

# Chern-Simons portal

The Chern-Simons portal adds a new spin-1 massive neutral particle,  $X$  boson, interacting with the Standard model electroweak gauge bosons via the effective dimension-6 operators [1, 2]:

$$\mathcal{L} = \frac{1}{\Lambda_Y^2} \epsilon^{\mu\nu\rho\sigma} H^\dagger D_\mu H X_\nu F_Y^{\rho\sigma} + \frac{1}{\Lambda_{SU(2)}} \epsilon^{\mu\nu\rho\sigma} H^\dagger F_{SU(2)}^{\rho\sigma} D_\mu H X_\nu - \frac{1}{4} F_{\mu\nu, X} F_X^{\mu\nu} + \frac{m_X^2}{2} X_\mu X^\mu, \quad (1)$$

where  $H$  is the Higgs doublet,  $F_{\mu\nu, Y/SU(2)}$  is the SM  $U_Y(1)/SU(2)$  gauge field strength,  $D_\mu$  is the long derivative and  $\Lambda$  denotes the dimension 1 coupling.

After acquiring the Higgs VEV, the low energy effective interaction of the  $X$  boson with the gauge bosons becomes

$$\mathcal{L}_X = \mathcal{L}_{X, \text{kin}} + \epsilon^{\mu\nu\alpha\beta} (W_\mu X_\nu \partial_\alpha W Y^\dagger_\beta + \text{h.c.} + c_Z Z_\mu X_\nu \partial_\alpha Z_\beta + c_{Z\gamma} Z_\mu X_\nu \partial_\alpha A_\beta), \quad (2)$$

where  $c_{W/Z/Z\gamma}$  are effective dimensionless couplings.

## References

- [1] S. Alekhin et al., *A facility to Search for Hidden Particles at the CERN SPS: the SHiP physics case*, *Rept. Prog. Phys.* **79** (2016), no. 12 124201, [[arXiv:1504.04855](#)].
- [2] I. Antoniadis, A. Boyarsky, S. Espahbodi, O. Ruchayskiy, and J. D. Wells, *Anomaly driven signatures of new invisible physics at the Large Hadron Collider*, *Nucl. Phys.* **B824** (2010) 296–313, [[arXiv:0901.0639](#)].