Flavor physics & DM connection

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virtually@FlavCC workshop

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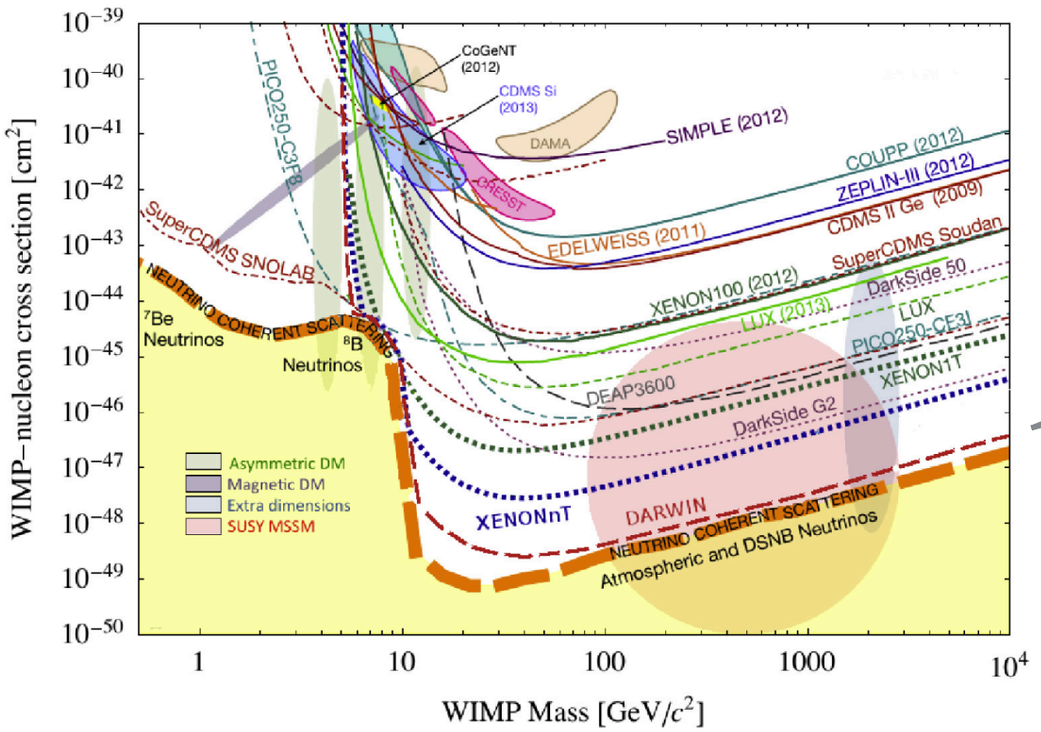
Introduction

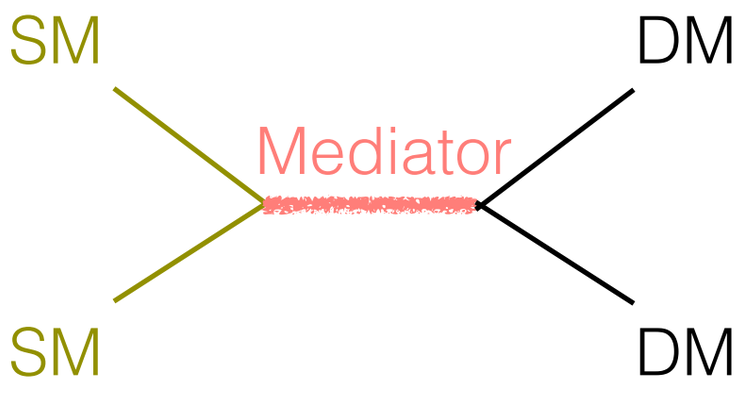
- Only known interaction for Dark Matter (DM) is gravitational in nature

