Production and Detection of Scalar and Vector Particles from the Sun

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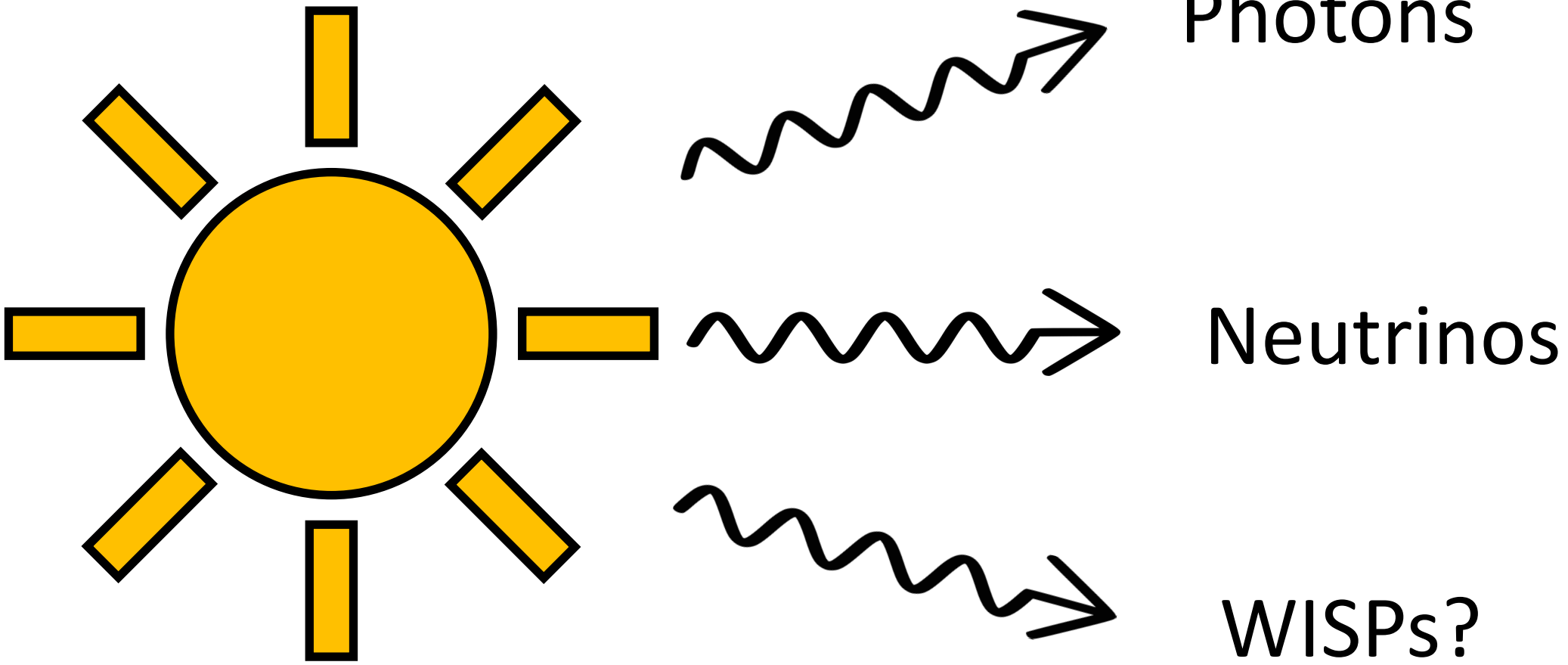
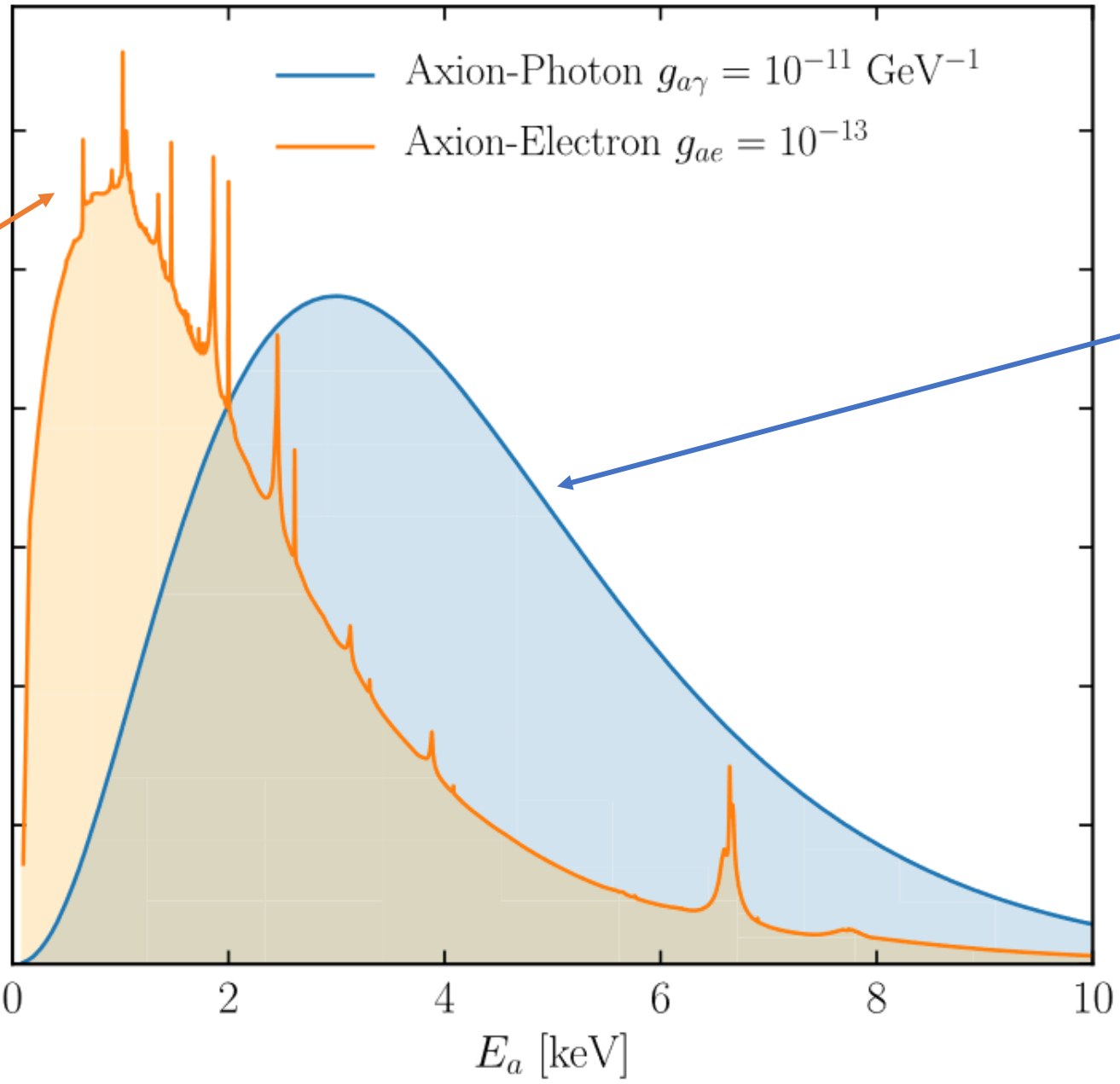
CAPA – Universidad de Zaragoza
2nd Cosmic WISPers General Meeting
Istanbul, 4 September 2024

Universidad Zaragoza
1542

COSMIC WISPERS
CA21106

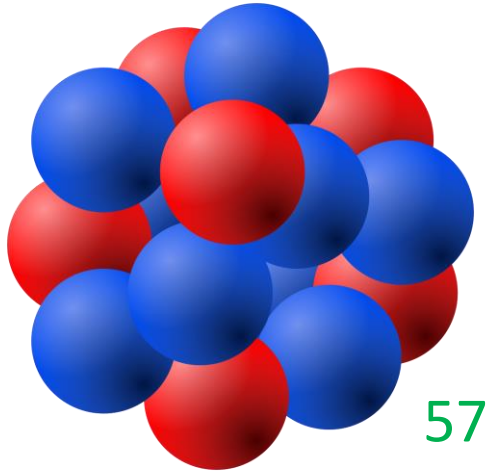

Photons
Neutrinos
WISPs?



Axiorecombination
Bremsstrahlung
Compton

Primakoff

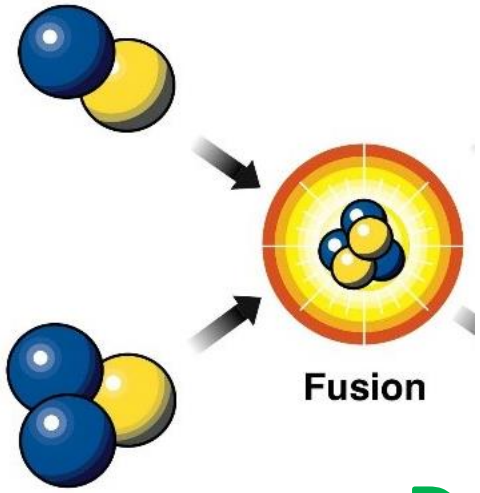
T. Dafni et. al. (2019)



