

KLOE: Analysis report

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36th Meeting of the LNF Scientific committee

21 May 2008

1) Kaon physics

2) $\sigma(e^+e^- \rightarrow \text{had})$

3) Scalar and pseudoscalar mesons

Kaon physics

V_{us}	Absolute BR's for K_{l3}^\pm	JHEP0802:098
	K^+ lifetime	JHEP0801:073
	Absolute BR for $K^+ \rightarrow \pi^+ \pi^0$	ArXiv:0707.2654 (sub. to PLB)
	Form factor slopes for $K_{L\mu 3}$	JHEP0712:105
	Combined V_{us} determination	JHEP0804:059
	Update for FF's slopes for $K_{L\mu 3}$ *	preliminary Wint. Conf.
	Update K_L lifetime *	ongoing
	Update for FF's slopes for $K_{Le 3}$ *	ongoing
LFV	Form factor slopes for $K_{\ell 3}^\pm$	ongoing
	$\Gamma(K^\pm \rightarrow e\nu)/\Gamma(K^\pm \rightarrow \mu\nu)$ *	preliminary ArXiv:0707.4623

* whole data sample

Kaon physics

CPT & QM Bell-Steinberger update $K_s K_L$ interferometry* JHEP 0612:011 → review in PDG'08 preliminary Wint. Conf. (final available)

χ PT	$BR(K_s \rightarrow \gamma\gamma)^*$	JHEP0805:051
	$d\Gamma(K_L \rightarrow \pi e v \gamma) / dE_\gamma$	Accepted by EPJC
	$UL(K_s \rightarrow e^+ e^-)^*$	ArXiv:0707.2687 (final)
	$BR(K_s \rightarrow \pi^+ \pi^- e^+ e^-)^*$	preliminary Wint. Conf.
	$BR(K^\pm \rightarrow \pi^\pm \pi^\pm \pi^\pm)$	ongoing
	$BR(K^\pm \rightarrow \pi^0 \pi^0 e v)^*$	ongoing

neutral kaon mass

JHEP 0712:073

* whole data sample

Unitarity test of CKM: G_F universality

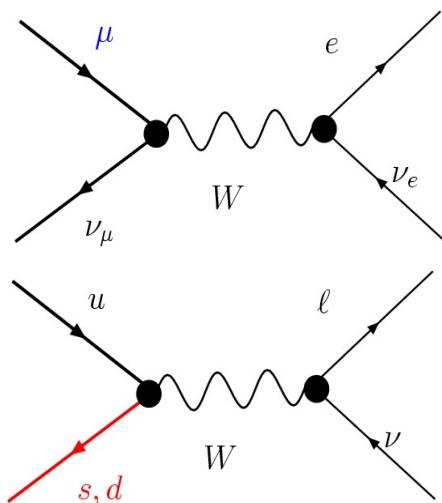
$$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 \equiv 1$$



Universality of Weak

coupling- $G_F = (g_w/M_w)^2$

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



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

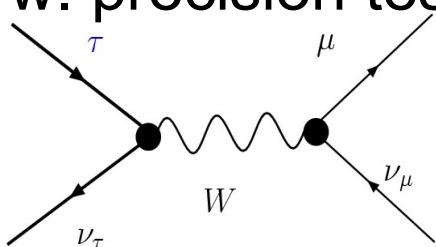
V_{us} at 0.5%

$$G_{CKM} = 1.16xx(04) \times 10^{-5} \text{ GeV}^{-2}$$

$$G_{e.w.} = 1.1655(12) \times 10^{-5} \text{ GeV}^{-2}$$

$$G_\tau = 1.1678(26) \times 10^{-5} \text{ GeV}^{-2}$$

$\alpha + M_w + s_w$
[e. w. precision tests]



Probe for Physics beyond SM

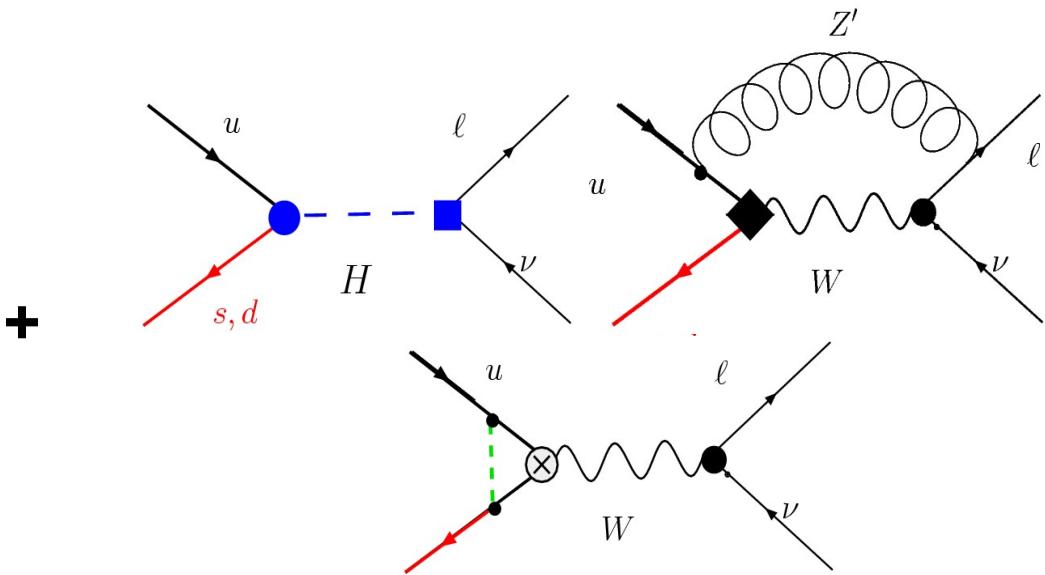
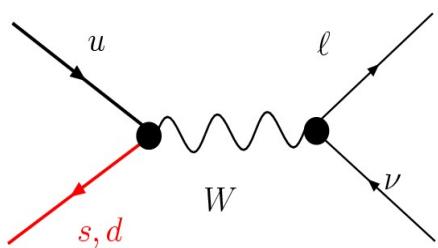
$$|V_{ud}|^2 + |V_{us}|^2 + |\cancel{V}_{ub}|^2 \equiv 1$$



Universality of Weak coupling- $G_F = (g_w/M_w)^2$

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

Standard Model



naively:

$$G_{CKM} = G_F [1 + a(M_w/M_M)^2]$$

Tree level

$$a \sim 1$$

$$M_M \sim 13 \text{ TeV}$$

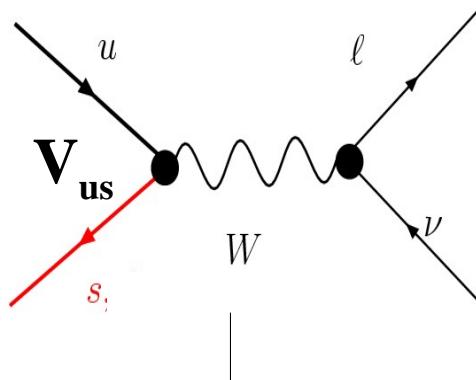
loops

$$a \sim g_w^2 (16\pi^2)$$

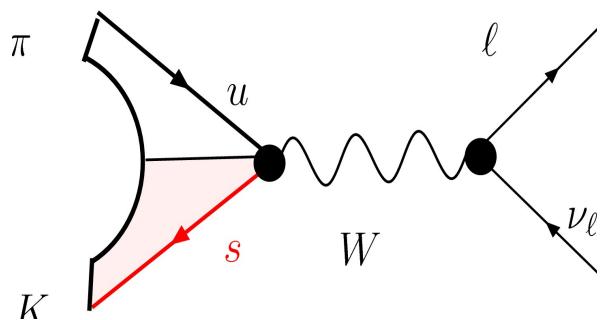
Sensitivity

$$M_M \sim 1 \text{ TeV}$$

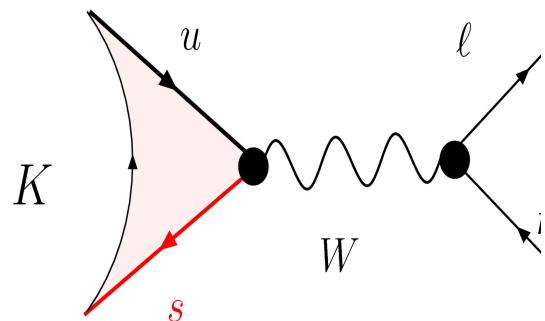
Kaon high precision observables



Short distance physics



Experimental
processes



$\mathbf{K}_{\ell_3}: K \rightarrow \pi \ell \nu$

Not helicity
suppressed

$\mathbf{K}_{\ell_2}: K \rightarrow \ell \nu$
helicity suppressed:
more sensitive to new physics

K_{ℓ3} decays

Vector transition protected against ~~SU(3)~~ corrections: [Ademollo-Gatto]

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

$$I_{K\ell}(\{\lambda\}_{K\ell}) (1 + 2\Delta_K^{SU(2)} + 2\Delta_{K\ell}^{EM})$$

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

$K_{\ell 2}$ decays

[Mariciano]

Small uncertainties in f_K/f_π from lattice → determine V_{us}/V_{ud}
 Reduced uncertainty from e.m. Structure Dependence corrections

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

Inputs from theory:

f_K/f_π	Ratio of pseudoscalar decay constants
C_K, C_π	Radiative inclusive electroweak corrections
$1 + \alpha(C_K - C_\pi) = 0.9930(35)$	

Reduced uncertainty
from SD virtual
corrections

Inputs from experiment:

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

the KLOE's role

We have measured all (but τ_s) relevant inputs for 6 channels

PLB 632 (2006)

$$\text{BR}^{(0)}(K_L \rightarrow \pi e \nu) = 0.4049(21)$$

$$\text{BR}^{(0)}(K_L \rightarrow \pi \mu \nu) = 0.2726(16)$$

K_L

PLB 626 (2005)

$$\tau_L = 50.92(30) \text{ ns}$$

PLB 636 (2006)

$\lambda'_+ \times 10^3$	$\lambda''_+ \times 10^3$
25.5 ± 1.8	1.4 ± 0.8

$f_+(t)$

PLB 636 (2006)

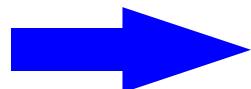
$$\text{BR}(K_s \rightarrow \pi e \nu) = 7.046(91) \times 10^{-4}$$

K_s

PLB 636 (2006)

$$\text{BR}(K^\pm \rightarrow \mu^+ \nu (\gamma)) = 0.6366(17)$$

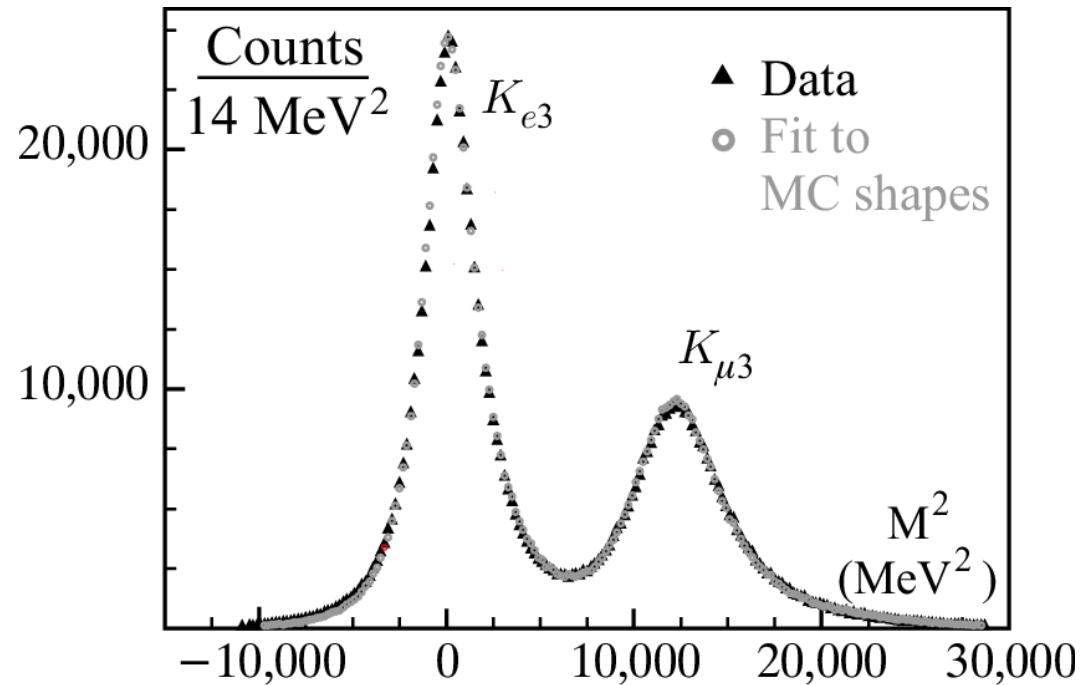
K^\pm



Absolute BR for K_{l3}^\pm

- 4 independent tag samples: $K^\pm \rightarrow \mu\nu$, $K^\pm \rightarrow \pi^\pm\pi^0$
- Number of signal events from a fit of distribution of lepton mass squared (M^2) known from TOF
- Perform measurement of absolute BR on each tag sample separately, check consistency

