Hadronic contribution to the muon g-2

K. Hagiwara (KEK)

@ TAU04 2004. 9. 15

based on the work with

A. D. Martin (Durham)

D. Nomura (Durham → Michigan)

T. Teubner (CERN → Liverpool)

HMNT02 : hep-ph/0209187 ⇒ PLB557:69-75:2003

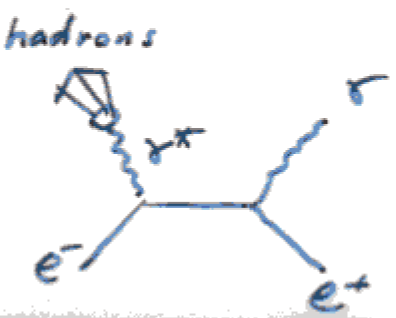
HMNT03 : hep-ph/0312250 ⇒ PRD69:093003:2004

note-added-proof includes

- ★ final data from BNL
- ★ QED update by Kinoshita-Nio
- ★ l-by-l evaluation by Melnikov-Vainshtein

New result from KLOE @ DAΦNE

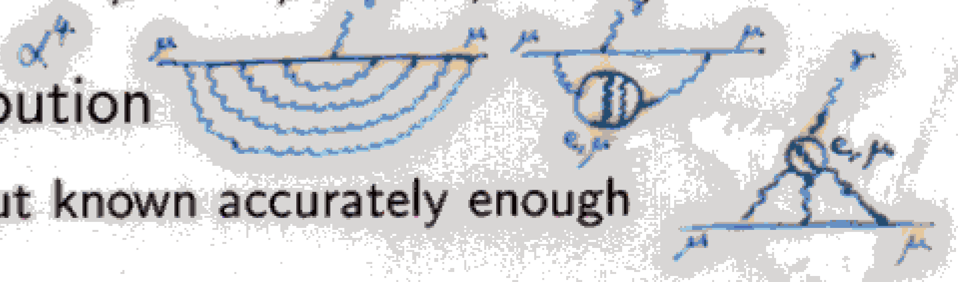
hep-ex/0407048 (2004. 7. 27)



the first result from the 'radiative return' measurements, to be followed by Babar, Belle, CLEO-C, BEPC II, ...

Standard Model contribution

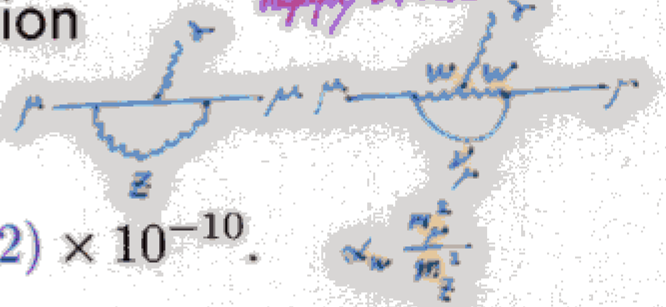
3 contributions: $a_\mu^{\rm SM} = a_\mu^{\rm QED} + a_\mu^{\rm EW} + a_\mu^{\rm had}$



- **QED** contribution
  - Dominant but known accurately enough

$$a_\mu^{\rm QED} = 11\,658\,470.56\,(0.29) \times 10^{-10}$$

" 471.935(0.143) --- Kinoshita Nio hep-ph/0402206

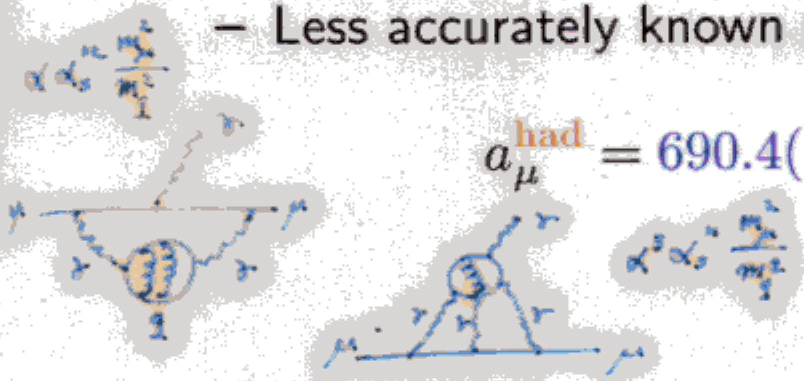


- **Electroweak** contribution
  - Small but non-negligible

$$a_\mu^{\rm EW} = 15.4\,(0.2) \times 10^{-10}.$$

- **Hadronic** contribution
  - Less accurately known (pQCD not useful)

$$a_\mu^{\rm had} = 690.4(7.4) \times 10^{-10}.$$



$\Longrightarrow$ next slides...

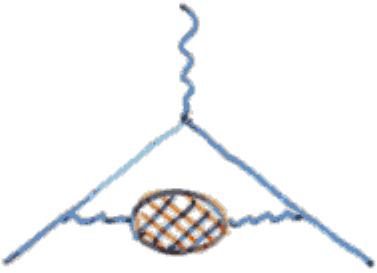
★ (cf. **Exp.** : $a_\mu^{\rm exp} = 11\,659\,203\,(8) \times 10^{-10}$)

" 208 (6) ... BNL final hep-ex/0401008

Hadronic contributions

$$a_\mu^{had} = a_\mu^{had,LO} + a_\mu^{had,NLO} + a_\mu^{had,l\text{-}by\text{-}l} + a_\mu^{had,i\text{-}l\text{-}by\text{-}l}$$

LO



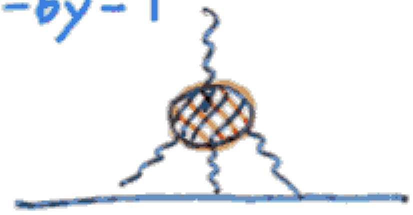
$$a_\mu^{had,LO} = 692.4(6.0) \times 10^{-10}$$ HMNT03

NLO

$$a_\mu^{had,NLO} = -9.8(0.1) \times 10^{-10}$$ HMNT03

$-10.0(0.6)$ --- Krause (1997)

l-by-l

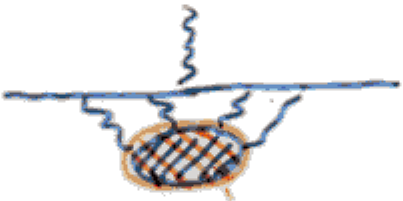


$$a_\mu^{had,l\text{-}by\text{-}l} = 13.6(2.5) \times 10^{-10}$$ K. Melnikov & A. Vainshtein hep-ph/0312226

$8.0(4.0)$ --- Nyffeler (2002)

"short-distance contribution has been accounted for."

i-l-by-l



$$a_\mu^{had,i\text{-}l\text{-}by\text{-}l} = -0.06(0.06) \times 10^{-10}$$ HMNT03

$+10(10)$ --- Narison (2003)

'σ'

Our Reevaluation of $a_\mu^{\mathrm{had,LO}}$

Use the dispersion relation

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

$\sim \int_{s_{th}}^{\infty} ds\, \frac{R}{s^2}$

$\hat{K}(m_\pi^2) = 0.40$, $\hat{K}(4m_\pi^2) = 0.63$, $\hat{K}(\infty) = 1$ (increases)

- The weight function $\hat{K}(s)/s = \mathcal{O}(1)/s$
  - Lower energy region more important
  - pQCD not useful

$s_{th} < s < s_{data}$ … ch PT …; $s_{data} < s < s_{pQCD} \sim (10\,\mathrm{GeV})^2$

$s_{th} = (2 m_\pi)^2$: $e^+e^- \to \pi^+\pi^-$

$s_{th} = (m_\pi)^2$: $e^+e^- \to \pi^0\gamma$

$s_{th} = (3 m_\pi)^2$: $e^+e^- \to \pi^+\pi^-\pi^0$

$\Longrightarrow$ We have to rely on exp. data for $\sigma_{\mathrm{had}}(s)$
  - Good data crucial
  - Correct treatment of statistics important

How to combine different data sets?

- $\int \sum$ ... leads to an overestimate of the errors.

$\Longrightarrow$ next slides...

$$R(s) \equiv \frac{\sigma(e^+e^- \to \gamma^* \to \text{hadrons})^{(0)}}{\sigma(e^+e^- \to \gamma^* \to \mu^+\mu^-)^{(0)}_{m_\mu = 0}}$$

(0) ... tree-level in QED

R(s) vs $\sqrt{s}$

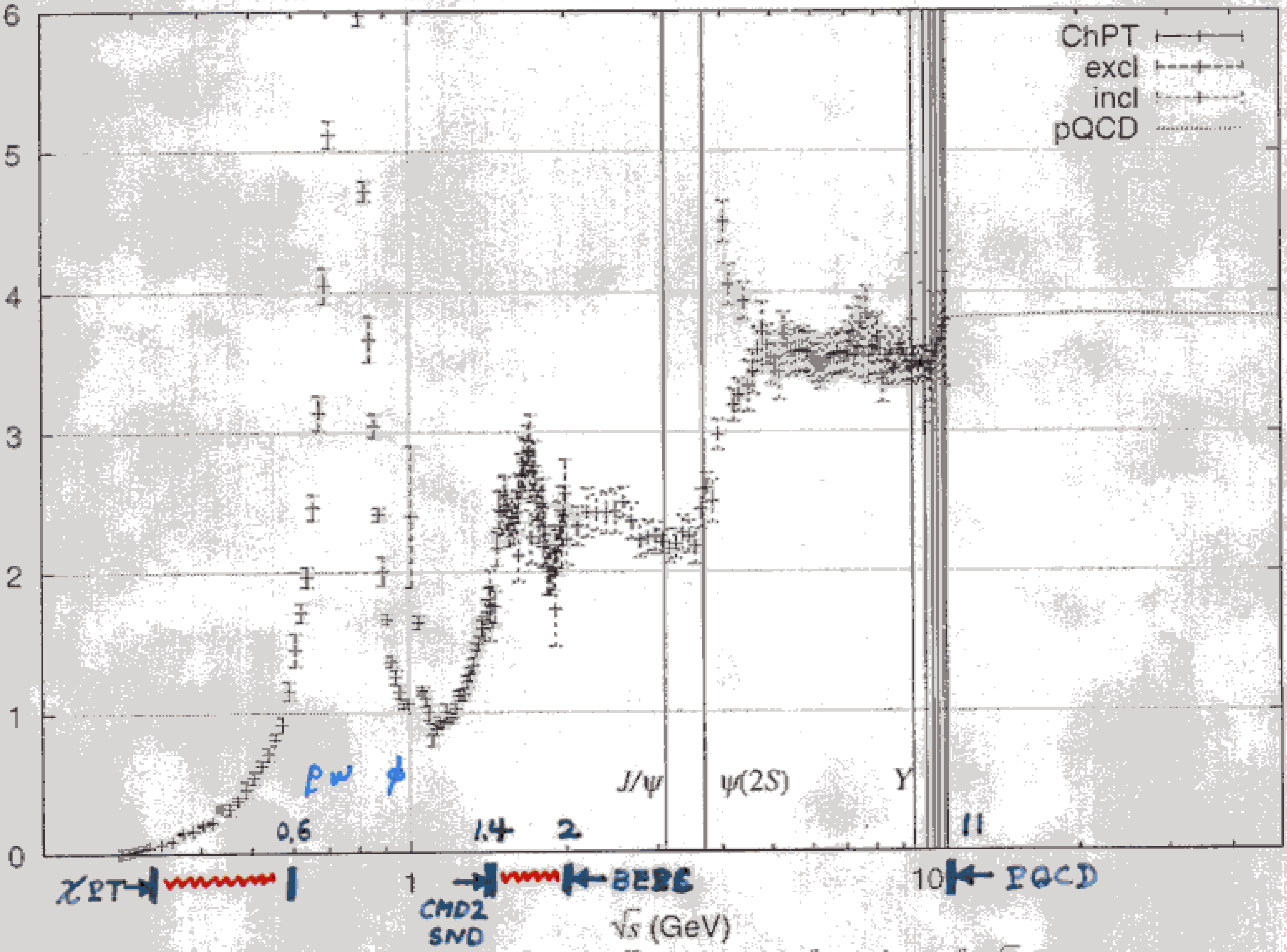


Figure 9: The hadronic R ratio as a function of $\sqrt{s}$.

