Neutrino-Nucleus Cross Section in the Gross Theory

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Outline

Introduction

-Finding a global model for astrophysical applications

-Theoretical models

Brief description of Gross Theory beta decay model

-Actual improvements

Numerical Results for GTBD

Neutrino-nucleus interaction

-Importance of nuclear structure calculations

-Formalisms

-Gross Theory for neutrino-nucleus reaction

Numerical results for GTNR

Summaring conclusions

Introduction: Why is necessary a global model?

- Nucleosynthesis of heavy elements in stellar reaction takes place in regions far away of β-stability line.
- In these regions there exist very few (or not) experimental data.
- Great number of nuclei involved in the reactions:

p-process ~ 2000 nuclei (γ,n),(γ,p),(γ, α),n-,p-, μ-cap, β+

s-process ~ 400 nuclei (n,γ), β-, EC

α-process ~1000 nuclei n-,p-, ν-capture, photodis.

r-process ~ 4000 nuclei (n,γ),(γ,n), β-, βdn, α-decay,fission.

A Global Model for nuclear astrophysics application

Introduction: Theoretical Models

(i) models with microscopical formalism with detailed nuclear structure, solves the microsc. quantum-mechanical Schrodinger or Dirac equation, provides nuclear wave functions and (g.s.-shape E_{sp} , J^{π} , log (ft), $\tau_{1/2}$ …)

Examples:

Shell Model (Martinez etal. PRL83, 4502(1999))

Self-Consistent Skyrme-HFB+QRPA

(Engel etal. PRC60, 014302(1999))

Density Functional+Finite Fermi Syst.

(Borzov etal. PRC62, 035501 (2000))

(ii) models describing overall nucler properties statistically where the parameters are adjusted to exp. data, no nuclear wave funct., polynomial or algebraic express.

Examples:

Gross Theory of β-decay (GTBD)

Takahashi etal. PTP41,1470 (1969)

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New exponential law for β^+.....

(Zhang etal. PRC73,014304(2006))

$\tau_{1/2}$ from ~GT in r-proc.

(Kar etal., astro-ph/06034517(2006))

Introduction : Why this model?

i) GTBD describes systematically the nuclear properties in the β-stability line and allows a extension to driplines.

ii) It is a parametric model that combines single-particle arguments and statistical arguments in phenomenological way.

GTBD original developed by K. Takahashi & M. Yamada PTP41,1470 (1969)

SGT semi gross theory : nuclear shell effects (nse) by Nakata etal. NPA625, 521 (1995)

GT2 nse+move the peak IAS from GT+ modification $D_{\Omega}(E,\varepsilon)$ by Tachibana RIKEN Rev. 26 (2000) 109.

GTBD (Gross Theory Beta decay) model (i)

GTBD estimates the β-decay strength function $|M_\Omega (E)|^2$ where Ω is the β-decay operator. Here all the final nuclear levels are treated as an averaged function based on sum rules of the β-decay strengths.

Experimental definition - Duke etal. NPA151(1970)609.

$$S_\beta = C\,|M_\Omega(E)|^2 = C\,\overline{|(\Psi_l,\Omega\Psi_0)|}^2\,\rho(E)$$

β-transition matrix element

level density

$$S_\beta(E) = \frac{b(E)}{f(Z,Q_\beta - E)\tau_{1/2}}$$

b(E) absolute β-feeding per MeV

f(Z,Qβ-E) Fermi function

$\tau_{1/2}$ β-decay half life

Sum rules

$$\int_{-Q}^{\infty} \left|M_\Omega(E)\right|^2 dE = \left(\Psi_0,\Omega^+\Omega\Psi_0\right)$$

$$\int_{-Q}^{\infty} E\left|M_\Omega(E)\right|^2 dE = \left(\Psi_0,\Omega^+[H,\Omega]\Psi_0\right)$$

$$\tau_{1/2} = \frac{1}{\sum_{0\le E_j\le Q_\beta} S_\beta(E_j)\,f(Z,Q_\beta - E_j)}$$

GTBD model (ii)

$$|M_\Omega(E)|^2 = \overline{|(\Psi_l, \Omega\Psi_0)|^2}\rho(E)$$

β-decay strength function is treated as an averaged nuclear matrix element

$$|M_\Omega(E)|^2 = \int D_\Omega(E,\varepsilon)W(E,\varepsilon)\frac{dn_1}{d\varepsilon}d\varepsilon$$

one-particle strength function

weight function

one-particle level density

Gausssian type

$$D_\Omega(E) = \frac{1}{\sqrt{2\pi\sigma_\Omega}}e^{-(E-E_\Omega)^2/(2\sigma_\Omega)^2}$$

Lorentz type

$$D_\Omega(E) = \frac{\Gamma_\Omega}{2\pi}\frac{1}{(E-E_\Omega)^2+(\Gamma_\Omega/2)^2}.$$

$$\Omega \equiv F, GT$$

GTBD model (iii)

For Fermi strength in limit of good isospin

$$\int |M_F(E)|^2 dE = N - Z$$

$$E_F = \pm(1.44 Z A^{-1/3} - 0.7825) MeV; \beta^{\pm}.$$
$$\sigma_F = \sigma_C = 0.157 Z A^{1/3} MeV.$$

