E1 and M1 Giant Resonances within Skyrme RPA

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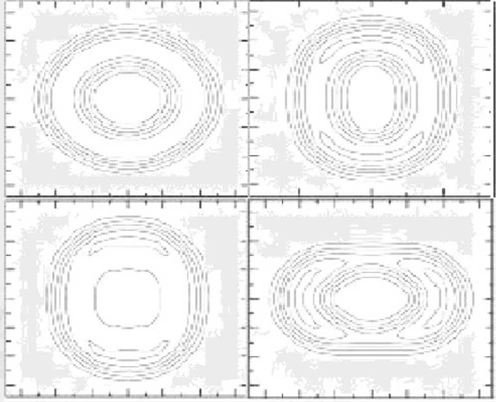


Skyrme Functional I

Motivation of the Skyrme Functional:

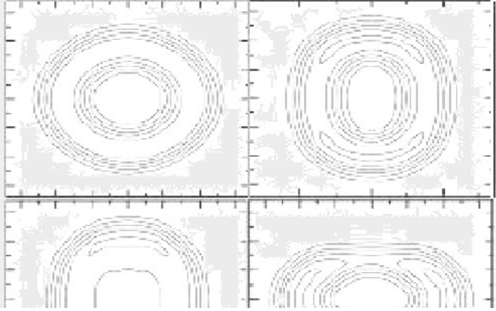
Skyrme original paper: T.H.R. Skyrme, Phil. Mag. 1, (1956) 1043

efective NN potencial:

$$
\begin{aligned}
V_{\text{skyrme}} = {} & t_0(1+x_0\hat{P}_\sigma)\delta(\vec{r}_1-\vec{r}_2) + \frac{1}{2}t_1(1+x_1\hat{P}_\sigma)[\overleftarrow{k}'^2\delta(\vec{r}_1-\vec{r}_2)+\delta(\vec{r}_1-\vec{r}_2)\vec{k}^2] + \\
& + t_2(1+x_2\hat{P}_\sigma)\overleftarrow{k}'.\delta(\vec{r}_1-\vec{r}_2)\vec{k} + \frac{1}{6}t_3(1+x_3\hat{P}_\sigma)\delta(\vec{r}_1-\vec{r}_2)\rho^\alpha(\frac{\vec{r}_1+\vec{r}_2}{2}) + \\
& + it_4\overleftarrow{k}'.\delta(\vec{r}_1-\vec{r}_2)(\vec{\sigma}_1+\vec{\sigma}_2)\times\vec{k}
\end{aligned}
$$

$$\overleftarrow{k}' = -\frac{\overleftarrow{\nabla}_1-\overleftarrow{\nabla}_2}{2i} \qquad \vec{k} = \frac{\vec{\nabla}_1-\vec{\nabla}_2}{2i}$$

- Very general form – actually expansion up to second order in momenta
- Effective 3-body force (or density dependent term)
- Spin-orbital term



Skyrme Functional II

$$\mathcal{H}_{Skyrme} = \frac{\hbar^2}{2m}\tau +$$

$$+\frac{1}{2}t_0\left[(1+\frac{1}{2}x_0)\rho^2 - (x_0+\frac{1}{2})\sum_{q=n,p}\rho_q^2\right]$$

$$-\frac{1}{16}t_1(1+\frac{1}{2}x_1)\left[3\rho\Delta\rho - 4(\rho\tau - \vec{j}^2)\right] - \frac{1}{16}t_1(1+2x_1)\sum_{q=n,p}\left[-\frac{3}{2}\rho_q\Delta\rho_q + 2(\rho_q\tau_q - \vec{j}_q^2)\right]$$

$$+\frac{1}{16}t_1x_1\left[\text{Galilean inv. term} \ (\vec{s}.\vec{T} - \vec{J}^2)\right] - \frac{1}{16}t_1\sum_{q=n,p}\left[\text{Galilean inv. term} \ (\vec{s}_q.\vec{T}_q - \vec{J}_q^2)\right]$$

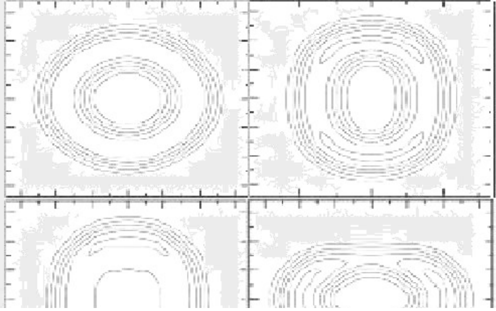
$$+\frac{1}{16}t_2(1+\frac{1}{2}x_2)\left[\rho\Delta\rho + 4(\rho\tau - \vec{j}^2)\right] + \frac{1}{16}t_2(1+2x_2)\sum_{q=n,p}\left[\frac{1}{2}\rho_q\Delta\rho_q + 2(\rho_q\tau_q - \vec{j}_q^2)\right]$$

$$+\frac{1}{16}t_2x_2\left[\text{Galilean inv. term} \ (\vec{s}.\vec{T} - \vec{J}^2)\right] + \frac{1}{16}t_2\sum_{q=n,p}\left[\text{Galilean inv. term} \ (\vec{s}_q.\vec{T}_q - \vec{J}_q^2)\right]$$

$$+\frac{1}{8}t_3\left[(1+\frac{1}{2}x_3)\rho^2 - (x_3+\frac{1}{2})\sum_{q=n,p}\rho_q^2\right]\rho^\alpha -$$

$$-\frac{1}{2}t_4\sum_{q_1q_2}(1+\delta_{q_1q_2})\left[\qquad \rho_{q_2}\vec{\nabla}.\vec{J}_{q_1}\right]$$

J.R. Stone, P.-G. Reinhard, Progress in Particle and Nuclear Physics 58 (2007) 587–657



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& + \frac{1}{16}t_1x_1\left[(\vec{s}.\vec{T} - \vec{J}^2)\right] - \frac{1}{16}t_1\sum_{q=n,p}\left[(\vec{s}_q.\vec{T}_q - \vec{J}_q^2)\right] \\
& + \frac{1}{16}t_2(1+\frac{1}{2}x_2)\left[\rho\Delta\rho + 4(\rho\tau - \vec{j}^2)\right] + \frac{1}{16}t_2(1+2x_2)\sum_{q=n,p}\left[\frac{1}{2}\rho_q\Delta\rho_q + 2(\rho_q\tau_q - \vec{j}_q^2)\right] \\
& + \frac{1}{16}t_2x_2\left[(\vec{s}.\vec{T} - \vec{J}^2)\right] + \frac{1}{16}t_2\sum_{q=n,p}\left[(\vec{s}_q.\vec{T}_q - \vec{J}_q^2)\right] \\
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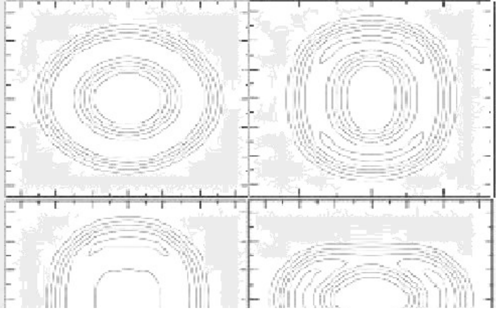
Skyrme Functional II



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& + \frac{1}{2}t_0\left[(1+\frac{1}{2}x_0)\rho^2 - (x_0+\frac{1}{2})\sum_{q=n,p}\rho_q^2\right] - \frac{1}{2}t_0\left[\frac{1}{2}x_0\vec{s}^2 - \frac{1}{2}\sum_{q=n,p}\vec{s}_q^2\right] \\
& - \frac{1}{16}t_1(1+\frac{1}{2}x_1)\left[3\rho\Delta\rho - 4(\rho\tau - \vec{j}^2)\right] - \frac{1}{16}t_1(1+2x_1)\sum_{q=n,p}\left[-\frac{3}{2}\rho_q\Delta\rho_q + 2(\rho_q\tau_q - \vec{j}_q^2)\right] \\
& + \frac{1}{16}t_1x_1\left[-\frac{3}{2}\vec{s}\Delta\vec{s} + (\vec{s}.\vec{T} - \vec{J}^2)\right] - \frac{1}{16}t_1\sum_{q=n,p}\left[-\frac{3}{2}\vec{s}_q\Delta\vec{s}_q + (\vec{s}_q.\vec{T}_q - \vec{J}_q^2)\right] \\
& + \frac{1}{16}t_2(1+\frac{1}{2}x_2)\left[\rho\Delta\rho + 4(\rho\tau - \vec{j}^2)\right] + \frac{1}{16}t_2(1+2x_2)\sum_{q=n,p}\left[\frac{1}{2}\rho_q\Delta\rho_q + 2(\rho_q\tau_q - \vec{j}_q^2)\right] \\
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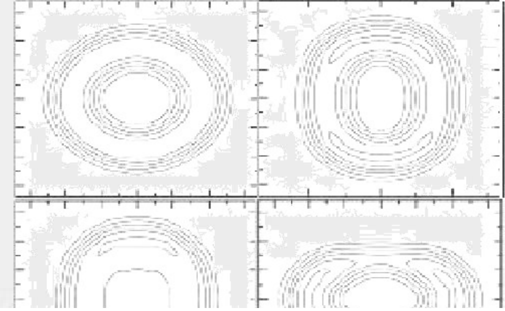
& + \frac{1}{8}t_3\left[(1+\frac{1}{2}x_3)\rho^2 - (x_3+\frac{1}{2})\sum_{q=n,p}\rho_q^2\right]\rho^\alpha - \frac{1}{8}t_3\left[\frac{1}{2}x_3\vec{s}^2 - \frac{1}{2}\sum_{q=n,p}\vec{s}_q^2\right]\rho^\alpha \\
& - \frac{1}{2}t_4\sum_{q_1q_2}(1+\delta_{q_1q_2})\left[(\vec{\nabla}\times\vec{j}_{q_1}).\vec{s}_{q_2} + \rho_{q_2}\vec{\nabla}.\vec{J}_{q_1}\right]
\end{aligned}
$$

J.R. Stone, P.-G. Reinhard, Progress in Particle and Nuclear Physics 58 (2007) 587–657



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\begin{aligned}
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&+\frac{1}{2}t_0\left[(1+\frac{1}{2}x_0)\rho^2 - (x_0+\frac{1}{2})\sum_{q=n,p}\rho_q^2\right] + \frac{1}{2}t_0\left[\frac{1}{2}x_0\vec{s}^2 - \frac{1}{2}\sum_{q=n,p}\vec{s}_q^2\right] \\
&-\frac{1}{16}t_1(1+\frac{1}{2}x_1)\left[3\rho\Delta\rho - 4(\rho\tau - \vec{j}^2)\right] - \frac{1}{16}t_1(1+2x_1)\sum_{q=n,p}\left[-\frac{3}{2}\rho_q\Delta\rho_q + 2(\rho_q\tau_q - \vec{j}_q^2)\right] \\
&+\frac{1}{16}t_1x_1\left[-\frac{3}{2}\vec{s}\Delta\vec{s} + (\vec{s}.\vec{T} - \vec{J}^2)\right] - \frac{1}{16}t_1\sum_{q=n,p}\left[-\frac{3}{2}\vec{s}_q\Delta\vec{s}_q + (\vec{s}_q.\vec{T}_q - \vec{J}_q^2)\right] \\
&+\frac{1}{16}t_2(1+\frac{1}{2}x_2)\left[\rho\Delta\rho + 4(\rho\tau - \vec{j}^2)\right] + \frac{1}{16}t_2(1+2x_2)\sum_{q=n,p}\left[\frac{1}{2}\rho_q\Delta\rho_q + 2(\rho_q\tau_q - \vec{j}_q^2)\right] \\
&+\frac{1}{16}t_2x_2\left[\frac{1}{2}\vec{s}\Delta\vec{s} + (\vec{s}.\vec{T} - \vec{J}^2)\right] + \frac{1}{16}t_2\sum_{q=n,p}\left[\frac{1}{2}\vec{s}_q\Delta\vec{s}_q + (\vec{s}_q.\vec{T}_q - \vec{J}_q^2)\right] \\
&+\frac{1}{8}t_3\left[(1+\frac{1}{2}x_3)\rho^2 - (x_3+\frac{1}{2})\sum_{q=n,p}\rho_q^2\right]\rho^\alpha + \frac{1}{8}t_3\left[\frac{1}{2}x_3\vec{s}^2 - \frac{1}{2}\sum_{q=n,p}\vec{s}_q^2\right]\rho^\alpha \\
&-\frac{1}{2}t_4\sum_{q_1q_2}(1+\delta_{q_1q_2})\left[(\vec{\nabla}\times\vec{j}_{q_1}).\vec{s}_{q_2} + \rho_{q_2}\vec{\nabla}.\vec{J}_{q_1}\right]
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$$

