BOOSTED LIGHT DARK MATTER FROM PRIMORDIAL BLACK HOLES @ DARKSIDE-50

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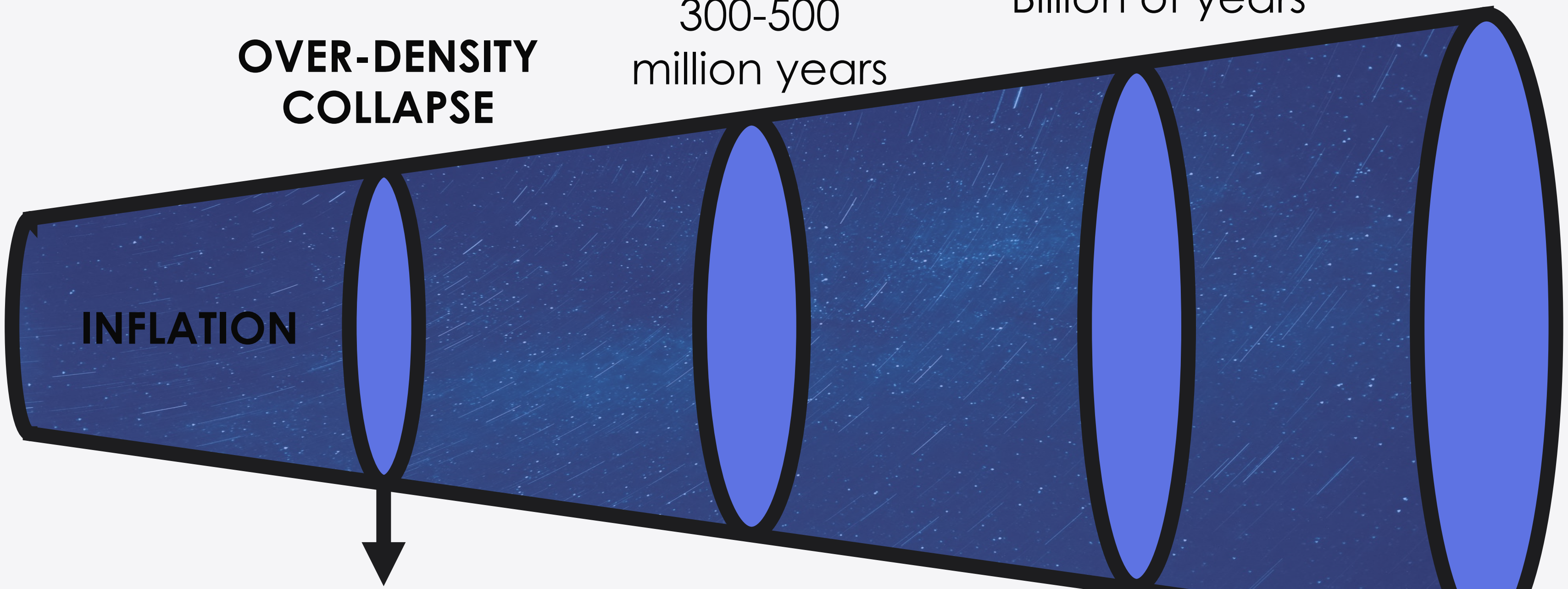
On behalf of the DarkSide collaboration

A follow up of *Phys. Rev. D* 105 (2022) 10, 103024 and *Phys. Rev. D* 105 (2022) 2, L021302

PRIMORDIAL BLACK HOLES

S. W. Hawking, Commun.Math.Phys. 1975
B. J. Carr, Astrophys.J. 1975
J. Auffinger, arXiv: 2206.02672



PRIMORDIAL

BLACK HOLES

MASS $[0.1 - 10^{50}]$g
CHARGE
SPIN

Black Holes born before the star formation from the collapse of enhanced energy density perturbations.

WHY PRIMORDIAL BLACK HOLES

Dark Matter
(Candidate: B.J. Carr and S.W. Hawking, MNRAS 1974. Source: L. Morrison et al, JCAP 2019)

Early Universe
(A.M. Green, Fundam. Theor. Phys. 2015)

Baryogenesis & Leptogenesis
(S. W. Hawking, Nature 1974; Y. B. Zeldovich, Pisma Zh. Eksp. Teor. Fiz. 1976)

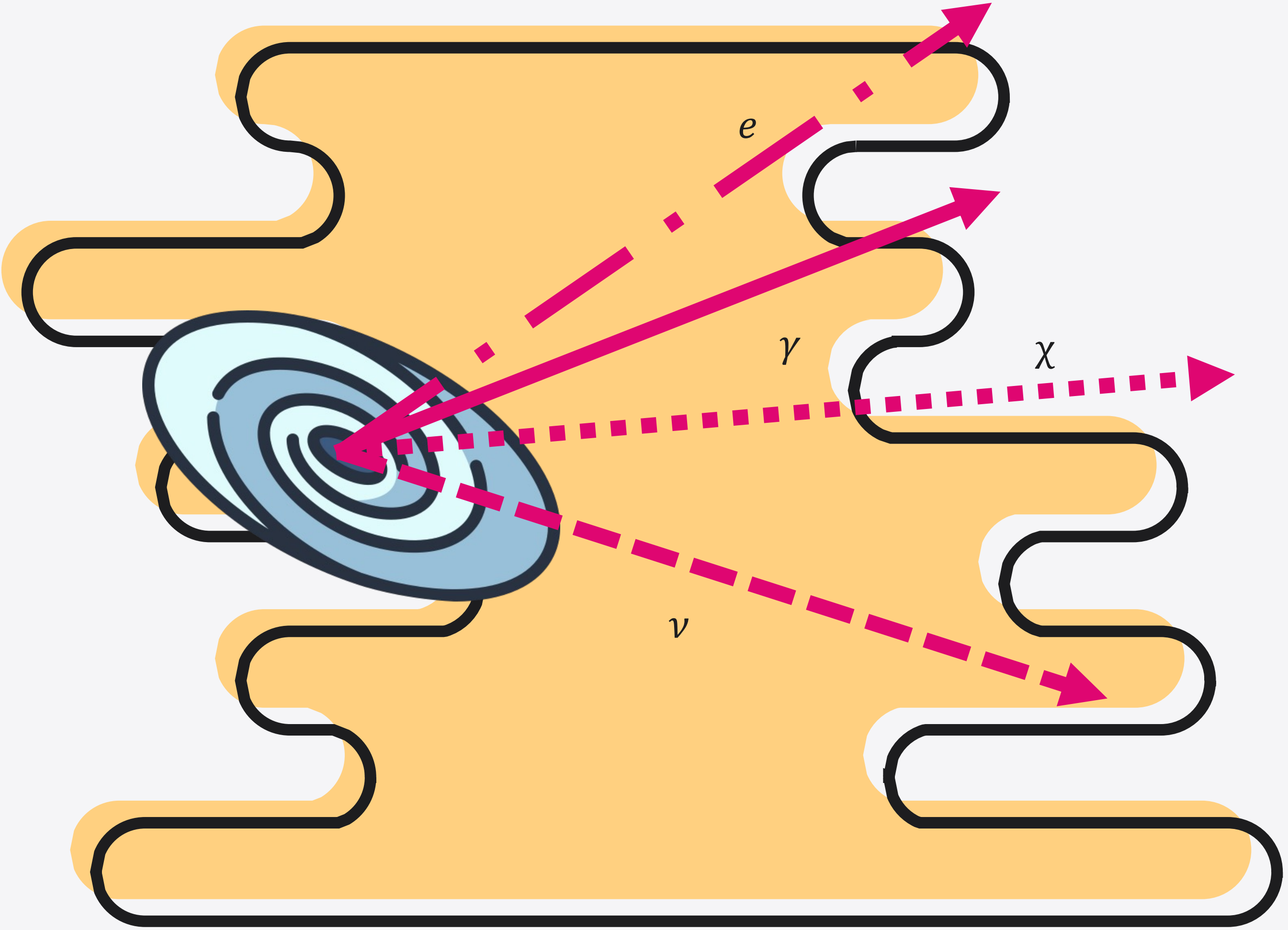
Seeds for Supermassive Black Holes
(B. J. Carr and M. J. Rees, MNRAS 1984)

