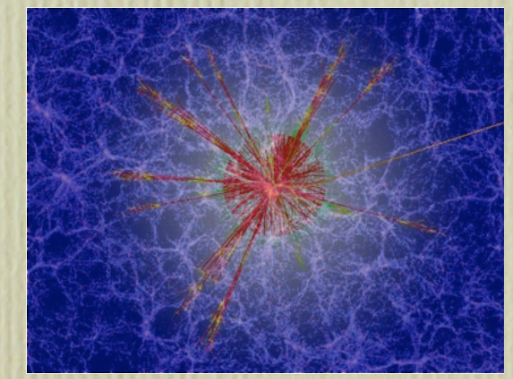
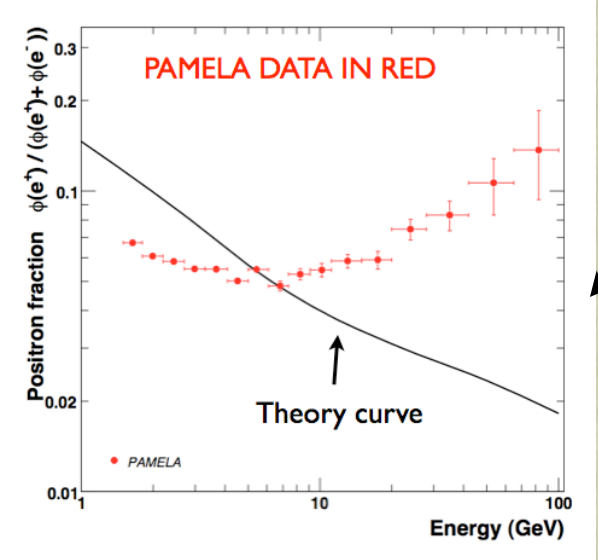
Searching for Dark Forces at SuperB



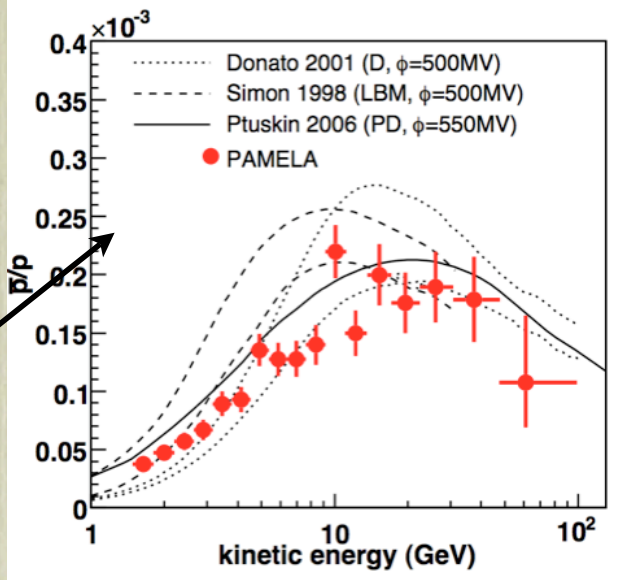
Matt Graham
SLAC
SuperB General Meeting
December 1, 2009

ATIC/PAMELA/FERMI etc.



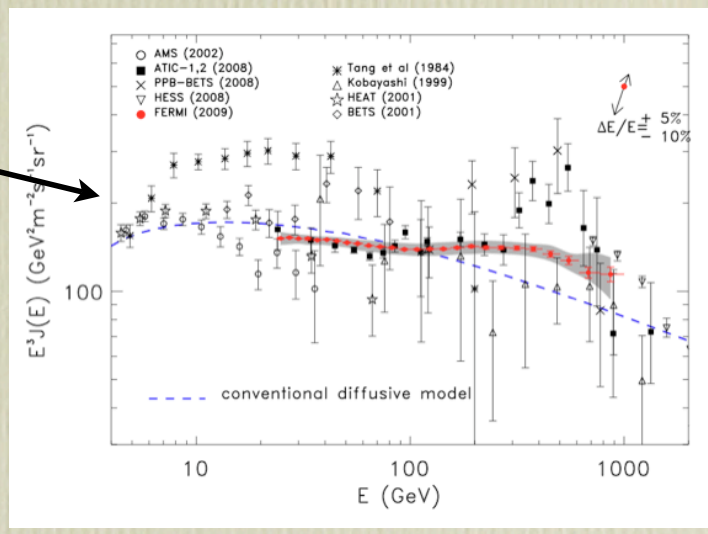
excess in pos/ele ratio

...but not in pbar/p ratio



- excess also seen in total e^+e^- flux
  - new FERMI result sort of between PAMELA/ATIC and naive expectation

Is this astrophysics or particle physics?

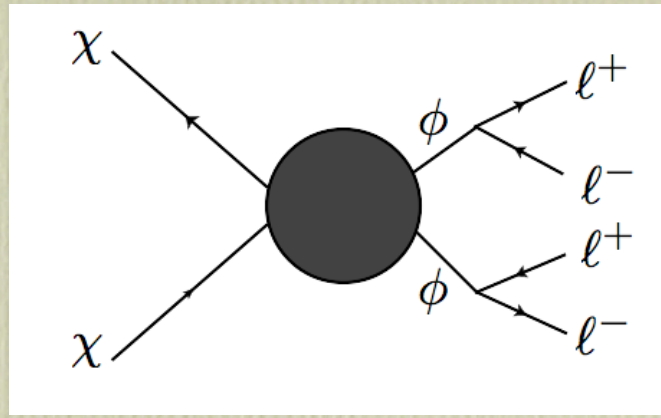


See also Fabio Bossi's talk earlier today

"A theory of dark matter"

