III. Nuclear Probes for Neutrino Nuclear Responses

Nuclei as micro-laboratories.

- **Nuclei are quantum systems of nucleons with good quantum numbers of $J^{\pi}T$ E.**

- **Used for studies of fundamental properties**
- **of elementary interactions and fundamental**
- **Interactions.**

- **Nuclei are chosen so as to select particular**
- **signals/processes of interest and reject other events/processes.**

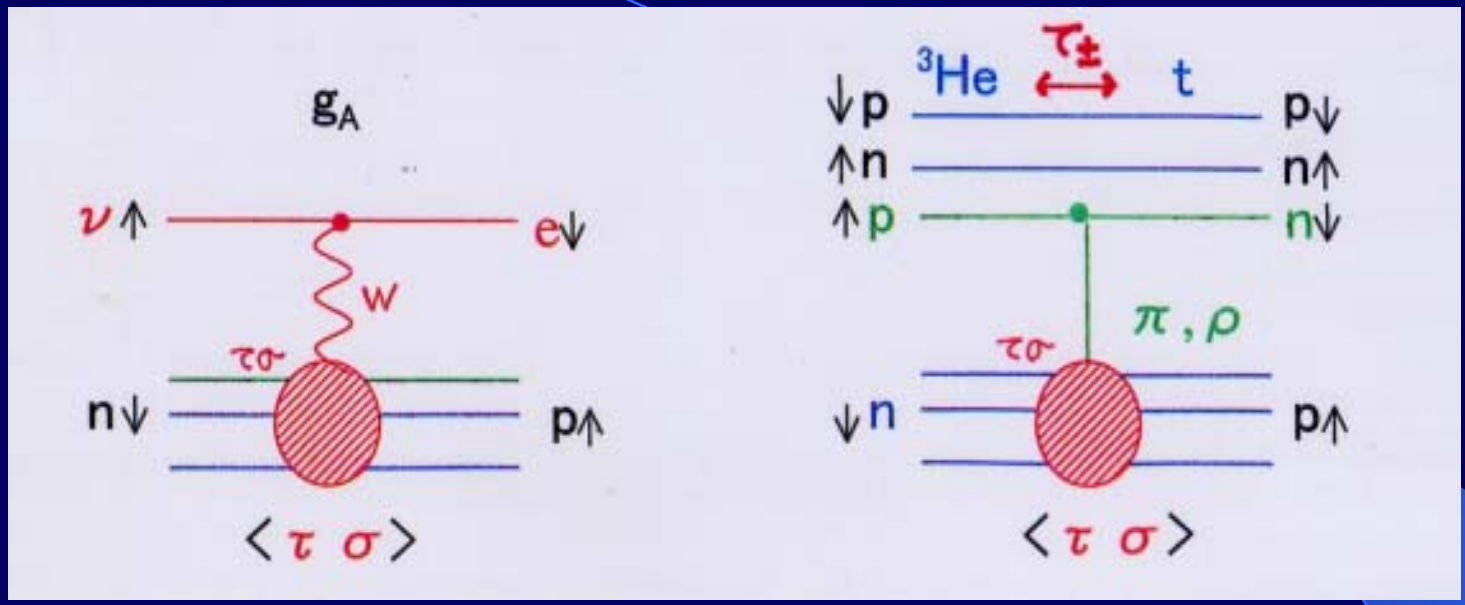
Hadron probes

1. Charged current spin responses by charge exchange spin flip reactions.

2. Neutral ones by inelastic reactions, but both isovector and isoscalar components.

3. Non-central interactions, distortions, multi step processes and others.

Chare exchange spin flip reactions



(d,^{2}He), (^{3}He,t), (t.^{3}He),(^{7}Li.^{7}Be),(^{11}B,^{11}Li).

- E/A ~ 0.2 GeV Large $V_{\tau\sigma,}$ and small distortion, preferential $\tau\sigma$ excitation.

