# The $A'$ Experiment (APEX)

## The Search for new fundamental forces at Jefferson Lab

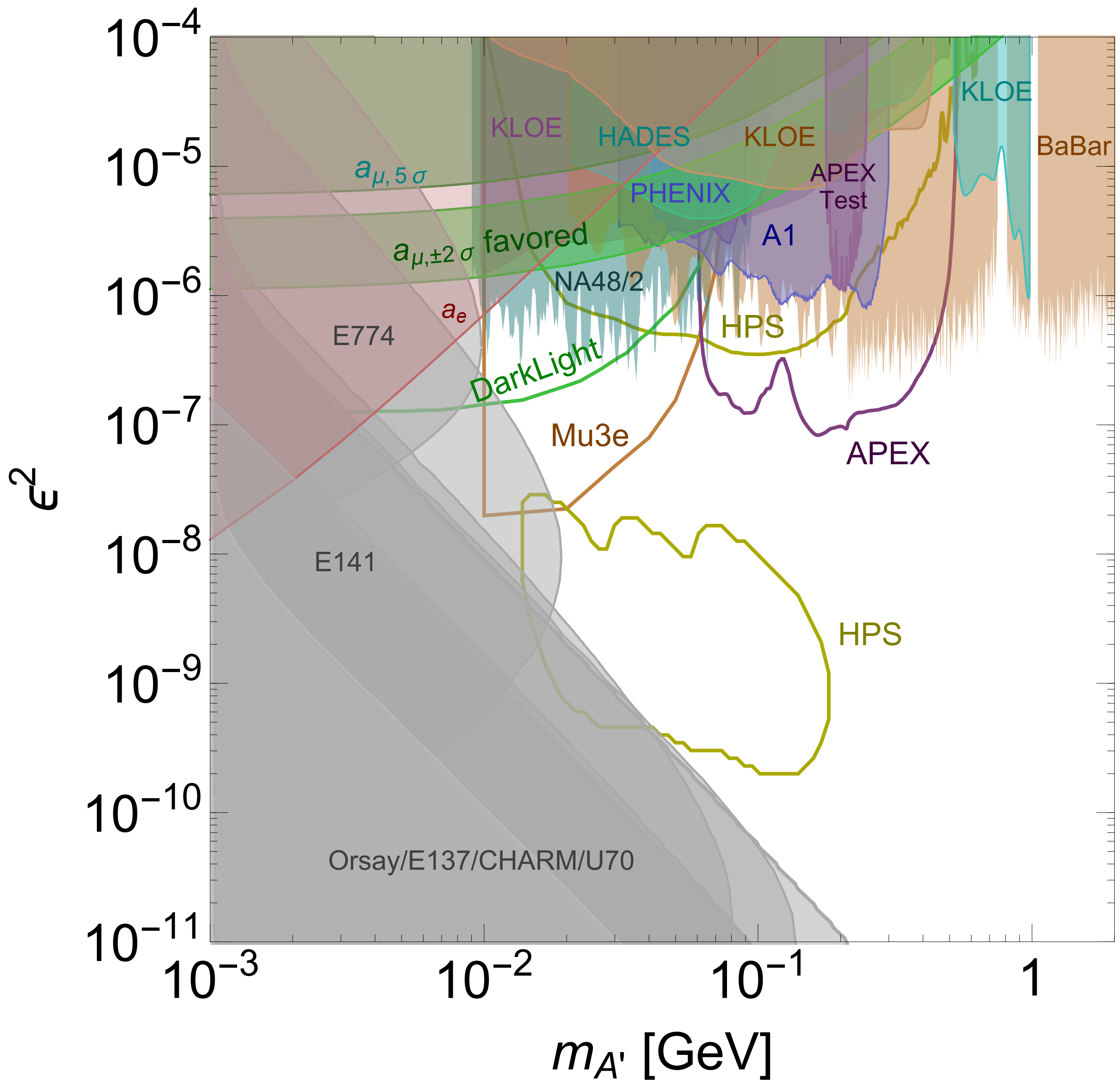
on behalf of the APEX collaboration

APEX spokespeople
Rouven Essig
Philip Schuster
Natalia Toro
Bogdan Wojtsekhowski

Experimental Readiness Review
April 7, 2016

# Overview

In brief: APEX is a spectrometer-based search, at JLab Hall A, for 50-550 MeV dark photons decaying promptly to $e^+e^-$



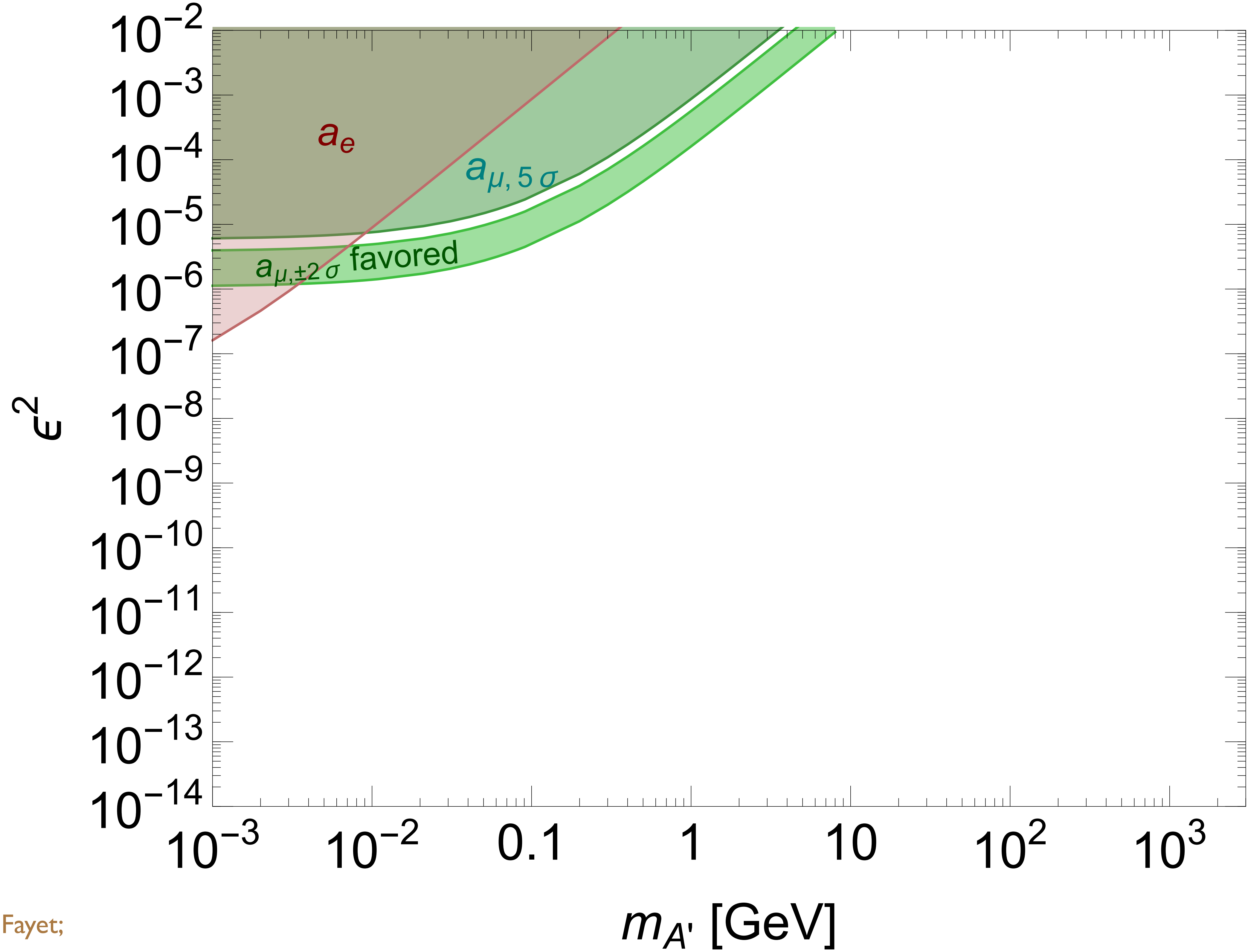

## APEX:

- has unique reach among dark photon experiments worldwide
- is pioneering, low-cost, proven in a test run

# Why search for Dark Photons?

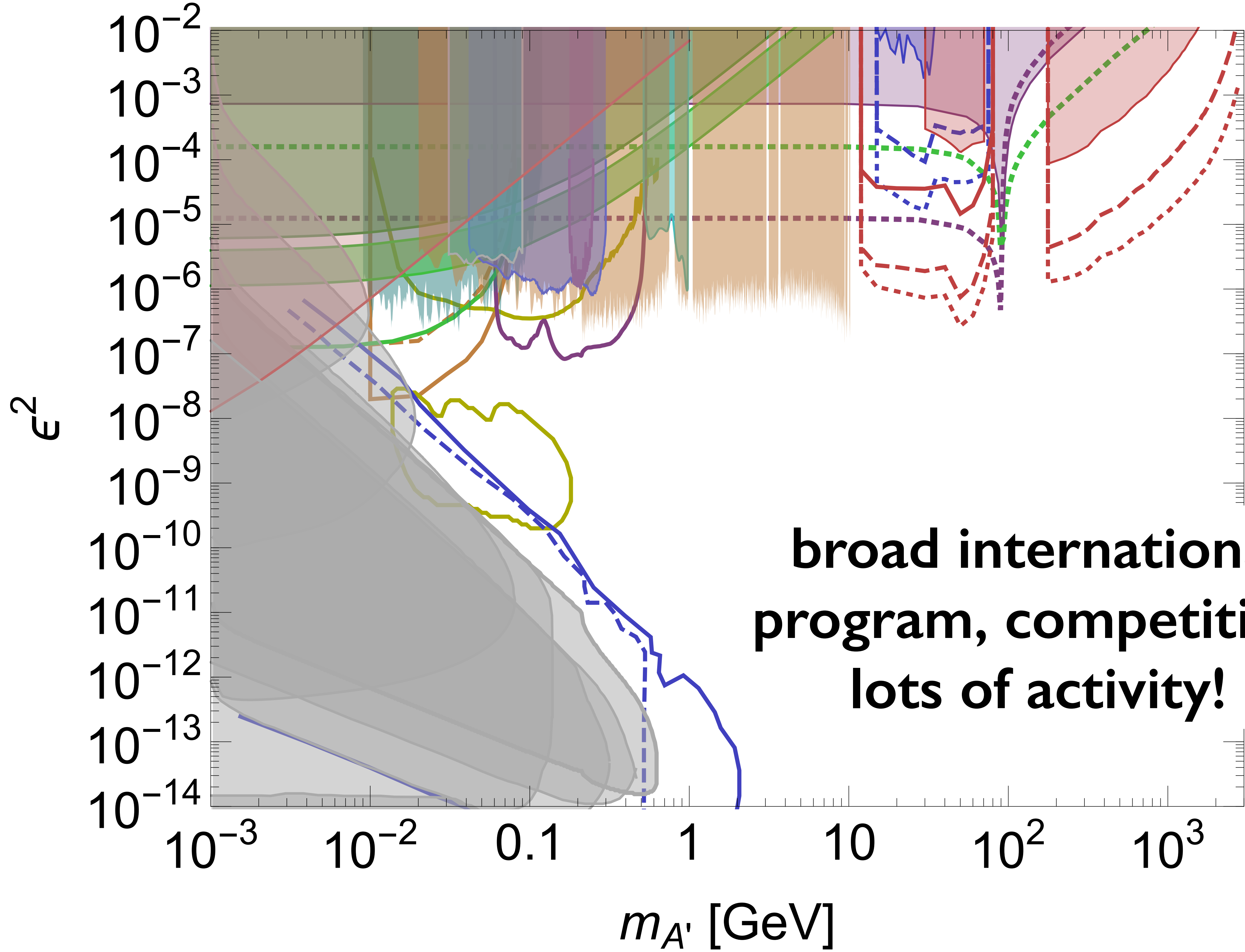
- Simple and ubiquitous in Beyond SM scenarios; dark photon portal could easily be most accessible portal — theoretically, ε could be O(1)!
- muon g-2
- A′ could couple to dark matter, leading to an amazing variety of possible signatures:
  - data "anomalies" can guide specific scenarios
  - simple, well-motivated DM models (e.g. sub-GeV DM) motivate new searches/interpretations

