

The future of light (dark) new physics

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Plan

1. Motivations for light (dark) new physics
2. One specific example: the dark photon at current and future colliders
3. “Beyond” colliders: the long-lifetime frontier

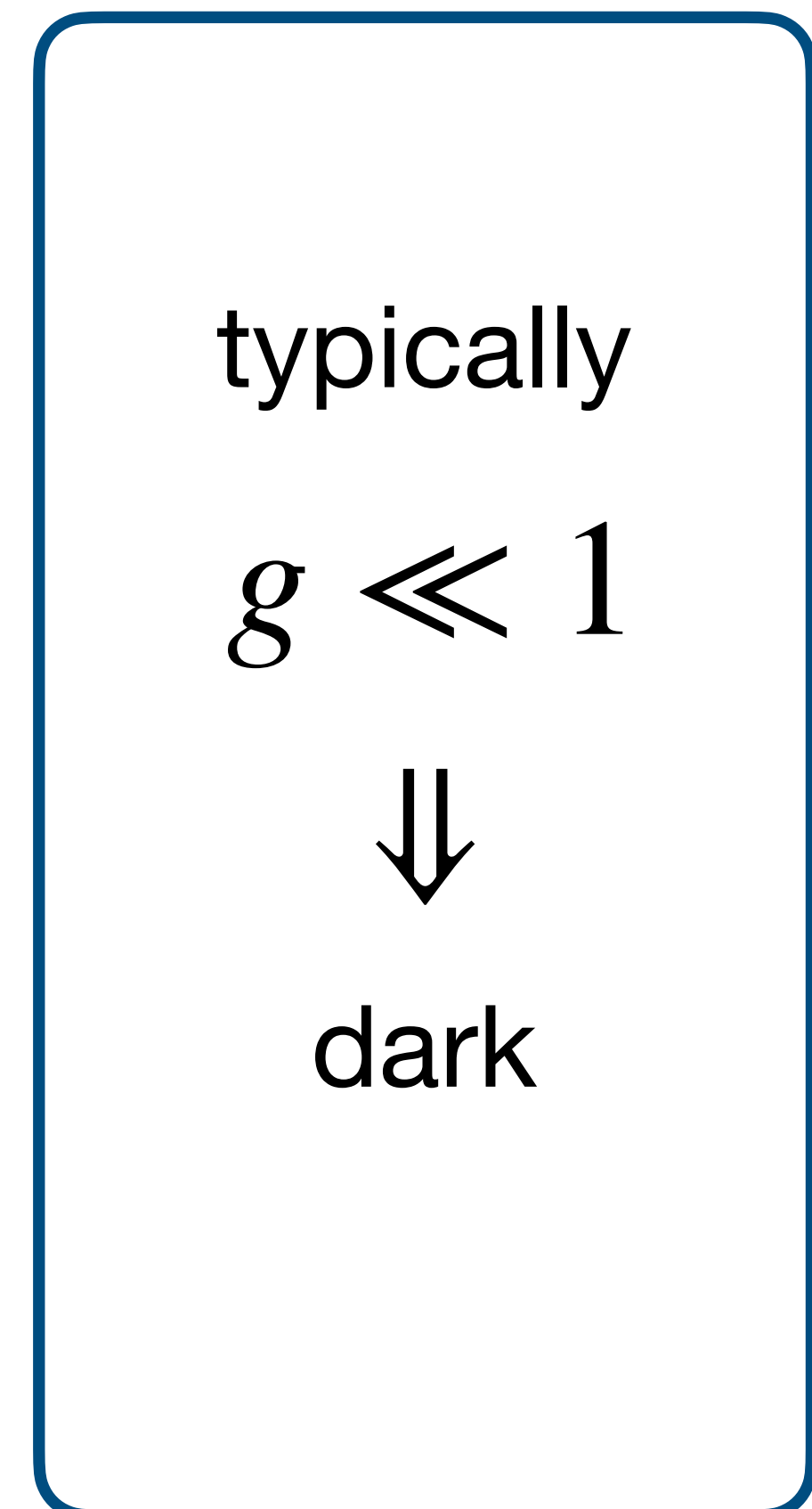
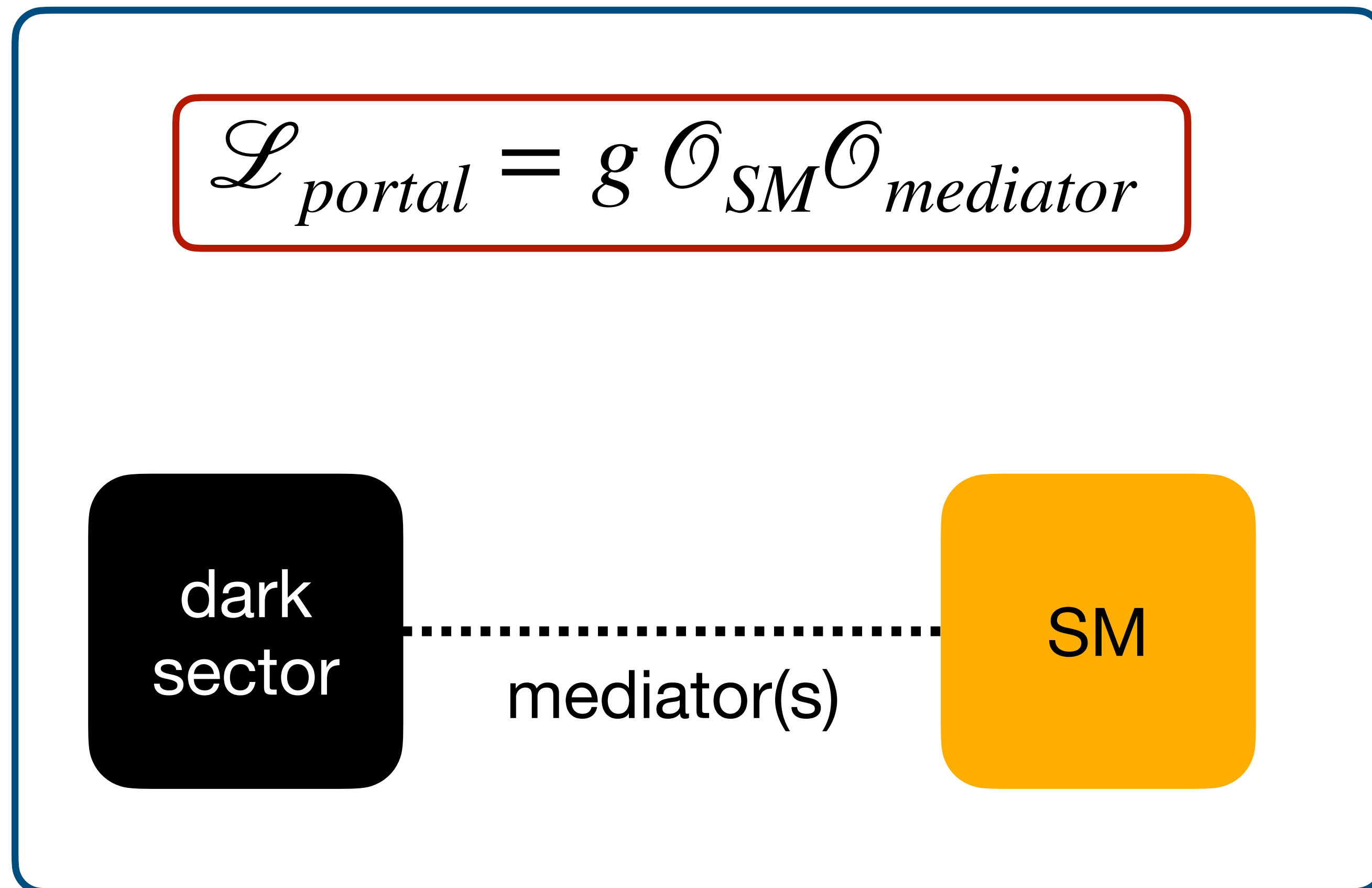
“Dark” new physics

