Title: Hidden sectors at the luminosity frontier

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Abstract: Light hidden sectors are a generic possibility for new physics, and recent astrophysical signals motivate hidden sector dark matter. I will discuss probes of a minimal secluded U(1) hidden sector scenario with high luminosity particle physics experiments.

Hidden Sectors at the Luminosity Frontier*

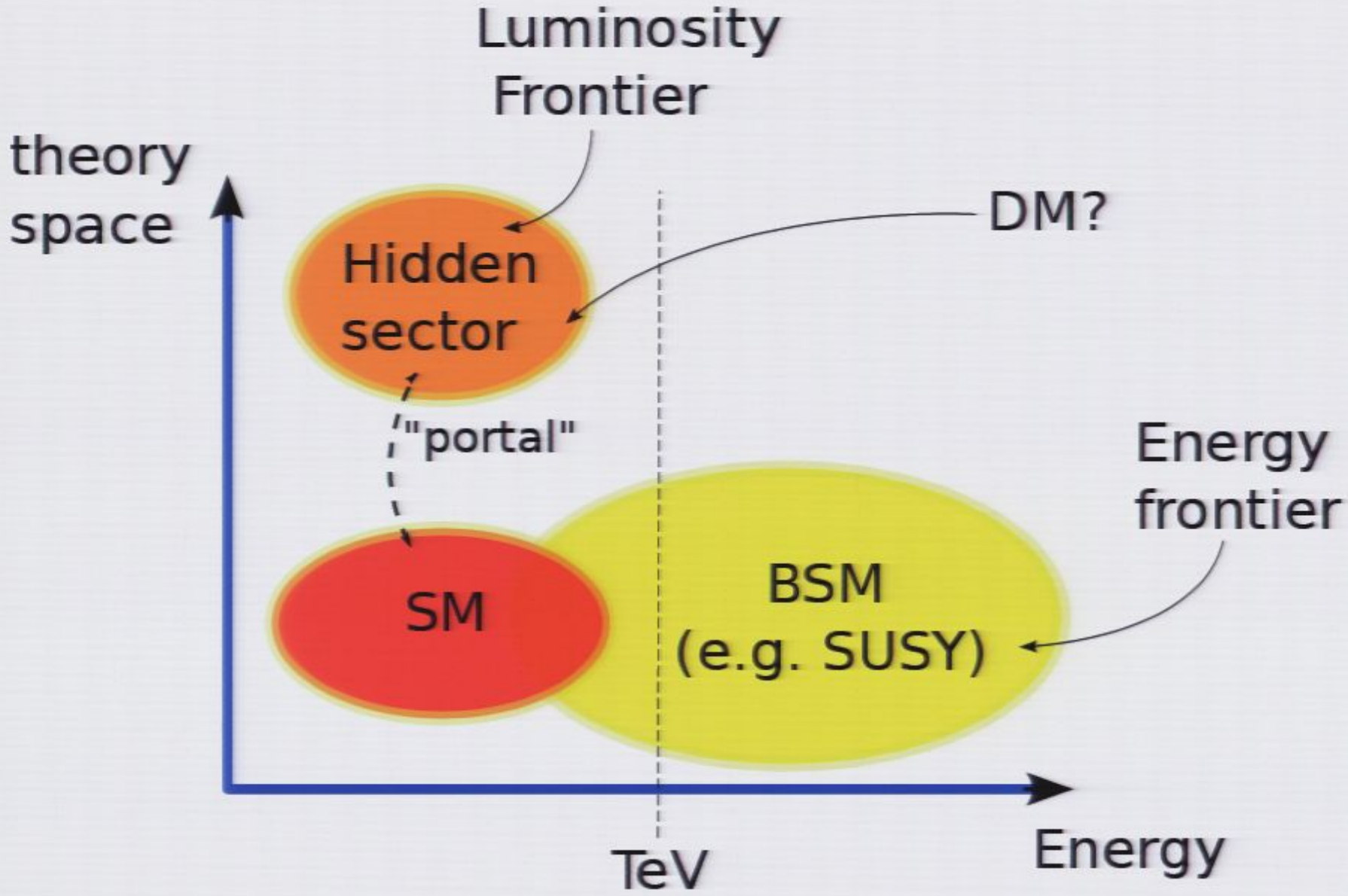
Brian Batell

Perimeter Institute

*with Maxim Pospelov and Adam Ritz
- arXiv:0903.0363, to appear

Outline

- Hidden sectors, portals, and dark matter
- Dark matter through the U(1) portal
- Probes of a U(1) portal with high luminosity experiments
  - Colliders
    - B-factories
  - Fixed Target Experiments
    - LSND, Miniboone, Minos ...


Luminosity
Frontier
theory
space
DM?
Hidden
sector
"portal"
Energy
frontier
SM
BSM
(e.g. SUSY)
TeV
Energy

2

Hide and seek

How to find the hidden sector:

- "Mediator" - particle charged under both sectors
- Higher dimensional operator
- "Portal" - renormalizable, gauge invariant operator to connect SM and hidden sector

$B_{\mu\nu}$	U(1) portal (dim = 2),
$H^\dagger H$	Higgs portal (dim = 2),
LH	Neutrino portal (dim = 5/2),

Dark Matter through the U(1) portal

Pospelov, Ritz, Voloshin '07

...

