$K\pi$ form factors and determination of V_{us} from τ decays

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Outline :

1. Introduction and Motivation

2. Dispersive representation of the $K\pi$ form factors

3. Fits to the $\tau \to K\pi\nu_\tau$ and K_{l3} decays

4. Conclusion and outlook

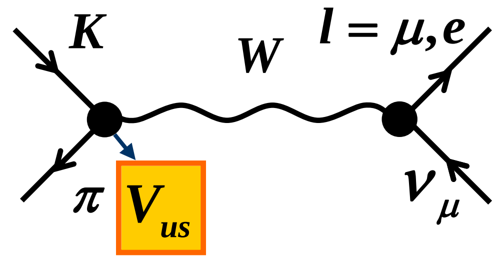
1. Introduction and Motivation

1.1 Test of New Physics : Vus

- Studying τ and K_{l3} decays ⇨ indirect searches of new physics, several possible high-precision tests:
  - ➢ Extraction of V_{us}

$$\left(K \to \pi l \nu_l\right)$$

$$\left(l = e, \mu\right)$$



$$\boxed{\Gamma_{K^{+/0} l3} = N \left| f_+(0) V_{us} \right|^2 I^l_{K^{+/0}}}$$

with

$$\boxed{I^l_{K^{+/0}} = \int dt \frac{1}{m^8_{K^{+/0}}} \lambda^{3/2} F\left(t, \bar{f}_+(t), \bar{f}_0(t)\right)}$$

From Lattice QCD

$f_+(0)$

$\boxed{f_+(0)\left|V_{us}\right|} \longrightarrow \boxed{\left|V_{us}\right|}$ ⇨ Test of unitarity $\boxed{\left|V_{ud}\right|^2 + \left|V_{us}\right|^2 + \left|V_{ub}\right|^2 \overset{?}{=} 1}$

$0^+ \to 0^+$ β decays

K_{l3} decays

Negligible (B decays)

1.1 Test of New Physics : Vus

- Studying τ and K_{l3} decays ⇨ indirect searches of new physics, several possible high-precision tests:
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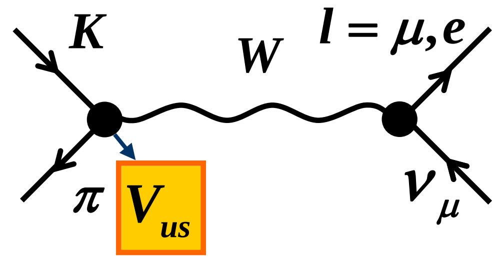
$$\left(l = e, \mu\right)$$



$$\boxed{\Gamma_{K^{+/0}l3} = N \left| f_+(0) \mathrm{V}_{us} \right|^2 I^l_{K^{+/0}}}$$

with

$$\boxed{I^l_{K^{+/0}} = \int dt \frac{1}{m^8_{K^{+/0}}} \lambda^{3/2} F\left(t, \bar{f}_+(t), \bar{f}_0(t)\right)}$$

⇨ Knowledge of the two form factors:

$$\boxed{\left\langle \pi(p_\pi) \right| \bar{\mathrm{s}} \gamma_\mu \mathrm{u} \left| \mathrm{K}(\mathrm{p_K}) \right\rangle = \left[\left(p_K + p_\pi\right)_\mu - \frac{\Delta_{K\pi}}{t} \left(p_K - p_\pi\right)_\mu \right] \underset{\text{vector}}{f_+(t)} + \frac{\Delta_{K\pi}}{t} \left(p_K - p_\pi\right)_\mu \underset{\text{scalar}}{f_0(t)}}$$

$$t = q^2 = (p_\mu + p_{\nu_\mu})^2 = (p_K - p_\pi)^2, \quad \bar{f}_{0,+}(t) = \frac{f_{0,+}(t)}{f_+(0)}$$

1.1 Test of New Physics : Callan-Treiman theorem

- Callan-Treiman (CT) theorem : *Bernard, Oertel, E.P., Stern'06*

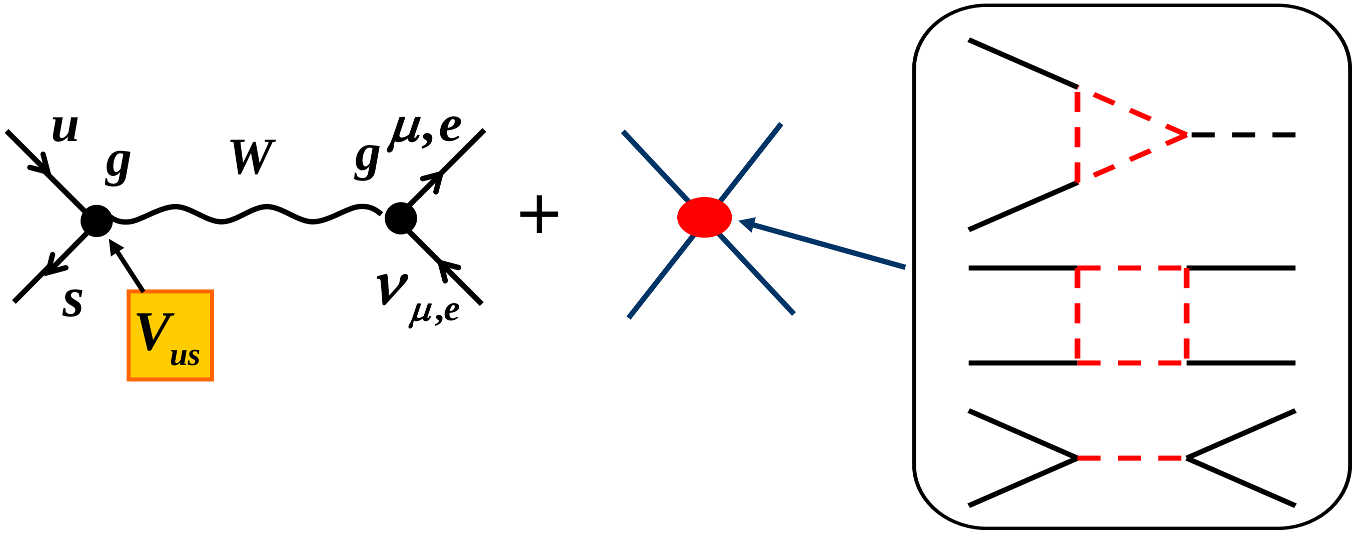
$$C = \bar{f}_0(\Delta_{K\pi}) = \frac{F_K}{F_\pi f_+(0)} + \Delta_{CT} = \underbrace{\frac{F_K |V^{us}|}{F_\pi |V^{ud}|} \frac{1}{f_+(0) |V^{us}|} |V^{ud}|}_{\text{Very precisely known from Br(Kl2/}\pi\text{l2), }\Gamma\text{(Ke3) and }|V_{ud}|} r + \Delta_{CT}$$

$$\Delta_{K\pi} = m_K^2 - m_\pi^2$$

  – In the Standard Model : $\boxed{r = 1}$ $\left(\ln C_{SM} = 0.2141(73)\right)$

  – In presence of new physics, new couplings : $\boxed{r \neq 1}$

Test of New Physics :



SUSY loops
Z’, Charged Higgs,
Right-Handed
Currents,….