# A′ Status 2008



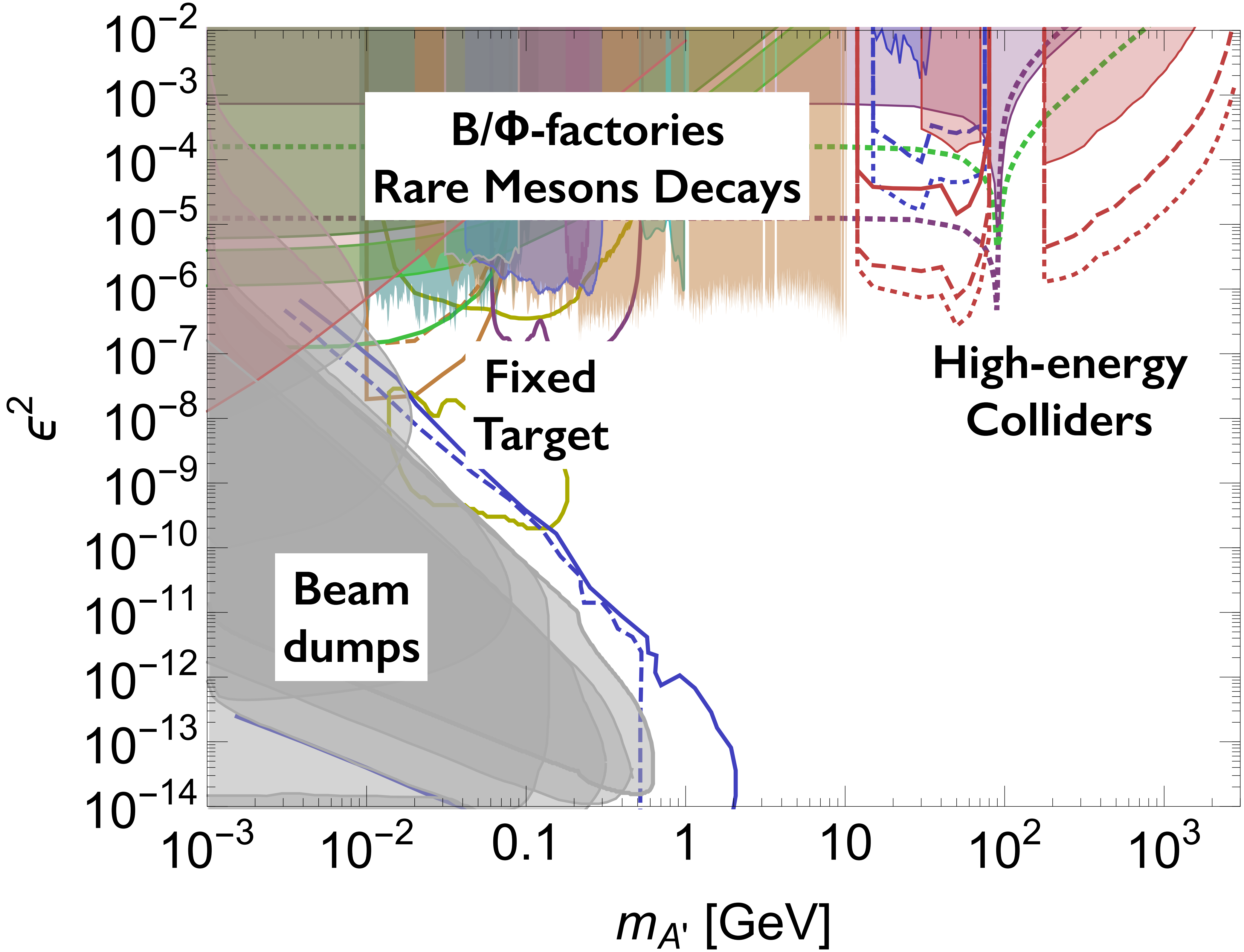

Pospelov; Fayet;

