GUT inspired Gauge-Higgs Unification Model

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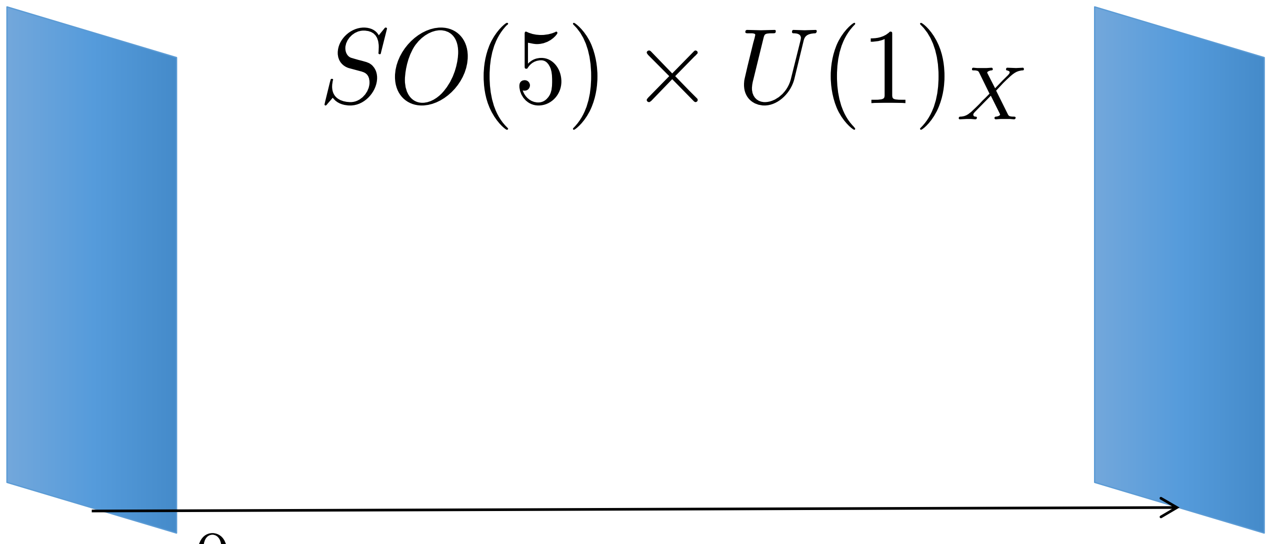
Symmetry breakings

Gauge-Higgs Unification model

$$SO(5) \times U(1)_X$$



$y = 0$ $\qquad$ $y = L$

AdS $\quad \Lambda = -6\,k^2$

$$ds^2 = e^{-2k|y|} dx^\mu dx_\mu + dy^2$$

Symmetry breakings

$$SO(5) \times U(1)_X$$

Boundary Condition

$$\to SU(4) \times U(1)_X \simeq SU(2)_R \times SU(2)_L \times U(1)_X$$

Brane scalar

$$Z_R, W_R$$

$$\to SU(2)_L \times U(1)_Y$$

Hosotani mechanism

$$Z, W$$

$$\to U(1)_{em} \quad \gamma$$

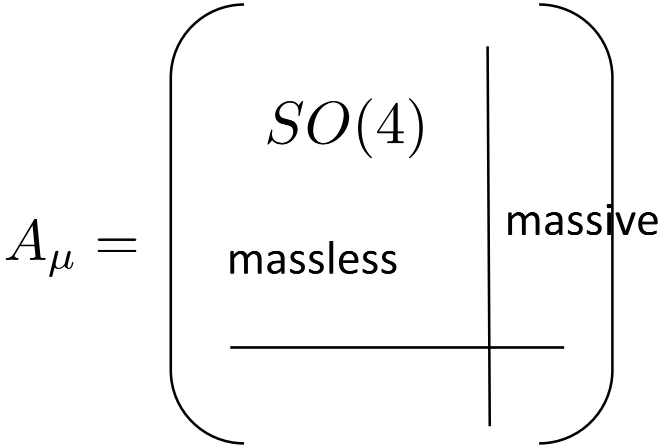
Zero mode

$$A_\mu(x,-y) = P A_\mu(x,y) P^{-1} \qquad A_y(x,-y) = -P A_y(x,y) P^{-1}$$

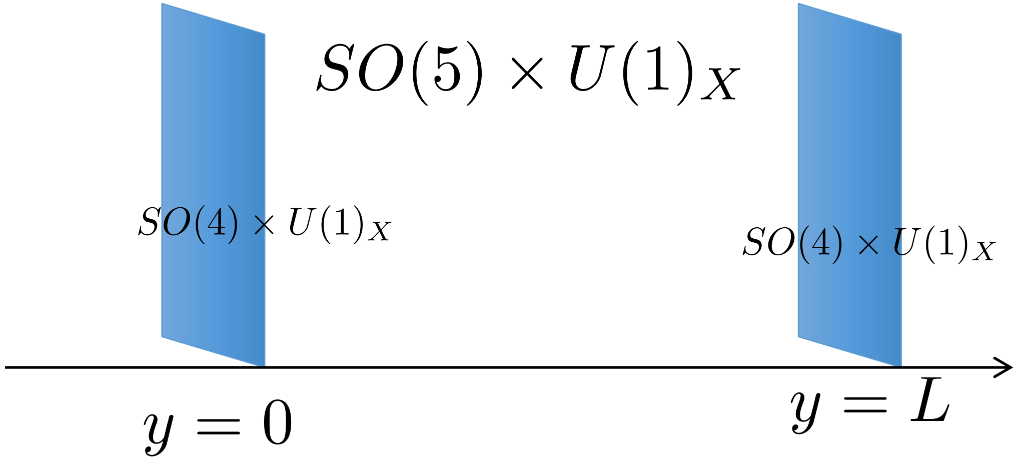
$$A_\mu = \left(\begin{array}{c|c} (+,+) & (-,-) \\ \hline & \end{array}\right) \qquad A_y = \left(\begin{array}{c|c} (-,-) & (+,+) \\ \hline & \end{array}\right)$$