For Gamow-Teller strength Ikeda sum rule

$$\int |M_{GT}(E)|^2 dE \cong 3(N - Z)$$

$$E_{GT} \approx E_F$$
$$\sigma_{GT} = \sqrt{\sigma_C^2 + \sigma_N^2}$$

Adjustable parameter

$$E_{GT} = E_F + 26 A^{-1/3} - 18.5(N - Z)/A$$
$$E_{GT} = E_F + \delta$$

$$E_{GT} = E_F + 6.7 - 30(N - Z)/A$$

Tachibana etal. PTP84(1990)641

Nakayama etal. PLB114(1982)217

Spin-orbit splitting $\Delta_{ls} \approx 20\ A^{-1/3}$

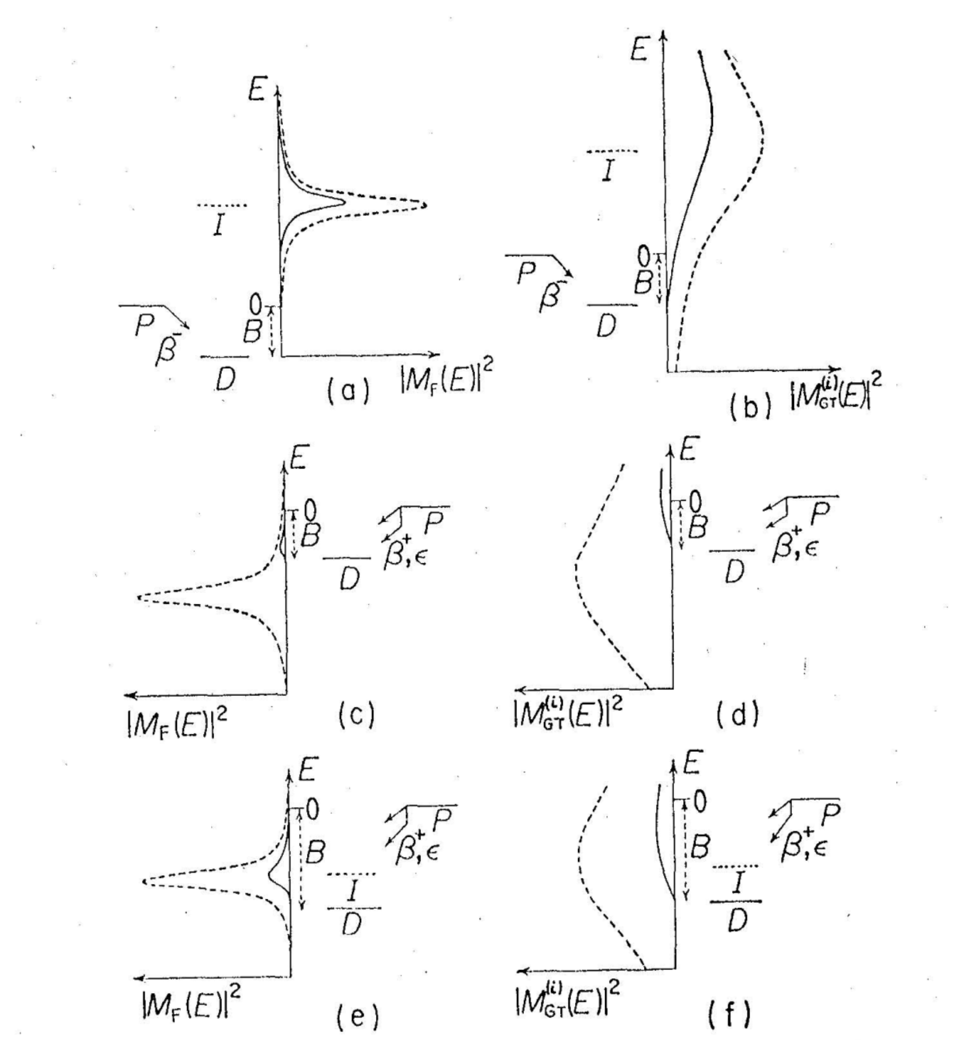
Isospin dependence

GTBD model (iv)

Total decay rate for allowed transitions

$$\lambda_\beta = \frac{G^2}{2\pi^3}\sum_j \left\{ g_V^2 \left|\int \hat{1}\right|^2 + g_A^2 \left|\int \hat{\sigma}\right|^2 \right\} f(E_I - E_j)$$

$$\lambda_\beta \approx \frac{G^2}{2\pi^3}\int_{-Q_\beta}^{0} \{ g_V^2 |M_F(E)|^2 + g_A^2 |M_{GT}(E)|^2 \} f(-E)dE$$



Schematic ilustration of GTBD

Solid lines $|M_F(E)|^2$: (a),(c),(e)

$|M_{GT}(E)|^2$: (b),(d),(f)

dashed within Pauli Principle,

(e),(f) superallowed transition

P: parent nucleus

D: daughter nucleus

I: IAS, B: range of β-decay

Credit figure: Takahashi & Yamada, PTP 41,1470(1969)

GTBD model- Fitting procedure (i)

- GTBD1

$$\chi_A^2 = \sum_{n=1}^{N_0} \left[\log_{10}\left(\tau_{1/2}^{cal}(n)/\tau_{1/2}^{exp}(n)\right)\right]^2,$$

i) Branching ratio AT ~ 50% total branching ratio

ii) Q_β –gs ≥10A$^{-1/3}$

- GTBD2

$$\chi_B^2 = \sum_{n=1}^{N_0'} \left[\frac{\log_{10}(\tau_{1/2}^{cal}(n)/\tau_{1/2}^{exp}(n))}{\delta \log_{10}(\tau_{1/2}^{*exp}(n))}\right]^2,$$

i) Explicit dependence exp. Error

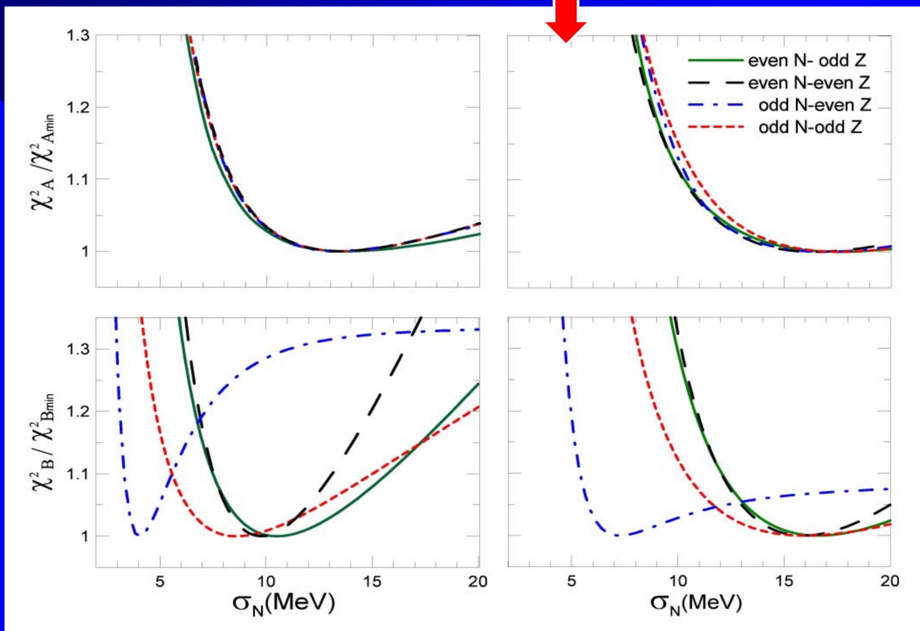
$$\delta \log_{10}(\tau_{1/2}^{*exp}(n)) = \left|\log_{10}[\tau_{1/2}^{exp}(n) + \delta\tau_{1/2}^{exp}(n)] - \log_{10}[\tau_{1/2}^{exp}(n)]\right|.$$

ii) log ft ≤ 6

iii) In both calculations the nuclei were separated in (N,Z) even-even, odd-odd, even-odd, odd-even

GTBD model- Fitting procedure (ii)

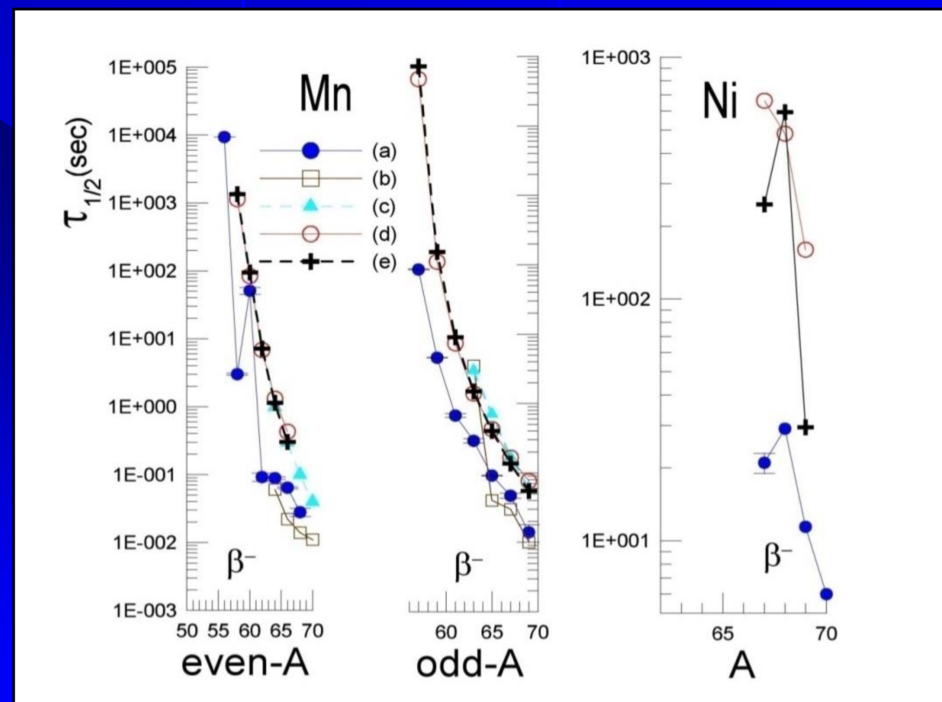
$$E_{GT} = E_F + \delta$$



$$E_{GT} \approx E_F$$

$$\chi^2_A = \sum_{n=1}^{N_0} \left[\log_{10}\left(\tau^{cal}_{1/2}(n)/\tau^{exp}_{1/2}(n)\right)\right]^2,$$

