PRIMORDIAL BLACK HOLE DARK MATTER EVAPORATING ON THE NEUTRINO FLOOR

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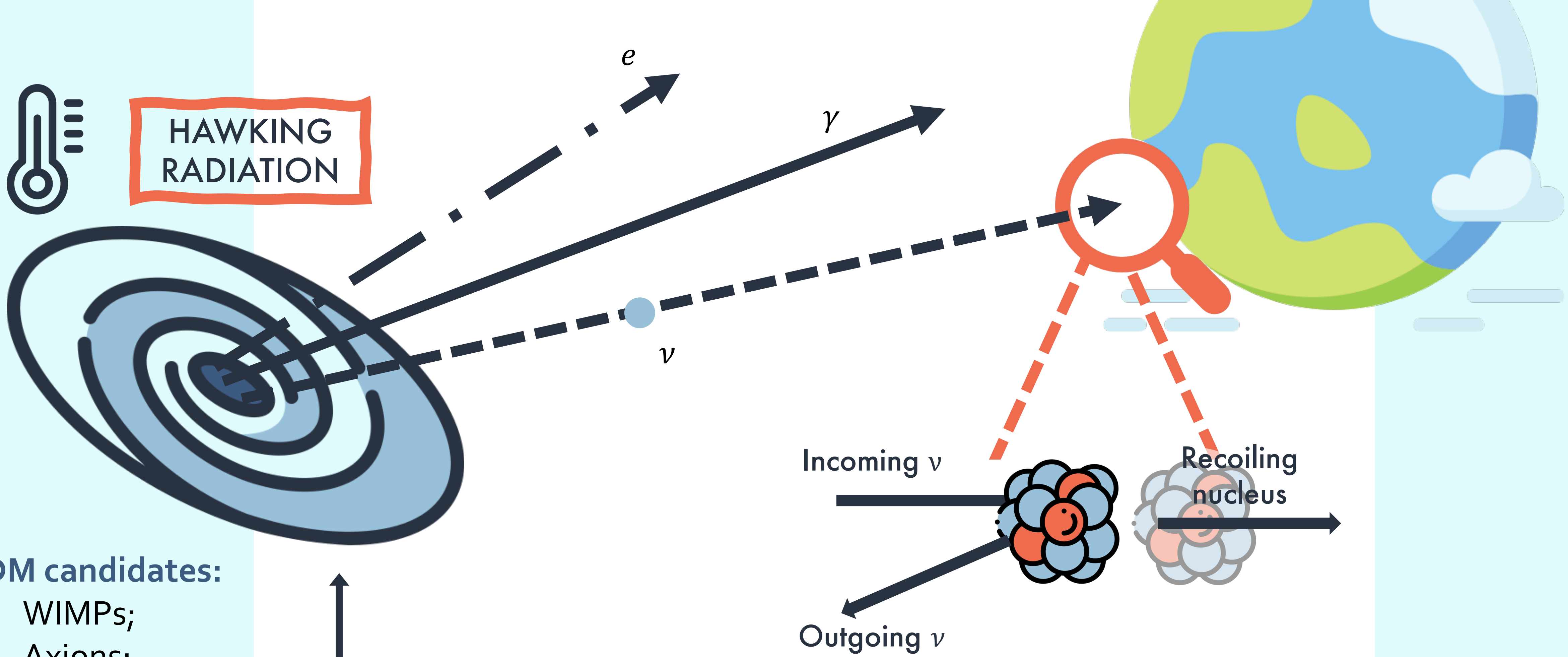
BASED ON ARXIV: 2106.02492

MAIN IDEA



DM candidates:

- WIMPs;
- Axions;
- *PBHs* ;
- ....

Detection of neutrinos emitted from PBHs by **Coherent Elastic Neutrino Nucleus Scattering ($CE\nu NS$)**

INTRODUCTION

Primordial Black Holes

Primordial black holes could be cold **Dark Matter** candidates. They originate from **large matter over densities** in the early universe.

PBHs Abundance

The fraction of DM made up of PBHs is:

$$f_{PBH} = \frac{\rho_{PBH}}{\rho_{DM}}$$

Various constraints on it are viable in literature.

Hypothesis

We consider PBHs with masses $\sim 10^{15} g$.