Nuclear de-excitation

^{57}Fe

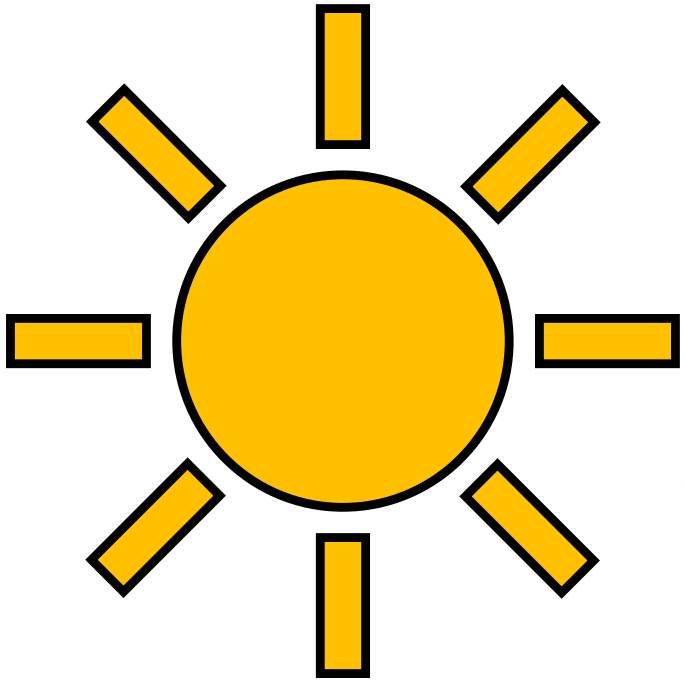
14.4 keV



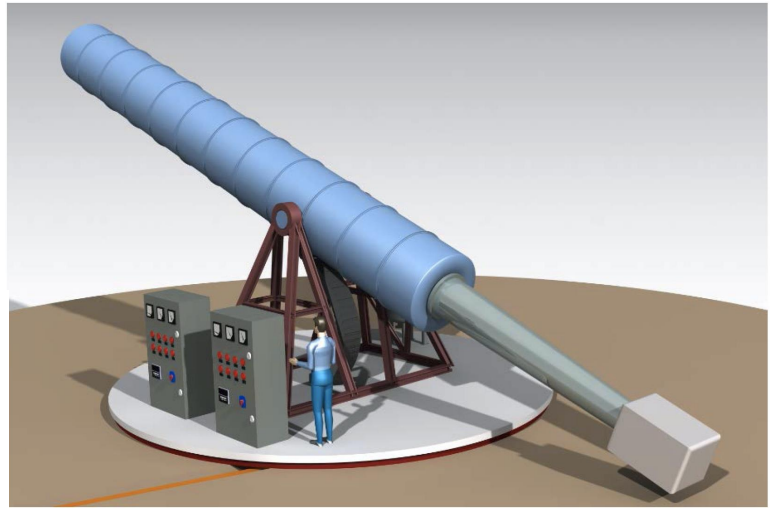
Fusion

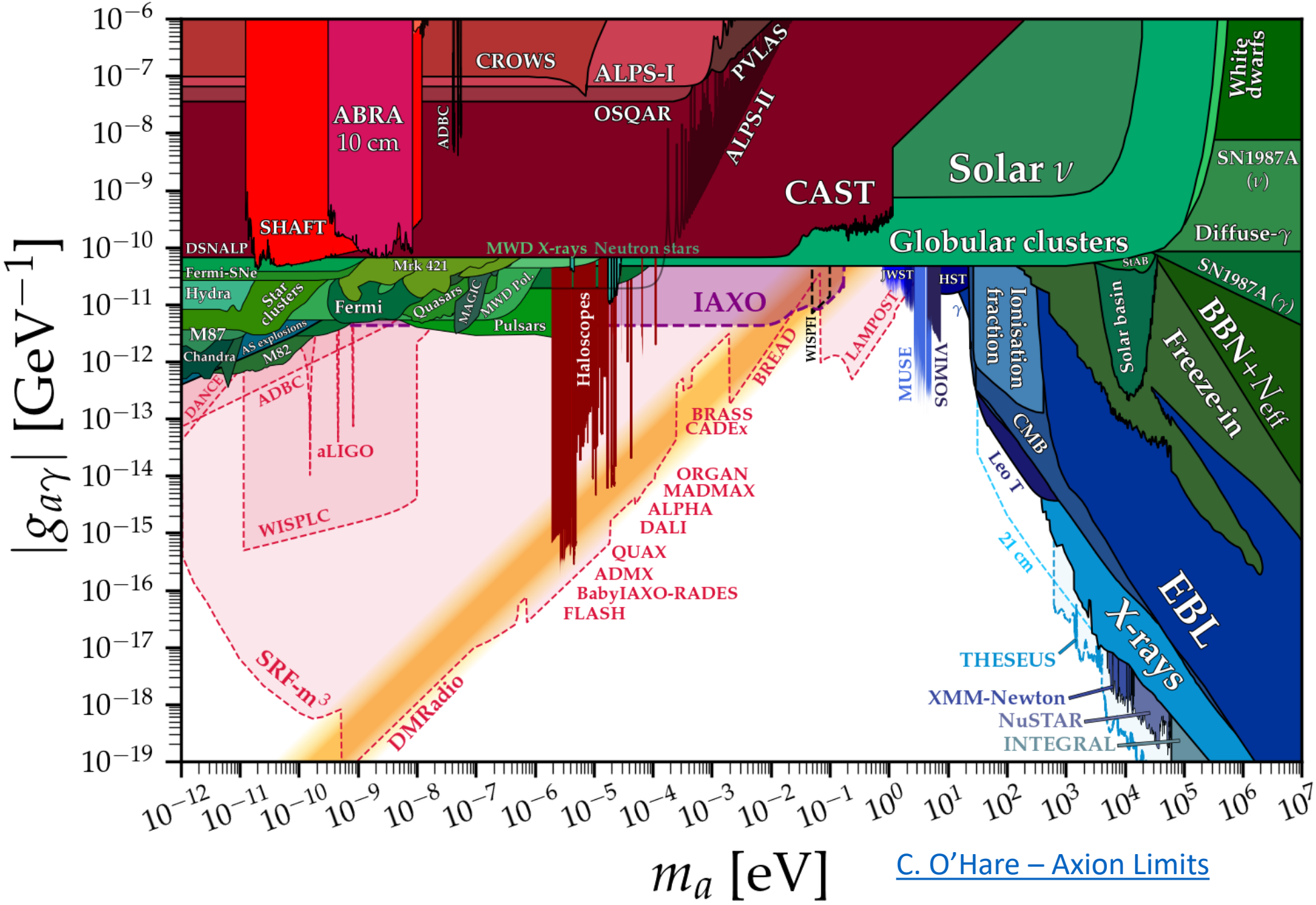
p + D

5.49 MeV




AXION



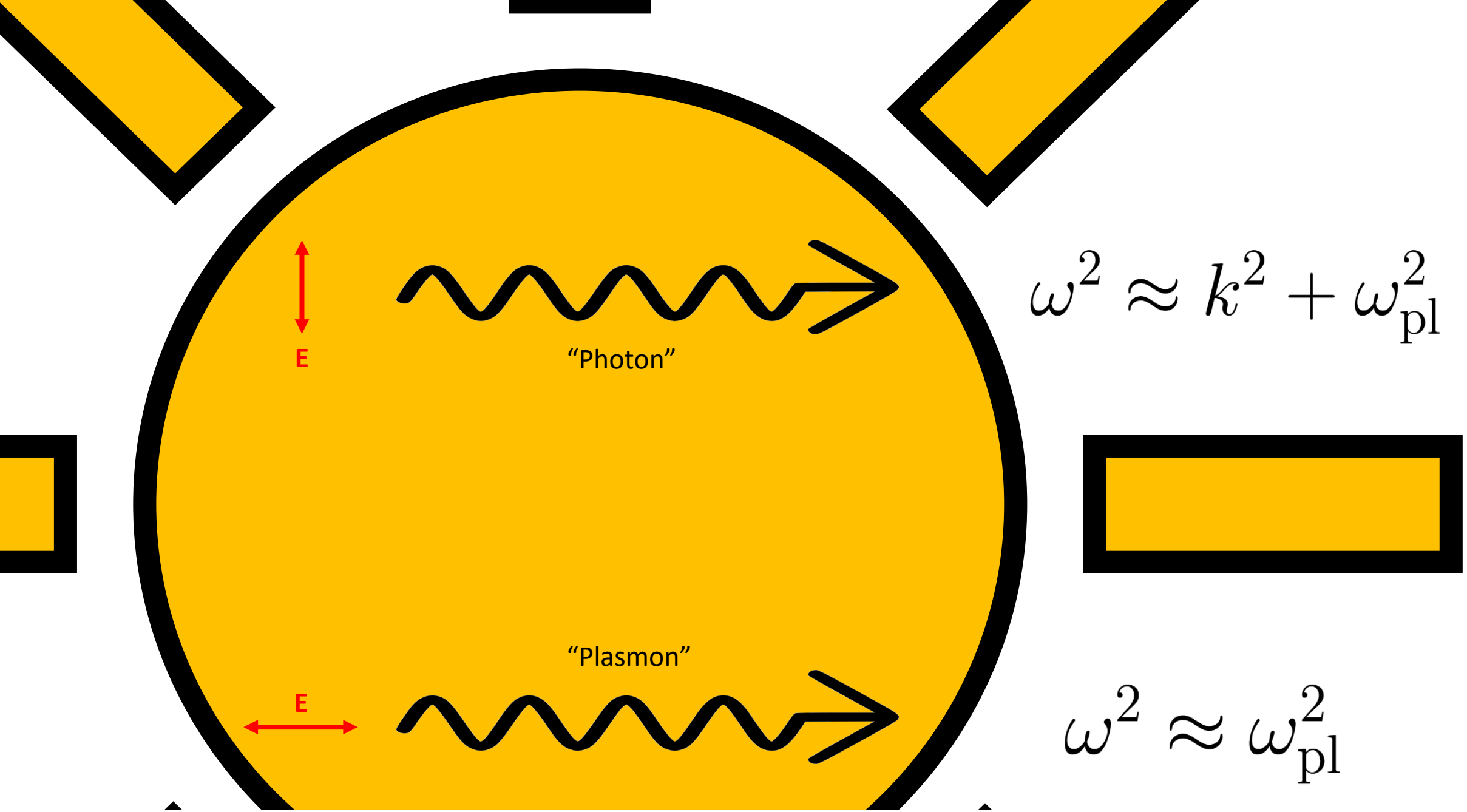


C. O'Hare – Axion Limits

Dark (hidden) photon

$$\mathcal{L} = -\frac{1}{4}A_{\mu\nu}A^{\mu\nu} - A_\mu j^\mu - \frac{1}{4}A'_{\mu\nu}A'^{\mu\nu} + \frac{1}{2}m^2 A'_\mu A'^\mu - \frac{1}{2}\chi A_{\mu\nu}A'^{\mu\nu}$$