[E.g. Bernard et al’06,’07, Deschamps et al’09, Cirigliano et al’10, Jung et al’10, Buras et al’10…]

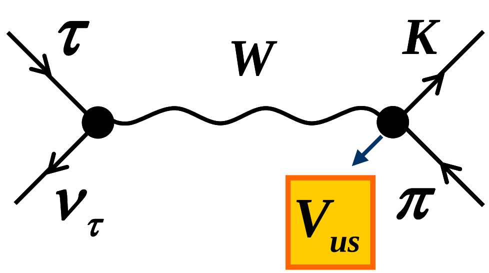
1.2 Determination of the Kπ form factors

- $\bar{f}_+(t)$ accessible in K_{e3} and $K_{\mu 3}$ decays

- $\bar{f}_0(t)$ only accessible in $K_{\mu 3}$ (suppressed by m_l^2/M_K^2) + correlations
  ⇨ difficult to measure

- Data from *Belle* and *BaBar* on $\tau \to K\pi\nu_\tau$ decays (*Belle II*, *SuperB* soon!)
  ⇨ Use them to constrain the form factors and especially $\bar{f}_0$

- $\tau \to K\pi\nu_\tau$ decays



Hadronic matrix element: Crossed channel

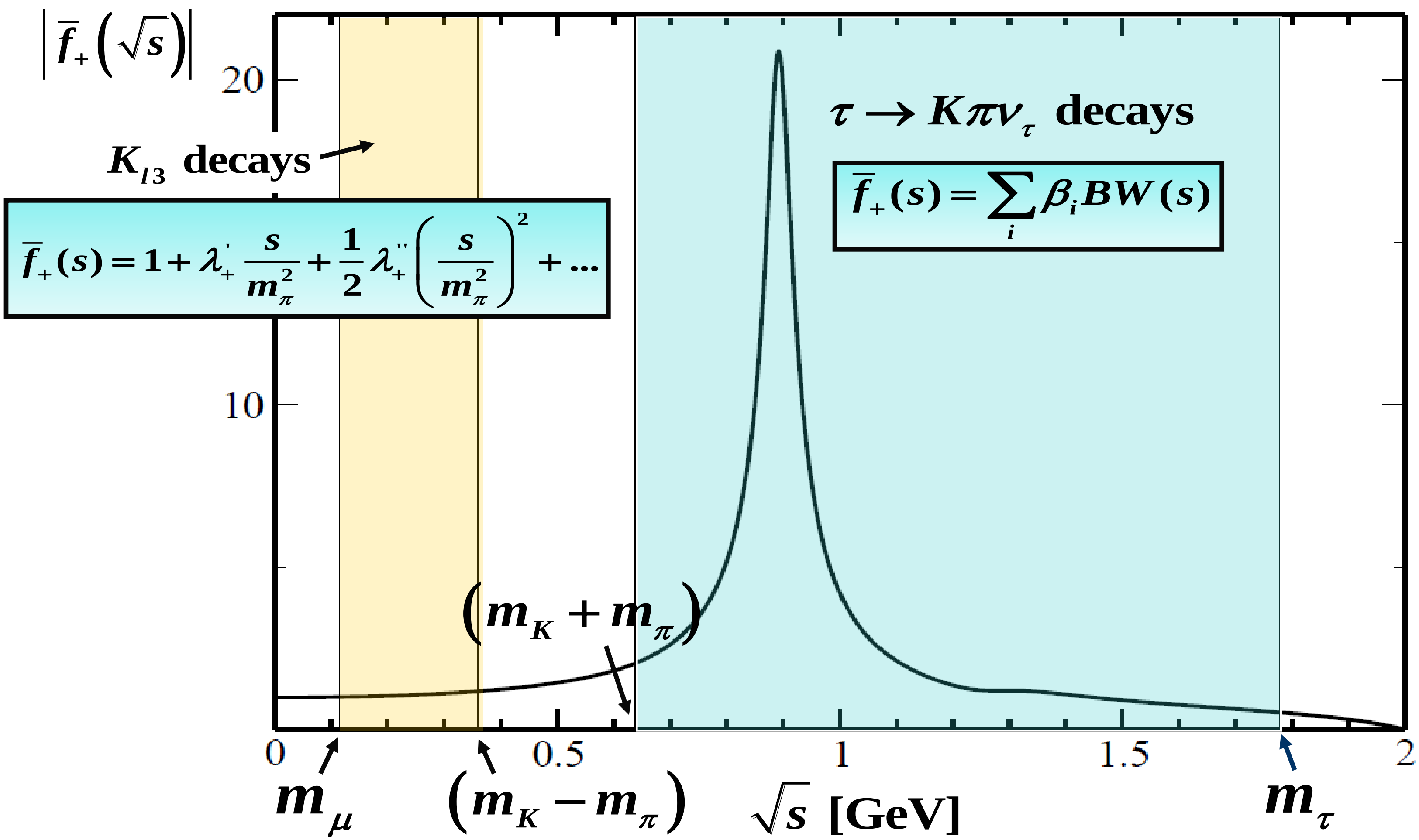
$$\boxed{\langle \mathbf{K}\pi | \, \bar{\mathbf{s}}\gamma_\mu \mathbf{u} \, | \mathbf{0} \rangle = \left[(p_K - p_\pi)_\mu + \frac{\Delta_{K\pi}}{s} (p_K + p_\pi)_\mu \right] \underbrace{f_+(s)}_{\text{vector}} - \frac{\Delta_{K\pi}}{s} (p_K + p_\pi)_\mu \underbrace{f_0(s)}_{\text{scalar}}}$$

with $s = q^2 = (p_K + p_\pi)^2$

2. Dispersive Representation of the Kπ form factors

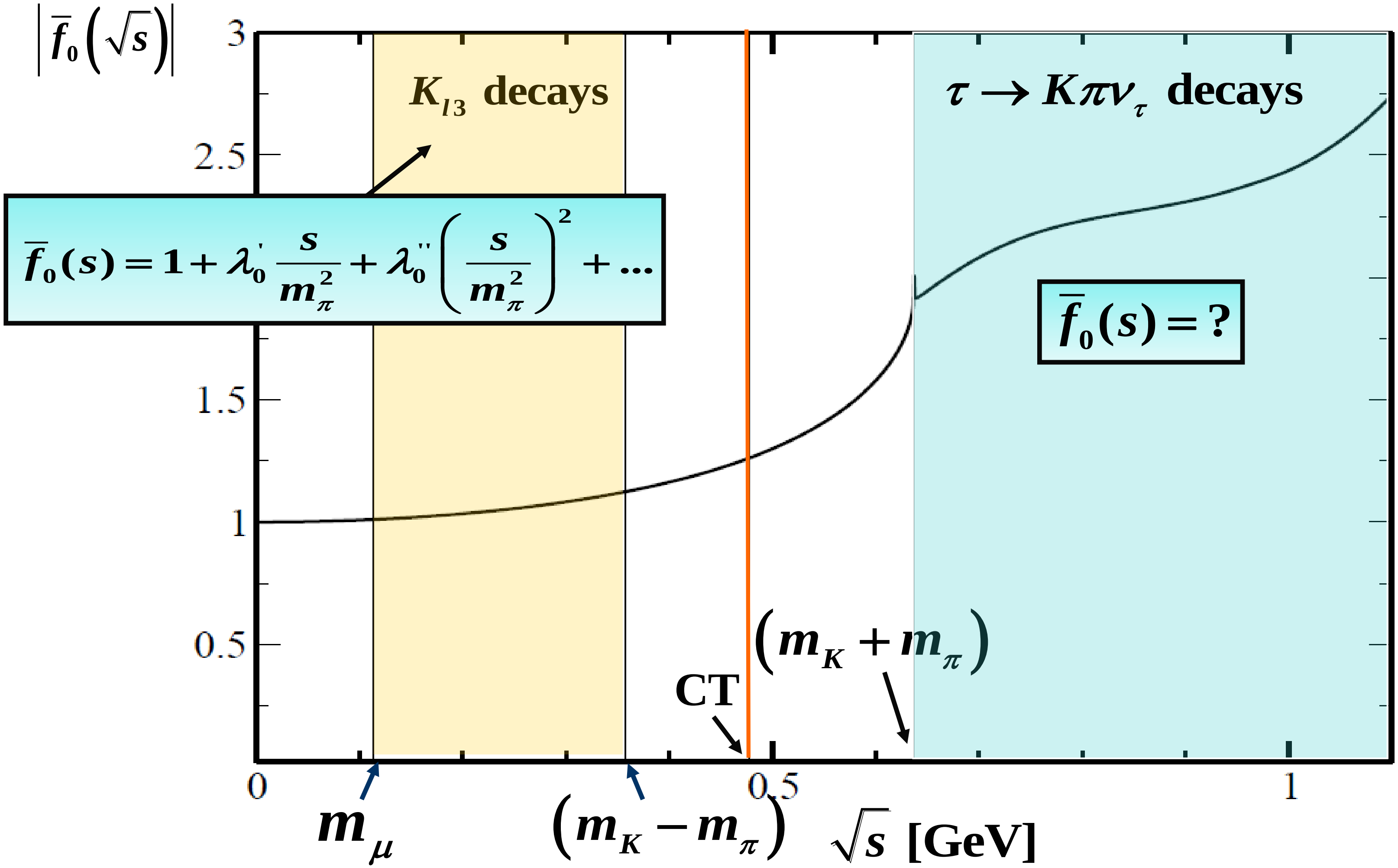
2.1 Introduction

- Parametrization to analyse both K_{l3} and τ
  - Vector form factor: ⇨ Dominance of K*(892) resonance



