

Connection to other RF: Muon $g-2$ and LFV

Accelerator Based Dark Sector
Searches Agora

Apr/22/2022

Rodolfo Capdevilla
Perimeter Institute for Theoretical Physics
and University of Toronto

Outline

1. Muon Anomalous Magnetic Moment

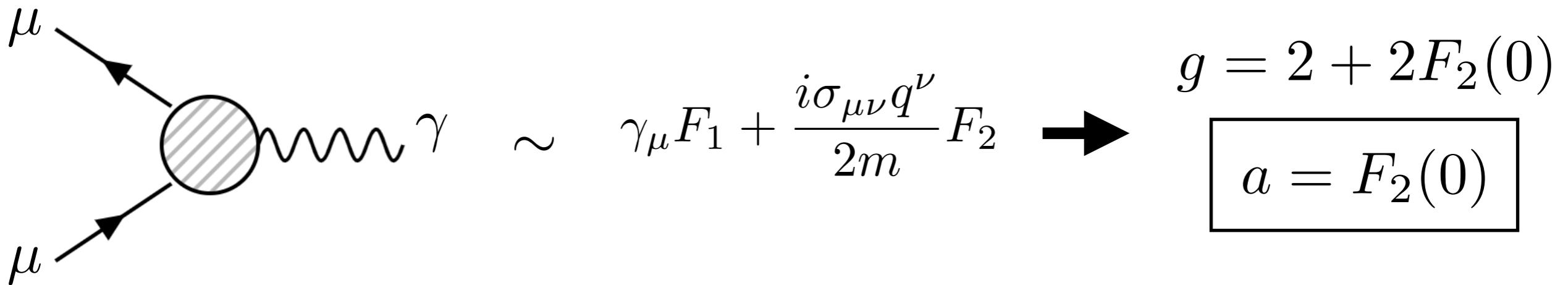
- Dark sectors
- Accelerator searches

2. Lepton Flavor Violation

- Searches for LFV
- Fixed-target searches?

3. Summary

1. Muon Anomalous Magnetic Moment



$$a_\mu^{\text{exp}} = 116592061(41) \times 10^{-11}$$

Muon g-2 Collaboration (BNL), Phys. Rev. D 73 (2006) 072003
 Muon g-2 Collaboration (FNAL), Phys. Rev. Lett. 126 (2021) 14, 141801

$$a_\mu^{\text{QED}} = 116584718.931(104) \times 10^{-11}$$

$$a_\mu^{\text{EW}} = 153.6(1.0) \times 10^{-11}$$

$$a_\mu^{\text{HVP}} = 6845(40) \times 10^{-11}$$

$$a_\mu^{\text{HLbL}} = 106.8(14.7) \times 10^{-11}$$

T. Aoyama, T. Kinoshita, M. Nio, Atoms 7, 28 (2019)

A. Czarnecki et al., Phys. Rev. D 67, 073006 (2003)

A. Czarnecki et al., Phys. Rev. D 73, 119901 (2006)

C. Gnendiger et al., Phys. Rev. D 88, 053005 (2013)

M. Davier et al., Eur. Phys. J. C 77 (2017) 12, 827

M. Hoferichter et al., JHEP 08 (2019) 137

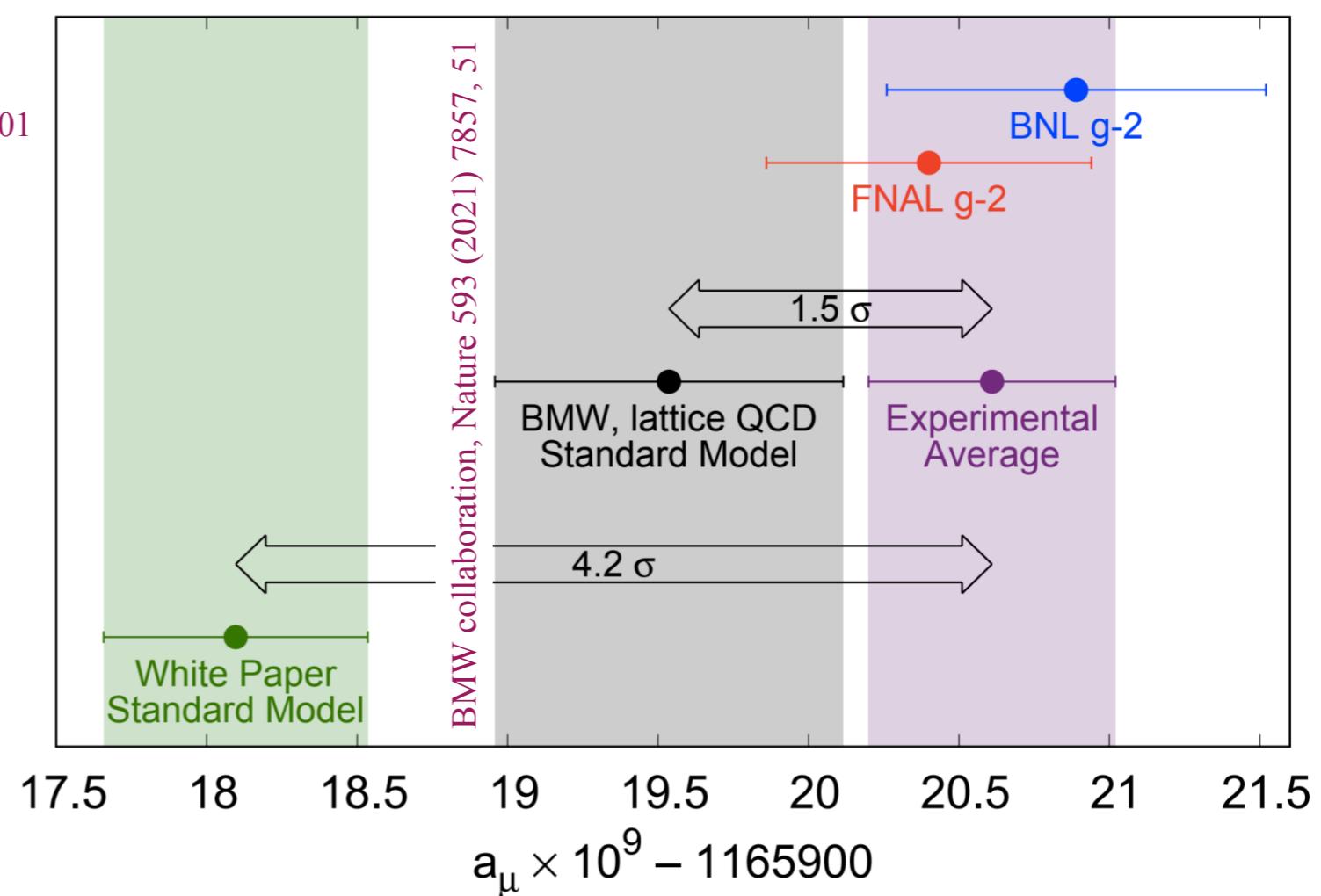
A. Kurz et al., Phys. Lett. B 734 (2014) 144-147

K. Melnikov, A. Vainshtein, Phys. Rev. D 70 (2004) 113006

V. Pauk, M. Vanderhaeghen, Eur. Phys. J. C 74 (2014) 8, 3008

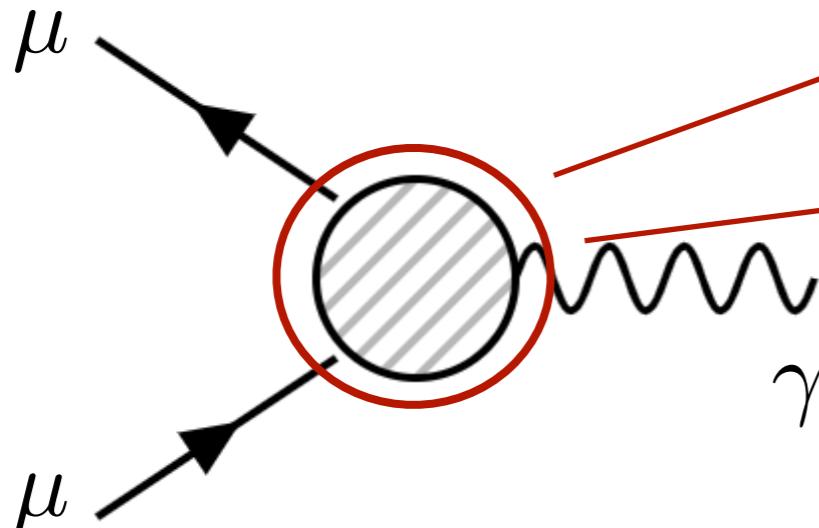
T. Blum et al., Phys. Rev. Lett. 124 (2020) 13, 132002

En-Hung Chao et al., Eur. Phys. J. C 81 (2021) 7, 651

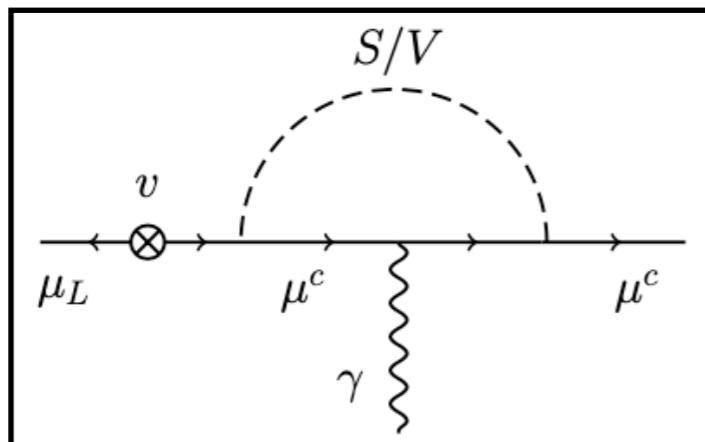


1. Muon Anomalous Magnetic Moment

- Ingredients for $(g-2)\mu$

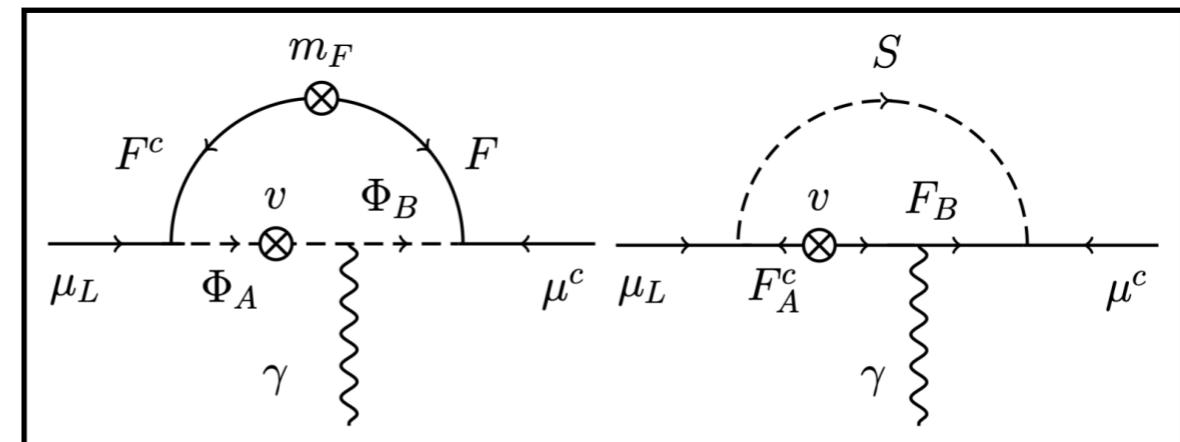


Capdevilla, Curtin, Kahn, Krnjaic, Phys. Rev. D 103 (2021) 7, 075028
Capdevilla, Curtin, Kahn, Krnjaic, Phys. Rev. D 105 (2022) 1, 015028
Capdevilla, Curtin, Kahn, Krnjaic, arXiv:2112.08377



