

CP violating dark photon kinetic mixing and Type-III Seesaw



Yu Cheng¹, Xiao-Gang He^{1,2}, Michael J. Ramsey-Musolf^{1,3,4} and Jin Sun¹

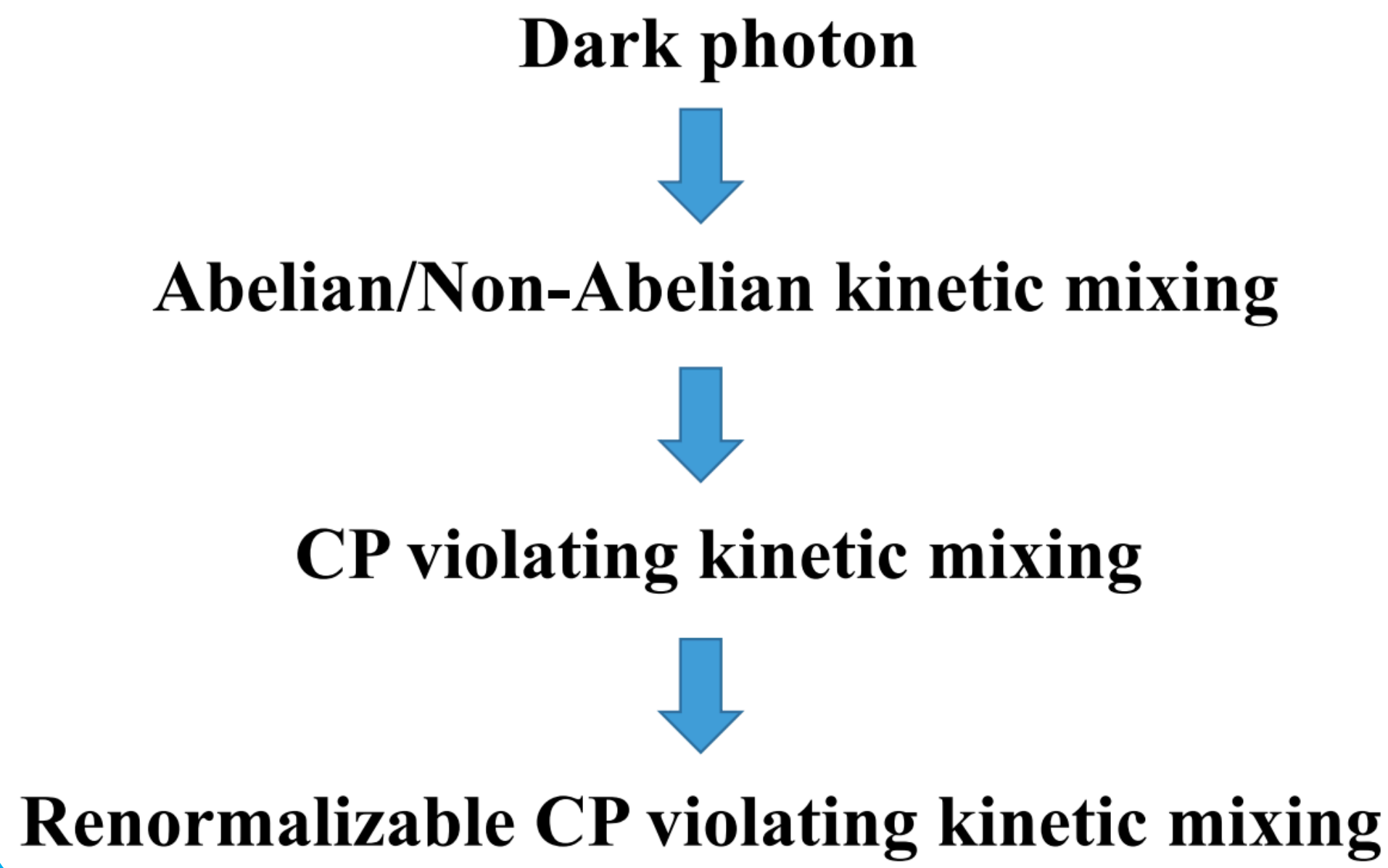
¹ Tsung-Dao Lee Institute, Shanghai Jiao Tong University, Shanghai 201210, China. (019072910096@sjtu.edu.cn)

² NCTS and Department of Physics, National Taiwan University, Taipei 10617, Taiwan.

³ Amherst Center for Fundamental Interactions, Department of Physics, University of Massachusetts, Amherst, MA 01003, USA, USA

⁴ Kellogg Radiation Laboratory, California Institute of Technology, Pasadena, CA91125, USA

1. Research logic



2. Research problem

The portals between the dark sector and visible sectors include the Higgs, axion, neutrino, and dark photon. We focus on the novel possibility of CP-violating (CPV) dark photon portal interactions.

