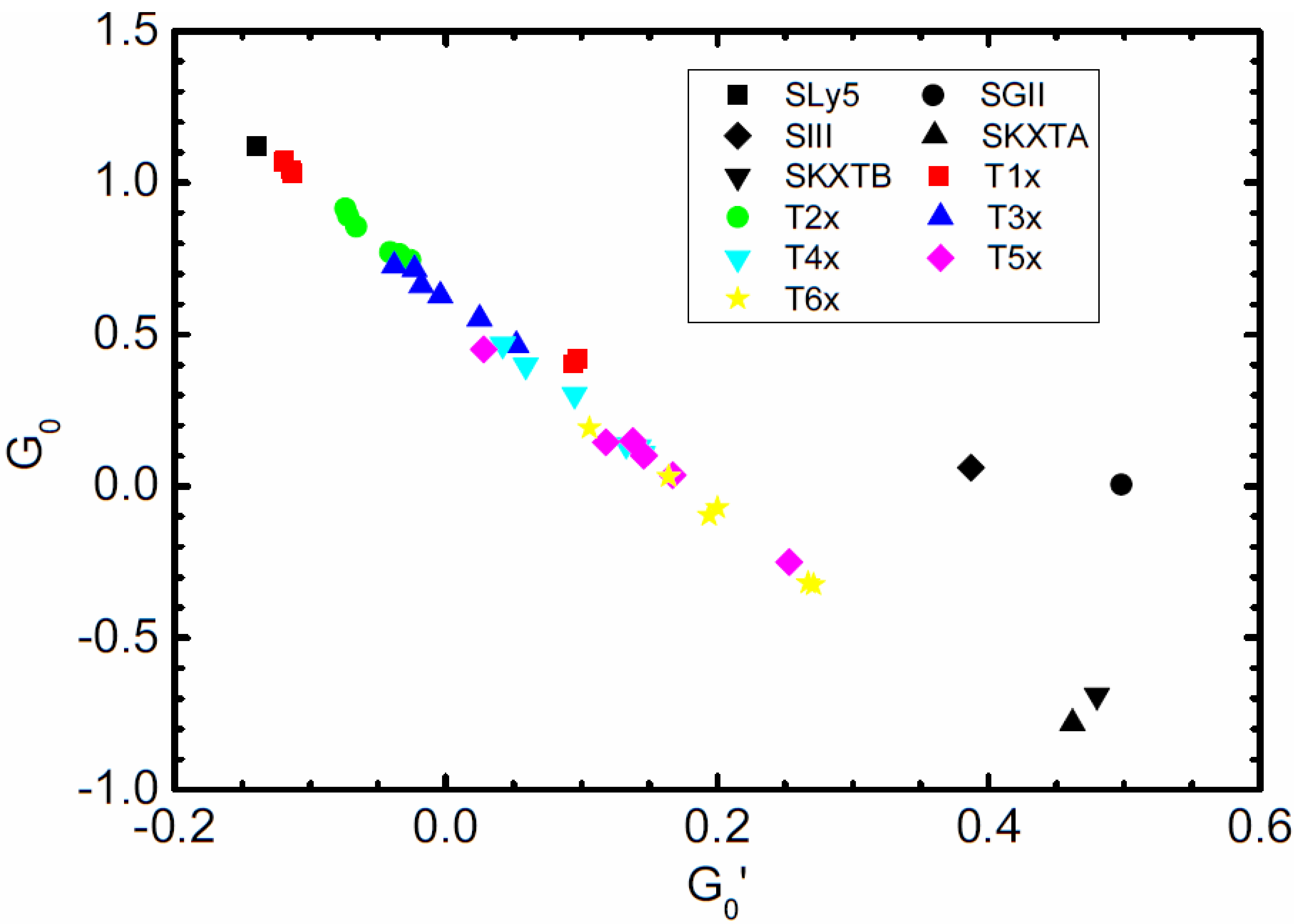
(a)
^{208}PB(p,n)^{208}Bi SD 0$^-$ unpert
no tensor
with tensor
SD strength(fm^2)
E$_{cf}$(MeV)
(b)
^{208}Pb(p,n)^{208}Bi SD 1$^-$ unpert
no tensor
with tensor
SD strength(fm^2)
E$_{cf}$(MeV)
(c)
^{208}Pb(p,n)^{208}Bi SD 2$^-$ unpert
no tensor
with tensor
SD strength(fm^2)
E$_{cf}$(MeV)
(d)
^{208}Pb(p,n)^{208}Bi GT unpert
no tensor
with tensor
GT strength
E$_{cf}$(MeV)


(a)
208Pb(n,p)208Tl SD 0- unpert
no tensor
with tensor
SD strength(fm2)
Ecf(MeV)
(b)
208Pb(n,p)208Tl SD 1- unpert
no tensor
with tensor
SD strength(fm2)
Ecf(MeV)
(c)
208Pb(n,p)208Tl SD 2- unpert
no tensor
with tensor
SD strength(fm2)
Ecf(MeV)
(d)
208Pb(n,p)208Tl GT unpert
no tensor
with tensor
GT strength
Ecf(MeV)