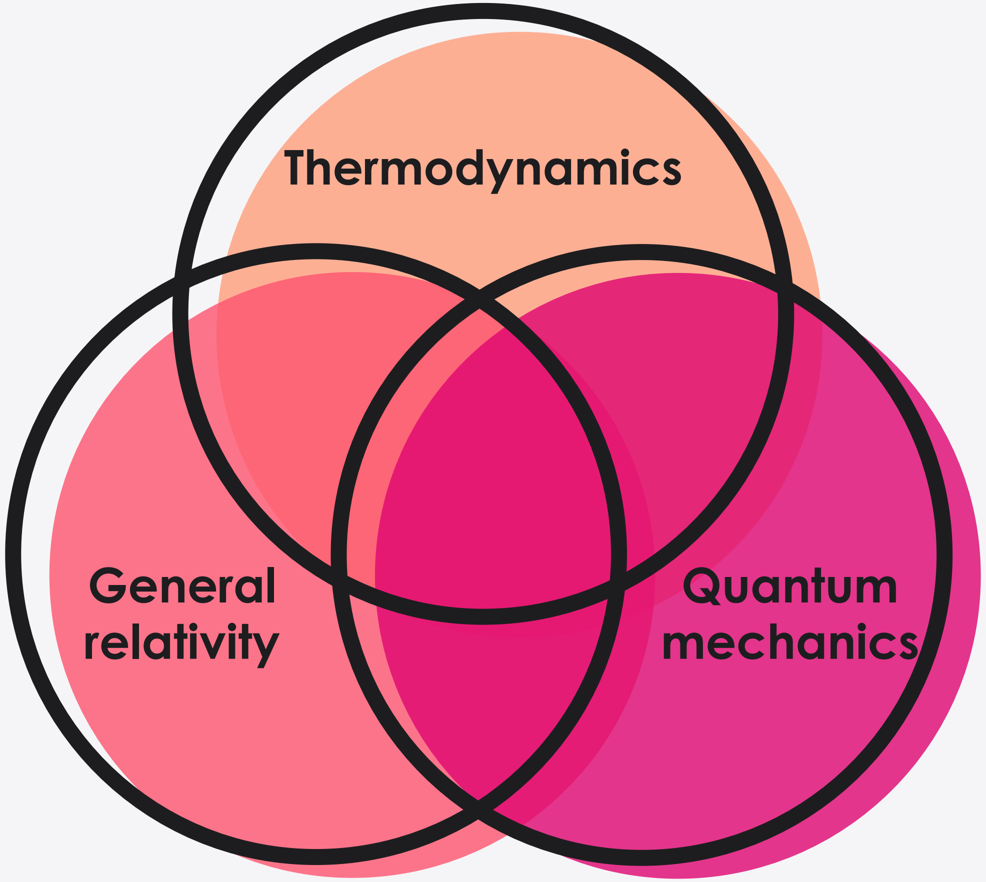
Hawking Radiation
(S. W. Hawking, CMP 87 (1983) 577)

See also D. Gaggero, A. Cuoco, P. Pani, R. Key, and S. Zhang talks!

WHY PRIMORDIAL BLACK HOLES

Primordial Black Holes represent an intrinsic link between three pillars of modern physics!

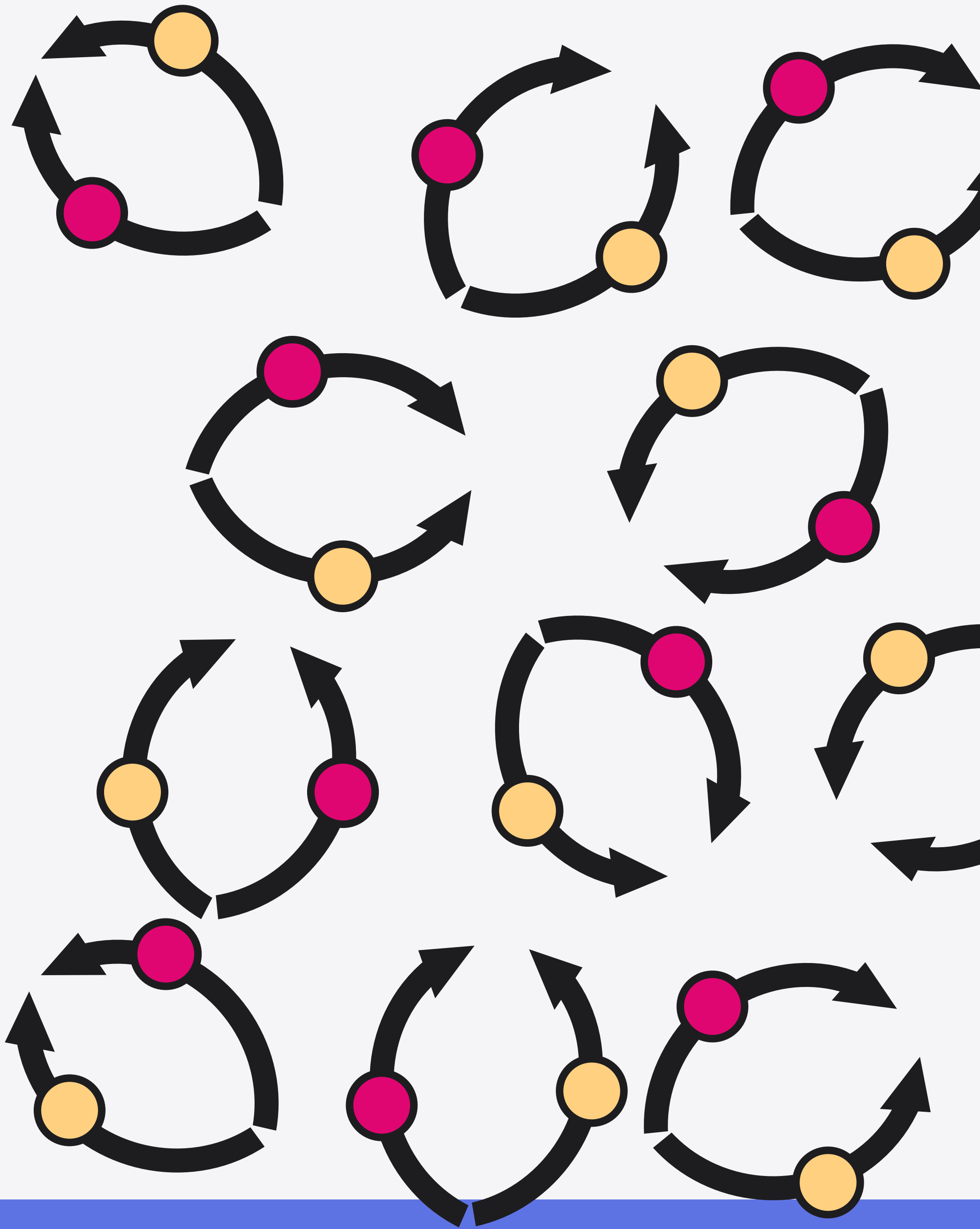




HAWKING RADIATION

Uncertainty principle → the vacuum is a medium in which particle and antiparticle pairs appear and disappear

$$E_p(\infty) + E_{\overline{p}}(\infty) = 0$$



S. W. Hawking, CMP 87 (1983) 577
G.W. Gibbons and S. W. Hawking, PRD 15 (1977)
H. J. Trashen, arXiv gr-qc/0010055

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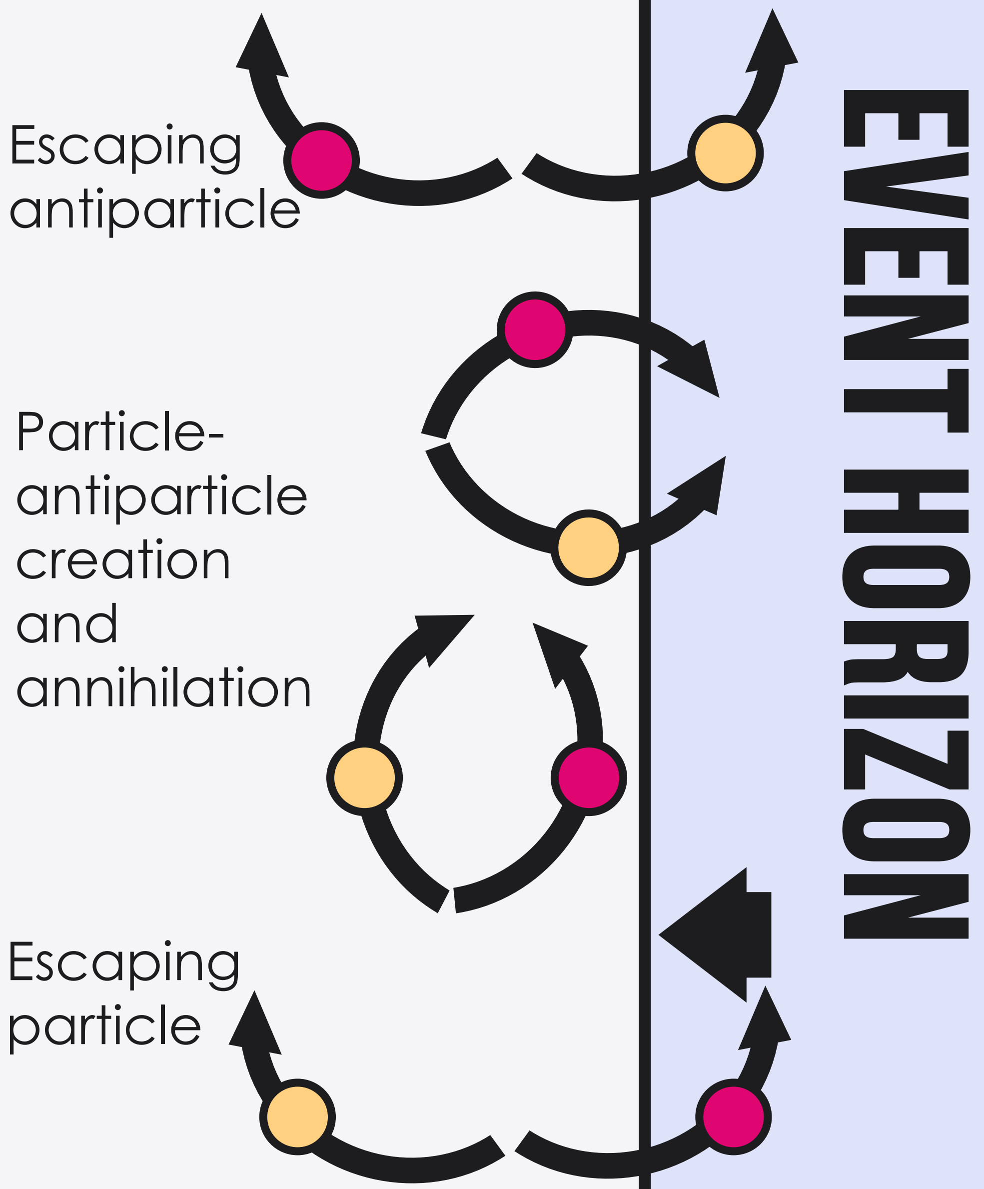
What happens near the event horizon?



