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THE K$\bar{K}$ SYSTEM AT LOW RELATIVE ENERGIES AND THE PROBLEM OF THE f_0 (975) AND a_0 (983) MESONS

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THE $K\bar{K}$ SYSTEM AT LOW RELATIVE ENERGIES AND THE PROBLEM OF THE f_0 (975) AND a_0 (983) MESONS

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Abstract : Some interesting features of meson production near threshold in few body reactions are emphasized. In particular the region of $K\bar{K}$ thresholds studied in pd → ^{3}He X at LNS could be an excellent tool to bring new information about the a_0 (983) and f_0 (975) meson structure dilemma.

I would like to stress in this short contribution how much as nice meson production near threshold is a spectroscopic tool in the studies of meson structure.

As you know, the pd → ^{3}He X reaction is being extensively studied at LNS in which the missing mass for X goes from the η to the φ mesons [ref 1]. A precursor work was done a few years ago[ref 2] covering the excitation function close to thresholds from π - to φ - mesons by large energy steps except in the region of the η - meson where precise data were taken. Near η threshold a very interesting pattern was observed between the two channels (^{3}He+ η) and (^{3}He+X),the X-system being either 2 pions in a 1^- state or 3 pions in relative S-states forming 0^- systems in the final state [ref 3].

Let me recall firstly what are the experimental conditions in such experiments and the specific assets of the "Excitation function for meson production near threshold" or in *abrege* in french"*courbe des seuils*".

The proton beam delivered by the Mimas/Saturne complex , continuously variable in energy from 150 to 2900 Mev by 1 Mev step, is focussed on a liquid deuterium target at a special position relatively to the SPES4 spectrometer allowing the detection of the scattered ^{3}He particles at 0 degre . For each choosen incident proton energy, the SPES4 beam line is tuned at a central magnetic field value corresponding to a null c. m.momentum for the ^{3}He (and consequently the same for X, the missing system). So, at each measurement, the c.m. energy goes into the production of the mass of X.Due to the momentum acceptance of the SPES4 spectrometer, which is about $\pm$ 3% in dp/p for fully transmission,the c.m.relative energy of X with respect to ^{3}He is at most a few MeV.If X is a meson,the available phase space is zero at threshold: if the production of X is observed it is due either to the limited momentum resolution of the apparatus or to the energy width of the meson if this one is larger than the energy resolution. Consequently,the study of this meson production near threshold allows the determination of its variation as a function of the relative c.m. momentum between ^{3}He and X, for very small values of it.

Above two meson production threshold,the excitation of a particular meson generally appears over a multipion background, or at even more higher energy, over a $K\bar{K}$ production.

One of the most important features of the "*courbe des seuils*" is that, as the proton beam energy is varied,a specific bosonic object X is selected in a S-wave with respect to the ^{3}He : this is a very nice kinematical situation in the search for η - or η'-meson nucleus or S-wave resonance effects.

Another interesting feature arises at the crossing of 2 pions, 3 pions.., 2 kaons thresholds : these multi-meson productions are done at rest in their c.m. allowing the search for and the study of S-wave resonances between them. Due to Lorentz boost, the angular acceptance given by SPES4 near thresholds is equal or close to 4π. Among these multi -meson productions at threshold, the 2 kaon case seems very promising in view of the possible existence of $K\bar{K}$ molecules weakly bound as predicted by WEINSTEIN and ISGUR [ref 8] in their variational calculation of q^2-$\bar{q}^2$ states.

Before going further in the pd $\rightarrow$ ^{3}He X "*courbe des seuils*", let me take as a reference work the nice experiment performed in the 70's at the Nimrod accelerator by a group from Imperial College [ref4], studying the reaction $\pi^- p \rightarrow n X$ near the thresholds for the production of η, ω , η', f_0 and ϕ. The experiment used pion beams between 0.7 and 4 GeV/c and was settled to detect the neutrons at 0 degre.On figure 1-a is shown their results around the phi production.The peak corresponding to the phi is appearing with some difficulty over a multipion background. It is only when a $K\bar{K}$ selection by charged particle detectors placed around the target is operated than a clear phi signal emerges from the background(fig 1-b) ; this allows the determination of the ratio of the ϕ production to multipions, to be a few percents.

