e^+e^- Collider Working Group

Summary

Matt Graham & Adam Ritz

Thesaurus

dark photon = hidden photon = secluded U(1) = U-boson = ...

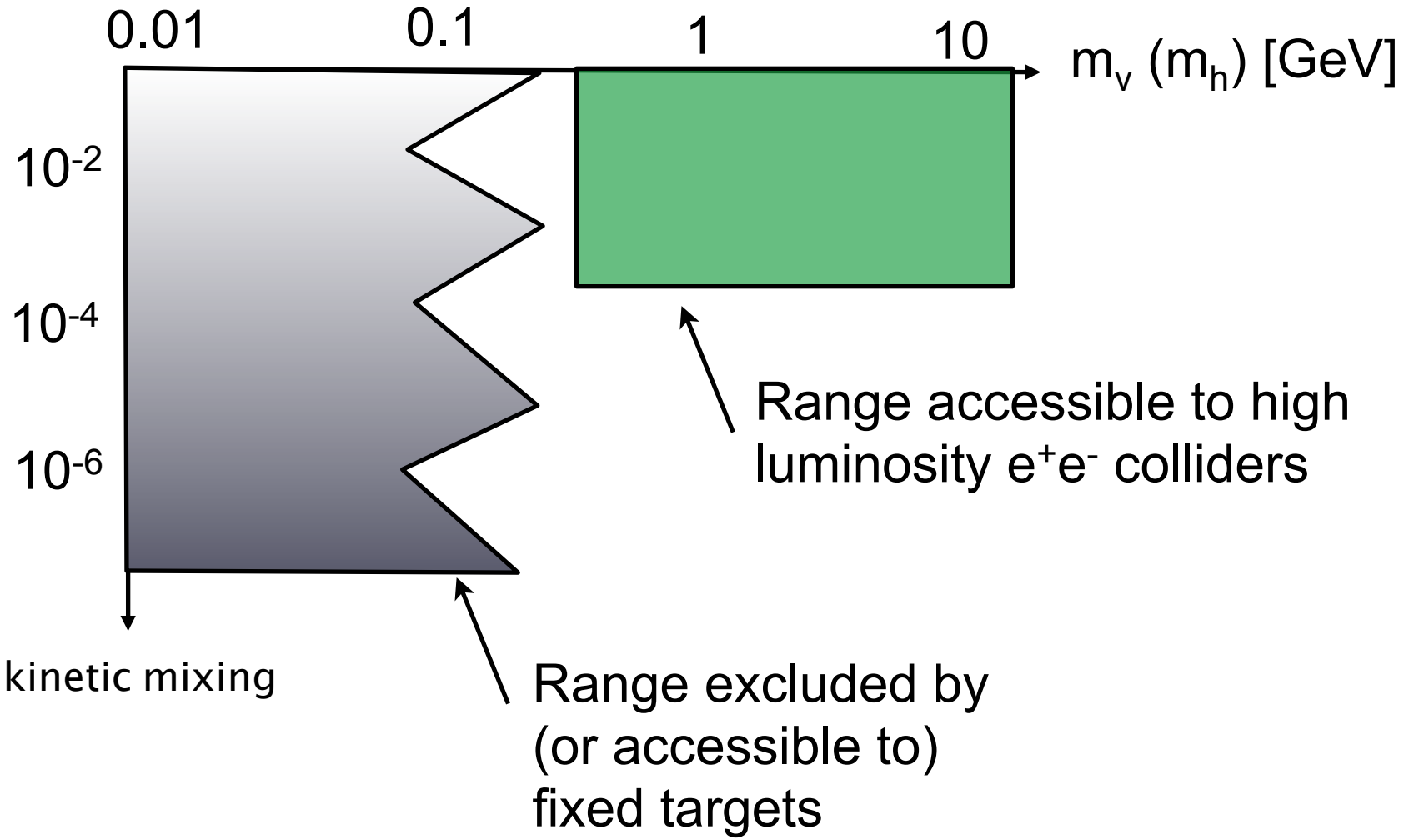
$$\gamma' = V = U = b = \cdots$$

kinetic mixing parameter

