Phenomenology of the relic neutrino interaction with unstable nuclei and experimental challenges towards their detection

M. Messina, *University of Bern and LHEP, Switzerland*

A.G. Cocco, G.Mangano and M.Messina, JCAP06(2007)015

ABSTRACT

- The methods proposed so far for the Cosmological Relic Neutrinos detection.
- A new process to detect Cosmological Relic Neutrinos.
- Details about cross section calculations.
- Gravitational clustering effect that might enhances the interaction rate.
- Possible experimental approaches.
- Conclusions
- Outlook

Cosmic recipe

Material	Particles	<E> or m	N	$\langle\rho\rangle/\rho_C$
Radiation	γ	0.1 meV	10^{87}	0.01%
Hot Dark Matter	Neutrinos	>0.04 eV <0.6 eV	10^{87}	>0.1% <2%
Ordinary Matter	p,n,e	MeV-GeV	10^{78}	5%
Cold Dark Matter	WIMPs? Axions?	>100GeV <meV	$<10^{77}$ $>10^{91}$	25%
Dark Energy	?	10^{-33} meV	?	70%

A.Ringwald, hep-ph/0505024

The Cosmological Relic Neutrinos

We know that Cosmological Relic Neutrinos (CRN) are weakly-clustered

$$\sim 1\sec > BigBang$$

Date of birth

$$\bar{n}_{\nu_i 0} = \bar{n}_{\bar{\nu}_i 0} = \frac{3}{22}\bar{n}_{\gamma 0} = 56cm^{-3}$$

density per flavour

$$T_{\nu,0} = \left(\frac{4}{11}\right)^{1/3} T_{\gamma 0} = 1.95K$$

temperature

$$\bar{p}_{\nu_i 0} = \bar{p}_{\bar{\nu}_i 0} = 3T_{\nu,0} = 5\times 10^{-4}eV$$

mean kinetic energy

$$\lambda = \frac{1}{\bar{p}_{\nu_i}} = \frac{0.12cm}{\left\langle p/T_{\nu,0\bar{p}_{\nu_i 0}}\right\rangle}$$

Wave function extension

$$f_0 = 1/\left(1 + \exp\left(p/T_{\nu,0}\right)\right)$$

p distribution without late-time small scale clustering and $\mu / T_\nu < 0.1$

The detection methods proposed so far!

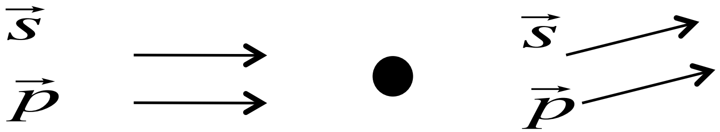
The longstanding question (I)

Is it possible to measure the CRN?

Method 1

The first method proposed for the detection of CRN was based on the fact that given the null mass of the neutrinos (today we know it is small) any variation of ν momentum (Δp) implies a variation of the ν spin (ΔJ) (R.R. Lewis Phy. Rev. D**21** 663, 1980):

$$\Delta J = \mp \hat{\lambda} \cdot \Delta \vec{p}$$



Neutrino and anti-neutrino with the same momentum they transfer opposite sign Δp and so the same ΔJ.

Then if we use a torque-balance to detect the angular acceleration we exploit the major advantage to be sensitive to any mixture of neutrino and anti-neutrino provided that <dp/dt> ≠0. The neutrinos and anti-neutrinos transfer to the balance the same “amount of rotation” ΔJ.

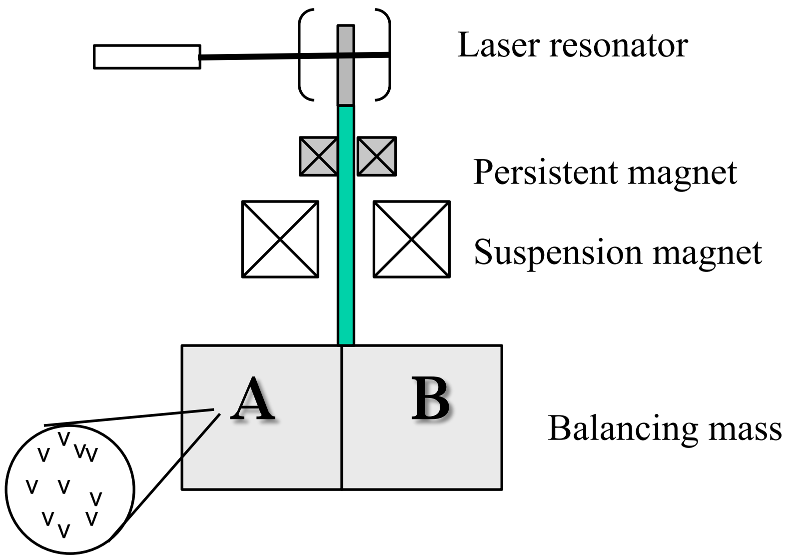
The longstanding question (II)

Is it possible to measure the CRN?

Method 1

Unfortunately what assumed by Lewis was shown by Cabibbo and Maiani (Phys. Lett. **B114** 115,1982) to vanish at first order in Fermi constant G_F.

But there is still an effect (Stodolsky Phys. Rev. Lett. **34,** 110) at first order in G_F where a polarized target experiences a force due to the scattering with polarized neutrinos (only a tiny part of the CRN flux). The effect can only be seen if : $f = \left(\nu - \bar{\nu}\right) \neq 0$



Since the ν wave length is ~ mm (λ) can be envisaged an enhancement of the interaction rate due to coherent sum of the invariant scattering amplitudes in a volume λ^3. Under this assumption:

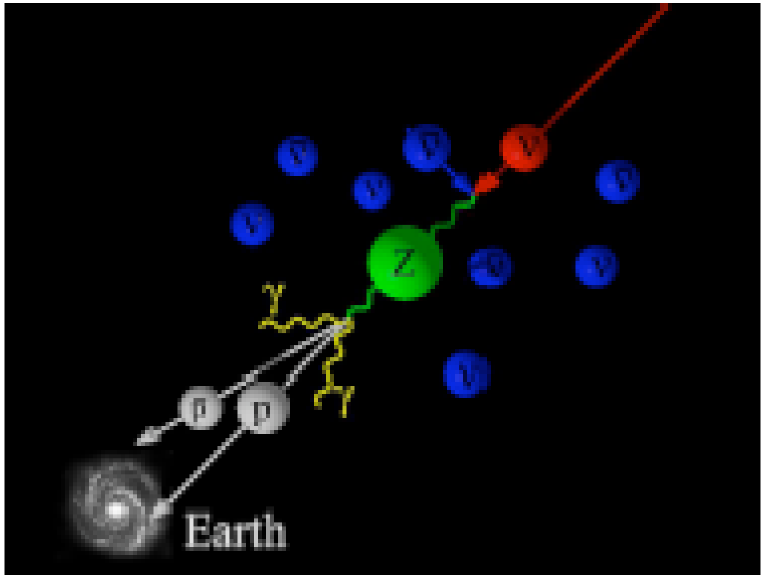
$$a_{G_F} \approx 10^{-27} \frac{cm}{\sec^2} f\left(\frac{\beta_{earth}}{10^{-3} c}\right)$$

The value of acceleration expected is almost 15 order of magnitude far from the current sensitivity of any accelerometers used today in a Cavendis-like experiment.

The longstanding question

Is it possible to measure the CRN ?

Method 2



In the second method resonant annihilation of EECν off CRN into Z-boson is proposed. This process occurs at energy:

$$E^{res}_{\nu_i} = \frac{m_Z^2}{2m_{\nu_i}} \approx 4x10^{21}\left(\frac{eV}{m_{\nu_i}}\right)eV$$

The signature might be a deep in the neutrino flux around 10^{22} eV or an events excess of photons or protons beyond the GKZ deep (where the photons of CMB are absorbed by protons to produce pions).

Such energetic neutrino sources are unknown so far.

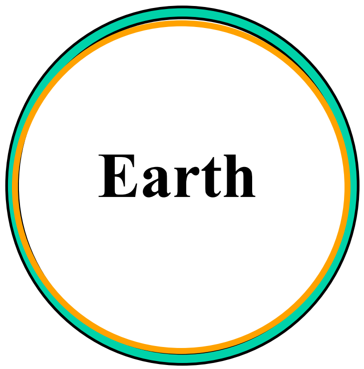
The longstanding question

Is it possible to measure the CRN ?

Method 3

The third method propose the observation of interactions of extremely high energy protons from terrestrial accelerator beams with the relic neutrinos.

Accelerator



In this case even with an accelerator ring (VLHC) of $\sim 4 \times 10^4$ km length (Earth circumference) with $E_{beam} \sim 10^7$ TeV the interaction rate would be negligible.

Summarizing

Is it possible to measure the CRN ?

All the methods proposed so far require unrealistic experimental apparatus or astronomical neutrino sources not yet observed and not even hypothesized .

