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ADDENDUM TO THE PROPOSAL FOR AN EXPERIMENT ON K_{e4} DECAY

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In our proposal of April 1967 on K_{e4} decay, we mentioned only qualitatively how the background, which is due to the Dalitz decay of π^0 could be eliminated.

We have now made further Monte-Carlo calculations and we can give the efficiency of our rejection criteria for all types of backgroung :

1) $K^+ \rightarrow \pi^+ \pi^0 \rightarrow \pi^+ e^+ e^- \gamma$
2) $\pi^+ \pi^0 \pi^0 \rightarrow \pi^+ e^+ e^- \gamma \gamma \gamma$
3) $\mu^+ \pi^0 \nu \rightarrow \mu^+ e^+ e^- \gamma \nu$
4) $e^+ \pi^0 \nu \rightarrow e^+ e^+ e^- \gamma \nu$

All calculations were made with homogeneous Dalitz plots. The Dalitz decay of the π^0 was calculated from the expressions given in ref. 1.

1. Two electrons identified.

First we will reject all events showing clearly two electrons i.e. two showers in the shower chamber. Using an efficiency of 80 % for the shower chamber we obtain a rejection of 64 %.

2. Cut of small angle and low invariant mass pairs.

An event is identified only if it has a well identified electron i.e. a reconstructed trajectory passing through the cell of the Cerenkov which triggered the system, and giving a shower at the end.

If it is a positron then we can form only one pair of particles of opposite charges likely to be an electron pair. If it is an electron we can form two pairs.

As we know, the angular opening of Dalitz pairs is peaked at 0° (see fig. 1.). We will reject all events having a pair with an angle smaller than 3°. We also know that the invariant mass of the electron pair from a Dalitz decay is strongly peaked at small values (fig. 2). We will also apply a cut for pairs with invariant mass smaller than 30 MeV. These two cuts are not independent as can be seen from the expression giving the invariant mass of the electron pair :

$$M_{ee}^{2} = 2\, p_{e+}\, p_{e-}\, (1 - \cos \Theta_{ee}).$$

The Monte-Carlo calculation generates events of the type 1) to 4) with a Dalitz decay of the π°. The 2 cuts mentioned above were applied successively to the events accepted by the spectrometer.

3. Detection of a γ.

Each of the background events yields at least one γ, which will be detected in order to improve the rejection. The detection can occur either in the shower chamber at the end of the spectrometer if the γ goes through the magnet gap or in a lead-scintillator sandwich located in front of the magnet yoke.

For each type of background the Monte-Carlo program giving the probability for a γ to reach the shower chamber or the γ-counter.

4. Invariant mass of the K^{+}.

Finally for each remaining event we can calculate the invariant mass of the K^{+} assuming K_{e4} decay. The background events will be spread over a wide spectrum while the true K_{e4} will give a peak with a full width at half maximum of 20 MeV. (This latter value is given by the spectrometer i.e. by the resolution of the spark chambers and the multiple scattering effects). A cut on each side of the peak will further reduce the background. Fig. 3 shows that for instance the $K_{\pi 2}$ events will be rejected very efficiently by a cut at about 530 MeV.

Conclusion.

Table 1 summarizes our results. All calculations were made for 2.5 GeV/c incident K^+. The geometry of the set-up is the same as in fig. 1 of the proposal at the exception of the γ counter added in front of the magnet. The last column of table 1 gives the contribution of each decay channel normalized to 1 K^+ decay. All the cuts mentioned above were also applied to the true K_{e4} events generated by Monte-Carlo. This is reported in the lower lines of table 1.

We conclude that the contamination for the $\Delta Q = \Delta S$ channel will be of 2.1 %. We have not yet investigated the effect of this contamination on the assymetries which are used to determine the π - π phase shifts but we are confident it will be quite small.

For the $\Delta S = -\Delta Q$ channel the contamination should be about the same as above (i.e. about 100 events if we have 5000 $\Delta S = \Delta Q$ K_{e4}). This would allow to reduce the upper limit for the $\Delta S = -\Delta Q$ rate to $1,5 \cdot 10^{-7}$ at the 95 % confidence level. This means an improvement of more than an order of magnitude over the present value.

