KAON '07

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WELCOME KAON '07

The Frascati National Laboratory of INFN is the home of KLOE, an experiment dedicated primarily to the study of K-mesons.

Everybody in the KLOE collaboration is very proud that the 2007 version of the KAON Conference is hosted by the LNF and joins in welcoming the partecipants.

KLOE is at present hibernating.

KLOE retired

KLOE MIGHT COME BACK

The KLOE collaboration is quite busy with the data collected before the stop in early 2006. The detector is parked in its assembly hall and is fully operational.

This fall, a crucial experiment will be carried out on the machine. There are good reasons to expect a significant increase in luminosity and improved background conditions.

If the experiment is a success, KLOE will be back in 2009.

All this will be presented Thursday afternoon during the panel discussion.

60 YEARS OF KAON PHYSICS

1963 was an important year for Kaons. That year Nicola Cabibbo (cited 2365 times) proposed Universality as way of avoiding introducing additional couplings in the weak interactions. Extending the idea of Cabibbo's angle, through GIM and then Kobayashi and Maskawa we got the flavor mixing CKM matrix, which can accomodate CP violation.

$\not{C}\not{P}$ was also discovered in 1963. While the official publication of Cronin, Christenson, Fitch, and Turlay is dated 1964 (cited 1331 times), the result was known before the end of '63, at least in Brookhaven.

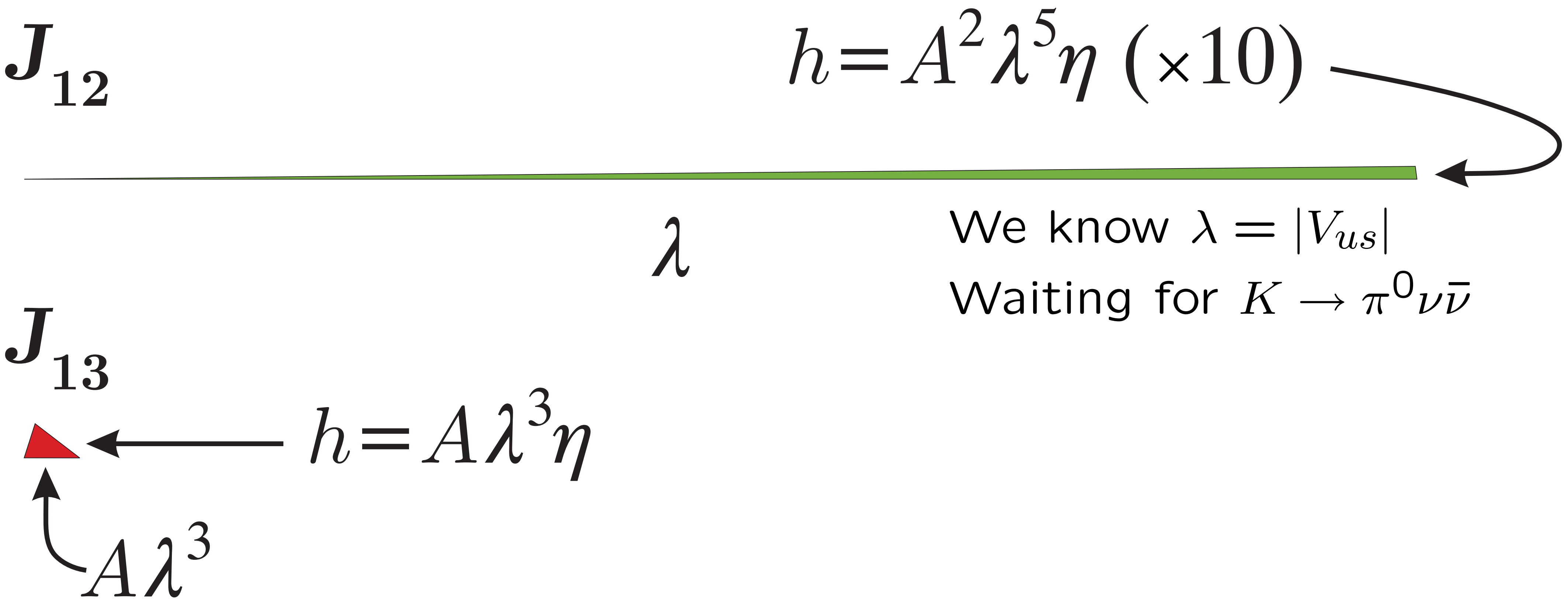
It took a long time to get to prove the existence of direct $\not{C}\not{P}$ and even longer to arrive to an accurate verification of Cabibbo unitarity.

In 2004, KTeV presented the first good measurements of the K_L semileptonic branching ratios in this hall. The following two years have seen quite a consolidation of our knowledge of $|V_{us}|$, essentially $\sin\theta_C$.

There are still some unsatisfactory points with the $|V_{us}|$ business, especially some wild discrepancies in the value of the form factor parameters.

I will briefly comment about some of this, also with respect to two questions raised at the last kaon meeting, Kaon05, by Vincenzo Cirigliano and Giancarlo D'Ambrosio.

Unitarity triangles



We know $\lambda = |V_{us}|$

Waiting for $K \to \pi^0\nu\bar{\nu}$

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Estimating error

Let $F(\mathbf{p}, x)$ be a PDF, where $\mathbf{p}$ is some parameter vector, which we want to determine. x is a running variable, like t, for instance. Before doing an experiment, we would like to know which accuracy we can reach.