For recent reviews on this subject see:
A.Ringwald “Neutrino Telescopes” 2005 – hep-ph/0505024
G.Gelmini G. B. Gemini Phys.Scripta T121:131-136,2005

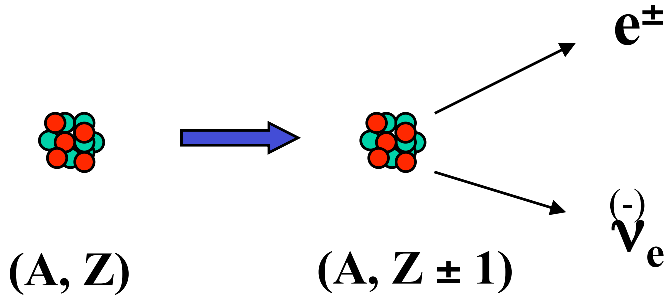
A new idea to detect
Cosmological Relic Neutrinos

We need a process where the ν can contribute only via its flavour quantum number where no additional energy is required!

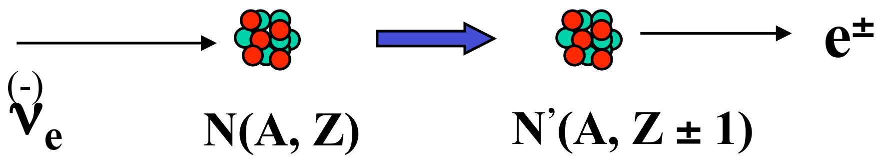
Our proposal (I)

A process without energy threshold

Beta decay



Neutrino Capture on a
Beta decaying nucleus



Since M(N)-M(N') $=Q_\beta>0$ the ν interaction on beta instable nuclei is always energetically allowed no matter the value of the incoming ν energy.

In this case the phase space does not put any energetic constraint to the neutrino CC interaction on a beta instable nucleus (NCB).

A '62 paper by S. Weinberg about ν chemical potential

PHYSICAL REVIEW VOLUME 128, NUMBER 3 NOVEMBER 1, 1962

Universal Neutrino Degeneracy

STEVEN WEINBERG*
Imperial College of Science and Technology, London, England
(Received March 22, 1962)

In the original idea a large neutrino chemical potential (μ) could distort the electron (positron) spectrum near the endpoint energy

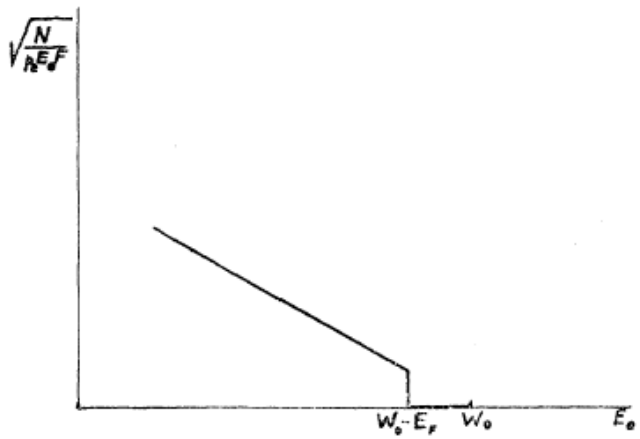


FIG. 1. Shape of the upper end of an allowed Kurie plot to be expected in a β^+ decay if neutrinos are degenerate up to energy E_F, or in a β^- decay if antineutrinos are degenerate.

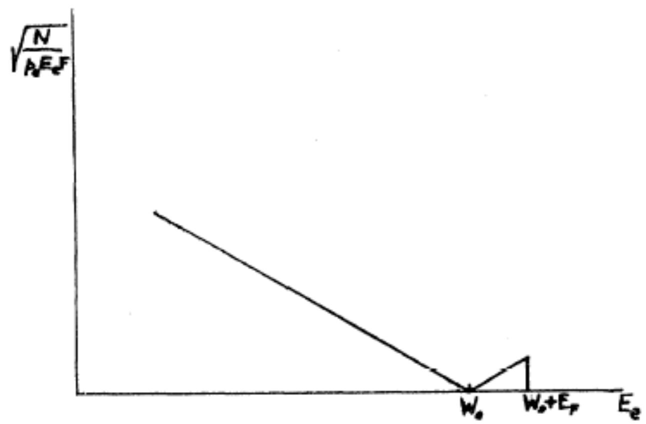


FIG. 2. Shape of the upper end of an allowed Kurie plot to be expected in a β^- decay if neutrinos are degenerate up to energy E_F, or in a β^+ decay if antineutrinos are degenerate.

Our proposal

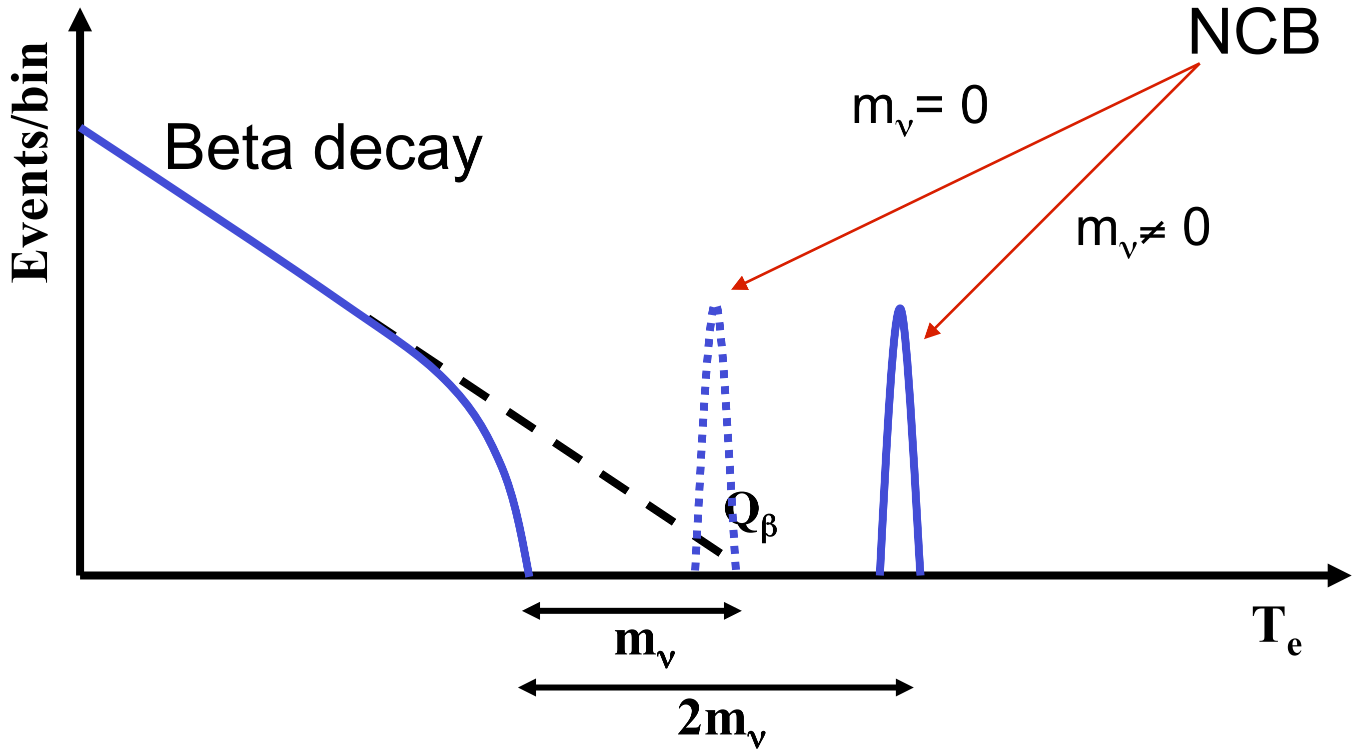
Our proposal is based on the fact that the $\sigma \bullet v$ does not vanishes when the ν energy is negligible reaching instead, a plateau value depending on the target nuclei.

Other authors adopted different ν cross section calculations❖:
$\sigma \approx m^2$ for not relativistic neutrinos ($m_\nu \sim 1eV$) and, $\sigma = \sigma_0 \, x E^2$ ($m_\nu \sim meV$) for relativistic neutrinos and subsequently they obtained cross section in the range $\sigma \approx 10^{-56}$ -10^{-62} cm^2.

❖ G. B. Gelmini Phys.Scripta T121:131-136, 2005 and references therein.

