30 May, 1967

TO : E.E.C. and N.P.R.C.

SOME DETAILS ON THE PROPOSED $\Delta S/\Delta Q$ EXPERIMENT

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In this note we wish to summarize some features of the proposed experiment as already presented in a recent discussion meeting.

I. K^0 - Beam of Known Momentum

Quasi-elastic charge-exchange on complex nuclei as a source of K^0 has been abandoned for three reasons:

(1) Low K^0 yield (3 effective neutrons per Cu nucleus).

(2) Poor momentum determination of K^0 from its decay products and no constraint against background.

(3) High background produced by the beam in the charge-exchanger which would have to be 0.5 interaction length (for π^+) and change of the relative K^0 and $\bar{K}^0$ amplitudes in the target by regeneration.

To overcome these difficulties we proposed to make use of the reaction

$$K^+ p \rightarrow K^0 p \pi^+ \qquad (1)$$

in a liquid hydrogen target.

The following kinematical quantities will be observed:

(1) Directions of p and π^+ detected in wire spark chambers around the target and direction of the incident K^+ will yield the K^0 production vertex .

(2) The K^0 decay vertex is observed in a K_{e3} detector and yields, together with the production vertex the K^0 direction.

(3) Knowledge of the directions of the 3 outgoing particles and of the four momenta of the incoming particles gives a one constraint fit to reaction (1), enabling us to resolve the ambiguity between π^+ and proton which are not identified and to determine the K^0 momentum. The goodness of fit can be judged from the mass of the decaying neutral particle if we suppose it to be unknown.

II. Time Resolution

It is the aim of this experiment to determine the rate of $(\pi^+ e^- \bar{\nu})$ and $(\pi^- e^+ \nu)$ decays as a function of proper time. The expected resolution in proper time has been calculated by Monte Carlo methods, from the resolution on decay length and on K^0 momentum and is shown in Fig. 1 versus proper time in units of τ_s.

The expected resolution in K^0 mass is shown in Fig. 2.
So, from the production alone we obtain the momentum and the mass of the decaying object.

By choosing a two-body decay of K^0, viz. $K^0 \to \pi^+\pi^-$, the momentum and mass of the decaying object can also be fully determined from the decay alone. A comparison between production and decay data enables us then to determine the time resolution experimentally.

It is also important in checking that other reaction channels with neutrals

$$K^+ p \to K^0 p \pi^+ \text{ (+ neutrals)} \qquad (2)$$

have been successfully eliminated.
The reconstructed K^0 mass distribution is flat in this case, as shown in Fig. 2. A portion of $5 \cdot 10^{-2}$ as compared to events from reaction (1) cannot be rejected by the one constraint fit to the production kinematics. This portion will be reduced further by requiring that the K^0 momentum obtained here coincides with one of the two possible values obtained from the K^0 decay secondaries. The small remaining background will be subtracted

in each bin of proper time. Its portion and shape can be determined experimentally by measuring $K^0 \rightarrow \pi^+\pi^-$.

Knowledge of the K^0 momentum from the production reaction would also enable us to select other 3-body decays of K^0 and to study interference in these channels.

III. K_{e3} Detector

Views of the detector are shown in Fig. 3. Two vertically separated cells of the Čerenkov counter detect electrons from K_{e3} . The detection efficiency of this apparatus, averaged over the whole decay volume is 0.10. The time-dependent detection efficiency, shown in Fig. 4, is a slowly varying function of proper time. This is of great importance as it has to be known with good precision for the final analysis.

The vector momenta of the charged secondaries from K^0 decay and the decay vertex position are determined by a wire spark chamber spectrometer. The resolution on the K^0 momentum as reconstructed from the observed decay secondaries is very different for two classes of events. Since the neutrino from K_{e3} decays is not observed, one has a zero kinematical constraint case (if the mass and the direction of the decaying object is known) and in general two solutions for the K^0 momentum. If the ν is emitted under 90° in the K^0 rest frame, the two solutions coincide. However, this case also corresponds to a pole in the derivative $dp_{K^0}/d\Theta_{K^0}$. Consequently, events with $|p_{K^0}^{(1)} - p_{K^0}^{(2)}| > 100$ MeV/c are reconstructed with 6% resolution in p_{K^0} , whereas the remaining events have an average resolution of 15% in p_{K^0} . The corresponding resolutions in proper time are shown in Fig. 5. The two classes are of about equal importance. In an experiment which relies on reconstruction of the K^0 momentum from the decay secondaries alone, the second class has to be eliminated. In our case information on the K^0 momentum comes from the production and we can keep both classes of events. The information from the decay simply adds one more constraint.

