Analysis of \( \Lambda(1405) \) production data in the \( \pi^- p \to K^0\pi\Sigma \) reaction at \( p_\pi = 1.69 \text{ GeV}/c \)

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Abstract: We have been studying the \((\Sigma\pi)^0\) mass distribution based on data from an old Hydrogen Bubble Chamber collected by Thomas et al. concerning the \( p(\pi^-)K^0\Sigma\pi \) reaction at \( p_\pi = 1.69 \text{ GeV}/c \). In this analysis we investigated the formation of the \( \Lambda(1405) \) state, using the Generalized Optical Theorem and \( T \)-matrix operator. We applied a combined transition operator, \( T_{\text{mix}} \), which contains \( T_{21} = T_{\pi\Sigma^-KN} \) and \( T_{22} = T_{\pi\Sigma^+\Sigma^-} \) due to the initial channel mixing in the \( \Lambda(1405) \) formation. We also considered a possible mixture of \( I = 0 \) and \( 1 \) in the wave function, as well as some background of the \( \Sigma(1385) \) population.

Keywords: \( \Lambda(1405) \) production, pion-proton reaction, data analysis, \( \Sigma \)-pion invariant mass

I. Introduction

Over the past decade, there has been growing interest in the existence of deeply bound kaonic nuclear states, both theoretically and experimentally. Although a quasi-bound state of \( \Lambda^* \) which we call here \( \Lambda^* \) has an important role in the production of those states and much research has been conducted,\(^1\)\(^-\)\(^5\) there are still vigorous debates concerning the nature of this \( \Lambda^* \) resonance, which was first predicted by Dalitz and Tuan theoretically.\(^6\) Experimentally, Alston et al. reported the production of \( \Lambda^* \) in \( p(K^-\Sigma^+\pi^-)\pi^- \) reaction at 1.15 GeV.\(^7\)

The Particle Data Group (PDG) has adopted the idea that the resonance state of \( \Lambda^* \) exists below the \( K\Sigma \) threshold with a mass of \( 1405.1^{+1.2}_{-1.0} \text{ MeV}/c^2 \) and a width of \( 50.5 \pm 2.0 \text{ MeV} \). It possesses \( I = 0 \), \( S = -1 \) and decays 100% to \( \Sigma\pi \).\(^5\) Previous studies conducted by the current authors have been adopted by PDG concerning the mass and width of \( \Lambda^* \),\(^9\)\(^,\)\(^10\) whereas there are many other theoretical calculations and experimental data, as listed in ref. 8.

In a previous paper,\(^11\) our focus was placed on calculating the invariant mass distribution in the \( K^- p \to \Sigma + \pi \) reaction, which was measured by Hemingway.\(^12\) Also, the role of the \( K^- p \to \Sigma\pi \) and \( \Sigma\pi \to \Sigma\pi \) channels in the spectrum is discussed in detail in ref. 13. Previously, the invariant-mass spectrum had been interpreted theoretically by using one of the transition operators (\( T \)-matrix elements) without a successful fitting. In this particular transition it was not clear which of the transition operators is responsible and, thus, instead we made use of a combined operator

\[
T_{\text{mix}} = (1 - f) T_{21} + f T_{22} \quad \text{(I.1)}
\]

where \( T_{21} \) is a transition amplitude for the \( T_{\Sigma\pi^-KN} \) process, \( f T_{22} \) is a transition amplitude for the \( T_{\Sigma\pi^-\Sigma\pi} \) process and \( f \) is a complex mixing parameter.\(^11\) The percentage of \( T_{21} \) is \( |1 - f|^2 / (|1 - f|^2 + |f|^2) \). We then found a good fitting of the Hemingway experimental data with a parameter of \( f = 0.38 \pm 0.02 \).

In the present work we attempt to analyze some other old experimental data of Thomas et al.\(^4\) concerning the \( p(\pi^-)K^0 \) reaction at \( p_\pi = 1.69 \text{ GeV}/c \) in a Hydrogen Bubble Chamber\(^4\) and the production of a \( \Lambda^* \) particle and its decay to the \( (\Sigma\pi)^0 \) channel to see whether they can be fitted by a combined operator or not. We also take into account the effect of isospin mixing between \( I = 0 \) and \( I = 1 \), as well as possible \( \Sigma(1385) \) contamination in the observed spectrum. The framework of the paper is as follows: in section II, the formulation of the problem...
is discussed. Section III is devoted to analysis and discussion; and the conclusion and summary are described in section IV.

