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Chiral Effective Field Theory for Coherent Neutrino-Nucleus Scattering

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10th ChEFT (Nan Jing)

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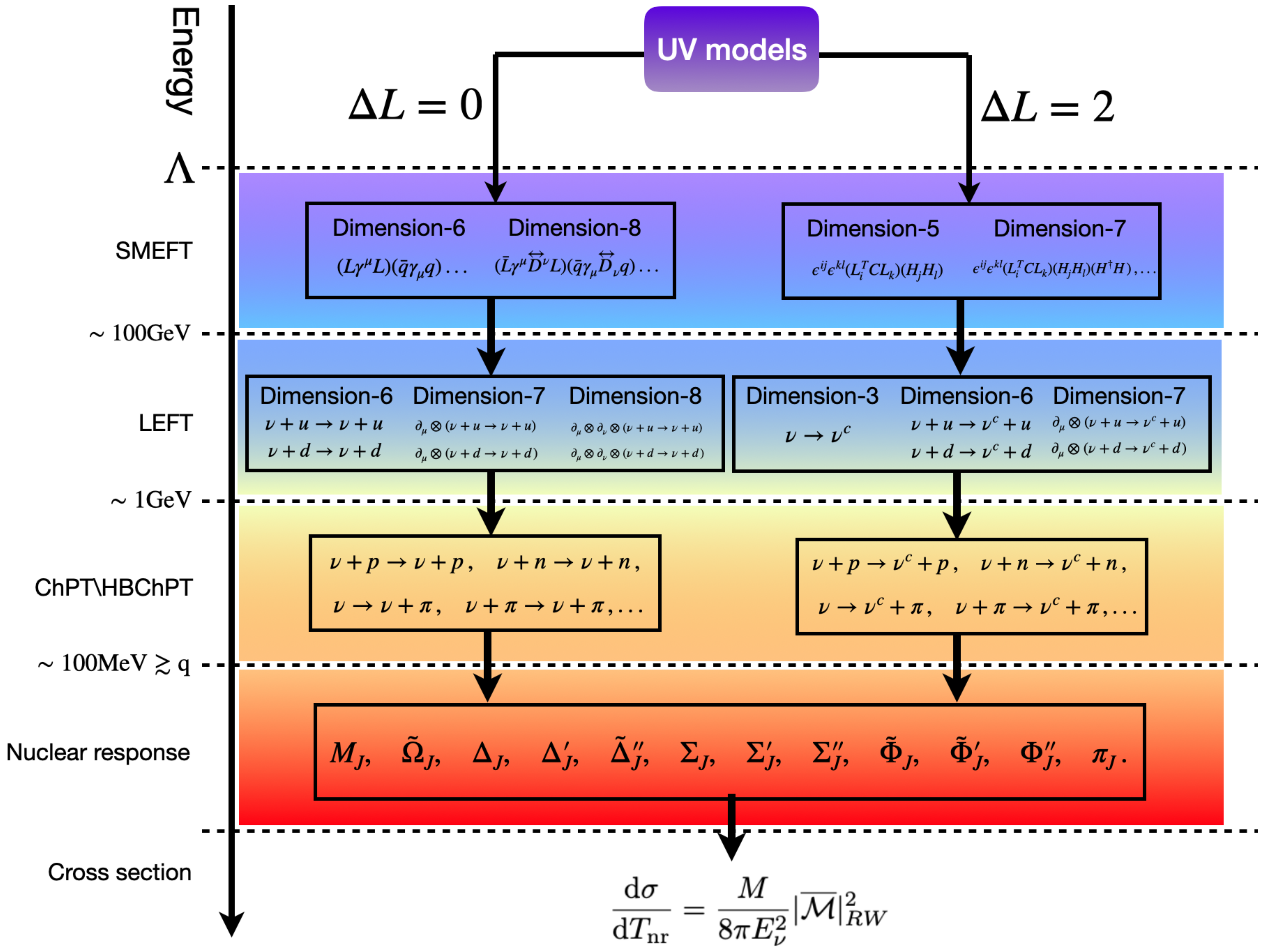
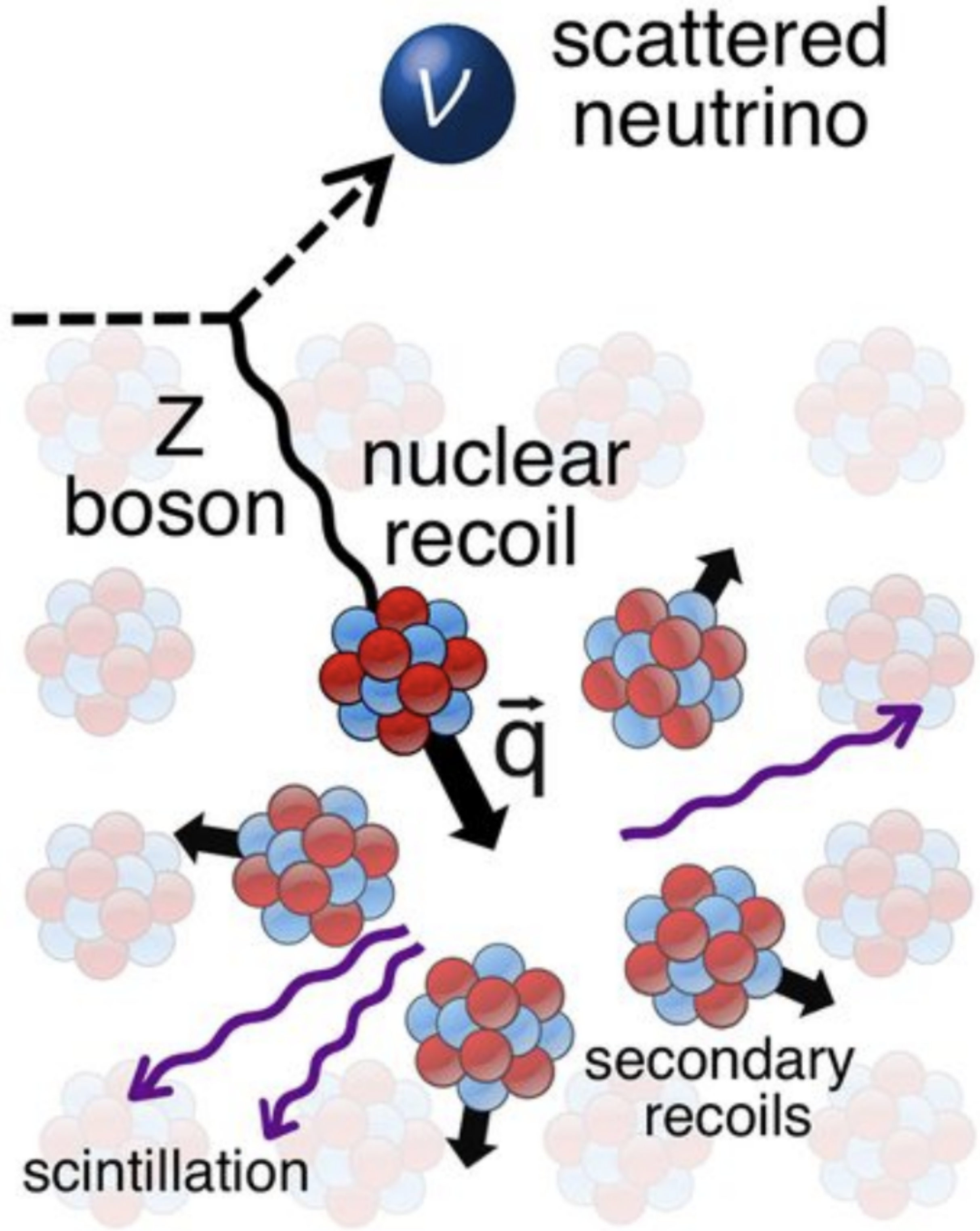
Introduction