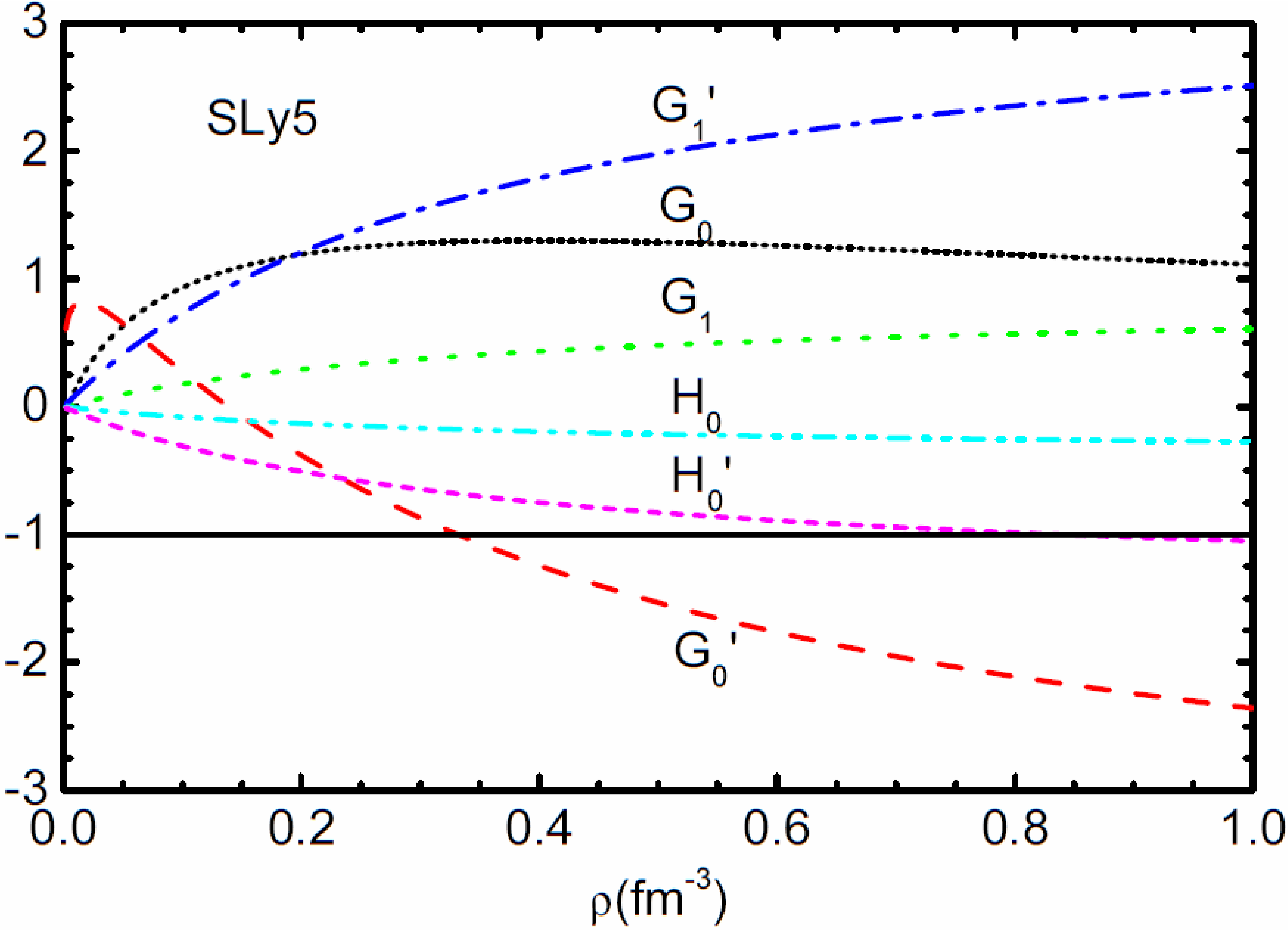
Ferromagnetic phase diagram: G & G'



