The muon $g-2$ discrepancy: errors or new physics?

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The present experimental values:

\[ a_e = 1159652180.73 \times 10^{-12} \]

0.24 parts per billion !! Hanneke et al., PRL100 (2008) 120801

\[ a_\mu = 116592080 (63) \times 10^{-11} \]

0.5 parts per million !! E821 - Final Report: PRD73 (2006) 072003

\[ a_\tau = -0.018 (17) \]

DELPHI - EPJC35 (2004) 159 \[a_\tau^{SM} = 117721(5) \times 10^{-8}, \text{Eidelman & MP '07}\]
LIFE OF A MUON: THE g-2 EXPERIMENT

Protons from AGS.

Hit Target.

Pions, weighing 1/6 proton, are created.

Pions decay to muons.

Muons are fed into a uniform, doughnut-shaped magnetic field and travel in a circle.

One of 24 detectors see an electron, giving the muon spin direction; g-2 is this angle, divided by the magnetic field the muon is traveling through in the ring.

After each circle, muon's spin axis changes by 12°, yet it keeps on traveling in the same direction.

After circling the ring many times, muons spontaneously decay to electron, (plus neutrinos,) in the direction of the muon spin.

Homepage of E821
The muon g-2: experimental result

Today: \( a_\mu^{\text{EXP}} = (116592080 \pm 54_{\text{stat}} \pm 33_{\text{sys}}) \times 10^{-11} \) [0.5ppm].

Future: a new \((g-2)_\mu\) exp aims at 0.14 ppm! [D. Hertzog, KLOE2 Physics Workshop, LNF, April 2009].

Are theorists ready for this? [not yet]
The anomalous magnetic moment: the basics

- The Dirac theory predicts for a lepton $l=e, \mu, \tau$:
  \[
  \bar{\mu}_l = g_l \left( \frac{e}{2m_l c} \right) \bar{s} \quad g_l = 2
  \]

- QFT predicts deviations from the Dirac value:
  \[
  g_l = 2 \left( 1 + a_l \right)
  \]

- Study the photon-lepton vertex:
  \[
  \bar{u}(p') \Gamma_{\mu} u(p) = \bar{u}(p') \left[ \gamma_{\mu} F_1(q^2) + \frac{i\sigma_{\mu\nu} q^\nu}{2m} F_2(q^2) + \ldots \right] u(p)
  \]

  \[
  F_1(0) = 1 \quad F_2(0) = a_l
  \]
The QED contribution to $a_\mu$

$$a_\mu^{\text{QED}} = \frac{1}{2}(\alpha/\pi) \quad \text{Schwinger 1948}$$

$$+ 0.765857408 \ (27) \ \left(\frac{\alpha}{\pi}\right)^2$$

Sommerfield; Petermann; Suura & Wichmann '57; Elend '66; MP '04

$$+ 24.05050959 \ (42) \ \left(\frac{\alpha}{\pi}\right)^3$$

Remiddi, Laporta, Barbieri ...; Czarnecki, Skrzypek; MP '04;
Friot, Greynat & de Rafael '05, Mohr, Taylor & Newell '08

$$+ 130.805 \ (8) \ \left(\frac{\alpha}{\pi}\right)^4$$

Kinoshita & Lindquist '81, ... , Kinoshita & Nio '04, '05;
Aoyama, Hayakawa, Kinoshita & Nio, June & Dec 2007

$$+ 663 \ (20) \ \left(\frac{\alpha}{\pi}\right)^5 \quad \text{In progress}$$

Kinoshita et al. '90, Yelkhovsky, Milstein, Starshenko, Laporta,
Karshenboim,..., Kataev, Kinoshita & Nio March '06.

Adding up, I get:

$$a_\mu^{\text{QED}} = 116584718.08 \ (14)(04) \times 10^{-11}$$

from coeffs, mainly from 5-loop unc

with $\alpha=1/137.035999084(51) \ [0.37 \ \text{ppb}]$.
\[ a_e^{\text{SM}} = \frac{1}{2} \left( \frac{\alpha}{\pi} \right) - 0.328\,478\,444\,002\,89(60) \left( \frac{\alpha}{\pi} \right)^2 \]