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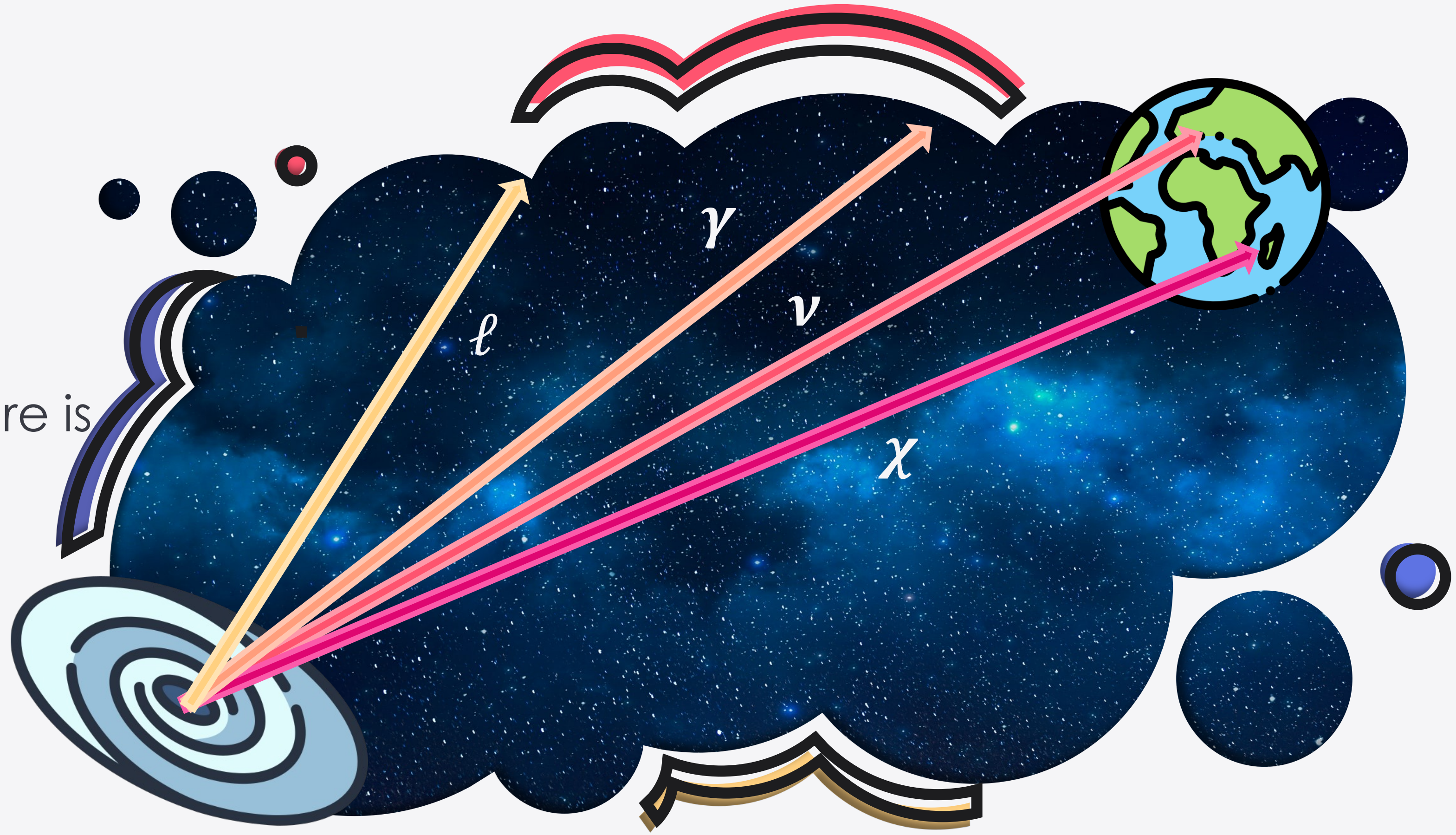
PARTICLE EMISSION

The emission is black-body-like, with a temperature given by

$$T_{BH} = \frac{\kappa}{2\pi}$$

For a **neutral** and **non-rotating** Primordial Black Hole, the Hawking temperature is

$$T_{PBH} = \frac{\hbar c^3}{8\pi G k_B M_{PBH}}$$



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PARTICLE EMISSION

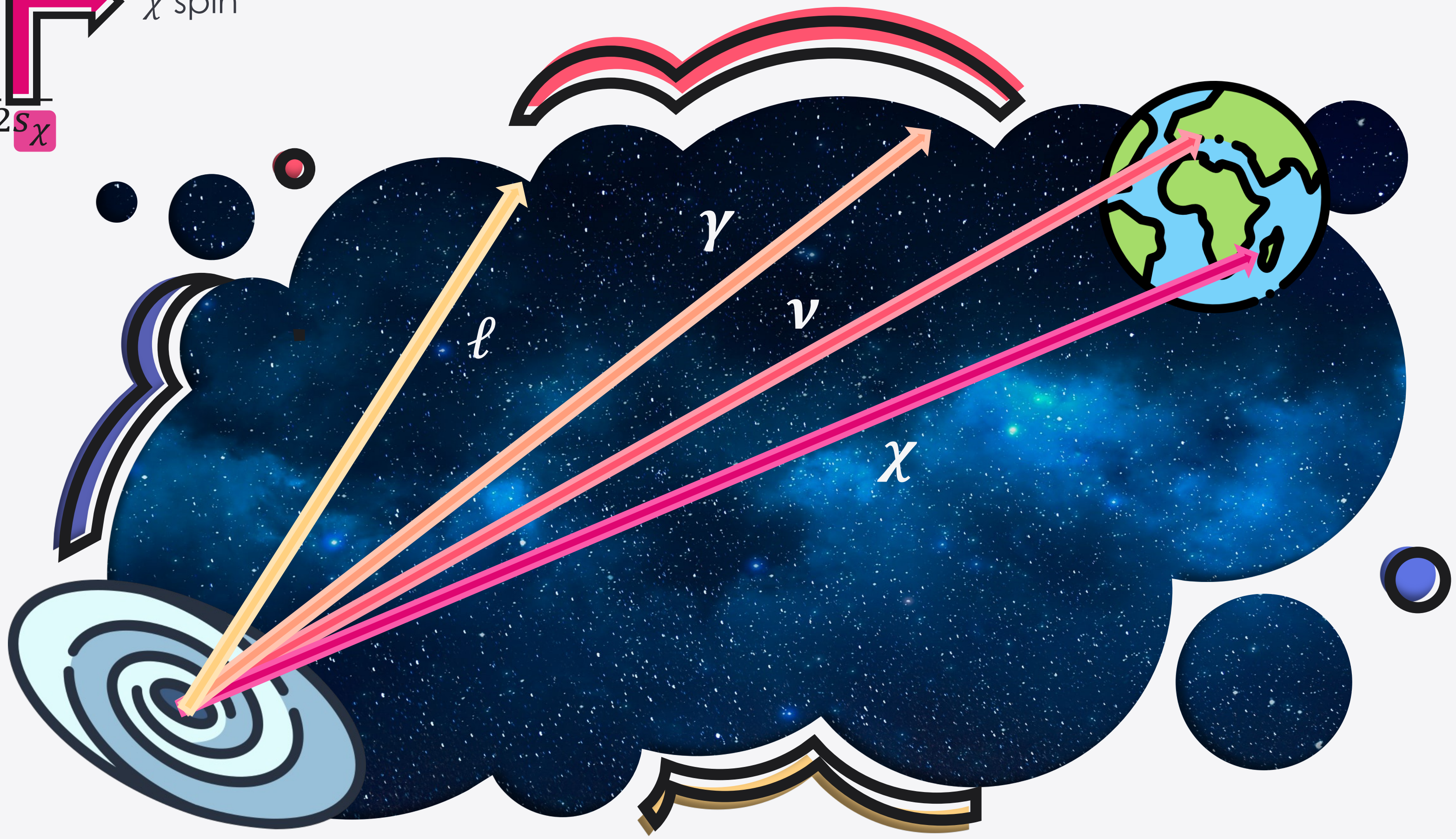
χ Degrees of freedom

Grey body factor

χ spin

$$\frac{dN}{dt\,dE_\chi} = \frac{g_\chi}{2\pi}\frac{\Gamma^\chi(E_\chi, T_{PBH})}{\exp(E_\chi/T_{PBH}) - (-1)^{2s_\chi}}$$