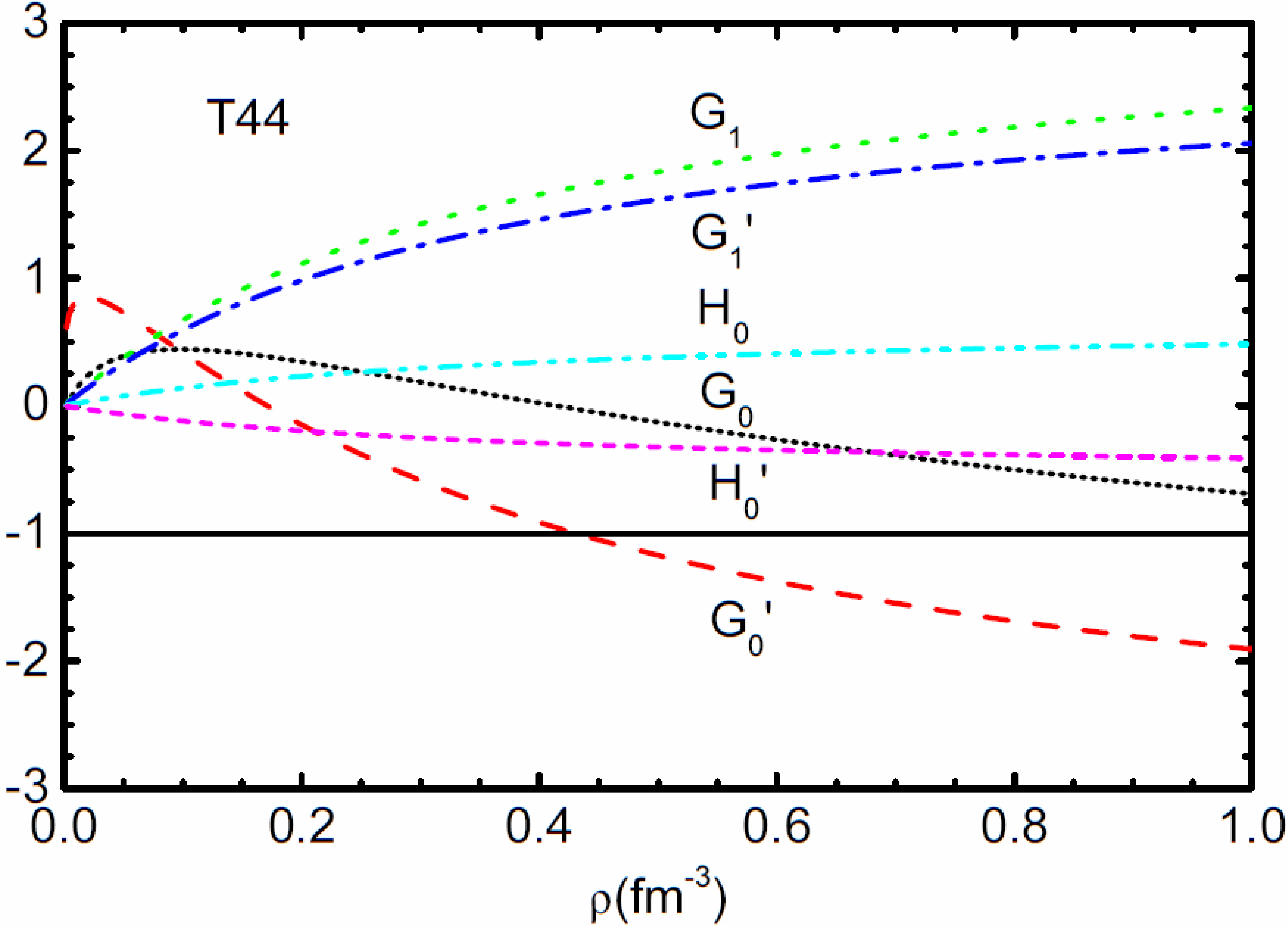
J. Margueron and HS,
J. of Phys. G, in press



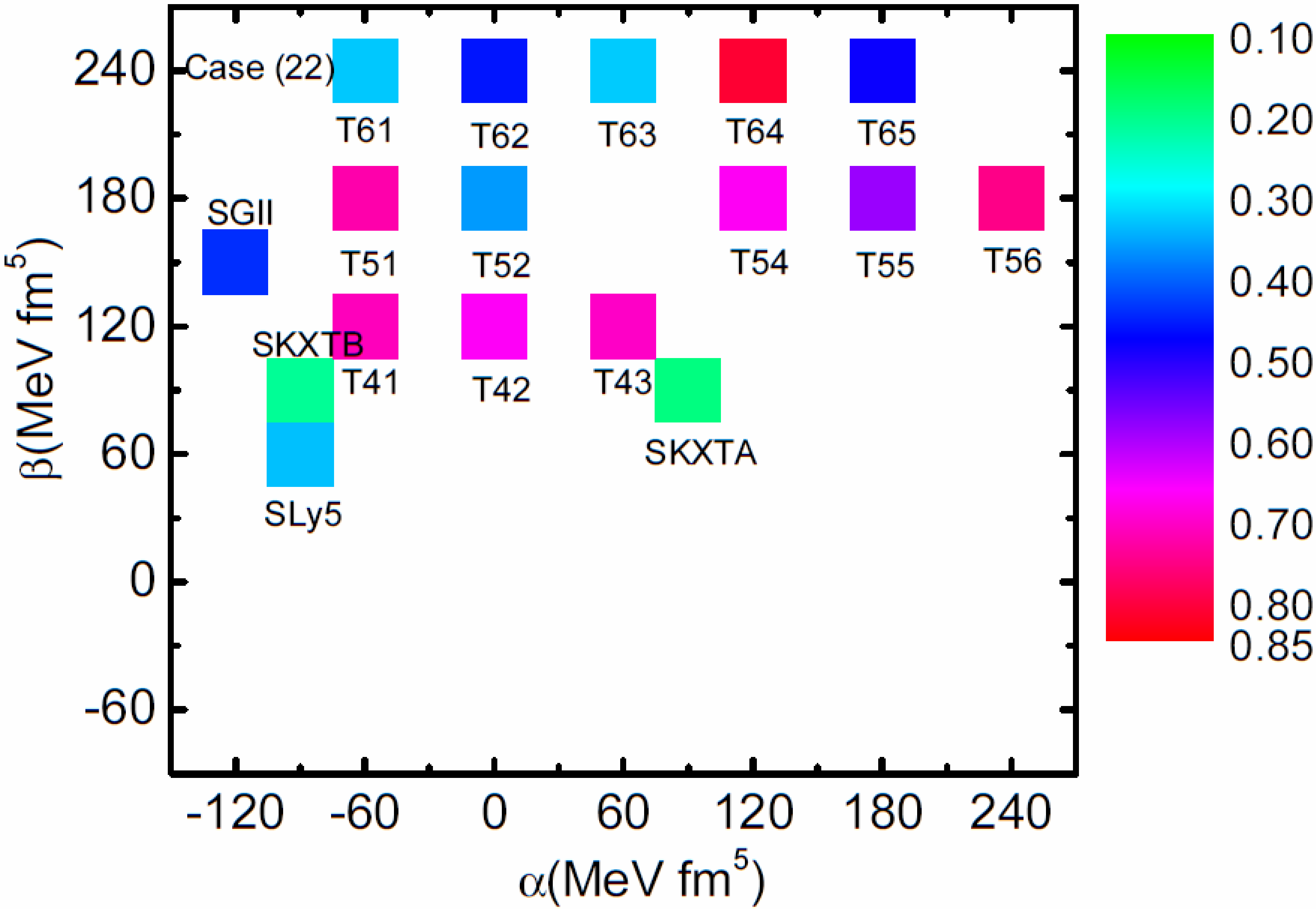
1.5
1.0
0.5
0.0
-0.5
-1.0
-0.2
0.0
0.2
0.4
0.6
G_0
G_0'
SLy5
SGII
SIII
SKXTA
SKXTB
T1x
T2x
T3x
T4x
T5x
T6x



