

NA48/NA62 Status and Prospects of Semileptonic and Leptonic Kaon Decays

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NA48/NA62 K_{l3} and K_{l2} :

- **1999 K_L running (NA48):**

K_{Le3} branching ratio and form factors,
 $K_{L\mu3}$ form factors, $K_{Le3\gamma}$

- **2003 and 2004 K^\pm running (NA48/2):**

K_{e3}^\pm , $K_{\mu3}^\pm$ branching ratios, K_{l3}^\pm form factors,
 $\Gamma(K_{e2})/\Gamma(K_{\mu2})$

- **2007 K^+ running (NA62):**

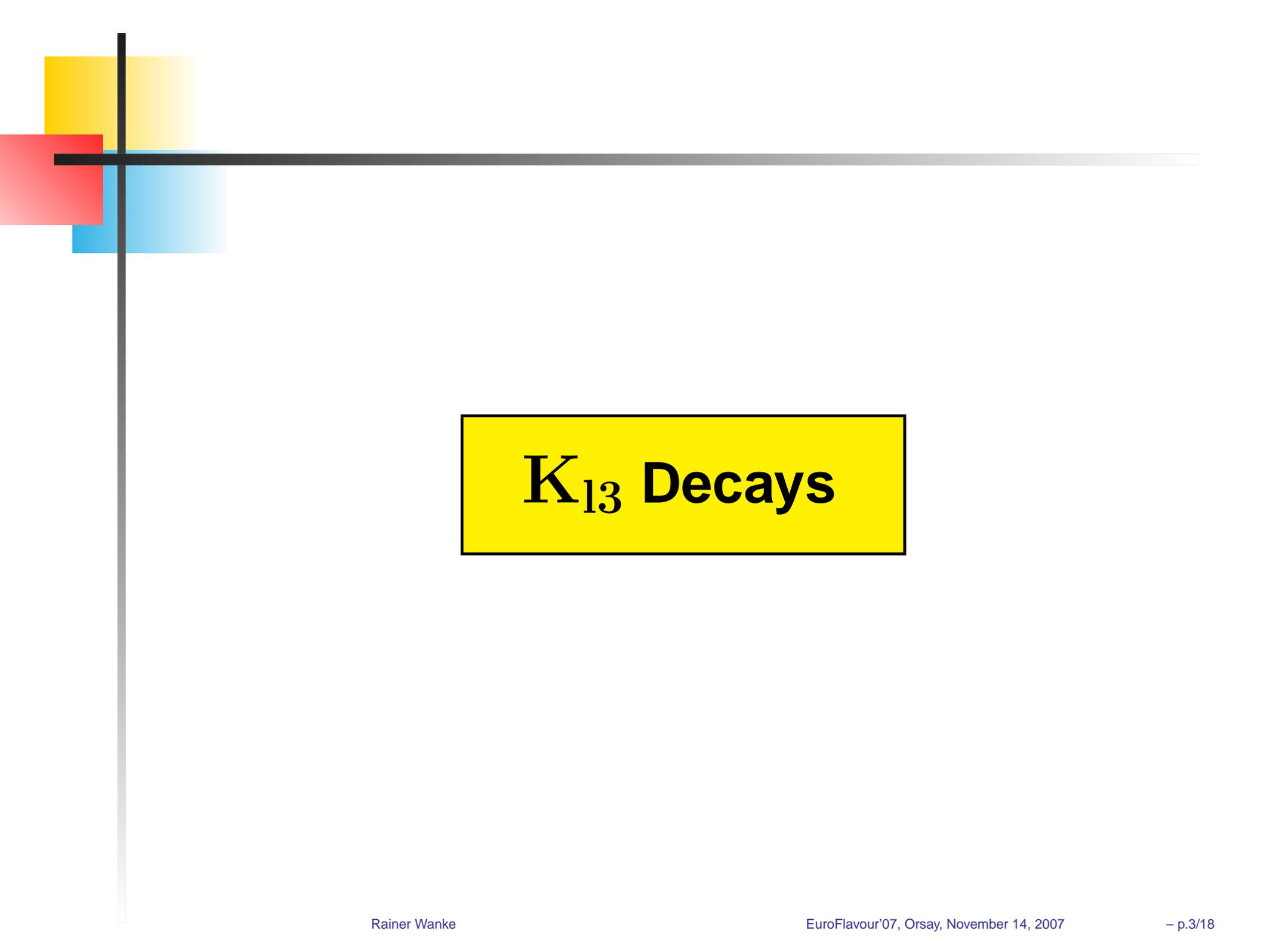
High statistics $\Gamma(K_{e2})/\Gamma(K_{\mu2})$.
 Possibility for K_{l3}^\pm , K_{Ll3}

All NA48 Semileptonic and Leptonic Analyses:

Minimum-bias data for precision measurements

⇒ High trigger efficiencies, small systematics.