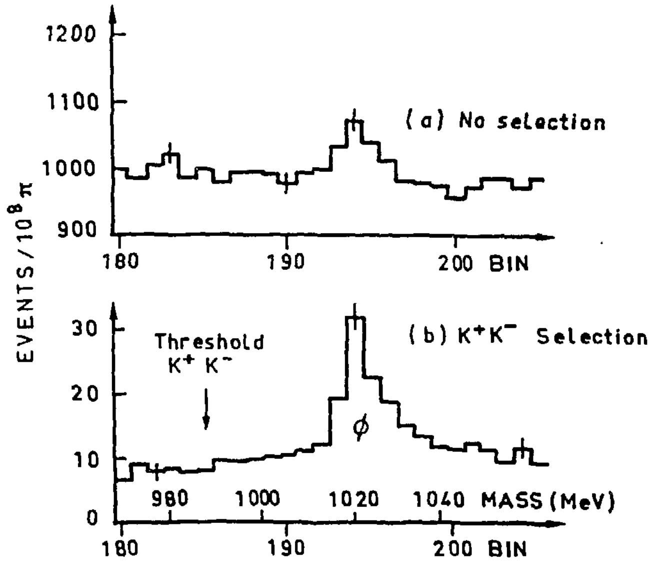


Fig. 1 : The $\pi^- p \rightarrow nX$ excitation function near the ϕ-meson production [ref. 4].

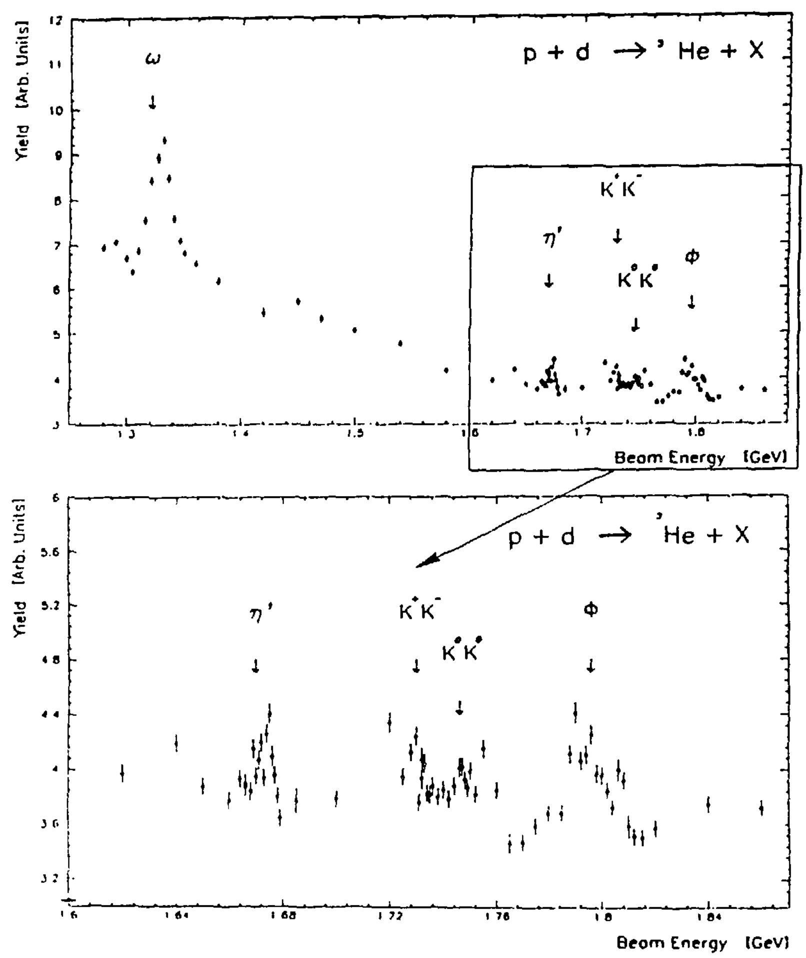


Fig. 2 : The LNS pd $\rightarrow$ ^{3}HeX "courbe des seuils" [ref. 1].

On figure 2 is shown the "courbe des seuils" for p d $\rightarrow$ ^{3}He X obtained at LNS in the experiment LI #183/219 [ref 1] as a function of the incident kinetic proton energy.The lower spectrum is a blow up of the upper curve.The excitations of the ω, η' and ϕ-mesons are clearly seen;in particular the ratio peak over background for the ϕ is better than the same ratio measured in the Nimrod experiment with the two kaons in coincidence : this demonstrates the high selectivity of the pd $\rightarrow$ ^{3}He X reaction to produce isospin 0 heavy mesons. This remark can be the starting point for a discussion about the $f_0(975)$ whose assigment and $q\bar{q}$ composition is controversial [ref5].

