PRECISION MEASUREMENT OF $R_K=\Gamma(K_{e2})/\Gamma(K_{\mu 2})$ BY THE NA62 EXPERIMENT AT CERN

Birmingham, CERN, Dubna, Fairfax, Ferrara, Florence, Frascati, Mainz, Merced, Moscow, Naples, Perugia, Pisa, Protvino, Rome, Saclay, San Luis Potosi, SLAC, Sofia, Triumf, Turin

TIMELINE OF NA48/NA62 EXPERIMENTS

NA62
Beam: K^+
Primary goal: $K^+\to\pi^+\nu\bar{\nu}$
2006-2013: R & D
2012: First data taking

NA48/2
Beams: K^+ and K^-
Primary goals: Direct CP, K_{e4} studies, Rare K decays

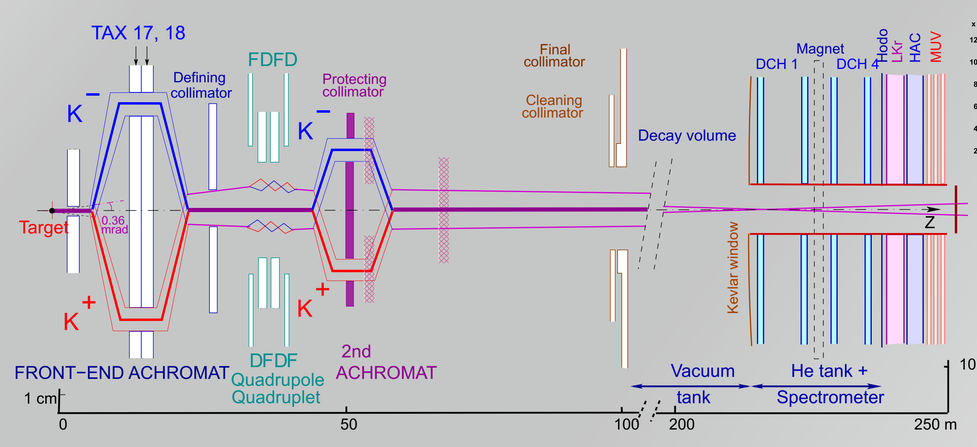
NA48
Beams: K_L and K_S
Primary goal: ε'/ε

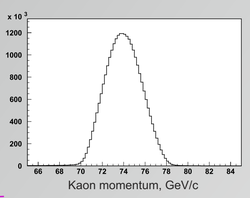
2013 2012 2011 2010 2009 2008 2007 2006 2005 2004 2003 2002 2001 2000 1999 1998 1997

NA62 (R_K)
Beam: K^+ and K^-
Primary goal: LFV test
$R_K=\Gamma(K_{e2})/\Gamma(K_{\mu 2})$
Tests for NA62
NA48/2 detector and beam line used

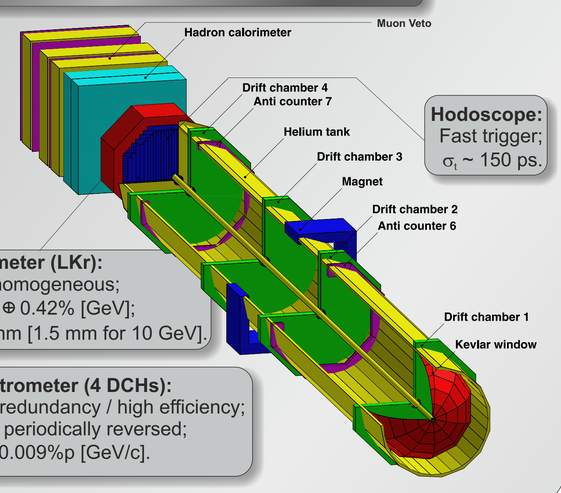
NA48/1
Beams: K_S
Primary goal: Rare K_S and Hyperon decays

NA62 BEAM LINE SCHEMATICS





NA48/62 DETECTOR SETUP



Hodoscope:
Fast trigger;
σ_t ~ 150 ps.

