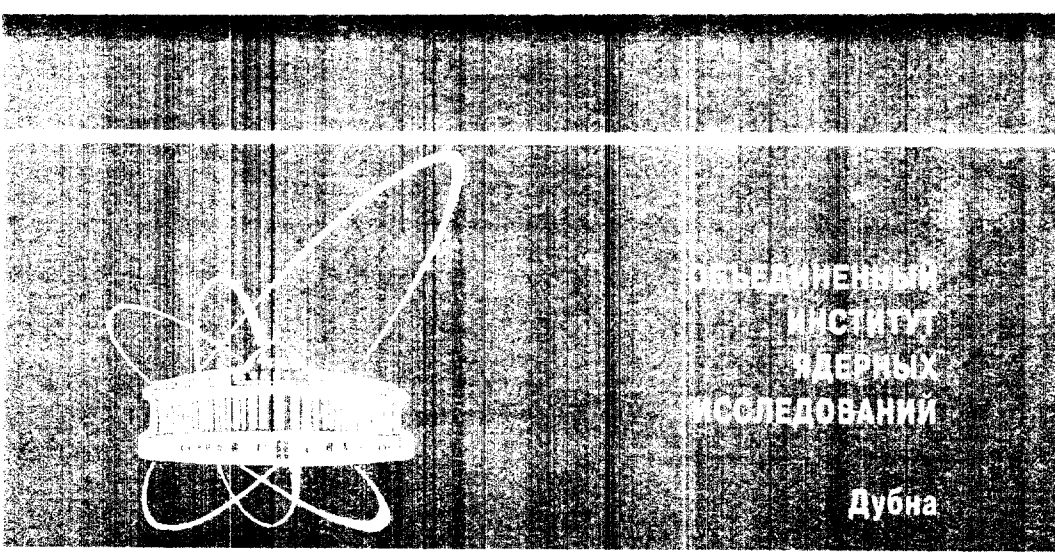

AB

E1-96-252

MEASUREMENT OF DALITZ-PLOT SLOPE PARAMETERS FOR $K^+ \to \pi^+ \pi^0 \pi^0$ DECAY

Serpukhov-167 Collaboration

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Introduction

Although extensive experimental data are available on K meson decays, physicists keep interest in this topic for many reasons. K decays provide very important information in such problems as CP-violation, $\Delta I = 1/2$ rule etc. There are also some new theoretical ideas on the effective QCD Lagrangian approach to K decay physics, which should be verified. Good way in new models verification is studying of non-leptonic $K_{3\pi}$ decays. The Dalitz plot slope parameters of these decays have recently attracted new theoretical interest /1-2/. The matrix element of such decays can be written in the form

$$|A|^2 = C(1 + gX + hX^2 + kY^2), \qquad (1)$$

where

$$X = (s_3 - s_0)/m_{\pi^+}^2; \quad Y = (s_2 - s_1)/m_{\pi^+}^2; \quad s_0 = (m_K^2 + m_{\pi^+}^2 + 2m_{\pi^0}^2)/3;$$

$$s_i = (p_K - p_i)^2; \quad p_i \text{ - 4-momenta; } i=1,2 \text{ for } \pi^0 \text{ meson; } i=3 \text{ for } \pi^+ \text{ meson.}$$

The measuring of all three slope parameters g, h and k is necessary to find out how different dynamical mechanisms contribute to the decay amplitude. CP-violating effects are of primary interest here. For instance the asymmetry in g parameters of CP-conjugated charged kaon decays would be an evidence of the direct CP-violation existence. Predictions for this asymmetry given by different models/2,3/ differ in orders of magnitude.

But one can't make reliable evaluation with existing experimental data, because of the quadratic coefficients h and k are measured with too low precision and there are discrepancies in the published values of linear coefficient g in $K^+ \to \pi^+\pi^0\pi^0$ decay matrix element.

To improve the situation we carried out an experiment, in which kinematical parameters of all particles were measured, to study the $K^+ \to \pi^+\pi^0\pi^0$ decay Dalitz-plot.

Experimental procedure

The experiment was made in Serpukhov with "HYPERON-2" spectrometer. The scheme of our experimental facilities is shown in fig.1.

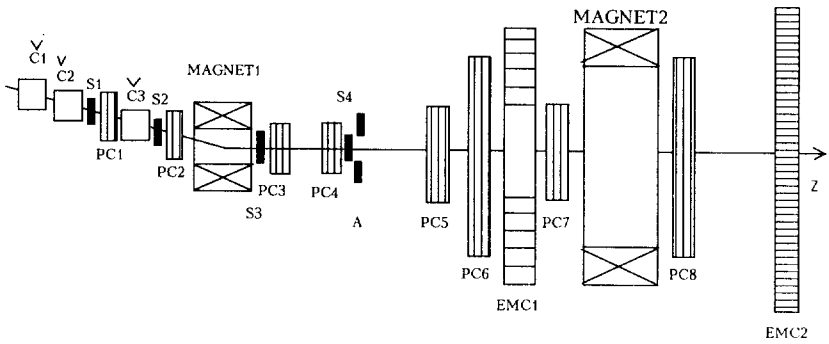

Fig. 1.