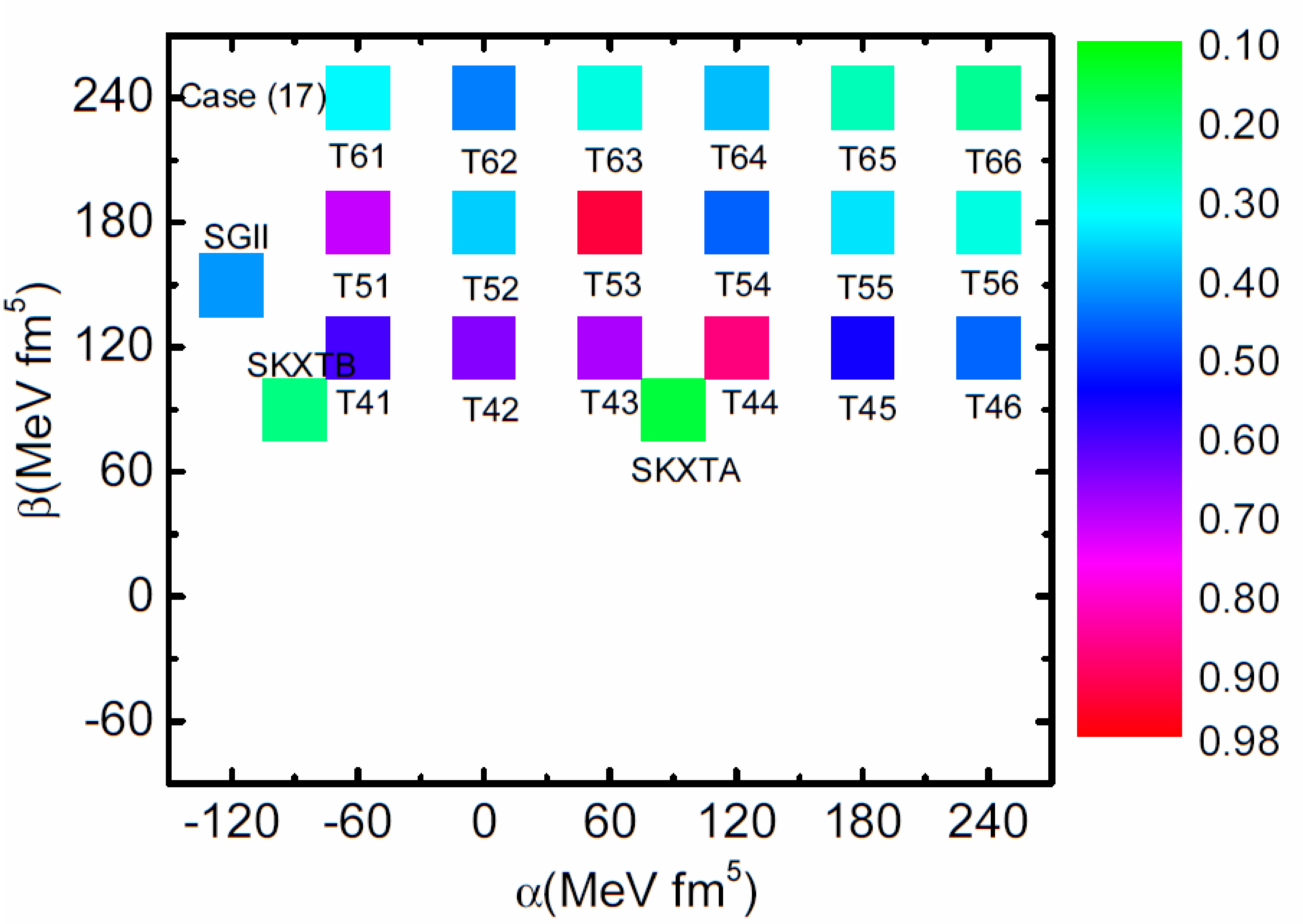
SLy5
G1'
G0
G1
H0
H0'
G0'
3
2
1
0
-1
-2
-3
0.0
0.2
0.4
0.6
0.8
1.0
ρ(fm-3)


T44
G1
G1'
H0
G0
H0'
G0'
3
2
1
0
-1
-2
-3
0.0
0.2
0.4
0.6
0.8
1.0
ρ(fm-3)