It is worthwhile emphasizing that after all the cuts mentioned above, the true K_{e4} rate (assuming the same beam intensity as in the proposal and for the same value of the coefficient η) is 80 events / day.

This event rate together with the figures of contamination strongly support the conclusion that the background can be sufficiently eliminated and won't affect seriously the precision of the experiment.

K^+ decay mode	Branching ratio (with Dalitz decay)	Acceptance of the spectrometer	Shower of 2^d electron	Cut on θ_{ee} and MeV	γ detected	K^+ mass	"Surviving"
$K_{\pi 2}$	$2.5 \cdot 10^{-3}$	$1.5 \cdot 10^{-2}$	0.34	0.1	0.33	0.03	$1.3 \cdot 10^{-8}$
$K_{\pi 3}$	$4 \cdot 10^{-4}$	$3 \cdot 10^{-2}$	0.34	0.015	0.1	0.6	$3.7 \cdot 10^{-9}$
$K_{\mu 3}$	$4.1 \cdot 10^{-4}$	$2.3 \cdot 10^{-2}$	0.34	0.05	0.2	0.3	$9.6 \cdot 10^{-9}$
$K_{e 3}$	$5.7 \cdot 10^{-4}$	$1.5 \cdot 10^{-2}$	0.34	0.03	0.3	0.2	$5.2 \cdot 10^{-9}$
							$3.15 \cdot 10^{-8}$
$K_{e^+ 4}$	$3.8 \cdot 10^{-5}$	$5.56 \cdot 10^{-2}$	--	0.85	--	0.83	$1.5 \cdot 10^{-6}$
$K_{e^- 4}$	$< 2 \cdot 10^{-6}$	$5.56 \cdot 10^{-2}$	--	0.72	--	0.83	$6.7 \cdot 10^{-8}$

Table 1. - Efficiency of rejection criteria. The last column is the product of the first six columns.

References.

1. N.M. Kroll and W. Wada, Phys. Rev. 98, 1355 (1955).

2. N.P. Samios, Phys. Rev. 121, 275 (1961).

Figure captions.

1. Angular opening of Dalitz pairs ($K\pi_2$). The angle θ_{ee} is given in the lab.

2. Invariant mass distribution of Dalitz pairs (from ref. 2). X is the invariant mass of the two electrons and μ is the mass of the π^0.

3. Invariant K^+ - mass distribution of $K\pi_2$ (Dalitz) events analyzed as K_{e4}, i.e. under assumption that the negatron has been erroneously taken for a pion.