Zero mode

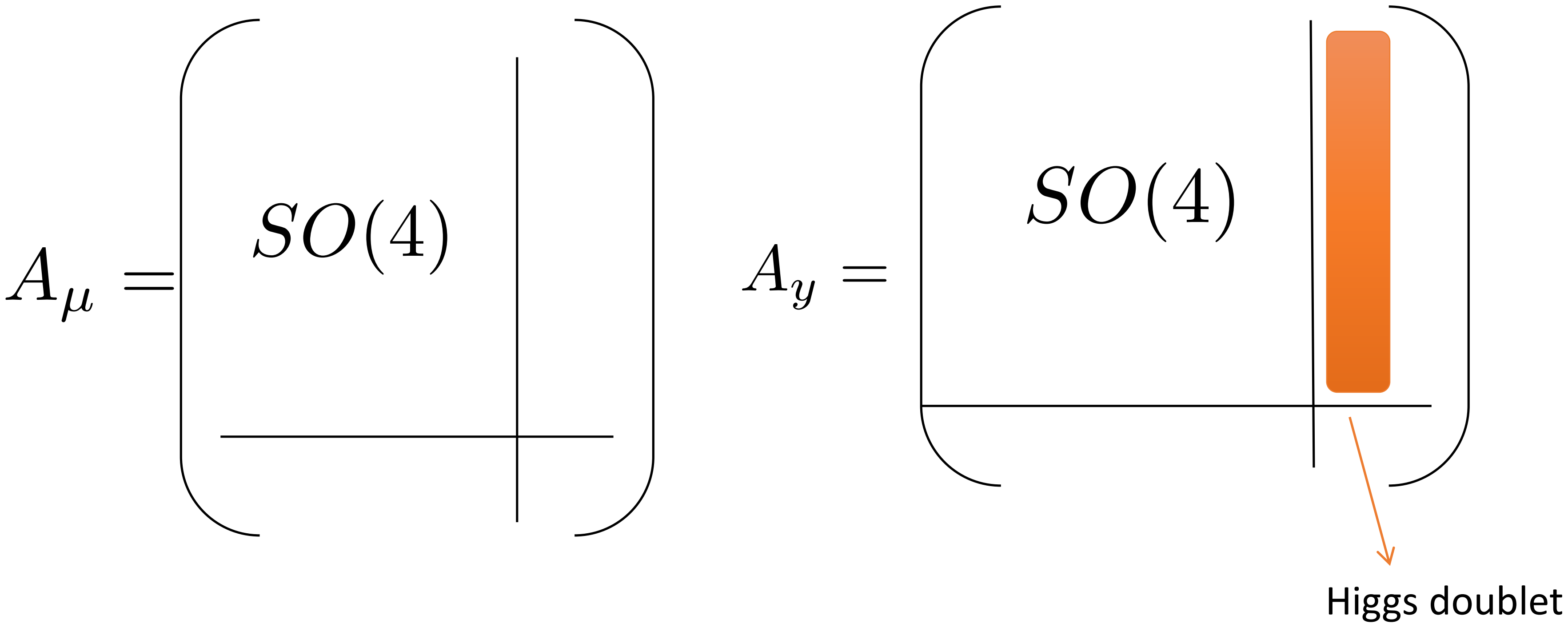
$$P = diag(-1,-1,-1,-1,1)$$



SO(5) gauge symmetry is broken by orbifold boundary condition



Higgs



Higgs doublet is massless SO(4) vector

gauge-Higgs unification

Higgs boson is a component of higher dimensional gauge bosons

↓

Quadratic divergence is protected by gauge symmetry

Brane scalars

A-model

$$S_{\rm brane} = \int d^5x\sqrt{-G}\ \delta(y)\Big\{ -(D_\mu\Phi)^\dagger D^\mu\Phi - \lambda_\Phi(\Phi^\dagger\Phi - w^2)^2 \Big\}\ ,$$

$$D_\mu\Phi = \Big(\partial_\mu - ig_A\sum_{a_R=1}^{3} A_\mu^{a_R}T^{a_R} + i\frac{1}{2}g_B B_\mu\Big)\Phi\ ,\quad \tilde\Phi = i\sigma_2\Phi^*$$

Breaks SO(4) symmetry

B-model

$$S^\Phi_{\rm brane} = \int d^5x\sqrt{-\det G}\,\delta(y)$$
$$\times\Big\{-(D_\mu\Phi_{(\mathbf{1},\mathbf{4})})^\dagger D^\mu\Phi_{(\mathbf{1},\mathbf{4})} - \lambda_{\Phi_{(\mathbf{1},\mathbf{4})}}\big(\Phi^\dagger_{(\mathbf{1},\mathbf{4})}\Phi_{(\mathbf{1},\mathbf{4})} - |w|^2\big)^2\Big\},$$

$$D_\mu\Phi_{(\mathbf{1},\mathbf{4})} = \Big\{\partial_\mu - ig_A\sum_{\alpha=1}^{10}A_\mu^\alpha T^\alpha - ig_BQ_XB_\mu\Big\}\Phi_{(\mathbf{1},\mathbf{4})}\ .$$

Hosotani Mechanism

Hosotani, 1983

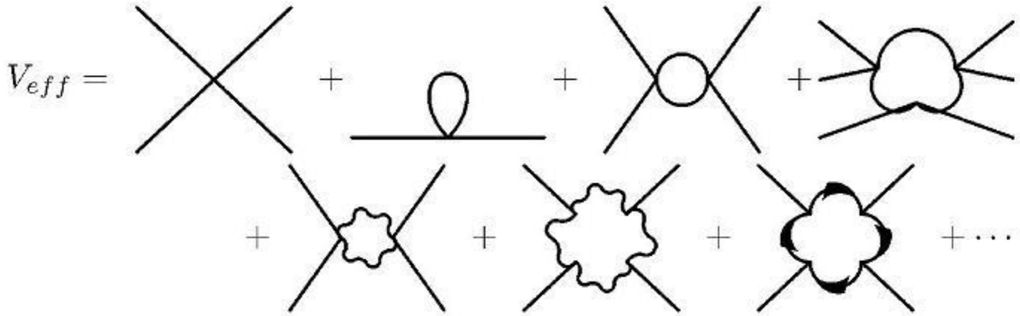
Wilson line phase θ_H is given by

$$exp\left(\frac{i}{2}\theta_H 2\sqrt{2}T^{\hat{4}}\right) = exp\left(ig_A\int_0^L dy\langle A_y\rangle\right)$$

$\theta_H \neq 0$ ➡ $SU(2)_L \times U(1)_Y \to U(1)_{EM}$

θ_H is a minimum of the effective potential

The Effective Potential



$$V_{eff}(\theta_H) = \sum \pm \frac{1}{2} \int \frac{d^4p}{(2\pi)^4} \sum_n ln \left(p^2 + m_n(\theta_H)^2\right)$$

A model

Old model

	A-model
Quark	$(\mathbf{3},\mathbf{5})_{\frac{2}{3}}$ $(\mathbf{3},\mathbf{5})_{-\frac{1}{3}}$
Lepton	$(\mathbf{1},\mathbf{5})_{0}$ $(\mathbf{1},\mathbf{5})_{-1}$
Dark fermion	$(\mathbf{1},\mathbf{4})_{\frac{1}{2}}$
Brane fermion	$(\mathbf{3},[\mathbf{2},\mathbf{1}])_{\frac{7}{6},\frac{1}{6},-\frac{5}{6}}$ $(\mathbf{1},[\mathbf{2},\mathbf{1}])_{\frac{1}{2},-\frac{1}{2},-\frac{3}{2}}$
Brane scalar	$(\mathbf{1},[\mathbf{1},\mathbf{2}])_{\frac{1}{2}}$

Table 1: Masses and widths of Z' bosons, $Z^{(1)}$, $\gamma^{(1)}$, and $Z_R^{(1)}$ ($N_F = 4$)

θ_H [rad.]	$\frac{z_L}{10^4}$	m_{KK} [TeV]	$m_{Z^{(1)}}$ [TeV]	$\Gamma_{Z^{(1)}}$ [GeV]	$m_{\gamma^{(1)}}$ [TeV]	$\Gamma_{\gamma^{(1)}}$ [GeV]	$m_{Z_R^{(1)}}$ [TeV]	$\Gamma_{Z_R^{(1)}}$ [GeV]
0.115	10	7.41	6.00	406	6.01	909	5.67	729
0.0917	3	8.81	7.19	467	7.20	992	6.74	853
0.0737	1	10.3	8.52	564	8.52	1068	7.92	1058

