Theory Review of Kaon Physics

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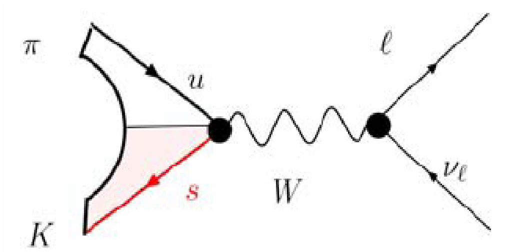
Focus on recent theoretical calculations and New-Physics possibilities through clean observables in Kaon

Theoretical Clean Observables

1) Tree-level mediated decays -> *CKM unitarity*

K–>π*l*ν



Hadronic uncertainties from

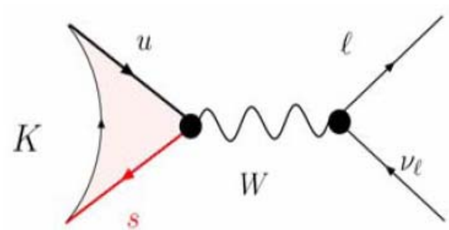
$$\langle \pi | \bar{s}\gamma^{\mu}u | K \rangle \Leftrightarrow f_{+,0}(q^2)$$

Novelty: *estimate of $f_+(0)$ on the Lattice at ~0.5%.* (RBC/UKQCD)

2) Elicity suppressed decays -> *sensitivity to the Higgs sector*

K–>μν

K–>μν/ K–>eν



Novelty:

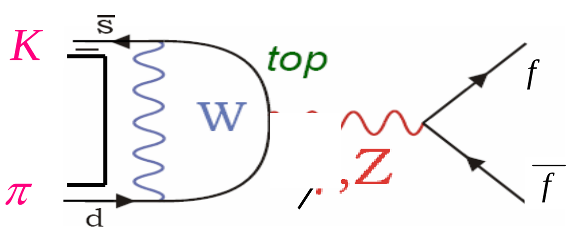
- *recent improving on f_K / f_π by Lattice* (HPQCD/UKQCD)
- *bounds on scalar couplings competitive to B*

New Golden mode => $K_{e2} / K_{\mu 2}$

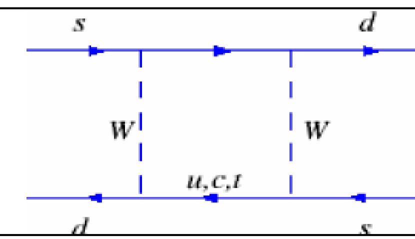
3) *FCNC processes* -> *SUSY, Little Higgs ....*

K–>πνν

K–>π*ll*



+ ε_K



see E. Gamiz's talk tomorrow

News :

1) *Improved theoretical estimate of SM contributions*
2) *"New Physics" model studies with all the constraints*

1

V_{us} determination and the CKM Unitarity

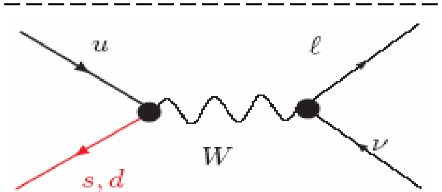
$$\left(|V_{ud}|^2+|V_{us}|^2+\cancel{|V_{ub}|^2}\right)\neq 1$$

$$G^2_{CKM}\equiv G^2_F\times\left(|V_{ud}|^2+|V_{us}|^2\right)\neq 1\times G^2_{Lepton}$$

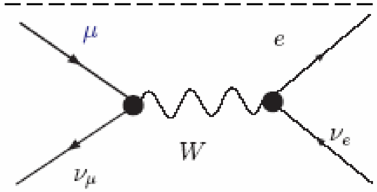
CKM Unitarity breaking

Gauge Universality Breaking between Leptons and Quarks

$\propto G_F^2\,|V_{uq}|^2$



/ $\propto G_F^2$



= New-Physics $\propto G_F^2\,\varepsilon^{CKM}$

G_F–Universality

G_{CKM} = 1.1662(04) 10^{-5} GeV^{-2}

G_μ = 1.166371(6) 10^{-5} GeV^{-2}

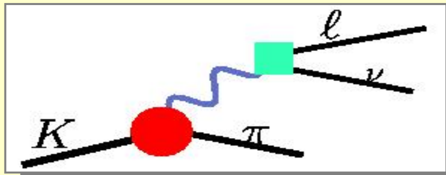
G_τ = 1.1678(26) 10^{-5} GeV^{-2}

G_{ew} = 1.1678(26) 10^{-5} GeV^{-2}

V_{us} at 0.5%

2007 Lattice Progress (RBC/UKQCD)

V_{us} below 1% makes CKM unitarity competitive to Electro-Weak Precision Test



V_{us} from $K_{\ell 3}$ decays

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

with $K = K^+, K^0$; $l = e, \mu$ and C_K^2 = 1/2 for K^+, 1 for K^0

Inputs from experiment:

$\Gamma(K_{l3(\gamma)})$ **Branching ratios** with well determined treatment of radiative decays; **lifetimes**

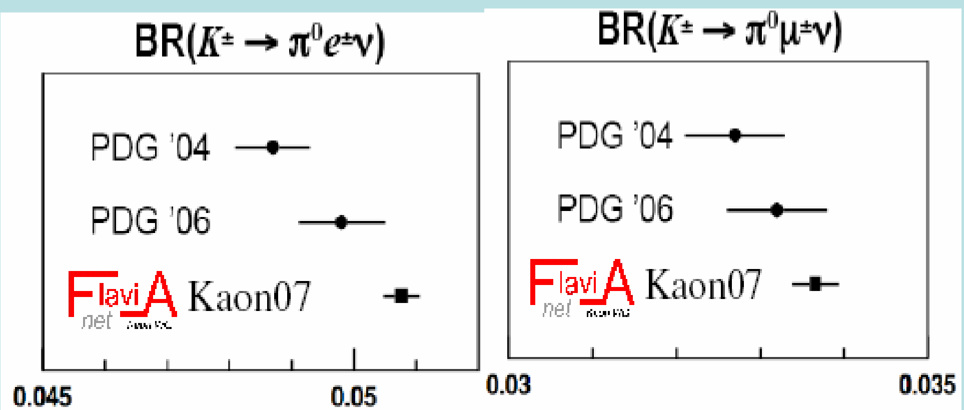
$I_{Kl}(\lambda)$ Phase space integral: λs parameterize form factor dependence on t :

K_{e3} : only λ_+ (or λ_+' λ_+'')

$K_{\mu3}$: need λ_+ and λ_0

Extraordinary experimental progress:
2004-06 PDG average superseded by the new results:

KLOE **ISTRA+** **NA48** **KTeV**



R. Wanke's talk

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with $K = K^+, K^0$; $l = e, \mu$ and C_K^2 = 1/2 for K^+, 1 for K^0

Inputs from theory:

S_{EW} Universal short distance EW correction (1.0232) → Marciano & Sirlin

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

Delicate Point! *recent progress on the lattice*

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

Δ_{Kl}^{EM} Long distance EM effects

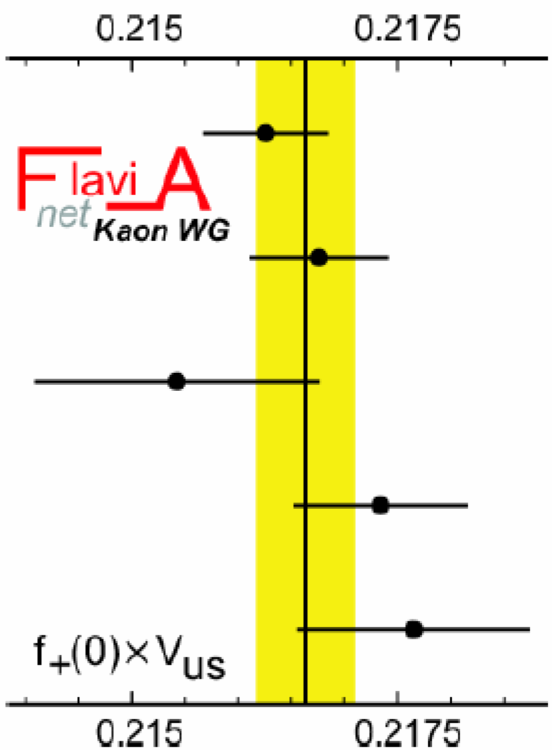
→ CHPT

Knecht et al. '00
Cirigliano et al. '02-'04
Andre '04; Gatti '05
Moussalam et al. '06
Neufeld prelim. '07

success of ChPT: exp. cross-check

$$\Gamma(K_{l3(\gamma)}) = \frac{C_K^2 G_F^2 M_K^5}{192\pi^3} S_{EW} |V_{us}|^2 |f_+^{K^0\pi^-}(0)|^2 I_{Kl}(\lambda) \left(1+2\Delta_K^{SU(2)} +2\Delta_{Kl}^{EM}\right)$$

measured with small th. and exp. uncertainties

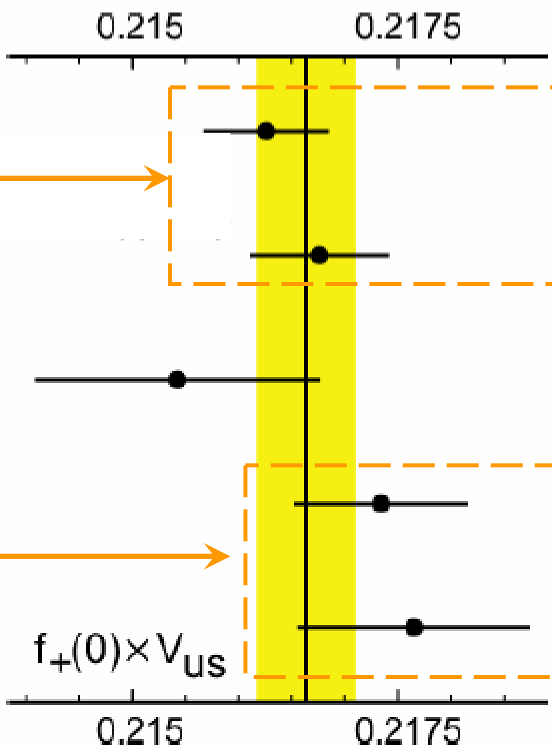


		% err	Approx. contr. to % err from: BR	τ	δ	I_{Kl}
$K_L e3$	0.2163(6)	0.28	0.09	0.19	0.15	0.09
$K_L \mu 3$	0.2168(7)	0.31	0.10	0.18	0.15	0.15
$K_S e3$	0.2154(13)	0.67	0.65	0.03	0.15	0.09
$K^{\pm} e3$	0.2173(8)	0.39	0.26	0.09	0.26	0.09
$K^{\pm} \mu 3$	0.2176(11)	0.51	0.40	0.09	0.26	0.15