Liquid Krypton Calorimeter (LKr):
High granularity, quasi-homogeneous;
$\sigma_E/E = 3.2\%E^{-1/2} \oplus 9\%E^{-1} \oplus 0.42\%$ [GeV];
$\sigma_x = \sigma_y = (4.2E^{-1/2} \oplus 0.6)$ mm [1.5 mm for 10 GeV].

Magnetic spectrometer (4 DCHs):
4 views / DCH: redundancy / high efficiency;
magnet polarity periodically reversed;
$\sigma_p/p = 0.48\% \oplus 0.009\%p$ [GeV/c].

PHYSICS MOTIVATION

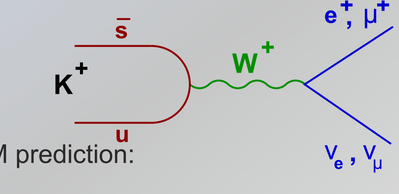
R_K in the Standard Model:

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

Radiative correction (few %) due to $K^+\to e^+\nu\gamma$ (IB) by definition included into R_K.
The ratio is sensitive to New Physics:

- the SM contribution is strongly suppressed (helicity suppression by ~10^{-5});
- hadronic uncertainties cancel in the ratio, which leads to very accurate SM prediction: $R_K^{SM} = (2.477 \pm 0.001) \times 10^{-5}$ [Phys. Rev. Lett. 99 (2007) 231801].

R_K very well suited for stringent test of lepton flavour universality.

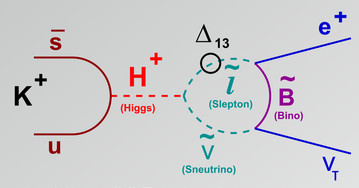


R_K beyond the Standard Model:

In MSSM – H^+ mediated lepton flavor violating contribution with emission of ν_τ.
[PRD 74 (2006) 011701, JHEP 0811 (2008) 042]

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

~1% effect in MSSM [arXiv:1202.4906]; limited by recent $B_s\to\mu^+\mu^-$ measurements [arXiv:1205.1411]



ANALYSIS STRATEGY

K_{e2} and $K_{\mu 2}$ candidates are collected simultaneously.
No dependency on K flux and cancellation of several effects at first order.

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

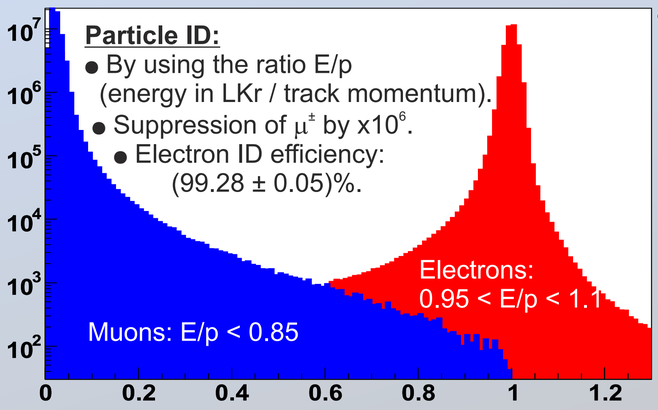
- Selected K_{l2} candidates
- Background events
- Acceptances (MC)
- ID eff.
- Trigger eff.
- Global LKr eff. f_{LKr}=0.9980(3)
- Downscaling of $K_{\mu 2}$ trigger

Strong momentum dependency of various backgrounds.
R_K calculated in 10 lepton momentum bins separately for K^+ and K^-, and for periods with and without Pb bar installed, as it strongly affects the acceptances.
Main source of systematic errors: $N_B(K_{e2})$.