2.1 Introduction

- Parametrization to analyse both K_{l3} and τ
  - Scalar form factor: ⇨ No obvious dominance of a resonance



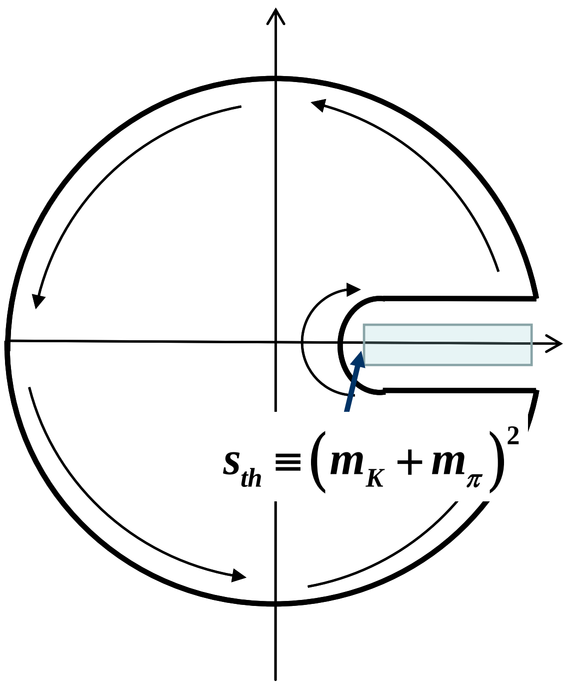
2.2 Dispersive representation

- Parametrization to analyse both K_{l3} and τ

  ⇨ Use dispersion relations

- Omnès representation: ⇨

$$\boxed{\bar{f}_{+,0}(s) = \exp\left[\frac{s}{\pi}\int_{s_{th}}^{\infty}\frac{ds'}{s'}\frac{\phi_{+,0}(s')}{s'-s-i\varepsilon}\right]}$$



$\phi_{+,0}$ (s): phase of the form factor

- $s < s_{in}$: $\phi_{+,0}(s) = \delta_{K\pi}(s)$

  $K\pi$ scattering phase

- $s \geq s_{in}$: $\phi_{+,0}(s)$ unknown

  ⇨ $\phi_{+,0}(s) = \phi_{+,0as}(s) = \pi \pm \pi \left(\bar{f}_{+,0}(s) \to 1/s\right)$

[Brodsky&Lepage]

- Subtract dispersion relation to weaken the high energy contribution of the phase. Improve the convergence but sum rules to be satisfied!

2.2 Dispersive representation

Bernard, Boito, E.P., in progress

- Dispersion relation with n subtractions in $\bar{s}$:

$$\boxed{\bar{f}_{+,0}(s) = \exp\left[P_{n-1}(s) + \frac{(s-\bar{s})^n}{\pi}\int_{s_{th}}^{\infty}\frac{ds'}{(s'-\bar{s})^n}\frac{\phi_{+,0}(s')}{s'-s-i\varepsilon}\right]}$$

➢ $\bar{f}_0(s)$ ⇨ dispersion relation with 3 subtractions: 2 in s=0 and 1 in s=$\Delta_{K\pi}$

[Callan-Treiman]

$$\boxed{\bar{f}_0(s) = \exp\left[\frac{s}{\Delta_{K\pi}}\left(\ln C + (s-\Delta_{K\pi})\left(\frac{\ln C}{\Delta_{K\pi}} - \frac{\lambda_0'}{m_\pi^2}\right) + \frac{\Delta_{K\pi}s(s-\Delta_{K\pi})}{\pi}\int_{(m_K+m_\pi)^2}^{\infty}\frac{ds'}{s'^2}\frac{\phi_0(s')}{(s'-\Delta_{K\pi})(s'-s-i\varepsilon)}\right)\right]}$$

For $s<s_{in}$: $K\pi$ scattering phase extracted from the data

Buettiker, Descotes-Genon, & Moussallam'02

2 parameters to fit to the data $\boxed{\ln C = \ln \bar{f}(\Delta_{K\pi})}$ and $\boxed{\lambda_0'}$

2.2 Dispersive representation

Bernard, Boito, E.P., in progress

- Dispersion relation with n subtractions in $\bar{s}$:

$$\bar{f}_{+,0}(s) = \exp\left[P_{n-1}(s) + \frac{(s-\bar{s})^n}{\pi}\int_{s_{th}}^{\infty}\frac{ds'}{(s'-\bar{s})^n}\frac{\phi_{+,0}(s')}{s'-s-i\varepsilon}\right]$$

➢ $\bar{f}_+(s)$ ⇨ dispersion relation with 3 subtractions in s=0

Boito, Escribano, Jamin'09,'10

$$\bar{f}_+(s) = \exp\left[\lambda_+'\frac{s}{m_\pi^2} + \frac{1}{2}\left(\lambda_+'' - \lambda_+'^2\right)\left(\frac{s}{m_\pi^2}\right)^2 + \frac{s^3}{\pi}\int_{(m_K+m_\pi)^2}^{\infty}\frac{ds'}{s'^3}\frac{\phi_+(s')}{(s'-s-i\varepsilon)}\right]$$

Extracted from a model including
2 resonances K*(892) and K*(1414)

Jamin, Pich, Portolés'08

7 parameters to fit to the data:

– $\boxed{\lambda_+'}$ and $\boxed{\lambda_+''}$ ⇨ can be combined with K_{l3} fits

– Resonance parameters: $\boxed{m_{K^*}, \Gamma_{K^*}, m_{K^{*'}}, \Gamma_{K^{*'}}, \beta}$

Mixing parameter

3. Fits to the $\tau \to K\pi\nu_\tau$ and K_{l3} decays

3.1 Kπ form factors from $\tau \to K\pi\nu_\tau$ and K_{l3} decays

- Fit to the $\tau \to K\pi\nu_\tau$ decay data
  - from *Belle [Epifanov et al'08]* (*BaBar?*)
  - from simulated *SuperB* data *[Antonelli, Lusiani, E.P. in progress]*

$$N_{events} \propto N_{tot}\, b_w\, \frac{1}{\Gamma_{K\pi}} \frac{d\Gamma_{K\pi}}{d\sqrt{s}} \quad \Rightarrow \quad \chi^2_\tau = \sum_{bins} \left(\frac{N_{events} - N_\tau}{\sigma_{N_\tau}} \right)^2$$

with

Number of events/bin

bin width

$$\frac{d\Gamma_{K\pi}}{d\sqrt{s}} = \frac{G_F^2 m_\tau^3}{32\pi^3 s} C_K^2 S_{EW} \left| f_+(0) V_{us} \right|^2 \left(1 - \frac{s}{m_\tau^2}\right)^2 \left[\left(1 + \frac{2s}{m_\tau^2}\right) q^3_{K\pi}(s) \left| \bar{f}_+(s) \right|^2 + \frac{3\Delta^2_{K\pi}}{4s} q_{K\pi}(s) \left| \bar{f}_0(s) \right|^2 \right]$$

- Normalization disappears by taking the ratio $\frac{1}{\Gamma_{K\pi}} \frac{d\Gamma_{K\pi}}{d\sqrt{s}}$

