ON THE STANDARD MODEL PREDICTION OF THE MUON g-2

M. PASSERA

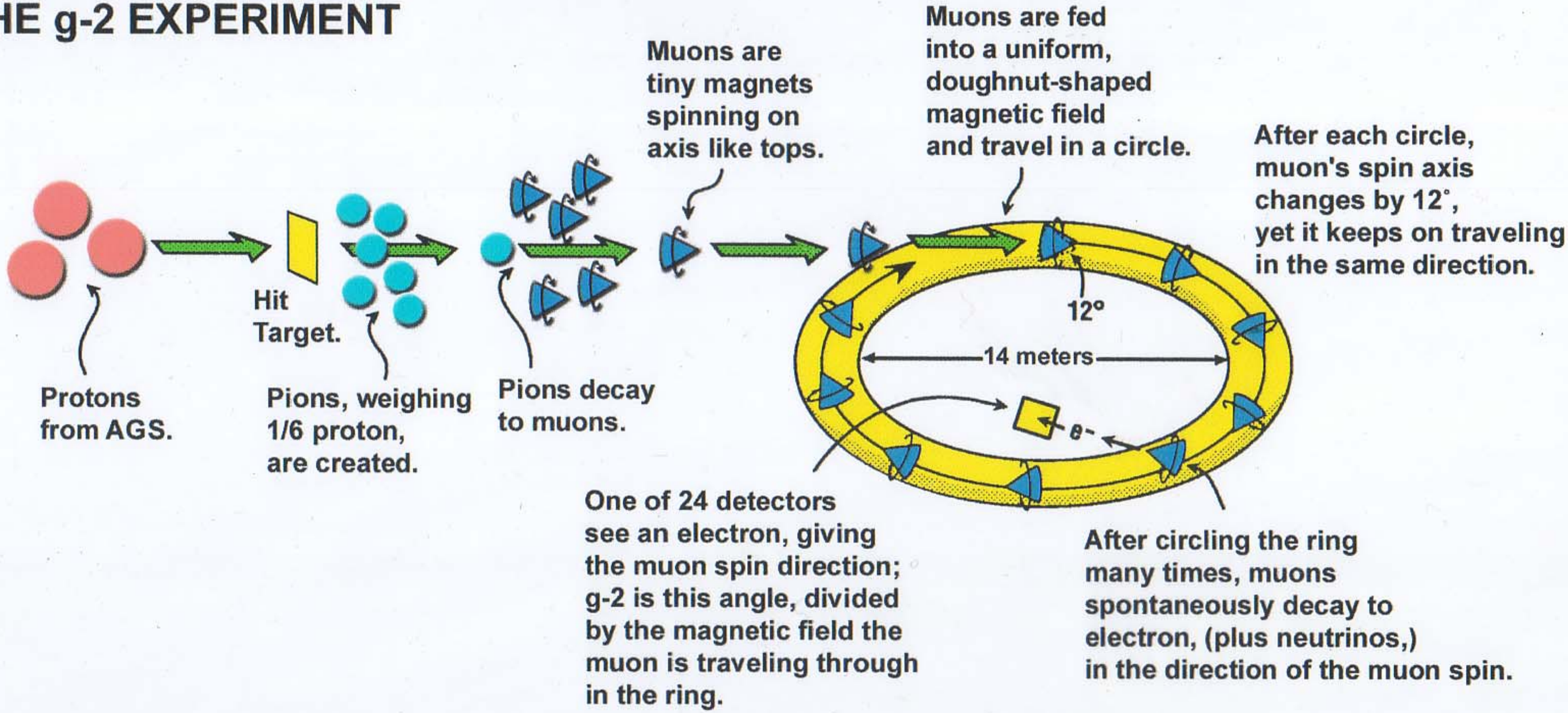
IFAE - Torino 2004

$$a_\mu = 116592080(60) \cdot 10^{-11}$$

0.5 ppm! Jan 2004 W.A.