JHEP0802:098



$$\text{BR}(K_{e3}^\pm) = 4.965(52)\%$$

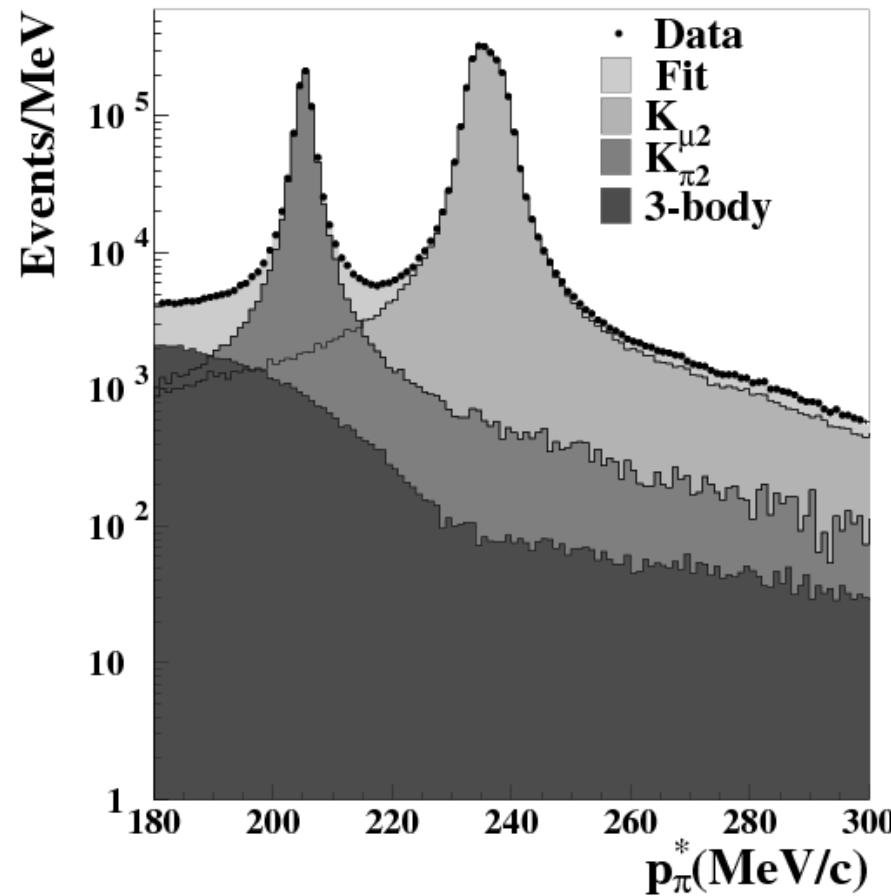
$$\text{BR}(K_{\mu 3}^\pm) = 3.233(39)\%$$

at $\tau_\pm = 12.385$ ns, with
 $d\text{BR}/\text{BR} = -0.5d\tau_\pm/\tau_\pm$

$\sigma_{\text{rel}} \sim 1\%$

Absolute BR for $K^+ \rightarrow \pi^+\pi^0$

- " Needed to perform a global fit to K^+ BRs
- " K_{l3}/K_{π^2} measured by NA48 and ISTRA
- " Available measurement dates back to '72
(no radiative corrections)
- " Normalization given by $K^- \rightarrow \mu^- \nu$ tag
- " Number of $K^+ \rightarrow \pi^+\pi^0$ events from a fit of the distribution of the momentum of the secondary particle in K rest frame, p^*



submitted to PLB

$$\text{BR} = (20.65 \pm 0.05_{\text{stat}} \pm 0.08_{\text{syst}})\%$$

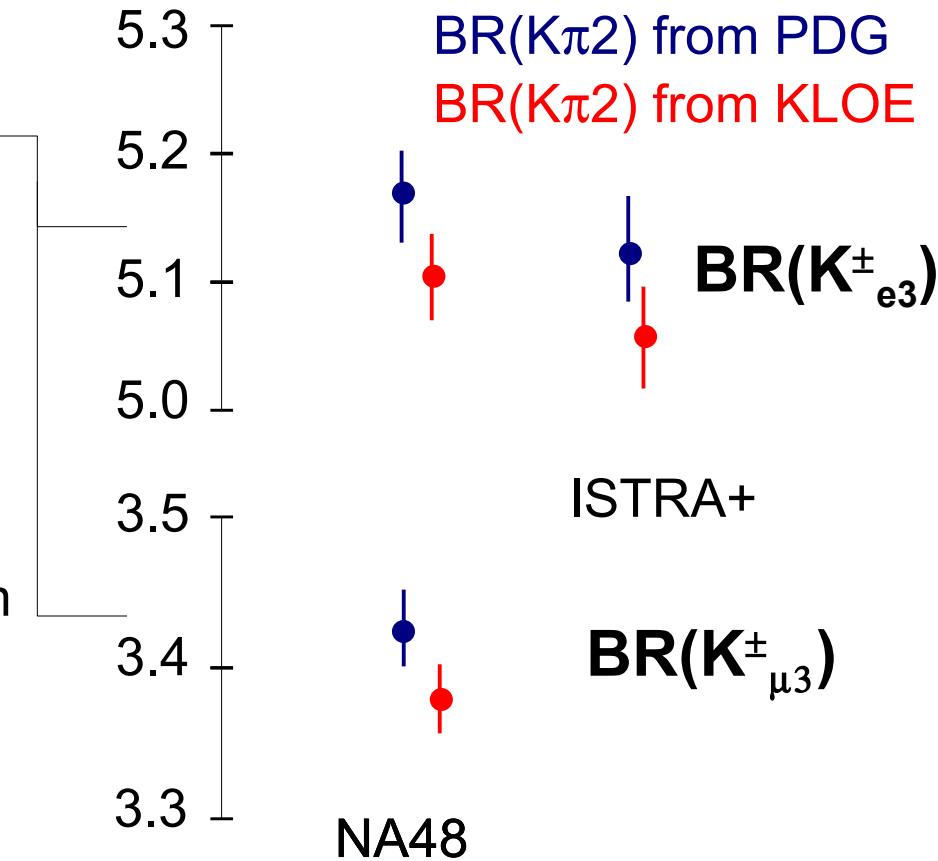
-1.3% respect to PDG'06

$$\sigma_{\text{rel}} \sim 0.5\%$$

ArXiv: 0707.4631

Absolute BR for $K^+ \rightarrow \pi^+ \pi^0$

- " Needed to perform a global fit to K^+ BRs
- " $K_{l3}/K_{\pi 2}$ measured by NA48 and ISTRA
- " Available measurement dates back to '72
(no radiative corrections)
- " Normalization given by $K^- \rightarrow \mu^- \nu$ tag
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submitted to PLB

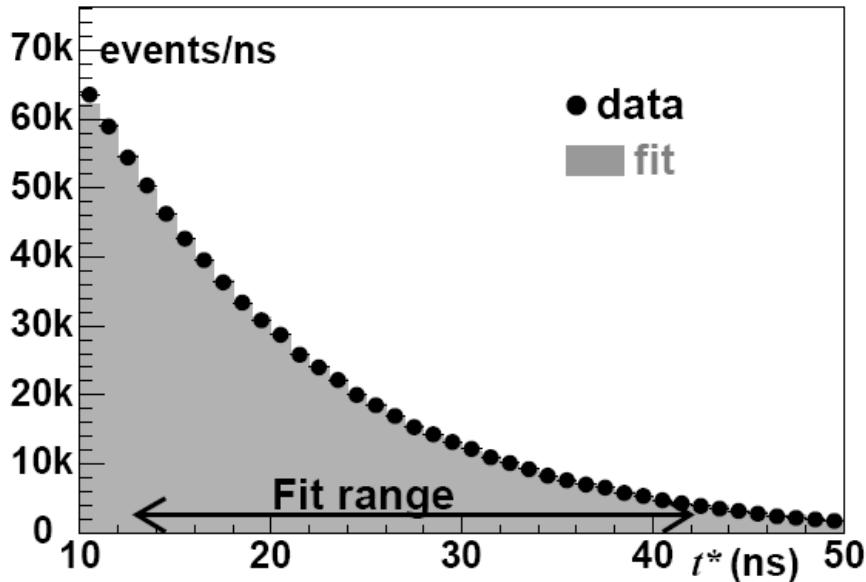
$$\text{BR} = (20.65 \pm 0.05_{\text{stat}} \pm 0.08_{\text{syst}})\%$$

-1.3% respect to PDG'06

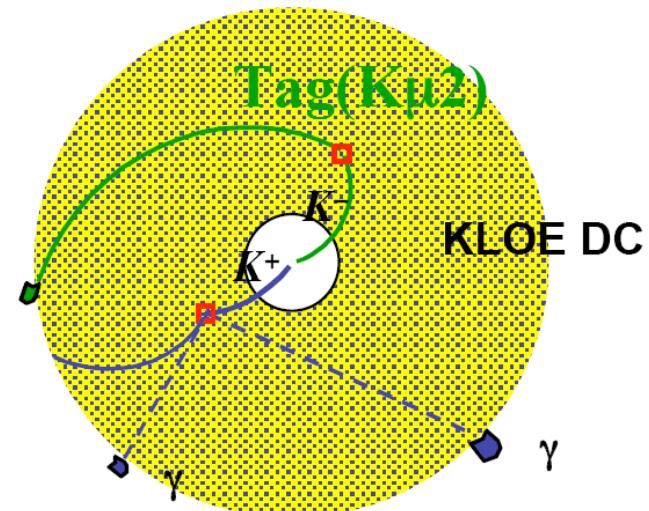
$$\sigma_{\text{rel}} \sim 0.5\%$$

ArXiv: 0707.4631

K^\pm lifetime



- Tag events with $K^\pm \rightarrow \mu\nu$ decay
- Identify a kaon decay on the opposite side



2 different methods:

from the K decay length

$$\tau_\pm = 12.364(31)(31) \text{ ns}$$

$$\rho = 0.34$$

JHEP0801:073

from the K decay time

$$\tau_\pm = 12.337(30)(20) \text{ ns}$$

$$\tau_\pm = 12.347(30) \text{ ns}$$

$$\sigma_{\text{rel}} \sim 0.4\%$$

$K_{\mu 3}$ form factor slopes

Standard method: fit t-spectrum,
 $t = (p_K - p_\pi)^2$

π/μ separation at low energies is difficult

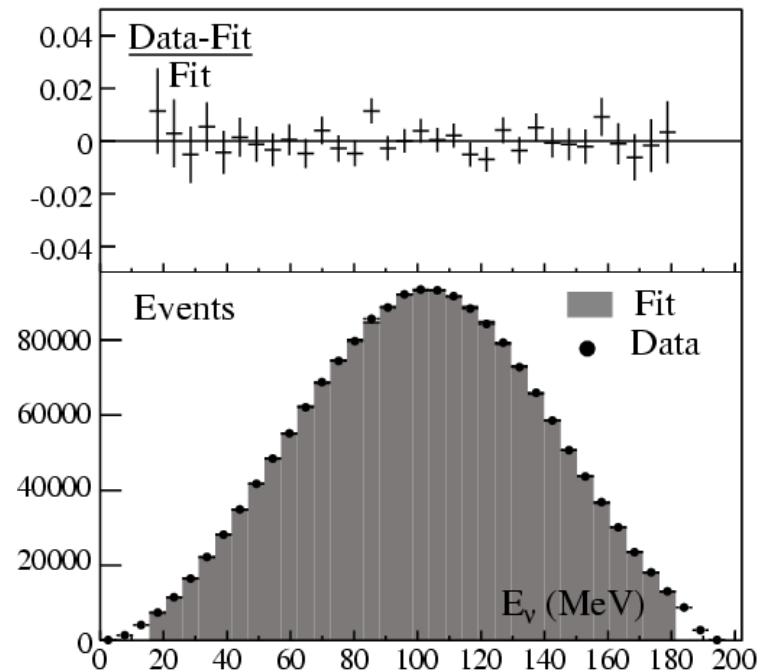
at the end of the spectrum, +1%

in signal counts $\rightarrow +15\%$ in λ_0

Fit E_ν spectrum, sensitivity loss:

$\times 2\text{-}3$ on $\sigma_{\text{stat}}(\lambda_0)$

... $\times 1.3$ with a combined fit with $K_{\text{Le}3}$



$$\lambda'_+ \times 10^3$$

$$25.6 \pm 1.8$$

$$\lambda''_+ \times 10^3$$

$$1.5 \pm 0.8$$

$$\lambda_0 \times 10^3$$

$$15.4 \pm 2.1$$

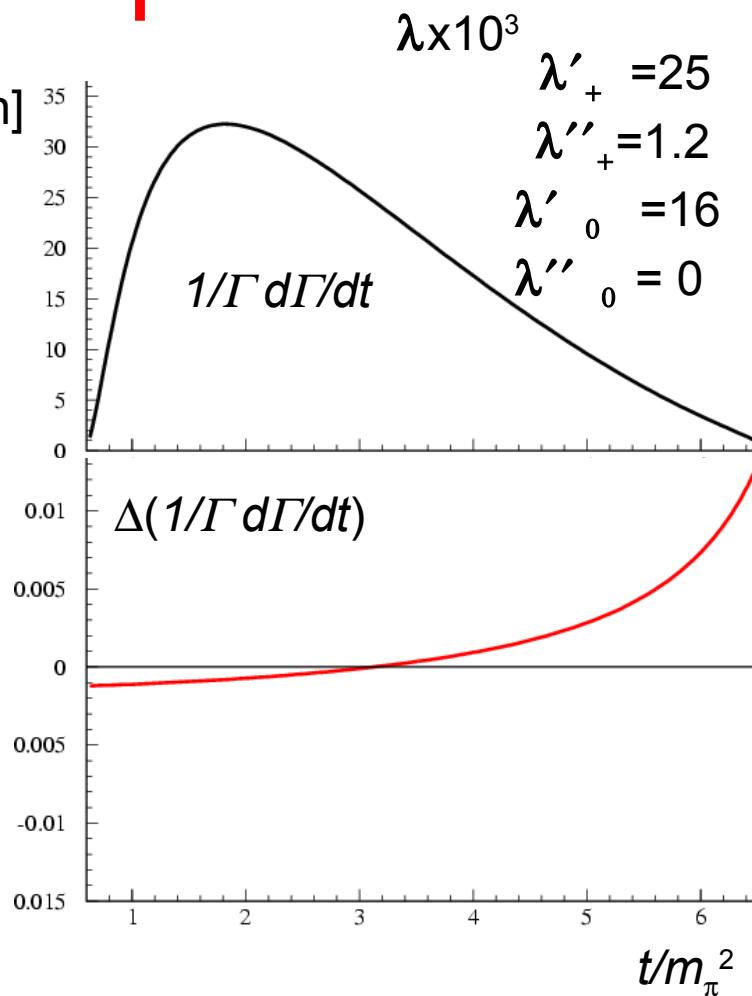
JHEP0712:105

$K_{\mu 3}$ form-factor slopes

- Knowledge of $\tilde{f}_0(t)$ important to test [Callan-Treiman]
QCD parameters: $f_0(\Delta_{K\pi} = m_K^2 - m_\pi^2) = f_K/f_\pi$
- Linear parametrization not a good physics approximation: hints for λ''_0 ?
- Fractional partial width difference by varying slopes values :

$\Delta(1/\Gamma d\Gamma/dt)$ [$\lambda''_0 = 0.4, 0$]

