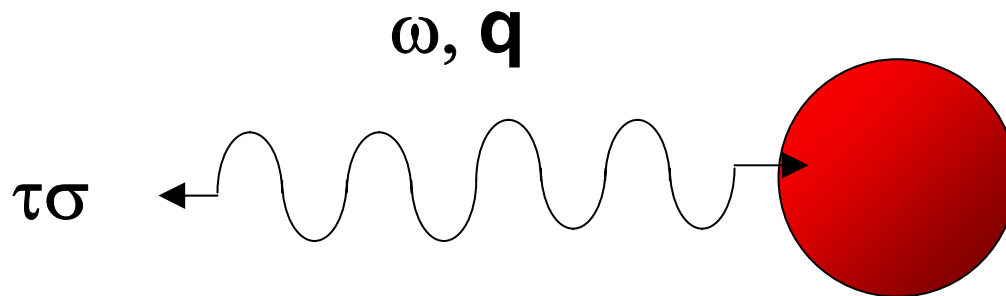


Unified Understanding of Spin Isospin Response Functions of Nuclei

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Various interesting subjects
depending on (\mathbf{q}, ω) region

Contrastive Phenomena

- **Quenching** of Gamow-Teller (GT) transition

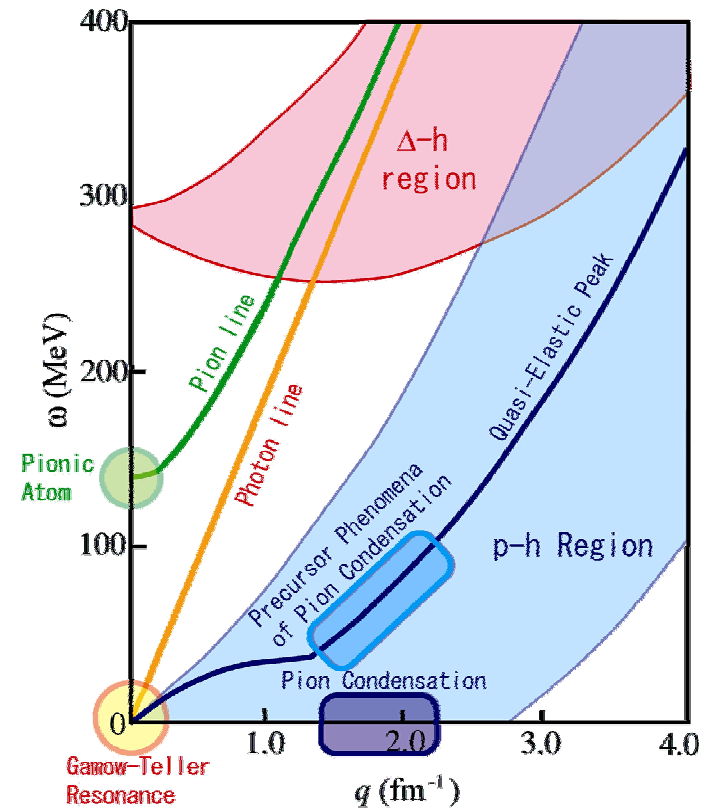
$$\tau\sigma : q \cong 0, \omega < 50\text{MeV}$$

- **Enhancement** of Pionic Response Functions

$$\tau\sigma \cdot q : q \cong q_c \cong 1.7\text{fm}^{-1}$$

$$\omega \cong q^2/2m$$

Quasi-elastic scattering (QES) region



Quenching of GT Transition

- GT response function $R_{GT}(\omega)$

$$O_{GT}^{\pm} = \mp \frac{1}{\sqrt{2}} \sum_{k=1}^A \left\{ \tau_{k,\pm 1} \boldsymbol{\sigma}_k + \frac{g_A^{N\Delta}}{g_A} (T_{k,\pm 1} \mathbf{S}_k - T_{k,\mp 1}^{\dagger} \mathbf{S}_k^{\dagger}) \right\}$$

$$R_{GT}^{\pm}(\omega) = \sum_n |\langle \Psi_n | O_{GT}^{\pm} | \Psi_0 \rangle|^2 \delta(\omega - (\mathcal{E}_n - \mathcal{E}_0))$$

$$\frac{d^2 \sigma_{1+}(q, \omega)}{d\Omega d\omega} = \hat{\sigma}_{GT} F(q, \omega) R_{GT}^{\pm}(\omega)$$

