4 Rare Kaon Decays

A. Sher and P. Truöl

in collaboration with:
J. Egger, W. D. Herold, H. Kaspar, and H. Weyer, Paul–Scherrer–Institut, CH-5234 Villigen
Brookhaven National Laboratory, Upton, NY-11973, USA, University of New Mexico, Albuquerque, NM-87131, USA, University of Pittsburgh, Pittsburgh, PA-15260, USA, Yale University, New Haven, CT-06511, USA, Institute for Nuclear Research, Academy of Sciences, 117 312 Moscow, Russia

Experiment E-865 at Brookhaven AGS

Experiment E865 at the Brookhaven AGS [1] was set up primarily to search for the lepton flavor violating decay $K^+ \to \pi^+\mu^+e^-$ ($K_{\pi\mu e}$) [2] with more than an order of magnitude increased sensitivity. The flexibility of the apparatus allowed also to obtain high statistics event samples on the following final states, where existing data were scarce:

$\pi^+e^+e^-$ ($K_{\pi ee}$) [3]
$\pi^+\mu^+\mu^-$ ($K_{\pi\mu\mu}$) [4]
$\pi^+\pi^-e^+\nu_e$ (K_{e4})
$\mu^+e^+e^-\nu_\mu$, $e^+e^+e^-\nu_e$ ($K_{\ell\nu\gamma^*}$)

From the $K_{\pi\mu\mu}$ and the K_{e4} samples we have also extracted considerably reduced upper limits for other lepton flavor violating modes like $\pi^+e^+\mu^-$, $\pi^-\mu^+e^+$, $\pi^-\mu^+\mu^+$, and $\pi^-e^+e^+$ [5].

The analysis of the $K_{\ell\nu\gamma^*}$ data is still in progress. Preliminary results indicate, that we will be able to determine for the first time separately the electroweak vector and axialvector kaon formfactors F_V and F_A, while previous experiments [6] with real photons in the final state were sensitive to $|F_A + F_V|$ only.

Though considerable progress in the reduction of the immense amount of data has been made last year (Thesis A. Sher, University of Zürich), the analysis of the final $K_{\pi\mu e}$ data set taken in 1998 has not been completed yet. We expect however to improve the sensitivity by at least a factor of three beyond our published limit of 2.8×10^{-11} [2].

The analysis of the K_{e4} data, performed by S. Pislak, has been completed and lead to the new, quite precise value for the s-wave $\pi\pi$ scattering length [7]:

$$a_0^0 = 0.228 \ \pm\ 0.012\ (\text{stat.})\ \pm\ 0.003\ (\text{syst.}),$$

which agrees well with the latest prediction from chiral perturbation theory (ChPT) [9]:

$$a_0^0 = 0.220\ \pm\ 0.005\ .$$

Figure 4.1 shows the phase shift difference $\delta_0^0 - \delta_1^1$ as a function of the $\pi^+\pi^-$ invariant mass extracted from our data in comparison to those from an older experiment [8] with twelve times less statistics, which measured $a_0^0 = 0.26\ \pm\ 0.05$. Aside from the scattering length we have extracted the momentum transfer dependence of the axialvector and vector decay form factors, which are an essential ingredient for the determination of the coefficients of the ChPT Hamiltonion to order $\mathcal{O}(p^4)$ [10]. A recent theoretical calculation by Colangelo *et al.* [12] already made use of our data, and of higher energy $\pi\pi$ scattering data to constrain the isotensor $\pi\pi$-channel through a reanalysis of the Roy equation [11]. The goal was to determine the size of the quark condensate $< 0|\bar{u}u|0 >$, which enters the Gell-Mann, Oakes and Renner (GOR) formula:

$$M_\pi^2 \approx (m_u + m_d)| < 0|\bar{u}u|0 > |/F_\pi^2\ .$$

The new precise value for the scattering length limits the range of possible values for the quantity $\bar{\ell}_3$, which is one of the coupling constants occuring in the effective chiral Lagrangian at order p^4. It relates the quantities in the GOR-expression, and confirms it nicely.

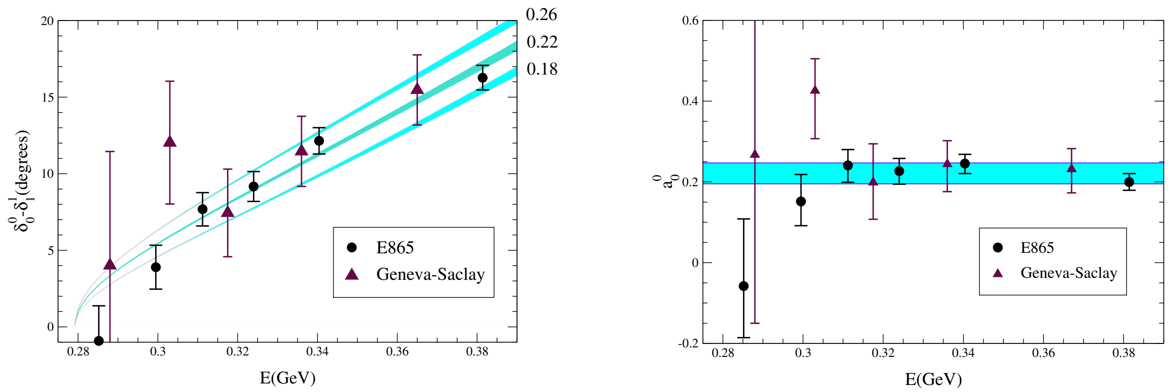

Figure 4.1: *Left: Phase shift difference* $\delta_0^0 - \delta_1^1$ *as a function of the* $\pi^+\pi^-$ *invariant mass. The curves show calculations [11] for three values of the S-wave scattering length* a_0^0*. The uncertainty band comes from experimental input at higher energies used in the Roy equations. Right: each phase shift value has been converted into a value for the scattering length. The horizontal band indicates the statistical average. Figures taken from [12]. (Geneva-Saclay: ref. [8]).*

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