Dark Sectors at Direct Detection Experiments

Tien-Tien Yu (University of Oregon)

DM@LHC — University of Washington, Seattle — August 15, 2019

SENSEI*

Dark Sectors at Direct Detection Experiment~~s~~

*but similar story for other experiments

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SENSEI

Sub-**E**lectron-**N**oise **S**kipper CCD **E**xperimental **I**nstrument

- fully-depleted 200 micrometer silicon CCD detector
- 4126 x 866 pixels
- operated at 140K
- currently at 1 gram, proposed to 100 grams
- skipper technology: measure charge/pixel multiple times

Comisión Nacional de Energía Atómica

Fermilab

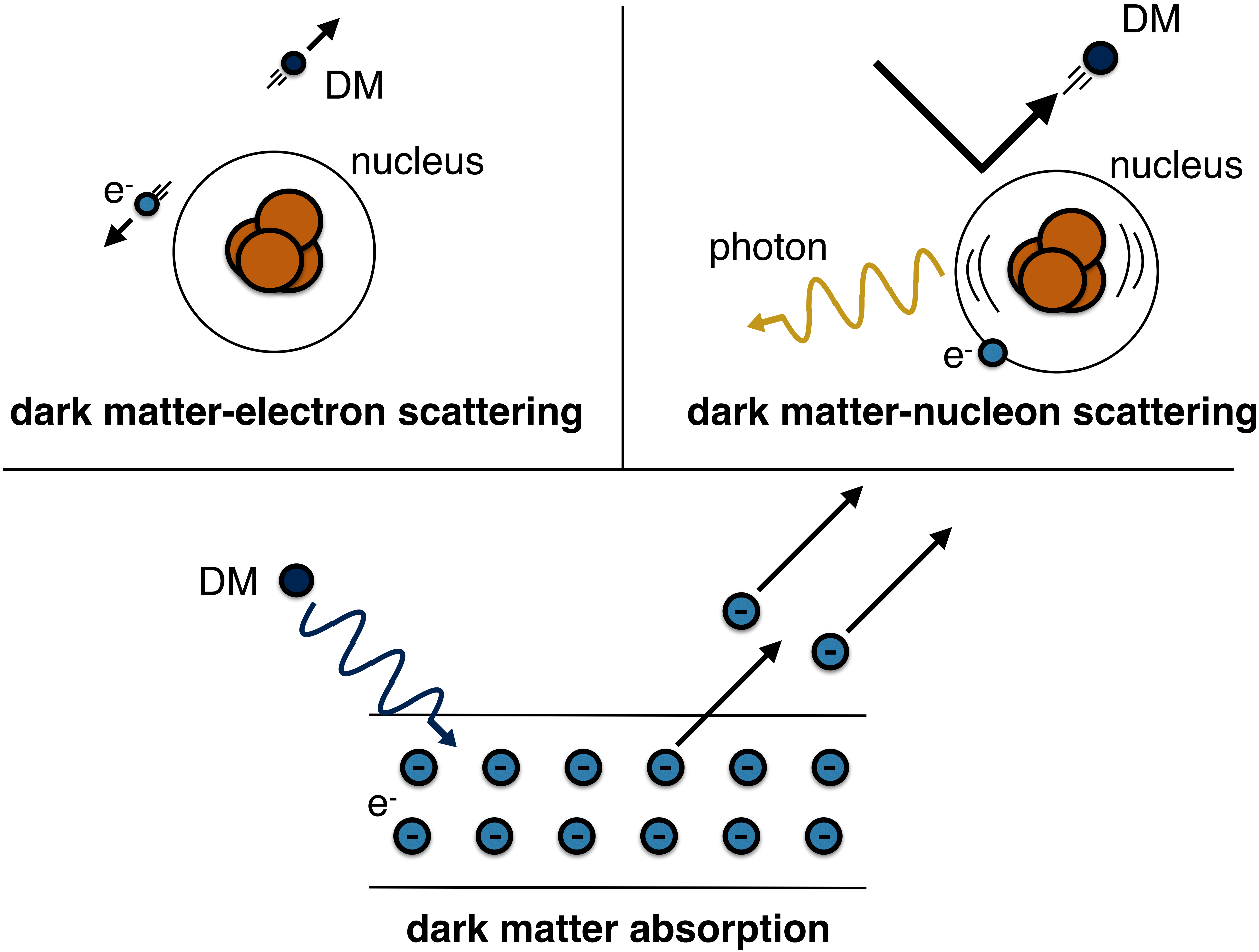
UNIVERSITY OF OREGON

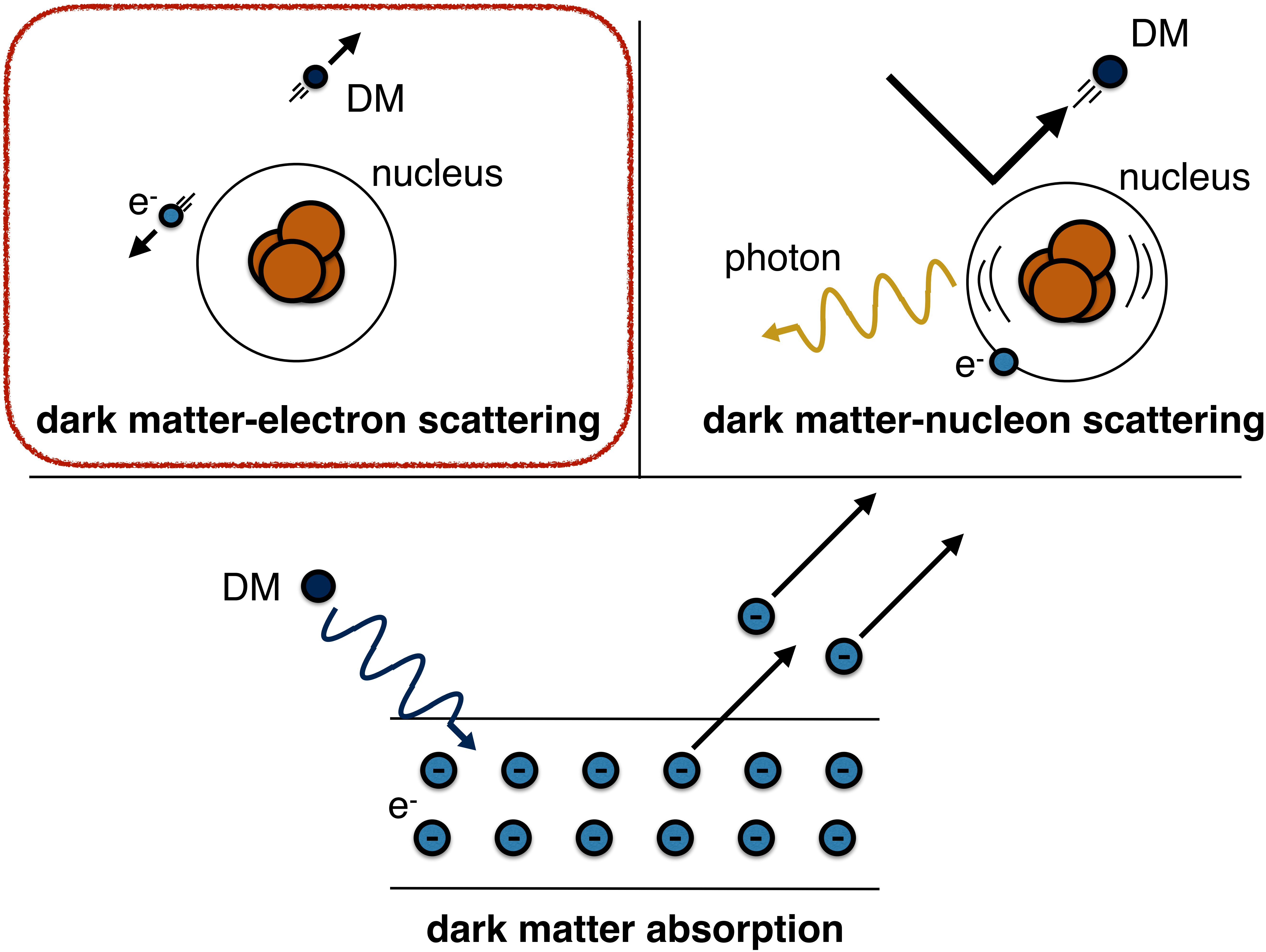
Stony Brook University

TEL AVIV UNIVERSITY

SENSEI

Sub-**E**lectron-**N**oise **S**kipper CCD **E**xperimental **I**nstrument


DM
nucleus
e-
dark matter-electron scattering
DM
nucleus
photon
e-
dark matter-nucleon scattering
DM
e-
dark matter absorption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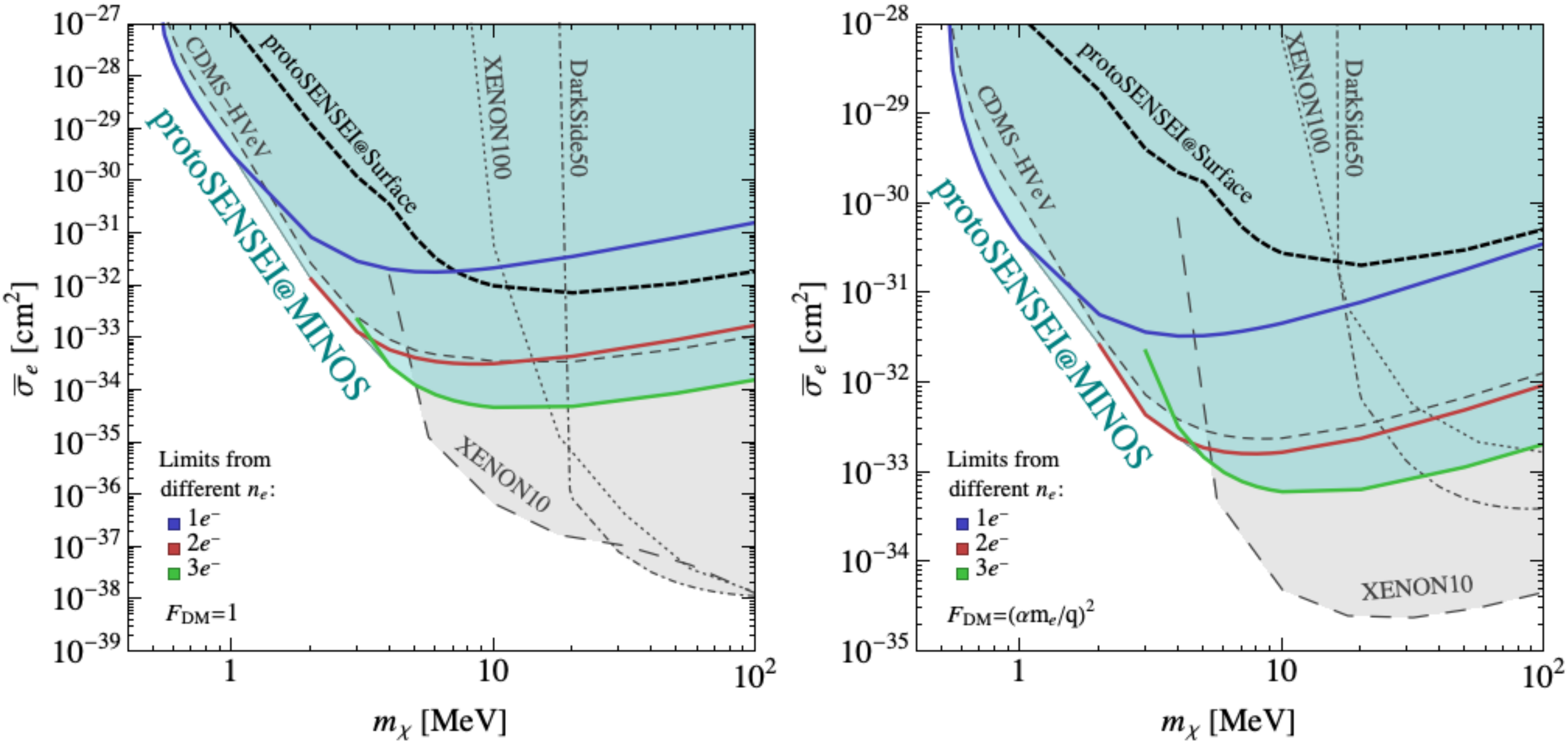
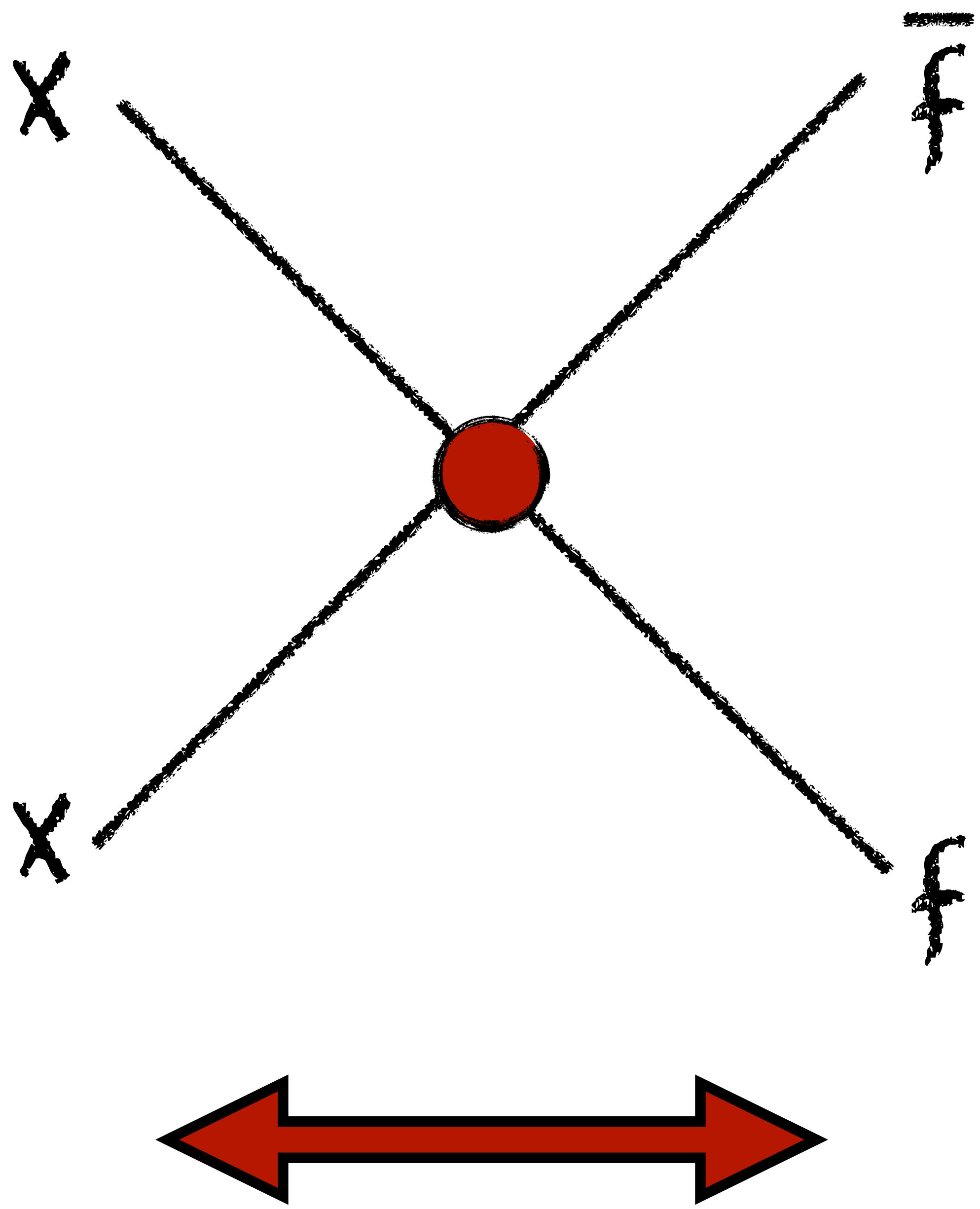
sub-GeV DM



0.246 gram-days with prototype

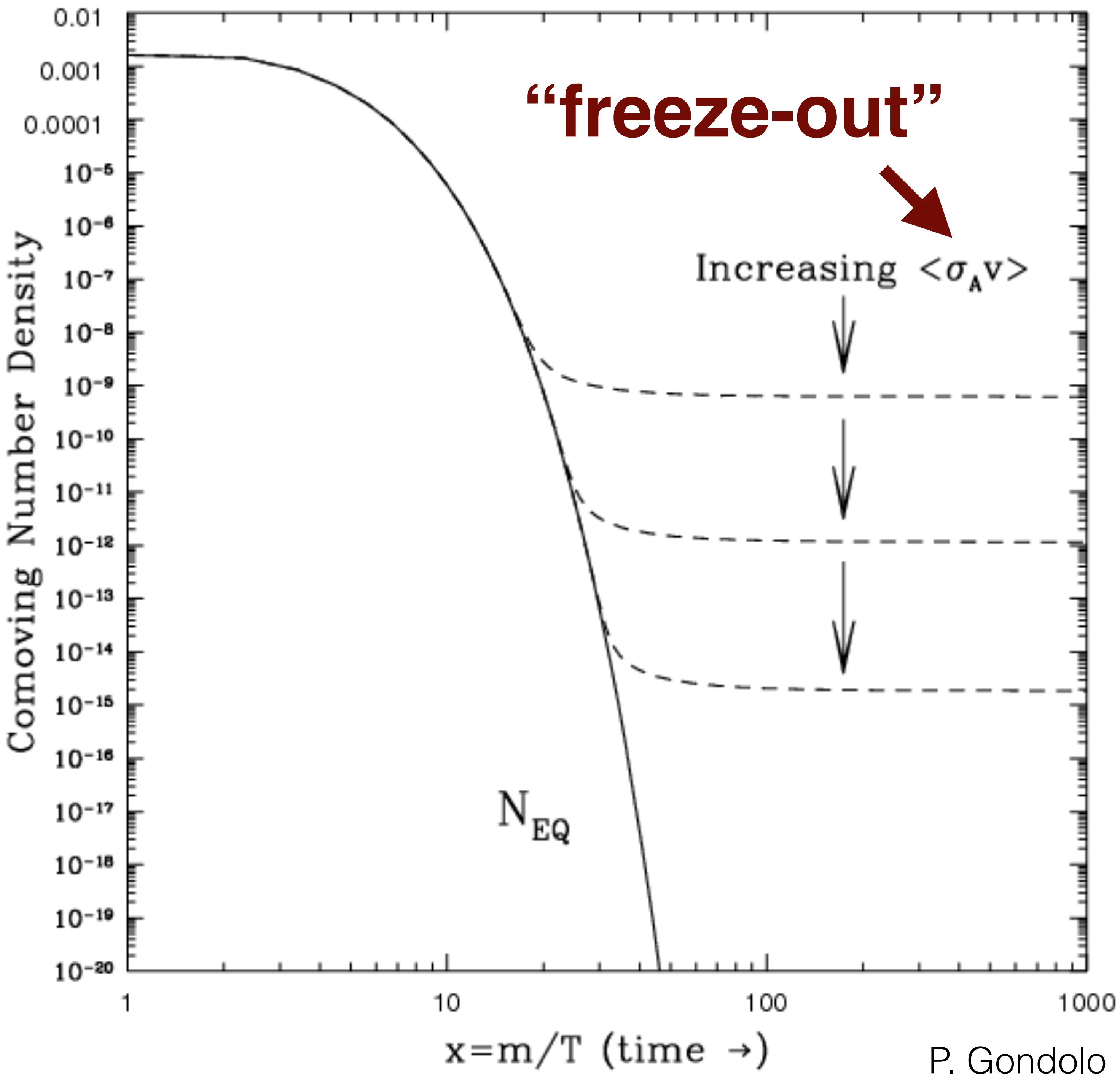
SENSEI collaboration, Phys. Rev. Lett. 122, 161801 [arXiv:1901.10478]

