Tests of lepton universality at NA62

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Lepton flavour universality

One of the key properties of the SM is lepton flavour universality (LFU): **the couplings with the gauge bosons do not depend on the flavour of the leptons involved**

The possibility for LFU violation is motivated by several tensions between the theoretical expectations and the experimental results:

- **Muon magnetic moment**
- **Cabibbo angle anomaly**
- **B mesons anomaly**

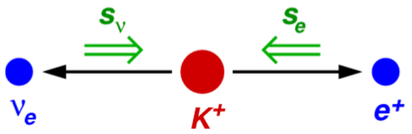
LFU tests in the kaon sector: the ratio R_K

A clean LFU tested is obtained measuring the ratio

$$R_K = \frac{\Gamma(K^+ \to e^+\nu_e)}{\Gamma(K^+ \to \mu^+\nu_\mu)}$$

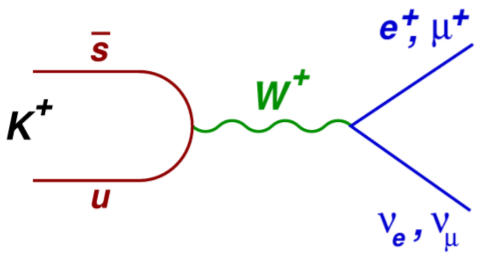
which is a good candidate for two main reasons:

- helicity suppression in the SM of $K^+ \to e^+\nu_e$



- very precise theoretical estimation

R_K in the Standard Model



$$R_K = \frac{\Gamma(K^+ \to e^+\nu)}{\Gamma(K^+ \to \mu^+\nu)} = \frac{m_e^2}{m_\mu^2} \cdot \left(\frac{m_K^2 - m_e^2}{m_K^2 - m_\mu^2}\right)^2 \cdot (1 + \delta R_K^{rad.corr.})$$

helicity suppression

- Very sensitive to new physics
- Hadronic uncertainties cancel in the ratio

SM prediction $R_K = (2.477 \pm 0.001) \times 10^{-5}$ Cirigliano and Rosell, Phys. Rev. Lett. 99, 231801

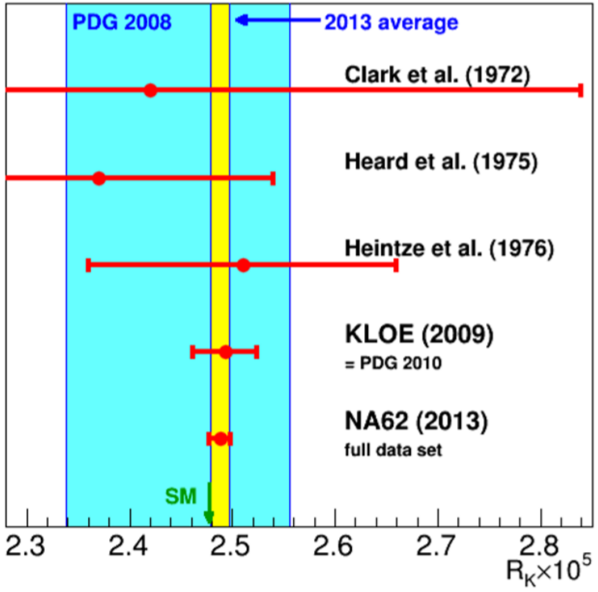
R_K beyond the SM

In BSM scenarios, R_K can receive contributions from

- leptoquarks
- 2HDM: dominant contributions from charged Higgs
- MSSM
- SM extensions with 4th generation, sterile neutrinos

