宇宙の進化と素粒子模型

令和３年度宇宙線研究所共同利用研究成果発表会

宇宙線研究所理論グループ　伊部昌宏

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国内旅費：20万円 (次年度繰越)

2021 業績一部

1) Gauge kinetic mixing and dark topological defects
By Takashi Hiramatsu, Masahiro Ibe, Motoo Suzuki, Soma Yamaguchi
e-Print: 2109.12771 [hep-ph]
DOI: 10.1007/JHEP12(2021)122

2) Chiral composite asymmetric dark matter
By Masahiro Ibe, Shin Kobayashi, Keiichi Watanabe
e-Print: 2105.07642 [hep-ph]
DOI: 10.1007/JHEP07(2021)220

3) Muon g-2 in Gauge Mediation without SUSY CP Problem
By Masahiro Ibe, Shin Kobayashi, Yuhei Nakayama, Satoshi Shirai
e-Print: 2104.03289 [hep-ph]
DOI: 10.1007/JHEP07(2021)098

4) On Stability of Fermionic Superconducting Current in Cosmic String
BY Masahiro Ibe, Shin Kobayashi, Yuhei Nakayama, Satoshi Shirai
e-Print: 2102.05412 [hep-ph]
DOI: 10.1007/JHEP05(2021)217

5) Anisotropies in Cosmological 21 cm Background by Oscillons/I-balls of Ultra-light Axion-like Particle
By Masahiro Kawasaki, Kazuyoshi Miyazaki, Kai Murai, Hiromasa Nakatsuka, Eisuke Sonomoto
e-Print: 2112.10464 [astro-ph.CO]

6) Physics of star formation history and the luminosity function of galaxies therefrom
By Masataka Fukugita, Masahiro Kawasaki
e-Print: 2111.01389 [astro-ph.GA]

7) Constraints on small-scale primordial density fluctuation from cosmic microwave background through dark matter annihilation
By Masahiro Kawasaki, Hiromasa Nakatsuka, Kazunori Nakayama
e-Print: 2110.12620 [astro-ph.CO]

8) Free Streaming Length of Axion-Like Particle After Oscillon/ I-ball Decays
By Kaname Imagawa, Masahiro Kawasaki, Kai Murai, Hiromasa Nakatsuka, Eisuke Sonomoto
e-Print: 2110.05790 [hep-ph]

9) Strong clustering of primordial black holes from Affleck-Dine mechanism
Masahiro Kawasaki, Kai Murai, Hiromasa Nakatsuka
e-Print: 2107.03580 [astro-ph.CO]
DOI: 10.1088/1475-7516/2021/10/025
Published in: JCAP 10 (2021), 025, JCAP 10 (2021), 025

10) Revisiting CMB constraints on dark matter annihilation
Masahiro Kawasaki, Hiromasa Nakatsuka, Kazunori Nakayama, Toyokazu Sekiguchi
e-Print: 2105.08334 [astro-ph.CO]
DOI: 10.1088/1475-7516/2021/12/015

11) SU(N)-natural inflation
Tomohiro Fujita, Hiromasa Nakatsuka, Kyohei Mukaida, Kai Murai
e-Print: 2110.03228 [hep-ph]

12) Gravitational wave trispectrum in the axion-SU(2) model
Tomohiro Fujita, Kai Murai, Ippei Obata, Maresuke Shiraishi
e-Print: 2109.06457 [astro-ph.CO]
DOI: 10.1088/1475-7516/2022/01/007