$\lambda \times 10^3$



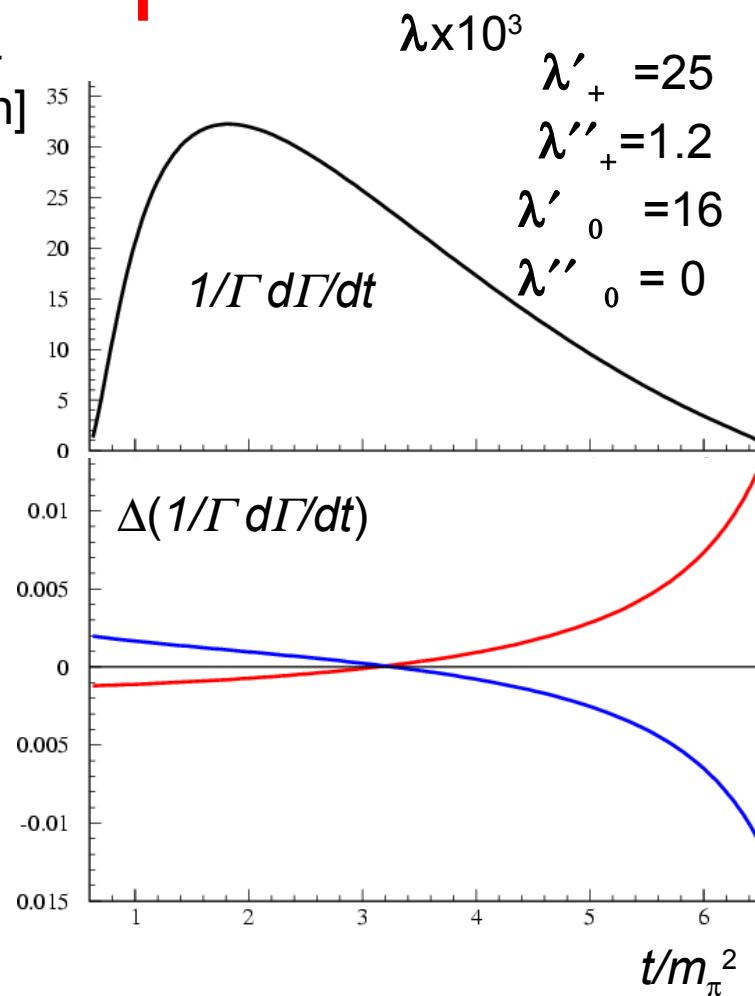
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- Fractional partial width difference by varying slopes values :

$\Delta(1/\Gamma d\Gamma/dt)$ [$\lambda''_0 = 0.4, 0$]

$\Delta(1/\Gamma d\Gamma/dt)$ [$\lambda'_0 = 14.7, 16$]

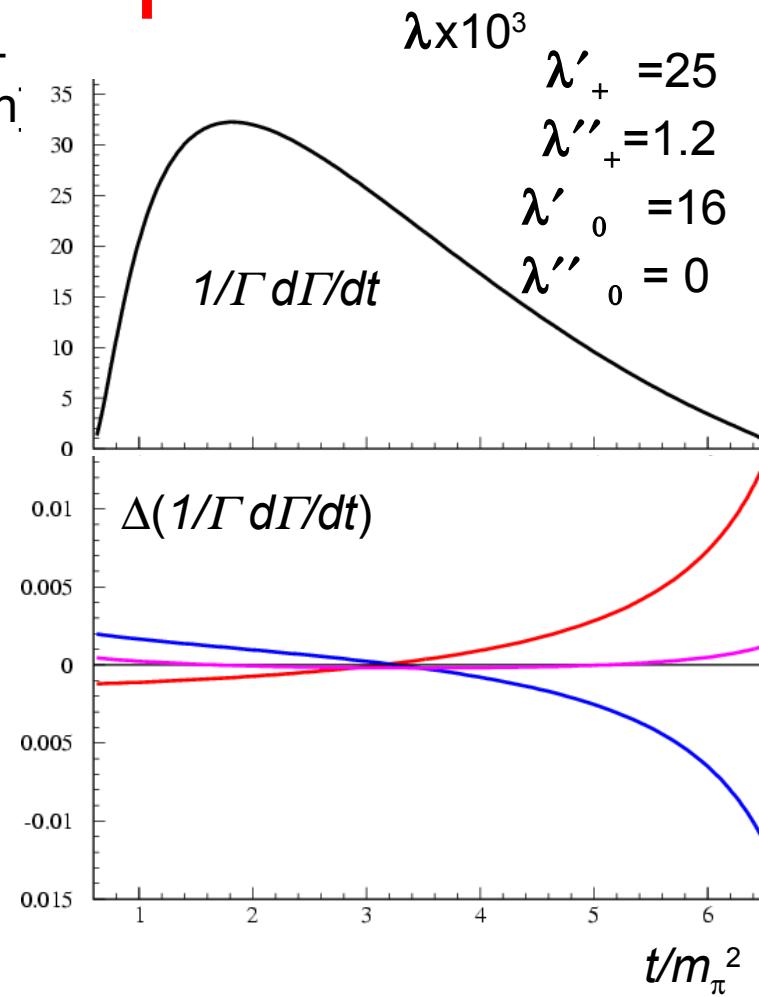
$\lambda \times 10^3$



$K_{\mu 3}$ form-factor slopes

- Knowledge of $\tilde{f}_0(t)$ important to test [Callan-Treiman] QCD parameters: $f_0(\Delta_{K\pi} = m_K^2 - m_\pi^2) = f_K/f_\pi$
- Linear parametrization not a good physics approximation: hints for λ''_0 ?
- Fractional partial width difference by varying slopes values :
- $\Delta(1/\Gamma d\Gamma/dt)$ [$\lambda''_0 = 0.4, 0$]
- $\Delta(1/\Gamma d\Gamma/dt)$ [$\lambda'_0 = 14.7, 16$]
- Almost exact cancellation
- $\Delta(1/\Gamma d\Gamma/dt)$ [$\lambda'_0 = 14.7, 16; \lambda''_0 = 0.4, 0$]
- Correlation matrix from Ideal t-spectrum experiment:

$$\begin{matrix} \lambda'_0 & 1 & -0.9996 & -0.97 & 0.91 & [\text{Franzini}] \\ \lambda''_0 & & 1 & 0.98 & -0.92 & \\ \lambda'_+ & & & 1 & -0.98 & \\ \lambda''_+ & & & & 1 & \end{matrix}$$



Simultaneous $\lambda'_0 \lambda''_0$ measurement not possible

Beyond quadratic parametrization

[Stern et al]

Dispersion relation for $\ln f_0(t)$ subtracted at $t = 0$ and $t = m_K^2 - m_\pi^2$, giving:

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

$G(t)$ evaluated using $K\pi$ scattering data

1 fit parameter:

$$\log C$$

$$\log C = 0.204 \pm 0.023$$

JHEP0712:105

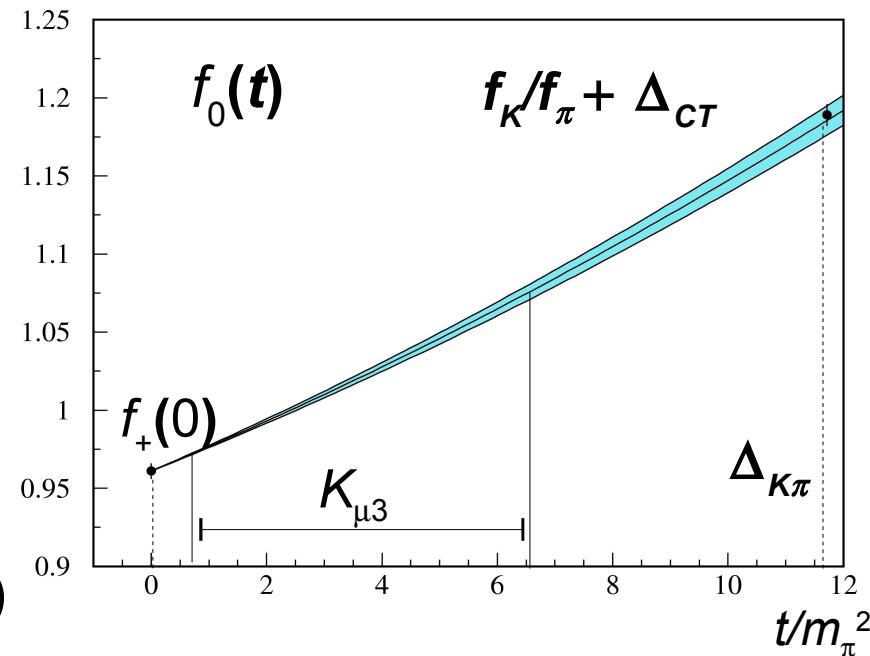
Very precise relation between $f_0(0)^*$
and f_K/f_π :

$$f_0(\Delta_{K\pi}) = f_K/f_\pi + \Delta_{CT}$$

$$\sim$$

$$f_+(0) f_0(\Delta_{K\pi}) = f_K/f_\pi + \Delta_{CT}$$

$$\Delta_{K\pi} = m_K^2 - m_\pi^2 ; \Delta_{CT} = 3.5 \times 10^{-3} \text{ SU}(2)$$



$K_{L\mu 3}$ form factor slopes

Preliminary results with $\sim 1\text{fb}^{-1}$

$5.8 \times 10^6 K\mu 3$ decays selected

Sensitivity to all FF's parameters

$$\lambda_+ = (25.7 \pm 5.1 \pm 2.5) \times 10^{-3}$$

$$\lambda_+ = (2.9 \pm 2.5 \pm 1.3) \times 10^{-3}$$

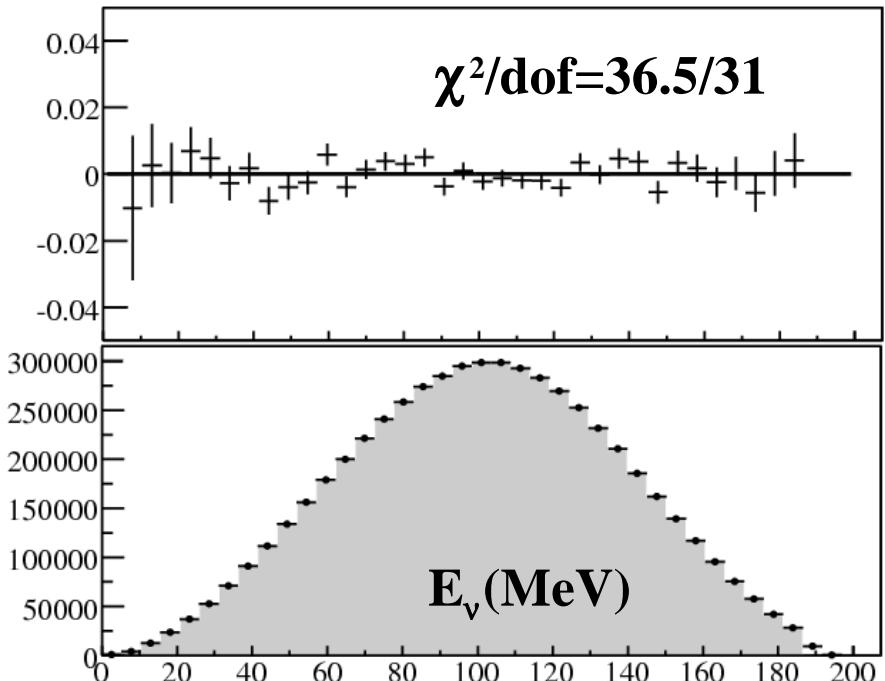
$$\lambda_0 = (14.3 \pm 2.9 \pm 2.4) \times 10^{-3}$$

$$\begin{pmatrix} -0.97 & 0.90 \\ & -0.80 \end{pmatrix}$$

Results obtained with dispersive relations for $f_{+,0}(t)$
averaged with published results

$$\lambda_+ = (26.0 \pm 0.5_{\text{STAT+SYST}}) \times 10^{-3}$$

$$\lambda_0 = (15.1 \pm 1.4_{\text{STAT+SYST}}) \times 10^{-3}$$



$$\log C = 0.217 \pm 0.016$$

$K_{\mu 3}$ form factor slopes

Preliminary

$$f_+(0) = 0.954 \pm 0.016$$

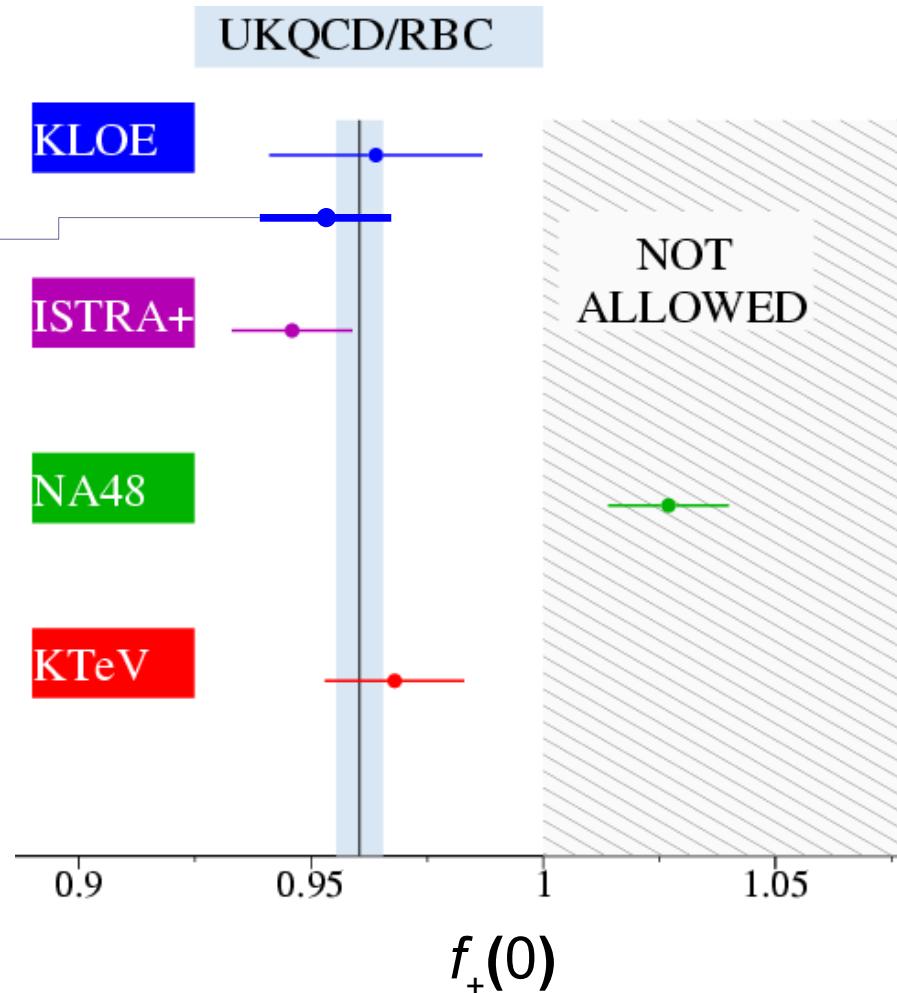
using:

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

and

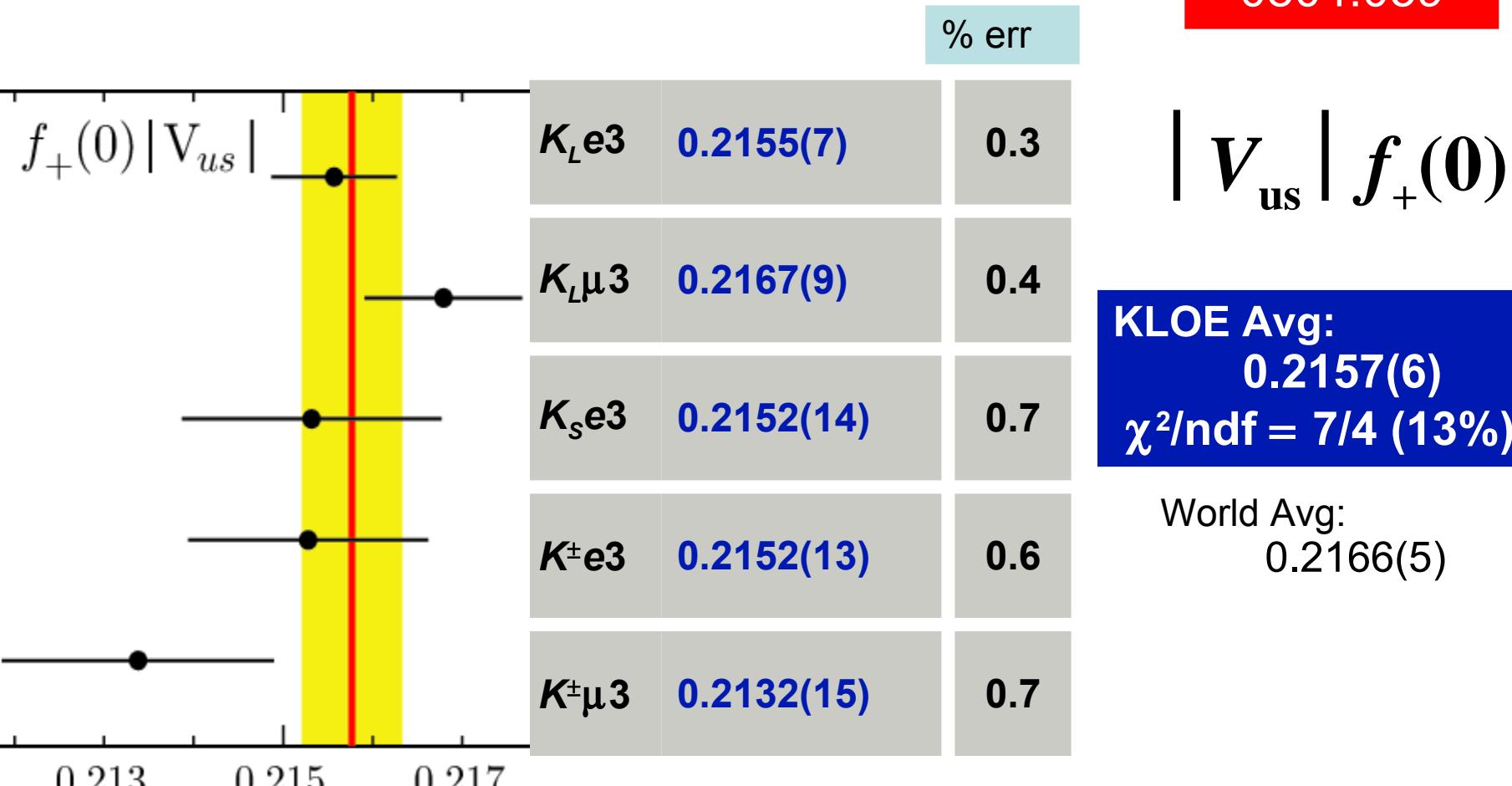
$$f_K/f_\pi = 1.189(7)$$

from HPQCD-UKQCD(MILC)



V_{us} from KLOE K_{l3} data

JHEP
0804:059



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

KLOE Avg:
 $0.2157(6)$
 $\chi^2/ndf = 7/4$ (13%)

World Avg:
 $0.2166(5)$

$$f_+(0)=0.964(5)$$

RBC/UKQCD, 07 prel.

$$V_{ud} = 0.97418(26)$$

arXiv:0710.3181

$$\Rightarrow V_{us} = 0.2237(13)$$

$$\Rightarrow 1 - V_{ud}^2 - V_{us}^2 = 9(8) \times 10^{-4}$$

V_{us}/V_{ud} from $K_{\mu 2}$

Marciano '04

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

Uncertainty from SD virtual corrections

HP/UKQCD '07
preliminary
arXiv:0706.1726

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

$$N_f = (2+1)_{\text{stag}}$$

Cancellation of lattice-scale uncertainties

PLB 636 (2006)

$$\text{BR}(K^+ \rightarrow \mu^+ \nu(\gamma)) = 0.6366(17)$$

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

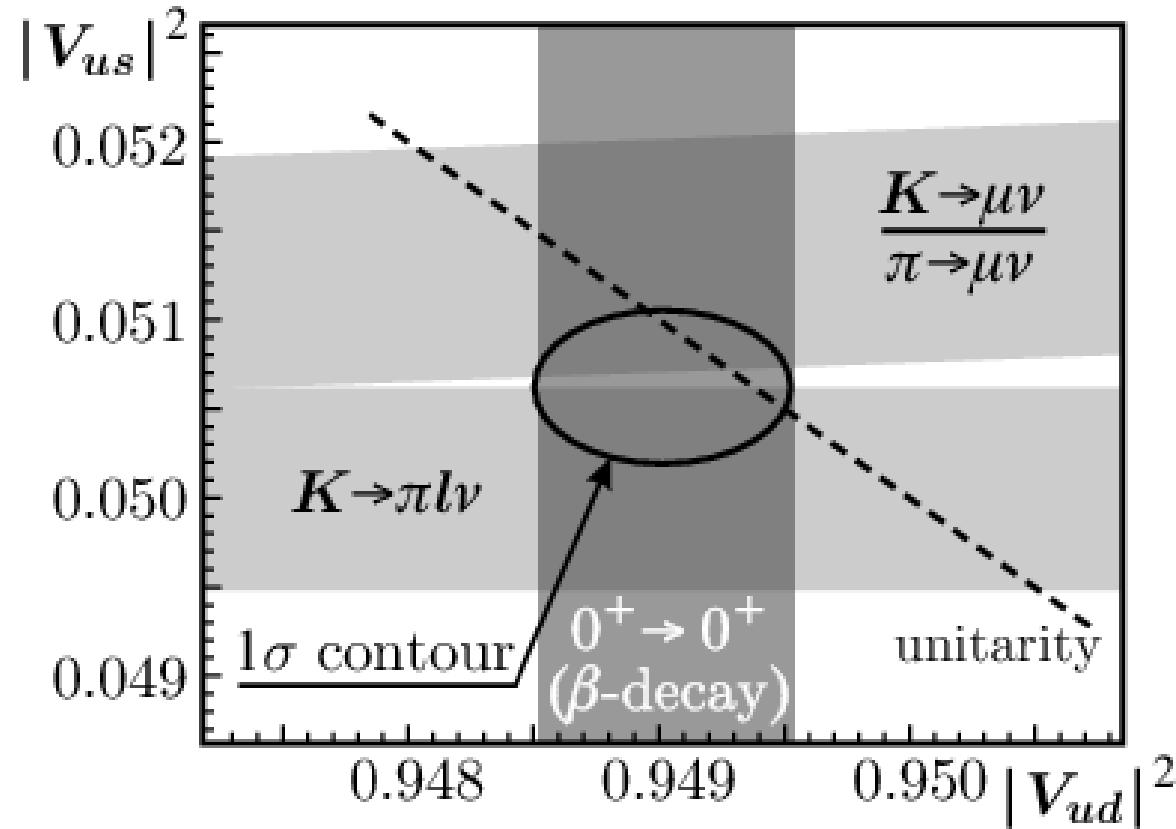
Counts $K^+ \rightarrow \mu^+ \nu$ from decay-momentum spectrum

$$V_{us}/V_{ud} = 0.2323(15)$$

V_{ud} , V_{us} and V_{us}/V_{ud}

JHEP

0804:059



no constraint:

$$V_{ud}^2 = 0.9490(5)$$

$$V_{us}^2 = 0.0506(4)$$

$$\chi^2/\text{ndf} = 2.3/1 \text{ (13\%)}$$

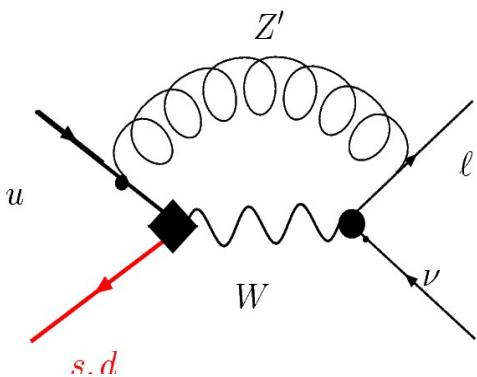
agreement with
unitarity:

$$1 - V_{ud}^2 - V_{us}^2 = 4(7) \times 10^{-4}$$

@ 0.6 σ

sensitivity to NP: Z'ooogy

1)



$$G_F = G_{CKM} [1 - 0.007 Q_{eL} (Q_{\mu L} - Q_{dL}) \frac{2 \ln(m_{Z'}/m_W)}{(m_{Z'}^2/m_W^2 - 1)}]$$

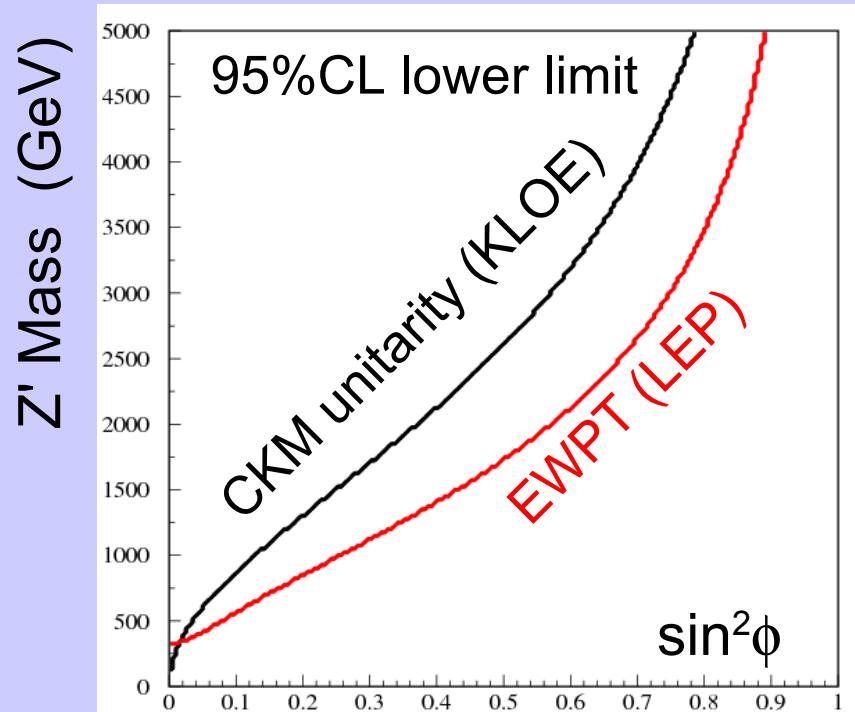
SO(10) Z_χ Boson: $Q_{eL} = Q_{\mu L} = -3Q_{dL} = 1$ [Marciano]

$m_{Z\chi} > 750 \text{ GeV } 95\% \text{ CL}$

2)

[K.Y. Lee]

Tree level breaking of unitarity in models with non-universal gauge interaction



sensitivity to NP: charged Higgs

Pseudoscalar currents, e.g. due to H^\pm , affect the K width:

JHEP
0804:059

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

Hou, Isidori-Paradisi

The observable

$$R_{\ell 23} = \left| \frac{V_{us}(K_{\mu 2})}{V_{us}(K_{\ell 3})} \times \frac{V_{ud}(0^+ \rightarrow 0^+)}{V_{ud}(\pi_{\mu 2})} \right|$$

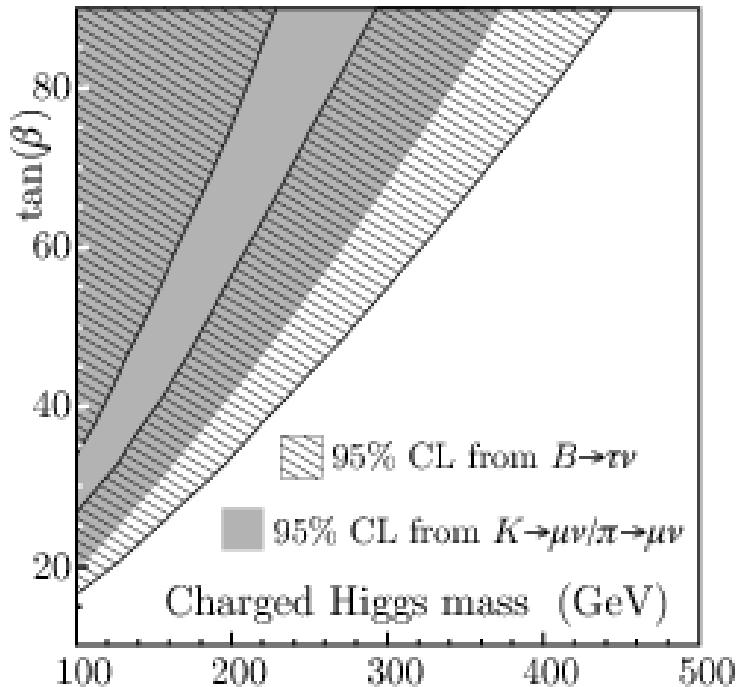
we get:

- $R_{\ell 23} = 1.008(8)$

(unitarity for K_{l3} and β -decays is used)

$R_{\ell 23}$ sensitivity to H^\pm exchange

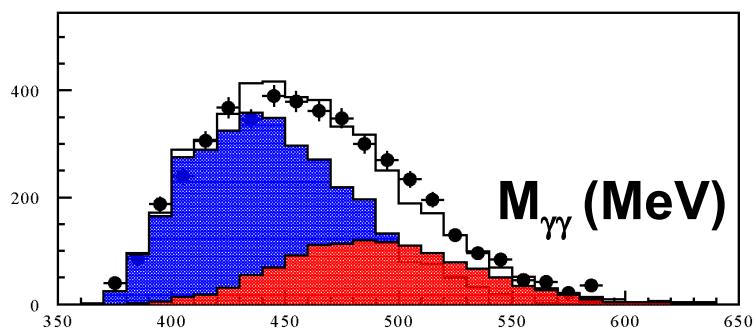
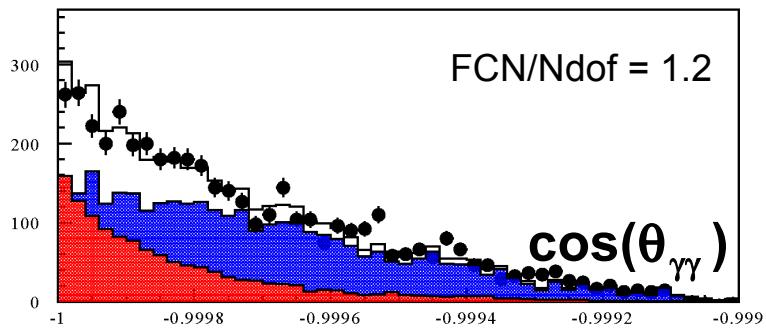
$$R_{\ell 23} = \left| 1 - \frac{m_{K^+}^2}{m_{H^+}^2} \left(1 - \frac{m_{\pi^+}^2}{m_{K^+}^2} \right) \frac{\tan^2 \beta}{1 + \epsilon_0 \tan \beta} \right|$$