$$\chi^2_B = \sum_{n=1}^{N'_0} \left[\frac{\log_{10}(\tau^{cal}_{1/2}(n)/\tau^{exp}_{1/2}(n))}{\delta \log_{10}(\tau^{*exp}_{1/2}(n))}\right]^2,$$



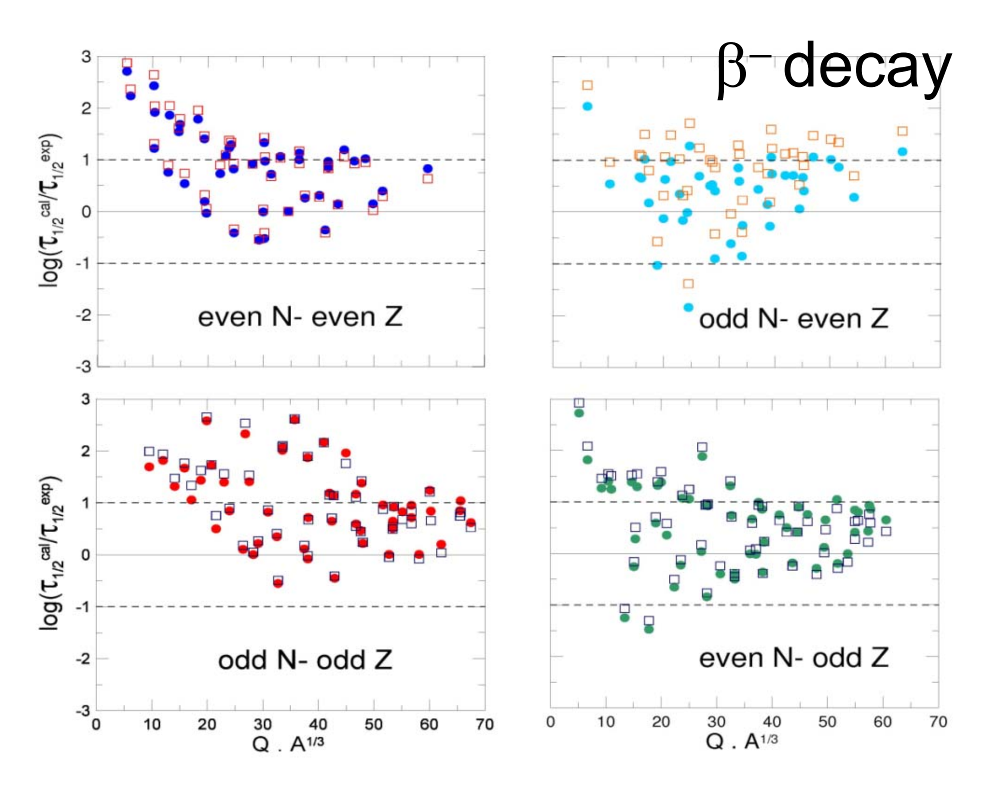
(a) Experimental
(b) EFTSI+CQRPA
(c) EFTSI+GT2
(d) GTBD1
(e) GTBD2

GTBD model
Numerical results (i)

$$E_{GT} \approx E_F \Rightarrow \sigma_N^* \quad \square$$

$$E_{GT} = E_F + \delta \Rightarrow \sigma_N \quad \bullet$$

$$\eta = 10^{\sqrt{\chi^2 / N_0}}$$



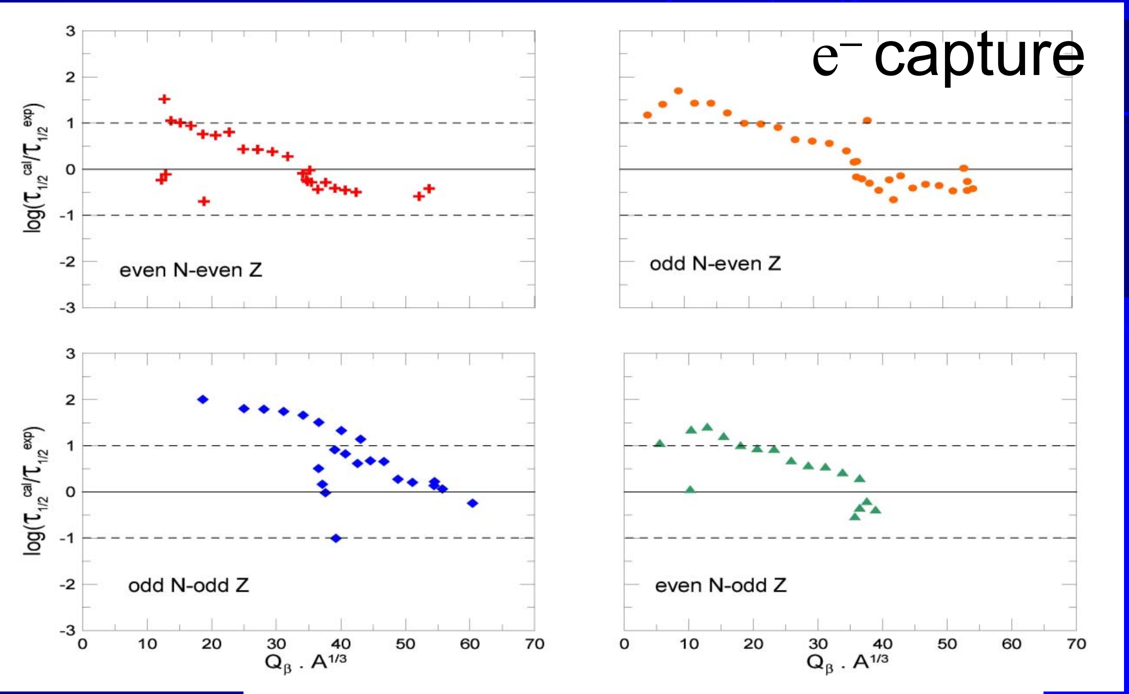
$N-Z$ (parent)	N_0	χ_A^2 σ_N^*	η^*	σ_N	η	χ_B^2 σ_N^*	η^*	σ_N	η
odd-odd	54	13.3 (5.0)	9.7 (45.5)	17.6	10.7	8.6	10.6	15.8	10.7
even-even	43	13.5 (4.5)	9.3 (12.9)	16.3	10.0	9.7	14.6	15.8	10.0
odd-even	40	13.0 (5.1)	6.1 (9.4)	16.8	6.4	4.1	15.6	7.2	9.8
even-odd	55	13.8 (5.1)	7.3 (6.5)	17.6	7.7	10.4	7.4	16.5	7.7

