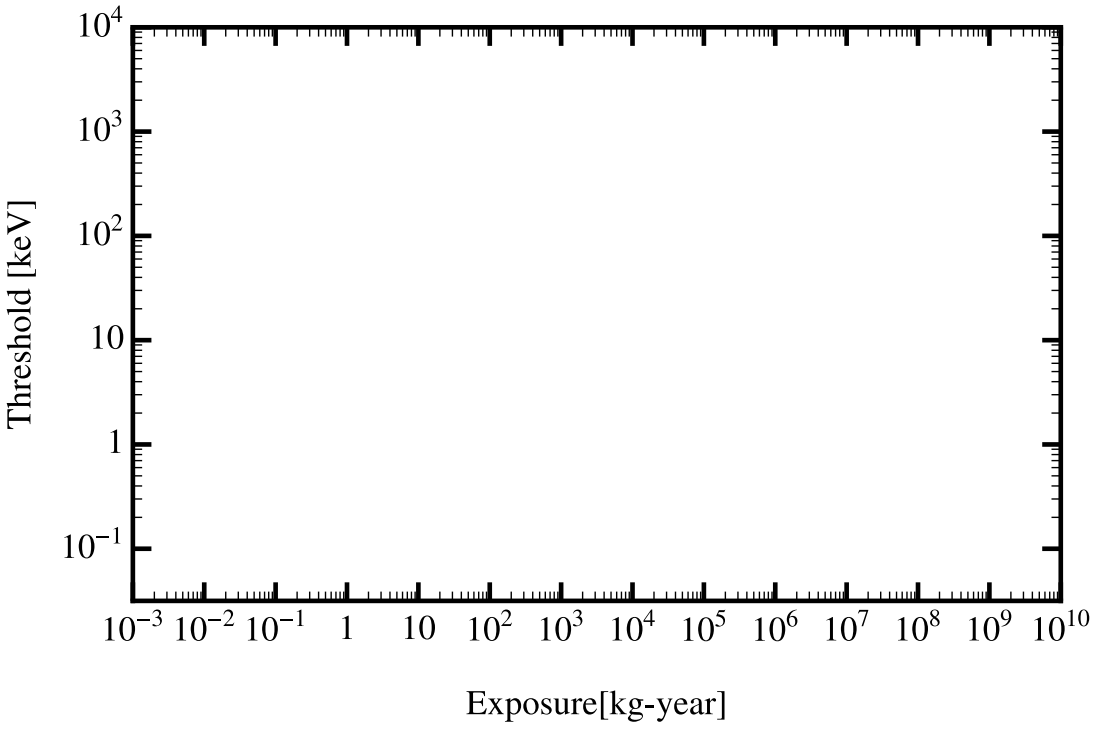
Exotic light dark matter signals at existing experiments

Jeff Dror

in collaboration with Gilly Elor, Robert McGehee, Tien-Tien Yu

Experiment vs Theory

The exposure-threshold tradeoff



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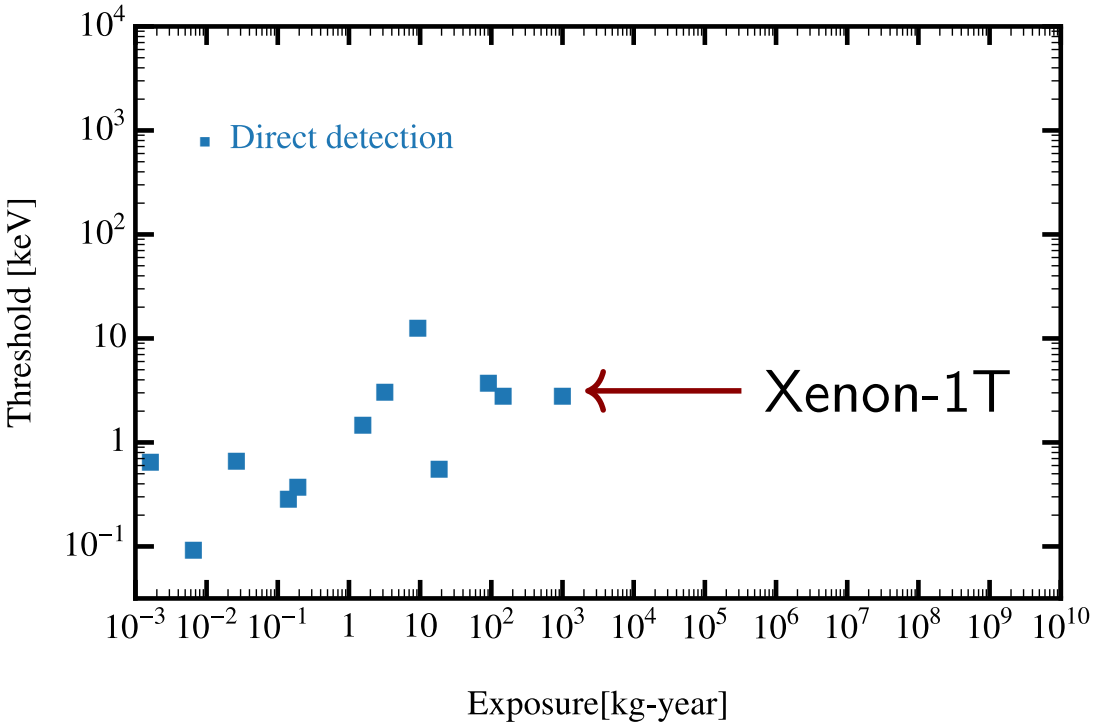

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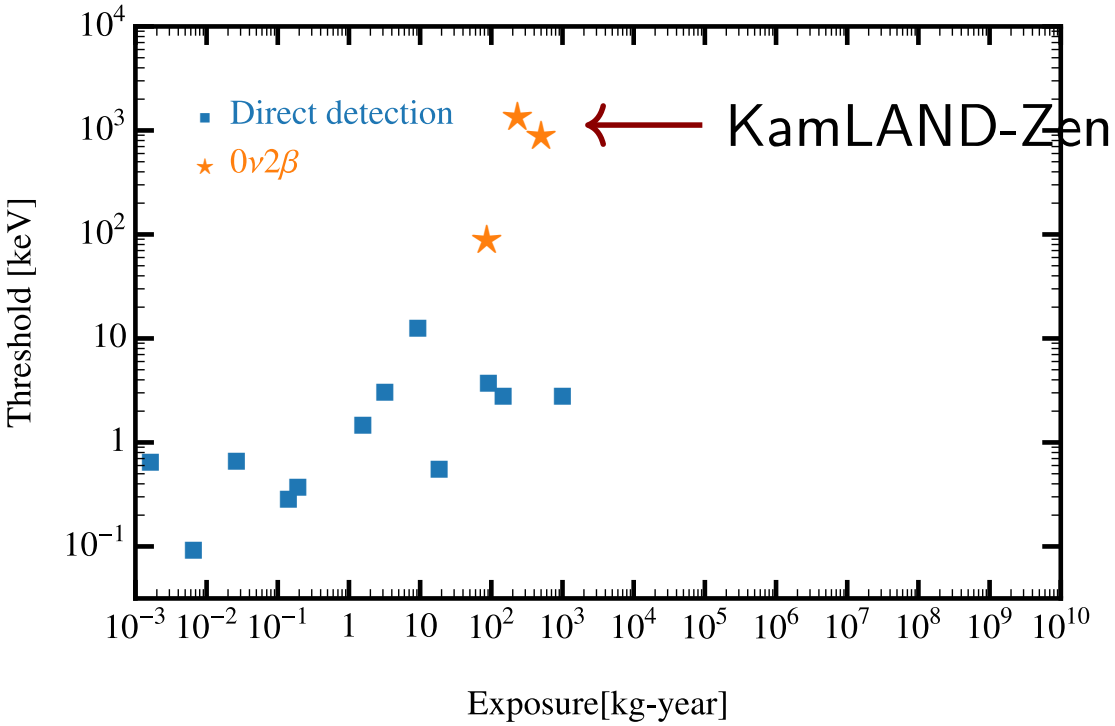

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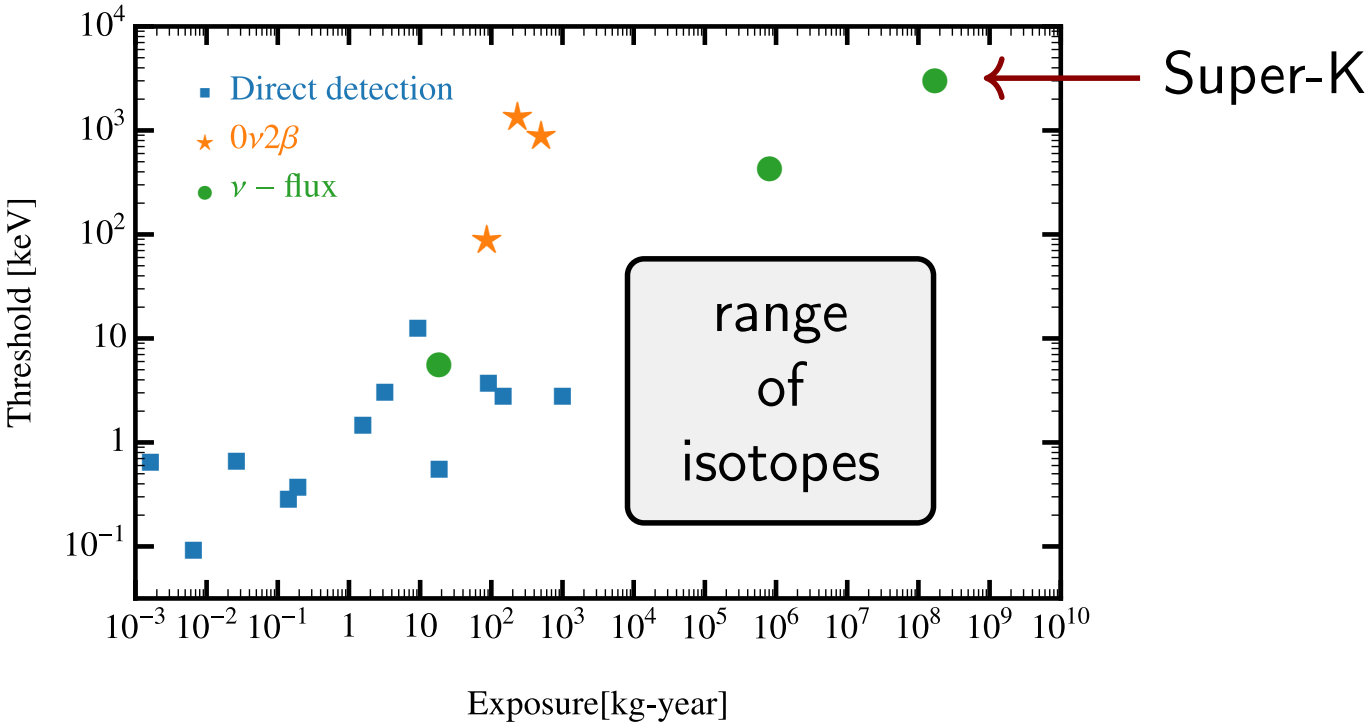

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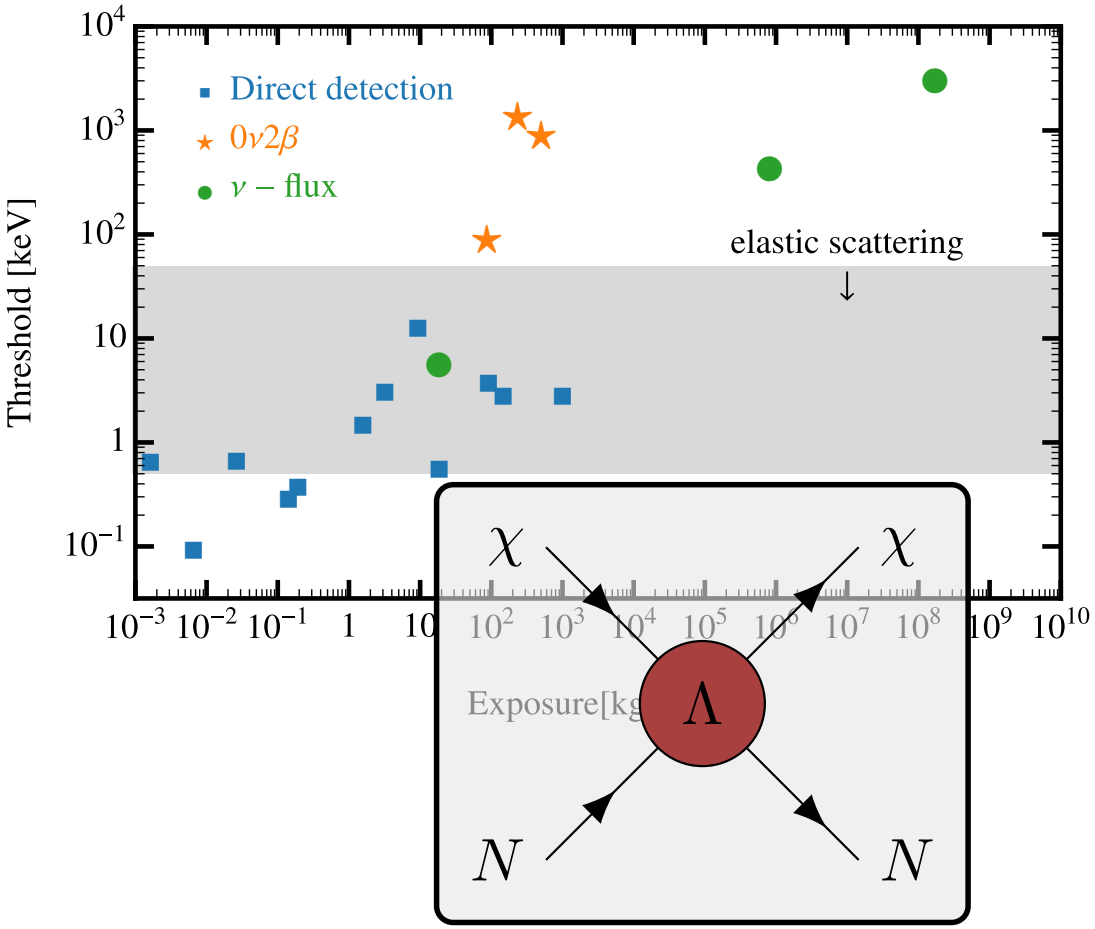

