Damping of quadrupole states in extended RPA with ground state correlations

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- Time-dependent density-matrix theory (TDDM) and its small-amplitude limit (STDDM)
- Giant quadrupole resonances (GQR) in $^{16,22}O$
- Summary

TDDM and STDDM

TDDM determines the time evolution of ρ and C_2

$$\rho(11':t) = \left\langle \Phi(t) \mid a^+(1')a(1) \mid \Phi(t) \right\rangle$$

$$C_2(121'2':t) = \left\langle \Phi(t) \mid : a^+(1')a^+(2')a(2)a(1) : \mid \Phi(t) \right\rangle$$

Time derivatives of ρ and C_2

$$i\hbar \frac{\partial}{\partial t}\rho = \left\langle \Phi(t) \mid [a^+(1')a(1), H] \mid \Phi(t) \right\rangle = F_1(\rho, C_2)$$

$$i\hbar \frac{\partial}{\partial t} C_2 = F_2(\rho, C_2, C_3) \approx F_2(\rho, C_2)$$

BBGKY hierarchy

Time-independent form of TDDM

Ground state: A stationary solution of TDDM eqs.

$$i\hbar \frac{\partial}{\partial t} n_{\alpha\alpha'} = F_{1\alpha\alpha'}(\varepsilon_\alpha, n, C) = 0$$

$$i\hbar \frac{\partial}{\partial t} C_{\alpha\beta\alpha'\beta'} = F_{2\alpha\beta\alpha'\beta'}(\varepsilon_\alpha, n, C) = 0$$

Gradient method can be used.

$$\begin{pmatrix} n(N+1) \\ C(N+1) \end{pmatrix} = \begin{pmatrix} n(N) \\ C(N) \end{pmatrix} - \alpha \begin{pmatrix} \frac{\delta F_1}{\delta n} & \frac{\delta F_1}{\delta C} \\ \frac{\delta F_2}{\delta n} & \frac{\delta F_2}{\delta C} \end{pmatrix}^{-1} \begin{pmatrix} F_1(N) \\ F_2(N) \end{pmatrix}$$

M. Tohyama et al., Eur. Phys. J. A 21, 217(2004)

STDDM: Linearization of TDDM eqs. for $\delta\rho$ and δC_2

$$\begin{pmatrix} a & c \\ b & d \end{pmatrix} \begin{pmatrix} x^{\mu} \\ X^{\mu} \end{pmatrix} = \omega_{\mu} \begin{pmatrix} x^{\mu} \\ X^{\mu} \end{pmatrix}$$

a, *b* and *d* contain *n* and *C* : g.s. correlations

Neglect of g.s. correlations: STDDM➔ Second RPA

GQR in $^{16,\,22}$O

Calculation parameters

Effective interaction: Skyrme III

Single-particle states：

n, C, X : $1p_{3/2}$, $1p_{1/2}$, $1d_{5/2}$, $2s_{1/2}$, ($1d_{3/2}$, $2f_{7/2}$)

