

# Maximizing Direct Detection with HYPER Dark Matter

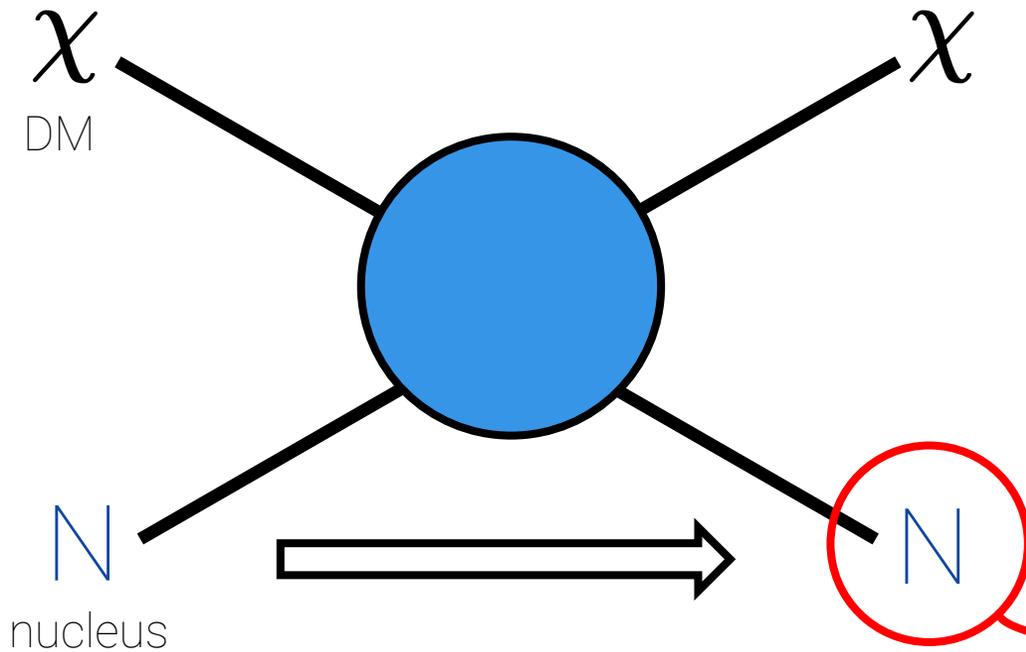
Robert McGehee



2112.03920  
w/ Gilly Elor & Aaron Pierce

PPC 2022, 6/7/22

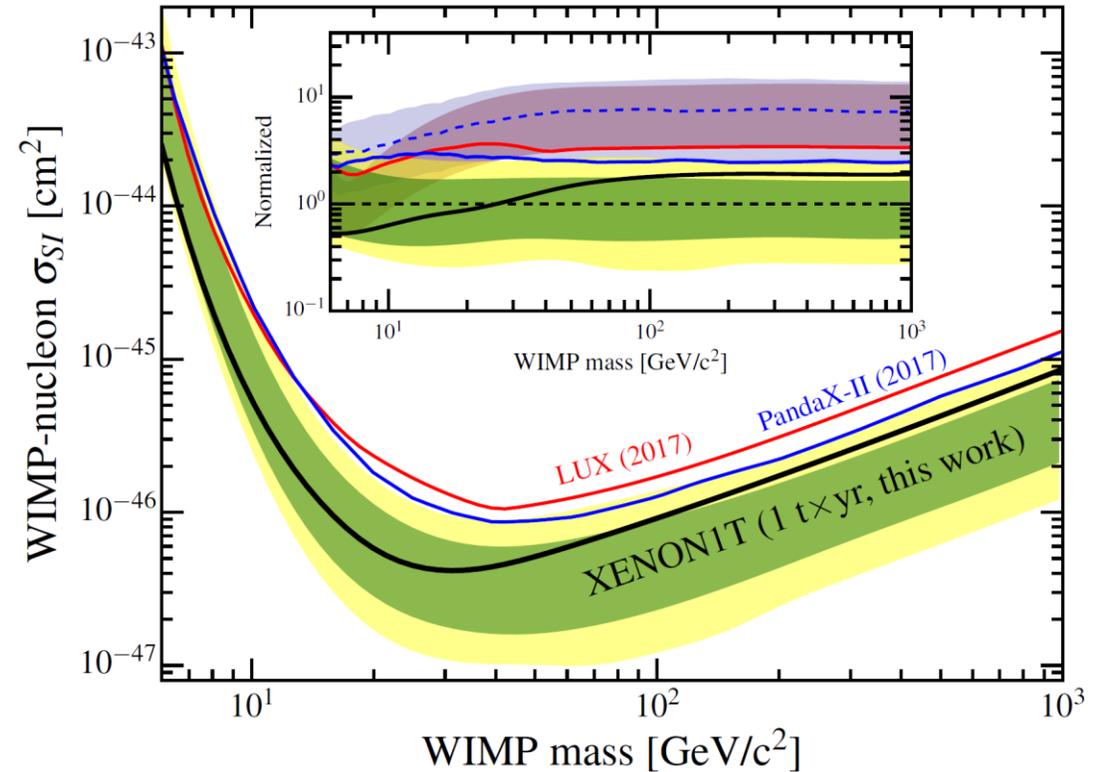
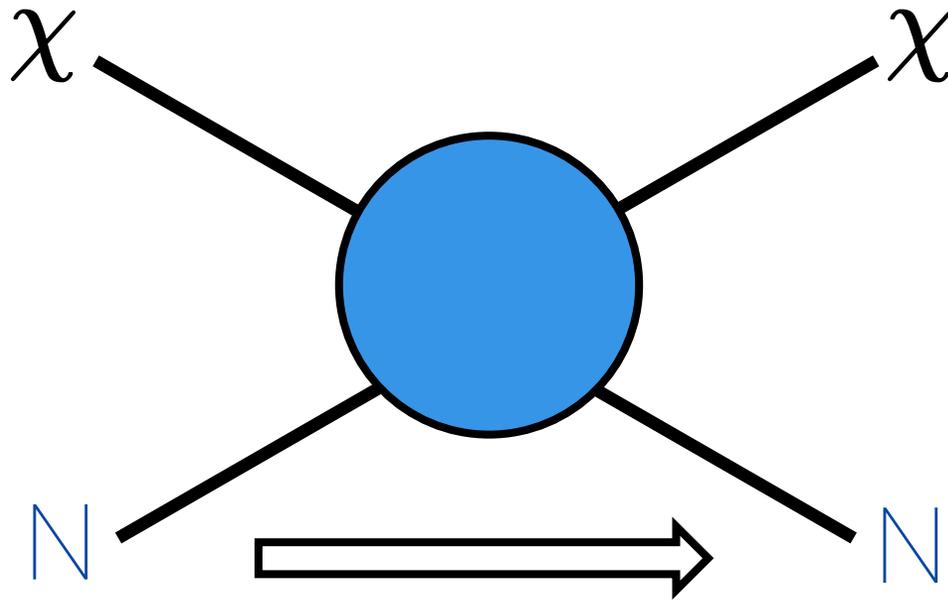
# Direct Detection Refresher



Credit: The XENON Experiment



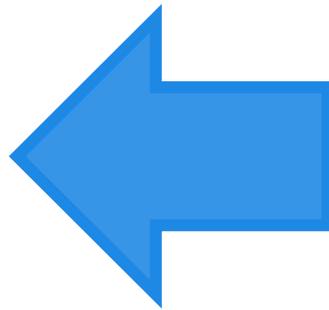
# Direct Detection Refresher



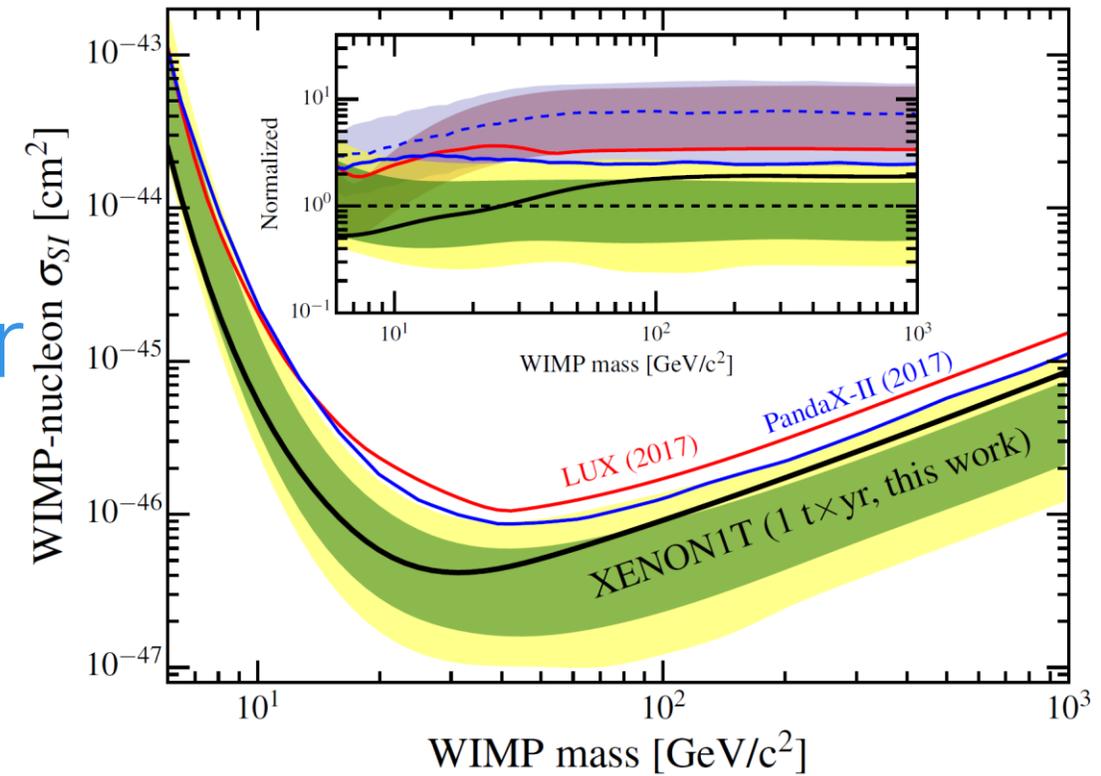
XENON Collaboration [1805.12562]

# Direct Detection Future

Go higher?