IV. Event Rate

At 3 GeV/c the cross section $K^+ p \rightarrow K^o p \pi^+$ as accepted by the target detector is 0.7 mb . The target length is 50 cm and we use a nominal decay length of $10 \cdot 10^{-10}$ s (to compare with the estimated precisions in Chapter V). We then expect to detect

$$P(K_{e3}) = 1.0 \times 10^{-6} \text{ per incident } K^+ .$$

Using $5 \cdot 10^4$ K^+ per burst in an improved m-beam (in a momentum bite of $\pm 2.5 \cdot 10^{-2}$ for $3 \cdot 10^{11}$ p/b or without sharing in $\pm 1.0 \cdot 10^{-2}$) and $3 \cdot 10^4$ b per typical CPS day, we expect

$$N(K_{e3}) = 1500/\text{CPS day} .$$

After the 1968 shut-down, the CPS repetition rate will be doubled. Allowing for a safety factor of $1/\pi$ for various reconstruction efficiencies we would then safely expect 1000 events per day and a total sample of 20.000 events.

V. Sensitivity to $\Delta S = -\Delta Q$ Amplitudes

Monte Carlo calculations folding in all experimental resolutions show that for 10^4 events one would expect the following variances, if the time dependent detection efficiencies are known.

$$\sigma(\text{Re}\,X) = \pm 0.016, \quad \sigma(\text{Im}\,X) = \pm 0.018$$

where $X = \dfrac{A(\Delta S = -\Delta Q)}{A(\Delta S = \Delta Q)}$.

If one could not rely on the knowledge of time-dependent detection efficiencies a factor 10 more events are needed to obtain the same precision. So, it is obvious that it pays to define a geometry which minimizes possible biases in detection efficiencies and lends itself to easy tests.

VI. BACKGROUND

Background from decays of particles other than K^0 is eliminated by the K^0 mass determination in the production reaction. Knowledge of the K^0 momentum also allows us to eliminate K^0 decays other than K_{e3}.

Decays $K^0 \to \pi^+\pi^-$ and $K^0 \to \pi^0\pi^0 \to \pi^0 e^+ e^- \gamma$ will contribute equally to the trigger rate. They will be eliminated in the analysis by their invariant mass at the cost of 10% of good events. $K^0 \to \pi^+\pi^-\pi^0$ decays will contribute at most 10^{-3} to the trigger and will be eliminated by the missing mass of the π^0. $K^0 \to \pi^0\pi^0\pi^0 \to \pi^0\pi^0 e^+ e^- \gamma$ decays will contribute at most $3 \cdot 10^{-3}$ to the trigger and will be eliminated by the missing mass.

K_{e3} Decay Matrix Element

This experiment would produce a large sample of K_{e3} decays of known K^0 momenta. There will be no ambiguities in the transformation to the K^0 rest system. A study of the Dalitz plot density will give information on the q^2 dependence of the form factor. Moreover, the detector does not bias the q^2 dependence as can be seen in Fig. 6.

FIGURE CAPTIONS

Figure 1 : Mean time resolution $\Delta\tau$ in units of τ_S (lifetime of K_S^o) as a function of proper time. K^o - momentum determined from production kinematics.

Figure 2 : Mass of the decaying neutral particle determined by production kinematics. Curve (a) for $K^+ p \to K^o p \pi^+$ curve, (b) for $K^+ p \to K^o p \pi^+$ (+ neutrals). At proper time $\tau = \tau_S$.

Figure 3 : Detection apparatus.

