25

Institute of Theoretical
and Experimental Physics

FERMILAB
MAR 2 2 2001
LIBRARY

30-00

ITEP-30-00

V. Baru, J. Haidenbauer, A. Kudryavtsev,
V. Tarasov, V. Chernyshev

The perspectives of study lightest scalar $a_0^-(980)$ in the reaction $pd \to ppa_0^- p_s$ close to threshold

Fermilab Library
0 1160 0089661 7

Moscow 2000

UDK 539.12 M-16

THE PERSPECTIVES OF STUDY LIGHTEST SCALAR $a_0^-(980)$ IN THE REACTION $pd \to ppa_0^- p_s$ CLOSE TO THRESHOLD: Preprint ITEP 30-00/

V. Baru[1,2], J. Haidenbauer[2], A. Kudryavtsev[1,2], V. Tarasov[2], V. Chernyshev[1,2]
– M., 2000 – 24p.

We give estimations of total and differential cross sections for the reaction $pn \to ppa_0^-$ close to threshold. The experimental information on this reaction could be extracted from the process $pd \to ppa_0^- p_s$ on a deuterium target. The privilege of this reaction is that all final particles but a_0^- are protons. That is why the effective mass of a_0^- may be reconstructed easily. We discuss how the extracted cross sections of the reaction $pn \to ppa_0^-$ may be used to get information on such fundamental characteristics of a_0^--meson as its nominal mass $\bar{m}$ and its coupling constants $g_{a_0\pi\eta}$ and $g_{a_0K\bar{K}}$.

Fig. – 7, ref. – 22 names

© Институт теоретической и экспериментальной физики, 2000

[1]Institute of Theoretical and Experimental Physics, 117259, B. Cheremushkinskaya 25, Moscow, Russia

[2]Institut für Kernphysik, Forschungszentrum Jülich GmbH, D–52425 Jülich, Germany

I. INTRODUCTION

The study of the lightest scalar mesons $f_0(980)0^+(0^{++})$ and $a_0(980)1^-(0^{++})$ is one of the most fundamental problem in physics of hadrons. Both these mesons are strongly coupled to the $K\bar{K}$-channel and have practically equal masses.

The standard interpretation of these mesons as $q\bar{q}$-states [1] has difficulties in explaining simultaneously both these facts. A more refined $q\bar{q}$-model was considered recently in ref. [2]. The authors of paper [2] have suggested, that the $f_0(980)$ is an admixture of $u\bar{u}$, $d\bar{d}$ and $s\bar{s}$-states. At the same time the $a_0(980)$ was build from non strange quarks only. There exists also an attempt to build the $f_0(980)$ from $s\bar{s}$-component only [3]. The coupling of $f_0(980)$ to the non strange sector in this model is due to nonperturbative QCD effects. Note, that in line with the models [1–3] it is difficult to explain the practical coincidence of the masses for the $f_0(980)$- and $a_0(980)$-mesons. It is also worth mention here the four-quarks model for lightest scalars proposed in Ref. [4]. This model could explain the mass degeneration for these mesons and their large branching into $K\bar{K}$-channel.

In Gribov's confinement model [5] the a_0 and f_0 are rather exceptional mesons and their properties should differ from the predictions of more standard quark models like [1–4]. In particular in Gribov's model the interaction cross sections of the a_0- and f_0-mesons with hadrons should be small.

We are to mention here also a more phenomenological "hadron molecular" model, in which both mesons are build from K and $\bar{K}$ [6]. The authors of the paper [7] have developed a meson-exchange model to describe the $f_0(980)$- and $a_0(980)$-mesons. In their approach both these mesons originate from the coupling of the $\pi\pi$-channel to the $K\bar{K}$- channel. But in contrast with the $f_0(980)$, the $a_0(980)$ would not appear to be a $K\bar{K}$ bound

state but a dynamically generated threshold effect with a relatively broad pole ($\Gamma_{a_0} \approx 200MeV, \bar{m}_{a_0} \approx 990MeV$). Note, that different approaches give different predictions for the parameters of the a_0- and f_0-mesons. So the precision measurement of parameters for the lightest scalars may really solve the problem of their nature.

Note, that the proposal to study properties of the a_0^+-meson in the reaction $pp \to da_0^+$ at the ANKE spectrometer of COSY was discussed already in detail in ref. [8]. In our paper we discuss the possibility to study the reaction $pd \to ppa_0^- p_s$ to get information on properties of the negative a_0^--meson.

The resonance $a_0^-(980)$ was observed for the first time in the reaction $K^-p \to \Sigma^+(1385)\eta\pi^-$ [9]. This meson manifests itself as a sharp peak in the $\pi^-\eta$-effective mass distribution. The mass of a_0^- was found to be $\bar{m} = 981MeV$ and the visible width of the peak to be around $50MeV$. The experimental data of the paper [9] were analyzed in ref. [10]. In that paper a two-channel parameterization for the S-matrix was used to get information on the parameters of the a_0^--meson. It was found, that the visible width of the peak $\Gamma_{vis} \approx 50MeV$ is smaller, than the bare width $\Gamma_{\pi\eta}$ for decay of a_0 into $\pi\eta$-channel ($\Gamma_{\pi\eta} \approx 80MeV$). The inequality $\Gamma_{vis} < \Gamma_{\pi\eta}$ is a consequence of the $K\bar{K}$-threshold, which is strongly coupled to the $a_0(980)$ and is situated only $10MeV$ above the position of the peak. Because of that reason the form of the peak is not of Breit-Wigner type but is strongly affected by the $K\bar{K}$-threshold (cusp). Note, that in the four-quark model [4] the bare width $\Gamma_{\pi\eta}$ should be much larger, namely of the order of $300MeV$, see in this connection also ref. [11]. That is why the form of the peak is sensitive to the quark content of $a_0(980)$-meson.

Note, that the experimental data [9] were not in contradiction to the following ratio for the coupling constants:

$$d = \frac{g^2_{a_0^- K^- K^0}}{g^2_{a_0^- \pi^- \eta}} = \frac{3}{2}. \tag{1}$$

This value d corresponds to the assumption that a_0 belongs to the $SU(3)$-octet of scalars and $\eta - \eta'$ mixing angle is zero, $\theta_{\eta\eta'} = 0$. Note, that in the

$SU(3) - 1^3P_0 q\bar{q}$-nonet interpretation of a_0 [2] the ratio d is:

$$d = \frac{\lambda}{2cos^2(\theta_{\eta\eta'})},$$

where $\lambda \approx 0.6$. That is why the branching of a_0-meson into the $K\bar{K}$-channel is to be relatively suppressed in this model in comparison to the predictions of the $SU(3)$-octet approach ($d \approx 0.8$ in [2]). The recent experimental data on a_0-production in the $\pi^- p$-collisions [12] give evidence for the ratio d to be close to unity. In particular, it follows from the analysis of ref. [12], that the charged a_0^+ has a larger mass, $\bar{m} = (998 \pm 4) MeV/c^2$. Its width is $\Gamma(a_0^+) = (69 \pm 11) MeV/c^2$ and the ratio $d = 0.91 \pm 0.11$. Note, that from the analysis of the paper [13] this ratio d is to be larger, $d = 1.16 \pm 0.18$. In the four-quark approach [4] the coupling to the $K\bar{K}$-channel is to be large. We conclude, that the ratio of the coupling constants is also very sensitive to the quark content of the $a_0(980)$-meson. Note, that in both experiments [9] and [12] only the $\pi\eta$ decay mode of a_0 was investigated. That is why the ratio of branchings for charged a_0's was never measured directly.

