The A′ Experiment (APEX)

Search for new forces at JLab

Welcome + APEX in Global Context

Rouven Essig (Stony Brook)
Philip Schuster (Perimeter)
Natalia Toro (Perimeter)
Bogdan Wojtsekhowski (JLab)
on behalf of APEX

APEX Collaboration Meeting, JLab
4/22/2014

Outline

- Why are we here?
- Physics overview & motivation
- APEX's unique role in global dark photon search

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- review APEX's current status, preparations, outstanding tasks
- while a small experiment, we need active involvement from collaborators to prepare for full run (possibly as early as 2016)
- update organizational structure and begin to identify point-persons for upcoming roles
- formalize and vote on collaboration rules (important for full run)

Agenda: April 22

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- 8:50 Welcome, APEX in Global Context (Essig)
- 9:15 JLab update (McKeown)
- 9:40 Update on HPS (Szumila-Vance)
- 10:10 APEX Goals and Strategy (Toro)
- 11:00 Hall A update (Keppel)
- 11:25 APEX Status: Big Picture (Wojtsekhowski)
- 11:55 Measuring charge asymmetry (Ron)

Blue: global picture
Gold: JLab, Hall A, HPS update
Green: details about an APEX subsystem
Purple: future/other physics w/ APEX

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- 1:30 HRS DAQ Rate Capability (Abrahamyan)
- 1:55 Software for high-rate VDC analysis (Riordan)
- 2:20 HRS Preparations (Allada)
- **3pm Colloquium: New Forces Beneath the Weak Scale (Schuster)**
- 4:30 Septa (Wojtsekhowski)
- 4:55 HRS Optics in the APEX Test Run (Huang)
- 5:20 A New Tool for Optics: SciFi (Markowitz)
- **7:00pm Group Dinner (Bonefish Grill)**

Agenda: April 23

- 9:20 The APEX target (Oriunno)
- 9:40 Outstanding Tasks for APEX Target (Schuster)
- *9:45 Collaboration business -- identify point persons, discuss bylaws, theses & publications, funding & manpower (moderated by Essig and Schuster)*
- 10:50 Radiation study update (Degtiarenko)
- 11:15 Remaining beam line items and vacuum chamber (Wojtsekhowski)
- 11:40 Bump-hunt analysis (Beacham)
- 12:05 Future APEX (Toro)
- 12:30 Concluding talk (Schuster)

Please sign up for Group Dinner

Bonefish Grill, Tuesday, 7pm

Group photo

TBA

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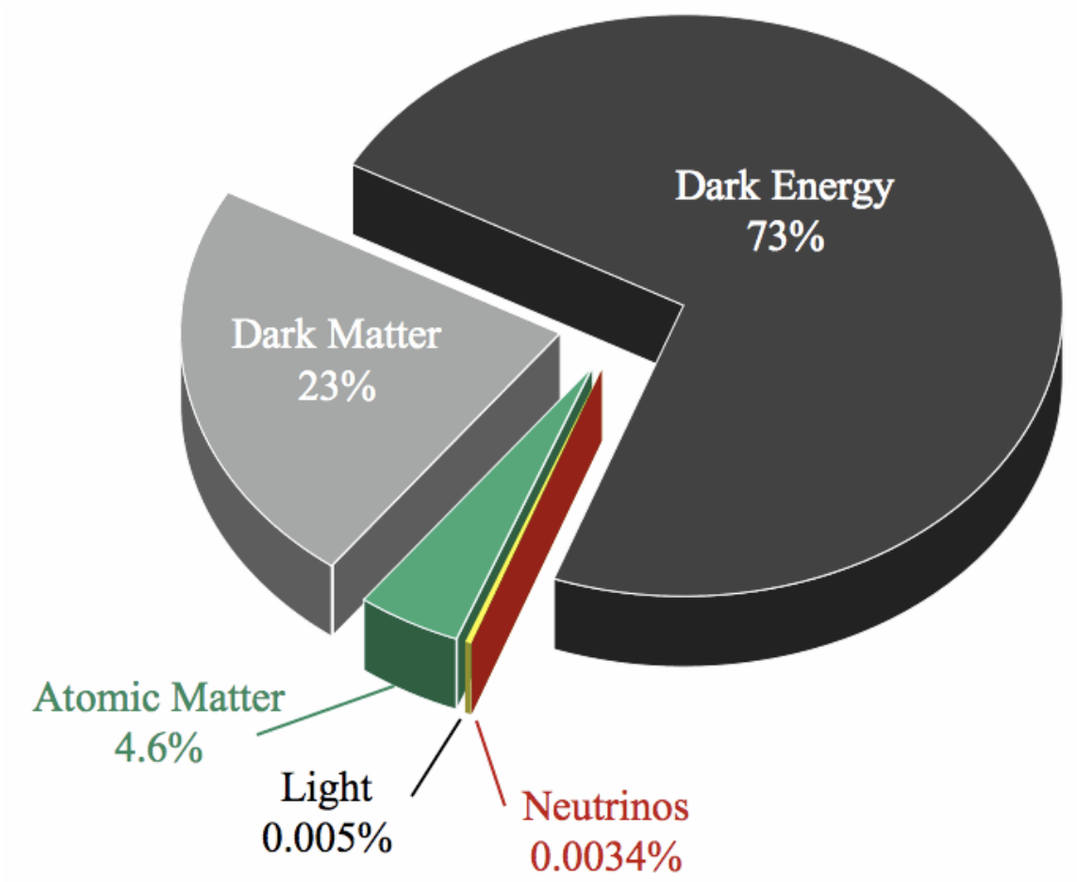
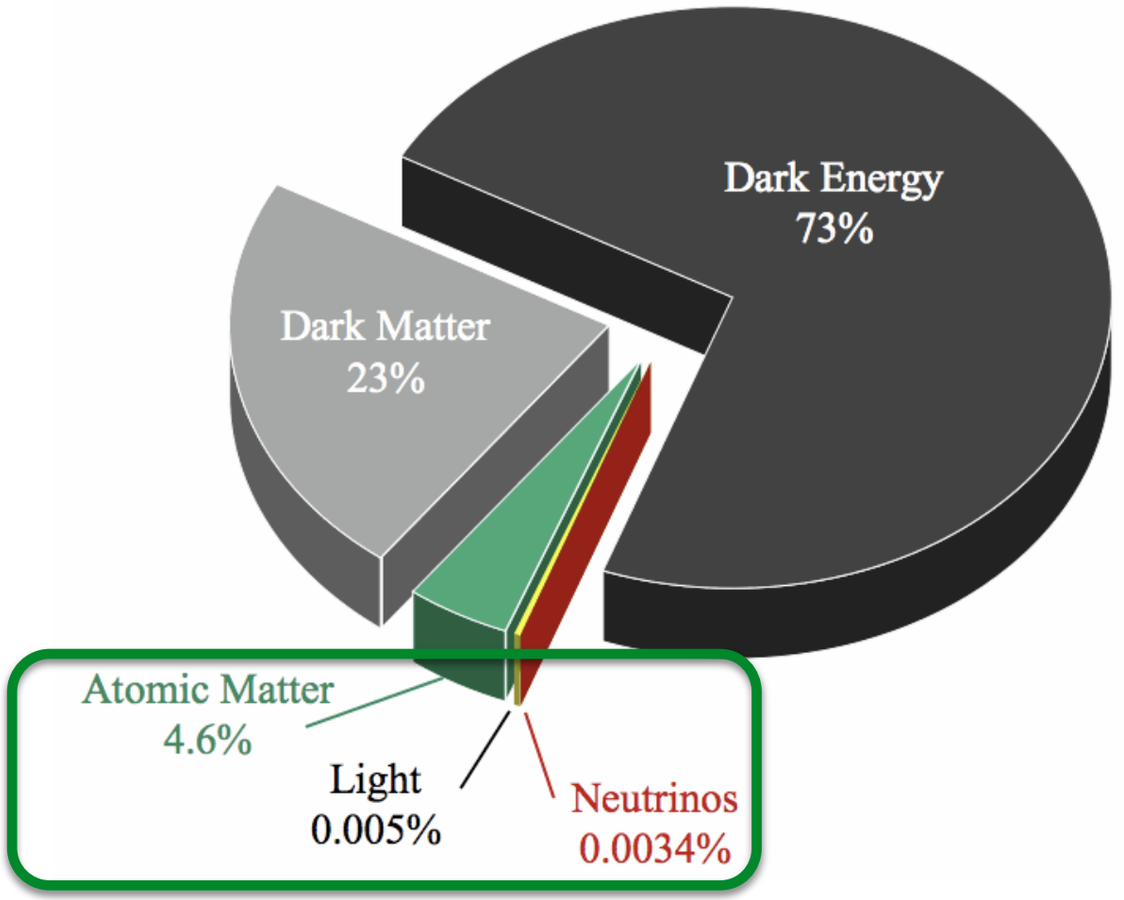
(see Philip's colloquium today for more details)

Physics Beyond the Standard Model



Physics Beyond the Standard Model

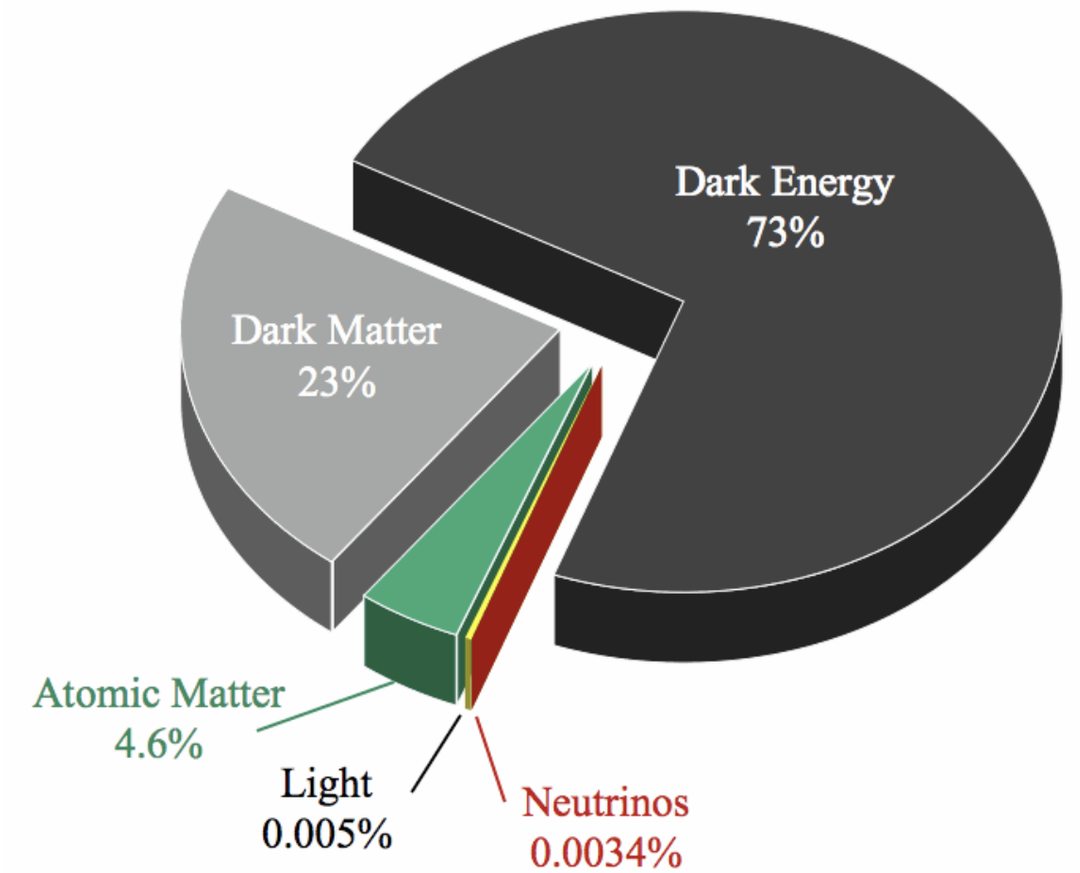
SM only describes this →



Physics Beyond the Standard Model

Dark Matter?

SM only describes this →



Physics Beyond the Standard Model

Dark Matter?

Dark Energy?

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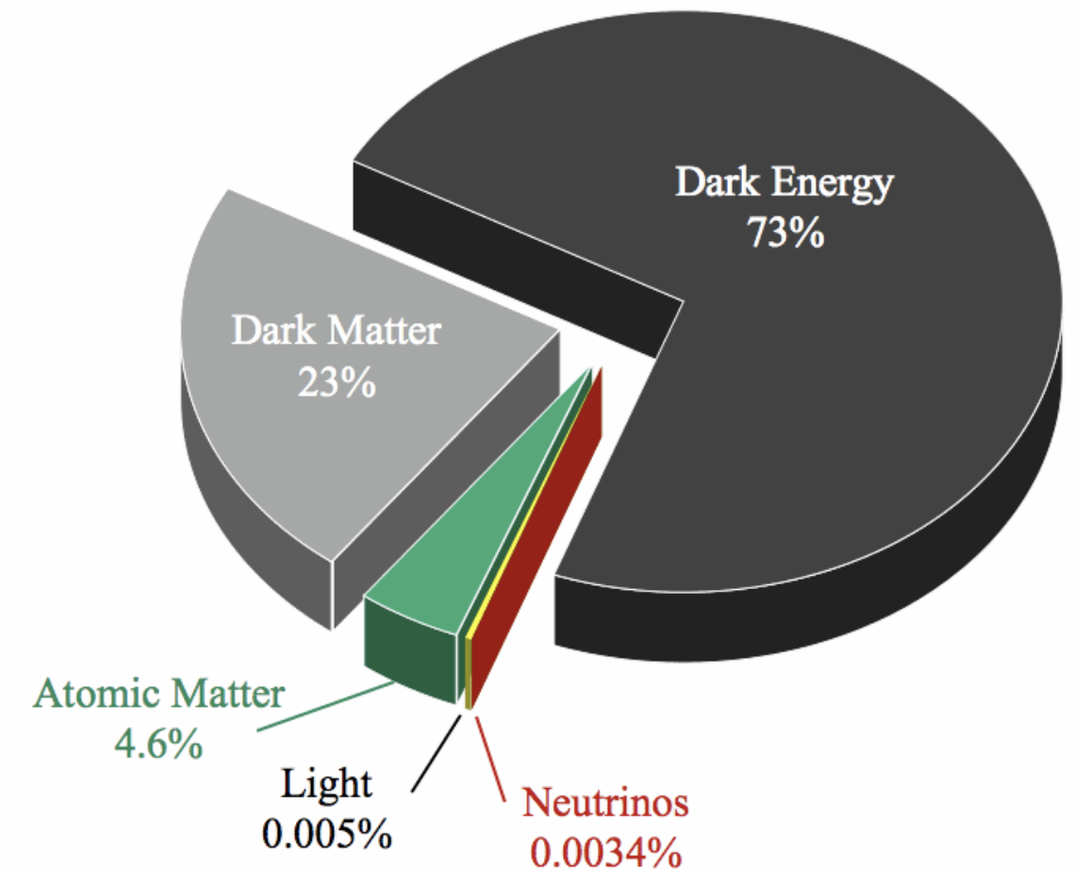

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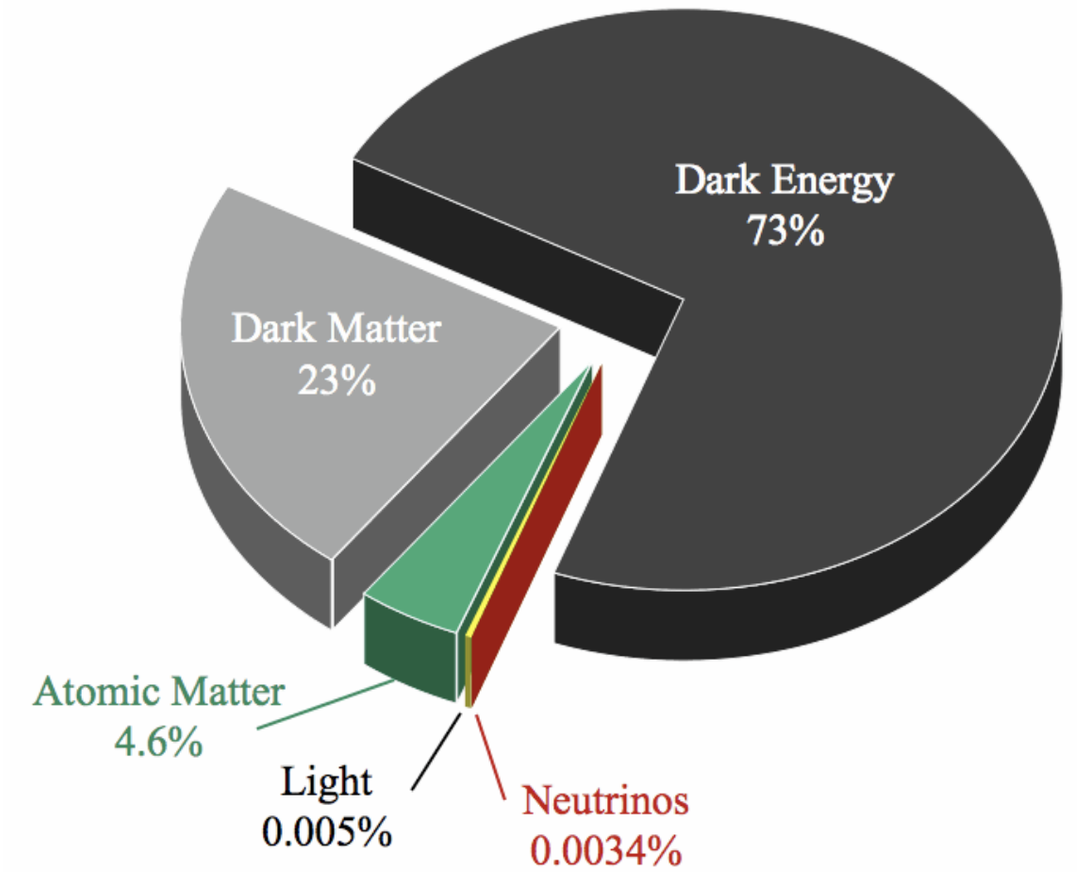

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Baryon asymmetry?