Table 2: Couplings of neutral vector bosons (Z' bosons) to fermions in unit of $g_w = e/\sin\theta_W$ for $\theta_H = 0.115$. Corresponding Z-boson coupling in the SM are $(g^L_{Z\nu}, g^R_{Z\nu}) = (0.57027, 0)$, $(g^L_{Ze}, g^R_{Ze}) = (-0.30651, 0.26376)$, $(g^L_{Zu}, g^R_{Zu}) = (0.39443, -0.17584)$ and $(g^L_{Zd}, g^R_{Zd}) = (-0.48235, 0.08792)$.

f	g^L_{Zf}	g^R_{Zf}	$g^L_{Z^{(1)}f}$	$g^R_{Z^{(1)}f}$	$g^L_{Z_R^{(1)}}$	$g^R_{Z_R^{(1)}f}$	$g^L_{\gamma^{(1)}f}$	$g^R_{\gamma^{(1)}f}$
ν_e	0.57041	0	−0.1968	0	0	0	0	0
ν_μ	0.57041	0	−0.1968	0	0	0	0	0
ν_τ	0.57041	0	−0.1967	0	0	0	0	0
e	−0.30659	0.26392	0.1058	1.0924	0	−1.501	0.1667	−1.983
μ	−0.30659	0.26391	0.1058	1.0261	0	−1.420	0.1667	−1.863
τ	−0.30658	0.26391	0.1057	0.9732	0	−1.354	0.1666	−1.767
u	0.39453	−0.17594	−0.1361	−0.7152	0	0.9846	−0.1111	1.2983
c	0.39453	−0.17594	−0.1361	−0.6631	0	0.9205	−0.1111	1.2036
t	0.39339	−0.17712	0.5068	−0.4764	1.0314	0.6899	0.4158	0.8666
d	−0.48247	0.087972	0.1665	0.3576	0	−0.4923	0.05557	−0.6491
s	−0.48247	0.087970	0.1664	0.3315	0	−0.4602	0.05556	−0.6018
b	−0.48254	0.087964	−0.6303	0.2387	1.0292	−0.3446	−0.2082	−0.4331

The model has universality

Low energy physics is described
by only one parameter θ_H

Dark Matter physics depends on n_F

Relic abundance ⇒ $n_F = 4$

GHU model has significant deviation and polarization dependence in forward-backward asymmetry

B model

Gut inspired Gauge-Higgs Unification model

$$SO(11) \supset SU(3)_C \times SO(5)_W \times U(1)_X$$

$$\begin{aligned}
\mathbf{1} &= (\mathbf{1}, \mathbf{1})_0 \ , \\
\mathbf{11} &= (\mathbf{3}, \mathbf{1})_{-\frac{1}{3}} \oplus (\overline{\mathbf{3}}, \mathbf{1})_{\frac{1}{3}} \oplus (\mathbf{1}, \mathbf{5})_0 \ , \\
\mathbf{32} &= (\mathbf{3}, \mathbf{4})_{\frac{1}{6}} \oplus (\mathbf{1}, \mathbf{4})_{-\frac{1}{2}} \oplus (\overline{\mathbf{3}}, \mathbf{4})_{-\frac{1}{6}} \oplus (\mathbf{1}, \mathbf{4})_{\frac{1}{2}} \ , \\
\mathbf{55} &= (\mathbf{8}, \mathbf{1})_0 \oplus (\mathbf{3}, \mathbf{1})_{\frac{2}{3}} \oplus (\overline{\mathbf{3}}, \mathbf{1})_{-\frac{2}{3}} \oplus (\mathbf{1}, \mathbf{1})_0 \oplus (\mathbf{3}, \mathbf{5})_{-\frac{1}{3}} \oplus (\overline{\mathbf{3}}, \mathbf{5})_{\frac{1}{3}} \oplus (\mathbf{1}, \mathbf{10})_0 \ .
\end{aligned}$$

SU(3) gauge boson

U(1) gauge boson

SO(5) gauge boson

TABLE III. Masses and widths of Z' bosons ($Z^{(1)}$, $\gamma^{(1)}$, and $Z_R^{(1)}$) are listed for $\theta_H = 0.10$ and three $m_{\rm KK} = 11, 13, 15$ TeV values in the upper table, and $m_{\rm KK} = 13$ TeV and three $\theta_H = 0.11, 0.10, 0.09$ values in the lower table. $m_Z = 91.1876$ GeV and $\Gamma_Z = 2.4952$ GeV [81]. The column "Name" denotes each parameter set, and the column "Table" indicates the table summarizing the coupling constants in each set.

Name	θ_H (rad)	$m_{\rm KK}$ (TeV)	z_L	k (GeV)	$m_{\gamma^{(1)}}$ (TeV)	$\Gamma_{\gamma^{(1)}}$ (TeV)	$m_{Z^{(1)}}$ (TeV)	$\Gamma_{Z^{(1)}}$ (TeV)	$m_{Z_R^{(1)}}$ (TeV)	$\Gamma_{Z_R^{(1)}}$ (TeV)	Table
$\rm B^L$	0.10	11.00	1.980×10^{8}	6.933×10^{11}	8.715	2.080	8.713	4.773	8.420	0.603	5
B	0.10	13.00	3.865×10^{11}	1.599×10^{15}	10.20	3.252	10.20	7.840	9.951	0.816	4
$\rm B^H$	0.10	15.00	2.667×10^{15}	1.273×10^{19}	11.69	4.885	11.69	11.82	11.48	1.253	6
Name	θ_H (rad)	$m_{\rm KK}$ (TeV)	z_L	k (GeV)	$m_{\gamma^{(1)}}$ (TeV)	$\Gamma_{\gamma^{(1)}}$ (TeV)	$m_{Z^{(1)}}$ (TeV)	$\Gamma_{Z^{(1)}}$ (TeV)	$m_{Z_R^{(1)}}$ (TeV)	$\Gamma_{Z_R^{(1)}}$ (TeV)	Table
B^+	0.11	13.00	1.021×10^{14}	4.223×10^{17}	10.15	3.836	10.15	9.374	9.951	0.924	7
B	0.10	13.00	3.865×10^{11}	1.599×10^{15}	10.20	3.252	10.20	7.840	9.951	0.816	4
B^-	0.09	13.00	2.470×10^{9}	1.022×10^{13}	10.26	2.723	10.26	6.413	9.951	0.732	8

TABLE IV. Coupling constants of neutral vector bosons, Z' bosons, to fermions in units of $g_w = e/\sin\theta_W^0$ are listed for $\theta_H = 0.10$ and $m_{\rm KK} = 13.00$ TeV (B) in Table III, where $\sin^2\theta_W^0 = 0.2306$. Their corresponding Z boson coupling constants in the SM are $(g_{Z_\nu}^L, g_{Z_\nu}^R) = (0.5703, 0)$, $(g_{Z_e}^L, g_{Z_e}^R) = (-0.3065, 0.2638)$, $(g_{Z_u}^L, g_{Z_u}^R) = (0.3944, -0.1748)$, $(g_{Z_d}^L, g_{Z_d}^R) = (-0.4823, 0.0879)$. Their corresponding γ boson coupling constants are the same as those in the SM. When the value is less than 10^{-4}, we write 0.