1. Abelian kinetic mixing: Renormalizable dimension-4 operator

$$\text{CP conserving: } X_{\mu\nu}B^{\mu\nu}, \quad \text{CP violating: } \tilde{X}_{\mu\nu}B^{\alpha\beta},$$

2. Non-Abelian kinetic mixing: No gauge invariant $X_{\alpha\beta}W_{\mu\nu}^a$

$$\text{CP conserving: } X_{\mu\nu}W_{\mu\nu}^a\Sigma^a, \quad \text{CP violating: } \epsilon^{\alpha\beta\mu\nu}X_{\alpha\beta}W_{\mu\nu}^a\Sigma^a.$$

Non-renormalizable \rightarrow Renormalizable CPV non-Abelian kinetic mixing \rightarrow Generate the kinetic mixing at loop level \rightarrow New fields of $SU(2)_L$ multiplet fermion \rightarrow Type-III seesaw model

3. Model particles

Gauge group $SU(3)_C \times SU(2)_L \times U(1)_Y \times U(1)_X$

1. SM particles has no $U(1)_X$ charge

2. Triplet scalar $\Sigma^a = (1, 3, 0)(0) \longrightarrow \epsilon^{\alpha\beta\mu\nu}X_{\alpha\beta}W_{\mu\nu}^a\Sigma^a$

3. Triplet fermion (No scalar) \longrightarrow **Type-III seesaw model**

$$f_1 = (1, 3, 0)(x_f), \quad f_2 = (1, 3, 0)(-x_f), \quad f_3 = (1, 3, 0)(0)$$

Gauge anomaly free

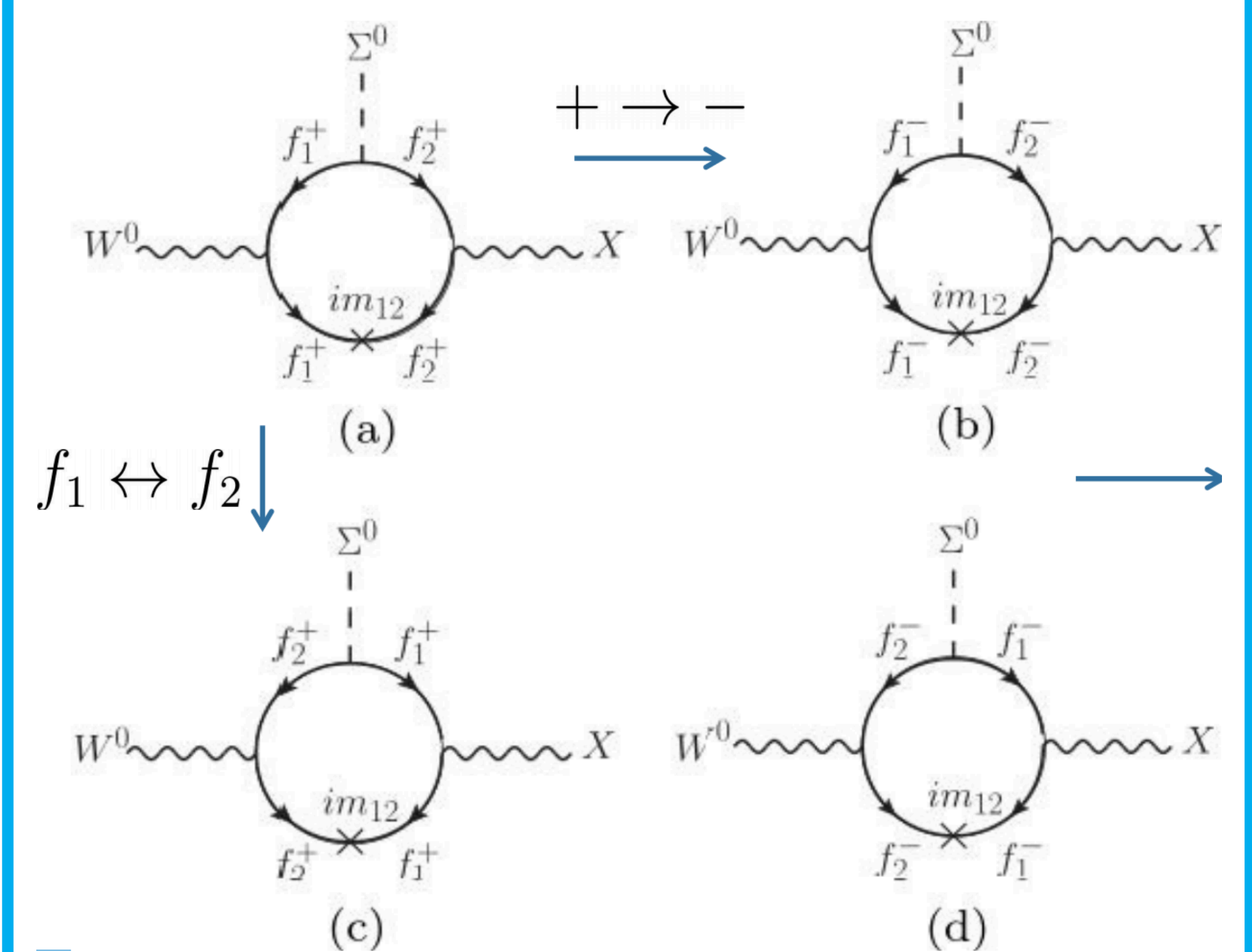
4. Singlet scalar \longrightarrow dark photon and heavy neutrino mass

