Hidden Sectors at the Luminosity Frontier

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Perimeter Institute

with Maxim Pospelov & Adam Ritz

Aspen Winter Meeting
February 18, 2010

Plan

- Motivation for a Hidden Sector

  Generalities, Dark Matter, Hidden Valley

- Example: Dark Forces

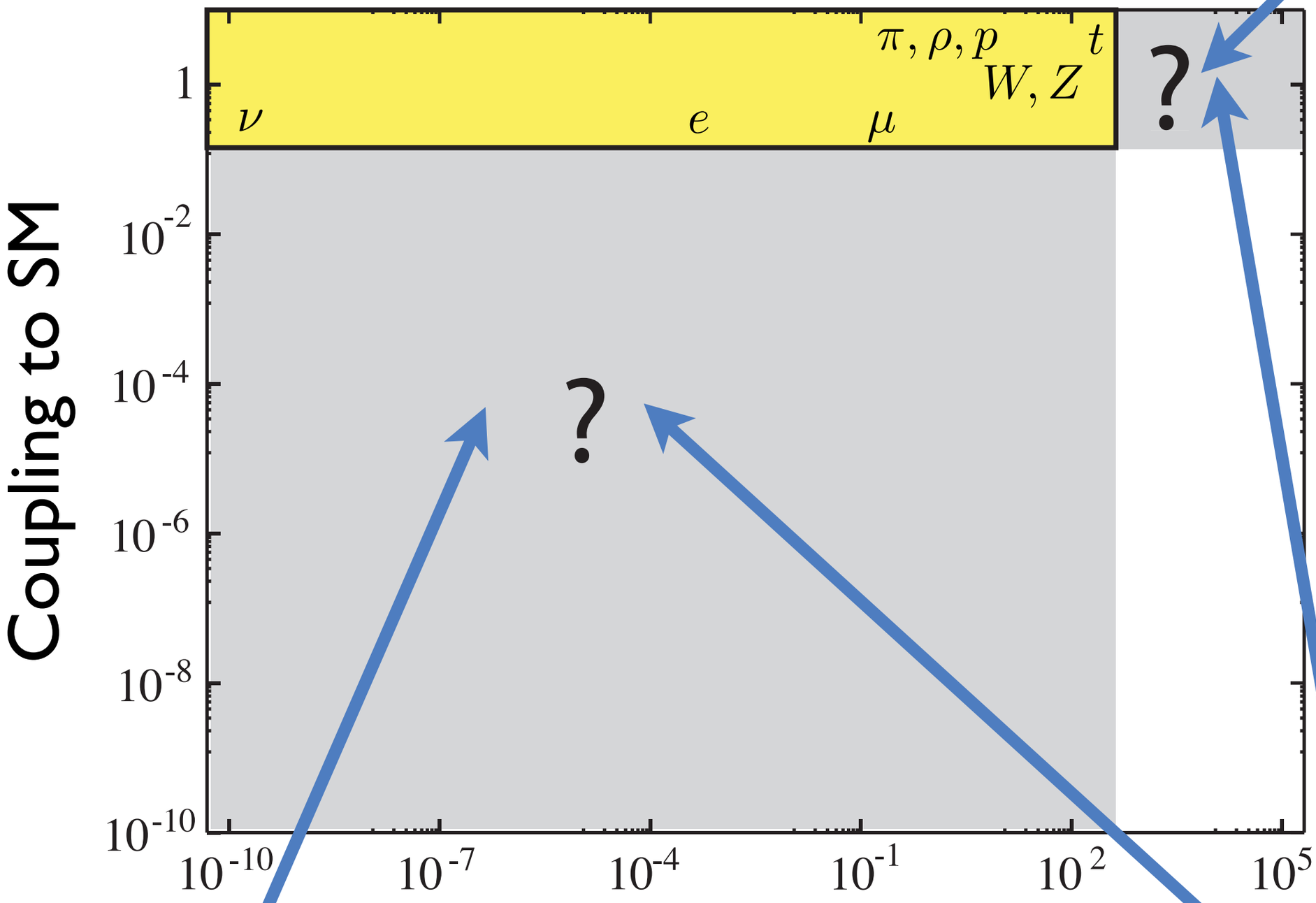
- High Intensity Probes of Dark Forces

  High Luminosity e+e- Colliders

  Fixed Target Experiments

Where are the new particles?

EWSB, Hierarchy



Hidden Sector

Dark Matter

A Light Hidden Sector?

- New light matter charged under the SM gauge symmetry is very constrained.

- New light SM gauge singlet matter and new forces weakly coupled to ordinary matter are allowed!