⇒ fit independant of V_{us}

3.1 $K\pi$ form factors from $\tau \to K\pi\nu_\tau$ and K_{l3} decays

- Fit to the $\tau \to K\pi\nu_\tau$ decay data
  - from *Belle [Epifanov et al'08]* (*BaBar?*)
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$$N_{events} \propto N_{tot}\, b_w \frac{1}{\Gamma_{K\pi}} \frac{d\Gamma_{K\pi}}{d\sqrt{s}} \quad \Rightarrow \quad \chi^2_\tau = \sum_{bins} \left(\frac{N_{events} - N_\tau}{\sigma_{N_\tau}} \right)^2 \quad \text{with}$$

N_{events}: Number of events/bin; b_w: bin width

$$\frac{d\Gamma_{K\pi}}{d\sqrt{s}} = \frac{G_F^2 m_\tau^3}{32\pi^3 s} C_K^2 S_{EW} \left| f_+(0) V_{us} \right|^2 \left(1 - \frac{s}{m_\tau^2}\right)^2 \left[\left(1 + \frac{2s}{m_\tau^2}\right) q_{K\pi}^3(s) \left| \bar{f}_+(s) \right|^2 + \frac{3\Delta_{K\pi}^2}{4s} q_{K\pi}(s) \left| \bar{f}_0(s) \right|^2 \right]$$

- Possible combination with K_{l3} decay data fits *[Flavianet Kaon WG'10]*

$$\chi^2 = \chi^2_\tau + \left(\lambda_+ - \lambda_+^{K_{l3}}\right)^T V^{-1} \left(\lambda_+ - \lambda_+^{K_{l3}}\right) + \left(\frac{\ln C - \ln C^{K_{l3}}}{\sigma_{\ln C}} \right) \quad \text{with} \quad \lambda_+ = \begin{pmatrix} \lambda_+' \\ \lambda_+'' \end{pmatrix}$$

3.1 Kπ form factors from $\tau \to K\pi\nu_\tau$ and K_{l3} decays

Bernard, Boito, E.P., in progress
Antonelli, Lusiani, E.P. in progress

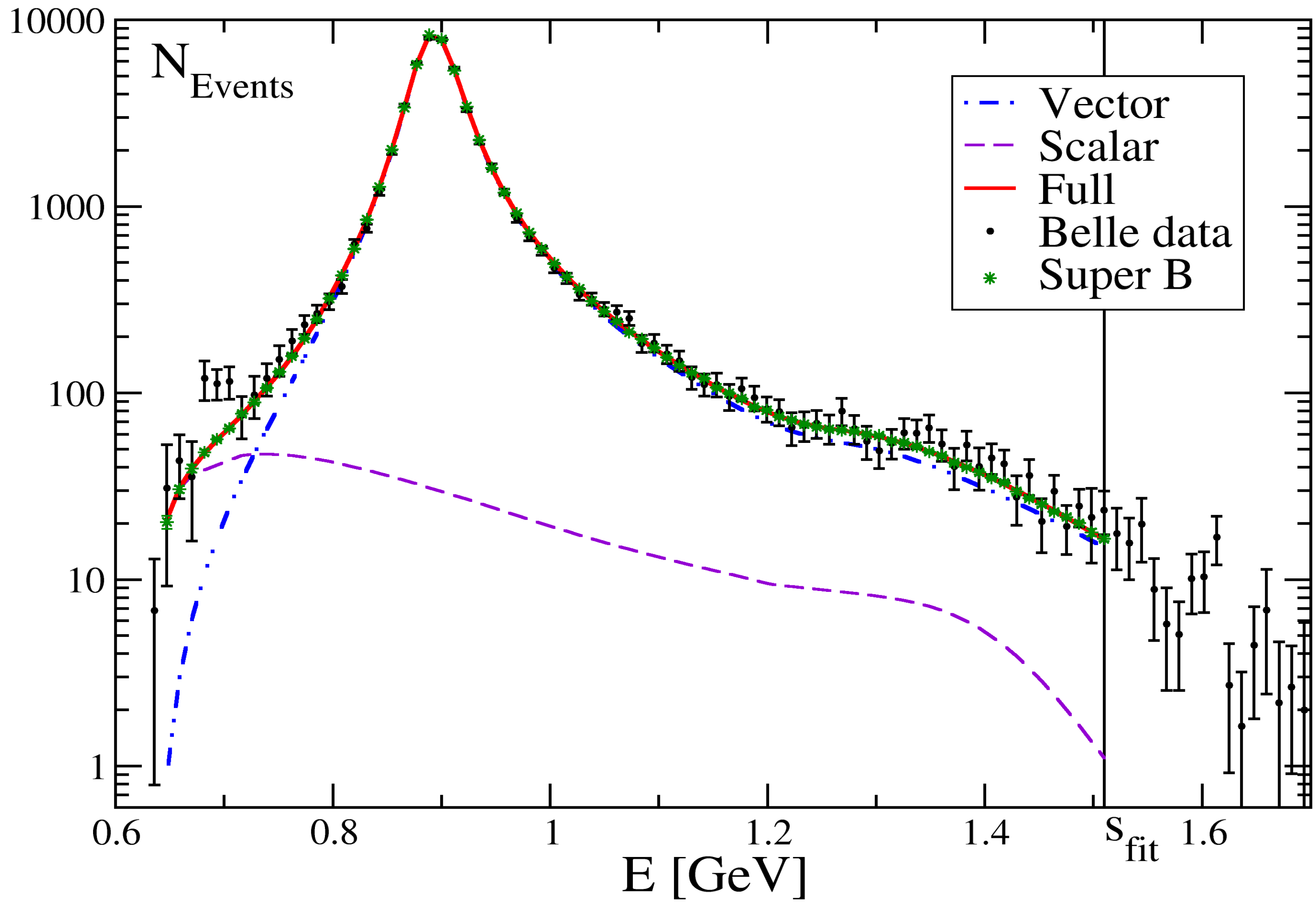
- Preliminary results :

	$\tau \to K\pi\nu_\tau$ & $K_{\ell 3}$ Belle	$\tau \to K\pi\nu_\tau$ & $K_{\ell 3}$ SuperB
$\ln C$	0.20193 ± 0.00892	0.20034 ± 0.00557
$\lambda'_0 \times 10^3$	13.139 ± 0.965	13.851 ± 0.592
m_{K^*} [MeV]	892.09 ± 0.22	892.01 ± 0.21
Γ_{K^*} [MeV]	46.287 ± 0.417	46.494 ± 0.436
$m_{K^{*\prime}}$ [MeV]	1292.5 ± 47.2	1259.8 ± 27.2
$\Gamma_{K^{*\prime}}$ [MeV]	171.64 ± 234.65	205.41 ± 10.27
β	-0.0204 ± 0.0289	-0.0350 ± 0.0229
$\lambda'_+ \times 10^3$	25.714 ± 0.332	25.655 ± 0.268
$\lambda''_+ \times 10^3$	1.1988 ± 0.0313	1.2176 ± 0.0089
$\chi^2/d.o.f$	$59.7/67$	$56.5/67$
I_K^τ	0.7655 ± 0.0416	0.7857 ± 0.0105
$f_+(0)V_{us}$	0.2134 ± 0.0061	0.21103 ± 0.0037

Only statistical errors but the dominant ones !

