Magnetic moment $(g-2)_\mu$ — evidence for new physics?

Dominik Stöckinger

Dresden

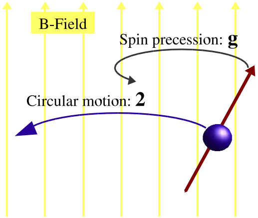
May 2009

Outline

1. Motivation
2. A 3σ deviation has been established
    - History
    - Current status and recent progress
3. Types of new physics
4. SUSY could explain the deviation
    - SUSY contributions
5. A new, better measurement?
6. Conclusions

Outline

Muon magnetic moment



$$H_{\text{magnetic}} = -2(1 + a_\mu)\frac{e}{2m_\mu}\vec{B}\cdot\vec{S}$$

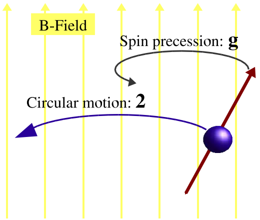
Measurement:

circular motion: $\omega_c = -\frac{e}{m_\mu}B$

spin precession: $\omega_s = -\frac{2(1+a_\mu)e}{2m_\mu}B$

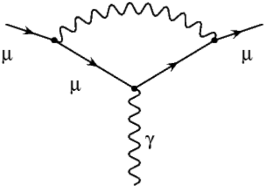
$\rightarrow$ measure $\omega_a = \omega_s - \omega_c = -a_\mu \frac{e}{m_\mu}B$

Muon magnetic moment



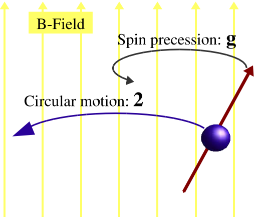
$$H_{\text{magnetic}} = -2(1 + a_\mu)\frac{e}{2m_\mu}\vec{B}\cdot\vec{S}$$

Quantum field theory:



$$\tilde{=}\,\bar{u}(p')\left[\gamma_\mu F_1 + \frac{i}{2m_\mu}\sigma_{\mu\nu}q^\nu a_\mu\right]u(p)$$

Muon magnetic moment



$$H_{\text{magnetic}} = -2(1 + a_\mu)\frac{e}{2m_\mu}\vec{B}\cdot\vec{S}$$

In principle, simple to measure and to calculate

⇓

One of the most precisely measured and calculated quantities in particle physics

⇓

rich history

Outline

1. Motivation
2. A 3σ deviation has been established
   - History
   - Current status and recent progress
3. Types of new physics
4. SUSY could explain the deviation
   - SUSY contributions
5. A new, better measurement?
6. Conclusions

History

'49 Schwinger: QED 1L: $\frac{\alpha}{2\pi}$

History

'49 Schwinger: QED 1L:	$\frac{\alpha}{2\pi}$
'68–'78 CERN measurement:	$\Rightarrow$ QED up to 4-loop needed
'76– had vac. pol.:	$(6.7 \pm .9) \times 10^{-8}$, also needed
'78 CERN result:	agreement between exp and (QED+had)

History

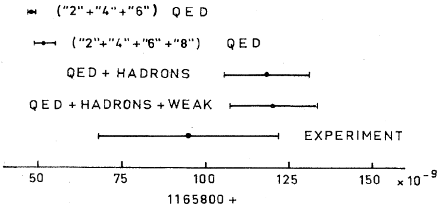
'49 Schwinger: QED 1L: $\frac{\alpha}{2\pi}$

'68–'78 CERN measurement: $\Rightarrow$ QED up to 4-loop needed

'76– had vac. pol.: $(6.7 \pm .9) \times 10^{-8}$, also needed

'78 CERN result: agreement between exp and (QED+had)

Calmet, Narison, Perrottet, and de Rafael:



History

'49 Schwinger: QED 1L: $\frac{\alpha}{2\pi}$

'68–'78 CERN measurement: $\Rightarrow$ QED up to 4-loop needed

'76– had vac. pol.: $(6.7 \pm .9) \times 10^{-8}$, also needed

'78 CERN result: agreement between exp and (QED+had)

'83–today: QED 4L,5L numerically [Kinoshita]

'85–today Had light-by-light: difficult!