Singlet Models

- Only new neutral particles!
- Relatively light particles

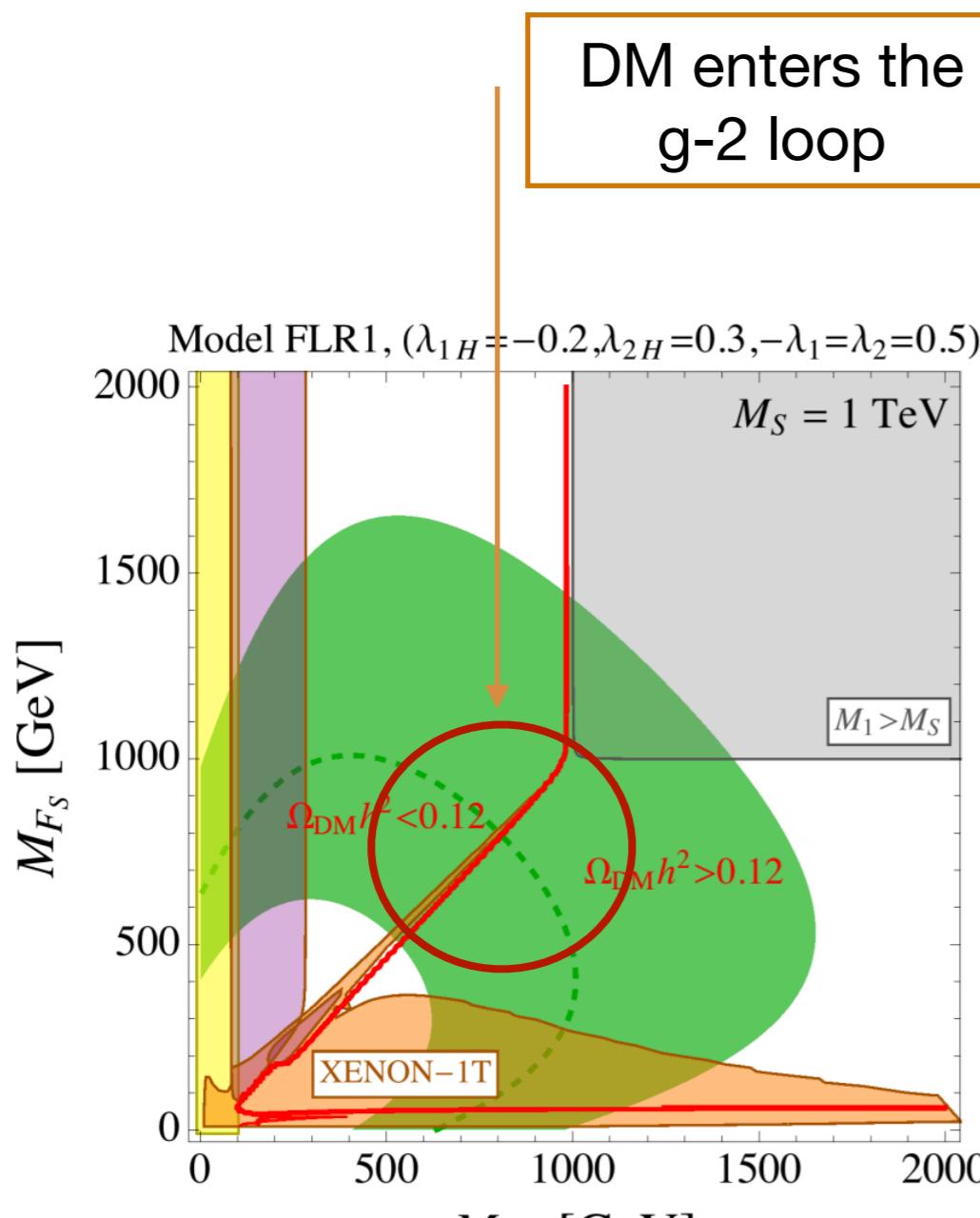


Electroweak Models

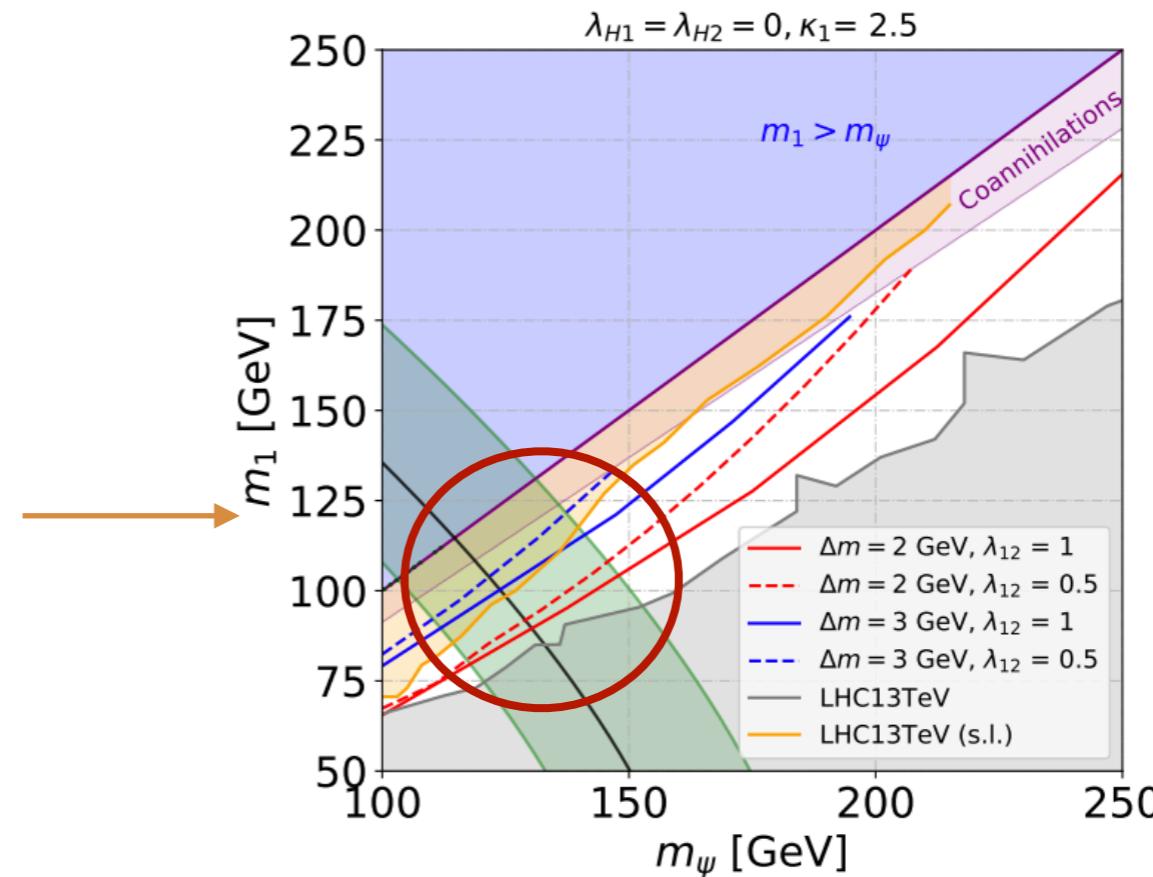
- Allow new charged particles
- Heavy particles