Schwinger 1948
Sommerfield; Petermann; Suura & Wichmann '57; Elend '66; MP '06

\[ A_2^{(4)} \left( \frac{m_e}{m_\mu} \right) = 5.197\,386\,78 \left( 26 \right) \times 10^{-7} \]

\[ A_2^{(4)} \left( \frac{m_e}{m_\tau} \right) = 1.837\,62 \left( 60 \right) \times 10^{-9} \]

+ 1.181\,234\,016\,827 \left( 19 \right) \left( \frac{\alpha}{\pi} \right)^3

Kinoshita, Barbieri, Laporta, Remiddi, ... , Li, Samuel; Mohr, Taylor & Newell '08, MP '06

\[ A_2^{(6)} \left( \frac{m_e}{m_\mu} \right) = -7.373\,941\,73 \left( 27 \right) \times 10^{-6} \]

\[ A_2^{(6)} \left( \frac{m_e}{m_\tau} \right) = -6.5819 \left( 19 \right) \times 10^{-8} \]

\[ A_3^{(6)} \left( \frac{m_e}{m_\mu}, \frac{m_e}{m_\tau} \right) = 1.909\,45 \left( 62 \right) \times 10^{-13} \]

- 1.9144 \left( 35 \right) \left( \frac{\alpha}{\pi} \right)^4

Kinoshita & Lindquist '81, ... , Kinoshita & Nio '05; Aoyama, Hayakawa, Kinoshita & Nio, June '07

+ 0.0 \left( 4.6 \right) \left( \frac{\alpha}{\pi} \right)^5

In progress (12672 mass ind. diagrams!)

Aoyama, Hayakawa, Kinoshita, Nio '07; Aoyama, Hayakawa, Kinoshita, Nio & Watanabe 06/2008

+ 1.682 \left( 20 \right) \times 10^{-12}

Hadronic

Mohr, Taylor & Newell '08; Davier & Hoecker '98, Krause '97, Knecht '03

+ 0.02973 \left( 52 \right) \times 10^{-12}

Electroweak

Mohr, Taylor & Newell, '08; Czarnecki, Krause, Marciano '96
... and the best determination of alpha

- The new measurement of the electron $g-2$ is:
  \[ a_e^{\text{exp}} = 1159652180.73 \times 10^{-12} \]

  vs. old (factor of 15 improvement, 1.8\(\sigma\) difference):
  \[ a_e^{\text{exp}} = 1159652188.3 \times 10^{-12} \]

- Equating $a_e^{\text{SM}(\alpha)} = a_e^{\text{exp}} \rightarrow$ best determination of alpha to date:
  \[ \alpha^{-1} = 137.035\ 999\ 084(12)(37)(2)(33) \ [0.37\text{ppb}] \]

- Compare it with other determinations (independent of $a_e$):
  \[ \alpha^{-1} = 137.036\ 000\ 00 \ (110) \ [7.7\text{ppb}] \]
  \[ \alpha^{-1} = 137.035\ 998\ 78 \ (91) \ [6.7\text{ppb}] \]
  \[ \alpha^{-1} = 137.035\ 999\ 45 \ (62) \ [4.6\text{ppb}] \]

Excellent agreement \(\rightarrow\) beautiful test of QED at 4-loop level!
Old and new determinations of alpha

Hanneke, Fogwell & Gabrielse, PRL 100 (2008) 120801
The Electroweak contribution

**One-loop term:**

\[ a_{\mu}^{EW} (1\text{-loop}) = \frac{5G_{\mu}m_{\mu}^2}{24\sqrt{2}\pi^2} \left[ 1 + \frac{1}{5} \left( 1 - 4\sin^2\theta_W \right)^2 + O \left( \frac{m_{\mu}^2}{M_{Z,W,H}^2} \right) \right] \approx 195 \times 10^{-11} \]

1972: Jackiw, Weinberg; Bars, Yoshimura; Altarelli, Cabibbo, Maiani; Bardeen, Gastmans, Lautrup; Fujikawa, Lee, Sanda.

**One-loop plus higher-order terms:**

\[ a_{\mu}^{EW} = 154 \ (2) \ (1) \times 10^{-11} \]

Kukhto et al. '92; Czarnecki, Krause, Marciano '95; Knecht, Peris, Perrottet, de Rafael '02; Czarnecki, Marciano, Vainshtein '02; Degrassi, Giudice '98; Heinemeyer, Stockinger, Weiglein '04; Gribouk, Czarnecki '05; Vainshtein '03.