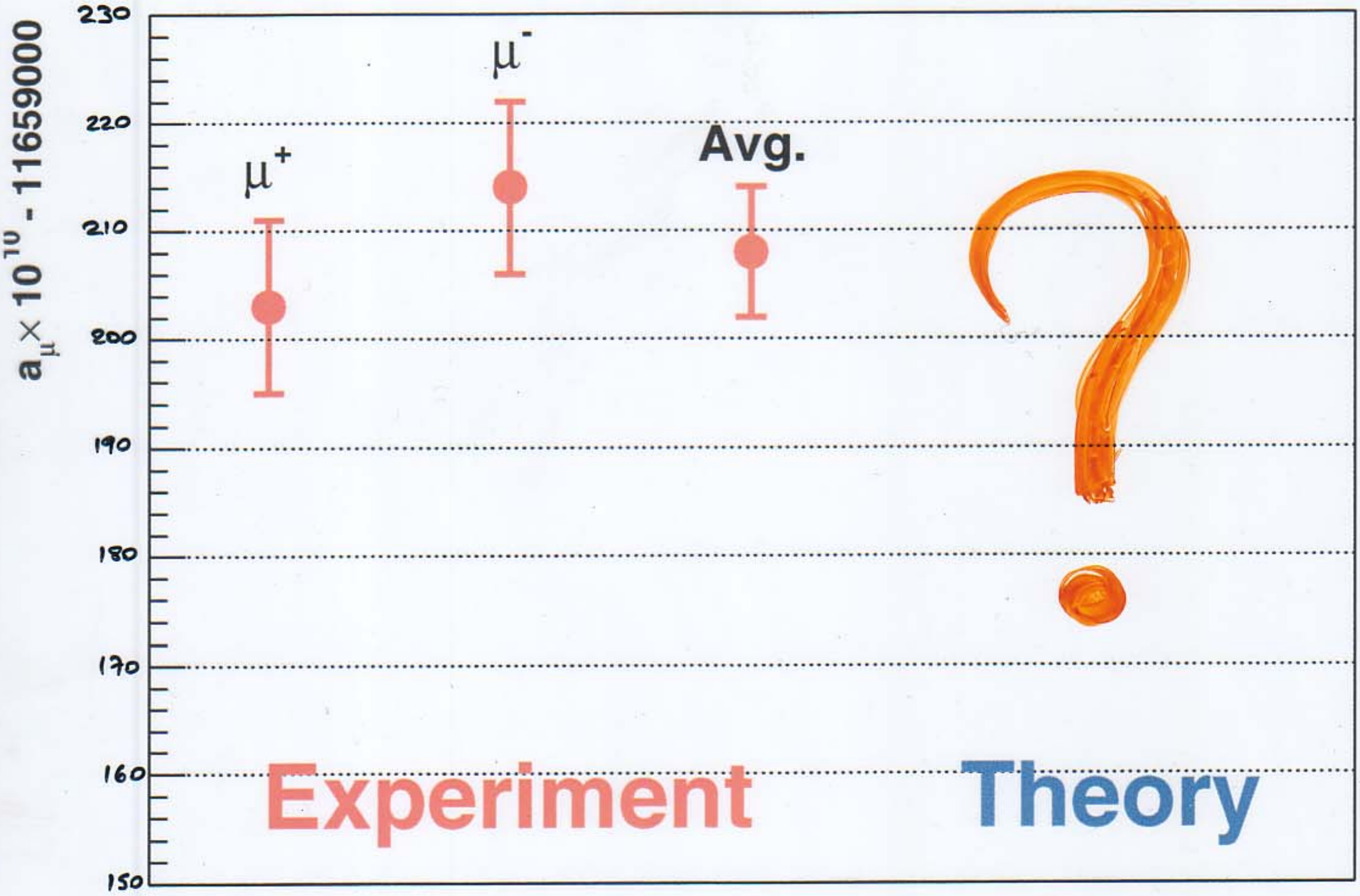
Overview of the experiment

LIFE OF A MUON: THE g-2 EXPERIMENT



E 821 Homepage

RESULTS :



$$a_\mu^{WA} = 116592080\,(60) \times 10^{-11}$$

0.5 ppm. Jan 2004 (hep-ex/0401008)

