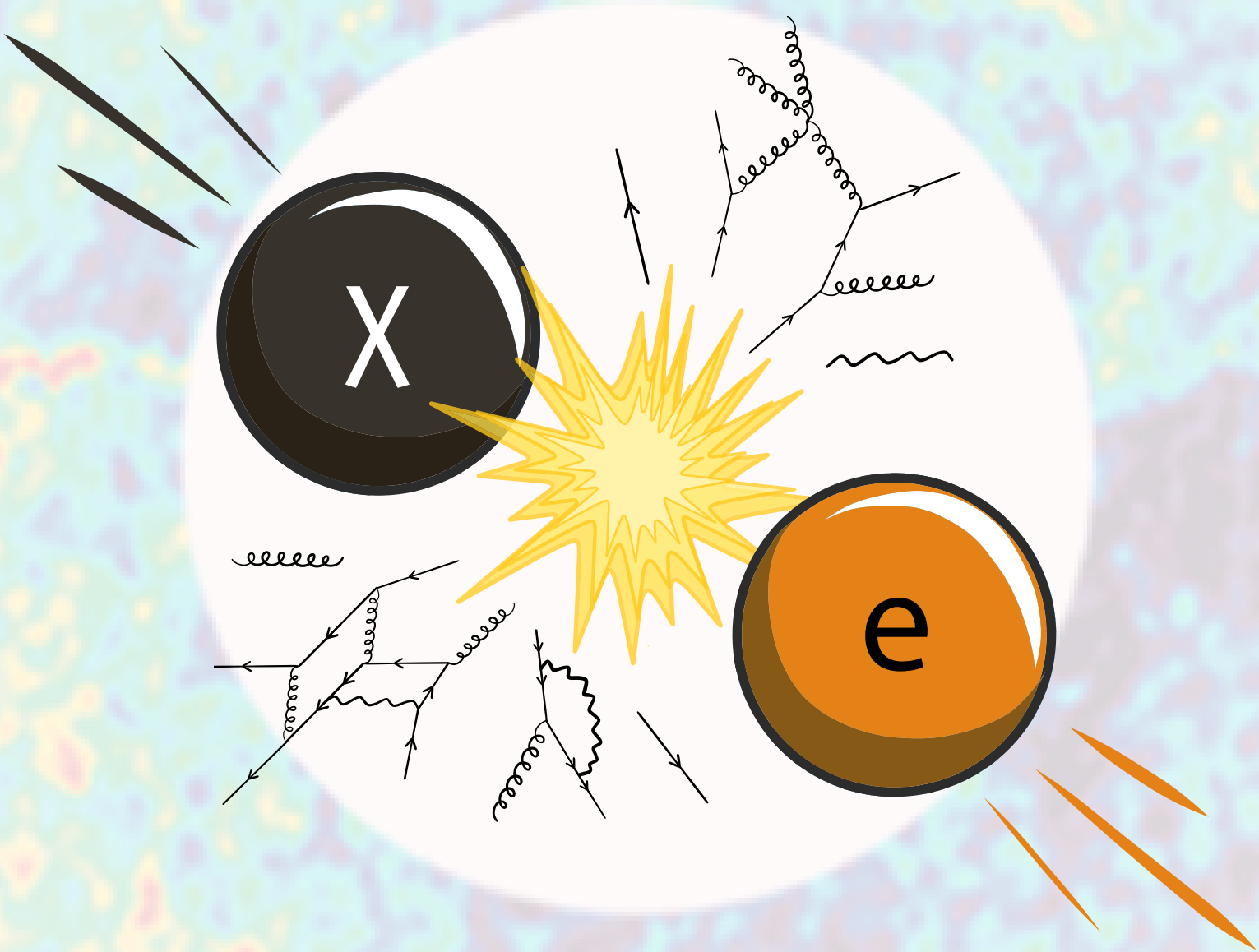
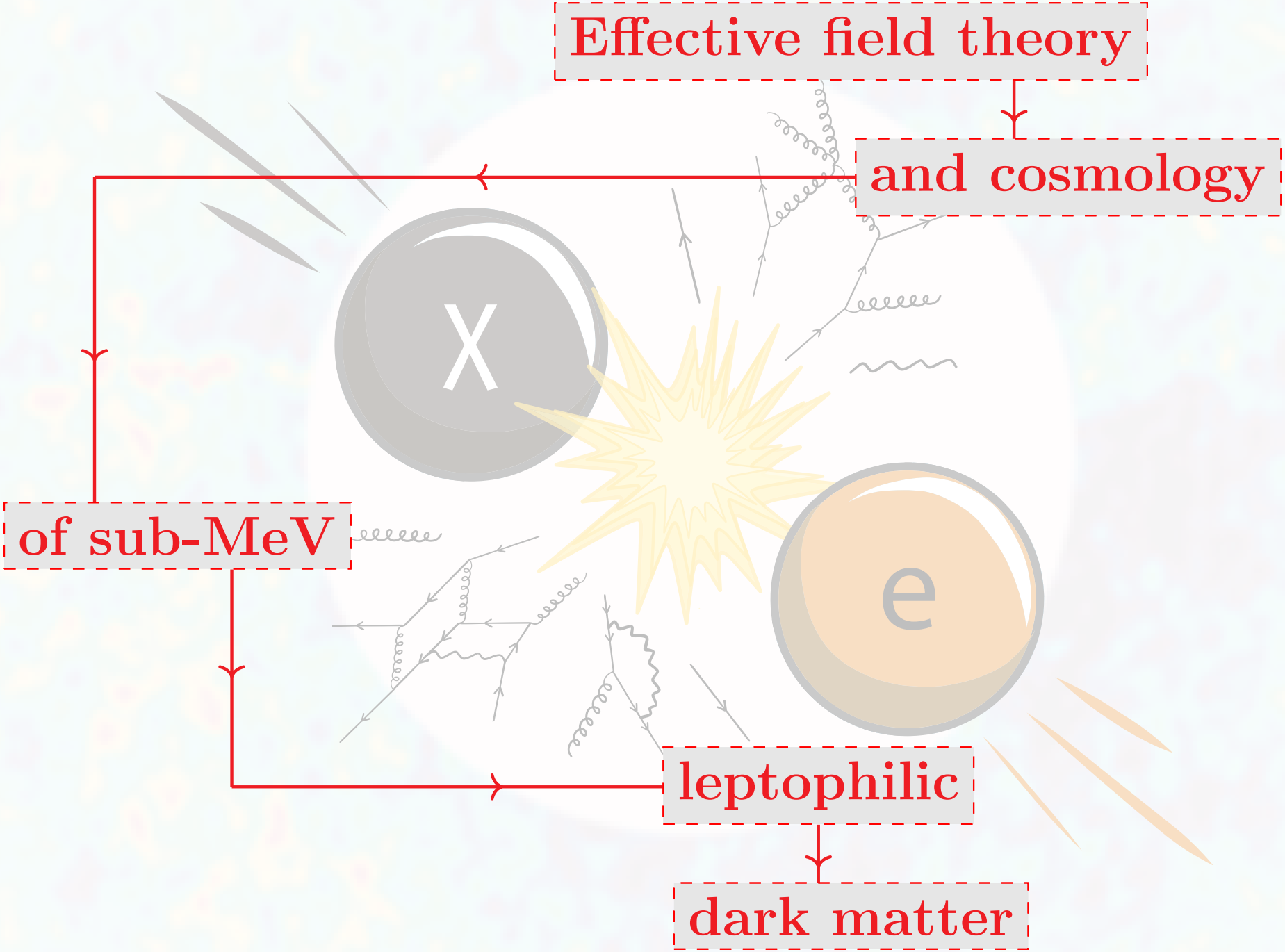
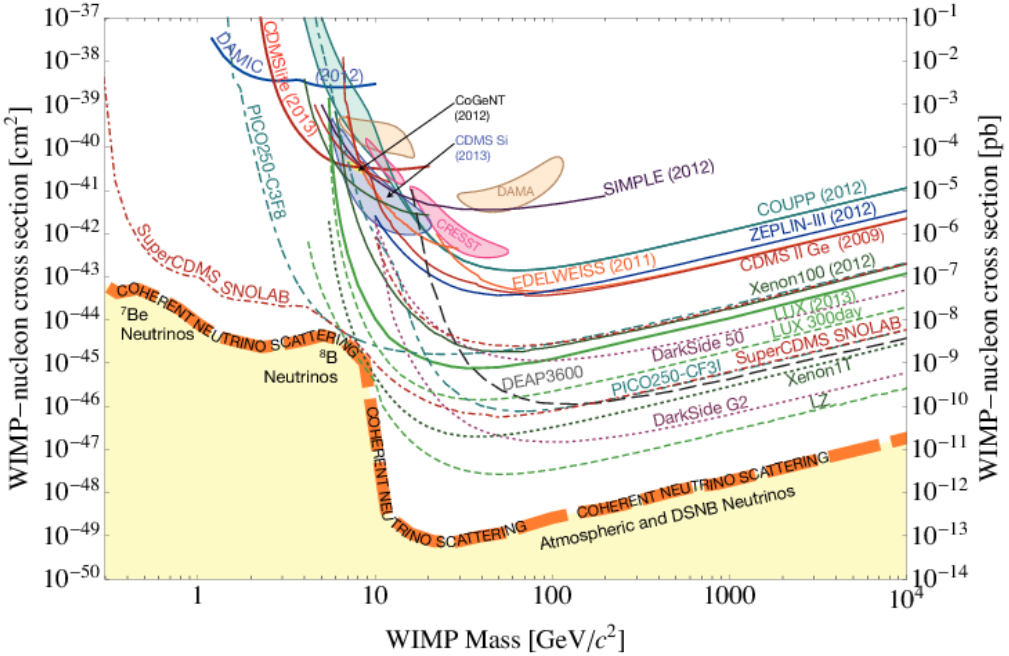