1. Dark Sectors

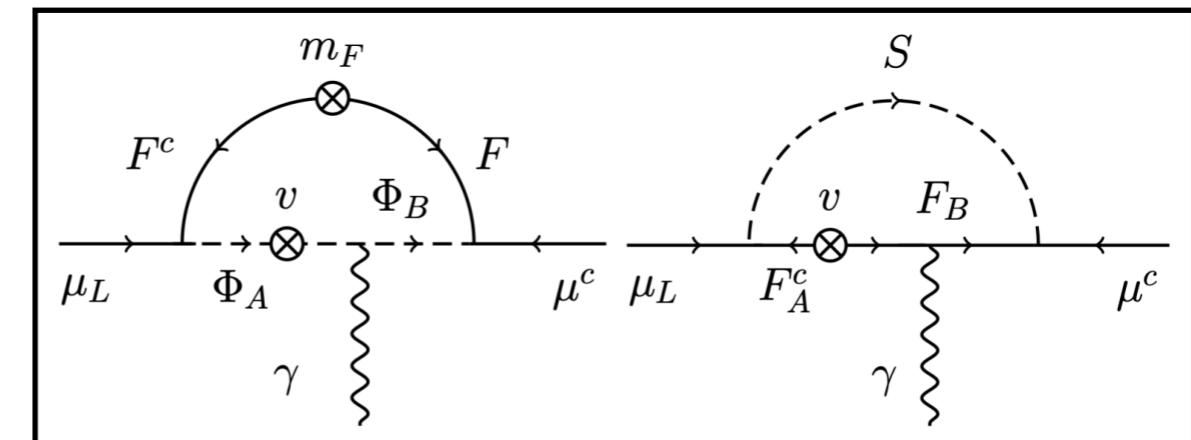
- EW Models



Calibbi, Ziegler, Zupan, JHEP 07 (2018) 046



Diaz Saez, Ghorbani, Phys. Lett. B 823 (2021) 136750

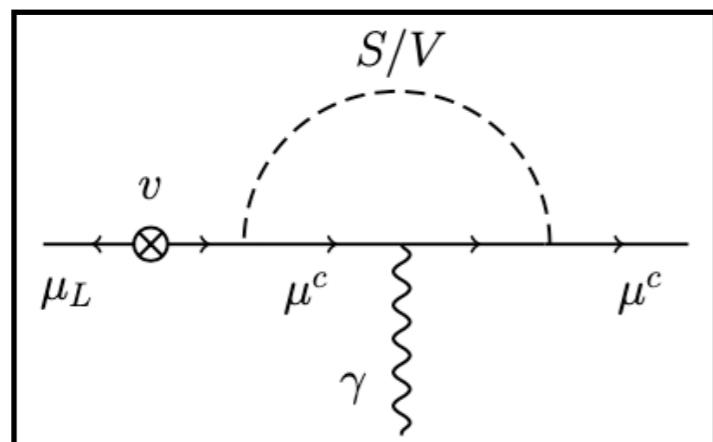


Electroweak Models

- Allow new charged particles
- Heavy particles

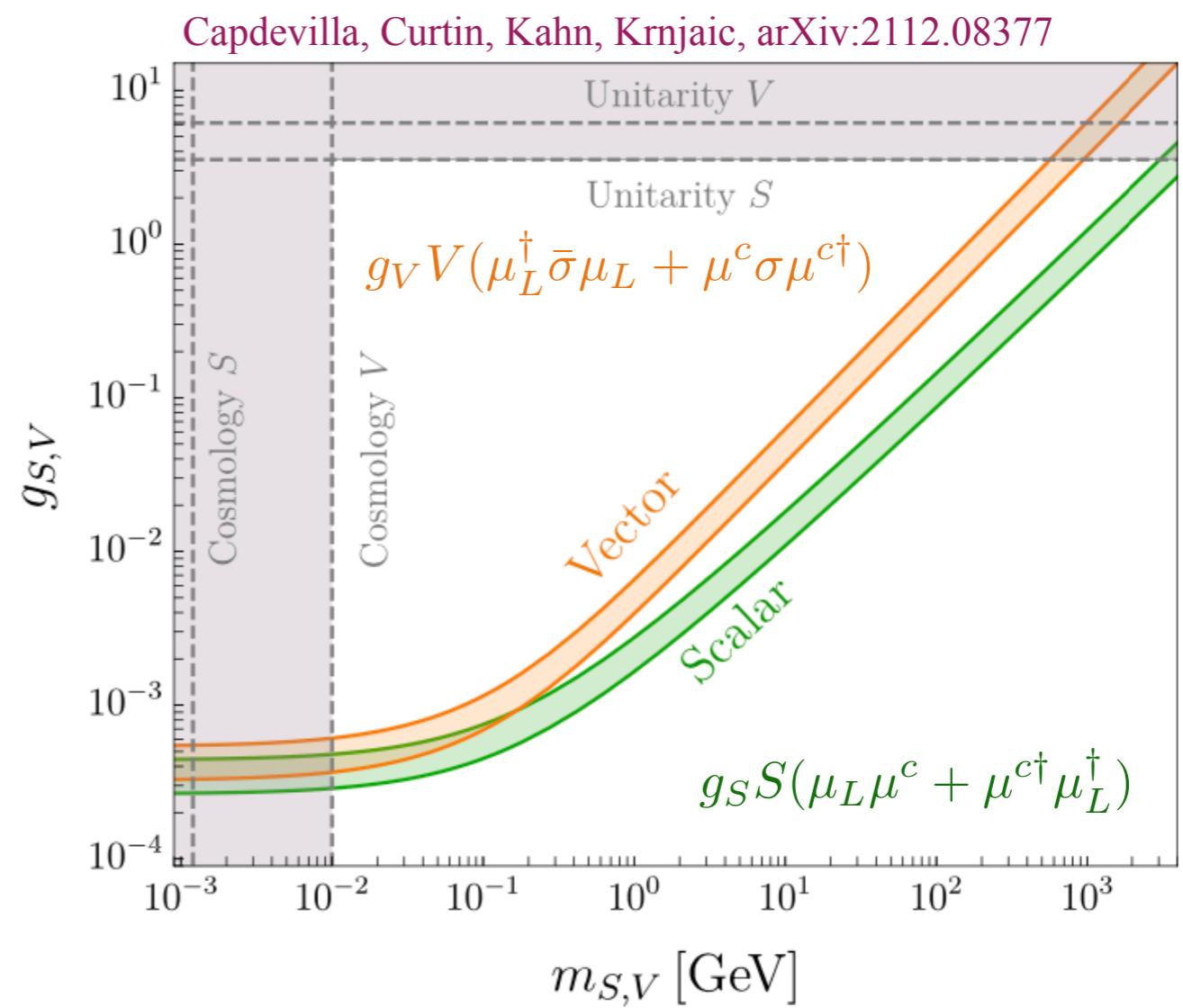
1. Dark Sectors

- Singlet Models



Singlet Models

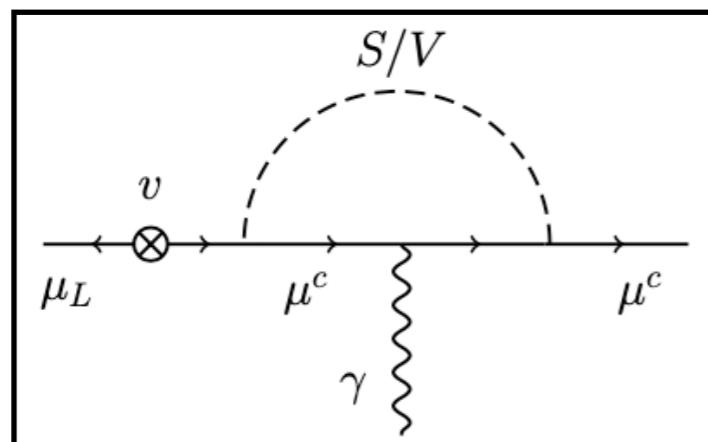
- Only new neutral particles!
- Relatively light particles



1. Dark Sectors

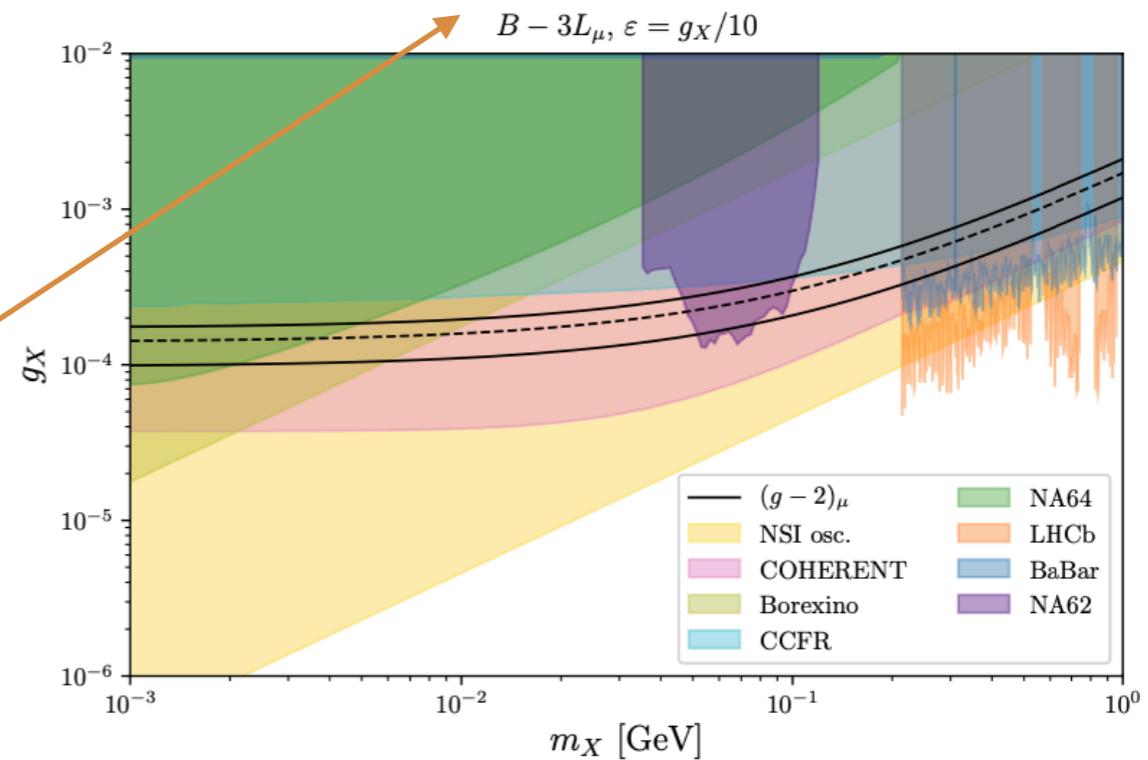
- Singlet Models

- Models coupling to B or e are highly constrained
- Models coupling to 2nd and 3rd generation of leptons have some parameter space open

