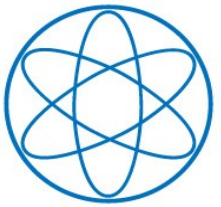
Neutrino bounds on dark matter

Alejandro Ibarra

Technische Universität München



NOW 2012
10 September 2012

Introduction

Many pieces of evidence for particle dark matter. However, very little is known about the properties of the dark matter particle:

Spin: 0 or 1/2 or 1 or 3/2 (possibly higher if composite)

Parity: + or −

Mass: 10^{-15} GeV (axions) $\longrightarrow$ 10^{15} GeV (WIMPzillas)

Self-annihilation cross section: 10^{-40} pb (gravitinos) $\longrightarrow$ 10^{-5} pb (neutralinos)

Interaction cross section with nucleons: 10^{-40} pb (gravitinos) $\longrightarrow$ 10^{-5} pb (neutralinos)

Lifetime: 10^{9} years $\longrightarrow$ infinity

Direct detection

DM nucleus → DM nucleus

Indirect detection

DM DM → γX, e^+X, νX... (annihilation)

DM → γX, e^+X, νX... (decay)

Collider searches

pp → DM X

Direct detection

DM nucleus $\rightarrow$ DM nucleus

Indirect detection

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DM $\rightarrow \gamma X, e^{+}X, \nu X...$ (decay)

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1st part ➡ Self-annihilation cross section: 10^{-40} pb (gravitinos) $\longrightarrow$ 10^{-5} pb (neutralinos)

2nd part ➡ Interaction cross section with nucleons: 10^{-40} pb (gravitinos) $\longrightarrow$ 10^{-5} pb (neutralinos)

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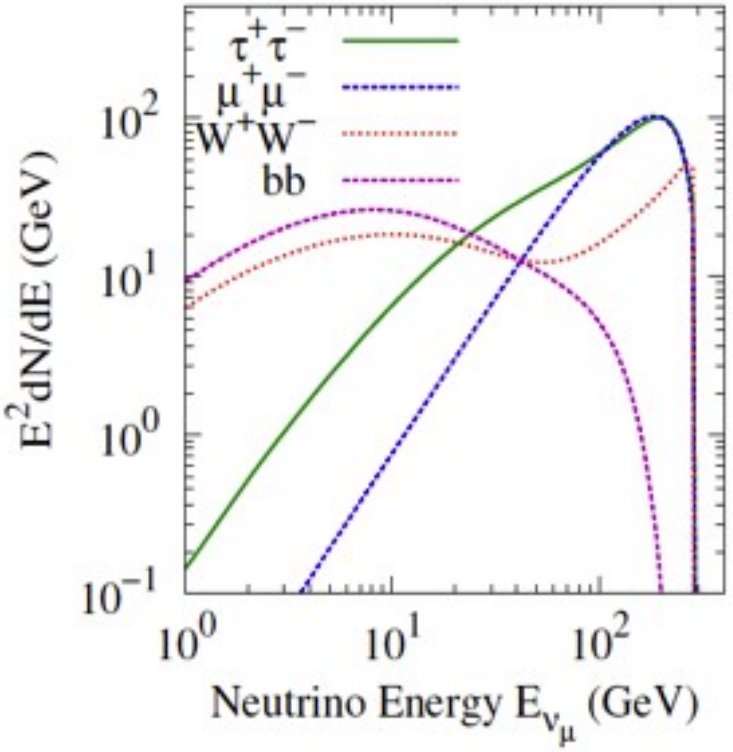
Limits on the annihilation cross-section

Neutrinos from dark matter annihilations in the Milky Way halo

$$\frac{dJ_{\rm halo}}{dE_\nu} = \frac{1}{4\pi}\left[\frac{\langle\sigma_{\rm ann}v\rangle}{2m^2_{\rm DM}}\sum_f \frac{dN^f_\nu}{dE_\nu}B_f\right] \times \int_{\rm l.o.s.} \rho^2(\vec{l})\, d\vec{l}$$

Source term (particle physics)

Line-of-sight integral (astrophysics)



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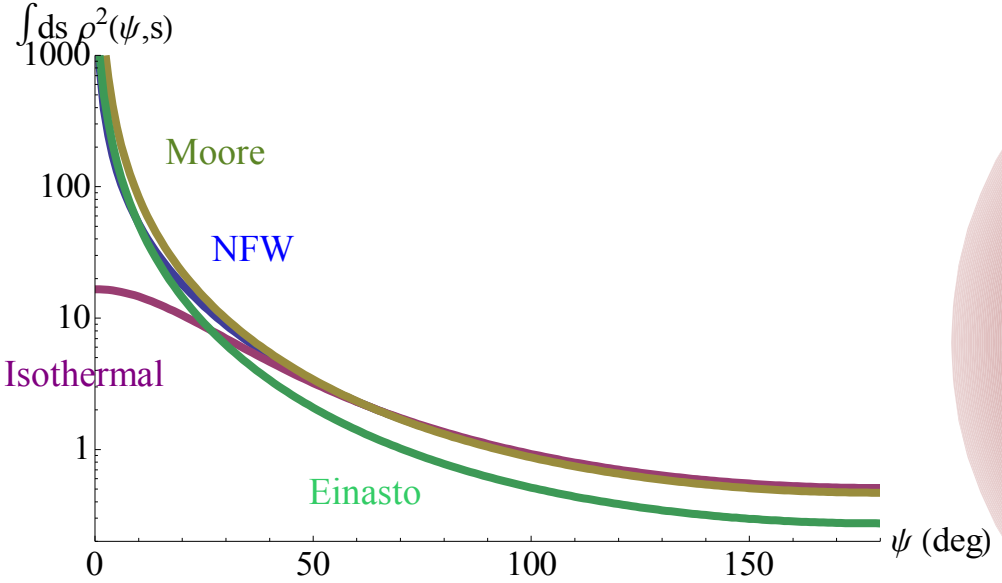

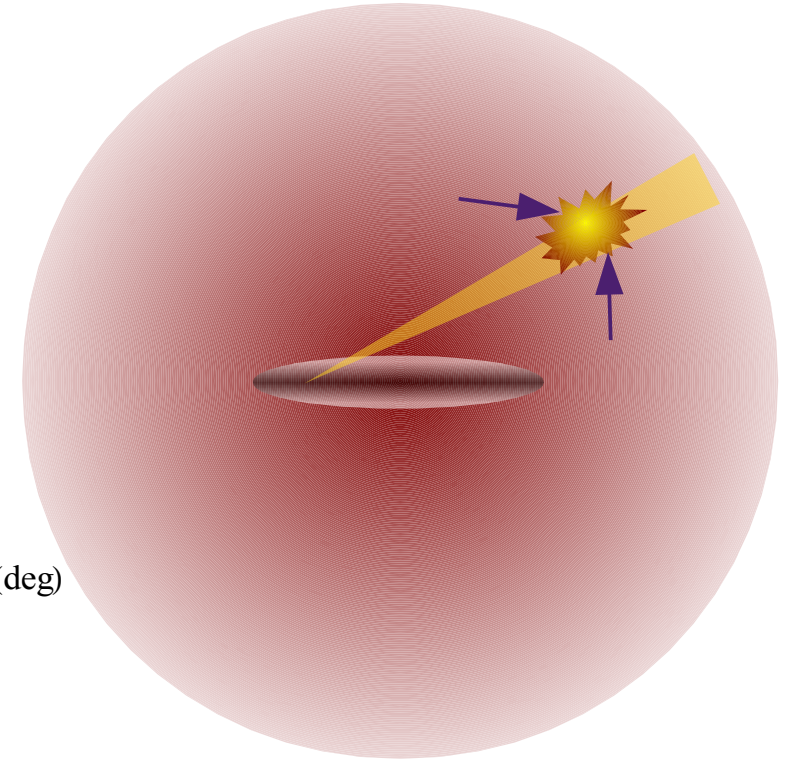

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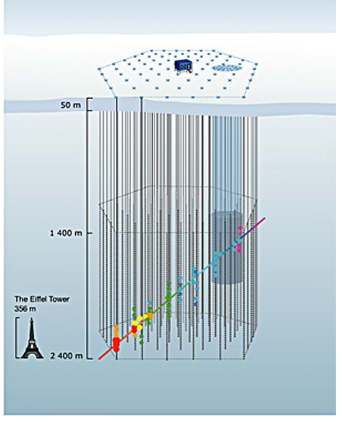
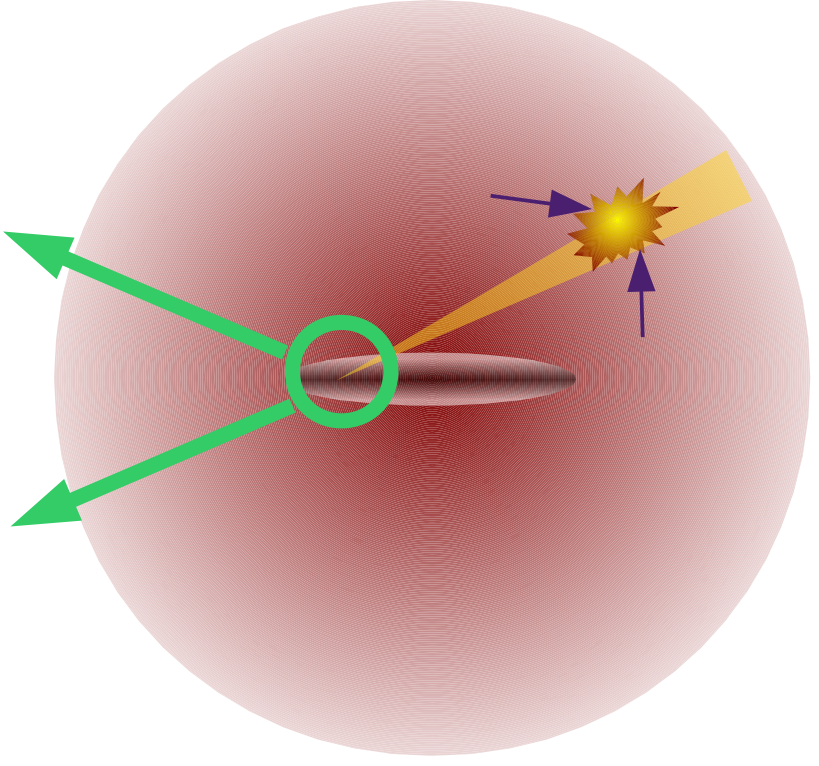
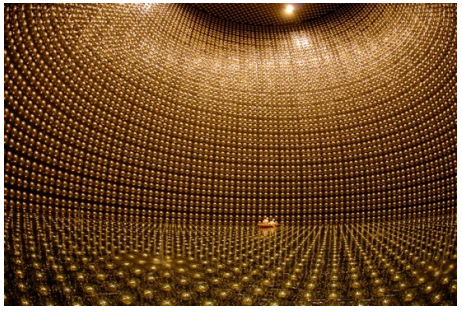
IceCube



