Impact of Beyond the Standard Model Physics in the Detection of the Cosmic Neutrino Background

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Helicity composition of the CνB

Since $\bar{p}_0 \approx 0.6\,\text{meV}$ and $m_\nu \approx \mathcal{O}(0.1\,eV)$

$\Rightarrow$ Relic neutrinos are non-relativistic.

Therefore, they are best classified by helicity. Using the current abundance of neutrinos in the Dirac and Majorana case, we find for the capture rate in $\nu_j + {}^3\text{H} \longrightarrow {}^3\text{He} + e^-$ that:

- Capture rate for Majorana Fermions is twice the Dirac ones, considering only SM.

$$\Gamma^M_{C\nu B} = 2\, \Gamma^D_{C\nu B}.$$

PTOLEMY experiment

The background in this experiment is the β-decay, because this process has no threshold. Considering $m_{^3H} \approx m_{^3He} \gg m_e \gg m_\nu$, we have

$$K_e^{C\nu B} \approx K_{end} + 2m_\nu$$

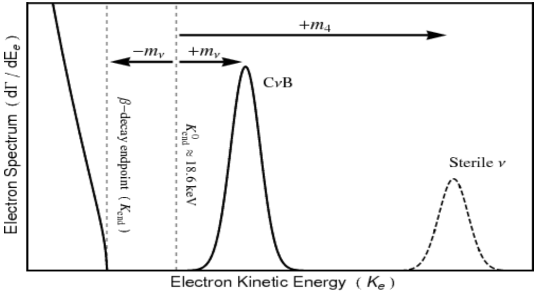


Figure 1: Signal of non-relativistic relic neutrinos captured by Tritium in the background of the β-decay at PTOLEMY.[2, 3]

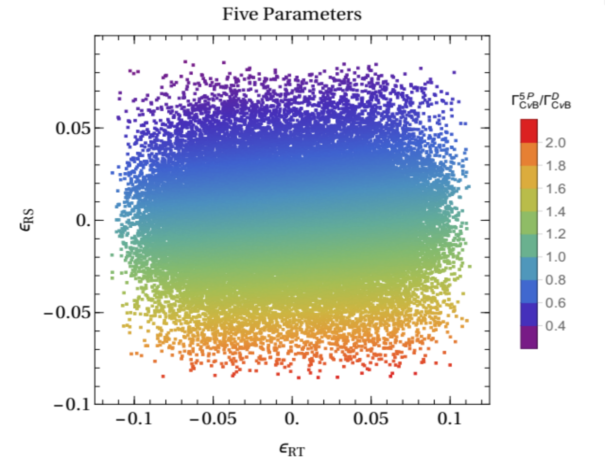
What is the effect of turning on BSM interactions?

$$\mathcal{L}_{\text{eff}} = -\frac{G_F}{\sqrt{2}} V_{ud} U_{ej} \left\{ [\overline{e}\gamma^\mu \mathbb{P}_L \nu_j][\overline{u}\gamma^\mu \mathbb{P}_L d] + \sum_{l,q} \epsilon_{lq} [\overline{e}\gamma^\mu \mathcal{O}_l \nu_j][\overline{u}\gamma^\mu \mathcal{O}_q d] \right\}$$

Table 1: Dimension 6 Effective operators. [1]

ϵ_{lq}	$\mathcal{O}_l$	$\mathcal{O}_q$
ϵ_{LL}	$\gamma^\mu(1-\gamma^5)$	$\gamma^\mu(1-\gamma^5)$
ϵ_{LR}	$\gamma^\mu(1-\gamma^5)$	$\gamma^\mu(1+\gamma^5)$
ϵ_{RL}	$\gamma^\mu(1+\gamma^5)$	$\gamma^\mu(1-\gamma^5)$
ϵ_{RR}	$\gamma^\mu(1+\gamma^5)$	$\gamma^\mu(1+\gamma^5)$
ϵ_{LS}	$(1-\gamma^5)$	1
ϵ_{RS}	$(1+\gamma^5)$	1
ϵ_{LP}	$(1-\gamma^5)$	$-\gamma^5$
ϵ_{RP}	$(1+\gamma^5)$	$-\gamma^5$
ϵ_{LT}	$\sigma^{\mu\nu}(1-\gamma^5)$	$\sigma_{\mu\nu}(1-\gamma^5)$
ϵ_{RT}	$\sigma^{\mu\nu}(1+\gamma^5)$	$\sigma_{\mu\nu}(1+\gamma^5)$

Results



BSM interactions can mimic SM Majorana neutrinos!

$$\Rightarrow \Gamma^{D-BSM}_{C\nu B} \approx 2\,\Gamma^{D}_{C\nu B} = \Gamma^{M}_{C\nu B}$$

Thank you!
Danke!