popular DM hypothesis— Weakly Interacting Massive Particles

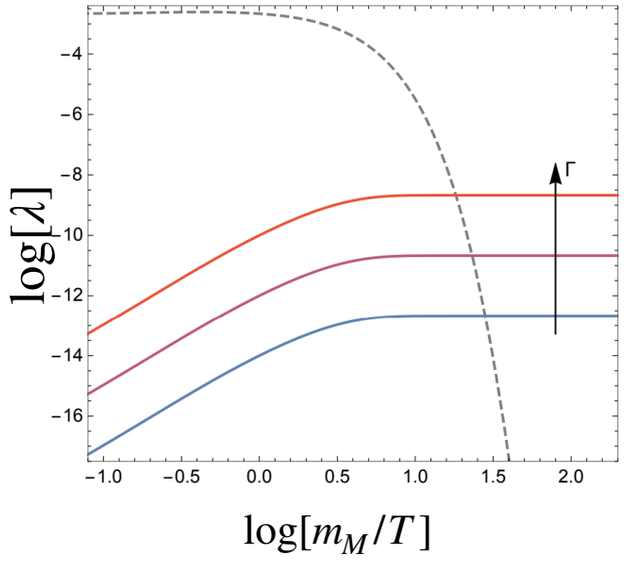


Direct detection experiments like XENONnT, LUX are ruling out most of the regions

Need for alternative mechanisms — Feebly Interacting Massive Particles



DM produced via decay of mediators



Introduction

- Smallness of QCD θ-term ($\leq 10^{-10}$) in SM has no theoretical explanation

$$\frac{\alpha_s \theta}{8\pi} G^{\mu\nu}\tilde{G}_{\mu\nu} \longrightarrow a(x)/f_a$$

axion field is a goldstone of spontaneously broken $U(1)_{\rm PQ}$ symmetry

Astrophysical & experimental searches disfavored PQ model

⟶ popular models KSVZ, DFSZ

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→ popular models KSVZ, DFSZ

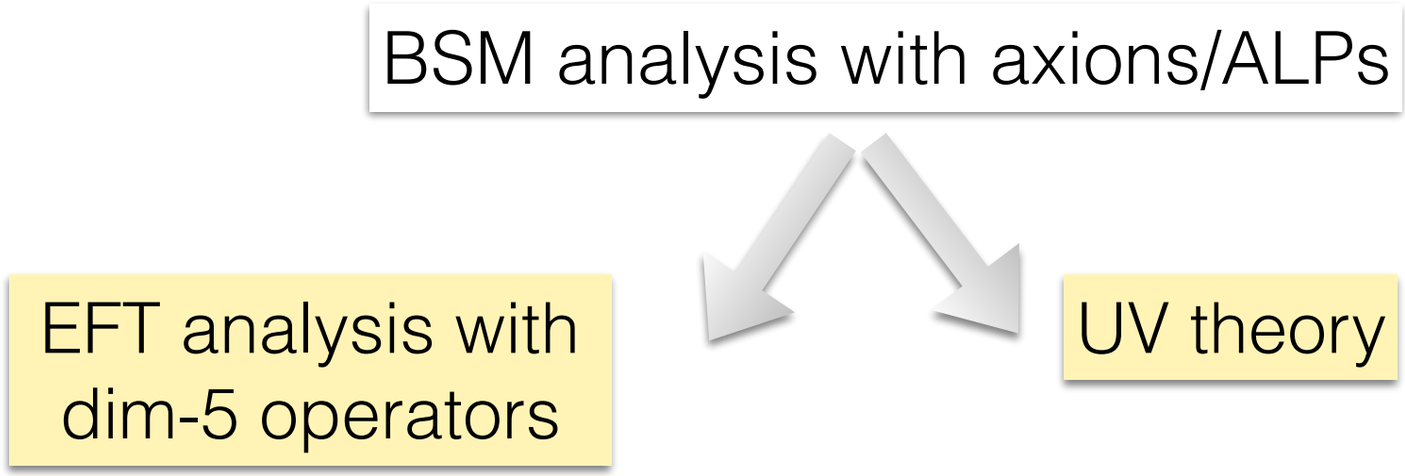
Similar idea motivates for BSM scenarios with SSB of global U(1)