- Singlets exist in SM: L, e_R, d_R, u_R, H, N

- Many possibilities for very weak interactions

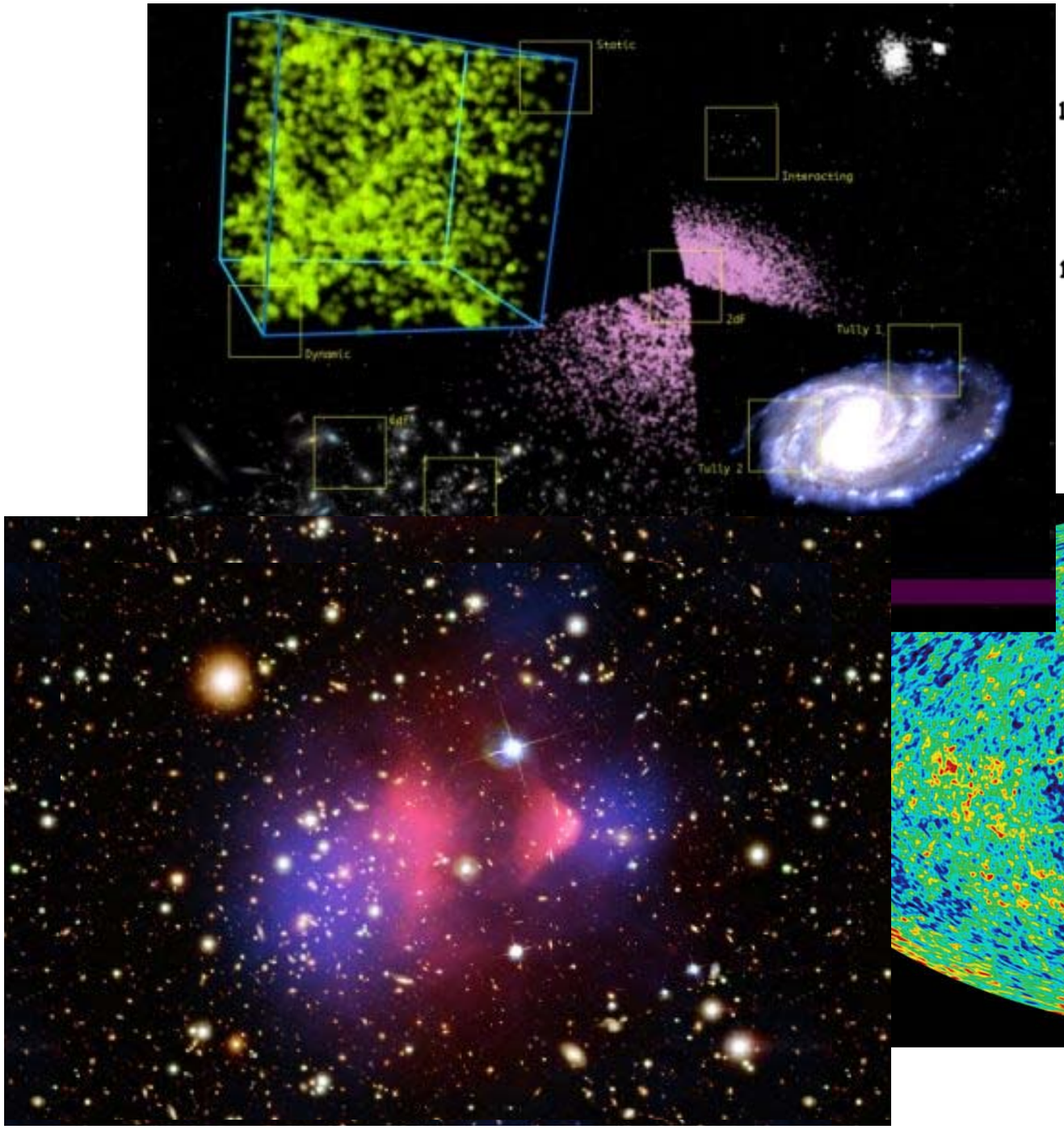
Hide & Seek

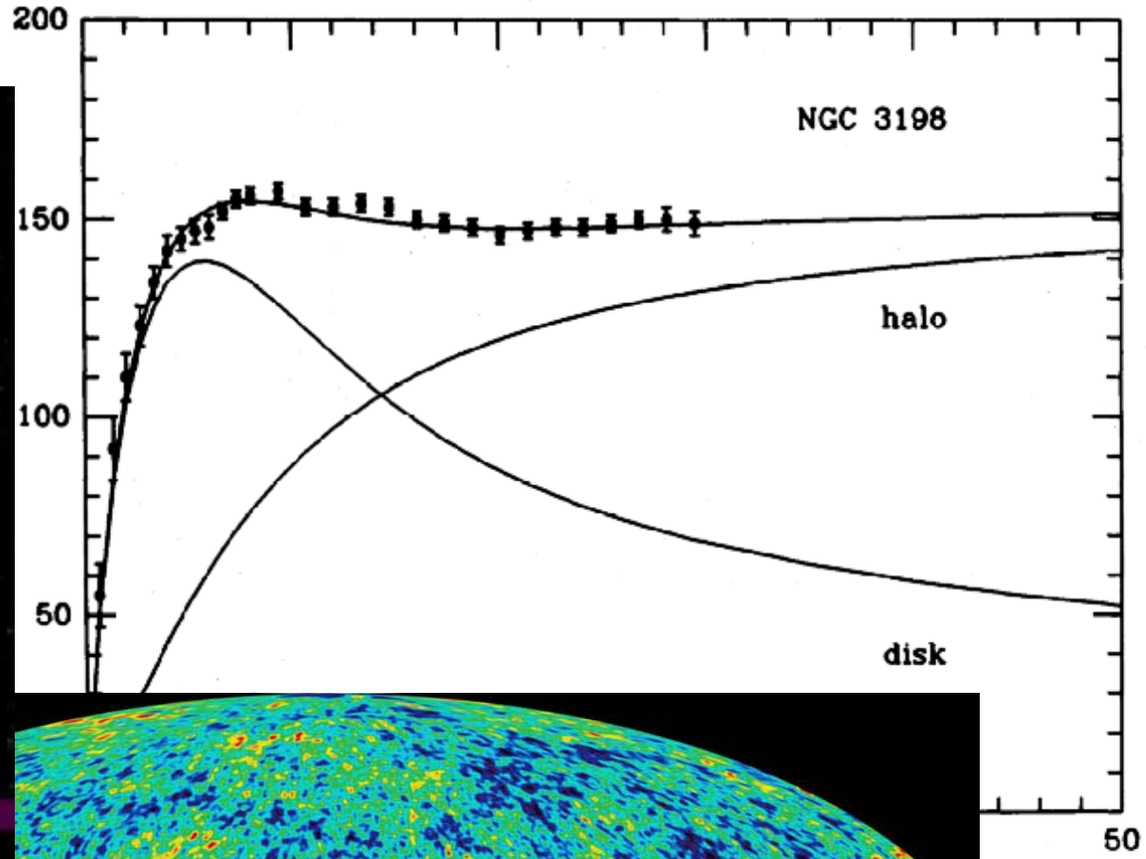
How to talk to the Hidden Sector:

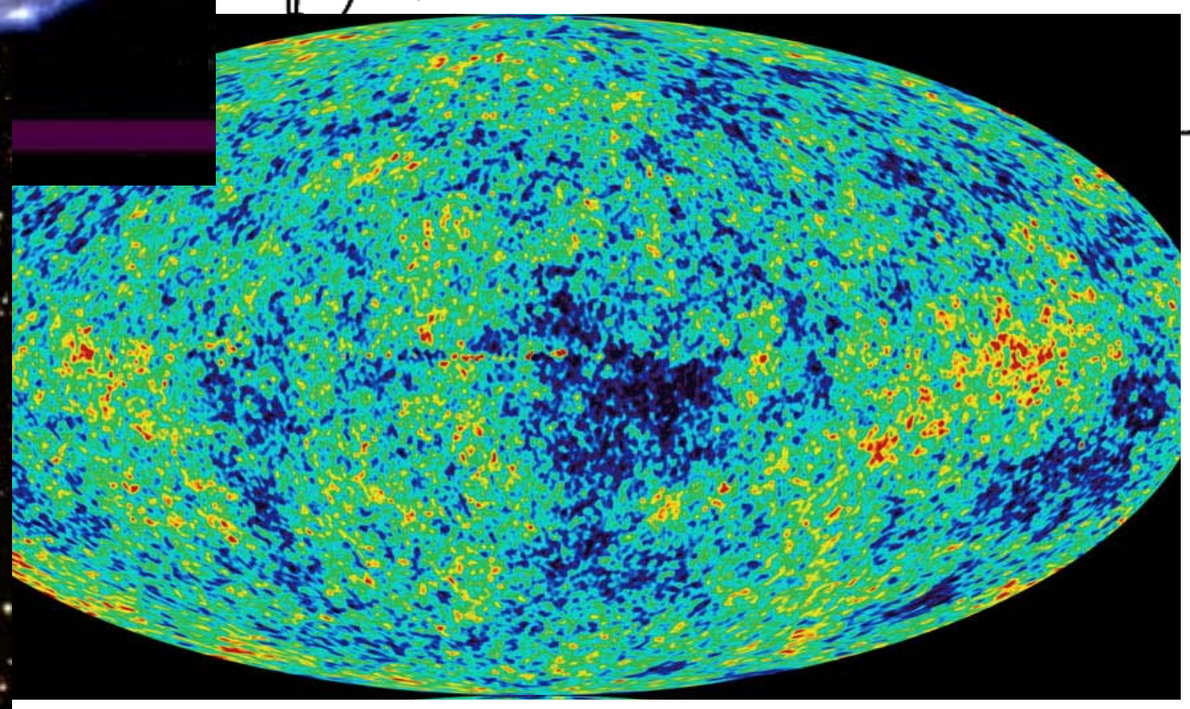
- `Connector' particle charged under both sectors
- Effective field theory: $\frac{1}{\Lambda^n}\mathcal{O}_{\rm HS}\mathcal{O}_{\rm SM}$
- Portals: renormalizable operators connecting the SM to the Hidden Sector

$-\frac{\kappa}{2}B_{\mu\nu}V^{\mu\nu}$	Kinetic Mixing Portal Holdom
$(AS+BS^2)H^\dagger H$	Higgs Portal
LHN	Neutrino Portal

Dark Matter


Static
Interacting
2dF
Fully 1
Dynamic
6dF
Fully 2


200
150
100
50
NGC 3198
halo
disk
50



Dark Matter is Neutral

Two Possibilities:

1) DM $\supset SU(2)_L \times U(1)_Y$ multiplet

2) DM is SM gauge singlet

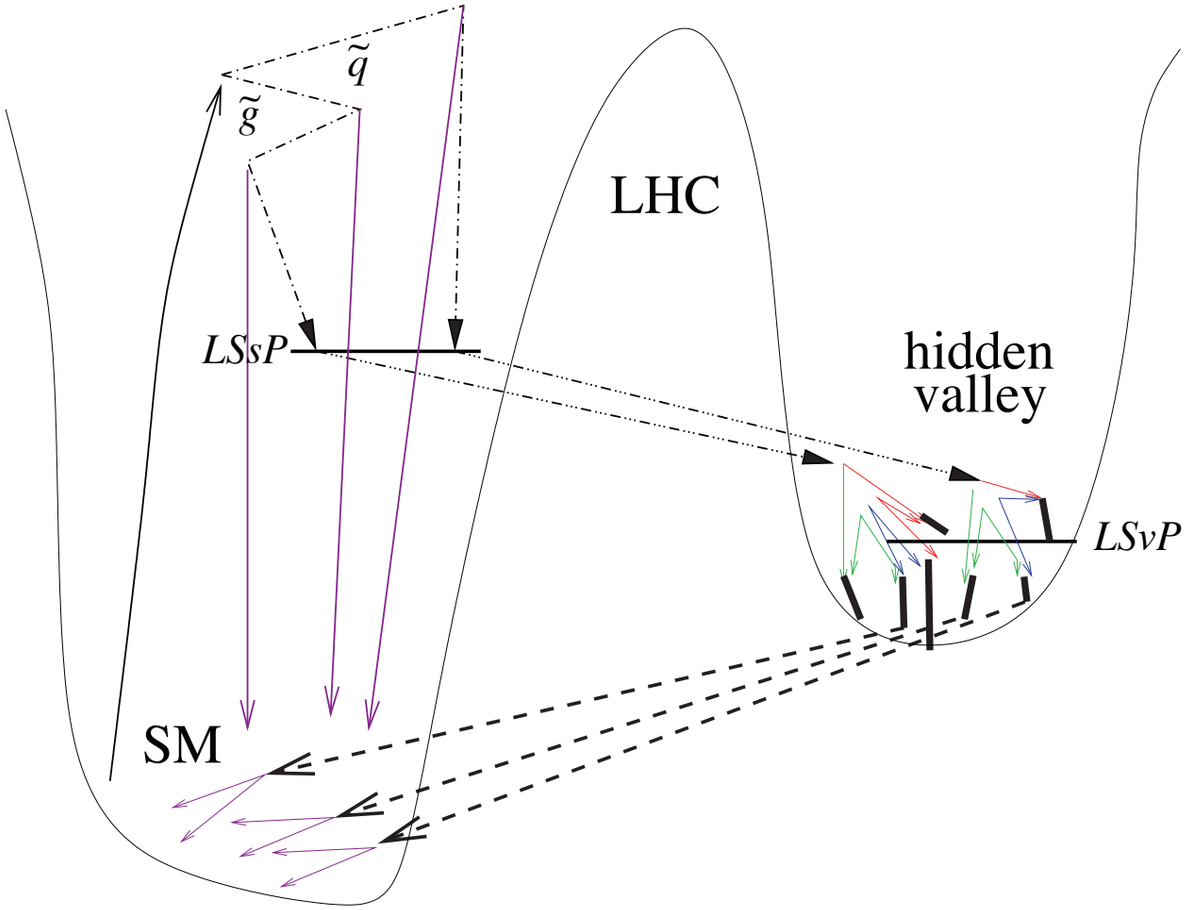
⇨ Hidden Sector

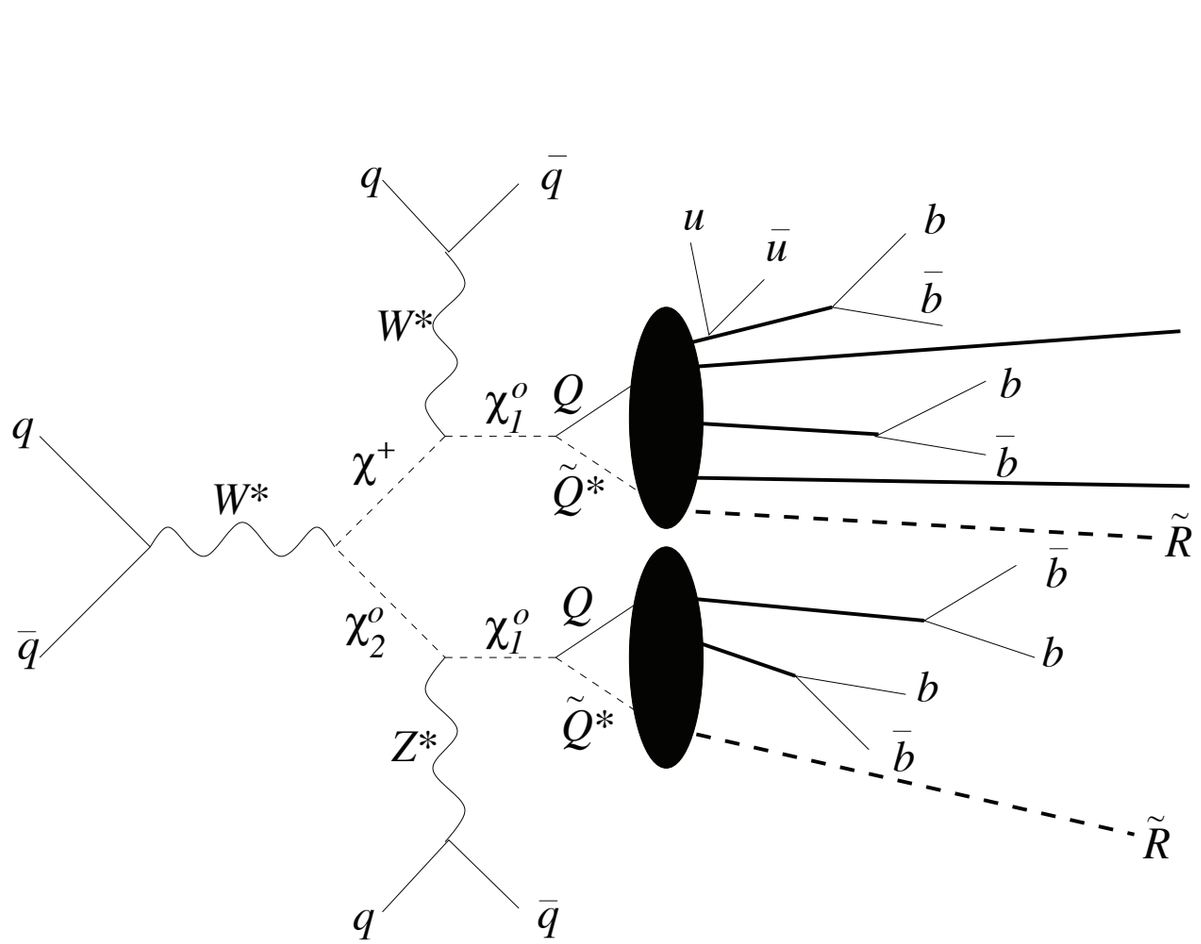
Hidden Valley

Strassler, Zurek

A light hidden sector can drastically alter the signatures at the energy frontier!

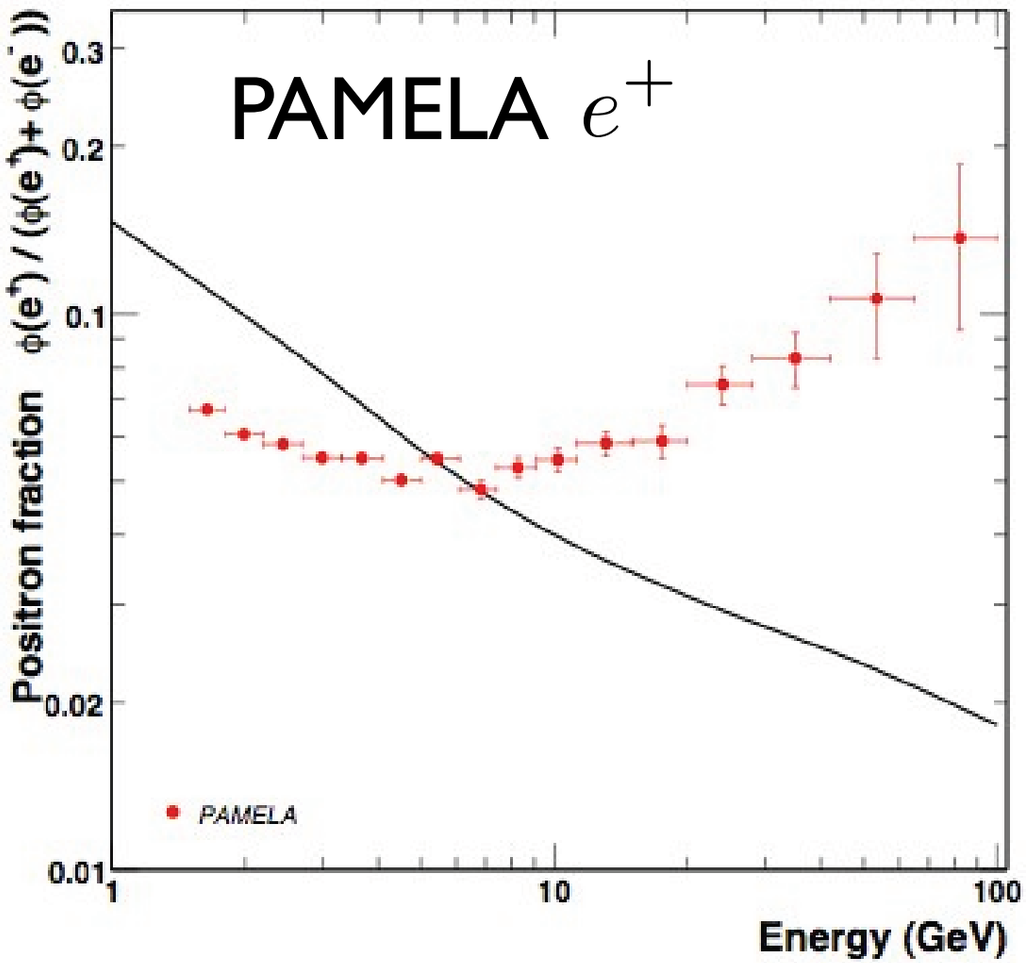
e.g SUSY + HV:

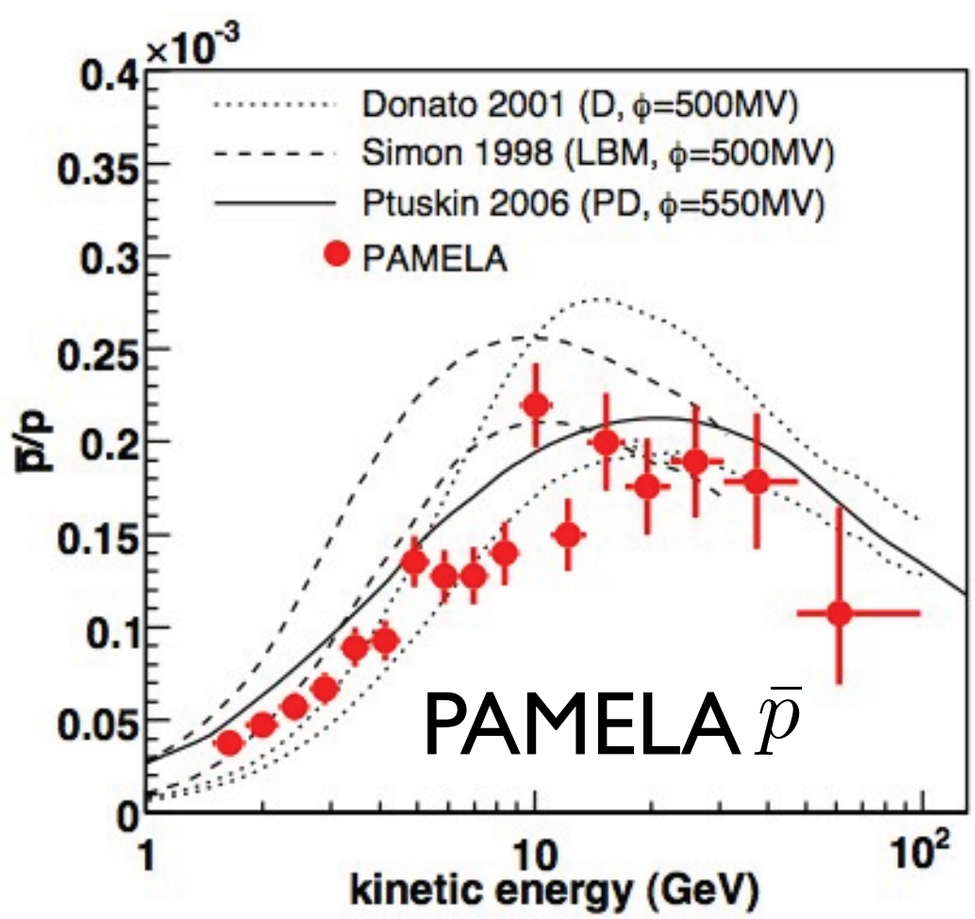




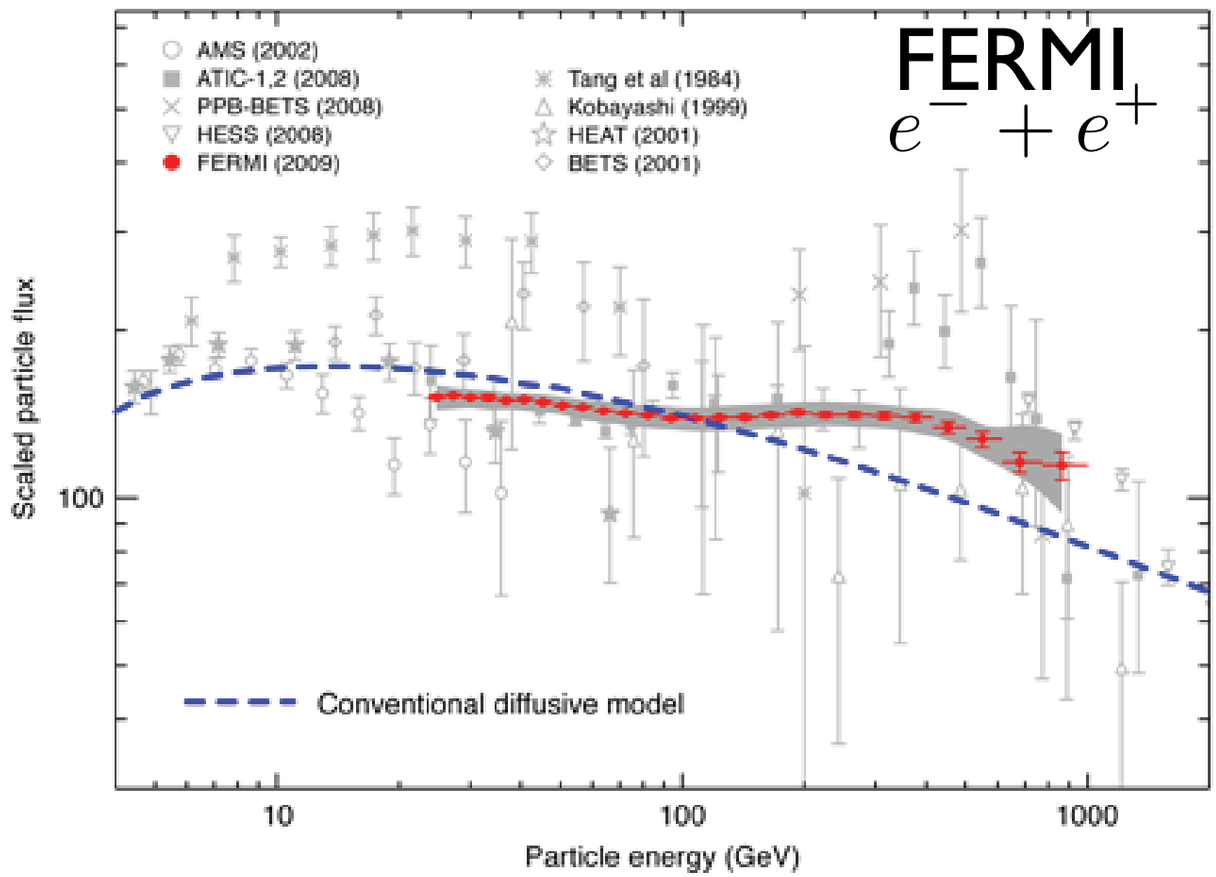
Dark Forces

Cosmic Ray Anomalies





Could be due
to Astrophysics...



Gev-Scale `Dark' Force

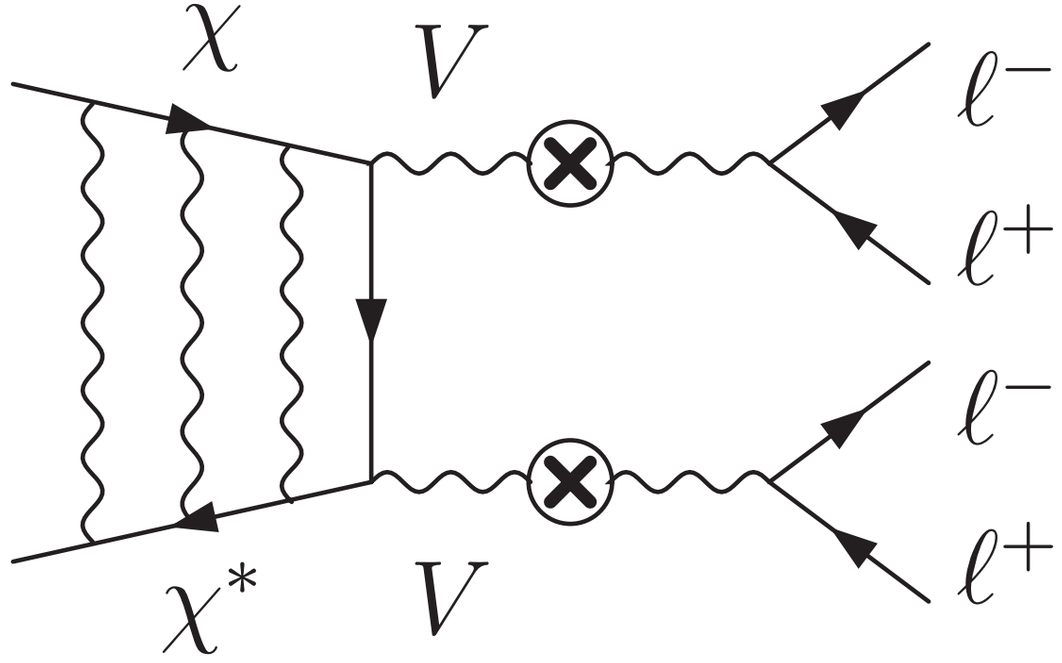
Arkani-Hamed, Finkbeiner, Slatyer, Weiner

Pospelov, Ritz

$$\mathcal{L} = i\bar{\chi}\gamma^{\mu}(\partial_{\mu} - ig_D V_{\mu})\chi - \frac{\kappa}{2} V_{\mu\nu} B^{\mu\nu}$$