$$\epsilon = \kappa = \chi = \cdots$$

Experimental Sensitivity

In very schematic form



Experimental Sensitivity

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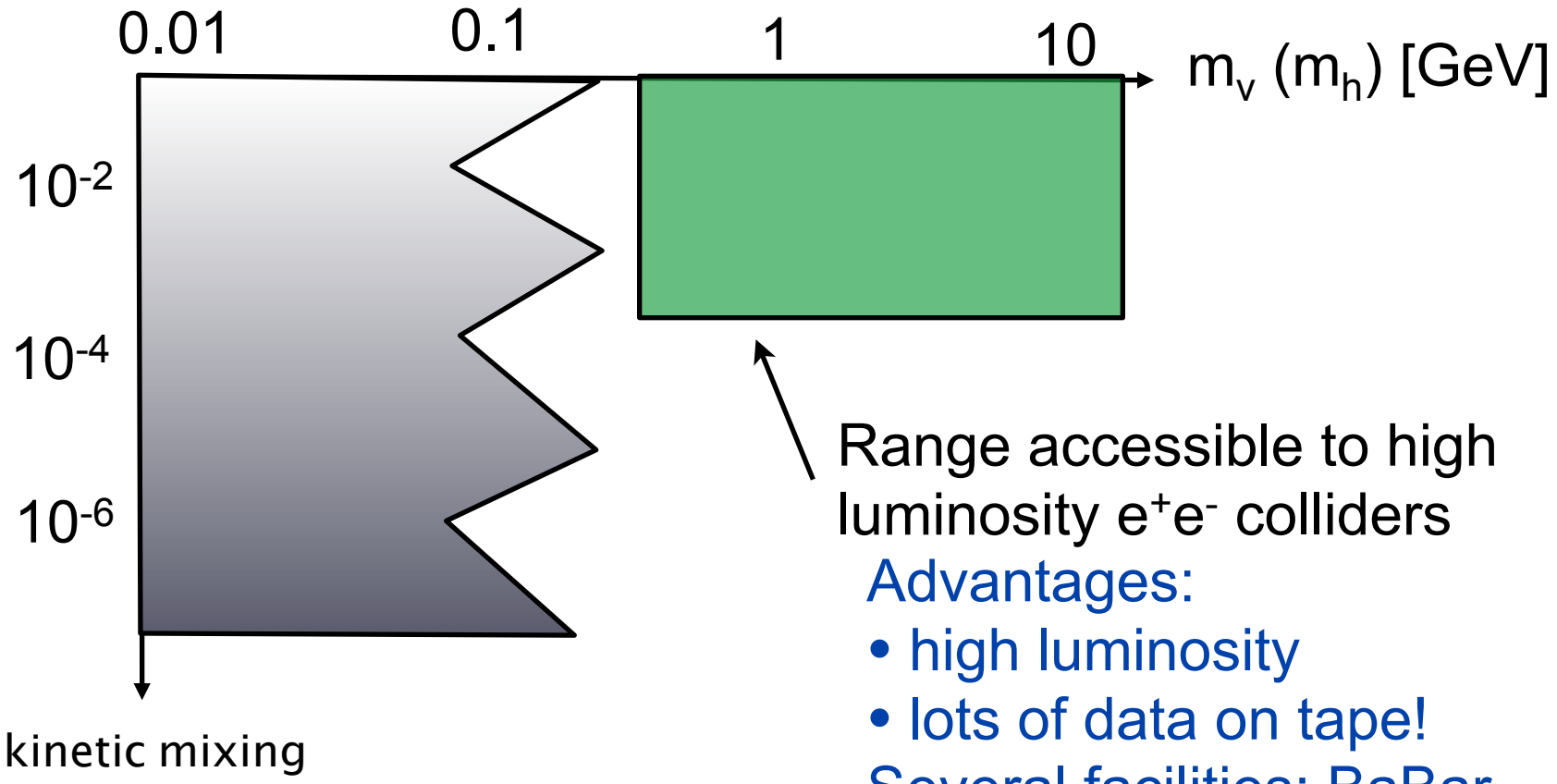


Advantages:

- high luminosity
- lots of data on tape!

