Searches for Dark Photons

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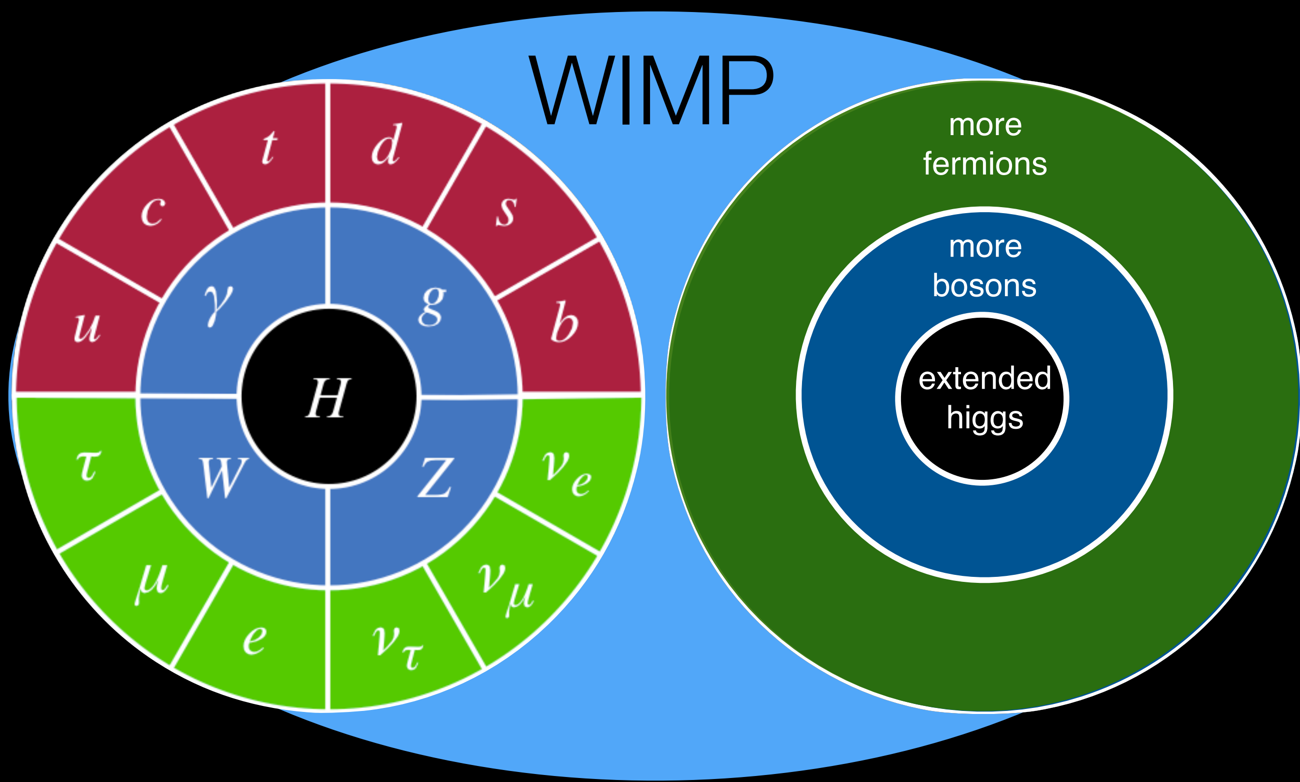
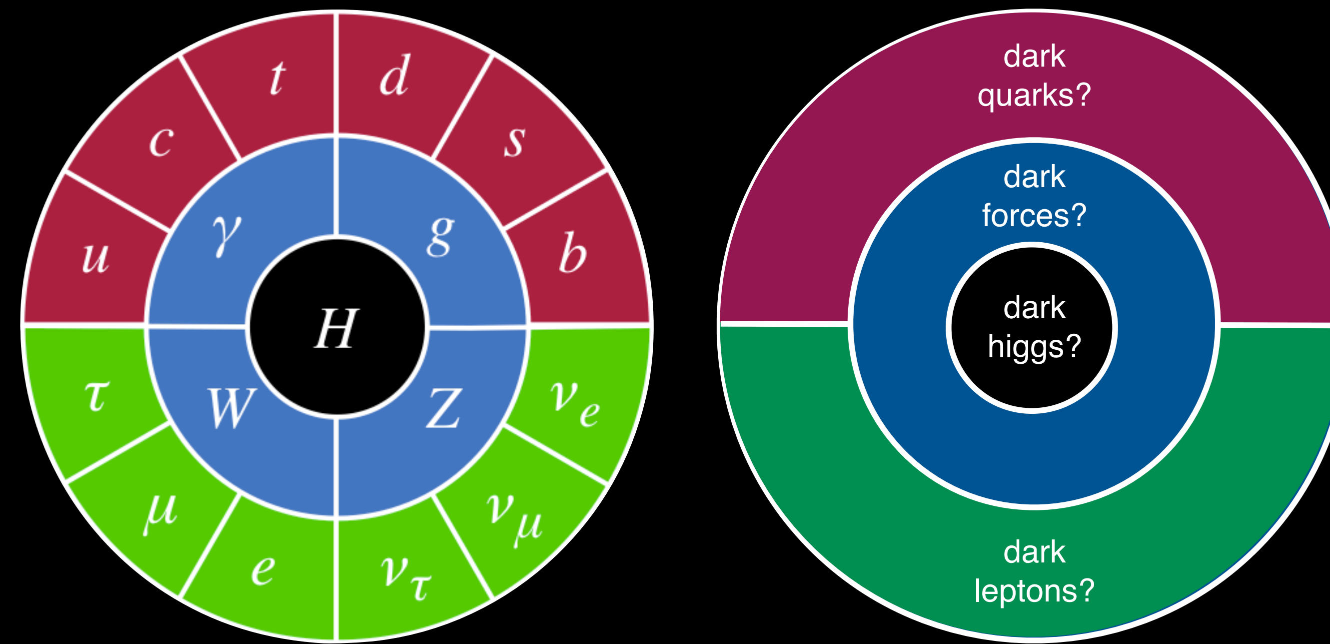
IPA

October 9, 2018

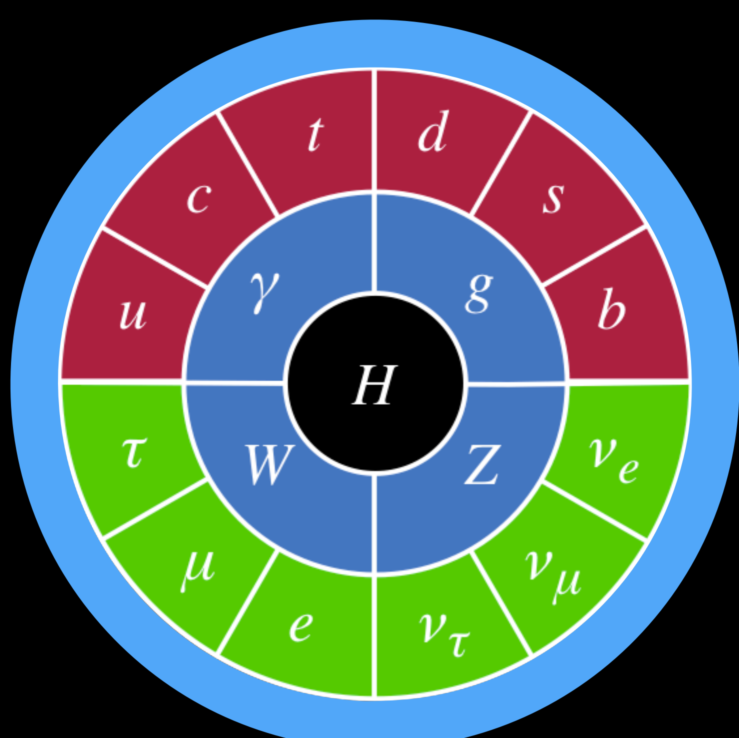
Dark Matter Paradigms



Hidden Sector(s)



