18/07/2022

IDM 2022 Wien

Primordial black hole dark matter evaporating on the neutrino floor

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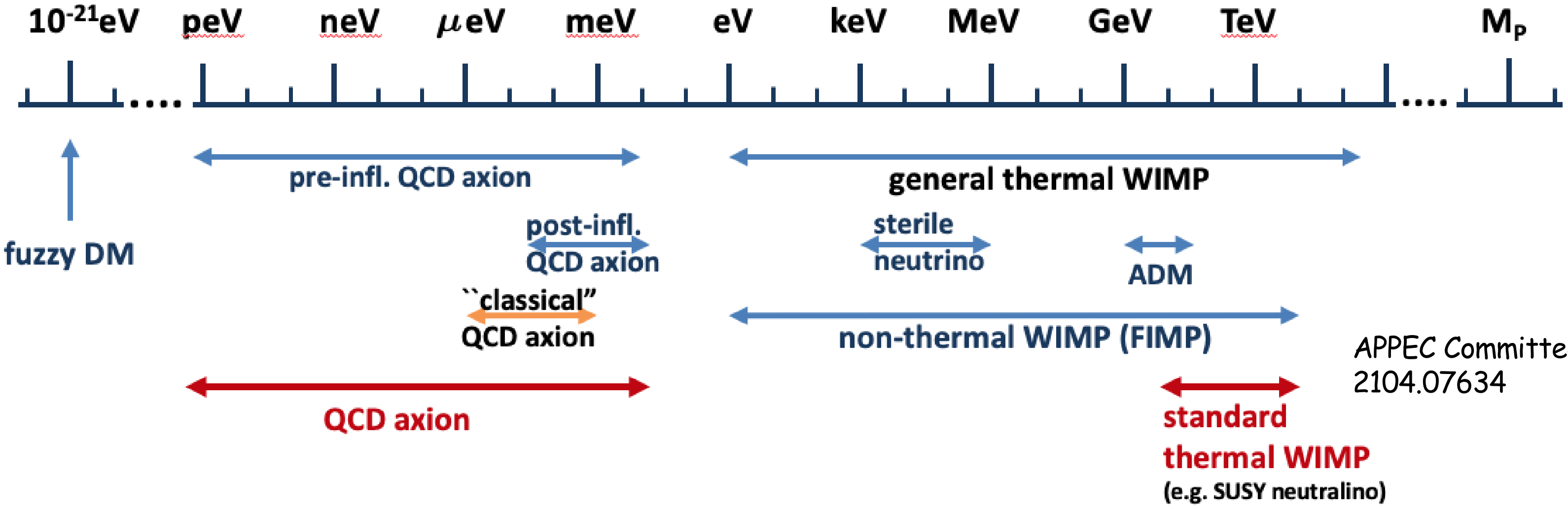
Bari University & INFN

Based on
Calabrese, Fiorillo, Miele, Morisi, Palazzo
arXiv: 2106.02492, PLB 2022

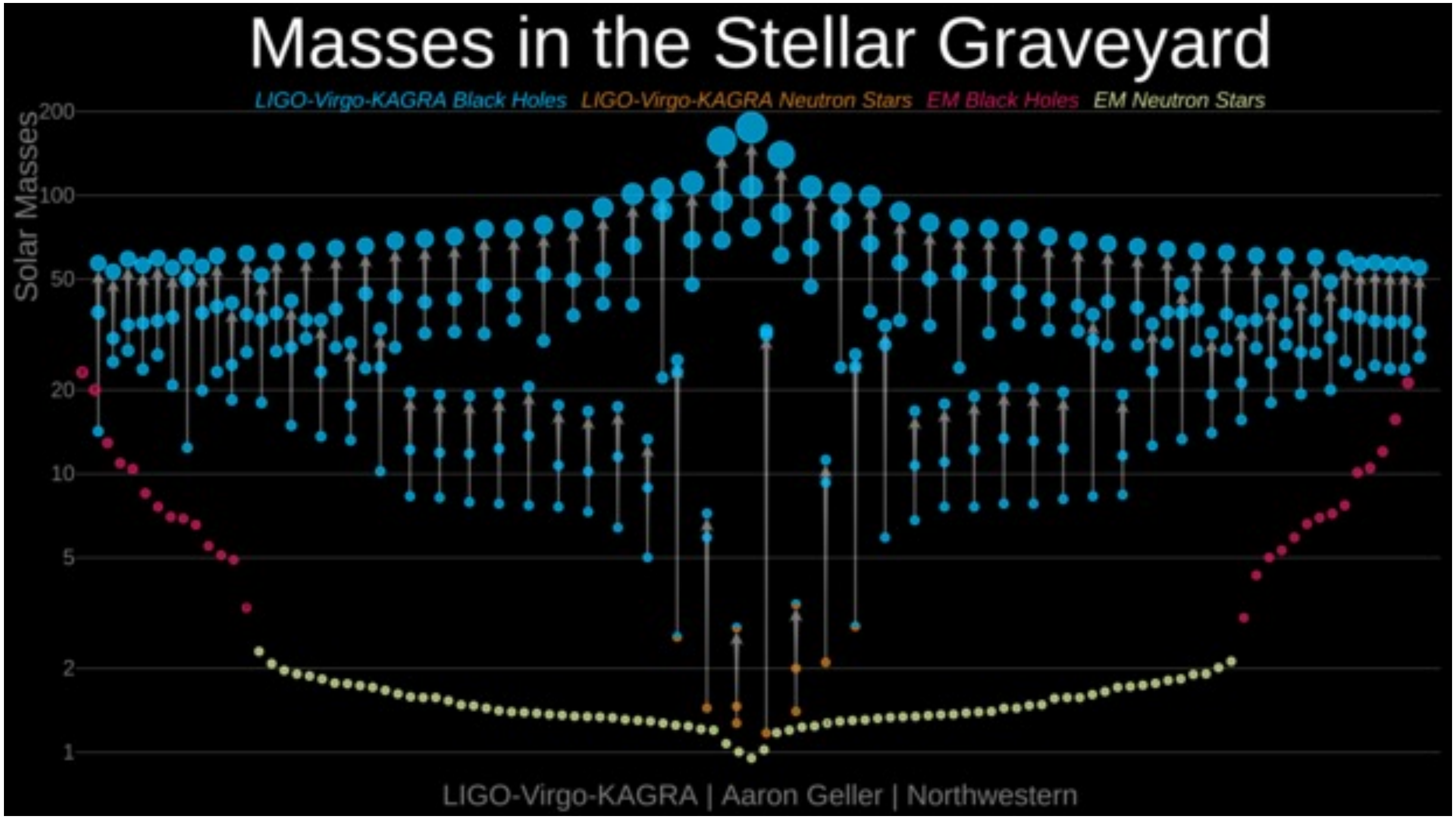
Many Particle Dark Matter candidates under scrutiny