In this paper we suggest to extract the parameters of the $a_0^-(980)$-meson measuring its production in nucleon-nucleon collisions. To be more concrete, we suggest to study the reaction $pn \to ppa_0^-$ using a deuterium target. To reconstruct kinematics, one needs to measure all final protons for the reaction $pd \to ppa_0^- p_s$, where p_s is the proton-spectator momentum. At the same time both decay channels of the a_0^- contain negative particles and/or could be easily identified through the photons from η-decay. In the case of identification of both leading decay channels for the a_0^--meson the study of this reaction at the ANKE spectrometer of COSY should provide a unique information on fundamental characteristics of this meson.

II. TOTAL CROSS SECTION FOR THE REACTION $pn \to ppa_0^-$.

Consider the process for exclusive production of a resonance in NN-collisions, i.e. the reaction

$$NN \to NNR.$$

As we shall demonstrate, the results for the absolute value of total cross section depend very drastically on measured interval of mass for resonance. The explanation is simple: in case of a threshold reaction $2 \to 3$ and under the constraint that the production amplitude is constant, the total cross section is proportional to Q^2, where Q is energy excess. That is why the production of a resonance with mass lighter than the nominal mass is getting more preferable and one needs to introduce some cut-off parameter. Let us illustrate this by some concrete formulae. In the case of production of stable particle of mass m in the pp-collision ($pp \to pp +$ "stable particle") we get the following expression for the diproton mass spectrum near threshold (production amplitude is taken to be constant!):

$$\frac{d\sigma}{dm_{pp}} \propto F(k)k\sqrt{Qm_p - k^2} \tag{2}$$

Here $F(k)$ is the proton-proton enhancement factor [14–16] and k is the relative momentum of the final protons, and $m_{pp} = 2m_p + k^2/m_p$. If we consider the production of resonance of finite width Γ, we should convolute the expression (2) with the spectral density $\rho(m, \Gamma)$. For a narrow resonance it can be parameterized by a Breit-Wigner function

$$\rho(m, \Gamma) = \frac{\Gamma/2\pi}{(m - \bar{m})^2 + \Gamma^2/4}, \tag{3}$$

where $\bar{m}$ is the averaged (nominal) mass of the unstable particle. Thus, instead of (2) we get:

$$\frac{d\sigma}{dm_{pp}} \propto F(k)k \int_{m_{min}}^{m_{max}} dm \frac{\Gamma/2\pi}{(m - \bar{m})^2 + \Gamma^2/4} \sqrt{m_p(Q + \bar{m} - m - k^2/m_p)}, \tag{4}$$

where $Q = \sqrt{s} - 2m_p - \bar{m}$ is the nominal threshold, $m_{max} = Q + \bar{m} - k^2/m_p$ and the value of the minimal mass m_{min} will be specified below.

Rewriting the integral in (4) in dimensionless variables we get

$$\frac{d\sigma}{dm_{pp}} \propto F(k)kI(x_0); \tag{5}$$

where

$$I(x_0) = \frac{1}{\pi} \int_0^{x_{max}} \frac{\sqrt{x}dx}{(x - x_0)^2 + 1}. \tag{6}$$

Here we introduced notations

$$x_0 = \frac{Q - k^2/m_p}{\Gamma/2}, \qquad x_{max} = \frac{Q + \bar{m} - m_{min} - k^2/m_p}{\Gamma/2}.$$

Now let us discuss, what is the reasonable value for cut off parameter m_{min} in the expression (4). As is seen from the BW-formula (3), the probability to find a very light a_0 is small. So it seems, that the diproton mass spectrum should not be sensitive to the choice of m_{min}. But this is not a correct statement. Indeed, taking in view that the leading decay channel for a_0^--meson is $a_0^- \to \pi^-\eta$, let us chose $m_{min} = m_\pi + m_\eta$. Making so, we immediately get $x_{max} \gg 1$ and $I(x_0) \propto 1/\sqrt{-x_0}$ for large negative x_0. It means, that

$$\frac{d\sigma}{dm_{pp}} \propto const$$

at $k^2 \gg m_p Q$ (i.e. for $m \ll \bar{m}$).

So the distribution (5) in this limit has a long constant tail in the region of large momenta k and the total cross section depends drastically on the chosen value of m_{min} (that is not the case for binary $2 \to 2$ reactions). In Figure 1 we give the dependence of the total cross section for the reaction $pn \to ppa_0^-$ for some typical values of minimal mass $m_{min} = \bar{m} - C$. The production amplitude is calculated in a simple fusion model and is discussed in the next Section. Figure 1 demonstrates the drastic dependence of the production cross section on the value of the cut off parameter C. The contribution from the region of the resonance peak with $\mid m - \bar{m} \mid \leq \Gamma/2$ to this cross section corresponds to the choice of the parameter $C \leq \Gamma$.

III. PRODUCTION AMPLITUDE FOR THE REACTION $pn \to ppa_0^-$

To estimate the production amplitude for the reaction $pn \to ppa_0^-$ close to threshold we use a simple fusion model with intermediate η- and π-mesons. The corresponding Feynman diagram is shown in Figure 2. We use the standard values for the πNN and ηNN coupling constants, $g^2_{\pi NN}/4\pi = 14.6$ and $g^2_{\eta NN}/4\pi = 3.0$. $a_0\eta\pi$-coupling is determined by the relation

$$\Gamma_{\pi\eta} = \frac{g^2_{a_0\pi\eta}}{8\pi} q_{\pi\eta}, \tag{7}$$

where $q_{\pi\eta}$ is the $\eta\pi$-relative momentum. For the bare partial width $\Gamma_{\pi\eta} = 80MeV$ we get from (7) that $g_{a_0\eta\pi} = 2.5$.

The amplitude M_{34}, which corresponds to the Feynman graph of Figure 2 is

$$M_{34} = \sqrt{2}\frac{g_{\eta NN}F_\eta(q_1^2)}{2m_p}\frac{g_{\pi NN}F_\pi(q^2)}{2m_p}g_{\pi\eta a_0}\bar{m}\frac{\bar{u}(p_3)\gamma^5\hat{q}u(p_1)\bar{u}(p_4)\gamma^5\hat{q}_1u(p_2)}{(q^2-m_\pi^2)(q_1^2-m_\eta^2)} \tag{8}$$

Here $\bar{m} = 983.4MeV$ is the averaged mass of a_0 and $F_{\pi,\eta}$ are form factors,

$$F_i(q^2) = \frac{\Lambda_i^2 - m_i^2}{\Lambda_i^2 - q^2}, \quad i = \pi, \eta. \tag{9}$$