Interesting because:

1. Possible connection with DM physics
2. Simplicity of SM extension
3. Possible connection with neutrino physics
4. ...

Portals - general structure

Operator constructed out of SM states + new states (mediators)



Portals - classifications

Lowest dimensional portals ($d = 4$)

$$\mathcal{L}_{portal} = \lambda |S|^2 |H|^2$$

scalar

$$\mathcal{L}_{portal} = \varepsilon Z'_{\mu\nu} B^{\mu\nu}$$

vector

simplest U(1)
extension

$$\mathcal{L}_{portal} = Y(LH)N$$

neutrino

simplest model for
neutrino masses

Portals - classifications

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SEE NEXT TWO
TALKS

simplest model for
neutrino masses

LNP@colliders (present & future)

Dark photons - visible vs invisible

(Quite recent review: 2005.01515)

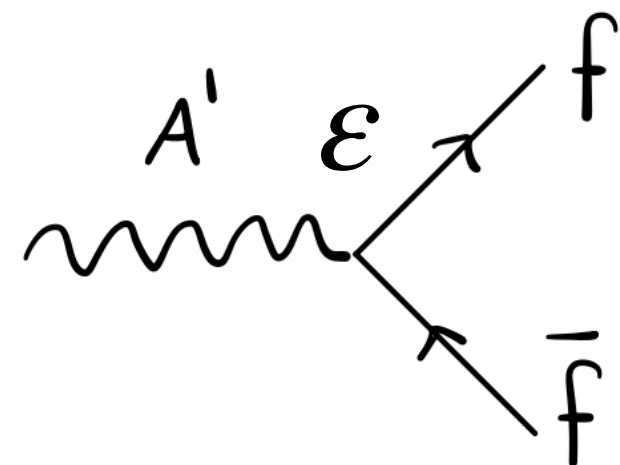
Portal coupling: kinetic mixing $\mathcal{L}_{portal} = \varepsilon Z'_{\mu\nu} B^{\mu\nu}$

- Two cases:
- Dark photon relevant for DM mediation (“invisible”)
 - Couples mainly to DM, coupling to visible particles suppressed
 - Dark photon just associated with additional U(1) (“visible”)
 - Couples only to visible particles (suppressed), no role in DM physics

Very different phenomenology!

