A Global Analysis of Resonance-enhanced Light Scalar Dark Matter

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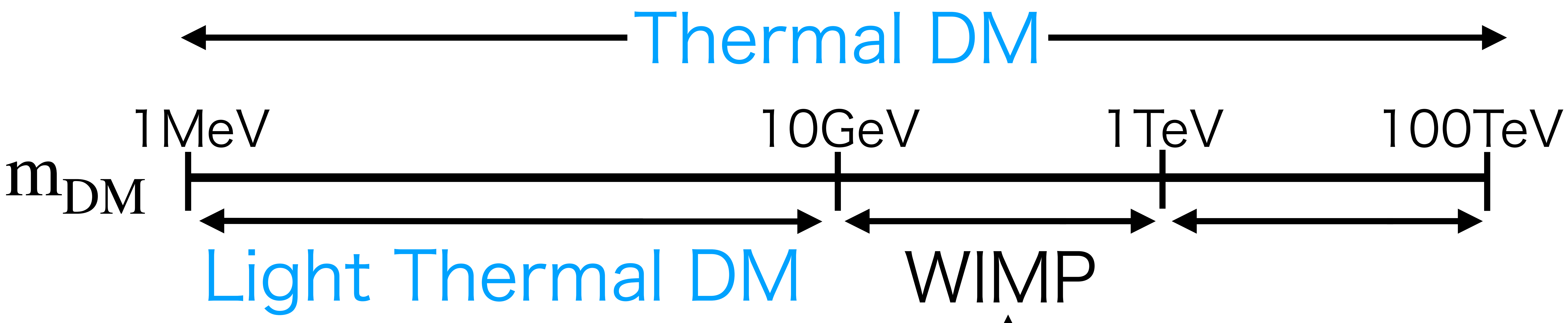
Introduction

Experienced an equilibrium with
SM particles in the early universe.



Velocity dependence is
needed by CMB.

intensively searched for,
but not been founded

s-channel, p-wave, etc

⋓

scalar singlet DM and mediator

Model

- The most general renormalizable Lagrangian is

$$\mathscr{L} = \mathscr{L}_{\rm SM} + \frac{1}{2}(\partial_\mu \chi)^2 - \frac{\mu_\chi^2}{2}\chi^2 - \frac{\lambda_{H\chi}}{2}|H|^2\chi^2 - \frac{\lambda_\chi}{4!}\chi^4$$

$$+ \frac{1}{2}(\partial_\mu \Phi)^2 - \frac{\mu_{\Phi\chi}}{2}\Phi\chi^2 - \frac{\lambda_{\Phi\chi}}{4}\Phi^2\chi^2 - V(\Phi, H),$$

$$V(\Phi, H) = \mu_{\Phi H}\Phi|H|^2 + \frac{\lambda_{\Phi H}}{2}\Phi^2|H|^2 + \mu_1^3\Phi + \frac{\mu_\Phi^2}{2}\Phi^2 + \frac{\mu_3}{3!}\Phi^3 + \frac{\lambda_\Phi}{4!}\Phi^4,$$