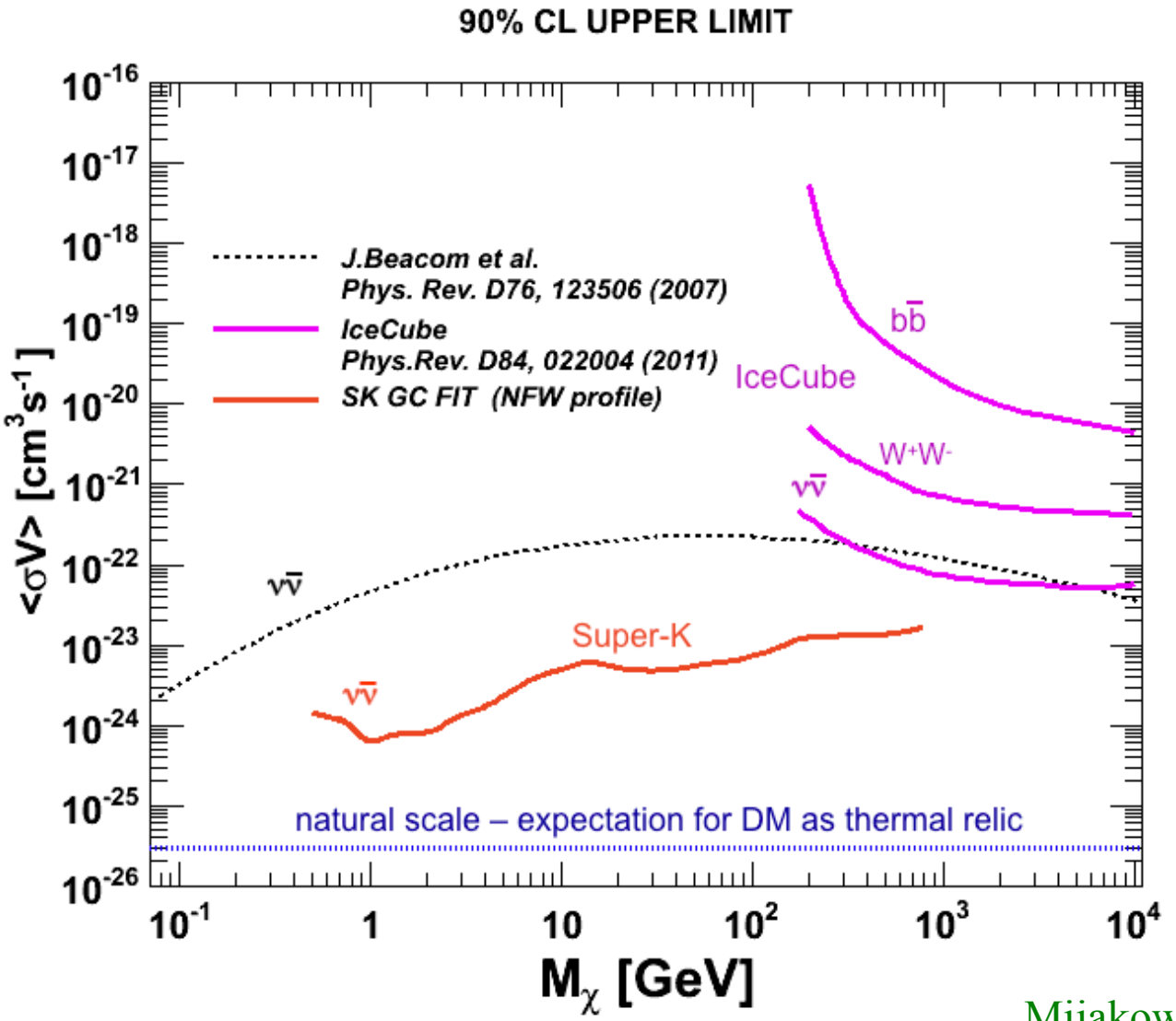


SuperK



Limits on the annihilation cross-section

Neutrinos from dark matter annihilations in the Milky Way halo

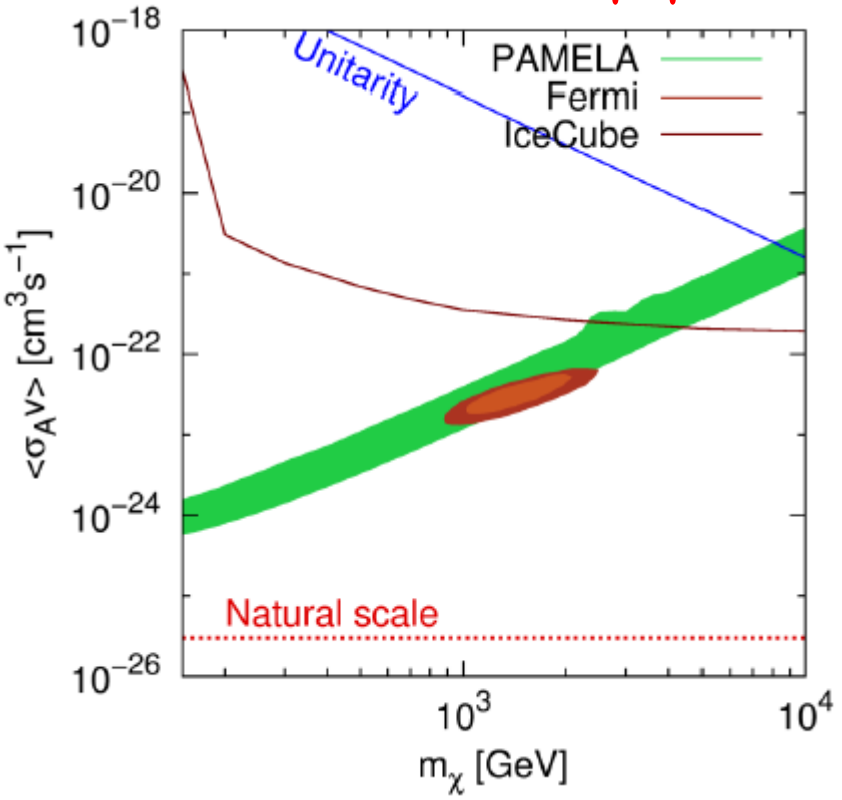


Mijakowski
Rencontres de Moriond 2012

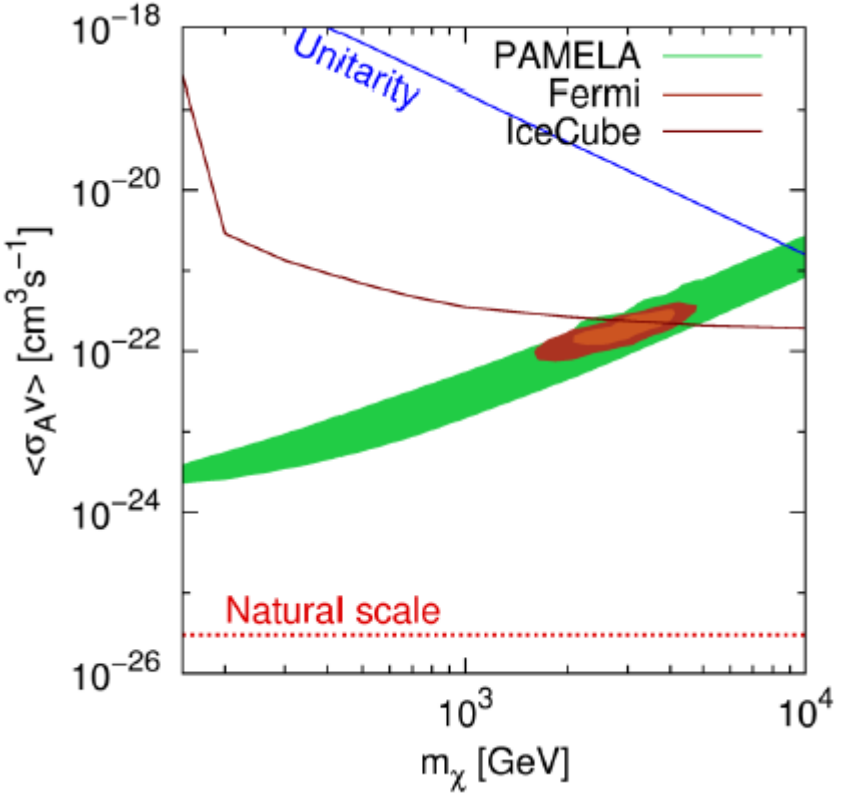
Limits on the annihilation cross-section