3.1 $K\pi$ form factors from $\tau \to K\pi\nu_\tau$ and K_{l3} decays

Bernard, Boito, E.P., in progress
Antonelli, Lusiani, E.P. in progress



3.2 Applications: V_{us}

- Very precise knowledge of the $K\pi$ form factors in the whole range of energy

$\Rightarrow$ $$\boxed{I_K = \int ds\, F\left(s, \bar{f}_+(s), \bar{f}_0(s)\right)}$$

- V_{us} from K_{l3} decays: very precise determination *see Cirigliano's talk*

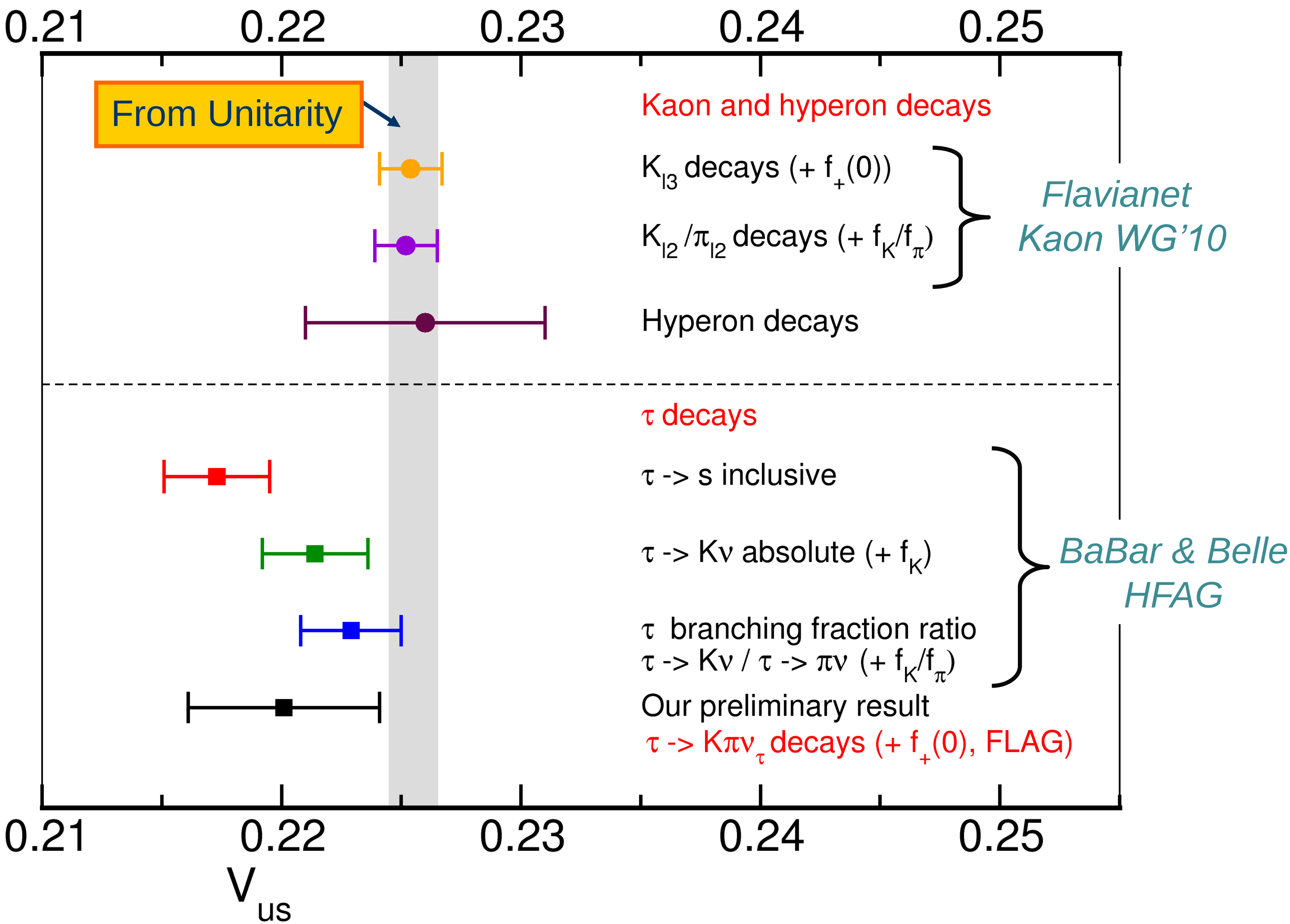
$$\boxed{\Gamma_{K^{+/0}l3} = N \left| f_+(0) V_{us} \right|^2 I^l_{K^{+/0}}}$$ with $$\boxed{I^l_{K^{+/0}} = \int dt \frac{1}{m^8_{K^{+/0}}} \lambda^{3/2} F\left(t, \bar{f}_+(t), \bar{f}_0(t)\right)}$$

$$\boxed{f_+(0)\left|V_{us}\right| = 0.2163 \pm 0.0005} \Rightarrow \boxed{\left|V_{us}\right| = 0.2254 \pm 0.0013}$$

- Similarly, V_{us} from $\tau \to K\pi\nu_\tau$ but not competitive yet!

$$\boxed{\Gamma_{\tau\to K\pi\nu_\tau} = N \left| f_+(0) V_{us} \right|^2 I^\tau_K}$$ with $$\boxed{I^\tau_K = \int ds\, F\left(s, \bar{f}_+(s), \bar{f}_0(s)\right)}$$

$$\boxed{\left|f_+(0) V_{us}\right| = 0.2111 \pm 0.0037} \Rightarrow \boxed{\left|V_{us}\right| = 0.2201 \pm 0.0040}$$


0.21
0.22
0.23
0.24
0.25
From Unitarity
Kaon and hyperon decays
K_{l3} decays (+ $f_+(0)$)
K_{l2}/π_{l2} decays (+ f_K/f_π)
Flavianet
Kaon WG'10
Hyperon decays
τ decays
τ -> s inclusive
τ -> Kν absolute (+ f_K)
BaBar & Belle
HFAG
τ branching fraction ratio
τ -> Kν / τ -> πν (+ f_K/f_π)
Our preliminary result
τ -> Kπν_τ decays (+ $f_+(0)$, FLAG)
V_{us}

3.2 Applications: Callan-Treiman

- Very precise knowledge of the Kπ form factors in the whole range of energy

$$\Rightarrow \boxed{I_K = \int ds\, F\left(s, \bar{f}_+(s), \bar{f}_0(s)\right)}$$

➢ V_{us} from K_{l3} decays: very precise determination *see Cirigliano's talk*

$$\boxed{\Gamma_{K^{+/0}l3} = N \left| f_+(0) V_{us} \right|^2 I^l_{K^{+/0}}} \quad \text{with} \quad \boxed{I^l_{K^{+/0}} = \int dt \frac{1}{m^8_{K^{+/0}}} \lambda^{3/2} F\left(t, \bar{f}_+(t), \bar{f}_0(t)\right)}$$

$$\boxed{f_+(0)|V_{us}| = 0.2163 \pm 0.0005} \Rightarrow \boxed{|V_{us}| = 0.2254 \pm 0.0013}$$

➢ Callan-Treiman test:

$\boxed{\ln C = 0.2002(55)}$ ~1.5σ from the SM : $\ln C_{SM} = 0.2141(73)$

3.2 Applications: K* pole

- Very precise knowledge of the Kπ form factors in the whole range of energy

$$\Rightarrow \boxed{I_K = \int ds\, F\left(s, \overline{f}_+(s), \overline{f}_0(s)\right)}$$

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$$\boxed{f_+(0)\left|V_{us}\right| = 0.2163 \pm 0.0005} \Rightarrow \boxed{\left|V_{us}\right| = 0.2254 \pm 0.0013}$$

➢ Precise extraction of Kπ scattering phase and good determination of K*: $\boxed{m_{K*} = 892.01 \pm 0.21 \text{ MeV}}$ and $\boxed{\Gamma_{K*} = 46.493 \pm 0.436 \text{ MeV}}$

PDG: $m_{K*} = 891.66 \pm 0.26 \text{ MeV}$ and $\Gamma_{K*} = 50.8 \pm 0.9 \text{ MeV}$

3.2 Applications: V_{us}

Antonelli, Lusiani, E.P. in progress

- Very precise knowledge of the $K\pi$ form factors in the whole range of energy
  - Use the $K\pi$ form factors and the Kaon Brs to try to reconcile the extraction of V_{us} from exclusive and inclusive modes

- Exclusive mode : $\tau \to K\nu_\tau$ / $\tau \to \pi\nu_\tau$

$$\boxed{\frac{\mathcal{B}(\tau^- \to K^-\nu_\tau)}{\mathcal{B}(\tau^- \to \pi^-\nu_\tau)} = \frac{|V_{us}|^2}{|V_{ud}|^2}\frac{f_K^2}{f_\pi^2}\frac{(1-m_K^2/m_\tau^2)^2}{(1-m_\pi^2/m_\tau^2)^2}(1+\delta_{LD})}$$