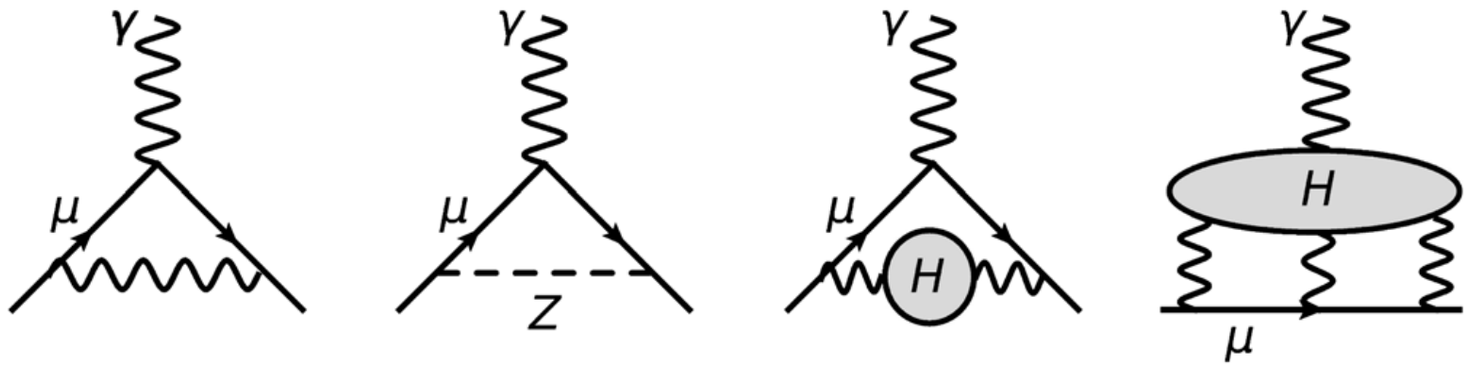
Muon g – 2 in Gauge Mediation without SUSY CP Problem

JHEP 07 (2021) 098

Masahiro Ibe, Shin Kobayashi, Yuhei Nakayama, Satoshi Shirai

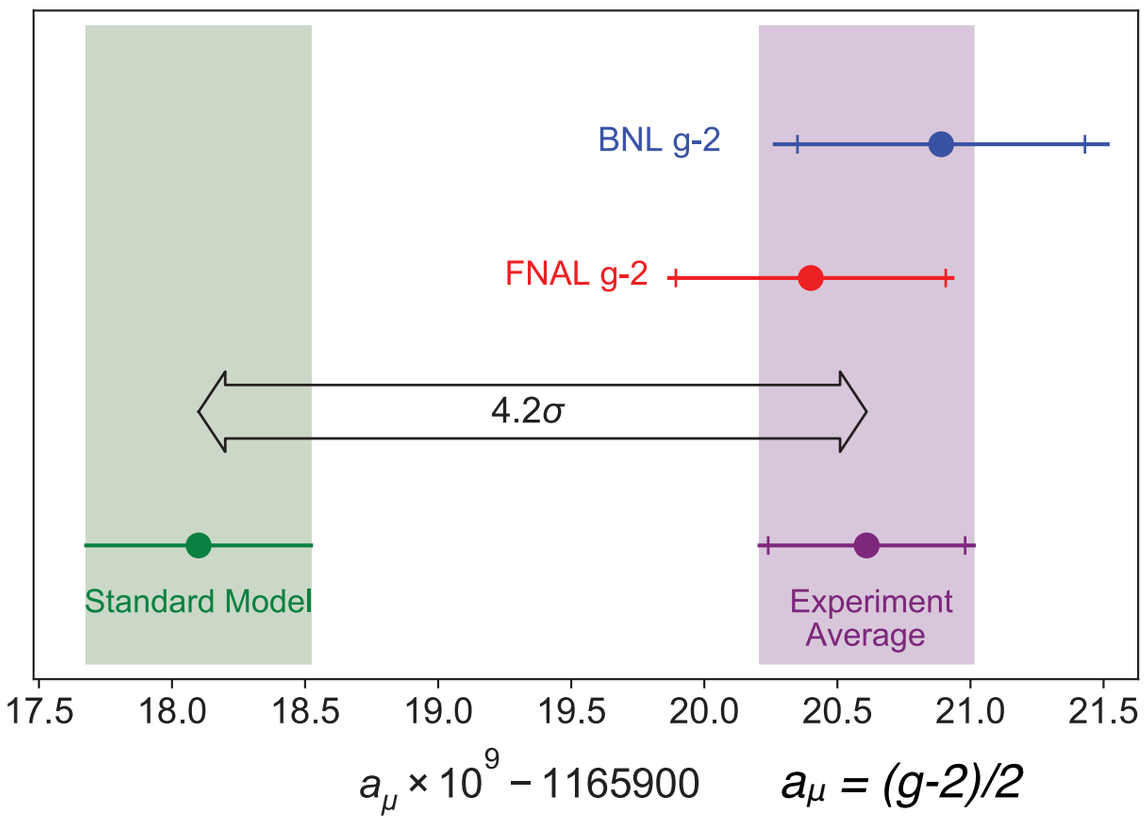
Muon anomalous magnetic moment : g-2

Theory



QED | EW | Hadronic vacuum polarization (HPV) | Hadronic light-By-light (Hlbl)