SELECTION AND PARTICLE IDENTIFICATION

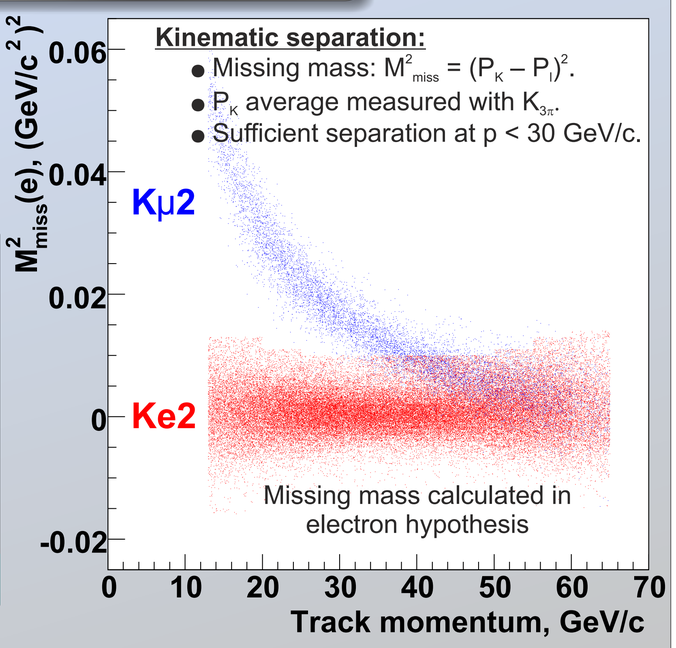
Common selection part:

- One reconstructed track.
- Geometrical acceptance cuts.
- Decay vertex defined as closest distance of approach of track and nominal kaon axis.
- Veto extra LKr energy deposition.
- Track momentum 13 < p < 65 GeV/c.



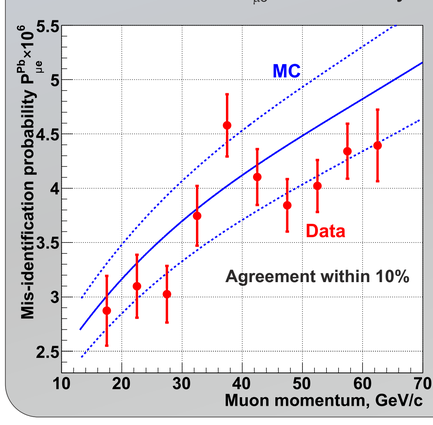
Kinematic separation:

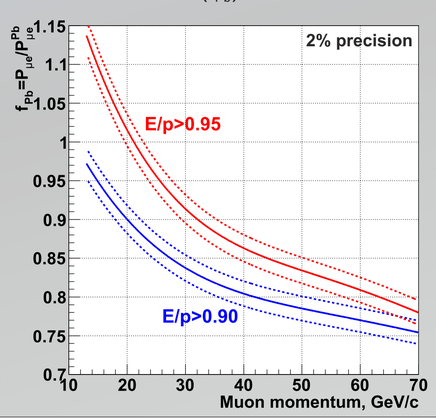
- Missing mass: $M^2_{miss} = (P_K - P_l)^2$.
- P_K average measured with $K_{3\pi}$.
- Sufficient separation at p < 30 GeV/c.

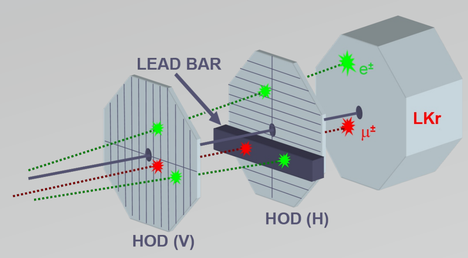


Main background source: 'catastrophic' muon bremsstrahlung with significant LKr energy deposit by the photon.

