Study of neutrino mass and muon $(g-2)$ anomaly in an extended left-right theory

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Plan of the talk

- Introduction
- Constructing the Model
- Generation of neutrino masses
- Model prediction on muon $(g-2)$ anomaly
- Summary

The Standard Model (SM)

- Theoretical prediction of SM matches really well with the experimental findings.
- Still there are some open problems :

(a) Origin of small Neutrino masses

(b) Parity violation in weak interaction

(c) Muon $(g-2)$ anomaly

(d) Dark matter and dark energy and so on…

$\Downarrow$

Indicate the existence of Beyond SM (BSM) framework.

Left-Right Symmetric Model (LRSM)

- Gauge Group : $G_{LR} \equiv SU(2)_L \times SU(2)_R \times U(1)_{B-L} \times SU(3)_C$.
- Particle Content : $q_L \equiv (2,1,1/3,3)$, $q_R \equiv (1,2,1/3,3)$,

$$\ell_L \equiv (2,1,-1,1),\ \ell_R \equiv (1,2,-1,1),$$

$$\Phi \equiv (2,2,0,1),\ \Delta_L \equiv (3,1,2,1),\ \Delta_R \equiv (1,3,2,1).$$

- The right-handed neutrino is the natural outcome of LRSM.
- LR parity breaking scale is related to the generation of neutrino masses.
- The light neutrino masses can be generated via type-I+II seesaw formula.

$$\Downarrow$$

A very high right-handed breaking scale ($>10^{14}$ GeV).

Constructing the Model for extended LRSM

- Gauge Group : $G_{LR}^{\mu\tau} \equiv G_{LR} \times U(1)_{L_\mu - L_\tau}$.
- With the usual particle content of manifest LRSM

  $\Downarrow$

  Degenerate eigenvalues from neutrino mass matrix

  $\Downarrow$

  Disagreement with the neutrino oscillation experiment data !!
- This degeneracy can be avoided by introducing another pair of triplet scalars with non-zero $L_\mu - L_\tau$ charge $\Longrightarrow$ the model no more remains minimal !!
- Another possible way to solve the degeneracy issue is replacing the $\Delta_{L,R}$ by $H_{L,R}$.
- To break the $U(1)_{L_\mu - L_\tau}$ symmetry we have to add one extra scalar χ.

Generation of neutrino masses

- Generation of neutrino masses via canonical seesaw mechanism provides a high right-handed braking scale ⇒ far beyond our present collider reach.

- As an alternative we take interest to generate neutrino masses in this model via inverse seesaw (ISS) mechanism.

$$\Downarrow$$

One needs to add three sterile neutrinos, one per each generation.

- Outcome : ISS scenario allows large light-heavy neutrino mixing which will be an important feature for explaining muon anomaly (will see later).

- Light neutrino mass : $\boxed{m_\nu = \left(\frac{M_D}{M}\right)\mu_s\left(\frac{M_D}{M}\right)^T}$

Model prediction on muon anomaly

(i) Interaction of singly charged gauge boson with neutral fermions :

(a) contribution due to W_L mediation

(b) contribution due to W_R mediation

(ii) Interaction of neutral vector boson (Z_R) with singly charged fermions.

(iii) Interaction of singly charged scalars with neutral fermions.

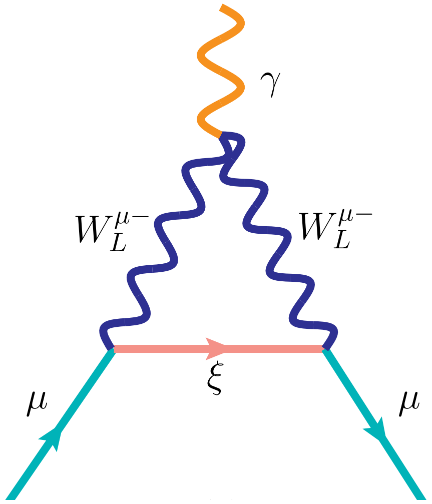
(iv) Interaction of neutral scalars with muons :

