Updated Constraints from $(G-2)_\mu$ on the NMSSM.

Florian Domingo

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in collaboration with Ulrich Ellwanger

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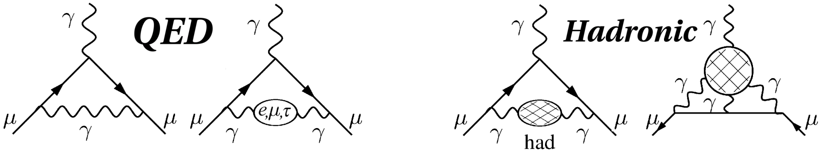
Muon Anomalous Magnetic Moment $a_\mu = (G-2)_\mu/2$: Standard Model Computation

Pure QED: 4-loop+estimated 5-loop [*Laporta, Remiddi (1996); Kinoshita et al. (2007)*]

$$a_\mu^{QED} = 11\,658\,471.8113(162) \times 10^{-10}$$



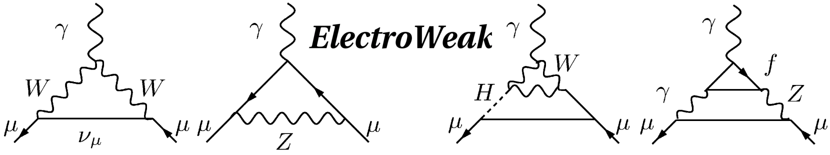
Hadronic contributions: e^+e^- data [*Hagiwara et al. (2006); Davier (2007); Jegerlehner (2007); Zhang (2008); Bijnens,Prades (2007)*]

- Leading Order: $a_\mu^{HLO}(e^+e^-) = (692.1 \pm 5.6) \times 10^{-10}$;
- Next to Leading Order: $a_\mu^{HNLO} = (-10.03 \pm 0.22) \times 10^{-10}$;
- Light-by-Light Scattering: $a_\mu^{LBL} = (11.0 \pm 4.0) \times 10^{-10}$

BUT: using data from τ decays [*Davier et al. (2003)*]: $a_\mu^{HLO}(\tau) = (710.1 \pm 5.8) \times 10^{-10}$!
Inconsistent with e^+e^- data (4.5σ)

Electroweak: [*Czarnecki et al. (2003,2006)*]

$$a_\mu^{EW} = (15.4 \pm 0.2) \times 10^{-10}$$



Experimental Measurement: E821 experiment at Brookhaven National Laboratory [*Bennett et al., (2006)*]

$$a_\mu^{EXP} = 11\,659\,208.0(5.4)(3.3) \times 10^{-10}$$

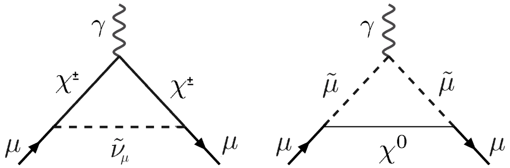
$$\Rightarrow \quad a_\mu^{EXP} - a_\mu^{SM} = (27.7 \pm 9.3) \times 10^{-10} \qquad \sim 3\sigma!$$

BUT: With τ data, about 1σ only.

Common Contributions to the MSSM and the NMSSM: One-Loop Contributions [*Martin, Wells (2001)*]

Chargino / Sneutrino Loop:

- Dominant contribution;
- Linear dependance on $\tan\beta$;
- Same sign as the SUSY parameter μ: $\mu > 0$ favoured;
- Light chargino/Sneutrino required.



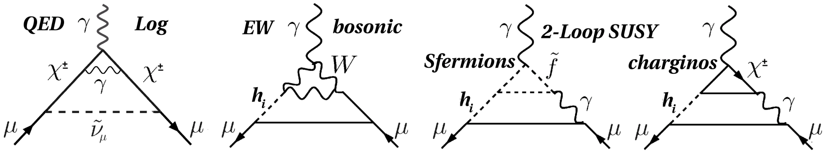
Neutralino / Smuon Loop:

Can be large enough even for low values of $\tan\beta$ when there is a light neutralino $\sim$ bino.