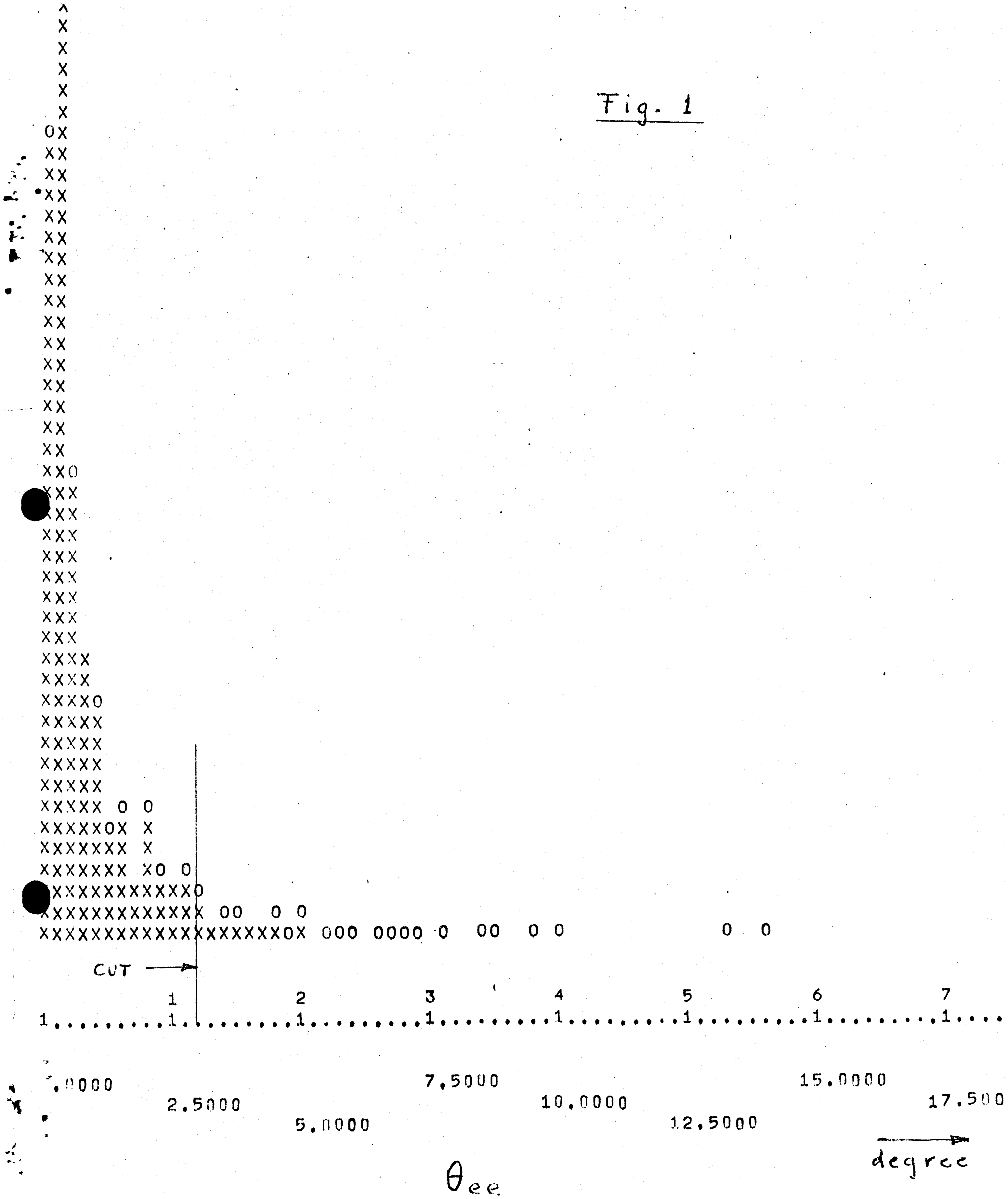

CUT
1 2 3 4 5 6 7
.0000
2.5000
5.0000
7.5000
10.0000
12.5000
15.0000
17.500
degree
θ_{ee}