II. Theoretical procedure

We start our discussions of the \( \pi^- p \rightarrow K^0(\Sigma\pi)^0 \) reaction by looking at the theoretical procedure applied in the coupled channel \( KN - \Sigma\pi \) treatment. A tree-level Feynman diagram of the \( p(\pi^-, K^0) \) reaction is illustrated in Fig. 1. There are 10 different coupled channels, such as \( K^-p, K^0n, \pi^0\Sigma^0, \pi^0\Lambda, \ldots \), for this reaction. In the current paper we consider \( KN \) (Channel 1) and \( (\Sigma\pi)^0 \) (Channel 2), since the \( \Lambda^* \) of our interest is an \( I=0 \) quasi-bound state in Channel 1 which appears as a Feshbach resonance\(^{15,16} \) in Channel 2. The \( T \)-matrix is given by the following coupled-channel equation:

\[
 t_{ij} = U_{ij} + \sum_{\ell=1,2} U_{i\ell} G_{\ell} t_{\ell j}, \tag{II.2}
\]

where \( i(j) \) is for Channel 1(2), \( U_{ij} \) is the interaction and \( G_{\ell} \) is Green’s function with the following loop integration:

\[
 G_{\ell} = \frac{2\mu_i}{\hbar^2} \int d\bar{q} g(\bar{q}) \frac{1}{k_\ell^2 - q^2 + i\varepsilon_0} g(q). \tag{II.3}
\]

Here, \( \mu_\ell \) is a reduced mass in the corresponding Channel \( \ell \), \( k_\ell \) is a relative momentum in the Channel \( \ell \) and \( g(q) \) is a Yukawa-type form factor applied in the separable potentials, \( v_{ij} \) and the transition matrices, \( t_{ij} \), of the current calculation:

\[
 \begin{align*}
 (\vec{k}_i^1 v_{ij})_j &= g(\vec{k}_i^1) U_{ij} g(\vec{k}_j^1), & \text{(II.4)} \\
 (\vec{k}_i^2 T_{ij})_j &= g(\vec{k}_i^2) t_{ij} g(\vec{k}_j^2), & \text{(II.5)} \\
 g(\vec{k}) &= \frac{\Lambda^2}{\Lambda^2 + \vec{k}^2}, & \text{(II.6)} \\
 \text{with } \Lambda &= 3.9 \text{ fm}^{-1} \text{ being a range parameter and } m_B \text{ is the mass of the exchanged boson (here, } \rho \text{ meson with } m_B = 770 \text{ MeV}/c^2 \text{ is adopted).} \\
\end{align*}
\]

The solution of eq. [II.2] in a matrix form is

\[
 t = [1 - U G]^{-1} U. \tag{II.7}
\]

In the framework of the model we describe in this article, \( U \) is Akaashi-Miyint-Yamazaki (AMY) interaction\(^{17} \) for the \( I=0 \) component of the \( KN \) interaction:

\[
 U_{ij} = \frac{1}{\pi^2} \frac{\hbar^2}{2\mu_i \mu_j} \frac{1}{\Lambda} s_{ij}, \tag{II.8}
\]

where \( \mu_i(\mu_j) \) is the reduced mass of Channel \( i(j) \) and \( s_{ij} \) is a non-dimensional strength parameter. \( s_{ij} \) is a function of the binding energy and width of the \( \Lambda^* \) resonance. We first obtain \( s_{11} \) and \( s_{12} \) from the \( M_{pole} \) and \( \Gamma \) values of the \( K^-p \) state assumed for data fitting. We then calculate the \( \Sigma\pi \) invariant mass distributions, \( M(\Sigma\pi) \). In this paper we consider the \( K^-p \) quasi-bound state, \( (\bar{K}N)^{I=0} \), as a Feshbach resonance\(^{15,16} \) embedded in the \( \Sigma\pi \) continuum using the AMY model.\(^{17} \) The kinematical variables of the decay rate of \( \Lambda(1405) \) to \( (\Sigma\pi)^0 \) are presented in Fig. 2 in the c.m. frame. Using these figures, the decay spectrum, \( S \), of the following two processes

\[
 K^- + p \rightarrow \Lambda^* \rightarrow \Sigma + \pi \quad (a), \\
 \Sigma + \pi \rightarrow \Lambda^* \rightarrow \Sigma + \pi \quad (b), \tag{II.9}
\]

is written as

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Fig. 1. Diagrams for the \( \pi^- p \rightarrow K^0(\Sigma\pi)^0 \) reaction and the internal processes proposed by the present paper: \( T_{21} \) and \( T_{22} \) channels.

