Nuclear Reponses for Neutrinos

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Abstract

- 1. Nuclear physics of ν's are new windows for physics beyond the SM and astrophysics.

- 2. Nuclear isospin spin responses of τY_λ and $\tau\sigma Y_\lambda$ responses for ν are crucial for ν studies in nuclei.

- RCNP, as a key node lab. of MESON(Medium Energy Science Open Network), should develop ν nuclear physics by LI (hadron), photon and lepton probes as well as the ν studies at Oto Cosmo (underground) Observatory

Neutrino Nuclear Physics

Physics of ν

Non accelerator lab.

Oto Cosmo Observatory

Nuclear responses for ν

Accelerator labs.

RCNP LI (Hadrons)

Spring 8 LEPS γ

Tokai Leptons ν–μ

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- MOON (Mo Obvatory Of Neutrions).

1. Neutrino & Weak Interaction studies in nuclei

Lepton Nuclear Physics Frontier

Neutrinos are windows for new particle and astronuclear physics.

- ν : Majorana/Dirac particle
- ν mass, ν helicity, left /right
- ν oscillation, flavor mixings, mass differenc
- ν interactions in the sun, supernova, and stars.

- Fundamental properties of ν's and week forces
- and ν astrophysics are well studied in nuclei.

- $\beta\beta$ in nuclei, ν-absorption(inverse β decay) of solar supernova and accelerator ν's and others
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Nuclear responses for ν studies

- Charged (τ_+,τ_-) and neutral (τ_3)
- Vector (σ^S S=0) and axial vector (σ^S S=1)
- Isospin $<\tau Y_L>$ and spin isospin $<\tau\sigma Y_L>_J$

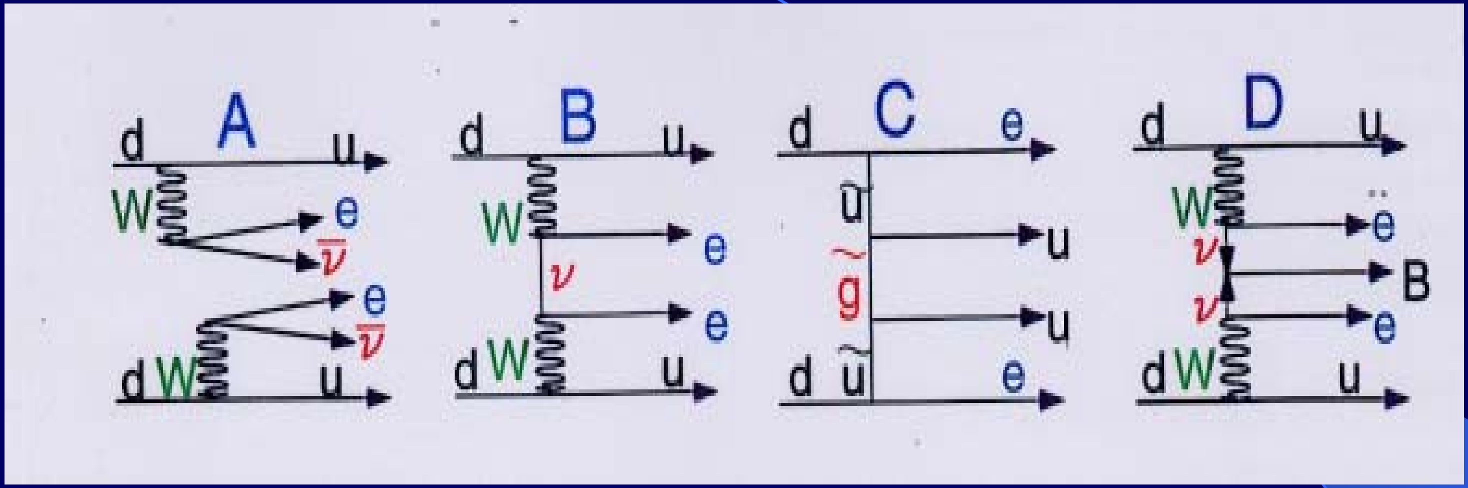
$0\nu\beta\beta$	L=0,1,2,3,4,5,	E < 50 MeV
$2\nu\beta\beta$	L = 0,1.	E < 20 MeV
Solar ν	L = 0,1.	E < 13 MeV
Supernova ν	L = 0,1.	E < 50 MeV

- Nuclear spin isospin giant resonances and
- Spin isospin polarizations play crucial roles

II. Nuclear Responsses for Neutrinos

$\beta\beta-\nu$, **solar** ν **and supernova** ν.

