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## Proposal for an experiment to establish if the
## f⁰ meson has or has not isospin zero

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The zero-isospin assignment to the $f^o$ meson is based on the fact that no peak has been observed in the invarient mass spectrum of the $(\pi^{\pm}\pi^{o})$ system (in the neighbourhood of 1250 MeV) in the reactions

$$\pi^{\pm}p \rightarrow \pi^{\pm}\pi^{o}p \; . \qquad (1)$$

It is worth emphasizing that the "non-existence" of a peak in the invariant mass spectrum of the $(\pi^{\pm}\pi^{o})$ systems in the reaction (1) has the following experimental basis; call

$\sigma_{f^{\pm}}$ the apparent[*] cross-section for $f^{\pm}$ production in reaction (1) $\pi^{\pm}p \rightarrow f^{\pm}p$
$$\searrow \pi^{\pm}\pi^{o}$$

$\sigma_{f^{o}}$   "    "    "    "    "  $f^{o}$   "    "    "    (2) $\pi^{-}p \rightarrow f^{o}n$
$$\searrow \pi^{\pm}\pi^{\mp}$$

the experimental results are:

$$\frac{\sigma_{f^{\pm}}}{\sigma_{f^{o}}} \lesssim 0.3 \quad \text{at} \quad 3 \text{ GeV/c incident } \pi$$

$$" \lesssim 0.25 \quad \text{at} \quad 4 \text{ GeV/c} \quad " \quad "$$

Recently Frazer et al. (preprint and P.R.L. 1964) have proposed a model which predicts for the above quantities the following values:

$$\frac{\sigma_{f^{\pm}}}{\sigma_{f^{o}}} = 0.20 \quad \text{at} \quad 3 \text{ GeV/c incident } \pi$$

$$" = 0.25 \quad \text{at} \quad 4 \text{ GeV/c} \quad " \quad " \quad .$$

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[*]
In order to see a bump it must be above the valley. If the valley between the two bumps ($\rho$ and $f$) is not deep it is hard to see the bump. The apparent cross-section is in fact the value of the bump above the valley.

This model is based on the peripheral production of the $f^o$ via one-pion and one-omega exchange processes. The interesting point is that to the $f^\pm$ production contribute
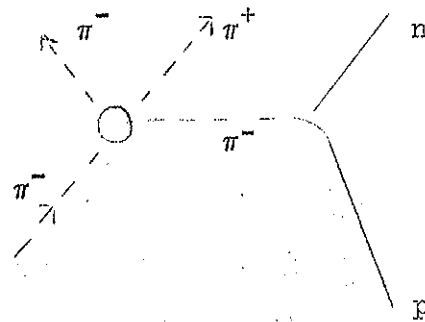
i) the one-pion
   exchange process

as well as

ii) the one-omega
    exchange process
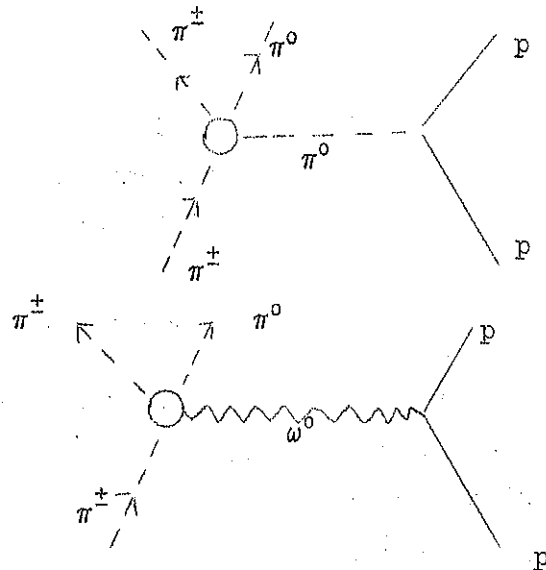


While to the $f^o$ production only the one pion exchange process



can contribute, because the exchanged particle must be charged. It is this difference in the production mechanism between charged and neutral f's that produces the above mentioned differences in the apparent cross-sections for production of charged and neutral f's.

