SEARCHES FOR LEPTON FLAVOUR AND LEPTON NUMBER VIOLATION IN K^+ DECAYS

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NA62 Experiment

- Main goal: measure ultra-rare $K^+ \to \pi^+ \nu\bar{\nu}$ with 10% precision, yet NA62 covers a broad kaon and beam-dump physics programme.
- Data-taking period 2016-18: $K^+ \to \pi^+ \nu\bar{\nu}$ analysis result published [1]. New data-taking period started in July 2021.

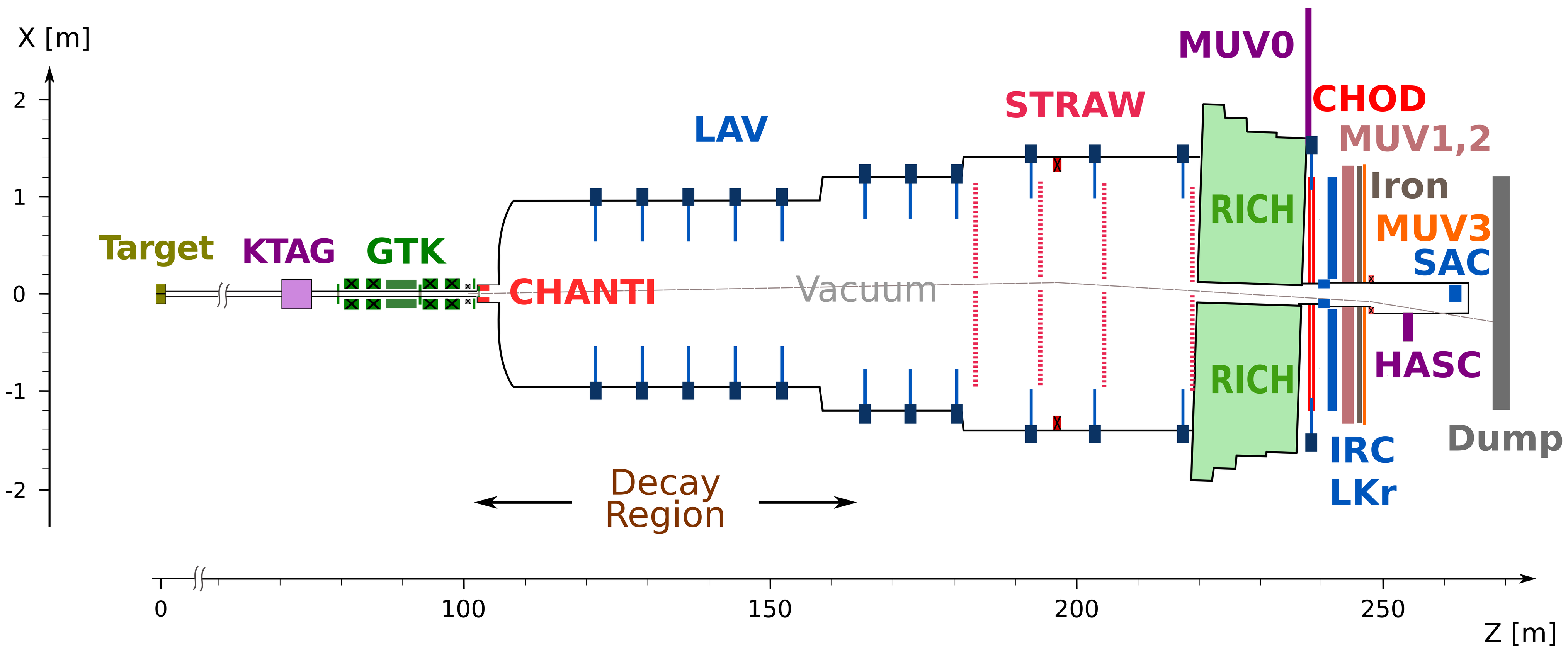

Figure 1: NA62 experimental setup (2017) [2].

- Fixed-target experiment at CERN SPS (north area).
- Primary p^+ beam 400 GeV/c impinges Be target and 75 GeV/c secondary beam is selected (750 MHz with $\sim 6\%$ of K^+).
- K^+ tagged by KTAG (70 ps time resolution) and 3-momentum determined by Si pixel beam spectrometer GTK.
- K^+ decay-in-flight in 60 m long decay region.
- Decay products' 3-momenta are measured by STRAW tracker and their time is measured by CHOD.
- RICH identifies π^+ and further hadron ID is given by combination of calorimeters LKr, MUV1, MUV2. Muon ID is provided by MUV3 placed behind iron wall.
- Photons can be vetoed by LKr and at large angles by 12 LAV stations or by SAC/IRC at small angles.
- Overall experimental time resolution reaches $\mathcal{O}(100)$ps.

