
6th International Workshop on the CKM
Unitarity Triangle
University of Warwick – 6th-10th Sept 2010
Vus and precise
SM tests
Barbara Sciascia, LNF - INFN
for the FlaviaNet Kaon WG

6th International Workshop on the CKM Unitarity Triangle
University of Warwick – 6th-10th Sept 2010

# The Cabibbo angle and precise SM tests

*Barbara Sciascia, LNF - INFN*
*for the FlaviaNet Kaon WG*

# From 2006…

## Introduction

Recent kaon physics results came from many

Experimental (ISTRA+, KTeV, KLOE, NA48...)

and Theoretical (Lattice groups, CHPT groups...) efforts

A KAON WG to

Officially combine results including preliminaries, suggest new measurements, compare parametrizations, compare MC generators, update theoretical inputs

Incomplete list

semi-leptonic related: Vus, Vus/Vud, Form Factor slopes, universality of lepton coupling, test of r.h. Currents...

CP, CPT related: $\varepsilon_K$, Bell-Steinberger Test, ...

Others: $\delta_0$-$\delta_2$,....

A WG on Precise SM tests in K decays M.Antonelli LNF-INFN – FLAVIANET meeting Barcelona

# *(the players)*

• Review of leptonic and semileptonic kaon decay data including recent results (determined by experiments with very different techniques):

**E865@BNL**: rare $K^+$ decays in flight; $\pi^0$ Dalitz decay in final states.

**KLOE@DaΦne**: pure K beams, lifetimes, absolute BR

**NA48@CERN**: intense $K^0$, $K^+$ beams from SPS proton beam, ratio of BR's

**KTeV@FermiLab**: intense $K_L$ beam from Tevatron proton beam, ratio of BR's

**ISTRA+@IHEP** (Protvino): ratio of $K^+$l3 BR's

• Substantial progress made in lattice calculations of the hadronic matrix elements

• Precise analytic calculations (ChPT) of radiative correction and isospin-breaking effects.

• **Very precise determination of Vus**

• **Stringent tests of the Standard Model**

• First outcome: FlaviaNet Kaon WG note (0801.1817[hep-ph]).

Eur. Phys. J. C
DOI 10.1140/epjc/s10052-010-1406-3

THE EUROPEAN PHYSICAL JOURNAL C

Regular Article - Theoretical Physics

(1005.2323[hep-ph])

# An evaluation of $|V_{us}|$ and precise tests of the Standard Model from world data on leptonic and semileptonic kaon decays

**M. Antonelli[2], V. Cirigliano[3], G. Isidori[2], F. Mescia[1], M. Moulson[2,a], H. Neufeld[8], E. Passemar[7], M. Palutan[2], B. Sciascia[2], M. Sozzi[5], R. Wanke[4], O.P. Yushchenko[6]**
**for the FlaviaNet Working Group on Kaon Decay[b]**

[1] Dep. ECM and ICC, Universitat de Barcelona, 08028 Barcelona, Spain
[2] Laboratori Nazionali di Frascati dell'INFN, 00044 Frascati RM, Italy
[3] Theoretical Division, Los Alamos National Laboratory, Los Alamos, NM 87545, USA
[4] Institut für Physik, Universität Mainz, 55099 Mainz, Germany
[5] Dipartimento di Fisica, Università di Pisa e Sezione dell'INFN di Pisa, 56100 Pisa, Italy
[6] Institute for High Energy Physics, 142284 Protvino, Russia
[7] Departament de Física Teòrica, IFIC, Universitat de València—CSIC, 46071 València, Spain
[8] Fakultät für Physik, Universität Wien, 1090 Vienna, Austria

Received: 13 May 2010 / Revised: 15 June 2010


**All results presented are from this paper**

FlaviA net Kaon WG

# *Leptonic and semileptonic K decays*

• Within the SM leptonic and semileptonic K decays can used to obtain the most accurate determination of the element Vus of the CKM matrix

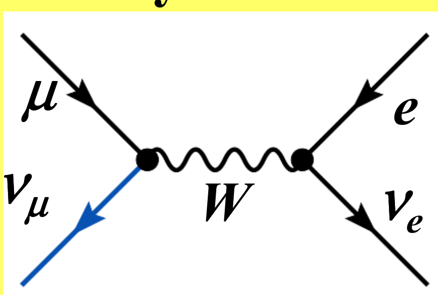
$$\Gamma(K_{\ell 3(\gamma)}) = \frac{G_F^2 m_K^5}{192\pi^3} C_K S_{\rm ew} \, |V_{us}|^2 f_+(0)^2 \, I_K^\ell(\lambda_{+,0}) \left(1 + \delta_{SU(2)}^K + \delta_{\rm em}^{K\ell}\right)^2$$

$$\frac{\Gamma(K^\pm_{\ell 2(\gamma)})}{\Gamma(\pi^\pm_{\ell 2(\gamma)})} = \left|\frac{V_{us}}{V_{ud}}\right|^2 \frac{f_K^2 m_K}{f_\pi^2 m_\pi} \left(\frac{1 - m_\ell^2/m_K^2}{1 - m_\ell^2/m_\pi^2}\right)^2 \times (1 + \delta_{\rm em})$$

• Test **unitarity of the quark mixing matrix** ($V_{CKM}$):

$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1 + \epsilon_{\rm NP} \qquad \epsilon_{\rm NP} \sim M_W^2/\Lambda_{\rm NP}^2$$

**μ decay**

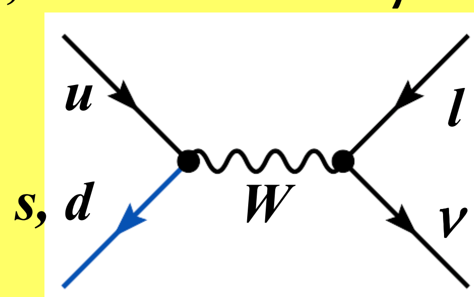



$$(g_\mu g_e)^2 \big/ M_W^4 = G_F^2$$

**?**

**=**

***K*, π and nuclear *β* decays**




$$(g_q g_l)^2 \left(|V_{ud}|^2 + |V_{us}|^2\right) \big/ M_W^4 = G_{CKM}^2$$

# *NP test from (semi)leptonic K decays*

Study within a **model-independent effective theory approach** the implications of precise measurements of Kl2 and Kl3 decays for SM extension [Cirigliano, Gonzalez-Alonso, and Jenkins, arXiv:0908.1754 hep-ph]

**Phenomenology in $U(3)^5$ flavor symmetry limit**

• Taking into account all the Precision Electroweak constraints, the maximal deviation of $|\Delta_{CKM}|$ allowed is:

$$-9.5 \times 10^{-3} \leq \Delta_{CKM} \leq 0.1 \times 10^{-3};$$

→ deviation from CKM unitarity at −1% level not ruled out by PEW tests.

• Even a % level test of CKM unitarity would provide information not available through other precision tests at low- and high-energy.

• **$\delta$Vus=0.5%** combined with **$\delta$Vud=0.02%** (nuclear beta decays) allow to probe NP effective scales of the **order of 10 TeV**.

