Exploring New Physics via High Energy Neutrinos at IceCube

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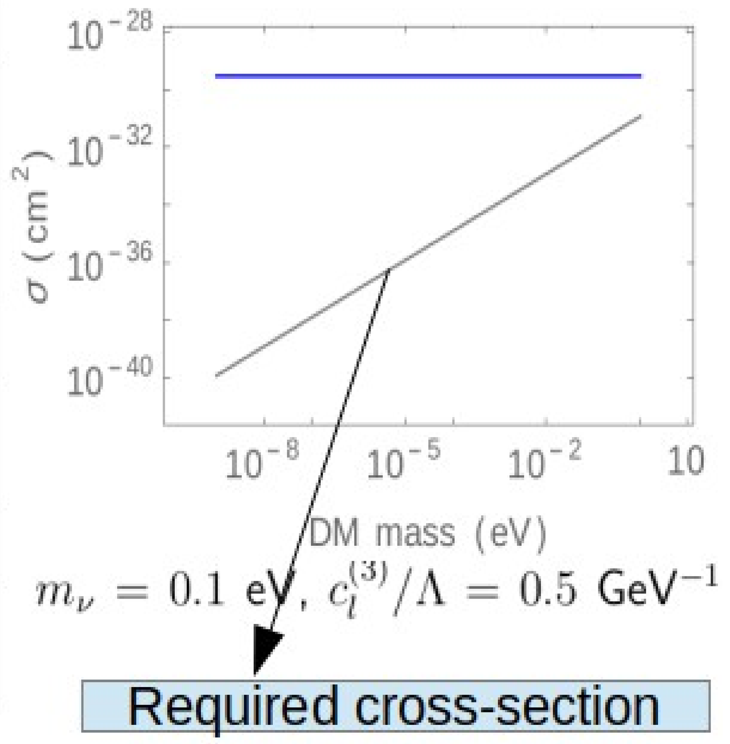
Abstract

The recent detection of astrophysical neutrinos at IceCube opens up a new avenue for explorations of new physics with visible matter and DM. Astrophysical neutrinos travel through cosmic distances to reach earth. In this work we explore the effect of neutrino-DM interactions : changes the flux and/or flavour ratio of the IC neutrino spectrum. Due to the high energy at IC, a comparative study of constraints with respect to LHC, on probing neutrino-quark NSIs is interesting.

Interaction	Constraints	Remarks
$\frac{c_l^{(1)}}{\Lambda^2}(\bar{\nu}i\partial\!\!\!/\nu)(\Phi^*\Phi)$	$c_l^{(1)}/\Lambda^2 \lesssim 8.8\times10^{-3}\,\mathrm{GeV}^{-2}$, $c_e^{(1)}/\Lambda^2 \lesssim 1.0\times10^{-4}\,\mathrm{GeV}^{-2}$, $c_\mu^{(1)}/\Lambda^2 \lesssim 6.0\times10^{-3}\,\mathrm{GeV}^{-2}$, $c_\tau^{(1)}/\Lambda^2 \lesssim 6.2\times10^{-3}\,\mathrm{GeV}^{-2}$	disfavoured
$\frac{c_l^{(2)}}{\Lambda^2}(\bar{\nu}\gamma^\mu\nu)(\Phi^*\partial_\mu\Phi - \Phi\partial_\mu\Phi^*)$	$c_l^{(2)}/\Lambda^2 \lesssim 1.8\times10^{-2}\,\mathrm{GeV}^{-2}$, $c_e^{(2)}/\Lambda^2 \lesssim 2.6\times10^{-5}\,\mathrm{GeV}^{-2}$, $c_\mu^{(1)}/\Lambda^2 \lesssim 1.2\times10^{-2}\,\mathrm{GeV}^{-2}$, $c_\tau^{(1)}/\Lambda^2 \lesssim 1.3\times10^{-3}\,\mathrm{GeV}^{-2}$	disfavoured
$\frac{c_l^{(3)}}{\Lambda}\bar{\nu^c}\nu\,\Phi^*\Phi$	$c_l^{(3)}/\Lambda \leq 0.5\,\mathrm{GeV}^{-1}$	favoured[a]
$\frac{c_l^{(4)}}{\Lambda^3}(\bar{\nu^c}\sigma^{\mu\nu}\nu)(\partial_\mu\Phi^*\partial_\nu\Phi - \partial_\nu\Phi^*\partial_\mu\Phi)$	$c_l^{(4)}/\Lambda^3 \lesssim 2.0\times10^{-3}\,\mathrm{GeV}^{-3}$	disfavoured
$\frac{c_l^{(5)}}{\Lambda^3}\partial^\mu(\bar{\nu^c}\nu)\partial_\mu(\Phi^*\Phi)$	$c_l^{(5)}/\Lambda^3 \lesssim 7.5\times10^{-4}\,\mathrm{GeV}^{-3}$	disfavoured
$\frac{c_l^{(6)}}{\Lambda^4}(\bar{\nu}\partial^\mu\gamma^\nu\nu)(\partial_\mu\Phi^*\partial_\nu\Phi - \partial_\nu\Phi^*\partial_\mu\Phi)$	$c_l^{(6)}/\Lambda^4 \lesssim 2.5\times10^{-5}\,\mathrm{GeV}^{-4}$, $c_e^{(6)}/\Lambda^4 \lesssim 1.2\times10^{-6}\,\mathrm{GeV}^{-4}$, $c_\mu^{(6)}/\Lambda^4 \sim c_\tau^{(6)}/\Lambda^4 \lesssim 10^{-5}\,\mathrm{GeV}^{-4}$	disfavoured



$Z \to inv$, LEP monophoton$+\not{E}_T$, $Z \to \mu^+\mu^-$, $Z \to \tau^+\tau^-$ and $(g-2)_{e,\mu}$.