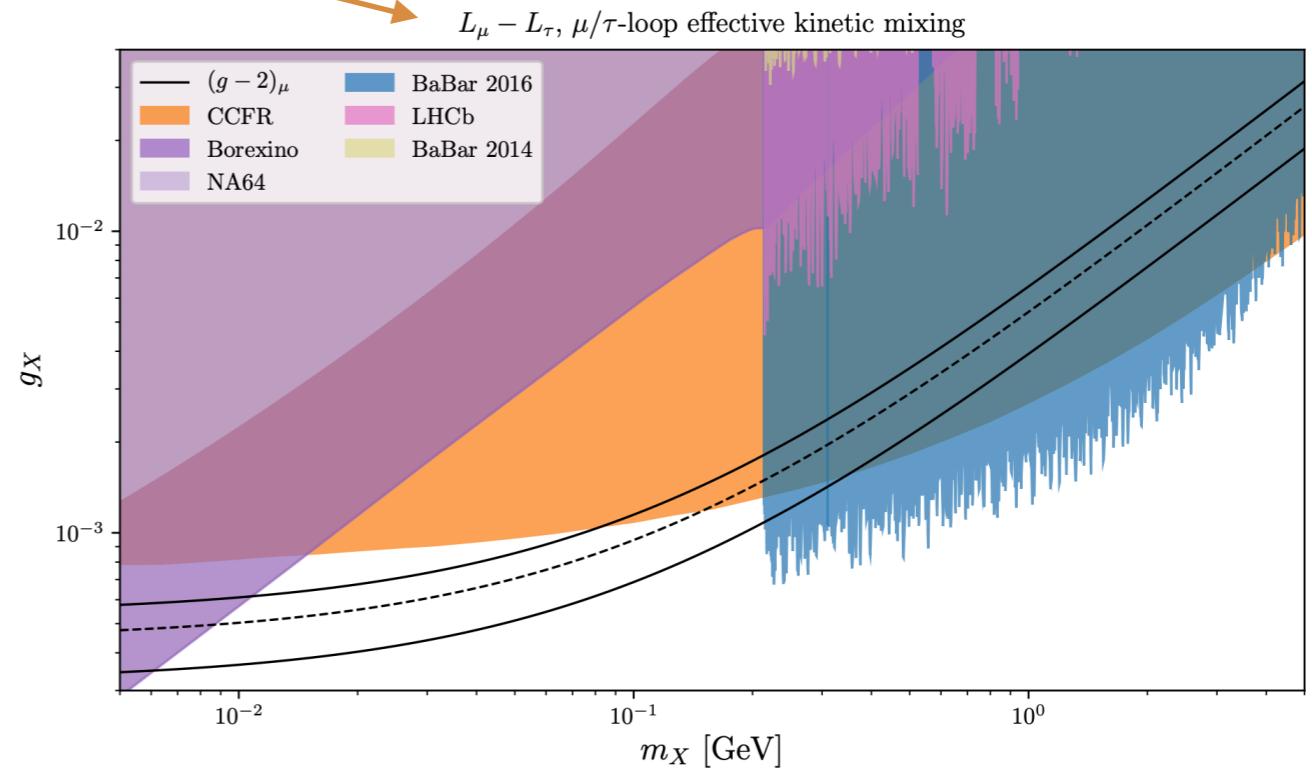


Singlet Models

- Only new neutral particles!
- Relatively light particles



Greljo, Soreq, Stangl, Eller Thomsen, Zupan, arXiv:2107.07518

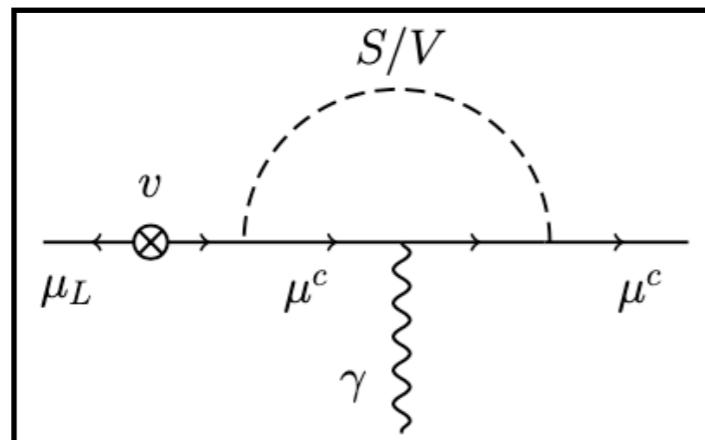


Greljo, Stangl, Eller Thomsen, Zupan, arXiv:2203.13731

1. Dark Sectors

- Singlet Models

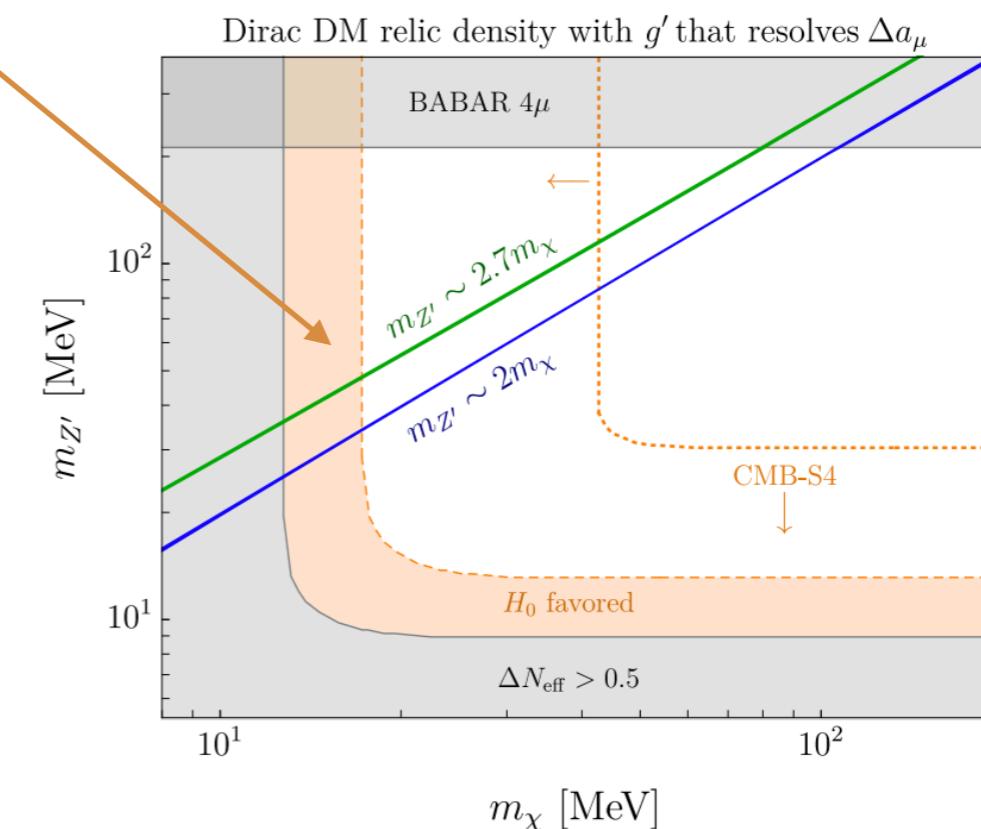
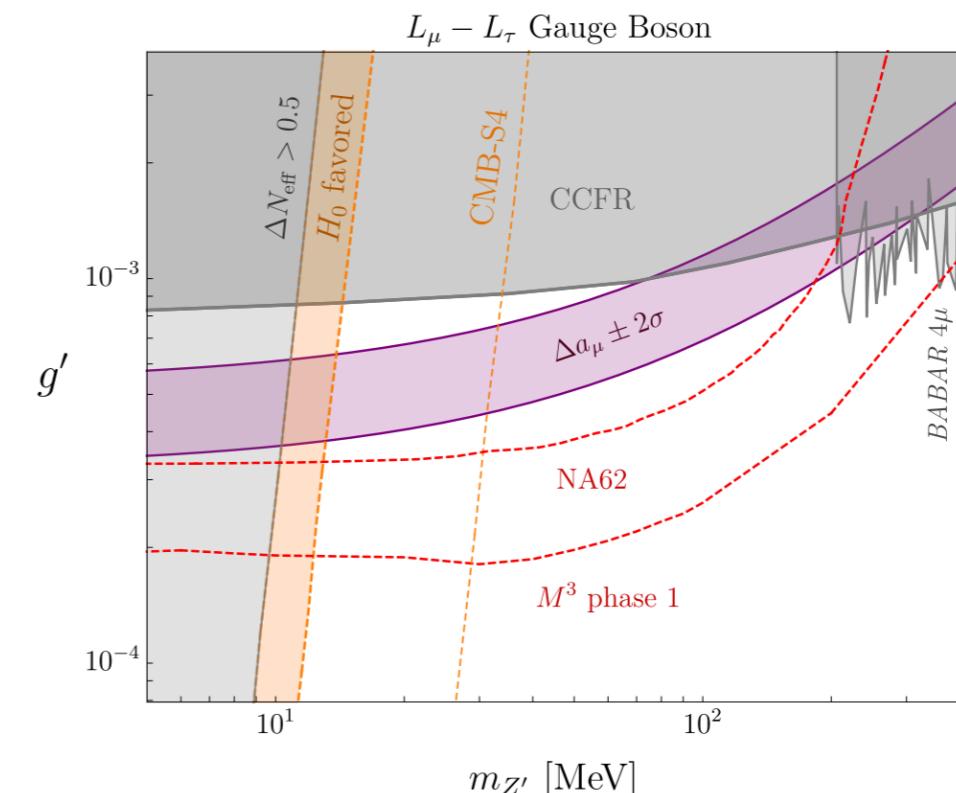
- Singlets communicate muons with DM
- Saturate the relic density for specific mass ratios



Singlet Models

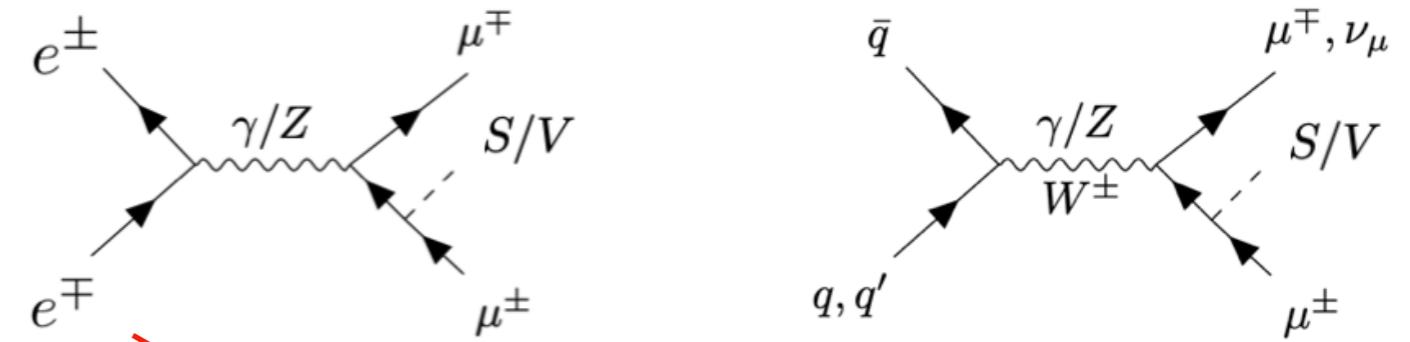
- Only new neutral particles!
- Relatively light particles