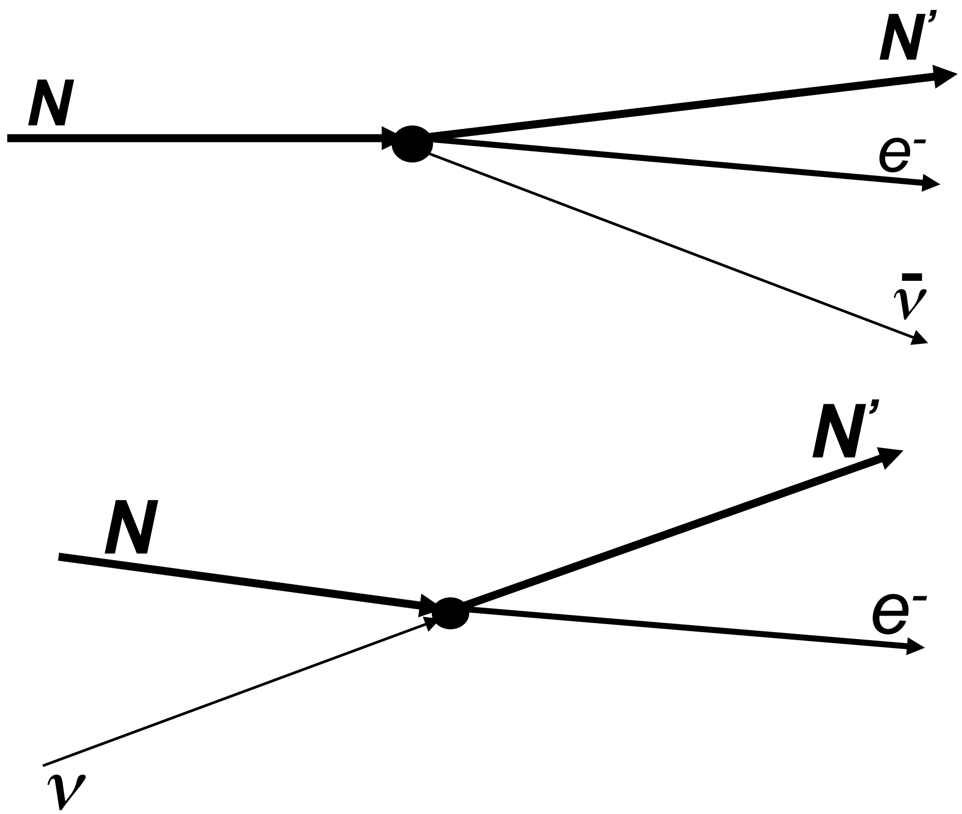
NCB signature

Neutrino masses of the order of 1 eV are compatible with the present picture of our Universe.



The events induced by Neutrino Capture have a unique signature: there is a gap of $2m_\nu$ between the NCB electron energy and the energy of beta decay electrons at the endpoint.

How to evaluate NCB cross section



The invariant amplitudes of the two processes are identical (due to ν crossing).
This fact allows to evaluate the NCB cross section in an easy way.

NCB Cross Section (I)

NCB $$\sigma_{\rm NCB} v_\nu = \frac{G_\beta^2}{\pi} p_{\rm e} E_{\rm e} F(Z, E_{\rm e}) C(E_{\rm e}, p_\nu)_\nu$$

$$E_{\rm e} = E_\nu + Q_\beta + m_{\rm e} = E_\nu + m_\nu + W_{\rm o}$$

Where $F(Z, E_{\rm e})$ the Fermi function and $C(E_{\rm e}, p_\nu)_\nu$ the nuclear shape factor which is an angular momentum weighted average of nuclear state transition amplitudes.

It is more convenient to focalize our attention on the interaction rate:

$$\lambda_\nu = \frac{G_\beta^2}{2\pi^3} \int_{W_{\rm o}+2m_\nu}^{\infty} p_{\rm e} E_{\rm e} F(Z, E_{\rm e}) C(E_{\rm e}, p_\nu)_\nu \cdot E_\nu p_\nu f(p_\nu)\, {\rm d}E_{\rm e},$$

NCB Cross Section (II)

The most difficult part of the rate estimation is the nuclear shape factor calculation:

$$C(E_{\mathrm{e}}, p_\nu)_\beta = \sum_{k_{\mathrm{e}}, k_\nu, K} \lambda_{k_{\mathrm{e}}} [M_K^2(k_{\mathrm{e}}, k_\nu) + m_K^2(k_{\mathrm{e}}, k_\nu) - \frac{2\mu_{k_{\mathrm{e}}} m_{\mathrm{e}} \gamma_{k_{\mathrm{e}}}}{k_{\mathrm{e}} E_{\mathrm{e}}} M_K^2(k_{\mathrm{e}}, k_\nu) m_K^2(k_{\mathrm{e}}, k_\nu)]$$

Where λ_{ke} , μ_{ke} and γ_{ke} are the Coulomb coefficients, k_e and k_ν are the electron and neutrino radial wave function indexes ($k=j+1/2$), $K=L-1$ represents the nuclear transition multipolarity ($|k_e - k_\nu| \leq K \leq |k_e + k_\nu|$) and, M^2 and m^2 are nuclear matrix element. Their calculation is the main source of uncertainty for σ_{NCB}.

On the other hand, the NCB (see previous slide) and the corresponding beta decay rates are strongly related thanks to the following formula:

$$\lambda_\beta = \frac{G_\beta^2}{2\pi^3} \int_{m_{\mathrm{e}}}^{W_\circ} p_{\mathrm{e}} E_{\mathrm{e}} F(Z, E_{\mathrm{e}}) C(E_{\mathrm{e}}, p_\nu)_\beta E_\nu p_\nu \, \mathrm{d}E_{\mathrm{e}}$$

$$C(E_{\mathrm{e}}, p_\nu)_\nu = C(E_{\mathrm{e}}, -p_\nu)_\beta$$

NCB Cross Section

The beta decay rate provides a relation that allows to express the mean shape factor:

$$\overline{C}_\beta = \frac{1}{f}\int_{m_e}^{W_o} p_e E_e F(Z, E_e) C(E_e, p_\nu)_\beta E_\nu p_\nu \, \mathrm{d}E_e,$$

in terms of observable quantities: $ft_{1/2} = \dfrac{2\pi^3 \ln 2}{G_\beta^2 \overline{C}_\beta}, \qquad f = \displaystyle\int_{m_e}^{W_o} F(Z, E_e) p_e E_e E_\nu p_\nu \, \mathrm{d}E_e.$

then if we derive G_β in terms of $\overline{C}_\beta$ and of $ft_{1/2}$ and replace it in the expression of the NCB cross section:

$$\sigma_{\mathrm{NCB}} v_\nu = \frac{G_\beta^2}{\pi} p_e E_e F(Z, E_e) C(E_e, p_\nu)_\nu$$

we obtain $$\sigma_{\mathrm{NCB}} v_\nu = 2\pi^2 \ln 2 p_e E_e F(Z, E_e) \frac{C(E_e, p_\nu)_\nu}{ft_{1/2} \overline{C}_\beta}$$

So the σ_{NCB} can be calculated in terms of well measured quantities and of $C(E_e,p_\nu)_\nu$ and $\overline{C}_\beta$ which depend on the same nuclear transition matrix elements.

NCB Cross Section

a new parameterization

It is convenient to introduce

$$\mathcal{A} = \int_{m_e}^{W_o} \frac{C(E'_e, p'_\nu)_\beta}{C(E_e, p_\nu)_\nu} \frac{p'_e}{p_e} \frac{E'_e}{E_e} \frac{F(E'_e, Z)}{F(E_e, Z)} E'_\nu p'_\nu dE'_e$$

where *A* depends only by E_ν . Then if we introduce *A* in the cross section expression we have:

$$\boxed{\sigma_{\mathrm{NCB}} v_\nu = \frac{2\pi^2 \ln 2}{\mathcal{A}\, t_{1/2}}}$$

Thus σ_{NCB} can be easily calculated in terms of the decay half-life of the corresponding beta decay process and of the quantity *A* where the neutrino energy dependency is hidden. The function *A* has the fundamental feature of showing only the ratio of the nuclear shape factors where the theoretical uncertainties vanish.

NCB Cross Section

on different types of decaying nuclei

Super-allowed transitions:

$$\sigma_{\mathrm{NCB}} v_\nu = 2\pi^2 \ln 2 \frac{p_e E_e F(Z, E_e)}{f t_{1/2}}$$

$0^+ \to 0^+$

This expression of the cross section is a very good approximation also for allowed transitions (Tritium case) since:

$$\frac{C(E_e, p_\nu)_\beta}{C(E_e, p_\nu)_\nu} \simeq 1$$

$J \to J$

K-th unique forbidden

$J \to J + K$

(Leptonic contribution)

$$u_1(p_\mathrm{e}, p_\nu) = p_\nu^2 + \lambda_2 p_\mathrm{e}^2,$$
$$u_2(p_\mathrm{e}, p_\nu) = p_\nu^4 + \tfrac{10}{3}\lambda_2 p_\nu^2 p_\mathrm{e}^2 + \lambda_3 p_\mathrm{e}^4,$$
$$u_3(p_\mathrm{e}, p_\nu) = p_\nu^6 + 7\lambda_2 p_\nu^4 p_\mathrm{e}^2 + 7\lambda_3 p_\nu^2 p_\mathrm{e}^4 + \lambda_4 p_\mathrm{e}^6$$

$$C(E_e, p_\nu)^i_\beta = \left[\frac{R^i}{(2i+1)!!}\right]^2 \left|{}^A F^{(0)}_{(i+1)\,i\,1}\right|^2 u_i(p_e, p_\nu)$$

