# Co-SIMP Miracle

**Juri Smirnov**

PHENO 2020: 05/05/20

In collaboration with: John Beacom (OSU, CCAPP)

# Dark Matter is a New Particle

Juri Smirnov, smirnov.9@osu.edu, CCAPP @ OSU; PHENO, 05/05/20

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Not ordinary Matter: $\Omega_{\mathrm{DM}} >> \Omega_{\mathrm{Baryons}}$

(CMB) (BBN, CMB)

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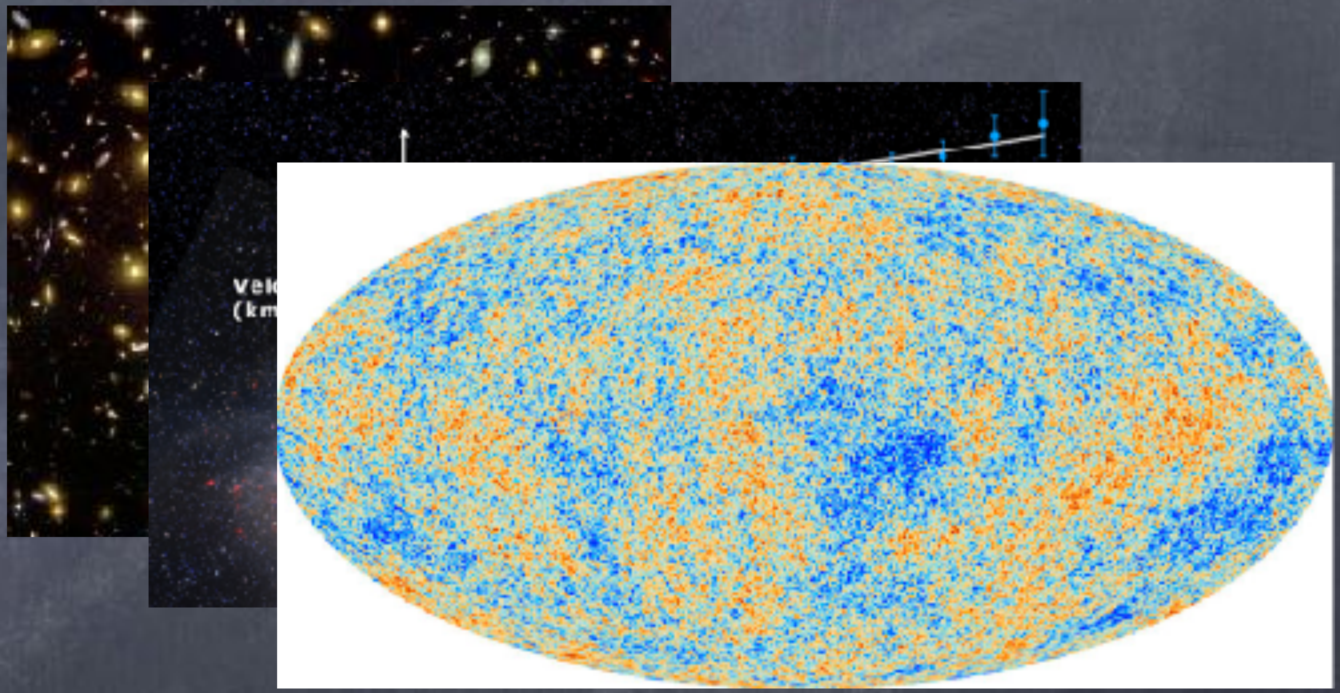

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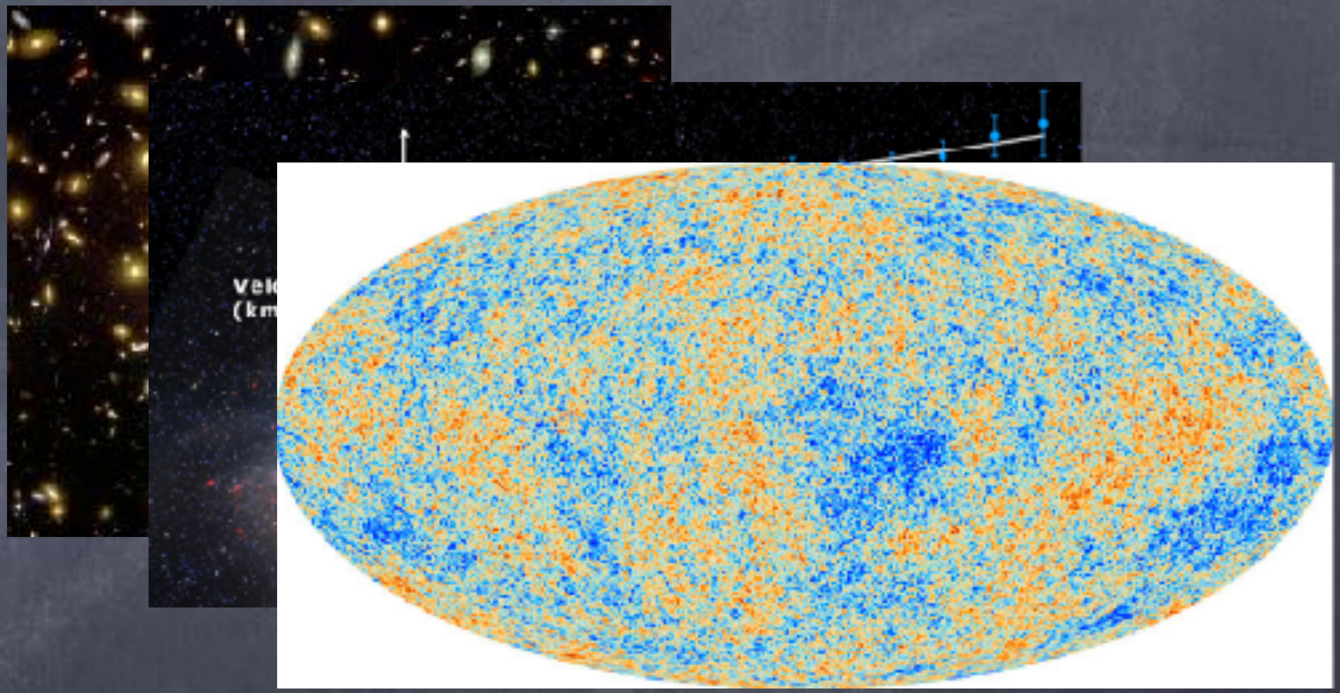

Not MOND:

Not light Neutrinos:

$$\Omega_\nu \approx 0.02 \left(\frac{m_\nu}{\mathrm{eV}}\right)$$

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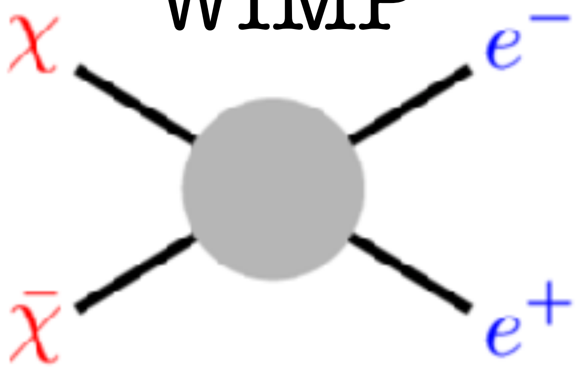
# Production

# Freezeout

**WIMP**

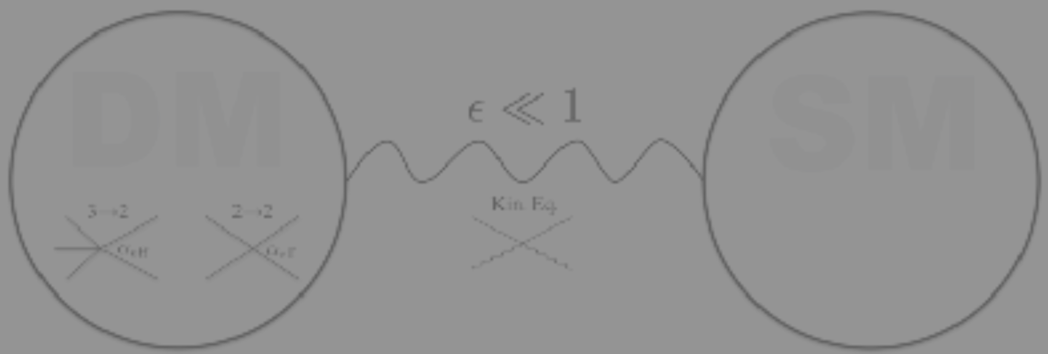


Zeldovich, Lee, Weinberg, Steigman, Turner,...

$$\Gamma_{\rm DM} = \langle \sigma v_{\rm rel.} \rangle \, n_{\rm DM} > H(T)$$

$$\Omega_{\rm DM}\, h^2 \approx \frac{0.12}{\langle \sigma v_{\rm rel.} \rangle \, [25 {\rm TeV}]^2}$$

**SIMP**



Hochberg, Kuflik, Volansky, Wacker

$$\Gamma_{\rm DM} = \langle \sigma_{3\to 2} v^2_{\rm rel.} \rangle \, n^2_{\rm DM} > H(T)$$

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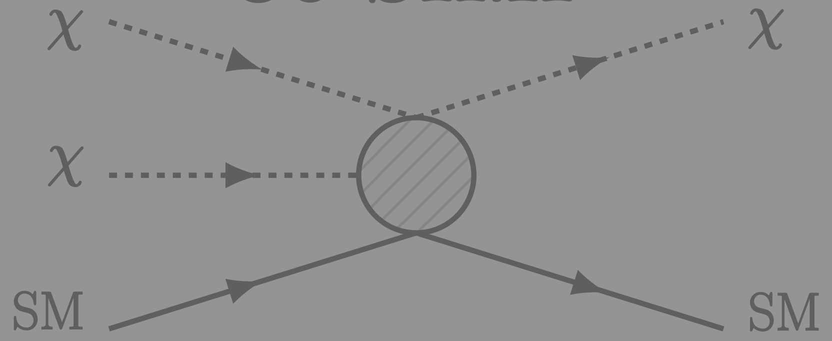
**Co-SIMP**



