Updates on Muon $g-2$

Daisuke Nomura (Tohoku U.)

talk at Toyama winter workshop

February 21, 2012

Based on J. Phys. **G38** (2011) 085003
by K. Hagiwara, R. Liao, A. D. Martin, DN & T. Teubner
(HLMNT)
+ updates (not necessarily from HLMNT)

Faculty of Science
Graduate School of Science
TOHOKU UNIVERSITY

TOHOKU UNIVERSITY

Muon $g-2$: introduction

Lepton magnetic moment $\vec{\mu}$:

$$\boxed{\vec{\mu} = -g\frac{e}{2m}\vec{s}}, \qquad \left(\vec{s} = \frac{1}{2}\vec{\sigma}\ \text{(spin)}, \qquad g = 2 + 2F_2(0)\right)$$

where

$$\overline{u}(p+q)\Gamma^\mu u(p) = \overline{u}(p+q)\left(\gamma^\mu F_1(q^2) + \frac{i\sigma^{\mu\nu}q_\nu}{2m}F_2(q^2)\right)u(p)$$

Anomalous magnetic moment: $a \equiv (g-2)/2$ $(= F_2(0))$

Historically,

★ $g = 2$ (tree level, Dirac)

★ $a = \alpha/(2\pi)$ (1-loop QED, Schwinger)

Today, still important, since...

★ One of the **most precisely measured** quantities

$$\boxed{a_\mu^{\text{exp}} = 11\ 659\ 208.9(6.3) \times 10^{-10}} \quad [0.5\text{ppm}]$$

(Bennett *et al*)

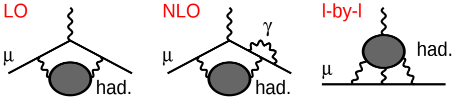
★ **Extremely useful** in **probing/constraining physics beyond the SM**

Introduction: Standard Model prediction for muon $g-2$

QED contribution	11 658 471.808 (0.015) $\times 10^{-10}$	Kinoshita & Nio, Aoyama et al
EW contribution	15.4 (0.2) $\times 10^{-10}$	Czarnecki et al
Hadronic contribution		
LO hadronic	**694.9 (4.3)** $\times 10^{-10}$	HLMNT11
NLO hadronic	-9.8 (0.1) $\times 10^{-10}$	HLMNT11
light-by-light	10.5 (2.6) $\times 10^{-10}$	Prades, de Rafael & Vainshtein
Theory TOTAL	**11 659 182.8 (4.9)** $\times 10^{-10}$	
Experiment	**11 659 208.9 (6.3)** $\times 10^{-10}$	world avg
Exp − Theory	**26.1 (8.0)** $\times 10^{-10}$	**3.3 σ discrepancy**

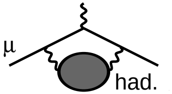
(Numbers taken from HLMNT11, arXiv:1105.3149)

n.b.: hadronic contributions:

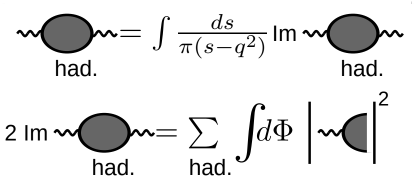


Introduction for $a_\mu^{\rm had,LO}$

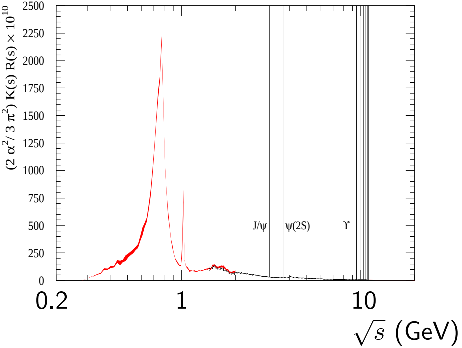
The diagram to be evaluated:



pQCD not useful. Use the dispersion relation and the optical theorem.



$$a_\mu^{\rm had,LO} = \frac{m_\mu^2}{12\pi^3}\int_{s_{\rm th}}^{\infty} ds\ \frac{1}{s}\hat{K}(s)\sigma_{\rm had}(s)$$