Fig. 1

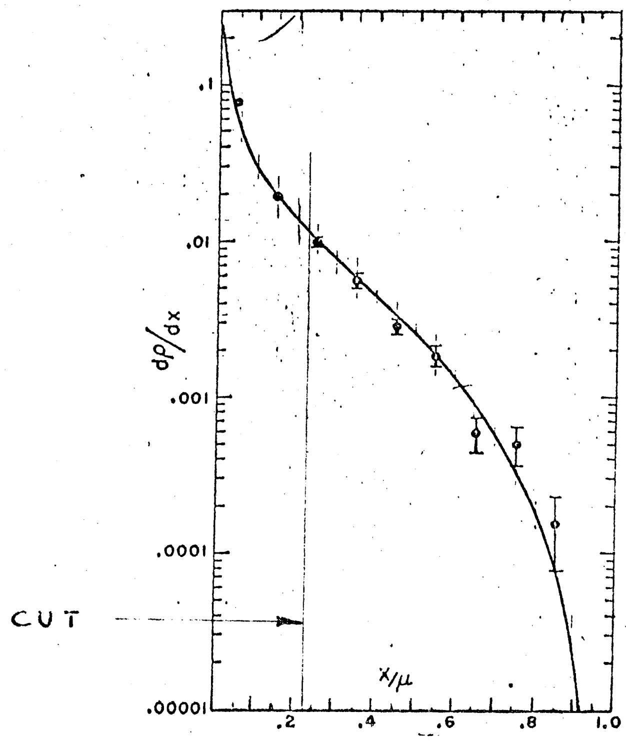
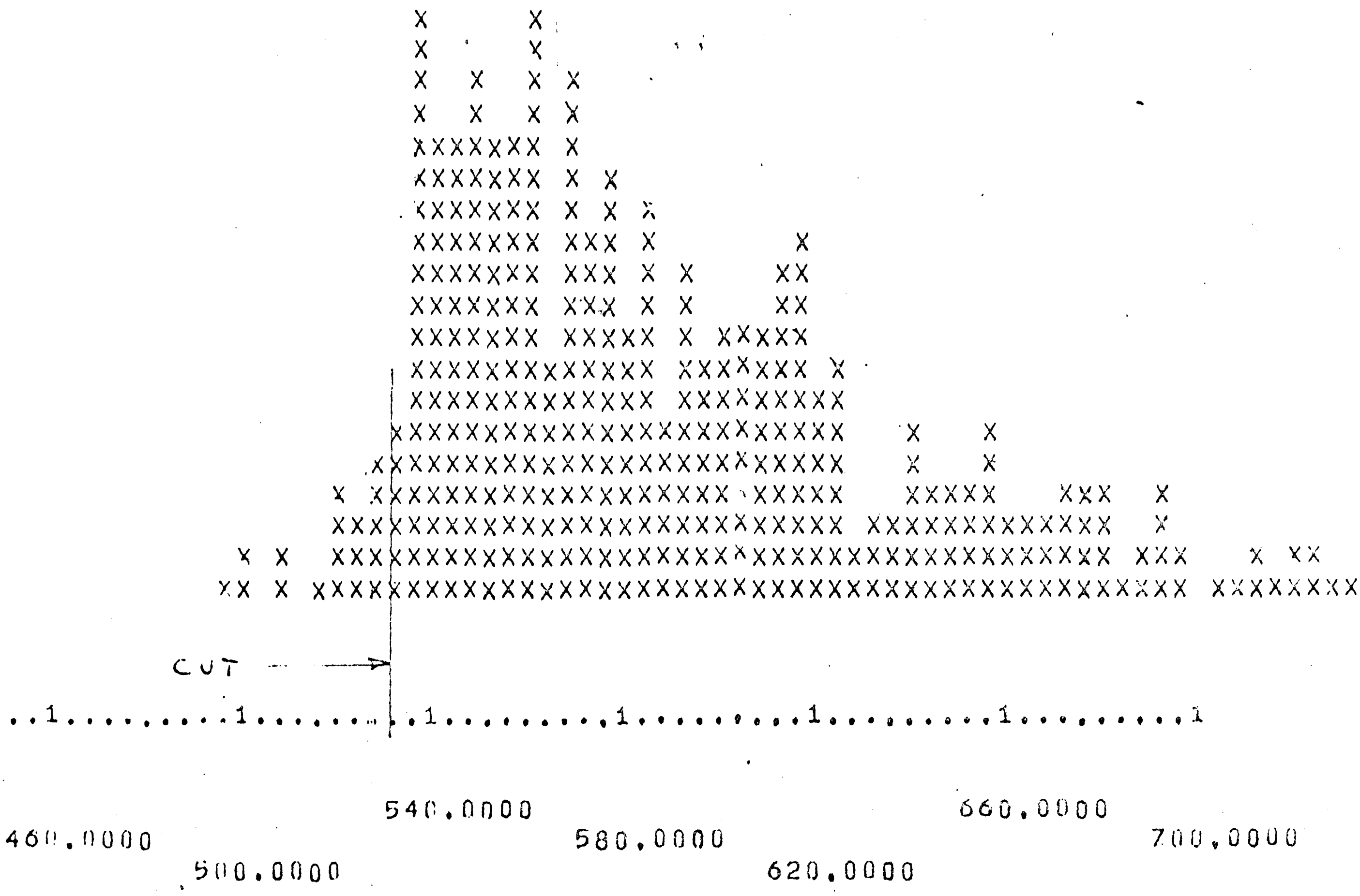


Fig. 2

Fig. 3



K+ mass (MeV)