# Isoscalar pairing and spin-isospin response

Hiroyuki Sagawa　　RIKEN/University of Aizu

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- Introduction

- Pairing correlations  T=1,S=0 and T=0,S=1 pairs
  Energy spectra of N=Z odd-odd nuclei.

- Gamow-Teller excitations in N=Z *pf*- shell nuclei
  interplay between  T=1 and T=0 pairing

- IS and IV spin response and spin polarizability in *sd*-shell nuclei

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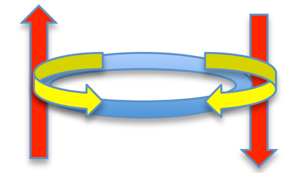
## Two particle systems

T=1, S=0 pair

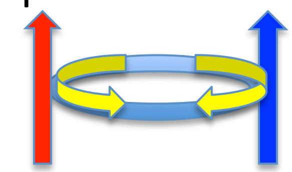


p(n) p(n)

$$\left|(L=S=0)J=0,T=1\right\rangle \Rightarrow \left|(j=j^{'})J=0,T=1\right\rangle$$

T=0, S=1 pair

p n



$$\left|(L=0,S=1)J=1,T=0\right\rangle \Rightarrow$$

$$a\left|(l=l^{'}j=j^{'})J=1,T=0\right\rangle + b\left|((l=l^{'})j,j^{'}=j\pm 1)J=1,T=0\right\rangle$$

If there is strong spin-orbit splitting, it is difficult to make (T=0,S=1)pair.

T=0 J= $1^{+}$ state could be M1 or Gamow-Teller states in nuclei with N~Z

➔ strong M1 or GT states in N~Z nuclei

(J=0,T=1) and (J=1,T=0) are SU(4) supermultiplet in spin-isospin space

Well-known in light p-shell nuclei (LS coupling dominance)

The spin-singlet $T$=1 pairing $V^{(T=1)}(\mathbf{r},\mathbf{r}') = -G^{(T=1)} \sum_{i,j} P^{(1,0)\dagger}_{i,i}(\mathbf{r},\mathbf{r}') P^{(1,0)}_{j,j}(\mathbf{r},\mathbf{r}')$

$$\langle (j_i j_i)T=1, J=0 | V^{(T=1)} | (j_j j_j) T=1, J=0 \rangle = -\sqrt{(j_i+1/2)(j_j+1/2)}\, G^{(T=1)} I^2_{ij} \qquad (5)$$

where $I_{ij}$ is the overlap integral given by,

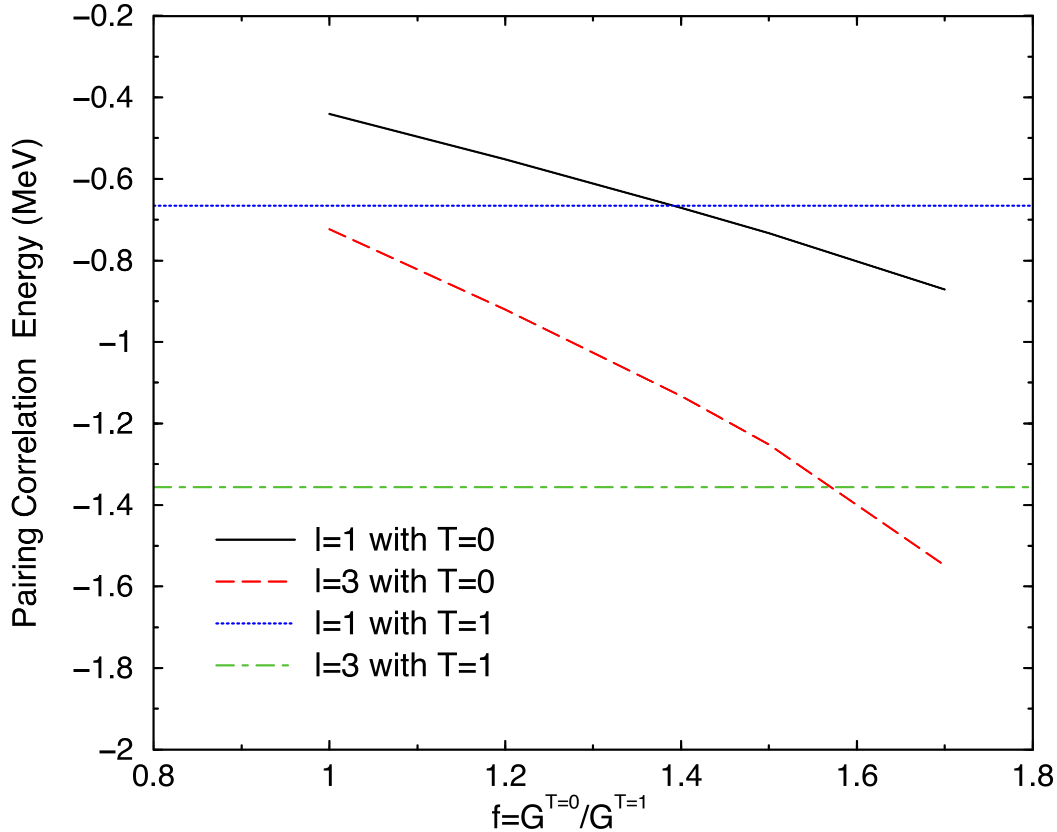
$$I_{ij} = \int \psi_i(\mathbf{r})^* \psi_j(\mathbf{r}) d\mathbf{r} \qquad (6)$$

($T$=0, $S$=1) pairing $V^{(T=0)}(\mathbf{r},\mathbf{r}') = -fG^{(T=1)} \sum_{i \geqq i', j \geqq j'} P^{(0,1)\dagger}_{i,i'}(\mathbf{r},\mathbf{r}') P^{(0,1)}_{j,j'}(\mathbf{r},\mathbf{r}')$

$$\langle (j_1 j_2)T=0, J=1 | V^{(T=0)} | (j'_1 j'_2) T=0, J=1 \rangle =$$
$$- \left\langle \left[ \left( l_1 \frac{1}{2} \right)^{j_1} \left( l_2 \frac{1}{2} \right)^{j_2} \right]^{J=1} \middle| \left[ (l_1 l_2)^{L=0} \left( \frac{1}{2} \frac{1}{2} \right)^{S=1} \right]^{J=1} \right\rangle$$
$$\times \left\langle \left[ \left( l'_1 \frac{1}{2} \right)^{j'_1} \left( l'_2 \frac{1}{2} \right)^{j'_2} \right]^{J=1} \middle| \left[ (l'_1 l'_2)^{L=0} \left( \frac{1}{2} \frac{1}{2} \right)^{S=1} \right]^{J=1} \right\rangle$$
$$\times \frac{\sqrt{2l_1+1}\sqrt{2l'_1+1}}{\sqrt{1+\delta_{j_1,j_2}}\sqrt{1+\delta_{j'_1,j'_2}}} fG^{T=1} (I_{j_1 j'_1} I_{j_2 j'_2} + I_{j_1 j'_2} I_{j_1 j'_2}),$$

TABLE I: The transformation coefficient $R$ between the $jj$ coupling and the $LS$ coupling for the pair wave functions, $R = \langle [(l\frac{1}{2})^{j}(l\frac{1}{2})^{j'}]^{J=1} | [(ll)^{L=0}(\frac{1}{2}\frac{1}{2})^{S=1}]^{J=1} \rangle$. $\Omega$ is defined as $\Omega \equiv 3(2l+1)^2$ .

| $j$ | $j'$ | $R$ | $l=1$ | $l=3$ |
|---|---|---|---|---|
| $l+1/2$ | $l+1/2$ | $\sqrt{\frac{(2l+2)(2l+3)}{2\Omega}}$ | $\frac{1}{3}\sqrt{\frac{10}{3}}$ | $\frac{2\sqrt{3}}{7}$ |
| $l+1/2$ | $l-1/2$ | $-\sqrt{\frac{4l(l+1)}{\Omega}}$ | $-\frac{2}{3}\sqrt{\frac{2}{3}}$ | $-\frac{4}{7}$ |
| $l-1/2$ | $l-1/2$ | $-\sqrt{\frac{2l(2l-1)}{2\Omega}}$ | $-\frac{1}{3}\sqrt{\frac{1}{3}}$ | $-\frac{\sqrt{5}}{7}$ |
| $l-1/2$ | $l+1/2$ | $\sqrt{\frac{4l(l+1)}{\Omega}}$ | $\frac{2}{3}\sqrt{\frac{2}{3}}$ | $\frac{4}{7}$ |




Pairing correlation energy of (J,T)=(0,1) and (1,0) states in *pf* shell

Even with large spin-orbit splitting for *f* -orbits, the spin-triplet correlations will be larger than the spin-singlet one for f>1.5

HS, Y. Tanimura and K. Hagino, PRC87, 034310 (2013)

TABLE I. Strengths of triplet and singlet interactions from shell-model fits and their ratios. See text for details.

| Source | $v_s$ (MeV fm$^3$) | $v_t$ (MeV fm$^3$) | Ratio |
|---|---|---|---|
| *sd* shell [8] | 280 | 465 | 1.65 |
| *fp* shell [9] | 291 | 475 | 1.63 |

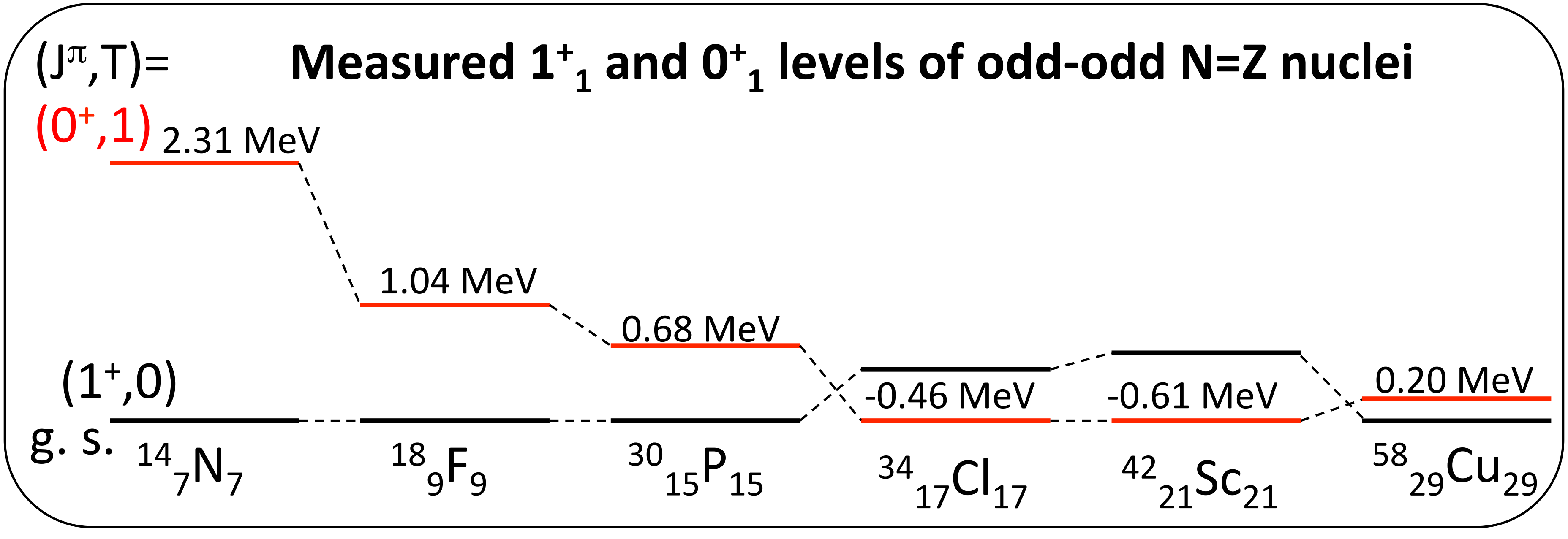
G.F. Bertsch and Y. Luo, PRC81, 064320 (2010)