→ ALPs with no general connection to strong CP problem

but new ideas with mirror universe [Hook et.el.: PRL 124, 221801 (2020)]

very weakly coupled— good mediator for FIMP DM scenarios

EFTs


BSM analysis with axions/ALPs
EFT analysis with dim-5 operators
UV theory

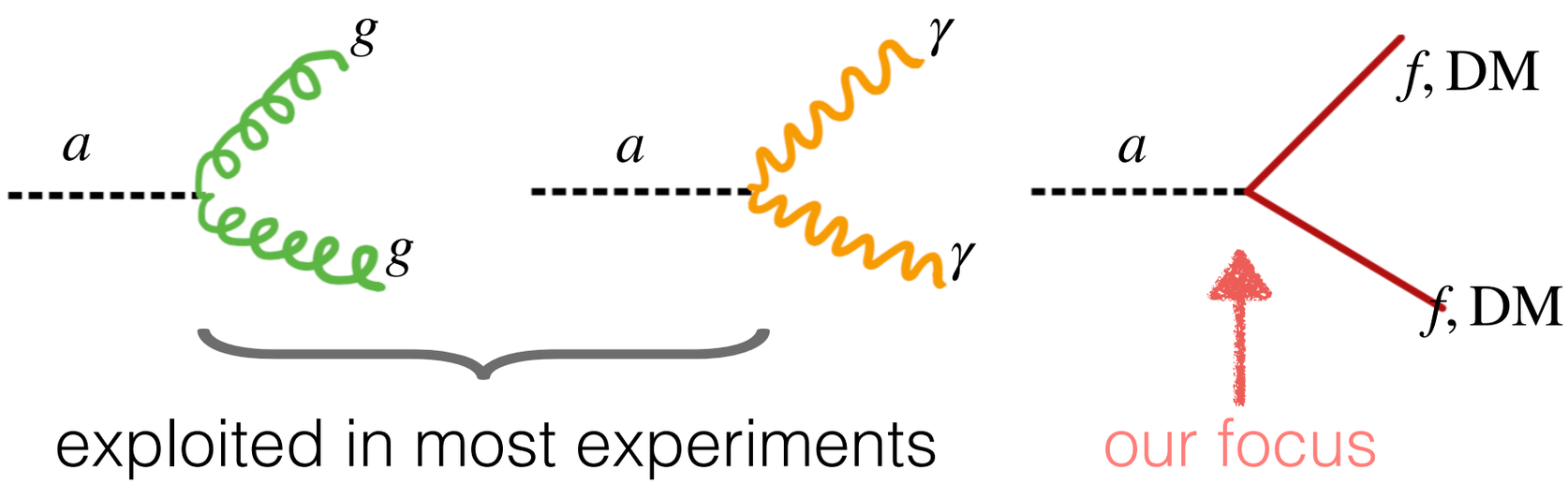
EFTs

BSM analysis with axions/ALPs

