Testing lepton universality with kaon decays

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On behalf of the NA48/2 collaboration

Cambridge, CERN, Chicago, Dubna, Edinburgh, Ferrara, Firenze, Mainz, Northwestern, Perugia, Pisa, Saclay, Siegen, Torino, Wien

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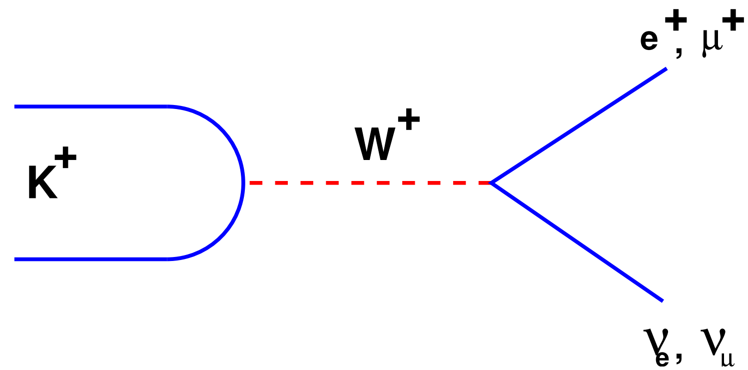
Outline

- **$K_{\ell 2}$ decays and physics beyond the SM**
- **Experimental situation**
- **NA48 detector**
- **Preliminary NA48/2 results on $\Gamma(K_{e2})/\Gamma(K_{\mu 2})$**
- **Run 2007**
- **Summary**

$K_{e2}/K_{\mu 2}$ – Introduction

$K_{\ell 2}$ decays



Let's consider the ratio R_K:

M. Finkemeier, **PLB 387 (1996) 391**

$$R_K = \frac{\Gamma(K^\pm \to e^\pm \nu)}{\Gamma(K^\pm \to \mu^\pm \nu)} = R_K^0 \times (1 + \delta_{R_K}) = (2.472 \pm 0.001) \times 10^{-5}$$

$$= (2.477 \pm 0.001) \times 10^{-5}$$

(δ_{R_K} Convention: Include IB, exclude DE)

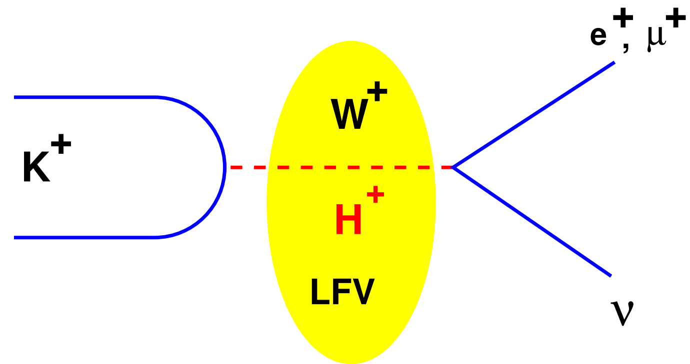
V. Cirigliano and I. Rosell, **arXiv:0707.4464**

- K_{e2} decay is strongly helicity suppressed
- Hadronic uncertainties cancel in the ratio
- Very well–known quantity in the SM

Can be used to test lepton flavour violation!

R_K and the physics beyond SM

A recent work (A. Masiero et al., PRD 74, 2006) has shown that SUSY effects can shift the SM prediction for R_K by a relative amount in the percent range (in some configuration up to 3%)

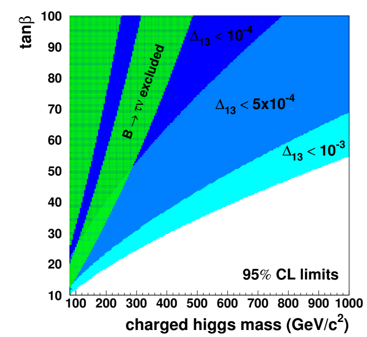


SUSY with LFV couplings like $H^\pm \to \ell_i \nu_k$ (in particular $i = e, \mu$ and $k = \tau$) modify R_K

$$R_K^{\text{LFV}} \approx R_K^{\text{SM}} \left[1 + \left(\frac{m_K^4}{m_{H^\pm}^4} \right) \left(\frac{m_\tau^2}{m_e^2} \right) |\Delta_{13}|^2 \tan^6 \beta \right]$$

Δ_{13}: Lepton–flavour violating term

Using $\tan\beta \simeq 40, m_{H^\pm} \simeq 500 GeV$ ➜ $R_K^{\text{LFV}} \approx R_K^{\text{SM}}(1 + 0.013)$



Remarkably no effects experimentally observable are expected in $\pi_{\ell 2}$ and τ decays

A precise measurement of R_K probes μ–e universality and provides a test of the SM

