Challenges

in

High

P r e c i s i o n

P h y s i c s

High precision physics: Muon g-2, CP violation and lattice QCD

J. Bijnens, E.P., J. Prades, PRL 75 (1995), NPB 626 (2002)
E.P., A. Pich, I. Scimemi NPB 617 (2001)
S. Bertolini, J. Eeg, M. Fabbrichesi, PRD 63 (2001)
C.-J.D. Lin et al., NPB650 (2002), PLB 553 (2003)
M. Golterman, E.P., JHEP 0110 (2001); hep-lat/0212008

Anomalies, neutrinos and large extra dimensions

M. Fabbrichesi et al., PRD 66 (2002)
M. Fabbrichesi, M. Piai, G. Tasinato, PRD 64 (2001)
M. Fabbrichesi, M. Piai, G. Tasinato, EPJ C27 (2003)

Flavour dynamics

F. Bazzocchi et al., hep-ph/0306184

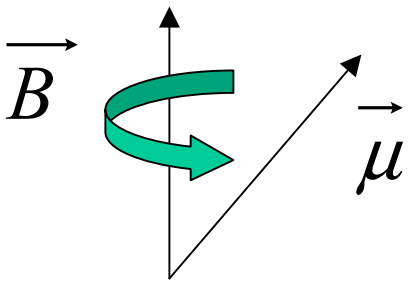
Muon g-2

$$\vec{\mu} = g \frac{e}{2m} \vec{S}$$

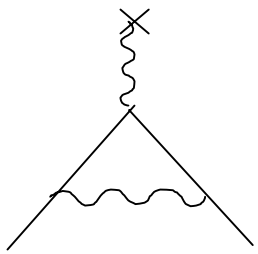
g = Lande g-factor = $2 + O(\alpha)$

Dirac value

$$a = \frac{g-2}{2}$$



Schwinger 1948



$$a_e = a_\mu = \frac{\alpha}{2\pi} \approx 0.0011614$$

$$a_e^{\exp} = 0.0011597\ !$$

QED pushed to its limits

$$a_{e,\mu} \to O(\alpha^4)$$

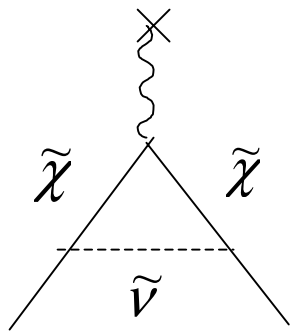
$$a_\mu = a_\mu^{QED} + a_\mu^{HAD} + a_\mu^{WEAK} + ?$$

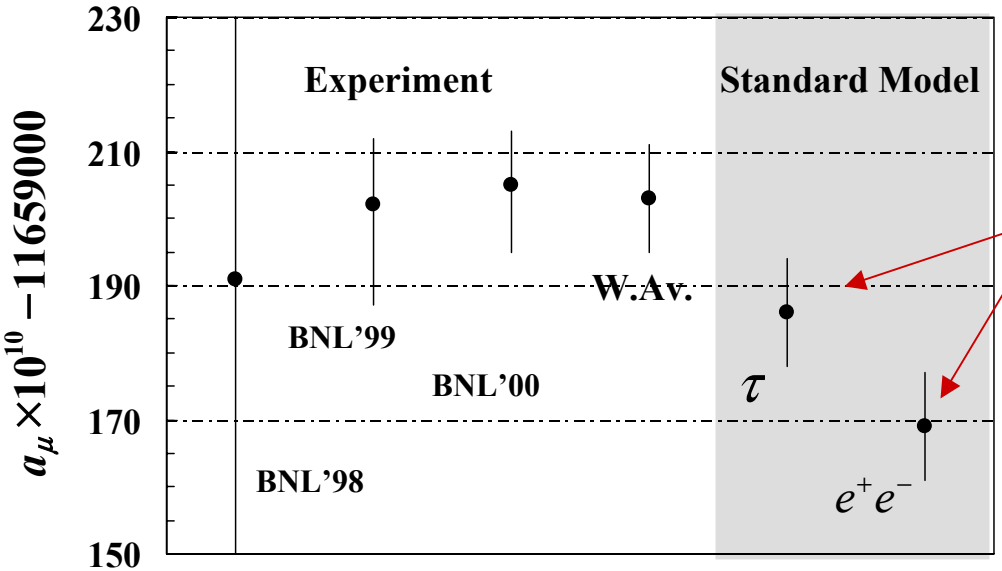
Higher order in α

Hughes, Kinoshita Rev. Mod. Phys. 71 (1999) s133
Marciano, Lee Roberts, hep-ph/0105056
Davier et al., hep-ph/0208177 (2002)
Bijnens,E.P.,Prades, PRL 75 (1995), NPB 626 (2002)
Knecht, Nyffeler, PRD 65 (2002)