# N=Z odd-odd nuclei with 3-body model

Y. Tanimura, HS, K. Hagino, PTEP 053D02 (2014)

- n-p pairing interactions
  - ✓ T=0, 1 two channels
  - ✓ T=0, S=1 is attractive stronger than T=1, S=0 pair
    cf. deuteron, matrix elements in shell models
  - ✓ In finite nuclei N>Z , the strong spin-orbit coupling
    may quench or even kill T=0 pairing

when *l* is larger , the spin-orbit is larger and T=0 pair correlations decrease



# Three-body Model

**Total 3-body Hamiltonian**

$$H = \frac{\boldsymbol{p}_p^2}{2m} + \frac{\boldsymbol{p}_n^2}{2m} + V_{pC}(\boldsymbol{r}_p) + V_{nC}(\boldsymbol{r}_n) + V_{pn}(\boldsymbol{r}_p, \boldsymbol{r}_n) + \frac{(\boldsymbol{p}_p+\boldsymbol{p}_n)^2}{2A_C m}$$

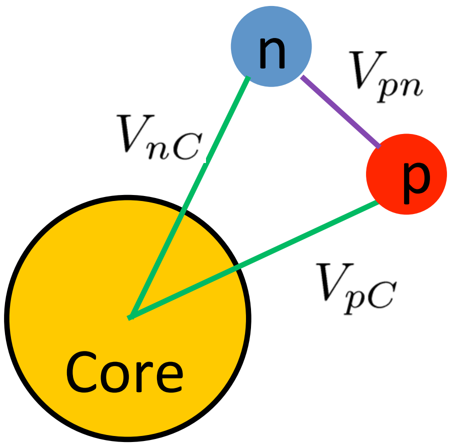
**Core-N mean field**

$$V_{(p/n)C}(r) = v_0 f(r) + v_{ls}\frac{1}{r}\frac{d}{dr}f(r)(\boldsymbol{l}\cdot\boldsymbol{s})(+Coulomb)$$

$$f(r) = \frac{1}{1+e^{(r-R)/a}}$$

**p-n interaction**

$$V_{pn} = \hat{P}_s v_s \delta(\boldsymbol{r}_p - \boldsymbol{r}_n)[1 + x_s(\frac{\rho(r)}{\rho_0})^\alpha] + \hat{P}_t v_t \delta(\boldsymbol{r}_p - \boldsymbol{r}_n)[1 + x_t(\frac{\rho(r)}{\rho_0})^\alpha]$$




Determination of parameters
$v_0$, $v_{ls}$: neutron separation energy
$v_s$, $v_t$: pn scattering length with $E_{cut}$ (= 20 MeV)
$v_s/v_t$=1.7 (spin-triplet pairing is much stronger than spin-singlet)
$x_S$, $x_t$, $\alpha$: $1^+$, $3^+$, $0^+$ in $^{18}F$ energies are fitted

⇨ Diagonalization in a large model space

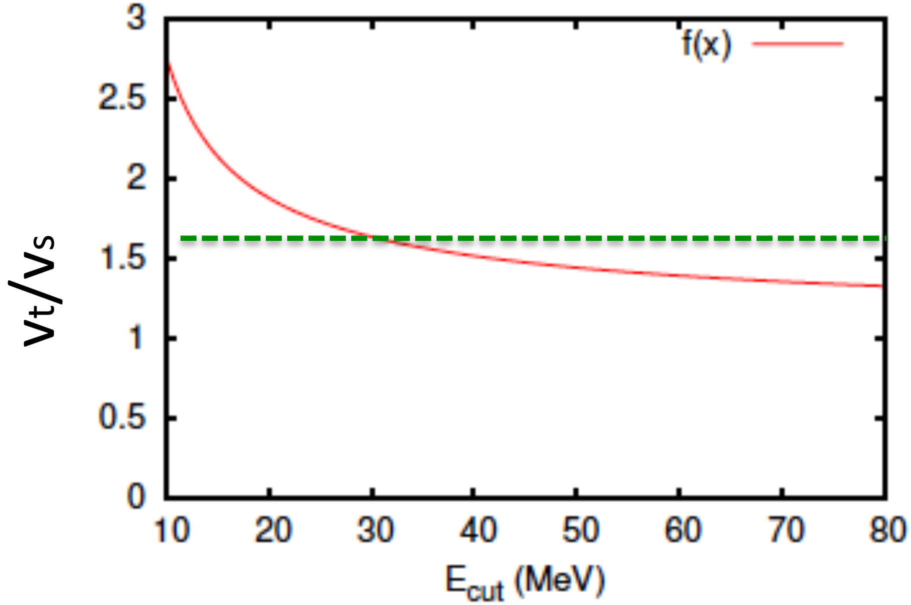
## pn pairing interaction

$$V_{np}(\boldsymbol{r}_1,\boldsymbol{r}_2) = \hat{P}_s v_s \delta(\boldsymbol{r}_1-\boldsymbol{r}_2)\left[1+x_s\left(\frac{\rho(r)}{\rho_0}\right)^{\alpha}\right] + \hat{P}_t v_t \delta(\boldsymbol{r}_1-\boldsymbol{r}_2)\left[1+x_t\left(\frac{\rho(r)}{\rho_0}\right)^{\alpha}\right]$$

$$\hat{P}_s = \frac{1}{4}-\frac{1}{4}\boldsymbol{\sigma}_p\cdot\boldsymbol{\sigma}_n,\ \hat{P}_t = \frac{3}{4}+\frac{1}{4}\boldsymbol{\sigma}_p\cdot\boldsymbol{\sigma}_n.$$

$$v_s = \frac{2\pi^2\hbar^2}{m}\frac{2a_{pn}^{(s)}}{\pi-2a_{pn}^{(s)}k_{\rm cut}},$$

$$v_t = \frac{2\pi^2\hbar^2}{m}\frac{2a_{pn}^{(t)}}{\pi-2a_{pn}^{(t)}k_{\rm cut}},$$




$$a_{pn}^{(s)} = -23.749 \text{ fm and } a_{pn}^{(t)} = 5.424 \text{ fm}$$

$E_{cut}=k_{cut}^2/2m$

Y. Tanimura, HS, K. Hagino, PTEP 053D02 (2014)

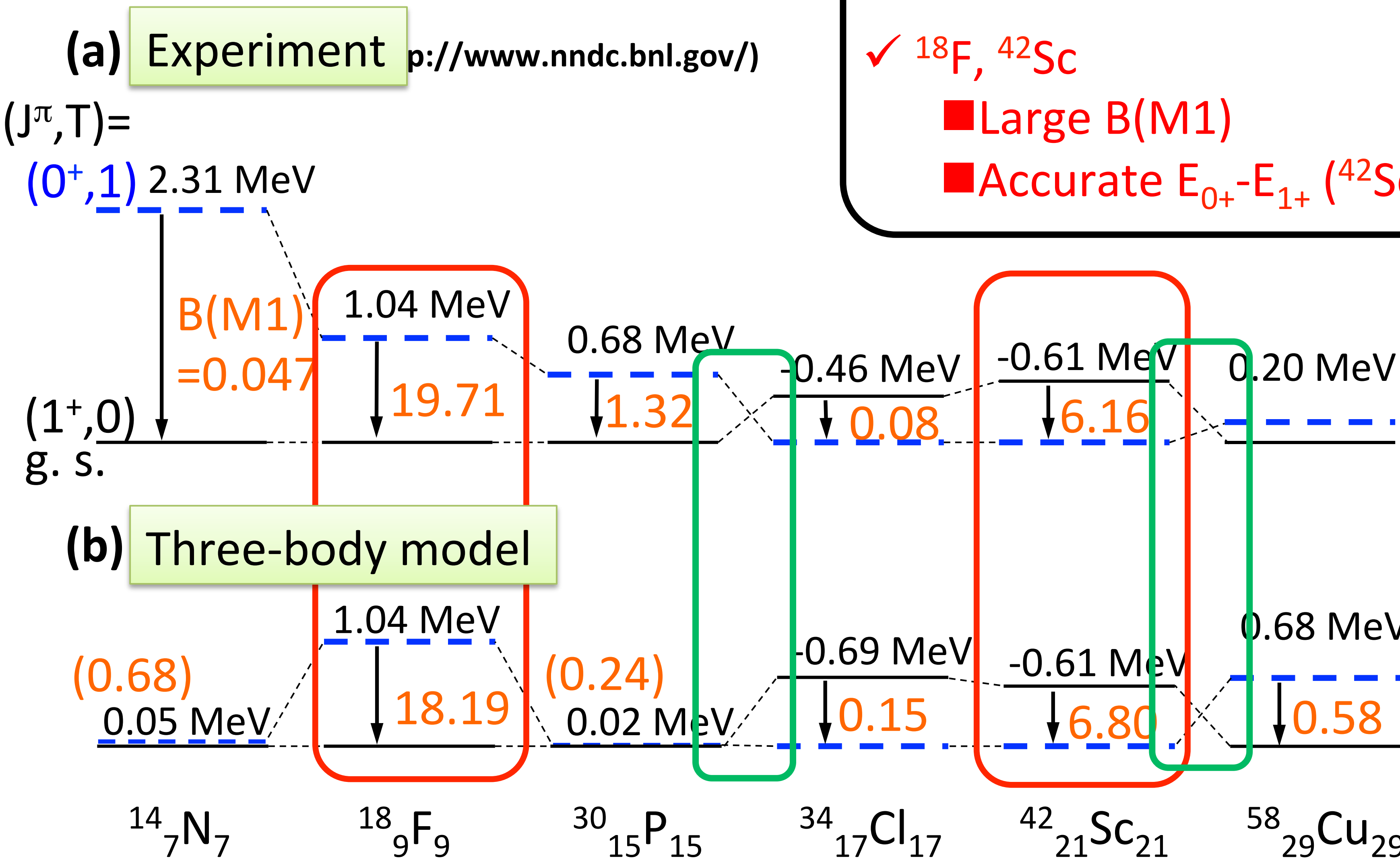
# 1. $E_{0+}-E_{1+}$ and B(M1)

✓ Inversion of $1^+$ and $0^+$

✓ $^{18}F$, $^{42}Sc$

■ Large B(M1)

■ Accurate $E_{0+}-E_{1+}$ ($^{42}Sc$)



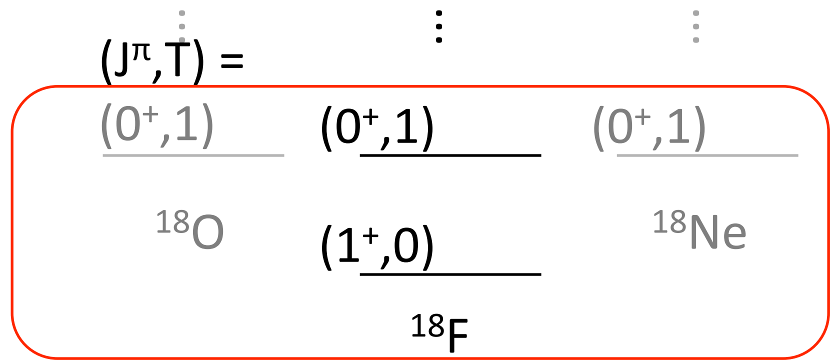

The inversion of 1+ and 0+ shows a clear manifestation of the competition between spin-orbit and the spin-triplet pairing.