'96-'05 e.w. contributions: $(15.2 \pm 0.2) \times 10^{-10}$

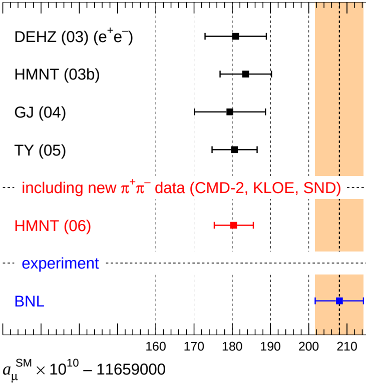
History

'49 Schwinger: QED 1L:	$\frac{\alpha}{2\pi}$
'68–'78 CERN measurement:	$\Rightarrow$ QED up to 4-loop needed
'76– had vac. pol.:	$(6.7 \pm .9) \times 10^{-8}$, also needed
'78 CERN result:	agreement between exp and (QED+had)
'83–today: QED	4L,5L numerically [Kinoshita]
'85–today Had light-by-light:	difficult!
'96-'05 e.w. contributions:	$(15.2 \pm 0.2) \times 10^{-10}$
'01 first BNL result:	weak contributions needed!
'06 final BNL result:	bad agreement between exp and (QED+had+weak)

Era of the muon $g-2$ experiment at Brookhaven

$$a_\mu^{\text{exp}} = (11\,659\,208 \pm 6) \times 10^{-10}$$

Current status: SM prediction



Full SM: $a_\mu \times 10^{10} - 11659000$

HMNT06:	. . . 180.4(5.1)	(3.4σ)
DEHZ06:	. . . 180.5(5.6)	(3.3σ)
FJ08:	. . . 179.5(6.5)	(3.1σ)
MRR07:	. . . 178.5(6.1)	(3.4σ)
dR08:	. . . 178.5(5.1)	(3.6σ)

Exp:

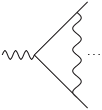
BNL06: . . . 208.0(6.3)

3σ deviation established

Current status: SM prediction

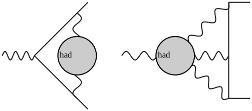
In units of $[10^{-10}]$, according to [de Rafael ’08]

QED:



11 658 471.8(0.1)

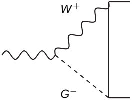
had:



vp(LO+NLO) 680.8(4.4)

lbl 10.5(2.6)

weak:

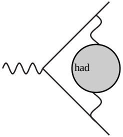


15.2(0.2)

Exp: 11 659 208.0(6.3)

Current status: SM prediction

Hadronic vacuum polarization contributions:

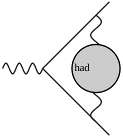


$\leftrightarrow e^+e^- \rightarrow \gamma^* \rightarrow$hadrons

- consensus on methods — final result/error depends on exp data
- τ-data ($\tau \rightarrow \nu + W^* \rightarrow \nu+$hadrons) less reliable
- recent years: convergence of theoretical determinations
- new exp data (CMD2, SND, KLOE, B-factories)
  $\Rightarrow$ significantly more precise!

Current status: SM prediction

Hadronic vacuum polarization contributions:

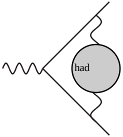


Recent evaluations: $a_\mu \times 10^{10} - 11659000$

HMNT06:	$\ldots 689.4(4.5)$
DEH**Z**08:	$\ldots 690.8(4.4)$
Jegerlehner08:	$\ldots 691.0(5.3)$

Current status: SM prediction

Hadronic vacuum polarization contributions:



Recent evaluations: $a_\mu \times 10^{10} - 11659000$

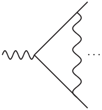
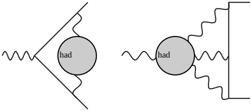
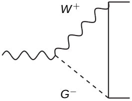
HMNT06:	$\ldots 689.4(4.5)$
DEH**Z**08:	$\ldots 690.8(4.4)$
Jegerlehner08:	$\ldots 691.0(5.3)$

Recent progress:

- [Benayoun et al '07] possible explanation of τ-based results
  → confirmation of e^+e^--based evaluations
- new precise KLOE data
  (will be incorporated in fits soon)

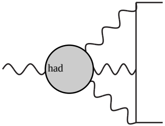
Current status: SM prediction

In units of [10^{-10}], according to [de Rafael '08]

QED:			11 658 471.8(0.1)
had:		vp(LO+NLO) lbl	680.8(4.4) 10.5(2.6)
weak:			15.2(0.2)
Exp:			11 659 208.0(6.3)

Current status: SM prediction

Hadronic light-by-light contributions



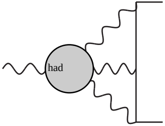
['85 Kinoshita et al]	$+4.9 \pm 0.5$
['95 Kinoshita et al]	-5.2 ± 1.8
['96 Prades et al]	-9.2 ± 3.2
['98 Kinoshita et al]	-7.9 ± 1.5
['01 Knecht, Nyffeler]	sign error identified

Cannot be computed from first principles — Error difficult to assess!