# A′ Status Today

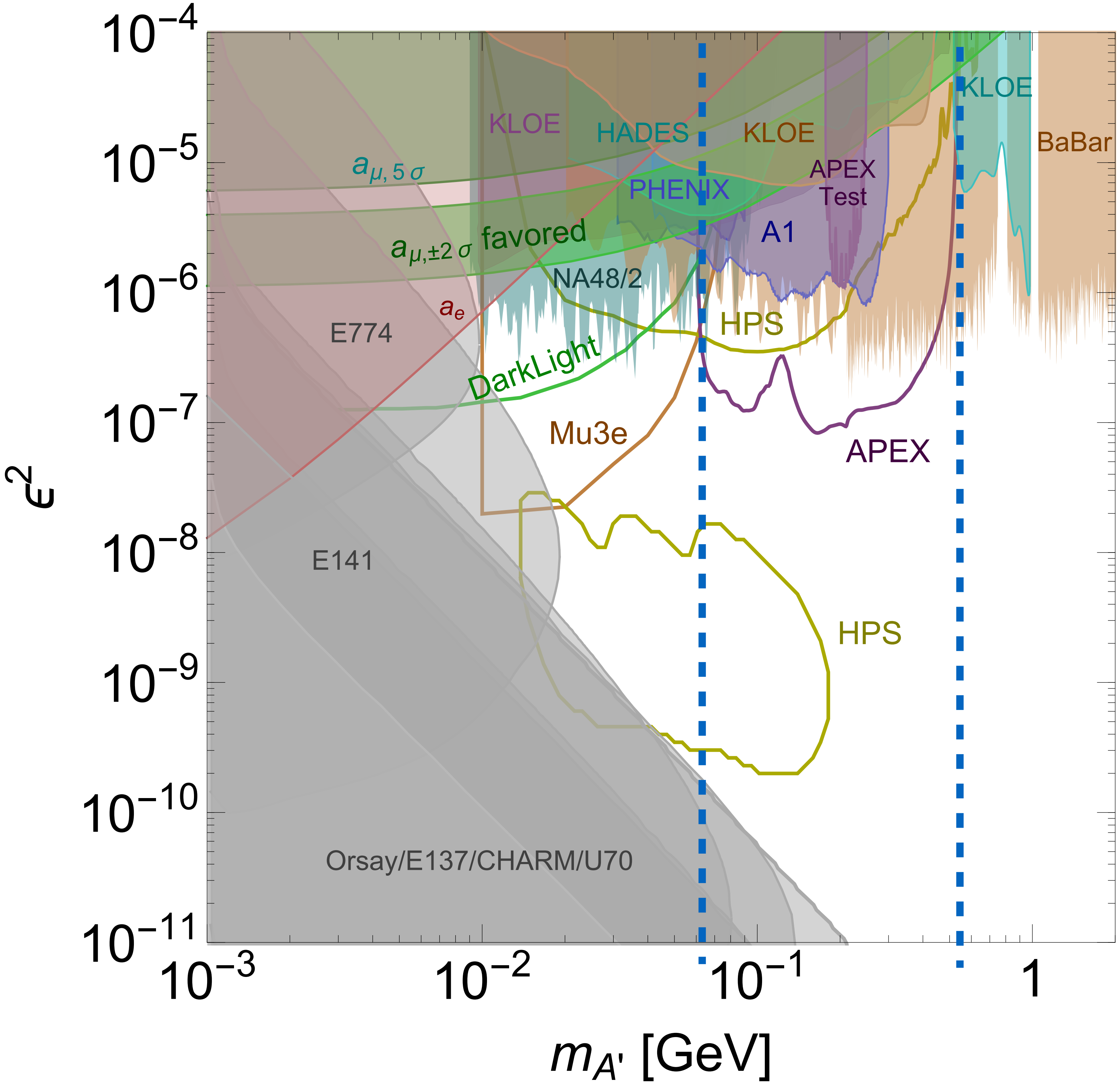



**broad international program, competitive, lots of activity!**

# A′ Status Today

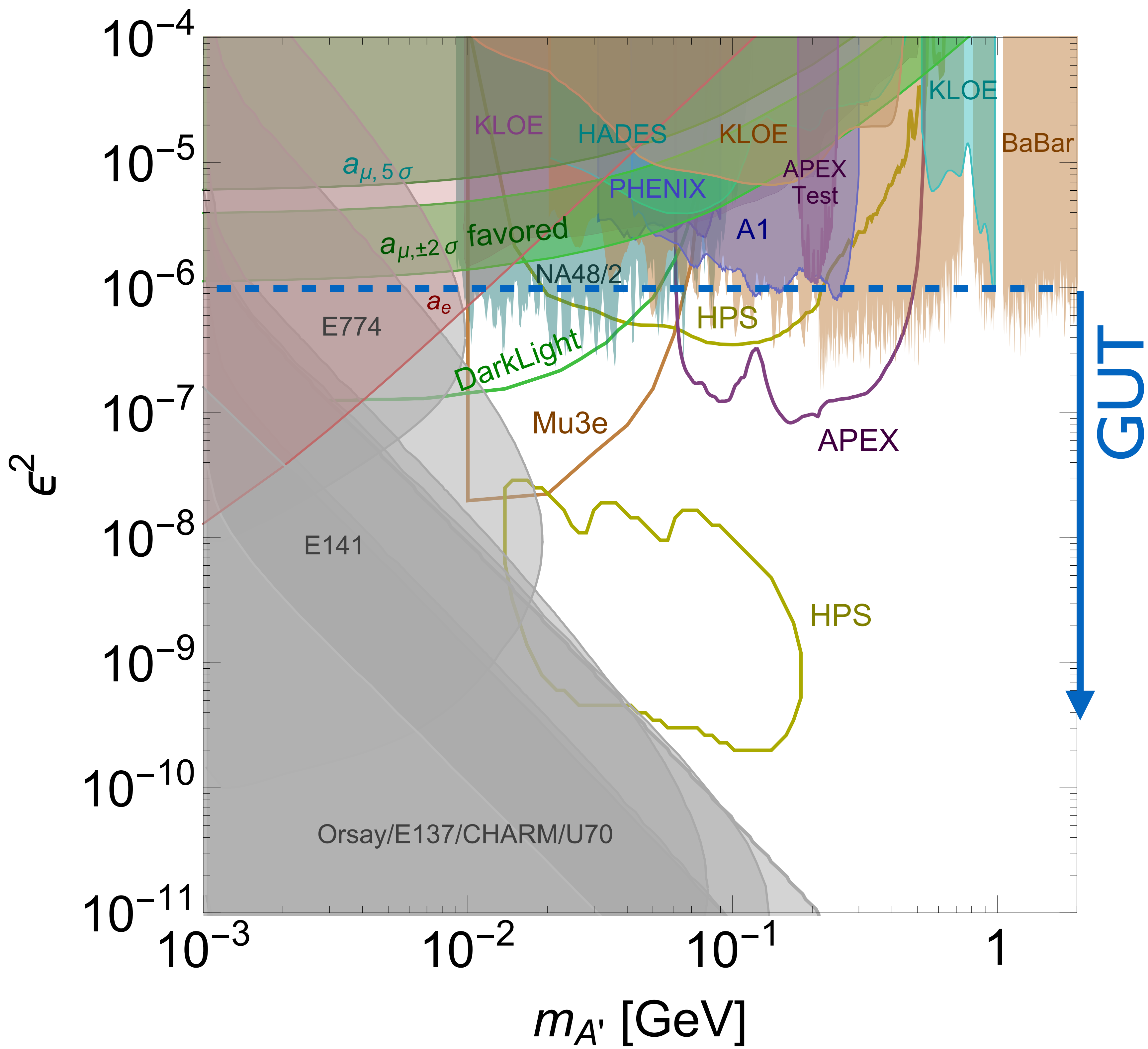


# APEX: unique + important reach




unique reach
at high masses

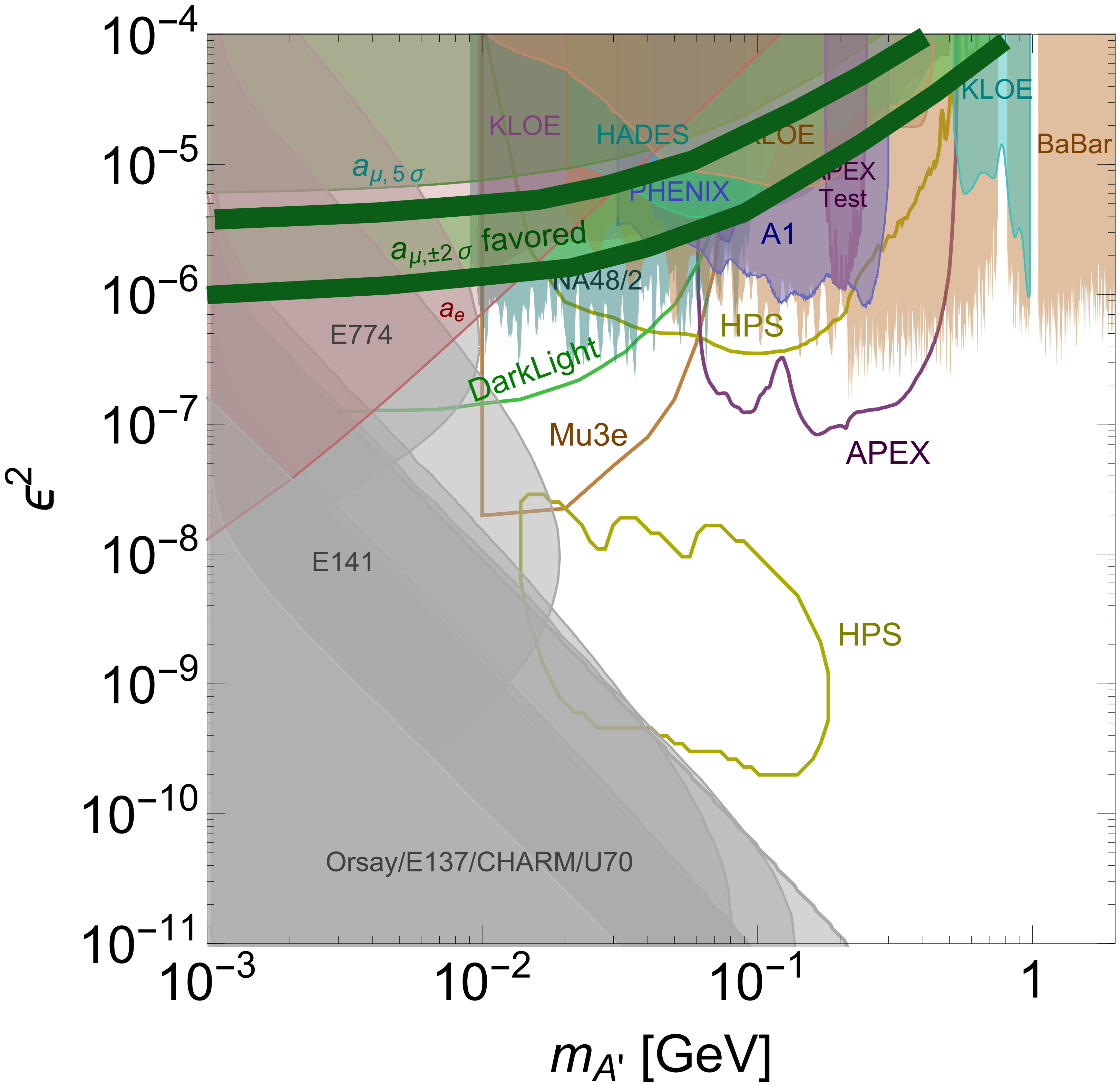
# APEX: unique + important reach




unique reach at high masses

first major exploration of ε region expected from GUT symmetry

# APEX: unique + important reach

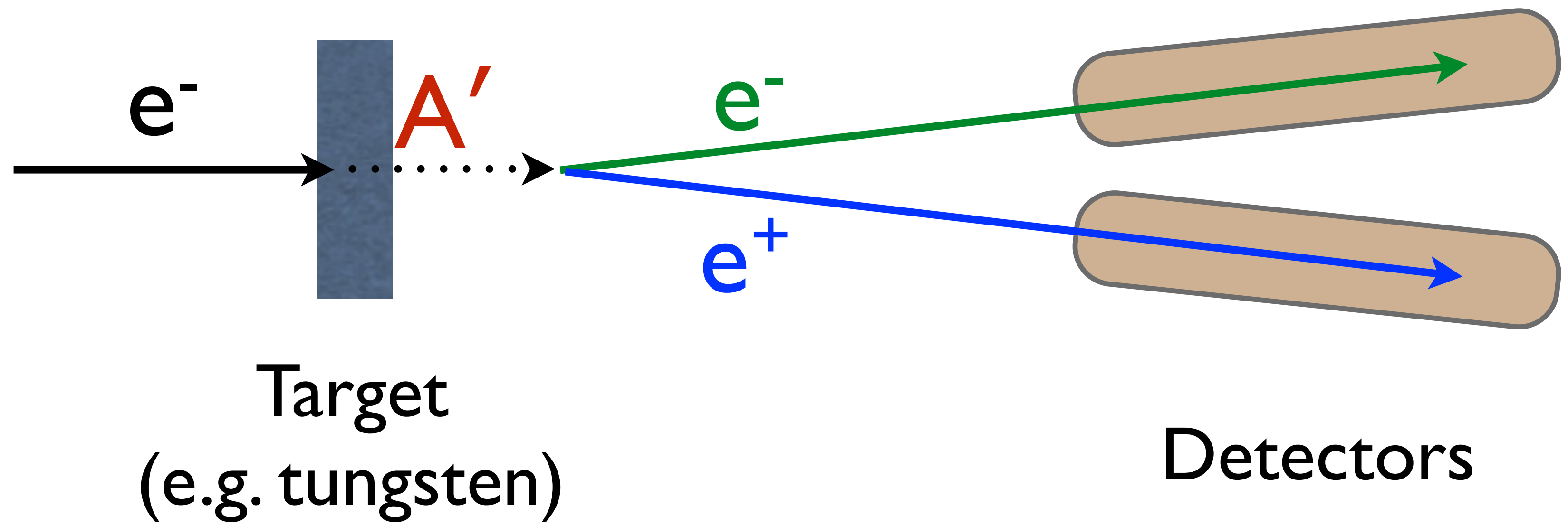


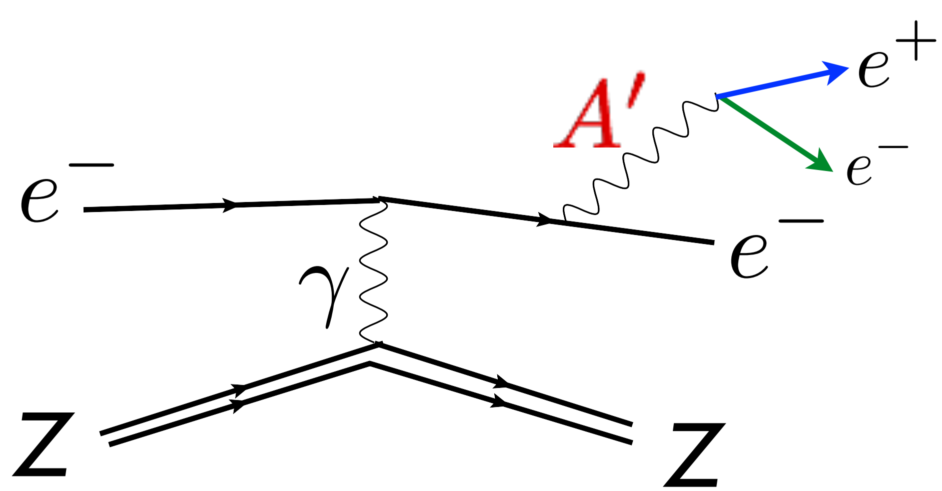

unique reach at high masses

first major exploration of ε region expected from GUT symmetry

can probe g-2 for $\mathrm{Br}(A' \to \text{visible}) \gtrsim 1\%$ !