Need lattice input $\dfrac{f_K}{f_\pi}$

see V.Cirigliano's talk

$\Rightarrow$ $\boxed{|V_{us}| = 0.2255 \pm 0.0024}$

FLAG'11

$$\left(\frac{f_K}{f_\pi} = 1.193 \pm 0.005\right)$$

3.2 Applications: V_{us}

Antonelli, Lusiani, E.P. in progress

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- Inclusive modes: $\tau \to s$

$$\boxed{|V_{us}|^2 = \frac{R^{00}_{\tau,S}}{\dfrac{R^{00}_{\tau,V+A}}{|V_{ud}|^2} - \delta R^{00}_{\tau,th}}}$$

τ data: $R^{00}_{\tau,S} = 0.1612(38)$ and $R^{00}_{\tau,V+A} = 3.467(11)$

PDG 10: $|V_{ud}| = 0.97425(22)$

$\delta R^{00}_{\tau,th}$ computed from phenomenology

Gámiz, Jamin, Pich, Prades,Schwab'02 '03
Maltman et al.'09

$\delta R^{00}_{\tau,th} = 0.240(32) \Rightarrow \boxed{|V_{us}| = 0.2173 \pm 0.0020_{\mathrm{exp}} \pm 0.0010_{\mathrm{th}}}$

3.4σ away from unitarity!

3.2 Inclusive τ decays from kaon decays

Antonelli, Lusiani, E.P. in progress

- Modes measured in the strange channel for $\tau \to s$:

HFAG'12

Branching fraction	HFAG Winter 2012 fit
$\Gamma_{10} = K^- \nu_\tau$	$(0.6955 \pm 0.0096) \cdot 10^{-2}$
$\Gamma_{16} = K^- \pi^0 \nu_\tau$	$(0.4322 \pm 0.0149) \cdot 10^{-2}$
$\Gamma_{23} = K^- 2\pi^0 \nu_\tau$ (ex. K^0)	$(0.0630 \pm 0.0222) \cdot 10^{-2}$
$\Gamma_{28} = K^- 3\pi^0 \nu_\tau$ (ex. K^0, η)	$(0.0419 \pm 0.0218) \cdot 10^{-2}$
$\Gamma_{35} = \pi^- \overline{K}^0 \nu_\tau$	$(0.8206 \pm 0.0182) \cdot 10^{-2}$
$\Gamma_{40} = \pi^- \overline{K}^0 \pi^0 \nu_\tau$	$(0.3649 \pm 0.0108) \cdot 10^{-2}$
$\Gamma_{44} = \pi^- \overline{K}^0 \pi^0 \pi^0 \nu_\tau$	$(0.0269 \pm 0.0230) \cdot 10^{-2}$
$\Gamma_{53} = \overline{K}^0 h^- h^- h^+ \nu_\tau$	$(0.0222 \pm 0.0202) \cdot 10^{-2}$
$\Gamma_{128} = K^- \eta \nu_\tau$	$(0.0153 \pm 0.0008) \cdot 10^{-2}$
$\Gamma_{130} = K^- \pi^0 \eta \nu_\tau$	$(0.0048 \pm 0.0012) \cdot 10^{-2}$
$\Gamma_{132} = \pi^- \overline{K}^0 \eta \nu_\tau$	$(0.0094 \pm 0.0015) \cdot 10^{-2}$
$\Gamma_{151} = K^- \omega \nu_\tau$	$(0.0410 \pm 0.0092) \cdot 10^{-2}$
$\Gamma_{801} = K^- \phi \nu_\tau (\phi \to KK)$	$(0.0037 \pm 0.0014) \cdot 10^{-2}$
$\Gamma_{802} = K^- \pi^- \pi^+ \nu_\tau$ (ex. K^0, ω)	$(0.2923 \pm 0.0068) \cdot 10^{-2}$
$\Gamma_{803} = K^- \pi^- \pi^+ \pi^0 \nu_\tau$ (ex. K^0, ω, η)	$(0.0411 \pm 0.0143) \cdot 10^{-2}$
$\Gamma_{110} = X_s^- \nu_\tau$	$(2.8746 \pm 0.0498) \cdot 10^{-2}$

3.2 Inclusive τ decays from kaon decays

Antonelli, Lusiani, E.P. in progress

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$\Gamma_{40} = \pi^-\overline{K}^0\pi^0\nu_\tau$	$(0.3649 \pm 0.0108) \cdot 10^{-2}$
$\Gamma_{44} = \pi^-\overline{K}^0\pi^0\pi^0\nu_\tau$	$(0.0269 \pm 0.0230) \cdot 10^{-2}$
$\Gamma_{53} = \overline{K}^0h^-h^-h^+\nu_\tau$	$(0.0222 \pm 0.0202) \cdot 10^{-2}$
$\Gamma_{128} = K^-\eta\nu_\tau$	$(0.0153 \pm 0.0008) \cdot 10^{-2}$
$\Gamma_{130} = K^-\pi^0\eta\nu_\tau$	$(0.0048 \pm 0.0012) \cdot 10^{-2}$
$\Gamma_{132} = \pi^-\overline{K}^0\eta\nu_\tau$	$(0.0094 \pm 0.0015) \cdot 10^{-2}$
$\Gamma_{151} = K^-\omega\nu_\tau$	$(0.0410 \pm 0.0092) \cdot 10^{-2}$
$\Gamma_{801} = K^-\phi\nu_\tau(\phi \to KK)$	$(0.0037 \pm 0.0014) \cdot 10^{-2}$
$\Gamma_{802} = K^-\pi^-\pi^+\nu_\tau$ (ex. K^0, ω)	$(0.2923 \pm 0.0068) \cdot 10^{-2}$
$\Gamma_{803} = K^-\pi^-\pi^+\pi^0\nu_\tau$ (ex. K^0, ω, η)	$(0.0411 \pm 0.0143) \cdot 10^{-2}$
$\Gamma_{110} = X_s^-\nu_\tau$	$(2.8746 \pm 0.0498) \cdot 10^{-2}$

~70% of the decay modes crossed channels from Kaons!

3.2 Inclusive τ decays from kaon decays

Antonelli, Lusiani, E.P. in progress

- The Brs of these 3 modes can be predicted using Kaon Brs very precisely measured + form factor information

  - $\tau \to K\nu_\tau$:

$$\mathcal{B}_K^{\text{uni}} = \frac{\tau_\tau \mathcal{B}_{K\to\mu\nu}}{\tau_K} \frac{m_\tau^3}{2 m_K m_\mu^2} \left(\frac{1 - m_K^2/m_\tau^2}{1 - m_\mu^2/m_K^2} \right)^2 \delta_{\tau/K}$$

$$\Rightarrow \boxed{B_K^{uni} = (0.715 \pm 0.003)\%}$$

  - $\tau \to K\pi\nu_\tau$: precise knowledge of phase space required (dispersive ff in I_K)

$$\mathrm{BR}(\tau \to K\pi\nu_\tau) = \frac{8 m_\tau^3}{m_K^5} \frac{C_K^{\tau 2}}{C_K^2} \frac{S_{\mathrm{EW},\tau}}{S_{\mathrm{EW,K}}} \frac{I_K^\tau}{I_K^\ell} \frac{\left(1 + \delta_{\mathrm{EM}}^\tau + \delta_{\mathrm{SU(2)}}^\tau\right)^2}{\left(1 + \delta_{\mathrm{EM}}^{K\ell} + \delta_{\mathrm{SU(2)}}^{K\pi}\right)^2} \frac{\tau_\tau}{\tau_K} \mathrm{BR}(K_{e3})$$

$$\Rightarrow \boxed{B^{uni}_{\tau\to K^-\pi^0\nu_\tau} = (0.4376 \pm 0.0106)\%}$$ and $$\boxed{B^{uni}_{\tau\to \overline{K}^0\pi^-\nu_\tau} = (0.8752 \pm 0.0212)\%}$$