We take $\Lambda_\pi = 1300MeV$ and $\Lambda_\eta = 1500MeV$ in correspondence to the Bonn potential model [17]. The total production amplitude is to be antisymmetrized with respect to spin and space variables of the final protons ($34 \to 43$). Finally for averaged production matrix element we get:

$$\mid \bar{M} \mid^2 = g_{\pi NN}^2 g_{\eta NN}^2 g_{a_0\pi\eta}^2 \frac{F_\pi^2(q^2)F_\eta^2(q_1^2)m_p^2\bar{m}^4}{(q^2-m_\pi^2)^2(q_1^2-m_\eta^2)^2}, \tag{10}$$

where $q^2 = q_1^2 = -m_p\bar{m}$. Taking into account the effect of the strong final state interaction between the final protons (enhancement factor $F(k)$), we get the following expression for the production cross section

$$\sigma_{pn\to ppa_0} = \frac{\mid \bar{M} \mid^2}{4I}\frac{1}{8\pi^3(2m_p+\bar{m})}\sqrt{\frac{2\mu_3}{m_p^3}}\,\Phi(Q,\Gamma), \tag{11}$$

where

$$\Phi(Q,\Gamma) = \int_0^{k_{max}} dk F(k) k^2 \int_{m_{min}}^{m_{max}} \frac{dm\ \Gamma/2\pi}{(m-\bar{m})^2+\Gamma^2/4}\sqrt{m_p(Q+\bar{m}-m-k^2/m_p)},$$

$m_{min} = \bar{m} - C$, $m_{max} = Q + \bar{m} - k^2/m_p$, $k_{max} = \sqrt{m_p(Q+\bar{m}-m_{min})}$.
$\mu_3 = 2m_p\bar{m}/(2m_p+\bar{m})$, $I = 2E_1 \mid \vec{p}_1 \mid = (2m_p+\bar{m})\sqrt{\bar{m}(\bar{m}+4m_p)}/2$.

The momentum dependence of the pp-enhancement factor $F(k)$ was discussed in details in refs. [14,15]. For the reaction with high momentum transfer like $NN \to NN\pi$ (η, η', *etc.*) this momentum dependence practically doesn't depend on any concrete form of production amplitude and is universal. At the same time the absolute value of the enhancement factor as it was

recently clarified in refs. [16,18] depends on the production amplitude and on sort of the emitted particle. In our treatment we use the standard form of the pp−enhancement factor $F_{Ya}(k)$, calculated with a separable Yamaguchi potential [14]. The absolute value of enhancement factor is obtained by introducing the rescaling factor ξ, so

$$F(k) = \xi F_{Ya}(k).$$

The factor ξ reflects the suppression of the absolute value of the enhancement factor in realistic NN-potentials (Bonn and/or Paris). In line with our estimations in ref. [18] we take $\xi = 1/5$.

The resulting cross section versus excess energy Q is shown in Figure 1 for different values of C. The expression (11) for the cross section ignores the influence of the $K\bar{K}$-threshold. To get the expression for partial cross sections $pn \to ppK^-K^0$ and $pp \to pp\pi^-\eta$ we substitute the spectral density in equation (3) by

$$\rho(m, \Gamma(m)) = \frac{1}{2\pi} \frac{\Gamma_{\pi\eta} + \Gamma_{K\bar{K}}(m)}{\mid m - \bar{m} + i(\Gamma_{\pi\eta} + \Gamma_{K\bar{K}}(m))/2 \mid^2} \tag{12}$$

In this formula we put again $\Gamma_{\pi\eta}$ to be constant, but include the dependence of $\Gamma_{K\bar{K}}$ on mass:

$$\Gamma_{K\bar{K}} = \frac{g^2_{a_0 K\bar{K}}}{8\pi} \sqrt{2m_{K^-K^0}(m - m_{K^0} - m_{K^-})}, \tag{13}$$

where $m_{K^-K^0} = m_{K^-} m_{K^0}/(m_{K^-} + m_{K^0})$.

In this two-channel approach the total and partial cross sections for the reaction $pn \to ppa_0^-$ are shown in Figures 3a and 3b for different values of the ratio $d = 0, 3/2$ and 3. As it is seen from Figure 3a, the total cross section is getting smaller, when $g_{a_0^- K^0 K^-}$ increases. This decreasing of the cross section is a consequence of a destructive interference between the direct decay amplitude $a_0 \to \pi\eta$ and the amplitude for the decay $a_0 \to \pi\eta$ through the intermediate $K\bar{K}$-state.

IV. HOW TO EXTRACT PARAMETERS OF a_0^--MESON FROM THE EXPERIMENT

We are to extract the following parameters for the a_0^--meson: its nominal mass $\bar{m}$ and the coupling constants $g_{a_0\pi\eta}$ and $g_{a_0K\bar{K}}$. These are the parameters which determine the form of the resonance peak.

The ratio of the coupling constants d (1) may be extracted from the direct measurement of the ratio for branchings at a fixed mass of a_0-meson:

$$\frac{Br(a_0 \to K\bar{K})}{Br(a_0 \to \pi\eta)} = \frac{g^2_{a_0K\bar{K}}}{g^2_{a_0\pi\eta}} \frac{\sqrt{2m_{K^-K^0}(m - m_{K^0} - m_{K^-})}}{q_{\pi\eta}} \tag{14}$$

After getting the experimental information on the ratio (14) we have still to determine two parameters $\bar{m}$ and $g_{a_0\pi\eta}$. We see two alternative ways how to extract these parameters.

i) Study of effective mass spectrum. In the case of the reaction $pn \to ppa_0^-$ close to threshold the strong pp-FSI has to be taken into account. The distribution over the effective $\pi\eta$-mass is given by the following expression

$$\frac{d\sigma}{dm_{\pi\eta}} = \frac{|M|^2}{4I} \frac{\Gamma_{\pi\eta}}{8\pi^4 m_p\sqrt{s}} \sqrt{\frac{\bar{m}}{2m_p+\bar{m}}} \frac{1}{|m-\bar{m}+i\Gamma/2|^2} \int_0^{k_{max}} F(k)\sqrt{k^2_{max}-k^2}\, k^2 dk \tag{15}$$

where $k_{max} = \sqrt{m_p(Q - m + \bar{m})}$. In addition to the phase volume the dependence of expression (15) on the mass m comes from the enhancement factor $F(k)$ in the integral:

$$\int_0^{k_{max}} F(k)\sqrt{k^2_{max} - k^2}\, k^2 dk \tag{16}$$

The form of the resonance mass spectrum given by expression (15), is presented in Figures 4a and 4b for different values of $\Gamma_{\pi\eta}$, ratio of couplings d and mass $\bar{m}$ of a_0. It illustrates the sensitivity of the mass spectrum to these parameters. The Figure for $d\sigma/dm_{K\bar{K}}$ at different values of d and $\Gamma_{\pi\eta}$ is also shown (see Figure 5).

ii) Binnie's method. In the paper of Binnie et al. [19] this method was used to study the production of ω -,η - and η'-mesons in the reaction $\pi^-p \to nX$. The method consists in studying the resonance excitation curve

versus beam momentum under the condition that the momentum of the final neutron is kept fixed.