- Weight function $\hat{K}(s)/s = \mathcal{O}(1)/s$

$\Longrightarrow$ Lower energies more important

$\Longrightarrow$ $\pi^+\pi^-$ channel: 73% of total $a_\mu^{\rm had,LO}$

Included Hadronic Final States

Channel	Experiments with References
$\pi^+\pi^-$	OLYA [16, 17, 18], OLYA-TOF [19], NA7 [20], OLYA and CMD [21, 22], DM1 [23], DM2 [24], BCF [25, 26], MEA [27, 28], ORSAY-ACO [29], CMD-2 [10, 11, 30]
$\pi^0\gamma$	SND [31, 32]
$\eta\gamma$	SND [32, 33], CMD-2 [34, 35, 36]
$\pi^+\pi^-\pi^0$	ND [22], DM1 [37], DM2 [38], CMD-2 [10, 13, 34, 39], SND [40, 41], CMD [42]
K^+K^-	MEA [27], OLYA [43], BCF [26], DM1 [44], DM2 [45, 46], CMD [22], CMD-2 [34], SND [47]
$K_S^0K_L^0$	DM1 [48], CMD-2 [10, 14, 49], SND [47]
$\pi^+\pi^-\pi^0\pi^0$	M3N [50], DM2 [51], OLYA [52], CMD-2 [53], SND [54], ORSAY-ACO [55], $\gamma\gamma$2 [56], MEA [57]
$\omega(\to\pi^0\gamma)\pi^0$	ND and ARGUS [22], DM2 [51], CMD-2 [53, 58], SND [59, 60], ND [61]
$\pi^+\pi^-\pi^+\pi^-$	ND [22], M3N [50], CMD [62], DM1 [63, 64], DM2 [51], OLYA [65], $\gamma\gamma$2 [66], CMD-2 [53, 67, 68], SND [54], ORSAY-ACO [55]
$\pi^+\pi^-\pi^+\pi^-\pi^0$	MEA [57], M3N [50], CMD [22, 62], $\gamma\gamma$2 [56]
$\pi^+\pi^-\pi^0\pi^0\pi^0$	M3N [50]
$\omega(\to\pi^0\gamma)\pi^+\pi^-$	DM2 [38], CMD-2 [69], DM1 [70]
$\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$	M3N [50], CMD [62], DM1 [71], DM2 [72]
$\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0$	M3N [50], CMD [62], DM2 [72], $\gamma\gamma$2 [56], MEA [57]
$\pi^+\pi^-\pi^0\pi^0\pi^0\pi^0$	isospin-related
$\eta\pi^+\pi^-$	DM2 [73], CMD-2 [69]
$K^+K^-\pi^0$	DM2 [74, 75]
$K_S^0\pi K$	DM1 [76], DM2 [74, 75]
K_S^0X	DM1 [77]
$\pi^+\pi^-K^+K^-$	DM2 [74]
$p\bar{p}$	FENICE [78, 79], DM2 [80, 81], DM1 [82]
$n\bar{n}$	FENICE [78, 83]
incl. (< 2 GeV)	$\gamma\gamma$2 [84], MEA [85], M3N [86], BARYON-ANTIBARYON [87]
incl. (> 2 GeV)	BES [88, 89], Crystal Ball [90, 91, 92], LENA [93], MD-1 [94], DASP [95], CLEO [96], CUSB [97], DHHM [98]

Table 1: Experiments and references for the e^+e^- data sets for the different exclusive and the inclusive channels as used in this analysis. The recent re-analysis from CMD-2 [10] supersedes

channel	inclusive (1.43,2 GeV)		exclusive (1.43,2 GeV)	
	$a_\mu^{\rm had,LO}$	$\Delta\alpha_{\rm had}(M_Z^2)$	$a_\mu^{\rm had,LO}$	$\Delta\alpha_{\rm had}(M_Z^2)$
$\pi^0\gamma$ (ChPT)	0.13 ± 0.01	0.00 ± 0.00	0.13 ± 0.01	0.00 ± 0.00
$\pi^0\gamma$ (data)	4.50 ± 0.15	0.36 ± 0.01	4.50 ± 0.15	0.36 ± 0.01
$\pi^+\pi^-$ (ChPT)	2.36 ± 0.05	0.04 ± 0.00	2.36 ± 0.05	0.04 ± 0.00
$\pi^+\pi^-$ (data)	502.78 ± 5.02	34.39 ± 0.29	503.38 ± 5.02	34.59 ± 0.29
$\pi^+\pi^-\pi^0$ (ChPT)	0.01 ± 0.00	0.00 ± 0.00	0.01 ± 0.00	0.00 ± 0.00
$\pi^+\pi^-\pi^0$ (data)	46.43 ± 0.90	4.33 ± 0.08	47.04 ± 0.90	4.52 ± 0.08
$\eta\gamma$ (ChPT)	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00	0.00 ± 0.00
$\eta\gamma$ (data)	0.73 ± 0.03	0.09 ± 0.00	0.73 ± 0.03	0.09 ± 0.00
K^+K^-	21.62 ± 0.76	3.01 ± 0.11	22.35 ± 0.77	3.23 ± 0.11
$K_S^0K_L^0$	13.16 ± 0.31	1.76 ± 0.04	13.30 ± 0.32	1.80 ± 0.04
$2\pi^+2\pi^-$	6.16 ± 0.32	1.27 ± 0.07	14.77 ± 0.76	4.04 ± 0.21
$\pi^+\pi^-2\pi^0$	9.71 ± 0.63	1.86 ± 0.12	20.55 ± 1.22	5.51 ± 0.35
$2\pi^+2\pi^-\pi^0$	0.26 ± 0.04	0.06 ± 0.01	2.85 ± 0.25	0.99 ± 0.09
$\pi^+\pi^-3\pi^0$	0.09 ± 0.09	0.02 ± 0.02	1.19 ± 0.33	0.41 ± 0.10
$3\pi^+3\pi^-$	0.00 ± 0.00	0.00 ± 0.00	0.22 ± 0.02	0.09 ± 0.01
$2\pi^+2\pi^-2\pi^0$	0.12 ± 0.03	0.03 ± 0.01	3.32 ± 0.29	1.22 ± 0.11
$\pi^+\pi^-4\pi^0$ (isospin)	0.00 ± 0.00	0.00 ± 0.00	0.12 ± 0.12	0.05 ± 0.05
$K^+K^-\pi^0$	0.00 ± 0.00	0.00 ± 0.00	0.29 ± 0.07	0.10 ± 0.03
$K_S^0K_L^0\pi^0$ (isospin)	0.00 ± 0.00	0.00 ± 0.00	0.29 ± 0.07	0.10 ± 0.03
$K_S^0\pi^\mp K^\pm$	0.05 ± 0.02	0.01 ± 0.00	1.00 ± 0.11	0.33 ± 0.04
$K_L^0\pi^\mp K^\pm$ (isospin)	0.05 ± 0.02	0.01 ± 0.00	1.00 ± 0.11	0.33 ± 0.04
$K\bar{K}\pi\pi$ (isospin)	0.00 ± 0.00	0.00 ± 0.00	3.63 ± 1.34	1.33 ± 0.48
$\omega(\to\pi^0\gamma)\pi^0$	0.64 ± 0.02	0.12 ± 0.00	0.83 ± 0.03	0.17 ± 0.01
$\omega(\to\pi^0\gamma)\pi^+\pi^-$	0.01 ± 0.00	0.00 ± 0.00	0.07 ± 0.01	0.02 ± 0.00
$\eta(\to\pi^0\gamma)\pi^+\pi^-$	0.07 ± 0.01	0.02 ± 0.00	0.49 ± 0.07	0.15 ± 0.02
$\phi(\to$ unaccounted$)$	0.06 ± 0.06	0.01 ± 0.01	0.06 ± 0.06	0.01 ± 0.01
$p\bar{p}$	0.00 ± 0.00	0.00 ± 0.00	0.04 ± 0.01	0.02 ± 0.00
$n\bar{n}$	0.00 ± 0.00	0.00 ± 0.00	0.07 ± 0.02	0.03 ± 0.01
$J/\psi, \psi'$	7.30 ± 0.43	8.90 ± 0.51	7.30 ± 0.43	8.90 ± 0.51
$\Upsilon(1S-6S)$	0.10 ± 0.00	1.16 ± 0.04	0.10 ± 0.00	1.16 ± 0.04
inclusive R	73.96 ± 2.68	92.75 ± 1.74	42.05 ± 1.14	81.97 ± 1.53
pQCD	2.11 ± 0.00	125.32 ± 0.15	2.11 ± 0.00	125.32 ± 0.15
sum	692.38 ± 5.88	275.52 ± 1.85	696.15 ± 5.68	276.90 ± 1.77