As a matter of fact, the 0^{++} multiplet $^3P_0$ (see figure 3) is not yet well understood.In particular in the non-strange partners of this multiplet, the $a_0(983)$ and $f_0(975)$ are too close in mass while the $a_0(983)$ and the $f_0(1400)$ are too far : it is difficult to understand why the $f_0(975)$ which has a 20% branching ratio to $K\bar{K}$ and so a significant $s\bar{s}$ component, can be degenerated in mass as much to be below the $a_0(983)$ which is known to have no strange component($K\bar{K}$ B.R.only seen).This fact lead to the idea that the $a_0(983)$ and the $f_0(975)$ are not $q\bar{q}$ states.Different theoretical predictions exist;some of them are mentionned here :

- based on experimental results of the study of pp $\rightarrow$ pp(MM) at CERN ISR,AU et al. [ref 6] have proposed the existence of a glueball S(991) with a width of $\Gamma = \pm 21$ MeV.

-in a M.I.T. bag model, JAFFE [ref 7] found $q^2\bar{q}^2$ states with hidden $s\bar{s}$ component with large $K\bar{K}$ coupling.

-as already mentionned,WEINSTEIN and ISGUR [ref 8] in a variational calculation in a non relativistic potential model found $q^2\bar{q}^2$ states weakly bound in $K\bar{K}$ S-wave molecular shape, coming with J=0 and I=0 or 1.

-very recently , CANNATA et al.[ref. 9], in the study of $K\bar{K}$ threshold effects by means of a separable potential formalism have added to the usual π - π and K-$\bar{K}$ channels an exotic channel with heavy constituents and found a strong coupling between this new channel and the $K\bar{K}$ one.As a consequence the $f_0(975)$ appears to behave like a $K\bar{K}$ molecule bound by this exotic channel.

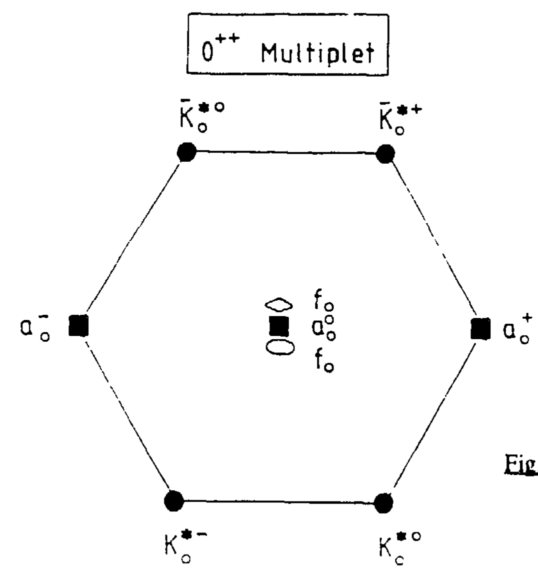
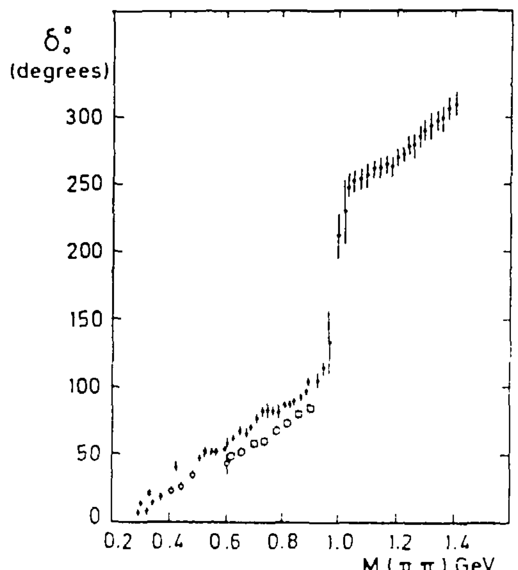