# Electron-beam Fixed-Target Concept

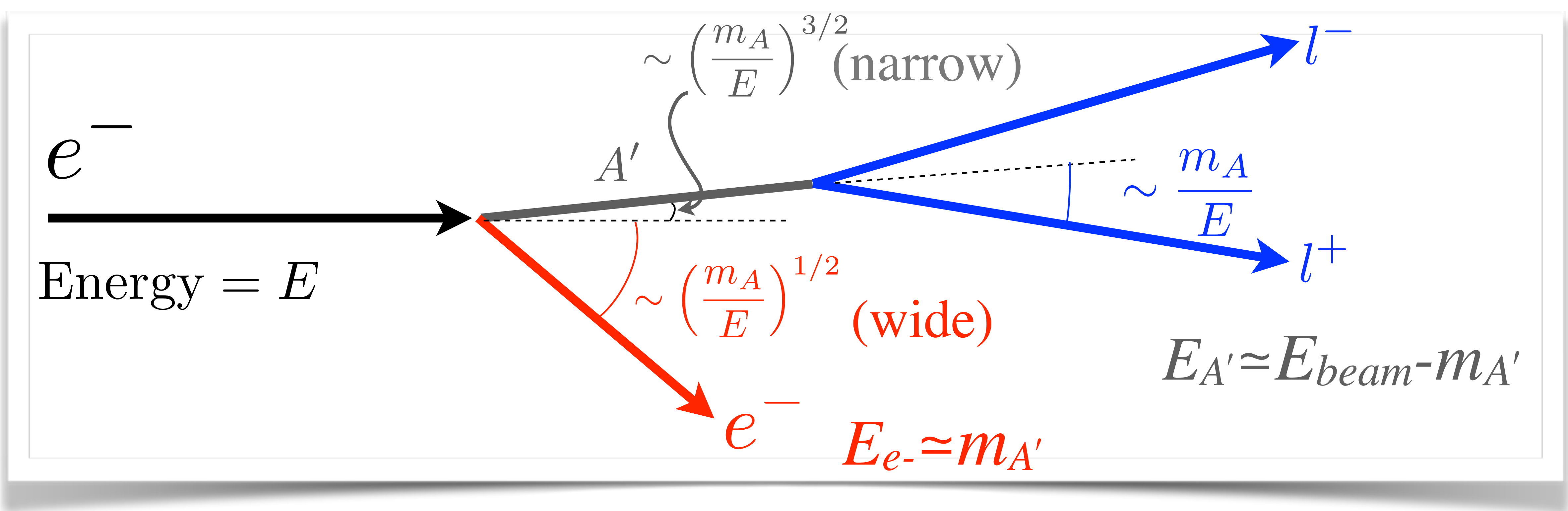


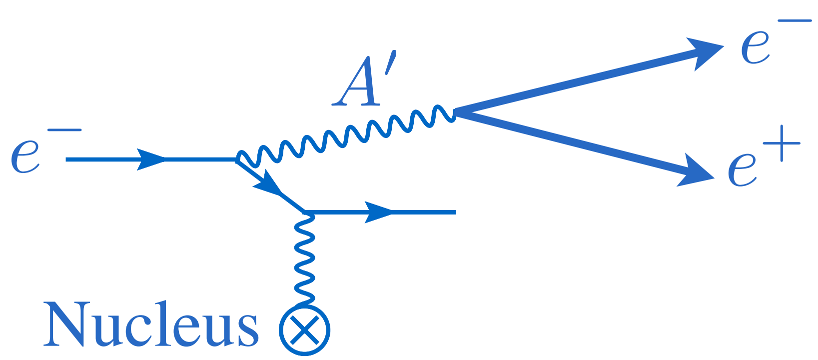



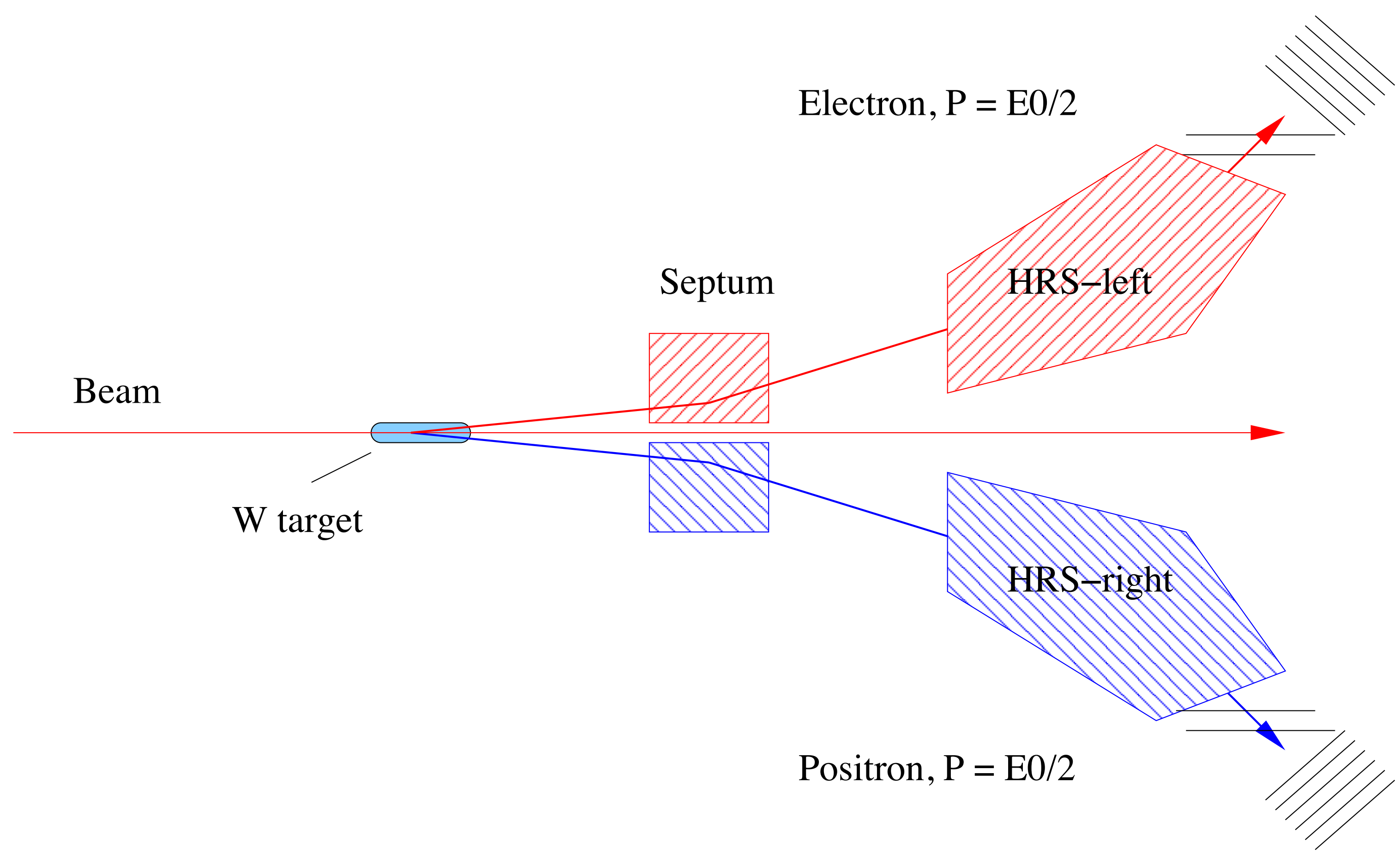

look for A′ → $e^+e^-$
**resonance** ("bump hunt")
or **displaced vertex**

existing (beam dump) constraints & strategies outlined in
Bjorken, RE, Schuster, Toro *PRD, 2009*