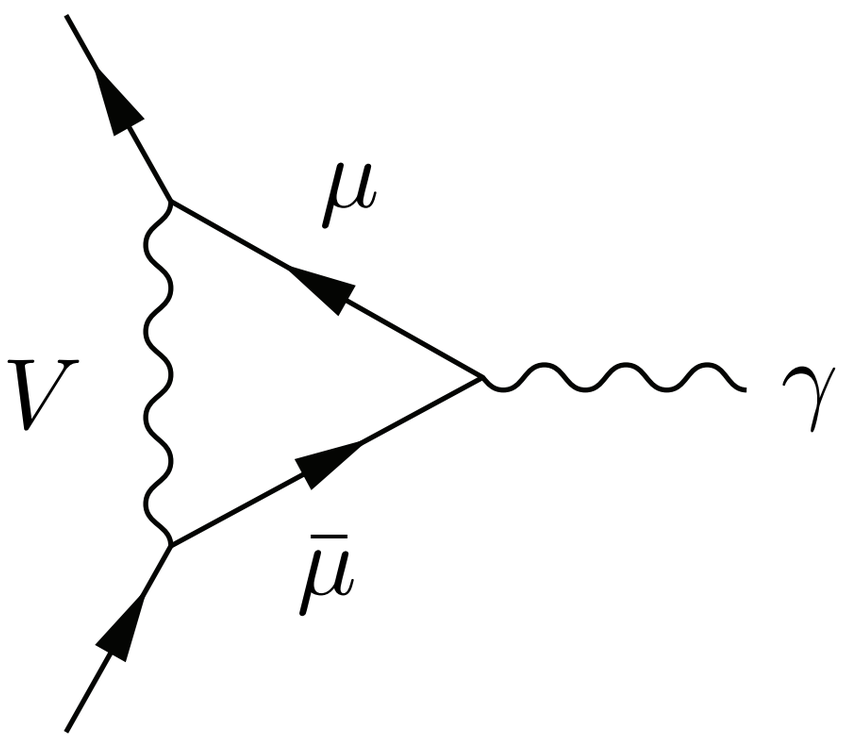
Long-range attractive force enhances $\langle \sigma v \rangle_{\rm halo}$

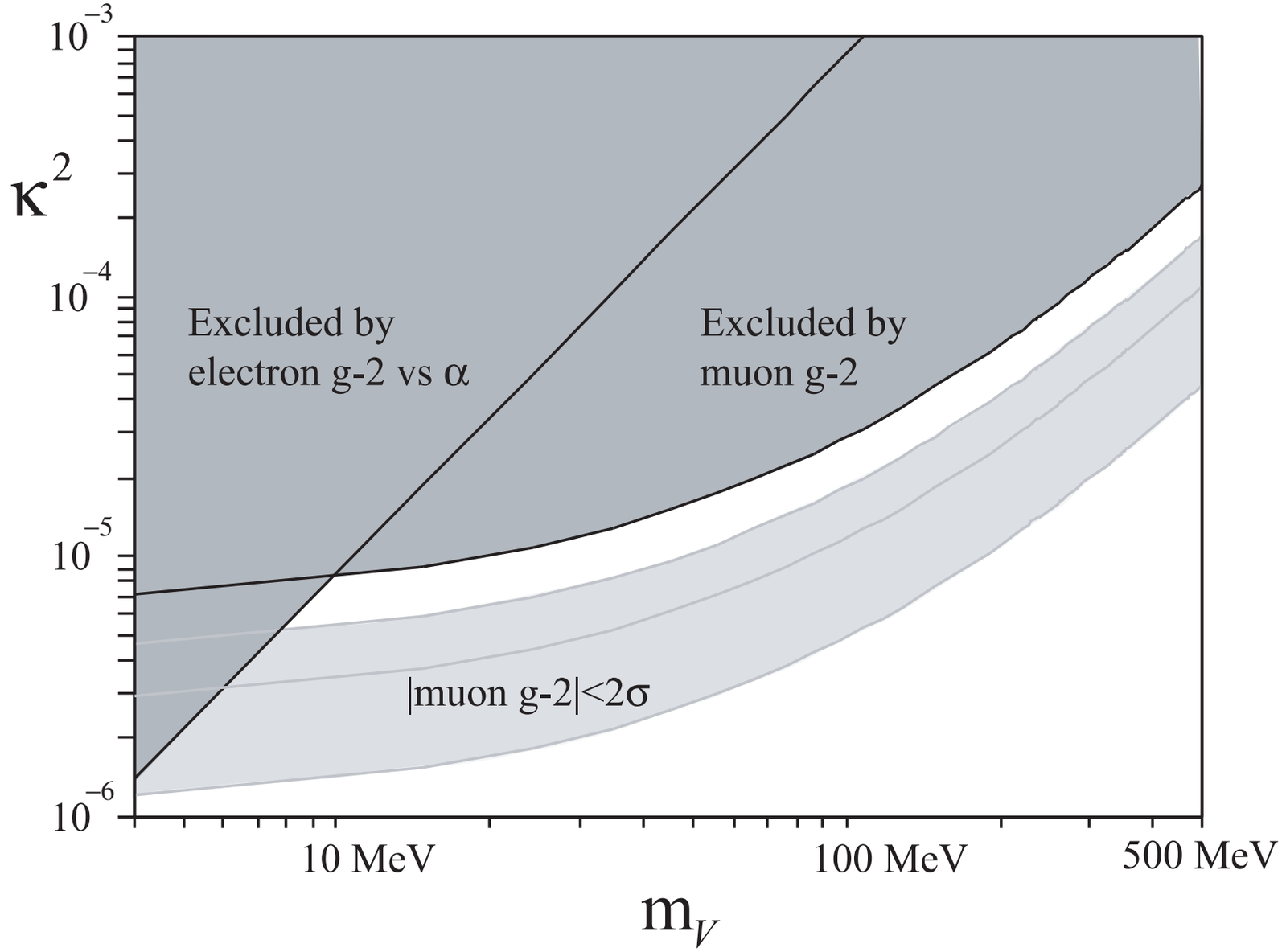
Annihilation products cannot decay to antiprotons by kinematics



$(g-2)_\mu$ ~ 3σ discrepancy

Kinetically mixed vector can help!





Pospelov

Models of the Dark Force

- Secluded dark matter

  Minimal model

  Pospelov, Ritz, Voloshin

- Non-abelian models

  Radiative DM splitting (for e.g IDM)

  Arkani-Hamed, Finkbeiner, Slatyer, Weiner; Baumgart, Cheung, Ruderman, Wang, Yavin; Alves, Behbahani, Schuster, Wacker

- SUSY models

  Link GeV-scale to weak scale

  Arkani-Hamed, Weiner; Baumgart, Cheung, Ruderman, Wang, Yavin; Katz, Sundrum; Morrissey, Poland, Zurek

- Axion portal

  Nomura, Thaler

Experimental probes of a Dark Force

1) High Luminosity e+e- colliders

2) Fixed Target Experiments

3) High Energy Colliders (no time in this talk)