GTBD model
Numerical results (ii)

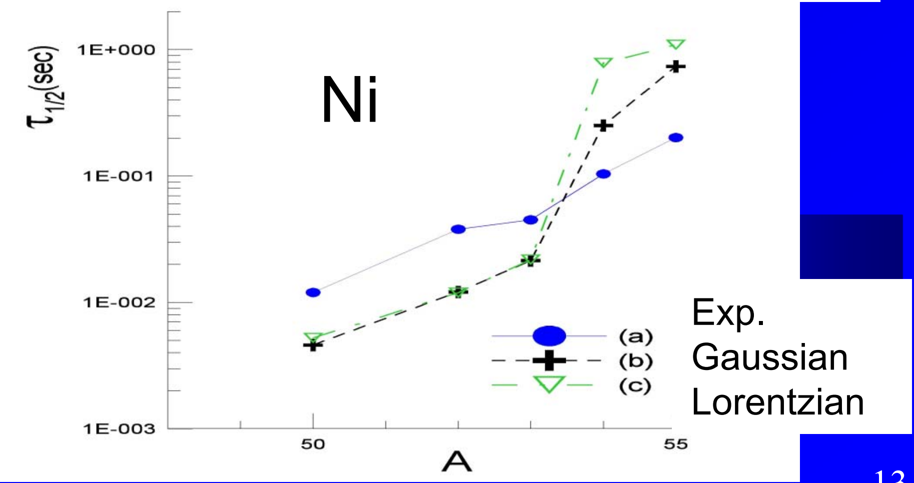
$$E_{GT} \approx E_F \Rightarrow \sigma_N^*$$ □

$$E_{GT} = E_F + \delta \Rightarrow \sigma_N$$ ●

$$\eta = 10^{\sqrt{\chi^2 / N_0}}$$



$N-Z$		χ^2_A		χ^2_B	
(parent)	N_0	σ_N	η	σ_N	η
odd-odd	23	9.7	10.7	10.4	10.7
even-even	24			9.9	5.2
odd-even	32	12.5	6.4	11.8	9.8
even-odd	17	12.2	7.7	12.2	7.7



Neutrino-nucleus interaction (i)

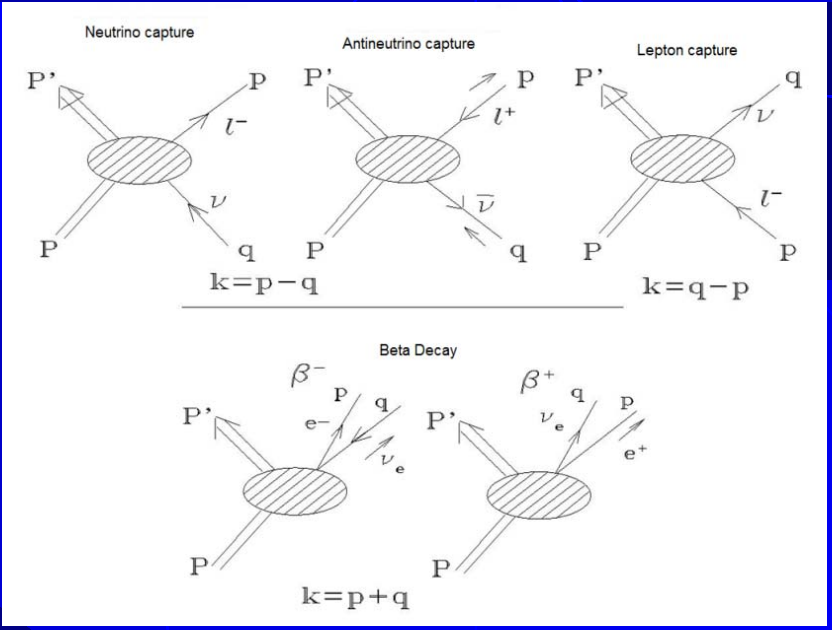
Semileptonic weak interactions with 12C, O'Connell, Donnelly &Walecka PRC6, 719(1972), J.D.Walecka, Muon Physics, Acad.N.Y. 1972.

$$\nu_e + A(Z,N) \Rightarrow A^*(Z+1,N-1) + e^-$$
$$\overline{\nu}_e + A(Z,N) \Rightarrow A^*(Z-1,N+1) + e^+$$

Charged Current neutrino

$$H_W(\vec{r}) = \frac{G}{\sqrt{2}} J_\alpha l_\alpha e^{-i\vec{k}\cdot\vec{r}}$$

Weak Hamiltonian (Walecka's book)
G : Fermi coupling constant



$$J_\alpha = \{\vec{J}, iJ_\Theta\} = \{-g_A\vec{\sigma} - i\overline{g}_W\vec{\sigma}\times\vec{k} - \overline{g}_V\hat{k} + \overline{g}_{P2}(\vec{\sigma}\cdot\hat{k})\hat{k} + g_V(-i\nabla/M), i[g_V + (\overline{g}_A + \overline{g}_{P1})(\vec{\sigma}\cdot\hat{k}) - g_V(\vec{\sigma}\cdot(-i\nabla/M))]\}$$

Hadronic current operator non-relativistic (Krmpotic etal. PRC71, 044319(2005))

$$\sigma(E_l, J_f) = \frac{p_l E_l}{2\pi} F(Z+1, E_l) \int_{-1}^{1} d(\cos\theta) T_\sigma(|\vec{k}|, J_f)$$

Neutrino-nucleus cross section

$$O_\alpha = \langle J_f M_f | J_\alpha e^{-i\vec{k}\cdot\vec{r}} | J_i M_i \rangle$$

$$T_\sigma(|\vec{k}|, J_f) \equiv \frac{1}{2J_i+1} \sum_{s_l s_\nu} \sum_{M_f M_i} |\langle J_f M_f | H_W | J_i M_i \rangle|^2 = \frac{G^2}{2J_i+1} \sum_{M_f M_i} O_\alpha O_\beta^* L_{\alpha\beta}$$

Nuclear Matrix element
Lepton trace

Transition amplitude

Neutrino-nucleus interaction (ii)

(i) J.D.Walecka, Theor. Nuc. and Subnuc. Phys. '95

(ii) Kuramoto etal. NPA 512, 711 (1990)
(iii) Luyten etal. NP41,236 (1963)(μ-capture)
(iv) Krmpotic etal. PRC71, 044319(2005).
$\approx$ all are equivalents.