Preliminary

3.2 Inclusive τ decays from kaon decays

Antonelli, Lusiani, E.P. in progress

- Modes measured in the strange channel for $\tau \rightarrow s$:

HFAG'12

Branching fraction	HFAG Winter 2012 fit	
$\Gamma_{10} = K^- \nu_\tau$	$(0.6955 \pm 0.0096) \cdot 10^{-2}$	$\Rightarrow$ $(0.715 \pm 0.003)\ .\ 10^{-2}$
$\Gamma_{16} = K^- \pi^0 \nu_\tau$	$(0.4322 \pm 0.0149) \cdot 10^{-2}$	$\Rightarrow$ $(0.4376 \pm 0.0106)\ .\ 10^{-2}$
$\Gamma_{23} = K^- 2\pi^0 \nu_\tau$ (ex. K^0)	$(0.0630 \pm 0.0222) \cdot 10^{-2}$	
$\Gamma_{28} = K^- 3\pi^0 \nu_\tau$ (ex. K^0, η)	$(0.0419 \pm 0.0218) \cdot 10^{-2}$	
$\Gamma_{35} = \pi^- \overline{K}^0 \nu_\tau$	$(0.8206 \pm 0.0182) \cdot 10^{-2}$	$\Rightarrow$ $(0.8752 \pm 0.0212)\ .\ 10^{-2}$
$\Gamma_{40} = \pi^- \overline{K}^0 \pi^0 \nu_\tau$	$(0.3649 \pm 0.0108) \cdot 10^{-2}$	
$\Gamma_{44} = \pi^- \overline{K}^0 \pi^0 \pi^0 \nu_\tau$	$(0.0269 \pm 0.0230) \cdot 10^{-2}$	
$\Gamma_{53} = \overline{K}^0 h^- h^- h^+ \nu_\tau$	$(0.0222 \pm 0.0202) \cdot 10^{-2}$	
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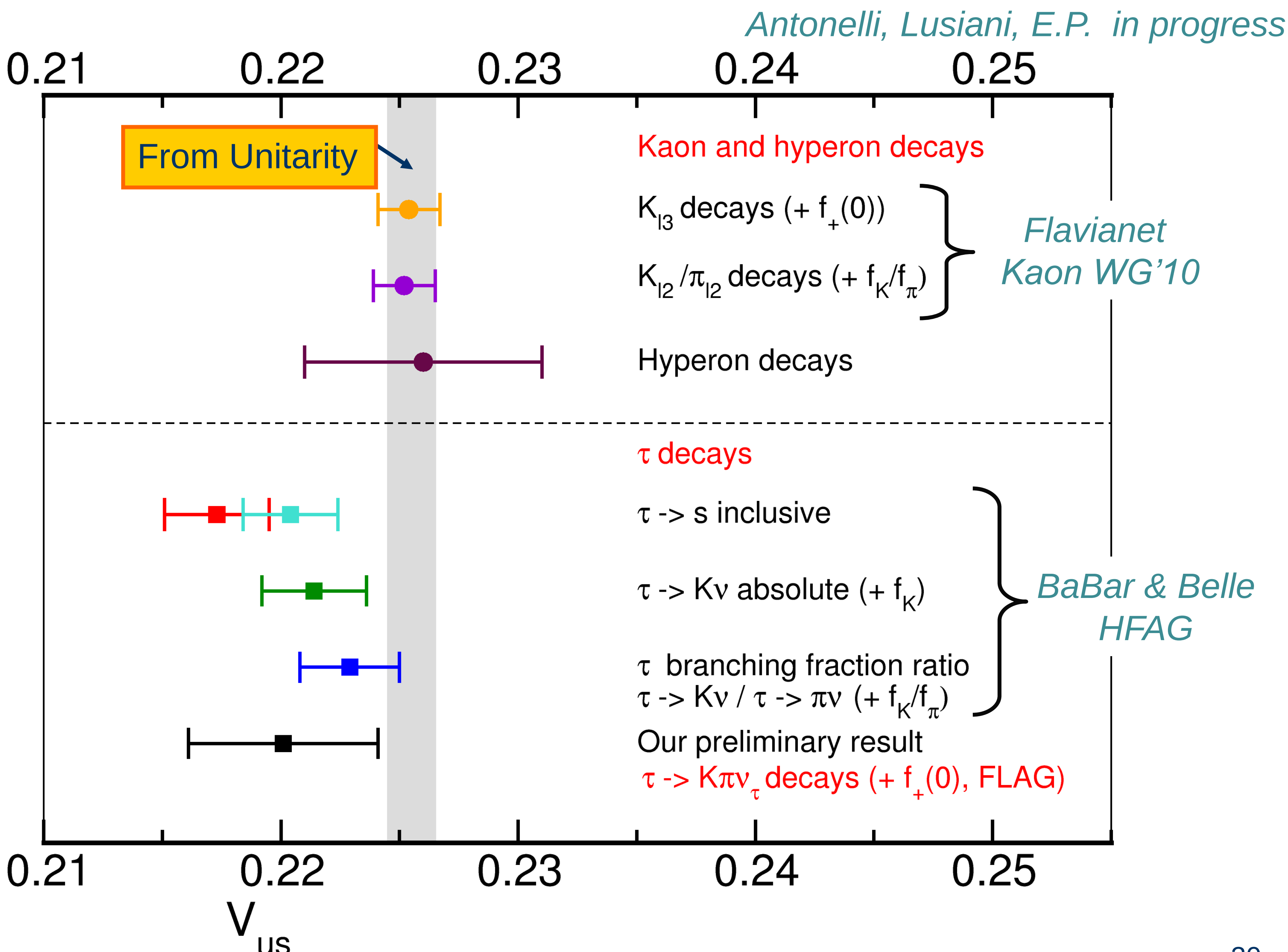
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0.21
0.22
0.23
0.24
0.25
From Unitarity
Kaon and hyperon decays
K_{l3} decays (+ $f_+(0)$)
K_{l2} / π_{l2} decays (+ f_K/f_π)
Flavianet
Kaon WG'10
Hyperon decays
τ decays
τ -> s inclusive
τ -> Kν absolute (+ f_K)
BaBar & Belle
HFAG
τ branching fraction ratio
τ -> Kν / τ -> $\pi\nu$ (+ f_K/f_π)
Our preliminary result
τ -> K$\pi\nu_\tau$ decays (+ $f_+(0)$, FLAG)
V_{us}

4. Conclusion and outlook

4. Conclusion and outlook

- Possibility to get interesting constraints on the $K\pi$ form factors from $\tau \to K\pi\nu_\tau$ decays
  - New data available from Belle and BaBar
  - Build a parametrization using dispersion relations to have a precise parametrization and theoretically well motivated to fit the data

- Dispersive parametrization possible combination with K_{l3} data to have constraints from different energy regions

- Possibility to test the Standard Model: $\Rightarrow$ $\boxed{V_{us}}$

- Possibility to reconcile the different determinations of V_{us} using kaon data

- Work still in progress

- High precision era in τ: - more precise data with Belle II, SuperB
  - theoretical: EM, IB corrections

5. Back-up

Exclusive decays: $\tau \to K\nu_\tau$ decays vs. $\tau \to K\nu_\tau / \tau \to \pi\nu_\tau$

- $$\mathcal{B}(\tau^- \to K^- \nu_\tau) = \frac{G_F^2 f_K^2 |V_{us}|^2 m_\tau^3 \tau_\tau}{16\pi\hbar} \left(1 - \frac{m_K^2}{m_\tau^2}\right)^2 S_{EW}$$