$x_{\alpha\alpha'}$: $\varepsilon_\alpha < 40$MeV, $\ell \leqq 4$, R = 20fm

Ground states of $^{16,22}O$

Occupation numbers

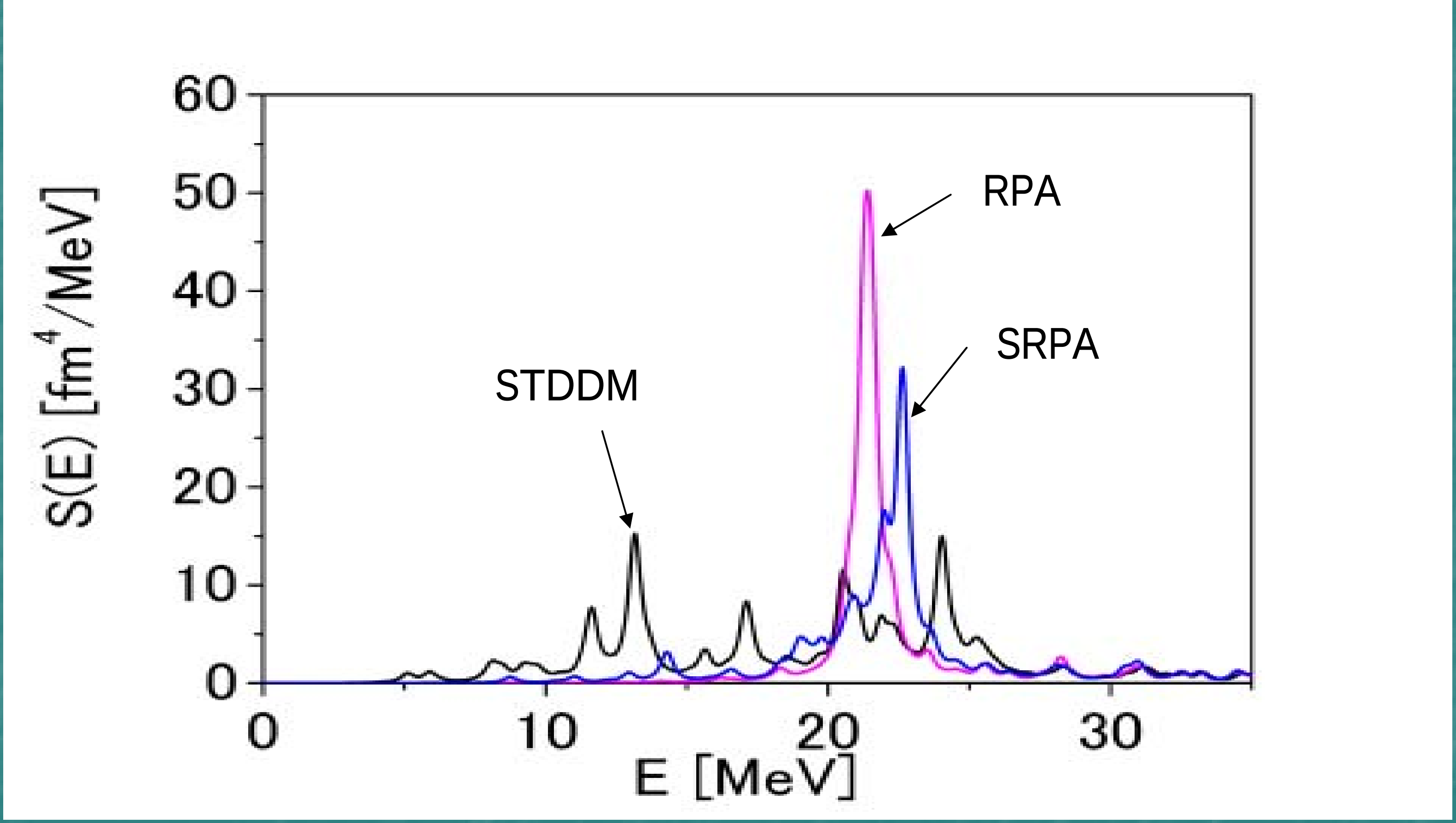
^{16}O

	Protons		Neutrons	
	ε_α(MeV)	n_α	ε_α(MeV)	n_α
$1p_{3/2}$	-18.3	0.90	-21.9	0.90
$1p_{1/2}$	-12.3	0.88	-15.7	0.88
$1d_{5/2}$	-3.8	0.10	-7.1	0.10
$2s_{1/2}$	1.0	0.02	-1.5	0.02