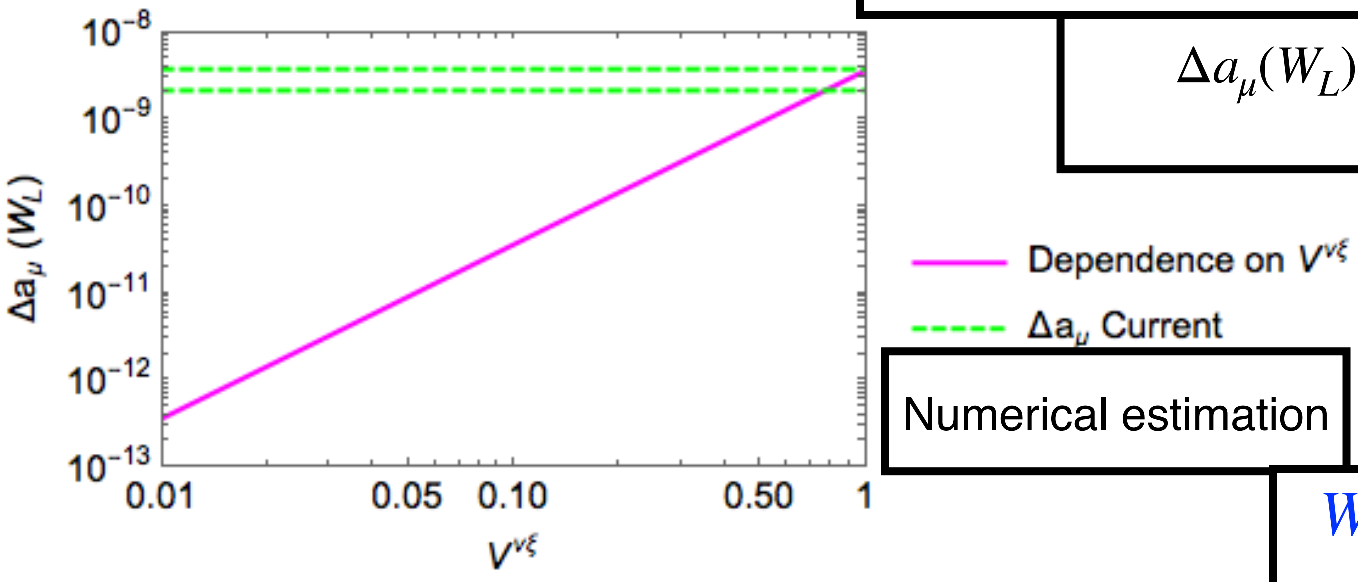
(a) contribution due to CP-even scalar mediation

(b) contribution due to CP-odd scalar mediation

(v) Interaction of light new gauge boson $Z_{\mu\tau}$ with muons.

Interaction of singly charged gauge boson with neutral fermions :





Theoretical Prediction

$$\Delta a_\mu(W_L) \simeq 9.06 \times 10^{-9}\ g_L^2 \sum_{i=1,..,6} |\,V_{\mu i}^{\nu\xi}|^2$$