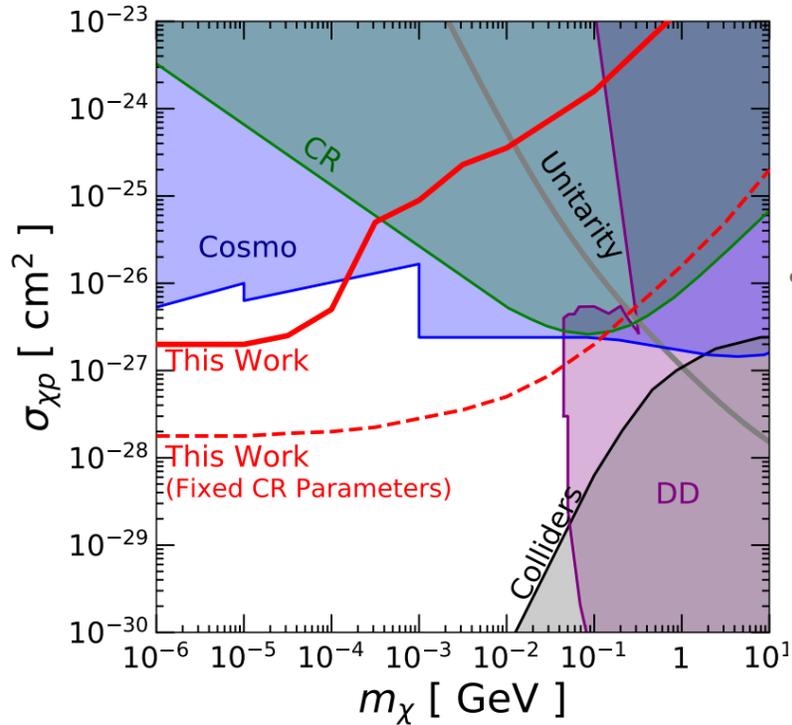


Go lighter

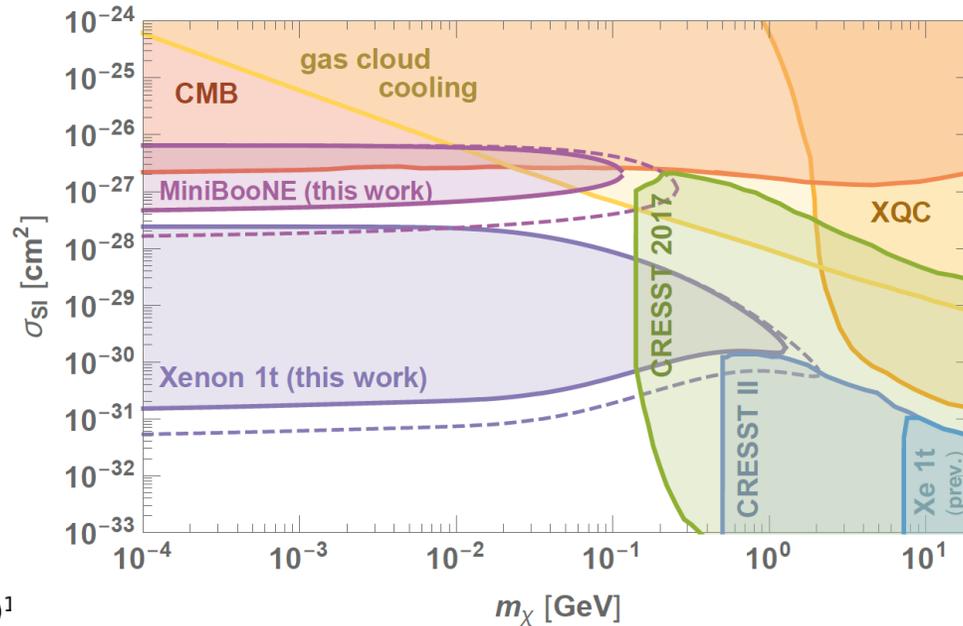


Go lower

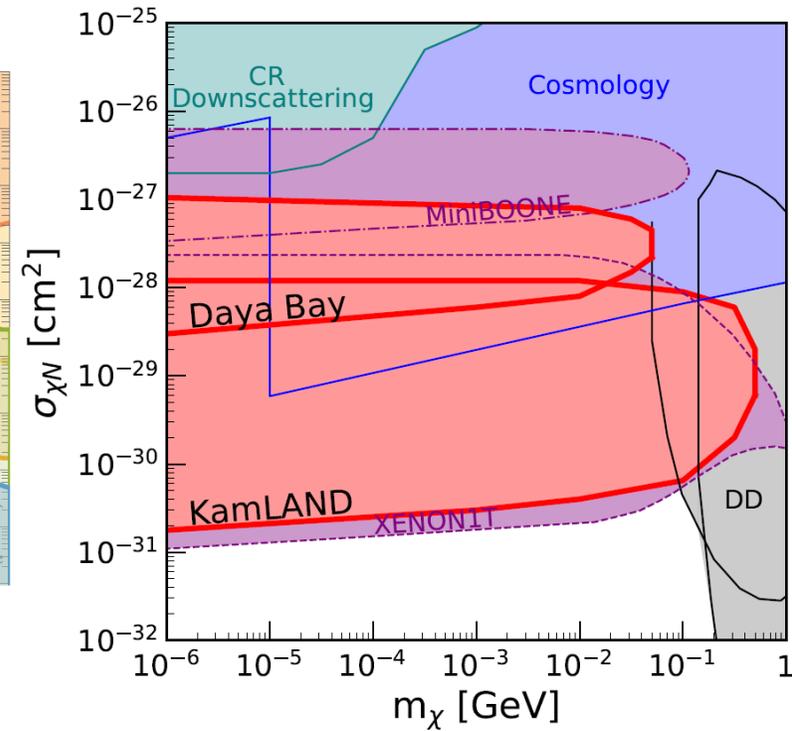
# Bounds from Cosmic Ray Scattering



C. Cappiello, K. Ng, J. Beacom  
[1810.07705]

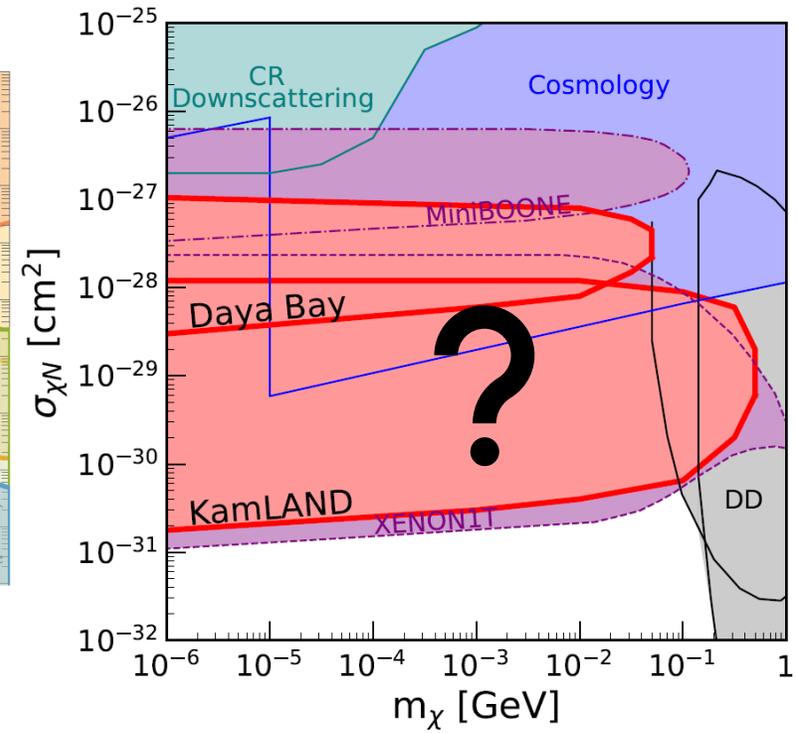
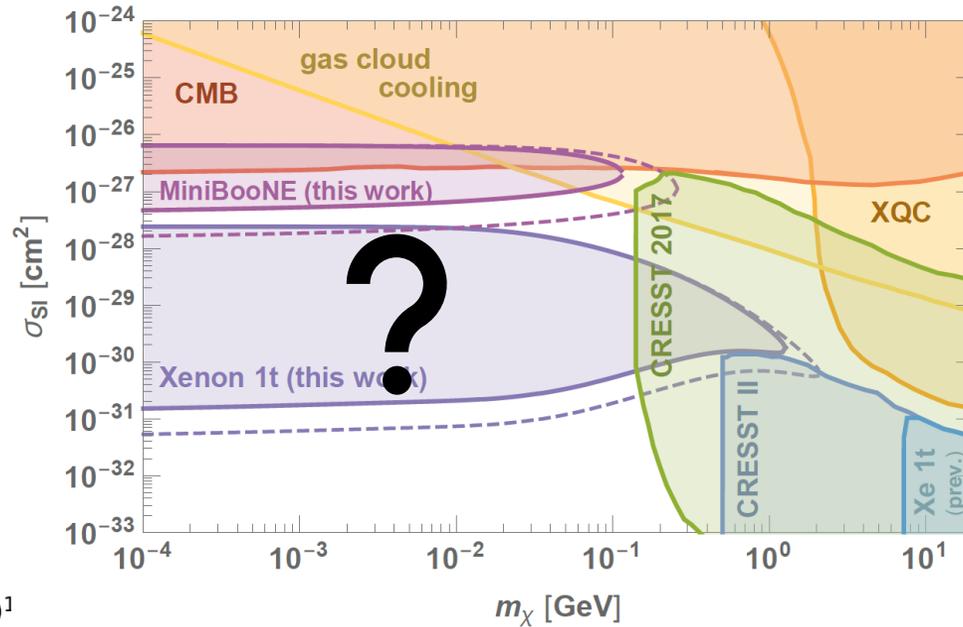
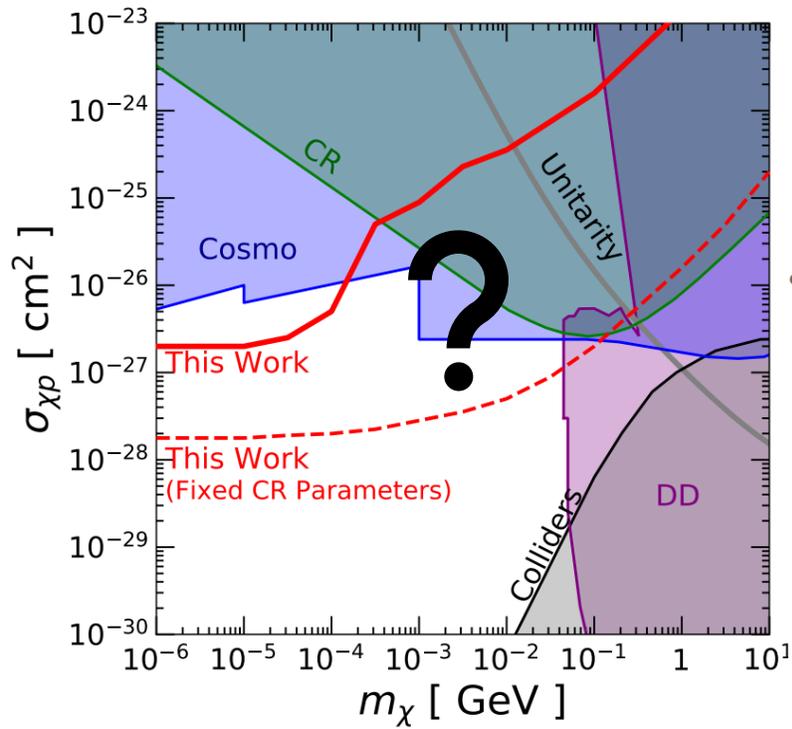