Smirnov, Beacom

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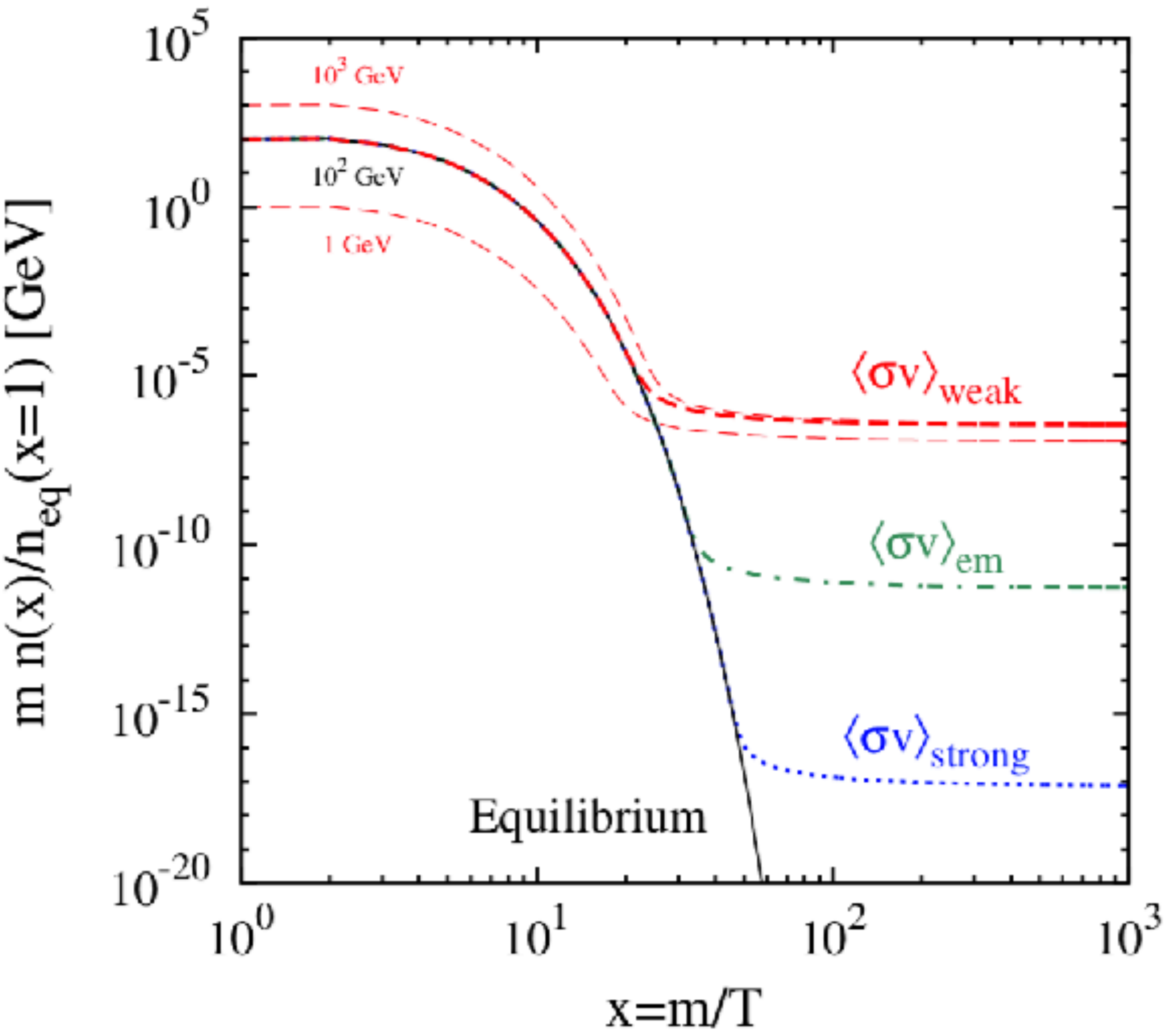
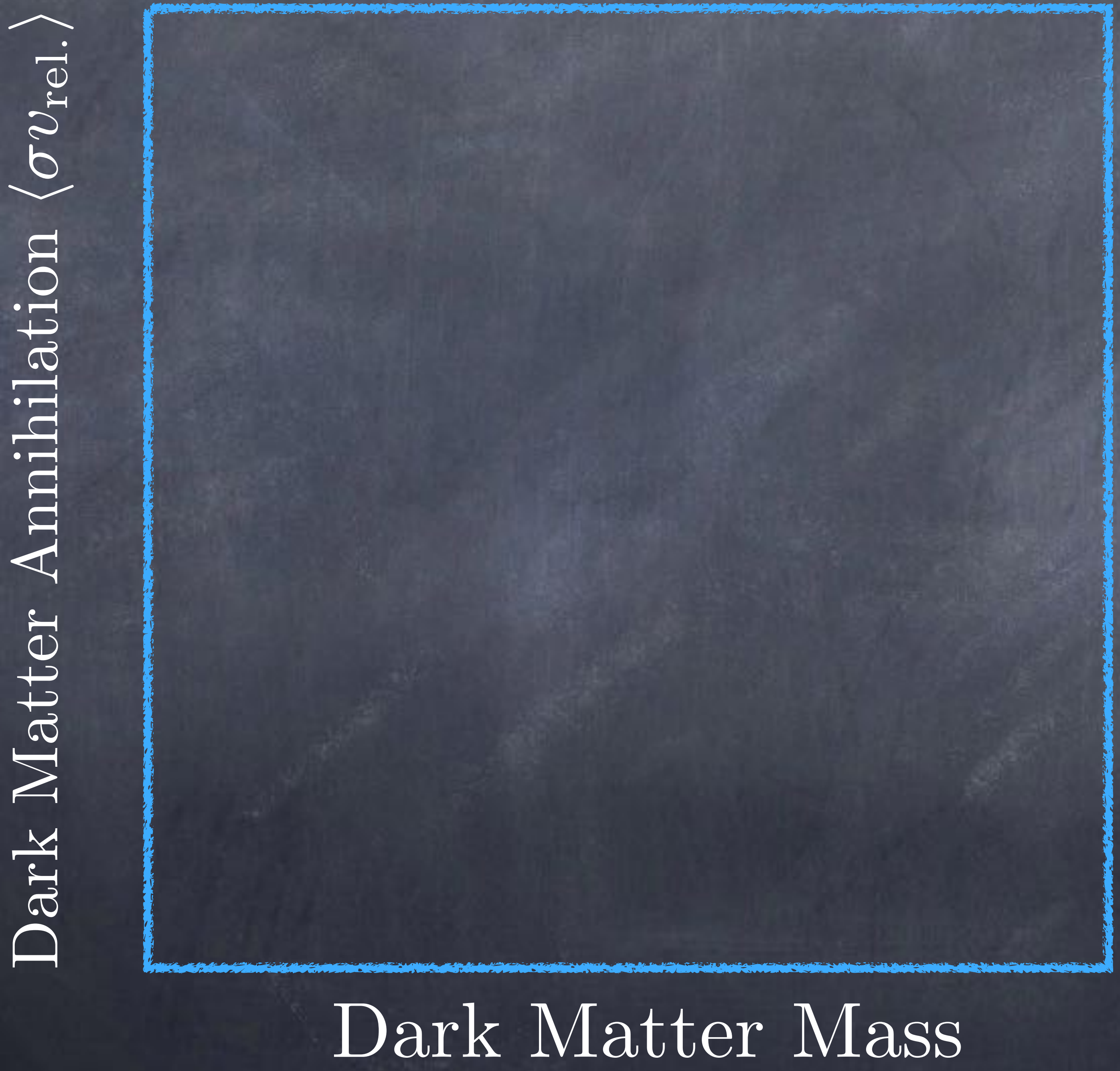


Steigman, Dasgupta, Beacom
**arXiv: 1204.3622**

# Cartoon Overview of Approach



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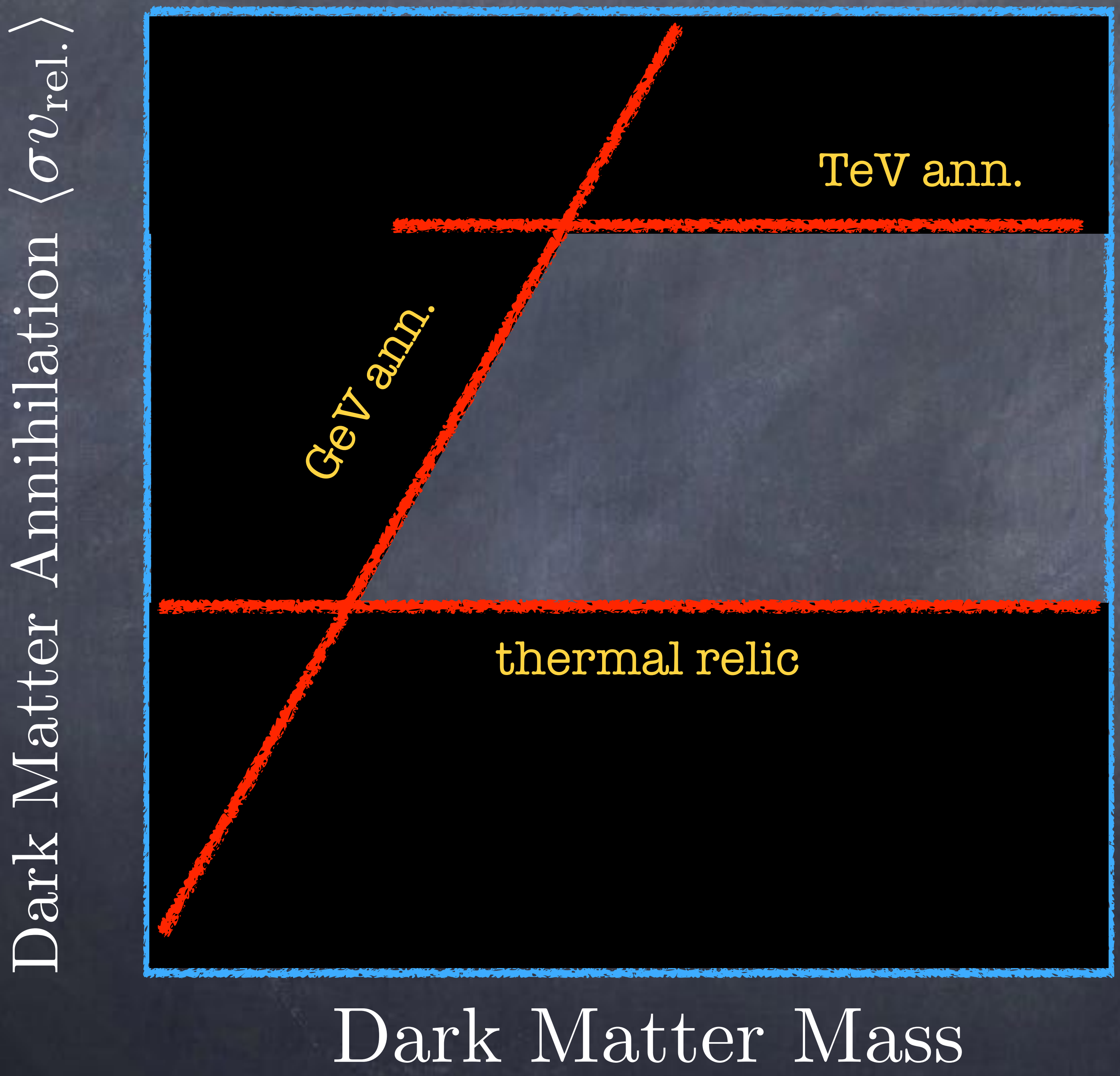

