

ν mass and $(g - 2)_\mu$
with dark $U(1)_D$ symmetry

박명훈



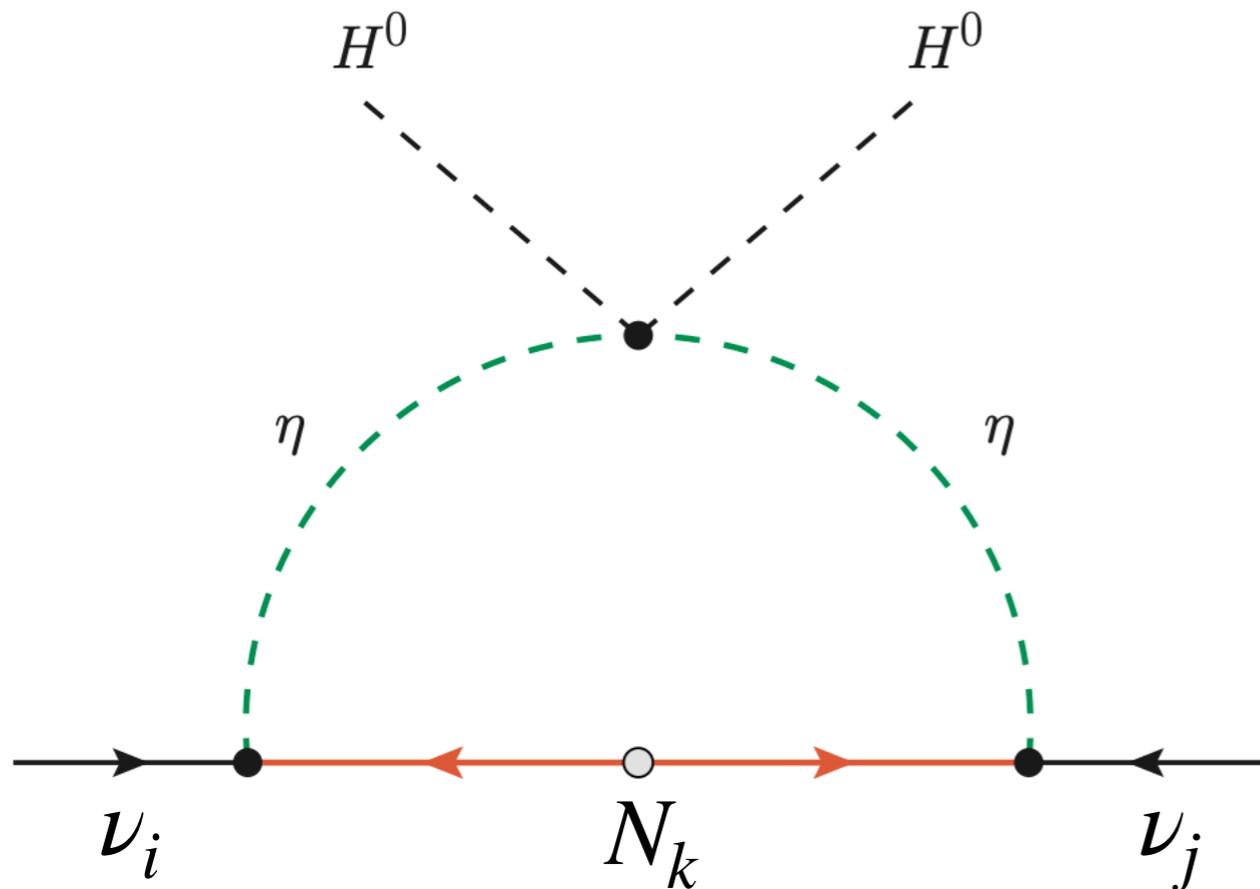
arXiv:2104.09205

강신규 교수님, Dr. Arnab Dasgupta

Muon Anomalies Workshop (MAW)
SNU

Scotogenic model

- Radiative seesaw **neutrino mass** + **Dark Matter**
(under Z_2 parity)