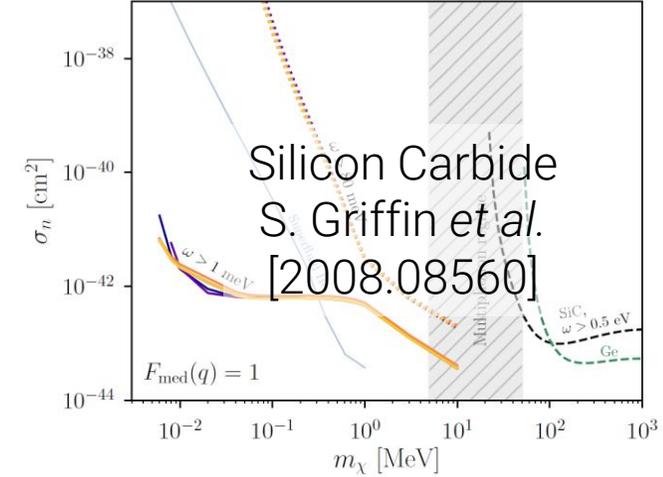
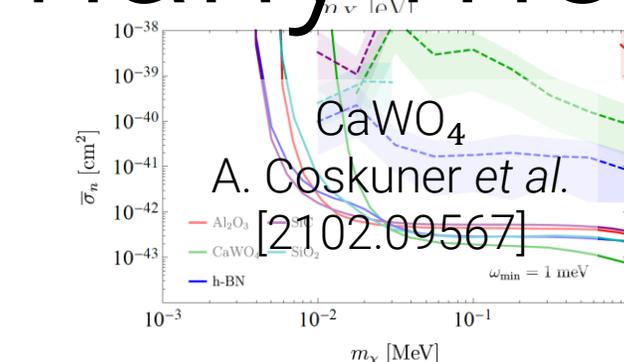
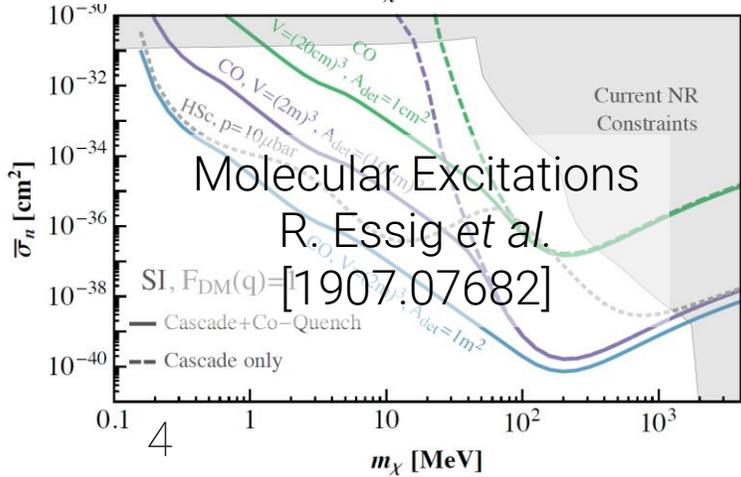
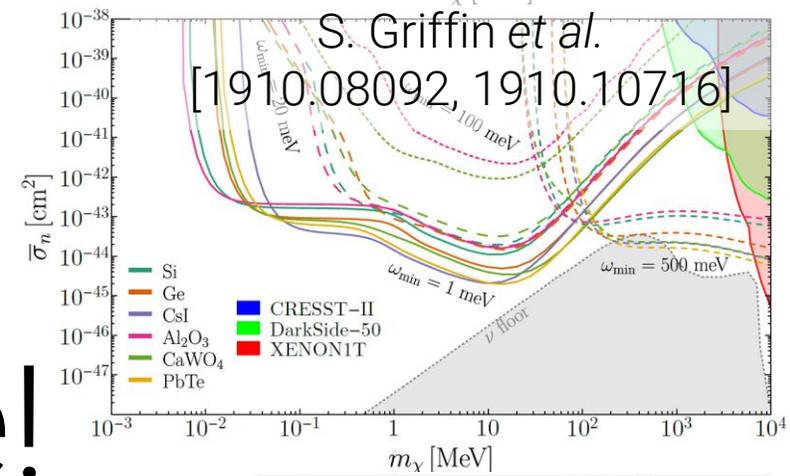
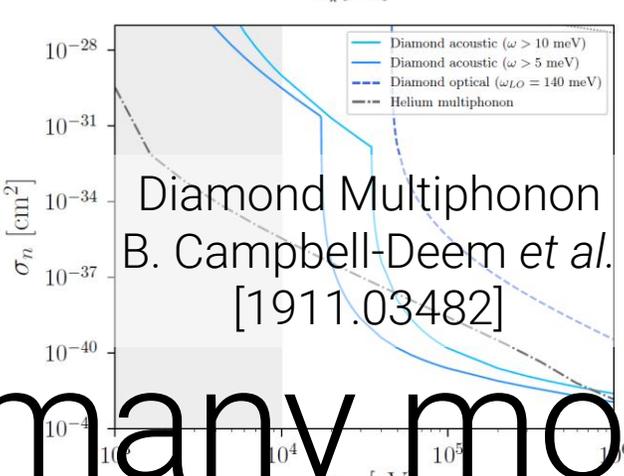
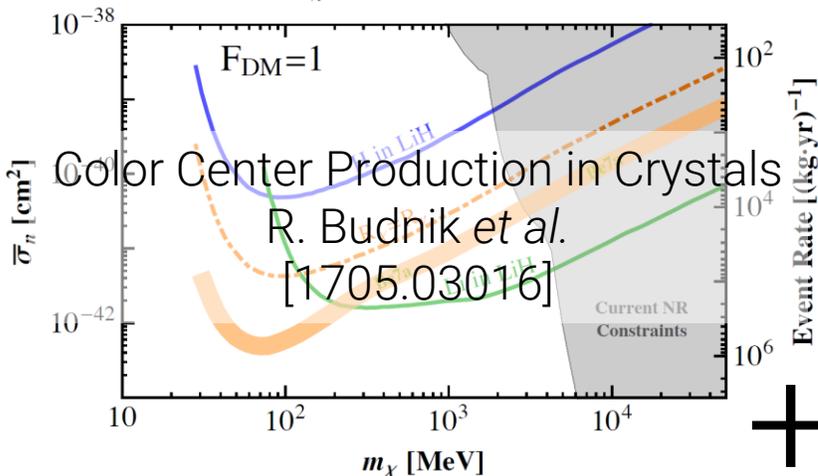
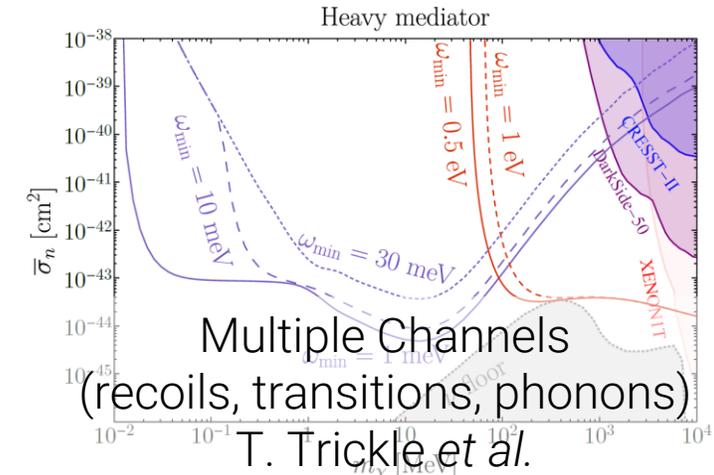
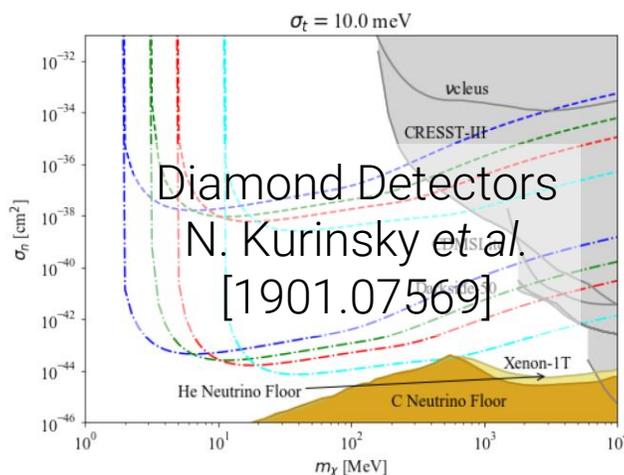
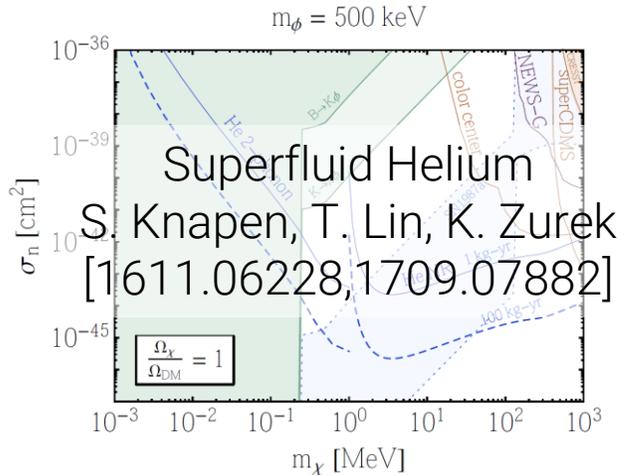
T. Bringmann, M. Pospelov  
[1810.10543]



C. Cappiello, J. Beacom  
[1906.11283]

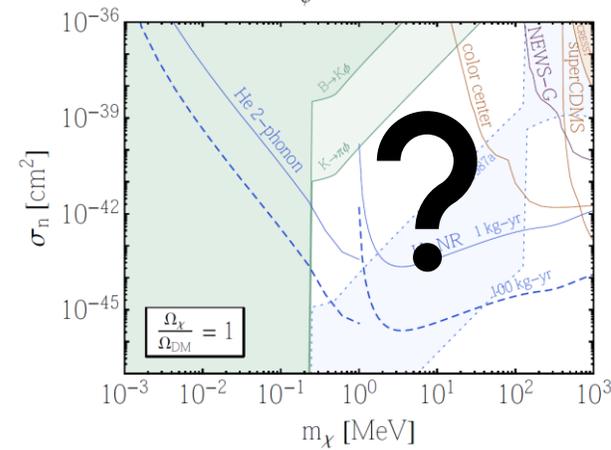
# Is Dark Matter here?



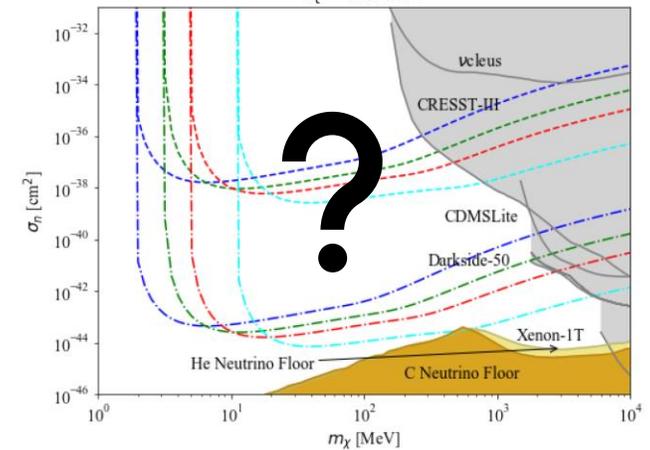


+ many more!

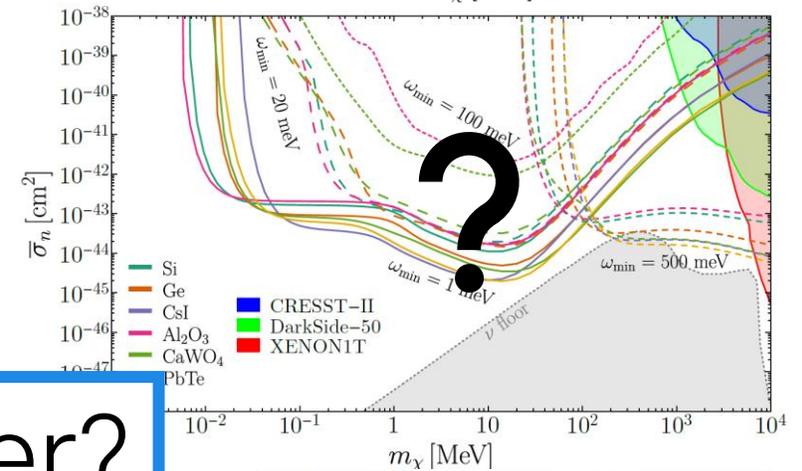
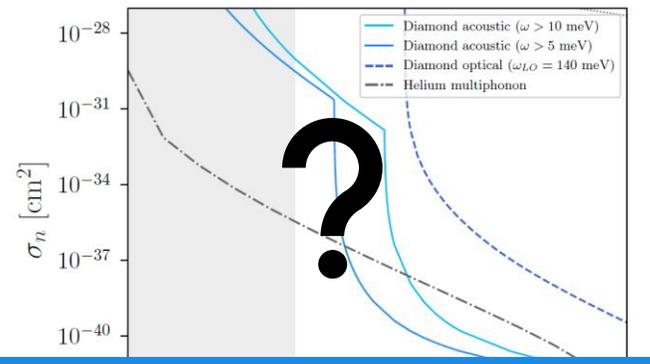
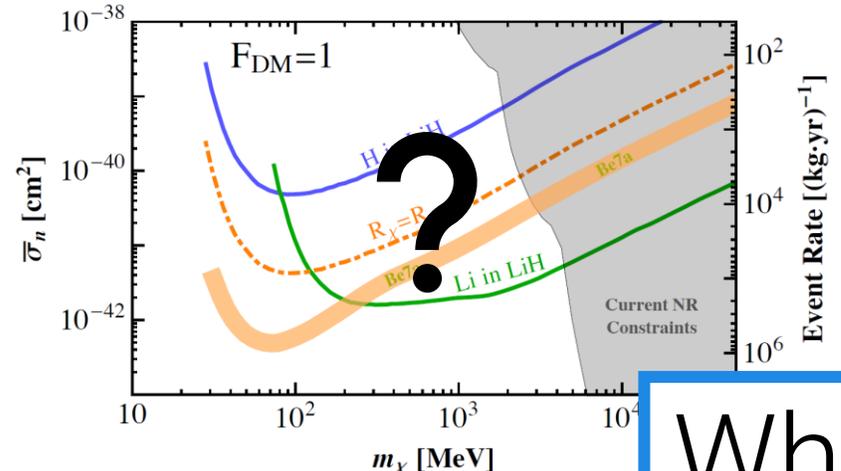
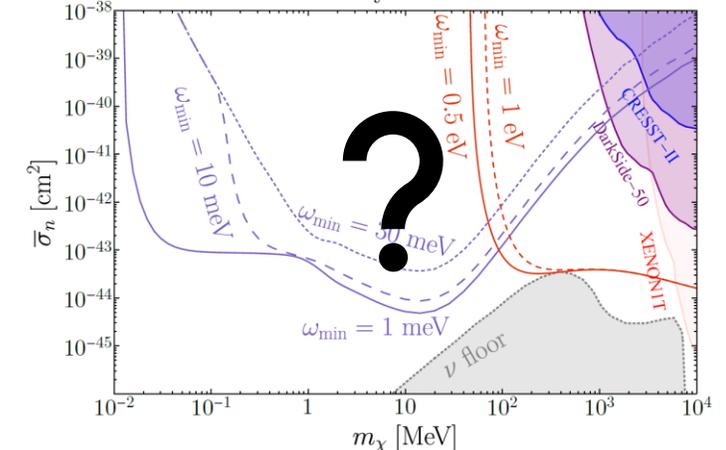
$m_\phi = 500 \text{ keV}$



