

Muon $g-2$ and Dark Matter in the MSSM

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With P. Cox, T. T. Yanagida, arXiv:1805.02802

Standard Model

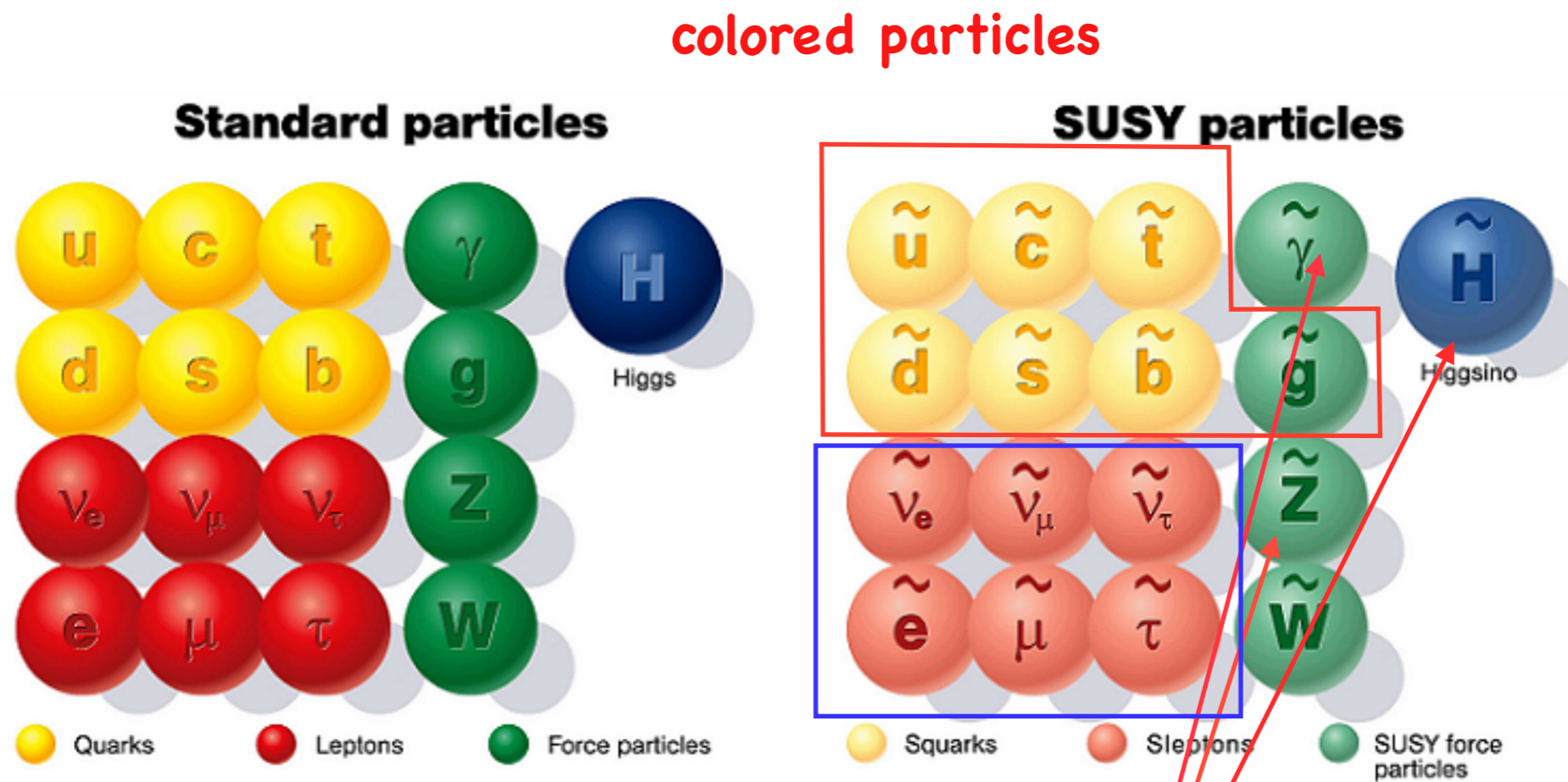
Standard Model of Elementary Particles

		three generations of matter (fermions)				
		I	II	III		
mass		$\approx 2.4 \text{ MeV}/c^2$	$\approx 1.275 \text{ GeV}/c^2$	$\approx 172.44 \text{ GeV}/c^2$	0	$\approx 125.09 \text{ GeV}/c^2$
charge		$2/3$	$2/3$	$2/3$	0	0
spin		$1/2$	$1/2$	$1/2$	1	0
		u up	c charm	t top	g gluon	H Higgs
	QUARKS	$\approx 4.8 \text{ MeV}/c^2$	$\approx 95 \text{ MeV}/c^2$	$\approx 4.18 \text{ GeV}/c^2$	0	
		$-1/3$	$-1/3$	$-1/3$	0	
		$1/2$	$1/2$	$1/2$	1	
		d down	s strange	b bottom	γ photon	
		$\approx 0.511 \text{ MeV}/c^2$	$\approx 105.67 \text{ MeV}/c^2$	$\approx 1.7768 \text{ GeV}/c^2$	$\approx 91.19 \text{ GeV}/c^2$	
		-1	-1	-1	0	
		$1/2$	$1/2$	$1/2$	1	
		e electron	μ muon	τ tau	Z Z boson	
	LEPTONS	$< 2.2 \text{ eV}/c^2$	$< 1.7 \text{ MeV}/c^2$	$< 15.5 \text{ MeV}/c^2$	$\approx 80.39 \text{ GeV}/c^2$	
		0	0	0	± 1	
		$1/2$	$1/2$	$1/2$	1	
		ν_e electron neutrino	ν_μ muon neutrino	ν_τ tau neutrino	W W boson	
						SCALAR BOSONS
						GAUGE BOSONS