This model of Frazer et al. throws serious doubts on the validity of the isospin-zero assignment of the $f^o$ meson. Moreover, the angular distribution of the decay products strongly favours $J = 1$ (see fig. 1 which is taken from the paper of Frazer et al.).

Noticing that the mass and the width of the $f^o$ are equal (within errors) to those of the B meson, the elegant suggestion of Frazer et al. becomes extremely plausible, namely that the B and the f mesons are nothing but different decay modes of the same particle, called $\rho'$ by Frazer et al.

This particle $\rho'$ must have I = 1, as can be deduced from the fact that the B meson decays strongly into a $\pi$ and an $\omega$ . It follows that the decay of the $f^o$ meson into 2 $\pi^o$'s,

$$f^o \text{ (or } \rho') \to \pi^o + \pi^o \text{ ,}$$

has to be forbidden.

On the other hand if the isospin of the $f^o$ is zero, the branching ratio of the neutral to charged $\pi$-decay mode is expected to be

$$\frac{f^o \to \pi^o \pi^o}{f^o \to \pi^- \pi^+} = \frac{1}{2} \text{ .} \tag{3}$$

We propose here an experiment to establish if the decay of the $f^o$ into two neutral pions takes place according to the predicted rate (3). We have considered the following production processes:

1) $\pi^- p \to f^o n$      (hydrogen target) $+ \pi^-$ beam
      $\hookrightarrow \pi^o \pi^o$

2) $\pi^+ n \to f^o p$      (deuterium target) $+ \pi^+$ beam
      $\hookrightarrow \pi^o \pi^o$

3) $d + d \to {}^4He + f^o$      (deuterium target) + deuteron beam .
      $\hookrightarrow \pi^o \pi^o$

1) The advantage of the first reaction lies in the fact that everything is known from bubble chamber data about cross-section and angular distributions of the decay products of the $f^o$ produced. In order to estimate the expected rate we consider the following example:

Take a 4 GeV/c $\pi^-$ beam ($m_3$ beam) with ~ $5 \times 10^5$ $\pi$/burst

~ 20 cm Hydrogen target

~ 3% efficiency for neutron detection

~ 80% efficiency to detect and measure the high-energy $\pi^o$ from the $f^o$ decay

~ 40% efficiency to detect the low-energy $\pi^o$ from $f^o$ decay

~ 15% solid angle for n recoil

~ 10% solid angle for $f^o$ decay

we get

$$16 \text{ events/hour if } \frac{f^o \to \pi^o \pi^o}{f^o \to \pi^- \pi^+} = \frac{1}{2} .$$

See figs. 2 and 3 for details.

The background from other processes has been considered and it appears to give no troubles up to a level of 1/10 of the expected $f^o \to \pi^o \pi^o$ rate. This point has to be established experimentally during the test run. Also the triggering rate from unwanted processes has to be determined during the test run. This vital information will be obtained by varying the primary $\pi$ energy. For instance, by working below $f^o$ production we will get very useful information on background.

2) The advantage of the second reaction lies in the presence of the proton instead of the neutron in the final state. On the other hand this proton comes from a neutron bound in the D nucleus.

3) The third reaction has the advantage that only $I = 0$ states can be produced. If the $f^o$ has isospin zero it can be produced via this process and its neutral $\pi$-decay mode is expected to be $\frac{1}{2}$ of the charged $\pi$-decay mode. If the $f^o$ does not have isospin zero it cannot be produced.

The study of this reaction appears very clean to us.