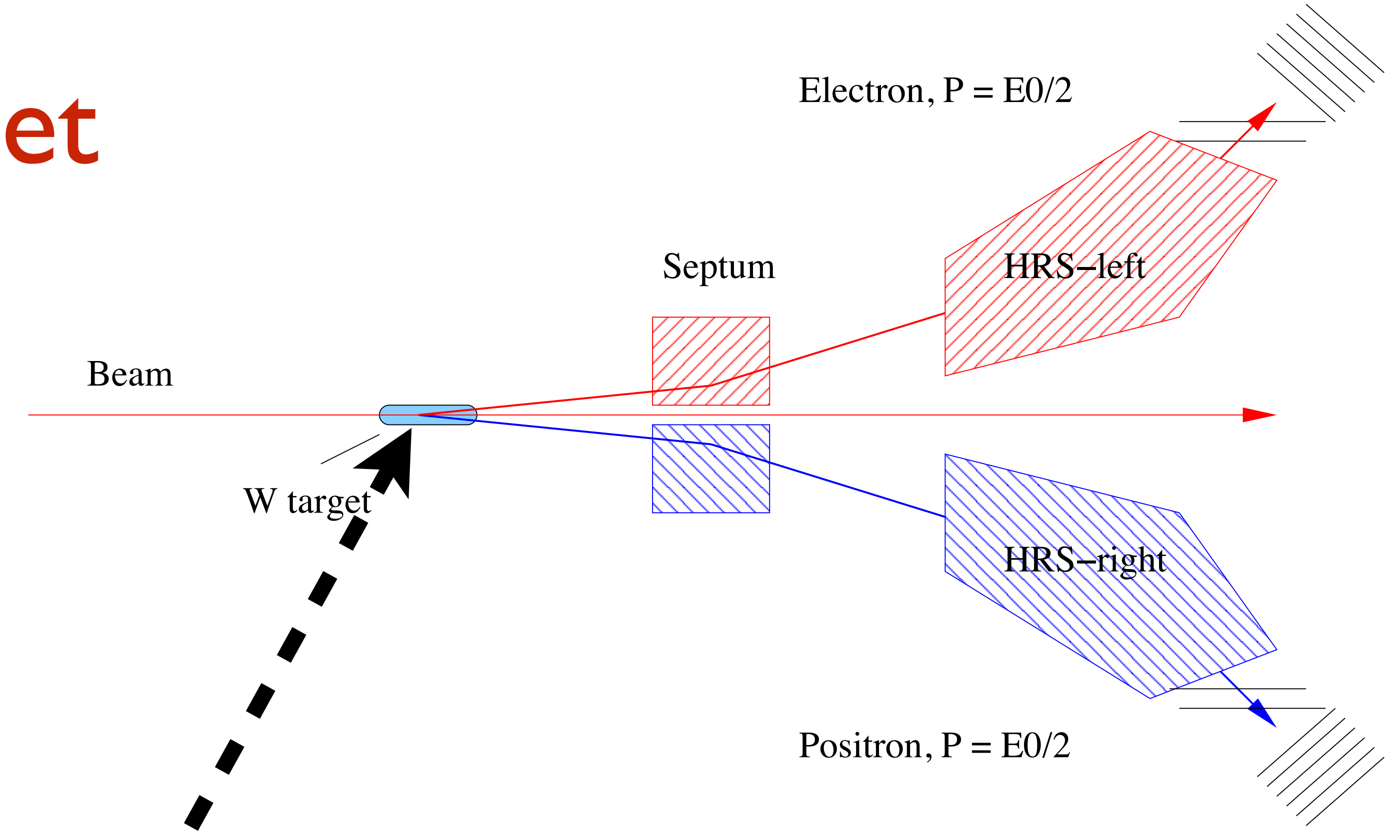
# A′ Production & APEX Setup



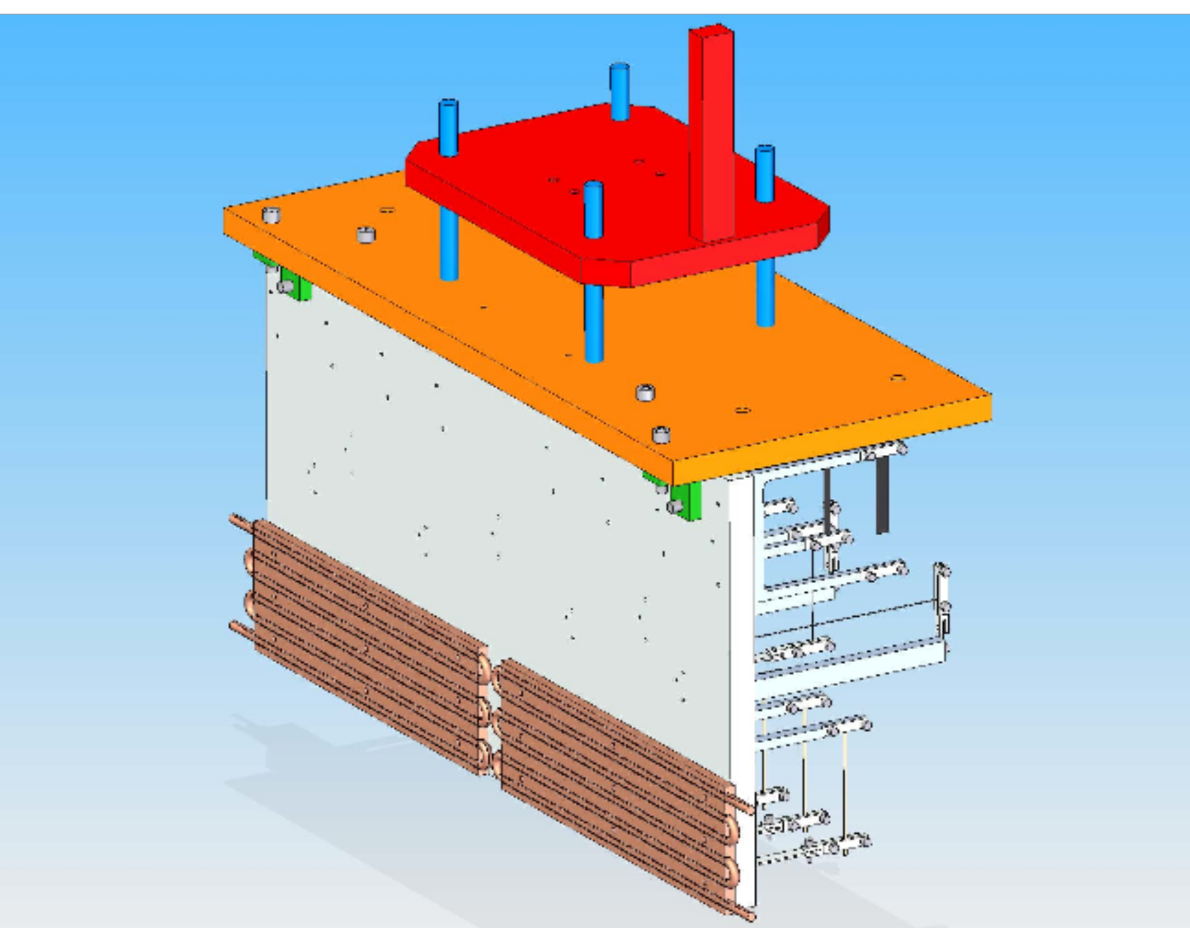



# Experimental Setup: target

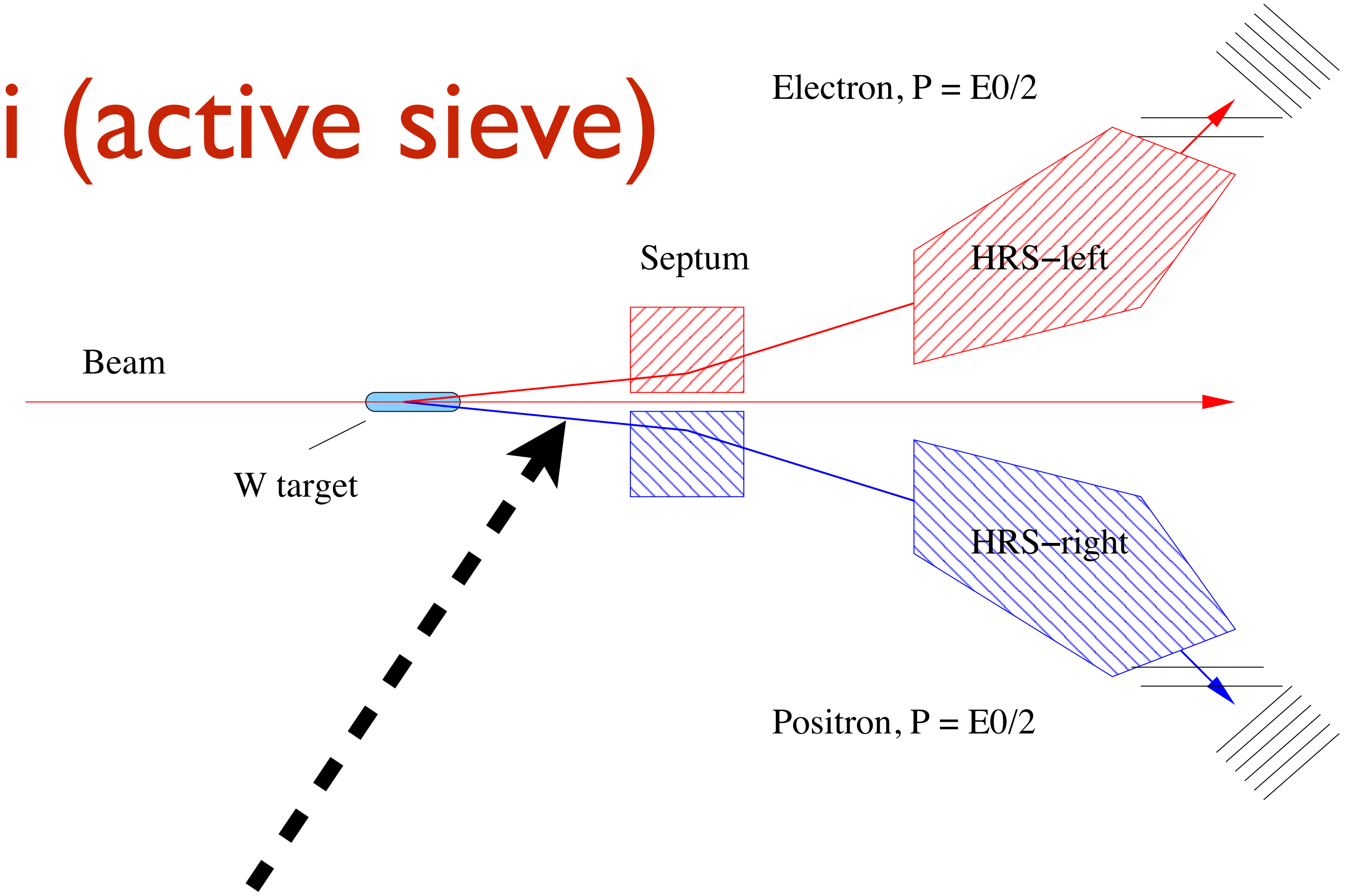



multiple foils achieve large rate while keeping multiple scattering to a minimum

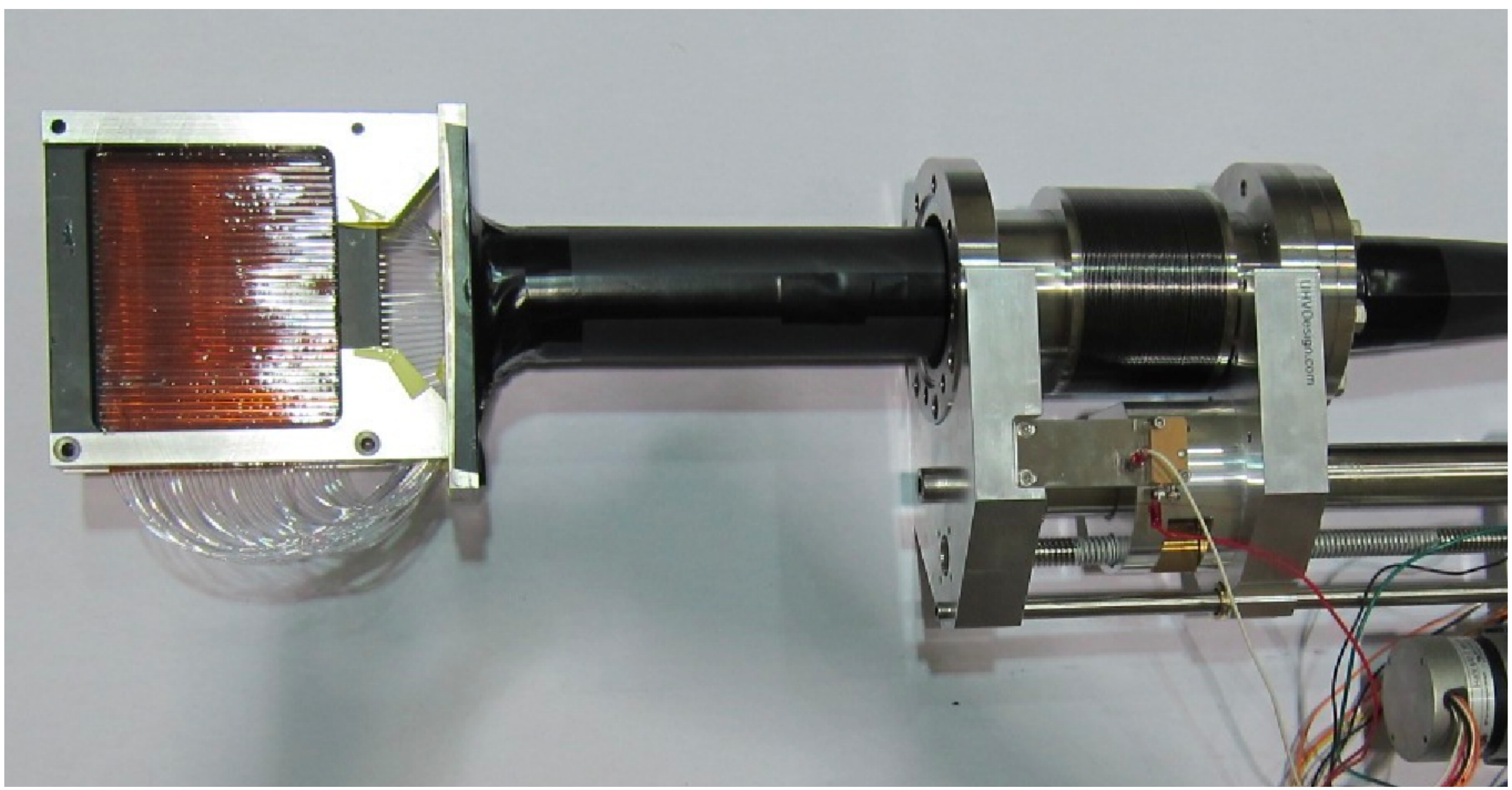


see Silviu Covrig's talk

# Experimental Setup: SciFi (active sieve)



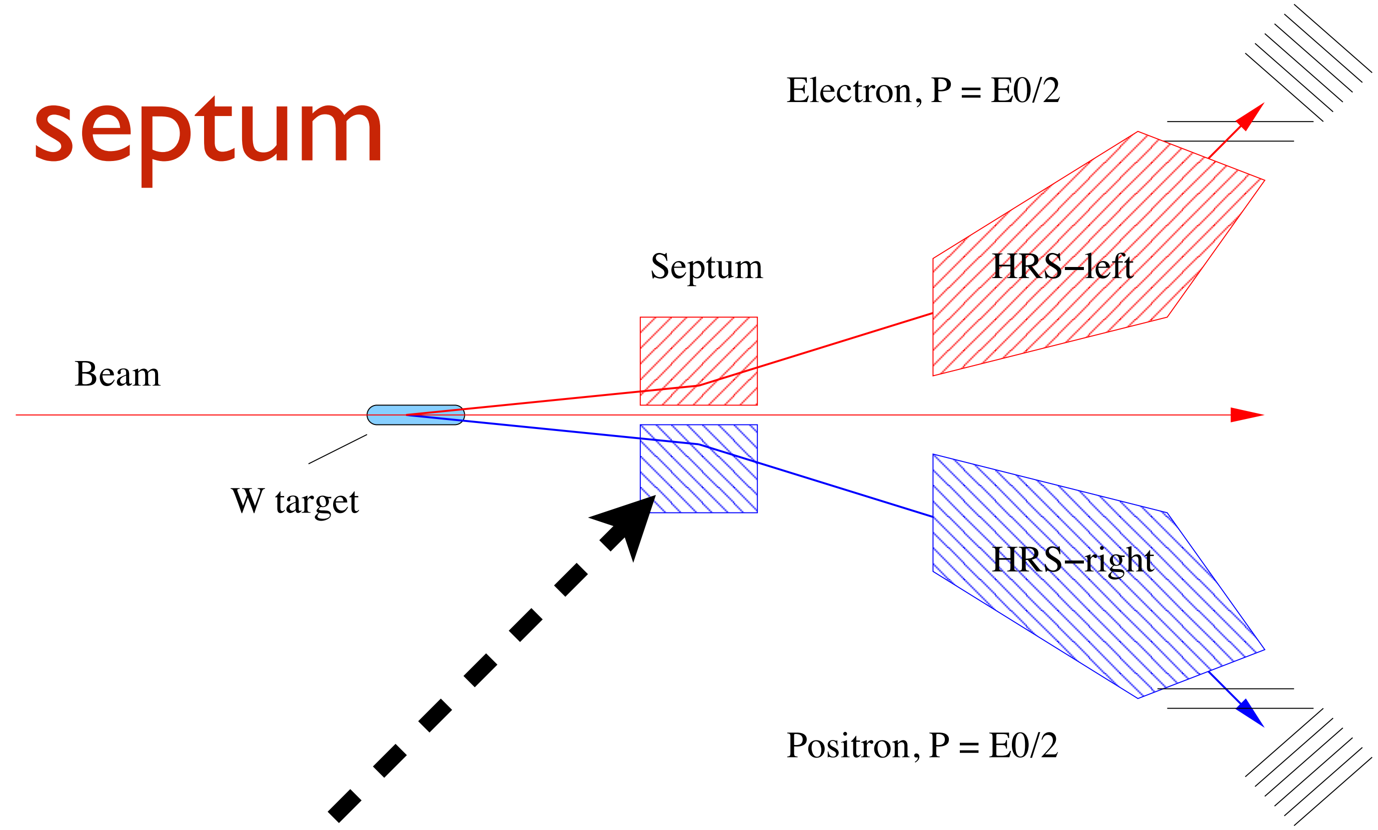

needed to achieve
excellent mass resolution

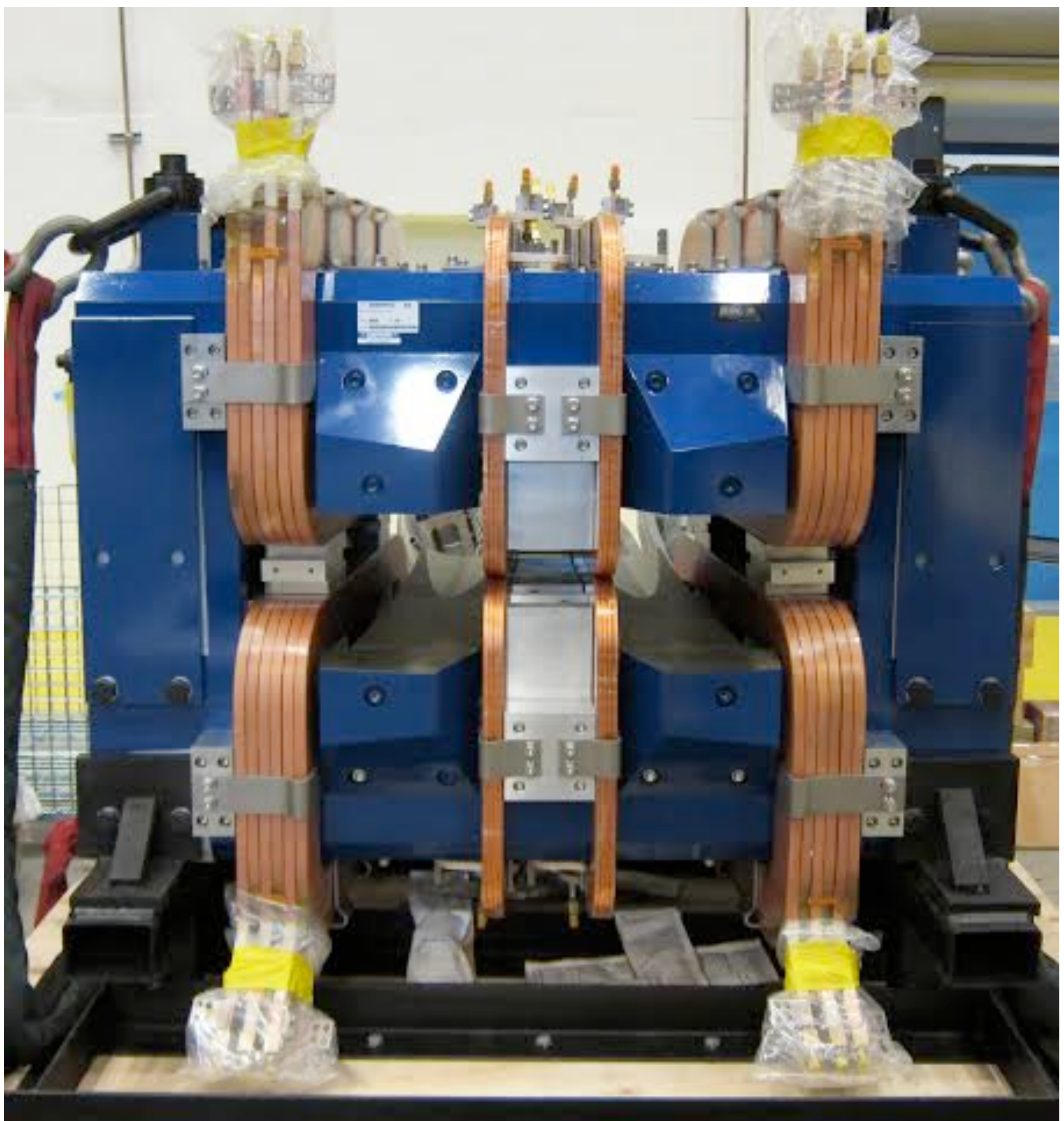


see
Gregg Franklin's
talk