: W_L Contribution

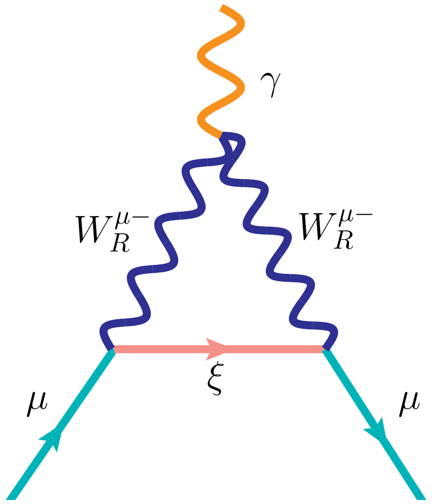
Numerical estimation

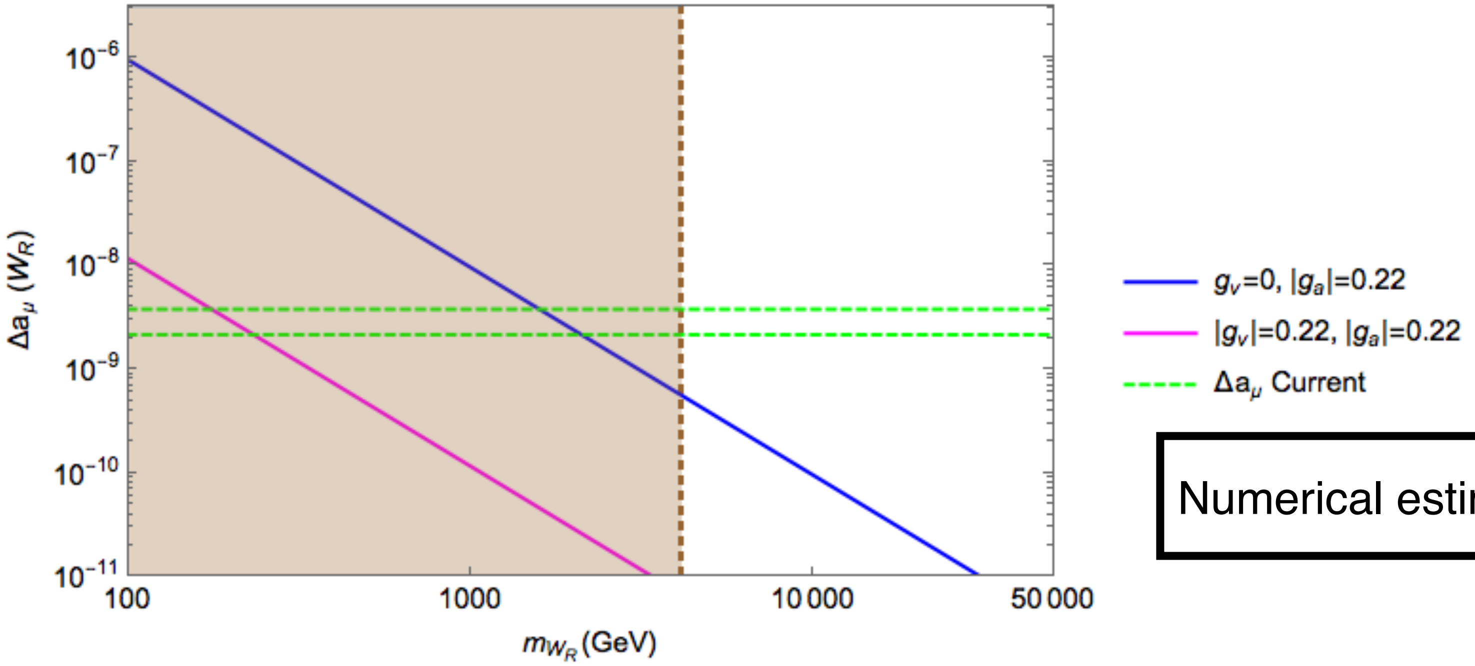
W_L is a good candidate to explain muon anomaly .

W_R Contribution :

Theoretical Prediction

$$\Delta a_\mu(W_R) \simeq \frac{1}{4\pi^2}\frac{m_\mu^2}{m_{W_R}^2}\left[|\,g_v^\mu|^2\left(\frac{5}{6}\right) + |\,g_a^\mu|^2\left(\frac{5}{6}\right)\right]$$