Visible dark photons - their present...

See e.g. 2005.01515, 2309.16003



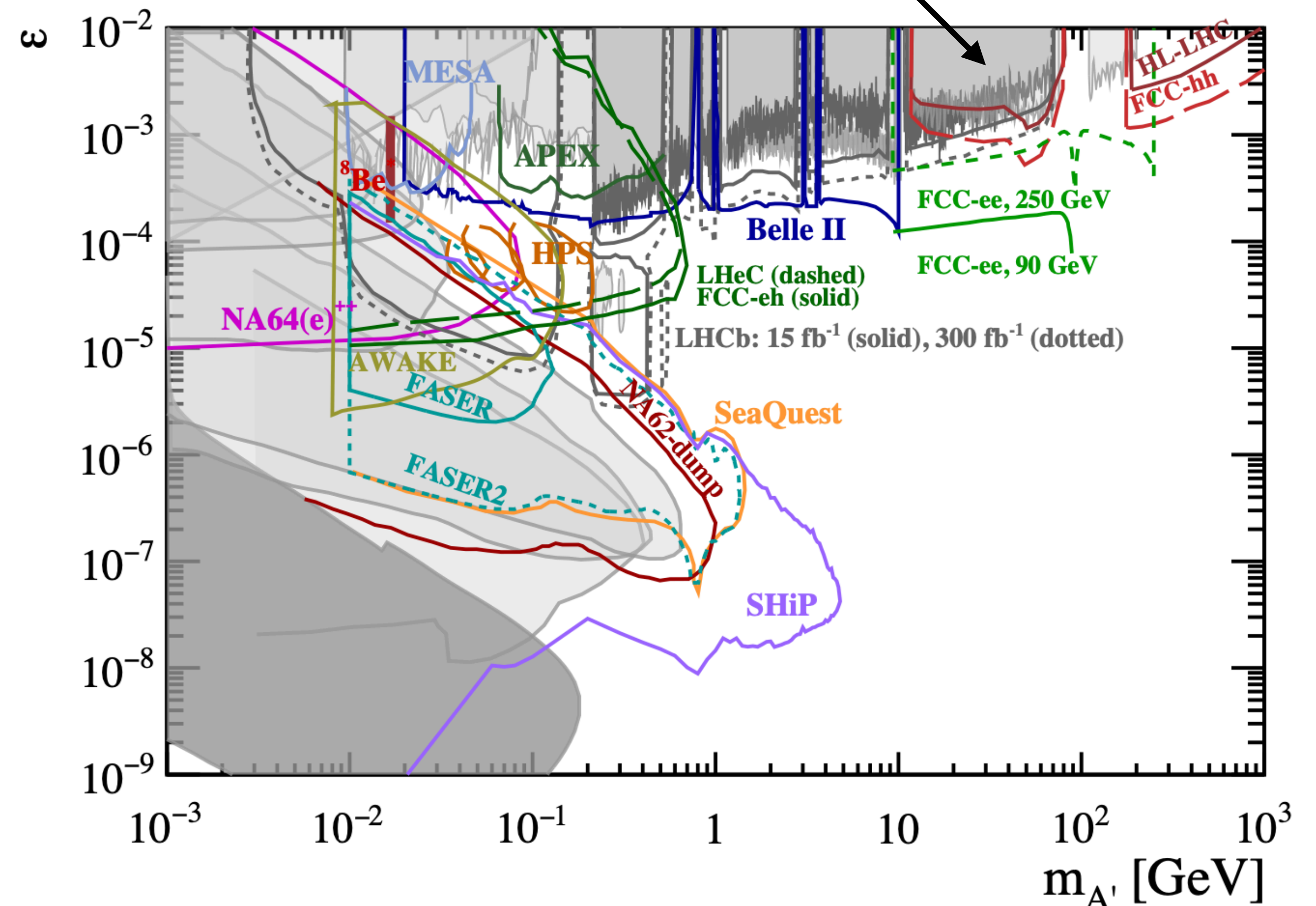
(visible dark photon)