- High E resolution($\Delta E < 50$ keV) for solar ν, and I = 0~3 for $\beta\beta$ and supernova ν

EM probes

- e, γ, and high Z Coulomb excitation

- Neutral current and includes T = 0,1, and magnetic s and l contributions.
- Stretched transitions with J = J'+L,J'-L.

$$\langle T_\gamma(\mathrm{M}J)\rangle = \left(g_{\gamma p}(\mathrm{M}L)\frac{1-\tau_3}{2} + g_{\gamma n}(\mathrm{M}L)\frac{1+\tau_3}{2}\right)\langle \mathrm{i}^{J-1}[\boldsymbol{Y}_{J-1}\times\boldsymbol{\sigma}]_J\rangle,$$

$$g_{\gamma p}(\mathrm{M}L) = \frac{e\hbar}{2MC}(J(2J+1))^{1/2}\left(\mu_p - \frac{1}{J+1}g_{\ell p}\right),$$

$$g_{\gamma n}(\mathrm{M}L) = \frac{e\hbar}{2MC}(J(2J+1))^{1/2}\left(\mu_n - \frac{1}{J+1}g_{\ell n}\right),$$

Weak probes / processes

1. ν beams, direct way but need intense ν beams of
- 10^{15}/sec and large detectors(10 tons) because of
- $\sigma \sim 10^{-41\text{-}42}$ cm^2
-

Souse	E GeV	N_p	N_ν	Detector
SNS	1	$6\ 10^{15}$	$7\ 10^{14}$	ORLaND
JHF	3	$1.2\ 10^{15}$	$3\ 10^{14}$	(MOON)

2. μ^- by (μ,ν_μ) captures for T_+ up to 100 MeV
- with very large cross sections