APPEC Committee Report
2104.07634

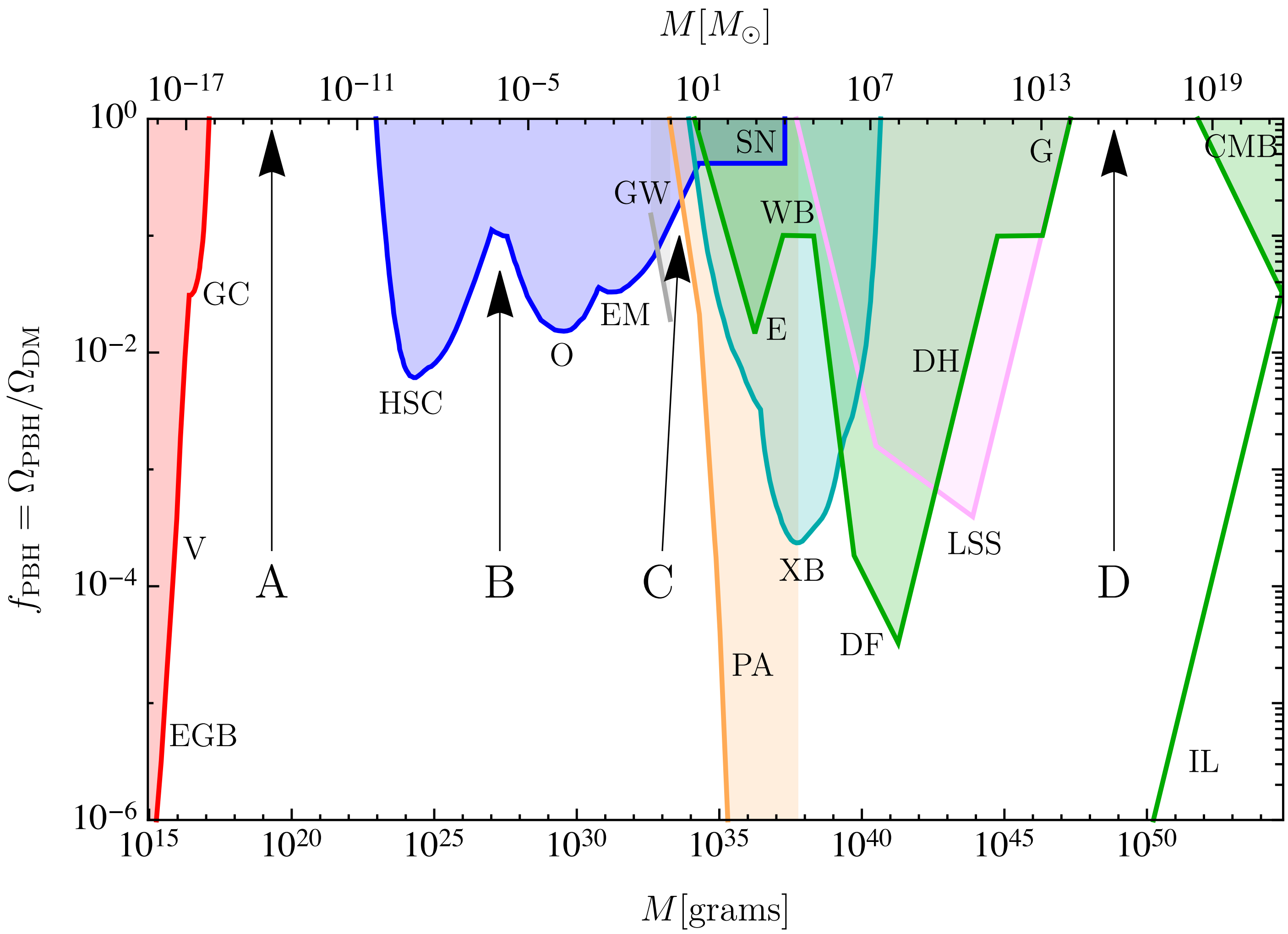
But other kinds of candidates are worthy of attention …

Unexpected BH merger events in GWs



Refuelled attention towards PBHs

Many limits on PBHs set in a vast range of masses



Carr & Kühnel
2006.02838

Basic Facts

PBHs may originate from large density overfluctuations in the early universe

If their lifetime is larger than the age of the Universe PBHs can form (part of) the Dark Matter

For masses in the range [5×10^{14}g – 5×10^{15}g] Hawking evaporation gives rise to emission of elementary particles with energy of tens of MeV

In the Hawking radiation also neutrinos are emitted with peak energy $\sim 4T_{PBH}$

PBHs neutrino detection already proposed in the past:

Halzen, Keszthelyi, Zas, hep-ph/9502268

Bugaev & Konishchev, astro-ph/0005295

More recent work using SK, JUNO, DUNE and THEIA

Dasgupta, Laha, Ray, 1912.01014

Wang et al., 2010.16053

De Romeri, Martínez-Miravé, Tórtola, 2106.05013

Neutrinos emitted by PBHs

$$k_B T_{\rm PBH} = \frac{\hbar c^3}{8\pi G_N M_{\rm PBH}} \simeq 1.06 \left[\frac{10^{16}{\rm g}}{M_{\rm PBH}}\right] {\rm MeV}$$

Hawking Temperature

$$\frac{d^2 N_\nu}{dE_\nu dt} = \frac{1}{2\pi} \frac{\Gamma_\nu(E_\nu, M_{\rm PBH})}{\exp\left[E_\nu / k_B T_{\rm PBH}\right] + 1}$$

