SUSY in light of muon g-2 and CLFV

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Outline

1 Introduction to SUSY

2 SUSY confronted with muon g-2

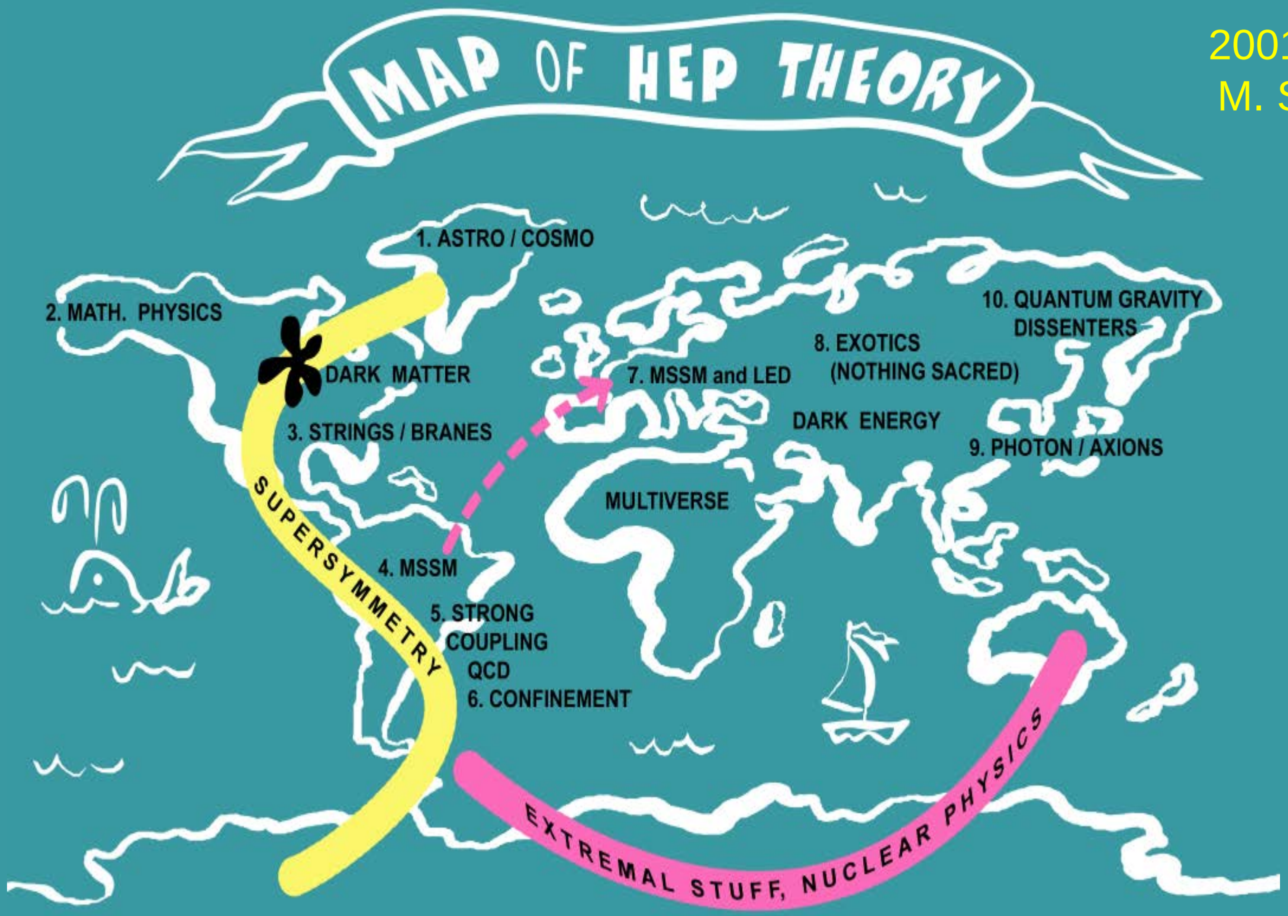
- **Can SUSY jointly explain muon g-2 and W-mass ?**

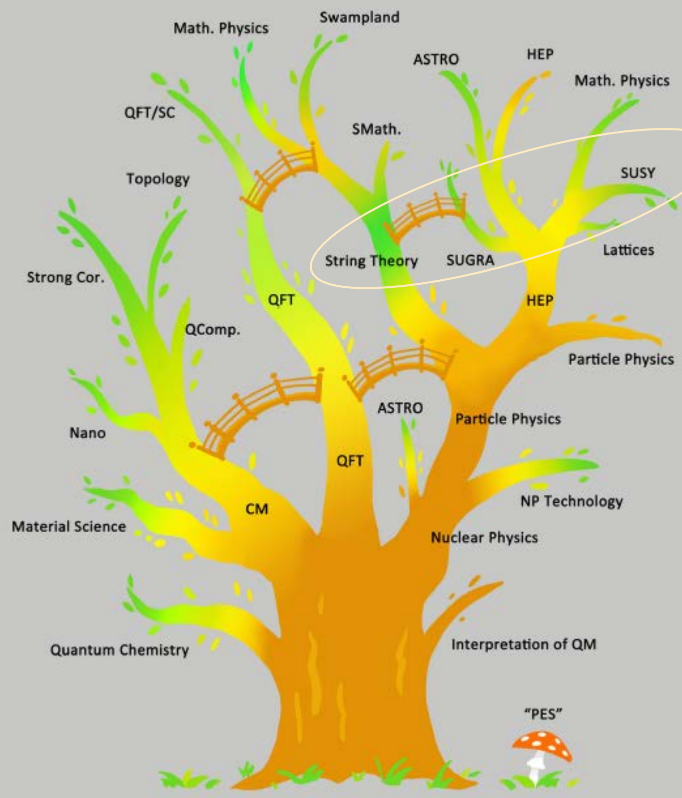
3 SUSY confronted with CLFV

4 Summary

1 Introduction to SUSY

2001.00101
M. Shifman





Quantum Tree

ASTRO - Astrophysics • **CM** - Condensed Matter • **HEP** - High Energy Physics
Math. Physics - Mathematical Physics • **Nano** - Nanotechnology • **NP Technology** - Nuclear Physics Technology
"PES" - "Post-Empirical Science" • **QComp.** - Quantum Computers • **QFT** - Quantum Field Theories
QFT/SC - Strongly Coupled QFT • **QM** - Quantum Mechanics • **SMath.** - String Math
Strong Cor. - Strong Correlations • **SUGRA** - Supergravity • **SUSY** - Supersimmetry

2001.00101
M. Shifman

- LHC discover a 125 GeV Higgs boson

A great triumph of SUSY !

SUSY predicts 5 Higgs bosons

At tree level: $m_h < m_Z|\cos 2\beta| < m_Z$

At loop-level:

$$M_{\tilde{t}}^2 = \begin{pmatrix} M_{\tilde{Q}}^2 + m_Z^2 \cos 2\beta(\frac{1}{2} - \frac{2}{3}s_W^2) + m_t^2 & m_t(A_t - \mu \cot\beta) \\ m_t(A_t - \mu\cot\beta) & M_{\tilde{U}}^2 + \frac{2}{3}m_Z^2 \cos 2\beta s_W^2 + m_t^2 \end{pmatrix}$$

$$\equiv \begin{pmatrix} m_{\tilde{t}_L}^2 & m_t X_t \\ m_t X_t & m_{\tilde{t}_R}^2 \end{pmatrix}$$

$$m_{\tilde{t}_{1,2}}^2 = \frac{1}{2}\left(m_{\tilde{t}_L}^2 + m_{\tilde{t}_R}^2\right) \mp \frac{1}{2}\sqrt{\left(m_{\tilde{t}_L}^2 - m_{\tilde{t}_R}^2\right)^2 + 4m_t^2 X_t^2}$$

$$M_S^2 \equiv \left(m_{\tilde{t}_1}^2 + m_{\tilde{t}_2}^2\right)/2$$

$$m_h^2 \le m_Z^2 + \epsilon = m_Z^2 + \frac{3m_t^4}{2\pi^2 v^2}\left[\log\frac{M_S^2}{m_t^2} + \frac{X_t^2}{M_S^2}\left(1 - \frac{X_t^2}{12M_S^2}\right)\right]$$

$$\le 135\ GeV \quad (for\ M_S \le 2TeV)$$

- LHC discover a 125 GeV Higgs boson

A great triumph of SUSY !

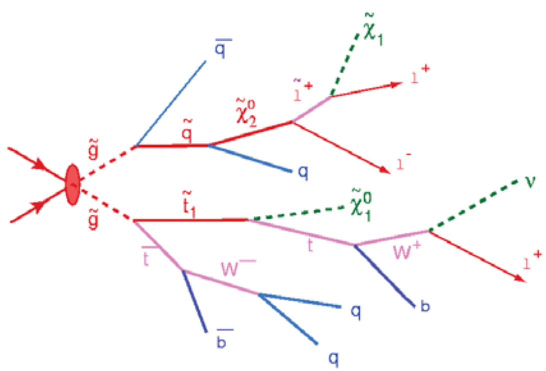
Require top squarks (colored sparticles) above TeV

- LHC discover a 125 GeV Higgs boson

A great triumph of SUSY !

Require top squarks (colored sparticles) above TeV

- LHC direct search not seen any sparticles



Missing E_T + high p_t jets + Leptons

- LHC discover a 125 GeV Higgs boson

A great triumph of SUSY !

Require top squarks (colored sparticles) above TeV

- LHC direct search not seen any sparticles

Push colored sparticles above TeV

- LHC discover a 125 GeV Higgs boson

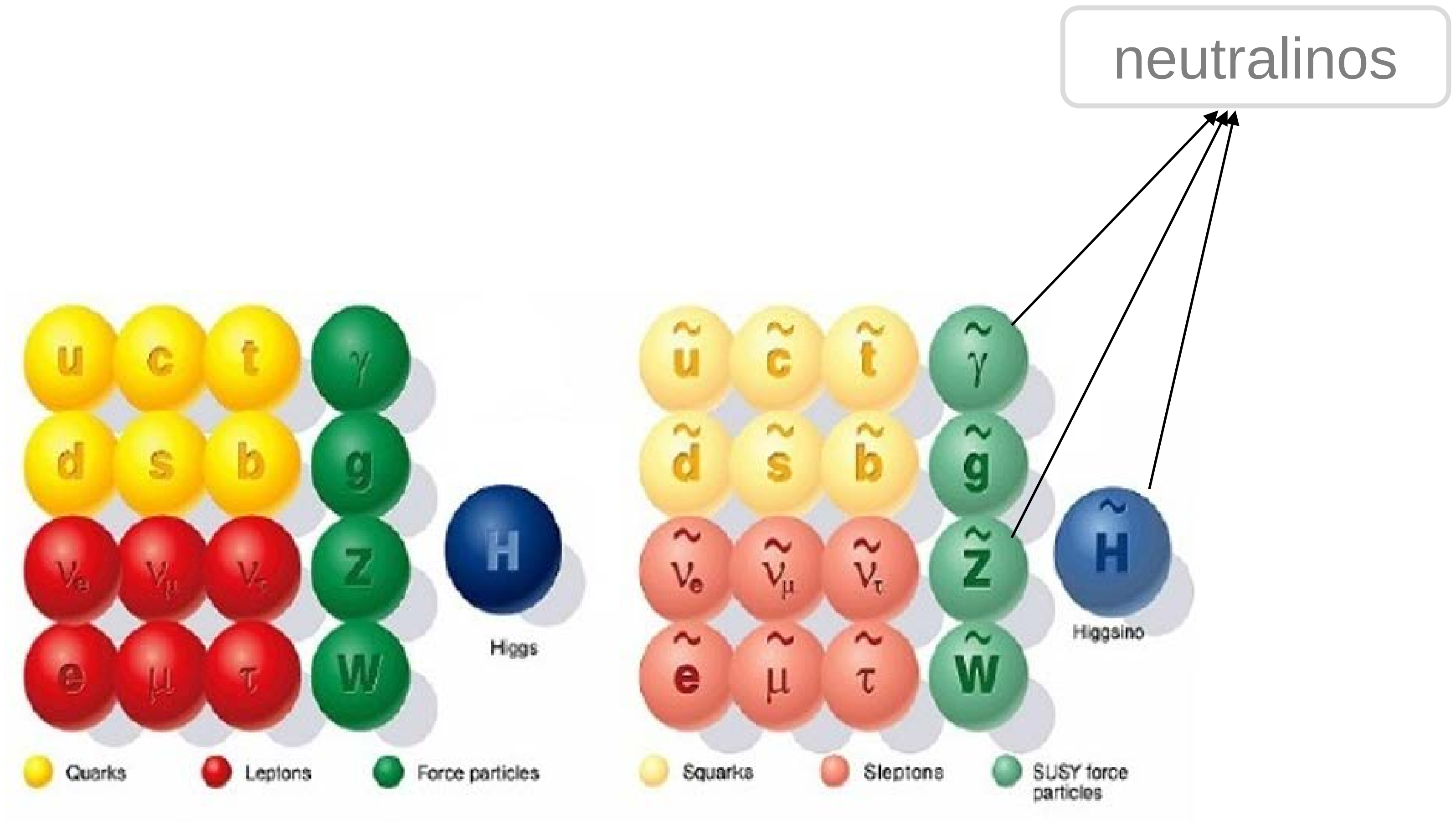
A great triumph of SUSY !