Field	$SU(3)_c$	$SU(2)_L$	$U(1)_Y$	Z_2
ℓ_L	1	2	$-1/2$	$+$
e_R	1	1	-1	$+$
H	1	2	$1/2$	$+$
η	1	2	$1/2$	$-$
N	1	1	0	$-$

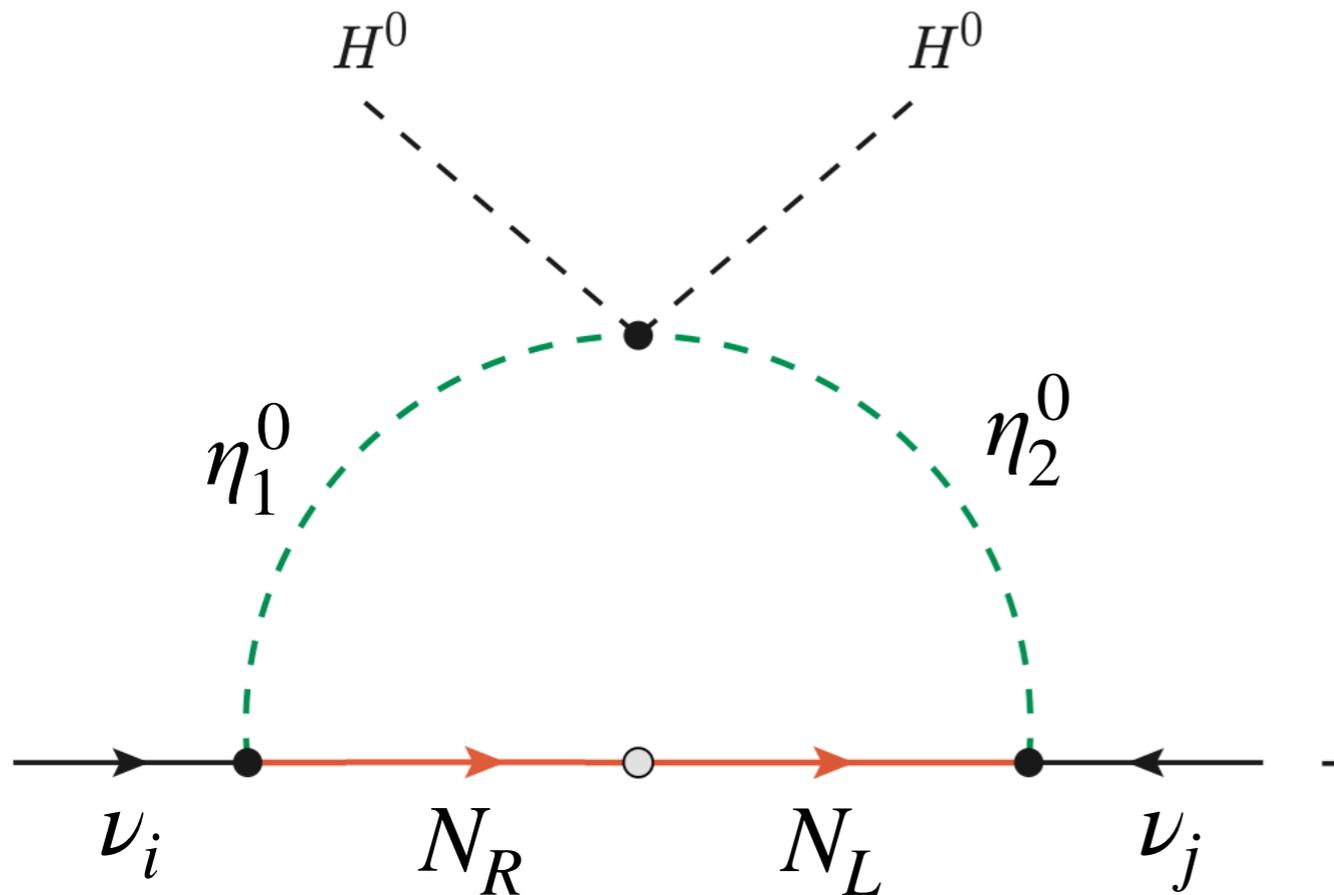
Pablo Escribano arXiv:2004.05172
(Ernest Ma, hep-ph/0601225)