Kaons are a golden mode for SUSY LFV searches

The experimental situation

The experimental knowledge on R_K has been poor so far

PDG 2006 averages three measurements dating back to the seventies obtaining:

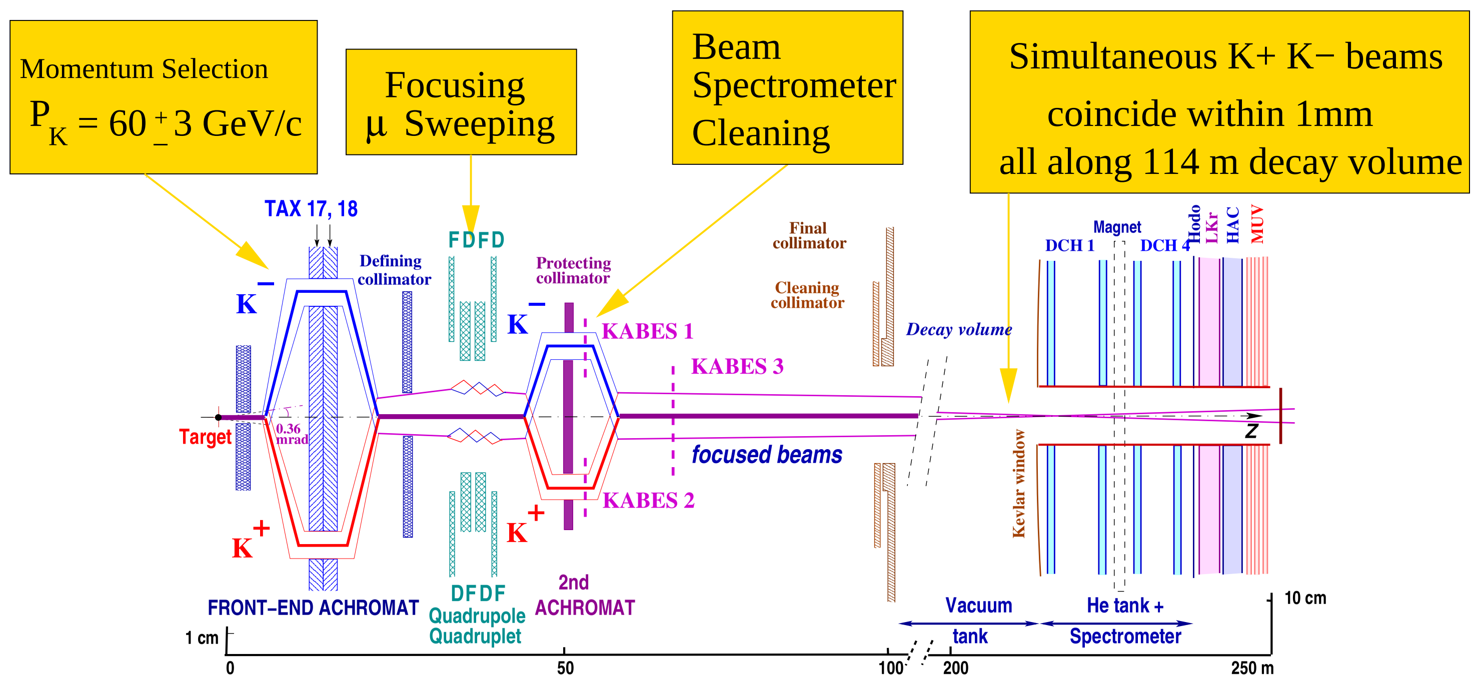
$$R_K = \frac{\Gamma(K^{\pm} \to e^{\pm}\nu)}{\Gamma(K^{\pm} \to \mu^{\pm}\nu)} = (2.45 \pm 0.11) \times 10^{-5}$$

The experimental error on R_K is two orders of magnitude larger than the theory one