χ Energy



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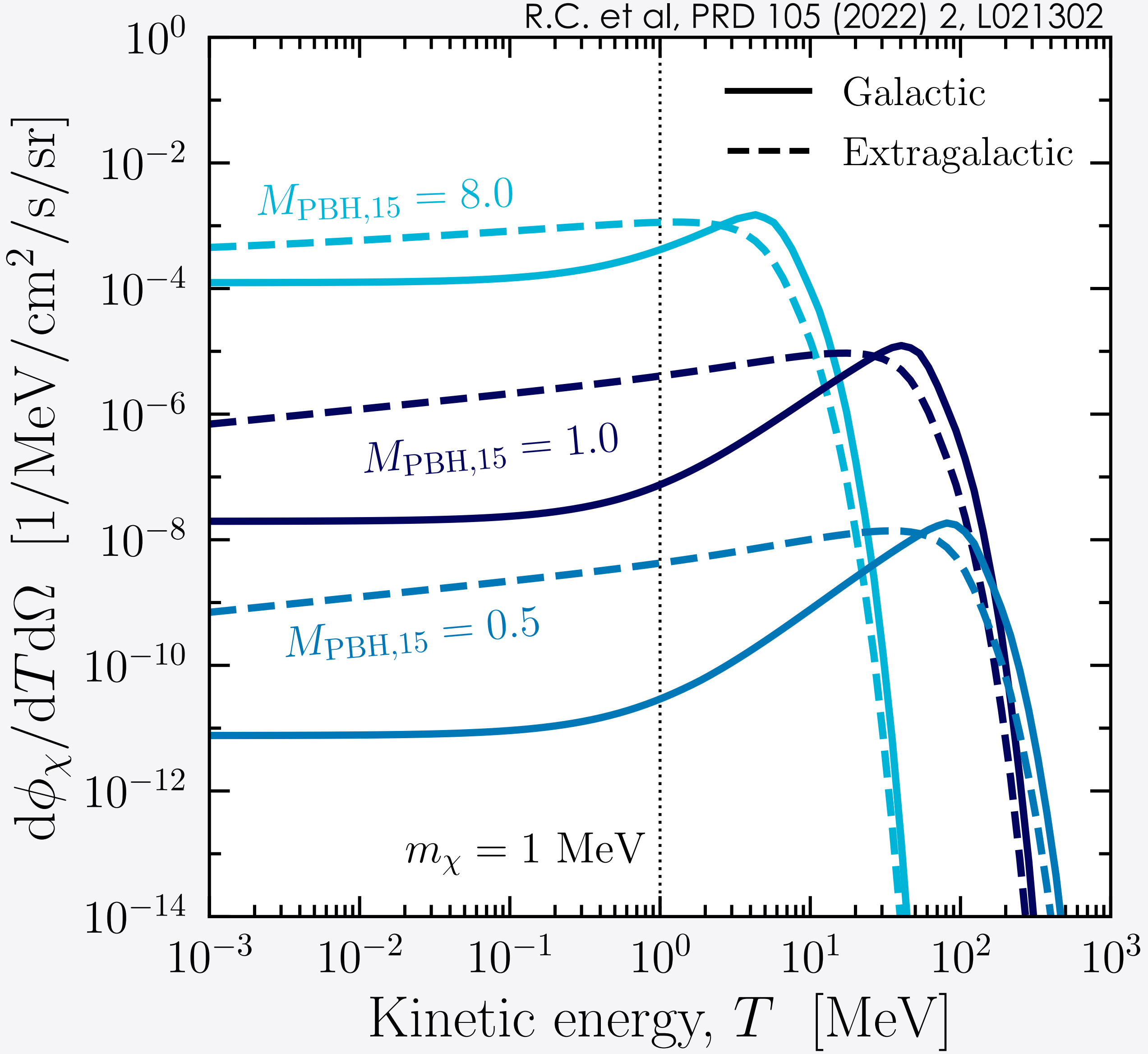
LIGHT DARK MATTER FLUX

Light Dark Matter usually produces recoil energies below the energy threshold. Scenarios considering Dark Matter endowed with **high kinetic energies** overcome this experimental limitation!

R.C. et al, PRD 105 (2022) 2, L021302



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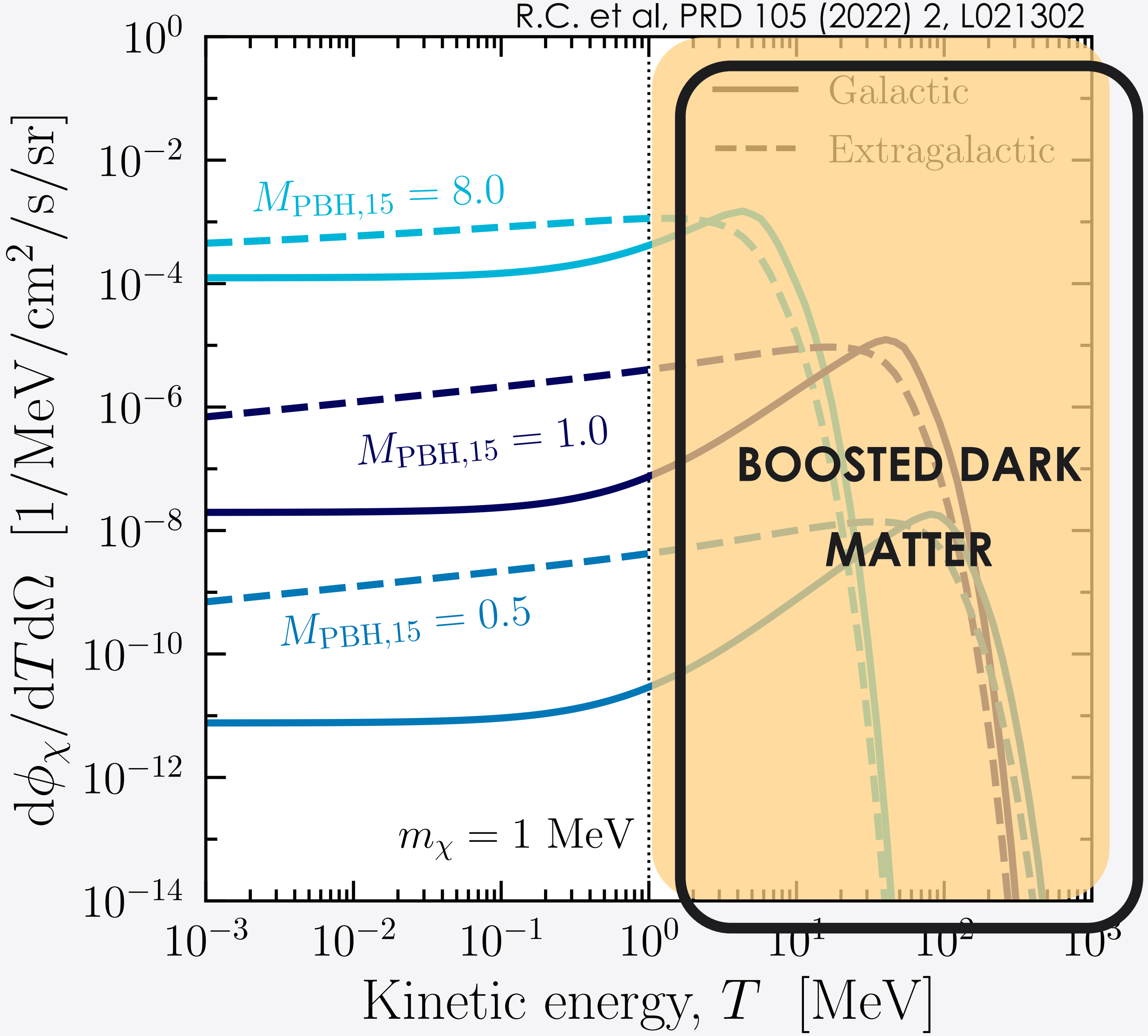
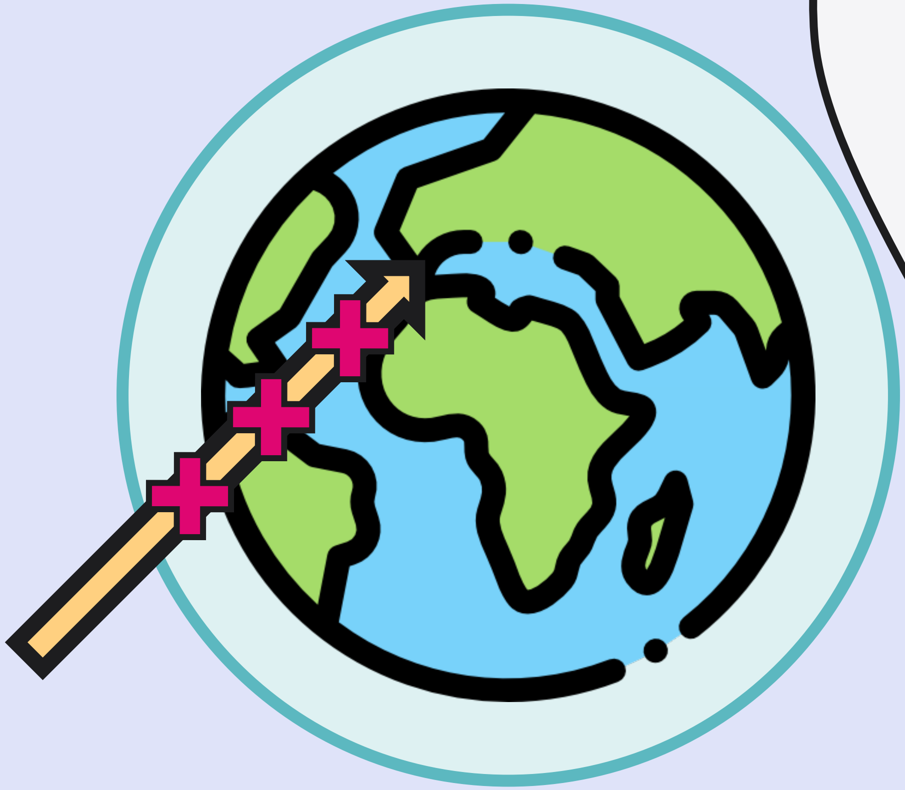
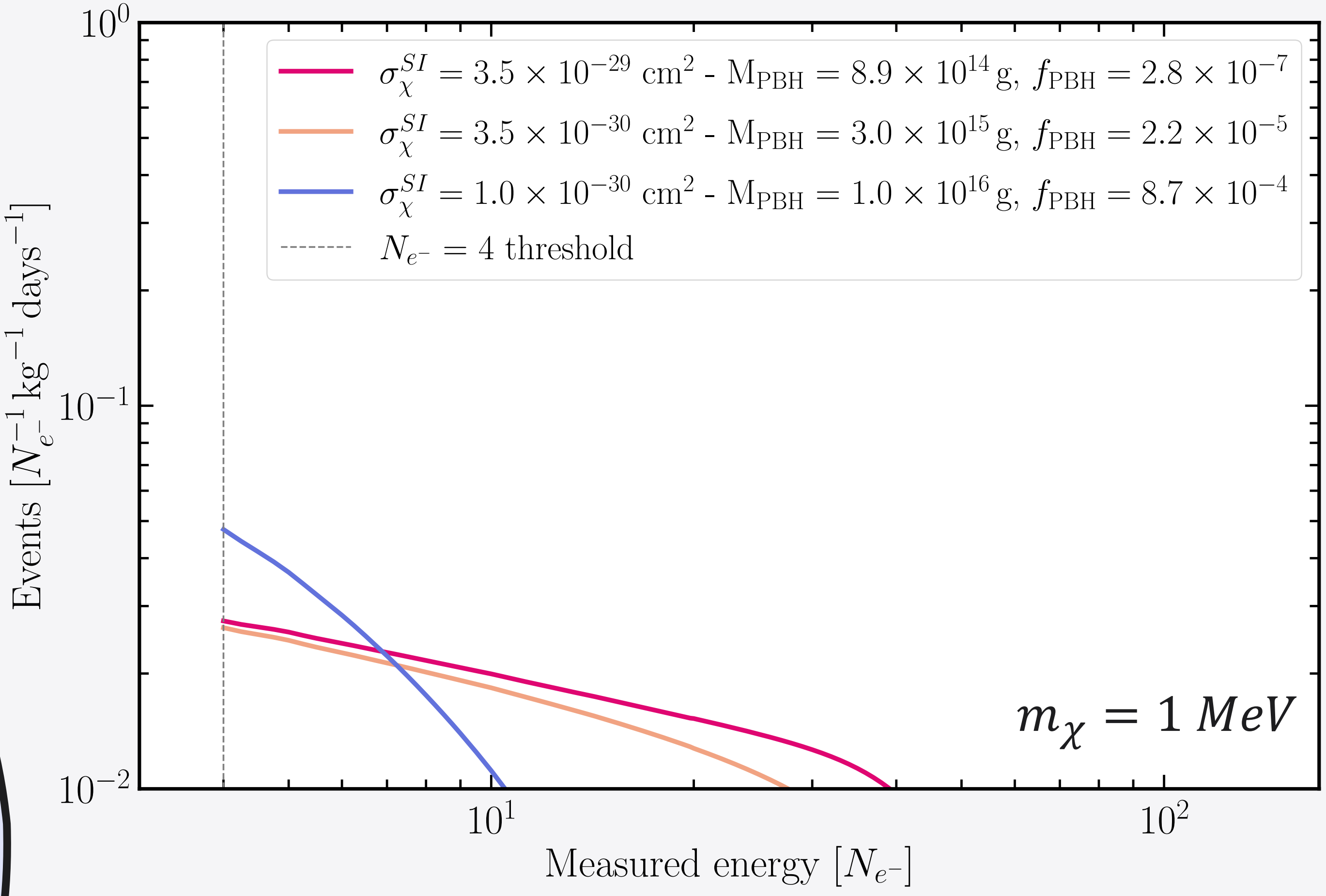