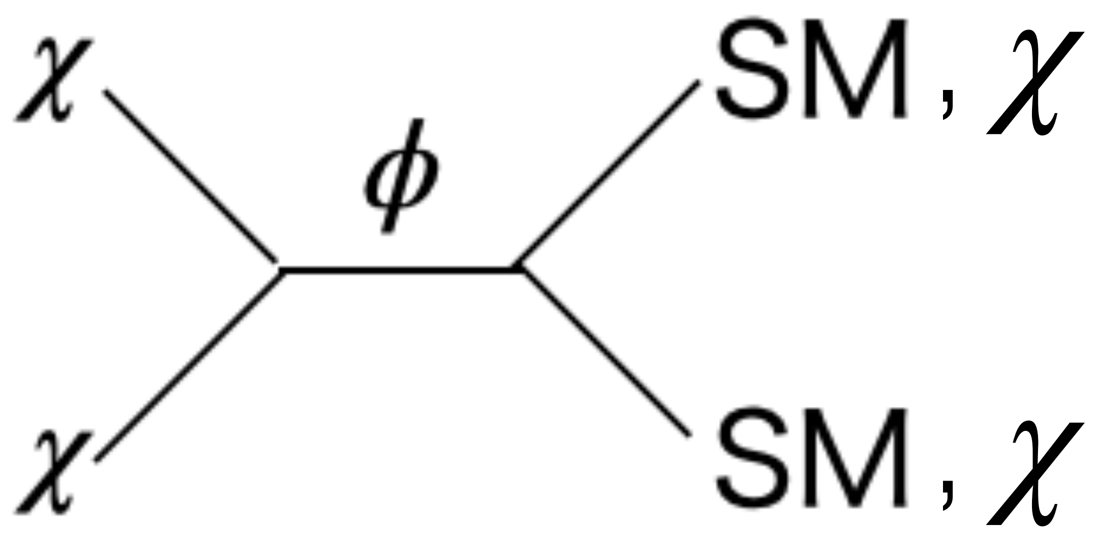
χ ⋯ DM

H ⋯ Higgs

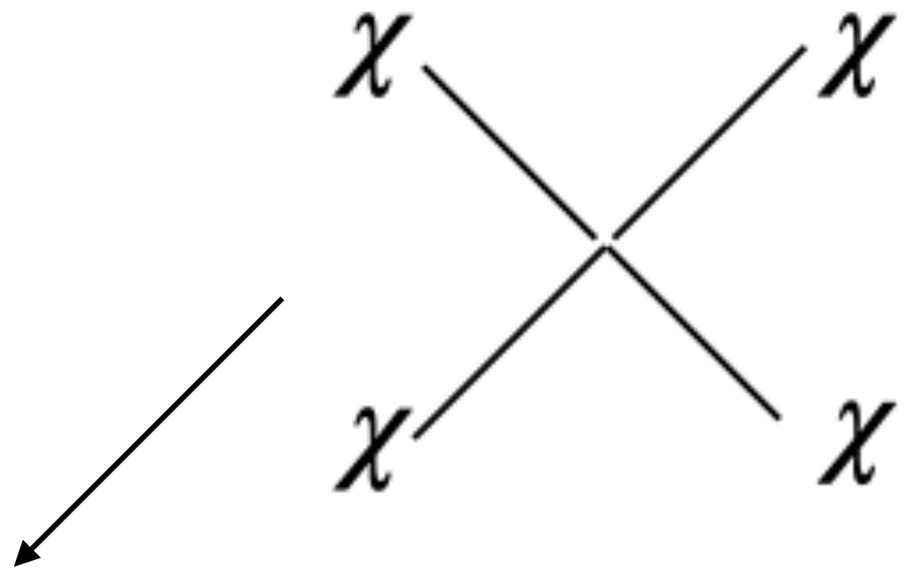
Φ ⋯ mediator

Model

- We assume $m_\phi \simeq 2m_\chi$ (**s-channel resonance**).

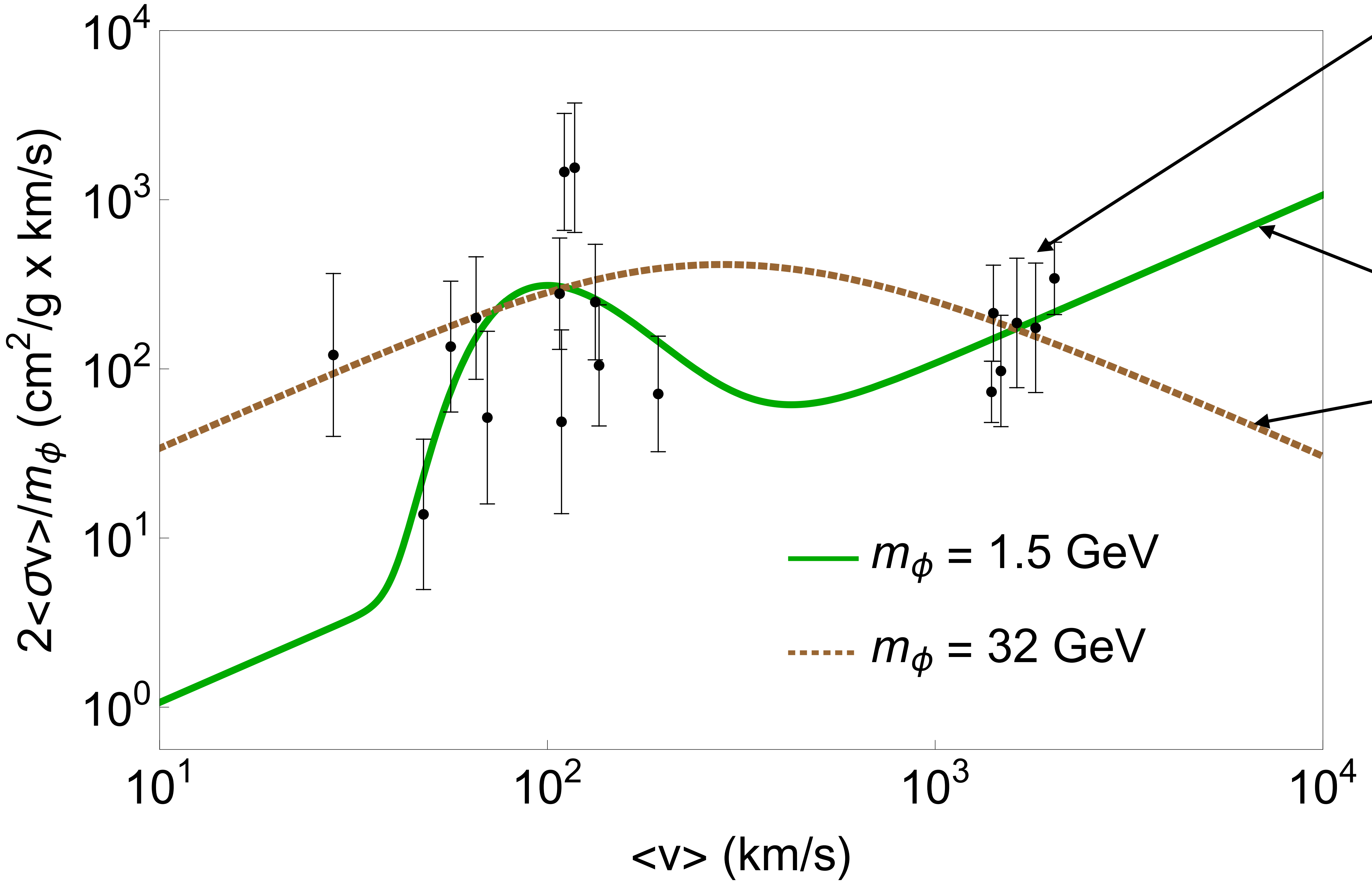


- Phenomenologically important parametars are
  - m_ϕ ⋯ mass of mediator
  - v_R ⋯ place of resonance ($\equiv 2(m_\phi/m_\chi - 2)^{1/2}$)
  - $\sin\theta$ ⋯ mixing angle between Φ and H
  - γ_ϕ ⋯ invisible decay rate of Φ
  - σ_0 ⋯ velosity-independent part of the self-scattering cross section



Self-Scattering

- Core-cusp problem ··· mismatch of DM density profiles at GC prefered by simulation(cusp) and observation(core).
- Self-scattering of DM may solve this by thermalizing DM at GC.