BR($K_S \rightarrow \gamma\gamma$)

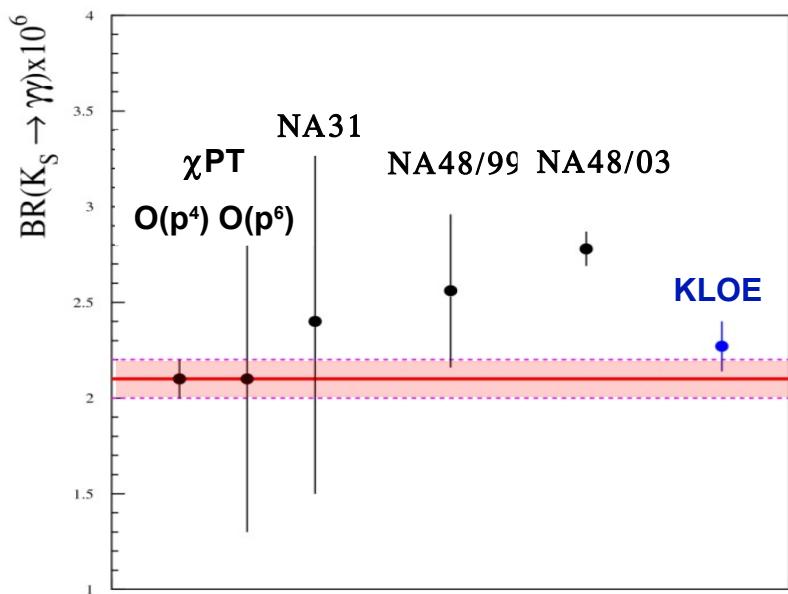
$N_{\text{sig}} = 600.3 \pm 34.8$

5.8% stat. error



- DATA
- MC all {
- Signal
- Background

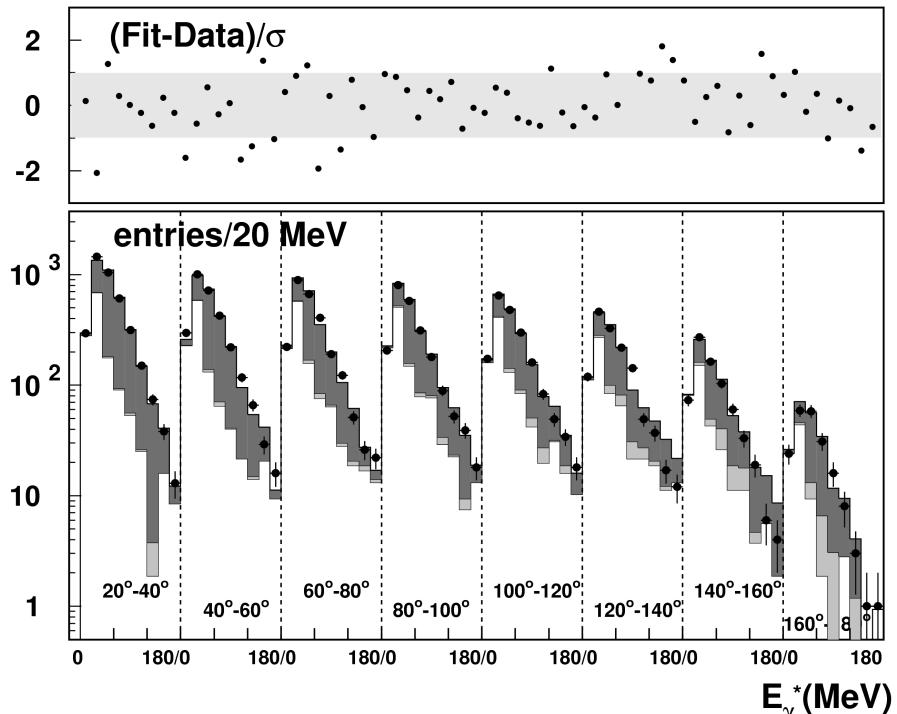
$$\text{BR} = (2.27 \pm 0.13^{+0.03}_{-0.04}) \times 10^{-6}$$



2.9 σ discrepancy with NA48
KLOE agrees with $\chi\text{PT } O(p^4)$

$BR(K_L \rightarrow \pi e \nu \gamma)$

accepted by EPJC

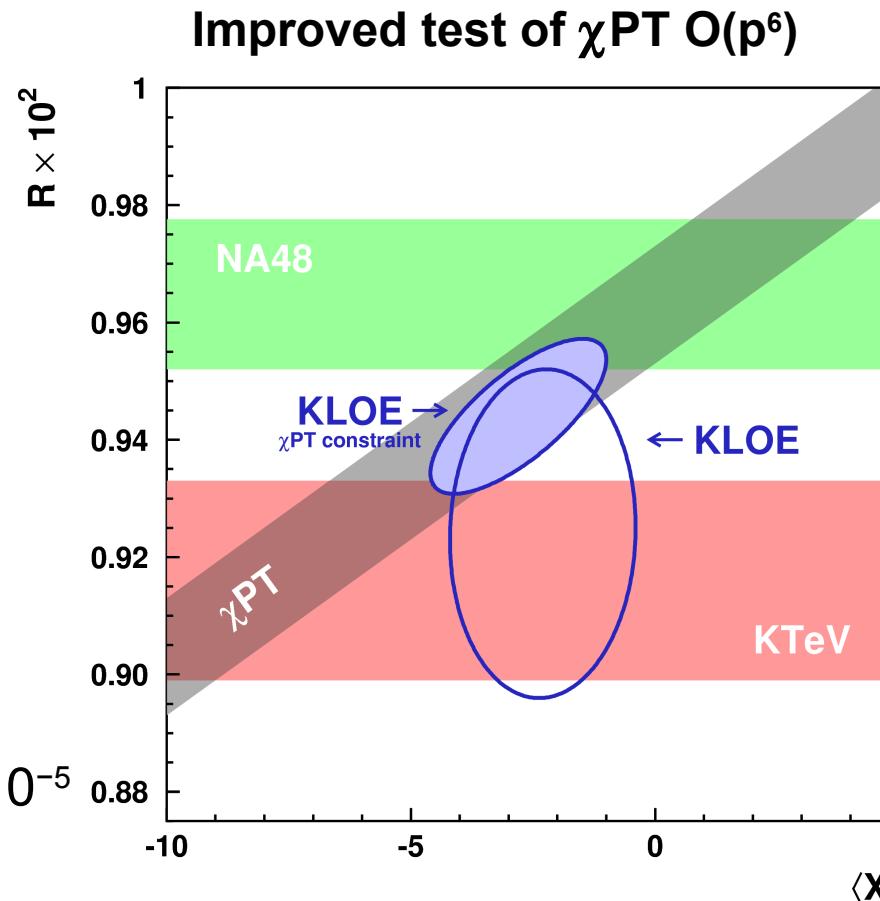


$$R = \frac{BR(K_L \rightarrow \pi e \gamma)}{BR(K_L \rightarrow \pi e \nu)} = (924 \pm 23_{\text{stat}} \pm 16_{\text{syst}}) \times 10^{-5}$$

$$\langle X \rangle = -2.3 \pm 1.3_{\text{stat}} \pm 1.4_{\text{syst}}$$

Effective strength parameter describing direct emission

$E_\gamma^* > 30 \text{ MeV}$ $\theta_{e\gamma} > 20^\circ$



$BR(K_S \rightarrow \pi^+ \pi^- e^+ e^-)$

Amplitude dominated by CP even IB component (needed to predict the CP violation in $K_L \rightarrow \pi\pi ee$)

CP test through measurement of angular asymmetry between $\pi\pi$ and ee planes

K_S tagged by K_L crash

Fit the distribution of $(E_{miss} - P_{miss})_{\pi\pi ee}$

Normalize to the number of $K_S \rightarrow \pi^+ \pi^-$

NA48



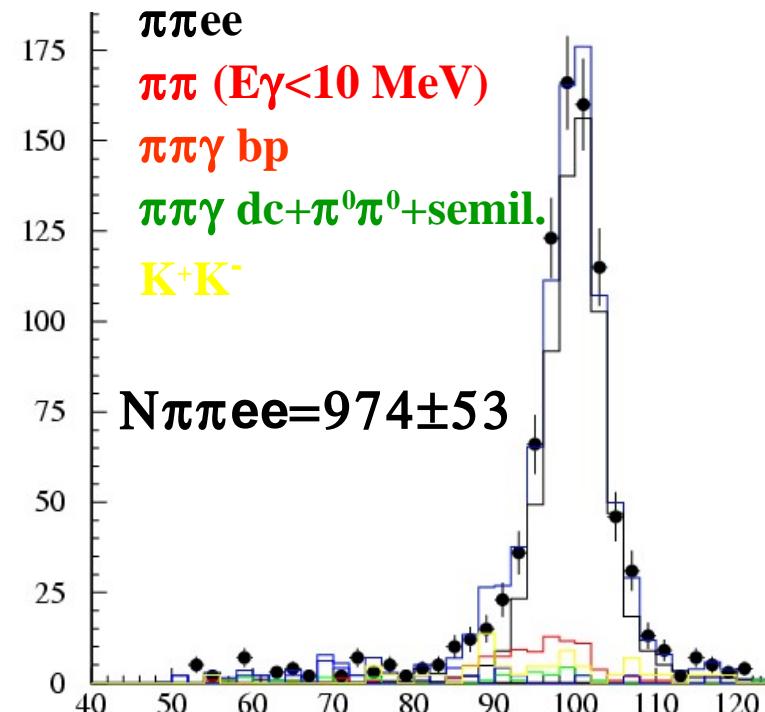
KLOE



Theory



3.8 4 4.2 4.4 4.6 4.8 5 5.2



Preliminary results (900 pb⁻¹)

$BR = (4.48 \pm 0.24_{\text{Stat}} \pm 0.15_{\text{Syst}}) \times 10^{-5}$
Asymmetry soon

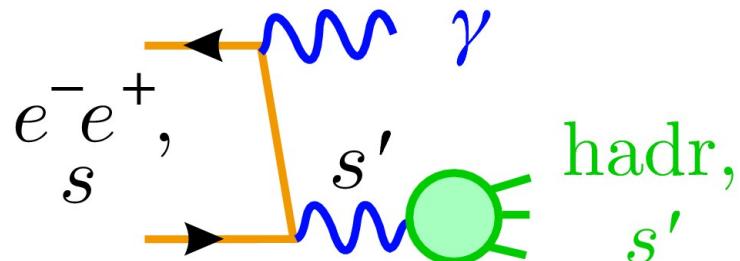
1) Kaon physics

2) $\sigma(e^+e^- \rightarrow \text{had})$

3) Scalar and pseudoscalar mesons

$\sigma(e^+e^- \rightarrow \text{had})$: the ISR method

Exploit ISR to extract $\sigma(e^+e^- \rightarrow \pi^+\pi^-)$
for $\sqrt{s'} = M_{\pi\pi}$ from $2m_\pi \rightarrow \sqrt{s}$

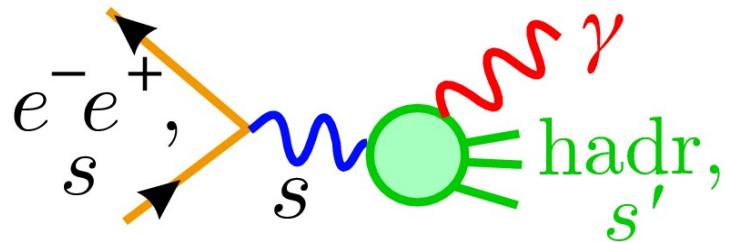


$$M_{\pi\pi}^2 \underbrace{\frac{d\sigma(\pi\pi\gamma, M_{\pi\pi}^2)}{dM_{\pi\pi}^2}}_{\text{we measure}} = H(M_{\pi\pi}^2) \underbrace{\sigma(\pi\pi, M_{\pi\pi}^2)}_{\substack{\text{precise} \\ \text{QED} \\ \text{calc.}}} \underbrace{\text{extract}}$$

- Have to watch out for **hard FSR**:

Rate ~ same order as ISR signal

FSR causes events with $M_{\gamma^*} = \sqrt{s}$ to
be assigned to lower $\sqrt{s'}$ values



Two analysis strategies

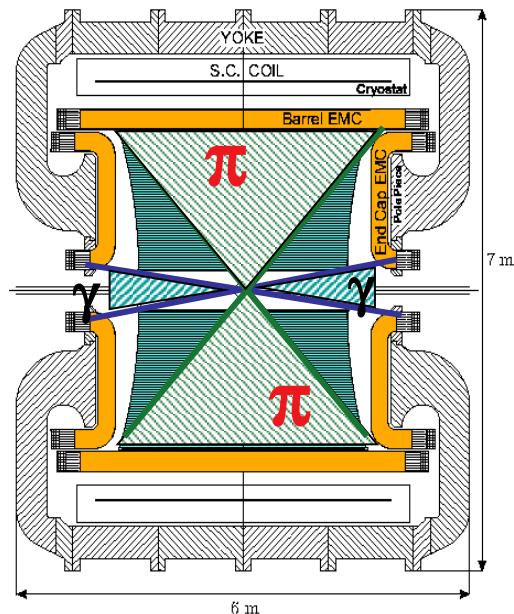
1) Photons at small angles

→ No photon detection: $p_\gamma = p_\phi - p_+ - p_-$

2 samples:

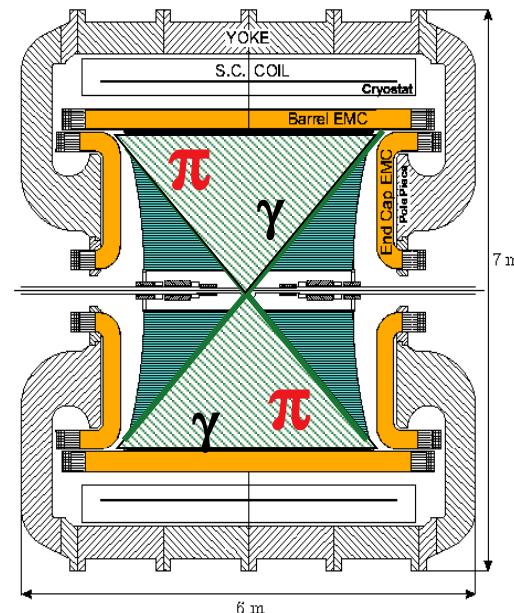
2001 data → $a_\mu^{\pi\pi}$ to 1.3% PLB 606(2005)