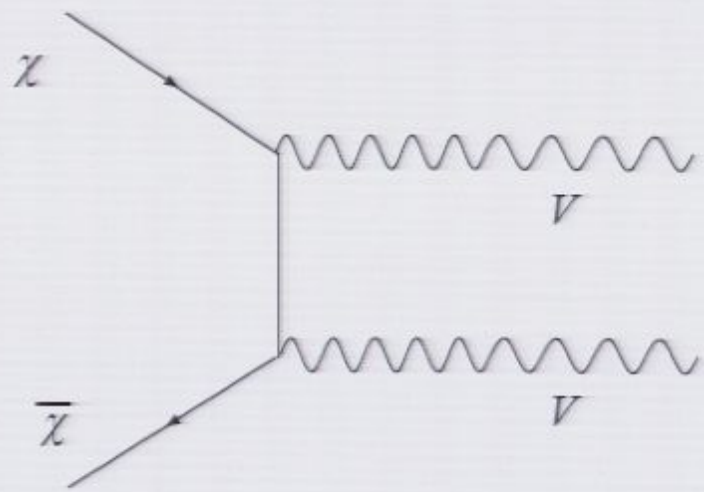
$$\chi \text{ ----- } V_{\mu\nu} B^{\mu\nu} \text{ ----- SM}$$

Holdom '86

"Secluded" regime

- $m_\chi > m_V$
  - Annihilation via $\overline{\chi}\chi \to VV$
  - Relic abundance independent of kinetic mixing
  - Makes direct detection, collider signatures tricky if mixing small.

  Can't rule out WIMP hypotheses in principle if secluded



Astrophysical consequences

Arkani-Hamed, Finkbeiner, Slatyer, Weiner '08

Pospelov, Ritz '08

If the U(1) is light ($m_V \leq$ GeV):

- Long range force can lead to an enhanced galactic annihilation cross section (e.g. Sommerfeld enhancement)
- vector can't decay to (anti-)protons by kinematics

Connection with PAMELA, ATIC, FERMI, HESS, ...?

A minimal $U(1)_S$ model

$$\mathcal{L} = \mathcal{L}_{\rm WIMP} - \frac{1}{4}V_{\mu\nu}^2 + \frac{1}{2}m_V^2 V_\mu^2 + \frac{1}{2}(\partial_\mu h')^2 - \frac{1}{2}m_{h'}^2 h'^2 + \mathcal{L}_{int}$$

$$\mathcal{L}_{int} = -\frac{\kappa}{2}V_{\mu\nu}F^{\mu\nu} + \frac{m_V^2}{v'}h'V_\mu^2 + \ldots$$

- Assume all other particles in hidden sector are heavy
- Effective coupling to SM: κe

Need *high luminosity* experiments!

B-factory Signatures

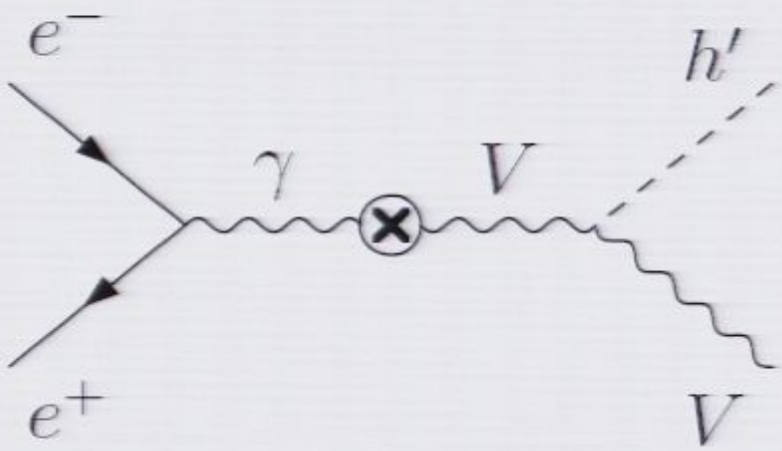
BB, Pospelov, Ritz '09
Essig, Schuster, Toro '09
Reece, Wang '09

B-factories

B-factories BaBar and Belle have the following advantages in probing a GeV scale hidden sector:

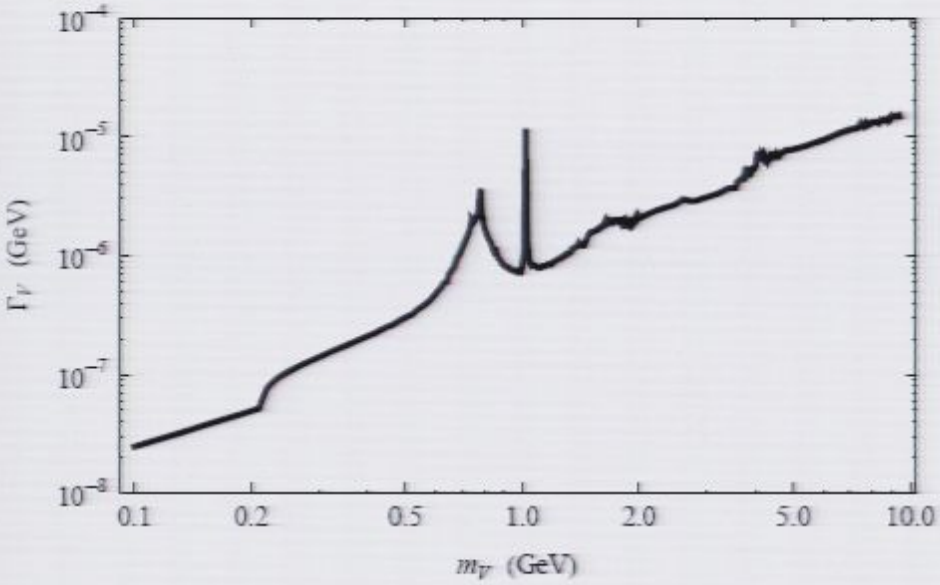
- Large data sets ~ 500 fb^{-1}
- COM energy $\sqrt{s} \simeq 10$ GeV, close to masses of V, h'