EFT analysis with dim-5 operators

UV theory

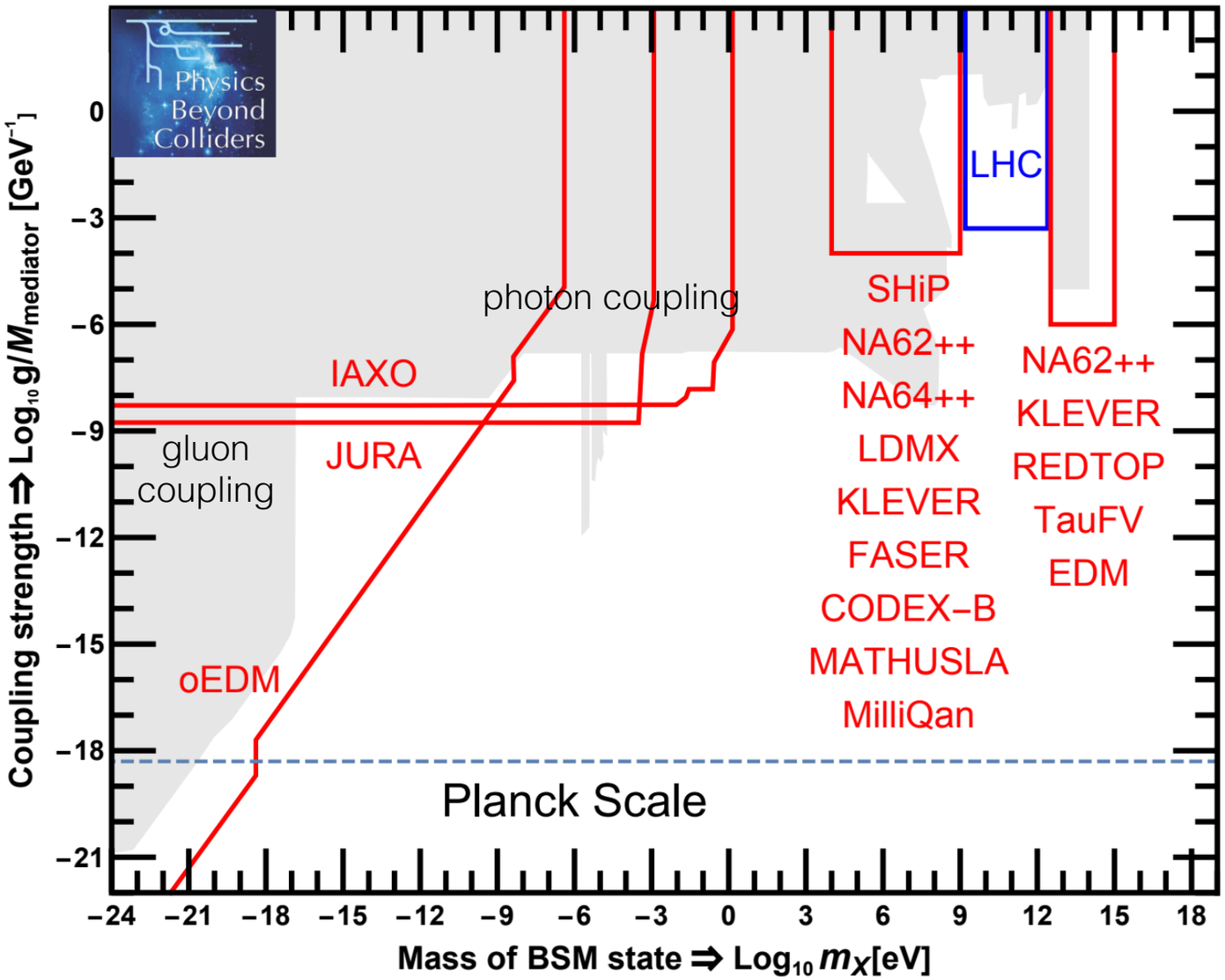
$$\mathscr{L}_{\text{ALP}} \subset -\frac{\alpha_s}{8\pi}\frac{C_{ag}}{f_a} a\, G^{\mu\nu}\tilde{G}_{\mu\nu} - \frac{\alpha}{8\pi}\frac{C_{a\gamma}}{f_a} a\, F^{\mu\nu}\tilde{F}_{\mu\nu} + \frac{C_{af}}{f_a}\partial_\mu a\, \bar{\psi}_f \gamma^\mu \gamma_5 \psi_f$$