Figure 1. Constraints on neutrino-DM interaction [1].

Flux suppression

We consider neutrino-DM interaction of type ν-ν̄-Φ-Φ, where Φ represent scalar DM. In order to explore neutrino-DM interaction exhaustively, we take a rigorous approach by considering renormalisable as well as effective interactions and mention the constraints as shown in Fig. 1. We expect a successful model that leads to flux changes should decrease the flux by at least 1%. The successful model is dim-5 interaction shown in the right panel.

Energy dependent flavour ratio

The potential induced by such interactions drastically affects neutrino oscillations, so that the DM profile gets imprinted on the energy dependence of the flavour ratios of neutrinos detected at neutrino telescopes. The flavour ratio depends on DM density profile at source and detector and is observed as track to shower ratio at IceCube, as shown in Fig. 2.

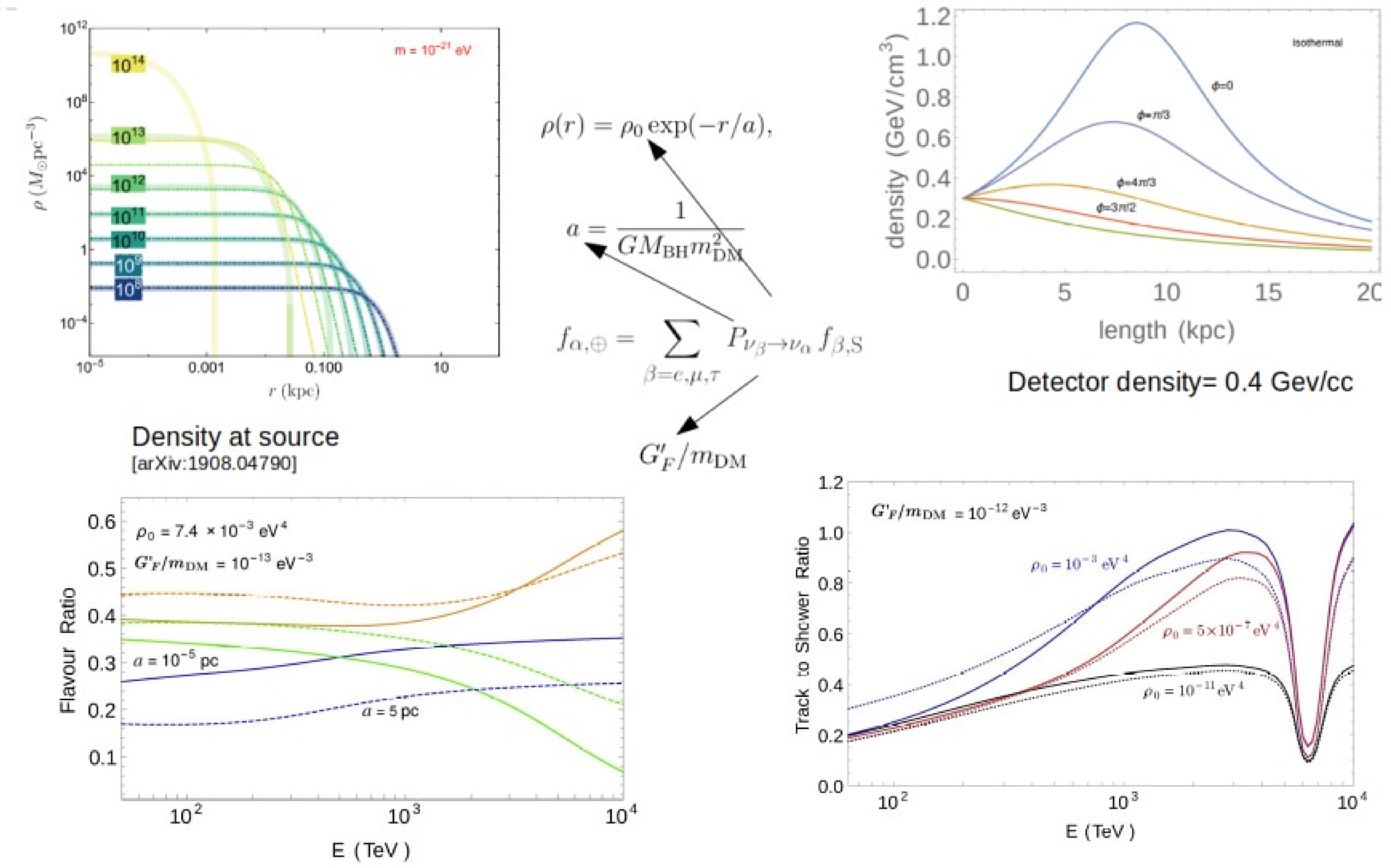


Figure 2. Flavour ratio changes due to neutrino-DM interaction [3].