Fig. 2. Kinematical variables in the center-of-mass frame for the \( K^- p \rightarrow \Sigma\pi \) channel.
\[ S(x) = \frac{2(2\pi)^5}{\hbar c} \frac{E_k E_\pi}{E_\Sigma + E_\pi} |\langle k|T|0\rangle|^2 k, \quad \text{[II.10]} \]

where \( k(0) \) is a relative momentum in the final (initial) channel, \( T \) is the transition matrix given in eq. [II.5], and \( E_\Sigma(E_\pi) \) is the energy of the \( \Sigma(\pi) \) particle in the final state. The spectrum, \( S(x) \), is a function of the invariant-mass variable, \( x = IM(\Sigma\pi) \), with some fitting parameters. We use a notation in which the already optimized parameters are omitted, then, for example, \( S(x; M_{\text{pole}}, \Gamma) \) means that the parameters \( M_{\text{pole}} \) and \( \Gamma \) are to be fitted.

The \( \Sigma^+\pi^- \) mass distribution for the \( \pi^-p \rightarrow \Sigma^+\pi^-K^0 \) reaction at 1.69 GeV/c is presented by a histogram in Fig. 3 of ref. 14. The mass and the width of \( \Lambda(1405) \), deduced in this experiment in ref. 14, are \( M = 1405 \text{ MeV}/c^2 \) and \( \Gamma = 45-55 \text{ MeV} \), respectively. The mass range of the data is from \( x = 1340 \text{ MeV}/c^2 \) to \( 1430 \text{ MeV}/c^2 \), lying between the \( \Sigma\pi \) threshold (1332 MeV/c^2) and the \( K\pi \) threshold (1432 MeV/c^2). Therefore, we have 10 points of data, which should be used to perform the \( \chi^2 \) analysis, as follows:

\[ \chi^2(M_{\text{pole}}, \Gamma) = \sum \left( \frac{N_i - cS_i(M_{\text{pole}}, \Gamma)}{\sigma_i} \right)^2, \quad \text{[II.11]} \]

where \( N_i \) is the experimental data, \( \sigma_i \) is the statistical errors and \( S_i(M_{\text{pole}}, \Gamma) \) is the theoretical decay rate calculated with the mass, \( M_{\text{pole}} \), and the width, \( \Gamma \), as parameters; \( c \) is a fixed normalization parameter that makes the theoretical values and the experimental data in the same order and obtained by dividing the maximum value of data by a theoretical one in the same mass.

### III. Interpretation of the results

In this section, our theoretical results for the invariant-mass spectrum, \( M(\Sigma\pi) \), of the mixed transition matrix, \( T_{\text{mix}} \), are investigated in detail. To evaluate the goodness of the performed fitting, the \( \chi^2 \) analysis was carried out in each case of combined \( T_{21} \) and \( T_{22} \). Our main concern is to extract the pole position (the best-fit \( M_{\text{pole}} \)) and width (the best-fit \( \Gamma \)) of \( \Lambda(1405) \) from the data. By changing \( T_{21} \) and \( T_{22} \), since \( \Lambda(1405) \) is the \( I = 0 \) resonance pole on the \( K\pi - \Sigma\pi \) \((+,-)\) sheet, we have treated the coupled two major \( I = 0 \) channels (as ones having essential roles among 10 channels). Our procedure is a phenomenological one with some fitting parameters, \( f \) and \( (M_{\text{pole}}, \Gamma) \), the obtained pole position and width for \( \Lambda(1405) \). Therefore, in subsection A, \( T_{\text{mix}} \) with \( I = 0 \) is considered and then in subsection B the contribution of the \( I = 0 \) and \( I = 1 \) components in the spectrum are investigated.