FlaviA net Kaon WG

# NP test from (semi)leptonic K decays

Study within a **model-independent effective theory approach** the implications of precise measurements of Kl2 and Kl3 decays for SM extension [Cirigliano, Gonzalez-Alonso, and Jenkins, arXiv:0908.1754 hep-ph]

**Beyond $U(3)^5$ limit**.

- Corrections to the $U(3)^5$ limit can be introduce within MFV and via generic flavor structures (pseudoscalar and tensor structures).
- A high sensitive probe of $U(3)^5$ violating structures is provided by comparing the Vus value extracted by the helicity suppressed Kμ2 decays and the helicity allowed Kl3 modes, using the ratio

$$R_{\mu 23} = \left(\frac{f_K/f_\pi}{f_+(0)}\right)^{-1} \left(\left|\frac{V_{us}}{V_{ud}}\right|\frac{f_K}{f_\pi}\right)_{\mu 2} \frac{|V_{ud}|_{0^+\to 0^+}}{[|V_{us}|f_+(0)]_{\ell 3}}$$

(minimize impact of $f_K$ and e.m. corrections)

Within SM, $R_{\mu 23}=1$; the inclusion of Higgs-mediated scalar currents leads to

$$R_{\mu 23} \approx \left|1 - \frac{m^2_{K^+}}{m^2_{H^+}} \frac{\tan^2\beta}{1+\epsilon_0 \tan\beta}\right|$$

# Determination of $V_{us}$ from Kl2 decays

Within SM, the ratio of photon inclusive $K_{l2}$ to $\pi_{l2}$ decay rates is:

$$\frac{\Gamma(K_{\mu 2(\gamma)})}{\Gamma(\pi_{\mu 2(\gamma)})} = \frac{|V_{us}|^2}{|V_{ud}|^2} \frac{|f_K|^2}{|f_\pi|^2} \times \frac{M_K(1-m_\mu^2/M_K^2)^2}{m_\pi(1-m_\mu^2/m_\pi^2)^2} \times (1+\delta_{em})$$

**Obtain $|V_{us}|$ from**:

- measurements of the inclusive $K_{l2}$ and $\pi_{l2}$ decay widths;
- **$|V_{ud}|$=0.97425(22)** from super-allowed $0^+ \rightarrow 0^+$ nuclear beta decays
  [Hardy and Towner, Phys. Rev. C79(2009) 055502]

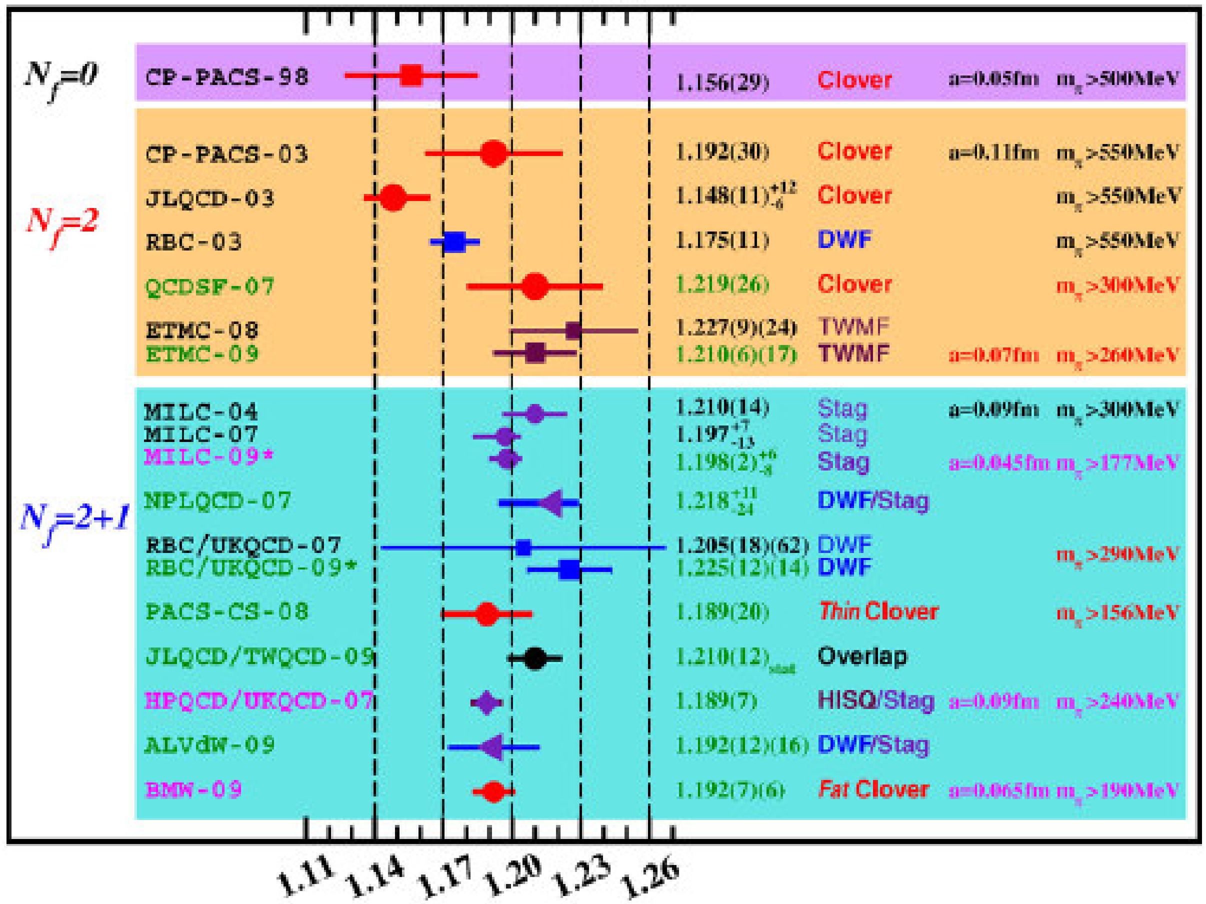
Use precise evaluation of long-distance e.m. corrections **$\delta_{em}$ = –0.0070(18)**.

$f_K/f_\pi$ not protected by the Ademollo-Gatto theorem: only lattice.

(lattice calculation of $f_K/f_\pi$ and radiative corrections benefit of cancellations).

# Theoretical estimate of $f_K/f_\pi$

Summary of lattice QCD determinations of $f_K/f_\pi$.




**$f_K/f_\pi$ (our choice)**: average (stat. error only + smallest syst. error) of results with analysis of all systematics [BMW, MILC09, HPQCD/UKQCD]: **1.193(6)**

- consistent with other choices, e.g.: **1.196(10)** [LAT2009] and **1.190(10)** [FLAG].