$$\left(\frac{d\sigma_{i\to f}}{d\Omega_\ell}\right)_{\nu,\bar{\nu}} = \frac{(G_F V_{ud})^2 p_\ell E_\ell}{\pi}\frac{\cos^2\frac{\Theta}{2}}{(2J_i+1)}F(Z\pm 1,\epsilon_\ell)\left[\sum_{J=0}^{\infty}\sigma_{CL}^J + \sum_{J=1}^{\infty}\sigma_T^J\right],$$

where

$$\sigma_{CL}^J = |\langle J_f\|\tilde{M}_J(q) + \frac{\omega}{q}\tilde{L}_J(q)\|J_i\rangle|^2$$

and

$$\sigma_T^J = \left(-\frac{q_\mu^2}{2q^2} + \tan^2\frac{\Theta}{2}\right)\times\left[|\langle J_f\|\tilde{J}_J^{\mathrm{mag}}(q)\|J_i\rangle|^2 + |\langle J_f\|\tilde{J}_J^{\mathrm{el}}(q)\|J_i\rangle|^2\right]$$
$$\mp\tan\frac{\Theta}{2}\sqrt{\frac{-q_\mu^2}{q^2}+\tan^2\frac{\Theta}{2}}\times\left[2\,\mathrm{Re}\langle J_f\|\tilde{J}_J^{\mathrm{mag}}(q)\|J_i\rangle\langle J_f\|\tilde{J}_J^{\mathrm{el}}(q)\|J_i\rangle^*\right].$$

$$\mathsf{Y}_{JM}(\kappa\mathbf{r}) = j_J(\kappa r)Y_{JM}(\hat{\mathbf{r}})$$
$$\mathsf{S}_{JLM}(\kappa\mathbf{r}) = j_L(\kappa r)[Y_L(\hat{\mathbf{r}})\otimes\boldsymbol{\sigma}]_{JM}$$
$$\mathsf{P}_{JLM}(\kappa\mathbf{r}) = j_L(\kappa r)[Y_L(\hat{\mathbf{r}})\otimes\mathbf{v}]_{JM}$$
$$\mathsf{Y}_{JM}(\kappa\mathbf{r},\boldsymbol{\sigma}\cdot\mathbf{v}) = j_J(\kappa r)Y_{JM}(\hat{\mathbf{r}})(\boldsymbol{\sigma}\cdot\mathbf{v})$$

using four elemental operator from (iv)

$$\mathcal{M}_V(J) = i^{-J}\sqrt{\frac{4\pi}{2J_i+1}}\langle J_f\|\mathsf{Y}_J(\kappa\mathbf{r})\|J_i\rangle,$$
$$\mathcal{M}_A^M(J) = \sqrt{\frac{4\pi}{2J_i+1}}\sum_L i^{-L}F_{JLM}\langle J_f\|\mathsf{S}_{JL}(\kappa\mathbf{r})\|J_i\rangle,$$
$$\mathcal{M}_{A'}(J) = i^{-J}\sqrt{\frac{4\pi}{2J_i+1}}\langle J_f\|\mathsf{Y}_J(\kappa\mathbf{r},\boldsymbol{\sigma}\cdot\mathbf{v})\|J_i\rangle,$$
$$\mathcal{M}_{V'}^M(J) = \sqrt{\frac{4\pi}{2J_i+1}}\sum_L i^{-L}F_{JLM}\langle J_f\|\mathsf{P}_{JL}(\kappa\mathbf{r})\|J_i\rangle.$$

$$\mathcal{T}_\sigma(\kappa, J_f)$$
$$= G^2\sum_J\Big\{\mathcal{L}_{\emptyset\emptyset}\big[g_V^2|\mathcal{M}_V(J)|^2 + |(\overline{g}_A+\overline{g}_{P1})\mathcal{M}_A^0(J) - g_A\mathcal{M}_{A'}(J)|^2\big] + \mathcal{L}_{00}\big[\Re[(\overline{g}_V\mathcal{M}_V(J) - 2g_V\mathcal{M}_{V'}^0(J))\times\overline{g}_V\mathcal{M}_V^*(J)] + (\overline{g}_{P2}^2 - 2g_A\overline{g}_{P2})|\mathcal{M}_A^0(J)|^2\big]$$
$$+\sum_{M=0,\pm1}\mathcal{L}_{MM}|(g_A - M\overline{g}_W)\mathcal{M}_A^M(J) - g_V\mathcal{M}_{V'}^M(J)|^2$$
$$+2\mathcal{L}_{\emptyset 0}\Re\big(g_V[\overline{g}_V\mathcal{M}_V(J) - g_V\mathcal{M}_{V'}^0(J)]\mathcal{M}_V^*(J) + (g_A - \overline{g}_{P2})[(\overline{g}_A+\overline{g}_{P1})\mathcal{M}_A^0(J) - g_A\mathcal{M}_{A'}(J)]\mathcal{M}_A^{0*}(J)\big)\Big\}. \quad (2.37)$$

$$\mathsf{M}_J^M(\kappa\mathbf{r}) = \mathsf{Y}_{JM}(\kappa\mathbf{r}),$$
$$\Delta_J^M(\kappa\mathbf{r}) = \left(\frac{i\mathsf{M}}{\kappa}\right)\mathsf{P}_{JJM}(\kappa\mathbf{r}),$$
$$\Delta_J'^M(\kappa\mathbf{r}) = i^J\sqrt{2}\left(\frac{\mathsf{M}}{\kappa}\right)\sum_{L=J\pm1}i^{-L}F_{JLM}\mathsf{P}_{LJM}(\kappa\mathbf{r}),$$
$$\Sigma_J^M(\kappa\mathbf{r}) = \mathsf{S}_{JJM}(\kappa\mathbf{r}), \quad (2.46)$$
$$\Sigma_J'^M(\kappa\mathbf{r}) = i^{J-1}\sqrt{2}\sum_{L=J\pm1}i^{-L}F_{JLM}\mathsf{S}_{JLM}(\kappa\mathbf{r}),$$
$$\Sigma_J''^M(\kappa\mathbf{r}) = i^{J-1}\sum_{L=J\pm1}i^{-L}F_{JL0}\mathsf{S}_{JLM}(\kappa\mathbf{r}),$$
$$\Omega_J^M(\kappa\mathbf{r}) = \left(\frac{i\mathsf{M}}{\kappa}\right)\mathsf{Y}_{JM}(\kappa\mathbf{r},\boldsymbol{\sigma}\cdot\mathbf{v}).$$

(i) $\leftrightarrow$(iv)

(ii) $\leftrightarrow$(iv)

$$M_V^2 = \left(\frac{E_\nu}{m_\mu}\right)^2\sum_J|\mathcal{M}_V(J)|^2,$$
$$M_A^2 = \left(\frac{E_\nu}{m_\mu}\right)^2\sum_J\sum_{M=0,\pm1}|\mathcal{M}_A^M(J)|^2,$$
$$M_P^2 = \left(\frac{E_\nu}{m_\mu}\right)^2\sum_J|\mathcal{M}_A^0(J)|^2.$$

$$|\langle f|\tilde{1}|i\rangle|^2 = \sum_J|\mathcal{M}_V(J)|^2,$$
$$\langle f|\tilde{\sigma}|i\rangle|^2 = \sum_J\sum_{M=0,\pm1}|\mathcal{M}_A^M(J)|^2,$$
$$\Lambda = \frac{1}{3}\sum_J(|\mathcal{M}_A^0(J)|^2 - |\mathcal{M}_A^1(J)|^2);$$