T. O'Shea, M. Giannotti, I. G. Irastorza, L. M. Plasencia, J. Redondo, J. Ruz, J. K. Vogel - JCAP 06 (2024)

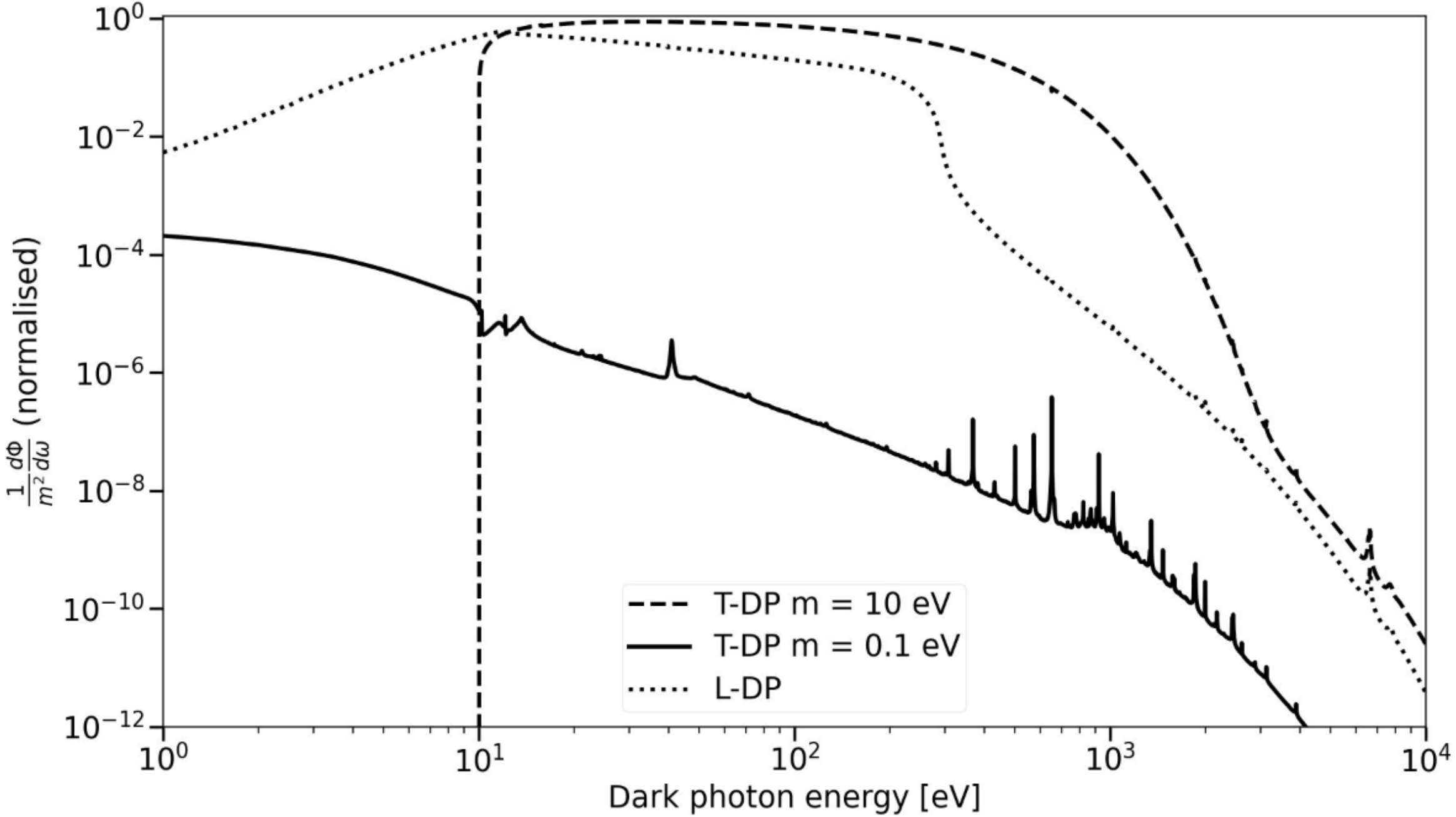


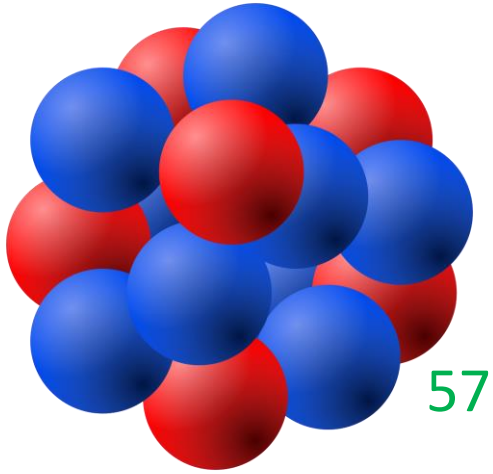
$$\omega^2 \approx k^2 + \omega_{\mathrm{pl}}^2$$

$$\omega^2 \approx \omega_{\mathrm{pl}}^2$$

$$P_{A_t \to \tilde{S}_t} = \frac{\chi^2 m^4}{(m_\gamma^2 - m^2)^2 + (\omega\Gamma)^2}$$

$$P_{A_l \to \tilde{S}_l} = \frac{\chi^2 m^2 \omega^2}{(m_\gamma^2 - \omega^2)^2 + (\omega\Gamma)^2}$$


10^0
10^{-2}
10^{-4}
10^{-6}
10^{-8}
10^{-10}
10^{-12}
$\frac{1}{m^2}\frac{d\Phi}{d\omega}$ (normalised)
10^0
10^1
10^2
10^3
10^4
Dark photon energy [eV]
T-DP m = 10 eV
T-DP m = 0.1 eV
L-DP