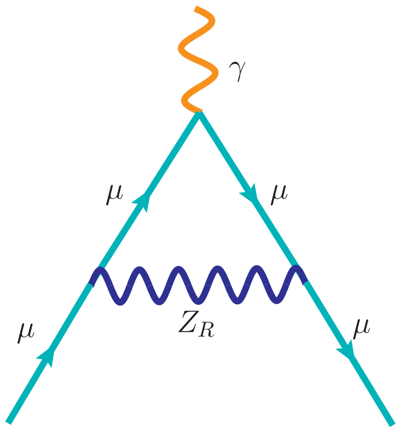


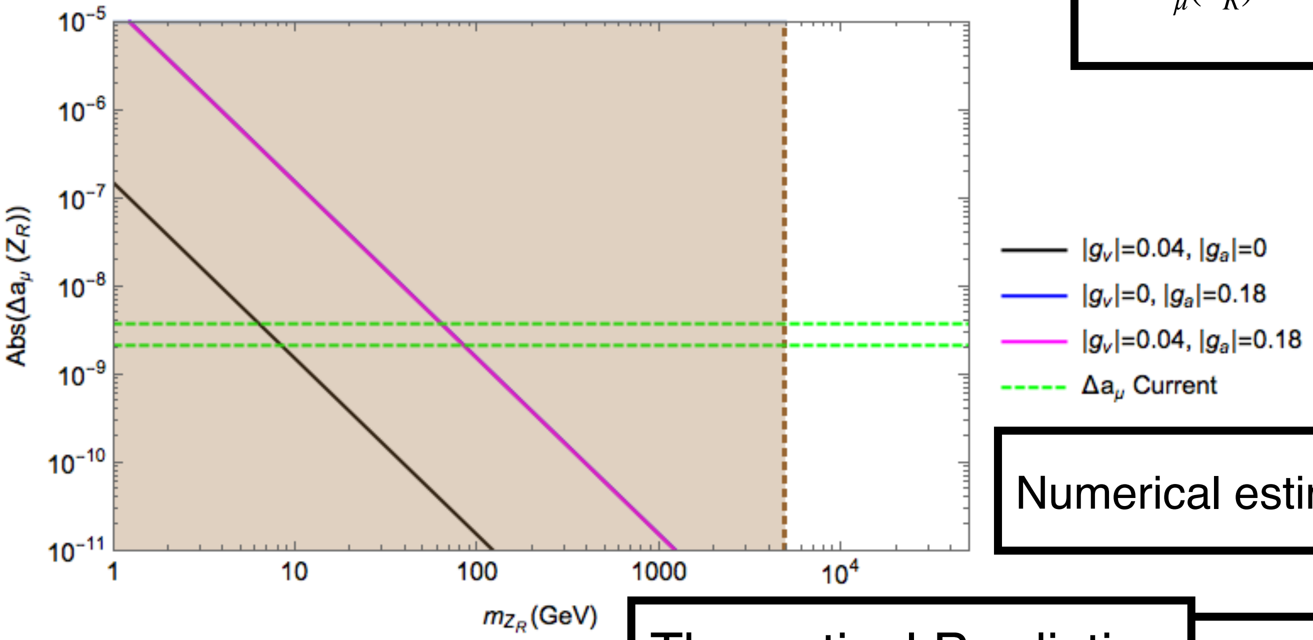


Numerical estimation

W_R is not a good candidate!!

Contribution due to Z_R mediation :





Theoretical Prediction

$$\Delta a_\mu(Z_R) \simeq -\frac{1}{4\pi^2}\frac{m_\mu^2}{m_{Z_R}^2}\left[\left(-\frac{1}{3}\right)|g_v^\mu|^2+\left(\frac{5}{3}\right)|g_a^\mu|^2\right]$$

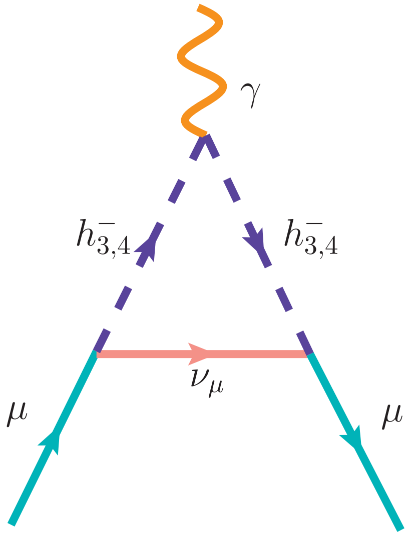
Z_R is not a good candidate !!