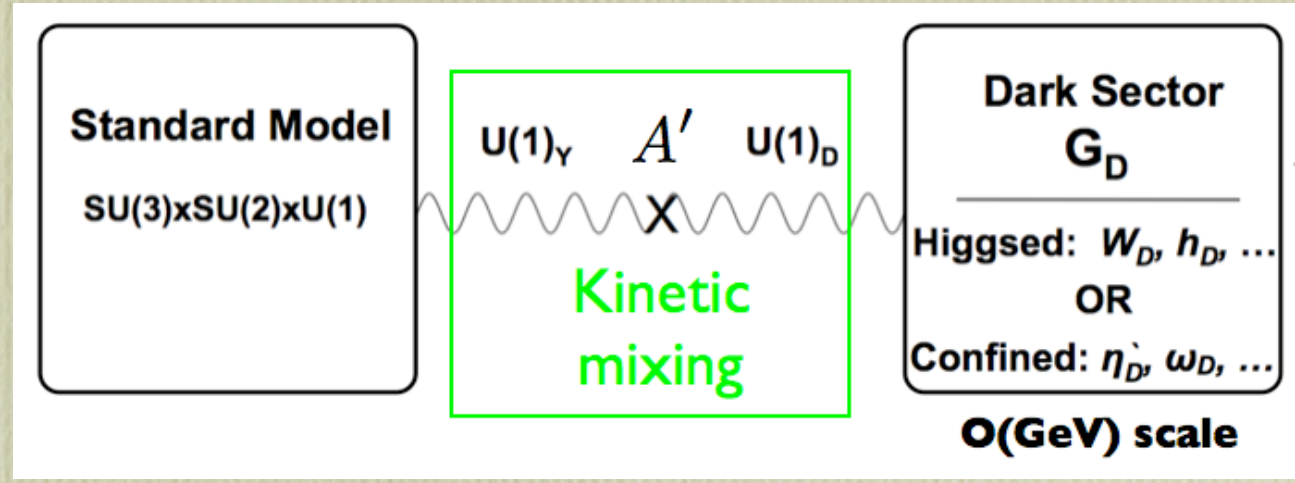
Arkani-Hamed, Finkbeiner, Slatyer, Weiner (hep-ph/0810.0713)

Pospelov, Ritz (hep-ph/0810.1502)



- new "dark force" with gauge boson φ~ GeV while the dark matter particle is ~TeV scale
- gauge boson decays to lepton pairs (e^+e^-, $\mu^+\mu^-$) but not pp because φ is below pp threshold (2GeV) (also can decay to pions...BR goes as R)
- the φ couples to the SM photon...we might see something in the B-Factories!

Structure of the Dark Sector



- Abelian $U(1)_D$ common to all models…mixes with SM hypercharge with coupling κ (or ϵ depending on the paper); "dark higgs" to give mass
- Structure in the dark sector is wide open…
  - could have nothing interesting (just he U(1))
  - Higgsed non-abelian SU(2): "dark EW"
    - Arkani-Hamed, Finkbeiner, Slatyer, Weiner (hep-ph/0810.0713)
  - Confined non-abelian SU(N): "dark color"
    - Alves, Behbahani, Schuster, Wacker (hep-ph/0903.3945)

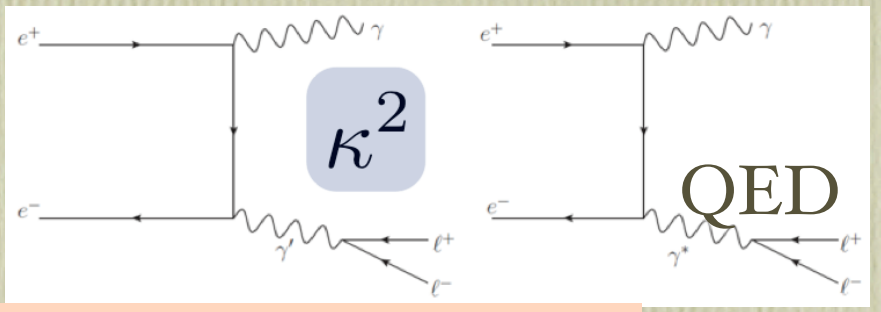
Some preliminaries...

- We haven't settled on the jargon yet...
  - dark photon=hidden photon=U-boson etc.

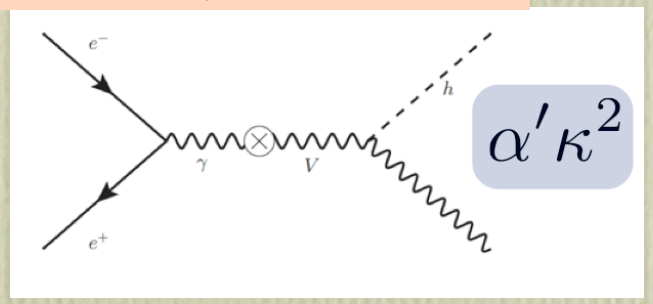
$$\phi = U = A' = \gamma_D = V \sim W_D = W'$$

  - dark higgs: $h' = h_D$
  - kinetic mixing parameter: $\varepsilon = \kappa = \chi$
  - dark sector coupling constant: $\alpha' = \alpha_D$

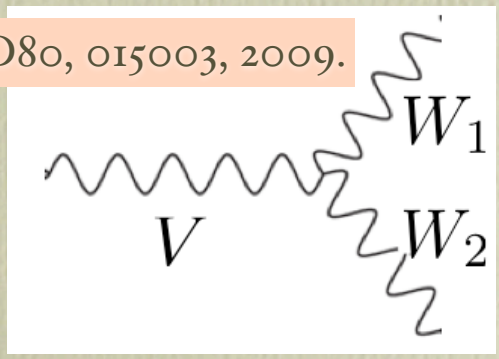
What to look for...direct production



Batell et al., PRD79, 115008, 2009.