SET-UP

The main part of the set-up is the high-energy $\pi^0$ detector.
This detector consists of a 0.5 cm Pb foil followed by an 8-gap thin foil
spark chamber (to allow kinematical reconstruction of the shower originating
in the lead radiator) and by a total absorption lead-glass Č counter.
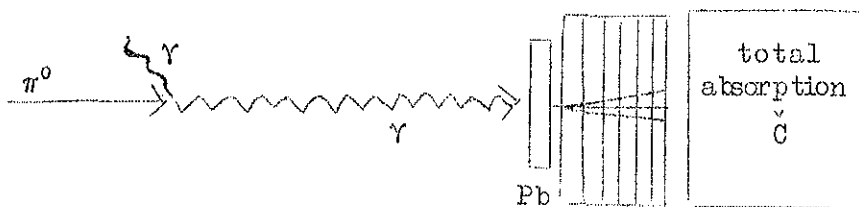


The lead-glass Č counter will trigger our spark chamber if the energy of the
gamma ray is higher than a fixed threshold. Our triggering system will only
select those $\pi^0$'s with forward $\gamma$ decays.

The low-energy $\pi^0$ detector is either a sandwich type or a heavy
plate spark chamber type detector.

Machine time required

Two weeks of parasiting time for calibrations of the $\pi^0$ detector,
for checking all other parts of the set-up and for a test run.

Two weeks of main users with maximum intensity in target 1 (machine
energy 17 GeV, flat top 300 msec) for data taking.

Final remarks

The elegant proposal of Frazer et al. seems to us extremely
plausible, as we have tried to point out in the first part of this proposal.
The value of an experiment which should establish if the $f^0$ meson has or has
not isospin zero is therefore remarkable.

We propose this experiment to be performed very quickly. This
is why we should like to know as soon as possible if we have to go on with this
proposal or not.

## Figure Captions

Figure 1.     Cos $\Theta_{\pi\pi}$   distribution of peripheral events from the reaction $\pi^- p \to n\pi^-\pi^+$ with $M_{\pi\pi}$   in the $f^0$ peak.  (Taken from Frazer et al.).

Figure 2.     Kinematics for $\pi^- + p \to f^0 + n$ at 4.0 GeV/c pion momentum.  The shaded region of the curve is the region in which we observe the neutrons.  The centre-of-mass angle of the $f^0$ and the corresponding $f^0$ laboratory angles and momenta are marked on the curve.