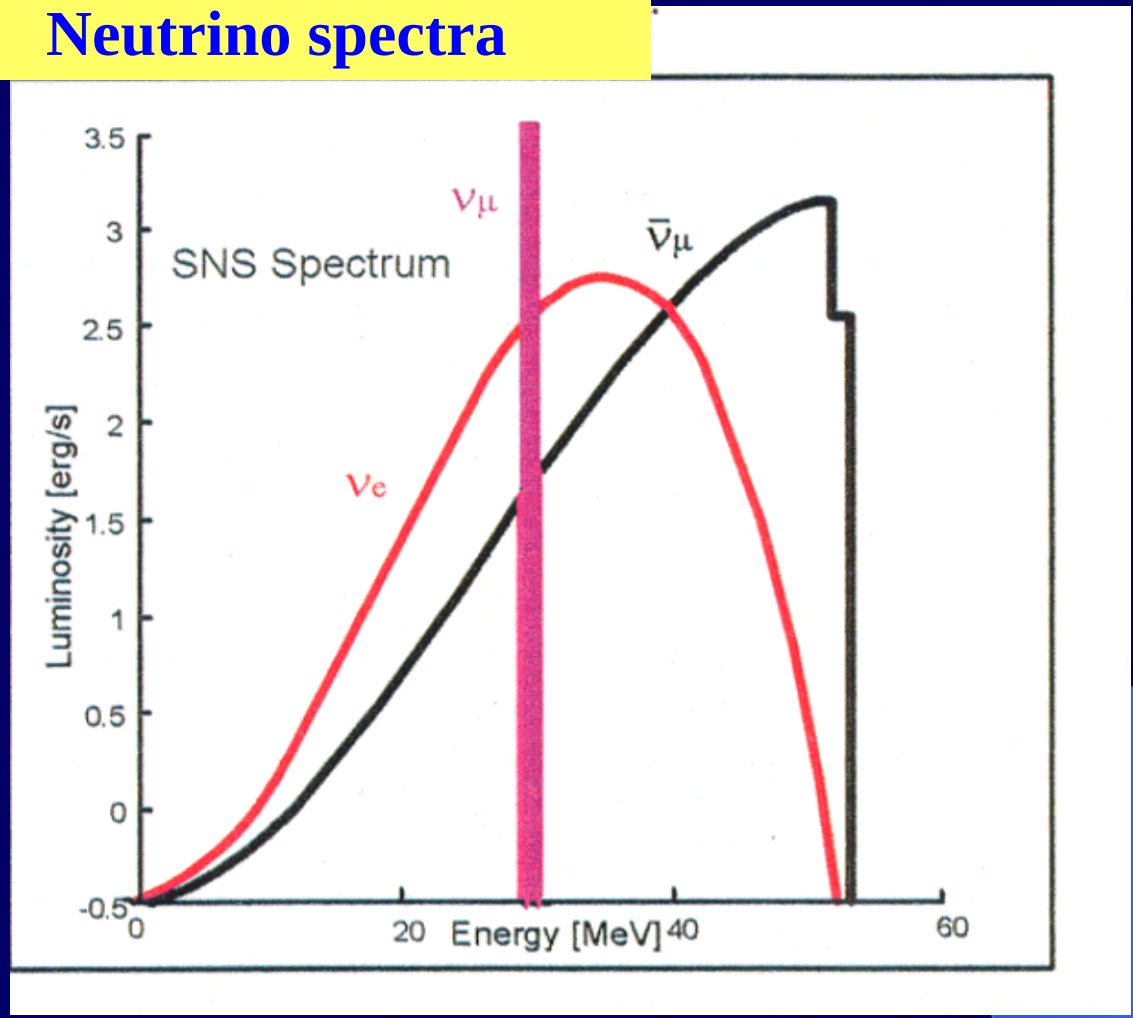
Neutrinos from stopped π^+

$p + Hg \rightarrow n\,\pi^+$

$\pi^+ \rightarrow \mu^+ + \nu_\mu$

$\mu^+ \rightarrow e^+ + \nu_e + \underline{\nu}_\mu$

Neutrino spectra



Intense (~10^{15}/sec) ν's with 1 MW p, time structures and ν spectra in the E region of the astro nuclear particle physics interest.

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IV. Concluding remarks

Concluding remarks

- 1. Neutrinos are new windows for new physics.
- 2. Nuclear τ σ responses for ν are crucial for ν studies in nuclei.
- RCNP is expected to promote ν nuclear physics by LI(hadron), photon and lepton probes as well as the ν studies at Oto Cosmo (underground) Observatory.

http://www.rcnp.osaka-u.ac.jp/~ejiri 100 papers

1.Hadron probes at cyclotron lab.

- Nuclear responses for ν's are studied by τ and σ mode hadron reactions with medium energy(E/A~0.2-0.2GeV) LI.

- High resolution studies with t,d,He, Li, and B
- $\tau_i\sigma^S Y_\lambda$ with I=3,+,-, S=0,1, λ=0~3.

- Decay branches of γ,p,n

EM probes at LEPS

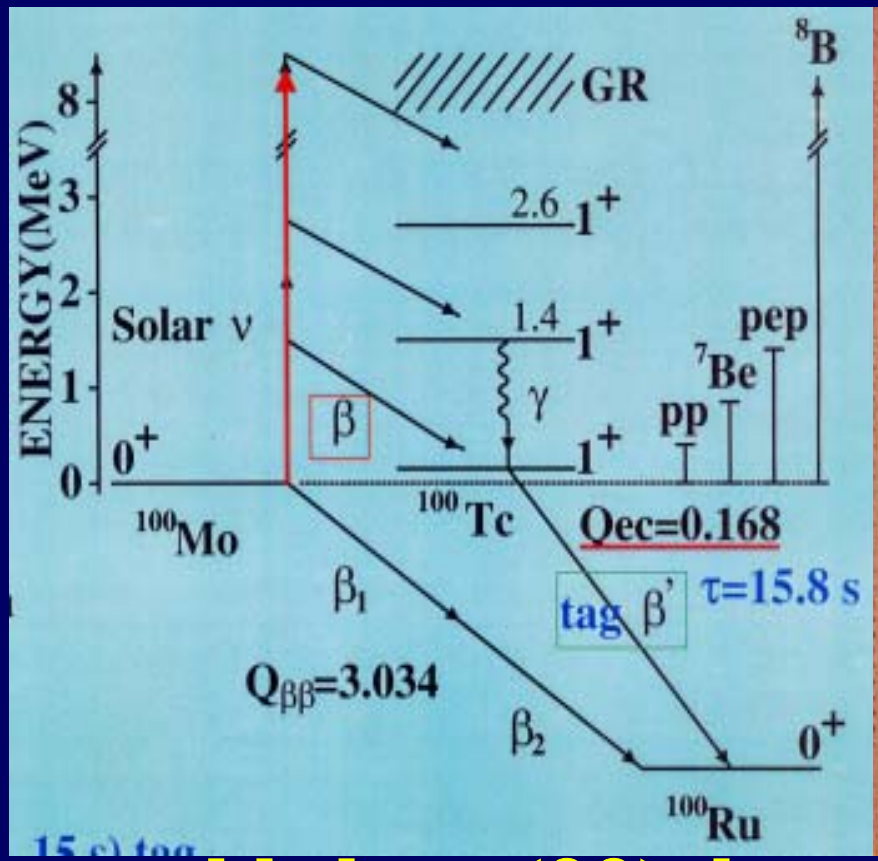
- **Mediun energy (sub. GeV) LEPS for**
- **Neutral current interactions.**