1997	ϵ'/ϵ run	$K_L + K_S$
1998	ϵ'/ϵ run	$K_L + K_S$
1999	ϵ'/ϵ run $K_L + K_S$	K_S Hi. Int.
2000	K_L only NO Spectrometer	K_S High Intensity
2001	ϵ'/ϵ run $K_L + K_S$	K_S High Int.
2002	K_S High Intensity	
2003	K^\pm High Intensity	
2004	K^\pm High Intensity	
⋮		
2007	K^\pm Minimum Bias	



K_{13} Decays

K_L Semileptonics — Branching Fractions

Minimum-bias K_L run 1999:

About two days of data-taking after ϵ'/ϵ run.

Branching fraction measurements:

■ K_{e3} :

From **6.76 million K_{e3}** decays: (PLB 602 (2004) 41)

$$\text{Br}(K_L \rightarrow \pi e \nu) / \text{Br}(K_L \rightarrow \text{all 2-track}) = 0.4978 \pm 0.0035$$

■ $K_{e3\gamma}$:

About **19 000 $K_{e3\gamma}$** decays: (PLB 605 (2005) 247)

$$\begin{aligned} \text{Br}(K_{e3\gamma}^0, E_\gamma^* > 30 \text{ MeV}, \theta_{e\gamma}^* > 20^\circ) / \text{Br}(K_{e3}^0) \\ = (0.964 \pm 0.008^{+0.011}_{-0.009})\% \end{aligned}$$

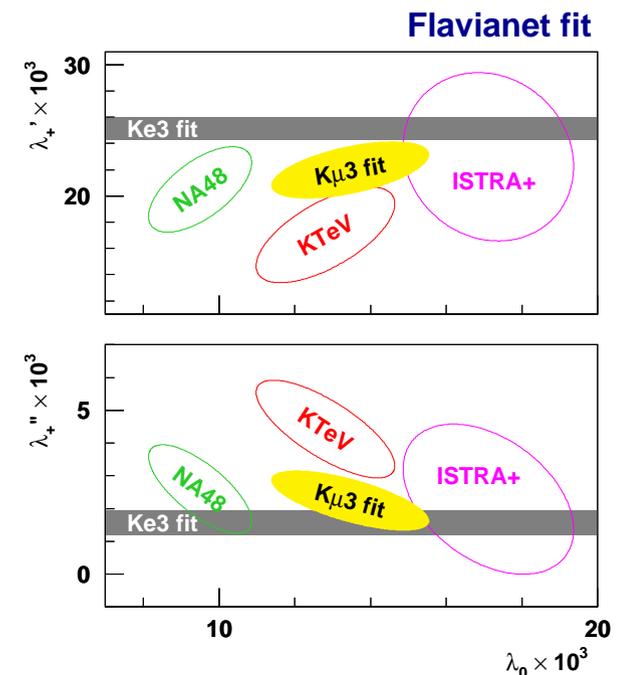
In agreement with theory, but in disagreement with KTeV measurement. (New KLOE result compatible with both.)

K_L Semileptonics — Form Factors

K_L form factor slopes from NA48 1999 data:

Channel	$\lambda'_+ \times 10^3$	$\lambda''_+ \times 10^3$	$\lambda_0 \times 10^3$
$K_L e3$ (PLB 604 (2004) 1)	28.0 ± 2.4	0.4 ± 0.9	
$K_L \mu3$ (PLB 647 (2007) 341)	16.8 ± 3.3	4.0 ± 1.4	9.1 ± 1.4

- $K_L e3$ data agree well with other experiments within errors (although no quadratic slope seen).
- $K_L \mu3$ result on λ_0 does not agree at all with other experiments. (In particular, when correlations are taken into account.)
- Indication for right-handed currents in $K_L \mu3$, but again not confirmed by other experiments.