Recently added data

- Most important channels with changes in input data since ~2006

The main exps. for 'low' energy hadronic cross sections in e^+e^-; channels

– CMD-2, [VEPP-2M], Novosibirsk $(K^+K^-,\ 2\pi^+2\pi^-\pi^0,\ 2\pi^+2\pi^-2\pi^0)$

– SND, [VEPP-2M], Novosibirsk $(K^+K^-,\ K^0_S K^0_L)$

– KLOE, [DAΦNE], Frascati $(\pi^+\pi^-(\gamma),\ \omega\pi^0)$

– BaBar, [PEP-II], SLAC, Stanford $(\pi^+\pi^-(\gamma),\ K^+K^-\pi^0,\ K^0_S\pi K,\ 2\pi^+2\pi^-\pi^0,$
$K^+K^-\pi^+\pi^-\pi^0,\ 2\pi^+2\pi^-\eta,\ 2\pi^+2\pi^-2\pi^0)$

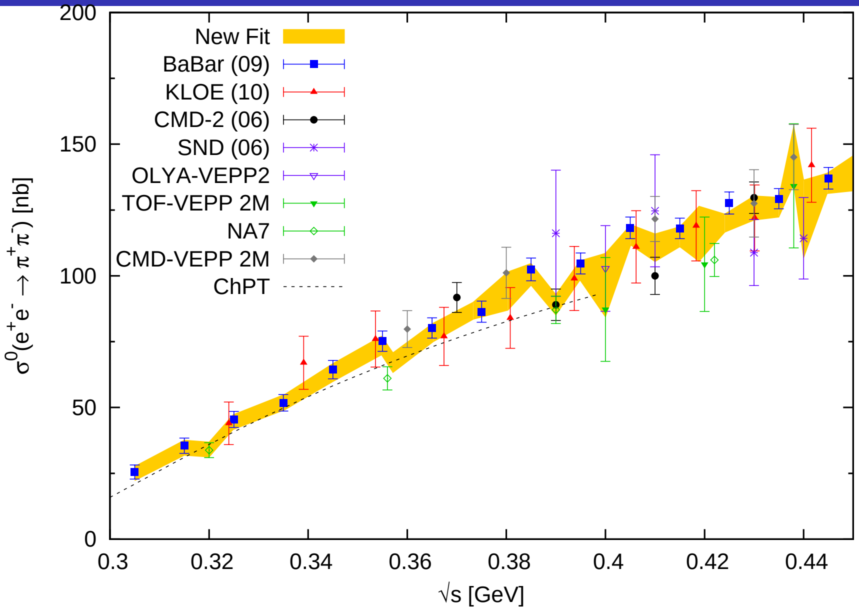
– BELLE, [KEKB], KEK, Tsukuba

– BES, [BEPC], Beijing (inclusive $R = \sigma(e^+e^- \to hadrons)/\sigma(e^+e^- \to \mu^+\mu^-)$ data)

