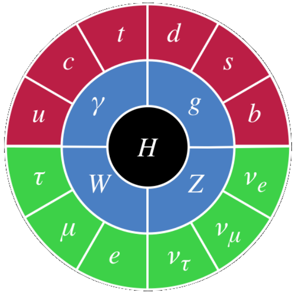
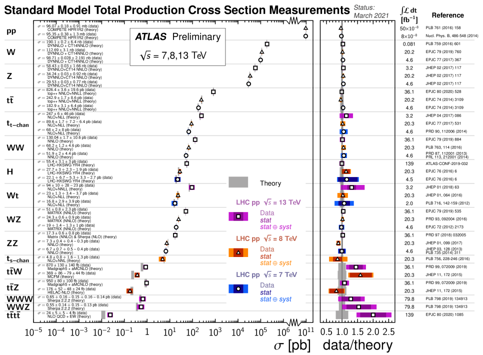
Connecting $(g-2)_\mu$ to neutrino mass in the extended neutrinophilic 2HDM

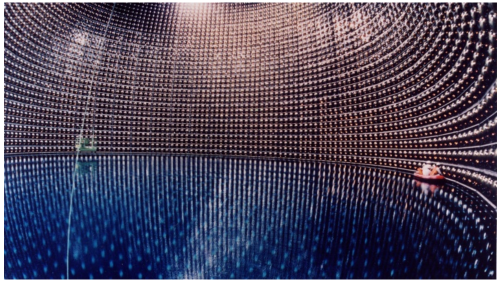
Adriano Cherchiglia, G. De Conto, C. C. Nishi

JHEP08(2023)170

Motivation

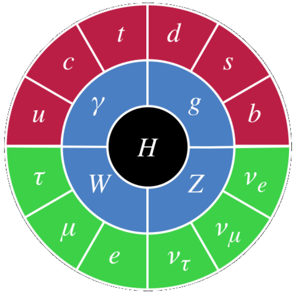


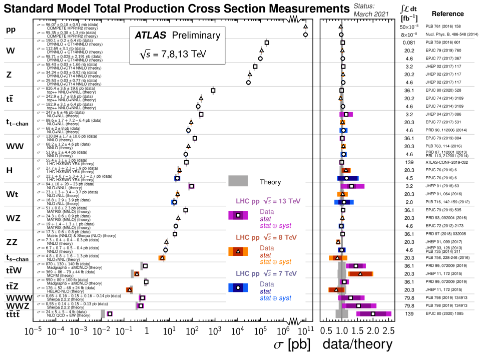


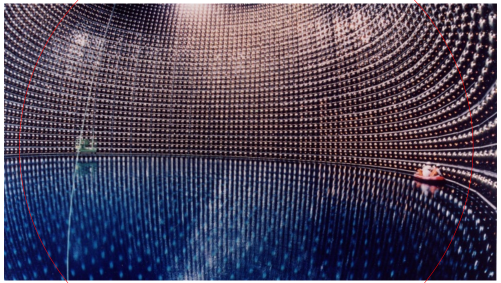


- Neutrino masses?
- Dark matter?
- Matter-antimatter asymmetry?
- .....

Motivation







- Neutrino masses?
- Dark matter?
- Matter-antimatter asymmetry?
- .....

Motivation

White paper theory evaluation (2020)