ββ for ν and weak interaction



$T^{2n} = G^{2n} M^{2n}(\tau\sigma\tau\sigma)$

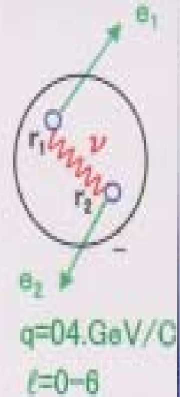
- $T^{0\nu}$-$G^{0\nu}$ $M^{0\nu}(\tau\sigma\tau\sigma rp)(\langle m_\nu\rangle + \langle RHC\rangle)^2$
- Majorana ν,
- Absolute mass scale of $\langle m_\nu\rangle \sim \Sigma m_j U_j^2$ in 0.01 ~0.1 eV of the oscillation mass region.

Nuclear Responses ($M^{0\nu}$) for ββ

Nuclear Responses for $0\nu\ \beta\ \beta$

$$H(r_1, r_2, \tau_1, \tau_2, \sigma_1, \sigma_2) \sim f(r_1, r_2)\, \tau_1 \tau_2 \sigma_1 \sigma_2 \ldots$$

$$f(r_1, r_2) = 1/|r_1 - r_2|$$



Separable Form for Nucleon $r_n < r_i, r_j <$ Nuclear R_N

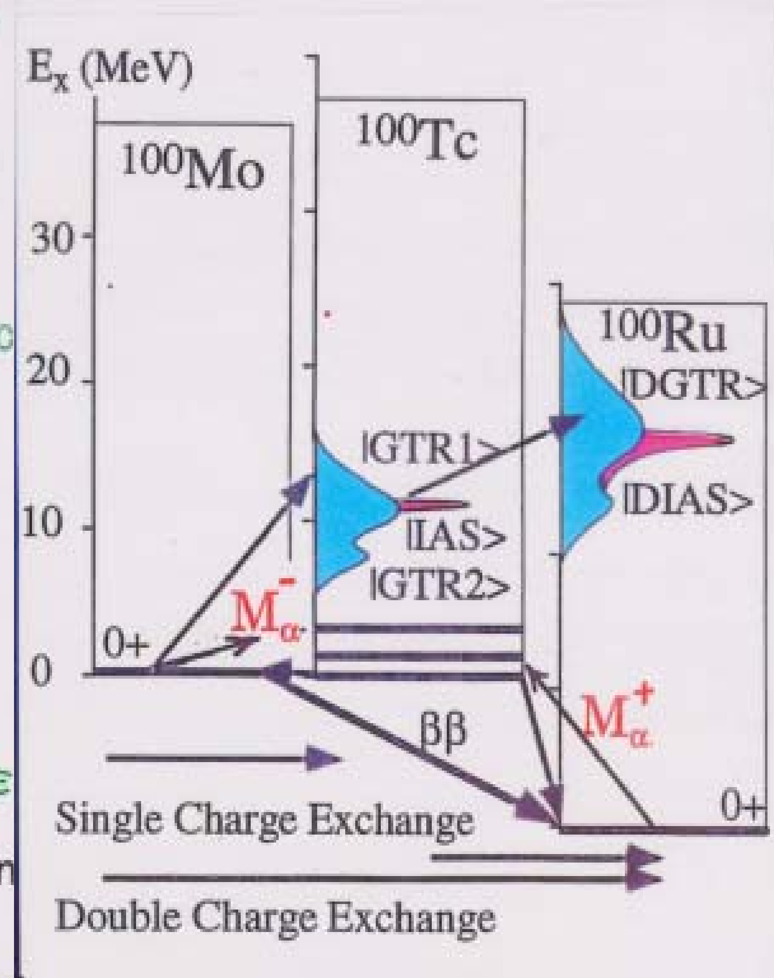
$f(r_1, r_2) \sim \sum_\ell f_\ell\, h_\ell(r_1)\, h_\ell(r_2)$ Ejiri, Belyaev

$M^{0\nu} \sim \Sigma f_\ell < 0_f | T_\ell^+ | i >< i | T_\ell^+ | 0_i >$ $T_\ell = h_\ell(\gamma)\, \tau\, \sigma$

$M^{0\nu} \sim \Sigma M_\ell^+(SP) M_\ell^-(SP) + (M_\ell^+(GR)\, M_\ell^-(GR) \rightarrow \varepsilon$

