

Testing LFV measuring $K \rightarrow e \nu / K \rightarrow \mu \nu$ in NA48: Measurement and Prospectives

TAU06 Workshop

September 21th 2006



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on behalf of NA48/2 Collaboration

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



Former Physical Motivations

The measurement of $\Gamma(K_{e2})/\Gamma(K_{\mu2})$ ratio is a test of SM
Lepton Universality and *V-A Coupling*.

SM Prediction of the ratio is:

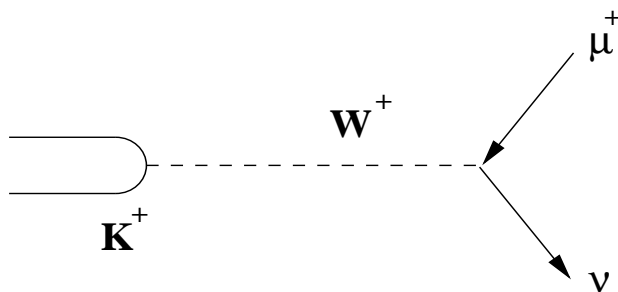
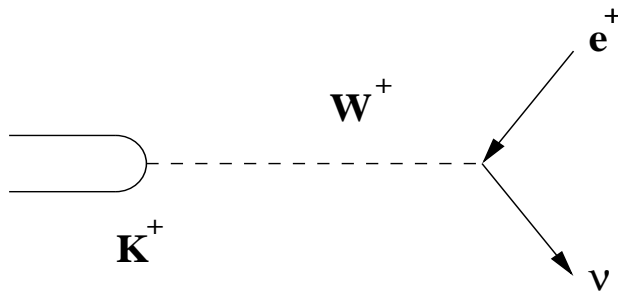
$$\frac{\Gamma(K \rightarrow e \nu(\gamma))}{\Gamma(K \rightarrow \mu \nu(\gamma))} = \mathbf{R_K} = \frac{m_e^2}{m_\mu^2} \left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2} \right)^2 (1 + \delta R_K)$$

$$\mathbf{R_K = R_K^{(0)}(1 + \delta R_K) = (2.472 \pm 0.001) \times 10^{-5}}$$

Experimental Results:

$$\mathbf{PDG Average (2005): 2.45 \pm 0.11 \cdot 10^{-5}}$$

Experiments with low energy K^+ beam stopped in a target, decay at rest



New Physical Motivations

PR D74 (2006) 011701 (A. Masiero et al.)

This recent paper shows that **SUSY LFV** contributions could shift R_K by a relative amount of a **few per cent** (2-3%) in either direction with parameters $\tan\beta \sim 50$ and $M_{H^\pm} \sim 500 \text{ GeV}/c^2$

These **values** are in the range of **RPC SUSY** models satisfying g-2, WMAP and $b \rightarrow s\gamma$, where χ are CDM primary component: PR D73 015013 (2006) (B. Allanach and C. Lester)

Remarkably, **SUSY LFV** contributions to pions and tau leptonic decays are far below the present experimental precision, while heavier mesons leptonic decay measurement are experimentally very challenging.