Higgs mass, \( M_{\text{top}} \) error, 3-loop nonleading logs

Hadronic loop uncertainties:
The hadronic leading-order (HLO) contribution

\[ a_{\mu}^{\text{HLO}} = \frac{1}{4\pi^3} \int_{4m_{\pi}^2}^{\infty} ds \ K(s) \sigma^{(0)}(s) = \frac{\alpha^2}{3\pi^2} \int_{4m_{\pi}^2}^{\infty} \frac{ds}{s} K(s) R(s) \]

\[ K(s) = \int_{0}^{1} dx \frac{x^2(1-x)}{x^2 + (1-x)s/m_{\mu}^2} \]

Bouchiat & Michel 1961; Gourdin & de Rafael 1969

Central values

Errors²

F. Jegerlehner, PhiPsi 08, Frascati, April 2008

Hagiwara et al., PRD 69 (2004) 093003
The HLO contribution: \(e^+e^-\) data

\[
\alpha_\mu^{HLO} = 6909 (39)_{\text{exp}} (19)_{\text{rad}} (7)_{\text{qcd}} \times 10^{-11}
\]

S. Eidelman, ICHEP06; M. Davier, TAU06

\[
= 6894 (42)_{\text{exp}} (18)_{\text{rad}} \times 10^{-11}
\]

Hagiwara, Martin, Nomura, Teubner, PLB649(2007)173

\[
= 6923 (60)_{\text{tot}} \times 10^{-11}
\]

F. Jegerlehner, PhiPsi 08, Frascati, April 2008

\[
= 6944 (48)_{\text{exp}} (10)_{\text{rad}} \times 10^{-11}
\]

de Troconiz & Yndurain, PRD71 (2005) 73008

Radiative Corrections (Luminosity, ISR, Vacuum Polarization, FSR) are a very delicate issue! Are they all under control?

CMD2: The 1998 \(\pi^+\pi^-\) data in the \(\rho\) energy range, published in 2007, agree with their earlier 1995 ones.

SND's \(\pi^+\pi^-\) 2006 data reanalysis in agreement with CMD2.
The RADIATIVE RETURN (ISR) Method: KLOE & BaBar.
Collider operates at fixed energy but $s_\pi$ can vary continuously. Important independent method made possible by beautiful interplay between theory and experiment.


Agreement between KLOE (2008) and CMD2-SND below the $\rho$, some discrepancies above. Their contributions to $a_\mu^{HLO}$ agree.

BaBar: $\pi^+\pi$ preliminary results (from 0.5 to 3 GeV) presented at Tau08. Disagreement with CMD2, SND and KLOE. Better agreement with $\tau$ results, especially with Belle. Let's wait for a publication.
CMD2 & SND vs KLOE

CMD2 2007:
361.5±1.7_{STAT}±2.0_{SYST}

SND 2006:
361.0±2.0_{STAT}±4.7_{SYST}

KLOE 2008:
356.7±0.4_{STAT}±3.0_{SYST}

G. Venanzoni, Tau08, Novosibirsk, September 2008

band: KLOE error
data points: CMD2/SND experiments
The HLO contribution: Tau-decay data (Aleph, Opal, Cleo & Belle)

- The $\tau$ data of ALEPH and CLEO are significantly higher than the CMD2-SND-KLOE ones, particularly above the $\rho$.

- The 2008 $a_\mu^{\pi\pi}\tau$ result of Belle agrees with Aleph-Cleo-Opal. Some deviations from Aleph’s spectral functions.

- Value: $a_\mu^\text{HLO} = 7110 (58) \times 10^{-11}$

by Davier, Eidelman, Hoecker, Zhang, EPJC31 (2003) 503. NB: Davier & Eidelman chose not to include $\tau$ data in their updates of this article until the discrepancy is understood.