Average from *Flavianet KW* [arXix:0801.1817]: $|V_{us}|\, f_+(0) = 0.2166(5) \Rightarrow \sigma_{rel} \sim 0.21\%$

The $|V_{us}|\, f_+(0)$ ratio among Neutral and Charged modes:

$\Delta^{SU(2)}_{exp}$ = 2.86(38)% → success of CHPT calculations $[\Delta^{SU(2)}_{th}$ = 2.31(22)%]



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$f_+(0)$ - Determinations

$f_+(0)$ Chiral Properties:

the Ademollo-Gatto Theorem: *chiral corrections* $\propto (m_s - m_u)^2$

χpT

$$f_+(0) = 1 + f_2 + f_4 + O(p^8)$$

Vector Current Conservation $m_s = m_u$

$f_2 = -0.023$

(NO UNCERTAINTY!)

$O(m_s - m_u)^2$ – AG Theorem

NO LECs

DOMINANT UNCERTAINTY !!

$O(m_s - m_u)^2$ – AGT

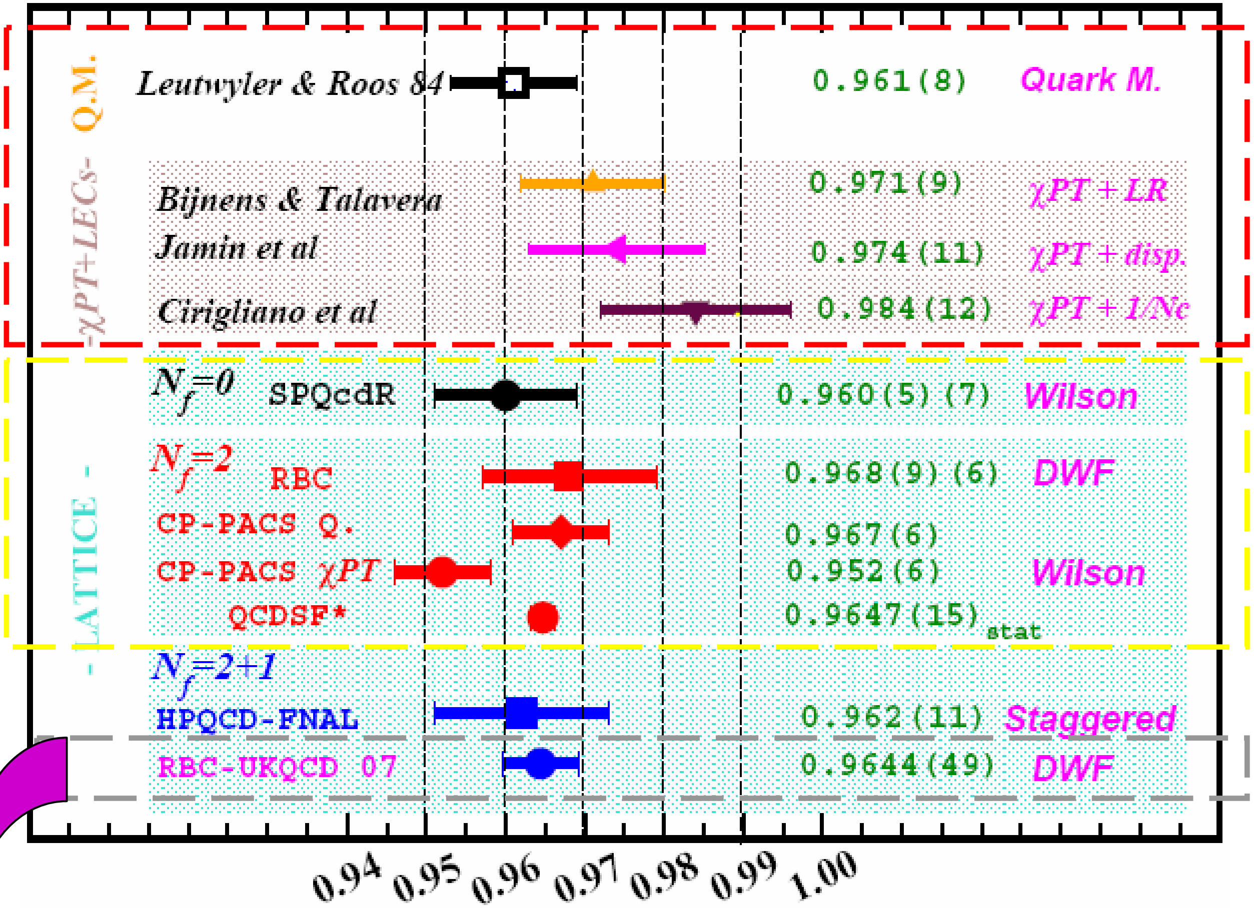
$$f_4 = \underline{\Delta^{loops}(\mu)} - \frac{8}{f_\pi^4}\underline{(C_{12}(\mu) + C_{34}(\mu))}(M_K^2 - M_\pi^2)^2$$

Bijnens-Talavera ('03), Post-Schilcher ('01)

unknown LECs

the origin of the present uncertainty

$f_+^{K^0\pi^-}(0)$ - Evaluations



Over the years, many theoretical approaches to measure f_4:

- *Quark Model,*
- *Dispersive Method*
- *Resonance Saturation*
- *$1/N_c$ limit*

- First estimate by LR in 1984 => $f_+(0)$=0.961(8)

- Present values agree with each other at 1-2%

- **Improvement below 1% relies on Lattice approach**
- Many lattice estimates already available, typically at heavy $\mathbf{m_\pi} \geq 500$ **MeV** <=> large chiral uncertainties

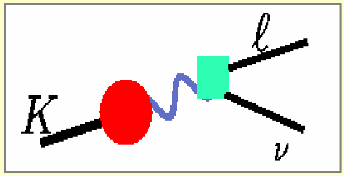
- ***Encouraging result from UKQCD-RBC:***

$N_F = 2+1$, DWF, $m_\pi \geq 300$ MeV

$f_+(0)$=0.964(5) ==> σ~0.5%

2007 Theory Progress

V_{us} from $K_{\ell 2}$ decays



- Being f_K/f_π better determined than f_K

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

Inputs from experiment:

$\Gamma(K_{\mu 2(\gamma)})$, $\Gamma(\pi_{\mu 2(\gamma)})$: Rates with well-determined treatment of radiative decays:

- Branching ratios
- lifetimes

Inputs from theory:

f_K/f_π — Ratio of pseudoscalar decay constants

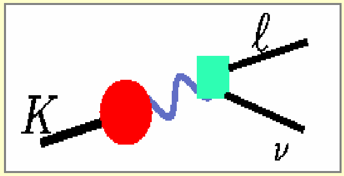
C_K, C_π — Radiative inclusive electroweak corrections

$$1+\alpha(C_K - C_\pi) = 0.9930(35)$$

Marciano'04, Cirigliano-Rosell'07

$$|V_{us}|/|V_{ud}| \times f_K/f_\pi = 0.2760 \pm 0.0006 \Rightarrow \sigma_{rel} \sim 0.21\%$$

V_{us} from $K_{\ell 2}$ decays



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$$|V_{us}|/|V_{ud}| \times f_K/f_\pi = 0.2760 \pm 0.0006 \Rightarrow \sigma_{rel} \sim 0.21\%$$

f_K/f_π Properties:

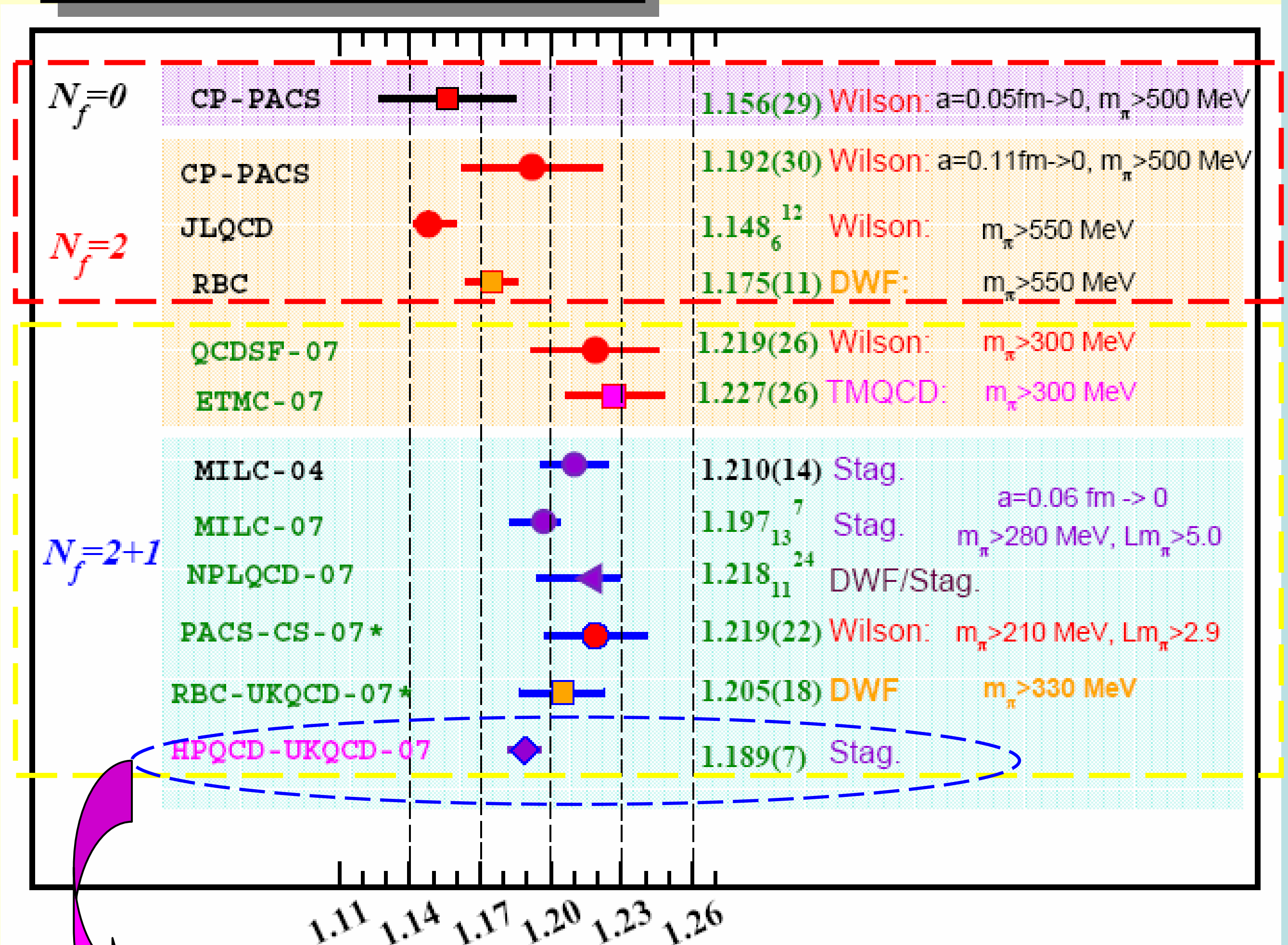
- No competition from non-Lattice approaches

- No AdemolloGatto Protection: *chiral dependence* $\propto (m_s - m_u)$

$$\frac{f_K}{f_\pi} = 1+\Delta^{loops}(\mu) - \frac{1}{f_\pi^2} LEC(\mu)(M_K^2 - M_\pi^2)$$

- *sensitivity to the lightest pion simulated*
  (kew point in order to match with ChPt Logs)

f_K/f_π - Evaluations



Old simulations with heavy pions => f_K/f_π underestimate

Recently, many Lattice calculations, with rather light quark masses, $m_\pi \geq 280$ MeV:

- $N_F=2$ **and** $N_F=2+1$;
- ***First signs of chiral logs***

- ***Overall accuracy ~ 1%***

- ***A complete study with all the systematic is still missing***

- **Interest result from HPQCD: $N_F=2+1$, Staggered, $m_\pi \geq 280$ MeV**

$$f_K/f_\pi=1.189(7) \Longrightarrow \sigma_{rel} \sim 0.6\%$$

2007 Progress

need confirmation!!

Consistency Test between *experimental information* and *Lattice QCD*

- ***Callan-Treiman soft-pion theorem*** $\Rightarrow$

$$\left(\frac{f_K}{f_\pi}\frac{1}{f_+(0)}\right) = \underline{f_0\,(m_K^2 - m_\pi^2)} + \delta_{SU(2)}^{CT}$$

by the experimental phase space

small $SU(2)$ corrections: 3×10^{-3} by ChPT

- *Callan-Treiman soft-pion theorem* $\Rightarrow$

$$\left(\frac{f_K}{f_\pi} \frac{1}{f_+(0)} \right) = f_0\,(m_K^2 - m_\pi^2) + \delta_{SU(2)}^{CT}$$

fit to the q^2 bins by an improved disp. relation

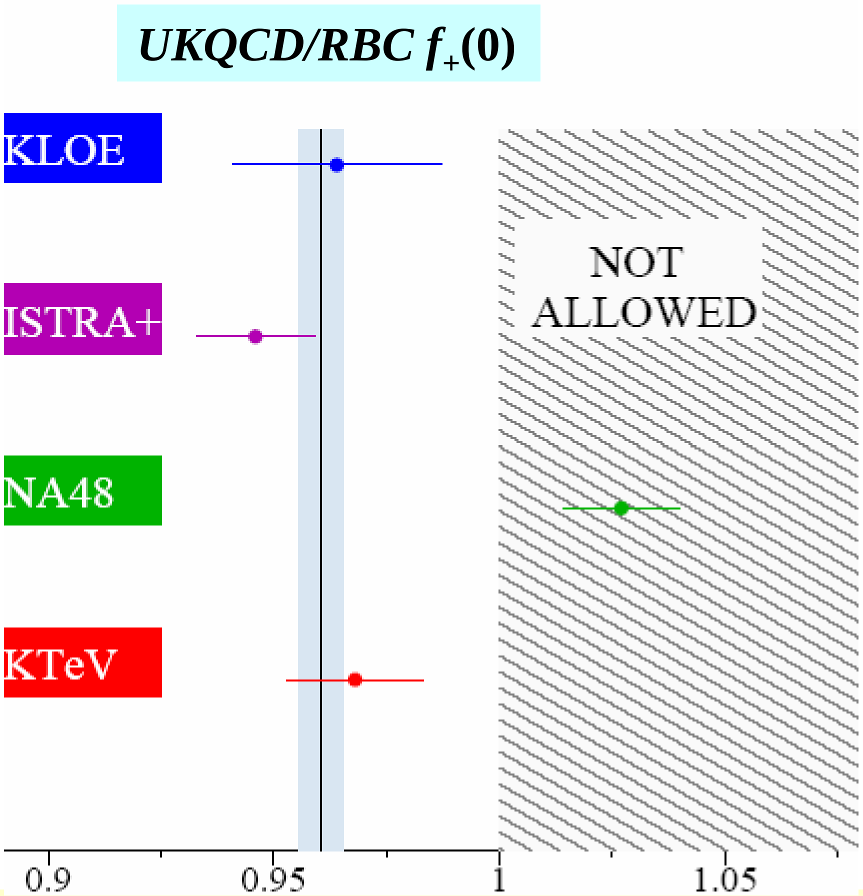
Bernard, Oertel, Passemar & Stern '06
Jamin, Oller & Pich '07

exp. input

f_K/f_π=1.189(7)
from HPQCD'07

+

$$f_+(0)^{exp}_{CT}$$

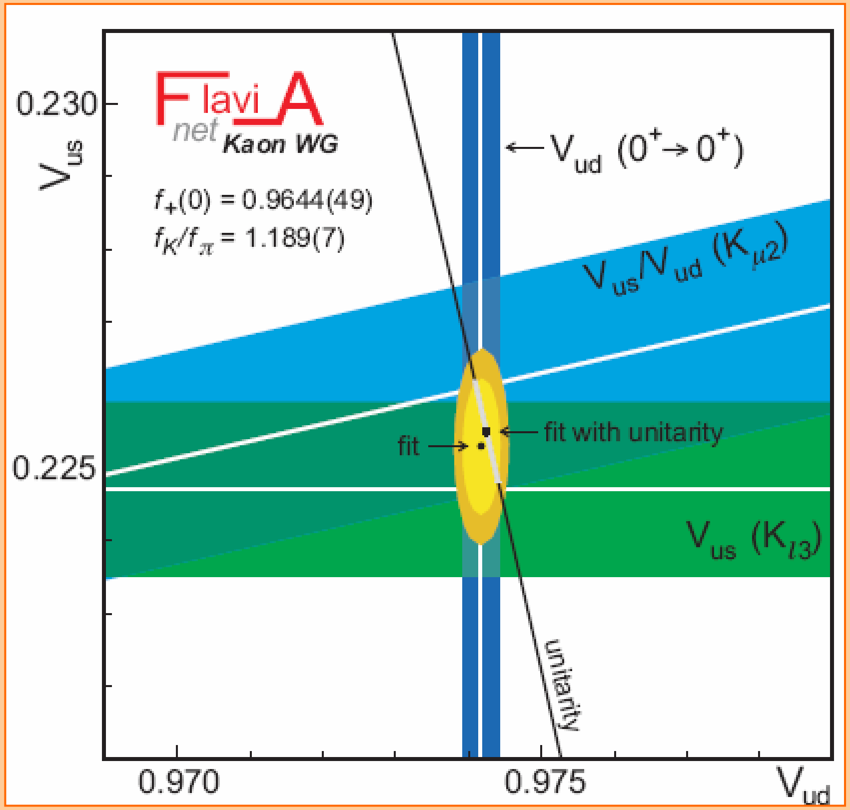


consistency test between experiments and Lattice QCD

V_{us} and CKM Unitarity at Spring 2008

$f_+(0)$=0.964(5) **from UKQCD / RBC'07**
$|V_{us}|$=0.2246(12) *from Kl3*

f_K/f_π=1.189(7) **from HPQCD'07**
$|V_{us}/V_{ud}|$=0.2323(15) *from Kl2*



Fit results, no constraint:

$$|V_{ud}|=0.97417(26)$$
$$|V_{us}|=0.2253(9)$$
$$\chi^2/\text{ndf } 0.65/1 \ (42\%)$$

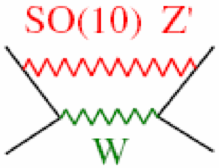
Fit results, unitarity constraint:

$$|V_{us}| = \sin\theta = 0.2255(7)$$
$$\chi^2/\text{ndf } 0.80/2 \ (67\%)$$

$$\left|V_{ud}\right|^2 + \left|V_{us}^{Kl3}\right|^2 = 0.9995(7)$$

This is a highly non-trivial constraint for NP models...

