# CROSS-SECTIONS FOR THE SOLAR NEUTRINOS CAPTURE AND CHARGE-EXCHANGE RESONANCES

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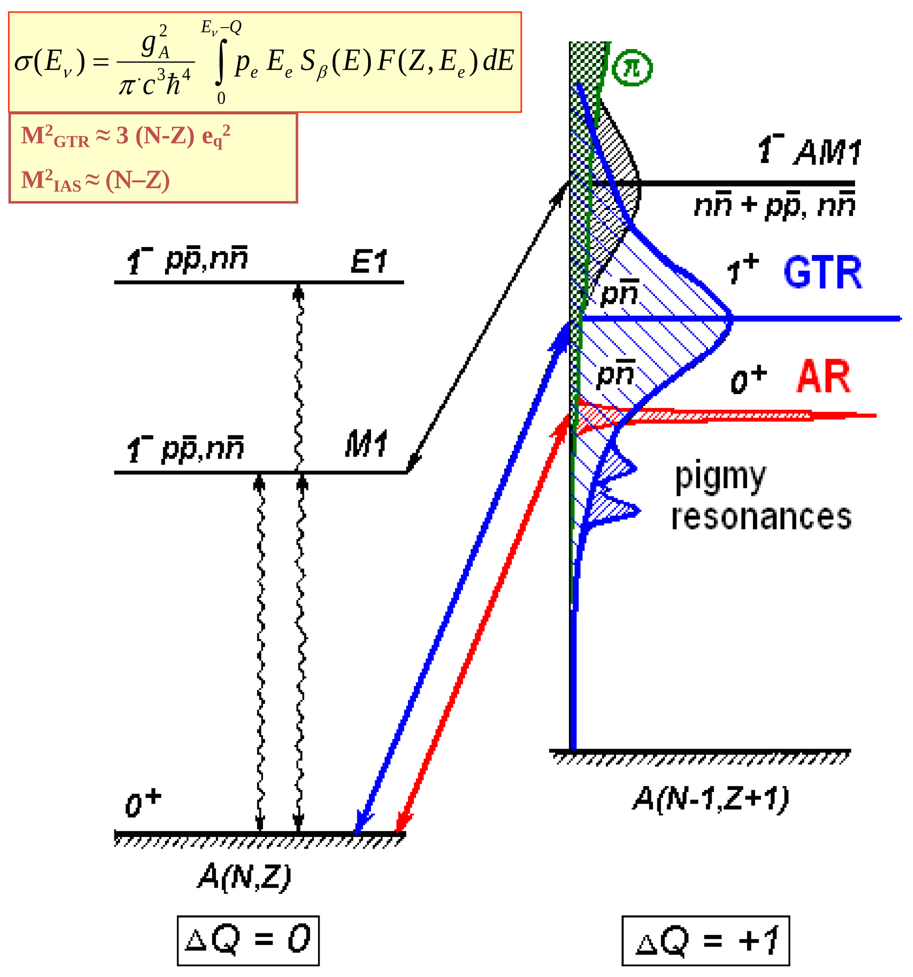
## Abstract

Investigation of charge-exchange resonances is important for calculating neutrino capturing cross-sections σ(*E*) of nuclei that can be used in neutrino detectors. Analog resonance, Gamow-Teller resonance (GTR) and three pigmy resonances are selected. Calculations were performed using the self-consistent theory of finite Fermi systems for Ga-71, Mo-98 and I-127. Even not accounting GTR gives a decrease of the σ(*E*) value more than 25%. Numbers of events in the interaction of solar neutrinos with these three nuclei calculated. It is shown that boron neutrinos make the main contribution and it is important to take into account all resonances.

## Nuclear Resonances




Neutral ( ΔQ = 0 ) and charge ( ΔQ = 1 ) excitation branches of nuclei. Gamow–Teller resonance (GTR), analog resonance (AR), and three pygmy resonances (PR1, PR2, PR3) are indicated for the A(N-1,Z+1) nucleus. **[1]**