WIMP miracle



thermal equilibrium

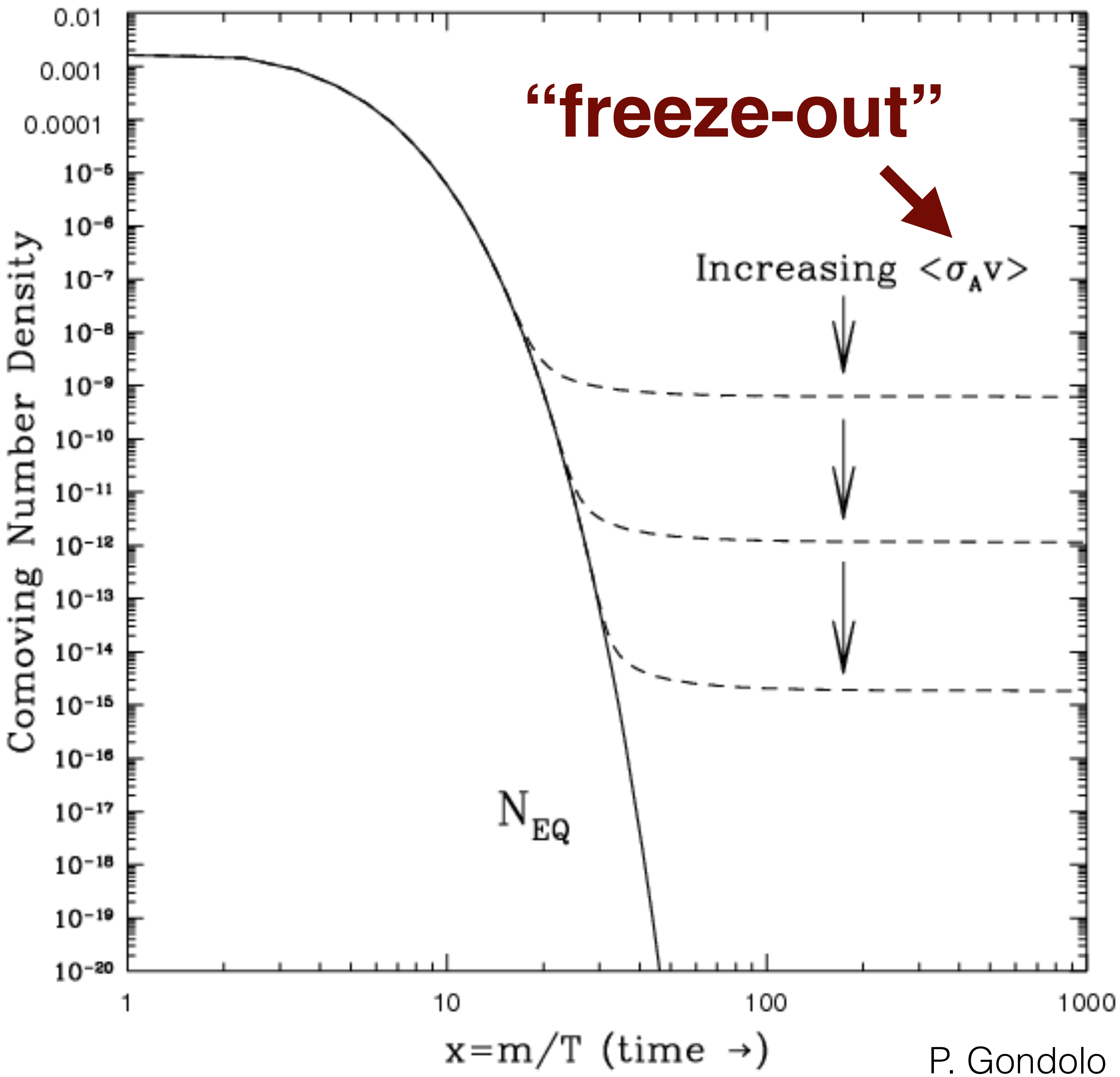
WIMP miracle



P. Gondolo

$$\Omega h^2 \simeq \frac{10^{-37}\ \text{cm}^2}{\langle \sigma_{\text{ann}} v \rangle} \simeq 0.1$$

WIMP miracle



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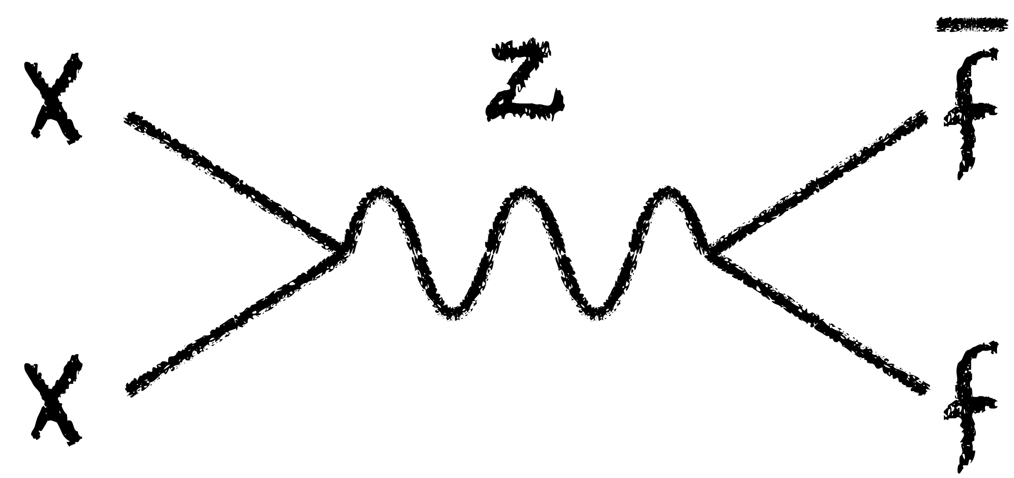
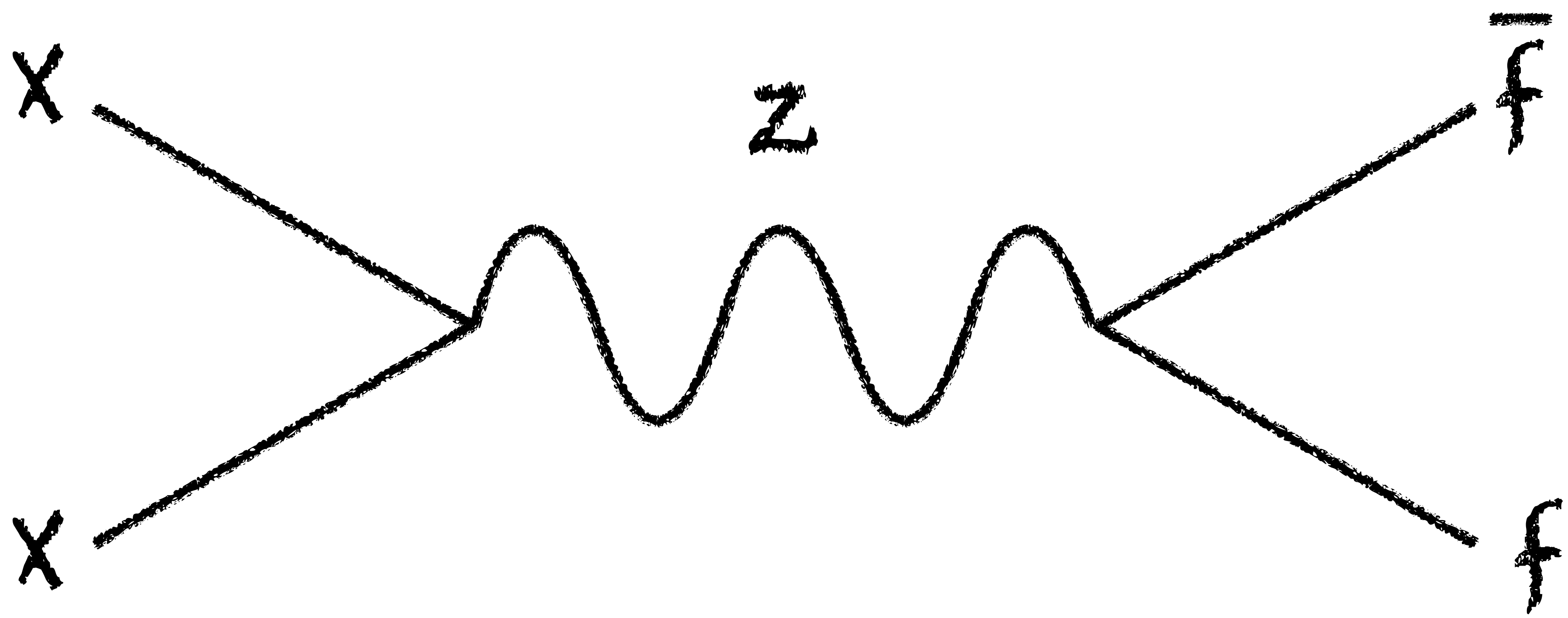


