Explanation of W boson mass anomaly and flavor physics in a model with extra U(1) gauge symmetry

Takaaki Nomura (Sichuan Univ. [四川大学])

Based on K.Nagao, TN, H.Okada, arXiv: 2206.15256

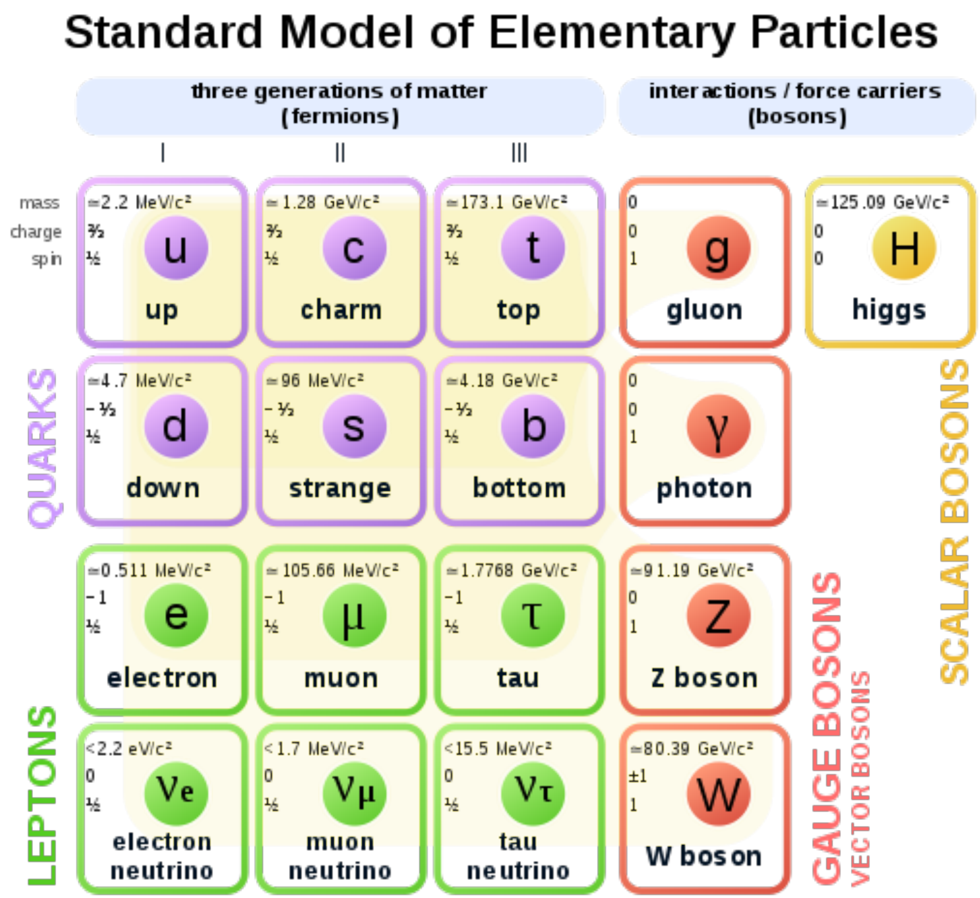
2022-10-25 International CEPC workshop 2022

Out line of the talk

1. Introduction
2. A model with leoptophobic U(1)
3. Phenomenology of the model
4. Summary

1. Introduction

The standard model (SM) of particle physics is successful



The SM is based on gauge symmetry $SU(3)_c \times SU(2)_L \times U(1)_Y$

However there should be beyond the SM (BSM) physics

1. Introduction

There are some experimental anomalies that can be hints of new physics

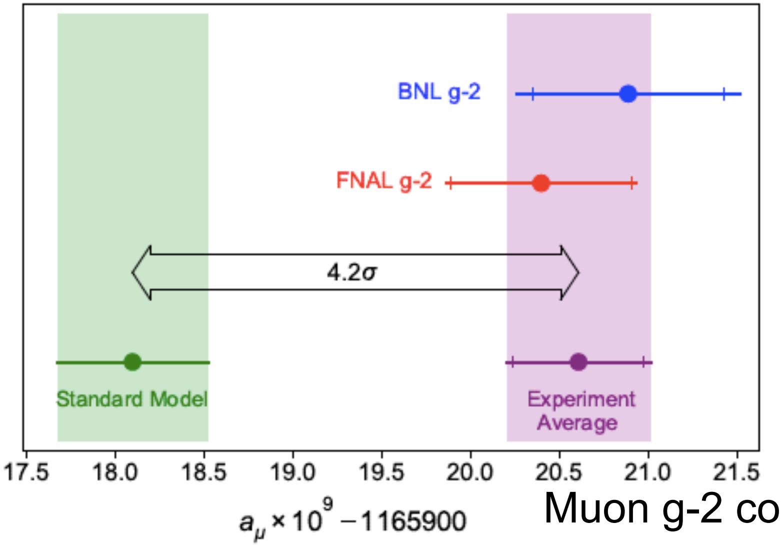
CDF II W bosom mass

$$m_W = (80.433 \pm 0.0064_{\rm stat} \pm 0.0069_{\rm syst})\ {\rm GeV}$$ (CDFII corraboration, 2022)

SM prediction: 80.357 ± 0.006 GeV (PDG)

CDF II W boson mass is deviated from the SM prediction by 7σ

Muon anomalous dipole magnetic moment (muon g-2)



$$a_\mu^{BNL} = (11659208.9 \pm 5.4 \pm 3.3) \times 10^{-10}$$

$$a_\mu^{FNAL} = (11659204.0 \pm 5.1 \pm 1.9) \times 10^{-10}$$

$$\Delta a_\mu = a_\mu^{\exp} - a_\mu^{SM} = (25.1 \pm 5.9) \times 10^{-10}$$

Combined result (4.2σ deviation)

Muon g-2 collaboration, PRL126 (2021)

They can be explained by extending the SM

One simple extension of the SM

⇨ A model with extra U(1) gauge symmetry

◆ The SM is based on gauge symmetry

⇨ **The BSM would be also described by gauge symmetry**

◆ It restricts interactions :
good for phenomenological model building

- Controlling interactions by symmetry
- It provide new neutral gauge boson: **Z' boson**
- U(1) breaking scalar VEV → Higgs physics
- Explaining experimental anomalies: **muon g-2**, **W boson mass**
- Etc.