$$\mathcal{L}_Y = f_{ij}(\phi^- \nu_i + \bar{\phi}^0 l_i) l_j^c + h_{ij}(\nu_i \eta^0 - l_j \eta^+) N_j + H.c.$$

$$\mathcal{L}_{\text{Majorana}} = \frac{1}{2} M_i N_i N_i + H.c.$$

Scotogenic model + $U(1)_D$

- Z_2 parity is promoted to a local $U(1)_D$



Ernest Ma, arXiv:1308.5313

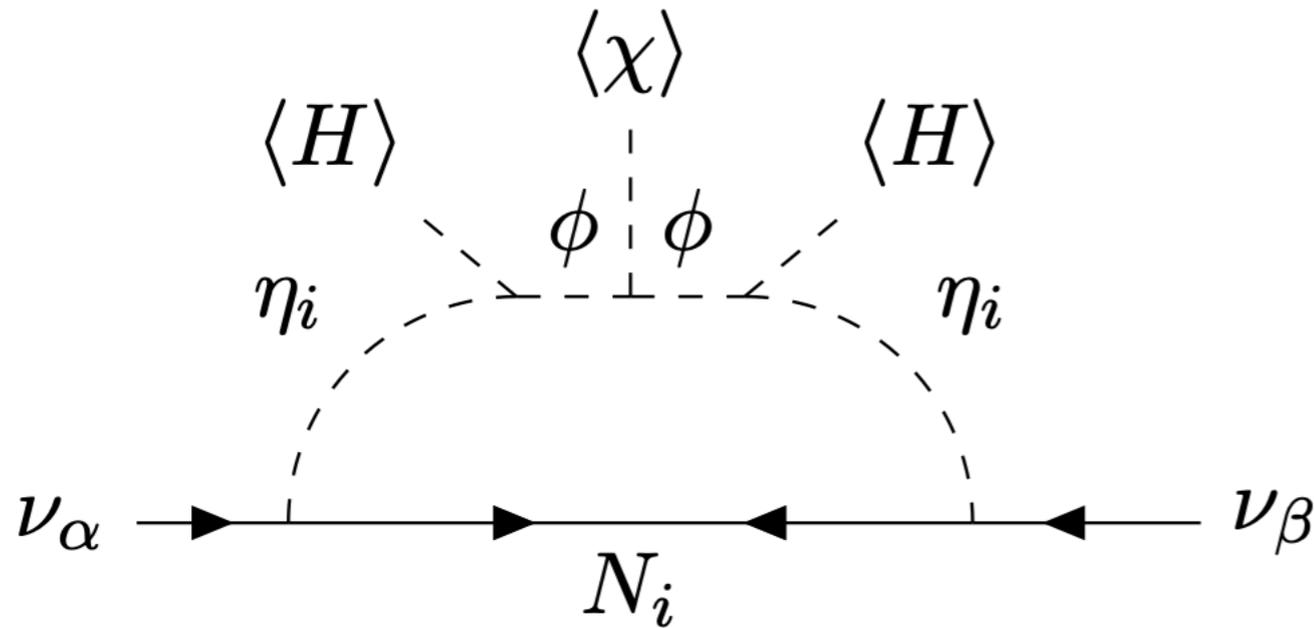
$$\left. \begin{aligned} (\eta_1^+, \eta_1^0) &\sim 1 \\ (\eta_2^+, \eta_2^0) &\sim -1 \\ N_{1,2,3} &\sim 1 \end{aligned} \right\} \text{under } U(1)_D$$

$\zeta \sim 2$ breaks $U(1)_D$

$\mathcal{L} \ni \zeta \eta_1^\dagger \eta_2$ allows splitting of the real and imaginary part of $\eta_{1,2}$