Physics Beyond the Standard Model

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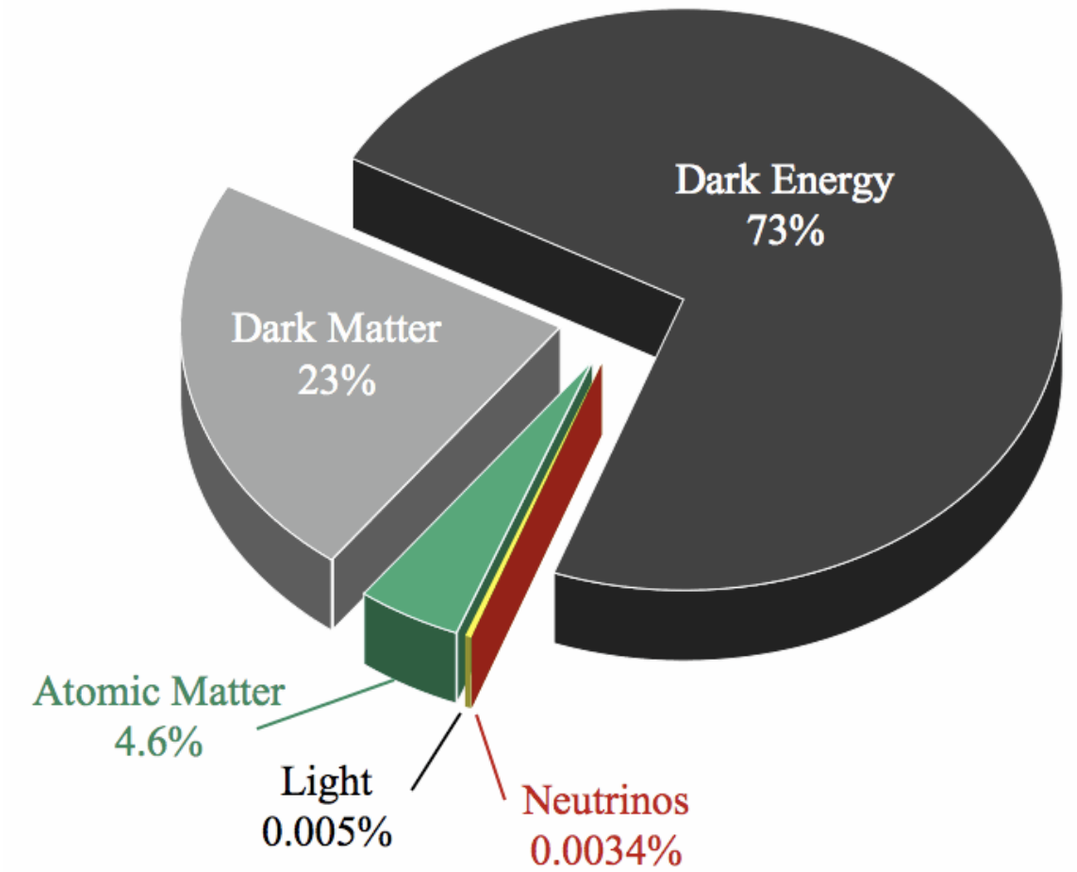

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Baryon asymmetry?

Why is gravity so weak?

etc...

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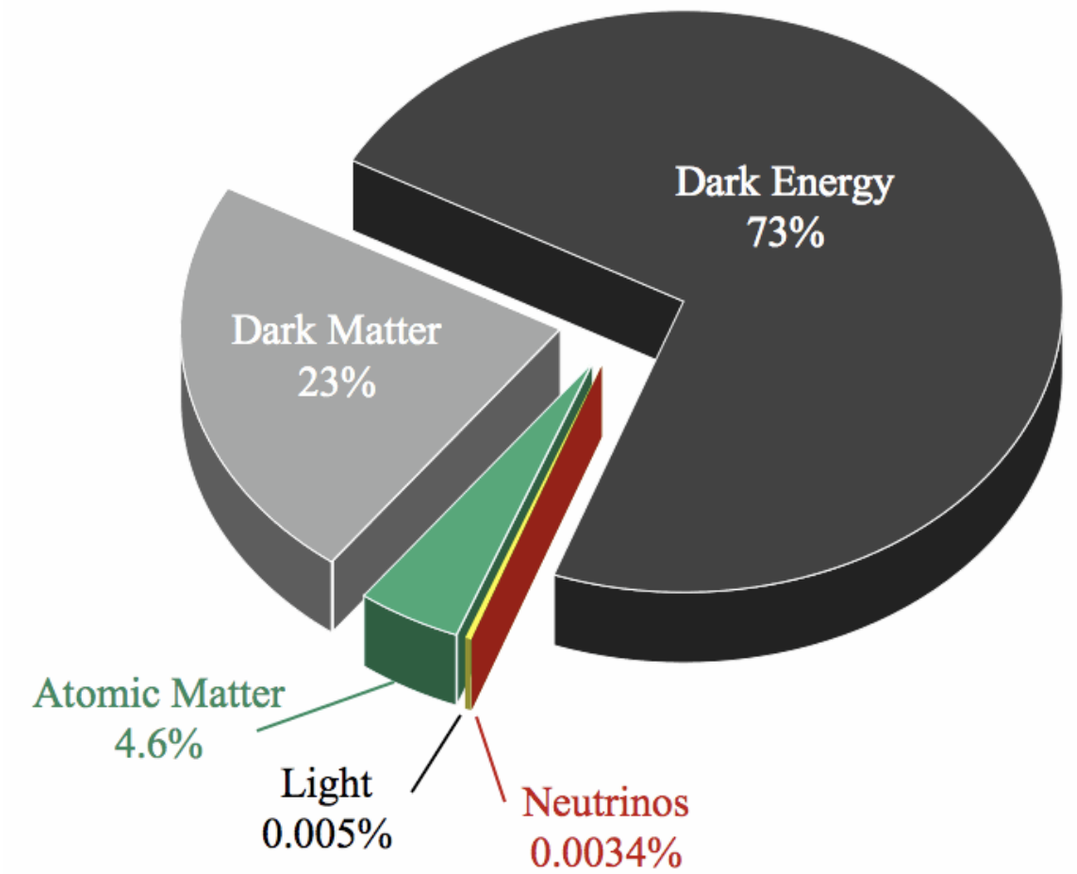

Dark Energy?

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Baryon asymmetry?

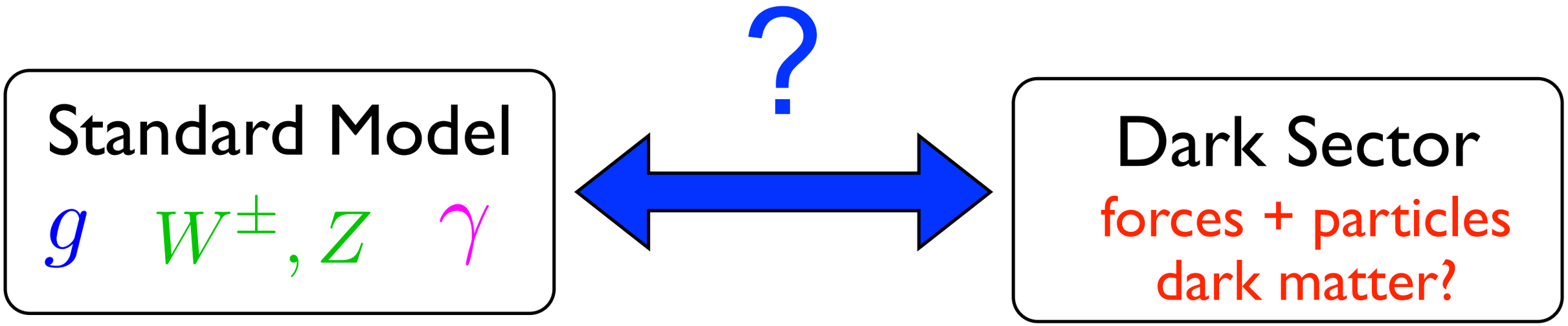
Why is gravity so weak?

etc...

Dark matter suggests the presence of a dark sector, neutral under all Standard Model forces

Portals to a dark sector?

only a few important interactions exist that are allowed by Standard Model symmetries



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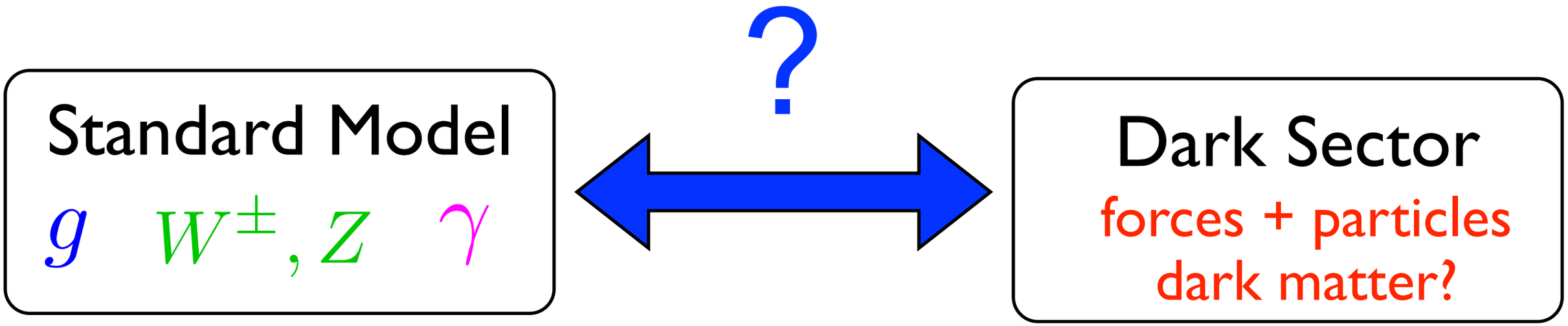
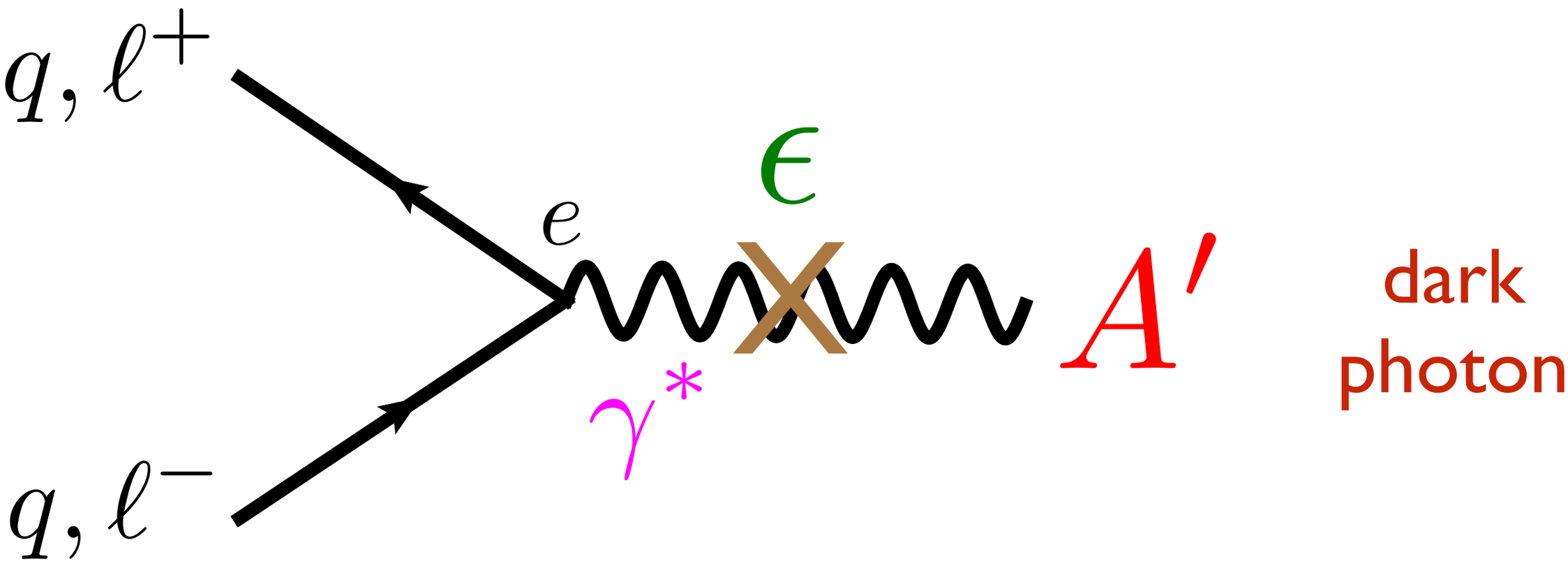


APEX built to probe the
dark photon portal

A′ couples to Quarks and charged Leptons



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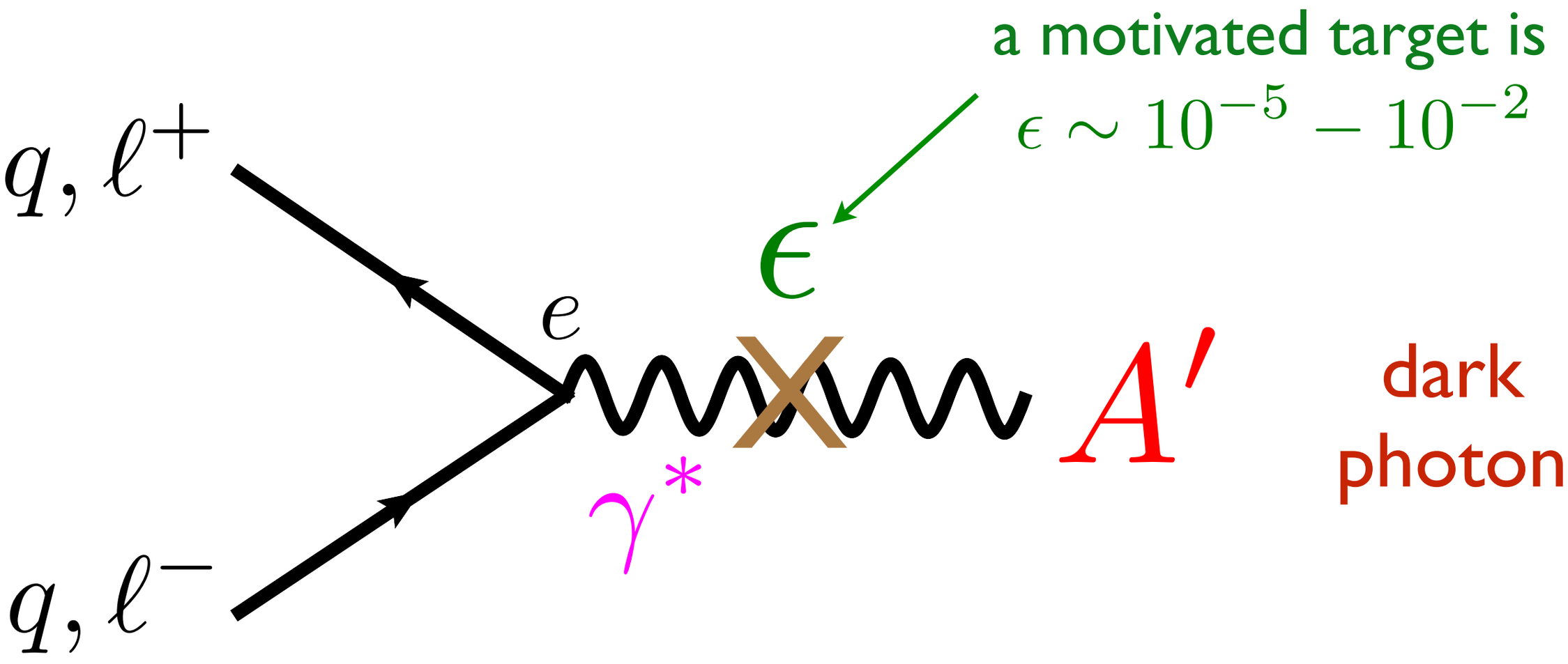

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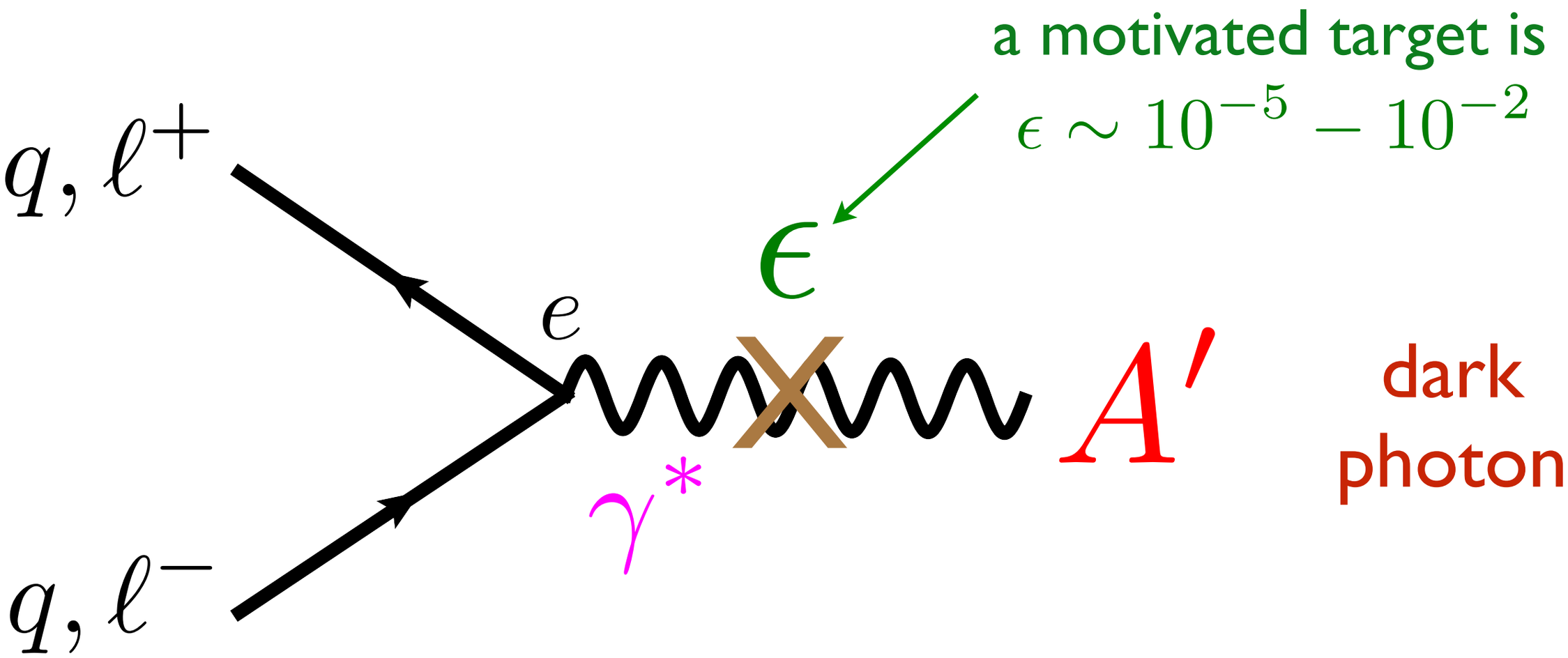
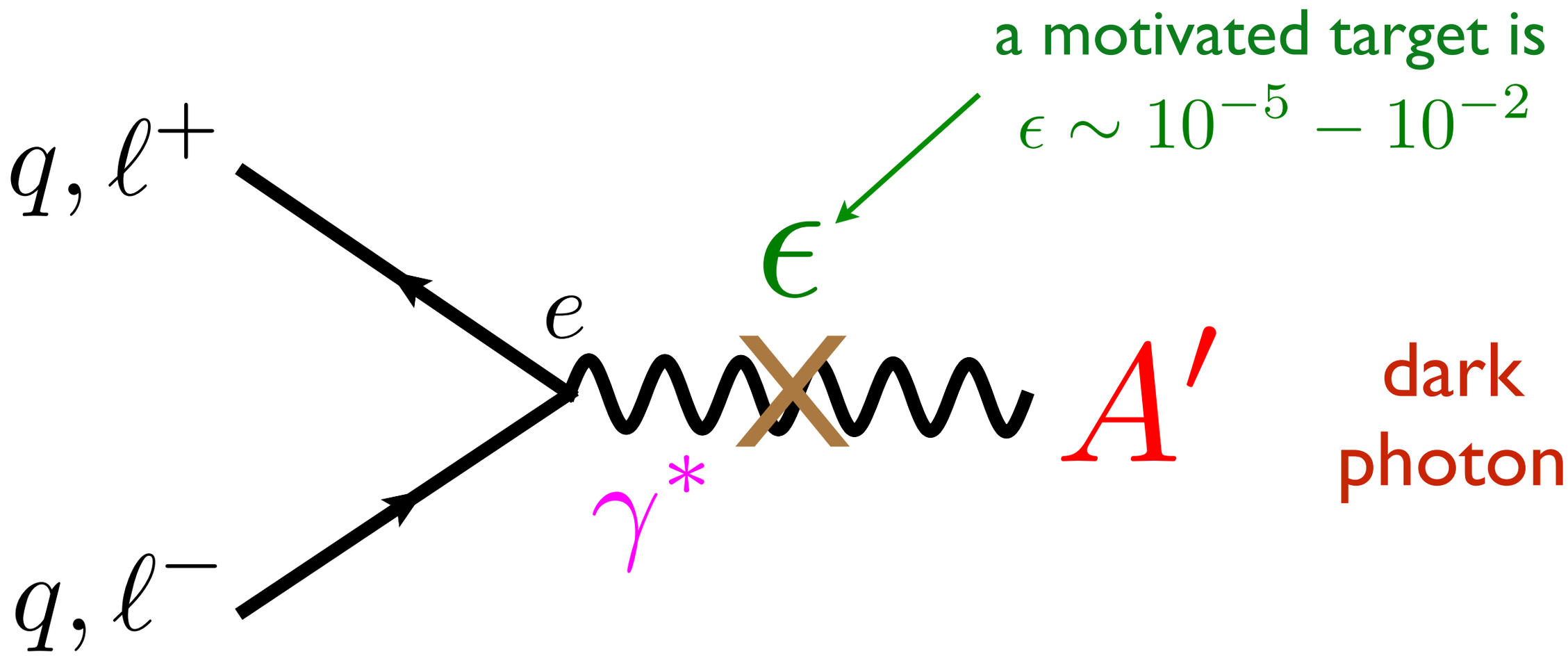


focus on $m_{A'} \sim 1\ \mathrm{MeV} - 1\ \mathrm{GeV}$

(theoretically natural, motivated from data:
muon g-2 + anomalies related to dark matter)

A′ couples to Quarks and charged Leptons



allows production of A′ in e^+e^- colliders, electron & proton beam dumps, meson decays etc.

