A process to detect neutrinos of vanishing kinetic energy by means of unstable target nuclei

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23/05/2008

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Outline

- 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%

The Cosmological Relic Neutrinos

The Cosmological Relic Neutrinos (CRN) are weakly-clustered

$$\sim 1\sec > BigBang$$

Date of birth

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

density per flavor

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

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!

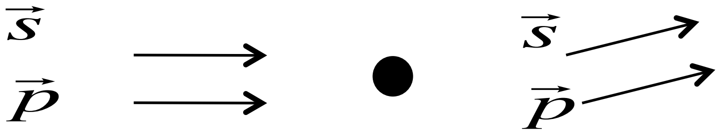
The longstanding question (I)

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 the same ΔJ and opposite sign Δp. This is due to the fact the opposite sign of spin is compensated by the opposite sign of the scattering amplitude. The latter implies a different refraction index for ν (n>1) and anti-ν (ν<1) and subsequently a different scattering angle and a Δp of different sign.

Then if we use a torque-balance to detect the angular acceleration due to the CRNs scattering we exploit the major advantage to be sensitive to any mixture of neutrino and anti-neutrino whose effect on the balance is added up.

The longstanding question (II)

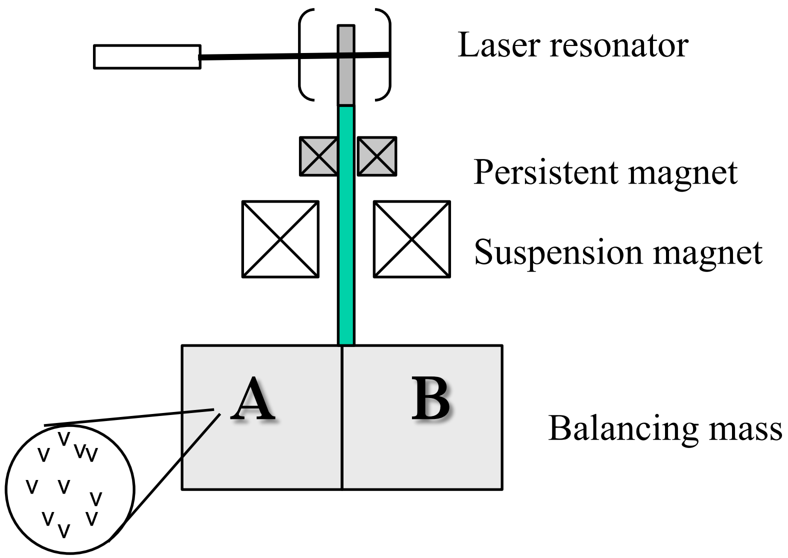
Is it possible to measure the CRN?

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 :

$$f = \left(\frac{\nu - \bar{\nu}}{100}\right) \neq 0$$



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:

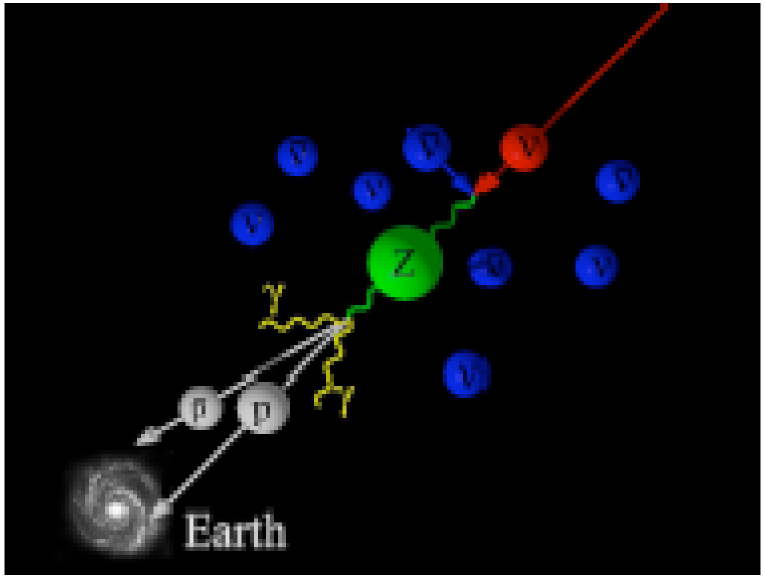
$$a_{G_F} \approx 10^{-27}\left(\frac{100}{A}\right)\left(\frac{cm}{R}\right) f\left(\frac{\beta_{earth}}{10^{-3}c}\right)\frac{cm}{\sec^2}$$

The value of acceleration expected is almost 15 order of magnitude far from the current sensitivity of any accelerometers used today in “Cavendish” experiments.

The longstanding question

Is it possible to measure the CRN ?

Method 2



In the second method a resonant annihilation of EECν off CRN into Z-boson was proposed. The annihilation occurs at energy:

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

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 (GKZ: where the photons of CMB are absorbed by protons to produce pions).

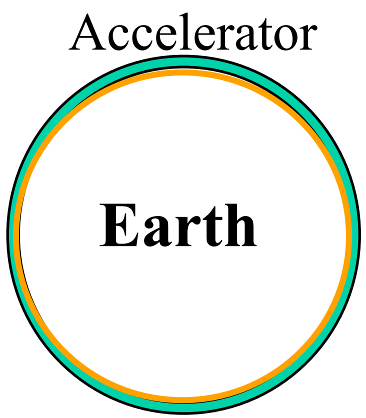
Such energetic neutrino sources are unknown so far.