exploited in most experiments

our focus

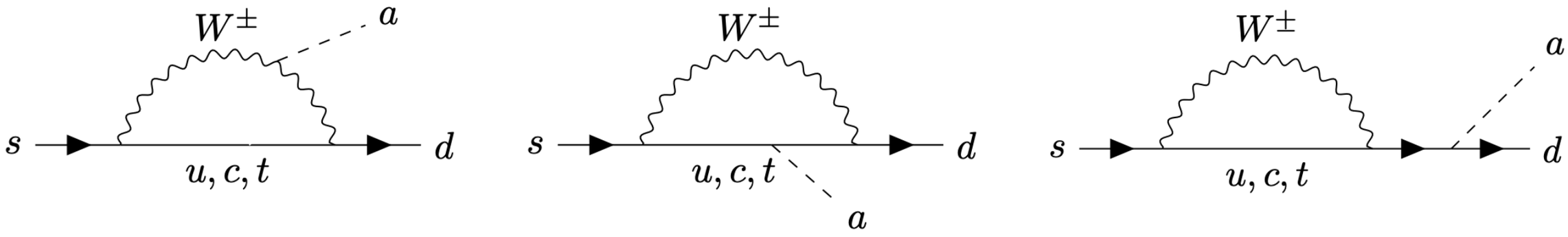
EFTs



Several ongoing & proposed experiments can probe different mass scales — GeV range ALPs are less explored

EFTs

Wide set of observables in meson and baryon decays



- All computations depend on cut-off scale via Log divergent terms
  —normal way is to identify cut-off as U(1) breaking scale

- Although some couplings are chosen vanishing at high-scale:
  RGE generates non-zero values [Bauer et.el. 2110.10698]

EFTs

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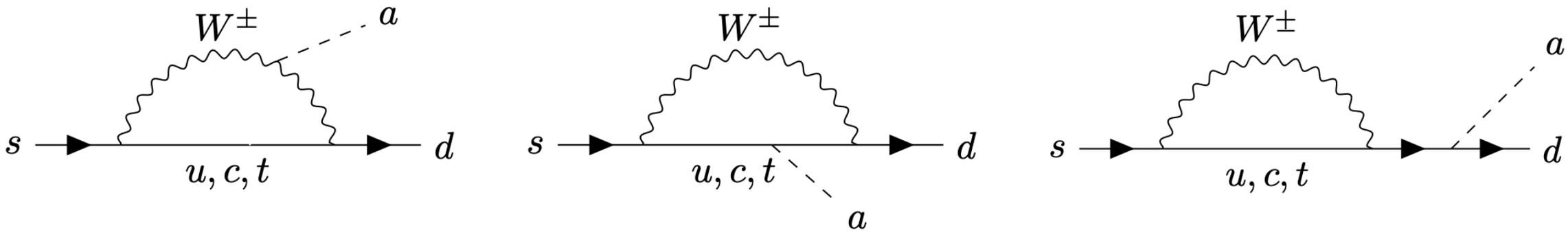

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- Although some couplings are chosen vanishing at high-scale:
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- Non-perturbative effects via gluon coupling are missing

- Improved/new prediction for 2- & 3-body hadron decays
  with ALP in finalstate [Camalich et.el. PRD 102, 015023 (2020)]

UV

- DFSZ model: 2HDM (type-II)+ PQ breaking complex scalar

  $s \to da$ FCNC results $\Lambda_{\rm DFSZ} = m_{H^+}$ [Alvarez et.el. JHEP 07 (2020) 059]

  several order differences compared to an EFT analysis

  RGEs are trusted only with the full spectrum of the model

Extension of such models with DM candidates will give different outcomes

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- Identify U(1) as Froggatt-Neilson

