

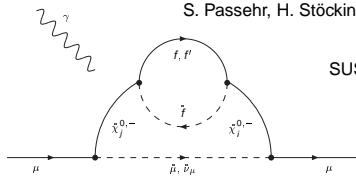
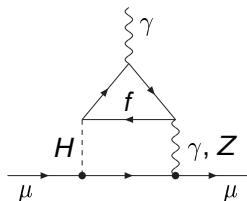
Electroweak contributions to $(g - 2)_\mu$ after the M_H measurement

Dominik Stöckinger

[1306.5546] with C. Gneidiger, H. Stöckinger-Kim

TU Dresden

[1309.0980] with H. Fargnoli, C. Gneidiger,
S. Passehr, H. Stöckinger-Kim



SUSY partner contributions

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Motivation

- Future experimental progress on a_μ
- Recent theory progress on QED and hadronic contributions
- EW contributions?

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- Future experimental progress on a_μ
- Recent theory progress on QED and hadronic contributions
- EW contributions?
 - ▶ So far most advanced: [Czarnecki, Marciano, Vainshtein '03]

$$a_\mu^{\text{EW}} = (154 \pm 1_{\text{rest}} \pm 2_{\text{Higgs}}) \times 10^{-11}$$

- ▶ depend on **Higgs mass** — only unknown SM input parameter
 - ▶ Measurement at LHC — take $M_H = 125.6 \pm 1.5\text{GeV}$
 - ▶ \exists more precise 2-loop calculation: [Heinemeyer, DS, Weiglein '04]
[Czarnecki, Gribouk '05]
- **eliminate M_H uncertainty, use most precise calculations!**

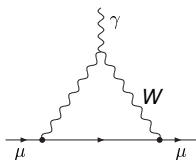
Outline

- 1 1-loop
- 2 2-loop
- 3 3-loop
- 4 Remarks on SUSY 2-loop contributions
- 5 Conclusions

1-loop contributions

Parametrization: $m_\mu, G_F, M_Z, m_t, M_H$

M_W predicted by SM: $M_W = 80.363 \pm 0.013 \text{ GeV}$ see also [Ferroglia, Sirlin '12]



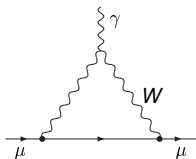
$$a_\mu^{\text{EW}(1)} = \frac{G_F}{\sqrt{2}} \frac{m_\mu^2}{8\pi^2} \left[\frac{5}{3} + \frac{1}{3}(1 - 4s_W^2)^2 \right]$$

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(don't use $M_W^{\text{exp}} = 80.385 \pm 0.015 \text{ GeV}$)

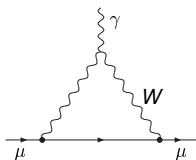


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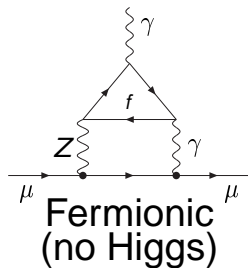
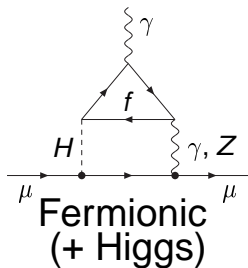
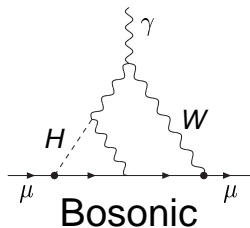


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$$= (194.80 \pm 0.01) \times 10^{-11}$$

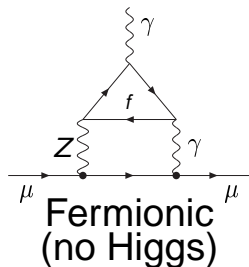
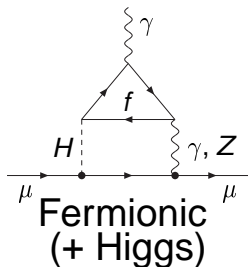
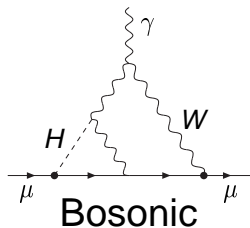
Error: from M_W within

$$s_W = \sqrt{1 - M_W^2/M_Z^2}$$

2-loop contributions — classification



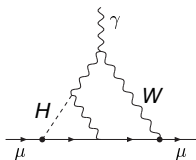
2-loop contributions — parametrization



Parametrization: All $\propto G_F \alpha!$ Which α ? $\alpha(0)$? $\alpha(M_Z)$? $\alpha \rightarrow G_F$?