m_X~100 GeV

Lee-Weinberg Bound

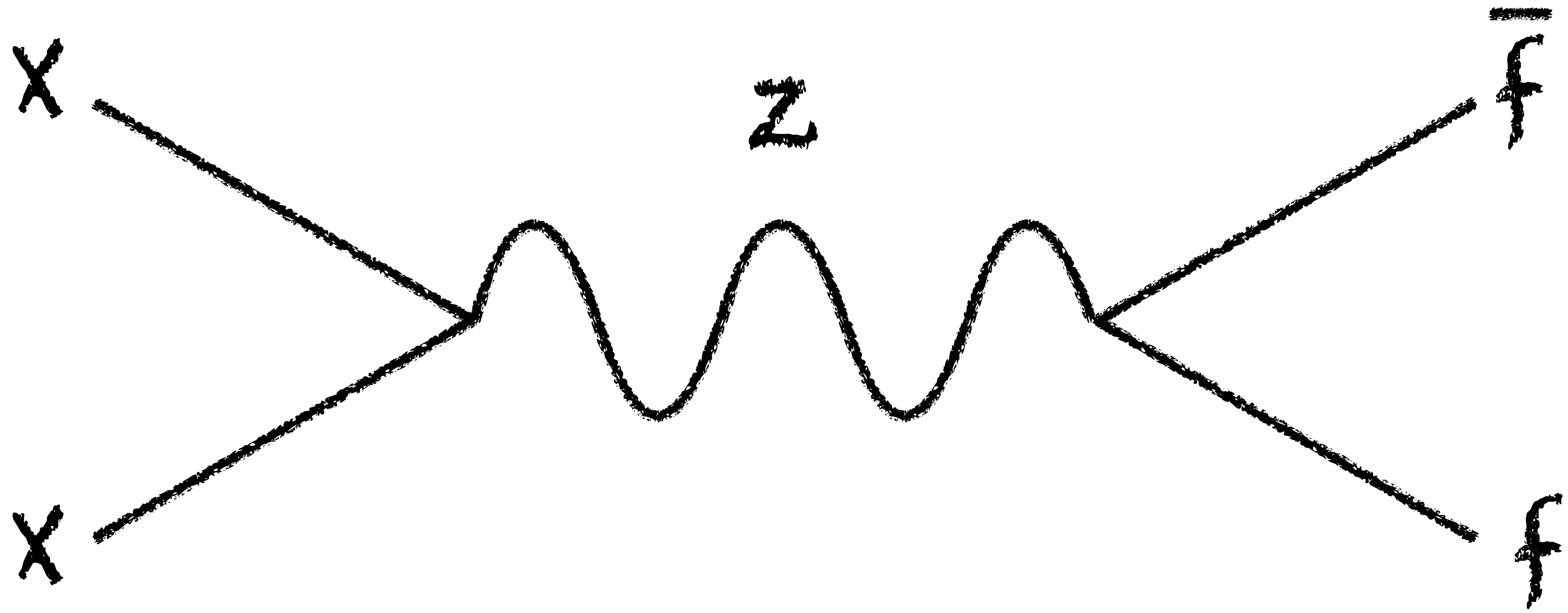


$\Omega_X h^2 \lesssim 0.1 \quad \Rightarrow \quad m_X \gtrsim$ few GeV

B. W. Lee and S. Weinberg, Phys. Rev. Lett. 39, 165 (1977)

E.W. Kolb and K. Olive, Phys.Rev. **D34** (1986) 2531

Lee-Weinberg Bound



$$\Omega_X h^2 \lesssim 0.1 \quad \Rightarrow \quad m_X \gtrsim \text{ few GeV}$$

Way out: have new light boson that mediates the interaction

Boehm and Fayet [hep-ph/0305261]

Pospelov et al [0711.4866]

Dark Photon

$$SU(3)_C \times SU(2)_W \times U(1)_Y \times U(1)_X$$

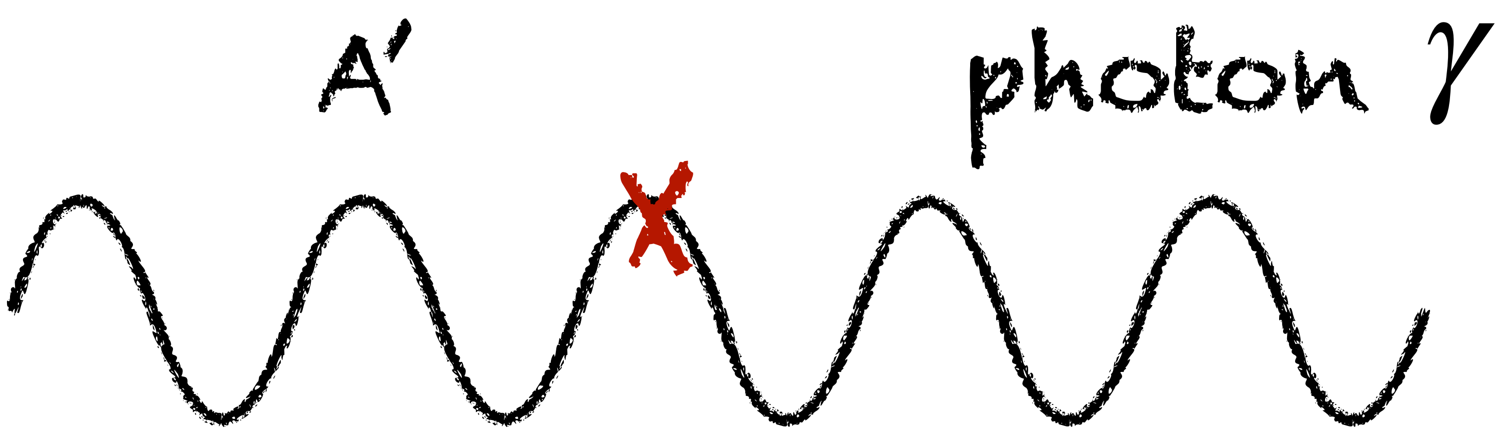
$$\mathscr{L} \supset -\frac{1}{4}F'^{\mu\nu}F'_{\mu\nu} - \frac{\epsilon}{2}F^{\mu\nu}F'_{\mu\nu} + \frac{1}{2}m_{A'}A'^{\mu}A'_{\mu}$$

kinetic mixing

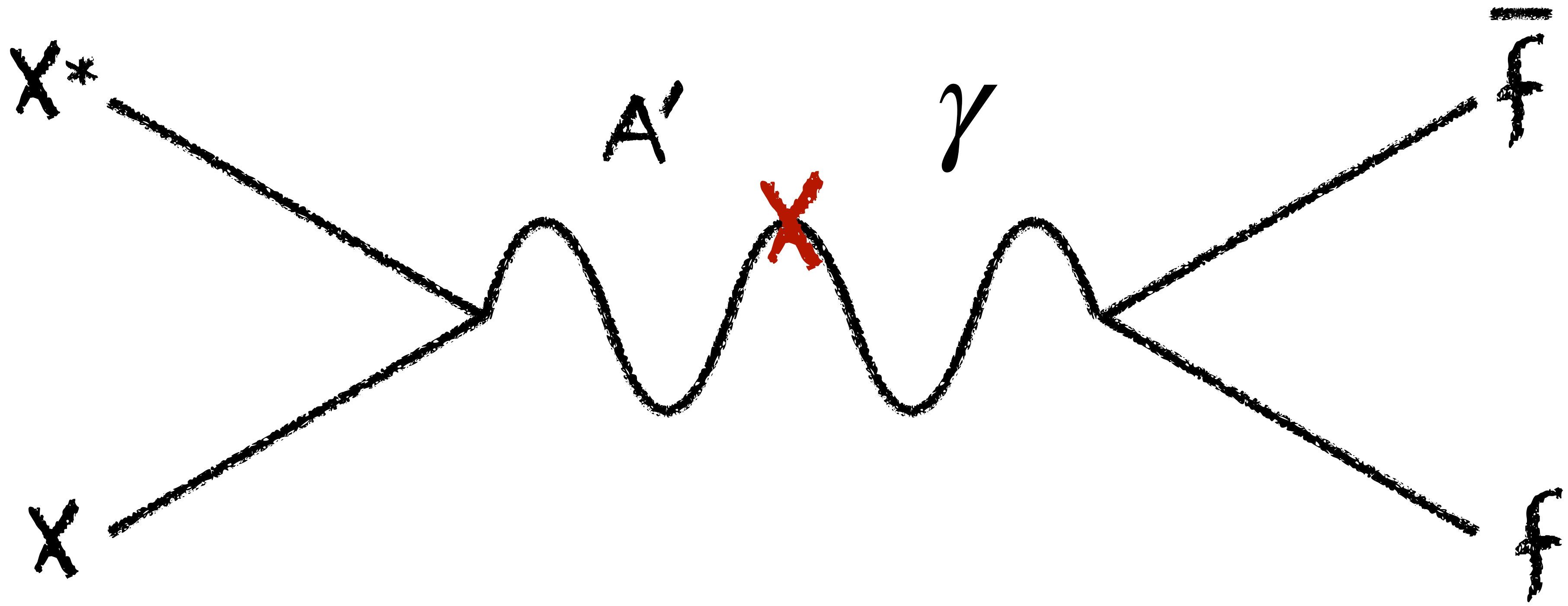
Dark Photon

$$SU(3)_C \times SU(2)_W \times U(1)_Y \times U(1)_X$$

$$\mathscr{L} \supset -\frac{1}{4}F'^{\mu\nu}F'_{\mu\nu} - \frac{\epsilon}{2}F^{\mu\nu}F'_{\mu\nu} + \frac{1}{2}m_{A'}A'^{\mu}A'_{\mu}$$