X
e


Effective field theory
and cosmology
X
e
of sub-MeV
leptophilic
dark matter


WIMP–nucleon cross section [cm^2]
WIMP–nucleon cross section [pb]
WIMP Mass [GeV/c^2]
DAMIC
CDMSlite (2013)
(2012)
PICO250-C3F8
CoGeNT (2012)
CDMS Si (2013)
DAMA
SIMPLE (2012)
CRESST
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
EDELWEISS (2011)
Xenon100 (2012)
LUX (2013)
LUX 300day
SuperCDMS SNOLAB
DarkSide 50
PICO250-CF3I
Xenon1T
DEAP3600
DarkSide G2
LZ
SuperCDMS SNOLAB
COHERENT NEUTRINO SCATTERING
^{7}Be Neutrinos
^{8}B Neutrinos
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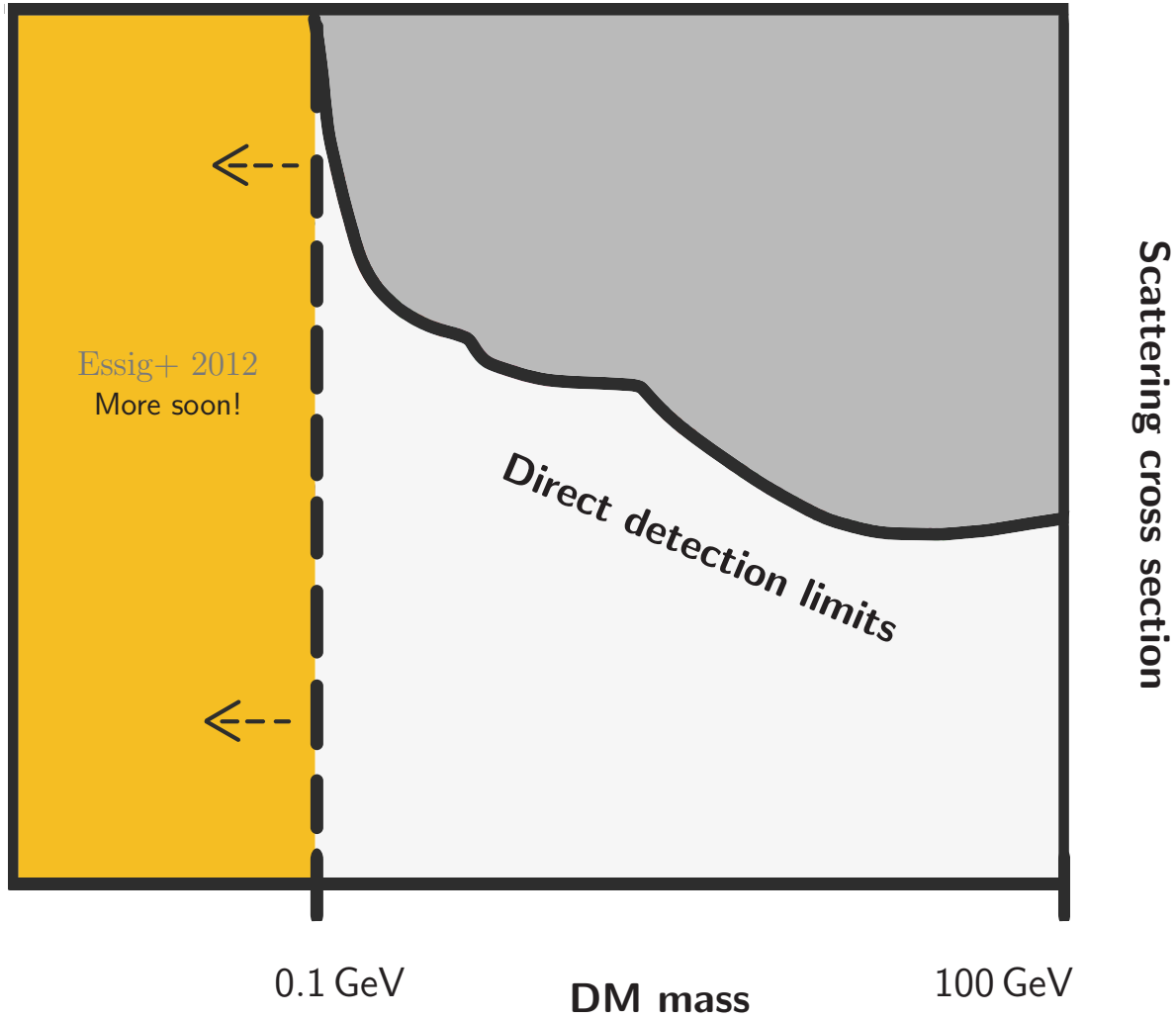
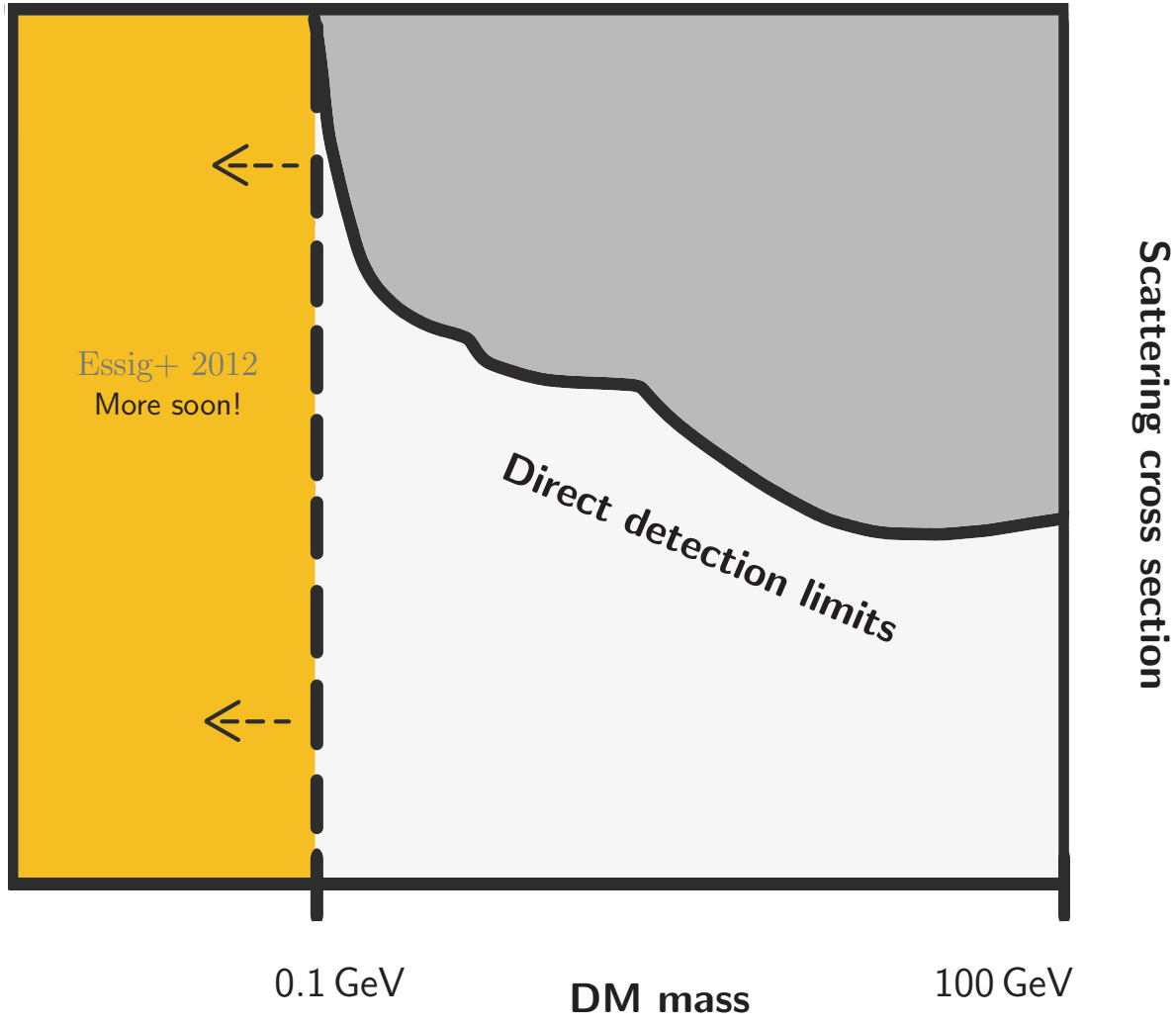
COHERENT NEUTRINO SCATTERING
Atmospheric and DSNB Neutrinos

Cooley 2014


Scattering cross section
Direct detection limits
Essig+ 2012
More soon!
0.1 GeV
DM mass
100 GeV

$$m_{\mathrm{DM}} \ll m_{\mathrm{target}}$$

$$E_{\mathrm{recoil}} \sim \left(\frac{m_{\mathrm{DM}}}{m_{\mathrm{target}}}\right) m_{\mathrm{DM}}$$



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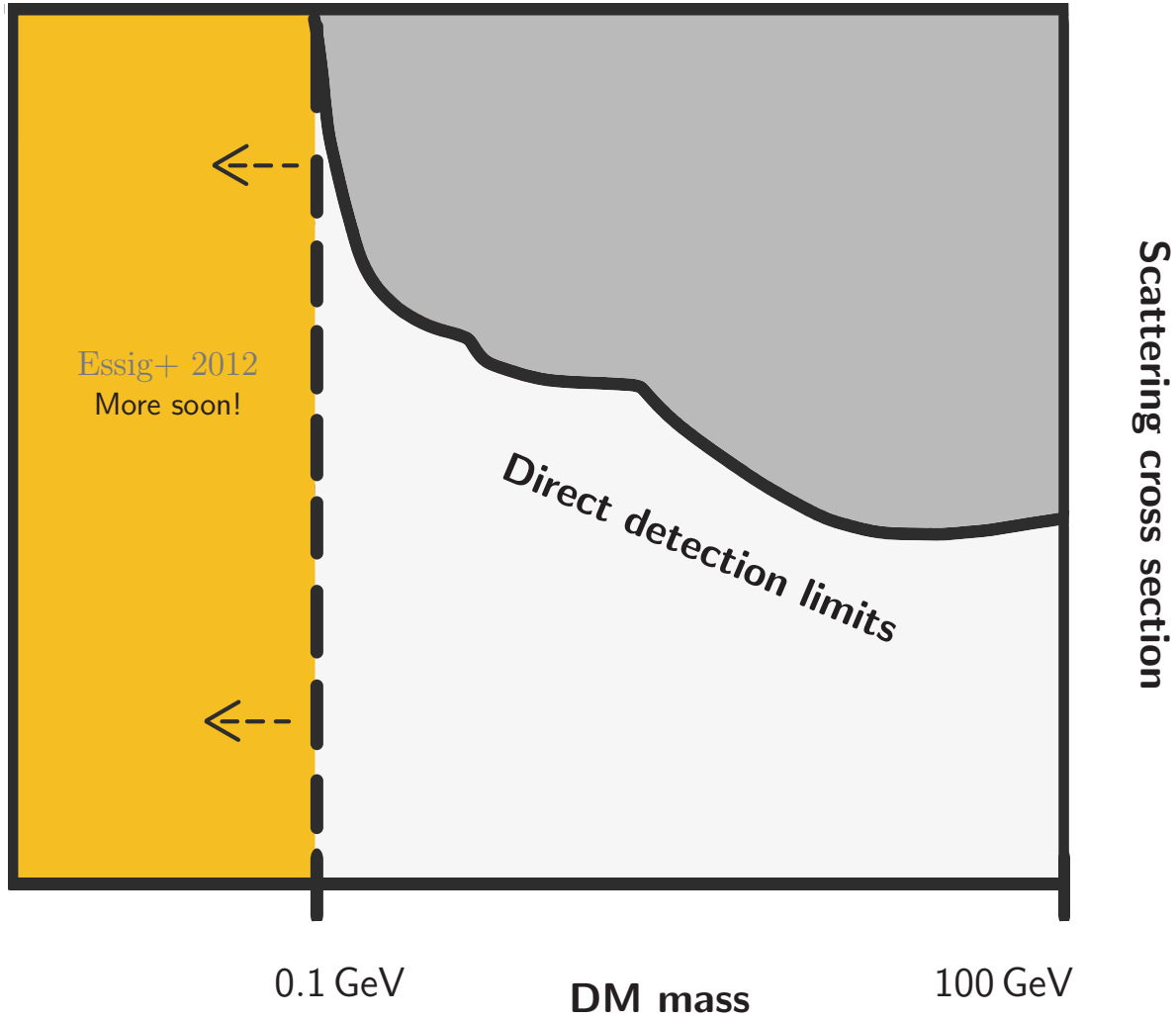