We consider a **monochromatic mass distribution**

We consider **neutral** and **non-rotating** PBHs

BHs lose mass emitting all the elementary particles whose mass is lower than the BHs temperature (**Hawking Radiation** ~ black body like). BHs temperature is inversely proportional to the BHs mass. Ordinary BHs evaporation is small due to their temperature.

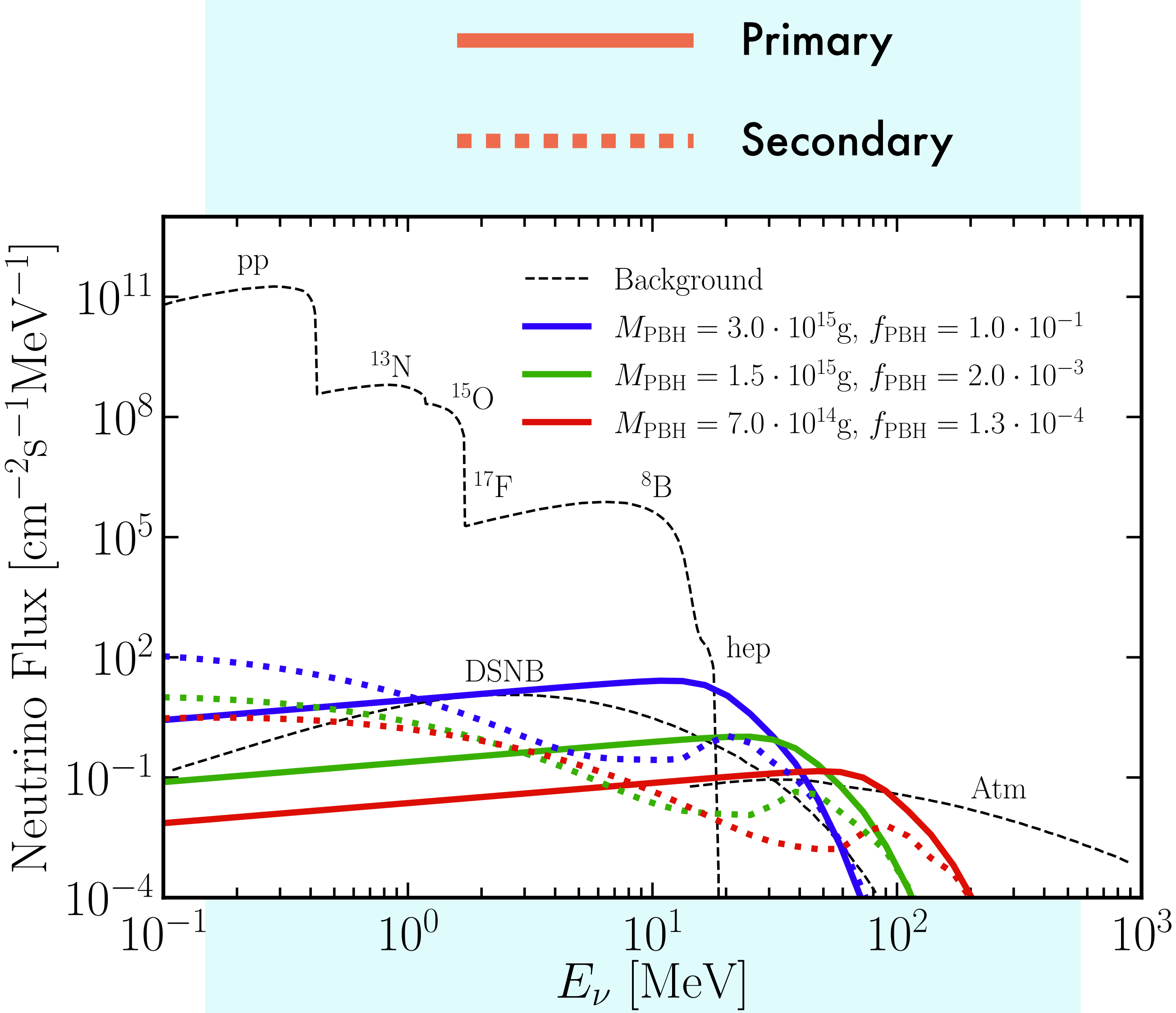
NEUTRINO FLUX

$$\frac{d\phi^{MW}}{dE_\nu} = \int \frac{d\Omega}{4\pi} \frac{dN}{dt dE_\nu} \int dl \, \frac{f_{PBH}\rho_{NFW}[r(l,\psi)]}{M_{PBH}}$$

$$\frac{d\phi_\nu^{EG}}{dE_\nu} = \int dt[1+z(t)] \frac{f_{PBH}\rho_{DM}}{M_{PBH}} \frac{dN}{dt \, d\widetilde{E_\nu}}\bigg|_{\widetilde{E_\nu}=E[1+z(t)]}$$