Scotogenic model + $U(1)_{D+} (g-2)_\mu$

(강신규, Arnab Dasgupta, 박명훈)



$$\begin{pmatrix} \Psi_L \\ \Psi_R \end{pmatrix} = \begin{pmatrix} \cos \theta_N & \sin \theta_N \\ -\sin \theta_N & \cos \theta_N \end{pmatrix} \begin{pmatrix} N_1 \\ N_2 \end{pmatrix}$$

Field	$SU(2)_L$	$U(1)_Y$	$U(1)_D$	$2S+1$
η_1	2	$\frac{1}{2}$	-1	1
η_2	2	$\frac{1}{2}$	1	1
ϕ	1	0	1	1
χ	1	0	2	1
Ψ_L	1	0	1	2
Ψ_R	1	0	-1	2

$$\mathcal{L}_F \supset y_{1\nu} \bar{L} \tilde{\eta}_1 \Psi_R + y_{2\nu} \bar{\Psi}_L^c \tilde{\eta}_2 L + y_{\Psi_L} \chi^* \bar{\Psi}_L^c \Psi_L + y_{\Psi_R} \chi \bar{\Psi}_R^c \Psi_R + M_\Psi \bar{\Psi}_L \Psi_R + h.c.$$

The vev $\langle \chi \rangle$ splits $N : N_2 \rightarrow N_1 + \gamma_D, N_1 + h_D$

Scotogenic model + $U(1)_D + (g-2)_\mu$

(강신규, Arnab Dasgupta, 박명훈)

χ gets a VEV, breaking $U(1)_D$

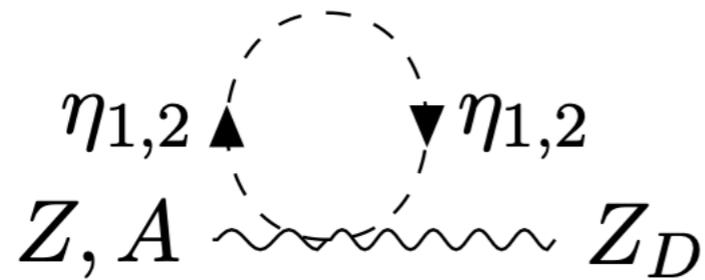
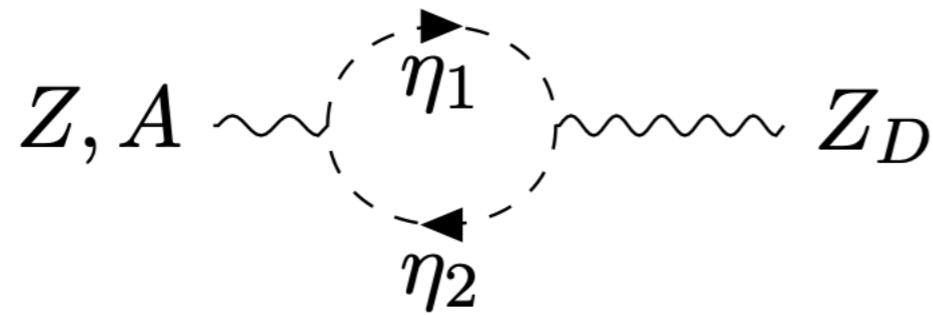
$$\chi = v_\chi + h_\chi + i\xi_\chi$$

$$\begin{pmatrix} H^0 \\ \chi \end{pmatrix} = \begin{pmatrix} \cos \theta & \sin \theta \\ -\sin \theta & \cos \theta \end{pmatrix} \begin{pmatrix} h_1 \\ h_2 \end{pmatrix}$$

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Scotogenic model + $U(1)_D + (g-2)_\mu$

(강신규, Arnab Dasgupta, 박명훈)



$$\begin{pmatrix} \hat{A}_\mu \\ \hat{Z}_\mu \\ \hat{V}_\mu \end{pmatrix} = \begin{pmatrix} 1 & 0 & -\frac{\epsilon}{D} \\ 0 & 1 & -\frac{\epsilon Z_V}{D} \\ 0 & 0 & \frac{1}{D} \end{pmatrix} \begin{pmatrix} A_\mu \\ Z_\mu \\ Z'_\mu \end{pmatrix}$$