K^\pm Semileptonics — Branching Fractions

Eight hours of 2003 data-taking with minimum bias trigger:

- About **89000 reconstructed K_{e3}^\pm** and **77000 $K_{\mu3}^\pm$** decays.
⇒ Quite enough for high-precision BR measurement.

$$R_{K_{e3}/K_{2\pi}} = 0.2470 \pm 0.0009 \pm 0.0004$$

$$R_{K_{\mu3}/K_{2\pi}} = 0.1637 \pm 0.0006 \pm 0.0003$$

$$R_{K_{e3}/K_{\mu3}} = 0.1663 \pm 0.0003 \pm 0.0001$$

- Result dominated by statistical error.

Determination of V_{us} : (using $\text{Br}(K_{2\pi}) = 0.2092 \pm 0.0012$)

$$|V_{us}| \times f_+(0) = 0.2188 \pm 0.0012$$

K^\pm Semileptonics — Form Factors

Expectations for 2004 minimum-bias data-taking:

- Much more data than in 2003.
- In particular: **More than 4 million $K_{\mu 3}^\pm$ decays.**

(Compare with 2.3 million in $K_L \mu 3$.)

⇒ Very precise **form factor measurement** possible!

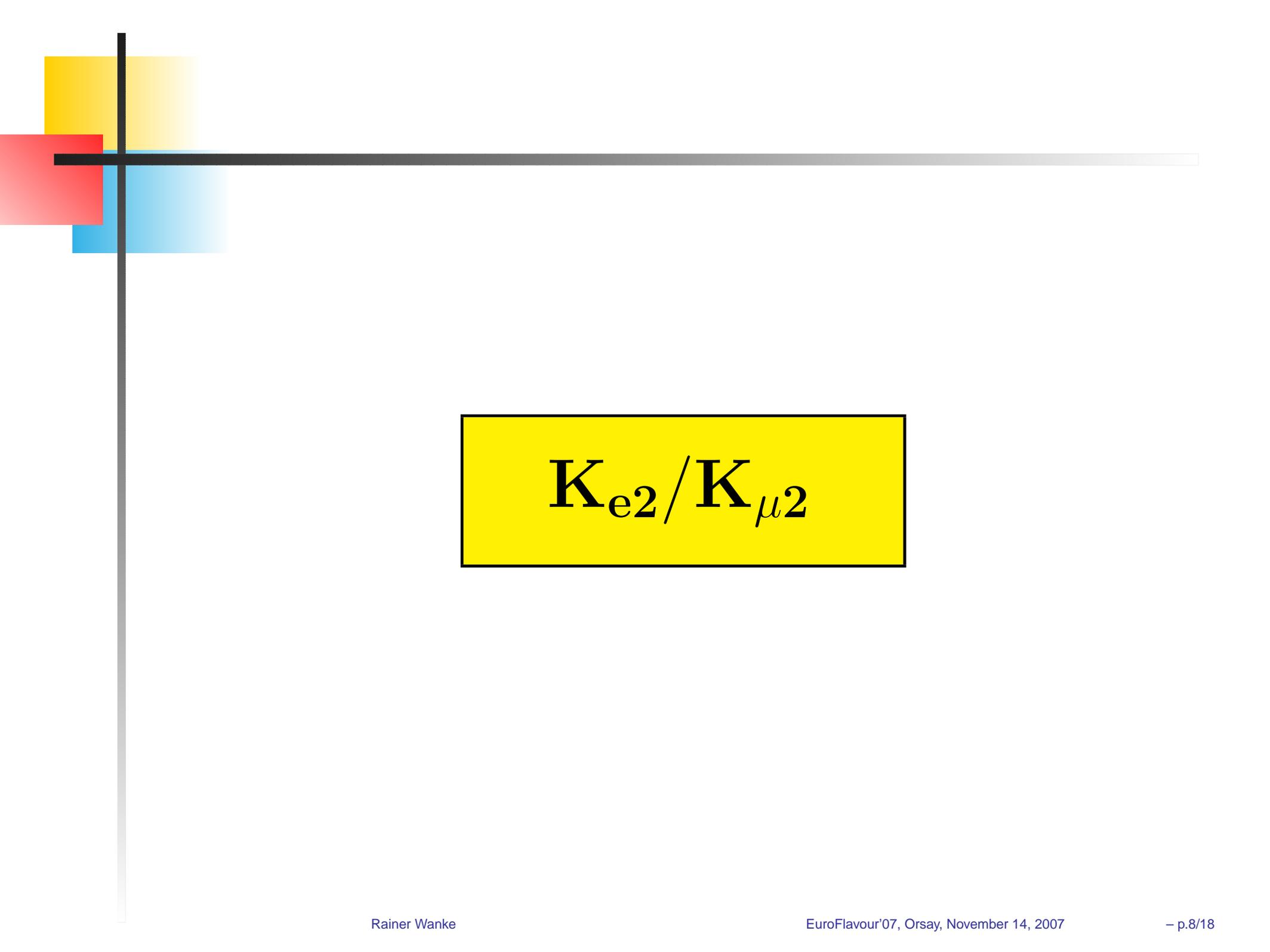
K^\pm momentum known and π^0 reconstruction straight-forward:

⇒ Analysis expected to be much less tricky than in $K_{\mu 3}^0$

(but background from $K_{2\pi}^\pm$ has to be suppressed).