Physics Reports 887 (2020) 1–166

Contents lists available at ScienceDirect

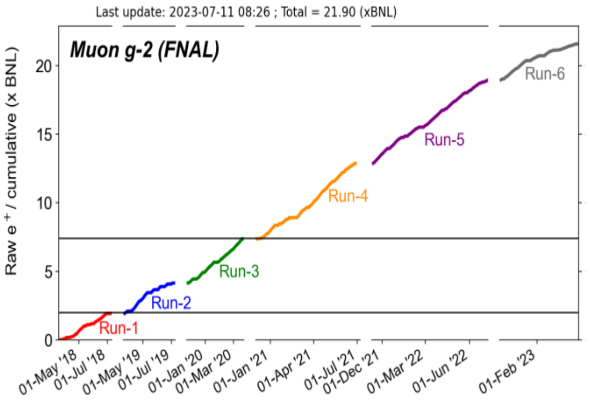
Physics Reports

journal homepage: www.elsevier.com/locate/physrep

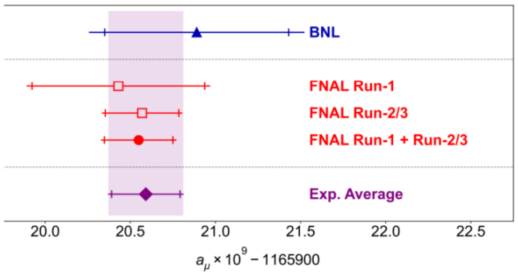
ELSEVIER

The anomalous magnetic moment of the muon in the Standard Model

T. Aoyama [1,2,3], N. Asmussen [4], M. Benayoun [5], J. Bijnens [6], T. Blum [7,8],

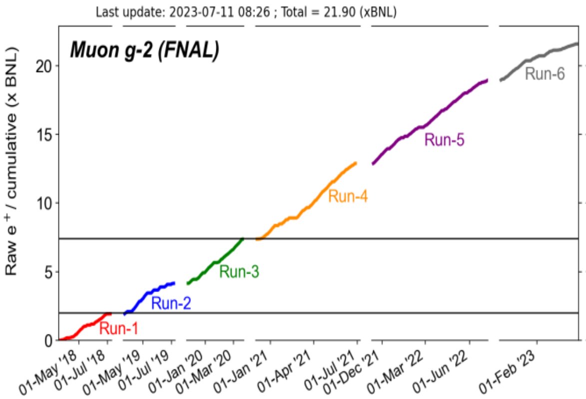


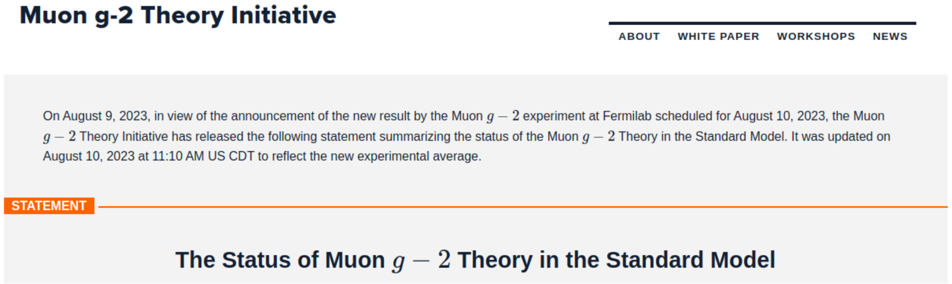
Result Aug 10, 2023: arXiv:2308.06230 [hep-ex]



5σ!!!

Motivation





Muon g-2 Theory Initiative

ABOUT | WHITE PAPER | WORKSHOPS | NEWS

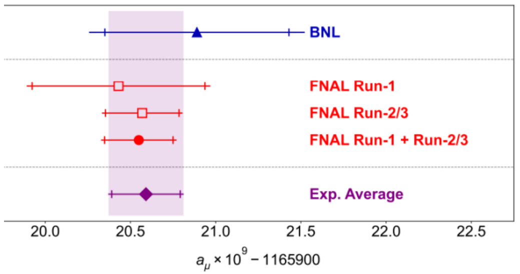
On August 9, 2023, in view of the announcement of the new result by the Muon $g-2$ experiment at Fermilab scheduled for August 10, 2023, the Muon $g-2$ Theory Initiative has released the following statement summarizing the status of the Muon $g-2$ Theory in the Standard Model. It was updated on August 10, 2023 at 11:10 AM US CDT to reflect the new experimental average.