# Results

## Large B(M1) in $^{18}$F and $^{42}$Sc

**$^{18}$F :**

- $1^+ \rightarrow$ P(S=1) = 90.1%, $(1d)^2$
- $0^+ \rightarrow$ P(S=0) = 82.2%, $(1d)^2$

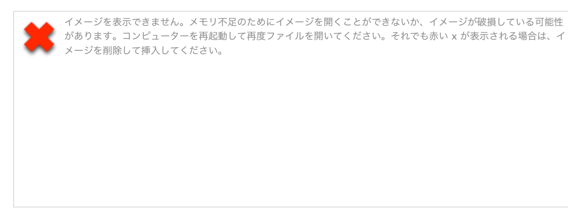


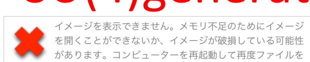

SU(4) multiplet

$1^+$ and $0^+$ can be considered as the states in the same SU(4) multiplets (LST) = (0,1,0), (0,0,1)
The same as 42Sc in 1f-orbits

$$O(\mathrm{M1}) \propto \sum_i [g_s(i)\boldsymbol{s}(i) + g_\ell(i)\boldsymbol{\ell}(i)]$$

$$= \underbrace{g_s^{IV}}_{\text{Large}} \underbrace{\sum_i \tau_3(i)\boldsymbol{s}(i)}_{\text{SU(4)generator}} + \underbrace{g_s^{IS}}_{\text{(small)}} \sum_i \boldsymbol{s}(i) + \sum_i g_\ell(i)\boldsymbol{\ell}(i)$$



# results

## $^{18}$F and $^{42}$Sc: large B(M1)

Separate Contribution to <f||O(M1)||i> ($\mu_N$)

| | $^{14}$N | $^{18}$F | $^{30}$P | $^{34}$Cl | $^{42}$Sc | $^{58}$Cu |
|---|---|---|---|---|---|---|
| Valence orbital | p1/2 | d5/2 | s1/2 | d3/2 | f7/2 | p3/2 |
| orbital | 1.09 | **1.28** | 0.21 | 2.28 | **2.91** | 0.09 |
| $g_s^{IV}\sum_i \tau_3(i)\boldsymbol{s}(i)$ | -2.78 | **7.44** | -1.21 | -3.65 | **6.34** | **1.47** |
| $g_s^{IS}\sum_i \boldsymbol{s}(i)$ | $5\times10^{-5}$ | $3\times10^{-3}$ | $3\times10^{-5}$ | $-1\times10^{-4}$ | $2\times10^{-3}$ | $-2\times10^{-3}$ |
| B(M1)↓ ($\mu_N^2$) Exp. | 0.047 | 19.71 | 1.32 | 0.08 | 6.16 | --- |
| Calc. | 0.68 | **18.19** | 0.24 | 0.15 | **6.80** | 0.58 |

- ✓ $(j=l-1/2)^2$ spin and orbital are cancelled (Lisetskiy et al., PRC60, 064310 ('99)) ⇒ $^{14}$N, $^{34}$Cl B(M1) **small**
- ✓ $(j=l+1/2)^2$ spin and orbital coherent (Lisetskiy et al., PRC60, 064310 ('99))
- ✓ **good SU(4) symmetry**

⇒ $^{18}$F, $^{42}$Sc B(M1)**large**

- ✓ even j=l+1/2 not good **SU(4) symmetry** ⇒ $^{58}$Cuは(M1)**small**

## Cooperation of T=0 and T=1 pairing in Gamow-Teller states in N=Z nuclei

C. L. Bai, H.S., M.Sasano, T. Uesaka, K. Hagino, H.Q. Zhang, X.Z. Zhang,F.R.Xu

Phys. Lett. B719, pp. 116-121 (2013)

HFB+QRPA with T=1 and T=0 pairing
- T=1 pairing in HFB
- T=0 pairing in QRPA

How large is the spin-triplet T=0 pairing?

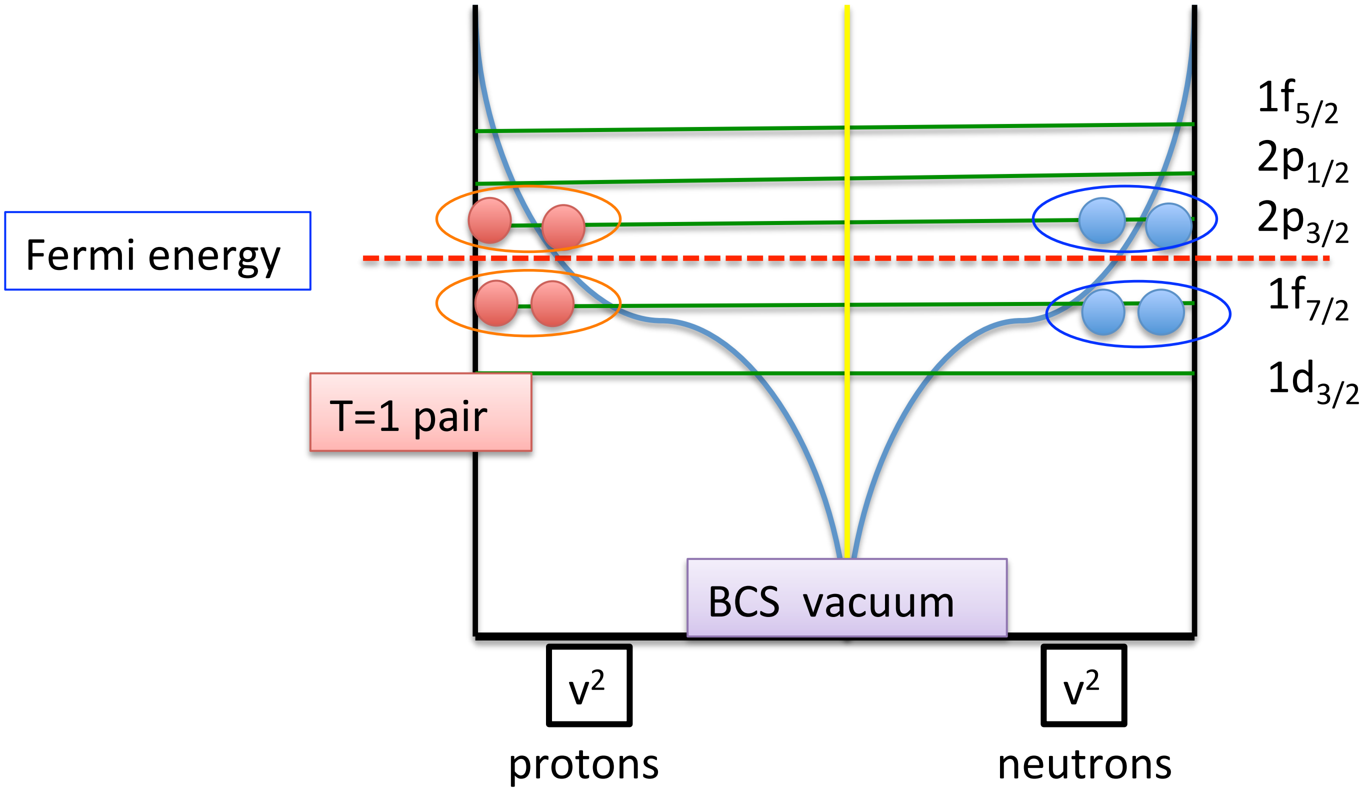
$$V_{T=1}(\mathbf{r}_1,\mathbf{r}_2) = V_0\frac{1-P_\sigma}{2}\left(1-\frac{\rho(\mathbf{r})}{\rho_o}\right)\delta(\mathbf{r}_1-\mathbf{r}_2), \quad (1)$$

$$V_{T=0}(\mathbf{r}_1,\mathbf{r}_2) = fV_0\frac{1+P_\sigma}{2}\left(1-\frac{\rho(\mathbf{r})}{\rho_o}\right)\delta(\mathbf{r}_1-\mathbf{r}_2), \quad (2)$$

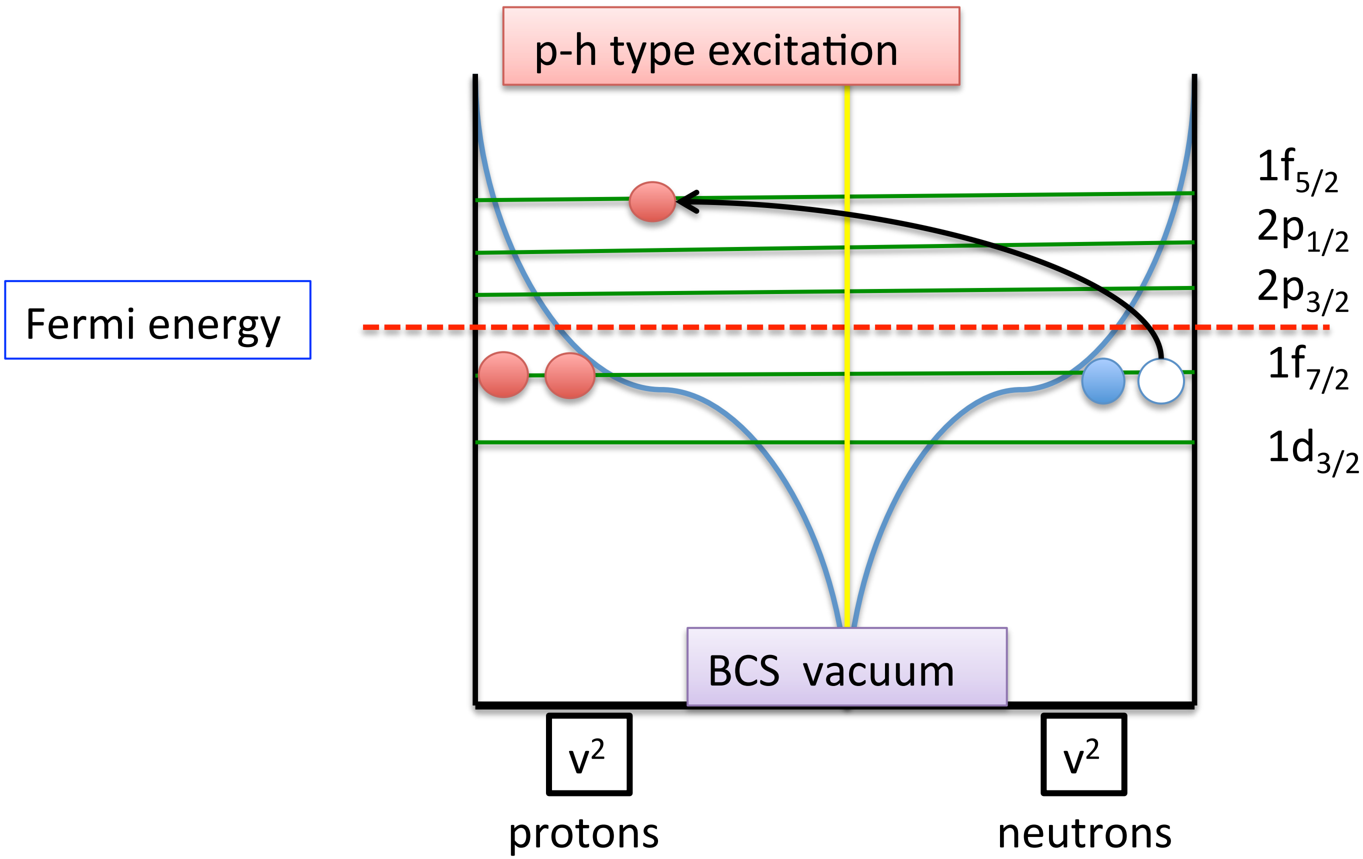
As a possible manifestation of T=0 S=1 pairing correlations in nuclei N=Z.