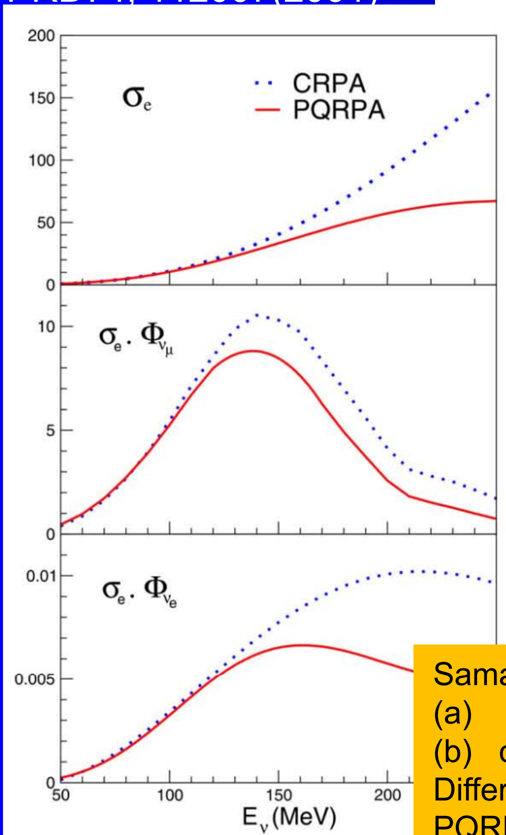
(iii) $\leftrightarrow$(iv)

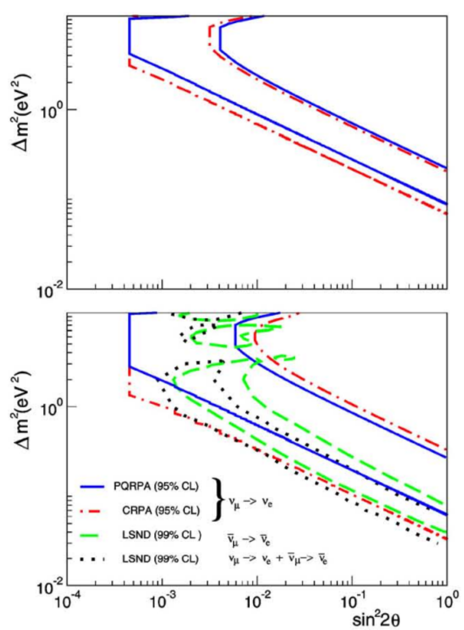
Neutrino-nucleus interaction (iii)

Neutrino-nucleus cross section is important to constrain parameters in neutrino oscillations.

LSND experiment
PRD74, 112007(2001)

$\bar{\nu}_\mu \to \bar{\nu}_e$ $\nu_\mu \to \nu_e$





Samana et al. PLB642 (2005) 100
(a) increasing probability oscillations.
(b) confidence level region is diminished
Difference in σ_e between
PQRPA and CRPA

Neutrino-nucleus cross section is important in astrophysics:

Fuller & Meyer, AsJ 453, 792 (1995)
'Neutrino Capture and Supernova Nucleosynthesis'

$$\sigma_i \approx \langle G \rangle \frac{\ln 2}{ft_{ij}} (m_e c^2)^{-5} (Q_n^{ij} + E_\nu)^2$$

$$S_\beta \equiv \sum_f (|M_{GT}|^2)_{if} = \sum_{if} n_p^i n_n^f \, 6 \begin{Bmatrix} 1/2 & 1/2 & 1 \\ j_i & j_f & l \end{Bmatrix}^2$$

McLaughlin & Fuller, AsJ 455, 202 (1995)
'Neutrino Capture on Heavy Nuclei'

$$S(E) = \exp\left[\frac{-(E-E_{GT})^2}{k^2 T_{\nu_e}^2 w^2}\right] \Bigg/ \int_{E_{gs}}^{\infty} \exp\left[\frac{-(E-E_{GT})^2}{k^2 T_{\nu_e}^2 w^2}\right] dE$$

Neutrino-nucleus interaction (iv)

Y.-Z. Qian etal. PRC55, 1532(1997)
‘Neutrino-induced spallation and supernova r-process nucleosynthesis’

$$\sigma(E_\nu) = \frac{G^2{}_F \cos^2\theta_c}{\pi} k_e E_e F(Z+1, E_e)[|M_F(E)|^2 + (g_A^{eff})^2 |M_{GT}(E)|^2],$$
$$|M_{GT}(E)|^2 \approx S \exp[-(E-E_{GT})^2/\Delta^2].$$

Balantekin & Fuller JPG29,2513(2003)
‘Supernova neutrino-nucleus astrophysics’
-analise open question for neutrino-nucleus interactions in core-collapse supernovae,
-implications in neutrino mixing in supernovae.

We will use the GTBD to estimate neutrino-nucleus cross section

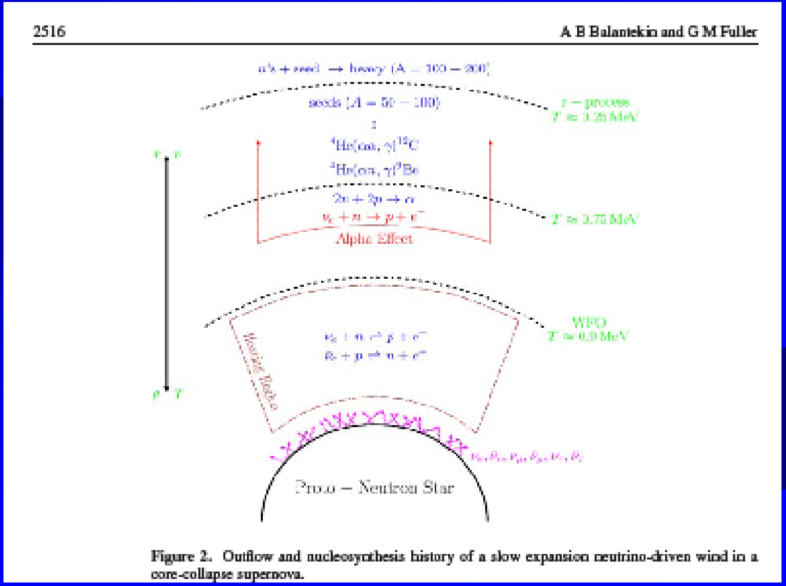


Figure 2. Outflow and nucleosynthesis history of a slow expansion neutrino-driven wind in a core-collapse supernova.

Gross Theory for the neutrino reaction (GTNR)

Neutrino-nucleus cross section dependent of E_ν (Krmpotic etal PRC71 (2005) 044319)

$$\sigma(E_l, J_f) = \frac{p_l E_l}{2\pi} F(Z+1, E_l) \int_{-1}^{1} d(\cos\theta) T_\sigma(|\vec{k}|, J_f)$$

in stellar conditions

$$|\vec{k}| \to 0$$

allowed transition

$$\sigma(E_\nu) = \frac{G^2}{\pi} \int_0^{E_\nu - m_e} p_e E_e F(Z+1, E_e)[g_V^2 |M_F(E)|^2 + g_A^2 |M_{GT}(E)|^2] dE$$