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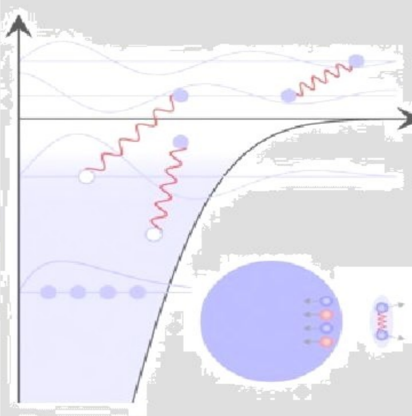
SRPA technique I



time dependent formulation:

$$E(J_\alpha(\vec{r},t)) =< \Psi(t)|\hat{H}|\Psi(t) >$$

$$J_\alpha(\vec{r},t) = \bar{J}_\alpha(\vec{r}) + \delta J_\alpha(\vec{r},t)$$

linear regime – small time-dependent perturbations

$$\delta J_\alpha(\vec{r},t) =< \Psi(t)|\hat{J}_\alpha|\Psi_t > - < HF|\hat{J}_\alpha|HF >$$

$$\hat{h}(\vec{r},t) = \hat{h}_0(\vec{r}) + \hat{h}_{res}(\vec{r},t)$$

Mean field Hamiltonian:
static g.s. + time-dependent response

$$= \sum_\alpha \left[\frac{\delta E}{\delta J_\alpha}\right]_{J=\bar{J}} \hat{J}_\alpha(\vec{r}) + \sum_{\alpha\alpha'} \left[\frac{\delta^2 E}{\delta J_\alpha \delta J_{\alpha'}}\right]_{J=\bar{J}} \delta J_{\alpha'}(\vec{r},t)\hat{J}_\alpha(\vec{r})$$

$$|\Psi(t) >\approx |\mathrm{HF} > +|\delta\Psi(t) >$$

perturped many-body w.f.
we need to specify it…

Three steps

$$|\Psi(t) >= \prod_{k=1}^{K} \exp\left[-q_k(t)\hat{P}_k\right] \exp\left[-p_k(t)\hat{Q}_k\right]|HF >$$

$$\hat{h}_{res} = \sum_{k=1}^{K}[-q_k(t)\hat{X}_k + p_k(t)\hat{Y}_k] = \frac{1}{2}[\kappa_{k,k'}\delta\hat{X}_{k'}\hat{X}_k + \eta_{k,k'}\delta\hat{Y}_{k'}\hat{Y}_k]$$

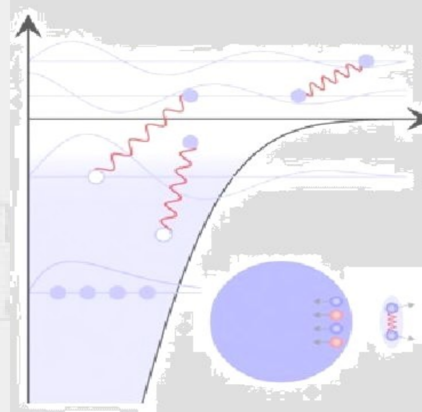
$$|\Psi(t) >_{Th}= \prod_{k=1}^{K}\left[1 + \sum_{ph} c_{ph}(t)\hat{A}_{ph}\right]|HF >$$

$$c_{ph}(t) = c^{+}_{ph}(t)\mathrm{e}^{i\omega t} + c^{-}_{ph}(t)\mathrm{e}^{-i\omega t}$$

$$\delta\hat{X}(t)_{sc} = \delta\hat{X}(t)_{Th}$$

Three steps

SRPA technique I



I) macroscopic step: perturped w.f. via scaling

$$|\Psi(t)>=\prod_{k=1}^{K}\exp\left[-q_k(t)\hat{P}_k\right]\exp\left[-p_k(t)\hat{Q}_k\right]|HF>$$

$$\hat{h}_{res}=\sum_{k=1}^{K}[-q_k(t)\hat{X}_k+p_k(t)\hat{Y}_k]=\frac{1}{2}[\kappa_{k,k'}\delta\hat{X}_{k'}\hat{X}_k+\eta_{k,k'}\delta\hat{Y}_{k'}\hat{Y}_k]$$

$$\hat{Q}_k=\hat{Q}_k^{+},\quad \hat{T}\hat{Q}_k\hat{T}^{-1}=\hat{Q}_k$$

$$\hat{P}_k=i[\hat{H},\hat{Q}_k]_{ph}=\hat{P}_k^{+},\quad \hat{T}\hat{P}_k\hat{T}^{-1}=-\hat{P}_k$$

$$q_k(t)=\overline{q}_k\cos(\omega t)$$

$$p_k(t)=\overline{p}_k\sin(\omega t)$$

II) microscopic step:

$$|\Psi(t)>_{Th}=\prod_{k=1}^{K}\left[1+\sum_{ph}c_{ph}(t)\hat{A}_{ph}\right]|HF>$$

$$c_{ph}(t)=c^{+}_{ph}(t)\mathrm{e}^{i\omega t}+c^{-}_{ph}(t)\mathrm{e}^{-i\omega t}$$

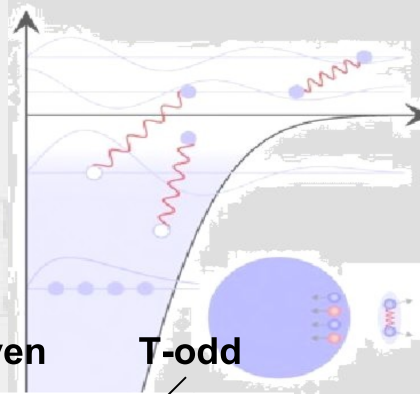
perturped w.f. via Thouless theorem

III) merging step:

$$\delta\hat{X}(t)_{sc}=\delta\hat{X}(t)_{Th}$$

$$\delta\hat{Y}(t)_{sc}=\delta\hat{Y}(t)_{Th}$$

we equal scaling&Thouless variatins



SRPA technique II

Final RPA equations:

$$\sum_k [\bar{q}_k (F_{kk'}(XX) - \kappa^{-1}_{kk'}) + \bar{p}_k F_{kk'}(XY)] \;=\; 0$$
$$\sum_k [\bar{q}_k F_{kk'}(YX) + \bar{p}_k (F_{kk'}(YY) - \eta^{-1}_{kk'})] \;=\; 0$$

T-even **T-odd**

$$H = h_0 + \frac{1}{2}\sum_{kk'}[\kappa_{kk'}\hat{X}_k\hat{X}_{k'} + \eta_{kk'}\hat{Y}_k\hat{Y}_{k'}]$$

$\det[F(\omega_j)] = 0$ ⟹ **RPA spectrum**

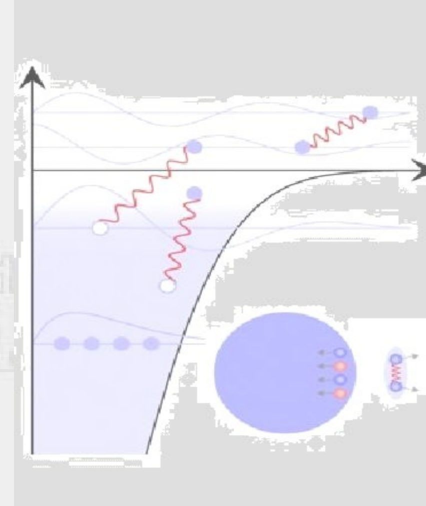
where e.g. $F_{kk'}(XY) = \sum_{ph}\left[\frac{<px|\hat{X}_k|HF>^* + <px|\hat{Y}_{k'}|HF>}{\varepsilon_{ph} - \omega} + \frac{<px|\hat{X}_k|HF> + <px|\hat{Y}_{k'}|HF>^*}{\varepsilon_{ph} + \omega}\right]$

$$\kappa^{-1}_{kk'} \;=\; i < HF|[\hat{X}_k, \hat{P}_{k'}]|HF >$$
$$\eta^{-1}_{kk'} \;=\; i < HF|[\hat{Y}_k, \hat{Q}_{k'}]|HF >$$

$$\hat{X}_{sk} = \sum_{s'} \hat{X}^{s'}_{sk} = i \sum_{\alpha'\alpha s'} \frac{\delta^2 E}{\delta J^{\alpha'}_{s'} \delta J^{\alpha}_{s}} \langle [\hat{P}_{sk}, \hat{J}^{\alpha}_{s}] \rangle \hat{J}^{\alpha'}_{s'}$$

$$\hat{Y}_{sk} = \sum_{s'} \hat{Y}^{s'}_{sk} = i \sum_{\alpha'\alpha s'} \frac{\delta^2 E}{\delta J^{\alpha'}_{s'} \delta J^{\alpha}_{s}} \langle [\hat{Q}_{sk}, \hat{J}^{\alpha}_{s}] \rangle \hat{J}^{\alpha'}_{s'}$$

$$c^{\pm}_{ph} = -\sum_{k'} \frac{\bar{q}_{k'} < ph|\hat{X}_{k'} > \mp \bar{p}_{k'} < ph|\hat{Y}_{k'} >}{2(\varepsilon_{ph} \pm \omega_j)}$$



SRPA technique III

Choice of the input operator Q & P

Depending what excitation spectra (giant resonances of which multipolarity) we intend to calculate we choose:

Electric transitions

the generalized momentum partner to Q

$$Q_k(\vec{r}) \propto f_k(r)(Y_{\lambda\mu}(\Omega) + \mathrm{h.c.})$$

$$\hat{P}_{sk} = i[\hat{H}, \hat{Q}_{sk}]$$

$$f_k(r) = r^{\lambda+2(k-1)}$$

$$= j_\lambda(q_k r)$$

time-even

time-odd

surface

volume contribution

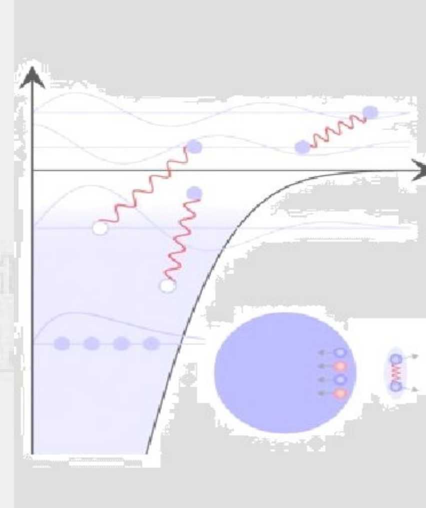
Magnetic transitions

$$\hat{Q}_{sk} = i[\hat{H}, \hat{P}_{sk}]$$

$$\hat{P}_{sk} = -\sqrt{\lambda(2\lambda+1)}\sum_{i=1}^{A} r_i^{l+2(k-1)}\left[\frac{2g_l^{(i)}}{\lambda+1}[l_i \otimes Y_l(r_i)]_{\lambda\mu} + g_s^{(i)}[s_i \otimes Y_l(r_i)]_{\lambda\mu}\right]$$

time-even

time-odd



SRPA technique IV

Strength function:

$$S_L(Z\lambda\mu;E)=\sum_\nu B(Z\lambda\mu;\,|RPA\rangle\to|\nu\rangle)(\hbar\omega_\nu)^L\delta(E-\hbar\omega_\nu)$$ ← definition

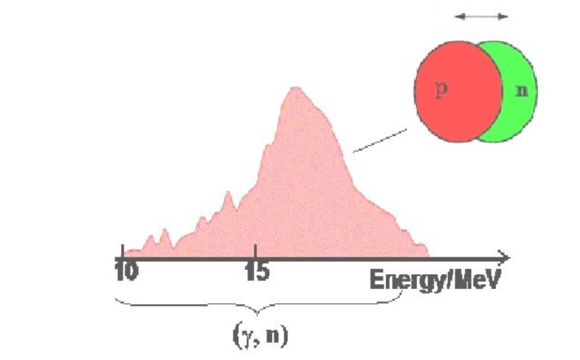
$$S_L(Z\lambda\mu;E)=\sum_\nu Res\left[\frac{z^L\sum_{k\tau}\sum_{k'\tau'}A^\dagger_{k\tau}(z)F_{k\tau,k'\tau'}(z)A_{k'\tau'}(z)}{\pi\det F(z)}\right]_{z=\pm\omega_\nu}$$ ← difficult calculation

simplier calculation → $$\approx Res[...]_{z=\omega\pm i\Delta/2}+\sum_{ph}Res[...]_{z=\pm\epsilon_{ph}}$$ by Cauchy theorem

$$S_L(Z\lambda\mu;E)=\mathrm{Im}\left[\frac{z^L\sum_{k\tau}\sum_{k'\tau'}A^\dagger_{k\tau}(z)F_{k\tau,k'\tau'}(z)A_{k'\tau'}(z)}{\pi\det F(z)}\right]_{z=E+i\frac{\Delta}{2}}+$$ ← **contribution of residual inter.**

