Using Helicity to Distinguish Dark Matter Models at Lepton Colliders

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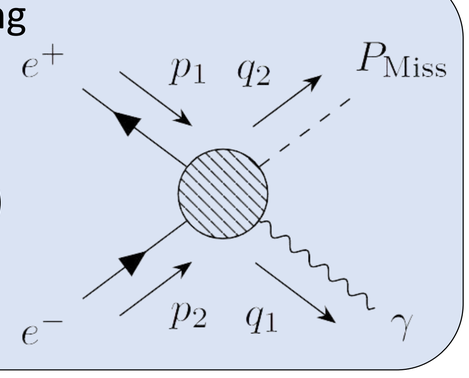
Process: $e^+ + e^- \to \gamma +$ missing



Standard Model Background

- $e^+e^- \to \gamma\gamma\ (\gamma)$
- $e^+e^- \to e^+e^-\gamma\ (\gamma)$ **(Dominating)**
- $e^+e^- \to \nu_l\bar{\nu}_l\gamma\ (\gamma)$

Analysis of Photon Helicity

- Helicity = projection of spin vector onto momentum
- Photon Helicity $s(\gamma)$ • Electron Helicity $s(e^-)$
- $\cos\theta_\gamma$= angle between photon and z-axis
- Percentage of $s(\gamma) = s(e^-)$ as a function $\cos\theta_\gamma$ and $m_{ALP/\gamma'}$
- Coupling constant same for all diagrams
- $30° \leq \cos\theta_\gamma \leq 163°$ (Detector limits from Belle II)

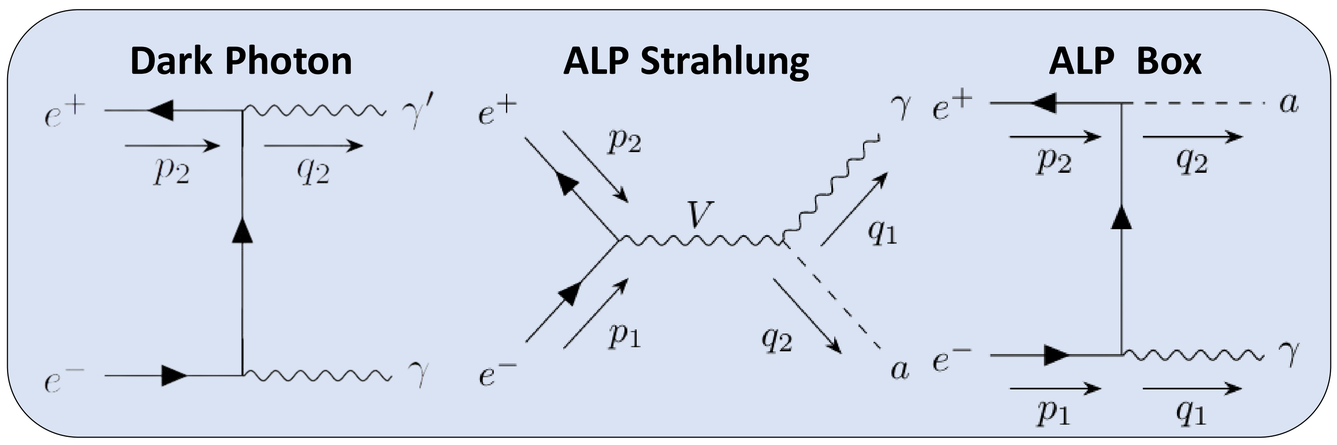
SM Results:
Helicities are 50-50 split between left- and right-handed photons, independent of $\cos\theta_\gamma$

Dark Matter Models

Particle	Property		Couplings	
	Type	Spin	Photons	Fermions
Axion-like-particles (ALPs)	Pseudo - Scalar	0	$-\frac{1}{4}g_{a\gamma\gamma}aF_{\mu\nu}\tilde{F}^{\mu\nu}$	$-\frac{c_{ff}}{f_a}\sum_\psi m_\psi\bar{\psi}\gamma^5\psi$
Dark Photon	Boson	1	NA	$-g_X X_\mu \sum_{e,\mu,\tau}(\bar{L}\gamma^\mu L + \bar{l}\gamma^\mu l)$