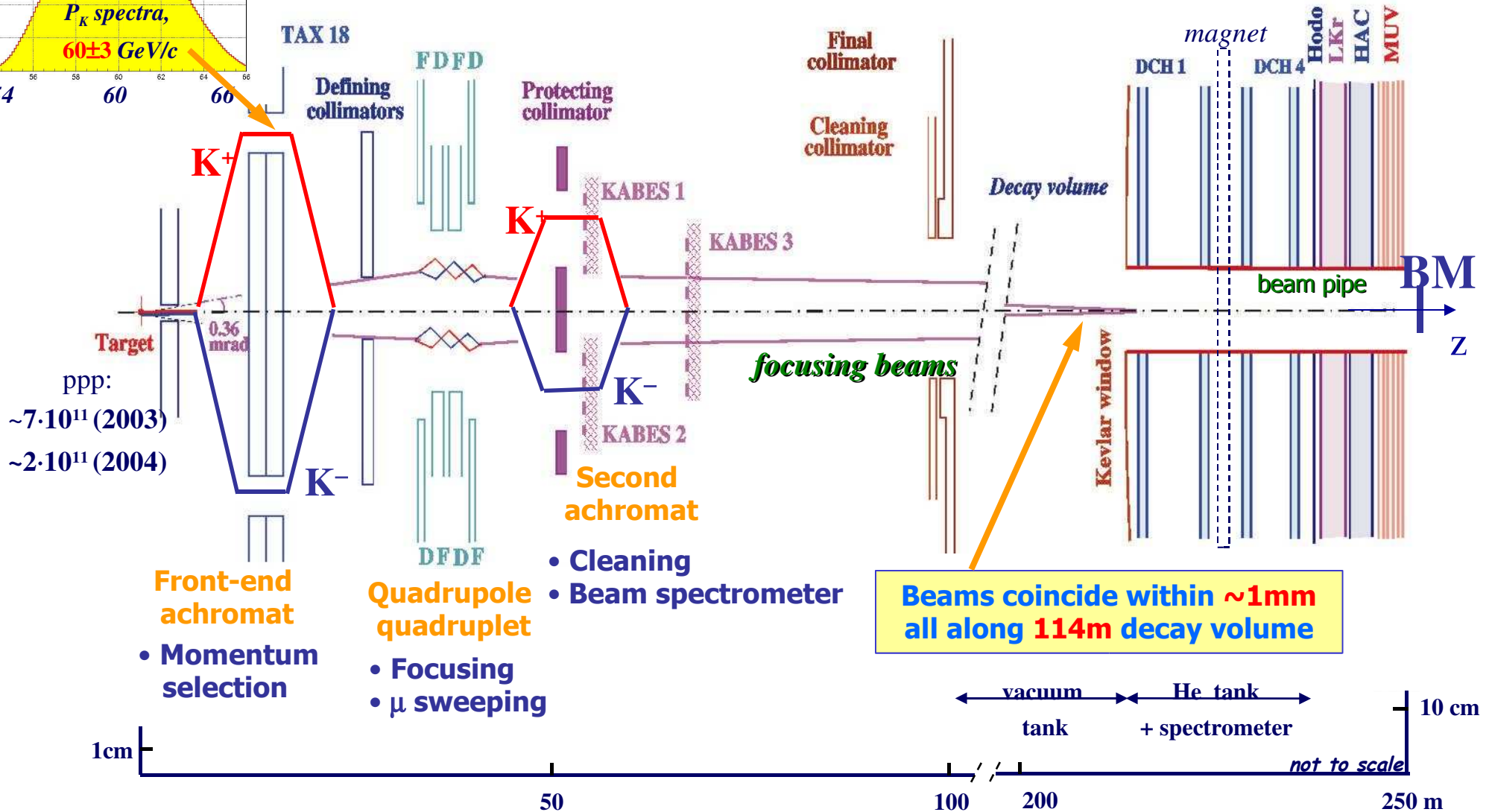
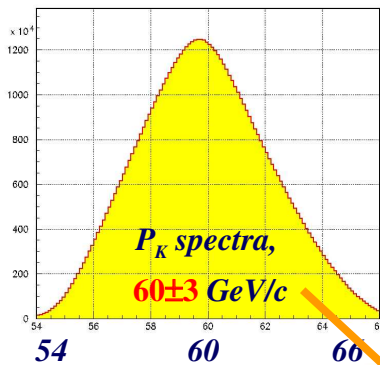
Kaon leptonic decays are golden modes to search for SUSY LFV effects!

NA48/2 Contribution to R_K measurement

NA48/2 is analyzing 2 sample of Data for R_K measurement:

- A sample collected during 2003 Data taking:
1 month of Data taking with a downscaled trigger
- A sample collected at the end of 2004 Data taking:
56 hours with a minimum bias trigger
 - Analysis in progress

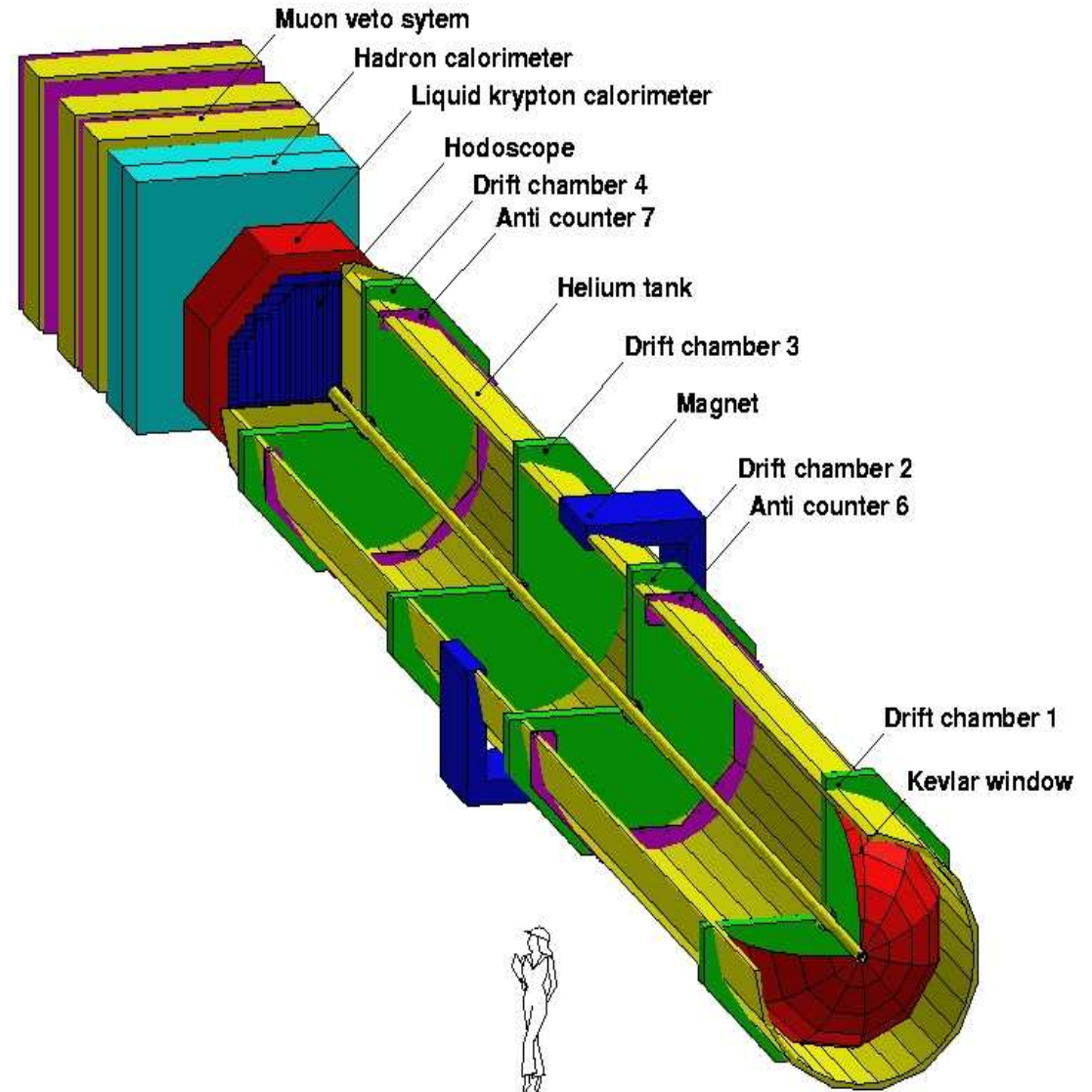
NA48/2 Beam Line (2003, 2004)