Layout of "HYPERON-2" spectrometer

The unseparated 10 GeV/c positive particles beam contains about 5% of K mesons which can be picked out by the threshold gas Cherenkov counters $\check{C}1$-$\check{C}3$.

The beam spectrometer consists of scintillator counters S1-S4, beam analysing magnet MAGNET1 and 16 planes of wire proportional chambers PC1-PC4. The secondary particles spectrometer is based on spectrometric magnet MAGNET2. There are 19 proportional chambers in front of (12 planes) and behind (7 planes) the magnet. A distinctive feature of the whole arrangement is a set of two big (884 amplitude channels in total) lead glass hodoscope electromagnetic calorimeters (EMC1 and EMC2), which are used simultaneously. To let forward photons and charged particles pass through the spectrometer the EMC1 has a $50\times50 cm^2$ hole in its center. All lead glass blocks have 14 radiation lengths along the beam direction; their cross sections are different: $100\times100\,mm^2$ in EMC1 and $85\times85\,mm^2$ and $42.5\times42.5\,mm^2$ in EMC2. Spectrometer characteristics are described in details in /4/.

The trigger is defined by the following requirements:

1) beam particle is K^+ meson,
2) number of gammas $N_\gamma \geq 3$ in both calorimeters (to determine N_γ on the trigger level all cells in EMC2 were joined into 5 groups and EMC1 was included as one group),
3) energy summed in each group of cells must be above a definite threshold (adjustable).

Data processing

Data processing was made with the programme set completely developed by our group. Some data processing methods we used are described in /5-9/.

The $K^+ \to \pi^+\pi^0$ decay which is not completely suppressed by the trigger give us a very good possibility of e/m-calorimeters calibration. We made it by fitting γ-quanta effective mass to π^0 mass.

To get the most unambiguous sample we have chosen events with the following requirements:

1. One beam track and one secondary track are detected in proportional chambers.
2. Decay point is in the region between beam spectrometer and secondary particle spectrometer.
3. The angle between beam track and secondary one is more than 4mrad.
4. Four gammas with energies larger than 500 MeV are detected in both e/m calorimeters.
5. π^+-momentum is measured in MAGNET2.
6. The chosen 6C-fit event fits $K^+ \to \pi^+\pi^0\pi^0$ hypothesis at the confidence level 97%.

Using these criteria we have collected slightly more than 33000 events of $K^+ \to \pi^+\pi^0\pi^0$ decay. Each Dalitz plot bin represents the ratio of observed event number to a number of events generated with constant matrix element.

The Monte-Carlo simulation takes into account the same trigger and reconstruction criteria and detector efficiencies as for the real events.

Background

We have - under above listed conditions - no contribution of other K decays. To estimate the diffraction scattering $K^+N \to K^+N\pi^0\pi^0$ contribution we simulated this process with our data processing requirements. It is found to be negligible. We also changed the decay region length, so that it included scintillator counter and some chambers, to study the final results dependence on amount of matter in the beam and the results did not change.

Results

Approximating the Dalitz-plot with the matrix element form (1) we obtained:

$$g = 0.736 \pm 0.014 \pm 0.012,$$
$$h = 0.128 \pm 0.015 \pm 0.024, \qquad (2)$$
$$k = 0.0197 \pm 0.0045 \pm 0.003,$$

with $\chi^2 = 1.5/ndf$

Here the first errors are statistical and the second ones are systematic (see below).

The approximation of Dalitz-plot with k=0 gives

$$g = 0.704 \pm 0.012,$$
$$h = 0.104 \pm 0.014, \qquad \text{with } \chi^2 = 1.8/ndf$$

These values slightly differ from (2) and χ^2 is larger.

In spite of the k-value differ from zero, we performed an analysis of X-distribution (fig.2) to obtain g and h parameters. We fitted it with the expression $F(X) = C(1 + gX + hX^2)$. The obtained parameter values

$$g = 0.703 \pm 0.012,$$
$$h = 0.106 \pm 0.013, \qquad (\chi^2 = 0.91/ndf);$$

agree with those obtained from Dalitz-plot with k=0. In the above cases we quote statistical errors only.