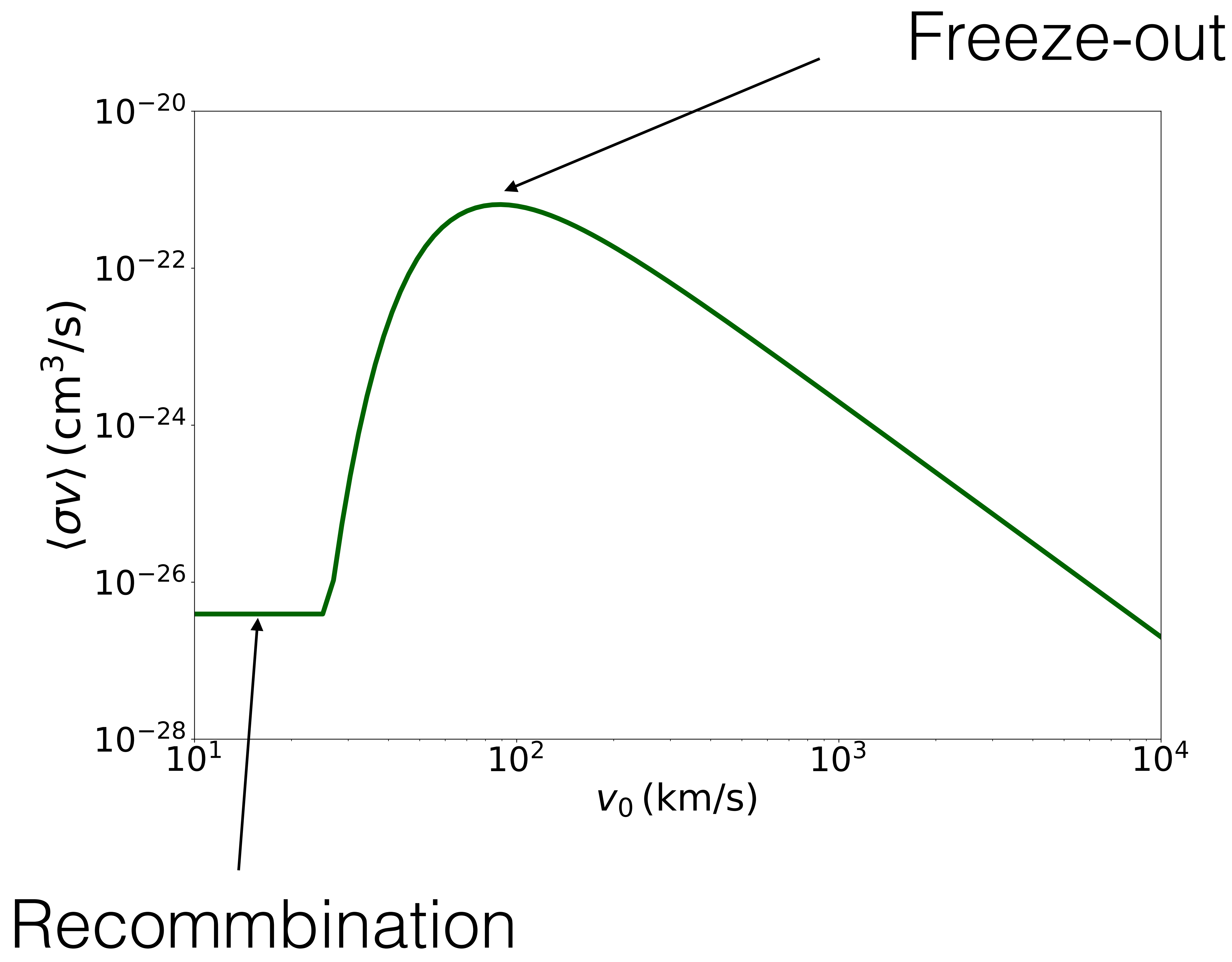
Data of cross sections

Our model

- Fittig seems to be good.

CMB

- Annihilation of DM into primordial plasma may modify anisotropy of the CMB $\rightarrow f_{eff}\langle\sigma v\rangle/m_\chi < 4.1\times10^{-28}\mathrm{cm}^3/\mathrm{s}/\mathrm{GeV}$