(Nuclear contribution)

$$\mathcal{A}_i = \int_{m_e}^{W_o} \frac{u_i(p'_e, p'_\nu) p'_e E'_e F(Z, E'_e)}{u_i(p_e, p_\nu) p_e E_e F(Z, E_e)} E'_\nu p'_\nu \mathrm{d}E'_e$$

NCB Cross Section Evaluation

The case of Tritium

Using the expression $$\sigma_{\rm NCB} v_\nu = \frac{G_\beta^2}{\pi} p_e E_e F(Z, E_e) C(E_e, p_\nu)_\nu$$

we obtain $$\sigma_{\rm NCB}(^3{\rm H})\,\frac{v_\nu}{c} = (\ 7.7 \pm 0.2\ ) \times 10^{-45}\ {\rm cm}^2$$

where the uncertainty is due to Fermi and Gamow-Teller matrix element uncertainties

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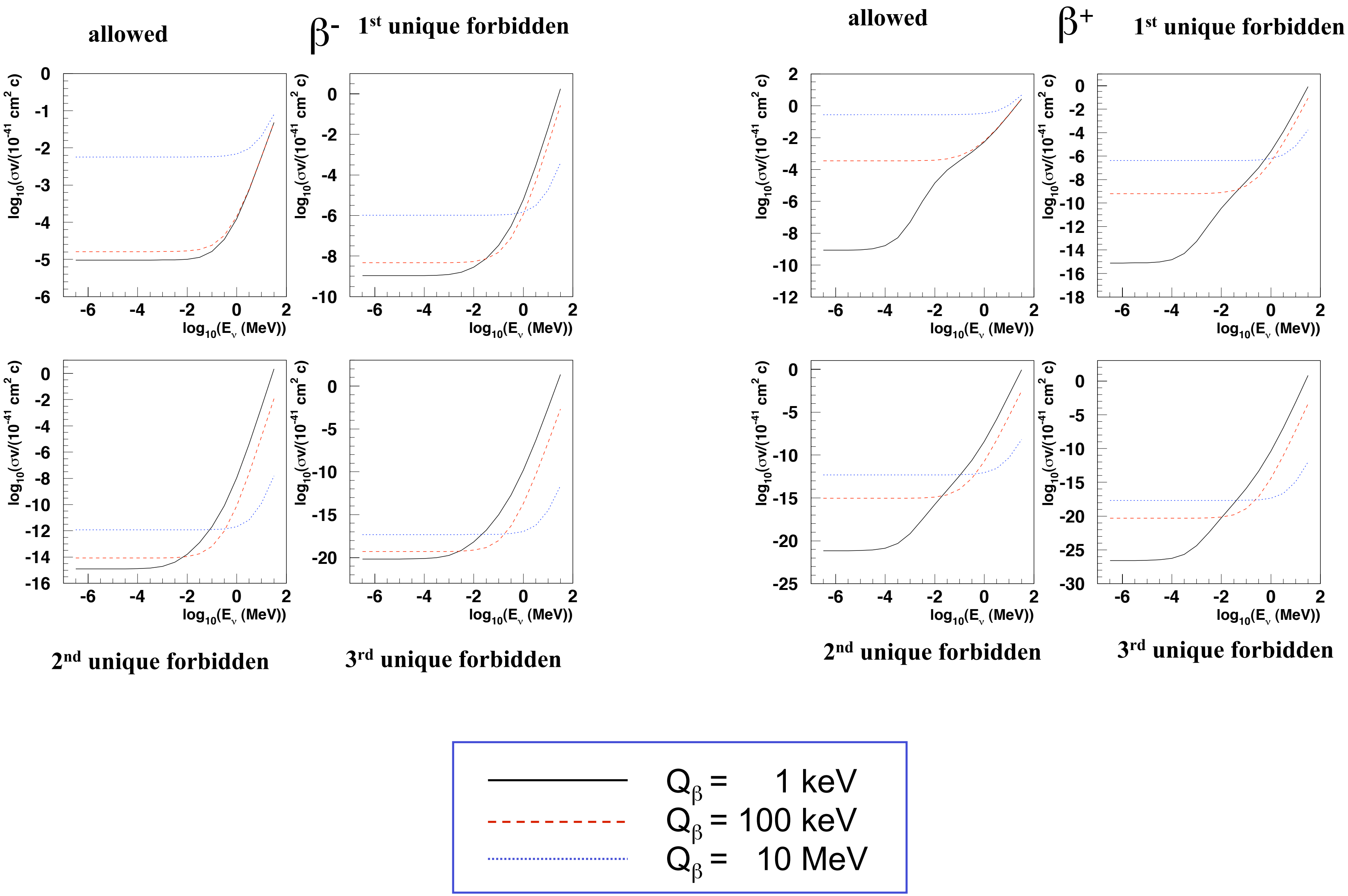
Using shape factors ratio $$\sigma_{\rm NCB} v_\nu = \frac{2\pi^2 \ln 2}{\mathcal{A}\, t_{1/2}}$$

$$\sigma_{\rm NCB}(^3{\rm H})\frac{v_\nu}{c} = (\ 7.84 \pm 0.03\ ) \times 10^{-45}\ {\rm cm}^2$$

where the uncertainty is due only to uncertainties on Q_β and $t_{1/2}$

NCB Cross Section

as a function of E_ν, Q_β and forbiddance level



NCB Cross Section
the major results of our paper

- Exist a process (NCB) that allows in principle the detection of neutrino of vanishing energy!

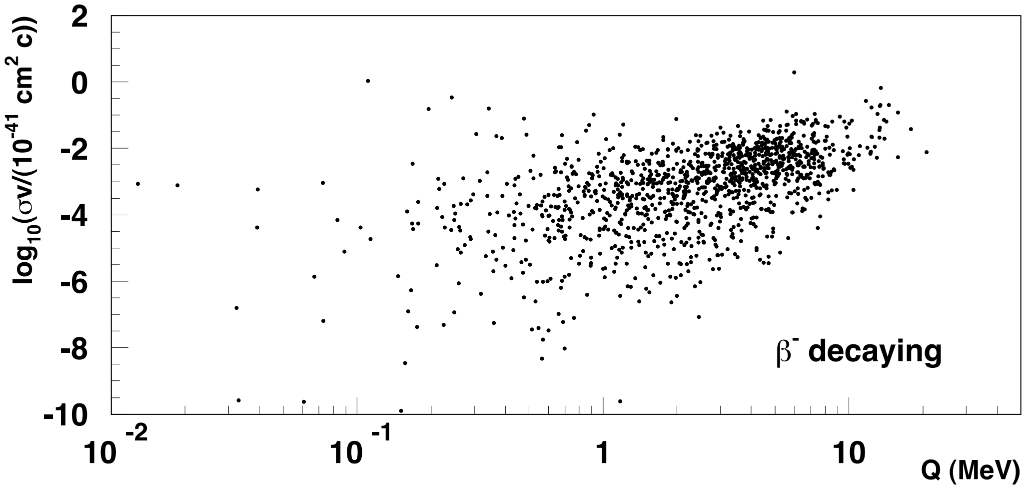
- The cross section (times the neutrino velocity) does not vanish when the neutrino energy becomes negligible!

- We described a method to calculate any NCB cross section by means of measured known quantities ($t_{1/2}$) and the ratio of the nuclear shape factors. Reduced theoretical uncertainties!

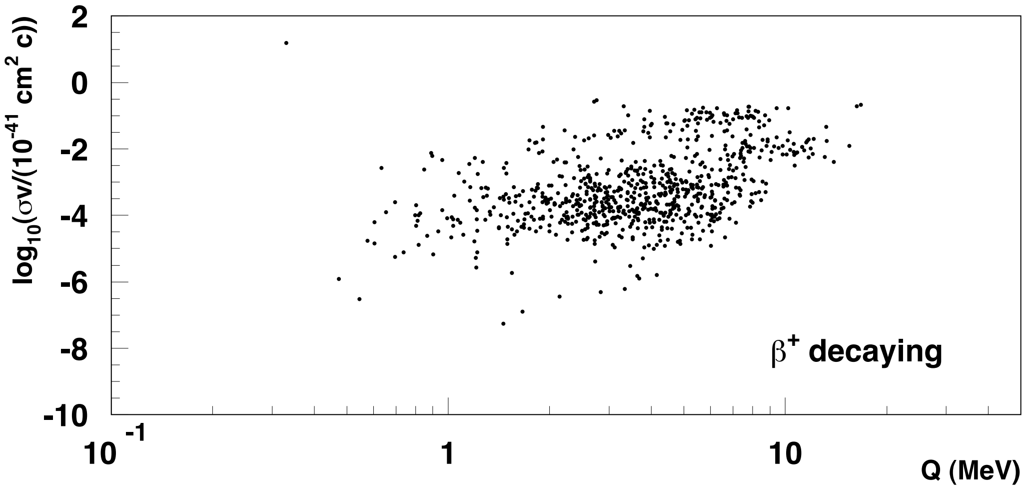
NCB Cross Section Evaluation

using measured values of Q_β and $t_{1/2}$

1272 β^- nuclei



799 β^+ nuclei



Beta decaying nuclei having BR($\beta^\pm$) > 5 %
selected from 14543 decays listed in the ENSDF database