Essig et al., PRD80, 015003, 2009.

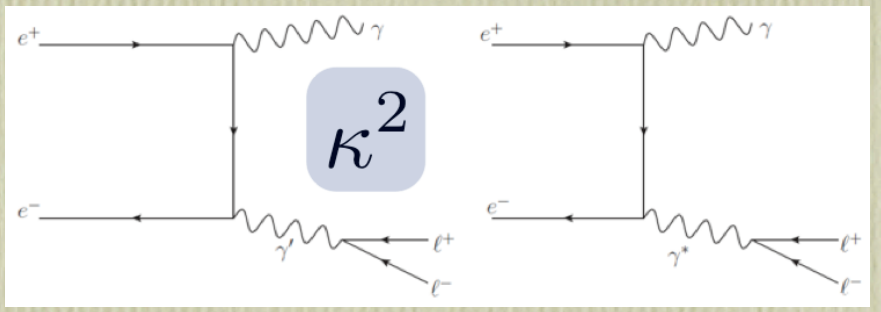


generic: $\gamma l^+ l^-$
look for a bump in ll mass
huge QED background

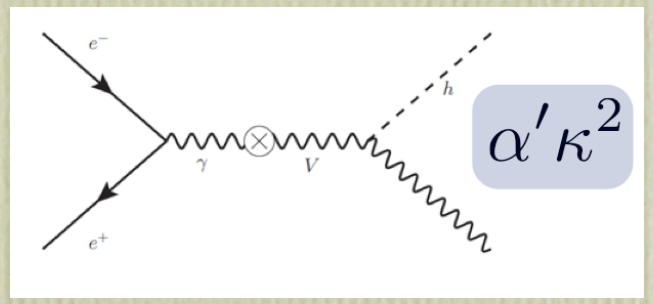
generic+Higgs: 6l or 2l+$\not{E}$
small QED background

generic non-Abelian: 4l
small QED background

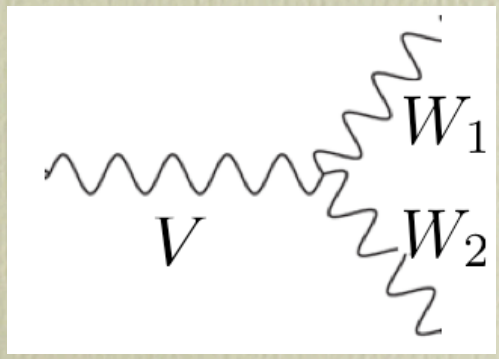
What to look for...direct production



CLEO: PRL 101, 151802 (2008)
Babar: PRL 103, 081803 (2009)