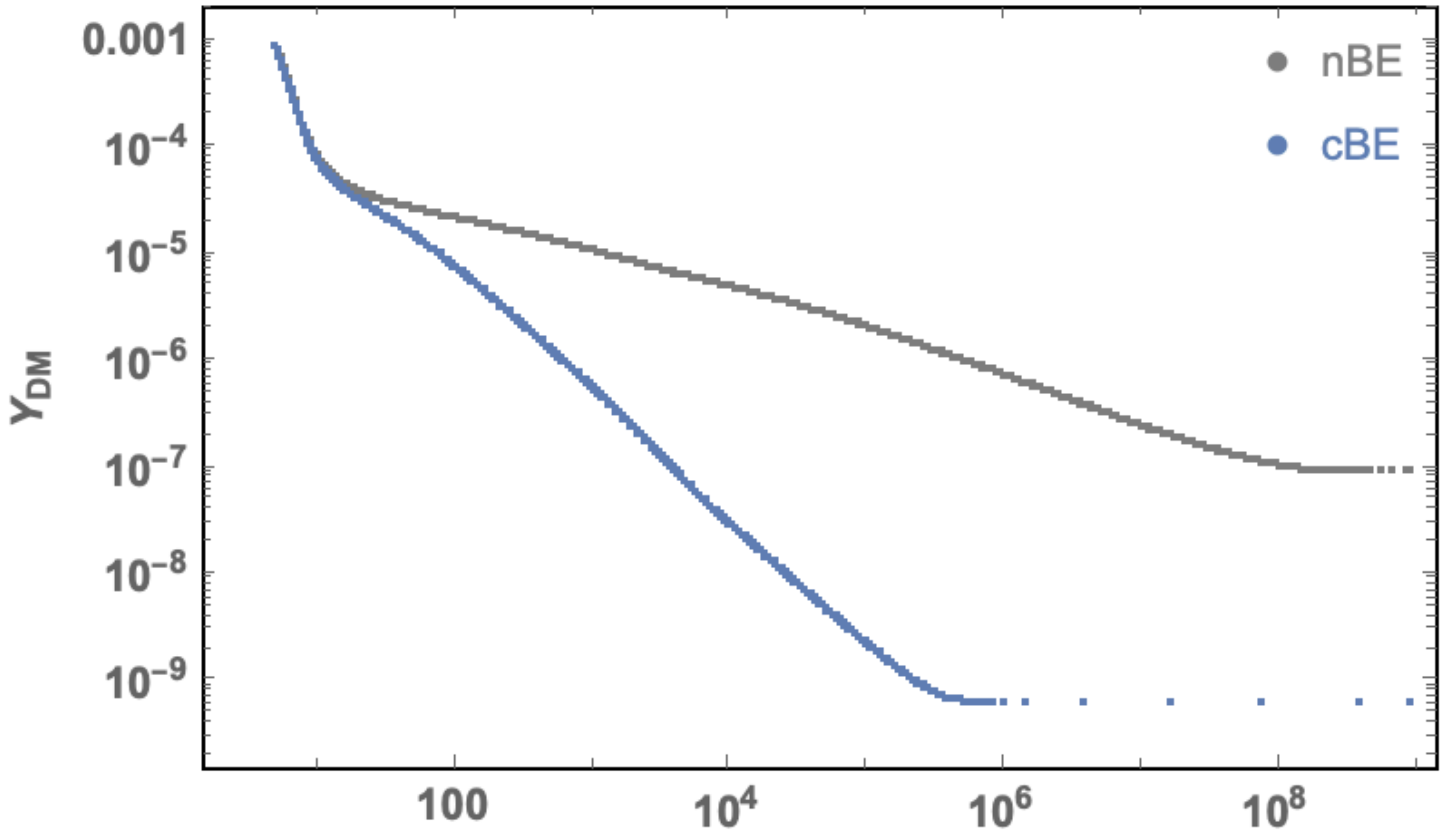


- $\langle\sigma v\rangle$ can be enhanced(suppressed) at freeze-out(recommbination)

Relic abundance

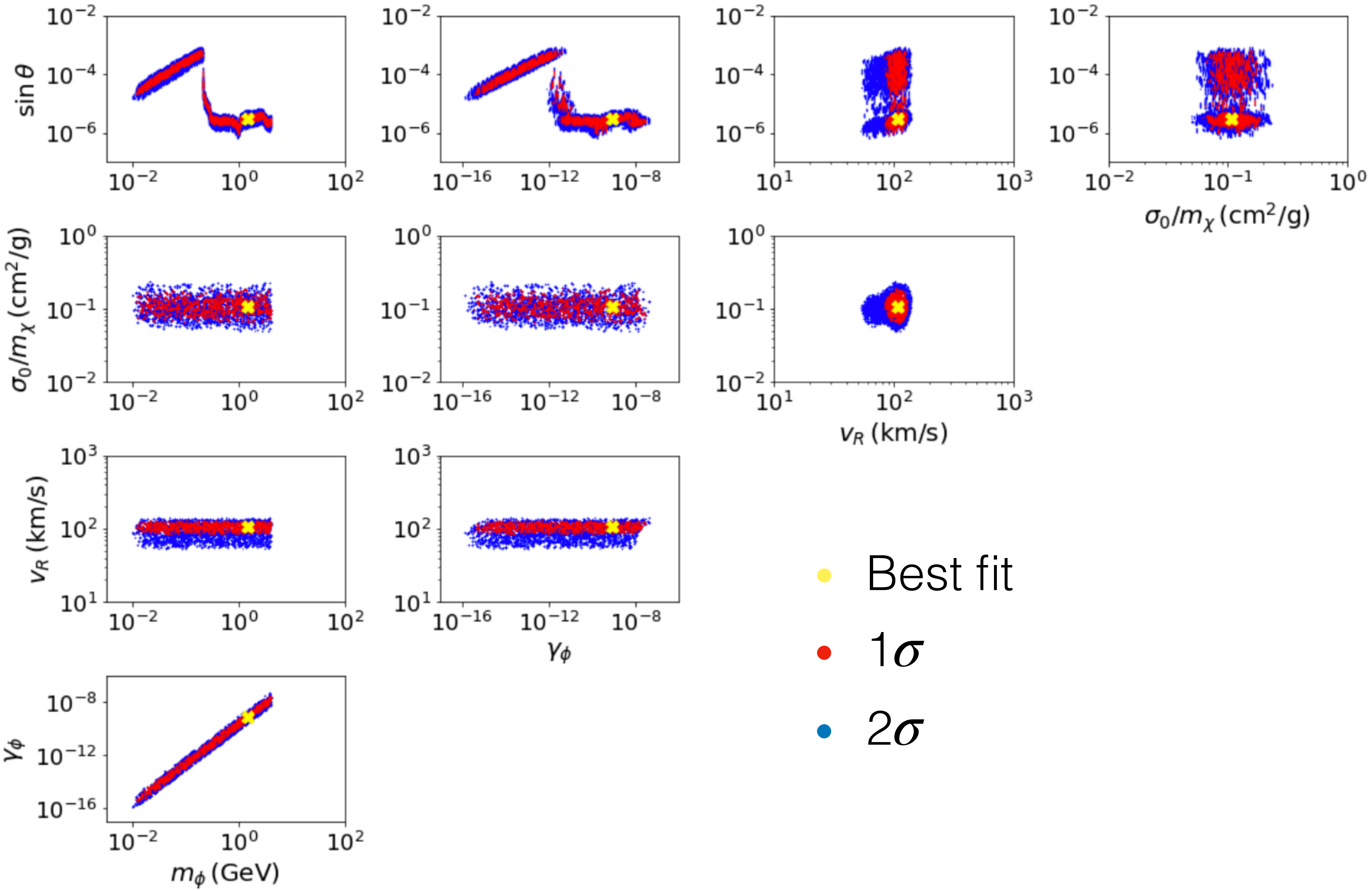
- We required that abundance of DM is thermally produced.