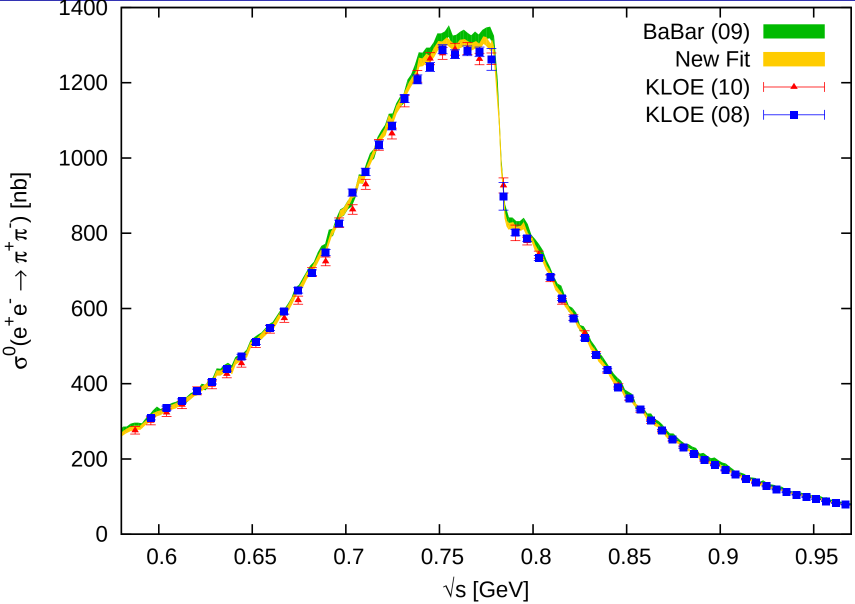
– CLEO, [CESR], Cornell (inclusive R)

T. Teubner, talk at Tau2010

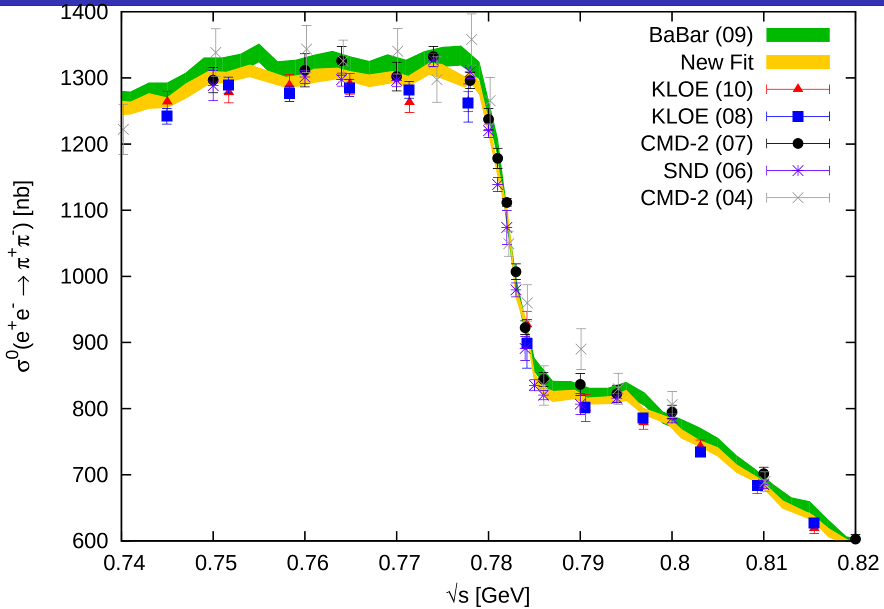
$\pi^+\pi^-$ channel: Low Energy Tail



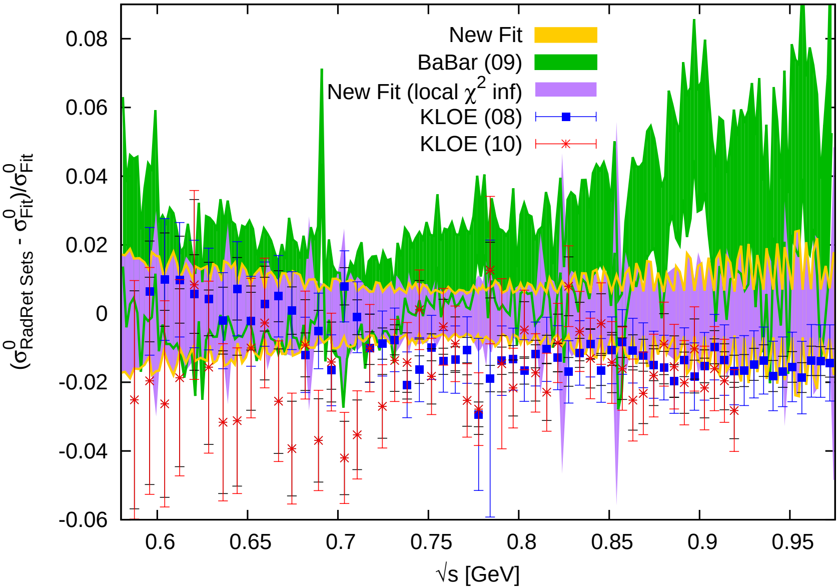
$\pi^+\pi^-$ channel: New Radiative Return Data



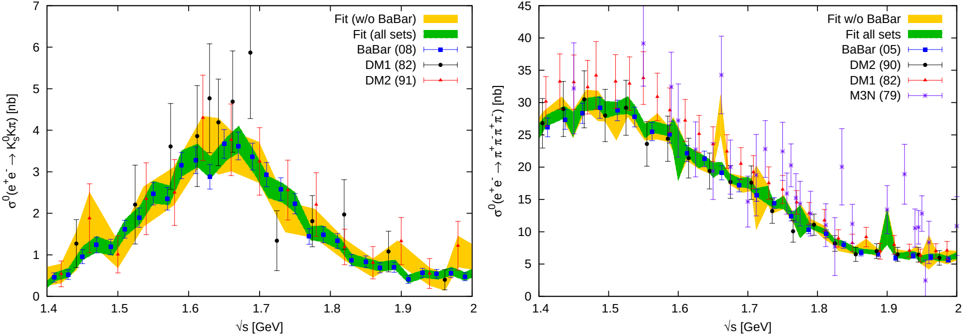
$\pi^+\pi^-$ channel: Zoom-In at ρ-ω Region