The inverse of the covariance matrix is given by:

$$(\mathbf{G}^{-1})_{ij} = -\frac{\partial^2 \ln L}{\partial p_i \partial p_j}$$

Therefore, for N events

$$\langle (\mathbf{G}^{-1})_{ij} \rangle = N \int \frac{1}{F} \frac{\partial F}{\partial p_i} \frac{\partial F}{\partial p_j} \, \mathrm{d}v$$

FF parameters, K_{e3}

FF in $\langle\pi|J_\alpha^{\rm hadr}|K\rangle =\propto \tilde f_+(t)\times(P+p)_\alpha$. A common choice for the FF is $\tilde f_+(t)=1+\lambda'(t/m^2)+\lambda''(t^2/m^4)$. λ' and λ'' are 95% correlated, *i.e.* error(s) are ~3x than that for linear. The error matrix is

$$\mathbf{G}=\begin{pmatrix}\overline{\delta\lambda'^{\,2}_+} & \overline{\delta\lambda'_+\delta\lambda''_+}\\ \overline{\delta\lambda''_+\delta\lambda'_+} & \overline{\delta\lambda''^{\,2}_+}\end{pmatrix}=\frac{1}{N}\begin{pmatrix}1.25993^2 & -0.945278\\ -0.945278 & 0.509766^2\end{pmatrix}$$

I find the identical result, to $1/10^7$, using $p_\perp$ instead of E_π. For 1,000,000 events,

$$\delta\lambda'=0.00126\sim5\% \qquad \rho(\lambda',\lambda'')=-94.5\%$$
$$\delta\lambda''=0.00051\sim40\%$$

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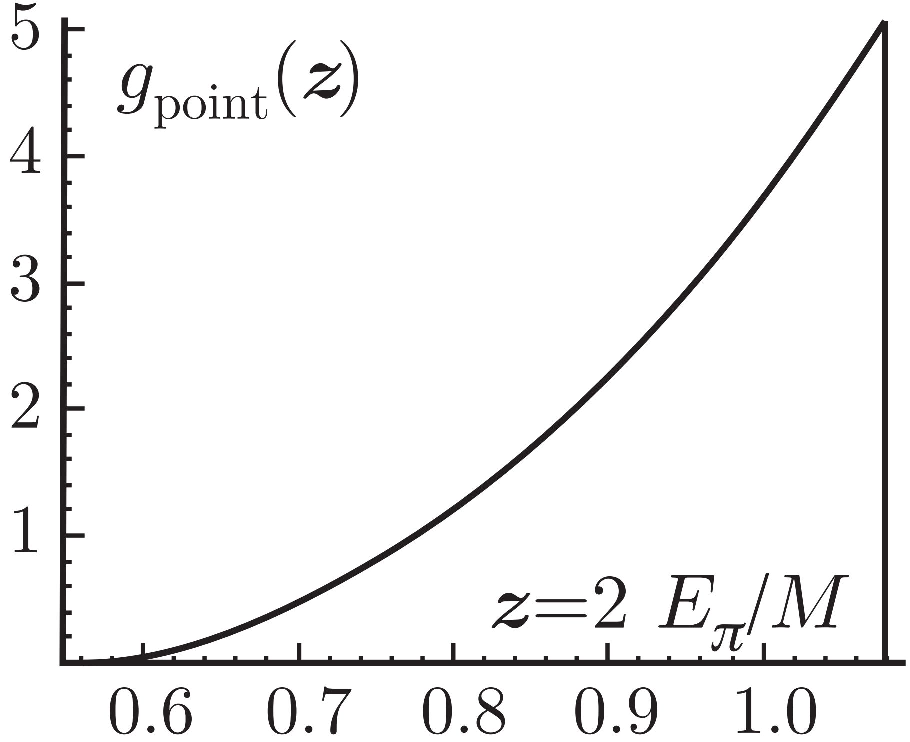
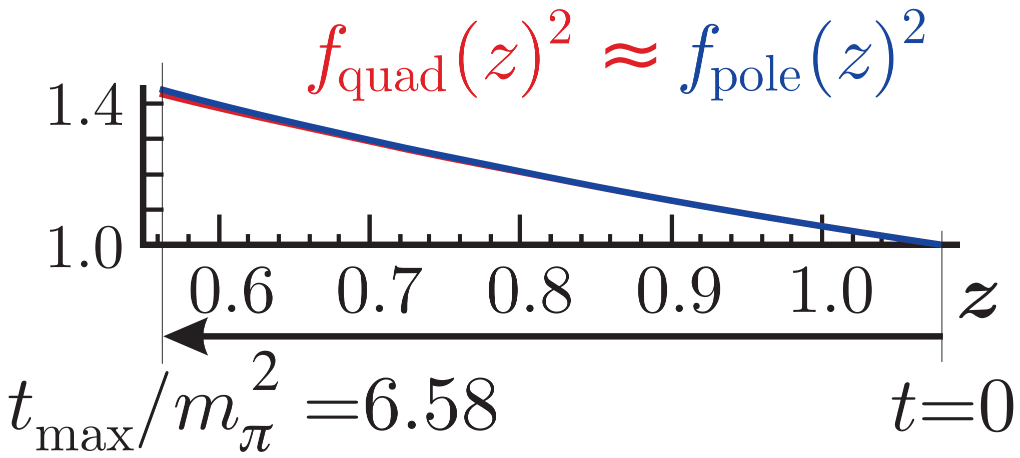
K_{e3} FF cntn'd

$\tilde{f}(t)$ multiplies the point like spectrum which vanishes at min(E_π) where FF is largest.





$$t = M^2 + m^2 - 2E_\pi M$$

A power expansion of $\tilde{f}(t)$ is truly an infelicitous choice. Another choice is $\tilde{f}(t) = M_V^2/(M_V^2 - t)$ *i.e.* a pole in the $\pi - K$ scattering amplitude. Only one parameter!

FF cntn'd

In real life, errors are larger, $\times 2$-$\times 3$, because of systematic uncertainties. Errors will also be enlarged by poor resolution and kinematics ambiguities, *eg* two solutions.

Fitting to a pole is much more robust against statistical fluctuation. Several authors justify the pole and experiment agrees[†]. More than 100 million events however are necessary to distinguish pole from a quadratic form. Note that:

$$\frac{M_V^2}{M_V^2 - t} = 1 + \frac{t}{M_V^2} + \frac{t^2}{M_V^4} \dots$$

i.e.

$$\lambda' = \frac{m^2}{M_V^2}, \;\; \lambda'' = 2\,\lambda'^2$$

† Answer to Giancarlo: Yes, we should use the pole.