NA48/2 Detectors (2003, 2004)

Main detector components:

- Magnetic spectrometer (4 DCHs):
magnet kick of 121 MeV/c
 $\Delta p/p = 1.0\% + 0.044\%*p$ [GeV/c]
- Liquid Krypton EM calorimeter (LKr)
 $\Delta E/E = 3.2\%/\sqrt{E} \oplus 9\%/E \oplus 0.42\%$ [GeV]
- Kaon Beam spectrometer, Hadron calorimeter, photon vetos, muon veto counters

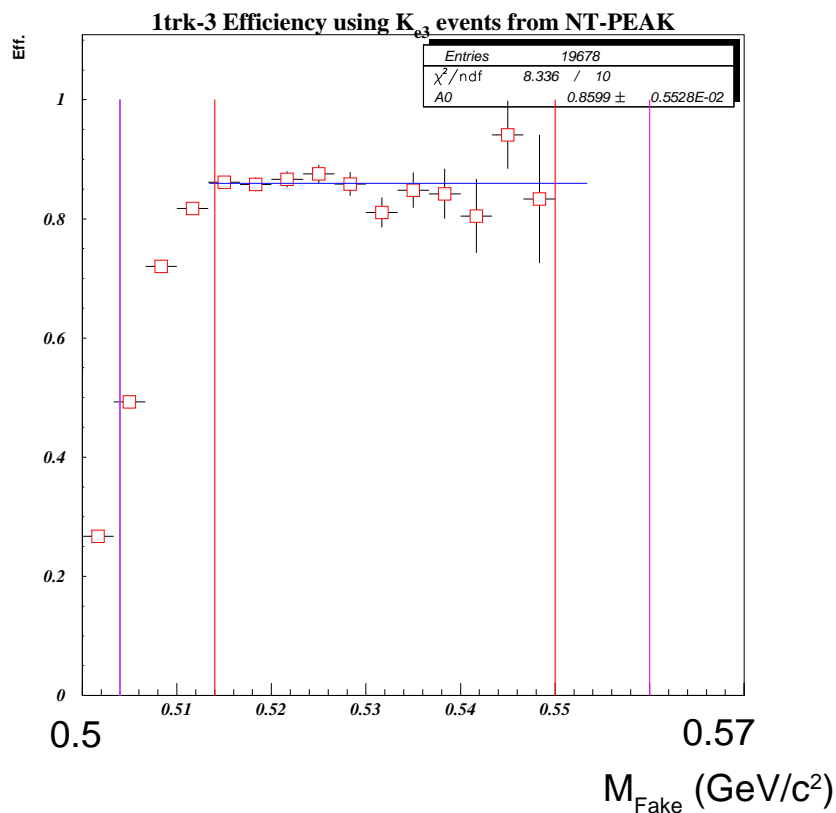


2003 Analysis

Trigger Logic and Efficiency (2003)

- $K_{\mu2}$ events: L1 Signal from Charged Hodoscope (downscaled 10000)
- K_{e2} events:
 - L1 Hodoscope Signal + >10 GeV Energy in EM Calorimeter
 - L2 Online invariant mass reconstruction:

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$$M_{\text{Fake}}^2 = M_K^2 + M_\pi^2 - S$$