Neutrinos from dark matter annihilations in the Milky Way halo

DM DM → $\mu^+\mu^-$



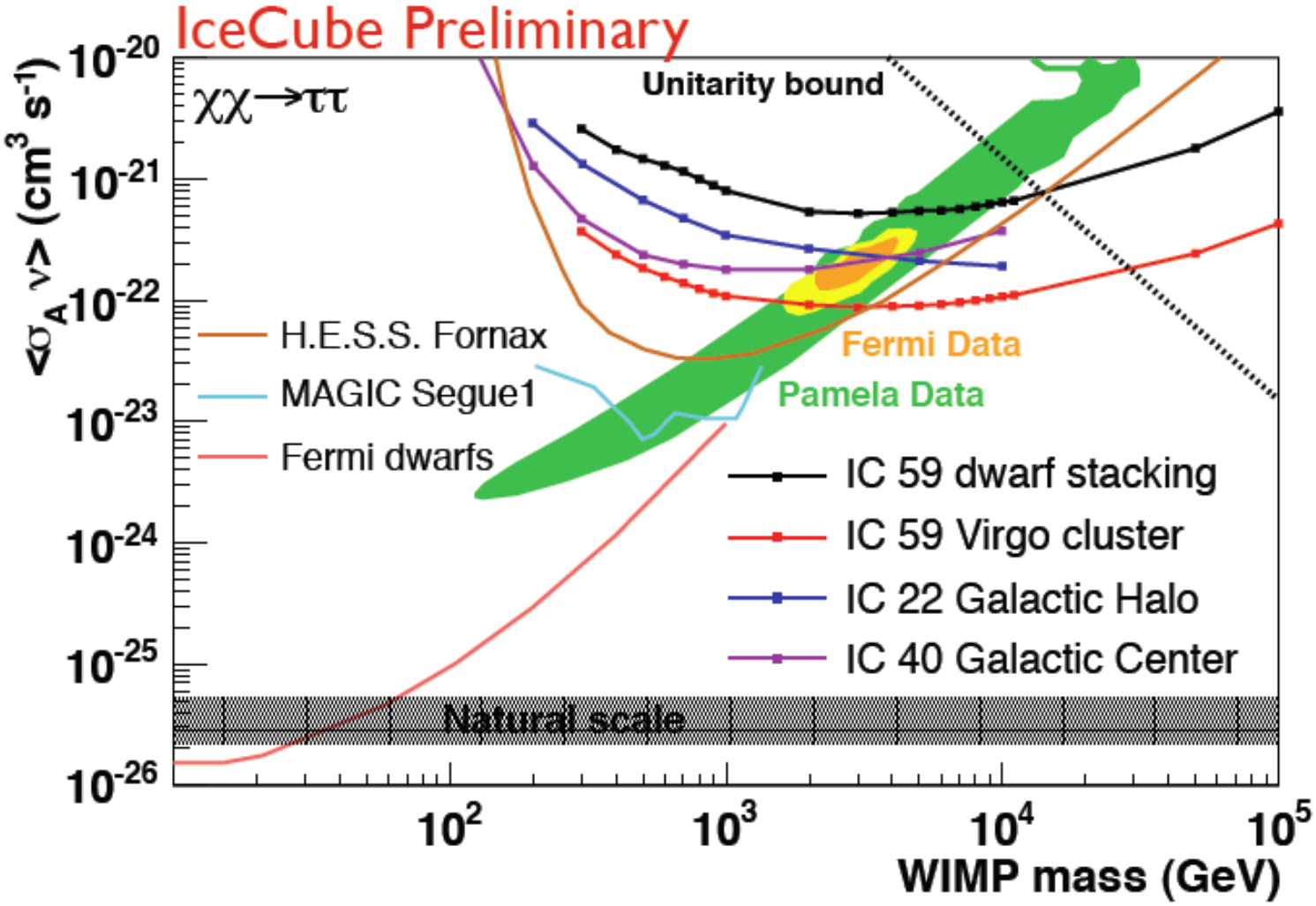
DM DM → $\tau^+\tau^-$



Abbasi et al.
arXiv:1101.3349

Limits on the annihilation cross-section

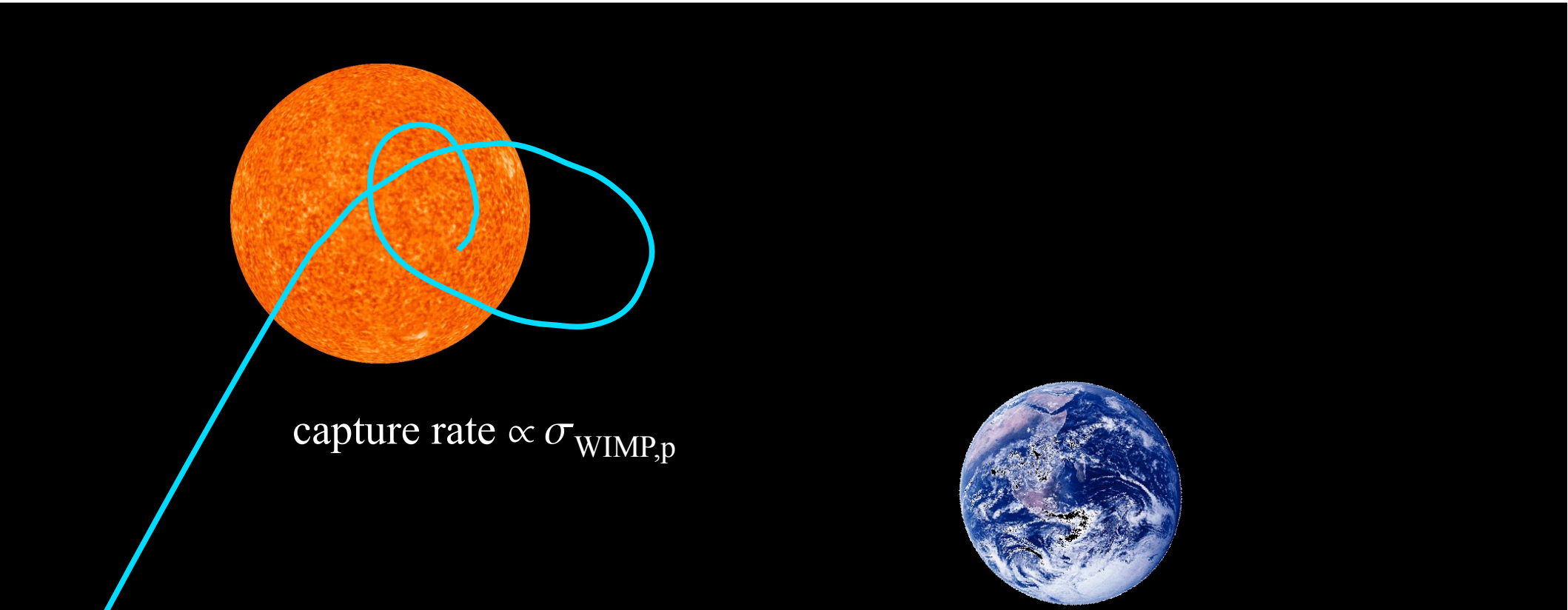
Neutrinos from dark matter annihilations in dwarf galaxies & galaxy clusters



Courtesy of Carsten Rott

Limits on the scattering cross-section

- If the dark matter particles have a "sizable" interaction cross section with ordinary matter, they can be captured inside the Sun and inside the Earth.



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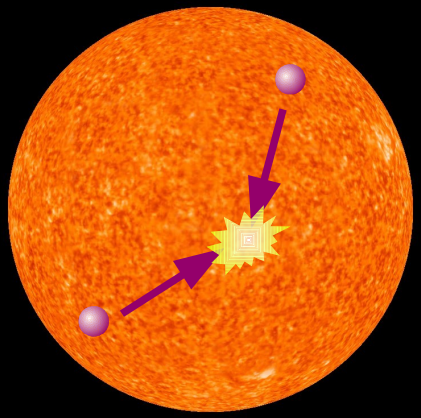
- DM particles captured inside the Sun/Earth can annihilate.



annihlation rate $\propto \langle \sigma\, v \rangle$

$$\Gamma_A \simeq \frac{C_c}{2}$$

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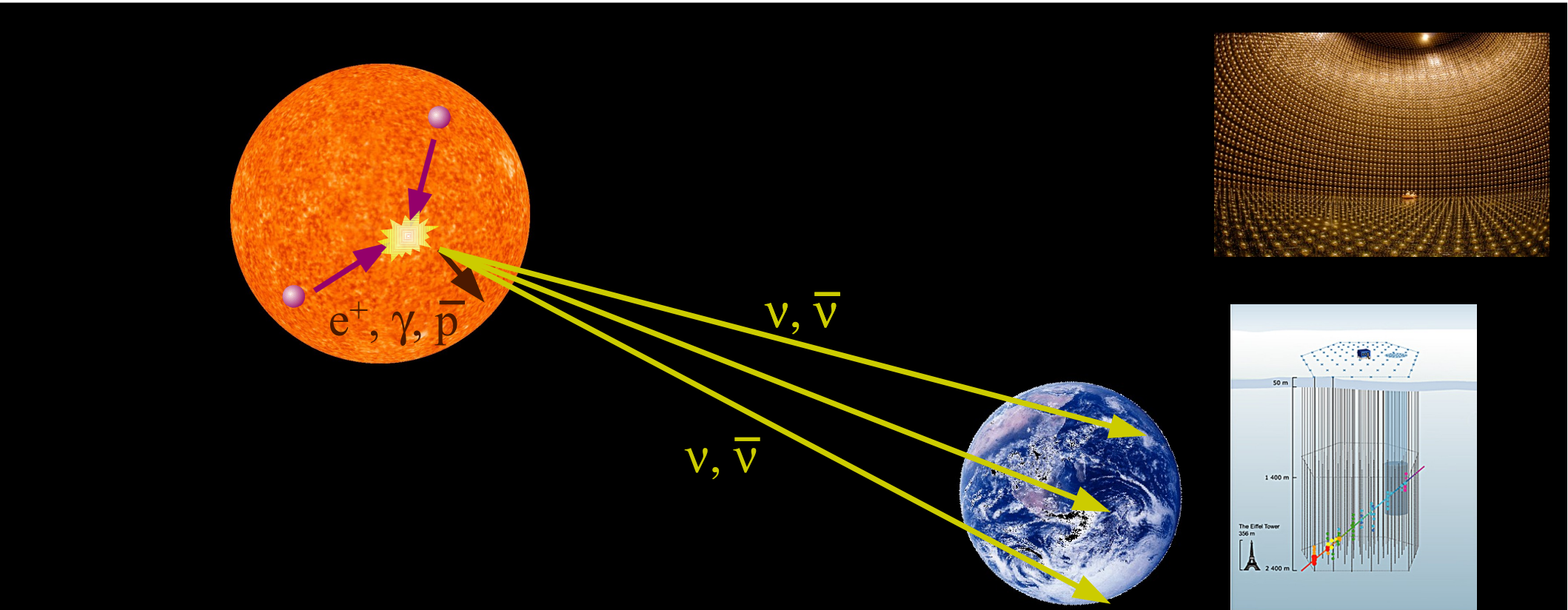
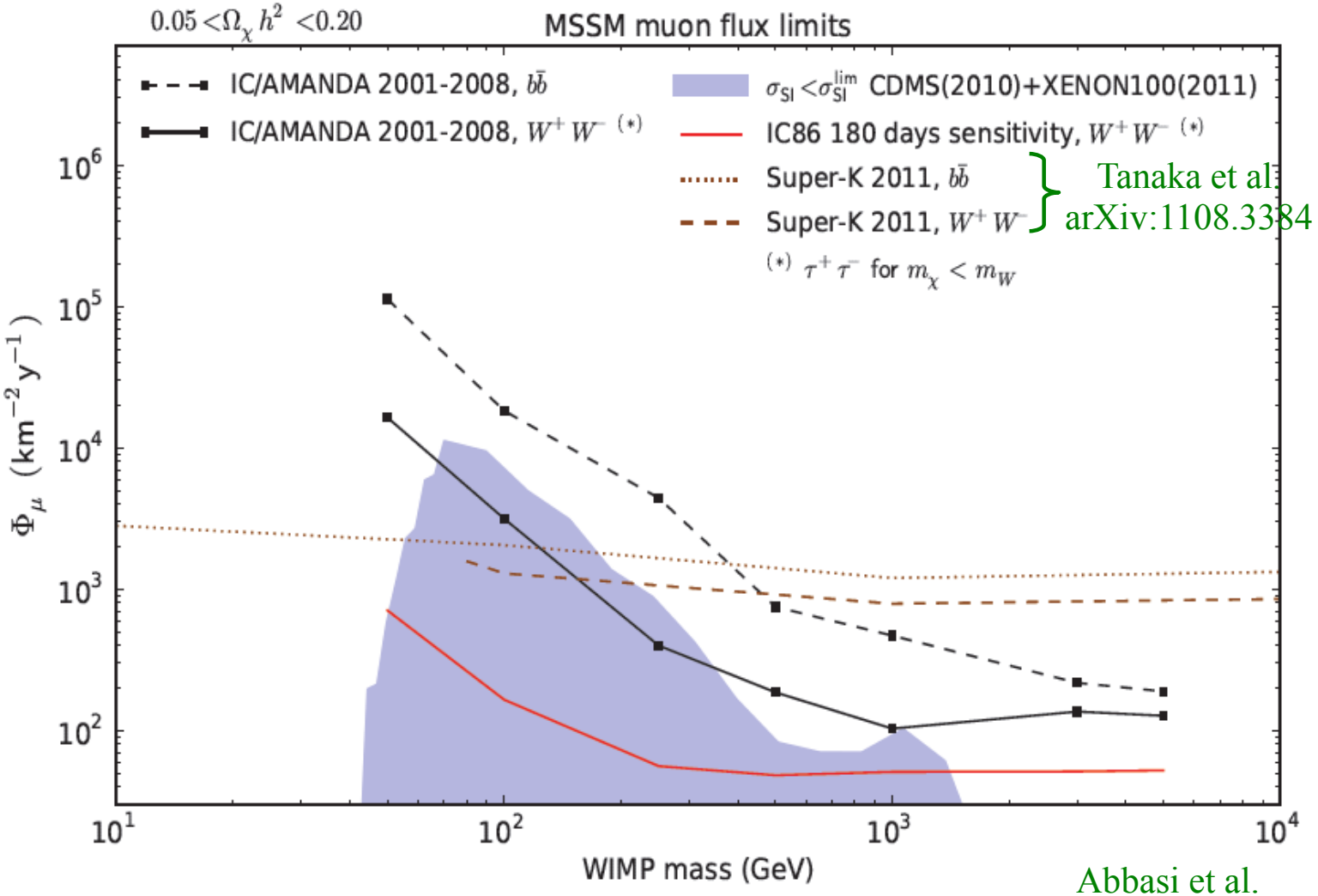
- DM particles captured inside the Sun/Earth can annihilate.