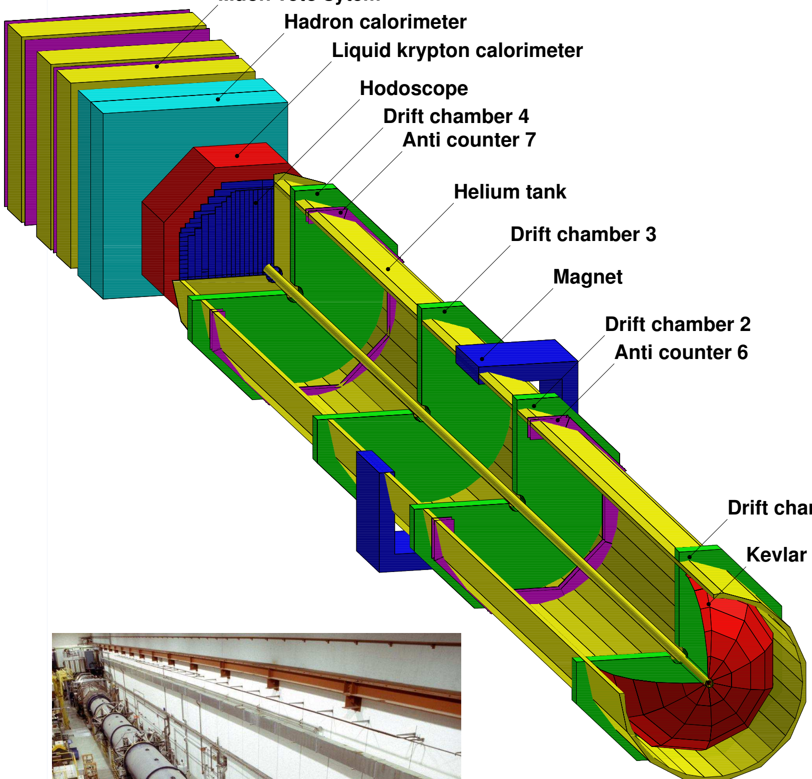
- Here will be reported the new (and preliminary) NA48/2 result based on the 2004 data
  - 56 hours (out of 60 days) special run with "minimum bias" conditions
  - Simplified trigger logic
  - Low intensity beam $I_{SR} \sim 1/4I$
- Also KLOE recently (KAON2007) presented a preliminary result

The NA48/2 beam line

- Na48/2 was designed primarily for the search of direct CP violation in $K^{\pm} \to 3\pi$ decays
- Simultaneous K^{+} and K^{-} beams of 60 GeV energy
- K^{+} flux $\simeq 3.2 \times 10^{6}$; $K^{+}/K^{-} \simeq 1.78$ (production rate @target)



The NA48 detector



Magnetic Spectrometer

4 drift chambers

$\frac{\sigma_p}{p}(\%) = 0.48 \oplus 0.009\ p$ (GeV/c)

Dipole magnet with 121 MeV/c p_T kick

Hodoscope

Fast trigger

Precise time measurement

$\sigma_t \simeq 150$ ps

Liquid Krypton EM Calorimeter

Quasi–homogeneous, high granularity

$\frac{\sigma_E}{E}(\%) = \frac{3.2}{\sqrt{E}} \oplus \frac{9.0}{E} \oplus 0.42$ (GeV)

13248 cells of 2cm$\times$2cm

Muon Counter

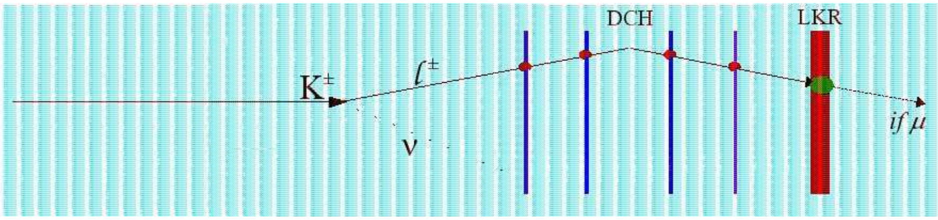
25cm$\times$25cm cells

$\sigma_t \simeq 350$ ps

Event Selection

Geometry

- 1 track topology
- $15 < p < 50$ GeV/c
- Good vertex
- Geometrical acceptance



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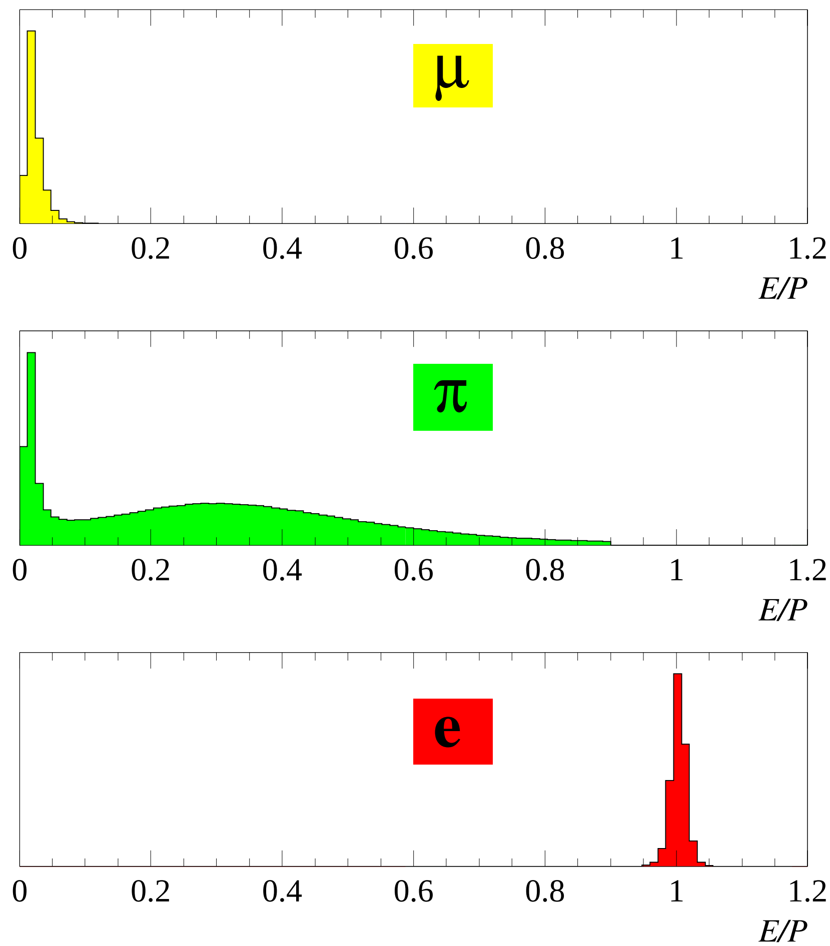
Particle ID