Currently ok — future bottleneck

Current status: SM prediction

Hadronic light-by-light contributions



new estimates with correct sign,
using different approximations

[Bijnens, Prades '07]	10.0 ± 4.0
[Melnikov, Vainshtein '03]	13.6 ± 2.5
[Jegerlehner '08]	11.4 ± 3.8
[Prades, Vainshtein, de Rafael '08]	10.5 ± 2.6

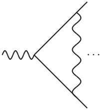
Cannot be computed from first principles — Error difficult to assess!

Currently ok — future bottleneck

Current status: SM prediction

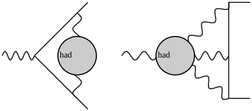
In units of $[10^{-10}]$, according to [de Rafael '08]

QED:



11 658 471.8(0.1)

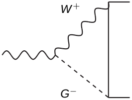
had:



vp(LO+NLO) 680.8(4.4)

lbl 10.5(2.6)

weak:



15.2(0.2)

Exp: 11 659 208.0(6.3)

Discrepancy

In spite of . . .

many discovered errors

new developments

The case for a real discrepancy gets stronger

SM prediction too low by $\approx (28 \pm 8) \times 10^{-10}$

Why?

Possibilities

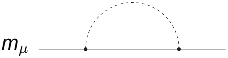
- Statistical fluctuation of experimental result
- missing higher-order contributions in SM-prediction
- underestimated theory error
- (computational error)
- physics beyond the SM

Outline

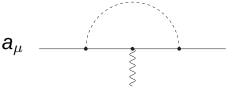
Relation a_μ–m_μ

generally: $$\frac{\delta m_\mu(\mathrm{N.P.})}{m_\mu} = C \;\Leftrightarrow\; \delta a_\mu(\mathrm{N.P.}) = \mathcal{O}(C)\left(\frac{m_\mu}{M}\right)^2$$

In loops: new heavy particles, coupling to muons ⇒



$$\delta m_\mu \sim \frac{c^2}{16\pi^2}\,M$$

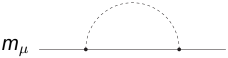


$$\delta a_\mu \sim \frac{c^2}{16\pi^2}\frac{m_\mu}{M}$$

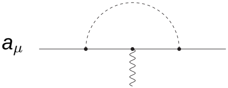
Relation a_μ–m_μ

generally: $$\frac{\delta m_\mu(\mathrm{N.P.})}{m_\mu} = C \;\Leftrightarrow\; \delta a_\mu(\mathrm{N.P.}) = \mathcal{O}(C)\left(\frac{m_\mu}{M}\right)^2$$

In loops: new heavy particles, coupling to muons $\Rightarrow$



$$\delta m_\mu \sim \frac{c^2}{16\pi^2}\, M$$



$$\delta a_\mu \sim \frac{c^2}{16\pi^2}\frac{m_\mu}{M}$$

Therefore, assuming $|\delta m_\mu / m_\mu| < 1$:

$$\delta a_\mu = C\left(\frac{m_\mu}{M}\right)^2, \qquad |C| < \mathcal{O}(1) \qquad [\textit{Czarnecki}, \textit{Marciano}'01]$$

Classification of new physics

generally: $$\frac{\delta m_\mu(\mathrm{N.P.})}{m_\mu} = C \;\Leftrightarrow\; \delta a_\mu(\mathrm{N.P.}) = \mathcal{O}(C)\left(\frac{m_\mu}{M}\right)^2$$

Allows classification of types of new physics:

$C = \mathcal{O}(\frac{\alpha}{4\pi})$,	Z', W', extra dim., ...
$C = \mathcal{O}(1)$,	radiative muon mass generation technicolor, ... [Czarnecki,Marciano '01]
$C = \mathcal{O}(\tan\beta\frac{\alpha}{4\pi})$,	supersymmetry

Classification of new physics

generally: $$\frac{\delta m_\mu(\mathrm{N.P.})}{m_\mu} = C \;\Leftrightarrow\; \delta a_\mu(\mathrm{N.P.}) = \mathcal{O}(C)\left(\frac{m_\mu}{M}\right)^2$$

Allows classification of types of new physics:

$C = \mathcal{O}(\frac{\alpha}{4\pi})$, Z', W', extra dim., ...

contributions very small! $\delta a_\mu \sim 28 \times 10^{-10}$ for M<100GeV

$C = \mathcal{O}(1)$, radiative muon mass generation technicolor, ... [Czarnecki,Marciano '01]

$C = \mathcal{O}(\tan\beta\frac{\alpha}{4\pi})$, supersymmetry

Classification of new physics

generally: $$\frac{\delta m_\mu(\mathrm{N.P.})}{m_\mu} = C \;\Leftrightarrow\; \delta a_\mu(\mathrm{N.P.}) = \mathcal{O}(C)\left(\frac{m_\mu}{M}\right)^2$$

Allows classification of types of new physics:

$C = \mathcal{O}(\frac{\alpha}{4\pi})$, Z', W', extra dim., ...