- The annihilation produces a neutrino flux which might be detected in neutrino observatories. All other annihilation products (gammas, positrons, antiprotons...) are absorbed before escaping the Sun/Earth.



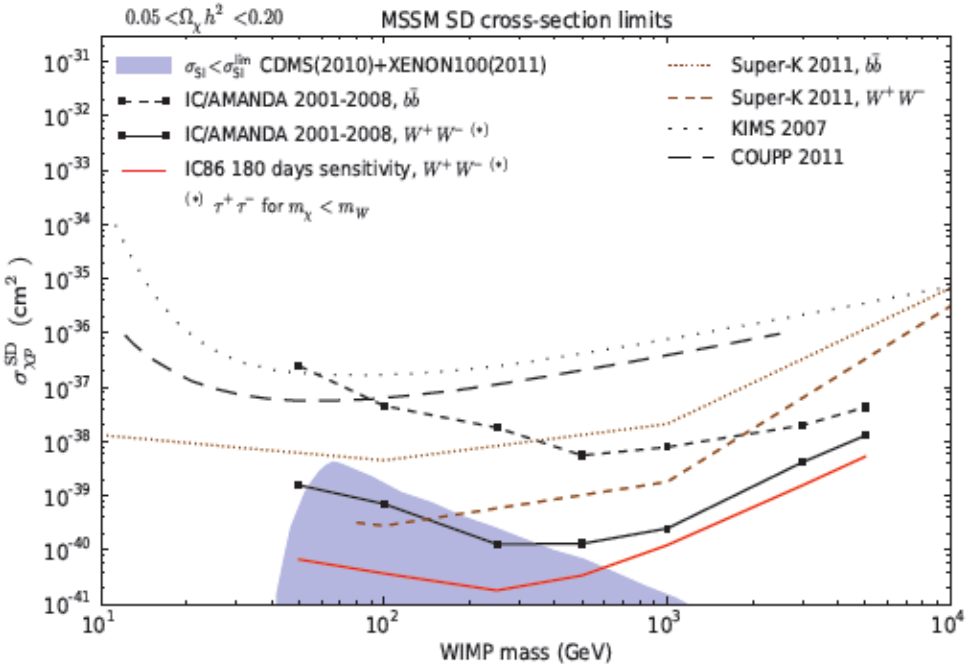
Limits on the scattering cross-section

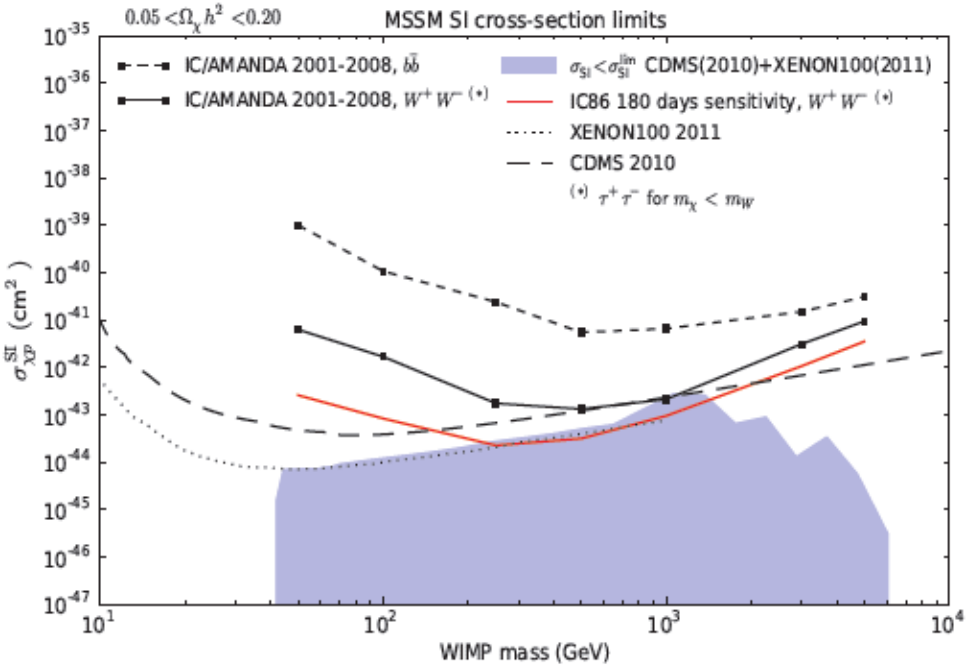
90% C.L. upper limits on the muon flux from neutralino annihilations in the Sun:



Limits on the scattering cross-section

Limits on the SD and SI scattering cross sections





Abbasi et al.
arXiv:1112.1840

Limits on the dark matter lifetime

Neutrinos from dark matter decay in the galactic halo

$$\frac{dJ_{\rm halo}}{dE_\nu} = \frac{1}{4\pi}\left[\frac{1}{\tau_{\rm DM}\, m_{\rm DM}}\sum_f \frac{dN_\nu^f}{dE_\nu} B_f\right] \times \int_{\rm l.o.s.} \rho(\vec{l})\, d\vec{l}$$

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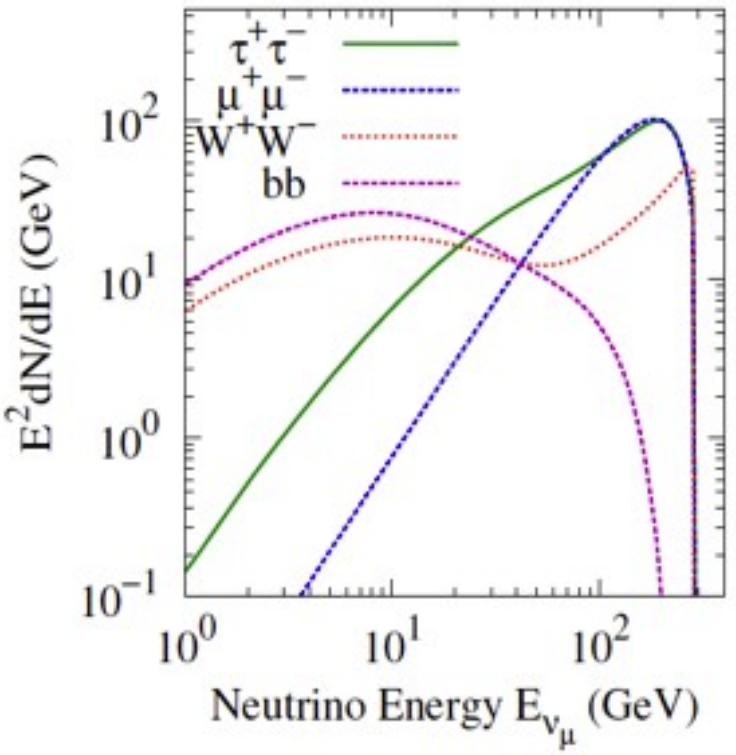