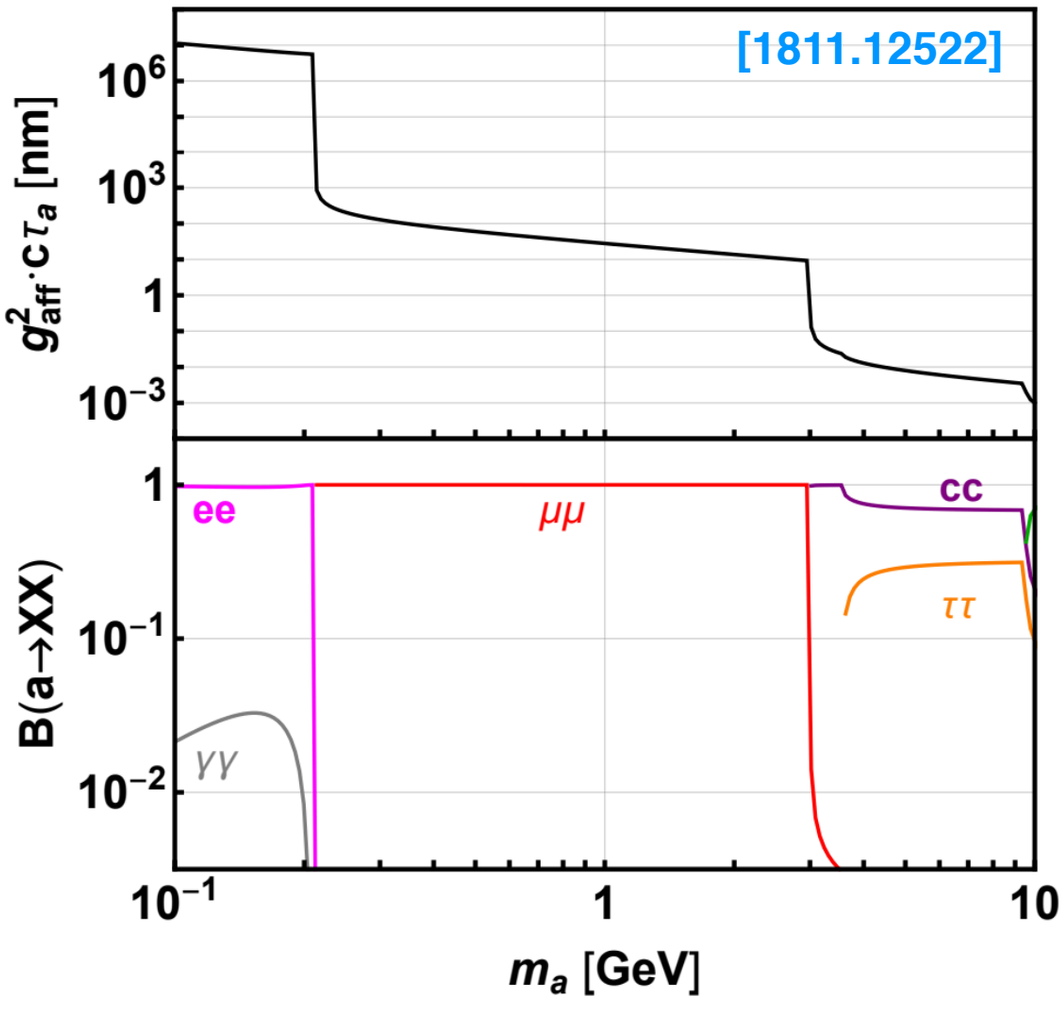
  Axiflavon models in PQ case $U(1)_{\rm PQ} \equiv U(1)_{\rm FN}$ [Callibbi et.el. PRD 95 095009 (2017)]