Experiment vs Theory

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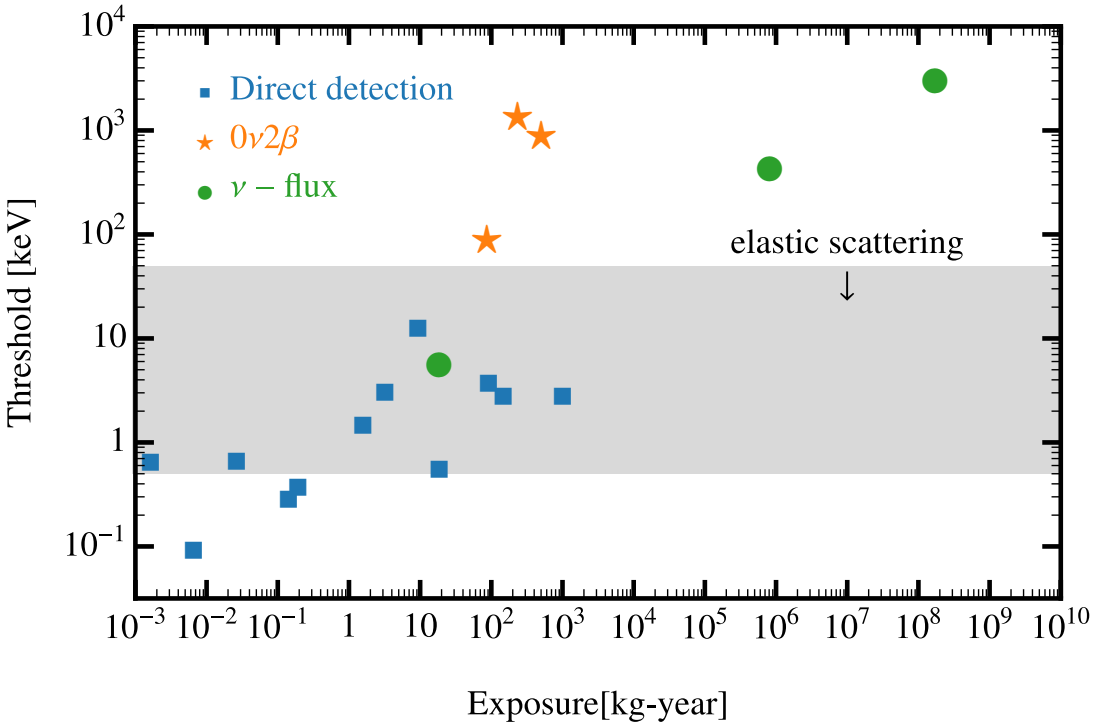


Many other possibilities

$$\chi_1 N \to \chi_2 N$$

$$\chi N \to N$$

$$\chi_2 N \to \chi_1 N$$

$$\chi p \to p(\chi N \to \chi N)$$

$$\chi_2\chi_2 \to \chi_1(\chi_1 N \to \chi_1 N)$$

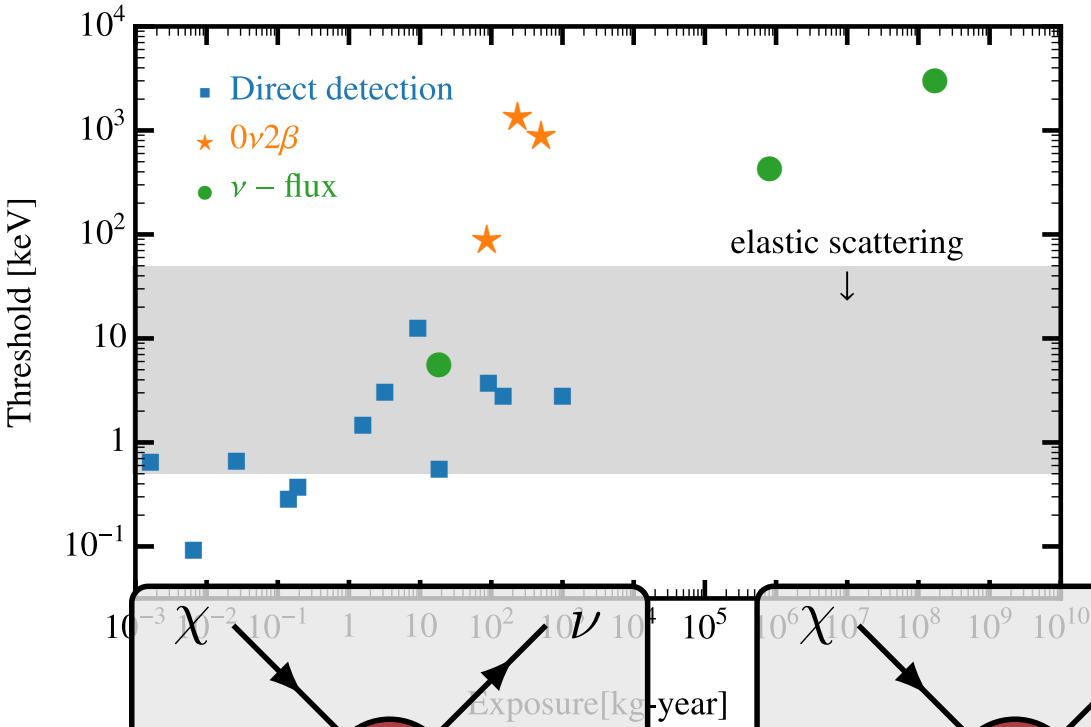
$$\chi_2 N \to \chi_1^* N$$

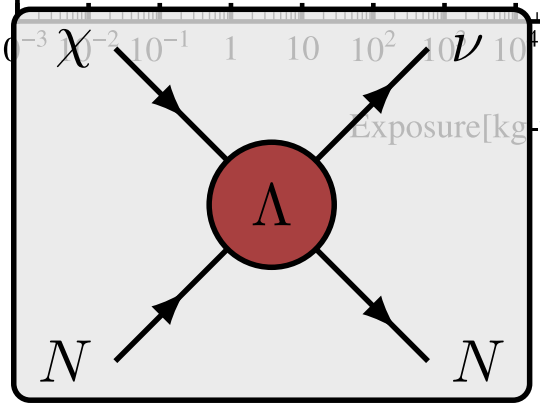
$$\chi N \to eN$$

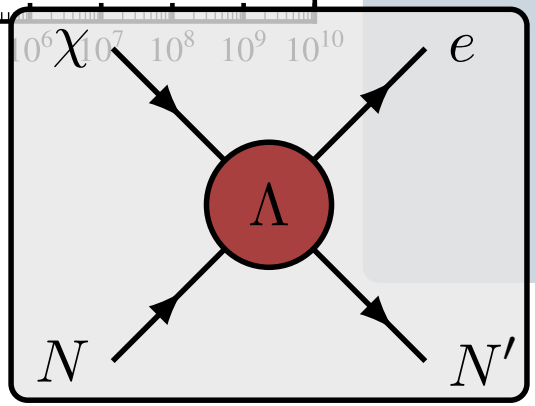
$$\chi N \to \nu N$$

Experiment vs Theory

The exposure-threshold tradeoff







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$$\chi_2\chi_2 \to \chi_1(\chi_1 N \to \chi_1 N)$$

$$\chi_2 N \to \chi_1^* N$$

$$\boxed{\begin{array}{c}\chi N \to eN \\ \chi N \to \nu N\end{array}}$$

[0908.3892 - Kile, Soni]
[1905.12635 - JD, Elor, McGehee]
[1908.10861 - JD, Elor, McGehee]
[2008.00743 - Li, Liao]
[2005.13384 - Hurtado et al]

Nuclear transitions ("charged current")

β^- :

β^+ :

Nuclear transitions ("charged current")

$$\beta^- : \qquad \chi + n \to p + e^- \;\Rightarrow\; \chi + {}^{A}_{Z}\mathrm{N} \to {}_{Z+1}^{A}\mathrm{N} + e^-$$

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unstable

stable

β decays w/o DM	~~β decay w/o DM~~
Thresholdless	$m_{\mathrm{th}} \equiv M_{A,Z+1} + m_e - M_{A,Z}$
Arbitrarily light χ	Need: $m_\chi > m_{\mathrm{th}} \sim \mathrm{MeV}$
Small experiments	Large experiments

Nuclear transitions ("charged current")

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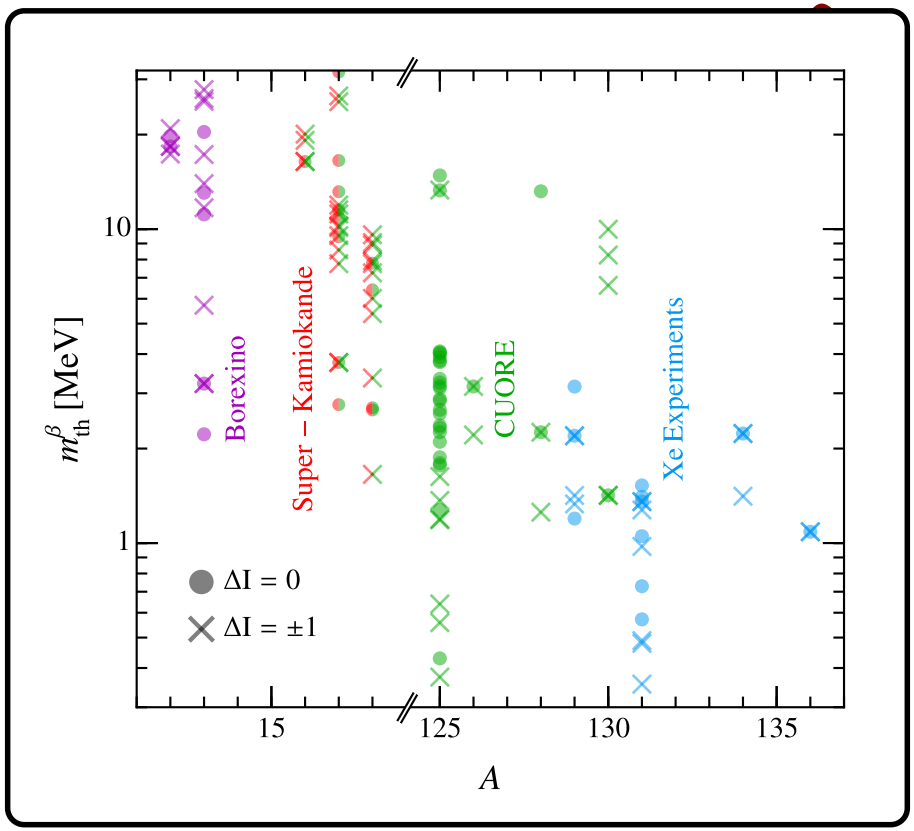

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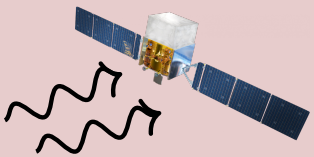
Large experiments