FNAL Muon g-2 Experiment (PRL.126.141801)



$a_\mu^{SM} = 116591810(43) \times 10^{-11}$

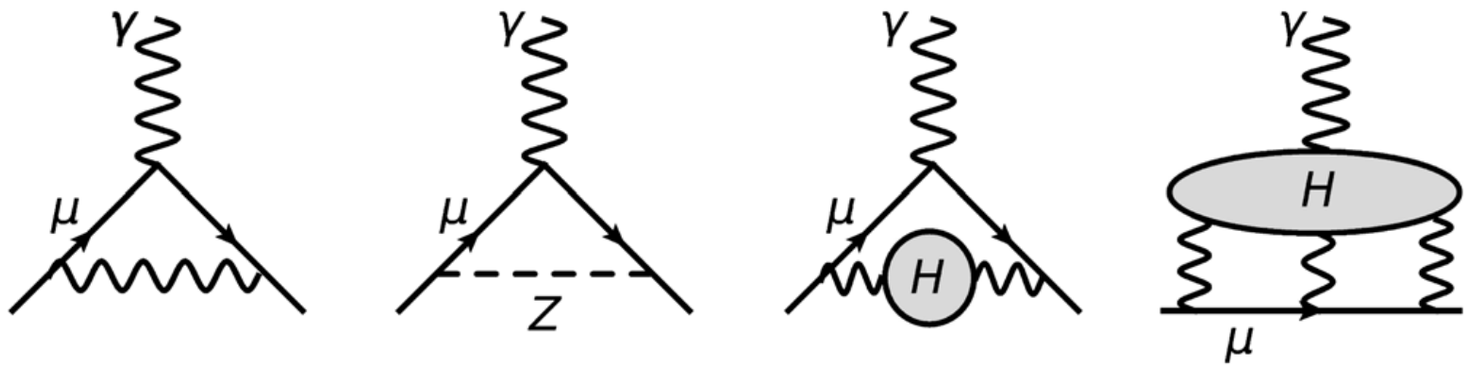
$a_\mu^{FNAL} = 116592040(54) \times 10^{-11}$

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

4.2σ discrepancy !

