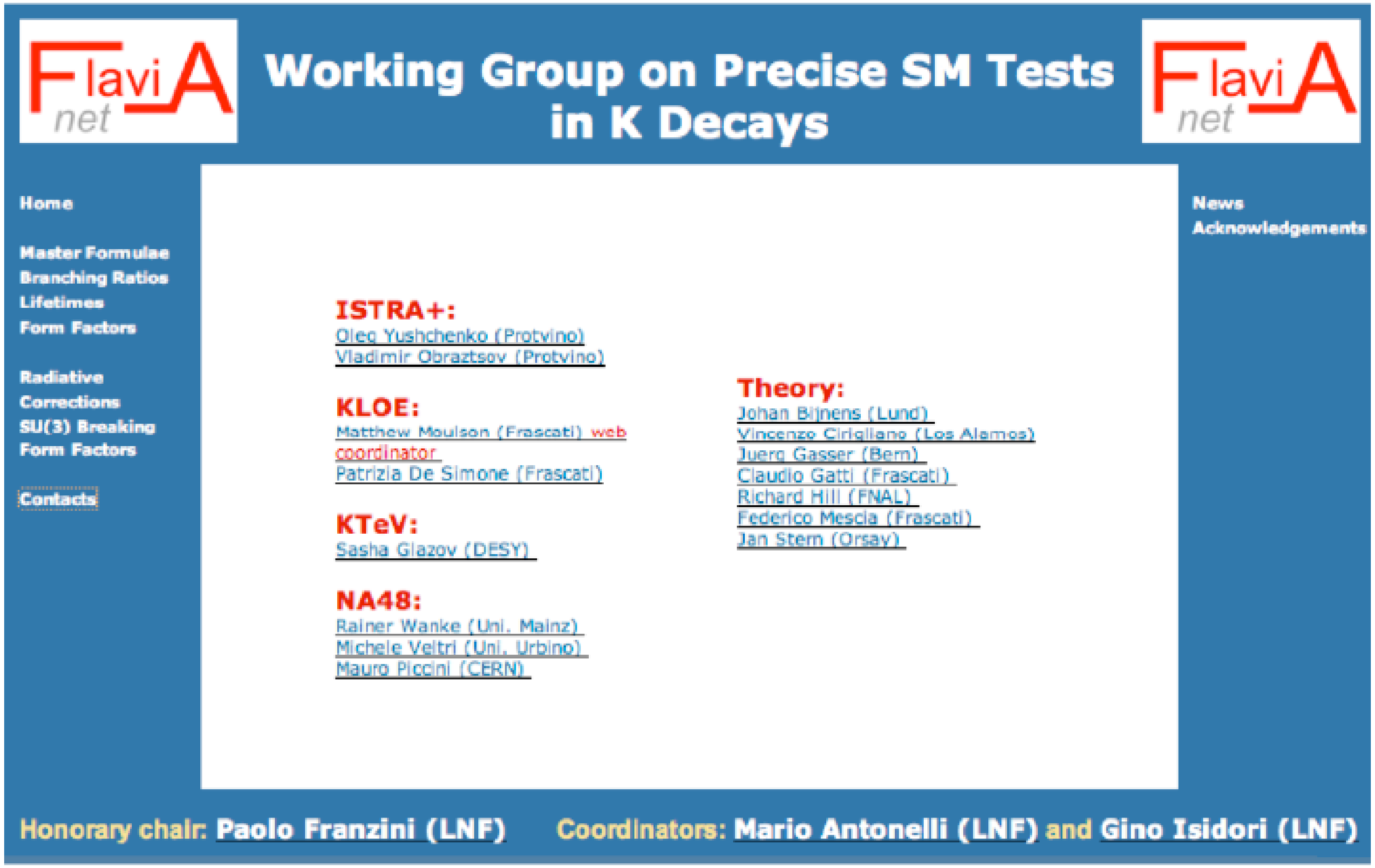
Precision Test from Kaons



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on behalf of Kaon FlaviaNet Working Group

16 November, 2007

$V_{us} f_+(0)$ & V_{us}/V_{ud}

Interest for V_{us} meaurement with kaons

in SM, universality of weak coupling dictates

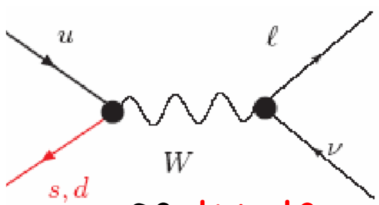
$$G_{CKM}^2 = (|V_{ud}|^2 + |V_{us}|^2)\, G^2_F \text{ (from } \mu \text{ lifetime)} = (g_w/M_w)^2 \quad [V_{ub} \text{ negligible}]$$

we can test for possible breaking of the conditions

<u>CKM unitarity</u> $(|V_{ud}|^2 + |V_{us}|^2) = 1$

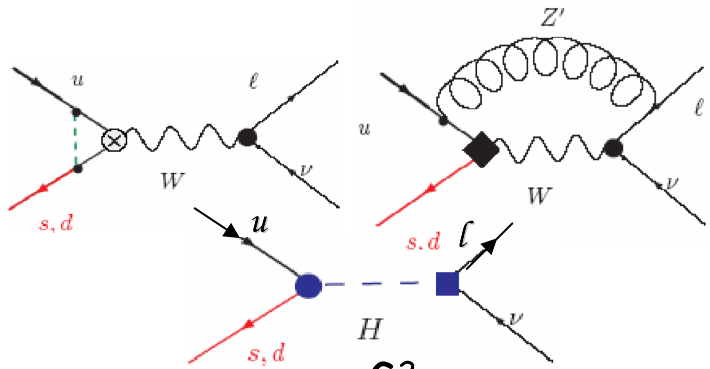
<u>Universality</u> $G_{CKM}^2 = (|V_{ud}|^2 + |V_{us}|^2)\, G^2_F$

Standard Model



$\propto G^2_F |V_{uq}|^2$

+



$\propto G^2_F\, \varepsilon$

$\varepsilon \sim 10^{-3}$

$\varepsilon \sim 10^{-2}$

New Physics

<u>G_{CKM} = 1.16XX(04) x10^{-5} GeV^{-2} → V_{us} at 0.5%</u> makes CKM unitarity test with kaons competitive to Electro-Weak precision test [$G_{e.w.}$ = 1.1655(12)x10^{-5} GeV^{-2}]

reference value G_F = 1.166371(6)x10^{-5} GeV^{-2} (from μ lifetime)

V_{us} from semileptonic kaon decays

FlaviA net [Ademollo Gatto]

Vector transition protected against SU(3) corrections:

$$\Gamma(K_{\ell 3(\gamma)}) = \frac{C_K^2 M_K^5}{192\pi^3} S_{EW} G_F^2 |V_{us}|^2 |f_+^{K^0\pi^-}(0)|^2 \times I_{K\ell}(\{\lambda\}_{K\ell}) (1 + 2\Delta_K^{SU(2)} + 2\Delta_{K\ell}^{EM})$$

with $K \in \{K^+, K^0\}$; $\ell \in \{e, \mu\}$, and:

C_K^2 1/2 for K^+, 1 for K^0

S_{EW} Universal SD EW correction (1.0232)

Inputs from theory:

$f_+^{K^0\pi^-}(0)$ Hadronic matrix element (form factor) at zero momentum transfer ($t = 0$)

$\Delta_K^{SU(2)}$ Form-factor correction for $SU(2)$ breaking

$\Delta_{K\ell}^{EM}$ Form-factor correction for long-distance EM effects

Inputs from experiment:

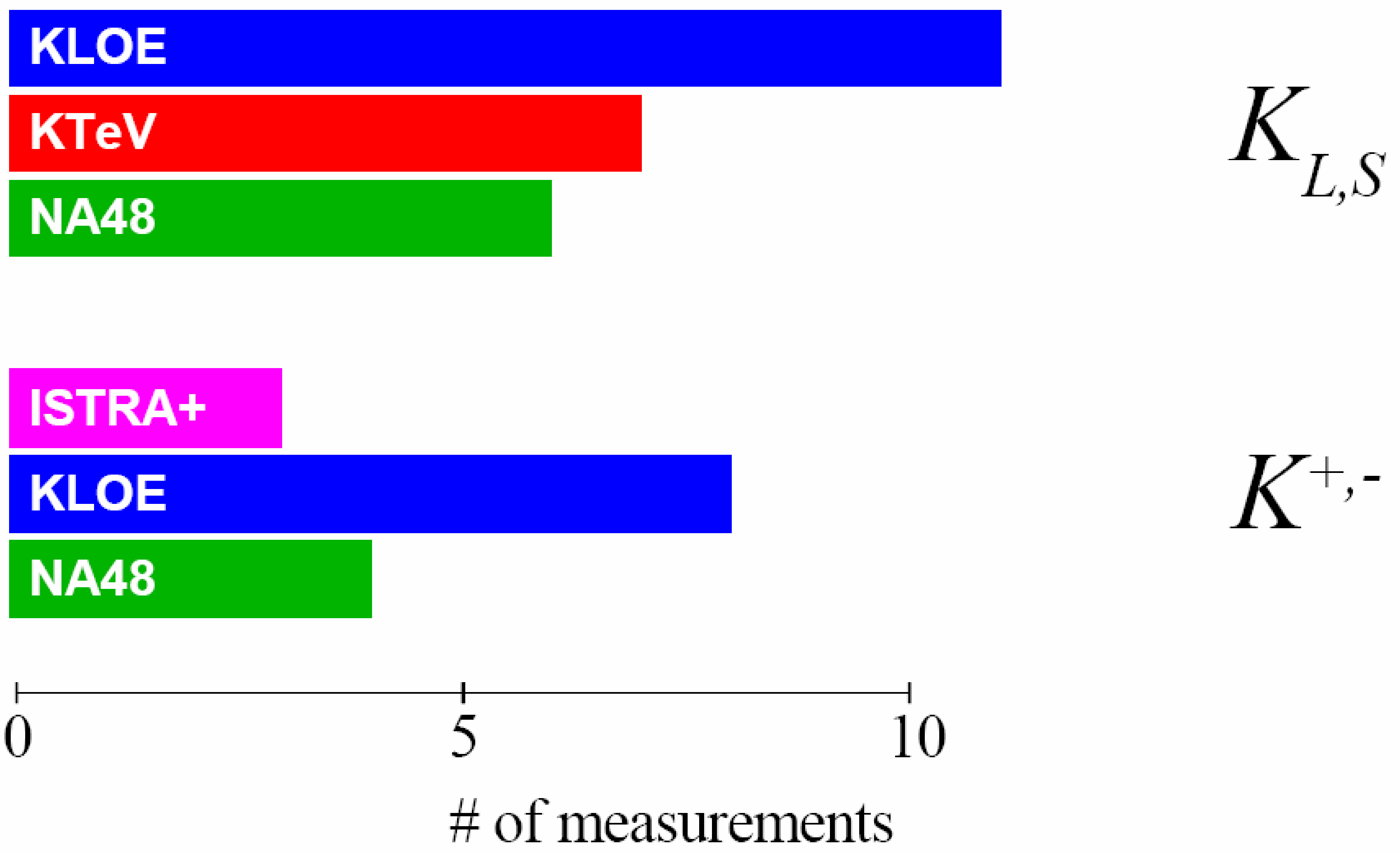
$\Gamma(K_{\ell 3(\gamma)})$ Rates with well-determined treatment of radiative decays:

- Branching ratios
- Kaon lifetimes

$I_{K\ell}(\{\lambda\}_{K\ell})$ Integral of dalitz density (includes ff) over phase space:

- K_{e3}: Only λ_+ (or λ_+', λ_+'')
- $K_{\mu 3}$: Need λ_+ and λ_0

measurements since '04



K_L Branching Ratios

FlaviA net

KTeV
PRD 70 (2004)

5 ratios of main BRs from independent samples of 10^5-10^6 events collected with a single trigger

2-track ratios

BR($K_{\mu 3}/K_{e3}$) = 0.6640(26)

BR($\pi^+\pi^-\pi^0/K_{e3}$) = 0.3078(18)

BR($\pi^+\pi^-/K_{e3}$) = 0.004856(28)

Neutral ratio

BR($2\pi^0/3\pi^0$) = 0.004446(25)

Mixed ratio

BR($3\pi^0/K_{e3}$) = 0.4782(55)

6 decays = 99.93% of K_L width
KTeV combines ratios to extract BRs

Our fit uses these BR ratios
Correlations available

NA48
PLB 602 (2004)

K_L beam only, 2-track sample, 80M events (6M signal)

$$\frac{\mathrm{BR}(K_{e3})}{\mathrm{BR(2\ track)}} = 0.4978(35) \approx \frac{\mathrm{BR}(K_{e3})}{1 - \mathrm{BR}(3\pi^0)}$$

NA48
preliminary

From BR($K_L \to 3\pi^0$)/BR($K_S \to 2\pi^0$)

$$\mathrm{BR}(3\pi^0) = 0.1966(34)$$

K_L Branching Ratios

KLOE
PLB 632 (2006)

Absolute BRs: K_L decays tagged by $K_S \to \pi^+\pi^-$
Errors on absolute BRs dominated by error on τ_L
Dependence on τ_L of geometrical efficiency known

For KLOE results: Set Σ_x BR($K_L \to x$) = 1 and solve for τ_L
For our fit: Use unconstrained BRs with dependence on τ_L

BR$^{(0)}$($Ke3$) = 0.4049(21)
BR$^{(0)}$($K\mu3$) = 0.2726(16)
BR$^{(0)}$($3\pi^0$) = 0.2018(24)
BR$^{(0)}$($\pi^+\pi^-\pi^0$) = 0.1276(15)

at $\tau_L^{(0)}$ = 51.54 ns, with
d BR/BR = 0.67$d\tau_L/\tau_L$

Correlations available

KLOE
PLB 626 (2005)

Lifetime: Direct measurement with $K_L \to 3\pi^0$ events
High, uniform reconstruction efficiency over 0.4λ_L
Independent of BR measurement

τ_L = **50.92(30) ns** cf. Vosburgh '72: τ_L = 51.54(44) ns

Results of fit to K_L BR's, τ

18 input measurements:

- **5 KTeV** ratios
- **NA48** BR($Ke3$/2 track)
- **NA48** $\Gamma(3\pi^0)$ [prelim.]
- **4 KLOE** BRs
  with dependence on τ_L
- **KLOE**, **NA48** BR($\pi^+\pi^-/Kl3$)
- **KLOE**, **NA48** BR($\gamma\gamma/3\pi^0$)
- **PDG** ETAFIT BR($2\pi^0/\pi^+\pi^-$)
- **KLOE** τ_L from $3\pi^0$
- **Vosburgh '72** τ_L

1 constraint: Σ BR = 1

Parameter	Value	S
BR($Ke3$)	0.40563(74)	1.1
BR($K\mu3$)	0.27047(71)	1.1
BR($3\pi^0$)	0.19507(86)	1.2
BR($\pi^+\pi^-\pi^0$)	0.12542(57)	1.1
BR($\pi^+\pi^-$)	$1.9966(67)\times10^{-3}$	1.1
BR($2\pi^0$)	$8.644(42)\times10^{-4}$	1.3
BR($\gamma\gamma$)	$5.470(40)\times10^{-4}$	1.1
τ_L	51.173(200) ns	1.1

χ^2/ndf = 20.2/11 (4.3%)

compare PDG '07: 28.0/14 (1.42%)

PDG omits $3\pi^0$ results → large pulls for $Ke3$ and $3\pi^0$ measurements
Reflected in scale factors large errors for these BRs in PDG '07 fit

Comparison complicated: calculation of scale factors changed in PDG '07

BR($K_S \to \pi e \nu$) and K_S lifetime

KLOE
PLB 636 (2006)

Using tagged K_S beam

BR($K_S \to \pi e \nu$)/BR($K_S \to \pi^+\pi^-$) = 10.19(13) × 10^{-4}

KLOE
EPJC 48 (2006)

410 pb^{-1}, averaged with KLOE ’02 result (17 pb^{-1})

BR($K_S \to \pi^+\pi^-$)/BR($K_S \to \pi^0\pi^0$) = 2.2549(54)

These two measurements completely determine main K_S BRs

BR($K_S \to \pi e \nu$) = 7.046(91) × 10^{-4}

PDG

τ_S = 0.08958(5) ns

From fit to *CP* parameters, does not assume *CPT*

Dominated by **NA48 ’02** and **KTeV ’03** τ_S values

Recent results on $K^{\pm}$ BR's

NA48/2
EPJC 50 (2007)

Final results on BR($K^{\pm}e3/\pi\pi^0$) and BR($K^{\pm}\mu3/\pi\pi^0$)

BR($K^{\pm}e3$)/BR($\pi\pi^0$) = 0.2470(9)(4)

BR($K^{\pm}\mu3$)/BR($\pi\pi^0$) = 0.1637(6)(3)

ISTRA+
arXiv:0704.2052

Final value for BR($K^{-}e3/\pi\pi^0$) submitted for publication

BR($K^{-}e3$)/BR($\pi\pi^0$) = 0.2449(4)(14)

KLOE
arXiv:0707.2532

Absolute BR($K^{\pm}e3$) and BR($K^{\pm}\mu3$) measurements

Separate measurements for each charge

Tagged by $K \to \mu\nu$ and $K \to \pi\pi^0$: 8 measurements total

BR$^{(0)}$($K^{\pm}e3$) = 4.965(53)%

BR$^{(0)}$($K^{\pm}\mu3$) = 3.233(39)%

KLOE
arXiv:0707.2654

Absolute BR($\pi\pi^0$) measurement

BR($K^{+} \to \pi^{+}\pi^{0}$) = 0.20658(60)(95)

Uses $K^{-} \to \mu^{-}\nu$ to tag 2-body K decays

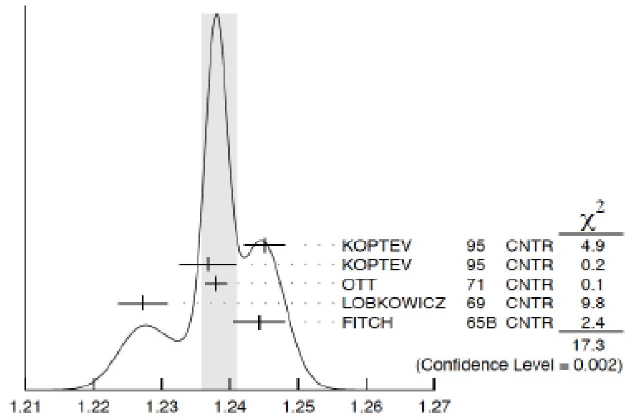
Counts $K^{+} \to \pi^{+}\pi^{0}$ from decay-momentum spectrum