- S-channel resonance → Abundance continues to dicrease even after freeze-out.



- S-channel is enhanced, however t,u-channel are not enhanced.
  →Early kinetic decoupling

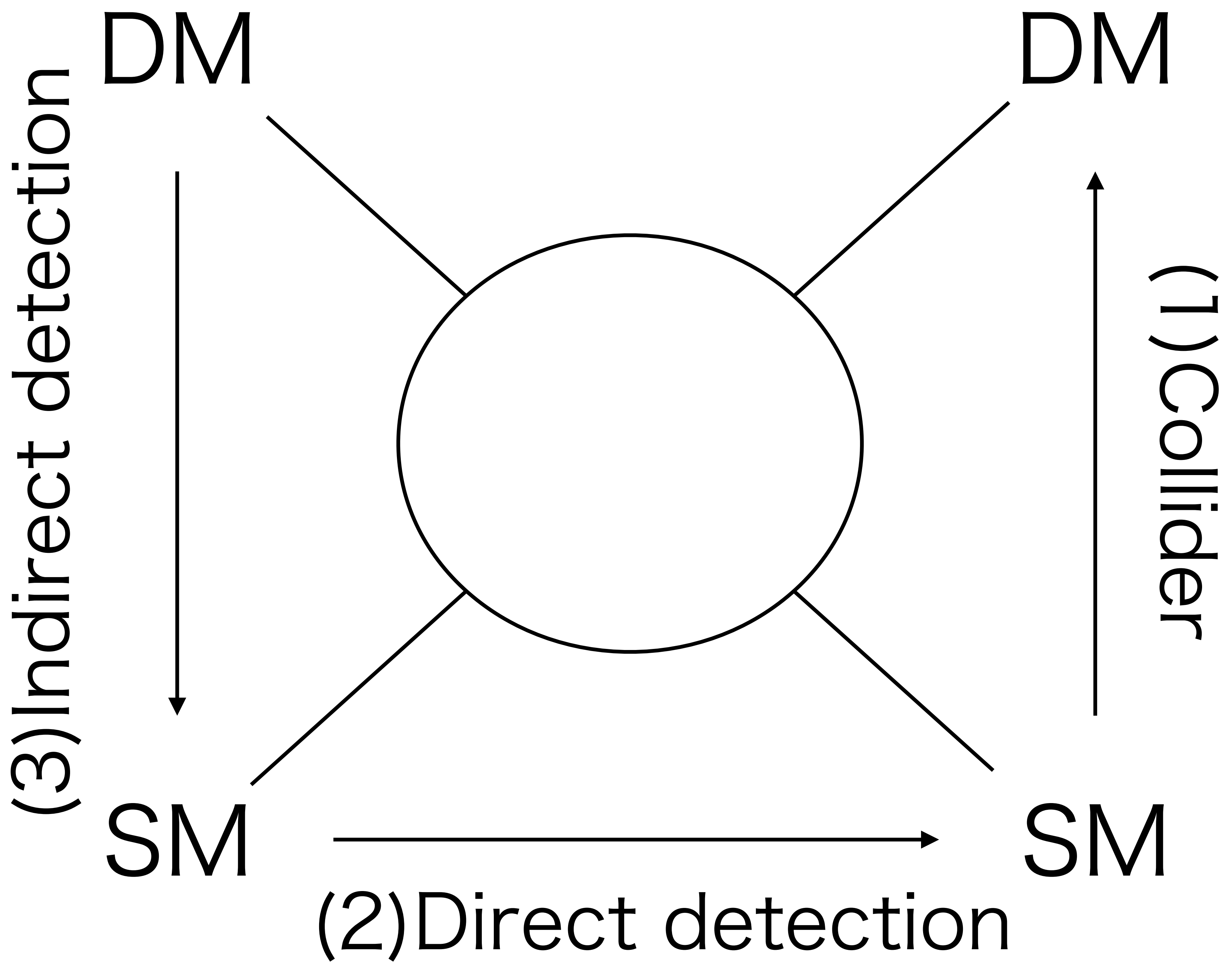
Favored parameter region



- Best fit
- 1σ
- 2σ

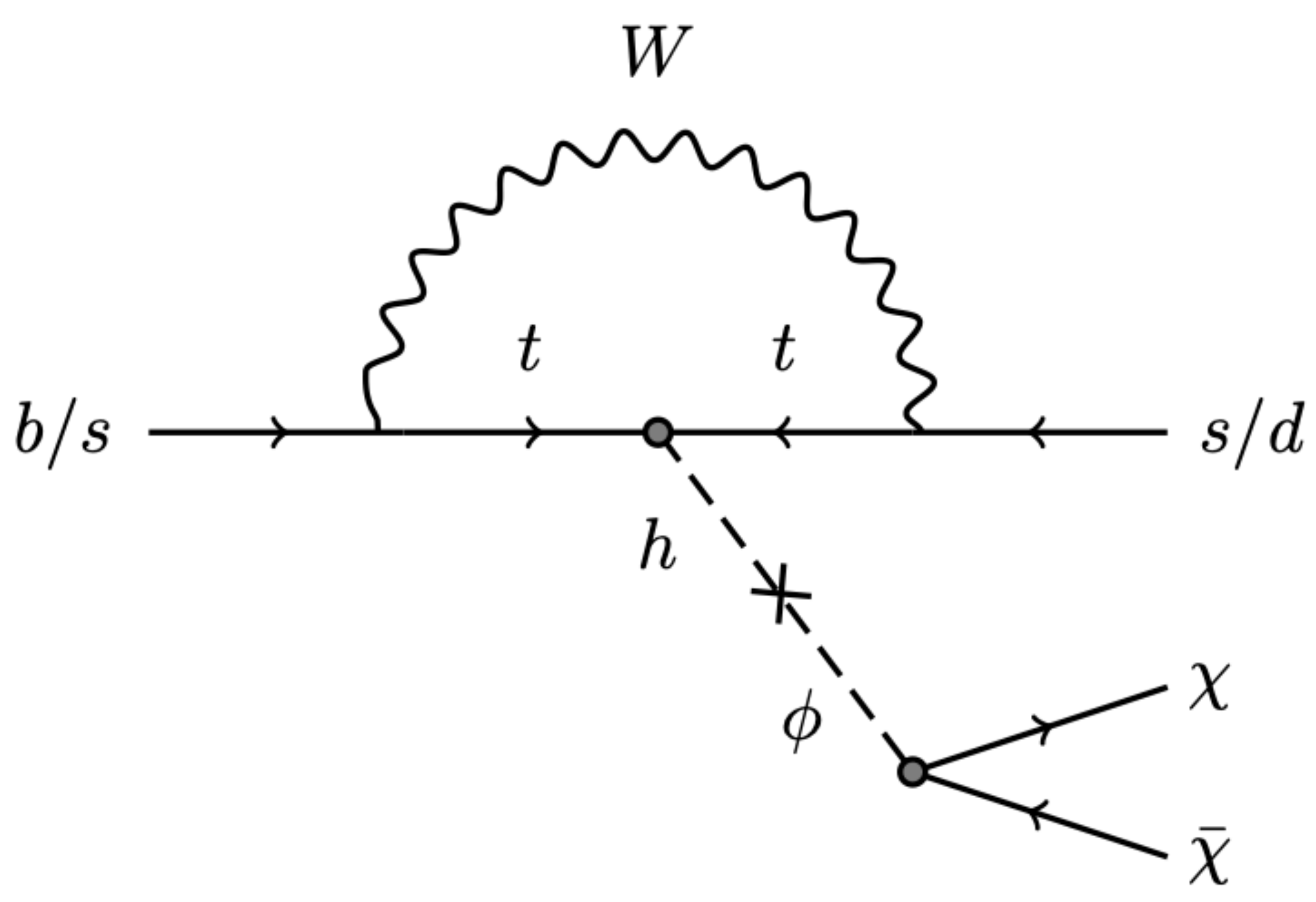
Experiments

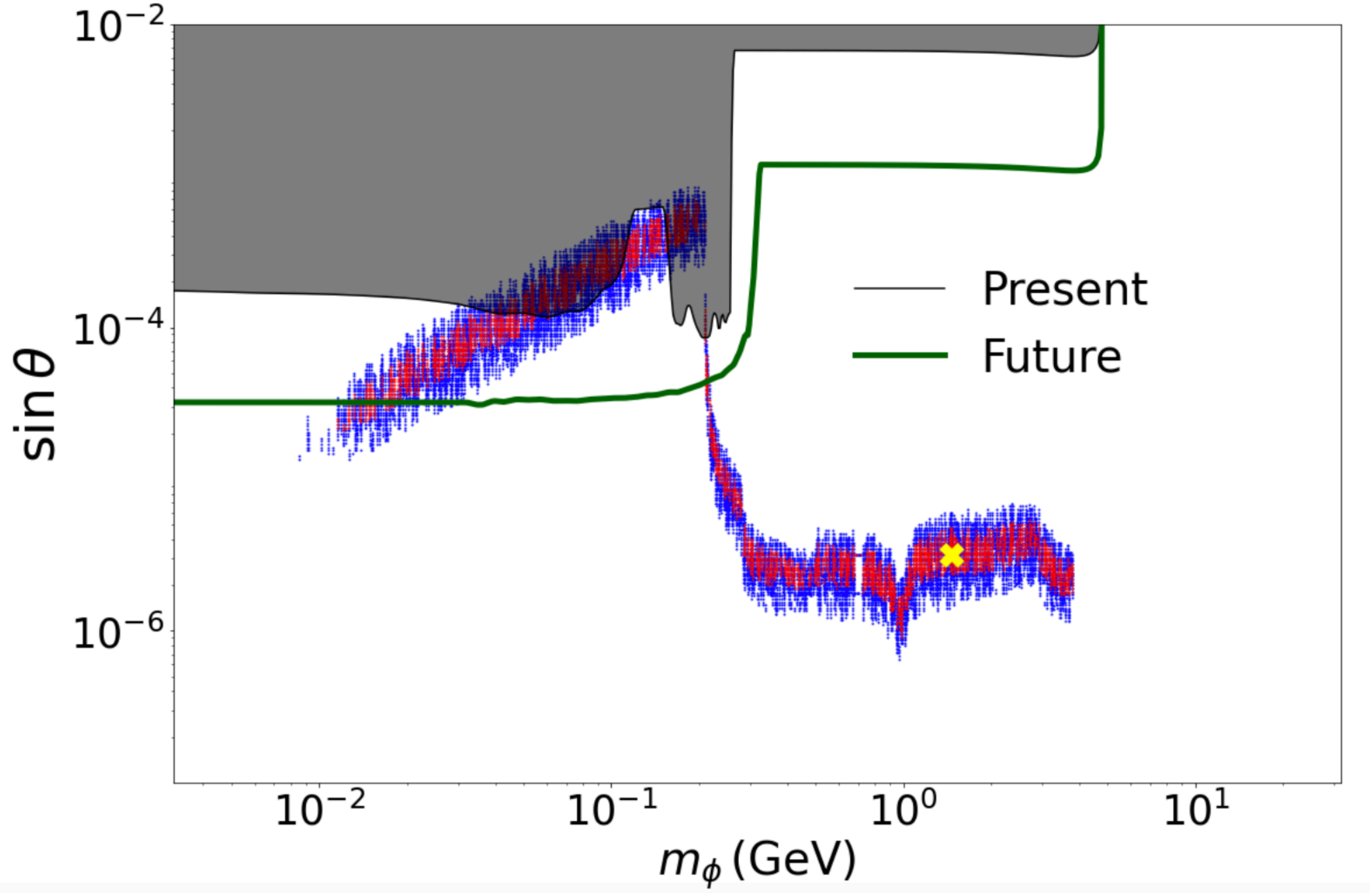
- There are 3 type experiments