Coloured grey region:
current exclusion

$\epsilon \gtrsim 10^{-(4\div 3)}$ — colliders

$\epsilon \gtrsim 10^{-4}$ — beam dumps

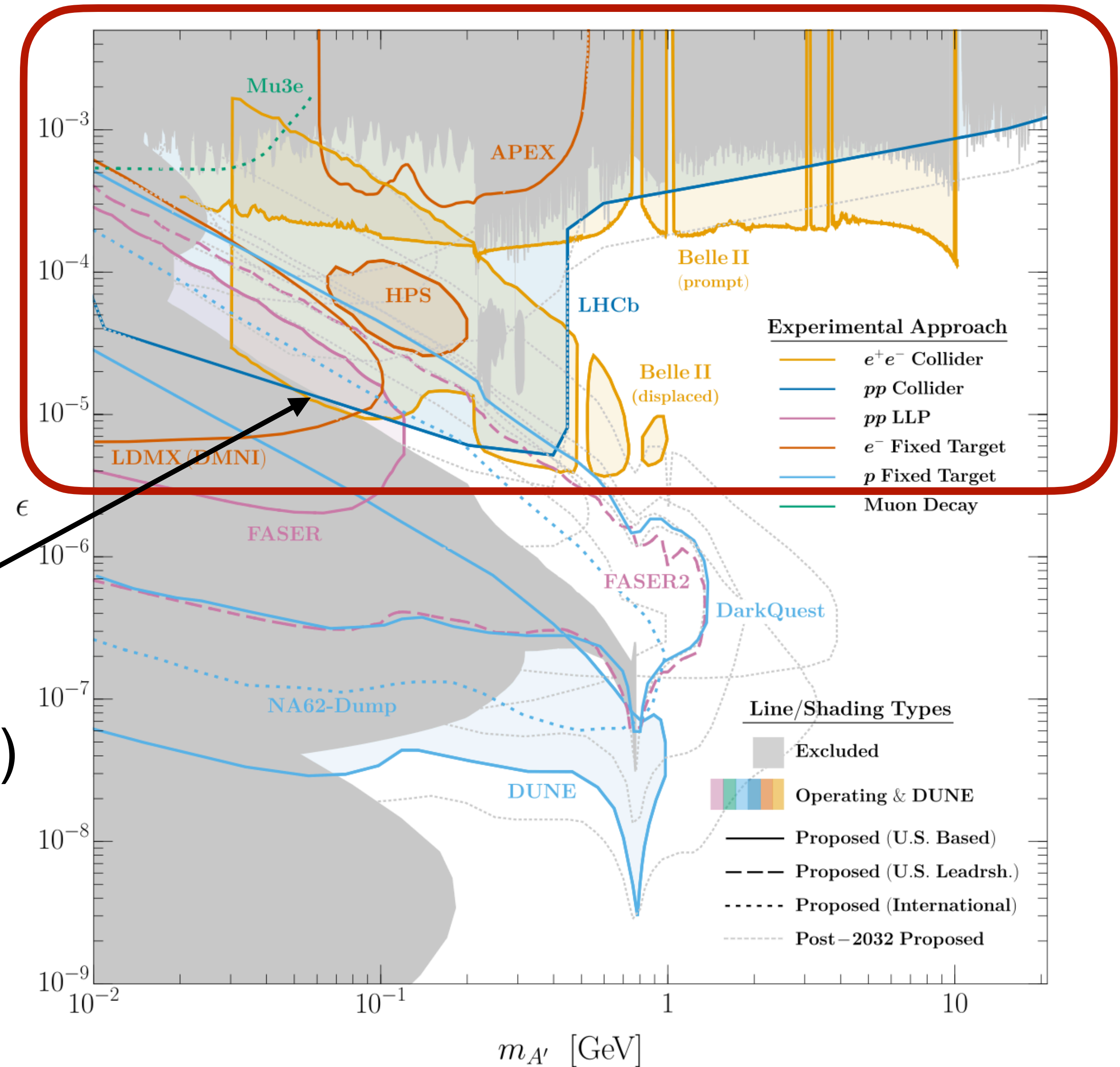
LHCb, Babar, CMS



Visible dark photons - ... and their future