$C = \mathcal{O}(1)$, radiative muon mass generation technicolor, ... [Czarnecki,Marciano '01]

contributions large! $\delta a_\mu \sim 28 \times 10^{-10}$ for M>1TeV

$C = \mathcal{O}(\tan\beta\frac{\alpha}{4\pi})$, supersymmetry

Classification of new physics

generally: $$\frac{\delta m_\mu(\text{N.P.})}{m_\mu} = C \Leftrightarrow \delta a_\mu(\text{N.P.}) = \mathcal{O}(C)\left(\frac{m_\mu}{M}\right)^2$$

Allows classification of types of new physics:

$C = \mathcal{O}(\frac{\alpha}{4\pi})$, Z', W', extra dim., ...

$C = \mathcal{O}(1)$, radiative muon mass generation
technicolor, ... [Czarnecki,Marciano '01]

$C = \mathcal{O}(\tan\beta\frac{\alpha}{4\pi})$, supersymmetry

fits well! $\delta a_\mu \sim 28 \times 10^{-10}$ for M$\sim$300GeV, $\tan\beta \sim 10$

a_μ and new physics

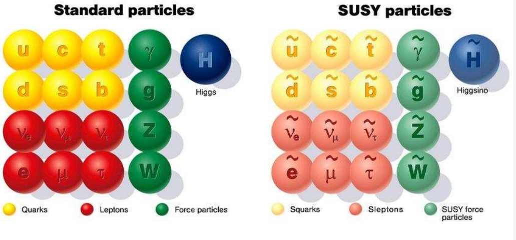
- Different types of new physics can lead to very different contributions to a_μ
- a_μ is highly useful to discriminate between these different types of new physics

Outline

1. Motivation
2. A 3σ deviation has been established
   - History
   - Current status and recent progress
3. Types of new physics
4. SUSY could explain the deviation
   - SUSY contributions
5. A new, better measurement?
6. Conclusions

SUSY and the MSSM

- MSSM:



- free parameters: $\tilde{p}$ masses and mixings, μ and tan β

$g-2$ in the MSSM

Key to understand $g-2$ in SUSY:

$g-2$ = chirality-flipping interaction

$$\bar{u}_R(p')\frac{\sigma_{\mu\nu}q^\nu}{2m_\mu}u_L(p)+(L\leftrightarrow R)$$

in each Feynman diagram we need to pick up one chirality flip

$$\mu_L\to\mu_R \text{ or } \tilde{\mu}_L\to\tilde{\mu}_R$$

In SM or MSSM: chirality flips governed by λ_μ, $m_\mu=\lambda_\mu\langle H_1\rangle$

$g-2$ in the MSSM

In MSSM: second Higgs doublet H_2 important

$$\tan\beta = \frac{\langle H_2\rangle}{\langle H_1\rangle}, \qquad \mu = H_2 - H_1 \text{ transition}$$

some terms

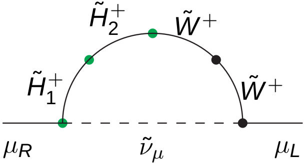
$$\propto \lambda_\mu \langle H_1\rangle = m_\mu \qquad \rightarrow a_\mu^{\mathrm{SUSY}} \propto \frac{m_\mu^2}{M_{\mathrm{SUSY}}^2}$$

some terms

$$\propto \lambda_\mu\, \mu \langle H_2\rangle = m_\mu\ \mu\ \tan\beta \qquad \rightarrow a_\mu^{\mathrm{SUSY}} \propto \tan\beta\,\mathrm{sign}(\mu)\,\frac{m_\mu^2}{M_{\mathrm{SUSY}}^2}$$

potential enhancement $\propto \tan\beta = 1\ldots 50$ (and $\propto$sign(μ))