2002 data → $a_\mu^{\pi\pi}$ to 1.0% **Final**



2) Photons at large angles

→ Photon is observed on the EMC



Improvements w.r.t. published analysis

systematic error table for $\sigma(\pi)$
published analysis (2001 data)

Reconstruction filter	0.6%
Background	0.3%
M_{trk} cuts	0.2%
Particle ID	0.1%
Tracking	0.3%
Vertex	0.3%
Trigger	0.3%
Acceptance	0.3%
Unfolding	0.2%

Improved machine conditions
(luminosity and background) in 2002

Improved offline-event filter reduces its
systematic uncertainty to < 0.1%

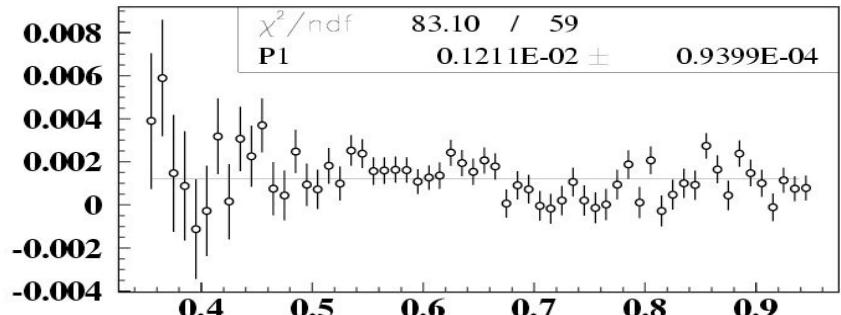
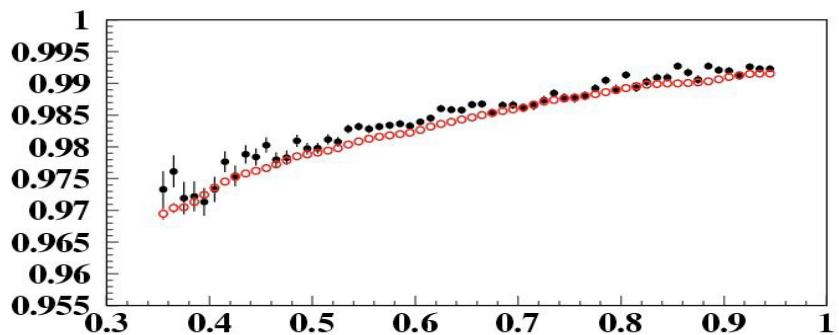
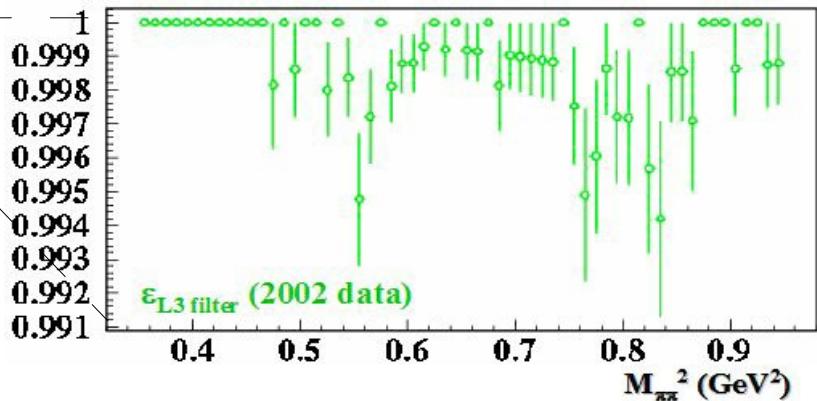
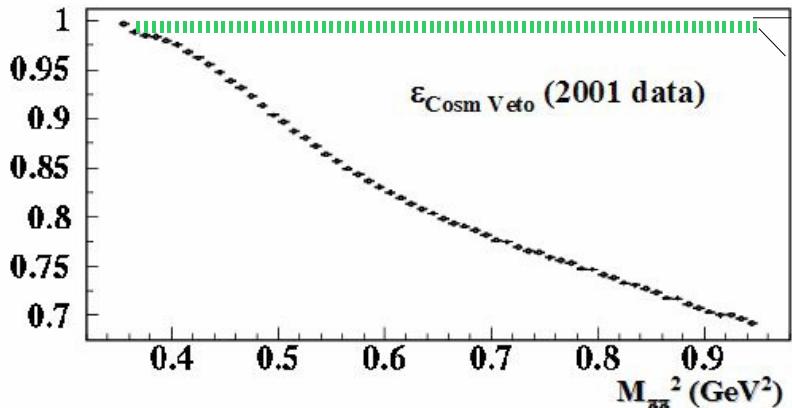
Improvements: no vertex required,
+ new methods/c.s. for correction

30% inefficiency (veto of cosmic rays)
recovered by introducing L3 trig,
+ new trigger requirements (self-trigger π s),
+ new methods for efficiency

Luminosity ($0.5_{\text{th}} \oplus 0.3_{\text{exp}}$)%	0.6%
Radiator H	0.5%
Vacuum polarization	0.2%

New generator BABAYAGA@NLO -
theoretical error of Bhabha reference
cross section goes from 0.5% to 0.1%
(central value 0.7% lowered)

Improvements: trigger



Systematic error table comparison

systematic error table for $\sigma(\pi)$

published analysis (2001 data)

Reconstruction filter	0.6%
Background	0.3%
M_{trk} cuts	0.2%
Particle ID	0.1%
Tracking	0.3%
Vertex	0.3%
Trigger	0.3%
Acceptance	0.3%
Unfolding	0.2%

0.9%

Luminosity ($0.5_{\text{th}} \oplus 0.3_{\text{exp}}$)%	0.6%
Radiator H	0.5%
Vacuum polarization	0.2%

0.9%

systematic error table for $\sigma(\pi)$

New analysis (2002 data)

Reconstruction filter	--
Background	$M^2 \text{ dep}(0.1-0.8\%)$
M_{trk} cuts	0.2%
Particle ID	0.3%
Tracking	0.3%
Vertex	--
Trigger	$(0.1 \oplus 0.3_{\text{L3}})\%$
Acceptance	$M^2 \text{ dep}(0.1\%)$
Unfolding	0.2%

0.7%

Luminosity ($0.1_{\text{th}} \oplus 0.3_{\text{exp}}$)%	0.3%
Radiator H	0.5%
Vacuum polarization	--

0.6%

Result on a_μ

Dispersion integral for 2π -channel in energy interval $0.35 < M_{\pi\pi}^2 < 0.95 \text{ GeV}^2$

$$a_\mu^{\pi\pi} = 1/4\pi^3 \int_{0.35\text{GeV}^2}^{0.95\text{GeV}^2} ds \sigma(e^+e^- \rightarrow \pi^+\pi^-) K(s)$$

$$a_\mu^{\pi\pi}(0.35-0.95\text{GeV}^2) = (389.2 \pm 0.8_{\text{stat}} \pm 3.5_{\text{syst}}) \cdot 10^{-10}$$

The diagram consists of a horizontal line with two vertical lines extending downwards from its center, forming a bracket shape. This bracket is positioned below the central value and above the experimental and theoretical components.

$$2.9_{\text{exp}} \oplus 1.9_{\text{th}}$$

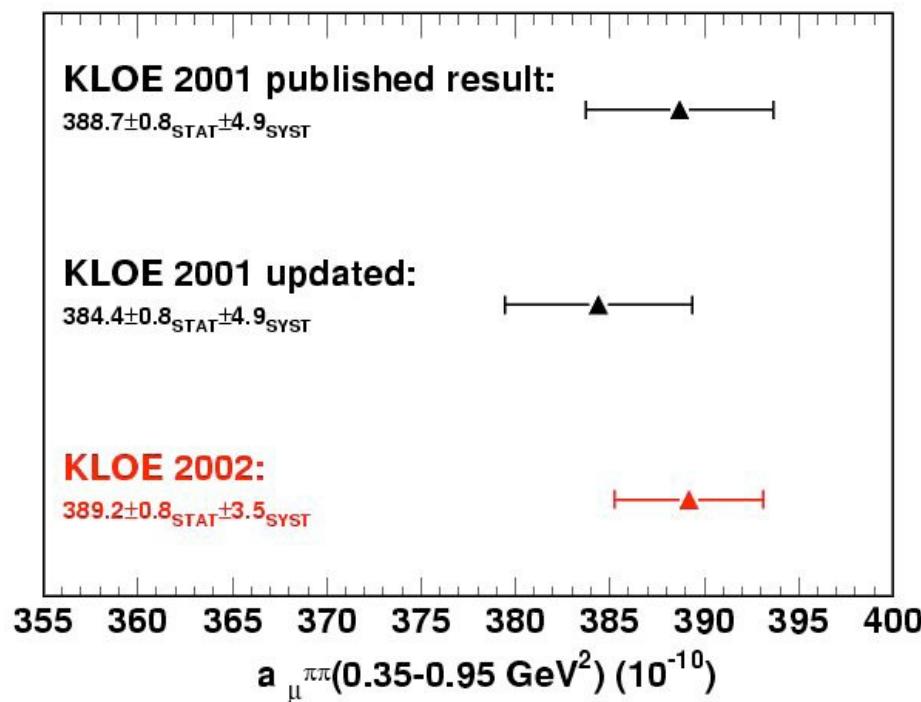
2001 published result (Phys. Lett. B606 (2005) 12):

$$a_\mu^{\pi\pi}(0.35-0.95\text{GeV}^2) = (388.7 \pm 0.8_{\text{stat}} \pm 4.9_{\text{syst}}) \cdot 10^{-10}$$

Applying update for trigger eff. and change in Bhabha-cross section used for luminosity evaluation:

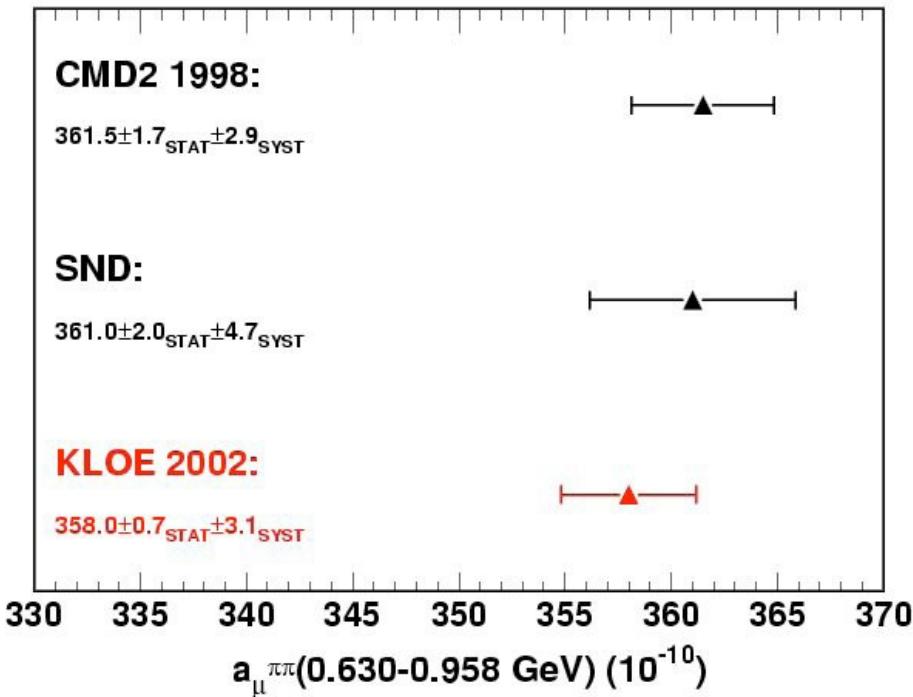
$$a_\mu^{\pi\pi}(0.35-0.95\text{GeV}^2) = (384.4 \pm 0.8_{\text{stat}} \pm 4.9_{\text{syst}}) \cdot 10^{-10}$$

Comparison with previous results



KLOE results are consistent

Comparison with other e^+e^- experiments



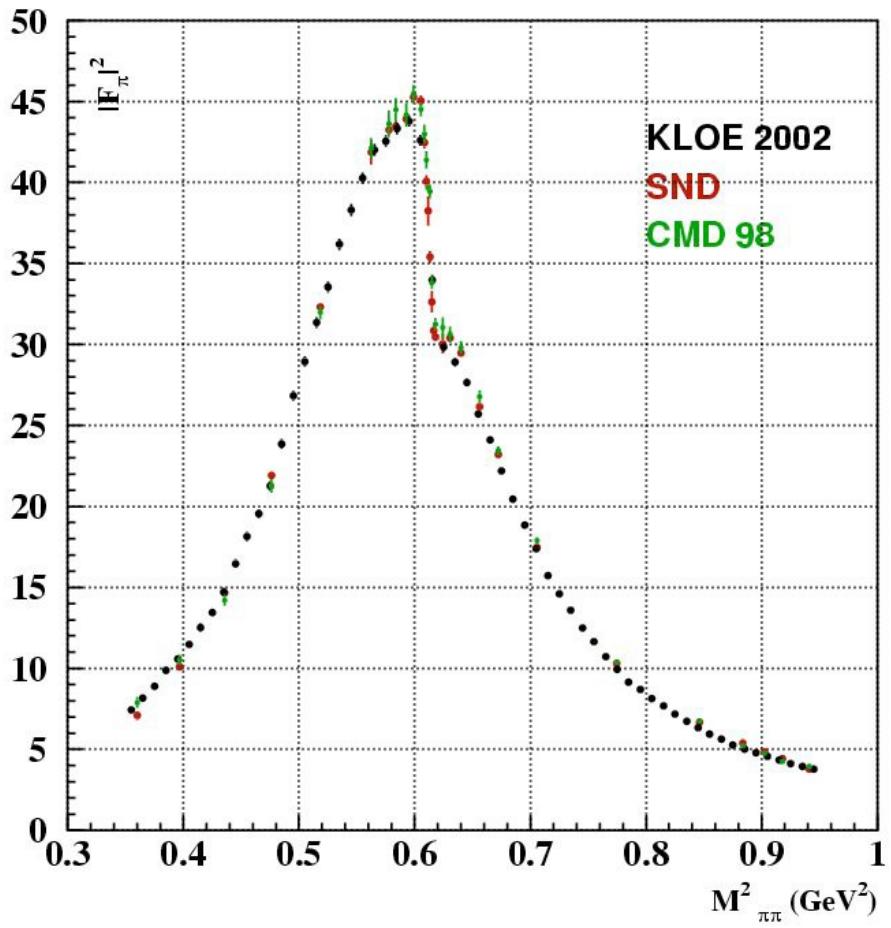
KLOE result is in agreement with CMD2 and SND values