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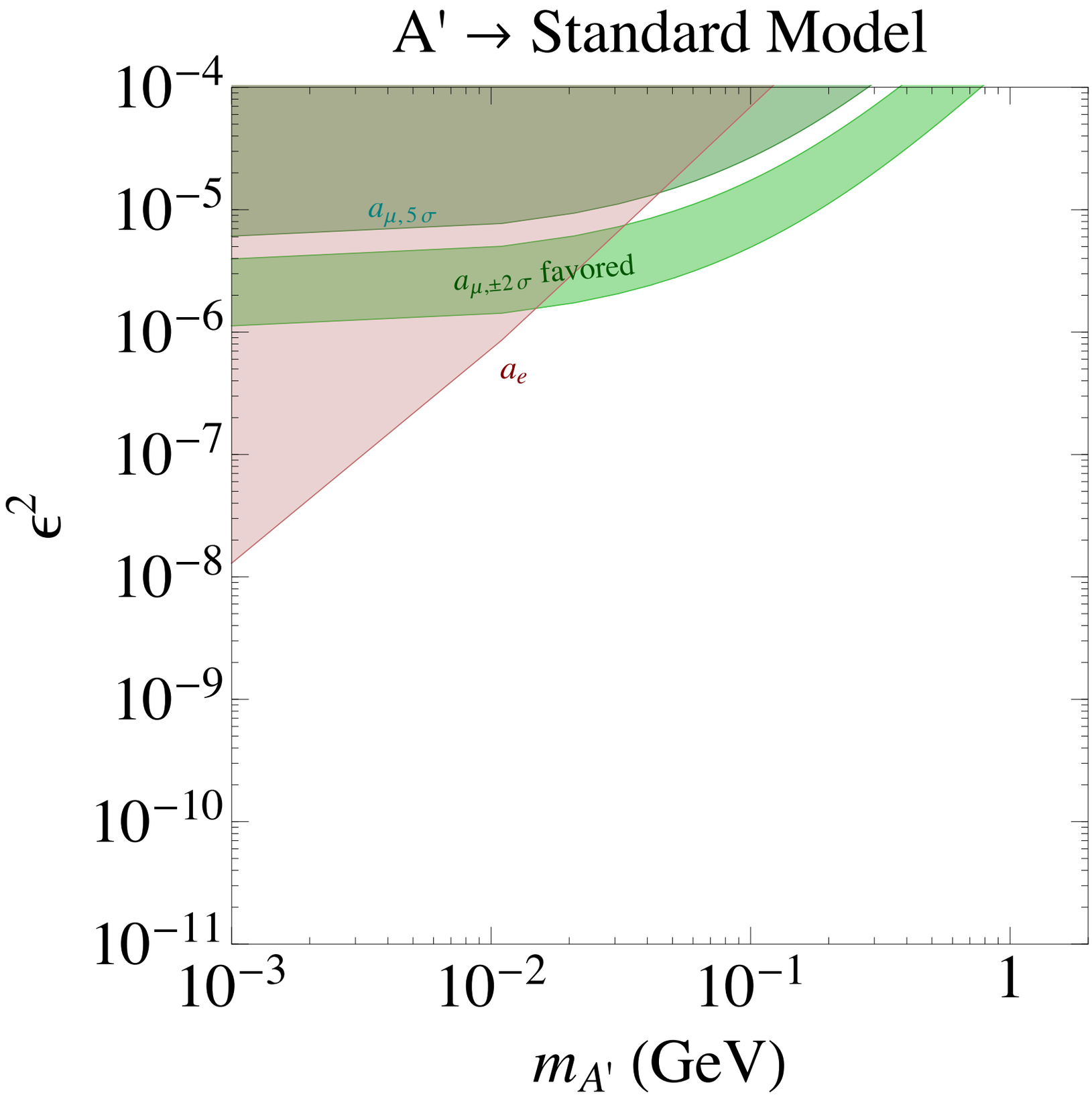
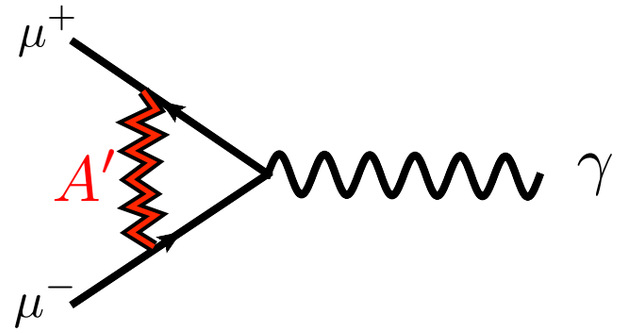
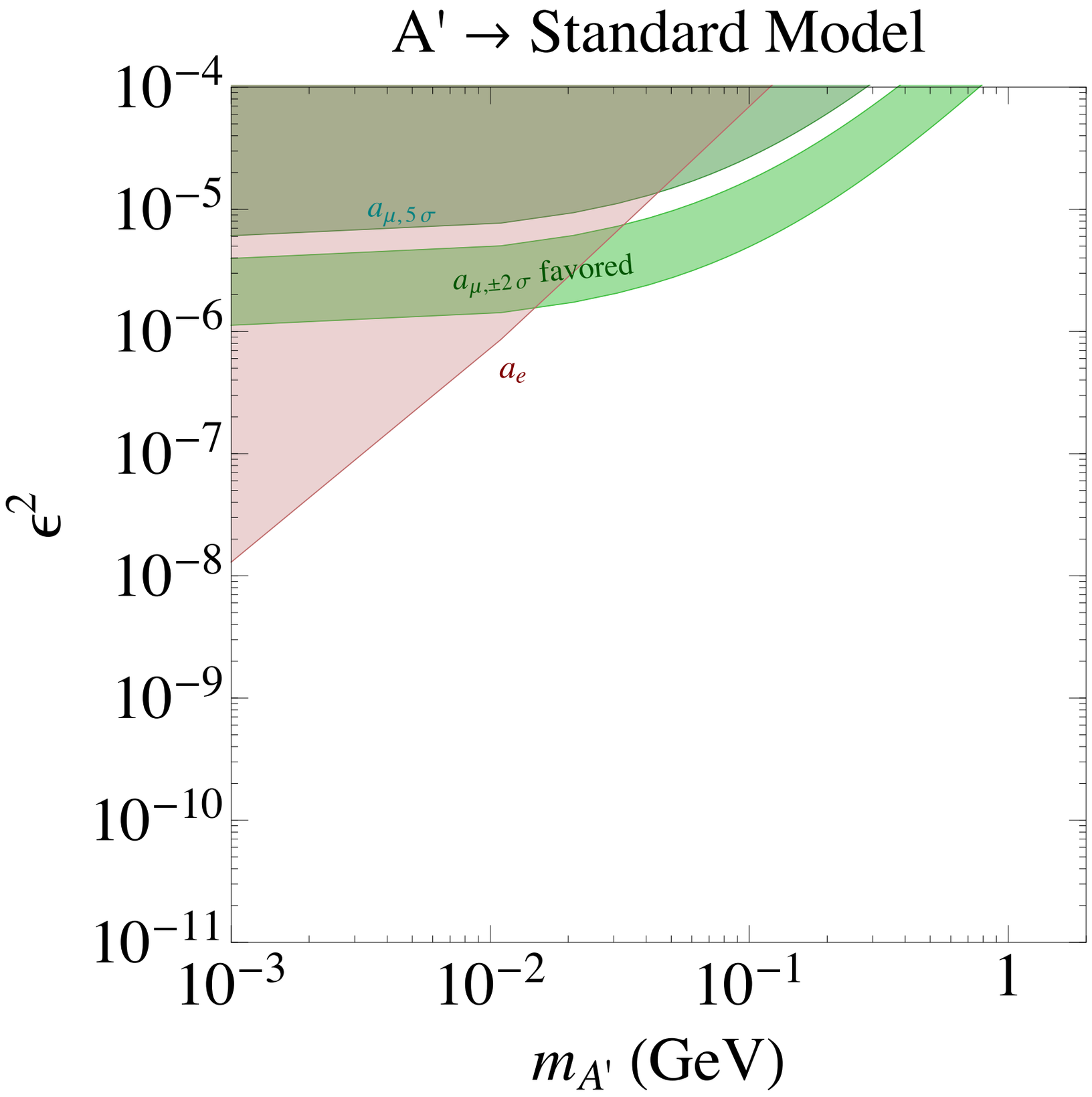
Status ~2008

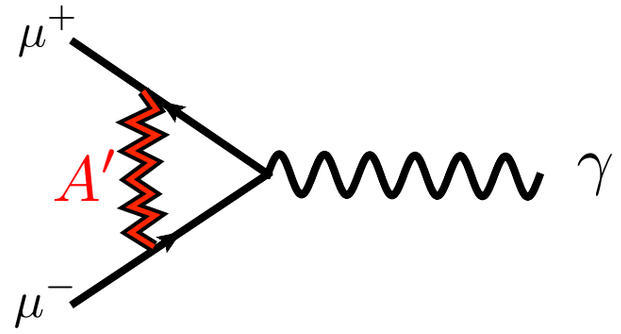




dark photon can explain muon g-2 in green band

Status ~2008





dark photon can explain muon g-2 in green band

dark photons considered well before 2008, but constraints never discussed in detail

Lots of activity since then, e.g.

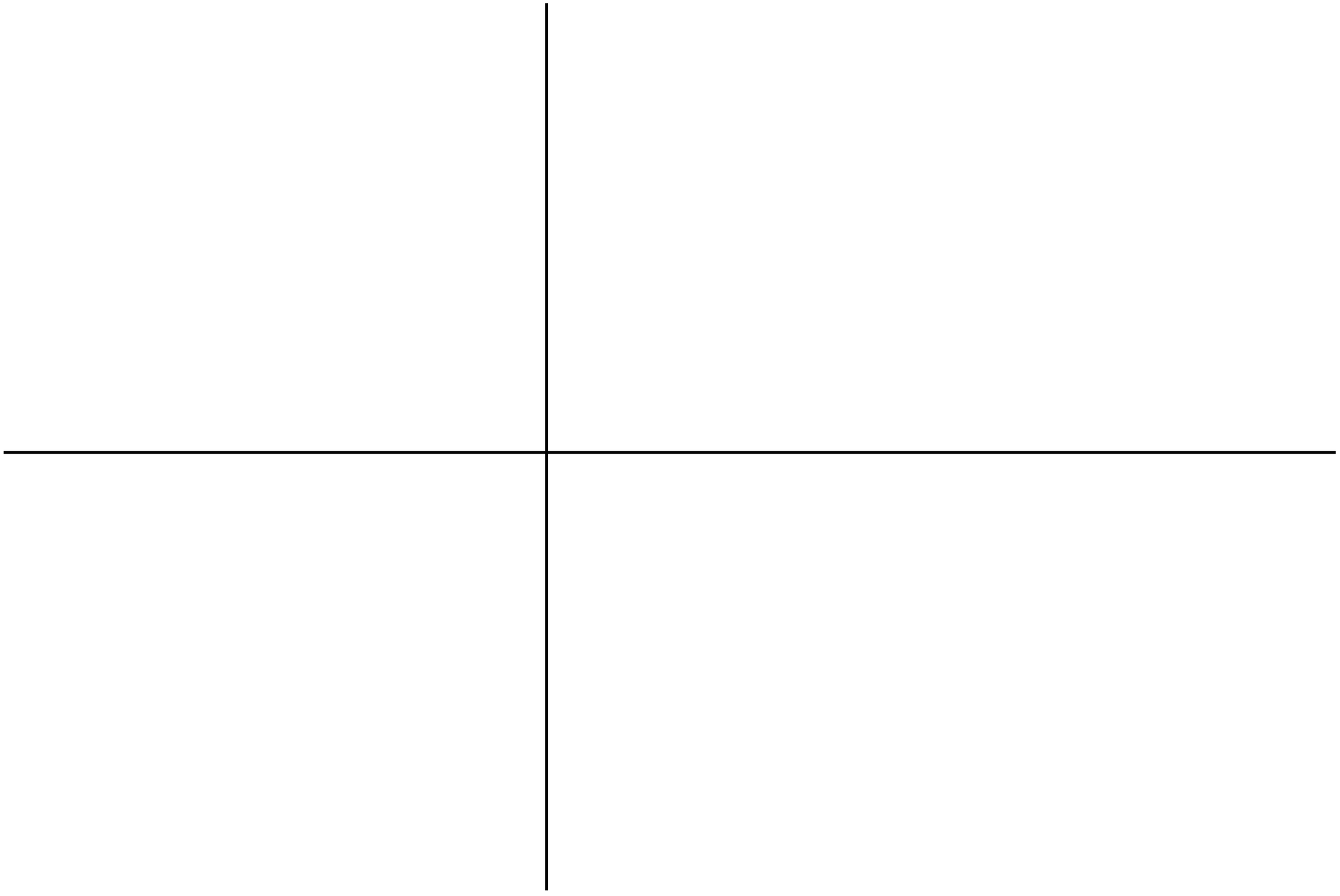
- Dark forces workshop, SLAC Sept. 2009:
  http://www-conf.slac.stanford.edu/darkforces2009/

- Searching for a New Gauge Boson at JLab, Sept. 2010:
  http://conferences.jlab.org/boson2010/program.html

- Intensity Frontier Workshop:
  http://www.intensityfrontier.org
  Summary document — arXiv:1205.2671

- Snowmass 2013
  http://www.snowmass2013.org/
  Major summary document — arXiv:1311.0029

Producing an A'



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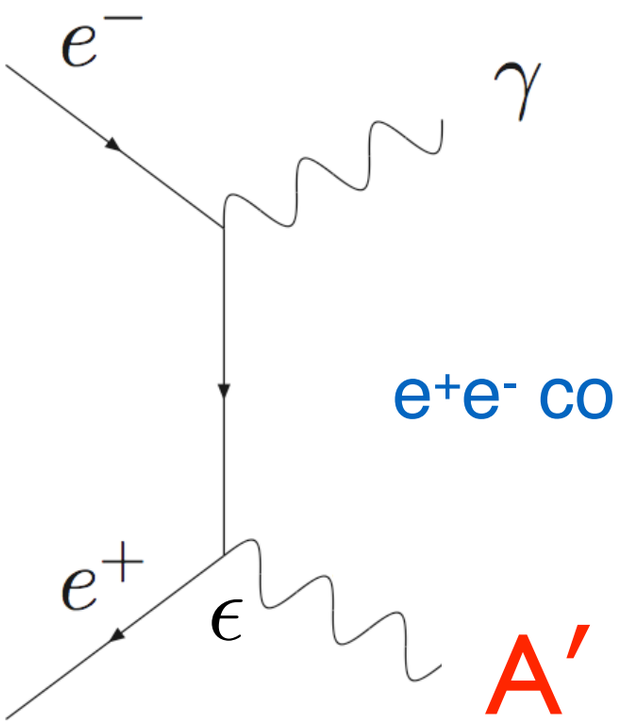

e^+e^- collision

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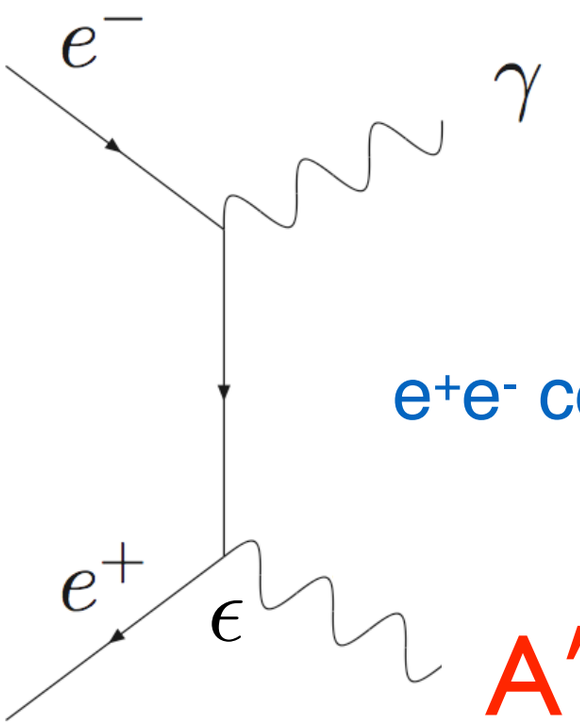

e⁺e⁻ collision

rare meson decays

$$\pi^0 \to \gamma A'$$

$$\phi \to \eta A'$$

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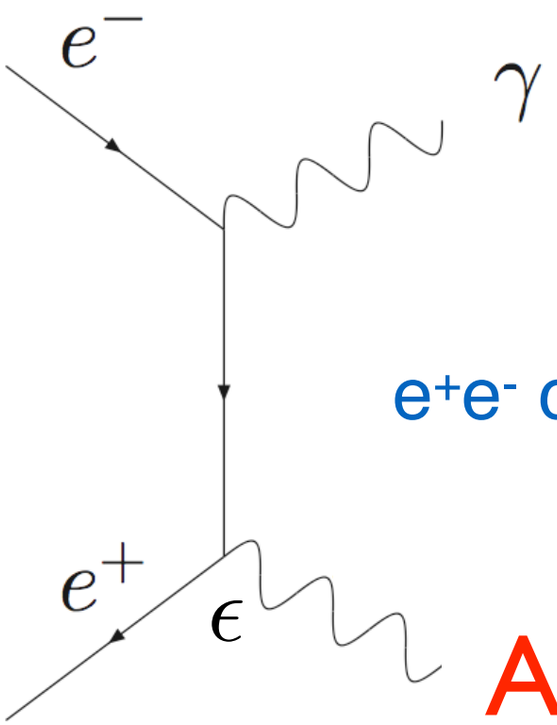