Successful to describe most of the low energy phenomenologies

- Grand unification
- Hierarchy Problem
- Dark matter

SUSY particles

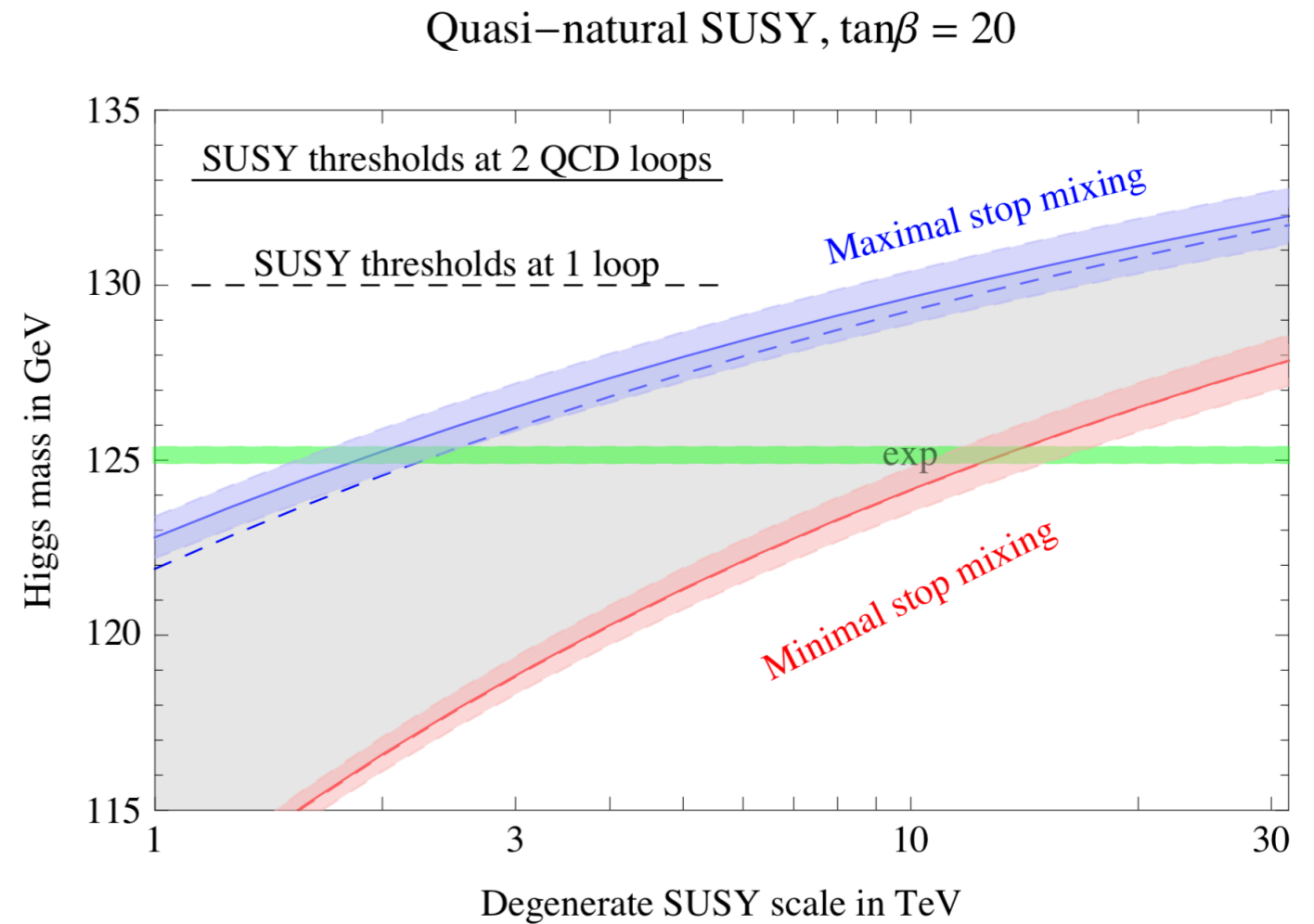


sleptons

Lightest is the dark matter candidate

Where is SUSY scale?