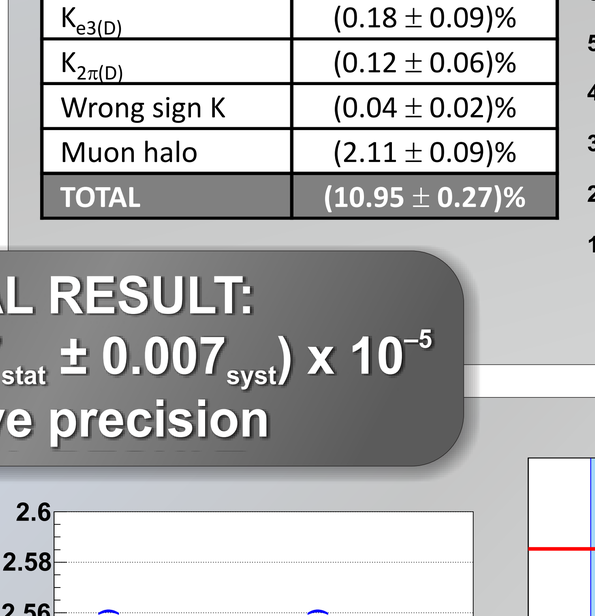
- Direct measurement of $P_{\mu e}$: ~ 3×10^{-6} and momentum-dependent.
- Pb bar (9.2 X_0) installed in front of LKr during ~50% of data taking: suppression of electron contamination.
- Selected $K_{\mu 2}$ candidates, track traversing Pb, p>30 GeV/c, E/p>0.95; electron contamination <10^{-8}.
- $P_{\mu e}$ is modified by the Pb bar due to ionization losses (at low p) and bremsstrahlung in Pb (at high p).
- Correction to $P_{\mu e}$ obtained by Geant4 simulation (f_{Pb}).



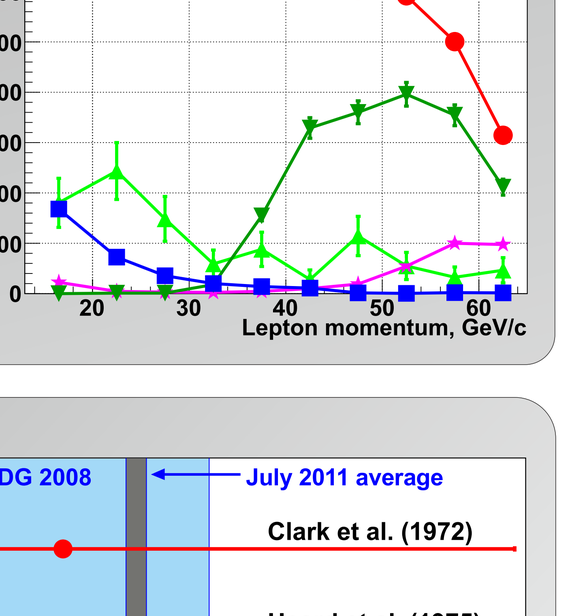




K_{e2} SAMPLE
145'958 candidates
10.95% background



$K_{\mu 2}$ SAMPLE
42.817 x 10^6 candidates
0.50% background



BACKGROUND BREAKDOWN IN K_{e2} SAMPLE

Source	B/(S+B)
$K_{\mu 2}$	(5.64 ± 0.20)%
$K_{\mu 2}$ ($\mu\to e$)	(0.26 ± 0.03)%
$K_{e2\gamma}$ (SD^+)	(2.60 ± 0.11)%
$K_{e3(D)}$	(0.18 ± 0.09)%
$K_{2\pi(D)}$	(0.12 ± 0.06)%
Wrong sign K	(0.04 ± 0.02)%
Muon halo	(2.11 ± 0.09)%
TOTAL	(10.95 ± 0.27)%

NA62 FINAL RESULT:
$R_K = (2.488 \pm 0.007_{stat} \pm 0.007_{syst}) \times 10^{-5}$
0.4% relative precision

Uncertainty source	$\delta R_K\times10^5$
Statistical	0.007
$K_{\mu 2}$ background	0.004
Muon halo background	0.002
$K_{e2\gamma}$ (SD^+) background	0.002
K_{e3} and $K_{2\pi}$ background	0.003
Matter composition	0.003
Acceptance correction	0.002
DCH alignment	0.001
Electron identification	0.001
1-track trigger efficiency	0.001
LKr readout inefficiency	0.001
Total	0.010