unperturbed 2qp strength

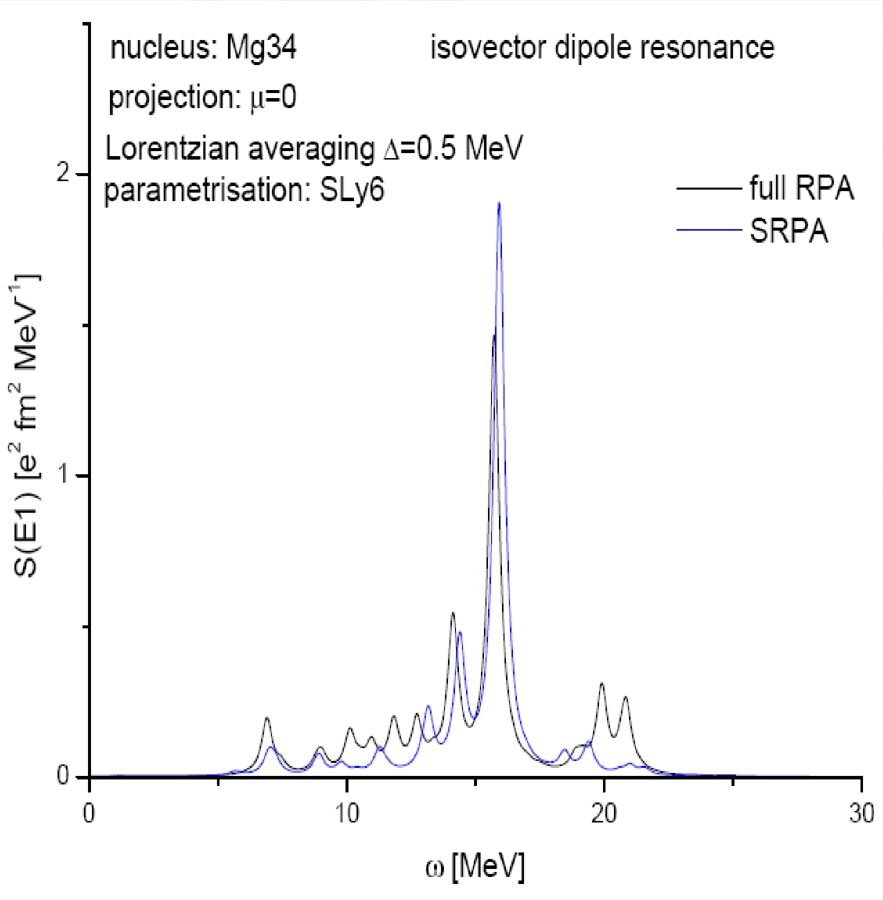
$$+\frac{\Delta}{\pi}\sum_{\substack{\overline{\omega}\\ \overline{\omega}=ij,\overline{ij},i\overline{j}}}\varepsilon^L_{\overline{\omega}}\left|\langle\overline{\omega}|\hat{M}_{Z\lambda\mu}|\rangle\right|^2\left\{\frac{1}{(E-\varepsilon_{\overline{\omega}})^2+\left(\frac{\Delta}{2}\right)^2}-\frac{1}{(E+\varepsilon_{\overline{\omega}})^2+\left(\frac{\Delta}{2}\right)^2}\right\}$$

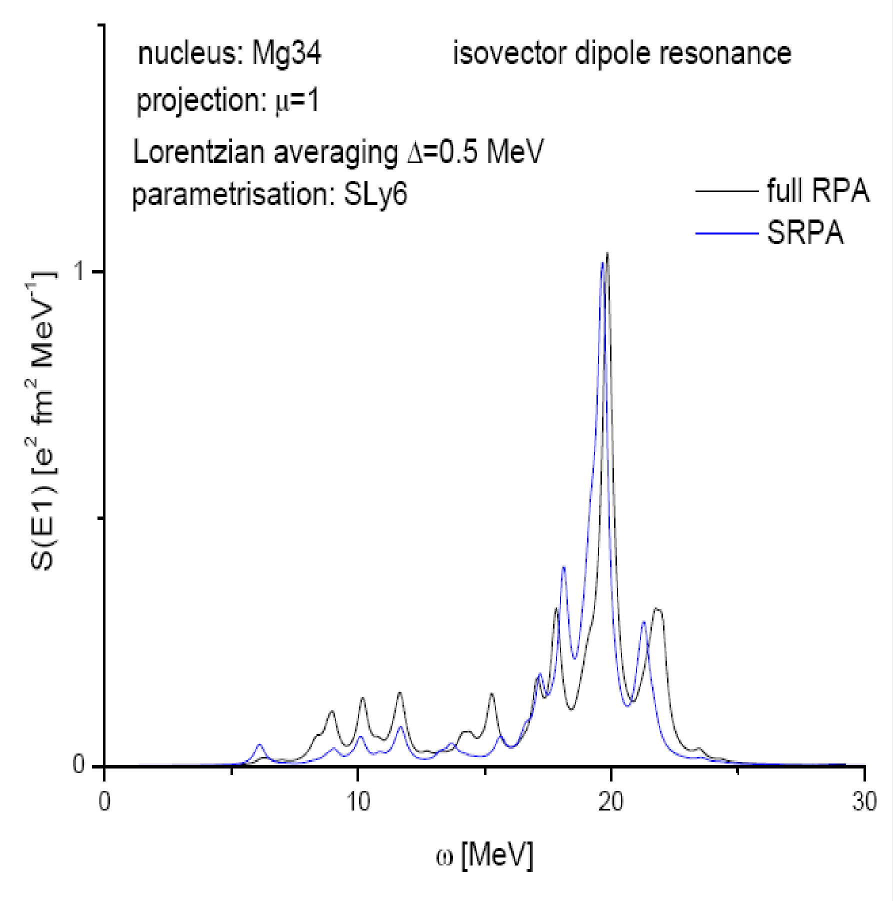


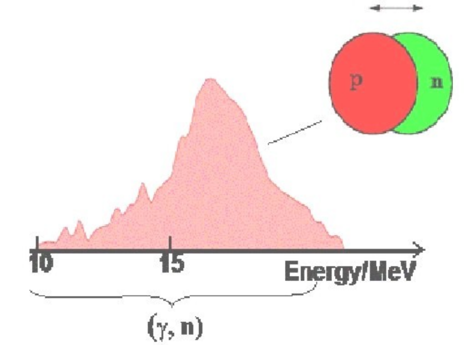
SRPA technique V

Comparison of fullRPA & SRPA… without pairing

configuration space: 1s,1p,2s,1d,1f,2p,$1g_{9/2}$
i.e. first 50 states







Calculations & Results I

Energy-weighted sum rules:

$$EWSR(\lambda > 1, T = 0) = \frac{(he)^2}{8\pi\, m}\lambda(2\lambda + 1)^2 A\left\langle r^{2\lambda-2}\right\rangle_A$$

$$EWSR(\lambda > 1, T = 1) = \frac{(he)^2}{8\pi\, m_1^*}\lambda(2\lambda + 1)^2 A\left\langle r^{2\lambda-2}\right\rangle_A$$

$$EWSR(\lambda = 1, T = 1) = \frac{(he)^2}{8\pi\, m_1^*}9\frac{NZ}{A} = \frac{(he)^2}{8\pi\, m}9\frac{NZ}{A}(1+k)$$

E. Lipparini and S. Stringari, Phys. Rep. 175, 103 (1989):

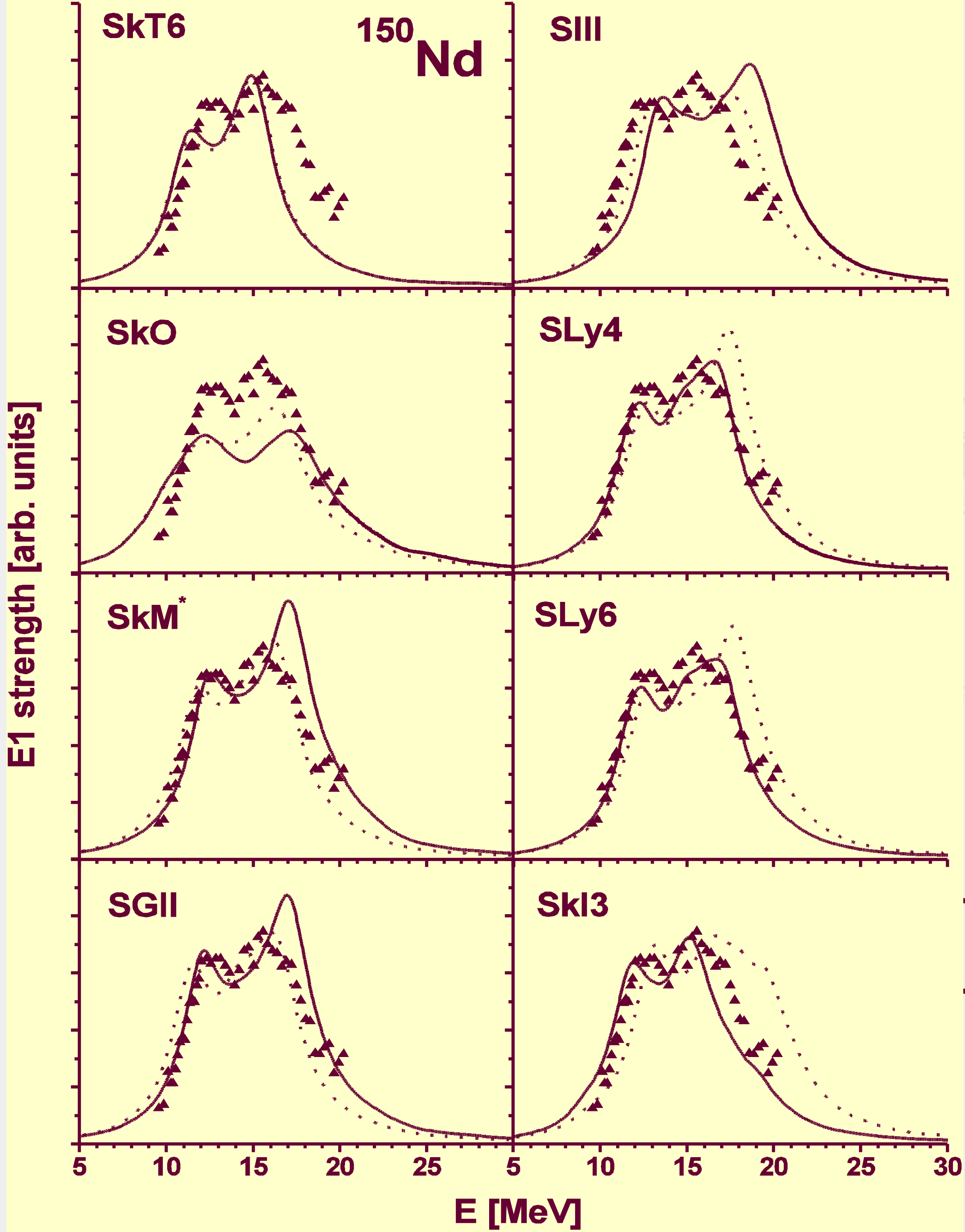
For isoscalar modes the effective mass (τ) contribution to the mean field part EWSR(T=0) and effective mass & current (j) contributions to residual int. part EWSR(T=0) fully compensate each other and so EWSR(T=0) acquires the bare mass m.
For isovector modes the compensation is not complete and so EWSR(T=1) has the isovector effective mass m_1^*

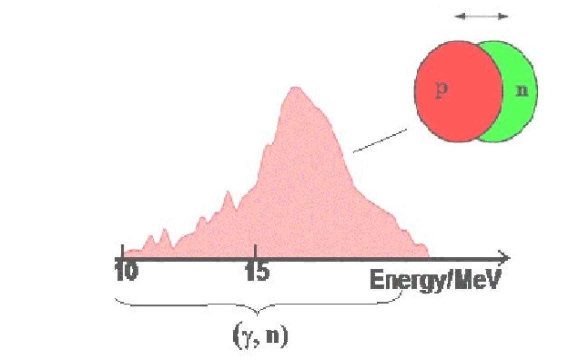
^{150}Nd

	SkT6	SkM*	SLy6	SkI3
$\alpha(E1, T=1) =$	0.99	0.90	0.94	0.93
$\alpha(E2, T=0) =$	0.96	0.97	0.95	0.95
$\alpha(E3, T=0) =$	0.75	0.74	0.73	0.72

Sum rules: $\alpha = \frac{EWSR_{SRPA}}{EWSR_{estim}}$

	SkM*	Sly6	SkI3
m_0^*/m	0.79	0.69	0.58
m_1^*/m	0.65	0.80	0.80





E1 (T=1) giant resonance in ^{150}Nd

▲▲▲ experiment

P.Carlos et al., NPA 172, 437 (1971)

P.Carlos et al., NPA 172, 437 (1971)

B.L.Bergman et al, RMP 47, 713 (1971)