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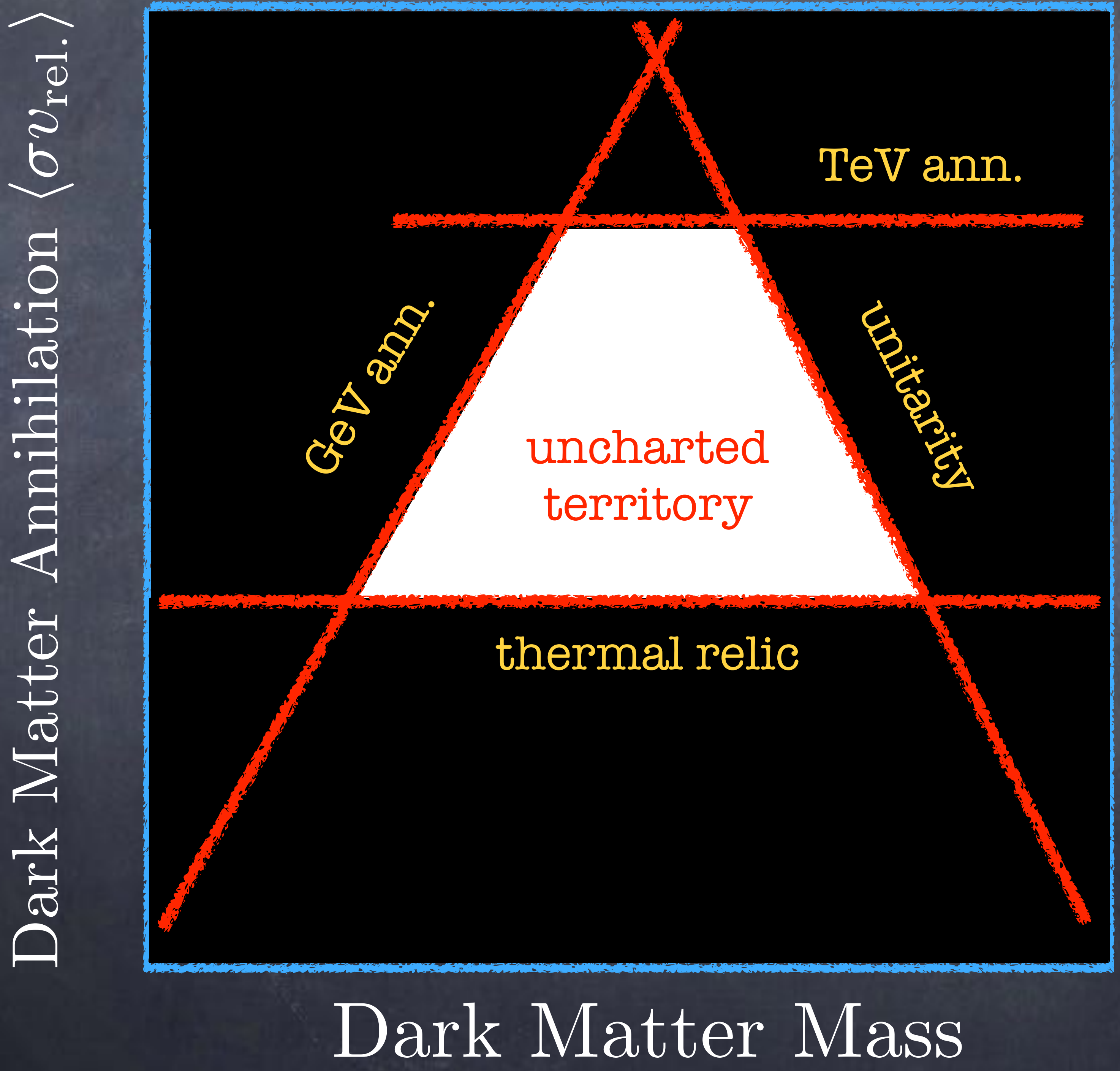

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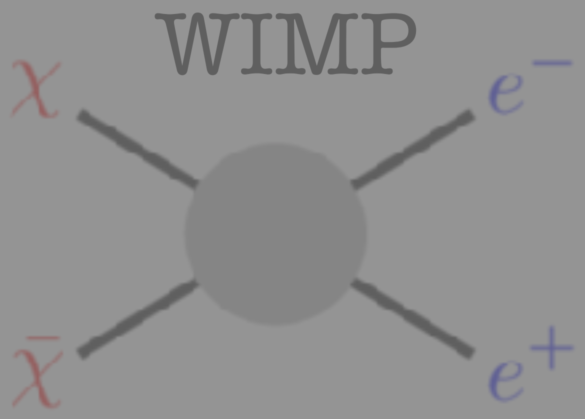
# Other Types of Freezeout



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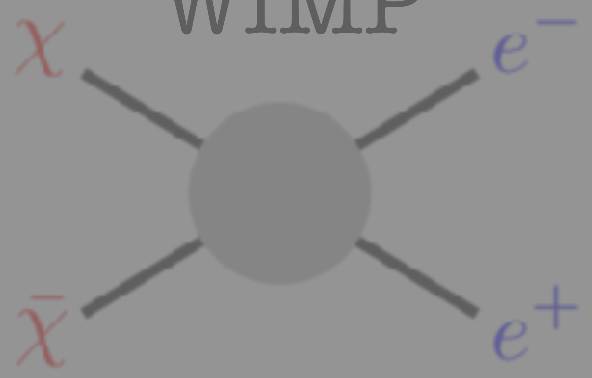

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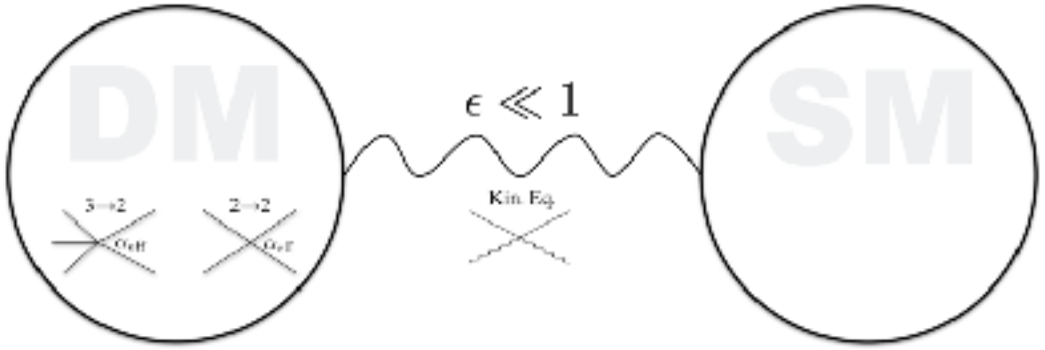
SIMP



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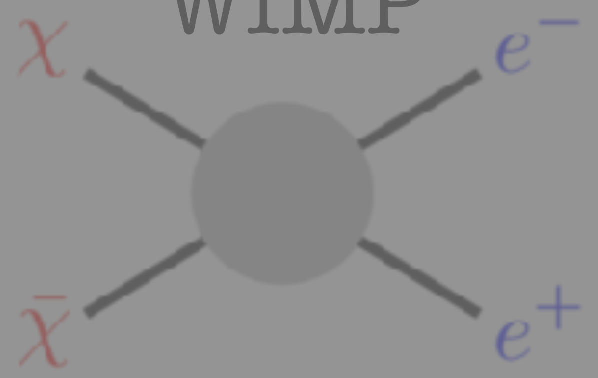

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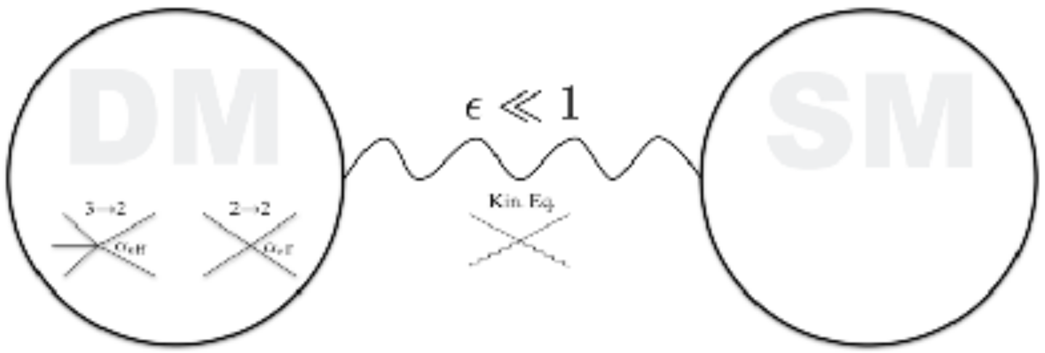

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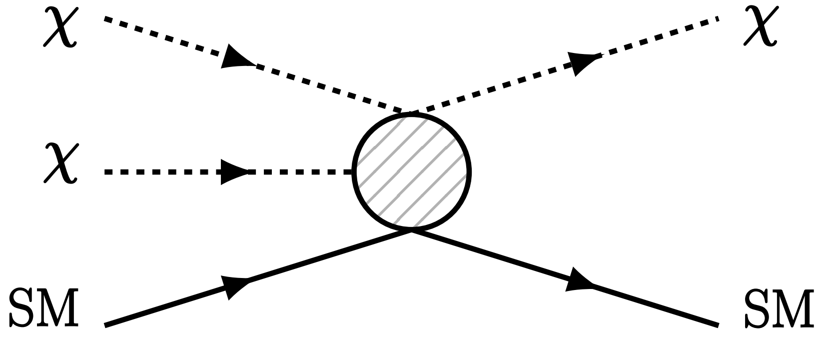