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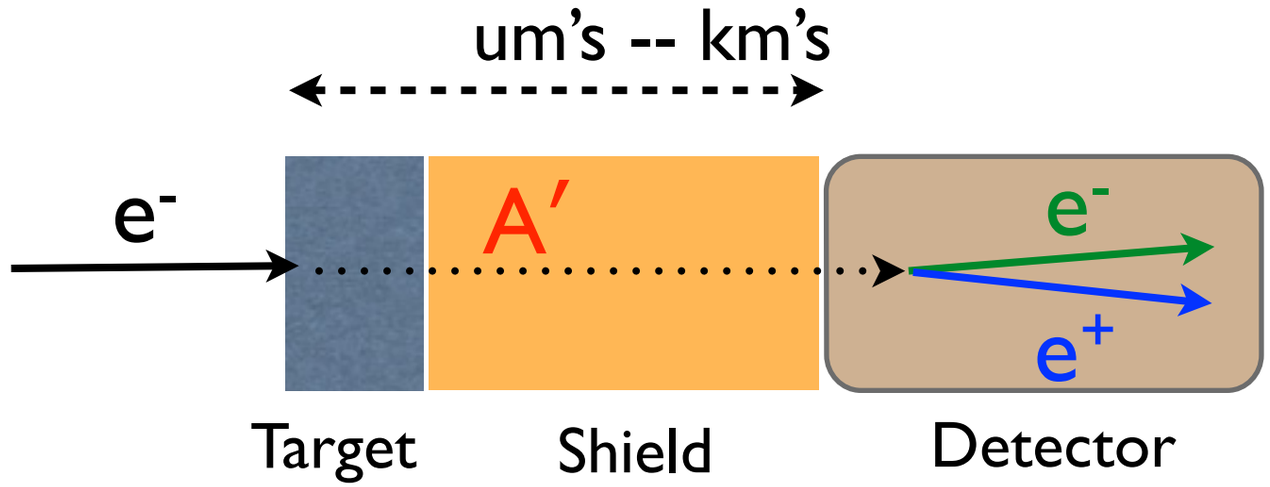

electron fixed target

e.g. APEX

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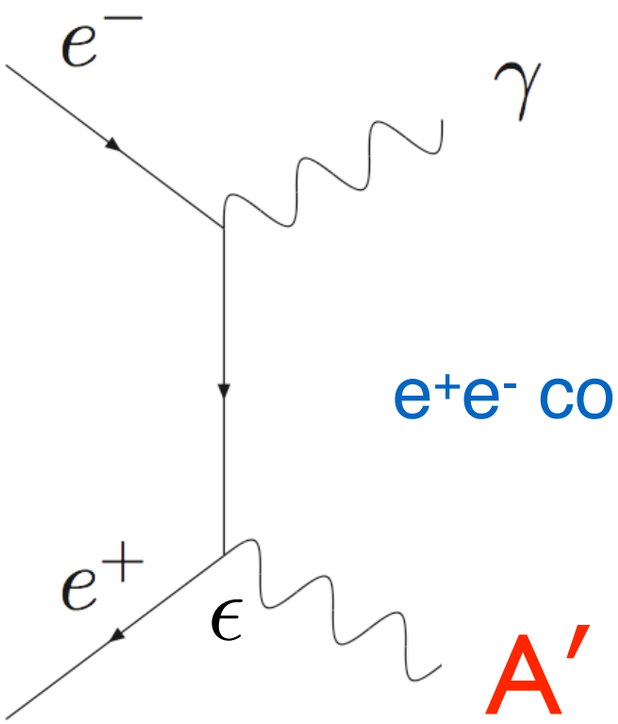

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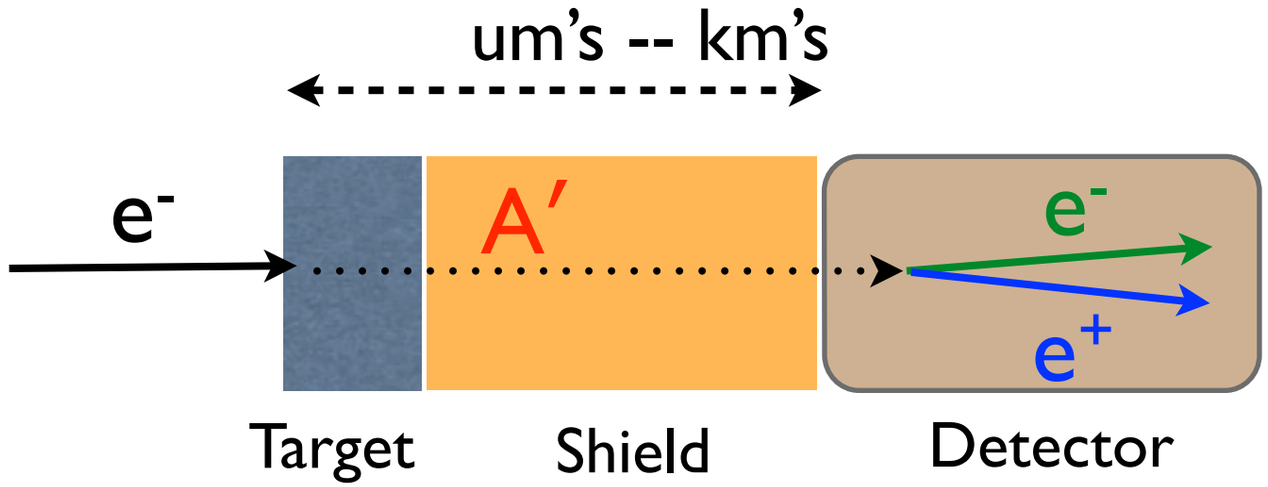
A′



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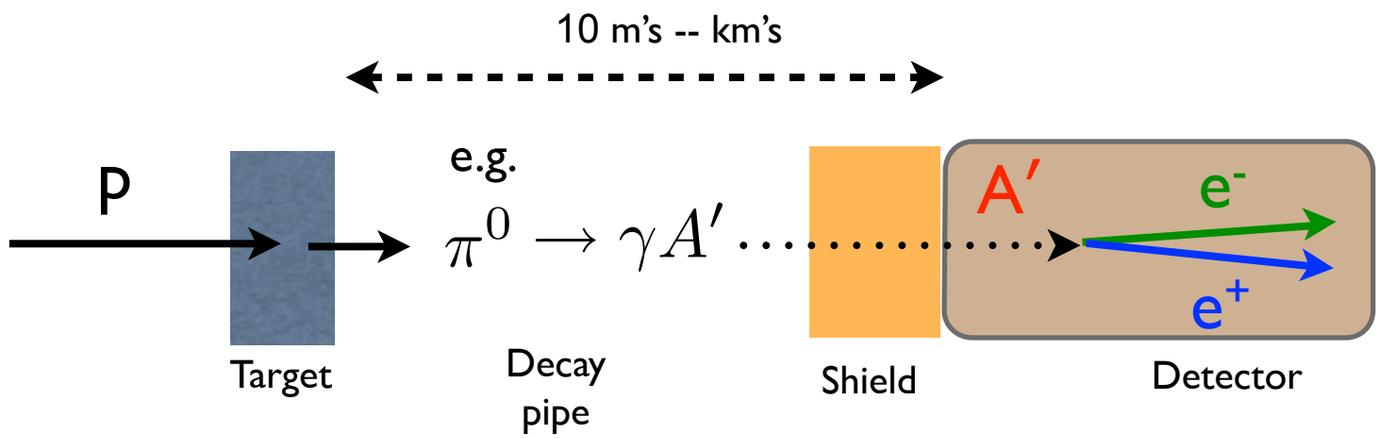
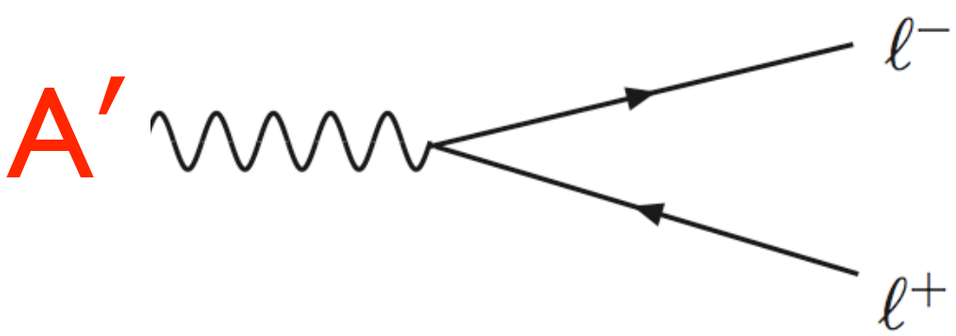
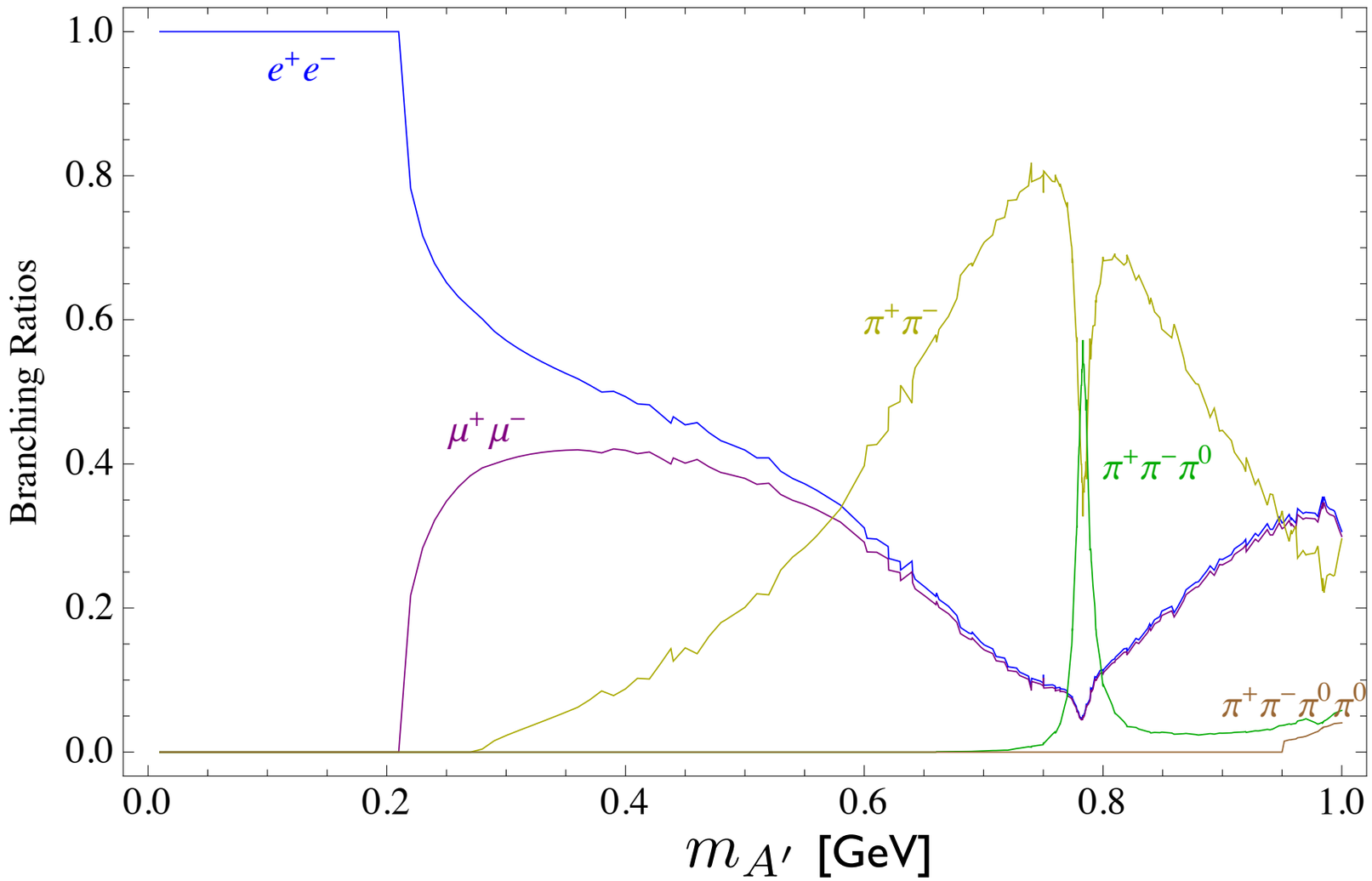


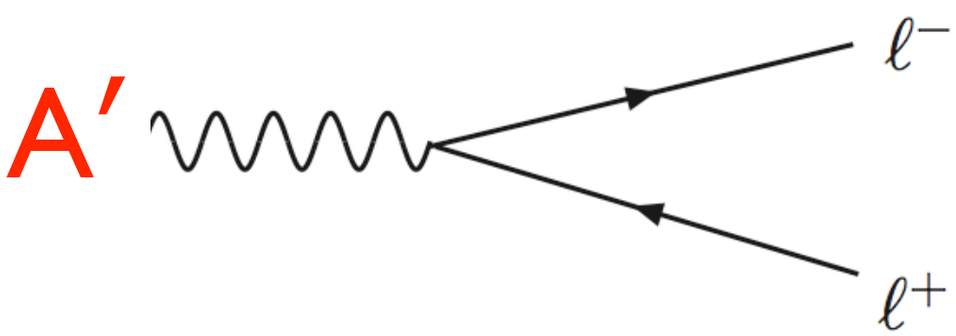
proton fixed target

A′ decays

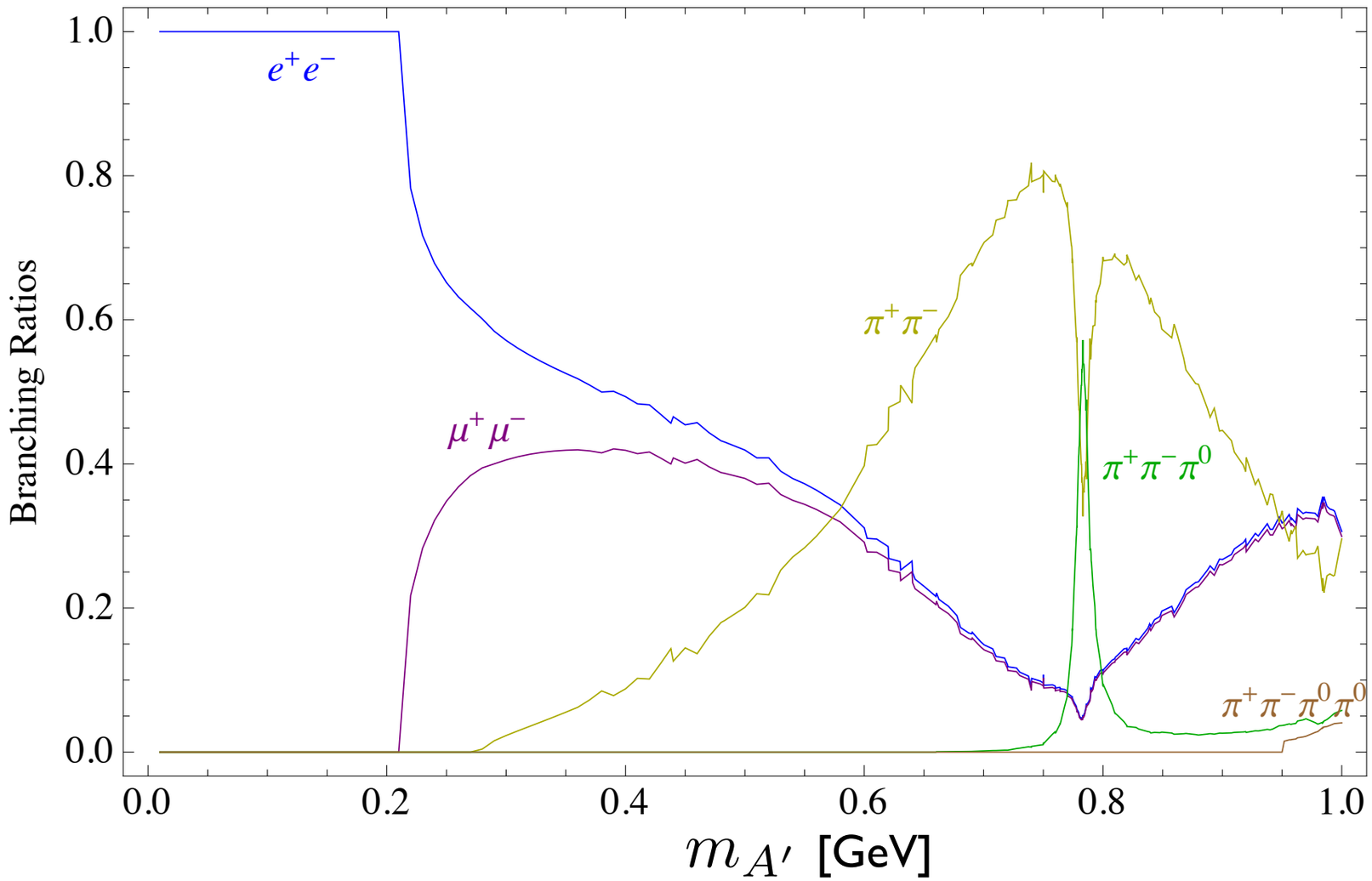

A′
ℓ−
ℓ+


1.0
0.8
0.6
0.4
0.2
0.0
Branching Ratios
0.0
0.2
0.4
0.6
0.8
1.0
$m_{A'}$ [GeV]
e^+e^-
$\mu^+\mu^-$
$\pi^+\pi^-$
$\pi^+\pi^-\pi^0$
$\pi^+\pi^-\pi^0\pi^0$