125 GeV Higgs



arXiv:1407.4081, E. Bagnaschi, G. F. Giudice, P. Slavich, A. Strumia

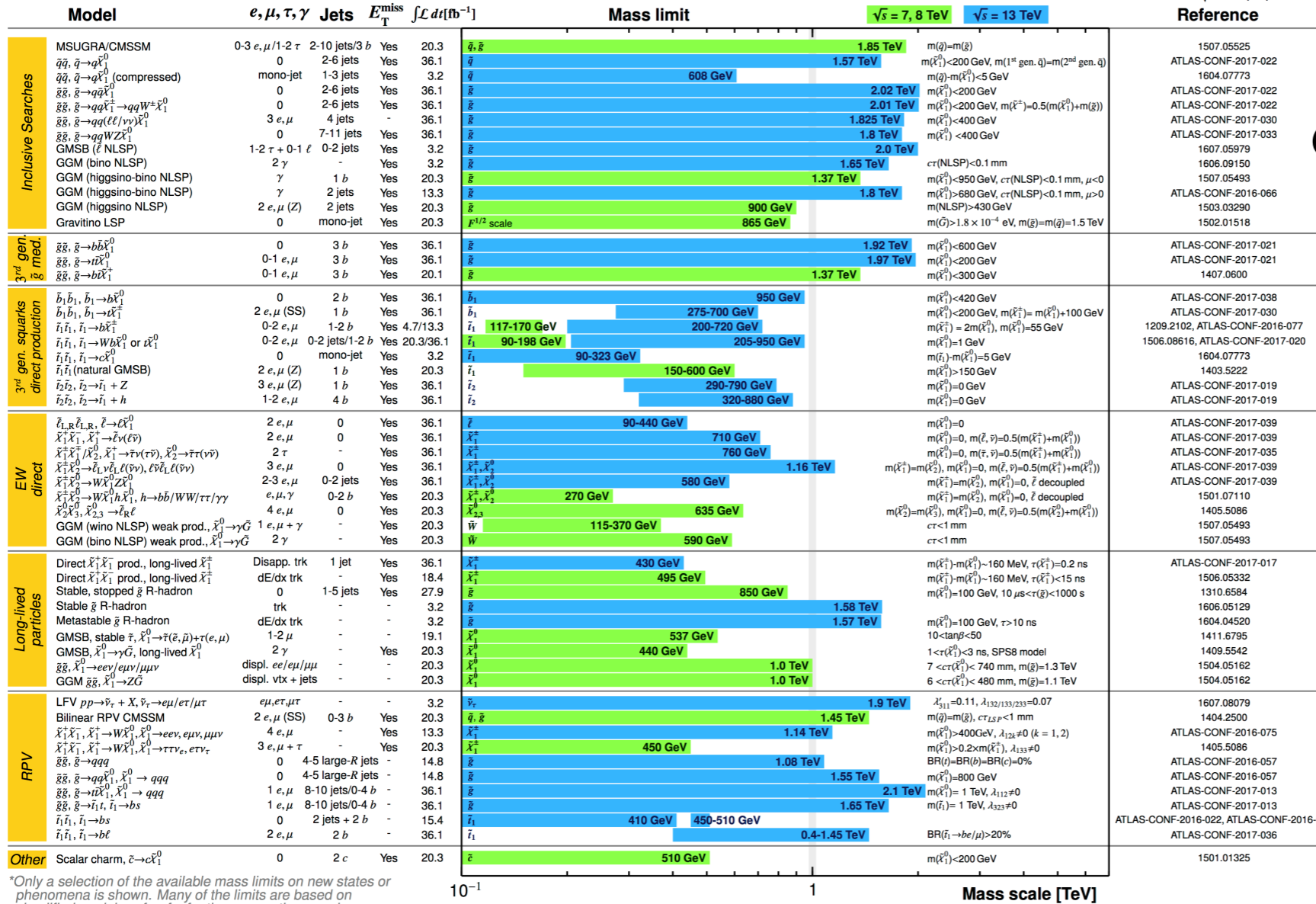
Colored sparticles should be beyond TeV scale!