Common Contributions to the MSSM and the NMSSM: Two-Loop Contributions

Large QED Logarithms: [*Degrassi, Giudice (1998)*]

$$a_\mu^{SUSY} = a_\mu^{SUSY\,1L}\left(1 - \frac{4\alpha}{\pi}\ln\frac{M_{SUSY}}{m_\mu}\right)$$

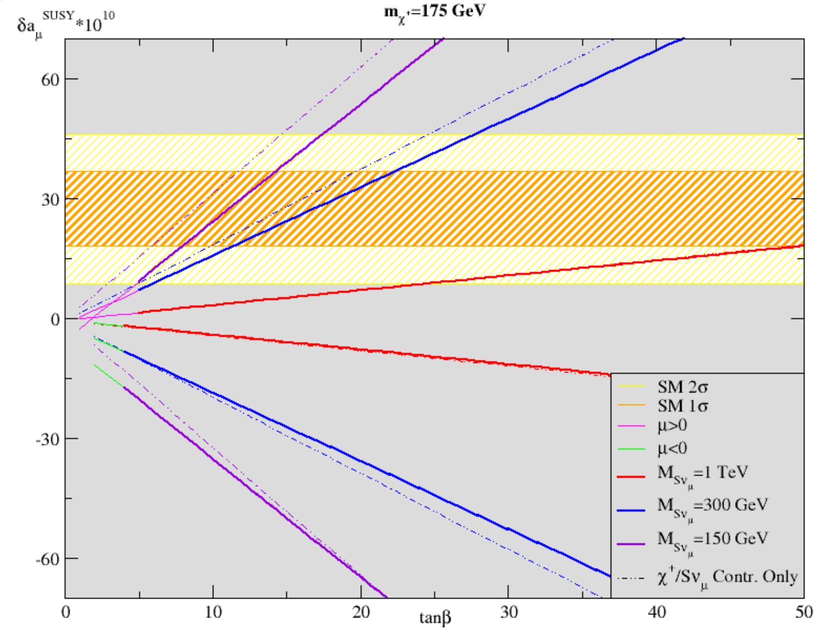


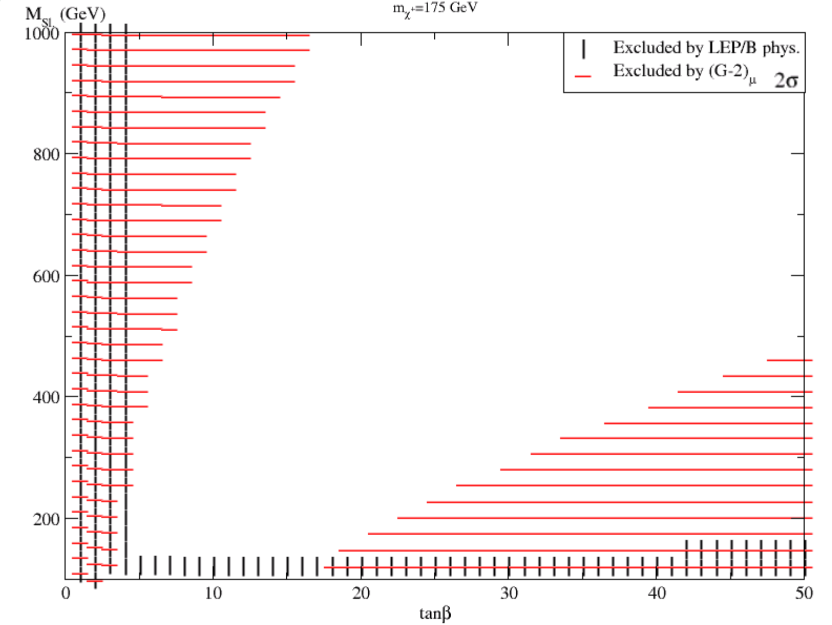
SM-like 2L Diagrams: [*Heinemeyer et al. (2004)*]

2-loop Bosonic Electroweak Diagrams: reproduce the SM value.