Neutrino thermal flux: zero-chemical potential Fermi-Dirac distribution

$$\Phi(E_\nu) = \frac{N}{2\pi} \frac{E_\nu^2}{e^{E_\nu/T_\nu} + 1}$$

Thermal Neutrino-nucleus cross section

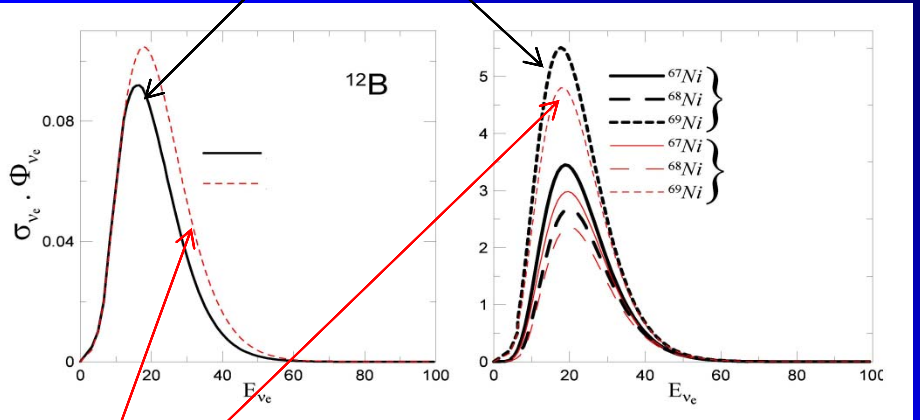
$$\langle \sigma_\nu \rangle = \int_{E_{th}}^{\infty} \Phi(E_\nu) \sigma(E_\nu) dE$$

GTNR Numerical Results (i)

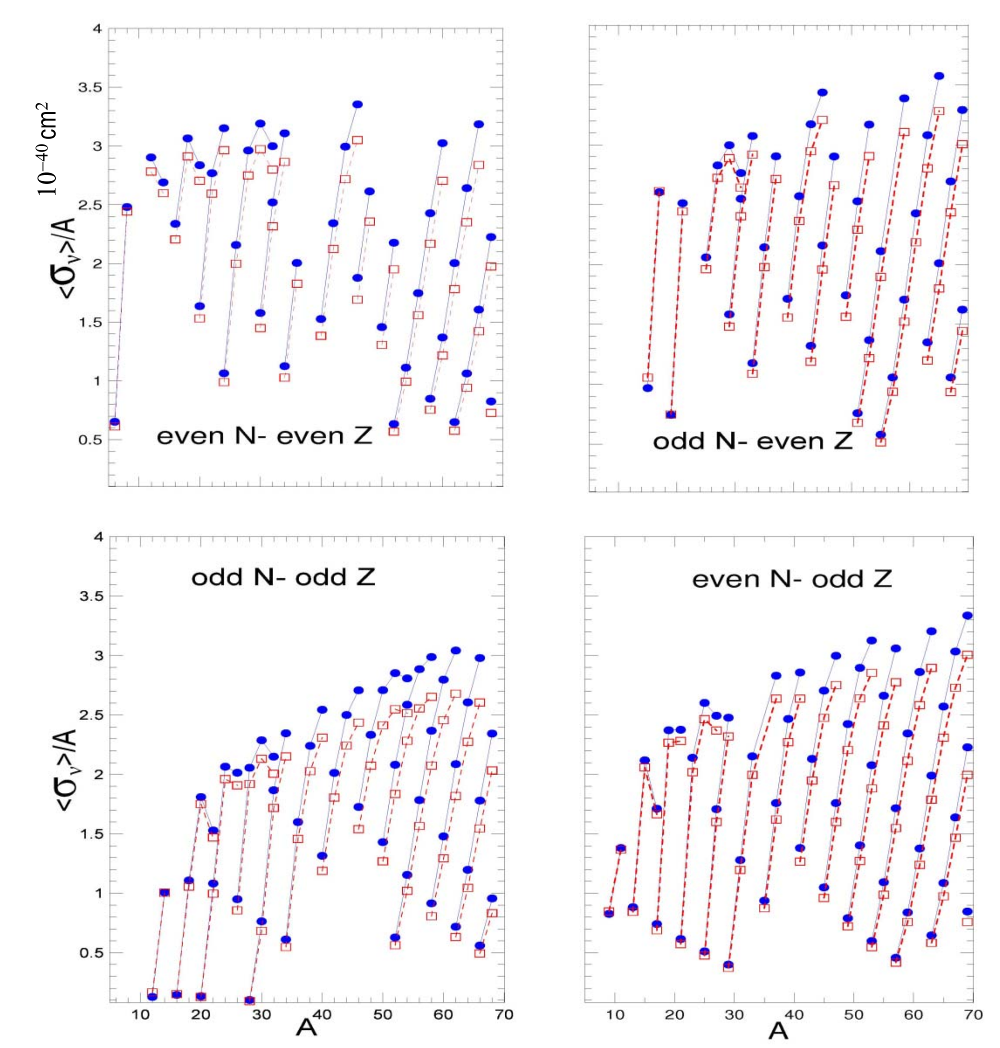
$$\langle \sigma_\nu \rangle = \langle \sigma_\nu \rangle (T_\nu)$$

is a function of temperature.
We evaluate in Tν=4 MeV.