FlaviA net Kaon WG

# Determination of $V_{us}$ from Kl3 decays

$$\Gamma(K_{l3(\gamma)}) = \frac{C_K^2\, G_F^2 M_K^5}{192\pi^3} S_{EW} |V_{us}|^2 |f_+(0)|^2 I_{K,l}(\lambda)\,(1+\delta_K^{SU(2)}+\delta_{K,l}^{EM})^2$$

**(with K = $K^+$, $K^0$; $l$ = e,μ and $C_K^2$ = 1/2 for $K^+$, 1 for $K^0$)**

| | Theory | | | Experiment |
|---|---|---|---|---|
| Decay Rate | | | | $\Gamma(K_{l3(\gamma)})$ BR and lifetimes |
| Form Factor | $f_+(0)$ hadronic matrix element at zero momentum transfer | | | $I_{K,l}(\lambda)$ Phase space: λ param. form factor dependence on t |
| Corrections | $S_{EW}$ short distance EW | $\delta_K^{SU(2)}$ strong SU(2) breaking | $\delta_{K,l}^{EM}$ long distance EM | |

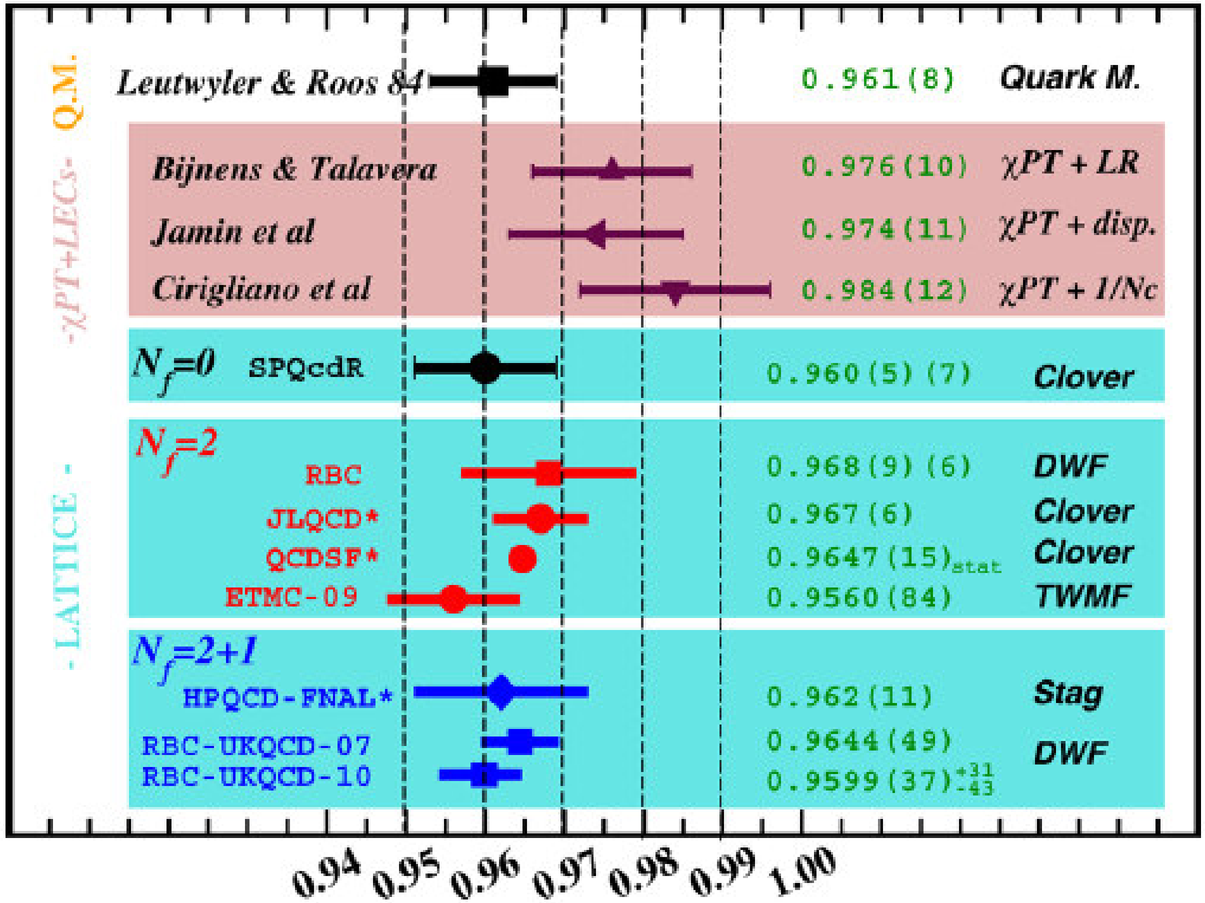
$\delta_{SU(2)}$=0.029(4)
EPJC 04, 006 (2008)

| Mode | $\delta_{EM}^{K\ell}$ (%) |
|---|---|
| $K_{e3}^0$ | 0.495 ± 0.110 |
| $K_{e3}^\pm$ | 0.050 ± 0.125 |
| $K_{\mu3}^0$ | 0.700 ± 0.110 |
| $K_{\mu3}^\pm$ | 0.008 ± 0.125 |

JHEP 11, 006(2008)

# Theoretical estimate of $f_+(0)$

Present determinations of $f_+(0)=f_+^{K0\pi-}(0)$ from analytical or semi-analytical approaches, and lattice QCD,



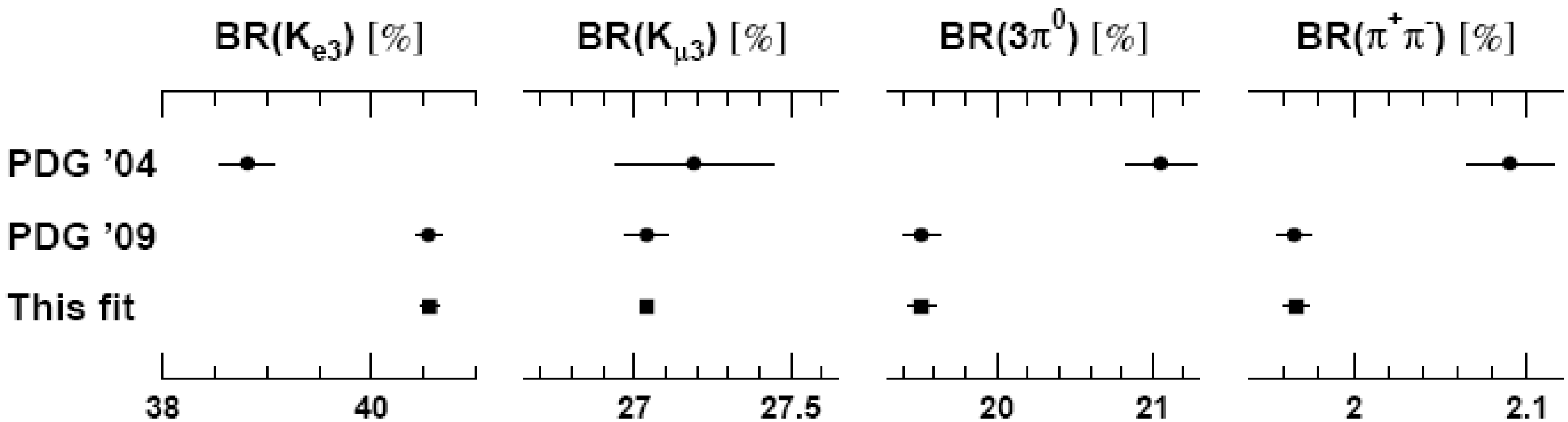

**$f_+(0)$ (our choice)**: **0.959(5)**, our error symmetrization of RBC/UKQCD-10

- fairly representative of results and spread of values
- consistent with $N_f$=2 and $N_f$=2+1 average: **0.962(5)** [PoS LAT2009, 013(2009)].