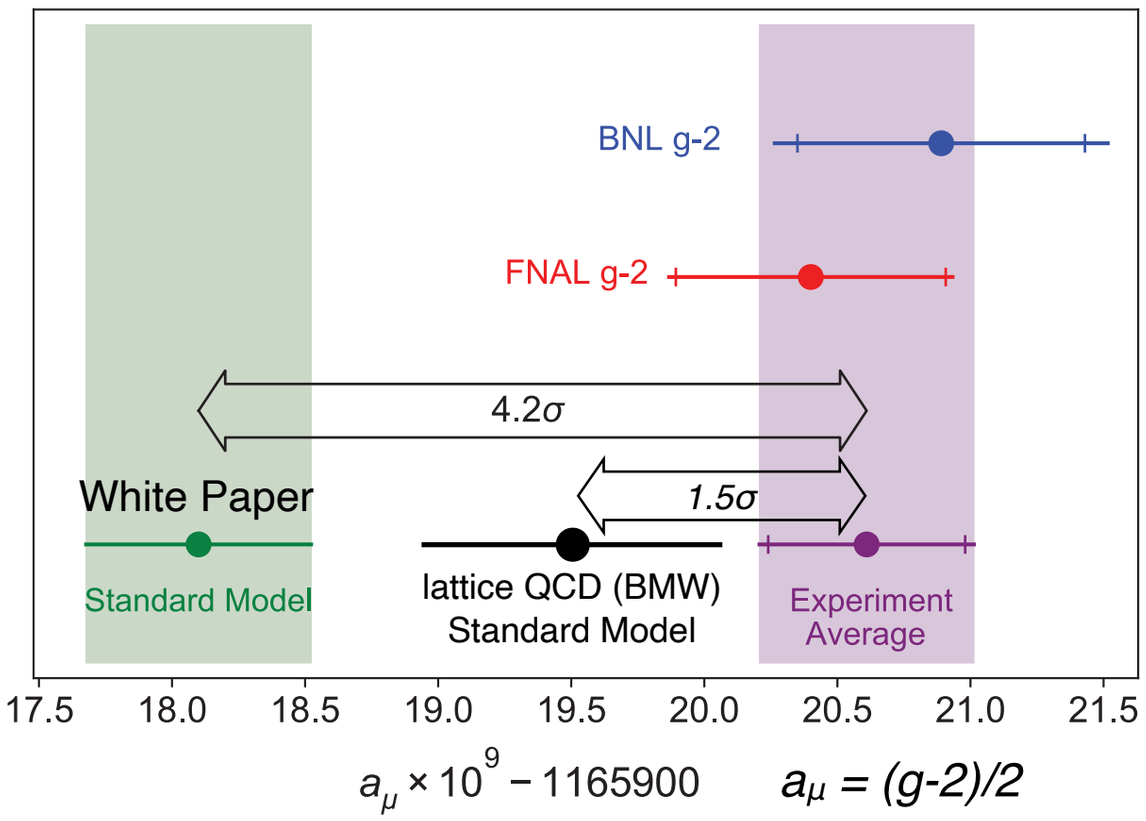
Muon anomalous magnetic moment : g-2

Theory



QED | EW | Hadronic vacuum polarization (HPV) | Hadronic light-By-light (Hlbl)

FNAL Muon g-2 Experiment (PRL.126.141801)



The latest lattice result for HVP reduces tension…[BMW, Nature 2021]

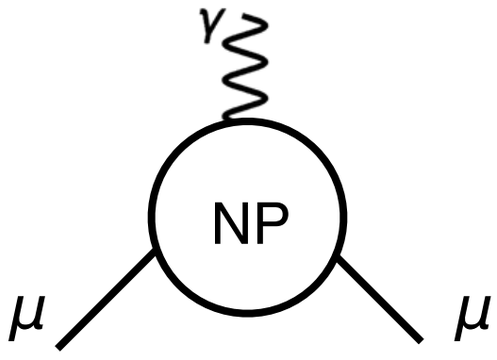
(In the White Paper analysis, HVP is estimated by the phenomenological method.)

BMW HVP causes additional tension in $e^-e^+ \rightarrow 2\pi$ cross section observation…

[Colangelo et.al. arXiv:2010.07943]

New Physics Explanation ?

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

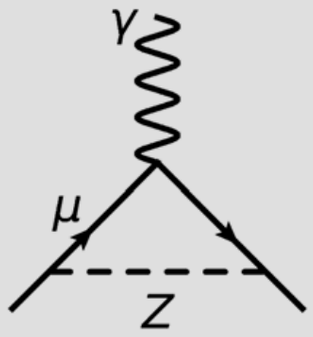


New physics with

$a_\mu^{NP} = O(100) \times 10^{-11}$

can explain the discrepancy !

cf.



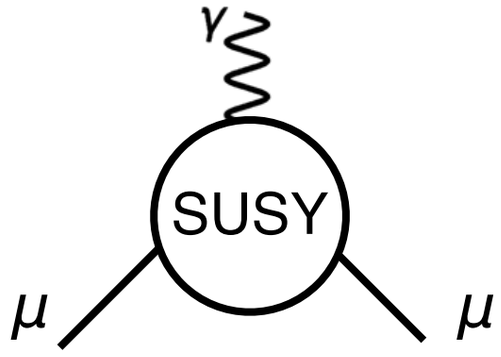
Electroweak loop contribution :

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

New physics within a TeV range can explain the deviation !

Supersymmetry (SUSY) ?

SUSY explanation of g-2 is no more easy…



$a_\mu^{SUSY} = O(100) \times 10^{-11}$

requires SUSY particles within a TeV

⇕

Observed Higgs boson mass m_h = 125.15 ± 0.17 GeV requires

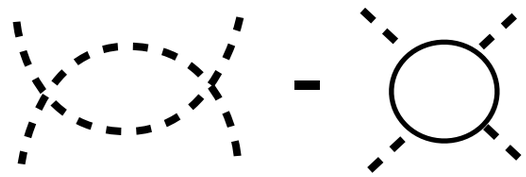
$$m_h^2 \sim m_Z^2 + \frac{3y_t^2 m_t^2}{4\pi^2} \log \frac{m_{\rm SUSY}^2}{m_t^2}$$

m_{SUSY} = multi-TeV range

Tree-level quartic term:

$$\lambda = \frac{1}{2}(g_1^2 + g_2^2)\cos^2 2\beta$$

One-loop log enhanced:

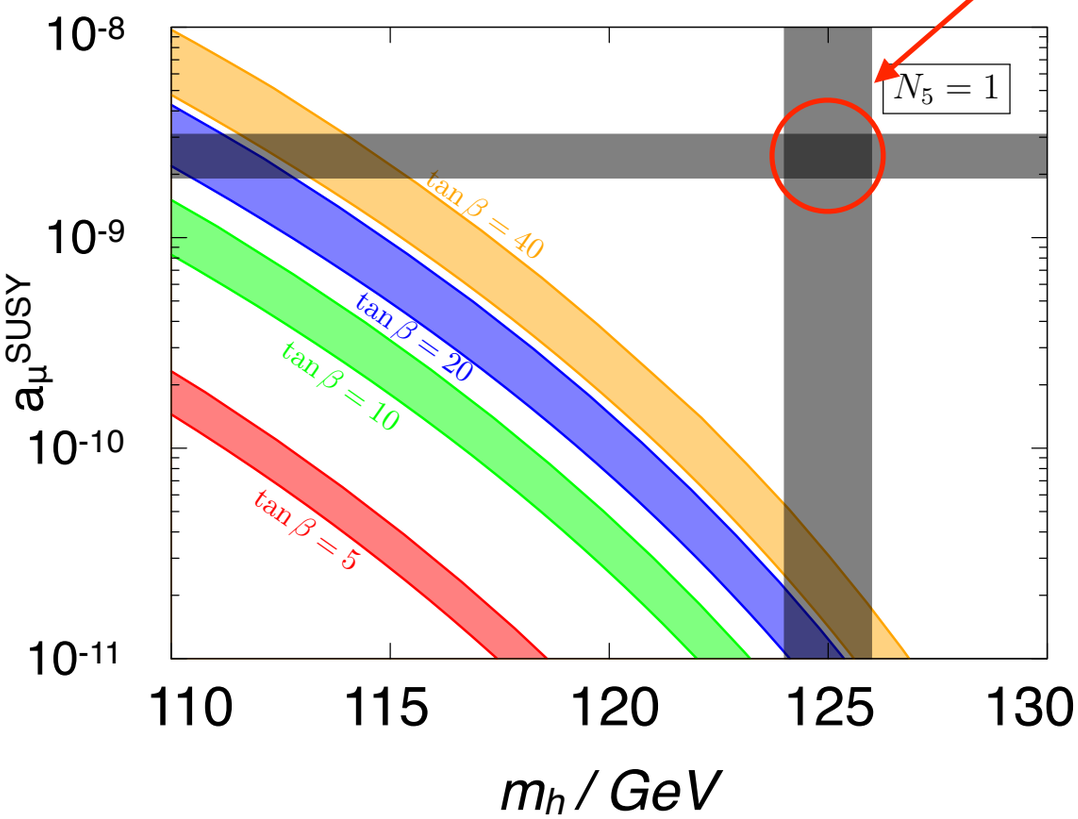


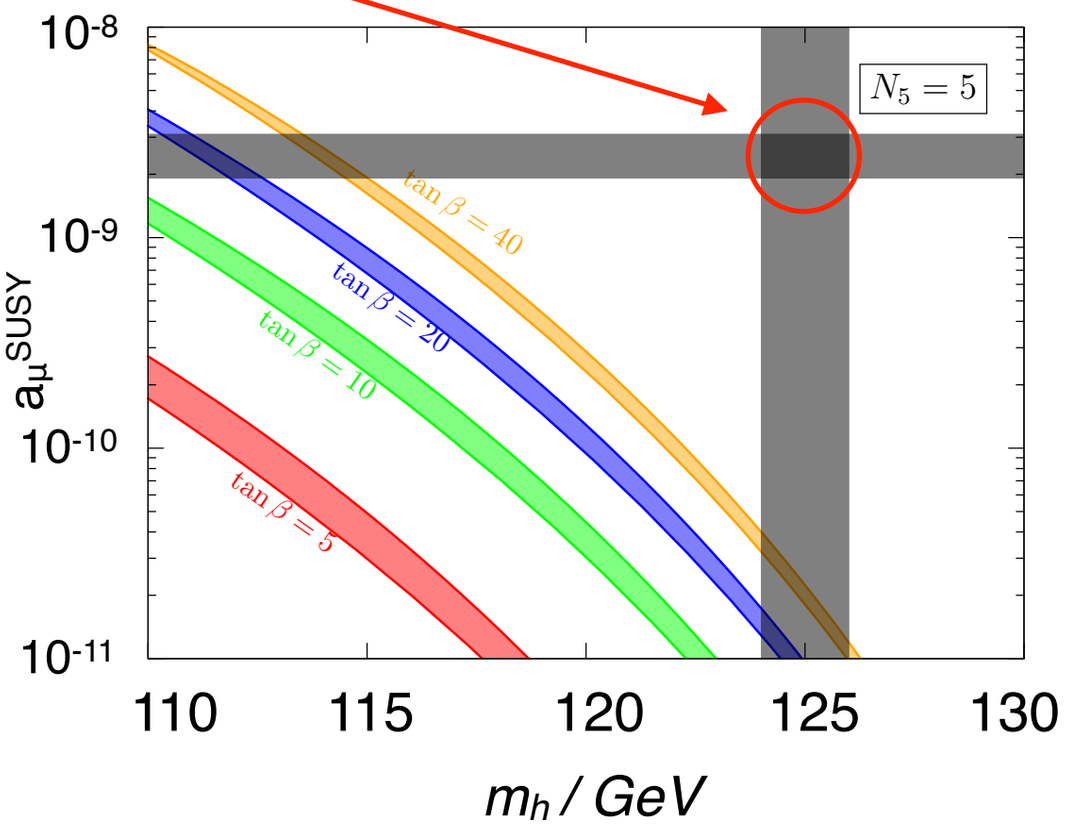
SUSY explanation of g-2 is no more easy…