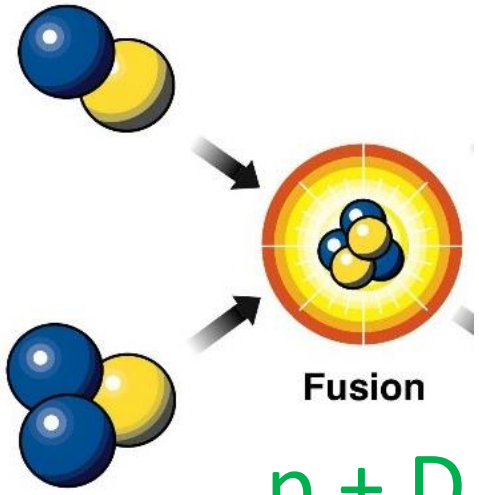


Nuclear de-excitation

^{57}Fe

A'^{μ}

14.4 keV



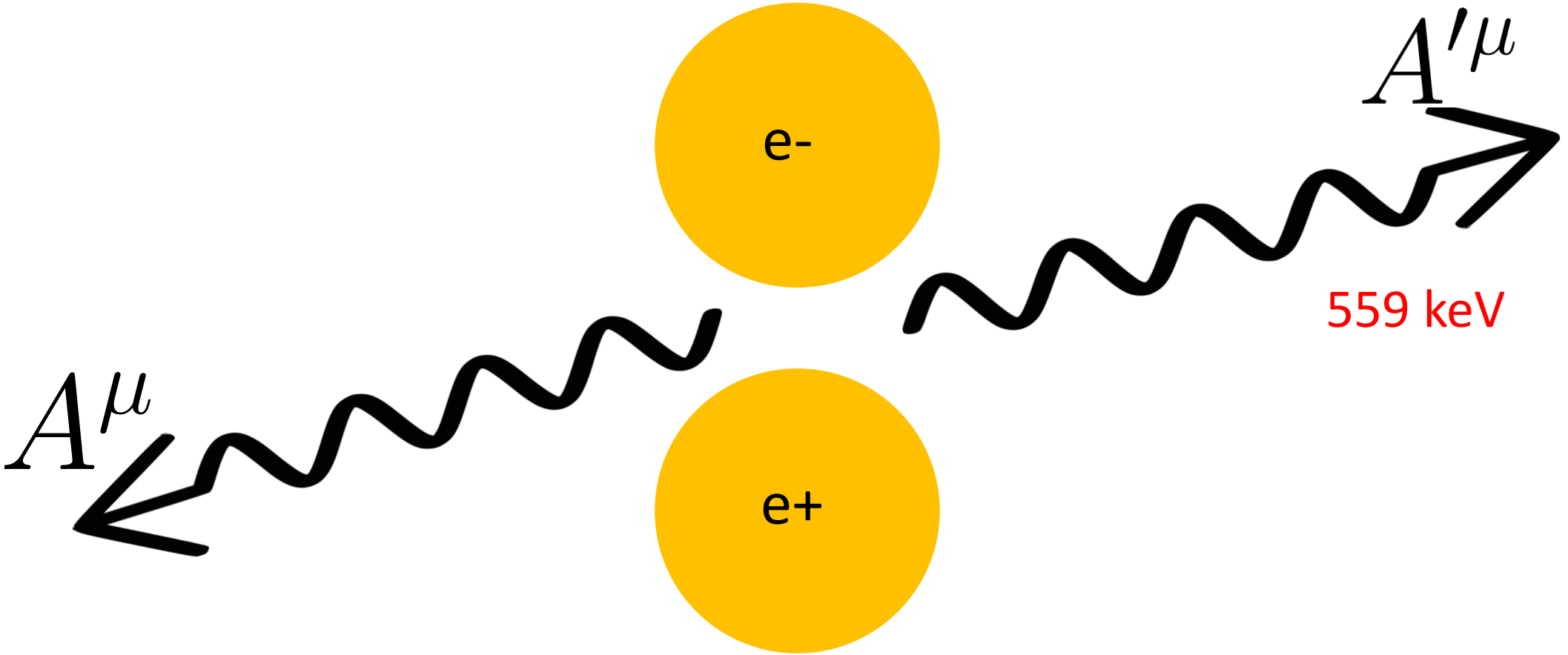
Fusion

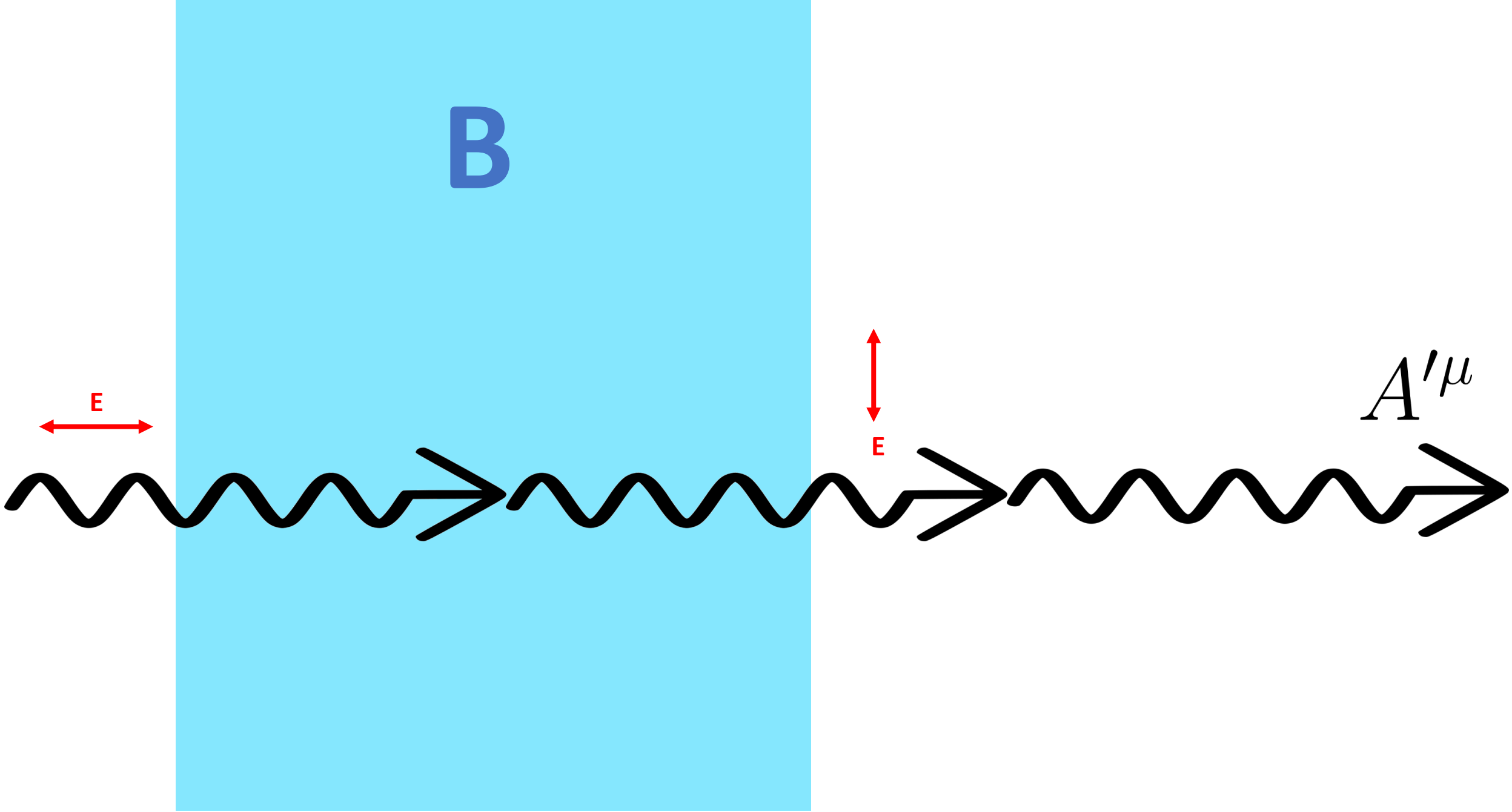
p + D

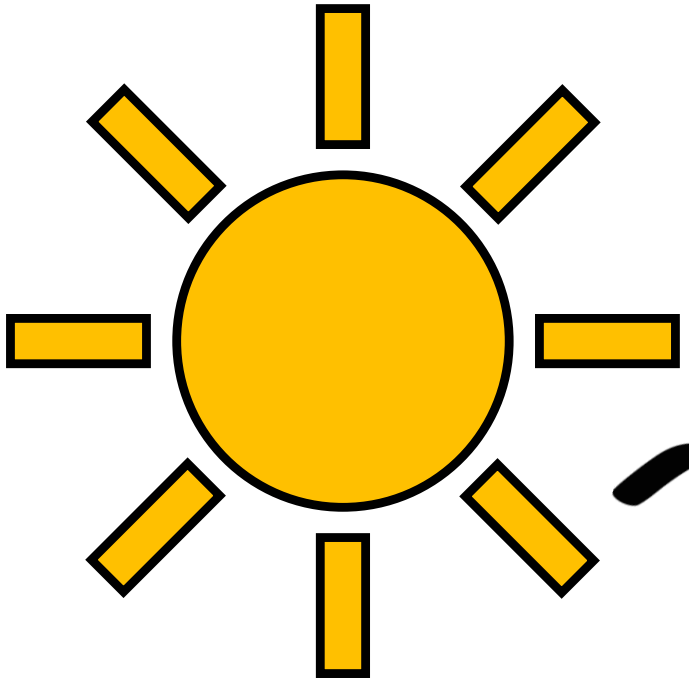
A'^{μ}

5.49 MeV

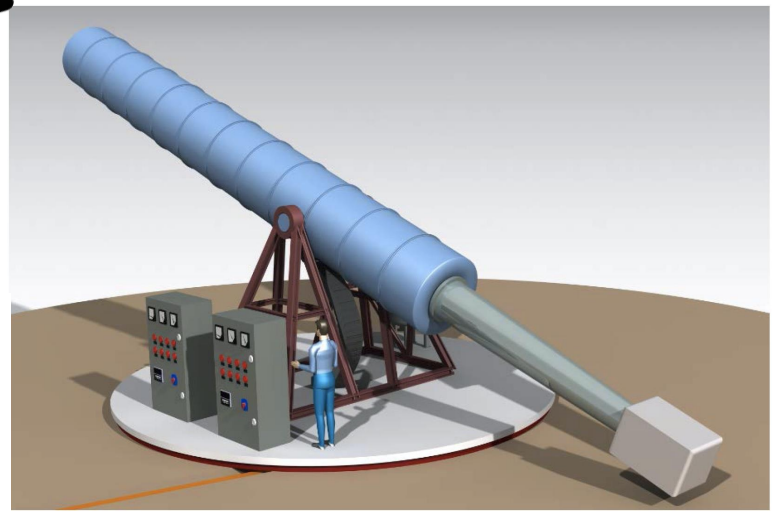
Annihilation

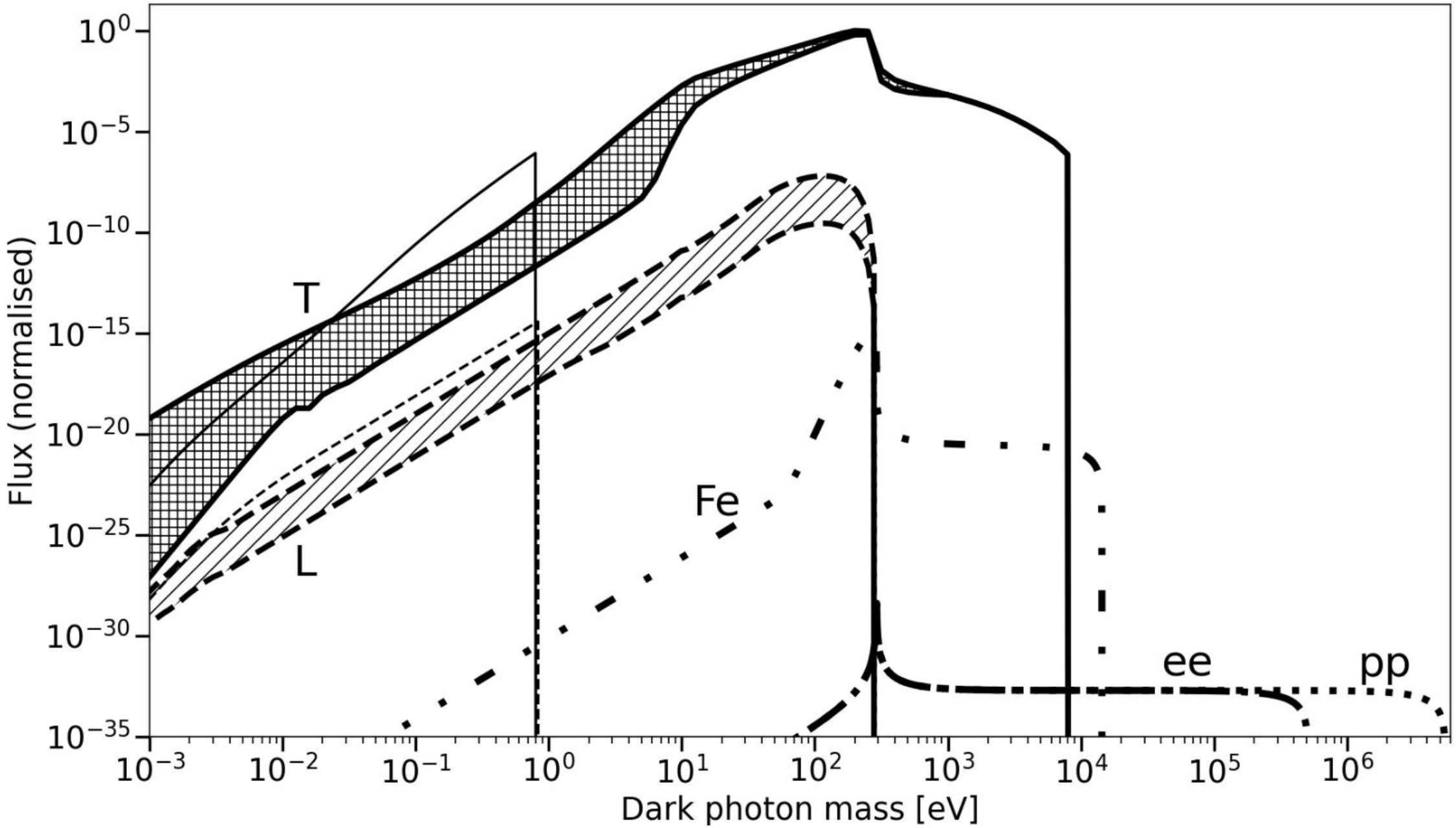


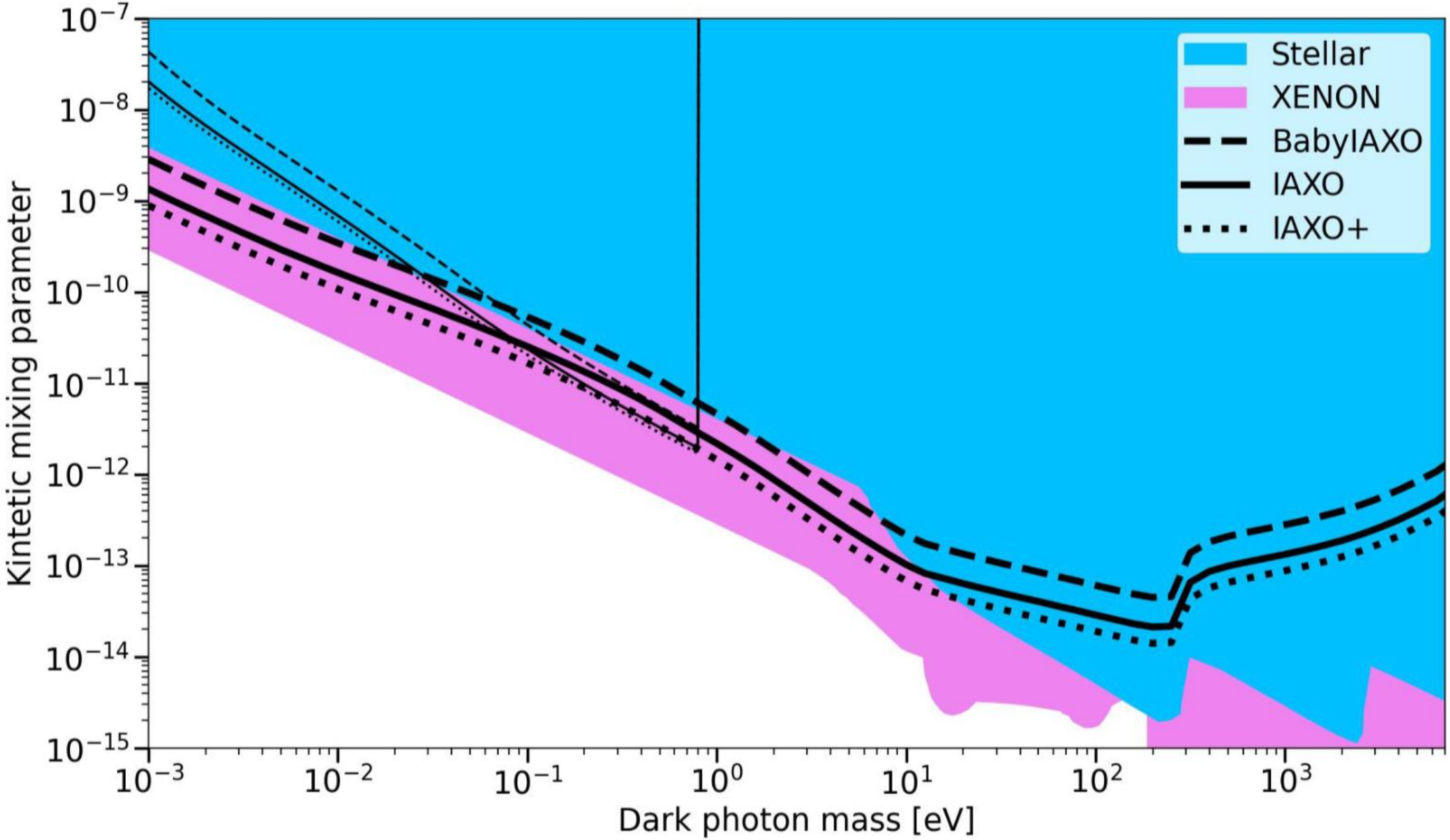

B
E
E
A'^{μ}

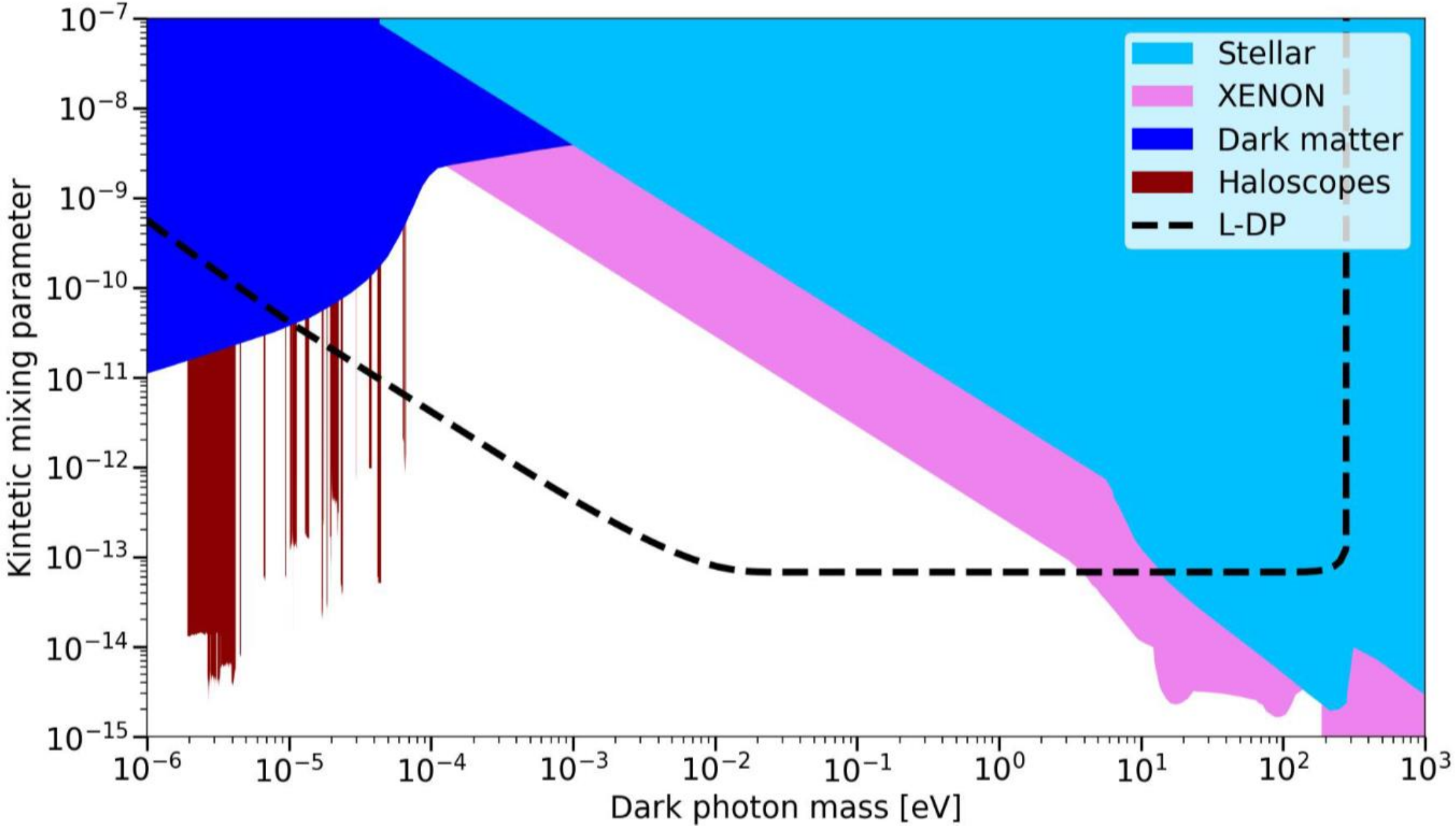


A'^{μ}

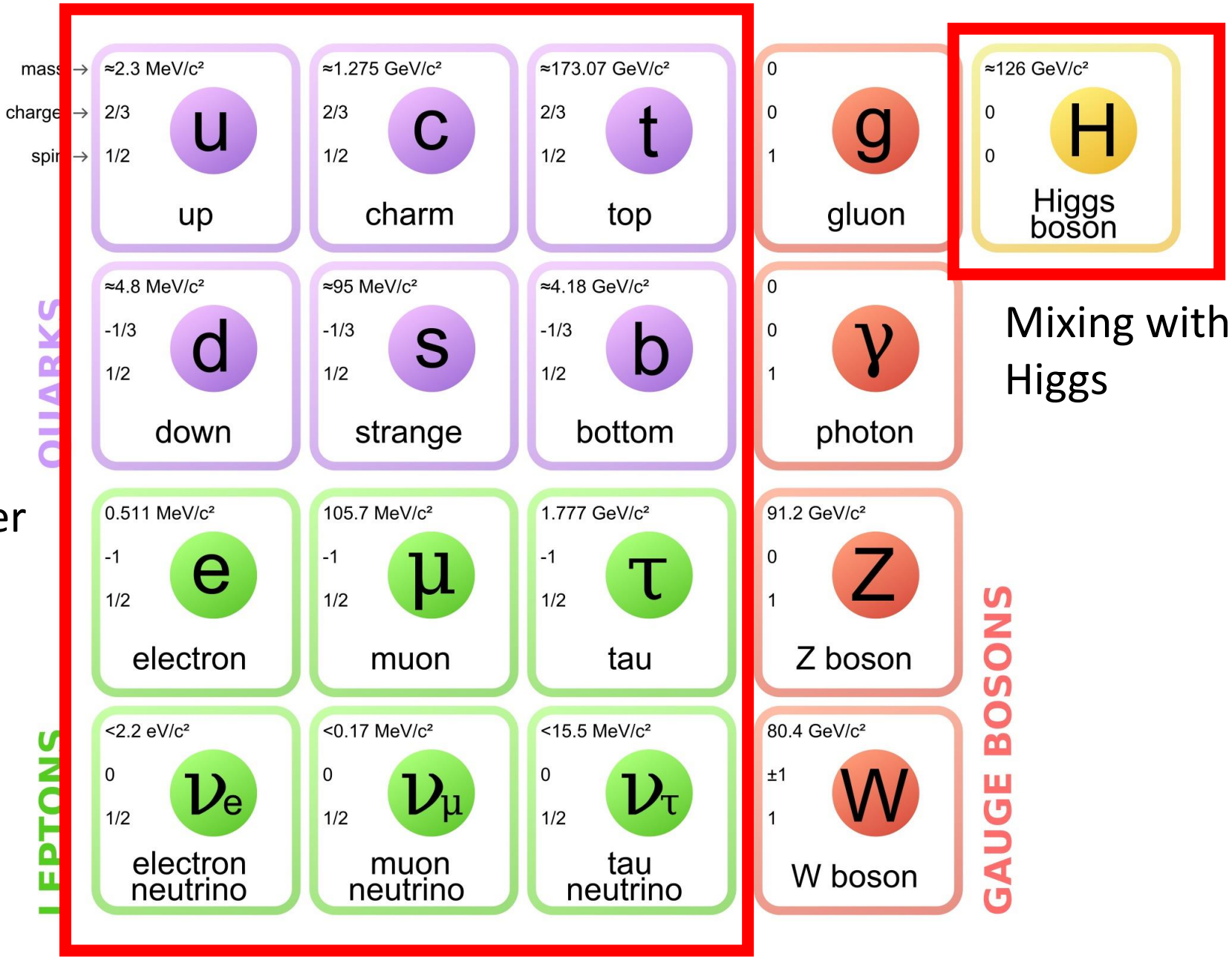



Flux (normalised)
10^{0}
10^{-5}
10^{-10}
10^{-15}
10^{-20}
10^{-25}
10^{-30}
10^{-35}
T
L
Fe
ee
pp
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
Dark photon mass [eV]


Stellar
XENON
BabyIAXO
IAXO
IAXO+
Kintetic mixing parameter
Dark photon mass [eV]
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}


Stellar
XENON
Dark matter
Haloscopes
L-DP
Kintetic mixing parameter
Dark photon mass [eV]
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-6}
10^{-5}
10^{-4}
10^{-3}
10^{-2}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}