The longstanding question

Is it possible to measure the CRN ?

Method 3

In the third method the observation of interactions of extremely high energy protons from terrestrial accelerator beams with the relic neutrinos is proposed.



In this case even with an accelerator ring (VLHC) of $\sim 4\text{x}10^4$ 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

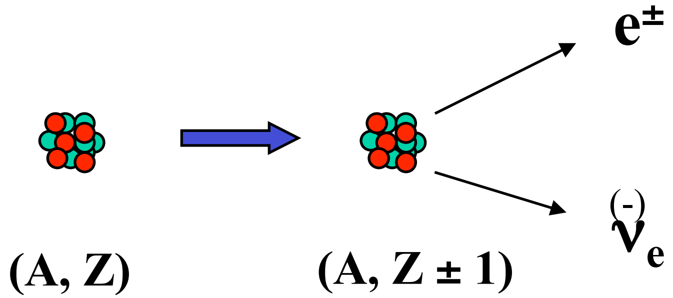
A new idea to detect
Cosmological Relic Neutrinos

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

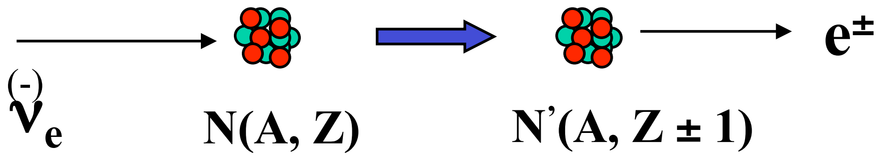
Our proposal (I)

A process without energy threshold

Beta decay



Neutrino Capture on a
Beta decaying nucleus



Since M(N)-M(N')=Q_β>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).

Our proposal (II)

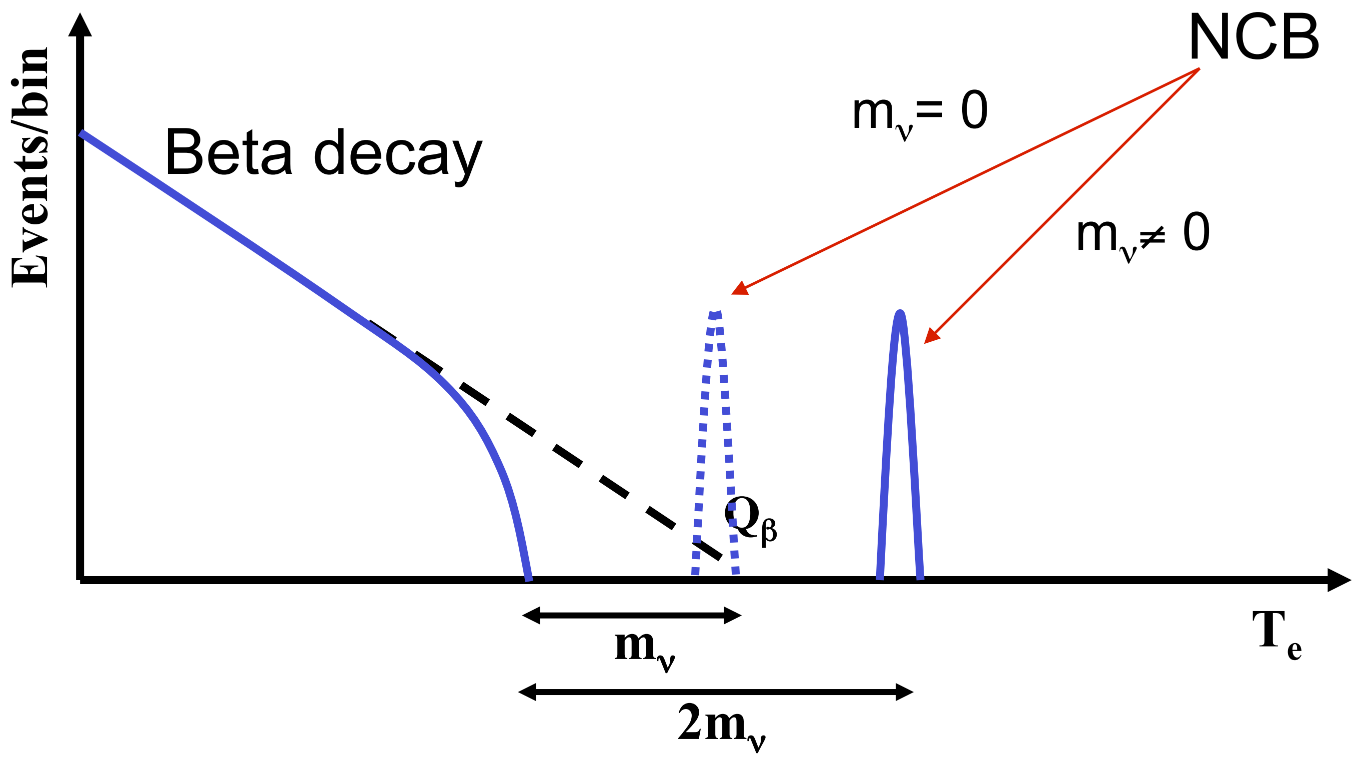
Our proposal is based on the fact that the $\sigma \cdot v$ does not vanishes when the ν energy is negligible but, it reaches a plateau value depending on the target nuclei.