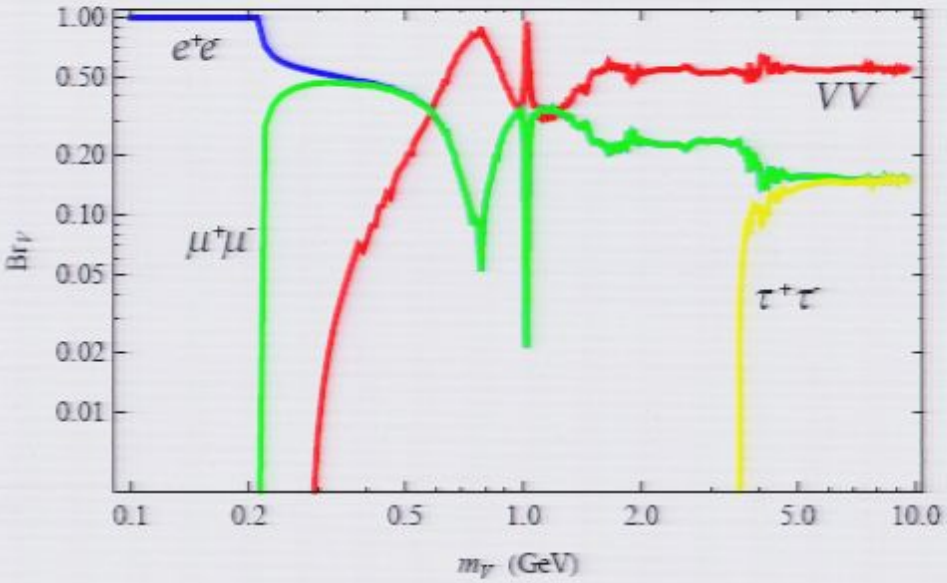
Higgs′-strahlung



- Leads to 6-lepton final states

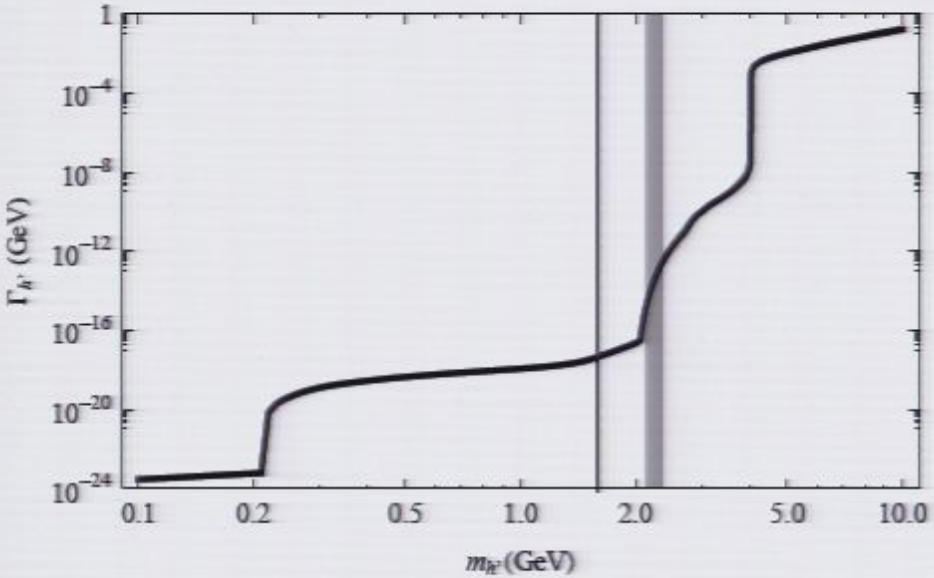
V_μ decays

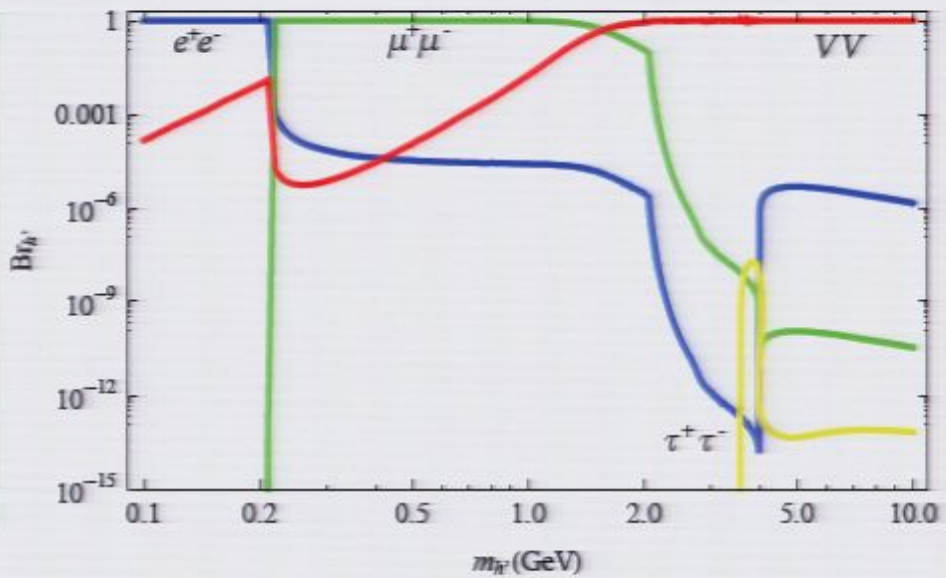




- V_μ always has a significant branching to leptons