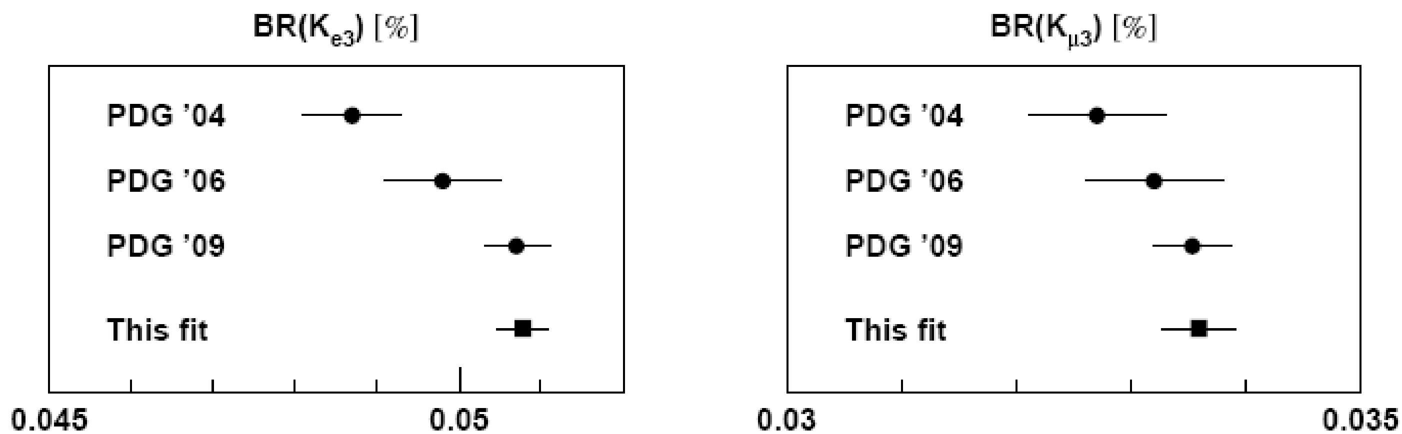
# *Note on BR and lifetime data set*

**Careful reading of the original papers → definition of different data set and/or parameters wrt to PDG**

$K_L$




$K^\pm$




**Wrt to PDG09: minor differences on the fit results**

# Parameterization of form factors

**$|V_{us} f_+(0)|$ extraction needs calculation of the phase space integrals:**

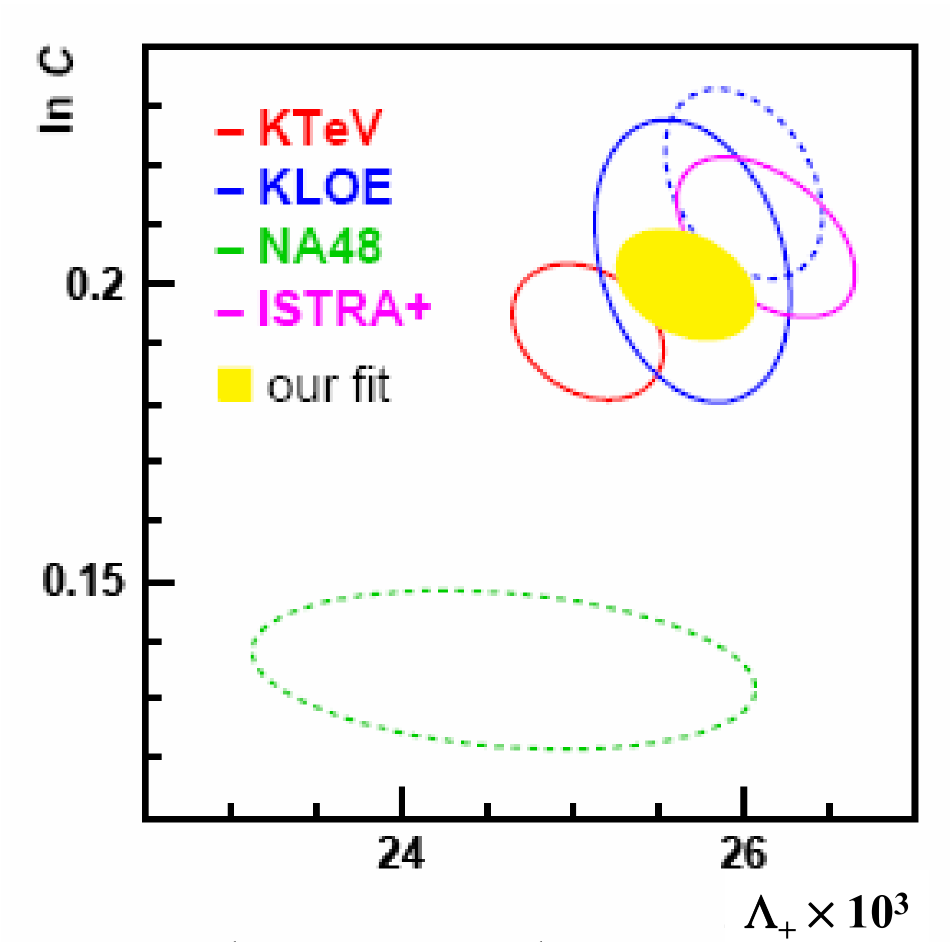
$$I_K^\ell = \int_{m_\ell^2}^{t_0} dt \, \frac{1}{m_K^8} \, \lambda^{3/2} \left(1 + \frac{m_\ell^2}{2t}\right) \left(1 - \frac{m_\ell^2}{2t}\right)^2 \left(\bar{f}_+^2(t) + \frac{3 m_\ell^2 \Delta_{K\pi}^2}{(2t + m_\ell^2)\lambda} \bar{f}_0^2(t)\right)$$

• **Class II**: based on a systematic mathematical expansion (e.g. Taylor, "z-par.")
- freedom to determine high-order terms from data
- strong par. correlation → no sensitivity to high order terms ($\lambda_0''$) **[PoS 2008(KAON)002]**
- accurate description in physical region needs at least 2nd Taylor exp. **[PLB638(2009)480]**
- test of low-energy dynamics involving Callan-Treiman th. needs orders>2nd.

• **Class I**: to reduce the number of parameters, impose additional physical constraints
- **pole**: dominance of single resonance $M_{V,S}$ (one free parameter)
  vector: K*(892) ok; scalar: no obvious dominance.
- **dispersive**: ff analytic (except real $t>(m_K+m_\pi)^2$) functions in the complex t-plane.
  vector: numerically similar to pole (K*(892) dominance);
  scalar: necessary without dominant one-particle intermediate state.

# *Form factors: dispersive approach*

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




$$\Lambda_+ \times 10^3 = \mathbf{25.66 \pm 0.41}$$
$$\ln C = \mathbf{0.2004(91)}$$
$$\rho(\Lambda_+, \ln C) = -0.33$$
$$\chi^2/\text{ndf} = 5.6/5\ (34\%)$$

**Integrals**

| Mode | Quad-lin | Disp |
|---|---|---|
| $K^0{}_{e3}$ | 0.15457(20) | **0.15476(18)** |
| $K^+{}_{e3}$ | 0.15894(21) | **0.15922(18)** |
| $K^0{}_{\mu3}$ | 0.10266(20) | **0.10253(16)** |
| $K^+{}_{\mu3}$ | 0.10564(20) | **0.10559(17)** |