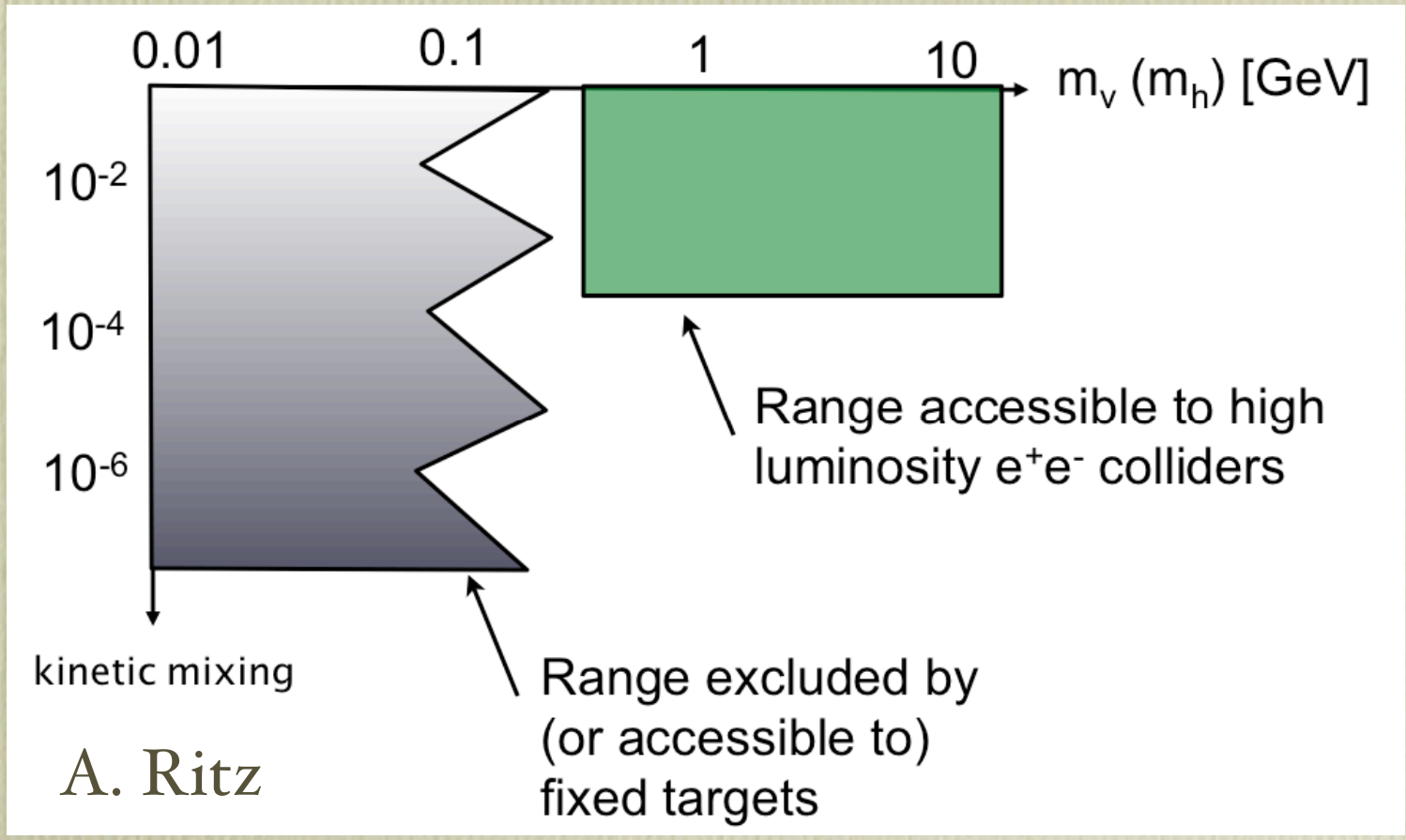


Nothing yet!



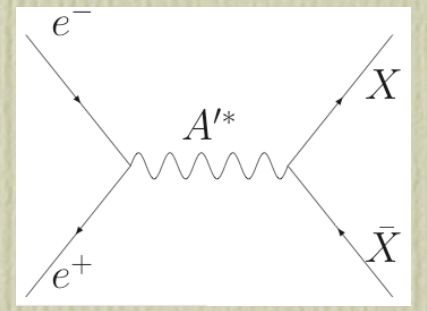
Babar: hep-ex/0908.2821

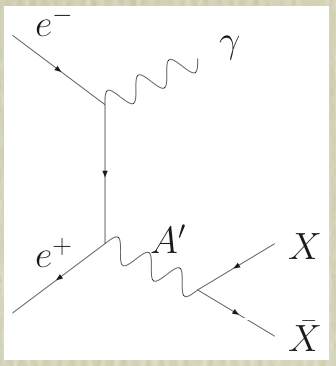
What we may reach...