$g-2$ in the MSSM



In MSSM: second Higgs doublet H_2 important

$$\tan\beta = \frac{\langle H_2\rangle}{\langle H_1\rangle}, \qquad \mu = H_2 - H_1 \text{ transition}$$

some terms

$$\propto \lambda_\mu \langle H_1\rangle = m_\mu \qquad \rightarrow a_\mu^{\rm SUSY} \propto \frac{m_\mu^2}{M_{\rm SUSY}^2}$$

some terms

$$\propto \lambda_\mu\, \mu \langle H_2\rangle = m_\mu\, \mu\ \tan\beta \qquad \rightarrow a_\mu^{\rm SUSY} \propto \tan\beta\, \mathrm{sign}(\mu)\, \frac{m_\mu^2}{M_{\rm SUSY}^2}$$

potential enhancement $\propto \tan\beta = 1\ldots 50$ (and $\propto$sign(μ))

a_μ in the MSSM

1-Loop result if μ, $m_{\tilde\mu}$, $m_{\tilde\chi} \approx M_{\rm SUSY}$

$$a_\mu^{\rm SUSY} \approx \frac{\alpha}{\pi\, 8 s_W^2} \tan\beta\ {\rm sign}(\mu)\ \frac{m_\mu^2}{M_{\rm SUSY}^2}$$

numerically

$$a_\mu^{\rm SUSY} \approx 12 \times 10^{-10} \tan\beta\ {\rm sign}(\mu) \left(\frac{100{\rm GeV}}{M_{\rm SUSY}}\right)^2$$

- $\propto \tan\beta\ {\rm sign}(\mu)$
- $\propto 1/M_{\rm SUSY}^2$, but complicated dependence on individual masses

a_μ in the MSSM

1-Loop result if μ, $m_{\tilde{\mu}}$, $m_{\tilde{\chi}} \approx M_{\rm SUSY}$

$$a_\mu^{\rm SUSY} \approx \frac{\alpha}{\pi \, 8 s_W^2} \tan\beta \, {\rm sign}(\mu) \, \frac{m_\mu^2}{M_{\rm SUSY}^2}$$

numerically

$$a_\mu^{\rm SUSY} \approx 12 \times 10^{-10} \tan\beta \, {\rm sign}(\mu) \left(\frac{100{\rm GeV}}{M_{\rm SUSY}}\right)^2$$

e.g. $a_\mu^{\rm SUSY} = 24 \times 10^{-10}$ for

$$\begin{array}{ll} \tan\beta = 2, & M_{\rm SUSY} = 100\text{ GeV} \\ \tan\beta = 50, & M_{\rm SUSY} = 500\text{ GeV} \end{array} \quad (\mu > 0)$$

$\Rightarrow$ SUSY could easily be the origin of the observed deviation!

a_μ in the MSSM

1-Loop result if μ, $m_{\tilde\mu}$, $m_{\tilde\chi} \approx M_{\rm SUSY}$

$$a_\mu^{\rm SUSY} \approx \frac{\alpha}{\pi\, 8 s_W^2} \tan\beta\, {\rm sign}(\mu)\, \frac{m_\mu^2}{M_{\rm SUSY}^2}$$

numerically

$$a_\mu^{\rm SUSY} \approx 12 \times 10^{-10} \tan\beta\, {\rm sign}(\mu) \left(\frac{100{\rm GeV}}{M_{\rm SUSY}}\right)^2$$

e.g. $a_\mu^{\rm SUSY} = -96 \times 10^{-10}$ for

$$\tan\beta = 50, \quad M_{\rm SUSY} = 250\text{ GeV} \quad (\mu < 0)$$

$\Rightarrow$ such parameter points are ruled out by a_μ!

a_μ in the MSSM

Answers:

SUSY could be the origin of the observed $(28 \pm 8) \times 10^{-10}$ deviation!

a_μ significantly restricts the SUSY parameters

→ generically, positive μ, large $\tan\beta$/small $M_{\rm SUSY}$ preferred

Precise analysis justified!

SUSY prediction

- 1-loop and most 2-loop contributions known
- remaining theory uncertainty of SUSY prediction: [DS '06]

$$\delta a_\mu^{\mathrm{SUSY}} \approx 3 \times 10^{-10}$$

while

$$\delta a_\mu^{\mathrm{exp-SM}} \approx 8 \times 10^{-10}$$

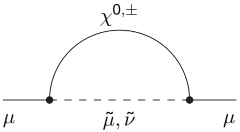
In view of future SM/exp improvements:

Long-term programme: full 2-loop MSSM prediction

Status of SUSY prediction

1-Loop

$\propto \tan\beta$



[Fayet '80],. . .

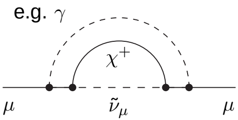
[Kosower et al '83],[Yuan et al '84],. . .

[Lopez et al '94],[Moroi '96]

complete

2-Loop (SUSY 1L)

e.g. $\propto \log \frac{M_{\mathrm{SUSY}}}{m_\mu}$

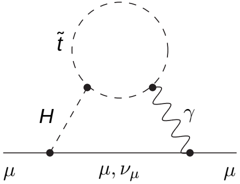


[Degrassi,Giudice '98]

leading log

2-Loop (SM 1L)

e.g. $\propto \tan\beta\,\mu\,m_t$



[Chen,Geng'01][Arhib,Baek '02]

[Heinemeyer,DS,Weiglein '03]

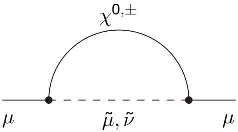
[Heinemeyer,DS,Weiglein '04]

complete

Status of SUSY prediction

1-Loop

$\propto \tan\beta$



[Fayet '80],. . .