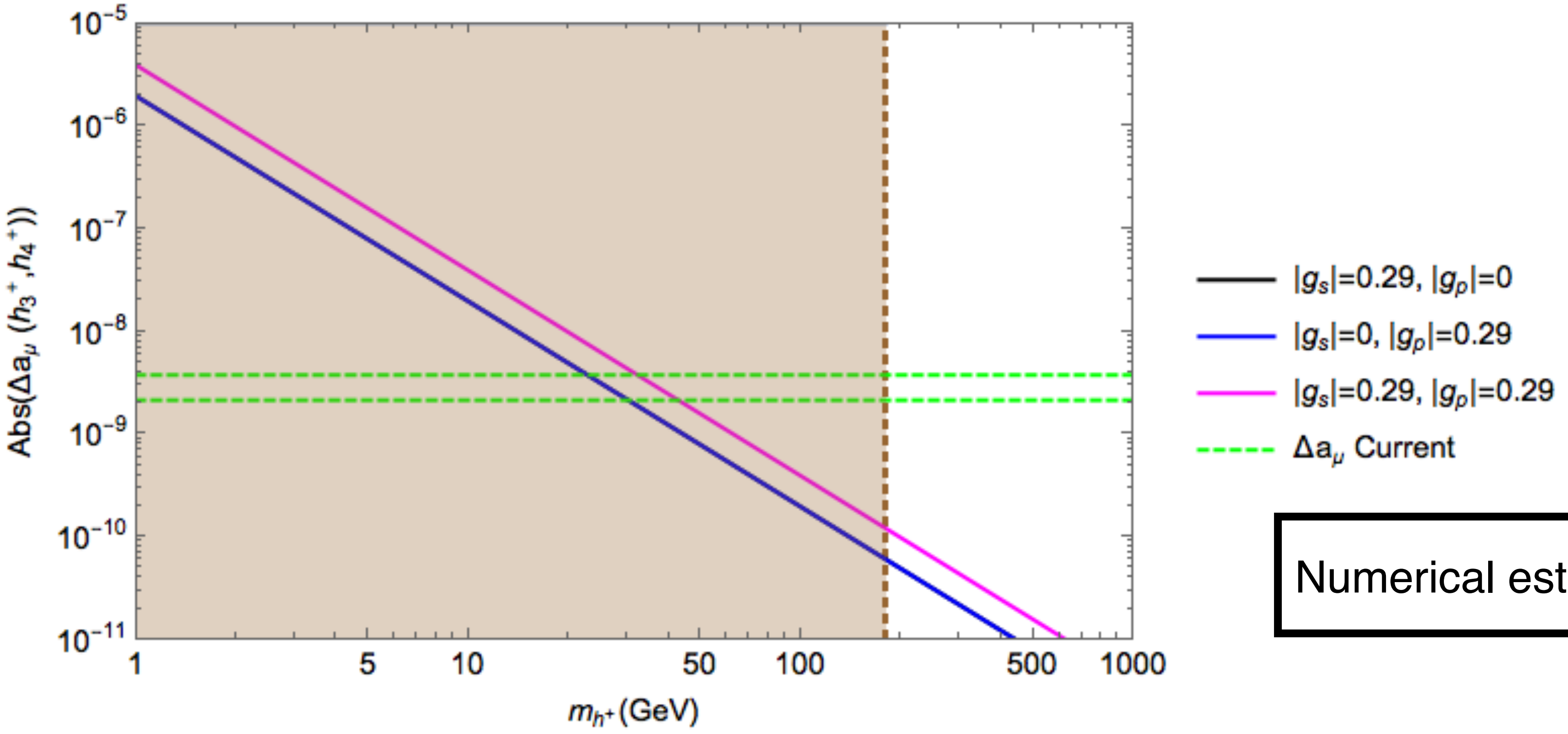
Numerical estimation

Contribution due to singly charged scalar:

Theoretical Prediction

$$\Delta a_\mu(h_i^+) \simeq -\frac{1}{4\pi^2}\frac{m_\mu^2}{m_{h_i^+}^2}\left[|g_s^\mu|^2\left(\frac{1}{12}\right)+|g_p^\mu|^2\left(\frac{1}{12}\right)\right]$$