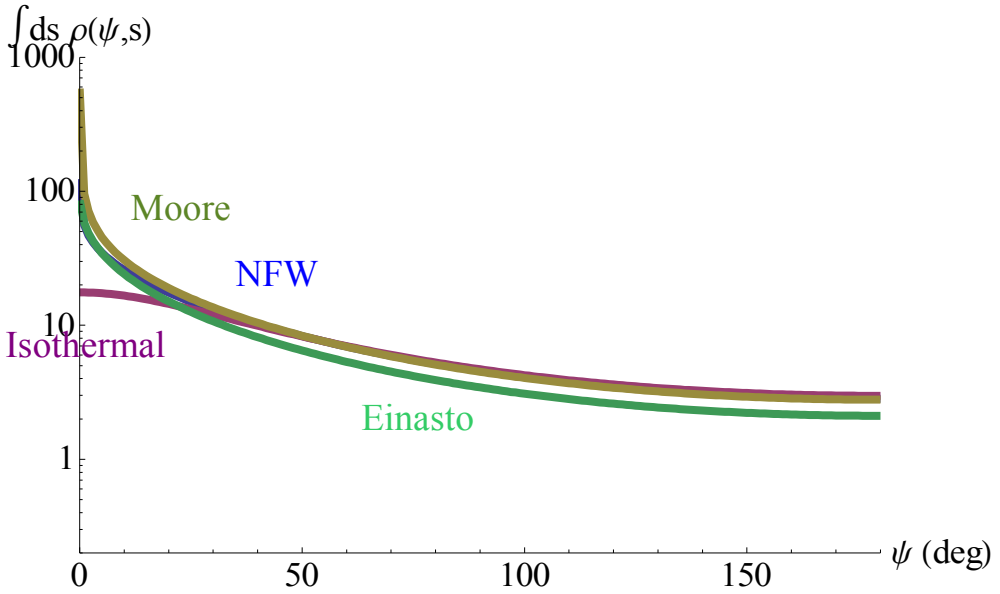

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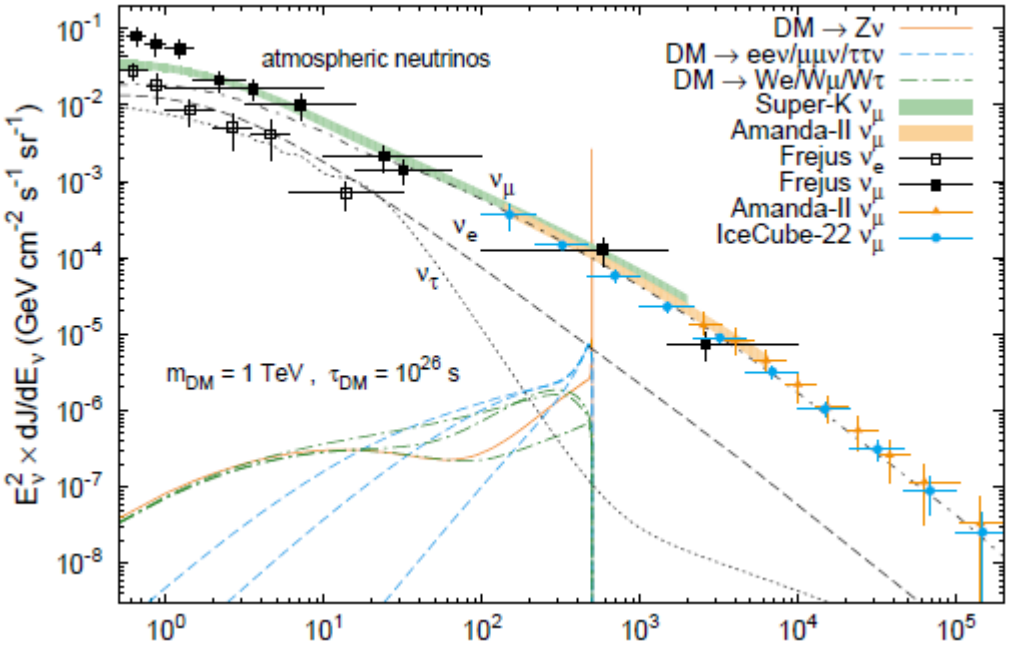
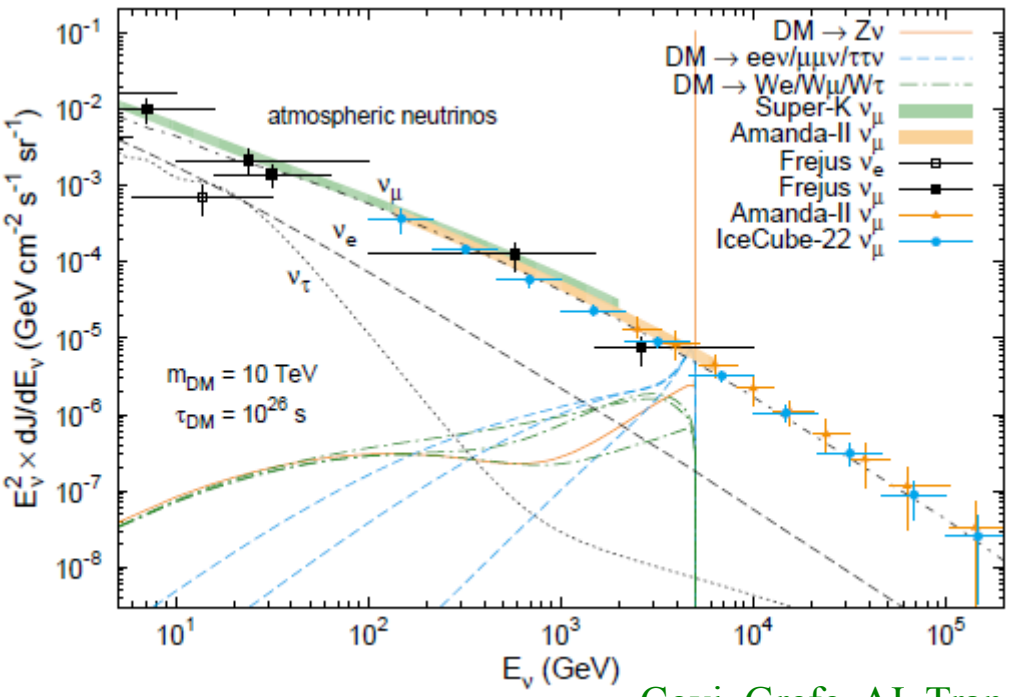




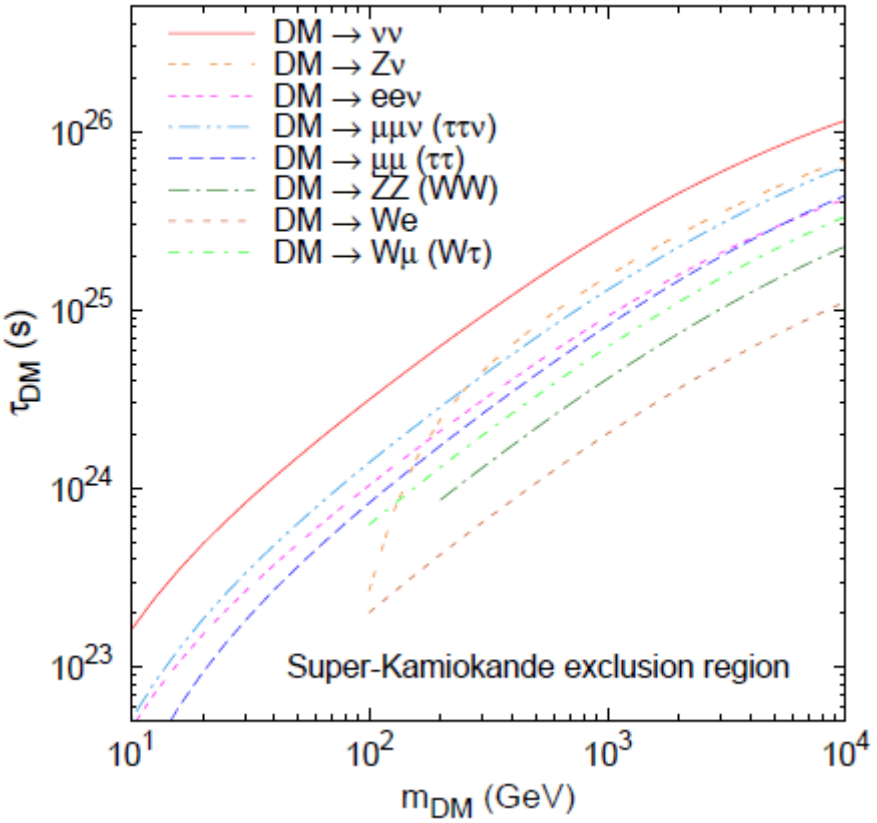
Covi, Grefe, AI, Tran
arXiv:0912.3521

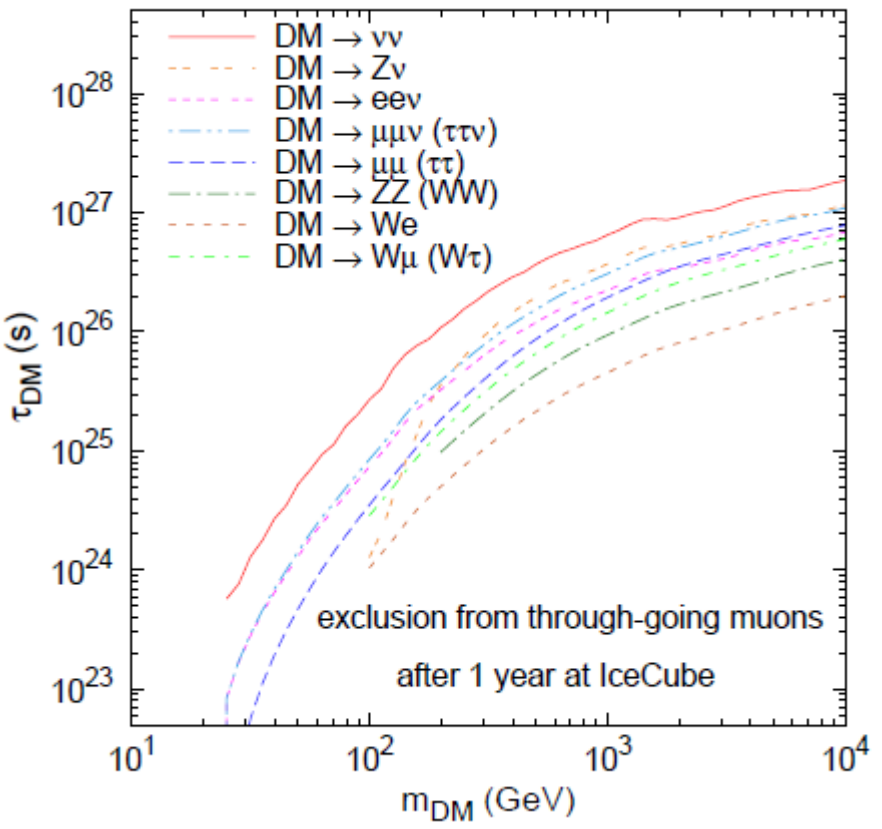
Typical lifetime of a fermionic dark matter particle, decaying via a dimension 6 operator suppressed by M

$$\tau_{\rm DM} \sim 10^{26}{\rm s} \left(\frac{\rm TeV}{m_{\rm DM}}\right)^5 \left(\frac{M}{10^{15}{\rm GeV}}\right)^4$$