Considering the case of the reaction $pn \to ppa_0^-$, let us look at the expression for the following differential cross section:

$$\frac{d^6\sigma}{d\vec{k}d\vec{P}} = \frac{|M(E,\vec{P},\vec{k})|^2}{4I} \frac{F(k)}{(16\pi)^2 m_p \mu_3 \sqrt{s}} \frac{\Gamma_{\pi\eta}}{|Q - P^2/2\mu_3 - k^2/m_p + i\Gamma/2|^2} \tag{17}$$

where $\vec{P} = \vec{p}_3 + \vec{p}_4$, $2\vec{k} = \vec{p}_3 - \vec{p}_4$. Let us also fix the momenta P and k in some small intervals ΔP^* and Δk^* . In this case the dependence of the double differential cross section $d^2\sigma/dP^*dk^*$ is determined by the following equation:

$$d^2\sigma \mid_{P^*,k^*} = \frac{|M|^2}{4I} \frac{F(k^*)\Gamma_{\pi\eta}}{|Q - P^{*2}/2\mu_3 - k^{*2}/m_p + i\Gamma/2|^2} \frac{P^{*2}k^{*2}\Delta P^*\Delta k^*}{(2\pi)^4 m_p \mu_3 \sqrt{s}} \tag{18}$$

As is seen, the energy dependence for this expression (18) reproduces the form of resonance. To apply this method, one needs to vary the beam energy and to study the curve of resonance excitation of a_0-meson. Note, that application of both methods **i)** and **ii)** should help getting additional information on the dependence of the production amplitude $M(\sqrt{s})$ on energy $\sqrt{s}$.

V. SOME REMARKS ON KINEMATICS

In the case of the reaction $pn \to ppa_0^-$ in the laboratory system close to threshold all final fast moving particles are in a narrow cone around the beam direction. The longitudinal momenta of all these three particles are of the order of $1GeV$ and the perpendicular momenta are small. For example for energy excess $Q = 50MeV$ the maximal laboratory scattering angles for kaons are around 20°. The scattering angles for η and π are larger because of larger energy release in the decay $a_0 \to \pi\eta$.

To measure the reaction $pn \to ppa_0^-$ we are to use the deuteron target, i.e. to study the reaction $pd \to ppa_0^- p_s$. We suggest to study this reaction for small momenta of the proton-spectator, $p_s \leq 200MeV/c$. In the Table we give values of threshold energies for this reaction at some typical values of momentum of spectator. To estimate the cross section on deuteron, we suggest a simple pole mechanism for this reaction. The corresponding Feynman diagram is shown in

Figure 6. Usually pole approximation works well up to momenta of spectator $p_s \lesssim 150 - 200MeV$. In this region all re-scattering diagrams give negligible corrections to this leading pole term. The distribution over the spectator momentum which corresponds to pole mechanism of Figure 6 , is given by the expression:

$$\frac{d\sigma}{d\vec{p}_s} = \mid \psi_d(\vec{p}_s) \mid^2 \sigma_{np \to ppa_0^-}(\sqrt{s'}), \tag{19}$$

where $\psi_d(\vec{p})$ is the deuteron wave function in the momentum space. The relation between s and s' is determined by kinematics. The distribution over the proton-spectator momenta for $\sqrt{s'}$ being fixed is shown in Figure 7. Note, that near the threshold the production cross section for the reaction $pn \to ppa_0^-$ is a rather sharp function of $\sqrt{s'}$. That is why the expression (19) at fixed energy of beam may be used to study the energy dependence for the cross section $pn \to ppa_0^-$.

Table 1:

$p_s(MeV/c)$	$\cos \vec{p}\vec{p}_s$	$T_p(MeV/c^2)$	$\sqrt{s_{a_0 p_s}}(MeV/c)$
0	-	2454	2159
100	-1	2884	2268
100	0	2484	2169
100	1	2165	2080
200	-1	3538	2434
200	0	2577	2198
200	1	1971	2025
300	-1	4581	2678
300	0	2738	2248
300	1	1846	1987

VI. IS IT POSSIBLE TO EXTRACT THE a_0N-AMPLITUDE FROM THE REACTION $pd \to ppa_0p_s$?

In Section 5 we suggested to use pole approximation to estimate the production of a_0^- on deuteron at small spectator momenta $p_s \leq 200MeV/c$. Usually at small p_s this pole mechanism works well and all the corrections due to the FSI- effects are small.

The produced a_0^- interacts with the fast protons as well as with the slowly moving spectator. What about the interaction of the a_0 with spectator, it is evidently negligibly small in this kinematics. The main reason is, that the produced a_0^- moves in forward direction with high momentum. That is why the total energy of the system "a_0+ spectator" is also large. In Table we present values for invariant energy $\sqrt{s_{a_0 p_s}}$ for some typical values of momenta and angles of the spectators. As is seen from the Table, typical values of $\sqrt{s_{a_0 p_s}}$ are large, much larger, than $m_{a_0} + m_{p_s} = 1922 MeV$. That is why the process of interaction of the produced meson with the proton-spectator should be considered as only a small corrections to the main amplitude. The signal of this interaction may be definitely found only in the case, when the spectator moves along the direction of beam and has momenta $> 300 MeV/c$. Unfortunately the number of events in this geometry is seriously limited because of small probability to find in deuteron a proton with a large momentum, see also Figure 7.

At the same time the interaction of the a_0 with a fast proton may be observed (if exists or if is not negligibly small ; in Gribov's approach it is small, see [5]). Near the threshold in their rest frame both protons and a_0 move slowly. That is why the interaction between a_0 and proton is effected and gives serious influence on $a_0 p$- and pp-effective mass distributions. In the papers [14,20] we gave some examples of these distributions for the cases of η- and η'- production in the pp-collisions. In the case of a_0-production these distributions are to be corrected because of a large width of the produced a_0 in comparison to that we have in η and η' cases.

To conclude, let us stress again, that the measurement of momenta for fast protons as well as spectator momentum gives possibility to reconstruct the effective mass of the a_0^- and identify the process. Additional measurements of the final states for the a_0^--meson should provide opportunity to find the mass and the coupling constants for this lightest negative scalar. The similar idea for measuring the reaction $pn \to pp\pi^-$ on deuteron target at 2 GeV was realized in the ref. [21]. Recently the reaction $pd \to pp\pi^- p_s$ was also studied in the ref. [22].

Acknowledgments

The authors are very indebted to V.A.Gani for an invaluable help in the preparation of the manuscript. A.K. acknowledges the hospitality of the Institute für Theoretische Kernphysik IKP, Forschungzentrum Jülich. A.K., V.B. and V.T. are also thankful to the Russian Foundation for Basic Research (grant 98-02-17618) for partial support.

REFERENCES

[1] N.A.Tornquist, Phys.Rev.Lett. **49**, 624 (1982).

[2] V.V.Anisovich, E-print hep-ph/9712504, Dec. 1997

[3] A.Veinstein et al., EPAN (Elementarnie Chastizi Atomnoe Yadro), **13**, 542 (1982).

[4] N.N.Achasov and G.N.Shestakov, Sov.Phys.Uspechi, **161**, N.6, 53 (1991); **142**, 361 (1984); Z.Phys., **C 41**. 309 (1988).

[5] V.N.Gribov, LU-TP-91-7;ORSAY Lectures on Confinement1, LPT HE-ORSAY-92-60; V.N.Gribov, Eur. Phys.J., **C10**, 91 (1999); F.Close et al., Phys.Lett., **B319**, 291 (1993).

[6] J.Weinstein, N.Isgur., Phys. Rev., **D41**, 2236 (1990); N.Isgur, K.Maltman, J.Weinstein and T. Barnes, Phys.Rev.Lett., **64**, 161 (1990).

[7] G.Janssen, B.C. Pearce, K. Holinde and J.Speth, Phys. Rev., **D52**, 2690 (1995).

[8] L.A.Kondratyuk et al., Preprint ITEP-19-97, Moscow (1997); V.Tchernishev et al., COSY proposal N.55: "Study of a_0^+-mesons at ANKE" (1997).