Require top squarks (colored sparticles) above TeV

- LHC direct search not seen any sparticles

Push colored sparticles above TeV

Consistent


neutralinos
Higgs
Quarks
Leptons
Force particles
Higgsino
Squarks
Sleptons
SUSY force particles

lightest neutralino $\tilde{\chi}_1^0$

- weak coupling $g \sim 0.5$
- massive $g \sim 500$ GeV

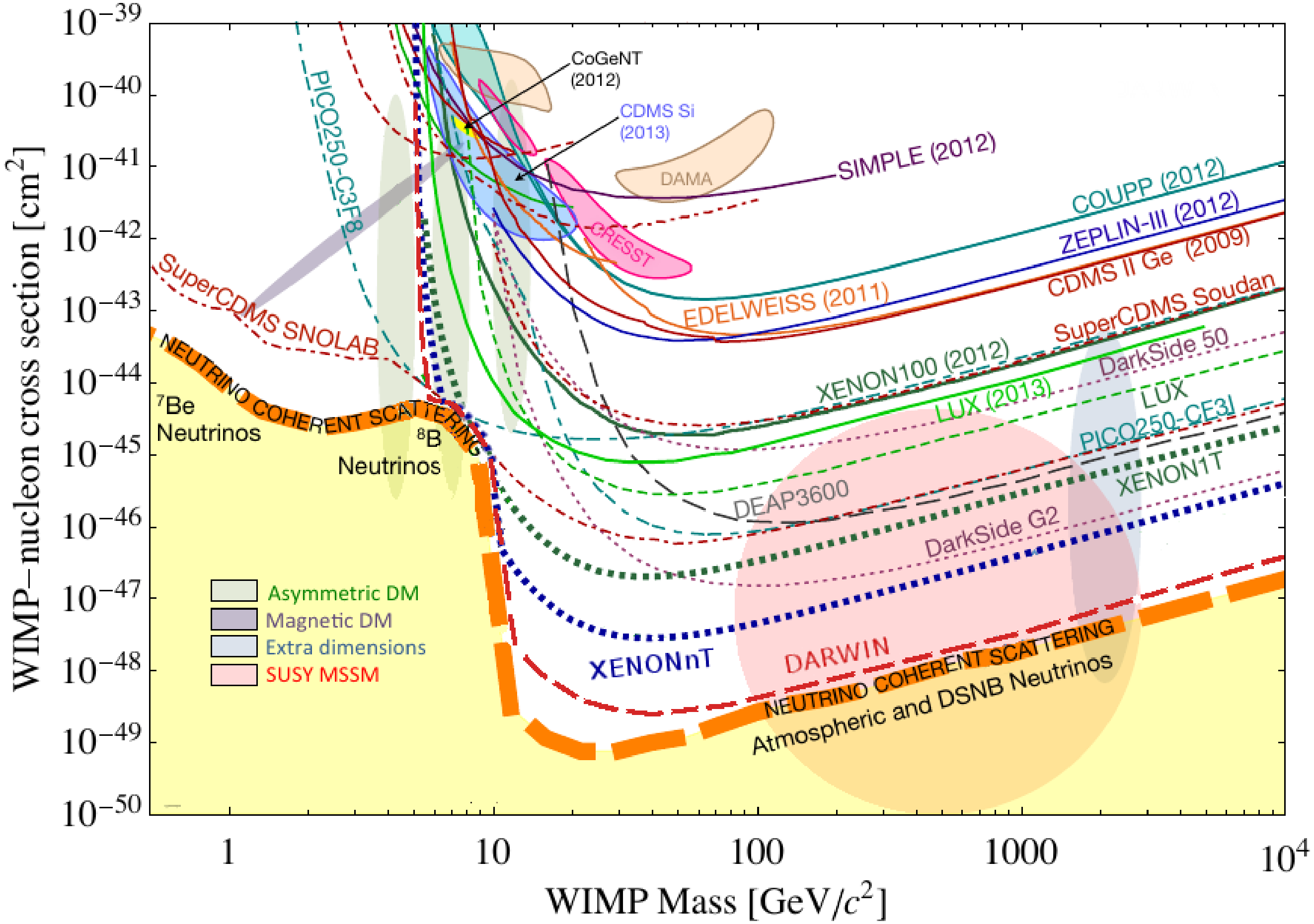
→ WIMP

WIMP miracle for dark matter

$$\Omega_{DM} h^2 \equiv \frac{\rho_{DM}}{\rho_{\rm tot}} h^2 \simeq \frac{3 \times 10^{-27} {\rm cm}^3 {\rm s}^{-1}}{\langle \sigma v \rangle} \qquad 0.1199 \pm 0.0027$$

$$\langle \sigma v \rangle \sim \frac{g^4}{16\pi} \frac{1}{M^2} \simeq (6 \times 10^{-26} {\rm cm}^3\, {\rm s}^{-1}) \left(\frac{g}{0.5}\right)^4 \left(\frac{500\,{\rm GeV}}{M}\right)^2$$

MSSM

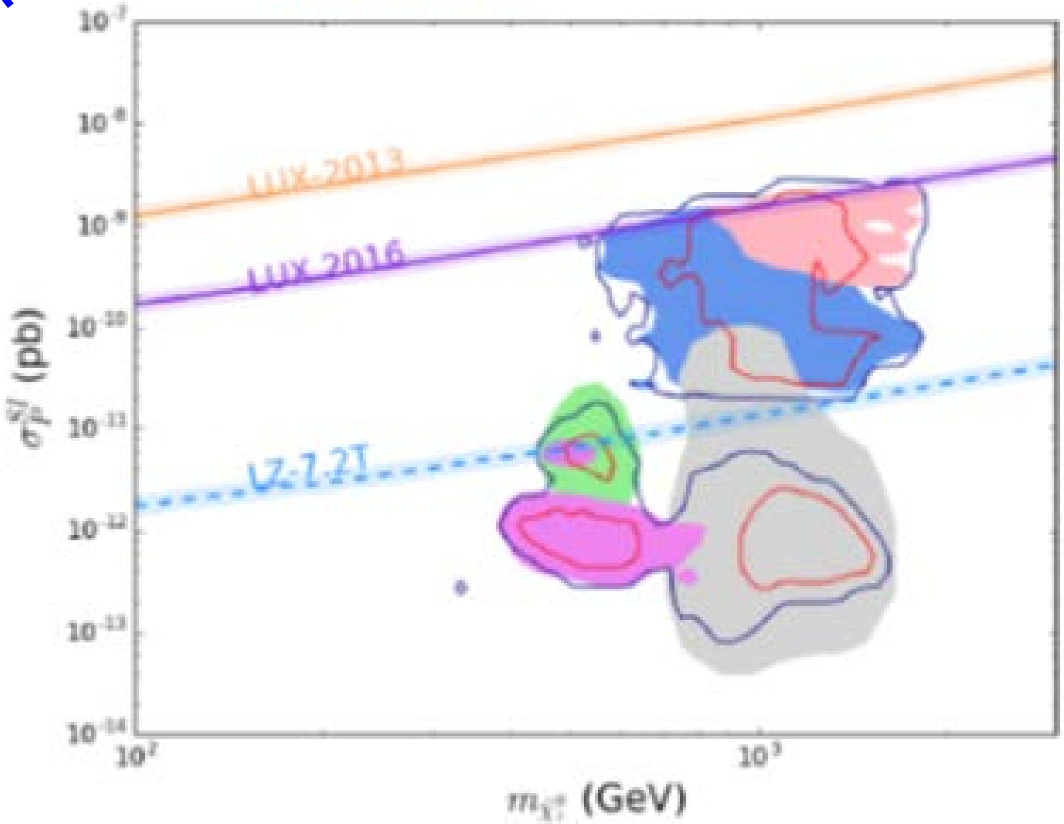


WIMP–nucleon cross section [cm^2]
WIMP Mass [GeV/c^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
1
10
100
1000
10^4
CoGeNT (2012)
CDMS Si (2013)
DAMA
SIMPLE (2012)
CRESST
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
EDELWEISS (2011)
SuperCDMS Soudan
PICO250-C3F8
SuperCDMS SNOLAB
XENON100 (2012)
DarkSide 50
LUX (2013)
LUX
PICO250-CF3I
XENON1T
DEAP3600
DarkSide G2
XENONnT
DARWIN
NEUTRINO COHERENT SCATTERING
^{7}Be Neutrinos
^{8}B Neutrinos
NEUTRINO COHERENT SCATTERING
Atmospheric and DSNB Neutrinos
Asymmetric DM
Magnetic DM
Extra dimensions
SUSY MSSM

CMSSM/mSUGRA

1612.02296
Han, Hikasa, Wu, Yang, Zhang

Run-1 + Run-2
LUX-2016



SUSY neutralino as dark matter is ok !

- **Relic density is ok**
- **Direct detection limits satisfied**

2 SUSY confronted with muon g-2

- What is muon g-2
- Recent measurement
- Implication on SUSY

What is muon g-2

李松，肖洋，JMY， 缪子反常磁矩浅析，现代物理知识，Vol 4, 40-47（2021）

S. Li，Y. Xiao，JMY，A pedagogical review on muon g-2，arXiv 2110.04673

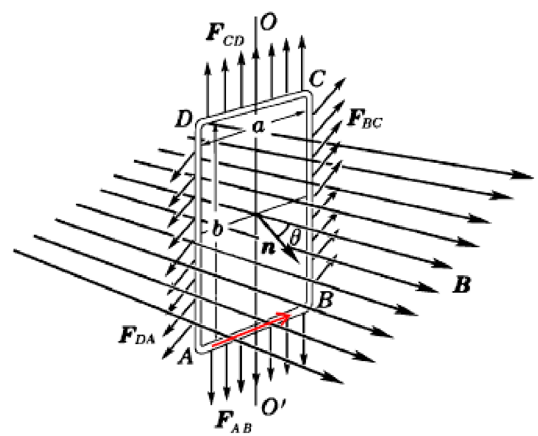
- **矩形载流线圈的磁矩**

合力 = 0，合力矩 ≠ 0

力矩 = 径向矢量×作用力

$$L = F_{BC}\frac{a}{2}\sin\theta + F_{DA}\frac{a}{2}\sin\theta$$

$$= IabB\sin\theta = ISB\sin\theta$$

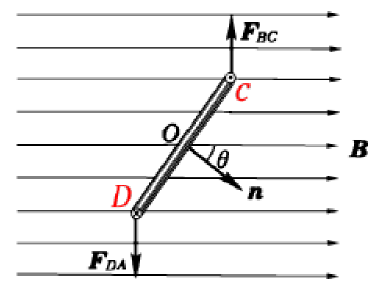


$$\vec{L} = IS\vec{n}\times\vec{B} = \begin{cases} \text{大小} & ISB\sin\theta \\ \text{方向} & \vec{n}\times\vec{B}\ \text{的方向} \end{cases}$$

注意：$\vec{n}$的方向与线圈电流成右手关系

$\vec{m} = IS\vec{n}$ 线圈的磁矩

从上往下看



What is muon g-2

- 任意载流线圈的磁矩

线圈受合力是0 但受力矩不是0 有转动趋势

力矩 = 径向矢量×作用力

将线圈分割成若干个小窄条

小窄条所受力矩 dL

$$dF_1 = Idl_1 B\sin\theta_1 = IBh$$

$$dF_2 = Idl_2 B\sin\theta_2 = IBh$$

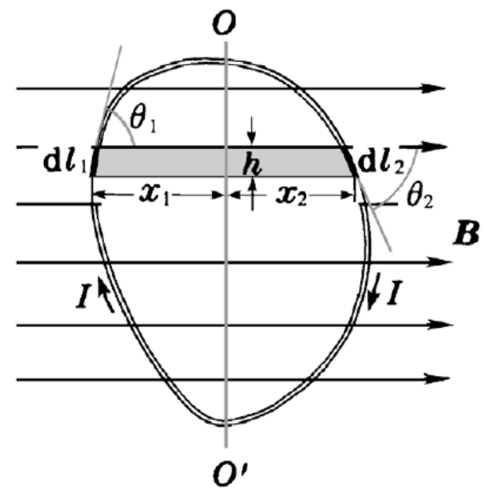
$$dL = IBh(x_1 + x_2) = IBdS$$

$$L = \sum dL = \sum IBdS = IBS$$

方向：向下

若线圈平面与磁场成任意角度

$$\vec{L} = IS(\vec{n} \times \vec{B}) = \vec{m} \times \vec{B}$$



$$\vec{m} = IS\,\vec{n}$$

线圈的磁矩

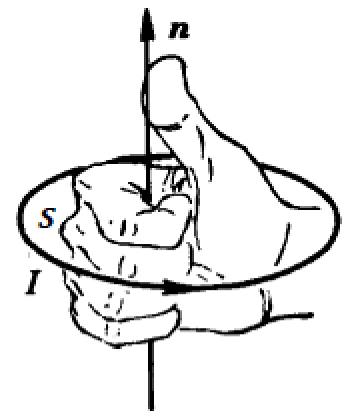
注意：$\vec{n}$的方向与线圈电流成右手关系

What is muon g-2

- 任意载流线圈的磁矩

线圈的磁矩 $\vec{m} = IS\vec{n}$

所受的力矩 $\vec{L} = \vec{m} \times \vec{B}$



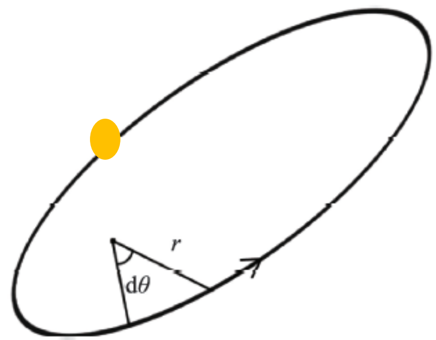
线圈受合力是0
但受力矩不是0
有转动趋势

所受合力 = 0

What is muon g-2

- 缪子的轨道运动磁矩（经典）

$$M = IA = \frac{e}{\tau}\ \frac{L\tau}{2m} = \frac{e}{2m}\ L$$



$I = e/\tau$ τ 周期（运动一周需要的时间）

面积 $A = \int_0^{2\pi} \frac{1}{2} r \cdot r \mathrm{d}\theta = \int_0^{\tau} \frac{1}{2} r^2 \omega \mathrm{d}t = \frac{1}{2m} \int_0^{\tau} mr^2 \omega \mathrm{d}t$