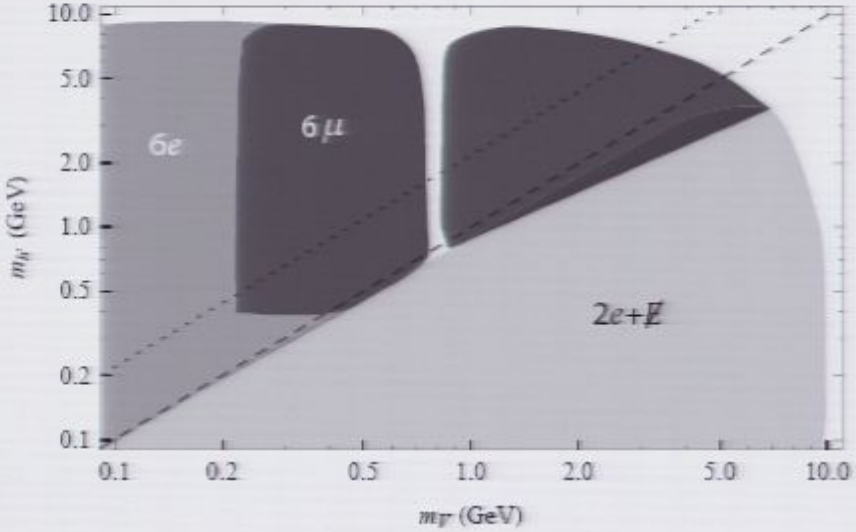
h' decays

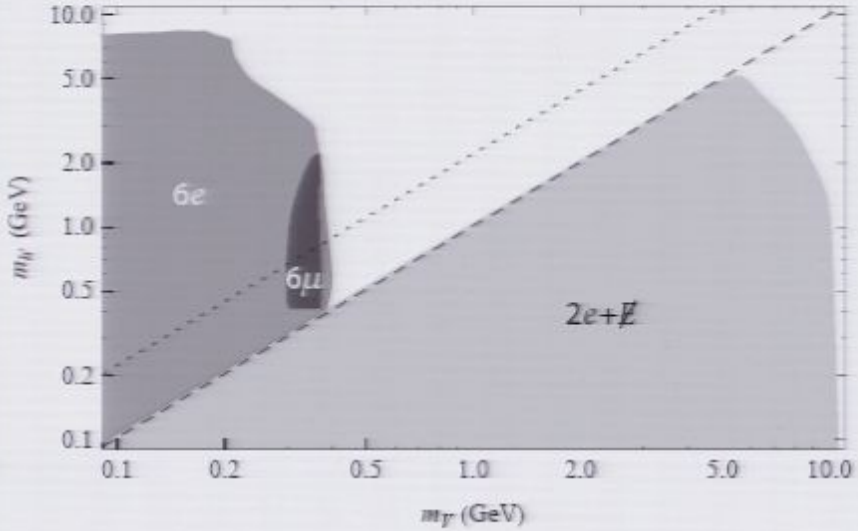




- Decays of h' depend on whether $m_{h'} > m_V$ or $m_{h'} < m_V$

Sensitivity





- Could be 1000s of events on tape!