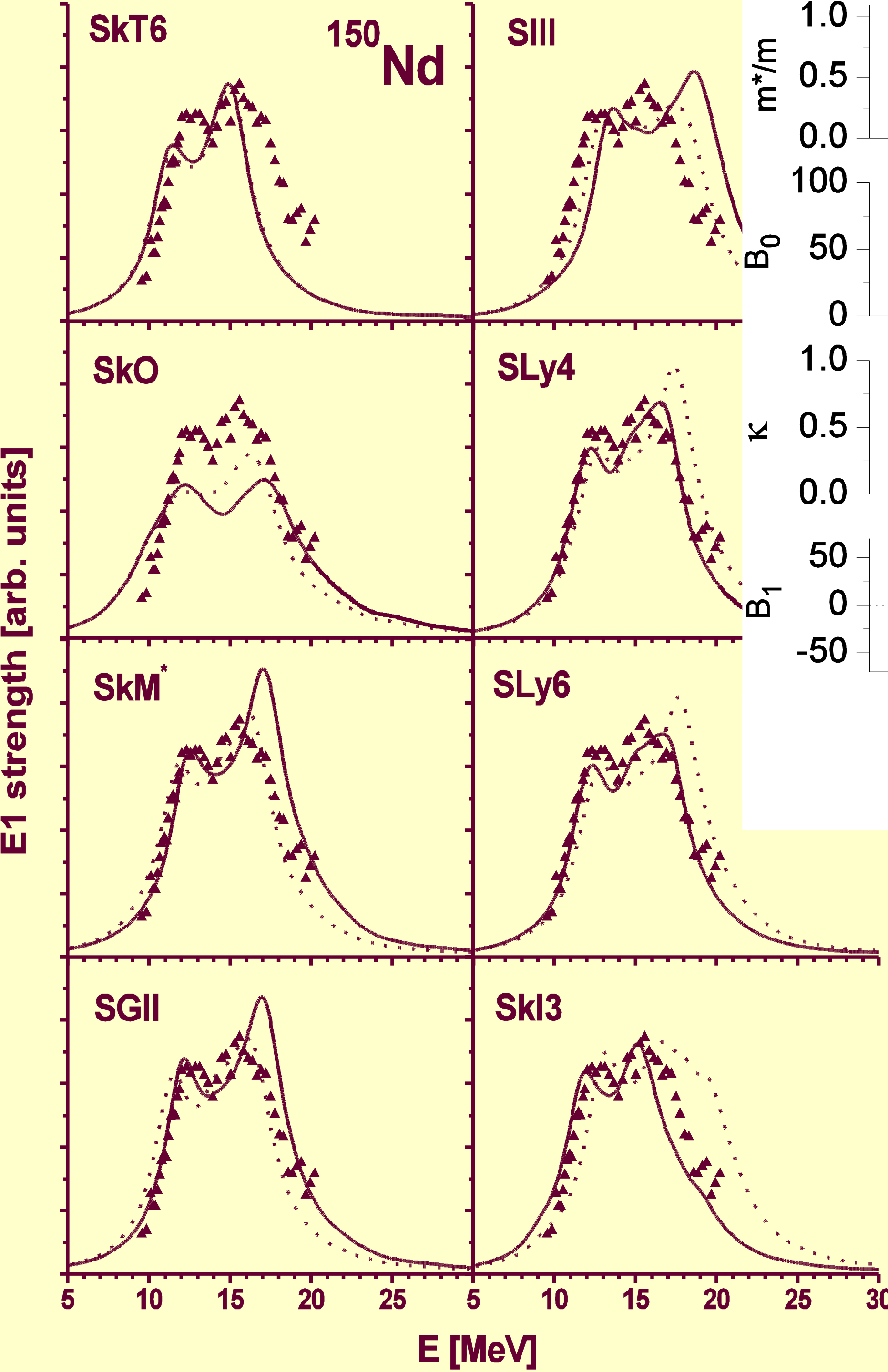
A.V.Varlamov et al., Atlas of Giant R., INDC(NDS)-394, 1999

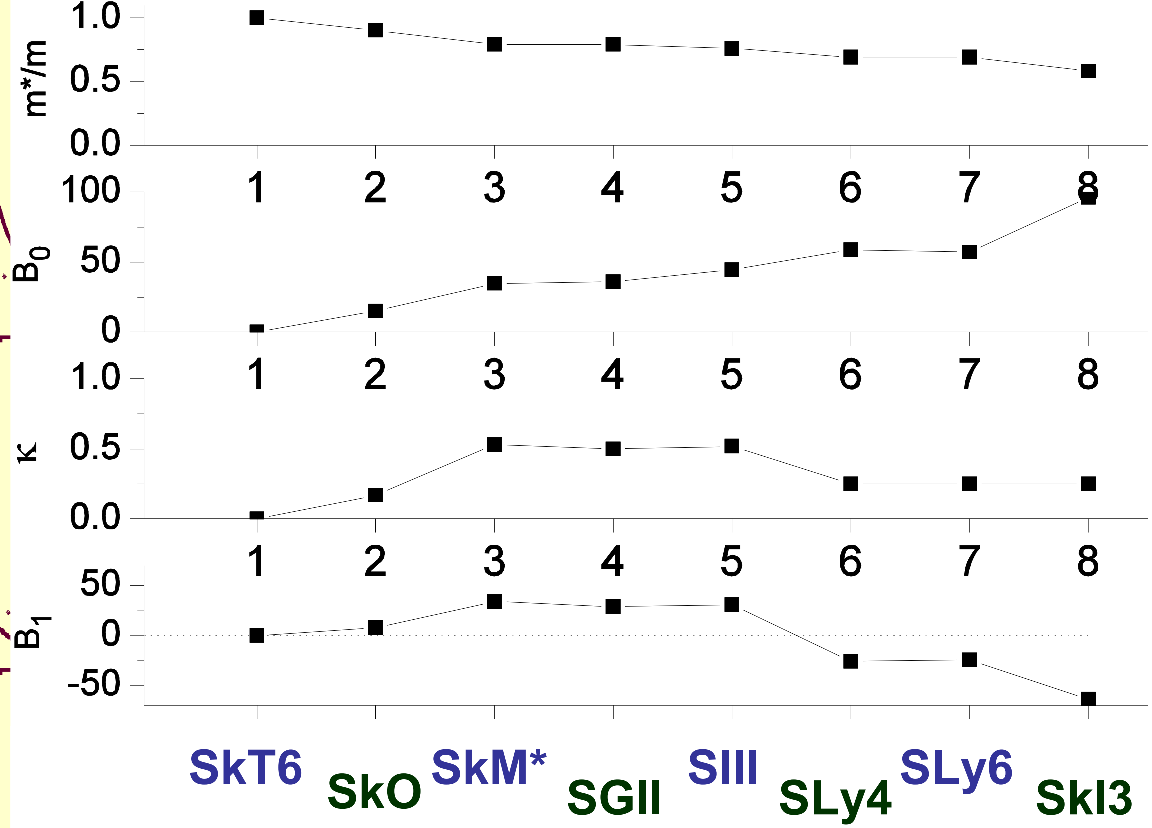
JANIS database

——— with time-odd current

……… without time-odd current

$$(r\,Y_{1\mu} + r^3 Y_{1\mu})$$



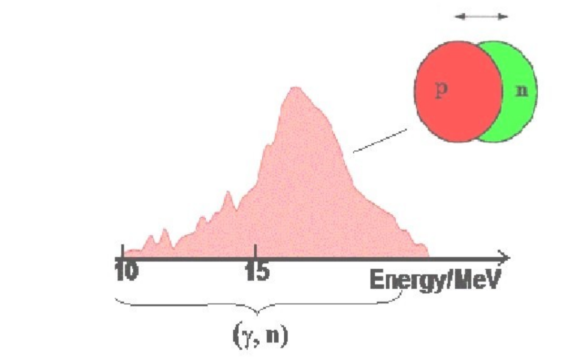


with time-odd current

without time-odd current

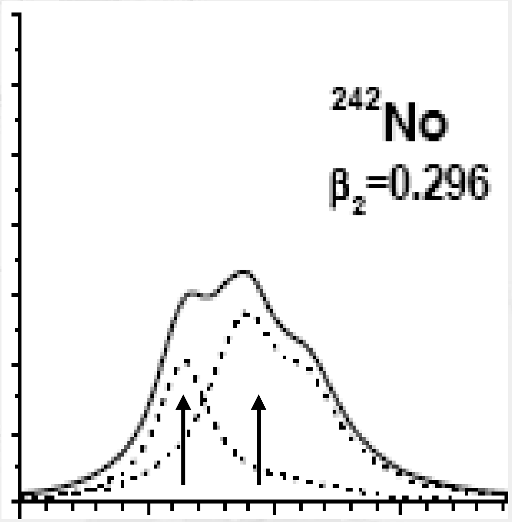
- dependence of isoscal./isovec. eff. masses on the isosc./isov. parameters B_0, B_1
- consequnces for the energy-weighted sum rule (EWSR)

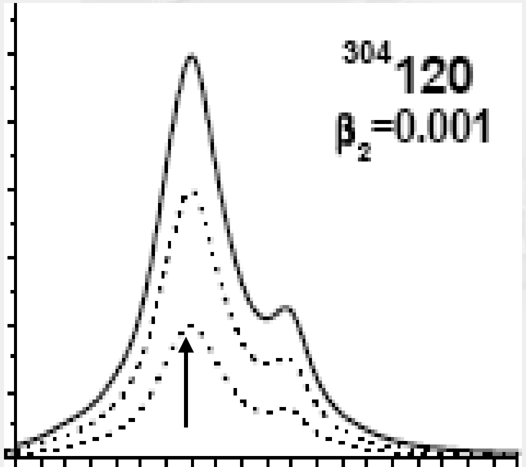
Giant resonances widths I

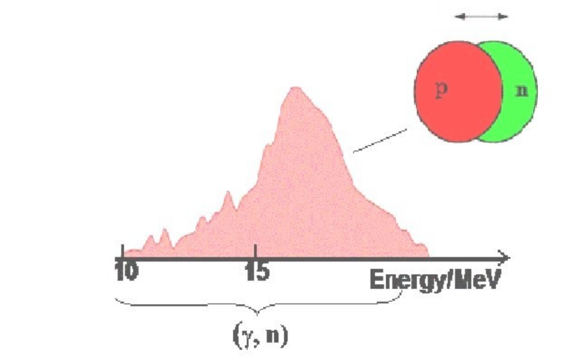


The physical mechanisms of widths:

- deformation
- Landau fragmentation (dumping) (interaction with the nearby 2qp poles)
- continuum
- contribution by complex configurations (higher phonon excit.)







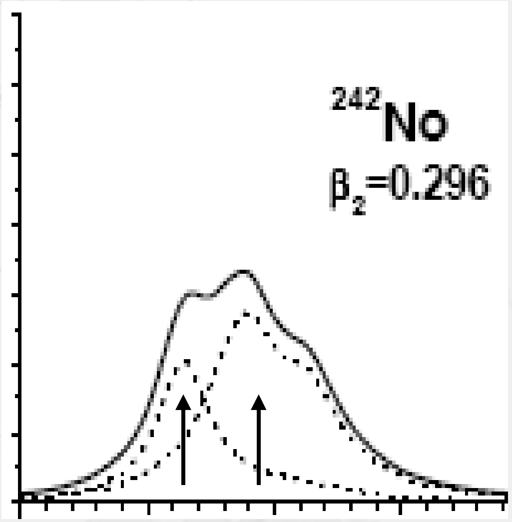
Giant resonances widths I

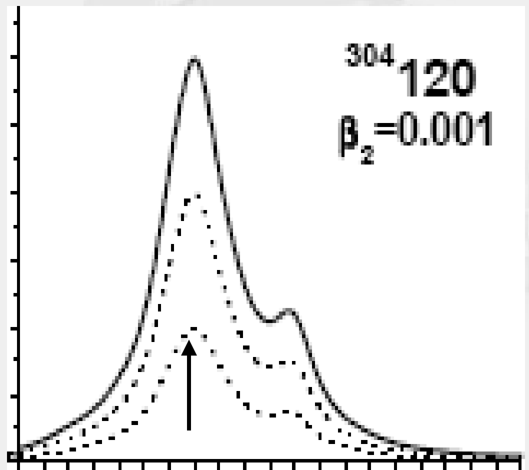
The physical mechanisms of widths:

- deformation
- Landau fragmentation (dumping)
(interaction with the nearby 2qp poles)
- continuum
- contribution by complex
configurations (higher phonon excit.)