f	g_{Zf}^L	g_{Zf}^R	$g_{Z^{(1)}f}^L$	$g_{Z^{(1)}f}^R$	$g_{Z_R^{(1)}f}^L$	$g_{Z_R^{(1)}f}^R$	$g_{\gamma^{(1)}f}^L$	$g_{\gamma^{(1)}f}^R$
ν_e	0.5687	0	3.2774	0	−1.0322	0	0	0
ν_μ	0.5687	0	3.1207	0	−0.9852	0	0	0
ν_τ	0.5687	0	3.0165	0	−0.9539	0	0	0
e	−0.3058	0.2629	−1.7621	−0.0584	−1.0444	0	−2.7587	0.1071
μ	−0.3058	0.2629	−1.6778	−0.0584	−0.9969	0	−2.6268	0.1071
τ	−0.3058	0.2629	−1.6218	−0.0584	−0.9652	0.0001	−2.5391	0.1070
u	0.3934	−0.1753	2.1951	0.0390	0.3415	0	1.7807	−0.0714
c	0.3934	−0.1753	2.1147	0.0389	0.3296	0	1.7154	−0.0714
t	0.3938	−0.1749	1.7406	−0.3269	0.2740	−0.7395	1.4121	0.6017
d	−0.4811	0.0876	−2.6842	0.1162	0.3297	−0.1801	−0.8904	−0.2113
s	−0.4811	0.0876	−2.5858	0.1460	0.3182	−0.2197	−0.8577	−0.2657
b	−0.4811	0.0876	−2.1284	0.2900	0.2646	−0.4096	−0.7059	−0.5279

	B-model
Quark	$(\mathbf{3},\mathbf{4})_{\frac{1}{6}}$ $(\mathbf{3},\mathbf{1})^{+}_{-\frac{1}{3}}$ $(\mathbf{3},\mathbf{1})^{-}_{-\frac{1}{3}}$
Lepton	$(\mathbf{1},\mathbf{4})_{-\frac{1}{2}}$
Dark fermion	$(\mathbf{3},\mathbf{4})_{\frac{1}{6}}$ $(\mathbf{1},\mathbf{5})^{+}_{0}$ $(\mathbf{1},\mathbf{5})^{-}_{0}$
Brane fermion	$(\mathbf{1},\mathbf{1})_{0}$
Brane scalar	$(\mathbf{1},\mathbf{4})_{\frac{1}{2}}$

Action

$$S_{\text{bulk}}^{\text{gauge}} = \int d^5x \sqrt{-\det G} \left[-\operatorname{tr}\left(\frac{1}{4} F^{MN} F_{MN} + \frac{1}{2\xi} (f_{\text{gf}})^2 + \mathcal{L}_{\text{gh}} \right) \right],$$

$$F_{MN}^{(A)} = \partial_M A_N - \partial_N A_M - i g_A \left[A_M, A_N \right],$$

$$f_{\text{gf}} = z^2 \left\{ \eta^{\mu\nu} \mathcal{D}_\mu^{\text{c}} A_\nu^{\text{q}} + \xi k^2 z \mathcal{D}_z^{\text{c}} \left(\frac{1}{z} A_z^{\text{q}} \right) \right\},$$

$$\mathcal{L}_{\text{gh}} = \bar{c} \left\{ \eta^{\mu\nu} \mathcal{D}_\mu^{\text{c}} \mathcal{D}_\nu + \xi k^2 z \mathcal{D}_z^{\text{c}} \frac{1}{z} \mathcal{D}_z \right\} c \ ,$$

Action

$$S_{\text{bulk}}^{\text{quark}} = \int d^5x \sqrt{-\det G} \sum_{\alpha=1}^{3} \Big\{ \overline{\Psi}_{(\mathbf{3},\mathbf{4})}^{\alpha} \mathcal{D}(c_\alpha) \Psi_{(\mathbf{3},\mathbf{4})}^{\alpha} + \overline{\Psi}_{(\mathbf{3},\mathbf{1})}^{+\alpha} \mathcal{D}(c_{D_\alpha^+}) \Psi_{(\mathbf{3},\mathbf{1})}^{+\alpha}$$

$$+ \overline{\Psi}_{(\mathbf{3},\mathbf{1})}^{-\alpha} \mathcal{D}(c_{D_\alpha^-}) \Psi_{(\mathbf{3},\mathbf{1})}^{-\alpha} - m_{D_\alpha} \Big(\overline{\Psi}_{(\mathbf{3},\mathbf{1})}^{+\alpha} \Psi_{(\mathbf{3},\mathbf{1})}^{-\alpha} + \overline{\Psi}_{(\mathbf{3},\mathbf{1})}^{-\alpha} \Psi_{(\mathbf{3},\mathbf{1})}^{+\alpha} \Big) \Big\},$$

$$\mathcal{D}(c) = \gamma^A {e_A}^M \left(D_M + \frac{1}{8} \omega_{MBC} [\gamma^B, \gamma^C] \right) - c\sigma'(y) \ ,$$

$$D_M = \partial_M - i g_S A_M^{SU(3)} - i g_A A_M^{SO(5)} - i g_B Q_X A_M^{U(1)} \ .$$

Effective potential

$$V_{\rm eff}(\theta) = 2(3-\xi^2)A_W(\theta) + (3-\xi^2)A_Z(\theta) + 3\xi^2 A_S(\theta) - 12A_{\rm top}(\theta) - 12A_{\rm bottom}(\theta)$$
$$-12n_F A_F(\theta) - 8n_N A_N(\theta),$$

$$A_p(\theta) \equiv \frac{(kz_L^{-1})^4}{(4\pi)^2}\int_0^\infty dq q^3 \ln\left[1+\sum_{n=1}^{2} Q_p^{(n)}(q)\cos(n\theta)\right],$$

$$\begin{aligned}
Q_W^{(1)}(q) &= 0, \\
Q_W^{(2)}(q) &= -\frac{iq}{4z_L\hat{C}(q)\hat{S}(q)+iq}. \\
Q_Z^{(1)}(q) &= 0, \\
Q_Z^{(2)}(q) &= -\frac{iq(1+\sin\phi^2)}{4z_L\hat{C}(q)\hat{S}(q)+iq(1+\sin\phi^2)}. \\
Q_S^{(1)}(q) &= 0, \\
Q_S^{(2)}(q) &= -\frac{iq}{2z_L\hat{C}(q)\hat{S}(q)+iq}.
\end{aligned}$$