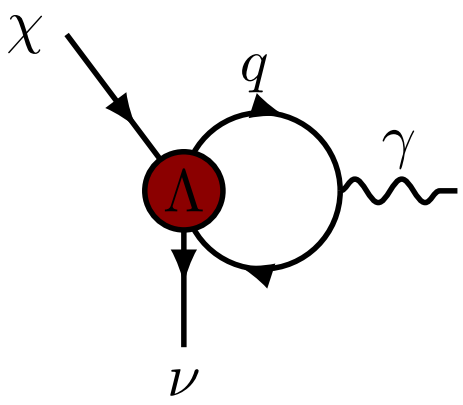
Decays and other bounds

Consistency checks

Decays



$\chi \to \nu\gamma$



Decays and other bounds

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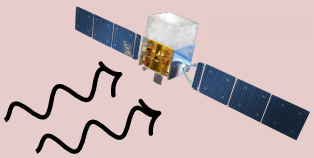

$$\chi \to \nu\gamma$$

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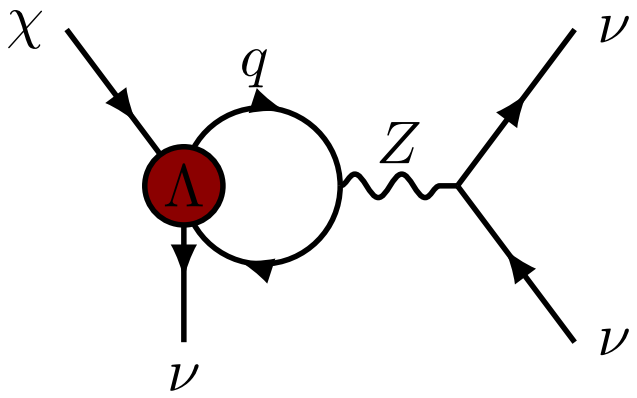

Decays and other bounds

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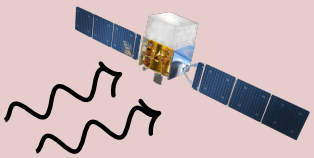

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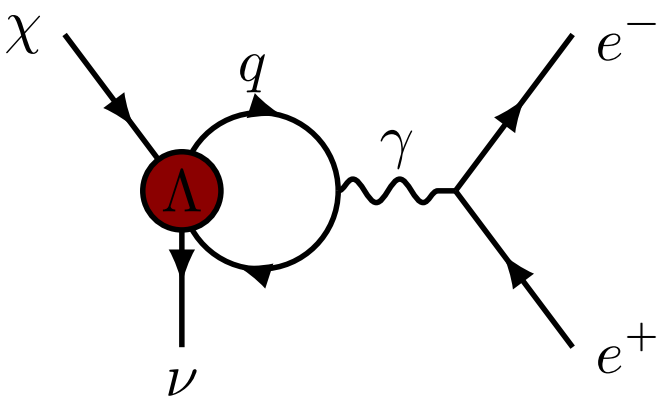

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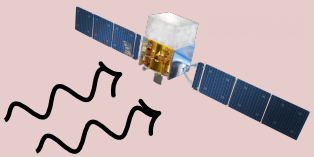

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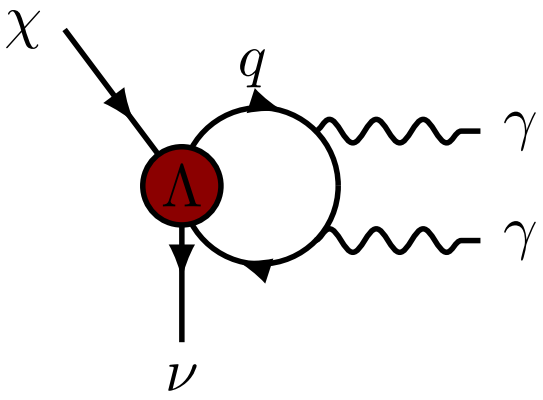

Decays and other bounds

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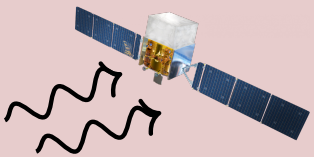

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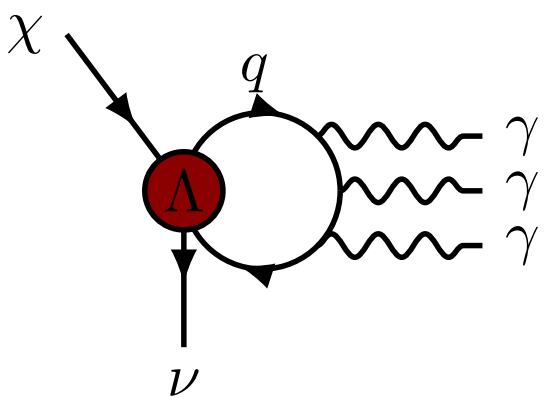

Decays and other bounds

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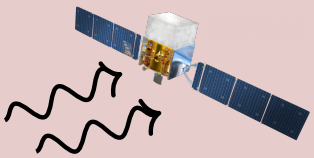

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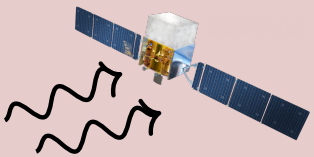
Direct production

Decays and other bounds

Consistency checks

Decays



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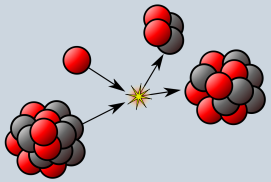
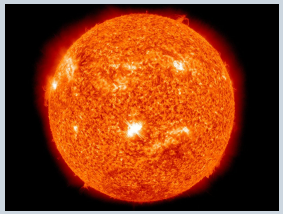
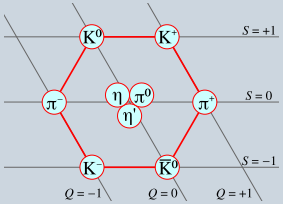
Direct production