An extra U(1) would appear from higher scale

- From grand unified theory (GUT)

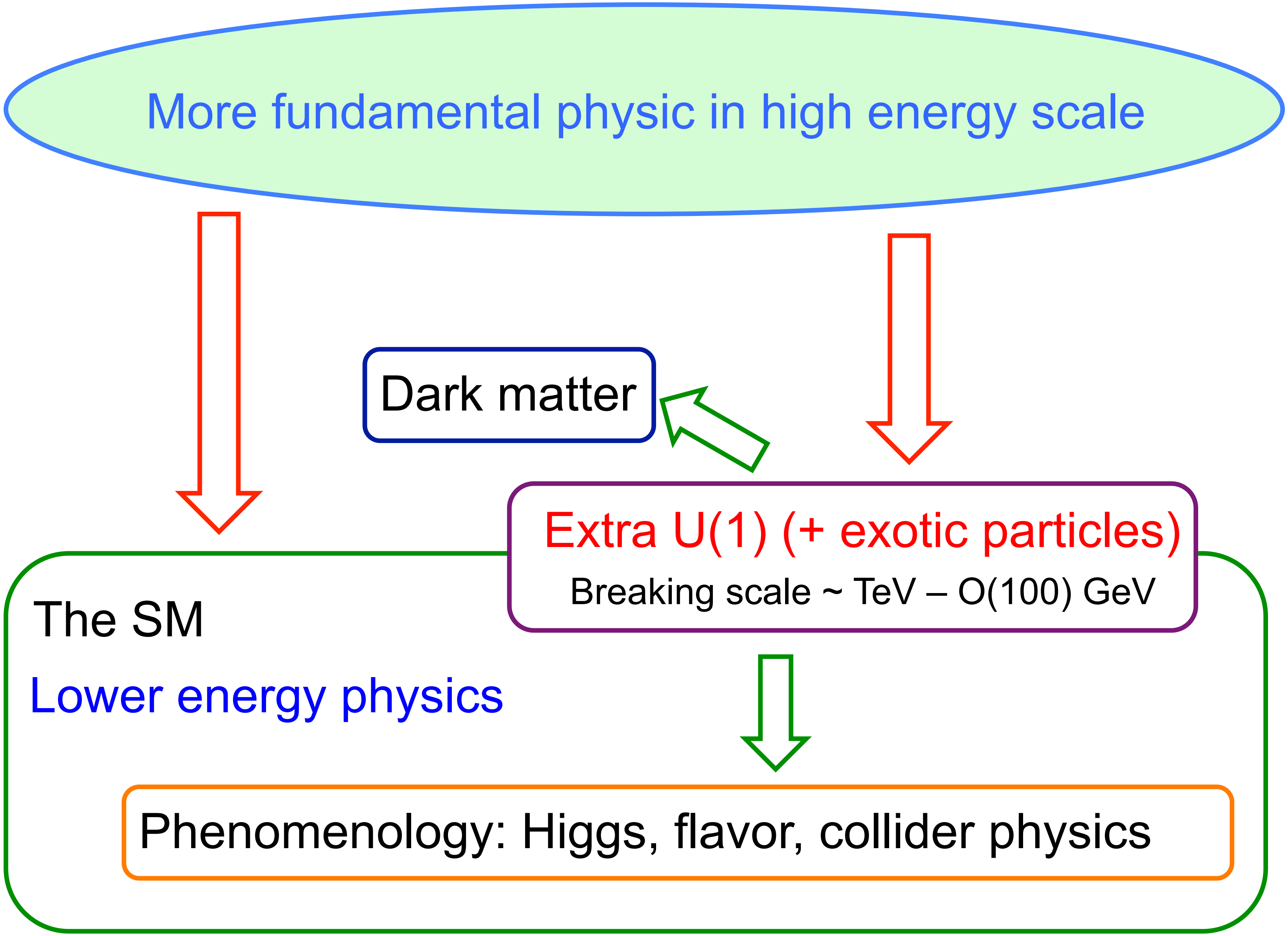
$$SO(10) \supset SU(3) \times SU(2)_L \times SU(2)_R \times U(1)_{B-L} \supset SU(3) \times SU(2)_L \times U(1)_R \times U(1)_{B-L}$$

$$E_6 \supset SO(10) \times U(1)_\psi \supset SU(5) \times U(1)_\psi \times U(1)_\chi$$

- From other gauge extended theories
- From string theory
- Etc.

In ~TeV scale we may just see the SM + extra U(1) gauge symmetry

1. Introduction



Phenomenology of a new model: Z'

Z' boson ⟺ SM particles

Interaction

Experimentally tested and models should satisfy constraints

Models can be excluded/confirmed in future experiments

For heavy Z' case (TeV scale or higher)

- Direct test at collider experiments: LHC, CEPC, ILC, etc.
- Indirect test by scattering process:
- Constraint from flavor physics: e.g. flavor dependent Z'

For light Z' case (less than GeV scale)

- It can be tested by low energy experiments
- Direct production at lower energy collider: like Bell II experiment etc.