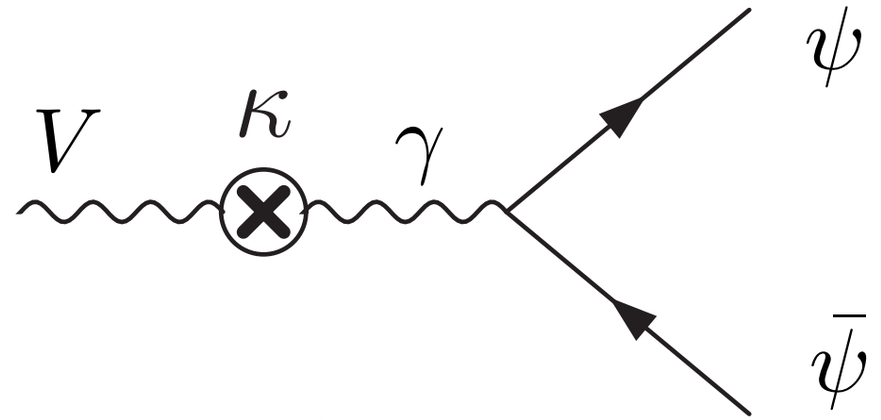
- SUSY ⇨ Hidden valley scenario

Arkani-Hamed, Weiner; Cheung, Ruderman, Wang, Yavin

- Lepton jets

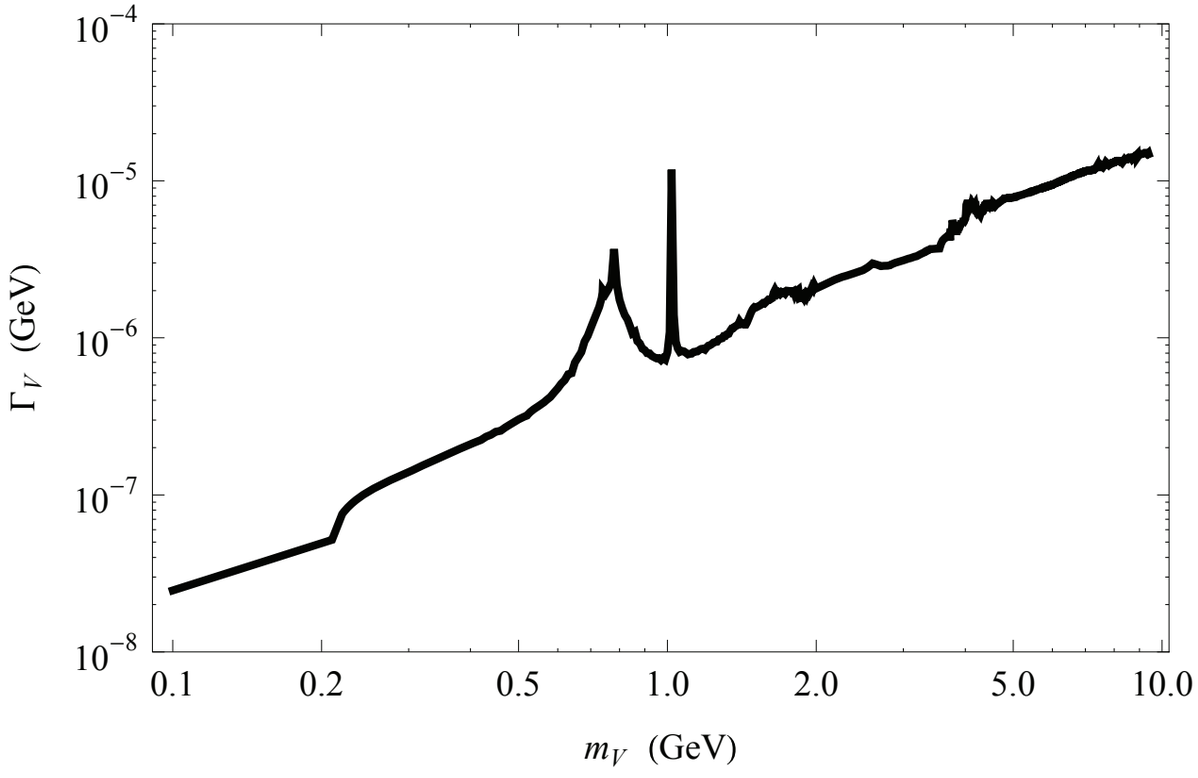
see A. Askew's talk (Thursday)

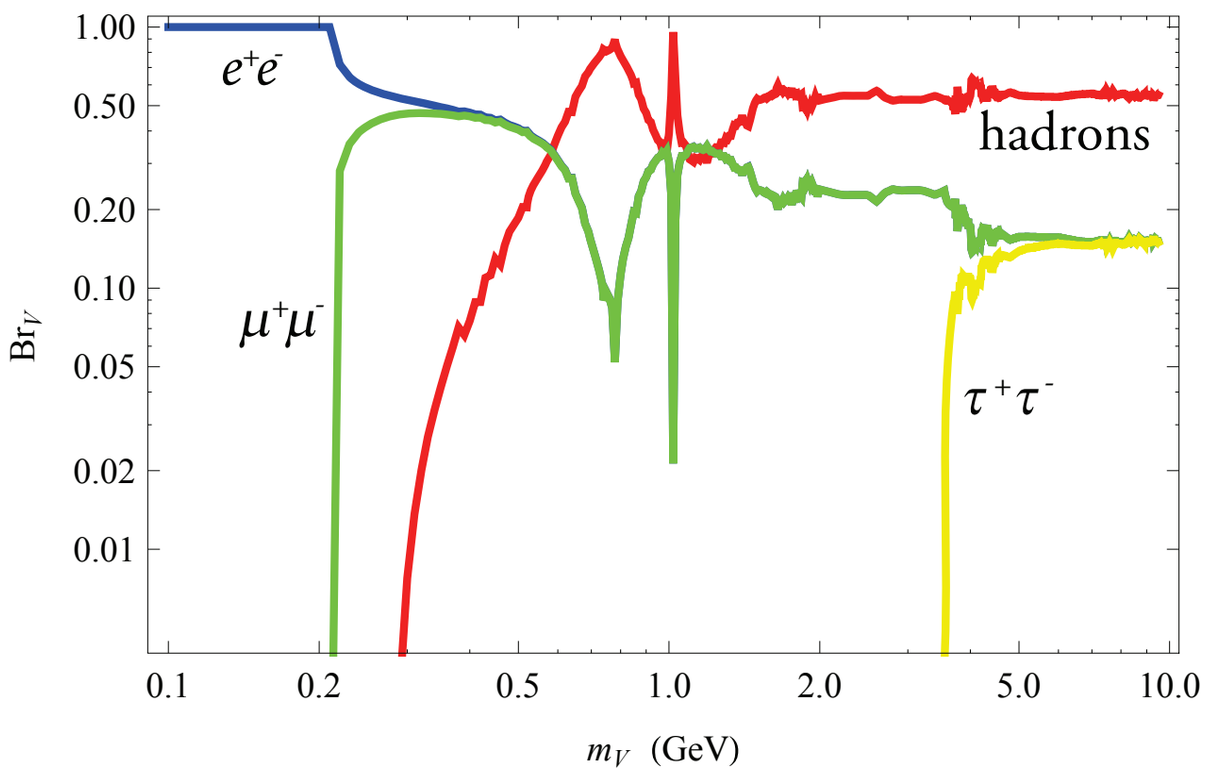
V_μ decays



- $\Gamma_V \approx \mathcal{O}(\mathrm{keV}) \times \left(\frac{\kappa^2}{10^{-5}}\right) \left(\frac{m_V}{\mathrm{GeV}}\right) [N_l + R(s = m_V)]$

- $R = \dfrac{\sigma_{e^+e^- \to hadrons}}{\sigma_{e^+e^- \to \mu^+\mu^-}}$





BB, Pospelov, Ritz

Direct Production & Rare Decays at High Luminosity e+e- Colliders

BB, Pospelov, Ritz;
Essig, Schuster, Toro;
Reece, Wang

$$N_{\rm evt} \sim \frac{\kappa^2 \mathcal{L}}{s}$$

Meson Factories: BaBar, BELLE, CLEO-c, KLOE, BESIII

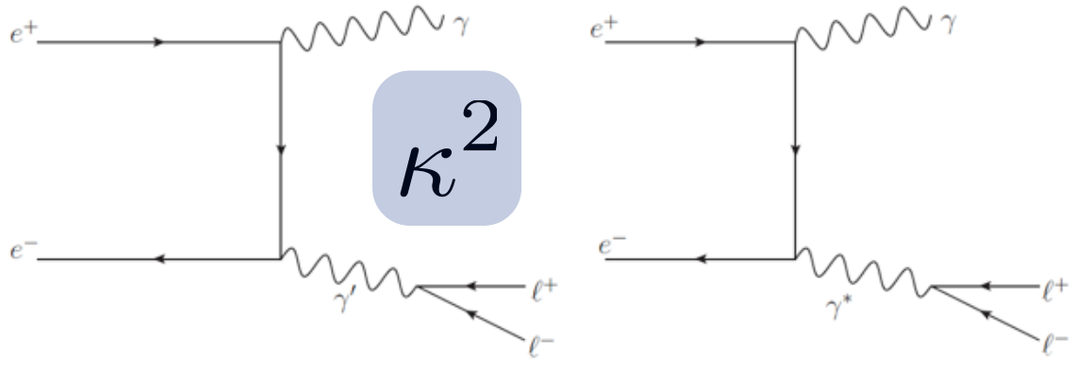
Advantages:

- Large Data Sets Exist
  (e.g B-factories: $\mathcal{L} > 1\ \mathrm{ab}^{-1}$)

- Low center-of-mass energy

Final States (direct production)

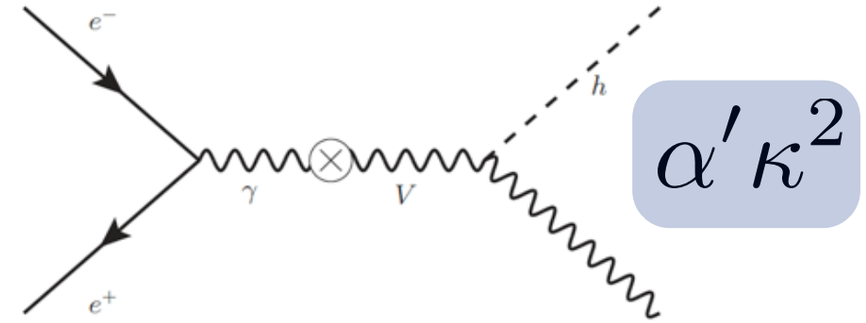
- "Generic": $e^+e^- \to \gamma l^+ l^-$