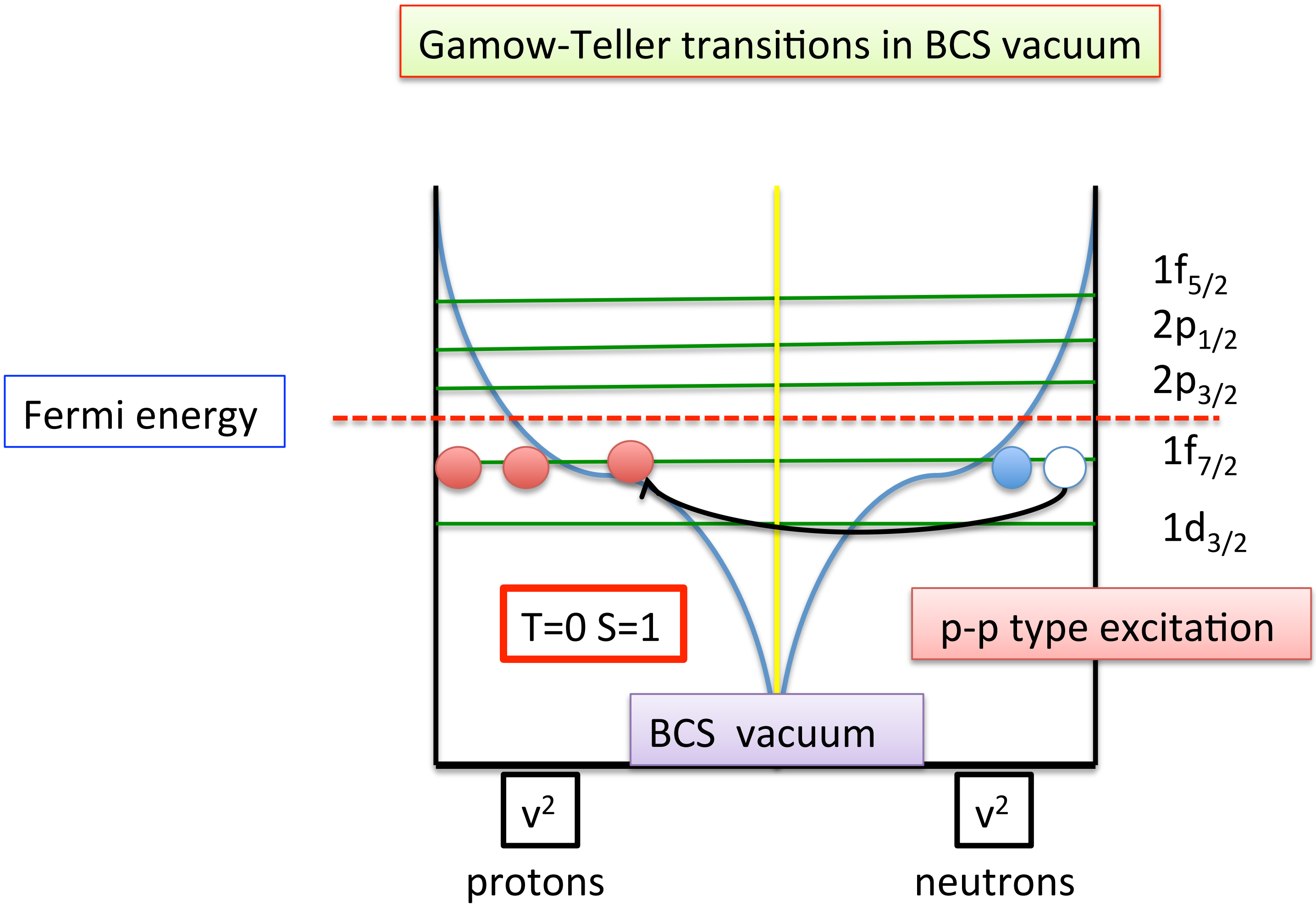
$$\hat{O}(GT) = \sigma\tau_{\pm}$$

## Gamow-Teller transitions from BCS vacuum in N=Z nuclei

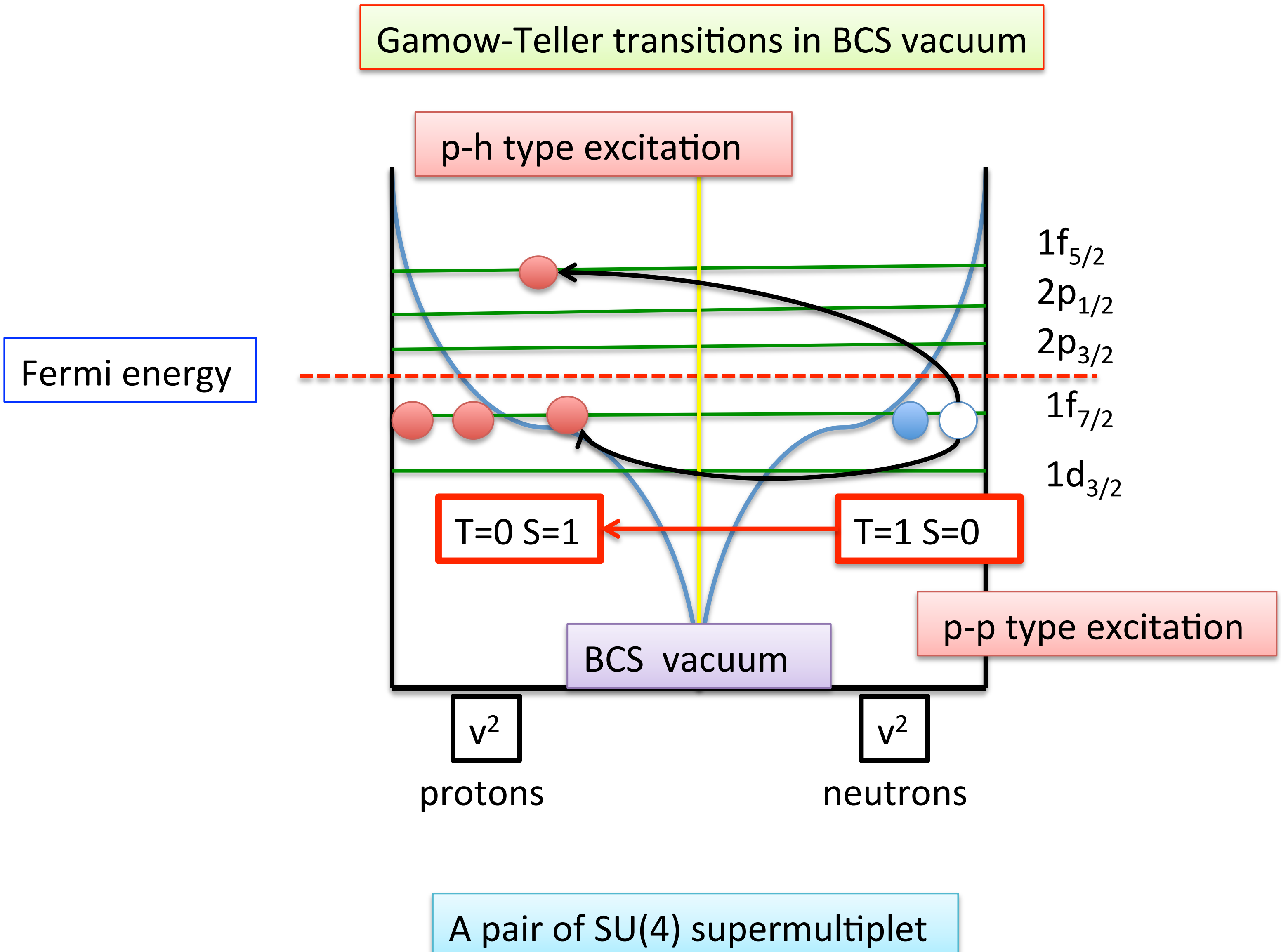


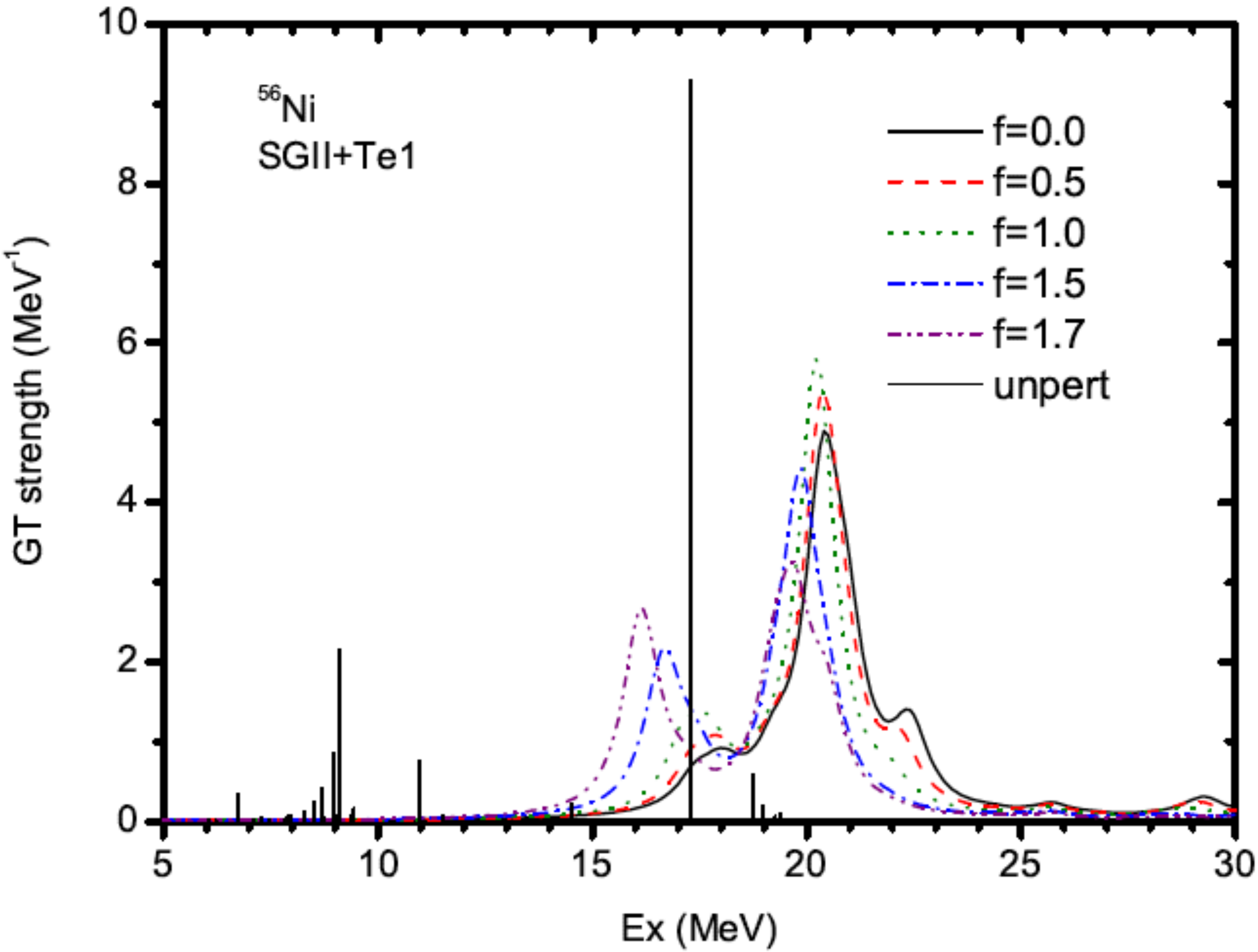
# Gamow-Teller transitions in BCS vacuum





Gamow-Teller transitions in BCS vacuum
Fermi energy
1f5/2
2p1/2
2p3/2
1f7/2
1d3/2
T=0 S=1
p-p type excitation
BCS vacuum
v2
v2
protons
neutrons


Gamow-Teller transitions in BCS vacuum
p-h type excitation
Fermi energy
1f5/2
2p1/2
2p3/2
1f7/2
1d3/2
T=0 S=1
T=1 S=0
p-p type excitation
BCS vacuum
v2
v2
protons
neutrons
A pair of SU(4) supermultiplet



$^{56}$Ni
SGII+Te1
f=0.0
f=0.5
f=1.0
f=1.5
f=1.7
unpert
GT strength (MeV$^{-1}$)
Ex (MeV)
0
2
4
6
8
10
5
10
15
20
25
30

TABLE I: Amplitudes of main ($\pi p$) particle-hole and particle-particle type configurations of GT states in $^{56}$Ni. The QRPA calculations are performed without and with the T=0 pairing interaction in the cases of $f = 0$ and $f = 1.5$, respectively. The Skyrme interaction T21 is used for HF and p-h matrix calculations. The abbreviations B and C correspond to the GT reduced matrix element B=$(X u_\pi v_\nu - Y u_\nu v_\pi)\langle \pi || \hat{O}(\mathrm{GT}) || \nu \rangle$ and the normalization factor C=$X^2 - Y^2$, respectively, where $X$,$Y$ are QRPA amplitudes and $\hat{O}$(GT) is GT transition operator in Eq. (3).

