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STATUS OF ASYMMETRY MEASUREMENT AND RARE DECAYS AT NA48/2 EXPERIMENT

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FOR NA48/2 COLLABORATION

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A high statistics study of charged kaon decays, using a novel design for simultaneous K^+/K^- beams and an upgraded NA48 setup, is in progress. The main goal is to measure the CP-violating asymmetry in the matrix element linear slope of the $K^\pm \to \pi^+\pi^-\pi^\pm$ decays with an accuracy of 2.2×10^{-4}. In addition, the analogous CP-violating asymmetry is measured in $K^\pm \to \pi^0\pi^0\pi^\pm$ decays. More than 10^6 K_{e4} decays allow to measure the scattering length parameter a_0^0 with an accuracy better than 0.01, and some other rare decays of charged kaons are studied as well.

Keywords: NA48/2, CP-violating asymmetry, charged kaons, rare decays.

1. Introduction

A high precision study of charged kaon decays has been proposed using a novel design for simultaneous K^+/K^- beams and an upgraded NA48 set-up [1] at CERN SPS. The main goal is to search for the direct CP-violation in $K^\pm \to \pi^+\pi^-\pi^\pm$ decays. The experiment is designed to reach a sensitivity, limited by statistics rather than systematics, of $\sim 10^{-4}$ in the measurement of the direct CP-violating asymmetry

$$A_g = (g^+ - g^-)/(g^+ + g^-),$$

where g^+ and g^- are the slope parameters describing, respectively, the linear dependence of the K^+ and K^- decay probabilities on the u kinematic variable which is related to the energy (E^*_π) of the *odd* pion (the pion having the sign opposite to that of the decaying kaon) in the kaon system as follows:

$$u = (2M_K/m^2)\cdot(M_K/3 - E^*_\pi),$$

where M_K and m are the kaon and pion masses, respectively.

The present knowledge of several rare decays of the charged kaon can be extended as well. This will allow χPT predictions at next-to-leading order to be tested.

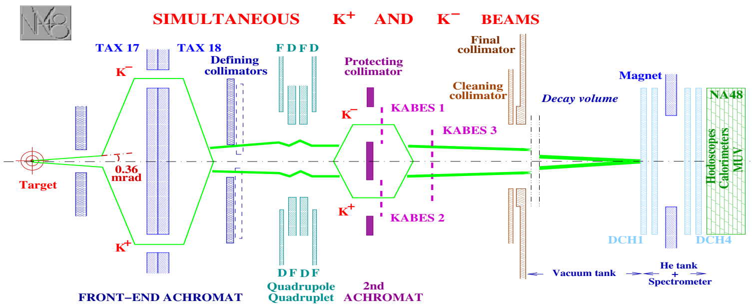

Fig. 1. Schematic vertical section of the simultaneous K^+ and K^- beam line (not to scale).

2. Simultaneous K^+/K^- beams

The new K12 beam line has been designed and built to transport simultaneously positive and negative particles with central momentum 60 GeV/c to the NA48/2 detector. The charged particles are produced at the target station T10 by 400 GeV/c primary protons – transported via the P42 beam line – at a chosen nominal intensity of $7 \cdot 10^{11}$ppp (with 16.8 s cycle time and 4.8 s flat-top)(fig. 1).

3. Data Taking

The statistics for the present analysis was collected during a one month of NA48/2 run in 2003. In order to minimize systematic uncertainties related to the apparatus asymmetry and beam structure, the spectrometer magnet current was alternated on a daily basis, and all the beam line magnets were cycled and inverted once per week.

The 3π invariant mass spectra were reconstructed for $K^+ \rightarrow \pi^+\pi^+\pi^-$ and $K^- \rightarrow \pi^-\pi^-\pi^+$ decays by implementing simple selection criteria (leaving ~ 720 and ~ 400 million $K^+_{3\pi}$ and $K^-_{3\pi}$ charged decays, respectively).