Rad. Rtn. Data (for $\pi^+\pi^-$) and Our Combined Result



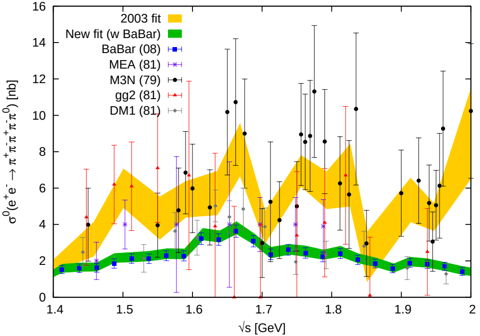
Impacts from New BaBar Data in subleading channels: (1)

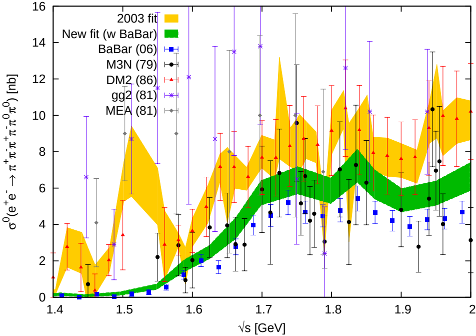


$e^+e^- \to K_S^0 K\pi$ (left) and $e^+e^- \to 2\pi^+ 2\pi^-$ (right)

In these cases, the new BaBar data agree well with the old data, and improve them in a peaceful way.

Impacts from New BaBar Data in subleading channels: (2)



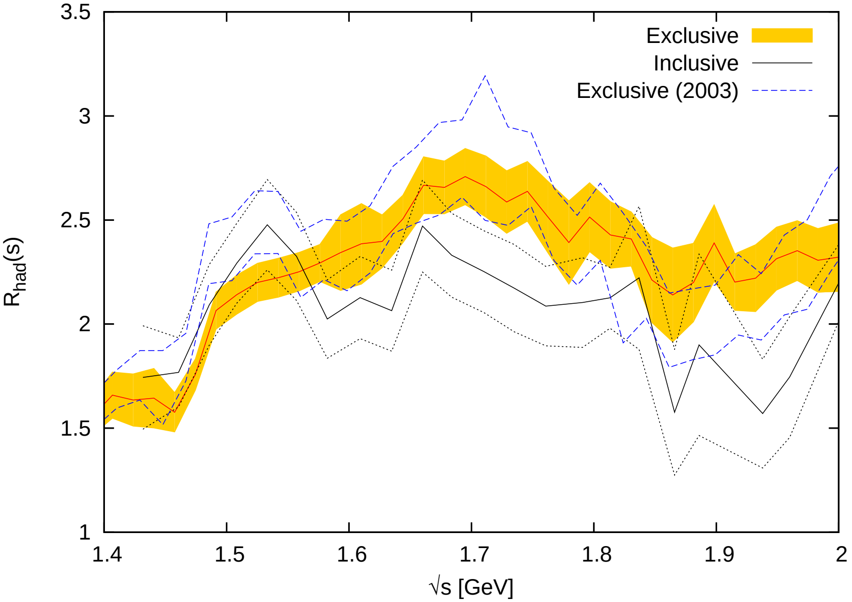


$e^+e^- \longrightarrow 2\pi^+2\pi^-\pi^0$ (left) and $2\pi^+2\pi^-2\pi^0$ (right)

In these cases, the new BaBar data do not agree very well with the old data, and improve them ‘radically’.

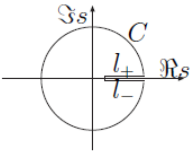
Note that the old data are really old (those from the ’80s or older...)

Region between 1.4 – 2.0 GeV



Check against perturbative QCD: QCD $\sum$-rule analysis

- Evaluate QCD $\sum$-rules of the form:



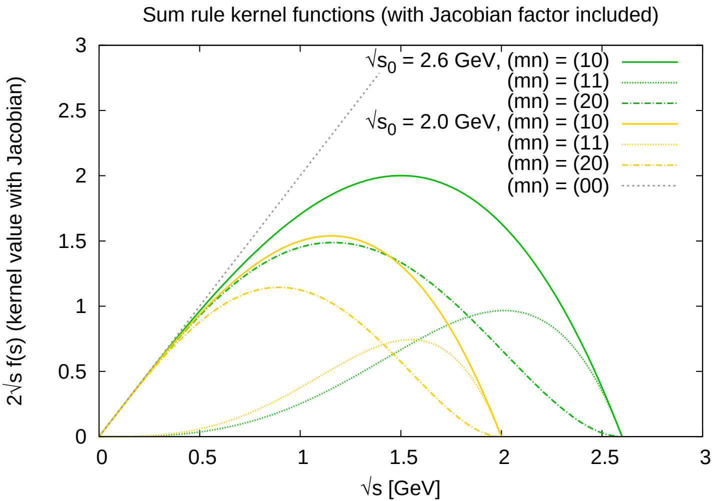
$$\int_{s_{\rm th}}^{s_0} {\rm d}s\, R(s) f(s) = \int_C {\rm d}s\, D(s) g(s)\,, \qquad \text{with} \;\; D(s) \equiv -12\pi^2 s \frac{\rm d}{{\rm d}s}\left(\frac{\Pi(s)}{s}\right)$$

- The Adler D function is calculable in pQCD: $D(s) = D_0(s) + D_{\rm m}(s) + D_{\rm np}(s)$.
- Take $f(s) = (1 - s/s_0)^m (s/s_0)^n$ to maximise sensitivity to the required region, $g(s)$ follows.
- Choose s_0 below the open charm threshold ($n_f = 3$ for pQCD).
- For $m = 1$, $n = 0$ one gets e.g.