- GT sum rule and Quenching factor Q

$$S_{GT}^{\pm}(\omega_{\text{top}}^{\pm}) = \int^{\omega_{\text{top}}^{\pm}} R_{GT}^{\pm}(\omega) d\omega$$

$$Q = \frac{S_{GT}^{-}(\omega_{\text{top}}^{-}) - S_{GT}^{+}(\omega_{\text{top}}^{+})}{3(N - Z)}$$

If nucleus is made only of nucleons, $Q=1$

Enhancement of Pionic Response

- Pionic response function

Isovector spin-longitudinal response function R_L

$$O_L^\lambda(\mathbf{q}) = \sum_{k=1}^A \left\{ \tau_{k,\lambda} \boldsymbol{\sigma}_k \cdot \hat{\mathbf{q}} + \frac{f_{\pi N \Delta}}{f_{\pi NN}} \left(T_{k,\lambda} \mathbf{S}_k \cdot \hat{\mathbf{q}} + (-1)^\lambda T_{k,-\lambda}^\dagger \mathbf{S}_k^\dagger \cdot \hat{\mathbf{q}} \right) \right\} e^{i\mathbf{q} \cdot \mathbf{r}_k},$$

$$R_L^\lambda(q, \omega) = \sum_n |\langle \Psi_n | O_L^\lambda(\mathbf{q}) | \Psi_0 \rangle|^2 \delta(\omega - (\mathcal{E}_n - \mathcal{E}_0)),$$

- Precursor phenomena of pion condensation

R_L : Enhanced and soften

W.M. Alberico, M. Ericson and A. Molinari, Nucl. Phys. A379, 429(1982)



Extraction of R_L

- Spin-longitudinal polarized cross section ID_q
Polarization transfer coefficients D_{ij}

$$ID_q = \frac{I}{4} (1 - D_{nn} + D_{qq} - D_{pp})$$

- Eikonal approximation

$$ID_q = K \frac{A_{\text{eff}}}{A} |E|^2 R_L$$

Directly calculate ID_q by DWIA + continuum RPA



Method of Analysis

- Continuum RPA with orthogonality condition
 - Δ isobar is included
 - Woods-Saxon type mean field
 - Local effective mass

$$m^*(r) = m_N - \frac{f_{\text{WS}}(r)}{f_{\text{WS}}(0)}(m_N - m^*(0))$$

- Spreading widths

- DWIA + Two step processes

*K. Kawahigashi, K. Nishida, A. Itabashi and M. Ichimura,
Phys. Rev. C 63, 044609 (2001)*

Y. Nakaoka, Phys. Rev. C 65, 064616 (2002)



Effective Interaction

- $\pi + \rho + g'$ model

$$V^{\text{eff}}(\mathbf{q}, \omega) = V_{\text{LM}} + V_{\pi}(\mathbf{q}, \omega) + \mathbf{V}_{\rho}(\mathbf{q}, \omega)$$

- Landau-Migdal parameters

$$\begin{aligned} V_{\text{LM}} = & \frac{f_{\pi NN}^2}{m_{\pi}^2} g'_{NN} (\boldsymbol{\tau}_1 \cdot \boldsymbol{\tau}_2) (\boldsymbol{\sigma}_1 \cdot \boldsymbol{\sigma}_2) \\ & + \left[\left\{ \frac{f_{\pi NN} f_{\pi N\Delta}}{m_{\pi}^2} g'_{N\Delta} \left((\boldsymbol{\tau}_1 \cdot \mathbf{T}_2) (\boldsymbol{\sigma}_1 \cdot \mathbf{S}_2) + (\boldsymbol{\tau}_1 \cdot \mathbf{T}_2^{\dagger}) (\boldsymbol{\sigma}_1 \cdot \mathbf{S}_2^{\dagger}) \right) \right. \right. \\ & \left. \left. + \frac{f_{\pi N\Delta}^2}{m_{\pi}^2} g'_{\Delta\Delta} (\mathbf{T}_1 \cdot \mathbf{T}_2^{\dagger}) (\mathbf{S}_1 \cdot \mathbf{S}_2^{\dagger}) \right\} + (1 \leftrightarrow 2) \right] \end{aligned}$$