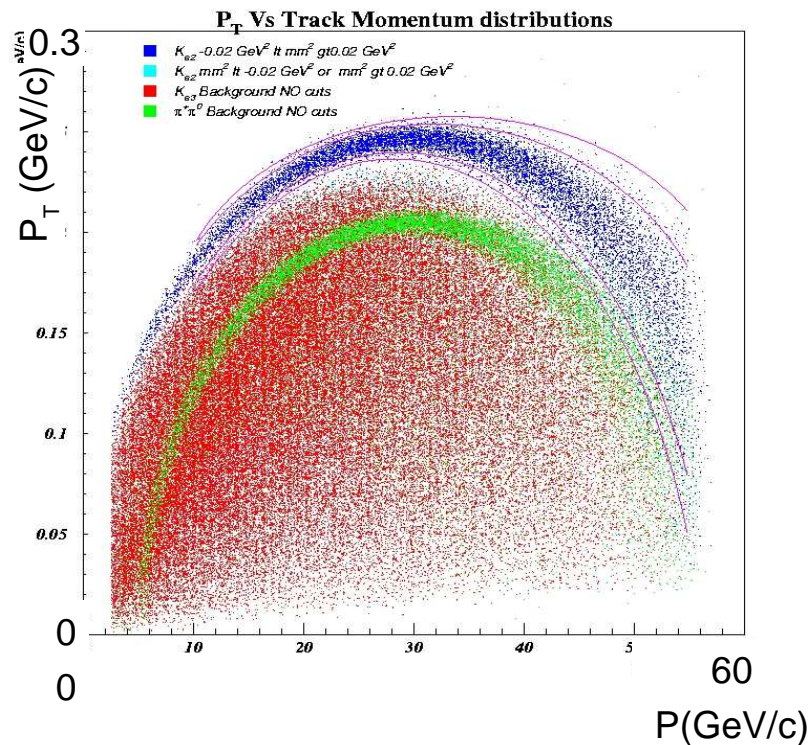
$$S = MM^2(\pi) = (p_K - p_\pi)^2 \quad p_K \equiv (0, 0, 60) \text{ GeV}/c$$

1-TRK3 Trigger Eff. (%):

$$85.6 \pm 0.5_{(\text{stat})} \pm 0.2_{(\text{syst})}$$

Selection and Acceptance (2003)

K_{e2} and $K_{\mu2}$ CUTS

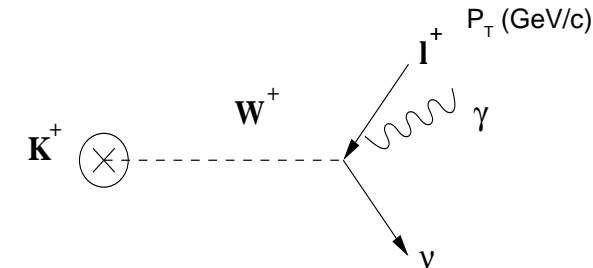
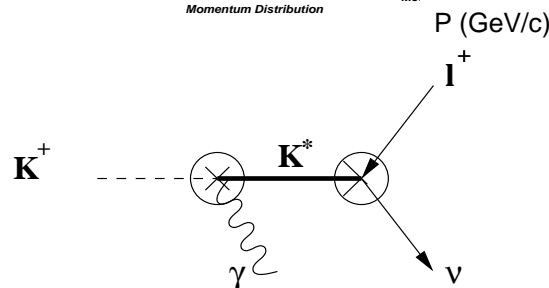
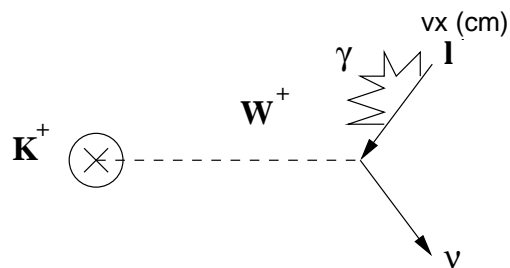
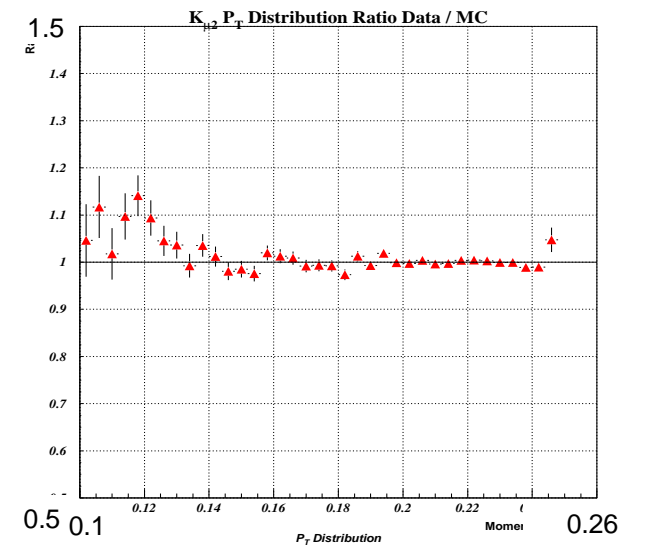
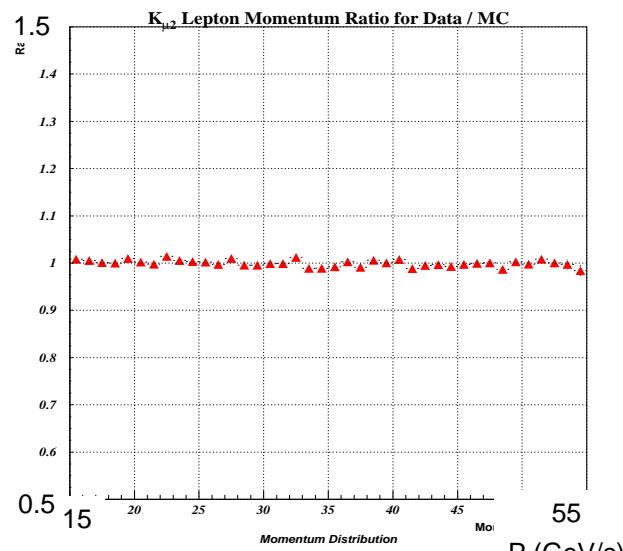
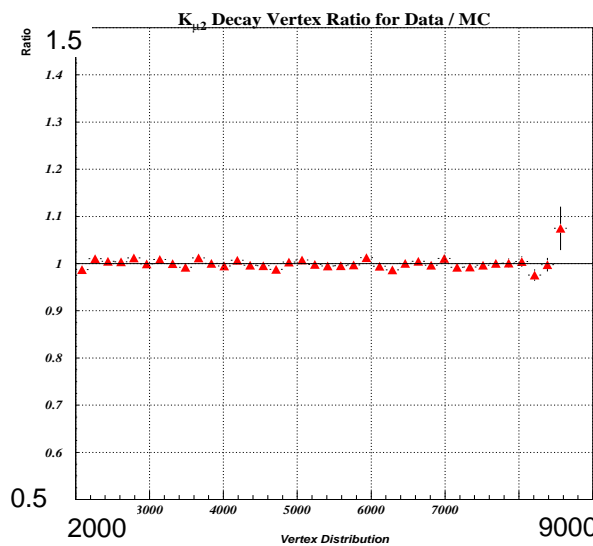