(0.6-1 GeV) wa accuracy improved by~15% wrt hep-ph/0703125

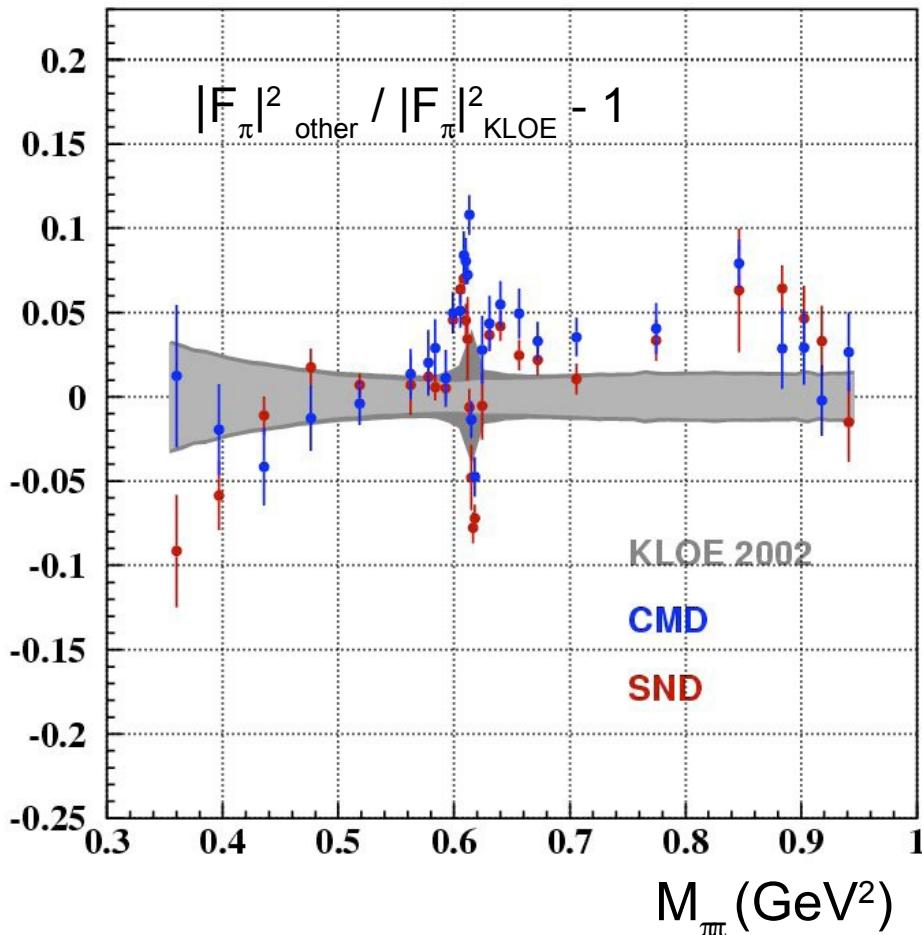
Jegerlehner (hep-ph/0703125):

$$\Delta a_\mu = a_\mu^{\text{exp}} - a_\mu^{\text{the}} = (28.7 \pm 9.1) \cdot 10^{-10} \rightarrow (29.1 \pm 9.0) \cdot 10^{-10}$$

F_π comparison with other results



only statistical errors are shown
better agreement on the rho peak



1) Kaon physics

2) $\sigma(e^+e^- \rightarrow \text{had})$

3) Scalar and pseudoscalar mesons

Scalar and pseudoscalar mesons

$e^+e^- \rightarrow \phi \rightarrow \omega\pi^0$ *

ArXiv:0707.4130 (final available)

$\phi \rightarrow a_0(980) \gamma \rightarrow \eta \pi^0 \gamma$

ArXiv:0707.4609 (final available)

UL on $\phi \rightarrow K^0\bar{K}^0\gamma$ **

ArXiv:0707.4148 (final ~available)

η mass

JHEP 0712:073

$\eta \rightarrow \pi^0\pi^0\pi^0$ Dalitz parameters

ArXiv:0705.4137

$\eta \rightarrow \pi^+\pi^-\pi^0$ Dalitz parameters

JHEP08:05006

$\eta - \eta'$ & η' gluonium content

full int. about ready

* energy scan 2006

** whole data sample

Scalars

$\phi \rightarrow f_0 \gamma$: toward a combined fit

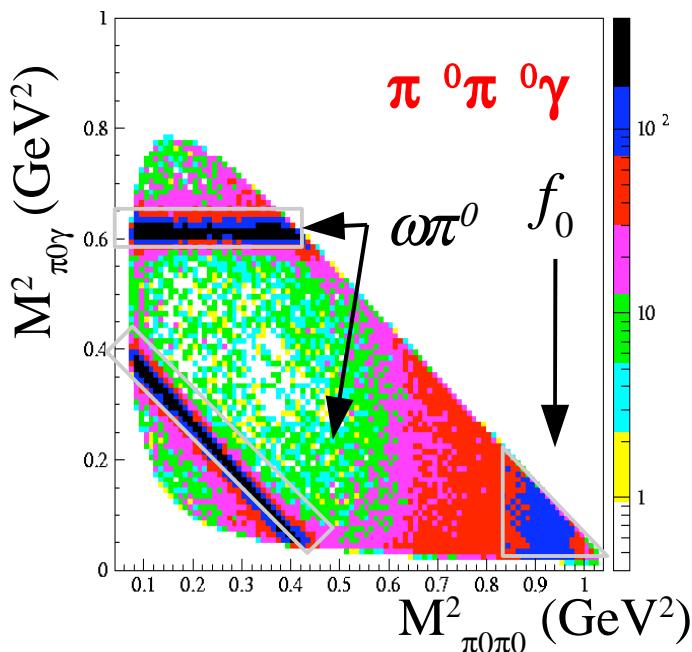
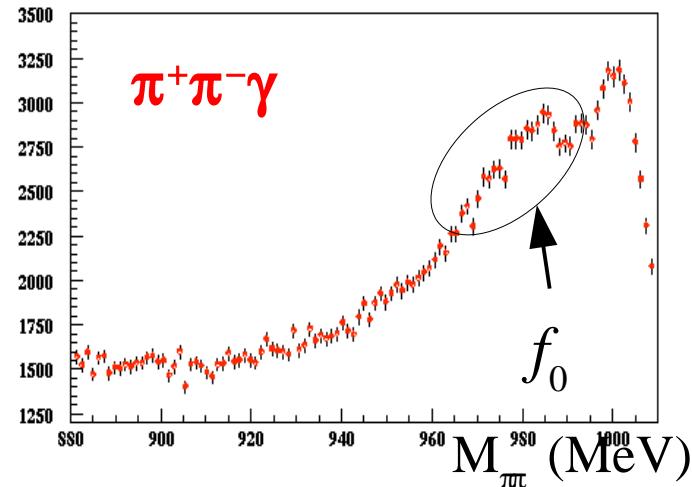
450 pb⁻¹ of L_{int}

Charged with M $\pi\pi$ spectra fit

Neutral with Dalitz plot density analysis

(KL) New σ coupling used for both
[PRD 74 2006 (E)]

	$\pi^+\pi^-$	$\pi^0\pi^0$
M_{f0}	983.7	984.7 ± 2.1
g_{f0KK}	4.74	3.97 ± 0.46
$g_{f0\pi\pi}$	-2.2	-1.82 ± 0.20
$R(g_{f0KK}/g_{f0\pi\pi})^2$	4.6	4.8



Pseudoscalars

η mass

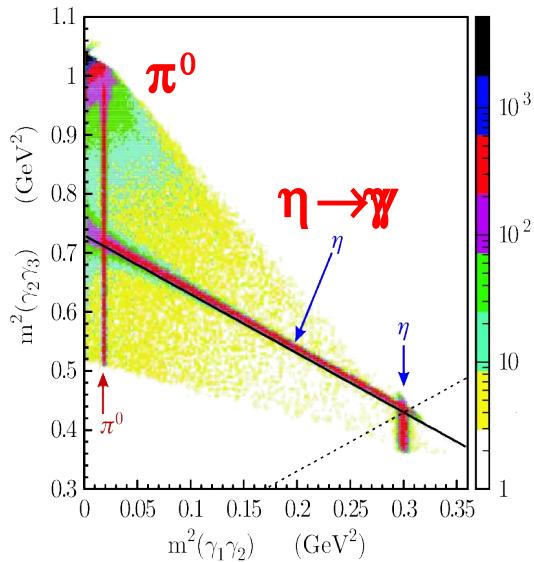
PDG 2006: disagreement between η mass

precise measurements

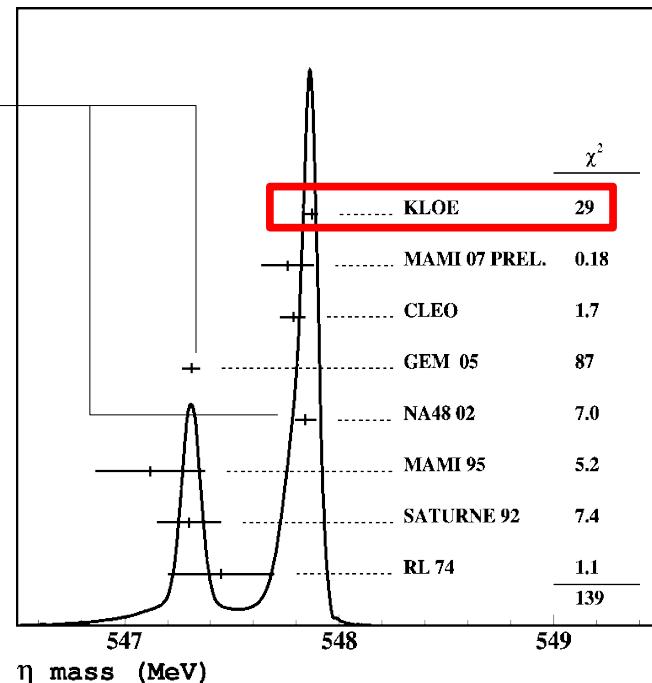
450 pb^{-1} of L_{int} ($\sim 20 \times 10^6 \eta$ produced)

KLOE measurement is based on γ direction

Using the decay $\phi \rightarrow \pi^0 \eta \rightarrow 3\gamma$



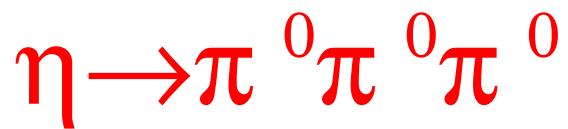
Main systematic effect (keV)	100
Detector uniformity	18
Dalitz plot cut	17



Absolute energy scale by comparing
 $e^+e^- \rightarrow \phi \rightarrow K_S K_L$ lineshape results with CMD-2

$$M_\eta = 547.873 \pm 0.007 \pm 0.031 \text{ MeV}$$

JHEP 0712:073



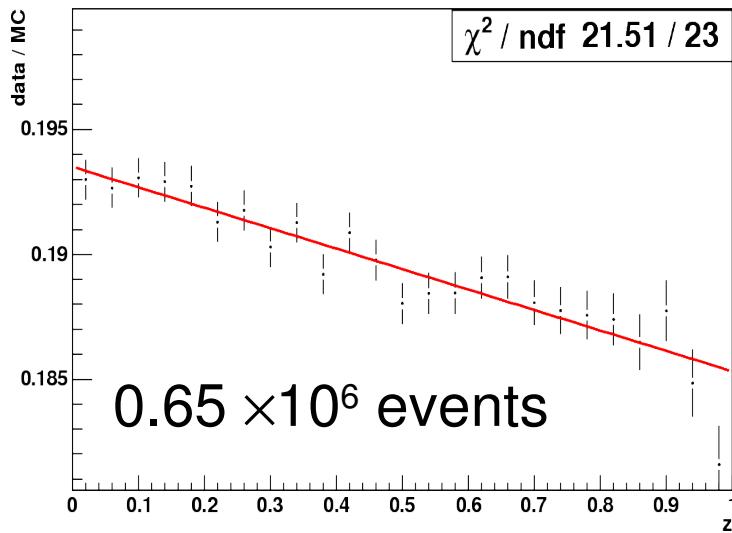
Dalitz plot density described with a single variable z (η mass dependent)

$$z = \frac{2}{3} \sum_i \left(\frac{3E_i - m_\eta}{m_\eta - 3m_{\pi^0}} \right)^2 = \frac{\rho^2}{\rho_{MAX}^2}$$

E : Energy of the pion in η rest frame
 ρ : Distance from the Dalitz plot center
 ρ_{MAX} : Maximum value of ρ

The slope α is evaluated normalizing data to Montecarlo density

$$|A_{\eta \rightarrow 3\pi^0}(z)|^2 \sim 1 + 2\alpha z(M_\eta)$$



KLOE preliminary

$$\alpha_{KLOE} = -0.027 \pm 0.004^{+0.004}_{-0.006}$$

$$\eta \rightarrow \pi^+ \pi^- \pi^0$$

JHEP08:05006

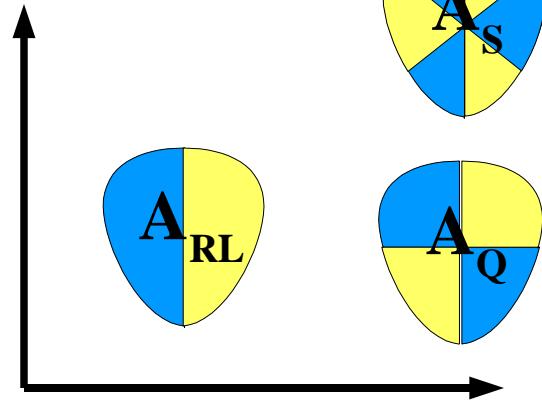
450 pb^{-1} of L_{int} ($\sim 20 \times 10^6 \eta$ produced) $\rightarrow 1.34 \times 10^6$ event

$\eta \rightarrow \pi^+ \pi^- \pi^0$ Dalitz plot analysis

Asymmetry (C invariance test):