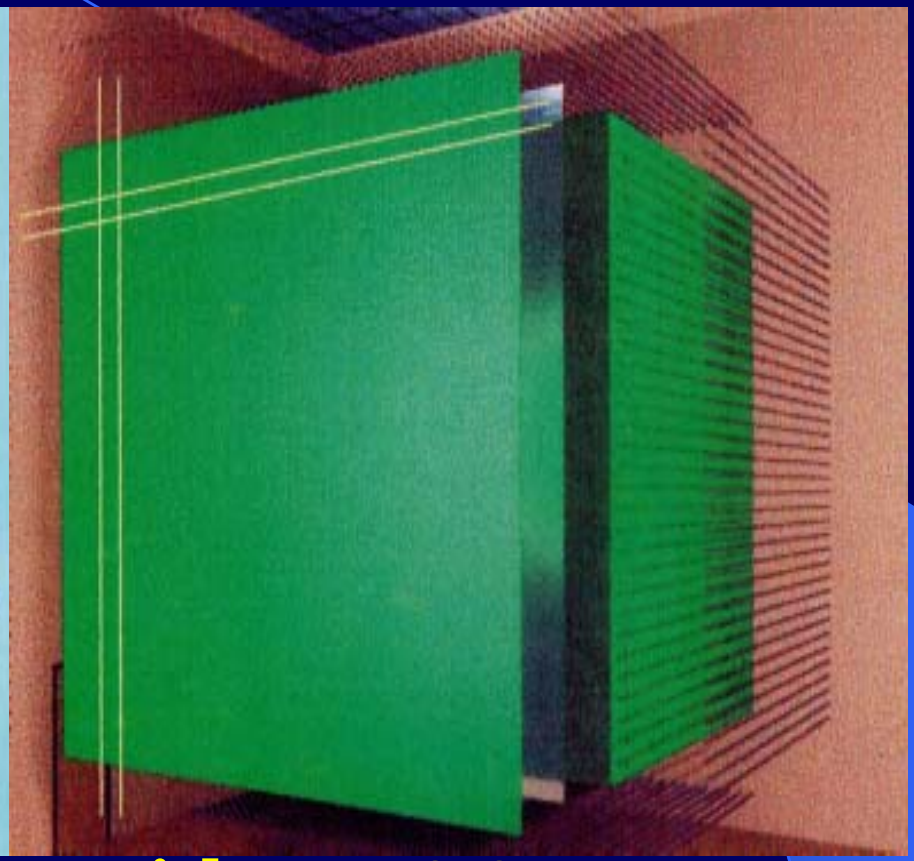
Weak probes of ν and μ

- 1. One possible direct probe is the low energy(0.1 GeV) ν sources from 3 GeV ring at JAERI/Tokai, combined with large ν detectors ORLaND and MOON.
-
- 2. μ beams from RCNP ring and JAERI

MOON (Mo Observatory Of Neutrinos)