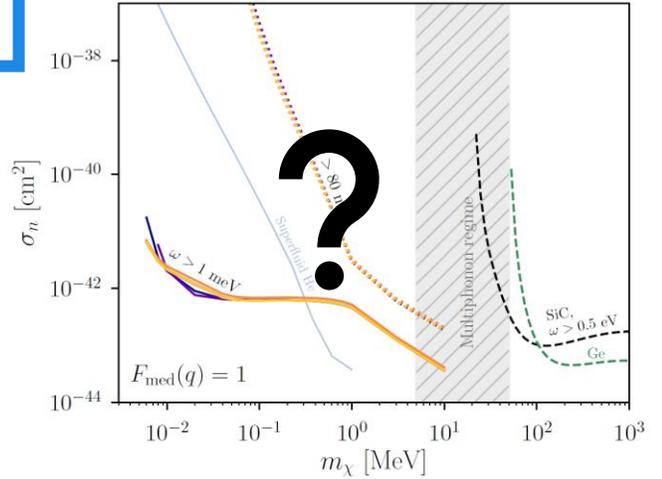
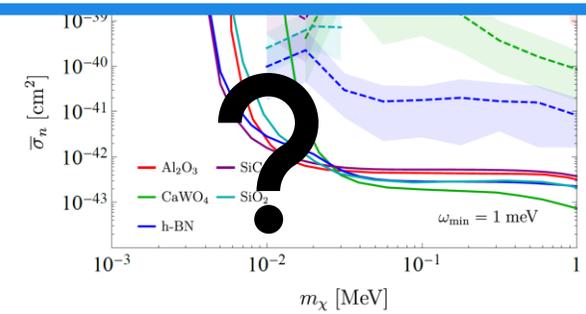
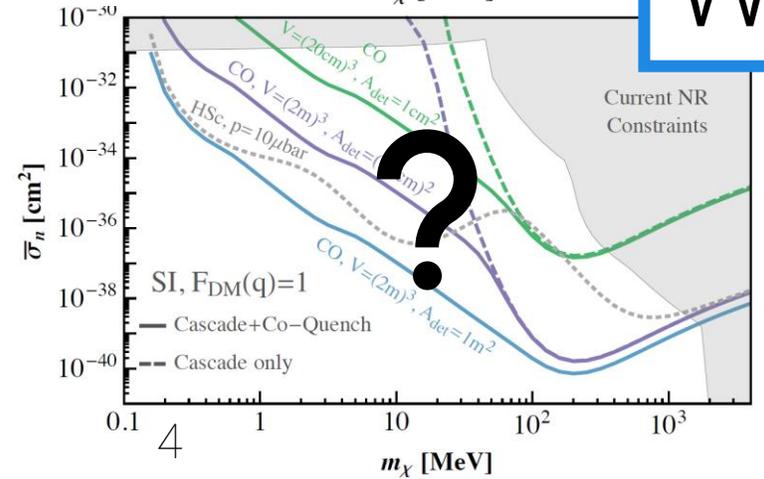
$\sigma_t = 10.0 \text{ meV}$



Heavy mediator



# Where is Dark Matter?



# Outline

Is Dark Matter here?

↳ What is the **max cross section** of sub-GeV DM scattering off nucleons?

Where is the Dark Matter?

↳ Is there a sub-GeV DM candidate which

1. may be **detected at proposed experiments?**
2. may **approach** such a **max cross section?**

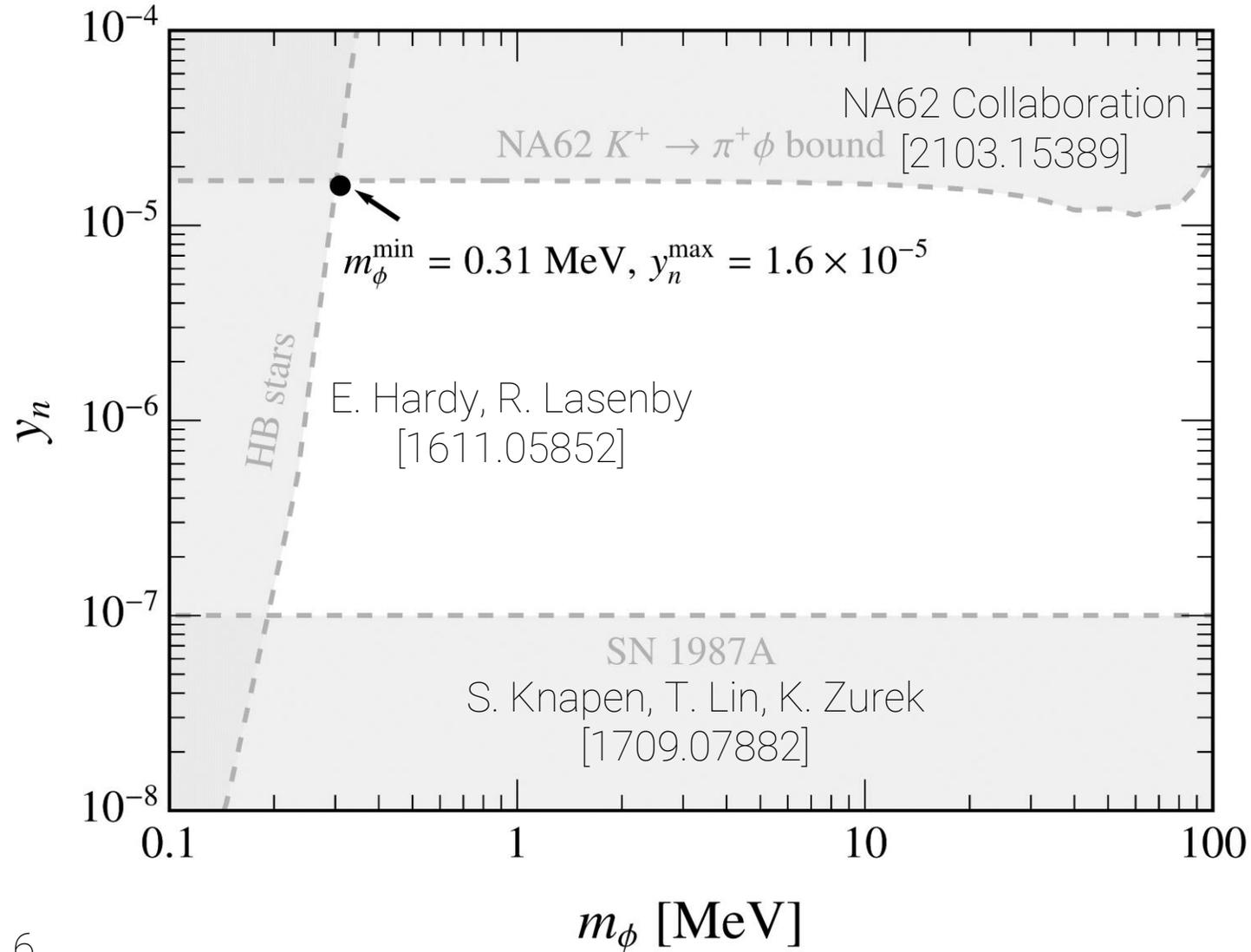
What is the **max cross section** of sub-GeV DM scattering off nucleons?

# The Basics

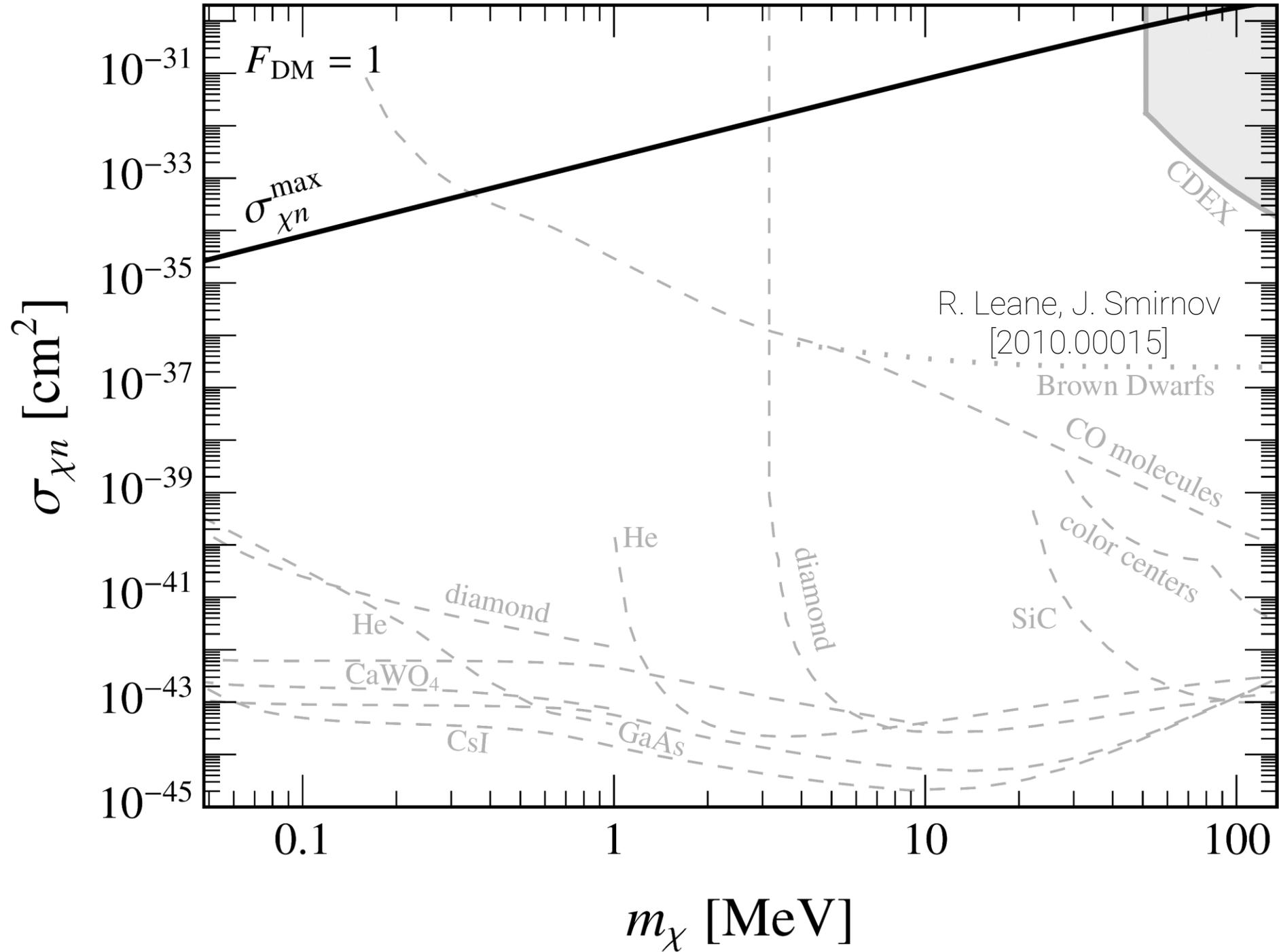
$$\mathcal{L} \supset -m_\chi \bar{\chi} \chi - y_n \phi \bar{n} n - y_\chi \phi \bar{\chi} \chi$$

$$\sigma_{\chi n}^{\max} \equiv \frac{(y_n^{\max} y_\chi^{\max})^2}{4\pi} \frac{\mu_{\chi n}^2}{\left[ \left( m_\phi^{\min} \right)^2 + v_{\text{DM}}^2 m_\chi^2 \right]^2}$$