Smirnov, Beacom

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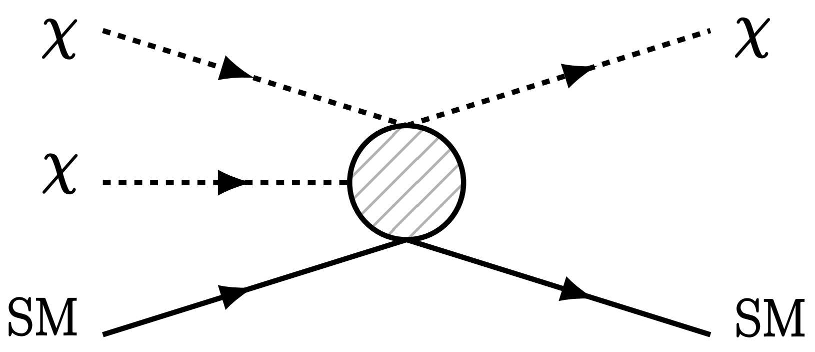
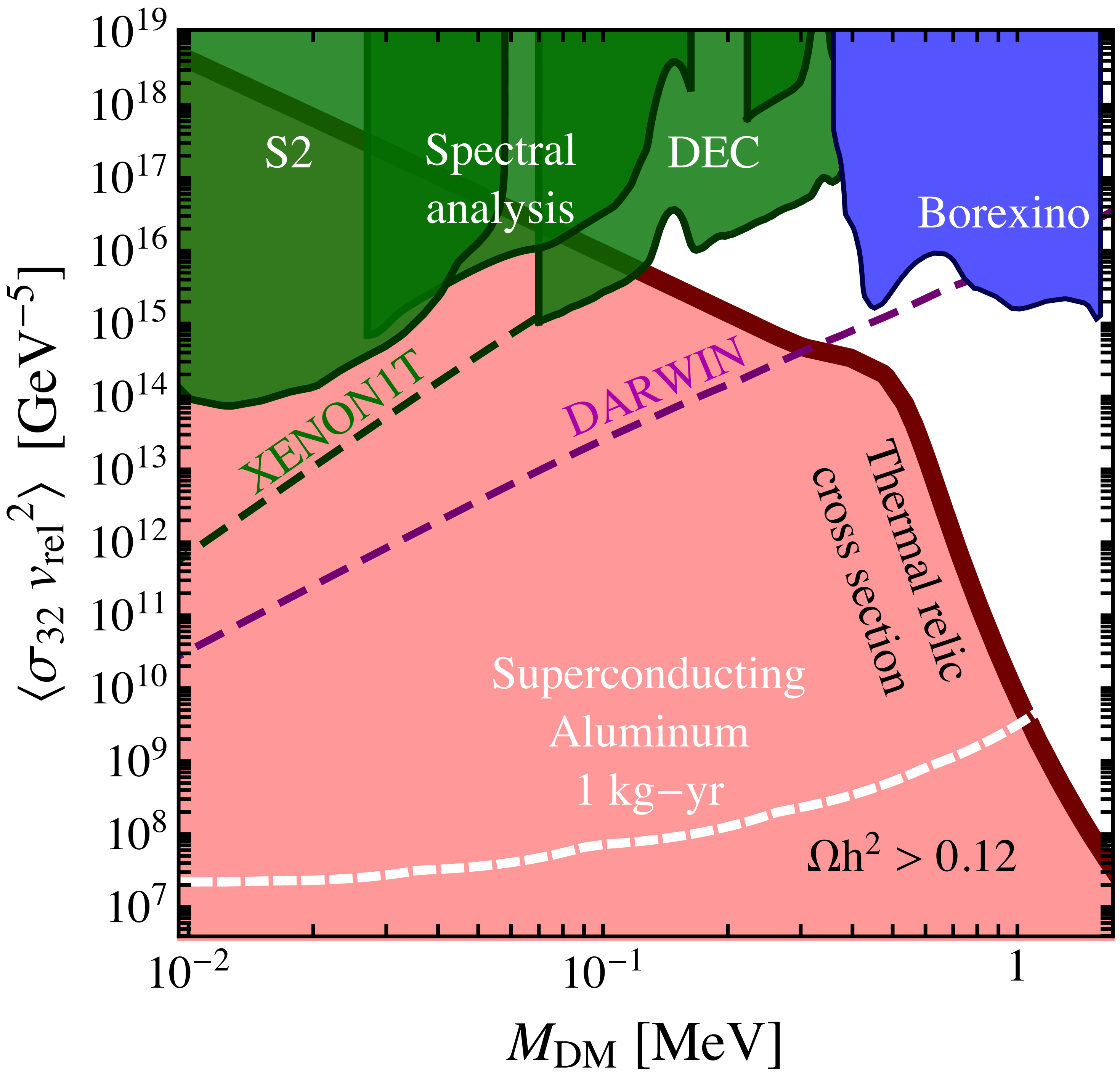
# Electrophilic Co-SIMP

# Co-SIMP Parameter Space



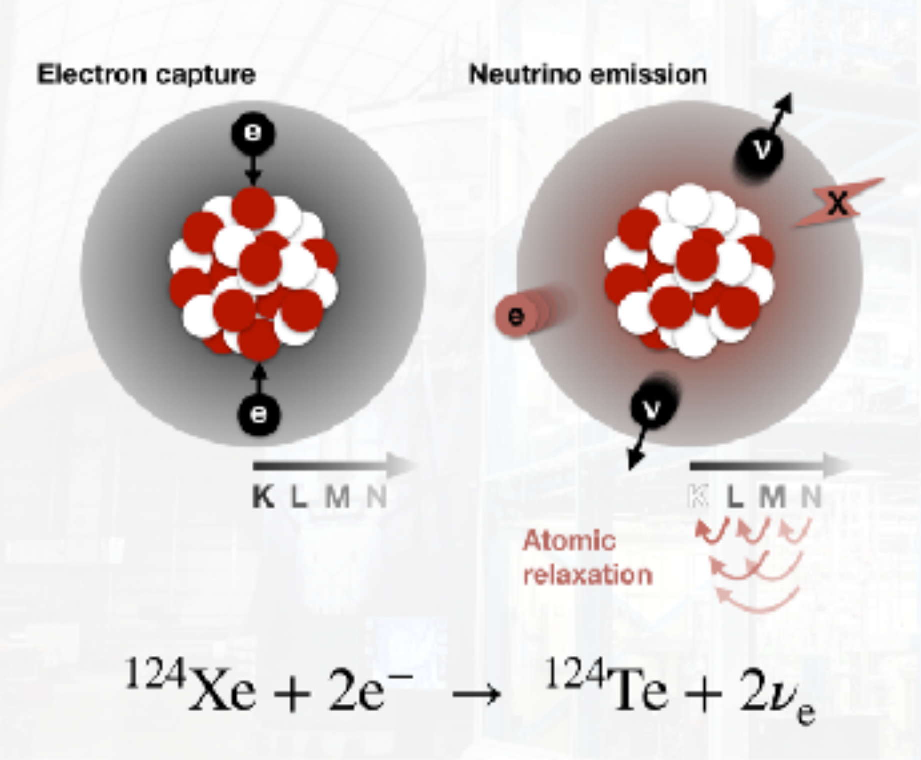
$$M_\chi < 2M_{\rm el.}$$



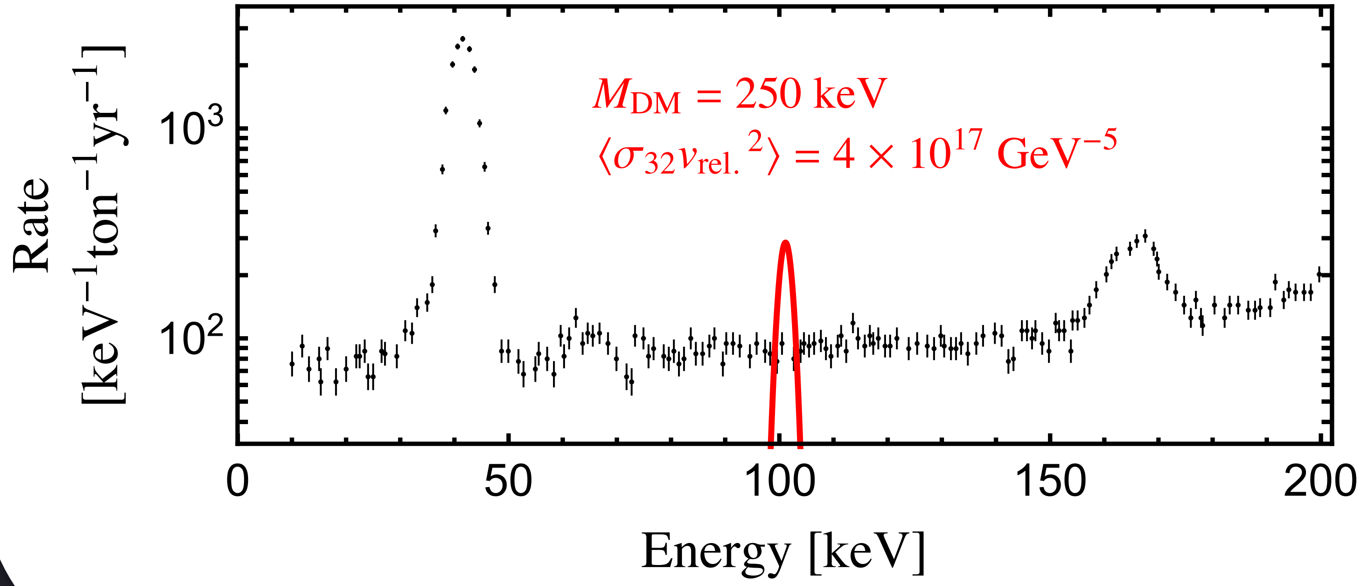
arXiv: 2002.04038; J. Smirnov, J. Beacom