$= \frac{L\tau}{2m}$

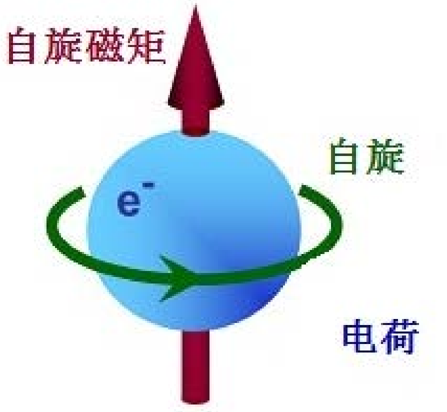
L 轨道运动角动量

What is muon g-2

- 缪子的自旋磁矩（经典）

$$M = \frac{e}{2m} S$$

（S 缪子的自旋）



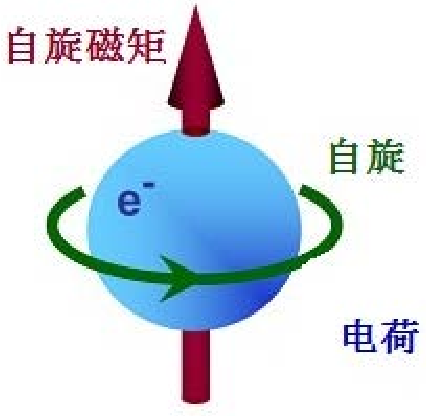
What is muon g-2

- **缪子的自旋磁矩（量子）**

从狄拉克方程（量子力学）可以推出来（曾谨言书上有推导）

$$M = \frac{e}{m} S$$

（S 缪子的自旋）

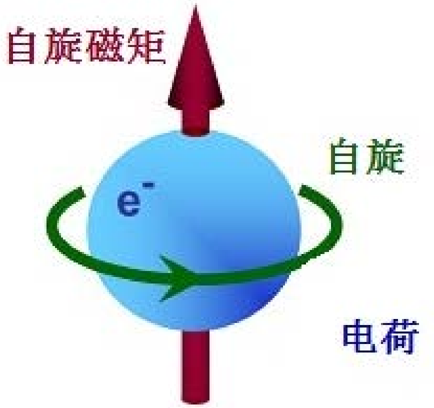


What is muon g-2

- 缪子的自旋磁矩（量子）

从狄拉克方程（量子力学）可以推出来（曾谨言书上有推导）

$$M = \frac{e}{m} S = \frac{ge}{2m} S \qquad (g = 2)$$



$$\boldsymbol{a} \equiv \frac{g-2}{2}$$

反常磁矩（简称 muon g-2）

What is muon g-2

- 缪子的自旋磁矩（量子）

$$a \equiv \frac{g-2}{2}$$

$= 0$

- 狄拉克方程（量子力学）（曾谨言书上有推导）
- 量子场论（量子电动力学QED）的树图

$\neq 0$

- 量子场论（量子电动力学QED）的圈图

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反常磁矩（简称 muon g-2）

What is muon g-2

- 缪子的自旋磁矩（量子）

$$a \equiv \frac{g-2}{2} = 0$$

$$(g = 2)$$

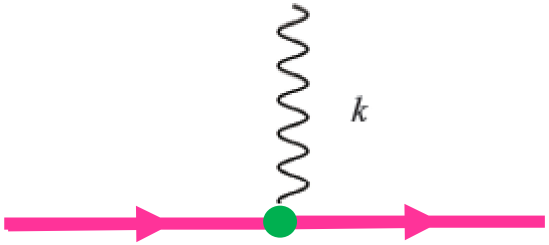
带电粒子在磁场 $\vec{B}(x)$ 中的势能

$$V(x) = -\vec{M}\cdot\vec{B}(x)$$

计算出相应粒子在磁场中的势能，

就可以把磁矩找出来

- 量子场论（量子电动力学QED）的树图



$$\mathcal{H}_I = eA_\mu(x)\overline{\psi}(x)\gamma^\mu\psi(x)$$

一阵猛算（此处省去20步推导）

$$\approx -\frac{e}{m}\vec{B}\cdot\underbrace{\left[(\zeta' e^{-ip'x})^\dagger\frac{\vec{\sigma}}{2}(\zeta e^{-ipx})\right]}_{\vec{S}}$$

What is muon g-2

- 缪子的自旋磁矩（量子）

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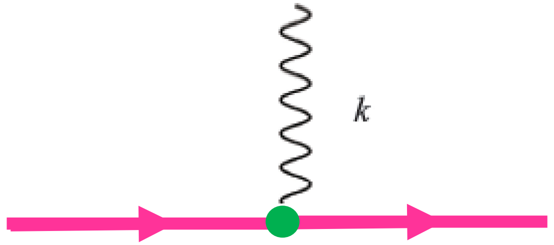

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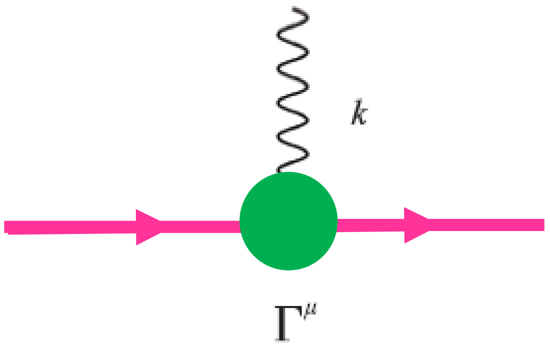
$$\vec{S}$$

$$M_{tree} = \frac{e}{m} S = \frac{ge}{2m} S \quad (g = 2)$$

What is muon g-2

- **缪子的反常磁矩** $a \equiv \frac{g-2}{2}$

量子场论（量子电动力学QED）的圈图



有效相互作用

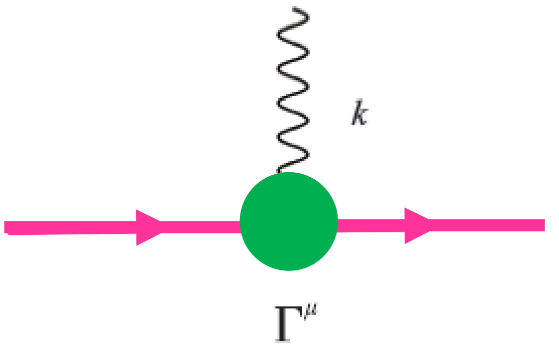
$$-ie\epsilon_{\mu}(k)\bar{u}(p')\Gamma^{\mu}u(p)$$

$$\Gamma^{\mu}=\gamma^{\mu}F_E(k^2)+\left(\gamma^{\mu}-\frac{2mk^{\mu}}{k^2}\right)\gamma_5F_A+i\sigma^{\mu\nu}\frac{k_{\nu}}{2m}F_M(k^2)+\sigma^{\mu\nu}\frac{k_{\nu}}{2m}\gamma_5F_D(k^2)$$

What is muon g-2

- 缪子的反常磁矩 $a \equiv \frac{g-2}{2}$

量子场论（量子电动力学QED）的圈图



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一阵猛算（此处省去10步推导）

$$-\frac{eF_M(0)}{m}\vec{B}\cdot\left[\left(\zeta' e^{-ip'x}\right)^{\dagger}\frac{\vec{\sigma}}{2}\left(\zeta e^{-ipx}\right)\right]$$

$\vec{S}$

带电粒子在磁场 $\vec{B}(x)$ 中的势能

$V(x) = -\vec{M}\cdot\vec{B}(x)$

$$M_{loop} = \frac{eF_M(0)}{m}S$$

What is muon g-2

- 缪子的反常磁矩 $a \equiv \frac{g-2}{2}$

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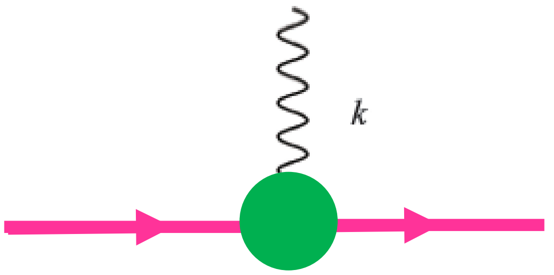

Γ^μ

有效相互作用

$$-ie\epsilon_\mu(k)\bar{u}(p')\Gamma^\mu u(p)$$

$$\Gamma^\mu = \gamma^\mu F_E(k^2) + \left(\gamma^\mu - \frac{2mk^\mu}{k^2}\right)\gamma_5 F_A + i\sigma^{\mu\nu}\frac{k_\nu}{2m}F_M(k^2) + \sigma^{\mu\nu}\frac{k_\nu}{2m}\gamma_5 F_D(k^2)$$

一阵猛算（此处省去10步推导）

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$$M_{tree} = \frac{e}{m} S$$

What is muon g-2

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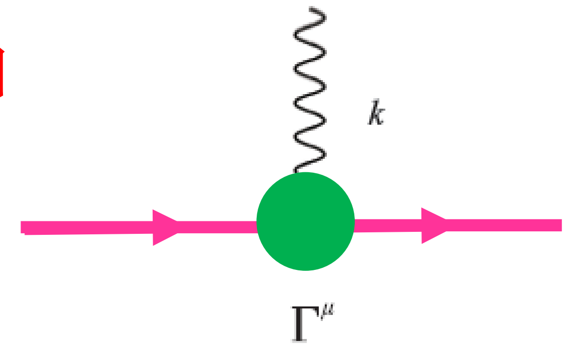


有效相互作用

$$-ie\epsilon_{\mu}(k)\bar{u}(p')\Gamma^{\mu}u(p)$$

$$\Gamma^{\mu}=\gamma^{\mu}F_{E}(k^{2})+\left(\gamma^{\mu}-\frac{2mk^{\mu}}{k^{2}}\right)\gamma_{5}F_{A}+i\sigma^{\mu\nu}\frac{k_{\nu}}{2m}F_{M}(k^{2})+\sigma^{\mu\nu}\frac{k_{\nu}}{2m}\gamma_{5}F_{D}(k^{2})$$

$$-\frac{eF_{M}(0)}{m}\vec{B}\cdot\left[\left(\zeta' e^{-ip'x}\right)^{\dagger}\frac{\vec{\sigma}}{2}\left(\zeta e^{-ipx}\right)\right]$$

$\vec{S}$

带电粒子在磁场 $\vec{B}(x)$ 中的势能

$$V(x)=-\vec{M}\cdot\vec{B}(x)$$

$$M_{loop}=\frac{eF_{M}(0)}{m}S$$

$$M_{tree}=\frac{e}{m}S$$

$$a=F_{M}(0)$$

For a charged lepton ℓ the magnetic moment:

spin

$$\vec{\mu}_\ell = g_\ell \frac{e\hbar}{2m_\ell c}\vec{s}$$

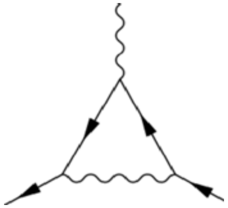
$g_\ell = 2$ at tree level (classical level)
from Dirac Equation (Dirac 1928)

The anomalous magnetic moment is defined as

fine structure constant

$$a_\ell = \frac{g_\ell - 2}{2} = \frac{\alpha}{2\pi} + \cdots$$

one-loop result
Schwinger 1948
engraved on his tombstone



The anomalous magnetic moment of a charged lepton ℓ is a probe to new physics

$$\delta a_\ell \propto \frac{\alpha}{\pi}\frac{m_\ell^2}{M^2} \quad (M \gg m_\ell)$$

$$(m_\mu/m_e)^2 \simeq 4 \times 10^4$$

muon g-2 is a best probe to NP
(tau lepton is too short-lived)

$$\begin{aligned} \tau_e &= \infty \\ \tau_\mu &= 2.197 \times 10^{-6}\ \mathrm{s} \\ \tau_\tau &= 2.906 \times 10^{-13}\ \mathrm{s} \end{aligned}$$