| $^{56}$Ni | | $f = 0$ | | | |
|---|---|---|---|---|---|
| $E_x$ (MeV) | B(GT) | $\nu(v_\nu^2)$ | $\pi(v_\pi^2)$ | B | C |
| 17.5 | 1.41 | $2p_{3/2}(0.20)$ | $2p_{3/2}(0.21)$ | 0.358 | 0.127 |
| | | $1f_{7/2}(0.69)$ | $1f_{5/2}(0.09)$ | −0.229 | 0.006 |
| | | $1f_{7/2}(0.69)$ | $1f_{7/2}(0.67)$ | 1.341 | 0.802 |
| 18.3 | 1.49 | $2p_{1/2}(0.10)$ | $2p_{3/2}(0.21)$ | 0.260 | 0.153 |
| | | $2p_{3/2}(0.20)$ | $2p_{1/2}(0.11)$ | 0.846 | 0.740 |
| 21.3 | 7.88 | $1f_{7/2}(0.69)$ | $1f_{5/2}(0.09)$ | 2.48 | 0.742 |
| $S_-$(GT)=18.28 | | | | | |
| $^{56}$Ni | | $f = 1.5$ | | | |
| $E_x$ (MeV) | B(GT) | $\nu(v_\nu^2)$ | $\pi(v_\pi^2)$ | B | C |
| 16.6 | 4.82 | $2p_{3/2}(0.20)$ | $2p_{1/2}(0.11)$ | −0.203 | 0.049 |
| | | $2p_{3/2}(0.20)$ | $2p_{3/2}(0.21)$ | −0.682 | 0.491 |
| | | $1f_{7/2}(0.69)$ | $1f_{5/2}(0.09)$ | −0.237 | 0.007 |
| | | $1f_{7/2}(0.69)$ | $1f_{7/2}(0.67)$ | −0.790 | 0.339 |
| 20.5 | 4.10 | $1f_{7/2}(0.69)$ | $1f_{5/2}(0.09)$ | −1.900 | 0.437 |
| $S_-$(GT)=14.75 | | | | | |

$$B = (X u_\pi v_\nu - Y u_\nu v_\pi)\left\langle \pi \left\| \hat{O}(GT) \right\| \nu \right\rangle$$

$$C = X^2 - Y^2$$

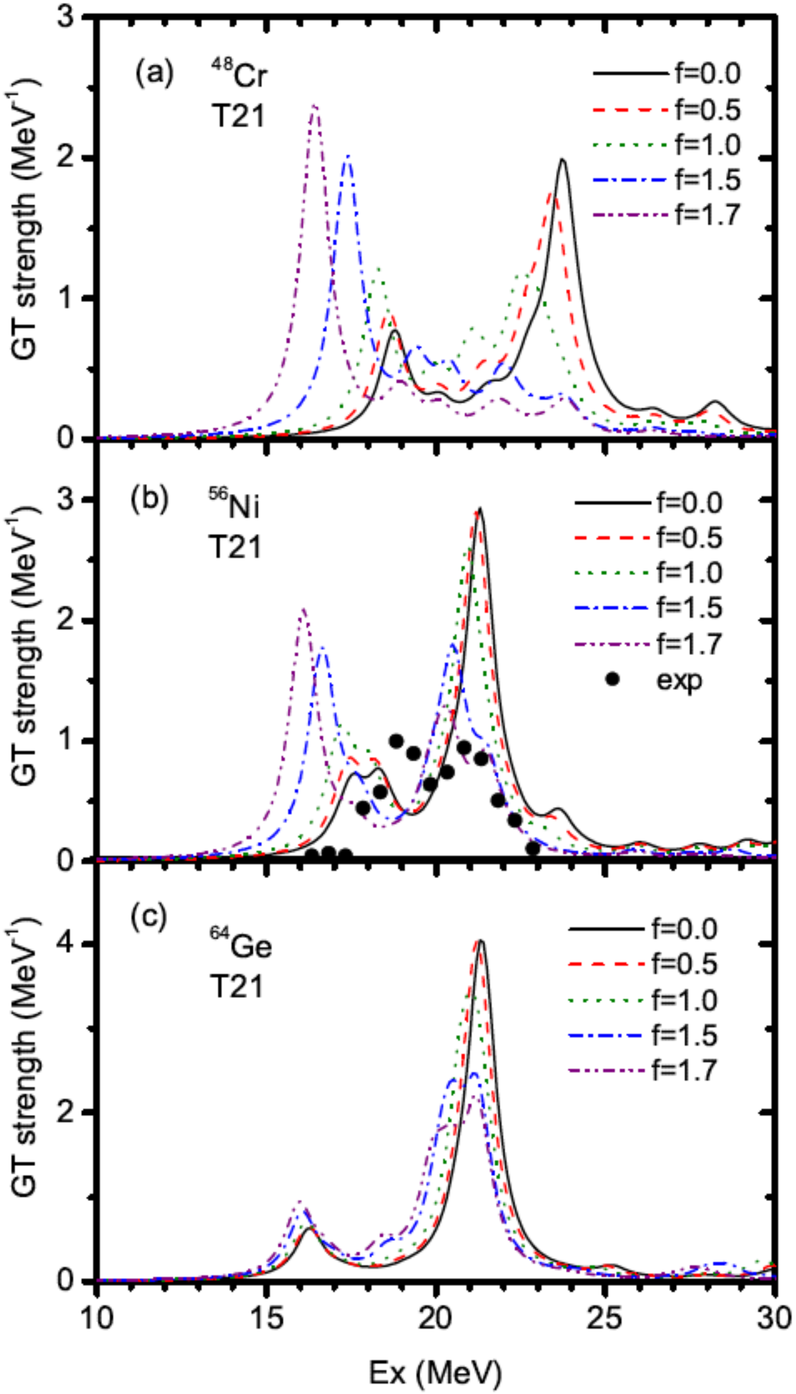
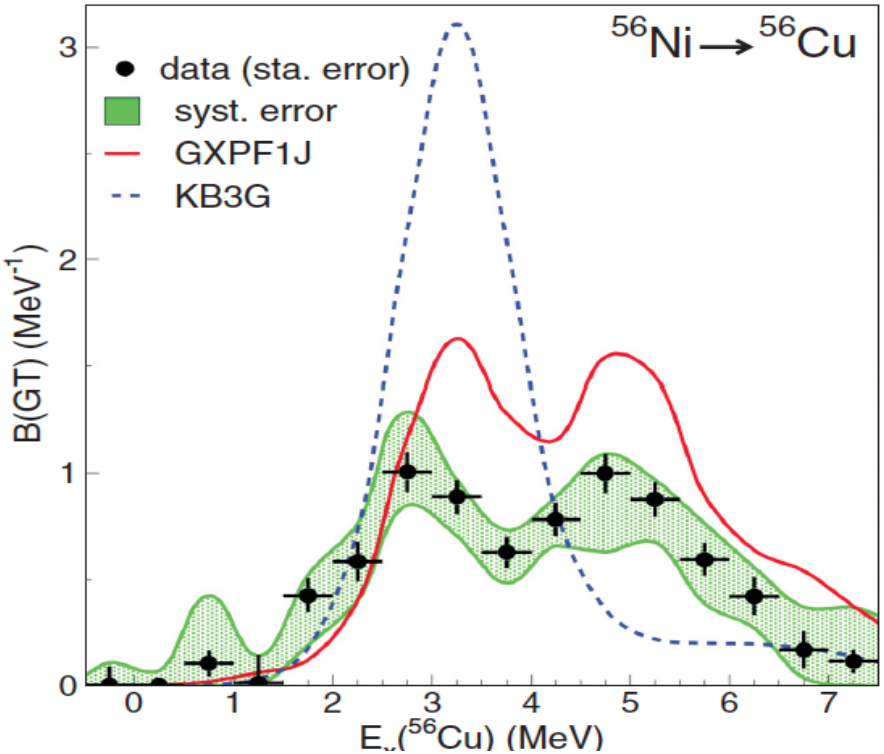


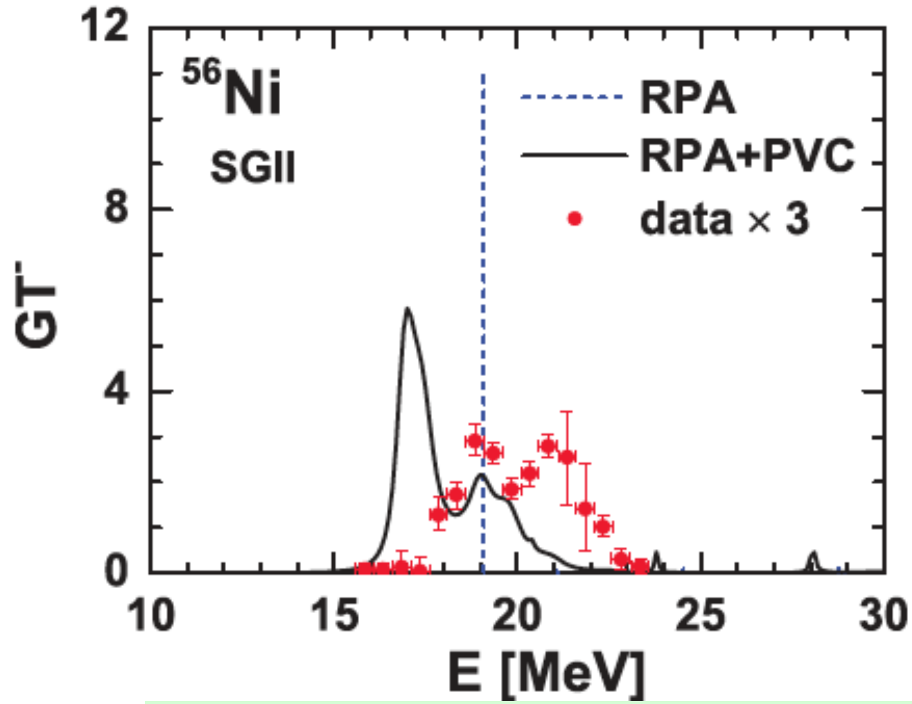

TABLE II: Same as Table I, but for $^{48}$Cr and $^{64}$Ge with the T=0 pairing interaction $f = 1.5$.

| $^{48}$Cr | | $f = 1.5$ | | | |
|---|---|---|---|---|---|
| $E_x$ (MeV) | B(GT) | $\nu(v_\nu^2)$ | $\pi(v_\pi^2)$ | B | C |
| 17.4 | 5.68 | $2p_{3/2}(0.12)$ | $2p_{3/2}(0.12)$ | 0.186 | 0.062 |
| | | $1d_{3/2}(0.85)$ | $1d_{3/2}(0.84)$ | 0.251 | 0.204 |
| | | $1f_{7/2}(0.33)$ | $1f_{5/2}(0.07)$ | 0.268 | 0.021 |
| | | $1f_{7/2}(0.33)$ | $1f_{7/2}(0.32)$ | 1.04 | 0.558 |
| 19.4 | 1.19 | $2p_{3/2}(0.12)$ | $2p_{1/2}(0.07)$ | 0.215 | 0.081 |
| | | $2p_{3/2}(0.12)$ | $2p_{3/2}(0.12)$ | 0.559 | 0.461 |
| | | $1d_{3/2}(0.85)$ | $1d_{3/2}(0.84)$ | −0.217 | 0.142 |
| | | $1f_{7/2}(0.33)$ | $1f_{5/2}(0.07)$ | 0.383 | 0.038 |
| | | $1f_{7/2}(0.33)$ | $1f_{7/2}(0.32)$ | −0.384 | 0.054 |
| $S_-$(GT)=11.77 | | | | | |
| $^{64}$Ge | | $f = 1.5$ | | | |
| $E_x$ (MeV) | B(GT) | $\nu(v_\nu^2)$ | $\pi(v_\pi^2)$ | B | C |
| 16.1 | 2.15 | $2p_{3/2}(0.48)$ | $2p_{1/2}(0.21)$ | −1.316 | 0.889 |
| 21.2 | 5.21 | $1f_{5/2}(0.14)$ | $1f_{7/2}(0.90)$ | −0.187 | 0.353 |
| | | $1f_{7/2}(0.92)$ | $1f_{5/2}(0.15)$ | 2.392 | 0.561 |
| $S_-$(GT)=17.26 | | | | | |

Fine adjustment of shell model int.