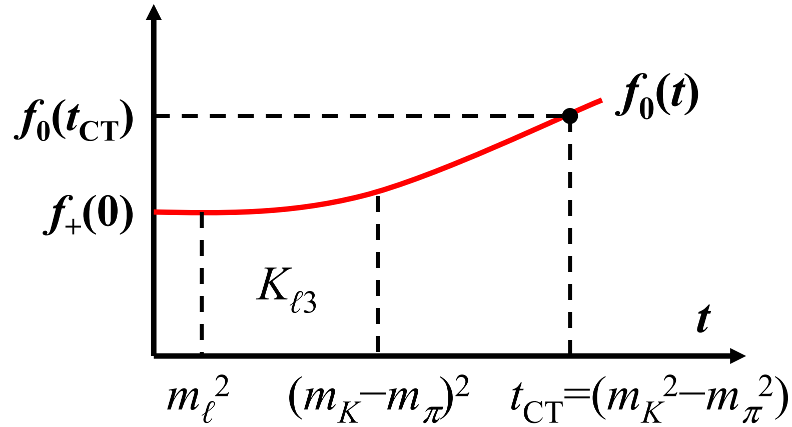
**Maximum change 0.2% if same data used as for quad-lin fits**

**Dashed lines** show **NA48*** and **preliminary KLOE** data **not in fit**

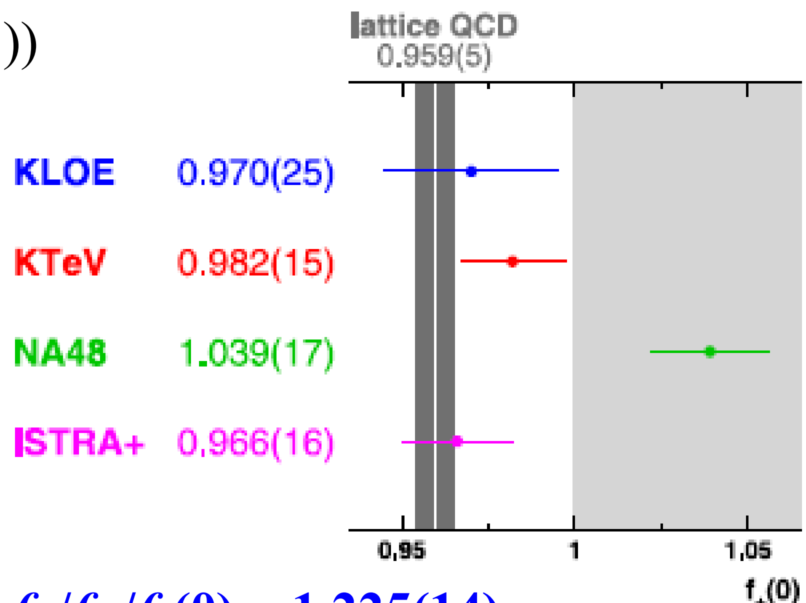
# $K\mu 3$ scalar ff: test of $\chi PT$

Dispersive parameterization for $f_0(t)$ plus Callan-Treiman relation

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




- Assuming a $f_K/f_\pi$ value, obtain a value for $f_+(0)$.
- Consistency test between scalar ff measurement and lattice calculations: WA for ln C (0.2004(91)) gives: $f_+(0) = 0.974(12)$



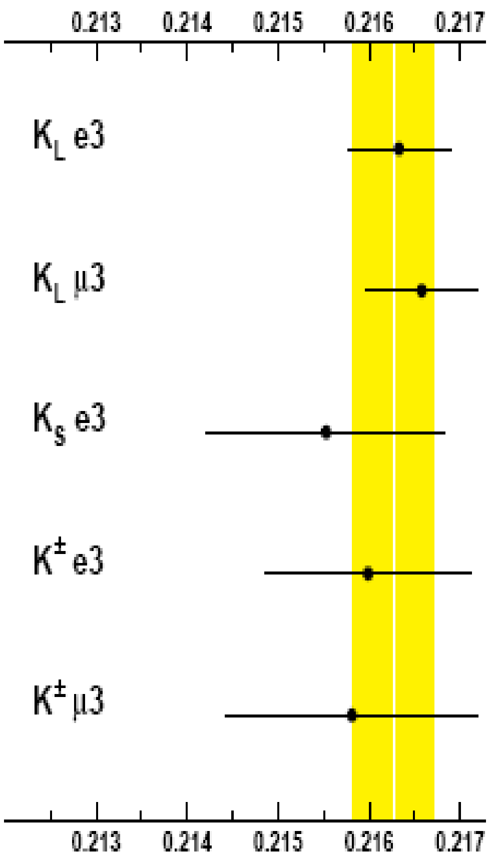

- NA48 value is inconsistent with theoretical expectations: $f_+(0)<1 \rightarrow$ exclude NA48 $K\mu 3$ ff from averages used for $V_{us}$.

**WA exp. data on ln C alone gives $f_K/f_\pi / f_+(0) = 1.225(14)$ completely independent of any information from lattice estimates**

FlaviA net Kaon WG

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

$|V_{us}|\,f_+(0)$




| | | | Approx. contrib. to % err from: | | | |
|---|---|---|---|---|---|---|
| | | % err | BR | $\tau$ | $\Delta$ | Int |
| $K_Le3$ | **0.2163(6)** | **0.26** | 0.09 | **0.20** | 0.11 | 0.06 |
| $K_L\mu3$ | **0.2166(6)** | **0.29** | 0.15 | **0.18** | 0.11 | 0.08 |
| $K_Se3$ | **0.2155(13)** | **0.61** | **0.60** | 0.03 | 0.11 | 0.06 |
| $K^{\pm}e3$ | **0.2160(11)** | **0.52** | **0.31** | 0.09 | **0.40** | 0.06 |
| $K^{\pm}\mu3$ | **0.2158(14)** | **0.63** | **0.47** | 0.08 | **0.39** | 0.08 |

**Average: $|V_{us}|\,f_+(0) = 0.2163(5)$ $\chi^2/\text{ndf} = 0.77/4$ (94%)**

FlaviA net Kaon WG

# Accuracy of SU(2)-breaking corrections

Fit 5 modes with separate values of $|V_{us}|\, f_+(0)$ for $K^\pm$ and $K_{L,S}$ modes; $K^\pm$ modes modes are corrected for the isospin-breaking using $\delta^{SU(2)}_{\text{theory}} = 2.9(4)\%$.

When fit performed without $SU(2)$ corrections for $K^\pm$ modes; from ratio of neutral- charged-modes, obtains an **experimental estimate of $\delta^{SU(2)}$**:

$$\delta^{SU(2)}_{\text{exp}} = 2.7(4)\%$$

- Check of the $\delta^{SU(2)}$ estimate from $\chi$PT; the uncertainty on $\delta^{SU(2)}_{\text{theory}}$ contributes significantly on the overall uncertainty of $|V_{us}| f_+(0)$ from charged modes.

- Since $\delta^{SU(2)}$ can be expressed in terms of the quark mass ratio (at LO):

$$\delta^{K^\pm\pi^0}_{\text{SU(2)}} = \frac{3}{4}\frac{1}{R}\ , \ \text{with} \quad R = \frac{m_s - \hat{m}}{m_d - m_u}$$

its phenomenological determination can be **used to derive constraints on the ratio of quark masses**.