#### A. Different contributions of \( T_{21} \) and \( T_{22} \) amplitudes

In this subsection, various combinations of \( T_{21} \) and \( T_{22} \) components are taken into account. For this purpose, \( T_{\text{mix}} \) is defined in eq. [I.1]. The factor \( f \) consists of an initial reaction process, \( b_i \), times the channel propagator, \( G_i(x) \), as depicted in Fig. 1. The \( b_i \) depends on the meson-baryon interaction, which is considered to be on the order of the \( \rho \)-meson exchange, \( \hbar c/770 \text{ MeV} \). Because this interaction is of short-range nature, the energy dependence of \( b_i \) becomes weak in the relevant invariant-mass region between 1332 (\( \Sigma\pi \) threshold) and 1432 (\( K\pi \) threshold) MeV/c^2. As for the \( x \)-dependence of the propagator, we calculated \( b_i G_i(x) T_{\text{mix}}(x) \) in a typical case (\( \Lambda(1405) \) of PDG value) and compared it with \( f T_{\text{mix}}(x) \), as shown in Fig. 3. Therefore, the factor \( f \) is treated as being a constant in our analysis. In this way, in addition to \( M_{\text{pole}} \) and \( \Gamma \), \( f \) is considered to be a free parameter in the fitting process, and it is necessary to check the \( \chi^2 \) values for various \( f \). The fitting process is performed for three \( (M_{\text{pole}}, \Gamma, f) \) parameters, and \( \chi^2 \) values are obtained for each step.

We took the same \( M_{\text{pole}} \) and \( \Gamma \) for both channels, and regarded them as being free parameters varied in the “\( \Lambda^* \) mass region”, since both of the peak structures (seen in Fig. 3, for example) in \( T_{21} \) spectrum and \( T_{22} \) spectrum come from a single pole lying on the \( K\pi - \Sigma\pi \) \((+,-)\) sheet. Currently, the chiral dynamics models claim double poles, a higher-mass pole (1st pole) and a lower-mass pole (2nd pole), for \( \Lambda(1405) \). The peak structure in the \( T_{21} \) spectrum comes from the 1st pole. However, some chiral papers, like Magas et al.,\(^{20} \) insist that the peak structure in the \( T_{22} \)
spectrum comes from the 2nd pole. This statement concerning the role of the 2nd pole seems to be incorrect. Both of the peak structures in the $T_{21}$ spectrum and the $T_{22}$ spectrum come from the 1st pole, as discussed in refs. 13 and 18. This means that, even if the chiral double-pole picture is adopted, the same ($M_{\text{pole}}, \Gamma$) parameter set should be used for both channels, as is done in this paper.

In the following, for each value of $f$, a set of ($M_{\text{pole}}$ and $\Gamma$) that gives the best fit are obtained, as presented in Fig. 4. It can be seen from Figs. 8 and 9 explained in the next section that $\chi^2_{\text{min}} = 3.9$ is attained for $f = 0.5$, $M_{\text{pole}} = 1370$ MeV/$c^2$ and $\Gamma = 67$ MeV, and the contribution of each channel is about 50%.

To see how sensitively the pole mass is determined by $\chi^2$ fitting, diagrams of $\chi^2$ versus the pole mass for various $f$ parameters are depicted in Fig. 5. In this figure, it is clear that $f = 0.5$ gives the minimum $\chi^2$ when $\chi^2 = 3.9$. In the next figure ($M_{\text{pole}}, \Gamma$) are fixed to PDG value and the optimum $f$ is obtained (see Fig. 6). In this figure $\chi^2_{\text{min}} = 29$ is attained for $f = 0.2$, which means a 94% contribution of the $T_{21}$ channel and 6% $T_{22}$ ones.

B. The contribution of the $I=0$ and $I=1$ components in the spectrum. In this section we investigate the importance of the isospin $I=0$ and $I=1$ components as well as their mixing in the calculated spectrum. The charge-basis $T$-matrices are related to isospin-basis $T$-matrices as

$$|T_{\Sigma^+\pi^+}|^2 \approx \frac{1}{3} |T_{I=0}|^2 + \frac{1}{2} |T_{I=1}|^2 + \frac{2}{3} \text{Re}[T_{I=0}T_{I=1}],$$

[III.12]

$$|T_{\Sigma^0\pi^+}|^2 \approx \frac{1}{3} |T_{I=0}|^2 + \frac{1}{2} |T_{I=1}|^2 - \frac{2}{3} \text{Re}[T_{I=0}T_{I=1}].$$

[III.13]

The absolute values of the $I=0$ and $I=1$ components for the $T_{21}$ and $T_{22}$ channels are depicted in Fig. 7, where the $I=1$ component is calculated using Shevchenko’s interaction. This figure shows that the $I=1$ component has a small contribution in the total spectrum, and for the smaller region of the invariant mass $M(\Sigma\pi)$ it has a monotonic decrease, whereas the $I=0$ part has a large portion and includes the resonance state.