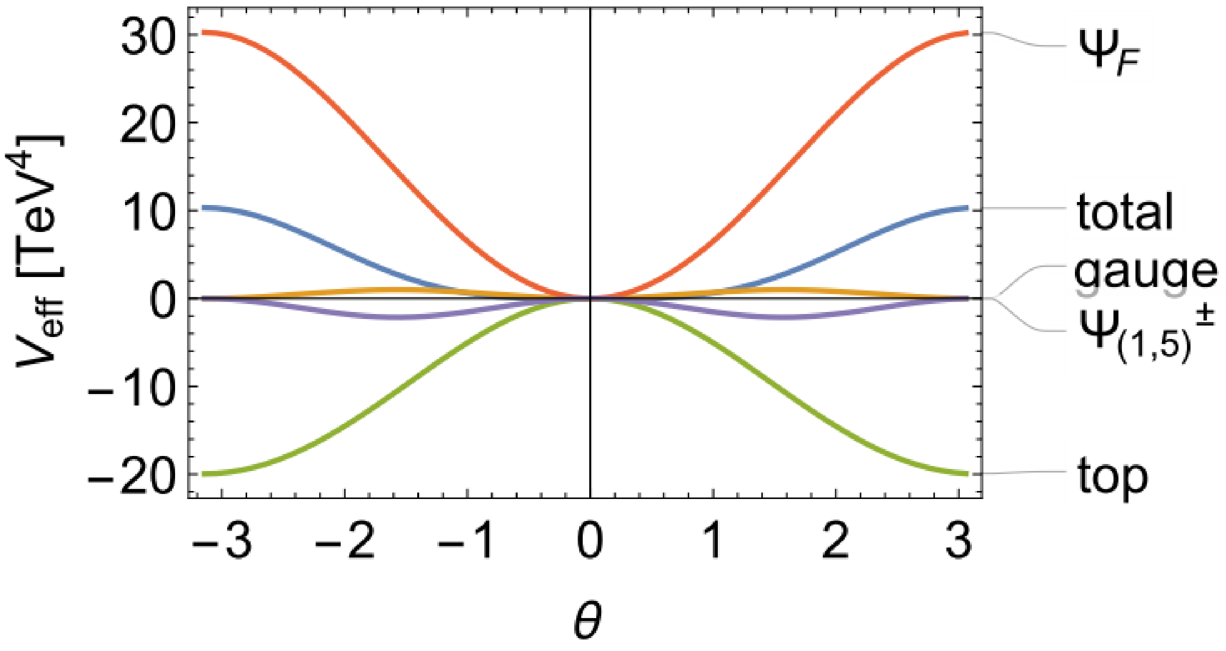
$$\begin{aligned}
Q_N^{(1)}(q) &= 0, \\
Q_N^{(2)}(q) &= -\frac{2}{\hat{B}_0(q;c_V,m_V)},
\end{aligned}$$

$$\begin{aligned}
\hat{B}_0(q;c_V,m_V) &= \hat{C}_L(q;c_V+m_V)\hat{C}_R(q;c_V-m_V)+\hat{C}_L(q;c_V-m_V)\hat{C}_R(q;c_V+m_V) \\
&\quad +\hat{S}_L(q;c_V+m_V)\hat{S}_R(q;c_V-m_V)+\hat{S}_L(q;c_V-m_V)\hat{S}_R(q;c_V+m_V).
\end{aligned}$$

$$\begin{aligned}
Q_{top}^{(1)}(q) &= -\frac{1}{2\hat{S}_L(q;c_t)\hat{S}_R(q;c_t)+1}, \\
Q_{top}^{(2)}(q) &= 0,
\end{aligned}$$

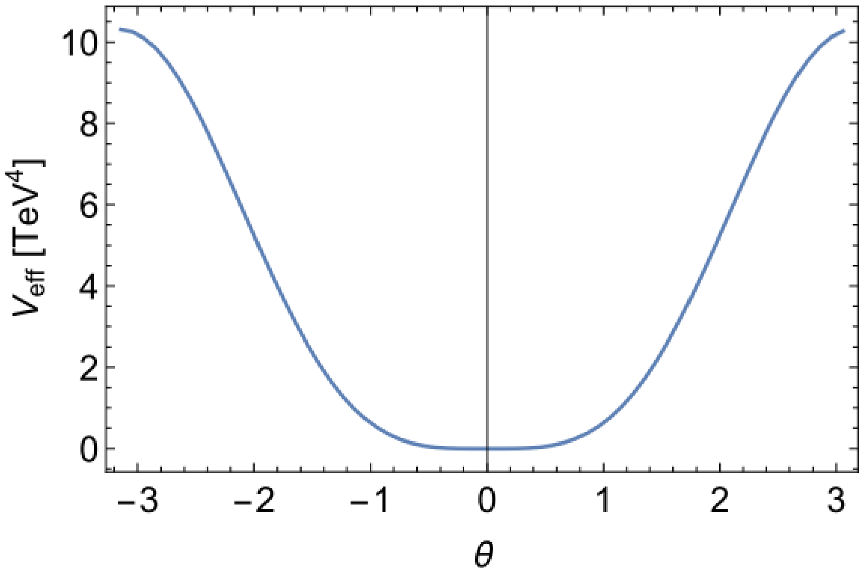
$$\begin{aligned}
Q_F^{(1)}(q) &= \frac{1}{2\hat{S}_L(q;c_F)\hat{S}_R(q;c_F)+1}, \\
Q_F^{(2)}(q) &= 0.
\end{aligned}$$

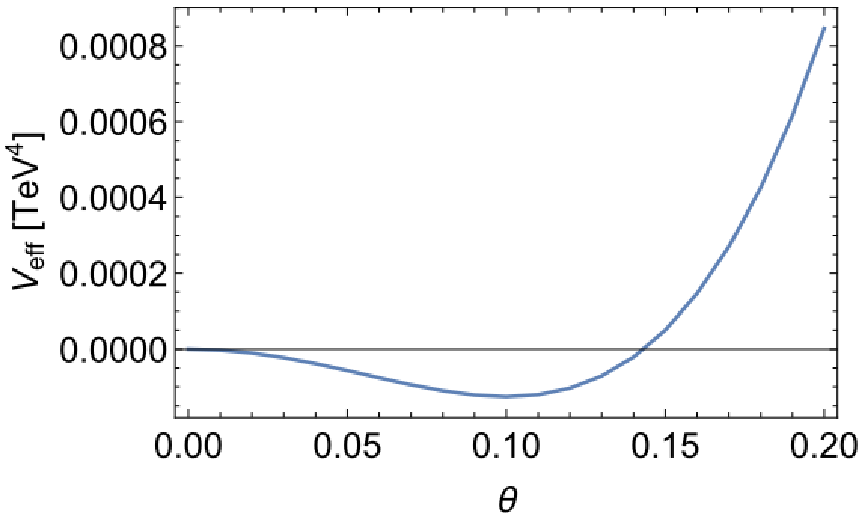
Effective potential



	Positive	Negative
π	Gauge boson	Dark Fermion(vector)
2π	Dark Fermion(spinor)	Top quark

Potential minimum





Parameters

n_N: number of $\Psi^{\pm\gamma}_{(\mathbf{1},\mathbf{5})}$

n_F: number of Ψ^{β}_{F}

c_V: bulk mass of $\Psi^{\pm\gamma}_{(\mathbf{1},\mathbf{5})}$

C_F: bulk mass of Ψ^{β}_{F}

m_V: pseudo-Dirac bulk mass of $\Psi^{\pm\gamma}_{(\mathbf{1},\mathbf{5})}$

Parameters

n_N, n_F, c_V, C_F, m_V

Free parameters

$$\left.\frac{dV_{\text{eff}}}{d\theta}\right|_{\theta=\theta_H} = 0$$

$$m_H = 125.1\text{GeV}.$$

Asymmetry

LHC	ILC
Proton-Proton collision - Composite particle - Background	Electron-Positron collision - Elementary particle - Clean signal
High energy - Peak (mass) Search	Low energy - Asymmetry search