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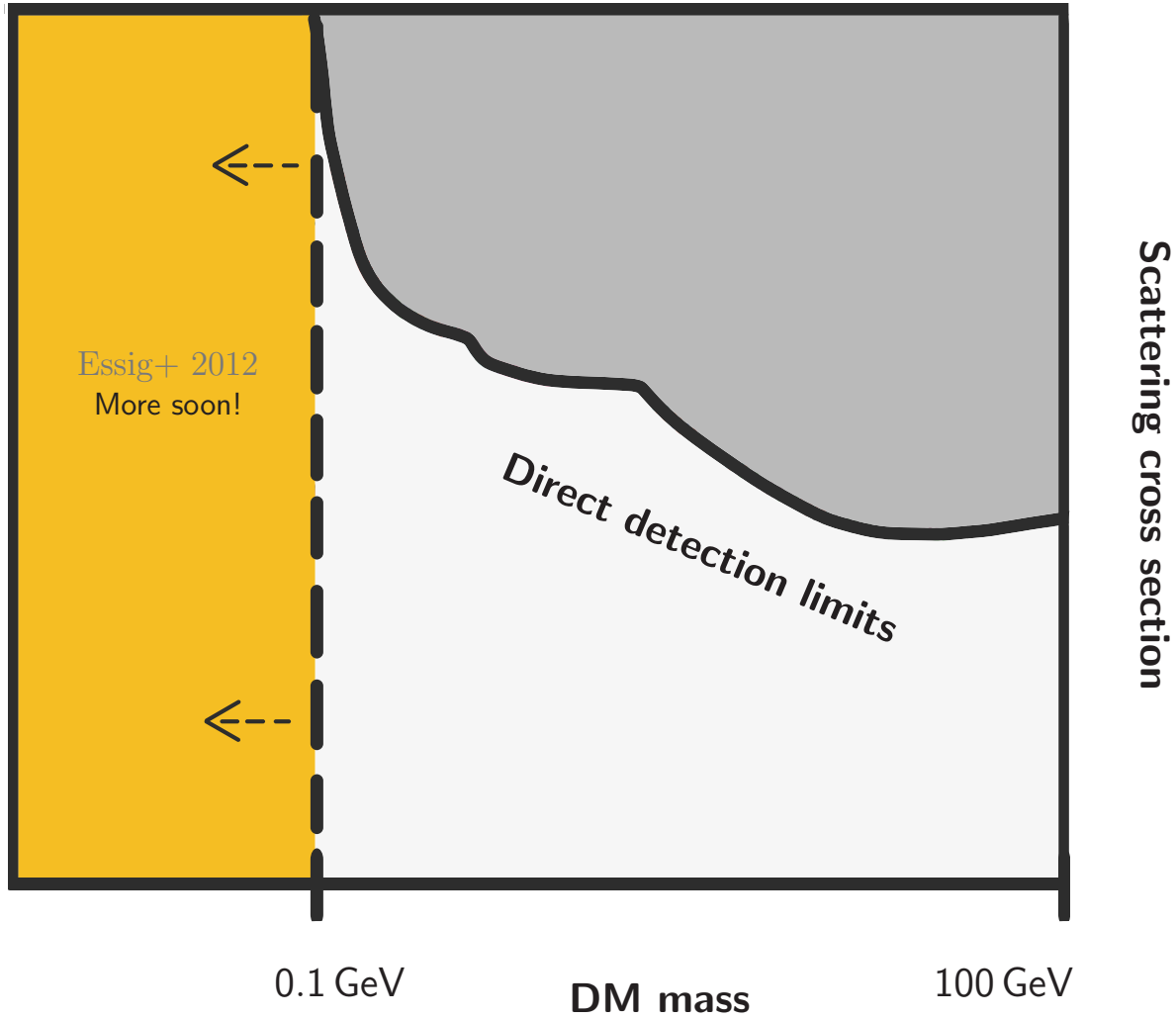
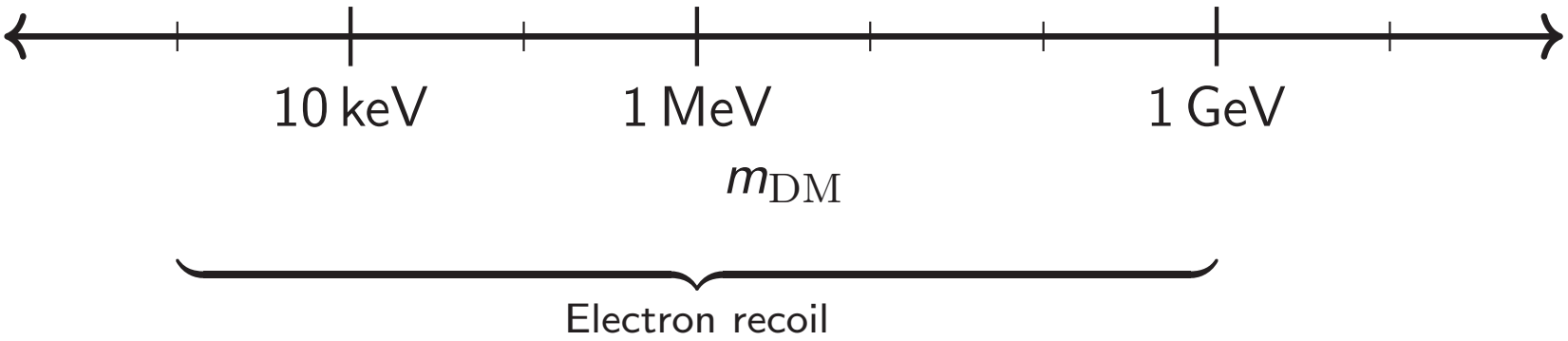
Electron recoil?

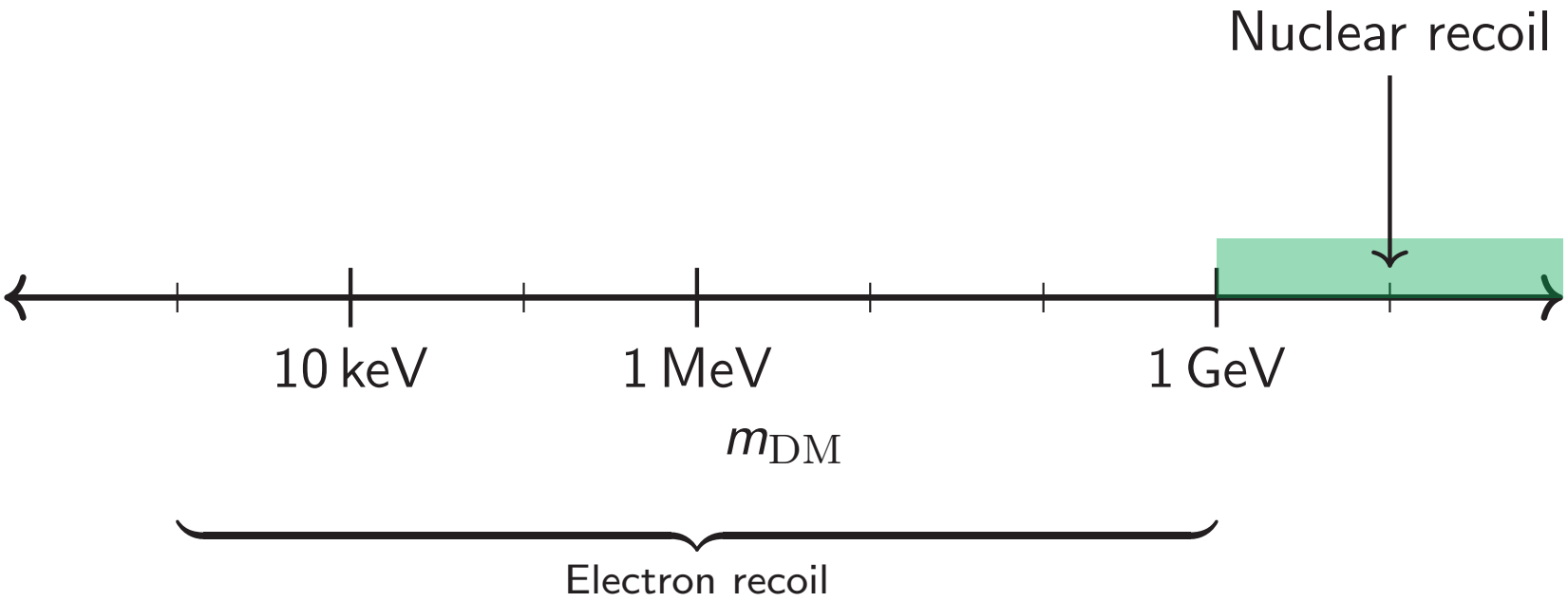


Light DM parameter space



Hochberg+ 2016

Light DM parameter space



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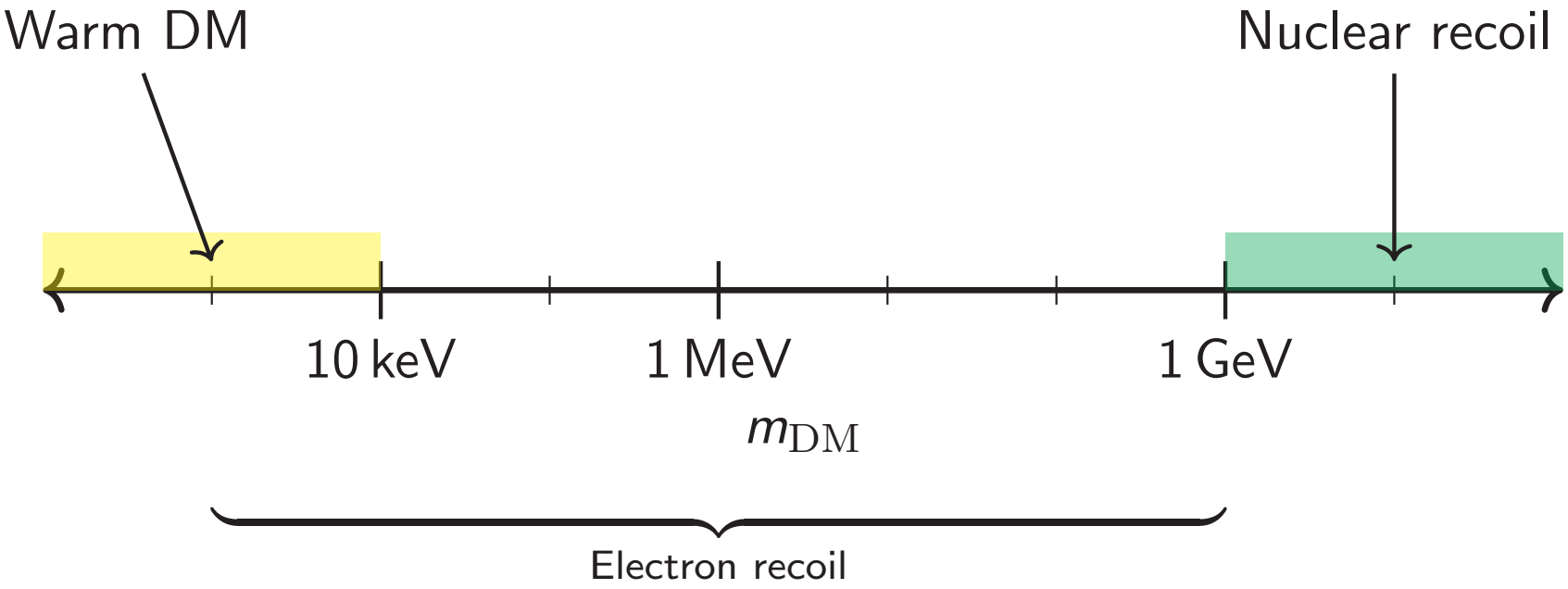