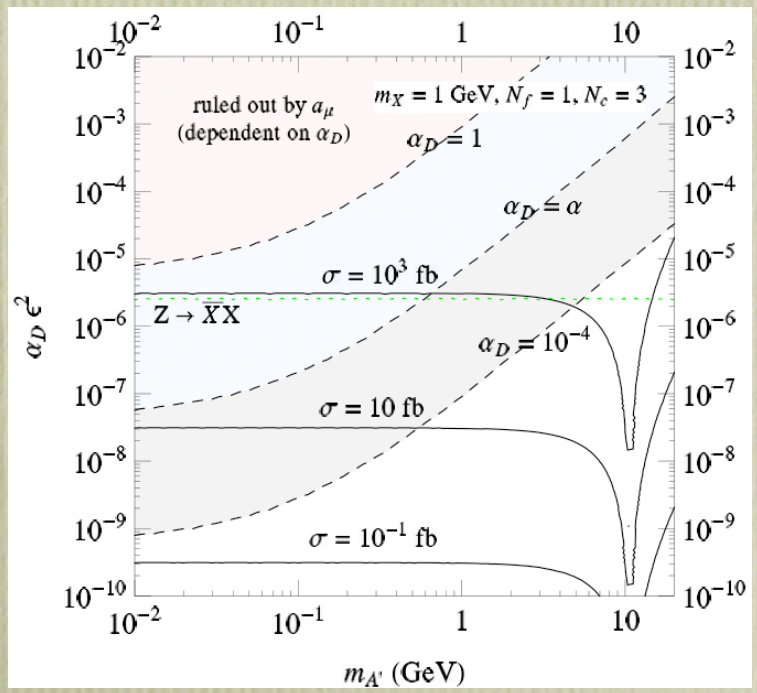


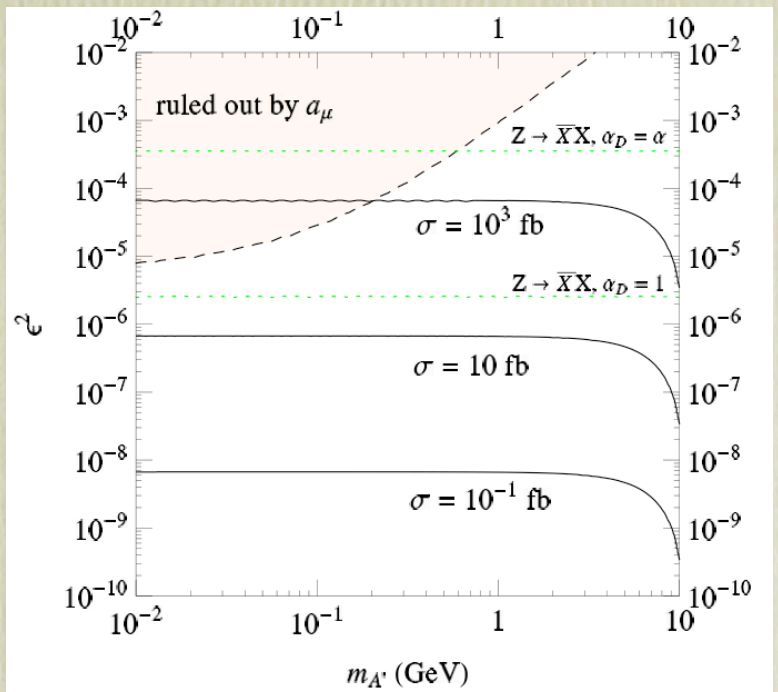
A. Ritz

Dark Forces at e+e- Colliders

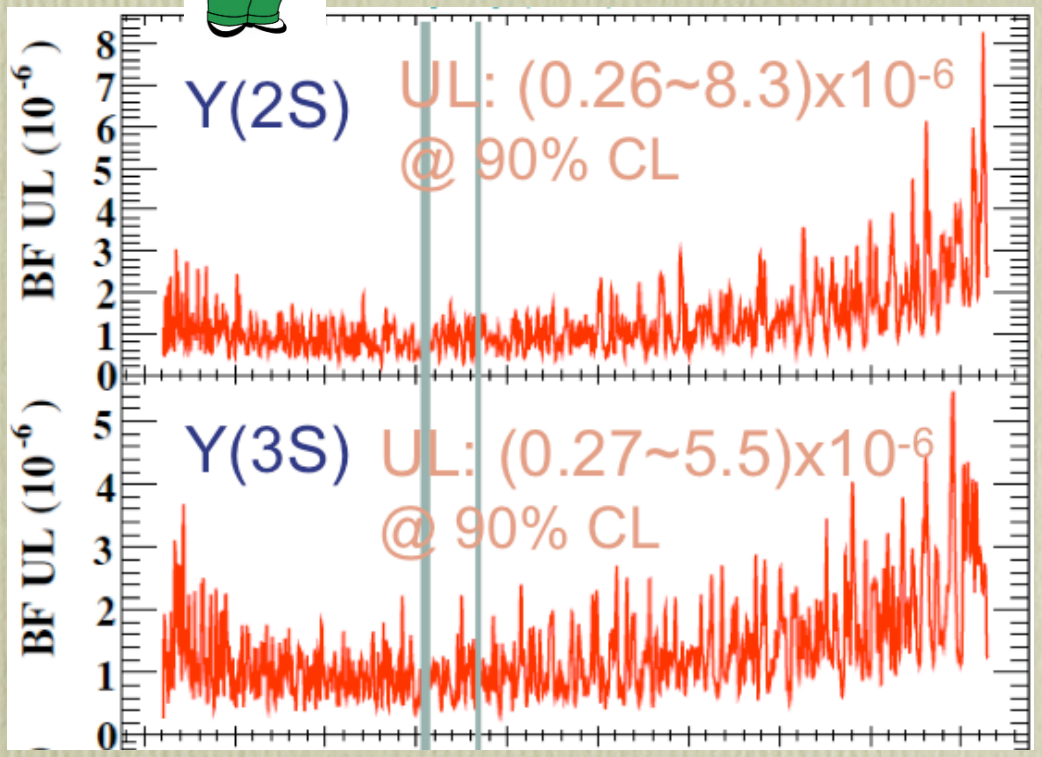








$e^+e^- \to \gamma\mu^+\mu^-$



30.22/fb @ Y(3s)
14.45/fb @ Y(2s)

PRL 103, 081803 (2009)

Analysis designed to look for light higgs (A_o), but works for this too...but big QED bkg.

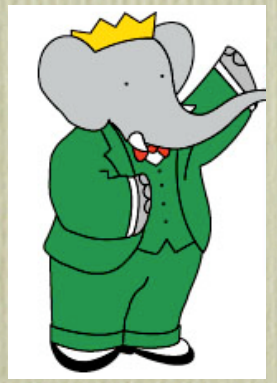
→corresponding limit on $\epsilon \sim 5\times10^{-3}$

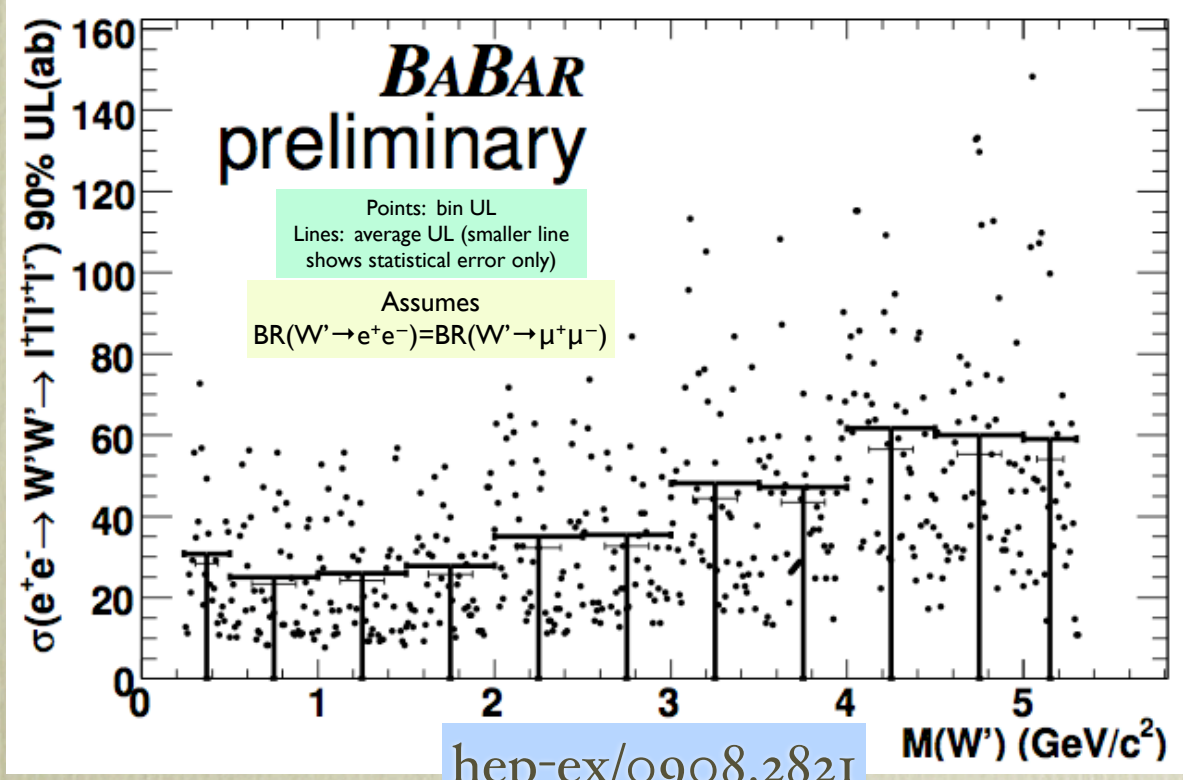
Remember...scaling of ϵ goes as: $\sqrt[4]{\mathcal{L}}$ so adding full dataset (x10) reduces limit by ~x 1.8.