The ANOMALOUS MAGNETIC MOMENT

- THE DIRAC THEORY PREDICTS

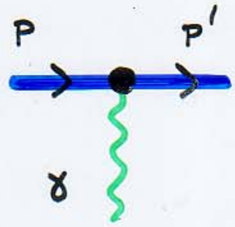
$$\vec{\mu} = g\left(\frac{e}{2mc}\right)\vec{s}$$

$$g = 2$$

- QED PREDICTS DEVIATIONS from DIRAC THEORY

$$g = 2(1+a)$$

- PHOTON - LEPTON VERTEX



$$\bar{u}(p')\,\Gamma_\mu\,u(p) =$$

$$\bar{u}(p')\left[\gamma_\mu F_1(q^2) + \frac{i\sigma_{\mu\nu}q^\nu}{2m}F_2(q^2)\right]u(p)$$

→ P conserved

$$F_1(0) = 1$$

$$F_2(0) = a$$

QED CONTRIBUTION to a_μ

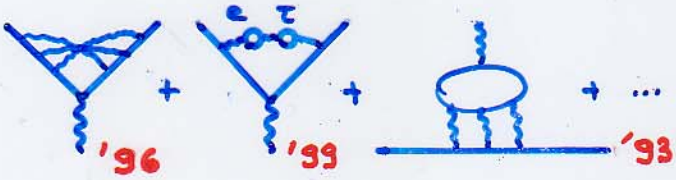
- $a_\mu^{QED} = \frac{\alpha}{2\pi}$

Schwinger 1948

$+ \; 0.765857376(27) \left(\frac{\alpha}{\pi}\right)^2$

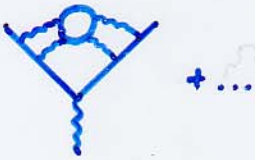
Eland '66 (*)

$+ \; 24.05050898(35) \left(\frac{\alpha}{\pi}\right)^3$



Laporta & Remiddi
Czarnecki & Skrzypek (*)

$+ \; 130.975(39) \left(\frac{\alpha}{\pi}\right)^4$

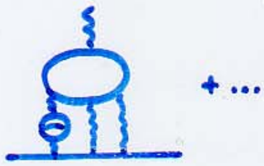


NEW VALUE!

Kinoshita 2003
Kinoshita & Nio 2003-4 (*)

In progress...

$+ \; 930(170) \left(\frac{\alpha}{\pi}\right)^5$



ESTIMATE

Kinoshita et al. 90
Karshenboim 93

- ADDING UP I GET:

$$a_\mu^{QED} = 116584720.7\,(1.2) \cdot 10^{-11}$$

$$\alpha = 1/137.03599875\,(52)$$ FROM $(g-2)_e$

Nyffeler 2003

OR:

$$a_\mu^{QED} = 116584719.3\,(1.4) \cdot 10^{-11}$$

$$\alpha = 1/137.03600030\,(100)$$ FROM ATOM INT.

Wicht et al. 2002

(*) Latest only!

THE ELECTRON g−2

- **THEORY**

$$a_e^{th} = \frac{\alpha}{2\pi} - 0.328478444\left(\frac{\alpha}{\pi}\right)^2 + 1.181234\left(\frac{\alpha}{\pi}\right)^3 \underline{-1.7502(384)}\left(\frac{\alpha}{\pi}\right)^4 + \dots + \underbrace{1.70(3)\times 10^{-12}}_{\text{HADRONIC \& WEAK}}$$

→ NEW! soon OLD!

Kinoshita 2003
Marciano, Knecht 2003

- **EXPERIMENT**

$$a_e^{exp} = 1159652188.3\,(4.2)\times 10^{-12} \qquad (3.6\ \text{ppb!})$$

Dehmelt et al. 1987

- **FROM $a_e^{th}(\alpha) = a_e^{exp} \Rightarrow \alpha$**

$$\alpha = 1/137.03599875\,(52)$$

→ 3.8 ppb!