Holst, Hooper, Krnjaic, Phys. Rev. Lett. 128 (2022) 14, 141802

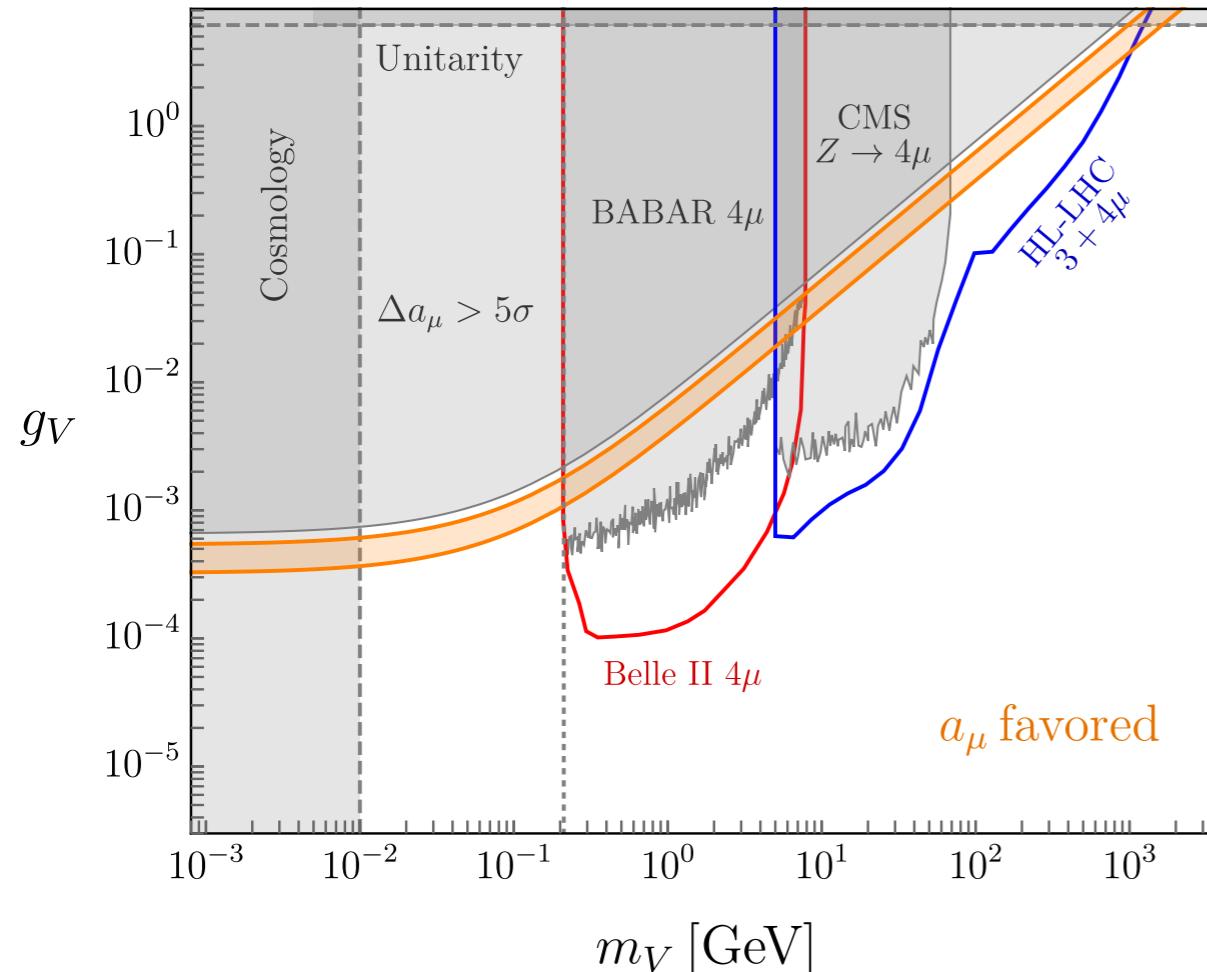


1. Accelerator Searches

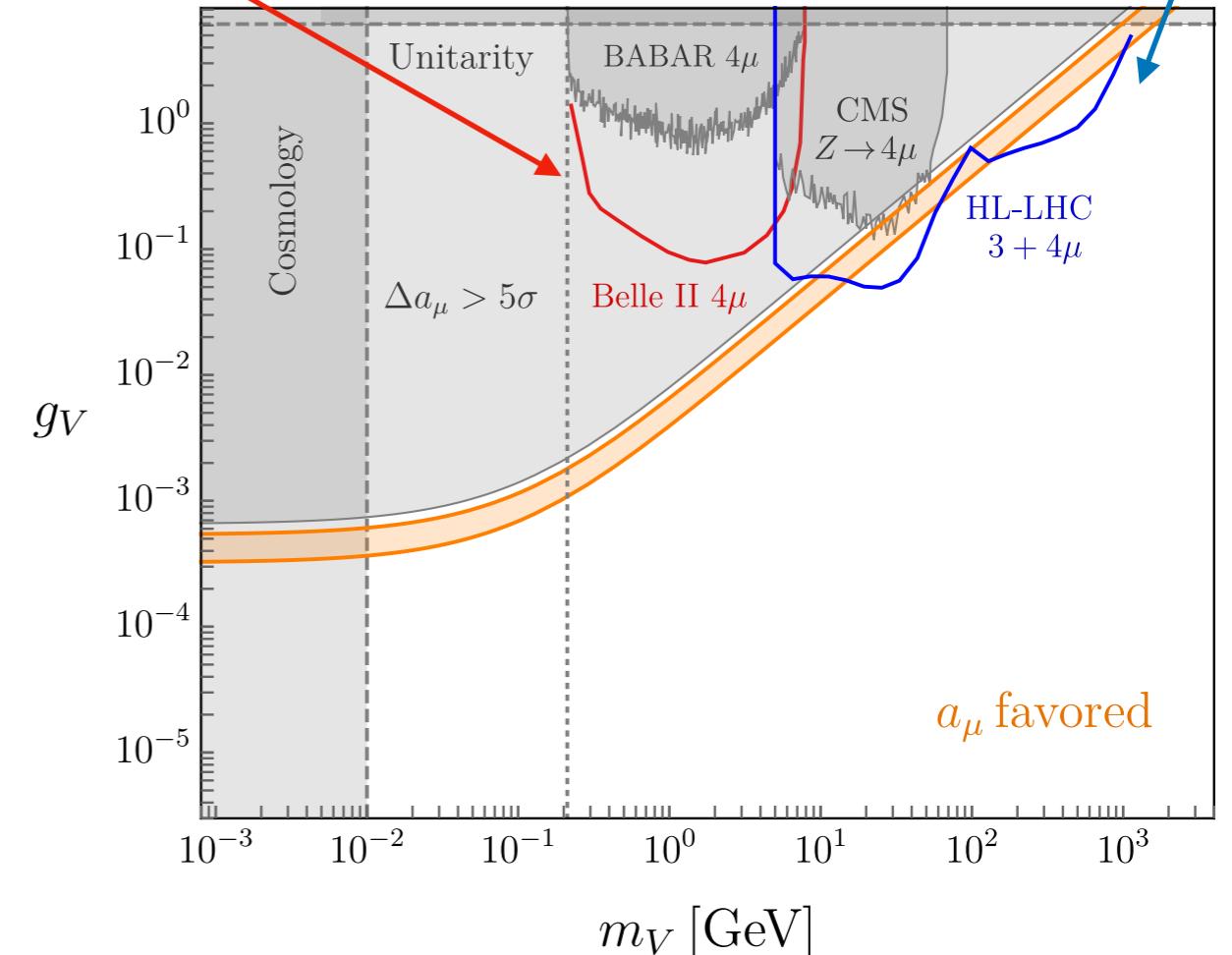
- Singlet Models



Vector, $\text{BR}(V \rightarrow \mu^+ \mu^-) = 1$ for $m_V > 2m_\mu$

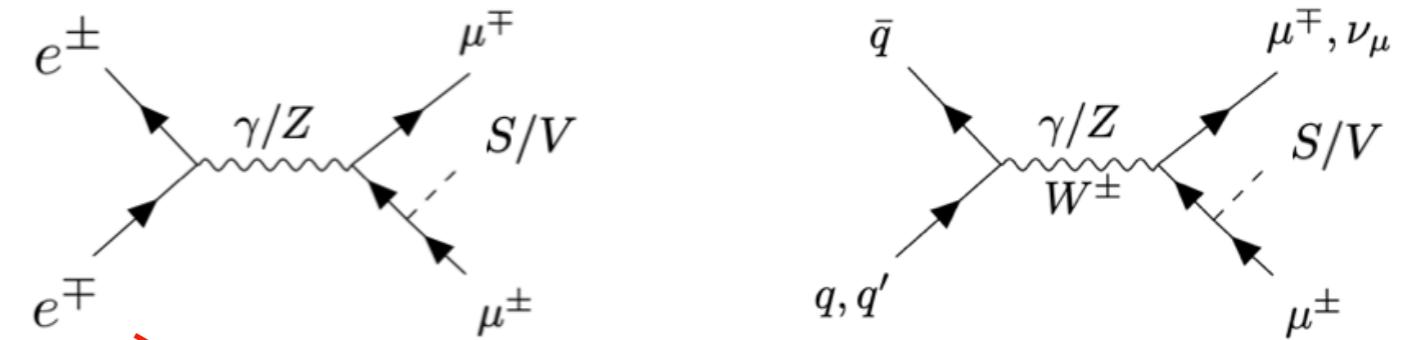


Vector, $\text{BR}(V \rightarrow \mu^+ \mu^-) = \text{min.}$ for $m_V > 2m_\mu$

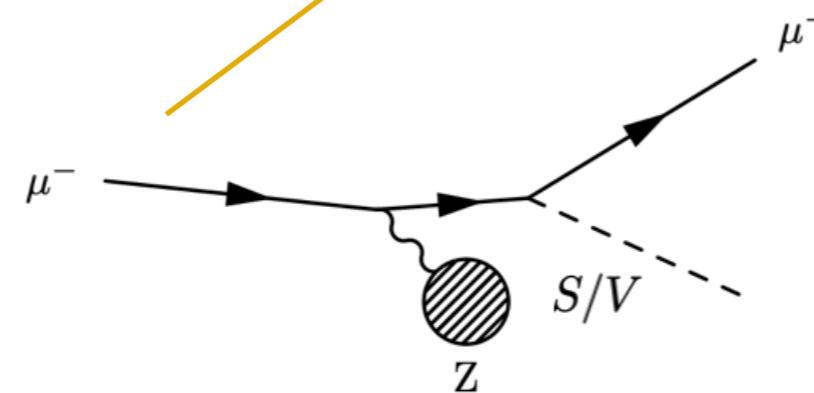
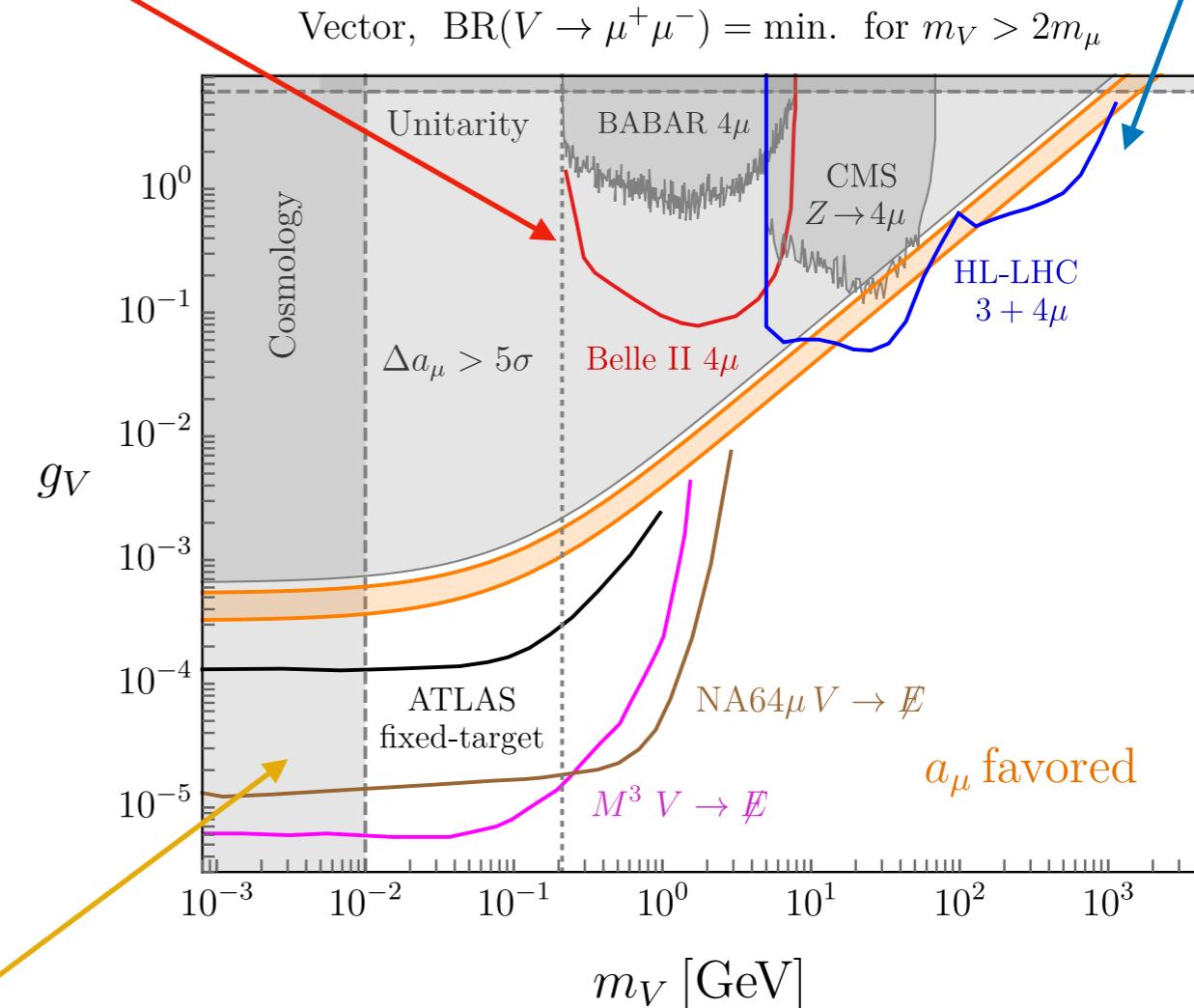
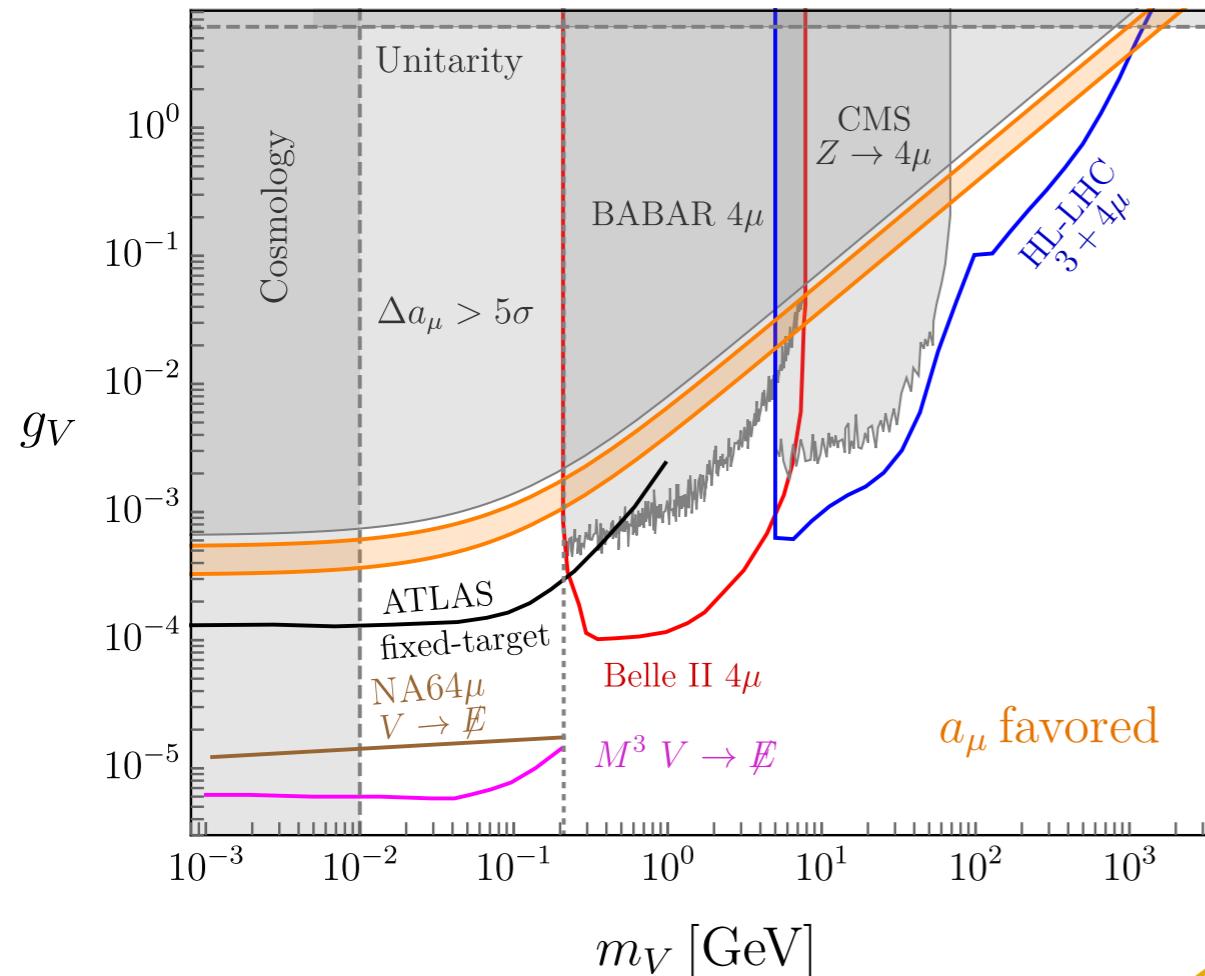