[9] J.B.Gay et al., Phys. Lett., **63**, 220 (1976).

[10] S.M.Flatte, Phys. Lett., **63**, 224 (1976).

[11] N.N.Achasov, S.A. Devyanin, G.N.Shestakov., Yad.Fiz., **32**, 1098 (1980).

[12] S.Teige et al., Phys. Rev. D, **59**, 012001 (1999)

[13] D.Bugg et al., Phys. Rev. D. **50**, 4412 (1994)

[14] B.L.Druzhinin, A.E.Kudryavtsev and V.E.Tarasov, Z.Phys., **A359**, 205 (1997)

[15] C. Wilkin, G.Fäldt, Phys. Lett., **B382**, 208 (1996)

[16] C.Hanhart and K.Nakayama, E-print nucl-th/9809059. Sept 1998.

[17] R.Machleidt, K.Holinde and Ch.Elster, Phys.Rep., **149**, N1 (1987)

[18] V.Baru, A.Gasparyan, J.Haidenbauer, A.Kudryavtsev and J.Speth, E-print nucl-th/0006075, to be published in Phys.At.Nucl., **64** (2001)

[19] D.M.Binnie et al., Phys.Rev. **D8**, 9, 2789 (1973).

[20] V.Baru, J. Haidenbauer, C. Hanchart, A. Kudryavtsev, P.Moskal and J.Speth, Eur. Phys. J., **A6**, 445 (1999)

[21] B.Abramov et al., Z.Phys., **C69**, 409 (1996).

[22] F.Duncan et al., Phys. Rev. Lett., **80**, 4390-4393, (1998)

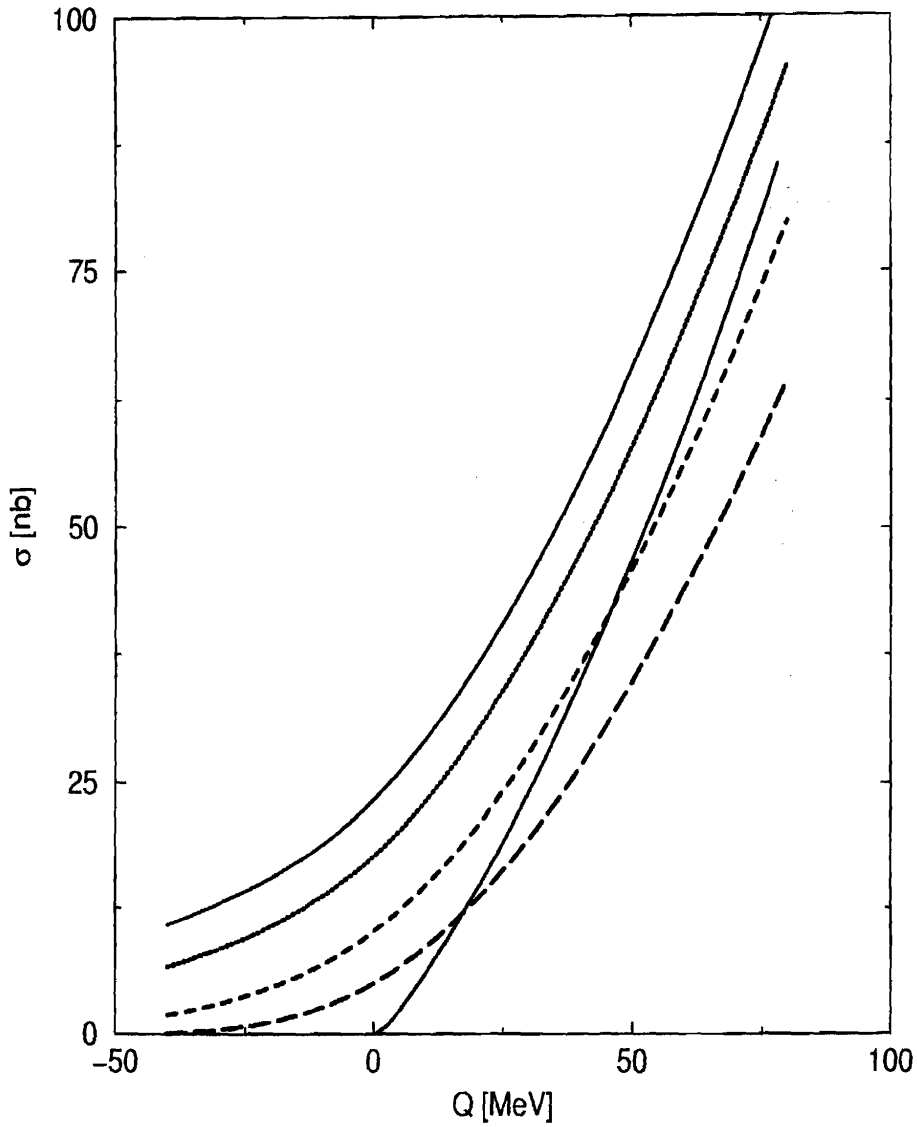

FIG. 1. *Total cross section for the reaction* $pn \to ppa_0^-$ *versus excess energy* Q *at different values of* $m_{min} = \bar{m} - C$. *Solid line* - $C = 290MeV$, *dotted line* - $C = 200MeV$, *dashed line* - $C = 100MeV$, *long-dashed line* - $C = 50MeV$. $\Gamma = 50MeV$. *The curve for the production cross section in the case of stable* a_0*-meson is also shown.*

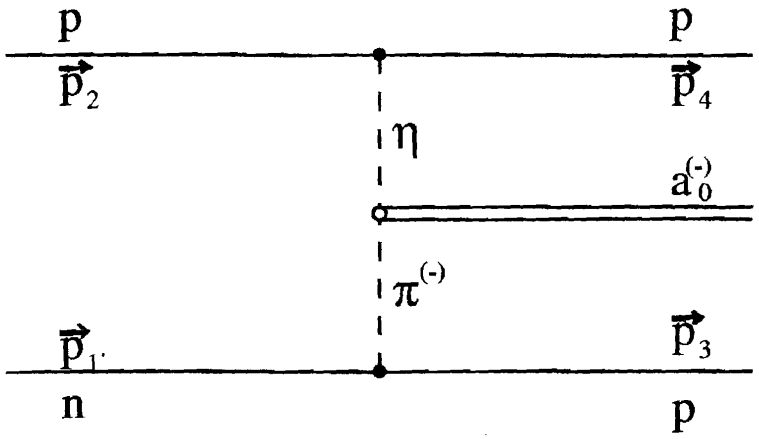

FIG. 2. *Feynman diagram for the production amplitude of the reaction* $pn \to ppa_0^-$.