...even SuperB only gets it down to ~1×10^{-3}...it's not a winning game...

$e^+e^- \rightarrow$ 4-leptons

- Very clean mode (esp 4μ) designed to search for a non-Abelian dark sector...requires 2 resonances within ~10MeV
- Used full BaBar runs 1-7 dataset...~540/fb



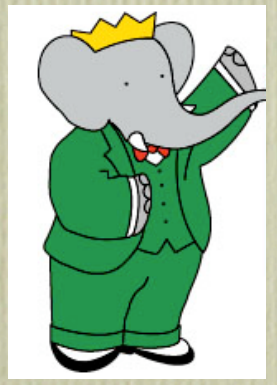


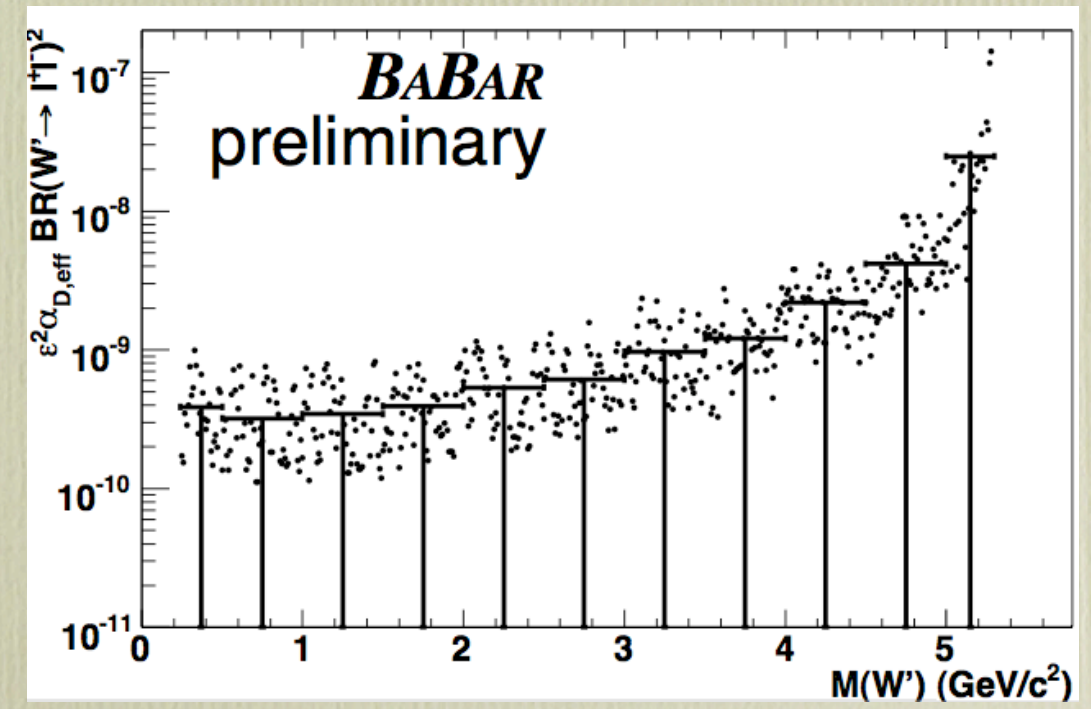
hep-ex/0908.2821

$e^+e^- \rightarrow$ 4-leptons

$$\sigma(e^+e^- \rightarrow W_D W_D) \sim \frac{\pi\varepsilon\alpha\alpha_{D,eff}}{E_{cm}^2}\left(1-\frac{4m_{W_D}^2}{E_{cm}^2}\right)^{3/2}$$