Scalar fields

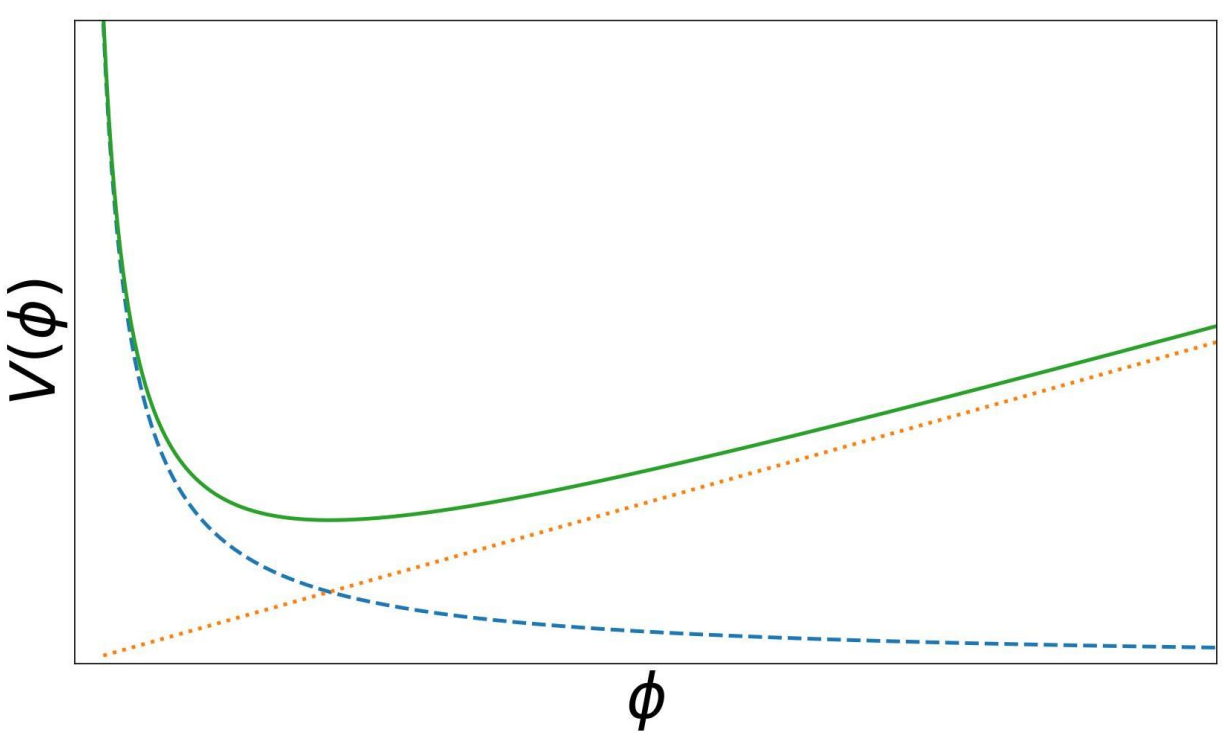


Mixing with Higgs

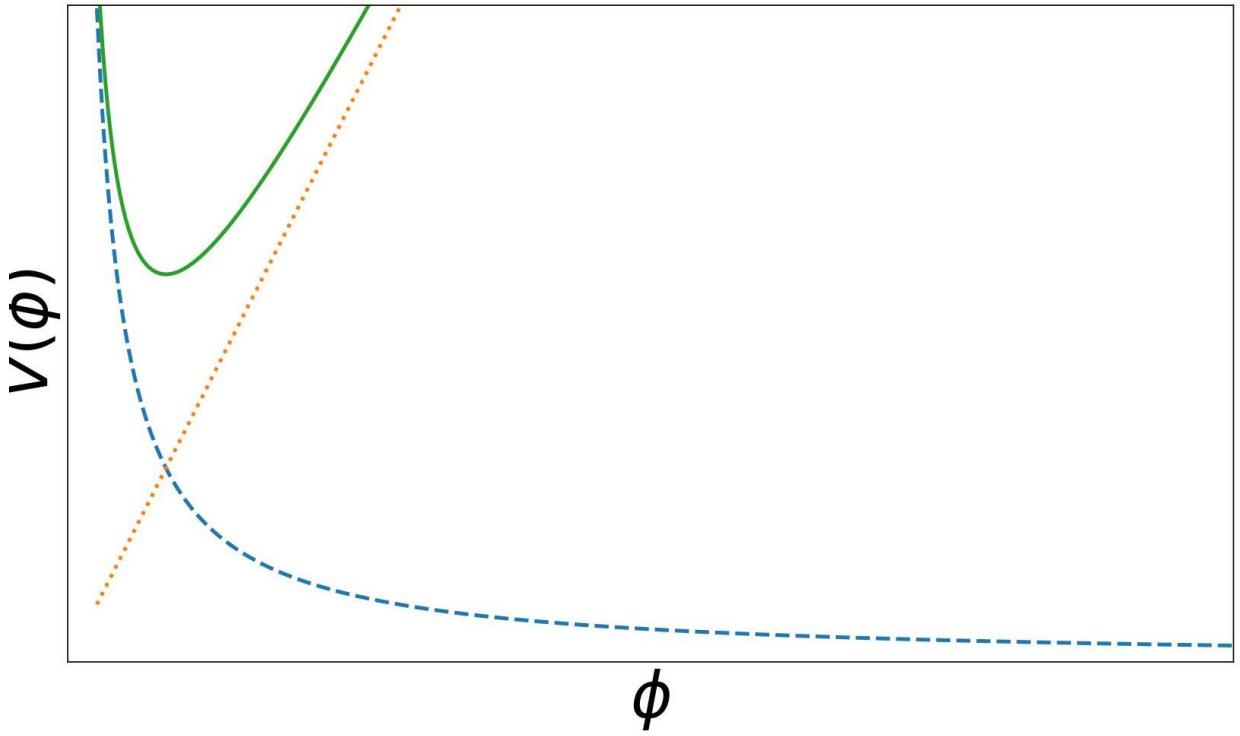
Coupling to matter

Chameleon mechanism

$$V(\phi) = \frac{\Lambda^{n+4}}{\phi^n}$$



Low density



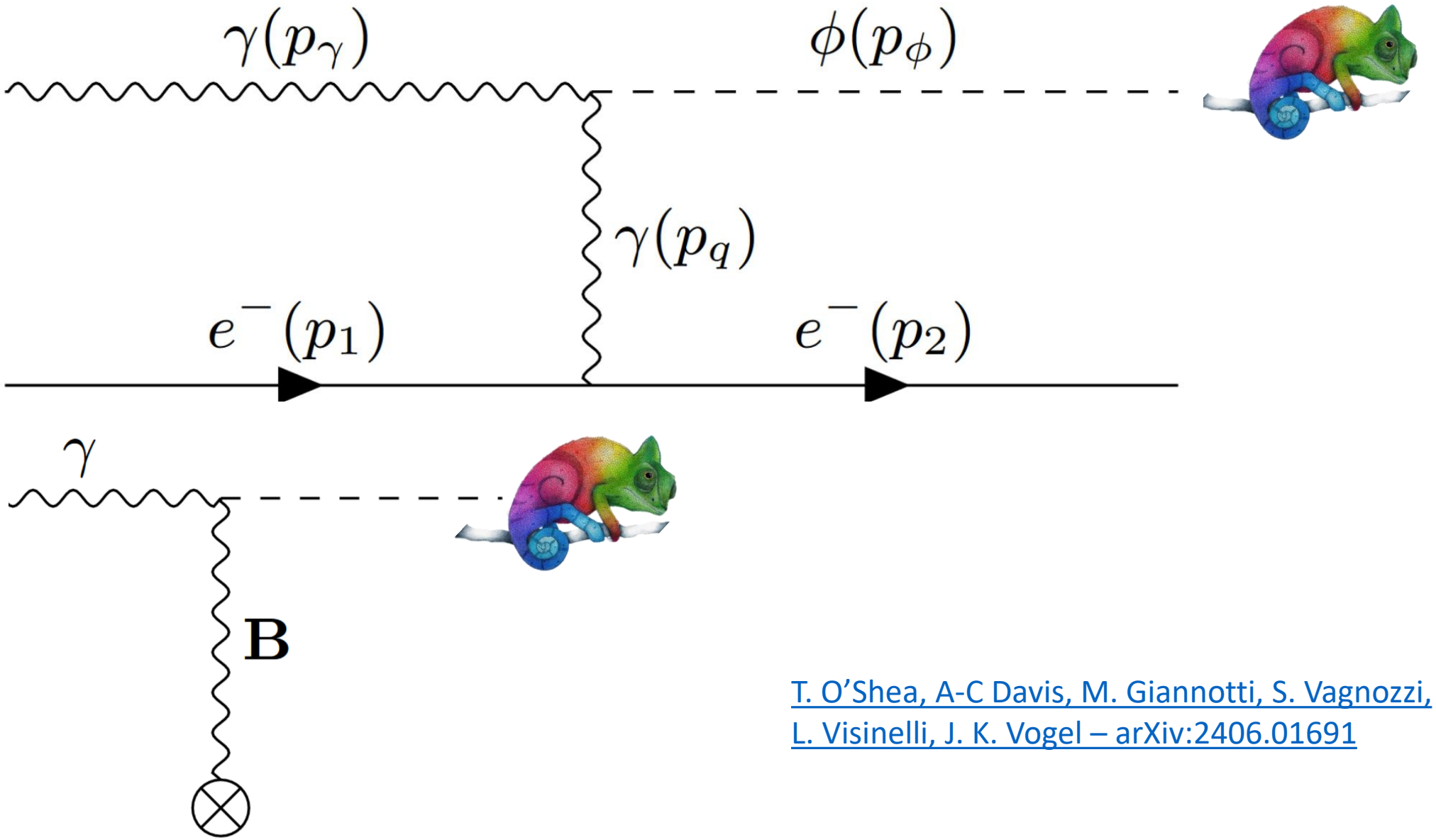
High density

See talk by Anne Davis

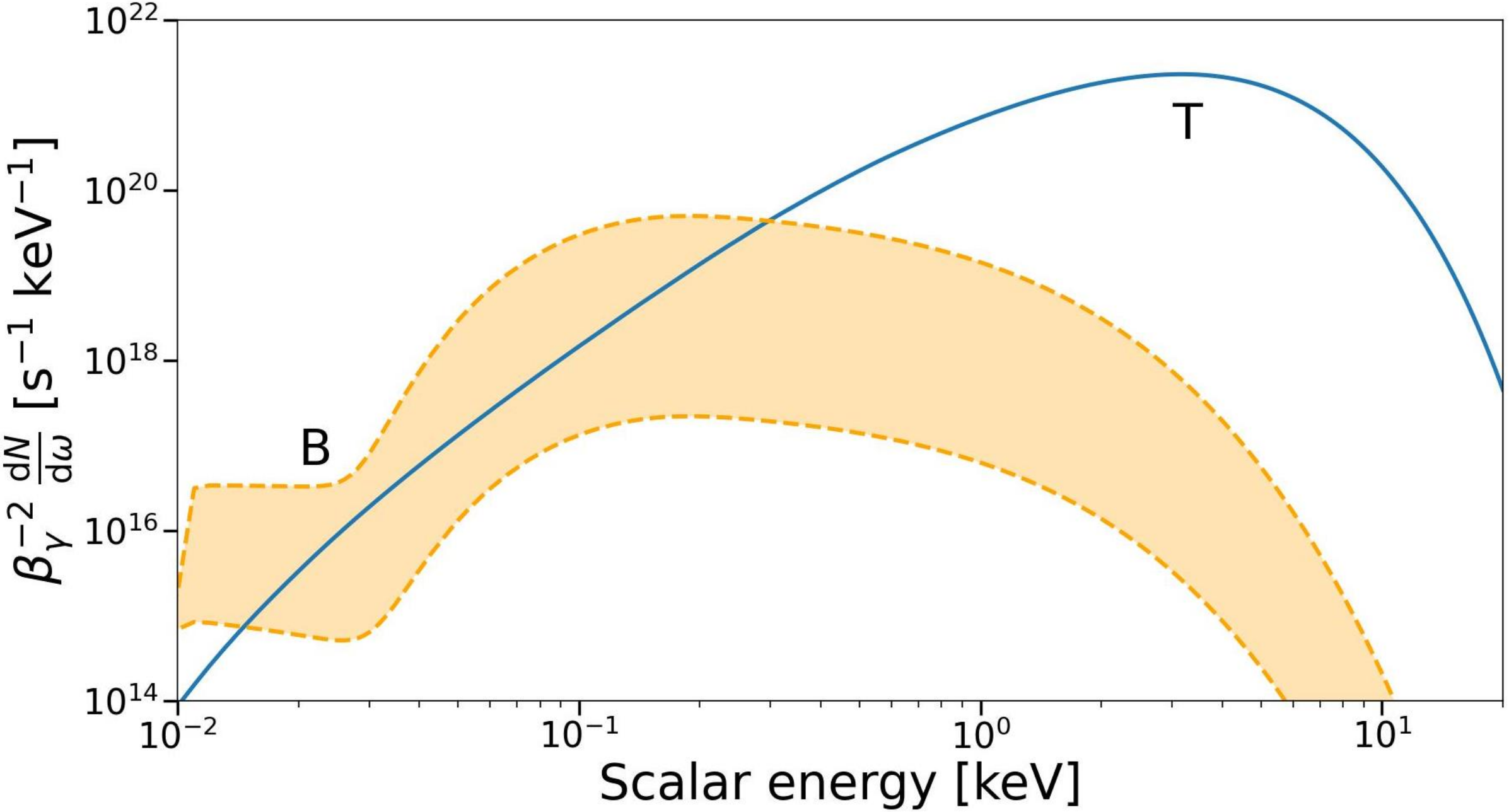
Scalar fields

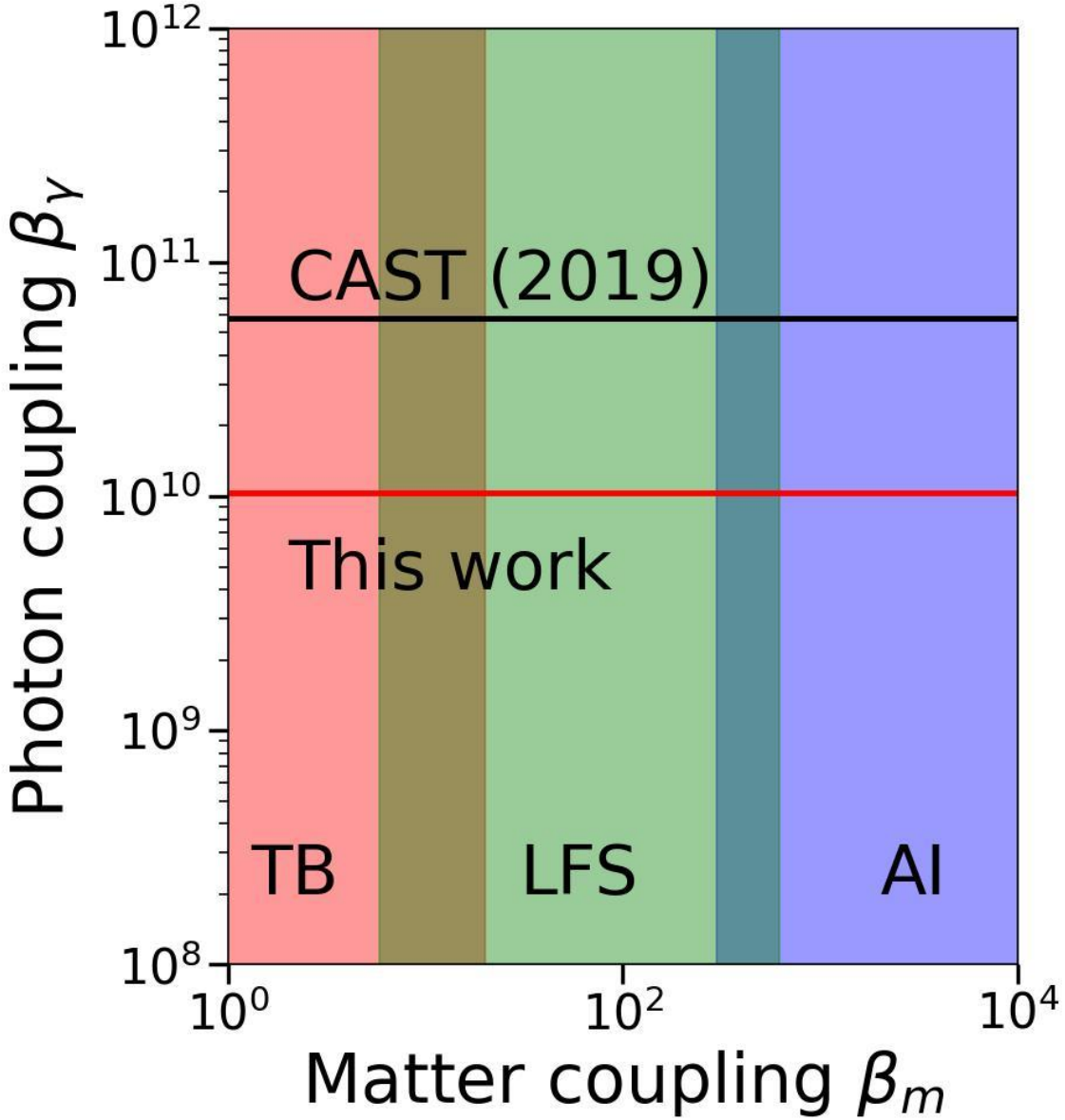
$$\mathcal{L}_\phi \supset \frac{g_{\phi\gamma\gamma}}{4}\phi F_{\mu\nu}F^{\mu\nu}$$