In conventional SUSY (here we assume gauge mediation)

model predictions = colored bands

g-2 and m_h cannot be explained simultaneously…





JHEP 07 (2021) 098 MI et. al.

SUSY explanation of g-2 is no more easy…

Closer Look :

- ✔ $a_\mu^{SUSY} = O(100) \times 10^{-11}$ *requires*

  SUSY partners of the muon and the weak bosons within a TeV

- ✔ $m_h = 125.15 \pm 0.17$ *GeV requires*

  SUSY partners of the top quark in the multi-TeV

Can we make consider models with

$m_{stop} \sim 10TeV$

$m_{smuon}, m_{wino}, m_{Bino}, m_{Higgsino} < TeV$ *?*

Naive models end up with too large CP violation…

Electron EDM : $$\left|\frac{d_e}{e}\right| \sim \frac{1}{2}\frac{m_e}{m_\mu^2} \times a_\mu|_{\rm SUSY} \sim 10^{-24}\,{\rm cm} \times \left(\frac{a_\mu|_{\rm SUSY}}{2\times 10^{-9}}\right) ,$$

Experimental constraint : $$\left|\frac{d_e}{e}\right| < 1.1 \times 10^{-29}\,{\rm cm}$$ [*ACME*]

Muon g – 2 in Gauge Mediation without SUSY CP Problem

Masahiro Ibe, Shin Kobayashi, Yuhei Nakayama, Satoshi Shirai

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Our model achieves :

$m_{stop} \sim 10\,TeV$

$m_{smuon}, m_{wino}, m_{Bino}, m_{Higgsino} < TeV$

No serious CP violation without fine-tuning

- ✔ $a_\mu^{SUSY} = O(100) \times 10^{-11}$ *is achieved*
- ✔ $m_h = 125.15 \pm 0.17\,GeV$ *is achieved*
- ✔ *No SUSY CP problem (← Highly Non-Trivial !)*