No evidence for new particles in direct search

SUSY prediction: colored sparticles should be heavy, not reach yet

ATLAS SUSY Searches* - 95% CL Lower Limits
May 2017

ATLAS Preliminary
 $\sqrt{s} = 7, 8, 13$ TeV



Colored sparticles > 1-2 TeV

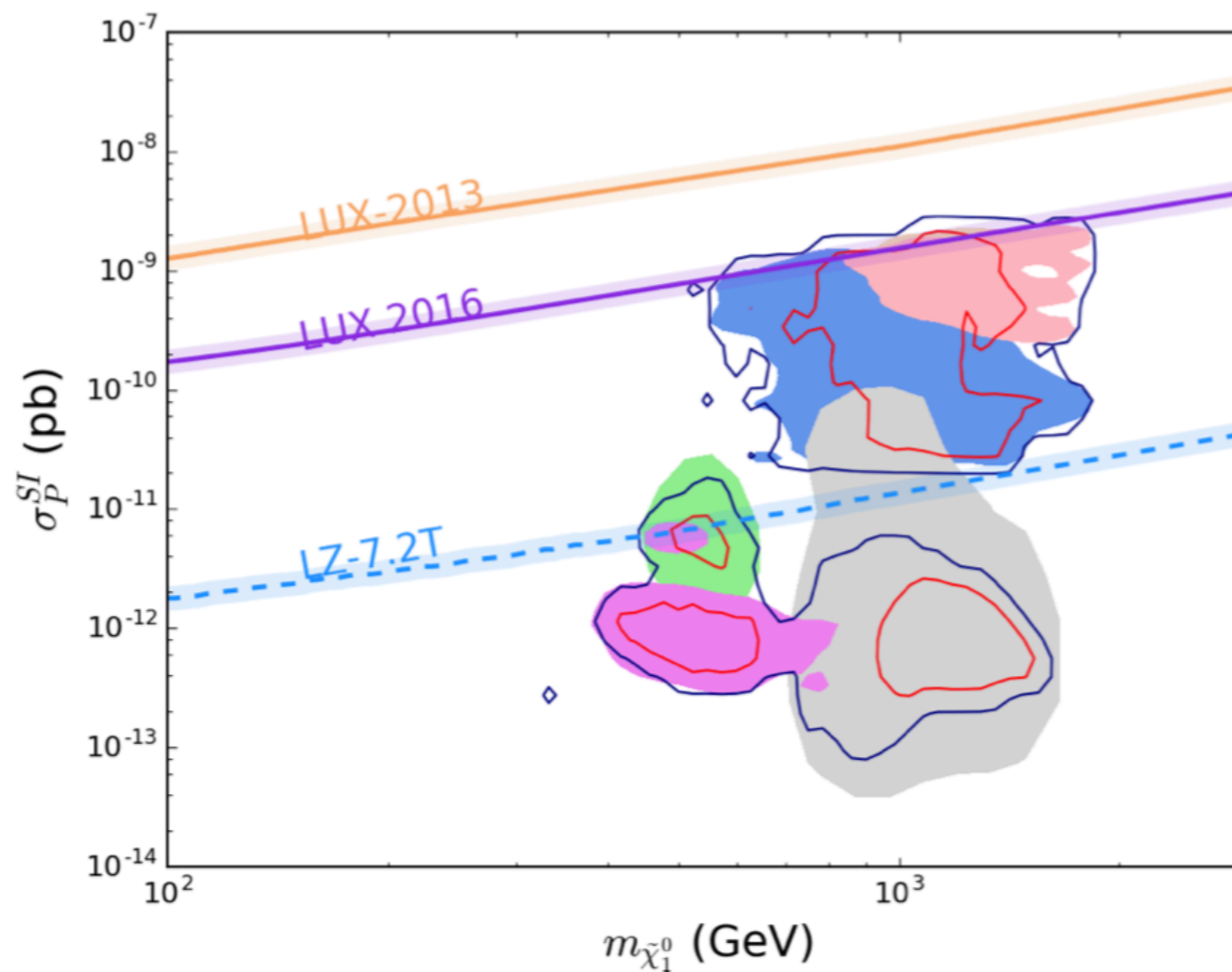
slepton or electroweakino
few hundred GeV still
allowed

*Only a selection of the available mass limits on new states or phenomena is shown. Many of the limits are based on simplified models, c.f. refs. for the assumptions made.

Status of dark matter in SUSY

Example: Dark matter result for CMSSM

Han, et al, Phys.Lett. B769 (2017) 470-476



Slepton (green), StopC (purple), AF (blue), FP (yellow), Slepton&AF (gray) and AF&FP (pink)

Any other indication of low energy SUSY particles?

Muon g-2

$$\mathcal{H} = -\vec{\mu} \cdot \vec{B}, \quad \vec{\mu} = g \left(\frac{e}{2m} \right) \vec{S}$$

$$a = (g - 2)/2$$

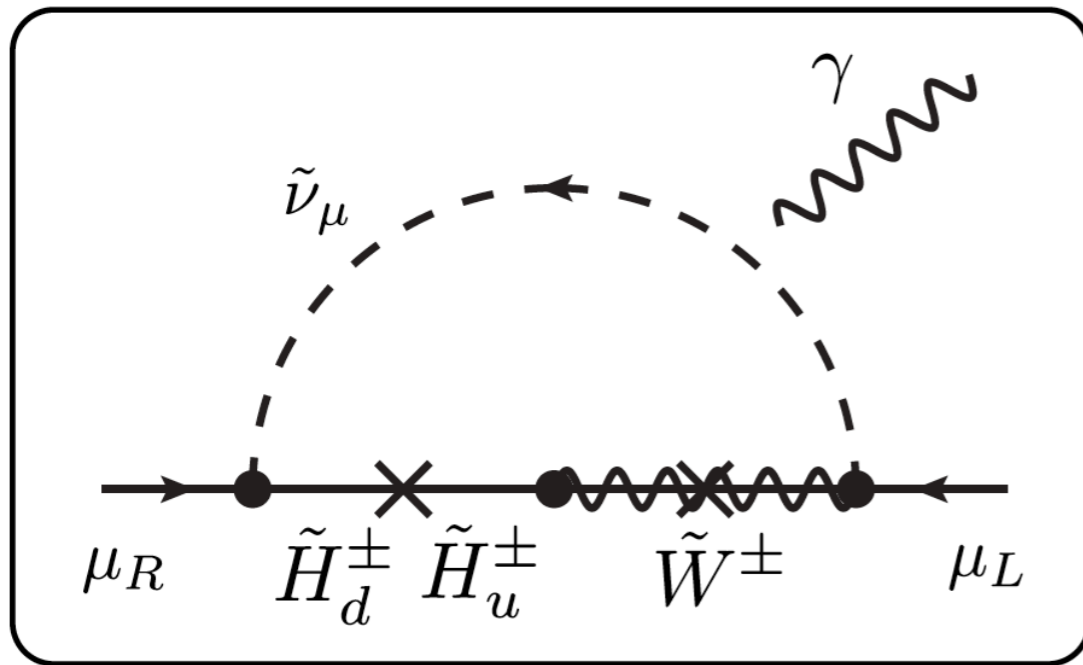
$$a_{\mu}^{\text{exp}} - a_{\mu}^{\text{SM}} = (2.68 \pm 0.63 \pm 0.43) \times 10^{-9}$$