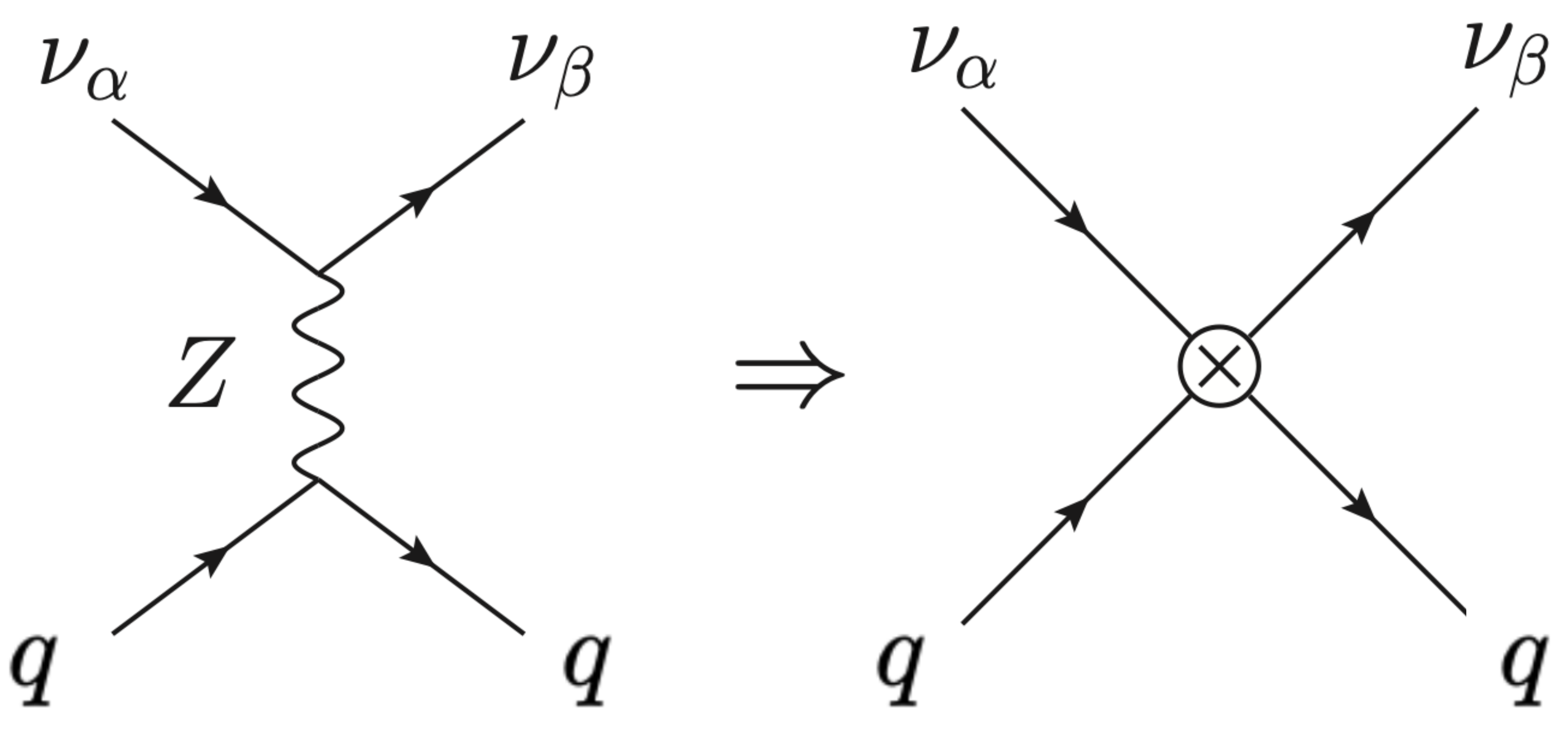


D.Z Freedman, “Coherent Neutrino Nucleus Scattering as a Probe of the Weak Neutral Current”, Phys.Rev.D 9(1974) 1389-1392

COHERENT Collaboration, “Observation of Coherent Elastic Neutrino-Nuclues Scattering”, Science 357 (2017) 6356, 1123-1126

LEFT operators for neutrino-nucleus scattering

$$\mathcal{L}_{\mathrm{LEFT}} = \sum_{d,a} \hat{\mathcal{C}}_a^d \mathcal{O}_a^d \,, \qquad \hat{\mathcal{C}}_a^d = \frac{\mathcal{C}_a^d}{\Lambda_{\mathrm{EW}}{}^{d-4}} \,,$$



