$(g-2)$ anomalies and neutrino masses

Based on: Carolina Árbelaez, RC, Renato Fonseca, Martin Hirsch
PRD 102 (2020) 7, 075005 (arXiv: 2007.11007)

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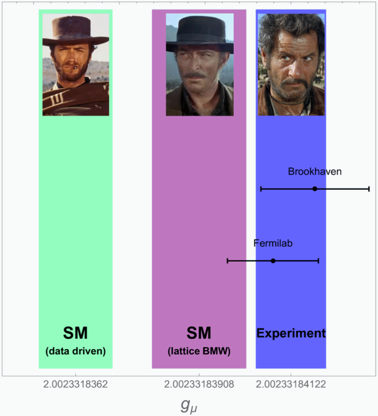
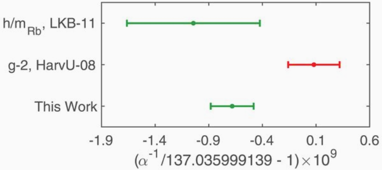
(g-2) anomalies

[Resonaances blog (Jester)]





$a_\mu = (251 \pm 59) \times 10^{-11}$ $(4.2\,\sigma)$

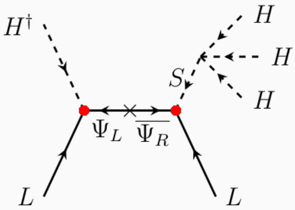
[Muon g-2 colab.(2021)]

$a_e = -(87 \pm 36) \times 10^{-14}$ $(2.5\,\sigma)$

[Parker et al, 2018]

BNT model

Approach here: dimension 7 operator $LLHH(H^\dagger H) \Rightarrow m_\nu = c\,\frac{\langle H\rangle^3}{\Lambda^2}$



[Babu, Nandi, Tavartkiladze (2009)]

	$\mathrm{SU}(3)_c$	$\mathrm{SU}(2)_L$	$\mathrm{U}(1)_Y$
$\Psi_{L,R}$	**1**	**3**	1
S	**1**	**4**	$\frac{3}{2}$

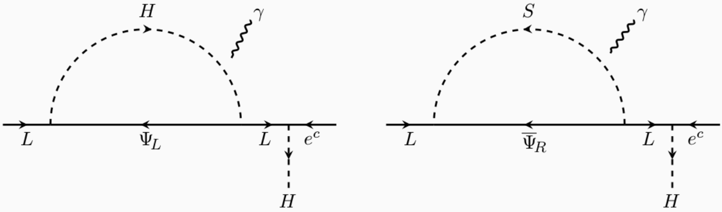
- New physics mass scale of $\mathcal{O}(1-10)$ TeV
- Particles with many electrical charges ($S^{\pm\pm\pm}$, $\Psi^{\pm\pm}$, ...)
- Yukawa matrices that enter in CLFV processes, $(g-2)$ and EDM

[BNT pheno see: Gosh, Jana, Nandi (2018)]

$(g\text{-}2)_\alpha$ in the BNT

Effective EM dipole moment operator: $c_R^{\alpha\beta}\ \overline{\ell_\alpha}\sigma_{\mu\nu}P_R\ell_\beta F^{\mu\nu}$

$$a_\alpha = -4\frac{m_{\ell_\alpha}}{e}\,\mathrm{Re}\,c_R^{\alpha\alpha} \qquad \mathrm{Br}\left(\ell_\beta \to \ell_\alpha\gamma\right) = \frac{m^3_{\ell_\beta}}{4\pi\Gamma_{\ell_\beta}}\left(\left|c_R^{\alpha\beta}\right|^2 + \left|c_R^{\beta\alpha}\right|^2\right)$$