# Experimental Setup: new septum

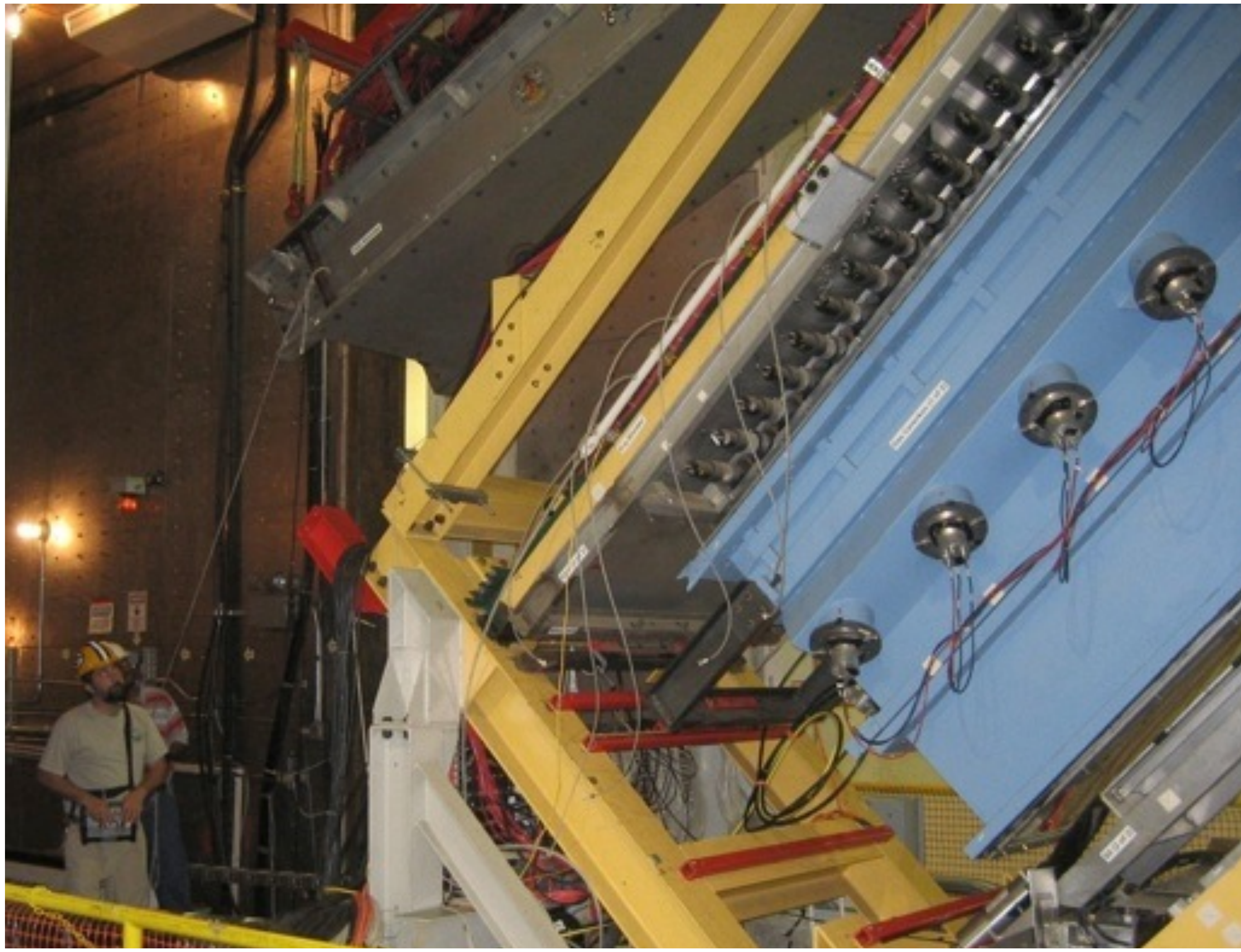
detect small-angle $e^+e^-$ pairs
to maximize S/B

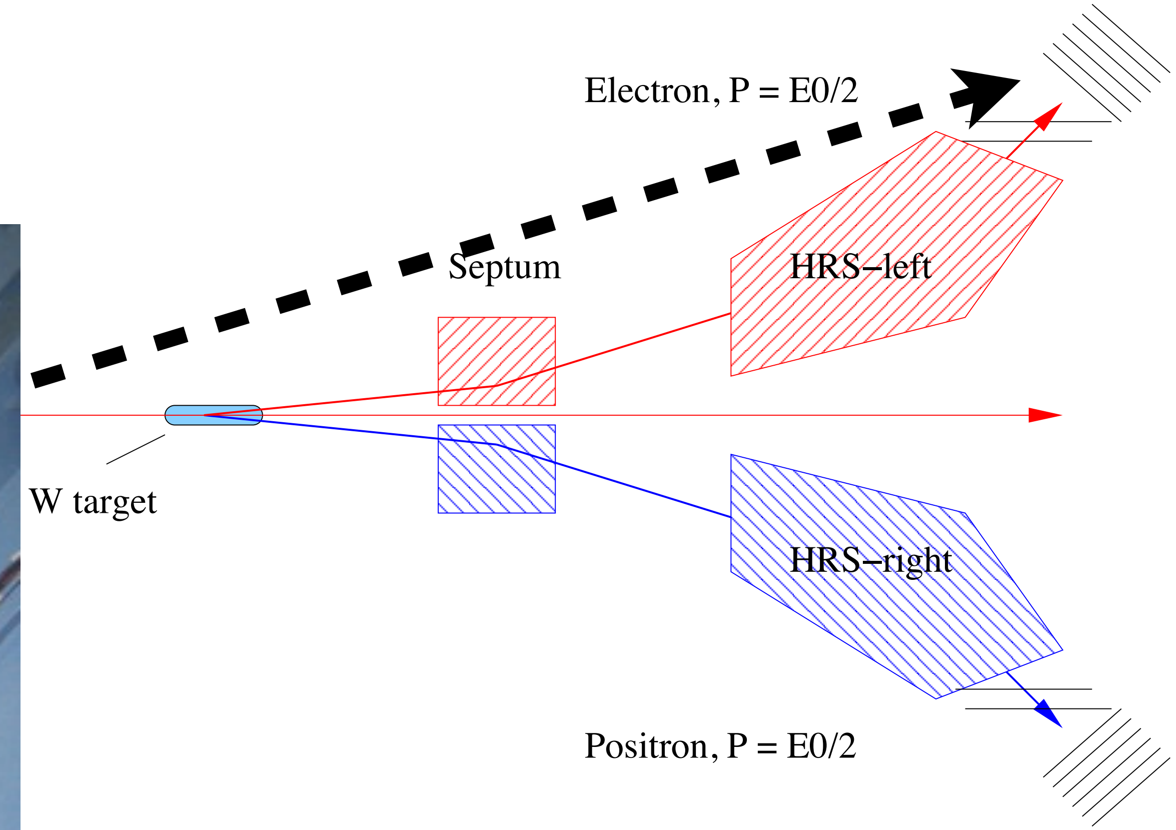


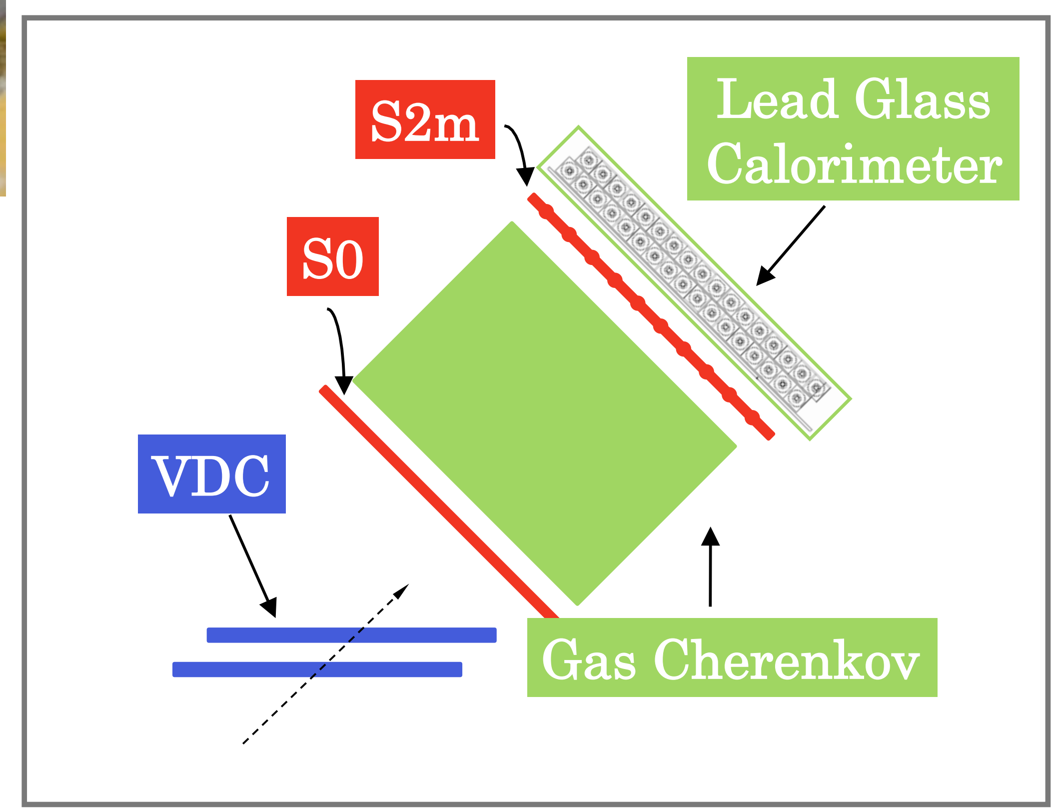
see
Robin Wines &
Jessie Butler's
talks

# Experimental Setup: HRS






| | | |
|---|---|---|
| Momentum resolution | | $1\times10^{-4}$ |
| Angular resolution : | Horizontal | 0.5 mrad |
| | Vertical | 1.0 mrad |
| Momentum acceptance | $(\delta p/p)$ | $\pm4.5\%$ |
| Angular acceptance : | Horizontal | $\pm30$ mrad |
| | Vertical | $\pm60$ mrad |
| Min. central angle | | $12.5°$ |