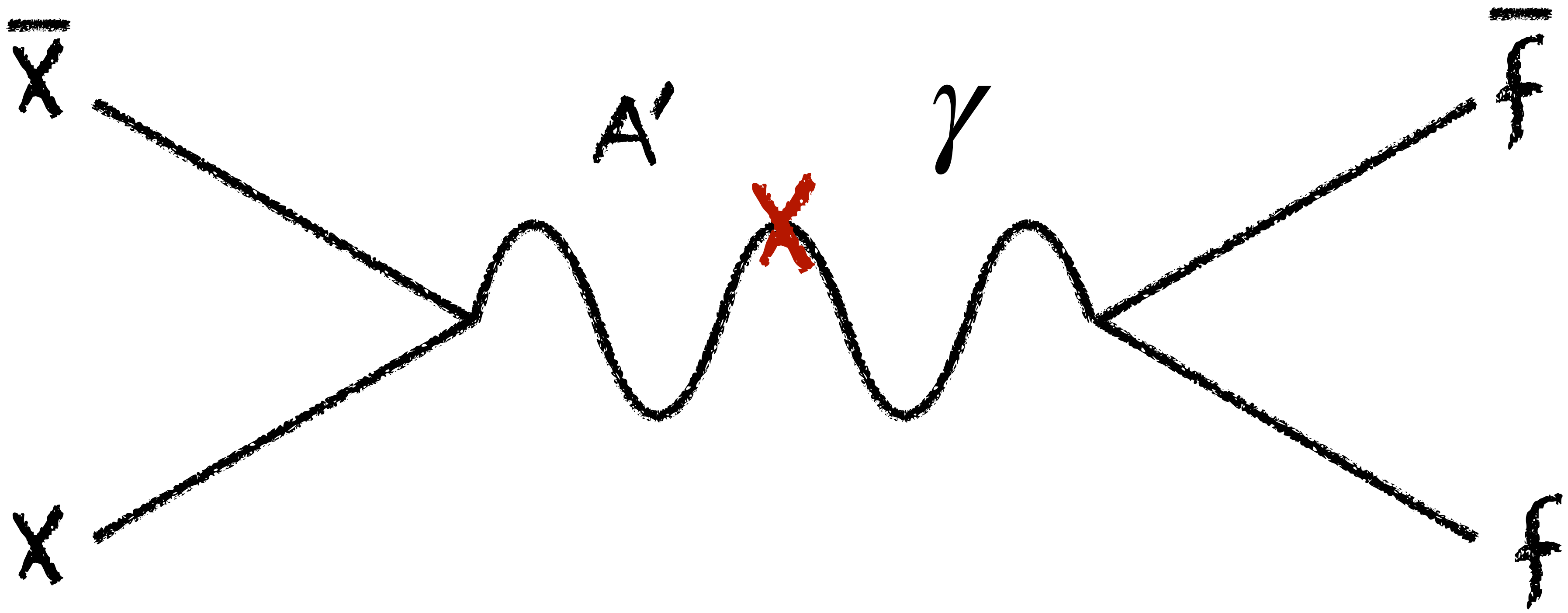
Thermal Scalar



$$m_{A'} > 2m_\chi \qquad \langle \sigma v \rangle \sim \frac{\alpha \alpha_D \epsilon^2}{m_{A'}^4}$$