Diagrams with a closed SUSY Loop: [*Arhrib, Baek (2002), Heinemeyer et al. (2004), Stöckinger (2006)*]

Sfermion; chargino diagrams.


m_{χ^+}=175 GeV
$\delta a_\mu^{SUSY}*10^{10}$
60
30
0
-30
-60
0
10
20
30
40
50
tanβ
SM 2σ
SM 1σ
μ>0
μ<0
$M_{S\nu_\mu}$=1 TeV
$M_{S\nu_\mu}$=300 GeV
$M_{S\nu_\mu}$=150 GeV
$\chi^+/S\nu_\mu$ Contr. Only

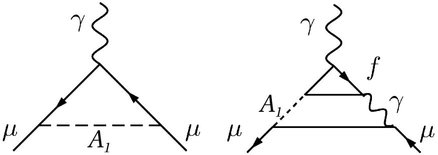

$m_{\chi^\pm}$=175 GeV
M_{Sl} (GeV)
1000
800
600
400
200
0
10
20
30
40
50
tanβ
Excluded by LEP/B phys.
Excluded by $(G\text{-}2)_\mu$
2σ

Specific NMSSM Contributions: Light Pseudoscalar

Light Pseudoscalars in the NMSSM:

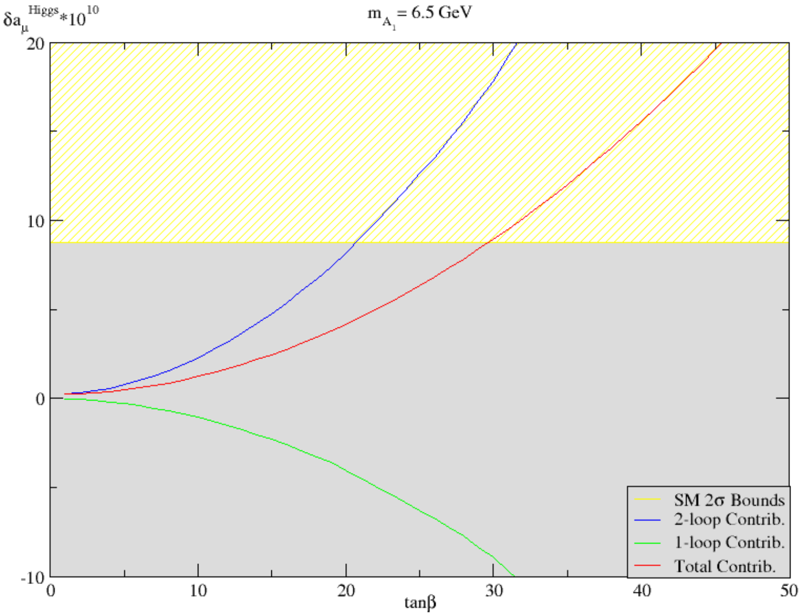
- Higgs Effects negligible in the SM and the MSSM: $m_H \geq 114\, GeV \quad \Rightarrow \quad a_\mu^H \leq 5.10^{-14}$;
- NMSSM: Pseudoscalars A_1 can be very light ($\sim$ a few GeV) without violating LEP constraints;
- B-constraints ($B_s \to \mu^+\mu^-$) can be avoided too.

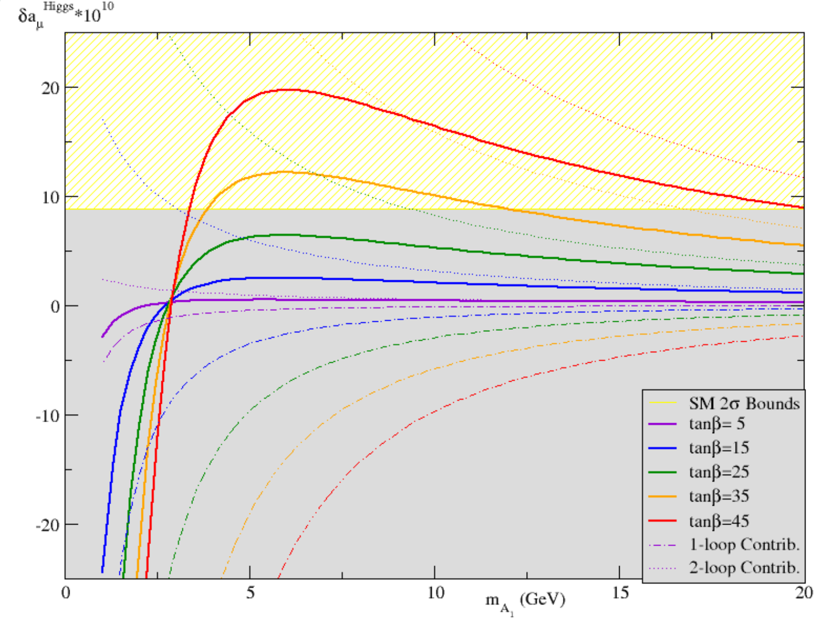
Light Pseudoscalars can lead to a non-negligible effect on a_μ, specific to the NMSSM.