EVENT RATE



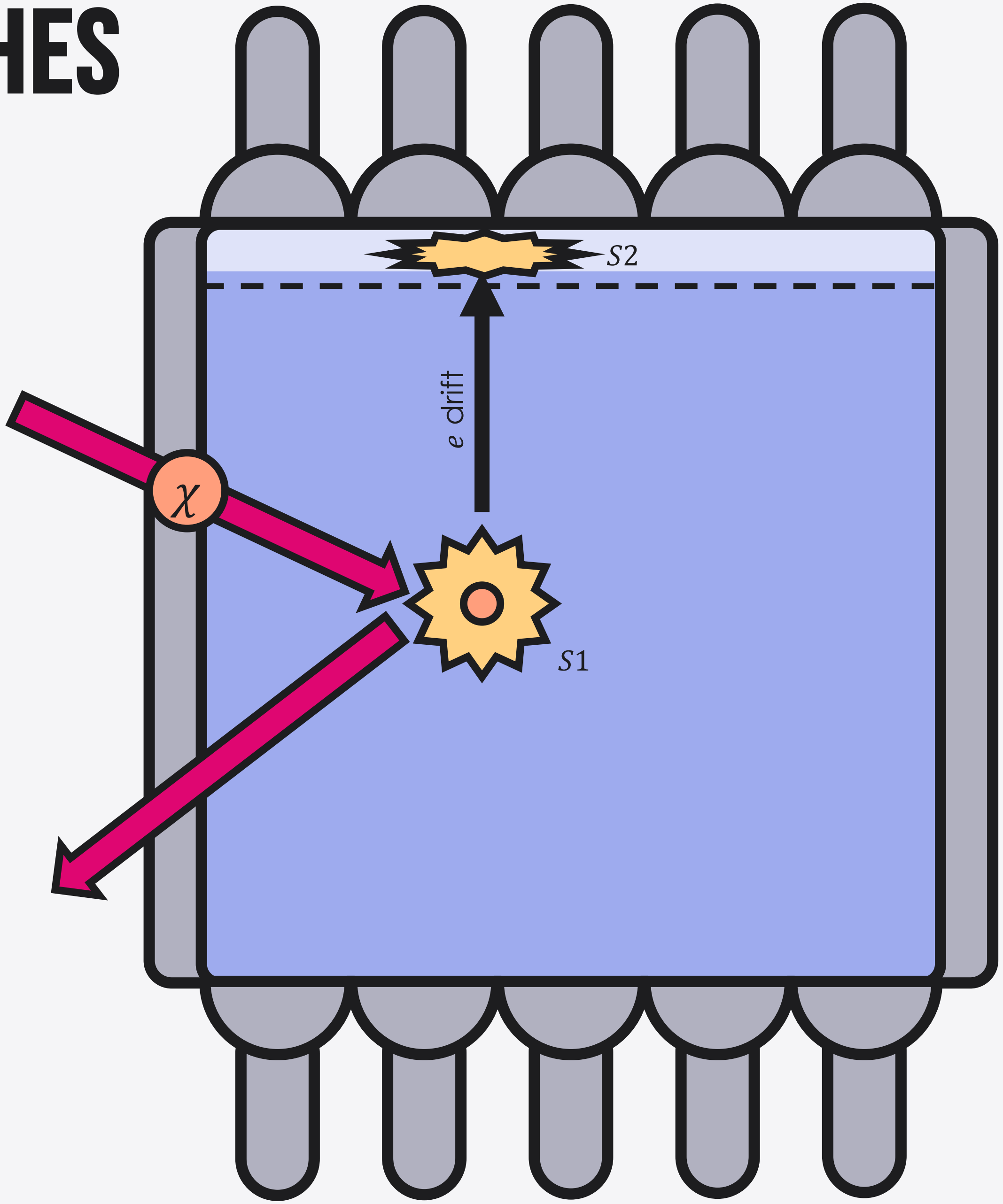


Propagation effects are relevant for cross-sections $\gtrsim 10^{-31} cm^2$

DARKSIDE-50 LOW MASS SEARCHES

★ **Event signatures:**

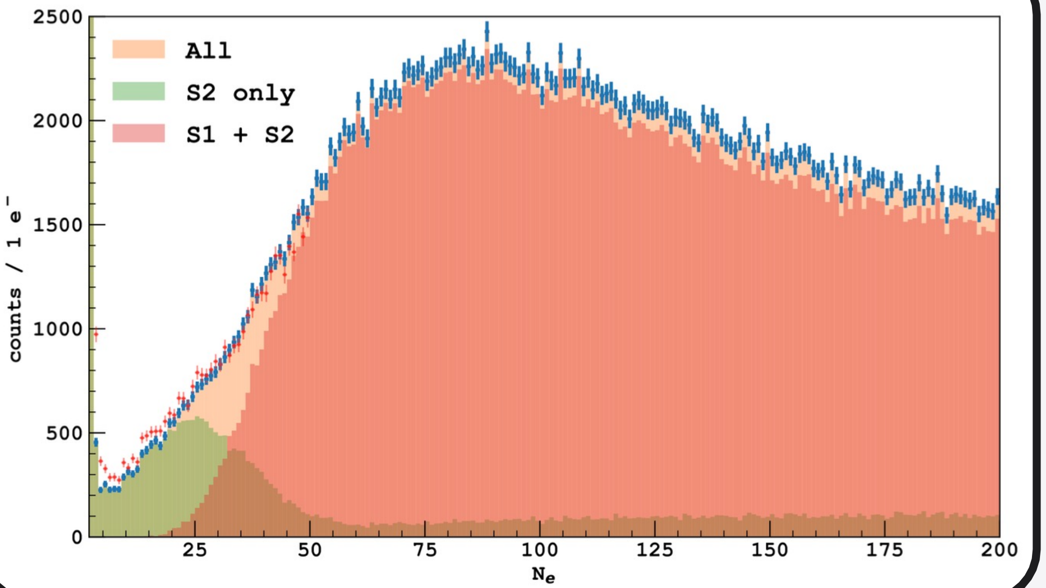
- **Scintillation** light (**S1 signal**)
- **Ionization**: electrons drifted upwards and multiplied in the gas phase electroluminescence light (**S2 signal**)



DARKSIDE-50 LOW MASS SEARCHES

- ★ Studying both the S1 and the S2 signal electronic recoil (ER) vs nuclear recoil (NR) discrimination
- ★ Requiring S1+S2 lower energy threshold is too high (below threshold: the S1 signal is too small to be detected)
- ★ Requiring **only S2 good lower energy threshold of** , but we have to deal with the **ER background**

It is crucial to develop an **accurate background** and **detector response model** and the related **systematic effects**, since they in turn have an impact on the sensitivity to low mass DM candidates.