Lepton flavour & lepton number violation in K^+ decays

Lepton number (LN) L is a charge corresponding to an accidental $U(1)$ symmetry of the Standard Model (SM), moreover it is conserved for each flavour L_e, L_μ, L_τ in the SM processes. Notable example of lepton flavour (LF) violation are neutrino oscillations. Observation of LF or LN violation also in charged processes would reveal more about the underlying mechanism, like e.g.:

- Type-I seesaw mechanism:

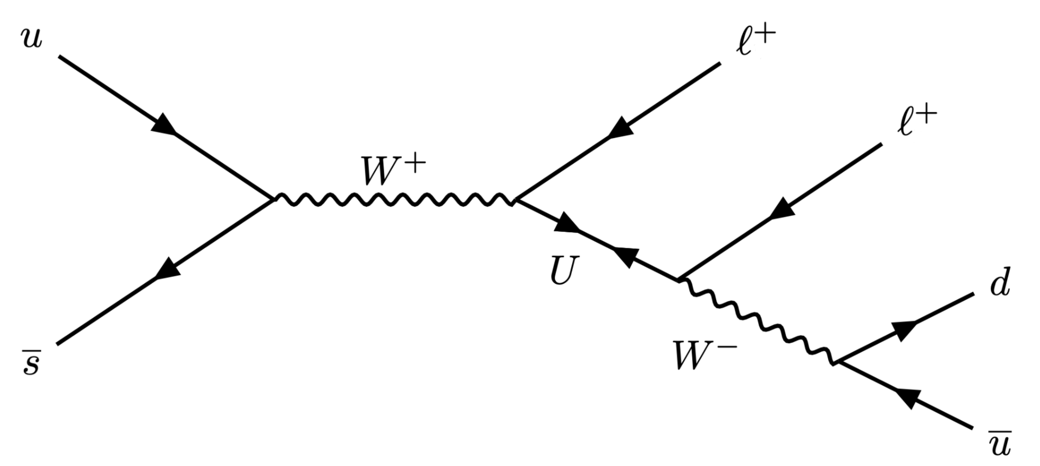

Figure 2: LN violating ($\Delta L = 2$) $K^+ \to \pi^- l^+ l^+$ decay mediated by Majorana neutrino U [3].

- or leptoquark mechanism:

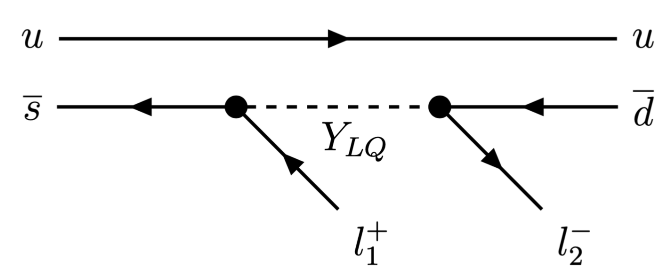

Figure 3: Lepton flavour violating $K^+ \to \pi^+ l_1^+ l_2^-$ decay (e.g. $K^+ \to \pi^+\mu^-e^+$: $\Delta L_e = 1$, $\Delta L_\mu = 1$) mediated by leptoquark Y_{LQ} [4].

$K^+ \to \pi^- e^+ e^+$ decay

Searched for in 2017 NA62 data. The expected number of background events in signal region (SR) is $n_{\rm bg} = 0.16 \pm 0.03$ with background arising from $\pi \rightleftarrows e$ misidentification (see fig.4). No signal is observed resulting in upper limit $\mathcal{B}_{K^+\to\pi^-e^+e^+} < 2.2 \times 10^{-10}$ @90% CL.