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with $\epsilon = \frac{eg_D}{48\pi^2} \ln \left(\frac{M_{\eta_1}^2}{M_{\eta_2}^2} \right)$ & neutral component of these $\eta_{1,2}$ can be **DM**

Scotogenic model + $U(1)_D + (g - 2)_\mu$

(강신규, Arnab Dasgupta, 박명훈)

- by dark scalar χ through $H - \chi$ mixing
- by dark photon through $A - A_D$ mixing
- by inert-doublet and neutral fermion

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$$\Delta a_\mu = \Delta a_\mu(Z') + \Delta a_\mu(\eta, N)$$

+
-

I ignore two-loop Barr-Zee contribution and light dark scalar

Study points

- Mass of lightest inert neutral scalar $\geq \mathcal{O}(500) \text{ GeV}$
- Mass splitting between η_{DMR} and $\eta_{DMI} \sim \mathcal{O}(KeV)$ to avoid DM-DD constraints with Z boson mediation.
- Mass of Dark photon $\sim 100 \text{ MeV}$

$$1\text{GeV} \lesssim m_{\eta_1} \lesssim 1000\text{GeV},$$

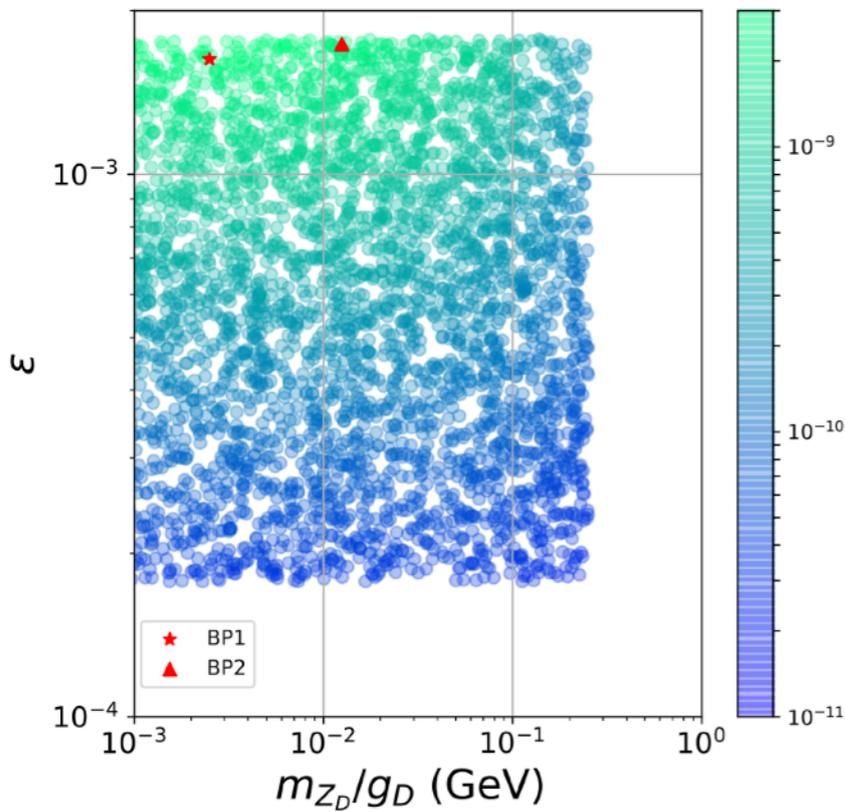