> 3 sigma deviation

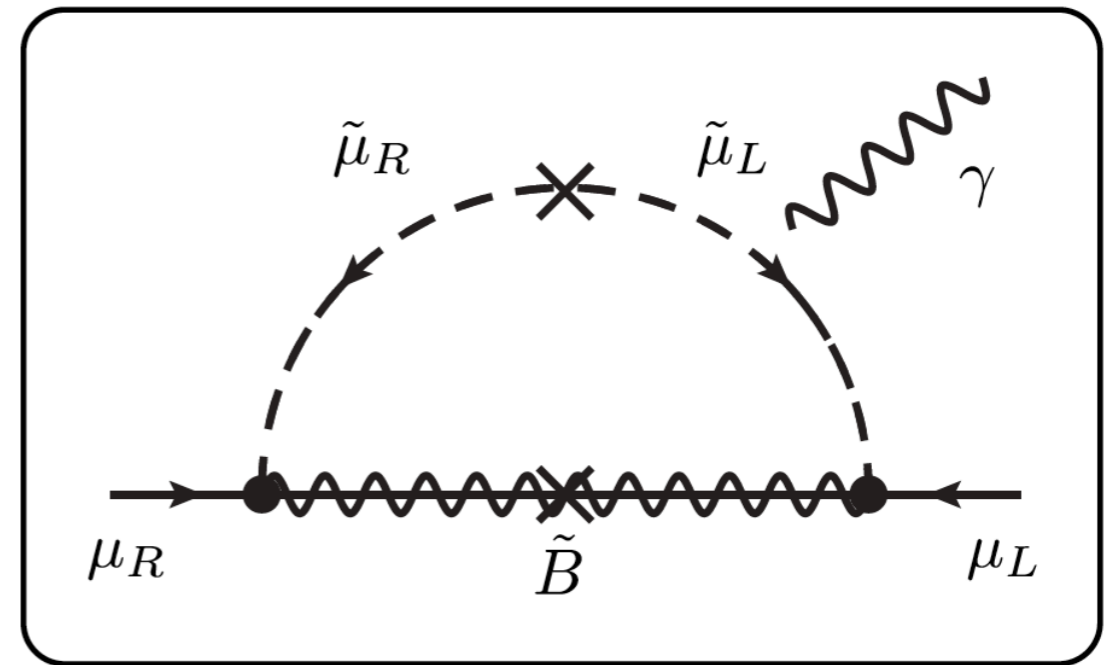
Details see the afternoon's talk

Indication of low energy slepton or electroweakino

chargino-muon sneutrino



neutralino-smuon



$$a_\mu(\text{SUSY}) \sim \frac{\alpha_2(\alpha_Y)}{4\pi} \frac{m_\mu^2}{m_{\text{soft}}^2} \tan \beta \quad (\tan \beta \sim 10)$$