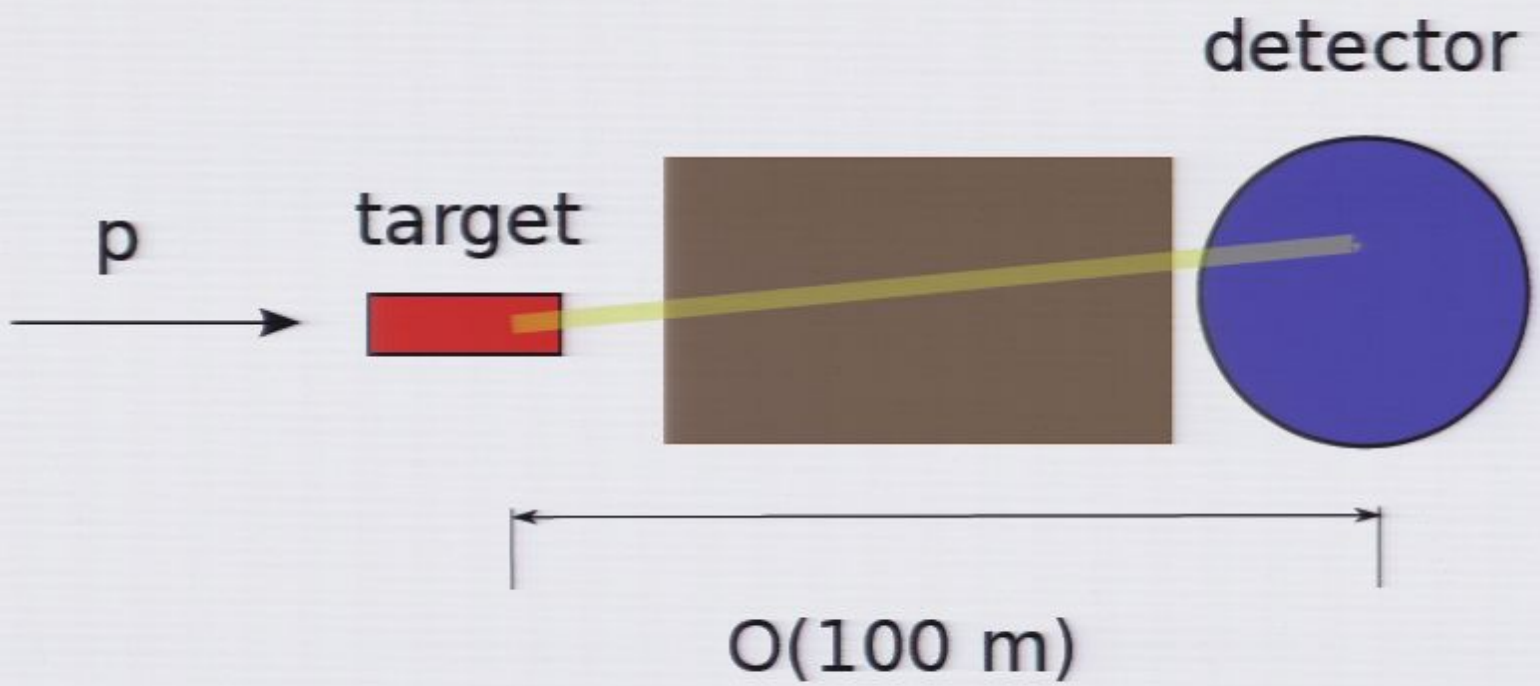
Fixed Target Experiments

electron beam:
Reece, Wang '09
Bjorken, Essig, Schuster, Toro '09

proton beam:

BB, Pospelov, Ritz, to appear;

Experiments:
LSND, MiniBooNE, NuMi/Minos, Nova, T2K . . .



Advantages of fixed targets

- Huge luminosity (10^{21} protons on target (POT)):

$$\mathcal{L} = N_{\rm POT}\left(\frac{N_A \rho L}{A}\right) \sim 10^{46} - 10^{47}{\rm cm}^{-2}$$

  – compare to $\sim 10^{41}{\rm cm}^{-2}$ for colliders

- Low background for neutrino experiments ("earth filters out the junk!")

- Probe long-lived states $\longrightarrow$ small κ regime (complementary to collider probes for larger κ)

Event rate estimates

$$N_{events} = N_V \times P_{det}$$

- Direct production: $N_V = \sigma(p + A \to V + X) \times \mathcal{L}$
- Decays of secondary hadrons: $N_V = N_H \times \mathrm{Br}(H \to V + X)$

$$P_{det} \sim \left(\frac{d\Omega_{c.o.m.}}{4\pi}\right)\left(\frac{\Delta z}{\gamma v \tau}\right)$$

Light vectors: $m_V <$ few hundred MeV

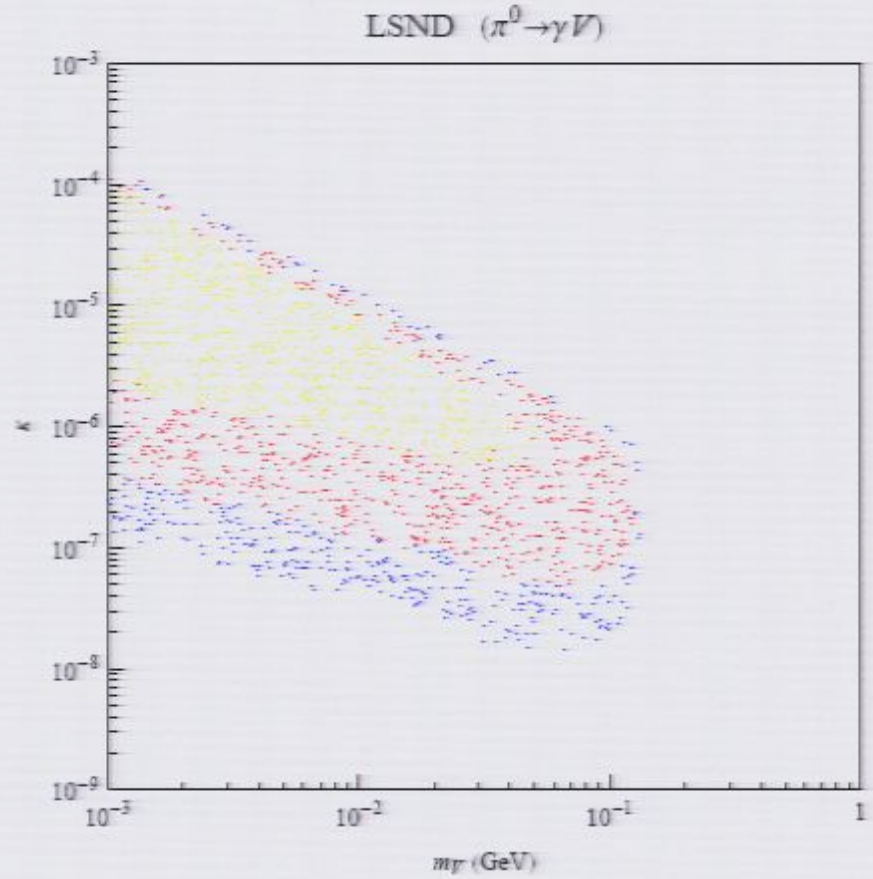
- $V \to e^+e^-(\mu^+\mu^-)$:

$$c\tau \approx 80\mathrm{m} \times \left(\frac{10^{-7}}{\kappa}\right)^2 \left(\frac{100\mathrm{MeV}}{m_V}\right)$$

- LSND provides strongest sensitivity:
  - 800 MeV proton beam
  - Detector 30 m away from target
  - 10^{23} protons on target!