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. Gemini Phys.Scripta T121:131-136, 2005 and references therein.

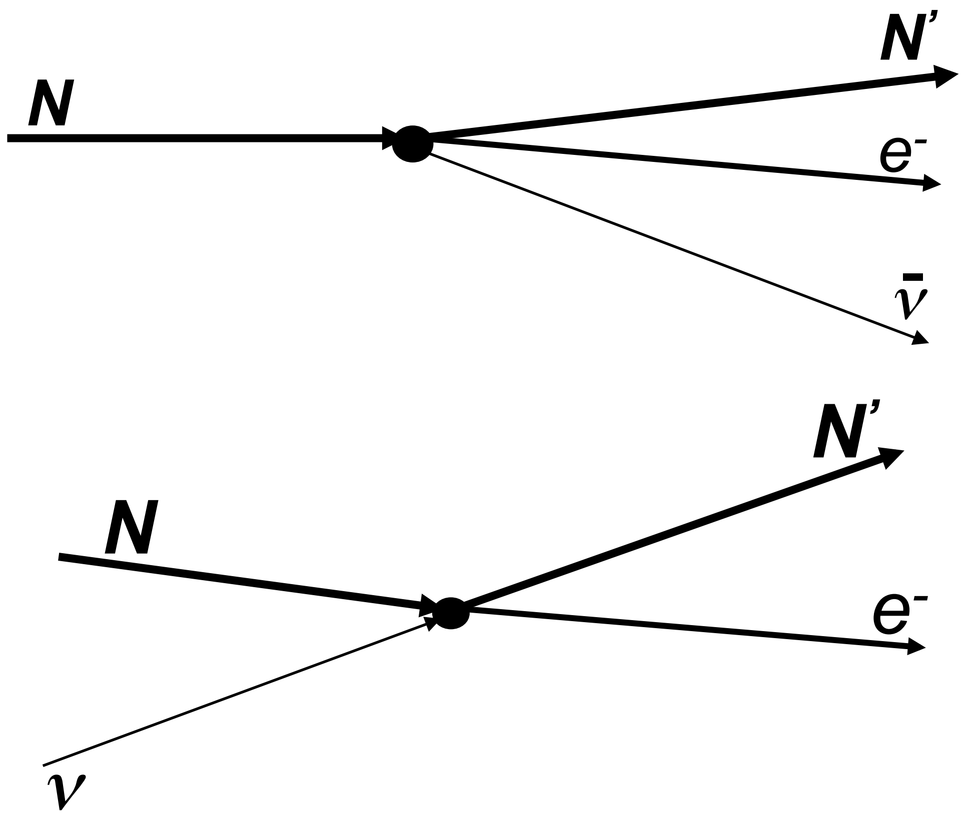
NCB signature

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

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

Where $F(Z, E_{\mathrm{e}})$ the Fermi function and $C(E_{\mathrm{e}}, p_\nu)_\nu$ 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:

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

NCB Cross Section (II)

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

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

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 form factors. 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:

$$\lambda_\beta = \frac{G_\beta^2}{2\pi^3} \int_{m_e}^{W_o} p_e E_e F(Z, E_e) C(E_e, p_\nu)_\beta E_\nu p_\nu \, dE_e$$

$$C(E_e, p_\nu)_\nu = C(E_e, -p_\nu)_\beta$$

NCB Cross Section

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

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

in terms of observable quantities:

$$f = \int_{m_e}^{W_o} F(Z,E_e^`) p_e^` E_e^` E_\nu^` p_\nu^` \, dE_e^`.$$

$$f t_{1/2} = \frac{2\pi^3 \ln 2}{G_\beta^2 \overline{C}_\beta},$$

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 we obtain:

$$\sigma_{NCB} v_\nu = 2\pi^2 \ln 2 \cdot p_e E_e F(Z,E_e) \frac{C(E_e,p_e)_\nu}{f t_{1/2} \overline{C}_\beta} = \frac{2\pi^2 \ln 2}{t_{1/2}} \frac{p_e E_e F(Z,E_e) \cdot C(E_e,p_e)_\nu}{\int_{m_e}^{W_0} p_e^' E_e^' F(Z,E_e^') \cdot C(E_e^',p_e^')_\beta \, dE_e^'}$$

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:

$$\sigma_{NCB} v_\nu = \frac{2\pi^2 \ln 2}{t_{1/2}} \frac{1}{\int_{m_e}^{W_0} \frac{C(E_e', p_e')_\beta}{C(E_e, p_e)_\nu} \cdot \frac{p_e'}{p_e} \frac{E_e'}{E_e} \frac{F(Z, E_e')}{F(Z, E_e)} dE_e'} = \frac{2\pi^2 \ln 2}{A \cdot t_{1/2}}$$

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: $$\sigma_{\mathrm{NCB}} v_\nu = 2\pi^2 \ln 2 \frac{p_e E_e F(Z, E_e)}{f t_{1/2}}$$ $0^+ \rightarrow 0^+$