K± lifetime

PDG average

12.385(25) ns
S = 2.1

Poor consistency
Needs confirmation



Using $K \to \mu\nu$-tagged vertices in drift chamber:

KLOE arXiv:0705.4408

Fit to t^* distribution from decay length

Coverage: 16-30 ns → $1.1\tau_\pm$

Evaluation of t^* includes dE/dx (2 mm steps)

$\tau_\pm$ **= 12.367(44)(65) ns**

Fit to t^* distribution from decay time

Coverage: 13-42 ns → $2.3\tau_\pm$

$\tau_\pm$ **= 12.391(49)(25) ns**

ρ **= 0.34**

Results of fit to $K^{\pm}$ BR's, τ

26 input measurements:

- 5 older τ values in PDG
- 2 KLOE τ
- KLOE BR $\mu\nu$, $\pi\pi^0$
- KLOE $Ke3$, $K\mu3$ BRs
  with dependence on τ
- ISTRA+ BR $Ke3/\pi\pi^0$
- NA48/2 BR $Ke3/\pi\pi^0$, $K\mu3/\pi\pi^0$
- E865 BR $Ke3/K$Dal
- 3 old BR $\pi\pi^0/\mu\nu$
- 2 old BR $Ke3$/2 body
- 3 $K\mu3/Ke3$ (2 old)
- 2 old + 1 KLOE results on 3π

1 constraint: Σ BR = 1

Parameter	Value	S
BR($\mu\nu$)	63.569(113)%	1.1
BR($\pi\pi^0$)	20.644(80)%	1.1
BR($\pi\pi\pi$)	5.5953(308)%	
BR($Ke3$)	5.0780(258)%	1.2
BR($K\mu3$)	3.3650(271)%	1.7
BR($\pi\pi^0\pi^0$)	1.7495(261)%	1.1
$\tau_{\pm}$	12.3840(193) ns	1.7

χ^2/ndf = 42/20 (0.31%)

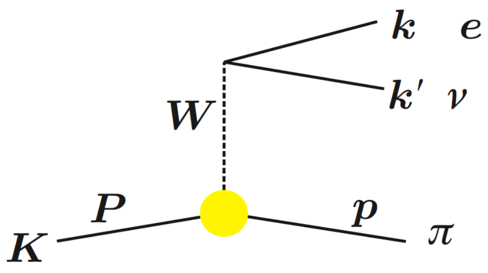
compare PDG '07: 30.0/19 (5.2%)

Improves to χ^2/ndf = 24.3/16 (8.4%) with no changes to central values or errors, if 5 older $\tau_{\pm}$ measurements replaced by PDG avg (with S = 2.1)

K_{l3} form factor slopes

Hadronic matrix element:

$$\langle\pi|\, J_\alpha \,|K\rangle = f(0) \times [\tilde{f}_+(t)(P+p)_\alpha + \tilde{f}_-(t)(P-p)_\alpha]$$



$f_-(t)$ term only important for $K_{\mu 3}$.

For $K_{\mu 3}$, use $f_+(t)$ and $f_0(t) = f_+(t) + \dfrac{t}{m_K{}^2 - m_{\pi^+}{}^2} f_-(t)$

For V_{us}, need integral over phase space of squared matrix element

Expand form factor:

Linear: $\tilde{f}_{+,0}(t) = 1 + \lambda_{+,0}\,[t/m_{\pi^+}{}^2]$

Quadratic: $\tilde{f}_{+,0}(t) = 1 + \lambda'_{+,0}\,[t/m_{\pi^+}{}^2] + 1/2\, \lambda''_{+,0}\,[t/m_{\pi^+}{}^2]^2$

Pole: $\tilde{f}_{+,0}(t) = \dfrac{M_{V,S}{}^2}{M_{V,S}{}^2 - t}$ $\qquad \lambda' = (m_{\pi^+}/M)^2$

$\lambda'' = 2\lambda'^2$

Fits to t-distribution give poor sensitivity to quadratic terms

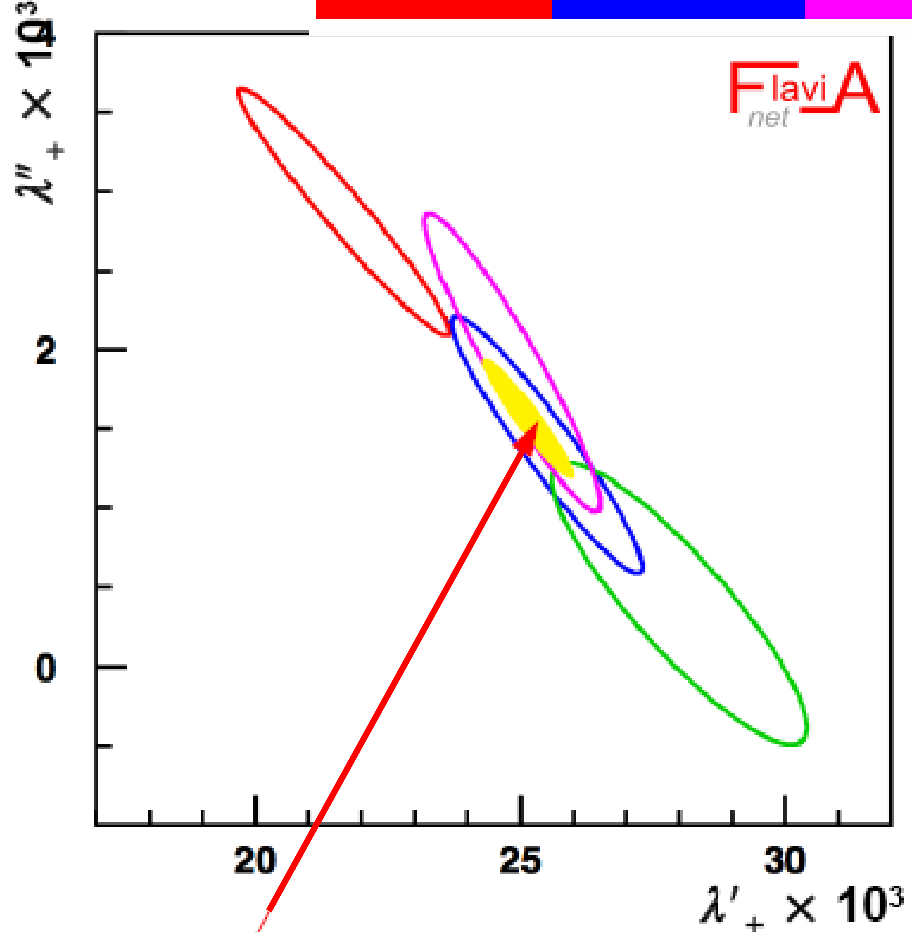
Results on K_{e3} form factor slopes

FlaviA net

	Type	$\lambda'_+ \times 10^3$	$\lambda''_+ \times 10^3$	Analysis
KTeV PRD 70 (2004)	K_L	21.7 ± 2.0	2.9 ± 0.8	$t_\perp^\pi$
KLOE PLB 636 (2006)	K_L	25.5 ± 1.8	1.4 ± 0.8	t from K_S
NA48 PLB 604 (2004)	K_L	28.0 ± 2.4	0.4 ± 0.9	$(E_\nu^*, t_{\mathrm{low}}, t_{\mathrm{high}})$
ISTRA+ PLB 581 (2004)	K^-	24.9 ± 1.7	1.9 ± 0.9	(y, z) 2C fit

K_{e3} slopes comparison

slopes from **KTeV** **KLOE** **ISTRA+** **NA48** **This fit**



Slope parameters $\times 10^3$		
λ'_+	=	25.15 ± 0.87
λ''_+	=	1.57 ± 0.38
$\rho(\lambda'_+, \lambda''_+)$	=	-0.941
χ^2/ndf	=	5.3/6 (51%)

significance of $\lambda''_+ > 4\sigma$

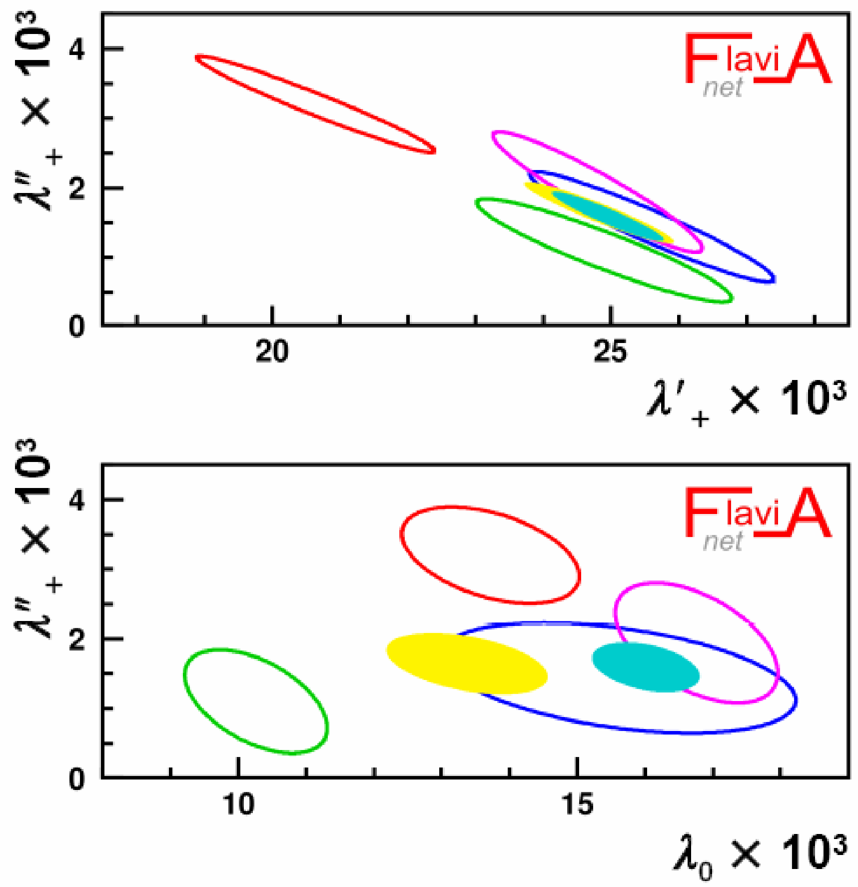
good agreement with the pole parametrization as expected from dispertion relations (Stern et al., Pich et al.)