Dark Photon
- $U(1)_{B-L}$ Baryon - Lepton Number Difference

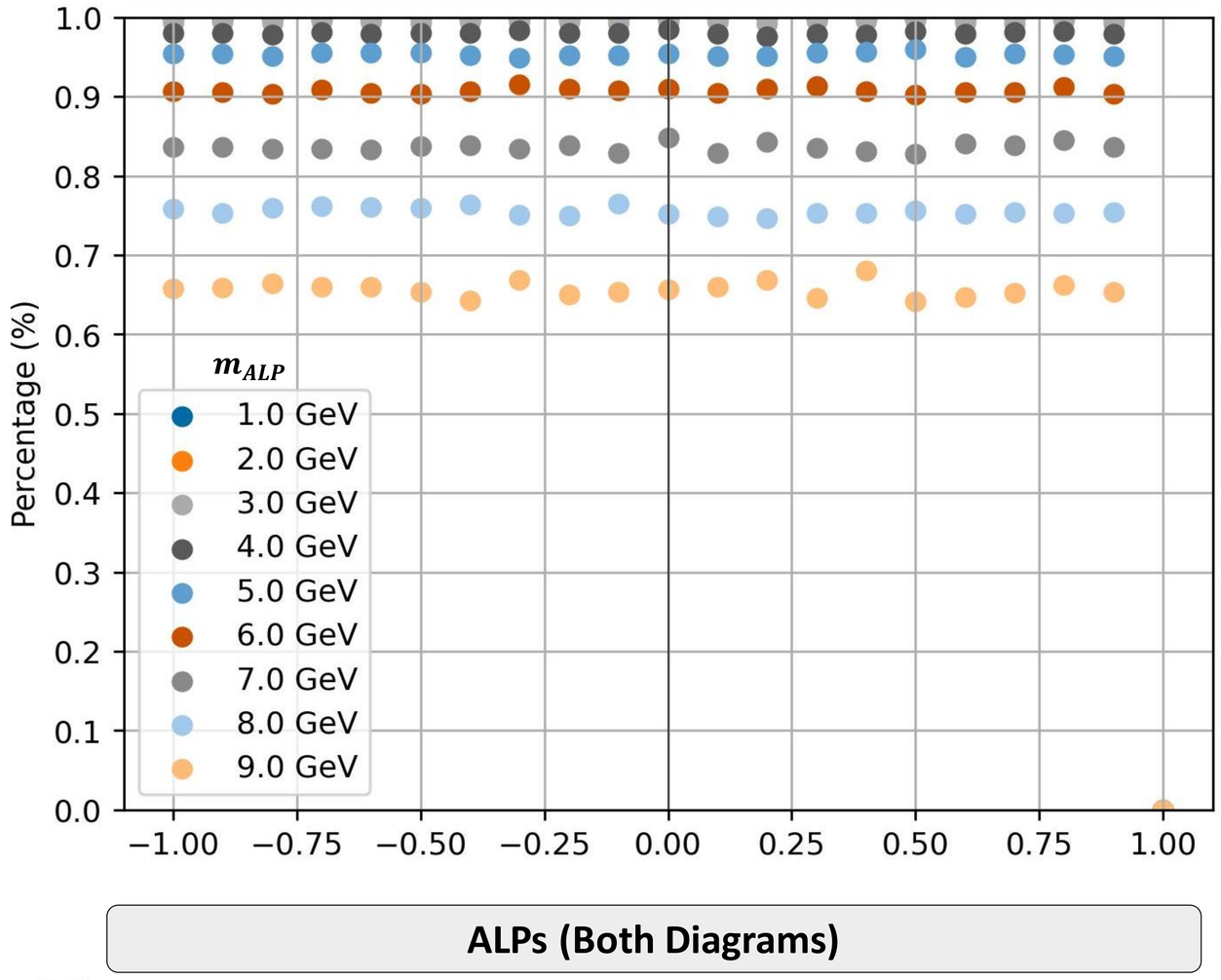
ALPs
- General Effective Lagrangian



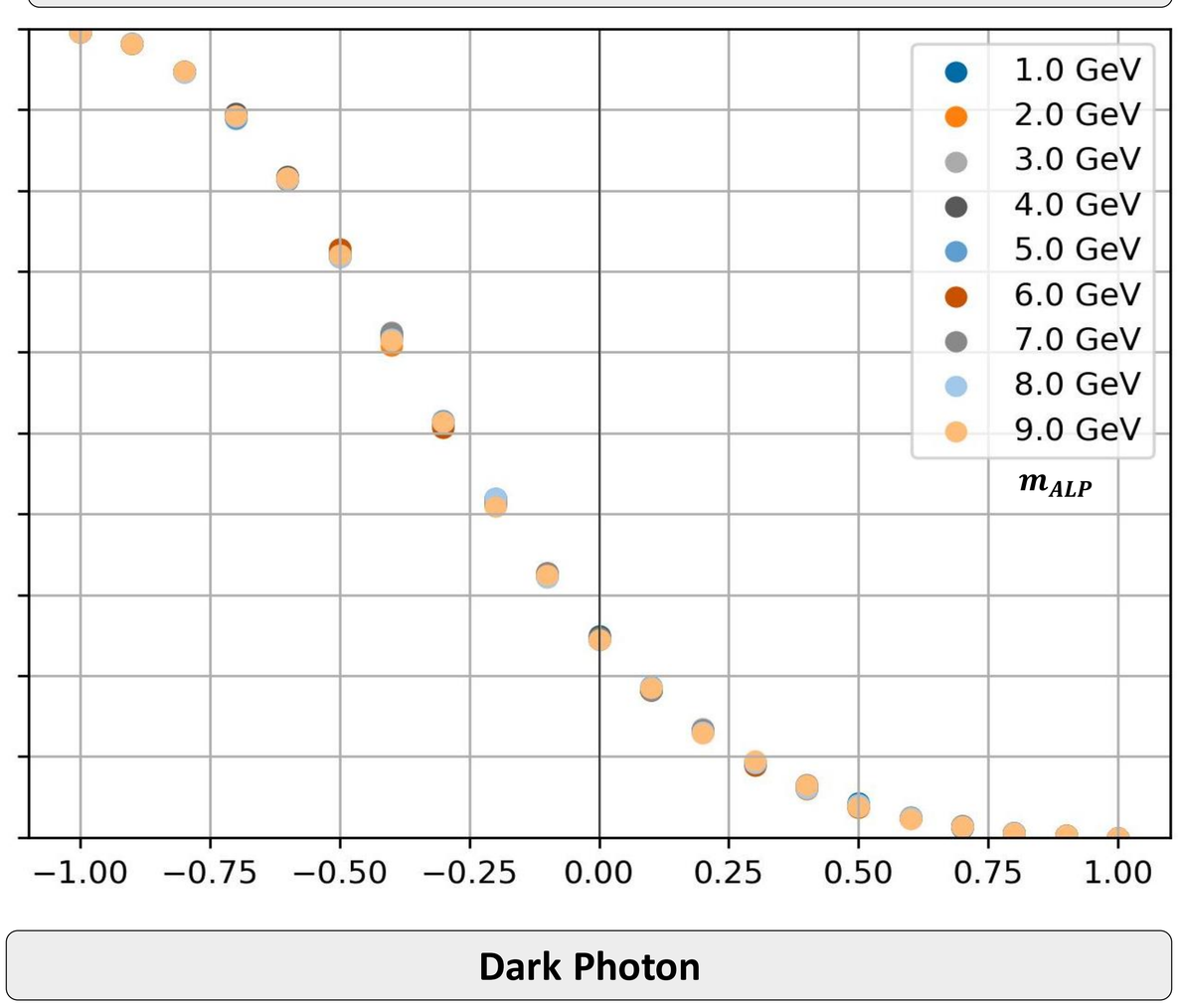
Results

- Changing $\cos\theta_\gamma$ cuts can result in left-right helicity asymmetry for the outgoing photons
- Skew due to uneven beam energies: $E_{e^+} = 4$ GeV and $E_{e^-} = 7$ GeV