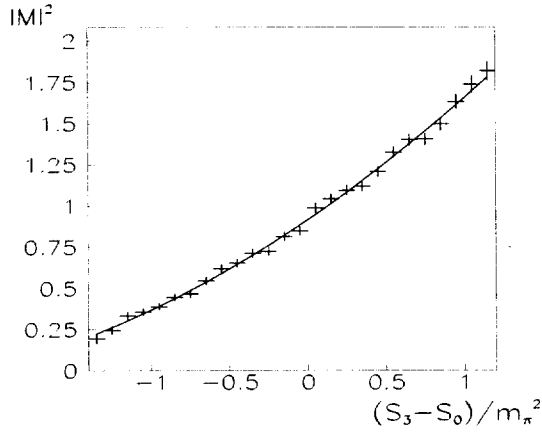

Fig.2.

X-distribution of $K^+ \to \pi^+\pi^0\pi^0$ decay

Systematic errors

We estimated systematic errors comparing the results (2) with those obtained by fitting Dalitz-plots which were collected in the following ways:

1. we fitted separately three samples of events which were taken in different runs under different trigger conditions (groups threshold in calorimeters);
2. we set one of variables in kinematics fit to be "unknown", for instance π^+ or photon energy, and compared with 6C-fit results;
3. we rejected events, in which γ-quanta hitted EMC1 near the hole in its center;
4. we cut the edge of the Dalitz-plot.

The maximum deviations of parameter values from (2) in above cases are 0.012, 0.024 and 0.003 for g, h and k respectively. We have taken these values as systematic errors for the slope parameters.

We also took into account that π^0 can be reconstructed from "wrong" gammas. The influence of this effect was studied by simulation. Such events amount to about 1% and do not affect the result.

By fitting events to $K^+ \to \pi^+\pi^0\pi^0$ hypothesis we checked parameters of distributions called "normalized stretch values" or "pulls" /10/ for each variable. If one have no systematic errors and set correct experimental errors in kinematics fit, these "pulls" should follow standardized Gaussian distribution with mean value 0 and standard deviation 1. Our "pulls" are in a good agreement with standardized Gaussian distribution.

For further self-test reason we determined the well known vector formfactor slope parameter λ_+ in semileptonic $K^+ \to \pi^0 e^+ \nu$ decay using the same HYPERON-2 experimental data and the same data processing method as for $K_{\pi 3}$ decay. Our preliminary result based on 13000 events gives $\lambda_+ = 0.0288 \pm 0.0043$ and it agrees well with the world average value $\lambda_+ = 0.0286 \pm 0.0022$.

Conclusion

There is the discrepancy between our data and world average parameters (g=0.594±0.019; h=0.035±0.015). The PDG averages and their small errors are mainly due to the most precise data on K^--decay of Bolotov's group /11/. The spread of coefficient values given by other experiments is significant. We understand, that such dramatic discrepancy is hardly due to the CP-asymmetry in K^+ and K^- decays. It is in our opinion due to some unknown systematic errors in available data (including our own ones). We checked very carefully all steps of our data processing but did not see an error. Apparently, the situation should be cleared up in future experiments.

To conclude we mention that our experiment is the only electronic one with all involved particles momenta measured.

Authors are grateful to A.Bel'kov and A.Laniov for helpful discussions and to the JINR and IHEP Directorates for the possibility of carrying out this experiment.

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Батусов В.Ю. и др. E1-96-252

Измерение параметров наклона диаграммы Далитца для распада $K^+ \to \pi^+\pi^0\pi^0$

Для распада $K^+ \to \pi^+\pi^0\pi^0$ были измерены параметры наклона диаграммы Далитца. Точность измерений выше, чем в предыдущих экспериментах, однако полученные значения существенно отличаются от большинства предлагаемых ранее. Эксперимент проводился на установке ГИПЕРОН-2 серпуховского ускорителя в пучке положительных частиц с энергией 10 ГэВ. Было отобрано около 33000 событий, в которых измерены импульсы всех частиц.

Работа выполнена в Лаборатории ядерных проблем ОИЯИ.

Препринт Объединенного института ядерных исследований. Дубна, 1996

Batusov V.Y. et al. E1-96-252

Measurement of Dalitz-Plot Slope Parameters for $K^+ \to \pi^+\pi^0\pi^0$ Decay

We have determined the Dalitz-plot slope parameters for $K^+ \to \pi^+\pi^0\pi^0$ decay. They have been measured with an accuracy higher, than those in the previous experiments. The values obtained are significantly different from most of the previous results. The experiment was carried out in Serpukhov PS with the HYPERON-2 spectrometer at the 10 GeV/c positive particle beam. We have collected about 33000 events with all particles momenta measured.

The investigation has been performed at the Laboratory of Nuclear Problems, JINR.

Preprint of the Joint Institute for Nuclear Research. Dubna, 1996

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