Figure 3.     Kinematics for the $\pi^0\pi^0$   decay mode of the $f^0$ at 4.0 GeV/c. The shaded regions correspond to the angular and energy ranges selected by our set-up.
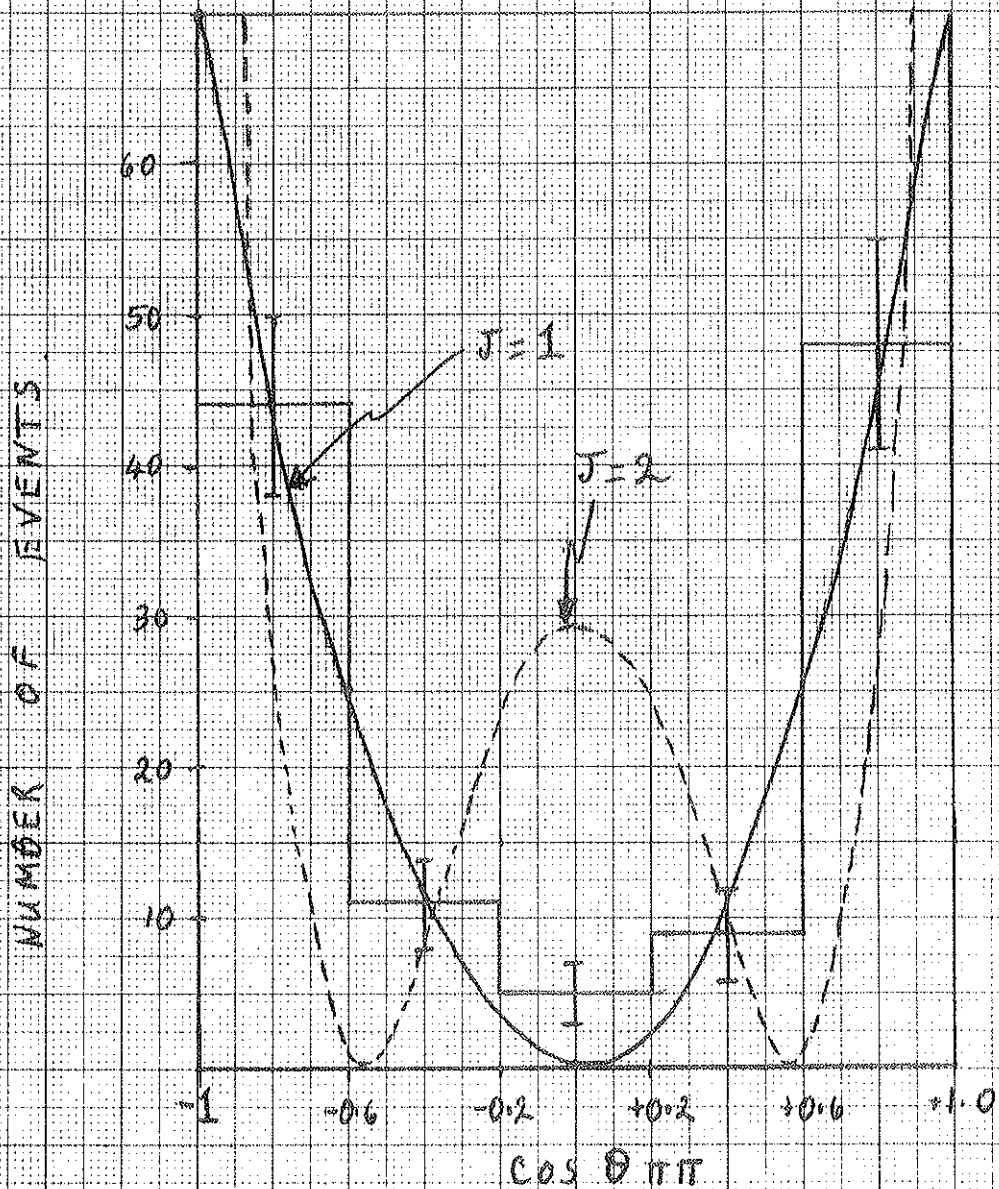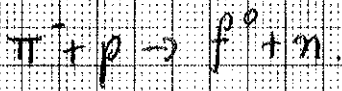
Fig 1 Cos θ ππ distribution of peripheral events from the reaction π⁻ + p → n + π⁺ + π⁻ with M ππ in the ρ₀ peak. (curve 'c' of Frazer et Al.)

Fig. 2

$\pi^+ + p \rightarrow f^0 + n$.    $\pi^-$ momentum $= 4.0$ Gev/c.

$f^0$ mass $= \cancel{1250\,Mev}$ $1.25$ Gev.

c.m. angle of $f^0$ =

40°

30°

20°

$0° = 0°$ Lab + $4.0$ Gev/c for $f^0$

$10° = 2.4°$ Lab + $3.76$ Gev/c for $f^0$.

REGION OF OBSERVATION.

Mev
300

200

100

(KINETIC ENERGY) OF T? NEUTRON LAB.