Collider

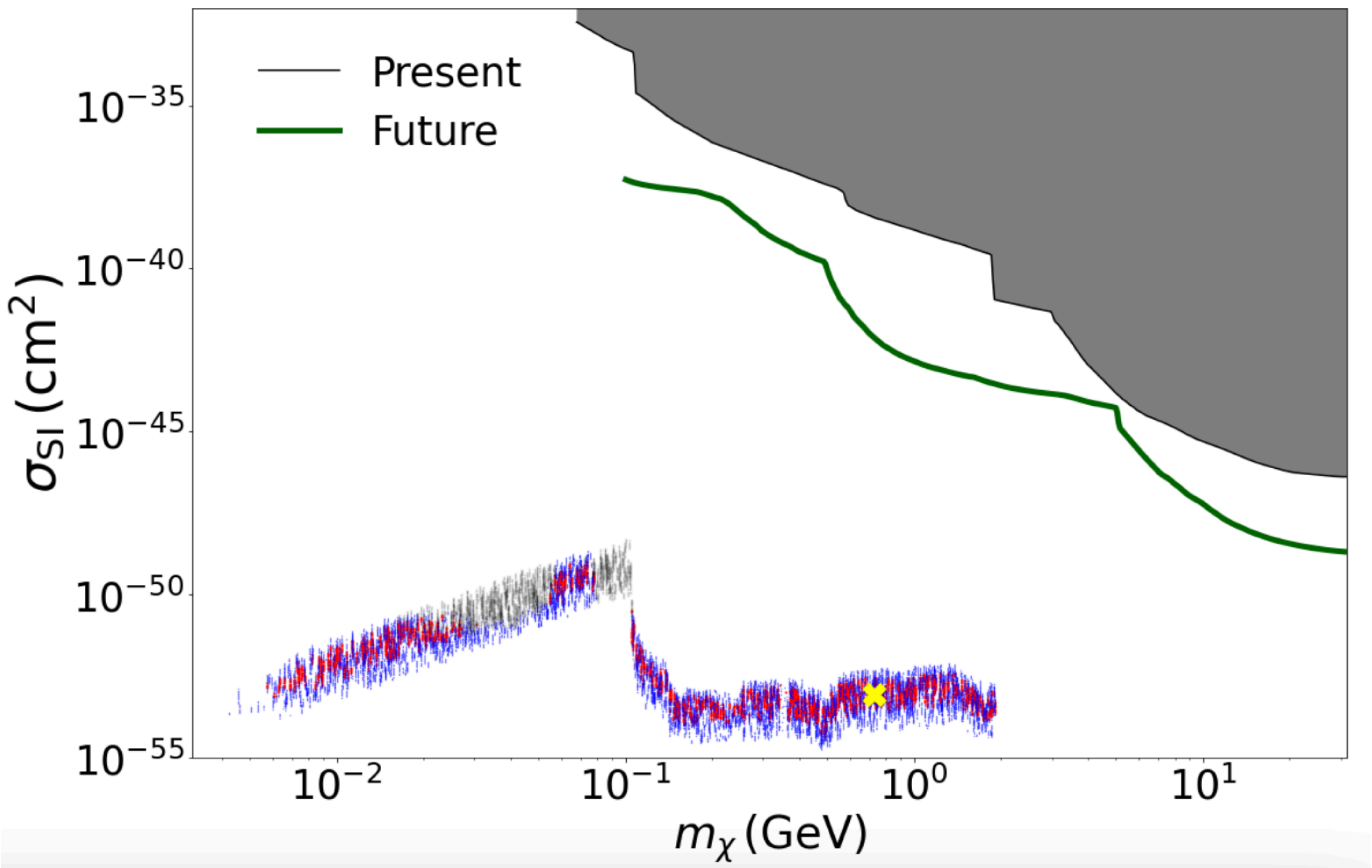
- $B^{\pm}, K^{\pm}, K_L \to K^{\pm}, \pi^{\pm}, \pi^0 + \Phi(\to \text{missing})$





- Several parameter sets are constrained.