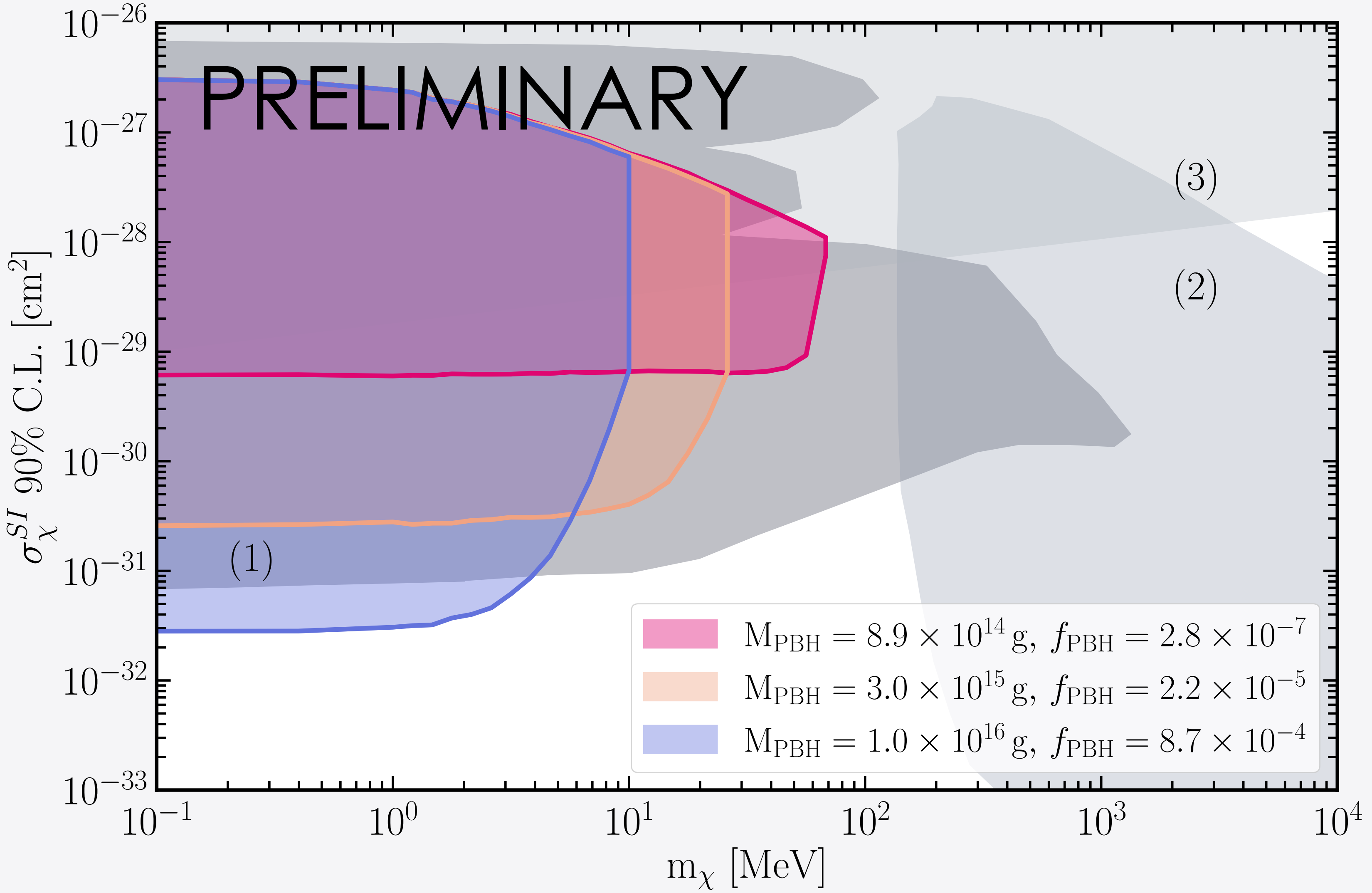


ANALYSIS

- **Assumptions:**
  - monochromatic mass distribution of non-rotating and neutral Primordial Black Holes
  - highest f_{PBH} allowed by existing constraints
- **Aim:** constrain the Dark Matter parameter space.
- **Data and Analysis:**
  - **S2-only data** collected by DS-50 from December 12, 2015 to February 24, 2018 ($\epsilon_{DS} = 635.1 days$)
  - We employed the **Bayesian analysis** shown in "*Search for low mass dark matter in DarkSide-50: the bayesian network approach*" (Eur.Phys.J.C 83 (2023) 322)

CONSTRAINTS WITH DARKSIDE-50

- ★ **Lower limit:** based on the Asimov dataset, obtained on the nominal pre-fit best estimation of the θ_{nuis}, $r_{B,src}$, and ε parameters.
- ★ **Upper limit:** obtained looking for the cross-section at which the event rate is pushed below the threshold (work in progress)

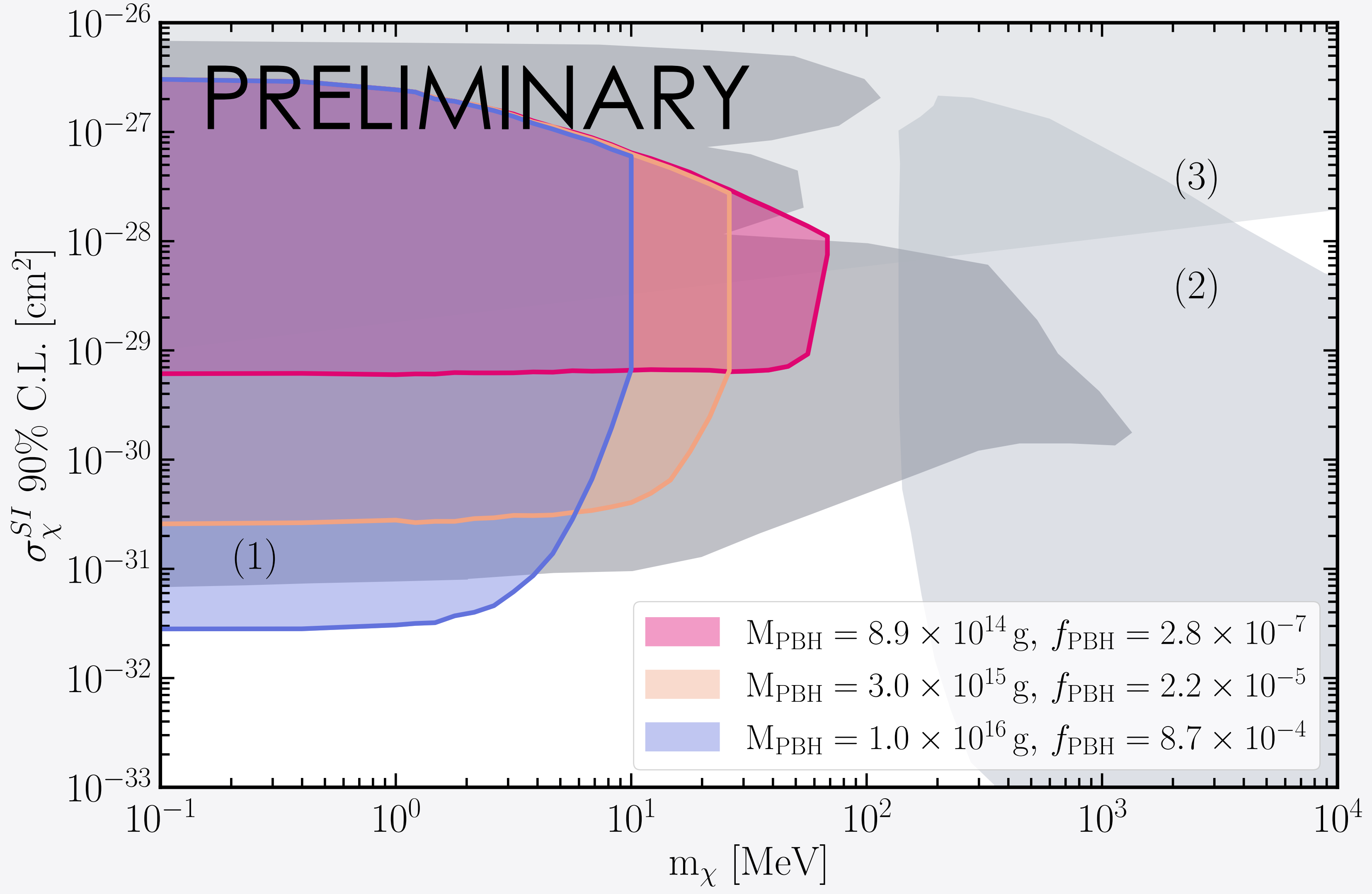


CONSTRAINTS WITH DARKSIDE-50

(1) Cosmic Rays up-scatterings (T. Bringmann and M. Pospelov, PRL 2019; Christopher Cappiello; John F. Beacom, PRD 2019; X. Cui et al; (PandaX-II), Phys. Rev. Lett. 128, 171801420 (2022));