Number of neutrinos x unit time and energy

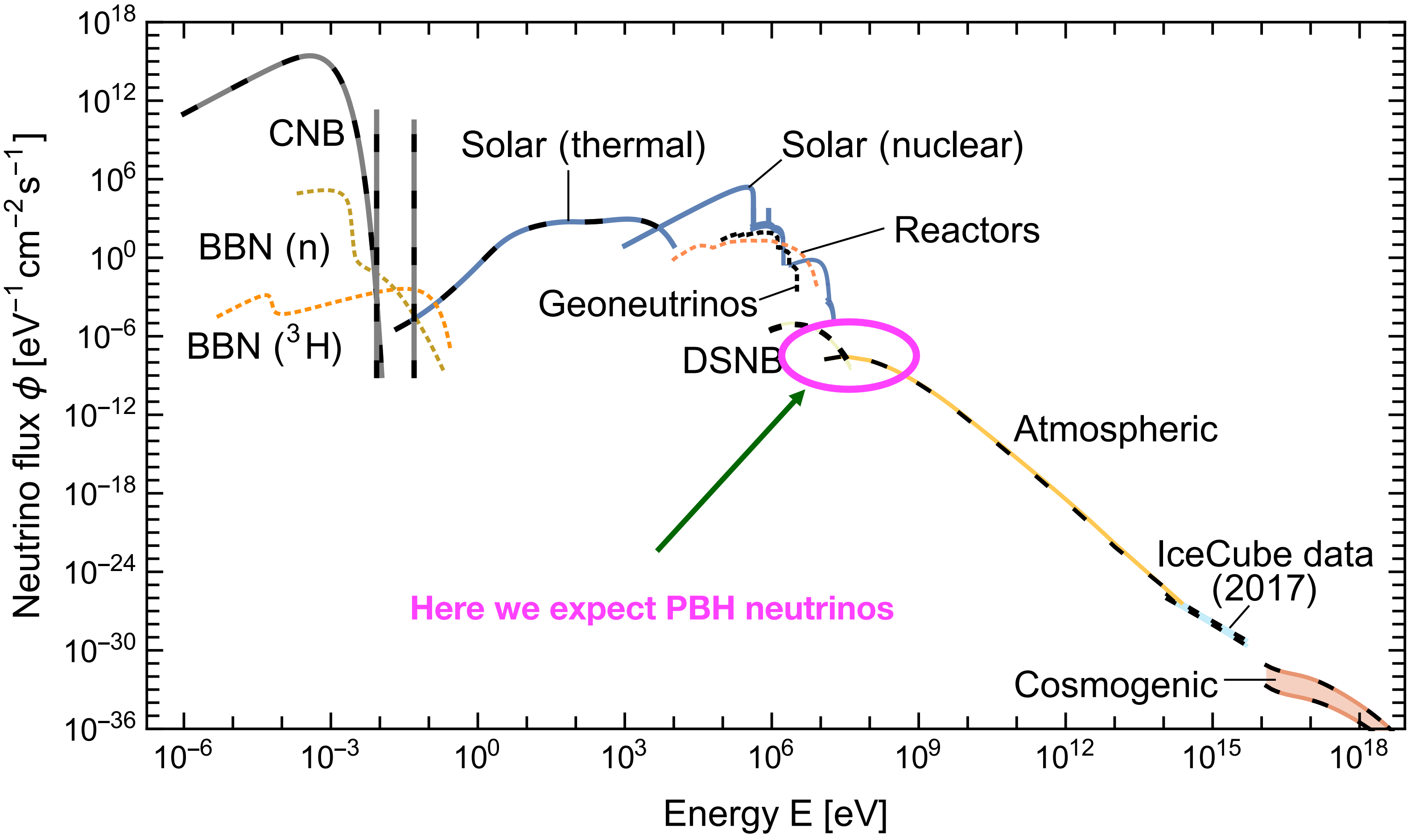
$$\frac{d\phi_\nu^{\rm MW}}{dE_\nu} = \int \frac{d\Omega}{4\pi} \frac{d^2 N}{dE_\nu dt} \int dl \, \frac{f_{\rm PBH} \, \rho_{\rm MW}\left[r(l,\psi)\right]}{M_{\rm PBH}}$$

Milky Way Neutrino Flux

$$\frac{d\phi_\nu^{\rm EG}}{dE_\nu} = \int_{t_{min}}^{t_{max}} dt \; \left[1 + z(t)\right] \frac{f_{\rm PBH} \rho_{\rm DM}}{M_{\rm PBH}} \frac{d^2 N_\nu}{d\tilde{E}_\nu dt}\Big|_{\tilde{E}_\nu = [1+z(t)]E_\nu}$$