$\Delta L = 0$

$$\mathcal{O}_1^{6p/n} = (\bar\nu_{L\alpha}\gamma^\mu\nu_{L\beta})(\bar q\gamma_\mu\tau^{p/n}q)\,, \qquad \mathcal{O}_2^{6p/n} = (\bar\nu_{L\alpha}\gamma^\mu\nu_{L\beta})(\bar q\gamma^5\gamma_\mu\tau^{p/n}q)\,,$$

$$\mathcal{O}_1^{7p/n} = (\bar\nu_{L\alpha}\gamma^\mu\nu_{L\beta})(\bar q\overleftrightarrow{\partial}_\mu\tau^{p/n}q)\,, \qquad \mathcal{O}_2^{7p/n} = (\bar\nu_{L\alpha}\gamma^\mu\nu_{L\beta})(\bar q\gamma^5\overleftrightarrow{\partial}_\mu\tau^{p/n}q)\,,$$

$$\mathcal{O}_1^{8p/n} = (\bar\nu_{L\alpha}\gamma^\mu\nu_{L\beta})\partial^2(\bar q\gamma_\mu\tau^{p/n}q)\,, \qquad \mathcal{O}_2^{8p/n} = (\bar\nu_{L\alpha}\gamma^\mu\nu_{L\beta})\partial^2(\bar q\gamma^5\gamma_\mu\tau^{p/n}q)\,.$$

$$\mathcal{O}_3^{8p/n} = (\bar\nu_{L\alpha}\gamma^\mu\overleftrightarrow{\partial}^\nu\nu_{L\beta})(\bar q\gamma_\mu\overleftrightarrow{\partial}_\nu\tau^{p/n}q)\,, \qquad \mathcal{O}_4^{8p/n} = (\bar\nu_{L\alpha}\gamma^\mu\overleftrightarrow{\partial}^\nu\nu_{L\beta})(\bar q\gamma^5\gamma_\mu\overleftrightarrow{\partial}_\nu\tau^{p/n}q)\,,$$

$$\mathcal{O}_5^{8p/n} = (\bar\nu_{L\alpha}\gamma^\mu\nu_{L\beta})(\bar q\gamma^\nu T^A\tau^{p/n}q)G^A_{\mu\nu}\,, \qquad \mathcal{O}_6^{8p/n} = (\bar\nu_{L\alpha}\gamma^\mu\nu_{L\beta})(\bar q\gamma^5\gamma^\nu T^A\tau^{p/n}q)G^A_{\mu\nu}\,,$$

$$\mathcal{O}_7^{8p/n} = (\bar\nu_{L\alpha}\gamma^\mu\nu_{L\beta})(\bar q\gamma^\nu T^A\tau^{p/n}q)\tilde G^A_{\mu\nu}\,, \qquad \mathcal{O}_8^{8p/n} = (\bar\nu_{L\alpha}\gamma^\mu\nu_{L\beta})(\bar q\gamma^5\gamma^\nu T^A\tau^{p/n}q)\tilde G^A_{\mu\nu}\,,$$

$$\mathcal{O}_9^{8} = (\bar\nu_{L\alpha}\gamma^\mu\overleftrightarrow{\partial}^\nu\nu_{L\beta})G^A_{\mu\rho}G^{A\rho}_{\nu}\,,$$

$\Delta L = 2$

$$\mathcal{O}_1^{5} = (\nu^T_{L\alpha}C\sigma^{\mu\nu}\nu_{L\beta})F_{\mu\nu}\,, \qquad \mathcal{O}_3^{6p/n} = (\nu^T_{L\alpha}C\sigma^{\mu\nu}\nu_{L\beta})(\bar q\sigma_{\mu\nu}\tau^{p/n}q)\,,$$

$$\mathcal{O}_4^{6p/n} = (\nu^T_{L\alpha}C\nu_{L\beta})(\bar q\tau^{p/n}q)\,, \qquad \mathcal{O}_5^{6p/n} = (\nu^T_{L\alpha}C\nu_{L\beta})(\bar q\gamma^5\tau^{p/n}q)\,,$$

$$\hat{\mathcal{C}}_1^{6p/n}\Big|_{\mathrm{SM}} = \mp\frac{G_F}{\sqrt2}\left(1-\frac{8(4)}{3}\sin^2\theta_W\right)\delta_{\alpha\beta}\,,$$

$$\hat{\mathcal{C}}_2^{6p/n}\Big|_{\mathrm{SM}} = \pm\frac{G_F}{\sqrt2}\delta_{\alpha\beta}\,,$$

$$\hat{\mathcal{C}}_1^{8p/n}\Big|_{\mathrm{SM}} = \mp\frac{G_F^2}{2}\left(1-\frac{8(4)}{3}\sin^2\theta_W\right)\delta_{\alpha\beta}\,,$$

$$\hat{\mathcal{C}}_2^{8p/n}\Big|_{\mathrm{SM}} = \pm\frac{G_F^2}{2}\delta_{\alpha\beta}\,.$$

$$q = (u, d)$$

Chiral operators for neutrino-nucleus scattering

$$(\bar{q}_L \Gamma \Sigma_L q_L), \quad (\bar{q}_R \Gamma \Sigma_R q_R), \quad (\bar{q}_R \Gamma \Sigma q_L), \quad (\bar{q}_L \Gamma \Sigma^\dagger q_R)\,,$$

$$\begin{aligned} u_\mu &= i(u^\dagger \partial_\mu u - u \partial_\mu u^\dagger)\,, \\ \Sigma_\pm &= u^\dagger \tau u^\dagger \pm u \tau u\,, \\ Q_\pm &= u^\dagger \tau u \pm u \tau u^\dagger \end{aligned} \qquad N = \begin{pmatrix} p \\ n \end{pmatrix}, \qquad u(x) = \exp\left(\frac{\phi(x)^a \lambda^a}{2f}\right)$$

$$\mathcal{M}_q = \begin{pmatrix} m_u & 0 \\ 0 & m_d \end{pmatrix}, \quad \chi_\pm = u^\dagger 2 B_0 \mathcal{M}_q u^\dagger \pm u 2 B_0 \mathcal{M}_q^\dagger u\,,$$

