# Magnetic moment $(g-2)_\mu$ and SUSY

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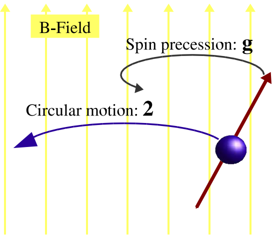
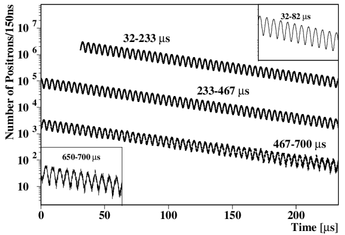
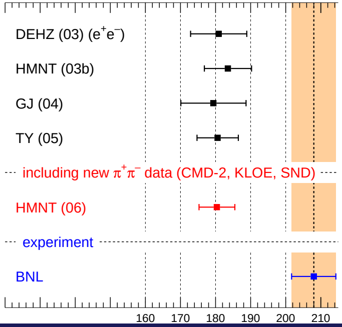
# $(g-2)$: Magnetic Moment of the Muon




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

$$a_\mu(\text{exp} - \text{SM}) = 28(8) \times 10^{-10}$$

3.4$\sigma$ deviation from SM-prediction!

# Outline

1. A $3\sigma$ deviation has been definitely established
2. SUSY can explain this deviation
3. Campaign for new, better measurement
4. Conclusions

# Outline

# Era of the Brookhaven experiment — current status

- Experiment:
  - 2001–2006: very stable development
  - final error: $6 \times 10^{-10}$, still statistics dominated
- SM Theory:
  - 2002: one sign error corrected in hadronic LbL contributions
  - problems with $\tau$-decay data: hardly used any more
  - apart from that: SM theory prediction very stable as well, precision of $a_\mu^{\rm had}$ increases as better $e^+e^- \to$hadron data become available (CMD-II, SND, KLOE, B-factories, . . . )

# Era of the Brookhaven experiment — current status

Very recently: spectacular progress

new SM evaluations, based on new exp data for $a_\mu^{\rm had}$:

$$a_\mu(\text{Exp-SM}) = \left\{ \begin{array}{ll} [HMNT06] & 28(8) \\ [DEHZ06] & 28(8) \\ [FJ07] & 29(9) \\ [MRR07] & 29(8) \end{array} \right\} \times 10^{-10}$$

better agreement between evaluations, more precise,
larger deviation from exp than ever before

$\Downarrow$

$3\sigma$ deviation has now been definitely established

# Outline

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# $a_\mu$ and SUSY

Two questions:

Could SUSY be the origin of the $(28 \pm 8) \times 10^{-10}$ deviation?

Which restrictions on SUSY follow from (e.g. $3\sigma$ band)

$$3 \times 10^{-10} \; < \; a_\mu^{\rm SUSY} \; < \; 51 \times 10^{-10}?$$

# $a_\mu$ in the MSSM

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

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

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

# $a_\mu$ in the MSSM

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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!

# $a_\mu$ in the MSSM

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

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

numerically

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

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

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

$\Rightarrow$ such parameter points are ruled out by $a_\mu$!

# $a_\mu$ in the MSSM

Answers:

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

$a_\mu$ significantly restricts the SUSY parameters

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

## Alternatives to SUSY?

Generic BSM physics at $M_{NP}$:

$$a_\mu^{NP} \sim 1 \times 10^{-10} \left( \frac{300\text{GeV}}{M_{NP}} \right)^2$$

much too small! Two advantages of SUSY:

- $\tan\beta$-enhancement
- low SUSY masses possible

# Example for "typical" behaviour

benchmark point SPS1a

$$a_\mu(\text{SUSY, SPS1a}) = 29.8(3.1) \times 10^{-10}$$ [DS '06]

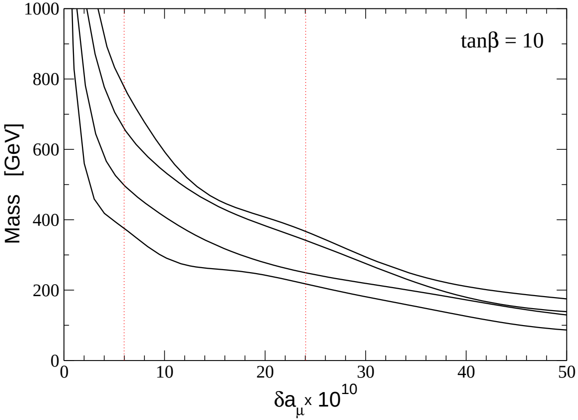
$$a_\mu(\text{Exp.} - \text{SM}) = 29.5(8.8) \times 10^{-10}$$ [Miller, de Rafael, Roberts '07]

$$M_W(\text{SPS1a}) = 80.381(18)\ \text{GeV}$$ [Heinemeyer, Hollik, DS, Weber, Weiglein '06]

$$M_W(\text{Exp.}) = 80.398(25)\ \text{GeV}$$ [CDF, LEPEWWG '07]

Agreement with experiment? very good!

