Kaon Listings

Cheng-Ju Lin (LBNL)
Giancarlo D'Ambrosio (INFN)

11 October 2008

Main Cast

Overseer: Cheng-Ju Lin (LBNL, experimentalist)
Encoder: Giancarlo D'Ambrosio (INFN, theorist)

Software (fitter) support: Orin Dahl (LBNL)
Editor: Piotr Zylar (LBNL)
Advisor: Tom Trippe (really really retired)

Thank you Tom for your countless years of service
and leadership to the Particle Data Group !!

Mini-Review authors:

M. Antonelli (INFN), E. Blucher (U. Chicago), G. D'Ambrosio (INFN),
C.-J. Lin (LBNL), L. Littenberg (BNL), W. J. Marciano (BNL),
T. Nakada (PSI), T. G. Trippe (LBNL), G. Valencia (Iowa State U.),
L. Wolfenstein (CMU).

New for RPP 2008

For K^+, K^0, K_S, and K_L :

- Reviewed ~40 publications and encoded ~100 measurements (Main contributors: NA48, KTeV, KLOE, KEK-391a, ISTRA+, etc.)
- Completely re-written mini-review on "*CPT Invariance Test in Neutral Kaon Decays*"
- "Rare Kaon Decays" and "V_{ud}, V_{us}, *Cabibbo Angle, and CKM Unitarity*" mini-reviews have been extensively updated
- Updated "*CP Violation in* K_L *Decays*" and "$K_{L,3}$ *Form Factors*" mini-reviews

HEP community is scrutinizing the content

Below is an example inquiry soon after RPP08 was released:

(from M. Moulson)

K^+ fit

The fit is said to use 31 measurements (of which the mean life, a decay rate, and 13 BR quantities) and 1 constraint to determine 8 parameters. The constraint is that the BRs included in the fit sum to unity. **Note!** When I parse the tables, I find **32 measurements** of **14 BR quantities,** as listed below. Is one of the below data points not included in the fit, or is the description of the fit wrong? Please see my note below on the BATLEY '07A data.

Measurements

No.	Parameter	Value	Source
1	τ	12.347(30) ns	Ambrosino '08
2	τ	12.451(30) ns	Koptev '95
3	τ	12.368(41) ns	Koptev '95
4	τ	12.380(16) ns	Ott '71
5	τ	12.272(36) ns	Lobkowicz '71
6	τ	12.443(38) ns	Fitch '65
7	$\Gamma(\pi^+\pi^+\pi^-)$	4.511(24) MHz	Ford '70
8	BR($\mu\nu$)	0.6366(09)(15)	Ambrosino '06A
9	BR($\mu\nu$)	0.6324(44)	Chiang '72

Kaon fits are now so complex, it's difficult for readers to fully comprehend the details !!!