$$\begin{aligned} \mathcal{L}_\pi = &\frac{\Lambda_\chi^2}{\Lambda_{\rm EW}^2} \mathcal{C}_{1,2}^{6p/n} (\bar{\nu}_{L\alpha} \gamma^\mu \nu_{L\beta}) \langle Q_\mp u_\mu \rangle + \frac{\Lambda_\chi^2}{\Lambda_{\rm EW}^2} 2 B_0 \mathcal{C}_{4,5}^{6p/n} (\nu_{L\alpha}^T C \nu_{L\beta}) \langle \Sigma_\pm \rangle \\ &+ \frac{\Lambda_\chi}{\Lambda_{\rm EW}^2} \mathcal{C}_3^{6p/n} (\nu_{L\alpha}^T C \sigma^{\mu\nu} \nu_{L\beta}) \Big\{ \Lambda_1 \langle \Sigma_+ [u_\mu, u_\nu] \rangle + \Lambda_2 \langle \Sigma_- [u_\mu, u_\nu] \rangle \Big\} \\ &+ \frac{\Lambda_\chi}{\Lambda_{\rm EW}^3} \mathcal{C}_{1,2}^{7p/n} (\bar{\nu}_{L\alpha} \gamma^\mu \nu_{L\beta}) \Big\{ g_1^\pi \langle \Sigma_\pm [\nabla^\nu u_\mu, u_\nu] \rangle + g_2^\pi \langle \nabla^\nu \Sigma_\pm [u_\mu, u_\nu] \rangle \\ &\quad + g_3^\pi \langle \Sigma_\pm [u_\mu, \chi_-] \rangle + g_4^\pi \langle \Sigma_\mp [u_\mu, \chi_+] \rangle + \varepsilon_{\mu\nu\rho\lambda} \langle u^\nu u^\rho \nabla^\lambda \Sigma_\mp \rangle \Big\} \\ &+ \frac{\Lambda_\chi^4}{\Lambda_{\rm EW}^4} \mathcal{C}_{5,6}^{8p/n} g_5^\pi (\bar{\nu}_{L\alpha} \gamma^\mu \nu_{L\beta}) \langle Q_\mp u_\mu \rangle \\ &+ \frac{\Lambda_\chi^2}{\Lambda_{\rm EW}^4} \mathcal{C}_{7,8}^{8p/n} (\bar{\nu}_{L\alpha} \gamma^\mu \nu_{L\beta}) \Big\{ g_6^\pi \langle u^\nu u_\nu [u_\mu, Q_\pm] \rangle + g_7^\pi \langle \chi_+ [u_\mu, Q_\pm] \rangle \Big\} \\ &+ \frac{\Lambda_\chi^2}{\Lambda_{\rm EW}^4} \mathcal{C}_9^{8p/n} g_8^\pi (\bar{\nu}_L \gamma^\mu \overleftrightarrow{\partial}^\nu \nu_L) \langle u^\rho u_\rho \rangle \langle u_\mu u_\nu \rangle + \dots \, . \end{aligned}$$

$$\begin{aligned} \mathcal{L}_{\pi N} = &\frac{(4\pi)^2}{\Lambda_{\rm EW}^2} (\bar{\nu}_{L\alpha} \gamma^\mu \nu_{L\beta}) \Big\{ \mathcal{C}_{1,2}^{6p/n} \left[(\bar{N}_v v_\mu Q_\pm N_v) + g_A (\bar{N}_v S_\mu Q_\mp N_v) \right] \Big\} \\ &\frac{(4\pi)^2 \Lambda_\chi^2}{\Lambda_{\rm EW}^4} (\bar{\nu}_{L\alpha} \gamma^\mu \nu_{L\beta}) \Big\{ \mathcal{C}_{5,6}^{8p/n} [(\bar{N}_v v_\mu Q_\pm N_v) + g_A^1 (\bar{N}_v S_\mu Q_\mp N_v)] \Big\} \\ &\frac{(4\pi)^2 \Lambda_\chi^2}{\Lambda_{\rm EW}^4} (\bar{\nu}_{L\alpha} \gamma^\mu \nu_{L\beta}) \Big\{ \mathcal{C}_7^{8p/n} (\bar{N}_v [u_\mu, Q_+] N_v) + \mathcal{C}_8^{8p/n} (\bar{N}_v [u_\mu, Q_-] N_v) \Big\} \\ &+ \frac{(4\pi)^2}{\Lambda_{\rm EW}^2} (\nu_{L\alpha}^T C \nu_{L\beta}) \Big\{ \mathcal{C}_{4,5}^{6p/n} \left[(\bar{N}_v \Sigma_\pm N_v) + (\bar{N}_v N_v) \langle \Sigma_\pm \rangle \right] \Big\} \\ &+ \frac{(4\pi)^2}{\Lambda_{\rm EW}^2} (\nu_{L\alpha}^T C \sigma^{\mu\nu} \nu_{L\beta}) \Big\{ \mathcal{C}_3^{6p/n} \left[\varepsilon_{\mu\nu\rho\lambda} (\bar{N}_v v^\rho S^\lambda \Sigma_+ N_v) + (\bar{N}_v [v_\mu, S_\nu] \Sigma_- N) \right] \Big\} \\ &+ \frac{(4\pi)^2 \Lambda_\chi}{\Lambda_{\rm EW}^3} (\bar{\nu}_{L\alpha} \gamma^\mu \nu_{L\beta}) \Big\{ \mathcal{C}_{1,2}^{7p/n} \left[(\bar{N}_v v^\mu \Sigma_\pm N_v) + (\bar{N}_v v^\mu N_v) \langle \Sigma_\pm \rangle \right] \Big\} \\ &+ \frac{\Lambda_\chi (4\pi)^2}{\Lambda_{\rm EW}^4} (\bar{\nu}_{L\alpha} \gamma^\mu \overleftrightarrow{\partial}^\nu \nu_{L\beta}) \Big\{ \mathcal{C}_{3,4}^{8p/n} \left[(\bar{N}_v Q_\pm v_\mu v_\nu N_v) + (\bar{N}_v Q_\mp S_\mu v_\nu N_v) \right] \Big\} + \dots\,, \end{aligned}$$

NDA

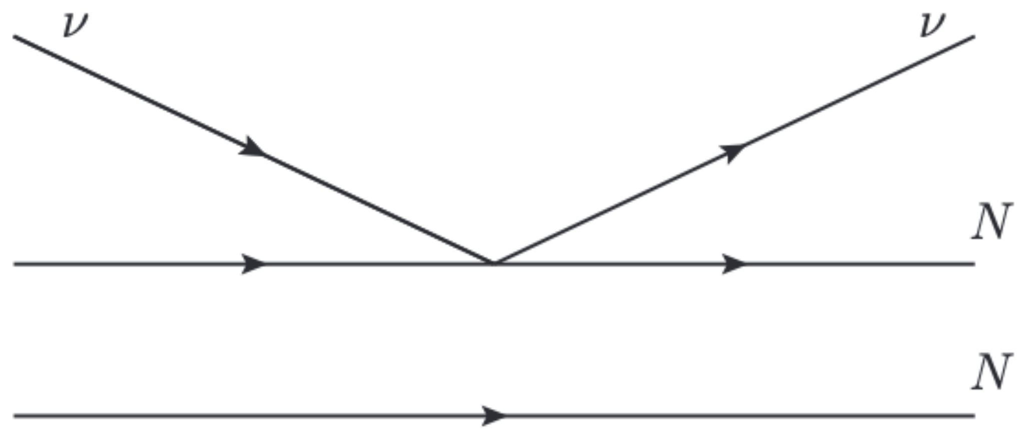
$$\text{LEFT:} \quad \frac{\Lambda_{\rm EW}^4}{16\pi^2} \left[\frac{\partial}{\Lambda_{\rm EW}}\right]^{N_p} \left[\frac{4\pi F}{\Lambda_{\rm EW}^2}\right]^{N_F} \left[\frac{4\pi\psi}{\Lambda_{\rm EW}^{3/2}}\right]^{N_\psi},$$