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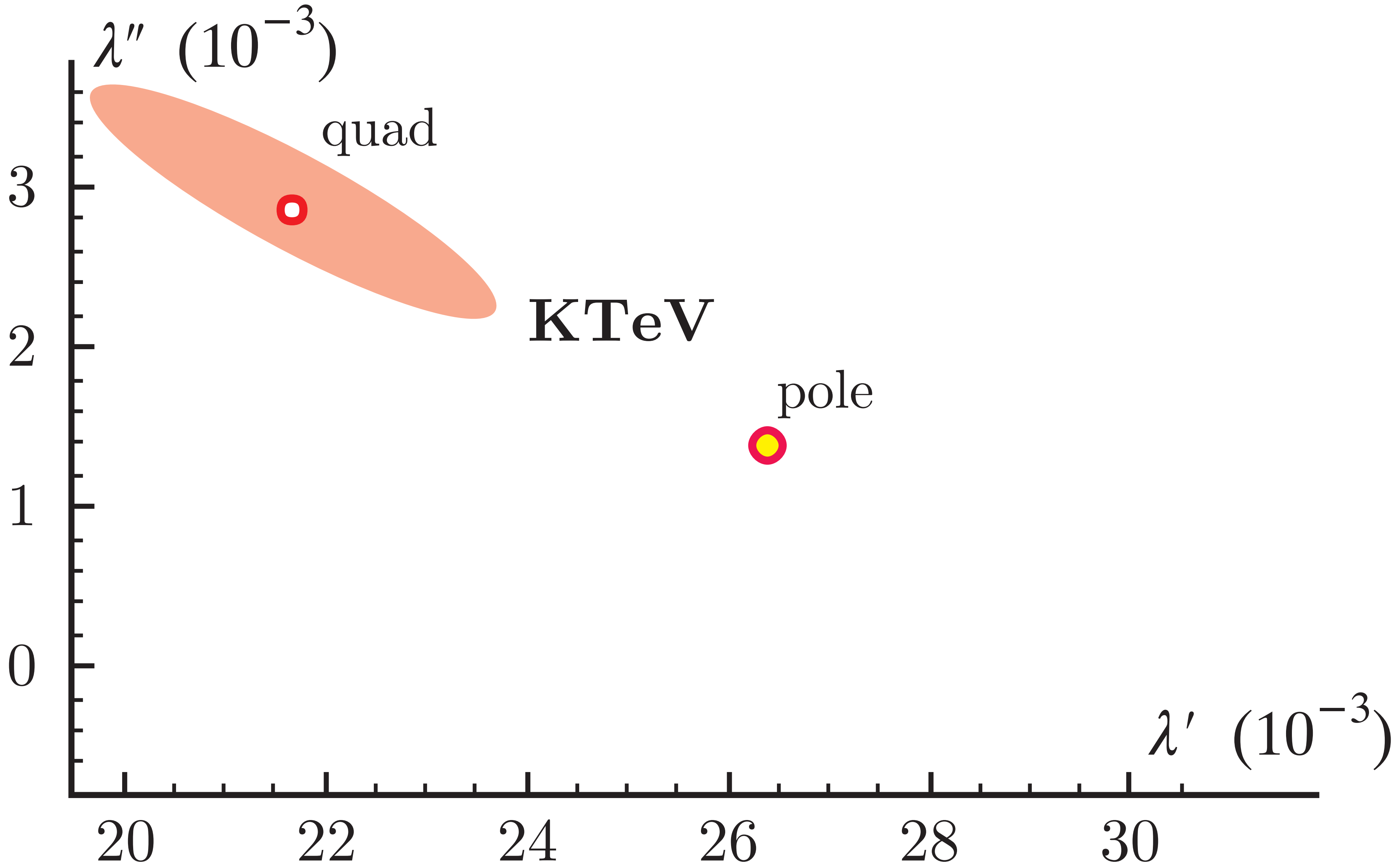
K_{e3}: λ' & λ''



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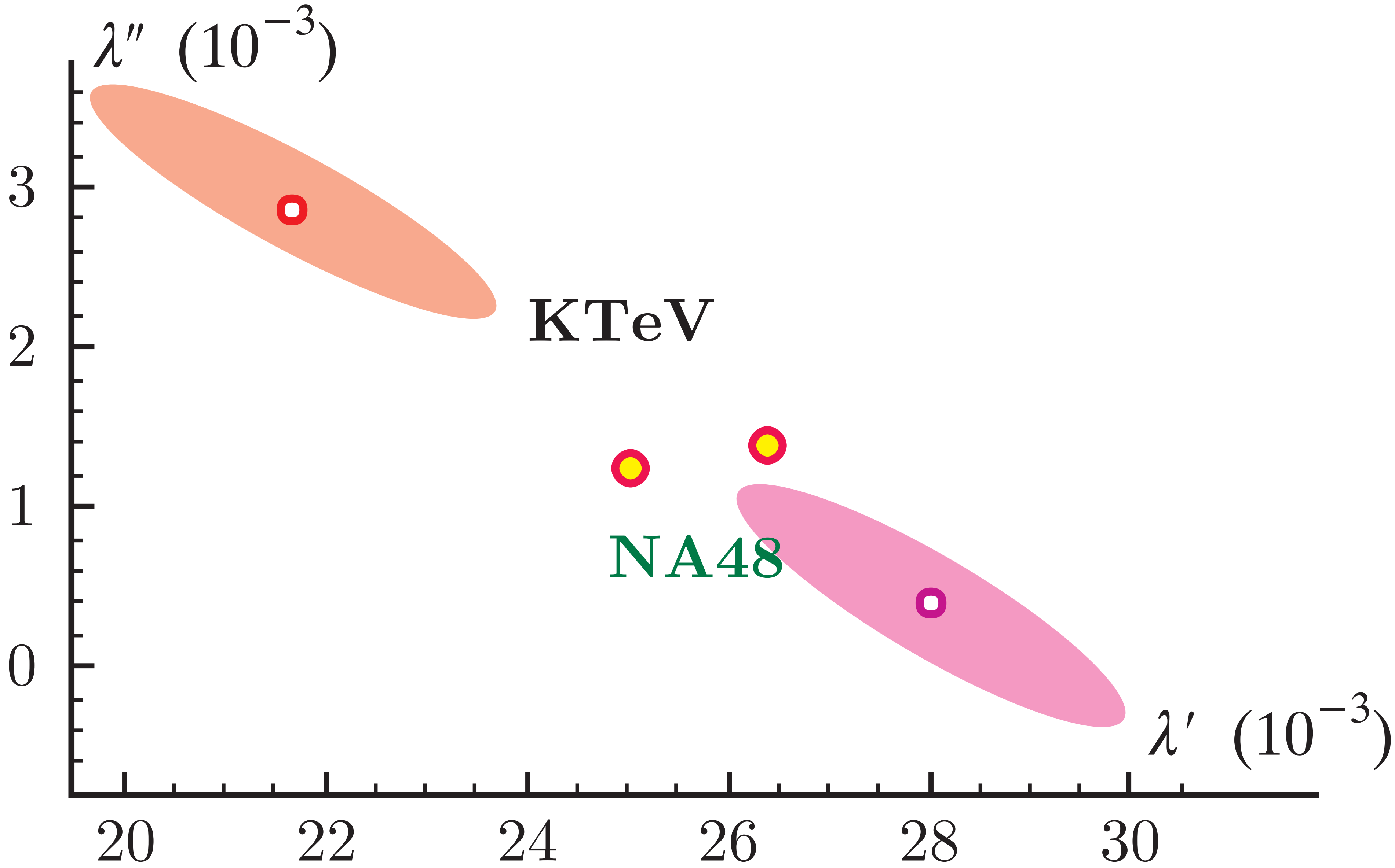