$$\int_{s_{\rm th}}^{s_0} {\rm d}s\, R(s)\left(1 - \frac{s}{s_0}\right) = \frac{i}{2\pi}\int_C {\rm d}s\left(-\frac{s}{2s_0} + 1 - \frac{s_0}{2s}\right) D(s)\,.$$

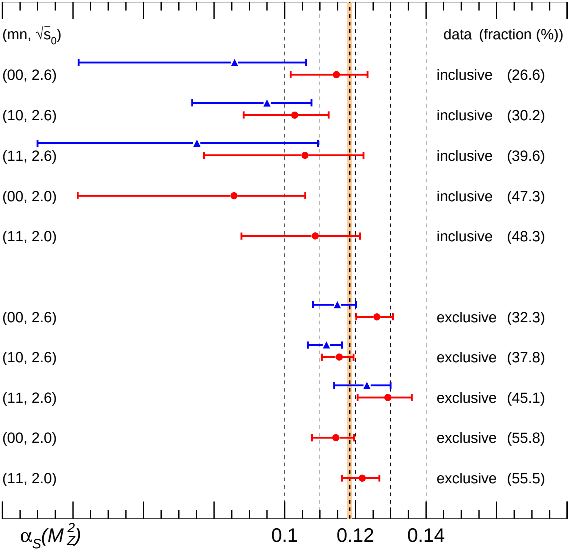
T. Teubner, talk at Tau2010

Sum Rules: choice of weight functions



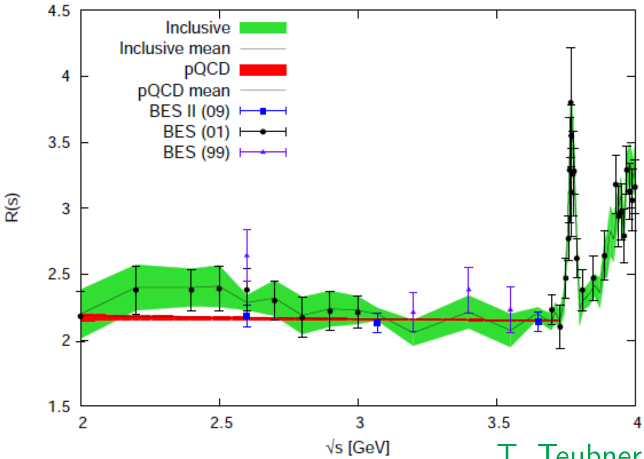
We choose the weight functions in such a way that they emphasize the region in question, 1.4–2.0 GeV.

Sum Rules for 1.4 – 2.0 GeV: Results



Sum of exclusive data: now more consistent with pQCD.

Perturbative QCD vs. inclusive data above 2 GeV (below charm threshold)

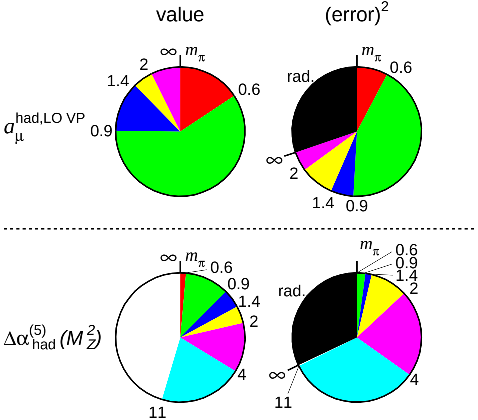


T. Teubner, talk at Tau2010

- R_{uds} from pQCD mostly below data fit in region above 2 GeV
- Latest BES data agree very well with pQCD

At 2.6–3.73 GeV we use pQCD (with the BESII (09) uncertainty)

Results: $a_\mu^{\rm had,LO}$, $a_\mu^{\rm had,NLO}$ and $\Delta\alpha_{\rm had}^{(5)}(M_Z^2)$

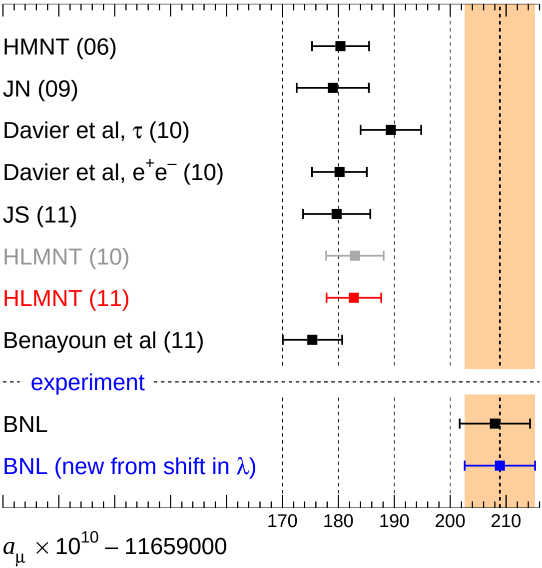


$$a_\mu^{\rm had,LO} = (694.91 \pm 3.72_{\rm exp} \pm 2.10_{\rm rad}) \times 10^{-10}$$

$$a_\mu^{\rm had,NLO} = (-9.84 \pm 0.06_{\rm exp} \pm 0.04_{\rm rad}) \times 10^{-10}$$

$$\Delta\alpha_{\rm had}^{(5)}(M_Z^2) = (276.26 \pm 1.16_{\rm exp} \pm 0.74_{\rm rad}) \times 10^{-4}$$

Full SM Result and Comparison with Other Groups



Byproducts (1): QED coupling at the Z-boson mass

★ $\alpha(M_Z^2)$: the least well known among $\{G_\mu, M_Z, \alpha(M_Z^2)\}$, which are used as **input** to precision electroweak fits.