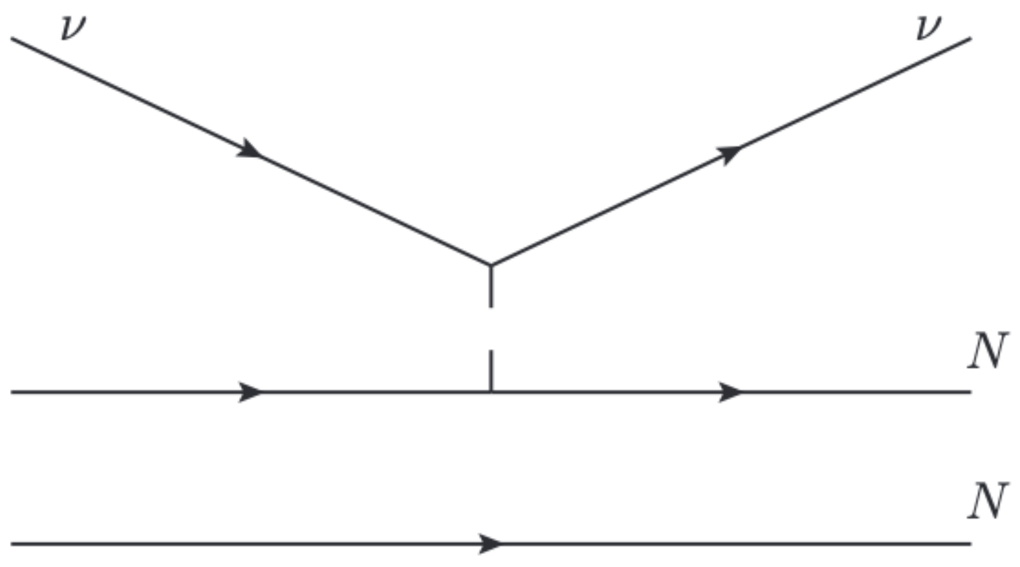
$$\text{ChPT:} \quad f^2 \Lambda_\chi^2 \left[\frac{\partial}{\Lambda_\chi}\right]^{N_p} \left[\frac{\psi}{f\sqrt{\Lambda_\chi}}\right]^{N_\psi} \left[\frac{F}{\Lambda_\chi f}\right]^{N_A},$$

$$\text{matching:} \quad \frac{\Lambda_{\rm EW}^4}{16\pi^2} \left[\frac{\partial}{\Lambda_{\rm EW}}\right]^{N_p} \left[\frac{4\pi F}{\Lambda_{\rm EW}^2}\right]^{N_F} \left[\frac{4\pi\psi}{\Lambda_{\rm EW}^{3/2}}\right]^{N_\psi} \sim \left[\frac{\Lambda_\chi}{\Lambda_{\rm EW}}\right]^{\mathcal{D}} \left(f^2 \Lambda_\chi^2 \left[\frac{\partial}{\Lambda_\chi}\right]^{N_p} \left[\frac{\psi}{f\sqrt{\Lambda_\chi}}\right]^{N_\psi} \left[\frac{F}{\Lambda_\chi f}\right]^{N_A} \right),$$