$$0.1 \lesssim g_D \lesssim 1,$$

$$m_{\eta_2} = 4m_{\eta_1},$$

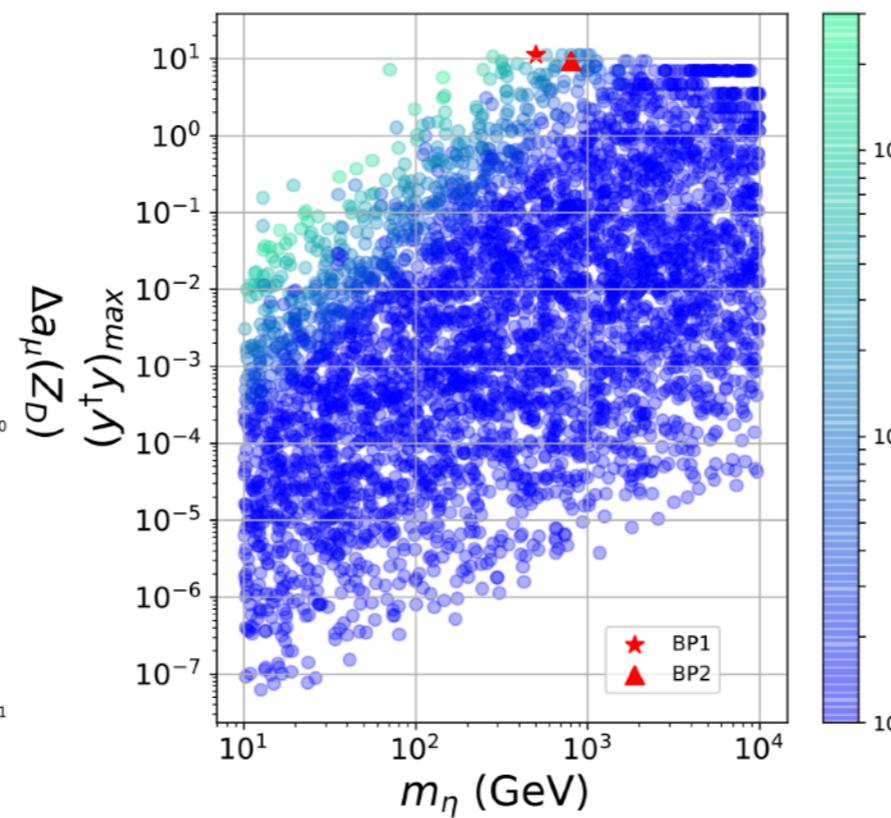
$$m_{\phi} = 5m_{\eta_1},$$

$$m_{N_i} = m_{\eta_1}.$$

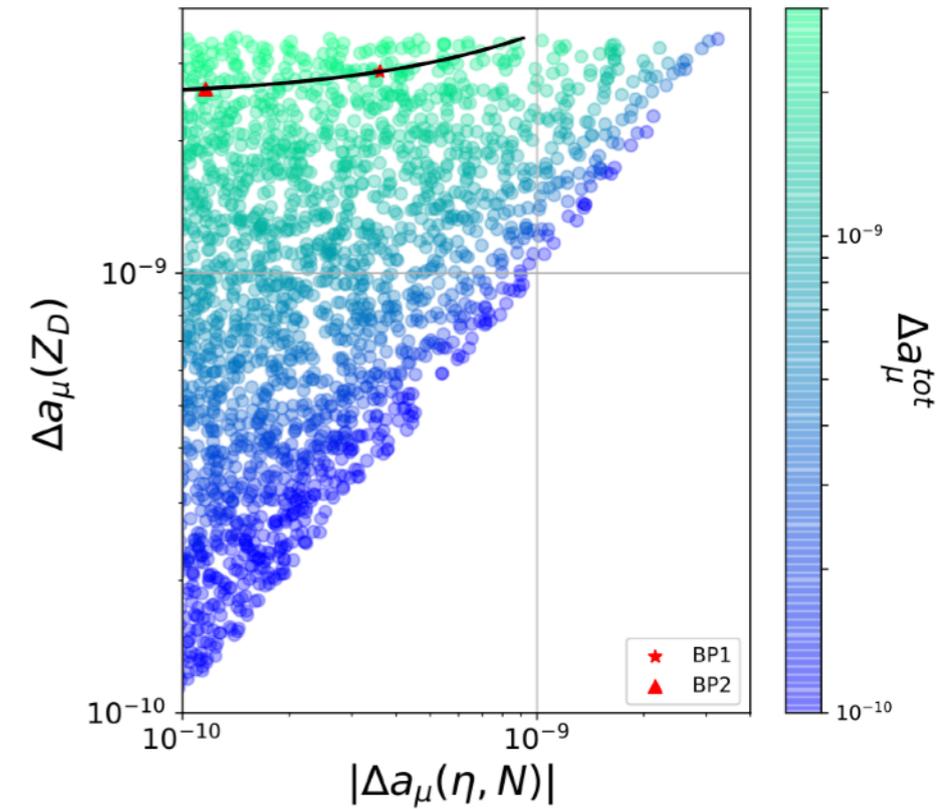
Study points



dark photon
phenomenology



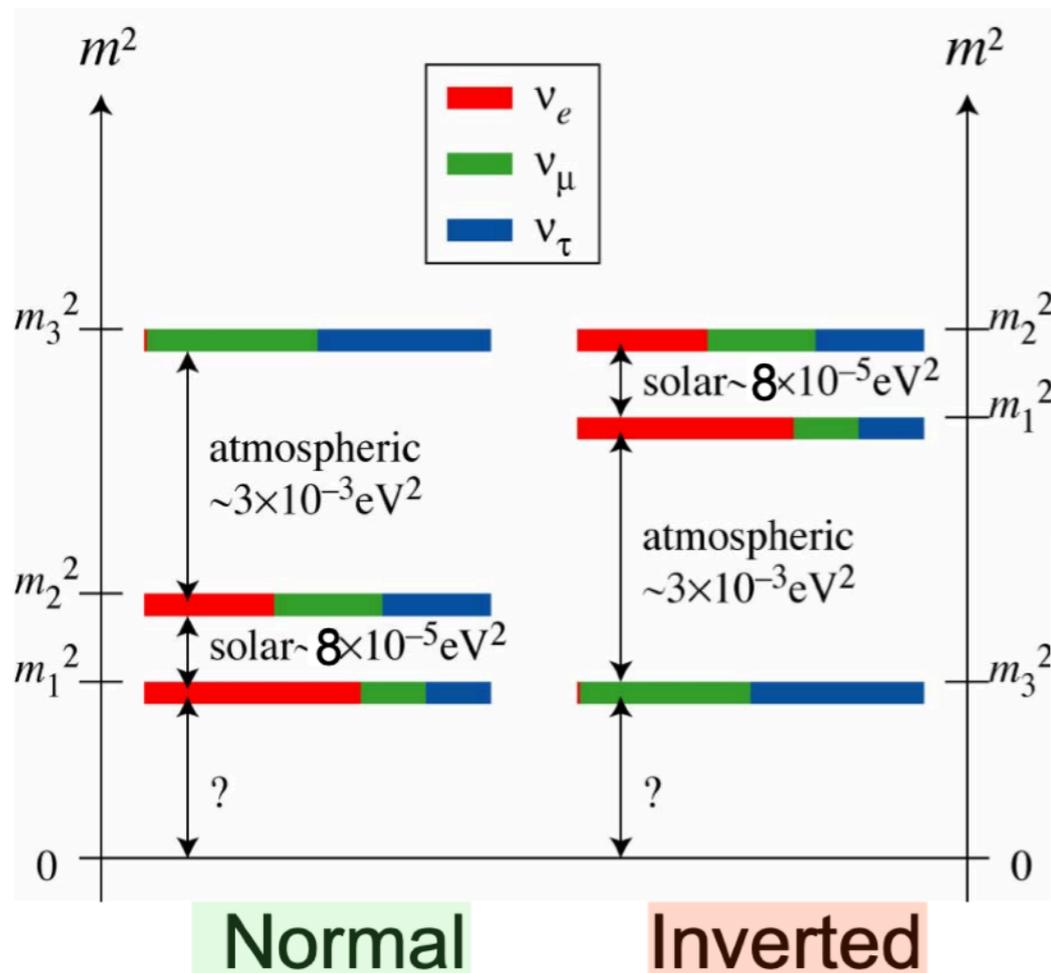
Dark matter
yukawa for ν



relative contribution
to $(g - 2)_\mu$

결론

- 중성미자 질량 + 암흑물질 + 뮤온 (g-2) 이상현상을 동시에 설명할 수 있는 모델 제안
- (g-2)에 대한 암흑광자와 암흑섹터 스칼라 입자들의 서로 다른 부호의 기여.