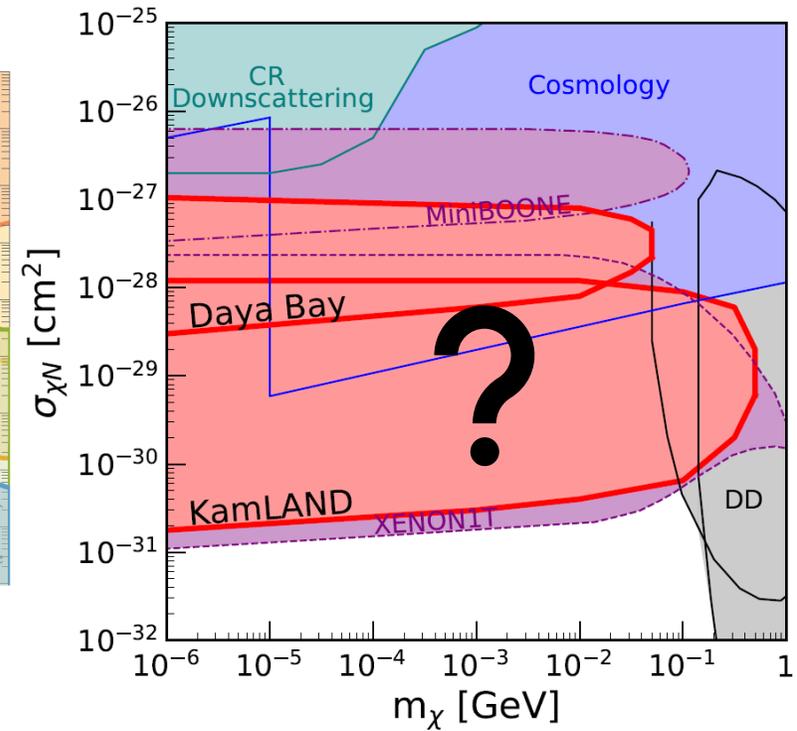
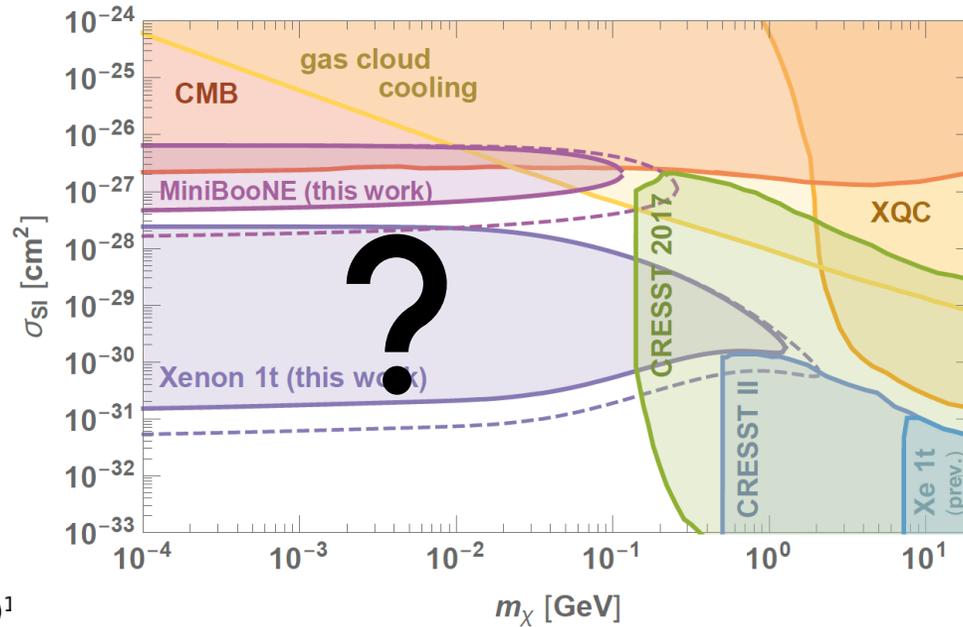
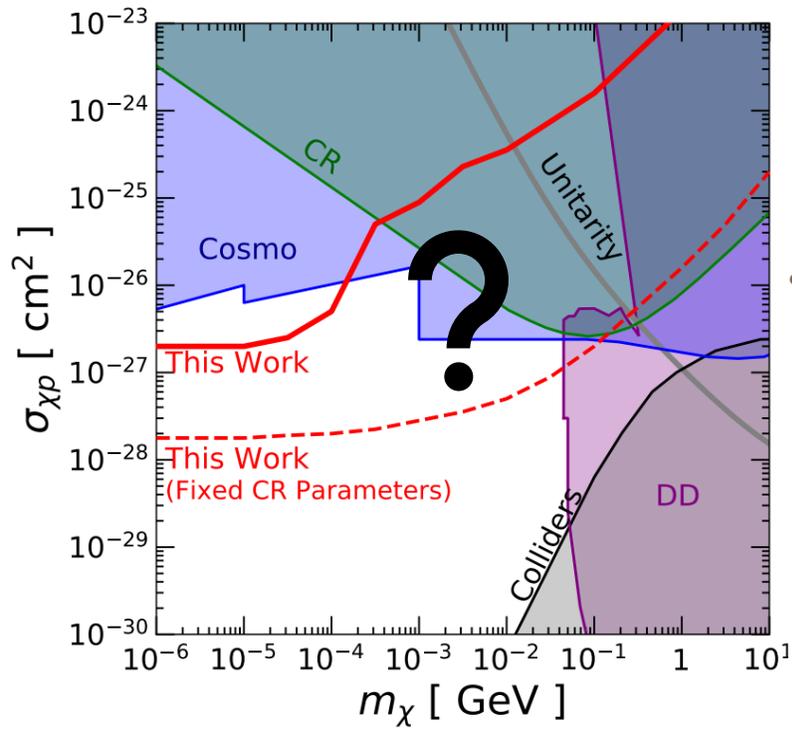
# The Basics



$$\sigma_{\chi\chi}/m_\chi \lesssim 1 \text{ cm}^2/\text{g} \text{ at } v \sim 10^{-3}$$

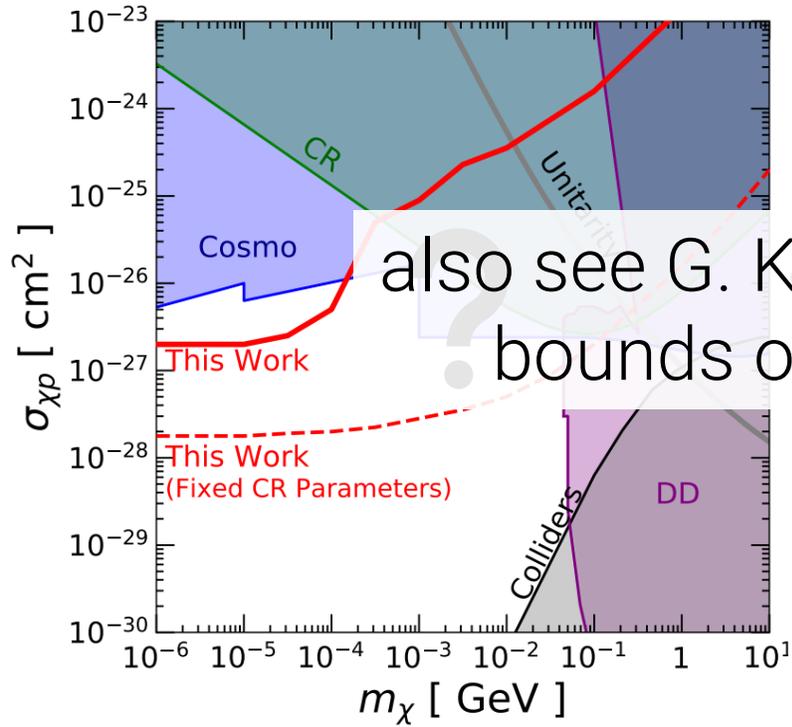


# Is Dark Matter here?

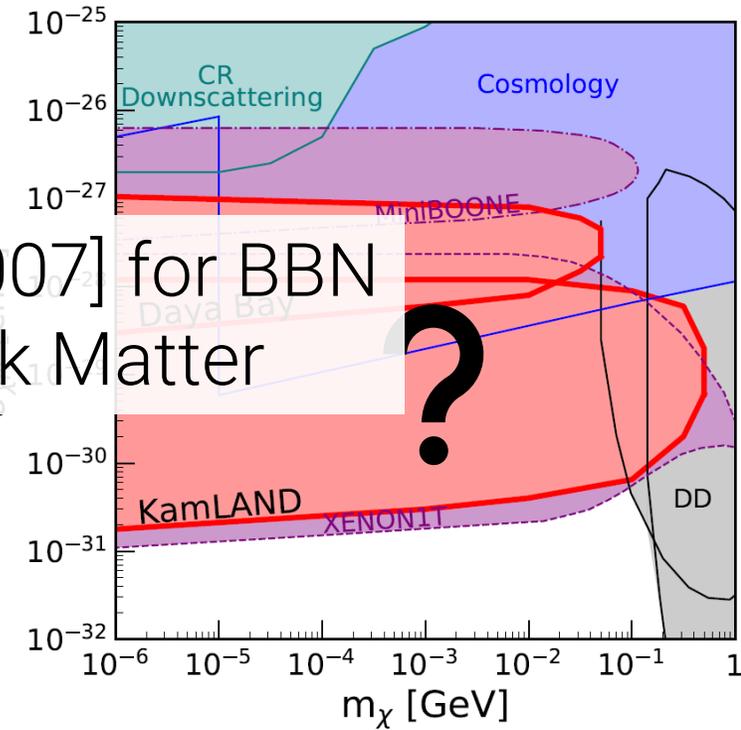
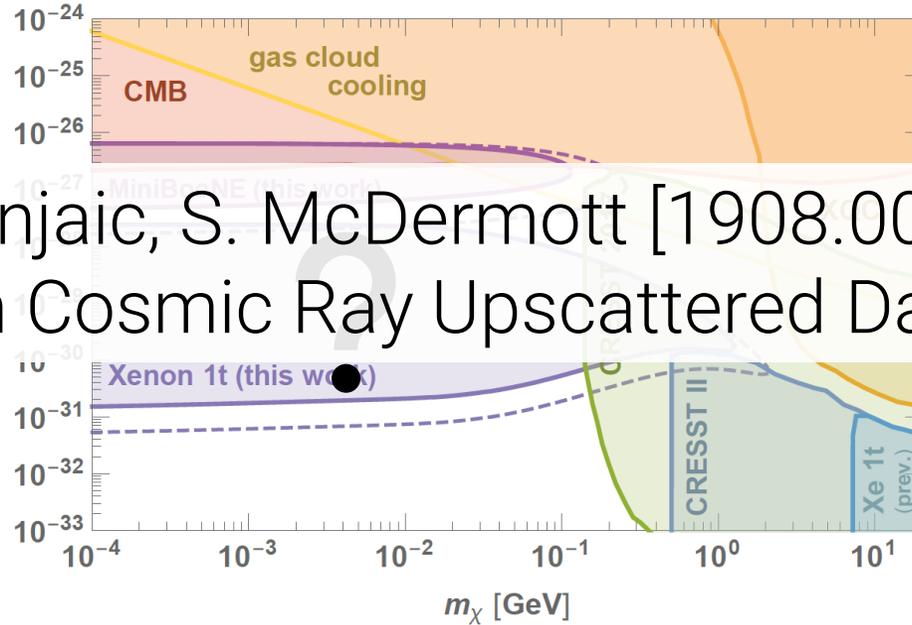


# Is Dark Matter here?

## Probably not.



also see G. Krnjaic, S. McDermott [1908.00007] for BBN bounds on Cosmic Ray Upscattered Dark Matter