Preliminary results expected next year.

- Also: similar amount of **$K_{e 3}^\pm$ decays.**


$$\mathbf{K}_{e2}/\mathbf{K}_{\mu2}$$

Two preliminary NA48 measurements from 2003/2004 data:

■ NA48/2 (2003 data), presented in 2005:

- About 4000 signal events from normal running period.
- Systematics dominated by trigger efficiencies.

$$\Gamma(K_{e2})/\Gamma(K_{\mu2}) = (2.416 \pm 0.043 \pm 0.024) \times 10^{-5}$$

■ NA48/2 (2004 data), presented in 2007:

- About 4000 signal events from special minimum bias trigger.
- Small systematics, except background.
(measured from data → large statistical uncertainty in syst. error.)
- Completely uncorrelated with 2003 measurement.

$$\Gamma(K_{e2})/\Gamma(K_{\mu2}) = (2.455 \pm 0.045 \pm 0.041) \times 10^{-5}$$

Both results in agreement with each other, PDG, KLOE and SM theory.

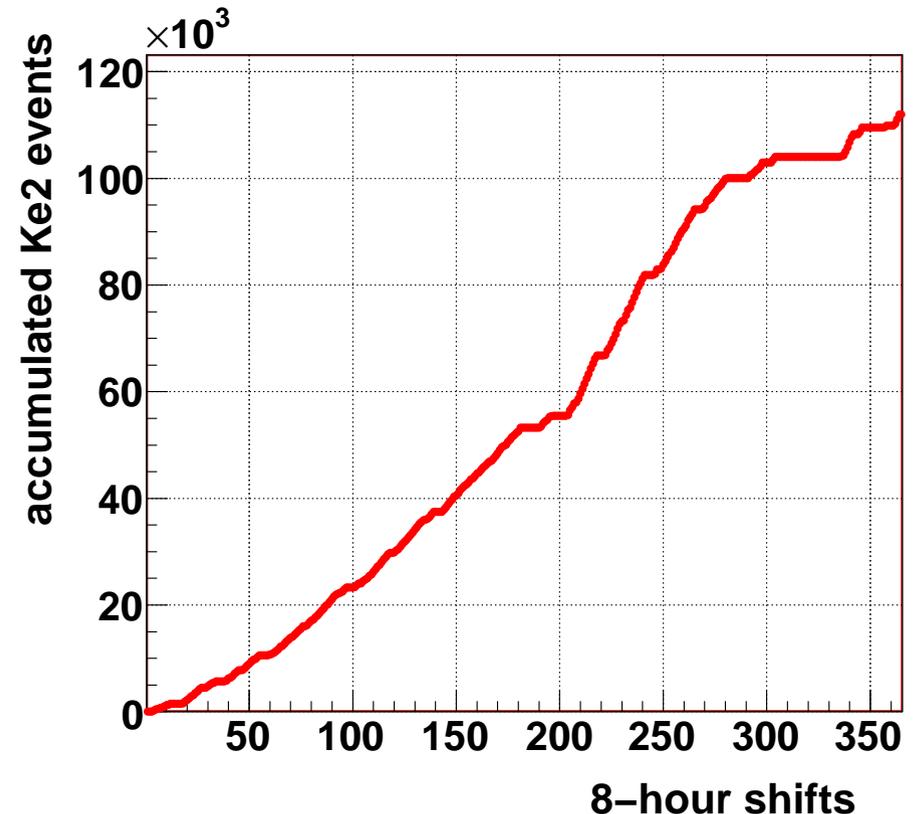
Special run for $K_{e2}/K_{\mu2}$ in 2007:

- About 120 days of minimum-bias data-taking, mainly K^+ decays.
- Old detector (w/o beam spectrometer and hadron calorimeter).
New collaboration: NA62

Accumulated statistics:

About **110 k K_{e2} events**

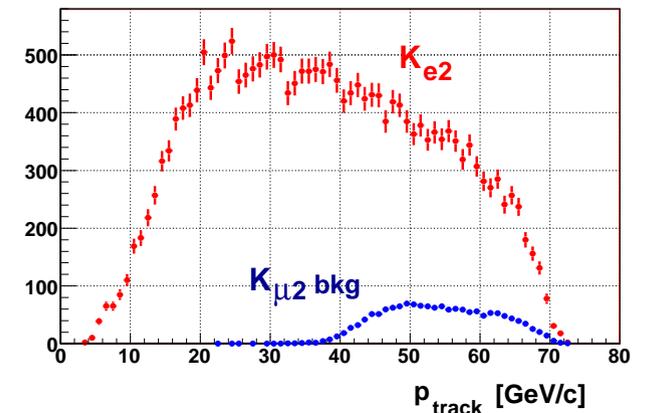
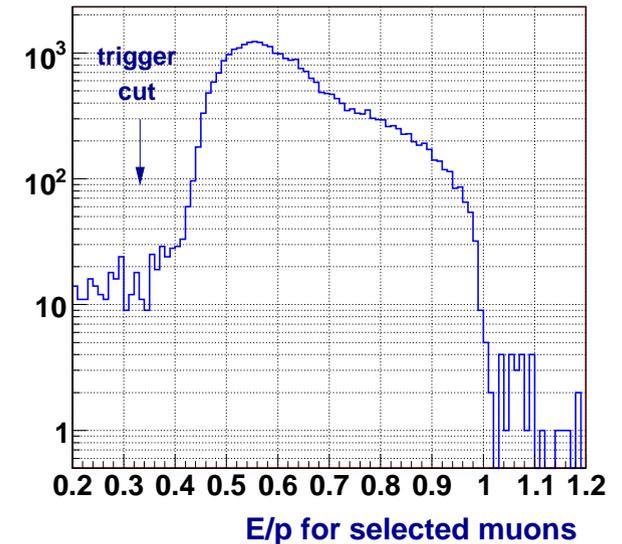
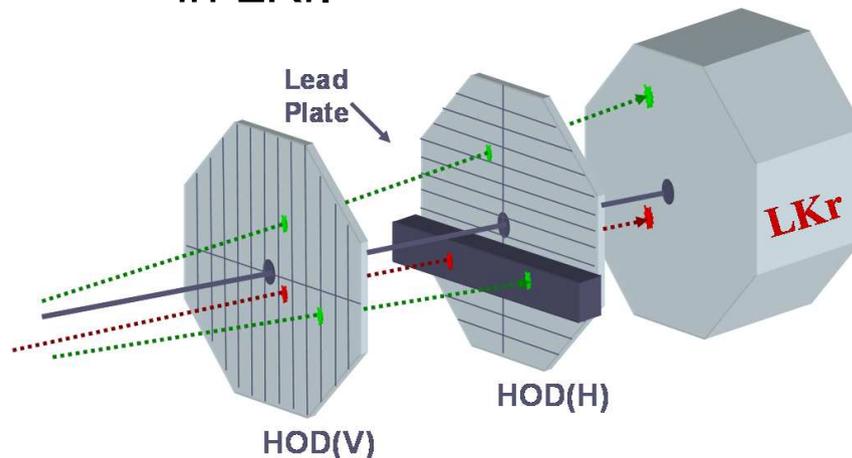
(Number might still change up or down, due to e.g. loosening analysis cuts or excluding run periods.)



NA62 $K_{e2}/K_{\mu2}$ — $K_{\mu2}$ Suppression

Background from $K_{\mu2}$ for large p_{track} :

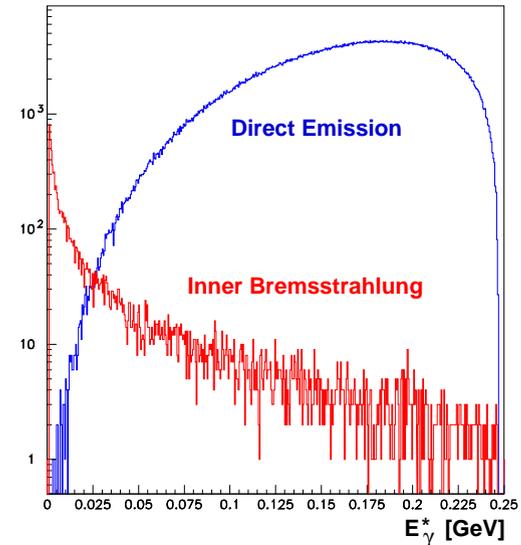
- **Catastrophic energy-loss** of $\sim 5 \cdot 10^{-6}$ of muons in the LKr.
⇒ mis-identified as electrons.
- **Solution:**
Lead bar in front of LKr, covering $\sim 18\%$ acceptance for 2/3 of the run
⇒ Only μ pass, E/p measured in LKr.