Appendix

Capture Rate:

$$\Gamma_{C\nu B} = \sum_{j=1}^{3} \Gamma_{C\nu B}(j) = N_T \sum_{j=1}^{3} \left[\sigma_j(+1) v_j n_{\nu_+^j} + \sigma_j(-1) v_j n_{\nu_-^j} \right]$$

Capture Cross Section:

$$\sigma_j^{BSM}(h_j)\, v_j \quad = \quad \frac{G_F^2}{2\pi} |V_{ud}|^2 \, |U_{ej}|^2 \, F_Z(E_e) \frac{m_{^3\mathrm{He}}}{m_{^3\mathrm{H}}} E_e p_e T_j(h_j, \epsilon_{lq}),$$

$$
\begin{aligned}
T_j(h_j, \epsilon_{lq}) &= \mathcal{A}(h_j) \left[g_V^2 (\epsilon_{LL} + \epsilon_{LR} + 1)^2 + 3 g_A^2 (\epsilon_{LL} - \epsilon_{LR} + 1)^2 \right. \\
&+ g_S^2 \epsilon_{LS}^2 + 48 g_T^2 \epsilon_{LT}^2 + \frac{2 m_e}{E_e} \left(g_S g_V \epsilon_{LS} (\epsilon_{LL} + \epsilon_{LR} + 1) \right. \\
&- \left. \left. 12 g_A g_T \epsilon_{LT} (\epsilon_{LL} - \epsilon_{LR} + 1) \right) \right] + \mathcal{A}(-h_j) \left[g_V^2 (\epsilon_{RR} + \epsilon_{RL})^2 \right. \\
&+ 3 g_A^2 (\epsilon_{RR} - \epsilon_{RL})^2 + g_S^2 \epsilon_{RS}^2 + 48 g_T^2 \epsilon_{RT}^2 \\
&+ \left. \frac{2 m_e}{E_e} \left(g_S g_V \epsilon_{RS} (\epsilon_{RR} + \epsilon_{RL}) - 12 g_A g_T \epsilon_{RT} (\epsilon_{RR} - \epsilon_{RL}) \right) \right] \\
&+ 2 \frac{m_j}{E_j} \left(g_S g_V \epsilon_{RS} (\epsilon_{LL} + \epsilon_{LR} + 1) + \epsilon_{LS} (\epsilon_{RR} + \epsilon_{RL}) \right. \\
&- \left. 12 g_A g_T \left(\epsilon_{RT} (\epsilon_{LL} - \epsilon_{LR} + 1) + \epsilon_{LT} (\epsilon_{RR} - \epsilon_{RL}) \right) \right) \\
&+ 2 \frac{m_j m_e}{E_j E_e} \left(g_V^2 (\epsilon_{LL} + \epsilon_{LR} + 1)(\epsilon_{RR} + \epsilon_{RL}) \right. \\
&+ 3 g_A^2 (\epsilon_{LL} - \epsilon_{LR} + 1)(\epsilon_{RR} - \epsilon_{RL}) + g_S^2 \epsilon_{RS} \epsilon_{LS} + 48 g_T^2 \epsilon_{RT} \epsilon_{LT}
\end{aligned}
$$

Bibliography

Martín Arteaga, Enrico Bertuzzo, Yuber F. Perez-Gonzalez, and Renata Zukanovich Funchal.
Impact of Beyond the Standard Model Physics in the Detection of the Cosmic Neutrino Background.
JHEP, 09:124, 2017.

S. Betts et al.
Development of a Relic Neutrino Detection Experiment at PTOLEMY: Princeton Tritium Observatory for Light, Early-Universe, Massive-Neutrino Yield.
In *Proceedings, 2013 Community Summer Study on the Future of U.S. Particle Physics: Snowmass on the Mississippi (CSS2013): Minneapolis, MN, USA, July 29-August 6, 2013*, 2013.

Andrew J. Long, Cecilia Lunardini, and Eray Sabancilar.
Detecting non-relativistic cosmic neutrinos by capture on tritium: phenomenology and physics potential.
JCAP, 1408:038, 2014.