Several facilities: BaBar, Belle, CLEO-c,BES-III, KLOE, ...

Production modes

- Direct production

  Tends to dominate for colliders operating a vector resonance, which cant decay to Vγ

- Rare decays

  Can be a significant probe (given the number of meson decays on tape) ***IF*** there is resonant production of final state

Production modes

- Direct production

  Tends to dominate for colliders operating a vector resonance, which cant decay to Vγ

  - Some analyses in progress/complete
  - Further anlyses discussed in WG

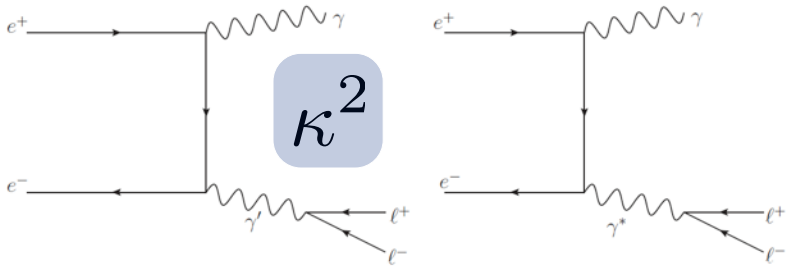
- Rare decays

  Can be a significant probe (given the number of meson decays on tape) ***IF*** there is resonant production of final state

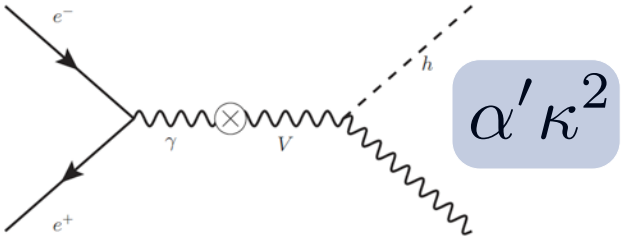
  - Scope for existing data to be “mined”
  - Further analyses possible

Final States (direct production)

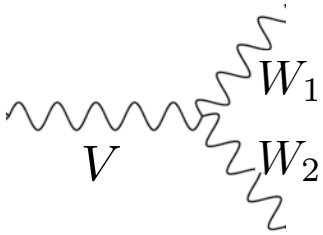
- "Generic": $e^+e^- \longrightarrow \gamma l^+ l^-$



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



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



Also: higher multiplicity (confining), 4l + $\not{E}_T$, ...

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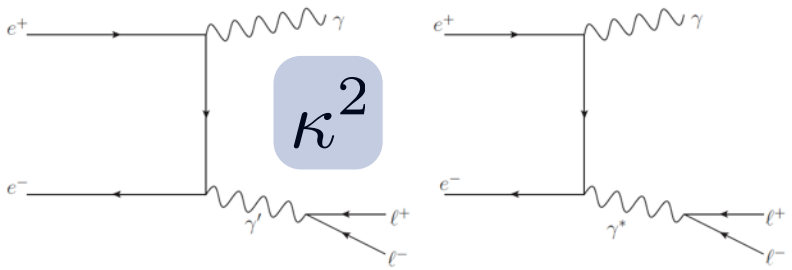

- BaBar [via Υ-decay search, H. Kim] ✓?
- Belle [Y. Kwon, J. Rorie]
- BES-III [H. Li, Y. Zheng]
- KLOE [F. Bossi]

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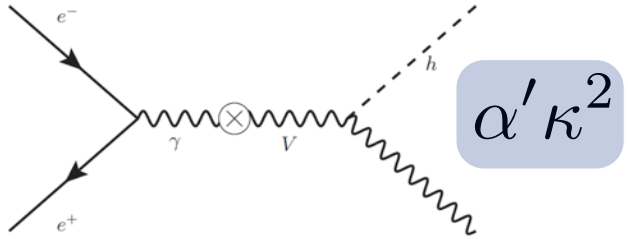

- not yet!
  [interest from BaBar, Belle, BES-III, KLOE]

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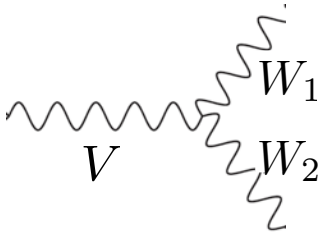


- BaBar [4l, M. Graham] ✓

Also: higher multiplicity (confining), 4l + $\not{E}_T$, ...