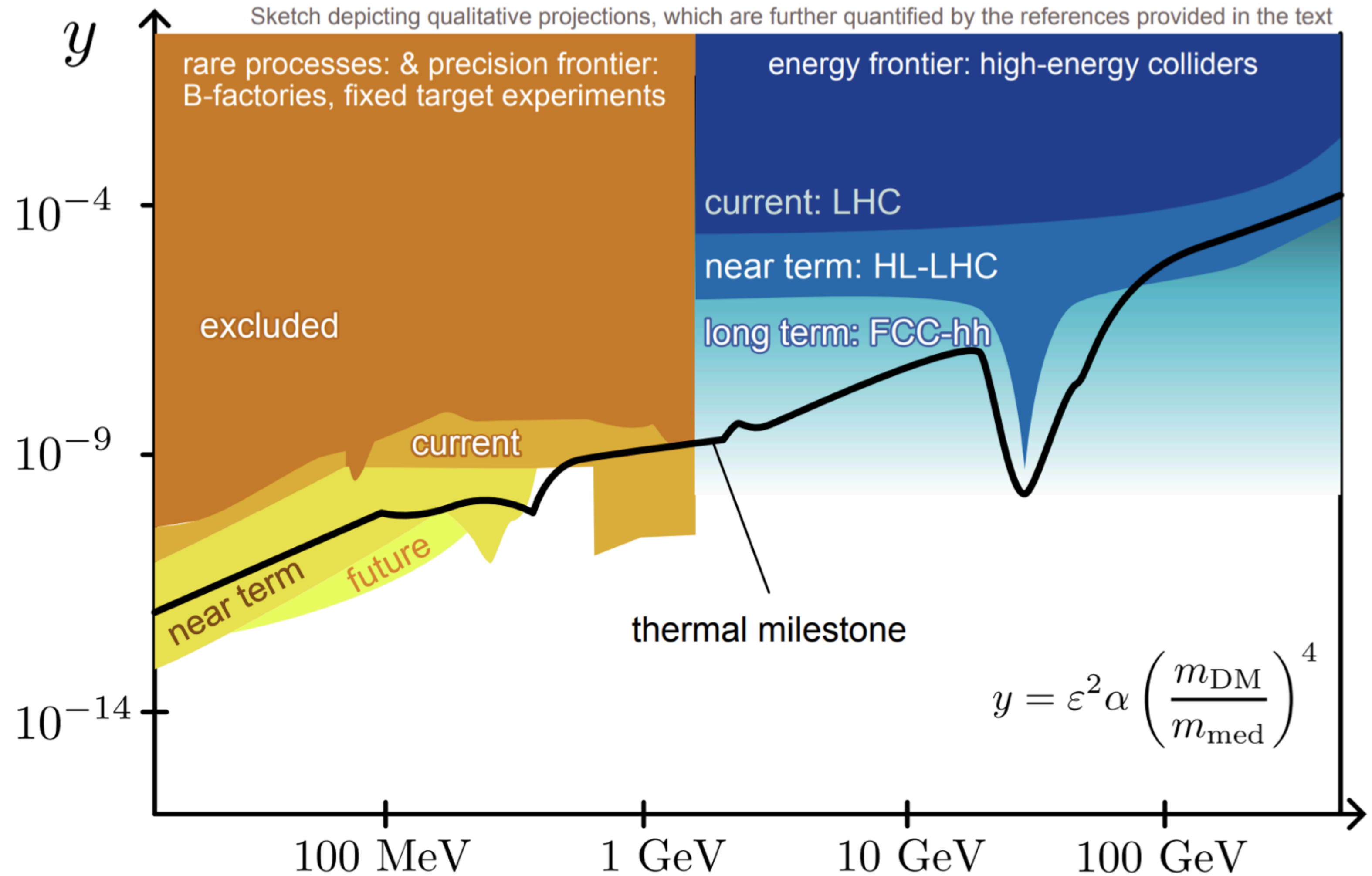
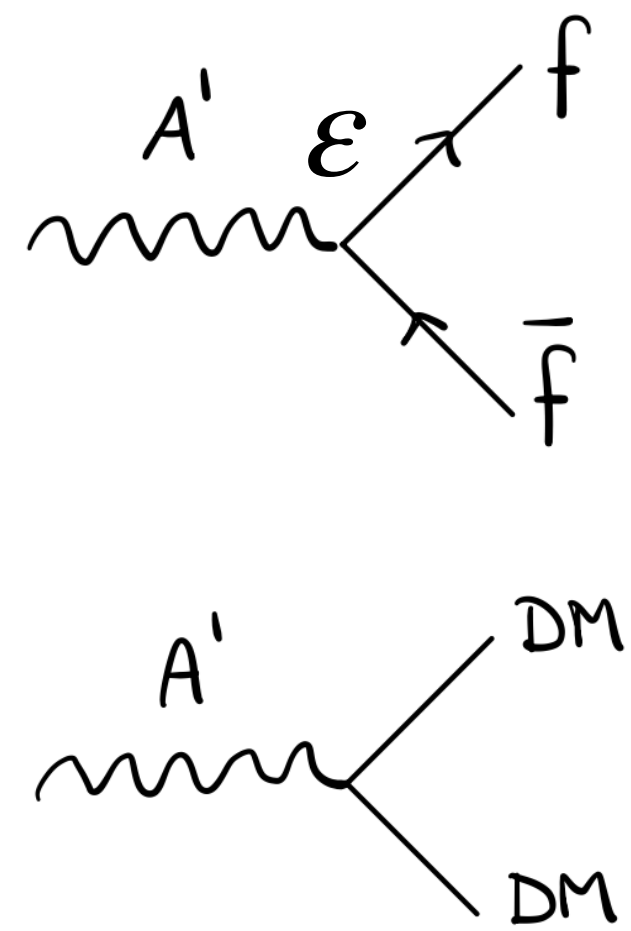
Coloured grey region:
current exclusion

see
2202.03452, 2203.03280 (Belle II)
2203.07048 (LHCb)



Invisible dark photons - present...