Sasano et al., PRC86, 034324(2012)



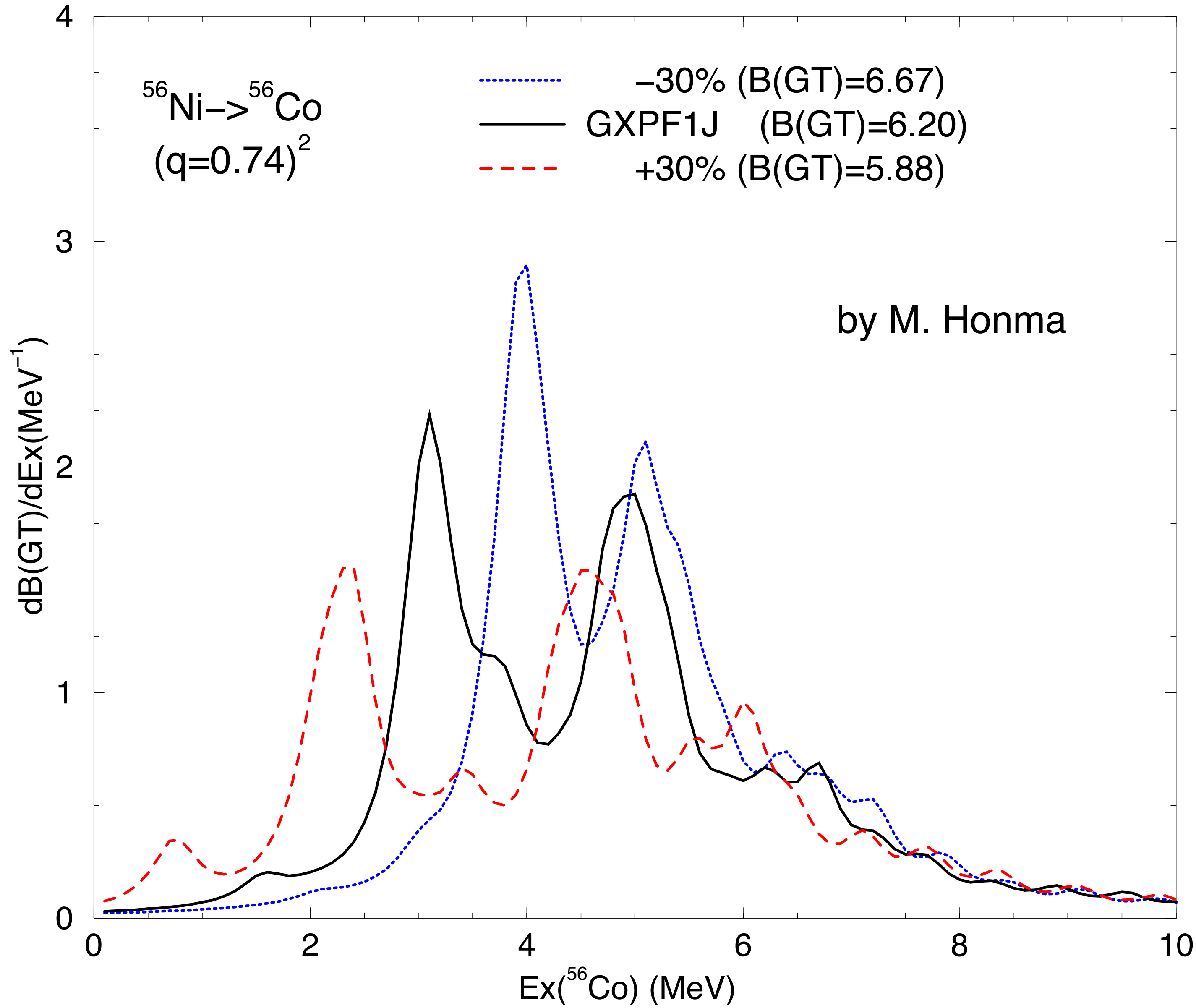

Beyond mean field effect:
Niu et al., PRC85, 034314(2012)

With $(0.74)^2$ quenching factor, still 30%missing strength

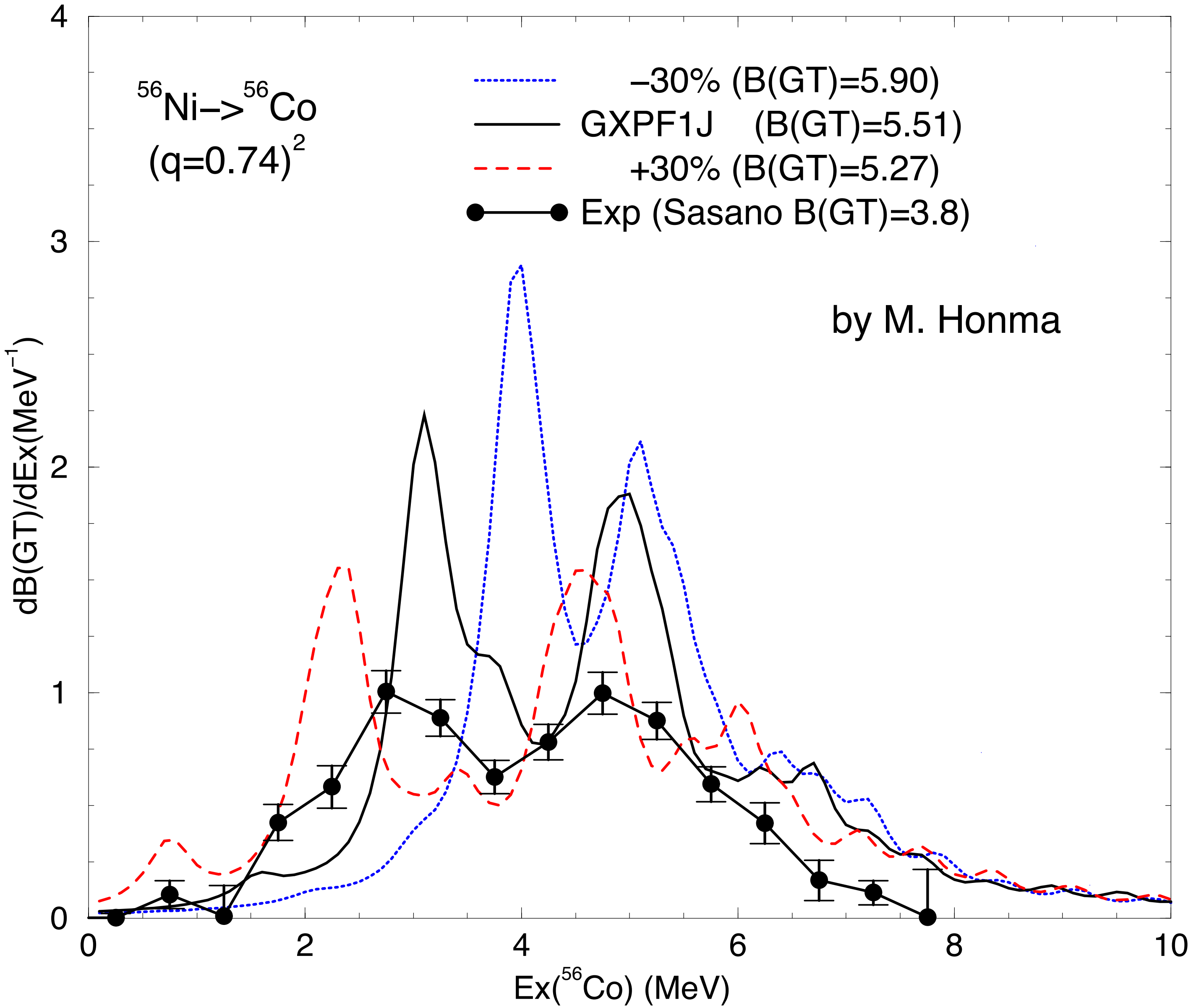
| | $E_x$ (MeV) | | |
|---|---|---|---|
| $^{56}$Ni → $^{56}$Cu | 0–7 | 3.8 ± 0.2(stat.) ± 0.8(syst.) | 5.5 (5.2) |
| $^{55}$Co → $^{55}$Ni(g.s.) | 0 | 0.267 (from Ref. [30]) | 0.209 (0.253) |
| $^{55}$Co → $^{55}$Ni | 0–15 | $5.3 \pm 0.5(\text{stat.})^{+2.5}_{-1.5}(\text{syst.})$ | 6.8 (6.2) |

[a]The quoted error margins do not include the uncertainty in the value for the unit cross section (15%), which would change all strengths by a common scaling factor.

[b]A quenching factor of $(0.74)^2$ [44] has been applied to the shell-model summed strengths.



$^{56}$Ni−>$^{56}$Co
$(q=0.74)^2$
−30% (B(GT)=6.67)
GXPF1J (B(GT)=6.20)
+30% (B(GT)=5.88)
by M. Honma
dB(GT)/dEx(MeV$^{-1}$)
Ex($^{56}$Co) (MeV)
0
1
2
3
4
0
2
4
6
8
10



$^{56}Ni \to ^{56}Co$
$(q=0.74)^2$
−30% (B(GT)=5.90)
GXPF1J (B(GT)=5.51)
+30% (B(GT)=5.27)
Exp (Sasano B(GT)=3.8)
by M. Honma
dB(GT)/dEx(MeV$^{-1}$)
Ex($^{56}$Co) (MeV)
0
1
2
3
4
0
2
4
6
8
10

IS and IV M1 response and T=0 spin-triplet pairing correlations
HS, T. Suzuki and M. Sasano (PRC94, 041303(R), 24. Oct. 2016)

USDB*=T=0 pairing matrix elements are 20% stronger than USDB
USDB**=USDB*+Δ-isobar coupling(q=0.9)

Exp. Data, Matsubara, et al., PRL115, 102501(2015)
High energy resolution proton inelastic scattering with $E_p$=295MeV