$$S_X = (1, 1, 0)(-2x_f),$$

5. Higgs scalar \longrightarrow Neutrino mass matrix

$$H'_{1,2} : (1, 2, -1/2)(\mp x_f)$$

4. Model Realization



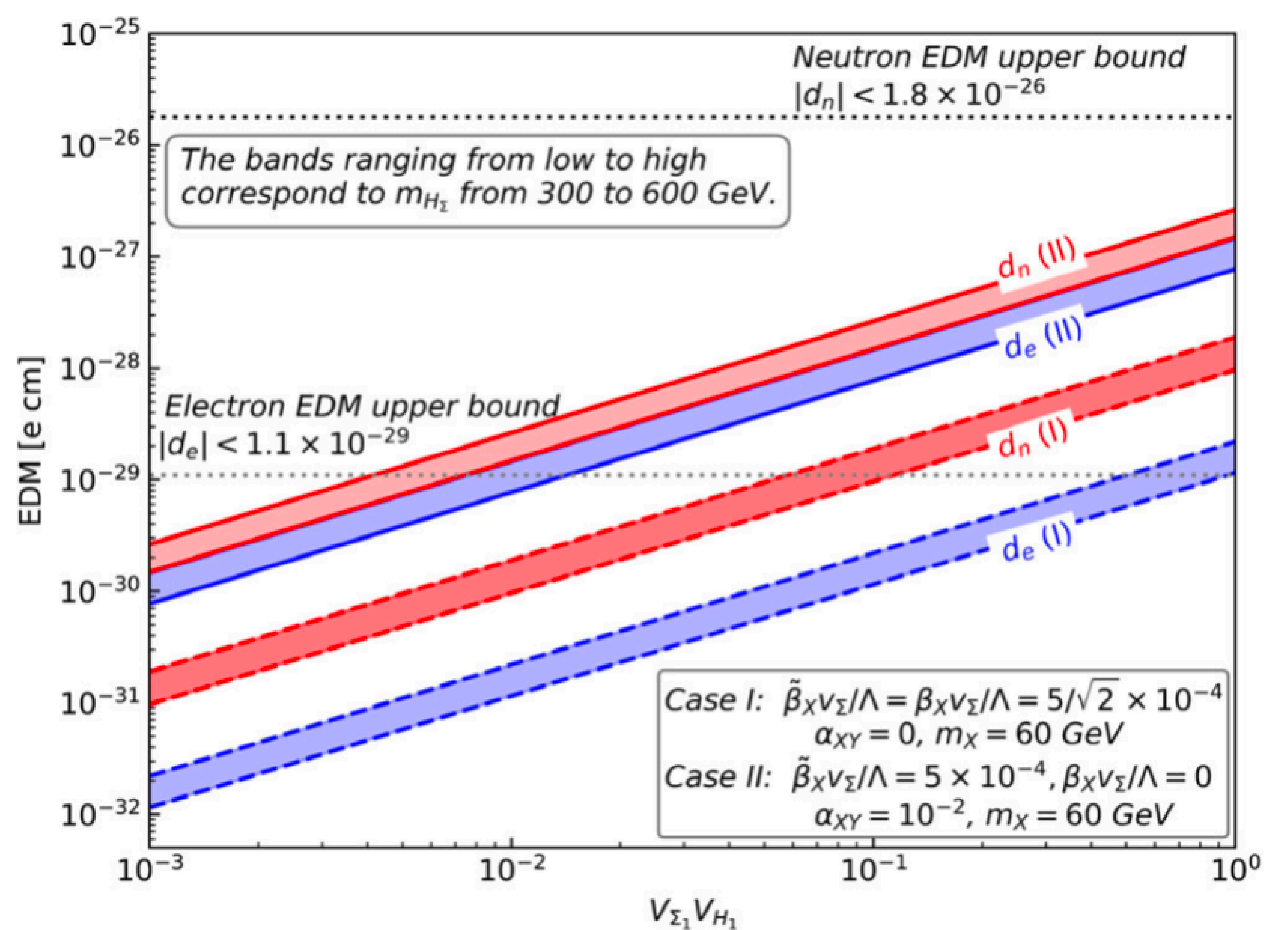
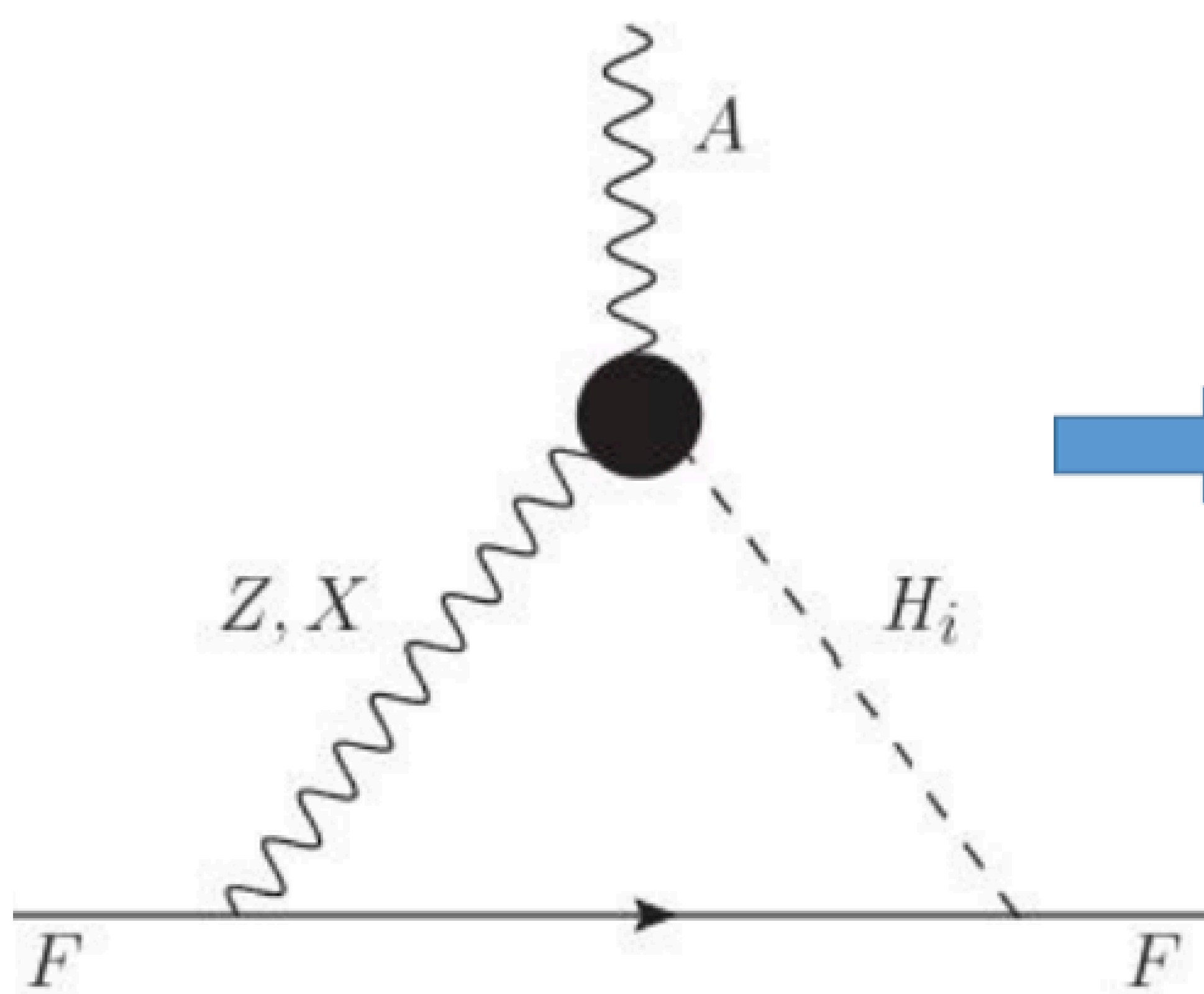
Dimension-5 operator

$$\text{CP conserving: } -(\beta_X/\Lambda)\text{Tr}(W_{\mu\nu}\Sigma)X^{\mu\nu}$$

$$\text{CP violating: } -(\tilde{\beta}_X/\Lambda)\text{Tr}(W_{\mu\nu}\Sigma)\tilde{X}^{\mu\nu}.$$

5. Phenomenology

SM fermion EDM



1. Construct firstly a renormalizable dark photon model with CPV kinetic mixing combining with the type-III seesaw model.
2. CPV kinetic mixing induced interaction dominates the contribution to eEDM which can be as large as experimental bound.
3. It provides a bridge connecting dark photon, neutrino physics and CPV, and are directly tested by future measurements.