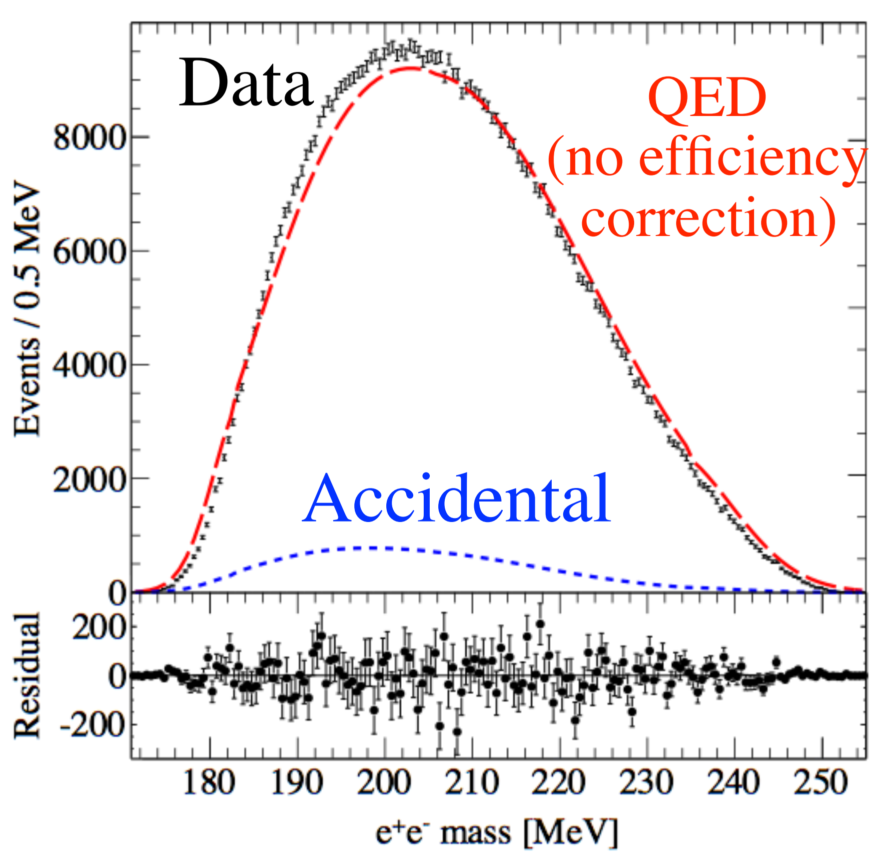


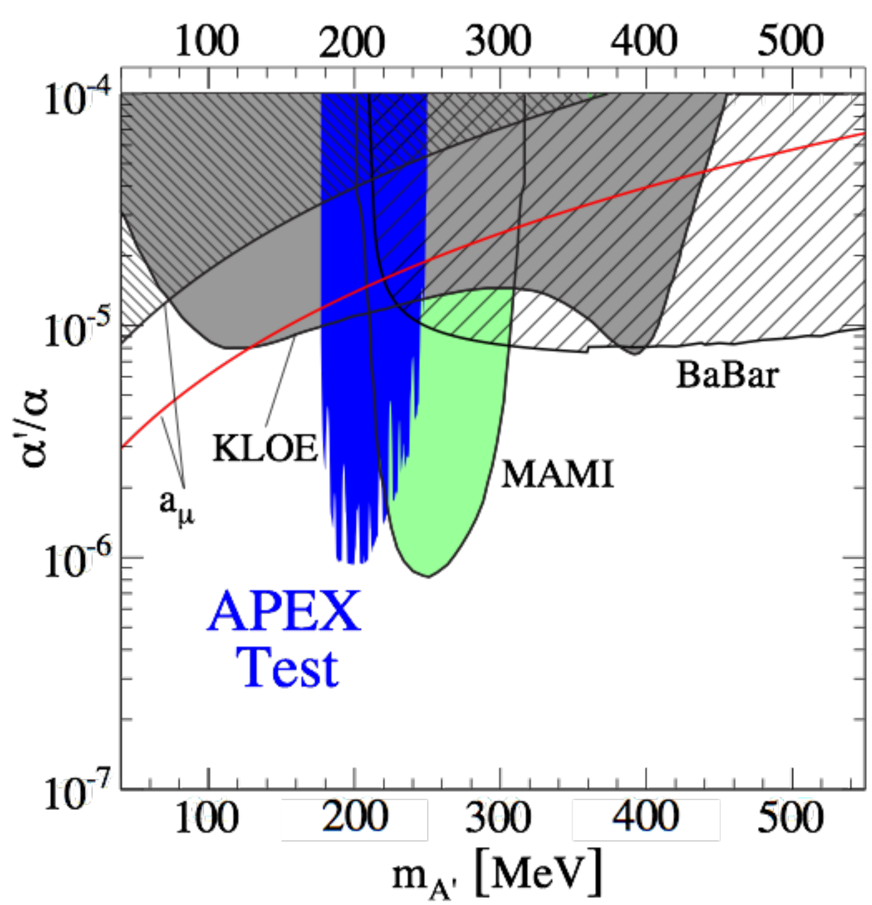

horiz. angular resolution
⇒ mass resolution ~0.5%

# APEX Test Run

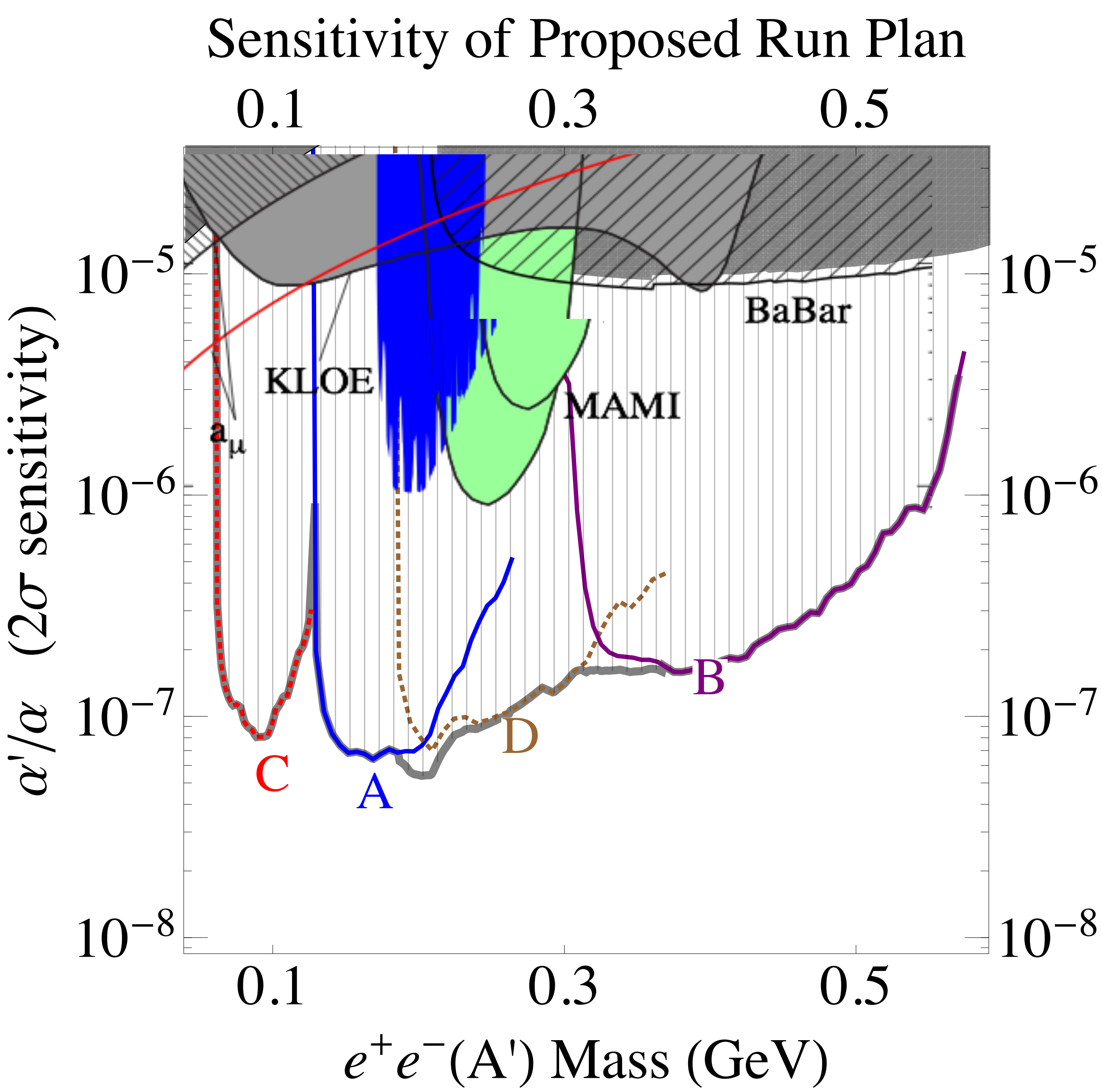
- Test run performed in Hall A, July 2010
- **Verified all key aspects of apparatus performance**
  - VDC tracking performance at 4–6 MHz singles rates
  - Gas Cherenkov detector in coincidence trigger to reject $\pi^+$'s
  - spectrometer optics & mass resolution
  - measurement of physics backgrounds
- Resonance search on 700K good trident events

*(highly cited PRL)*



# APEX Full Run




1 Month Beam Time

- 6 days at 1,2,3 GeV
- 12 days at 4.5 GeV)

>100x test-run statistics

Approved by JLab PAC 37 with recommendation to run as soon as possible, prioritized by PAC 41

Explores parameter space with **unparalleled efficiency** (particularly above ~300 MeV)

# Run Plan (more details)

Run plan describes activities starting from
the first closing of the Hall for the beam.