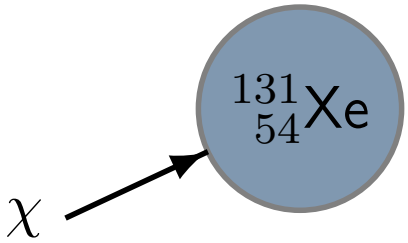


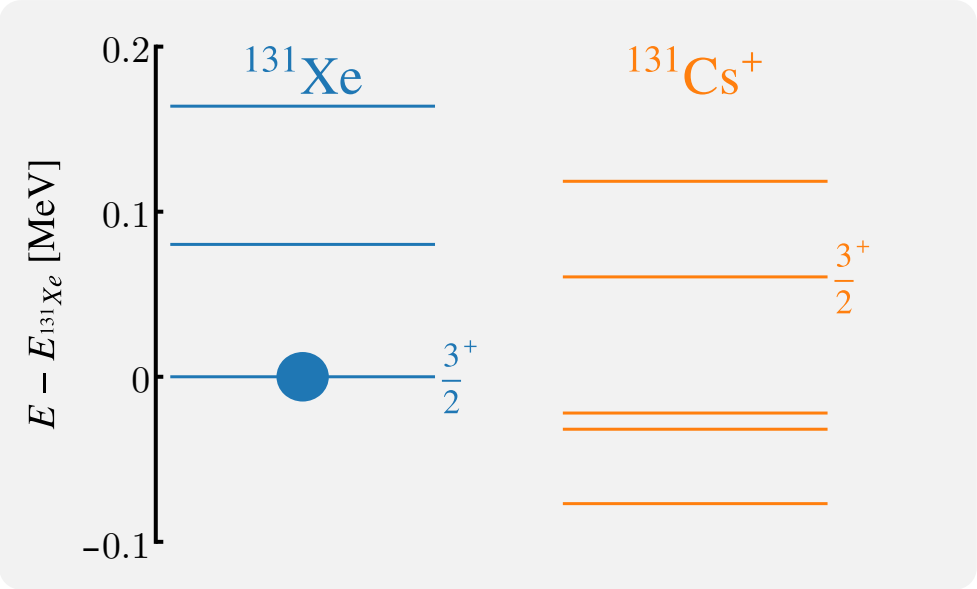




Signal

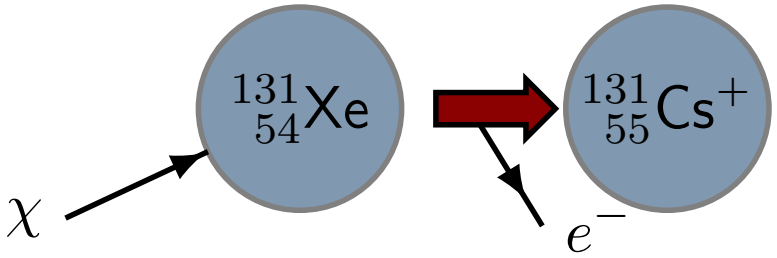
charged current process in Xenon

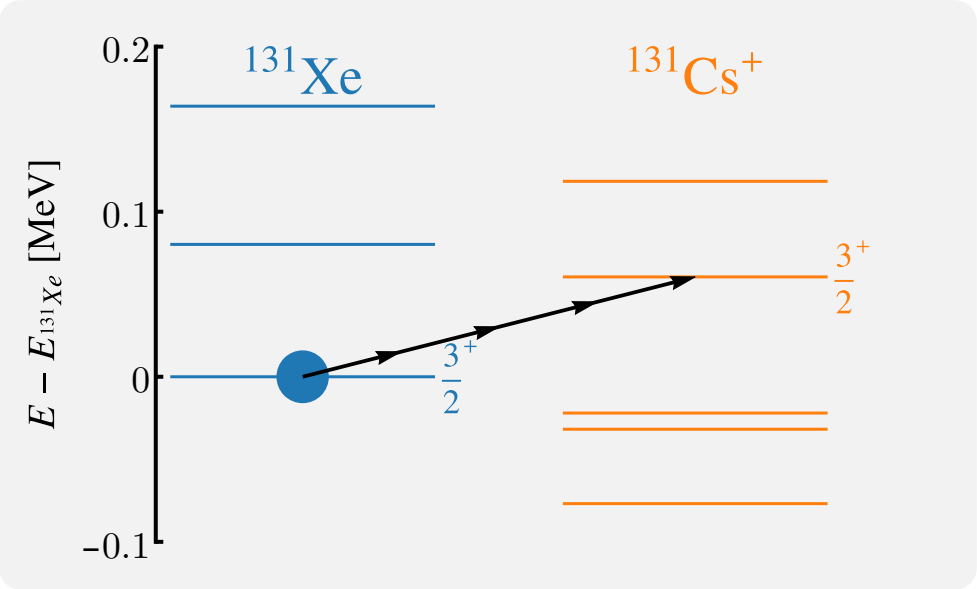




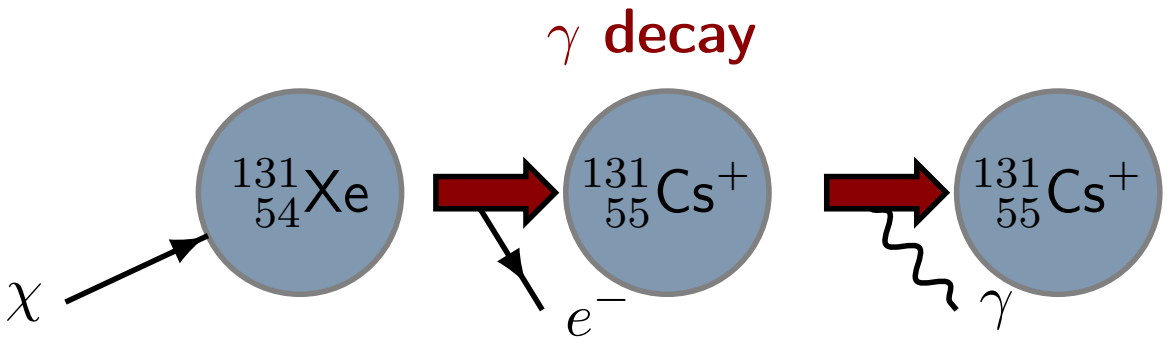
Signal

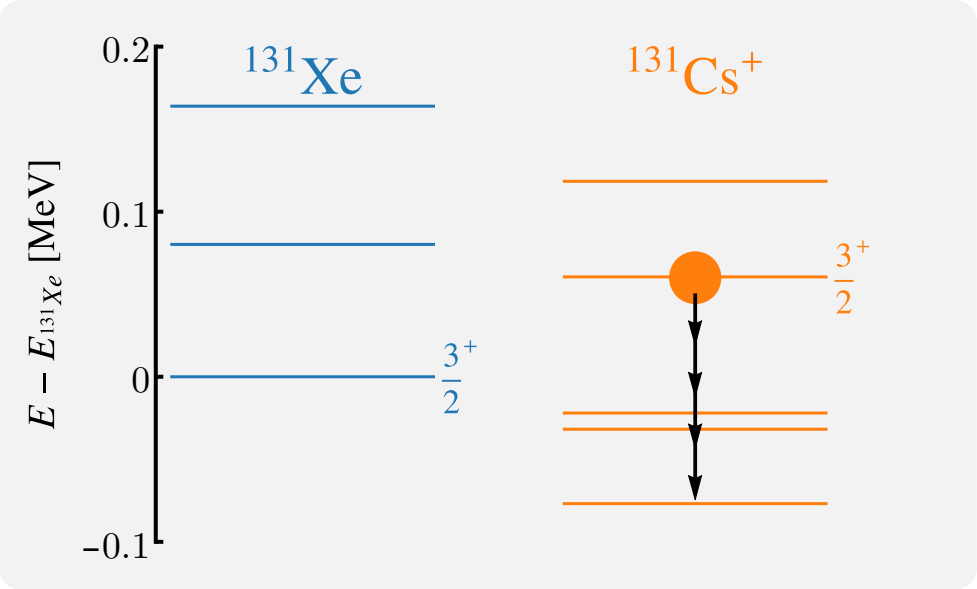
shoot off electron + nuclear recoil





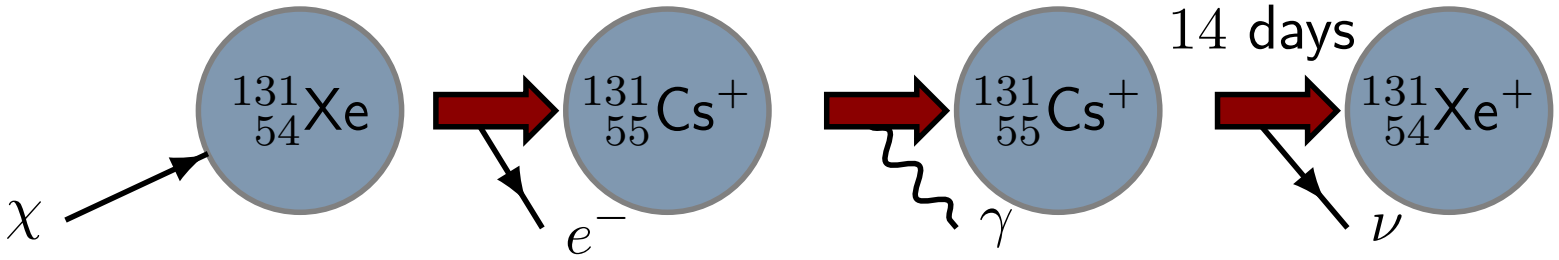
Signal

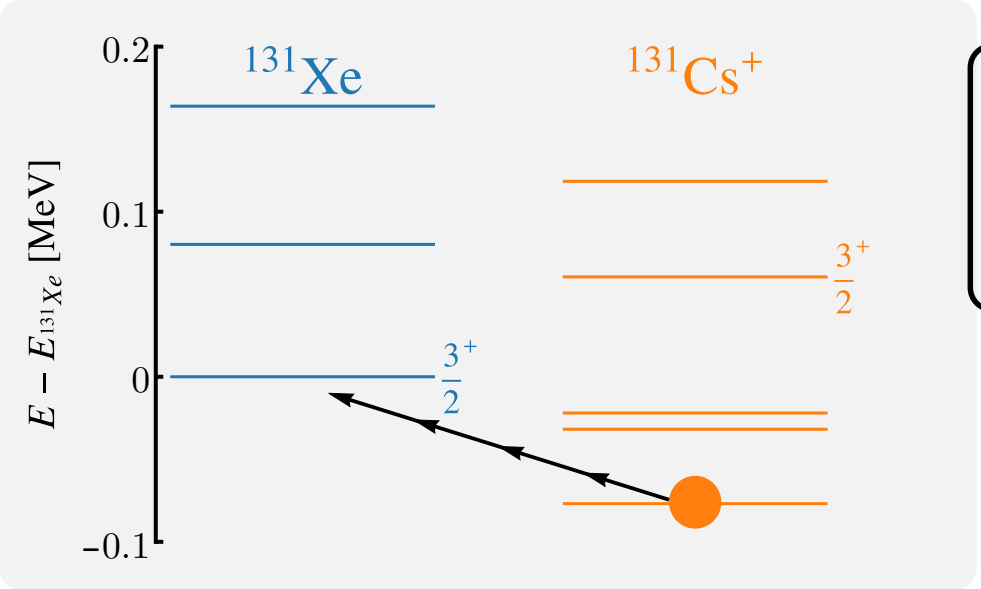

γ decay
χ
$^{131}_{54}$Xe
$^{131}_{55}$Cs$^+$
e^-
$^{131}_{55}$Cs$^+$
γ


$E - E_{^{131}Xe}$ [MeV]
0.2
0.1
0
−0.1
^{131}Xe
$\frac{3}{2}^+$
^{131}Cs$^+$
$\frac{3}{2}^+$

Signal

swallow an electron + nuclear recoil



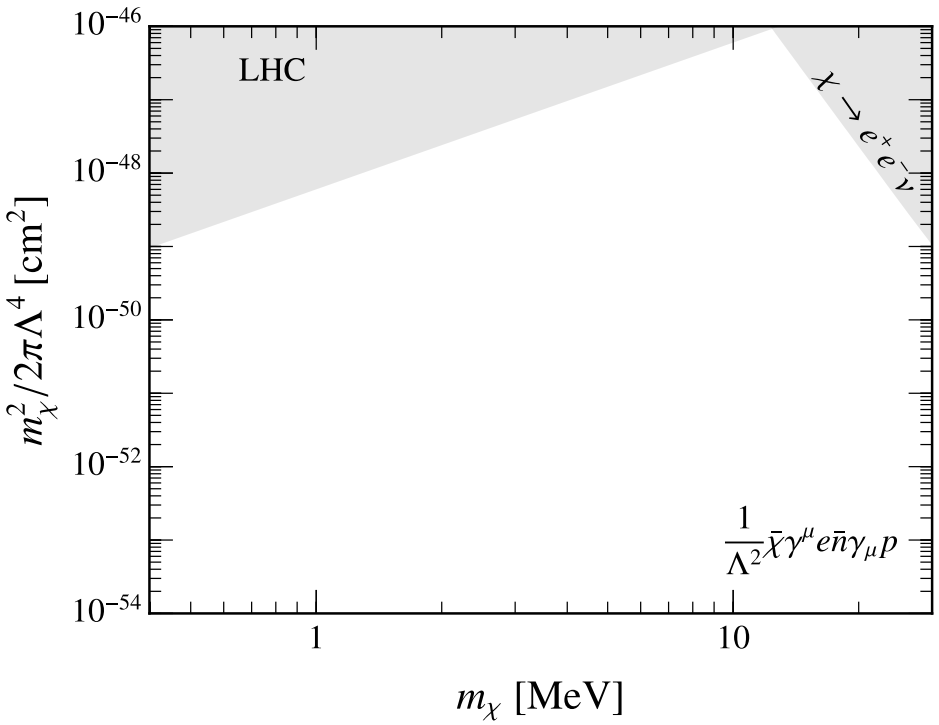


Details depend on isotope

See [2009.00535 - Haselschwardt et al] for ideas using timing and topology

Projections

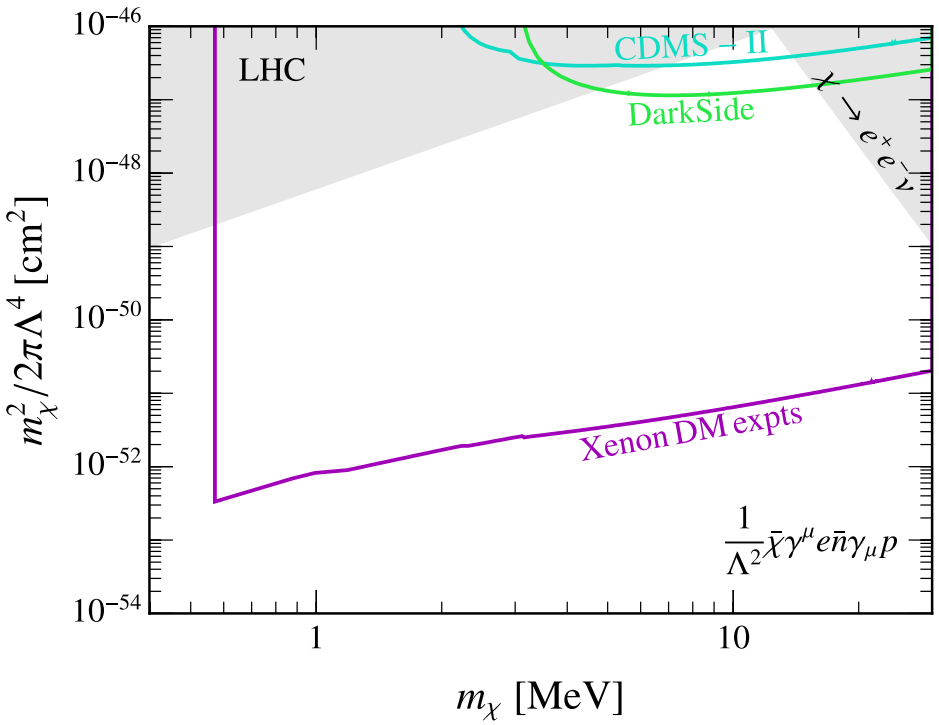
$$\chi + {}^{A}_{Z}\mathrm{N} \to {}^{A}_{Z+1}\mathrm{N} + e^-$$



other bounds

Projections

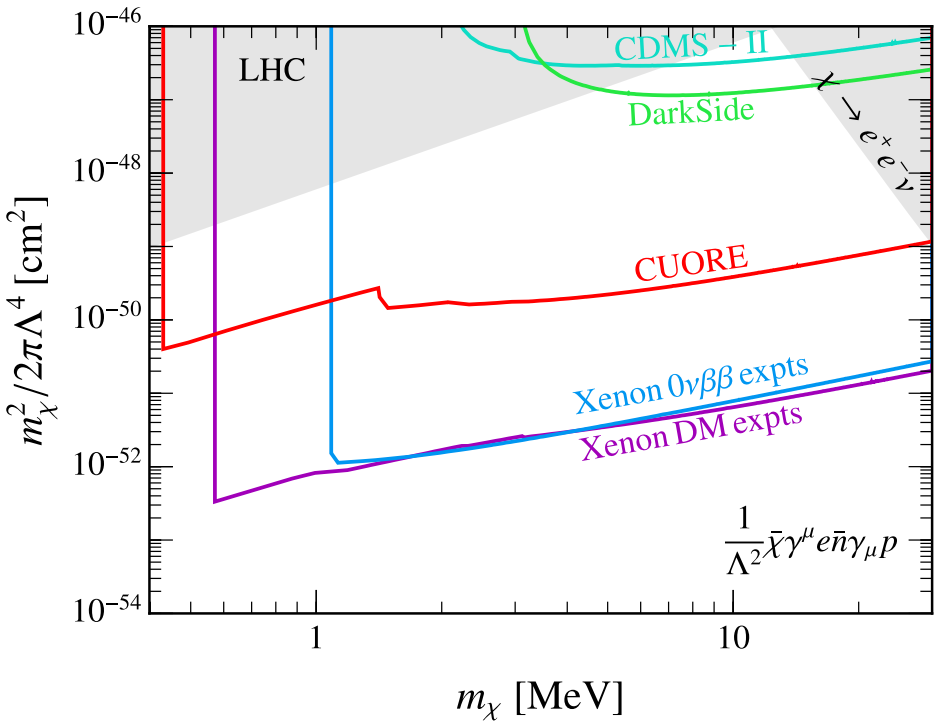
$$\chi + {}^{A}_{Z}\mathrm{N} \rightarrow {}^{A}_{Z+1}\mathrm{N} + e^{-}$$



Direct detection

Projections

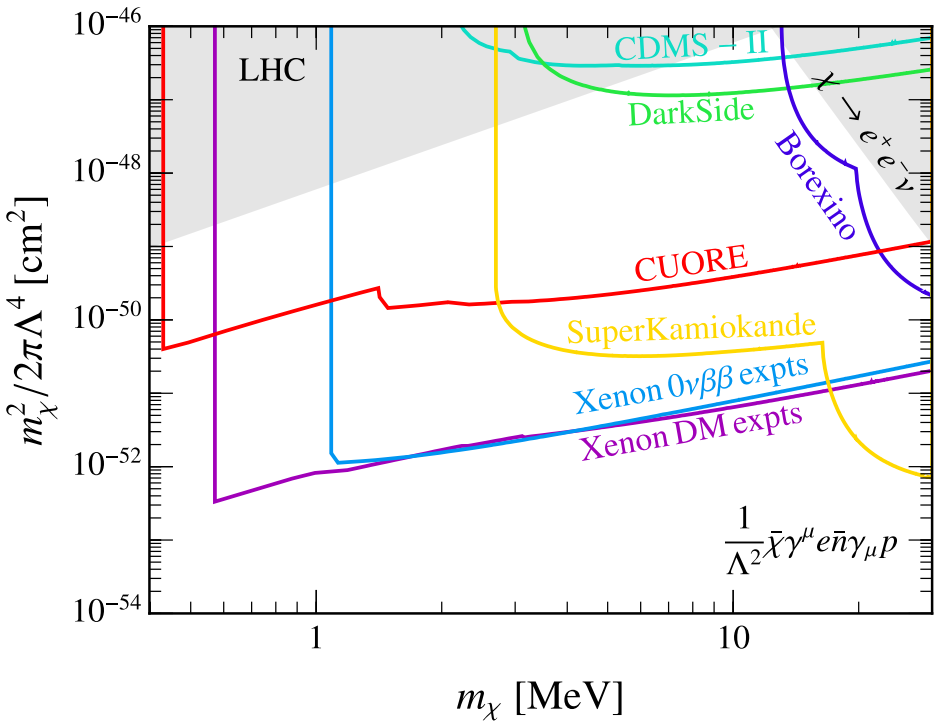
$$\chi + {}^{A}_{Z}\mathrm{N} \rightarrow {}^{A}_{Z+1}\mathrm{N} + e^{-}$$