See e.g. 2305.01715

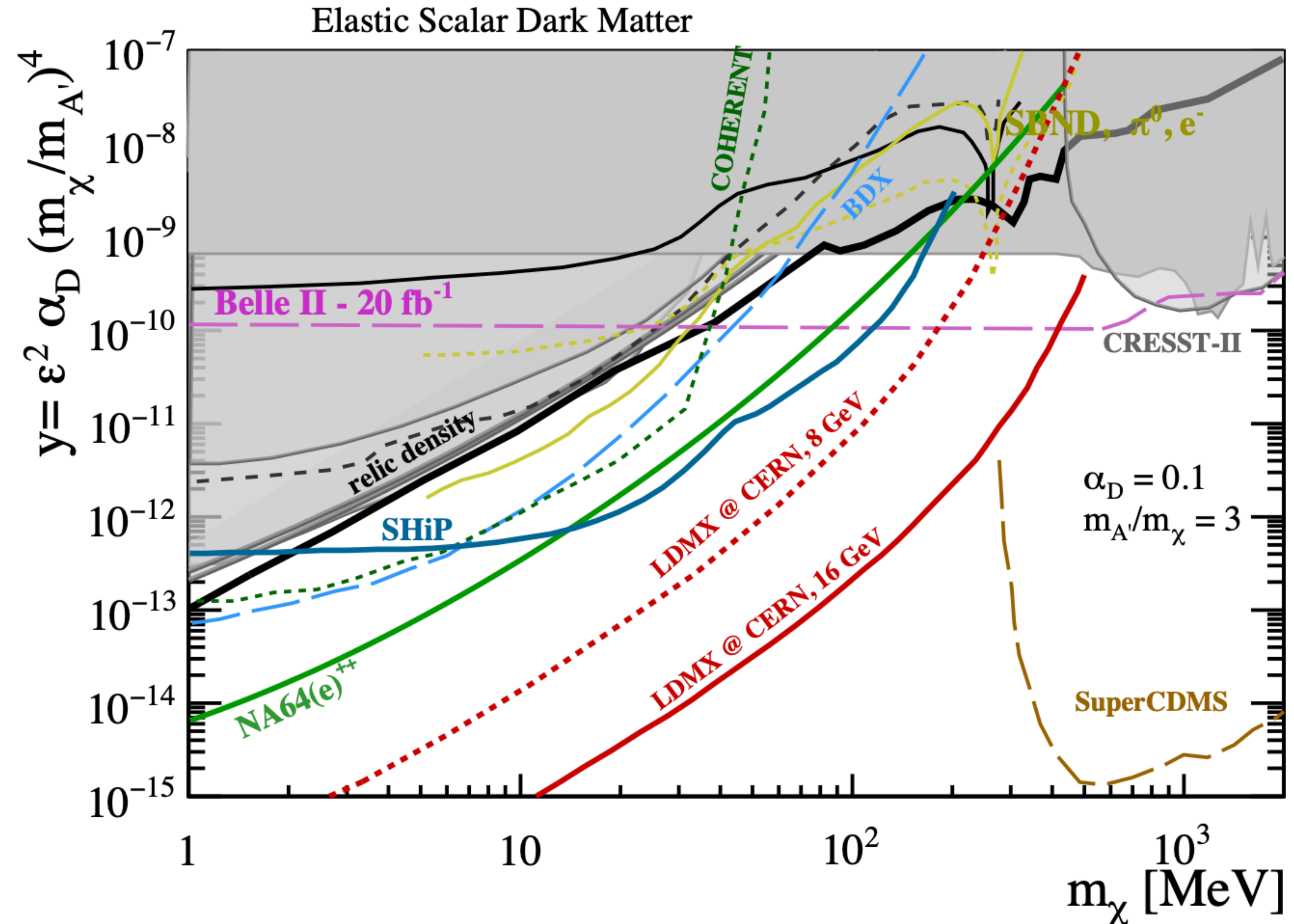


dark matter mass

(INvisible dark photon)