Phenomenology a new model: exotic signals

In a model we often have exotic particles

⇩

Some exotic signatures can be induced

For example, to explain muon g-2 we may need lepton flavor dependent interactions

⇨ Flavor violating signal can be induced

Tera-Z factory at CEPC is good opportunity to test such signal If flavor violation affect Z-interactions (10^{12} Z production)

In this talk, I would like to show such an example

Out line of the talk

1. Introduction
2. A model with leoptophobic U(1)
3. Phenomenology of the model
4. Summary

Structure of the model

(K.Nagao, TN, H.Okada, arXiv: 2206.15256)

	Q_L^a	u_R^a	d_R^a	L_L^a	e_R^a	N_R^a	N_L^a	E_L^a	E_R^a	H	φ_1	φ_2
$SU(3)_C$	**3**	**3**	**3**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**	**1**
$SU(2)_L$	**2**	**1**	**1**	**2**	**1**	**1**	**1**	**1**	**1**	**2**	**1**	**1**
$U(1)_Y$	$\frac{1}{6}$	$\frac{2}{3}$	$-\frac{1}{3}$	$-\frac{1}{2}$	-1	0	0	-1	-1	$\frac{1}{2}$	0	0
$U(1)_R$	0	1	-1	0	0	1	0	0	-1	1	-1	$-\frac{1}{2}$

New fermions **New scalars**

- Gauge anomalies are canceled between the SM fermion and new ones
- Gauge symmetry is broken by scalar VEVs
- SM leptons are not charged under new U(1)
- We don't have Yukawa interaction $\bar{L}_L e_R H$

Lagrangian of the model

$$-\mathcal{L}_Y = (y_\ell)_{ab}\bar{L}^a_L H E^b_R + (y_E)_{aa}\varphi_1 \bar{E}^a_L E^a_R + (m_{Ee})_{ab}\bar{E}^a_L e^b_R + (y_D)_{ab}\bar{L}^a_L \tilde{H} N^b_R + (y_N)_{aa}\varphi_1 \bar{N}^a_L N^a_R + (M_{N_L})_{ab}\bar{N}^a_L N^{cb}_L + \text{h.c.},$$

$$\mathcal{V} = \mu_1^2|\varphi_1|^2 - \mu_2^2|\varphi_2|^2 - \mu_H^2|H|^2 + \lambda_H|H|^4 + \lambda_1|\varphi_1|^4 + \lambda_2|\varphi_2|^4 - \mu_3(\varphi_1^*\varphi_2\varphi_2 + h.c.) + \lambda_3|\varphi_1|^2|H|^2 + \lambda_4|\varphi_2|^2|H|^2 + \lambda_5|\varphi_1|^2|\varphi_2|^2.$$

Scalar fields

$$H = \begin{bmatrix} w^+ \\ \frac{v+r+iz}{\sqrt{2}} \end{bmatrix}, \quad \varphi_{1,2} = \frac{v'_{1,2} + r'_{1,2} + iz'_{1,2}}{\sqrt{2}},$$

- Neutral scalar can mix: we consider r-r'$_1$ mixing
- We take mixing angle θ to be free parameter
- SM Higgs mass: m_h, heavy Higgs mass m_H

$$(r, r'_1)^T = O_R(h, H)^T, \quad O_R = \begin{bmatrix} c_\theta & s_\theta \\ -s_\theta & c_\theta \end{bmatrix}$$

Neutral gauge boson mass

New U(1) and electroweak symmetry breaking by scalar VEVs

⇩

Z-Z' mass matrix after symmetry breaking

$$m^2_{Z_{SM}Z'} \simeq \frac{1}{4}\begin{bmatrix} (g_1^2+g_2^2)v^2 & -2\sqrt{g_1^2+g_2^2}g'v^2 \\ -2\sqrt{g_1^2+g_2^2}g'v^2 & 4g'^2(v^2+v_2'^2) \end{bmatrix} = m^2_{Z'}\begin{bmatrix} \epsilon_1^2 & -\epsilon_1\epsilon_2 \\ -\epsilon_1\epsilon_2 & 1+\epsilon_2^2 \end{bmatrix}$$

⇩ Diagonalization: $V m^2_{Z_{SM}Z'} V^T \equiv \mathrm{Diag}(m_Z^2, m^2_{Z_R})$

$$m_Z^2 \approx m^2_{Z_{SM}}(1-\epsilon_2^2),\ m^2_{Z_R} \approx m^2_{Z'}(1+\epsilon_1^2\epsilon_2^2),$$

$$V \approx \begin{bmatrix} c_Z & s_Z \\ -s_Z & c_Z \end{bmatrix}, \quad \theta_Z = \frac{1}{2}\tan^{-1}\left[\frac{2\epsilon_1\epsilon_2}{1+\epsilon_2^2-\epsilon_1^2}\right].$$

2. A model with leptophobic U(1)

Charged lepton mass

$$\begin{pmatrix} \bar{e}_L \\ \bar{E}_L \end{pmatrix}^T \mathcal{M}_{\mathcal{E}} \begin{pmatrix} e_R \\ E_R \end{pmatrix} = \begin{pmatrix} \bar{e}_L \\ \bar{E}_L \end{pmatrix}^T \begin{bmatrix} 0 & m_{eE} \\ m_{Ee} & M_E \end{bmatrix} \begin{pmatrix} e_R \\ E_R \end{pmatrix},$$