To check the effects of the $I=1$ contribution we showed $T_{\text{mix}} = (1 - f) T_{21} + f T_{22}$ ($f = 0.5$) with various percentages of $I=1$ mixing the range of which is illustrated in Figs. 8(a) and (b). Figure 8(a) represents 0%, 25% and 50% $I=1$ mixing and the $\chi^2$ values for each curve. It is obvious from this figure that the best fit belongs to the $I=0$ contribution, and that adding $I=1$ does not change the results very much, and even makes it worse. Finally, Fig. 8(b) helps to clarify this situation, and shows that considering the $I=1$ component does not change the $\chi^2$ values, and that the shift of the pole position becomes negligible.

Figure 9 shows the $I=1$ contributions (from 0% to 100%) for $T_{\text{mix}} = (1 - f) T_{21} + f T_{22}$ with various $f$ values (from 0.0 to 0.8). From this figure it is found that as $f$ increases from 0.0 to 0.5, $\chi^2$ decreases and as $f$ increases from 0.5 to 0.8, $\chi^2$ increases (except 100% $I=1$ mixing). The best result with $\chi^2$/NDF = 0.4 is obtained for 0% $I=1$ mixing at $f = 0.5$. It should be noticed that this best fit to the data for 0% $I=1$ mixing at $f = 0.5$ is the consequence of an equal footing treatment of the $I=0$ and $I=1$ channels, as explained below. In the $\chi^2$ fitting process for the curves in Fig. 9, the parameters $f$ and implicitly $M_{\text{pole}}$, change the $I=0$ spectrum through the entrance-channel weight and pole position, and the $I=1$ mixing parameter, $m_{f=1}$, controls the $I=1$ spectrum. When we consider the $\chi^2$ contour map on the $(f, m_{f=1})$ plane, which is an equal-footing treatment of the $I=0$ and $I=1$ components, the lowest $\chi^2$ value is realized at $f = 0.5$ and the $m_{f=1} = 0\%$ point, as can be clearly seen from Fig. 9. Thus, it is justified to neglect the $I=1$ component and to apply the $I=0$ two-channel model in the present analysis of the Thomas et al. data.}

The $T_{\text{mix}}$ spectrum is decomposed into the $T_{21}$ and $T_{22}$ channels, shown in Fig. 10, to verify the dependence of the mixed channel on its components. It is found that $T_{21}$ has the dominant part of the mixed spectrum, but at the same time adding $T_{22}$ leads to a shift in the peak position for the total spectrum and a large cancellation due to the interference part. Therefore, the behaviors of the $T_{\text{mix}}$ and $T_{21}$ channels are different in the presence of $T_{22}$ mixing.

C. Effects of the population of the $\Sigma(1385)$ resonance. In this subsection, the possible background contribution of the production and decay of $\Sigma^0(1385)$ in the invariant mass spectrum with a branching ratio of 12% is considered.

Various incoherent contributions of the $\Sigma^0(1385)$ resonance from 0 to 100% are expressed by $|T_{\text{tot}}|^2 = |T_{\text{mix}}|^2 + A_{22}|BW(\Sigma^+)|^2$. $BW(\Sigma^+)$ is a Breit-Wigner amplitude for the $\Sigma(1385)$ resonance with the mass, 1384 MeV/$c^2$, and width, 36 MeV, presented in PDG, added to the previous spectra; $|T_{\text{mix}}|^2$. The peak position moves by changing $A_{22}$. 

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Fig. 4. Spectra of the best fit for mixed channels with each fixed $f$ parameter: $f = 0.0, 0.2, \ldots, 1.0$. The $M_{\text{pole}}$, $\Gamma$ and $\chi^2$ values of each curve are shown in addition to the experimental data.

Fig. 5. Diagrams of $\chi^2$ versus the pole mass for different values of $f$: 0.0, 0.2, \ldots, 1.0. $f = 0.5$ gives the $\chi^2_{\text{min}} = 3.9$.

Fig. 6. Spectra for the optimum $f$ parameters; for each curve ($M_{\text{pole}}$, $\Gamma$) is fixed to PDG values ($1405 \pm 1.3$, 50.5 $\pm$ 2.0) in MeV/$c^2$.

Fig. 7. Absolute values for the $T_{21}$ and $T_{22}$ channels with the $I_{F} = 1$ and $I_{F} = 0$ components.