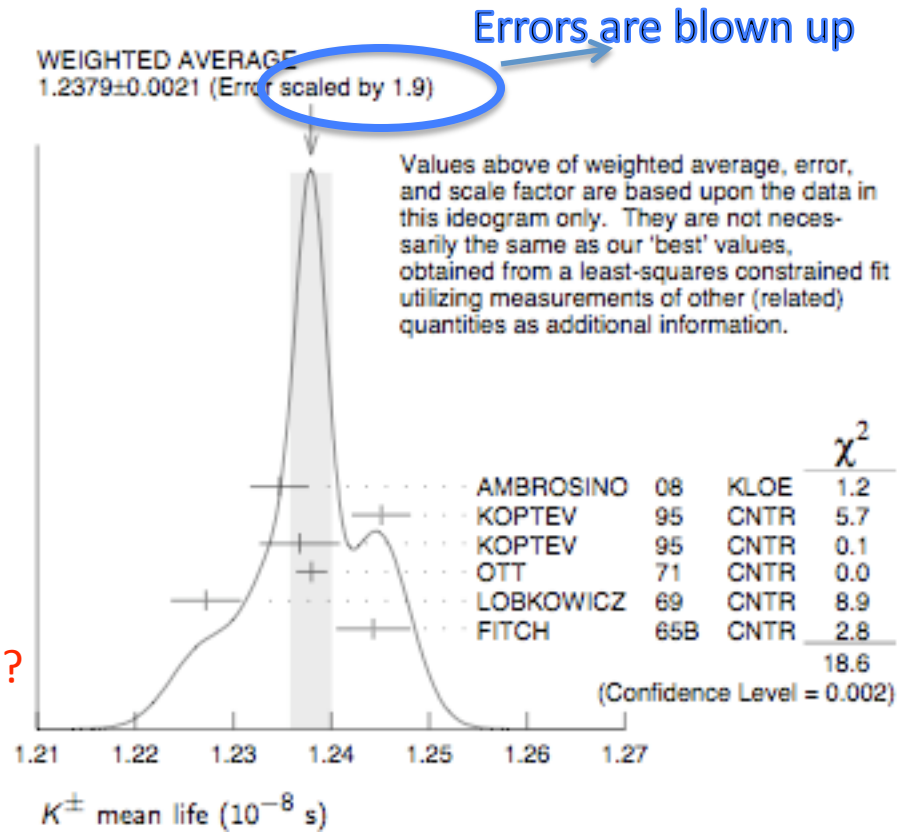
K^+ Listing Highlights

- New lifetime measurement from KLOE. KLOE collaboration questioned the validity of some old results

$K^\pm$ MEAN LIFE

VALUE (10^{-8} s)	EVTS	DOCUMENT ID		TECN	CHG	COMMENT
1.2380±0.0021 OUR FIT		Error includes scale factor of 1.9.				
1.2379±0.0021 OUR AVERAGE		Error includes scale factor of 1.9. See the ideogram below.				
1.2347±0.0030	15M	[5] AMBROSINO	08	KLOE	±	$\phi \to K^+K^-$
1.2451±0.0030	250k	KOPTEV	95	CNTR		K at rest, U target
1.2368±0.0041	150k	KOPTEV	95	CNTR		K at rest, Cu target
1.2380±0.0016	3M	OTT	71	CNTR	+	K at rest
1.2272±0.0036		LOBKOWICZ	69	CNTR	+	K in flight
1.2443±0.0038		FITCH	65B	CNTR	+	K at rest
• • • We do not use the following data for averages, fits, limits, etc. • • •						
1.2415±0.0024	400k	[6] KOPTEV	95	CNTR		K at rest
1.221 ±0.011		FORD	67	CNTR	±	
1.231 ±0.011		BOYARSKI	62	CNTR	+	

Under estimated uncertainties ???



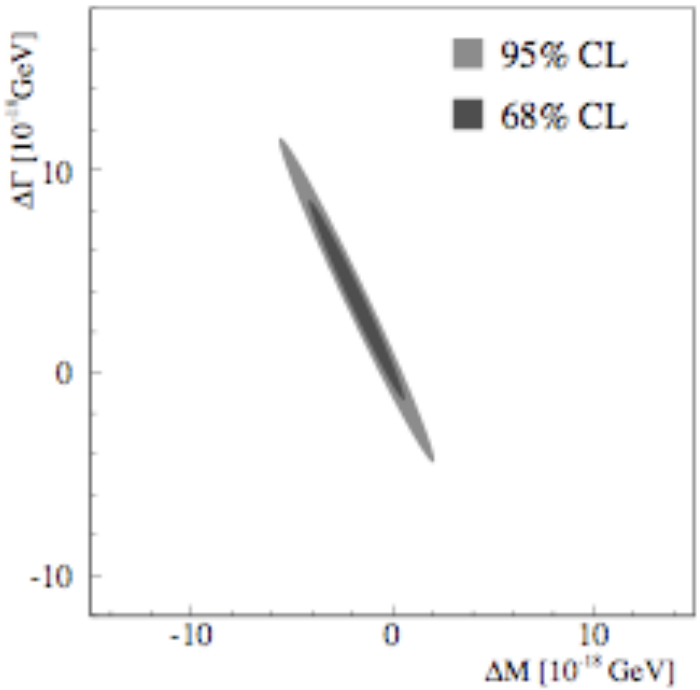
- New BR measurements

- Re-organized the Dalitz plot fit

K^0 Listing Highlights

- New K^0 mass measurement from KLOE
- New measurements on CP(T) violation parameter