1. Accelerator Searches

- Singlet Models

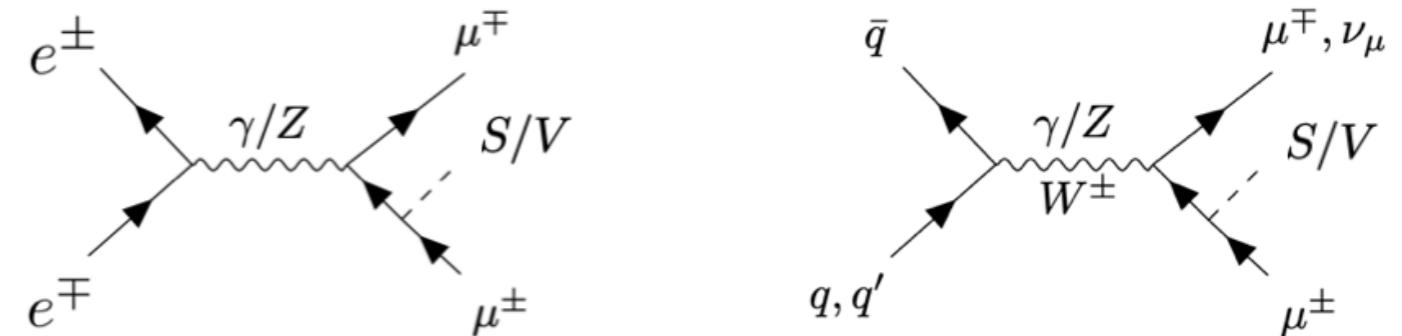


Vector, $\text{BR}(V \rightarrow \mu^+ \mu^-) = 1$ for $m_V > 2m_\mu$

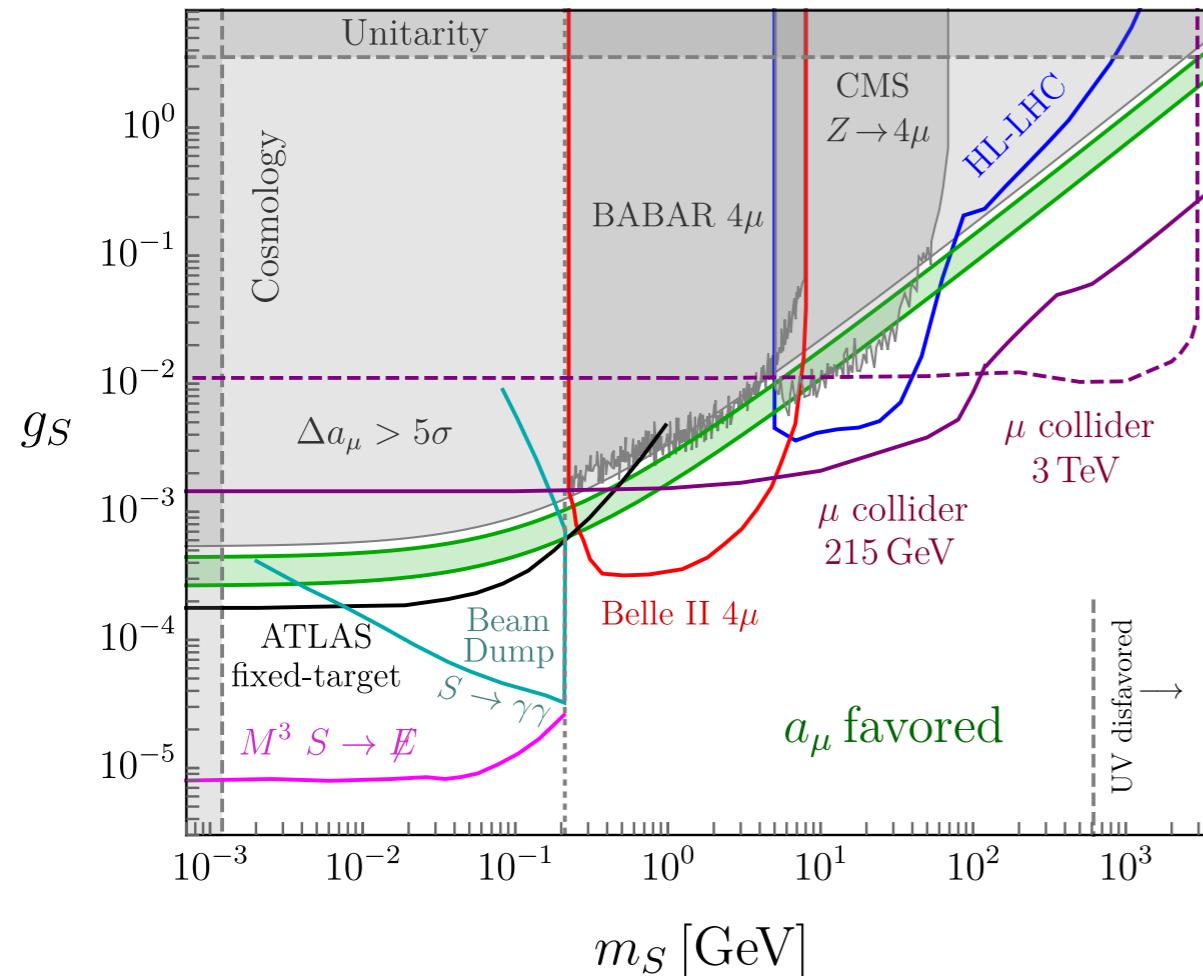


1. Accelerator Searches

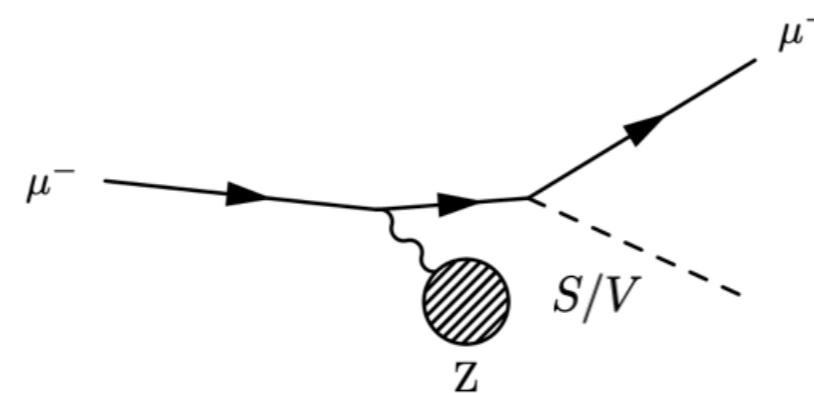
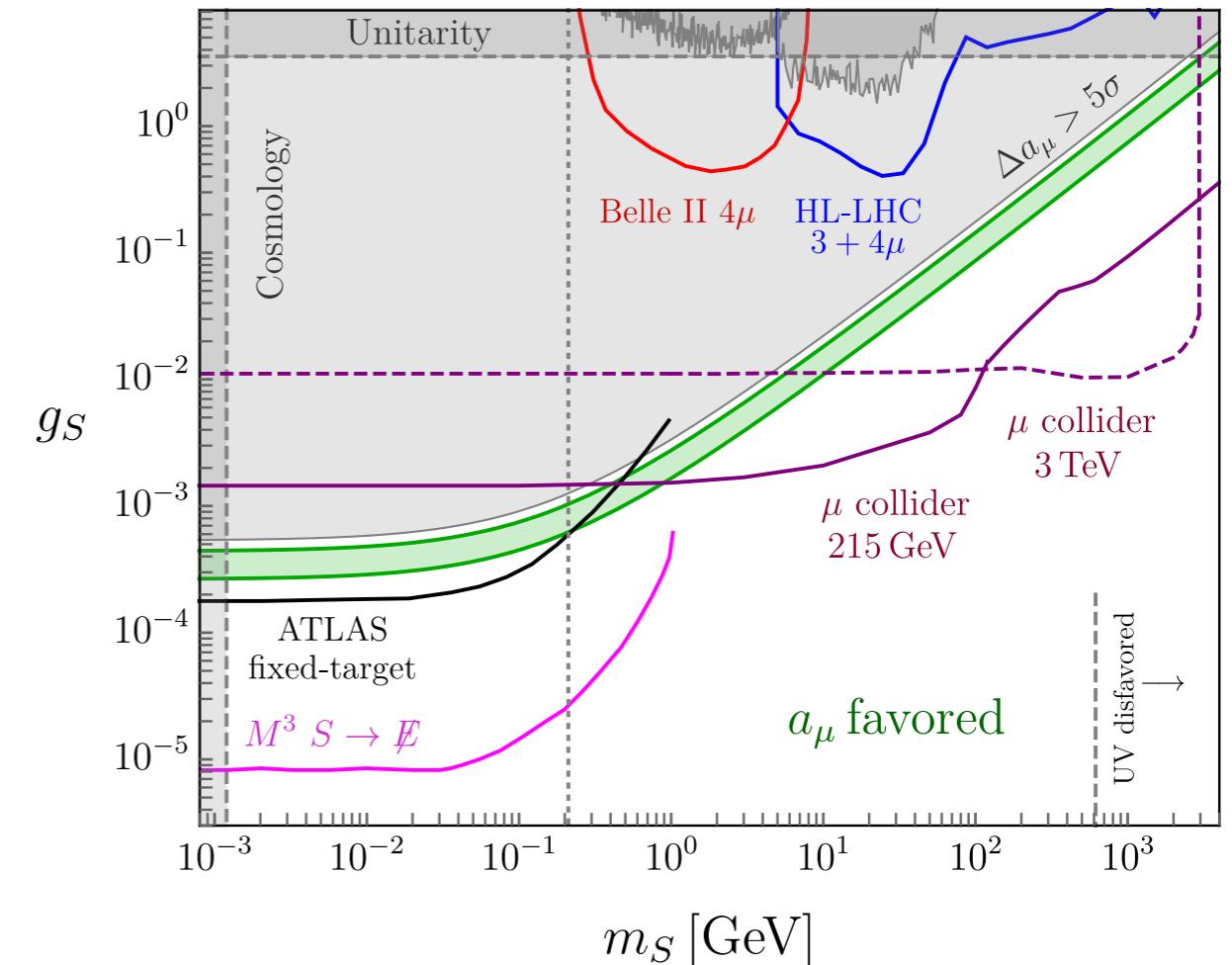
- Singlet Models



Scalar, $\text{BR}(S \rightarrow \mu^+\mu^-) = 1$ for $m_S > 2m_\mu$



Scalar, $\text{BR}(S \rightarrow \mu^+\mu^-) = \text{min.}$ for $m_S > 2m_\mu$



Outline

1. Muon Anomalous Magnetic Moment

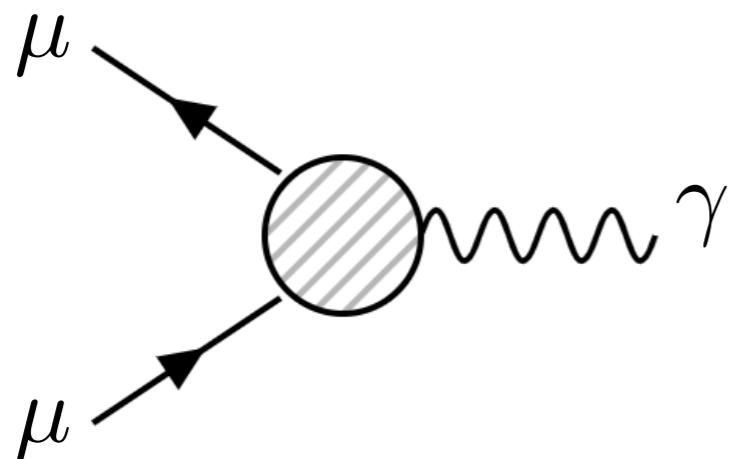
- Dark sectors
- Accelerator searches

2. Lepton Flavor Violation

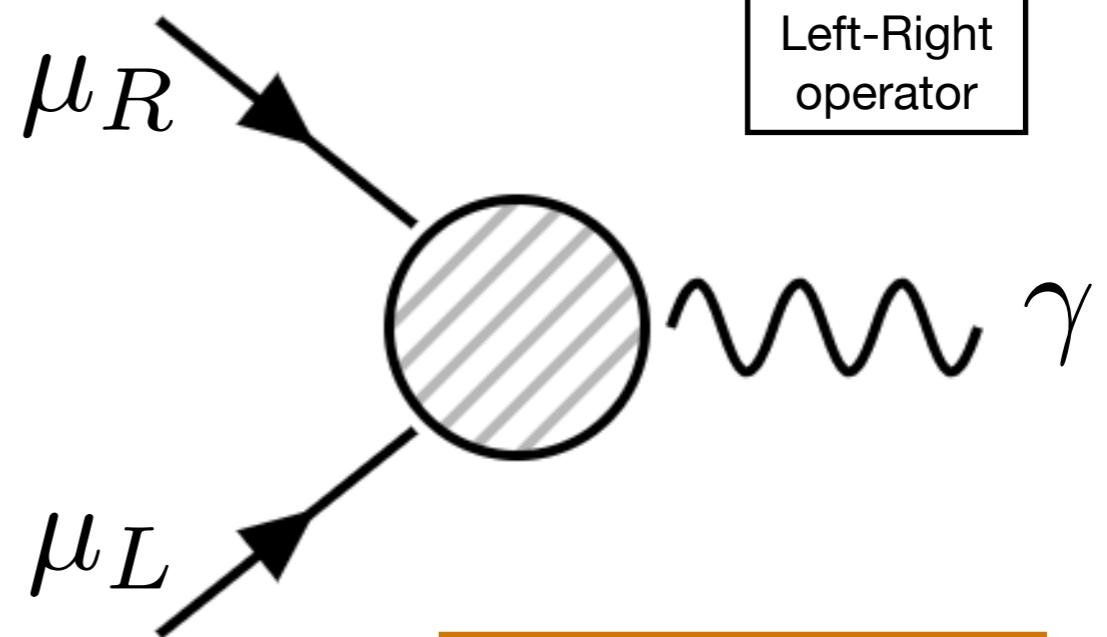
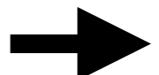
- Searches for LFV
- Fixed-target searches?

3. Summary

2. Lepton Flavor Violation

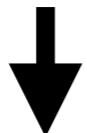


$$\gamma_\mu F_1 + \frac{i\sigma_{\mu\nu}q^\nu}{2m} F_2$$

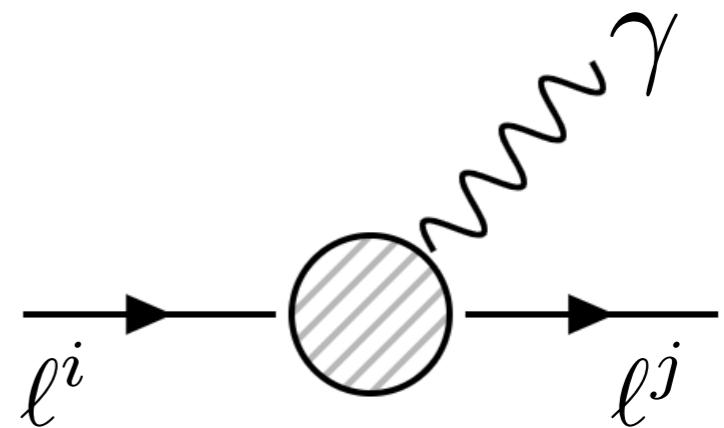