GHU : Heavy particle and Large asymmetry

Asymmetries

$P_{e^\pm} = +1$ corresponds to purely right-handed $e^\pm$

$$\Delta_{d\sigma}^{f\bar{f}}(P_{e^-}, P_{e^+}, \cos\theta) \equiv \frac{\frac{d\sigma_{\mathrm{GHU}}^{f\bar{f}}}{d\cos\theta}(P_{e^-}, P_{e^+}, \cos\theta)}{\frac{d\sigma_{\mathrm{SM}}^{f\bar{f}}}{d\cos\theta}(P_{e^-}, P_{e^+}, \cos\theta)} - 1$$

$$A_{LR}^{f\bar{f}}(P_{e^-}, P_{e^+}, \cos\theta) = \frac{\sigma^{f\bar{f}}(P_{e^-}, P_{e^+}, \cos\theta) - \sigma^{f\bar{f}}(-P_{e^-}, -P_{e^+}, \cos\theta)}{\sigma^{f\bar{f}}(P_{e^-}, P_{e^+}, \cos\theta) + \sigma^{f\bar{f}}(-P_{e^-}, -P_{e^+}, \cos\theta)}$$

$$A_{FB}^{f\bar{f}}(P_{e^-}, P_{e^+}) = \frac{\sigma_F^{f\bar{f}}(P_{e^-}, P_{e^+}) - \sigma_B^{f\bar{f}}(P_{e^-}, P_{e^+})}{\sigma_F^{f\bar{f}}(P_{e^-}, P_{e^+}) + \sigma_B^{f\bar{f}}(P_{e^-}, P_{e^+})},$$

$$\sigma_F^{f\bar{f}}(P_{e^-}, P_{e^+}) = \sigma^{f\bar{f}}(P_{e^-}, P_{e^+}, [0, +\cos\theta_{\max}]),$$

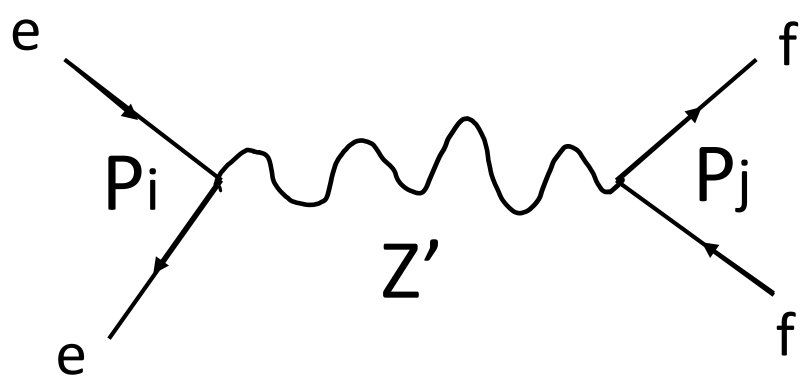
$$\sigma_B^{f\bar{f}}(P_{e^-}, P_{e^+}) = \sigma^{f\bar{f}}(P_{e^-}, P_{e^+}, [-\cos\theta_{\max}, 0]),$$

Asymmetries

$$\frac{d\sigma_{LR}^{f\bar{f}}}{d\cos\theta}(\cos\theta) = \frac{\beta s}{32\pi}\left\{[1+\beta^2\cos^2\theta]\{|Q_{e_Lf_L}|^2+|Q_{e_Lf_R}|^2\}+2\beta\cos\theta\{|Q_{e_Lf_L}|^2-|Q_{e_Lf_R}|^2\}+8\frac{m_f^2}{s}[\mathrm{Re}(Q_{e_Lf_L}Q^*_{e_Lf_R})]\right\},$$

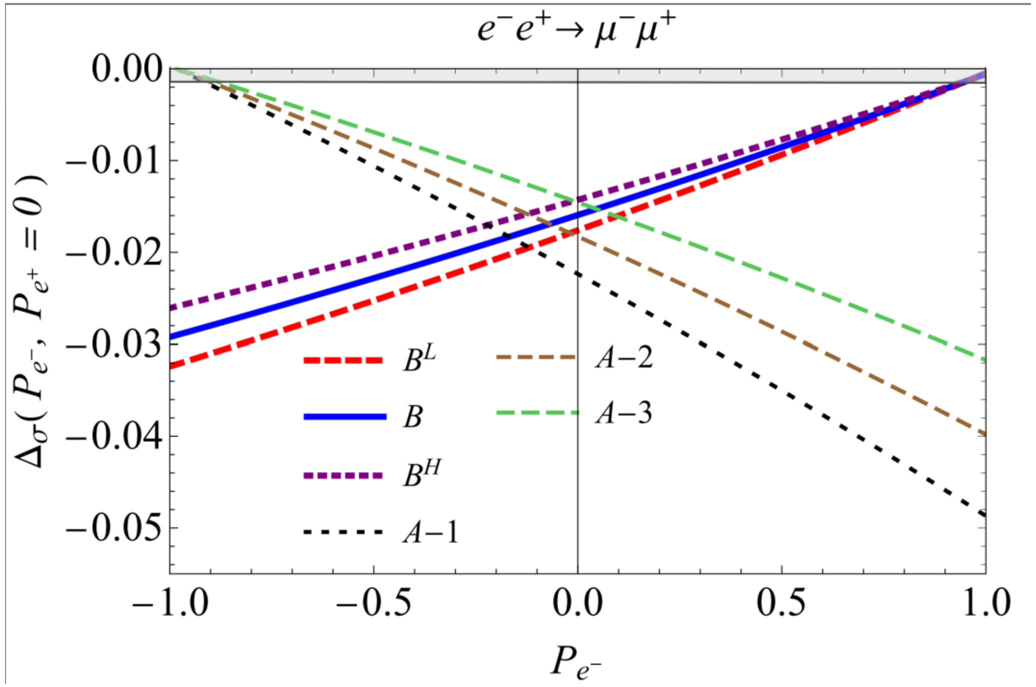
$$\frac{d\sigma_{RL}^{f\bar{f}}}{d\cos\theta}(\cos\theta) = \frac{\beta s}{32\pi}\left\{[1+\beta^2\cos^2\theta]\{|Q_{e_Rf_R}|^2+|Q_{e_Rf_L}|^2\}+2\beta\cos\theta\{|Q_{e_Rf_R}|^2-|Q_{e_Rf_L}|^2\}+8\frac{m_f^2}{s}[\mathrm{Re}(Q_{e_Rf_L}Q^*_{e_Rf_R})]\right\},$$