Recent measurement of muon g-2

$$a_\mu^{\rm QED} = 116\,584\,718.9(1)\times 10^{-11}$$

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

$$a_\mu^{\rm HVP,\,LO} = 6931(40)\times 10^{-11}$$

$$a_\mu^{\rm HVP,\,NLO} = -98.3(7)\times 10^{-11}$$

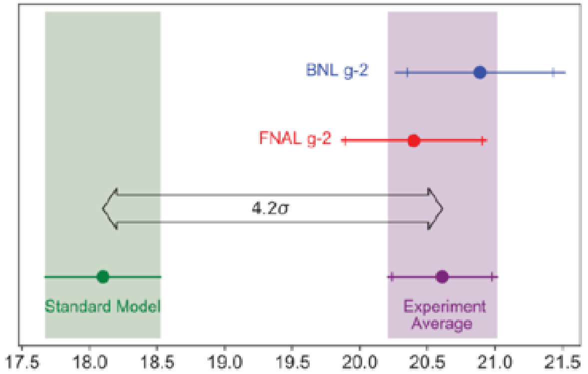
$$a_\mu^{\rm HVP,\,NNLO} = 12.4(1)\times 10^{-11}$$

$$a_\mu^{\rm HLBL} + a_\mu^{\rm HLBL,\,NLO} = 92(18)\times 10^{-11}$$

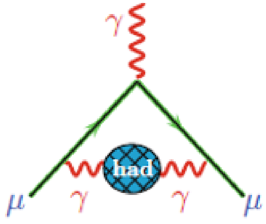
$$a_\mu^{\rm SM} = 116\,591\,810(43)\times 10^{-11}$$

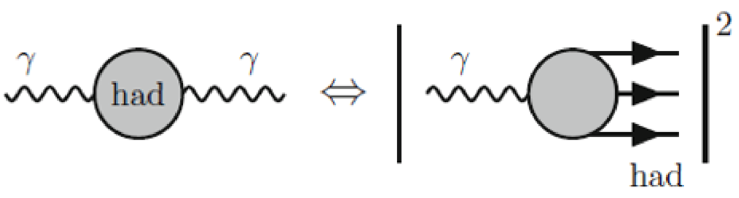
$$a_\mu^{\rm Exp} = 116\,592\,061(41)\times 10^{-11}$$

$$a_\mu^{\rm Exp} - a_\mu^{\rm SM} = 251(59)\times 10^{-11}$$



Theory uncertainty mainly from HVP





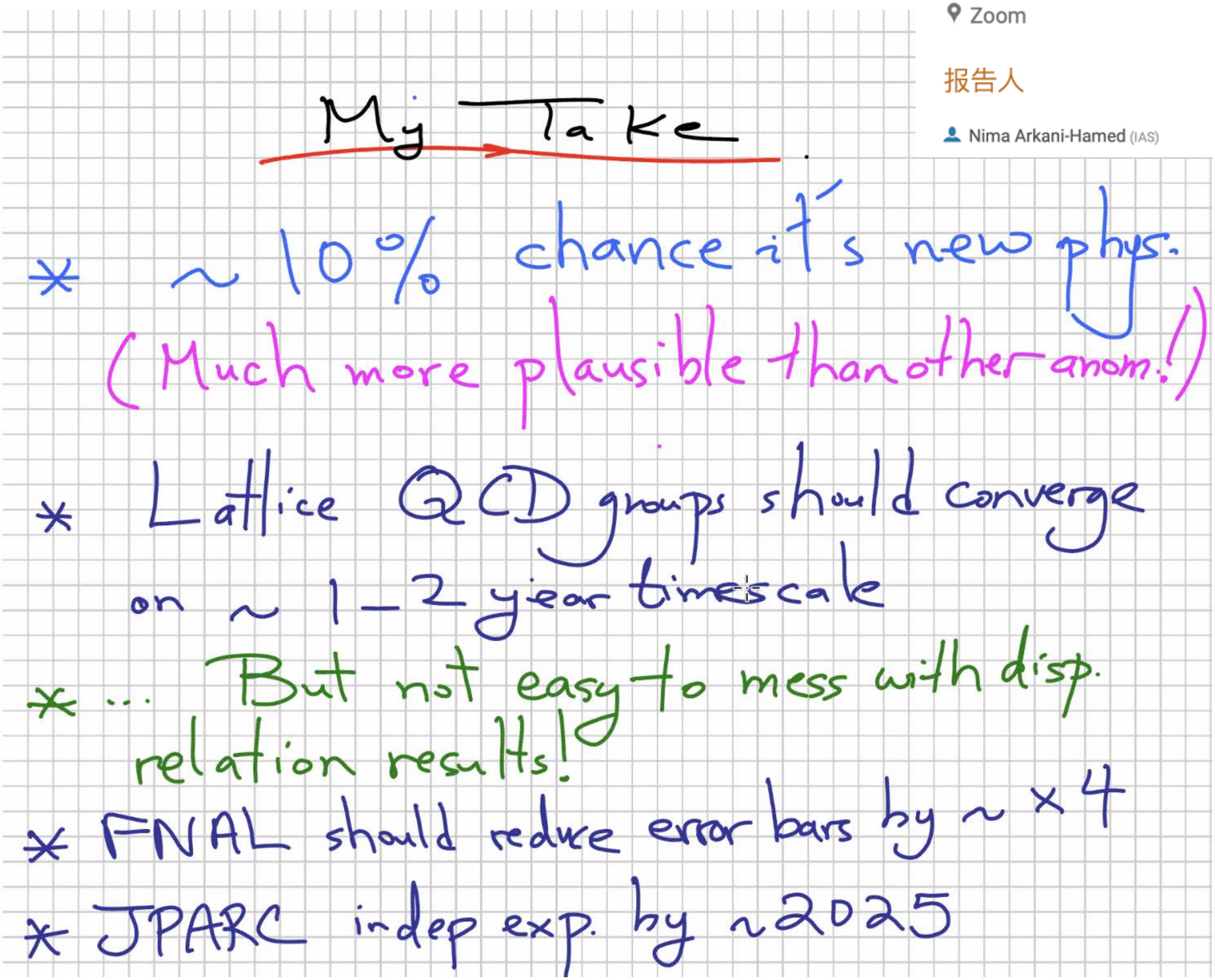
Recent measurement of muon g-2

Naturalness and the muon magnetic moment

2021年6月11日 上午9:50
40m
Zoom

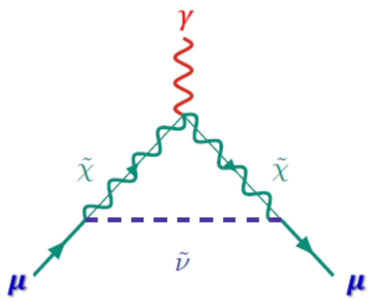
报告人

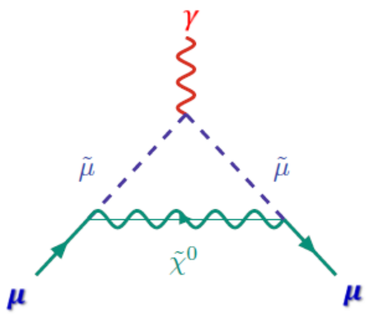
Nima Arkani-Hamed (IAS)



Muon g-2 implication on SUSY

SUSY can explain muon g-2, **but** not so easy





$$\delta a_\mu^{\rm SUSY} = 14 \tan\beta \left(\frac{100\ {\rm GeV}}{M_{\rm SUSY}} \right)^2 10^{-10}$$

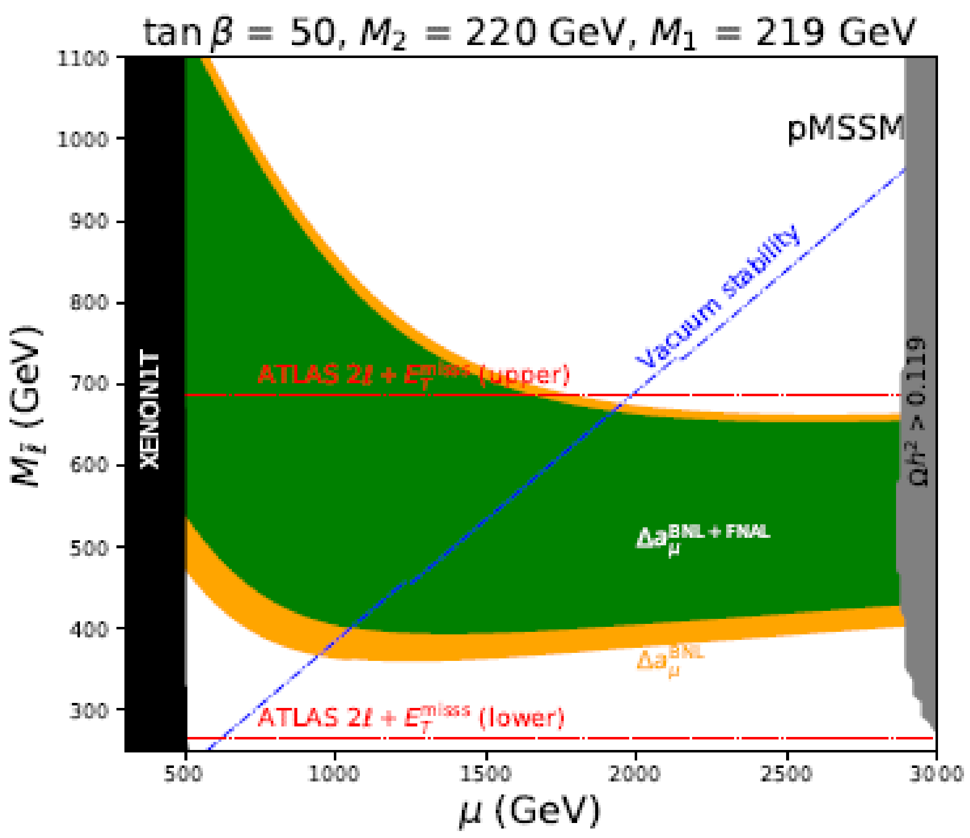
Moroi
hep-ph/9512396

Require light slepton, light electroweakino

(uncolored sparticles are light)

Muon g-2 implication on SUSY

MSSM
g-2 is OK



2104.03262
Wang, Wu, Xiao, Yang, Zhang

Figure 2. FNAL+BNL and BNL Δa_μ constraints for the BW scenario in the pMSSM. The orange and dark green regions can explain the BNL and the FNAL+BNL Δa_μ measurements at 2σ CL. The black region is excluded by Xenon-1T at 90% CL, while in the brown region the LSP is not bino-like neutralino. The areas between the two ATLAS $2\ell + E_T^{\rm miss}$ limits (red dash lines) are excluded by 13 TeV LHC searches for slepton-pair production at 95% CL. The regions on the right of blue dash lines spoil stability of the electroweak vacuum.

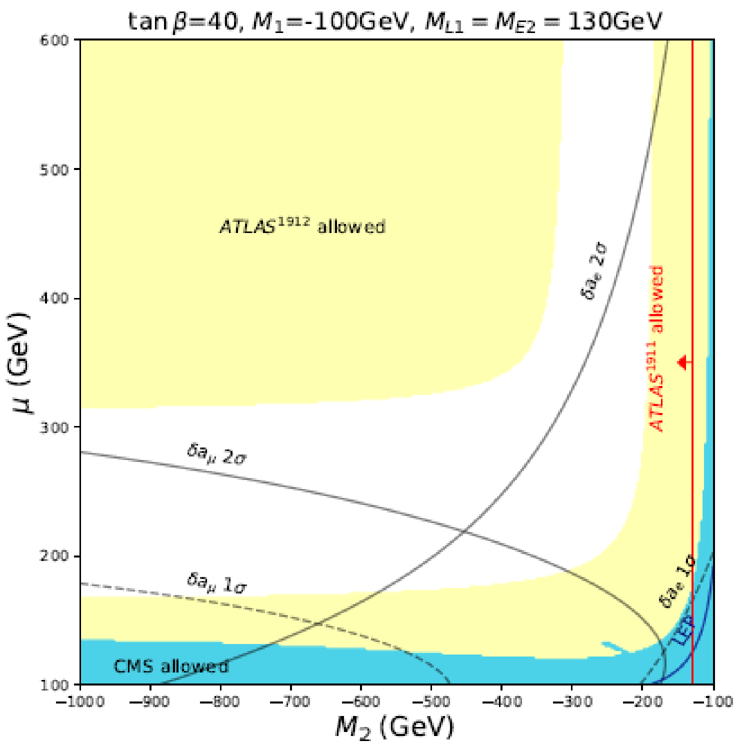
Muon g-2 implication on SUSY

MSSM： muon g-2 and electron g-2 simultaneously OK !

$$\Delta a_e^{\mathrm{Exp-SM}} = a_e^{\mathrm{Exp}} - a_e^{\mathrm{SM}}(\mathrm{Cs}) = (-8.8 \pm 3.6) \times 10^{-13}$$

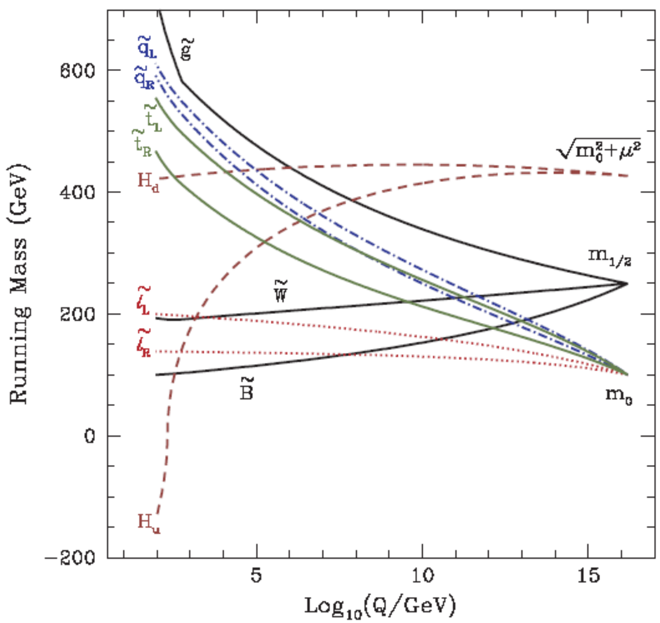
2107.04962
Li, Xiao, Yang

from measurement of fine-structure constant using ^{133}Cs atoms at Berkeley is 2.4σ below SM prediction