- e id. (E/p>0.95)
- μ id. (E/p<0.2)



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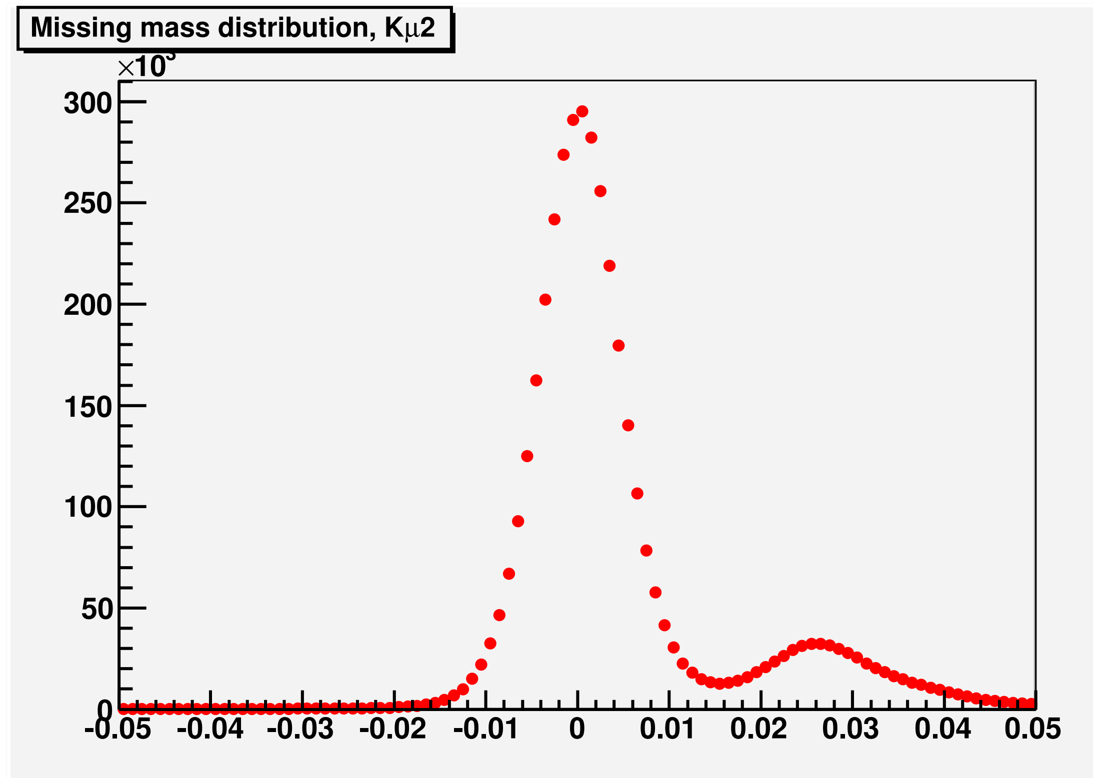
Kinematics

- Missing mass: $M^2_{miss}(\ell) = (P_K - P_\ell)^2$

  $\vec{P}_K = (0, 0, 60)$ GeV/c
- $-0.015 < M^2_{miss} < 0.015$ (GeV/c^2)^2



Events selected:

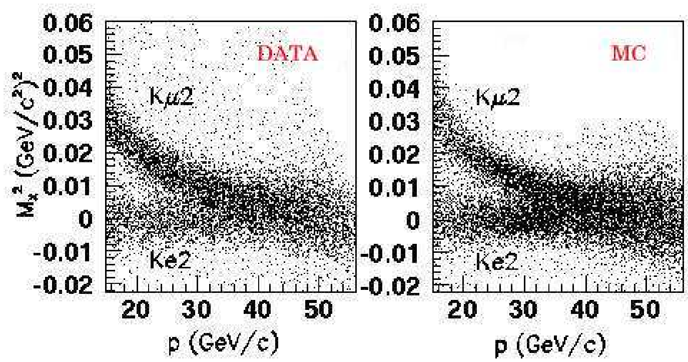
3930	K_{e2}
$\sim 3.4 \times 10^6$	$K_{\mu2}$

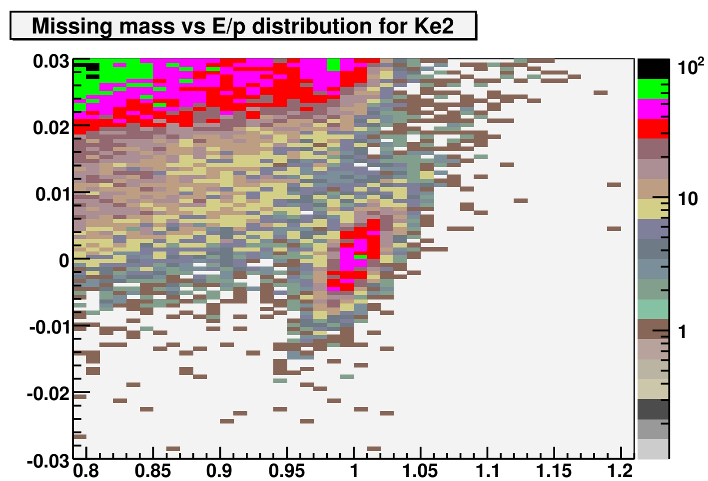
Background

The biggest source of uncertainty for this measurement is related to background subtraction

- The dominant background in the K_{e2} sample is due to $K_{\mu 2}$ events
  - Kinematically undistinguishable at high momenta
  - With a probability of $\sim 5 \times 10^{-6}$ the μ undergoes to a catastrophic energy loss in the LKr
  - The E/p of μ becomes close to 1 faking the e
  - This background is measured from data
- $K^{\pm}_{e3}$ background is obtained from MC
- $K^{\pm} \rightarrow \pi^{\pm}\pi^{0}$ bkg in the $K_{\mu 2}$ sample is negligible

$(3407 \pm 63_{stat} \pm 54_{syst})$ K_{e2} events





NA48/2 (2004 run) preliminary results for R_K

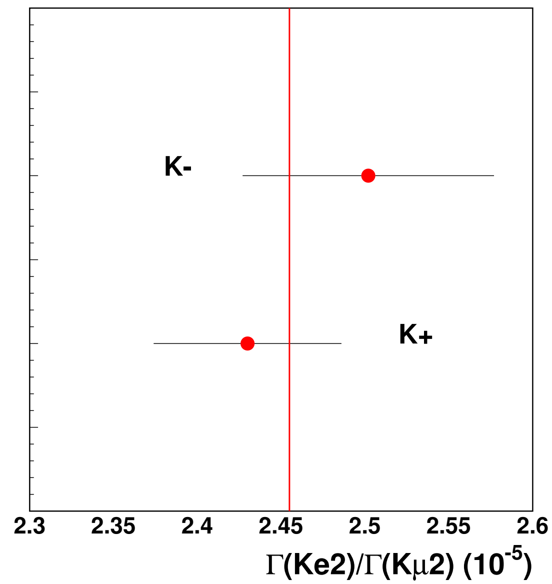
We measured:

$$R_K = \frac{N^{Rec}_{Ke2}}{\epsilon_{Ke2\ Trig} \times A_{Ke2} \times C_e} \frac{A_{K\mu 2} \times C_\mu}{N^{Rec}_{K\mu 2} \times D}$$

- $N^{Rec}_{K\ell 2}$ N. of events bkg subtracted
- $\epsilon_{Ke2\ Trig}$ K_{e2} Trigger eff. (DATA)
- C_ℓ Losses due to E/p cut (DATA)
- $A_{K\ell 2}$ Acceptance (MC)
- D Downscaling factor (50)

