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AN ATTEMPT TO ESTABLISH AN UPPER LIMIT
FOR THE PRODUCTION CROSS-SECTION OF A NEUTRAL BOSON
IN THE 400 MeV MASS REGION

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The situation of the scalar mesons, which had been postulated on several occasions both by theoreticians and by experimentalists, is far from being clarified.

For the weak interactions one would like these mesons to symmetrize the vector and the axial current¹⁾. Within the framework of the various symmetries and algebras, a scalar singlet and octet are predicted, for instance by $SU(3) \times SU(3)$ algebra²⁾, whilst they are not forbidden by $SU(6) \times O(3)$ symmetry³⁾; only a scalar octet is required in the tadpole model of $SU(3)$ breaking interactions⁴⁾; scalar mesons also appear in bootstrap theories.

Experimentally, the presence of possible scalar mesons has been suspected in quite a large range of masses; we will be talking about the so-called $\sigma(0^{++})$, an s-wave dipion system in the 400 MeV mass region. Its existence has been invoked from time to time as a convenient explanation for various experimental data such as:

- the nucleon-nucleon scattering amplitudes below 400 MeV⁶⁾;
- the nucleon axial-vector form factor⁷⁾;
- the π^-p backward scattering⁸⁾;
- the $K_L^0-K_S^0$ mass difference⁹⁾;
- the spectrum of the decay products and/or the branching ratios for the decays of the η , K , and X^0 *)^{10,11)}.

Several production experiments have also been performed in which a search was made for the σ meson by means of an analysis, in the final state, of the invariant mass spectrum of an $I = 0$ dipion system. A survey of the present situation is given elsewhere¹²⁾.

Complementary information could be obtained from experiments of the missing-mass type, and here we are going to analyse data collected in an experiment¹³⁾, the main object of which was the study of the neutral decay modes of the η . The layout of this experiment is shown in Fig. 1.

A 1.2 GeV/c negative pion beam was sent into a liquid-hydrogen target. and the time-of-flight of neutrons produced at $\theta_{lab} = 52^\circ \pm 1.4^\circ$ was measured. This angle is larger than the maximum angle (48.7 degrees) which is allowed for neutrons associated with η production at 1.2 GeV/c. Because

*) The most suitable decay is the one in which two pions are present in the final state, and no other hadrons, for instance K_{e^+} decay.

of the anticoincidence around the target, only events without charged particles in the final state were recorded. The TOF spectrum is reported in Fig. 2; the mass associated with a certain neutron TOF in the reaction under study is also given.

No bump appears in the 400 MeV region. An upper limit for the number of σ is the sum of events which, within a certain confidence level, could be expected above the smooth curve fitting the data. Obviously this number N_σ depends on the total width Γ_σ assumed for the particle.

A value for the $\sigma(0^{++})$ differential cross-section could then be obtained from the knowledge of the η production differential cross-section and the number N_η of $\eta \rightarrow$ neutrals which are detected for the same amount of incident pions and by the same apparatus, once the neutron telescope is put at a convenient angle:

$$\frac{d\sigma}{d\Omega_{\text{c.m.}}} (\pi^- p \rightarrow n\sigma) = \frac{N_\sigma}{N_\eta} \frac{1}{\Delta\Omega_\sigma^{\text{c.m.}}} \int_{\Delta\Omega_{\text{lab.}}} d\sigma (\pi^- p \rightarrow n\eta) \quad (1)$$

Here it has been assumed that the cross-section for σ production is nearly constant in the angular range $\Delta\theta_{\text{c.m.}}$ explored ($\theta_{\text{c.m.}} = 10.2 \pm 1.2^\circ$ for a 410 MeV/c² mass).

To perform the calculation indicated in Eq. (1), we used:

- the data of Ref. 14 for $d\sigma(\pi^- p \rightarrow n\eta)$ together with branching ratio values from Ref. 15;
- a number $N_\eta = 1.0 \times 10^4$, which was evaluated from the TOF spectrum¹³⁾ at $\theta_{\text{lab}} = 48^\circ \pm 1.4^\circ$ (the efficiency for detecting neutrons has been assumed equal in the two cases);
- the upper limit N_σ which was obtained by a fit of the spectrum in Fig. 2, away from the phase space peak. The fitting function was a second-degree polynomial plus a Gaussian, centred around a mass of 410 MeV/c², with a width Γ_σ between 50 and 100 MeV/c². We have checked that a fourth-degree polynomial would not give any improvement in the fit.

The results are given in Table 1, where we have taken into account the fact we could have observed only those sigma's that decay into $\pi^0\pi^0$,

the charged final state ($\frac{2}{3}$ of the total, because of the isospin) being anticoincided. For comparison, the cross-sections predicted by the OPE model¹⁶⁾ are also given.

Table 1

Γ_{σ} (MeV)	No. of events within two s.d.	Upper limit (95% c.l.) mb/sr	OPE model mb/sr
50	< 240	0.28	1.0
70	< 130	0.15	1.5
85	< 150	0.18	1.9

From the results of Table 1 we can conclude that a relatively narrow resonance such as the one ($M_{\sigma} = 410$ MeV, $\Gamma_{\sigma} = 50-85$ MeV) indicated by current algebra¹⁷⁾, for which some experimental evidence had been given^{11,18)} if it exists at all, is produced with a cross-section three or ten times smaller than the cross-section computed by using an OPE model.

Two of us (M.G. and P.S), together with Professors R. Querzoli and V. Silvestrini, and Drs. G. Di Giugno, G. Troise and F. Vanoli, participated in collecting the TOF spectra. Professor G. Fidecaro has suggested the successive analysis.

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Figure captions

- Fig. 1 : Experimental layout of Di Giugno et al.¹³).
- Fig. 2 : The neutron TOF spectrum at 52° . The continuous curve is the result of a fit with a 2nd degree polynomial between channels 50 and 115; the enhancement on the left is a phase-space effect.

Fig.1