In a general flavor structure the same operator gives LFV decays!

$$\mathcal{L} = -\frac{evC_\mu}{(4\pi)^2\Lambda^2} \bar{\mu}_L \sigma_{\alpha\beta} \mu_R F^{\alpha\beta} + \text{h.c.}$$

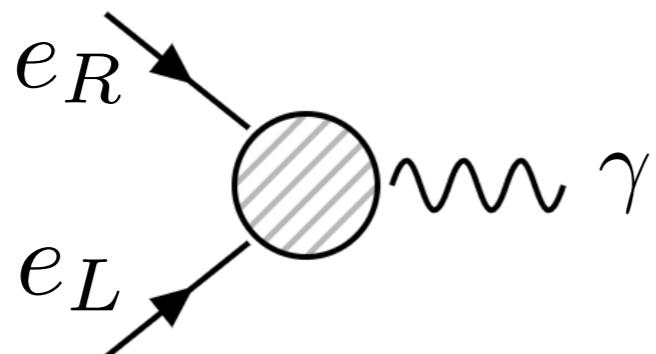


$$\mathcal{L} = -\frac{evC_{ij}}{(4\pi)^2\Lambda^2} \bar{\ell}_L^i \sigma_{\alpha\beta} \ell_R^j F^{\alpha\beta} + \text{h.c.}$$



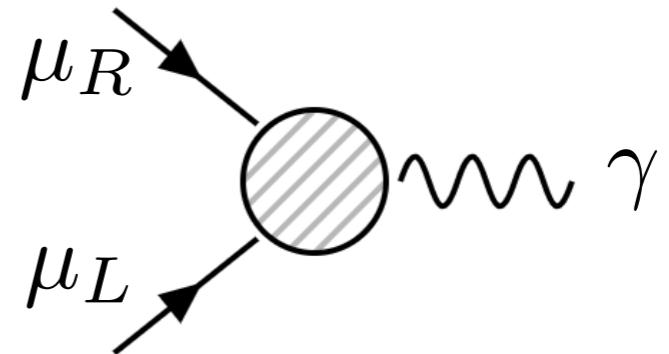
2. Lepton Flavor Violation

$$\mathcal{L} = -\frac{evC_{ij}}{(4\pi)^2 \Lambda^2} \bar{\ell}_L^i \sigma_{\alpha\beta} \ell_R^j F^{\alpha\beta} + \text{h.c.}$$



$$a_e^{\exp} = 1159652180.73(28) \times 10^{-12}$$

C11 entry given by electron magnetic moment



$$a_\mu^{\exp} = 116592061(41) \times 10^{-11}$$

C22 entry given by muon magnetic moment

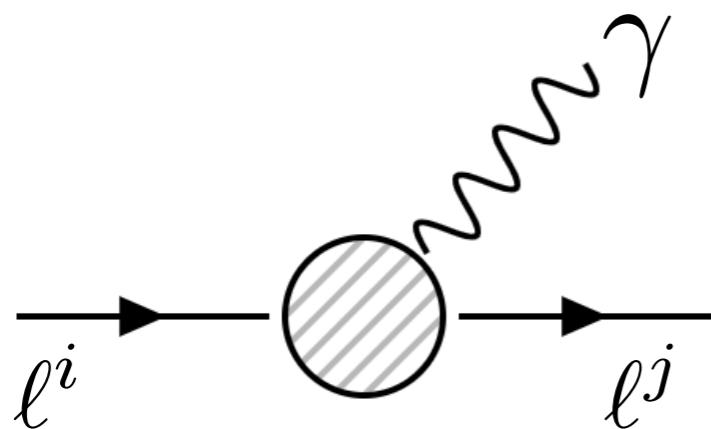
$$\frac{C_{ij}}{\Lambda^2} \sim \frac{1}{(14 \text{ TeV})^2} \left(\begin{array}{c} \lesssim 10^{-1} \\ \sim 10^{-5} \\ \lesssim 10^{-1} \\ \sim 10^{-1} \\ \lesssim 10^5 \end{array} \right)$$