CEvNS **is flavor blind :**

- no need to consider oscillation
- we consider all the active neutrinos.



$$\frac{d\phi_\nu}{dE_\nu} \propto f_{PBH}$$

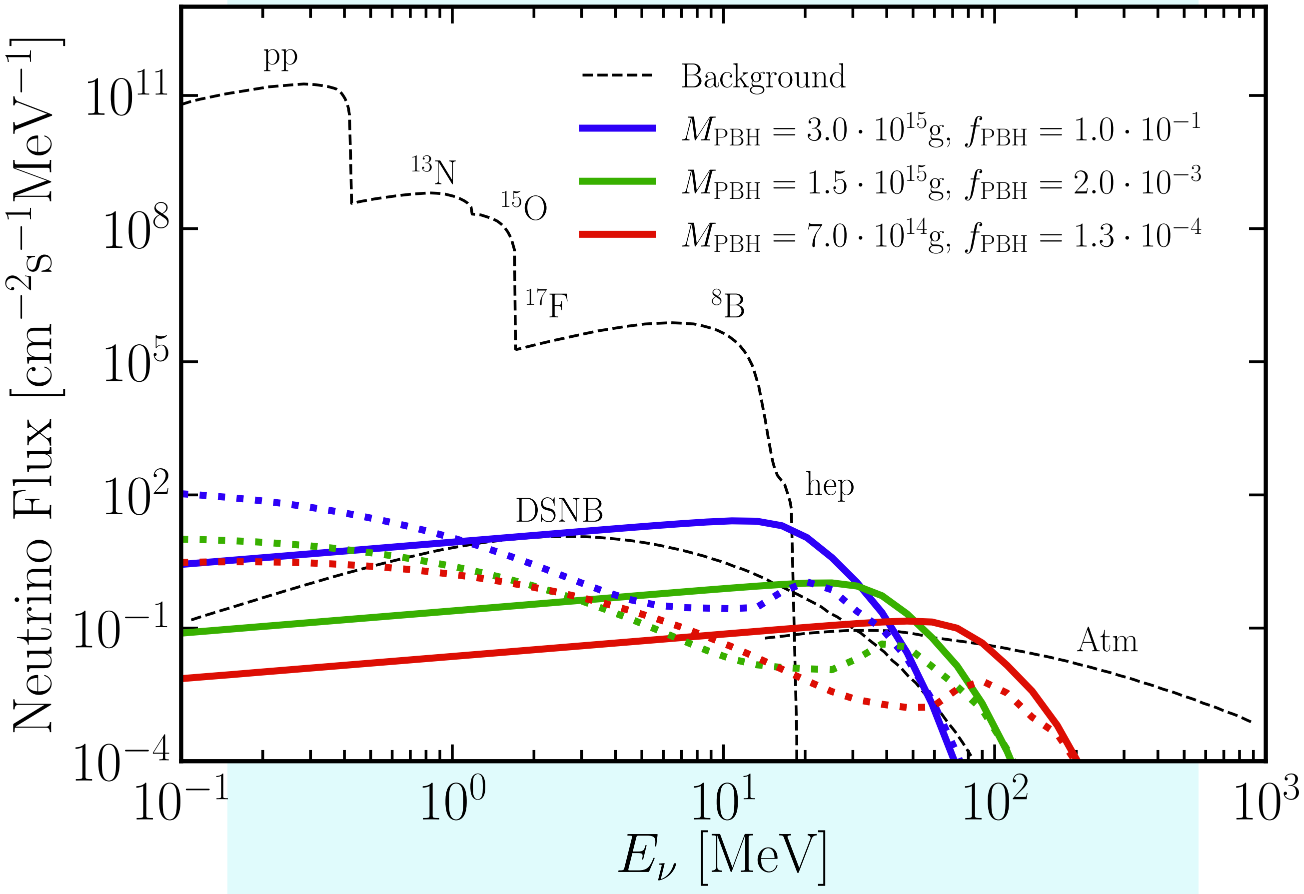
NEUTRINO FLUX

Primary

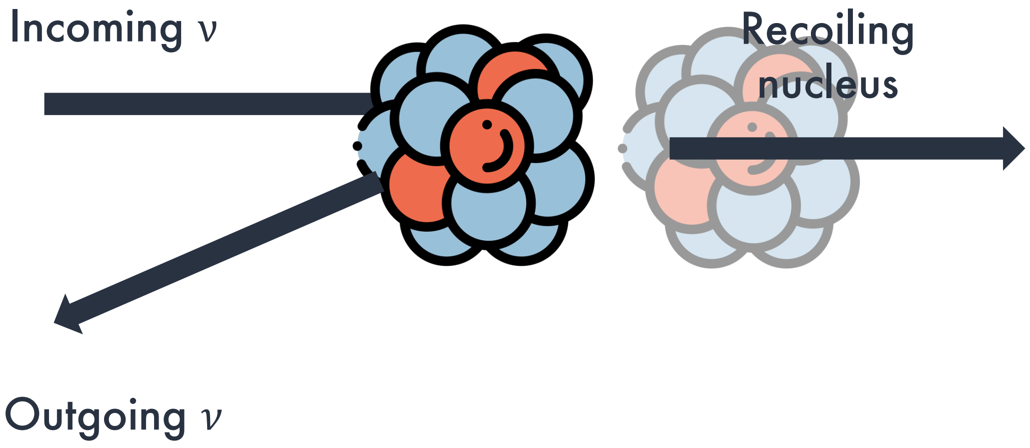
Secondary

We can see that PBHs neutrinos are visible after the abrupt fall-off of the solar hep neutrinos.

The background consists in Diffuse Supernova Neutrino Background **(DSNB)**, **hep** neutrinos and Atmospheric neutrinos **(Atm)**.



CEνNS



Coherent Neutrino-Nucleus Scattering occurs between an active neutrino flavor and a nucleus

$$\frac{d\sigma}{dE_r} = \frac{G_F^2 m_T}{4\pi}[N - Z(1 - 4\sin^2\theta_W^2)]^2\left(1 - \frac{m_T E_r}{2E_\nu^2}\right)F^2(\sqrt{2m_T E_r})$$