STATEMENT

The Status of Muon $g-2$ Theory in the Standard Model

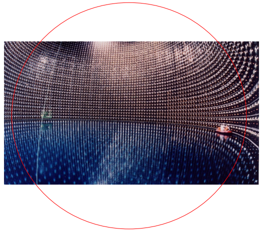
https://muon-gm2-theory.illinois.edu/

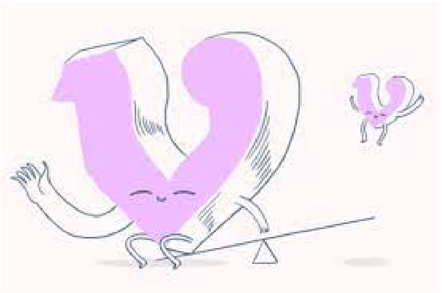
Result Aug 10, 2023: arXiv:2308.06230 [hep-ex]



$$5\sigma?$$

Motivation

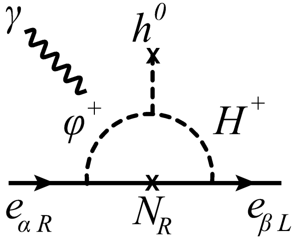




Same mediators for neutrino masses and g-2

TeV scale (or lower): low-scale seesaw

Charged Lepton Flavor Violation



Model (neutrinophilic 2HDM)

Ma, PRL (2001)
Ma, Raidal PRL (2001)

$$-\mathcal{L}_{\nu\text{-2HDM}} \supset \bar{\ell}_\alpha h_\alpha \Phi_2 e_{\alpha R} + \bar{N}_{iR} \lambda^{(1)}_{i\alpha} \tilde{\Phi}^\dagger_1 \ell_\alpha + \frac{1}{2} \bar{N}_{iR} M_{N_i} N^c_{iR} + h.c.$$

$$\mathbb{Z}_2 : \phi_1, N_R$$

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$$v_2 \sim 246\text{GeV}$$

$$v_1 \sim 10^{-3}\text{GeV}$$

$$M_\nu = -v_1^2 \lambda^{(1)\intercal} M_R^{-1} \lambda^{(1)}$$

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$v_2 \sim 246\mathrm{GeV}$

$v_1 \sim 10^{-3}\mathrm{GeV}$

$$M_\nu = -v_1^2 \lambda^{(1)\intercal} M_R^{-1} \lambda^{(1)}$$

$$v_1\lambda^{(1)}_{1\alpha} = i\sqrt{M_1}\left(\sqrt{m_2}c_z V^\dagger_{2\alpha} - \sqrt{m_3}s_z V^\dagger_{3\alpha}\right)$$

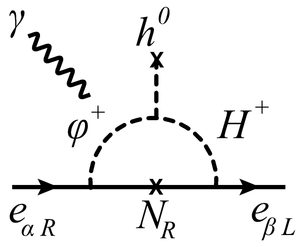
$$v_1\lambda^{(1)}_{2\alpha} = i\sqrt{M_2}\left(\sqrt{m_2}s_z V^\dagger_{2\alpha} + \sqrt{m_3}c_z V^\dagger_{3\alpha}\right)$$

Model (extended neutrinophilic 2HDM)

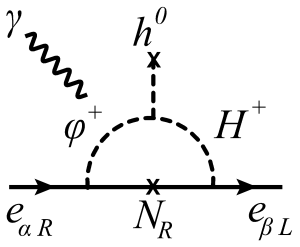
A.C, De Conto, Nishi, (2023)

$$-\mathcal{L}_{\nu\text{-2HDM}} \supset \bar{\ell}_\alpha h_\alpha \Phi_2 e_{\alpha R} + \bar{N}_{iR}\lambda^{(1)}_{i\alpha}\tilde{\Phi}^\dagger_1 \ell_\alpha + \frac{1}{2}\bar{N}_{iR} M_{N_i} N^c_{iR}$$
$$+ \ \mu_\varphi \Phi_2^\intercal \epsilon \Phi_1 \varphi^- + f_{i\alpha}\bar{N}_{iR} e^c_{\alpha R}\varphi^- + h.c.$$

$$\mathbb{Z}_2 : \phi_1, N_R, \varphi$$



Dipole moments and CLFV



$$a_\alpha = -\frac{4m_\alpha}{e}(C^{\sigma R}_{\alpha\alpha}),$$

$$\mathrm{Br}[\ell_\alpha \to \ell_\beta \gamma] = \frac{m_\alpha^3}{4\pi\Gamma_\alpha}(|C^{\sigma R}_{\alpha\beta}|^2 + |C^{\sigma R}_{\beta\alpha}|^2),$$