Muon g-2 implication on SUSY

CMSSM/mSUGRA, GMSB, AMSB： g-2 not OK



125 GeV Higgs → heavy top squarks

→ m_0 is large

→ heavy sleptons

→ cannot explain g-2

Muon g-2 implication on SUSY

GMSB/AMSB：g-2 not OK

Baer, Barger, Mustafayev, 1202.4038

To give a 125 GeV Higgs, SUSY particles are above 10 TeV

→ g-2 cannot be explained

Muon g-2 implication on SUSY

GMSB/AMSB：g-2 not OK

Extend GMSB:

1203.2336

Kang, Li, Liu, Tong, Yang

For example,

A Heavy SM-like Higgs and a Light Stop from Yukawa-Deflected Gauge Mediation

$$W_1 = \lambda_u S\bar{\Phi}_L H_u + \lambda_d \bar{S}\Phi_L H_d,$$

can have large A_t, giving 125 GeV Higgs without very heavy stops

→ *g-2* can be explained

Muon g-2 implication on SUSY

GMSB/AMSB： g-2 not OK

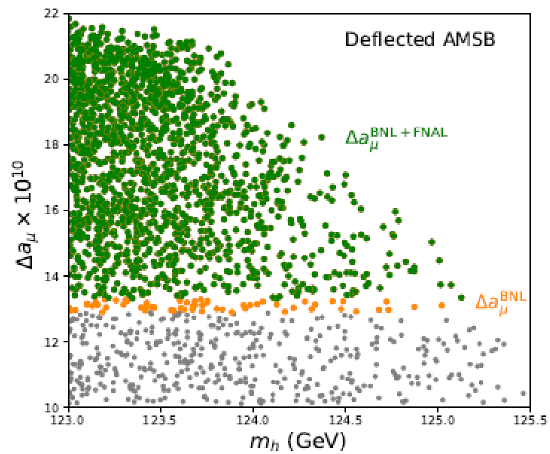
Extend AMSB:

1505.02785

Wang, Wang, Yang, Zhang

For example,

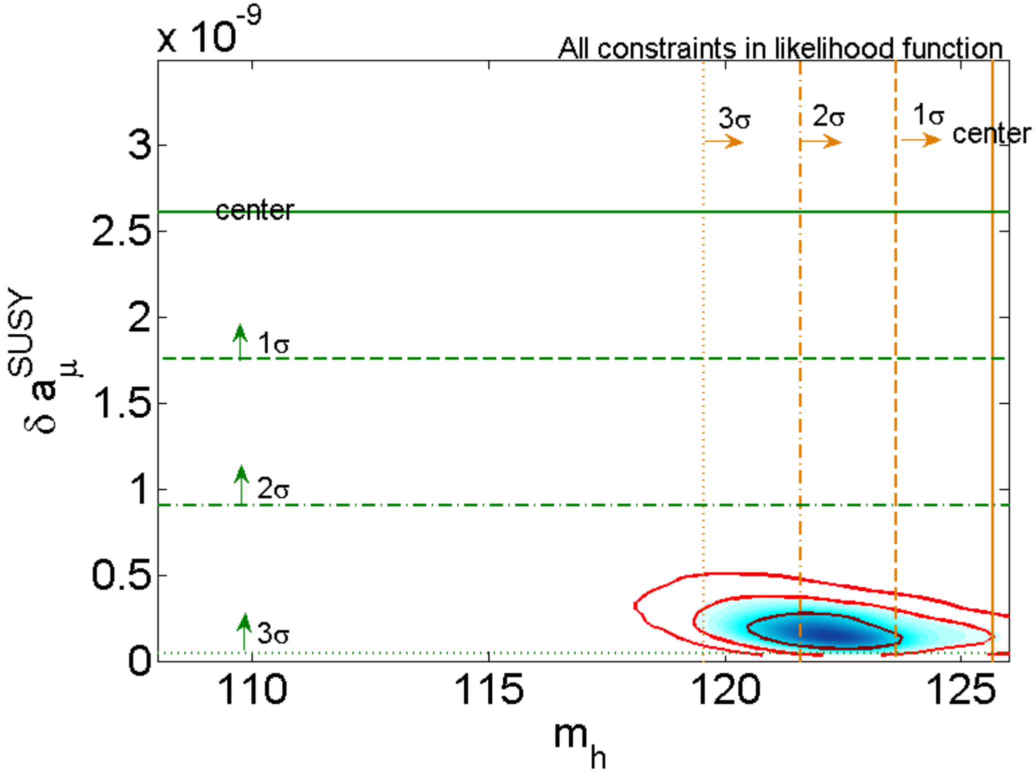
Heavy colored SUSY partners from deflected anomaly mediation



→ *g-2* can be explained

Muon g-2 implication on SUSY

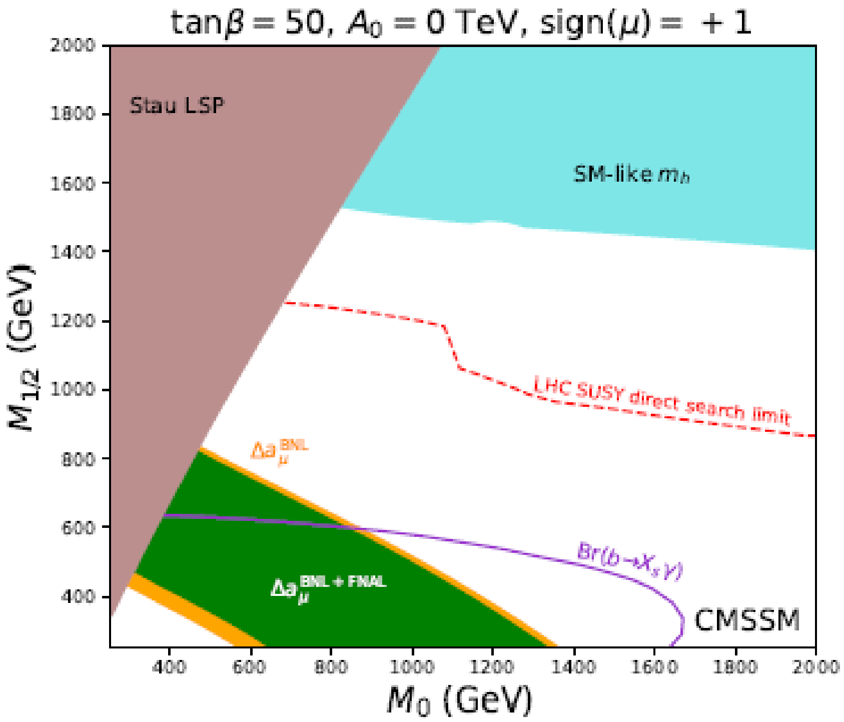
CMSSM/mSUGRA： g-2 not OK



1612.02296
Han, Hikasa, Wu, Yang, Zhang

Muon g-2 implication on SUSY

CMSSM/mSUGRA： g-2 not OK



2104.03262
Wang, Wu, Xiao, Yang, Zhang

Muon g-2 implication on SUSY

CMSSM/mSUGRA： g-2 not OK

Extend CMSSM/mSUGRA:

For example,

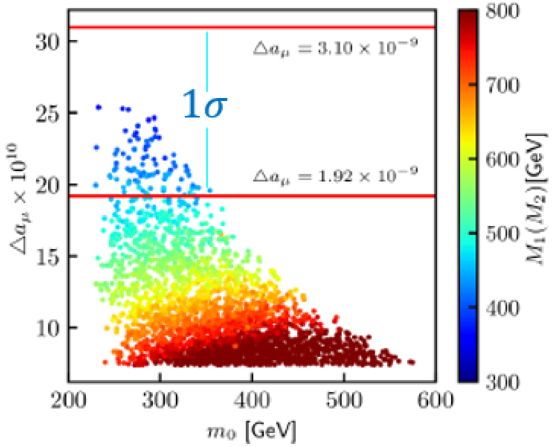
Reconcile muon g-2 anomaly with LHC data in SUGRA with generalized gravity mediation

Wang, Wang, Yang, 1504.00505

Wang, Wang, Yang, Zhu, 1808.10851

Gluino-SUGRA scenarios in light of FNAL muon g-2

Li, Liu, Wang, Yang, Zhang, 2106.04466

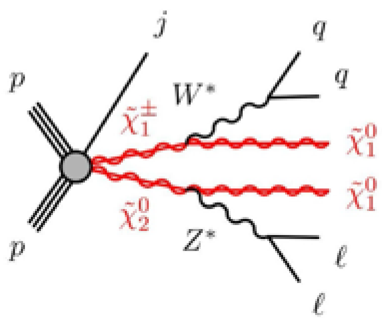


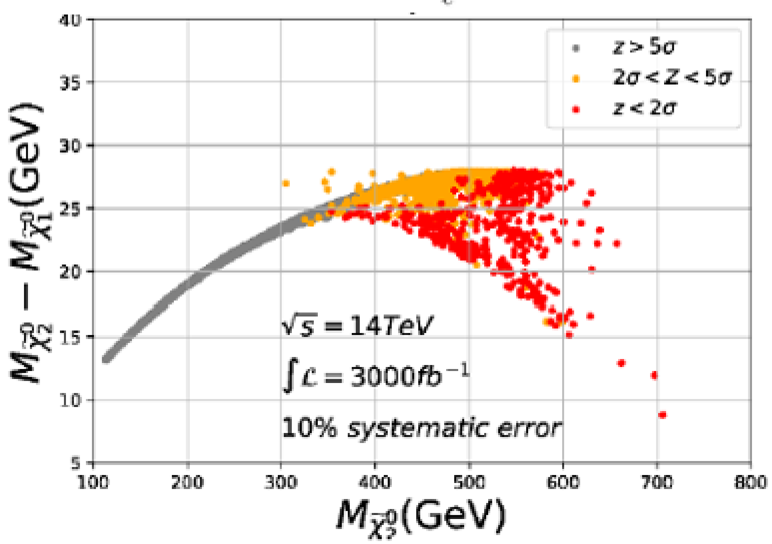
Muon g-2 implication on SUSY

Implication for MSSM search at LHC

1909.07792

Abdughani, Hikasa, Wu, Yang, Zhao

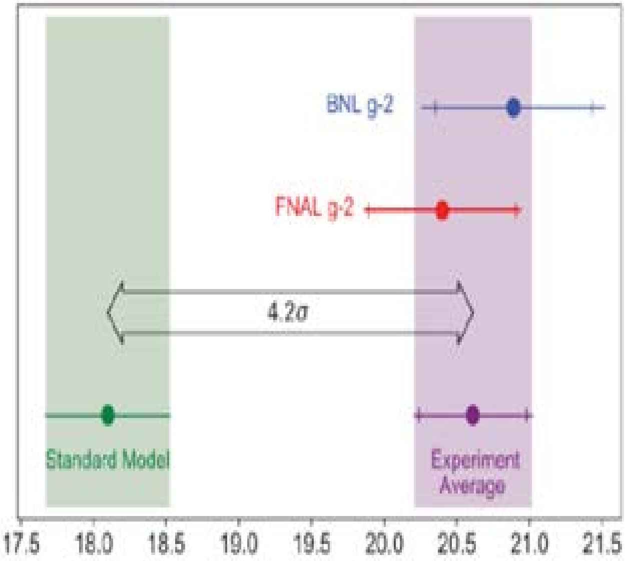




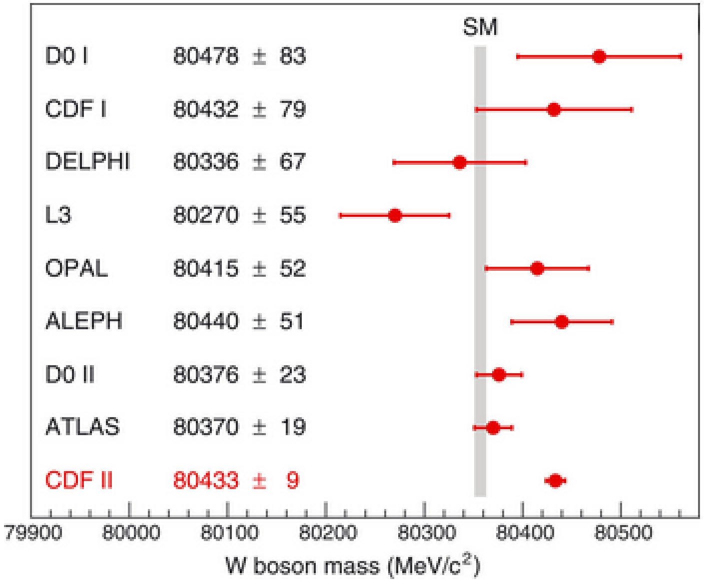
Can SUSY jointly explain muon g-2 and W-mass ?