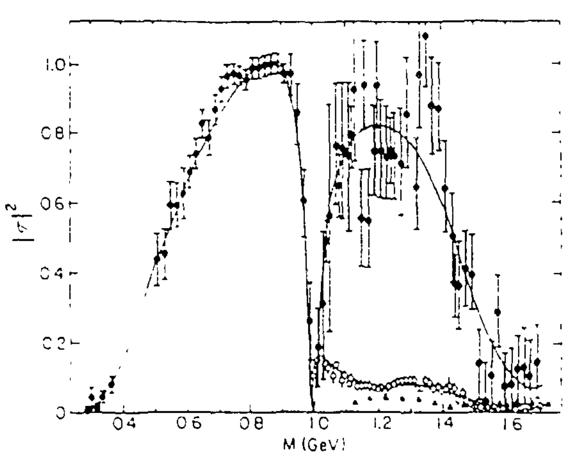
Fig. 3 : The $^3P_0$ meson nonet [from ref. 5].

Whatever could be the extra $q\bar{q}$ nature of these mesons,a search for the 0^{++} missing $q\bar{q}$ states would consequently be needed.

Coming back to the pd → ^{3}HeX excitation function shown on fig. 2, it is remarkable that not only the vector meson like the ω or ϕ are well excited but also the scalar ones like the η'. It may be possible to get complementary or even new information on the nature of the f_0 and a_0 mesons. What is known of the $f_0(975)$ comes out from phase shift analysis of π - π elastic scattering as shown on figure 4-a,where the I=J=0 π - π phase shifts are plotted as a function of the π - π mass [ref. 9]. The passage by 180 degres at 975 MeV (the $K\bar{K}$ threshold is at 987.3 MeV) corresponds to the classified $f_0(975)$, yielding a hole in the I=0 S-wave cross-section(see figure 4-b).



(fig. 4a)



(fig. 4b)

Fig. 4 : I = I = 0 π - π phase shifts [ref. 9] (fig. 4a) ; The resultant S wave cross section scaled by M^2 : the solid dots are for the ππ elastic cross section, the open circles are for ππ → KK and the triangles for ππ → ηη (fig. 4b) [from ref. 5, Morgan and Pennaington].

The LNS "*courbe des seuils* " presents interesting structures around the K^+K^- and K^oK^o thresholds with a small increase of the averaged cross-section in between the η' and ϕ mesons (see fig 2,lower part). Are those structures signature of cusp effects at thresholds superimposed on the f_0 and a_0 mesons ? It is clear that this mass region must be more precisely studied and this is already programmed to be done in july 1992. In the same run the higher mass region (around the $f_0(1400)$) will be explored.An investigation of a coincident experiment between the ^3He particles and two coplanar forward charged particles is also planned in a set up whose scheme is shown on figure 5.This configuration of the detector selects the $^3He\ K\bar{K}$ outgoing channel and so well suited to study the $K\bar{K}$ B.R.of the $f_0(975)$.

A similar coincident experiment with a more elaborated charged particles detectors is in development in Bonn (RFA) to be installed at the new Cosy facility for 1993-94 [ref. 10].

As a perspective, other reactions can also be promising : the pd $\rightarrow$ t X selects the I=1 channel and can usefully compared to the pd $\rightarrow$ ^3He X "*courbe des seuils*". The α-α $\rightarrow$ α-α X reaction at and above the $K\bar{K}$ thresholds, where the two outgoing α could be detected for instance with the SPES3 spectrometer, should select pure I=0 channels. A similar role can be played by the dd $\rightarrow$ αX reaction already studied in the past at Saturne [ref. 11].

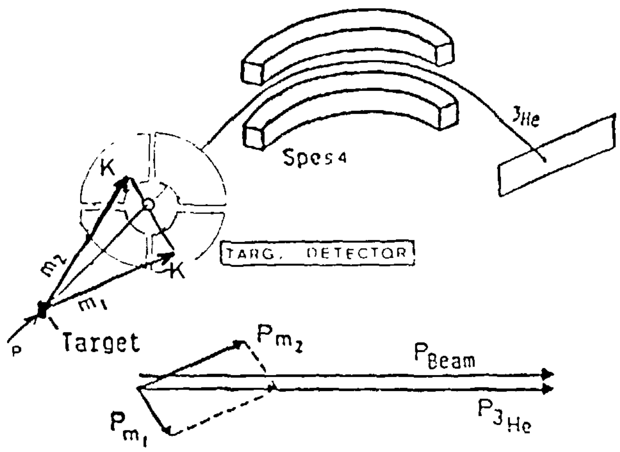


Fig.5

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