- Updated K^0 $\overline{K}^0$ mass difference:



(M. Antonelli & G. D'Ambrosio)

$|m_{K^0} - m_{\overline{K}^0}| / m_{\text{average}}$

A test of *CPT* invariance. "Our Evaluation" is described in the "Tests of Conservation Laws" section. It assumes *CPT* invariance in the decay and neglects some contributions from decay channels other than $\pi\pi$.

VALUE	CL%	DOCUMENT ID		TECN
$<8 \times 10^{-19}$	90	PDG	08	
• • • We do not use the following data for averages, fits, limits, etc. • • •				
$(-3 \pm 4) \times 10^{-18}$		[18] ANGELOPO...	99B	RVUE

[18] ANGELOPOULOS 99B assumes only unitarity and combines CPLEAR and other results.

Strong constraint on CPT

Note: Need to unify the mass difference result between the mini-review and listing

K_S Listing

- Ks was short and sweet for RPP2008
- One new branching ratio measurement from NA48:

$\Gamma(\pi^{\pm} e^{\mp} \nu_e)/\Gamma_{\text{total}}$ Γ_8/Γ

VALUE (units 10^{-4})	EVTS	DOCUMENT ID		TECN	COMMENT
7.04 ±0.08 OUR FIT					
7.04 ±0.08 OUR AVERAGE					
7.046±0.18±0.16		[32] BATLEY	07D	NA48	$K^0(\overline{K}^0)(t) \to \pi e \nu$
7.05 ±0.09	13k	[33] AMBROSINO	06E	KLOE	Not fitted
6.91 ±0.34±0.15	624	[34] ALOISIO	02	KLOE	Tagged K_S^0 using $\phi \to K_L^0 K_S^0$
• • • We do not use the following data for averages, fits, limits, etc. • • •					
7.2 ±1.4	75	AKHMETSHIN	99	CMD2	Tagged K_S^0 using $\phi \to K_L^0 K_S^0$

K_L Listing Highlights

- Very active section. Many new branching ratio measurements
- Reorganized K_L form factor section and introduced an additional form factor parametrization:

The dispersive parametrization is

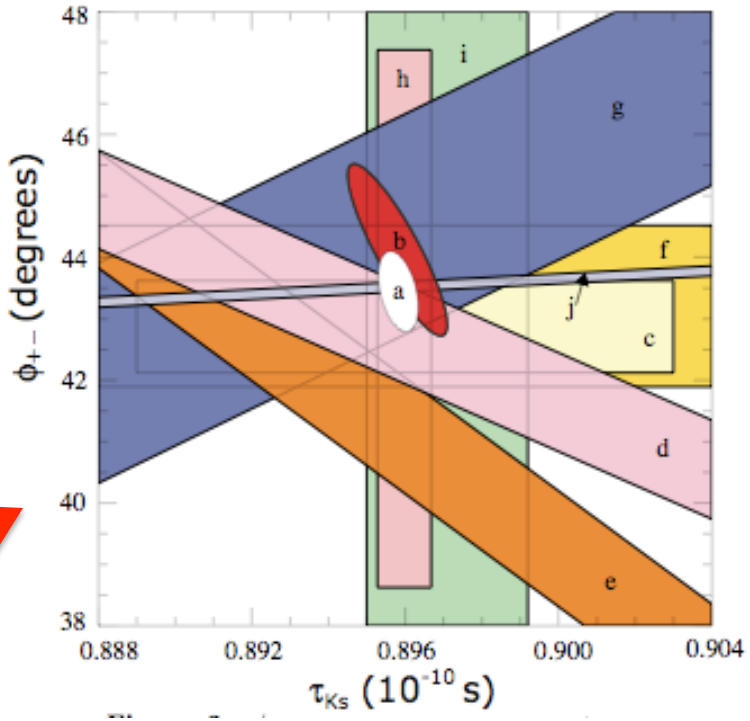
$$f_+(t) = f_+(0)\ \exp\left[\ \frac{t}{m_\pi^2}\ (\Lambda_+ + H(t))\ \right];$$