E.g.:



→ $M_{Z'}$: 0.72 TeV

2

New Physics Searches from K_{l2}

New Physics Searches from K_{l2}

New Golden Mode

- **Lepton Universality Test** $\Rightarrow$

$$B(K \to e\nu)/B(K \to \mu\nu)$$

Masiero, Paradisi & Petronzio
*large tan*β & LFV

$$B(K \to \mu\nu)/\ B(K \to \pi l\nu)$$

- ***MSSM*** → ***constrain on scalar densities***

  Hou - Isidori & Paradisi,

- ***a Higgsless model*** → ***constraint on right-handed currents***

  Bernard, Oertel, Passemar & Stern

promising as soon as lattice accuracy on f_K/f_π *improves*

Lepton Universality Test $\Rightarrow$ $B(K \to e\nu)/B(K \to \mu\nu)$

- *Leading QCD uncertainties from f_K cancel out*
- *Subleading effects calculated in ChPT to $O(e^2p^4)$*

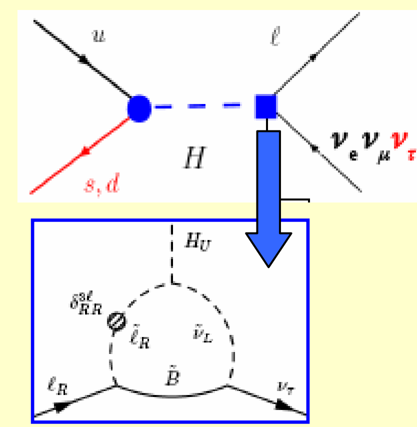
Cirigliano Rosell '07

$$\left.\frac{\Gamma(K \to e\nu_e)}{\Gamma(K \to \mu\nu_\mu)}\right|_{SM} = \frac{m_e^2}{m_\mu^2}\left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 \left(1 + O(e^2 p^n)\right)$$

$$R_K^{SM}: \quad (2.477 \pm 0.001) \quad \to \quad 0.04\% \text{ accuracy}$$

- In MSSM, sizeable LFV couplings at large tanβ enhance $K \to e\nu_\tau$

$$\left.\frac{\sum_i \Gamma(K \to e\nu_i)}{\sum_i \Gamma(K \to \mu\nu_i)}\right|_{\exp} \approx \frac{\Gamma(K \to e\nu_e) + \Gamma(K \to e\nu_\tau)}{\Gamma(K \to \mu\nu_\mu)} = R_K^{SM}\left(1 + \Delta r_K^{LFV}\right)$$



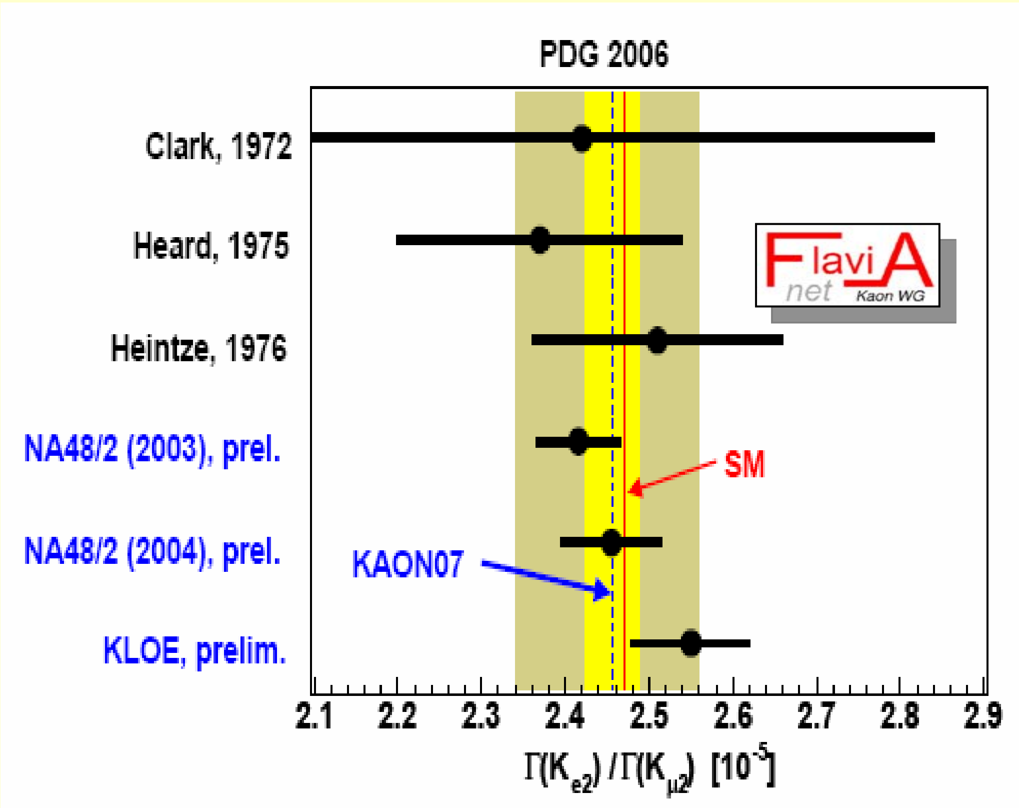
- up to 1% enhancement to the SM

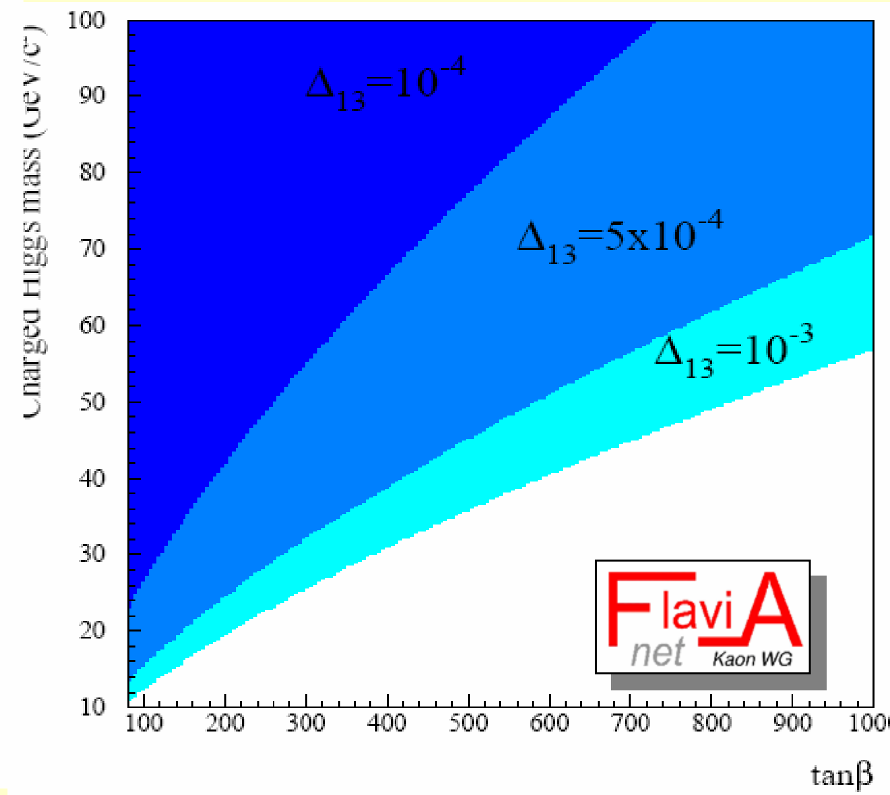
key ingredeints for visible effects in SUSY:

- Large $\tan\beta$, $M_H < 1\,TeV$
- Large LFV slepton minxings, $\delta_{3j} \sim \mathcal{O}(1)$, ($m_{SUSY} \geq 1\,\mathrm{TeV}$)