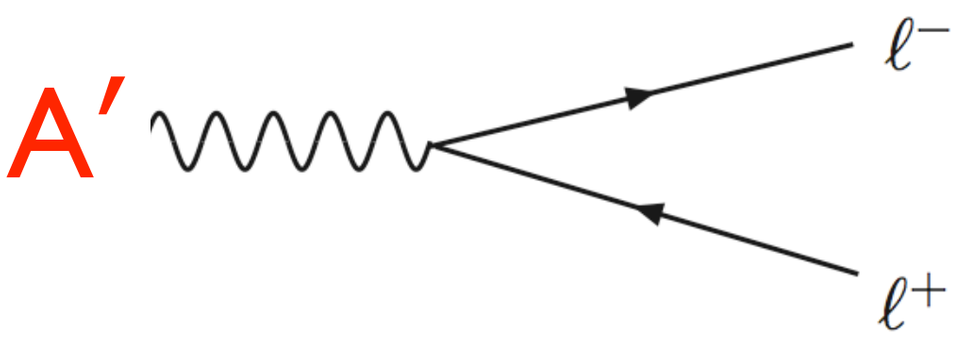
A′ decays



($A' \rightarrow$ other states also possible)



A′ decays



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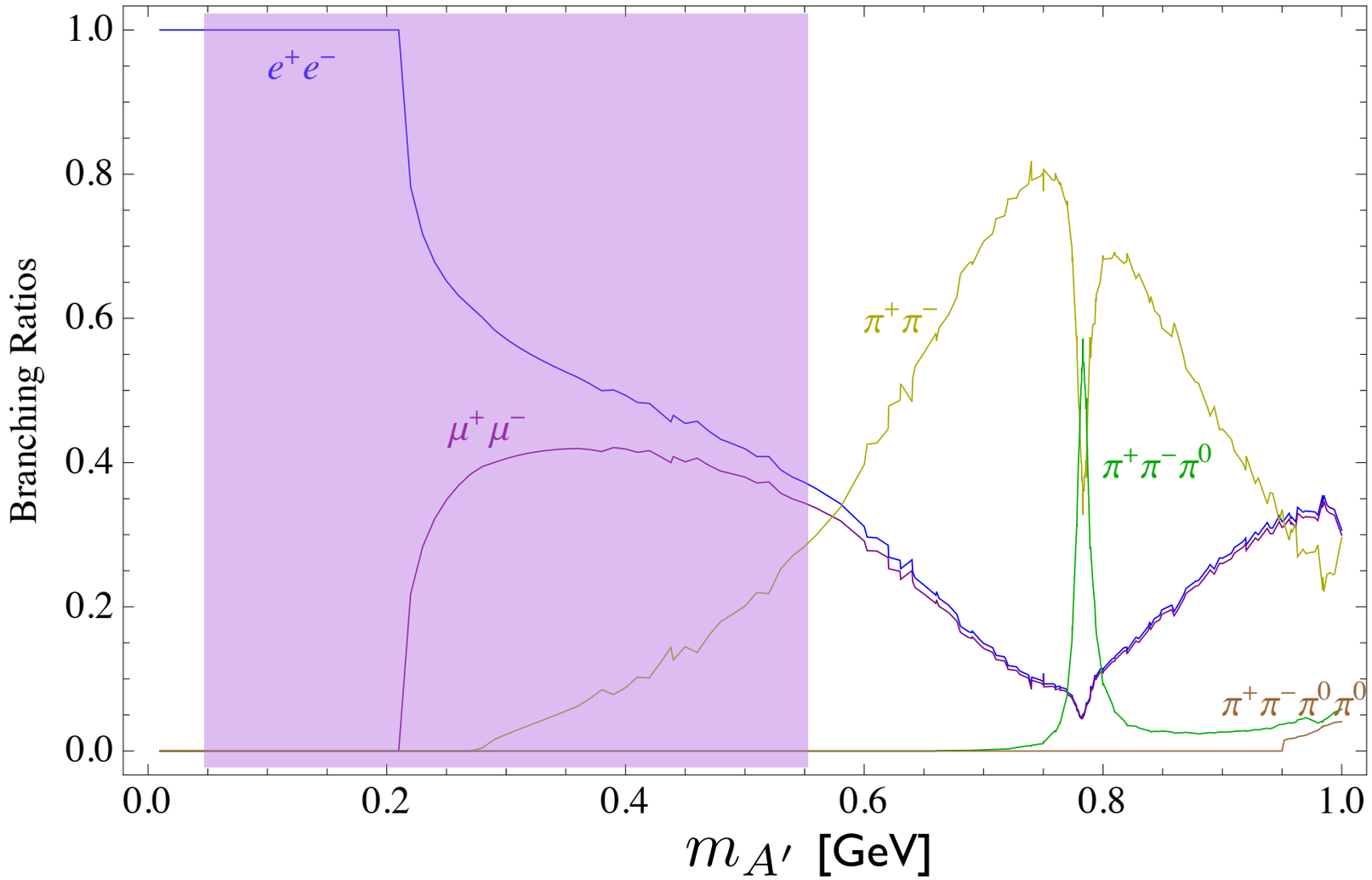
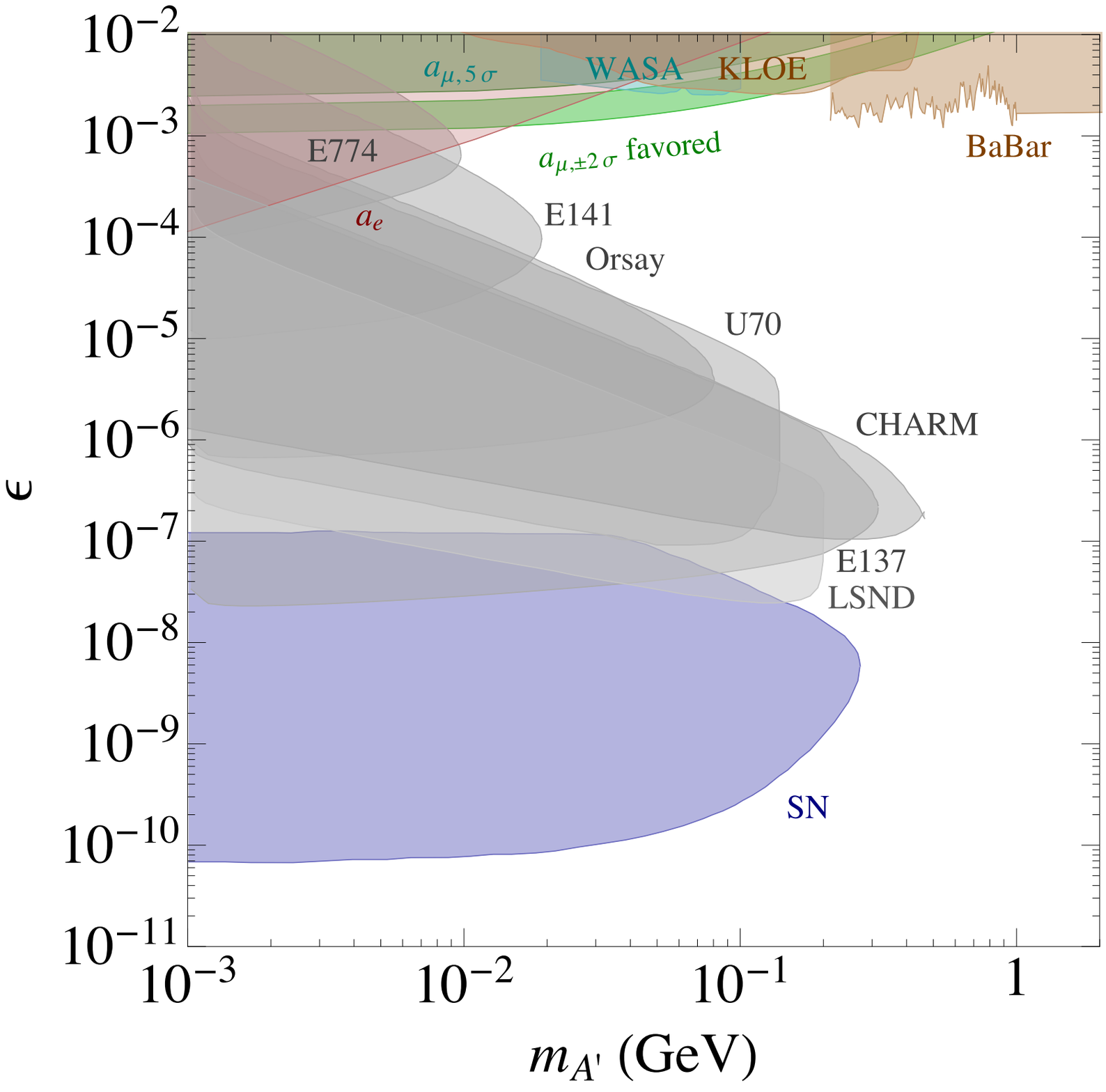
APEX mass range

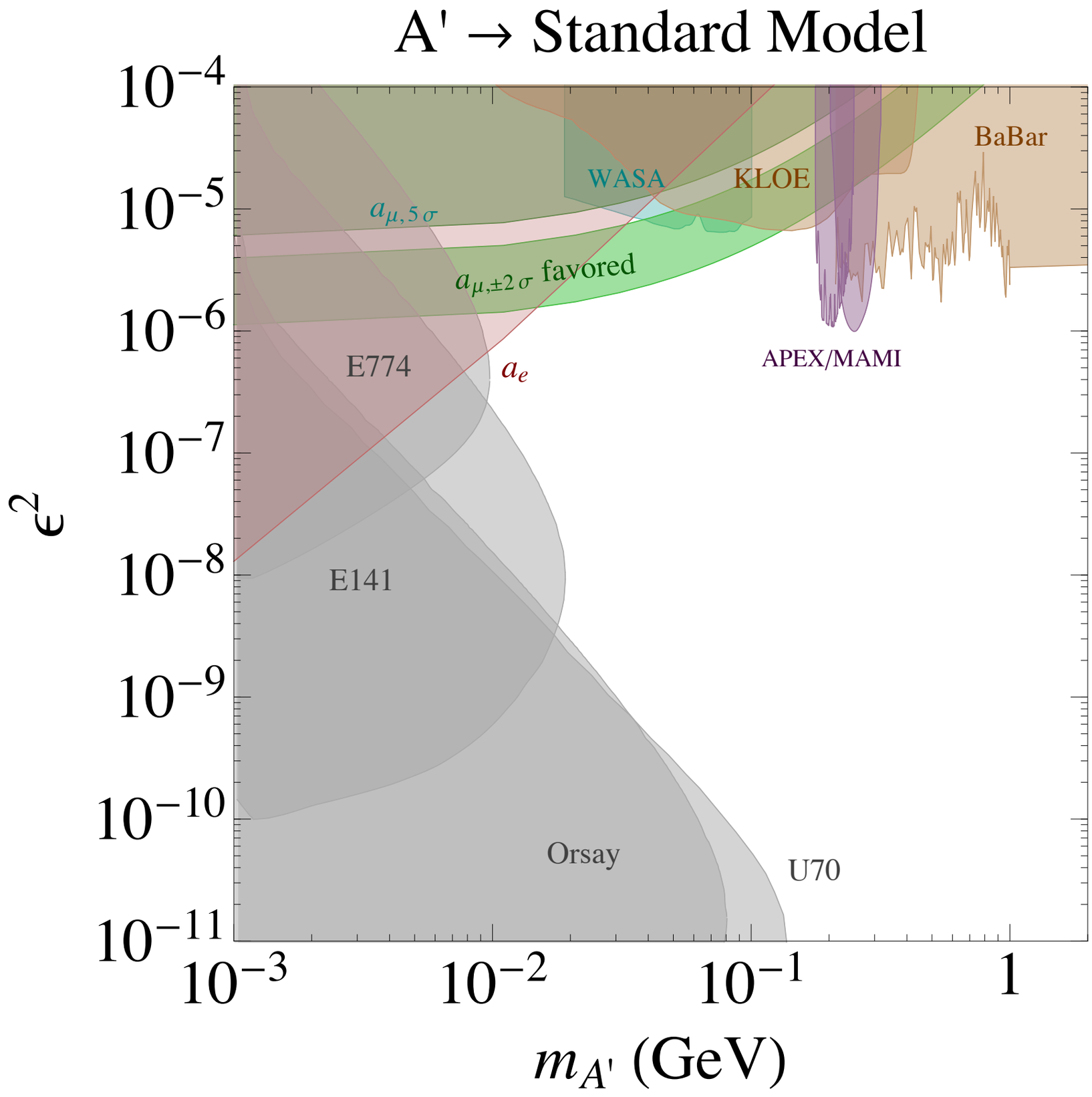


Status ~Today (published results)



(only showing strongest constraints)

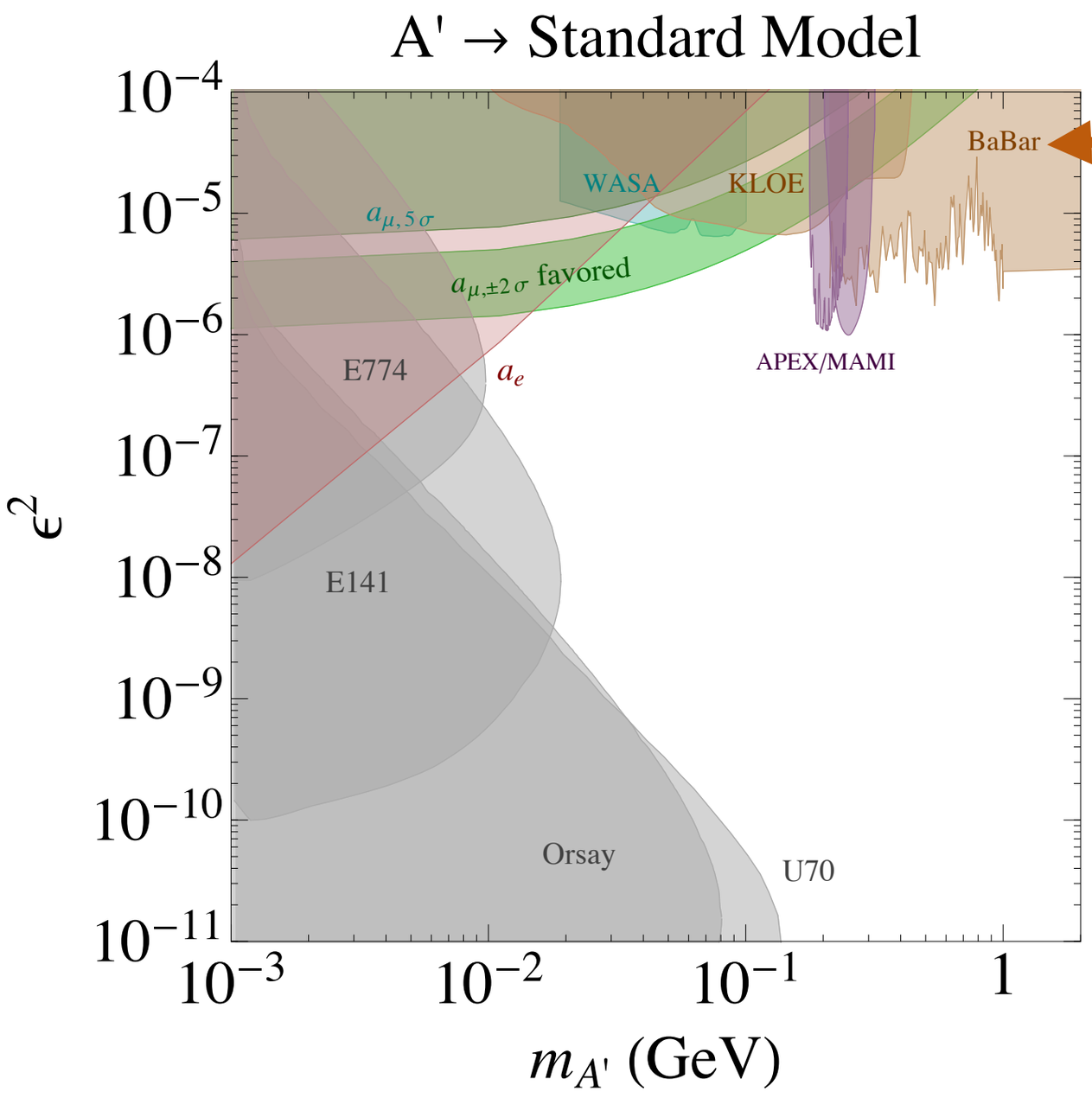
Status ~Today (published results, zoomed in)



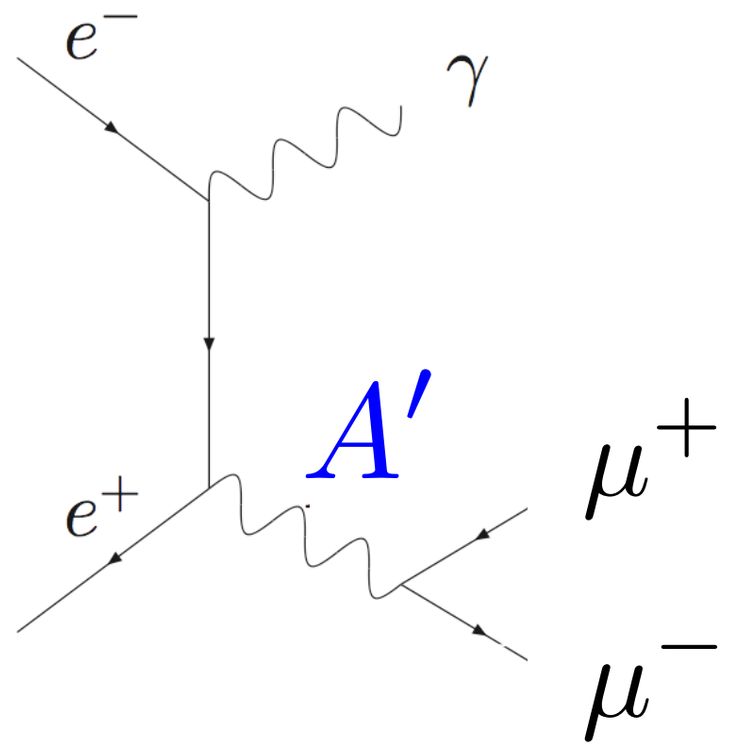
(only showing strongest constraints)

BaBar 2008

Re-interpretation by theorists of a BaBar analysis looking for pseudo-scalar decaying to $\mu^+\mu^-$