This expression of the cross section is a very good approximation also for allowed transitions (Tritium case) since: $\frac{C(E_e, p_\nu)_\beta}{C(E_e, p_\nu)_\nu} \simeq 1$ $J \rightarrow J$

- *K-th* unique forbidden $J \rightarrow J + K$

(Leptonic contribution)

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

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

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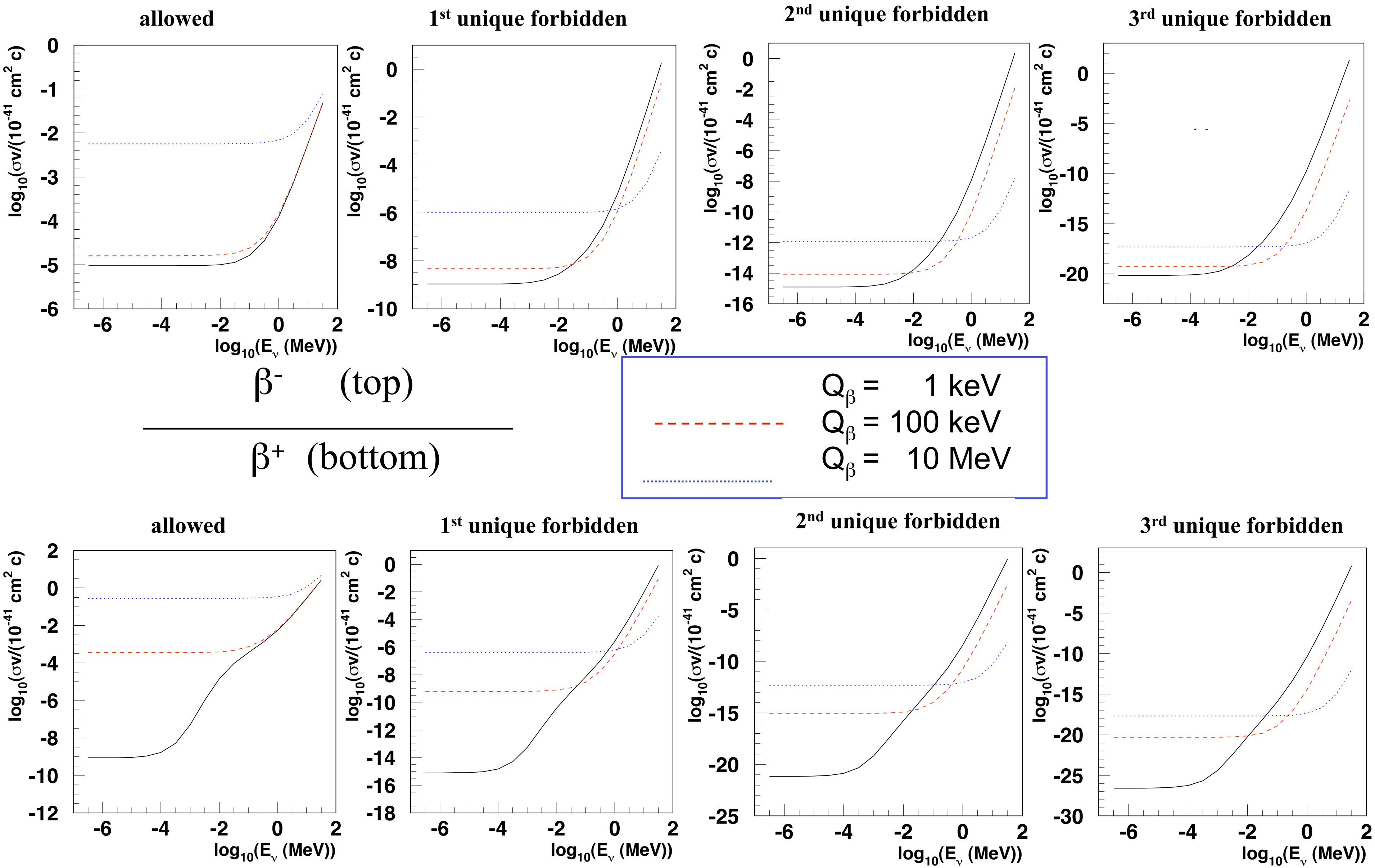
Using shape factors ratio
$$\sigma_{\rm NCB} v_\nu = \frac{2\pi^2 \ln 2}{\mathcal{A}\, t_{1/2}}$$

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

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 forbiddenness level



NCB Cross Section

the major results of our paper

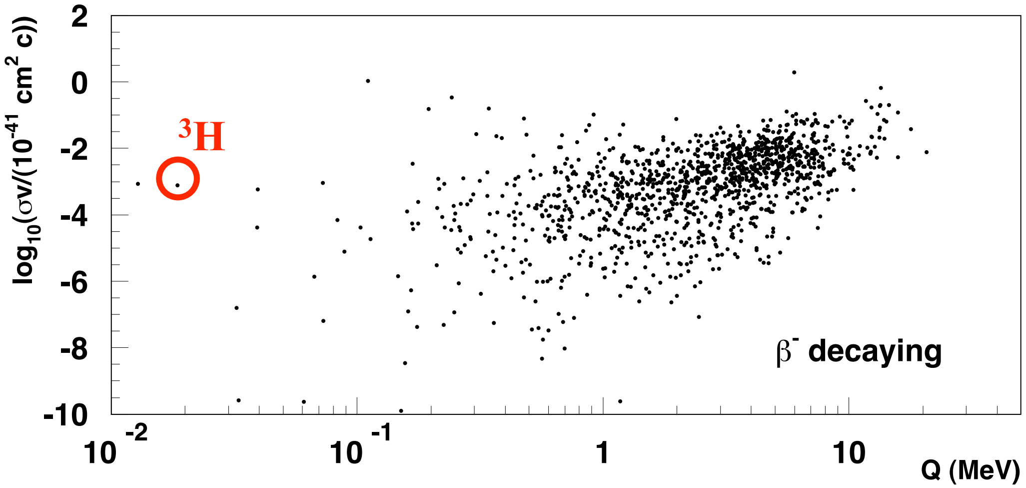
- **Exist a process (NCB) that allows in principle the detection of neutrino of vanishing energy!**