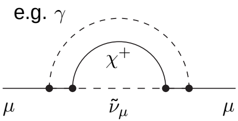
[Kosower et al '83],[Yuan et al '84],. . .

[Lopez et al '94],[Moroi '96]

complete

2-Loop (SUSY 1L)

e.g. $\propto \log \frac{M_{\text{SUSY}}}{m_\mu}$

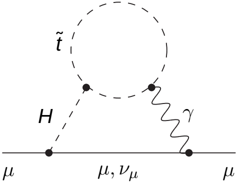


[Degrassi,Giudice '98]

leading log

2-Loop (SM 1L)

e.g. $\propto \tan\beta\, \mu\, m_t$



[Chen,Geng'01][Arhib,Baek '02]

[Heinemeyer,DS,Weiglein '03]

[Heinemeyer,DS,Weiglein '04]

complete

Aim: full computation!

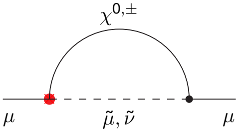
New results

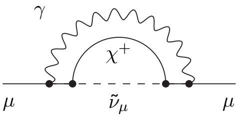
2-Loop (SUSY 1L)

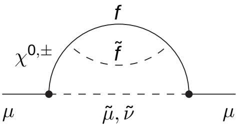
$(\tan\beta)^2$-terms

photon loops

$f/\tilde f$-loops







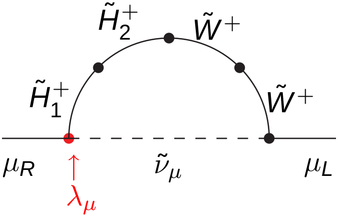
[Marchetti, Mertens, Nierste, DS ’08]

[Schäfer, Stöckinger-Kim, v. Weitershausen, DS ’09]

First step: $(\tan\beta)^2$ enhanced corrections

- So far, all leading corrections $\propto \tan\beta$
- Even all other genuine two-loop diagrams $\propto \tan\beta$
- However, one two-loop contribution $(\tan\beta)^2$

First step: $(\tan\beta)^2$ enhanced corrections

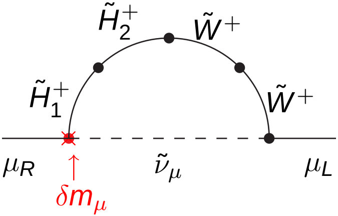


$a_\mu^{\mathrm{SUSY}} \propto$ chirality flip $\propto \lambda_\mu$

However, one-loop coupling to “wrong” Higgs doublet induces shift

$$\lambda_\mu \to \frac{\lambda_\mu}{1+\Delta_\mu} \qquad \text{or} \qquad \delta m_\mu^{\mathrm{OS}} = \frac{m_\mu}{1+\Delta_\mu} + \ldots$$

First step: $(\tan\beta)^2$ enhanced corrections



$a_\mu^{\mathrm{SUSY}} \propto$ chirality flip $\propto \lambda_\mu$

However, one-loop coupling to “wrong” Higgs doublet induces shift

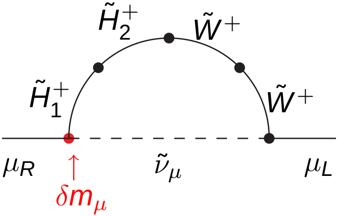
$$\lambda_\mu \to \frac{\lambda_\mu}{1+\Delta_\mu} \qquad \text{or} \qquad \delta m_\mu^{\mathrm{OS}} = \frac{m_\mu}{1+\Delta_\mu} + \ldots$$

Corresponding 2-loop shift in a_μ^{SUSY}

[Marchetti, Mertens, Nierste, DS ’08]

$$a_\mu^{\mathrm{SUSY}} \to \frac{a_\mu^{\mathrm{SUSY}}}{1+\Delta_\mu}$$

First step: $(\tan\beta)^2$ enhanced corrections



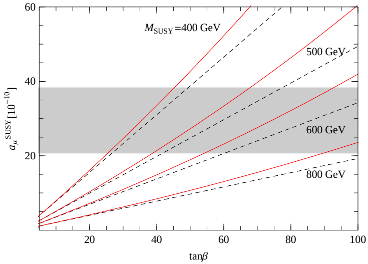
$$a_\mu^{\rm SUSY} \to \frac{a_\mu^{\rm SUSY}}{1+\Delta_\mu}$$