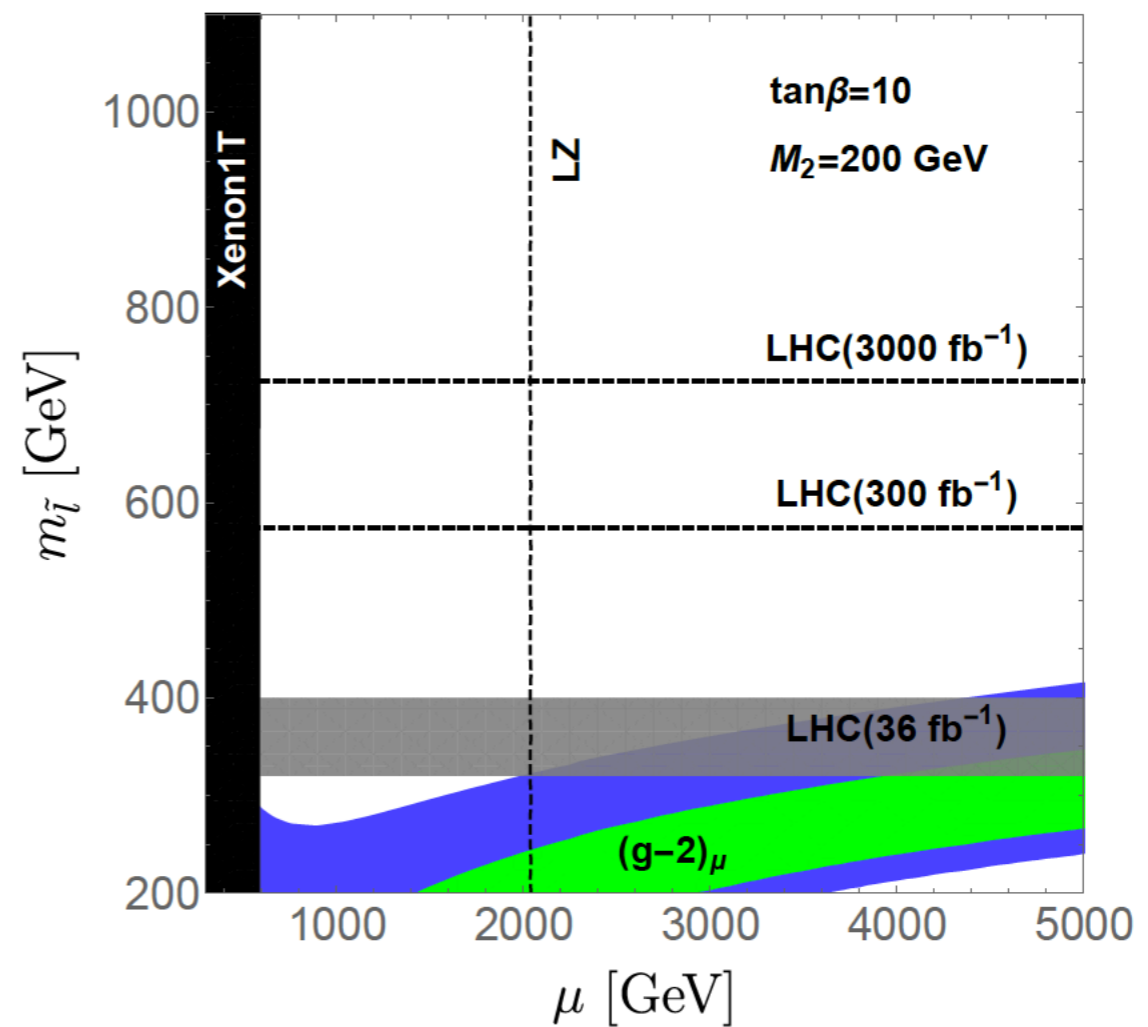
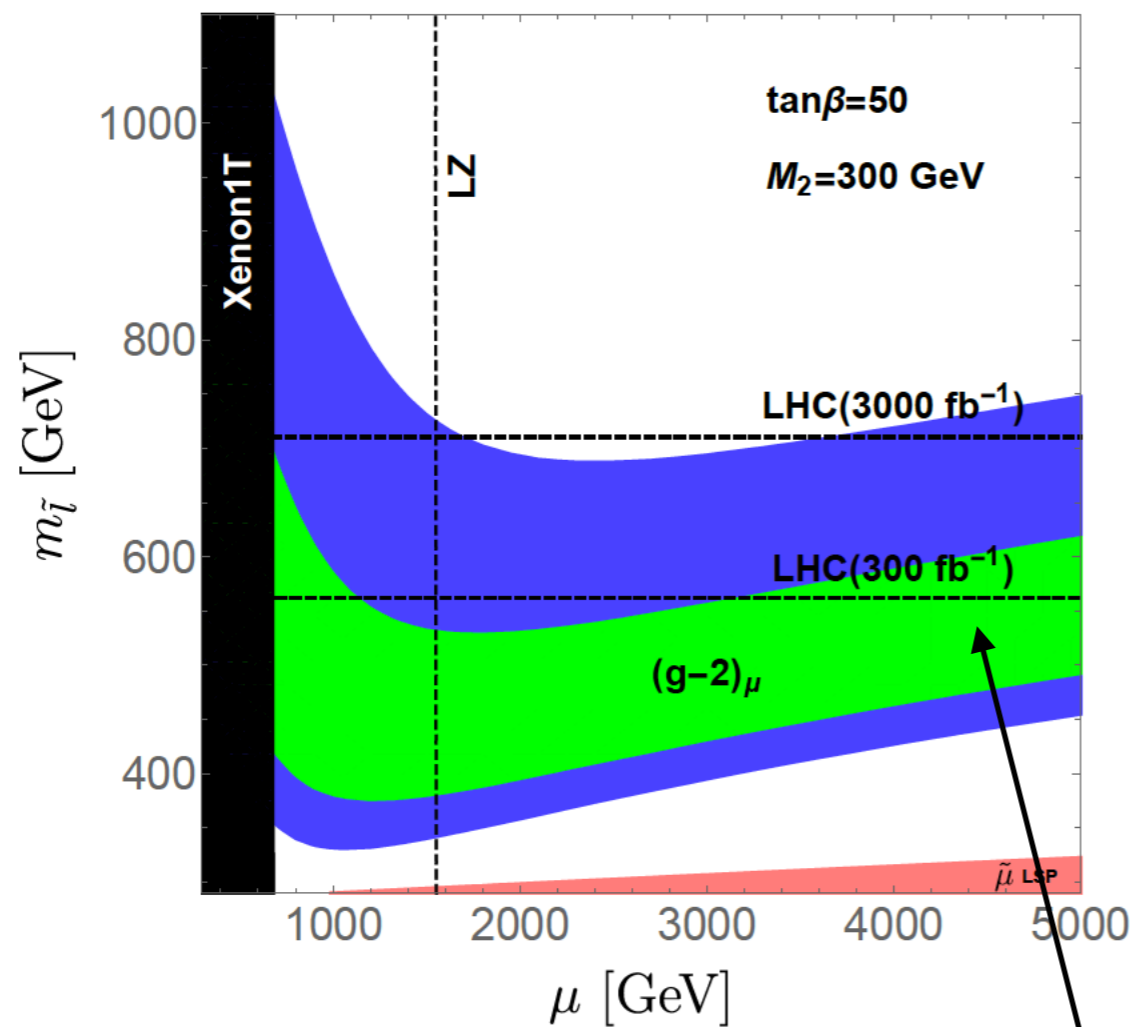
Enhanced by $\tan\beta$: $m_{\text{soft}}^2 = \mathcal{O}(100)\text{GeV}$

Dark matter and $g-2$?