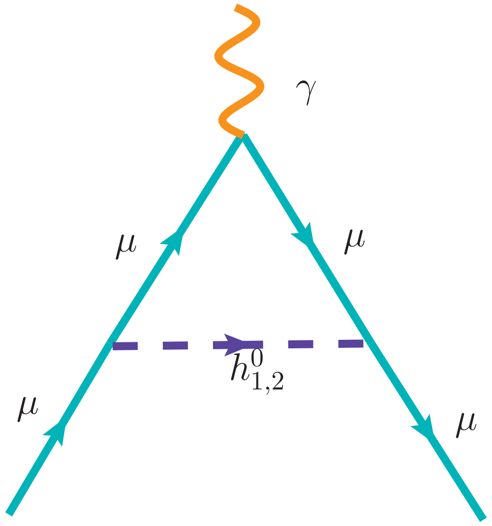




Numerical estimation

Singly charged scalars are not good candidates !!

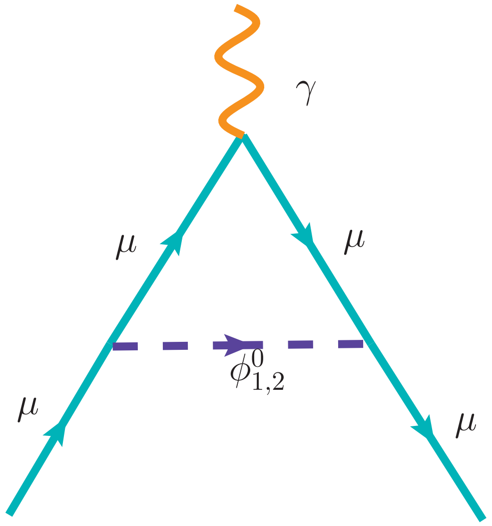
Interaction of neutral scalars with muons :