★ Running of α

$$\alpha(M_Z^2) = \frac{\alpha}{1 - \Delta\alpha_{\rm lep}(M_Z^2) - \Delta\alpha^{(5)}_{\rm had}(M_Z^2) - \Delta\alpha^{\rm top}(M_Z^2)}$$

where $\Delta\alpha_{\rm lep}(M_Z^2) = 0.03149769$ (Steinhauser), $\Delta\alpha^{\rm top}(M_Z^2) = -\ 0.0000728(14)$ and $\alpha = 1/137.035999679(94)$ (PDG10).

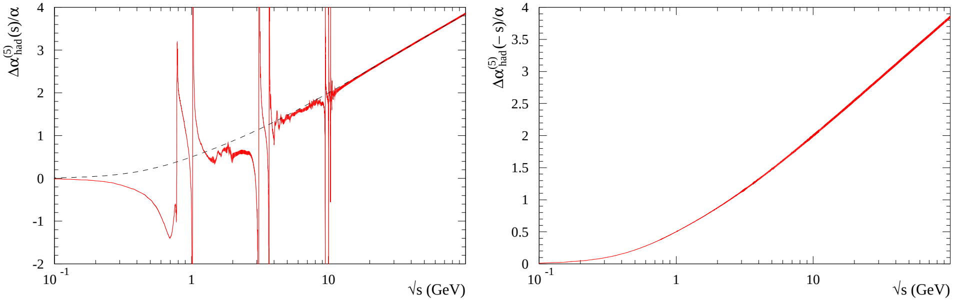
★ Similar dispersion relation: ($\Longrightarrow$ **byproduct** of $a_\mu^{\rm had,LO}$)

$$\Delta\alpha^{(5)}_{\rm had}(s) = -\frac{\alpha s}{3\pi}{\rm P}\int \frac{R(s')ds'}{s'(s'-s)}$$

★ Our results: $\Delta\alpha^{(5)}_{\rm had}(M_Z^2) = (276.3 \pm 1.4) \times 10^{-4}$,

$$\alpha(M_Z^2)^{-1} = 128.944 \pm 0.019.$$

The hadronic contribution $\Delta\alpha^{(5)}_{\rm had}(q^2)$ to the running QED coupling for $q^2 > 0$ (left) and $q^2 < 0$ (right)



Fortran subroutine to compute the above is available from us upon request

Before discussing another byproduct, do you know what the most precise way to measure the muon mass is?

(cf. $m_\mu = 105.6583668(38)$ MeV (PDG11))

Before discussing another byproduct, do you know what the most precise way to measure the muon mass is?

(cf. $m_\mu = 105.6583668(38)$ MeV (PDG11))

Answer: Muonium ground-state hyperfine splitting (MuHFS)

Mu HFS: Summary Table (as of 2002)

correction	contribution (in units of kHz)
ν_F	$4459031.920(511)_{m_\mu/m_e}(34)_\alpha$
$\Delta\nu(a_e)$	$5170.926(1)$
$\Delta\nu$(QED3)	-899.557
$\Delta\nu$(QED4)	$-0.55(22)$
$\Delta\nu$(weak)	-0.065
$\Delta\nu$(had-vp)	$0.231(3)$
$\Delta\nu$(had-h.o.)	$0.005(2)$
ν_{HFS}(theory)	$4463302.909(511)(34)(220)$
ν_{HFS}(exp)	$4463302.776(51)$

Table from Czarnecki, Eidelman & Karshenboim, PRD65 (2002) 053004 with updates from Eidelman, Karshenboim & Shelyuto, Can. J. Phys. **80** (2002) 1297

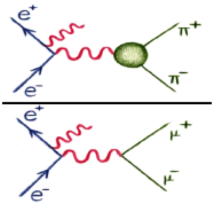
(Some of) Recent/Ongoing Activities (not ours but by others)

- New (preliminary) analysis from KLOE ("KLOE11")
- Update in QED contribution

New $\sigma_{\pi\pi}$ measurement from π/μ

An alternative way to obtain $|F_\pi|^2$ is the bin-by-bin ratio of pion over muon yields (instead of using absolute normalization with Bhabhas).

$$|F_\pi(s')|^2 \approx \underbrace{\frac{4(1+2m_\mu^2/s')\beta_\mu}{\beta_\pi^3}}_{\text{kinematical factor } (\sigma_{\mu\mu}^{Born}/\sigma_{\pi\pi}^{Born})} \underbrace{\frac{d\sigma_{\pi\pi\gamma}/ds'}{d\sigma_{\mu\mu\gamma}/ds'}}_{\text{meas. quantities}}$$



Many radiative corrections drop out:

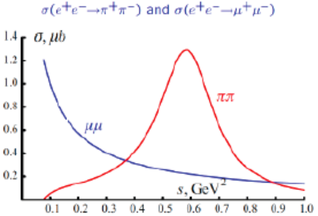
- *radiator function*
- *int. luminosity from Bhabhas*
- *Vacuum polarization*

M_{TRK} is the solution of the equation:

$$\left(\sqrt{s}-\sqrt{p_1^2+M_{TRK}^2}-\sqrt{p_2^2+M_{TRK}^2}\right)^2-(\vec{p}_1+\vec{p}_2)^2=0$$