$K_{e2}/K_{\mu2}$ — Other Backgrounds

Background from $K_{e2\gamma}$ events:

- **Inner bremsstrahlung (IB):**
Part of the decay and well-known.
⇒ Harmless.
- **Direct emission (SD+):**
BR and form factor not well-known.
⇒ Measured on the same data set.



Background from prompt muons:

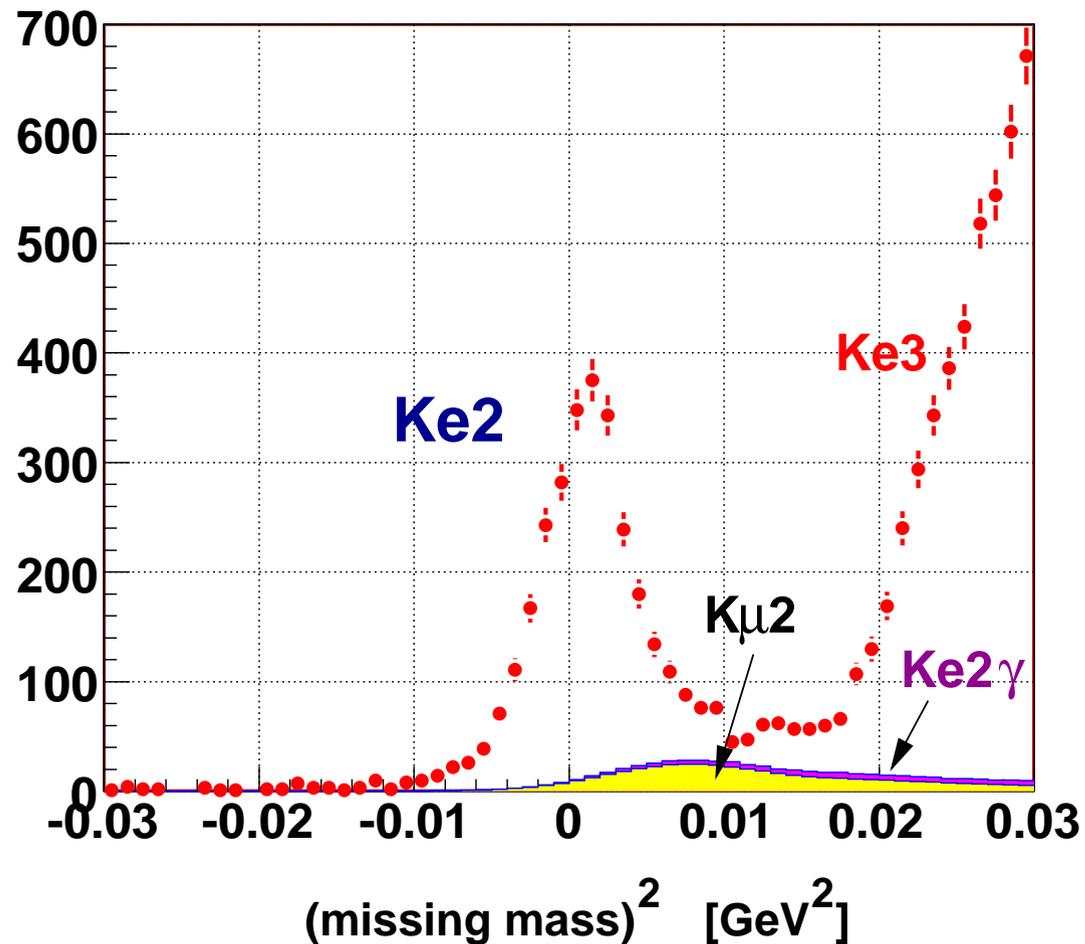
- Some muons (mainly μ^-) from π decay nearby the target not swept away by beam-line magnets.
- Took special K^- -only runs to measure background to K_{e2}^+ .

All backgrounds are measured from data.

$K_{e2}/K_{\mu2}$ — *First look at the 2007 data*

First look at 3% of the 2007 data:

(Still final calibrations & background estimation missing!)