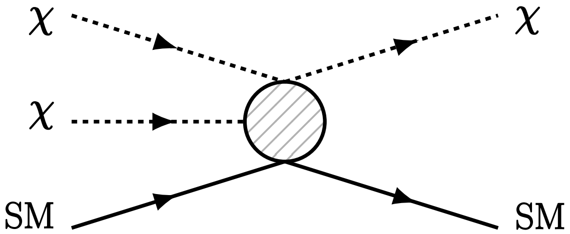
# Detection

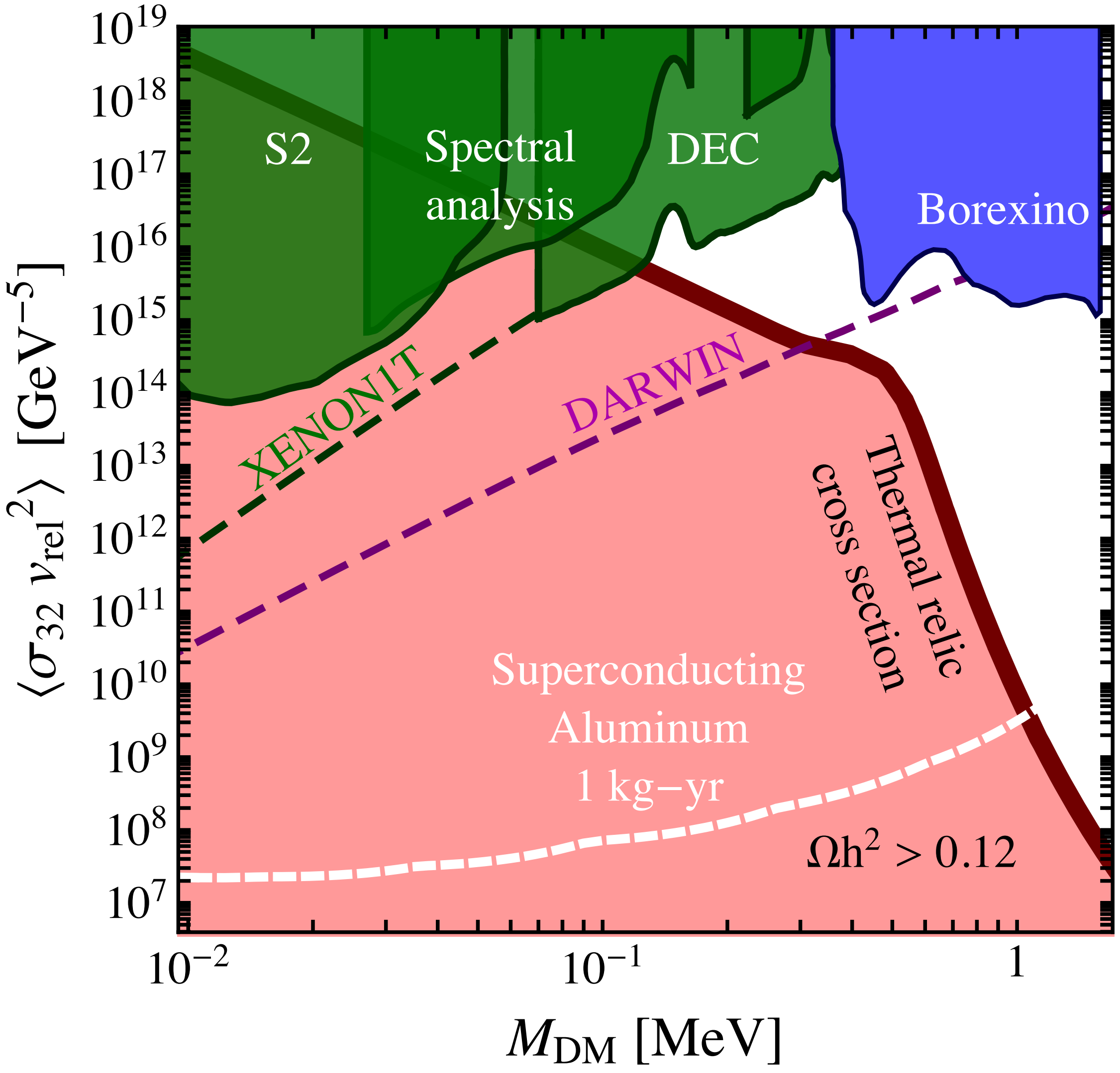
# Double Electron Capture



C. Wittweg, XENON1T Collaboration







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# We need lower Energy Thresholds

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Superfluid He

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Materials with Lattice Defects

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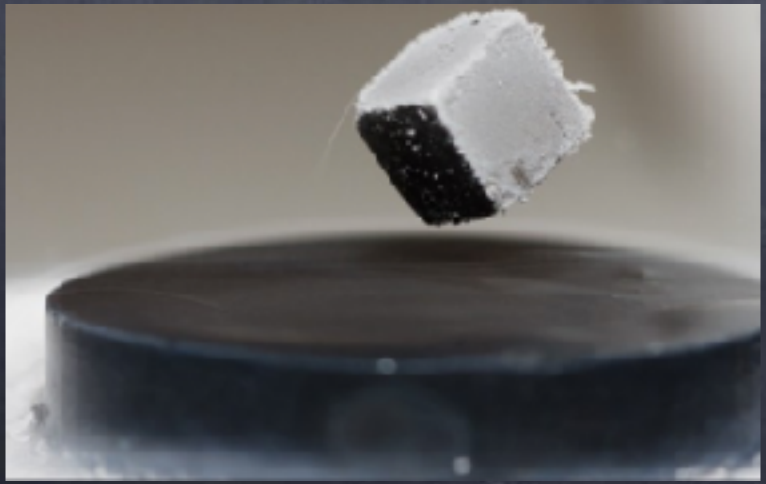

Superconductors

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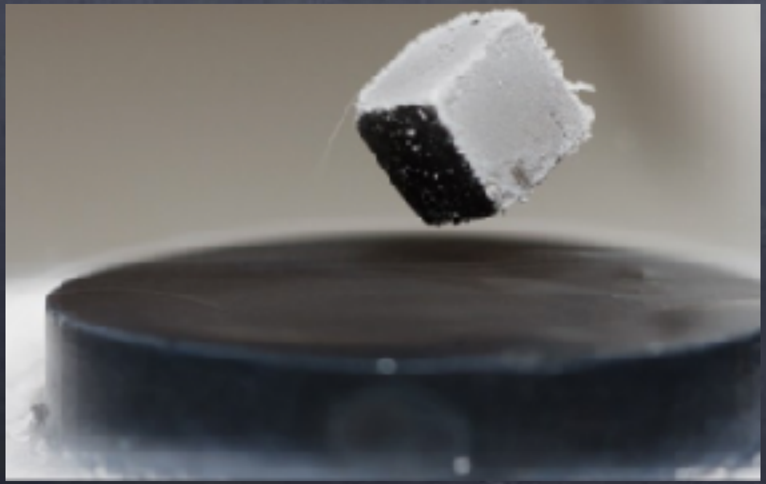
Superfluid He

Materials with Lattice Defects



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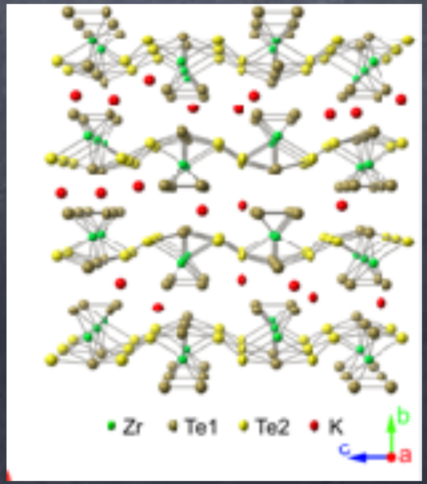


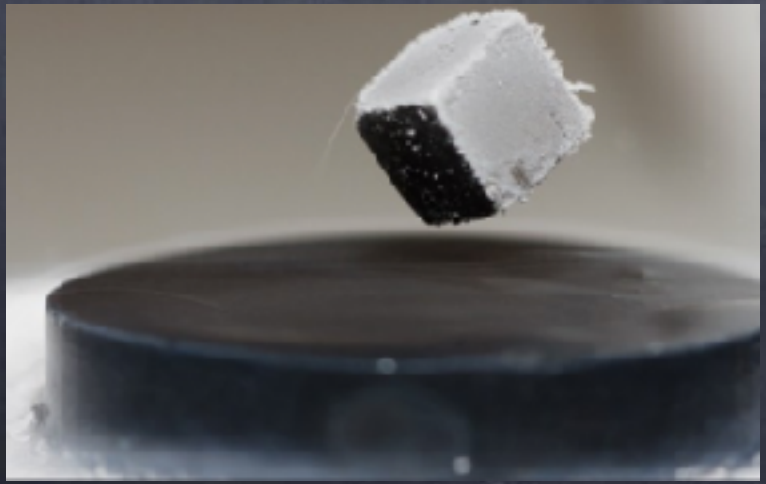
3D Dirac Materials

# We need lower Energy Thresholds

Superfluid He

Materials with Lattice Defects

Small $\Delta E$



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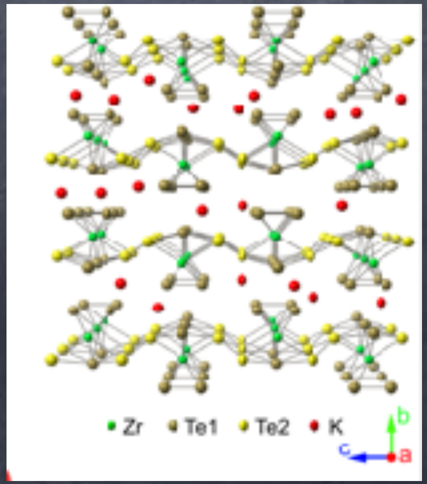
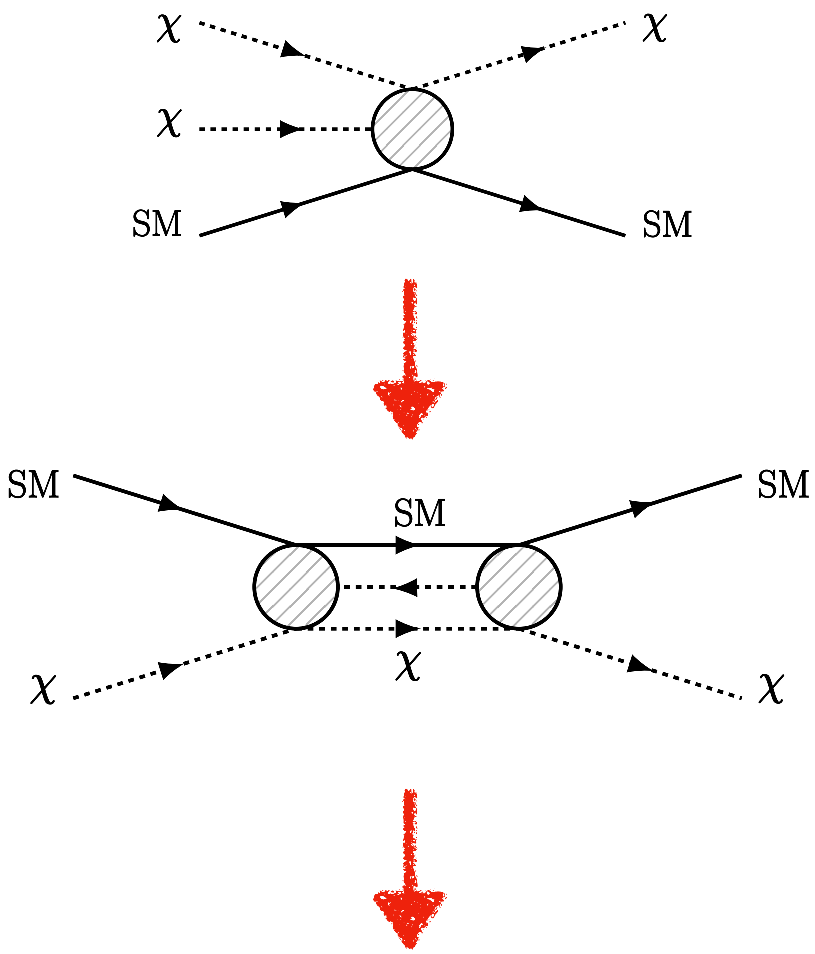