- At least 1 track (good χ^2) ; no extra cluster ($E_{\text{clu}} < 1.5$ GeV) ; no ghost tracks ;no in time tracks or anticounter hits
- $15 \text{ GeV}/c < P_{\text{track}} < 55 \text{ GeV}/c$
- P_T vs P selection
- $2000 \text{ cm} < \text{Vertex } z < 8500 \text{ cm}$
- $-0.02 \text{ GeV}^2/c^4 < MM^2 < 0.02 \text{ GeV}^2/c^4$

Difference in Acceptance between K_{e2} and $K_{\mu2}$

$$\Delta(R_K) = 1.116 \pm 0.002_{(\text{stat})} \pm 0.006_{(\text{syst})}$$

MC and Radiative Corrections (2003)



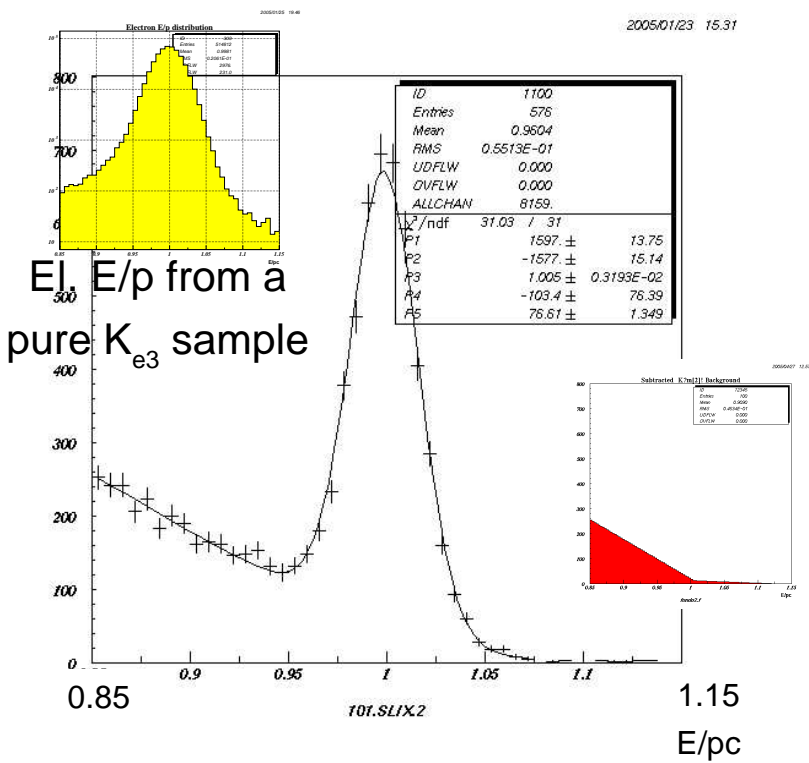
| Decay | B.R. | Acceptance | Correction |
|-------------------------------------|----------------------|---|------------|
| Ke2g $E_g > 3\text{MeV}$ (IB) | $1.56 \cdot 10^{-6}$ | $0.33 \cdot A(\text{Ke}2)$ | +6.5% |
| Ke2g SD | $1.5 \cdot 10^{-5}$ | $2.4 \cdot 10^{-3} \cdot A(\text{Ke}2)$ | -0.22% |
| K μ 2g $E_g > 3\text{MeV}$ (IB) | $6.5 \cdot 10^{-3}$ | $0.37 \cdot A(\text{K}\mu 2)$ | -0.64% |