BaBar

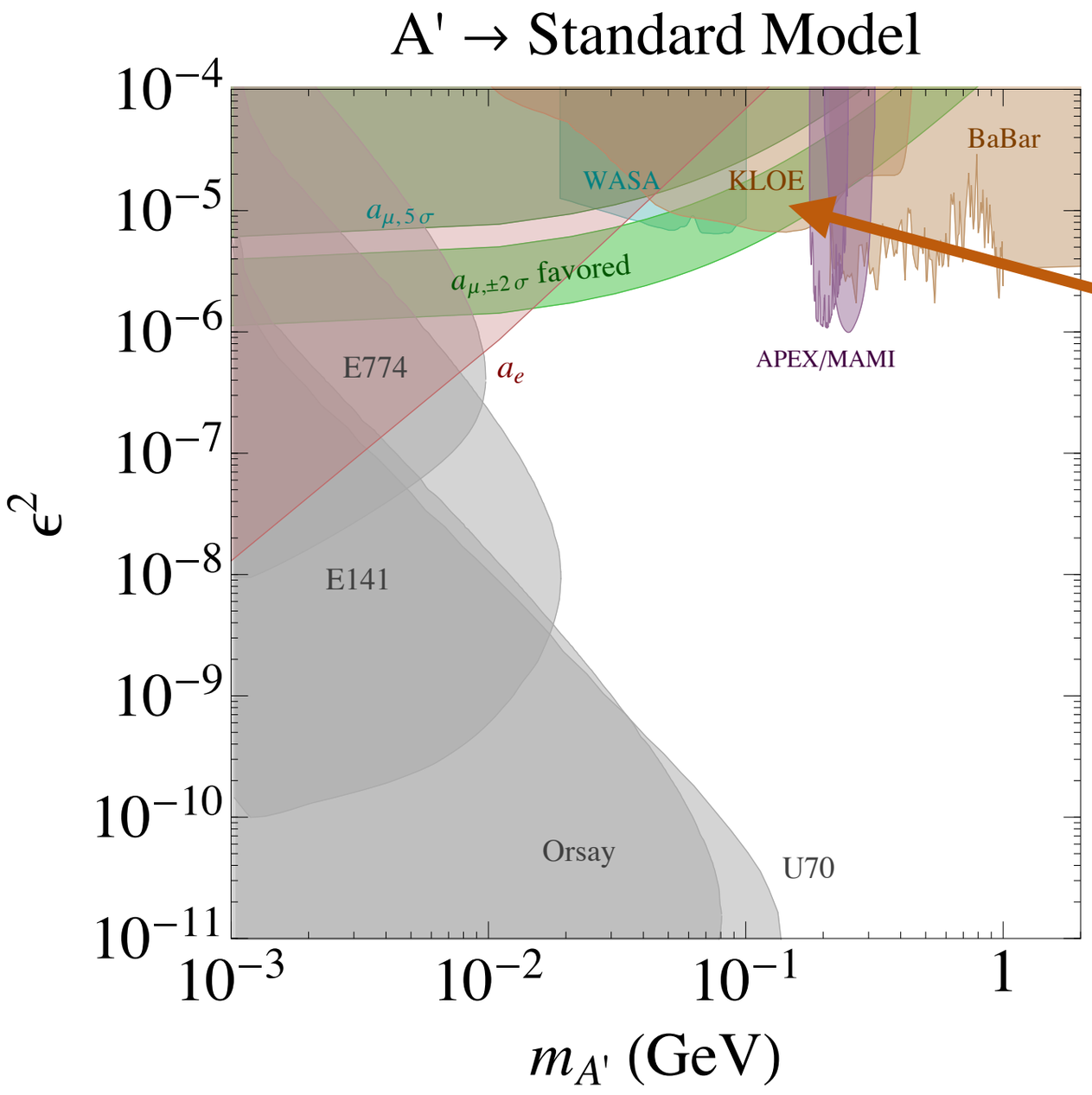


KLOE

2011, 2012

Use rare meson decays

$$\phi \to \eta A' \qquad A' \to e^+e^- \qquad \eta \to \pi^+\pi^-\pi^0$$
$$\eta \to \pi^0\pi^0\pi^0$$

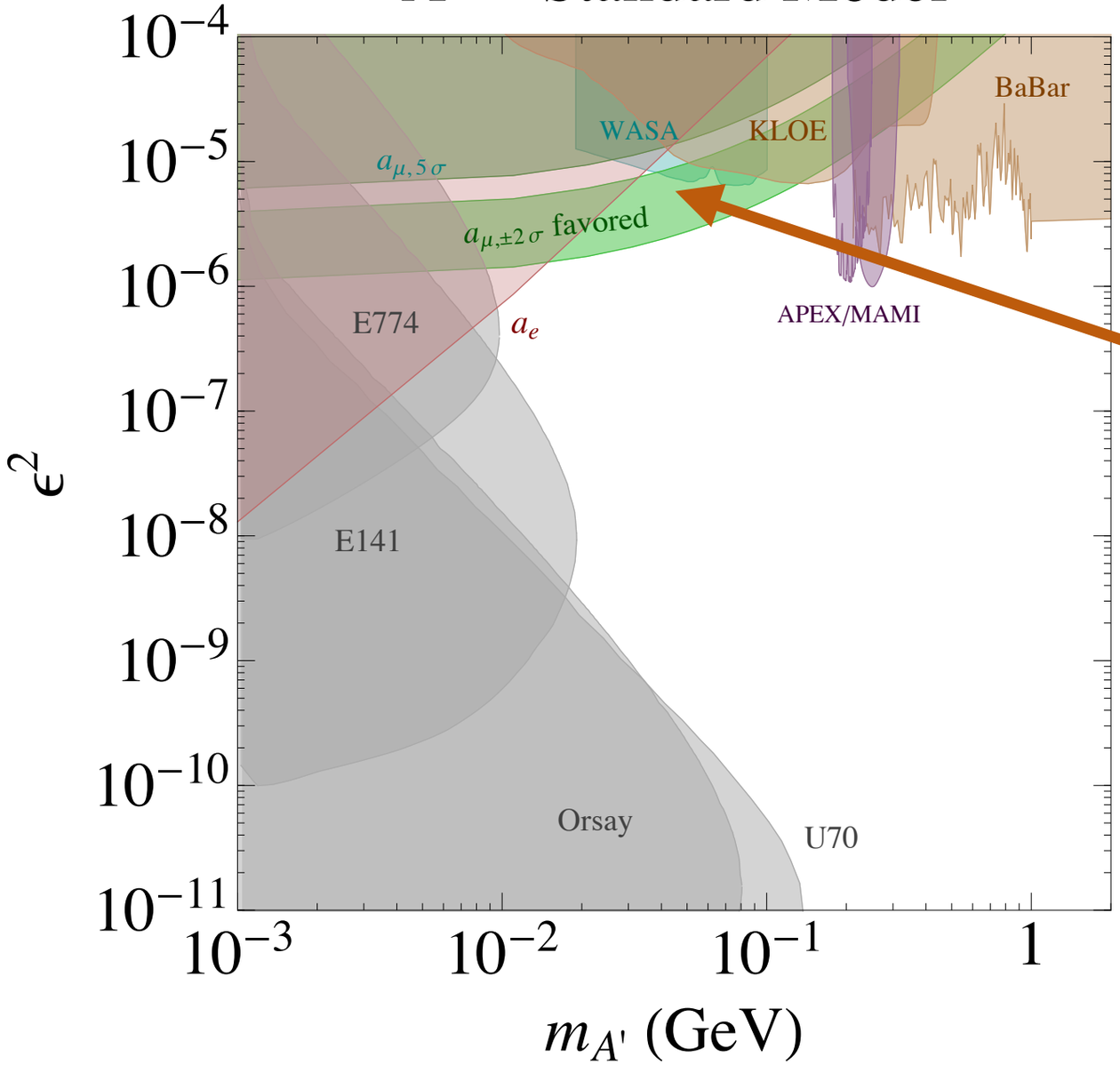


KLOE

WASA detector at COSY 2013

$$\pi^0 \to \gamma A' \qquad A' \to e^+e^-$$

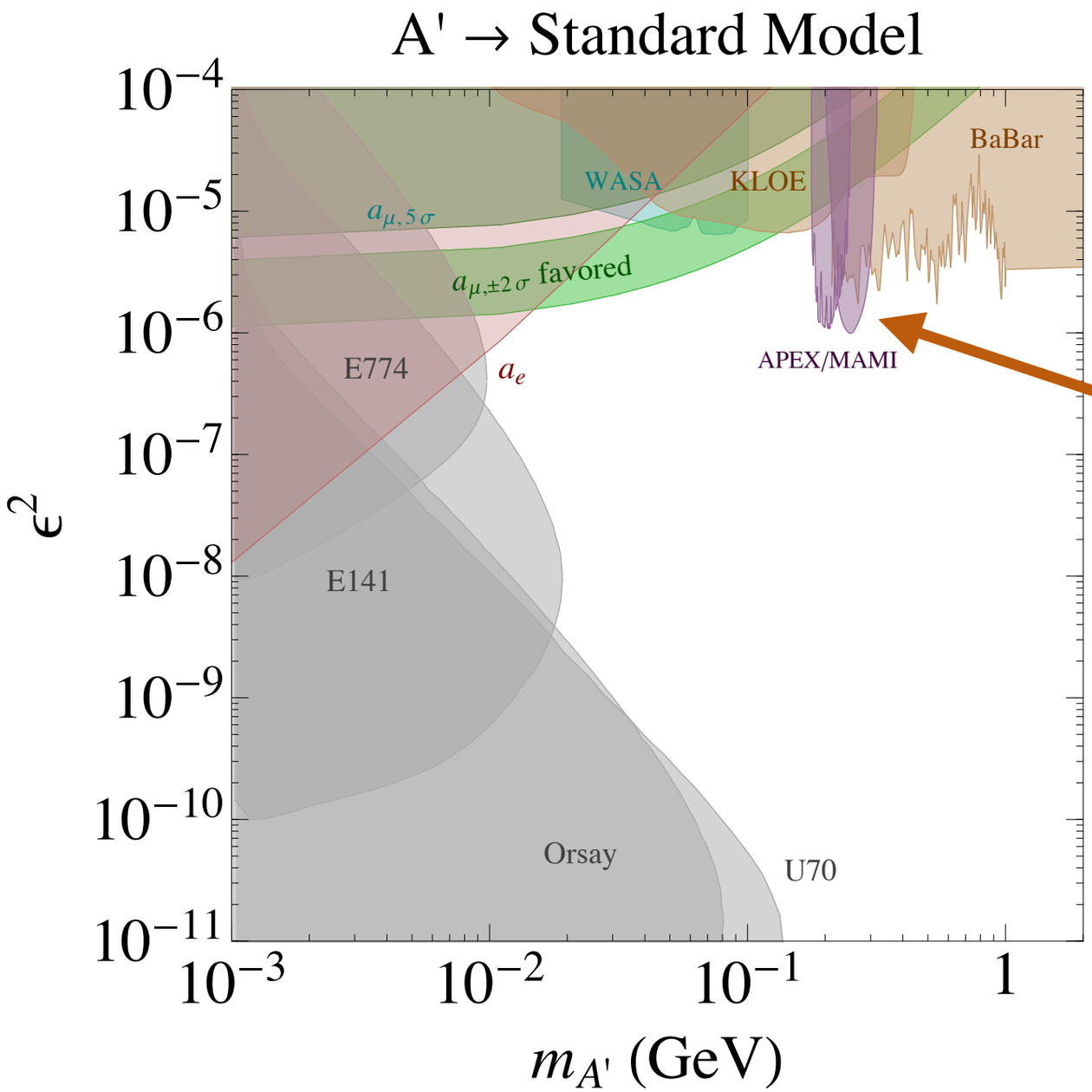
5×10^5 γe^+e^- events



WASA

APEX & MAMI Test Runs 2011

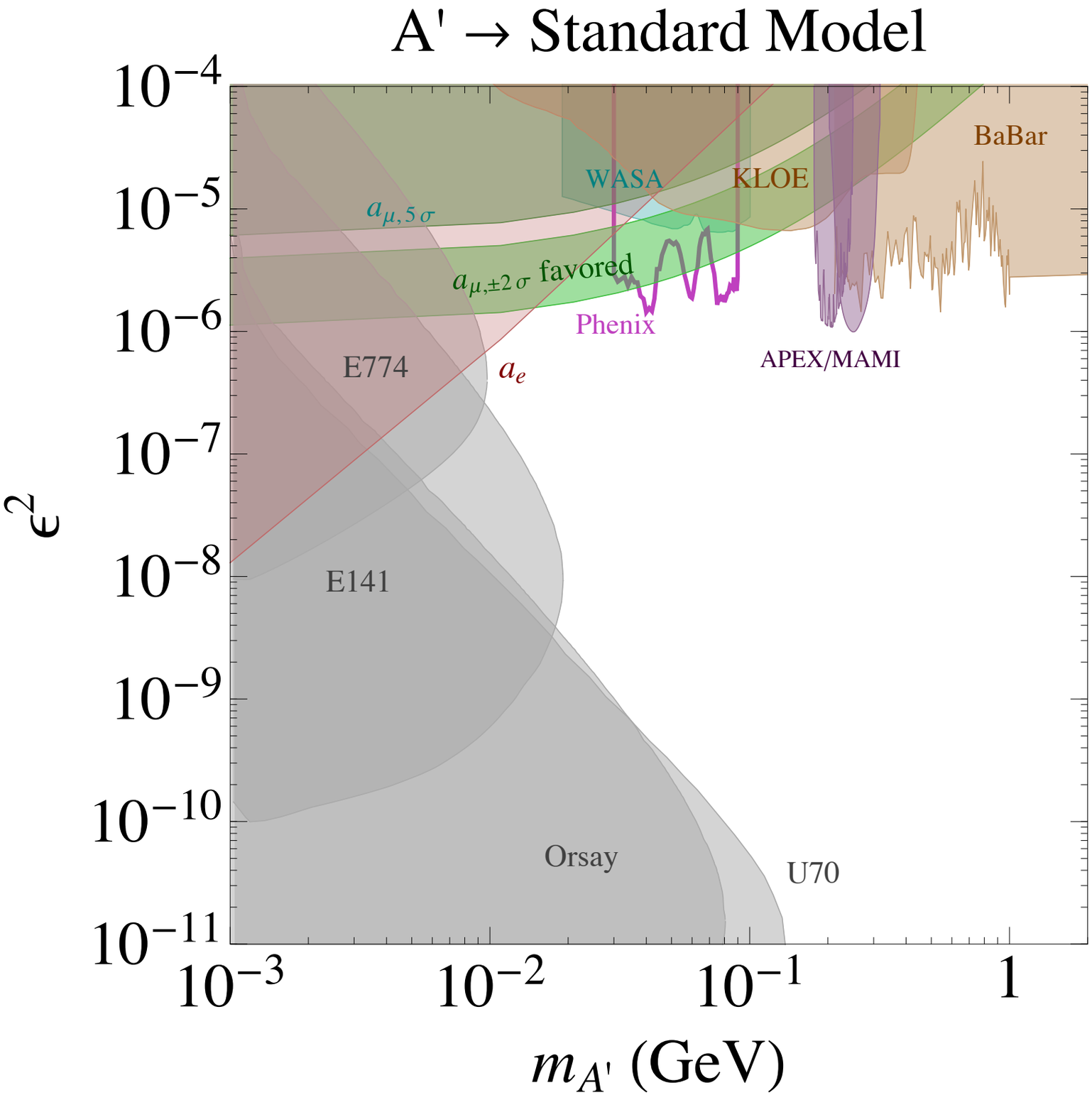
Two-arm spectrometer searches for A′ to e^+e^-



APEX & MAMI Test Runs

Proof of Principle for full-scale experiments

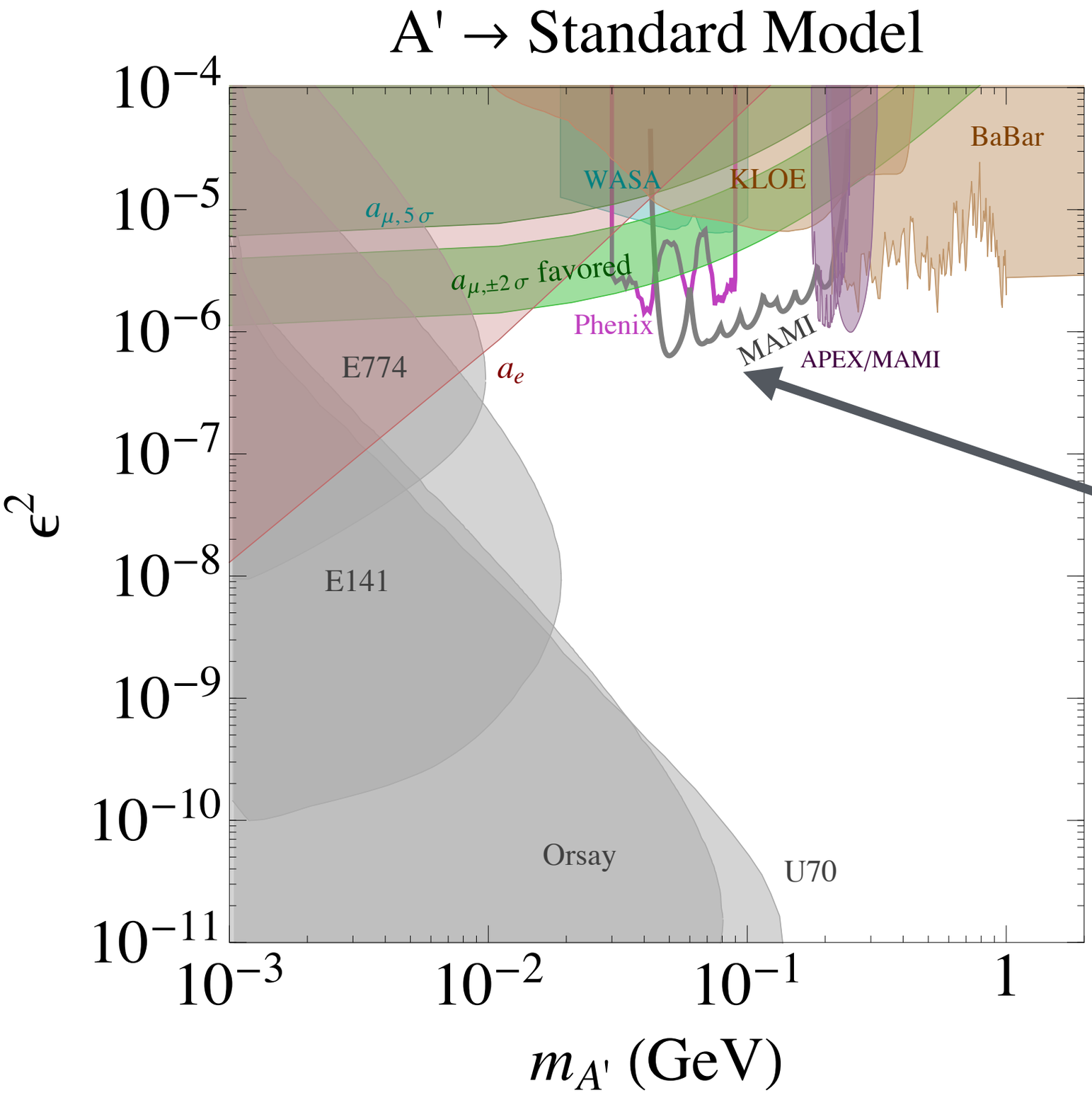
PHENIX@RHIC (BNL) 2013/14



$$\pi^0 \to \gamma A'$$
$$A' \to e^+ e^-$$

(unpublished, presented in a talk)

Status ~soon?