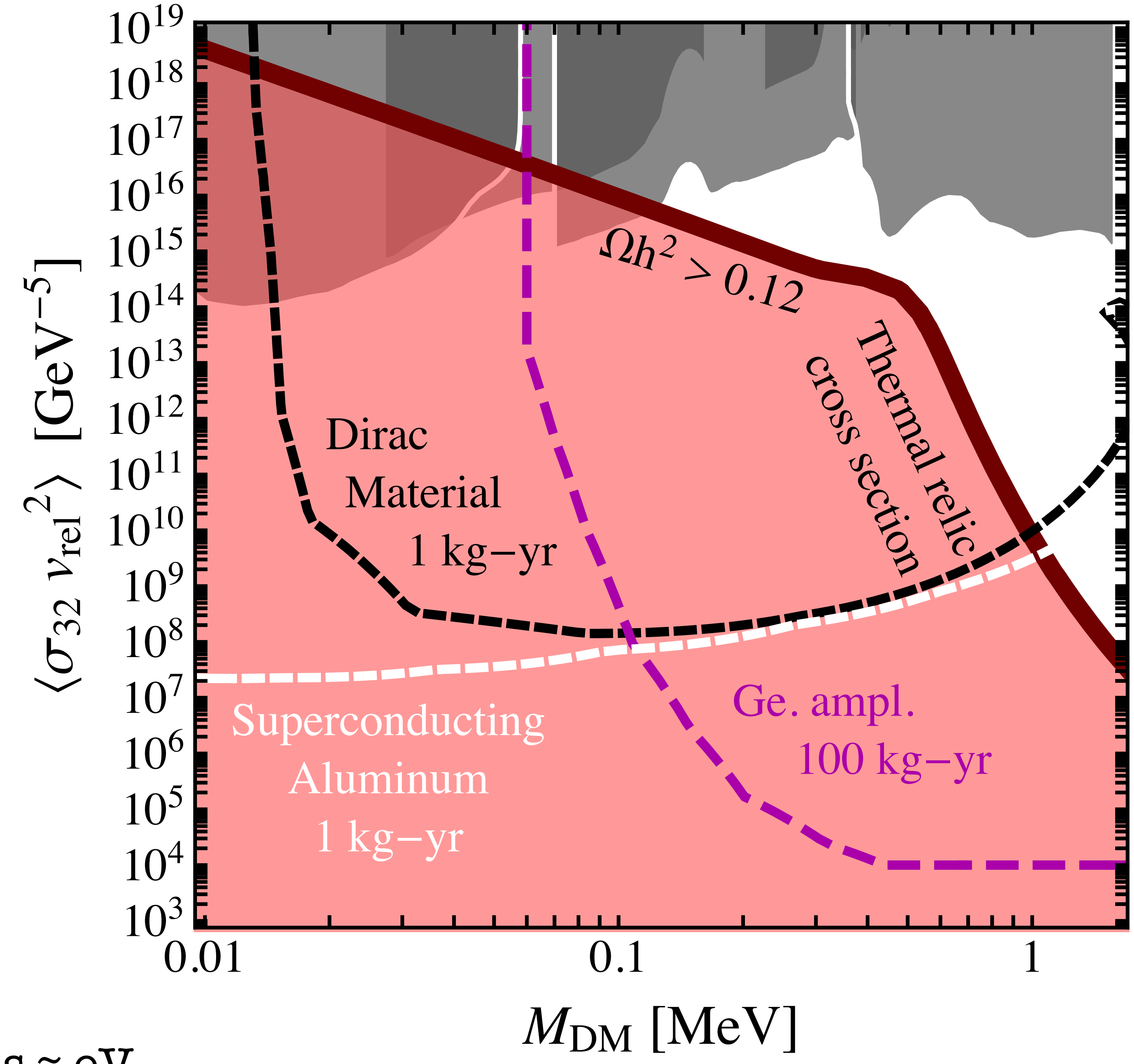
3D Dirac Materials

# Scattering off Electrons



$$E_R \approx v_{\rm rel}^2 \frac{\mu^2}{M_{\rm SM}}$$

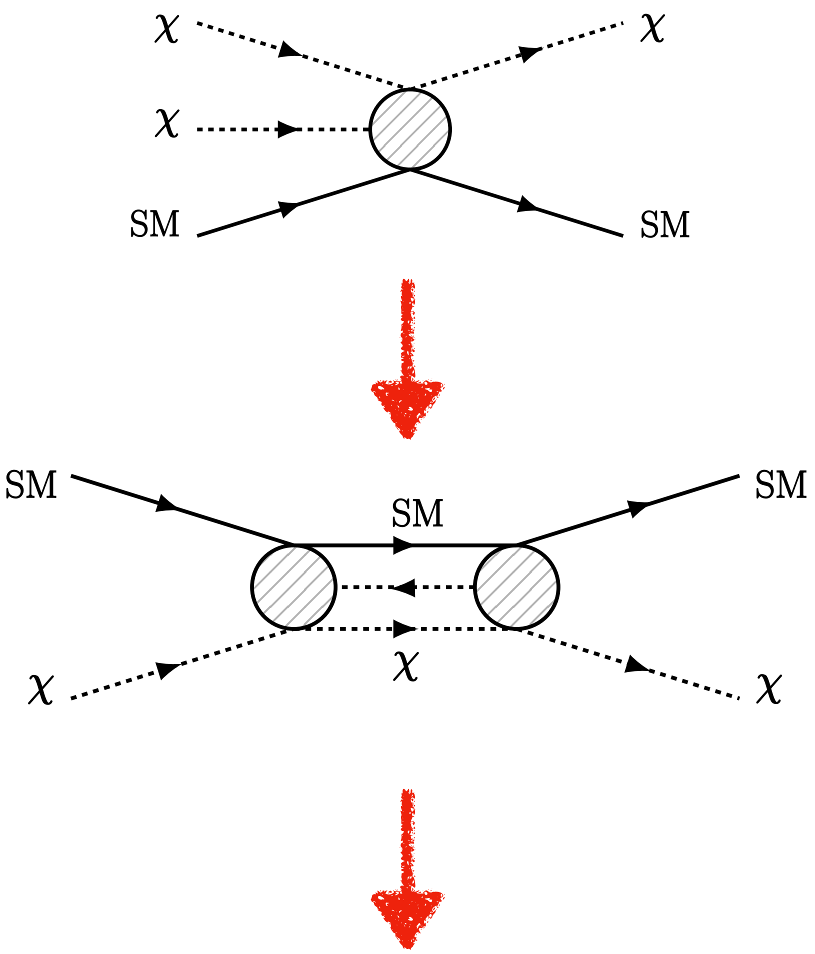
Detectors with lower energy thresholds ≈ eV



arXiv: 2002.04038; J. Smirnov, J. Beacom

# Nucleophilic Co-SIMP

# Scattering off Nucleons



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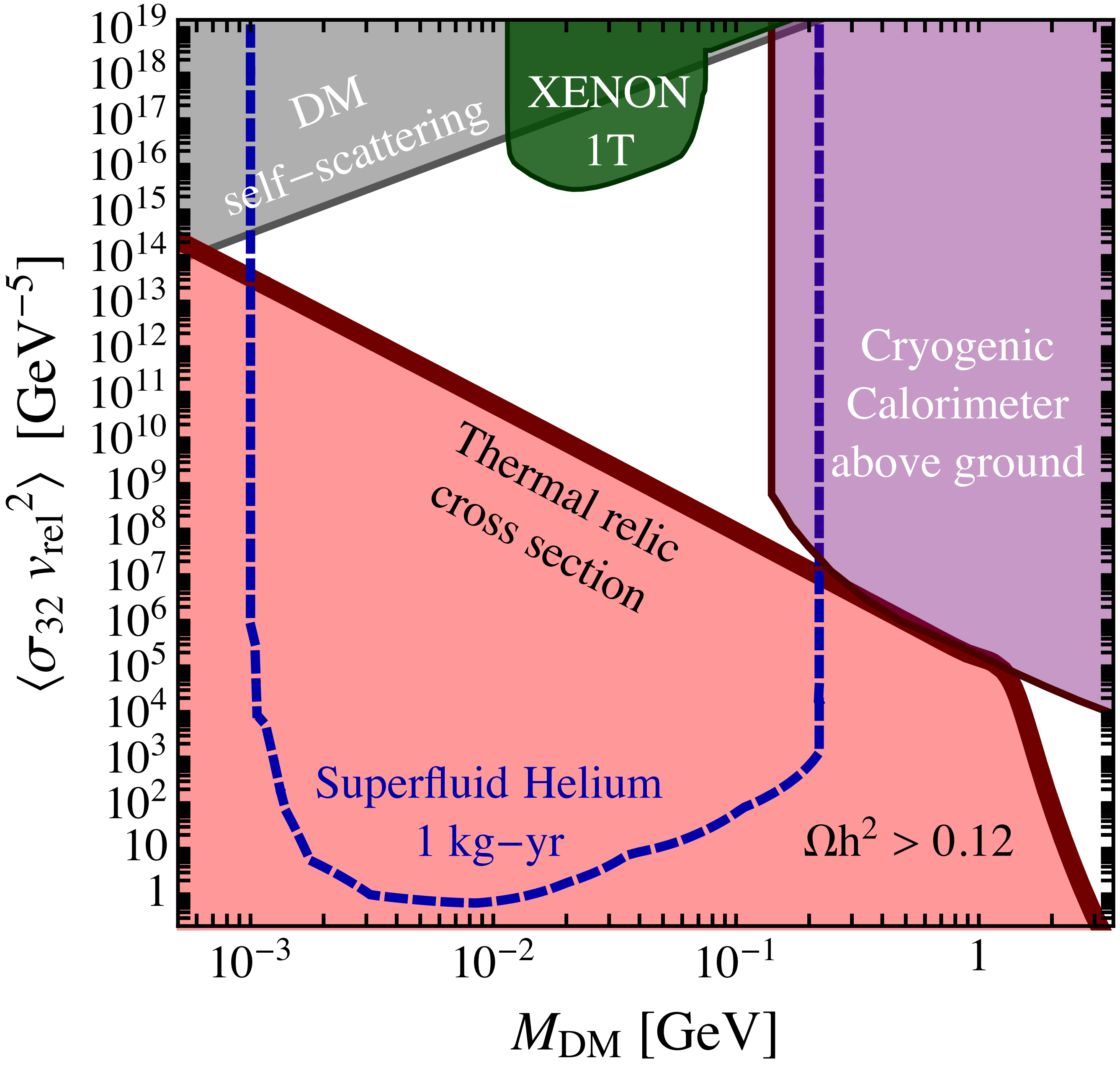

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# What next?