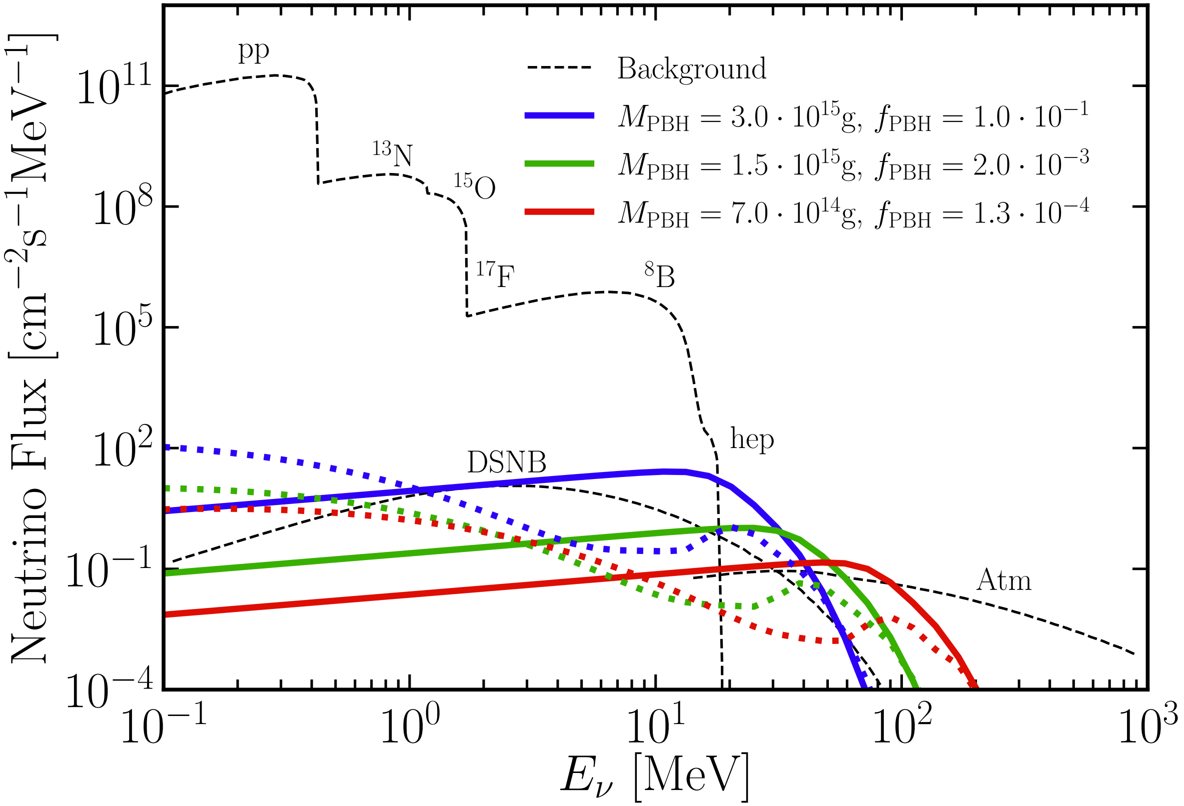
Extragalactic Neutrino Flux

Ordinary Neutrinos



Vitagliano et al. Rev Mod. Phys. 92 (045006)

Neutrinos fluxes from PBHs compared with the ordinary ones



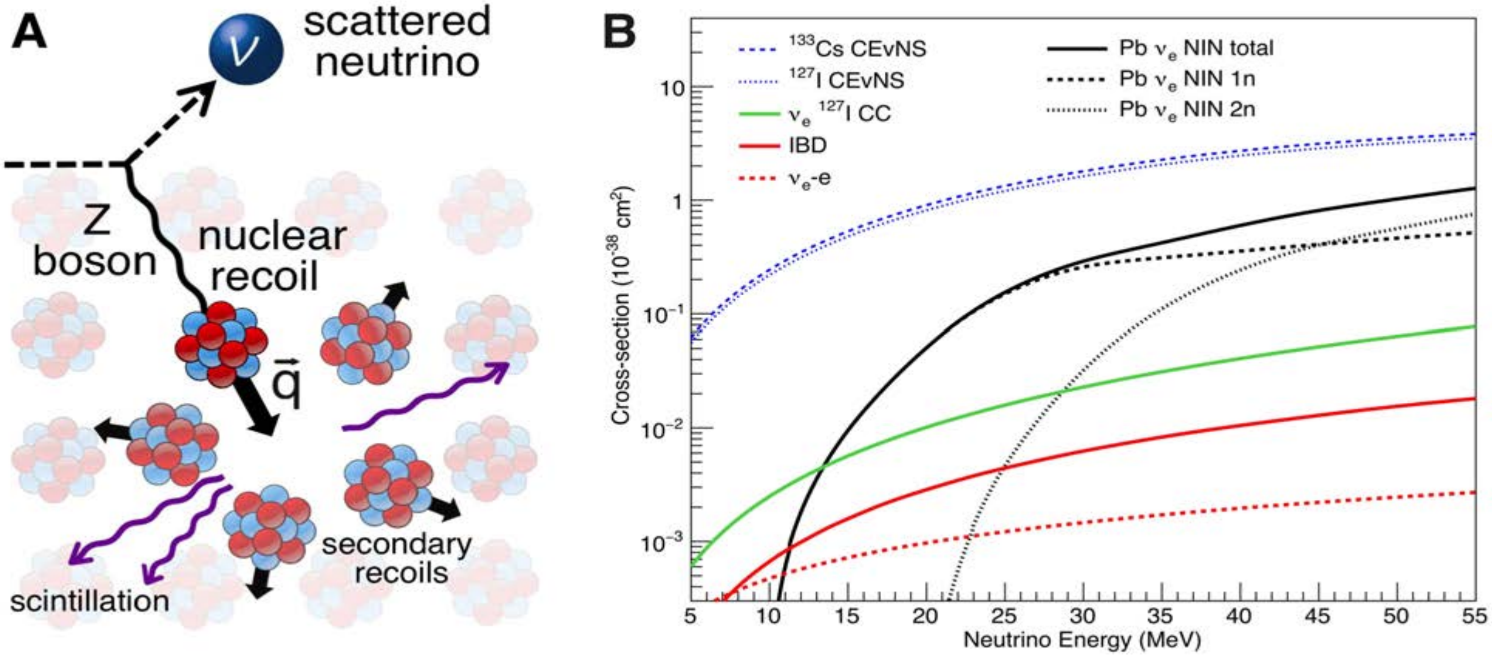
Continuos curves: Primaries

Dashed curves: Secondaries

Secondaries have a marginal role

PBH νs may be visible above the hep cut-off

How to detect such neutrinos having tens of MeV?



Science 2017

Coherent neutrino scattering CEvNS offers an opportunity!

