Low Energy Anomalies with Dark Sector HNLs

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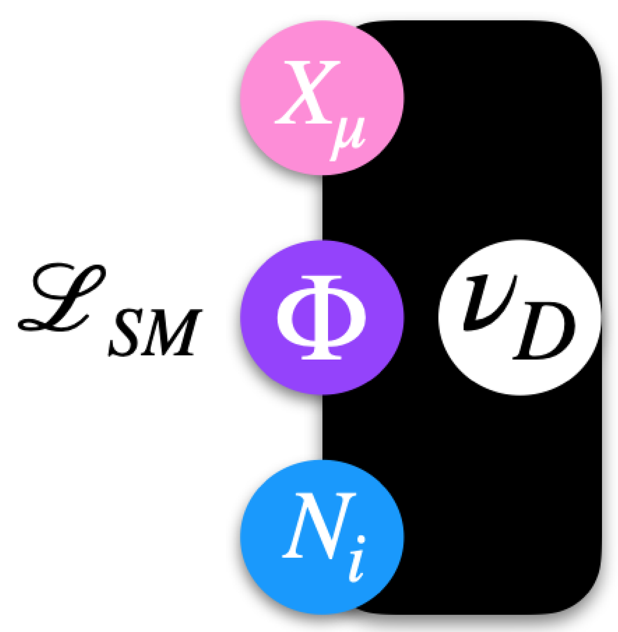
Abstract

We propose an anomaly-free model of neutrino masses that simultaneously explains the MiniBooNe low-energy excess, the anomalous magnetic moment of the muon, Δa_μ, and the excess of $K_L^0 \to \pi^0 \nu\bar{\nu}$ decays observed at KOTO. Model is compatible with the electron-like excesses reported by experiments PS-191/E816 and the mono-photon searches at BaBar.

Model

Hidden gauge symmetry, $U(1)_X$ - broken by the VEV of a scalar Φ. Three generations of sterile neutrinos, $N_{i=(1,2,3)}$. Pair of vector-like fermions, ν_{D_L} and ν_{D_R}, charged under the new force.

	SU(2)	$U(1)_Y$	$U(1)_X$
N_i	**1**	0	0
ν_{D_L}	**1**	0	Q_X
ν_{D_R}	**1**	0	Q_X
Φ	**1**	0	Q_X



Neutrino Portal Mixing between the hidden sector neutrinos and the active states occurs through the terms

$$\mathcal{L} \supset (\bar{L}H)YN^c + \bar{N}Y_N\nu_D^c\Phi\,. \quad (1)$$

Vector Portal Mixing between SM hypercharge and dark photon leads to the new gauge boson Z',

$$\mathcal{L} \supset -\frac{\sin\chi}{2}X_{\mu\nu}B^{\mu\nu}\,. \quad (2)$$

Higgs Portal Mixing between the SM Higgs and our dark scalar is also permissible through the term,