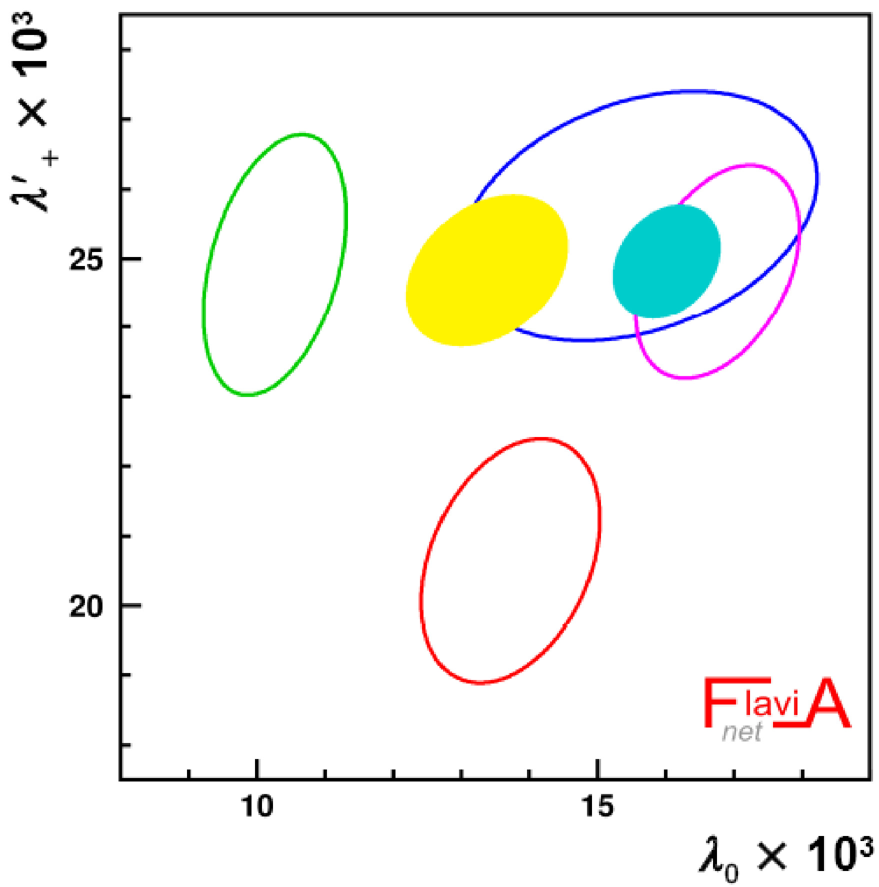
Results on $K_{\mu3}$ form factor slopes

	$\lambda'_+ \times 10^3$	$\lambda''_+ \times 10^3$	$\lambda_0 \times 10^3$	Analysis
KTeV PRD 70 (2004)	17.0 ± 3.7	4.4 ± 1.5	12.8 ± 1.8	$(t_\perp^\mu, M_{\pi\mu})$
KLOE arXive:0710.4470	25.6 ± 1.8	1.5 ± 0.8	15.4 ± 2.1	E_ν^*
NA48 PLB 647 (2007)	20.5 ± 3.3	2.6 ± 1.3	9.5 ± 1.4	(y, z) low
ISTRA+ PLB 589 (2004)	23.0 ± 6.4	2.3 ± 2.3	17.1 ± 2.2	(y, z) 2C fit

K_{l3} slopes comparison

e3 – μ3 averages from **KTeV** **KLOE** **ISTRA+** **NA48**





Kl3 fit, no NA48 *Kμ3*: χ^2=12.6/10 (24.9%) | *Kl3* fit, all data, χ^2=54/13 (10^{-6})

K_{l3} - beyond quadratic parametrization (I)

because of the strong correlation between λ_0' and λ_0'' , use of the linear rather than the quadratic parametrization gives $\lambda_0 \sim \lambda_0' + 3.5\,\lambda_0''$
to clarify this ➔ is necessary a ff parametrization with t and t^2 terms but one parameter

the Callan-Treiman relation fixes the value of $f_0(t) = \tilde{f}_0(t) f_+(0)$ at $t=\Delta_{K\pi}= m_K^2-m_\pi^2$

$$\tilde{f}_0(\Delta_{K\pi}) = \frac{f_K}{f_\pi}\frac{1}{f_+(0)} + \Delta_{CT}$$

where $\Delta_{CT} = -3.5 \times 10^{-3}$

recent parametrization from Stern & coll. *(PLB638 -2006)* allows such constraint to be exploited ➔ a dispersion relation for $\ln f_0(t)$ is subtracted at t=0 and $t=\Delta_{K\pi}$, giving

$$\tilde{f}_0(t) = \exp\left[\frac{t}{m_K^2 - m_\pi^2}(\ln C - G(t))\right]$$

such that $\tilde{f}_0(\Delta_{K\pi}) = C$, G(t) is derived from Kπ scattering data
as suggested by Stern & coll. a good approximation is given by

$$\tilde{f}_0(t) = 1+\lambda_0\frac{t}{m^2} + \frac{\lambda_0^2 + 0.000416}{2}\left(\frac{t}{m^2}\right)^2 + \frac{\lambda_0^3 + 3\text{x}0.000416\lambda_0 + 0.0000272}{6}\left(\frac{t}{m^2}\right)^3$$

similar parametrization is obtained for $\tilde{f}_+(t)$

K_{l3} - beyond quadratic parametrization (II)

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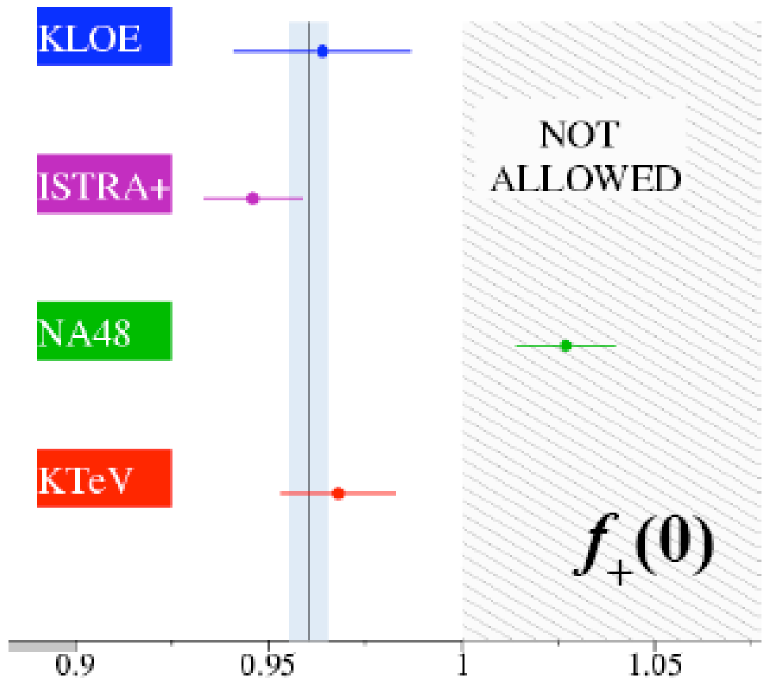
from Callan-Treaman relation we can give an evaluation of $f_+(0)$ given
f_K/f_π = 1.189(7) HPUKQCD 07

	Log *C direct*	Log *C* from $\lambda'_0, \lambda'_+, \lambda''_+$
KTeV PRD 70 (2004)	Not available	0.203 ± 0.015
KLOE **preliminary**	0.207 ± 0.024	0.207 ± 0.023
NA48 PLB 647 (2007)	0.144 ± 0.014	0.144 ± 0.012
ISTRA+ PLB 589 (2004)	Not available	0.226 ± 0.013

$f_+(0)$ = 0.961(5) RBC/UKQCD 07



Results of fit to the slopes

10 input measurements:

- KLOE $Ke3$, $K\mu3$ ff slopes
- ISTRA+ $Ke3$, $K\mu3$ ff slopes
- KTeV $Ke3$, $K\mu3$ ff slopes
- NA48 $Ke3$ ff slopes
  ($K\mu3$ ff not included)

2 Lattice determinations:

HPQCD/UKQCD $f_K/f_\pi = 1.189(7)$

UKQCD/RBC $f_+(0) = 0.9609(51)$

1 constraint:

$$C\, f_+(0) = (f_K/f_\pi + \Delta_{CT})$$

Slope parameters × 10³:

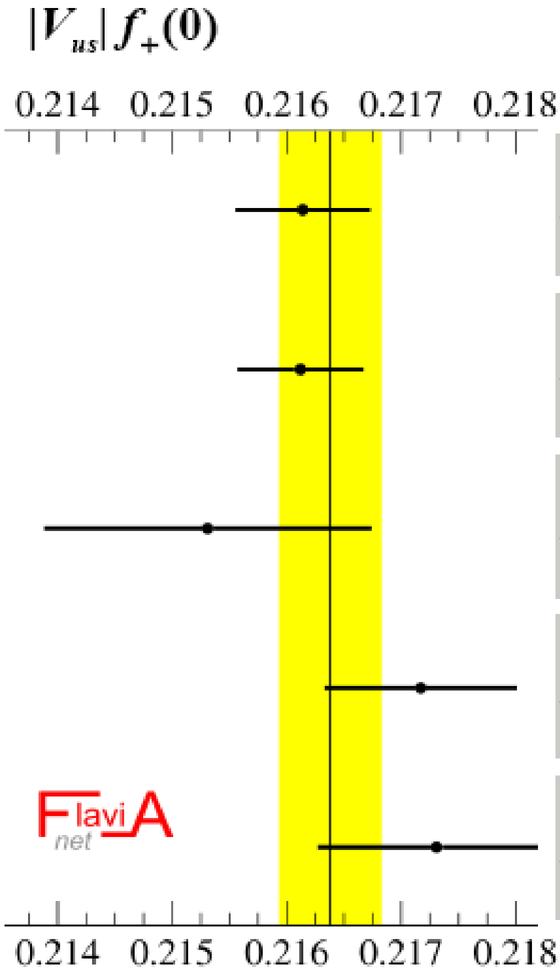
$$\lambda^c_+ = 25.63 \pm 0.21$$
$$\lambda^c_0 = 14.72 \pm 0.53$$
$$f_+(0) = 0.9602 \pm 0.0046$$
$$f_K/f_\pi = 1.1901 \pm 0.0061$$
$$\chi^2/\text{ndf} = 13.3/10\ (0.35)$$

Good agreement between lattice determinations and slopes measurements

Accuracy improved by 10-20%

~10% additional using $\Gamma_{K\mu3}/\Gamma_{Ke3}$~F(λ^c_0)

$V_{us}f_+(0)$ from K_{l3} data



Approx. contrib. to % err from:

		% err	BR	τ	Δ
K_Le3	**0.21614(59)**	**0.27**	0.09	0.19	0.15
$K_L\mu3$	**0.21612(55)**	**0.25**	0.10	0.18	0.15
K_Se3	**0.21531(143)**	**0.67**	0.65	0.03	0.15
$K^\pm e3$	**0.21717(84)**	**0.39**	0.26	0.09	0.26
$K^\pm\mu3$	**0.21731(104)**	**0.48**	0.40	0.09	0.26

Average: $|V_{us}|$ = 0.22535(116) χ^2/ndf =1.78/4 (78%)

$f_+(0)$ = 0.961(5) from UKQCD/RBC '07

V_{us}/V_{ud} & BR($K^+ \to \mu^+\nu(\gamma)$)

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Marciano '04

$$\frac{\Gamma(K^\pm \to \mu^\pm\nu(\gamma))}{\Gamma(\pi^\pm \to \mu^\pm\nu(\gamma))} = \frac{|V_{us}|^2 f_K^2 m_K (1 - m_\mu^2/m_K^2)^2}{|V_{ud}|^2 f_\pi^2 m_\pi (1 - m_\mu^2/m_\pi^2)^2} \times 0.9930(35)$$

Uncertainty from SD virtual corrections

KLOE
PLB 636 (2006)

BR($K^+ \to \mu^+\nu(\gamma)$) = 0.6366(17)

Uses $K^- \to \mu^-\nu$ to tag 2-body K decays

Counts $K^+ \to \mu^+\nu$ from decay-momentum spectrum

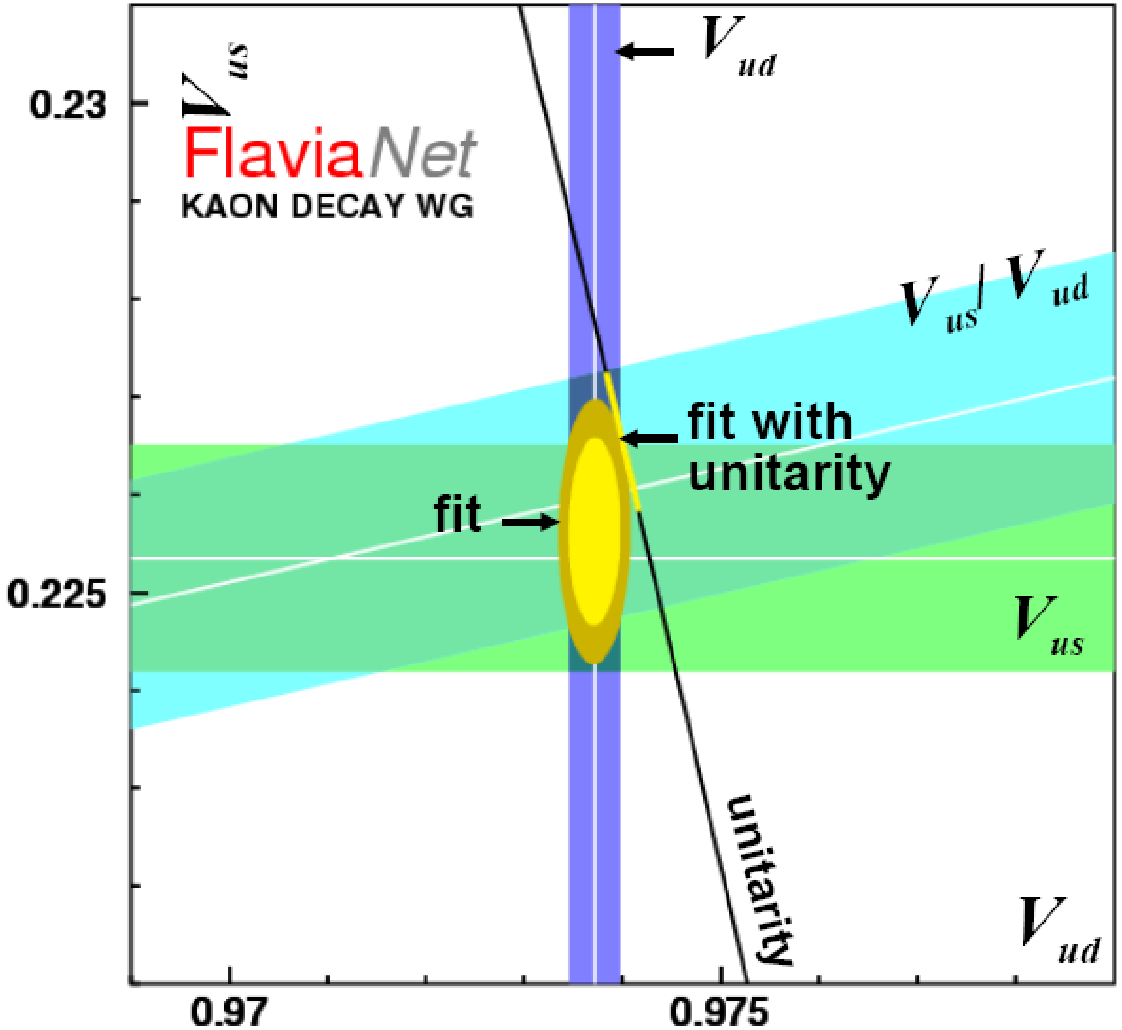
Use KLOE BR($K^+ \to \mu^+\nu(\gamma)$) instead of value from BR/lifetime fit:
Error slightly larger, but radiative contribution under better control

V_{us}/V_{ud} = 0.2321(13)

V_{us} - V_{ud} plane

$f_+(0)$ = 0.961(5) from UKQCD/RBC '07
$|V_{us}|$ = 0.22535(116) from K_{l3}

f_K/f_π = 1.189(7) from UKQCD '07
$|V_{us}/V_{ud}|$ = 0.2321(13) from K_{l2}



fit results, no constraint

V_{ud} = 0.97372(26)
V_{us} = 0.2256(10)
χ^2/ndf = 0.17/1 (68%)

fit results, unitarity constraint

$V_{us} = \sin\theta_c = \lambda$ = 0.2265(7)
χ^2/ndf = 2.24/2 (33%)

agreement with unitarity 1σ

Unitarity test of CKM: G_F universality

comparison between weak couplings from K decays (G_{CKM}) and from τ_μ (G_F)

$$G_F^2 \equiv G_{CKM}^2 = (|V_{ud}|^2 + |V_{us}|^2)\, G_F^2$$

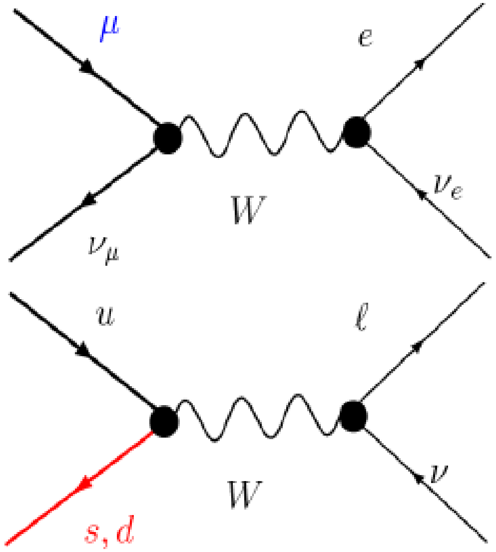
agreement within ~ 1.4σ

$G_F = 1.166371(6) \times 10^{-5}\ GeV^{-2}$

FlaviAnet

$G_{CKM} = 1.16581(39) \times 10^{-5}\ GeV^{-2}$

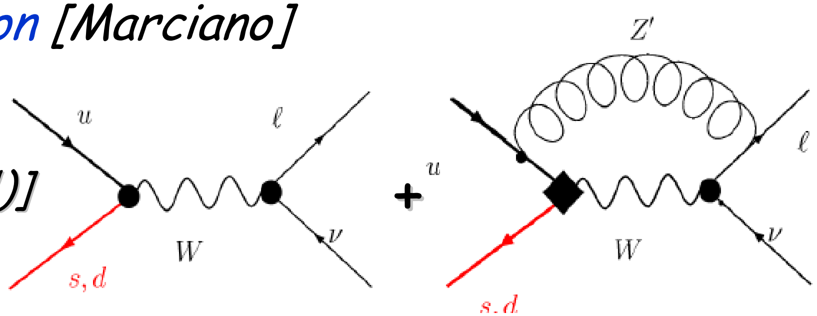
(39): $18 \oplus 20$ from V_{us}, V_{ud}



constraints on NP models, e.g. SO(10) Zχ boson [Marciano]