Two β ray Spectroscopy from ^{100}Mo



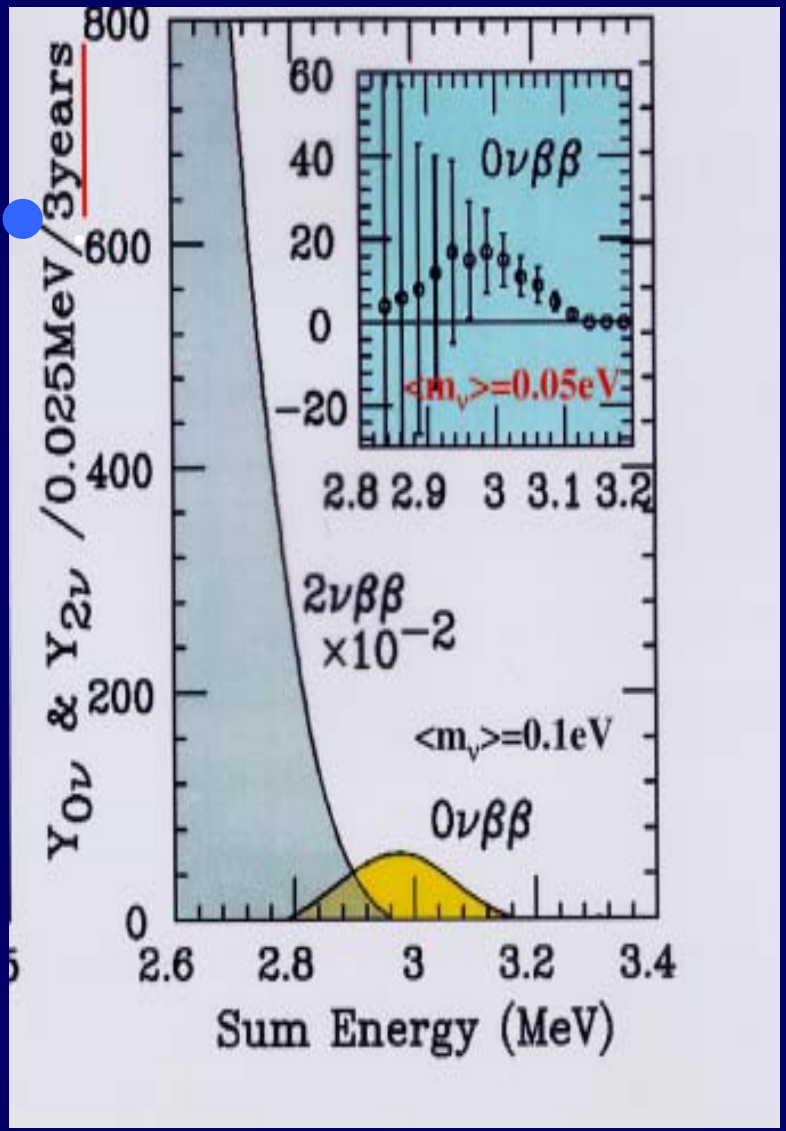


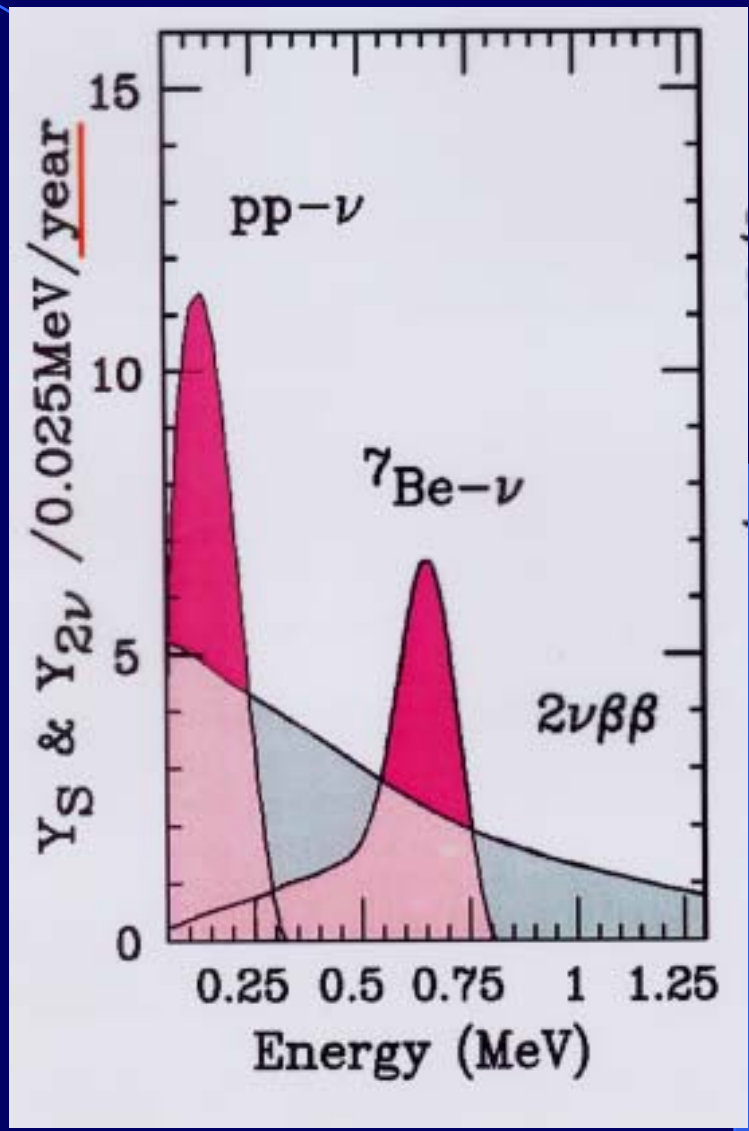
Double beta (ββ) decays with m_ν~0.03 eV.