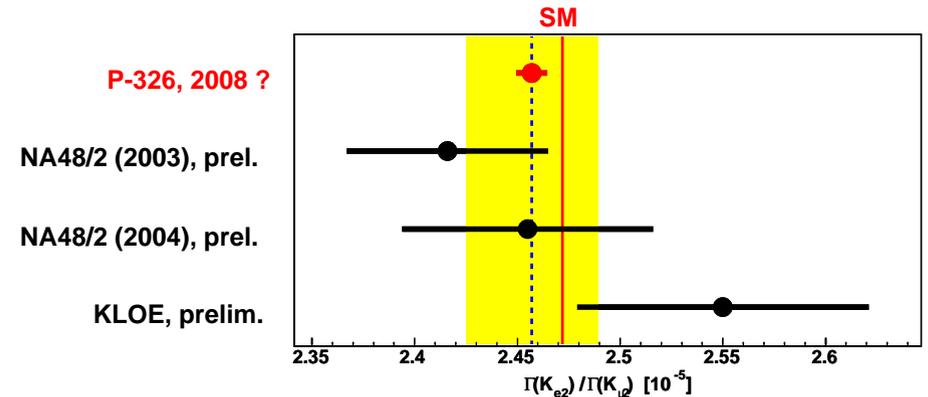
$K_{e2}/K_{\mu2}$ — Expectations from 2007

Expected precision on $K_{e2}/K_{\mu2}$:

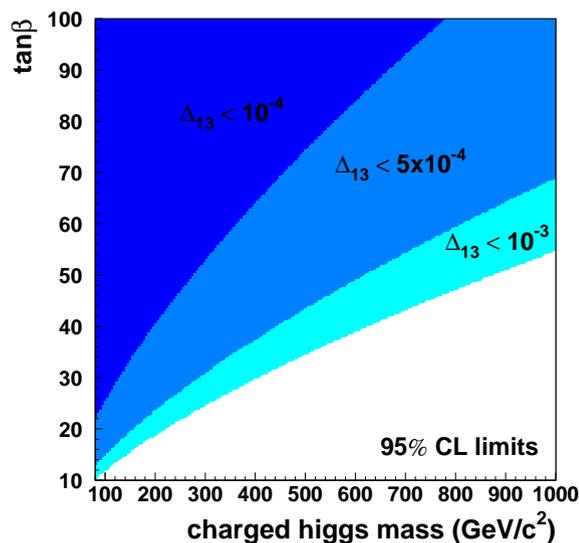
- Statistical: $\approx \pm 0.3\%$
- Systematic: $\leq \pm 0.2\%$

In total expected:

$$\sigma(R_K)/R_K \approx \pm 0.35\%$$

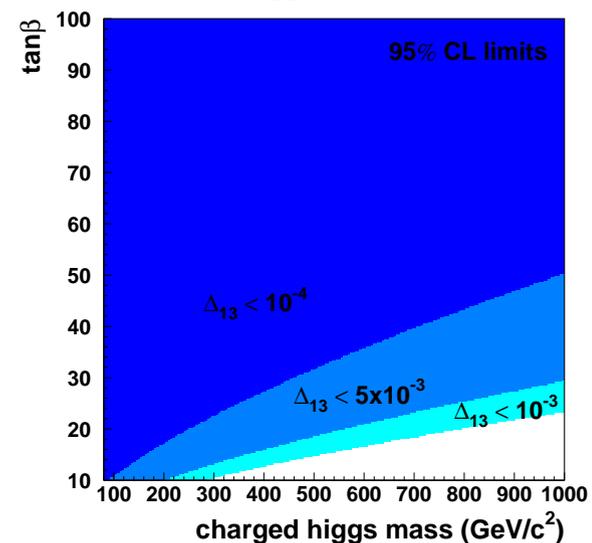


2007:



Next year?!

same R_K central value



Semileptonics from NA62 2007

K_{l3}^{\pm} from NA62 2007 data:

- 2007 trigger condition: Just 1 track + 15 GeV Lkr energy deposit
⇒ Ideal for K_{l3}^{\pm} (E_{π^0} usually > 15 GeV).
- $\sim 60\%$ of the run period LKr obstructed by lead bar, but remaining data still a lot!
- $K_{\mu 3}^+$: Statistics should be of $\mathcal{O}(20 \text{ million})!$

K_{Ll3} from NA62 2007 data:

- Special K_L run for measurement of electron ID efficiency
- Total statistics: About 20% more than in 1999 special run.
⇒ K_{Ll3} analyses could be repeated with a different data set.