- Inconsistencies in $e^+e^-$ or $\tau$ data? All possible isospin-breaking (IB) effects taken into account? Further recent IB corrections somewhat reduce the diff. with $e^+e^-$ data. Recent claims that $e^+e^-$ & $\tau$ data are consistent after IB effects & vector meson mixings considered (Marciano & Sirlin '88; Cirigliano, Ecker, Neufeld '01-'02, Flores-Baez et al. '06 & '07, Benayoun et al.'07).
Fujikawa, Hayashii, Eidelman [for the Belle Collab.], arXiv:0805.3773, May '08
The hadronic higher-order (HHO) contributions: VP

**HHO: Vacuum Polarization**

\[ a_\mu^{HHO}(vp) = -98 (1) \times 10^{-11} \]

O\((\alpha^3)\) contributions of diagrams containing hadronic vacuum polarization insertions:

Krause '96, Alemany et al. '98, Hagiwara et al. '03 & '06

Shifts by \(\sim -3 \times 10^{-11}\) if \(\tau\) data are used instead of the \(e^+e^-\) ones

Davier & Marciano '04.
The hadronic higher-order (HHO) contributions: LBL

**HHO: Light-by-light contribution**

Unlike the HLO term, for the hadronic l-b-l term one must rely on theoretical approaches.

This term had a troubled life! Its recent determinations vary between:

\[ a_\mu^{HHO}(lbl) = +80 (40) \times 10^{-11} \quad \text{Knecht & Nyffeler '02} \]
\[ a_\mu^{HHO}(lbl) = +136 (25) \times 10^{-11} \quad \text{Melnikov & Vainshtein '03} \]
\[ a_\mu^{HHO}(lbl) = +105 (26) \times 10^{-11} \quad \text{Prades, de Rafael, Vainshtein '09} \]
\[ a_\mu^{HHO}(lbl) = +116 (39) \times 10^{-11} \quad \text{Jegerlehner & Nyffeler '09} \]

(results based also on Hayakawa, Kinoshita '98 & '02; Bijnens, Pallante, Prades '96 & '02)

**Erler & Sanchez upper bound:** \( a_\mu^{HHO}(lbl) < 160 \times 10^{-11} \).

**Lattice?** Hard, but in progress: Rakow et al (QCDSF), Hayakawa et al.

It’s likely to become the ultimate limitation of the SM prediction.
Adding up all the above contribution we get the following SM predictions for $a_\mu$ and comparisons with the measured value:

<table>
<thead>
<tr>
<th>Ref.</th>
<th>$a_{\mu}^{SM} \times 10^{11}$</th>
<th>$\Delta a_{\mu} \times 10^{11}$</th>
<th>$\sigma$</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>116591788 (51)</td>
<td>292 (81)</td>
<td>3.6</td>
</tr>
<tr>
<td>2</td>
<td>116591773 (53)</td>
<td>307 (82)</td>
<td>3.7</td>
</tr>
<tr>
<td>3</td>
<td>116591802 (65)</td>
<td>278 (91)</td>
<td>3.1</td>
</tr>
<tr>
<td>4</td>
<td>116591823 (56)</td>
<td>257 (84)</td>
<td>3.1</td>
</tr>
<tr>
<td>5</td>
<td>116591986 (64)</td>
<td>94 (90)</td>
<td>1.0</td>
</tr>
</tbody>
</table>

with $a_\mu^{HHO(lbl)} = 105 (26) \times 10^{-11}$.

$\Delta a_\mu = a_\mu^{EXP} - a_\mu^{SM}$.

[1] Eidelman at ICHEP06 & Davier at TAU06 (update of ref. [5]).

The th error is now about the same as the exp. one!
The muon $g-2$ and the bounds on the Higgs mass

MP, W.J. Marciano & A. Sirlin

[PRD78, 013009 (2008)]
The effective fine-structure constant at the scale $M_z^2$ is given by:

$$\alpha(M_z) = \frac{\alpha}{1 - \Delta \alpha(M_z)}$$

with

$$\Delta \alpha = \Delta \alpha_{\text{lep}} + \Delta \alpha_{\text{had}}^{(5)} + \Delta \alpha_{\text{top}}$$

The light quarks part is determined by:

$$\Delta \alpha_{\text{had}}^{(5)}(M_z) = \frac{M_z^2}{4\alpha \pi^2} P \int_{4m_{\pi}^2}^{\infty} ds \frac{\sigma(s)}{M_z^2 - s}$$

Progress due to significant improvement of the data:

$$\Delta \alpha_{\text{had}}^{(5)}(M_z^2) =$$

- 0.02800 (70)  Eidelman, Jegerlehner'95
- 0.02775 (17)  Kuhn, Steinhauser 1998
- 0.02749 (12)  Troconiz, Yndurain 2005
- 0.02758 (35)  Burkhardt, Pietrzyk 2005
- 0.02768 (22)  Hagiwara et al. 2006
- 0.02761 (23)  F. Jegerlehner 2008
... and the EW Bounds on the SM Higgs mass

- The dependence of SM predictions on the Higgs mass, via loops, provides a powerful tool to set bounds on its value.