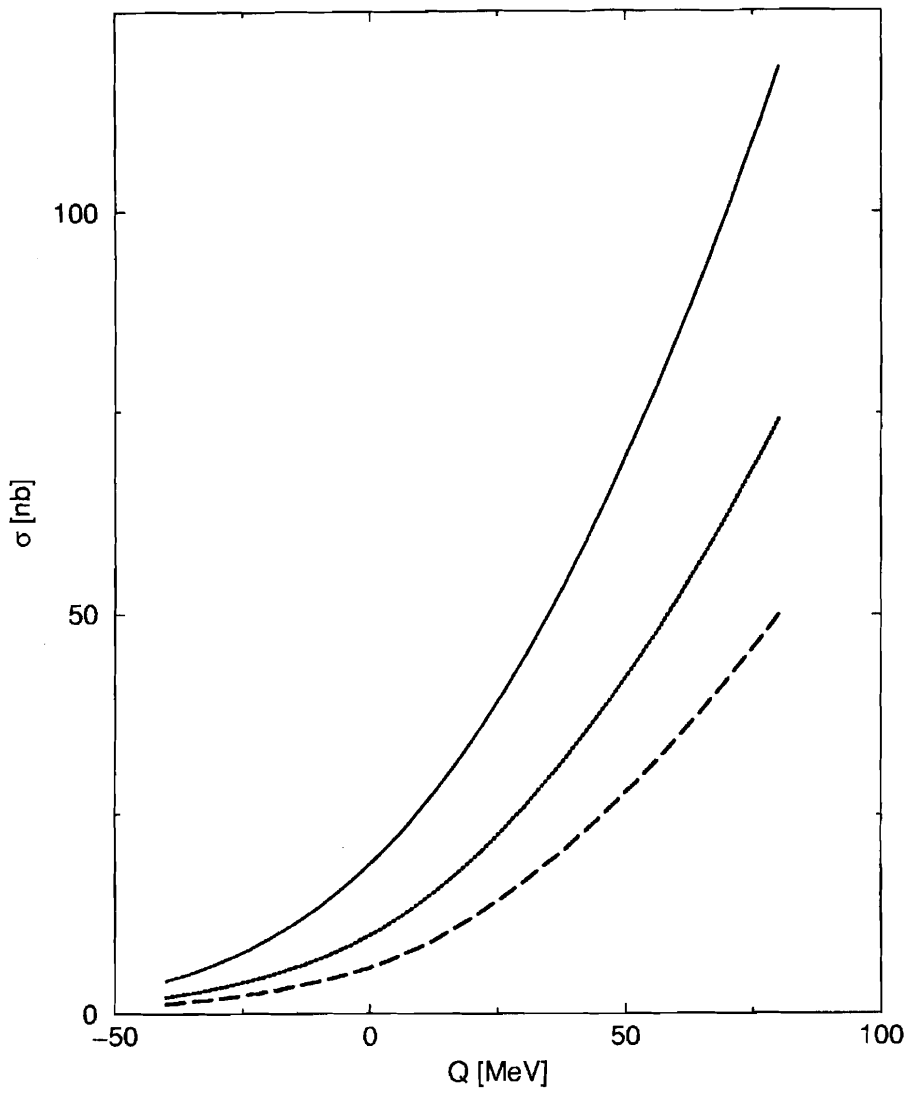

FIG. 3a. *Total cross section for the reaction* $pn \to ppa_0^-$ *at different values of* $d = g^2_{a_0^- K^- K^0}/g^2_{a_0^- \pi^- \eta}$. *Solid line* - $d = 0$, *dotted line* - $d = 1.5$, *dashed line* - $d = 3.0$. $\Gamma = 80 MeV$, $C = 100 MeV$ *for all considered cases.*

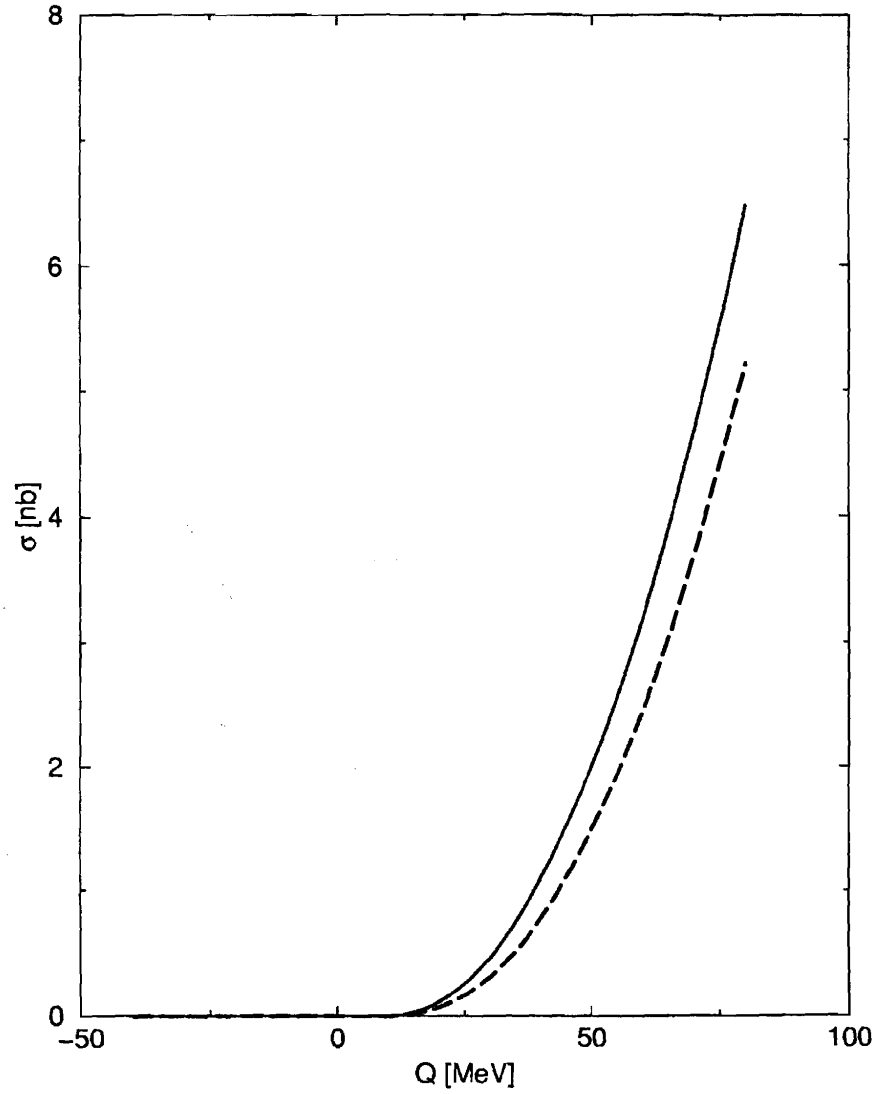

FIG. 3b. *Partial cross sections* $pn \to ppK^-K^0$ *at different values of* d. *Solid line* - $d = 3.0$, *dashed line* - $d = 1.0$. *The values of* Γ *and* C *are the same as in Figure 3a.*