However: No results expected for these channels soon.

Other K^\pm Decays

Of course many other new NA48 results on kaon decays:

- Search for **CP violation** in $K^\pm \rightarrow 3\pi$ decays.
- Measurements of **$\pi\pi$ scattering lengths** in K_{e4}^\pm and $K^\pm \rightarrow \pi^\pm \pi^0 \pi^0$.
- Measurement of the **interference term** in $K^\pm \rightarrow \pi^\pm \pi^0 \gamma$.
- ...

Just showing one of them...

First Measurement of $K^\pm \rightarrow \pi^\pm e^+ e^- \gamma$

In whole 2003/2004 K^\pm data:

(CERN-PH-EP/2007-033)

- **120 $K^\pm \rightarrow \pi^\pm e^+ e^- \gamma$ signal candidates** (Bkg: 7.3 ± 1.7 events)

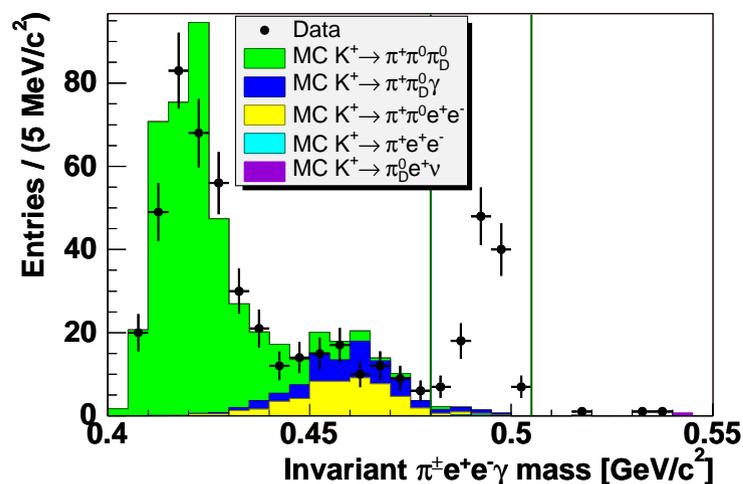
⇒ 4× the published $K^\pm \rightarrow \pi^\pm \gamma\gamma$ statistics!

- Model-independent branching fraction:

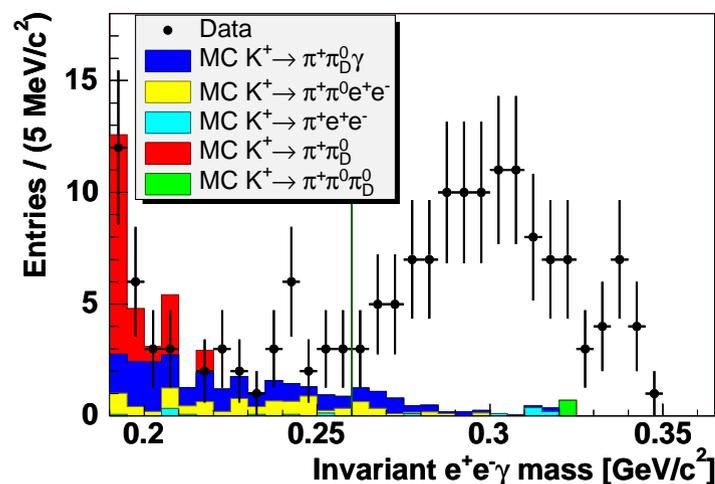
$$\text{Br}(K^\pm \rightarrow \pi^\pm e^+ e^- \gamma, m_{ee\gamma} > 260 \text{ MeV})$$

$$= (1.19 \pm 0.12_{\text{stat}} \pm 0.04_{\text{sys}}) \times 10^{-8}$$

- \hat{c} extraction: $\hat{c} = 0.90 \pm 0.45$



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- p.17/18

- Many new measurements of **semileptonic channels**:
Branching fractions and form factors.
- Open question of **$K_{L\mu 3}$ form factor result**:
In disagreement with other experiments.
⇒ Expect a NA48 measurement from $K_{\mu 3}^{\pm}$ in the future.
- Very successful **$K_{e2}/K_{\mu 2}$ run in 2007**.
⇒ More than 100 000 K_{e2} events collected.
- And, of course...:
Constructing a new experiment for measuring $K^+ \rightarrow \pi^+ \nu \bar{\nu}$!