$$\Delta(R_K) = 1.063 \pm 0.005_{(\text{syst})}$$

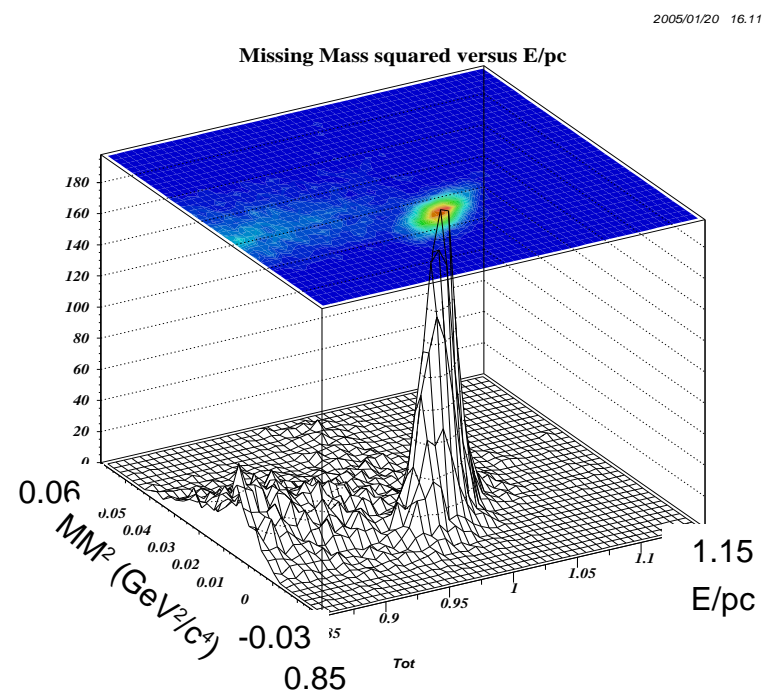
K_{e2} electron ID and Bkg study(2003)

Signal Region is defined by:
 $0.95 < E/pc < 1.05$ and
 $-0.02 < MM^2 < 0.02 \text{ (GeV}^2/c^4)$

| 2003 Data | |
|-------------------|---------------------------------------|
| Total N of Events | 5329 ± 73 |
| Background Events | 659 ± 26 |
| Signal Events | $4670 \pm 77^{+29}_{-8(\text{syst})}$ |