$$\mathcal{L} \supset -\lambda_{\Phi H}\,|H|^2\,|\Phi|^2\,. \quad (3)$$

MiniBooNe Low-Energy Excess

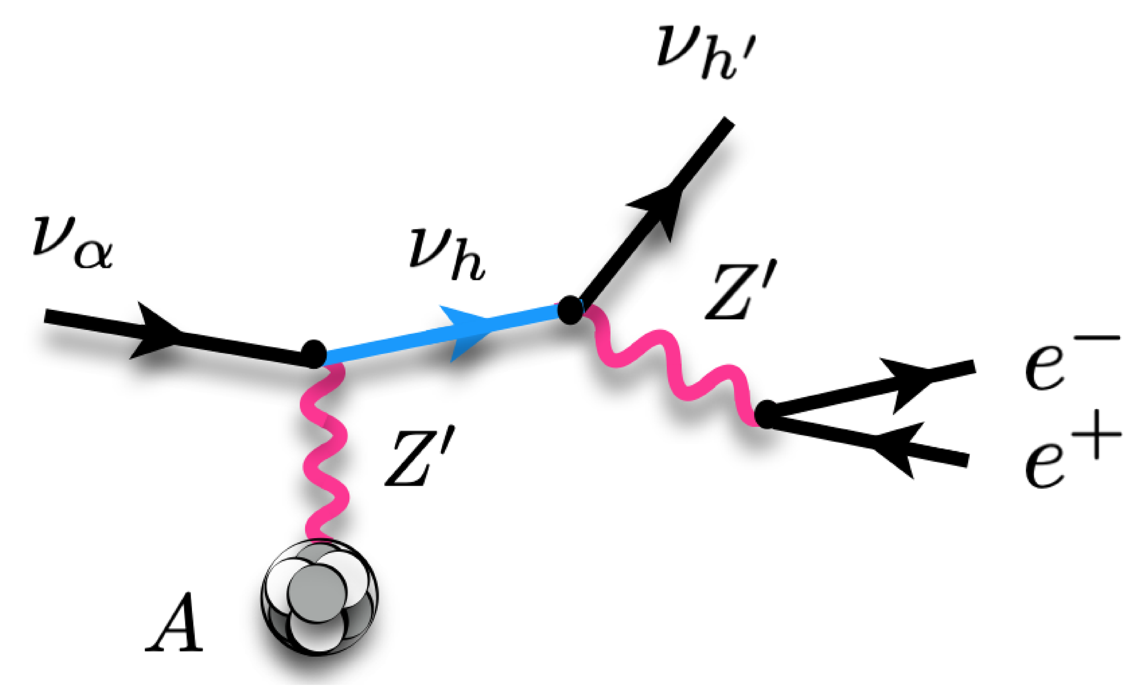


Figure 1:Incoherent upscattering through Z', possible signal at MiniBooNe.

We explain the excess of low-energy electron-like events at MiniBooNe [1] with incoherent (coherent) upscattering to heavier states, ν_h, which decay through emission of a Z', producing e^+e^- pairs. If these pairs have small angular separation, or are highly asymmetric in energy, they may constitute a signal.