NCB Cross Section Evaluation

specific cases

Isotope	Q_β (keV)	Half-life (sec)	$\sigma_{\rm NCB}(v_\nu/c)$ $(10^{-41}$ cm$^2)$
^{10}C	885.87	1320.99	5.36×10^{-3}
^{14}O	1891.8	71.152	1.49×10^{-2}
^{26m}Al	3210.55	6.3502	3.54×10^{-2}
^{34}Cl	4469.78	1.5280	5.90×10^{-2}
^{38m}K	5022.4	0.92512	7.03×10^{-2}
^{42}Sc	5403.63	0.68143	7.76×10^{-2}
^{46}V	6028.71	0.42299	9.17×10^{-2}
^{50}Mn	6610.43	0.28371	1.05×10^{-1}
^{54}Co	7220.6	0.19350	1.20×10^{-1}

Super-allowed $0^+ \rightarrow 0^+$

Isotope	Decay	Q (keV)	Half-life (sec)	$\sigma_{\rm NCB}(v_\nu/c)$ $(10^{-41}$ cm$^2)$
^{3}H	β^-	18.591	3.8878×10^8	7.84×10^{-4}
^{63}Ni	β^-	66.945	3.1588×10^9	1.38×10^{-6}
^{93}Zr	β^-	60.63	4.952×10^{13}	2.39×10^{-10}
^{106}Ru	β^-	39.4	3.2278×10^7	5.88×10^{-4}
^{107}Pd	β^-	33	2.0512×10^{14}	2.58×10^{-10}
^{187}Re	β^-	2.64	1.3727×10^{18}	4.32×10^{-11}
^{11}C	β^+	960.2	1.226×10^3	4.66×10^{-3}
^{13}N	β^+	1198.5	5.99×10^2	5.3×10^{-3}
^{15}O	β^+	1732	1.224×10^2	9.75×10^{-3}
^{18}F	β^+	633.5	6.809×10^3	2.63×10^{-3}
^{22}Na	β^+	545.6	9.07×10^7	3.04×10^{-7}
^{45}Ti	β^+	1040.4	1.307×10^4	3.87×10^{-4}

Nuclei having the highest product $\boldsymbol{\sigma_{\rm NCB}\, t_{1/2}}$

Relic Neutrino Detection

The cosmological relic neutrino capture rate is given by

$$\lambda_\nu = \int \sigma_{\rm NCB} v_\nu \frac{1}{\exp(p_\nu/T_\nu)+1} \frac{d^3 p_\nu}{(2\pi)^3}$$

$\boldsymbol{T_\nu = 1.7 \cdot 10^{-4}}$ **eV**

after the integration over neutrino momentum and inserting numerical values we obtain:

$$2.85 \cdot 10^{-2} \frac{\sigma_{\rm NCB} v_\nu / c}{10^{-45} {\rm cm}^2} \,{\rm yr}^{-1}\ {\rm mol}^{-1}$$

In the case of Tritium we estimate that 7.5 neutrino capture events per year are obtained using a total mass of 100 g

Relic Neutrino Detection (I)
signal to background ratio

The ratio between capture (λ_ν) and beta decay rate (λ_β) is obtained using the previous expressions:

$$\frac{\lambda_\nu}{\lambda_\beta} = \frac{2\pi^2 n_\nu}{\mathcal{A}}$$

In the case of Tritium $\lambda_\nu(^3H) = 0.66 \cdot 10^{-23}\,\lambda_\beta(^3H)$ is obtained under the assumption m_ν=0, n_ν ~50/cm^3 in the full energy range.

So far we considered the worst condition to calculate the CRN interaction rate. In fact, Fermi momentum distribution does not describe any neutrino density increase due to gravitational effect.

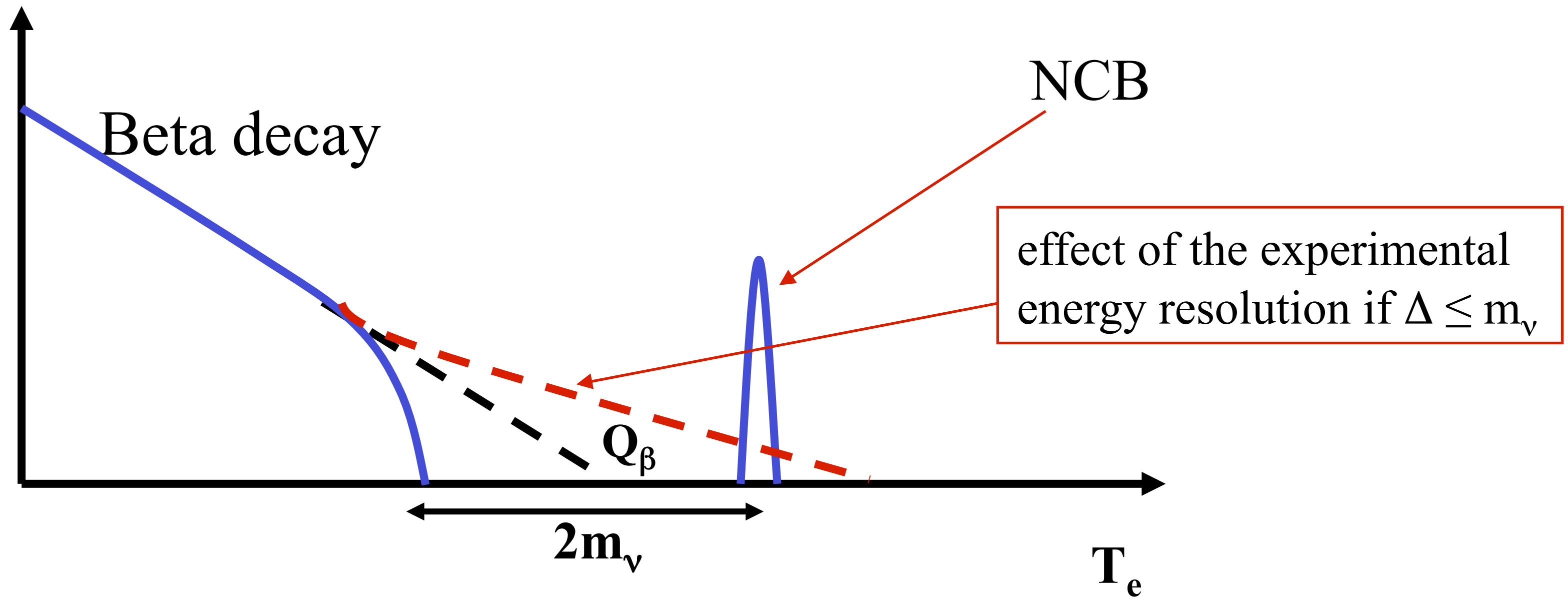
Relic Neutrino Detection (II)

signal to background ratio

As a general result for a given experimental resolution Δ the signal (λ_ν) to background (λ_β) ratio is given by

$$\frac{S}{B} = \frac{9}{2}\zeta(3)\left(\frac{T_\nu}{\Delta}\right)^3 \frac{1}{(1+2m_\nu/\Delta)^{3/2}}\left[\frac{1}{\sqrt{2\pi}}\int_{\frac{2m_\nu}{\Delta}-\frac{1}{2}}^{\frac{2m_\nu}{\Delta}+\frac{1}{2}} e^{-x^2/2}dx\right]^{-1}$$

where the last term is the probability for a beta decay electron at the endpoint to be measured beyond the $2m_\nu$ gap