Experiments used in our analysis (HMNT03):

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]
$\pi^0\gamma$ $\eta\gamma$	SND [31, 32] 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]
$\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$ $\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0$ $\pi^+\pi^-\pi^0\pi^0\pi^0\pi^0$	M3N [50], CMD [62], DM1 [71], DM2 [72] M3N [50], CMD [62], DM2 [72], $\gamma\gamma$2 [56], MEA [57] 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 their previously published data for $\pi^+\pi^-$ [11], $\pi^+\pi^-\pi^0$ [13] and $K_S^0K_L^0$ [14].

How to combine data sets (Clustering)

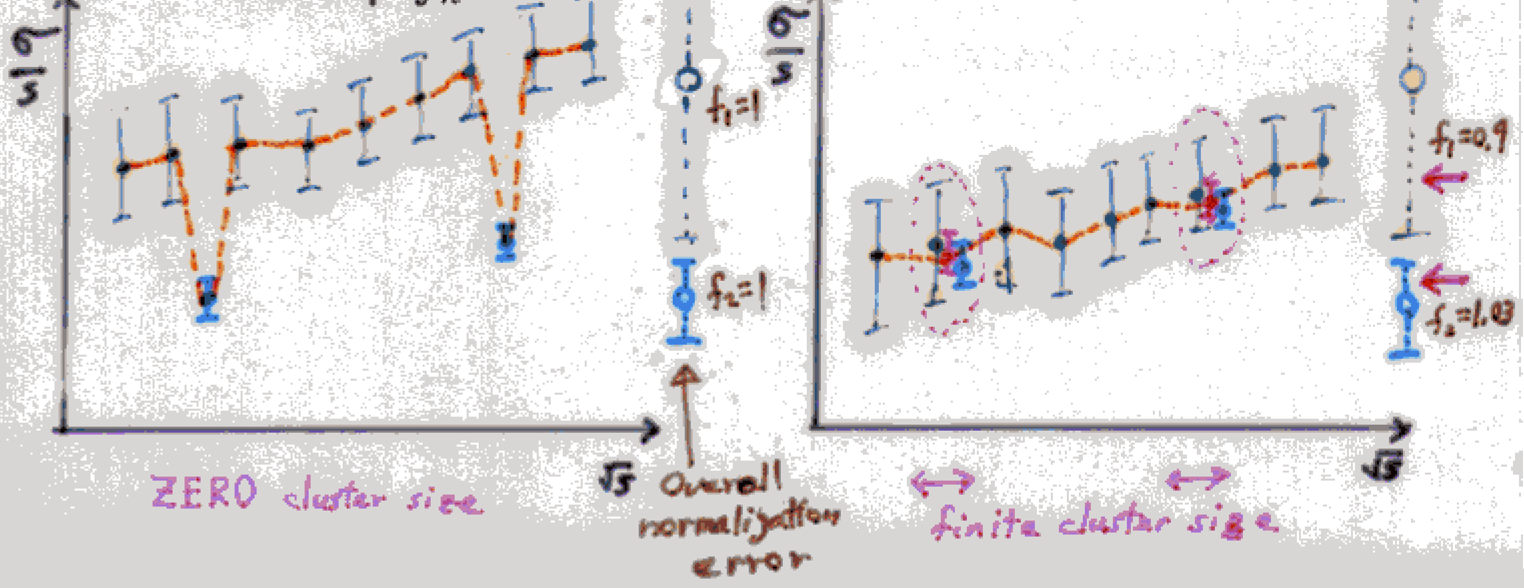
1. We model the true value of R by a piecewise-constant $\overline{R}_m$ within a Cluster of a given (min.) size.

2. Construct the χ^2 function as

$$\chi^2(\overline{R}_m, f_k) = \sum_{k=1}^{\#\text{ofexp.}} \left(\frac{1-f_k}{df_k}\right)^2 + \sum_{m=1}^{\#\text{ofClus.}} \sum_{i=1}^{N_{\{k,m\}}} \left(\frac{R_i^{\{k,m\}} - f_k \overline{R}_m}{dR_i^{\{k,m\}}}\right)^2$$

   from the raw data $R_i^{\{k,m\}} \pm dR_i^{\{k,m\}}$ and the normalization uncertainty of the k-th exp df_k.

3. Minimize it w. r. t. the fit parameter $\overline{R}_m$ at the m-th cluster and the unknown normalization factor of the k-th exp f_k.



Cluster size dependence of the integral ($\bar{a}_\mu$)
error ($\pm\Delta$)
χ^2_{min}/d.o.f.

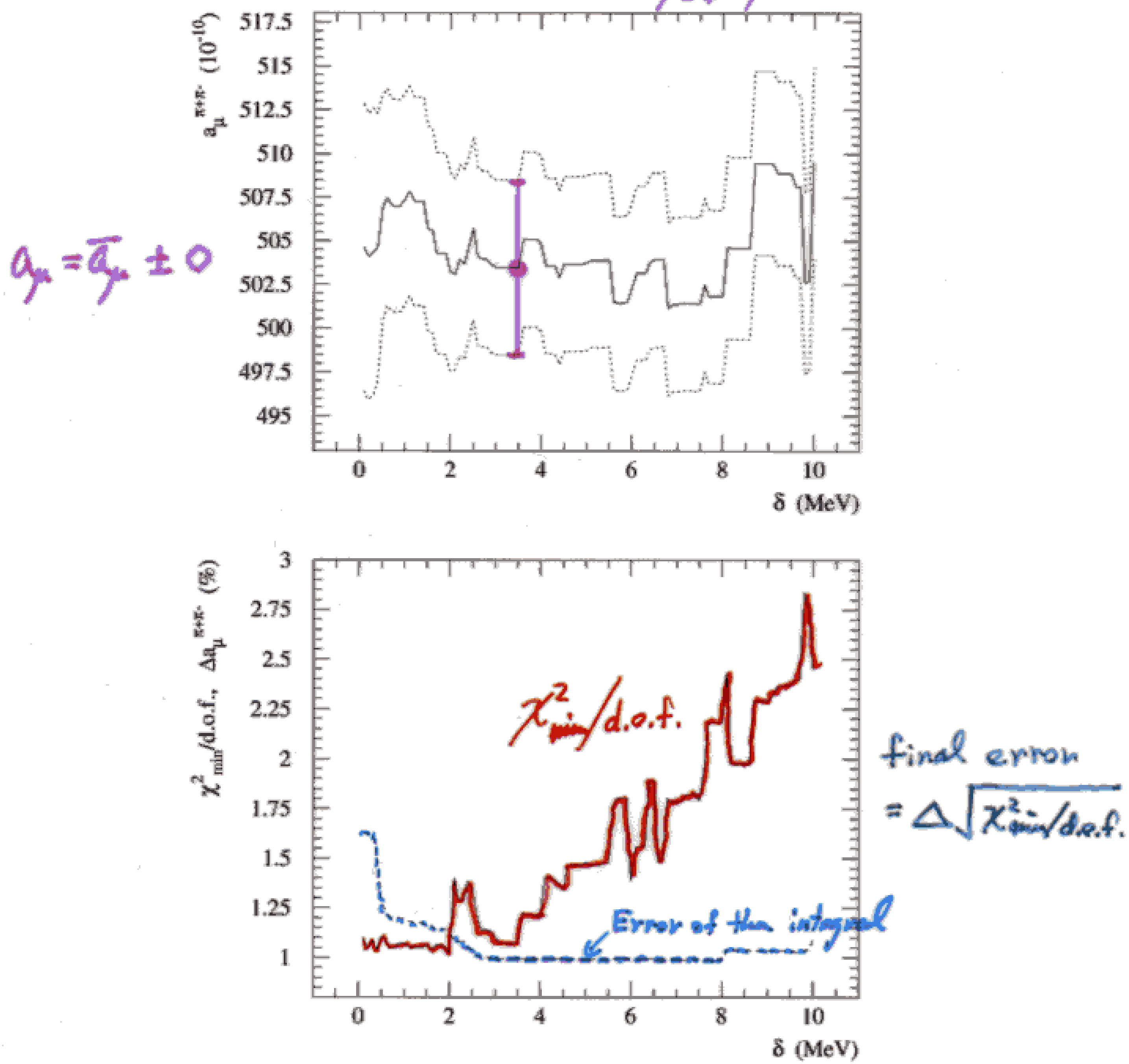


Figure 3: Dependence of the fit on the cluster size parameter δ in the case of the $\pi^+\pi^-$ channel: the band in the upper plot shows the contribution to a_μ and its errors for different choices of the cluster size. The three lines show $\bar{a}_\mu$ (solid), $\bar{a}_\mu + \Delta a_\mu$ and $\bar{a}_\mu - \Delta a_\mu$ (dotted), respectively. The lower plot displays the $\chi^2_{\rm min}$/d.o.f. (continuous line) together with the error size Δa_μ in % (dashed line).