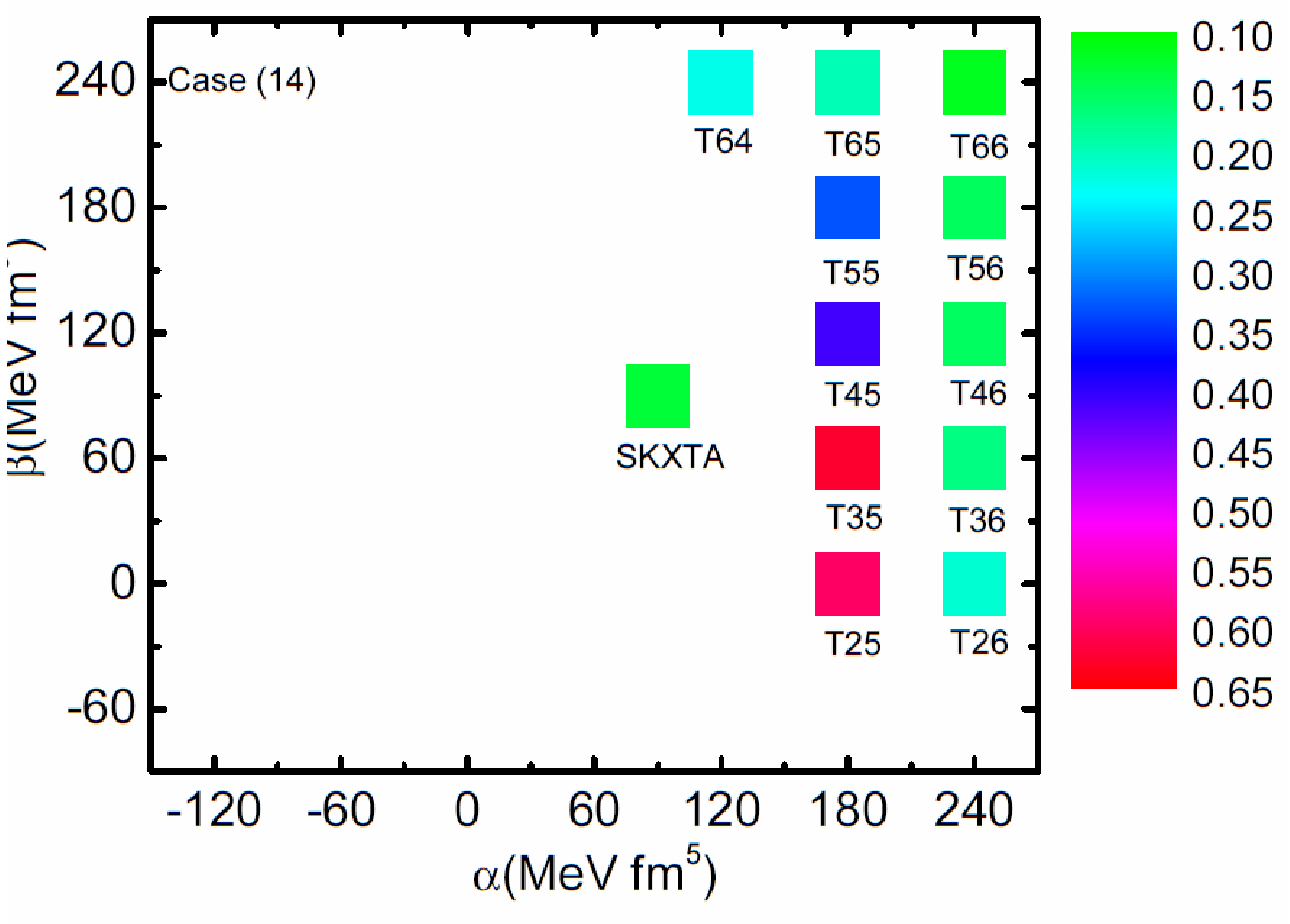
IS $l=0$ $1+G_0>0$ (without tensor)