- **Is there any viable region?**
- **How to test?**

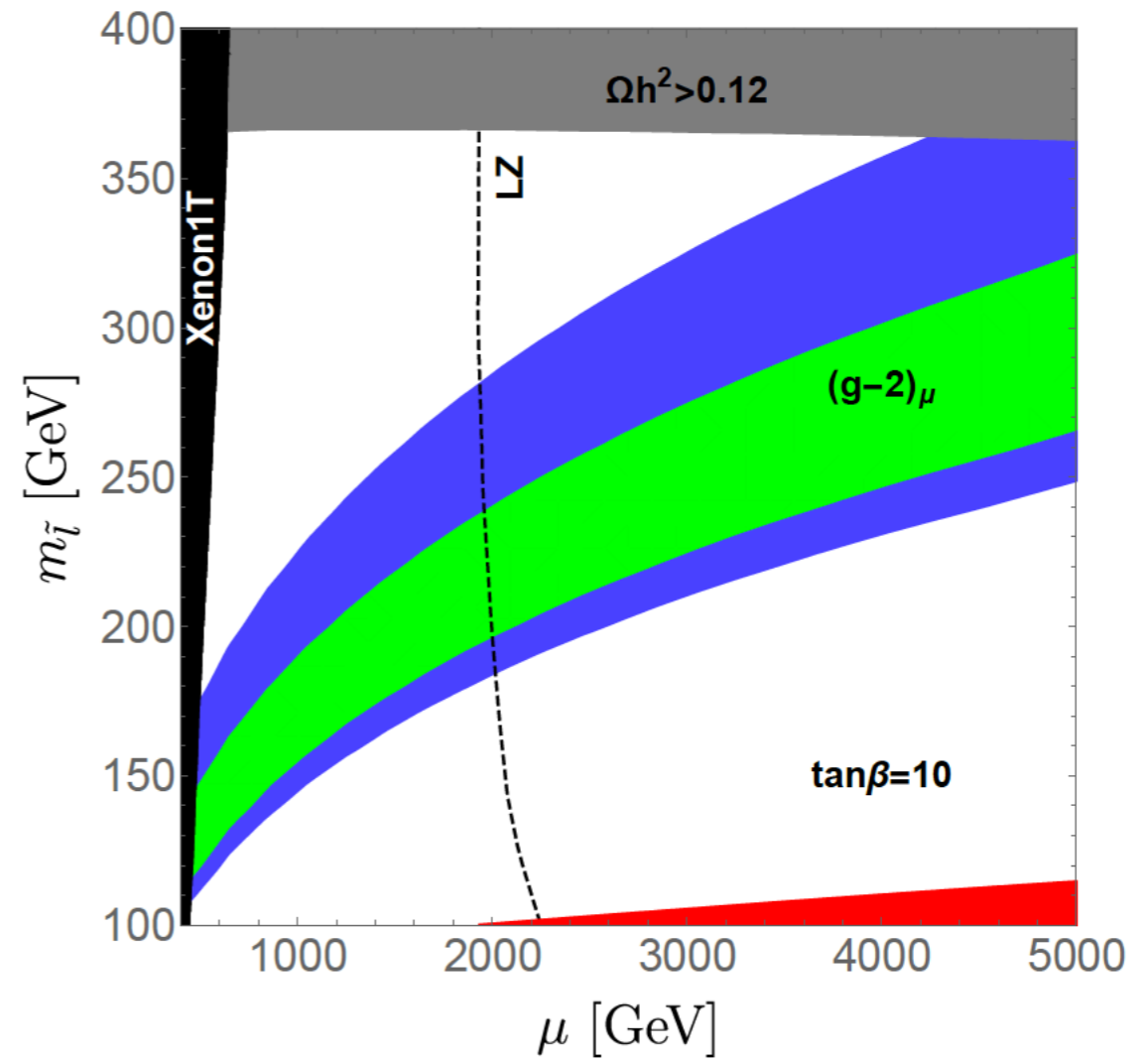
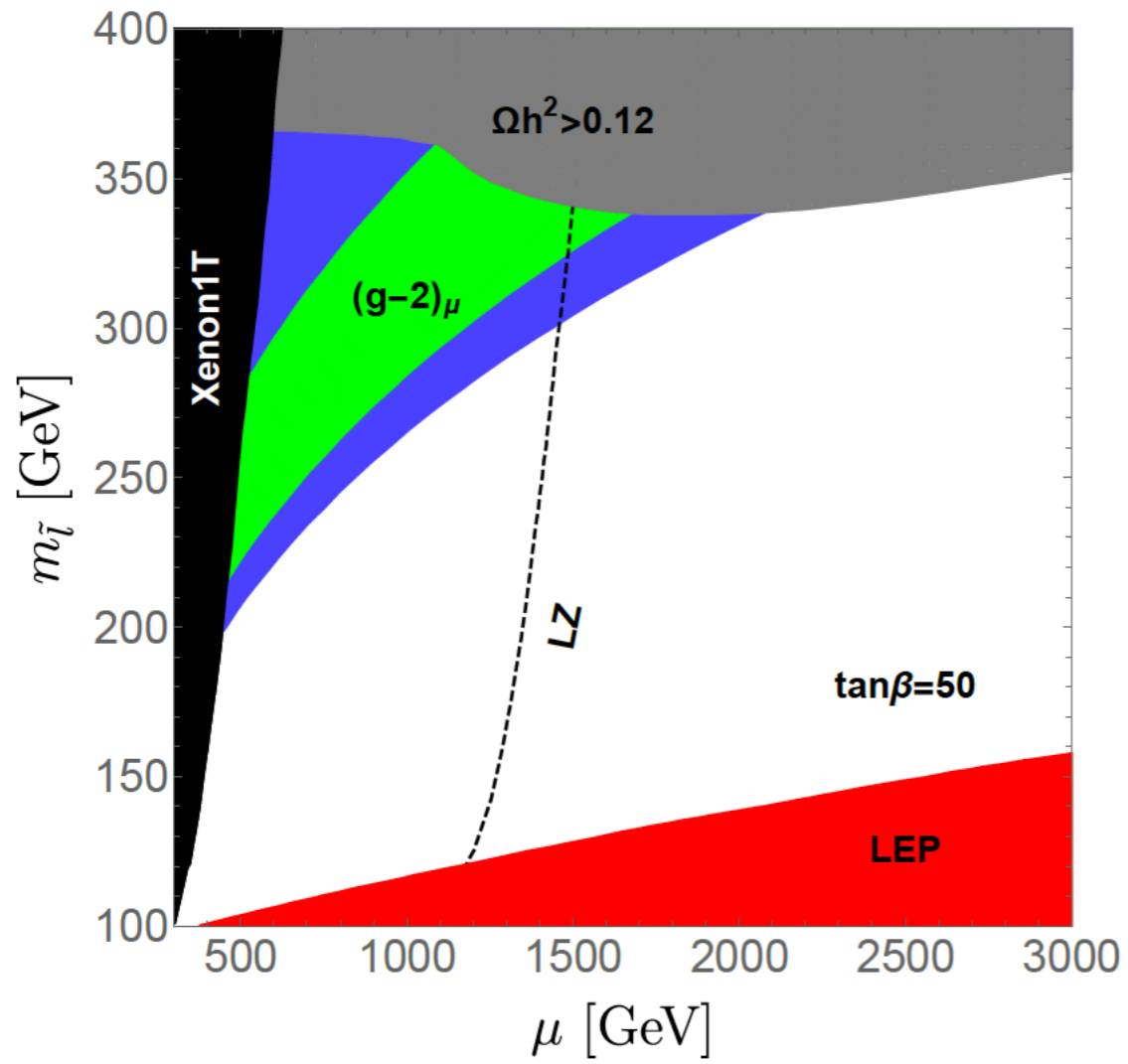
Wino-Bino coannihilation