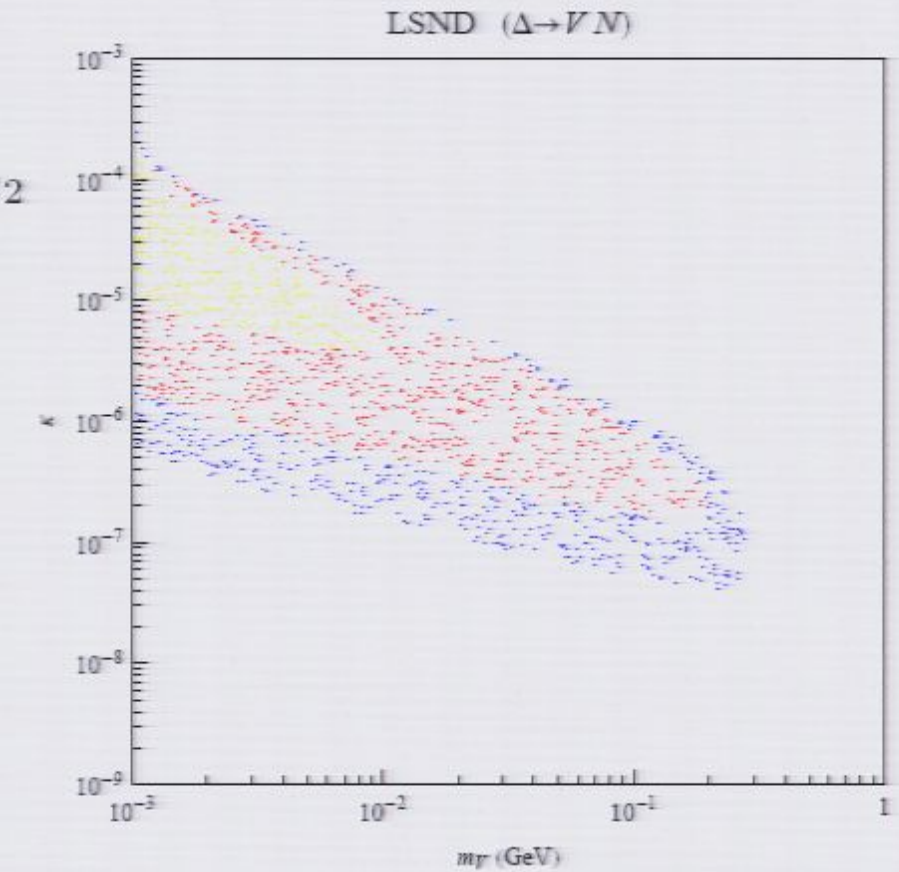
LSND: $\pi^0 \to \gamma + V$

$$\mathrm{Br}_{\pi^0 \to \gamma V} \simeq 2\kappa^2 \left(1 - \frac{m_V^2}{m_\pi^2}\right)^3$$



LSND: $\Delta \to N + V$

$$\mathrm{Br}_{\Delta\to NV} \simeq \mathrm{Br}_{\Delta\to N\gamma} \times \kappa^2 \left(1 - \frac{m_V^2}{(m_\Delta - m_N)^2}\right)^{3/2}$$



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Higgs' bosons

- $m_{h'} > m_V$: Direct decay $h' \to VV(VV^*)$ - too short lived
- $m_{h'} < m_V$: Loop induced decay $h' \to l^+l^-$ - too long lived
- $m_h \sim m_V$, intermediate regime - "just right"

Experiments:

- Light ($m_{h'} < 70$ MeV): LSND
- Medium ($m_{h'} < 300$ MeV): MiniBooNE
- Heavy ($m_{h'} \sim$ GeV): NuMi/Minos