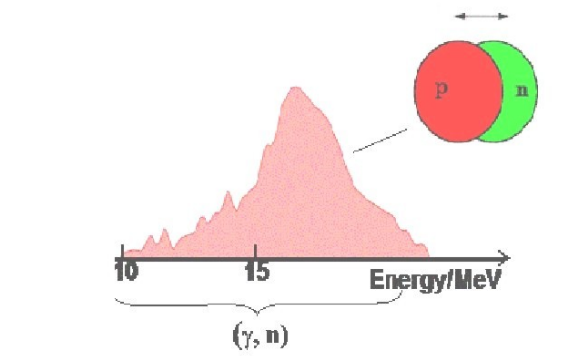
We simulate by the Lorentzian width Δ

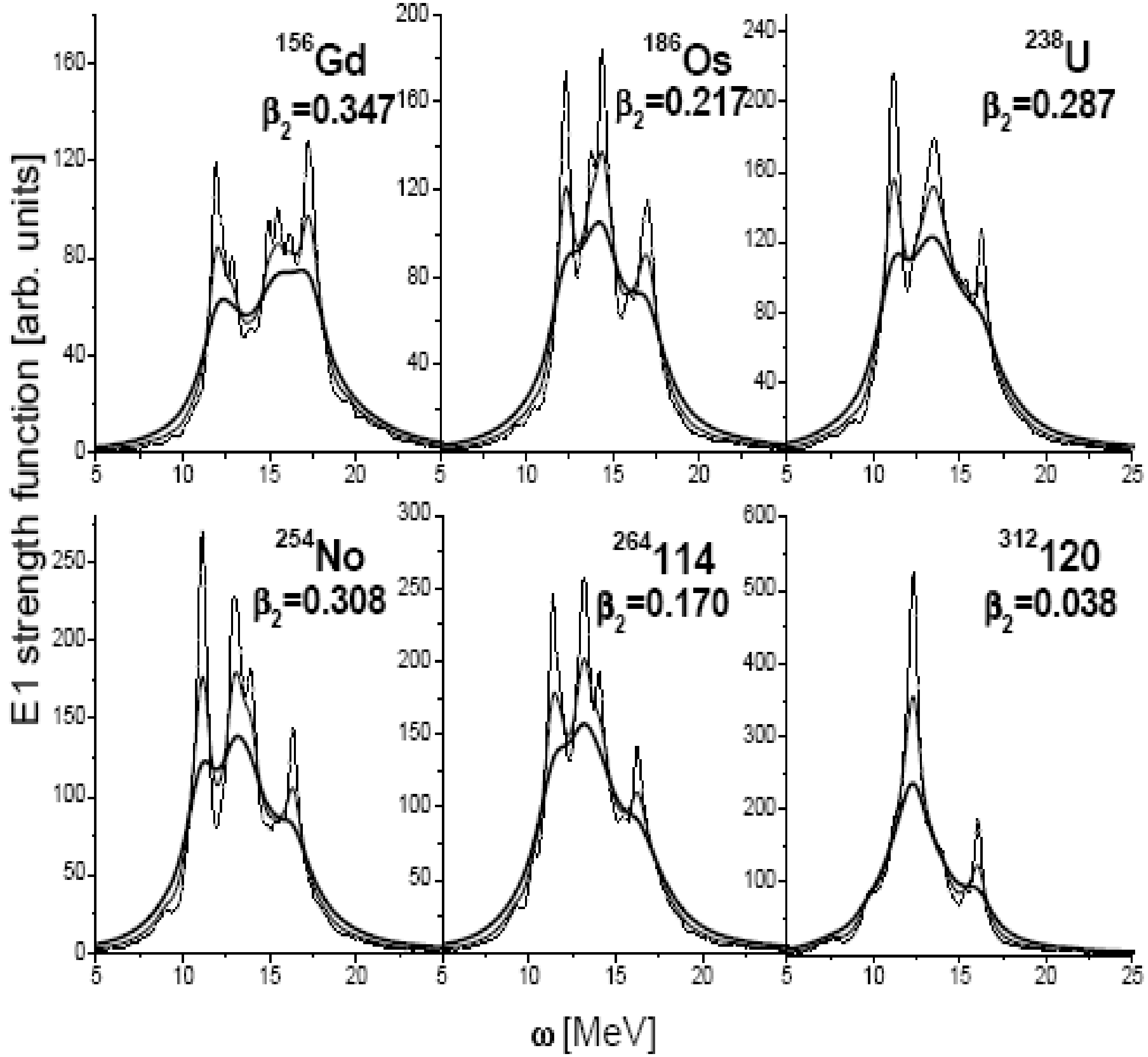
$$\zeta(\omega - \omega_j) = \frac{1}{2\pi} \frac{\Delta}{(\omega - \omega_\nu)^2 + (\Delta/2)^2}$$

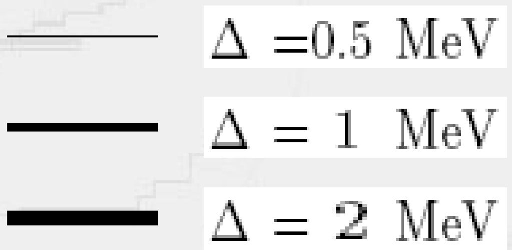




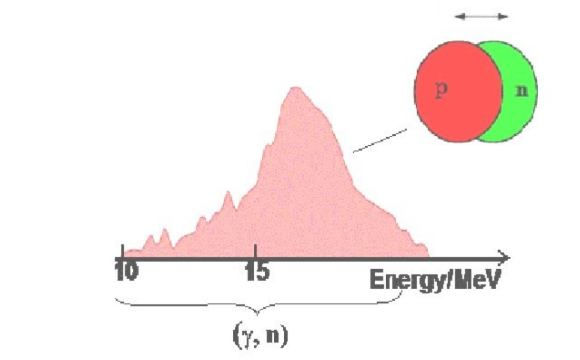
Giant resonances widths II







- Variation of width depending on Δ is small – dominant part of Γ by deform. & Landau
- deformation makes not more than 40 % of the total Γ



Spin-M1 resonance I

a few notes to the input operators (for magnetic modes):

$$\hat{P}_{sk} = -\sqrt{\lambda(2\lambda+1)} \sum_{i=1}^{A} r_i^{l+2(k-1)} \left[\frac{2g_l^{(i)}}{\lambda+1} [l_i \otimes Y_l(r_i)]_{\lambda\mu} + g_s^{(i)} [s_i \otimes Y_l(r_i)]_{\lambda\mu} \right]$$

$$\hat{Q}_{sk} = i[\hat{H}, \hat{P}_{sk}]$$ ← generalized coordinate to P_{sk}

for spin-M1 calc. we take 2 mag. op.

$f_{k=1}(r) = r^l$ $f_{k=2}(r) = r^{l+2}$

& 2 quadrupole el.

$Q_{k=3}(\vec{r}) \propto r^2 Y_{2\mu}$

$Q_{k=4}(\vec{r}) \propto r^4 Y_{2\mu}$

gyroscopic factors for the spin-M1 transition:

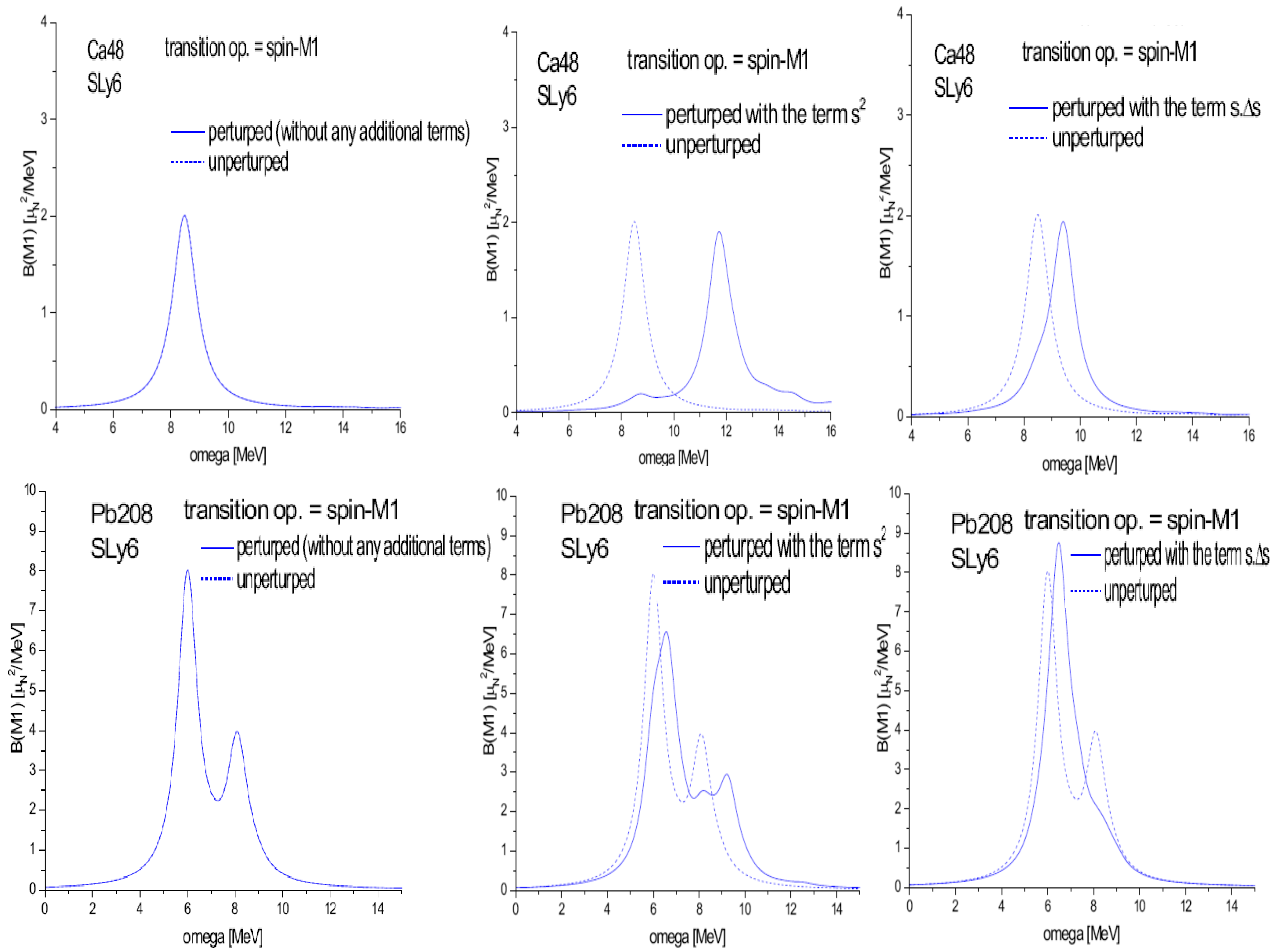
$g_l(\text{prot}) = 0$ $g_s(\text{prot}) = 5.59 * q_p * \mu_N$

$g_l(\text{neut}) = 0$ $g_s(\text{neut}) = -3.83 * q_n * \mu_N$

where $q_p=0.68$, $q_n=0.64$ (quenching factors)

We do not cause orbital-M1 trans.