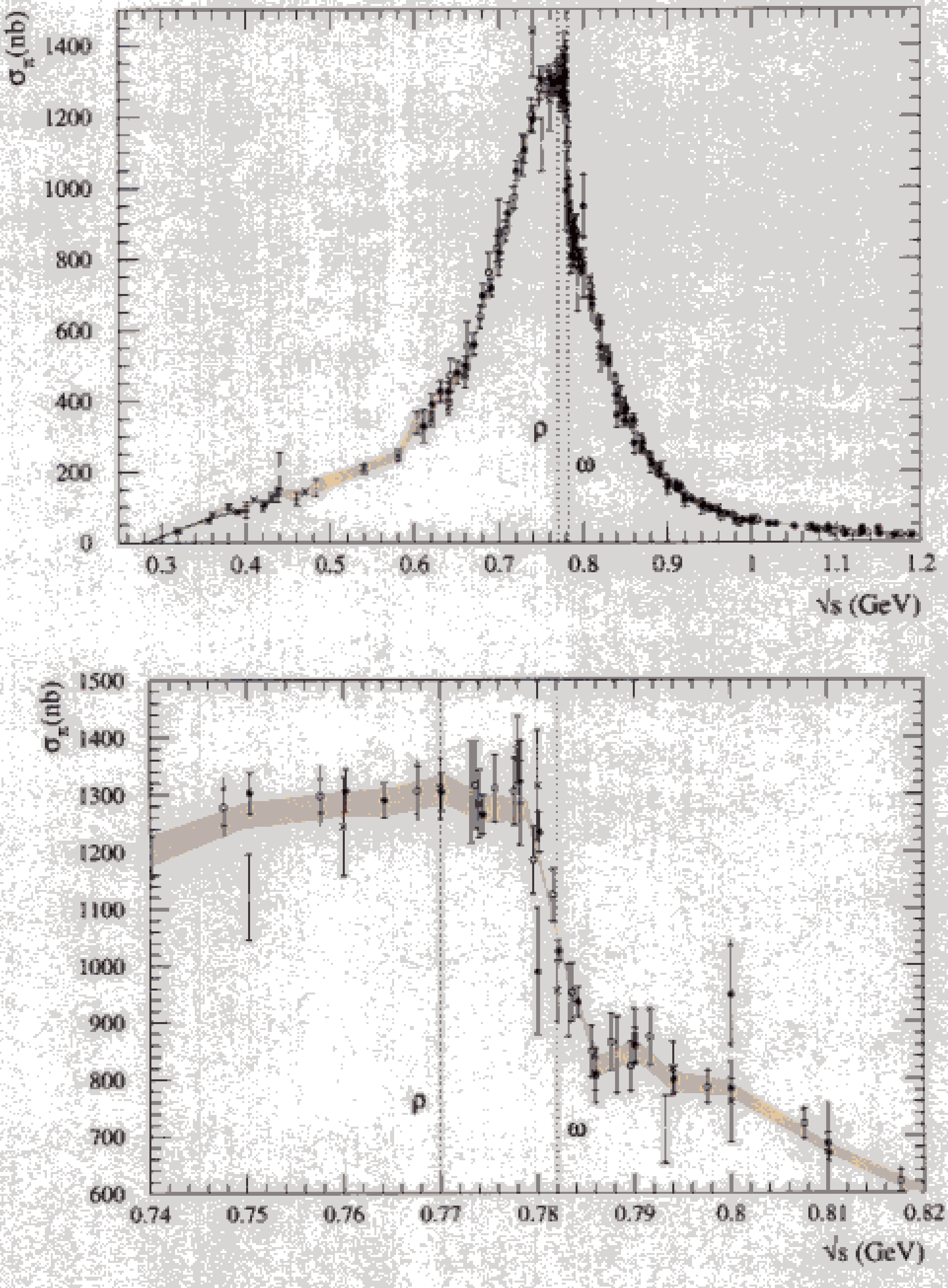
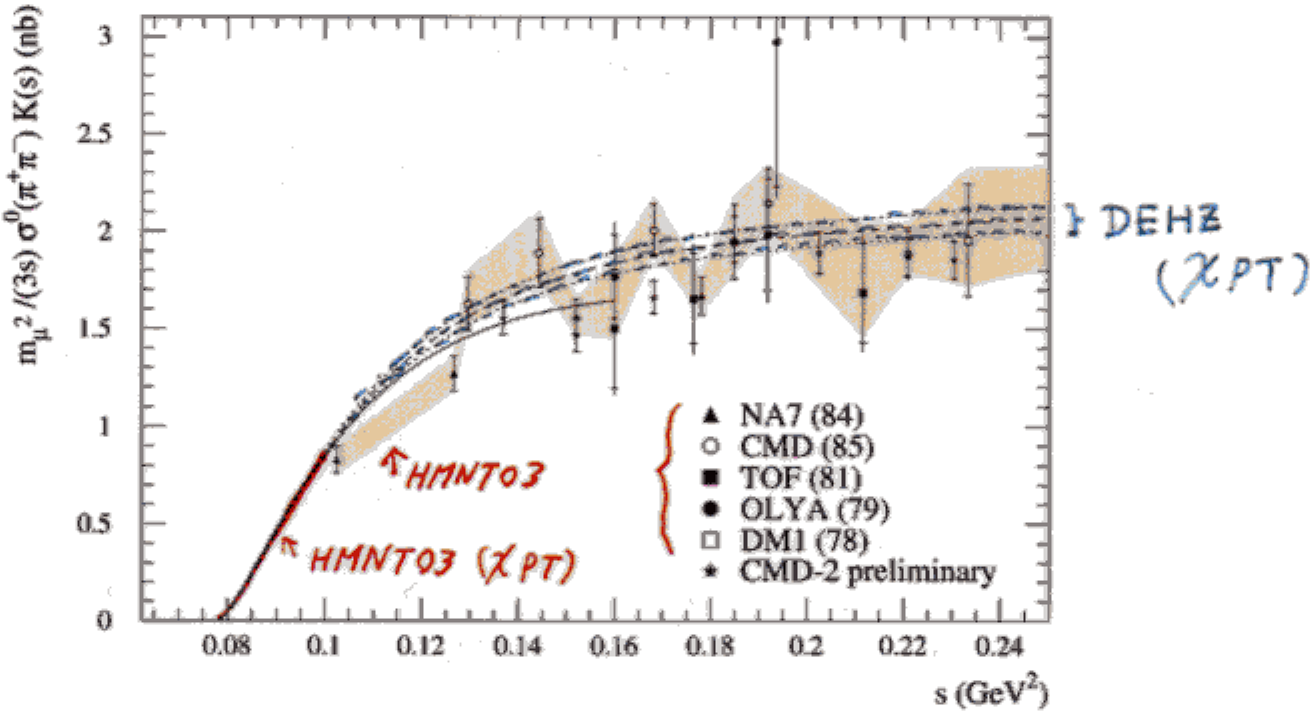


Figure 5: $e^+e^- \to \pi^+\pi^-$ data up to 1.2 GeV, where the shaded band shows the result, σ_π (obtained from R_m of (21)), of our fit after clustering. The width of the band indicates the error on the σ_π values, obtained from the diagonal elements of the full covariance matrix. The second plot is an enlargement of the ρ-ω interference region.

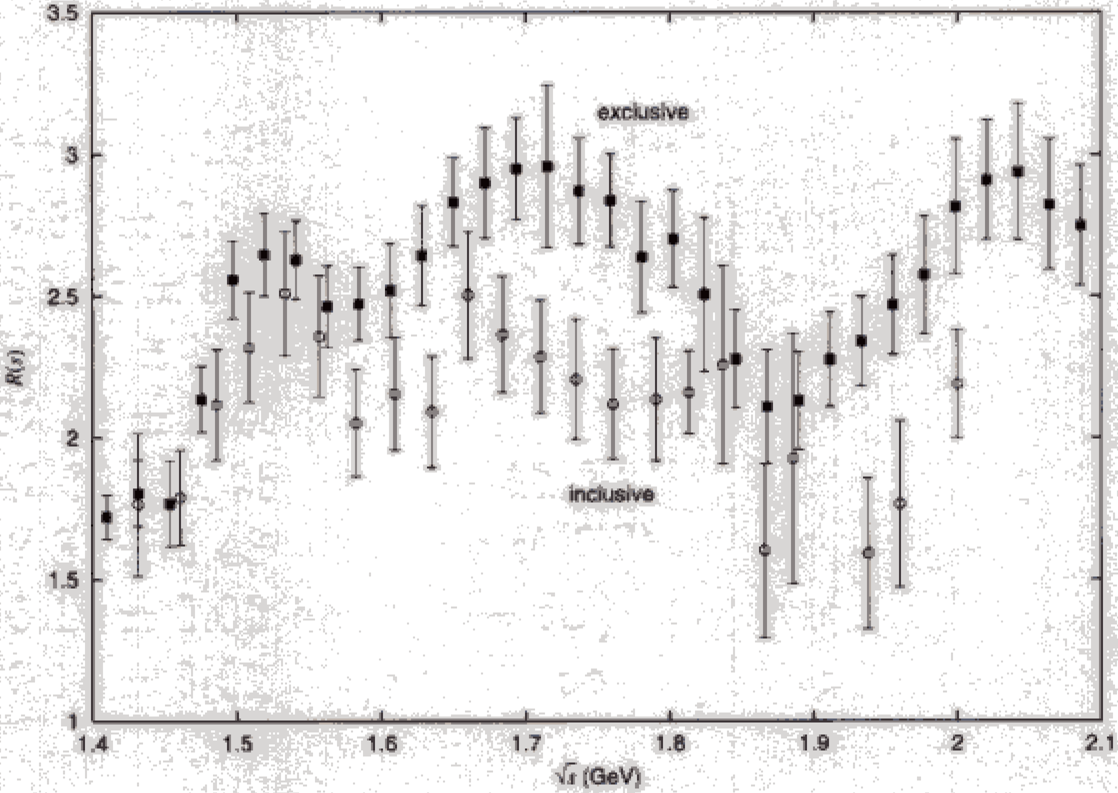
straight-forward integration over data points possible !

No need for ρ-ω interference parametrization.

★ The same applies for 3π data in the ω-ϕ region.


$m_\mu^2/(3s)\,\sigma^0(\pi^+\pi^-)\,K(s)$ (nb)
s (GeV^2)
NA7 (84)
CMD (85)
TOF (81)
OLYA (79)
DM1 (78)
CMD-2 preliminary
HMNT03
HMNT03 (χPT)
DEHZ
(χPT)

Incl. v. Excl. "puzzle"



- Sum of the excl. channels overshoots the inclusive measurement.

$\Longrightarrow$ Sum rule analysis to determine which is likely to be true (next slides...)