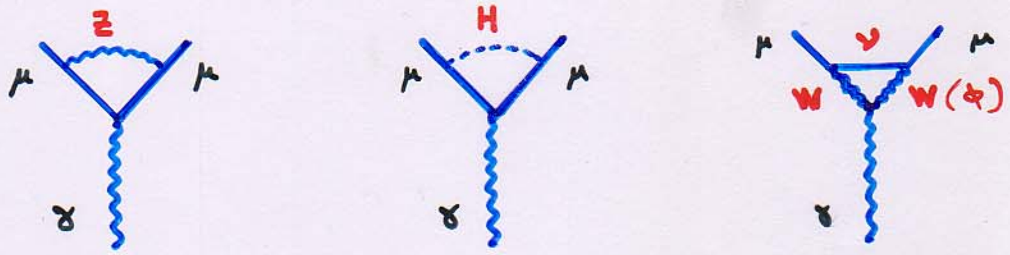
Nyffeler '03

- BEST DETERMINATION OF α
- TEST of QED AT 4 LOOP LEVEL
- NOT VERY SENSITIVE TO "NEW PHYSICS" (UNLIKE a_μ)

Back to a_μ ...

ELECTROWEAK Contributions

- ONE LOOP



$a_\mu^{EW,1} \simeq 195 \times 10^{-11}$

Jackiv & Weinberg
1972
Altarelli, Cabibbo & Maiani
⋮

- TWO LOOPS

$$a_\mu^{EW,1+2} = 154\ (1)(2) \times 10^{-11}$$

(1) hadronic, (2) M_{Higgs} ...

→ Czarnecki, Krause, Marciano 95-96

Czarnecki, Marciano, Vainstein 2002

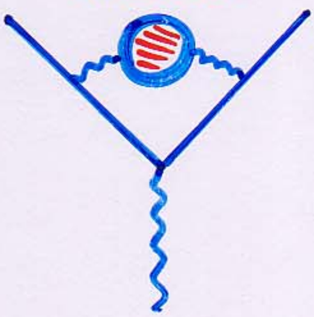
INCLUDES (TINY) LEADING LOG 3 LOOPS TERM

Degrassi, Giudice 1998

Knecht et al. 2002

HADRONIC CONTRIBUTIONS

- LEADING ORDER



$$a_\mu^{H,LO} = \frac{\alpha}{\pi^2}\int_0^\infty \frac{ds}{s}\, K(s)\, \mathrm{Im}\,\Pi(s)$$

$$= \frac{1}{4\pi^3}\int_{4m_\pi^2}^\infty ds\ K(s)\,\sigma(s)$$

$\sigma(s)$: $e^+e^- \to h$

$$K(s) = \int_0^1 dx\, \frac{x^2(1-x)}{x^2 + (1-x)s/m_\mu^2}$$

Bouchiat & Michel 1961

- FROM e^+e^- DATA (new CMD2, Aug '03)

$$a_\mu^{H,LO} = \begin{matrix} 6963\,(72) \\ 6924\,(64) \\ 6948\,(86) \\ 6996\,(89) \end{matrix} \times 10^{-11}$$

6963 (72)	DAVIER et al.	8-2003
6924 (64)	Hagiwara et al.	12-2003
6948 (86)	Ghozzi & Jegerlehner	10-2003
6996 (89)	Ezhela et al.	12-2003