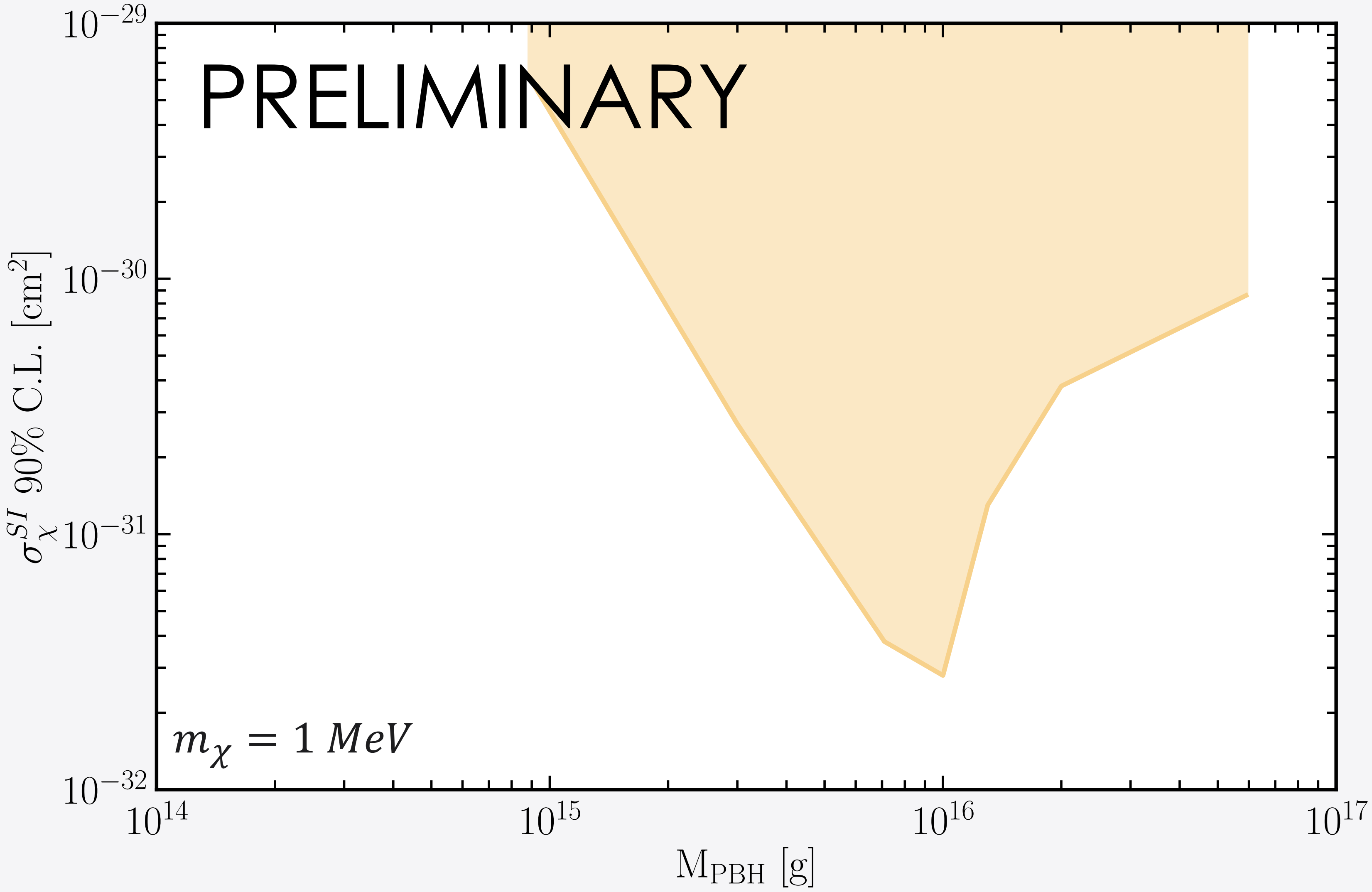
(2) CRESST experiment (G. Angloher et al, EPJC 2017; A. H. Abdelhameed et al, PRD 2019);

(3) Cosmology (V. Gluscevic and K. K. Boddy,PRL 2018; W. L. Xu et al, PRD 2018; T. R. Slatyer and C. L. Wu, PRD 2018; E. O. Nadler et al, AJL 2019).



CONSTRAINTS WITH DARKSIDE-50

- ★ Compared to the previous analysis using Xenon1T data (R.C. et al, PRD 105(2022) 2, L021302), we study a larger range $[5\times10^{14} - 8\times10^{15}]\,g \rightarrow [5\times10^{14} - 6\times10^{16}]\,g$
- ★ **Next step:** produce the forecast constraints for DarkSide-20k



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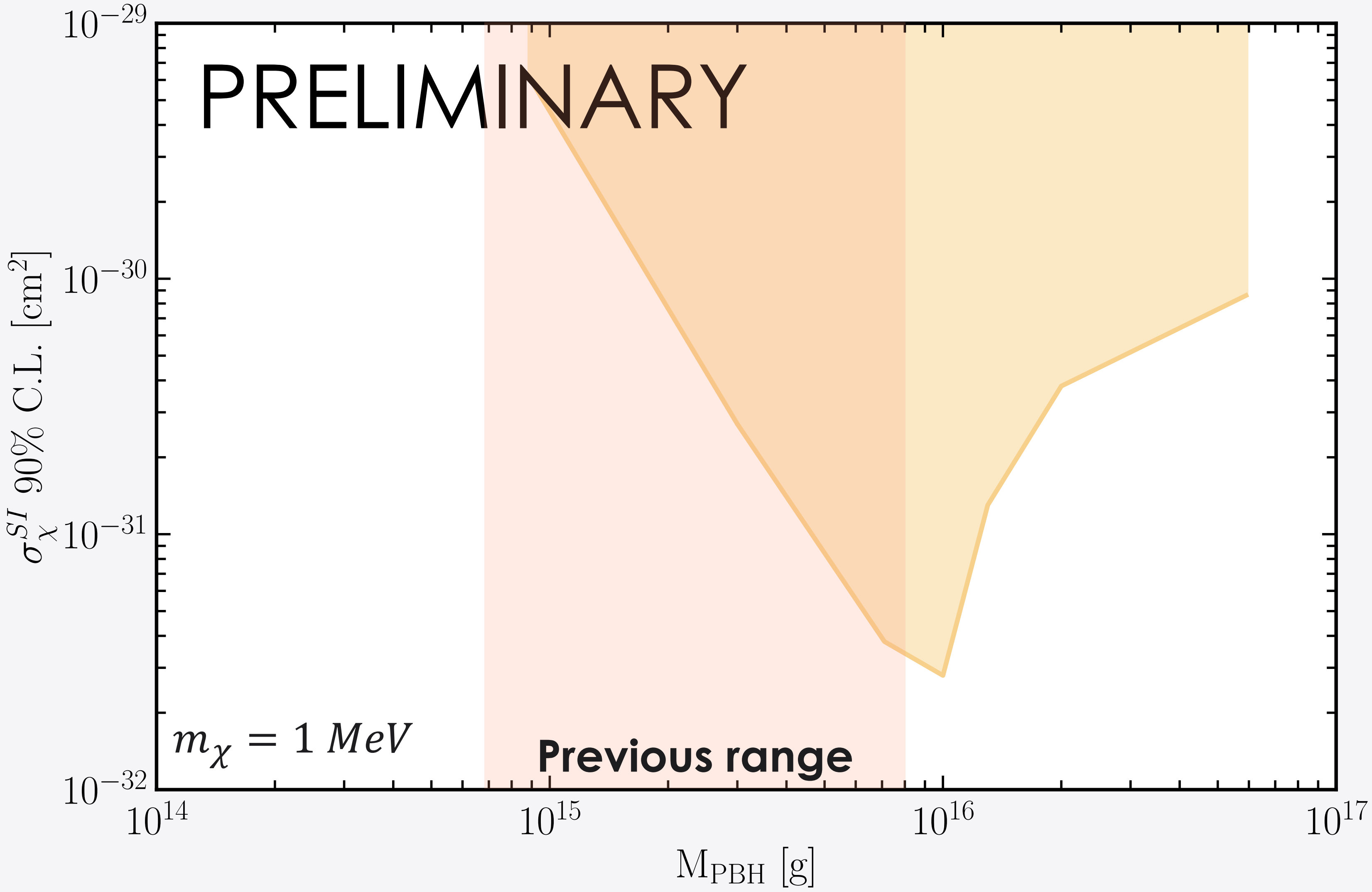

CONCLUSIONS

Thank you for the attention!