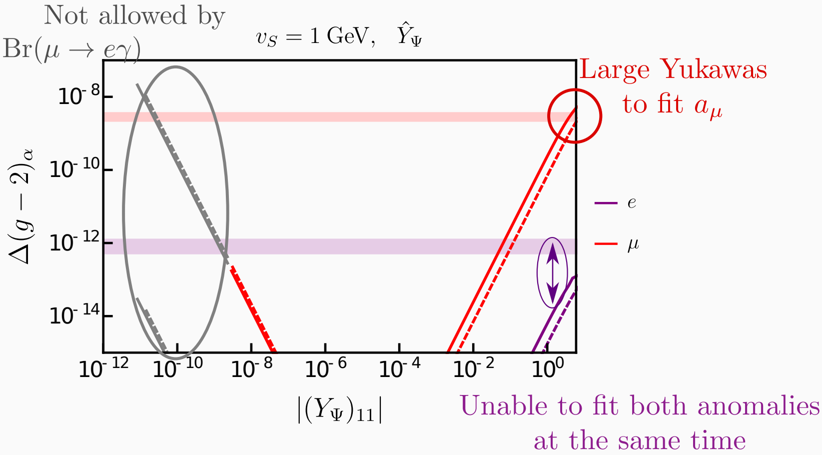


$(g-2)_\alpha$ is proportional to $m^2_{\ell_\alpha}$

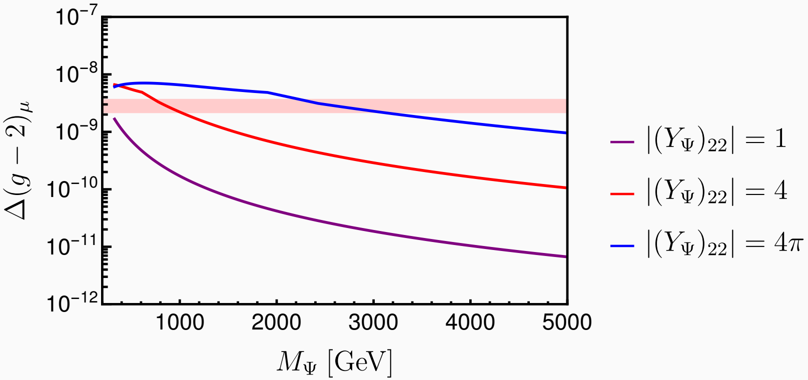
$\Rightarrow$ The diagonal of the Yukawas is related to $(g-2)$.

$\Rightarrow$ The off-diagonal participates in $(\ell \to \ell + \gamma)$.

(g-2)$_\alpha$ in the BNT



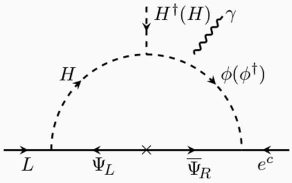
(g-2)$_\mu$ in the BNT



$M_\Psi < (1-3)$ TeV for a reasonable (perturbative) value of the Yukawas

Extended BNT model (BNTϕ)

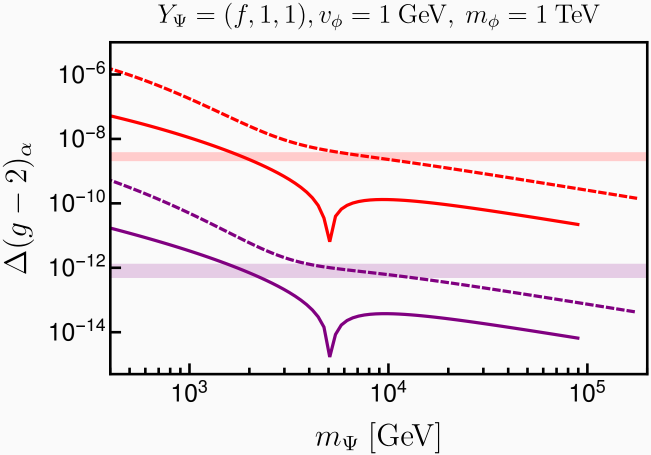
To explain both $(g-2)$ anomalies we add $\phi \equiv (\mathbf{1}, \mathbf{3}, 0)$.