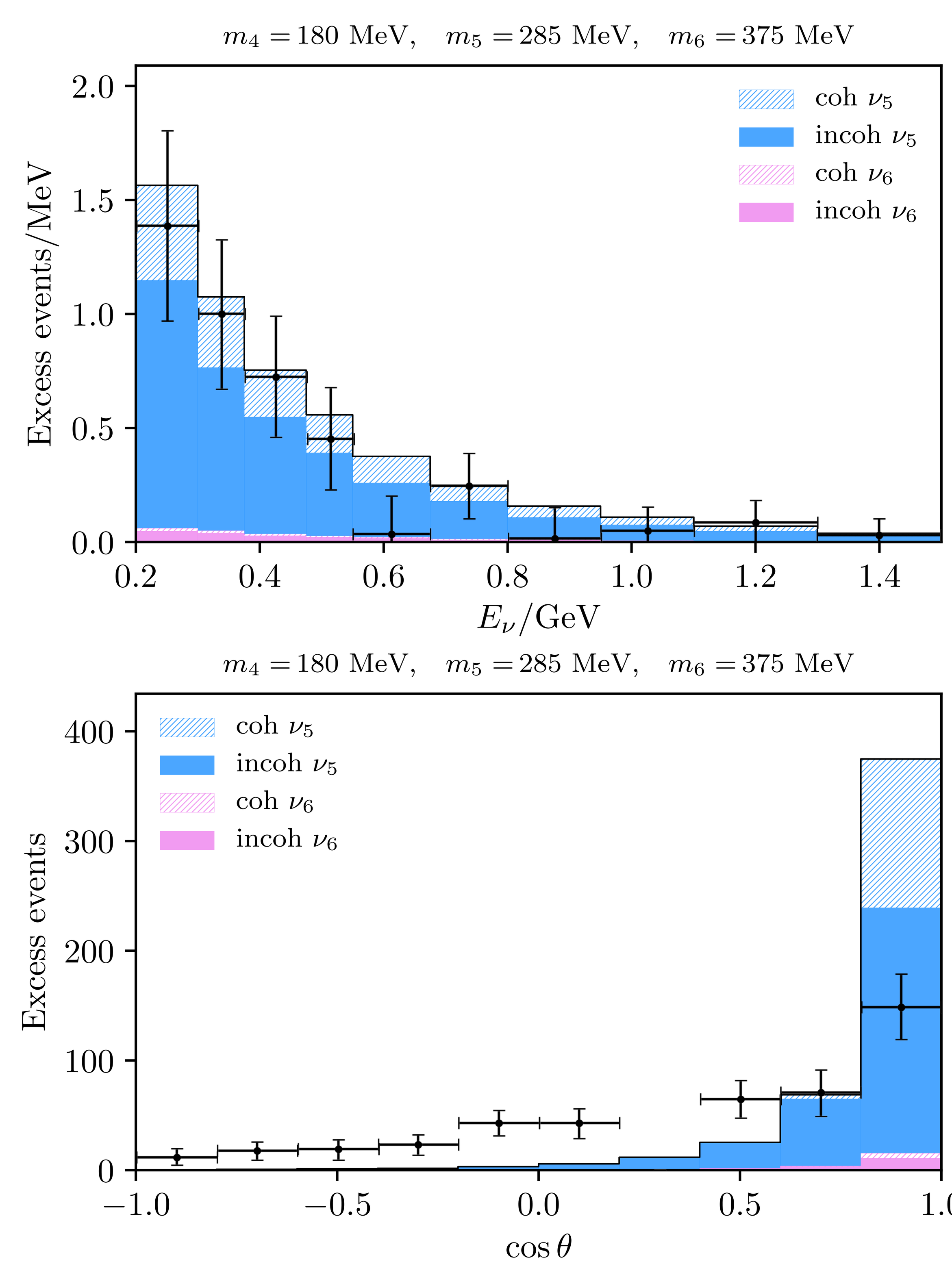


Figure 2:Model prediction for ν_μ upscattering to $\nu_6 \to \nu_4 e^+e^-$ (pink) and $\nu_5 \to \nu_4 e^+e^-$ (blue), $m_{Z'} = 1.25$ GeV.

Anomalous Muon $(g-2)_\mu$

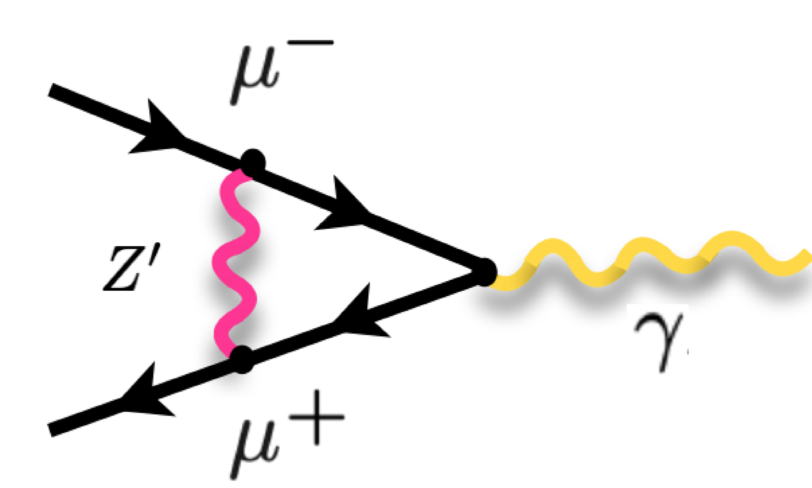


Figure 3:Z' contribution to muon magnetic moment.

Minimal dark photon explanation to Δa_μ ruled out by searches for visibly decaying dark photons, $Z' \to l^+l^-$, and by searches for invisibly decaying dark photons, $e^+e^- \to \gamma Z'$. Constraints significantly weakened for semi-visibly decaying Z' by keeping the branching ratio to invisibles small.

KOTO Anomaly

The KOTO experiment which searches for the rare SM decay $K_L^0 \to \pi^0\nu\bar{\nu}$ has reported 3 (+ 1 background) events giving a branching ratio roughly 70 times the SM rate [2]. We explain this excess with $K_L^0 \to \pi^0\phi$, where ϕ decays invisibly, $\phi \to \nu_{h'}\nu_{h'}$.