$(\sum \text{Exclusive}) - (\text{Inclusive}) = 4 \pm 2 \quad \times 10^{-10}$

$\frac{2}{3}$ of the total error (6×10^{-10})

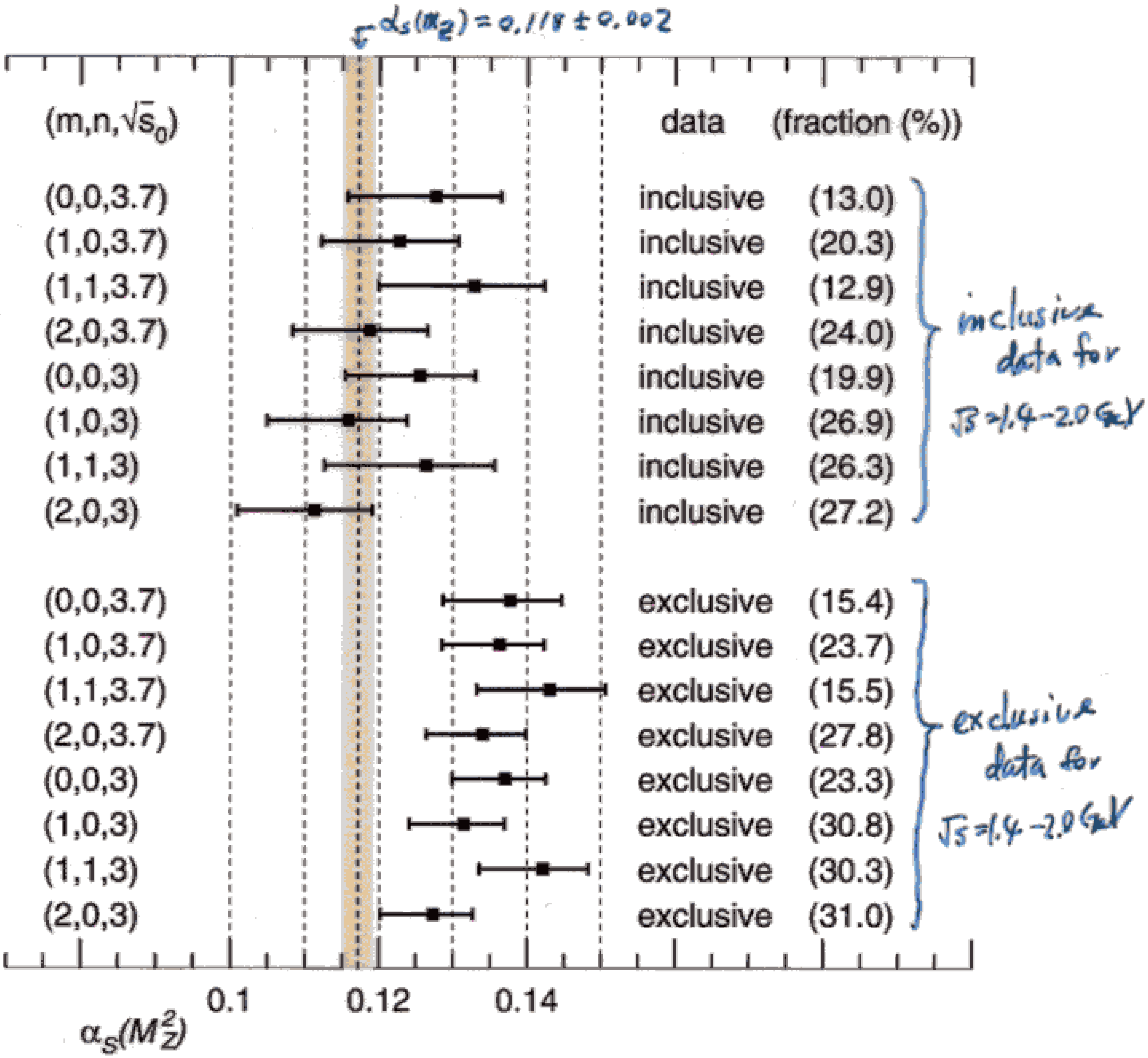
energy range (GeV)	comments	$a_\mu^{\rm had,LO} \times 10^{10}$	$\Delta\alpha_{\rm had}(M_Z^2) \times 10^4$
m_π–0.32	ChPT	2.36 ± 0.05	0.04 ± 0.00
0.32–1.43	excl. only	606.55 ± 5.22	47.34 ± 0.35
1.43–2	incl. only	31.91 ± 2.42	10.78 ± 0.81
	(excl. only	35.68 ± 1.71	12.17 ± 0.59)
2–11.09	incl. only	42.05 ± 1.14	81.97 ± 1.53
J/ψ and ψ'	narrow width	7.30 ± 0.43	8.90 ± 0.51
$\Upsilon(1S-6S)$	narrow width	0.10 ± 0.00	1.16 ± 0.04
11.09–∞	pQCD	2.11 ± 0.00	125.32 ± 0.15
Sum of all	incl. 1.43–2	692.38 ± 5.88	275.52 ± 1.85
	(excl. 1.43–2	696.15 ± 5.68	276.90 ± 1.77)

Table 7: A breakdown of the contributions to different intervals of the dispersion integrals for $a_\mu^{\rm had,LO}$ and $\Delta\alpha_{\rm had}(M_Z^2)$. The alternative numbers for the interval $1.43 < \sqrt{s} < 2$ GeV correspond to using data for either the sum of the exclusive channels or the inclusive measurements, see Fig. 4.

$\alpha_s(m_Z)$ extracted from $R(e^+e^- \to \text{hadrons})$ by using QCD Sum Rules $(0 < \sqrt{s} < 3.0\ \text{GeV}, 3.7\ \text{GeV})$

$$\int_{s_{th}}^{s_0} ds \left(\frac{s}{s_0}\right)^m \left(1 - \frac{s}{s_0}\right)^n R(s) = \int_C ds\, g(s)\, D(s)$$