$$f_0(t) = f_+(0)\ \exp\left[\ \frac{t}{m_K^2 - m_\pi^2}\ (\ln[C] - G(t))\ \right],$$

where Λ_+ is the slope parameter and $\ln[C] = \ln[\ f_0\ (m_K^2 - m_\pi^2\ )\ ]$ is the logarithm of the scalar form factor at the Callan-Treiman point. $H(t)$ and $G(t)$ are dispersive integrals.

- CP and CPT fits updated using new automated fitters (inputs are largely unchanged)

We can now generate pretty plots like this without having to manually enter fitted results into the database



Kaon Fits

- For RPP08, we have moved (or kludged) the entire Kaon fits in the RPP fitter framework. In the past, many fits were done in Excel spreadsheets and then hardcoded into the database

- The current (archaic) fitting framework is very restrictive. Cannot do a proper global CP violation fit at the moment

$$|\eta_{+-}| = \left[\frac{\mathrm{B}(K_L^0 \to \pi^+\pi^-)}{\tau_L}\,\frac{\tau_S}{\mathrm{B}(K_S^0 \to \pi^+\pi^-)}\right]^{1/2},$$

$$|\eta_{00}| = \left[\frac{\mathrm{B}(K_L^0 \to \pi^0\pi^0)}{\tau_L}\,\frac{\tau_S}{\mathrm{B}(K_S^0 \to \pi^0\pi^0)}\right]^{1/2}.$$

For example, would like to fit CP parameters and BRs simulataneously in a global fit

- Can try to kludge the current framework some more to improve the fitting method. But the lasting solution is to develop the proper fitter in the new framework as part of the computing upgrade

Concluding Thoughts

- Kaon physics has played historical roles since the 50's. The field continues to produce important results to this day

- PDG has to keep up to meet the needs and expectation of the community :

  - Simplify and automate the system to avoid making mistakes

  - Improve documentations in the listings to avoid confusing the audience

  - Examine the relevance of some of the mini-reviews

  - Desperately need the new computing upgrade/framework to streamline the fits and eliminate the kludges

- Look forward to an even better RPP 2010 !!!

Additional Slides

Theoretical Considerations in Kaon Results

Highlights from Giancarlo D'Ambrosio's
PDG Collaboration Meeting Talk

$K \to \pi l \nu$ and CKM unitarity

$|V_{ud}|^2 + |V_{us}|^2 + |V_{ub}|^2 = 1$ V_{ub} negligible

- Superallowed transitions $\Longrightarrow |V_{ud}| = 0.9738 \pm 0.0003 \overset{\text{Unit.}}{\Longrightarrow}$