Masiero, Petronzio, Paradisi '05

Limit on LFV in H⁺ coupling $\Rightarrow$ $B(K \to e\nu)/B(K \to \mu\nu)$



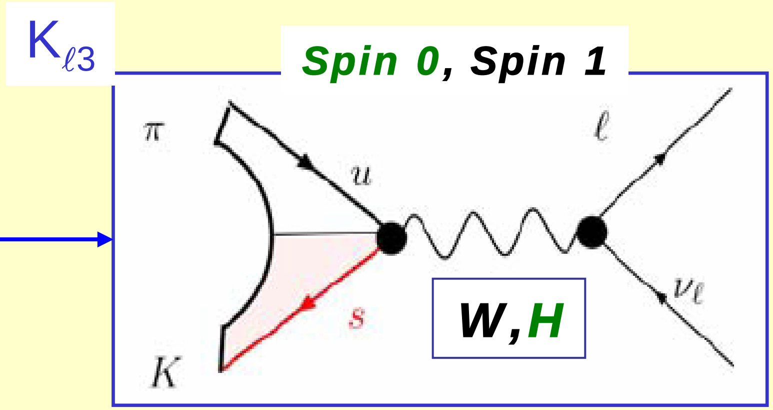


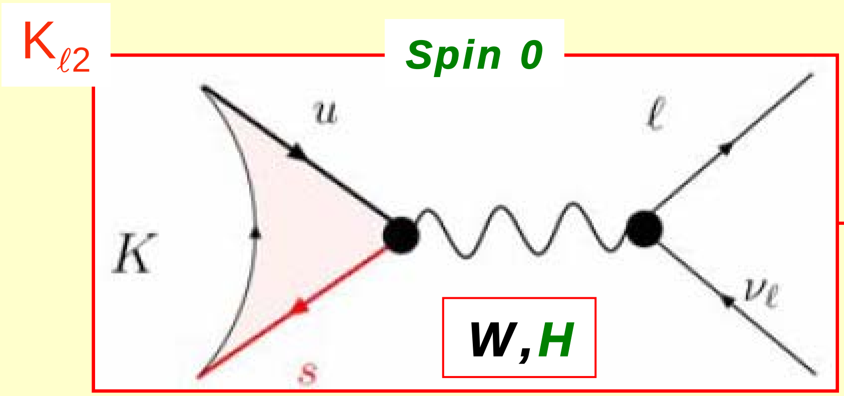
FlaviA net Kaon WG $\boxed{\Gamma(K_{e2})/\Gamma(K_{\mu 2}) = (2.457 \pm 0.032) \times 10^{-5}}$

R_K^{SM} : (2.477 ± 0.001) $\rightarrow$ 0.04% accuracy

Recent Results at O(1-2%) $\Rightarrow$ 0.3% from NA61

2HDM, Susy: Charged Higgs => SM + $\left(\bar{s}_R u_L\right)\left(\bar{\ell}\nu_L\right)$





K_{l3} : Higgs effects => $f_0(q^2)$ -> $f_0(q^2)(1 + g^H q^2/m^2_H)$

- to test g^H => <u>calculate</u> *slope and curvature* of $f_0(q^2)$!

$|V_{us}|^{Kl3}$ is NP free as soon as we use $f_0(q^2)$ from data

K_{l2} : Higgs effects=> $|V_{us}|^{Kl2}$-> $|V_{us}|^{Kl2}$ $(1 + g^H m^2_K/m^2_H)$

- to test g^H => f_K *from theory:* f_K/f_π *better determined*

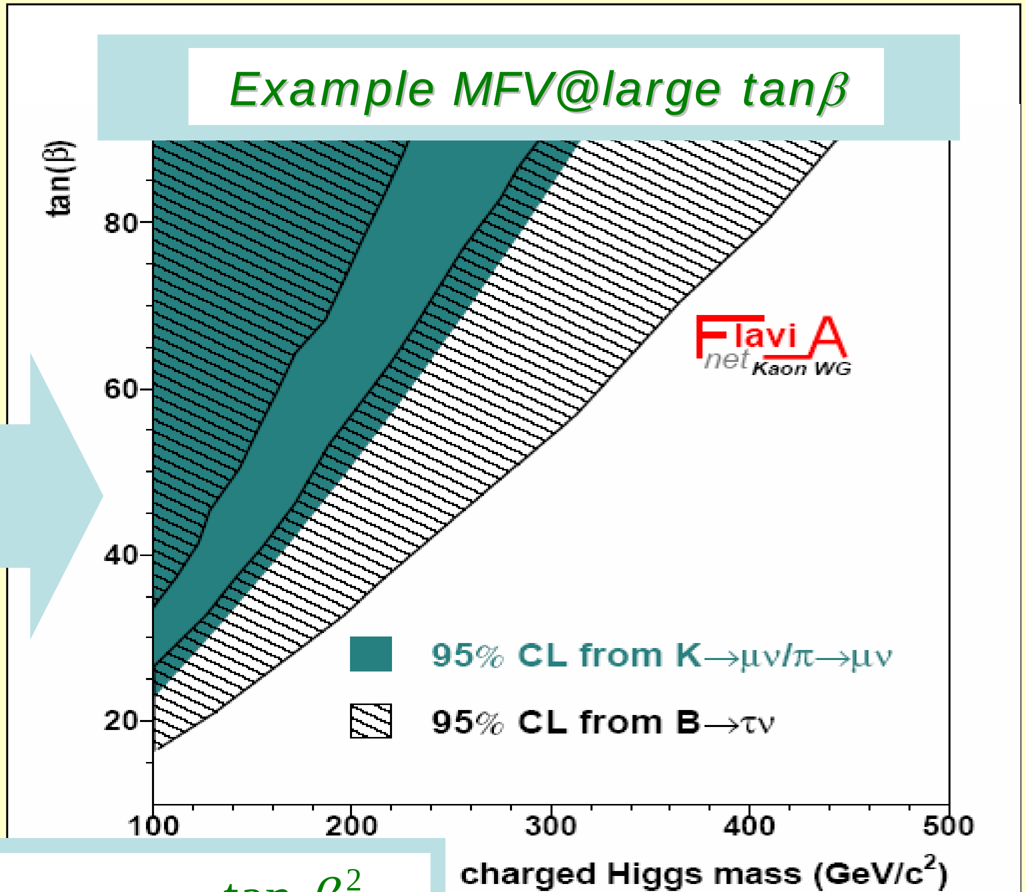
Hadronic uncertainties => **estimate directly this ratio on the lattice**

$$\frac{B(K\to\mu\nu)}{B(\pi\to\mu\nu)}\times\frac{B(n\to pl\nu)}{B(K\to\pi l\nu)}=\left(\frac{f_K}{f_\pi}\,\frac{1}{f_+(0)}\right)^2\times\left(1+g^H\frac{m_K^2}{m_{H^+}^2}\right)^2\ (\text{known f.s})$$

FlaviA net Kaon WG

$$1+g^H\frac{m_K^2}{m_{H^+}^2}=1.004(7)$$

Collider Signature: H^+



$$g^H=-\frac{\tan\beta^2}{1+\varepsilon_0\tan\beta}$$

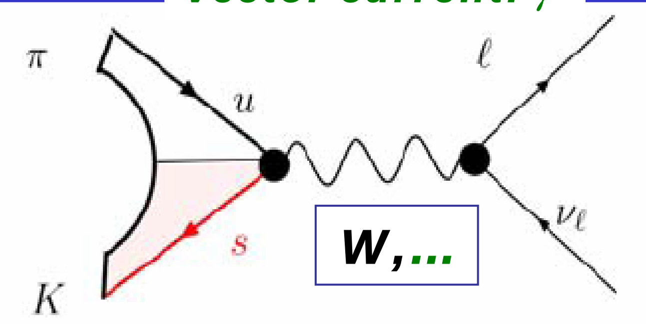
Higgsless Model: resonances => SM + $\left(\bar{s}\gamma_R^{\mu}u\right)\left(\bar{\ell}\gamma_L^{\mu}\nu\right)$

Bernard, Hirn, Oertel, Passemar & Stern

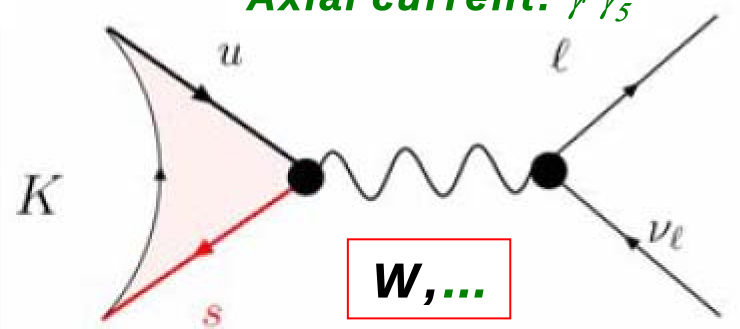
- *"Higgs-Goldstone field" to give mass to W and Z;*
- *no elementary Higgs particle => higher order operators (composite, partial, no Higgs)*

=> unbound effects by EWPT on right-handed currents:

$K_{\ell 3}$ **vector current:** γ^{μ}



$K_{\ell 2}$ **Axial current:** $\gamma^{\mu}\gamma_5$



K_{l3} : RHC =>
$|V_{us}|^{Kl3} \rightarrow |V_{us}|^{Kl3}(1 + \varepsilon^{RH})$

K_{l2} : RHC =>
$|V_{us}|^{Kl2} \rightarrow |V_{us}|^{Kl2}(1 - \varepsilon^{RH})$

FlaviA net Kaon WG

$$1-2\varepsilon^{RH} = 1.004(6)$$

Collider Signature:
W', Strong dynamics@TeV

3

Rare K Decays

• **Unique and precious test of the SM**: one-loop FCNC and $\Delta S=1$ transitions:

Hadronic uncertainties are small or under good theoretical control

• Highest CKM suppression $V_{ts}V_{td} \sim \lambda^5$

• Highly sensitive to New Physics $\rightarrow$ like ε'/ε

In other words ... as promising as sin(2β) from $B\rightarrow J/\psi\ K_S$

Rare K Decays: the four golden mode

	Short-distance [%] (sensitivity to e.w scale)	Irreducible th. error on the BR
$K_L \to \pi^0 \nu\bar{\nu}$	>99%	$< 2\%$
$K^+ \to \pi^+ \nu\bar{\nu}$	91%	$< 5\%$
$K_L \to \pi^0 e^+ e^-$	38%	$< 10\%$
$K_L \to \pi^0 \mu^+ \mu^-$	28%	$< 10\%$