Experimental status on R_K

NA62 provided the most precise measurement on R_K in 2013



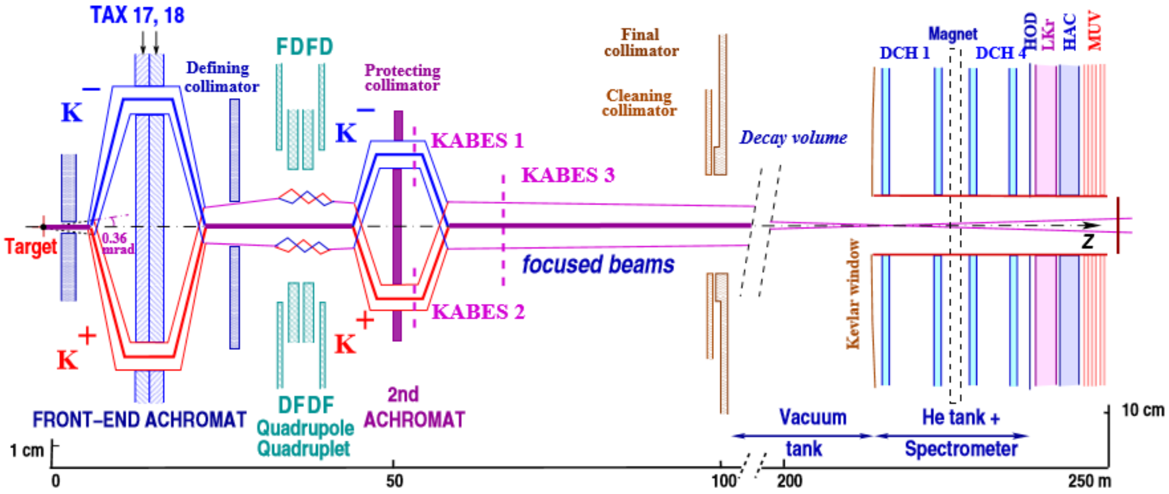
$$R_K^{exp} = (2.488 \pm 0.009) \times 10^{-5}$$

Remarkable experimental precision: **0.4%**

However **10x larger** than the theoretical uncertainty

The NA62-R_K experimental setup

Data taking with simultaneous K^+/K^- beams in 2007-2008



Kaon decays collected: 2 x 10^{10}

Analysis strategy

R_K measured using the following formula:

$$R_K = \frac{1}{D} \cdot \frac{N(K_{e2}) - N_B(K_{e2})}{N(K_{\mu 2}) - N_B(K_{\mu 2})} \cdot \frac{A(K_{\mu 2})}{A(K_{e2})} \cdot \frac{f_\mu \times \epsilon(K_{\mu 2})}{f_e \times \epsilon(K_{e2})} \cdot \frac{1}{f_{LKr}}$$

Main backgrounds:

- muon halo;
- muon misidentification as electrons in Lkr

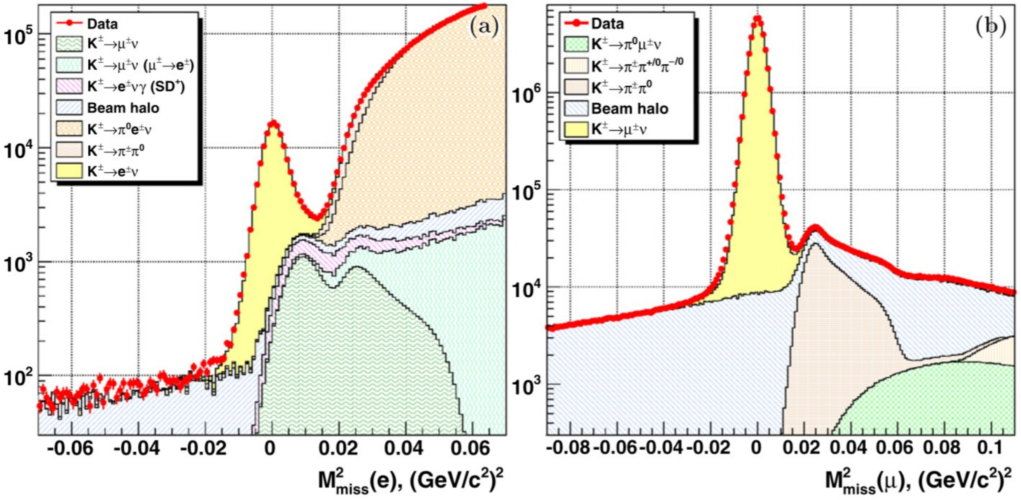
Mis-ID probability estimated using a specific dataset