...some O(1) s dependence absorbed into definition of $\alpha_{D,eff}$



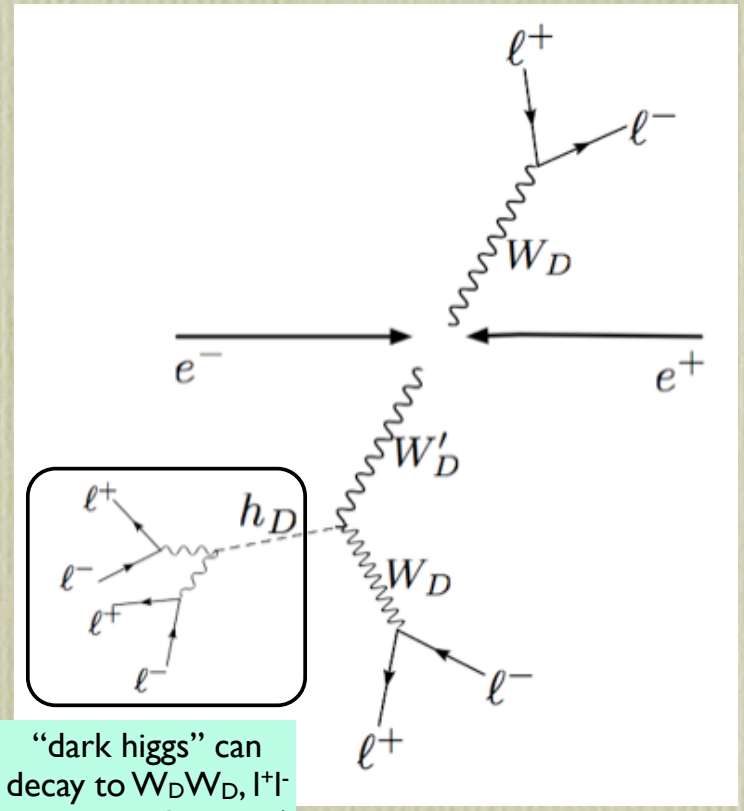


Remove BR(W→ll)² by dividing (2+R)²

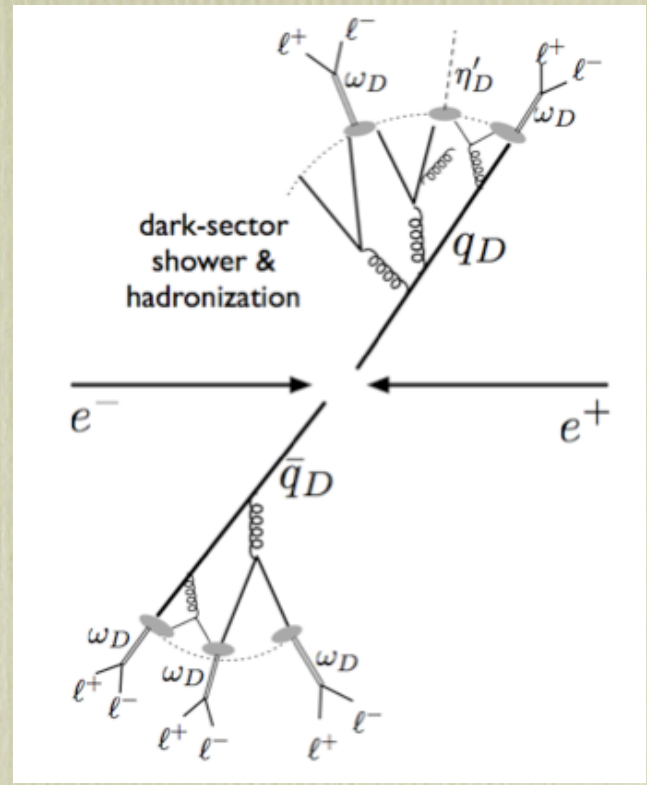
$\alpha_D \sim 10^{-2}$

$\epsilon < \sim 10^{-3}$
(for non-abelian hidden sector)

More exotic signatures...



"dark higgs" can decay to $W_D W_D$, l^+l^- or escape detector!



Non-Abelian Higgsed: 8 leptons or missing mass

Confined: lots of leptons; possibly missing mass depending on lifetimes..

...can also look for muons with a displaced vertex...

Searching for Dark Forces in Rare Decays

SuperB will be a meson factory...

$X \to YU$	n_X	$m_X - m_Y$ (MeV)	BR($X \to Y + \gamma$)	BR($X \to Y + \ell^+\ell^-$)	$\epsilon \leq$
$\eta \to \gamma U$	$n_\eta \sim 10^7$	547	$2 \times 39.8\%$	6×10^{-4}	2×10^{-3}
$\omega \to \pi^0 U$	$n_\omega \sim 10^7$	648	8.9%	7.7×10^{-4}	5×10^{-3}
$\phi \to \eta U$	$n_\phi \sim 10^{10}$	472	1.3%	1.15×10^{-4}	1×10^{-3}
$K_L^0 \to \gamma U$	$n_{K_L^0} \sim 10^{11}$	497	$2 \times (5.5 \times 10^{-4})$	9.5×10^{-6}	2×10^{-3}
$K^+ \to \pi^+ U$	$n_{K^+} \sim 10^{10}$	354	-	2.88×10^{-7}	7×10^{-3}
$K^+ \to \mu^+ \nu U$	$n_{K^+} \sim 10^{10}$	392	6.2×10^{-3}	7×10^{-8a}	2×10^{-3}
$K^+ \to e^+ \nu U$	$n_{K^+} \sim 10^{10}$	496	1.5×10^{-5}	2.5×10^{-8}	7×10^{-3}

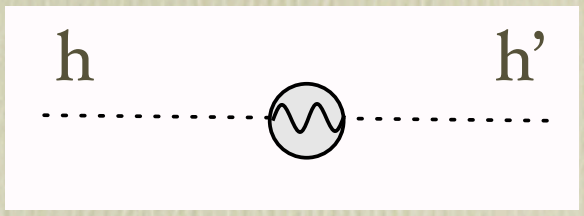
Reece & Wang 2009

Summary of estimates from existing samples...most of these are from fixed target experiments.

