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AN EXPERIMENTAL DETERMINATION OF THE PARAMETERS DESCRIBING THE $K^+ \to \pi^+\pi^o\pi^o$ DECAY MATRIX ELEMENT

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Abstract

The τ' decay Dalitz plot density and π^+ energy spectrum have been studied using two independent samples of events detected in the CERN 1.1 m^3 heavy liquid bubble chamber filled with a propane ethane mixture. For a parametrization of the matrix element in terms of the Mandelstam variables a combined analysis of both samples gives the values $g = 0.335 \pm 0.027$ and $h = 0.02 \pm 0.04$. From the Dalitz plot analysis the parameter j was found to be $j = -0.01 \pm 0.02$.

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The matrix element of the three pion decay mode of the K meson is usually expanded as a power series of variables proportional to the kinetic energy of the odd pion and to a combination of the like pion kinetic energies [1]. It can be written as :

$$M \approx 1 + g\left(\frac{S_1 - S_o}{m_1^2}\right) + h\left(\frac{S_1 - S_o}{m_1^2}\right)^2 + j\left(\frac{S_2 - S_3}{m_1^2}\right)^2$$

in terms of the Mandelstam variables $S_i = (P_K - P_i)^2$, $i = 1, 2, 3$ and $S_o = \frac{1}{3}(S_1 + S_2 + S_3)$. For the τ' decay, $K^+ \to \pi^+\pi^o\pi^o$, S_1 refers to the positive pion, while S_2 and S_3 refer to the like pions.

An analysis of the Dalitz plot density distribution gives information on the parameter j, which cannot be determined from the usual π^+ spectrum study. The present experiment was designed to study the decays of stopping K^+ mesons involving neutral pions. It is therefore one of the few experiments where a relatively large sample of kinematically reconstructed and fitted τ' events has been collected and which allows a study of the Dalitz plot density with essentially no background. In addition, a larger and independent sample of unfitted events was used to study the π^+ energy spectrum, so the analysis of the fitted events offers also the opportunity of performing a cross check of the results and consequently of the corrections applied to the unfitted sample.

Details of the experimental conditions, scanning criteria, event selection and detection efficiencies may be found elsewhere [2]. The fitted sample consists of 744 events having either 3 or 4 materialized γ-rays and a positive secondary track which stopped and decayed. The probability of the kinematic fit was required to be greater than 2 %. From a Monte Carlo study the background due to $K_{\mu 3}$ or τ' events having one or two spurious γ-rays is expected to be less than 1 %. In order to remove any scanning bias, a cut on the π^+ kinetic energy was applied ($T_{\pi^+} > 5$ MeV). A correction for the γ-ray detection efficiency was also applied, while the scanning procedure and the selection criteria adopted insured essentially a 100 % scanning efficiency for the π^+ mesons in this sample.

The losses due to the scattering of π^+ mesons were calculated directly using a sample of τ^+ decays. It was also verified that, due to the relatively small errors on the measured γ-ray momenta ($\frac{\Delta P}{P} \sim 9$ %), the problem of wrongly pairing γ-rays in the kinematic fit was negligible.

A three-parameter maximum likelihood analysis of the Dalitz plot density was performed giving the following values :

$$g = 0.335 \pm 0.042$$
$$h = -0.02 \pm 0.06 \qquad (\chi^2 = 41.9 \text{ for } N_D = 44)$$
$$j = -0.01 \pm 0.02$$

Assuming j=0 : $g = 0.348 \pm 0.041$ $\qquad (\chi^2 = 43.4 \text{ for } N_D = 45)$
$h = 0.00 \pm 0.06$

and assuming both second order parameters j and h to be zero :

$$g = 0.349 \pm 0.037 \qquad (\chi^2 = 44.8 \text{ for } N_D = 46)$$

The values of χ^2 quoted in brackets were obtained by comparing the data with the predictions of the maximum likelihood analysis.

An independent sample of 2519 unfitted events having two or less associated γ-rays, was selected according to the following criteria :

i) the π^+ meson was identified by a π-μ-e decay chain, this being visible in about 80 % of the cases ;

ii) only π^+ mesons having kinetic energy between 11 and 45 MeV were retained. This cut minimizes the loss of secondary low energy pions collinear to the K^+ and also the background due to $K_{\pi 2}$ and τ' decays in flight which is of the order of 3 %.

A correction for secondary π^+ mesons decaying in flight was also applied over the whole spectrum (~ 2 %).

The contribution of $K_{\mu 3}$ decays in which, due to multiple scattering, the muon simulates a π-μ-e chain was calculated to be 2 % on the basis of $K_{\mu 2}$ events found in the $K_{\pi 2}$ candidate sample. The losses due to secondary π^+ mesons which interact were

taken into account as discussed previously. After a partial double scan the single scanning efficiency was found to be 97 ± 6 %, independently of π^+ energy.