Separation btw $\pi\pi\gamma$ and $\mu\mu\gamma$ using M_{TRK}

- *muons: M_{Trk} < 115 MeV*
- *pions : M_{Trk} > 130 MeV*



Very important control of π/μ separation in the ρ region! ($\sigma_{\pi\pi}>>\sigma_{\mu\mu}$)

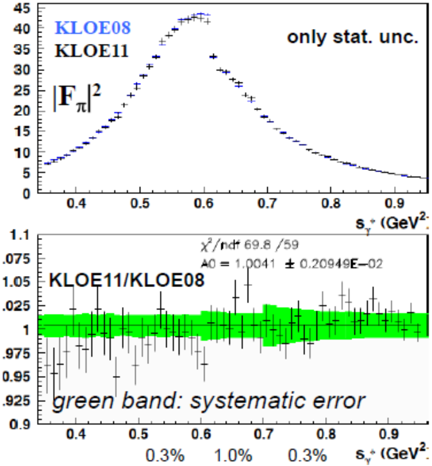
P. A. Lukin (KLOE, Budker), talk at Phipsi11

KLOE11 result on $|F_\pi|^2$ and comp. with KLOE08

	KLOE08	KLOE11
Syst. errors (%)	$\Delta^{\pi\pi}a_\mu$ abs	$\Delta^{\pi\pi}a_\mu$ ratio
Reconstruction Filter	negligible	negligible
Background subtraction	0.3	0.8 $(0.3_{\pi\pi\gamma} \oplus 0.7_{\mu\mu\gamma})$
Trackmass	0.2	0.4 $(0.2_{\pi\pi\gamma} \oplus 0.4_{\mu\mu\gamma})$
Particle ID	negligible	negligible
Tracking	0.3	0.6 $(0.3_{\pi\pi\gamma} \oplus 0.5_{\mu\mu\gamma})$
Trigger	0.1	0.1 $(0.1_{\pi\pi\gamma})$
Unfolding	negligible	negligible
Acceptance $(\theta_{\pi\pi})$	0.2	negligible
Acceptance (θ_π)	negligible	negligible
Software Trigger (L3)	0.1	0.1 $(0.1_{\pi\pi\gamma} \oplus 0.1_{\mu\mu\gamma})$
Luminosity	0.3 $(0.1_{th} \oplus 0.3_{exp})$	-
$\sqrt{s}$ dep. of H	0.2	-
Total exp systematics	0.6	1.0
Vacuum Polarization	0.1	-
FSR treatment	0.3	0.3
Rad. function H	0.5	-
Total theory systematics	0.6	0.3
Total systematic error	0.9	1.1

KLOE11 halves the theoretical error

preliminary



Preliminary KLOE11: $a_\mu^{\pi\pi}(0.35\text{-}0.95\,\mathrm{GeV}^2) = (384.1 \pm 1.2_{stat} \pm 4.0_{sys} \pm 1.2_{theo}) \cdot 10^{-10}$

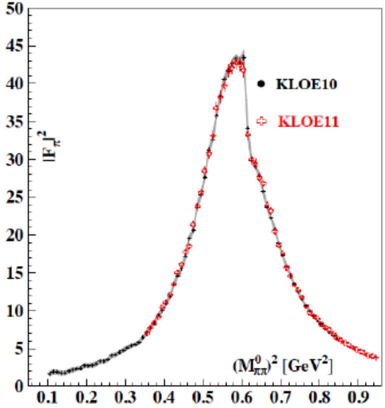
KLOE08: $a_\mu^{\pi\pi}(0.35\text{-}0.95\,\mathrm{GeV}^2) = (387.2 \pm 0.5_{stat} \pm 2.4_{sys} \pm 2.3_{theo}) \cdot 10^{-10}$

P. A. Lukin (KLOE, Budker), talk at Phipsi11

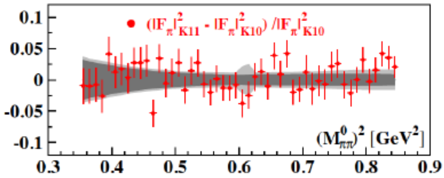
Comparison of results: KLOE11 vs KLOE10

KLOE11 result compared to KLOE10:

preliminary



Fractional difference:



band: KLOE10 error

Excellent agreement between the two measurements!

Comparison with other exp. in progress

Preliminary KLOE11: $a_\mu^{\pi\pi}(0.35\text{-}0.85\,\mathrm{GeV}^2) = (376.4 \pm 1.2_{stat} \pm 4.1_{sys\ tot}) \cdot 10^{-10}$

KLOE10: $a_\mu^{\pi\pi}(0.35\text{-}0.85\,\mathrm{GeV}^2) = (376.6 \pm 0.9_{stat} \pm 3.3_{sys\ tot}) \cdot 10^{-10}$

P. Lukin – PhiPsi11 Conference 22/09/11

P. A. Lukin (KLOE, Budker), talk at Phipsi11

Summary

- We (HLMNT) have updated our analysis with (lots of) new data including those from KLOE and BaBar
- We find 3.3 σ discrepancy between experiment and theory $\Longrightarrow$ **New Physics?**
- Two new experiments to measure the muon $g-2$ planned at J-PARC and Fermilab. Both experiments recently got stage-1 approval from KEK & Fermilab, respectively.
- To establish this discrepancy more firmly, it is very important to resolve the disagreement in the $\pi^+\pi^-$ channel between the KLOE and BaBar data $\Longrightarrow$ new precise data from VEPP-2000 and SuperKEKB very welcome