$0\nu 2\beta$

Projections

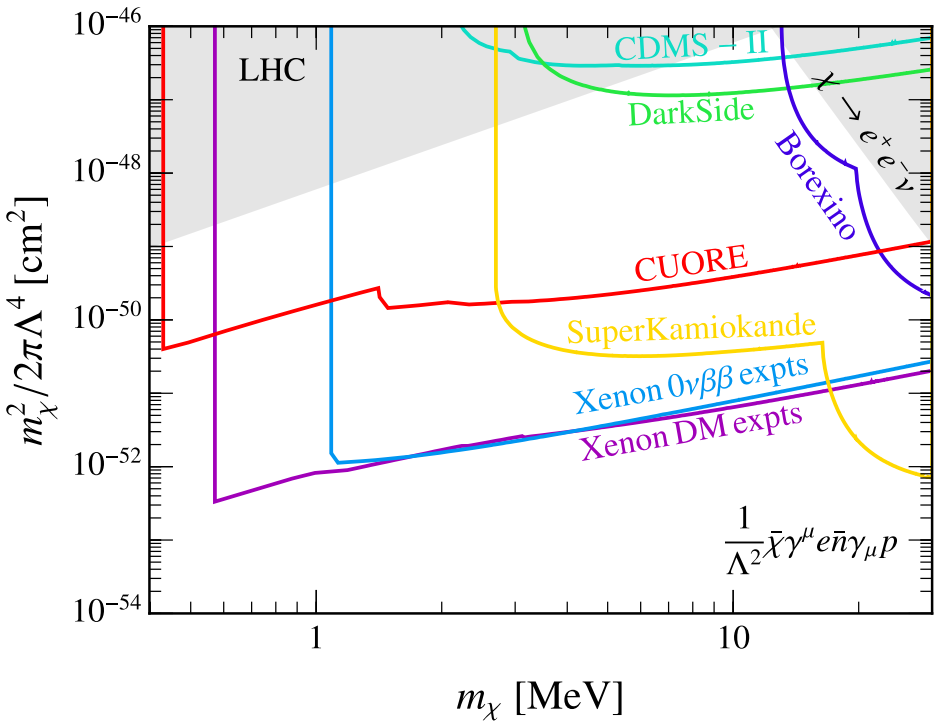
$$\chi + {}^{A}_{Z}\mathrm{N} \rightarrow {}^{A}_{Z+1}\mathrm{N} + e^{-}$$



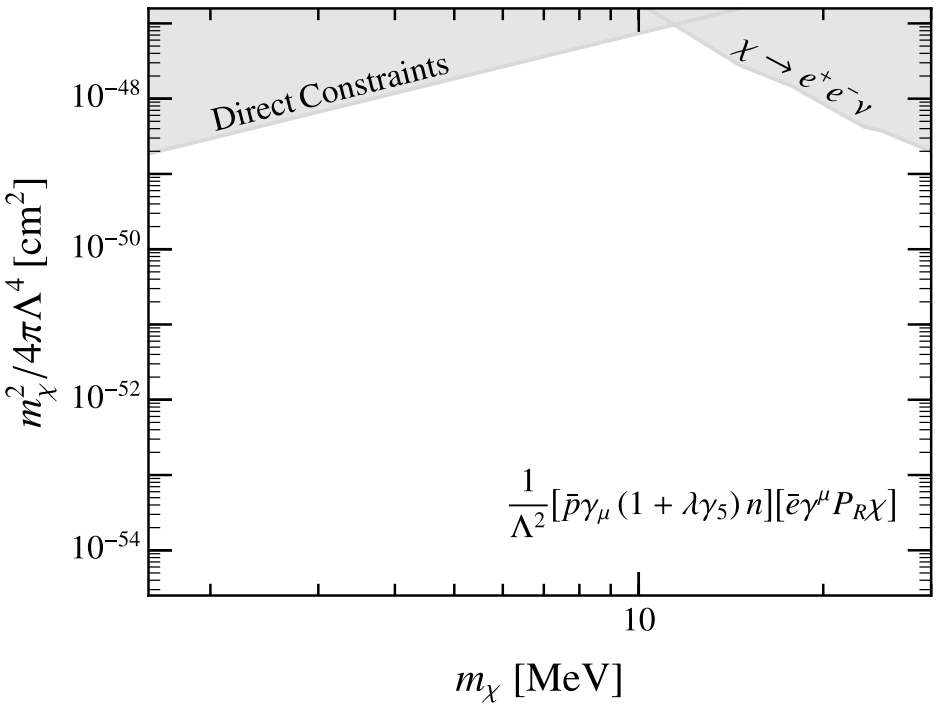
Neutrino flux

Projections

$$\chi + {}^{A}_{Z}\mathrm{N} \to {}^{A}_{Z+1}\mathrm{N} + e^-$$

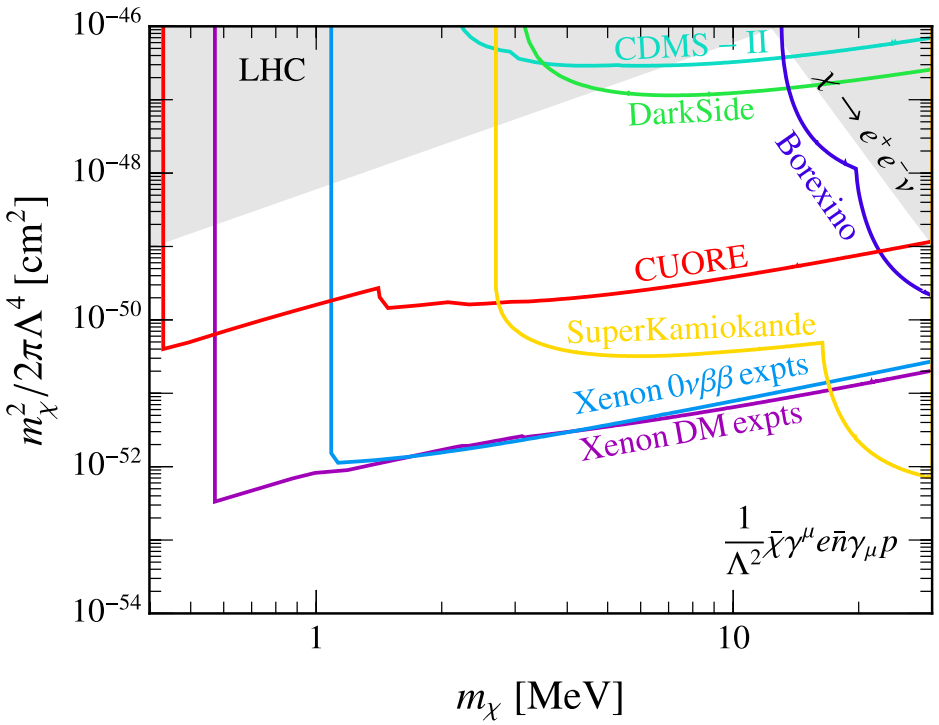


$$\chi + {}^{A}_{Z}\mathrm{N} \to {}^{A}_{Z-1}\mathrm{N} + e^+$$

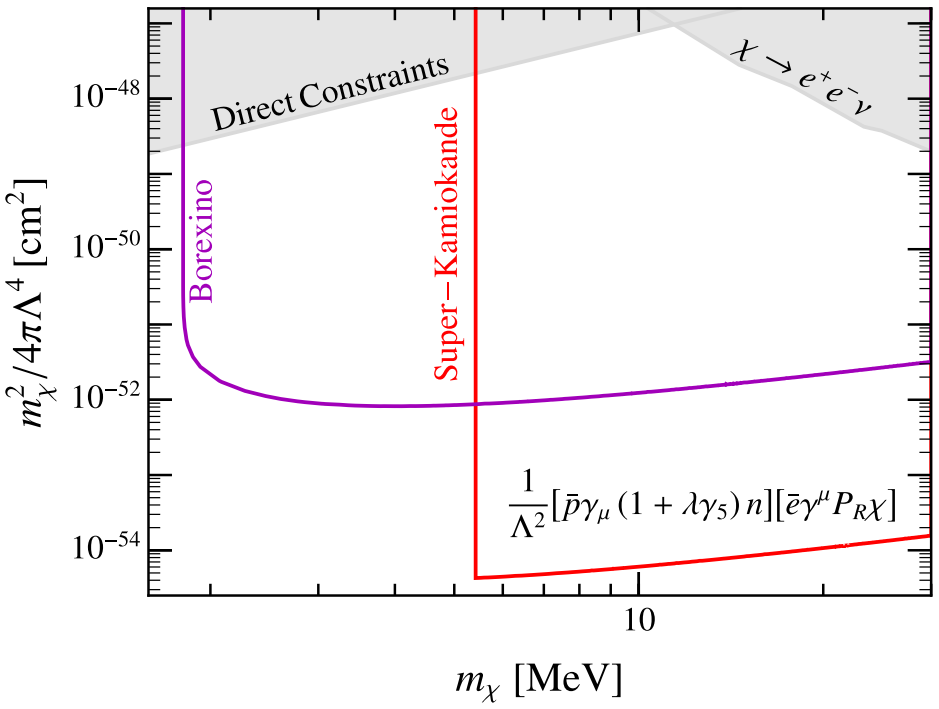


Projections

$$\chi + {}^{A}_{Z}\mathrm{N} \to {}^{A}_{Z+1}\mathrm{N} + e^-$$



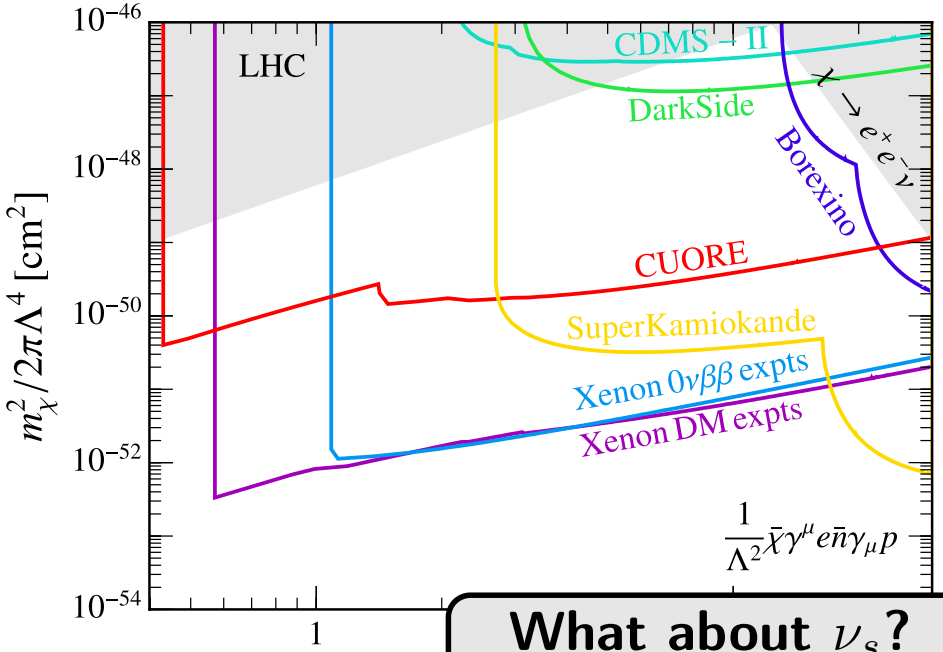
$$\chi + {}^{A}_{Z}\mathrm{N} \to {}^{A}_{Z-1}\mathrm{N} + e^+$$



Several orders of magnitude!

Projections

$$\chi + {}^{A}_{Z}\mathrm{N} \to {}^{A}_{Z+1}\mathrm{N} + e^-$$



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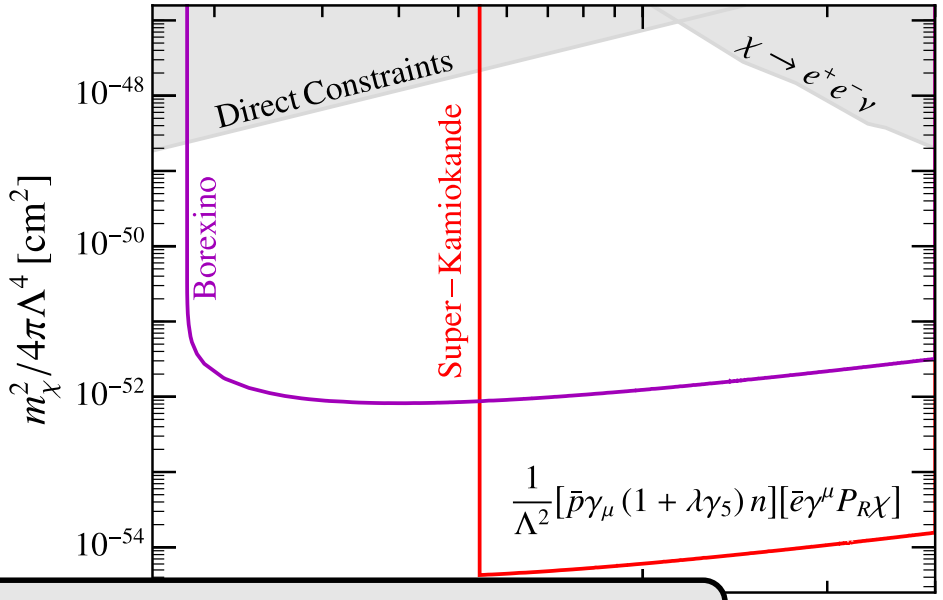
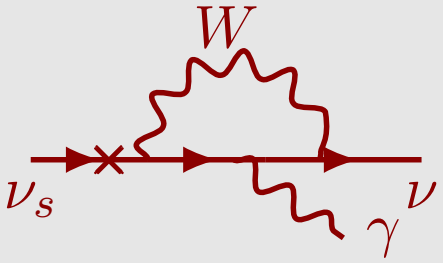
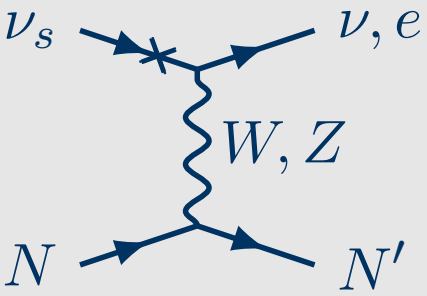


What about ν_s?