# $K_{\ell 3}$ data and lepton universality

For each state of kaon charge, evaluate:

$$r_{\mu e} = \frac{[|V_{us}| f_+(0)]^2_{\mu 3,\mathrm{exp}}}{[|V_{us}| f_+(0)]^2_{e3,\mathrm{exp}}} = \frac{\Gamma_{K\mu 3}}{\Gamma_{Ke3}} \frac{I_{e3}(1+2\delta^{Ke}_{\mathrm{EM}})}{I_{\mu 3}(1+2\delta^{K\mu}_{\mathrm{EM}})}$$

| Modes | 2004 BRs* | World data |
|---|---|---|
| $K_{L,S}$ | **1.040(13)** | **1.003(5)** |
| $K^{\pm}$ | **1.013(12)** | **0.998(9)** |
| **Avg** | **1.034(10)** | **1.002(5)** |

*Assuming current values for form-factor parameters and $\Delta^{\mathrm{EM}}$; $K_S$ not included

**As statement on lepton universality**

- compare to results from world data:

$\pi \to l\nu$ $(r_{\mu e}) = 1.0042(33)$

Ramsey-Musolf, Su & Tulin '07

$\tau \to l\nu\nu$ $(r_{\mu e}) = 1.000(4)$

Davier, Hoecker & Zhang '06

**As statement on calculation of $\delta^{\mathrm{EM}}$**

- highly successful
- results confirmed at per-mil level

# *Test of CKM unitarity*

Determine $|V_{us}|$ and $|V_{ud}|$ from a **fit to the results**:

$|V_{us} f_+(0)|=0.2163(5)$, $f_+(0)=0.959(5)$;

$|V_{us}|/|V_{ud}| f_K/f_\pi=0.2758(5)$, $f_K/f_\pi=1.193(6)$

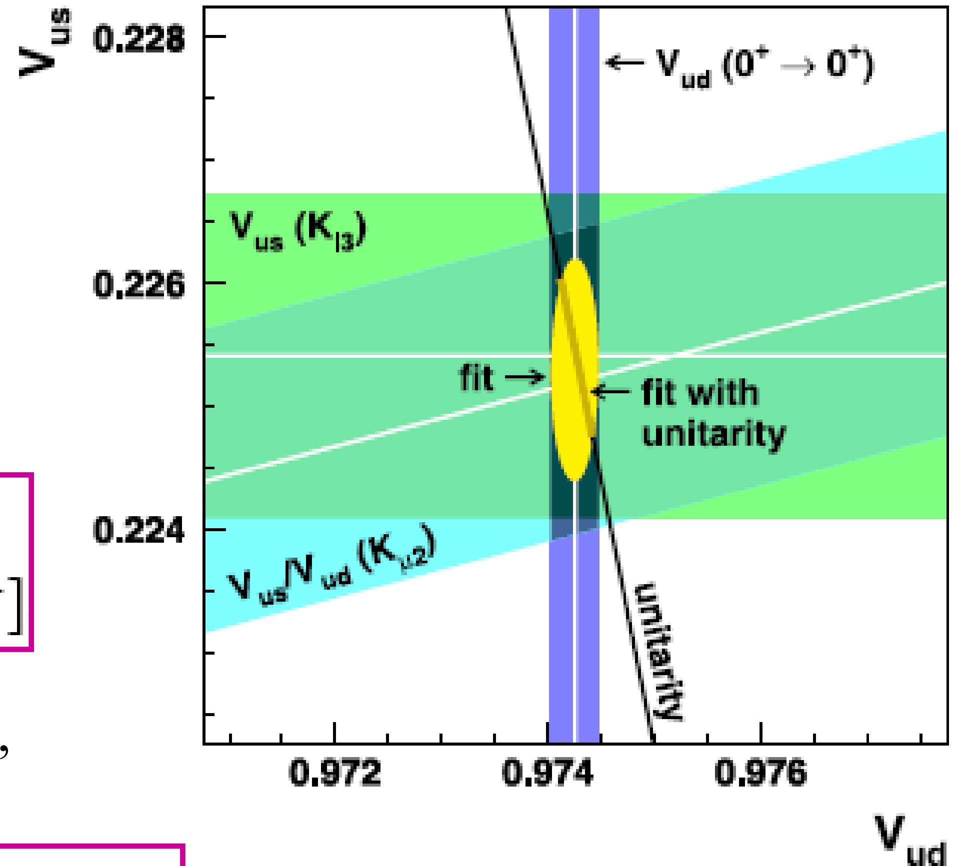
$$|V_{us}| = 0.2254(13) \quad [K_{\ell 3} \text{ only}],$$
$$|V_{us}/V_{ud}| = 0.2312(13) \quad [K_{\ell 2} \text{ only}]$$

Adding $|V_{ud}|=0.97425(22)$, obtains ($\chi^2$/ndf=0.014/1, P=91%, negligible correlation between $V_{us}$ and $V_{ud}$):

$$|V_{ud}| = 0.97425(22),$$
$$|V_{us}| = 0.2253(9) \quad [K_{\ell 3}, K_{\ell 2}, 0^+ \to 0^+]$$

Including in the fit the unitairty constraint, obtains ($\chi^2$/ndf=0.024/2, P=99%):

$$|V_{us}| = \sin\theta_C = \lambda = 0.2254(6) \quad [\text{with unitarity}]$$



# *Test of CKM unitarity*

FlaviA net Kaon WG

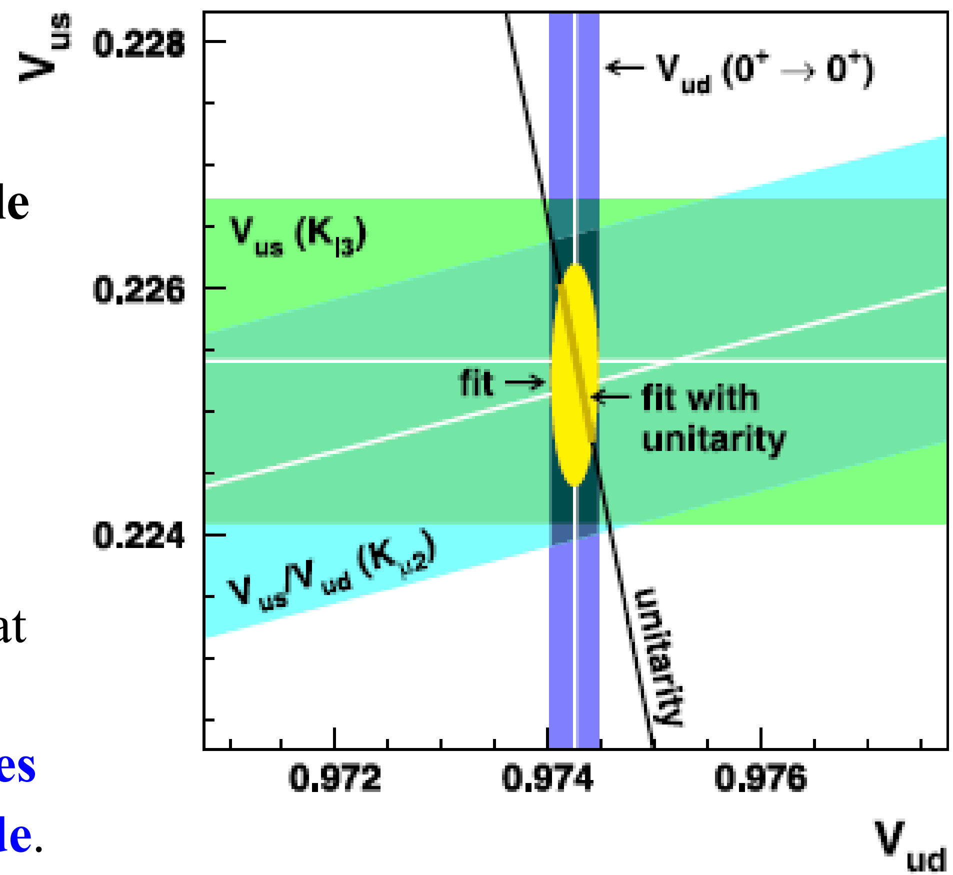
**Using the current WA value $|V_{ub}|$=0.00393(36), the first-row unitarity sum is $\Delta_{CKM}$=–0.0001(6), in striking agreement with unitarity hypothesis.**