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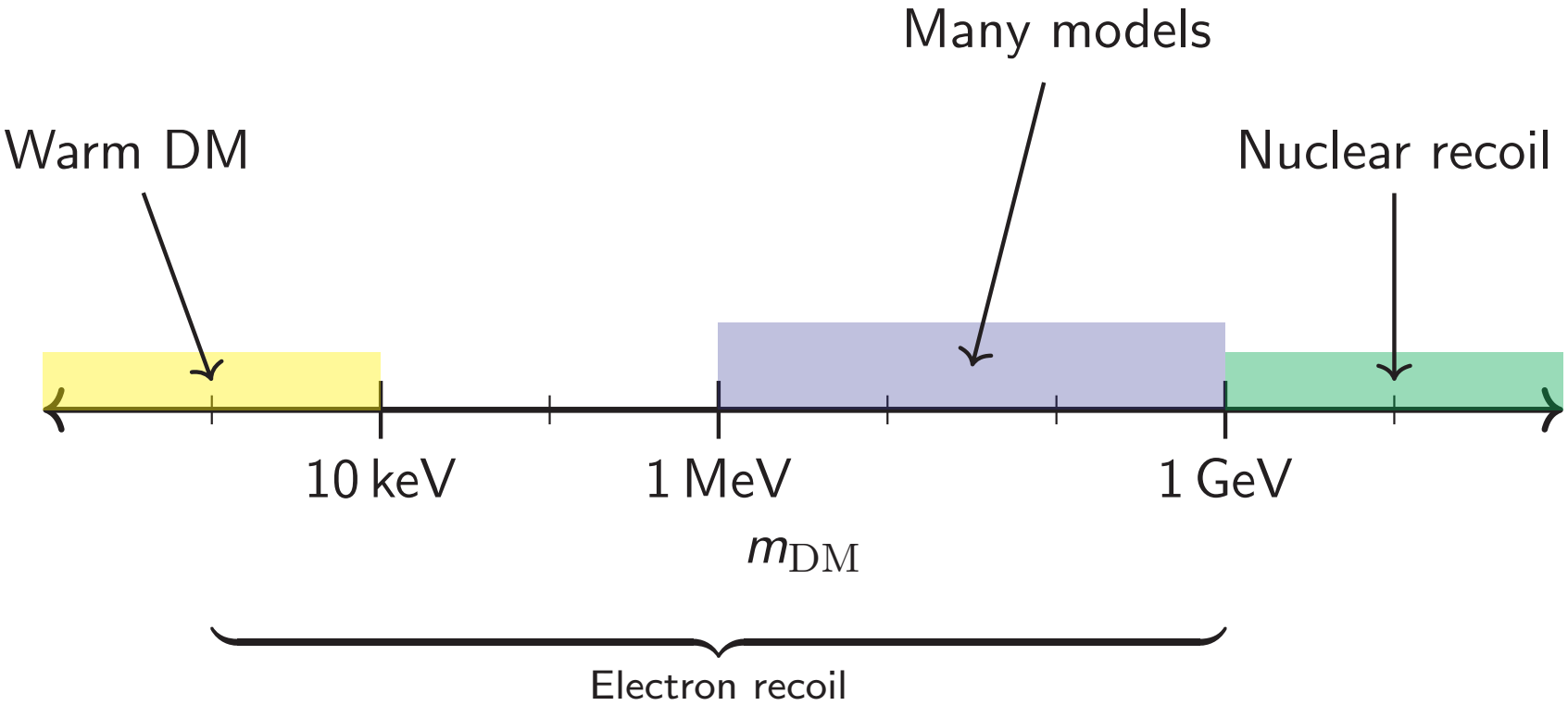

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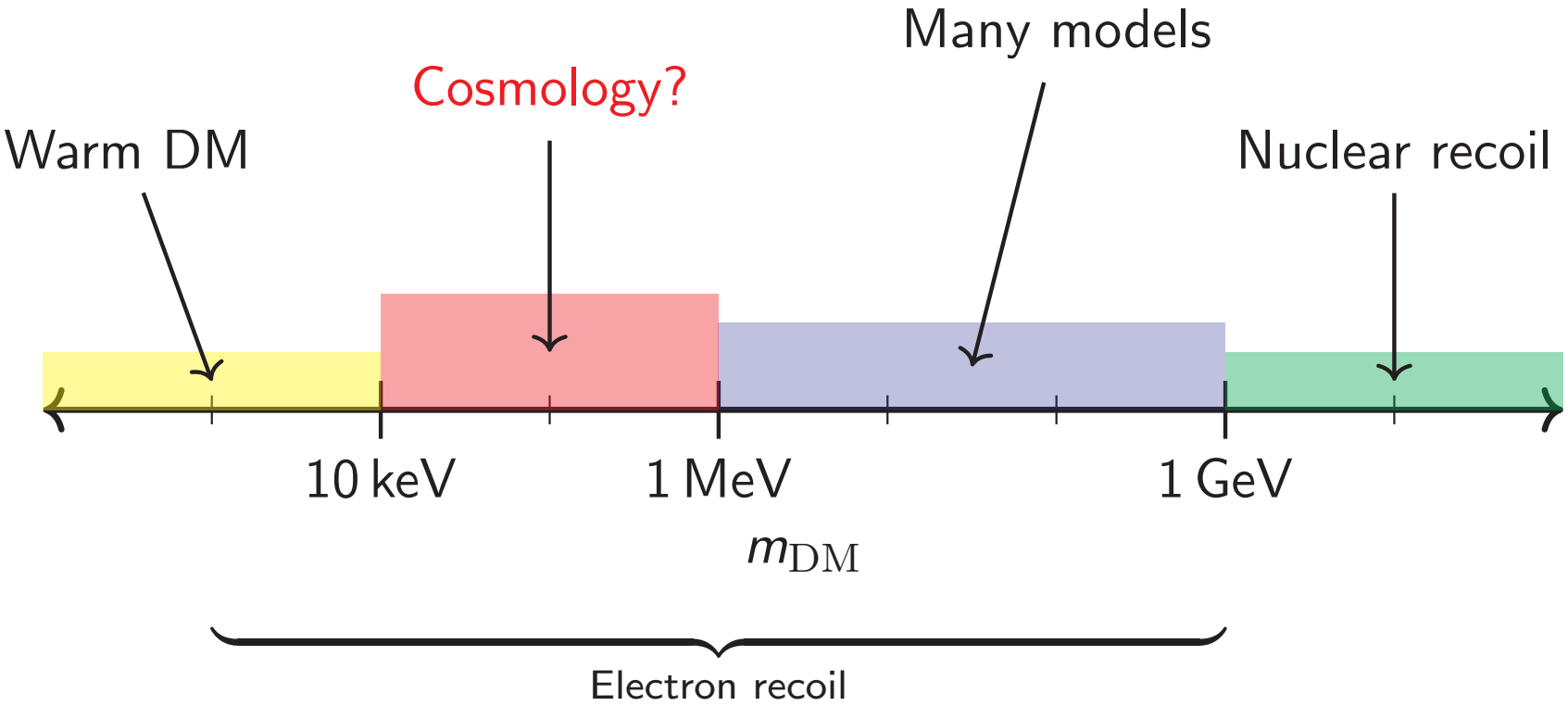

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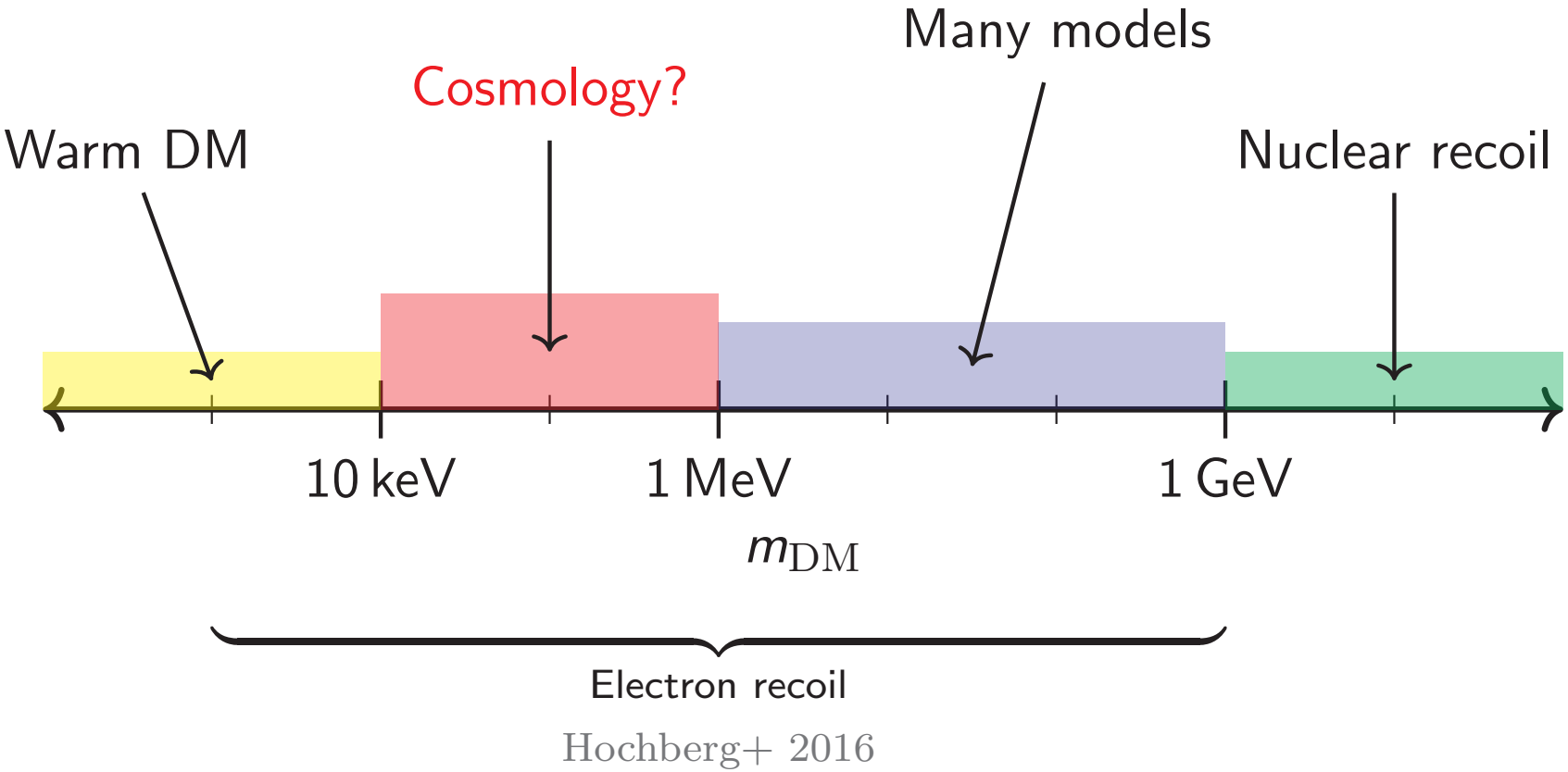

Hochberg+ 2016

What could electron recoil experiments see?

Sub-MeV DM

- For "vanilla" DM, **beating cosmology is hard**

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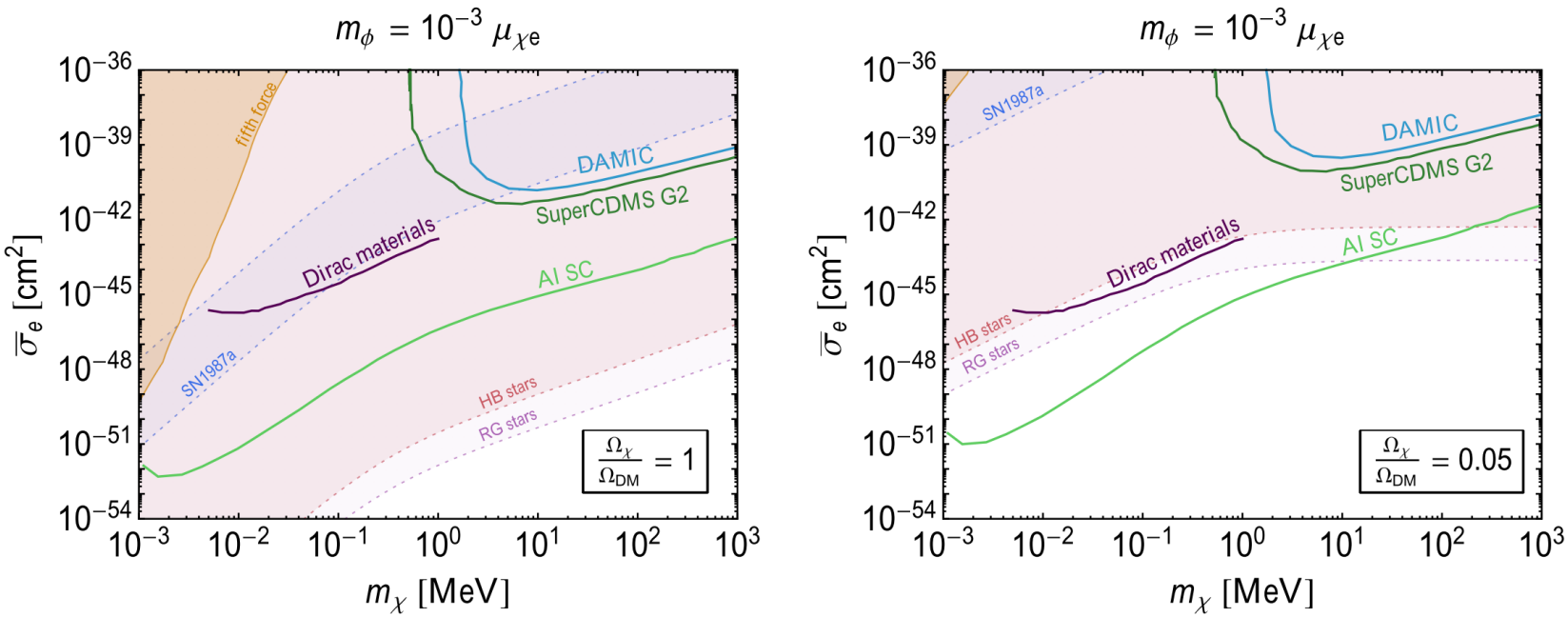
- Demonstrated by simplified models, e.g. Knapen+ 2017:



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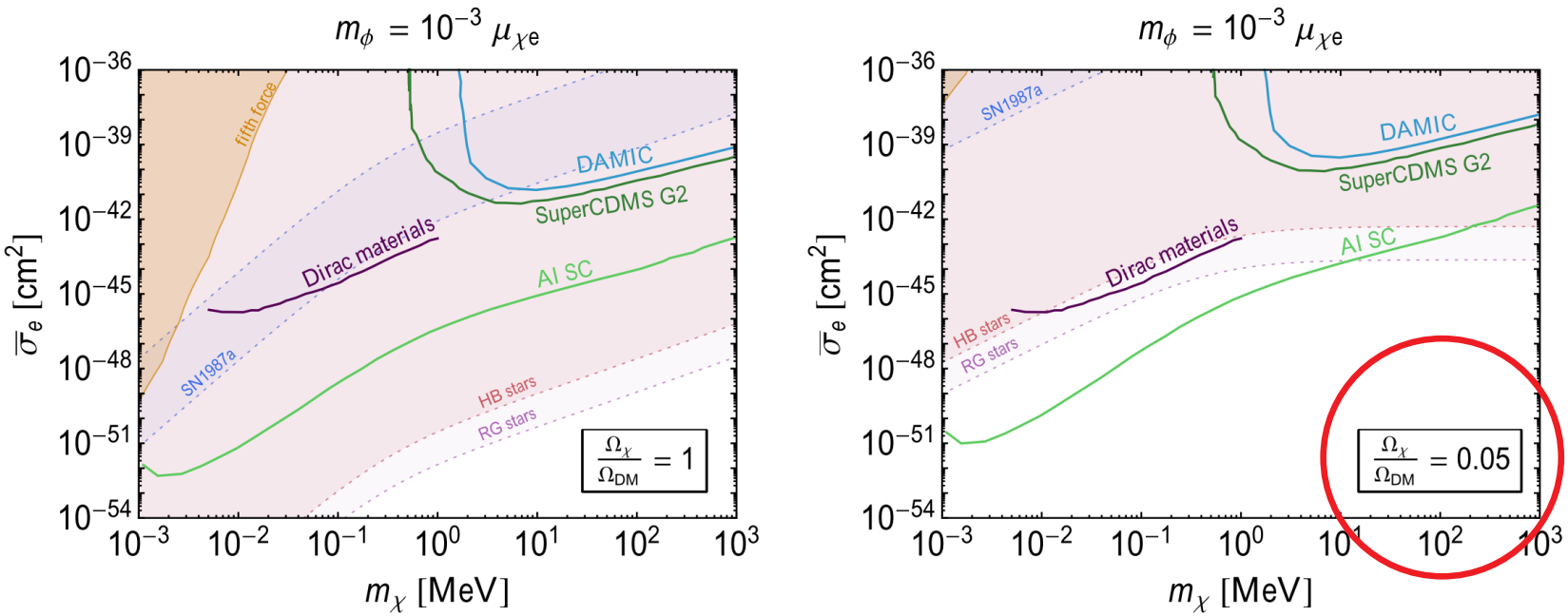

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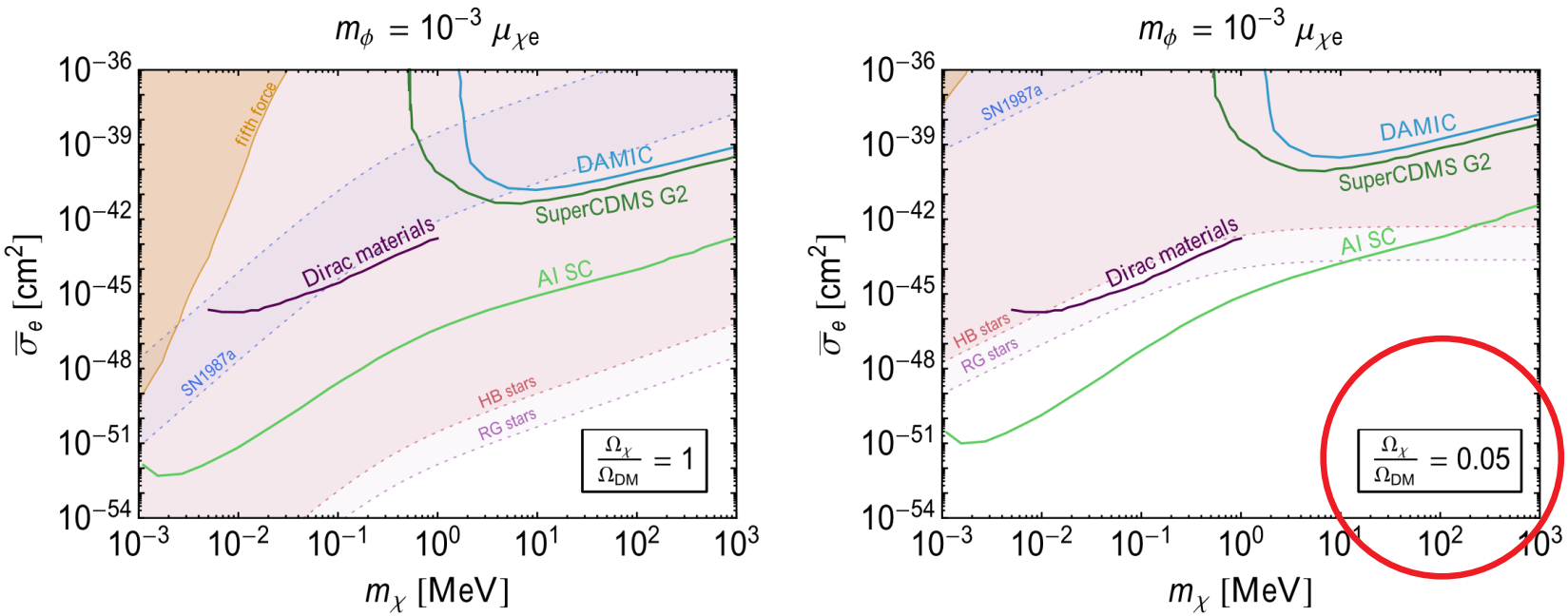
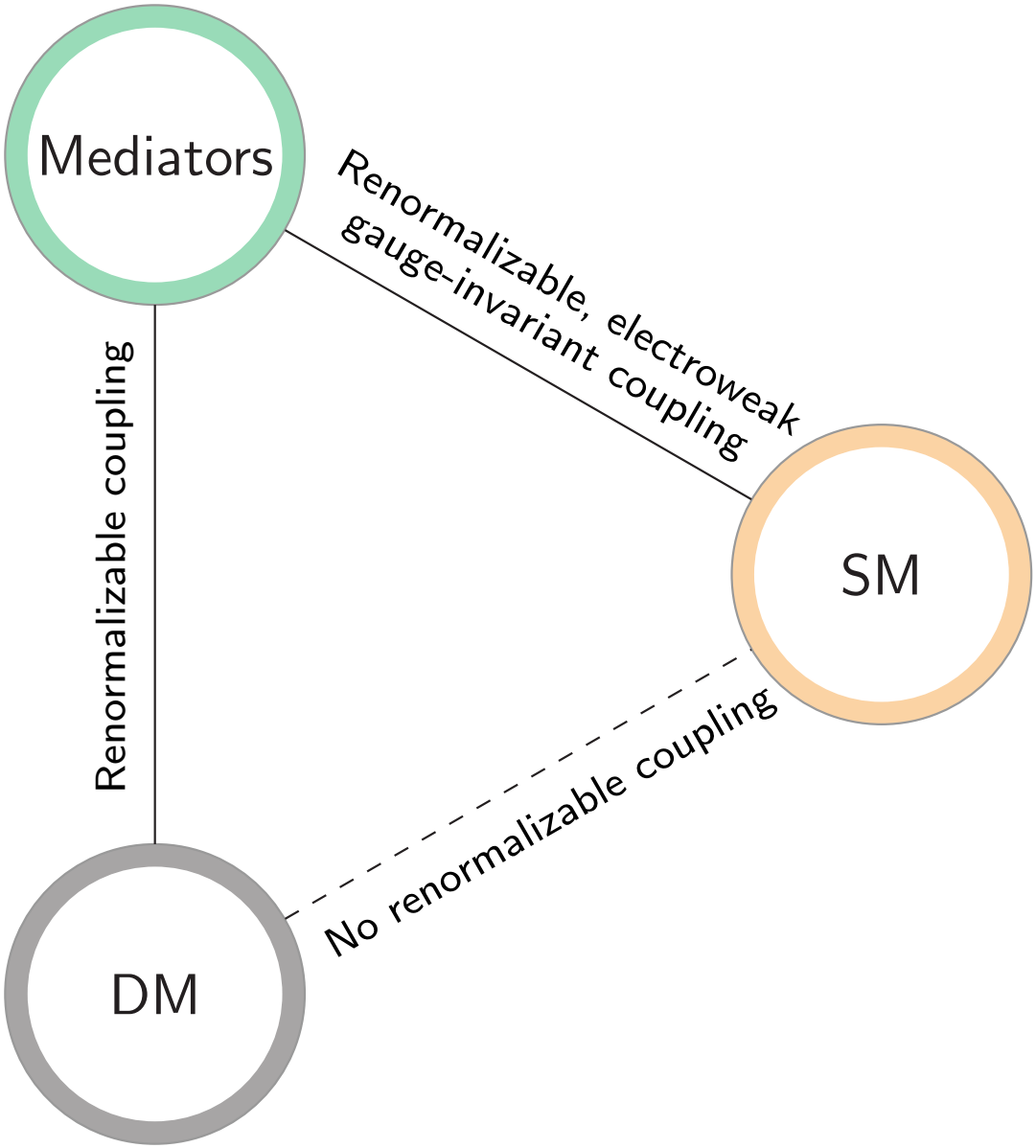
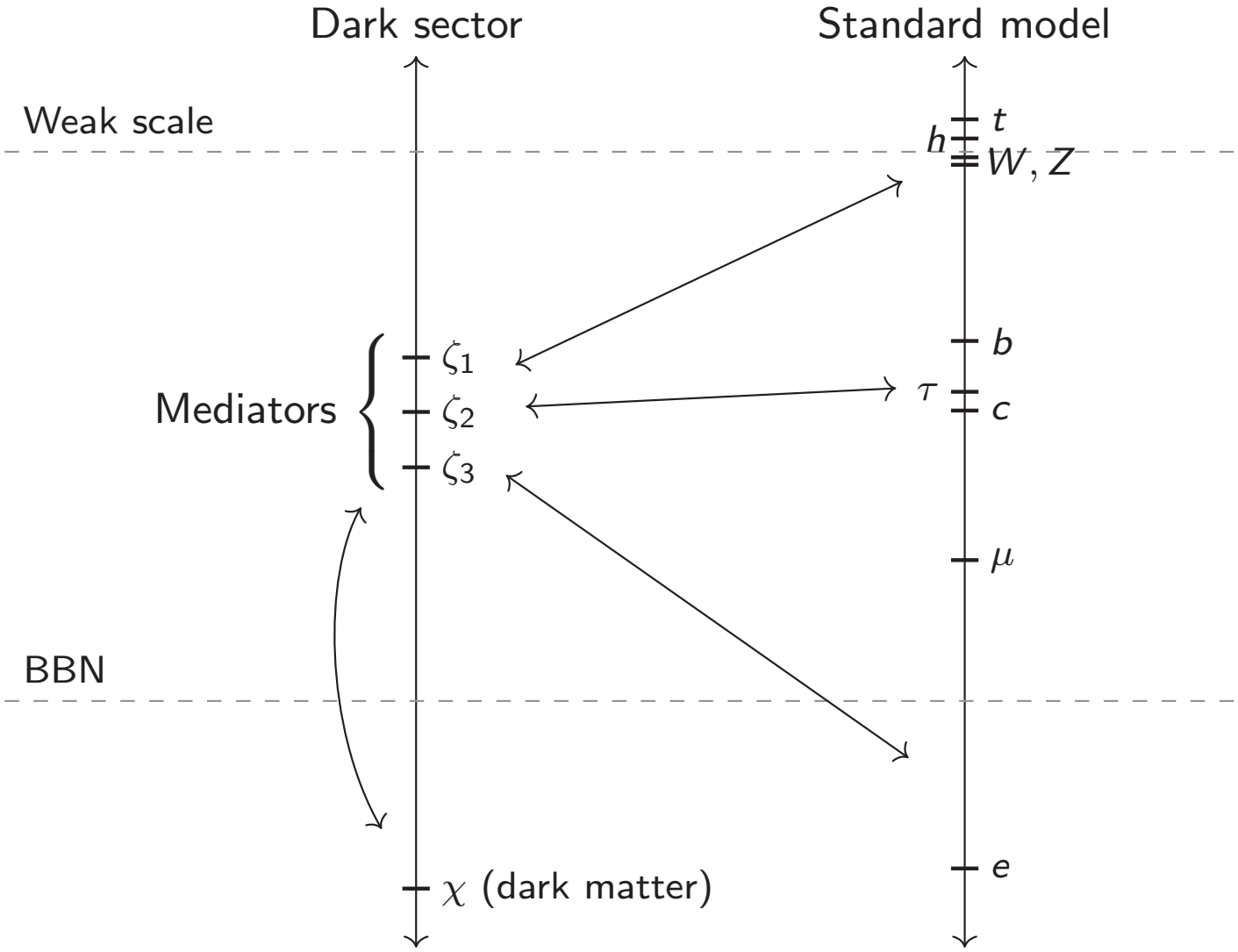