Real coefficients

Poorly constrained

2. Lepton Flavor Violation

$$\mathcal{L} = -\frac{evC_{ij}}{(4\pi)^2 \Lambda^2} \bar{\ell}_L^i \sigma_{\alpha\beta} \ell_R^j F^{\alpha\beta} + \text{h.c.}$$



$$\text{Br}(\mu \rightarrow e\gamma) < 4.2 \times 10^{-13}$$

$$\text{Br}(\tau \rightarrow \mu\gamma) < 4.4 \times 10^{-8} \quad (\text{also})$$

$$\text{Br}(\tau \rightarrow e\gamma) < 3.3 \times 10^{-8}$$

$\mu \rightarrow eee$
 $\mu \rightarrow e$
 conversion
 $\tau \rightarrow \mu\mu\mu$
 $\tau \rightarrow \mu\mu e$
 $\tau \rightarrow \mu ee$
 $\tau \rightarrow eee$

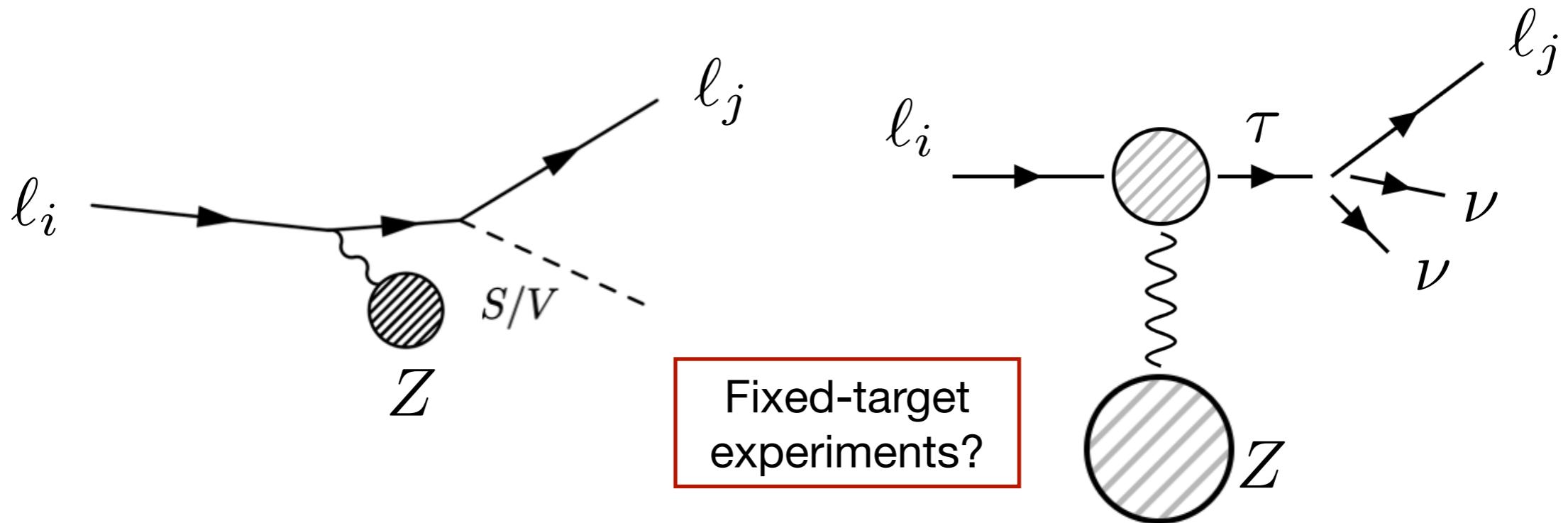
Off-diagonal entries
constrained by LFV
radiative decays

$$\frac{C_{ij}}{\Lambda^2} \sim \frac{1}{(14 \text{ TeV})^2} \left(\begin{array}{cccc} \lesssim 10^{-1} & & & \\ & \lesssim 10^{-5} & \lesssim 10^{-1} & \\ & 1 & & \\ & & \lesssim 10^{-1} & \\ & & & \lesssim 10^5 \end{array} \right)$$

Real
coefficients

2. Lepton Flavor Violation

$$\mathcal{L} = -\frac{evC_{ij}}{(4\pi)^2 \Lambda^2} \bar{\ell}_L^i \sigma_{\alpha\beta} \ell_R^j F^{\alpha\beta} + \text{h.c.}$$

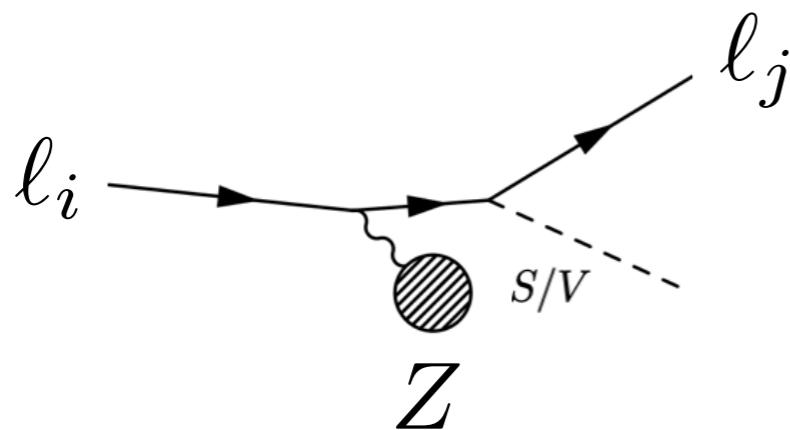


$$\frac{C_{ij}}{\Lambda^2} \sim \frac{1}{(14 \text{ TeV})^2} \left(\begin{array}{cc} \lesssim 10^{-1} & \lesssim 10^{-5} \\ 1 & \end{array} \right)$$

Real coefficients

2. Lepton Flavor Violation

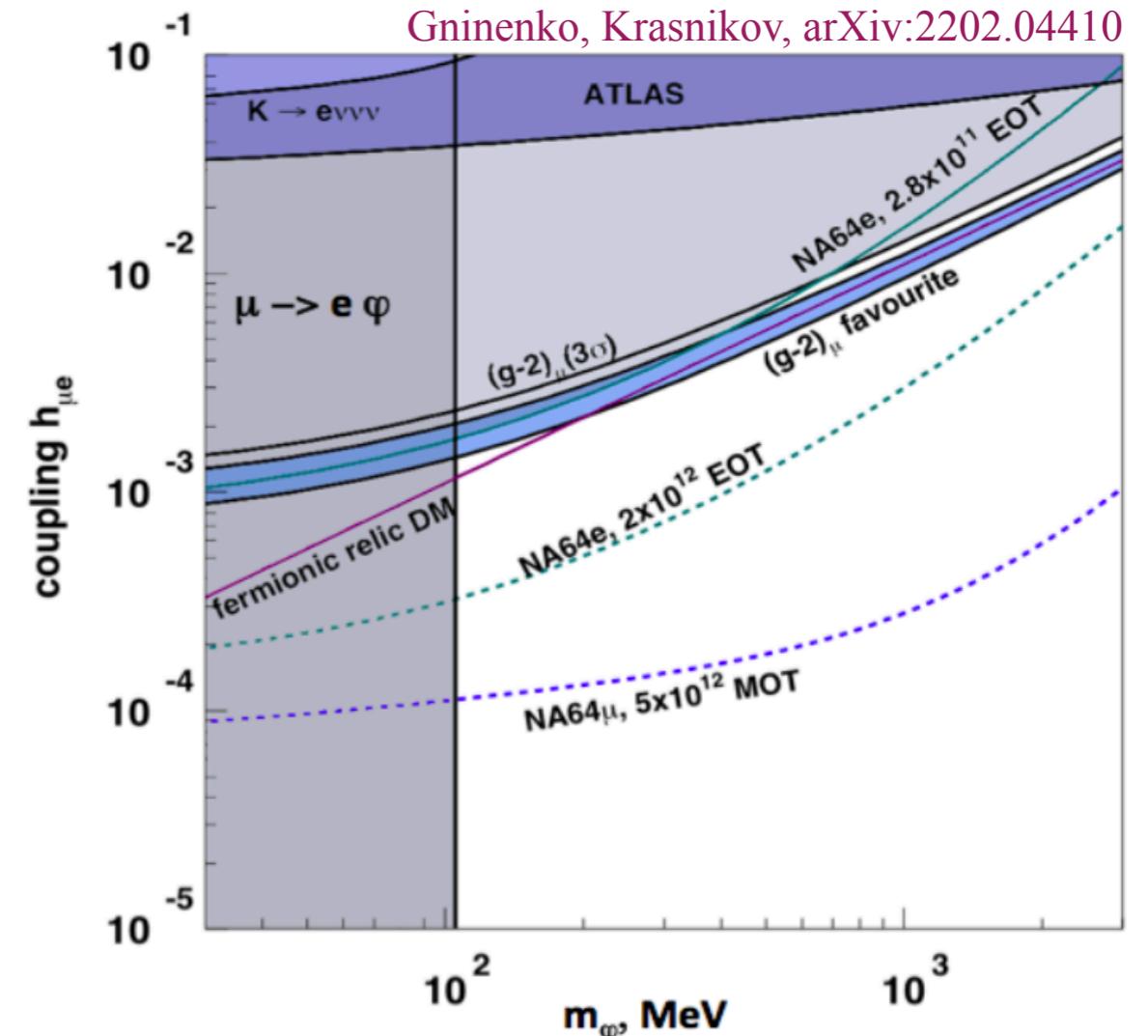
$$\mathcal{L} = -\frac{evC_{ij}}{(4\pi)^2 \Lambda^2} \bar{\ell}_L^i \sigma_{\alpha\beta} \ell_R^j F^{\alpha\beta} + \text{h.c.}$$



Fixed-target
experiments?

$$\frac{C_{ij}}{\Lambda^2} \sim \frac{1}{(14 \text{ TeV})^2} \left(\begin{array}{ccc} \lesssim 10^{-1} & \lesssim 10^{-5} & \lesssim 10^{-1} \\ & 1 & \\ \lesssim 10^{-5} & \lesssim 10^{-1} & \lesssim 10^5 \end{array} \right)$$

Real
coefficients



Thanks!