Invisible dark photons - and future

See e.g. 2005.01515

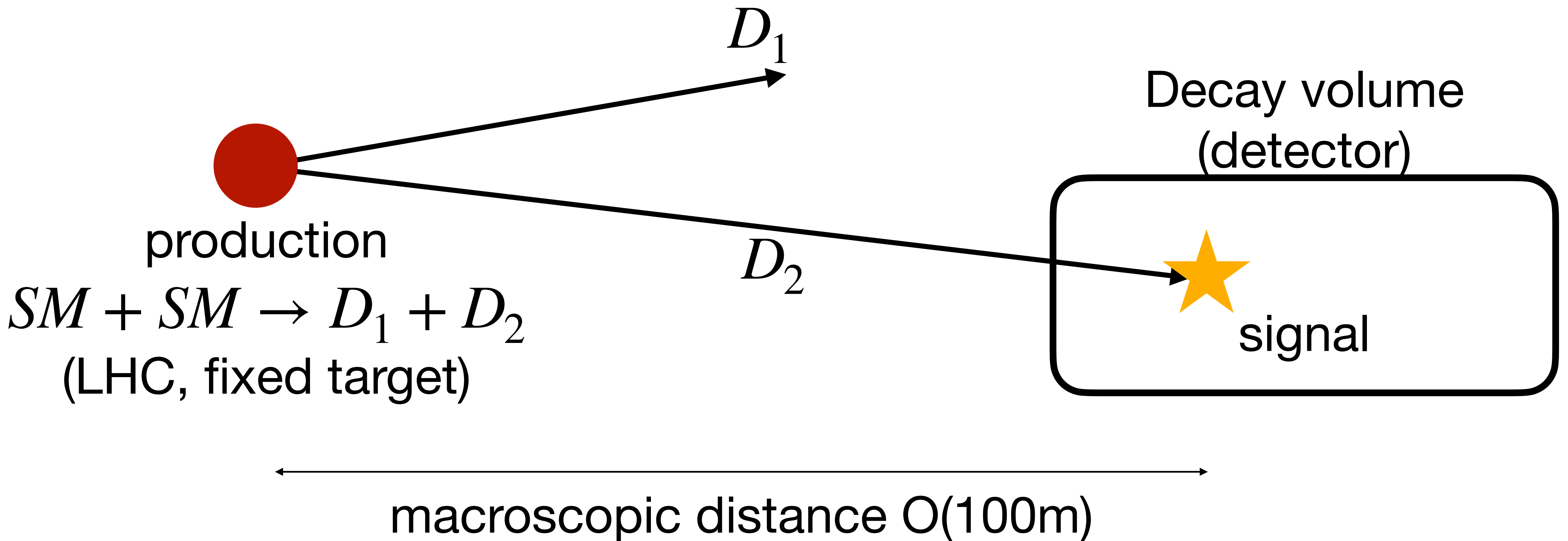


(INvisible dark photon)

The intensity/lifetime frontier

Sketch

Idea: explore (even) smaller couplings placing the detector far away



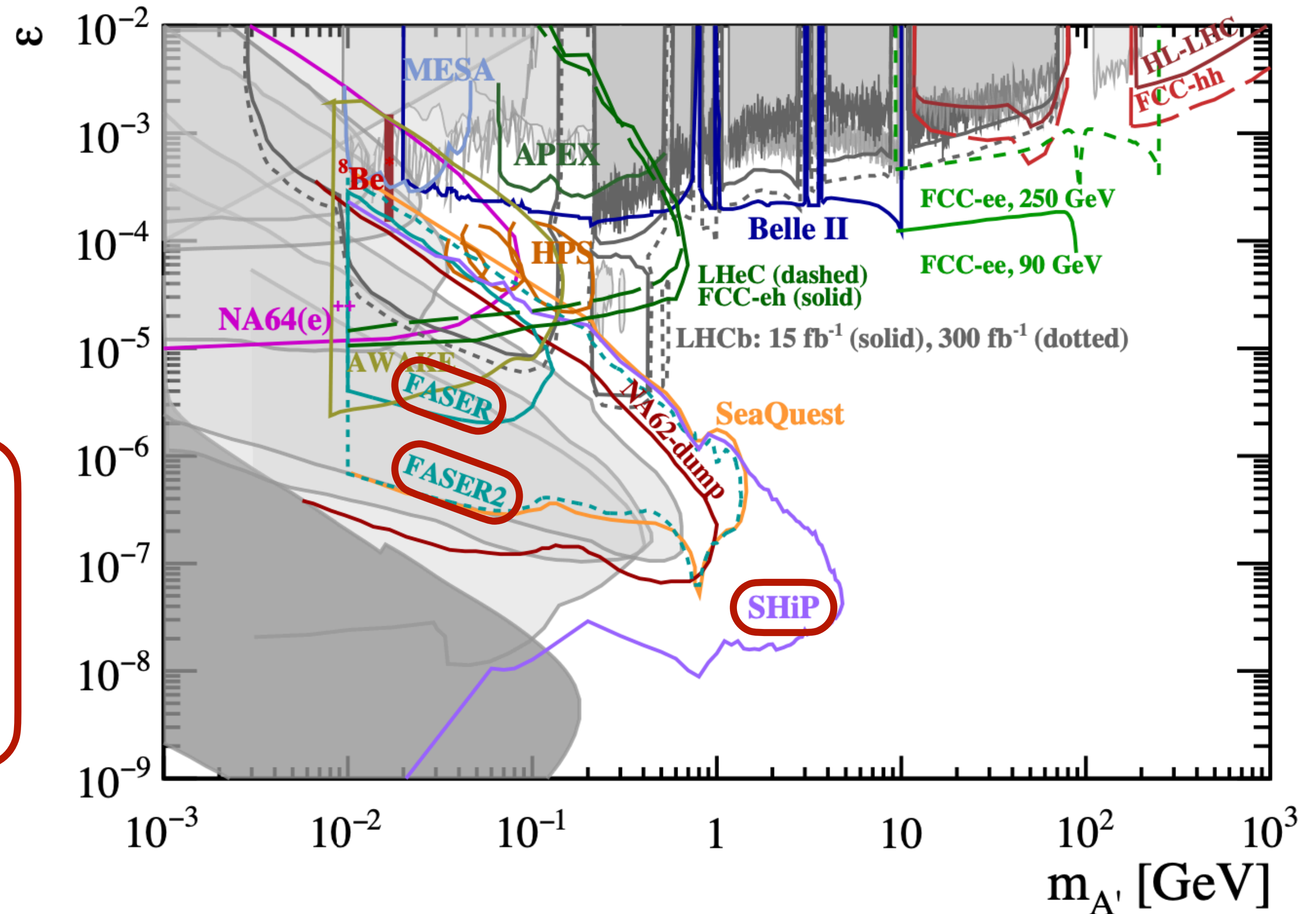
A (partial) list of proposals

1. SHiP (400 GeV p beam) ^{approved}
2. FASER (LHC beam) + future upgrade (FASER2) ^{taking data}
3. NA62 in beam-dump mode
4. MATHUSLA
5. Moedal/MAPP
6. ANUBIS
7. FACET
8. ...