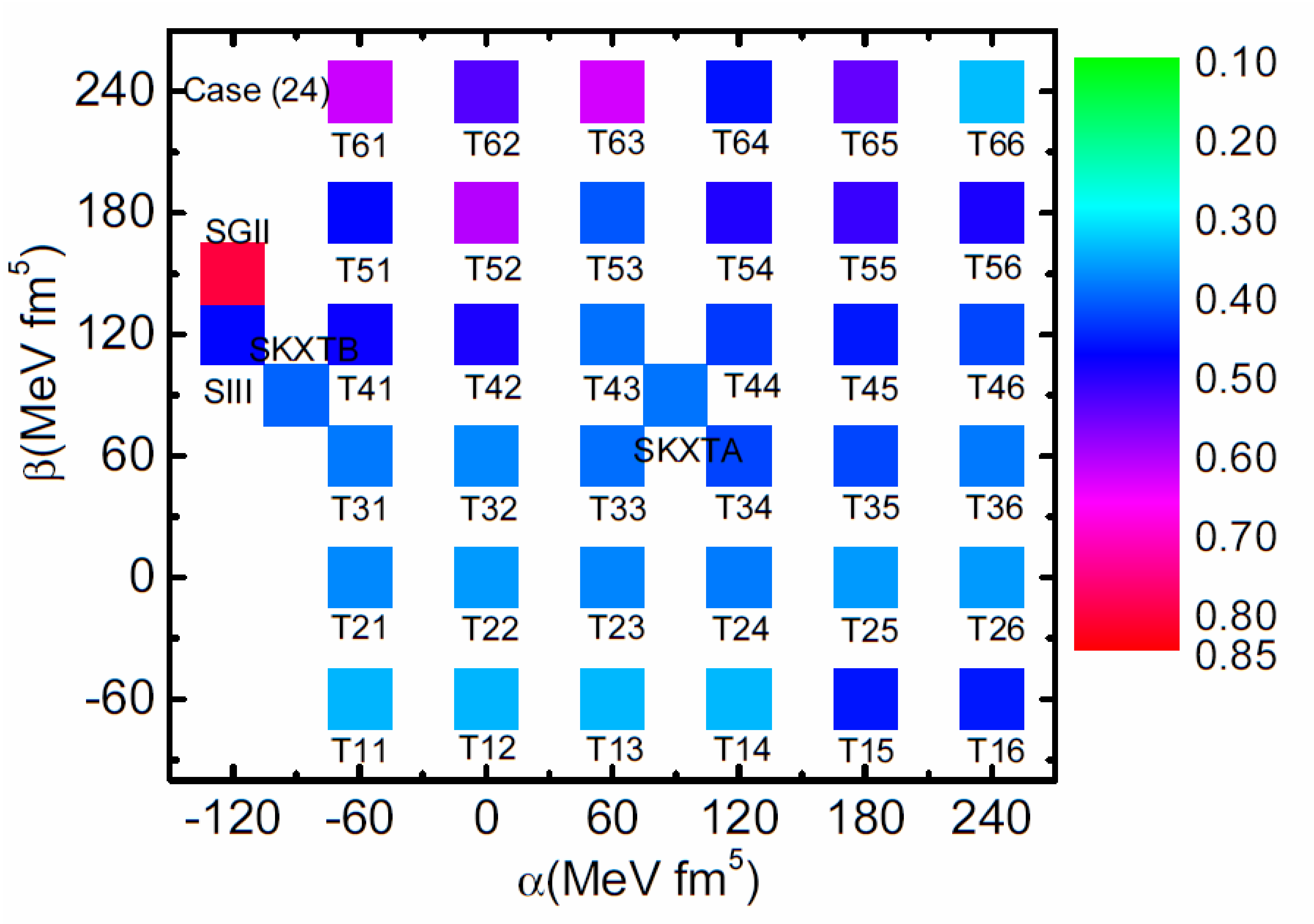
IS $J = 1^{+}$ $\quad (2+G_0) \pm \sqrt{G_0^{\,2} + 8H_0^{\,2}} > 0$



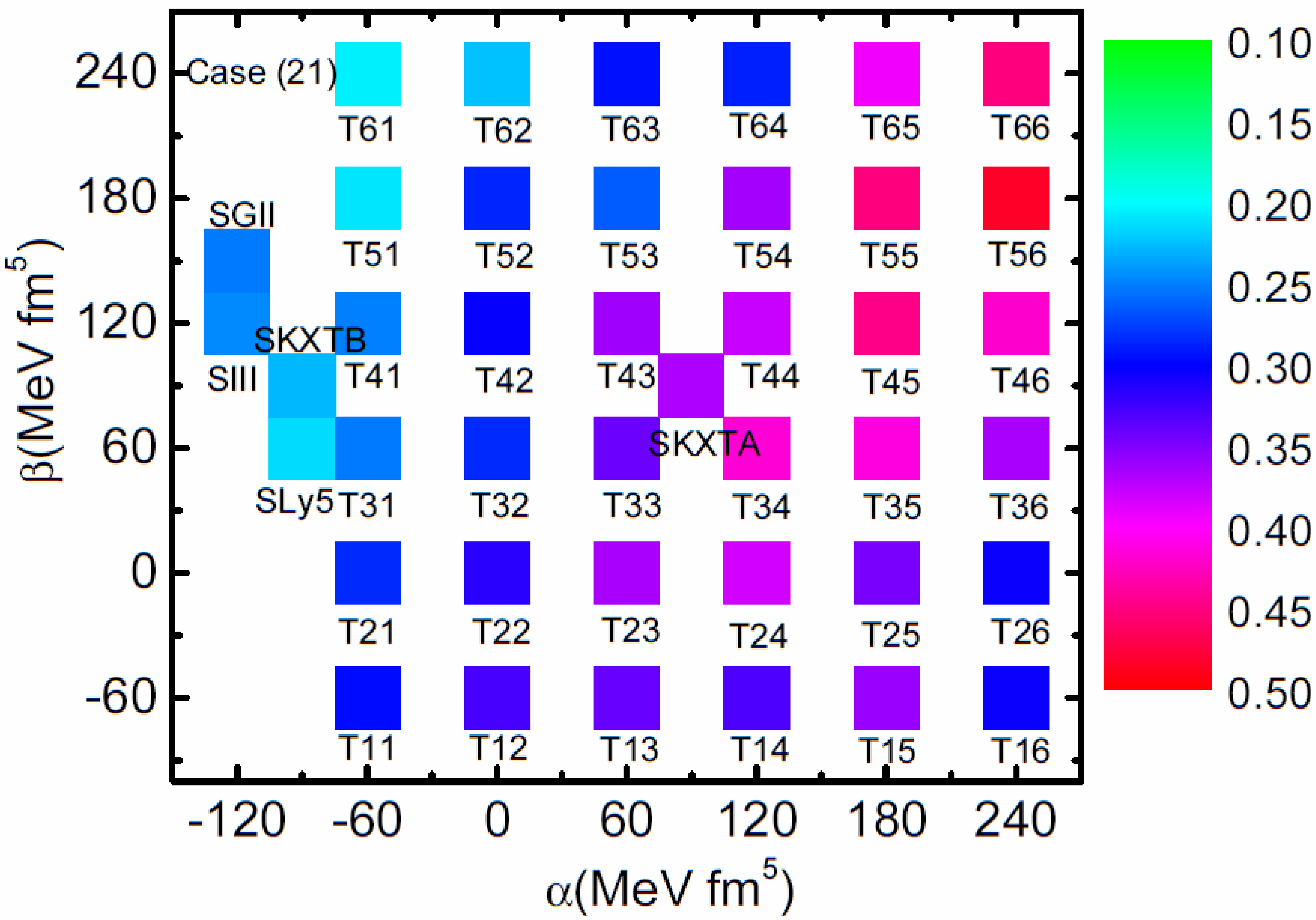
IS $J = 0^{-}$ $\frac{1}{3} G_{,P} - \frac{10}{3} H_0 > 0$