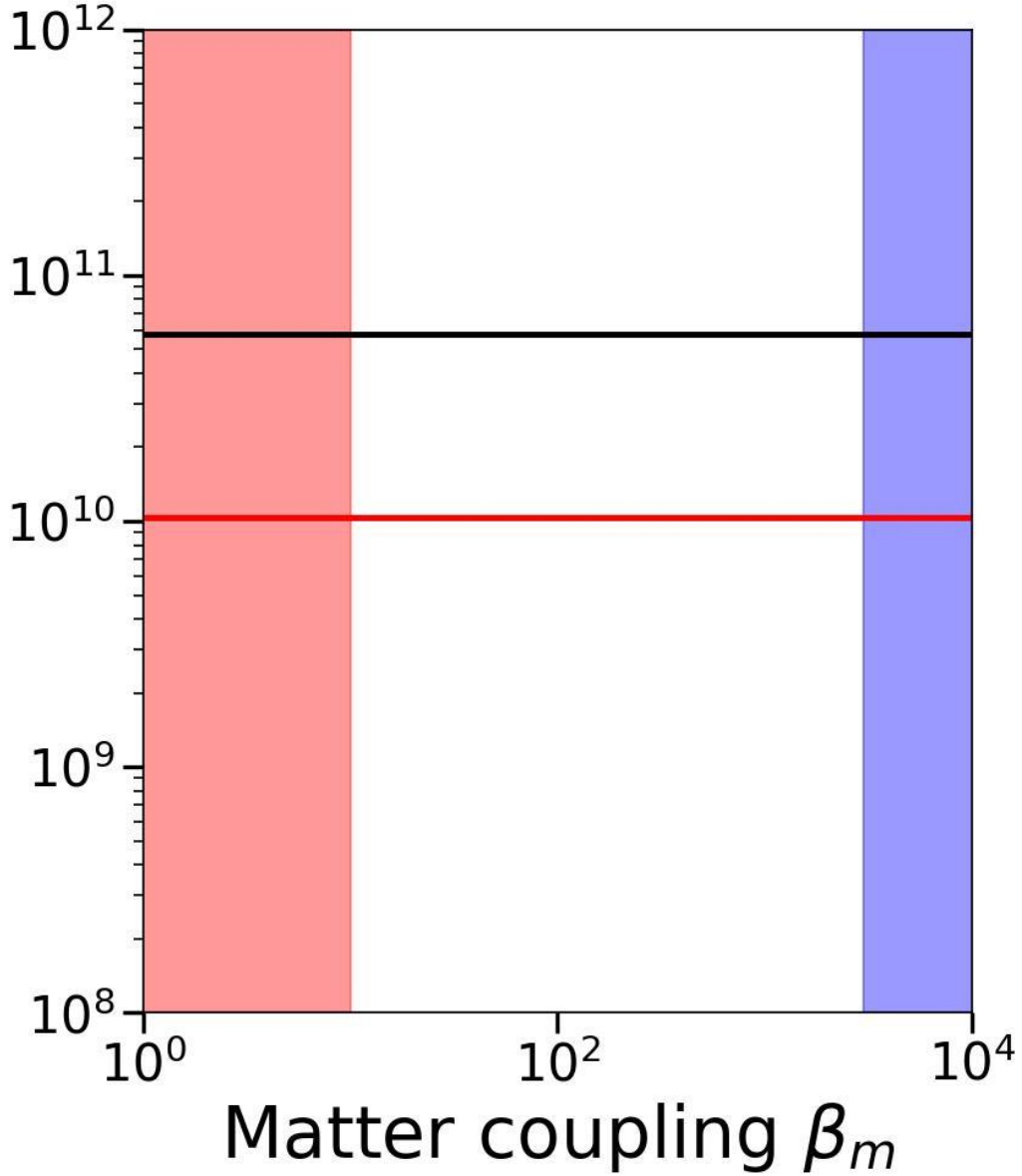
P. Brax, C. Burrage, A-C Davis, D. Seery, A. Weltman - Phys.Lett.B 699 (2011)



T. O'Shea, A-C Davis, M. Giannotti, S. Vagnozzi, L. Visinelli, J. K. Vogel – arXiv:2406.01691

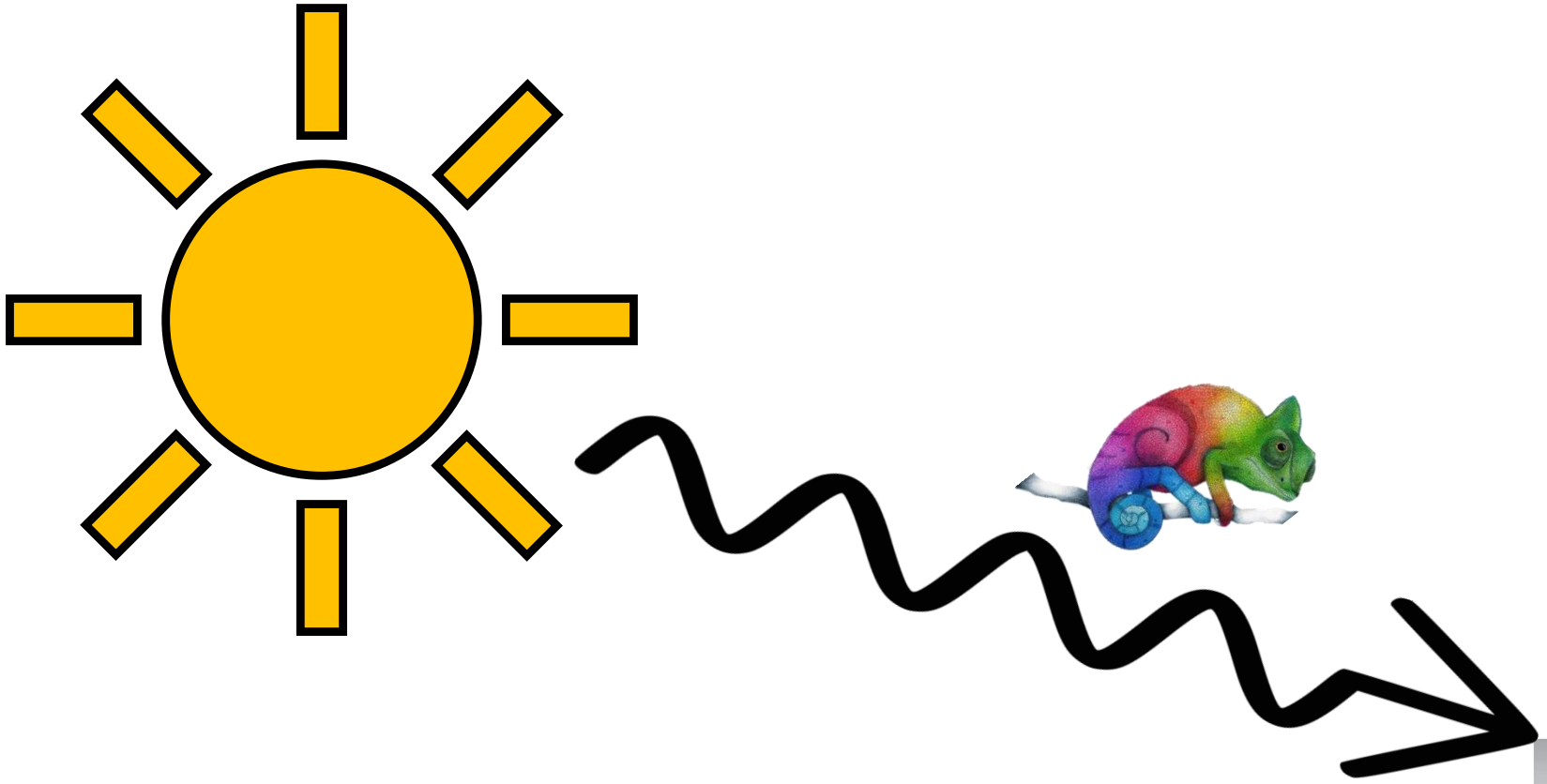

10^{22}
10^{20}
10^{18}
10^{16}
10^{14}
$\beta_\gamma^{-2} \frac{dN}{d\omega}$ [s^{-1} keV^{-1}]
T
B
10^{-2}
10^{-1}
10^{0}
10^{1}
Scalar energy [keV]