R. Alarcon, ***Phys. Rev. C40, R1097*** **(1989)**



Ca48
SLy6
transition op. = spin-M1
perturped (without any additional terms)
unperturped
B(M1) [μN2/MeV]
omega [MeV]
Ca48
SLy6
transition op. = spin-M1
perturped with the term s2
unperturped
B(M1) [μN2/MeV]
omega [MeV]
Ca48
SLy6
transition op. = spin-M1
perturped with the term s.Δs
unperturped
B(M1) [μN2/MeV]
omega [MeV]
Pb208
SLy6
transition op. = spin-M1
perturped (without any additional terms)
unperturped
B(M1) [μN2/MeV]
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Pb208
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transition op. = spin-M1
perturped with the term s2
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B(M1) [μN2/MeV]
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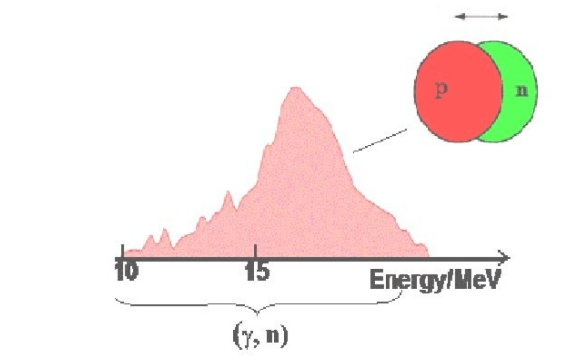
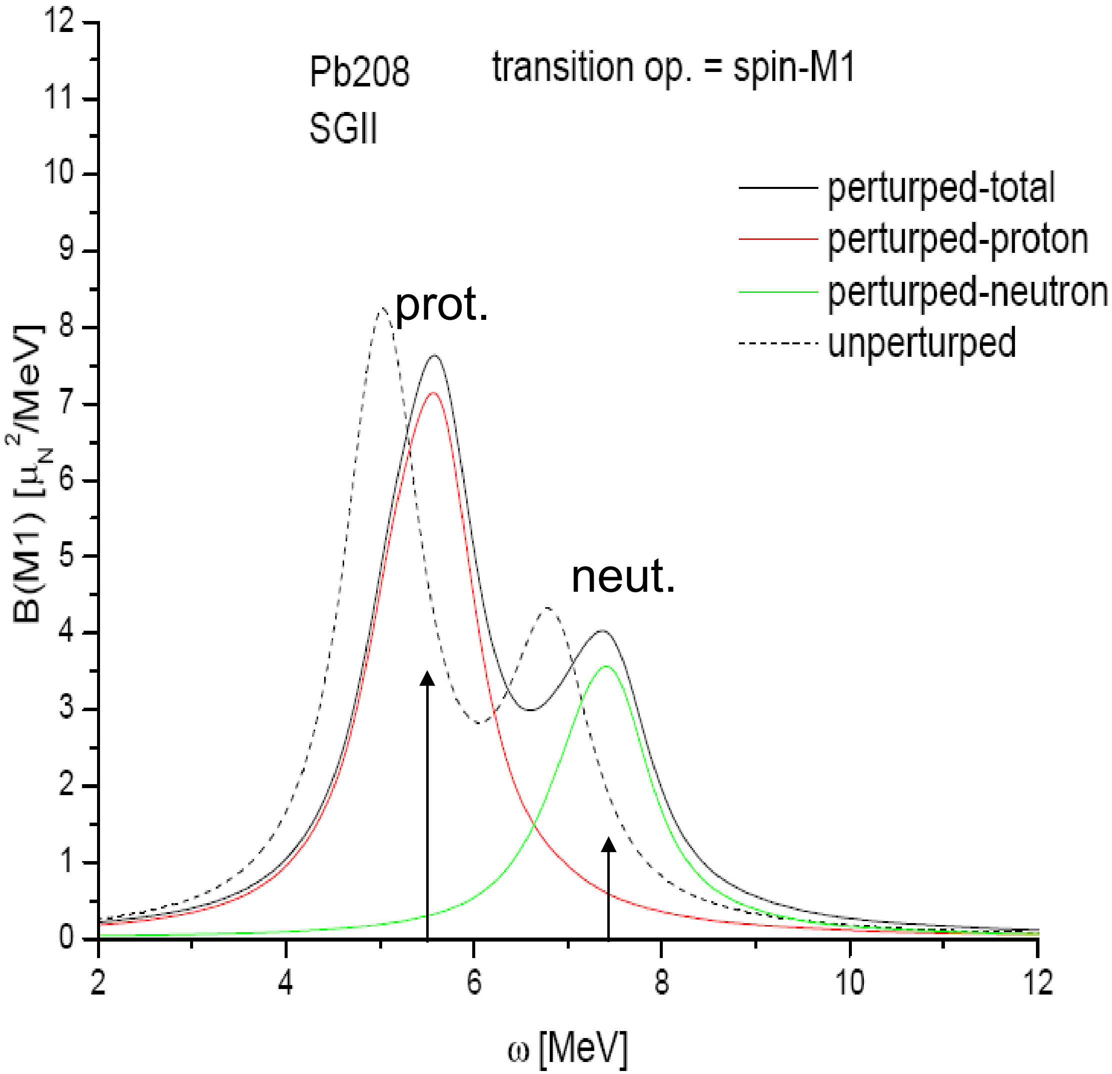
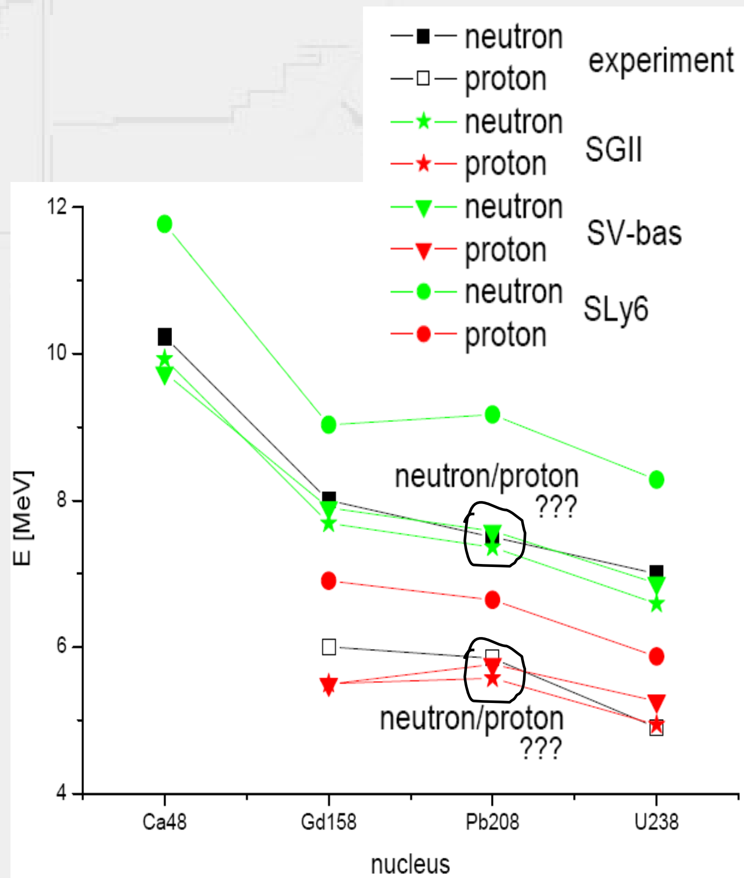
Pb208
SLy6
transition op. = spin-M1
perturped with the term s.Δs
unperturped
B(M1) [μN2/MeV]
omega [MeV]

Spin-M1 resonance III

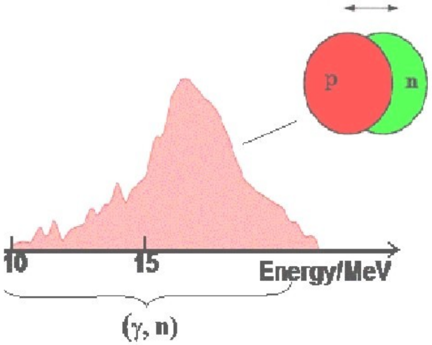


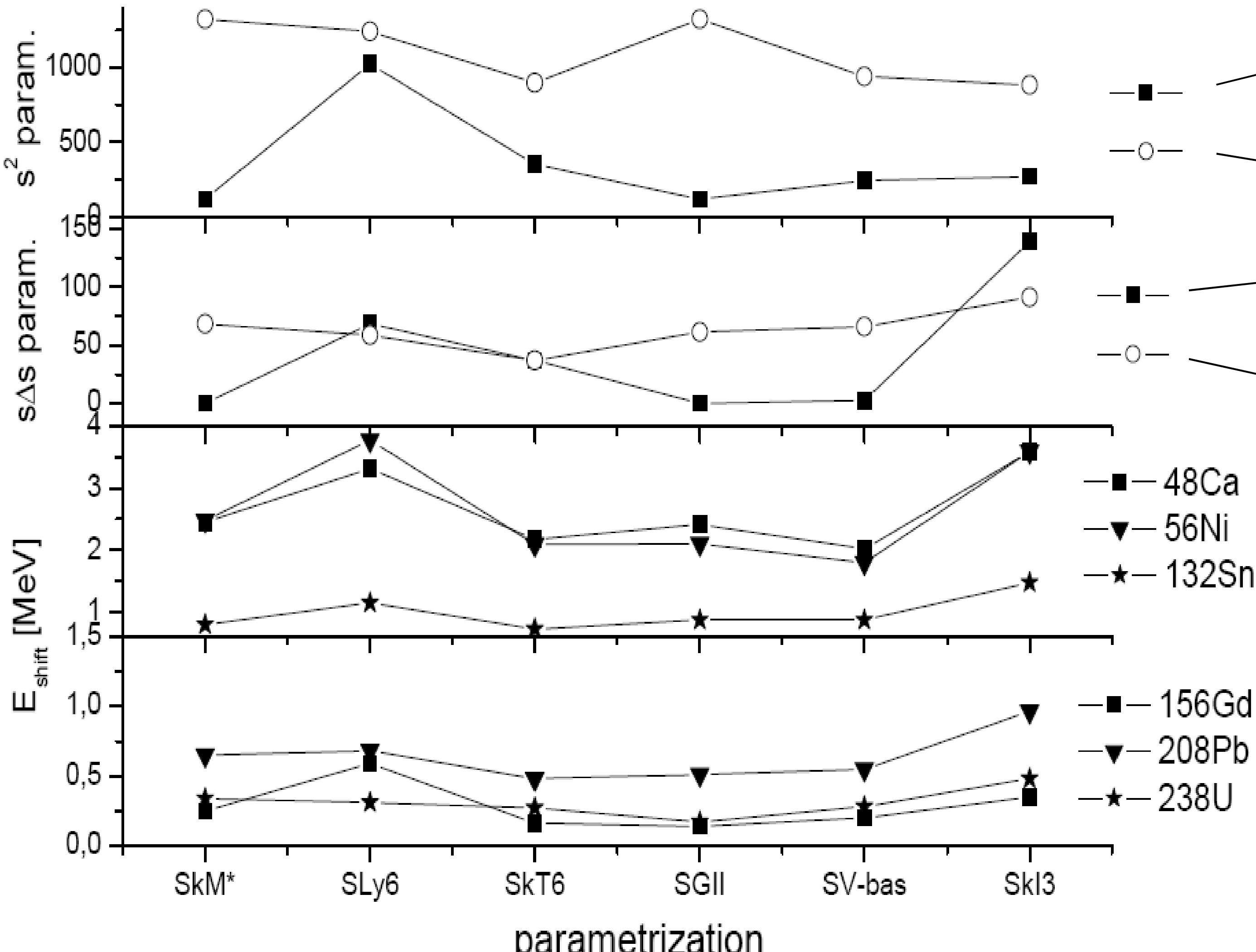


The spin-M1 resonance consists of proton & neutron bumps



Spin-M1 resonance IV





$$\frac{1}{4}t_0x_0\vec{s}^2$$

$$-\frac{1}{4}t_0\sum_{q=n,p}\vec{s}_q^2$$

$$\frac{3}{16}t_1x_1\vec{s}\Delta\vec{s}$$

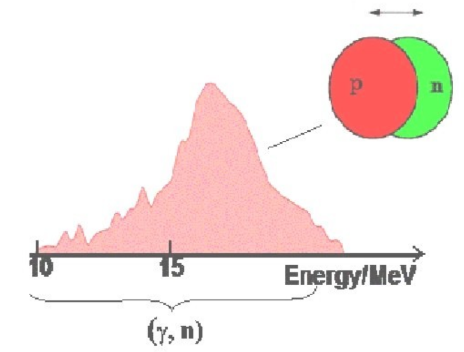
$$\frac{3}{16}t_1\sum_{q=n,p}\vec{s}_q\Delta\vec{s}_q$$