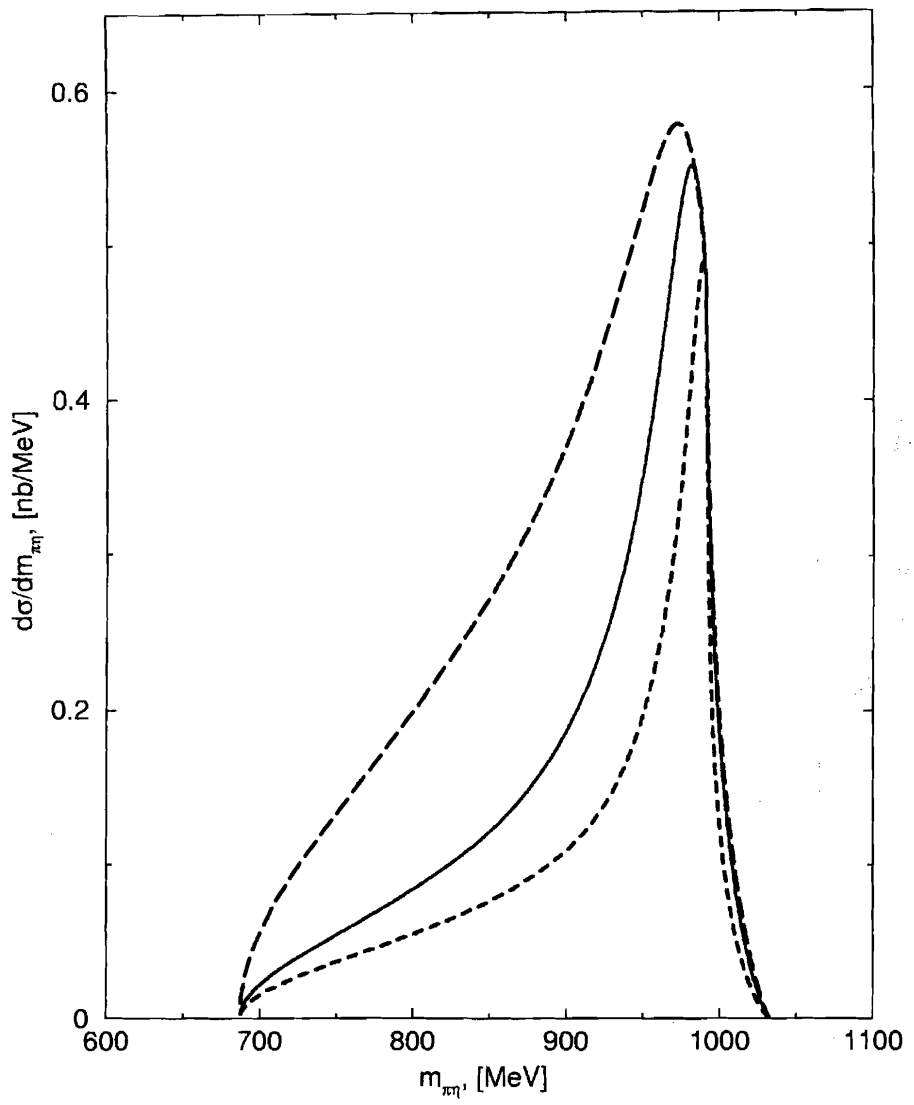

FIG. 4a. *Differential cross section* $d\sigma/dm_{\pi\eta}$ *at different values of* d *and* Γ. m_{a_0} *is equal to 983.5 MeV. Solid line* - $\Gamma = 80MeV$, $d = 1.5$. *long-dashed line* $\Gamma = 150MeV$, $d = 1.5$, *dashed line* - $\Gamma = 80MeV$, $d = 3.0$. *All curves on the figures 4 and 5 are presented at* $T_{lab} = 2636MeV$.

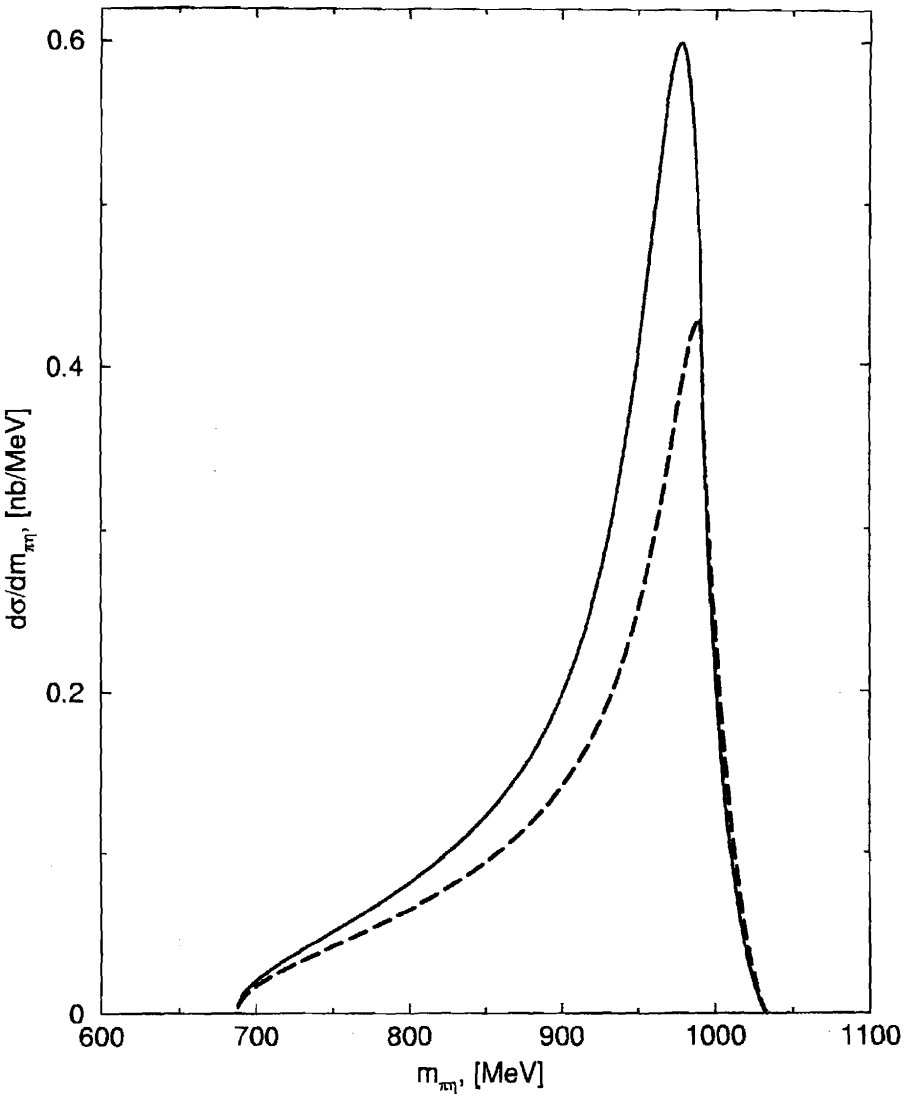

FIG. 4b. *Differential cross section* $d\sigma/dm_{\pi\eta}$ *at different masses of* a_0*-meson but at fixed* d *and* Γ *(d= 0.91,* Γ *= 80 MeV). Solid line -* $m_{a_0} = 983.5 MeV$*, dashed line -* $m_{a_0} = 999 MeV$.