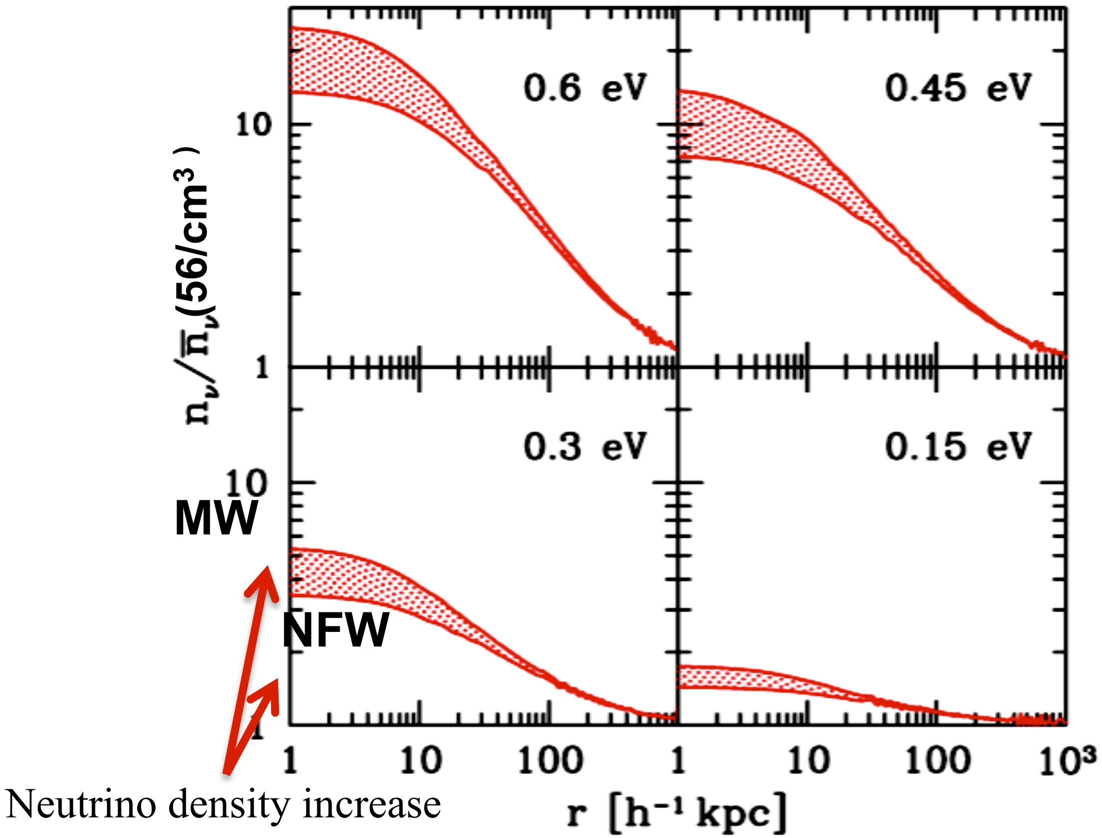
Relic Neutrino Detection

discovery potential

As an example, given a neutrino mass of 0.7 eV and an energy resolution at the beta decay endpoint of 0.2 eV a signal to background ratio of 3 is obtained. In the case of 100 g mass target of Tritium it would take one and half year to observe a 5σ effect.

Possible effects enhancing the NCB (I)

A.Ringwald and Y.Y.Wong (JCAP12(2004)005) made predictions about the CRN density by using an N-body simulation under two main assumptions. In one they considered the clustering of the CRN under the gravitational potential given by the Milk Way matter density as it is today. The second prediction was made considering a gravitational potential evolving during the Universe expansion (Navarro, Franck White). In both cases the neutrinos were considered as spectators and not participating to the potential generation.



Possible effects enhancing the NCB (II)

In the table the number of events per year are reported if we assume the target mass of 100 g of Tritium

m_ν(eV)	FD (events/yr)	NFW (events/yr)	MW (events/yr)
0.6	7.5	90	150
0.3	7.5	23	33
0.15	7.5	10	12

In the table the amount of target masses are reported for 7.5 events observed per year.

m_ν(eV)	mass/year (FD)	mass/year (NFW)	mass/year (MW)
0.6	100 g	8 g	5 g
0.3	100 g	33 g	25 g
0.15	100 g	75 g	62 g

No background has been considered so far!

Possible effects enhancing the NCB (III)

An interesting hypothesis was considered by R. Lazauskas, P. Vogel and C. Volpe in J.Phys.G35:025001,2008:

"Assuming that the ratio of the dimensionless neutrino and baryon density $\Omega_\nu/\Omega_b \sim 0.5\, m_\nu(eV)$ remains the same as in the Universe as a whole, we obtain:"

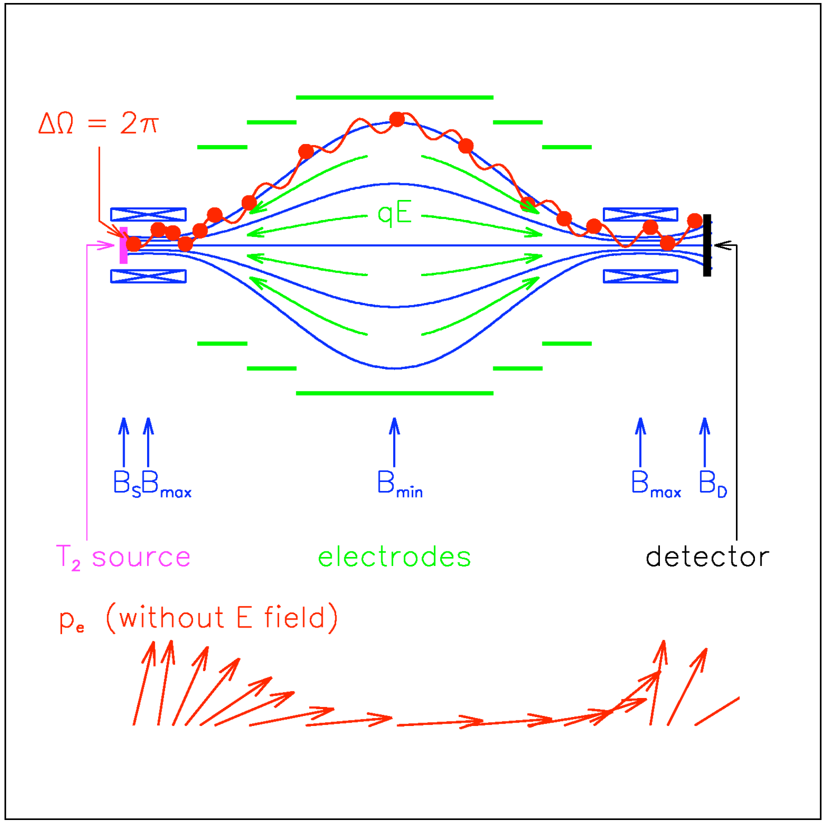
$$\frac{n_\nu}{\langle n_\nu \rangle} \sim 9 \times 10^6 n_b \left(\frac{m_\nu}{eV} \right) \sim 10^3 - 10^4$$

This hypothesis is particularly interesting if we consider the Re detectors where the mass of 10^8-10^9 g, needed to discover CRN, can be reduced up to 10^4 g.

One possible experimental approach (I) KATRIN

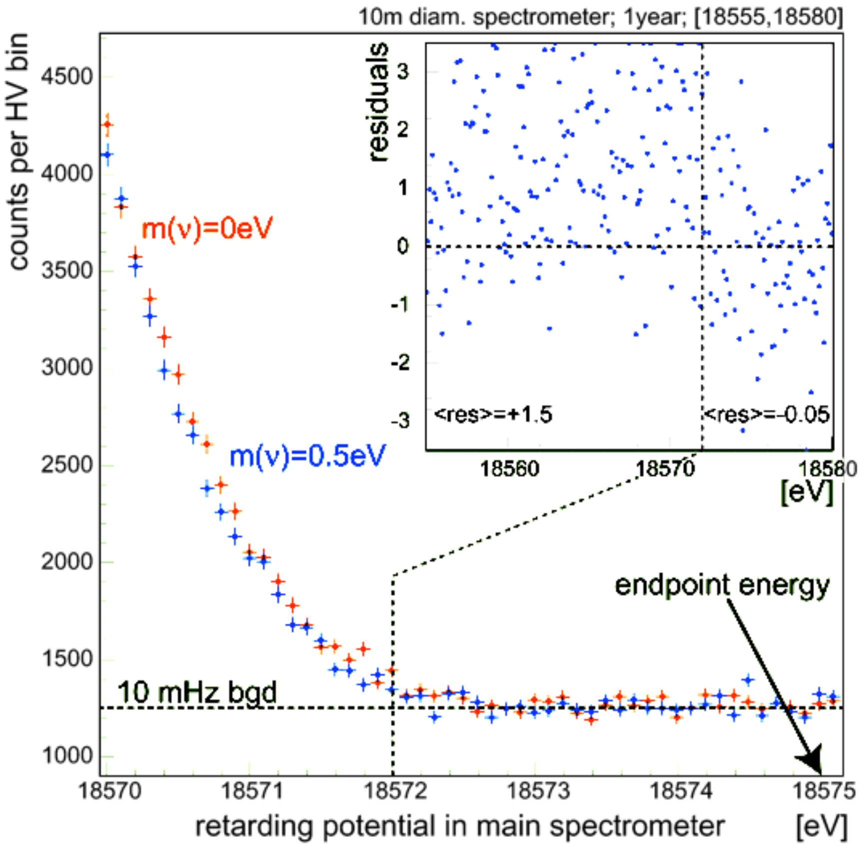
The beta electrons, isotropically emitted at the source, are transformed into a broad beam of electrons flying almost parallel to the magnetic field lines. This parallel beam of electrons is running against an electrostatic potential formed by a system of cylindrical electrodes. All electrons with enough energy to pass the electrostatic barrier are reaccelerated and collimated onto a detector, all others are reflected. Therefore the spectrometer acts as an integrating high-energy pass filter. The relative sharpness of this filter is given by the ratio of the minimum magnetic field B_{min} in the center plane and the maximum magnetic field B_{max} between beta electron source and spectrometer :

$$\frac{\Delta E}{E} = \frac{B_{\min}}{B_{\max}}$$



One possible experimental approach

1 year data data taking
and 0.2 eV resolution



Katrin collaboration foresees in a second step the following upgrade:

- **spectrometer with larger diameter 7 m to 9 m**
- **larger diameter source vessel 7 cm to 9 cm.**
- **1 mHz overall background rate**

How far can it be?