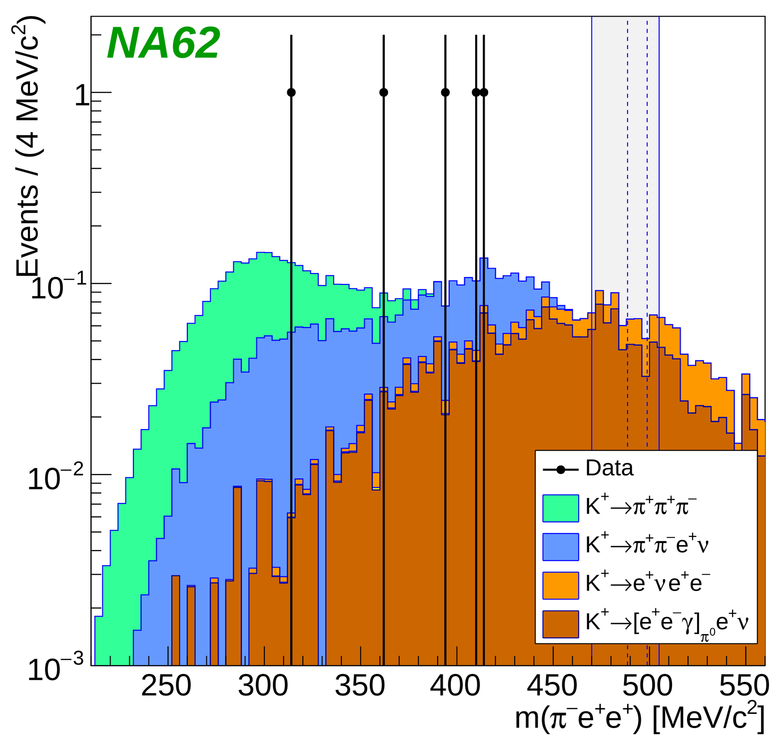

Figure 4: Reconstructed mass spectra of $\pi^-e^+e^+$ final state and SR bounded by dashed lines [5].

$K^+ \to \pi^- \mu^+ \mu^+$ decay

Searched in the same dataset as $K^+ \to \pi^- e^+ e^+$ with similar analysis strategy. $\pi \rightleftarrows \mu$ misidentification and $\pi \to \mu\nu$ decays are background sources with expected $n_{\rm bg} = 0.91 \pm 0.41$ in SR. One event is observed in SR, giving in upper limit $\mathcal{B}_{K^+\to\pi^-\mu^+\mu^+} < 4.2 \times 10^{-11}$ @90% CL.

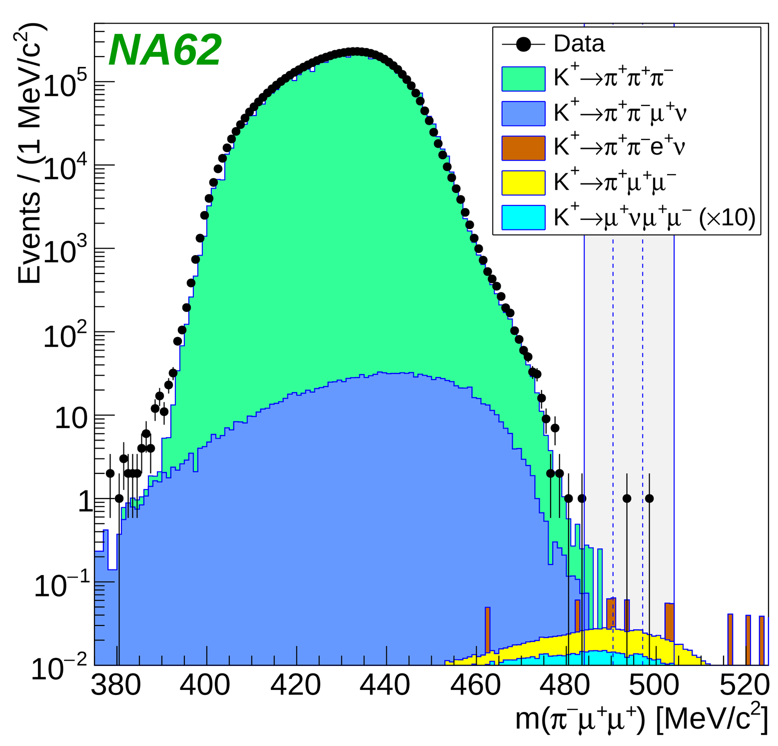

Figure 5: $\pi^-\mu^+\mu^+$ final state mass spectra, data overlaid with simulated background estimates [5].

$K^+ \to \pi^\pm \mu^\mp e^+$ decays

Searched in 2017-18 NA62 datasets using blind analysis strategy.
For $K^+ \to \pi^+\mu^-e^+$ decay $n_{\rm bg} = 0.92 \pm 0.34$ in SR are expected and 2 events are observed (see fig.6), resulting in $\mathcal{B}_{K^+\to\pi^+\mu^-e^+} < 6.6 \times 10^{-11}$ upper limit @90% CL.