Nuclear response and cross section

LO

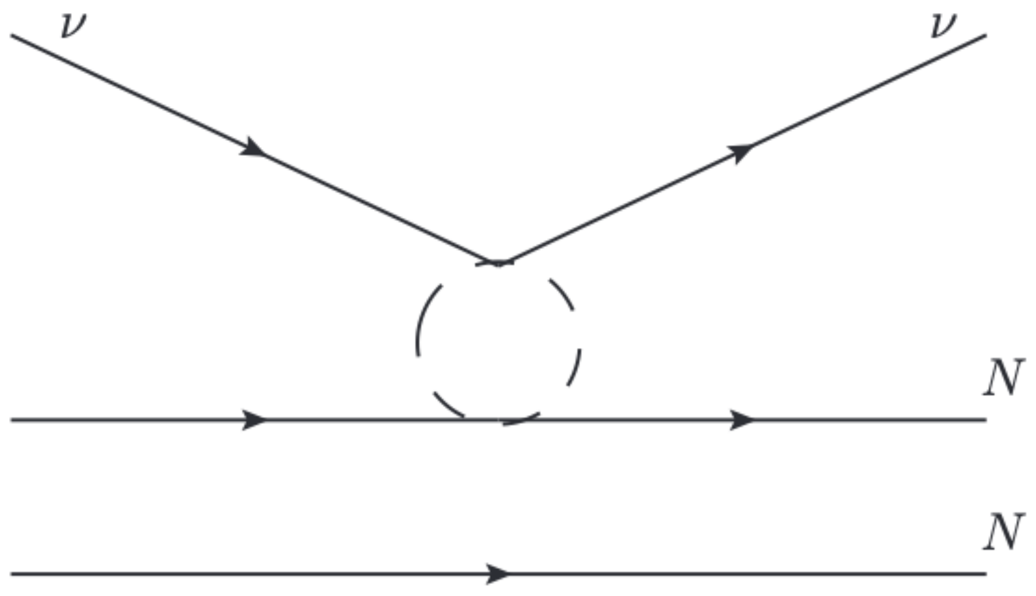


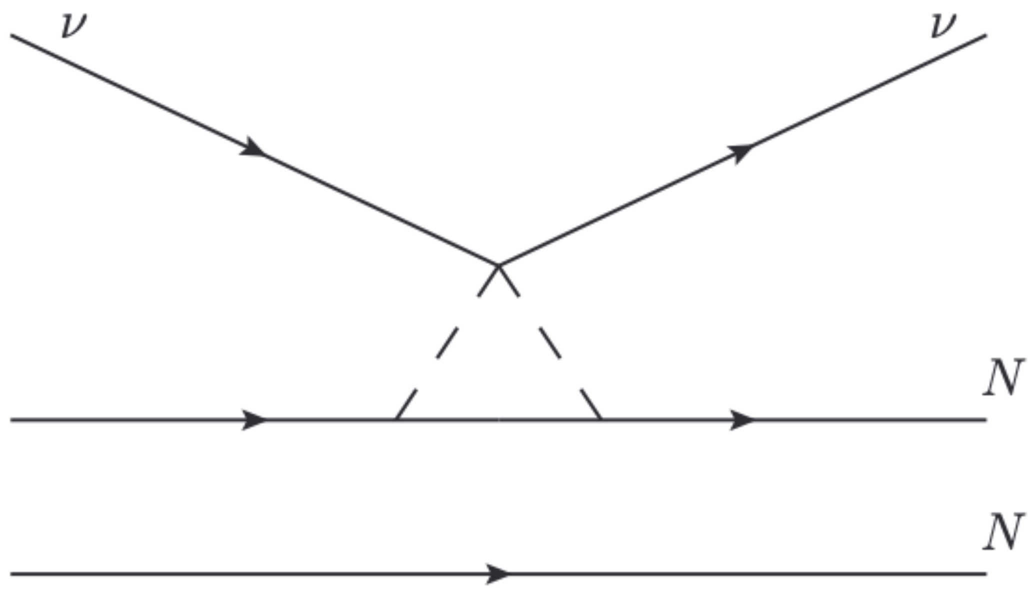


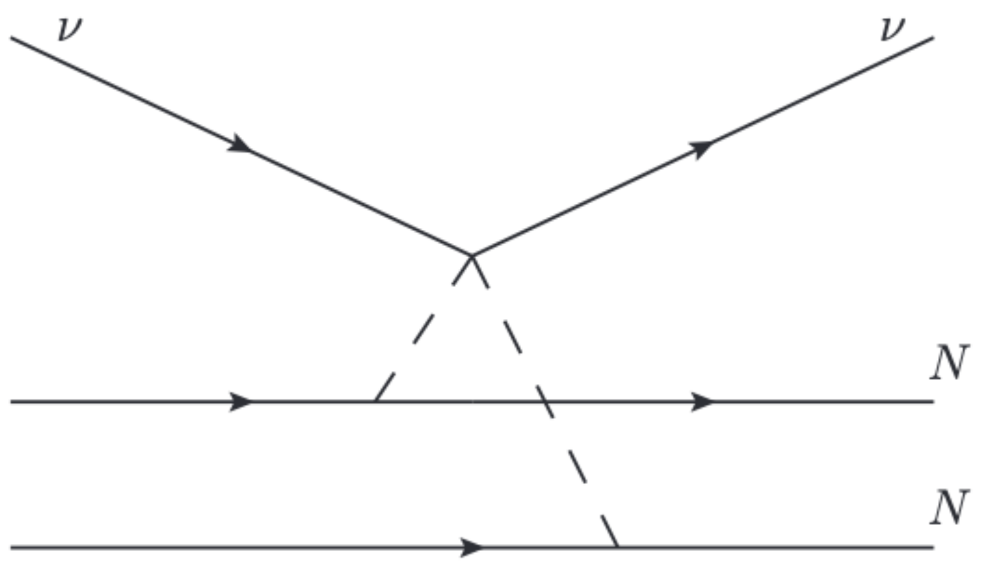
$$\langle f|\mathcal{O}^d|i\rangle \to \langle \nu'|\mathcal{O}^d_\nu|\nu\rangle \int d\mathbf{x} e^{-i\mathbf{q}\mathbf{x}} \langle N'|\mathcal{O}^d_N(\mathbf{x})|N\rangle$$

$$\langle f|\mathcal{O}^d|i\rangle \to \langle \nu'|\mathcal{O}^d_\nu|\nu\rangle \int d\mathbf{x} e^{-i\mathbf{q}\mathbf{x}} \langle N'N'|\mathcal{O}^d_N(\mathbf{x})|NN\rangle$$

NLO







$$e^{-i\mathbf{q}\mathbf{x}} \langle j_N|\mathcal{O}_N(\mathbf{x})|j_N\rangle$$

Multiple expansion

$$\boxed{M_J,\quad \tilde{\Omega}_J,\quad \Delta_J,\quad \Delta'_J,\quad \tilde{\Delta}''_J,\quad \Sigma_J,\quad \Sigma'_J,\quad \Sigma''_J,\quad \tilde{\Phi}_J,\quad \tilde{\Phi}'_J,\quad \Phi''_J,\quad \pi_J\,.}$$

Nuclear response and cross section

$$\mathcal{L}_{EFT}^{D} = \bar{\nu}_L l_0^D \bar{\nu}_L \cdot 1_N + \bar{\nu}_L l_{0,A}^D \bar{\nu}_L \cdot \left(\frac{\mathbf{K}\cdot\mathbf{S}_N}{m_N}\right) + \bar{\nu}_L \mathbf{l}_5^D \bar{\nu}_L \cdot (2\mathbf{S}_N)$$
$$+\bar{\nu}_L \mathbf{l}_M^D \bar{\nu}_L \cdot \left(\frac{\mathbf{K}}{2m_N}\right) + \bar{\nu}_L \mathbf{l}_E^D \bar{\nu}_L \cdot \left(-i\,\frac{\mathbf{K}\times\mathbf{S}_N}{m_N}\right).$$

$$\left\{1_N, \frac{\mathbf{K}\cdot\mathbf{S}_N}{m_N}, 2\mathbf{S}_N, \frac{\mathbf{K}}{2m_N}, -i\,\frac{\mathbf{K}\times\mathbf{S}_N}{m_N}\right\}.$$

$$|\overline{\mathcal{M}}_{1C}|^2 = \frac{4\pi}{2J_A+1}\sum_{\tau,\tau'}\Bigg\{\left[R_{MM}^{\tau\tau'}W_{MM}^{\tau\tau'}(y) + R_{\Sigma''\Sigma''}^{\tau\tau'}W_{\Sigma''\Sigma''}^{\tau\tau'}(y) + R_{\Sigma'\Sigma'}^{\tau\tau'}W_{\Sigma'\Sigma'}^{\tau\tau'}(y)\right]$$
$$+\frac{|\mathbf{q}|^2}{m_N^2}\left[R_{\Phi''\Phi''}^{\tau\tau'}W_{\Phi''\Phi''}^{\tau\tau'}(y) + R_{\tilde{\Phi}'\tilde{\Phi}'}^{\tau\tau'}W_{\tilde{\Phi}'\tilde{\Phi}'}^{\tau\tau'}(y) + R_{\Delta\Delta}^{\tau\tau'}W_{\Delta\Delta}^{\tau\tau'}(y)\right]$$
$$-\frac{2|\mathbf{q}|}{m_N}\left[R_{\Phi''M}^{\tau\tau'}W_{\Phi''M}^{\tau\tau'}(y) + R_{\Delta\Sigma'}^{\tau\tau'}W_{\Delta\Sigma'}^{\tau\tau'}(y)\right]\Bigg\},$$