## Solar neutrino spectrum

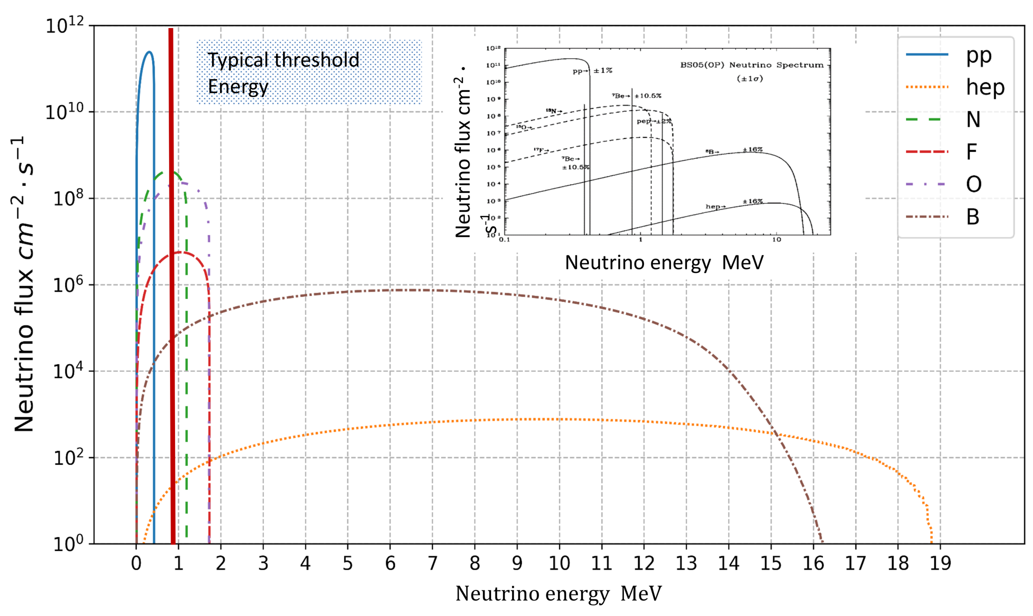



**Fig. 1.Solar neutrino spectrum in BS05(OP) model. [2]**

The neutrino capture rate was calculated from the formula :

$$R = \int_0^\infty \rho_{solar}(E_\nu)\, \sigma(E_\nu) \mathrm{d}E_\nu$$

The spectrum of solar neutrinos was taken from BS05(OP) model **[2]**. The greatest contribution to the capture rate is made by boron neutrinos.

## Theory

The Gamow–Teller resonances and other charge-exchange excitations of nuclei are described in Migdal TFFS-theory by the system of equations for the effective field:

$$V_{pn} = e_q V^{\omega}_{pn} + \sum_{p'n'} \Gamma^{\omega}_{np,n'p'} \rho_{p'n'} \qquad V^h_{pn} = \sum_{p'n'} \Gamma^{\omega}_{np,n'p'} \rho^h_{p'n'}$$

$$d^1_{pn} = \sum_{p'n'} \Gamma^{\xi}_{np,n'p'} \varphi^1_{p'n'} \qquad d^2_{pn} = \sum_{p'n'} \Gamma^{\xi}_{np,n'p'} \varphi^2_{p'n'}$$

where $V_{pn}$ and $V_{pn}{}^h$ are the effective fields of quasi-particles and holes, respectively;
$V_{pn}{}^{\omega}$ is an external charge-exchange field;
$d_{pn}{}^1$ and $d_{pn}{}^2$ are effective vertex functions that describe change of the pairing gap Δ in an external field;
$\Gamma^{\omega}$ and $\Gamma^{\xi}$ are the amplitudes of the effective nucleon–nucleon interaction in, the particle–hole and the particle–particle channel;
$\rho$, $\rho^h$, $\varphi^1$ and $\varphi^2$ are the corresponding transition densities. **[3]**
Local nucleon–nucleon δ-interaction $\Gamma^{\omega}$ in the Landau-Migdal form used:

$$\Gamma^{\omega} = C_0 (f_0' + g_0' \sigma_1 \sigma_2)\, \tau_1 \tau_2\, \delta(r_1 - r_2)$$

where coupling constants of: $f_0'$=1.35 – isospin-isospin and $g_0'$=1.22 – spin-isospin quasi-particle interaction with $L$ = 0. **[4]**
*Constants $f_0'$ and $g_0'$ are the phenomenological parameters.*

Matrix elements $M_{GT}$ : $$M^2_{GT} = \sum_{\lambda_1\lambda_2} \chi_{\lambda_1\lambda_2} A_{\lambda_1\lambda_2} V^{\varpi}_{\lambda_1\lambda_2}$$

where $\chi_{\lambda\nu}$ – mathematical deductions
G -T values are normalized in FFST: $$\sum_i M_i^2 = e_q^2 3(N - Z)$$

Effective quasiparticle charge $e_q^2 = 0.8 - 1.0$ is the "quenching" parameter of the theory.