# Numerical results

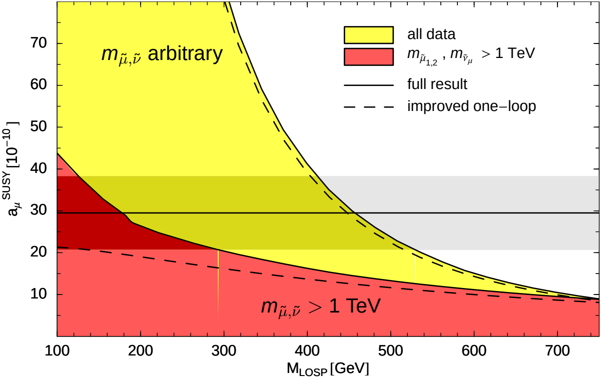



“aggressive”: require $a_\mu^{\text{SUSY}}$ within $2\sigma$ band [Byrne,Kolda,Lennon ’02]

$\Rightarrow$ upper mass bounds on four lightest sparticles

# Numerical results

Summary: scan for $\tan\beta = 50$, all parameters $< 3$ TeV [DS '06]




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

SUSY contributions in the observed range for low $M_{\mathrm{SUSY}}$!

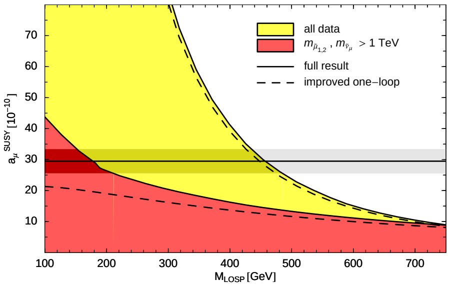
# Outline

# Potential of improved measurement

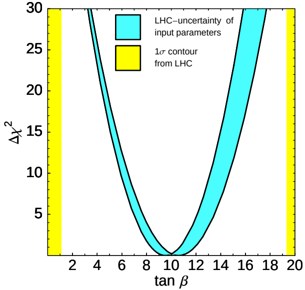
- new Brookhaven experiment proposed and feasible
- improved SM evaluation possible
- projected accuracy: $a_\mu$(Exp-SM) $= 29.5(3.9) \times 10^{-10}$ [Roberts, DS, et al 07]

Would be of tremendous importance as a complement of LHC

Constrain SUSY




Measure tan $\beta$ (case SPS1a)



# Potential of improved measurement

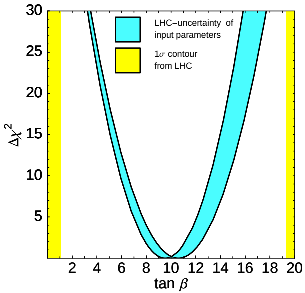
- new Brookhaven experiment proposed and feasible
- improved SM evaluation possible
- projected accuracy: $a_\mu(\text{Exp-SM}) = 29.5(3.9) \times 10^{-10}$ [Roberts, DS, et al 07]

Would be of tremendous importance as a complement of LHC

Distinguish
SUSY and UED

$$a_\mu^{\mathrm{SUSY}} = 29.8 \times 10^{-10}$$
$$a_\mu^{\mathrm{UED}} = -1.3 \times 10^{-10}$$

Measure tan $\beta$ (case SPS1a)



# Muon $(g-2)$ and the ILC

- $a_\mu$ prefers small SUSY (chargino, smuon) masses
  $\rightarrow$ very promising for ILC
- Both the ILC and a future $(g-2)$ experiment are complementary to the LHC but also to each other (e.g. independent determinations of $\tan\beta$ ($\rightarrow$ universality?))
  $\rightarrow$ we should want both experiments

$\rightarrow$ and there should be no competition between them

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# Conclusions

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

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

- 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 measurements very important and promising!