Computational details

https://blackhawk.hepforge.org

We use the publicly available code BlackHawk to compute neutrino fluxes

Arbey & Auffinger
1905.04268

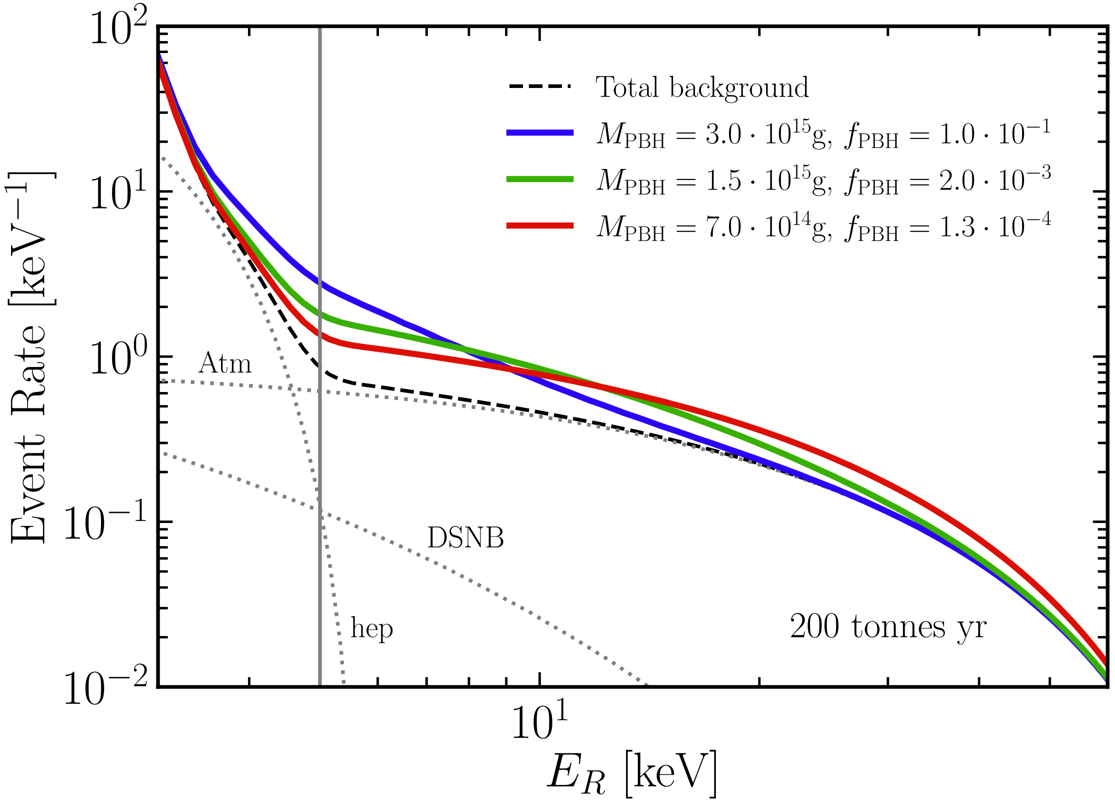
Secondary neutrinos have much lower energy than primary ones:
Small impact in our analysis

Nature of neutrino (Dirac vs Majorana) is irrelevant for our analysis:
the extra degrees of freedom of Dirac νs are sterile and do not participate to CEvNS.

CEvNS is equally sensitive to all flavors: Neutrino oscillations play no role.

We employ a Navarro-Frenk-White profile for MW halo with $r_\odot = 0.4$ GeV/cm^3