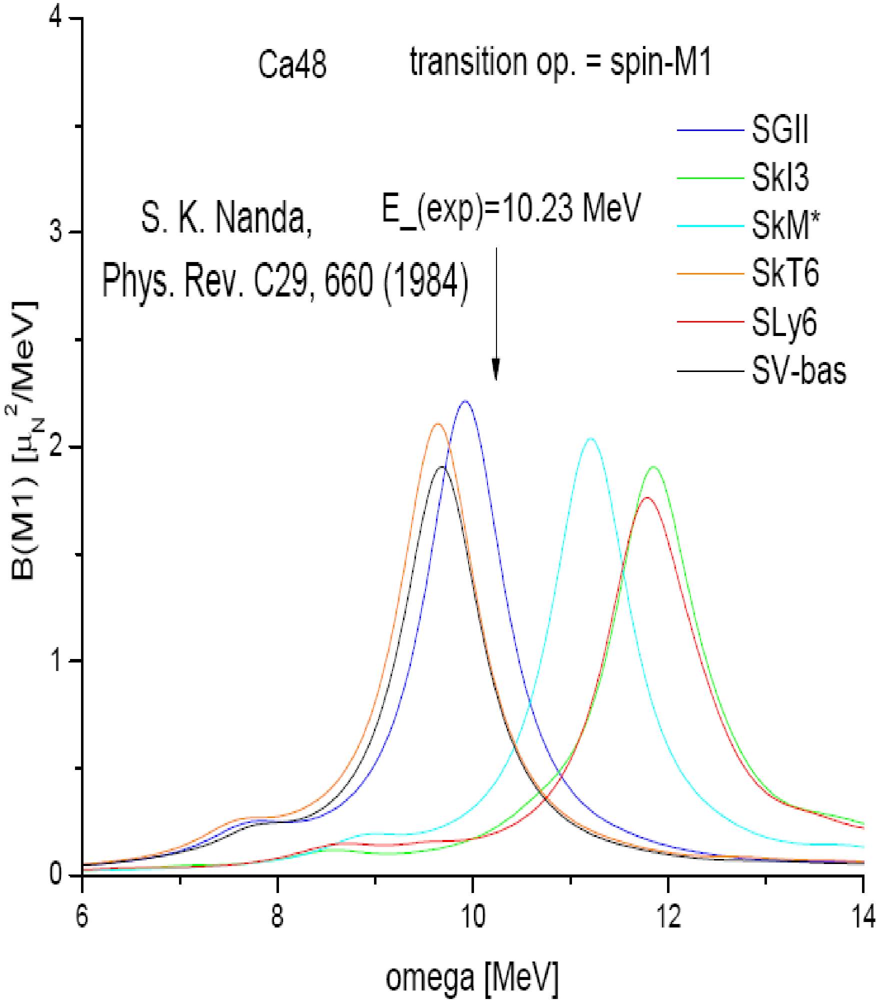
Energy shift

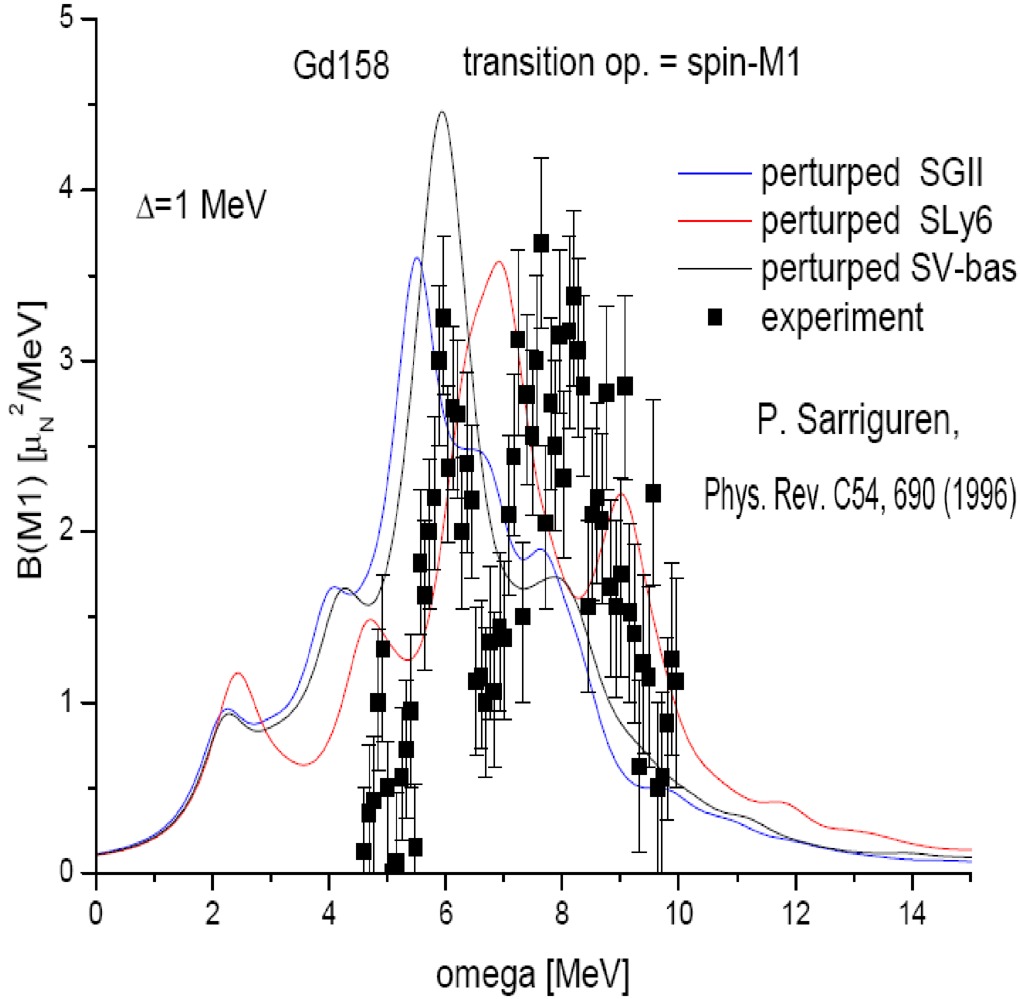
perturped/unperturped strength

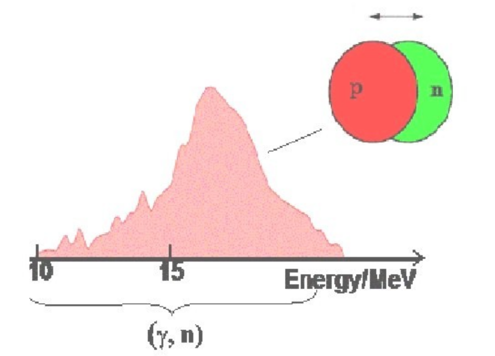
Spin-M1 resonance V

The comparison with available experimental data



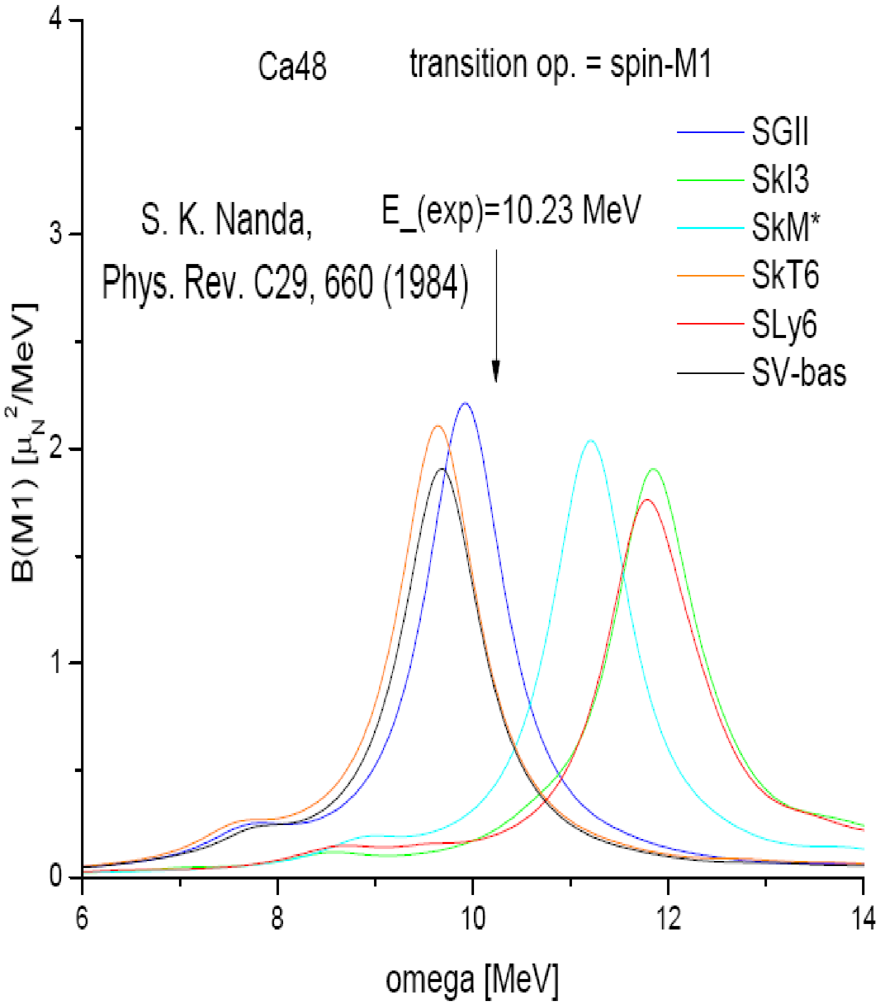






Spin-M1 resonance V

The comparison with available experimental data

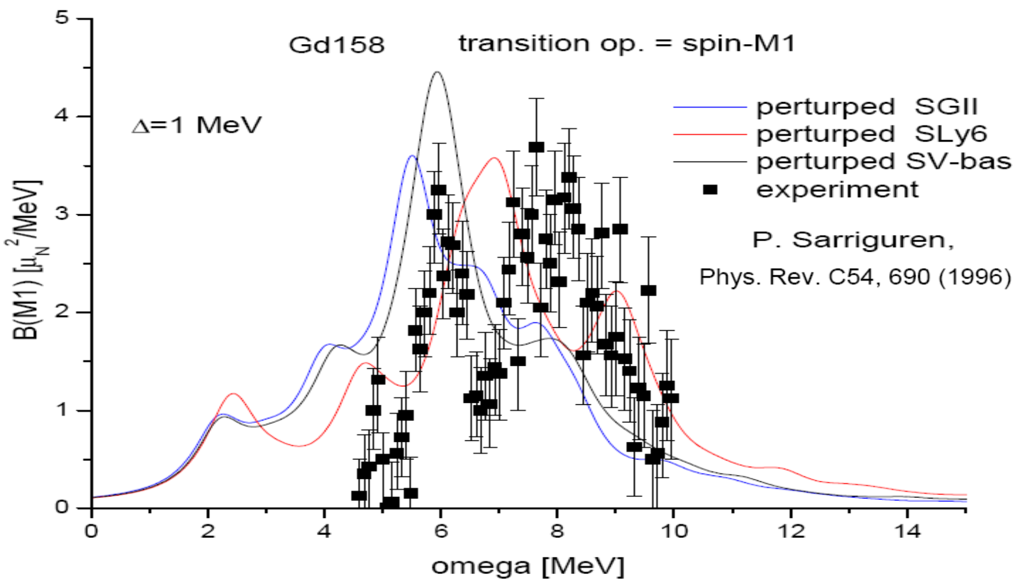


summed strength on the 0-12 MeV interval

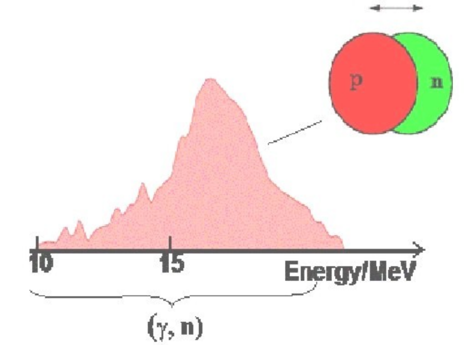
^{158}Gd

		other theor. data*
SGII:	14.07 μ_N^2	11.8 μ_N^2
SV-bas:	14.63 μ_N^2	
SLy6:	15.07 μ_N^2	

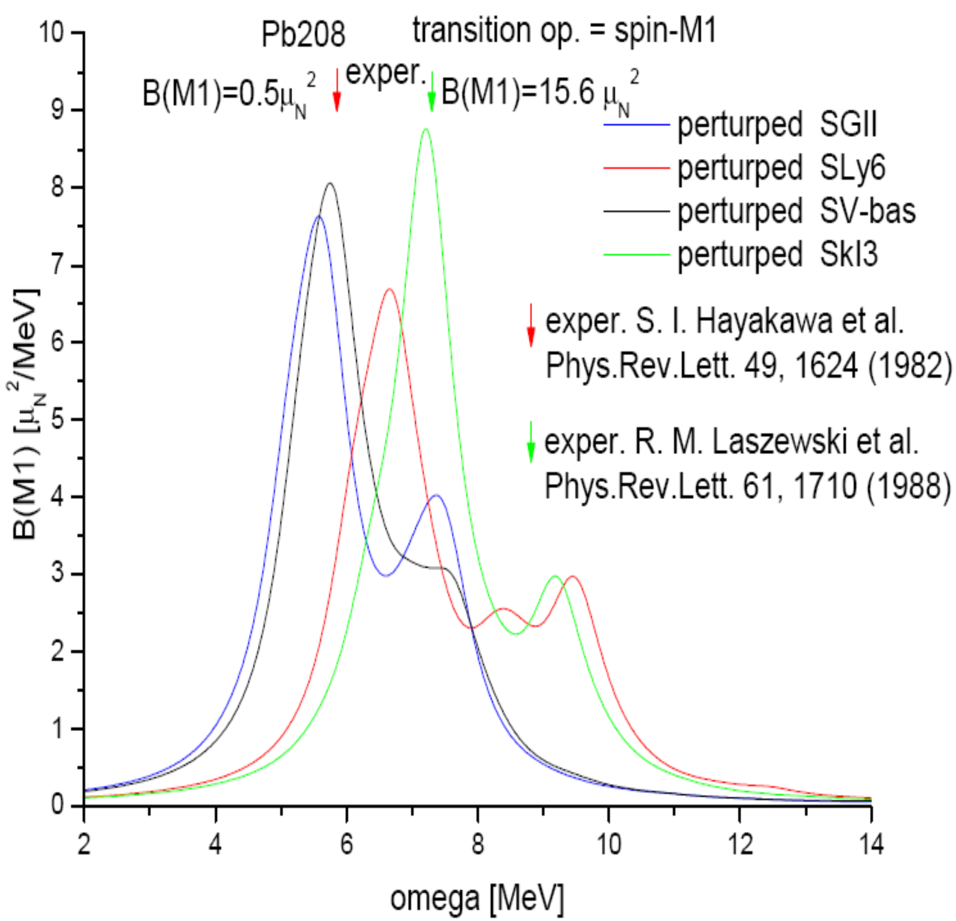
*P. Sarriguren, Phys. Rev. C54, 690 (1996)

