Testing the $\mu$-e universality with $K^{\pm} \rightarrow \ell^{\pm}\nu$ decays

Venelin Kozhuharov

University of Sofia “St. Kl. Ohridski” / JINR Dubna

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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, Vienna
Overview

- Physics motivation
- Experimental setup
- Data analysis
- Preliminary result for 2003 data
- Conclusions
Motivation

Within the Standard Model:

$$R_M := \frac{\Gamma(M \rightarrow e\nu_e(\gamma))}{\Gamma(M \rightarrow \mu\nu_\mu(\gamma))} = \frac{m_e^2}{m_\mu^2} \left( \frac{m_M^2 - m_e^2}{m_M^2 - m_\mu^2} \right)^2 \left( 1 + \delta R_M \right)$$

where $\delta R_M$ arises from the radiative corrections, $M=\pi^\pm, K^\pm$

For $K^\pm$: $\delta R_K = -(3.78 \pm 0.04)\%$, leading to

$$R_K = (2.472 \pm 0.001) \times 10^5$$


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Motivation

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For \( K^\pm \): \( \delta R_K = -(3.78 \pm 0.04)\% \), leading to

\[ R_K = (2.472 \pm 0.001) \times 10^{-5} \]

- The value of \( R_K \) could be different in case of SUSY and LFV models – the correction could be as high as 3% in both directions
- Measurement of \( R_K \) tests the \( \mu\)-e universality and provides a sensible test of the SM
Measurements

**PDG-05 average**: 2.45 ± 0.11

Standard Model

\[ R_K = (2.472 \pm 0.001) \times 10^{-5} \]

Experiments with stopped kaons

- Experimental error on \( R_K \): *two orders of magnitude* larger than the theoretical
Beam setup

Beam spectrometer

400 GeV protons

K+ / K− ~ 1 mm

Width ~ 5 mm

$P_K$ spectra

$60 \pm 3$ GeV/c
Detector setup

- **Magnetic spectrometer**
  - 4 drift chambers
  - $p_{\perp}^{\text{kick}} = 121 \text{ MeV/c}$
  - $\Delta p/p = 1\% \oplus 0.044* p [\text{GeV/c}]$

- **Hodoscope**
  - $\sigma(t) = 150 \text{ ps}$

- **Liquid Krypton Calorimeter**
  - $\Delta E/E \approx 3.2%/\sqrt{E} \oplus 9%/E \oplus 0.42%$

- **Hadron Calorimeter, Muon counters, Anticounters, Kaon Beam Spectrometer**

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Experiment primarily designed for the measurement of the charge asymmetry in $K^\pm \rightarrow \pi^- \pi^+ \pi^\pm$ and $K^\pm \rightarrow \pi^0 \pi^0 \pi^\pm$ decays.

2003 run: ~ 50 days nominal conditions
~ 12 hour special run

2004 run: ~ 60 days nominal conditions
~ 56 hour special run

~ 200 TB of data recorded

The huge statistics (~4·10^9 $K^\pm \rightarrow \pi^+\pi^-\pi^\pm$) allows to study rare kaon decays with high precision.
2003 data: Trigger

- **Kμ2 events**: signal from the charged hodoscope
- **Ke2 events**
  - **L1 trigger**: hodoscope signal + Energy deposition in the EM calorimeter > 10GeV
  - **L2 trigger**: online kinematics reconstruction
    
    \[
    M_{\text{Fake}}^2 = M_K^2 + M_\pi^2 - S
    \]

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

    **K±→π±π0 events**: \( M_{\text{Fake}} \) peaks at 495 MeV

**L2 efficiency using Ke3 events**

L2 trigger efficiency

\[
(85.6 \pm 0.5\text{ (stat)} \pm 0.2\text{ (syst)})\% \]

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• The similarity between the decays allows to exploit systematics cancellation
  – Charged track with momentum 15 GeV<P<55 GeV
  – No extra clusters with $E_{cl} > 1.5$ GeV, no hits in the anticounters, no in time tracks.
  – Vertex reconstructed within 2000 cm < Zvtx < 8500cm

• Kµ2 selection:
  – Muon hypothesis
  – $|M_{miss}^2| < 0.02 \text{ (GeV/c}^2)^2$

• Ke2 selection:
  – PID: $E/P_c > 0.95$
  – Electron hypothesis
  – $|M_{miss}^2| < 0.02 \text{ (GeV/c}^2)^2$

E – energy deposition in LKR
P – momentum from the spectrometer

Found 5329 Ke2 candidates
2003 data: MC simulation

- Full Geant3 based simulation of the detector response

Difference in acceptance: $\Delta(R_K) = 1.116 \pm 0.002\text{(stat)} \pm 0.006\text{(syst)}$

- Radiative corrections

<table>
<thead>
<tr>
<th>Decay</th>
<th>B.R.</th>
<th>Acceptance</th>
<th>Correction</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ke$^2$g $E_g &gt; 3\text{MeV}$ (IB)</td>
<td>$1.56 \cdot 10^{-6}$</td>
<td>0.33 $\cdot$ A(Ke2)</td>
<td>+6.5%</td>
</tr>
<tr>
<td>Ke$^2$g SD</td>
<td>$1.5 \cdot 10^{-5}$</td>
<td>$2.4 \cdot 10^{-3}$ $\cdot$ A(Ke2)</td>
<td>-0.22%</td>
</tr>
<tr>
<td>K$\mu$2g $E_g &gt; 3\text{MeV}$ (IB)</td>
<td>$6.5 \cdot 10^{-3}$</td>
<td>0.37 $\cdot$ A(Km2)</td>
<td>-0.64%</td>
</tr>
</tbody>
</table>

$\Delta(R_K) = 1.063 \pm 0.005$
2003 data: Background in Ke2

Missing mass vs track momentum

Dominant background is Kµ2

Background events: 659 ± 26

Signal events: 4670 ± 77(stat) +29 -8 (syst)
**2004 data**

- Dedicated data taking period:
  - 60 GeV kaon beam with diminished intensity
  - No Level-2 trigger – using only minimum bias triggers
- Simpler selection – better control of the systematics
- Analysis performed in momentum bins
  - Better background subtraction
- Sample with similar statistics as in 2003

Efficiency: ~100%

Deposited energy (GeV/c^2)^2

Efficiency: ~100%

Deposited energy in GeV

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**Results**

\[
\frac{\Gamma(K^\pm \rightarrow e^\pm \nu(\gamma))}{\Gamma(K^\pm \rightarrow \mu^\pm \nu(\gamma))}
\]

<table>
<thead>
<tr>
<th>Standard Model (theory)</th>
<th>( (2.472 \pm 0.001) \times 10^{-5} )</th>
</tr>
</thead>
<tbody>
<tr>
<td>PDG</td>
<td>( (2.45 \pm 0.11) \times 10^{-5} )</td>
</tr>
<tr>
<td>NA48: 2003 data</td>
<td>( (2.416 \pm 0.043 \pm 0.024) \times 10^{-5} )</td>
</tr>
<tr>
<td>NA48: 2004 data</td>
<td><em>in progress</em></td>
</tr>
</tbody>
</table>

**SM prediction**

NA48 measurement is already **two times** more precise than the world average
Conclusion

• $K^\pm \rightarrow l^\pm \nu$ decays provide a very challenging opportunity to search for physics beyond the Standard Model

• Preliminary result for $R_K$ based on 2003 data sample presented

• 2004 data analysis very advanced

• A sub-percent precision measurement of $R_K$ will allow to probe for New Physics or rule out regions in the parameters space in different models