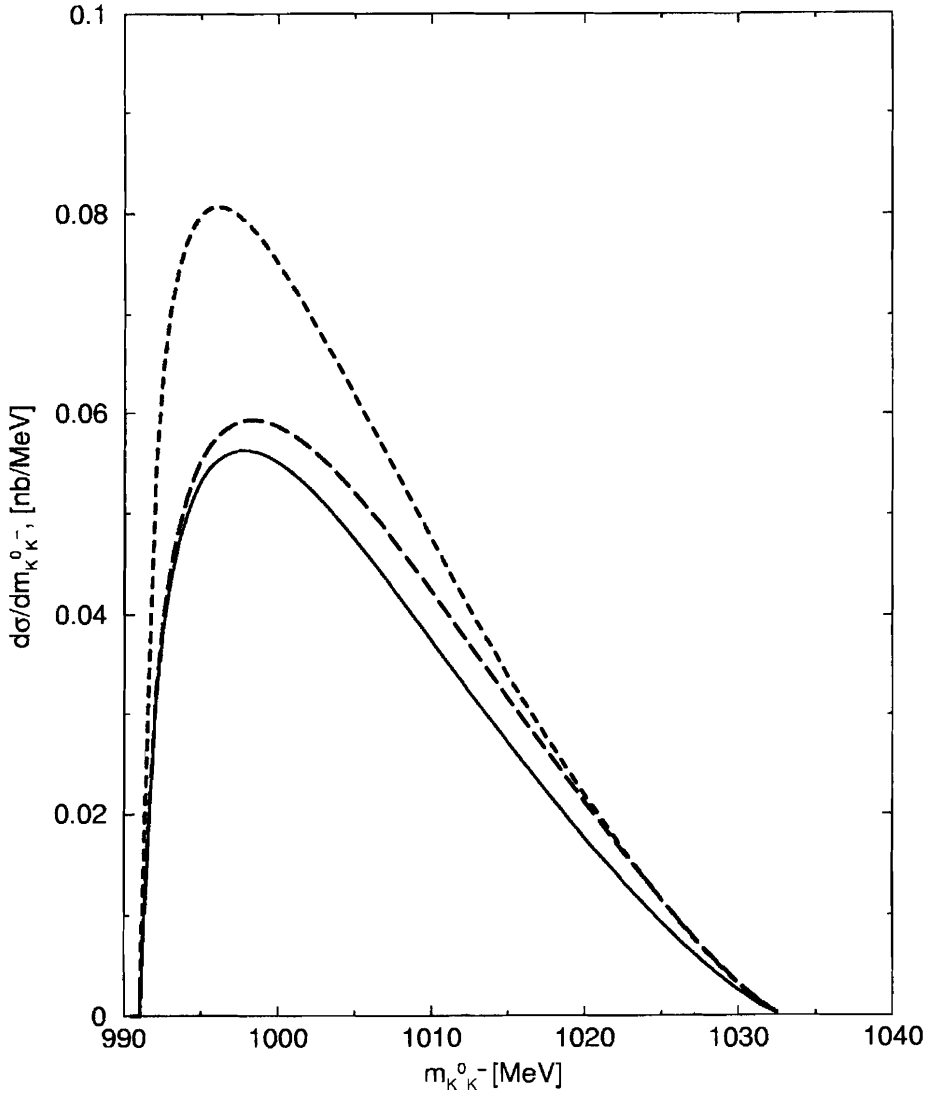

FIG. 5. *Differential cross section* $d\sigma/dm_{K\bar{K}}$ *at different values of* d *and* Γ. m_{a_0} *is equal to 983.5 MeV. The notation of the curves see in the caption to Figure 4a.*

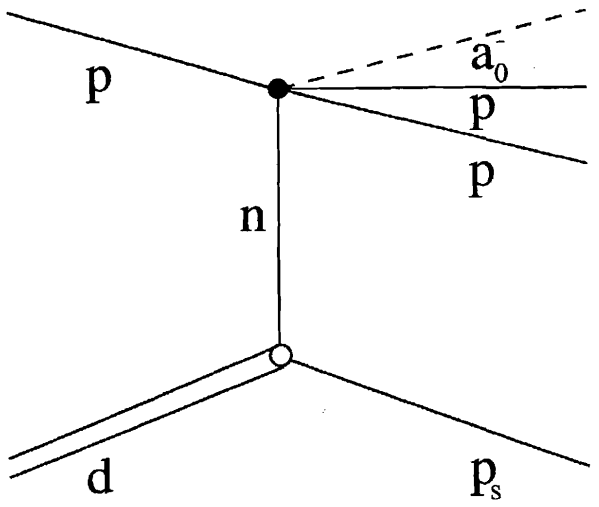

FIG. 6. *Feynman diagram for the reaction* $pd \to ppa_0^- p_s$.

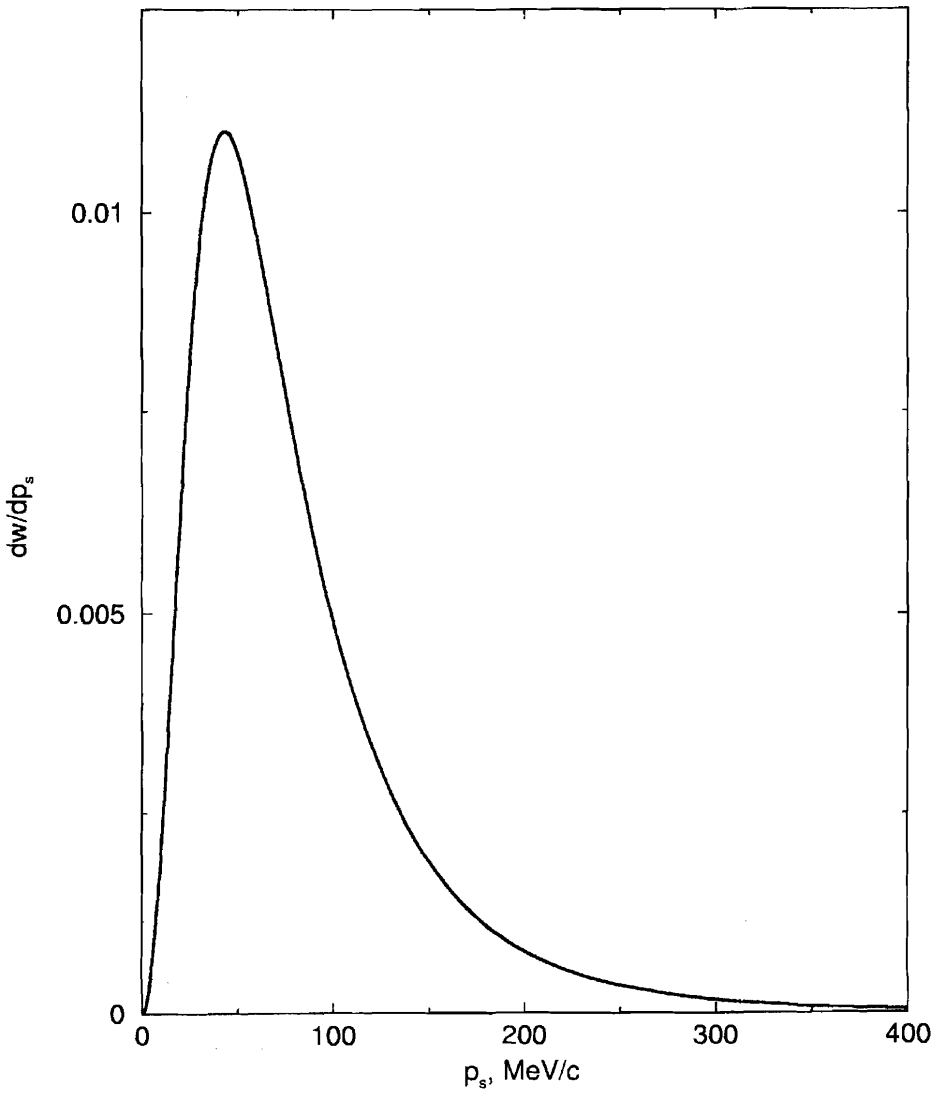

FIG. 7. *The distribution over the proton-spectator momentum for* $\sqrt{s'}$ *being fixed.*