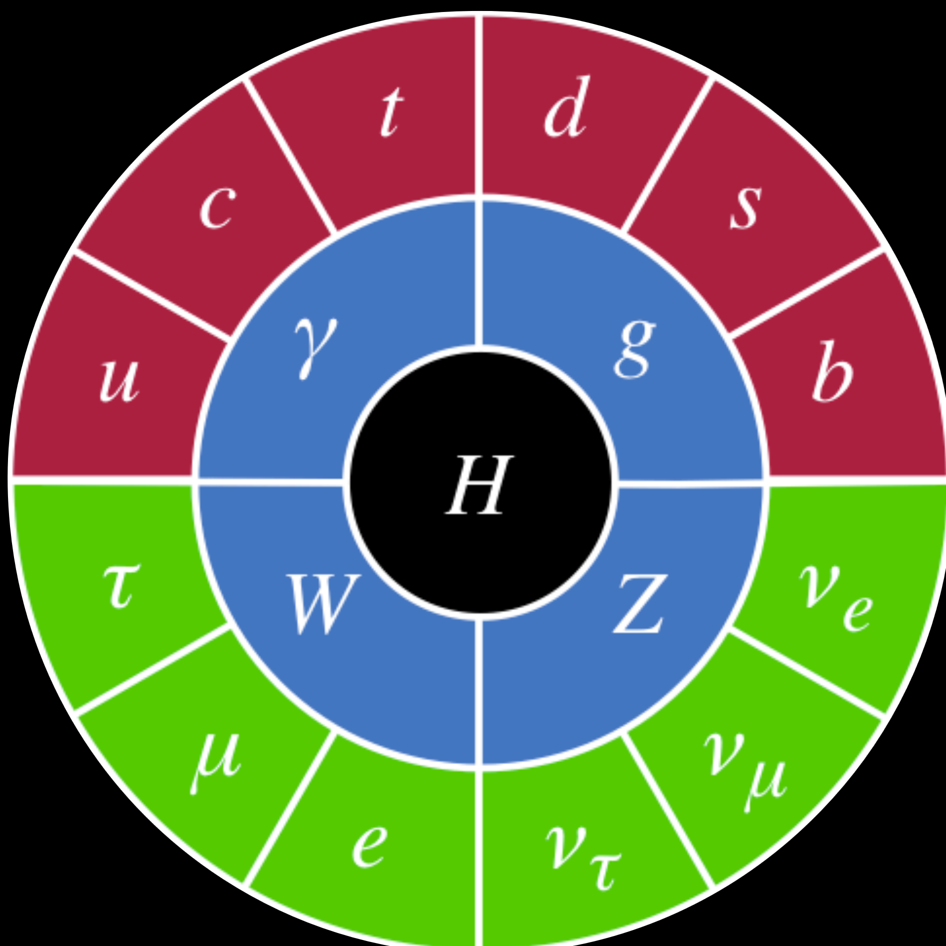
Minimal SM Extensions

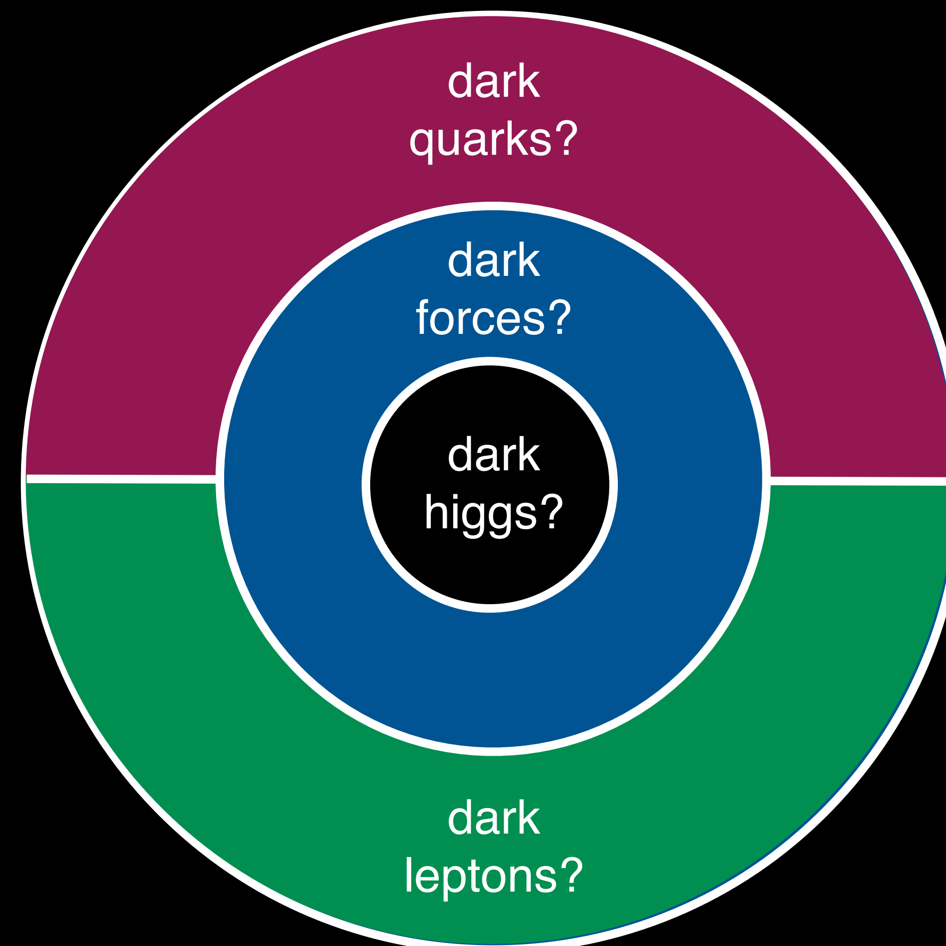


Primordial Black Holes

Hidden Sectors

What if the is no connection between the SM and dark sector up to the Planck scale?
(Hidden sectors are generic in string theory constructions.)

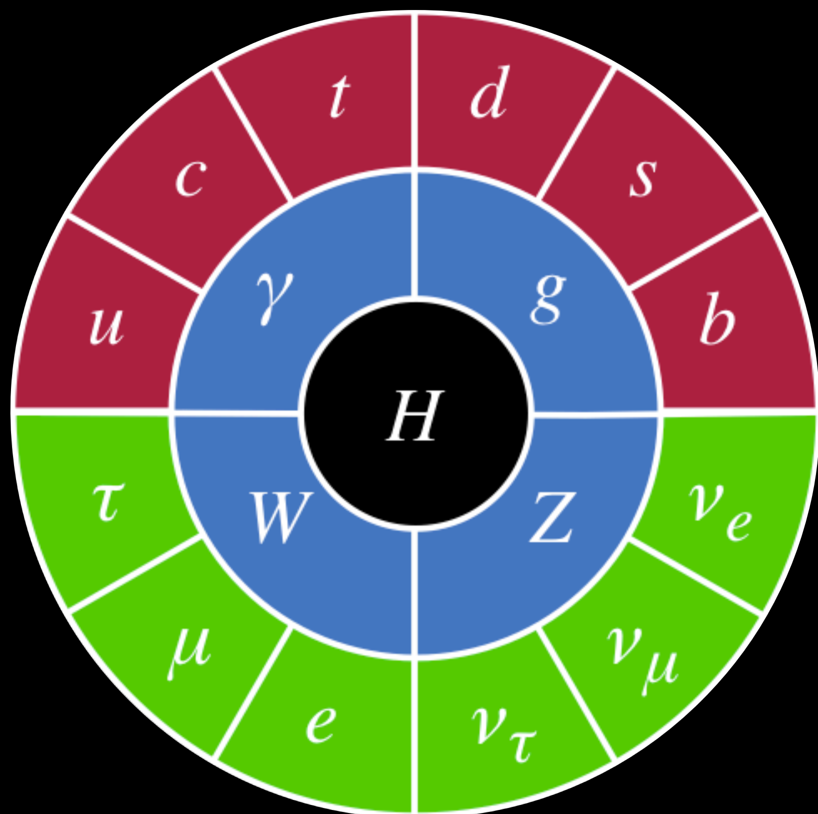


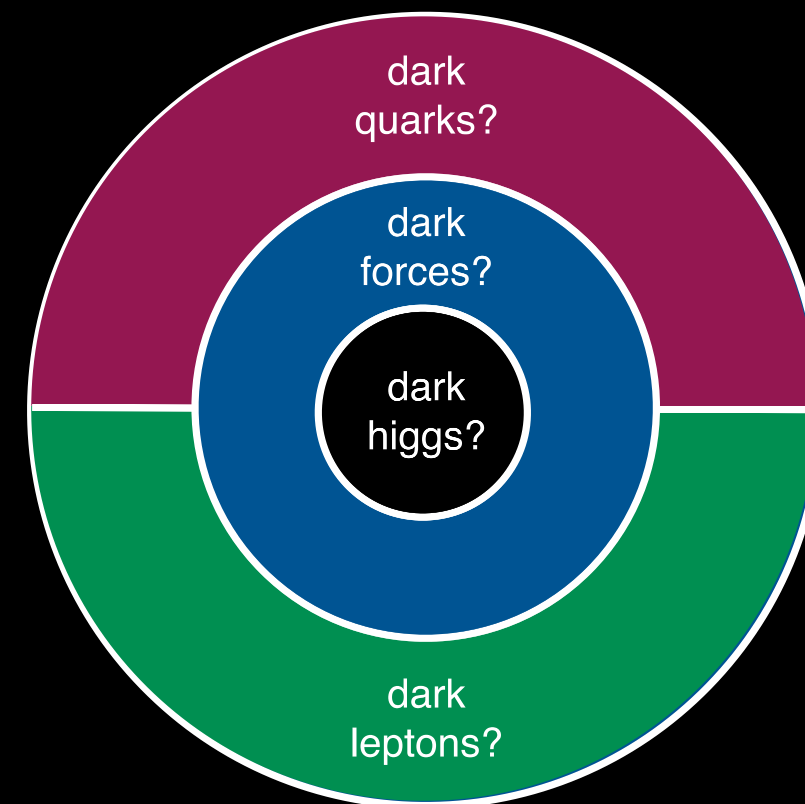


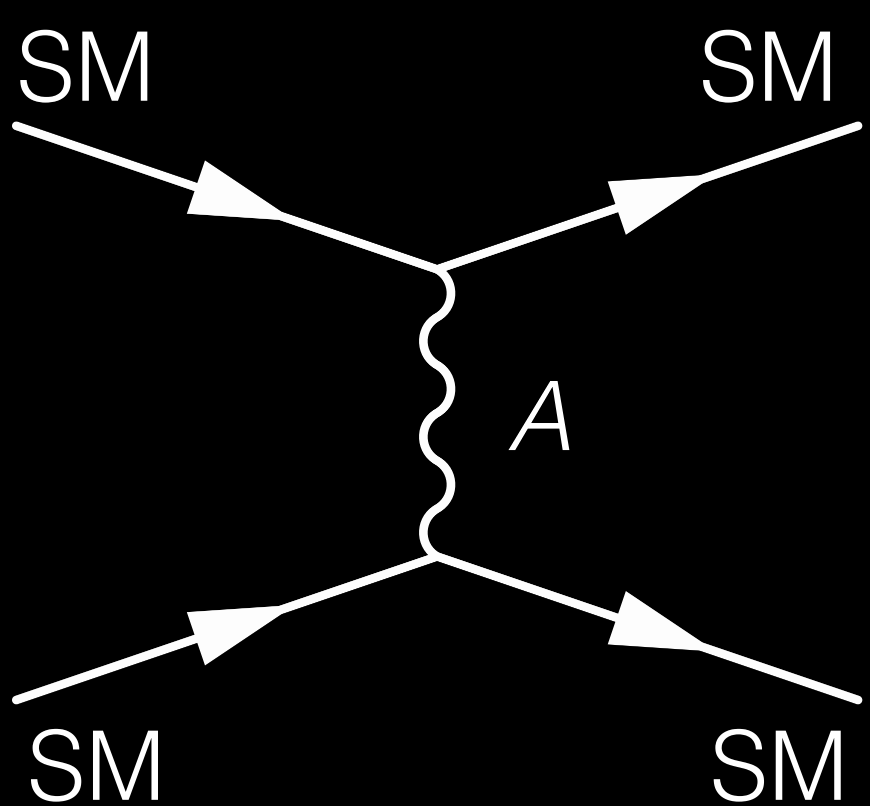
lightest DM particle could be
stable because it's (dark) charged

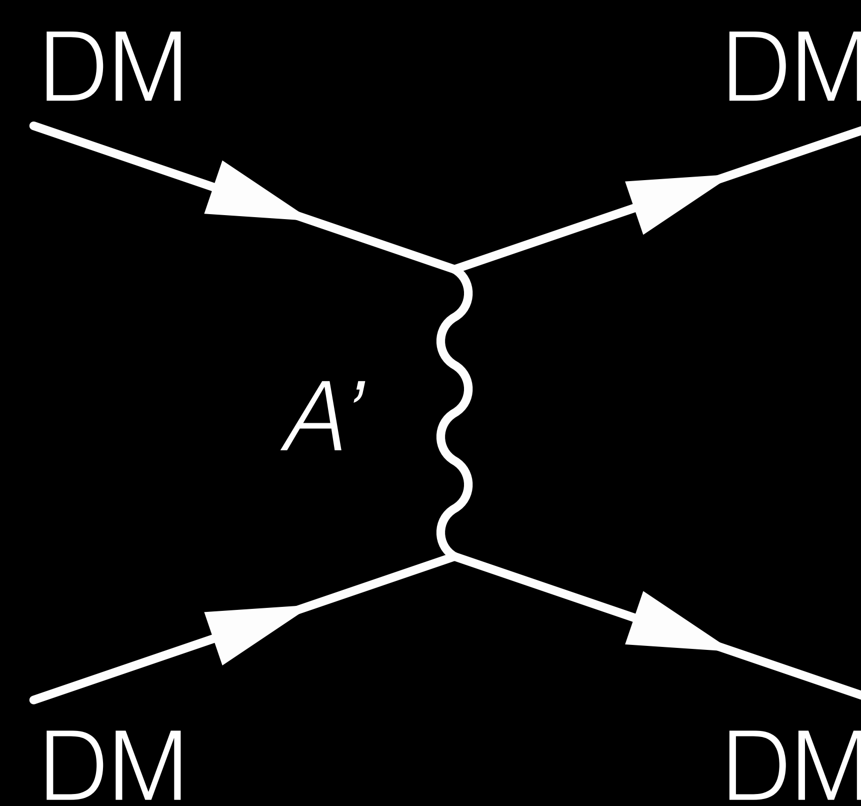
Quantum mechanics can generate portals between sectors, even if they do not interact classically. There are only 3 renormalizable options: the photon, Higgs, and neutrino portals. (The axion portal, while not renormalizable, is also a popular model.)