**Allow to set bounds on the effective scale of the operators that parametrize NP contributions to $\Delta_{CKM}$:**

**$\Lambda$> 11 TeV (90% C.L.).**

For three operators (ll, ϕl, ϕq), constraint at the same level as Z-pole measurements;

**for the 4-fermion operator (lq), improves LEP2 bounds by one order of magnitude.**



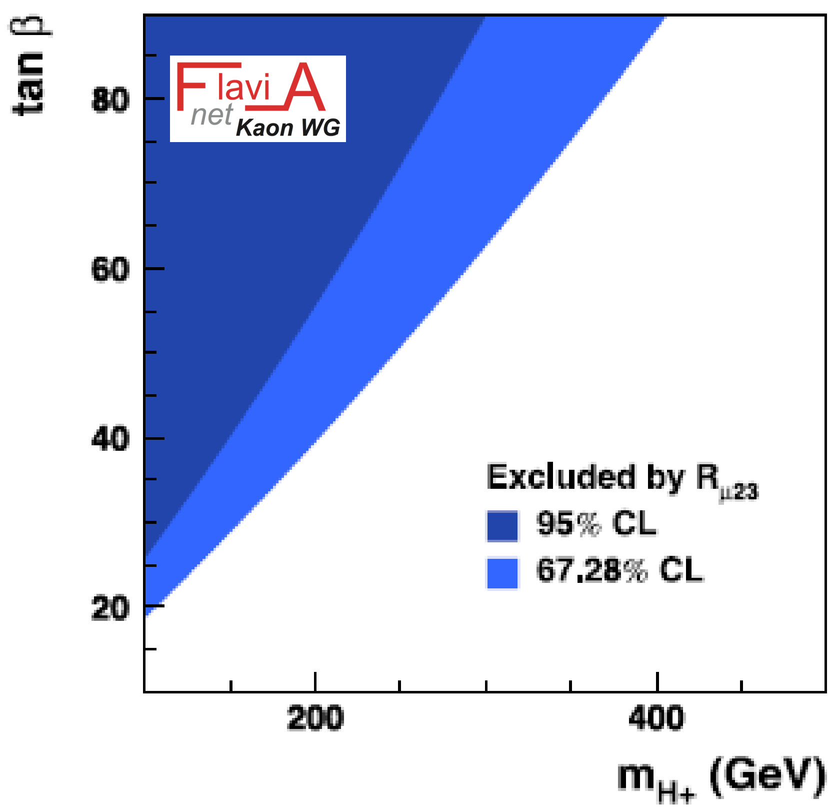
# Bounds on non helicity-suppressed amps

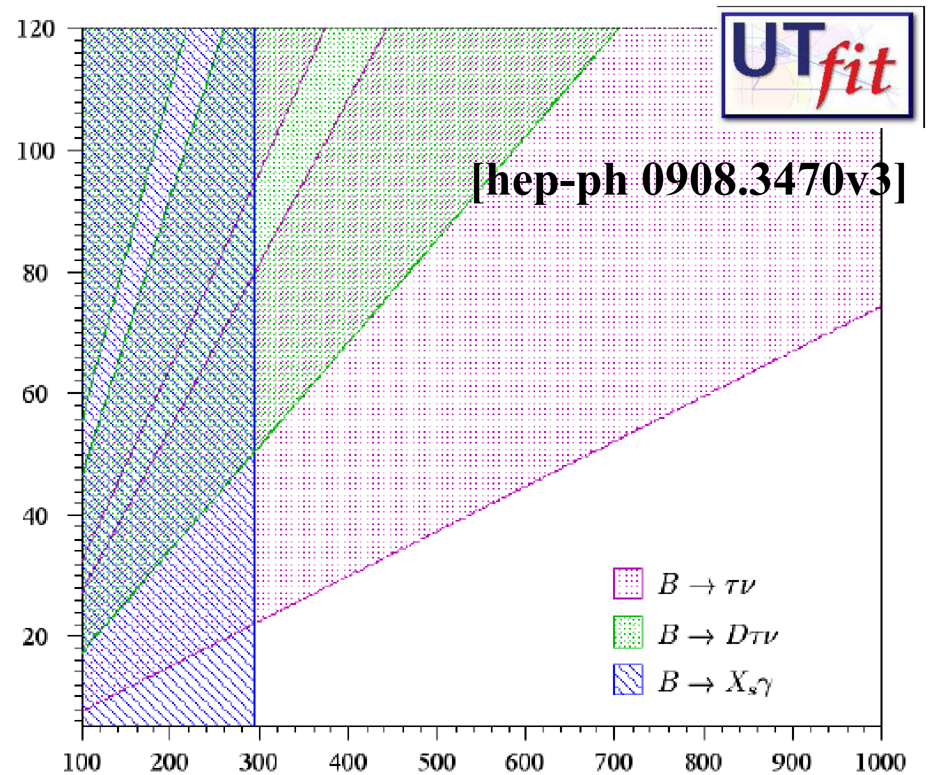
FlaviA net Kaon WG

With a 3-parameter fit ($V_{us}$ from Kl3, $V_{us}/V_{ud}$ from K$\mu$2, $V_{ud}$) with 1 constraint: $[V_{us}(K_{l3})]^2+[V_{ud}(0^+\to0^+)]^2+[V_{ub}]^2 = 1$, obtains ($\chi^2$/ndf=0.0003/1 P=99%, $\rho$= –0.55):

$$|V_{us}| = 0.2254(8) \quad [K_{\ell 3}, 0^+ \to 0^+, \text{unitarity}],$$
$$R_{\mu 23} = 0.999(7) \quad [K_{\mu 2}].$$

**this excludes the region at low $m_{H+}$ and large tg $\beta$ favoured by $B\to\tau\nu$.**



# $f_+(0)$ and $f_K/f_\pi$: straight calculation

$$Q_{\ell 2} = \frac{(|V_{us}|f_+(0))^2}{|V_{ud}|^2} \times \frac{1}{f_+(0)^2} \times \frac{f_K^2}{f_\pi^2}$$

From decay rates and rad. corr. — From nucl. β-decay — From Kl3

**Straight calculation from Kμ2/πμ2 relation and assuming SM:**

- Use $Q_{\ell 2} = \frac{\Gamma_{K^\pm_{\ell 2(\gamma)}}}{\Gamma_{\pi^\pm_{\ell 2(\gamma)}}} \frac{1}{(1+\delta_{em})}$ = 0.07604(26)
- Obtain $f_K/f_\pi / f_+(0) = 1.242(4)$

depends on decay rate data, radiative corrections; **unitarity not assumed, although $V_{us}$ equality in Kμ2 and Kl3 decays is**.