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C. What are possible UV completions? -> Currently working on it with: **Bei Zhou** and **John Beacom** from CCAPP at OSU.

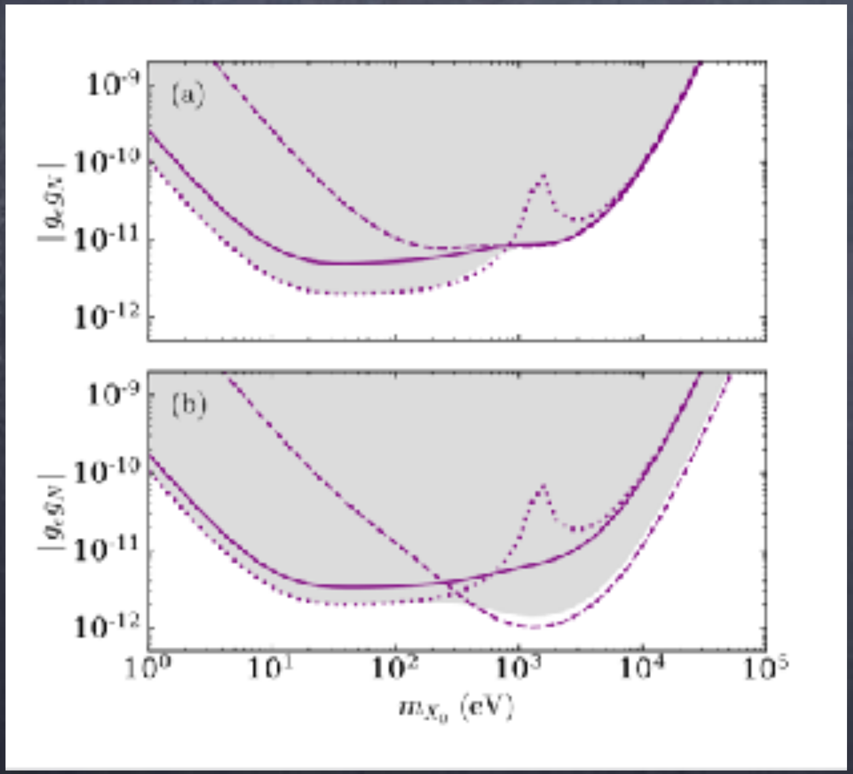
# Thanks!

# Backup

# New Forces

Long Range: light Z’

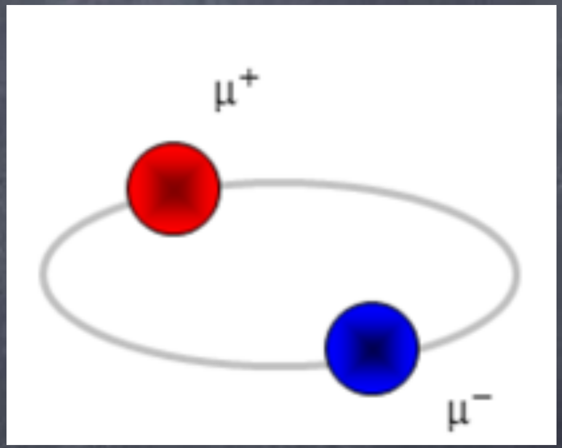
Rydberg Atoms (n>>1):



arXiv: Jones, Potviliege, Spannowsky

Short Range: loops, heavy Z’

Need compactness:
True Muonium



arXiv: Smirnov, Beacom
JCAP 1404 (2014) 022:

Kopp, Michaels, JS

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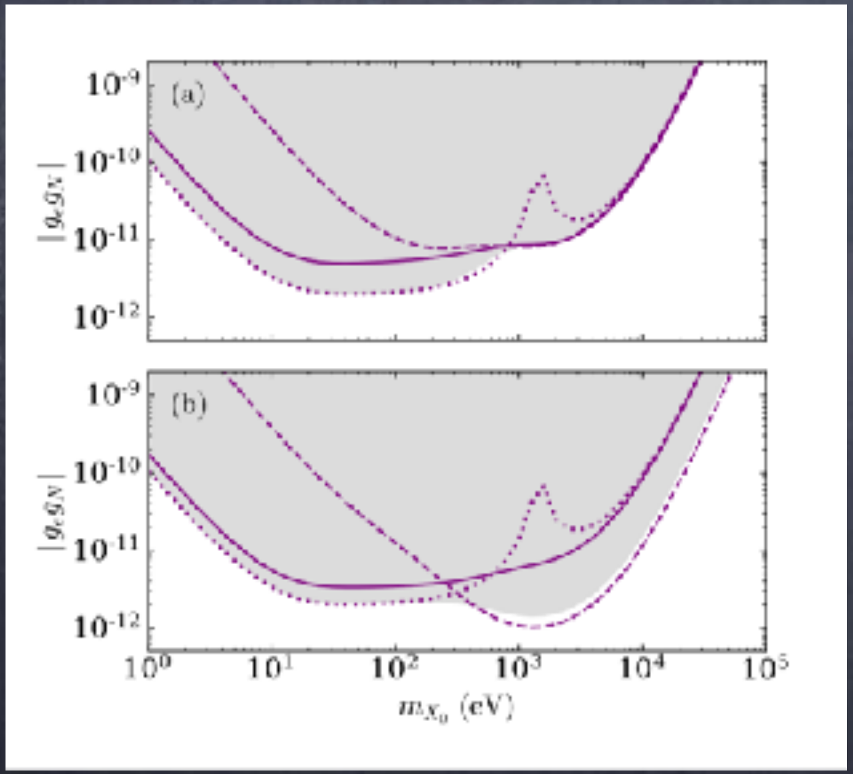

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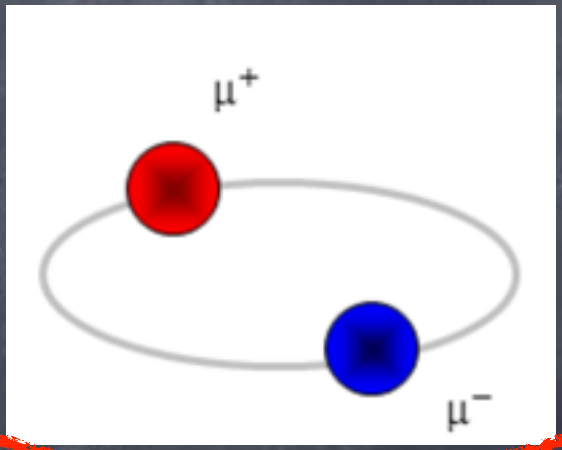

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# Positronium

$$\Delta E_{\rm hfs} \approx -\frac{\alpha_{\rm EM}^3 m_\ell^3}{8\pi}\,\frac{1}{128\pi^4\,\Lambda^2}$$

JCAP 1404 (2014) 022:

Kopp, Michaels, JS

$$\Delta E_{\rm hfs}^{e^+e^-} \approx -43\ {\rm Hz} \times \left(\frac{\rm GeV}{\Lambda}\right)^2$$

$$\Delta E/E \approx \mathcal{O}(10^{-10})$$

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JCAP 1404 (2014) 022:
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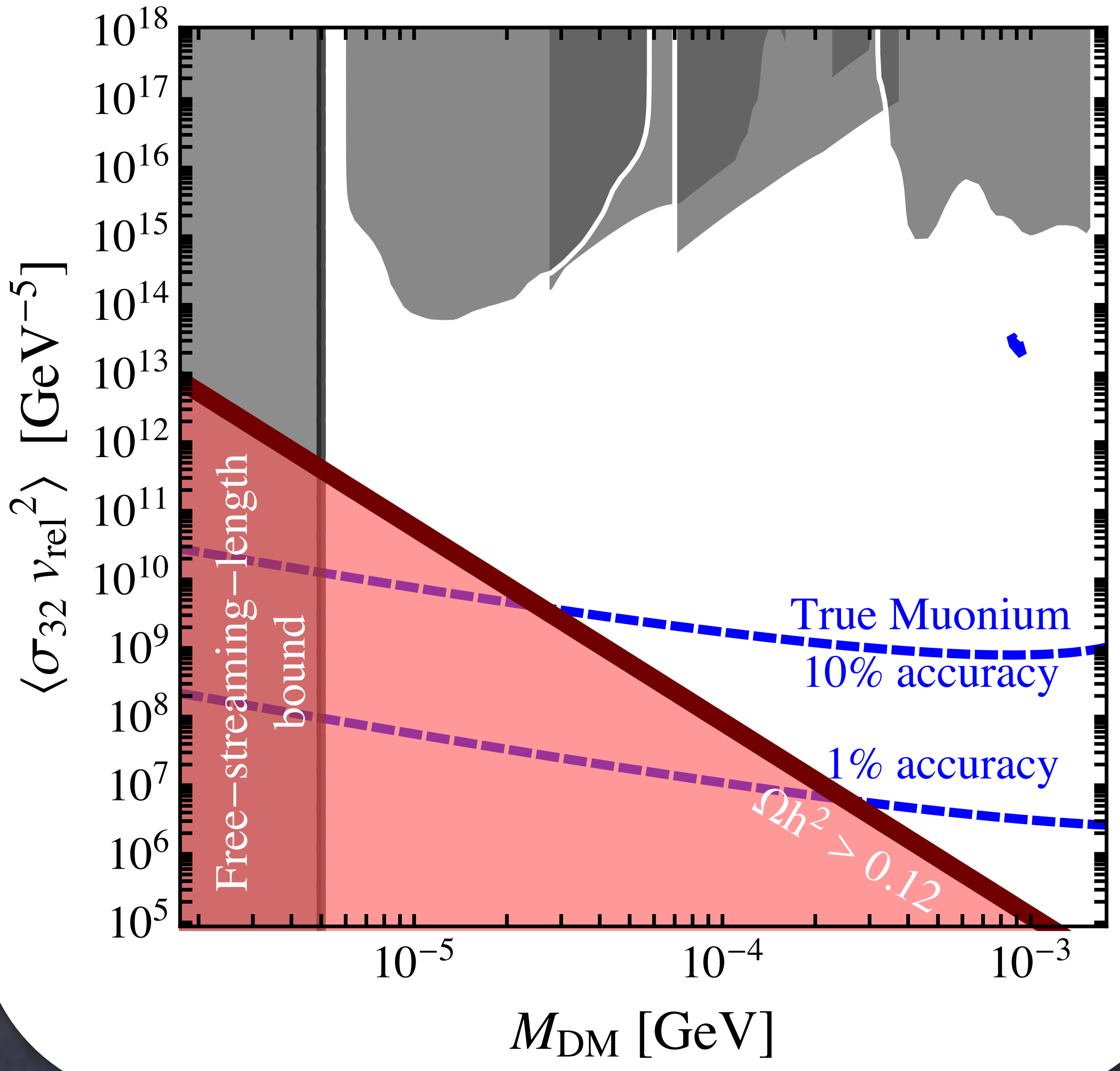
$$\Delta E/E \approx \mathcal{O}(10^{-10})$$