$K_{\mu2}$ is the main background

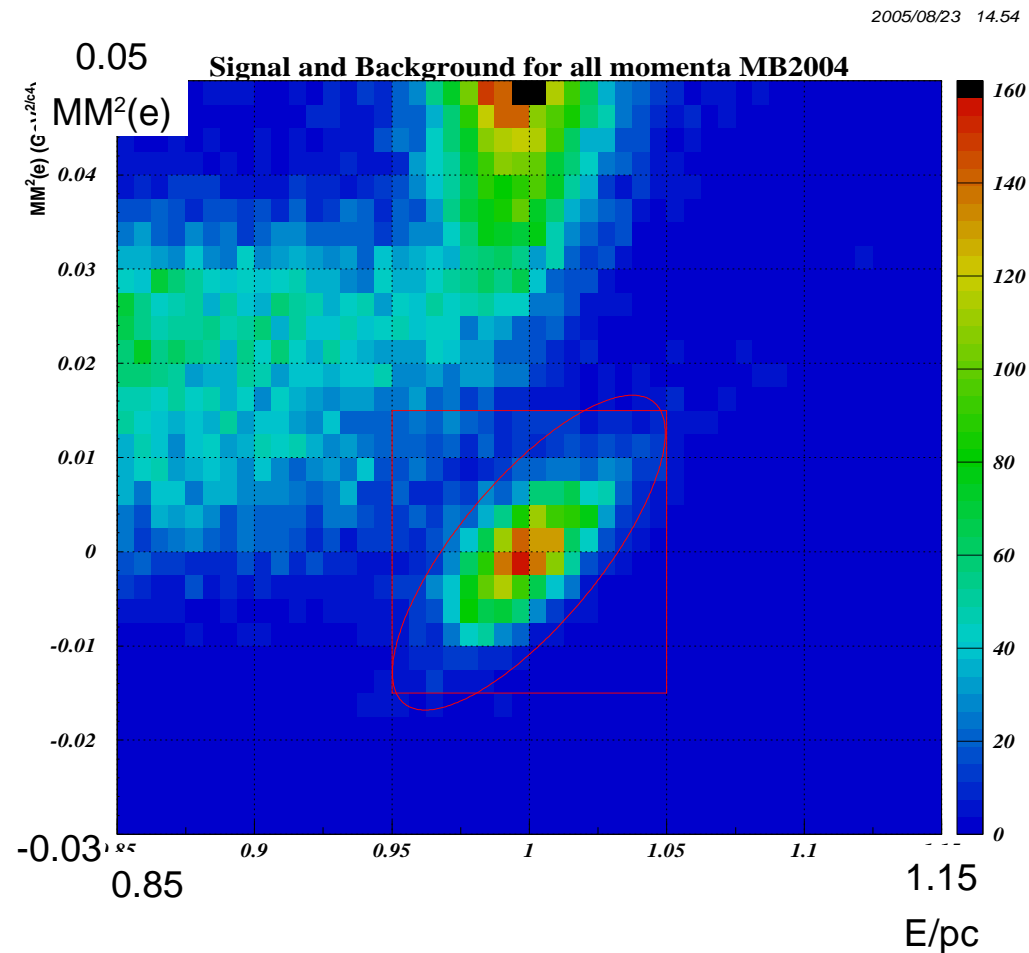


2004 Analysis

MB2004: changes w.r.t. 2003 Analysis

- 60 GeV/c K^\pm beam with intensity on T10 $\sim \frac{1}{4} I_0$
- **Different Trigger conditions** (no L2 trigger):
 - Main (K_{e2}) : $Q1 \times (E_{LKr} > 10)$ D=1 $\sim 45K$ Trigger/burst
 - Control Trigger ($K_{\mu2}$): Q1/10 D=5 $\sim 10K$ Trigger/burst
- **Different selection cuts** : better Trigger conditions allow a simpler selection with less systematics
- **Analysis in momentum bins** It leads to better background subtraction and allows to check for systematic dependences of the result as a function of the momentum.

Background in momentum bins (MB2004)



$K_{\mu2}$ is the main background, contributing in all momentum bins.

K_{e3} only contributes at low momentum, while $\pi^+\pi^0$ contributes at very high momentum only.

K_{e2} Background Subtraction: Results (MB2004)

Events in Signal Region

| Mom (GeV/c) | Total | Background | Difference |
|-------------|-------|------------|------------|
| 15-20 | 510 | 4,7 | 505,3 |
| 20-25 | 606 | 33,6 | 572,4 |
| 25-30 | 684 | 100 | 584 |
| 30-35 | 715 | 136 | 579 |
| 35-40 | 674 | 136,3 | 537,7 |
| 40-45 | 650 | 144,3 | 505,7 |
| 45-50 | 610 | 153,3 | 456,7 |
| 50-55 | 484 | 209,9 | 274,1 |
| All | 4933 | 918,1 | 4014,9 |

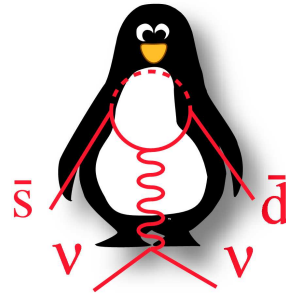
Results and comparison

| | $\frac{\Gamma(K \rightarrow e \nu(\gamma))}{\Gamma(K \rightarrow \mu \nu(\nu))} \cdot 10^5$ |
|---------------|---|
| SM prediction | 2.472 ± 0.001 |
| PDG value | 2.45 ± 0.11 |
| NA48/2 (2003) | $2.416 \pm 0.043_{(stat)} \pm 0.024_{(syst)}$ |
| NA48/2 (2004) | <i>Analysis in progress</i> |

- R_K measurement with 2003 statistics is already 2 times more precise than PDG world average. MB2004 Statistics is similar in size, with a better systematic error.
 - 2003 + 2004 yield is **NOT** sufficient to measure accurately a possible $\Delta R_K(\text{LFV}) \sim 2\text{-}3\%$

Future Prospects

P326



Present statistics is not sufficient to measure R_K with $<1\%$ error.

In the long term, the proposed P326 experiment ($K^+ \rightarrow \pi^+ \nu \nu$) could reach a sensitivity of few per mill thanks to RICH detector, double spectrometer, hermetic veto and high intensity beam.

Before P326, would it possible collect enough statistics to measure R_K with $<1\%$ precision, while keeping under control systematic effects?

Requirements:

- Magnetic Spectrometer composed by 4 drift chambers and a dipole magnet and equipped with a L2 trigger system;
- Scintillator hodoscope providing a fast L1 trigger for charged tracks;
- Liquid Krypton Calorimeter with L1 trigger system;
- SPS Beam Time.