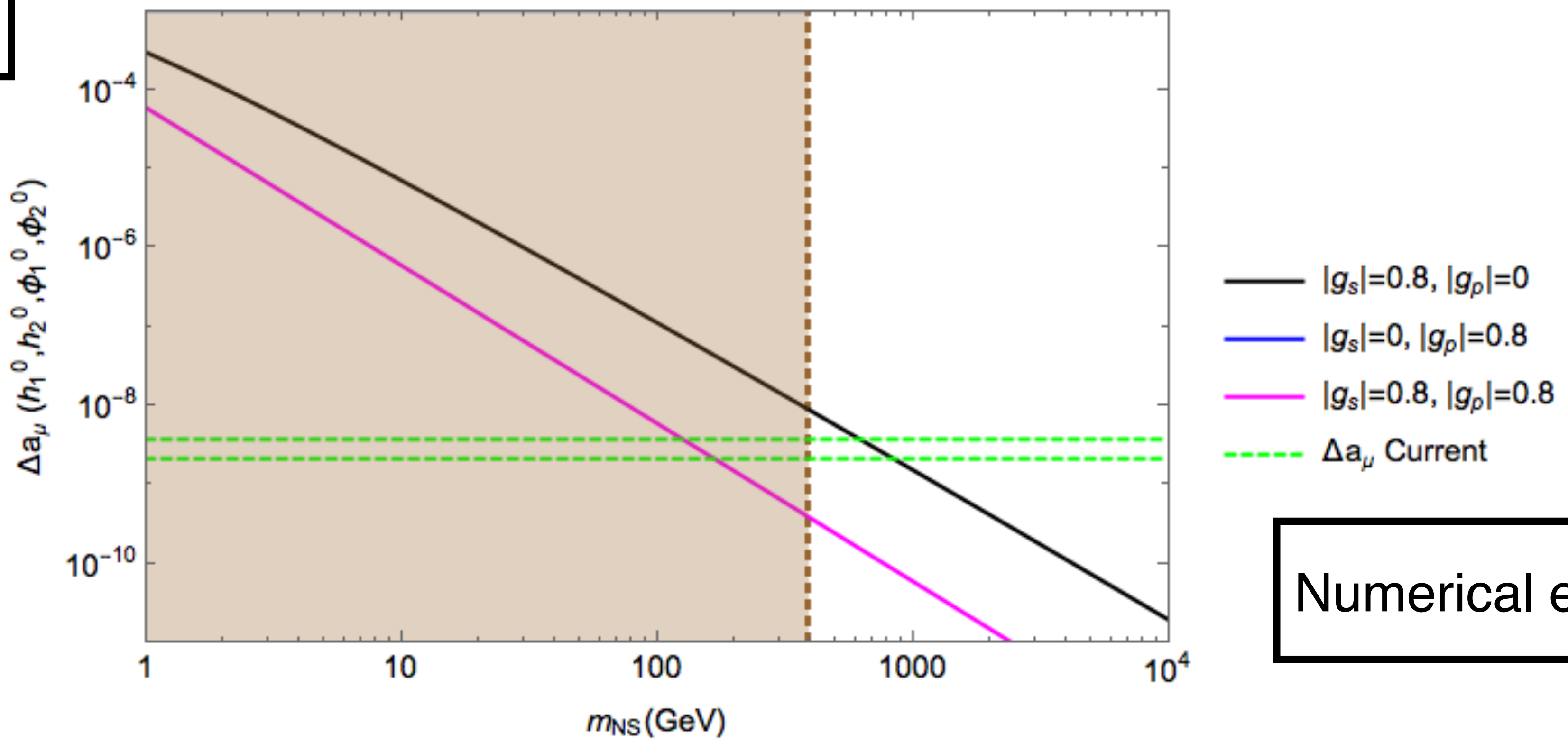
CP-even contribution

Theoretical Prediction

$$\Delta a_\mu(h_i^0/\phi_i^0) \simeq \frac{1}{4\pi^2}\frac{m_\mu^2}{m_{h_i^0/\phi_i^0}^2}\left[|g_s^\mu|^2\left(-\frac{7}{12}-\log\frac{m_\mu}{m_{h_i^0/\phi_i^0}}\right)+|g_p^\mu|^2\left(\frac{11}{12}+\log\frac{m_\mu}{m_{h_i^0/\phi_i^0}}\right)\right]$$



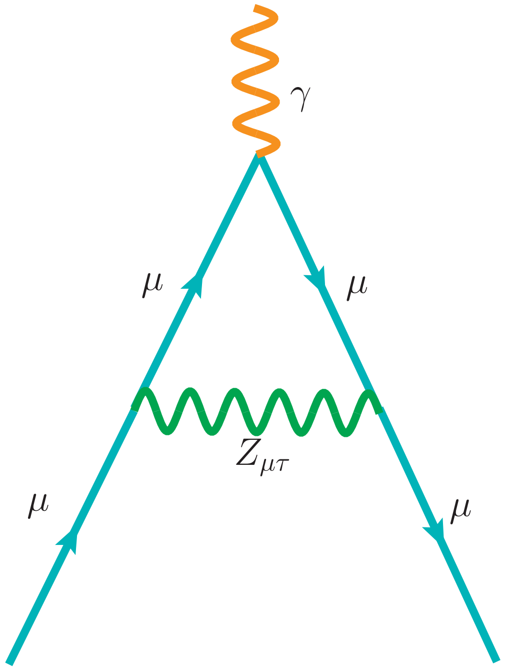
CP-odd contribution



Numerical estimation

CP-even scalars are good candidates to explain muon anomaly
CP-odd scalars are not !!!