$$|V_{us}|^{\text{Unit.}} = 0.2275 \pm 0.0012$$

$$|V_{us}|^{\text{PDG04}} = 0.2196 \pm 0.0026$$ Leutwyler, Roos

$$|V_{us}|^{\text{PDG06}} = 0.2257 \pm 0.0021$$

$$|V_{us}|^{\text{PDG08*}} = 0.22461 \pm 0.00048$$

All K's

Recent data on V_{us} agree with $V_{us}^{\text{Unit.}}$

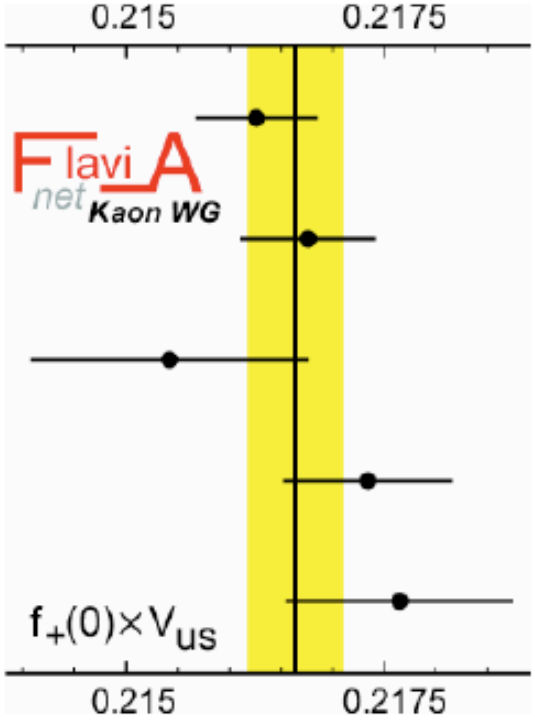
Direct V_{us} measurements are now more consistent with unitarity constraint!

$$\Gamma(K^i_{l3}) = \mathcal{N}_i |V_{us}|^2 |f_+(0)|^2 (1 + \delta^l_{rad}) I(\lambda_+, \lambda_0)$$

- Kaon revolution in 2004-2005: BNL E865, ISTRA,KTeV, NA48,KLOE $\Gamma(K^i_{l3})$ all increased by 6% All Major KL BRs Changed! ϵ_K changed by 3.7σ
- After 06 NA48, KLOE improvements in semileptonic BRs
- NA48, KLOE $R_K = \Gamma(K_{e2})/\Gamma(K_{\mu 2})$
- Better understanding theoretically of the form factor $f_{+,0}(t) = f_+(0)(1 + \lambda_{+,0} t/m^2_\pi)$ linear $\rightarrow$ quadratic $\rightarrow$ pole $\rightarrow$ dispersive approaches
- Blucher Marciano review the actual status in PDG08

Determination of $|V_{us}|\times f_+(0)$

$$\Gamma(K_{l3(\gamma)}) = \frac{C_K^2 G_F^2 M_K^5}{192\pi^3} S_{EW} |V_{us}|^2 |f_+^{K^0\pi^-}(0)|^2 I_{Kl}(\lambda_{+,0}) (1+\delta^K_{SU(2)}+\delta^{Kl}_{em})^2$$

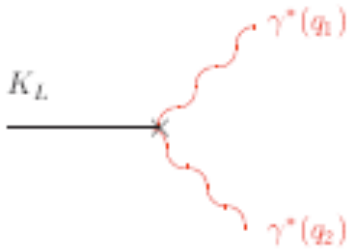


		% err	Approx. contr. to % err from: BR	τ	δ	I_{Kl}
K_Le3	0.2164(6)	0.26	0.09	0.19	0.11	0.09
$K_L\mu3$	0.2170(6)	0.29	0.10	0.18	0.11	0.15
K_Se3	0.2156(13)	0.62	0.60	0.03	0.11	0.09
$K^\pm e3$	0.2174(8)	0.38	0.26	0.13	0.25	0.09
$K^\pm\mu3$	0.2177(11)	0.51	0.40	0.13	0.25	0.15

Average: $|V_{us}| f_+(0) = 0.2167(5)$ $\chi^2/\text{ndf} = 2.83/4$ (59%)

Other ff : $K_L \to e^+ e^- \gamma$, $K_L \to \mu^+ \mu^- \gamma$, $K_L \to \mu^+ \mu^- e^+ e^-$

- Relevant to uncover short distance to $K_L \to \mu^+ \mu^-$
- Expts measure two ff's DIP and BMS



DIP: $$A(K_L \to \gamma^*\gamma^*) = A_{\gamma\gamma}^{\exp}\left[1 + \alpha\left(\frac{q_1^2}{q_1^2 - M_V^2} + \frac{q_2^2}{q_2^2 - M_V^2}\right) + \beta\frac{q_1^2 q_2^2}{(q_1^2 - M_V^2)(q_2^2 - M_V^2)}\right]$$

- We have different encodings for the different channels: however if we assume lepton univ. we could have a fit form all the channels