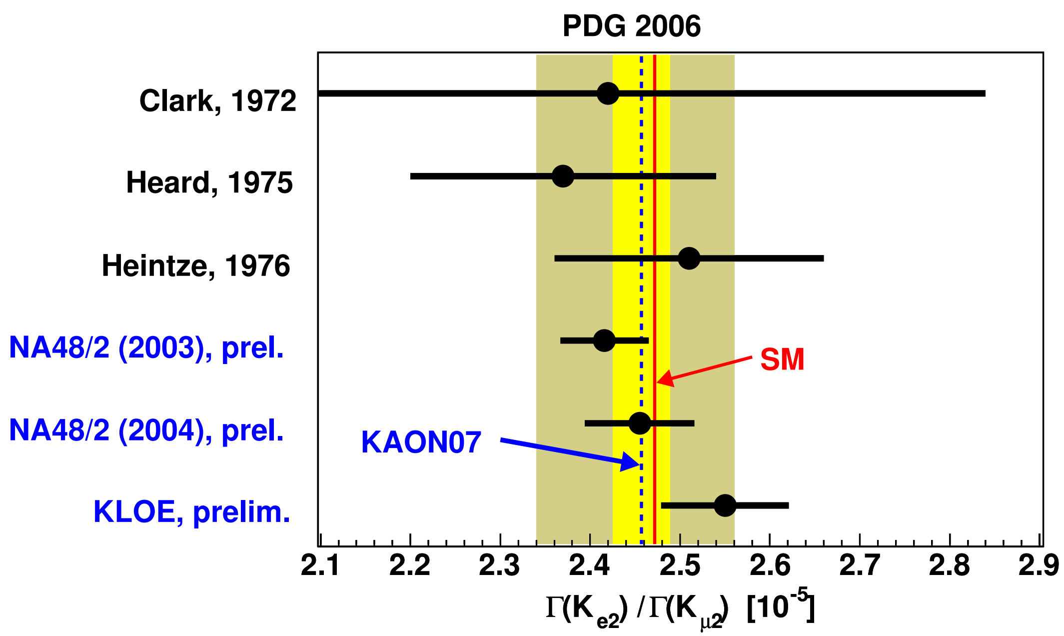
$R_K = (2.455 \pm 0.045 \pm 0.041) \times 10^{-5}$ NA48/2 PRELIMINARY

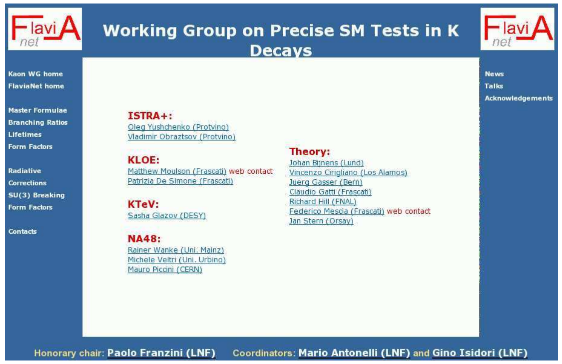
Systematic Source	Relative Error(%)
Background subtraction	1.59
Electron identification	0.24
K_{e2} Acceptance (MC stat)	0.30
K_{e2} Trigger efficiency	0.30



FlaviA net *fit for* R_K

Combining together PDG 2006 and the new preliminary NA48/KLOE results



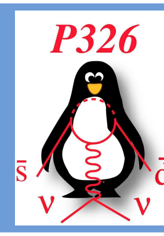


$$R_K = (2.457 \pm 0.032) \times 10^{-5} \quad (\chi^2/ndf = 2.44/3)$$

- Huge improvement w.r.t PDG 2006 σ_{rel}=1.3% now
- Perfect agreement with SM expectation

NA62 2007 Run

The NA48 evolution P326, also known as NA48/3, and very recently named NA62, is now taking data for a dedicated measurement of R_K (also tests for the future $K^+ \to \pi^+ \nu \overline{\nu}$ exp)



- 4 months data taking (June–October)
- Collect $\sim$ 150000 K_{e2} events
- Goal to reach $\sigma_{\mathrm{Rel}}(R_K) \sim \pm 0.3\%$

Big reduction of the systematics

➜ New beam and spectrometer conditions

➜ Precise mesurement of $K_{\mu 2}$ background

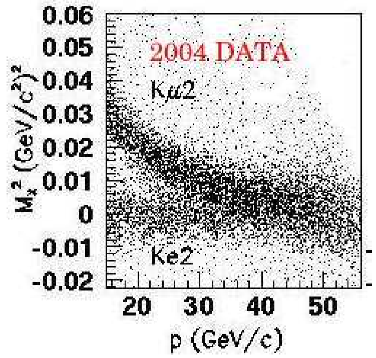
Minumum bias trigger conditions as for 2004 run

- K_{e2}: Hodoscope hits + min. energy in LKr
- $K_{\mu 2}$: Only hodoscope (downscaled)

NA62 2007 Run – Pulling down the systematics

The beam and spectrometer parameters have been optimized w.r.t. 2004 run

- Kaon momentum: 60 GeV/c ➜ 75 GeV/c
- Kaon momentum bite: ± 3 GeV/c ➜ $\pm$ 2.5 GeV/c
- p_T kick from spectrometer magnet: 120 MeV/c ➜ 263 MeV/c