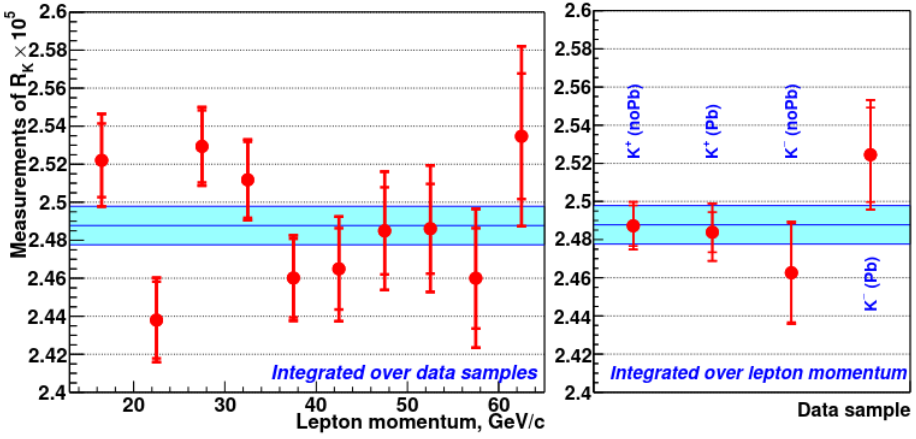
Event selection

- One downstream track, in acceptance of the downstream detectors, $13 < p < 65$ GeV/c
- CDA < 3.5 cm with respect to the beam axis (muon halo suppression)
- Reconstructed vertex in the decay volume
- No activity in the Lkr if not associated to the track
- Geometric cuts to suppress background from muon halo

Signal regions identified in the squared missing mass distributions

Results

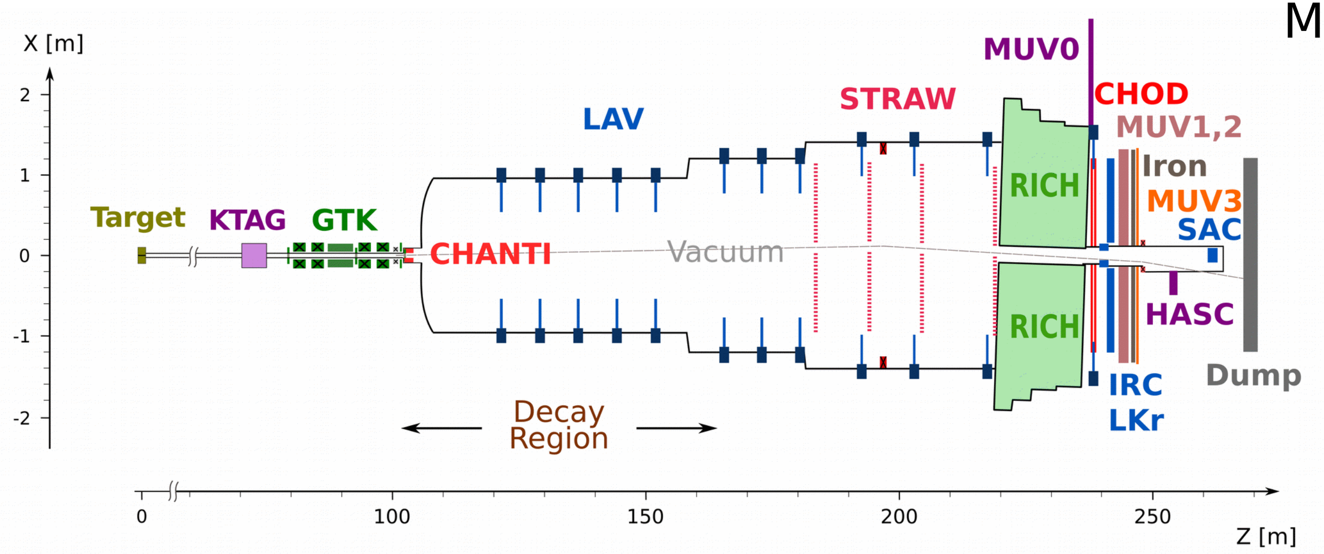




$$R_K = (2.488 \pm 0.010) \times 10^{-5}$$

Uncertainty dominated by the background in the K_{e2} region

The NA62 experiment



Main differences wrt NA62-RK:

- Beam spectrometer (GTK)
- Hermetic photon veto
- RICH detector for PID

Towards a better measurement of R_K

Source	$\delta R_K(\times 10^{-5})$
Statistical	**0.007**
$K_{\mu 2}$ background	0.004
$K^{\pm} \to e^{\pm}\nu\gamma(SD^{+})$ background	0.002
$K^{\pm} \to \pi^{0}e^{\pm}\nu,\ K^{\pm} \to \pi^{\pm}\pi^{0}$ backgrounds	0.003
Beam halo background	0.002
Spectrometer material composition	0.002
Acceptance correction	0.002
Spectrometer alignment	0.001
Electron identification inefficiency	0.001
Lkr readout inefficiency	0.001
1-track trigger inefficiency	0.001
Total systematic	**0.007**
Total	**0.010**

← Higher intensity beam

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Higher intensity beam (→ Statistical)

PID with RICH (→ $K_{\mu 2}$ background)

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PID with RICH (→ $K_{\mu 2}$ background)

Photon veto (→ $K^{\pm} \to e^{\pm}\nu\gamma(SD^{+})$ background; $K^{+} \to \pi^{0} e^{+} \nu,\ K^{+} \to \pi^{+}\pi^{0}$ backgrounds)

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Higher intensity beam (Statistical)

PID with RICH ($K_{\mu 2}$ background)

Photon veto ($K^{\pm} \to e^{\pm}\nu\gamma(SD^{+})$ background; $K^{+} \to \pi^{0}e^{+}\nu,\ K^{+} \to \pi^{+}\pi^{0}$ backgrounds)

KTAG, GTK (Beam halo background)

Towards a better measurement of R_K

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- Statistical → Higher intensity beam
- $K_{\mu 2}$ background → PID with RICH
- $K^\pm \to e^\pm \nu \gamma (SD^+)$ background, $K^+ \to \pi^0 e^+ \nu$, $K^+ \to \pi^+ \pi^0$ backgrounds → Photon veto
- Beam halo background → KTAG, GTK

Assuming conservatively the other contributions to be the same, a **factor 2 improvement (0.2%)** can be achieved

New measurement of R_K: strategy

The NA62 TDAQ system allows to collect data with different trigger streams

Each trigger stream is associated to a downscale factor in order to keep the data rate under control

Characteristics of an ideal trigger stream for R_K measurement:

- Same for K_{e2} and $K_{\mu 2}$ decays;
- no downscale;

"Pnn" trigger stream:

- ✔ D = 1
- ✗ Muon veto

To have the same trigger stream with D = 1, BR($K_{\mu 2}$) is extracted from events with muon decays in flight in the decay volume

New measurement of R_K: analysis status

R_K measured by:

$$R_K = \frac{N(K_{e2}) - N_B(K_{e2})}{N(K_{\mu e}) - N_B(K_{\mu e})} \cdot \frac{A(K_{\mu e})}{A(K_{e2})}$$

Common selection, signals regions defined in the squared missing mass distribution

Analysis ongoing: statistics collected much larger than NA62-R_K

Other LFU tests in the kaon sector

LFU can be checked also using other kaon decays:

- $K^+ \to \pi^+ l^+ l^-$ decays (see also M. D'Errico's talk)
- $K \to \pi l \nu$ decays (see also F. Brizioli's talk)

In particular, for the latter one has

$$r_{\mu e} = \frac{(R_{\mu e})_{obs}}{(R_{\mu e})_{SM}} = \frac{\Gamma_{\mu 3}}{\Gamma_3} \cdot \frac{I_{e3}(1+\delta_{e3})}{I_{\mu 3}(1+\delta_{\mu 3})}$$

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0.1% precision

few % precision

Currently, for charged kaons $r_{\mu e} = 0.999(9)$

Conclusions

LFU is a key parameter to search for New Physics

NA62 already contributed to LFU tests with the most precise measurement of R_K

Analysis ongoing to reduce the uncertainty thanks to the improved experimental setup

Other decays can be measured by NA62 to provide further tests of LFU