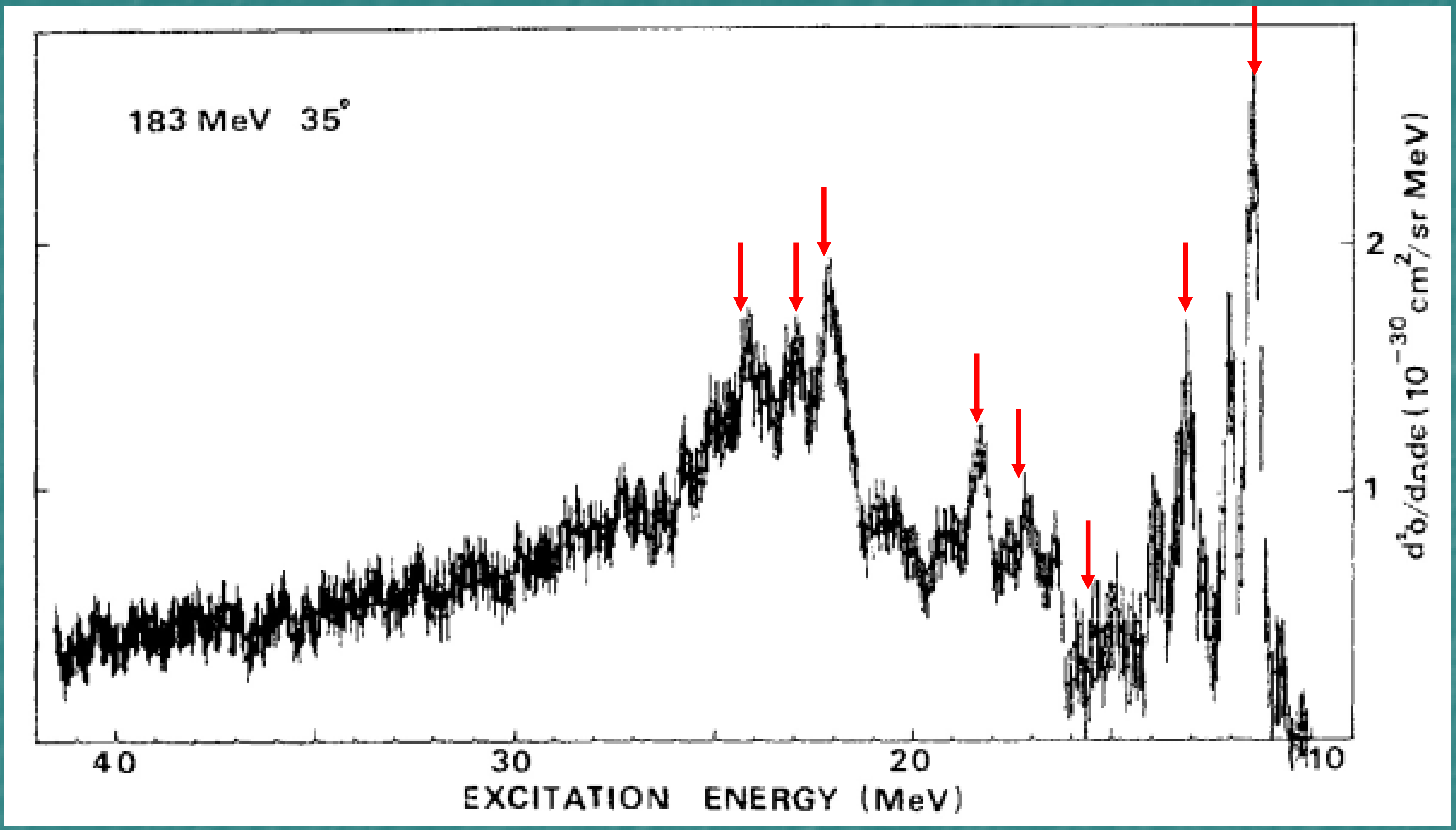
^{22}O

	Protons		Neutrons	
	ε_α(MeV)	n_α	ε_α(MeV)	n_α
$1p_{3/2}$	-29.0	0.985	-21.8	0.994
$1p_{1/2}$	-23.4	0.977	-17.1	0.993
$1d_{5/2}$	-14.4	0.012	-7.8	0.999
$2s_{1/2}$	-5.7	0.016	-2.6	0.022

^{16}O: Strength function for r^2Y_{20}



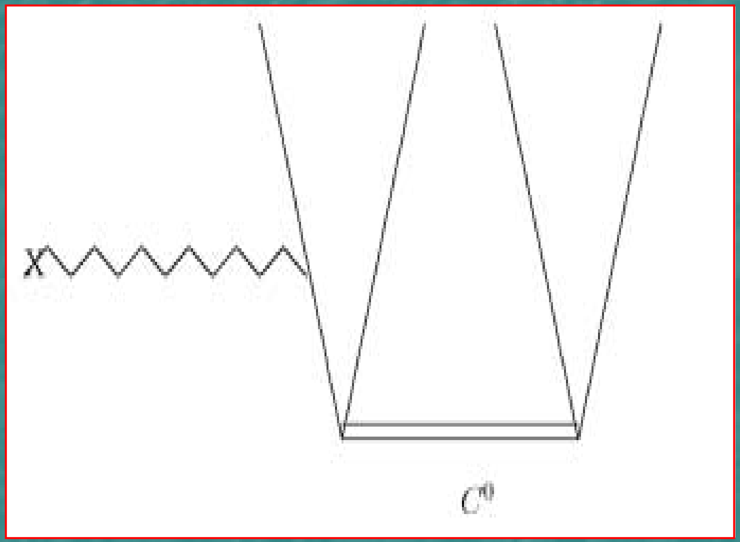
Spectrum of electrons scattered from ^{16}O