- For heavy mediator case, **use EFT for general bounds**

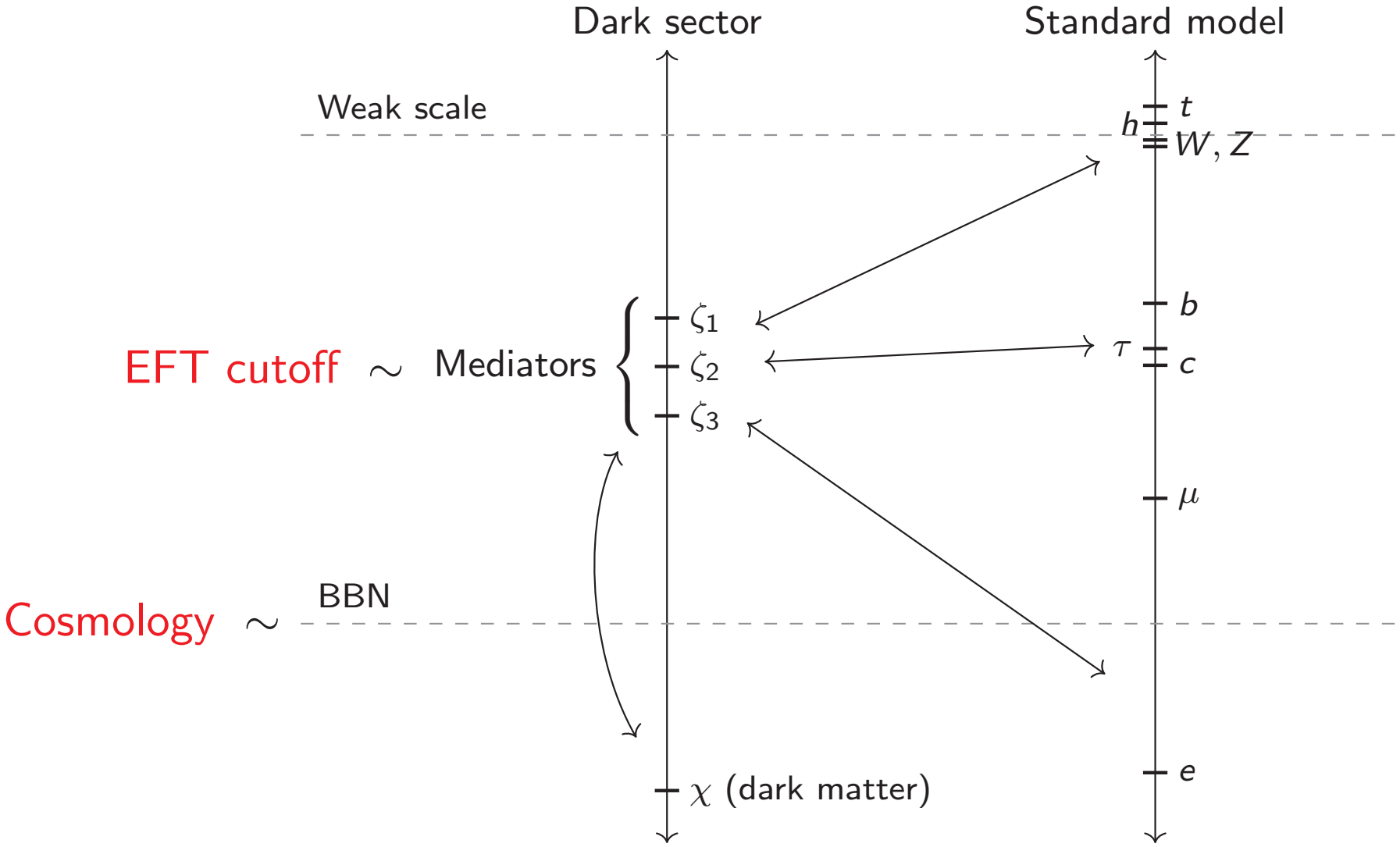
Overview


Mediators
Renormalizable, electroweak gauge-invariant coupling
SM
Renormalizable coupling
No renormalizable coupling
DM

Overview


Dark sector
Standard model
Weak scale
t
h
W, Z
ζ_1
b
Mediators
ζ_2
τ
c
ζ_3
μ
BBN
e
χ (dark matter)

Overview


Dark sector
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EFT cutoff $\sim$ Mediators
ζ_1
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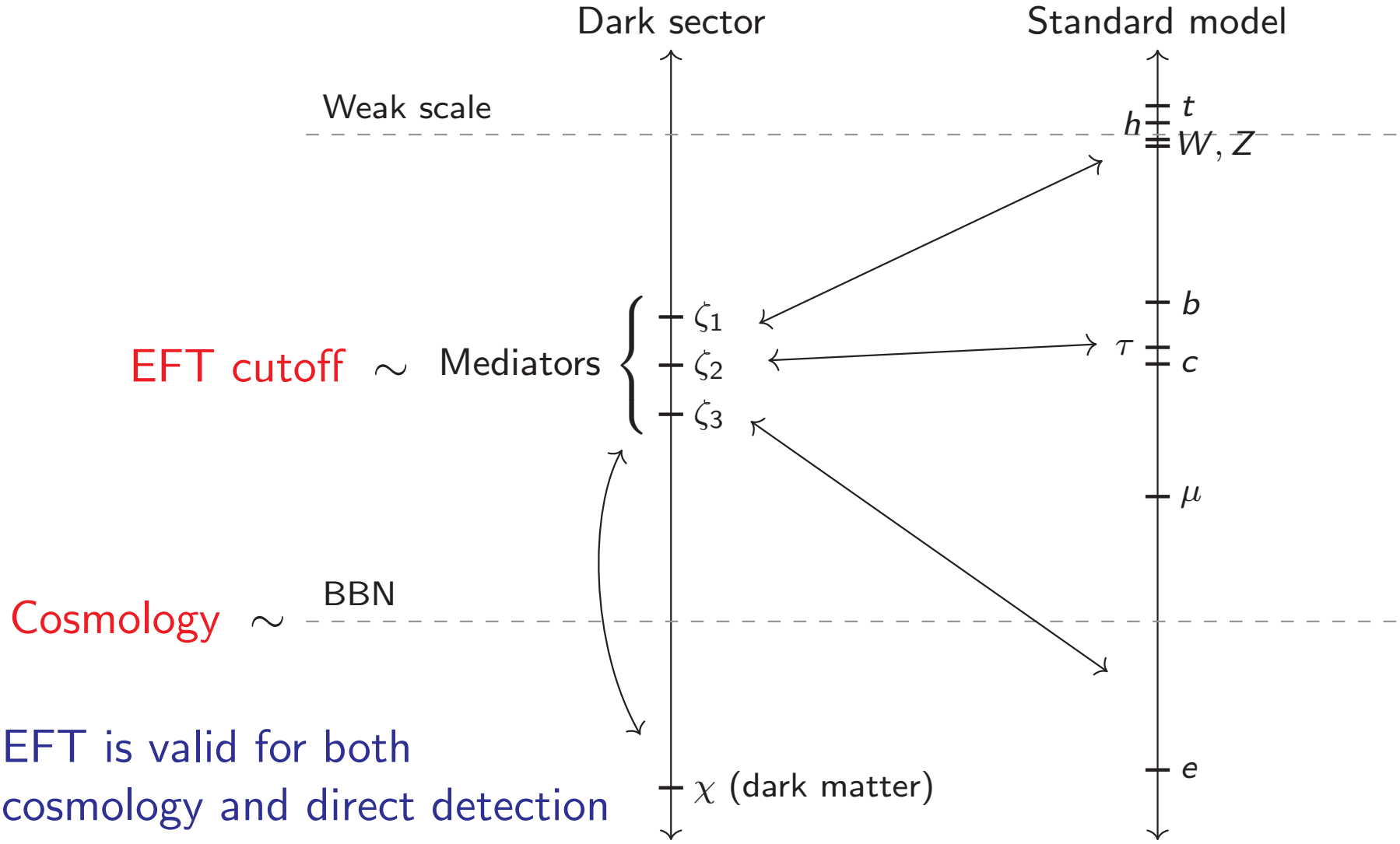
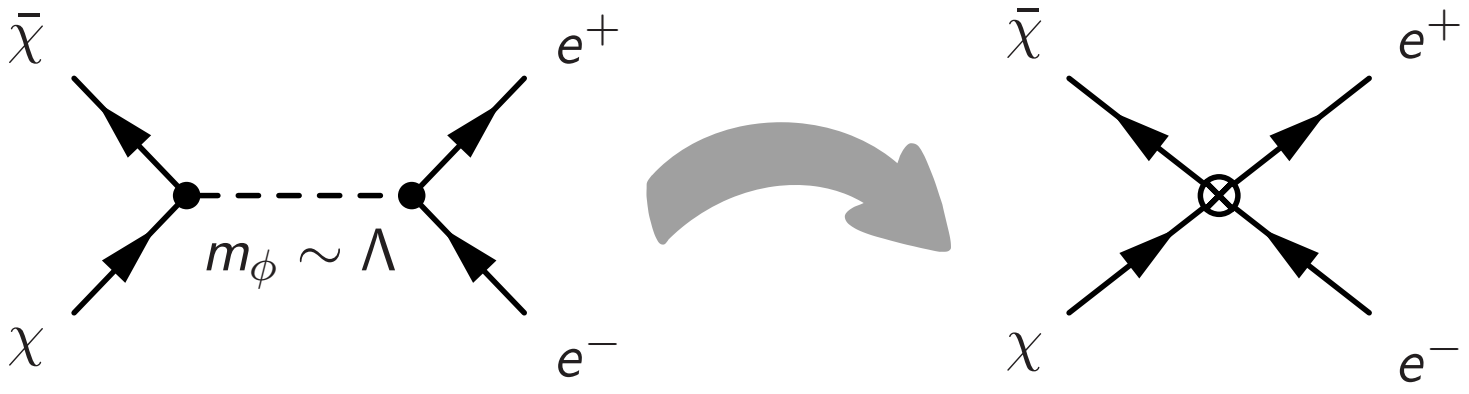
Overview