- ARE ALL R.C. UNDER CONTROL??
- PRELIMINARY RESULTS BY KLOE AGREE WITH (NEW) CMD-2 DATA

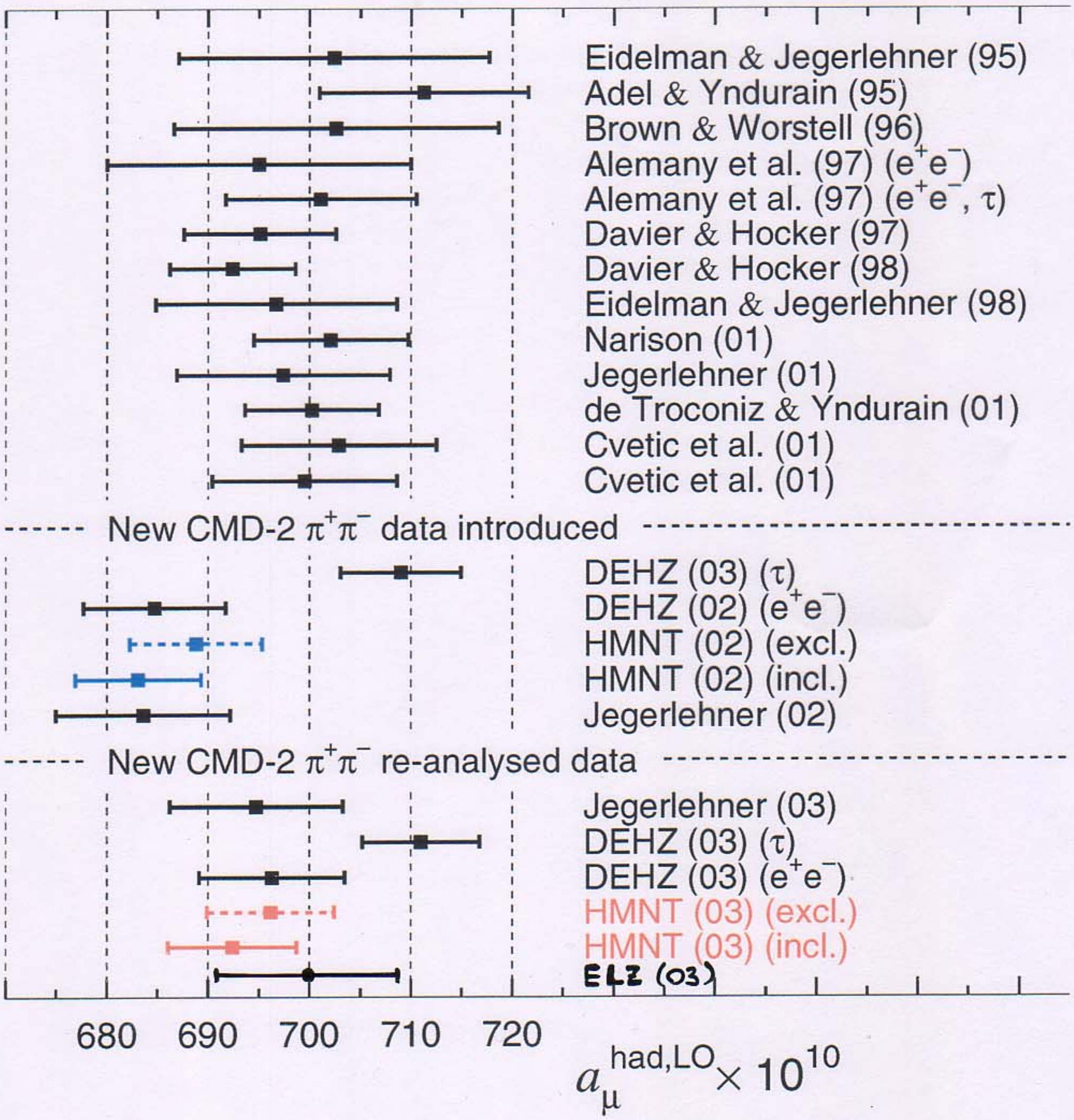
- FROM τ DATA (Aleph, Opal, CLEO)