$$\mathcal{M}_{\mathcal{E}} \mathcal{M}_{\mathcal{E}}^\dagger = \begin{bmatrix} m_{eE} m_{eE}^\dagger & m_{eE} M_E \\ M_E m_{eE}^\dagger & M_E^2 + m_{Ee} M_{Ee}^\dagger \end{bmatrix}, \quad \mathcal{M}_{\mathcal{E}}^\dagger \mathcal{M}_{\mathcal{E}} = \begin{bmatrix} m_{Ee}^\dagger m_{Ee} & m_{Ee}^\dagger M_E \\ M_E m_{Ee} & M_E^2 + m_{eE}^\dagger m_{eE} \end{bmatrix}$$

$$m_{eE} \equiv y_\ell v/\sqrt{2},\ M_E \equiv y_E v'/\sqrt{2}.$$

SM chargedd lepton masses are obtained by diagonalizing the mass matrix

⇨ $(e_{L(R)}, E_{L(R)}) \to \underline{V_{L(R)}} \ell_{L(R)}$

Unitary matrix

The mixing between lepton and heavy lepton modifies gauge interaction

Modification of Z-lepton interactions

Due to lepton mixing, we obtain

$$\frac{g_2}{c_W}\left[\left(-\frac{1}{2}\sum_{a=1}^{3} V^{\dagger}_{L_{ia}} V_{L_{aj}} + s_W^2 \delta_{ij}\right)\bar{\ell}_{L_i}\gamma^{\mu}\ell_{L_j} + s_W^2 \delta_{ij}\bar{\ell}_{R_i}\gamma^{\mu}\ell_{R_j}\right] Z_{\mu}$$

Z-interaction associated with left-handed charged lepton is modified

Note: we have flavor violating interaction (lepton FCNC)

⇨ Lepton flavor violating Z boson decay

It would be tested by Z-factory : Tera-Z/CEPC

Neutrino mass in the model

In our model neutrino mass can be obtain via Yukawa terms

$$(y_D)_{ab}\bar{L}^a_L \tilde{H} N^b_R + (y_N)_{aa}\varphi_1 \bar{N}^a_L N^a_R + (M_{N_L})_{ab}\bar{N}^a_L N^{cb}_L + \text{h.c.}$$

⇩ After spontaneous symmetry breaking, mass matrix is induced

$$M_N = \begin{bmatrix} 0 & m_D & 0 \\ m_D^T & 0 & M \\ 0 & M & M_{N_L} \end{bmatrix}$$

In the basis of (ν^c_L, N_R, N^c_L)

$m_D \equiv v y_D/\sqrt{2}$ and $M \equiv y_N v'_1/\sqrt{2}$.

⇨ $$m_\nu \simeq m_D M^{-1} M_{N_L} (M^T)^{-1} m_D^T.$$

Inverse seesaw mechanism is realized

Out line of the talk

1. Introduction
2. A model with leoptophobic U(1)
3. Phenomenology of the model
4. Summary

Explanation of W mass anomaly by Z-Z' mixing

Z-Z' mixing modify relation between Z and W masses

⇨ Shift of T parameter

It can be interpreted as shift of W boson mass

⇩

CDF II W boson mass can be fitted

Here we consider fitting in terms of T parameter:

$$0.09 \leq \Delta T \leq 0.14.$$

The range of new physics contribution to T for fitting data including CDF II

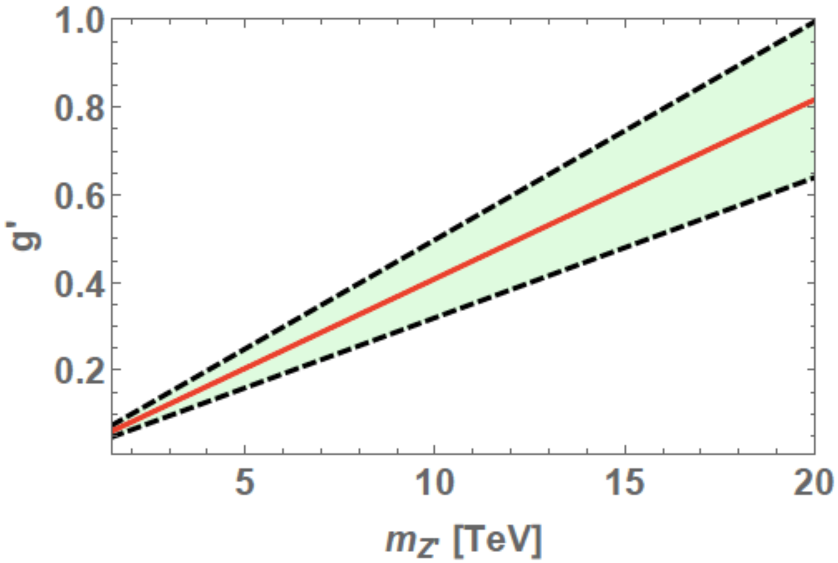
Explanation of W mass anomaly by Z-Z' mixing

We obtain modification of T-parameter

$$\Delta T = \frac{1}{\alpha_{\rm em}} \frac{m_{Z_{SM}}^2 - m_Z^2}{m_{Z_{SM}}^2} \simeq \frac{\epsilon_2^2}{\alpha_{\rm em}}, \quad \Rightarrow \quad \Delta T \simeq \frac{v^2}{\alpha_{\rm em}} \frac{g'^2}{m_{Z'}^2} = \frac{4 m_W^2}{g_2^2 \alpha_{\rm em}} \frac{g'^2}{m_{Z'}^2}$$

To resolve W bosom mass anomaly

$$0.09 \leq \Delta T \leq 0.14. \quad \Rightarrow \quad 20 \text{ TeV} \lesssim \frac{m_{Z'}}{g'} (= v_2') \lesssim 31 \text{ TeV}$$