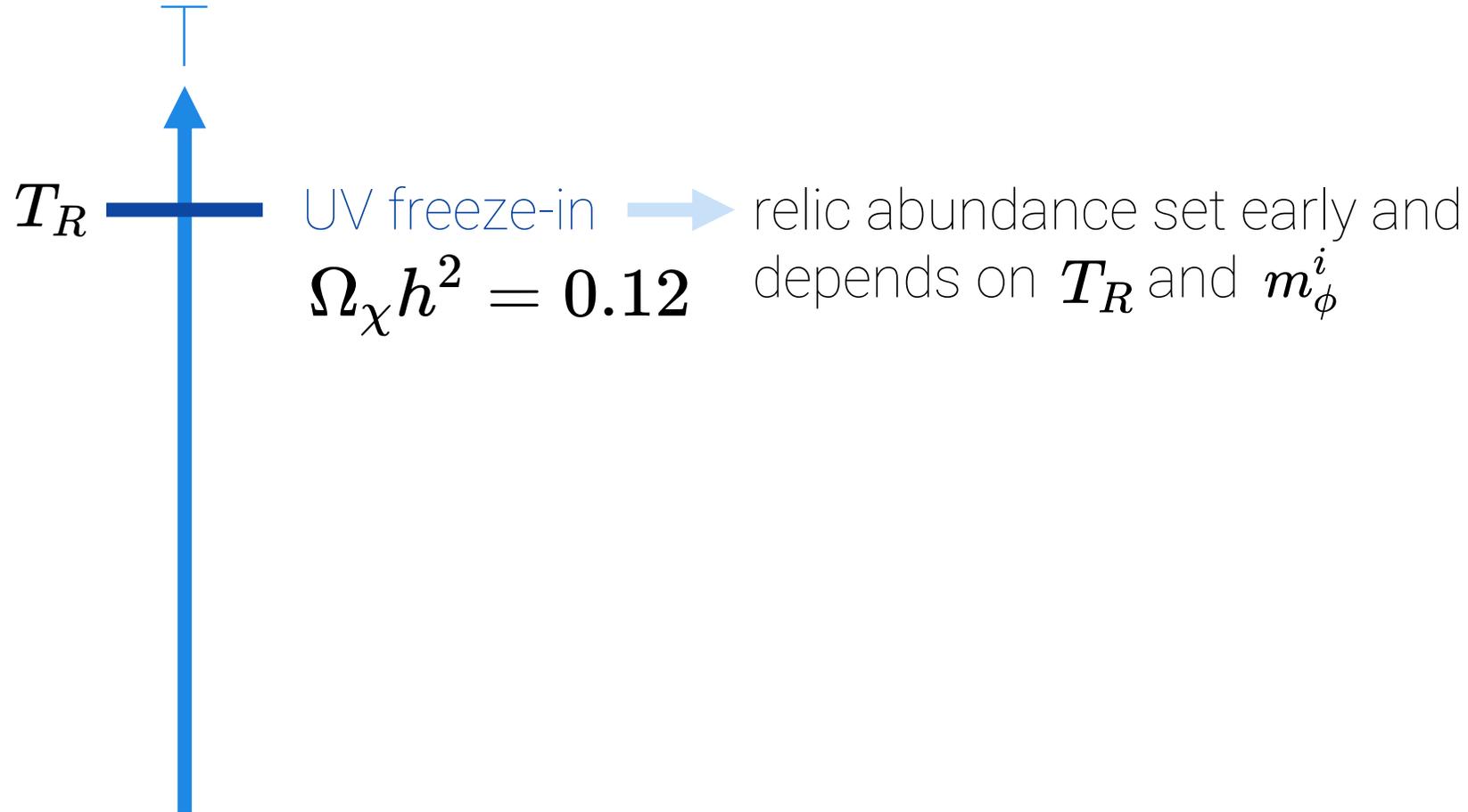


Is there a sub-GeV DM candidate which

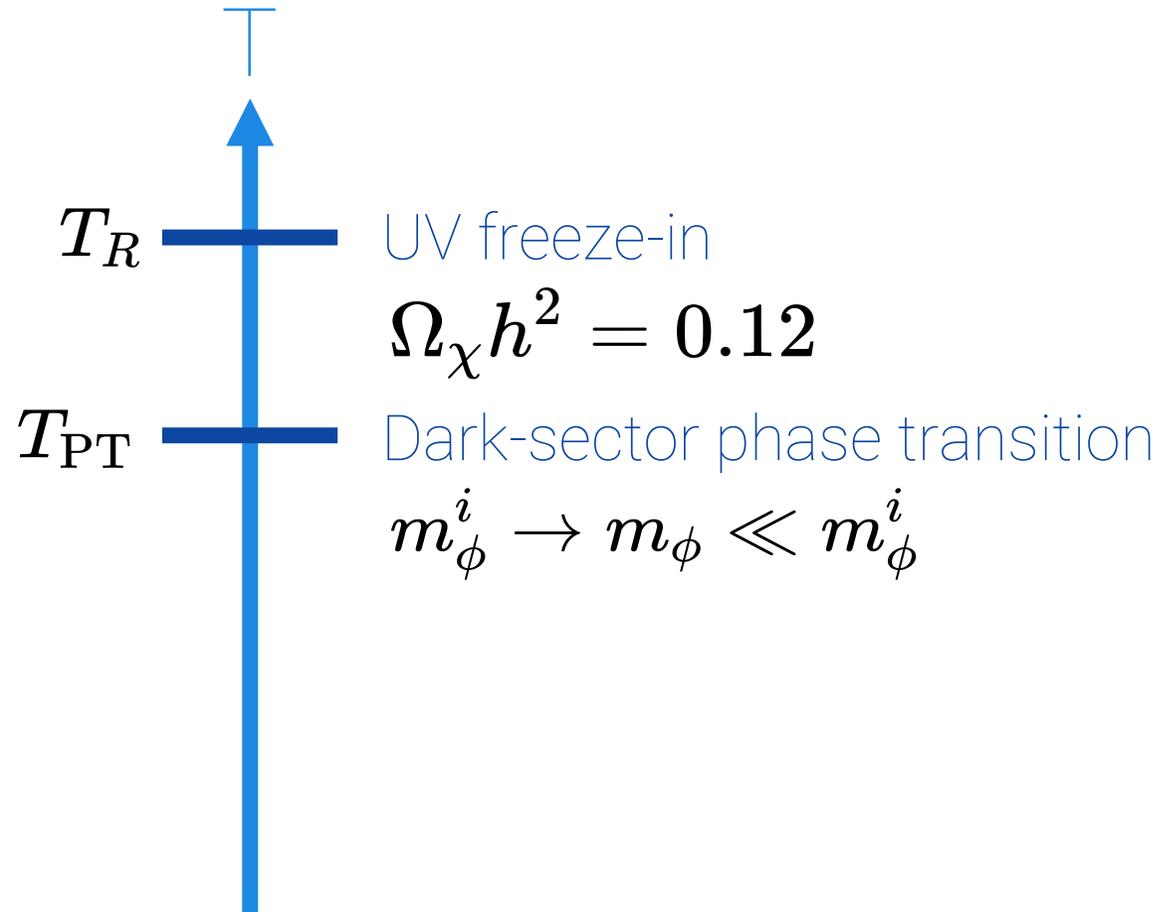
1. may be detected at proposed experiments?
2. may approach such a max cross section?

Highly interactive  
Particle Relics (HYPERs)

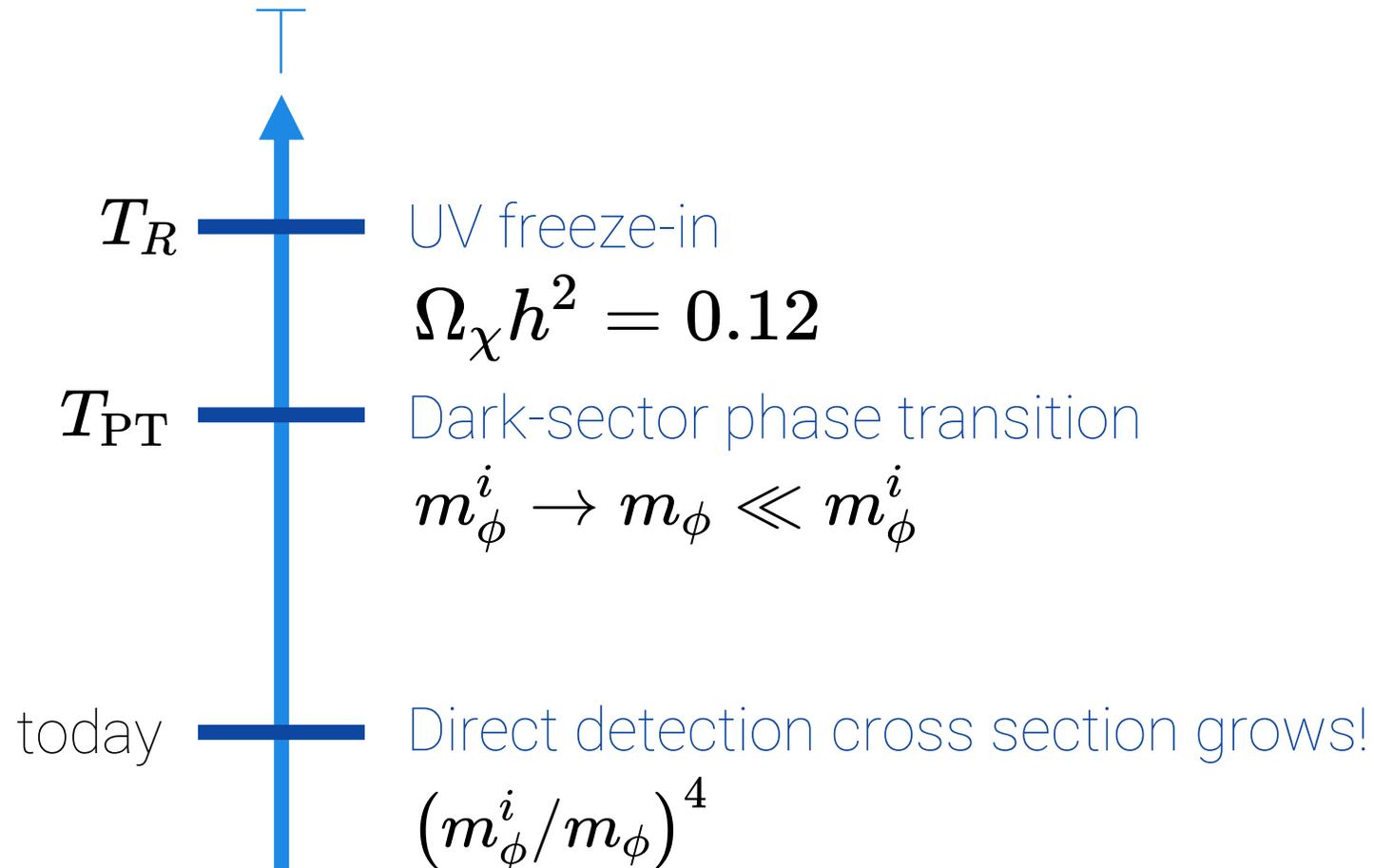
# HYPER History



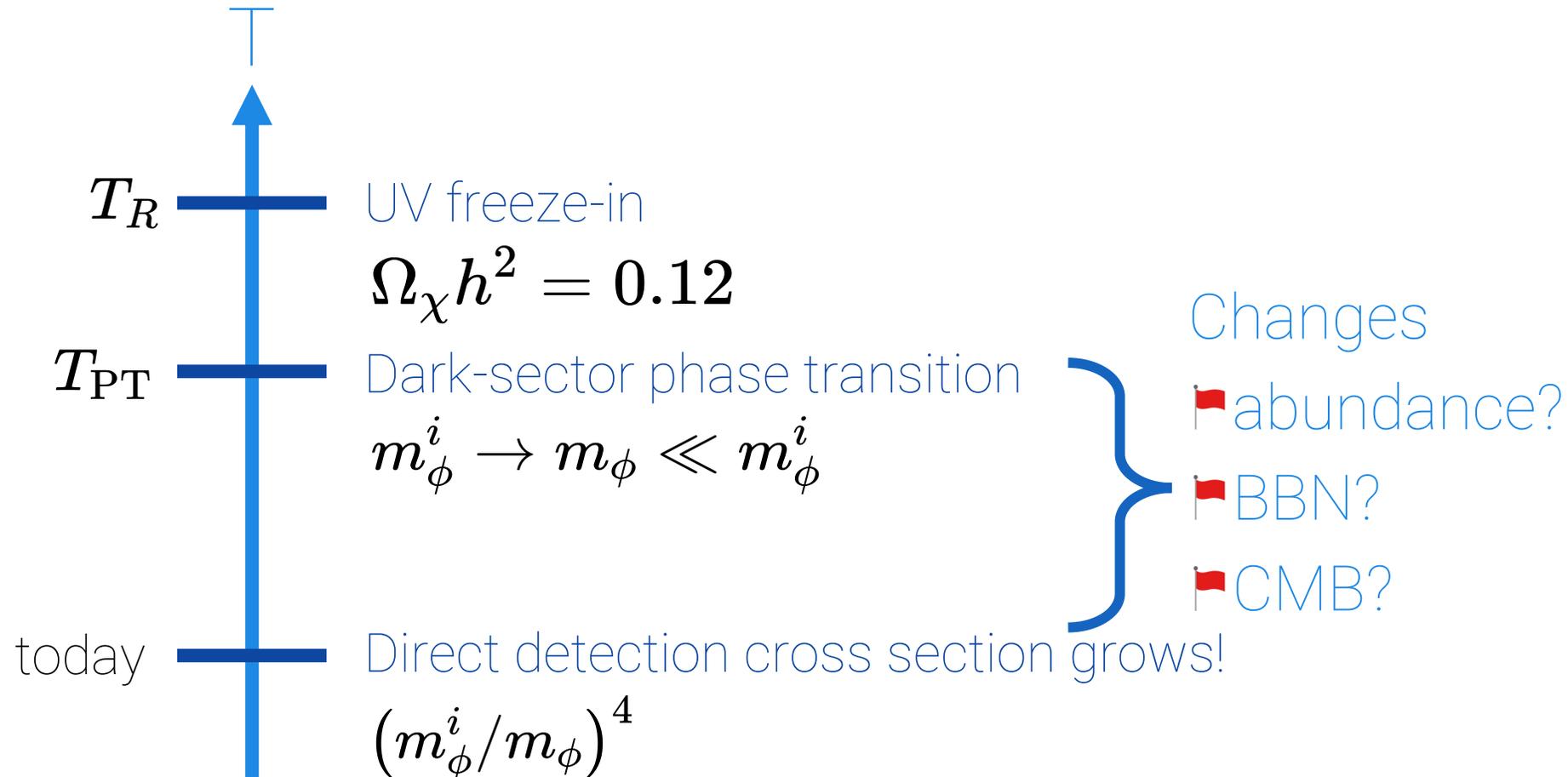
# HYPER History



# HYPER History



# HYPER History



🚩 Changes relic abundance?