Improved kinematic separation

- $p_{track} < 35$ GeV/c ($\sim$43%)

Kinematic separation

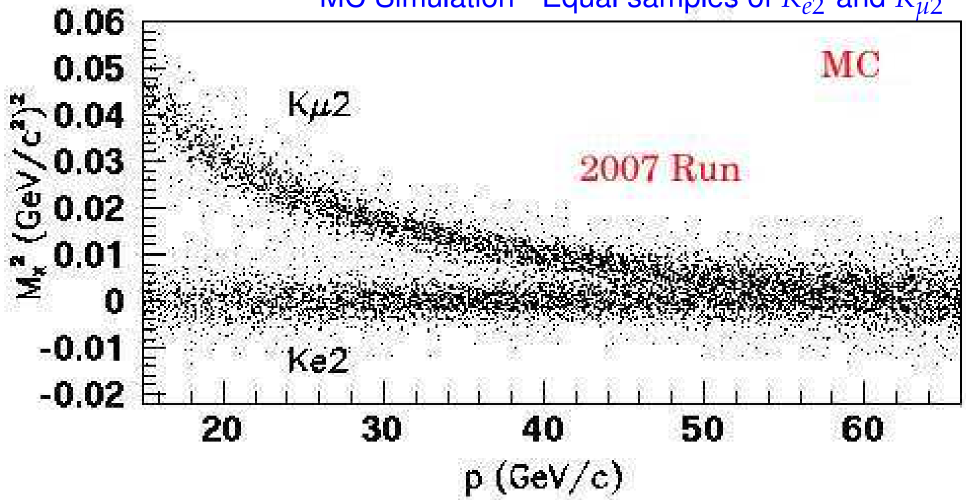
Build $M^2_{miss}(e)$ with e mass assumption

- $p_{track} > 35$ GeV/c ($\sim$57%)

Electron Identification

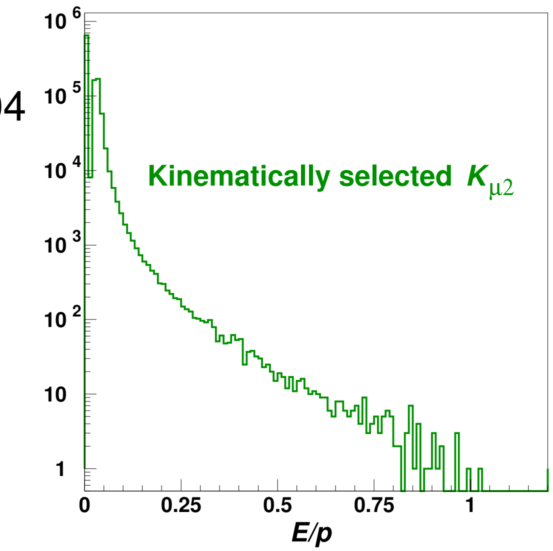
Require e–ID with E/p cut

MC Simulation - Equal samples of K_{e2} and $K_{\mu2}$



NA62 2007 Run – Pulling down the systematics

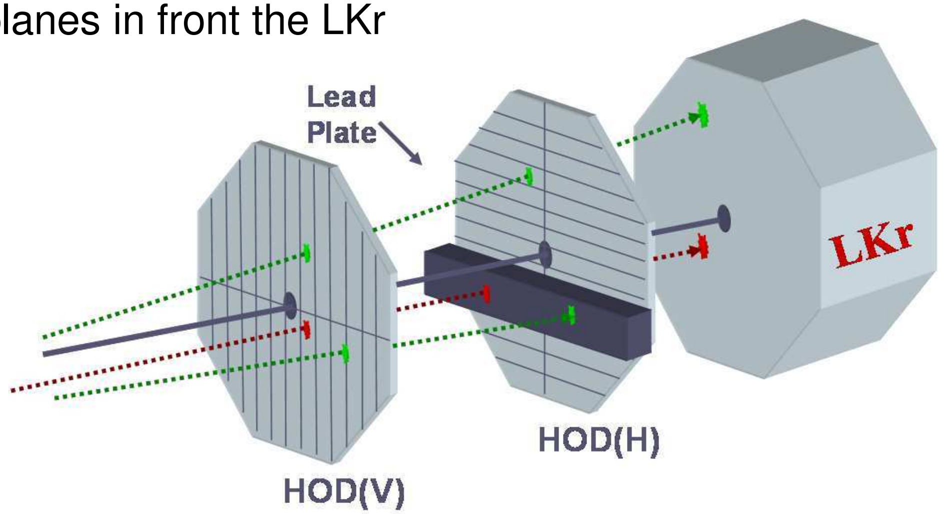
- Remember: the largest source of systematics for the 2004 result is related to background subtraction
- Mainly due to $K_{\mu 2}$ in K_{e2} sample
- Problems with muons with E/p$\simeq$ 1