Figure 4 : Time dependent detection efficiency, as a function of proper time.

Figure 5 : Mean time resolution $\Delta\tau$ in units of τ_S . K^o momentum determined from decay products. Curve (a) for $|p_K^{(1)} - p_K^{(2)}| > 100$ MeV/c, (b) for the other events.

Figure 6 : Dalitz plot projection on E_π and relative detection efficiency.

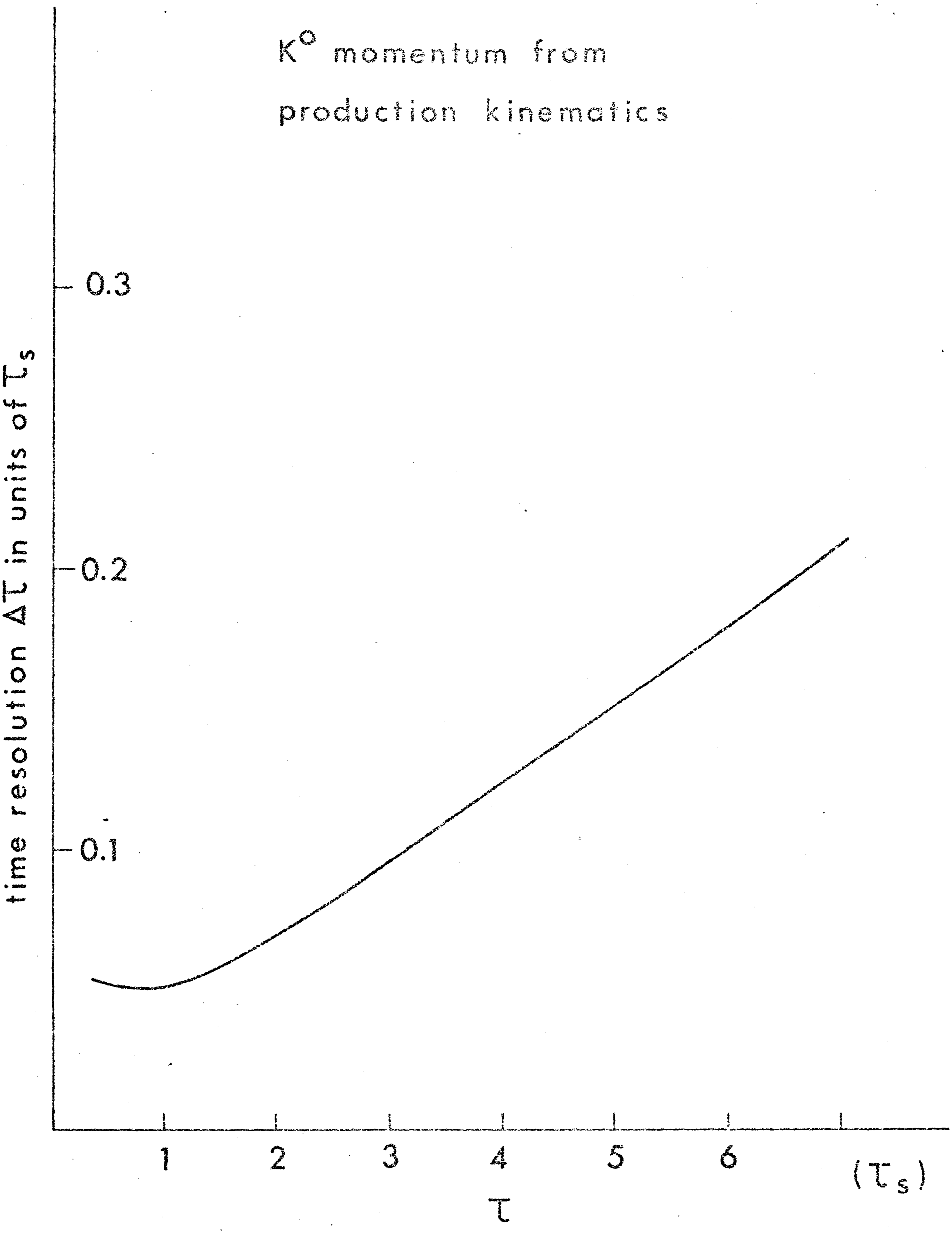
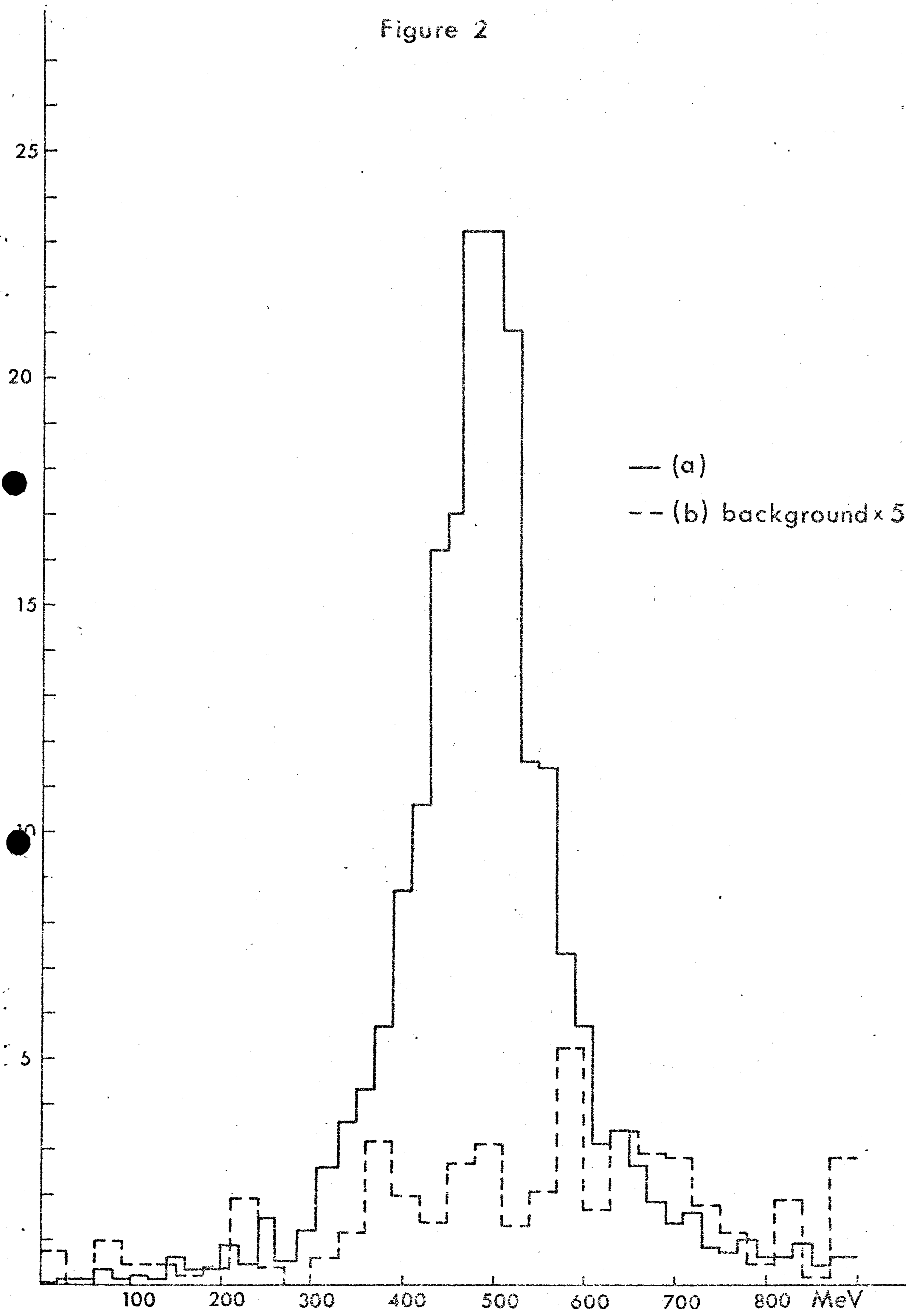