Sensitivities

- Depend crucially on
- distance
 - geometry

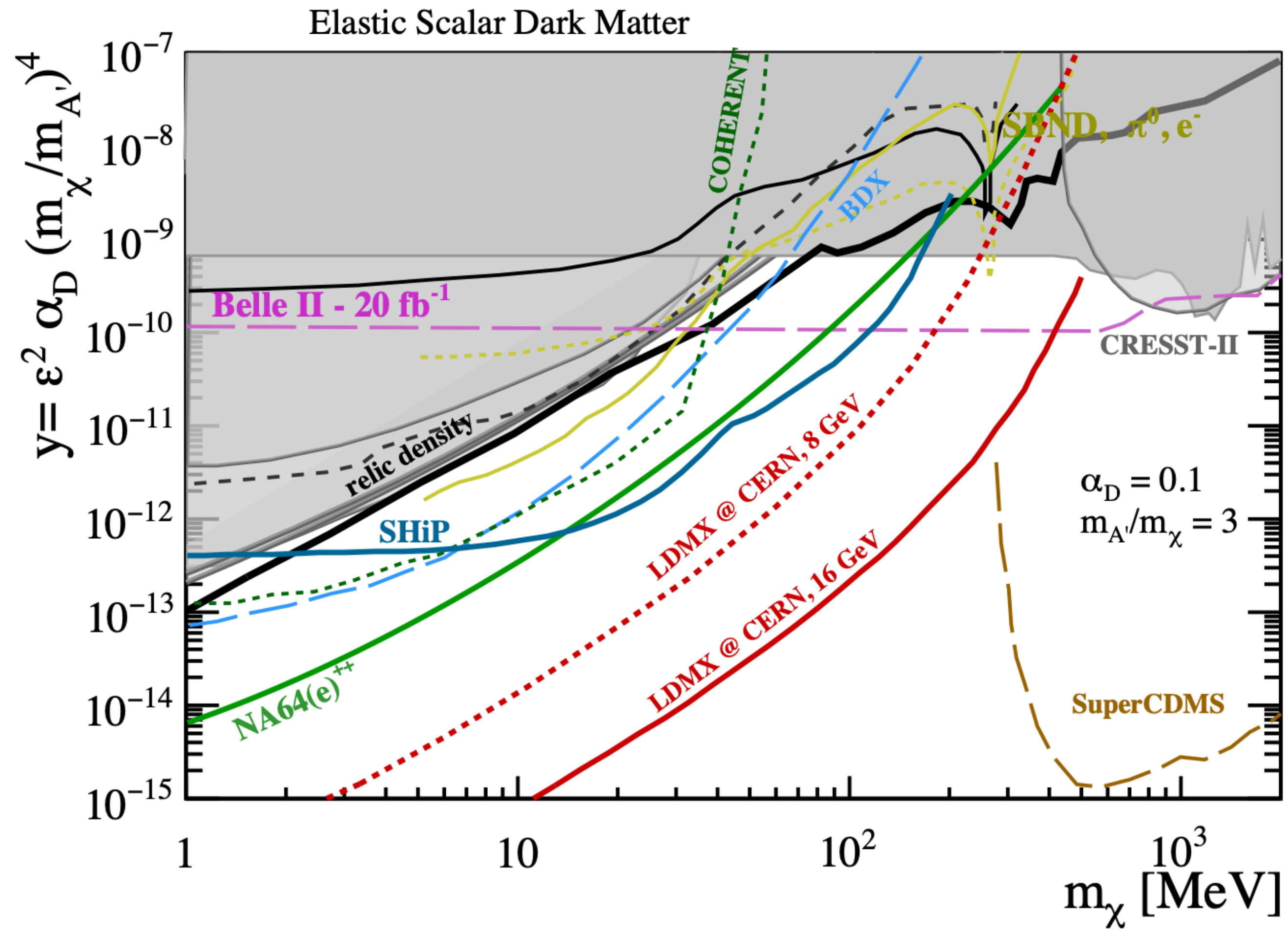
Sensitivities typically moved to lower masses because main production mechanism is now mesons decays



Conclusions

- Colliders are exploring the prompt region of light (dark) models
- Future colliders: bounds improved by orders of magnitude — mainly thanks to displaced searches
- Intensity frontier is a nice, complementary way to explore similar regions in mass and smaller couplings
- If connected to DM: future experiments will (partially) probe the thermal relic target

Backup material



The sensitivity curves for LDMX@SLAC and LDMX@CERN assume 10^{14} electrons-on-target and $E_{\text{beam}} = 4$ GeV and 10^{16} electrons-on-target and $E_{\text{beam}} = 16$ GeV, respectively.