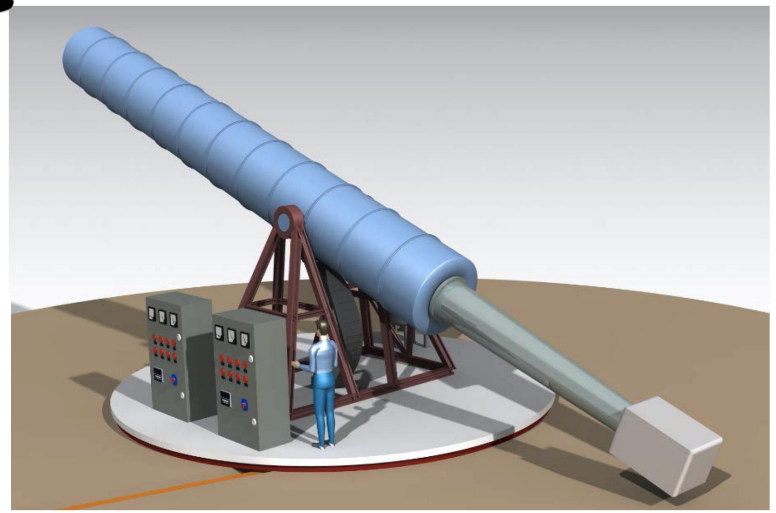

10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
Photon coupling β_γ
CAST (2019)
This work
TB
LFS
AI
10^{0}
10^{2}
10^{4}
Matter coupling β_m

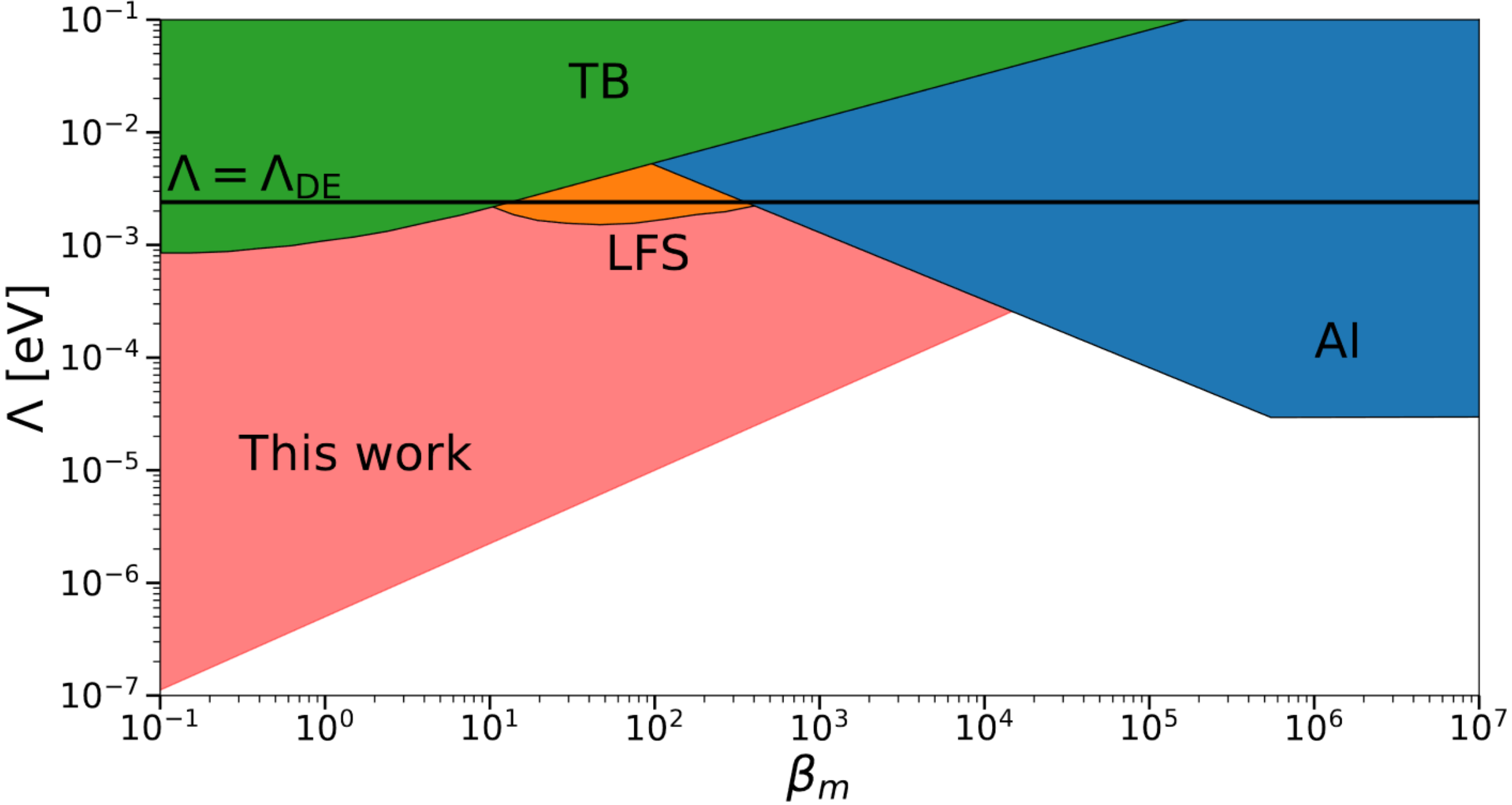

10^{12}
10^{11}
10^{10}
10^{9}
10^{8}
10^{0}
10^{2}
10^{4}
Matter coupling β_m

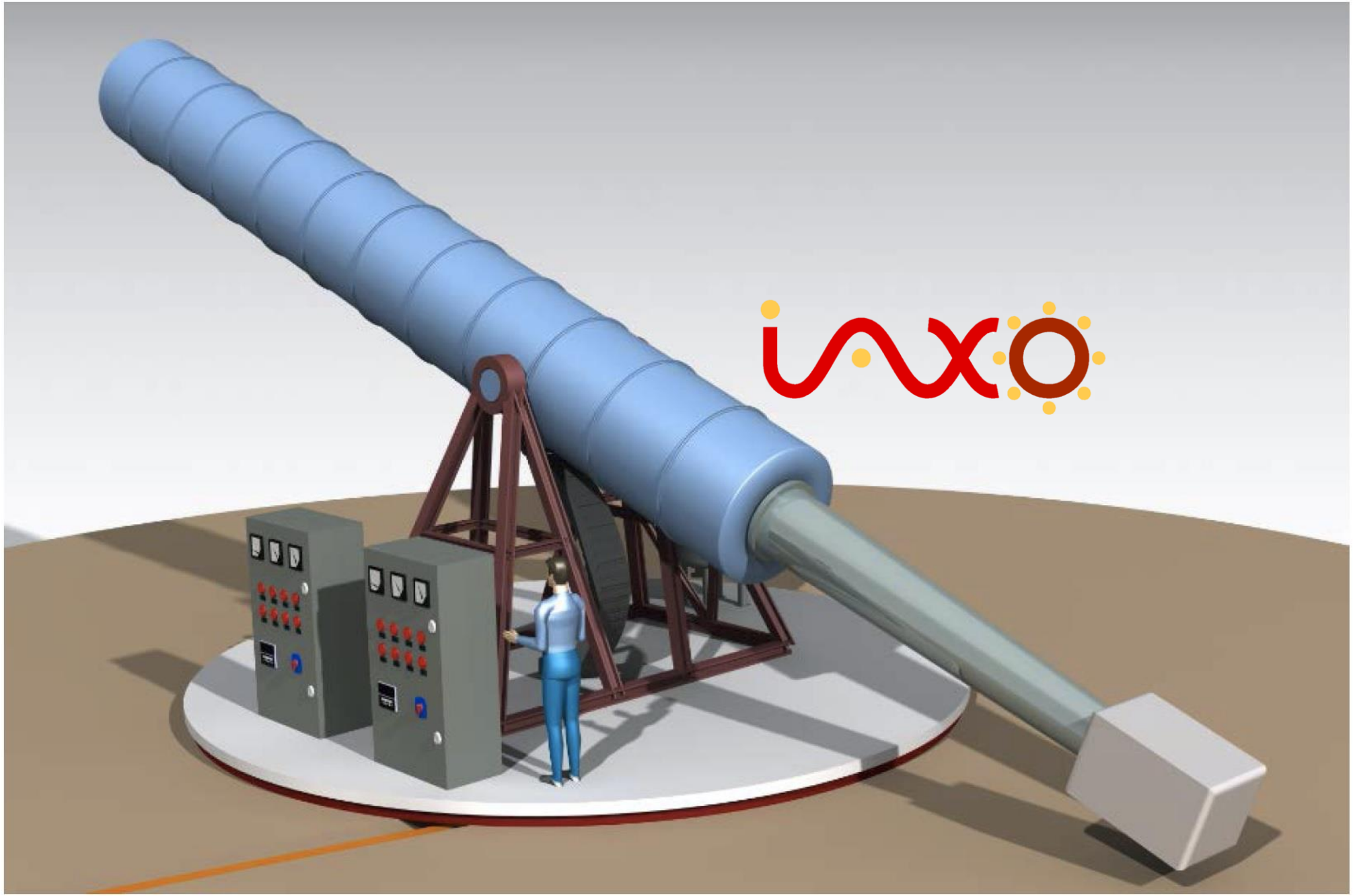
	Scalar	Pseudoscalar
E	Photon **Plasmon**	Photon
B	Photon	Photon **Plasmon**

$$\phi F_{\mu\nu}F^{\mu\nu} \propto \phi(B^2 - E^2) \qquad a\tilde{F}_{\mu\nu}F^{\mu\nu} \propto a\mathbf{E}\cdot\mathbf{B}$$






TB
$\Lambda = \Lambda_{DE}$
LFS
AI
This work
Λ [eV]
β_m
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-1}
10^{0}
10^{1}
10^{2}
10^{3}
10^{4}
10^{5}
10^{6}
10^{7}


inxo

A^μ

E

Polarised along B-field

B

A^μ

B

Polarised perpendicular to B-field

A'^μ

A^μ

Unpolarised

Summary

- Axions produced through photon, electron and nucleon couplings
- DPs produced through mixing with SM photon
- (Chameleon) scalars produced similarly to axions
  - Differences in plasma processes due to scalar/pseudoscalar differences
  - Matter couplings not yet explored
- All 3 detectable by IAXO
  - Will probe new axion and chameleon parameter space
  - DP parameter space excluded by XENON
  - Detection of longitudinal DPs is of great interest
  - Polarisation of back-converted photon tells us nature of particle