K° momentum from
production kinematics
time resolution $\Delta\tau$ in units of τ_s
0.3
0.2
0.1
1
2
3
4
5
6
(τ_s)
τ

Figure 1

Figure 2



ΔS/ΔQ EXPERIMENT

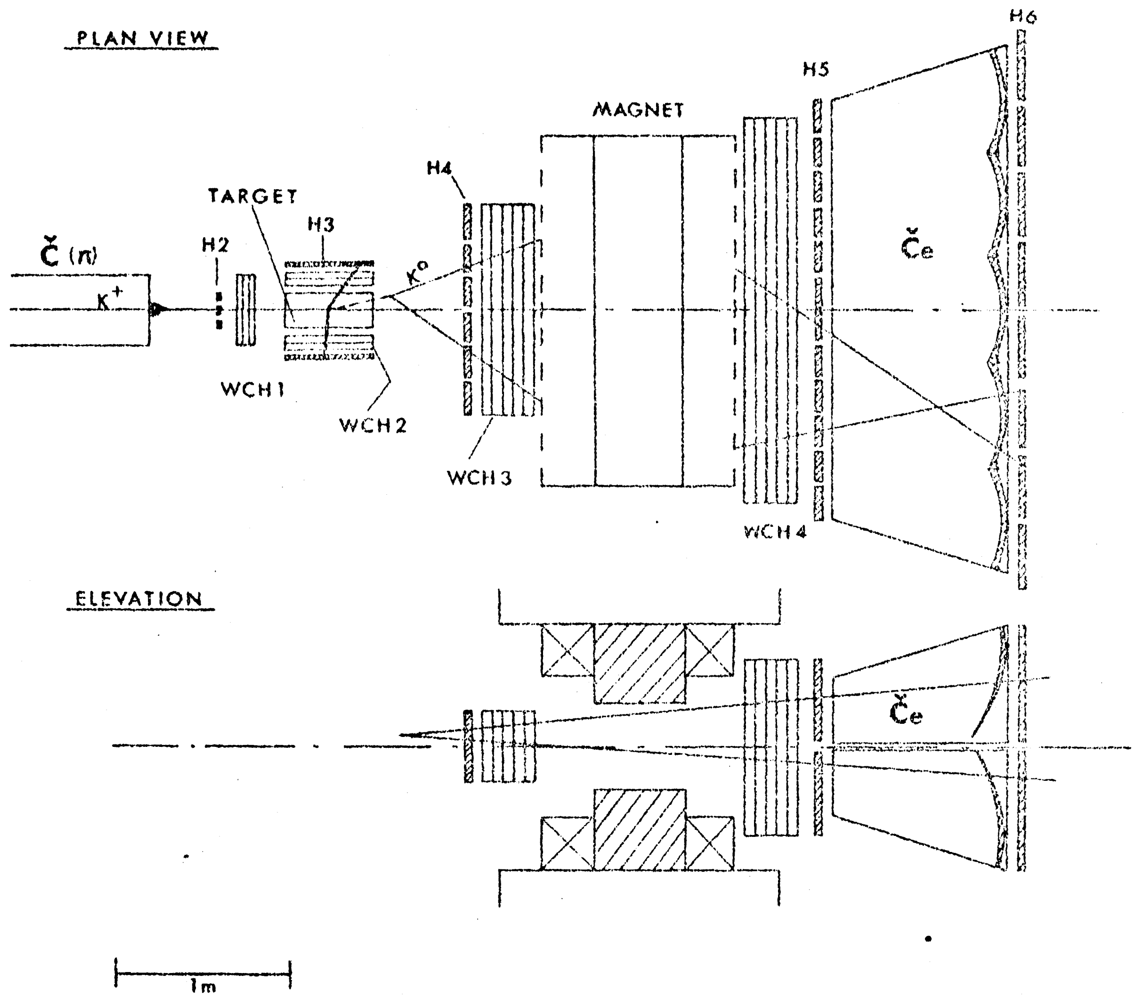


Fig. 3