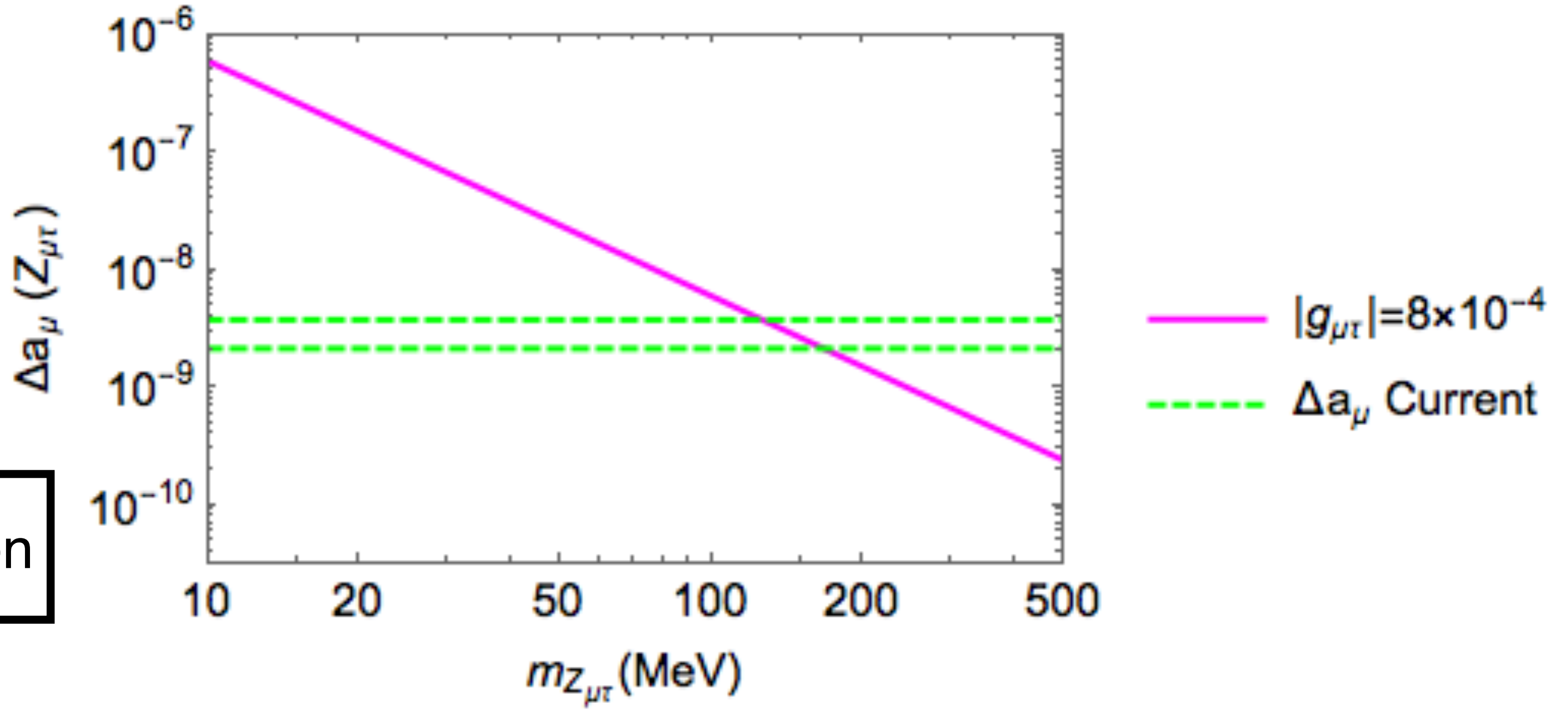
Interaction of light new gauge boson $Z_{\mu\tau}$ with muons



Theoretical Prediction

$$\Delta a_\mu(Z_{\mu\tau}) = \frac{g_{\mu\tau}^2}{12\pi^2}\frac{m_\mu^2}{m_{Z_{\mu\tau}}^2}$$

Numerical estimation



$Z_{\mu\tau}$ is a good candidate to explain muon anomaly.

Summary and Conclusion

- We have constructed an extended left-right model which can explain non-zero neutrino mass and muon anomalous magnetic moment within a single framework.
- Neutrino masses are generated in the model through inverse seesaw mechanism that allows large light-heavy neutrino mixing.
- Within this scenario we have three potential candidates (CP-even scalars, W_L, $Z_{\mu\tau}$) which can explain the entire anomaly.


THANK YOU!