Rare meson decays

Various facilities have sensitivity (~$\mathscr{L}$/s) through rare decays

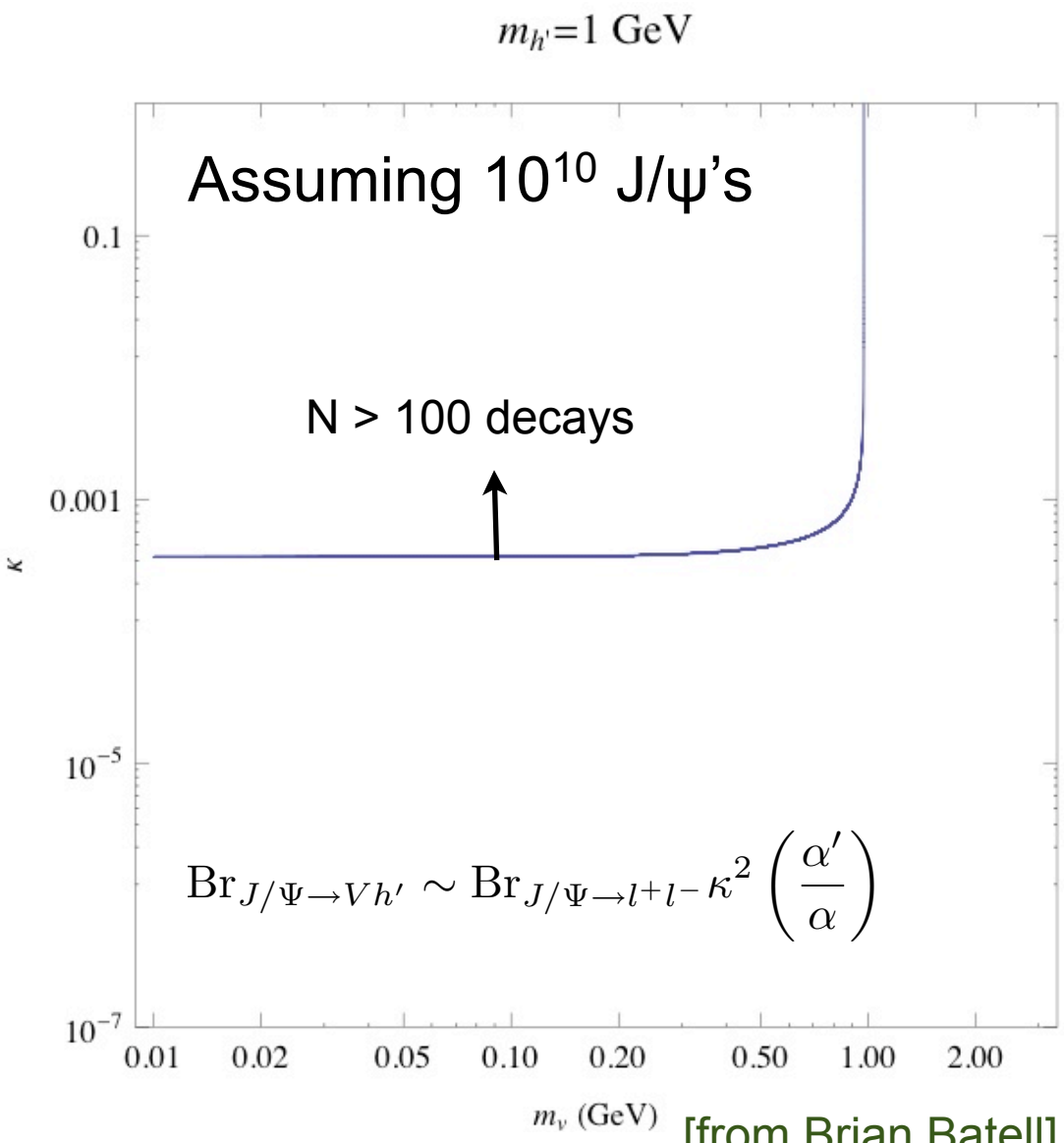
$X \to YU$	n_X	$m_X - m_Y$ (MeV)	BR($X \to Y + \gamma$)	BR($X \to Y + \ell^+\ell^-$)	$\epsilon \leq$
$\eta \to \gamma U$	$n_\eta \sim 10^7$	547	$2 \times 39.8\%$	6×10^{-4}	2×10^{-3}
$\omega \to \pi^0 U$	$n_\omega \sim 10^7$	648	8.9%	7.7×10^{-4}	5×10^{-3}
$\phi \to \eta U$	$n_\phi \sim 10^{10}$	472	1.3%	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 '09]