Differential Neutrino Event Rates

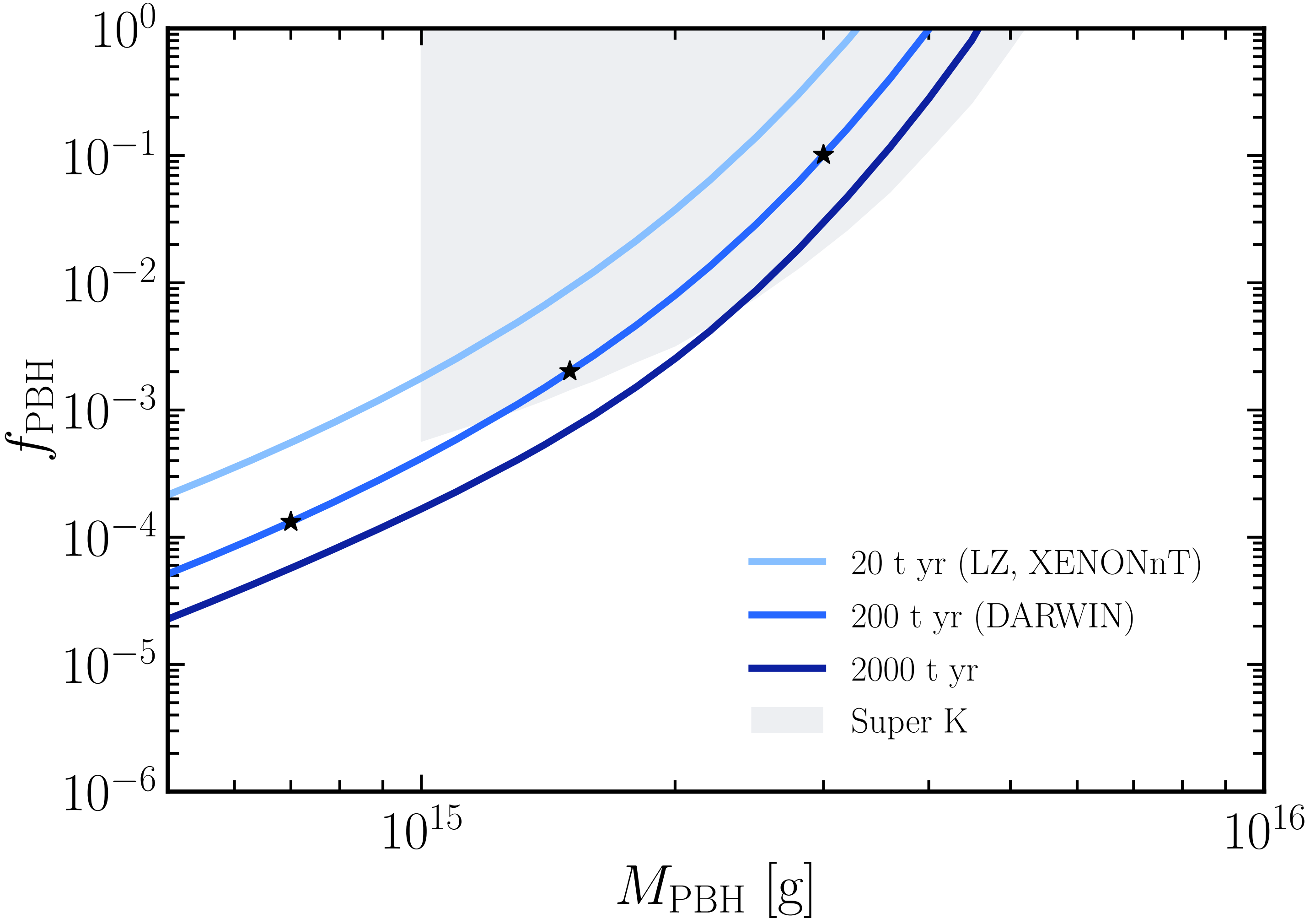


Energy threshold = 5 keV

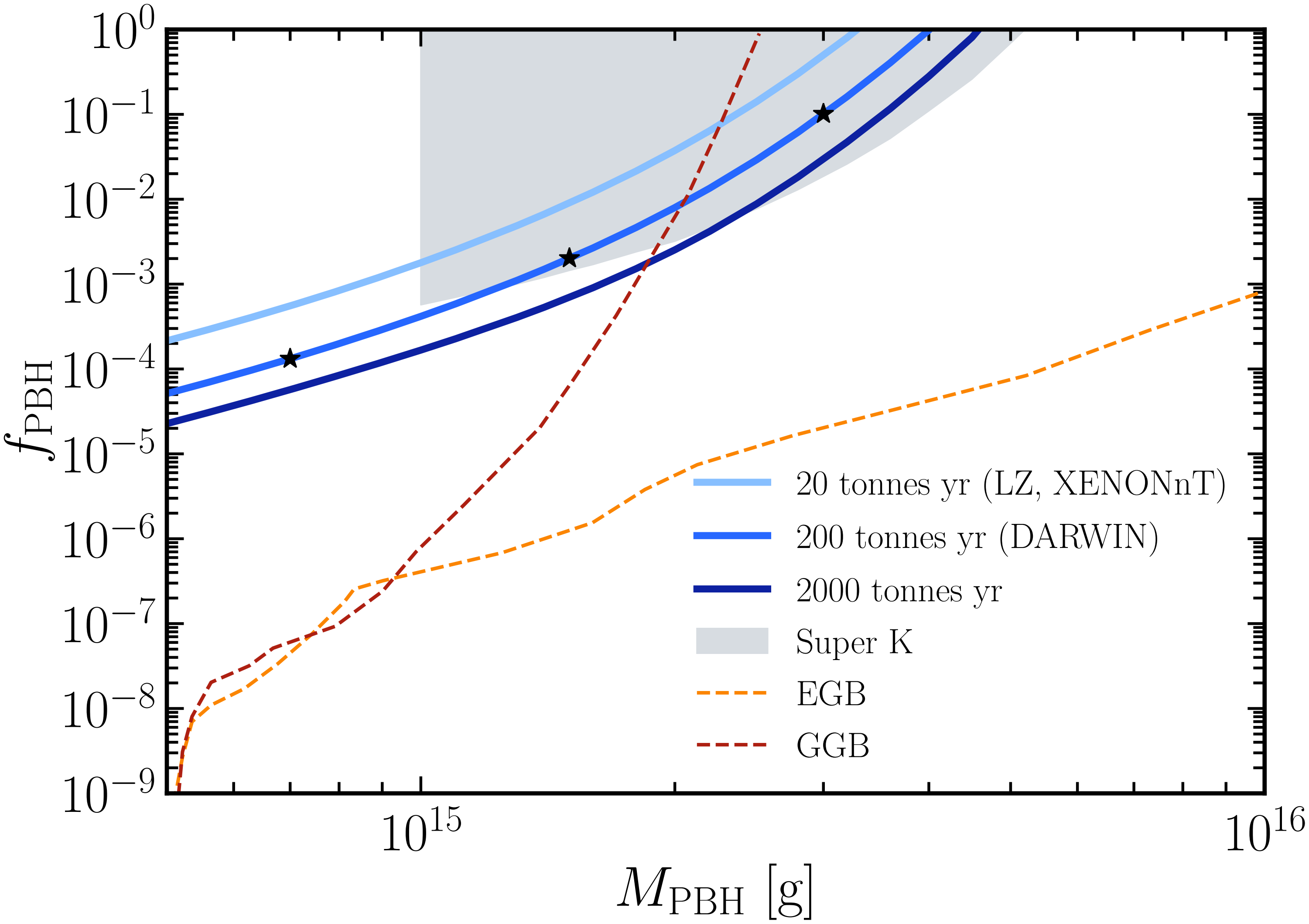
Atmospheric neutrinos are the dominant background