EFT is valid for both cosmology and direct detection

Effective field theory approach



UV-complete model
$(\sqrt{s} \gtrsim \Lambda)$

Effective theory
$(\sqrt{s} \ll \Lambda)$

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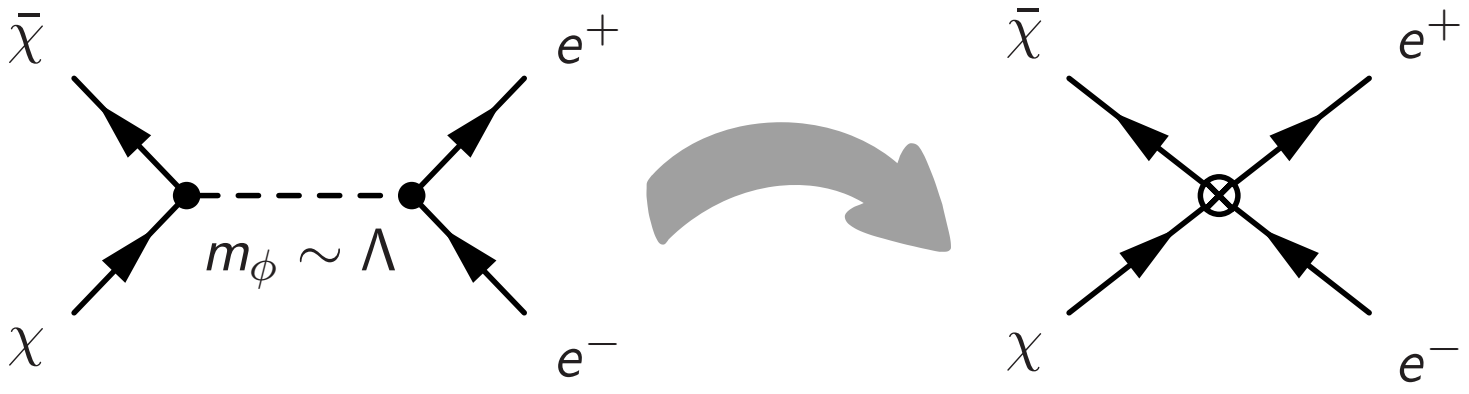

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Enumerate effective operators to dimension 6

$$\left\{ \frac{g}{\Lambda^2}\overline{\chi}\chi\overline{e}e, \quad \frac{g}{\Lambda^2}\overline{\chi}\gamma_\mu\chi\overline{e}\gamma^\mu e, \quad \dots \right\}$$

Calculate direct detection rates and cosmological limits

Observables

1. BBN
2. N_{eff} (CMB)
3. DM overproduction

} Fixed by DM decoupling temperature

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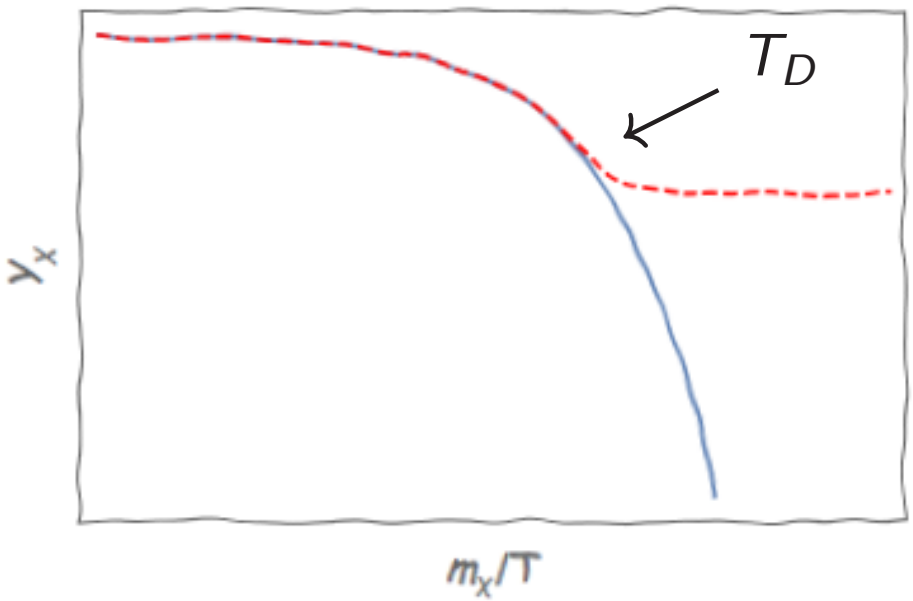

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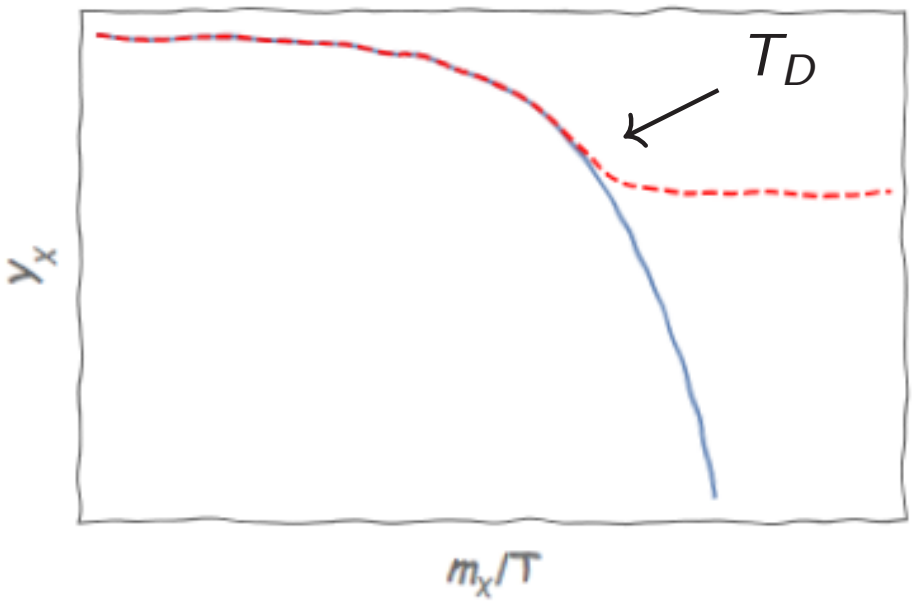

$$\Gamma(\chi\chi \to e^+e^-)|_{T_D} \simeq H|_{T_D}$$

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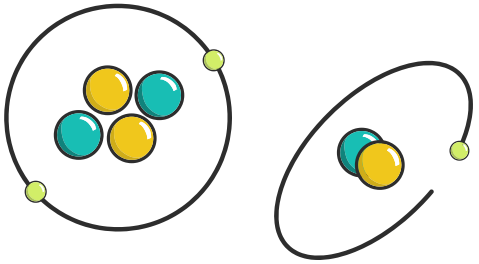

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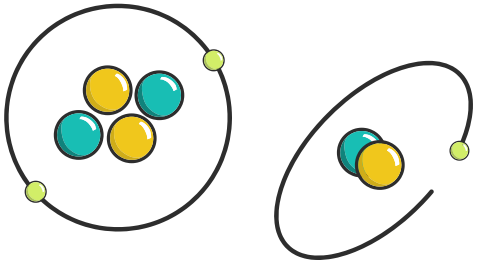

Requires $T_D \gtrsim 1\,\mathrm{MeV}$ (except real scalar)

(Pospelov & Pradler 2010)

CMB constraints (N_{eff})

N_{eff} measures T_ν / T_γ, but which sector does DM heat?

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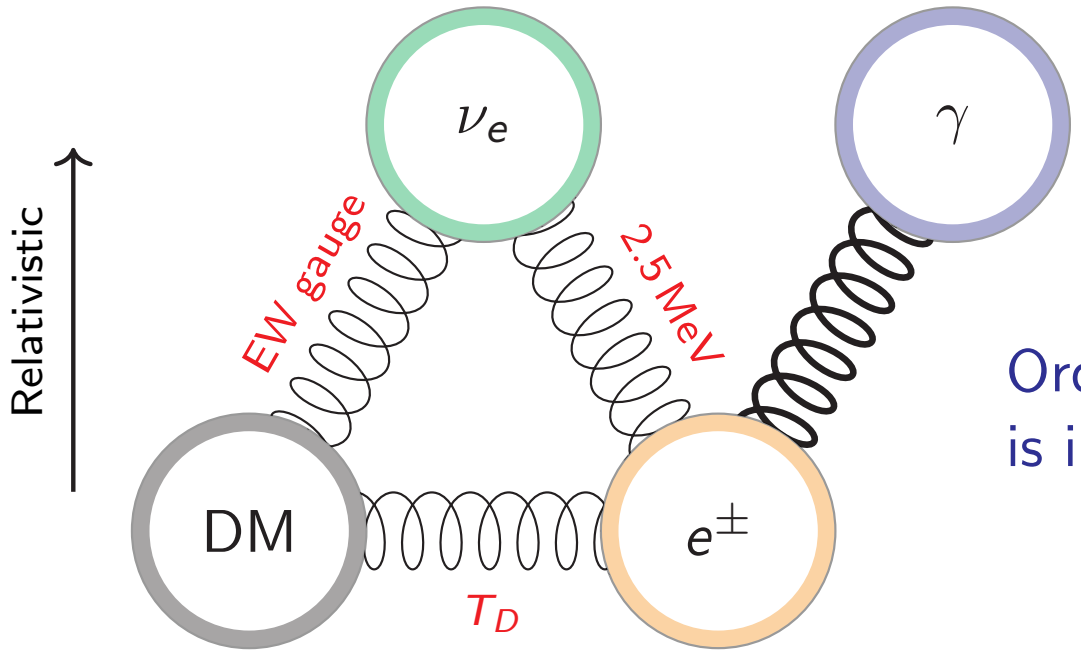