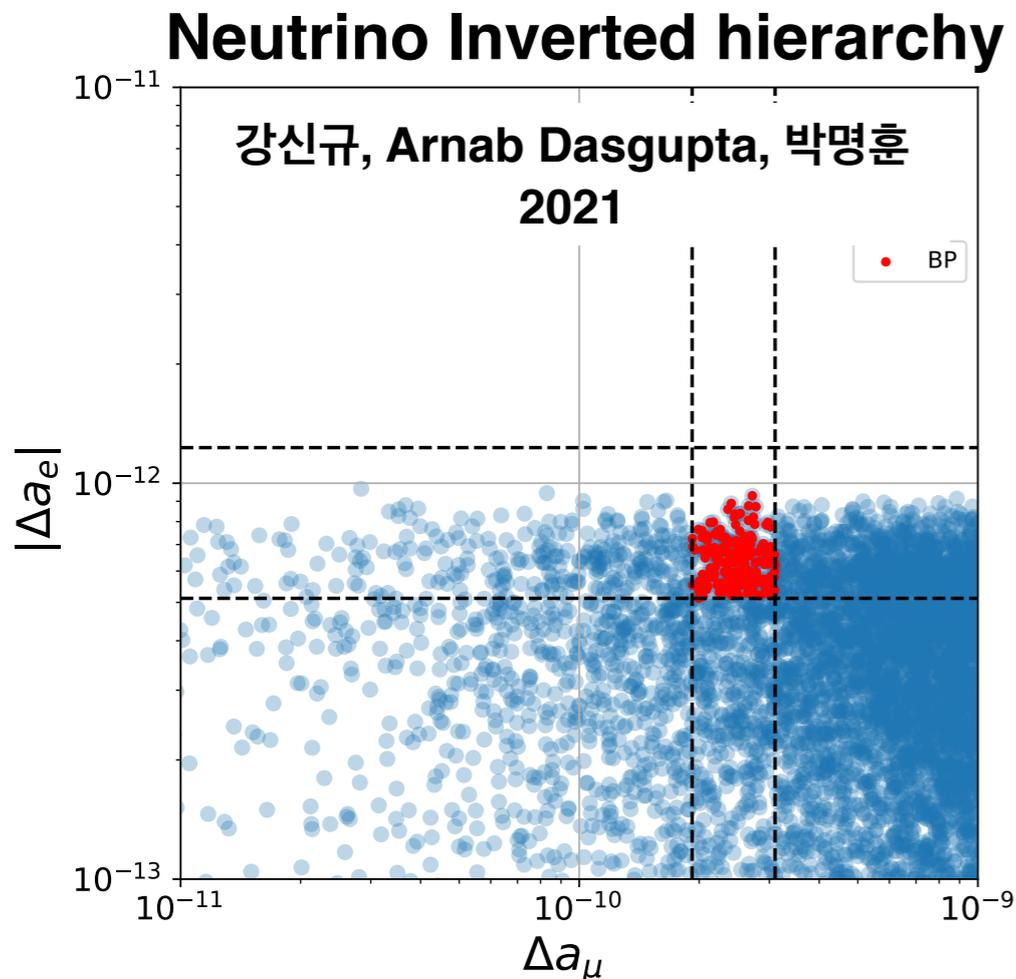
$$\Delta a_\mu = \Delta a_\mu(Z') + \Delta a_\mu(\eta, N)$$

$$\Delta a_\mu \equiv a_\mu^{\text{exp}} - a_\mu^{\text{SM}} = 261(79) \times 10^{-11}$$

$$\Delta a_e \equiv a_e^{\text{exp}} - a_e^{\text{SM}} = -88(36) \times 10^{-14}$$

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+ -

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