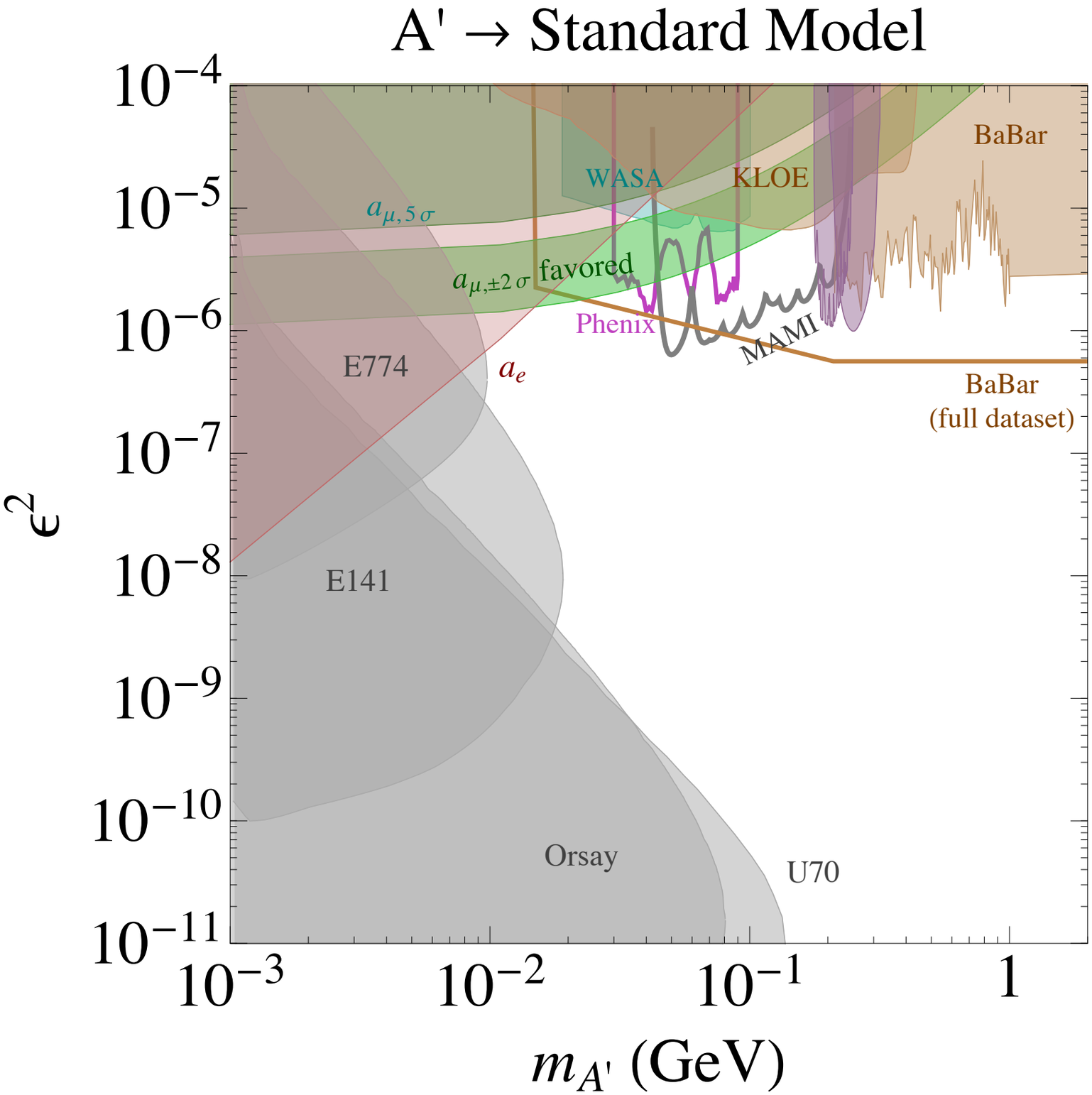


Existing data; analyses almost complete?

MAMI (various run settings)

projections are rough; final results may differ!!!

Status ~soon?

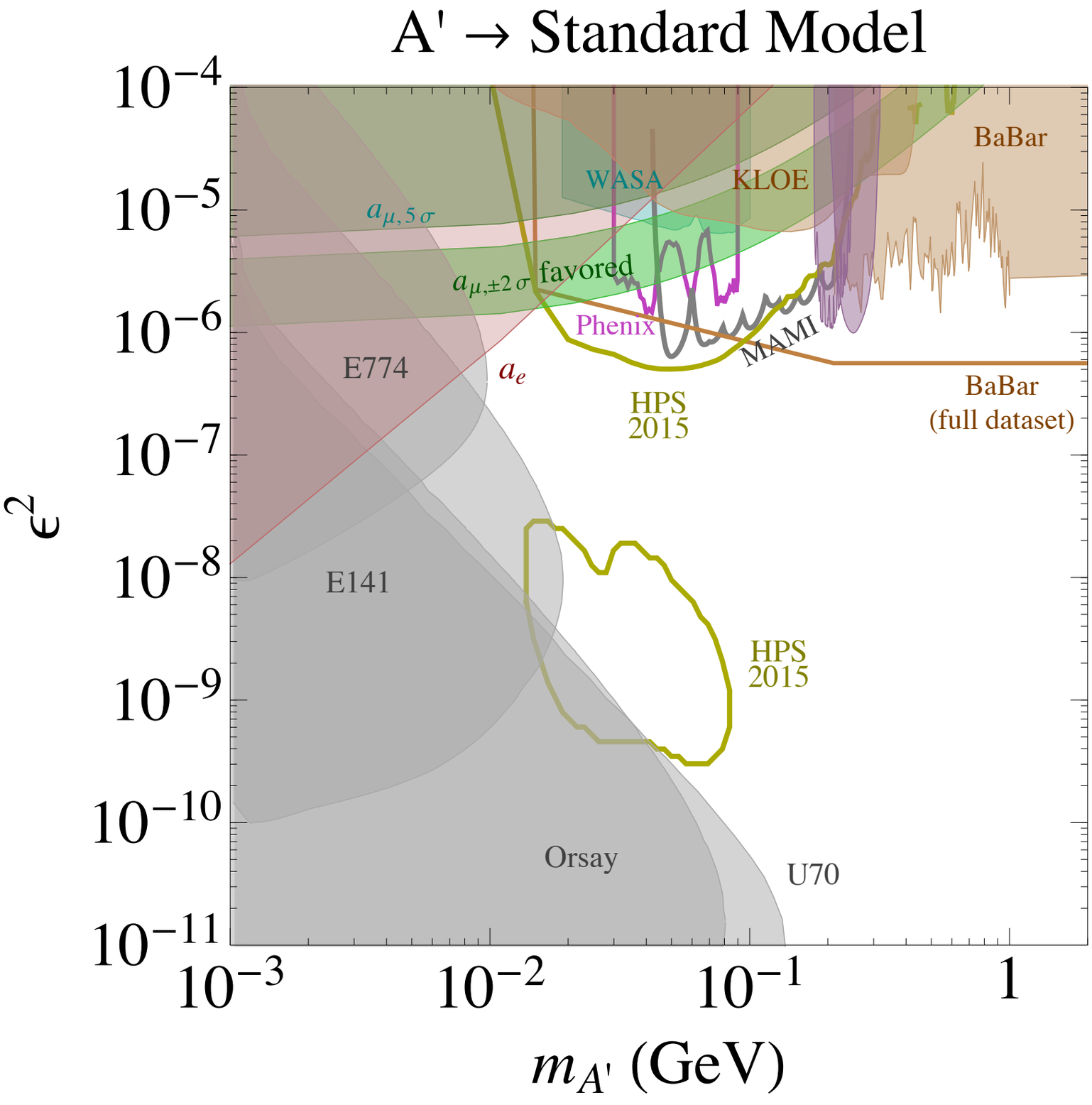


Existing data; analyses almost complete?

BaBar (full dataset, various final states)

projections are rough; final results may differ!!!

Status ~2015?

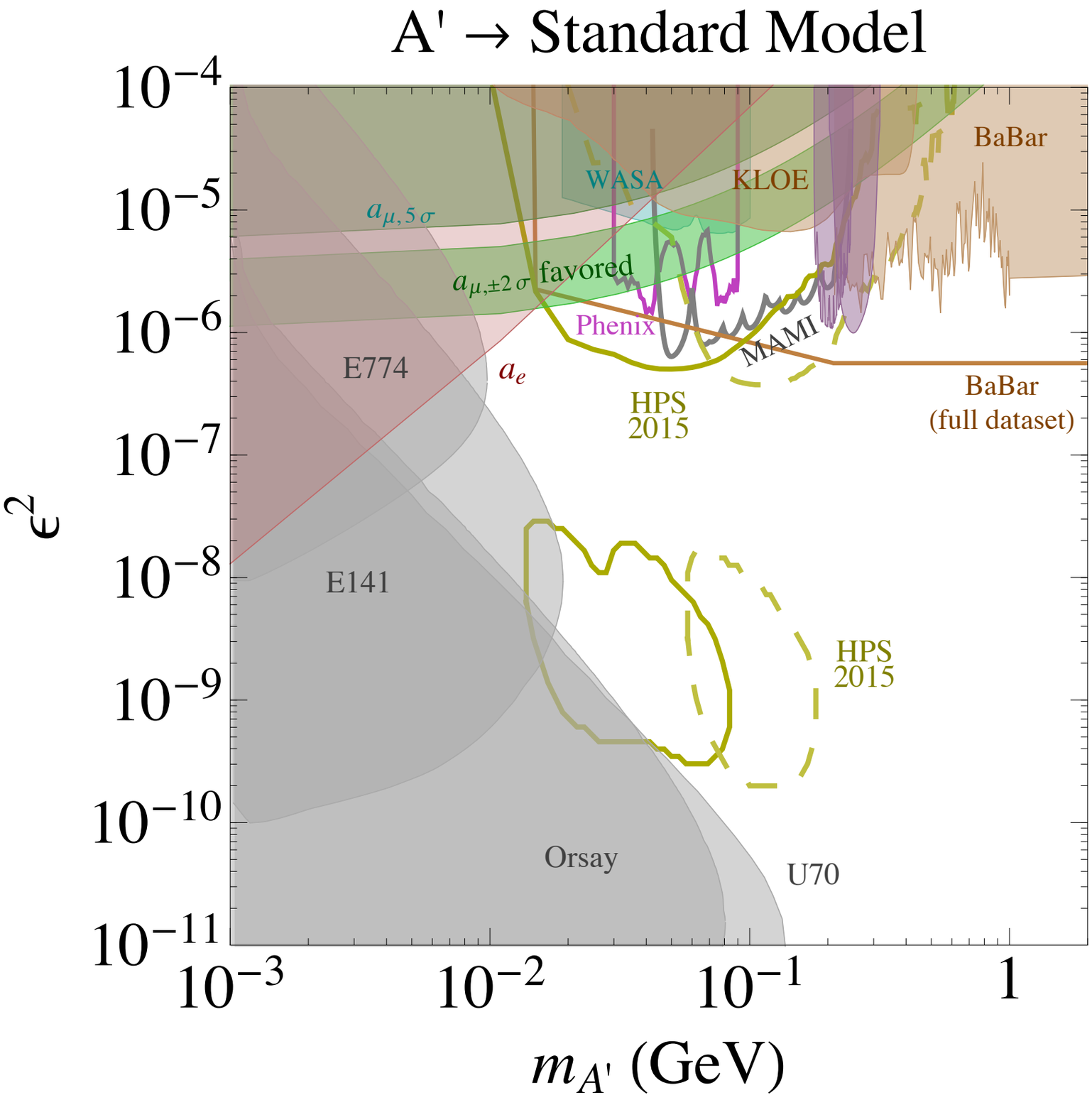


HPS

2015 engineering run in Hall B (approved settings of 1.1 & 2.2 GeV)

covers g-2 decisively, unique vertexing reach

Status ~2015?



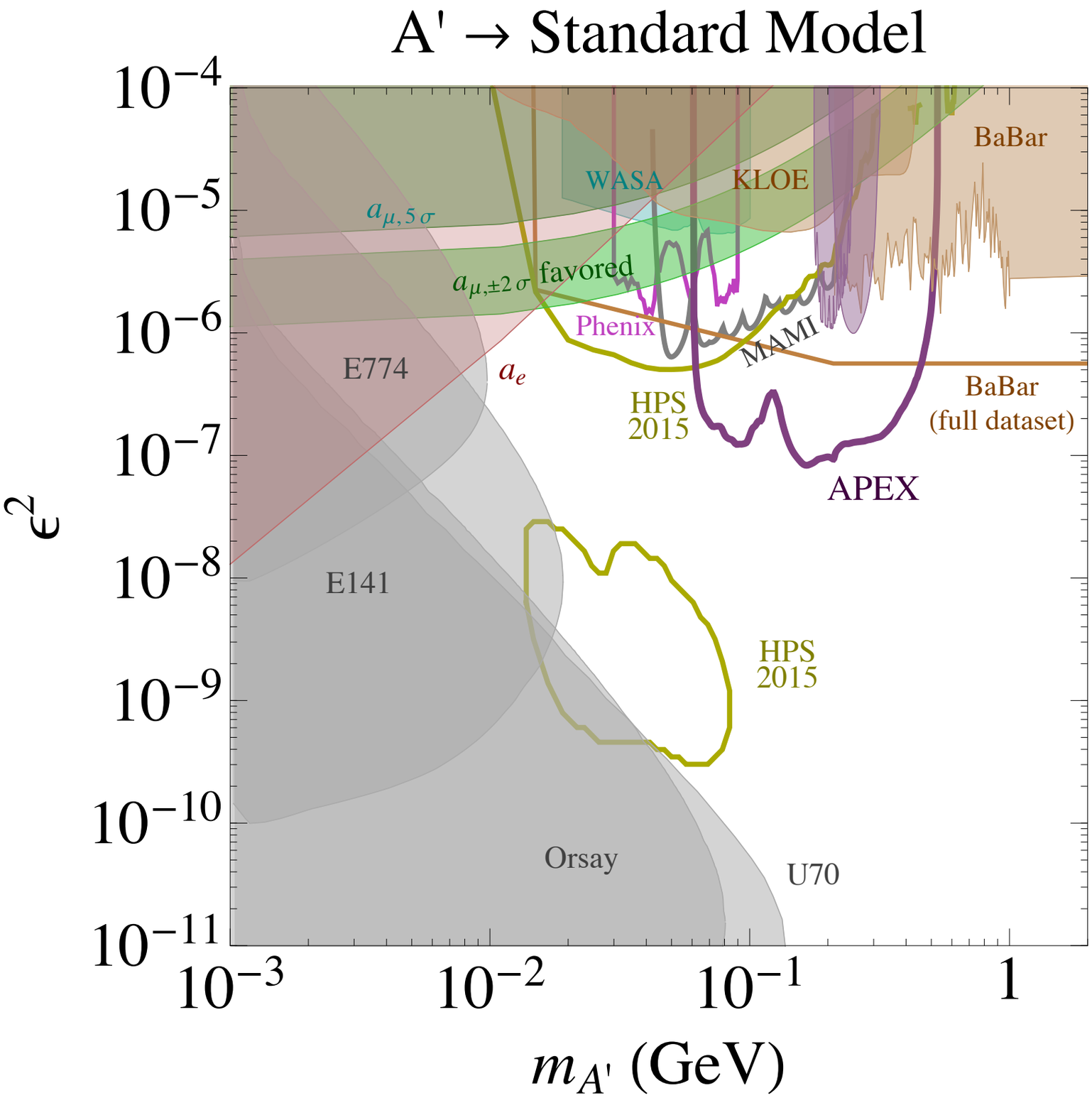
HPS

2015 engineering run in Hall B (approved settings of 1.1 & 2.2 GeV)

w/ additional 2 week run at 4.4 GeV (not yet approved)

covers g-2 decisively, unique vertexing reach

APEX

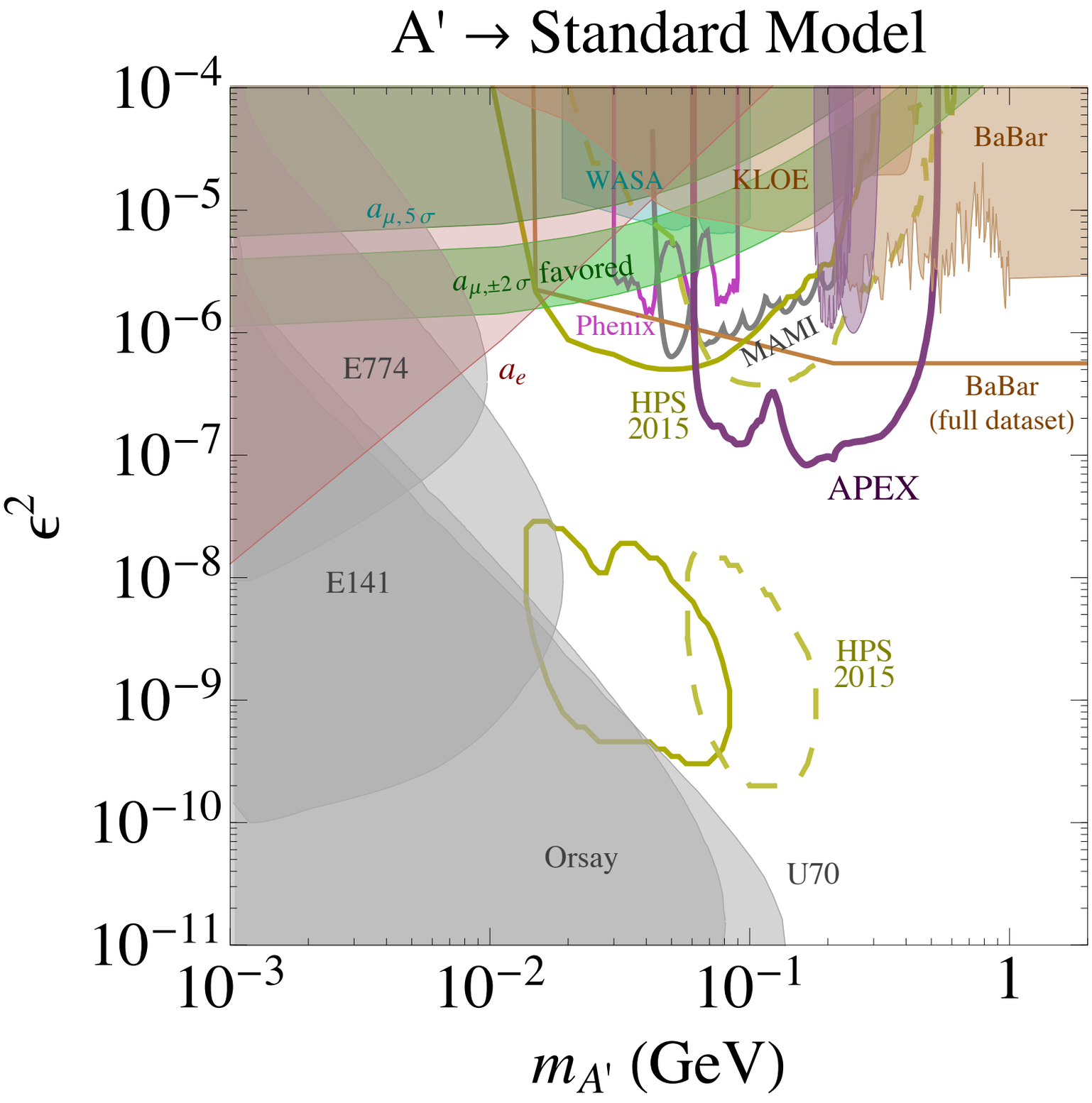


APEX's projected full run (as in PAC 37)