CMB constraints → scalar DM

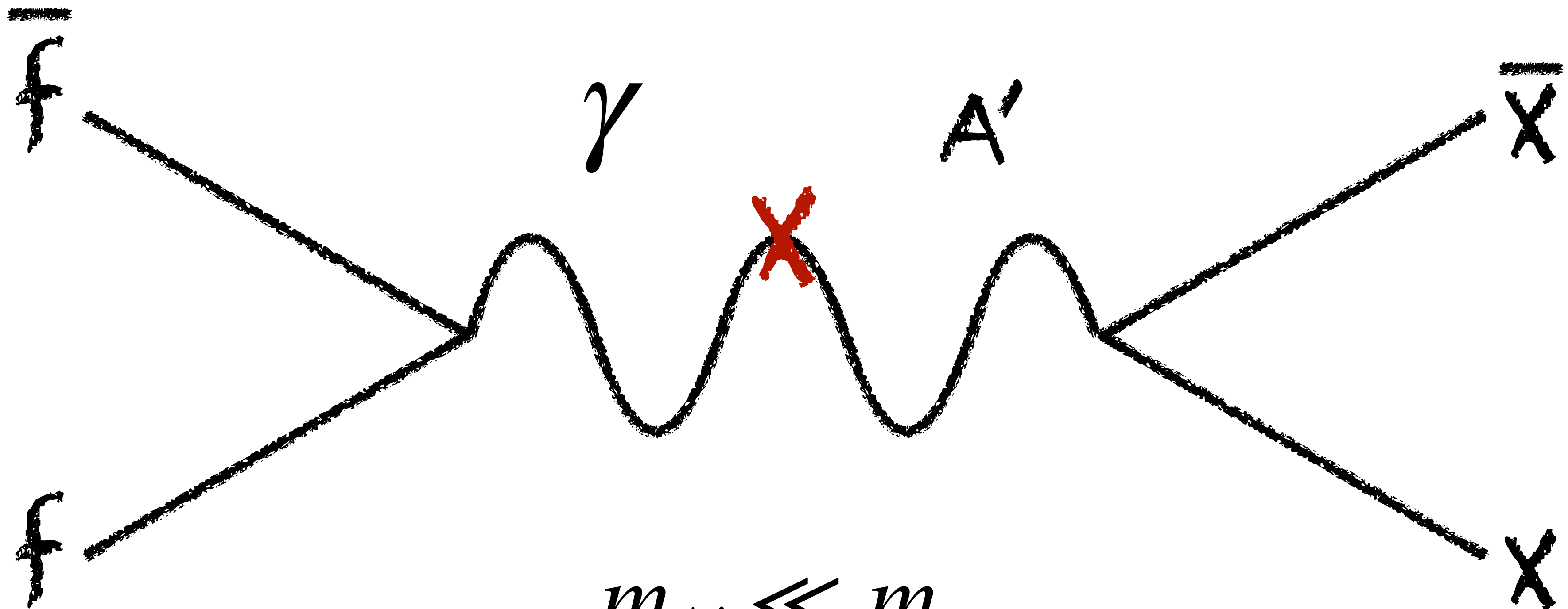
Asymmetric Fermion



present day abundance of DM from same mechanism
as baryon asymmetry

CMB constraints → lower bound on annihilation cross-section

Freeze-in DM

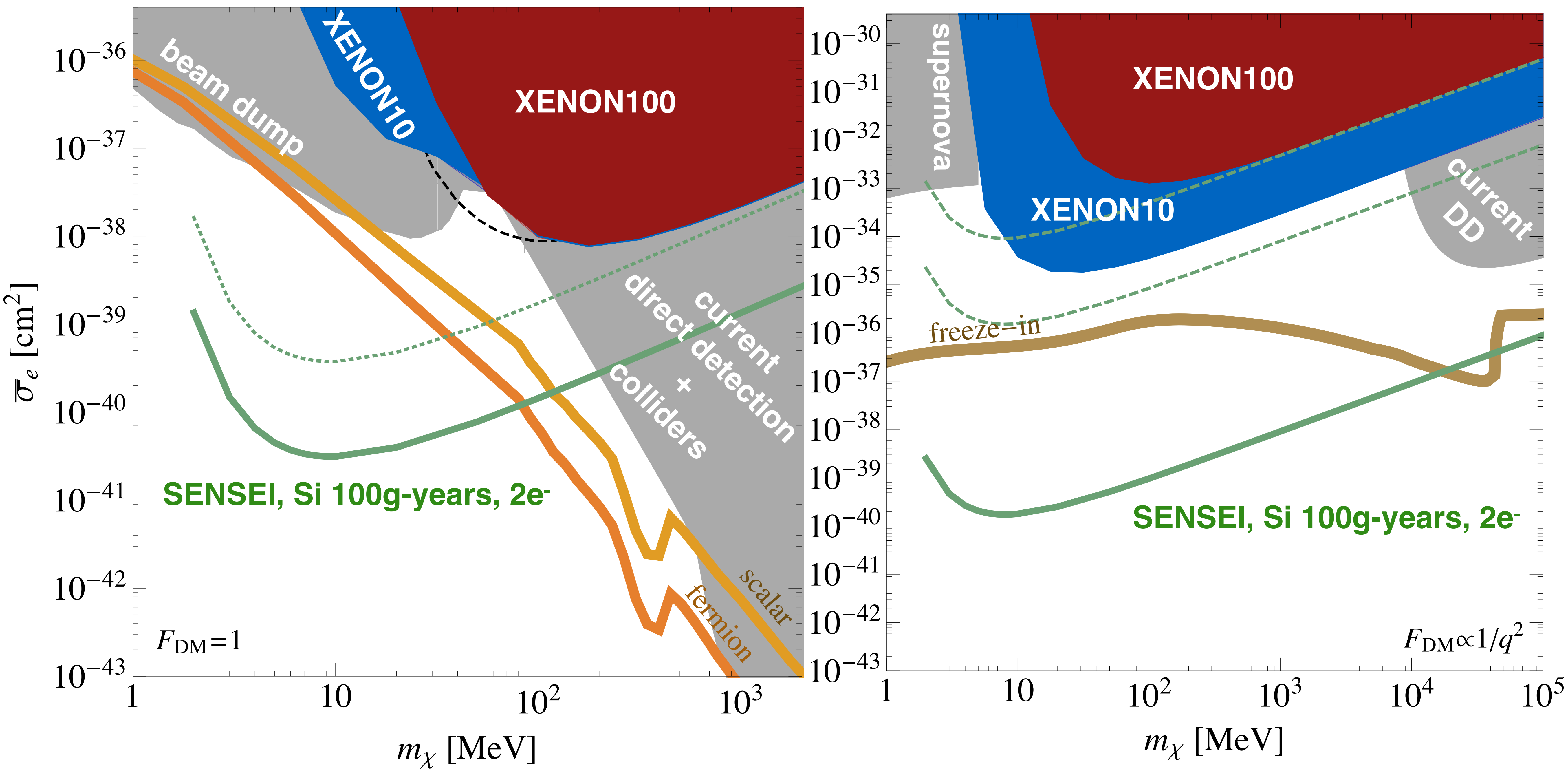


$$m_{A'} \ll m_\chi$$

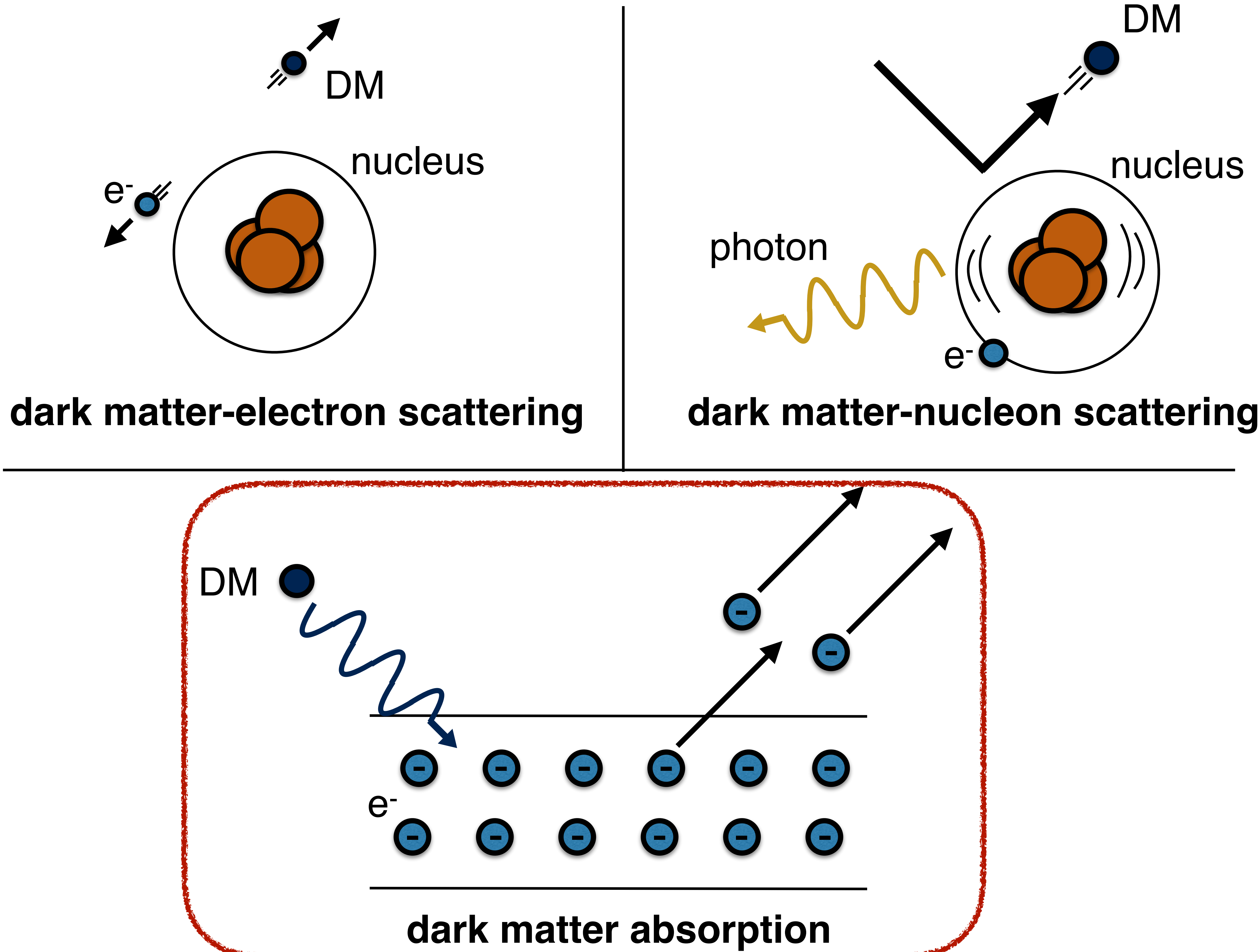
DM very weakly coupled to thermal bath

out of equilibrium scatterings
gradually populate DM

SENSEI projections



based on: Essig, Fernandez-Serra, Soto, Mardon, Volansky, TTY [1509.01598]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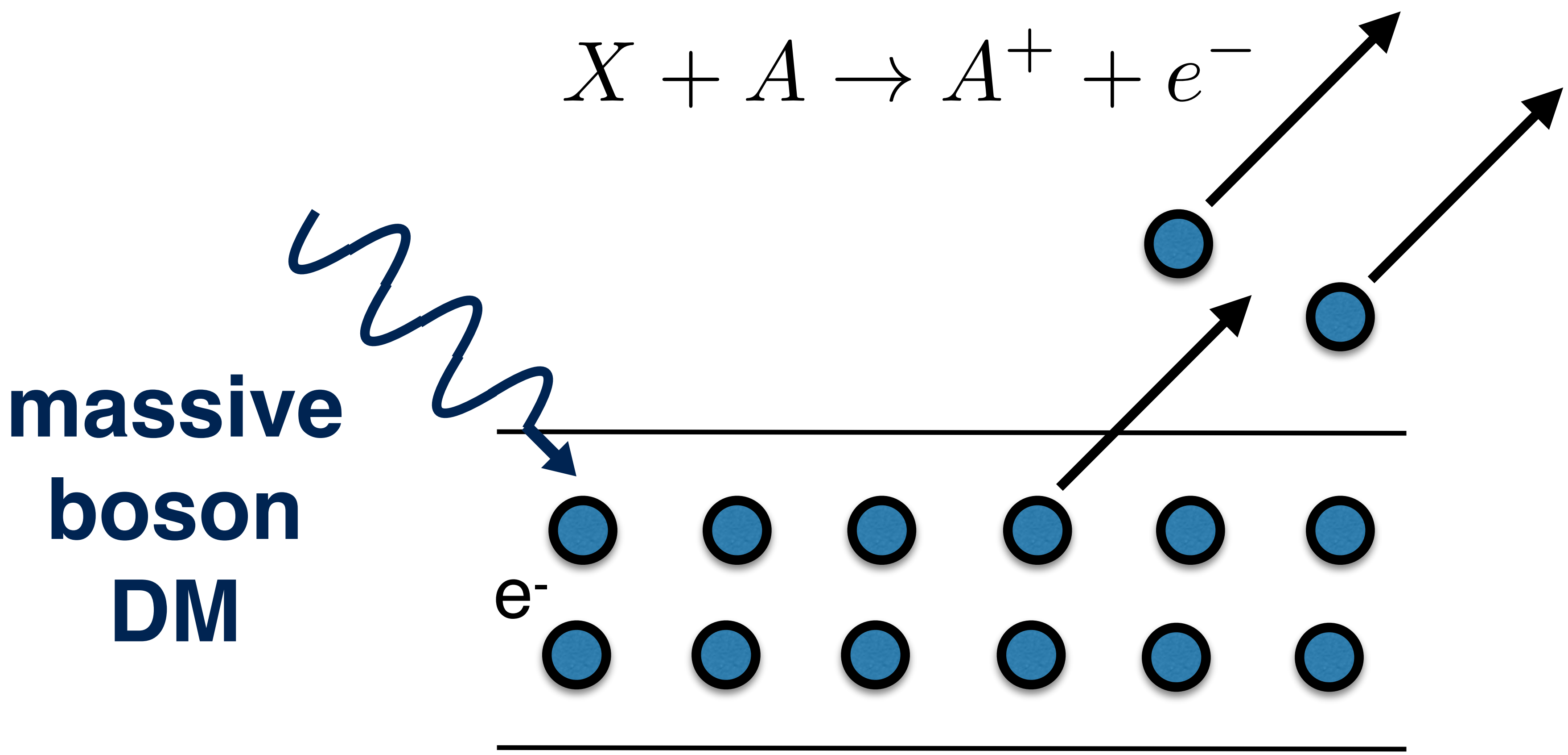
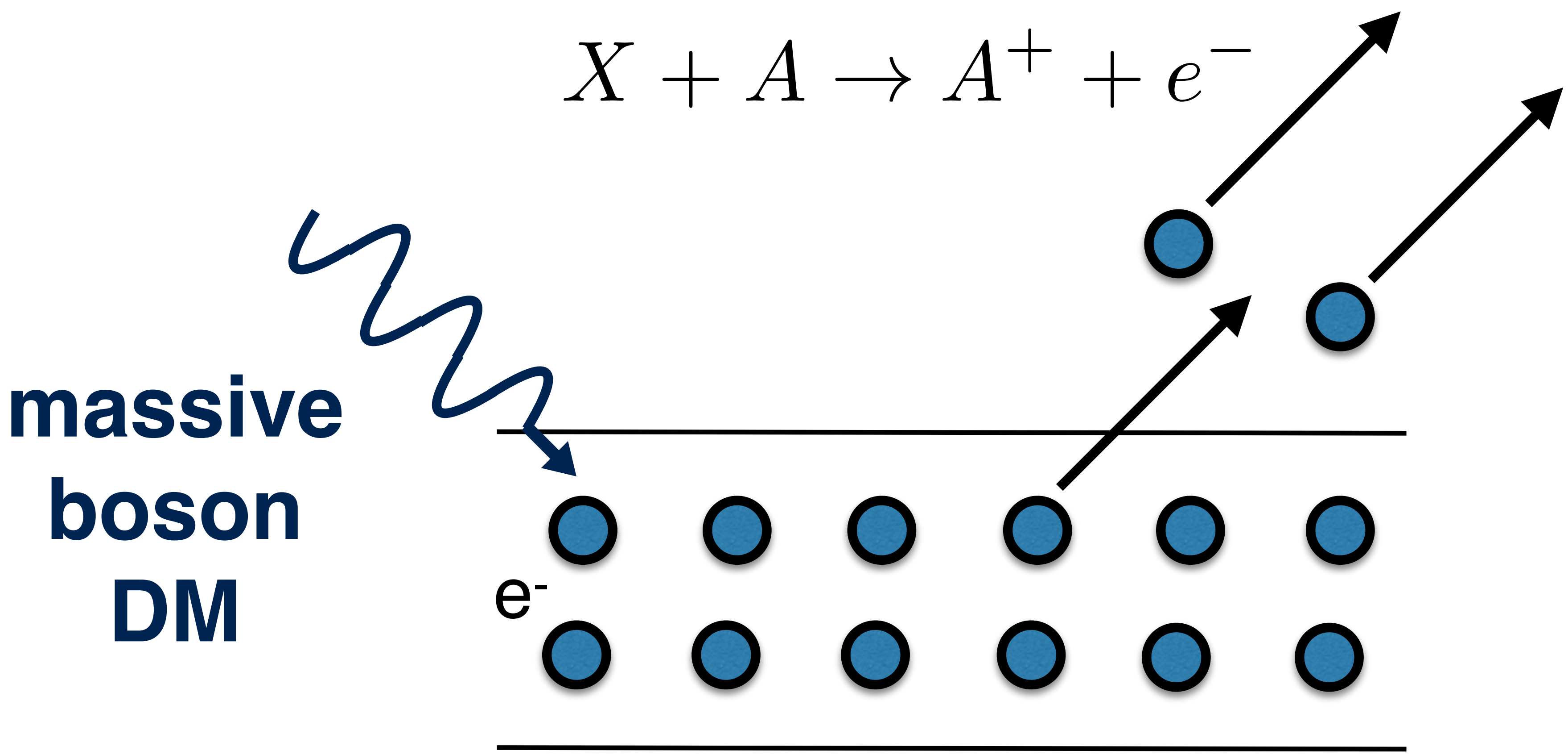
photoelectric effect