Yang, Zhang, arXiv: 2204.04202

muon g-2



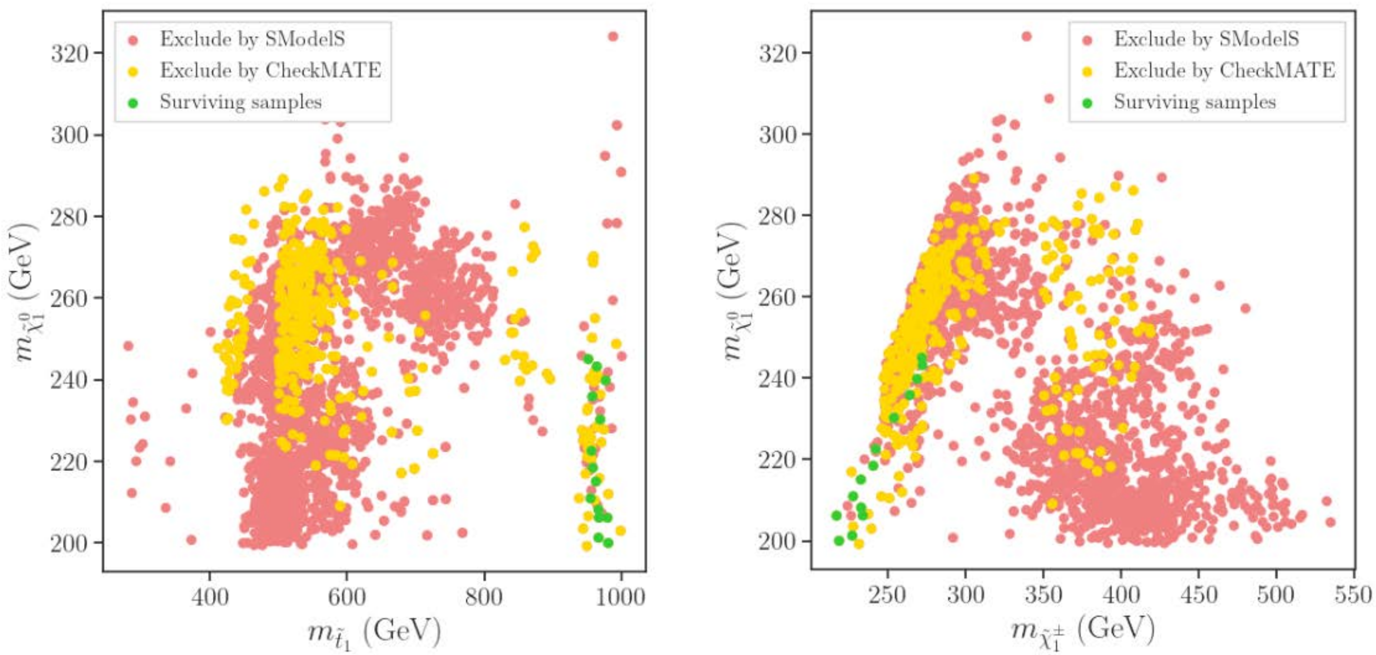
W-mass



Can SUSY jointly explain muon g-2 and W-mass ?

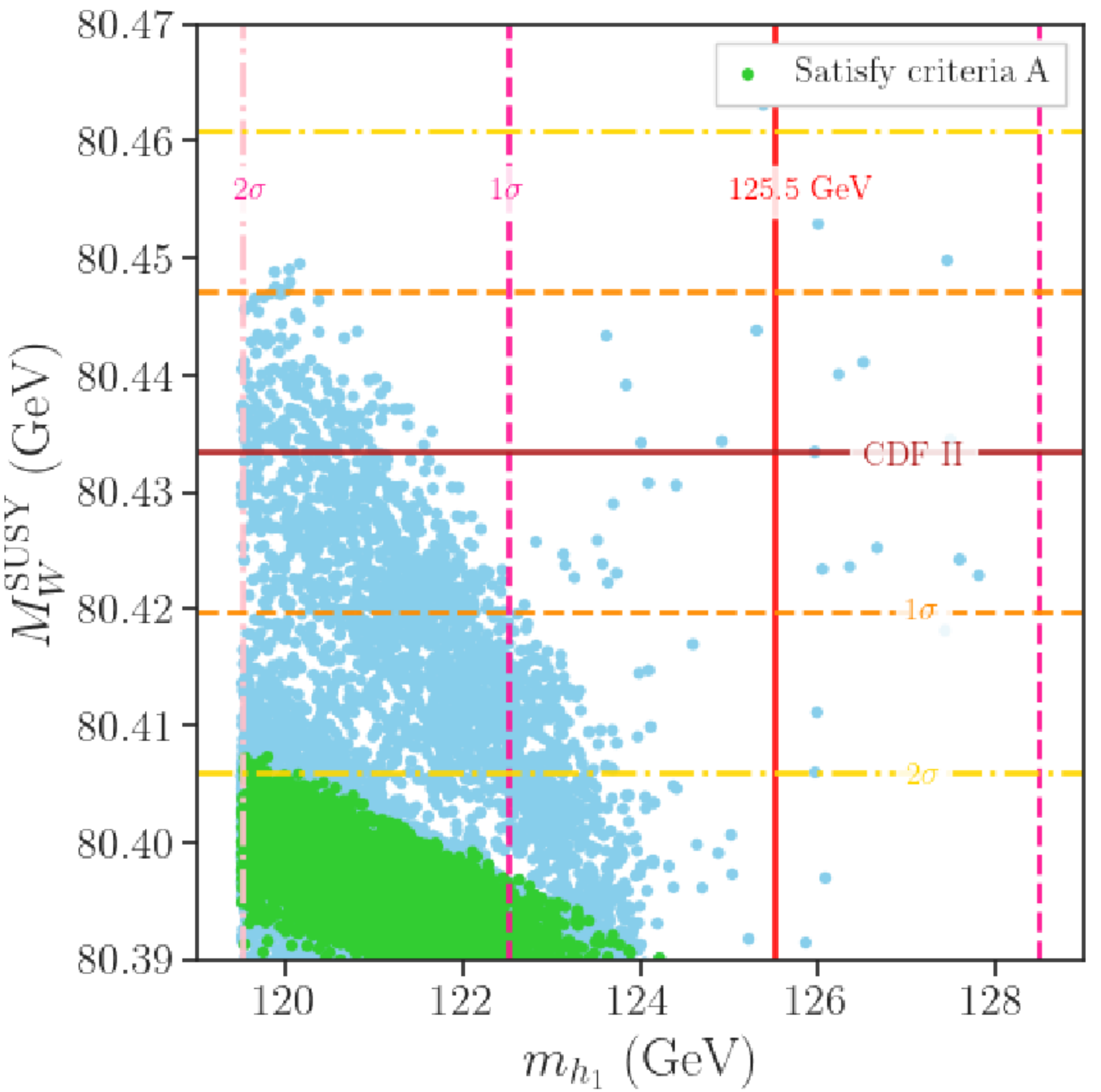
Yang, Zhang, arXiv: 2204.04202

- In the parameter space allowed by current experimental constraints from colliders and dark matter detections, MSSM can simultaneously explain both measurements at 2σ level.
- The favored parameter space, characterized by a compressed spectrum between (bino, wino, stau), with top-squark around 1 TeV.



Can SUSY jointly explain muon g-2 and W-mass ?

Yang, Zhang, arXiv: 2204.04202



3 SUSY confronted with CLFV

For a review, see,

Calibbi, Signorelli,

Charged Lepton Flavour Violation: An Experimental and Theoretical Introduction,

arXiv: 1709.00294

Han, Lopez, Melis, Vives, Wu, Yang,

LFV and (g-2) in non-universal SUSY models with light higgsinos,

arXiv:2003.06187

Cao, Xiong, Yang,

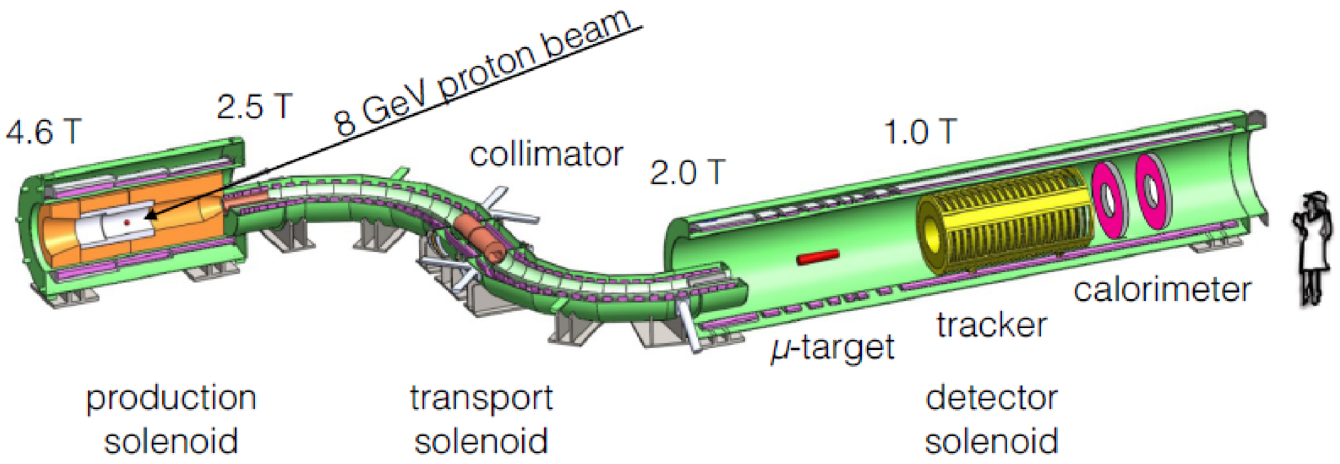
Lepton flavor violating Z decays in supersymmetric seesaw model,

arXiv:hep-ph/0307126.

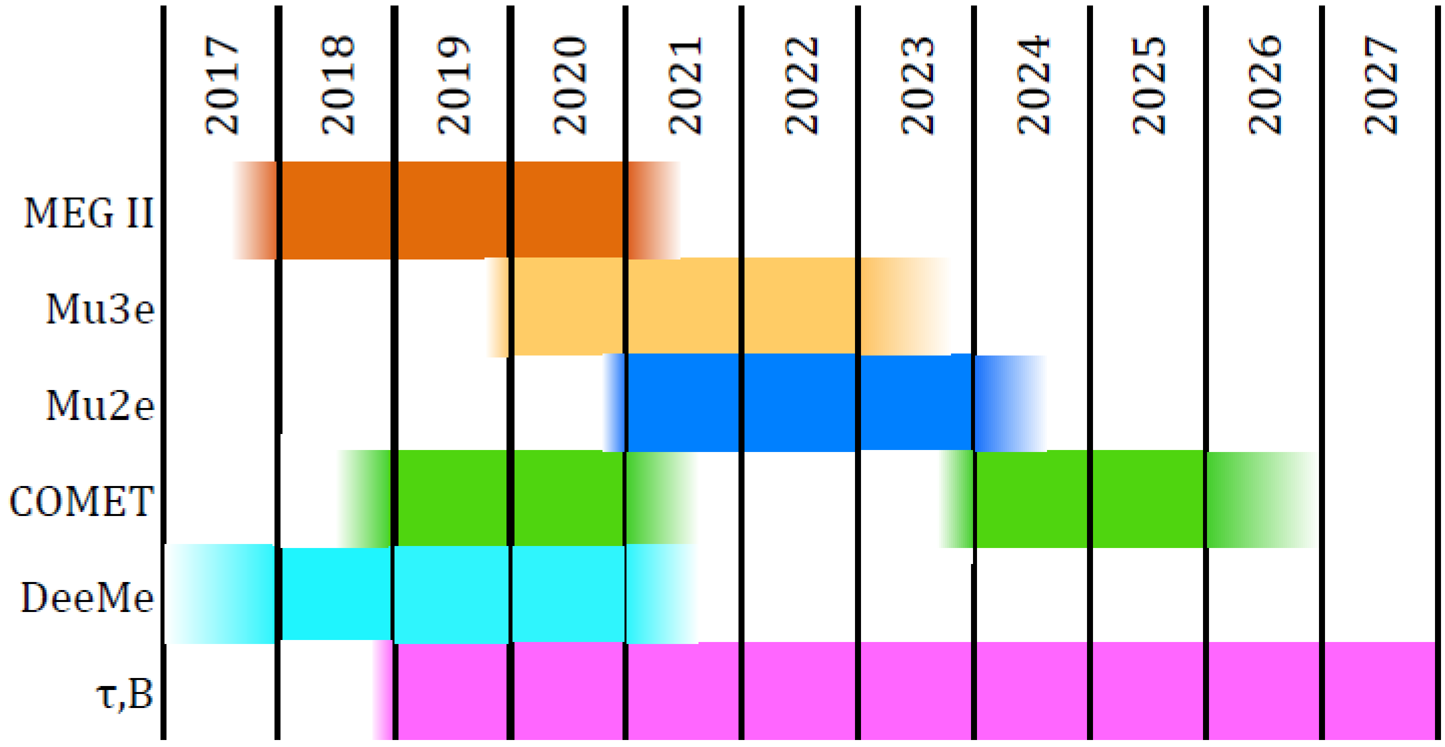
- CLFV is absent in SM with massless neutrinos
- CLFV is very small in SM with massive neutrinos
- CLFV would be a clear signal of NP beyond SM