$$F(Q) = \frac{3j_1(QR_0)}{QR_0}\exp\left(-\frac{1}{2}s^2Q^2\right)$$

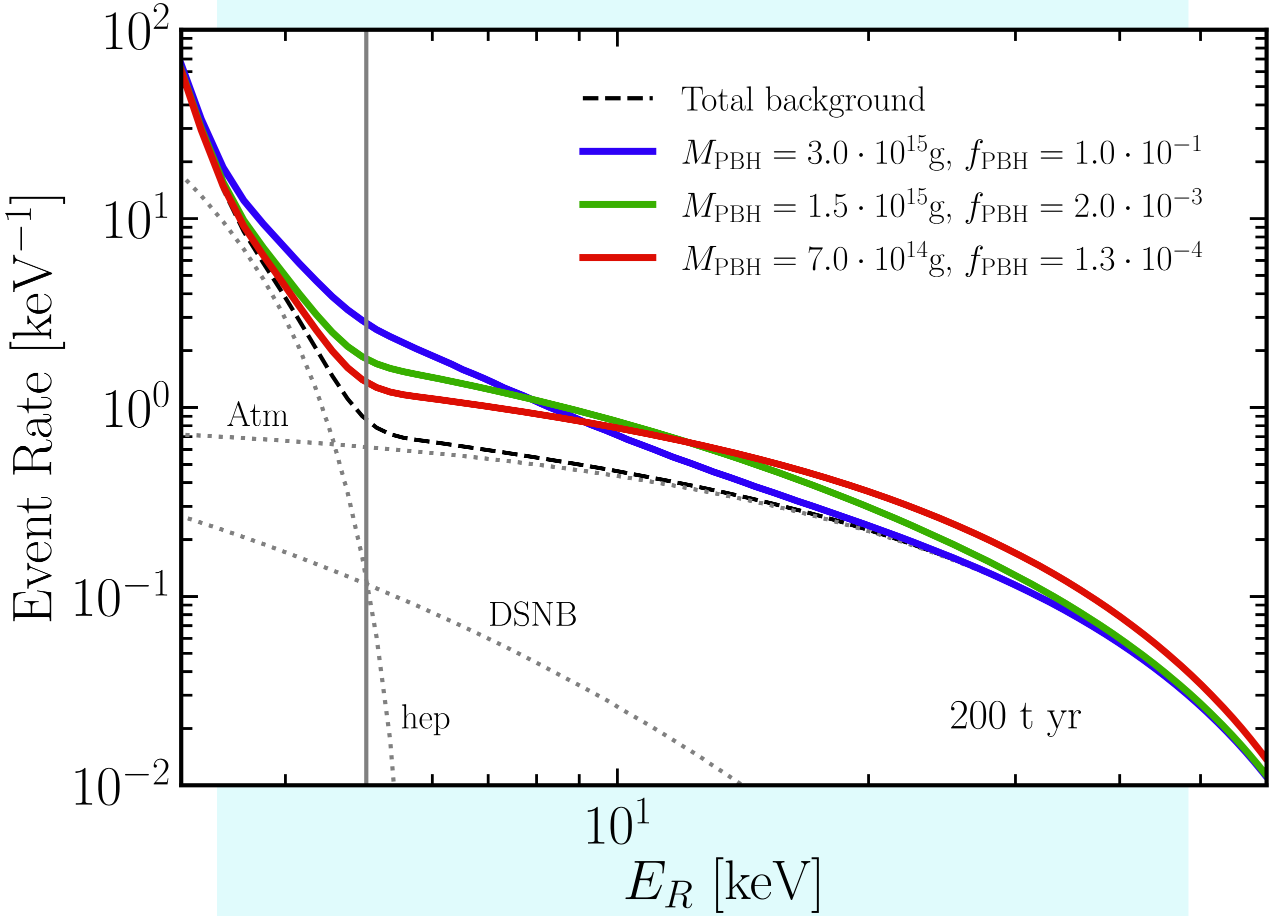
The interaction of astrophysical neutrinos through $CE\nu NS$ in the detector is described by

$$\frac{dR_{\nu \mathrm{N}}}{dE_r dt} = n_T \epsilon(E_r)\int dE_\nu \frac{d\sigma}{dE_r}\frac{d\phi}{dE_\nu}\Theta\left(\frac{2E_\nu^2}{m_T + 2E_\nu} - E_r\right)$$

EVENT RATE

We calculated the event rate of *CEvNS* In a multiton DM direct detection experiment **(DARWIN)**

The event spectrum of PBHs depends on the mass of the PBH. For higher masses it is similar to the background. For lower masses it is sensibly different.
We have employed a binned analysis to fully exploit the spectral information.



TEST STATISTIC

We implemented the χ^2 test statistic

$$\chi^2 = \min_{\boldsymbol{\alpha}}[\chi^2(\boldsymbol{\theta},\boldsymbol{\alpha}) + (1-\boldsymbol{\alpha})^T\Sigma_{\boldsymbol{\alpha}}^{-1}(1-\boldsymbol{\alpha})]$$

$$\Sigma_\alpha = diag\left(\sigma_{\alpha_1}^2, \sigma_{\alpha_2}^2, \sigma_{\alpha_3}^2\right) \quad \boldsymbol{\alpha}^T = [\alpha_1, \alpha_2, \alpha_3] \quad \boldsymbol{\theta}^T = [M_{PBH}, f_{PBH}]$$

For the uncertainties, we have assumed 30%, 50%, and 20% respectively for solar hep, DSNB, and atmospheric neutrinos.

$$\chi^2(\boldsymbol{\theta},\boldsymbol{\alpha}) = -2\ln\frac{\prod P\left(\overline{N}_{bck}^i, N_{PBH}^i(\theta)+N_{bck}^i(\alpha)\right)}{\prod P\left(\overline{N}_{bck}^i, \overline{N}_{bck}^i\right)}$$