absorb all of the energy
the incoming dark matter

photoelectric effect



photon

$$|\vec{q}| = \omega$$

bosonic dark matter

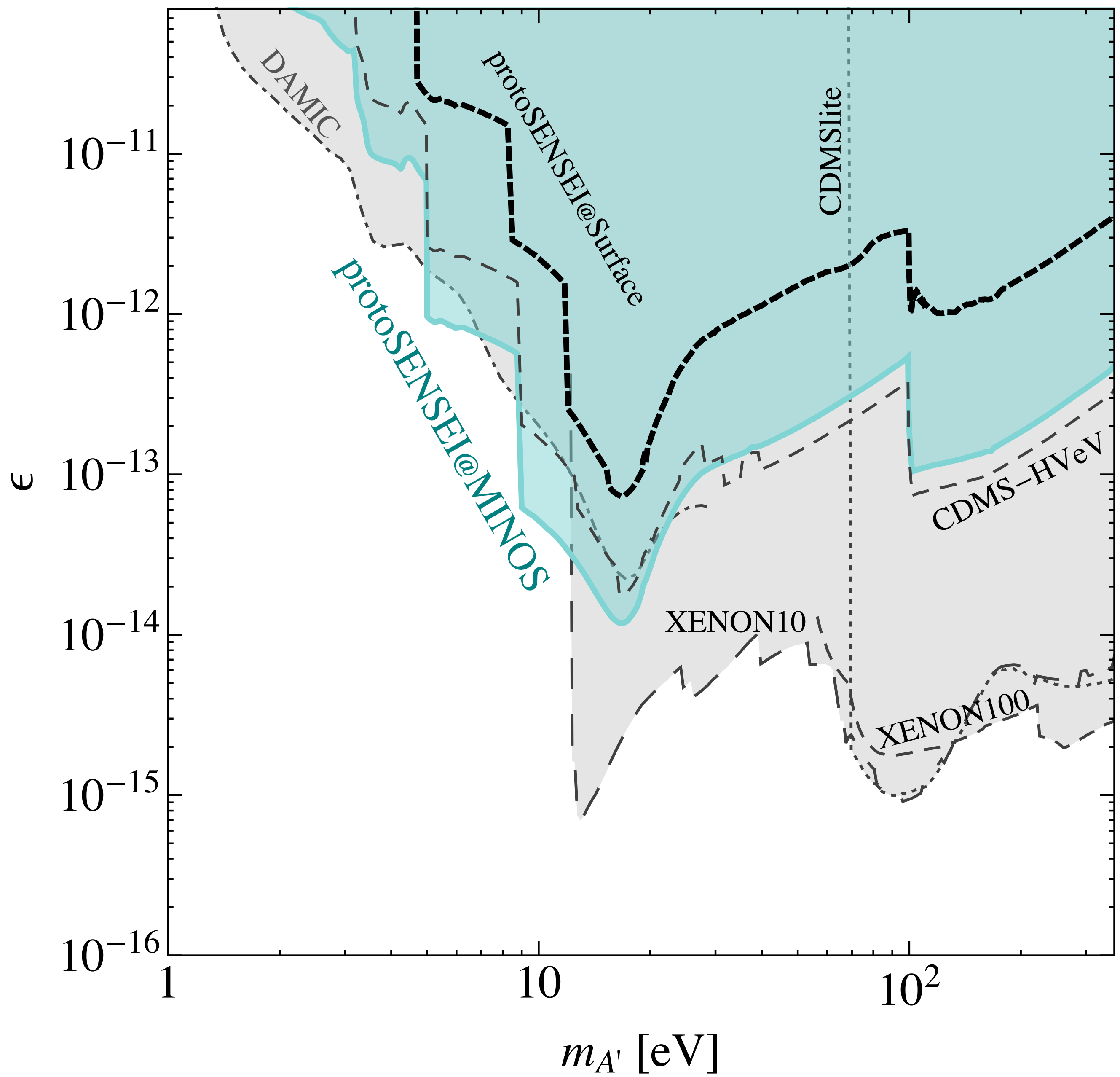
$$|\vec{q}| = m_X v_{\rm DM} \sim 10^{-3}\omega$$