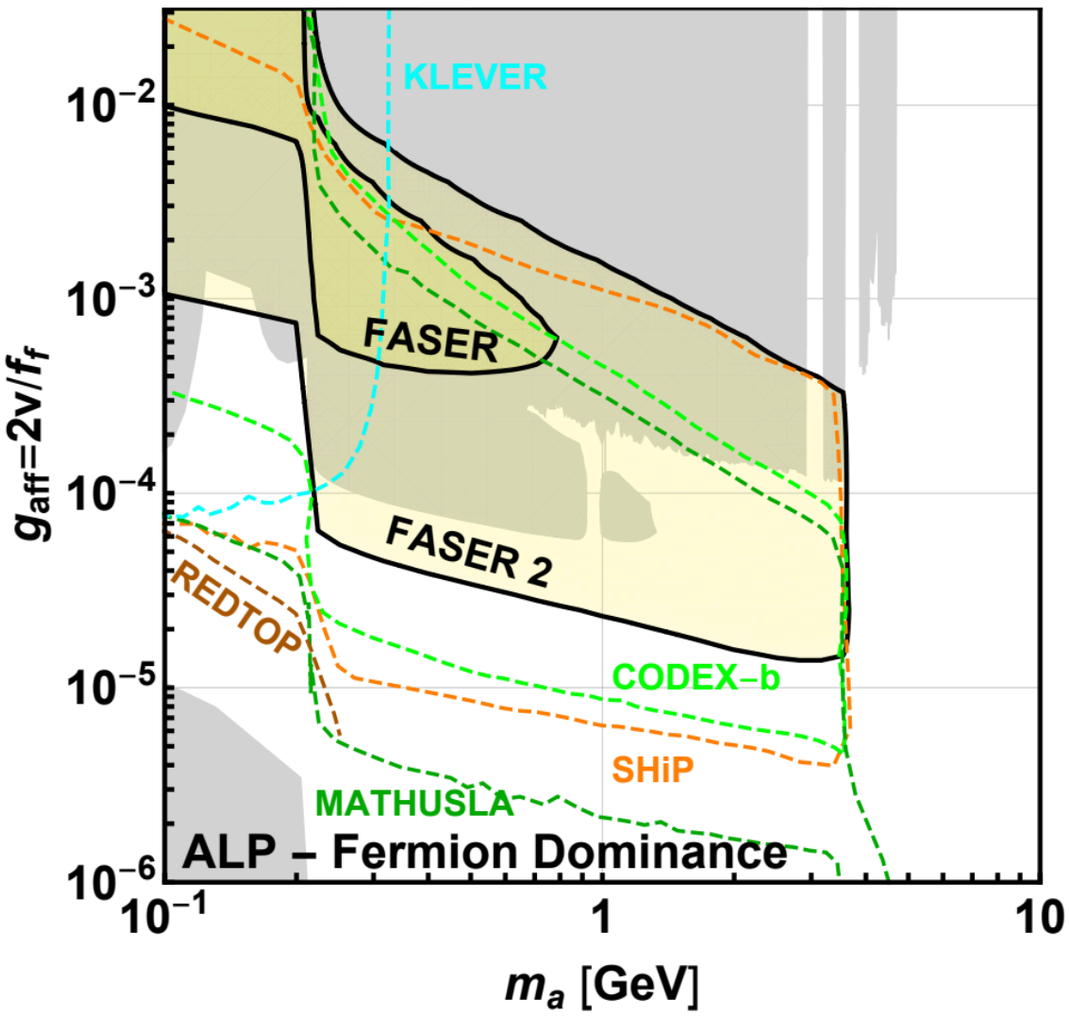
  Setup extended with ALP DM or ALP portal

Collider

- Feebly interacting → long lifetime → displaced signature

Scope at long lived particle search experiments e.g.,
MATHUSLA, CODEX-b, FASER, SHADOWS





Strongly coupled dark sector

- Dark color group like SU(3) → Dark meson/baryon

[G Kribs, A. Martin, T. Tong JHEP 08 (2019) 020]

joining as a postdoc in Siegen

New fermions charged under $SU(N_D)$ interacts to SM sector via Higgs & below 'dark confinement' scale it is an EFT of dark pions

Collider signatures like $pp \to \rho_D \to \pi_D \pi_D \qquad \pi_D \to ff', Wh, Zh$

- No study of DM analysis of relic, indirect detection etc.

Thank you for your attention