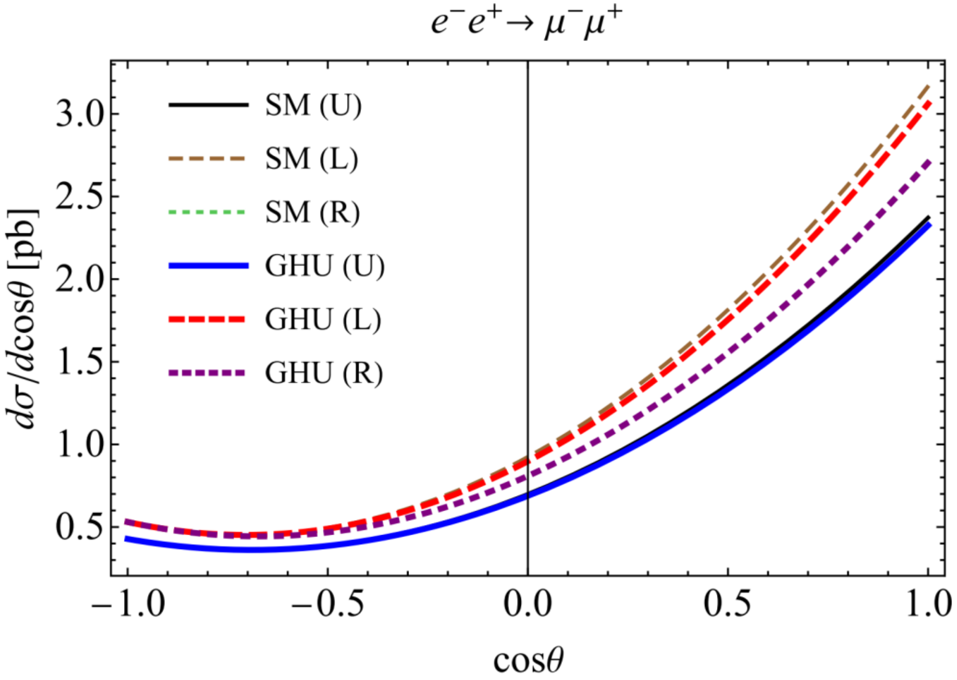
$Q_{e_if_j}$ =



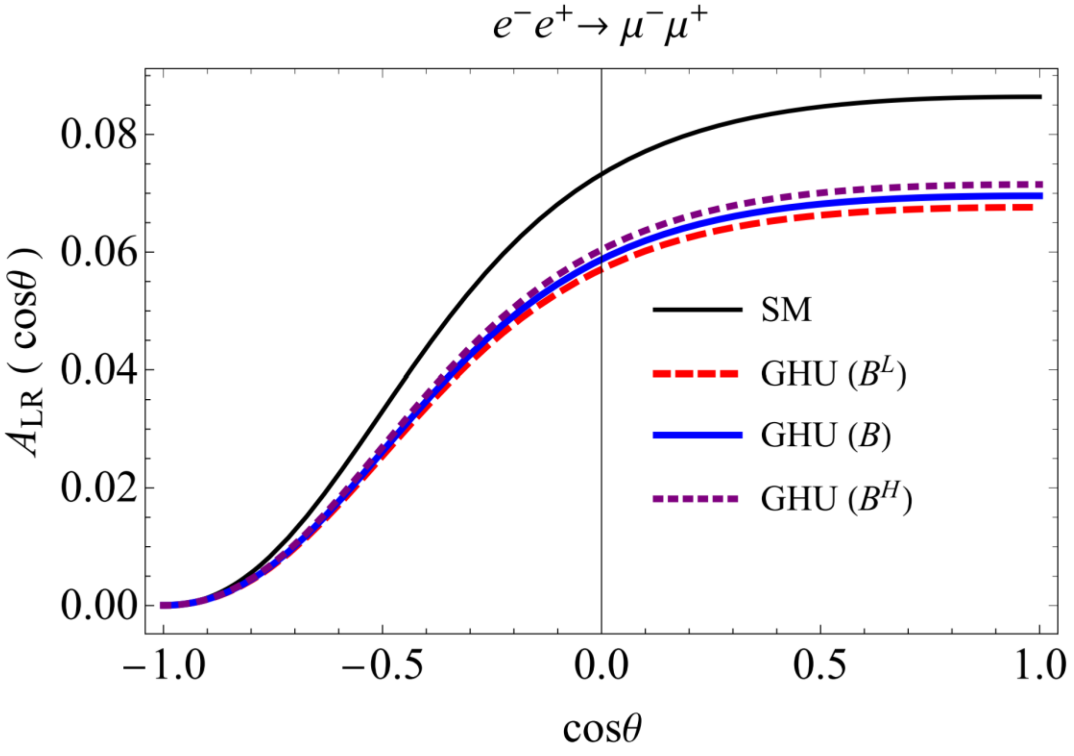
$$A_{LR,FB}^{f\bar{f}}(\cos\theta) = \frac{\left[\sigma_{LR}^{f\bar{f}}(\cos\theta)-\sigma_{RL}^{f\bar{f}}(\cos\theta)\right]-\left[\sigma_{LR}^{f\bar{f}}(-\cos\theta)-\sigma_{RL}^{f\bar{f}}(-\cos\theta)\right]}{\left[\sigma_{LR}^{f\bar{f}}(\cos\theta)+\sigma_{RL}^{f\bar{f}}(\cos\theta)\right]+\left[\sigma_{LR}^{f\bar{f}}(-\cos\theta)+\sigma_{RL}^{f\bar{f}}(-\cos\theta)\right]}$$