$R_{GT}(\omega)$ by MDA

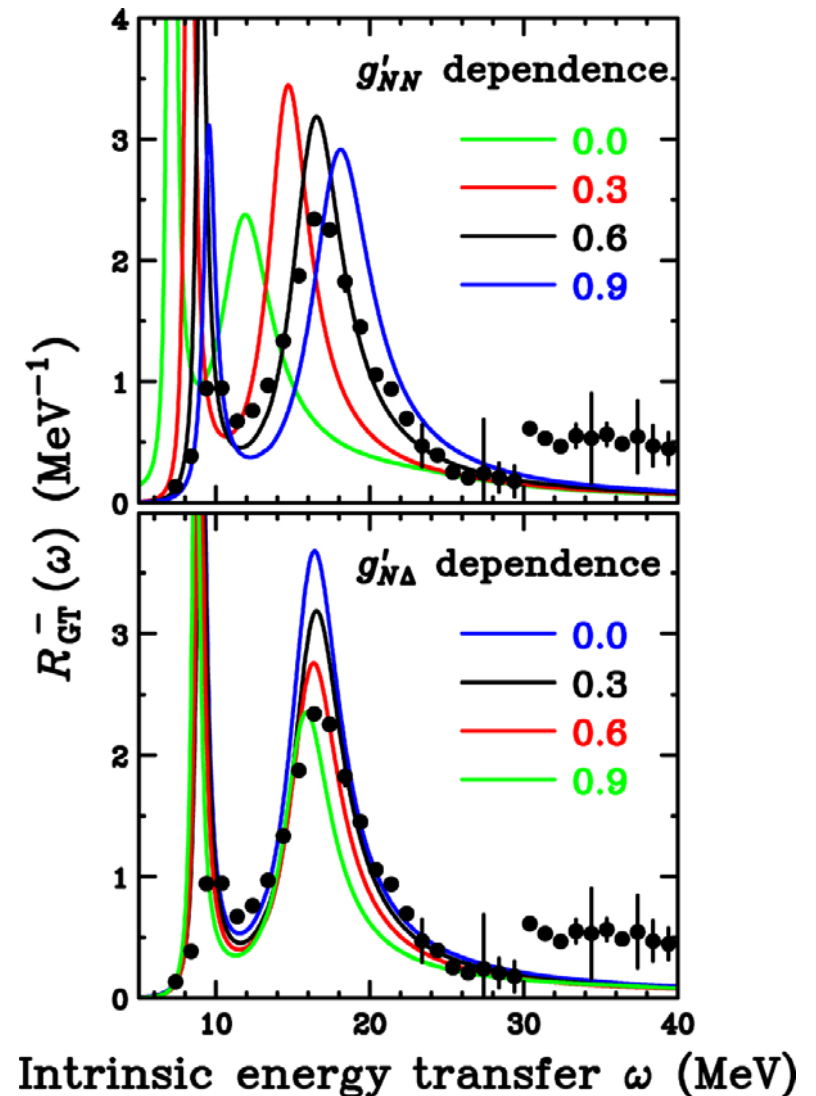
$^{90}\text{Zr}(p,n)^{90}\text{Nb}$, $T_p = 295$ MeV

T. Wakasa, et al.,

Phys. Rev. C 55 2909 (1997)