$R(s)$: Data $D(s)$: PQCD



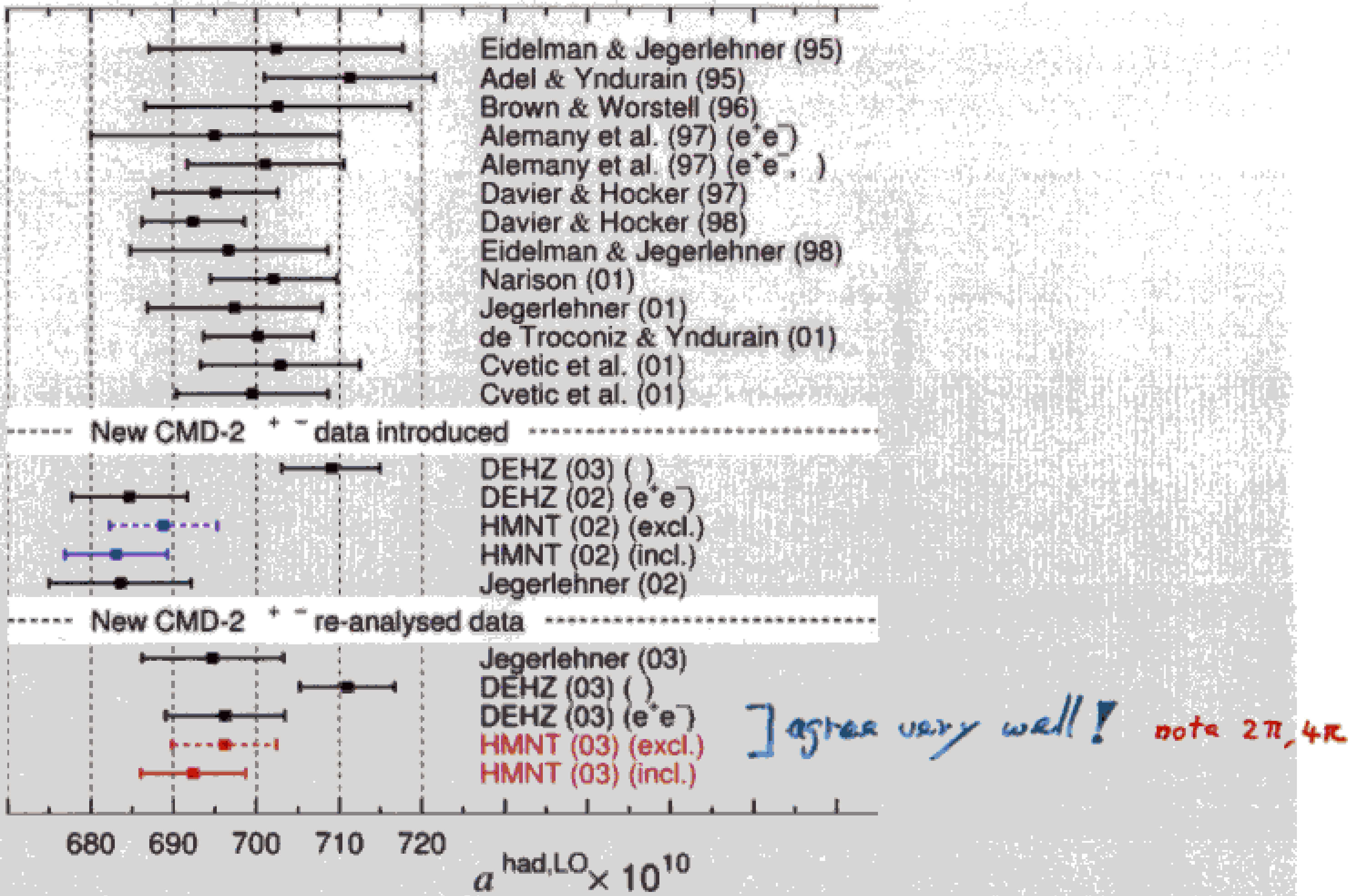
HMNT03 DEHZ03

channel	this work ($\sqrt{s} < 1.8$GeV)	DEHZ 03 ($\sqrt{s} < 1.8$GeV)	difference
$\pi^+\pi^-$ (ChPT)	2.36 ±0.05 (< 0.32GeV)	58.04 (± 2.06) (<0.5GeV)	
$\pi^+\pi^-$ (data)	503.24 ±5.02(> 0.32GeV)	450.16 (± 5.14) (>0.5GeV)	
$\pi^+\pi^-$ (total)	**505.60 ± 5.02**	**508.20 ± 5.53**	−2.60
$\pi^0\gamma$	0.13 ± 0.01 (ChPT)	0.93	
	4.50 ± 0.15 (data)	+37.96 × 0.0889 ($\omega \to \pi^0\gamma$)	
		+35.71 × 0.00124 ($\phi \to \pi^0\gamma$)	
$\eta\gamma$	0.01 ± 0.00 (ChPT)	+37.96 × 0.0007 ($\omega \to \eta\gamma$)	
	0.73 ± 0.03 (data)	+35.71 × 0.01299 ($\phi \to \eta\gamma$)	
$\pi^0\gamma + \eta\gamma$	**5.36 ± 0.15**	**= 4.84 ± 0.18**	+0.52
$\pi^+\pi^-\pi^0$	0.01 (± 0.00) (ChPT)	37.96 × 0.9104 ($\omega \to \pi^+\pi^-\pi^0$)	
		+4.20 ($0.81 < \sqrt{s} < 1.00$)	
	+46.97 (± 0.90) (data)	+35.71 × 0.155 ($\phi \to \pi^+\pi^-\pi^0$)	
		+2.45 ($1.055 < \sqrt{s} < 1.800$)	
	= 46.98 ± 0.90	**= 46.74 ± 1.09**	+0.24
K^+K^-	22.29 ± 0.76	4.63 + 35.71 × 0.492($\phi \to K^+K^-$)	
		= 22.20 ± 0.59	+0.09
$K^0_S K^0_L$	13.29 ± 0.32	0.94 + 35.71 × 0.337($\phi \to K^0_S K^0_L$)	
		= 12.97 ± 0.31	+0.32
$\phi(\not\to 3\pi, 2K, \pi^0\gamma, \eta\gamma)$	0.06 ± 0.06	35.71 × 0.002($\phi \not\to 3\pi, 2K, \pi^0\gamma, \eta\gamma$)	
		= 0.07 ± 0.00	−0.01
$\pi^+\pi^-\pi^0\pi^0$	18.34 ± 1.08	16.76 ± 1.33	+1.58
$\omega(\to \pi^0\gamma)\pi^0$	0.82 ± 0.03	0.63 ± 0.10	+0.19
$\pi^+\pi^-\pi^+\pi^-$	13.63 ± 0.70	14.21 ± 0.90	−0.58
$\pi^+\pi^-\pi^+\pi^-\pi^0$	2.05 ± 0.18	2.09 ± 0.43	−0.04
$\pi^+\pi^-\pi^0\pi^0\pi^0$	0.85 ± 0.30	1.29 ± 0.22 (isospin, η)	−0.44
$\omega(\to \pi^0\gamma)\pi^+\pi^-$	0.06 ± 0.01	0.08 ± 0.01	−0.02
$\pi^+\pi^-\pi^+\pi^-\pi^+\pi^-$	0.07 ± 0.01	0.10 ± 0.10	−0.03
$\pi^+\pi^-\pi^+\pi^-\pi^0\pi^0$	1.96 ± 0.18	1.41 ± 0.30	+0.55
$\pi^+\pi^-\pi^0\pi^0\pi^0\pi^0$	0.07 ± 0.07 (isospin, τ)	0.06 ± 0.06 (isospin, τ)	+0.01
sum from 6π	**2.11 ± 0.19**	**1.57 ± 0.34**	+0.54
$\eta\pi^+\pi^-$	0.43 ± 0.07	0.54 ± 0.07	−0.11
$K^0_S\pi K$	0.85 ± 0.09		
$K^0_L\pi K$	0.85 ± 0.09 (isospin)		
$K^0_S\pi K + K^0_L\pi K$	**1.71 ± 0.19**	1.84 ± 0.24	−0.13
$K^+K^-\pi^0$	0.18 ± 0.05		
$K^0_S K^0_L\pi^0$	0.18 ± 0.05 (isospin)		
$K^+K^-\pi^0 + K^0_S K^0_L\pi^0$	**0.36 ± 0.11**	0.60 ± 0.20	−0.24
$KK\pi\pi$	2.38 ± 0.98 (isospin)	2.22 ± 1.02	+0.16
total ($\sqrt{s} < 1.8$GeV)	**636.29 ± 5.43**	**636.85 ± 6.08**	−0.56

Table 9: The contributions of the individual e^+e^- channels, up to $\sqrt{s} = 1.8$ GeV, to dispersion relation (44) for $a_\mu^{\rm had,LO}$ ($\times 10^{10}$) that were obtained in this analysis and in the DEHZ03 study [3]. The last column shows the difference. "Isospin" denotes channels for which no data exist, and for which isospin relations or bounds are used. We have divided the DEHZ ω contribution into the respective channels according to their branching fractions [104], with their sum normalized to unity.

Hadronic vacuum polarization: e^+e^--based analysis

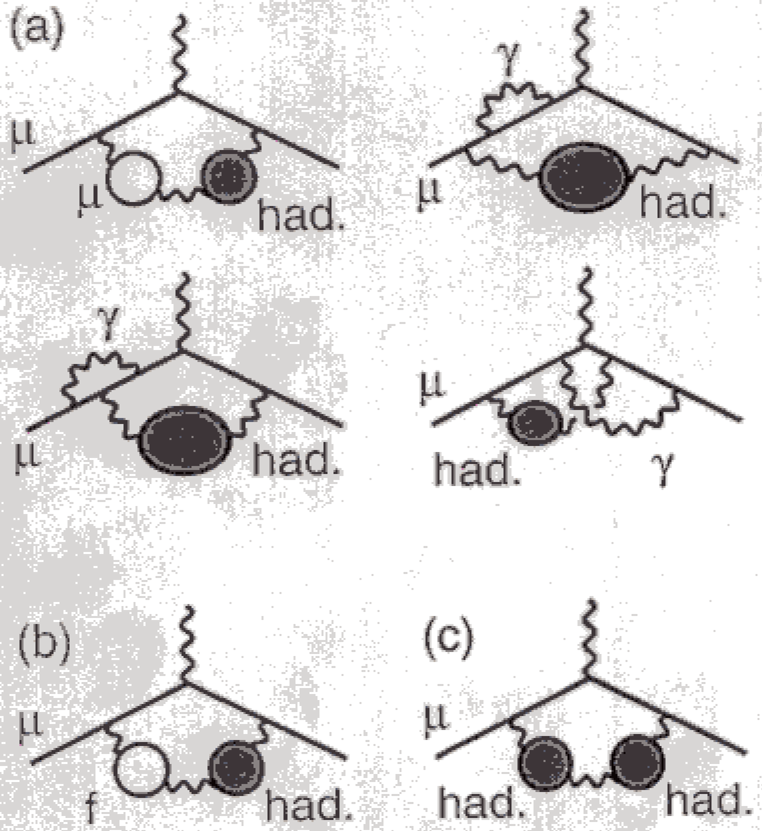
- Those analysis that use exclusively e^+e^--data agree well:



NLO calculation

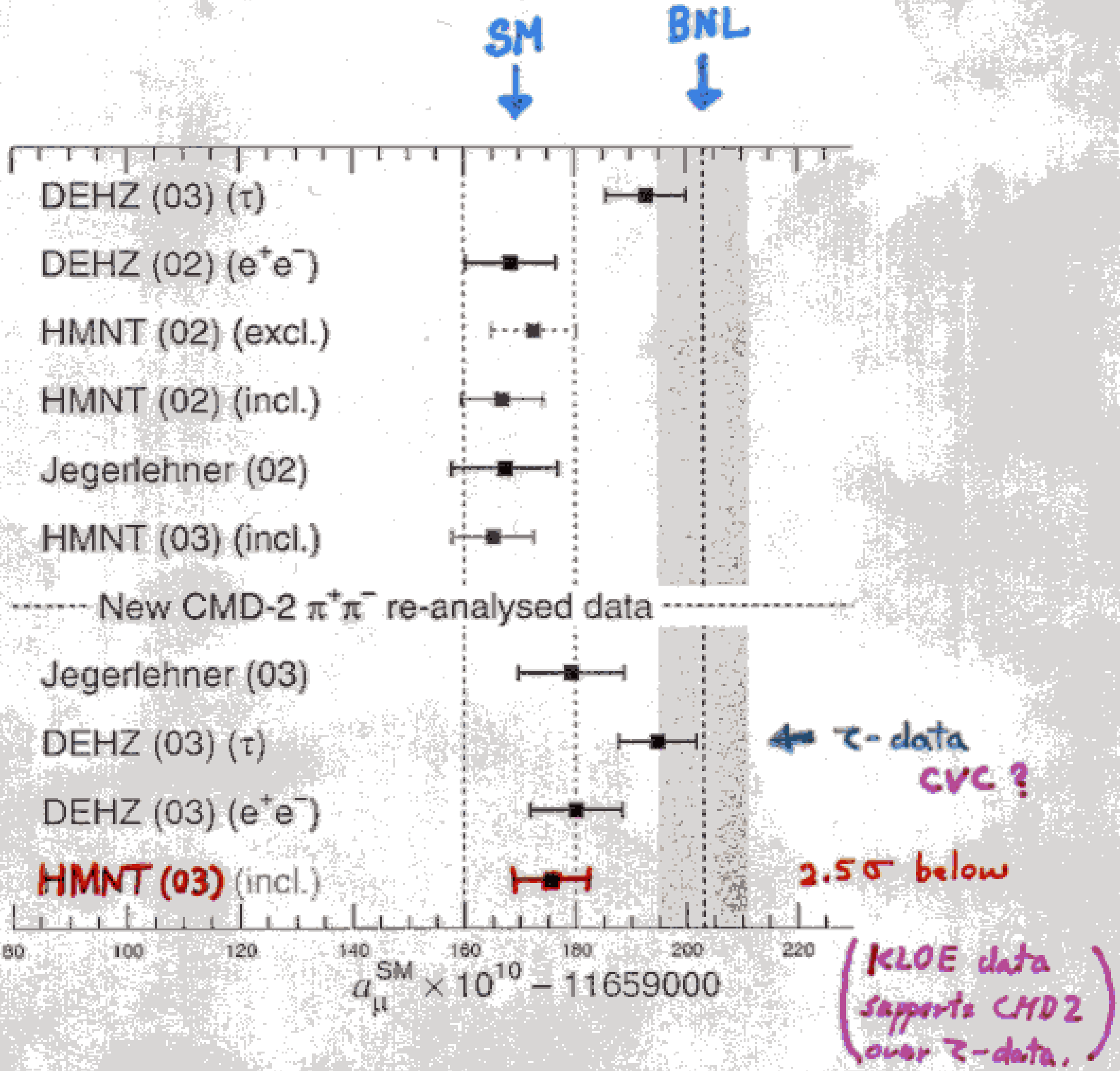
	Krause (1997)	HMNT (2003)
$10^{10}\cdot a_\mu^{(a)}$	$= -21.1\,(0.5)$	$= -20.74\,(0.18)$
$10^{10}\cdot a_\mu^{(b)}$	$= 10.7\,(0.2)$	$= 10.59\,(0.09)$
$10^{10}\cdot a_\mu^{(c)}$	$= 0.27\,(0.01)$	$= 0.34\,(0.01)$
$10^{10}\cdot a_\mu^{(a+b+c)}$	$= -10.1\,(0.6)$	$= -9.81\,(0.09)$

Errors from (a) & (b) are 100% correlated!
The same applies between LO & NLO.