- **Comparing the theoretical predictions of** $M_W$ **and** $\sin^2\theta_{\text{eff}}^{\text{lept}}$ 

  [convenient formulae in terms of $M_H$, $M_{\text{top}}$, $\Delta\alpha_{\text{had}}^{(5)}(M_Z)$ and $\alpha_s(M_Z)$ by Degrassi, Gambino, MP, Sirlin ’98; Degrassi, Gambino ’00; Ferroglia, Ossola, MP, Sirlin ’02; Awramik, Czakon, Freitas, Weiglein ’04 & ’06]

  with
  
  $M_W = 80.399 (25)$ GeV  
  $\sin^2\theta_{\text{eff}}^{\text{lept}} = 0.23153 (16)$

  and

  $\Delta\alpha_{\text{had}}^{(5)}(M_Z) = 0.02768 (22)$  
  $M_{\text{top}} = 172.4 (1.2)$ GeV  
  $\alpha_s(M_Z) = 0.118 (2)$

  we get

  $M_H = 88^{+32}_{-24}$ GeV  &  $M_H < 145$ GeV  95%CL

- The value of $\Delta\alpha_{\text{had}}^{(5)}(M_Z)$ is a key input of these EW fits...
Back to $\Delta a_\mu$: how do we explain it?

- $\Delta a_\mu$ can be explained in many ways: errors in HHO-LBL, QED, EW, HHO-VP, g-2 EXP, HLO; or New Physics.

- Can $\Delta a_\mu$ be due to hypothetical mistakes in the hadronic $\sigma(s)$?

- An upward shift of $\sigma(s)$ also induces an increase of $\Delta \alpha_{\text{had}}^{(5)}(M_Z)$.

- Consider:

- $a_{\mu}^{\text{HLO}}:
  \quad a = \int_{4m_{\pi}^2}^{s_u} ds \ f(s) \ \sigma(s), \quad f(s) = \frac{K(s)}{4\pi^3}, \quad s_u < M_Z^2$,

- $\Delta \alpha_{\text{had}}^{(5)}:
  \quad b = \int_{4m_{\pi}^2}^{s_u} ds \ g(s) \ \sigma(s), \quad g(s) = \frac{M_Z^2}{(M_Z^2 - s)(4\alpha\pi^2)}$,

and the increase

$$\Delta \sigma(s) = \epsilon \sigma(s)$$

($\epsilon > 0$), in the range:

$$\sqrt{s} \in [\sqrt{s_0} - \delta/2, \sqrt{s_0} + \delta/2]$$
Shifts of $a_\mu^{HLO}$ and $\Delta \alpha_{\text{had}}^{(5)}(M_Z)$

- If this shift $\Delta \sigma(s)$ in $[\sqrt{s_0} - \delta/2, \sqrt{s_0} + \delta/2]$ is adjusted to bridge the g-2 discrepancy, the value of $\Delta \alpha_{\text{had}}^{(5)}(M_Z)$ increases by:

$$\Delta b(\sqrt{s_0}, \delta) = \Delta a_\mu \frac{\int \sqrt{s_0 + \delta/2} g(t^2) \sigma(t^2) \, t \, dt}{\int \sqrt{s_0 - \delta/2} f(t^2) \sigma(t^2) \, t \, dt}$$

- Adding this shift to $\Delta \alpha_{\text{had}}^{(5)}(M_Z) = 0.02768(22)$ [HMNT07], with $\Delta a_\mu = 302(88) \times 10^{-11}$ [HMNT07], we obtain:
How much does the $M_H$ upper bound change when we shift $\sigma(s)$ by $\Delta\sigma(s)$ [and thus $\Delta\alpha^{(5)}_{\text{had}}(M_Z)$ by $\Delta b$] to accommodate $\Delta a_\mu$?
The muon g-2: connection with the SM Higgs mass (2)

- The LEP direct-search lower bound is $M_H^{LB} = 114.4 \text{ GeV} \ (95\%CL)$.

- The hypothetical shifts $\Delta \sigma = \varepsilon \sigma(s)$ that bridge the muon g-2 discrepancy conflict with the LEP lower limit when $\sqrt{s_0} > \sim 1.2 \text{GeV}$ (for bin widths $\delta$ up to several hundreds of MeV).