Obtained

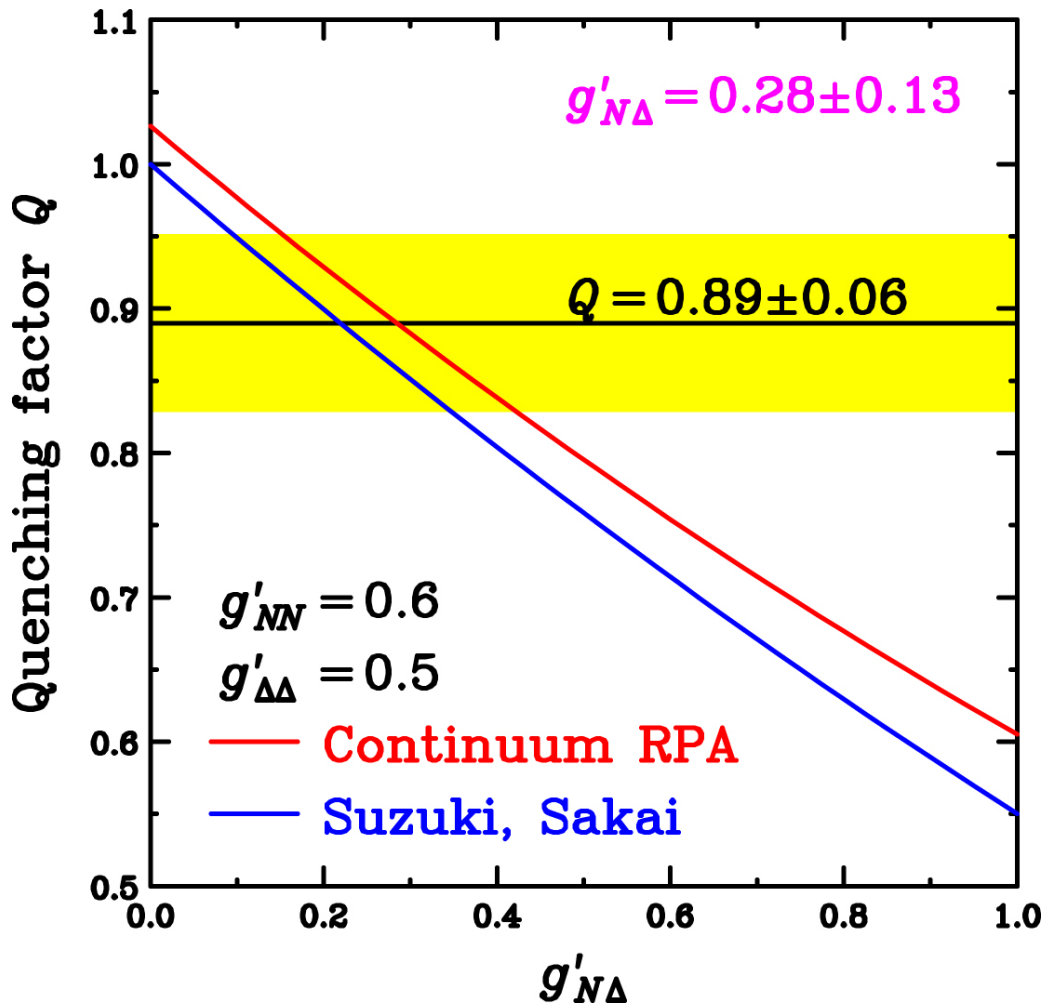
$$g'_{NN} \approx 0.6$$



GT Quenching Factor Q

Obtained

$$g'_{N\Delta} = 0.28 \pm 0.13$$



H. Sakai and K. Yako, Nucl. Phys. A731, 94 (2004)
T. Suzuki and H. Sakai, Phys. Lett. B 455, 25 (1999)



Summary

- Reproduced
the shape of the GT resonance,
the quenching of the total GT strength and
the enhancement of pionic response functions
in the same framework of the continuum RPA
with $V_\pi + V_\rho + V_{LM}$ including Δ degree of freedom.
(Unified way)
- Estimated the LM parameters and effective mass ,
which are common to all these phenomena.
 $g'_{NN} = 0.6-0.7$, $g'_{N\Delta} = 0.2-0.4$, $m^* = 0.7 m_N$
- $g'_{N\Delta}$ is much smaller than g'_{NN} and
universality ansatz does not hold