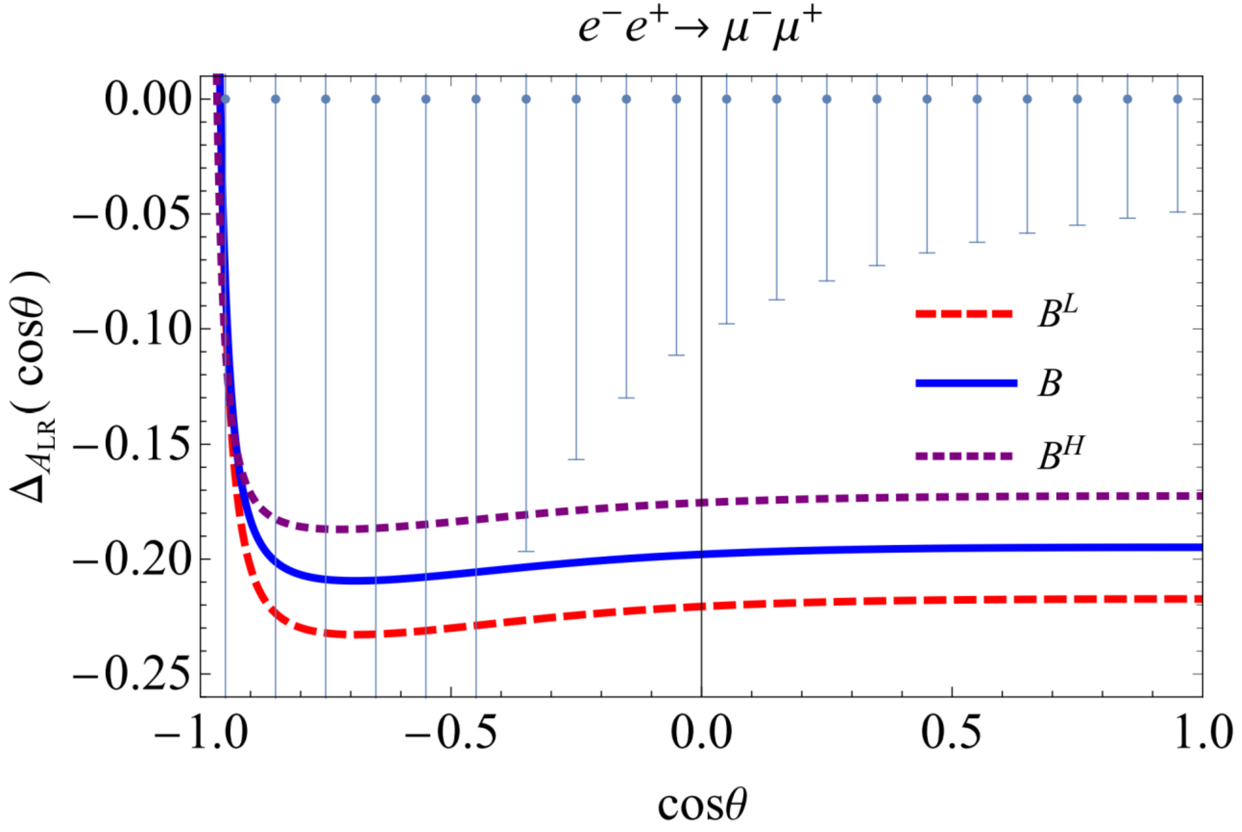
Cross section





Left-Right Asymmetry

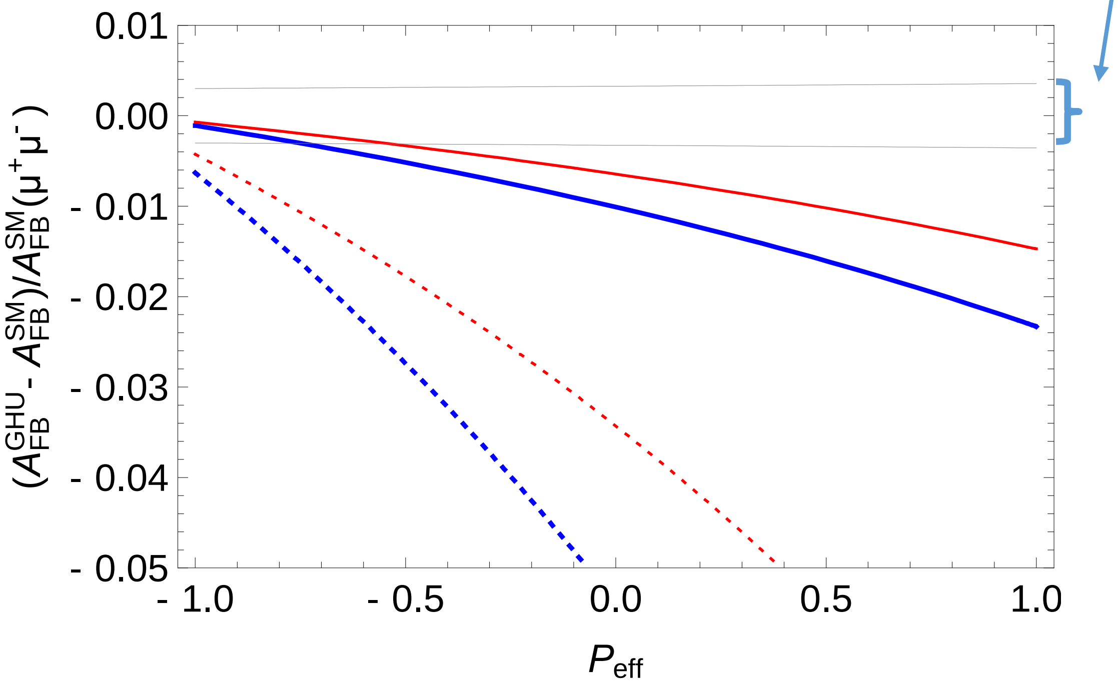




Forward-Backward Asymmetry

A model

Statistical uncertainty



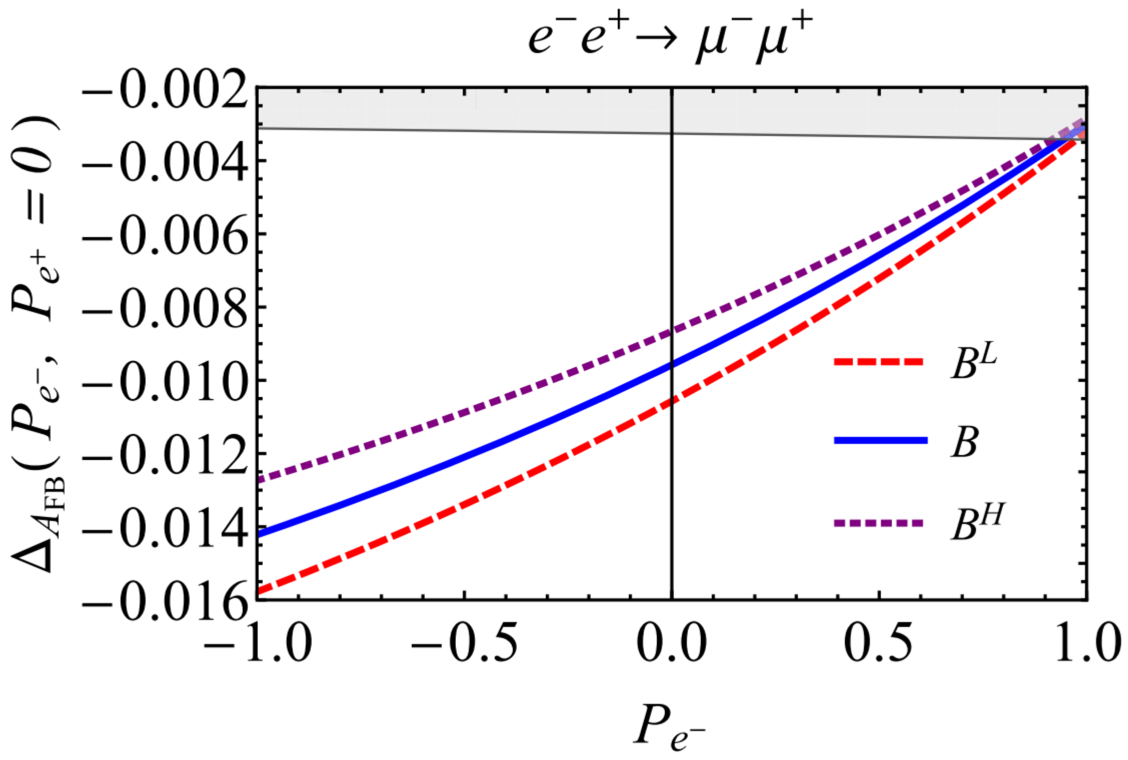
Solid: 250GeV

Dotted: 500GeV

Blue: θ_H=0.0917

Red: θ_H= 0.0737

B model



Left-Right Forward-Backward Asymmetry