Choice: $\alpha(0)$ [Czarnecki, Marciano, Vainshtein '03]

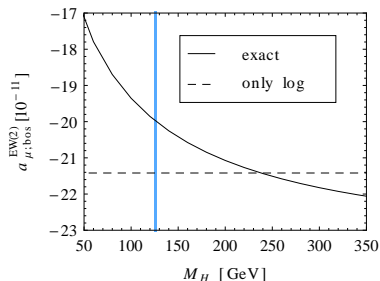
2-loop bosonic contributions



large M_H -limit: [Czarnecki, Krause, Marciano '95];

full: [Heinemeyer, DS, Weiglein '04] [Czarnecki, Gribov '05]

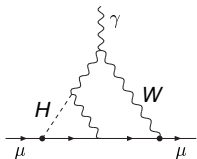
Recalculation with $G_F\alpha(0)$ parametrization:



$$a_{\mu; bos}^{EW(2)} = (-19.97 \pm 0.03) \times 10^{-11}$$

Error: essentially from M_H

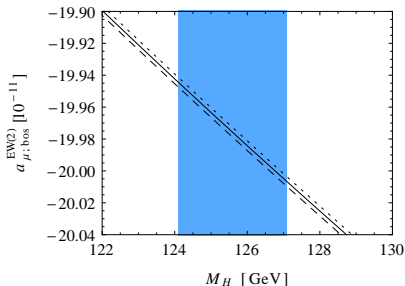
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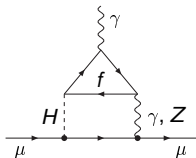


variation of M_W by $(-15, 0, +15)$ MeV

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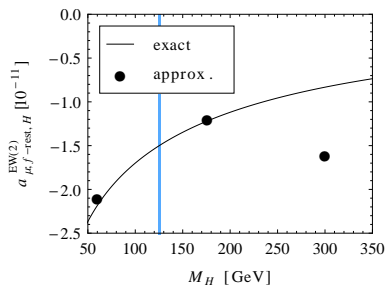
2-loop fermionic (+Higgs) contributions



in SM with limits $M_H \ll m_t$, $M_H = m_t$, $M_H \gg m_t$
and $(1 - 4s_W^2) \rightarrow 0$: [Czarnecki, Krause, Marciano '95]

in 2HDM, MSSM: [Cheung et al '01] [Wu et al '01] ...

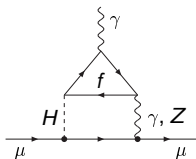
Recalculation in SM without approximations:



$$a_{\mu;f-rest,H}^{EW(2)} = (-1.50 \pm 0.01) \times 10^{-11}$$

Error: from M_H and m_t

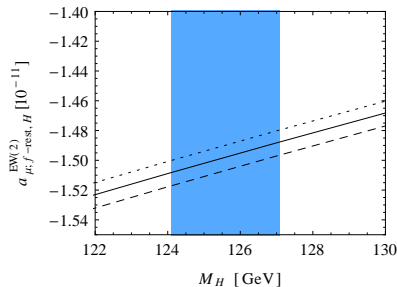
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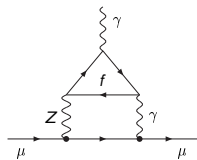


variation of m_t by $(-1.4, 0, +1.4)$ GeV

$$a_{\mu;f\text{-rest},H}^{\text{EW}(2)} = (-1.50 \pm 0.01) \times 10^{-11}$$

Error: from M_H and m_t

2-loop fermionic (no Higgs) contributions



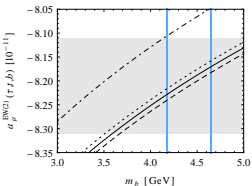
perturbative: [Czarnecki, Krause, Marciano '95]
non-pert.: [Peris, Perrottet, de Rafael '95] [Knecht+PPdR '02]
[Czarnecki, Marciano, Vainshtein '03] (Erratum!)

$$a_{\mu}^{\text{EW}(2)}(\tau, t, b) = -(8.21 \pm 0.10) \times 10^{-11}$$

$$a_{\mu}^{\text{EW}(2)}(e, \mu, u, c, d, s) = -(6.91 \pm 0.20 \pm 0.30) \times 10^{-11}$$

Error: quark masses, higher-order QCD corrections,
1st and 2nd generation hadronic uncertainties

2-loop fermionic (no Higgs) contributions



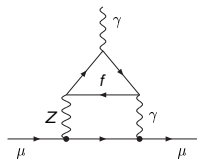
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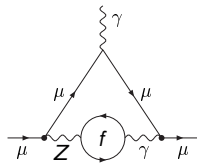


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[Czarnecki, Krause, Marciano '95] + [Czarnecki, Marciano, Vainshtein '03]
 [Gnendiger, DS, Stöckinger-Kim '13]

$$a_{\mu; f\text{-rest, no H}}^{\text{EW}(2)} = (-4.64 \pm 0.10) \times 10^{-11}$$

Error: estimate of neglected terms suppressed
 by $(1 - 4s_W^2)$ or M_Z^2/m_t^2

3-loop leading log contributions

$\alpha(m_\mu)$ -parametrization: [Degrassi, Giudice '98]