$G_F = G_{CKM}\,[1 - .007 \times 8/3 \times \ln(M_{Z\chi}/M_W)/(M_{Z\chi}^2/M_W^2 - 1)]$

implies $M_{Z\chi} > 1.4$ TeV @ 95% CL



$K_{\mu 2}$: sensitivity to charged Higgs

helicity suppressed decays can be sensitive to H^+ exchange, $\Gamma(K \to \mu\nu)$

$$\frac{\Gamma(M \to \ell\nu)}{\Gamma_{SM}(M \to \ell\nu)} = \left[1 - \tan^2\beta \left(\frac{m_{s,d}}{m_u + m_{s,d}}\right) \frac{m_M^2}{m_H^2}\right]^2$$

M = K,π

[Hou, Isidori, Paradisi]

sizable effects in $\Gamma(K \to \mu\nu)$ only

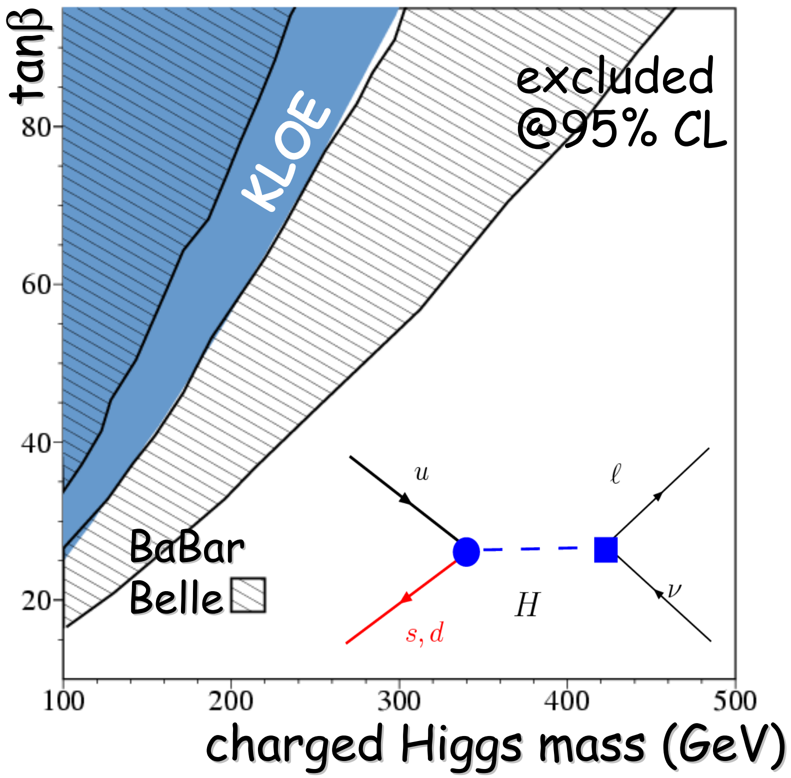
SM prediction, V_{us} from K_{l3} decays, V_{ud} from β-decays and $\pi_{\mu 2}$

FlaviA net BR($K^+ \to \mu\nu(\gamma)$) = 0.6353(77)

Measurement

KLOE BR($K^+ \to \mu\nu(\gamma)$) = 0.6366(17)

compare sensitivity with $B \to \tau\nu$
(BaBar Belle average)



LF violation test

Lepton universality from K_{l3}

For each state of kaon charge, we evaluate:

$$r_{\mu e} = \frac{(R_{\mu e})_{\text{obs}}}{(R_{\mu e})_{\text{SM}}} = \frac{\Gamma_{\mu 3}}{\Gamma_{e3}} \cdot \frac{I_{e3}\,(1+\delta_{e3})}{I_{\mu 3}\,(1+\delta_{\mu 3})} = \frac{[|V_{us}|\, f_+(0)]^2_{\mu 3,\text{ obs}}}{[|V_{us}|\, f_+(0)]^2_{e3,\text{ obs}}} = \frac{g_\mu^2}{g_e^2}$$

$r_{\mu e}$ = 1.0003(42) from Kl3

$\tau \to l\nu\nu$ decays:

$(r_{\mu e})_\tau$ = 1.0005(41) [PDG07]

$\pi \to l\nu$ decays:

$(r_{\mu e})_{\pi l2}$ = 1.0034(30) see Erler, Ramsey-Musolf '06

0.1% on gauge couplings

$r_{\mu e}$ = 1.0019(21) K, τ, π average

Lepton universality from $R_K = K_{e2}/K_{\mu 2}$

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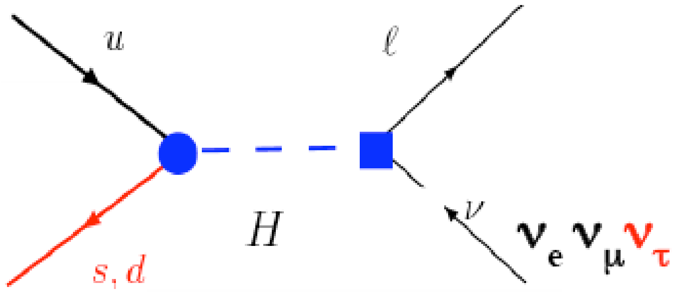
- extremely well known within SM $R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$
- in MSSM, LFV could give up to % deviations [Masiero, Paradisi, Petronzio]

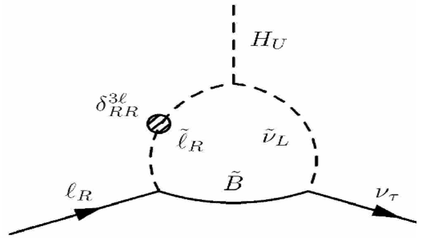
NP dominated by contribution of $e\nu_\tau$

$$R_K \approx \frac{\Gamma(K \to e\nu_e) + \Gamma(K \to e\nu_\tau)}{\Gamma(K \to \mu\nu_\mu)}$$



with effective coupling

$$eH^{\pm}\nu_\tau \to \frac{g_2}{\sqrt{2}} \frac{m_\tau}{M_W} \Delta_R^{31} \tan^2\beta$$



$$R_K \approx R_K^{SM}\left[1 + \frac{m_K^4}{m_H^4} \frac{m_\tau^2}{m_e^2} |\Delta^R_{31}|^2 \tan^6\beta\right]$$

1% effect ($\Delta^R_{31} \sim 5\times10^{-4}$, $\tan\beta \sim 40$, $m_{H+} \sim 500$ GeV) not unnatural
present accuracy on R_K @ 6% (PDG06) ➔ new precise measurements @ < 1%

$R_K = K_{e2}/K_{\mu 2}$: new results

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KLOE
arXiv:0707.4623

Preliminary result with 1.7 fb^{-1} (~ 8000 events)

$BR(K^{\pm}e2)/BR(K^{\pm}\mu 2) = 2.55(5)(5) \times 10^{-5}$

X 2 more data(1.7/2.5fb^{-1}) + 30%more from an independent sample σR_K ~ 1%

NA48/2 (2005)
Preliminary

Preliminary result with 2003 data (~ 4500 events)

$BR(K^{\pm}e2)/BR(K^{\pm}\mu 2) = 2.416(43)(24) \times 10^{-5}$

NA48/2 (2007)
Preliminary

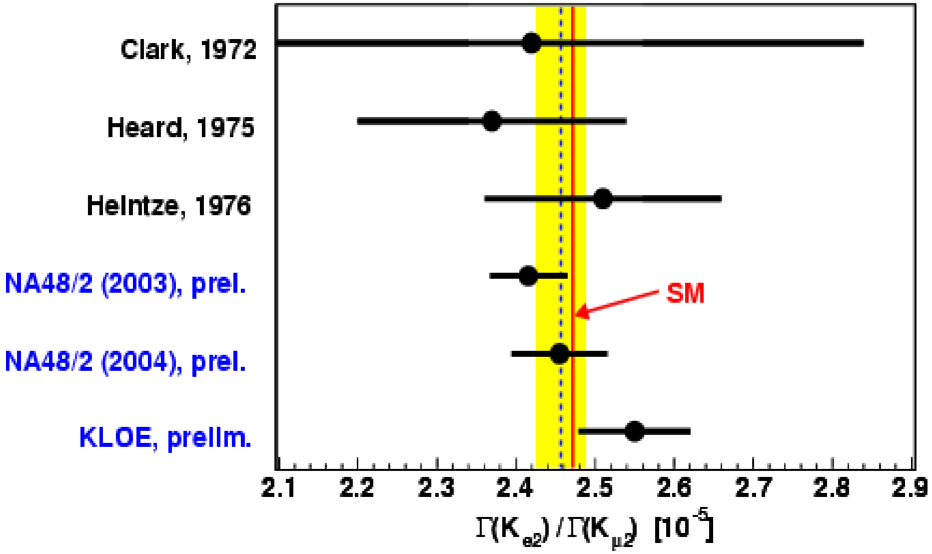
Preliminary result with 2004 data (~ 3500 events)