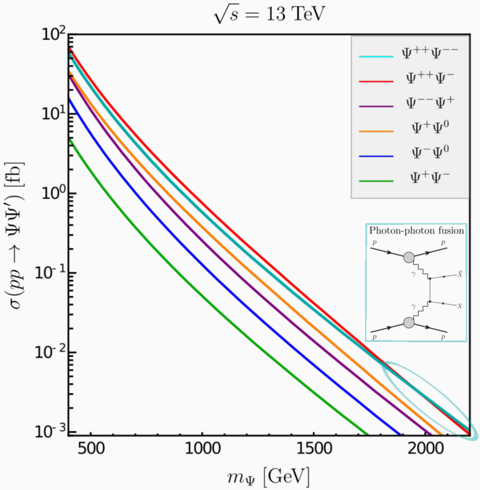
$(g-2)_\alpha$ is proportional to $m_\Psi \, m_{\ell_\alpha}$

$\frac{a_\mu}{a_e} \sim \frac{m_\mu}{m_e} \sim \frac{a_\mu^{\text{exp}}}{a_e^{\text{exp}}} \Rightarrow$ can explain both anomalies simultaneously

(g-2)$_\alpha$ in the BNTϕ



Full lines: $Y_\phi = 1$, Dashed lines: $Y_\phi = 4\pi$

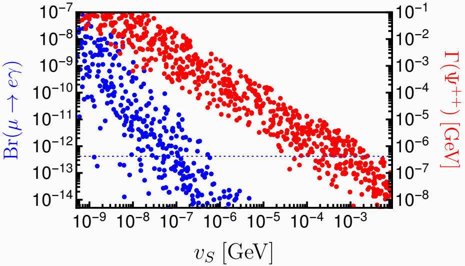


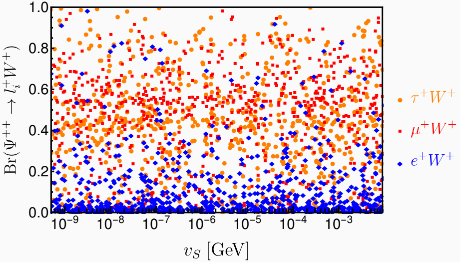
- High-lumi LHC: more than 100 (20) events for $m_\Psi = 1.5\,(1.8)$ TeV before cuts
- Current (non-dedicated) multi-lepton searches by CMS: optimistic rough estimate $m_\Psi > (800 - 900)$ GeV

Branching Ratios

Neutrino data requires that at least one Yukawa matrix to be non-diagonal:

$\Rightarrow$ flavour violating decays of Ψ^{++}, Ψ^{+} and Ψ^{0}



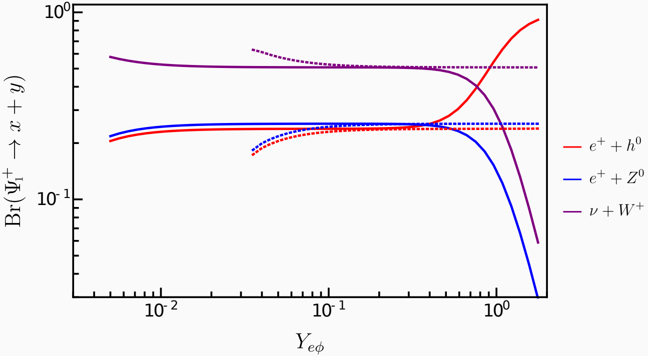


The upper limit on $\mathrm{Br}(\mu \to e\gamma)$ does not restrict the possibility to have flavour violating decays for Ψ.

Branching Ratios

BUT to explain a_μ, a_e and obey the upper bound from cLFV decays at the same time we need large diagonal Yukawa matrices.

$\Rightarrow$ Heavy fermion decays are very nearly **flavour diagonal**.



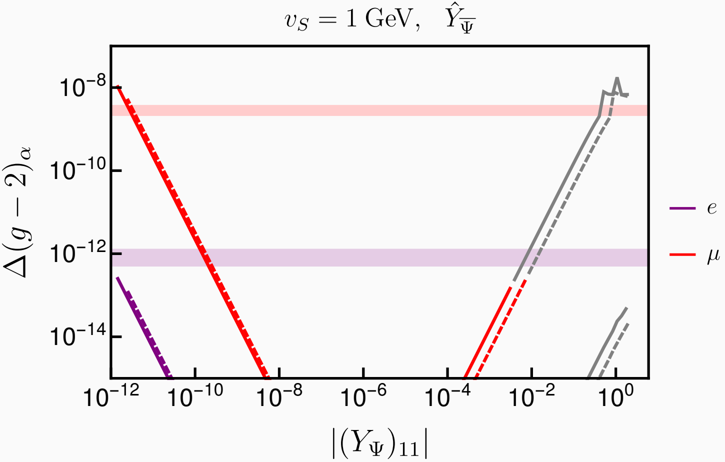
Enhancement of the decay $\Psi^+ \to e^+ h^0$, particular of the $BNT\phi$ model.