Spectral shape from PBH neutrinos can be different from background

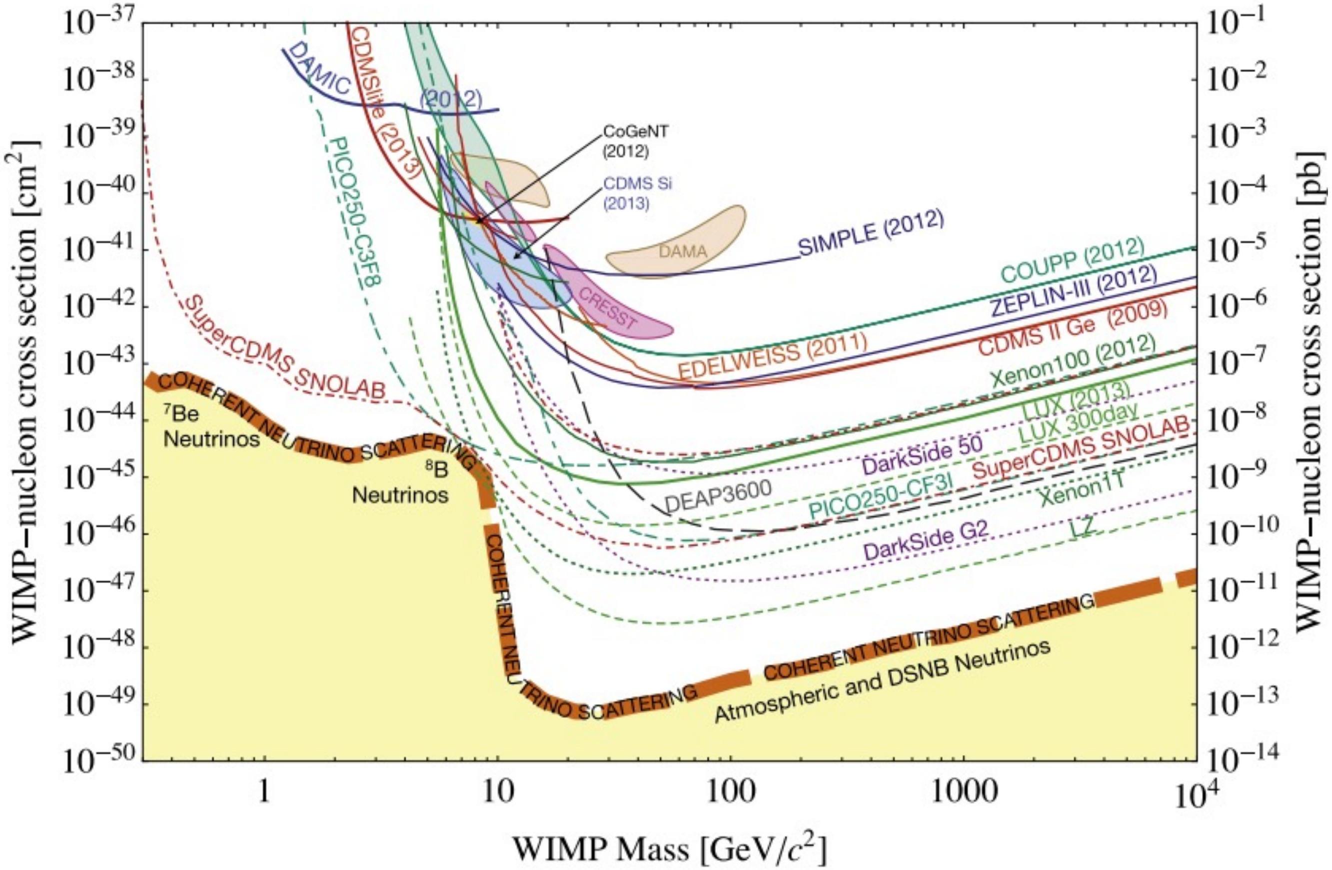
Upper Bounds on PBHs fraction of DM



Comparison with gamma-ray bounds

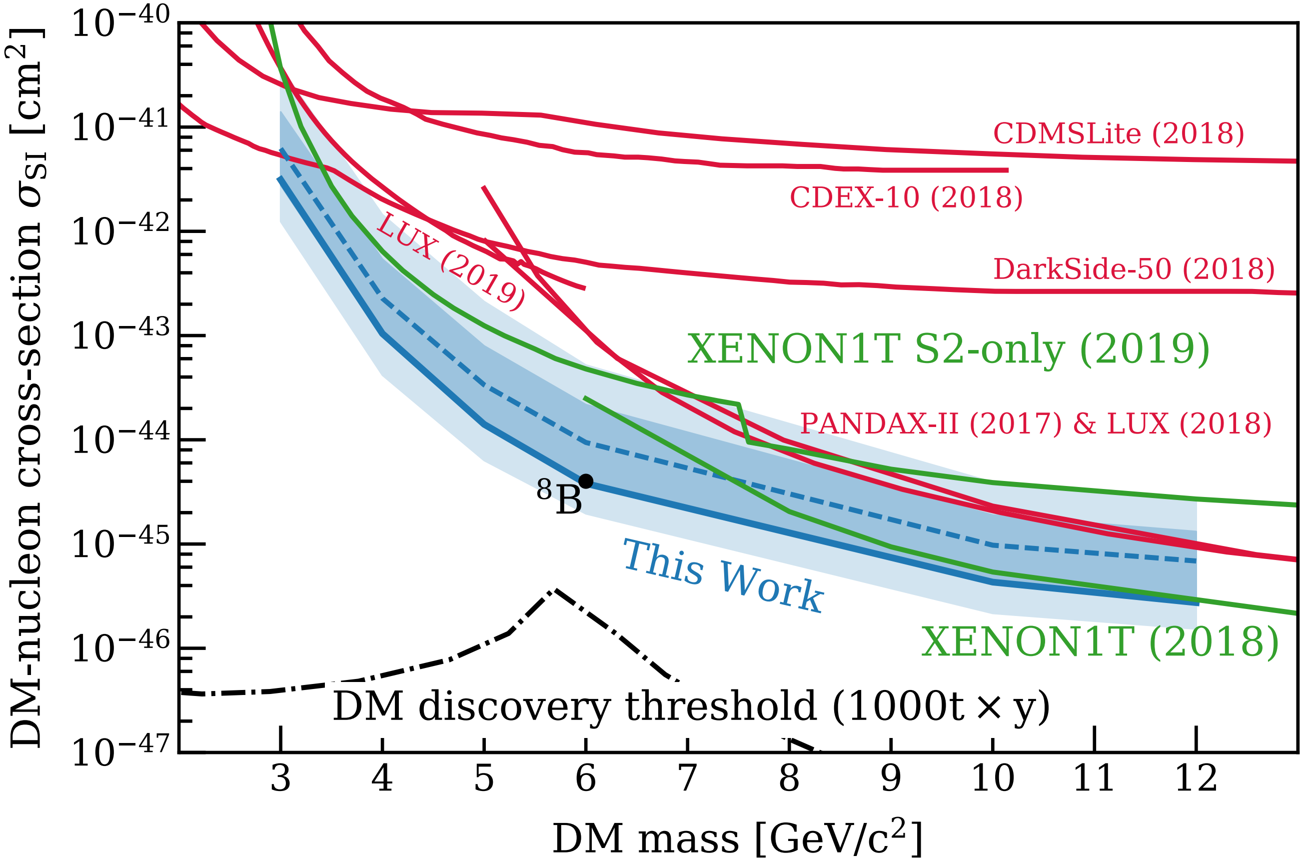


The Neutrino Floor



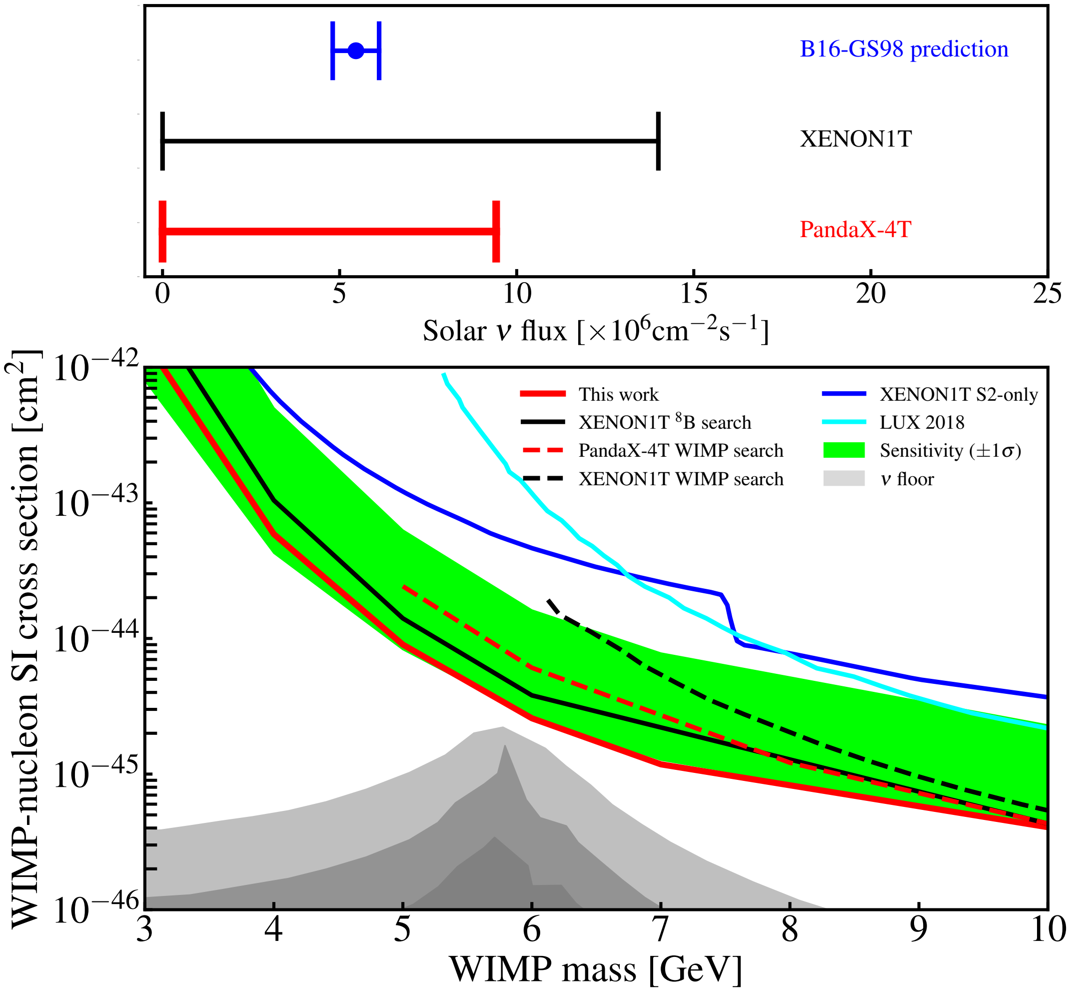
CEvNS by ordinary neutrinos is a background to direct DM searches

Detection of ^{8}B neutrinos is around the corner!



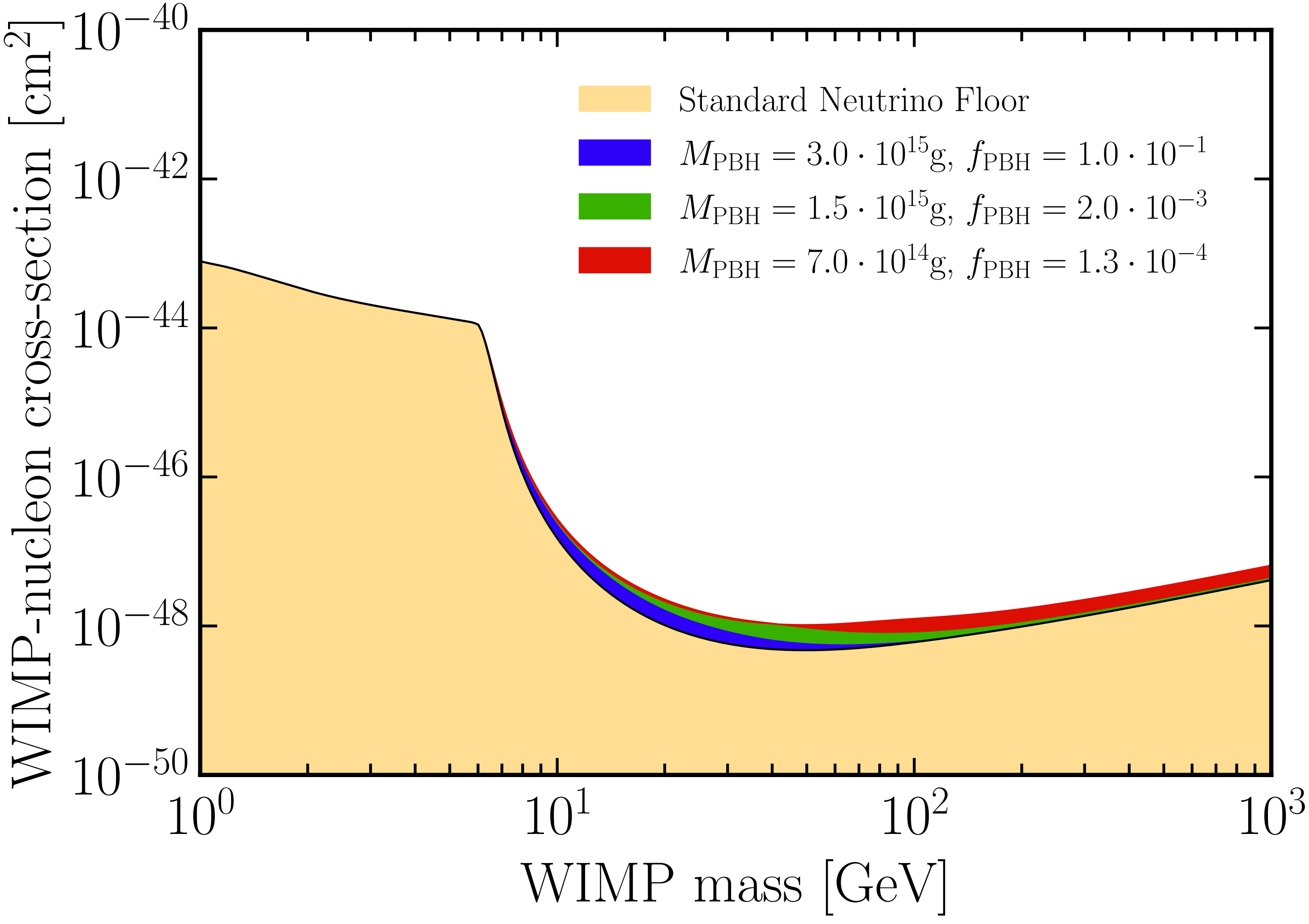
XENON1T
2012.02846

Detection of ^{8}B neutrinos is around the corner!



PANDAX-4T
2207.04883

Impact of PBHs on Neutrino Floor



Take home messages

PBHs in the range 5×10^{14}g – 5×10^{15} g emit neutrinos (E_ν tens of MeV)

CEvNS provides a new opportunity to detect PBHs neutrinos

Complementary to SK, JUNO, DUNE and THEIA

Improvement of sensitivity may be achieved with time/directional info

DM Direct detection experiments would work as low-energy neutrino telescopes