- ★ **Primordial Black Holes as source of Boosted light Dark Matter**
  - ★ We consider the effects of the Earth shielding on the Dark Matter flux
  - ★ Considering DarkSide-50 data, we limit σ_χ^{SI} assuming Primordial Black Holes existence
  - ★ We plan on obtaining forecast constraints for DarkSide-20k

ANALYSIS

We assume a **binned Poisson likelihood** defined as

$$p(\{x_i\}|\boldsymbol{\theta}) = \prod_i \frac{\lambda_i(\boldsymbol{\theta})^{x_i}}{x_i!} e^{-\lambda_i(\boldsymbol{\theta})},$$

where x_i is the **number of events** in the i-th bin, $\boldsymbol{\theta}$ indicates all the **parameters of the fit** related to the signal model and the detector response and the background model. In particular

$$\lambda_i = \frac{\mathcal{E}}{\mathcal{E}_{DS}}\left[r_{B,Ar} S_i^{Ar}(\boldsymbol{\theta_{nuis}}) + r_{B,Kr} S_i^{Kr}(\boldsymbol{\theta_{nuis}}) + r_{B,PMT} S_i^{PMT}(\boldsymbol{\theta_{nuis}}) + r_{B,cryo} S_i^{cryo}(\boldsymbol{\theta_{nuis}}) + f_{PBH} S_i^{PBH}(\sigma_\chi^{SI}, \boldsymbol{\theta_{nius}})\right]$$

- S_i^{src} = are the expected background and signal
- $r_{B,src}$ = are proportional to the rate of internal and external background components
- $\mathcal{E}$ ($\mathcal{E}_{DS}$) = total (nominal) exposure

WHAT DID WE DO IN THE PREVIOUS WORK?

We obtained constraints on the σ_χ^{SI} from the non observation of excess in XENON1T for $E_r \in [4.9 - 40.9]\mathrm{keV}$

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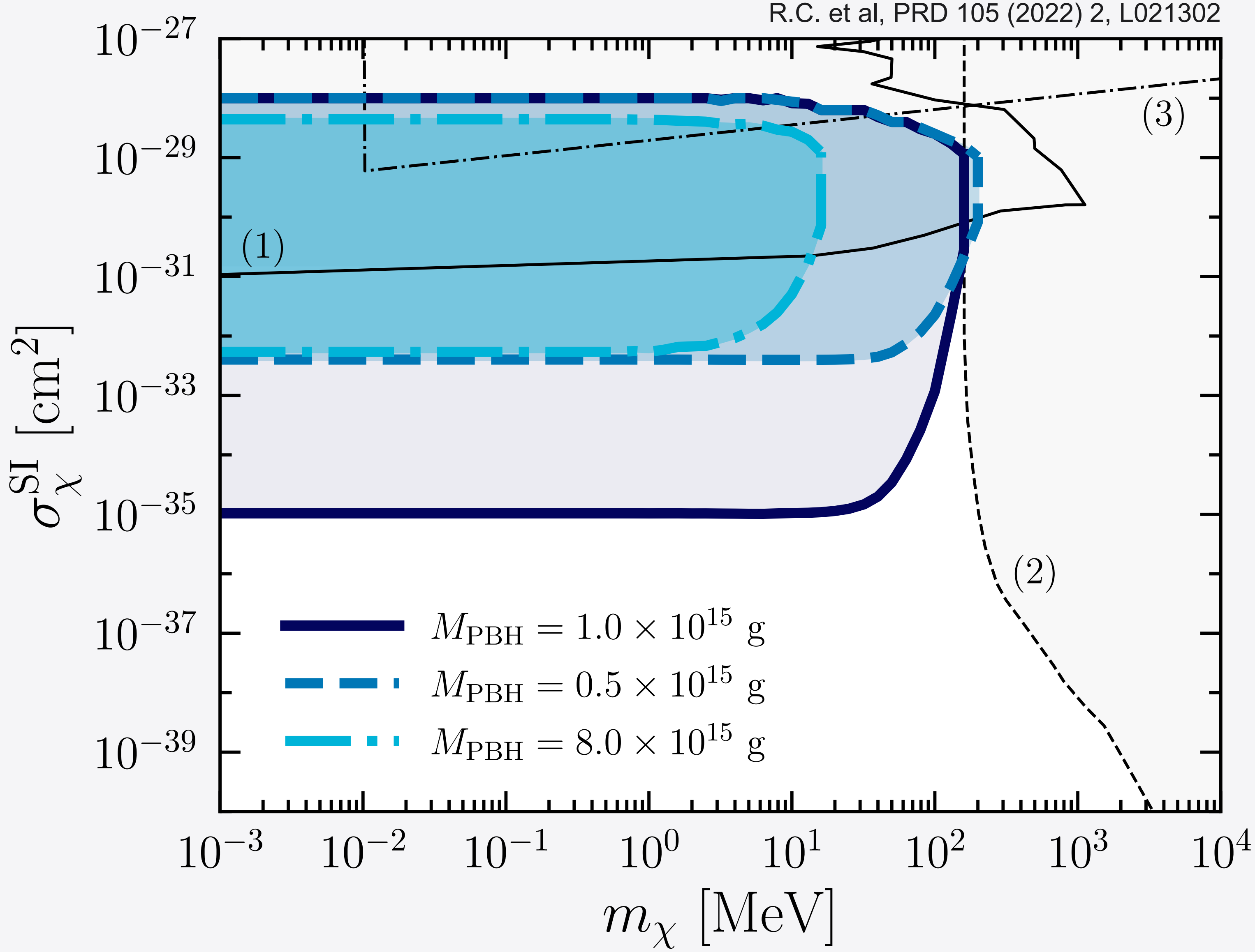
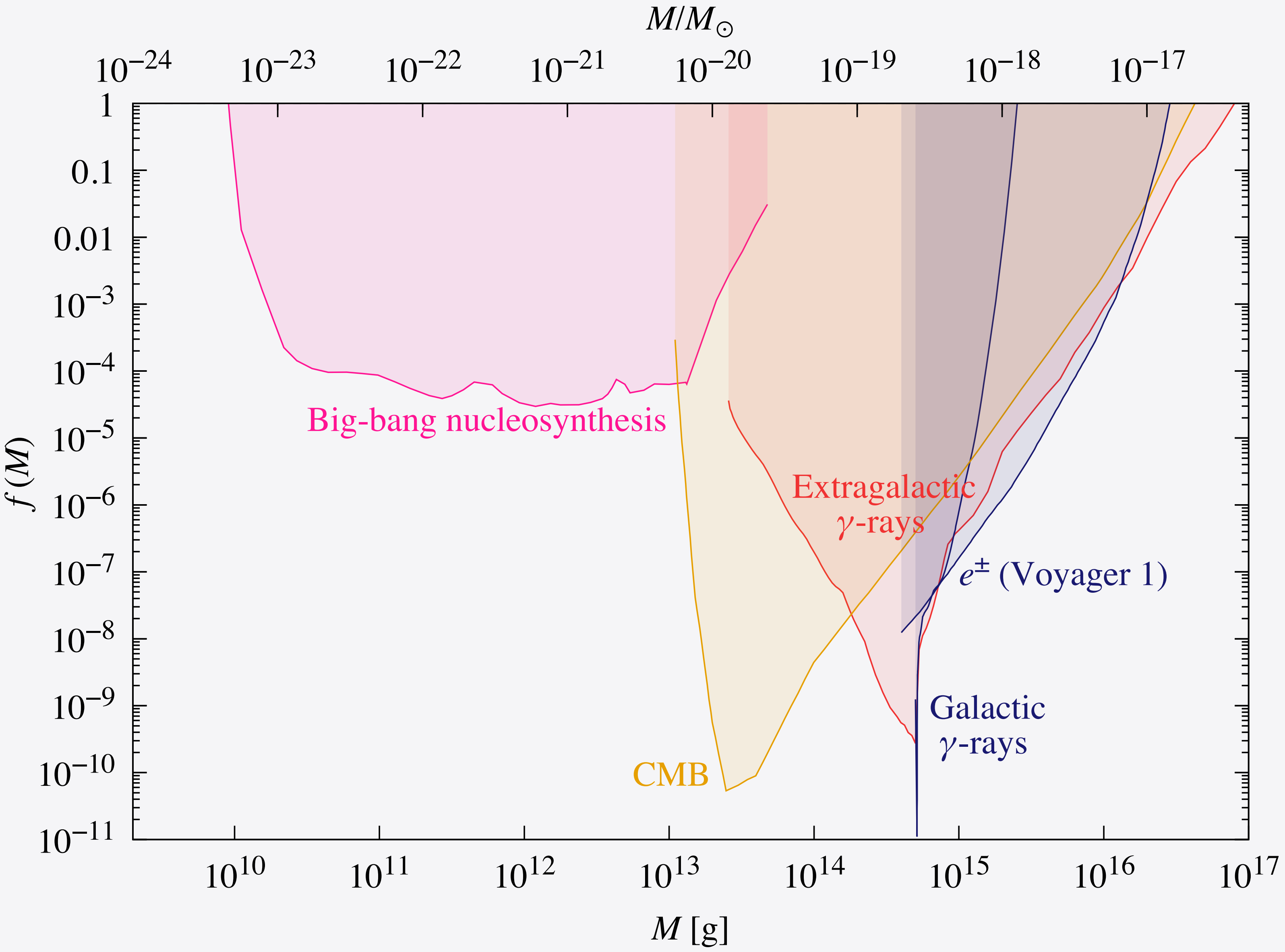


EXISTING BOUNDS



B. Carr et al, Rept.Prog.Phys. 84 (2021) 11, 116902