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

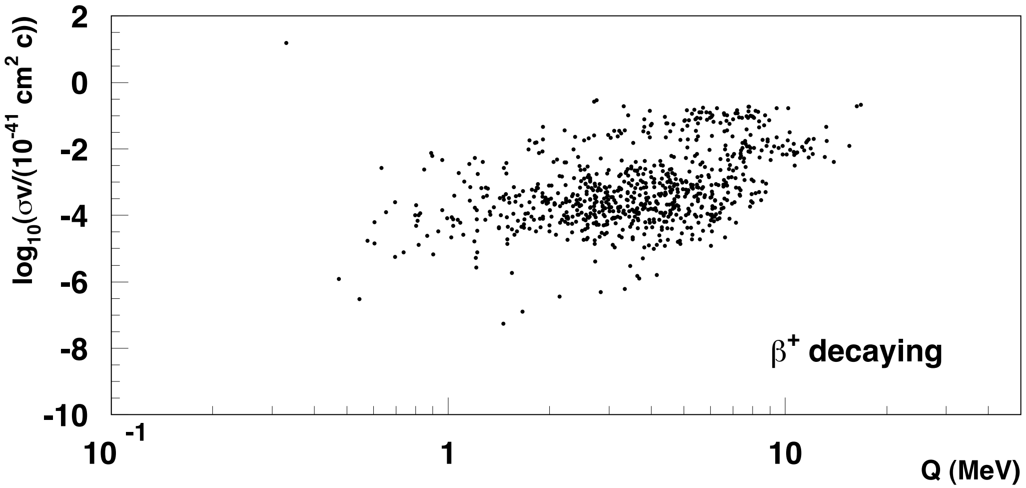
- **We described a method to calculate any NCB cross section by means of measured known quantities ($t_{1/2}$) and the ratio of the nuclear shape factors. The latter reduces significantly the theoretical uncertainties of the σ calculation!**

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(β±) > 5 %
selected from 14543 decays listed in the ENSDF database

NCB Cross Section Evaluation

specific cases

Isotope	Q_β (keV)	Half-life (sec)	$\sigma_{\rm NCB}(v_\nu/c)$ $(10^{-41}\ {\rm cm}^2)$
^{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)	$\sigma_{\rm NCB}(v_\nu/c)$ $(10^{-41}\ {\rm cm}^2)$
^{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 $m_\nu=0$, $n_\nu \sim 50/cm^3$ in the full energy range.

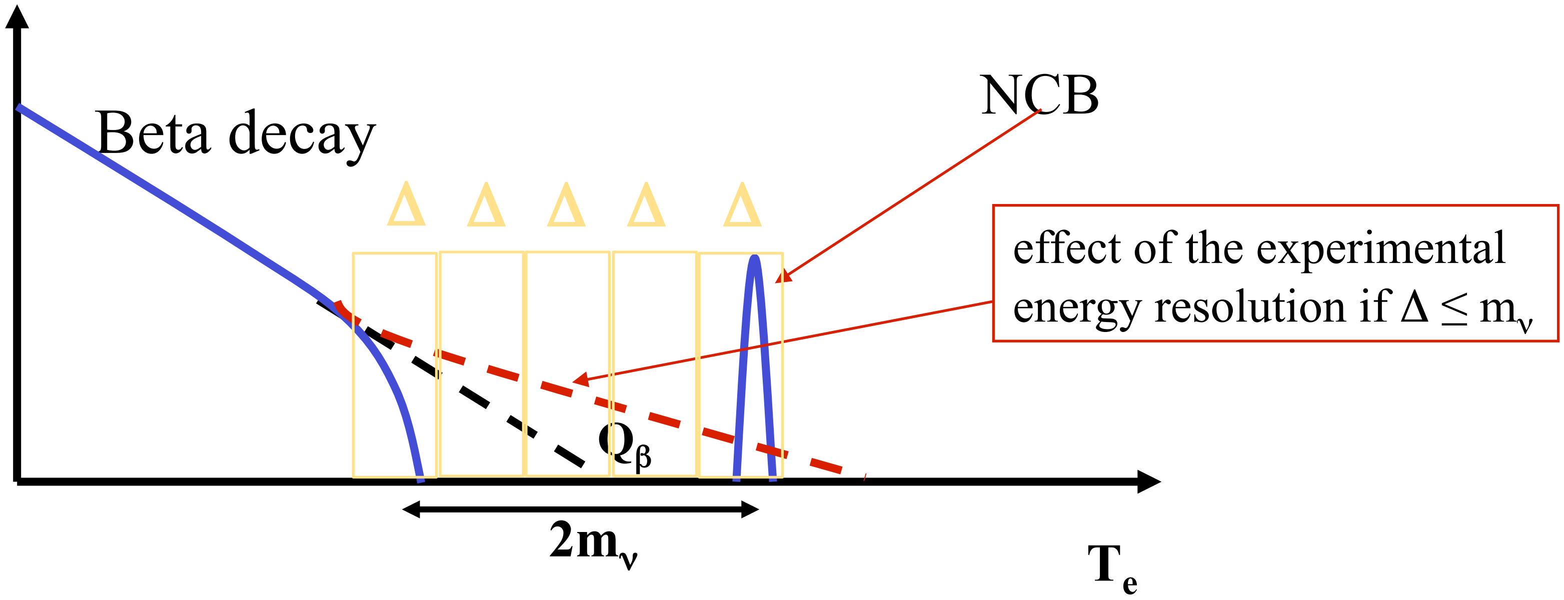
So far we considered the worst condition to calculate the CRN interaction rate. In fact, Fermi momentum distribution does not describe any neutrino density increase due to gravitational interaction.