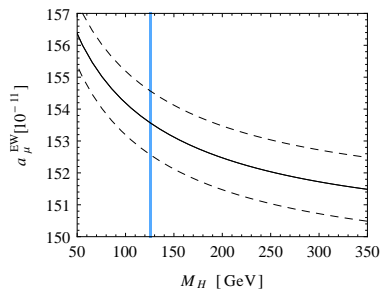
$\alpha(m_\mu), \alpha(0)$ -parametrizations: [Czarnecki, Marciano, Vainshtein '03]

Choice of $\alpha(0)$ parametrization: accidental cancellation!

$$a_\mu^{\text{EW}(\geq 3)} = (0 \pm 0.20) \times 10^{-11}$$

Error: estimate of non-leading log terms

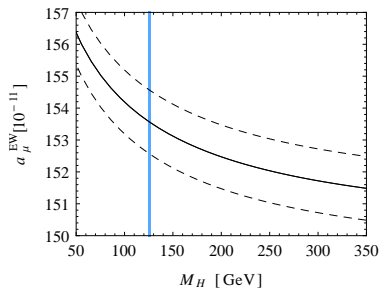
Full result



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

Error: mainly: EW hadronic,
subleading: unknown
three-loop

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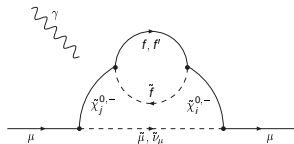
Combined with recent QED result [Aoyama, Hayakawa, Kinoshita, Nio '12] (shift of $+0.8 \times 10^{-11}$), had v.p. [h.o.: HLMNT], had l.b.l. [Prades, de Rafael, Vainshtein '08]:

$$a_{\mu}^{\text{exp}} - a_{\mu}^{\text{SM}} = \begin{cases} (287 \pm 80) \times 10^{-11} & \text{[Davier, Hoecker, Malaescu, Zhang '12]} \\ (261 \pm 80) \times 10^{-11} & \text{[Hagiwara, Liao, Martin, Nomura, Teubner '11]} \end{cases}$$

Results for $f\tilde{f}$ -loops: Large contributions from heavy squarks

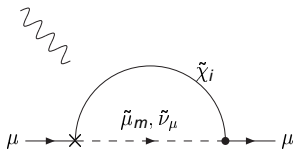
[Fargnoli, Gneidiger, Passehr, DS, Stöckinger-Kim '13]

1



$$\rightarrow a_{\mu}^{1L} \times \log(m_{\tilde{f}})$$

2



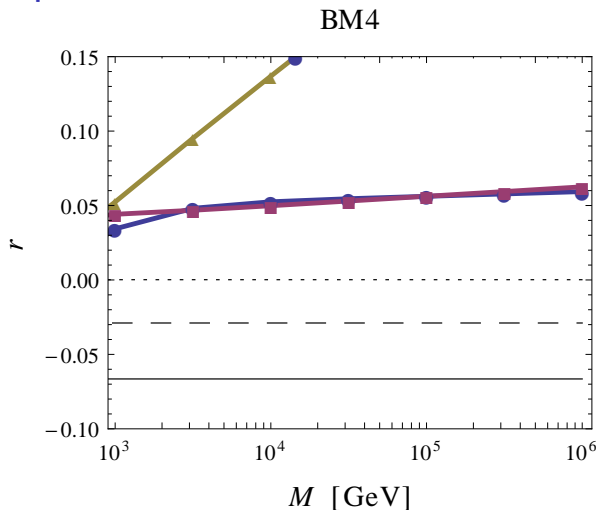
$$\rightarrow a_{\mu}^{1L} \times \Delta\rho$$

Some Motivation:

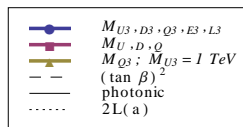
- Split spectra / remaining class with dependence on squarks
- maximum complexity: 5 heavy + 2 light scales

Results for $f\tilde{f}$ -loops: Large contributions from heavy squarks

[Fagnoli, Gneidiger, Passehr, DS, Stöckinger-Kim '13]



- non-decoupling
- can be largest 2L contribution $\mathcal{O}(10\% \dots 30\%)$



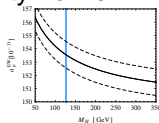
$$\mu = -160, M_1 = 140, m_{\tilde{\mu}_R} = 200, M_2 = m_{\tilde{\mu}_L} = 2000 \text{ GeV}, \tan \beta = 50$$

Summary

- Progress on all aspects of a_μ^{SM}

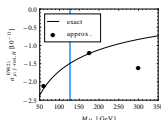
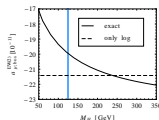
- ▶ EW contributions depend on $M_H \rightarrow$ this uncertainty now eliminated

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



- Exact (re)calculation of Higgs-dependent parts

- ▶ consistently used $\alpha(0)$



- Added updated remaining contributions from [Czarnecki, Marciano, Vainshtein '03]

- ▶ analytical expressions for new terms, checked error estimate

- Progress on SUSY prediction

- ▶ non-decoupling corrections from heavy squarks