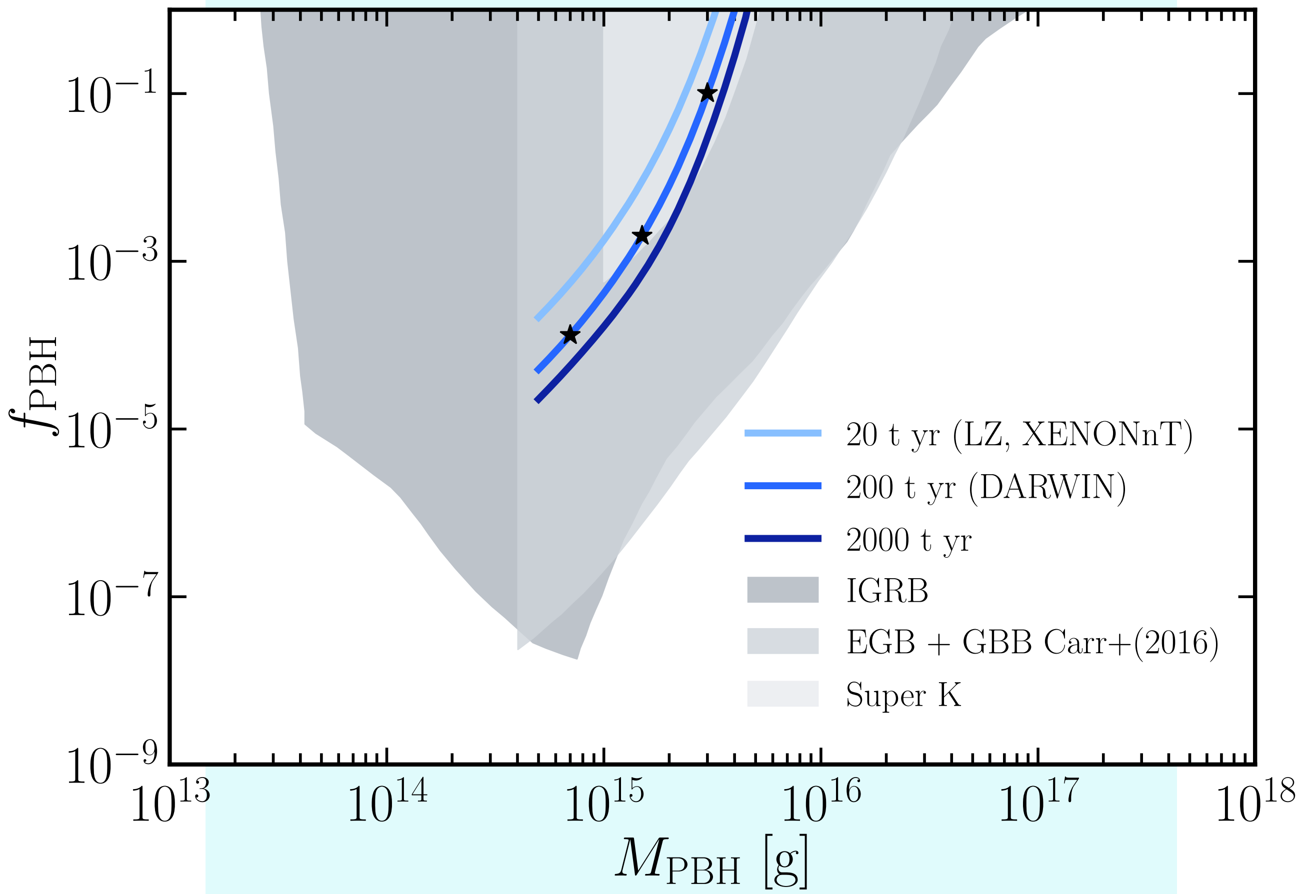
- 10 Bin
- $E_r \in [5, 50]KeV$

χ^2

UPPER LIMIT

CEνNS would allow us to improve the bounds derived from Super−Kamiokande and extend them to lower PBHs masses.