Muon g – 2 in Gauge Mediation without SUSY CP Problem

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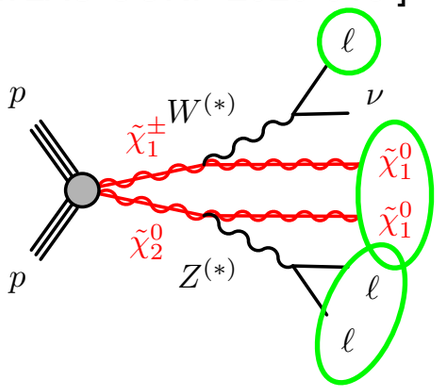
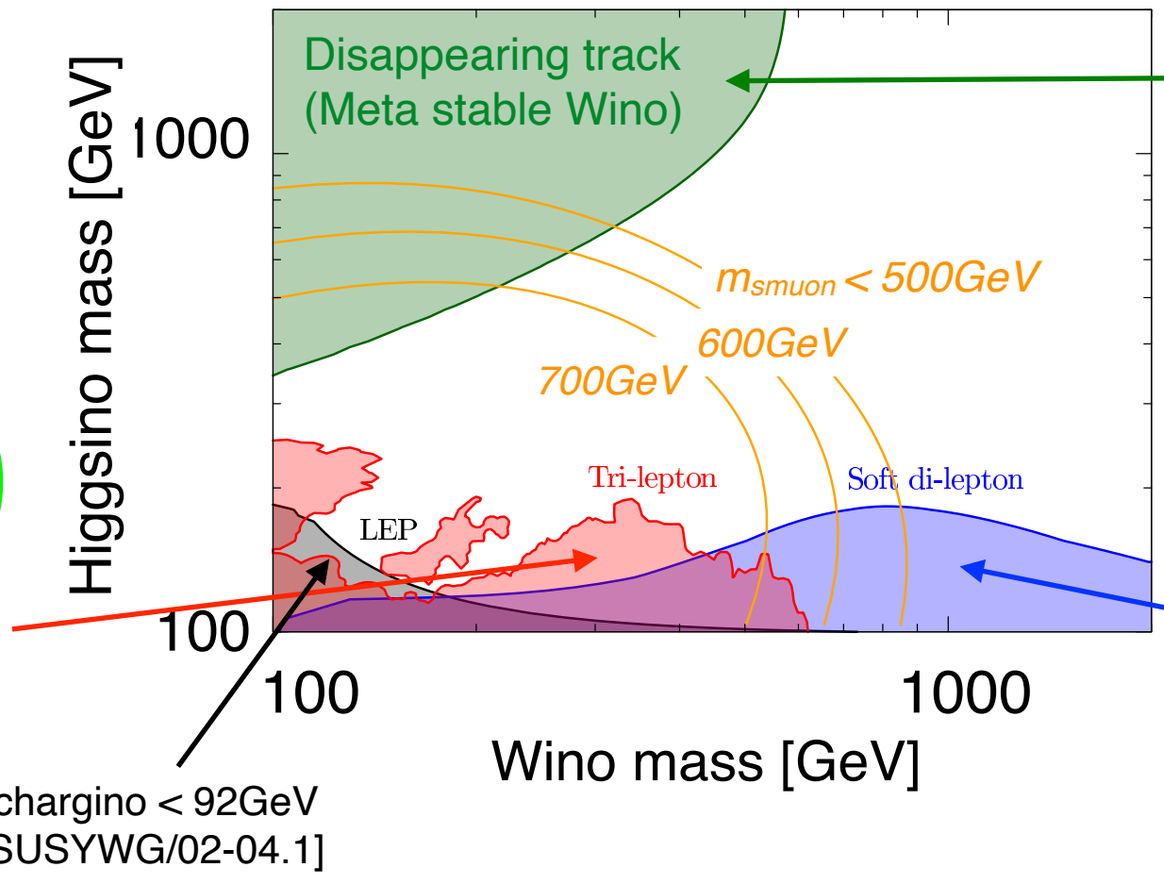
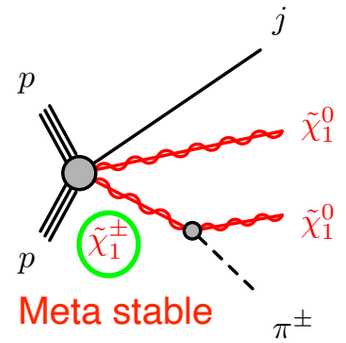
The orange lines are the upper limit on the smuon mass
to explain the ***g-2*** for a given (m_{wino}, $m_{Higgsino}$)

[ATLAS-CONF-2020-015]

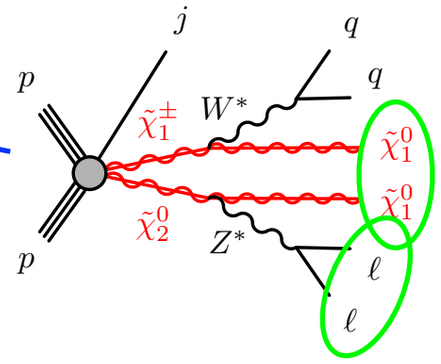




[ATLAS-CONF-2021-015]



[ATLAS : 1911.12606]



- ✔ The model can be tested
  LHC SUSY searches, ILC250 (virtual SUSY contribution)
- ✔ SUGRA effects also induce testable
  Electron EDM, Lepton Flavor Violations

Cosmology is terribly complicated…