Limits on the dark matter lifetime

Neutrinos from dark matter decay in the galactic halo





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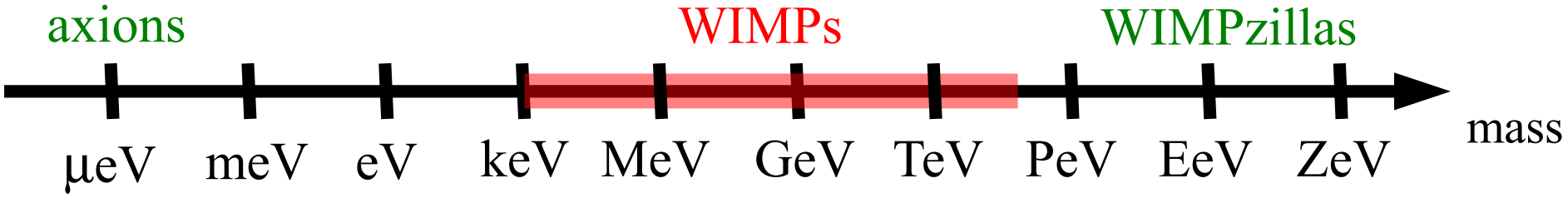
Limits on the dark matter lifetime

Opening up the dark matter mass window...



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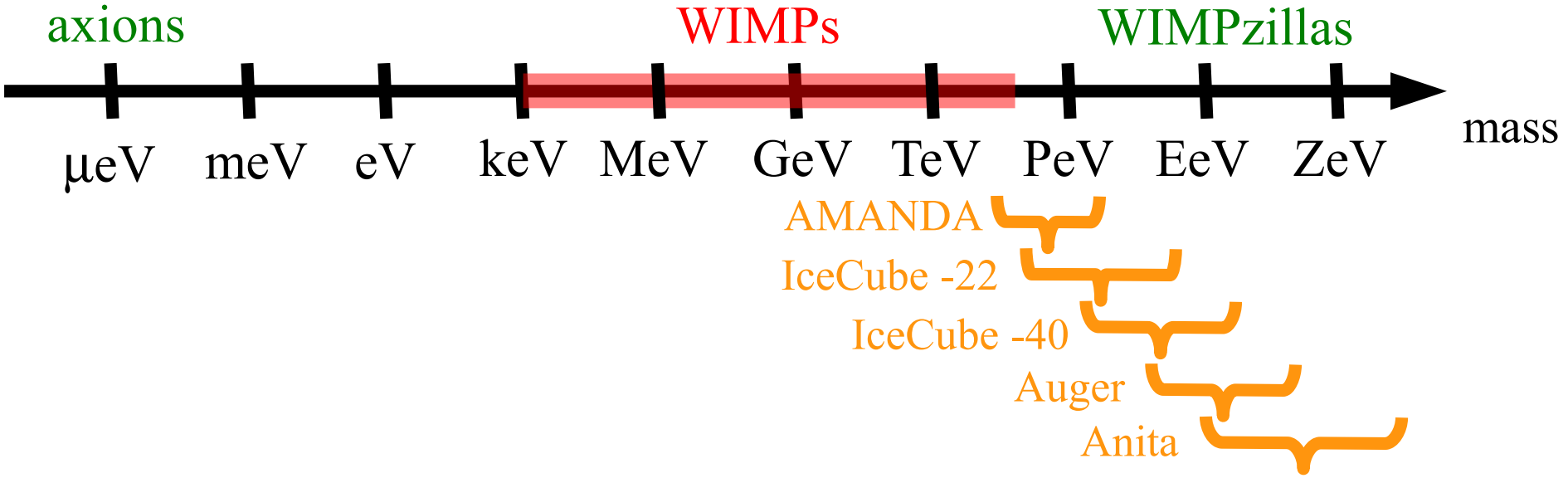
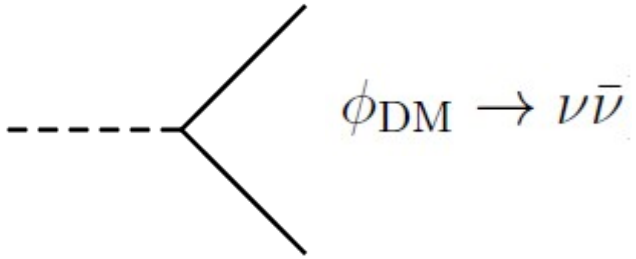


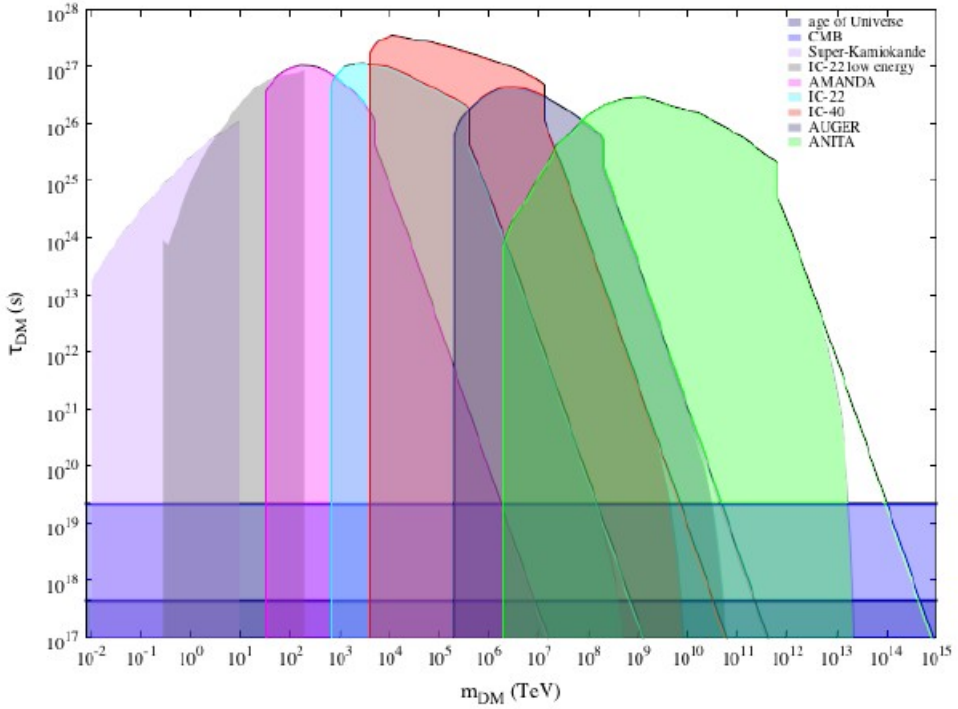
	$E_\nu^{\min} - E_\nu^{\max}$ (TeV)	$N_{\rm bg}$	$N_{\rm sig}$	$N_{\rm limit}$	
AMANDA	$16 - 2.5 \times 10^3$	6	7	5.4	arXiv:0705.1315
IceCube-22	$340 - 2 \times 10^5$	0.6	3	6.1	arXiv:1202.4564
IceCube-40	$2 \times 10^3 - 6.3 \times 10^6$	0.1	0	2.3	arXiv:1103.4250
Auger	$10^5 - 10^8$	0	0	2.3	arXiv:1202.1493
ANITA	$10^6 - 3.2 \times 10^{11}$	0.97	1	3.3	arXiv:1011.5004