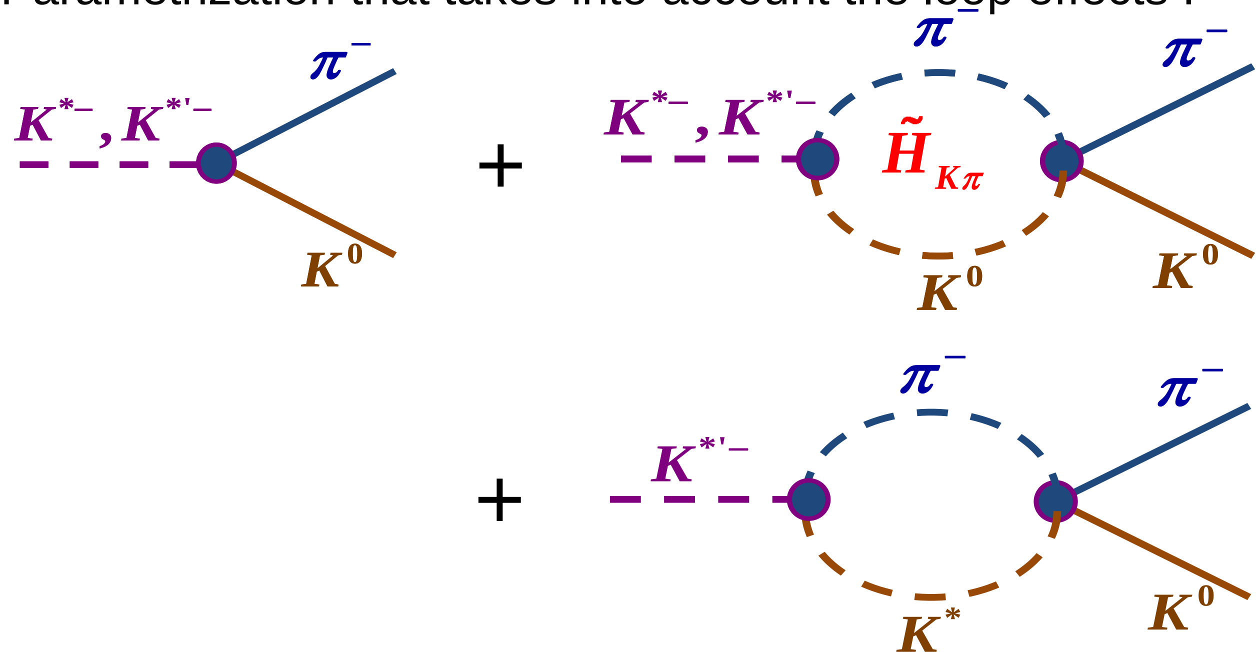
- $$\frac{\mathcal{B}(\tau^- \to K^- \nu_\tau)}{\mathcal{B}(\tau^- \to \pi^- \nu_\tau)} = \frac{|V_{us}|^2}{|V_{ud}|^2} \frac{f_K^2}{f_\pi^2} \frac{(1 - m_K^2/m_\tau^2)^2}{(1 - m_\pi^2/m_\tau^2)^2} (1 - \delta_{LD})$$

- For ϕ_+ (s): In this case instead of the data, use of a parametrization including 2 resonances K*(892) and K*'(1414) : *Jamin, Pich, Portolés'08*

$$\bar{f}_+(s) = \left[\frac{m_{K^*}^2 - \kappa_{K^*}\left(\mathrm{Re}\,\tilde{H}_{K\pi}(0) + \mathrm{Re}\,\tilde{H}_{K\eta}(0)\right) + \beta s}{D\left(m_{K^*},\Gamma_{K^*}\right)} - \frac{\beta s}{D\left(m_{K^{*\prime}},\Gamma_{K^{*\prime}}\right)}\right] \Rightarrow \tan\delta_{K\pi}^{P,1/2} = \frac{\mathrm{Im}\,\bar{f}_+(s)}{\mathrm{Re}\,\bar{f}_+(s)}$$

with $$D\left(m_n,\Gamma_n\right) = m_n^2 - s - \kappa_n \sum \mathrm{Re}\,\tilde{H} - i m_n \Gamma_n(s)$$

  – Parametrization that takes into account the loop effects :



  – Loops with K*(892)π dominant decay channel of K*'(1410) (>40%) also included but not in *Jamin, Pich , Portolés '08, Boito, Escribano , Jamin'08 '10*

3.2 Inclusive decays

- V_{us} can also be determined from inclusive decays $\tau \to hadrons$

- $$\boxed{R_\tau^{kl} = N_C S_{EW} \left\{ \left(|V_{us}|^2 + |V_{ud}|^2 \right) \left[1 + \delta^{kl(0)} \right] + \sum_{D \geq 2} \left[|V_{ud}|^2 \delta_{ud}^{kl(D)} + |V_{us}|^2 \delta_{us}^{kl(D)} \right] \right\}}$$

⇨ Use instead

$$\boxed{\delta R_\tau^{kl} \equiv \frac{R_{\tau,V+A}^{kl}}{|V_{ud}|^2} - \frac{R_{\tau,S}^{kl}}{|V_{us}|^2}} \approx N_C S_{EW} \sum_{D \geq 2} \left[\delta_{ud}^{kl(D)} - \delta_{us}^{kl(D)} \right]$$

- $$\boxed{\delta R_\tau^{kl} \approx 24 \frac{m_s^2(m_\tau^2)}{m_\tau^2} \Delta_{kl}(\alpha_S)} \Rightarrow m_s \text{ and/or } \boxed{V_{us}}$$

3.2 Inclusive τ decays

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- $$\boxed{R_\tau^{kl} = N_C S_{EW} \left\{ \left(|V_{us}|^2 + |V_{ud}|^2 \right) \left[1 + \delta^{kl(0)} \right] + \sum_{D\geq 2} \left[|V_{ud}|^2 \delta_{ud}^{kl(D)} + |V_{us}|^2 \delta_{us}^{kl(D)} \right] \right\}}$$

⇨ Use instead

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- $$\boxed{\delta R_\tau^{kl} \approx 24 \frac{m_s^2(m_\tau^2)}{m_\tau^2} \Delta_{kl}(\alpha_S)}$$ ⇨ m_s and/or $\boxed{V_{us}}$

3.2 Inclusive τ decays

- $$\boxed{|V_{us}|^2 = \frac{R^{00}_{\tau,S}}{\dfrac{R^{00}_{\tau,V+A}}{|V_{ud}|^2} - \delta R^{00}_{\tau,th}}}$$

τ data: $R^{00}_{\tau,S} = 0.1615(40)$ and $R^{00}_{\tau,V+A} = 3.479(11)$

PDG 10: $|V_{ud}| = 0.97425(22)$

$$\boxed{\delta R^{00}_{\tau,th} = 0} \Rightarrow \boxed{|V_{us}| = 0.210(3)}$$

.

- $\delta R^{00}_{\tau,th}$ computed from phenomenology *Gámiz, Jamin, Pich, Prades,Schwab'02 '03*

$$\delta R^{00}_{\tau,th} = 0.216(16) \Rightarrow \boxed{|V_{us}| = 0.2164 \pm 0.0027_{\mathrm{exp}} \pm 0.0005_{\mathrm{th}}}$$

dominated by experimental uncertainties

- V_{us} from unitarity: $\boxed{|V_{us}| = 0.2255 \pm 0.0010}$ 3σ away!

3.2 Inclusive τ decays from kaon decays

- Possible normalization problem:

Smaller $\tau \to$ K branching ratios ⇒ smaller $R_{\tau,S}$ ⇒ smaller $\boxed{V_{us}}$

$$\boxed{R^{00}_{\tau,S}\Big|_{\text{old}} = 0.1686(47)} \Rightarrow \boxed{R^{00}_{\tau,S}\Big|_{\text{new}} = 0.1615(40)}$$

$$\boxed{|V_{us}|_{\text{old}} = 0.2214 \pm 0.0031_{\text{exp}} \pm 0.0005_{\text{th}}} \Rightarrow \boxed{|V_{us}|_{\text{new}} = 0.2164 \pm 0.0027_{\text{exp}} \pm 0.0005_{\text{th}}}$$

Missing modes at B factories?

3.2 Inclusive τ decays

- Missing modes at B factories?

PDG 2010: « Fifteen of the 16 *B*-factory branching fraction measurements are smaller than the non-*B*-factory values. The average normalized difference between the two sets of measurements is -1.36 »