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



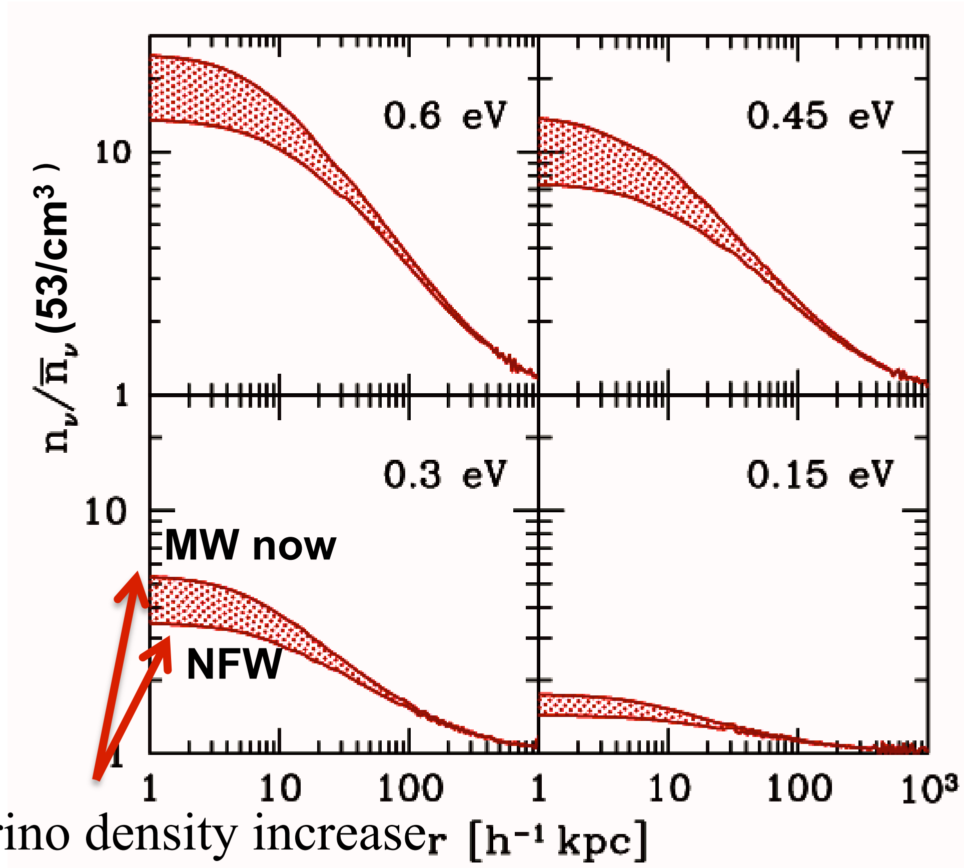
Relic Neutrino Detection

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

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.



Neutrino density increase

Possible effects enhancing the NCB

Probing low energy neutrino backgrounds
JCAP06(2007)015

Table 3. The number of NCB events per year for 100 g of ^{3}H, taking into account the effect of gravitational clustering in the neighbourhood of the Earth, compared to the case of a standard homogeneous Fermi–Dirac distribution with $T_\nu = 1.7 \times 10^{-4}$ eV (FD). We show for some value of neutrino mass the results for a Navarro, Frenk and White profile (NFW) and for present day mass distribution of the Milky Way (MW), using the local neutrino densities computed in [36].