- More existing data - K → eeγ , π → ee, η → ... (kTeV, BaBar/Belle, KLOE?)

- J/ψ→ 6l via higgs'strahlung ⇒ sensitivity to κ~10^{-3}-10^{-4} given 10^{10} at BES-III in 1yr!
- Rare B-decays....

Eg: Raw sensitivity at BES-III



[from Brian Batell]

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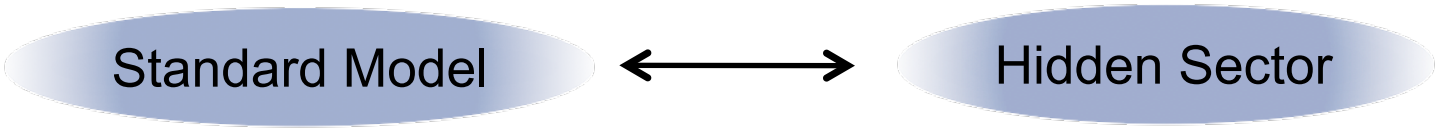
Additional portals



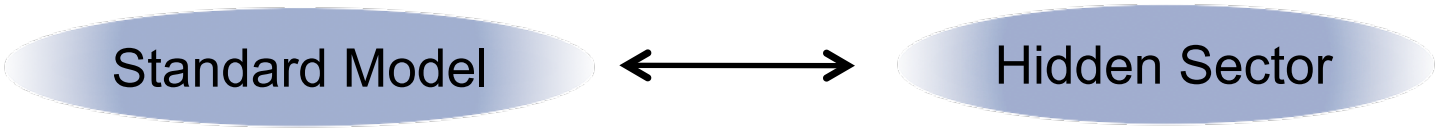
$$\mathcal{L}_{med} = \sum_{n,k,l}^{n=k+l-4} \frac{O_k^{(SM)} O_l^{(med)}}{\Lambda^n}$$

There are three renormalizable "portals" (with n=0)

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

Also interesting higher order portals involve current couplings: $\mathcal{L} = J^\mu_{\rm SM}(V_\mu, \partial_\mu a, \cdots)$

Additional portals



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Generically have both with a higgsed dark photon

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

Through higgs/higgs' mixing, the Higgs portal can be probed through flavor-changing decays

- e.g. B → K, K' (i.e. b → sh')

[Bird et al, '04, '06]

Further developments & issues

Super-B factories:

- higher luminosity (linear gain for “clean” modes)
- triggering (might need 3 tracks?)

Issues:

- To go from counts to sensitivity plots
  - Benchmark Models? [Abelian - Batell et al ’09
  - kinematic distributions? Nonabelian - Baumgart et al ’09]

- Tools - missing high multiplicity generators

[input from hadron collider tools?
L.-T. Wang, J. Wacker,...]

Summary

- Range of experiments: BaBar, Belle, CLEO-c, BES-III, KLOE (+Super-B-factories) probing the luminosity frontier

- Several dark force signatures, via direct production and rare decays

- Significant data sets exist, some analyses already complete/in progress (with null results), others feasible.

Outcomes:

- clearer picture of the primary analyses needed (i.e. benchmarks)
- further rare meson decay data can be mined

Thanks to the organizers and everyone in the e^+e^- WG !