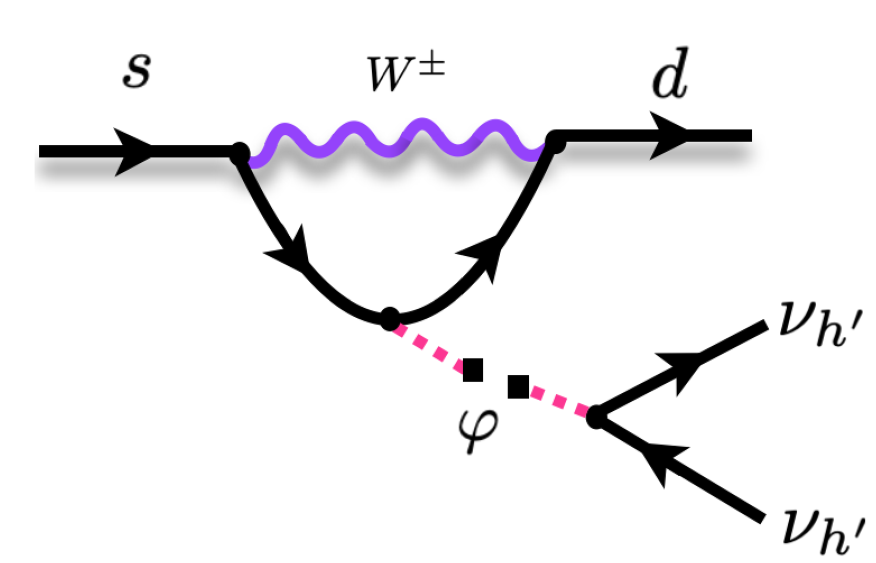


Figure 4:ϕ production and subsequent decay at KOTO.

PS-191 and E816 Excess

Explanation of the excess of electron-like events at PS-191 [3] and E816 [4] possible with upscattering and sub-mm decay to e^+e^- pair. Achieved with a third heavy neutrino $\nu_H \to \nu_h e^+e^-$ with mass between $160 - 400$ MeV.