4. Asymmetry measurement

The search for the CP-violating asymmetry A_g, leads us to consider the ratios:

$$R(u) = constant \cdot (N^+(u)/N^-(u)),$$

where $N^+(u)$ and $N^-(u)$ are the u spectra of $K^+ \rightarrow \pi^+\pi^+\pi^-$ and $K^- \rightarrow \pi^-\pi^-\pi^+$ decays, respectively, and the *constant* provides the normalization of $R(0) = 1$. We may consider two such ratios:

$$R_R(u) = N^+(u)_U/N^-(u)_D \text{ and } R_L(u) = N^+(u)_D/N^-(u)_U,$$

where the subscripts U and D indicate the direction of the field (*Up* and *Down*) in the spectrometer magnet. The subscripts R and L are chosen to indicate the direction of deflection (*Right* and *Left*) of corresponding kaons by the spectrometer magnet.

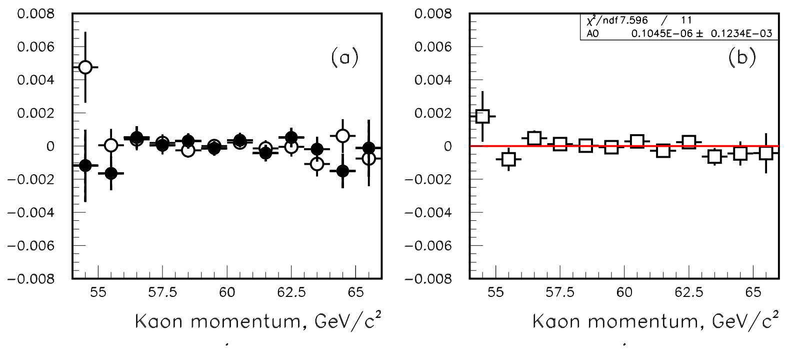

Fig. 2. *(a) The slopes A_R (•) and A_L (○), (b) their average in kaon momentum bins (an offset is introduced on the vertical scales).*

The corresponding slopes A_R, A_L, would be identical and, to first order, equal to Δg, which is related to A_g according to:

$$\Delta g = g^+ - g^- = 2g \cdot A_g,$$

where g is the average of g^+ and g^- ($g \simeq -0.2$ [2]). A deviation from zero in the average of these slopes would signal the CP-violating asymmetry, as long as both the set-up and the beams are either *stable in time* or *symmetric*. At this preliminary stage of the analysis the Collaboration considers it premature to show any number which could be ascribed to a real physics effect. Therefore, the above-mentioned slopes are shown with here offsets applied to the scale (fig. 2a, b).

All systematic uncertainties are estimated on the basis of Monte Carlo simulation and do not exceed the statistical presision of the A_g, which is equal to 2.7×10^{-4}.

5. Rare decays

High statistics ($\sim 10^6$) of K_{e4} can be analyzed allowing the $\pi - \pi$ scattering length parameter a_0^0 to be measured with an accuracy of better than 0.01. This permits the size of the $q\bar{q}$ condensate of the QCD vacuum postulated in χPT to be measured.

The accumulated samples of charged kaon rare decays: $K^\pm \to \pi^\pm e^+ e^-$, $K^\pm \to \pi^\pm \mu^+ \mu^-$, $K^\pm \to \pi^\pm \pi^0 \gamma$, $K^\pm \to \pi^\pm \gamma\gamma$ will allow tests of next-to-leading order predictions of Chiral Perturbation Theory to be undertaken.

High sensitivity studies and searches for the rare decays $K^\pm \to \pi^\pm \gamma l^+ l^-$, $K^\pm \to \pi^\pm \gamma\gamma\gamma$, $K^\pm \to l\nu l^+ l^-$, $\pi^\pm \to l\nu l^+ l^-$ are also performed on the 2003 data.

References

1. J. R. Batley *et al. Phys.Lett.* **B 544**, 97 (2002).
2. K. Hagiwara *et al.*, Particle Data Group Phys. Rev. D **66** (2002) 010001.