A. Hotta et al., Phys. Rev. Lett. 33(1974)790

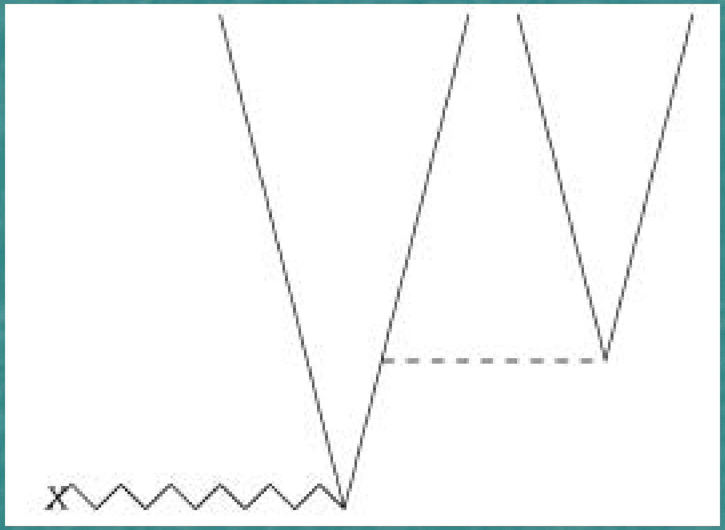
Damping processes

g. s. ⟶ 2p-2h



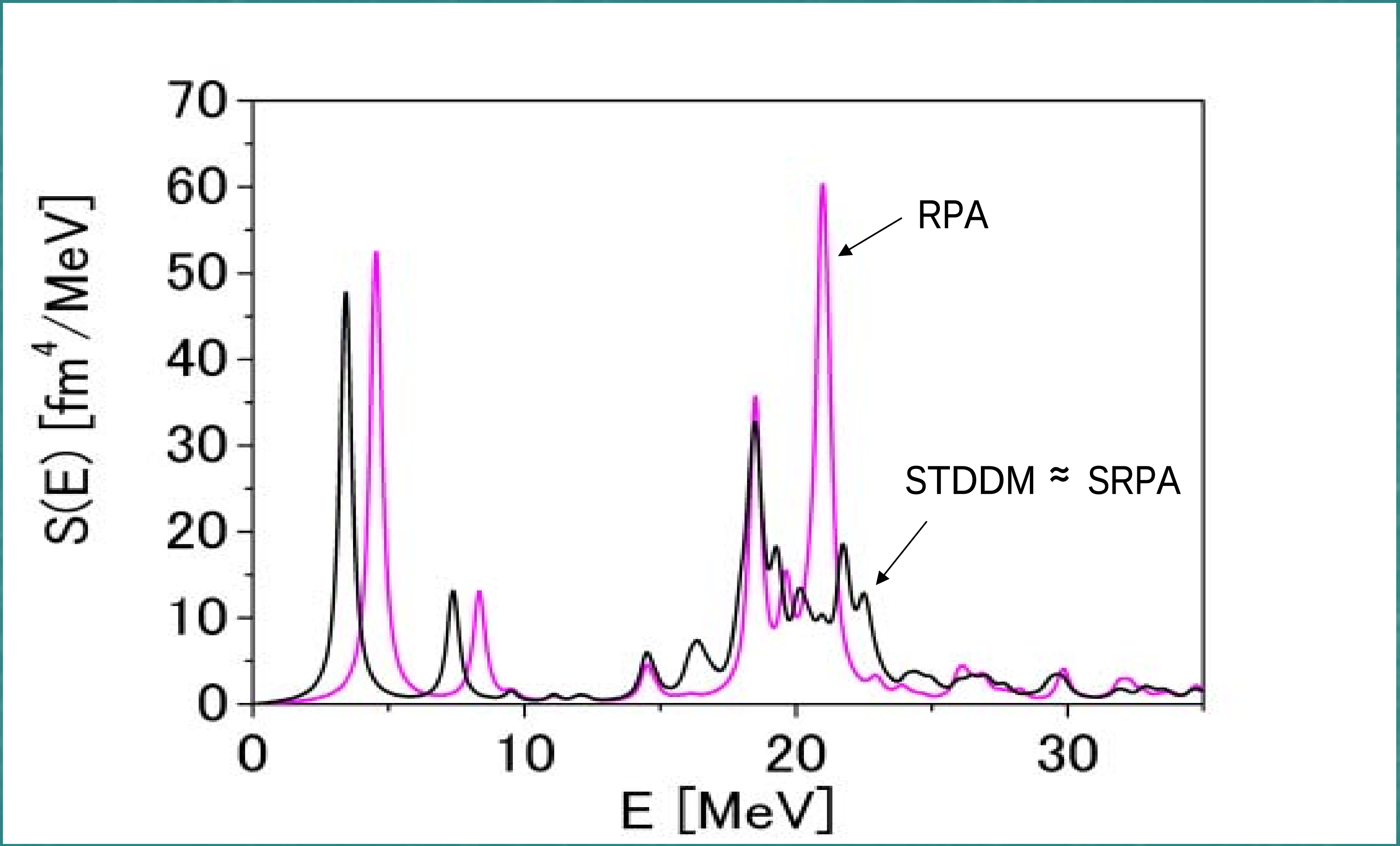
Only in STDDM

1p-1h ⟶ 2p-2h

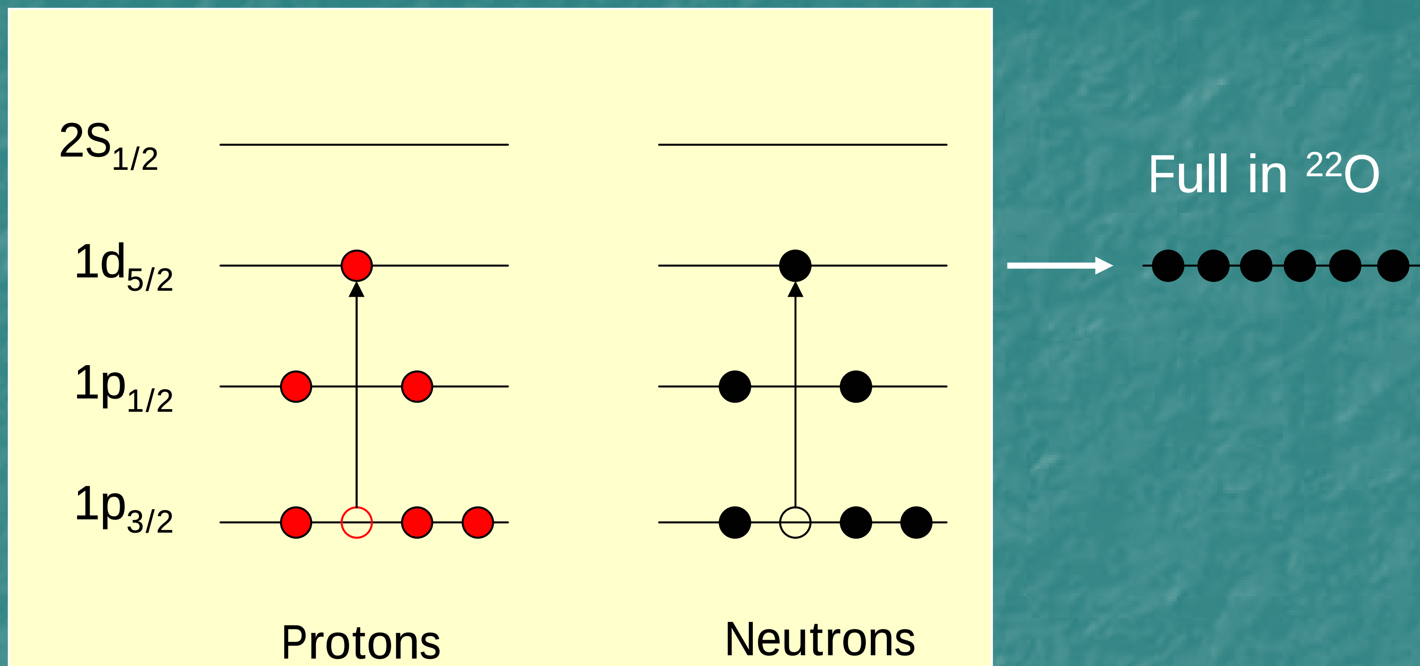


In SRPA and STDDM

^{22}O: Strength function for r^2Y_{20}



Important configurations in ^{16}O



Summary

- TDDM g.s. + STDDM was presented. Ground-state correlations are included.
- Larger fragmentation of GQR in ^{16}O was reproduced. Importance of ground-state correlations.
- GQR in ^{22}O has smaller spreading width due to excess neutrons.

M. Tohyama, Phys. Rev. C75, 044310(‘07).