$$a_\mu^{H,LO} = 7110\,(58) \times 10^{-11}$$ Davier et al. 8-2003

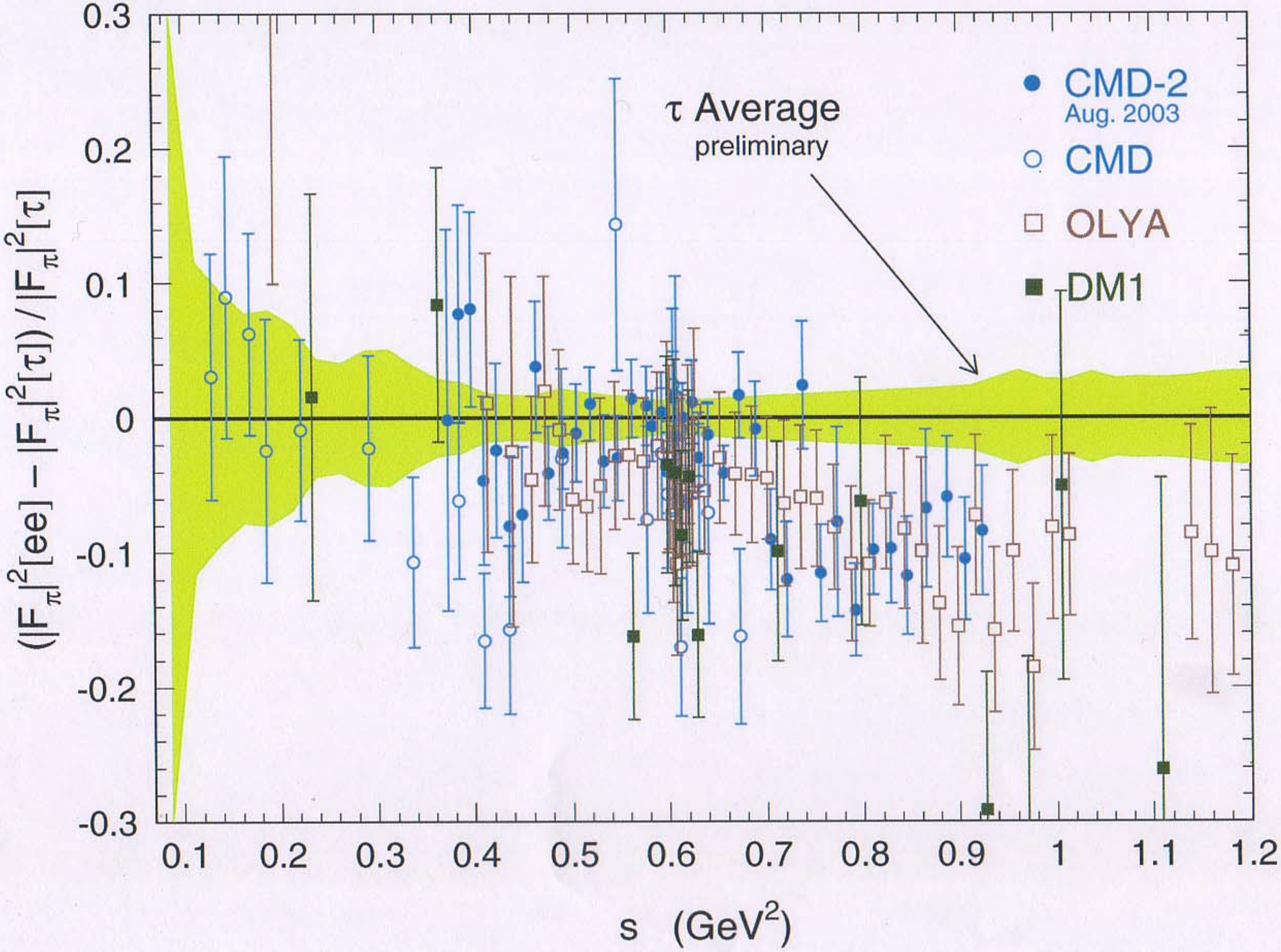
$\hookrightarrow \Delta = 147\,(92) \times 10^{-11}$

- ALL "KNOWN" ISOSPIN VIOLATION CORRECTIONS INCLUDED

Cirigliano et al. 2002



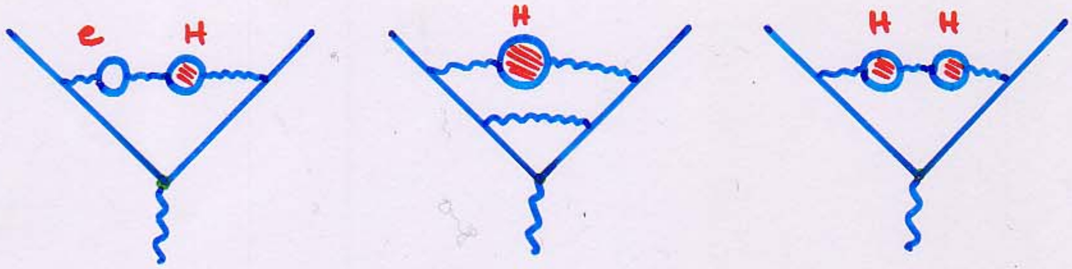
Hagiwara et al. HEP-PH/0312250



DAVIER et al. Eur. Phys. J. C31 (2003) 503.