## Theory vs Experiment

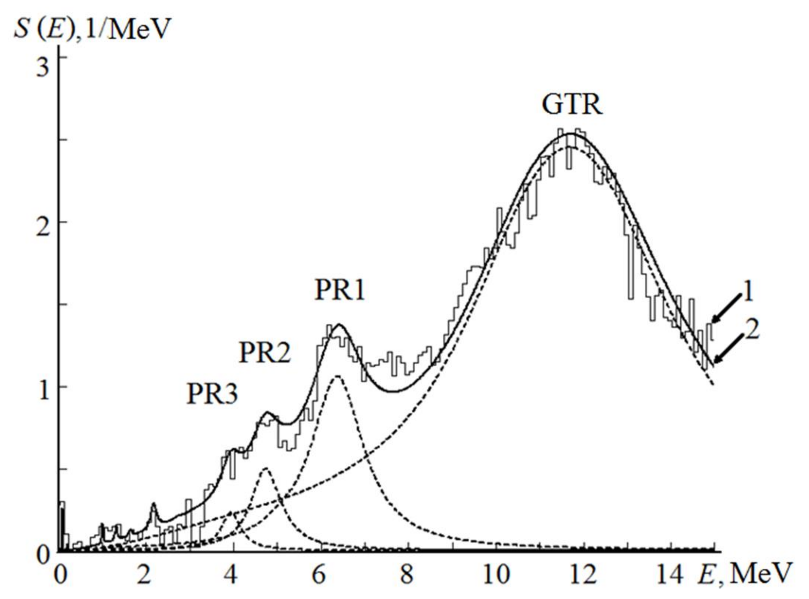



**Fig. 2. Theoretical [5] and experimental [6] strength functions for $^{71}Ga(p,n)^{71}Ge$ .**

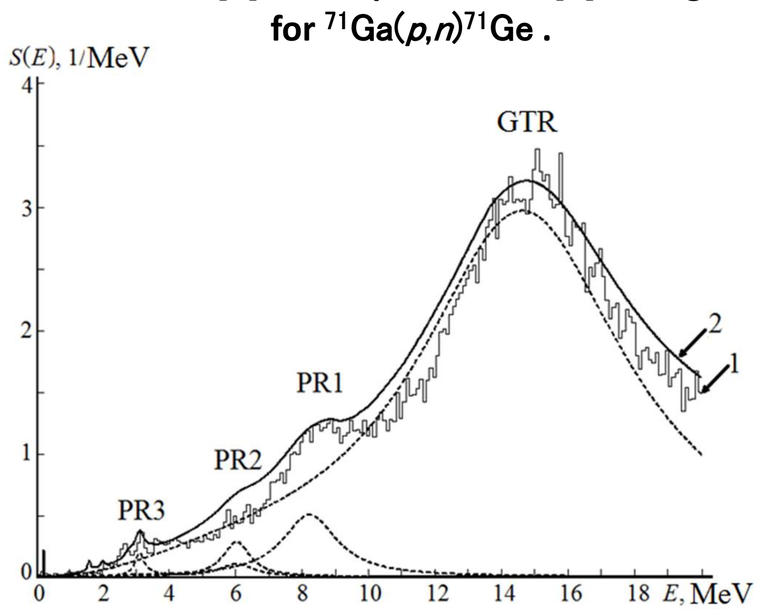



**Fig. 3. Theoretical [7, 8] and experimental [9] strength functions for $^{127}I(p,n)^{127}Xe$ .**

## Theory vs Experiment

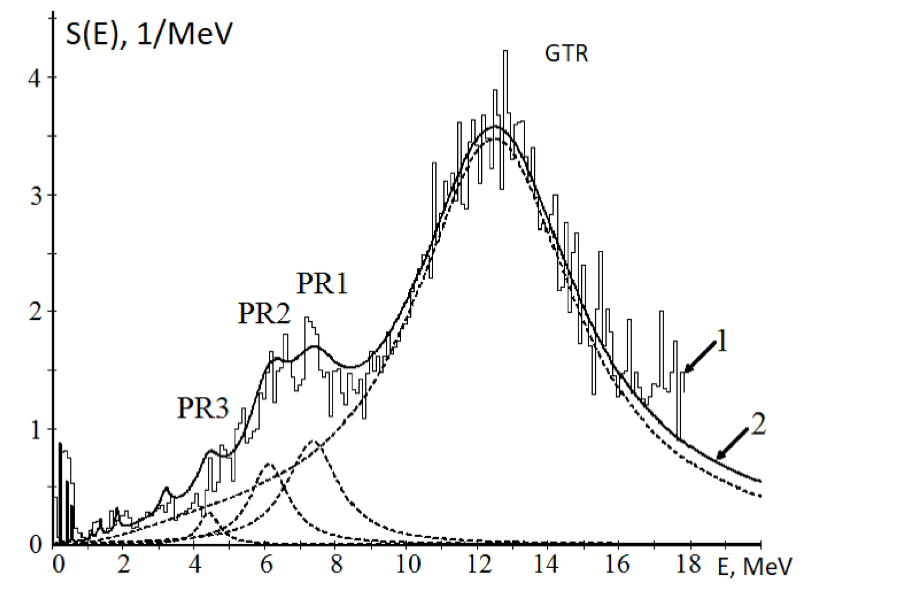



**Fig. 4. Theoretical and experimental [10] strength functions for $^{98}Mo(p,n)^{98}Tc$.**

## Neutrino capture cross-section example: $^{71}Ga(\nu,e)^{71}Ge$

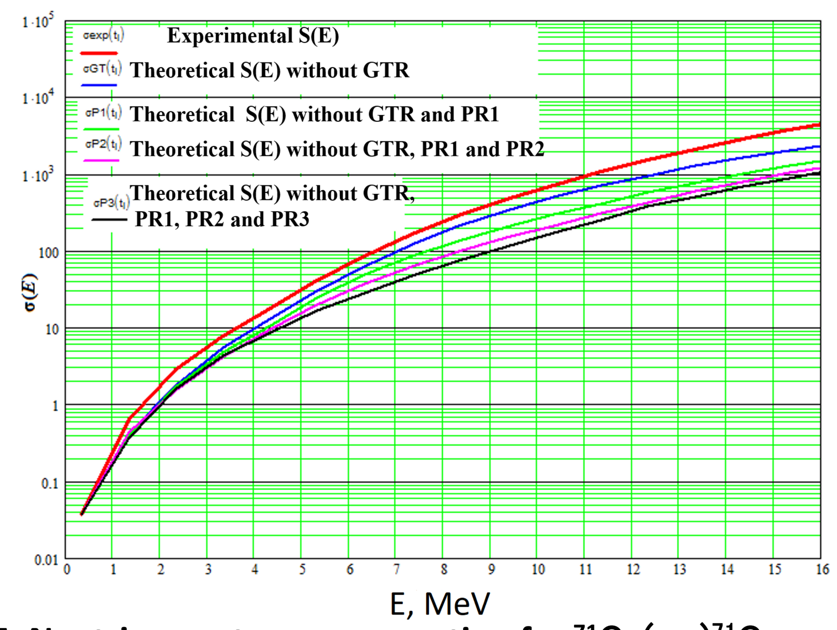



**Fig. 5. Neutrino capture cross-section for $^{71}Ga(\nu,e)^{71}Ge$ reaction as function of used model.**

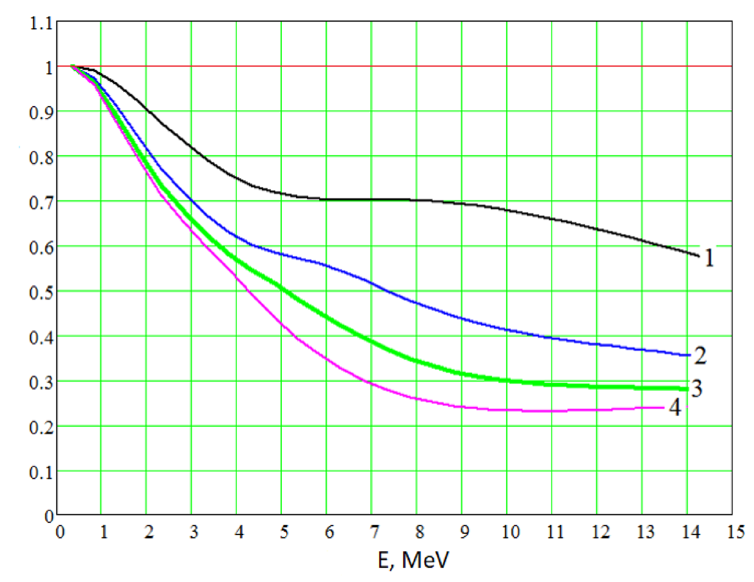



**Fig. 6. Relative cross-section dependence for next models:**
**1 – σ(tot)/σ(tot – without GTR);**
**2 – σ(tot)/σ(tot – without GTR and PR1);**
**3 – σ(tot)/σ(tot –without GTR, PR1 and PR2);**
**4 – σ(tot)/σ(tot – without GTR, PR1, PR2 and PR3)**

## Conclusions

- The are 3 types of the charge-exchange allowed resonances: Gamow–Teller and the analog resonances, and pygmy resonances.
- They can be good described using microscopic theory and in model approximation.
- The calculated values of the energies of Gamow–Teller and analog resonances, are in good agreement with their experimental data.
- Pygmy resonances may be described using the same approach as for Gamow–Teller and analog resonances.
- The role of pygmy resonances is very important in the charge-exchange reactions and in neutrino capturing and beta-delayed process.

| Isotope | Total flux (SNU) | Without GTR | Without PR1 and GTR |
|---|---|---|---|
| $^{71}Ga$ | 34.941 | 29.699 | 25.707 |
| $^{98}Mo$ | 17.463 | 11.643 | 10.078 |
| $^{127}I$ | 13.829 | 5.176 | 3.695 |

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