Constraints from Z→ll decay

Mixing between lepton and heavy lepton modify Z interaction

$$\frac{g_2}{c_W}\left[\left(-\frac{1}{2}\sum_{a=1}^{3}V^{\dagger}_{L_{ia}}V_{L_{aj}}+s_W^2\delta_{ij}\right)\bar{\ell}_{L_i}\gamma^{\mu}\ell_{L_j}+s_W^2\delta_{ij}\bar{\ell}_{R_i}\gamma^{\mu}\ell_{R_j}\right]Z_{\mu}$$

Decay widths of Z to charged lepton pair is

$$\Gamma(Z\to\ell_i\bar{\ell}_j)\simeq\frac{g_2^2}{24\pi c_W^2}m_Z\left[\left|-\frac{1}{2}\sum_{a=1}^{3}V^{\dagger}_{L_{ia}}V_{L_{aj}}+s_W^2\delta_{ij}\right|^2+s_W^4\delta_{ij}\right]$$

BRs are deviated from the SM

$$\Delta\mathrm{BR}(Z\to\ell_i\bar{\ell}_j)=\frac{\Gamma(Z\to\ell_i\bar{\ell}_j)-\Gamma(Z\to\ell_i\bar{\ell}_j)_{SM}}{\Gamma_Z^{\mathrm{tot}}}\quad \text{for i = j,}$$

$$\mathrm{BR}(Z\to\ell_i\bar{\ell}_j)=\frac{\Gamma(Z\to\ell_i\bar{\ell}_j)}{\Gamma_Z^{\mathrm{tot}}}\quad \text{for i}\neq\text{j,}$$

LFV Z decay

Muon g-2 and LFV processes

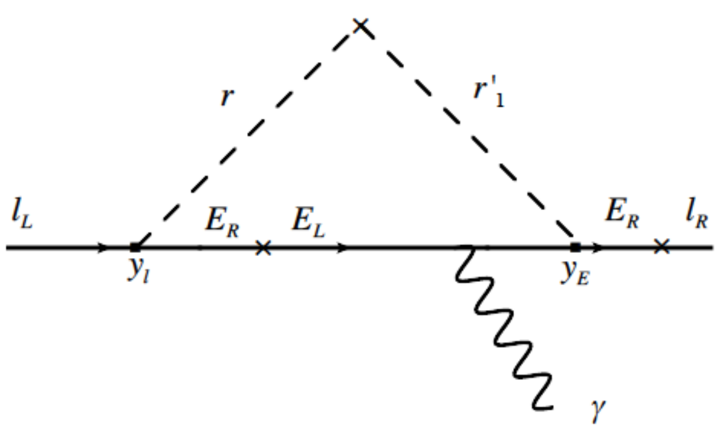
Relevant Lagrangian in mass basis

$$\mathcal{L}_{LFV} = (Y_{\alpha\beta} c_\theta - \tilde{Y}_{\alpha\beta} s_\theta) h \bar{\ell}_\alpha P_R \ell_\beta + (Y_{\alpha\beta} s_\theta + \tilde{Y}_{\alpha\beta} c_\theta) H \bar{\ell}_\alpha P_R \ell_\beta + h.c.,$$

$$Y_{\alpha\beta} \equiv \frac{1}{\sqrt{2}} \sum_{a=1,2,3} \sum_{b=1,2,3} (V_L^\dagger)_{\alpha,a} (y_\ell)_{ab} (V_R)_{b+3,\beta},$$

$$\tilde{Y}_{\alpha\beta} \equiv \frac{1}{\sqrt{2}} \sum_{a=1,2,3} \sum_{b=1,2,3} (V_L^\dagger)_{\alpha,a+3} (y_E)_{aa} (V_R)_{a+3,\beta}.$$

One-loop diagram inducing muon g-2 and LFVs $l \to l'\gamma$



Dominant contribution

Muon g-2 and LFV processes

Analytic formula

$$\mathrm{BR}(\ell_\beta \to \ell_\alpha \gamma) \simeq \frac{12\pi^2 C_{\beta\alpha}}{(4\pi)^4 m_{\ell_\beta}^2 G_F^2}(|a_{L_{\alpha\beta}}|^2 + |a_{R_{\alpha\beta}}|^2),$$

$$\Delta a_\mu \simeq -\frac{m_\mu}{(4\pi)^2}(a_{L_{22}} + a_{R_{22}}),$$

$$a_{L_{\alpha\beta}} \approx -\frac{1}{4}(Y^\dagger_{\alpha\rho} c_\theta - \tilde{Y}^\dagger_{\alpha\rho} s_\theta) D_{E_\rho} (Y^\dagger_{\rho\beta} c_\theta - \tilde{Y}^\dagger_{\rho\beta} s_\theta) F(h_1, D_{E_\rho})$$

$$-\frac{1}{4}(Y^\dagger_{\alpha\rho} s_\theta + \tilde{Y}^\dagger_{\alpha\rho} c_\theta) D_{E_\rho} (Y^\dagger_{\rho\beta} s_\theta + \tilde{Y}^\dagger_{\rho\beta} c_\theta) F(h_2, D_{E_\rho}),$$

$$a_{R_{\alpha\beta}} \approx -\frac{1}{4}(Y_{\alpha\rho} c_\theta - \tilde{Y}_{\alpha\rho} s_\theta) D_{E_\rho} (Y_{\rho\beta} c_\theta - \tilde{Y}_{\rho\beta} s_\theta) F(h_1, D_{E_\rho})$$

$$-\frac{1}{4}(Y_{\alpha\rho} s_\theta + \tilde{Y}_{\alpha\rho} c_\theta) D_{E_\rho} (Y_{\rho\beta} s_\theta + \tilde{Y}_{\rho\beta} c_\theta) F(h_2, D_{E_\rho}),$$

$$F(m_{h_i}, D_{E_\rho}) \approx \frac{m_{h_i}^4 - 4m_{h_i}^2 D_{E_\rho}^2 + 3D_{E_\rho}^4 - 2m_{h_i}^2(m_{h_i}^2 - 2D_{E_\rho}^2)\ln\left[\frac{m_{h_i}^2}{D_{E_\rho}^2}\right]}{(m_{h_i}^2 - D_{E_\rho}^2)^3},$$

$$C_{21} \approx 1,\ C_{31} \approx 0.1784,\ C_{32} \approx 0.1736,\ h_1 \equiv h,\ h_2 \equiv H$$