- While using $\tau$ data in the calculation of $a_\mu^{HLO}$ almost solves the muon g-2 discrepancy, it increases the value of $\Delta a_{\text{had}}^{(5)}(M_Z)$, leading to $M_H < 133 \text{ GeV} \ (95\%CL)$, in near conflict with $M_H^{LB}$.

- Recent claim: $e^+e^- & \tau$ data consistent below $\sim 1 \text{ GeV}$ (after isospin viol. effects & vector meson mixings). We could thus assume that $\Delta a_\mu$ is fixed by hypothetical errors above $\sim 1 \text{ GeV}$ (where disagreement persists). If so, $M_H^{UB}$ falls below $M_H^{LB}$!!

- Scenarios where $\Delta a_\mu$ is accommodated without affecting $M_H^{UB}$ are possible, but considerably more unlikely.
How realistic are these shifts $\Delta \sigma(s)$? When compared with the quoted exp. uncertainties? Study the ratio $\varepsilon = \Delta \sigma(s)/\sigma(s)$: 

$M_H$ 95% CL u.b. (GeV)
The minimum $\epsilon$ is $\sim +4\%$. It occurs if $\sigma$ is multiplied by $(1+\epsilon)$ in the whole integration region (!), leading to $M_{H^{UB}} \sim 70 \text{ GeV} (!!)$.

As the quoted exp. uncertainty of $\sigma(s)$ below 1 GeV is $\sim$ a few per cent (or less), the possibility to explain the muon $g-2$ with these shifts $\Delta \sigma(s)$ appears to be unlikely.

If, however, we allow variations of $\sigma(s)$ up to $\sim 6\% (7\%)$, $M_{H^{UB}}$ is reduced to less than $\sim 130 \text{ GeV} (131 \text{ GeV})$. E.g., the $\sim 6\%$ shift in the interval $[0.6, 1.2] \text{ GeV}$, required to fix $\Delta a_{\mu}$, lowers $M_{H^{UB}}$ to 126GeV. Tension with the $M_{H} > \sim 120 \text{ GeV}$ “vacuum stability” bound.

Reminder: the above $M_{H}$ upper bounds, like the LEP-EWWG ones, depend on the value of $\sin^2 \theta_{\text{lep}}^{\text{eff}}$. They also depend on $M_{t}$ & its unc. $\delta M_{t}$. We prepared simple formulae to translate easily $M_{H}$ upper bounds discussed above into new values corresponding to $M_{t}$ & $\delta M_{t}$ inputs different from those employed here.

How realistic are these shifts $\Delta \sigma(s)$? (2)
Conclusions

- $g$: Beautiful examples of interplay between theory and experiment:
  - $g_e$ probed at $<\text{ppt} \rightarrow \alpha$ and extraordinary test of QED’s validity;
  - $g_\mu$ probed at $<\text{ppb} \rightarrow$ test of the full SM and great opportunity to unveil (or just constrain) “New Physics” effects!

- The discrepancy $\Delta a_\mu$ is more than $3 \sigma$ if $e^+e^-$ data are used. With tau data, the deviation is only $\sim 1 \sigma$. BaBar $2\pi$? More $e^+e^-$ data & analyses eagerly awaited! QED & EW ready for new $g$-2 exp! LBL??

- $\Delta a_\mu$ can be due to New Physics, or to problems in $a_\mu^{SM}$ (or $a_\mu^{EXP}$).
  - Can it be due to hypothetical mistakes in the hadronic $\sigma(s)$? An increase $\Delta \sigma(s)$ could bridge $\Delta a_\mu$, leading however to a decrease on the EW upper bound on the SM Higgs mass $M_H$...

- By means of a detailed analysis we conclude that solving $\Delta a_\mu$ via an increase of $\sigma(s)$ is unlikely in view of current exp. error estimates. However, if this turns out to be the solution, then the $M_H$ upper bound drops to about 130 GeV which, in conjunction with the LEP 114 GeV direct lower limit, leaves a rather narrow window for $M_H$. 
The End
Back-up Slides
CMD-2, SND & KLOE vs BaBar (preliminary)

Deviation from 1 of ratio w.r.t. BaBar (stat + syst errors included)

M. Davier, Fermilab, January 2009