$$m_\chi < m_{\pi^0} \longrightarrow \cancel{\bar{\chi}\chi} \longrightarrow \text{hadrons}$$

$$T_{\text{PT}} \ll m_{\pi^0} \longrightarrow \text{hadrons} \longrightarrow \bar{\chi}\chi$$
$$\longrightarrow \cancel{\gamma\gamma} \longrightarrow \cancel{\phi(\phi)}$$

🚩 Changes relic abundance?

$$m_\chi < m_{\pi^0} \longrightarrow \cancel{\bar{\chi}\chi} \rightarrow \text{hadrons}$$

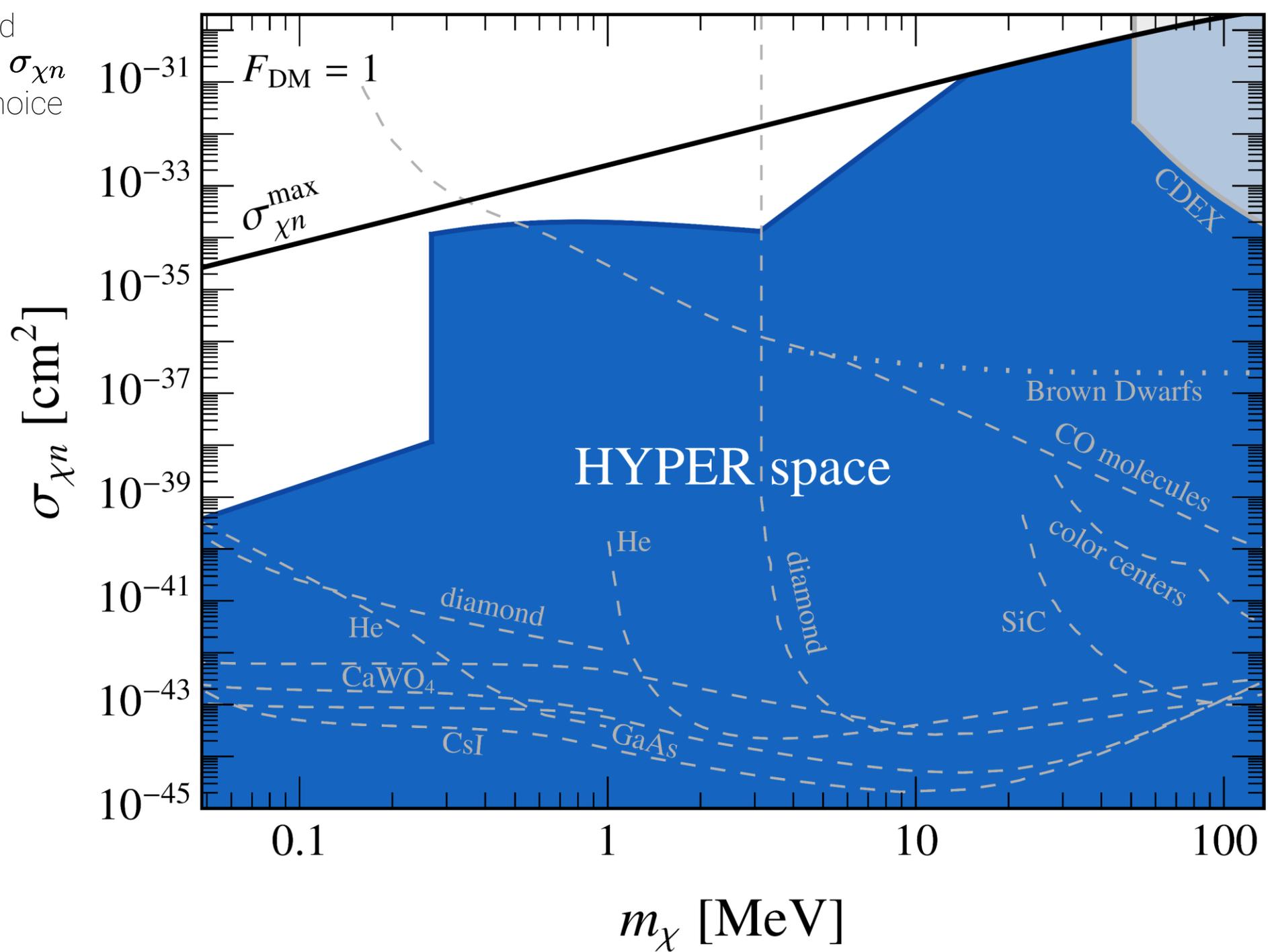
$$T_{\text{PT}} \ll m_{\pi^0} \longrightarrow \text{hadrons} \rightarrow \bar{\chi}\chi$$
$$\longrightarrow \cancel{\gamma\gamma} \rightarrow \phi(\phi)$$



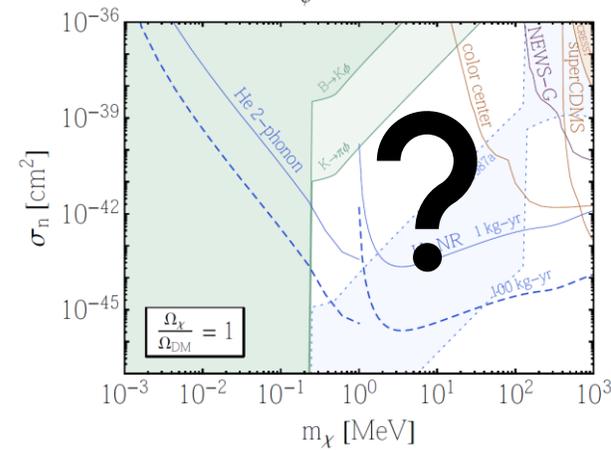
$$\bar{\chi}\chi \rightarrow \phi\phi$$

# Results

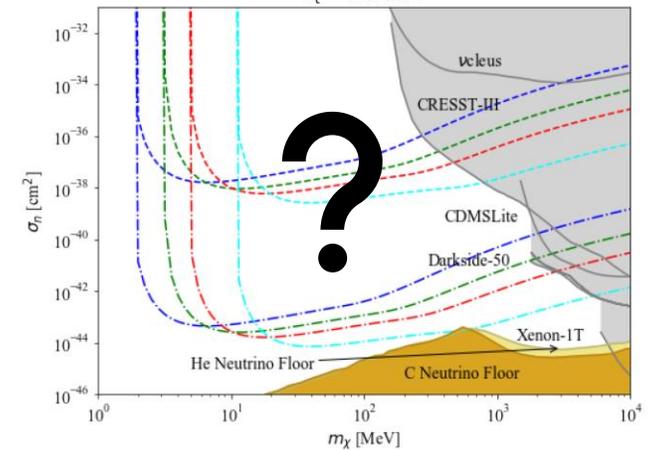
Boundary found  
by maximizing  $\sigma_{\chi n}$   
via judicious choice  
of  $(m_\phi, y_\chi)$



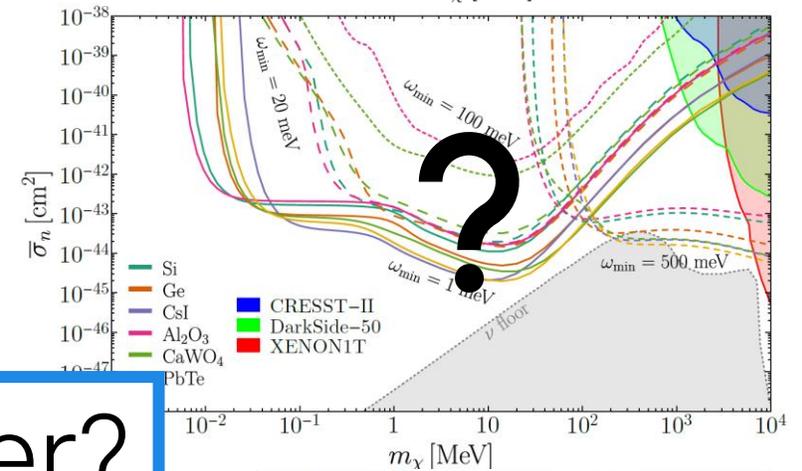
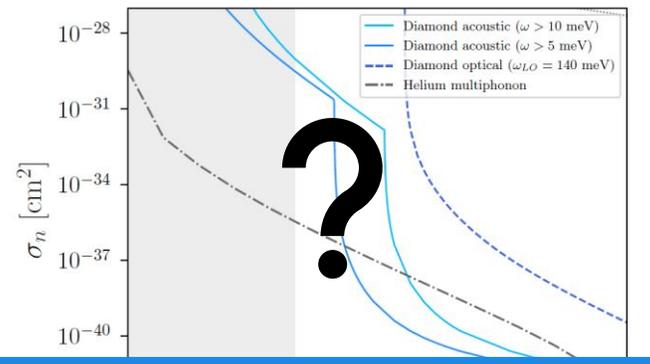
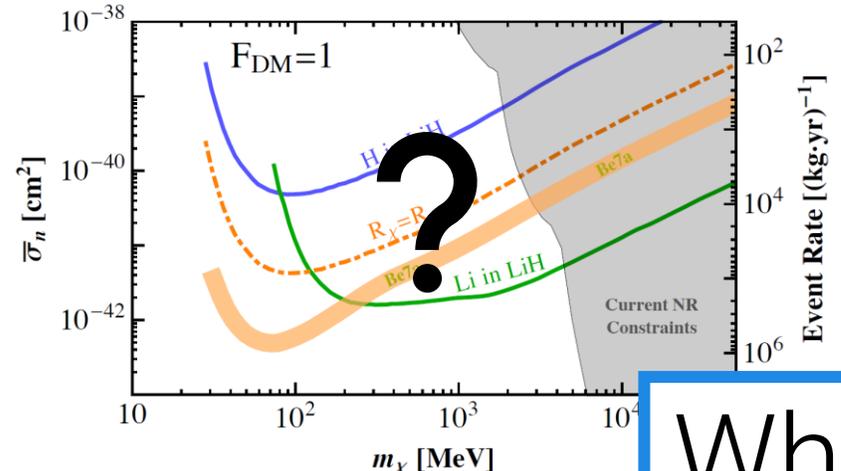
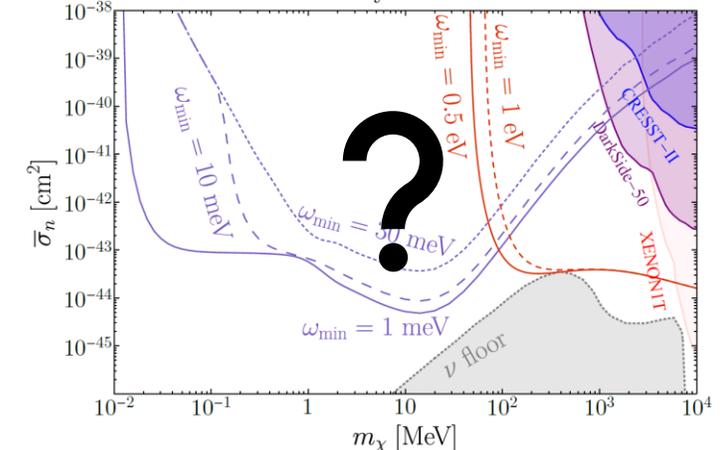
$m_\phi = 500 \text{ keV}$