Dark Photons



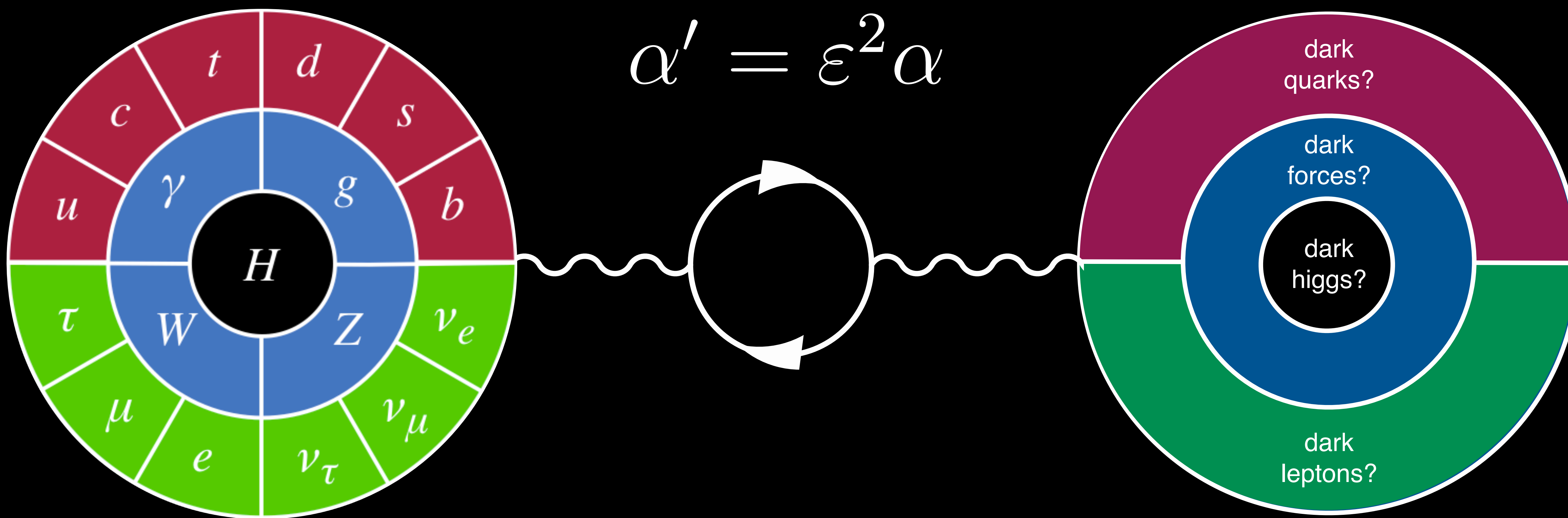


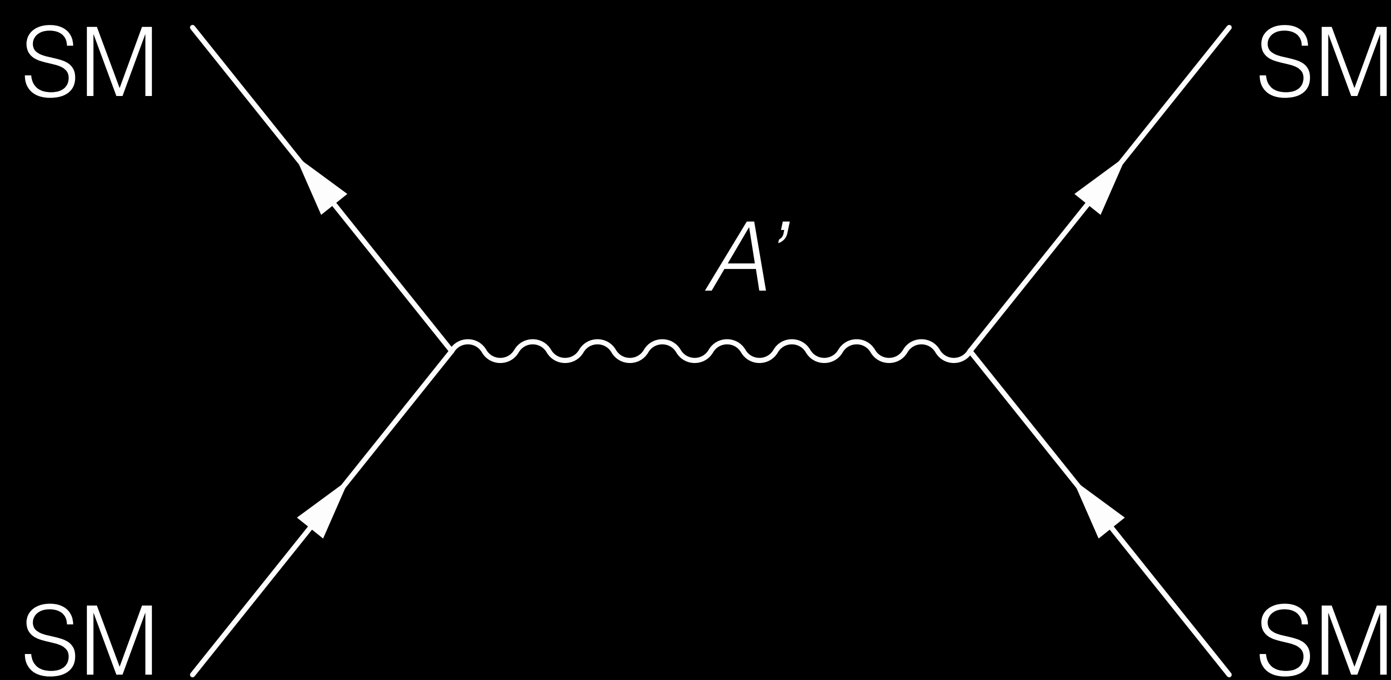




Dark Photons

$$\alpha' = \varepsilon^2 \alpha$$

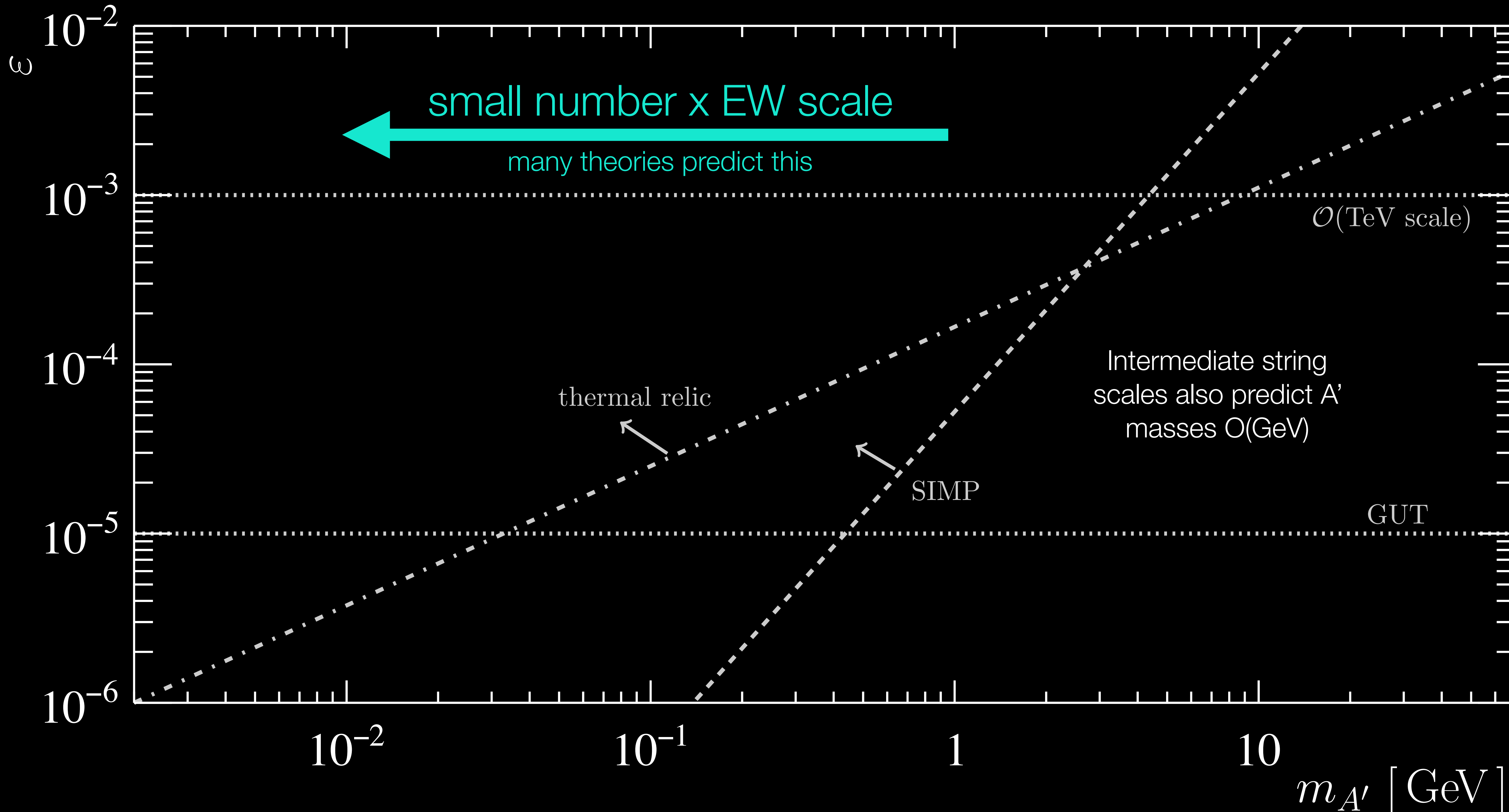




The A' couples to SM particles proportional to their electric charge.

Invisible A' Decays

If the A' is heavier than 2m(DM), then it will predominantly decay into DM final states.



Well defined thermal-relic targets in this case, since the DM annihilation cross section depends on the strength of the kinetic mixing.