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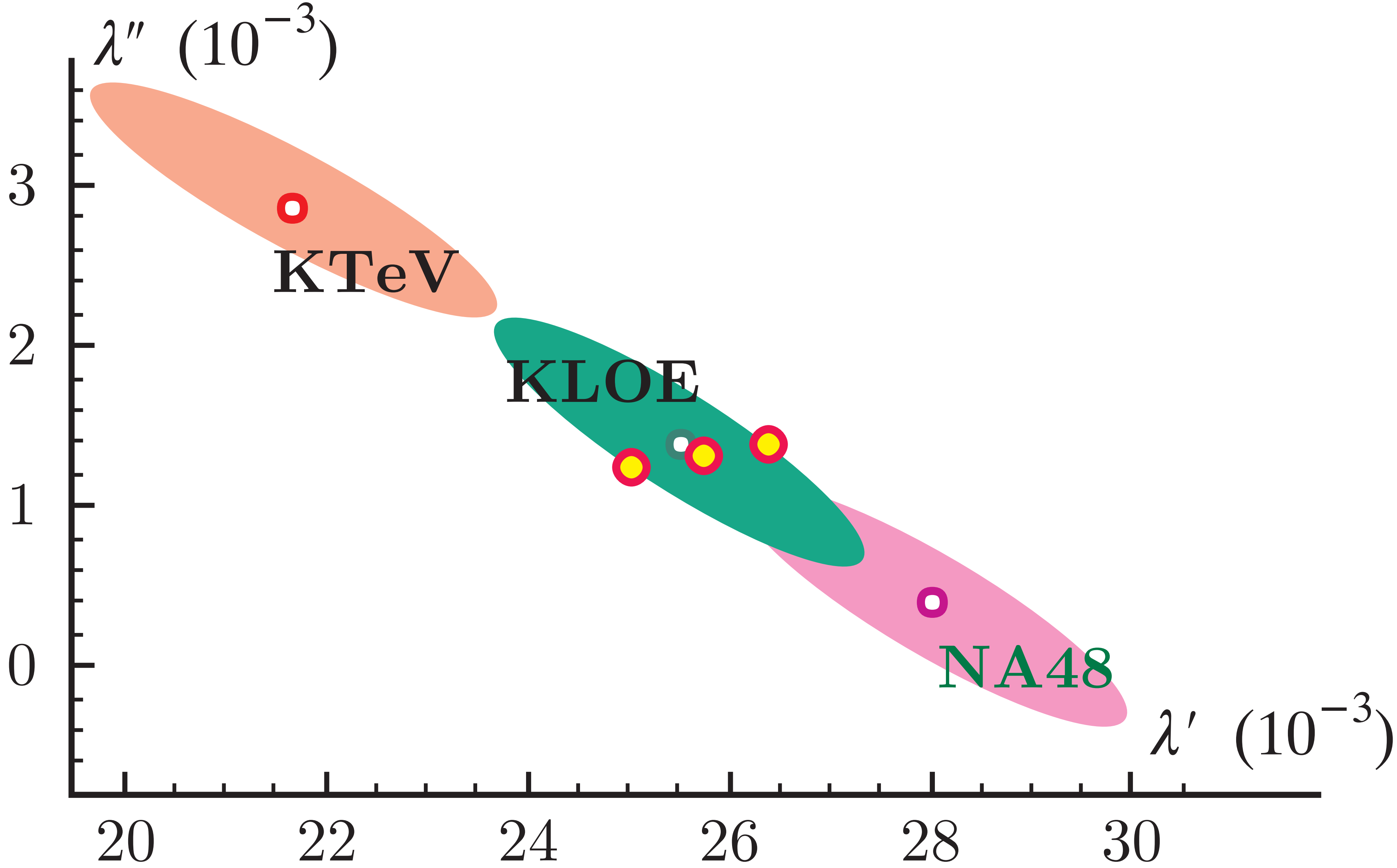