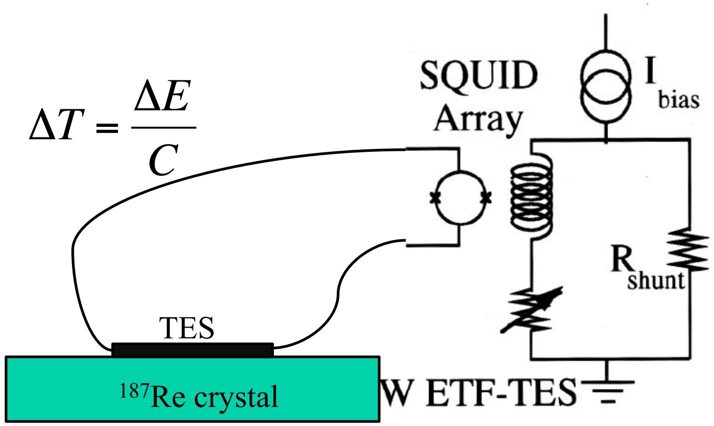
If we consider:

- ***Katrin sensitivity foreseen in the second experimental phase***
  0.2 eV energy resolution
  0.1 mHz detector background rate (only 1 o.o.m. better than KATRIN has foreseen)
- ***the cross section value we calculated (7.7 10^{-45} cm^2c)***
- ***NFW(MW) density assumption,***
- ***0.6 eV for the neutrino mass***
- ***we need 16(10) g of T to get 15 NCB events, 12 events of background and so 5 sigma evidence in one year (we neglected the background from beta decay: 1/20 (1/30).)***

Another experimental solution to detect the CRN

MARE detector

$$\Delta T = \frac{\Delta E}{C}$$



The key issue of the read-out system are the very low noise SQUID amplifier

$$\Delta V = V_{bias} \cdot A \cdot \frac{\Delta T}{T}$$

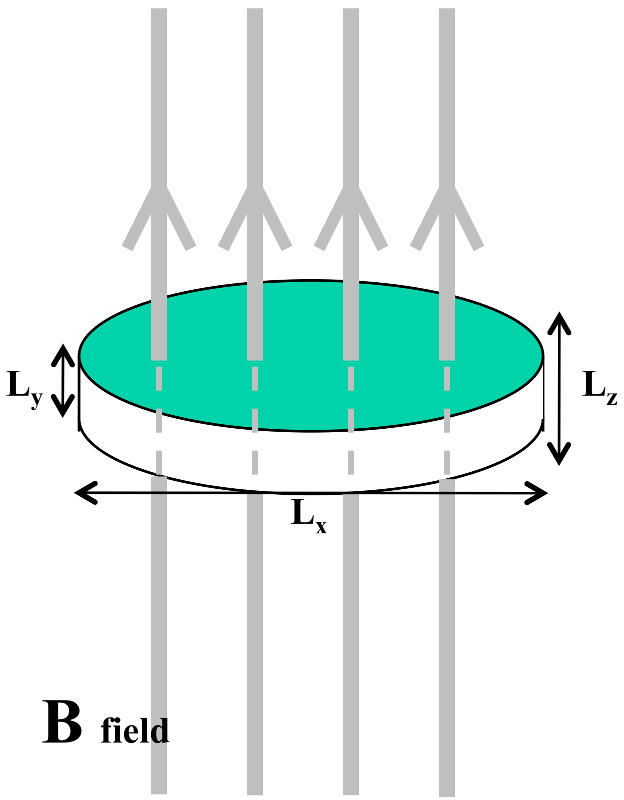
MARE collaboration claims that can achieve a resolution of part of eV. This would match our request but much large mass with respect to the case of Tritium is needed since the cross section of NCB on ^{187}Re is lower. The MARE collaboration foresees to have in ~2011 100000 micro calorimeters of 1-5 mg mass each. This is still 4-6 order of magnitude far from the mass we need but in principle this detector technology can be scaled up easily.

A new experimental options

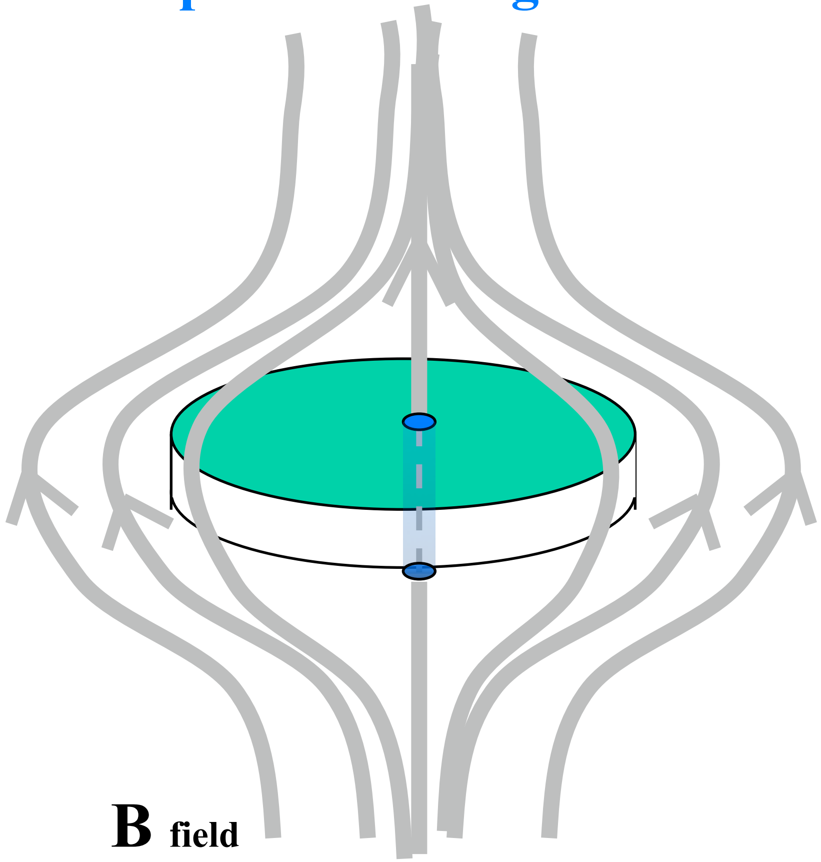
Geometrically-Metastable Superconducting Strips Detectors

Detection Principle

$T > T_C$
Normal State

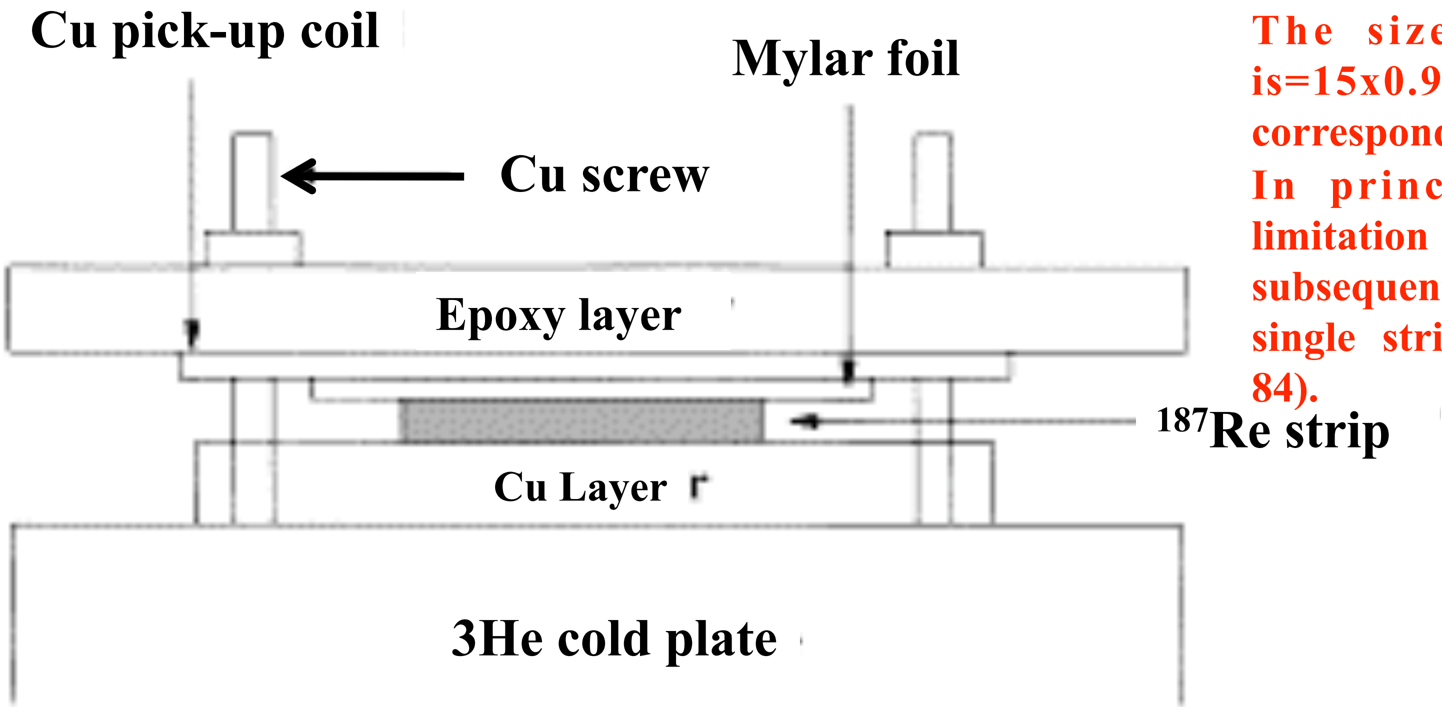


$T < T_C$
Superconducting State



(NIM A 370 (1996) 104, NIM A 373 (1996) 65 and reference therein.)