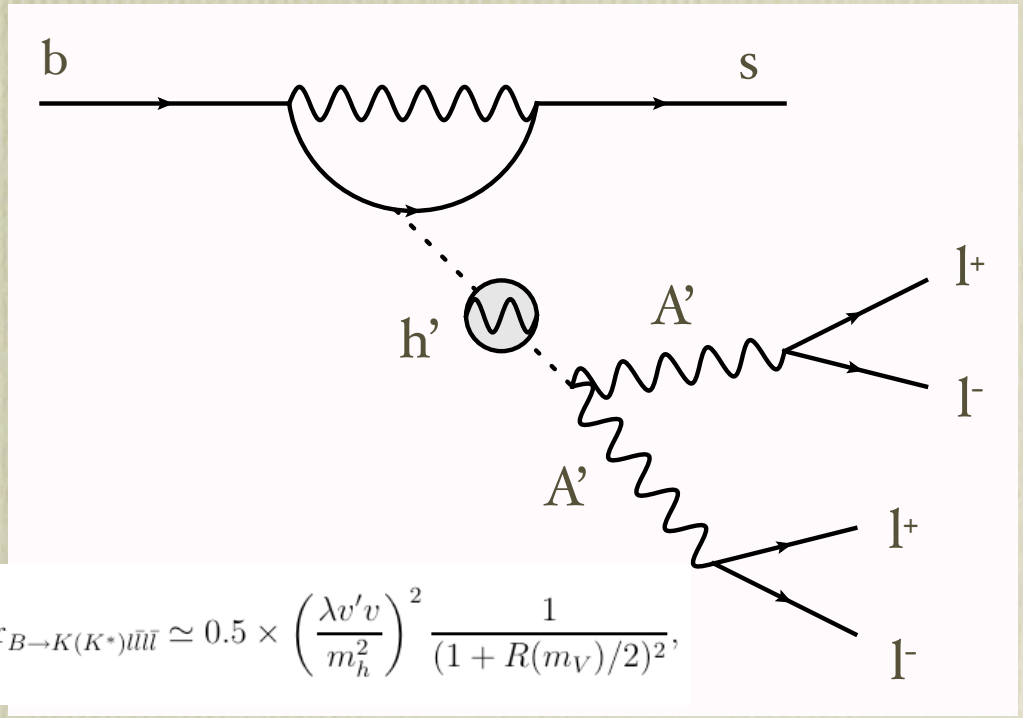
→SuperB will have a huge number of these and other meson decays from J/ψ, D, ϒ, and B...
→also, can look in π° Dalitz decays...

Rare B-Decays and the Higgs Portal

- Vector portal: $\mathcal{L} = -\frac{\kappa}{2} V^{\mu\nu} B_{\mu\nu}$
- Higgs portal: $\mathcal{L} = (-\lambda S^2 + \xi S) H^\dagger H$

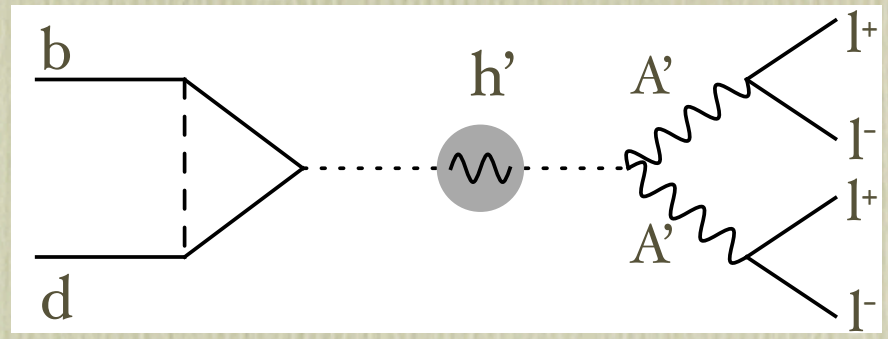


- In addition to kinetic mixing ("vector portal") there must also be a higgs portal.
- Because of the top dominating the loop, FCNC decays may be an interesting place to look for this...
  - Look for dilepton resonance in $K^{(*)}ll$
  - modes like $B \to K^{(*)}4l$ or $B^\circ \to 4l$ should be very clean



$$\mathrm{Br}_{B\to K(K^*)l\bar{l}l\bar{l}} \simeq 0.5 \times \left(\frac{\lambda v' v}{m_h^2}\right)^2 \frac{1}{(1+R(m_V)/2)^2},$$

Multilepton B° decays



Vector A'

$$\mathrm{Br}_{B_s \to VV} = 4 \times 10^{-5} \times \lambda^2 \lambda_{VV}^{1/2} \times \frac{1 - 4m_V^2/m_B^2 + 12m_V^4/m_B^4}{(1 - m_{h'}^2/m_B^2)^2},$$

- here, λ gives the mixing strength of the higgs-dark higgs and λ_{VV} is a phase space term
- reasonable to have BR~10^{-9}-10^{-11}
  - note that this eqn is for Bs decays...multiply by $|V_{td}/V_{ts}|$

Conclusions

- The possibility of a GeV scale, "dark" force has people excited
  - Addresses a number of anomalies...see dark forces workshop intro talk by N. Weiner for a nice summary of this
- The (super)B-Factories are a great place to look for evidence of dark forces, but limit on mixing in background dominated modes only scale by $L^{-1/4}$...the aim is $\epsilon < 10^{-3}$
  - many different models...many different modes.
  - look at very clean modes (6-lepton)
  - look for very rare decays ($b \rightarrow s\, 4l$)
- It would be great if we could look at modes like $2l+\not{E}$...triggering an issue at SuperB?
- We don't know the structure of hidden sector (duh!)...need to look at many different possible decay channels.