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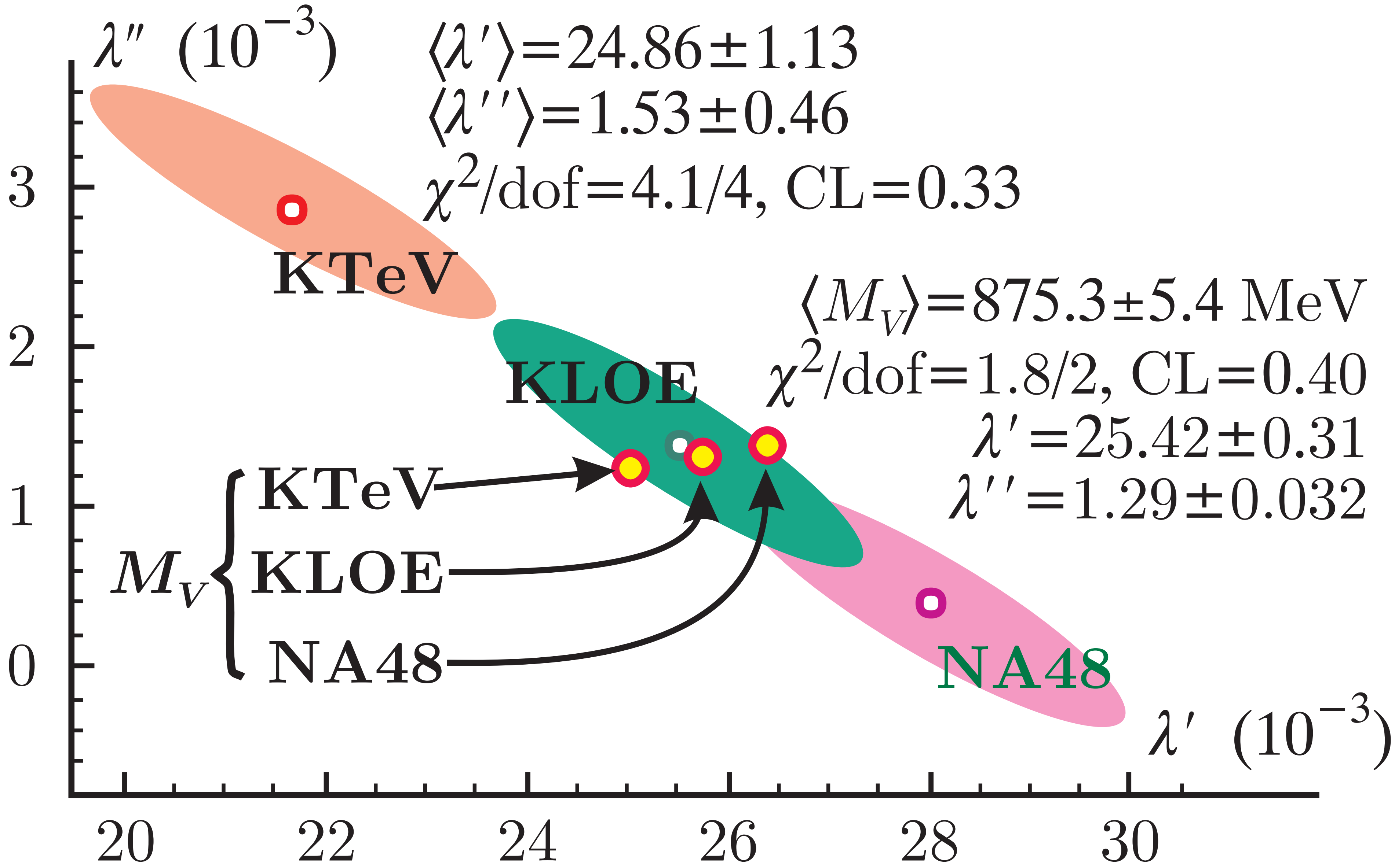
K_{e3}: λ' & λ''



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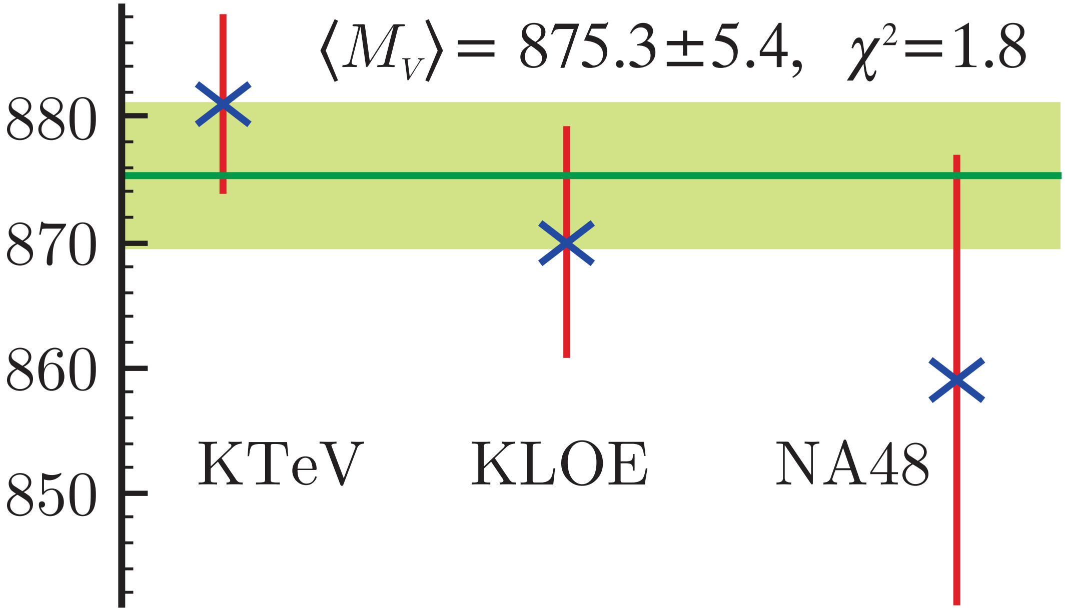
Pole fit, K_{e3}