$$|\overline{\mathcal{M}}_{1C}\overline{\mathcal{M}}_{2C}| = \frac{4\pi}{2J_A+1}\sum_{\tau,\tau'}\left[R_{\pi M}^{\tau\tau'}W_{\pi M}^{\tau\tau'}(y)\right] \qquad |\overline{\mathcal{M}}_{2C}|^2 = \frac{4\pi}{2J_A+1}\sum_{\tau,\tau'}\left[R_{\pi\pi}^{\tau\tau'}W_{\pi\pi}^{\tau\tau'}(y)\right]$$

$$\frac{\mathrm{d}\sigma}{\mathrm{dT}} = \frac{1}{32\pi m_A E_\nu^2}\left(|\overline{\mathcal{M}}_{1C} + \overline{\mathcal{M}}_{2C}|^2\right)$$

SMEFT and UV models

Dimension-6	
$\mathcal{O}_H$	$(H^\dagger H)^3$
$\mathcal{O}_{HW}$	$H^\dagger H W^I_{\mu\nu} W^{I\mu\nu}$
$\mathcal{O}_{HB}$	$H^\dagger H B_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_{HWB}$	$H^\dagger \tau^I H W^I_{\mu\nu} B^{\mu\nu}$
$\mathcal{O}_{HD}$	$\left(H^\dagger D^\mu H\right)^* \left(H^\dagger D^\mu H\right)$
$\mathcal{O}^{(1)}_{H\ell}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar\ell\gamma^\mu\ell)$
$\mathcal{O}^{(3)}_{H\ell}$	$(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar\ell\tau^I\gamma^\mu\ell)$
$\mathcal{O}^{(1)}_{Hq}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar Q\gamma^\mu Q)$
$\mathcal{O}^{(3)}_{Hq}$	$(H^\dagger i\overleftrightarrow{D}^I_\mu H)(\bar Q\tau^I\gamma^\mu Q)$
$\mathcal{O}_{Hu}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar u_R\gamma^\mu u_R)$
$\mathcal{O}_{Hd}$	$(H^\dagger i\overleftrightarrow{D}_\mu H)(\bar d_R\gamma^\mu d_R)$
$\mathcal{O}_{uB}$	$(\bar Q\sigma^{\mu\nu}u_R)\tilde H B_{\mu\nu}$
$\mathcal{O}_{uW}$	$(\bar Q\sigma^{\mu\nu}u_R)\tau^I\tilde H W^I_{\mu\nu}$
$\mathcal{O}_{dB}$	$(\bar Q\sigma^{\mu\nu}d_R) H B_{\mu\nu}$
$\mathcal{O}_{dW}$	$(\bar Q\sigma^{\mu\nu}d_R)\tau^I H W^I_{\mu\nu}$
$\mathcal{O}^{(1)}_{\ell q}$	$(\bar\ell\gamma^\mu\ell)(\bar Q\gamma_\mu Q)$
$\mathcal{O}^{(3)}_{\ell q}$	$(\bar\ell\gamma^\mu\tau^I\ell)(\bar Q\gamma_\mu\tau^I Q)$
$\mathcal{O}_{\ell u}$	$(\bar\ell\gamma^\mu\ell)(\bar u_R\gamma_\mu u_R)$
$\mathcal{O}_{\ell d}$	$(\bar\ell\gamma^\mu\ell)(\bar d_R\gamma_\mu d_R)$

Dimension-5	
$\mathcal{O}_5$	$\epsilon^{ik}\epsilon^{jl}(\ell_i^T C\ell_j)H_k H_l$
Dimension-7	
$\mathcal{O}_{QuLLH}$	$\epsilon^{ij}(\bar Q^k u_R)(\ell_k^T C\ell_i)H_j$
$\mathcal{O}_{dLQLH1}$	$\epsilon^{ij}\epsilon^{kl}(\bar d_R\ell_i)(Q_j^T C\ell_k)H_l$
$\mathcal{O}_{dLQLH2}$	$\epsilon^{ik}\epsilon^{jl}(\bar d_R\ell_i)(Q_j^T C\ell_k)H_l$
Dimension-8	
$\mathcal{O}_{l^2G^2D}$	$(\bar\ell\gamma^\mu i\overleftrightarrow{D}^\nu\ell)G^A_{\mu\rho}G^{A\rho}_\nu$
$\mathcal{O}^{(1)}_{l^2q^2G}$	$(\bar\ell\gamma^\mu\ell)(\bar Q\gamma^\nu T^A Q)G^A_{\mu\nu}$
$\mathcal{O}^{(2)}_{l^2q^2G}$	$(\bar\ell\gamma^\mu\ell)(\bar Q\gamma^\nu T^A Q)\widetilde G^A_{\mu\nu}$
$\mathcal{O}^{(3)}_{l^2q^2G}$	$(\bar\ell\gamma^\mu\tau^I\ell)(\bar Q\gamma^\nu T^A\tau^I Q)G^A_{\mu\nu}$
$\mathcal{O}^{(4)}_{l^2q^2G}$	$(\bar\ell\gamma^\mu\tau^I\ell)(\bar Q\gamma^\nu T^A\tau^I Q)\widetilde G^A_{\mu\nu}$
$\mathcal{O}^{(1)}_{l^2u^2G}$	$(\bar\ell\gamma^\mu\ell)(\bar u_R\gamma^\nu T^A u_R)G^A_{\mu\nu}$
$\mathcal{O}^{(2)}_{l^2u^2G}$	$(\bar\ell\gamma^\mu\ell)(\bar u_R\gamma^\nu T^A u_R)\widetilde G^A_{\mu\nu}$
$\mathcal{O}^{(1)}_{l^2d^2G}$	$(\bar\ell\gamma^\mu\ell)(\bar d_R\gamma^\nu T^A d_R)G^A_{\mu\nu}$
$\mathcal{O}^{(2)}_{l^2d^2G}$	$(\bar\ell\gamma^\mu\ell)(\bar d_R\gamma^\nu T^A d_R)\widetilde G^A_{\mu\nu}$
$\mathcal{O}^{(2)}_{l^2q^2D^2}$	$(\bar\ell\gamma^\mu\overleftrightarrow{D}^\nu\ell)(\bar Q\gamma_\mu\overleftrightarrow{D}_\nu Q)$
$\mathcal{O}^{(4)}_{l^2q^2D^2}$	$(\bar\ell\gamma^\mu\overleftrightarrow{D}^{I\nu}\ell)(\bar Q\gamma_\mu\overleftrightarrow{D}^I_\nu Q)$
$\mathcal{O}^{(2)}_{l^2u^2D^2}$	$(\bar\ell\gamma^\mu\overleftrightarrow{D}^\nu\ell)(\bar u_R\gamma_\mu\overleftrightarrow{D}_\nu u_R)$
$\mathcal{O}^{(2)}_{l^2d^2D^2}$	$(\bar\ell\gamma^\mu\overleftrightarrow{D}^\nu\ell)(\bar d_R\gamma_\mu\overleftrightarrow{D}_\nu d_R)$