Low E solar and supernova ν by inverse β & β'

http://npl.washington.edu/moon/index.html

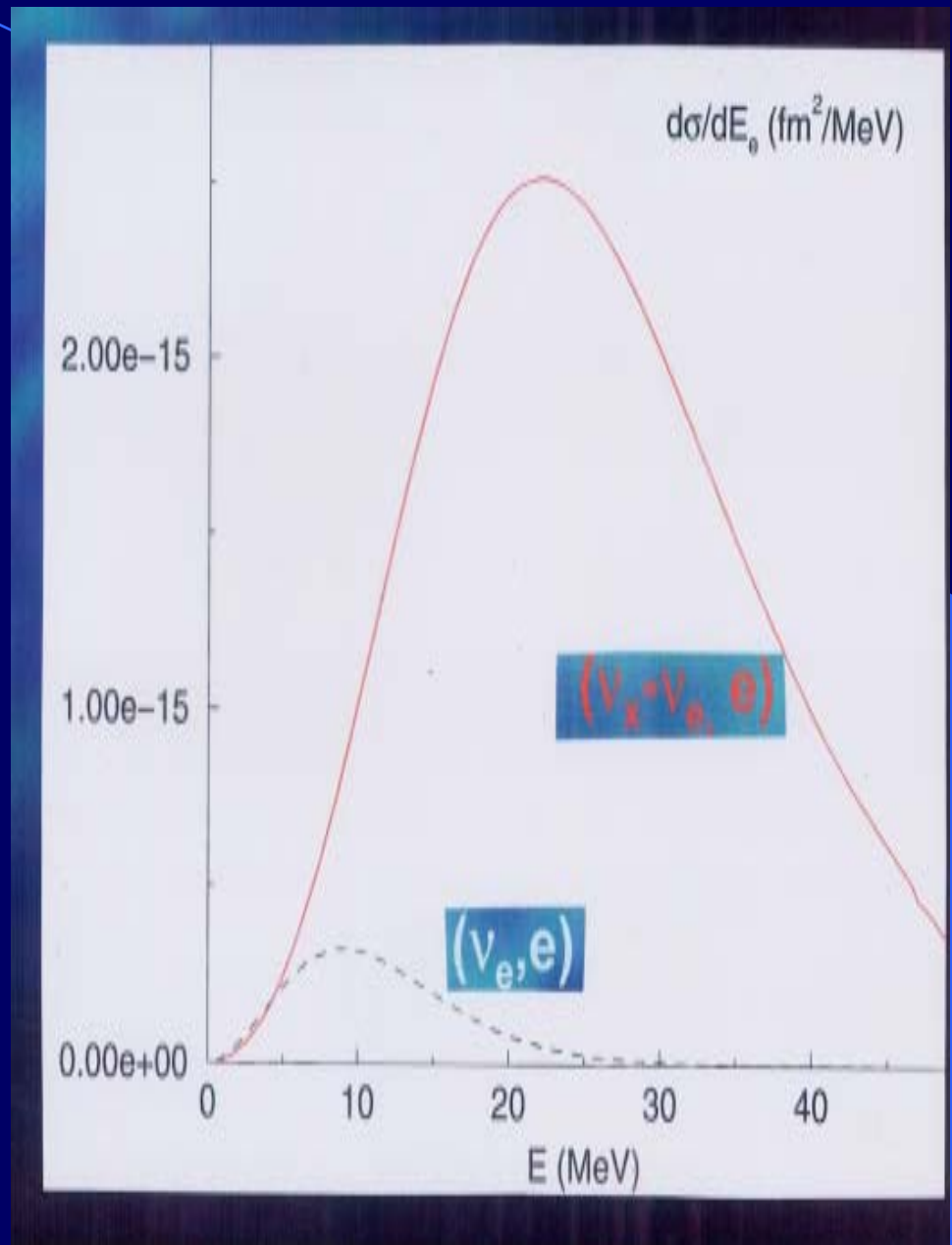
MOON simulation



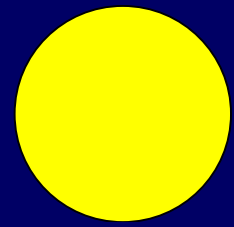


MOON for Supernova ν_e , ν_{xe}

1. Large response for CC by large GT
2. Energy spectra of ν by measuring E_e
3. Sensitive to low energy ν_e and ν_x-ν_e oscillation.
4. Scaled up MOON with 1 K ton natural Mo plates



Welcome to



MOON
collaboration

for
ββ, solar and supernova ν studies in Mo

Thank you for attention