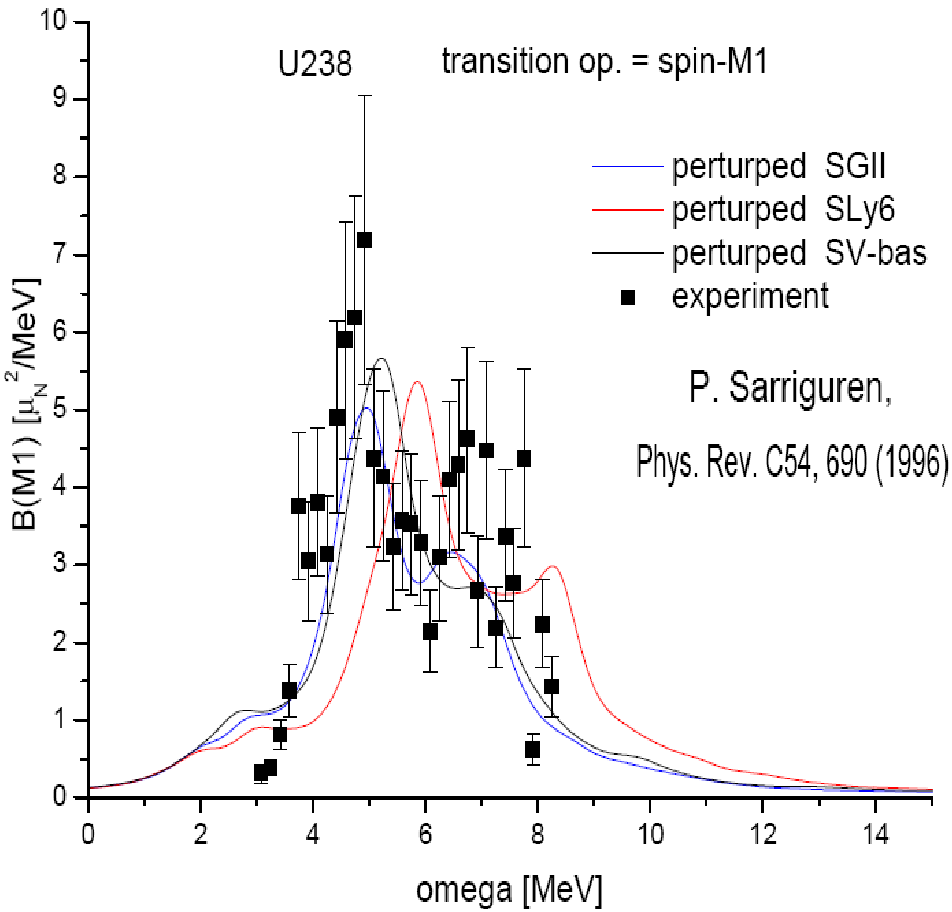


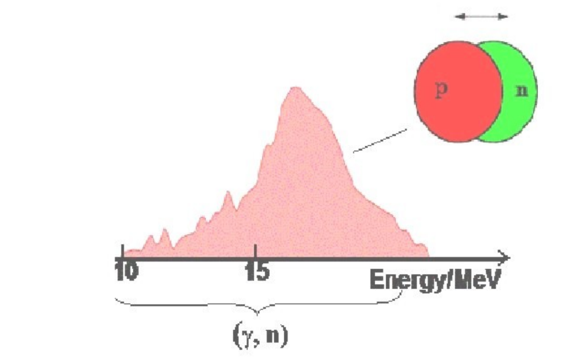
Spin-M1 resonance VI



→ parametrization SV-bas is our tip!







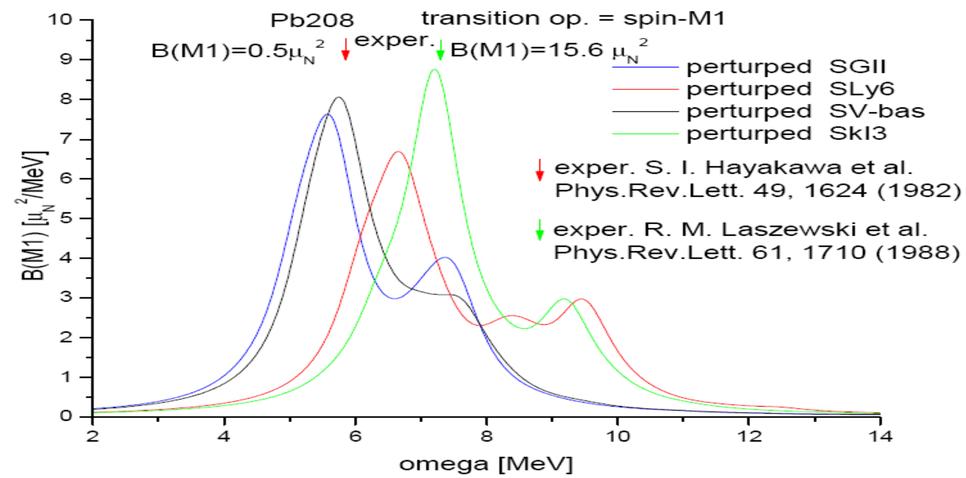
Spin-M1 resonance VI

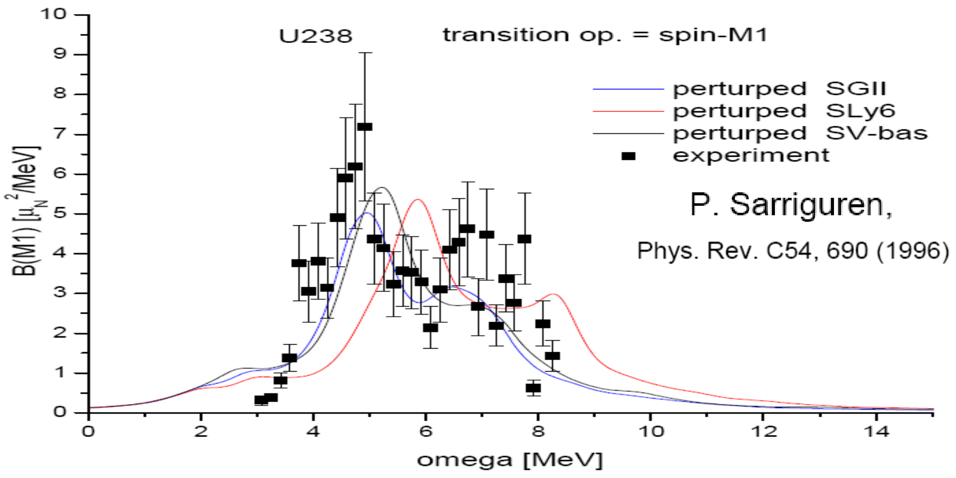
→ parametrization SV-bas is our tip!

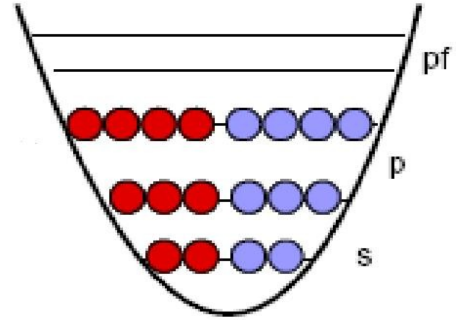
summed strength on the 0-12 MeV interval

	^{208}Pb	^{238}U	^{208}Pb	
			exp.*	
SGII:	18.79 μ_N^2	16.78 μ_N^2		
SV-bas:	18.61 μ_N^2	17.83 μ_N^2	$(1.9^{+0.7}_{-0.4})\ \mu_N^2$	bellow 6.4 MeV
SLy6:	18.53 μ_N^2	18.81 μ_N^2	17.5 μ_N^2	total strength

*Laszewski, Phys. Rev. Lett. 61, 1710 (1988)







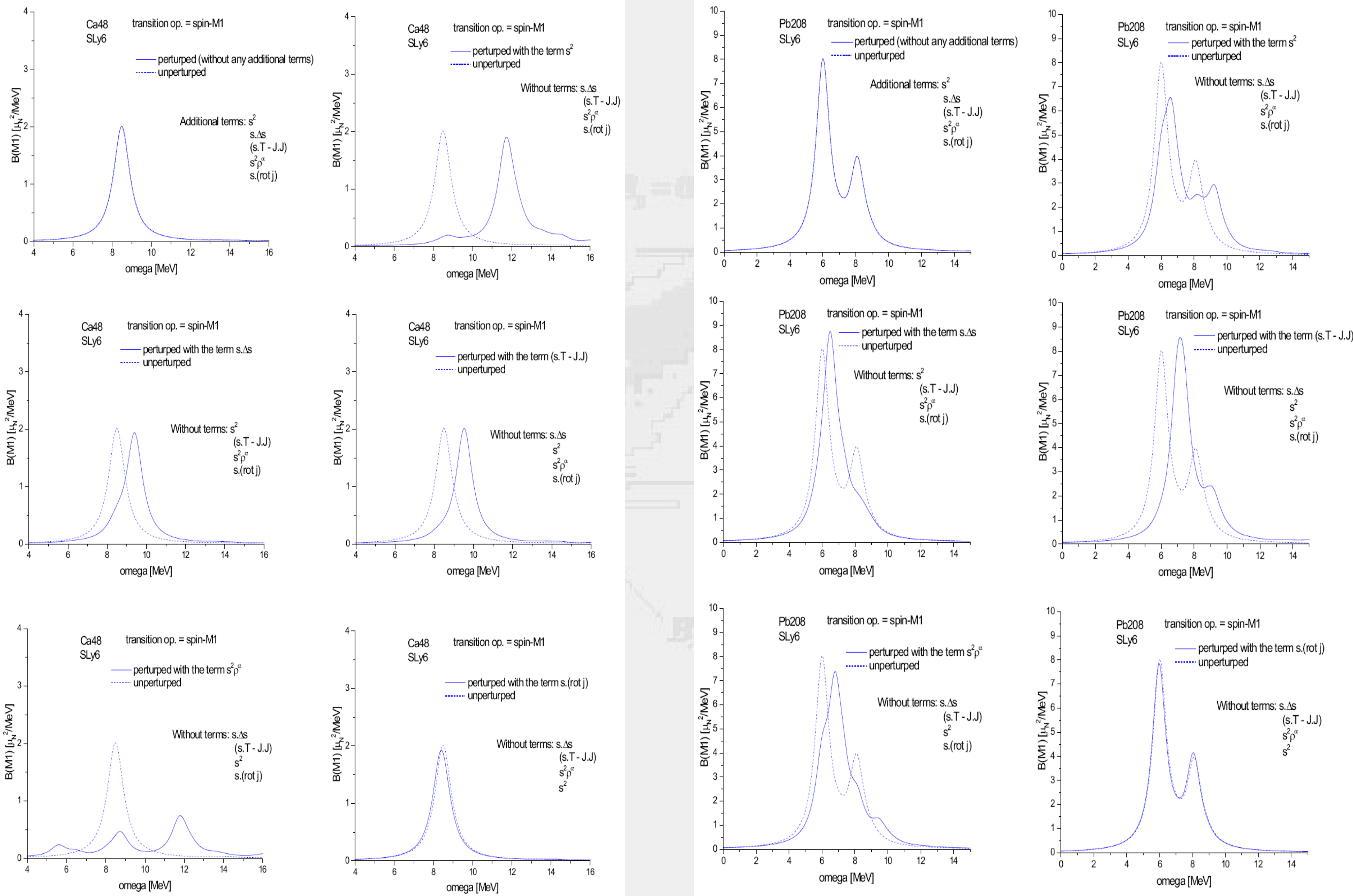
Conclusions

- We tested E1(T=1) GR → SLy6 seems to be best in comparison with exp. data
- Correlations between effective masses & time-odd terms contribution
- The role of Landau fragmentation onto strength width of E1 giant resonance
- SRPA is useful for the magnetic modes description as well, the collective shift just if we include the additional terms of Skyrme func.
- We tested spin-M1 → SV-bas seems best in comp. exp. data (modest s.o. split.)
- Correlation betw. energy shifts & strength constants of s^2 and $s\Delta s$ terms
    - ^{208}Pb as exceptional case (the complex configurations ?)

List of papers:

-- V.O.Nesterenko,J.Kvasil,P.-G.Reinhard, **Phys. Rev. C**66:044307 (2002)
-- V.O.Nesterenko,W.Kleinig,J.Kvasil,P.Vesely,P.-G.Reinhard,D.S.Dolci **Phys.Rev.C**74:064306, (2006) (also at **nucl-th/0609018**)
-- V.O.Nesterenko,W.Kleinig,J.Kvasil,P.Vesely,P.-G.Reinhard **Int.J.Mod.Phys.E**16:624-633,(2007) (also at **nucl-th/0610040**)
-- V.O. Nesterenko, W. Kleinig, J. Kvasil, P. Vesely, and P.-G. Reinhard, **Int. J. Mod. Phys.E**, 17, 89-99, (2008) (also at **nucl-th/0711.1090**)
-- W. Kleinig, V.O. Nesterenko, J. Kvasil, P.-G. Reinhard, P. Vesely **Phys. Rev. C**78:044314,(2008) (also at **nucl-th/0805.4787**)

Discussion



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SLy6
transition op. = spin-M1
perturped (without any additional terms)
unperturped
Additional terms: s²
s.Δs
(s.T - J.J)
s²ρ^α
s.(rot j)
B(M1) [μN²/MeV]
omega [MeV]
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SLy6
transition op. = spin-M1
perturped with the term s²
unperturped
Without terms: s.Δs
(s.T - J.J)
s²ρ^α
s.(rot j)
Pb208
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unperturped
Additional terms: s²
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s²ρ^α
s²

Discussion

s.o. splitting