Limits on the dark matter lifetime

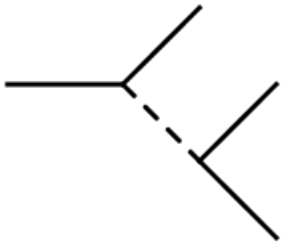
Monoenergetic neutrinos



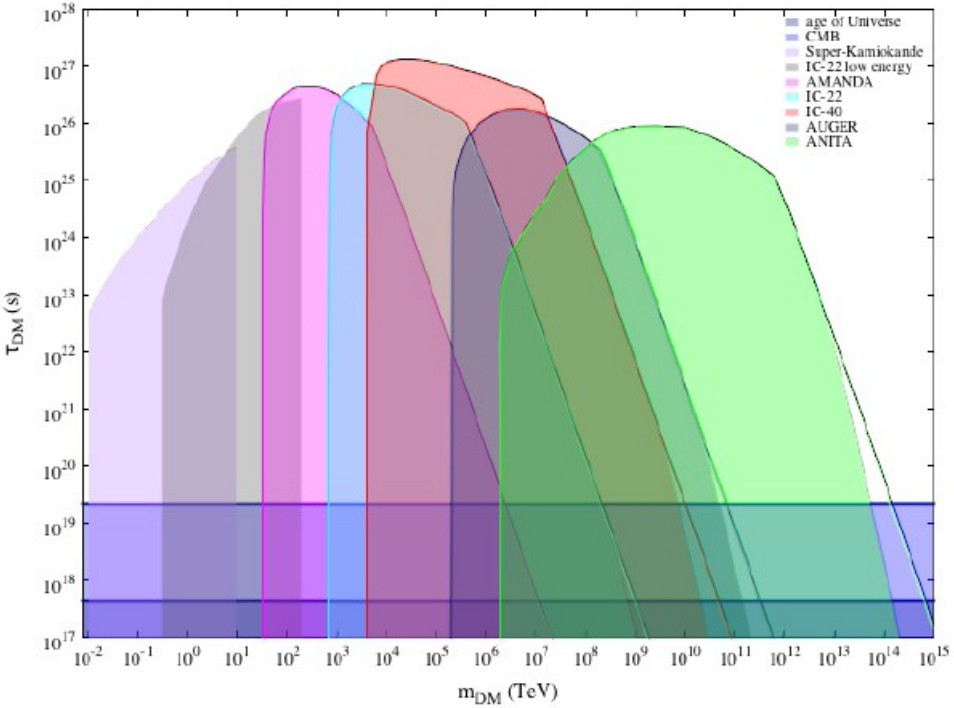
$$\phi_{\rm DM} \to \nu\bar{\nu}$$



Continuous energy distribution



$$\psi_{\rm DM} \to e^+e^-\nu$$



Esmaili, AI, Peres
arXiv:1205.5281

Limits on the dark matter lifetime

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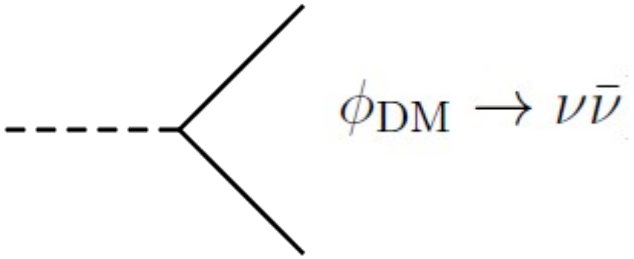
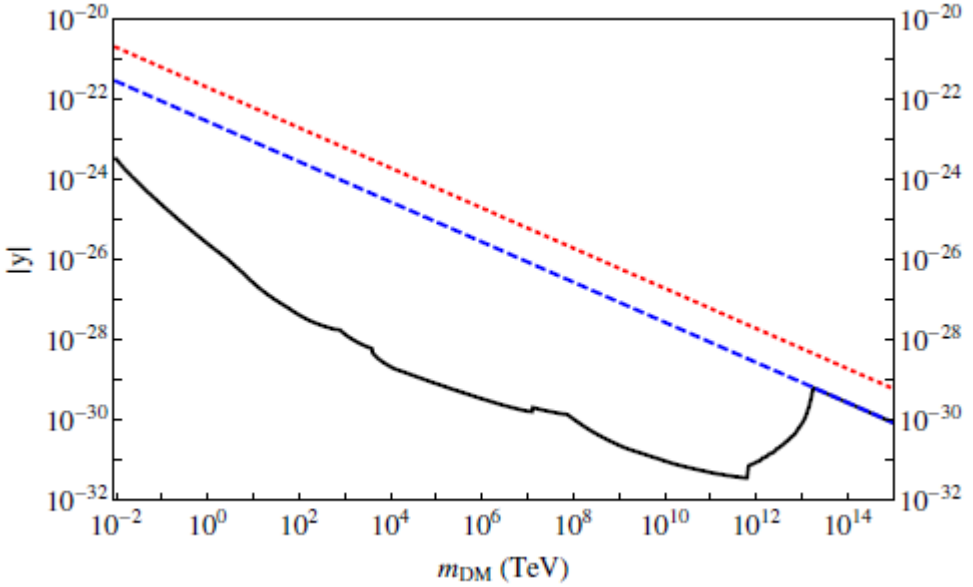


$$\phi_{\rm DM} \to \nu\bar{\nu}$$

$$\Gamma(\phi_{\rm DM} \to \nu\bar{\nu}) = \frac{|y|^2}{8\pi} m_{\rm DM}$$



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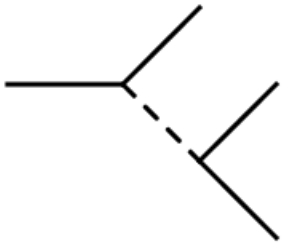
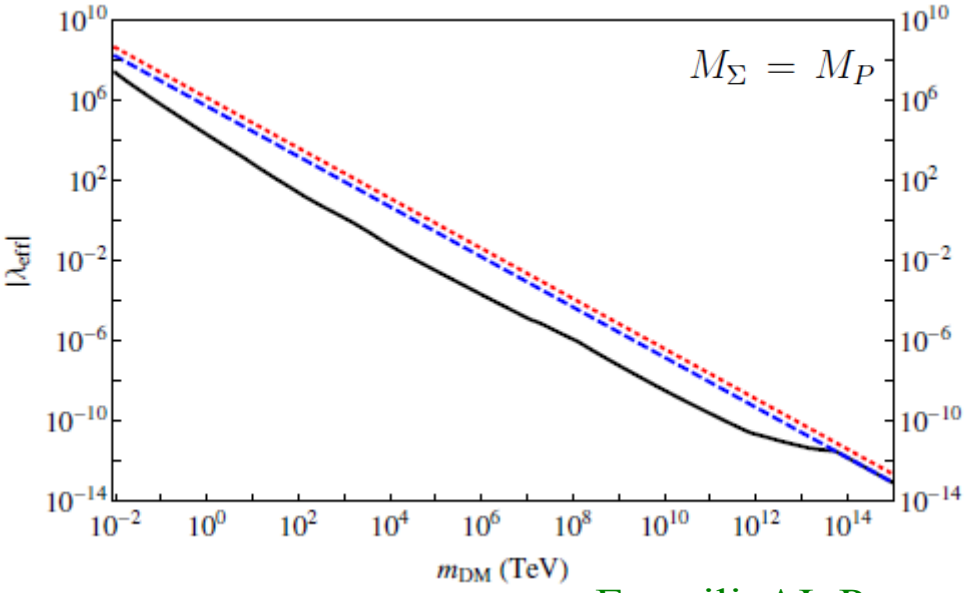


$$\psi_{\rm DM} \to e^+ e^- \nu$$

$$\Gamma(\psi_{\rm DM} \to e^+ e^- \nu) = \frac{|\lambda_{\rm eff}|^4}{3072\pi^3} \frac{m_{\rm DM}^5}{M_\Sigma^4}$$



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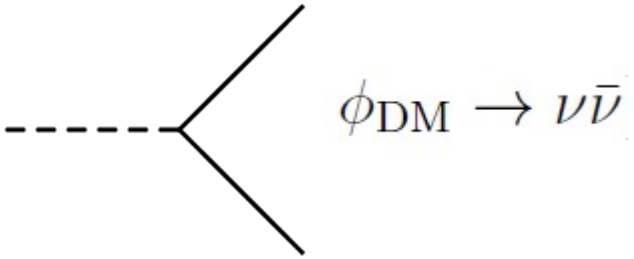

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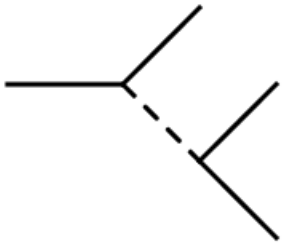

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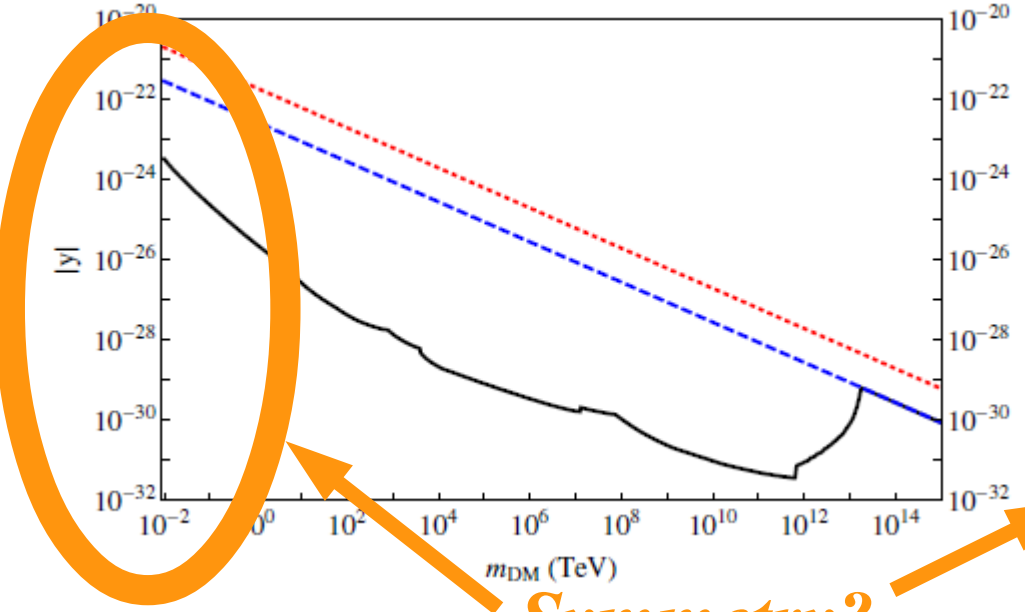

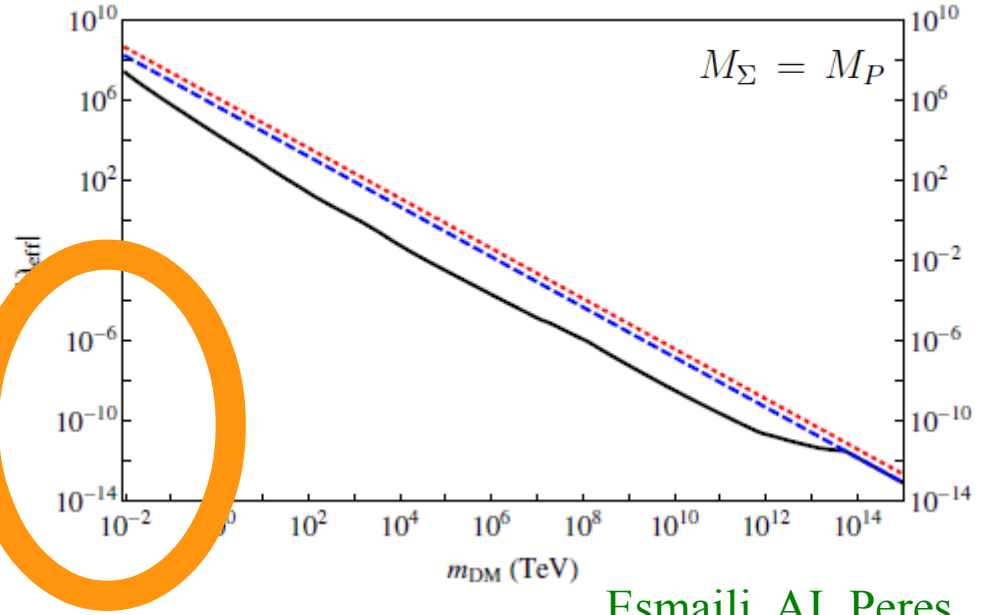

Symmetry?