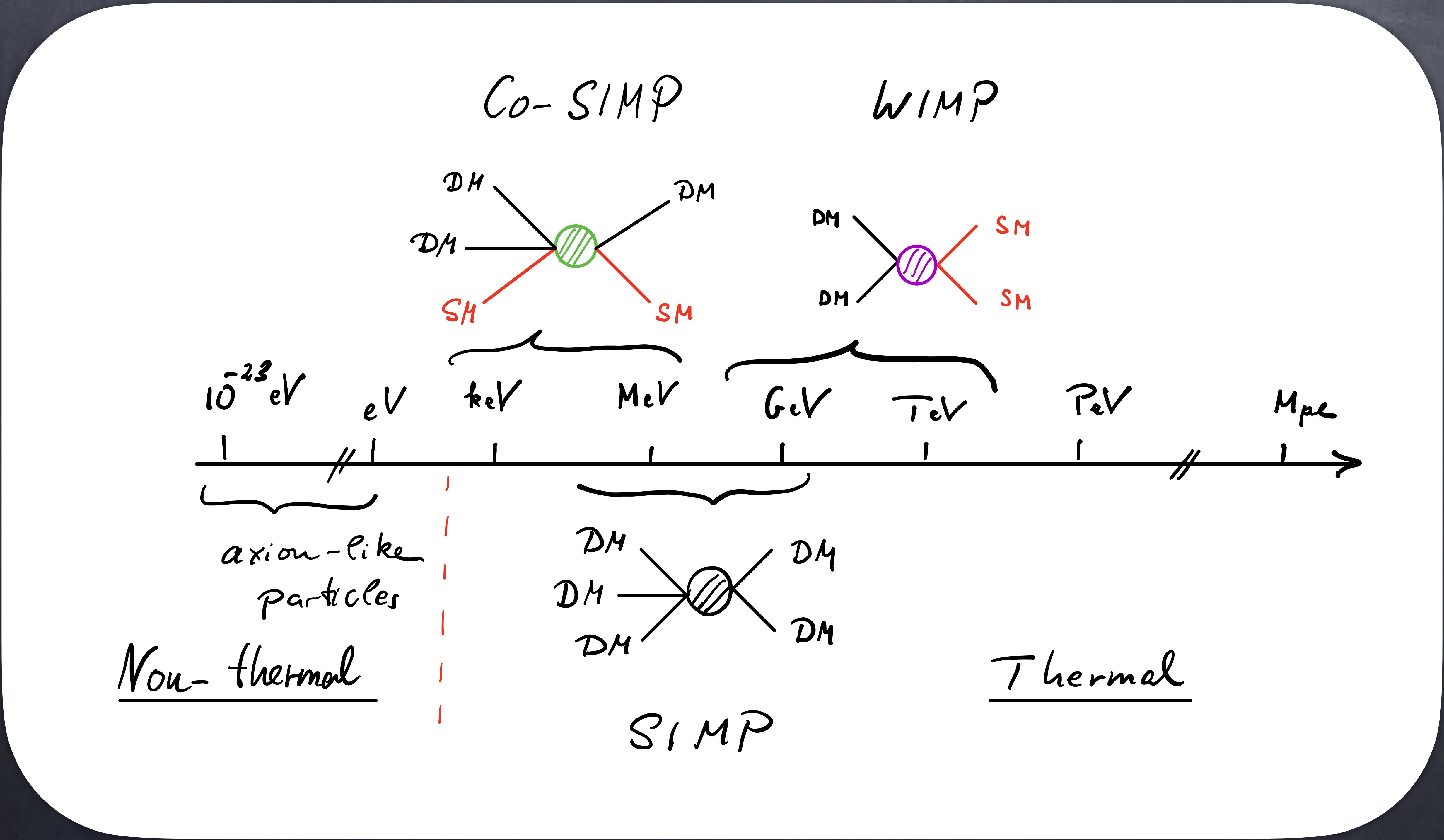
$$\Delta E_{\rm hfs}^{\mu^+\mu^-} \approx -380\ {\rm MHz}\times\left(\frac{\rm GeV}{\Lambda}\right)^2$$

Phys.Rev. D100 (2019) no.5, 053003: Vidal, Ilten, Plews, Shuve, Soreq

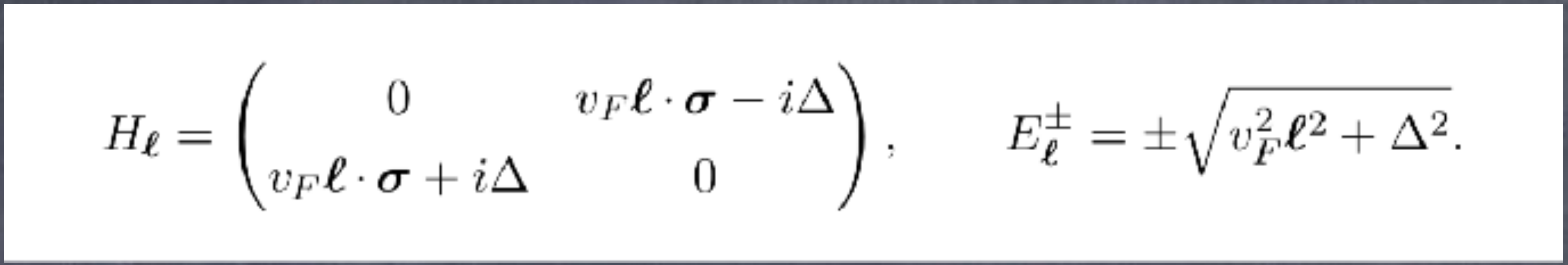


arXiv: Smirnov, Beacom

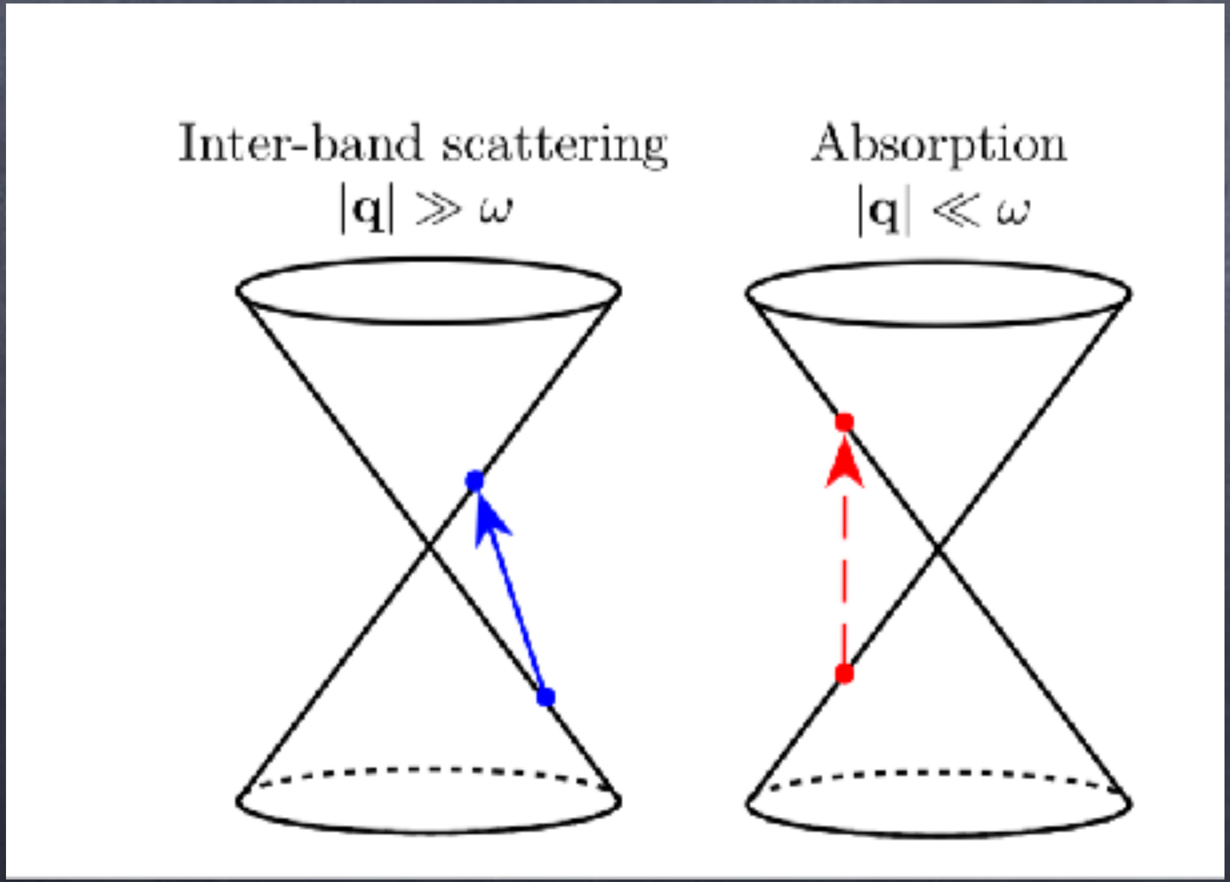
# Dark Particle Production



# Example: Dirac Materials



$$H_{\boldsymbol{\ell}} = \begin{pmatrix} 0 & v_F \boldsymbol{\ell} \cdot \boldsymbol{\sigma} - i\Delta \\ v_F \boldsymbol{\ell} \cdot \boldsymbol{\sigma} + i\Delta & 0 \end{pmatrix}, \qquad E^{\pm}_{\boldsymbol{\ell}} = \pm\sqrt{v_F^2 \boldsymbol{\ell}^2 + \Delta^2}.$$



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