Numerical analysis

Free parameters: $\{(y_\ell)_{ab}, (y_E)_{aa}, (m_{Ee})_{ab}, \sin\theta, m_H\}$

⇨ Searching solution to explain muon g-2

scanning

Constraints:

$$\mathrm{BR}(\mu \to e\gamma) \leq 4.2 \times 10^{-13}, \quad \mathrm{BR}(\tau \to \mu\gamma) \leq 4.4 \times 10^{-8}, \quad \mathrm{BR}(\tau \to e\gamma) \leq 3.3 \times 10^{-8}$$

$$\Delta\mathrm{BR}(Z \to e^\pm e^\mp) < \pm 4.2 \times 10^{-5}\,, \ \Delta\mathrm{BR}(Z \to \mu^\pm \mu^\mp) < \pm 6.6 \times 10^{-5}\,,$$

$$\Delta\mathrm{BR}(Z \to \tau^\pm \tau^\mp) < \pm 8.3 \times 10^{-5}\,, \ \mathrm{BR}(Z \to e^\pm \mu^\mp) < 7.5 \times 10^{-7}\,,$$

$$\mathrm{BR}(Z \to e^\pm \tau^\mp) < 9.8 \times 10^{-6}\,, \ \mathrm{BR}(Z \to \mu^\pm \tau^\mp) < 1.2 \times 10^{-5}\,.$$

Benchmark point

Input	
v_1'/GeV	284
m_H/GeV	245
$\sin\theta$	0.250
$[(y_\ell)_{11}, (y_\ell)_{12}, (y_\ell)_{13}]$	$[-0.000512,\ 0.00520,\ 0.00236]$
$[(y_\ell)_{21}, (y_\ell)_{22}, (y_\ell)_{23}]$	$[-0.000105,\ 0.000624,\ 0.0643]$
$[(y_\ell)_{31}, (y_\ell)_{32}, (y_\ell)_{33}]$	$[0.000148,\ 0.0145,\ 0.0647]$
$[(m_{eE})_{11}, (m_{eE})_{12}, (m_{eE})_{13}]/\mathrm{GeV}$	$[0.674,\ 16.8,\ 5.92]$
$[(m_{eE})_{21}, (m_{eE})_{22}, (m_{eE})_{23}]/\mathrm{GeV}$	$[-16.2,\ -46.3,\ 22.3]$
$[(m_{eE})_{31}, (m_{eE})_{32}, (m_{eE})_{33}]/\mathrm{GeV}$	$[-12.2,\ 69.5,\ 19.8]$
$[(y_E)_{11}, (y_E)_{22}, (y_E)_{33}]$	$[-3.26,\ 3.43,\ -3.41]$

Output	
$[m_{E_1}, m_{E_2}, m_{E_3}]/\mathrm{GeV}$	$[655,\ 690,\ 694]$
Δa_μ	2.11×10^{-9}
$\mathrm{BR}(\mu\to e\gamma)$	3.59×10^{-13}
$\mathrm{BR}(\tau\to e\gamma)$	9.91×10^{-11}
$\mathrm{BR}(\tau\to \mu\gamma)$	2.22×10^{-8}
$\Delta\mathrm{BR}(Z\to e^\pm e^\mp)$	-1.55×10^{-9}
$\Delta\mathrm{BR}(Z\to \mu^\pm \mu^\mp)$	-6.11×10^{-7}
$\Delta\mathrm{BR}(Z\to \tau^\pm \tau^\mp)$	-3.82×10^{-5}
$\Delta\mathrm{BR}(Z\to e^\pm \mu^\mp)$	6.27×10^{-17}
$\Delta\mathrm{BR}(Z\to e^\pm \tau^\mp)$	3.83×10^{-14}
$\Delta\mathrm{BR}(Z\to \mu^\pm \tau^\mp)$	3.64×10^{-11}