Esmaili, AI, Peres
arXiv:1205.5281

Limits on the dark matter lifetime

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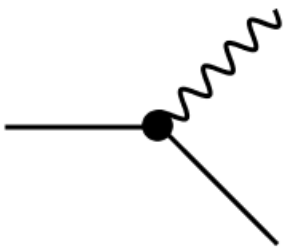

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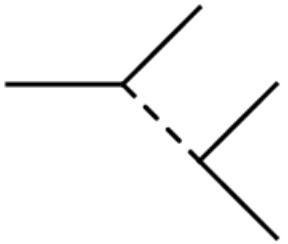

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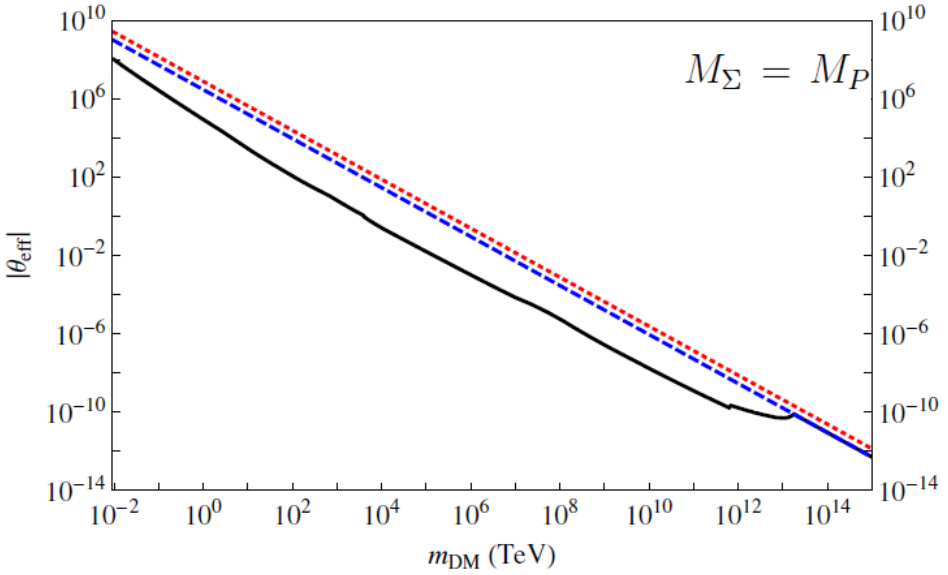

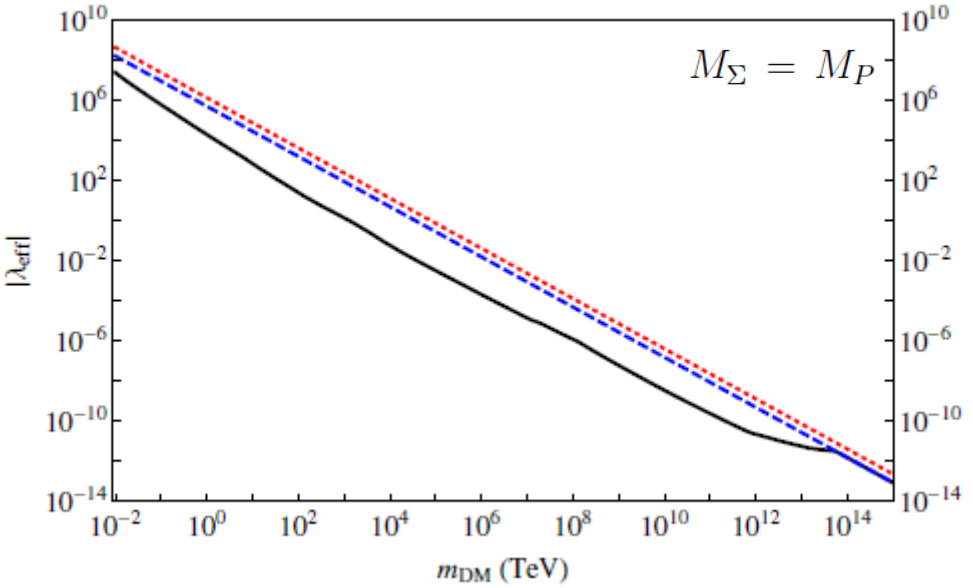

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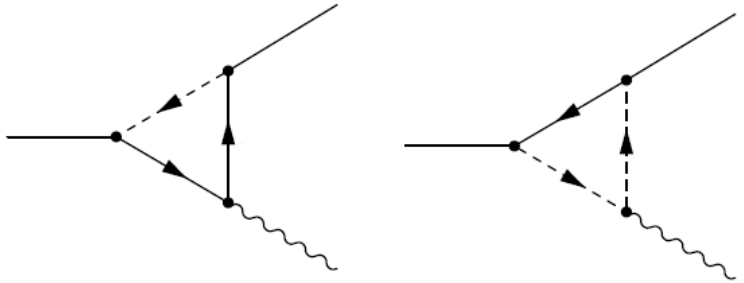
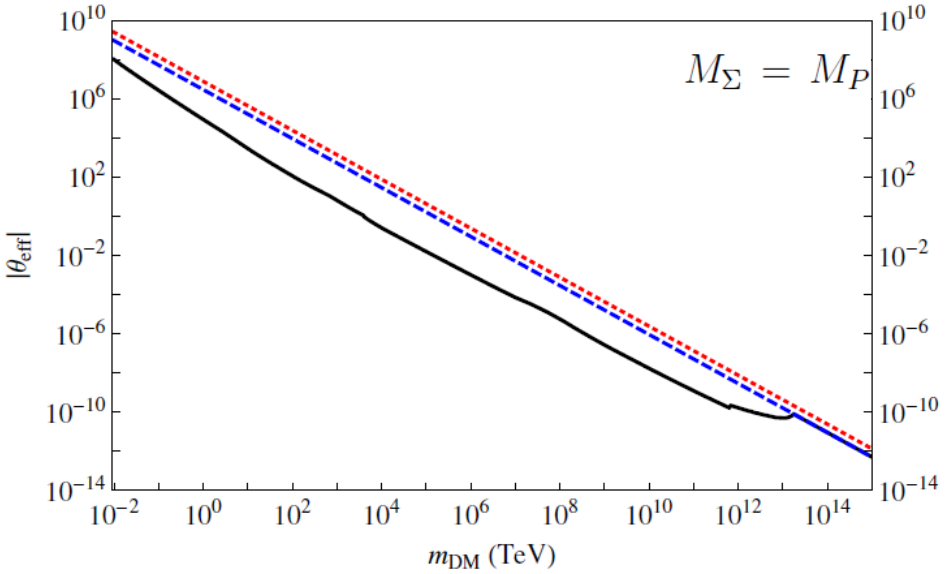
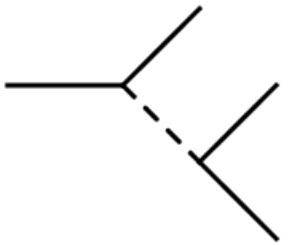


$$\Gamma(\psi_{\rm DM} \to \nu\gamma) = \frac{|\mu_{\rm eff}|^2}{8\pi} m_{\rm DM}^3$$

$$|\mu_{\rm eff}| = \frac{e\, m_{\rm DM}\, |\theta_{\rm eff}|^2}{64\pi^2 M_\Sigma^2}$$

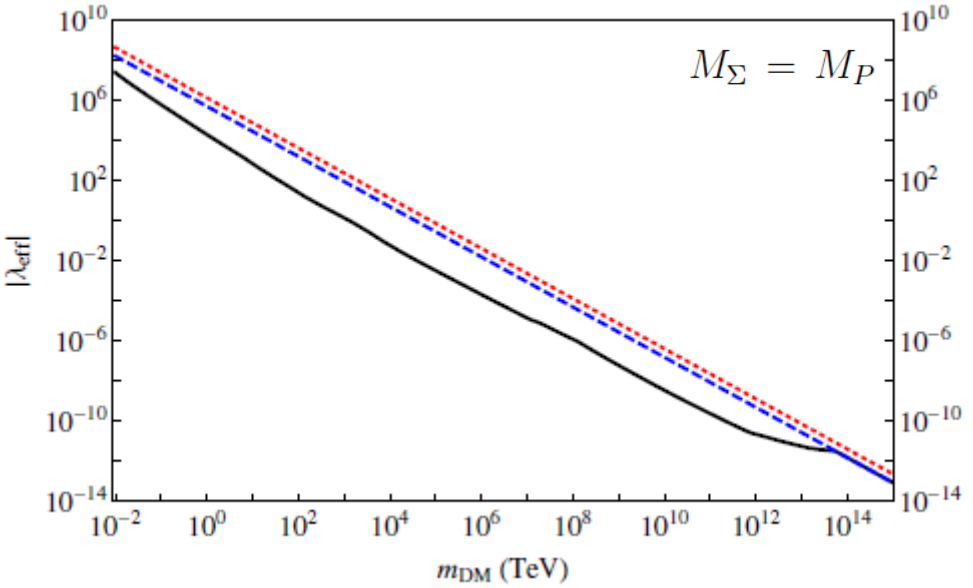


Continuous energy distribution



$$\psi_{\rm DM} \to e^+ e^- \nu$$

$$\Gamma(\psi_{\rm DM} \to e^+ e^- \nu) = \frac{|\lambda_{\rm eff}|^4}{3072\pi^3} \frac{m_{\rm DM}^5}{M_\Sigma^4}$$



Esmaili, AI, Peres
arXiv:1205.5281

Conclusions

Neutrinos are very elusive particles with tiny interaction cross sections with ordinary matter. Naively, a disadvantage when using neutrinos as messengers for indirect dark matter detection. In reality, an advantage (no deflection, no absorption), provided the small detection rates can be compensated by a large detector volume → SuperKamiokande, IceCube

- Limits on the self-annihilation cross section comparable, for large DM masses, to those from electrons/positrons.

- Best limits on the SD scattering cross section. Limits on the SI scattering cross section slightly worst than those from Xenon100, CDMS.

- Best limits on the lifetime of superheavy (m_{DM}>10 TeV) DM particles.

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Thank you for your attention!