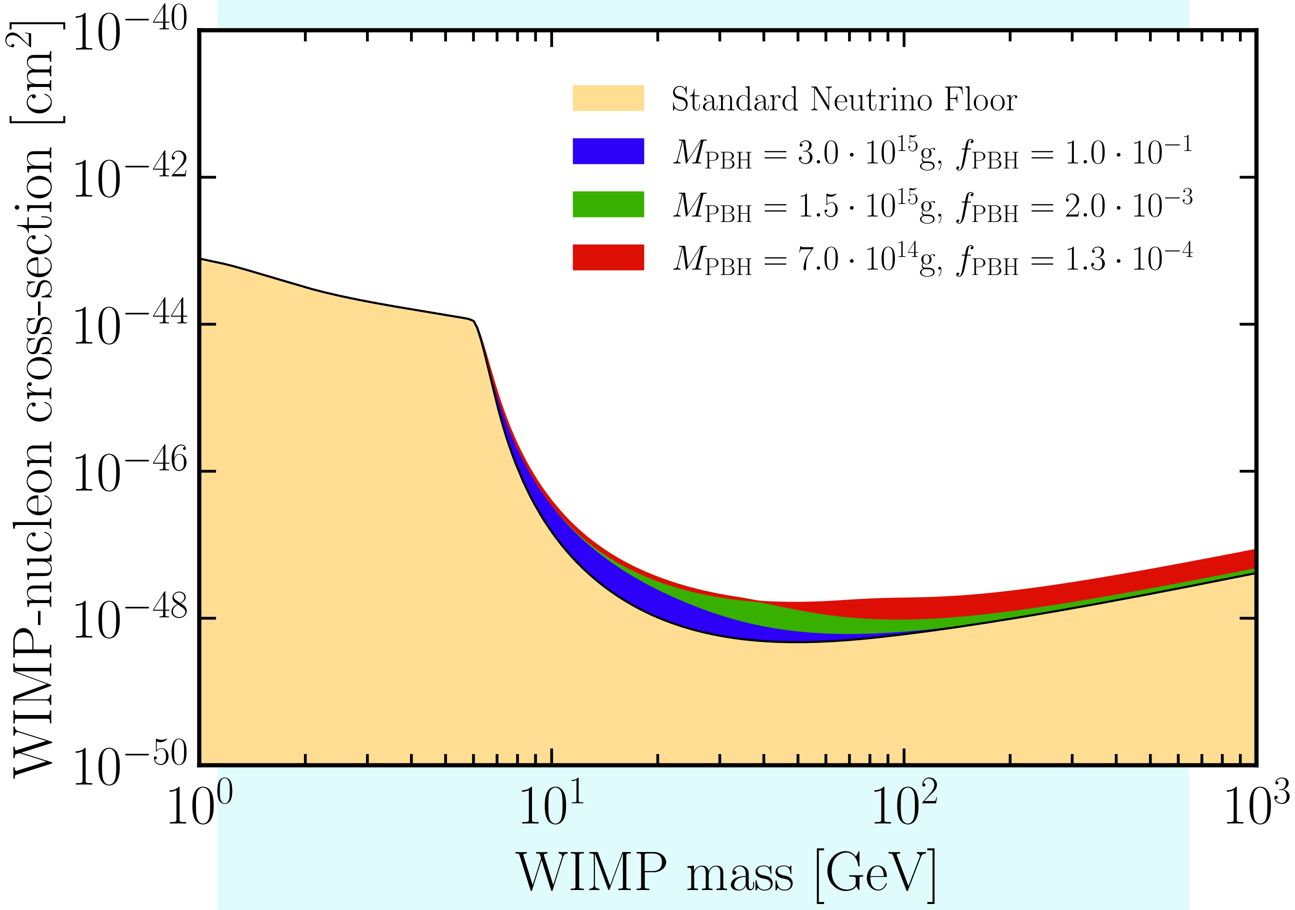
In the context of PBHs searches the direct DM experiments would rather operate as low-energy indirect observatories, complementary to the high-energy neutrino telescopes.



NEUTRINO FLOOR

The solar, DSNB and atmospheric neutrinos constitute an irreducible background for the WIMPs searches.