Measure this background during the 2007 run

Put a 9 X_0 lead bar between the hodoscope planes in front the LKr

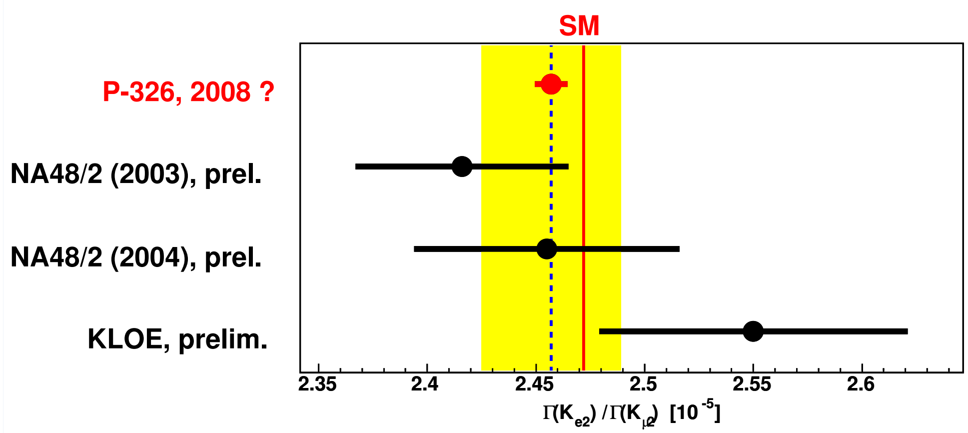
- Lose 18% of acceptance
- The e are stopped in the lead
- Only μ pass
- Measure E/p of μ in LKr

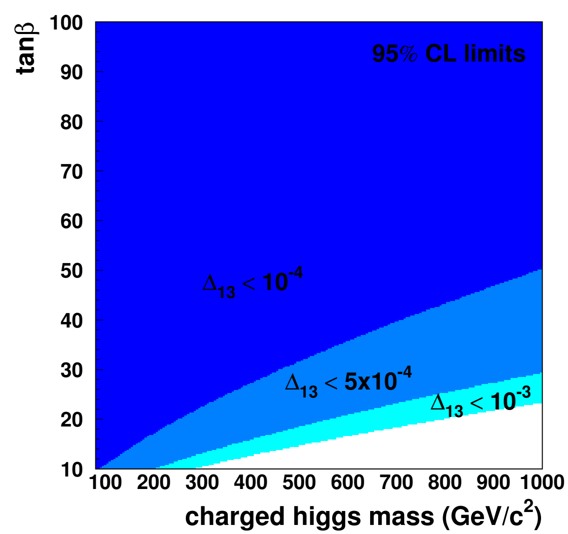


Summary

- $K_{\ell 2}$ decays provide a very challenging opportunity to test physics beyond the SM
- Within the framework of SUSY, violations of lepton universality up to 3% can be expected
- Preliminary results for R_K based on NA48/2 2004 data have been reported here
- The NA62 experiment at CERN is presently collecting data with the aim to measure R_K with sub–percent precision
- This measurement will either find deviations from the SM expectations or set very stringent limits in the SUSY parameter space

- Same R_K central value, $\delta R_K / R_K$ = 0.3%

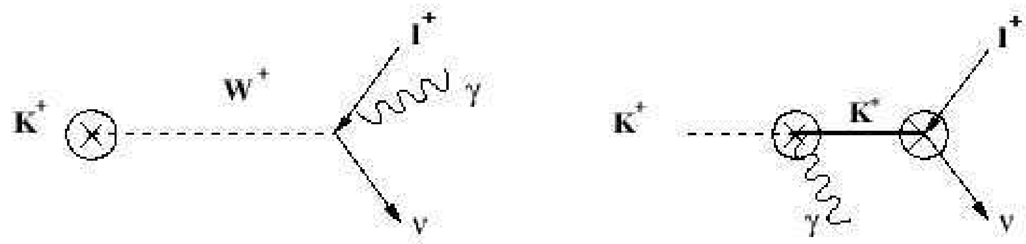




Spares

Radiative Corrections

- SM prediction for $\Gamma(K_{e2})/\Gamma(K_{\mu 2})$ includes IB but excludes DE component



- DE is negligible in $K_{\mu 2}$ decay and quite large in K_{e2} one

- All experiments measure inclusive $\Gamma(K_{e2(\gamma)})/\Gamma(K_{\mu 2(\gamma)})$ and subtract the DE contribution

- Effects on the acceptance

Proper treatment of radiative corrections is important