LSND: $\Delta \to N + V$

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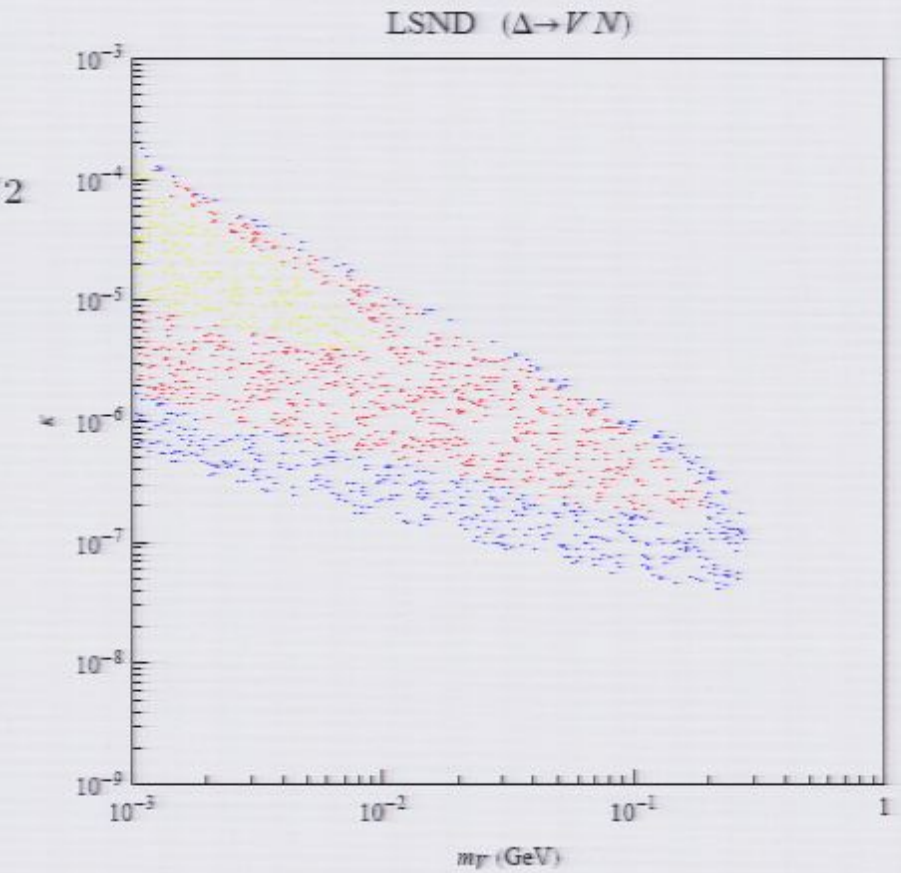

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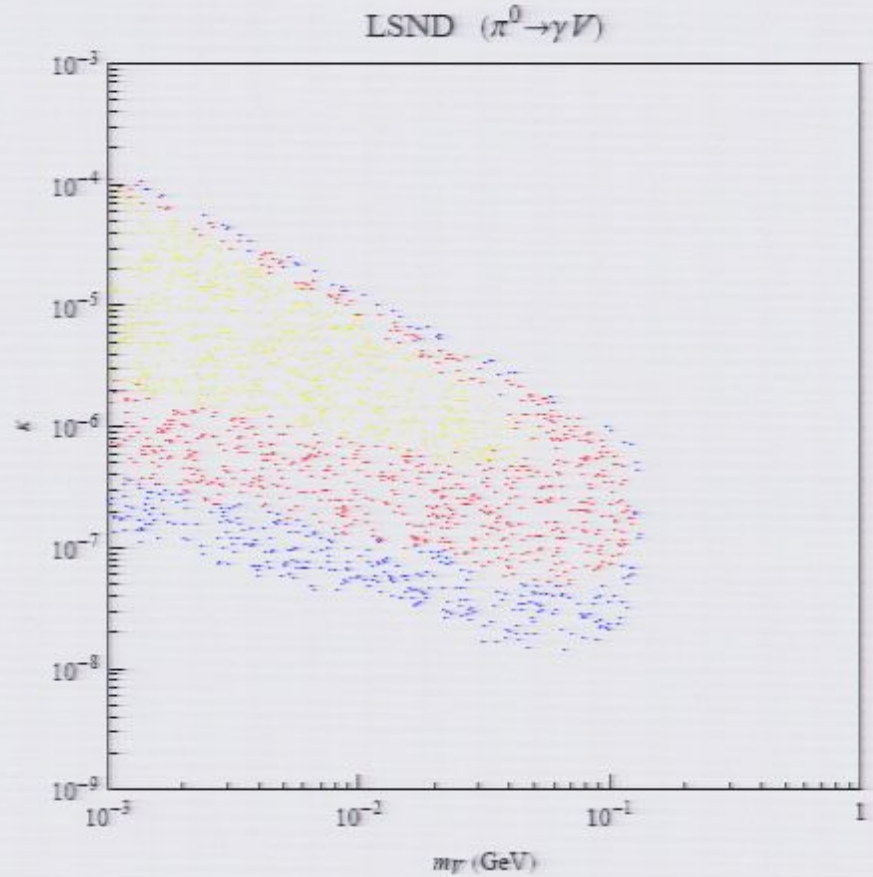