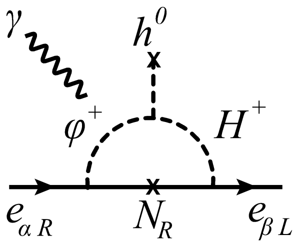
$$\mathcal{L}_{\gamma\text{-eff}} \supset C^{\sigma R}_{\alpha\beta}\bar{e}_{\alpha L}\sigma_{\mu\nu}e_{\beta R}F^{\mu\nu}$$

$$x_{kj} \equiv M^2_{N_j}/M^2_{S_k}$$

$$\frac{16\pi^2}{e}C^{\sigma R}_{\beta\alpha} = c_\gamma s_\gamma \frac{v_2}{v}\sum_j \frac{\lambda^{(1)\dagger}_{\beta j} f^*_{j\alpha}}{M_{N_j}}\left[x_{2j} f_S(x_{2j}) - x_{1j} f_S(x_{1j})\right],$$

Mixing-angle for charged scalars

Dipole moments and CLFV



$$-\mathcal{L}_{\nu\text{-2HDM}} \supset \bar{\ell}_\alpha h_\alpha \Phi_2 e_{\alpha R} + \bar{N}_{iR} \lambda^{(1)}_{i\alpha} \tilde{\Phi}_1^\dagger \ell_\alpha + \frac{1}{2} \bar{N}_{iR} M_{N_i} N^c_{iR}$$

$$+ \ \mu_\varphi \Phi_2^\intercal \epsilon \Phi_1 \varphi^- + f_{i\alpha} \bar{N}_{iR} e^c_{\alpha R} \varphi^- + h.c.$$

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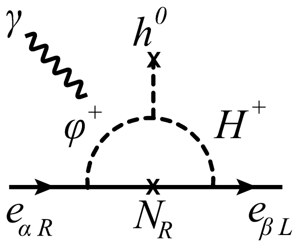
Mixing-angle for charged scalars

Dipole moments and CLFV



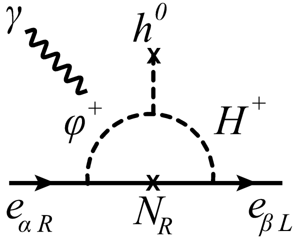
$$M_{N_1} = M_{N_2}$$

a_μ → $\lambda^{(1)\dagger}_{\mu 1} f^*_{1\mu},\ \lambda^{(1)\dagger}_{\mu 2} f^*_{2\mu} \sim O(1)$

$\mathrm{Br}[\mu \to \mathrm{e}\gamma]$ →

$$|\lambda^{(1)\dagger}_{\mu 1} f^*_{1e} + \lambda^{(1)\dagger}_{\mu 2} f^*_{2e}| \lesssim 10^{-5}\,, \quad |\lambda^{(1)\dagger}_{e1} f^*_{1\mu} + \lambda^{(1)\dagger}_{e2} f^*_{2\mu}| \lesssim 10^{-5}$$

Dipole moments and CLFV



$$M_{N_1} = M_{N_2}$$

$$a_\mu \longrightarrow \lambda^{(1)\dagger}_{\mu 1} f^*_{1\mu},\ \lambda^{(1)\dagger}_{\mu 2} f^*_{2\mu} \sim O(1)$$

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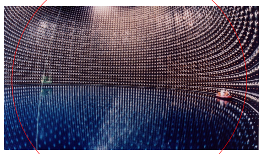
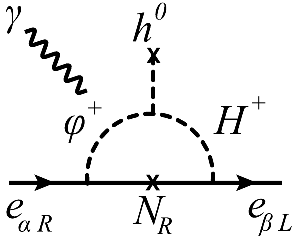