CL for pole fit 41%

CL for quadratic FF fit 33%

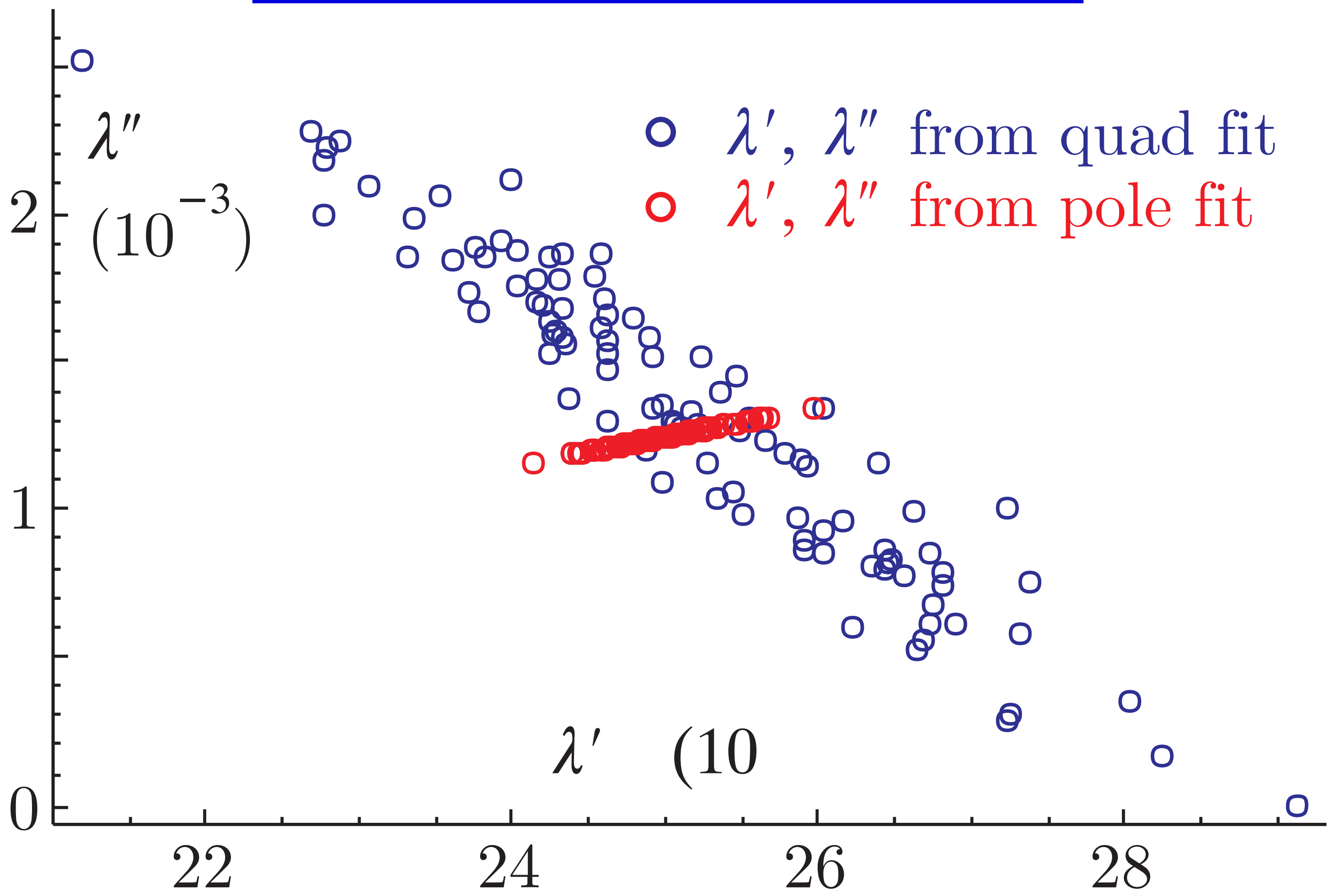
$\lambda'_{\mathrm{pole}} - \lambda'_{\mathrm{quad}} = 0.6 \pm 1.2$

$\lambda''_{\mathrm{pole}} - \lambda''_{\mathrm{quad}} = 0.24 \pm 0.46$

Pole and quad result similar for I_{e3}

Jamin *et al.*: $\lambda' = 25.6$, $\lambda'' = 1.31$ which corresponds to $M_V = 872.3$.

FF parameters, K_{e3}



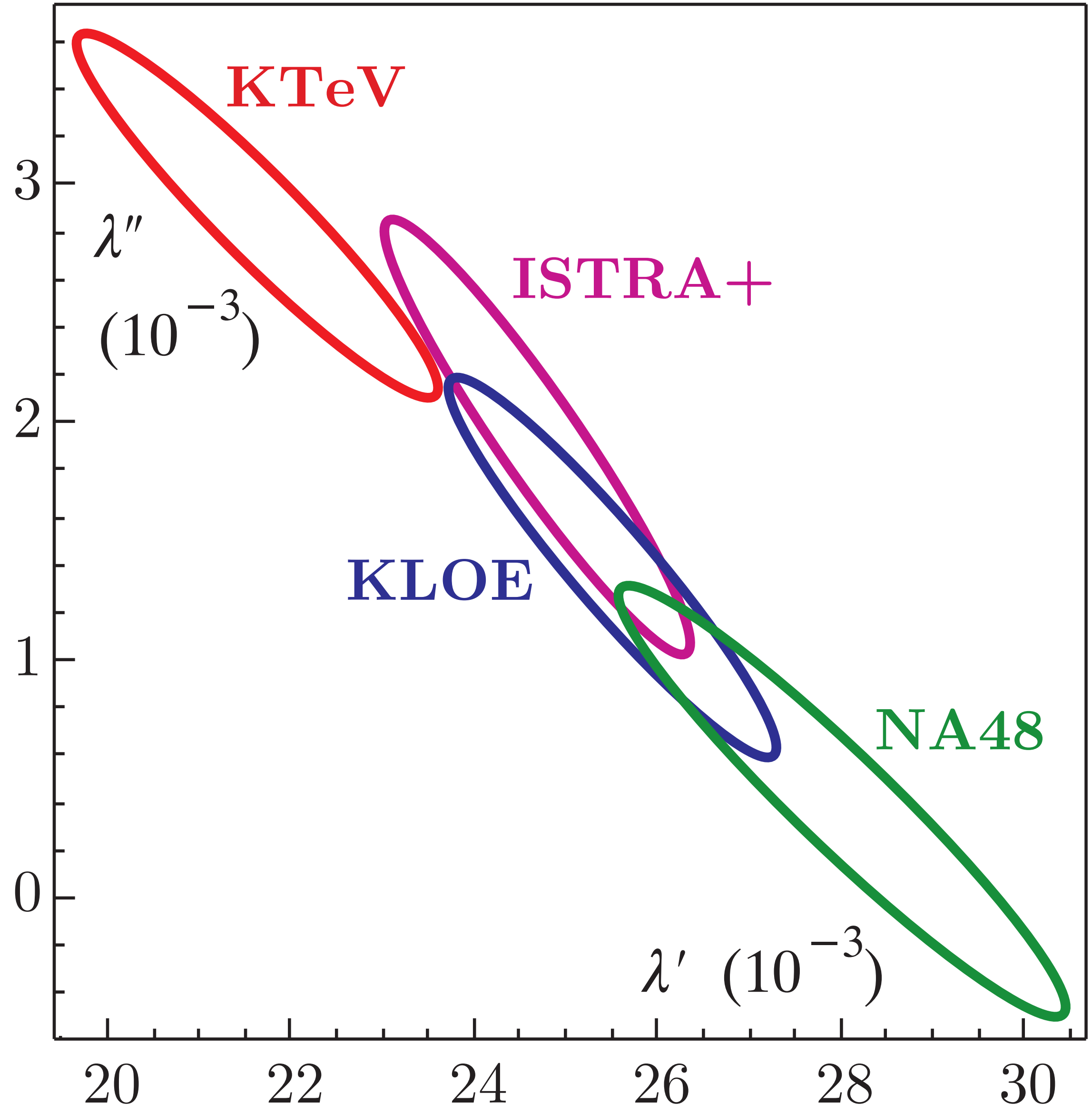
The -95% correlation between λ' and λ'' results in wild fluctuations while a pole fit is much more stable. 10^6 events.