$BR(K^{\pm}e2)/BR(K^{\pm}\mu 2) = 2.455(45)(41) \times 10^{-5}$

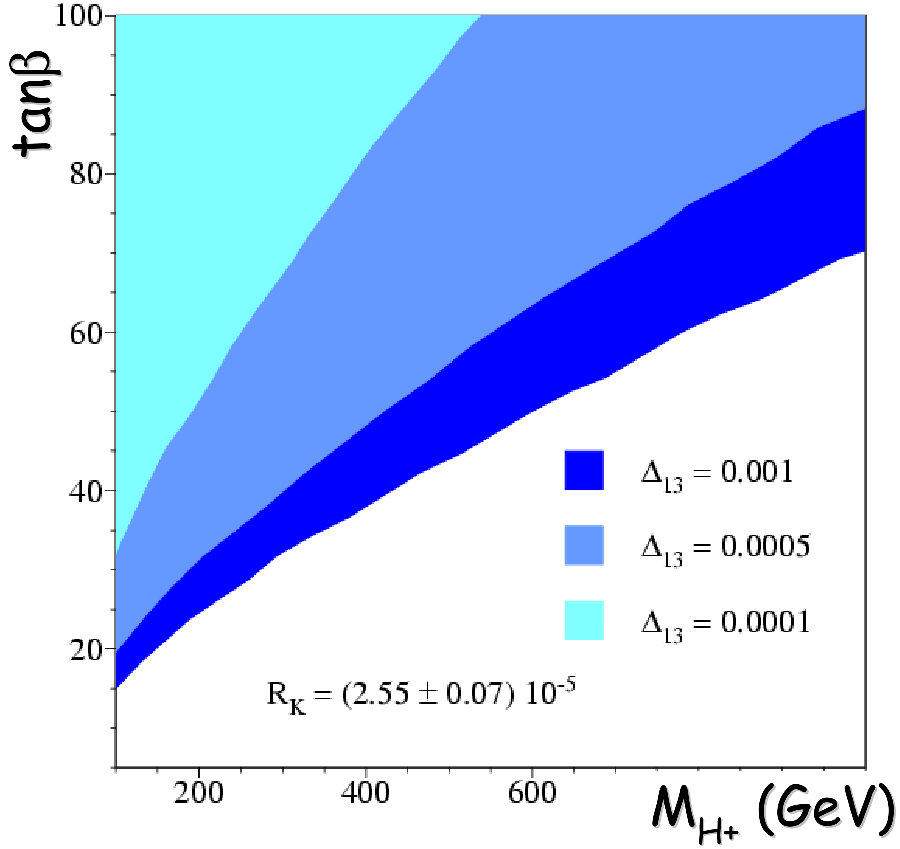
X 10 more data from new run (end in October) σR_K ~ 0.3%

$R_K = K_{e2}/K_{\mu2}$: new results

sensitivity shown as 95% C.L. excluded regions in the $\tan\beta$ – M_{H+} plane, for fixed values of the 1-3 slepton-mass matrix element, $\Delta_{13} = 10^{-3}, 0.5\times10^{-3}, 10^{-4}$



$BR(K_{e2})/BR(K_{\mu2}) = 2.457(32) \times 10^{-5}$



Conclusions

$V_{us} f_+(0)$ is known at ~0.2%

- *improved accuracy expected on τ'_{KL}, BR(K_Se3) (KLOE x 4 data)*
- *complete the measurements of the dominant BR($K^\pm$) decays (KLOE)*
- *constant improvements from lattice determinations of f+(0) and f_K/f_π ➔ average value needed*
- *Callan-Treiman constrain between λ_0, fK/f_π and $f_+(0)$ ➔ new precise experimental determinations of λ_0 (KLOE and NA48 on $K^\pm$, K_L) in progress*

Lepton universality from $K_{e2}/K_{\mu2}$

- *new measurements from NA48 @ 2.5% and KLOE @ 2.7%*
- *NA48 collected more than 100K evts ➔ 0.3%*
- *KLOE aims to reach 1%*

Next Kaon WG meeting
Anacapri 12-14 June 08
chairman Giancarlo D'Ambrosio

Spare slides

$K_L \to \pi^+\pi^-$

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New measurements of $K_L \to \pi^+\pi^-(\gamma)$ also useful in global fit

KTeV
PRD 70 (2004)

BR($\pi^+\pi^-/Ke3$) = 4.856(29) × 10^{-3}
1 of 5 ratios in K_L BR analysis
Contribution from direct emission (DE) negligible

KLOE
PLB 638 (2006)

BR($\pi^+\pi^-/K\mu3$) = 7.275(68) × 10^{-3}
Fully inclusive of DE component

NA48
PLB 645 (2007)

BR($\pi^+\pi^-/Ke3$) = 4.826(27) × 10^{-3}
Residual DE contribution of 0.19% subtracted

For consistency and to better satisfy Σ BR = 1 in global fit,
DE contribution of **1.52(7)%*** added to **KTeV** and **NA48** results

* From E731 '93, KTeV '01 and KTeV '06 $K_L \to \pi^+\pi^-\gamma$ results

What's new since KAON '07

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KLOE

New preliminary BR($\pi\pi^0$) with correlation to BR($\mu\nu$)