Typical experimental set-up



The size of the Re strip is=15x0.9x0.025 mm^3 that corresponds to a mass of 7 mg. In principle there are no limitation on the volume and subsequently on the mass of the single strip (NIM A444 (2000) 84).

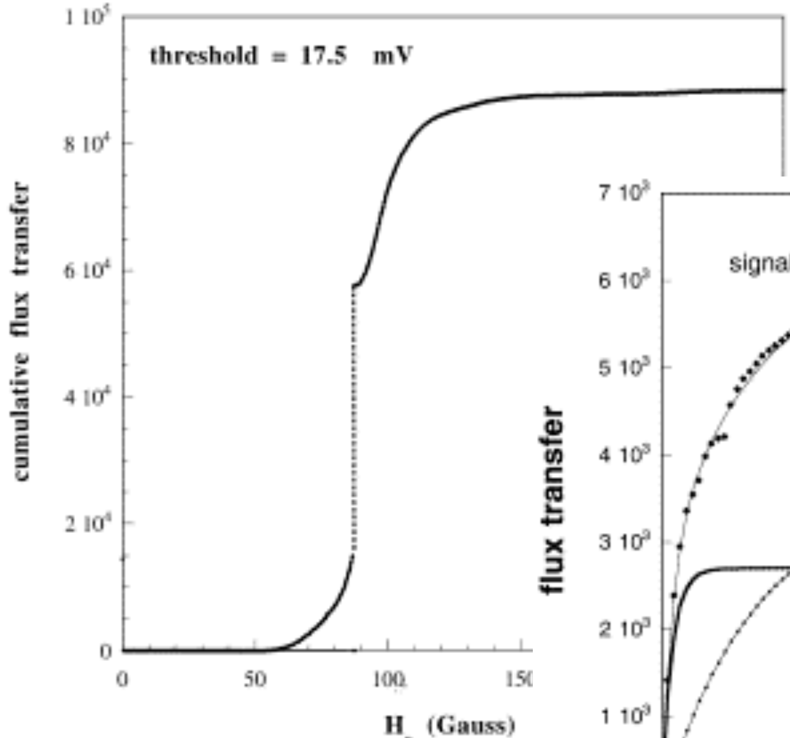
Why the signal is proportional to the energy release?

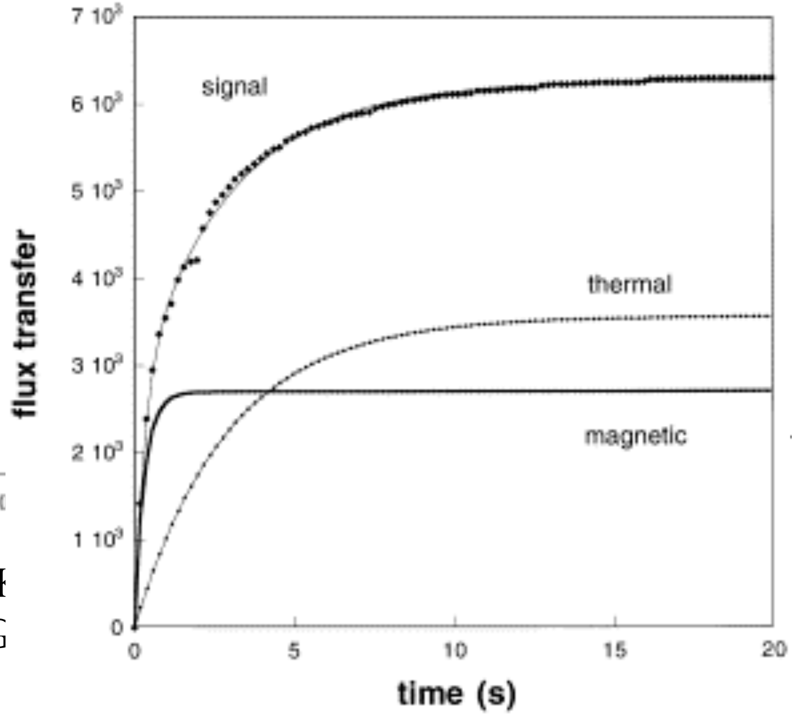
$$\frac{E_{released}}{L_y S} = \Delta h$$

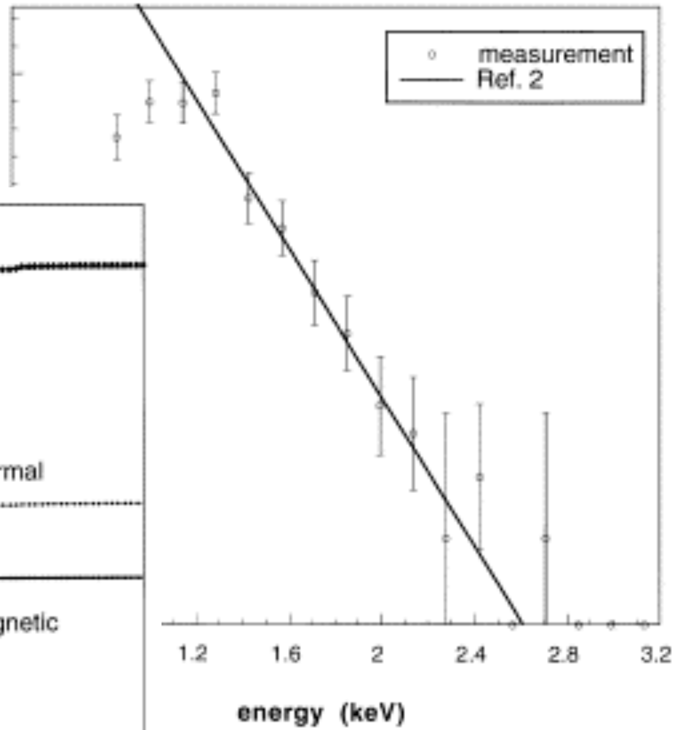
Where Δh is the variation of enthalpy density in the phase transition. The typical volume where the nucleation of flux tube take place is ~ 1-10 μm^3

$$V \sim \int \frac{d\phi}{dt} dt = H \cdot S \propto H \cdot \frac{E_{released}}{L_y \Delta h}$$

Some results from old measurements







The device was cooled (330m
B field was ramped from 88 G
above H_c (210 G).

From the plot it is visible that after ~20 s the efficiency drops down according to: $\varepsilon(t) = \frac{\tau_T}{\Delta t}\left[1 - e^{-\Delta t/\tau_T}\right]$**. After 20 s a new cycle of the B field starts again.**

Why this experimental approach is very promising

•The mass per strip can be increased almost without limit if we keep the aspect ratio of an ellipsoid where one axis is much larger than the other one (1/10). Under this hypothesis 1-10 g per strip is achievable.

• The limit of the single detector will be due to the time response of read-out chain. The signal rate that can be tolerated is ~ 10^5 Hz if the time response of the read-out electronic is ~10ns.

•The energy resolution envisaged in literature is at level of eV if the read-out is realized by means of a SQUID amplifier.

•A detector with a full mass of 1-10 kg is not out of reach even with the present status of the knowledge in the field of Geometrically-Metastable Superconducting Strip Detectors.

Conclusions

- The fact that neutrino has a nonzero mass has renewed the interest on Neutrino Capture on Beta decaying nuclei as a unique tool to detect very low energy neutrino
- The relatively high NCB cross section when considered in a favourable scenario could bring cosmological relic neutrino detection within reach in a near future if:
  - neutrino mass is in the eV range
  - an electron energy resolution of 0.1 – 0.2 eV is achieved

- So far we considered only two elements: ^{3}H and ^{187}Re. More elements are under study.
- From the point of view of the technological feasibility of the measurement we are only at beginning of the investigation. We are confident that a new technological improvement can soon make this measurement more realistic.
- Furthermore we started to investigate the technology of the Geometrically Metastable-Superconducting Strip Detector that appears to be very promising.