Dipole moments and CLFV



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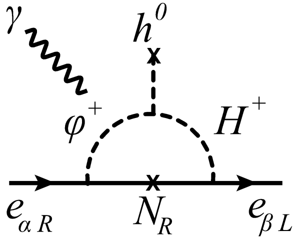
Dipole moments and CLFV



$$M_{N_1} = M_{N_2}$$

$$a_\mu \longrightarrow \lambda^{(1)\dagger}_{\mu 1} f^*_{1\mu},\ \lambda^{(1)\dagger}_{\mu 2} f^*_{2\mu} \sim O(1)$$

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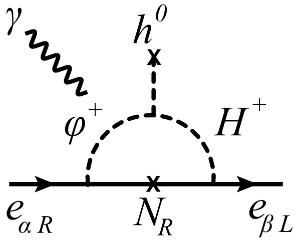
$$(f_{1\mu}, f_{2\mu}) = \zeta(\lambda^{(1)}_{2e}, -\lambda^{(1)}_{1e})$$

Dipole moments and CLFV



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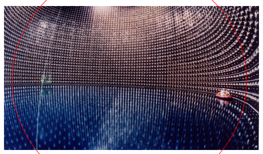
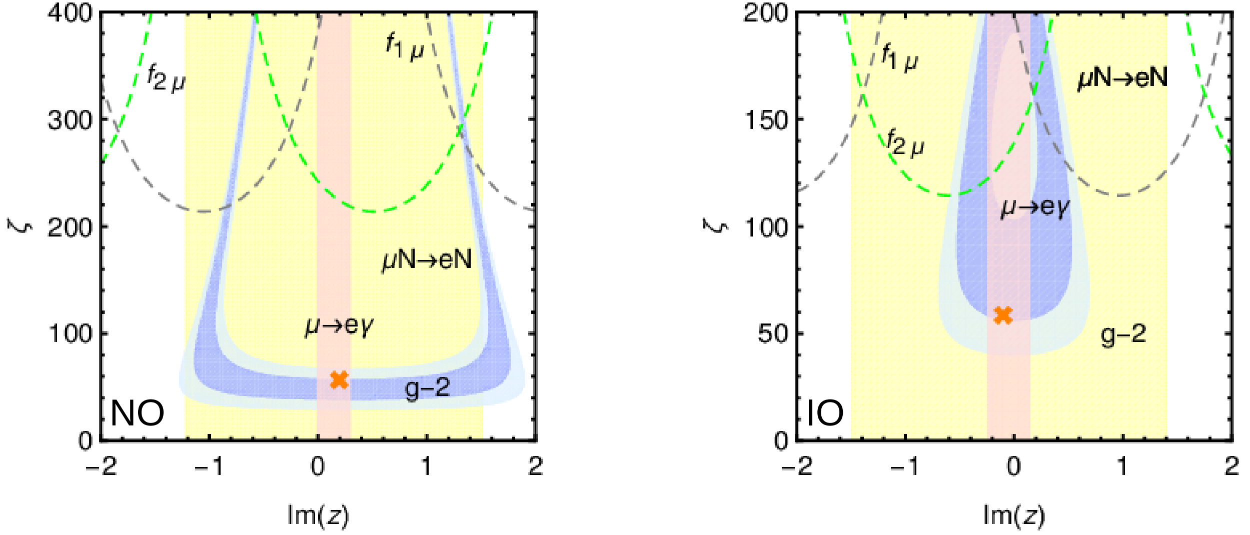


$$(f_{1\mu}, f_{2\mu}) = \zeta(\lambda^{(1)}_{2e}, -\lambda^{(1)}_{1e})$$

Dipole moments and CLFV

$$M_{N_1} = M_{N_2} = 1.0\ \text{TeV}$$

$$M_{S_1} = 350\ \text{GeV}\,, \quad \mathrm{M}_{\mathrm{S}_2} = 450\ \text{GeV}\,, \quad \mathrm{s}_\gamma = 0.1\,.$$