TIME DEPENDENT DETECTION EFFICIENCY ΔS/ΔQ

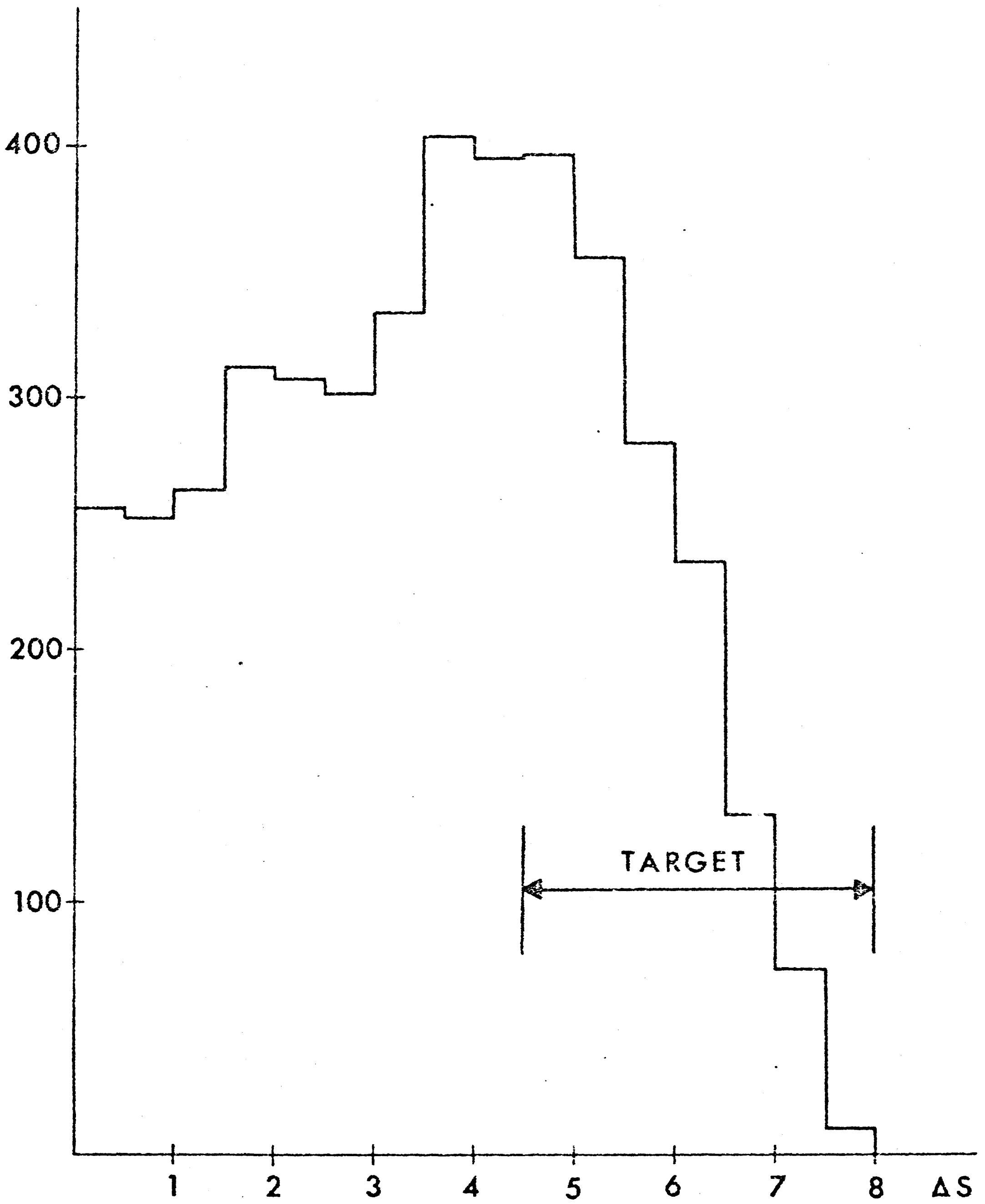
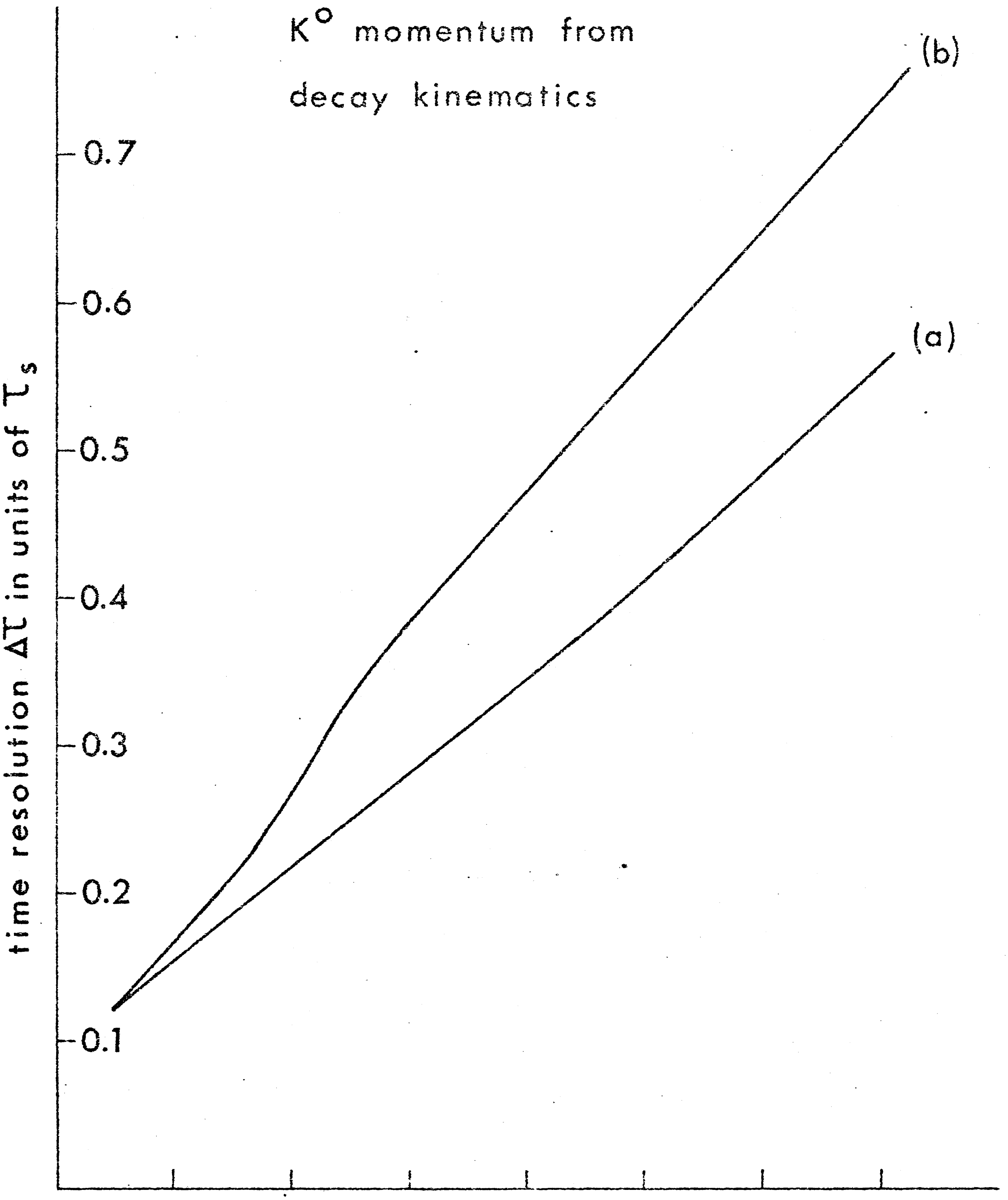