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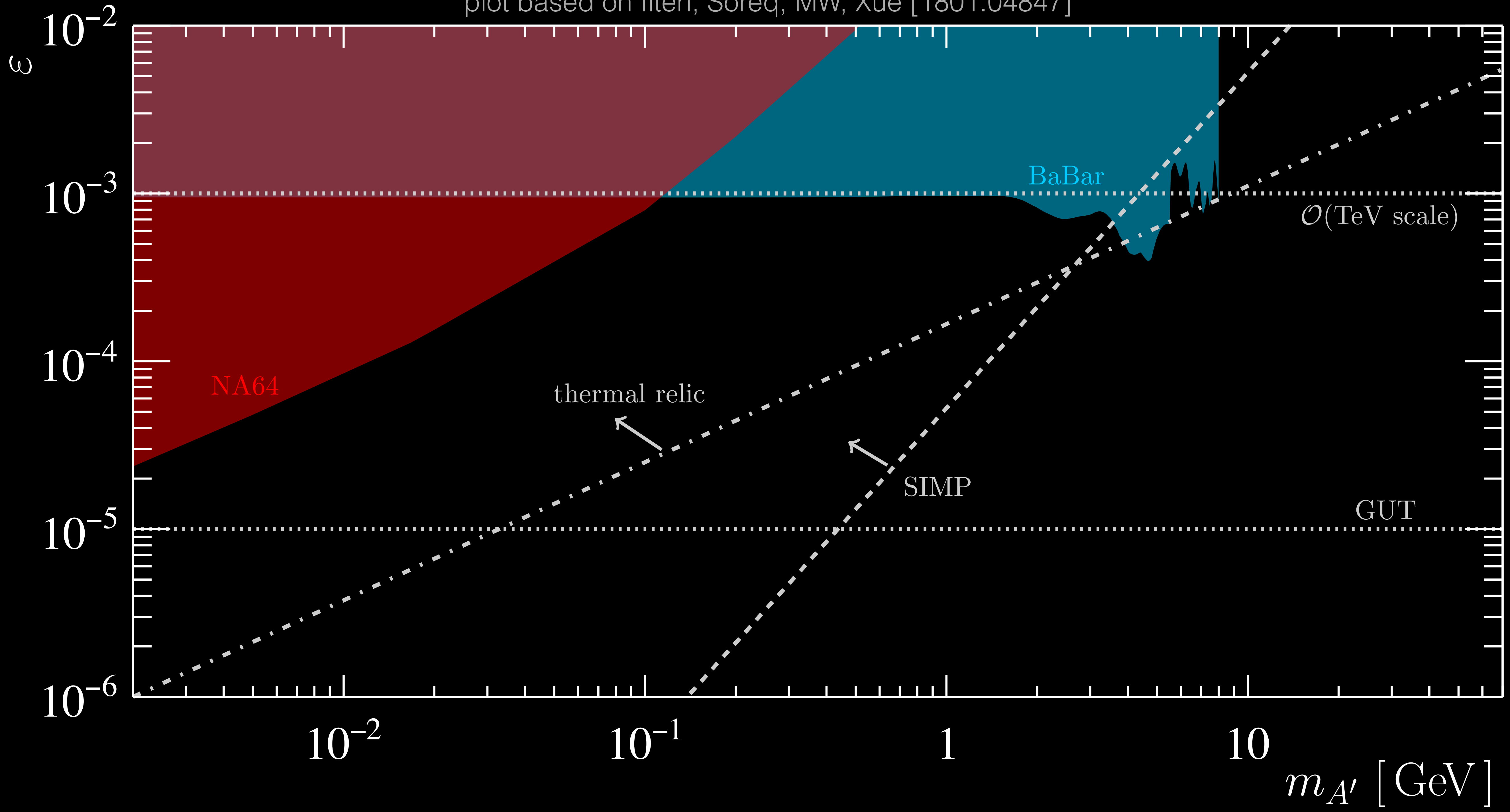
plot based on Ilten, Soreq, MW, Xue [1801.04847]



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Invisible A’ Decays

Near-future run at Belle-II can greatly expand the parameter-space coverage.

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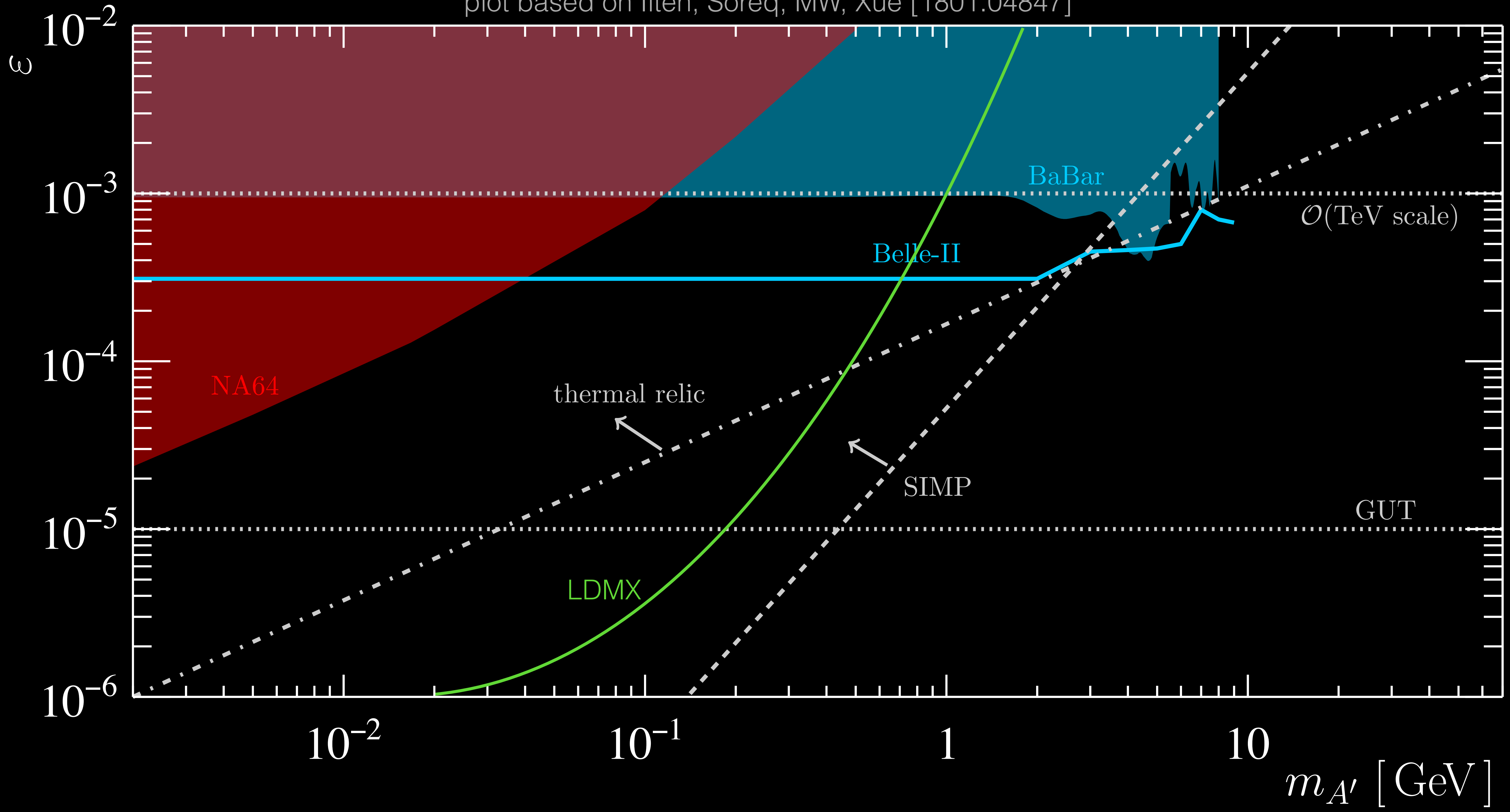

Including a future LDMX-type experiment covers most thermal-relic target space.

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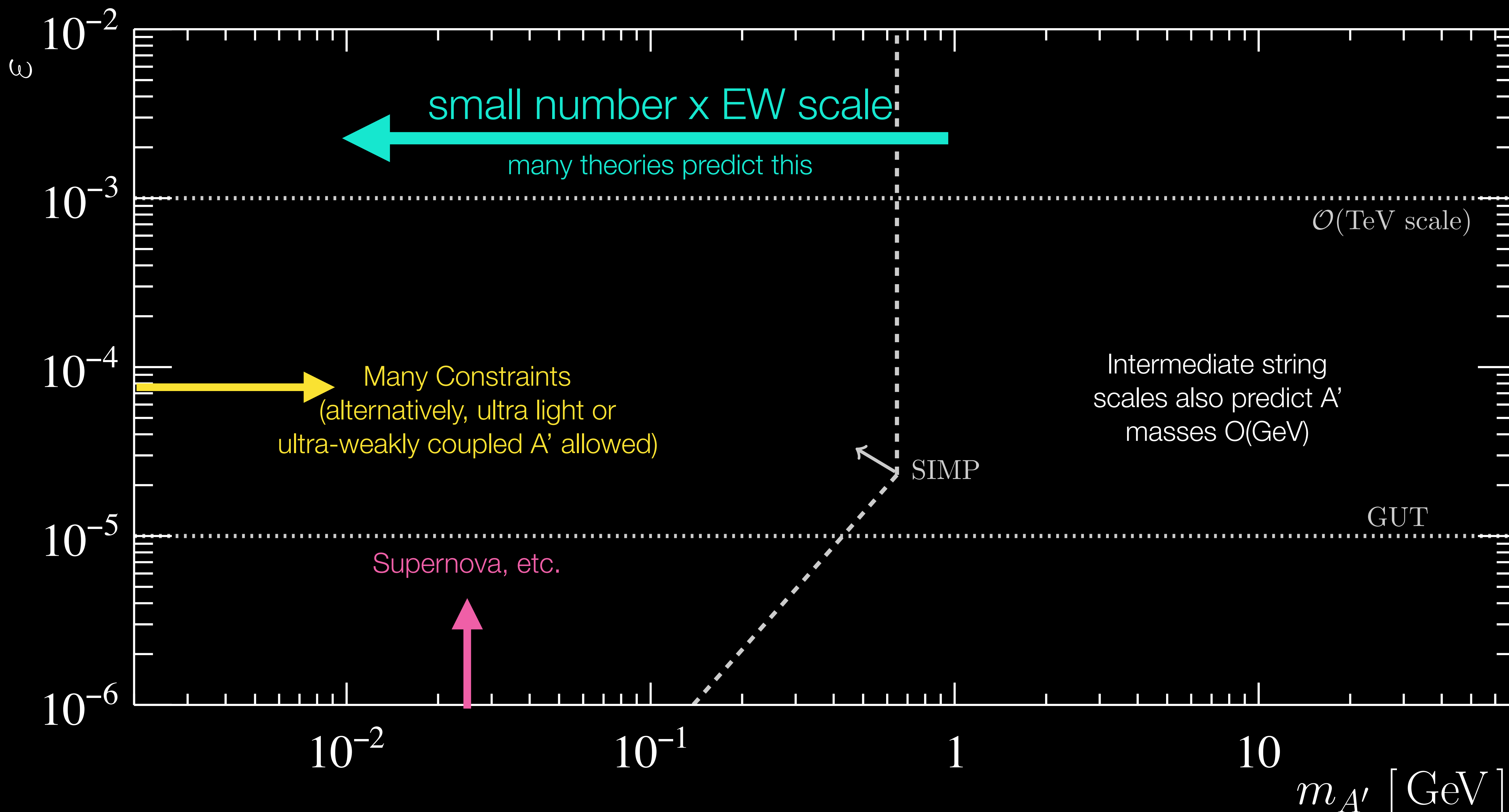

Well defined target range in epsilon (thermal DM requires $\varepsilon > 10^{-8}$); however, no obvious relic targets as DM is *secluded* for visible A' decays.