Summary

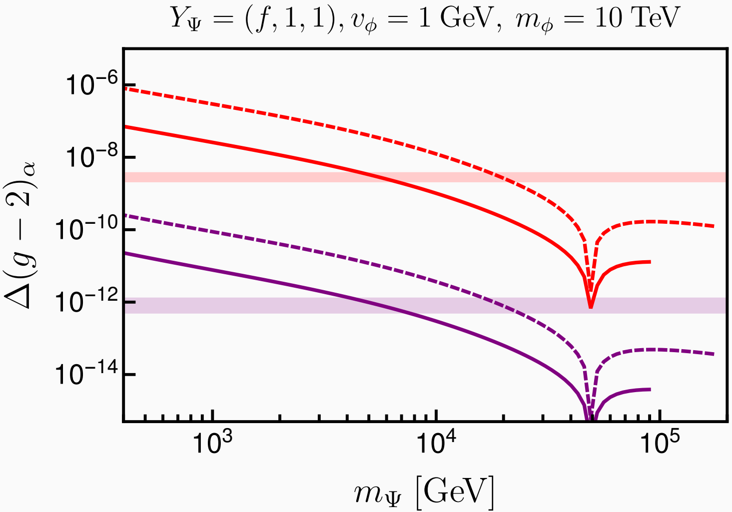
- The original BNT model can explain a_μ for $m_\Psi \lesssim (1-3)$ TeV, partially within reach of the high-luminosity LHC.
- Both anomalies can be explained extending the BNT with a triplet ϕ (BNTϕ model).
- The smallness of m_ν and the explanation of both anomalies, selects a specific part of the parameter space: large $\mathcal{O}(0.1-1)$ nearly diagonal Yukawas.
- To avoid CLFV bounds, decays of the heavy fermions are necessarily flavour conserving.
- The pattern of the branching ratios can trace the presence of ϕ in the model.

Backup (more... really?)

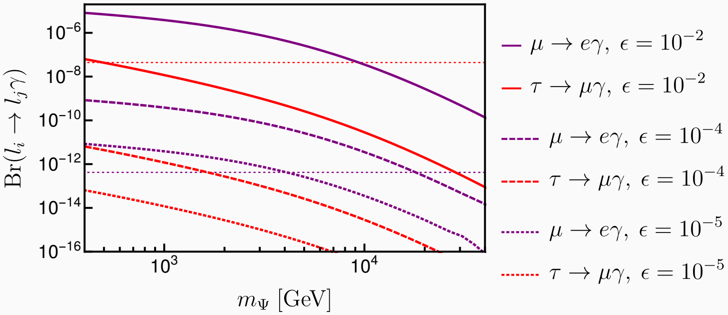
(g-2)$_\alpha$ in the BNT



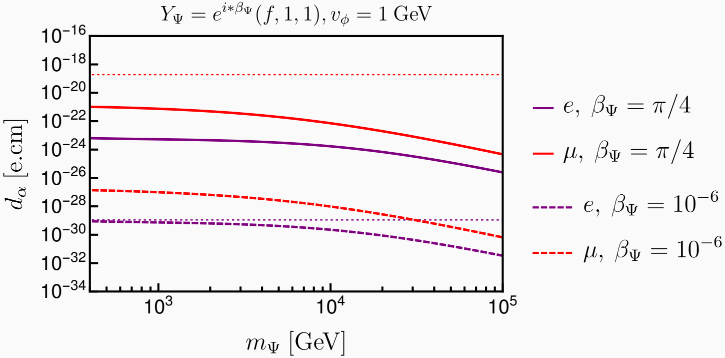
(g-2)$_\alpha$ in the BNTϕ



CLFV decays in the BNTϕ



EDM in the BNTϕ



Branching Ratio of Ψ_1^0