Pole fit much more reliable (corrections probably needed).

FF parameters, K_{e3}

The ISTRA+ K_{e3} results are quite consistent with the values above. They do not perform a pole fit, I asked them but...

Tilted contour, see later



FF parameters, $K_{\mu 3}$

Everything is worse for $K_{\mu 3}$, smaller t range, 3 or 4 parameters. It will never be possible to experimentally determine λ_0'' as an independent parameter. The error matrix, for N events is:

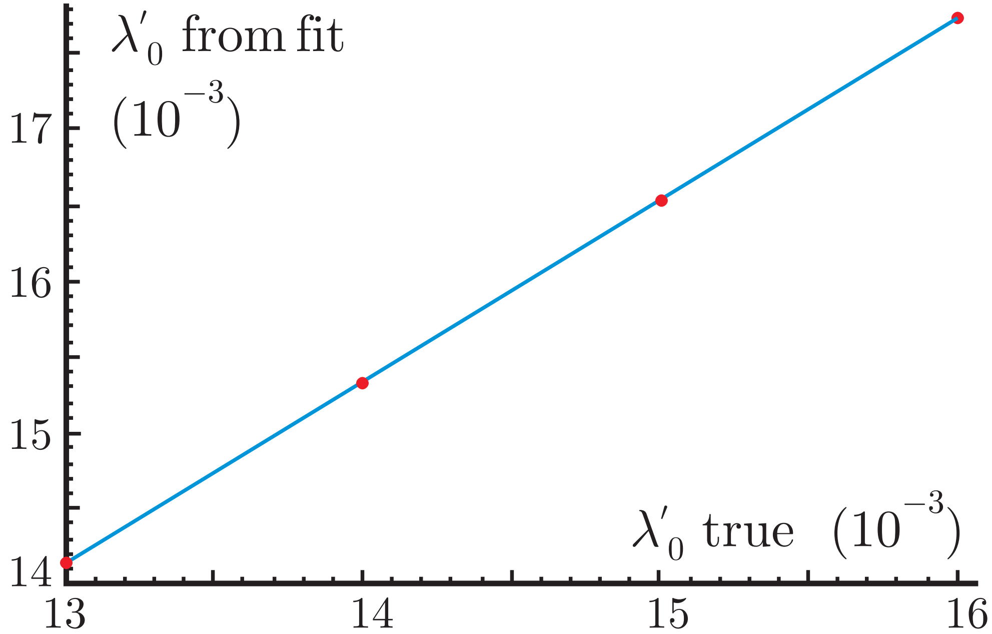
$$
\begin{array}{cccc} \lambda_0' & \lambda_0'' & \lambda' & \lambda'' \end{array}
$$

$$
\mathbf{G} = \frac{1}{N}\begin{pmatrix} 63.9^2 & -1200 & -923 & 197 \\ -1200 & 18.8^2 & 272 & -59 \\ -923 & 272 & 14.8^2 & -49 \\ 197 & -59 & -48 & 3.4^2 \end{pmatrix}
$$

In particular, for 1 million events, $\delta\lambda_0' = 0.064$, $\delta\lambda_0'' = 0.019$ and the correlation between λ_0' and λ_0'' is $\rho = -99.96\%$.

A direct measurement of λ_0' and λ_0'' is impossible

Assuming $\lambda_0' \sim 0.014$ and $\lambda_0'' \sim 2\lambda_0'^2 \sim 0.00039$, a fit to the pion spectrum from 1 million $K_{\mu 3}$ decay determines λ_0' and λ_0'' to an accuracy of $\pm 460\%$ and $\pm 4800\%$, respectively. 100 million events only get you $\pm 46\%$ and 480%, still not a measurement.†



Error on λ_0' if $\lambda_0'' = 2 \times \lambda_0'^2$.

However, ignoring λ_0'' leads to a systematic shift of λ_0' if a quadratic term is present.

†Answer to Vincenzo: no.

$K_{\mu 3}$, linear $f_0(t)$

$$\mathbf{G} = \frac{1}{N} \begin{pmatrix} \lambda'_0 & \lambda' & \lambda'' \\ 1.75^2 & 3.32 & -1.88 \\ 3.32 & 3.09^2 & -3.87 \\ -1.88 & -3.87 & 1.34^2 \end{pmatrix}$$

The error $\delta\lambda'_0$ is 0.00175 for 10^6 events, or $\delta\lambda_0/\lambda_0$=12% for λ_0=0.014. The result is however shifted:

$$\lambda'_{0,\text{ true}} \sim \lambda_{0,\text{ fit}} - 3.5\,\lambda''_0$$

ALL λ_0 RESULTS ARE TO SOME EXTENT WRONG!

Improving λ_0 error

Decay	$\delta\lambda_0$	$\delta\lambda'_+$	$\delta\lambda''_+$	$\rho_{\lambda_0,\lambda'_+}$	$\rho_{\lambda_0,\lambda''_+}$	$\rho_{\lambda'_+,\lambda''_+}$
K_{e3}, 1	-	1.26	0.51	-	-	-0.945
$K_{\mu3}$, 1	1.75	3.09	1.34	0.61	-0.80	-0.944
both, 1+1	0.94	1.16	0.47	0.37	-0.48	-0.936

It certainly pays to use λ' and λ'' from K_{e3} to improve the error on λ_0. It is however unwise to mix $K_{\mu3}$ data in an attempt to improve λ' and λ'', 8% on the error at best, possibly introducing uncontrolled shifts. Hopefully we will learn to get better $K_{\mu3}$ data.