- using $f_+(0) = 0.959(5)$ obtain $f_K/f_\pi = 1.192(8)$
- using $f_K/f_\pi = 1.193(6)$ obtain $f_+(0) = 0.960(6)$

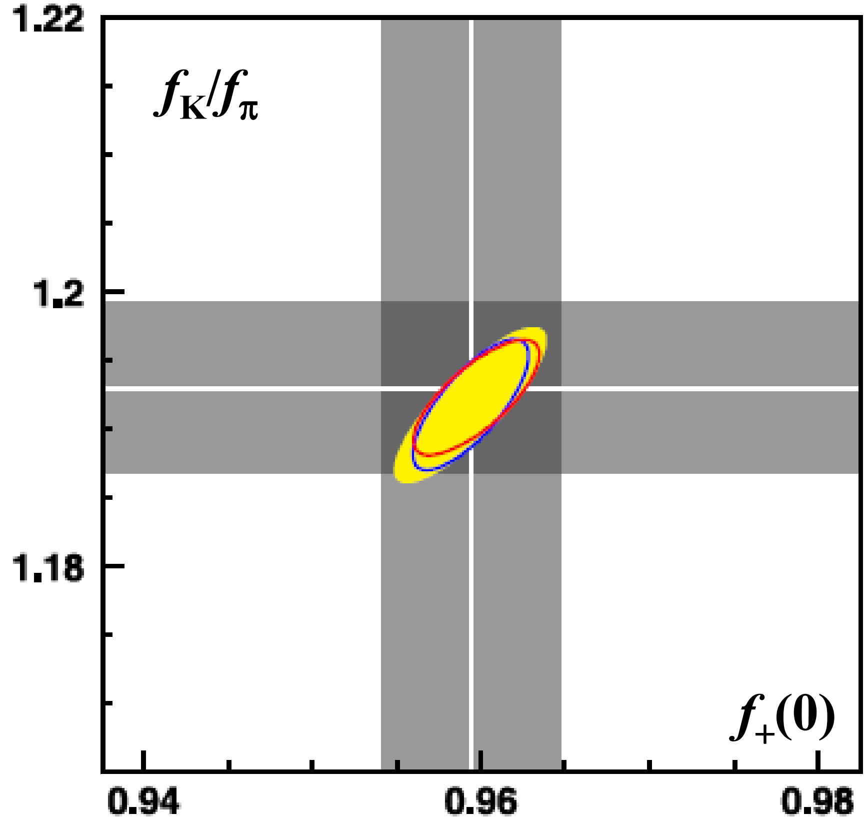
FlaviA net Kaon WG

# $f_+(0)$ and $f_K/f_\pi$: fit assuming unitarity

$$Q_{\ell 2} = \frac{(|V_{us}|f_+(0))^2}{|V_{ud}|^2} \times \frac{1}{f_+(0)^2} \times \frac{f_K^2}{f_\pi^2}$$

From decay rates and rad. corr. — From nucl. β-decay — From Kl3

Assuming SM




- $f_K/f_\pi$ and $f_+(0)$ values from a fit.
- 5 parameters: $V_{ud}$, $V_{us}f_+(0)$, $Q_{l2}$, $f_K/f_\pi$, and $f_+(0)$.
  - 3 inputs: $V_{ud}$, $V_{us}f_+(0)$, $Q_{l2}$
  - 2 constraints: $\Gamma(K\mu2)/\Gamma(\pi\mu2)$ relation and Unitarity
- Obtain (correlation ρ=0.84) :

$$f_+(0) = 0.959(5),$$
$$f_K/f_\pi = 1.192(6) \quad \text{[with unitarity]}$$

Lattice estimations

# $f_+(0)$ and $f_K/f_\pi$: fit assuming unitarity

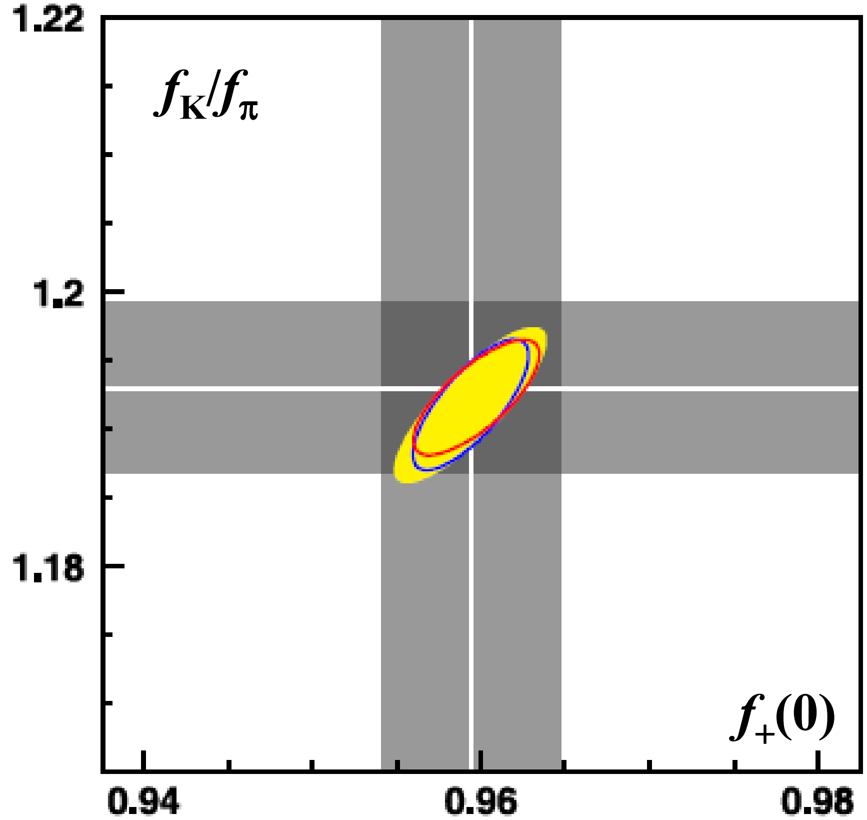
$$Q_{\ell 2} = \frac{(|V_{us}| f_+(0))^2}{|V_{ud}|^2} \times \frac{1}{f_+(0)^2} \times \frac{f_K^2}{f_\pi^2}$$

From decay rates and rad. corr.

From nucl. β-decay

From K13

Assuming SM




Lattice estimations

With either of reference values of $f_K/f_\pi$ or $f_+(0)$ as an **additional** input:

- with input $f_+(0)$=0.959(5), obtain
**$f_+(0)$=0.9594(34) and $f_K/f_\pi$ = 1.192(5)**

- with input $f_K/f_\pi$ = 1.193(6), obtain
**$f_+(0)$=0.960(4) and $f_K/f_\pi$ = 1.192(4)**.

Reference values are a near-perfect match with experimental data and SM assumptions

# Conclusions

**Experimental precision on K leptonic and semileptonic decays nicely matched below per cent level by theoretical precision**

- perform very precise measurements of SM parameters
- results: **$|V_{us} f_+(0)|$=0.2163(5) and $|V_{us}|/|V_{ud}| f_K/f_\pi$=0.2758(5)**
- set stringent bounds on beyond-SM physics

**In FlaviaNet Kaon WG (1005.2323[hep-ph]) updated analysis of:**

- overall determination of $V_{us}$, with and w/o imposing CKM unitarity
- $V_{us}(K\ell3)$ vs $V_{us}(K\mu2)$: constraints on deviation from V−A structure
- test of lepton universality in $K\ell3$ decays

**Moreover:**

- CKM matrix unitarity tested at 0.06%: O(10TeV) bound on NP-scale represents one of the most stringent constraints on beyond-SM physics.
- cross-checks of $\delta_{SU(2)}$ and $f_+(0)$ theoretical results (within SM only)

**Kaons can push fundamental principles at severe test, continuing to shed light on physics on and beyond SM**