Numerical value:

$$\Delta_\mu(M_{\rm SUSY}) \approx -0.0018\ \tan\beta\ \mathrm{sign}(\mu)$$

for large $\tan\beta$: $\mathcal{O}(10\%)$ increase of a_μ $\Rightarrow$ largest two-loop effect

First step: $(\tan\beta)^2$ enhanced corrections

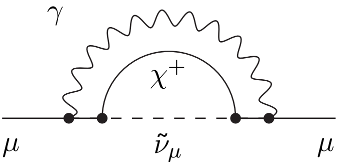


Leading two-loop corrections:

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

- QED-logs: $-7\ldots-9\%$ [Degrassi, Giudice '98]
- $(\tan\beta)^2$: $+1\ldots+15\%$ [Marchetti, Mertens, Nierste, DS '08]

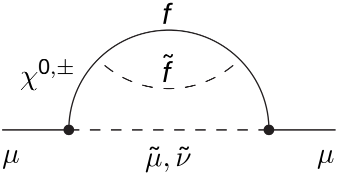
Second step: photon loops



All SUSY 1-loop diagrams with additional photon loop

- leading log: $-7\ldots-9\%$ [Degrassi, Giudice '98]
- full result: subleading logs, $\log(m_\chi/m_{\tilde{\nu}_\mu})$, non-log terms
- additional terms $\mathcal{O}(1\%)$
- full result more precise [v. Weitershausen, Schäfer, Stöckinger-Kim, DS '09]

Third step: $f/\tilde{f}$-loops



All SUSY 1-loop diagrams with additional $f/\tilde{f}$-loop (3rd generation)

- finite, gauge invariant class of contributions
- enhanced by top/bottom Yukawa coupling
- partial results [Schäfer, Stöckinger-Kim, v. Weitershausen, DS ’09]
- typically $\mathcal{O}(1\%)$

Outline

- We do not only need the LHC
- We do not only need the ILC
- We also need a better a_μ measurement!

Potential of improved measurement

- new experiment proposed and feasible (Brookhaven, FNAL, ???)
- improved SM evaluation possible
- projected accuracy: $a_\mu(\text{Exp-SM}) = 29.5(3.9 \text{ or } 3.4) \times 10^{-10}$

[Hertzog, Miller, de Rafael, Roberts, DS ’07]

Would be of tremendous importance as a complement of LHC

[Glasgow g-2 workshop 2007]

[Frascati PhiPsi workshop 2008]

- Constrain SUSY
- Superconservative bounds
- Selection criterion (SPS)
- Selection criterion (N.P.)
- $\tan\beta$ measurement

Potential of improved measurement

- new experiment proposed and feasible (Brookhaven, FNAL, ???)
- improved SM evaluation possible
- projected accuracy: $a_\mu(\text{Exp-SM}) = 29.5(3.9 \text{ or } 3.4) \times 10^{-10}$

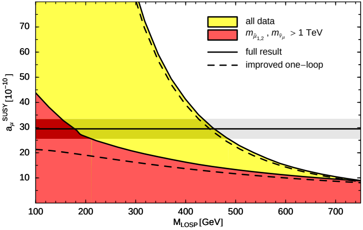
[Hertzog, Miller, de Rafael, Roberts, DS ’07]

Would be of tremendous importance as a complement of LHC

[Glasgow g-2 workshop 2007]

[Frascati PhiPsi workshop 2008]

- Constrain SUSY
- Superconservative bounds
- Selection criterion (SPS)
- Selection criterion (N.P.)
- tan β measurement



[DS ’06] ⇒ constrains general MSSM

Potential of improved measurement

- new experiment proposed and feasible (Brookhaven, FNAL, ???)
- improved SM evaluation possible
- projected accuracy: $a_\mu(\text{Exp-SM}) = 29.5(3.9 \text{ or } 3.4) \times 10^{-10}$

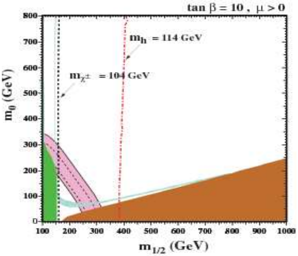
[Hertzog, Miller, de Rafael, Roberts, DS ’07]

Would be of tremendous importance as a complement of LHC

[Glasgow g-2 workshop 2007]

[Frascati PhiPsi workshop 2008]

- Constrain SUSY
- Superconservative bounds
- Selection criterion (SPS)
- Selection criterion (N.P.)
- tan β measurement