- **Left-Right** \bar{C}
- **Quadrant** \bar{C} ($\Delta l=2$)
- **Sextant** \bar{C} ($\Delta l=1$)

$$Y = \frac{3T_0}{Q_\eta} - 1$$



$$X = \sqrt{3} \frac{T_+ - T_-}{Q_\eta}$$

$$A_{LR} = (0.09 \pm 0.10^{+0.09}_{-0.14}) \times 10^{-2}$$

$$A_Q = (-0.05 \pm 0.10^{+0.03}_{-0.05}) \times 10^{-2}$$

$$A_S = (0.08 \pm 0.10^{+0.08}_{-0.13}) \times 10^{-2}$$

PDG06

$$A_{LR} = (0.09 \pm 0.17) \times 10^{-2}$$

$$A_Q = (-0.17 \pm 0.17) \times 10^{-2}$$

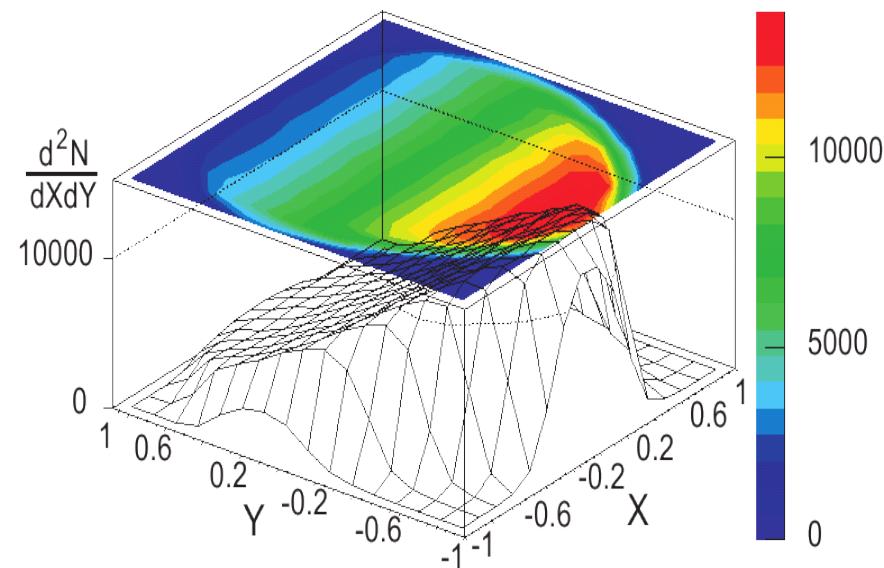
$$A_S = (0.18 \pm 0.4) \times 10^{-2}$$

Standard parametrization of Dalitz plot density:

$$|A_{+-0}(X, Y)|^2 \approx 1 + aY + bY^2 + cX + dX^2 + eXY + fY^3$$

$$X = \sqrt{3} \frac{T_+ - T_-}{Q_\eta} \quad Y = \frac{3T_0}{Q_\eta} - 1$$

CL	74%
$a \times 10^3$	$-1090 \pm 5^{+8}_{-19}$
$b \times 10^3$	$124 \pm 6 \pm 10$
$d \times 10^3$	$57 \pm 6^{+7}_{-16}$
$f \times 10^3$	$140 \pm 10 \pm 2$



alternative parametrization:

relation with $\eta \rightarrow 3\pi^0$ via Ispin

$$\alpha \pi^0 |A_{+-0}) = -0.038 \pm 0.003^{+0.012}_{-0.008}$$

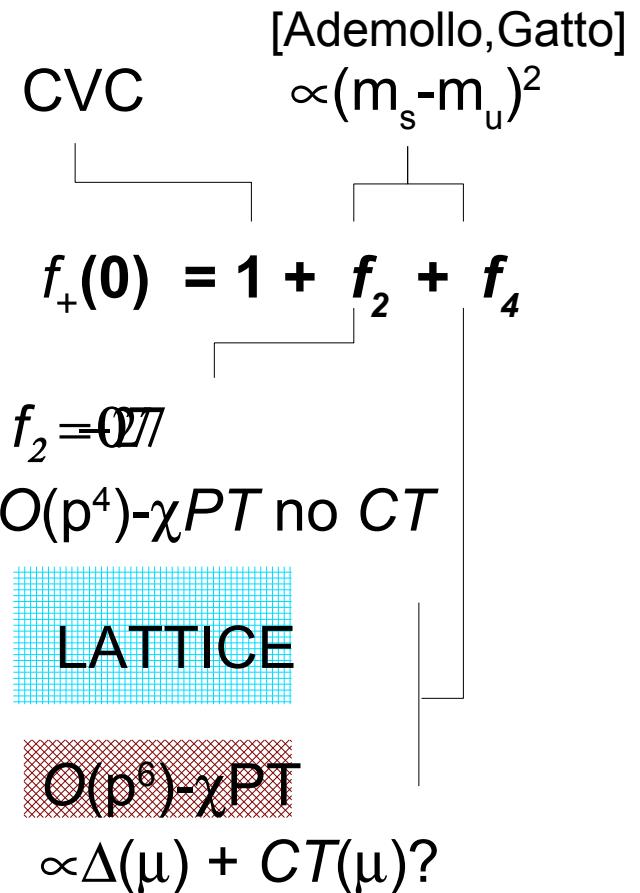
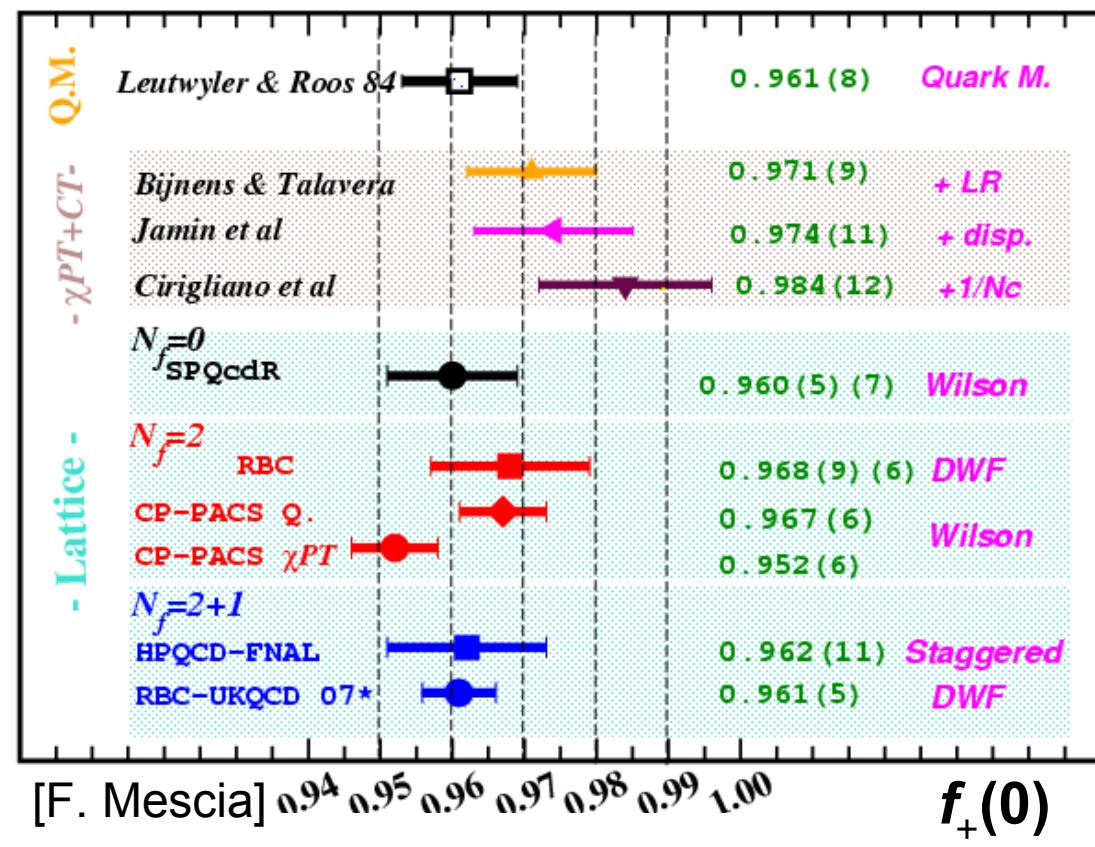
from $\eta \rightarrow 3\pi^0$:

$$\alpha = -0.027 \pm 0.004^{+0.004}_{-0.006}$$

CONCLUSIONS

- 8 publications + 2 final since last meeting
- Most important results
 - best measurements of V_{us}
 - best measurement of $a_\mu^{\pi\pi}(0.35\text{-}0.95 \text{ GeV}^2)$
- Many preliminary results + ongoing analyses
 - $K_{e2}/K_{\mu 2}$, K_{l3} slopes, $\sigma_{\text{had}}(\pi\gamma/\mu\gamma, \text{low } q^2)$,
 - $f_0 \rightarrow K\bar{K}\gamma$ $\eta \rightarrow \pi ee \dots$

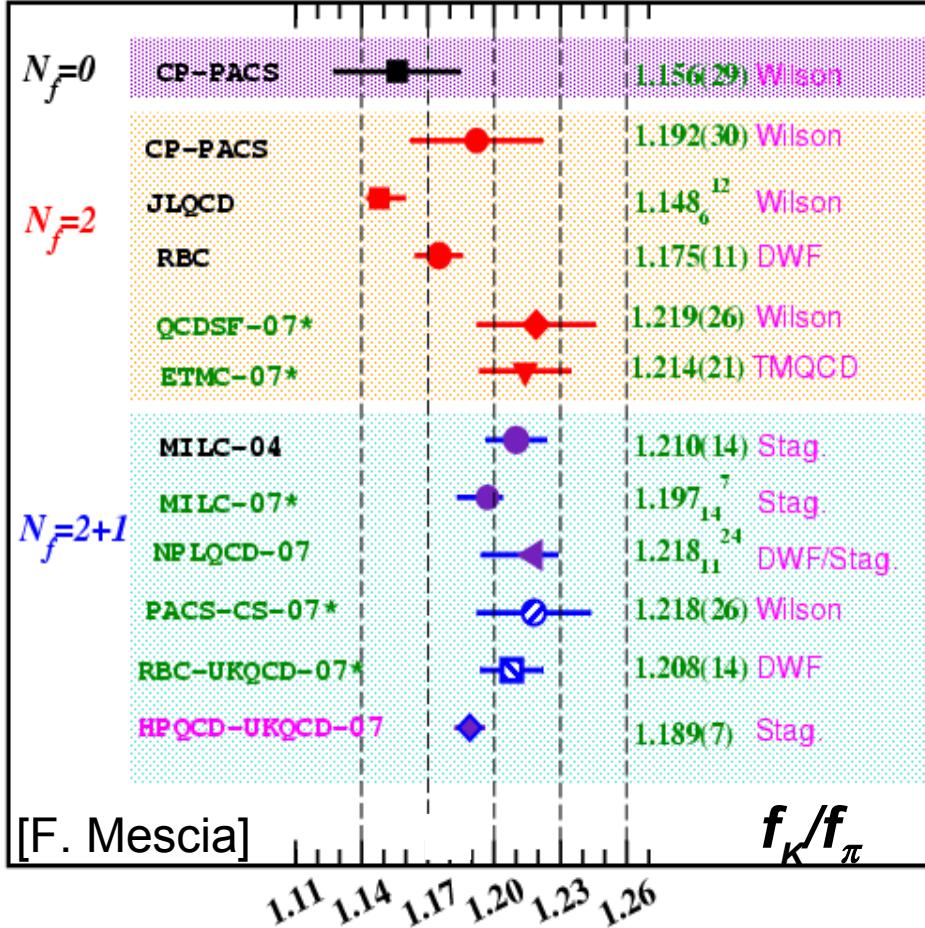
Evaluations of $f_+(0)$



encouraging results from UKQCD/RBC NF=2+1, DWF, $m_\pi >= 300\text{MeV}$:

$$f_+(0) = 0.9609(51)$$

Evaluations of f_K/f_π



No symmetry protection

$$\propto m_s - m_u$$

$$f_K/f_\pi = 1 + \text{loops}(\mu) + CT(\mu)$$

χPT CT already at NLO

Only LATTICE

delicate:

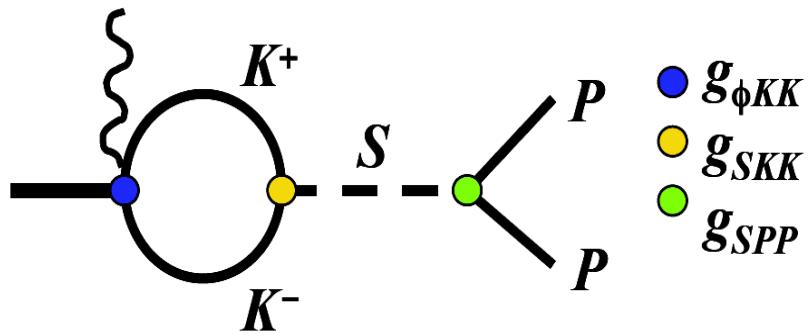
large chiral extrapolation

no need of q^2 extrapolation

updated result from HPQCD-UKQCD(MILC) $N_f=2+1$, Stag, $m_\pi \sim 240$ MeV!
 continuum limit: $f_K/f_\pi = 1.189(7)$

$\phi \rightarrow S\gamma$

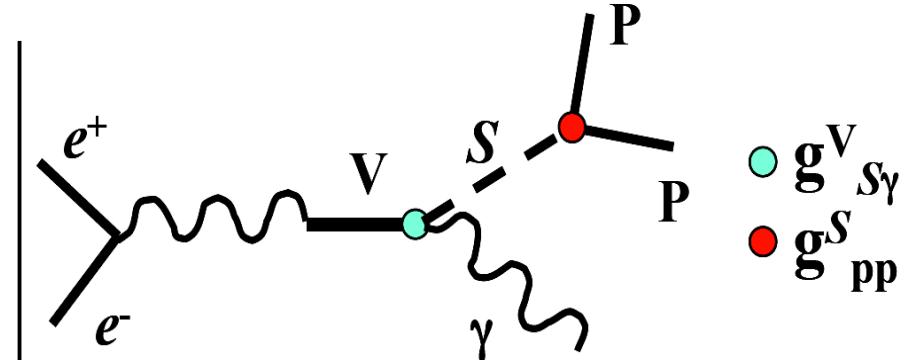
Kaon Loop Model (KL)



$$\frac{d\Gamma_R}{dm} = \frac{2|g(m^2)|^2 p_\gamma (M_\phi^2 - m^2)}{3(4\pi)^3 M_\phi^3} \left| \frac{g_{RK^+K^-} g_{RPP'}}{D_R(m^2)} \right|^2$$

Dipole transition ($\propto E_\gamma^3$) damped by the kaon loop function $g(m^2)$. The scalar propagator takes into account the finite width corrections.

No structure Model (NS)



$$M_{NS} \propto \frac{e}{4F_\phi} \frac{sM_\phi^2}{D_\phi(s)} \left[\frac{g_{SPP} g_{\phi S\gamma}}{D_s(m^2)} + \frac{a_0}{m_\phi^2} + a_1 \frac{m^2 - m_s^2}{m_\phi^4} \right]$$

Dipole transition ($\propto E_\gamma^3$) damped by a polynomial term (a_0 and a_1 complex) The scalar is a BW with energy-dependent width, taking into account the opening of $S \rightarrow KK$ thresholds.