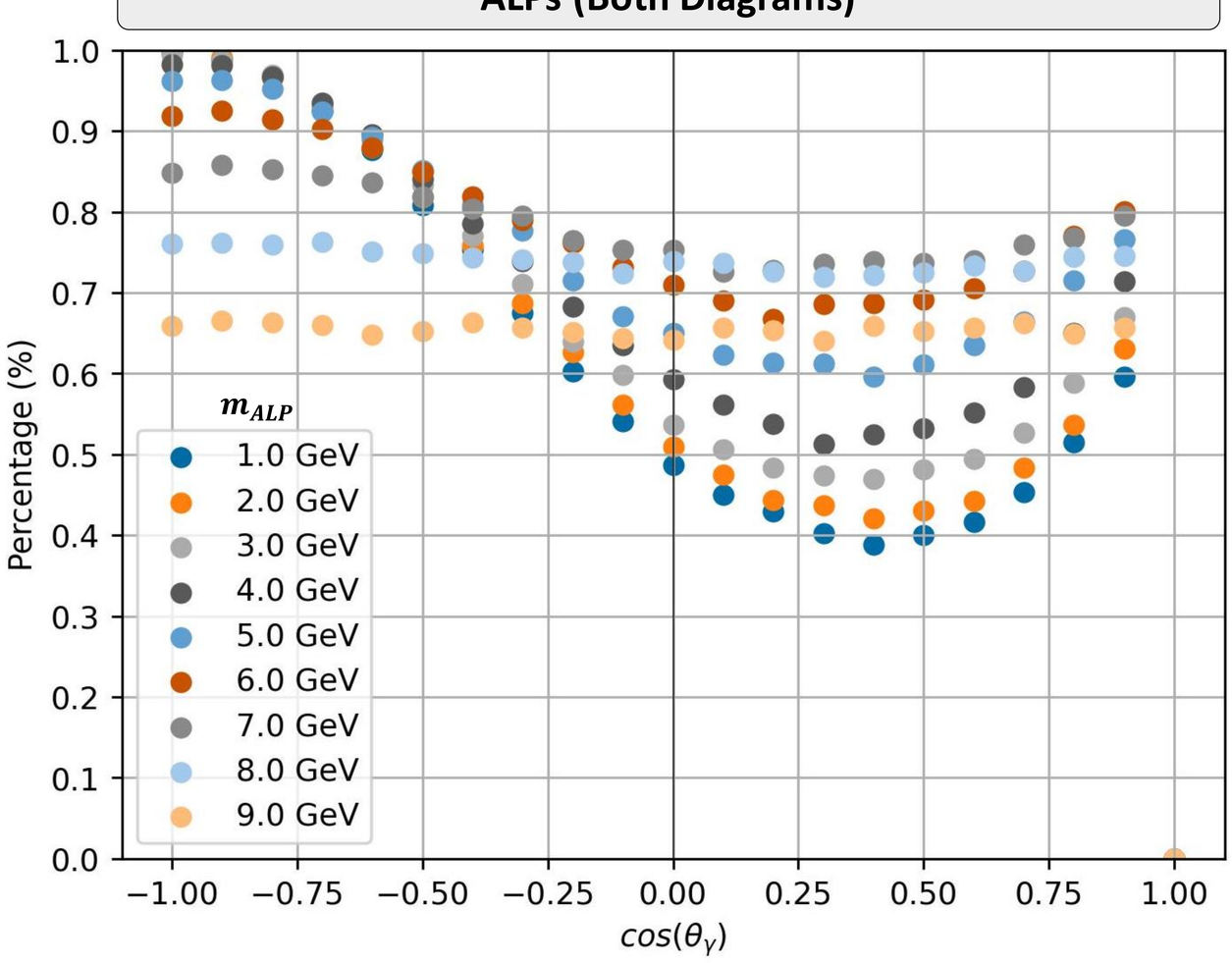
ALPs (Box Diagram)



ALPs (Strahlung Diagram)



ALPs (Both Diagrams)



Dark Photon