Mono-photon Searches @ BaBar

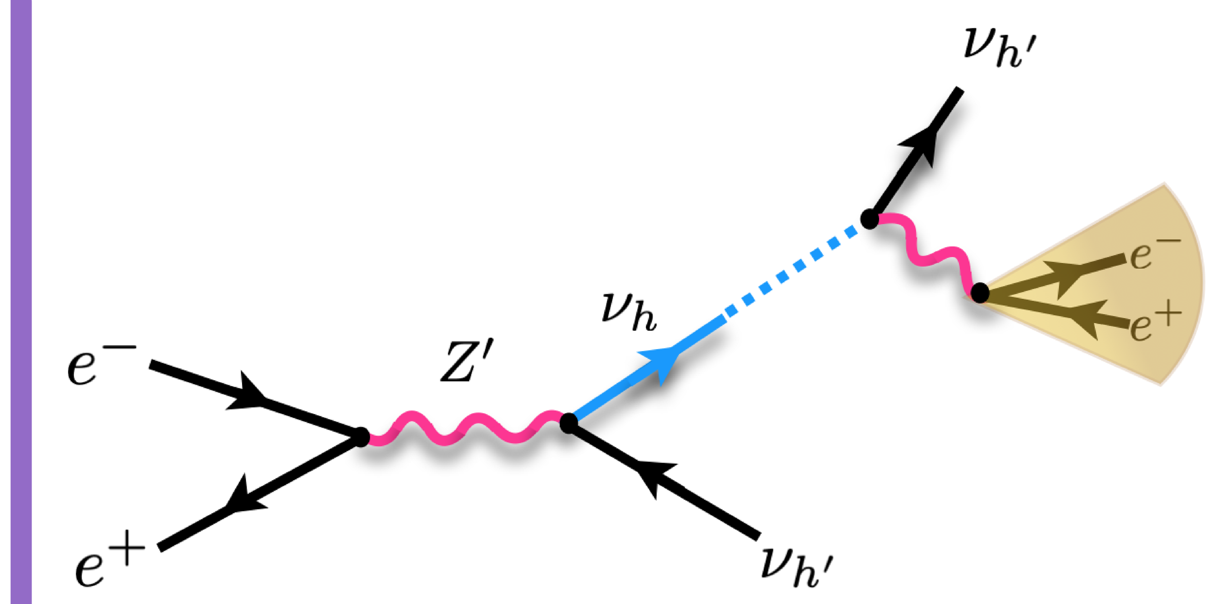


Figure 5:Model signature mimicking mono-photon event

Pair of heavy neutrinos produced in e^+e^- collisions via a Z'. Long-lived neutrino escapes the detector and the other decays in ECAL giving e^+e^- pair which are mis-identified, imitating mono-photon production at BaBar [5].

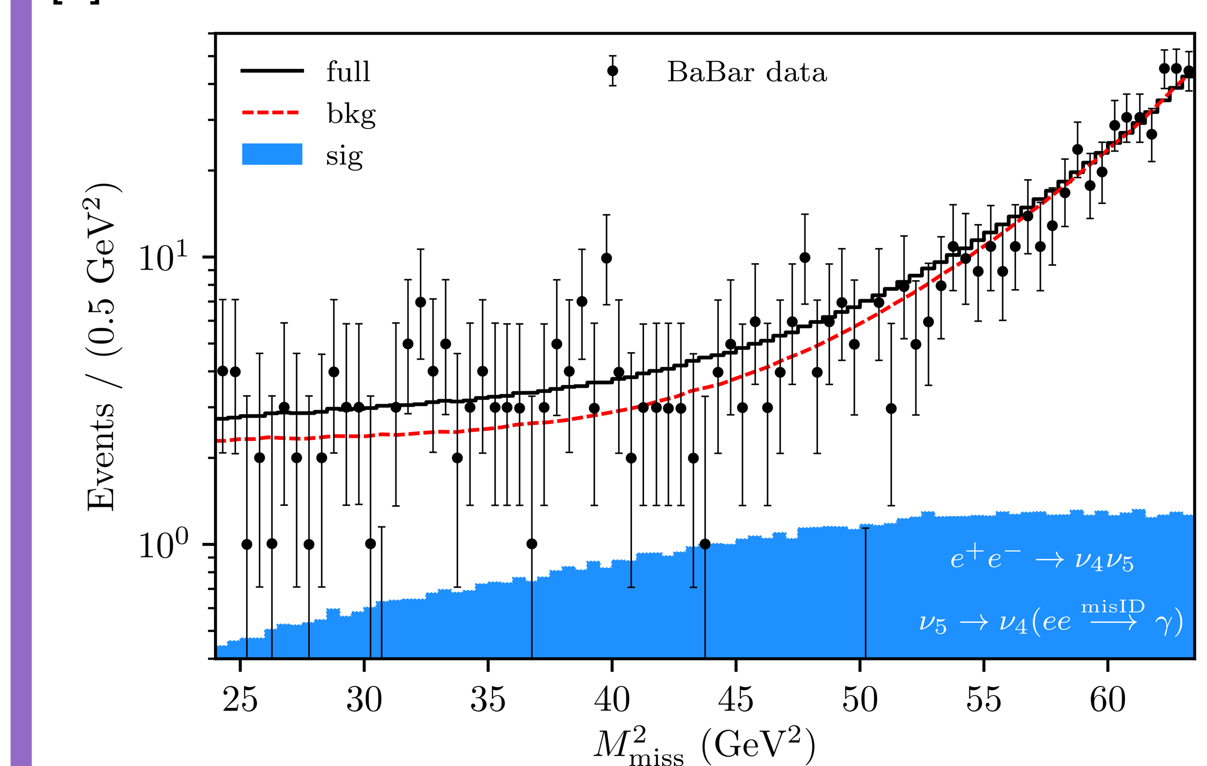


Figure 6:BaBar monophoton data at high missing mass $M^2_{\rm miss} = s - 2E^*_\gamma\sqrt{s}$.

References

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