Thermal: see Evans, Gori, Shelton [1712.03974]; SIMP: see Choi et al [1707.01434]

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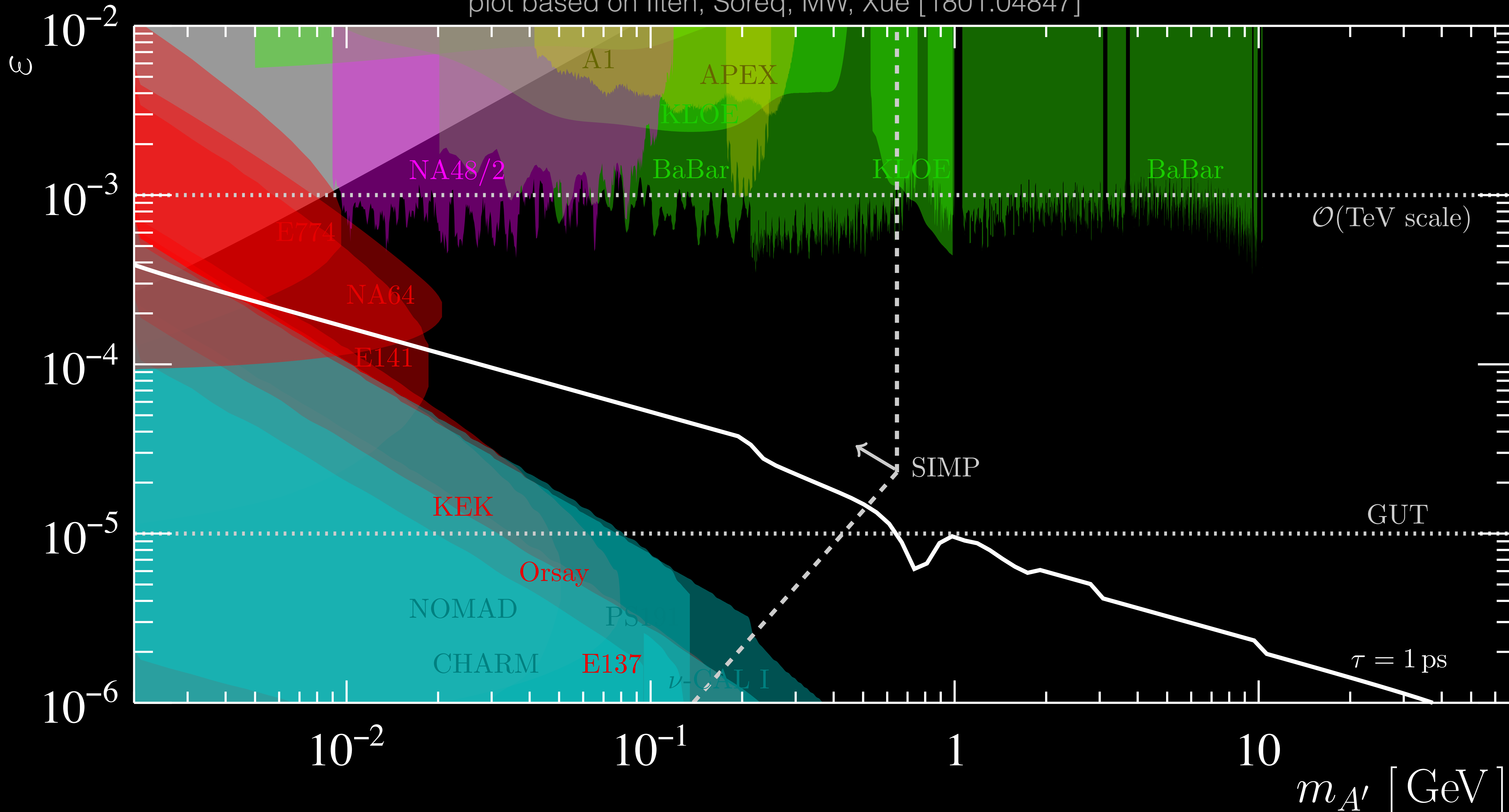

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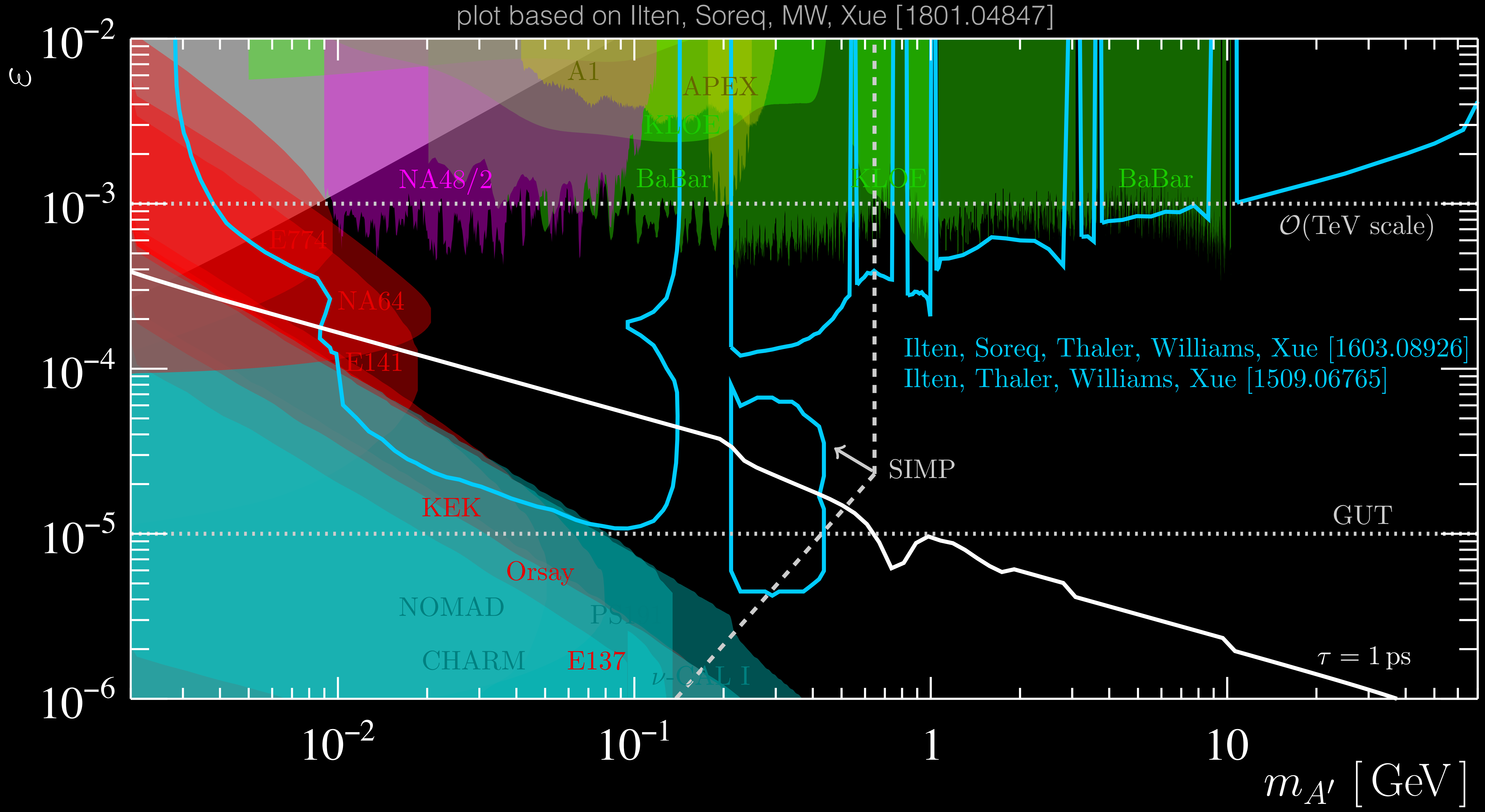
Visible A' Decays

Leverage LHCb's excellent τ resolution and move to triggerless readout in Run 3.

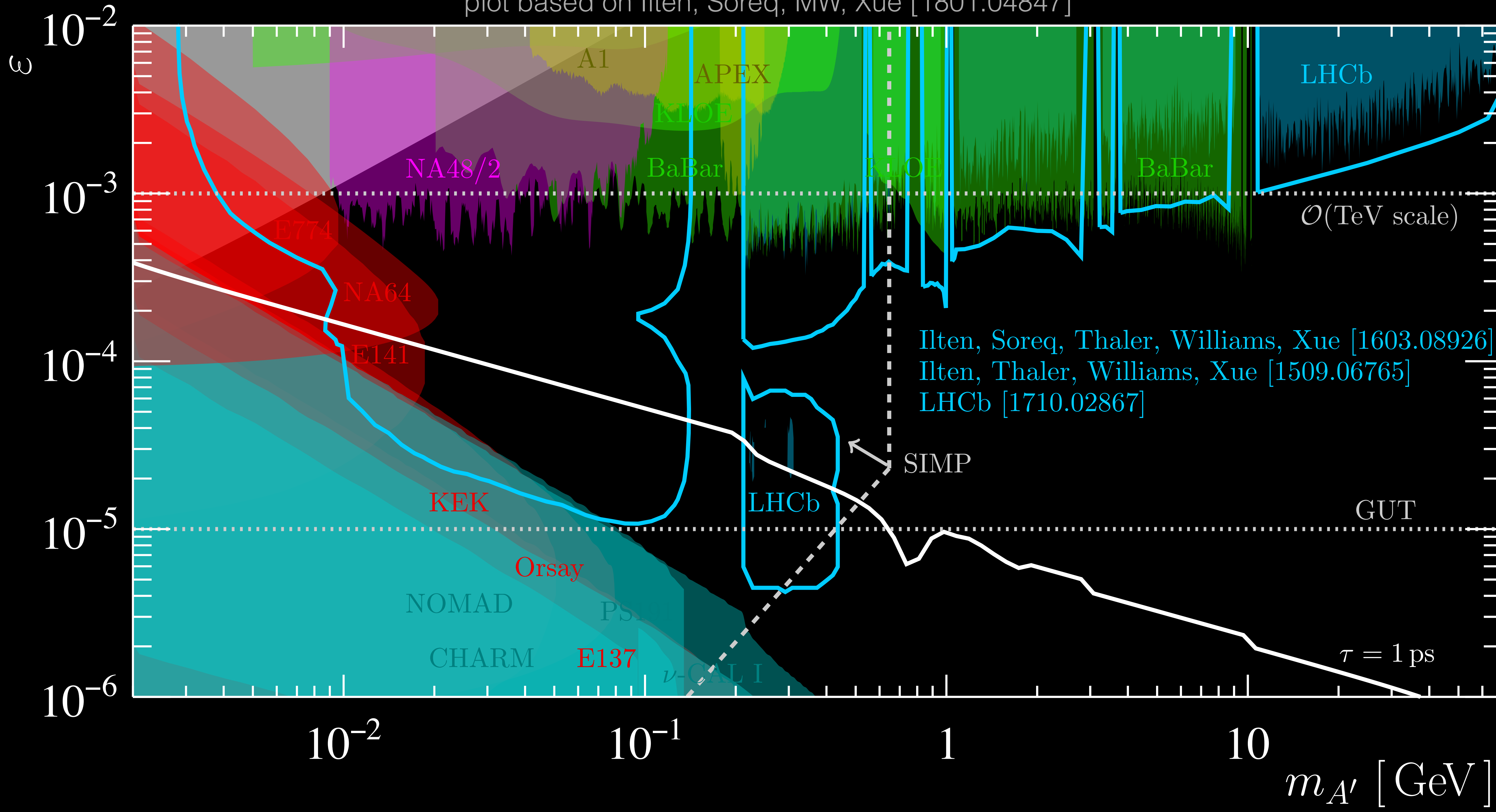


But why wait for Run 3? Triggers written in 2016 taking advantage of LHCb's move to real-time calibration and the introduction of a reduced-event-size data stream.