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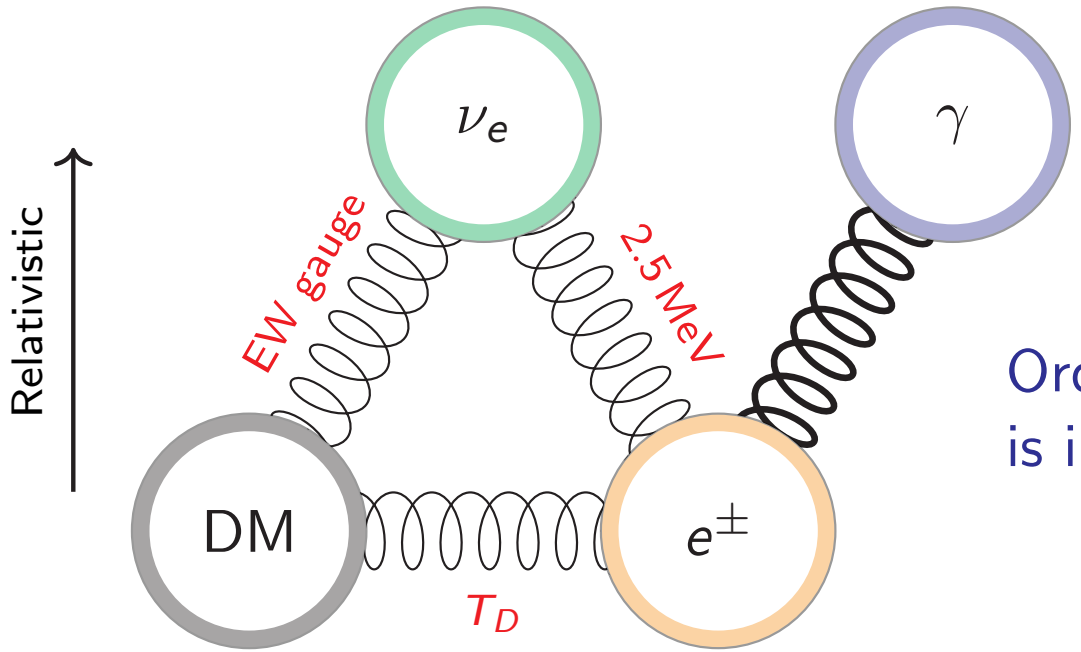

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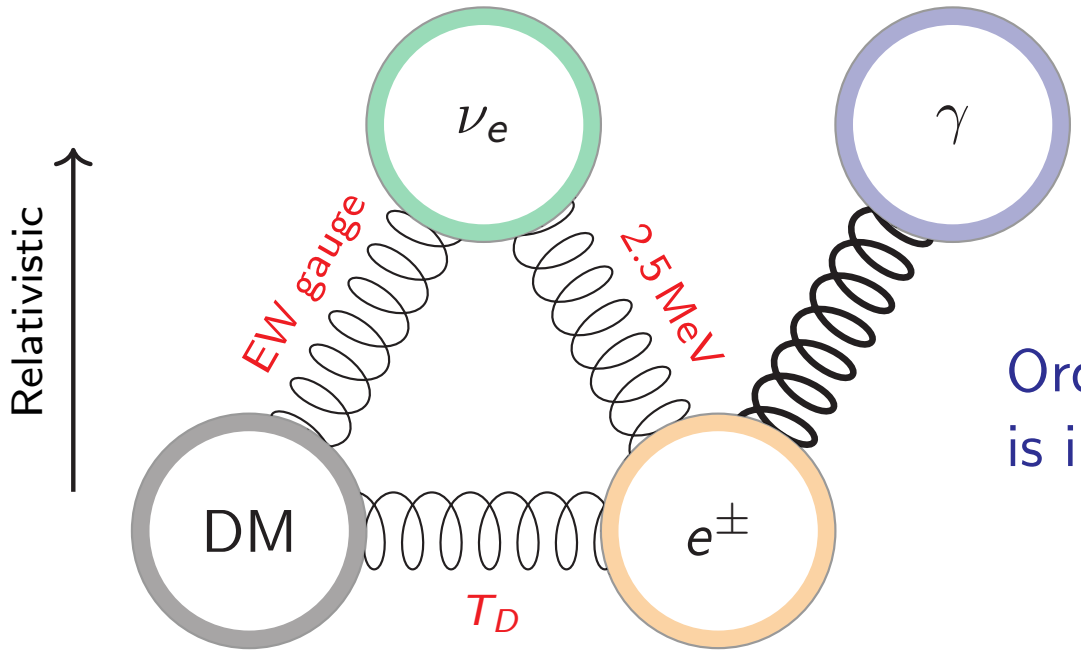

Ordering of decouplings is important

- Derive DM–ν_e decoupling T from EW gauge invariance
- Calculate entropy contributed to each sector

Overproduction constraints

What sets the relic abundance?

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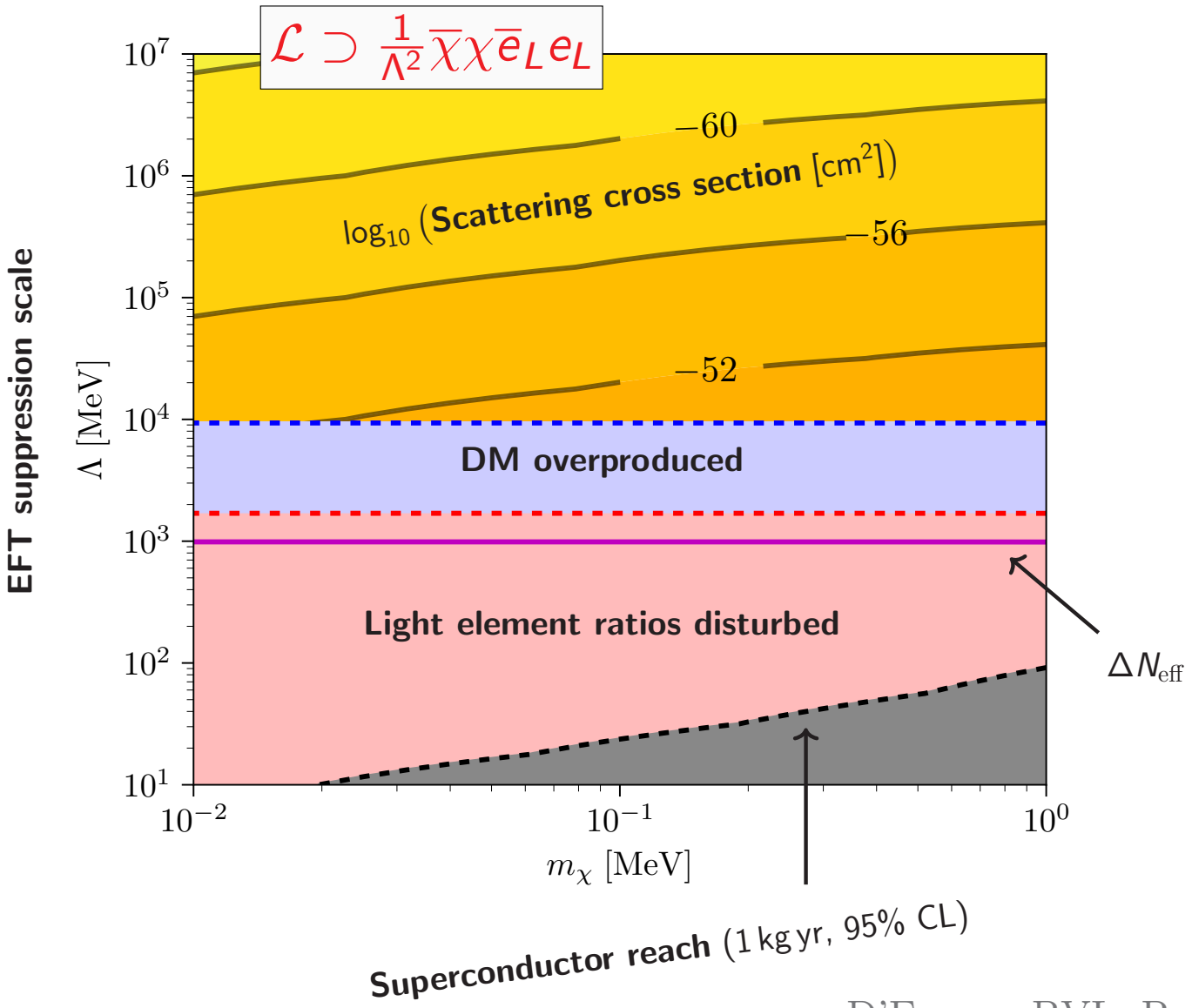
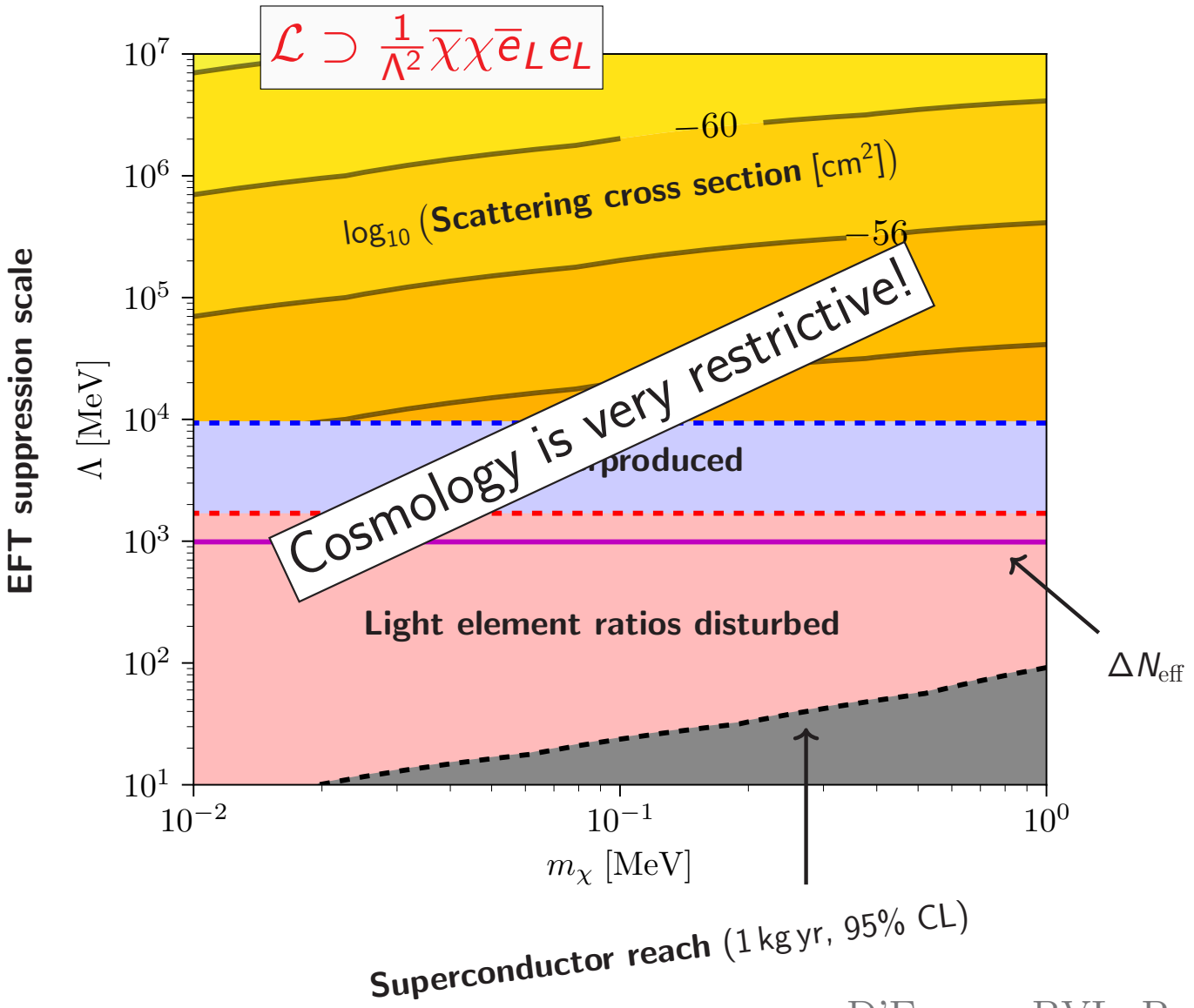
Overproduction starting with $Y_{\mathrm{DM}} = 0$ bounds coupling above



D'Eramo, BVL, Profumo in prep.



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- Sub-MeV DM $\longleftrightarrow$ heavy mediator $\longleftrightarrow$ $e^{\pm}$ is not a viable experimental target in our framework (real scalar may survive)
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