Studied by τ^- and τ^+ Charge Exchange Reaction

(^{3}He,t) and (t.^{3}He) reactions



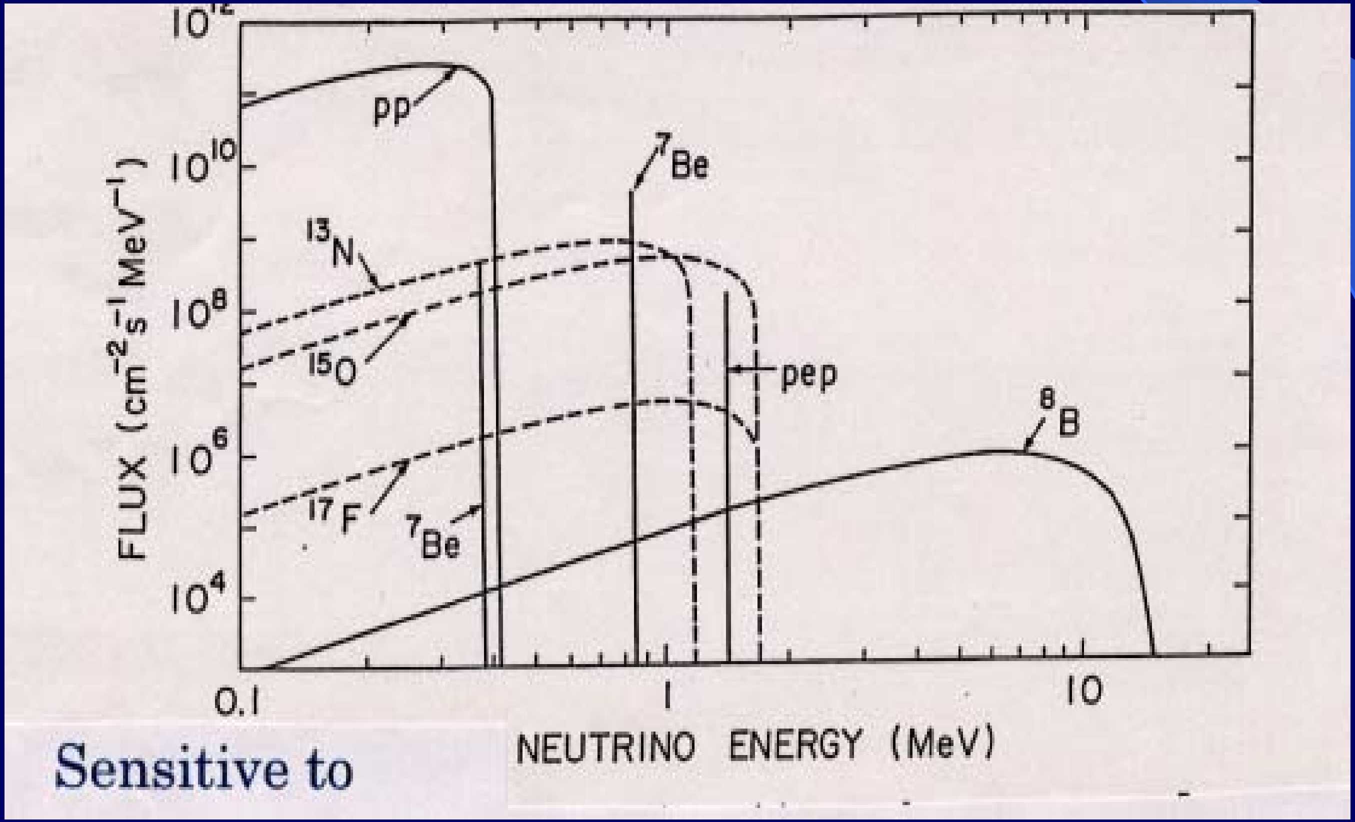
- **Single (^{3}He,t, t,^{3}He) and double charge exchange (^{11}B, ^{11}Li) at RCNP**

Solar ν in nuclei

- **Solar ν's production in the sun**

1..ν-oscillations to study ν-flavor θ_{ij} and Δm_j^2.

2. Inner sun T, ρ, ν , nuclear weak processes .



Solar ν responses

Nucleus	-Q(MeV)	pp	7Be	13N	pep	15O	8B	Tota
$^{2}H^{a}$	1.442	0	0	0	0	-	6	6
$^{37}Cl^{a}$	0.814	0	1.1	0.1	0.2	0.3	6.1	7.9
$^{40}Ar^{b}$	>1.505	0	0	0	0	0	7.2	7.2
$^{71}Ge^{c}$	0.236	70.8	35	3.7	2.9	5.8	12.9	132
$^{100}Mo^{d}$	0.168	639	206	22	13	32	27	965

- **1. Solar-ν rates: Intense low-E light ions at underground lab.**
- **2. Nuclear detector responses for charged and neutral currents**
- **3. d, ^{71}Ga, ^{100}Mo, ^{127}I, and others up to 15 MeV with a few % δ.**
- .