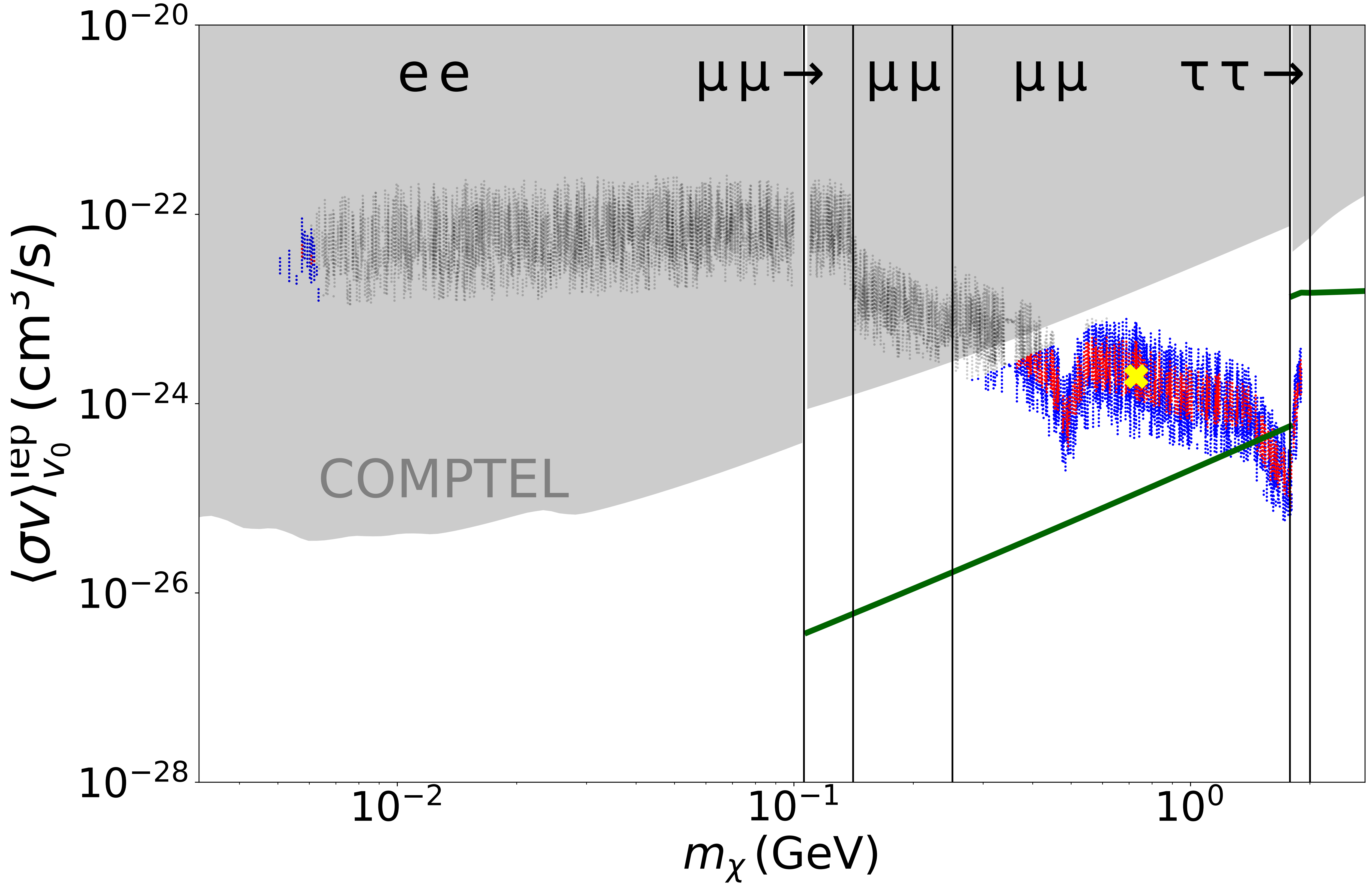
Direct detection



- Constraints are too weak because t,u-channel diagrams are not enhanced.

Indirect detection

- Voyager can observe $e^{\pm}$ produced by annihilation of DM.
- COMPTEL gives the most straingent constraint to the MeV γ-ray.
- There are large uncertainties e.g. DM profile, hadronic fragmentation functions of sub-GeV DM.



- Several parameter **survives at present**.
- Almost all of them can be **excluded in the near future**

Summary

- **Light thermal DM with velocity-dependent** $\langle \sigma v \rangle$ is an attractive DM candidate.

- As an example, we studied the model with **scalar singlet DM and mediator**.

- A part of attractive regions in which DM can solve core-cusp problem, explain the relic density and overcome the constraint from CMB is still **surviving** from constraints **at present** concerning the uncertainties.

- Almost all of these will be **constrained** by **near future** MeV γ-ray observations e.g. GECCO and COSI.