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

Statistical significance with increased density

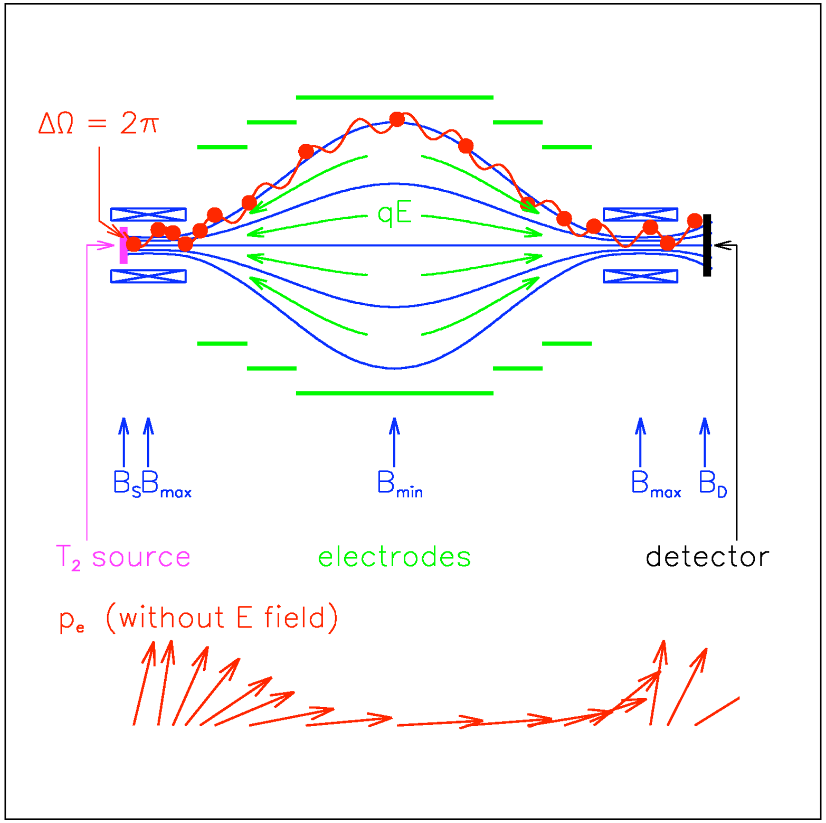
In the table is reported the mass needed in order to have a 5 sigma evidence of NCB (on Tritium target) in one year for different neutrino clustering model.

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

One possible experimental approach (I)

KATRIN detector: the ultimate direct neutrino mass measurement
aims at direct neutrino mass measurement through the study of the ^{3}H endpoint
(Q_{β} =18.59 keV, $t_{1/2}$ =12.32 y)

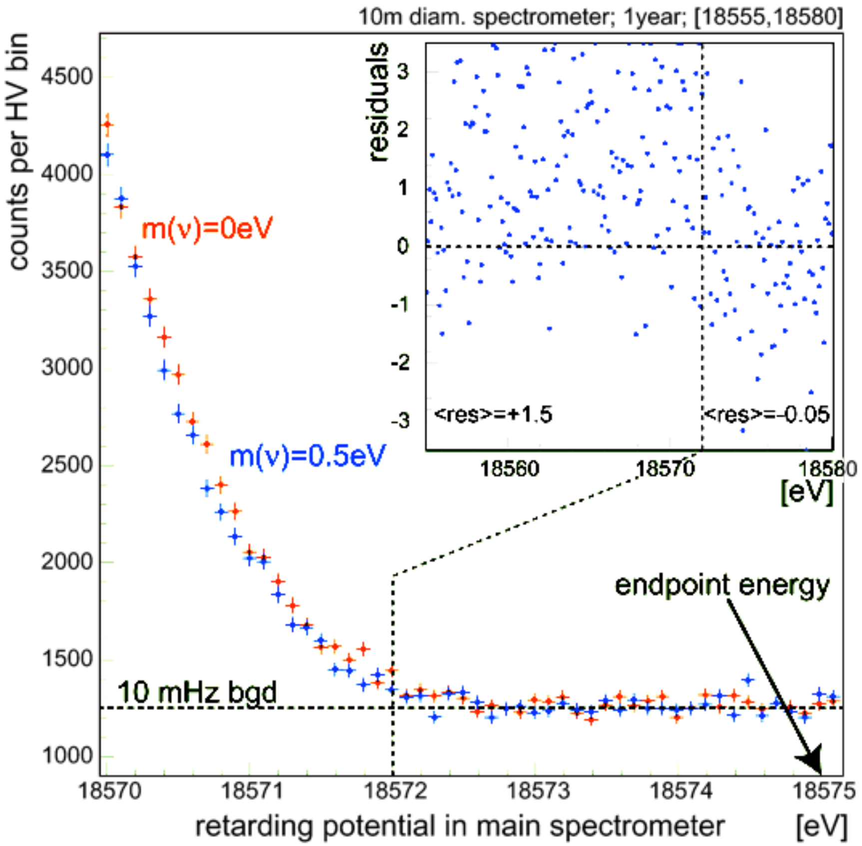
The beta electrons are transformed into a broad beam of electrons flying almost parallel to the magnetic field lines. The focalization capability of the magnetic field is based on the fact: $\vec{F} = \vec{\nabla}(\vec{\mu} \cdot \vec{B})$ **thus the cyclotron energy is transformed in longitudinal motion.**
The electrons are running against an electrostatic potential formed by a system of cylindrical electrodes.
Then all the 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

MC simulation of 1 year data taking



KATRIN phase I

- **Energy resolution 0.93 eV**
- **Tritium mass ~0.1mg**
- **10 mHz overall background rate**
- **first results 2011-2015**

KATRIN phase II

- **Energy resolution 0.2 eV**
- **spectrometer with larger diameter 7 m to 9 m**
- **larger diameter source vessel 7 cm to 9 cm.**
- **1 mHz overall background rate**
- **2015 ->**

How far can it be?