- ❖ We can get sizable muon g-2 while satisfying LFV constraints

Z’ signature at the LHC

$$pp \to Z' \to \bar{E}E, jj, NN$$

Extra fermions decays into SM fermion + Higgs boson

$$E_a \to \ell_i h,$$
$$N_a \to \nu_i h, \nu_i Z, \ell_i W,$$

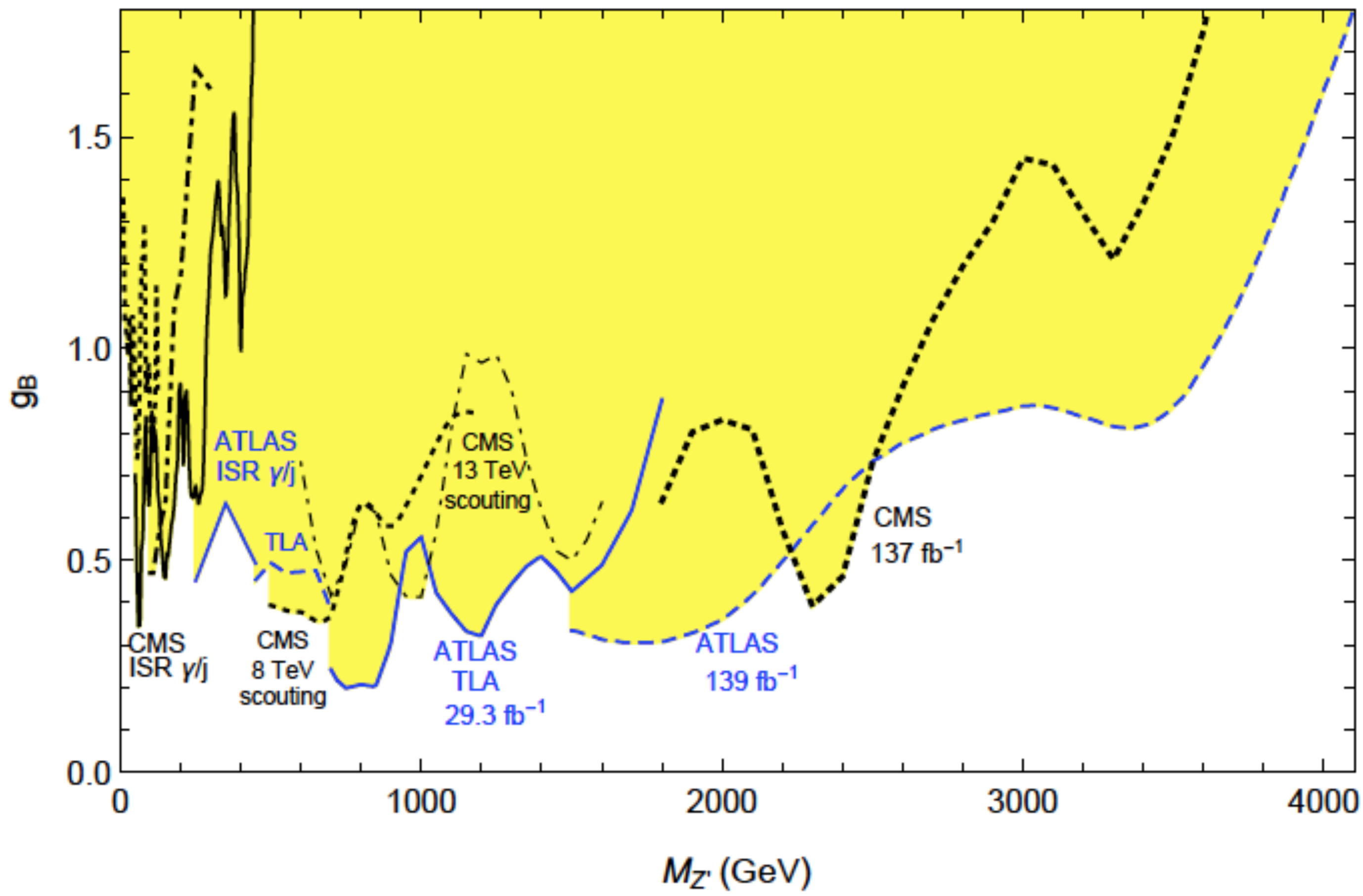
$$\Gamma(Z' \to f\bar{f}) = \frac{g'^2 N_c}{12\pi} m_{Z'} \sqrt{1 - \frac{4m_f^2}{m_{Z'}^2}} \left(1 - \frac{m_f^2}{m_{Z'}^2}\right)$$

Signal of Z’ at collider experiments:

⇨ Dijet, lepton+Higgs, letpton+W, Z/h + missing energy

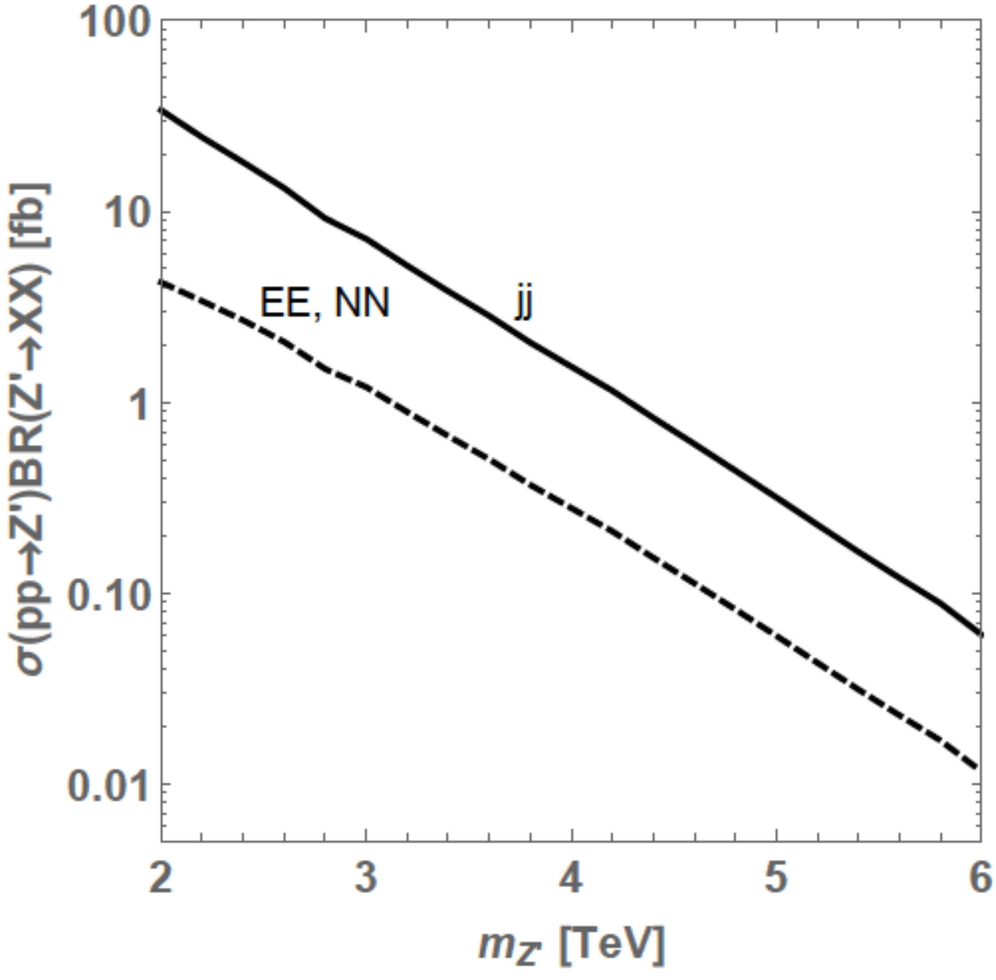
Current constraints (from dijet mode)