Sensitive to New Physics contributions: Supersymmetry?

$$a_\mu^{SUSY} \cong \left(\frac{100GeV}{M_{SUSY}} \right)^2 \cdot \tan\beta \cdot a_\mu^{WEAK}$$





Discrepancy

?

$$a_\mu^{\exp} = 11659203\,(8)\times 10^{-10}$$

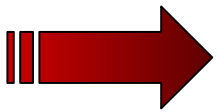
(0.7ppm)

$$\Delta a(New\ Physics) = a_\mu^{\exp} - a_\mu^{SM}$$

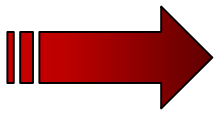
Assuming $\Delta a \approx \dfrac{m_\mu^2}{\Lambda^2}$

Sensitive to New Physics at scales $\Lambda \approx TeV$

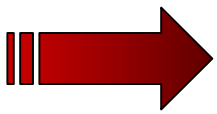
Next future challenges:



Sharpen the Standard Model prediction



Compare with increasing precision measurements



Put constraints on New Physics at very high energies

Breaking

CP symmetry

Our monitor of CP violation

$$L_{CP\not} = L_{\Delta F=0} + L_{\Delta F=1} + L_{\Delta F=2}$$

Flavour Changing

$\Delta F = 0$	$d_e < 1.5 \cdot 10^{-27}\, ecm$	$d_N < 6.3 \cdot 10^{-26}\, ecm$
$\Delta F = 1$	ε'/ε	K, B decays
$\Delta F = 2$	$\varepsilon, B \to J/\Psi K_S$	K, B decays

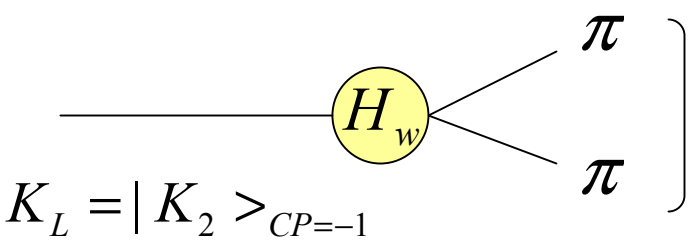
CP violation discovered (1964) in the neutral Kaon system

"*We must continue to seek the origin of the CP symmetry violation by all means at our disposal. We know that improvements in detector technology and quality of accelerators will permit even more sensitive experiments in the coming decades. We are hopeful, then, that at some epoch, perhaps distant, this cryptic message will be deciphered*" Cronin (1981)

Direct CP Violation

$$|K_L> = |K_2>_{CP=-1} + \varepsilon\,|K_1>_{CP=+1}$$

$$\xrightarrow{\not{CP}} \; |\pi\,\pi>_{CP=+1}$$



$$\Delta S = 1$$

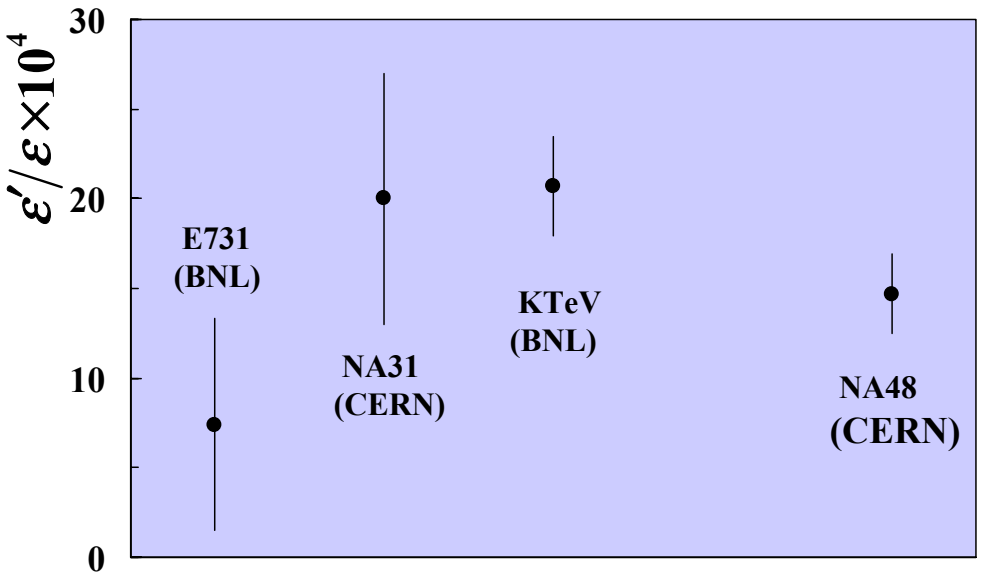
$$\eta_{00} = \frac{<\pi^0\pi^0\,|\,H_w\,|\,K_L>}{<\pi^0\pi^0\,|\,H_w\,|\,K_S>} = \varepsilon - 2\varepsilon'$$

$$\eta_{+-} = \frac{<\pi^+\pi^-\,|\,H_w\,|\,K_L>}{<\pi^+\pi^-\,|\,H_w\,|\,K_S>} = \varepsilon + \varepsilon'$$