If we consider:

- *Katrin sensitivity foreseen in the second experimental phase*
  0.2 eV energy resolution
  1 mHz detector background rate
- *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 59(35) g of ^2T to get 55 NCB events, 125 background events and so we have almost 5 sigma evidence in one year (we neglected the background from beta decay: ~1/6 (1/10) of the signal)*

If we consider:

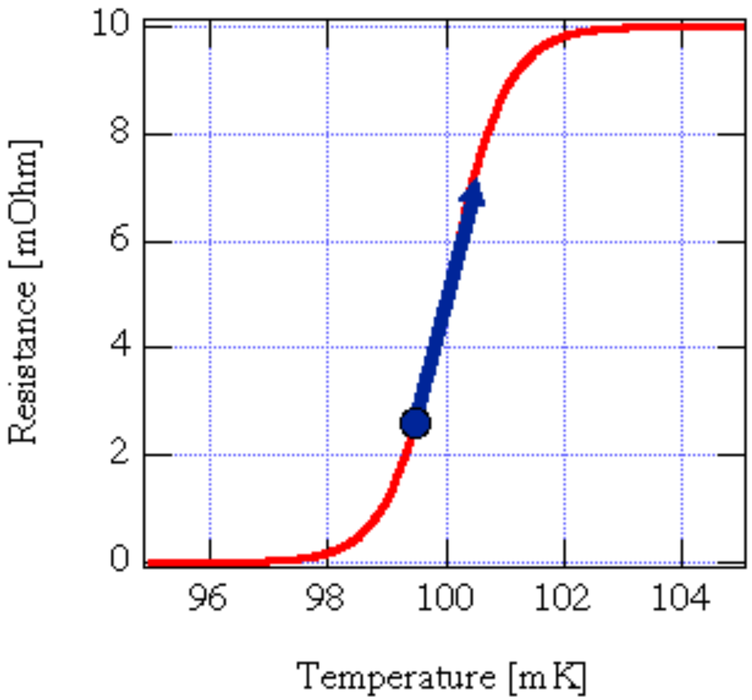
- *Katrin sensitivity foreseen in the second experimental phase*
  0.2 eV energy resolution
  0. 1 mHz detector background rate (only 1 o.o.m. better than KATRIN has foreseen)
- *the cross section value we calculated (7.7 10^{-45} cm^2c)*
- *NFW(MW) density assumption,*
- *0.6 eV for the neutrino mass*
- *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: future experiment based on solid state technology aiming at direct measurement through the study of the ^{187}Re endpoint (Q_β =2.2 keV, $t_{1/2}$ =4.3 10^{10} y), by using micro-bolometers @ 10mK temperature)

The detector is based on the technology of micro bolometers made of ^{187}Re crystals read-out by high sensitivity resistor Transition Edge Resistor (TER):

The detection principle is based on the fact that given the very low heat capacitance C also a small amount of energy release in the ^{187}R crystal can provoke a measurable: $\Delta T = \frac{\Delta E}{C(T)}$



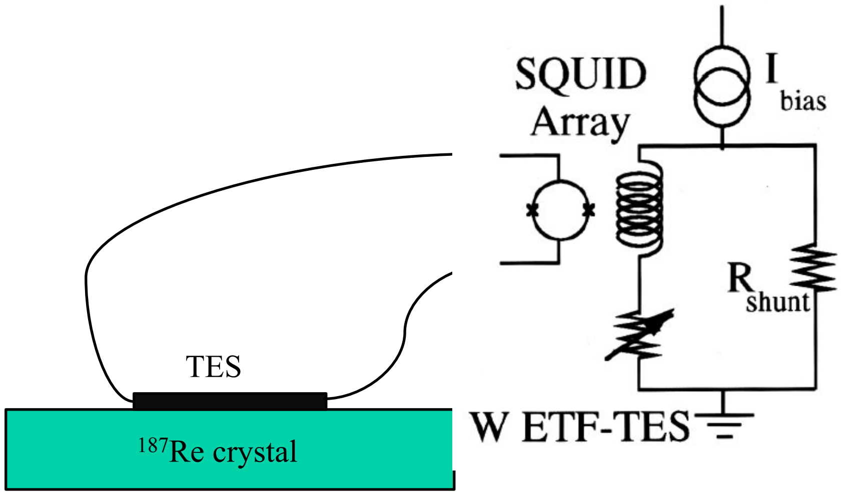
and subsequently an instantaneous TER resistance variation happen such that:

$$\Delta i = \int V \cdot R(T) dt$$

and the current variation will be measured.

Another experimental solution to detect the CRN

MARE detector: schematic drawing



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

The MARE collaboration claims that can achieve resolution of part of eV. This would mach 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 collaboration MARE 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.

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

- A detailed study of NCB cross section has been performed for a large sample of known beta decays and a method to reduce the uncertainty due to nuclear matrix elements evaluation has been found.

- 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

Outlook

- So far we considered only two elements: ^3H and ^{187}Re. More elements are under study

- Also elements EC instable show the nice feature of having sizeable cross section for neutrino CC cross section even if the neutrino has very low energy. The properties of those elements as neutrino target are still under evaluation.

- 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. (An electrostatic detector like KATRIN could be a possible experimental approach or also a large array micro calorimeters apparatus like MARE.)