10    20    30    40    50°    $\theta_{LAB}$ of neutron.
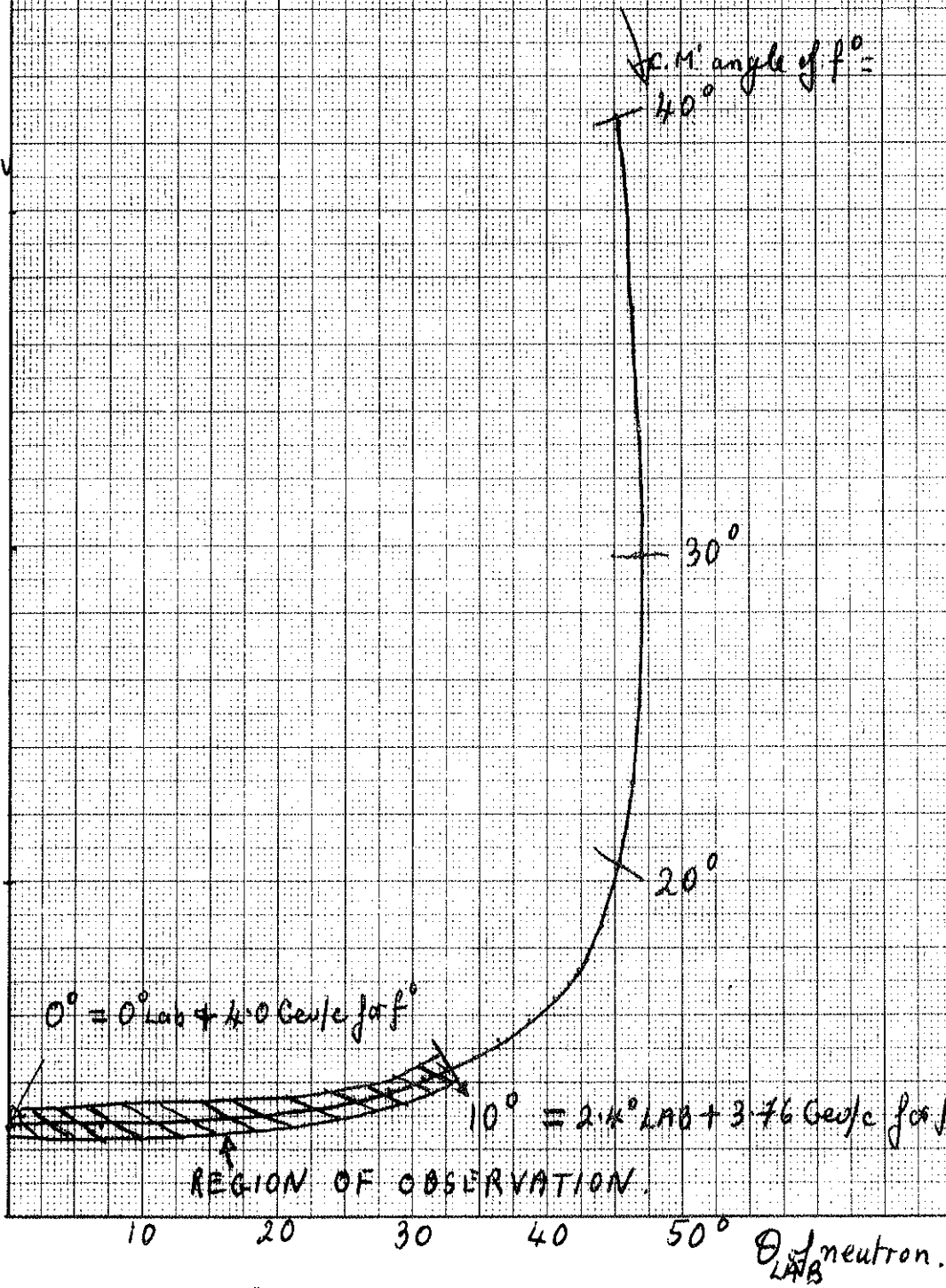
Fig-3

A shows high energy $\pi^0$
B shows low energy $\pi^0$
C show correlation $\theta_{High} - \theta_{Low}$ in these regions.

$\Theta^* \equiv$ Centre of Mass angles
$\Theta \equiv$ Lab. angles

$\theta_1^*(\theta_1)$

$\theta_2(\theta_1)$

$K.E._{\pi^0}(\theta)$