ε'/ε measures $\not{CP}$

ε'/ε A status report

Great improvement in the experimental determination !



$$(\varepsilon'/\varepsilon)_{W.Av.} = (15.7\pm2.4)\times10^{-4}$$

KTeV+NA48

$$(17.7\pm1.8)\times10^{-4}$$

Theory . . . . . Work in progress → Final State Interactions

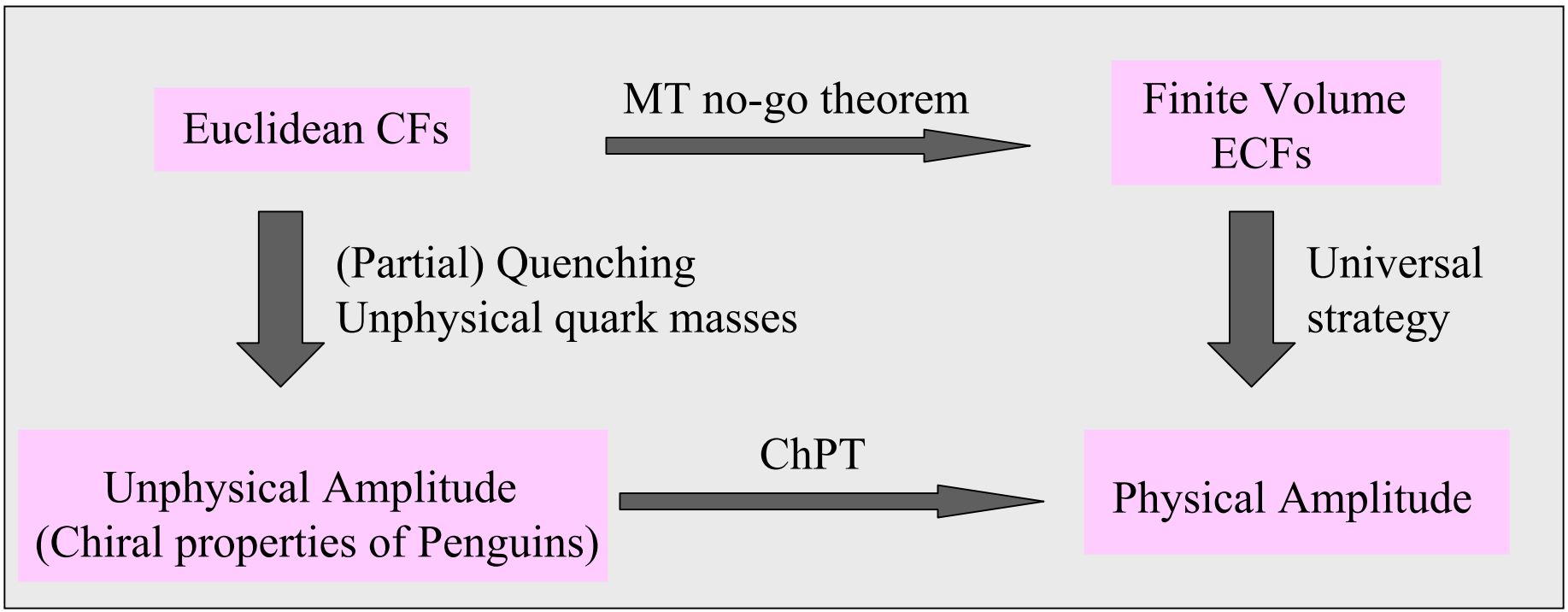
E.P.,Pich, PRL 84 (2000)
E.P., Pich, Scimemi NPB617 (2001)

$$\varepsilon'/\varepsilon = (17.0\pm9)\times10^{-4}$$

Kaon Decays on a Lattice

$$< H_{eff}^{\Delta S=1} > \;=\; \Sigma_i \, C_i(\mu) \cdot < \pi\,\pi | Q_i(\mu) | K >$$

Short distance — Long distance



Where we were back in 1964 . . . .

. . . . Now looking for the origin of CP violation
at large scales and small scales