Fig. 4



K^o momentum from
decay kinematics
(b)
(a)
time resolution $\Delta\tau$ in units of τ_s
0.7
0.6
0.5
0.4
0.3
0.2
0.1
1
2
3
4
5
6
(τ_s)
τ

Figure 5

RELATIVE DETECTION EFFICIENCY ----

IN Ke3 DALITZ PLOT PROJECTION ON Eπ ——

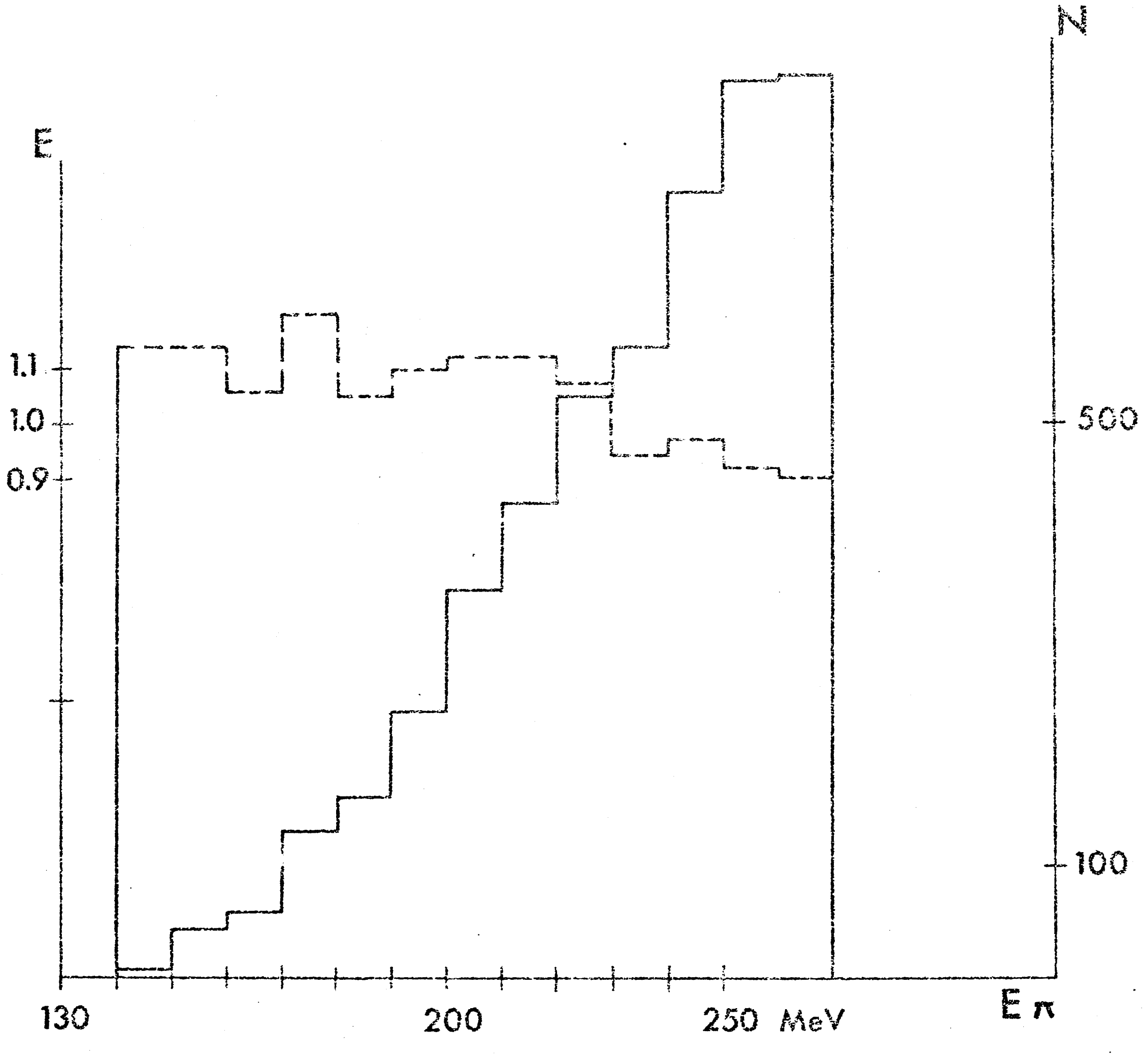


Fig. 6