Light Pseudoscalar contribution to a_μ [*Krawczyk (2002), Gunion et al. (2006)*]

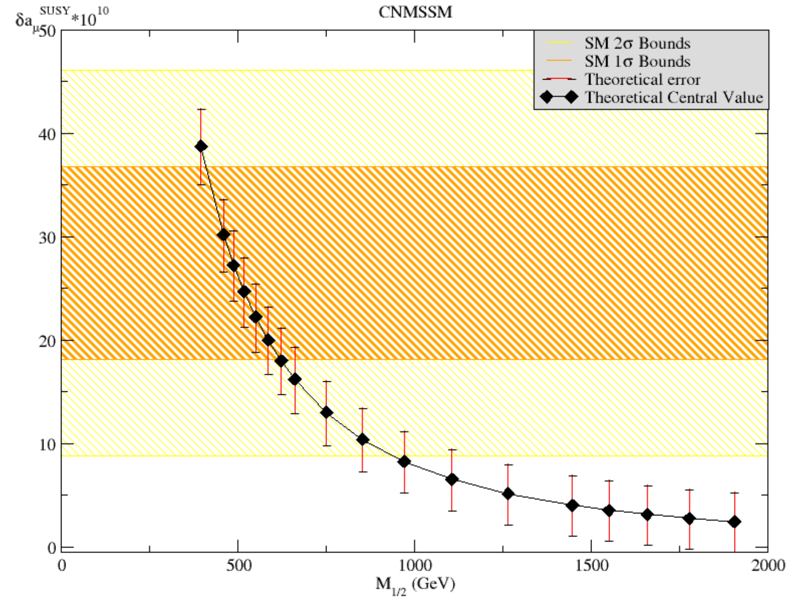
- 1-loop contribution negative / 2-loop contribution positive;
- When $m_{A_1} \geq 3\, GeV$, 2-loop contribution dominates;
- Proportional to $\tan^2\beta$;
- Proportional to A_1 coupling to the Standard sector.


$\delta a_\mu^{Higgs} * 10^{10}$
$m_{A_1} = 6.5$ GeV
20
10
0
-10
0
10
20
30
40
50
tanβ
SM 2σ Bounds
2-loop Contrib.
1-loop Contrib.
Total Contrib.



$\delta a_\mu^{Higgs} * 10^{10}$
20
10
0
-10
-20
0
5
10
15
20
m_{A_1} (GeV)
SM 2σ Bounds
tanβ= 5
tanβ=15
tanβ=25
tanβ=35
tanβ=45
1-loop Contrib.
2-loop Contrib.

$(G-2)_\mu$ and the CNMSSM. . .



Conclusions:

- $(G-2)_\mu$ is a possible hint for New Physics.
- Supersymmetric models are able to explain the 3σ deviation.
- If SUSY 1-loop diagrams dominate, Sleptons must be light or $\tan\beta$ must be large.
- The light pseudoscalar contribution is specific to the NMSSM and could lead to a significant contributions (positive for $m_{A_1} \gtrsim 3\,GeV$).
- The fully constrained version of the NMSSM can pass the constraint $(G-2)_\mu$, provided SUSY particles are not too heavy.
- Our Fortran code has been added to the NMSSMTools Package and could be used for the MSSM as well as the NMSSM.