Visible A’ Decays

2016 results are consistent with our predictions rescaled to this sample. Expect much better sensitivity using the full Run 2 sample (and close to predictions using Run 3 data).

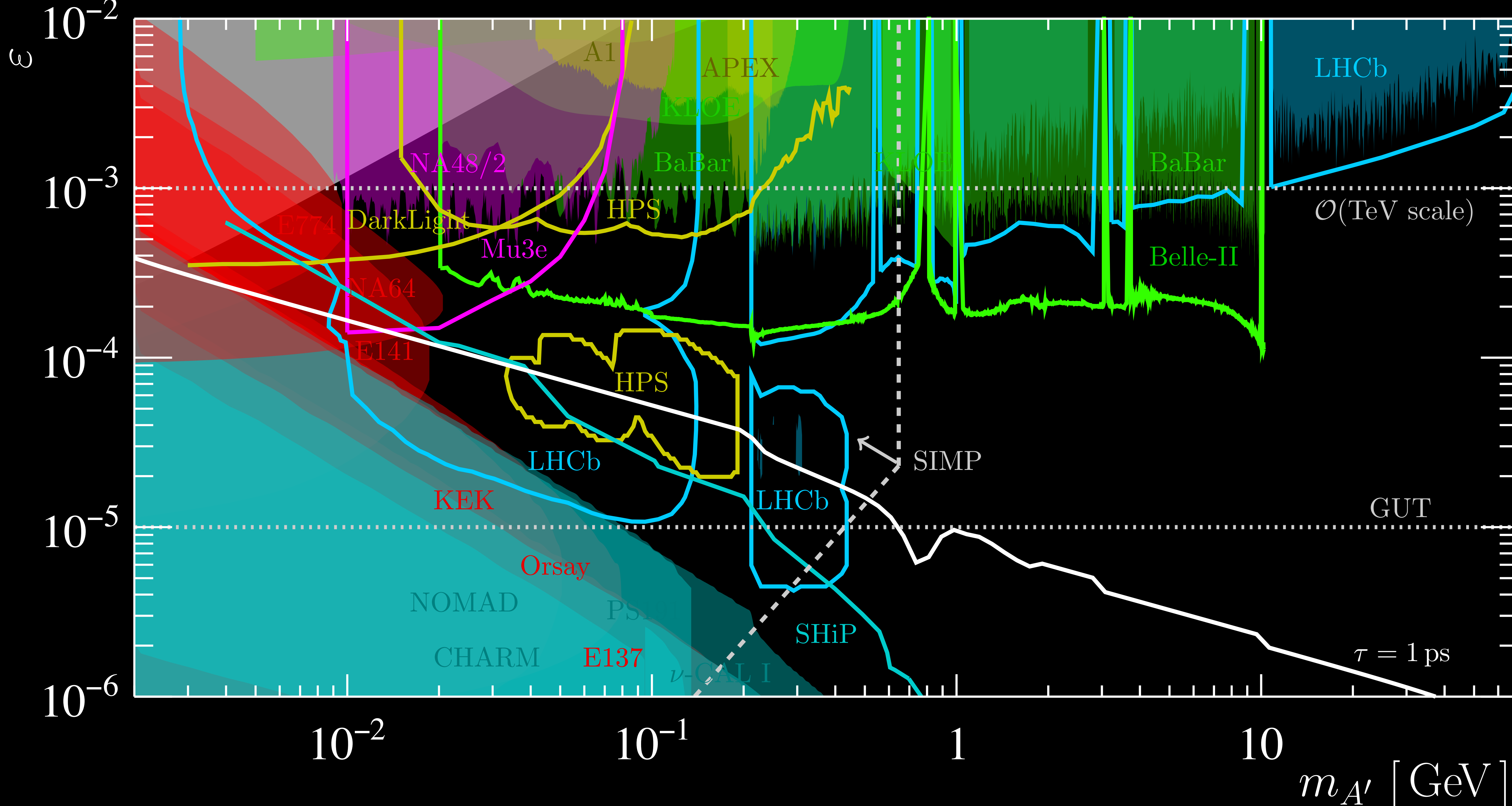
plot based on Ilten, Soreq, MW, Xue [1801.04847]



New triggers introduced in 2018 to look for e^+e^- decays. Also have triggers for non-standard decay topologies (e.g. SIMP Dalitz decays). Plan to publish results after Run 2 ends.

Visible A’ Decays

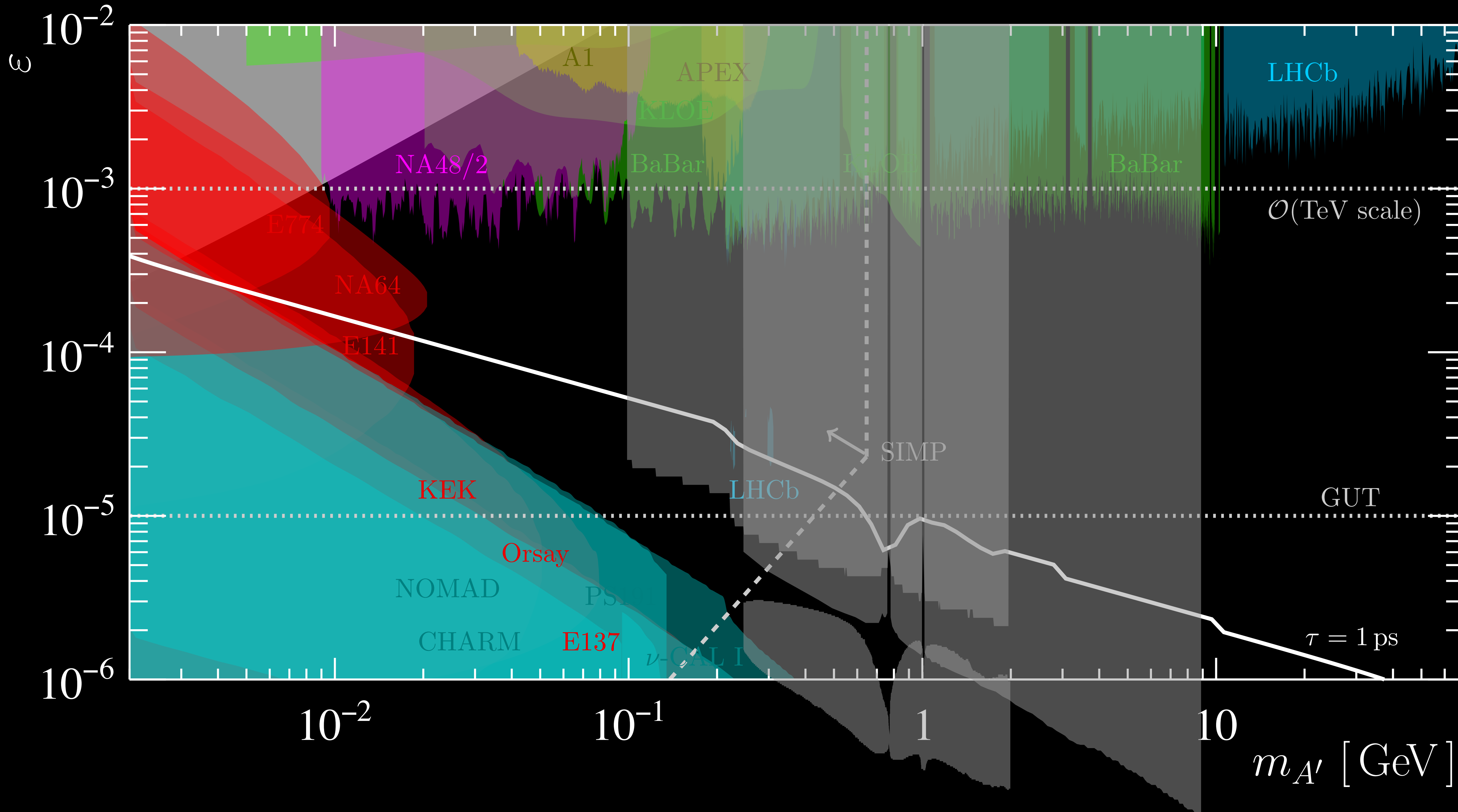
The majority of the most compelling parameter space can be covered in the next ~5 years.



Since LHCb can likely explore all space accessible to other experiments below 0.5 GeV, there is a chance for confirmation of any discovery by multiple experiments.

Visible A' Decays

Dark photon sensitivity can be very different in non-minimal models, e.g., if dark-sector fermions also couple to our Higgs boson allowing $H \to f_D f_D \to A'A'+X$ decays to occur.



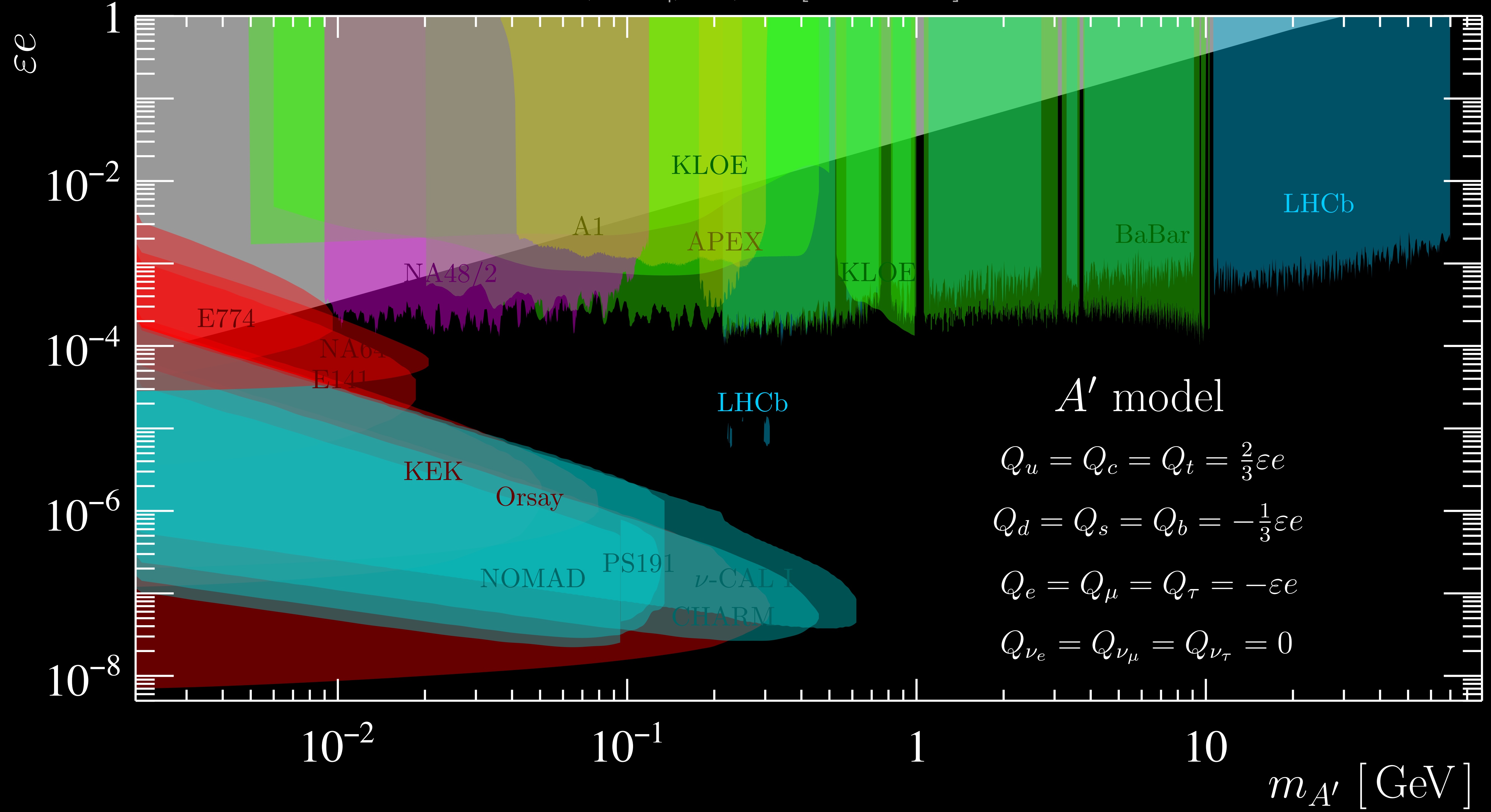
ATLAS/CMS limits shown here assume $B(H \to f_D f_D)$=10%.