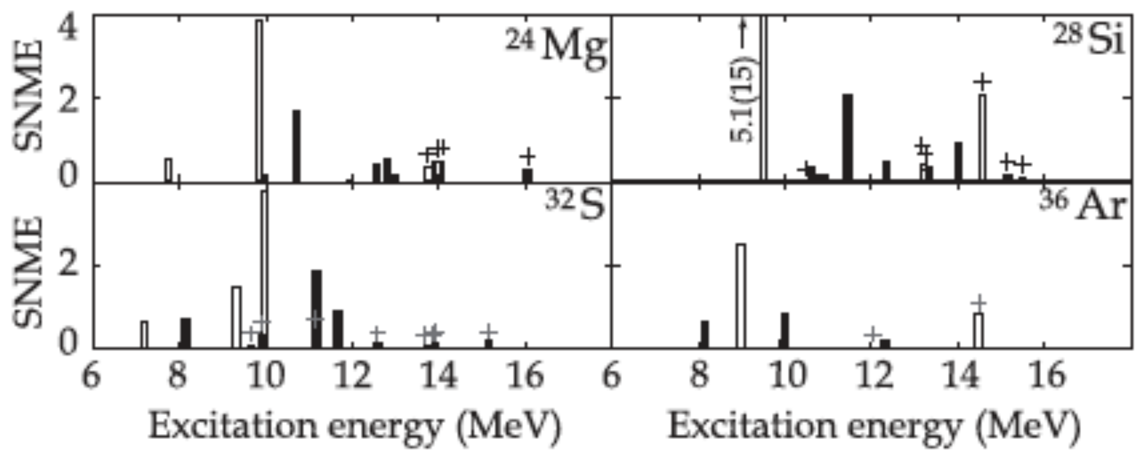
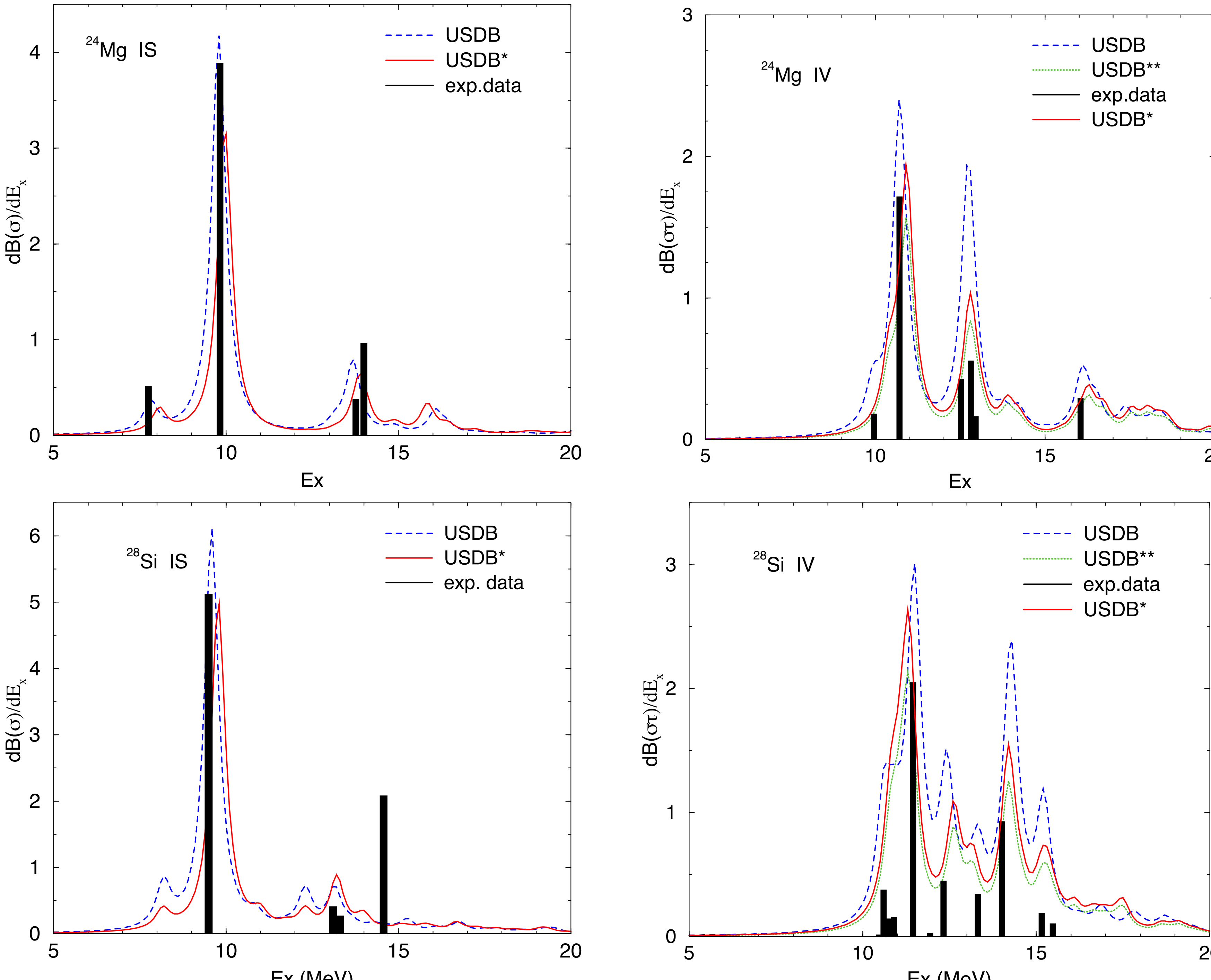
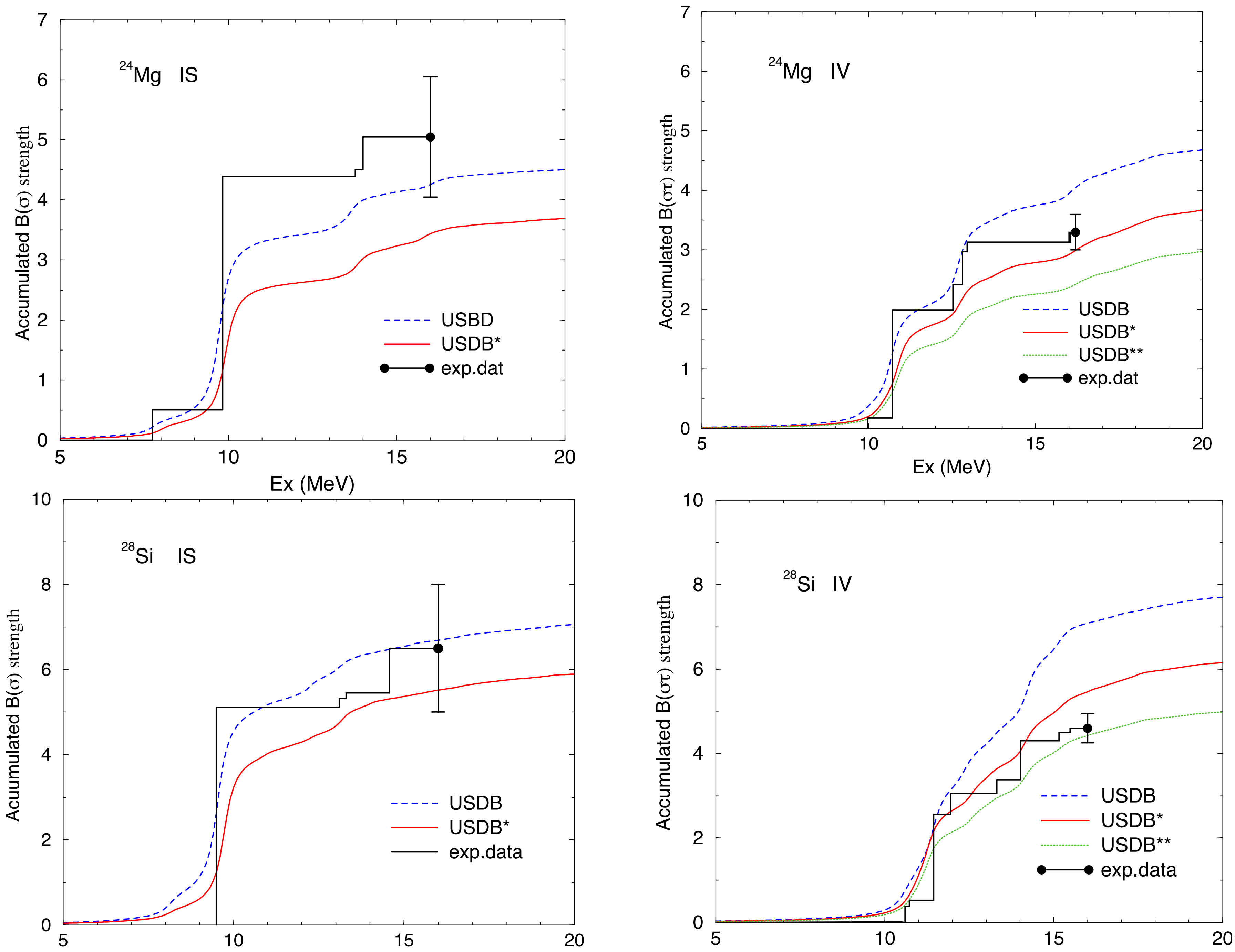


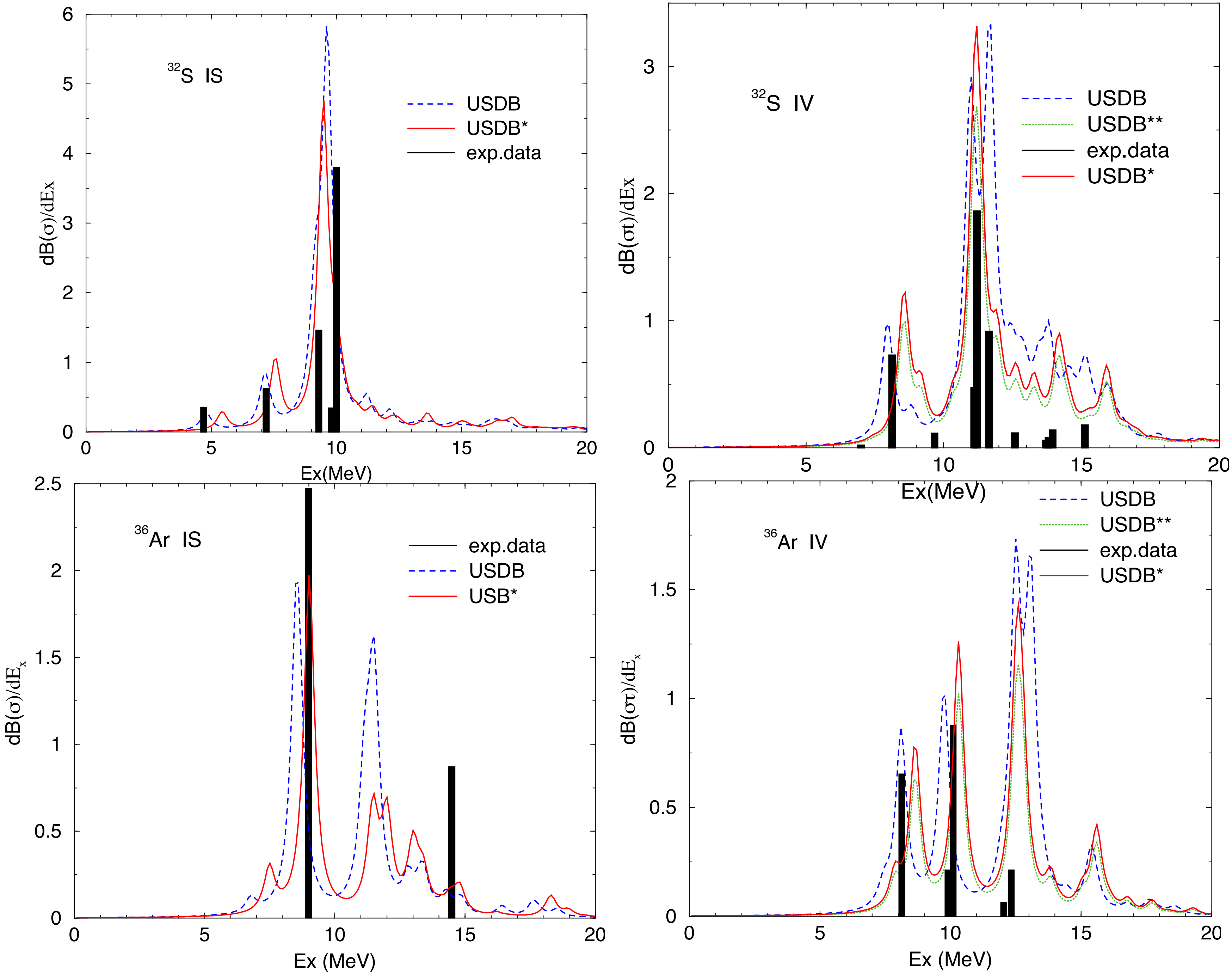

FIG. 2. Observed distributions of IS and IV-spin-$M1$ SNME [open (filled) bars represent IS (IV) transitions]. The bars labeled + indicate states with a less confident spin assignment.



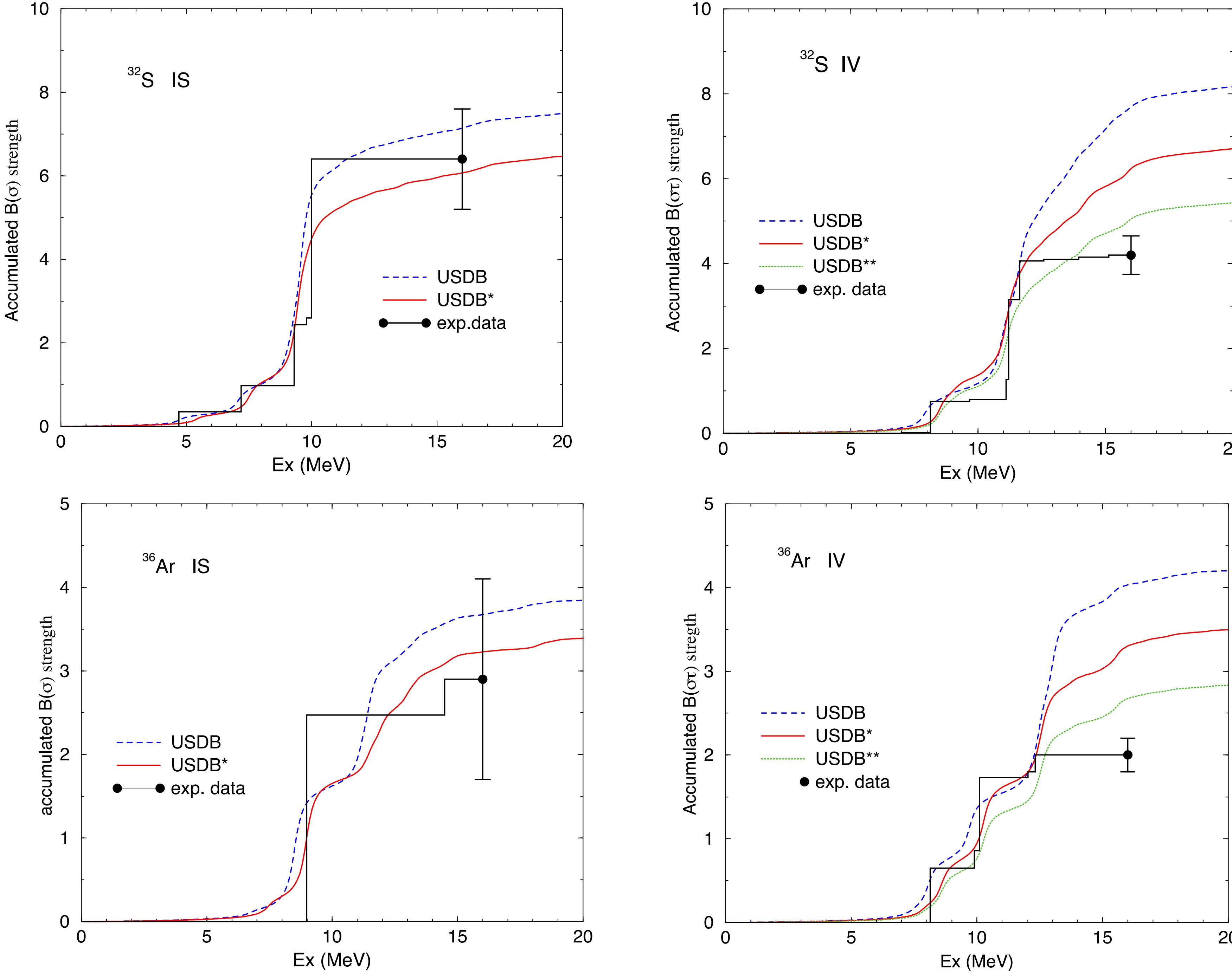
24Mg IS
USDB
USDB*
exp.data
dB(σ)/dEx
Ex
24Mg IV
USDB
USDB**
exp.data
USDB*
dB(στ)/dEx
Ex
28Si IS
USDB
USDB*
exp. data
dB(σ)/dEx
Ex (MeV)
28Si IV
USDB
USDB**
exp.data
USDB*
dB(στ)/dEx
Ex (MeV)