Non Standard Interaction with quarks

The upgoing neutrino events pass through large column of Earth matter which may lead to probe of NSI. Further, IceCube is a better probe than LHC of neutrino-quark NC NSI, for both intermediate-mass Z', of mass around 10 GeV and very heavy Z' with a mass around 500 GeV, as shown in Fig. 3. Thus, IceCube has enormous prospects for testing the NSI interactions with high energy neutrinos.

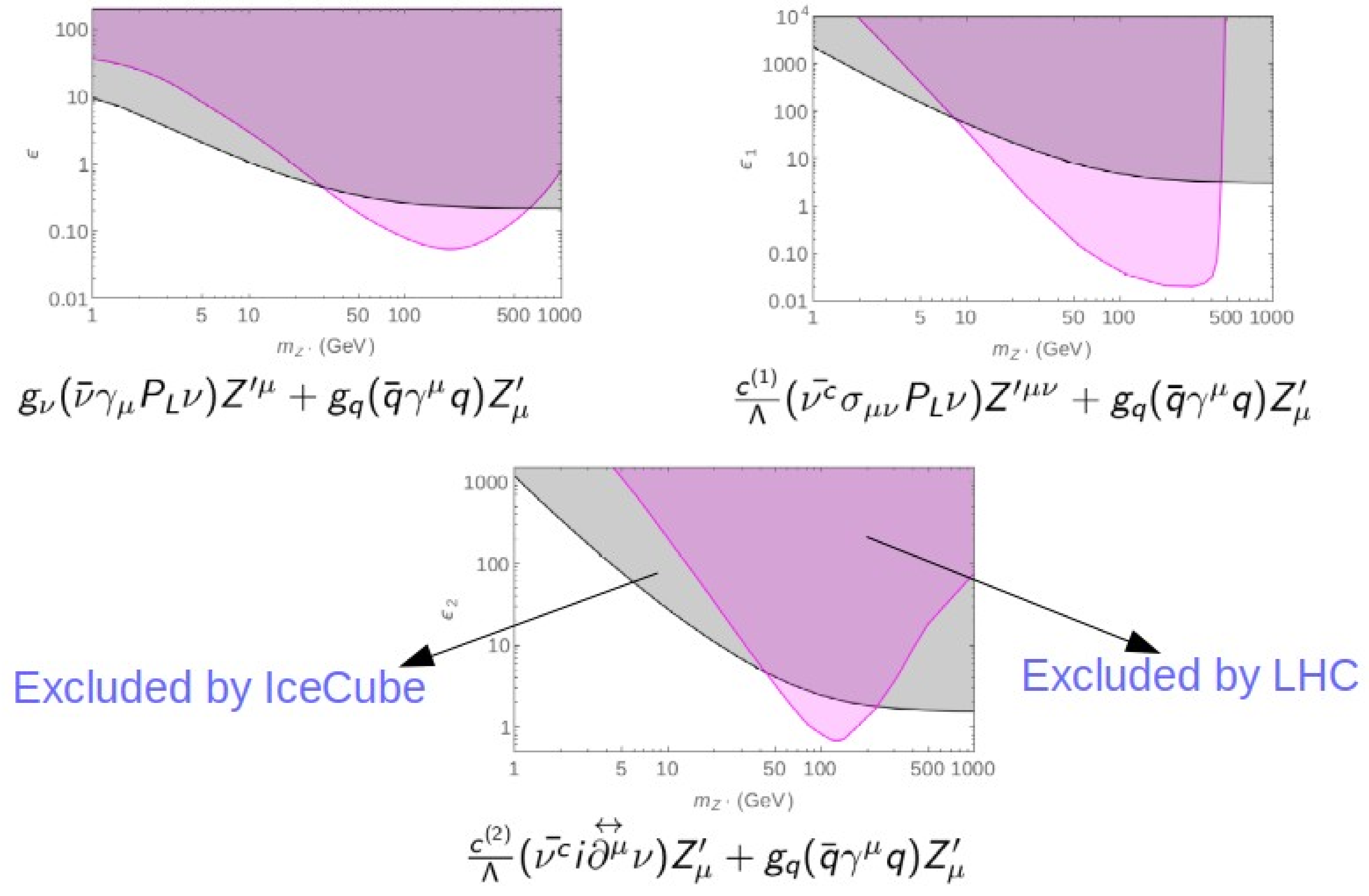


Figure 3. Constraints on NSI from IceCube [2].

Conclusion

Astrophysical neutrinos at IceCube has a huge potential in probing new physics which will be complementary to other experiments. New physics interactions with visible matter as well as with DM lead to visible effects in the observed neutrino spectrum.

Acknowledgments

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