(Taken from B.A.Dobrescu, F.Yu, arXiv: 2112.05392)

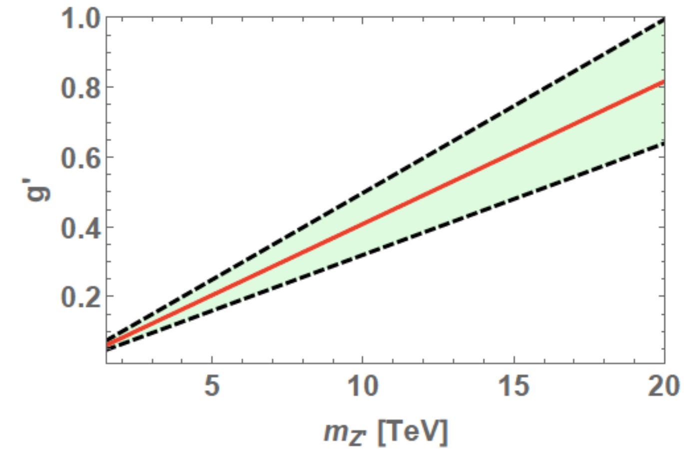


Our gauge coupling explaining W boson mass anomaly is below the constraint

Cross sections for Z’ signature at the LHC 14 TeV



Central value is used



✓ Gauge coupling is chosen to get best fit value of ΔT for W mass anomaly

Modification of leptonic Z boson decay

Predictions in our benchmark point

$\Delta\mathrm{BR}(Z \to e^{\pm}e^{\mp})$	-1.55×10^{-9}
$\Delta\mathrm{BR}(Z \to \mu^{\pm}\mu^{\mp})$	-6.11×10^{-7}
$\Delta\mathrm{BR}(Z \to \tau^{\pm}\tau^{\mp})$	-3.82×10^{-5}
$\Delta\mathrm{BR}(Z \to e^{\pm}\mu^{\mp})$	6.27×10^{-17}
$\Delta\mathrm{BR}(Z \to e^{\pm}\tau^{\mp})$	3.83×10^{-14}
$\Delta\mathrm{BR}(Z \to \mu^{\pm}\tau^{\mp})$	3.64×10^{-11}

Prospect of sensitivity at tera-Z factory of CEPC (10^{12} Z)

$$\mathrm{BR}(Z \to \mu e)_{\mathrm{CEPC}} \lesssim 3 \times 10^{-9} \;\; [1/\sqrt{N} \text{ scaling}]\,,\; 7 \times 10^{-12} \;\; [1/N \text{ scaling}]\,,$$
$$\mathrm{BR}(Z \to \tau e)_{\mathrm{CEPC}} \lesssim 2 \times 10^{-8} \;\; [1/\sqrt{N} \text{ scaling}]\,,\; 4 \times 10^{-11} \;\; [1/N \text{ scaling}]\,,$$
$$\mathrm{BR}(Z \to \tau \mu)_{\mathrm{CEPC}} \lesssim 2 \times 10^{-8} \;\; [1/\sqrt{N} \text{ scaling}]\,,\; 5 \times 10^{-11} \;\; [1/N \text{ scaling}]\,,$$

(CEPC-CDR vol.2)

It would be possible to test τμ mode at tera-Z/CEPC

Also precision measurement of $\tau^{+}\tau^{-}$ could find a deviation

Summary

Extension of the SM with extra U(1) gauge symmetry

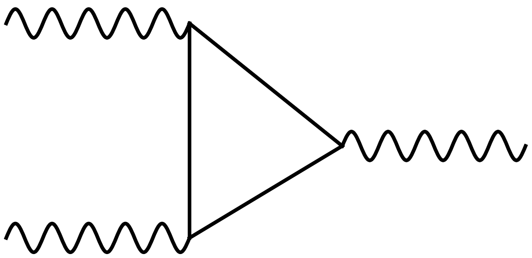
- ✓ Z' boson from extra U(1)
- ✓ Z' boson can induce interesting phenomenology
- ✓ Extra U(1) model may explain experimental anomalies

☐ A model with leptophobic U(1)

- ✓ Explaining muon g-2
- ✓ CDF W boson anomaly is also explained
- ✓ LFV and collider physics

Gauge anomaly free conditions

In constructing an extra $U(1)_X$ gauge symmetric model
charge assignment of fermion contents should be anomaly free



$$\sum_f \left(Tr[T_i T_j T_k]_R - Tr[T_i T_j T_k]_L \right) = 0$$

T_i : generator of gauge group

$[SU(3)_c]^2\, U(1)_X$ $[SU(2)_L]^2\, U(1)_X$

$[U(1)_Y]^2\, U(1)_X$ $[U(1)_X]^2\, U(1)_Y$

$[U(1)_X]^3$ $[\text{gravity}]^2\, U(1)_X$

Conditions in addition to the SM gauge anomaly free conditions