Most typical CLFV transitions:

$$\mu \to e\gamma,\ \mu \to eee,\ \mu \to e \text{ conversion in nuclei}$$

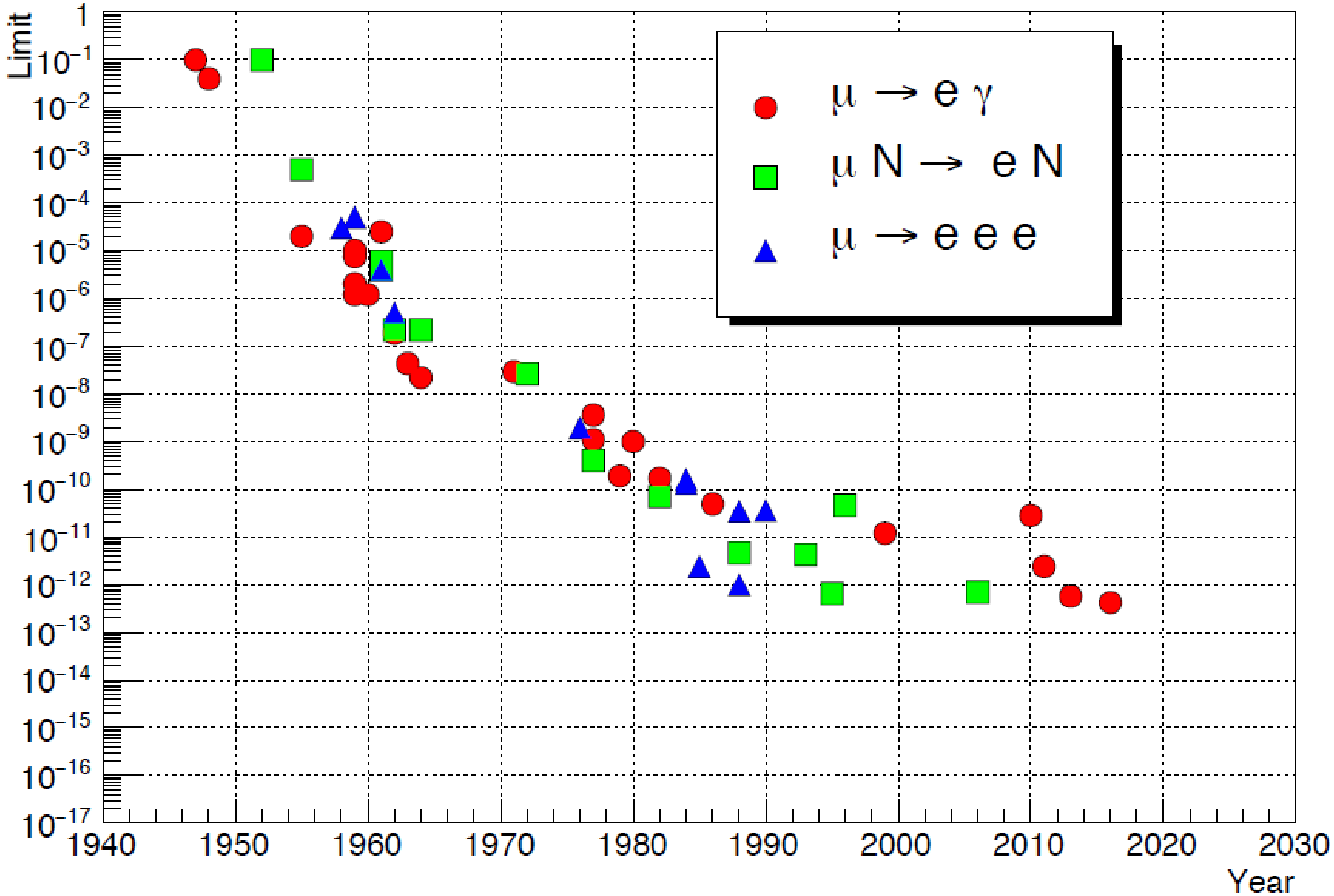


The Mu2e detector



Projected time lines for different projects searching for CLFV decays

process	current sensitivity	future
$\mu \to e\gamma$	$< 4.2 \times 10^{-13}$(MEG [6])	$\sim 10^{-14}$ (MEG II [7])
$\mu \to e\bar{e}e$	$< 1.0 \times 10^{-12}$(SINDRUM [8])	$\sim 10^{-16}$ (Mu3e [9])
μA$\to e$A	$< 7 \times 10^{-13}$(SINDRUM II [10])	$\sim 10^{-16}$ (COMET [11], Mu2e [12])
		$\sim 10^{-(18\to 20)}$ (PRISM/PRIME [13])
$\tau \to l\gamma$	$< 3.3 \times 10^{-8}$(Babar) [14]	$\sim 10^{-9}$(BelleII) [15]
$\tau \to 3l$	$<$ few$\times 10^{-8}$ (Belle) [16]	$\sim 10^{-9}$(BelleII) [15]
$\tau \to l\pi^0$	$< 8.0 \times 10^{-8}$ (Belle) [17]	$\sim 10^{-9}$ (BelleII) [15]
$\tau \to l\rho$	$< 1.2 \times 10^{-8}$ (Belle) [17]	$\sim 10^{-9}$ (BelleII) [15]



Limit
1
10^{-1}
10^{-2}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
10^{-15}
10^{-16}
10^{-17}
1940
1950
1960
1970
1980
1990
2000
2010
2020
2030
Year
$\mu \rightarrow e\gamma$
$\mu N \rightarrow eN$
$\mu \rightarrow eee$

In SM with massless neutrinos, lepton family numbers are individually conserved. There is no CLFV.

In SM with massive neutrinos, there is CLFV.
But because of unitarity of PMNS matrix, CLFV is proportional to differences of neutrino squared masses.

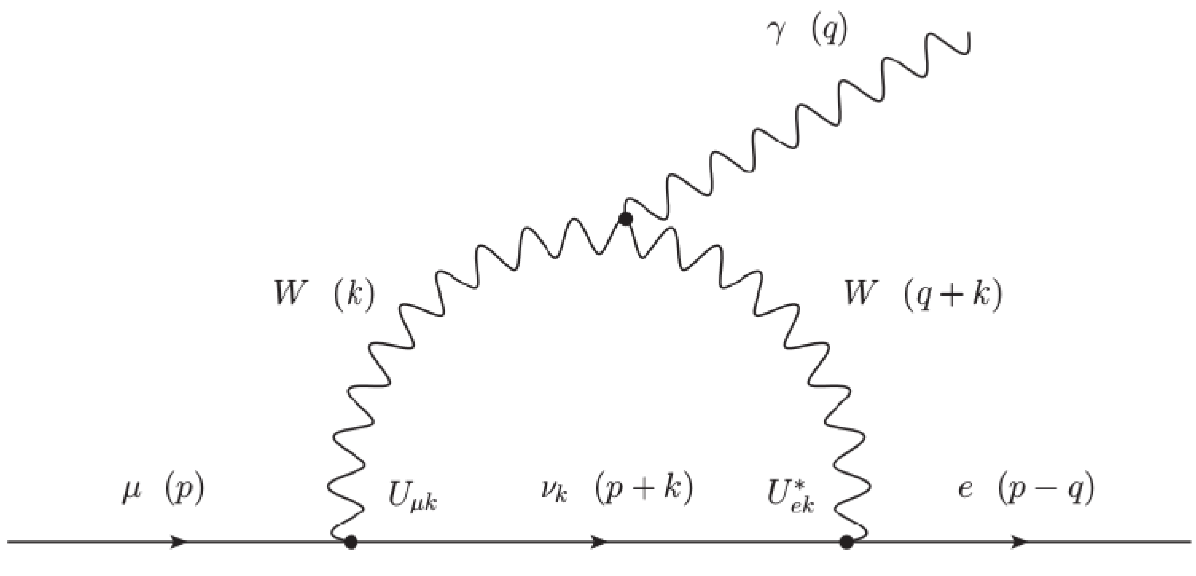


Diagram contributing to $\mu \to e\gamma$ in the SM with massive neutrinos.

In SM with massless neutrinos, lepton family numbers are individually conserved. There is no CLFV.

In SM with massive neutrinos, there is CLFV.
But because of unitarity of PMNS matrix, CLFV is proportional to differences of neutrino squared masses.

$$Br(\mu \to e\gamma) = 10^{-55} \sim 10^{-54}$$

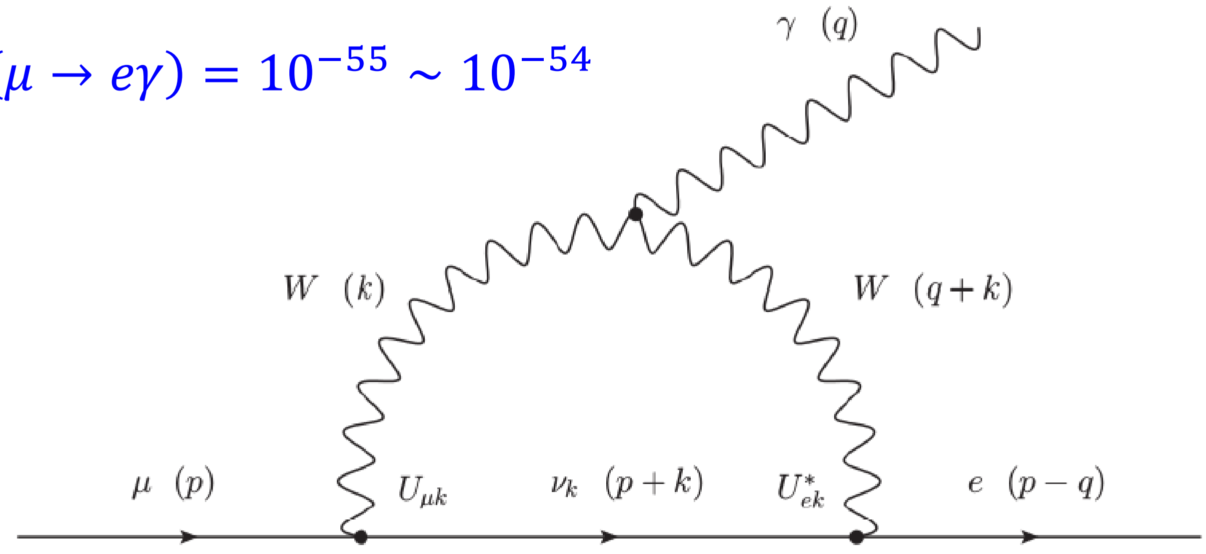
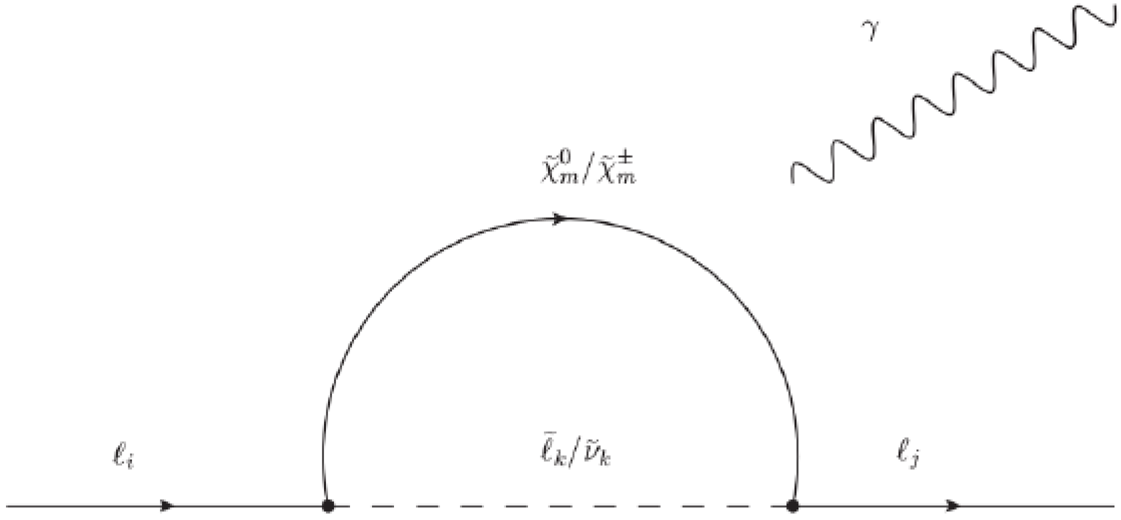


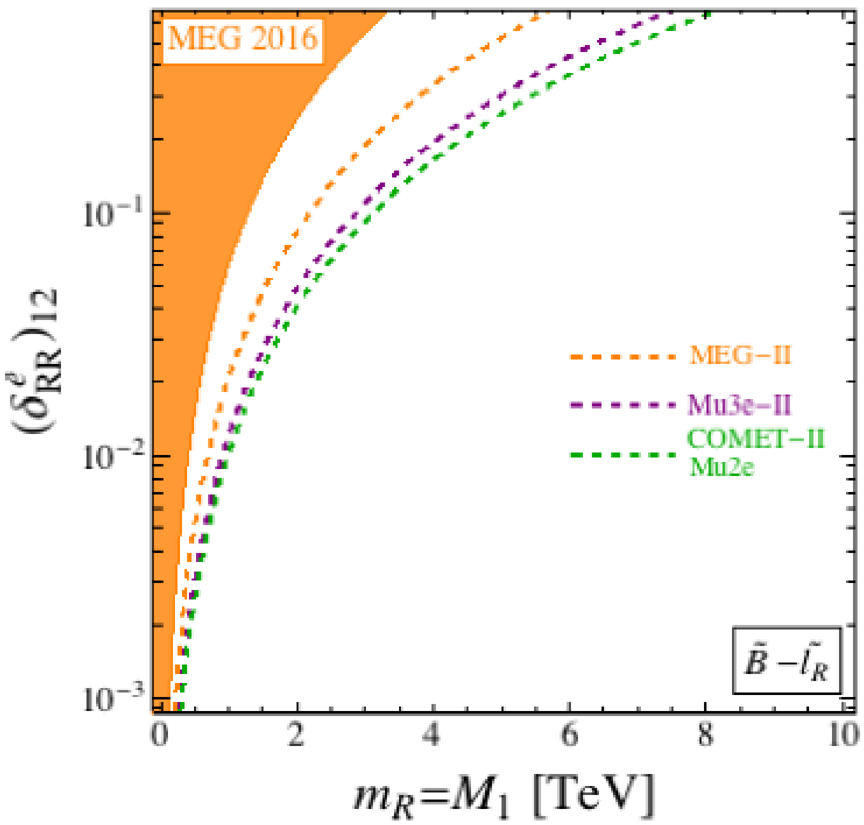
Diagram contributing to $\mu \to e\gamma$ in the SM with massive neutrinos.