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K_{e3} example

Input:

Spectrum generated with $\lambda'_+ = .025,\ \lambda''_+ = .00125$

1) Output of fit with quad FF:

$$\lambda'_+ = .025,\ \lambda''_+ = .00125$$

2) Output of fit with lin FF:

$$\lambda_+ = 0.0279$$

The phase space integral with 2) is larger by 0.4% than with 1)

K_{e3} fits, linear ff

Experiment	N	$\delta\lambda$ pred.	$\delta\lambda$ meas.	$\delta\lambda$ tot
ISTRA+	0.92	0.427	0.50	0.61
KTeV	1.95	0.294	0.43	0.57
NA48	5.60	0.173	0.40	1.20
KLOE	2.00	0.290	0.50	0.64

The values for λ_+ are, in the same order, 29.66, 28.32, 28.8 and 28.6, in quite reasonable agreement: χ^2/dof=2.78/3, CL 44%. The average is $\langle\lambda_+\rangle$=28.84±0.33

"pred." means pure statistical predicted error. "meas." is the given stat. error.

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K_{e3} fits, quadratic ff

Experiment	N	$\delta\lambda$ pred.	$\delta\lambda$ meas.	$\delta\lambda$ tot
ISTRA+	0.92	1.312	1.63	1.66
KTeV	1.95	0.901	1.43	1.99
NA48	5.60	0.532	1.90	2.59
KLOE	2.00	0.890	1.50	1.93

Istra uses the same systematic error for linear and quadratic fit. Total error should be $\sim$1.99. This would remove part of the tilt.

Theorem. Systematic errors behave like statistical errors.

K_{e3} fits, pole ff

Experiment	N	δM_V pred.	δM_V meas.	δM_V tot
KTeV	1.95	3.953	4.94	7.11
NA48	5.60	2.333	–	18.0
KLOE	2.00	3.904	6	9.86

λ_0

For λ_0, NA48 gives a statistical error equal to my calculation, which does not have wrong solution ambiguities.

My observation about FF errors

- ISTRA+ quoted errors are optimistic
- KTeV is more conservative
- and KLOE a bit more
- however NA48 seems to oscillate

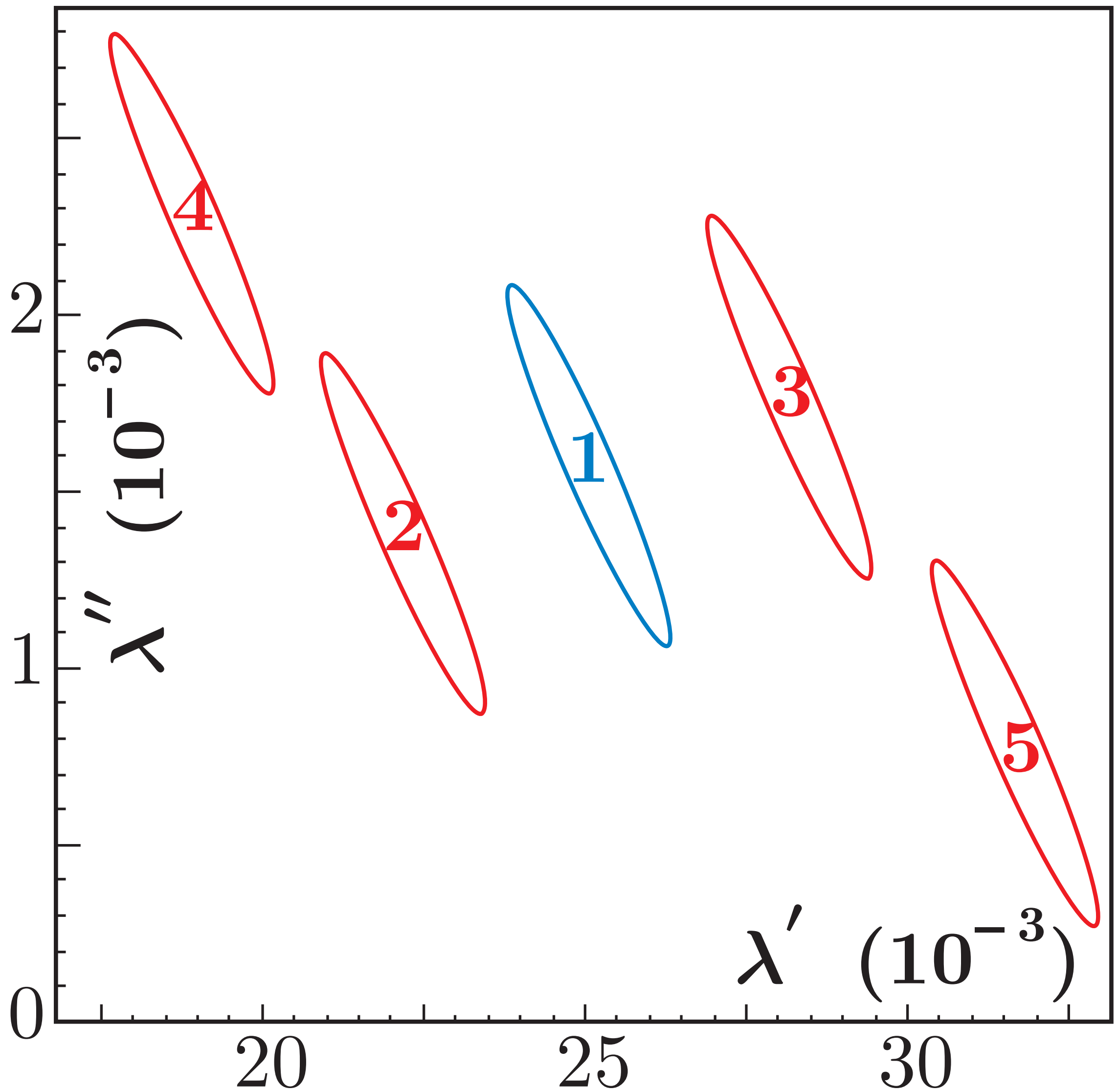
Conclusions

More work is necessary on both BR's and FF parameters, to reach $\mathcal{O}(0.1\%)$ accuracy on $|V_{us}|$. KLOE will reduce all its errors by a factor of two, which is significant.

Assuming that lattice makes good on its promises.

LET THE SHOW BEGIN

Distorsions



Distorsion is 0 to ±4%, linear and quadratic over $m < E_\pi < (M^2 + m2)/(2\,M)$ $= E_\pi^{\rm max}$.

Values change, errors and correlation do not.