- Babar $e^+e^- \to \gamma \mu^+ \mu^-$

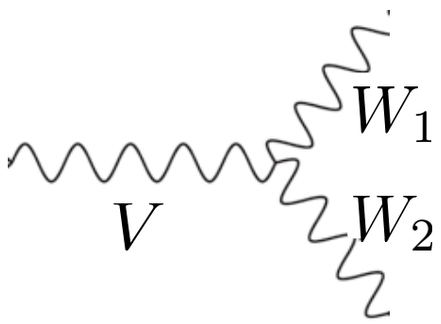
see talk by M. Graham, UCLA DM 2010

- "Generic + higgs": $e^+e^- \longrightarrow Vh' \longrightarrow 6l \;\; (or\; 2l + \not{E})$



- BaBar & KLOE studies underway

- "Nonabelian": $e^+e^- \to V^* \to 4l$



- Babar 0908.2821

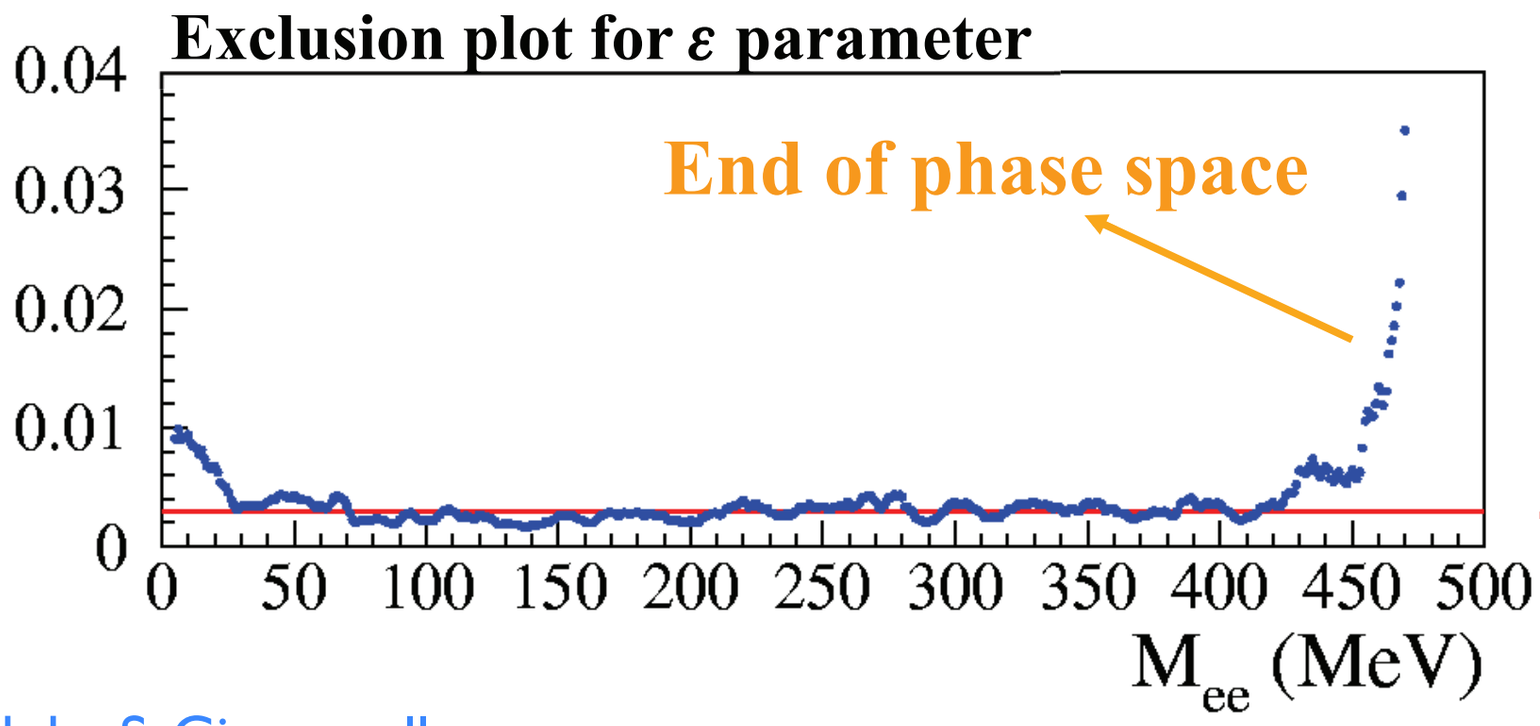
Slide updated from M.Graham, A. Ritz Dark Forces Workshop

Rare Meson Decays

$$\mathrm{Br}(X \to Y + V) \approx \kappa^2 \mathrm{Br}(X \to Y + \gamma)$$

e.g. $\phi \to \eta V$ Reece, Wang

Preliminary KLOE study:



Systematics not yet included

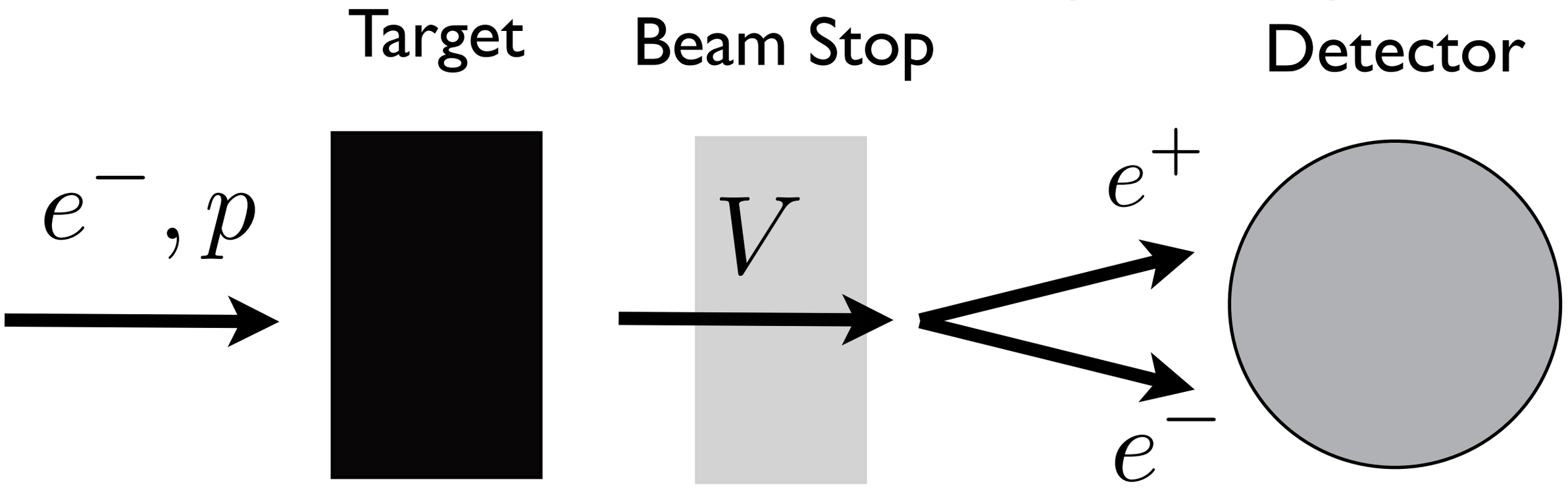
→ **~ 3×10^{-3}**

for $25<M_{ee}<425$ MeV

talk by S. Giovannella
DISCRETE 2010

Fixed Target Experiments

Reece, Wang;
Bjorken, Essig, Schuster, Toro;
BB, Pospelov, Ritz;
Freytsis, Ovanesyan, Thaler



Advantages:

- High Luminosity
- Large cross section

Proton Beam Sensitivities

BB, Pospelov, Ritz;
Essig, Harnik, Kaplan, Toro

e.g. LSND

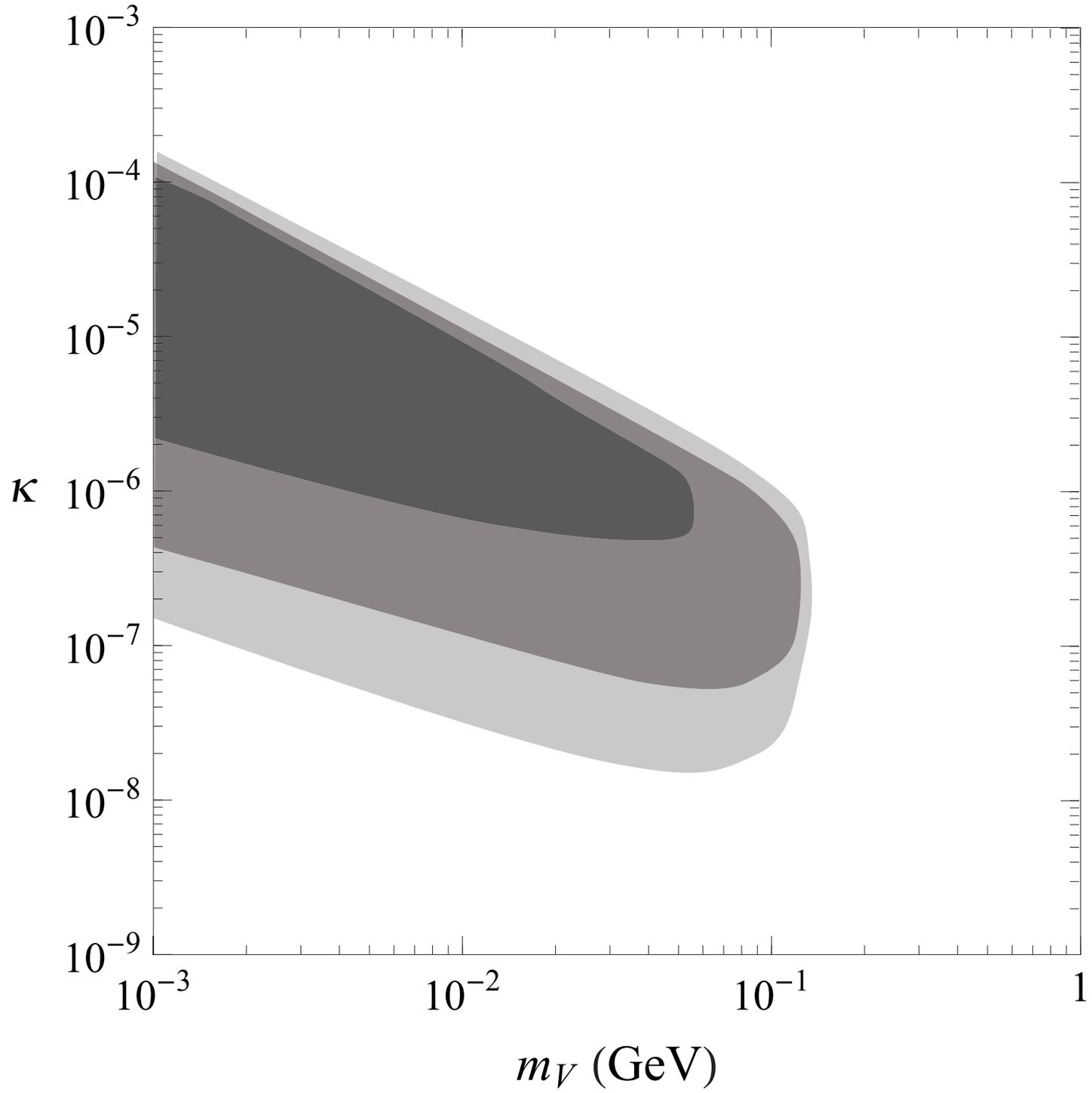
$$10^{23}\ \mathrm{POT}$$
$$\Longrightarrow \mathcal{L} \sim 10^{49}\mathrm{cm}^{-2}$$

Production via

$$p + A \to \pi^0 + X$$

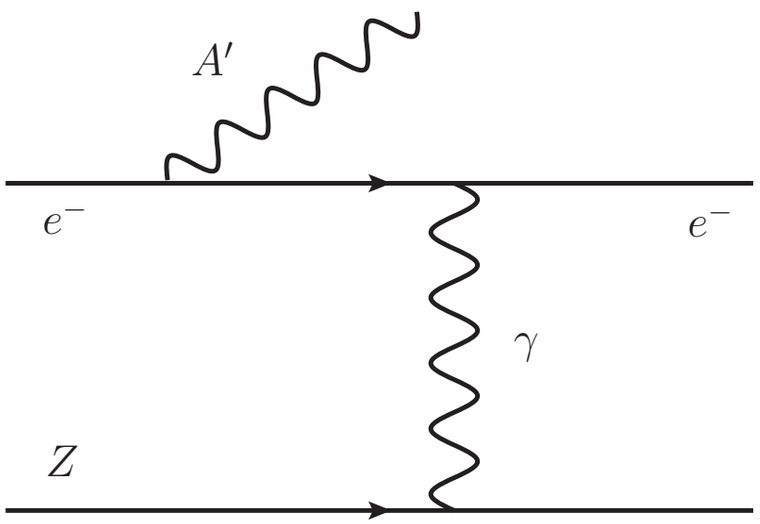
followed by

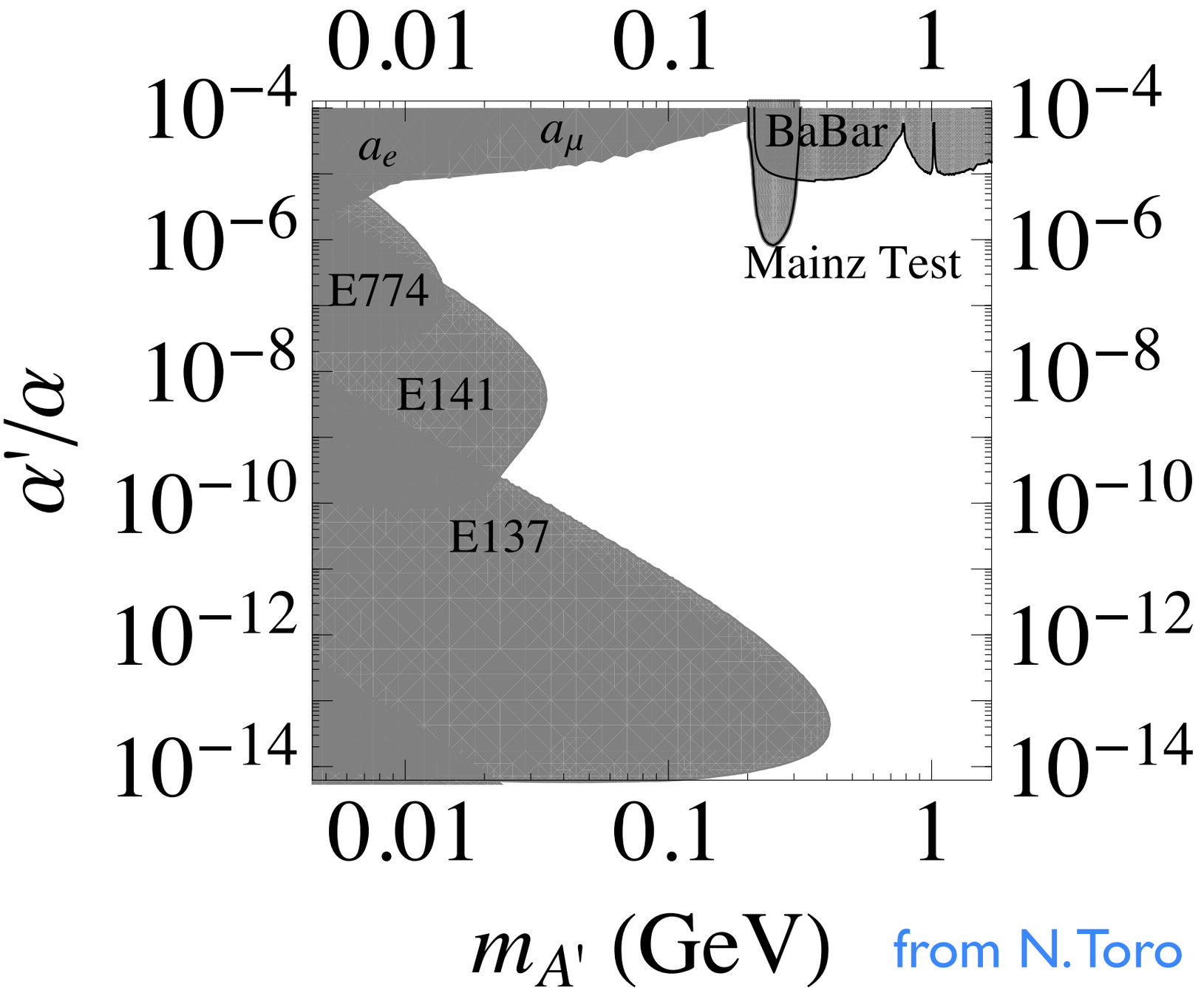
$$\pi^0 \to \gamma V \to \gamma e^+ e^-$$



Electron Beam Constraints

Bjorken, Essig, Schuster, Toro
Mainz Test Run: 1101.4091





from N. Toro

Next Step:

New Fixed Target Experiments to probe Dark Forces!

Closing thoughts

- Weakly-coupled, light particles are a generic & exciting possibility for physics beyond the Standard Model

- Can be systematically explored via portals

- Provide another physics rationale for the experimental program at the intensity frontier

Question:

What is the best way to utilize/expand existing experimental infrastructure for a more comprehensive physics program?