$M_1 \sim M_2$



Bino loop dominates $\frac{\alpha_Y}{4\pi} \frac{m_\mu^2 M_1 \mu}{m_{\tilde{\mu}_L}^2 m_{\tilde{\mu}_R}^2} \tan \beta \cdot f_N \left(\frac{m_{\tilde{\mu}_L}^2}{M_1^2}, \frac{m_{\tilde{\mu}_R}^2}{M_1^2} \right)$

Slepton coannihilation

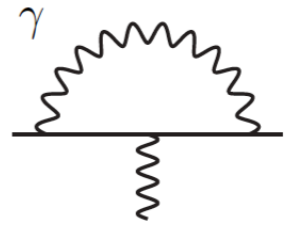
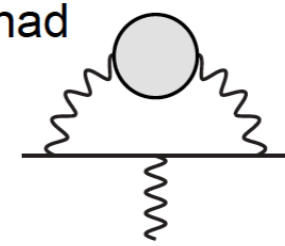
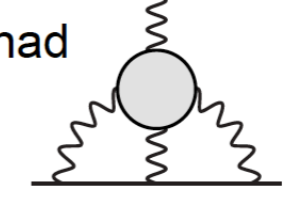


Lesson from SUSY

If $g-2$ is true, new physics below TeV!

Back up

Status of Muon $g-2$

Experiment (E821)		116 592 089	(63)	[10 ⁻¹¹]	
QED (α^5 , Rb)		116 584 718.951	(0.080)		
EW (W/Z/H _{SM} , NLO)		153.6	(1.0)		
Hadronic (leading)	[HLMNT]	6 949.1	(43)		
	[DHMZ]	6 923	(42)		
Hadronic (α higher)		-98.4	(0.7)		
Hadronic (LbL)	[RdRV]	105	(26)*		
	[NJN]	116	(39)		

$$a_{\mu}^{\text{exp}} - a_{\mu}^{\text{SM}} = \begin{cases} (261 \pm 80) \times 10^{-11} \\ (287 \pm 80) \times 10^{-11} \end{cases} > 3\sigma \text{ deviation}$$