A two parameter maximum likelihood analysis on the π^+ spectrum gave the following values :

$$g = 0.326 \pm 0.035 \qquad (\chi^2 = 43.6 \text{ for } N_D = 31)$$
$$h = 0.04 \pm 0.07$$

and assuming $h = 0$, gave $g = 0.317 \pm 0.020$. $(\chi^2 = 44.2 \text{ for } N_D = 32)$

The results obtained by the two different methods of analysis are self-consistent and in both samples there is no evidence of any second order terms significantly different from zero.

A combined analysis on the two independent samples gives $g = 0.335 \pm 0.027$, $h = 0.02 \pm 0.04$ and, as shown in fig. 1, the two parameters are only weakly correlated. Assuming $h = 0$ we find $g = 0.324 \pm 0.018$. $(\chi^2 = 72.3 \text{ for } N_D = 77)$.

We can conclude that the energy dependence of the decay matrix element is well compatible with a linear behaviour, in agreement with the results given by the most recent experiments [3].

We would like to express our thanks to those colleagues who have contributed to various stages of this experimental study of K^+ decays, without whose work this analysis would not have been possible.

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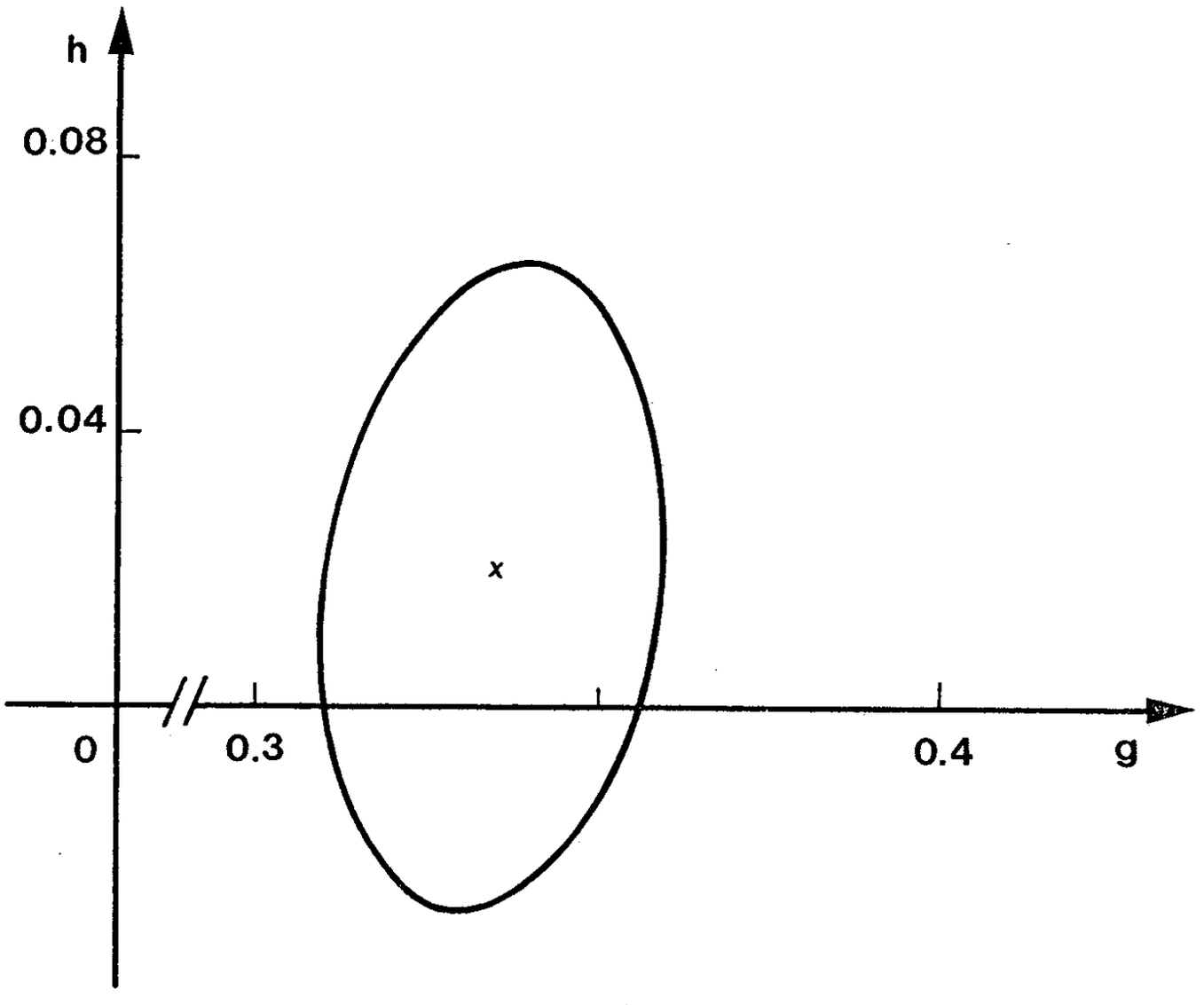

Fig.1 Result of the combined analysis for the parameters g and h.
The curve shows the 1_ standard deviation contour (68% confidence level)