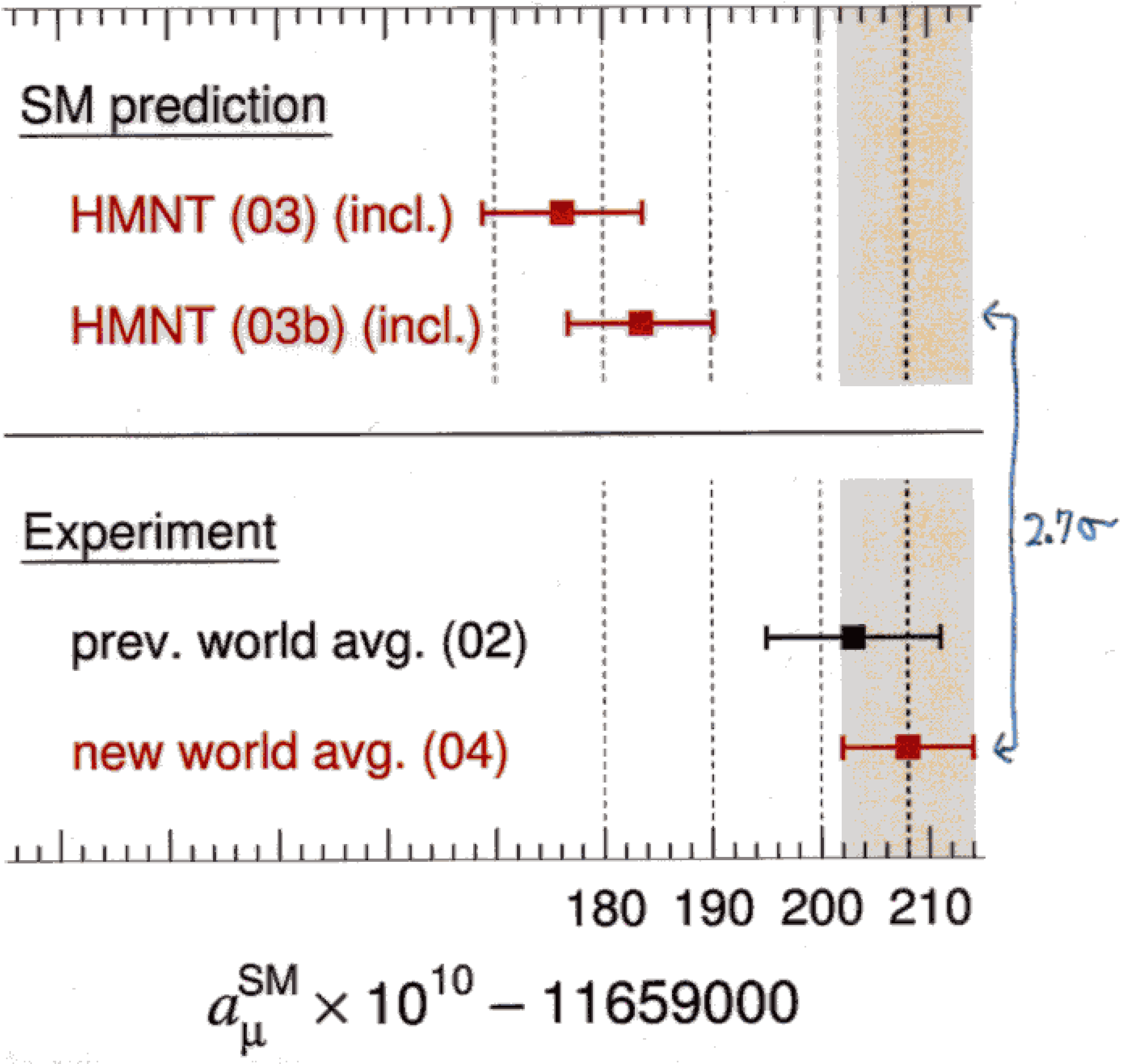


igure 13: The three classes of diagrams (a,b,c) which contribute to $a_\mu^{\rm had,NLO}$. Class (a) contain the first five diagrams. In the class (b) diagram, $f = e$ or τ, but not μ. Mirror counterpart nd diagrams with an interchange between the massless photon and the "massive photon" ropagators should be understood.

Status on a_μ^{SM}



igure 15: Recent evaluations of a_μ^{SM} and the current world-average of the measured value shown as a band). The band corresponds to a 1-σ range. The final values, HMNT(03), are the redictions of this work, and include the recently re-analysed CMD-2 $\pi^+\pi^-$ data [CMD2new] 1 our analyses.


SM prediction
HMNT (03) (incl.)
HMNT (03b) (incl.)
Experiment
prev. world avg. (02)
new world avg. (04)
2.7σ
180 190 200 210
$a_\mu^{SM} \times 10^{10} - 11659000$

Summary and Outlook

- BNL data $a_\mu^{exp} = 11659208\,(6) \times 10^{-10}$

  ------ 203 (8)

- SM prediction $a_\mu^{SM} = 11659183.53\,(6.73) \times 10^{-10}$ 2.7σ below

=	$11658471.935\,(0.143) \times 10^{-10}$		QED	• Kinoshita - Nio
+	15.4	(0.2)	EW	• Czarnecki - Marciano - Vainshtein
+	691.8	(6.1)	had, LO	• HMNT
+	− 9.81	(0.09)	had, NLO	• HMNT
+	13.6	(2.5)	had, l-by-l	• Melnikov - Vainshtein
+	− 0.06	(0.06)	had, i-l-by-l	• HMNT

- Data − SM $\Delta = 24.48 \pm 9.01 \times 10^{-10}$ 2.7σ

< 4.9 ... > 5σ future?

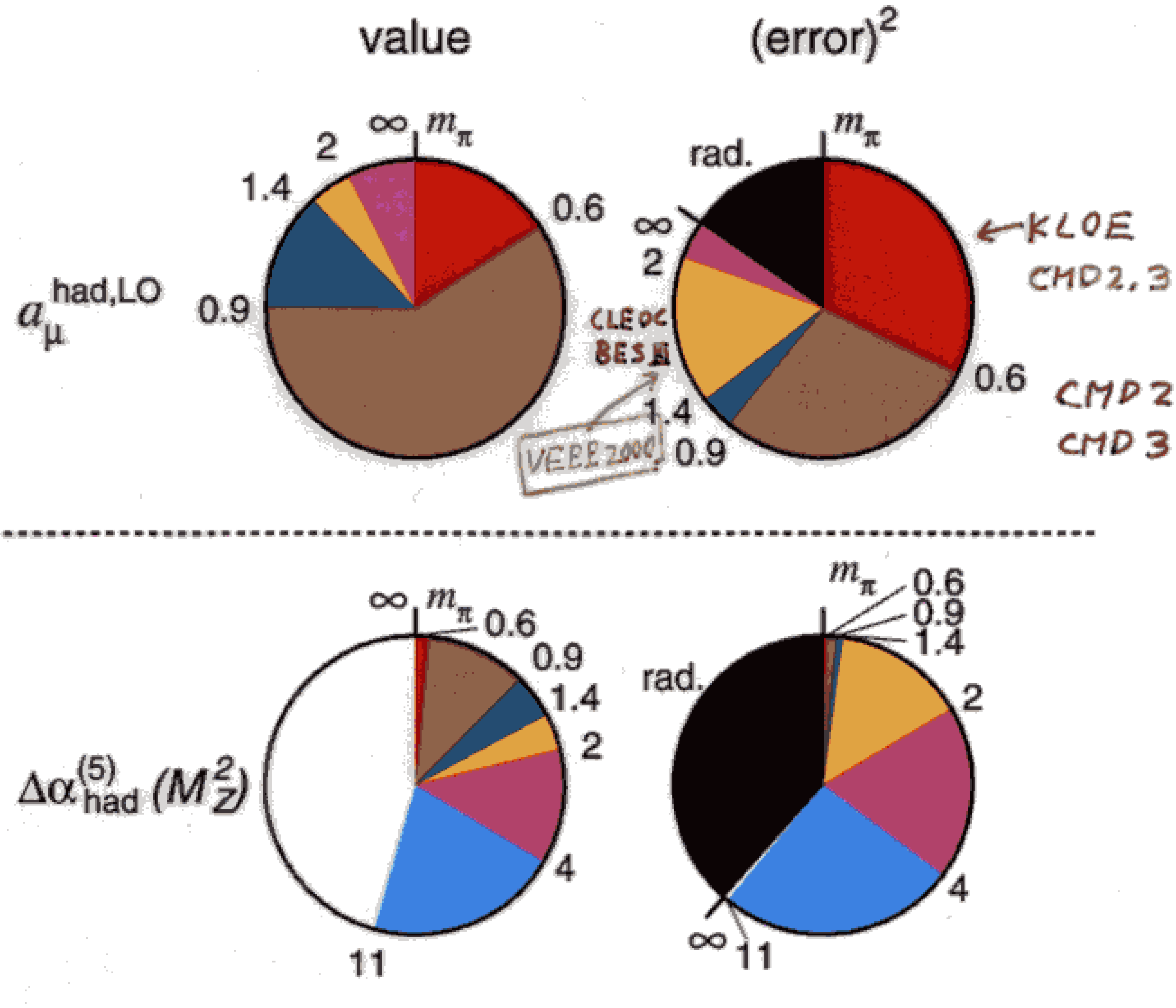
J-PARC μ

$\Delta a_\mu^{exp} < 3 \to 1$
$\Delta a_\mu^{TH} < 4 \to ?$
} possible?

3.5 ... had, LO
2.0 ... had, l-by-l

Note the limiting factor from the theory error

$a_\mu^{had,LO} \approx 700$ × 1% = 7
× 0.5% = 3.5
× 0.2% = 1.4



value
(error)^2
$a_\mu^{had,LO}$
∞
m_π
0.6
0.9
1.4
2
rad.
←KLOE
CMD2,3
CMD2
CMD3
CLEOc
BES III
VEPP2000
$\Delta\alpha^{(5)}_{had}(M_Z^2)$
4
11