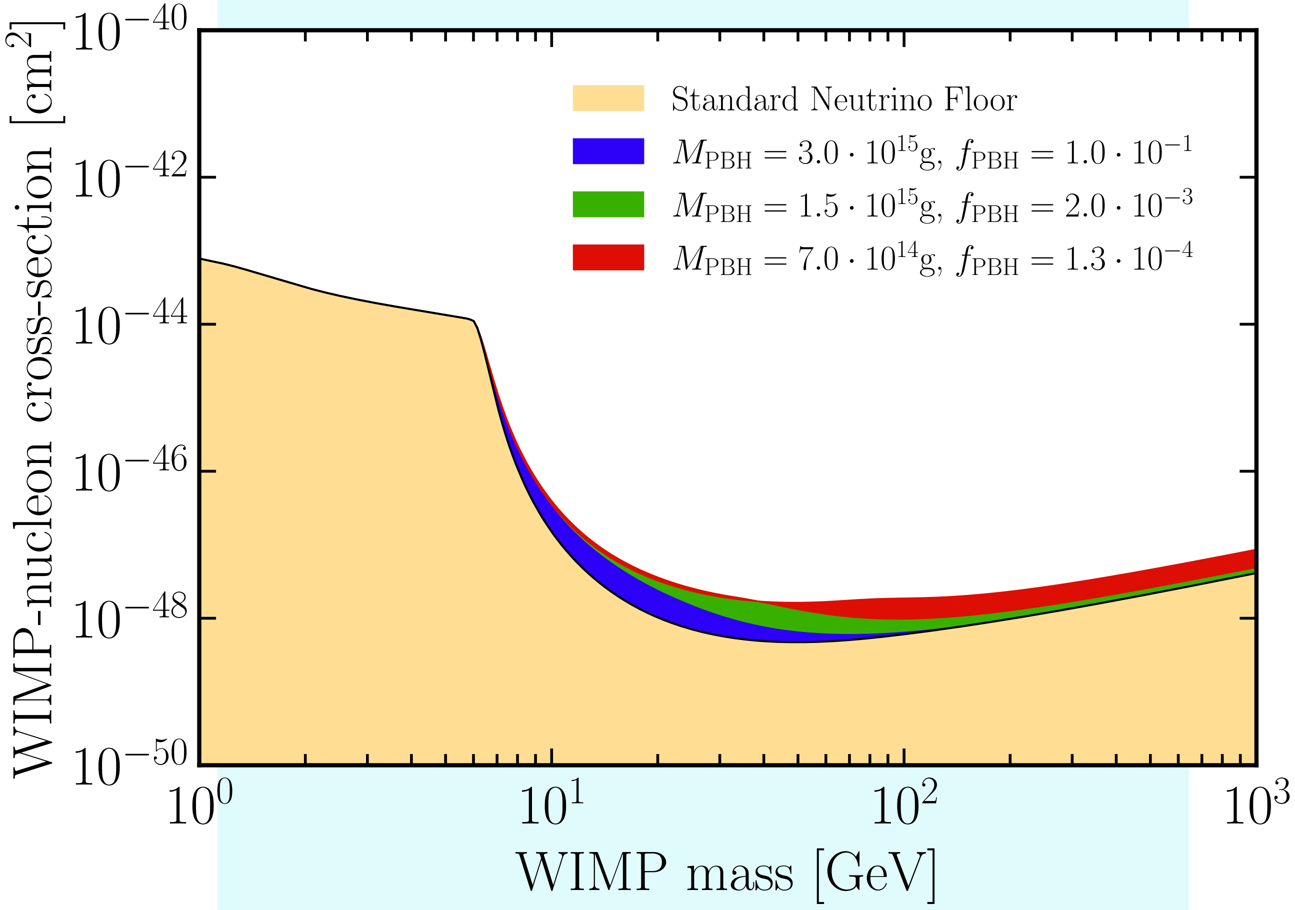
This background forms to the so-called “neutrino floor”, an ultimate limitation to the discovery potential of the DM experiments.



NEUTRINO FLOOR

Since the PBHs neutrinos lie on top of the "Standard" Background, the existence of a fraction of PBHs in the DM content would modify the neutrino floor.

We have quantified how much a signal from PBHs would heighten the "**neutrino floor**"



CONCLUSIONS

- The CEνNS would allow us to extend and improved Super-K constraints on PBH abundance.
- We used DM direct experiments as low-energy indirect observatories.
- We quantified how much the standard neutrino floor is affected by PBH neutrinos.

THANK YOU FOR THE ATTENTION