[Olive ’09] ⇒ orthogonal constraints on CMSSM parameters

Potential of improved measurement

- new experiment proposed and feasible (Brookhaven, FNAL, ???)
- improved SM evaluation possible
- projected accuracy: $a_\mu(\text{Exp-SM}) = 29.5(3.9 \text{ or } 3.4) \times 10^{-10}$

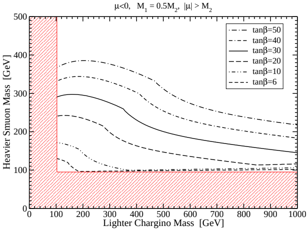
[Hertzog, Miller, de Rafael, Roberts, DS '07]

Would be of tremendous importance as a complement of LHC

[Glasgow g-2 workshop 2007]

[Frascati PhiPsi workshop 2008]

- Constrain SUSY
- Superconservative bounds
- Selection criterion (SPS)
- Selection criterion (N.P.)
- $\tan\beta$ measurement



[Martin, Wells '02] ⇒ region under the curves is excluded by a_μ and nothing else

Potential of improved measurement

- new experiment proposed and feasible (Brookhaven, FNAL, ???)
- improved SM evaluation possible
- projected accuracy: $a_\mu(\text{Exp-SM}) = 29.5(3.9 \text{ or } 3.4) \times 10^{-10}$

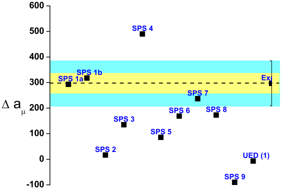
[Hertzog, Miller, de Rafael, Roberts, DS '07]

Would be of tremendous importance as a complement of LHC

[Glasgow g-2 workshop 2007]

[Frascati PhiPsi workshop 2008]

- Constrain SUSY
- Superconservative bounds
- Selection criterion (SPS)
- Selection criterion (N.P.)
- tan β measurement



[Hertzog, DS '08] ⇒ selects SPS "model"

Potential of improved measurement

- new experiment proposed and feasible (Brookhaven, FNAL, ???)
- improved SM evaluation possible
- projected accuracy: $a_\mu(\text{Exp-SM}) = 29.5(3.9 \text{ or } 3.4) \times 10^{-10}$

[Hertzog, Miller, de Rafael, Roberts, DS '07]

Would be of tremendous importance as a complement of LHC

[Glasgow g-2 workshop 2007]

[Frascati PhiPsi workshop 2008]

- Constrain SUSY
- Superconservative bounds
- Selection criterion (SPS)
- Selection criterion (N.P.)
- $\tan\beta$ measurement

Czarnecki/Marciano: [Ross '07]

$$\frac{\delta m_\mu^{\text{N.P.}}}{m_\mu} = C \;\Rightarrow\; \delta a_\mu^{\text{N.P.}} \approx C\left(\frac{m_\mu}{M}\right)^2$$

strong dependence on type of N.P.:

$$C = \mathcal{O}\left(\frac{\alpha}{4\pi},\ 1,\ \tan\beta\frac{\alpha}{4\pi}\right)$$

Potential of improved measurement

- new experiment proposed and feasible (Brookhaven, FNAL, ???)
- improved SM evaluation possible
- projected accuracy: $a_\mu(\text{Exp-SM}) = 29.5(3.9 \text{ or } 3.4) \times 10^{-10}$

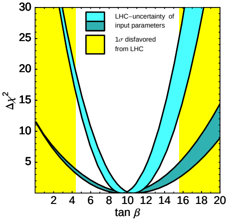
[Hertzog, Miller, de Rafael, Roberts, DS ’07]

Would be of tremendous importance as a complement of LHC

[Glasgow g-2 workshop 2007]

[Frascati PhiPsi workshop 2008]

- Constrain SUSY
- Superconservative bounds
- Selection criterion (SPS)
- Selection criterion (N.P.)
- tan β measurement



[Hertzog, Miller, de Rafael, Roberts, DS ’07]

[Sfitter, M.Rauch ’08]

Outline

1. Motivation
2. A 3σ deviation has been established
   - History
   - Current status and recent progress
3. Types of new physics
4. SUSY could explain the deviation
   - SUSY contributions
5. A new, better measurement?
6. Conclusions

Conclusions

- Experiment finalized, SM prediction has recently improved (and will further improve!)

$$a_\mu^{\mathrm{exp}} - a_\mu^{\mathrm{SM}} = (28 \pm 8) \times 10^{-10} \quad 3.4\sigma$$

- Case for new physics below the TeV scale gets stronger!
- SUSY with low mass scale $\sim 200 \ldots 600$ GeV fits very well and large parameter regions already excluded
- Future, more precise measurement very important in the quest to understand TeV-scale new physics — no matter what the result!