Golden Modes	Standard Model	Experiment	
$K^+ \to \pi^+ \nu\bar{\nu}$	$8.22^{+0.84}_{-0.84} \times 10^{-11}$	$14.7^{+13.0}_{-8.9} \times 10^{-11}$	E787 E949
$K_L \to \pi^0 \nu\bar{\nu}$	$2.76^{+0.40}_{-0.40} \times 10^{-11}$	$< 6.7 \times 10^{-8}$	$\boxed{\text{E391a}}$
$K_L \to \pi^0 e^+ e^-$	$3.5^{+1.0}_{-0.9} \times 10^{-11}$	$< 2.8 \times 10^{-10}$	KTeV
$K_L \to \pi^0 \mu^+ \mu^-$	$1.4^{+0.3}_{-0.3} \times 10^{-11}$	$< 3.8 \times 10^{-10}$	KTeV

CKM
$V_{ts}^* V_{td}$
$\mathrm{Im}\, V_{ts}^* V_{td} \sim \eta$
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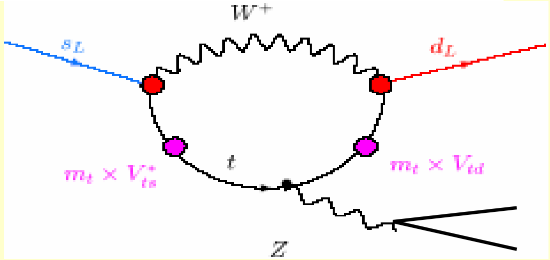
$\mathrm{Im}\, V_{ts}^* V_{td} \sim \eta$

But they have to be measured! JPARC@ KEK, $[K_L \to \pi\nu\nu]$ P326@CERN $[K^+ \to \pi\nu\nu]$

$K \to \pi + \nu\nu$ and $K \to \pi + ll$: SM Studies

$$H_{eff}\left(s \to d\right) \propto \left(y_\nu (\bar{s}\gamma_\mu d)(\bar{\nu}\gamma^\mu_L \nu) + y_{7V} (\bar{s}\gamma_\mu d)(\bar{\ell}\gamma^\mu \ell) + y_{7A} (\bar{s}\gamma_\mu d)(\bar{\ell}\gamma^\mu_L \gamma_5 \ell) \right)$$



1. *Top contribution dominant* $\propto G_F^2 m_t^2 \lambda^5 (1 - \rho + i\eta)$

2. $\langle \pi | (\bar{s}\gamma_\mu d) | K \rangle$ *related to the* $K_{\ell 3}$ $\langle \pi | (\bar{s}\gamma_\mu u) | K \rangle$ *ME by isospin* (Marciano-Parsa)

Recent Improvement

F.M. and C. Smith '07

$$\mathcal{B}\left(K^+ \to \pi^+ \nu\bar{\nu}(\gamma)\right) = \kappa_\nu^+ \left(1 + \underline{\Delta_{EM}}\right) |y_\nu|^2 \qquad \mathcal{B}\left(K_L \to \pi^0 \nu\bar{\nu}\right) = \kappa_\nu^L \left(\mathrm{Im}\, y_\nu\right)^2$$

New analysis: SU(2) corr. at NLO in ChPT *and the* *new Kl3 data*

$$\kappa_\nu^L = 3.3624(264) \cdot 10^{-5} \qquad \kappa_\nu^+ = 0.7867(43) \cdot 10^{-5}$$

errror reduced by a factor ~4 and ~7 respectively.

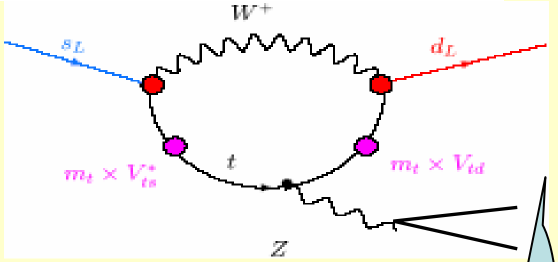
=> CKM uncertainty is the dominant source for the SM predictions.

updating at *www.lnf.infn.it/wg/vus*

FlaviA net Kaon WG

$K \to \pi + \nu\nu$ and $K \to \pi + ll$: *SM Studies*

$$H_{eff}\left(s \to d\right) \propto \left(y_{\nu}(\bar{s}\gamma_{\mu}d)(\bar{\nu}\gamma^{\mu}_{L}\nu) + y_{7V}(\bar{s}\gamma_{\mu}d)(\bar{\ell}\gamma^{\mu}\ell) + y_{7A}(\bar{s}\gamma_{\mu}d)(\bar{\ell}\gamma^{\mu}_{L}\gamma_5\ell) \right)$$



1. Top contribution dominant $\propto G_F^2 m_t^2 \lambda^5 \left(1-\rho+i\eta\right)$

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Further Improvement

- $K_L \to \pi^0 \nu\bar{\nu}$ *CP violating process → fully dominated by the top contribution* *no further uncertainties!*
- $K^+ \to \pi^+ \nu\bar{\nu}$ *uncertainties from charm and up contributions accurately estimated (~5%)*

  NNLO charm effects => Buras, Gorbahn, Haisch and Nierste '06

  Long Distance effects => Isidori, F.M, C.Smith '05
- $K_L \to \pi^0 e^+ e^- (\mu^+\mu^-)$ *reached a good theoretical control (~10%)*

  Isidori,Smith,Underdorfer '04; Friot,Greynat,de Raphael '03; Buchalla,D'Ambrosio,Isidori '03

Two classes of "*Beyond SM*" scenarios:

1. Minimal Flavour Violation:

flavour breaking induced only by SM Yukawa couplings, Y_U & $Y_{D.}$

(Y*: Wilson coefficient at* Λ_{flav}»1 TeV)

- *SM hierarchy of FV couplings:*

$(s\to d)_{MFV} = O(\lambda^5)\times[\ \mathrm{SM} + \text{new d.o.f}\ ]$

- Specific realisations in *SUSY, UED, LH, EFT*
- Small deviations in specific models:

$B(K_L\to\pi^0\nu\nu) \le O(20\%\text{-}30\%)$

- In specific models, stringent correlations can rise with either B physics ($B\to\ell\ell$, $B\to X\ell\ell$, $B\to X\nu\nu$) or EWPT ($\Delta\rho$)

2. New sources of Flavour Symmetry breaking at the TeV scale

- $s\to d$ new couplings no longer $O(\lambda^5)$ suppressed

$(s\to d)_{BMFV} = O(\lambda^5)\times \mathrm{SM} + O(1)\times(\text{new d.o.f})$

- *Many proposed models already killed from present data (B, K, EWPT & DM)*

- *One order of magnitude enhancement still possible in MSSM and LHT*

$B(K_L\to\pi^0\nu\nu) \le 5\,10^{-10}$

in reach of E391a upgrade

Pattern*:* effects on $B(K_L\to\pi^0\nu\nu) > B(K^+\to\pi^+\nu\nu) > B(K^+\to\pi^+\ell\ell)$

Peculiarity: $K_L\to\pi^0\mu\mu - K_L\to\pi^0 ee$ correlation

E787-E949
ex-0403034
ex-0403036

GN Bound
ph-9701313

MFV:

- D'Ambrosio *et al.* ph-0207036
- Buras *et al.* ph-0505110
- Haisch *et al.* 0706.2054

MSSM:

- Buras *et al.* ph-0408142.
- Isidori *et al.* ph-0604074.
- Mescia *et al.* ph-0606081

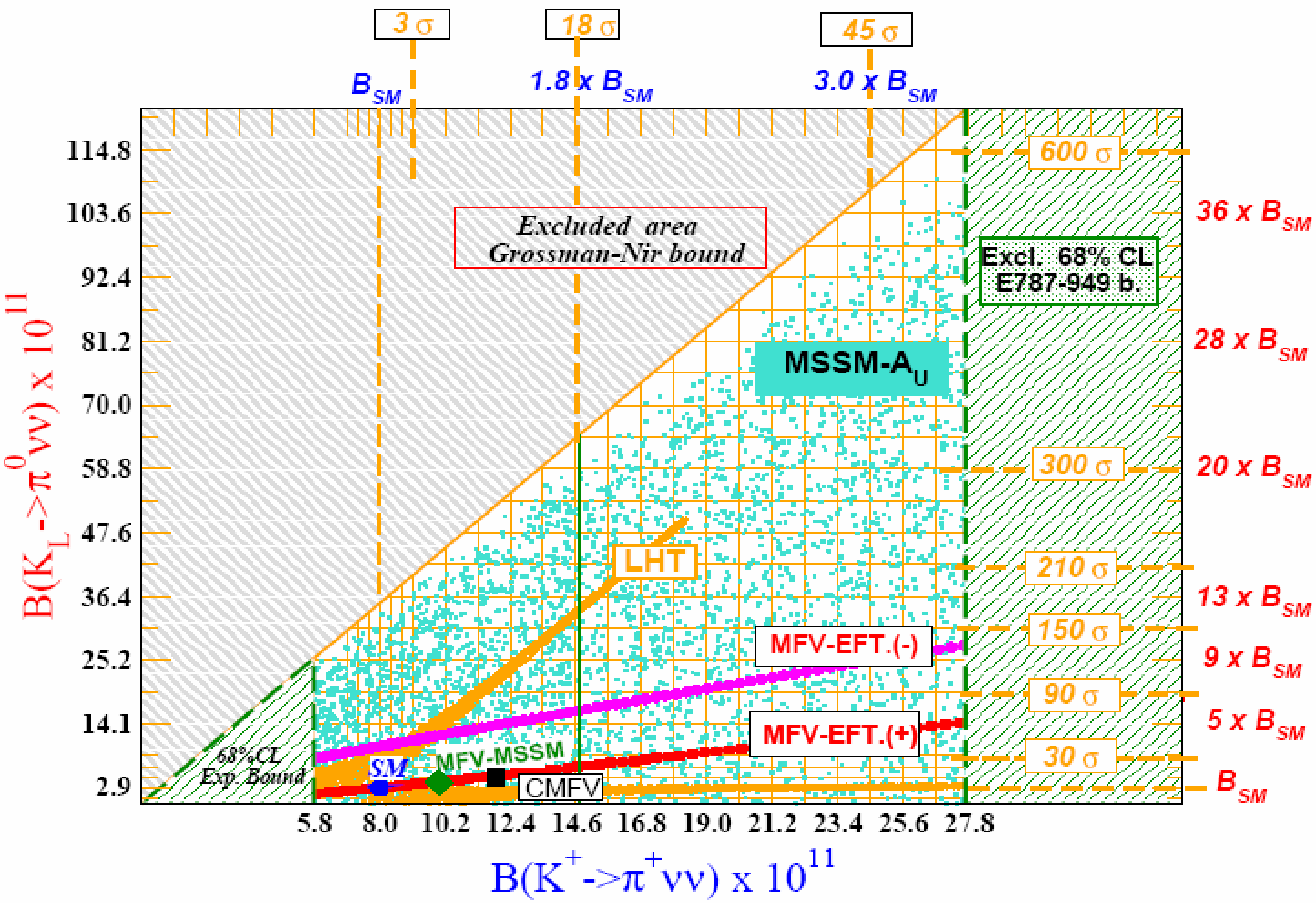
LHT:

- Blanke *et al.* ph-0604074

3-3-1 (Z'):

- Promberger *et al.* ph-0702169

Combining all present th. and exp. information, large deviations on $K \to \pi\nu\nu$ are still possible



rare K decays ⇒ *large not covered parameter space!*

- complementarity to Atlas/CMS searches ⇒ new particles
- supplementarity to LHcb/SuperB physics ⇒ gluinos

What can we ever learn from K-rare?

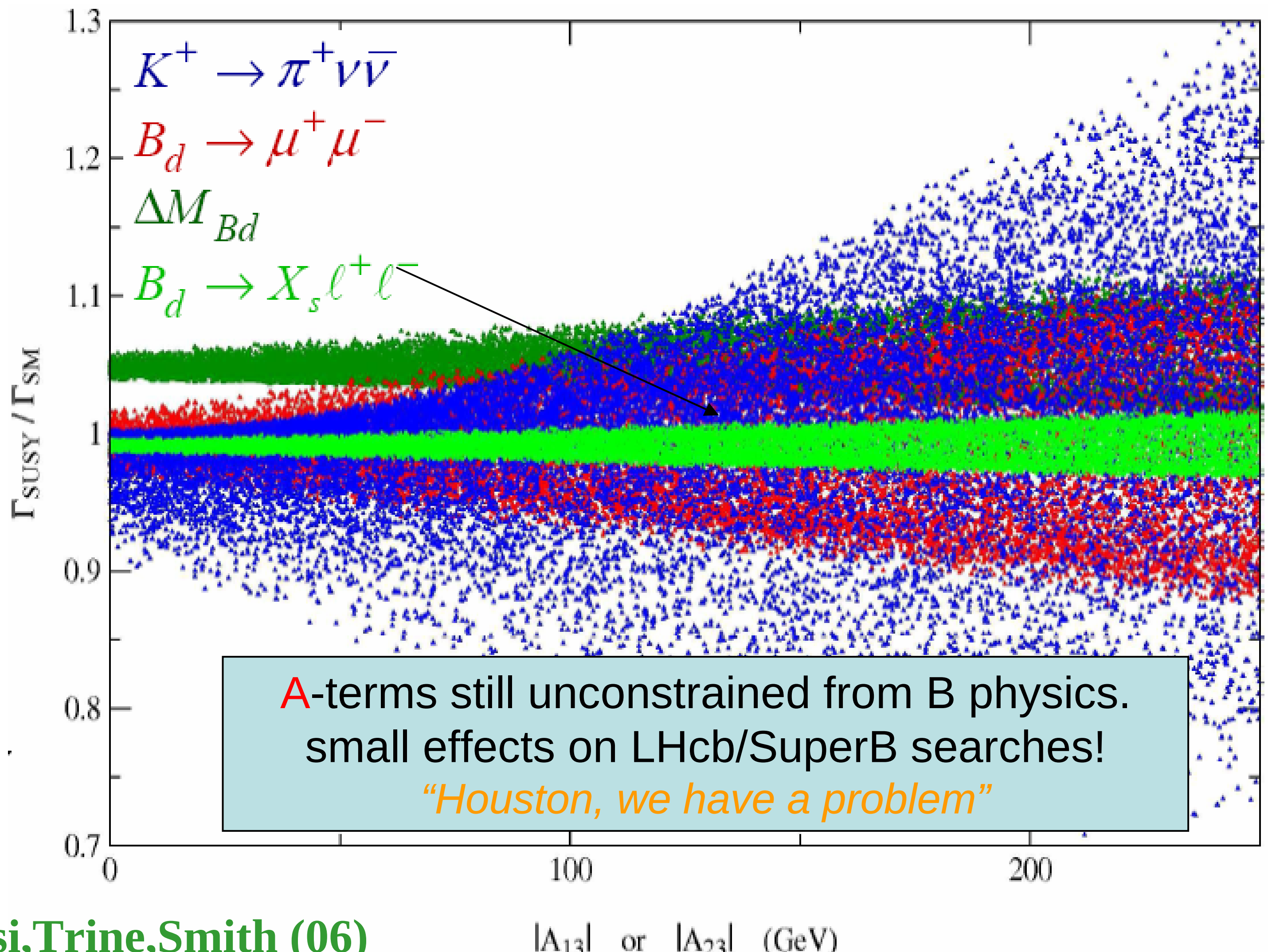
$K \to \pi\nu\nu$ are the *best probe* of the flavour structure of the A^U terms ($\propto M_t$)

$$\left(m_U^2\right)_{RL}^{i3} = \left(A^U - \mu \cot\beta\right)^{i3} M_t$$

$|\mathbf{A}_{13}^U|, |\mathbf{A}_{23}^U| \leq A_0 \lambda,$
$A_0 = 1\ \text{TeV}$
Phases left free.

LHC - spectrum

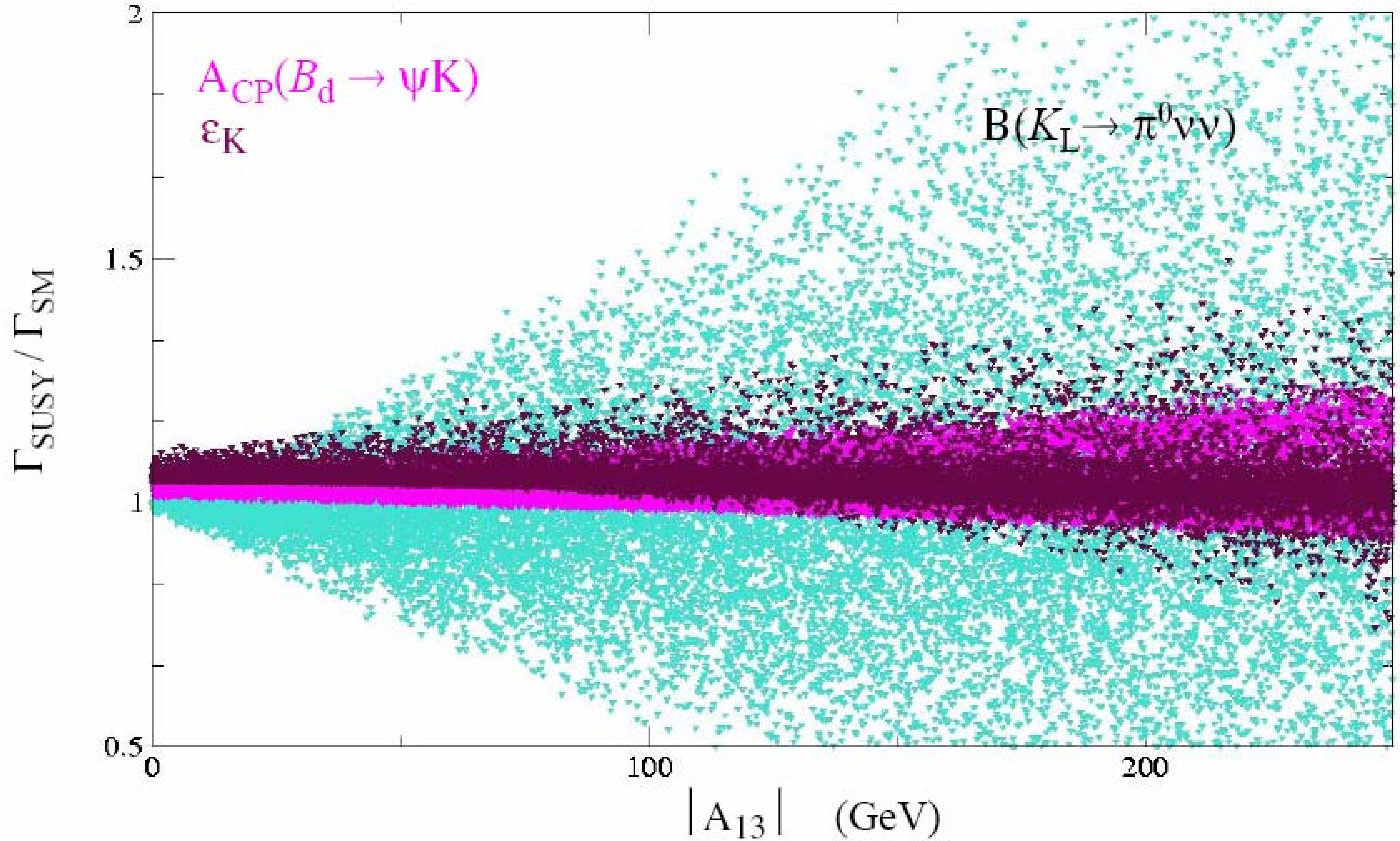
$\tan\beta = 2-4$
$\mu = 500 \pm 10\ \text{GeV}$
$M_2 = 300 \pm 10\ \text{GeV}$
$m_{u_R} = 600 \pm 20\ \text{GeV}$
$m_{q_L} = 800 \pm 20\ \text{GeV}$
$others: 2\ \text{TeV}$