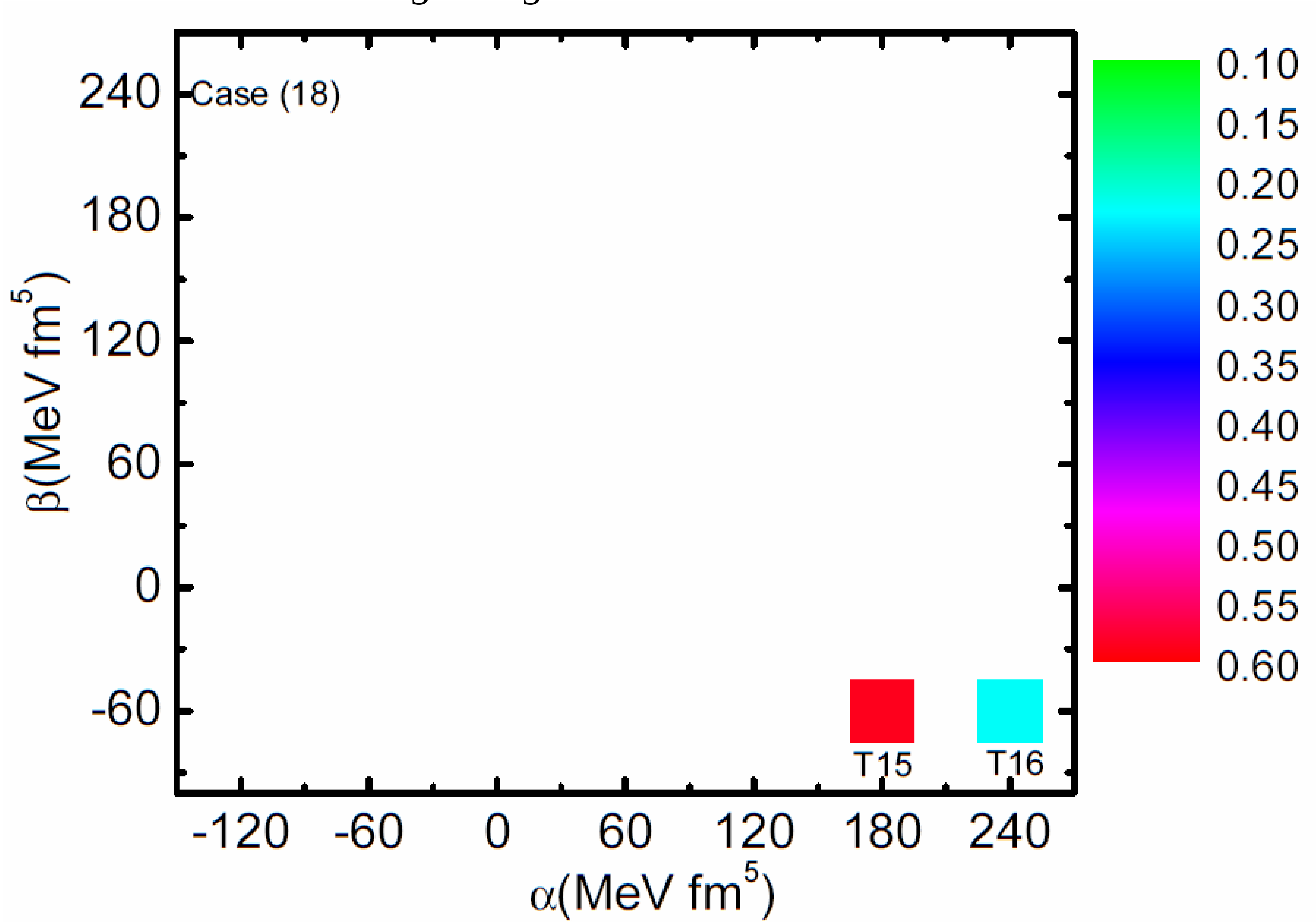
IV $l = 0$ $1+G_0' > 0$ (without tensor)