$E_{GT} \approx E_F$ ●

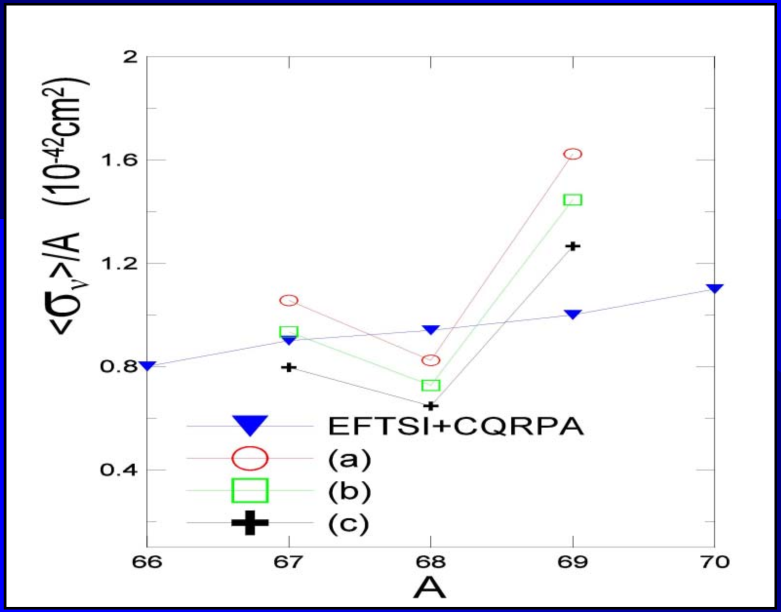


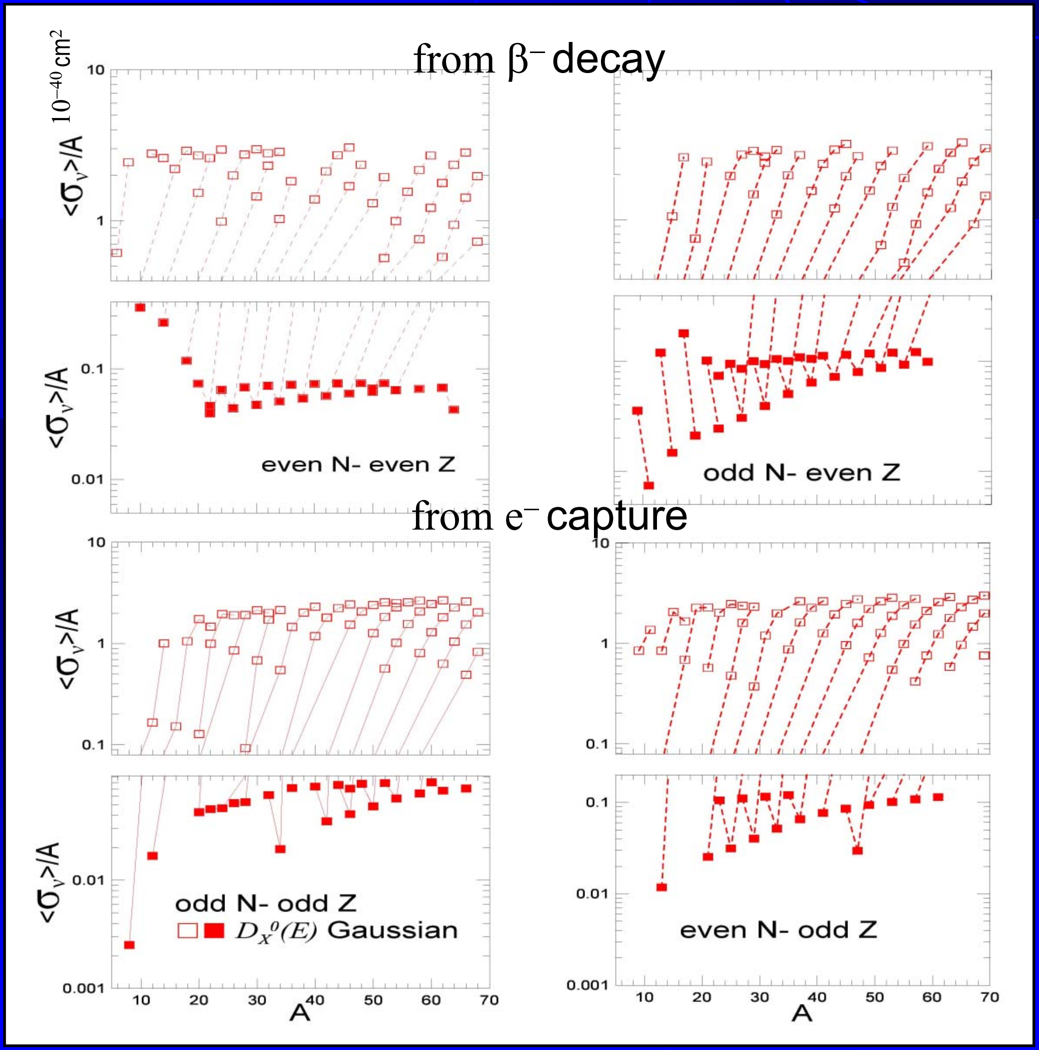
$E_{GT} = E_F + \delta$ □



Reduced thermal cross section $\langle \sigma_\nu \rangle / A$ Tν=4 MeV.

GTNR Numerical Results (ii)





EFTSI+CQRPA

Borzov et al. PRC62(2000)035501

(a) Gauss. $E_{GT} \approx E_F$

(b) Gaussian $E_{GT} \approx E_F + \delta$

(c) Lorentzian $E_{GT} \approx E_F + \delta$

Summaring Conclusions

- The results for the decay rates overestimate the experimental data. This is a general result for the GTBD.
- We have evaluated the folded neutrino-nucleus cross section with a neutrino thermic flux for nuclei with A<70.
- Our theoretical results for these cross section are closed to those obtained from other microscopical formalism more ellaborated.
- The actual $\langle\sigma\rangle$ can be ‘adopted’ as a superior limit for future microscopic calculations.

..and more

- The formalism of GTBD must be extended to take into account the forbidden transtions.
- Evaluate the neutrino-nucleus cross section with GT2 and SGT.
- Use these new $\langle\sigma\rangle$ to analise the r-process.

…and more

- Using the numerical results for the decay rates with A<70, we extend to evaluate these quantities in stellar conditions.

$$\lambda_{D\beta}^{(Z,A)}(\rho,T,Y_e) = \lambda_F^{(Z,A)}(\rho,T,Y_e) + \lambda_{GT}^{(Z,A)}(\rho,T,Y_e),$$

$$\lambda_F^{(Z,A)}(\rho,T,Y_e) = \frac{G_F^2 g_V^2}{2\pi^3}\int_{-Q}^{0} dE\,|\mathcal{M}_F(E)|^2\,\mathcal{P}(E,T)\Phi(\rho,T,Y_e,-E),$$

$$\lambda_{GT}^{(Z,A)}(\rho,T,Y_e) = \frac{3G_F^2 g_A^2}{2\pi^3}\int_{-Q}^{0} dE\,|\mathcal{M}_{GT}(E)|^2\,\mathcal{P}(E,T)\Phi(\rho,T,Y_e,-E),$$

$$\mathcal{P}(E,T) = \frac{exp-(\frac{-E+E_0}{k_B T})}{G(A,Z,T)},$$

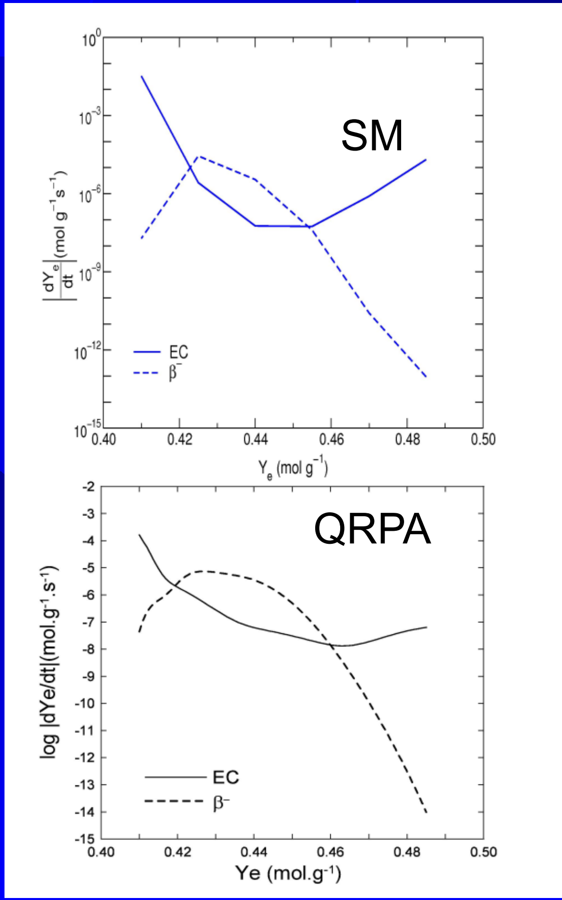
$$\Phi(\rho,T,Y_e,-E) = \int_0^{\frac{1}{c}\sqrt{E^2-m_e^2c^4}} (-E-E_e)^2 F(Z+1,E_e)p_e^2\mathcal{F}(E_e)dp_e,$$

...and more

- We pretend compare the results of the GTBD with more ellaborated formalism SM, QRPA, PQRPA and FQTDA

For example: evaluate isotopic abundances in presupernova scenario.

$$\frac{dY_e}{dt} = \frac{dY_e^{EC}}{dt} + \frac{dY_e^{\beta}}{dt}, = \sum_k \frac{X_k}{A_k}(-\lambda_k^{EC} + \lambda_k^{\beta}),$$



Results SM [2] < 1% that SM [3]

Results QRPA [4] >30% that SM [3]

[2] Langanke etal. NPA673(2000)481
[3]Aueferheide etal. AJS91(1994)389
[4]Dimarco, PhD thesis , SP, Brazil unpublished

THANKS