SUSY contributions



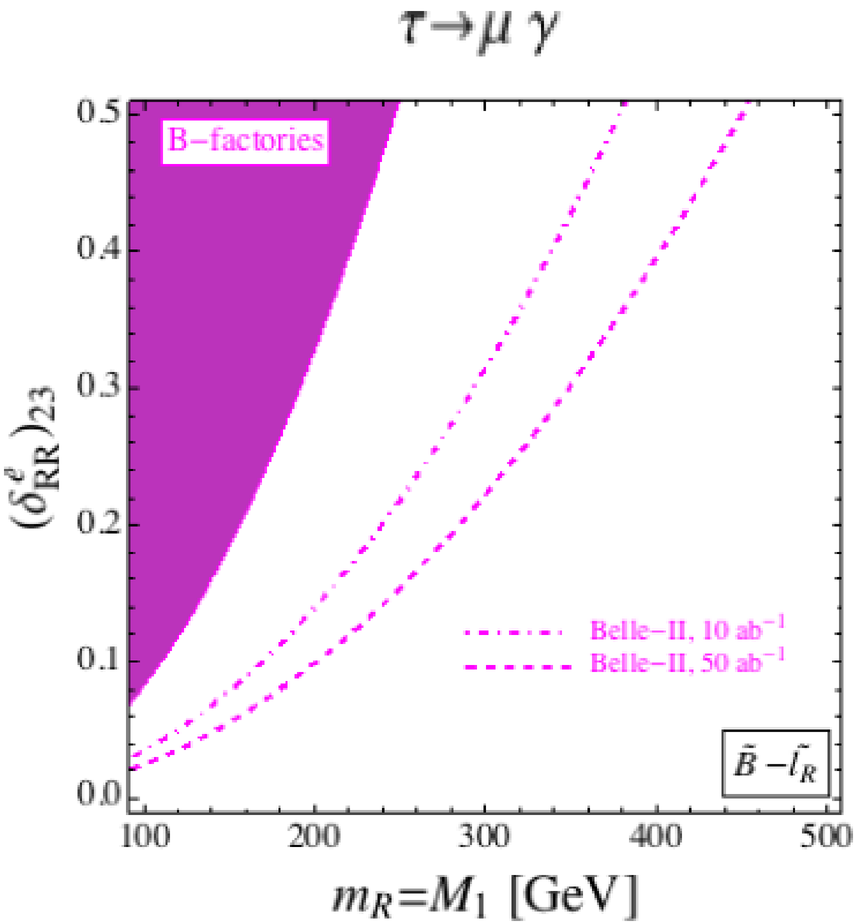
Supersymmetric contribution to $\ell_i \to \ell_j \gamma$

MSSM



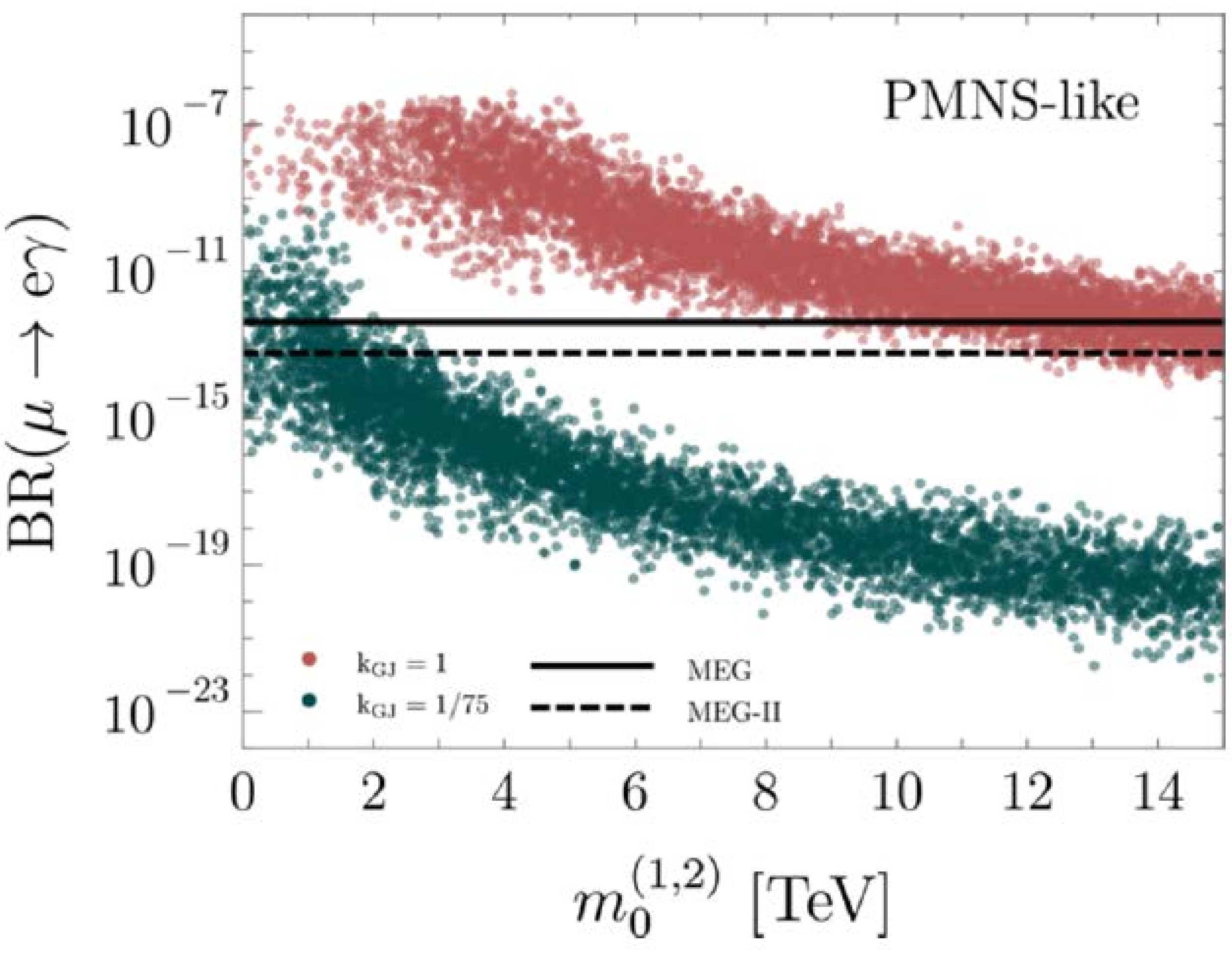
MEG 2016
MEG−II
Mu3e−II
COMET−II
Mu2e
$\tilde{B} - \tilde{l}_R$
$(\delta^e_{RR})_{12}$
10^{-1}
10^{-2}
10^{-3}
0
2
4
6
8
10
$m_R = M_1$ [TeV]

MSSM



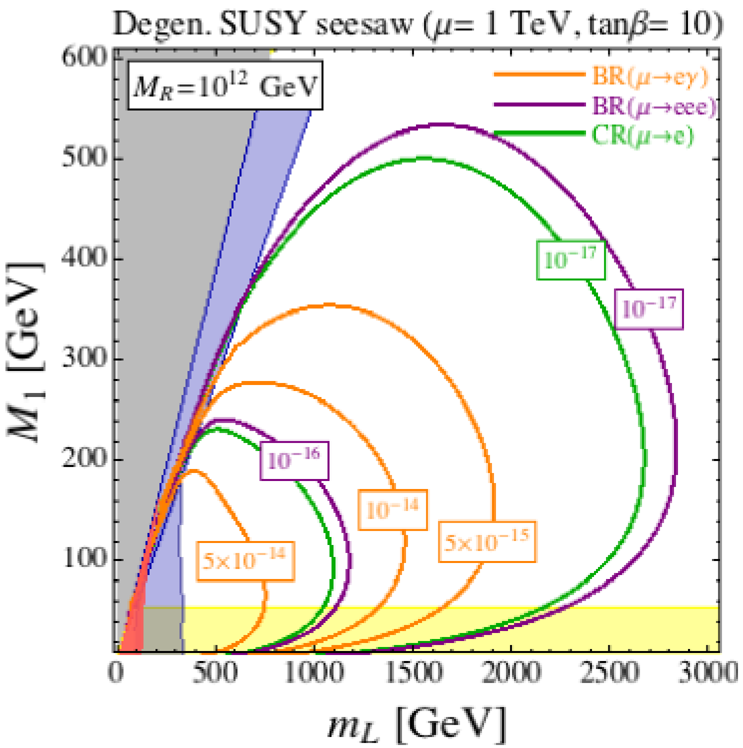
$\tau \to \mu\, \gamma$
B−factories
Belle−II, 10 ab^{-1}
Belle−II, 50 ab^{-1}
$\tilde{B} - \tilde{l}_R$
$(\delta^e_{RR})_{23}$
0.0
0.1
0.2
0.3
0.4
0.5
100
200
300
400
500
$m_R = M_1$ [GeV]

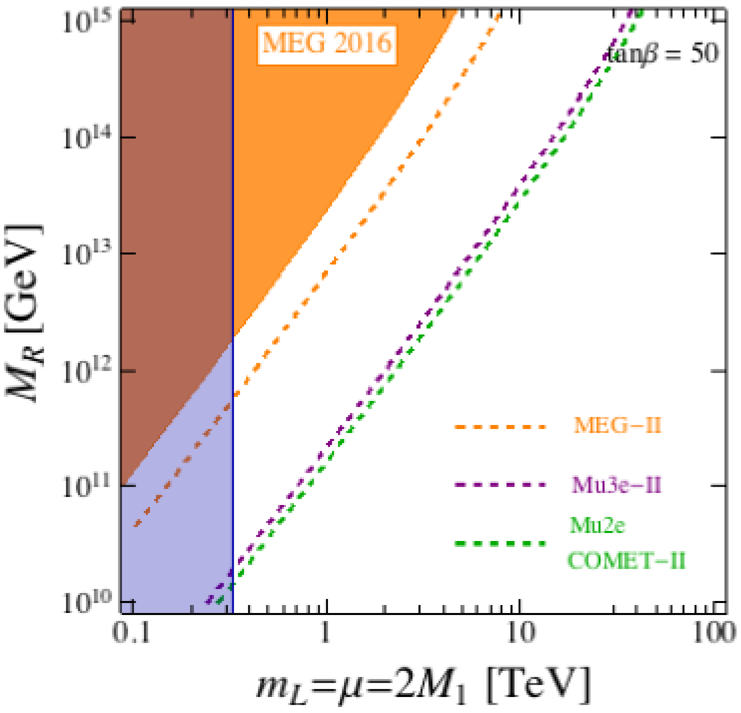
SUSY SO(10)



PMNS-like
10^{-7}
10^{-11}
10^{-15}
10^{-19}
10^{-23}
$\mathrm{BR}(\mu \to e\gamma)$
$k_{GJ} = 1$
$k_{GJ} = 1/75$
MEG
MEG-II
0
2
4
6
8
10
12
14
$m_0^{(1,2)}$ [TeV]

SUSY seesaw model with degenerate RH neutrinos





4 Summary

SUSY Status (in light of current experiments)

- Fancy models:

GMSB/AMSB: can give 125 GeV Higgs, but with very heavy stop (fine-tuning)

CMSSM/mSUGRA: can give 125 GeV Higgs; but cannot explain muon g-2

- Low energy effective models:

MSSM:
NMSSM: can fit all data well, but suffer from little fine-tuning

- Weird-smart models:

Split-SUSY: no problem (give up naturalness)

Stealth SUSY: no problem (can always escape detections)

Compressed SUSY: no problem (can escape detection at LHC)

4 Summary

SUSY Status (in light of current experiments)

Then, what is the problem of SUSY ?

- LHC direct search not seen any sparticles

  Push colored sparticles above TeV (stop mass $M_{SUSY} > \text{TeV}$)

- Quadratic divergence cancel, log divergence still exist

$$\Delta m_H^2 \sim (M_{SUSY}^2 - M_{SM}^2)\frac{\lambda_f^2}{16\pi^2}\ln\left(\frac{\Lambda}{M_{SUSY}}\right)$$

little fine-tuning problem

$$m_H^2 = m_0^2 - \Delta m_H^2$$

125 GeV   bare

SUSY is natural if $M_{SUSY} \sim \mathcal{O}(1)$ TeV

4 Summary

- SUSY confronted with LHC: ok
- SUSY confronted with DM: ok
- SUSY confronted with CLFV: ok
- SUSY confronted with muon g-2

CMSSM/mSUGRA, GMSB, AMSB: need to be extended

MSSM: ok

- light electroweakinos
- light sleptons

Most hopefully accessible at LHC

4 Summary

The on-going and future experiments

(LHC, DM, CLFV, g-2)

will continue to probe SUSY

Thanks for your attention ！