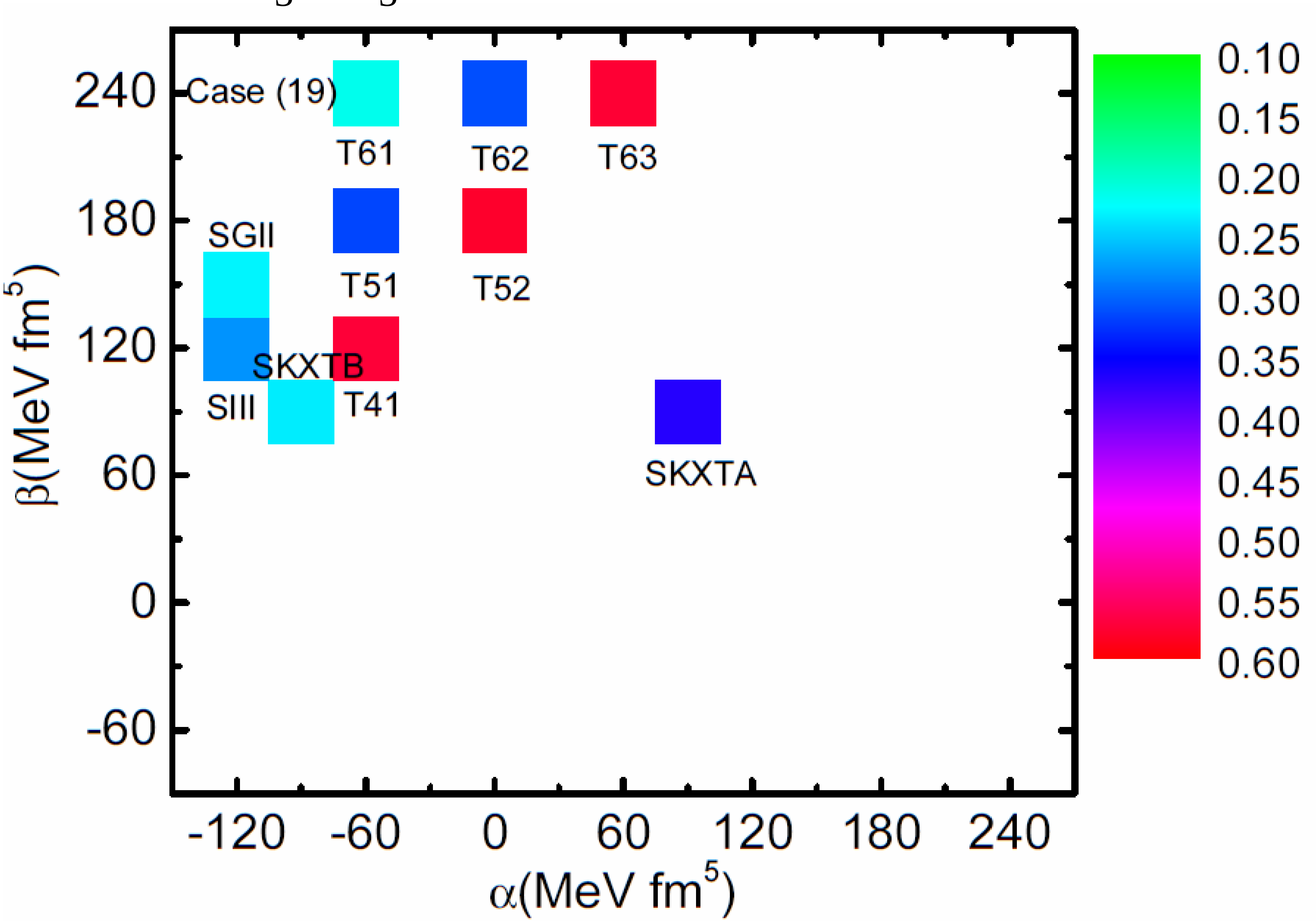
IV $J = 1^{+}$ $\quad (2+G_0^{'}) \pm \sqrt{G_0^{'2} + 8H_0^{'2}} > 0$



$\mathrm{IV}\ J=0^{-}\ \left(1+\frac{1}{3}a\right)G_1' - \frac{10}{3}H_0' > 0$



IV $J=1^{-}$ □ $D+\frac{1}{3}G_1^{'}+\frac{5}{3}H_0^{'}>0$



Summary and Future perspectives II

6. Spin and Spin-Isospin instability are strongly affected by the tensor inetractions.

7. Spin and Spin-isospin Landau parameters are improved by introducing spin and spin-isopsin density dependent interactions.

8. Good mass systematics is preserved within the rms deviation of less than 600keV by introducing new terms (S. Goriery) .

Mean Field Theories

Non-relativistic model

HF: Skyrme Interaction

T.H.R Skyrme(1956,1959)

D. Vautherin and D. Brink(1972)

F. Stancu, D. Brink and H. Flocard +tensor (1977)

Gogny Interaction (1975)

J. Decharge and D. Gogny (1980)

Relativistic model

RMF(Hartree)

J. D. Walecka (1974)

B. D. Serot and J. D. Walecka (1986)

RHF

A. Bouyssy, J.F.Mathiot, N.V.Giai and S. Marcos(1987)

TDA and RPA theory

Linear Response theory (coordinate space RPA)

G.F.Bertsch and S.F.Tsai (1975)

K.F.Liu and Nguyen Van Giai (1976) + continuum

M. Matsuo (2001) +pairing

RRPA

D. Vretenar, P. Ring ----, TDRMF(1994)

Z.Y. Ma, N.V.Giai, H. Toki ---(1997) RRPA linear response