$$v_1 \sim 10^{-3}\text{GeV}$$

Dipole moments and CLFV

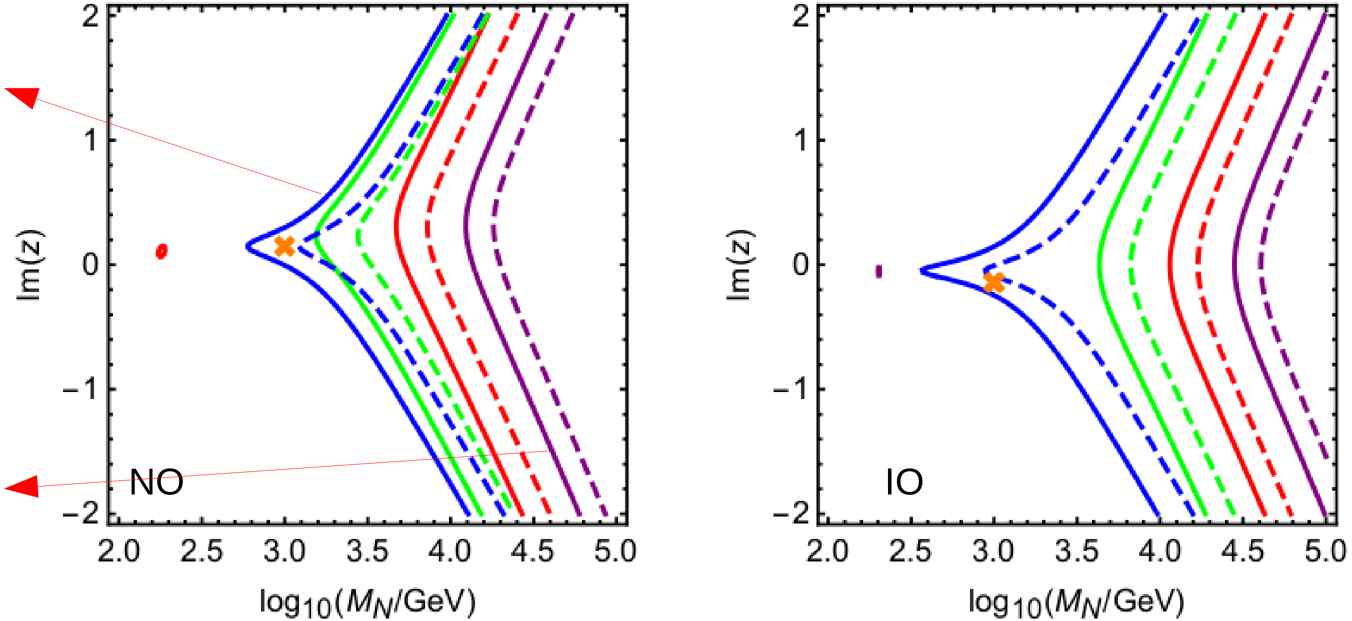
$$\Delta = M_2/M_1 - 1$$

$$M_{S_1} = 350\ \mathrm{GeV}\,, \quad \mathrm{M_{S_2}} = 450\ \mathrm{GeV}\,, \quad \mathrm{s}_\gamma = 0.1\,.$$