Updated (final) values for $K\mu3$ form-factor slopes

Others

$K^{\pm}$ BR measurements from Chiang '72 eliminated from fit

Use Kaon '07 values for Δ^{EM}, with correlations

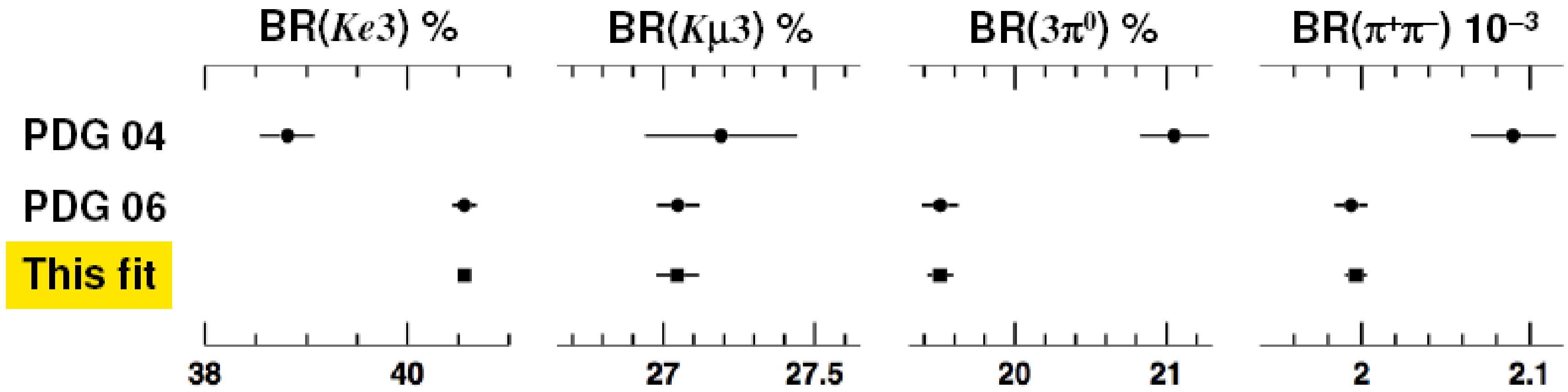
Use Kaon '07 value for $|V_{ud}|$

Use preliminary UKQCD/RBC result for $f_+(0)$

Use new UKQCD/HPQCD result for f_K/f_π

Updated comparisons with PDG 2007

Evolution of K_L BR's



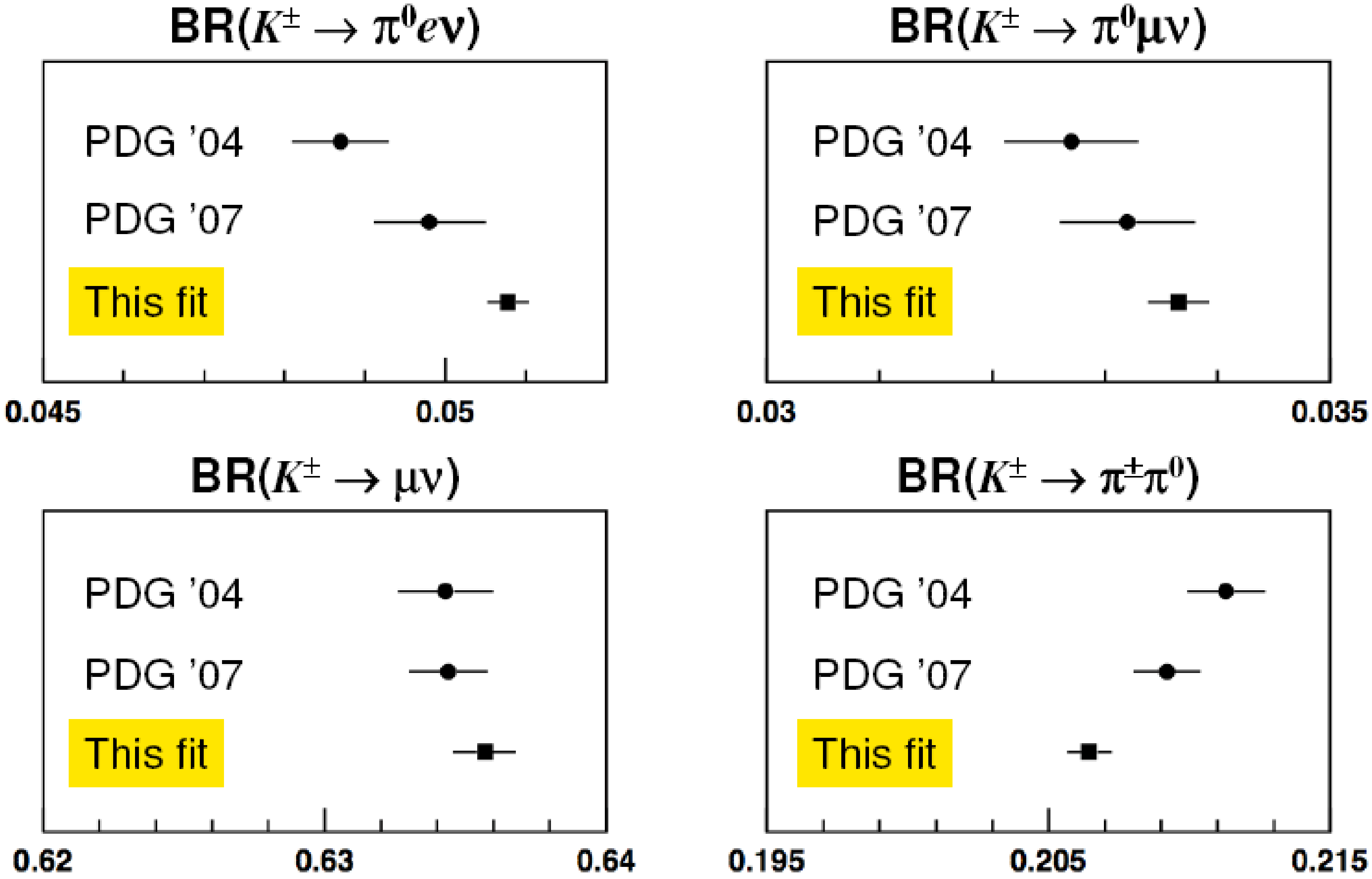
PDG '04 → PDG '06:

- Consistent use of proper radiative corrections important for $Ke3$
- Exclusion of NA31 measurements significantly reduces BR($3\pi^0$)

Differences between our fit and PDG '07 are minor

From K_L BRs:	PDG '04	This fit	
$R_{\mu e} = \Gamma(K\mu3/\ Ke3)$	0.701(9)	0.6668(24)	Better agreement with lepton universality
Re $\varepsilon'/\varepsilon \times 10^4$ using current K_S BRs	-9 ± 12	15 ± 9	Average of direct measurements: 16.7 ± 2.3

Evolution of K± BR's



SU(2) and EM corrections

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$$\Delta^{SU(2)} = \begin{cases} 0 & \text{for } K^0 l3 \\ +2.36(22)\% & \text{for } K^+ l3 \end{cases}$$

Cirigliano, ChPT
Kaon '07

Δ^{EM} for full phase space - all measurements assumed fully inclusive

Δ^{EM}	Cirigliano ChPT	Neufeld ChPT	Andre Had. model
K^0e3	+0.52(10)%	**+0.57(15)%**	+0.65(15)%
K^+e3	+0.03(10)%	**+0.08(15)%**	
$K^0\mu3$		**+0.80(15)%**	+0.95(15)%
$K^+\mu3$		**–0.12(15)%**	

Use new ChPT estimates (Kaon '07) for all channels

Correlations included, e.g.: $\rho(K^0e3, K^0\mu3) = +0.78$, $\rho(K^0e3, K^+e3) = +0.11$

$V_{us}f_+(0)$: $K^\pm$ vs $K_{L,S}$

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Fit 5 modes with separate values of $|V_{us}|\,f_+(0)$ for $K^\pm$ and $K_{L,S}$ modes

- Using results of overall fit to form-factor slopes
- With $SU(2)$ corrections for $K^\pm$ modes [$\Delta^{SU(2)}{}_{\text{th}} = 2.36(22)\%$]

$K^\pm$ modes
$|V_{us}|\,f_+(0) = 0.21738(83)$

↔

$K_{L,S}$ modes
$|V_{us}|\,f_+(0) = 0.21633(56)$

1.1σ difference

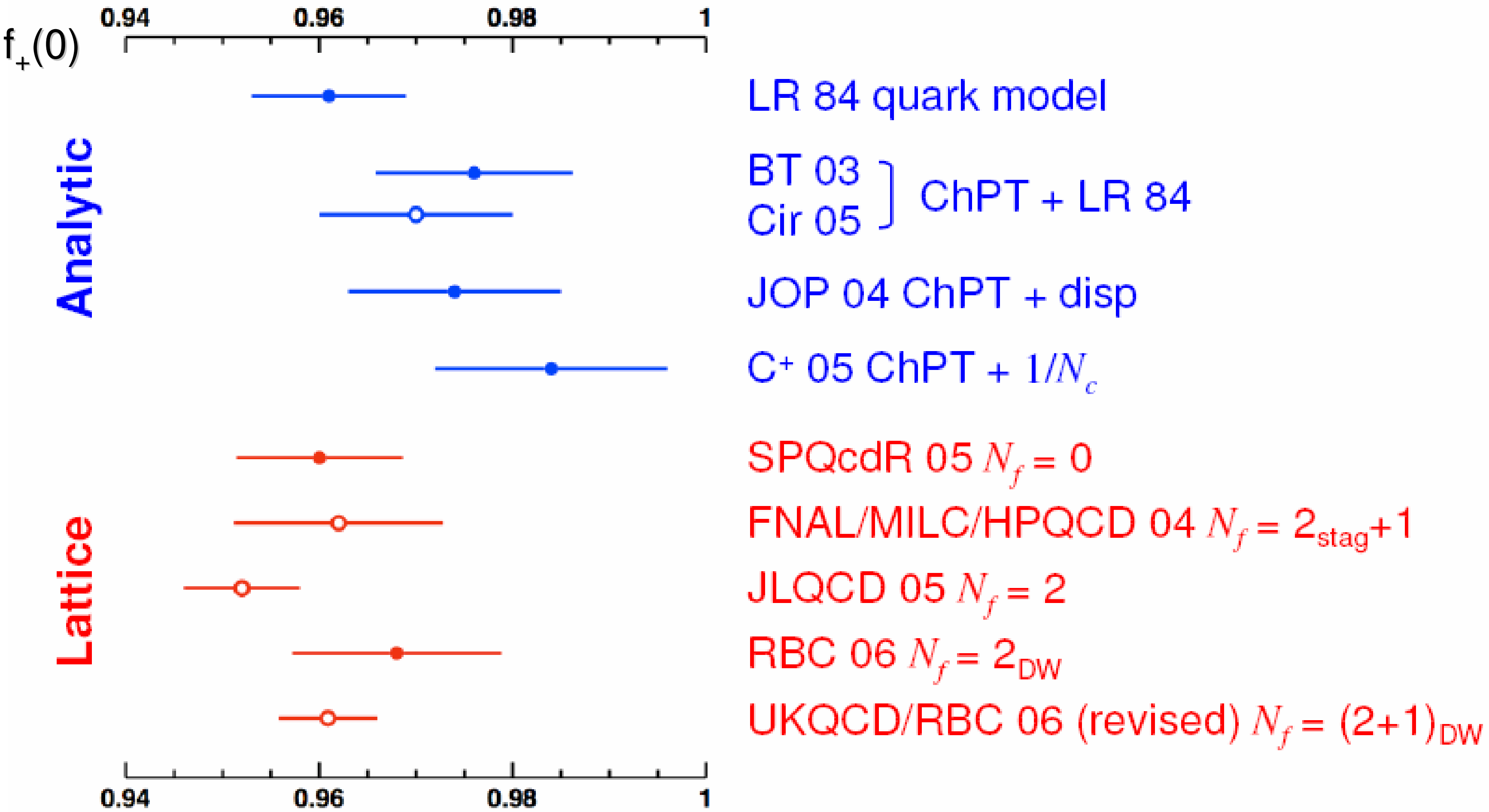
χ^2/ndf = 1.65/3 (65%) ρ = 0.10

When fit performed without $SU(2)$ corrections for $K^\pm$ modes, obtain an experimental value for $\Delta^{SU(2)}$

$K^\pm$ modes, no $SU(2)$
$|V_{us}|\,f_+(0) = 0.22251(70)$

$\Delta^{SU(2)}{}_{\text{exp}} = 2.86(39)\%$

Evaluations of $f_+(0)$



Leutwyler & Roos estimate (LR 84) still widely used: $f_+(0)$ = **0.961(8)**

UKQCD/RBC preliminary agrees well, has smaller error: $f_+(0)$ = **0.9609(51)**