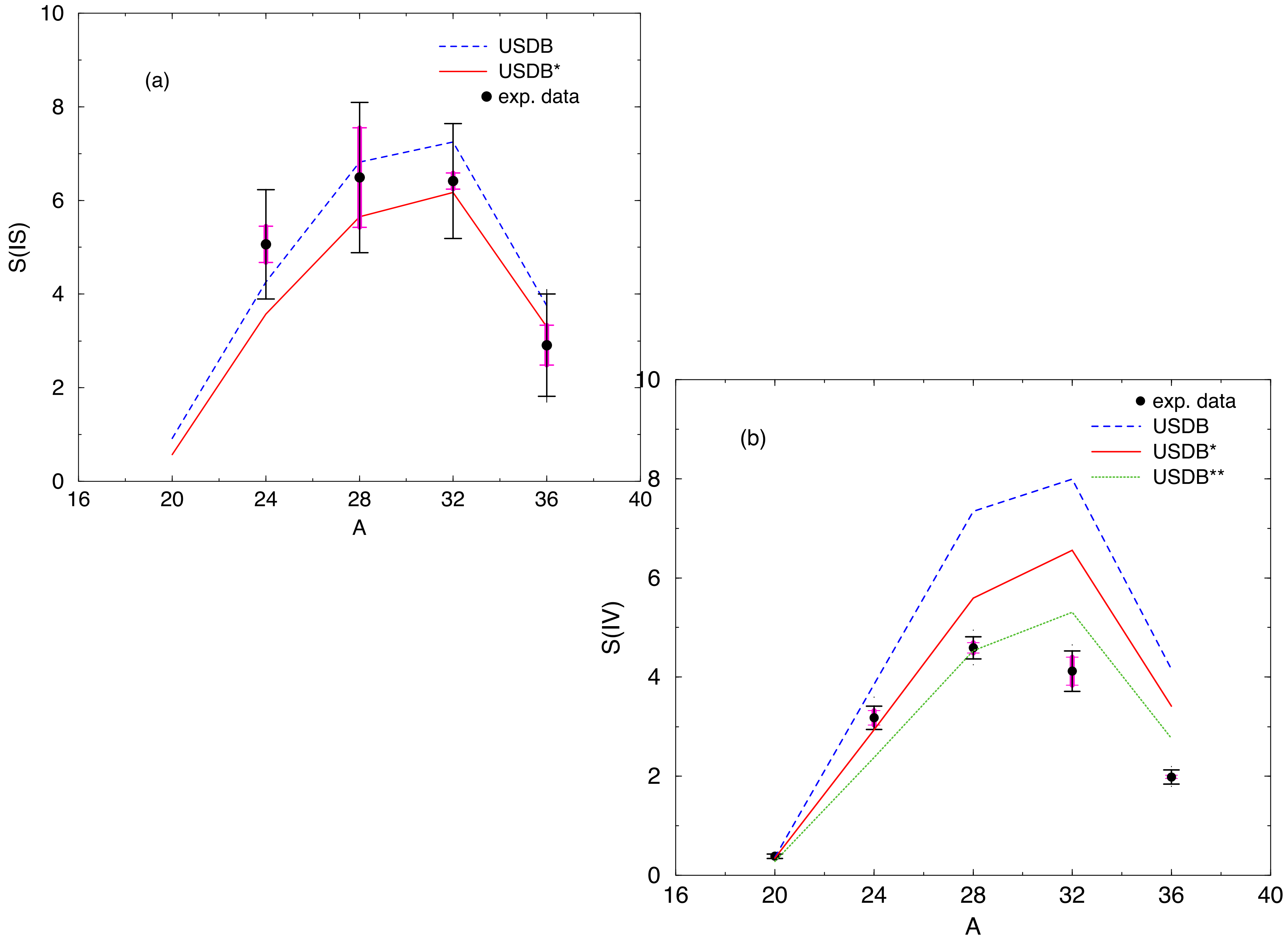
24Mg IS
Accumulated B(σ) strength
Ex (MeV)
USBD
USDB*
exp.dat
24Mg IV
Accumulated B(στ) strength
Ex (MeV)
USDB
USDB*
USDB**
exp.dat
28Si IS
Acuumulated B(σ) strength
USDB
USDB*
exp.data
28Si IV
Accumulated B(στ) stremgth
USDB
USDB*
USDB**
exp.data

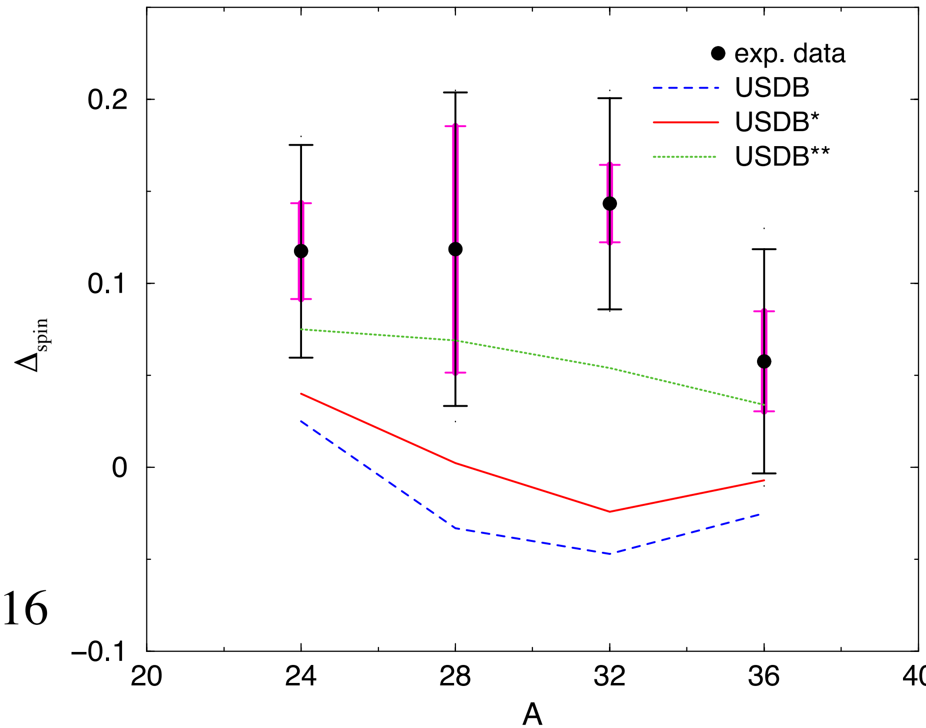


32S IS
USDB
USDB*
exp.data
dB(σ)/dEx
Ex(MeV)
32S IV
USDB
USDB**
exp.data
USDB*
dB(σt)/dEx
Ex(MeV)
36Ar IS
exp.data
USDB
USB*
dB(σ)/dEx
Ex (MeV)
36Ar IV
USDB
USDB**
exp.data
USDB*
dB(στ)/dEx
Ex (MeV)



$^{32}$S IS
USDB
USDB*
exp.data
Accumulated B(σ) strength
Ex (MeV)
$^{32}$S IV
USDB
USDB*
USDB**
exp. data
Accumulated B(στ) strength
Ex (MeV)
$^{36}$Ar IS
USDB
USDB*
exp. data
accumulated B(σ) strength
Ex (MeV)
$^{36}$Ar IV
USDB
USDB*
USDB**
exp. data
Accumulated B(στ) stregth
Ex (MeV)

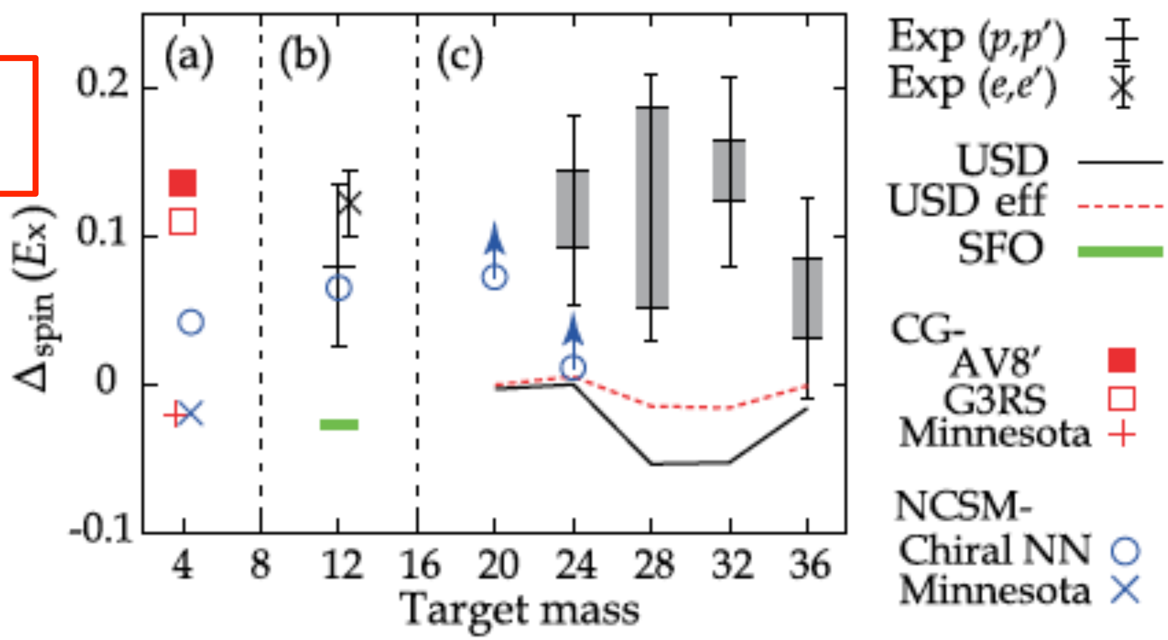

(a)
USDB
USDB*
exp. data
S(IS)
A
(b)
exp. data
USDB
USDB*
USDB**
S(IV)
A




p-n Ferromagnetic limit
0.25

p-n Paramagnetic limit
-0.75

$$\Delta_{spin} = (S(IS) - S(IV))/16 = \langle S_p \cdot S_n \rangle$$




Matsubara et al.,
PRL115, 102501(2015)

# Summary: N=Z nucleus

1. Inversion of 1+ and 0+ states in the energy spectra and strong M1 transitions in odd-odd N=Z nuclei is induced by a strong T=0 pairing correlations competing with T=1 pairing and spin-orbit force.

2. Cooperative role of T=0 and T=1 pairings is studied in Gamow-Teller transitions of N=Z nuclei
3. It is pointed out that the low energy peak appear due to the strong T=0 pairing correlations in the final states.
   Supermultiplets of T=1,S=0 and T=0 and S=1 pair
4. two GT peaks in $^{56}$Ni➔ large quenching
   --effective interactions ( IS pairing, smaller spin-orbit splitting)
   -- beyond mean field effect
5. Future perspective (experiment):
   New experiments in N=Z nuclei, $^{48}$Cr and $^{64}$Ge are approved by PAC Dec. 2016 in RIKEN .
6. Future perspectives (theory)
   a. HFB+QRPA+PV (Particle-vibration coupling
   Yifei Niu, Gianluca Colo
   b. Fine fittings of energy density functions for spin-isospin excitations
   (which was done already for Shell model interactions: GPFX1J
   BY Toshio Suzuki, Michio Honma)

Collaborators

- Pairing and Tensor correlations on spin-isospin excitations
  C.L. Bai (Sichun University 四川大学)
  Gianluca Colo (University of Milano)

- IS Pairing correlations (Three-body model)
  Y. Tanimura (Orsay -> GSI)
  K. Hagino (Tohoku University)

- IS and IV M1 and spin-spin correlations
  T. Suzuki (Nihon University)
  M. Sasano (RIKEN)