Nuclear transitions ("charged current")

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$$\beta^+ : \qquad \bar{\chi} + p \to n + e^+ \;\Rightarrow\; \chi + {}^{A}_{Z}\mathrm{N} \to {}_{Z-1}^{A}\mathrm{N} + e^+$$

unstable

stable

β decays w/o DM	~~β decay w/o DM~~
thresholdless	$m_{\mathrm{th}} \equiv M_{A,Z+1} + m_e - M_{A,Z}$
arbitrarily light χ	need: $m_\chi > m_{\mathrm{th}} \sim \mathrm{MeV}$
small experiments	large experiments

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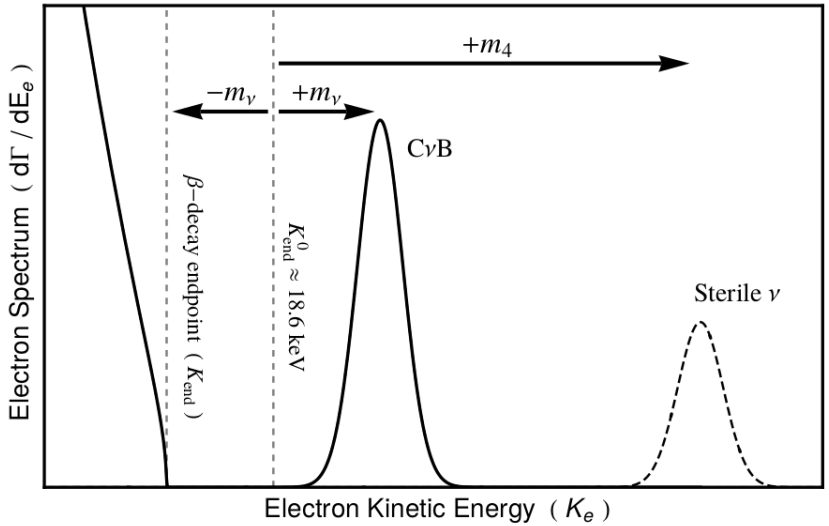


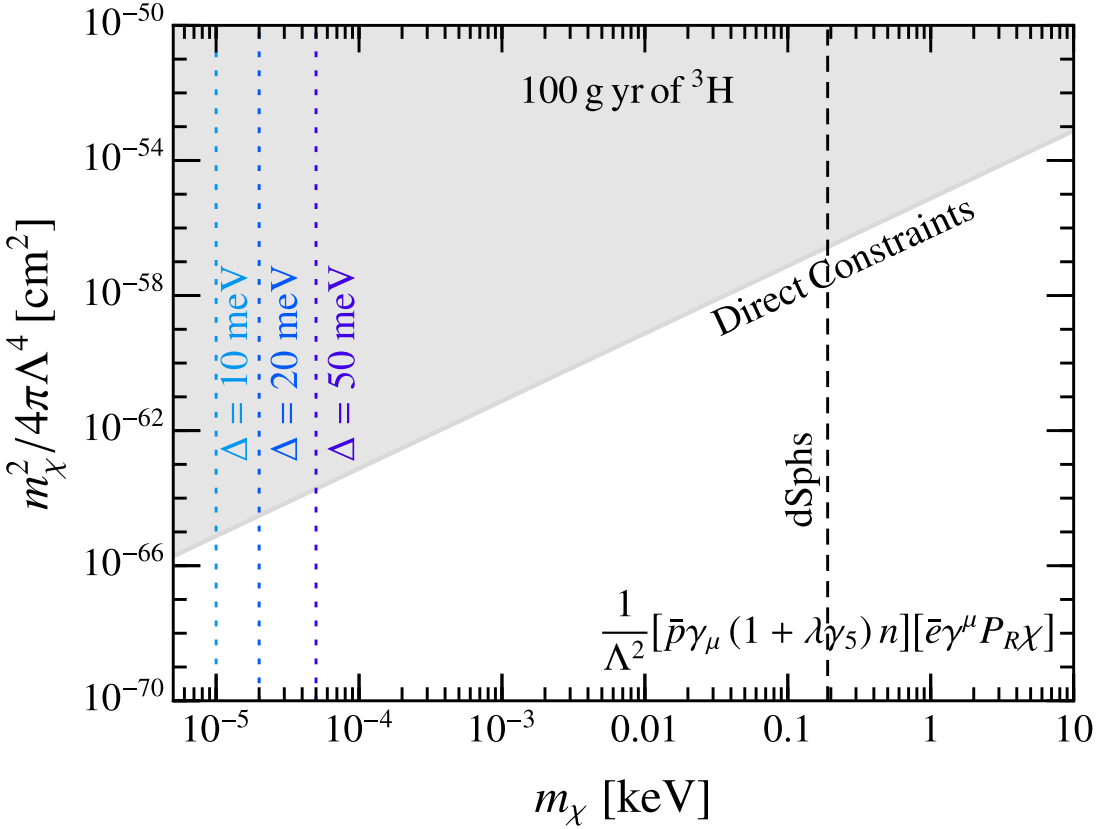
[Long, Lunardini, Sabancilar - 1405.7654]

large experiments

β endpoint

For "PTOLEMY"-type experiment SM: ${}^3_1\mathrm{H} \to {}^3_2\mathrm{He} + e^- + \nu$

DM: $\chi + {}^3_1\mathrm{H} \to {}^3_2\mathrm{He} + e^-$



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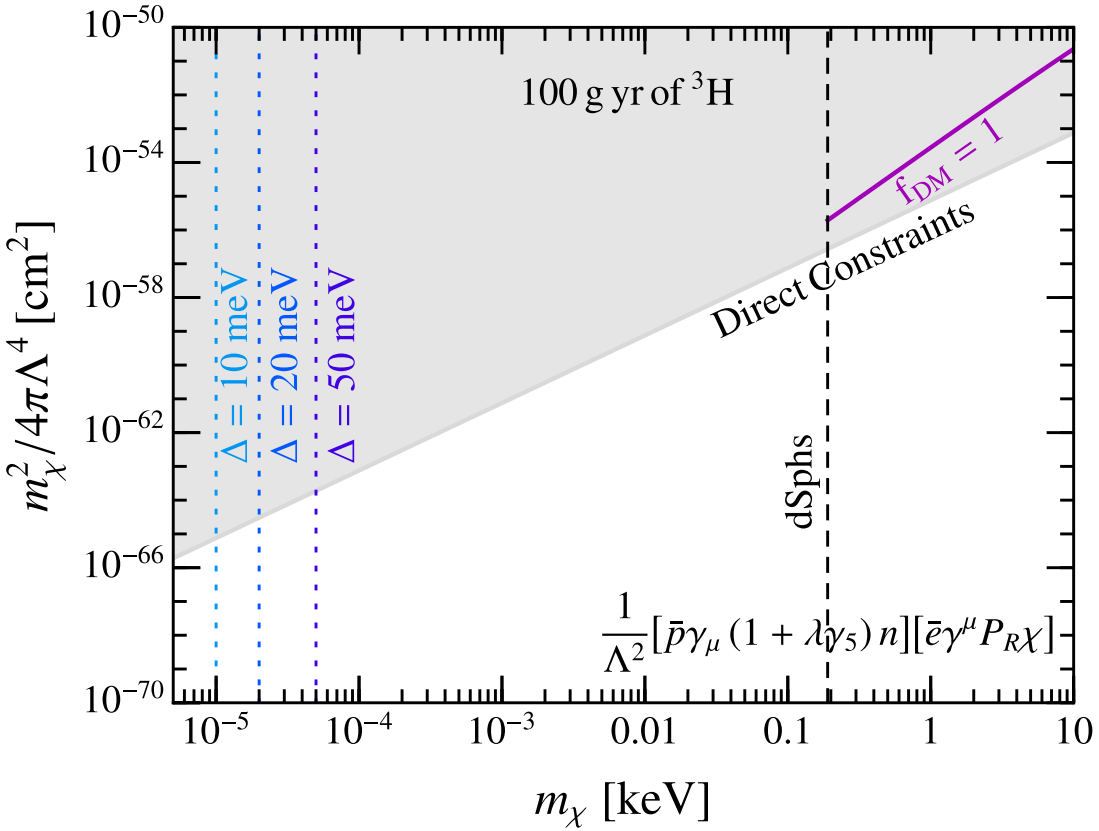

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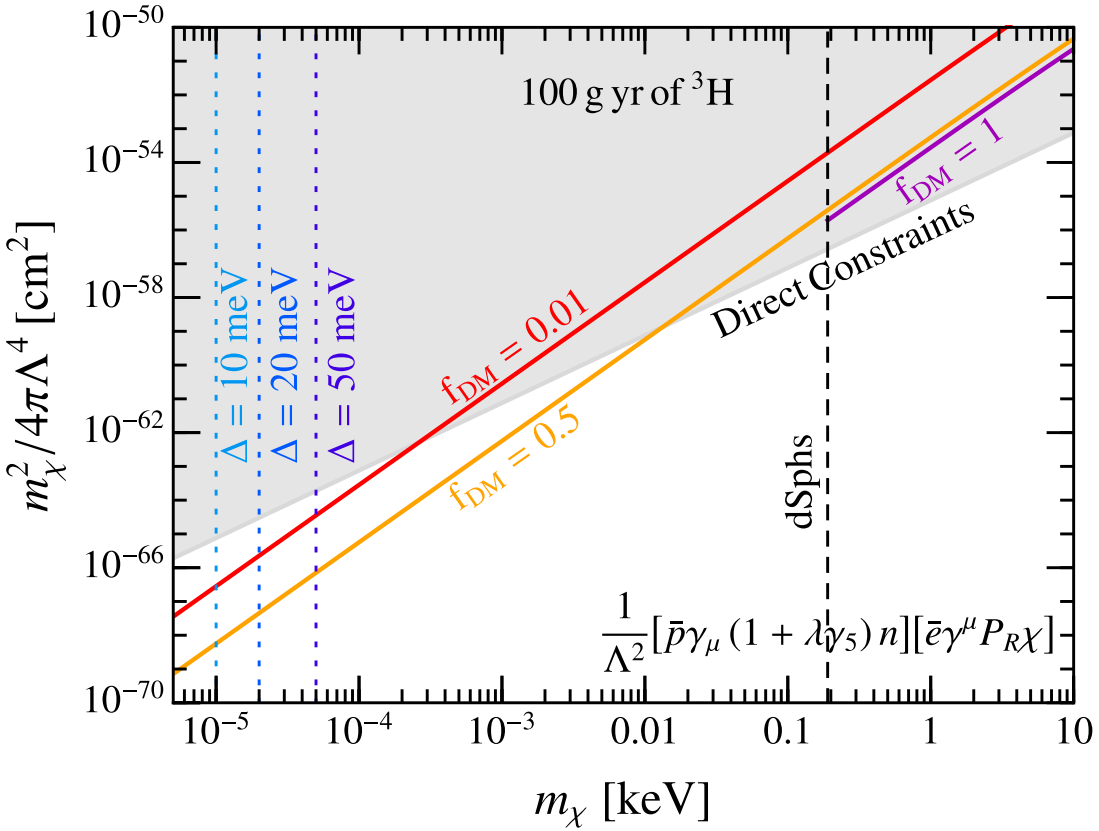
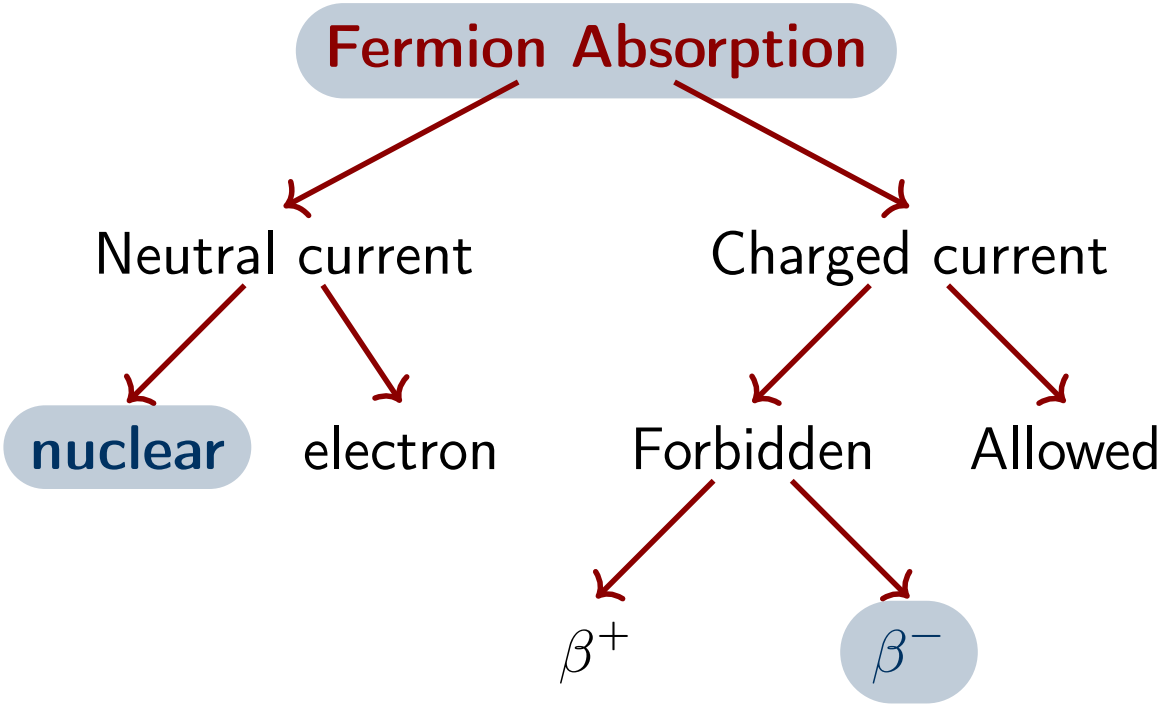