Statistics Improvements

Conservative estimates in Scenario with beam conditions as in 2003 and 2004

- Beam intensity $\frac{1}{2}$ of 2003 (compatible with LHC and CNGS requests)
- Same L1 AND L2 triggers as 2003
- Control Trigger ($Q1 \times E_{LKR} > 10 \text{ GeV}$)/4
- Control Trigger (Q1)/100 used also to record $K_{\mu2}$

During a fully efficient run of 3 weeks, corresponding to ~ 90000 good K_{e2} events with a 25% background, the statistical uncertainty would be of **0.40%**

The statistical uncertainty on the trigger efficiency would be of **0.22%**

The overall statistical uncertainty would be **$\pm 0.46\%$**

Background control

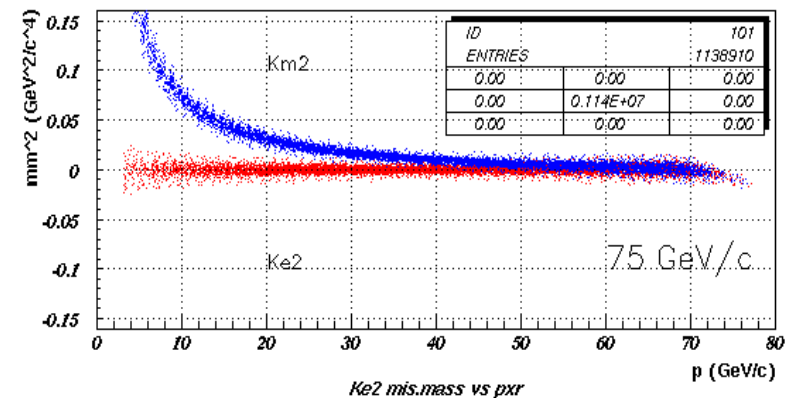
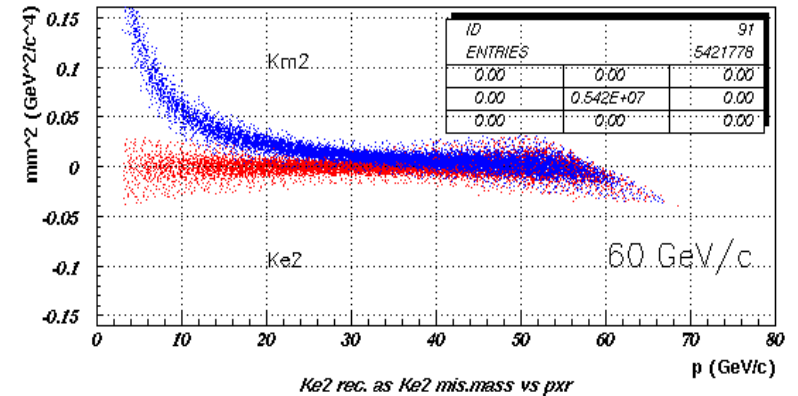
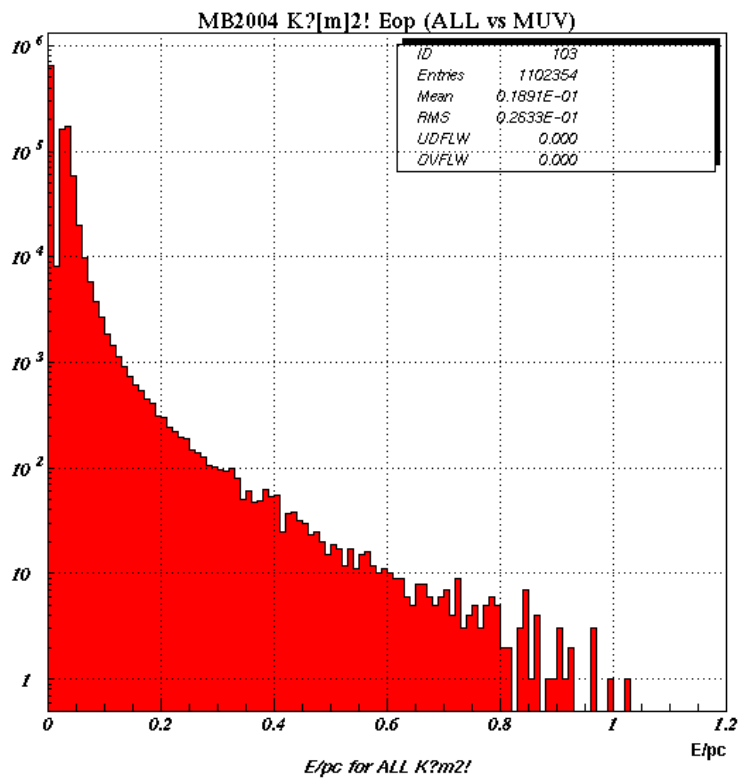
Control main background ($K_{\mu2}$ with high E/p) putting a layer of Pb 5 cm thick in front of 9 vertical counters of th HOD.

The loss in statistics would be of 15% rising the statistical error to **0.49%**

The systematic error on the background subtraction will be **<0.43%**

Other systematics can be controlled to the level of **0.3%**

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Conclusions

- Using the **whole statistics**, NA48/2 is able to measure R_K with a precision of **~2%** dominated by statistics uncertainty.

sub-percent precision measurement of R_K would be capable of **probing New Physics** or ruling out some region of the parameter space in realistic models.

- The collaboration is discussing practical issues for a dedicated run of **6 calendar weeks** (at 50% efficiency): it would yield a measurements of R_K with a precision of:

$$(0.49_{(stat)} \oplus 0.52_{(syst)})\% = 0.71\%$$

neglecting **possible improvements** on the beam and spectrometer resolution.

- P326** could reach a **per mill** uncertainty, adding a new item to its physics program.