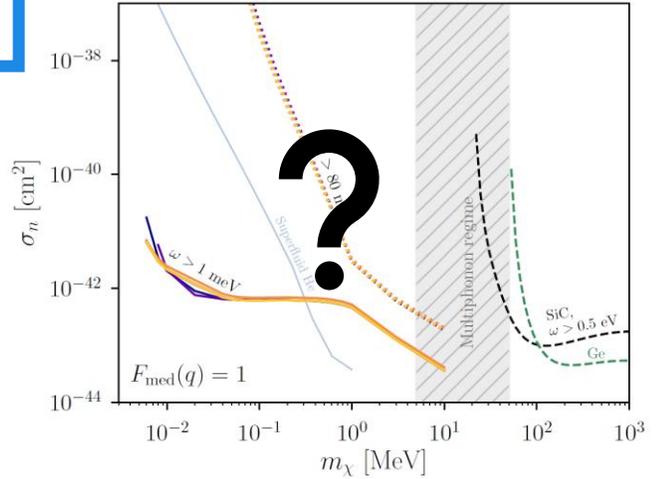
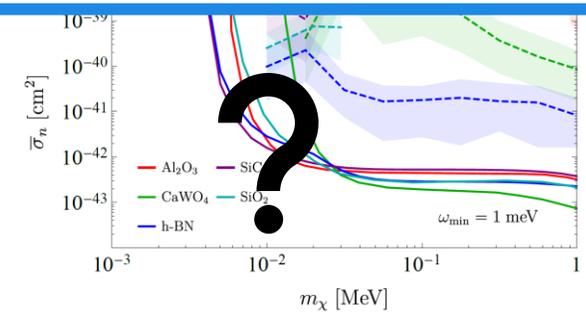
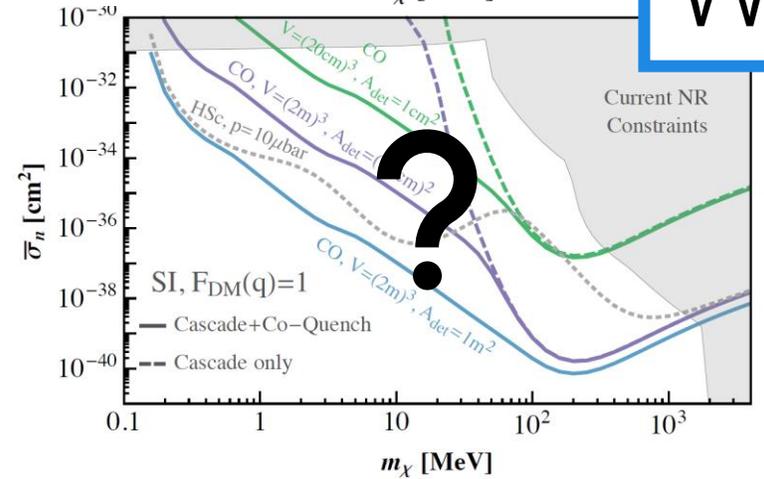
$\sigma_t = 10.0 \text{ meV}$



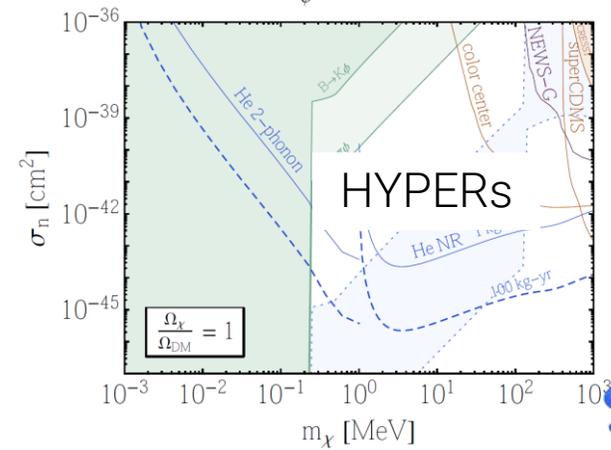
Heavy mediator



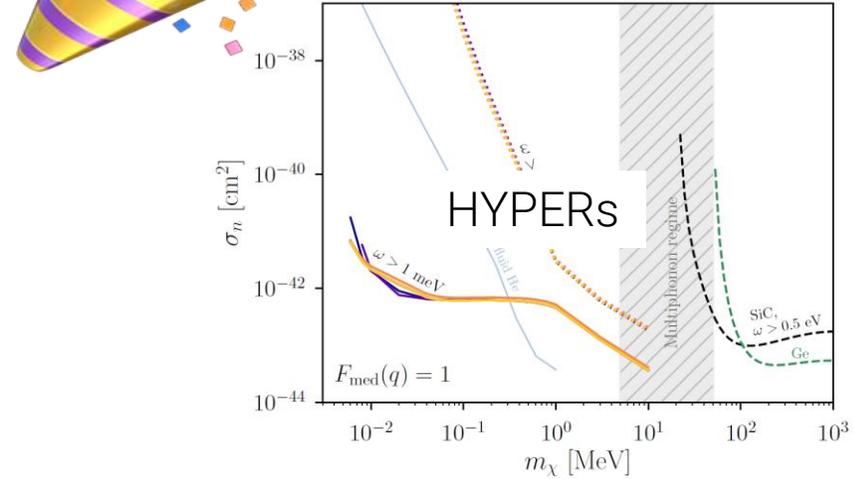
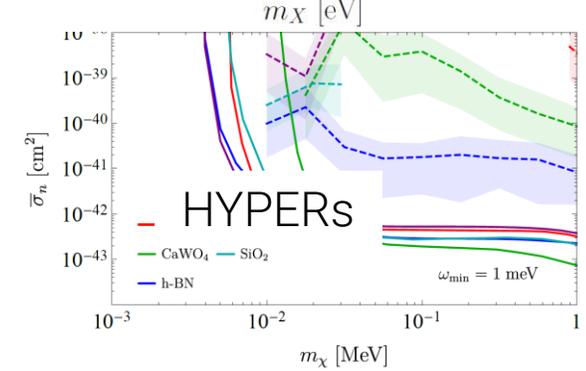
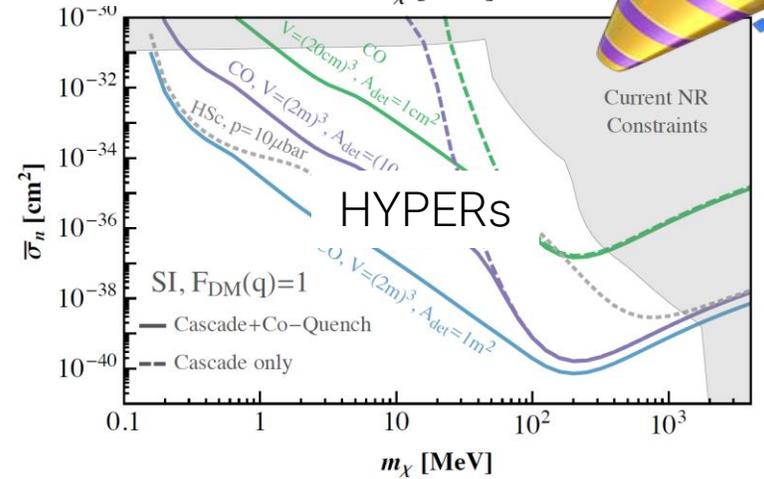
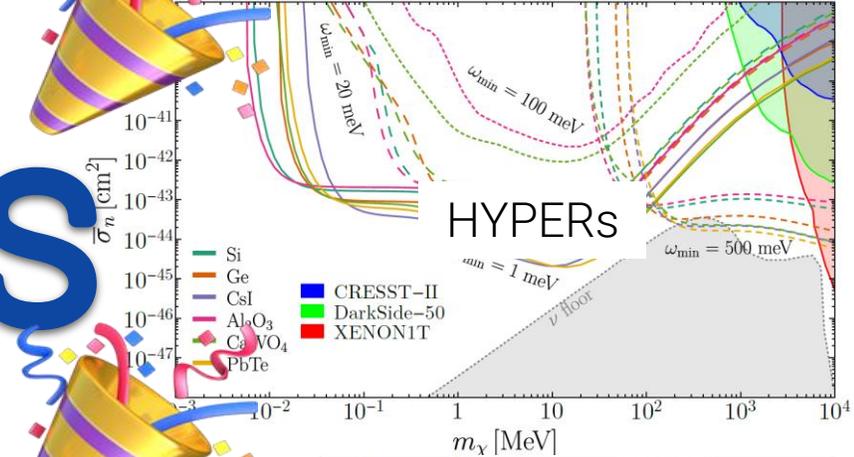
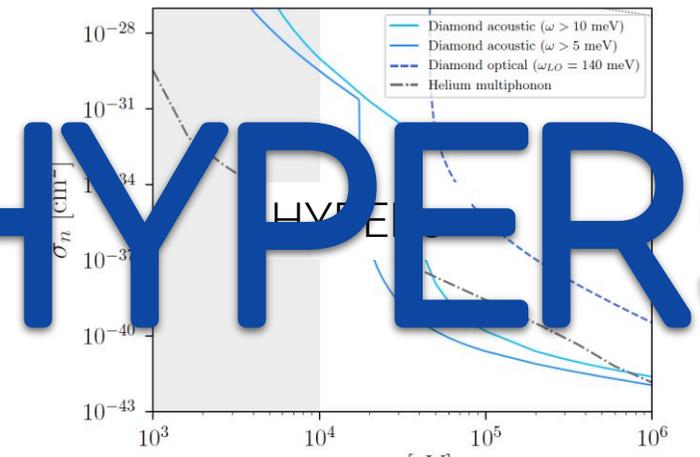
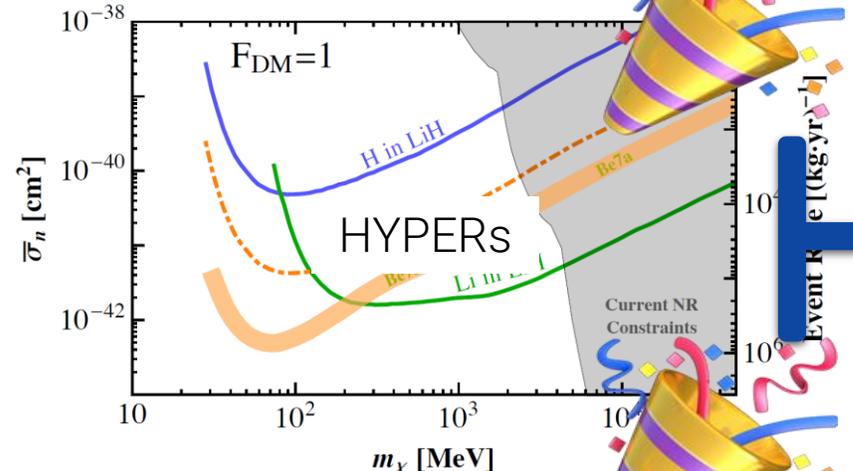
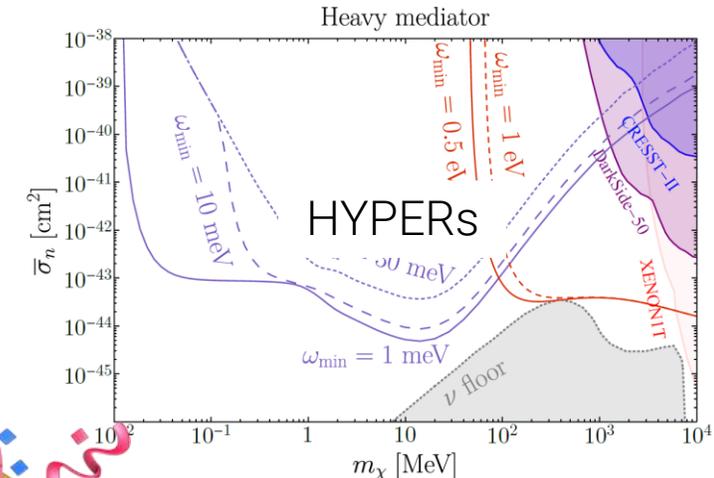
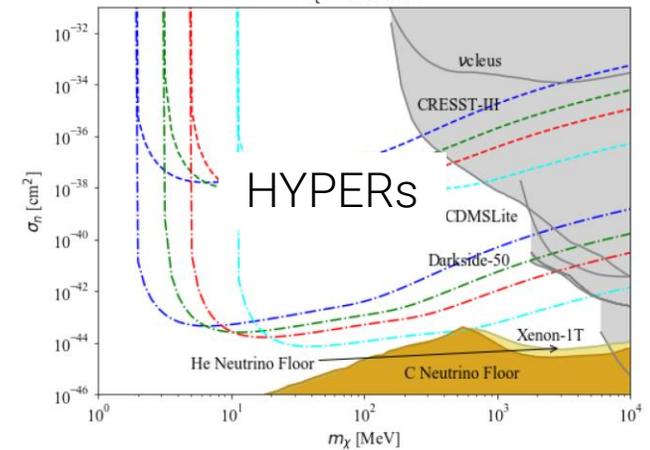
# Where is Dark Matter?



$m_\phi = 500 \text{ keV}$



$\sigma_t = 10.0 \text{ meV}$



# HYPERS

Is Dark Matter here?

↳ What is the **max cross section** of sub-GeV DM scattering off nucleons?

Where is the Dark Matter?

↳ Is there a sub-GeV DM candidate which

1. may be **detected at proposed experiments?**
2. may **approach** such a **max cross section?**

Is Dark Matter here?

↳ What is the **max cross section** of sub-GeV DM scattering off nucleons? **A: Not that big. Good to know.**

Where is the Dark Matter?

↳ Is there a sub-GeV DM candidate which

1. may be **detected at proposed experiments?**
2. may **approach** such a **max cross section?**

**A: HYPERs**