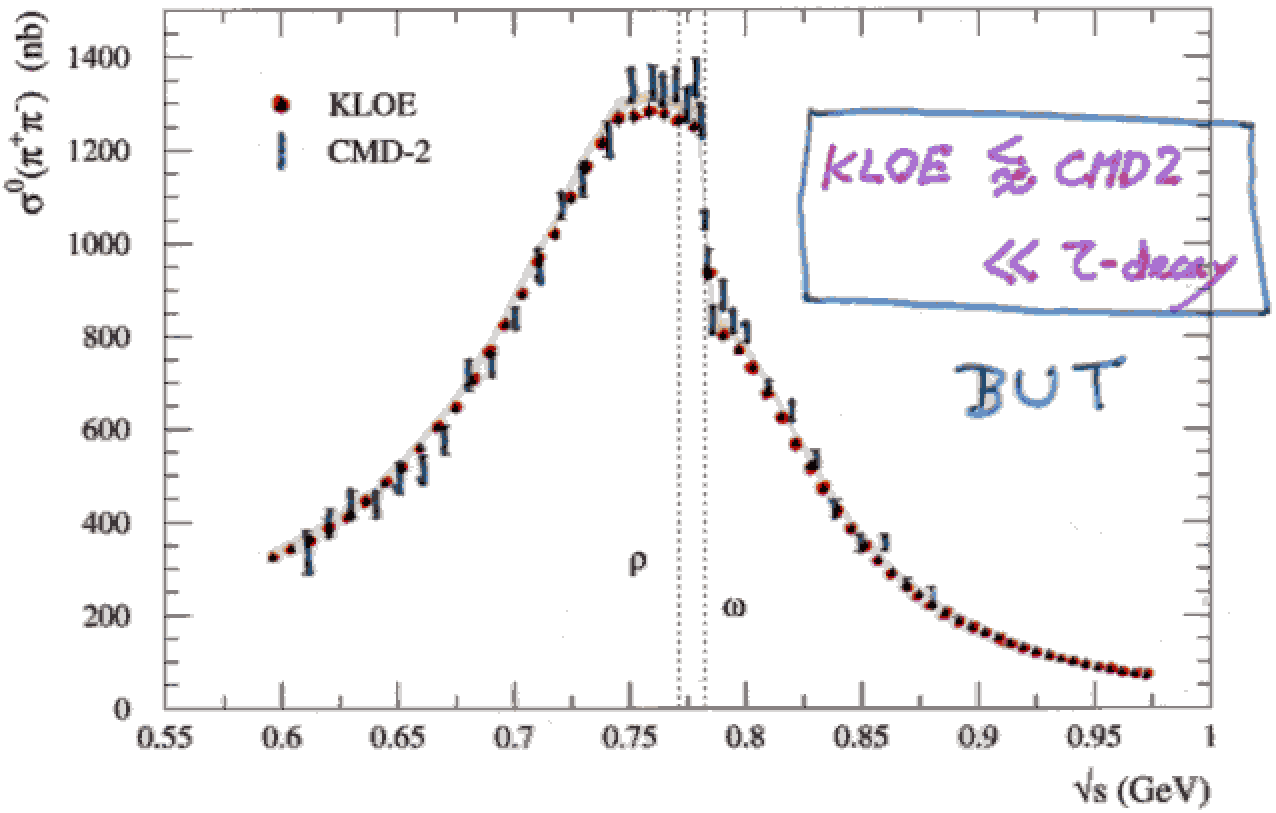
Breakdown of the integral

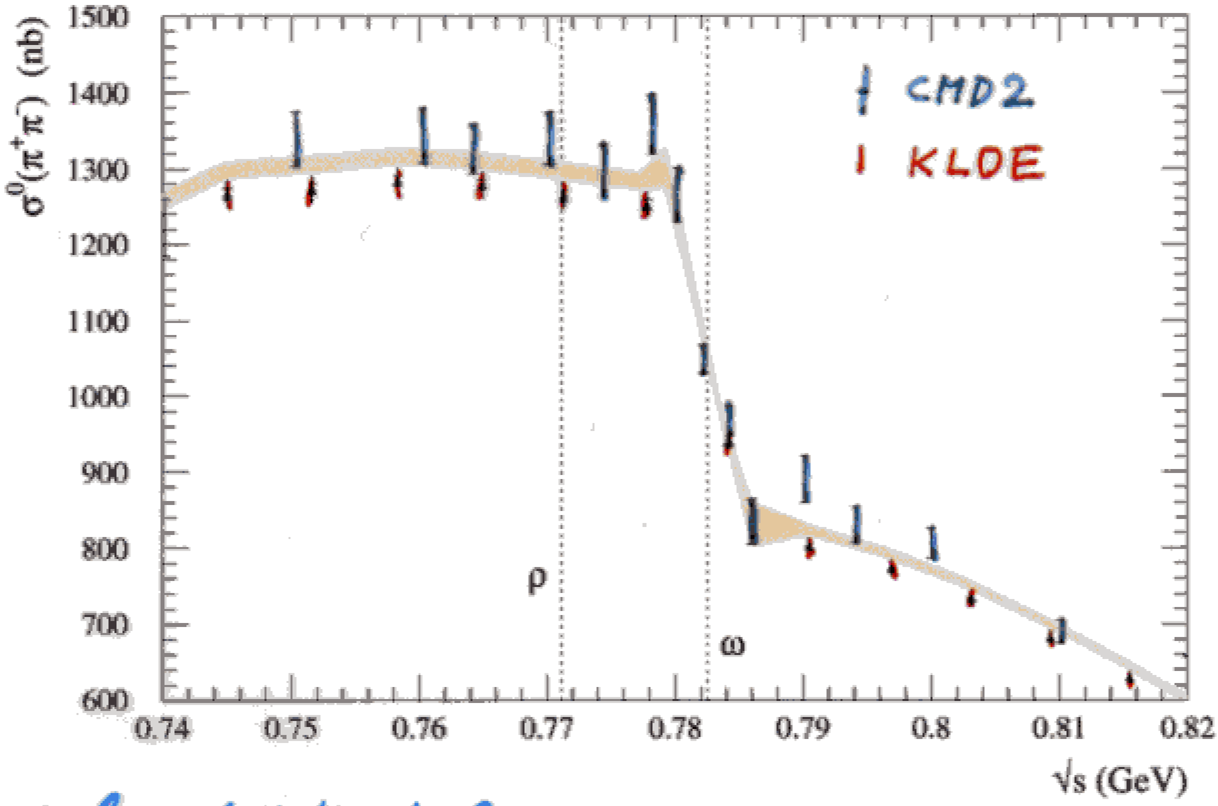
channel	inclusive (1.43,2 GeV) $a_\mu^{\text{had,LO}}$	inclusive (1.43,2 GeV) $\Delta\alpha_{\text{had}}(M_Z^2)$	exclusive (1.43,2 GeV) $a_\mu^{\text{had,LO}}$	exclusive (1.43,2 GeV) $\Delta\alpha_{\text{had}}(M_Z^2)$
$\pi^0\gamma$ (ChPT)	0.13 ± 0.01	0.00 ± 0.00	0.13 ± 0.01	0.00 ± 0.00
$\pi^0\gamma$ (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

charm & b factories

Table 5: Contributions to the dispersion relations (4) and (5) from the individual channels.

First result from KLOE hep-ex/0407048 (2004. 7. 27)



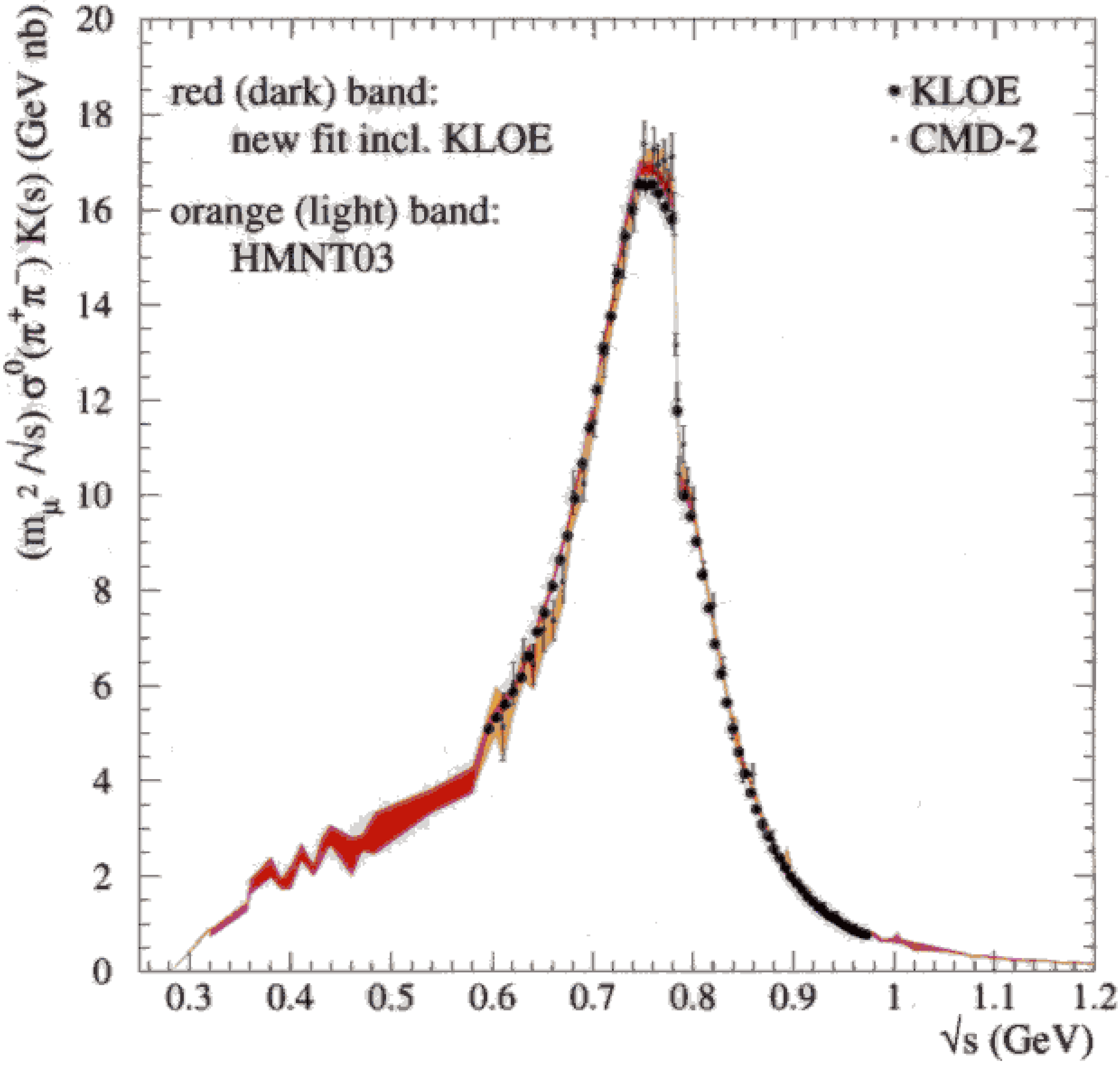


Individual contribution to a_μ:

$$a_\mu^{\pi\pi}(\text{KLOE}) = 375.6 \pm \underset{\text{stat}}{0.8} \pm \underset{\text{sys}}{4.8}$$

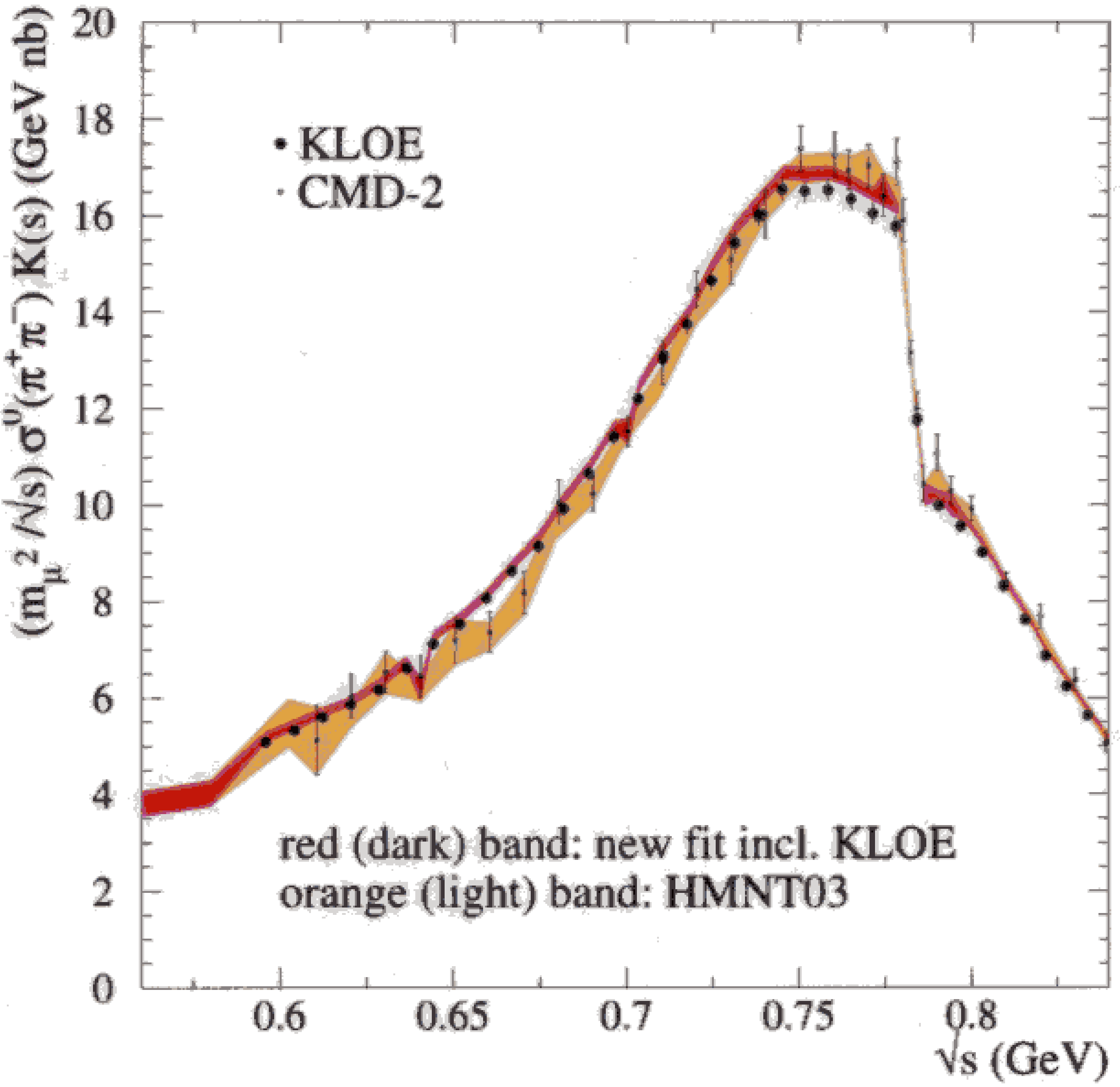
$$a_\mu^{\pi\pi}(\text{CMD2}) = 378.6 \pm 2.7 \pm 2.3$$