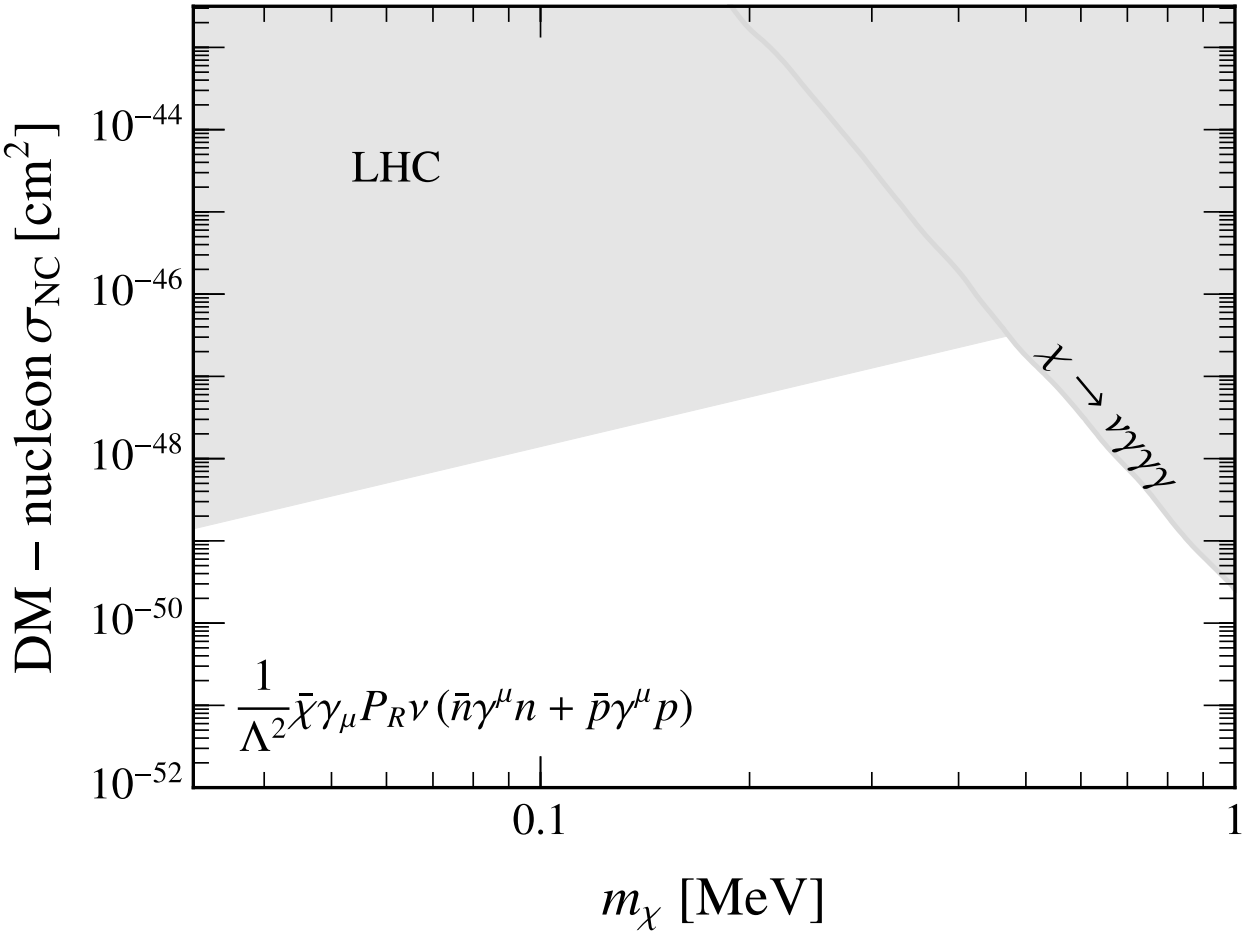
Conclusions

Can fermions be absorbed in DM experiments?



Nuclear neutral current

Projected sensitivity in LiH ($\sigma_{\rm NC} \equiv m_\chi^2/4\pi\Lambda^4$) - ^{6}Li, ^{7}Li,H



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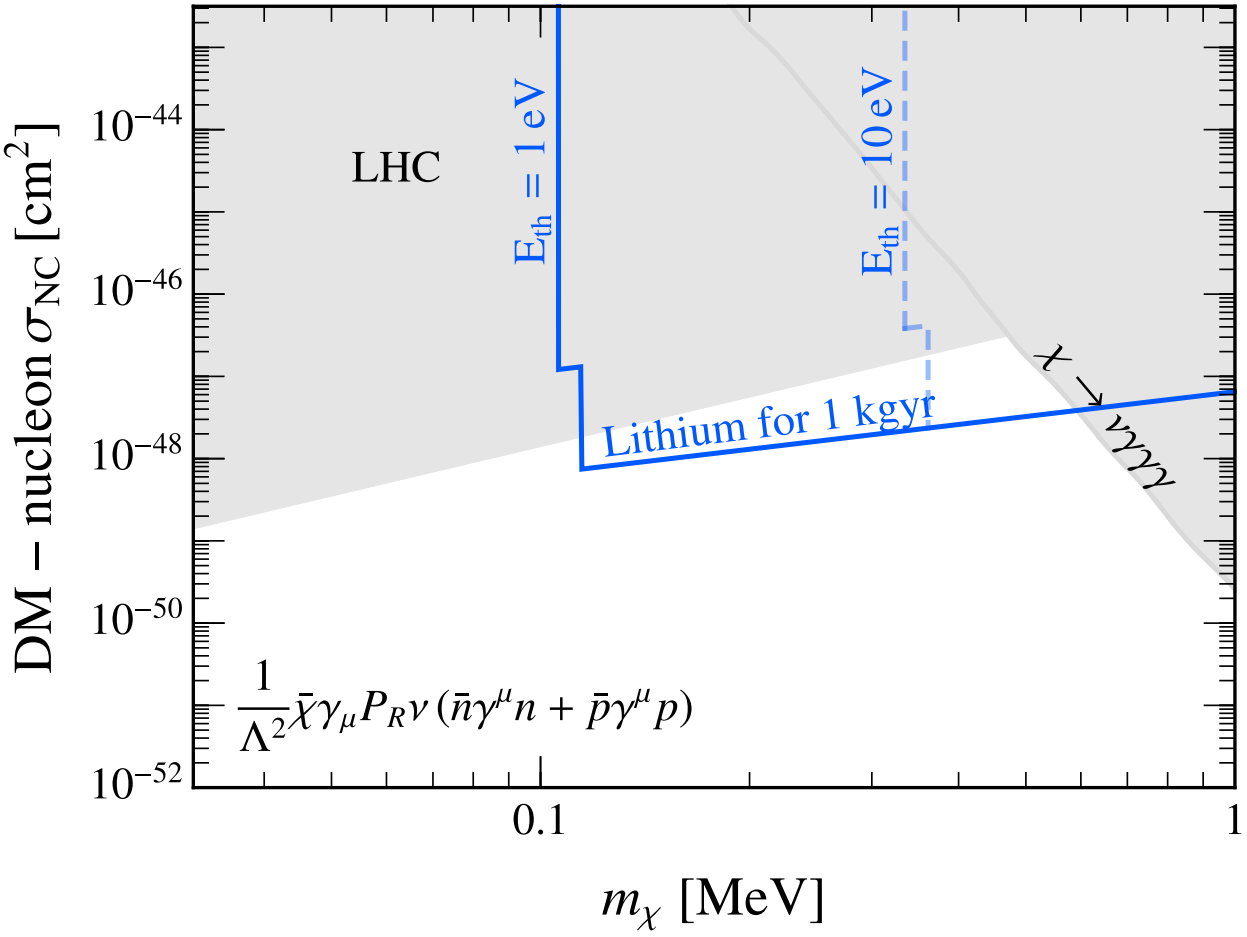

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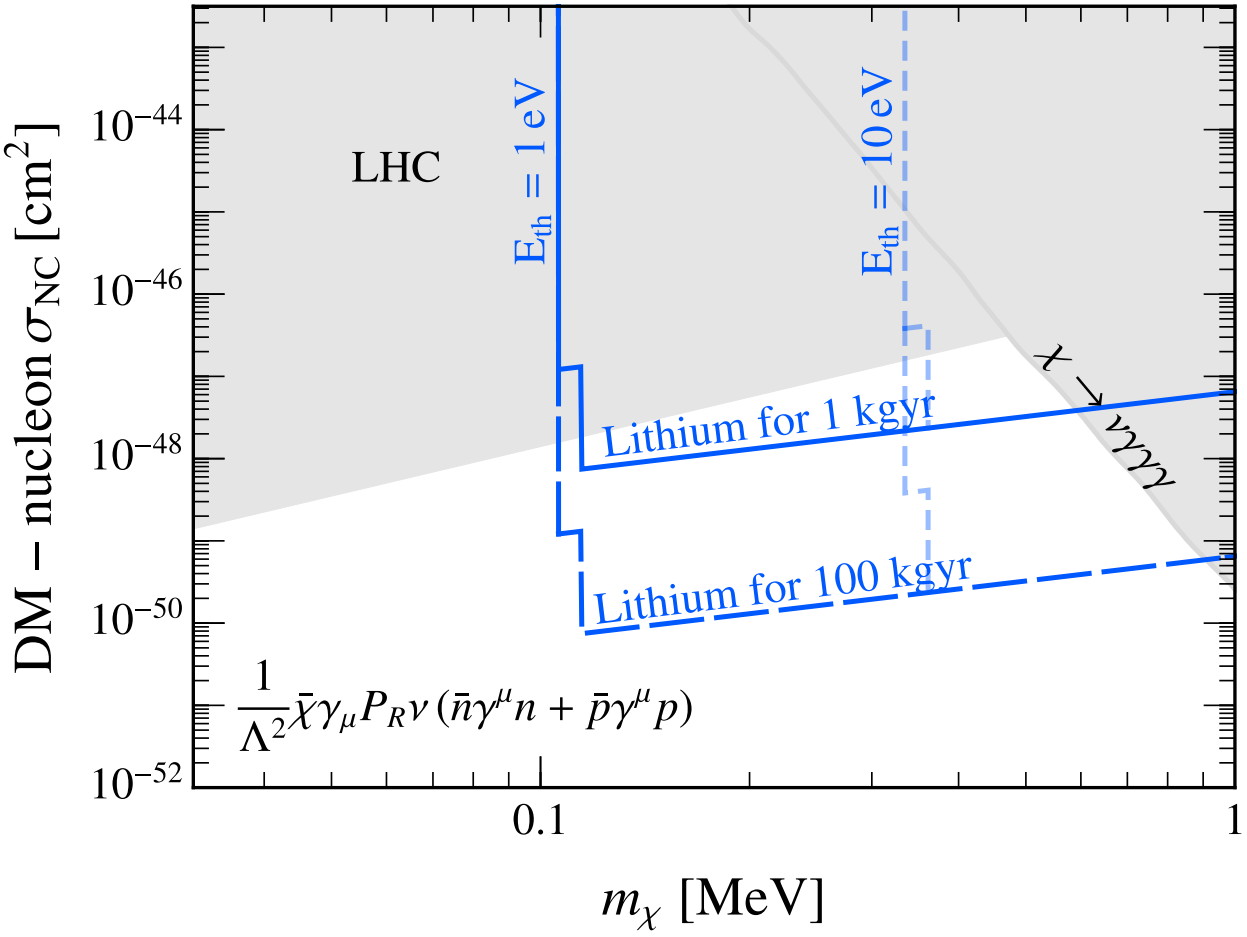