$$< \quad |\vec{q}_e|$$

can relate massive boson absorption to photon absorption

$$\sigma_{DM}(\omega) \propto \sigma_{\rm PE}(\omega)$$

Dark Photon DM



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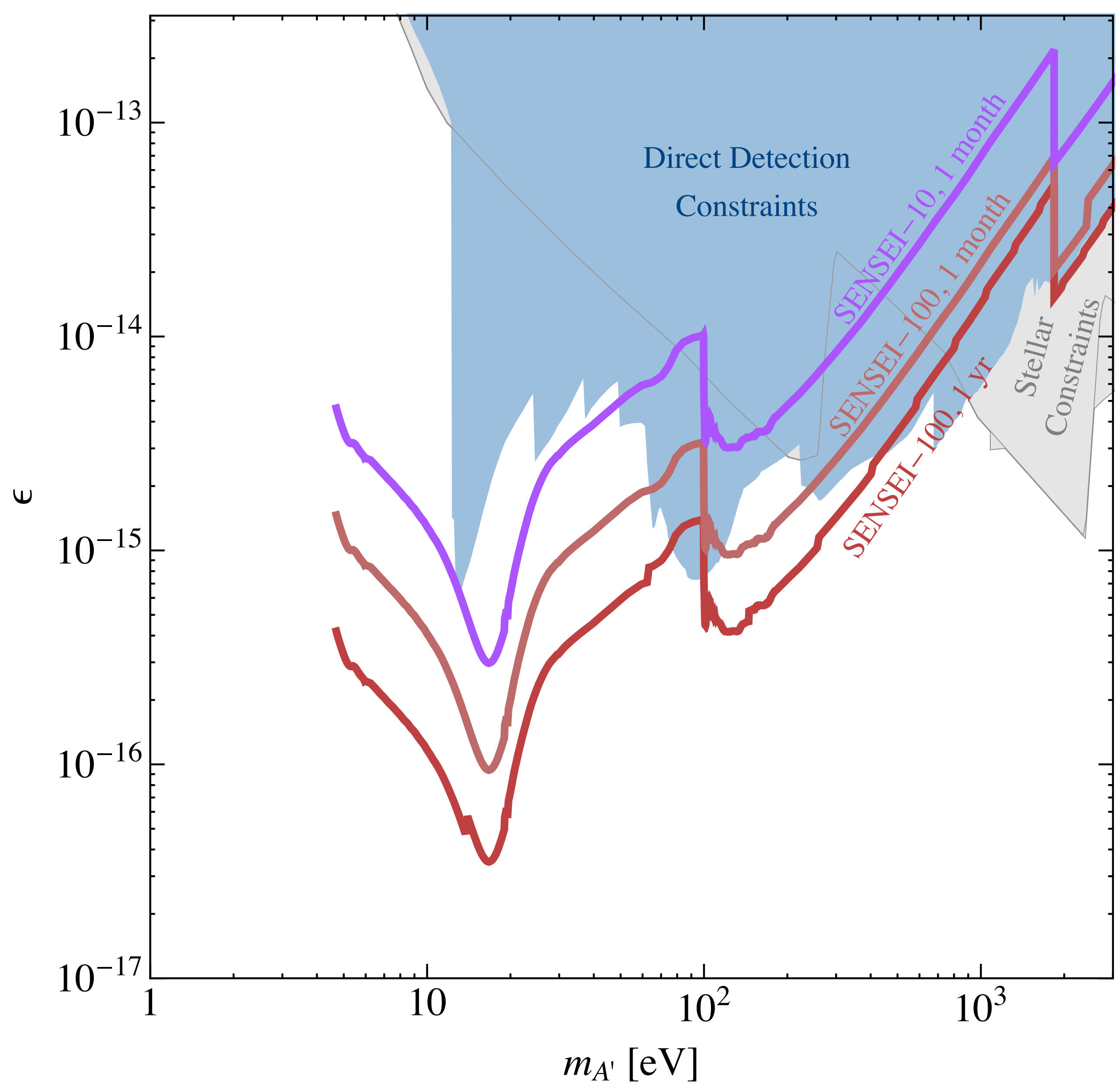
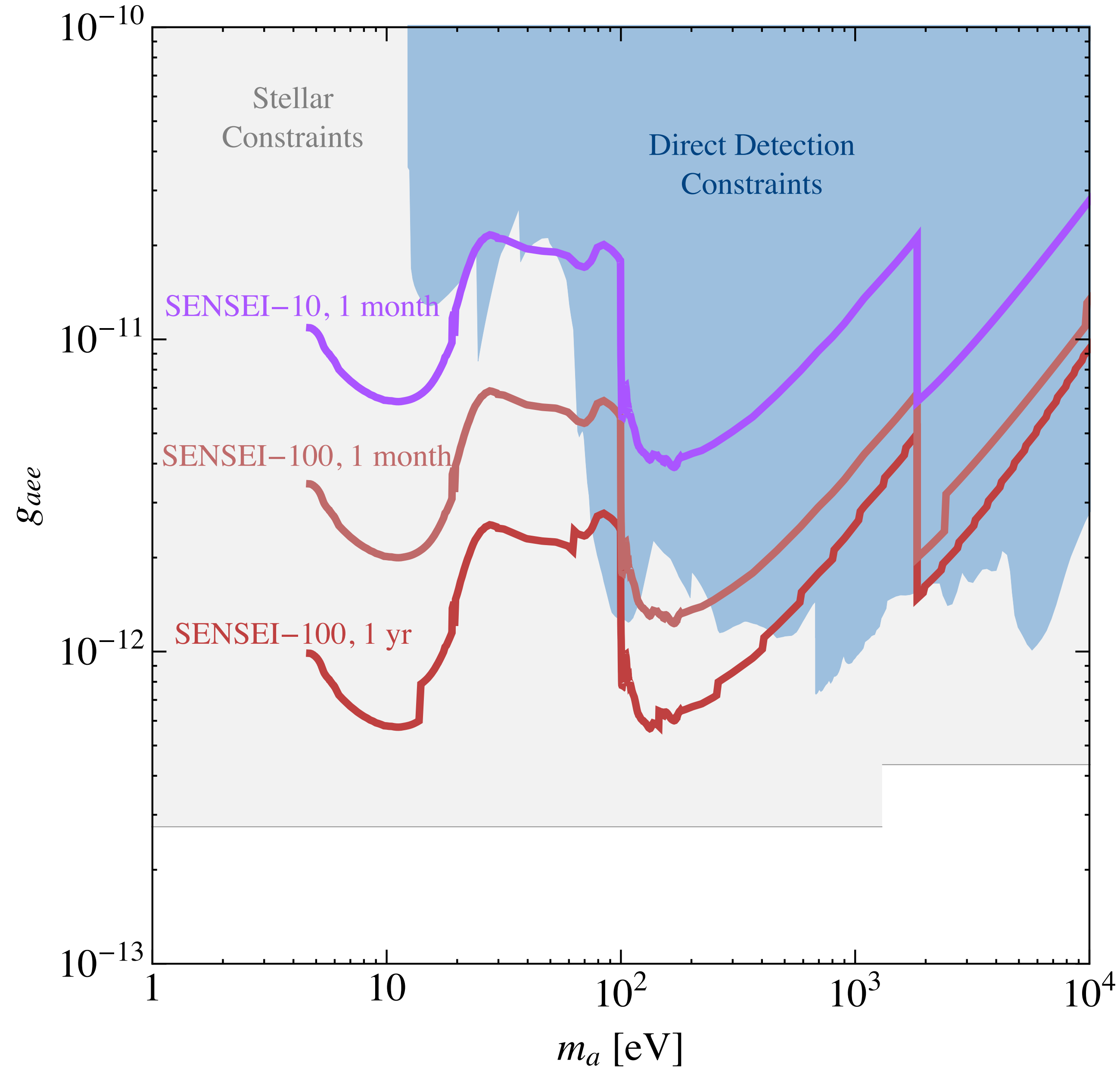
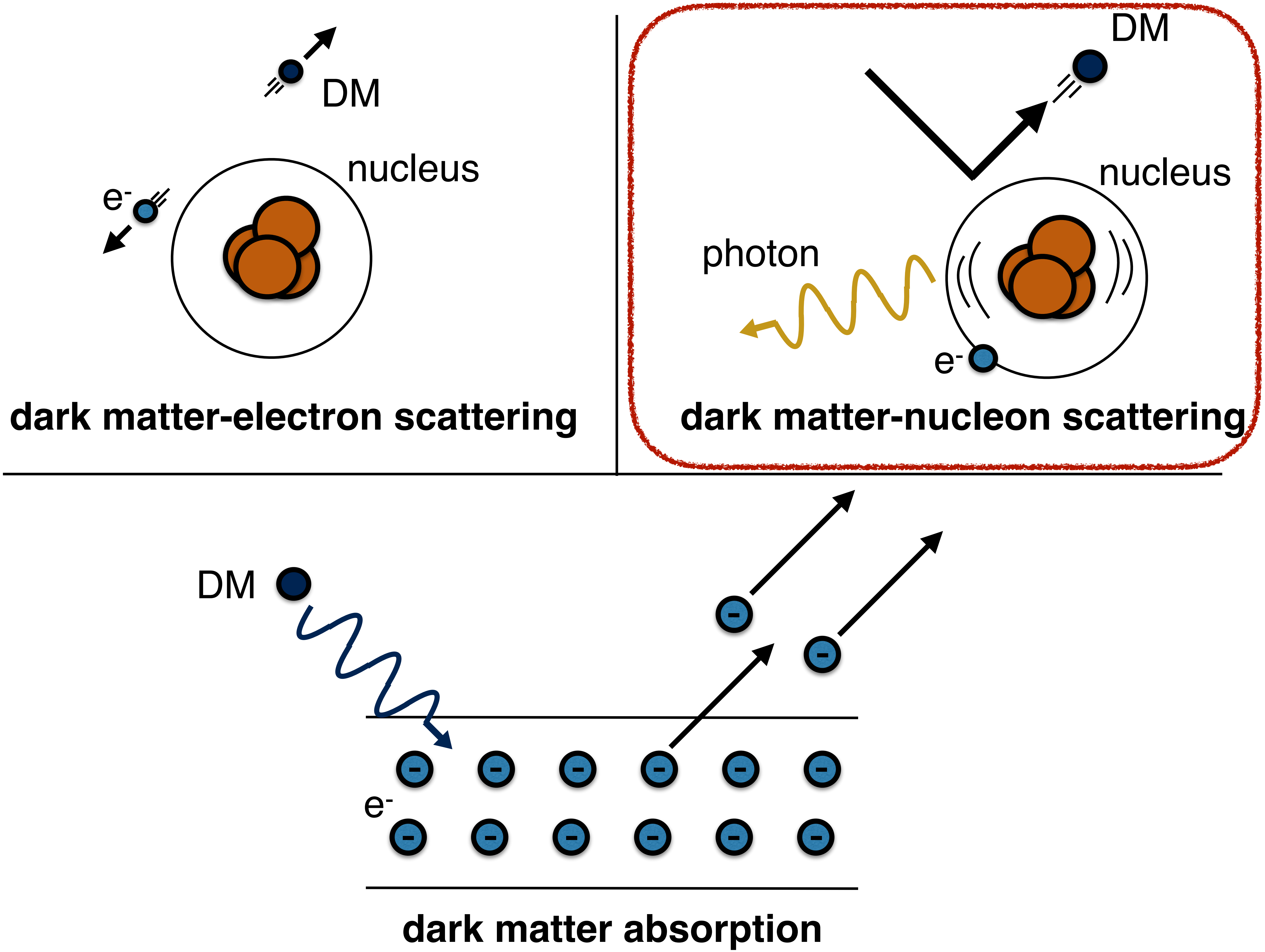
physics potential

bosonic absorption





based on: Bloch, Essig, Tobioka, Volansky, TTY [1608.02123]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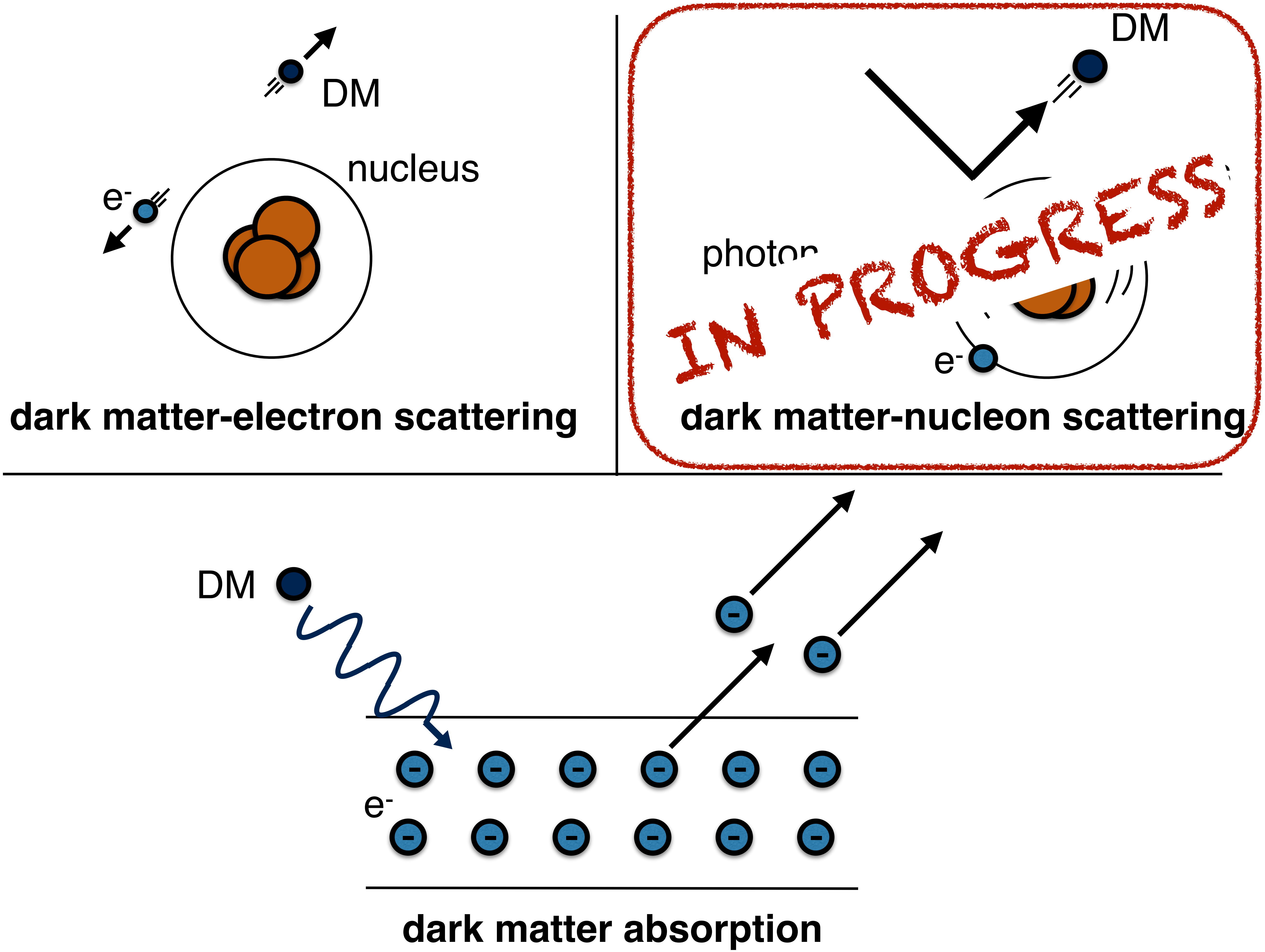

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IN PROGRESS
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dark sector candidates at direct detection exps