Dimension-6: $V_1(\mathbf{1},\mathbf{1})_0$ and $V_7(\mathbf{3},\mathbf{2})_{-\frac{5}{6}}$

$$\mathcal{L}_{\rm UV} = -2\mathcal{D}_{d^\dagger LS_{12}}\epsilon^{ij}[(\bar d)^a(L)_i](S_{12})_{aj} + 2\mathcal{D}_{d^\dagger L^\dagger V_7}[(\bar d)^a\gamma^\mu C\bar L_i](V_7)^i_{a\mu}$$

$$\mathcal{C}^{6n}_{1,2} = \frac{\Lambda^2_{\rm EW}}{\Lambda^2}C^{\alpha\beta}_{ld} = \Lambda^2_{\rm EW}\left(\frac{4\mathcal{D}_{d^\dagger L^\dagger V_7}\mathcal{D}_{d^\dagger L^\dagger V_7}}{M^2_{V_7}} - \frac{2\mathcal{D}_{d^\dagger LS_{12}}\mathcal{D}_{d^\dagger LS_{12}}}{M^2_{S_{12}}}\right)$$

Dimension-7: $F_{12}(\mathbf{3},\mathbf{2})_{\frac{7}{6}}$ and $V_9(\mathbf{3},\mathbf{3})_{\frac{2}{3}}$

$$\mathcal{L}^7_{\rm UV} = \mathcal{D}_{F_{12L}H^\dagger u^\dagger}(\bar u^a F_{12i})H^{\dagger i} + \mathcal{D}_{LQ^\dagger V_9}(\tau^I)^j_i(\bar q^{ai}\gamma_\mu\ell_j)V^{I\mu}_{9a} + \mathcal{D}_{LF_{12}V_9}\epsilon_{kj}(\tau^I)^k_i(\bar\ell^j\gamma_\mu F^{ai}_{12})V^{I\mu}_{9a} + \text{h.c.}$$

$$\mathcal{C}^{6p}_{4,5} = \frac{\Lambda^3_{\rm EW}}{\Lambda^3}C_{QuLLH} = \Lambda^3_{\rm EW}\frac{16\mathcal{D}_{F_{12L}H^\dagger u^\dagger}\mathcal{D}_{LQ^\dagger V_9}\mathcal{D}_{LF_{12}V_9}}{M_{F_{12}}M^2_{V_9}},$$

Experiment Constraints

$$\frac{\mathrm{d}\sigma}{\mathrm{dT}} = \frac{1}{32\pi m_A E_\nu^2}\left(|\overline{\mathcal{M}}_{1C} + \overline{\mathcal{M}}_{2C}|^2\right)$$

$$\frac{\mathrm{d}R_{\nu_\alpha}}{\mathrm{d}T_{\mathrm{nr}}} = \int_{E_{\nu,\mathrm{min}}}^{E_{\nu,\mathrm{max}}} dE_\nu \Phi_{\nu_\alpha}(E_\nu)\frac{\mathrm{d}\sigma}{\mathrm{d}T_{\mathrm{nr}}} \, ,$$

COHERENT

$$\Phi_{\nu_e}(E_\nu) = \mathcal{N}\frac{192E_\nu^2}{m_\mu^3}\left(\frac{1}{2} - \frac{E_\nu}{m_\mu}\right) \, ,$$

$$\Phi_{\bar{\nu}_\mu}(E_\nu) = \mathcal{N}\frac{64E_\nu^2}{m_\mu^3}\left(\frac{3}{4} - \frac{E_\nu}{m_\mu}\right) \, ,$$

$$\Phi_{\nu_\mu}(E_\nu) = \mathcal{N}\delta\left(E_\nu - \frac{m_\pi^2 - m_\mu^2}{2m_\pi}\right) \, ,$$

$\Lambda_{\mathrm{NSI}}/\mathrm{GeV}$	ν_e	ν_μ
$\hat{\mathcal{C}}_{1,u}^{(6)}$	390	395
$\hat{\mathcal{C}}_{1,d}^{(6)}$	407	414
$\hat{\mathcal{C}}_{2,u}^{(6)}$	44.7	68.4
$\hat{\mathcal{C}}_{2,d}^{(6)}$	26.4	40.9

^{8}B neutrinos

$$\Phi_{\nu_\alpha}(E_\nu) = \frac{\mathcal{E}}{M_{\mathrm{det}}}\langle P_{\nu_\alpha}\rangle\phi(^8\mathrm{B})$$

PandaX-4T

$\Lambda_{\mathrm{NSI}}/\mathrm{GeV}$	ν_e	ν_μ	ν_τ
$\hat{\mathcal{C}}_{1,u}^{(6)}$	287.46	289.61	286.70
$\hat{\mathcal{C}}_{1,d}^{(6)}$	304.61	306.88	303.80
$\hat{\mathcal{C}}_{2,u}^{(6)}$	14.70	14.81	14.60
$\hat{\mathcal{C}}_{2,d}^{(6)}$	23.32	23.48	23.15

XENONnT

$\Lambda_{\mathrm{NSI}}/\mathrm{GeV}$	ν_e	ν_μ	ν_τ
$\hat{\mathcal{C}}_{1,u}^{(6)}$	342.20	344.97	342.50
$\hat{\mathcal{C}}_{1,d}^{(6)}$	388.46	393.08	388.95
$\hat{\mathcal{C}}_{2,u}^{(6)}$	19.67	20.05	19.69
$\hat{\mathcal{C}}_{2,d}^{(6)}$	31.19	31.80	31.23

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Summary

- The formalism of calculating the cross section of coherent neutrino-nucleus scattering from the new physics scale has been obtained through the EFT framework.

- The SMEFT and LEFT operators are considered up to dimension-8 with some of the UV models.

- The chiral EFT up to NLO is contained, both of the loop order and two body case are considered in this work.

- The more details of the two body currents with different operators should be considered next.

Thanks !