$$v_1 \sim 10^{-3}\mathrm{GeV}\sqrt{\mathrm{M_1/TeV}}$$

$\Delta = 0$

$\Delta = 10^{-2}$



$$\zeta = 60$$

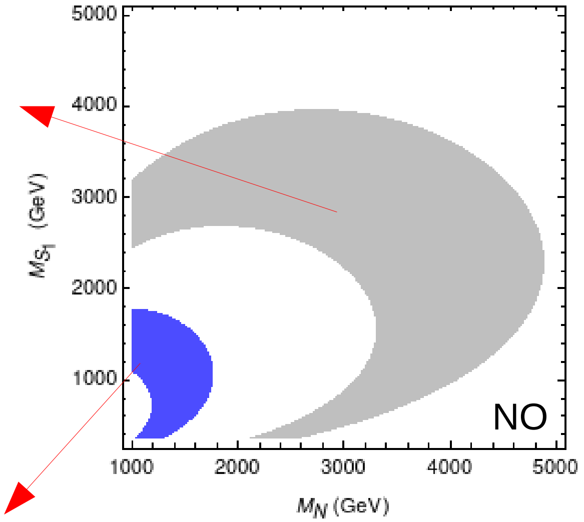
Dipole moments and CLFV

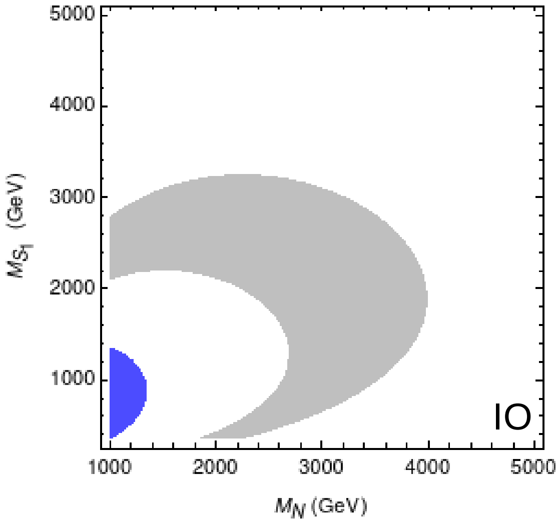
$$M_{N_1} = M_{N_2}$$

$$s_\gamma = 0.1\,, \quad z = 0.2\,i(-0.1\,i)\,, \quad \zeta = 60$$

$$v_1 \sim 10^{-3}\mathrm{GeV}\sqrt{\mathrm{M_1/TeV}}$$

$$M_{S_2} \sim 2M_{S_1}$$





$$M_{S_2} \sim 1.29M_{S_1}$$

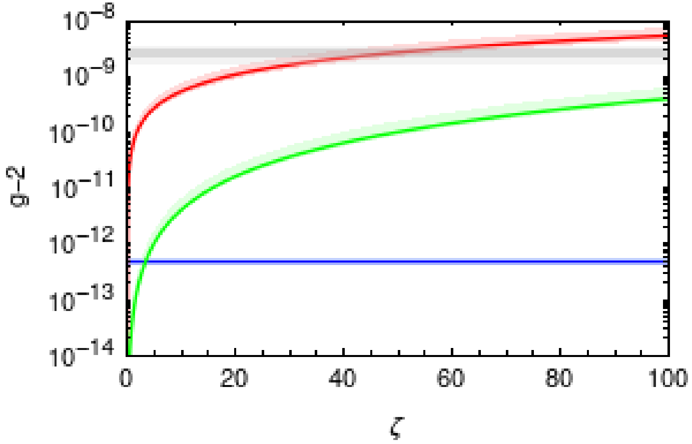
Summary

JHEP08(2023)170

We proposed an extended neutrinophilic 2HDM which:

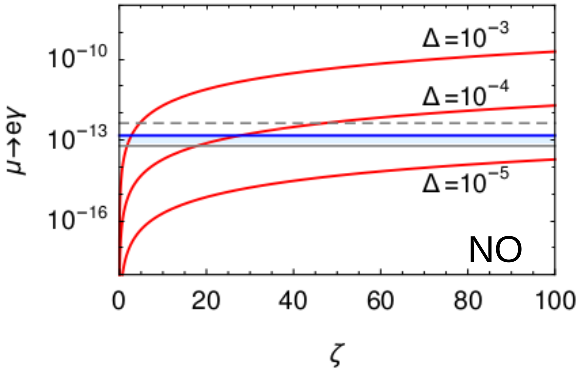
- Connects the solution to g-2 to a low-scale seesaw mechanism, with mediators at TeV;
- Avoids stringent constrains from CLFV.