ATLAS [1511.05542] (see also 1505.07645,CONF-2016-042), CMS [PAS-HIG-16-035].

Serendipity in A' Searches

Using e+e- data (and SU(3) symmetry) we developed a data-driven method for determining the hadronic decay widths and automatically recasting A' searches for any vector model.

Ilten, Soreq, MW, Xue [1801.04847]



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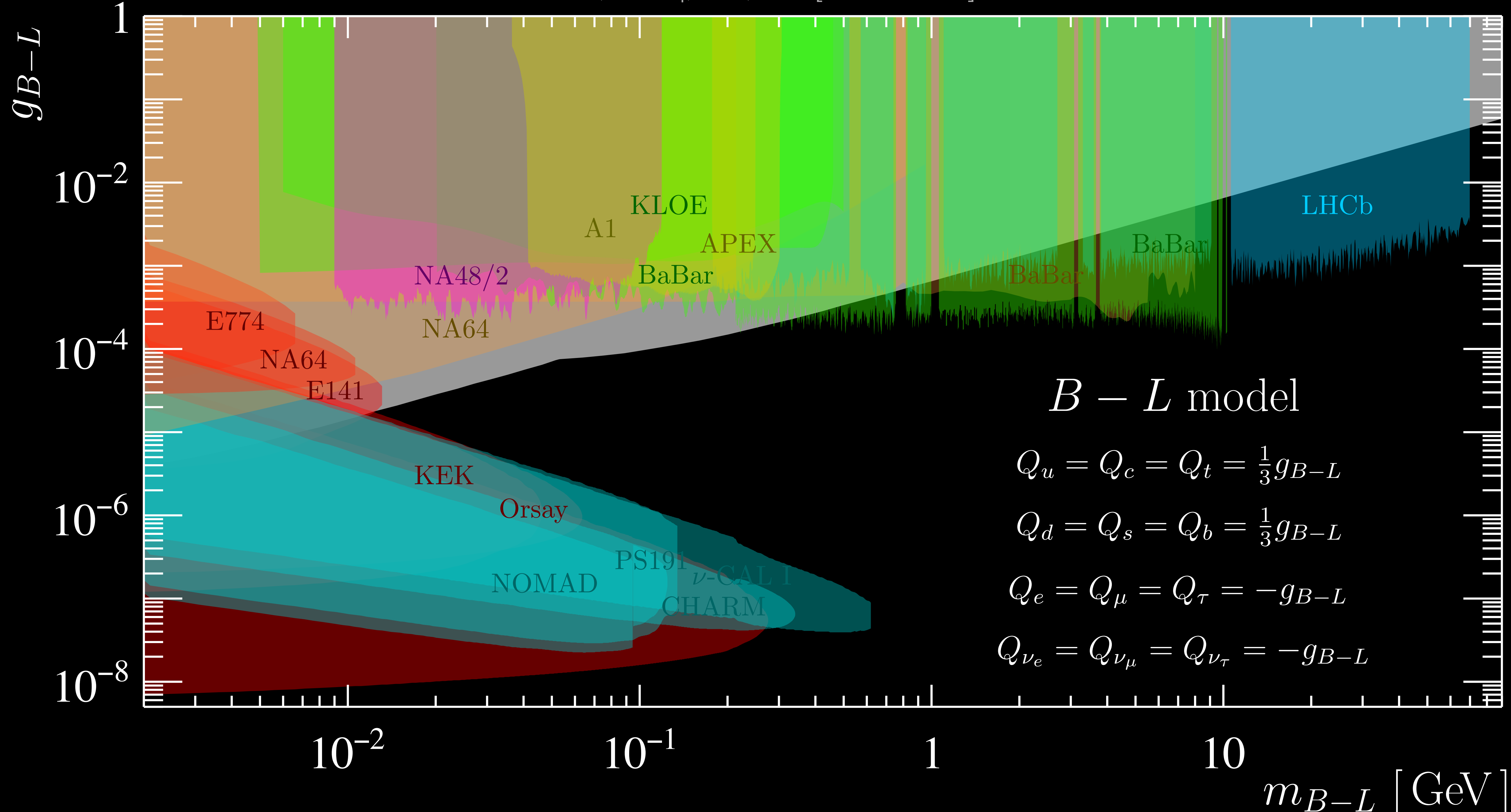

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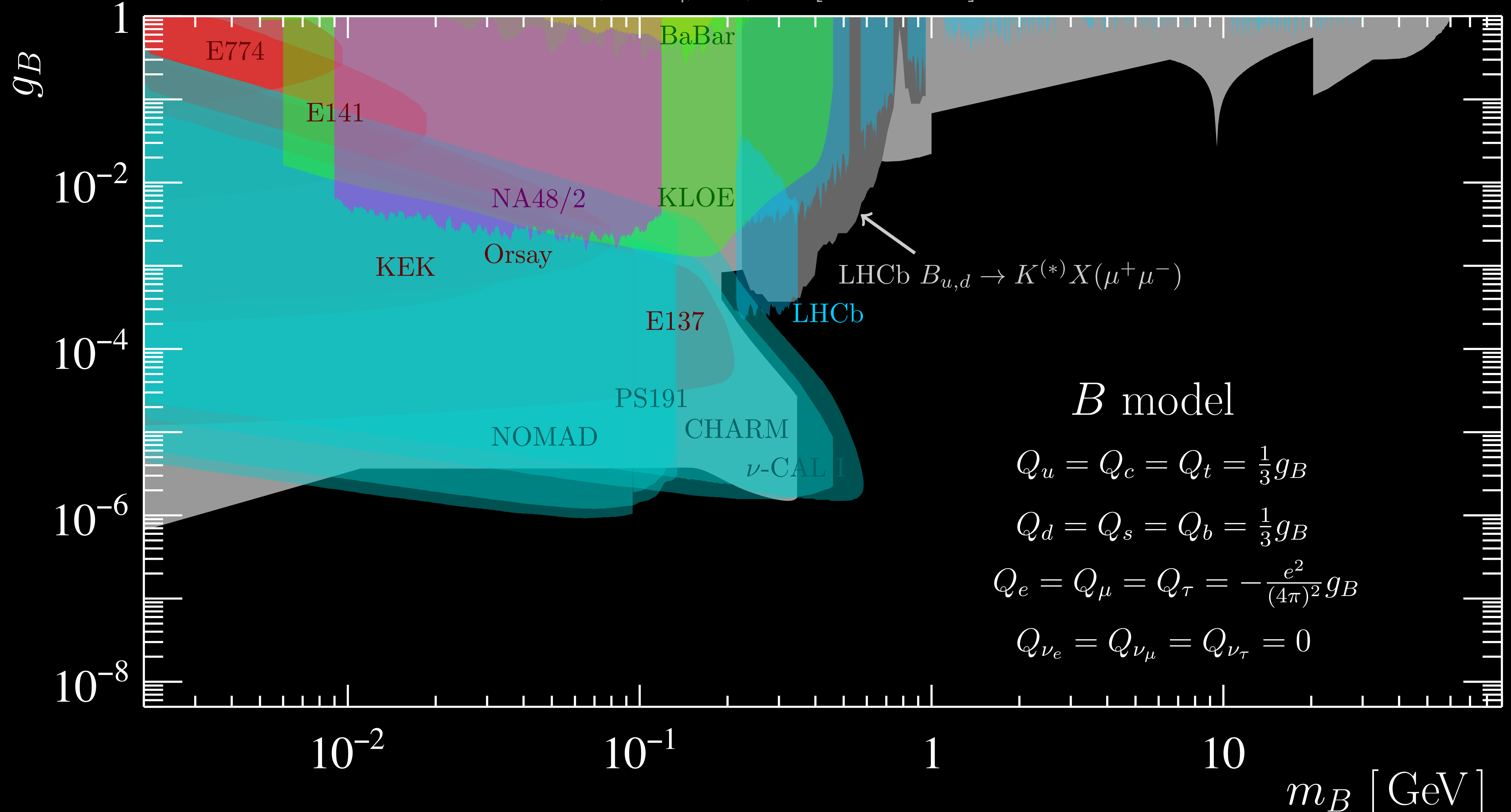