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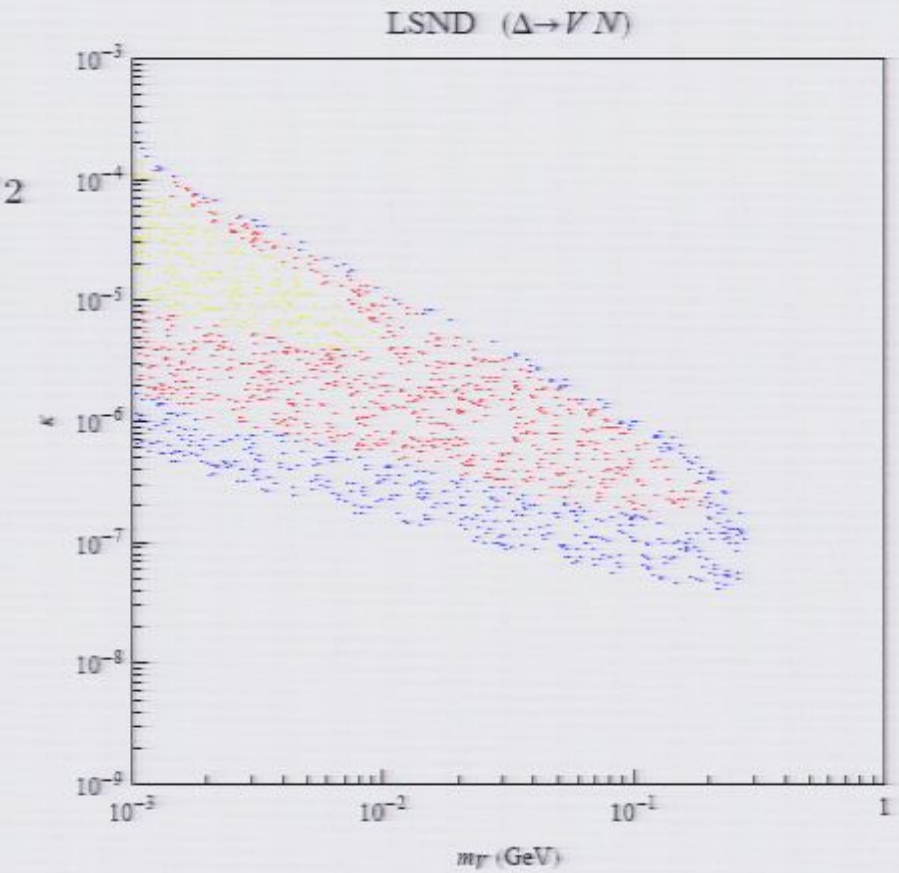

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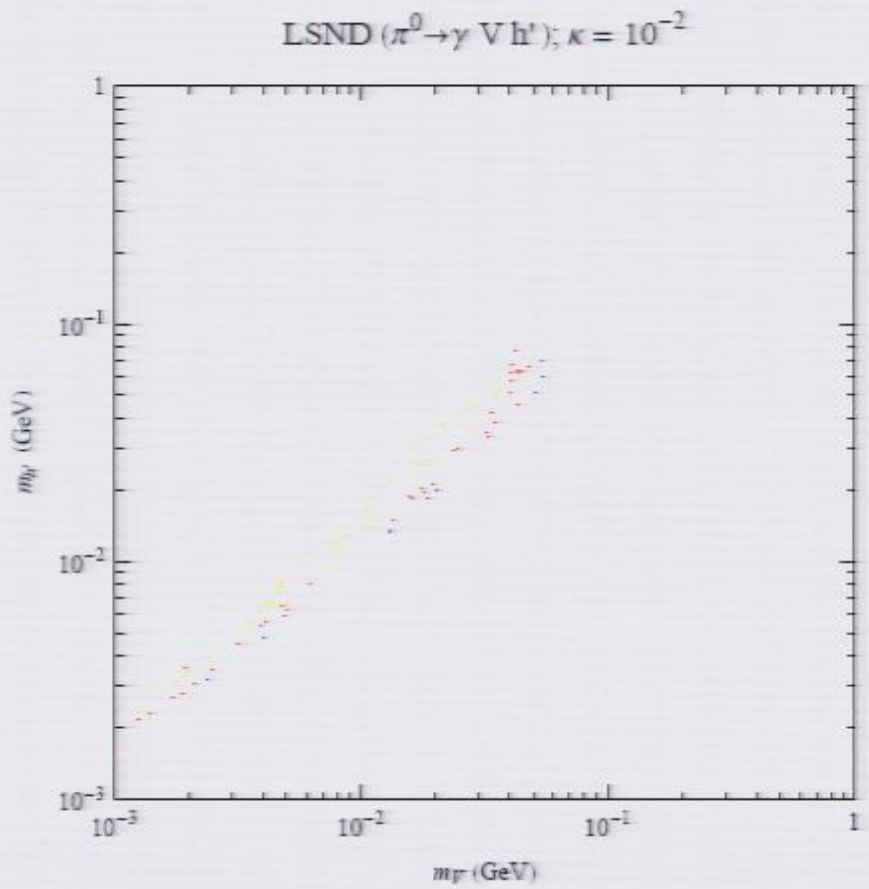
LSND: $\pi^0 \to \gamma + V + h'$

$$\mathrm{Br}_{\pi^0 \to \gamma V h'} \simeq \kappa^2 \alpha' I(m_{h'}, m_V, m_\pi).$$



MiniBooNE and MINOS - in progress

- Further constraints on h'
- Decays of ρ, ω to Vh'
- QCD production of V, h'
- $h' \to V$ conversion in the detector

Work in progress

- Projected sensitvities of next generation neutrino experiments on $U(1)_S$
- Dark matter "beam" $\rightarrow$ strong constraints on MeV dark matter models
- Constraints on other portals/hidden sector scenarios (Higgs, neutrino, axion, higher dim. ops)

Conclusions

- Hidden sectors are a generic and well-motivated possibility for new physcs.
- It is very well possible that dark matter resides in a hidden sector
- High luminosity probes of the U(1) portal:
- B-factory signals:
  - Higgs′-strahlung → multi-lepton final state
  - Probe $U(1)_S$ couplings $\kappa \sim O(10^{-2} - 10^{-3})$
- Fixed targets
  - Probe smaller couplings $\kappa \sim O(10^{-8} - 10^{-5})$ and masses