HIGHER ORDER HADRONIC

- HADRONIC VAC. POL. CONTRIBUTION TO $O(\alpha^3)$

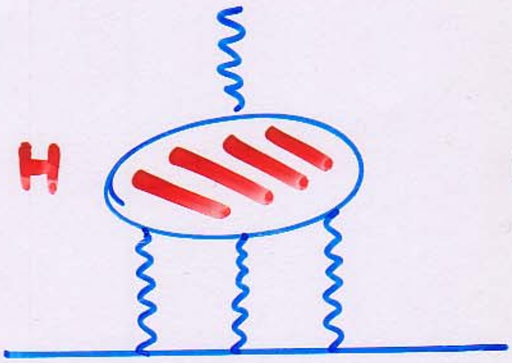


$a_\mu^{H,\,VP3} = -100\,(6) \times 10^{-11}$

Krause 96

Alemany, Davier, Höcker 98

- HADRONIC LIGHT-BY-LIGHT



Knecht & Nyffeler 2001

$a_\mu^{H,\,\ell\times\ell} = +80\,(40) \times 10^{-11}$ Nyffeler @ Marseille 2002

$a_\mu^{H,\,\ell\times\ell} = +136\,(25) \times 10^{-11}$ Melnikov & Vainshtein 2003

PROBABLY THE ULTIMATE LIMITATION OF THE STANDARD MODEL PREDICTION...

SM vs EXPERIMENT

$$a_\mu^{QED} = 116584720.7\,(1.2) \cdot 10^{-11}$$

$$a_\mu^{EW} = 154\,(2) \cdot 10^{-11}$$

$$a_\mu^{H,VP3} = -100\,(6) \cdot 10^{-11}$$

$$a_\mu^{H,l\times l} = +80\,(40) \cdot 10^{-11}$$

$$a_\mu^{H,LO} = \begin{matrix} 6963\,(72) & e^+e^- \\ 7110\,(58) & \tau \end{matrix} \cdot 10^{-11}$$ Davier et al.

$$a_\mu^{SM} = \begin{matrix} 116591818\,(83) \\ 116591965\,(71) \end{matrix} \times 10^{-11} \quad \begin{matrix} e^+e^- \\ \tau \end{matrix}$$

$$a_\mu^{WA} = 116592080\,(60) \times 10^{-11}$$

$$\Longrightarrow a_\mu^{WA} - a_\mu^{SM} = \begin{matrix} 262\,(102) \\ 115\,(93) \end{matrix} \cdot 10^{-11} : \begin{matrix} 2.6\sigma & e^+e^- \\ 1.2\sigma & \tau \end{matrix}$$

$3.1\,\sigma$	(2.7)	e^+e^-	Hagiwara et al.	Dec '03
$2.5\,\sigma$		e^+e^-	Ghozzi & Jegerlehner	Oct '03
$2.6\,\sigma$	(2.1)	e^+e^-	Davier et al.	Aug '03
$2.0\,\sigma$		e^+e^-	Ezhela et al.	Dec '03
$1.2\,\sigma$	(0.7)	τ	Davier et al.	Aug '03

CONCLUSIONS

There is not yet too much too conclude...

- e^+e^- VS τ PUZZLE STILL UNSOLVED, BUT THE DISCREPANCY DECREASED AFTER THE AUGUST 2003 CMD2 REANALYSIS

- e^+e^- and τ DATA ARE INDIVIDUALLY CONSISTENT AMONG EXPERIMENTS (& KLOE): ARE THERE UNACCOUNTED ISOSPIN VIOLATION CORRECTIONS ? (YES - NO, ACCORDING TO WHOM YOU ASK)

- FUTURE EXPERIMENTAL RESULTS ARE CRUCIAL (CMD2, KLOE, BABAR, Belle..) (MORE WORK NEEDED)

- THE UPSHOT :

$$\Delta(\text{EXP}-\text{SM}) \in [0.7, 3.1]\,\sigma$$

Stay tuned...