- Pre-production studies
    - beam line checkout (orbit, beam profile, energy spread, size)
    - beam line calibration (BPM, Dump, Safety IC, raster)
    - target – beam alignment check
    - 2.2 GeV beam for HRS detector checkout, timing + HV tune
    - HRS delta scan and optics in negative polarity
    - SciFi calibration in negative polarity (1 uA)
    - HRS-R optics with SciFi in positive polarity
    - HRS coincidence checkout, timing gate window tune
    - 4.4 GeV beam for HRS optics in negative polarity (septa check)
- Production
    - 2.2 kinematics
        - 1.1 GeV beam for HRS (1.1 GeV) optics in production mode (2.2 kinematics)
        - 2.2 GeV beam for production of 2.2 kinematics; 120 uA

# Run Plan (more details)

- Production (continue)
    - 2.2 GeV beam for HRS (1.1 GeV) optics; 1 uA (every day for 30')
  - 1.1 kinematics
    - 0.55 GeV beam for HRS (0.55 GeV) optics in production mode (1.1 kinematics)
    - 1.1 GeV beam for production of 1.1 kinematics; 120 uA
    - 1.1 GeV beam for HRS (0.55 GeV) optics; 1 uA (every day for 30')
  - 3.3 kinematics
    - 1.55 GeV beam for HRS (1.55 GeV) optics in production mode (3.3 kinematics)
    - 3.3 GeV beam for production of 3.3 kinematics; 120 uA
    - 3.3 GeV beam for HRS (0.55 GeV) optics; 1 uA (every day for 30')
  - 4.4 kinematics
    - 2.2 GeV beam for HRS (2.2 GeV) optics in production mode (4.5 kinematics)
    - 4.4 GeV beam for production of 4.4 kinematics; 120 uA
    - 4.4 GeV beam for HRS (2.2 GeV) optics; 1 uA (every day for 30')

# Summary

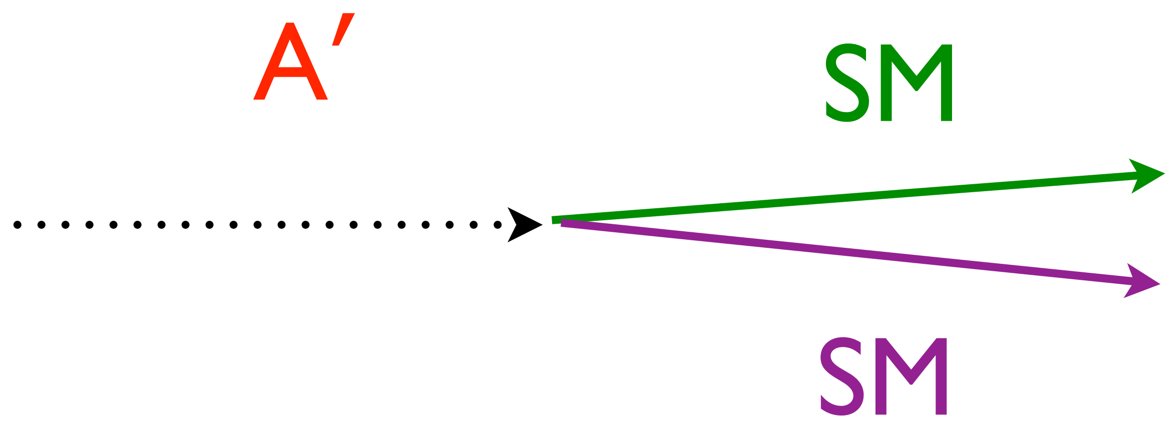
APEX has demonstrated feasibility and power of spectrometer searches for dark photons

Strong physics impact already from test run (highly cited Hall A result using very little beam time)

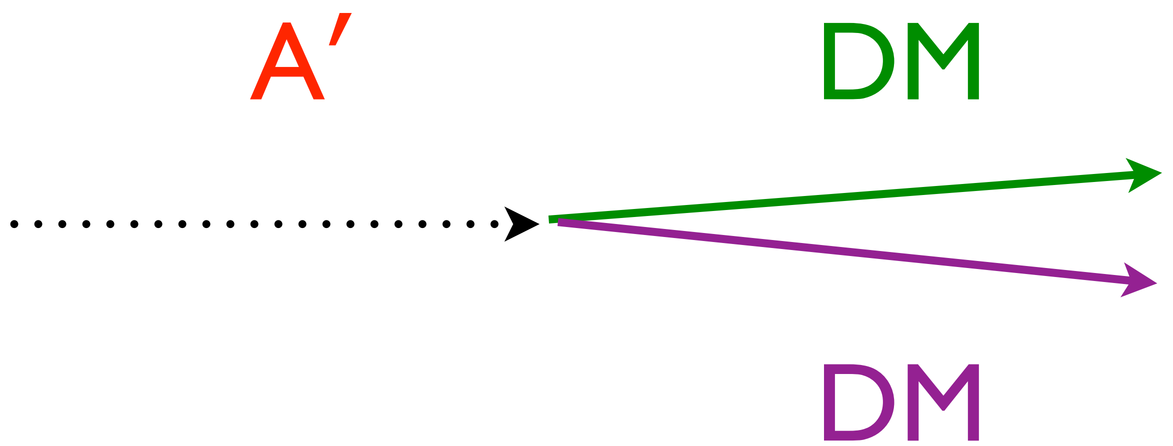
>6 years after proposal, physics case is still strong

# Backup

# Assume A′ → Dark Matter is possible

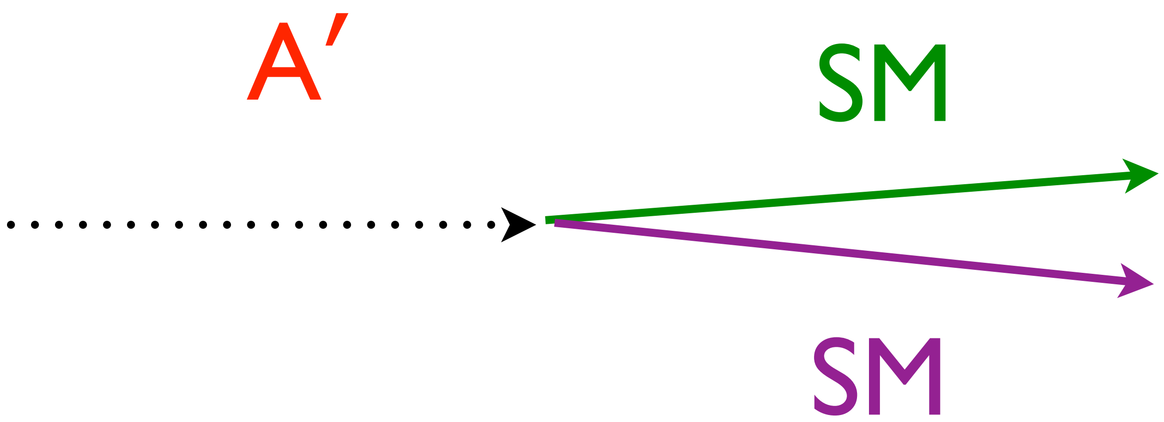



Controlled by ε

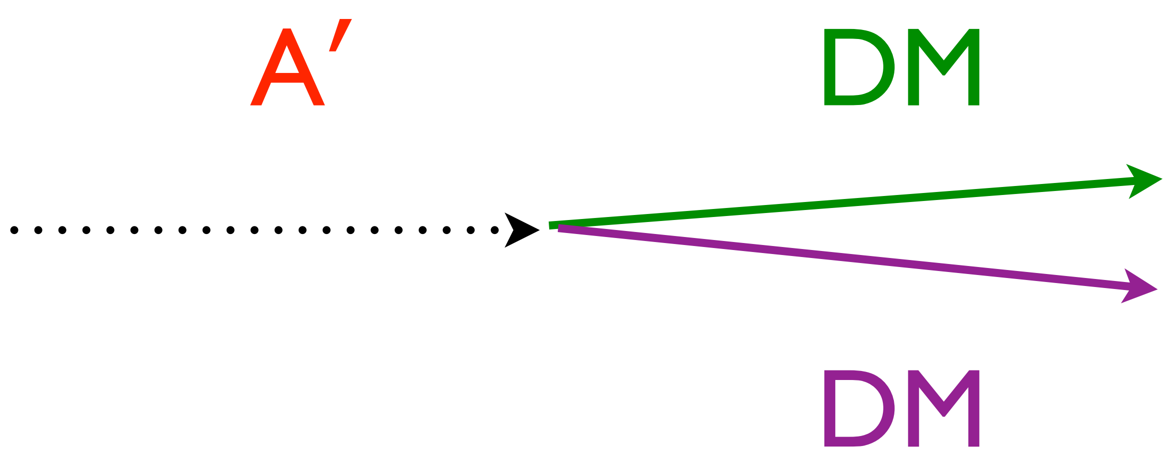



Controlled by $\alpha_D$

# Assume A′ → Dark Matter is possible



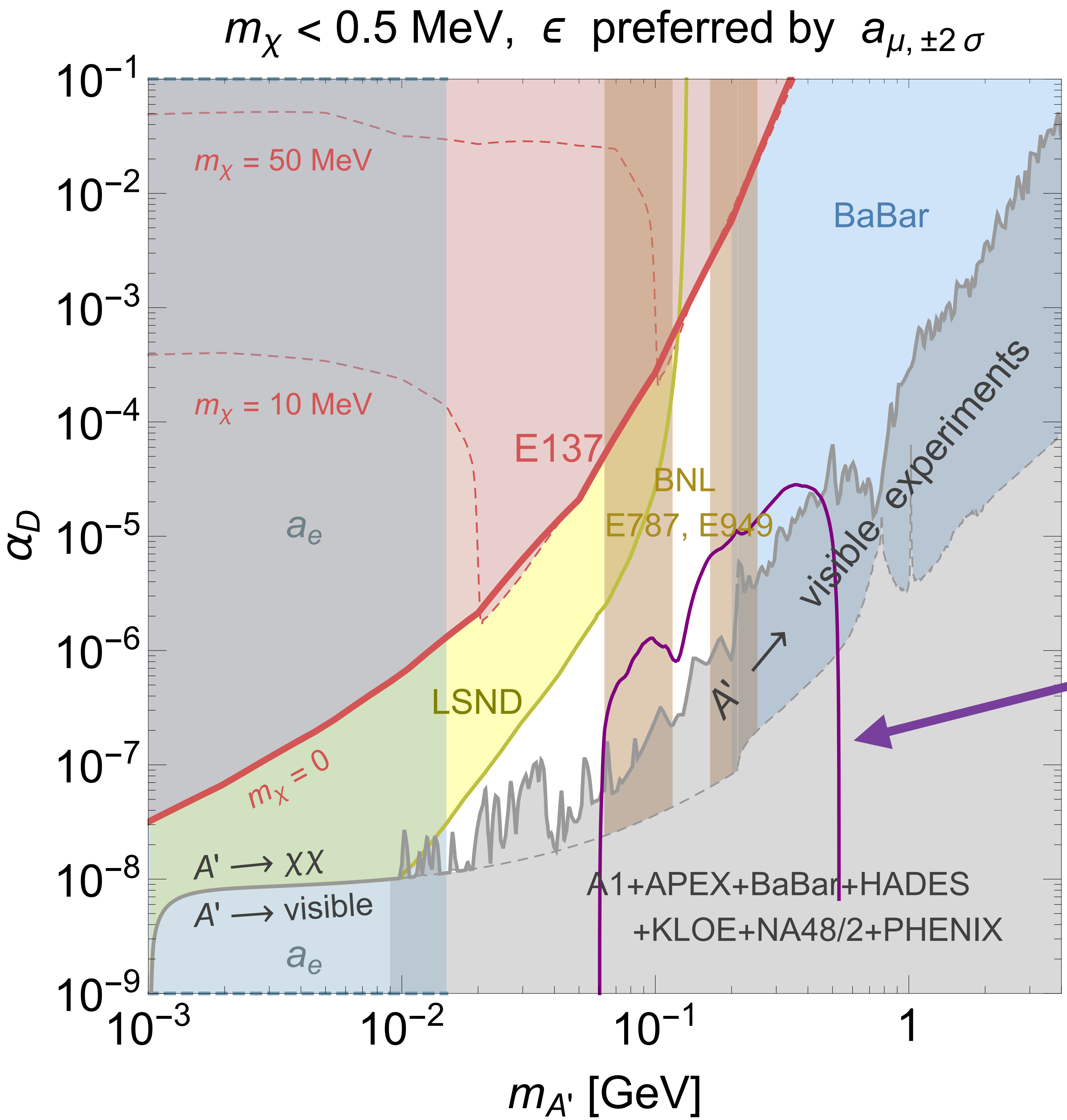

Controlled by ε




Controlled by $\alpha_D$

now fix ε to explain g-2…

# Constraint on g-2 region




APEX