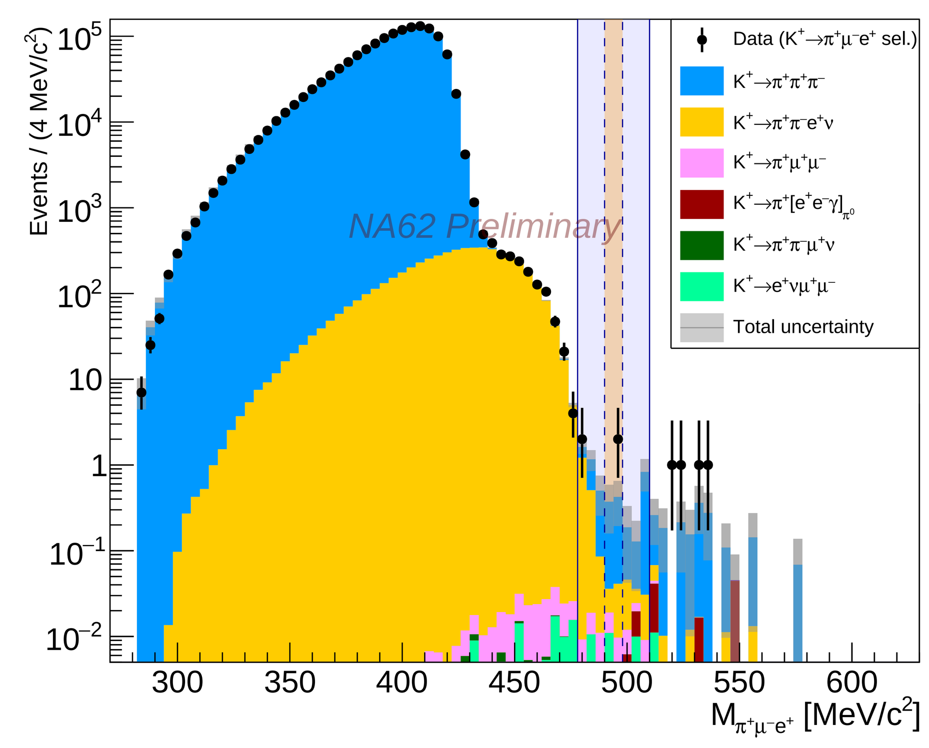

Figure 6: $M_{\pi^+\mu^-e^+}$ distribution in search for $K^+ \to \pi^+\mu^-e^+$ for data and simulated background samples and indicated signal and control regions [6].

For $K^+ \to \pi^-\mu^+e^+$ decay $n_{\rm bg} = 1.06 \pm 0.20$ is expected, 0 are observed (see fig.7), resulting in $\mathcal{B}_{K^+\to\pi^+\mu^-e^+} < 4.2 \times 10^{-11}$ @90% CL.

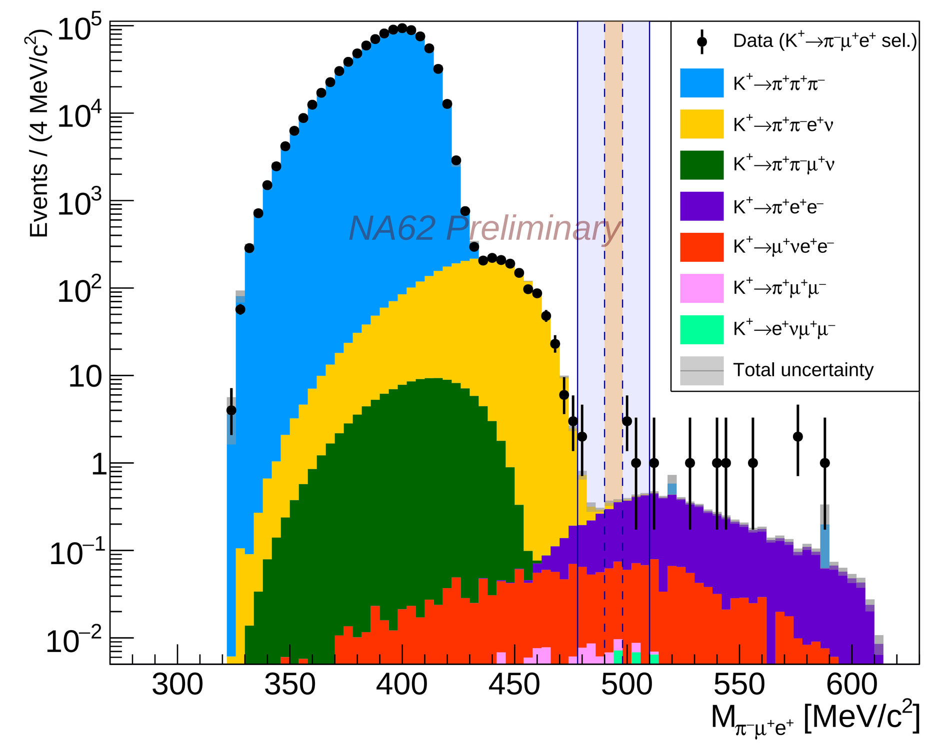

Figure 7: $M_{\pi^-\mu^+e^+}$ distribution for simulated background samples and observed data [6].

References

[1] Measurement of the very rare $K^+ \to \pi^+\nu\bar{\nu}$ decay. NA62 Collaboration. JHEP 06 (2021) 093. arXiv:2103.15389 [hep-ex].
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