A-terms still unconstrained from B physics.
small effects on LHcb/SuperB searches!
"Houston, we have a problem"

Isidori, F.M, Paradisi, Trine, Smith (06)

CPV observables at comparison:
large room left due to the A^U terms



small impact on ε_K & $\sin\beta$, complementarity to LHCb/SuperB

Isidori,F.M,Paradisi,Trine,Smith (06)

$K_L \to \pi^0 \mu\mu$ – $K_L \to \pi^0 ee$ correlation

1. alike to $K \to \pi\nu\nu \to \chi$ contributions by γ & Z peng.; *visible effects* on current-current operators

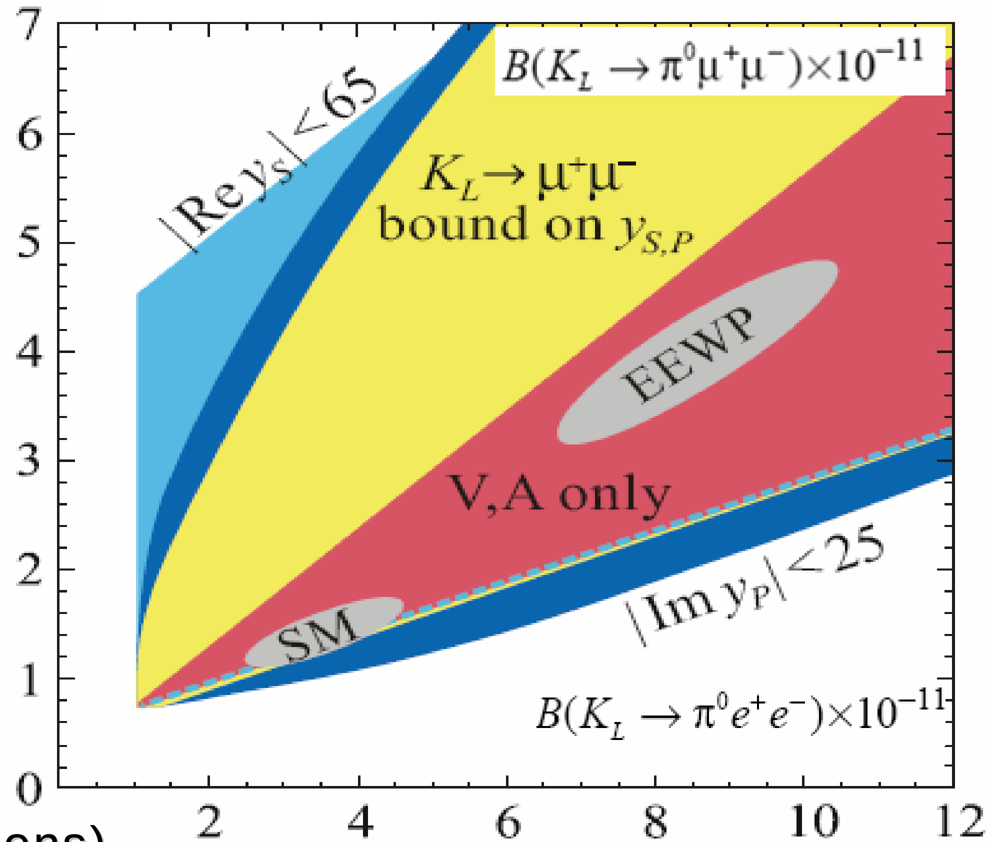
$$H_{eff}^{BSM}(s \to d) = X(\bar{s}\gamma_\mu d)(\bar{\nu}\gamma_L^\mu \nu)$$

$$+ y_{7V}(\bar{s}\gamma_\mu d)(\bar{\ell}\gamma^\mu \ell) + y_{7A}(\bar{s}\gamma_\mu d)(\bar{\ell}\gamma_L^\mu \gamma_5 \ell)$$

2. contrary to $K \to \pi\nu\nu \to$ sensitive to helicity-suppressed operators

$$+ y_S(\bar{s}d)(\bar{\ell}\ell) + y_P(\bar{s}d)(\bar{\ell}\gamma_5 \ell)$$

$\to$ H^0 penguins at large *tanβ*
(as $B \to \mu\mu$, but different mass insertions)



F.M, Trine, Smith (06)

$$y_{S,P} \sim (M_W^2/M_A^2)\tan^3\beta\,(1 + 0.01\tan\beta\,\mathrm{sign}\,\mu)^{-2}\left(\left(\delta_{LL}^D\right)_{12} + 18\left(\delta_{RR}^D\right)_{13}\left(\delta_{LL}^D\right)_{32}\right)$$

Retico, Isidori (02)/Buras,Chankowaki,Rosiek,Slawianowska(02)/
Foster ,Okumura,Roszkowski (05)

Conclusions from Kaon Physics

1. V_{us} at 0.1% precision not impossible

   $\Rightarrow$ *significant SM test competitive with EWPT*

2. A real possibility to discovering SUSY trough Ke2/Kμ2 mode => in the reach of current experimental runs NA61

3. Lattice efforts to improve f_K/f_π are welcome

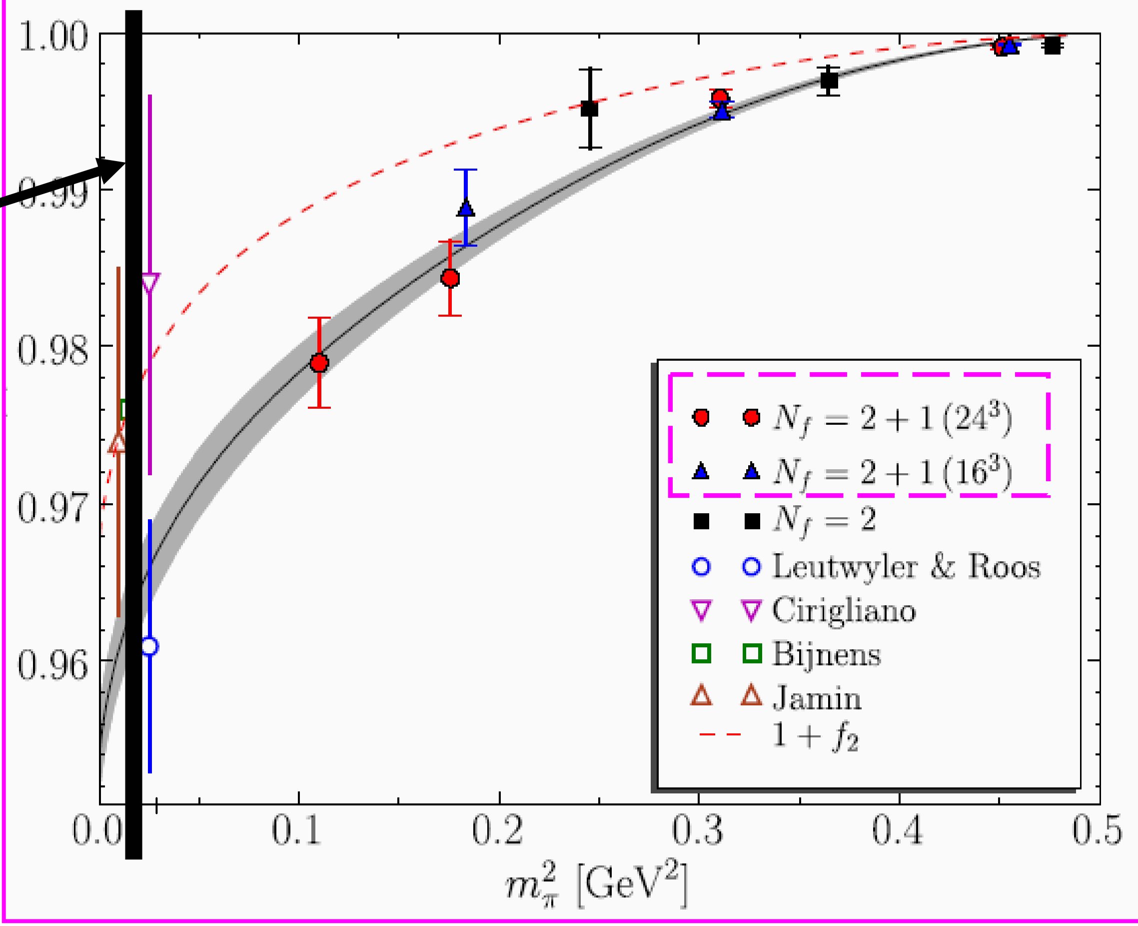
4. rare K decays by the E391a upgrade, JPARC and P326 is an unique opportunity for Flavour Physics with LHC running

$f_{+}^{K^0\pi^-}(0)$ - Evaluations

$$f_+(0) = 1 + f_2 + \Delta f$$

From UKQCD / RBC
arXiv:0710.5136

- *getting close to the physical point*



At the simulated quark masses,
- lattice data well mimic the f_2. chiral behaviour
  => free from LECs

- results point to a sizable and negative value for Δf

- ***Encouraging result from UKQCD-RBC:***

$N_F = 2+1$, DWF, $m_\pi \geq 300$ MeV

$f_+(0) = 0.964(5)$ ==> $\sigma \sim 0.5\%$

2007 Theory Progress