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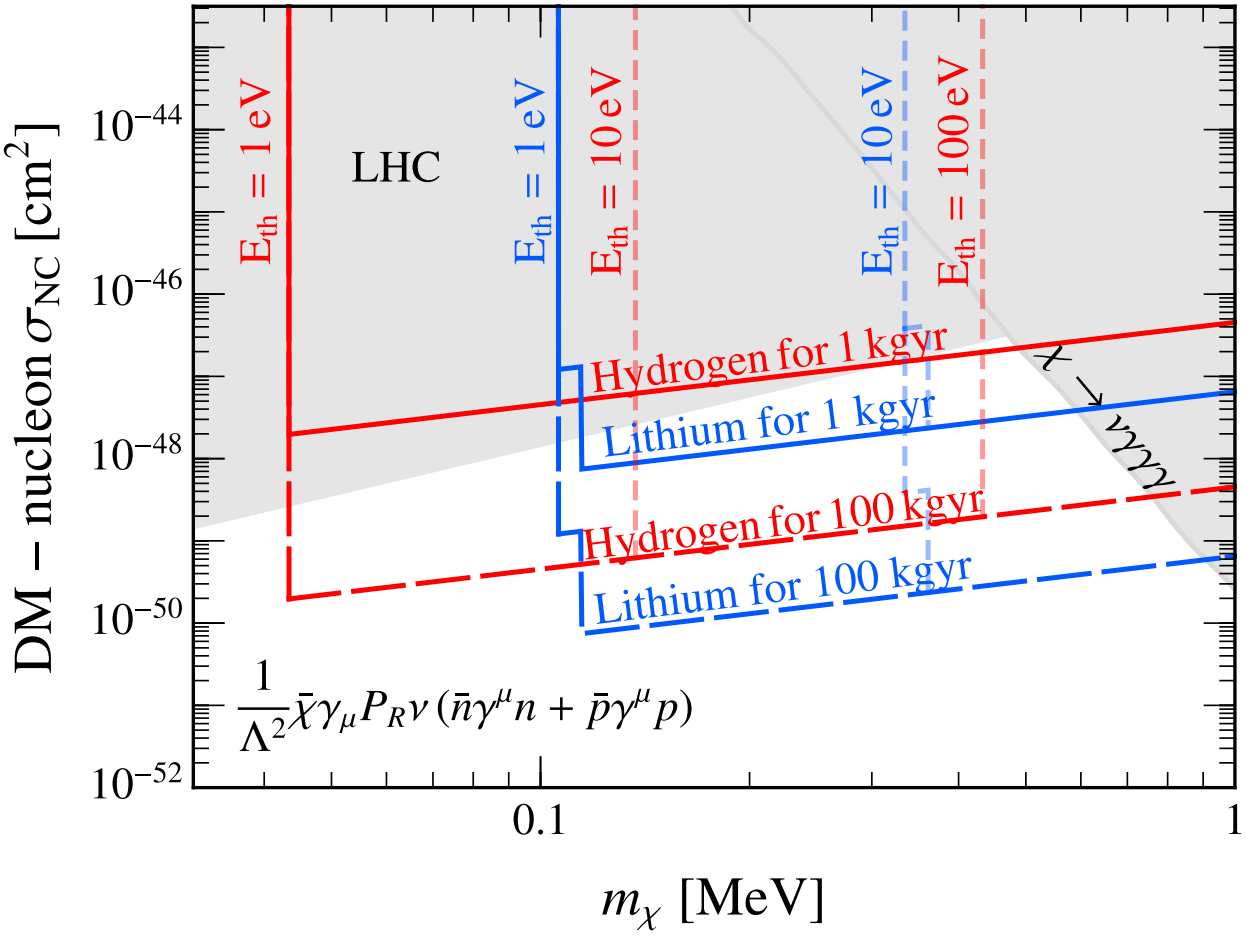
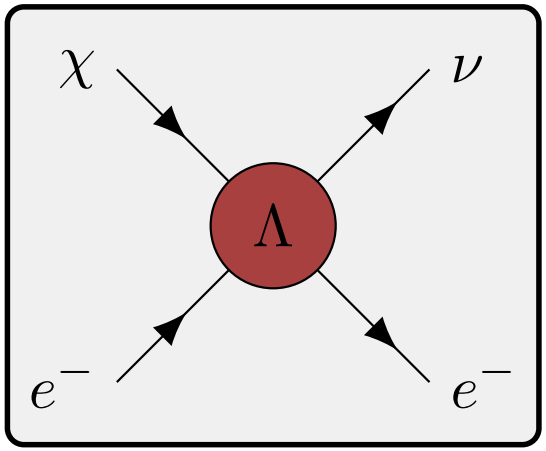


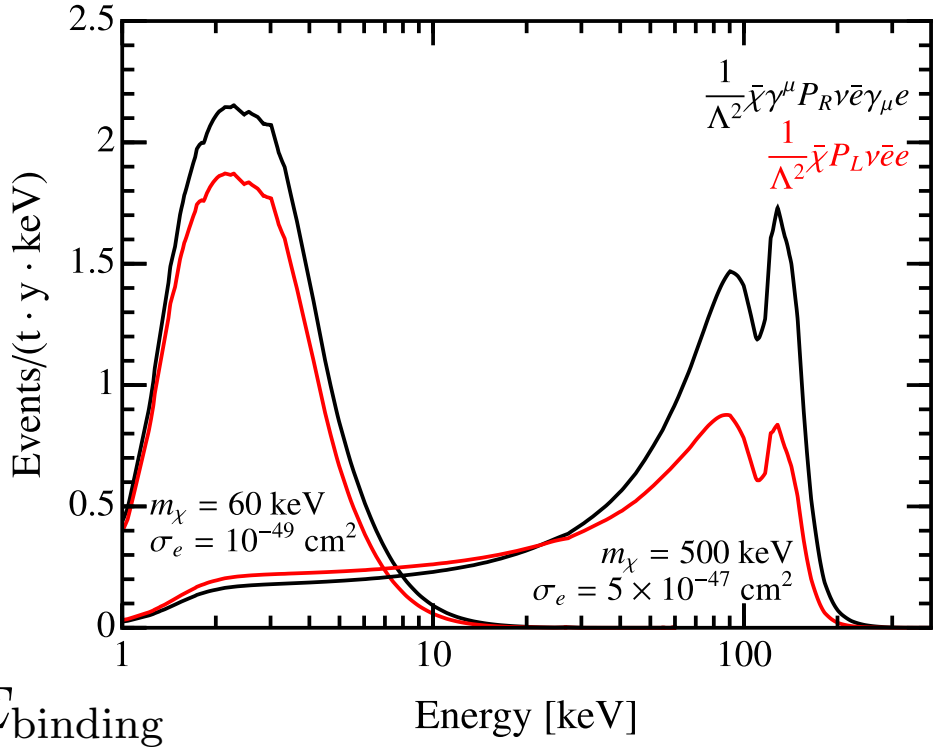
[LiH considered in: Budnik,Chesnovsky,Slone,Volansky - 1705.03016]

Electron scattering

Fermionic absorption off electrons?



preliminary



Ionize bound electrons

Well suited for $m_\chi \lesssim m_e$

Peaked spectra for $m_\chi \gg E_{\text{binding}}$

[20XX.XXXXX - JD, Elor, McGehee, Yu]

Electron scattering

Fermionic absorption off electrons?

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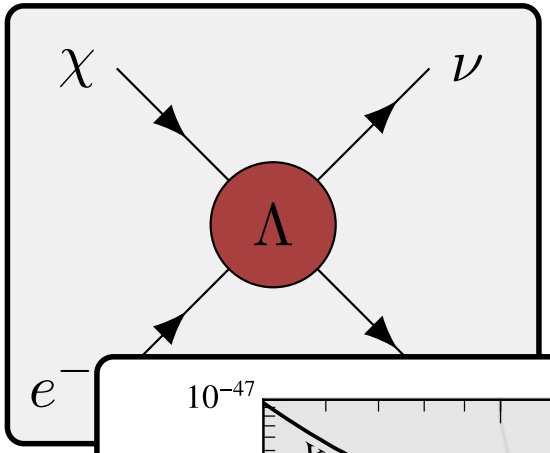

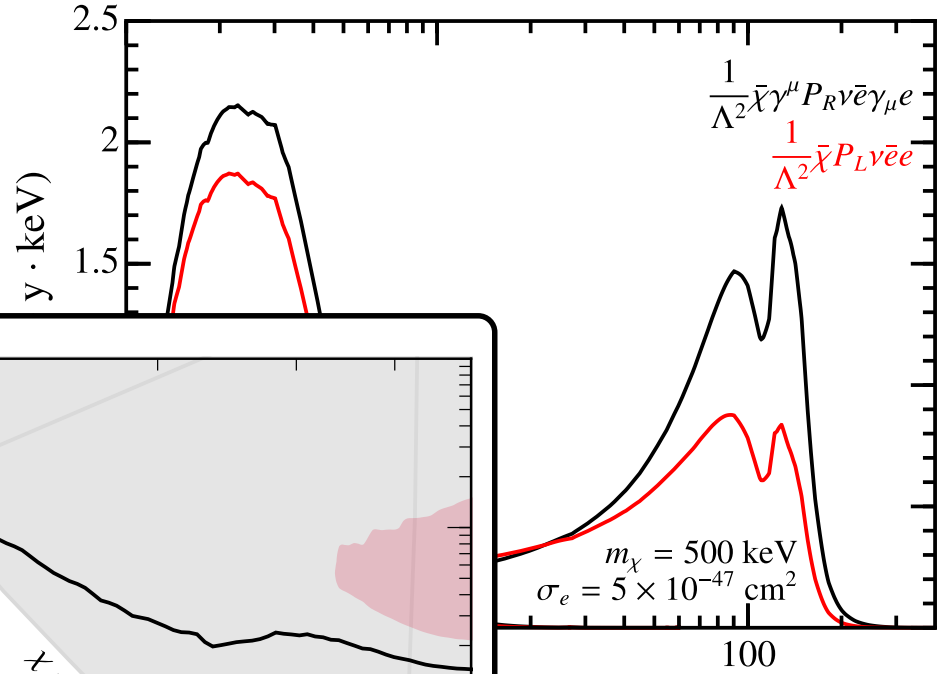

Ionize b

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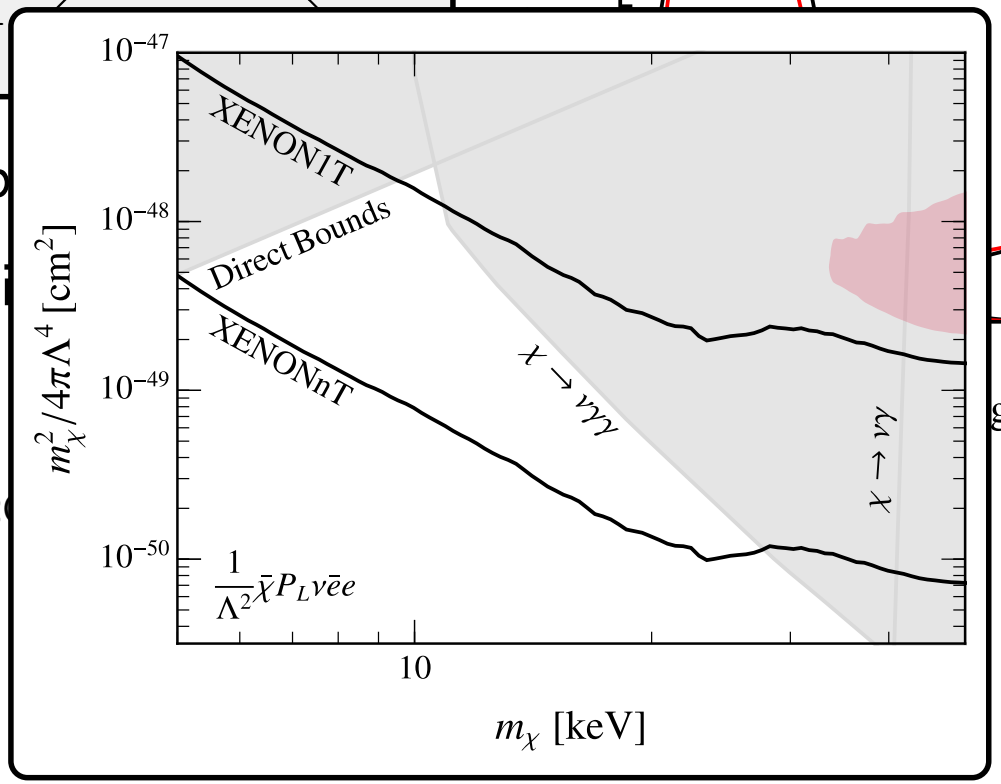
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