Will have significant new *unique* reach

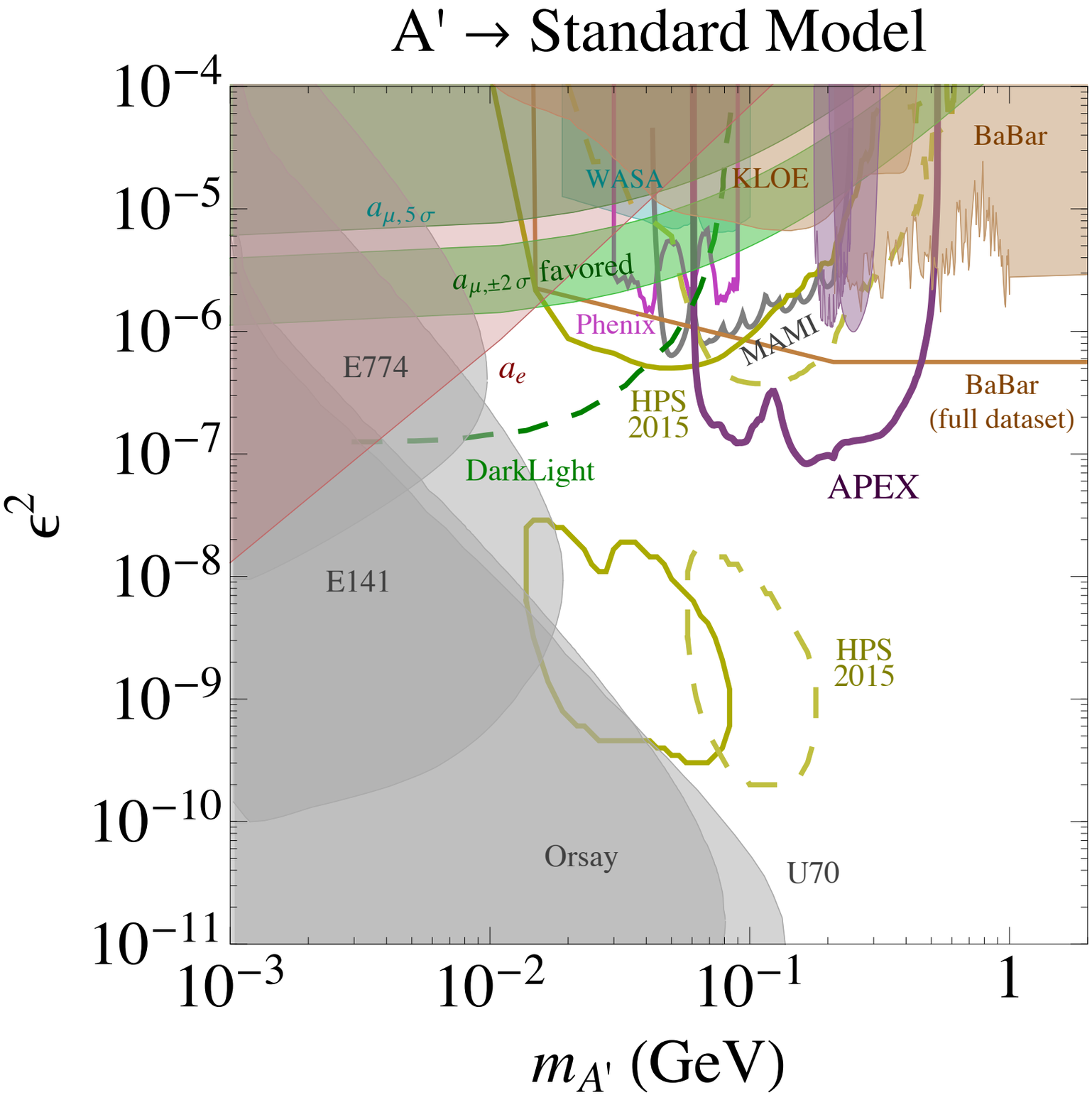
re-optimization of run plan in progress

APEX



even assuming HPS 4.4 GeV run, APEX has significant, new reach

DarkLight

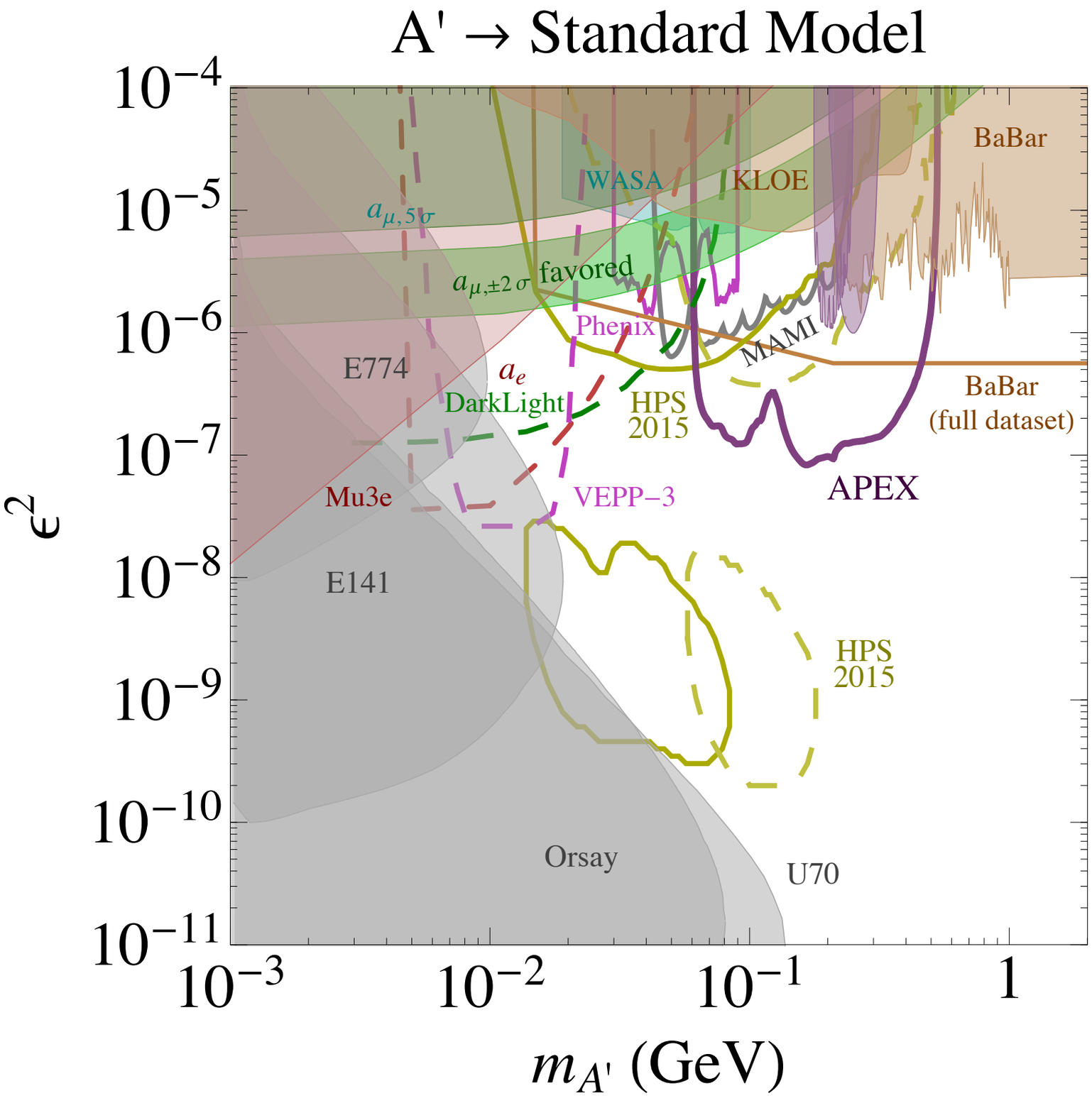


uses JLab FEL

H-gas target

2016?

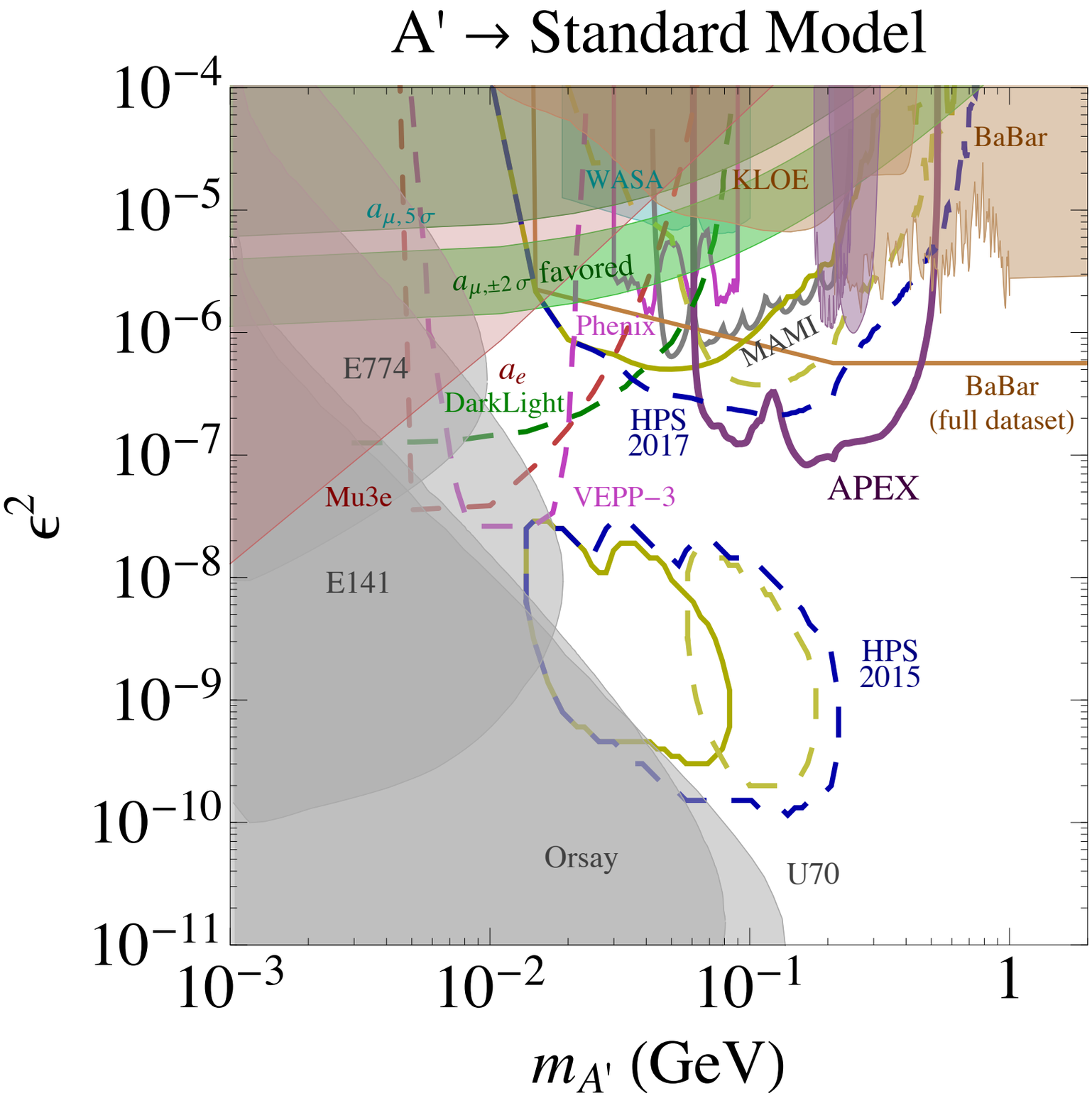
2016 and beyond?



VEPP-3

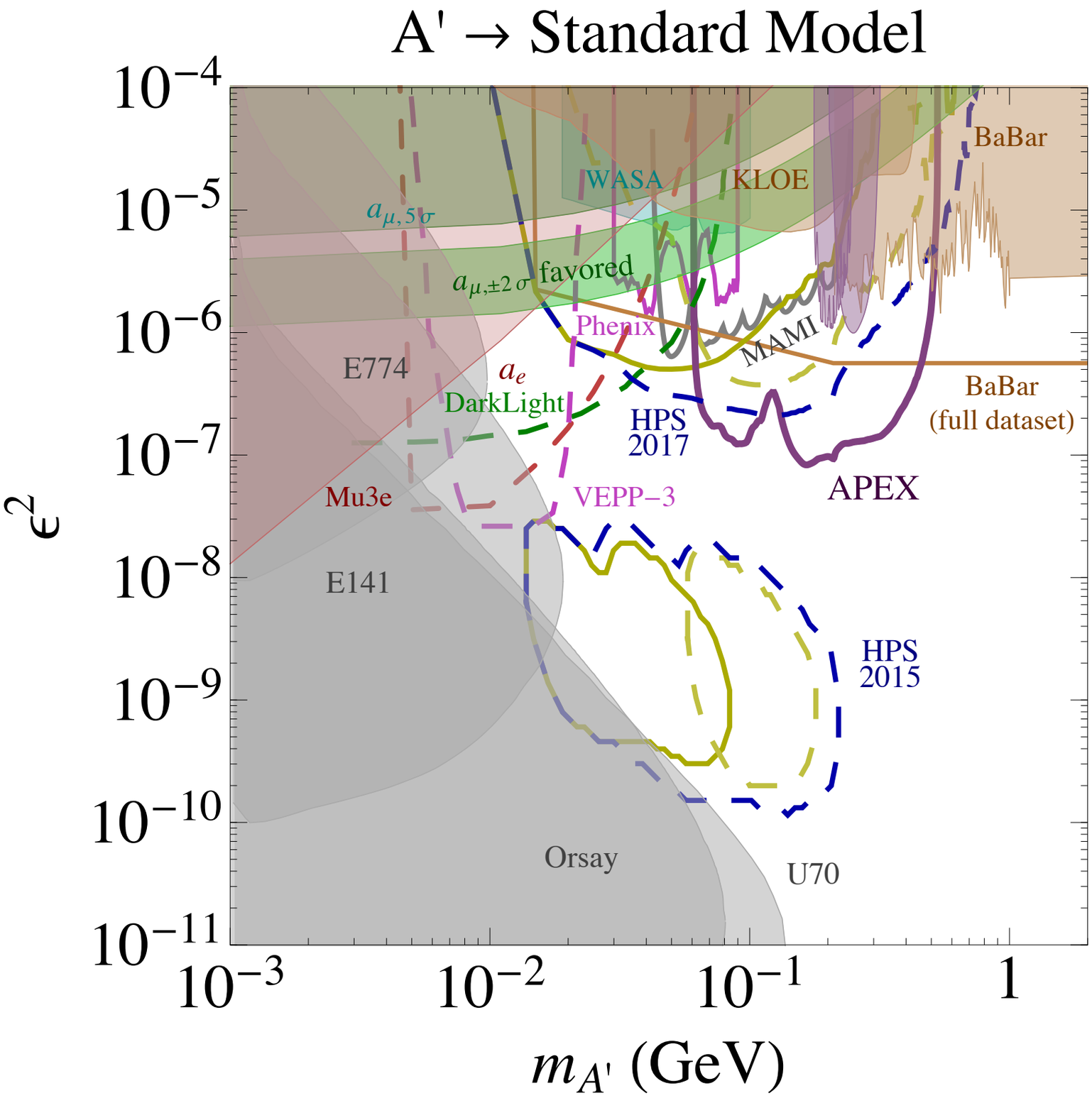
Mu3e

2017?



HPS 2017

2017?

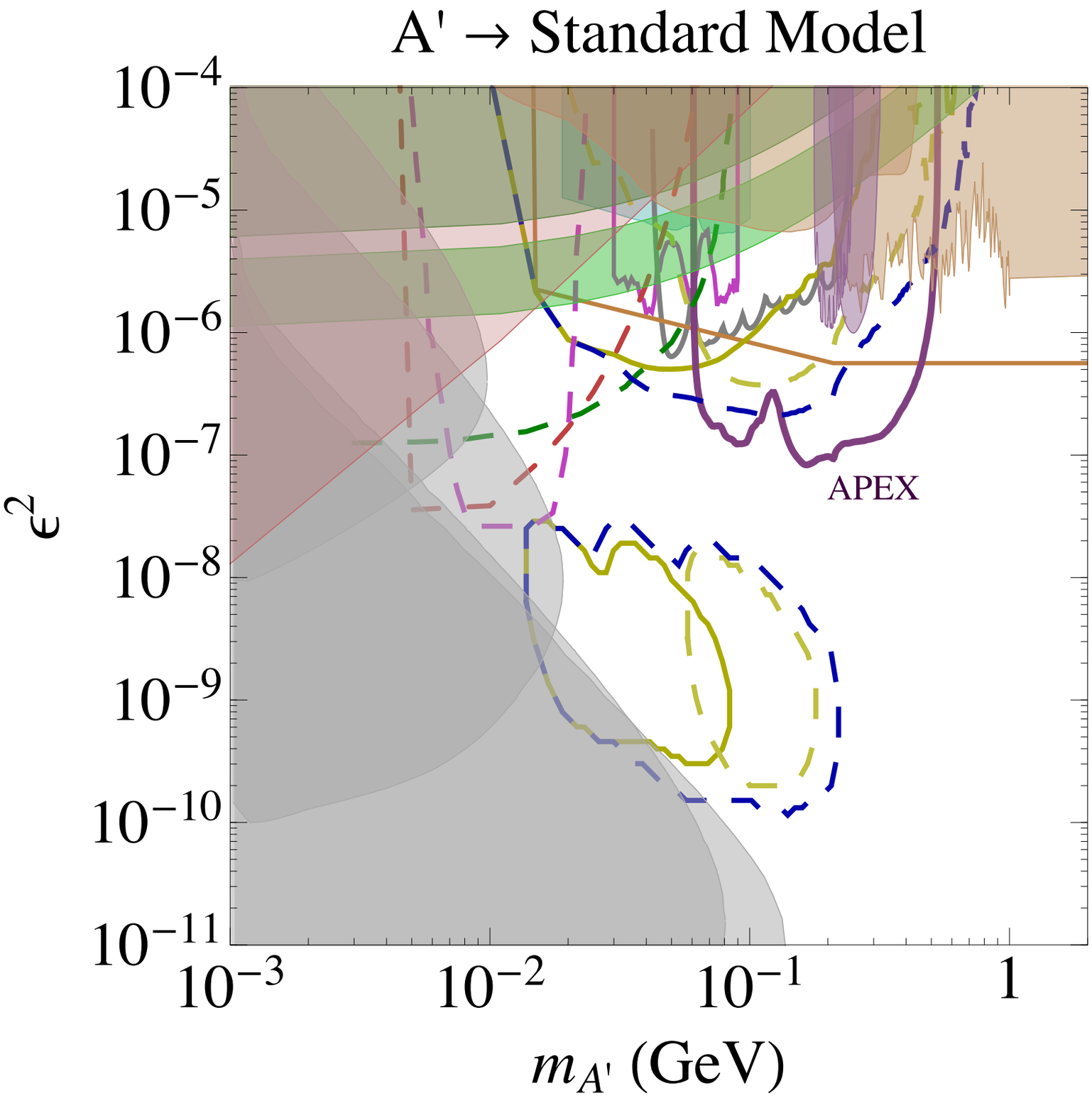


HPS 2017

Unclear:

What are final
MAMI and BaBar reach?
More Phenix data?
CERN-SPS?
other experiments?

2017?



as far as we know, over next several years, APEX will have unique sensitivity at higher masses

Field very active

APEX has important role to play