⇒ combine them by using clustering.



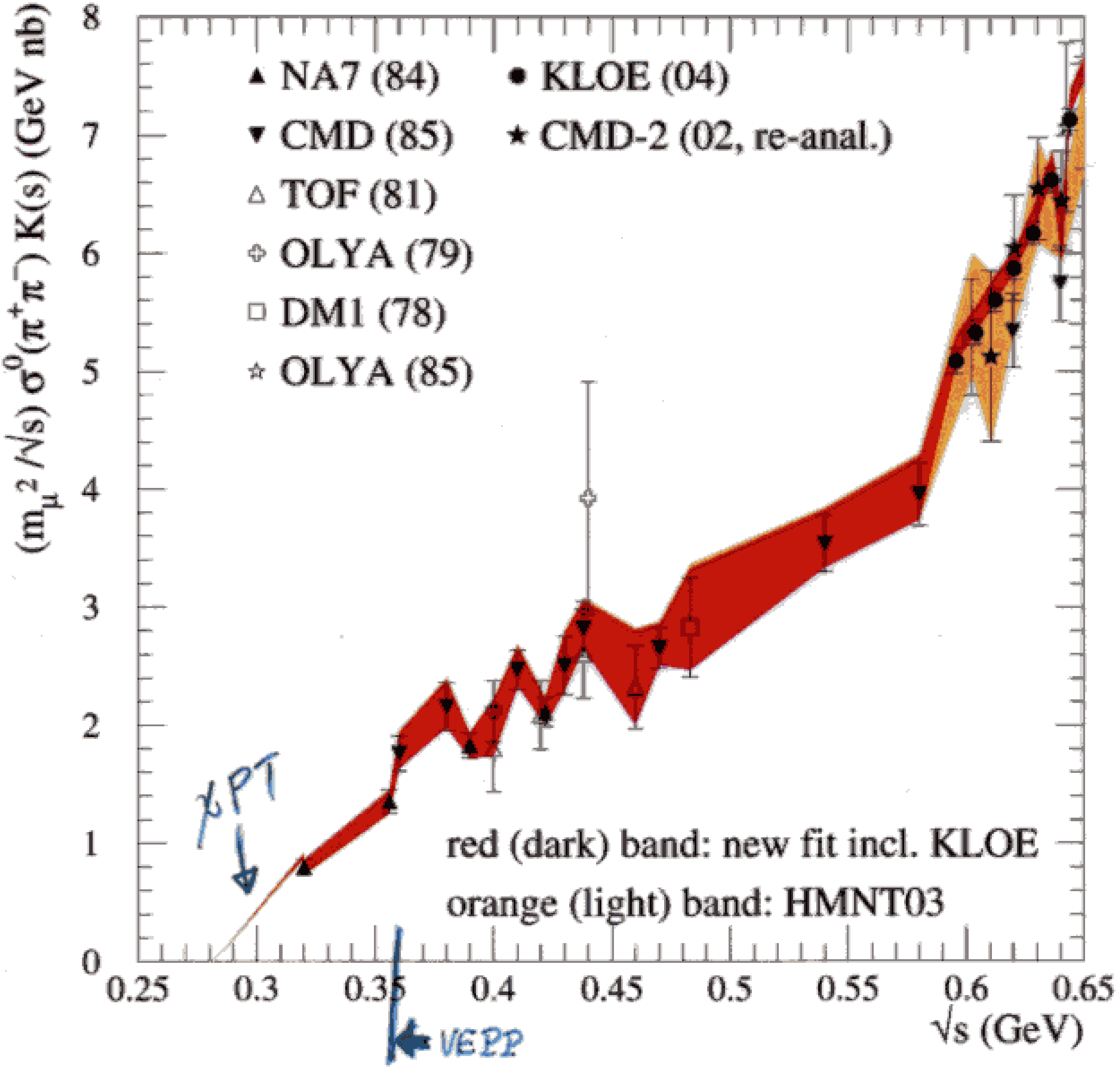
red (dark) band:
new fit incl. KLOE
orange (light) band:
HMNT03
KLOE
CMD-2
$(m_\mu^2/\sqrt{s})\,\sigma^0(\pi^+\pi^-)\,K(s)$ (GeV nb)
$\sqrt{s}$ (GeV)
20
18
16
14
12
10
8
6
4
2
0
0.3
0.4
0.5
0.6
0.7
0.8
0.9
1
1.1
1.2

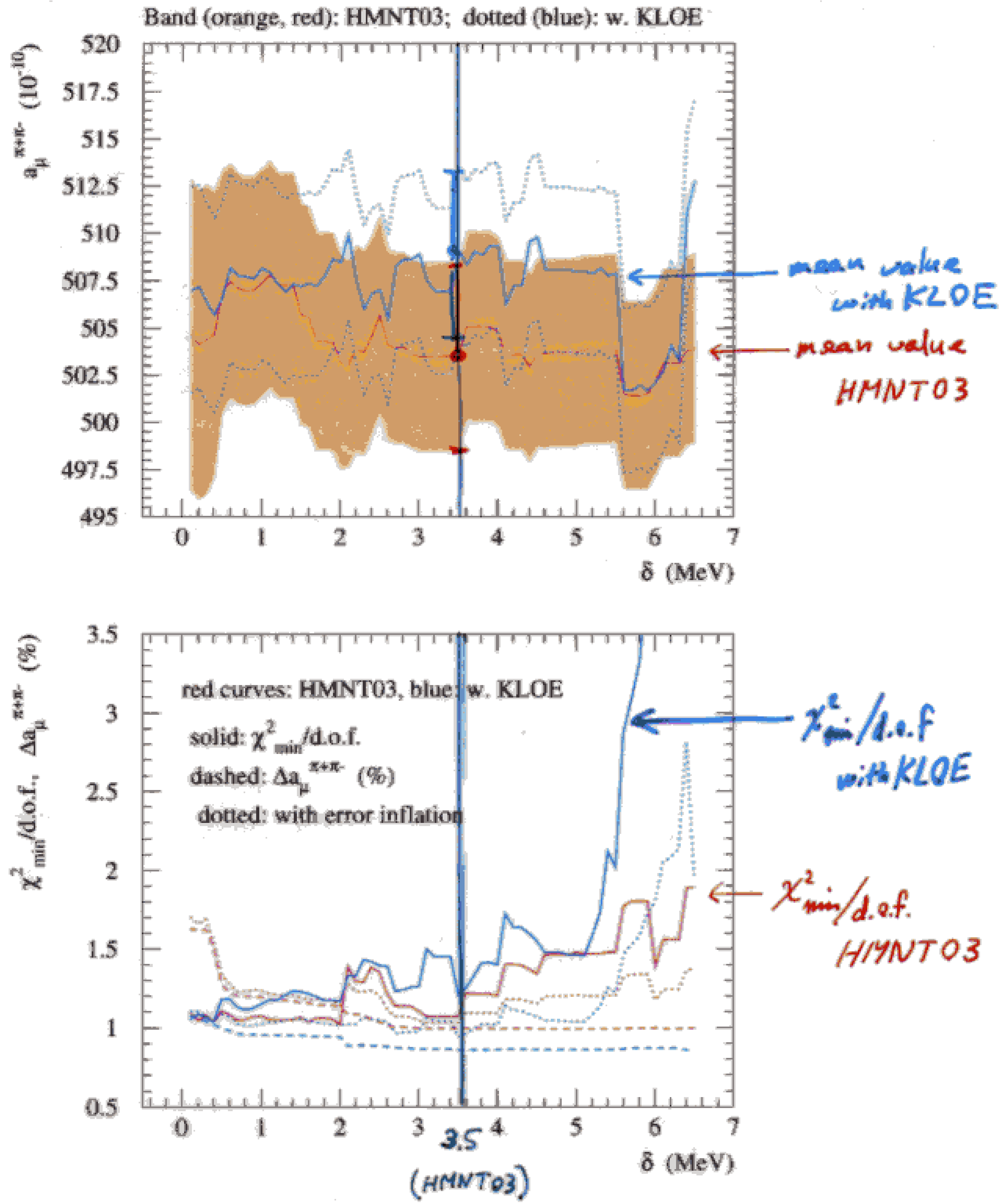
0.6 – 0.8 GeV



• KLOE
· CMD-2
red (dark) band: new fit incl. KLOE
orange (light) band: HMNT03
$(m_\mu^2/\sqrt{s})\,\sigma^0(\pi^+\pi^-)\,K(s)$ (GeV nb)
$\sqrt{s}$ (GeV)
0
2
4
6
8
10
12
14
16
18
20
0.6
0.65
0.7
0.75
0.8

$\sqrt{s_{\pi\pi}} < 0.6$ GeV





Band (orange, red): HMNT03; dotted (blue): w. KLOE
mean value with KLOE
mean value HMNT03
δ (MeV)
red curves: HMNT03, blue: w. KLOE
solid: χ²min/d.o.f.
dashed: Δa_μ^{π+π-} (%)
dotted: with error inflation
χ²min/d.o.f with KLOE
χ²min/d.o.f. HMNT03
3.5 (HMNT03)