

UV Scenarios of Dark Photons & Kinetic Mixing



Some Possible Directions:

- Explore the nature of the portal matter (PM) w/ both SM & Dark charges
 - use as tools to probe 'unification' of SM & Dark gauge symmetries/sectors
 - new fermions, scalars & gauge fields accessible at colliders ←
- Employ extra dimensions as tools to address issues in KM, eg, Γ ($h \rightarrow \text{inv}$)
 - Kaluza-Klein excitations of DP...etc. accessible to multiple accelerators

- Example 1: PM is a set of TeV-scale VLF(s), F , which transform analogous to the SM fields, f , with which they must mix to guarantee instability, via dark Higgs(S) Yukawa interactions (with $v_{\text{ev}} \sim v_S$)

$$\lambda F^c f S + \text{h.c.} \quad [\lambda \sim O(1)] \quad (\text{chiral!})$$

→ Pheno implications follow from the choice of f Two quick examples:

$f \sim b$ ($F=B$): B looks like a heavy VL b quark frequently searched for (& not found) at LHC via the $B \rightarrow Wt$, Zb or hb decay channels.. Not here!

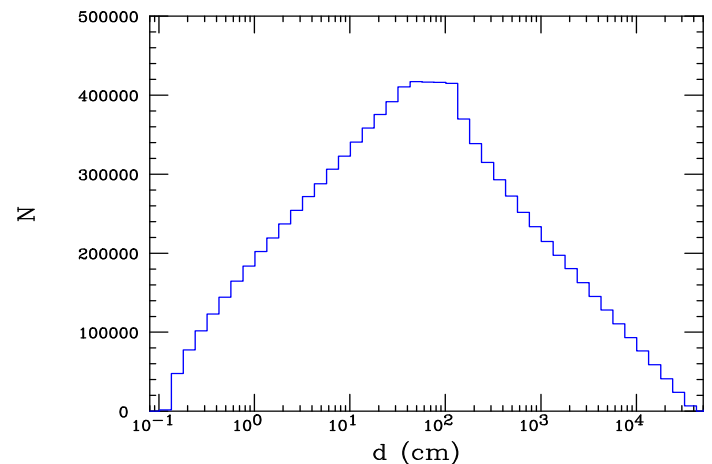
Here $B \rightarrow bV$ (the DP) or bS with equal BFs & are **FAR** dominant

$bV/bS \rightarrow 2$ b-jets+MET [b-squark-like search \sim boring] or 2 b-jets + 2 narrow lepton-jets (!)

depending upon parameter space location

→ new signatures

Boosted DP decay length distribution →



$f \sim \mu$ (F=M) $M \sim$ heavy VL muon that induces (via V/S) multiple new contributions to $(g-2)_\mu$ in addition to new collider signatures

→ Begs the question of the flavor-dependence of the interactions of the F's. F mixes with all generations? Different PM generations as in SM? PM ints with the SM connected to flavor? **New Directions!**

→ What if the PM are complex scalars? What's the analogous structure & collider implications? Scalar PM will not decay (no couplings to heavy SM quarks) as in usual searches for heavy scalars & involves DP/DH final states.. **New Directions!**

- Example 2: Try to 'unify' SM/Dark gauge interactions into a single (simple?) framework 'Unification' of forces always brings along multiple new ingredients to search for..

→ One working example (so far) ..**no** details here (see Refs) but includes 1-3 (?) generations of d-like and ν, l -like PM, 4 Higgs multiplets (some w/ dark charges) + extension of dark $U(1)_D$ symmetry to a SM-like structure... obvious flavor issues enter

→ $SU(2)_I \times U(1)_{I'}$ → $U(1)_D$...this breaking occurs at the \sim PM mass scale



with great originality called $Z_I, W_I^{(+)}$ - a pair of neutral, non-Hermitian fields

→ New PM fermions, new scalars & new gauge boson in the \sim few TeV range..

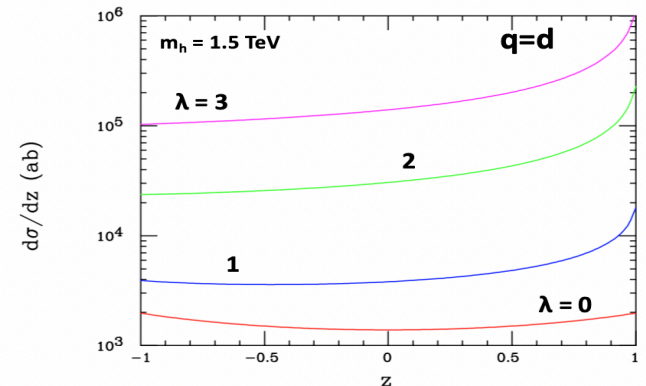
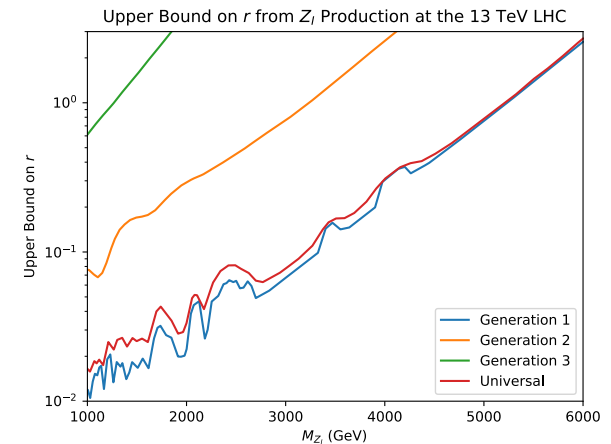
SM f's are $U(1)_D$ singlets but **not** $SU(2)_I \times U(1)_{I'}$ singlets...

The flavor structure of the PM sector allows for multiple scenarios

-- lots of collider pheno to explore!

→ A Sample Shopping List..

- Z_I can couple to only a single SM generation → σ 's & decays differ from usual searches, e.g., $b\bar{b} \rightarrow Z_I \rightarrow \tau\bar{\tau}$
- DP & DH t-channel exchange w/ Yukawa's $\lambda \sim O(1)$ alters QCD expectations for triplet PM in both σ 's and distributions (FB-asymmetries!) affecting acceptances--depending upon flavor assumptions
- DP/DH pair production via t-channel PM can lead to a large monojet rate - independent of ϵ but sensitive to PM mass



- W_1 cannot be produced **alone** on-shell but only in pairs or in association with the DP, DH or color-triplet PM as it has $Q_D \neq 0$

→ MANY New Directions!

Summary & Some Possible Directions

- The KM portal scenario **requires** the existence of new PM fields..
Question: what if we take this model seriously .. what can we learn?
- The PM sector leads to many types of new fermions, gauge bosons (& scalars) with interesting & unusual production & decay properties w/ lots of interesting pheno!
- Does PM provide a possible connection between flavor & the dark sector?
- No time to discuss ED extensions of KM idea
- This work is ongoing

References

- Extra Dimensions: 1801.08525, 1805.08150, 1902.08339, 2006.06858 & to appear
- Portal Matter: 1810.07531, 1909.09160 & to appear
Kim, Lane, Lee & Lewis, 1904.05893