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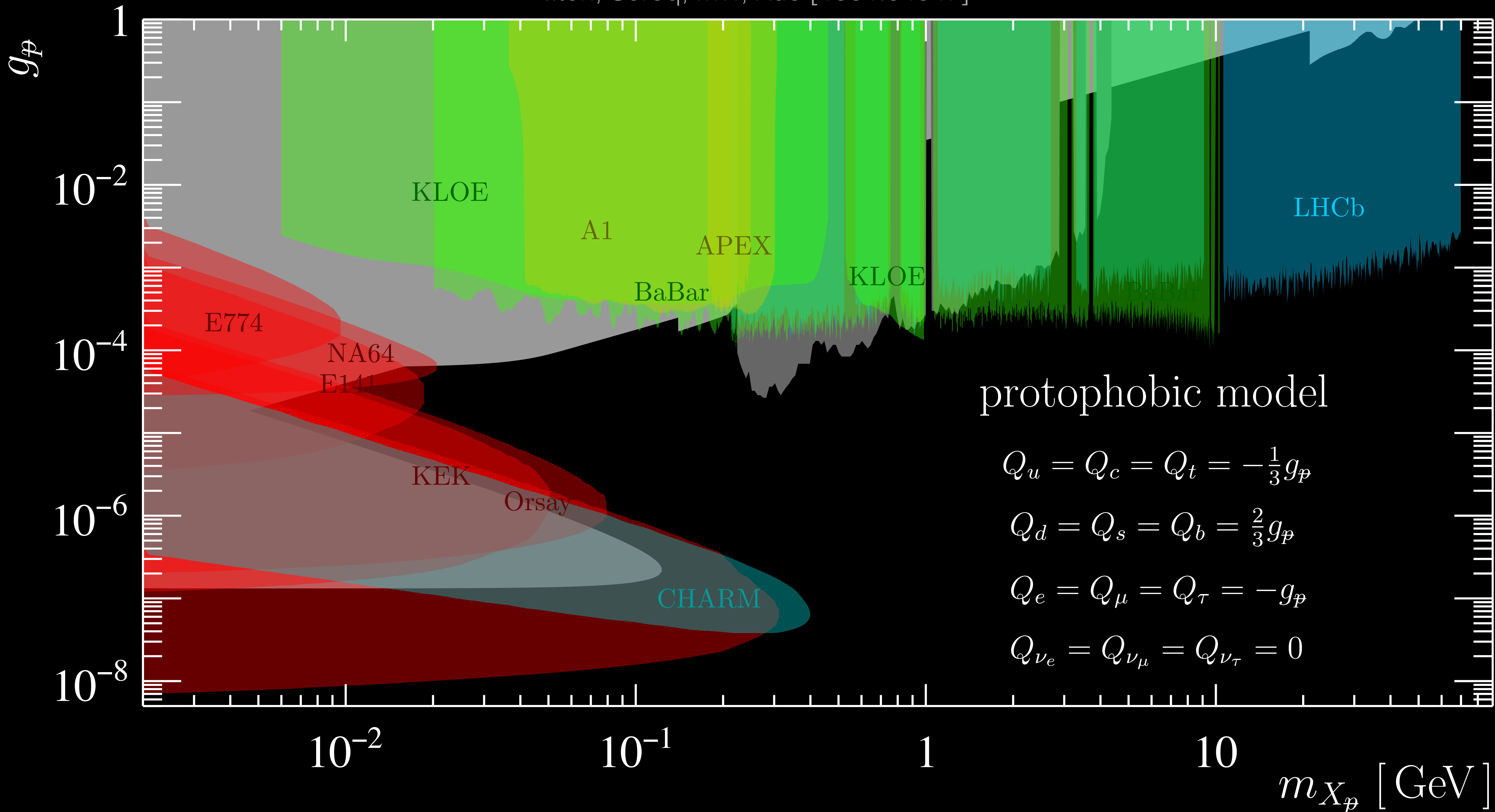

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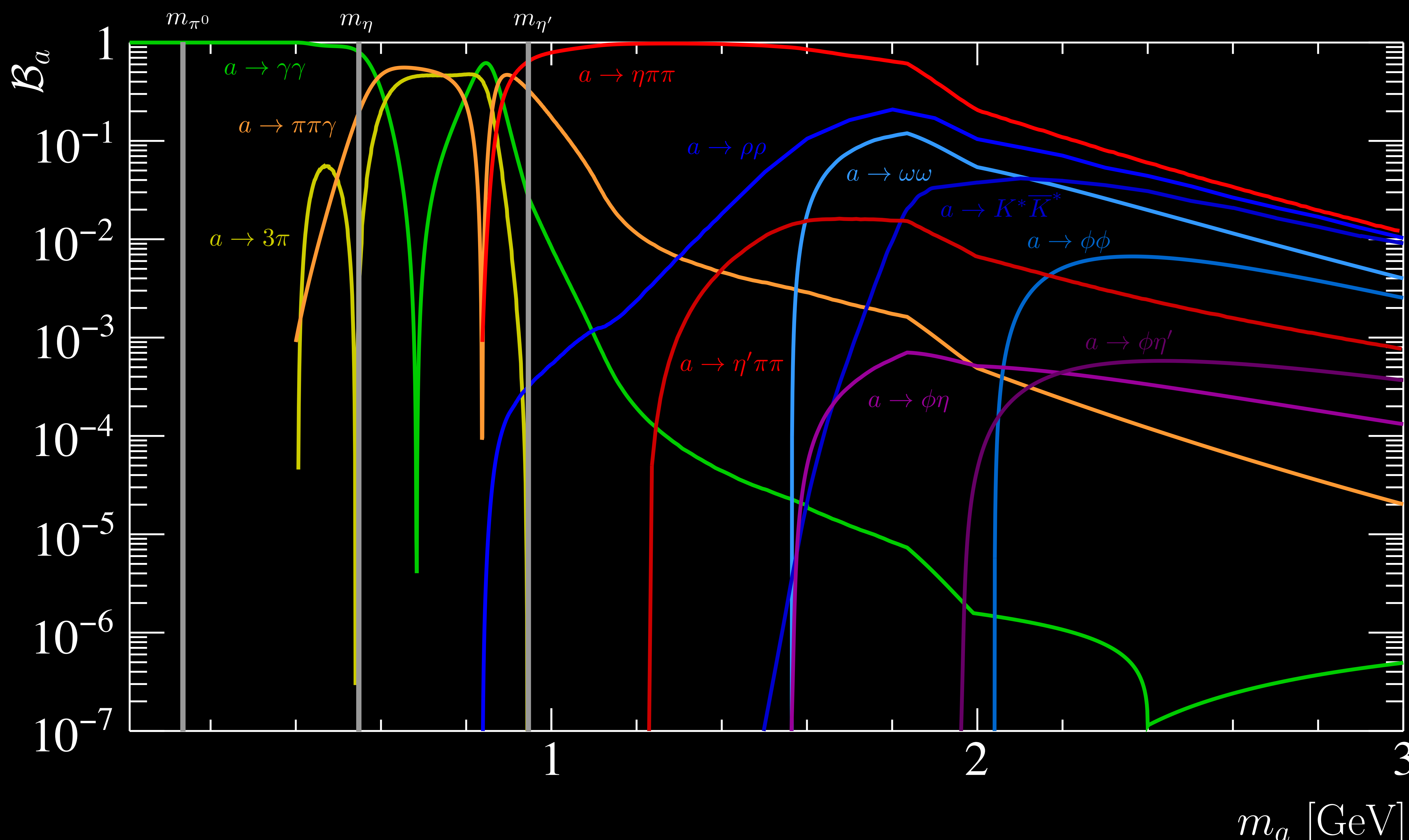
Data-Driven ALP Hadronic Widths

While more difficult, it's also possible to produce data-driven predictions for hadronic decays of axion-like particles. [Aloni, Soreq, MW, to appear soon]



In a related project, we have developed a data-driven way to cancel nuclear uncertainties in Primakoff ALP production and predict some old JLab data on tape has world-leading sensitivity to the ALP-photon coupling in the O(100 MeV) region (see backups).

Summary

- Dark photons are a compelling hidden-sector scenario. Dedicated worldwide effort underway to search for both visible and invisible dark photons.

- Existing limits fail to probe most of the parameter space expected if the mixing is generated at the 1-loop or 2-loop level (up to the GUT scale).

- Experimental searches to be carried out over the next 5-10 years can explore most of this few-loop parameter space (much of it potentially double covered).

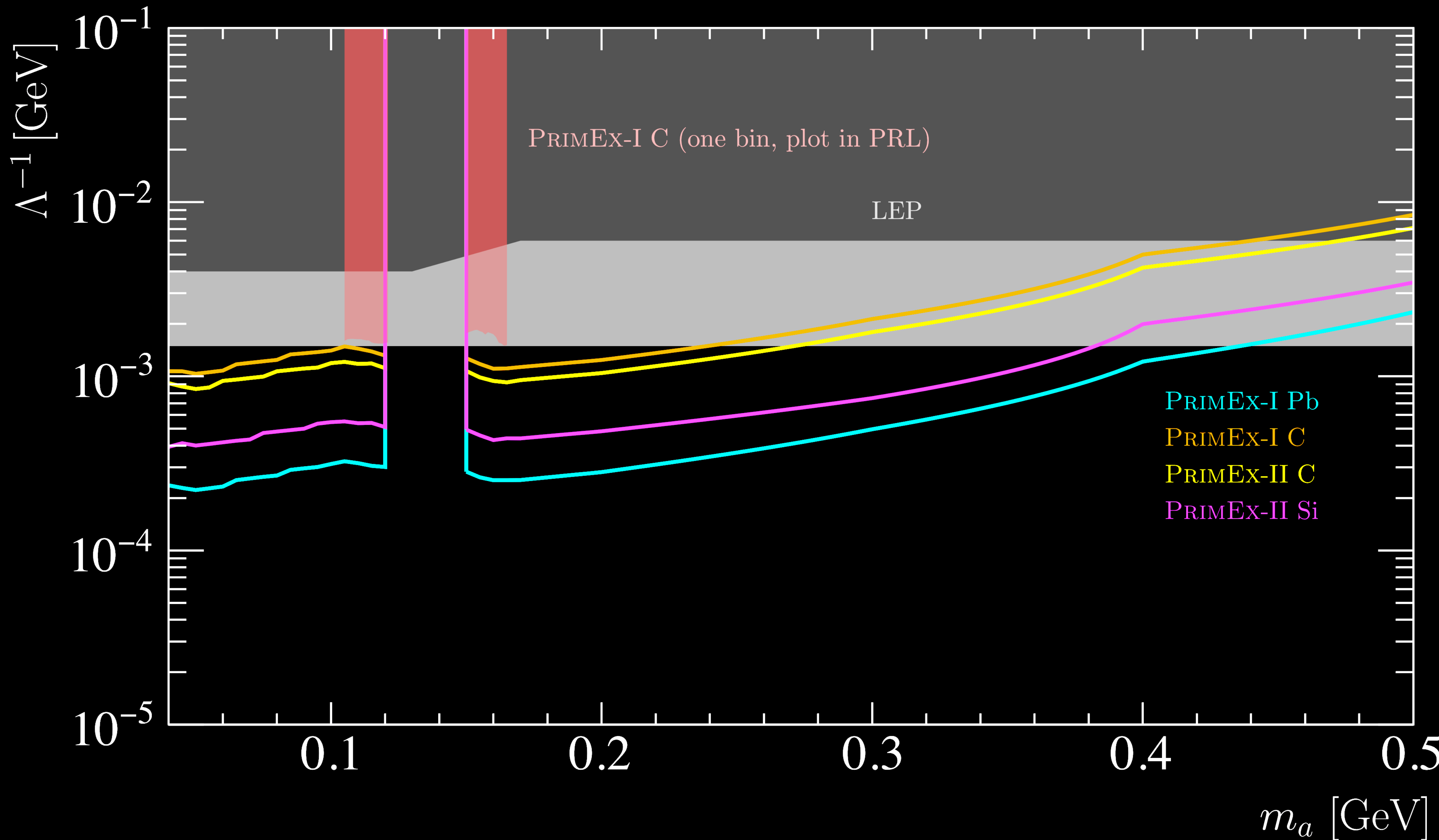
- Searches for dark photons have serendipitous discovery potential for other vector models. Different searches map to various models in different ways. It's good to explore as many production mechanisms/decay modes as possible.

- Looking forward to an historic discovery soon!

ALP-Photon Coupling

We have developed a data-driven method for canceling out nuclear uncertainties in ALP Primakoff production. One application is the PrimEx experiment (run over a decade ago), which will provide world-leading sensitivity. (PrimEx published the pi0 mass speak in one angular bin for C12. Recasting that plot into a limit is competitive itself.)

Aloni, Fanelli, Soreq, MW [to appear soon]



Ultra-Light A'

Ultra-light A' ruled out unless the mixing strength is tiny.

Jaeckel [1303.1821]