Supernova ν by inverse β

- Supernova type II   Gravitational collapse.

- ν_e T~3.5 MeV,   <E> ~ 11 MeV.
- Anti ν_e T ~ 5 MeV,   <E> ~ 16 MeV.
- ν_x T ~ 8 MeV,   <E> ~ 25 MeV.

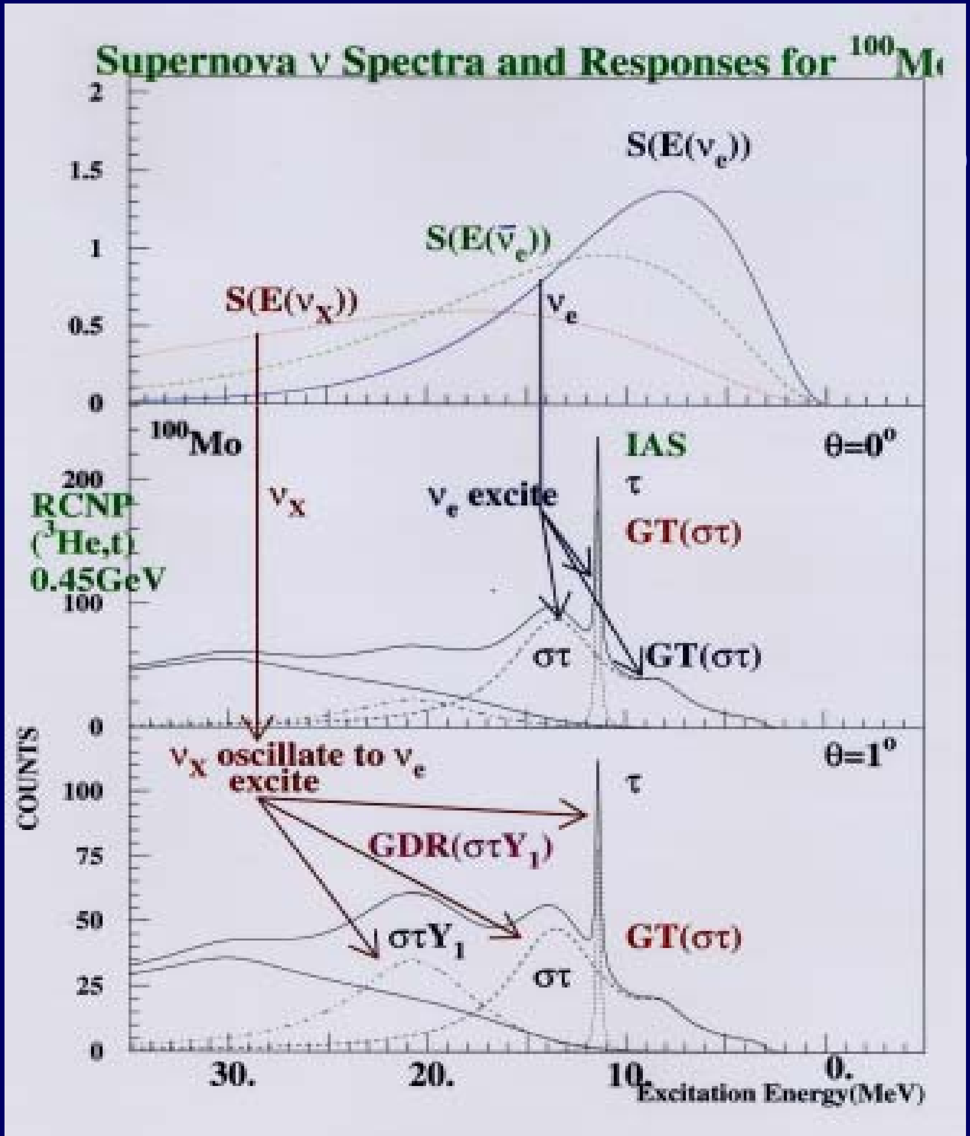
ν spectrum flux   supernova mechanism

ν spectrum distortion ν oscillation.

ν time ν mass in 30-50 eV region

Nuclear Responses of ^{100}Mo for SN-ν

H.Ejiri, J.Engel, N.Kudomi, PL B 2002: arXiv:astro-ph/ 0112379 .



σ (ν,e) cm² (10^{-41})

	ν_e	ν_x-ν_e
0+	0.7	8.9
0-	0.02	0.60
1+	4.62	35.5
1-	0.14	12.1
2+	0.04	4.7
2-	0.34	14.9
3+	0.03	3.78
3-		1.0
4+		0.23
4-		0.79
Total	5.84	80.5