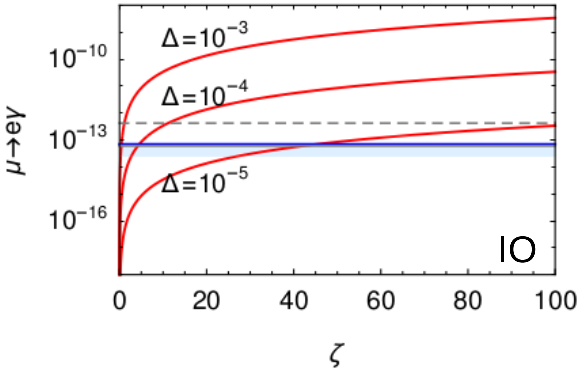
Backup



$$
\begin{aligned}
\frac{16\pi^2}{e} C^{\sigma R}_{\beta\alpha} = {} & c_\gamma s_\gamma \frac{v_2}{v} \sum_j \frac{\lambda^{(1)\,\dagger}_{\beta j} f^*_{j\alpha}}{M_{N_j}} \left[x_{2j} f_S(x_{2j}) - x_{1j} f_S(x_{1j}) \right] , \\
& + \; m_\alpha \frac{v_2^2}{v^2} \sum_j \lambda^{(1)\dagger}_{\beta j} \left[\frac{c_\gamma^2}{M^2_{S_1}} \tilde{f}_S(x_{1j}) + \frac{s_\gamma^2}{M^2_{S_2}} \tilde{f}_S(x_{2j}) \right] \lambda^{(1)}_{j\alpha} \\
& + m_\beta \sum_j f^{\mathsf{T}}_{\beta j} \left[\frac{s_\gamma^2}{M^2_{S_1}} \tilde{f}_S(x_{1j}) + \frac{c_\gamma^2}{M^2_{S_2}} \tilde{f}_S(x_{2j}) \right] f^*_{j\alpha} ,
\end{aligned}
$$

Backup

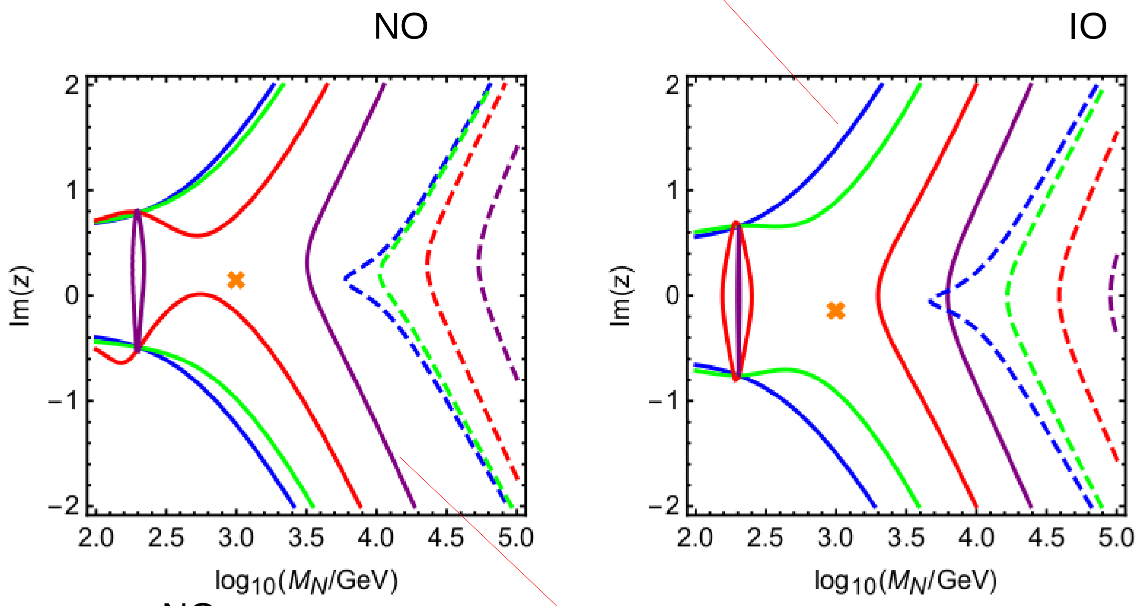




$$\Delta = M_2/M_1 - 1$$

Backup

$\Delta = 0$



NO

$$\Delta = M_2/M_1 - 1$$

$\Delta = 10^{-2}$