Fig. 8. (a) $I = 1$ contributions (from 0% to 50%) for $T_{\text{mix}}$ with a fixed $M_{\text{pole}} = 1370$ MeV/$c^2$, $\Gamma = 67$ MeV and (b) $I = 1$ contributions (from 0% to 80%) for $T_{\text{max}}$ channels ($f = 0.5$): $\chi^2$ and $M_{\text{pole}}$ versus the percentages of $I = 1$ are depicted.
Fig. 9. $I = 1$ contributions (from 0% to 100%) for $T_{\text{mix}} = (1 - f)T_{21} + fT_{22}$ channel: $\chi^2$ versus the percentages of $I = 1$ for various $f$ (from 0.0 to 0.8) is presented. The minimum value of $\chi^2 = 3.9$ is obtained at 0% $I = 1$ mixing for $f = 0.5$.

Fig. 10. Decomposition of the $T_{\text{mix}}$ best-fit spectrum ($f = 0.5$) (solid black curve) to its components: $T_{21}$ (dashed red curve) and $T_{22}$ (dotted blue curve) parts. The large cancellation due to the interference part and the dominance of the $T_{21}$ channel is clear.

Fig. 11. (upper) Diagram of $\chi^2$ and (lower) $M$ and $\Gamma$ of $\Lambda^*$ versus $f$ (effects of various contributions of the $T_{21}$ and $T_{22}$ channels).

Fig. 12. Diagrams of (a) $\chi^2$, (b) $M$ and (c) $\Gamma$ of $\Lambda^*$ versus $f$ (various contributions of $T_{21}$ and $T_{22}$ channels) for different mixtures of $\Sigma(1385)$.

Fig. 13. The best fit for $T_{\text{mix}}$ with 0% $\Sigma(1385)$: The solid line shows the curve of fixed $M_{\text{pole}} = 1405.1^{+1.9}_{-1.8}$ MeV/$c^2$ and $\Gamma = 50.5 \pm 2.0$ MeV (PDG values), $f = 0.2$ and $\chi^2 = 29$. The dashed line is for $M_{\text{pole}} = 1370^{+6}_{-5}$ MeV/$c^2$, $\Gamma = 67 \pm 5$ MeV, $f = 0.5$ and $\chi^2 = 3.9$. 
To show the very complicated behavior of the parameters \((f, \chi^2, \Delta \Sigma, \Gamma\) and \(M_{\text{pole}}\) with respect to each other, it is better to illustrate them in some individual figures. Figure 11 (upper) depicts the \(\chi^2\) versus \(f\) that shows a minimum of around \(f = 0.5\). To make this subject clear, the mass and width of the resonance are shown in Fig. 11 (lower) at the same values of \(f\). It is deduced from this figure that the minimum value of \(\chi^2\) is obtained for \(\Gamma = 67\) MeV and \(M_{\text{pole}} = 1370\) MeV/\(c^2\). To clarify this matter we illustrate the variations of \(\chi^2\) versus \(f\) for different portions of \(\Sigma(1385)\) in Fig. 12(a). For larger values of \(\Sigma(1385)\), moving of the mass occurs rapidly while the width shows a broad peak at around \(f = 0.5\), which gives the minimum value of \(\chi^2\) (see the (b) and (c) parts of Fig. 12).

Finally, the best fit for \(T_{\text{mix}}\) with 0% \(\Sigma(1385)\) is shown in Fig. 13. This figure has two curves: one for PDG values of the mass and width (\(M_{\text{pole}} = 1405.1\) MeV/\(c^2\) and \(\Gamma = 50.5\) MeV) with \(f = 0.2\) and \(\chi^2 = 29\) together with the curve of the best fit for \(M_{\text{pole}} = 1370\) MeV/\(c^2\) and \(\Gamma = 67\) MeV, \(f = 0.5\) and \(\chi^2 = 3.9\).

IV. Conclusion

Within the framework of the \(\bar{K}N-\Sigma\pi\) coupled channels, we have investigated the mass distribution, \(M_{\Sigma^\pi}\), in the \(\pi^-p \rightarrow \Sigma^-\pi^0K^0\) reaction at \(p_\pi = 1.69\) GeV/c provided by Thomas et al.\(^{14}\).

In this analysis the mixture of the two transition operators as \(T_{\text{mix}} = (1 - f)T_{21} + fT_{22}\) was applied, and showed that the mixture of \(f = 0.5\) gives a better fit to the Thomas et al. spectrum. We then considered a mixture of the two isospin states \(I = 1\) and 1. The experimental data are better accounted for by a small admixture of the \(I = 1\) state. Finally, we considered a possible incoherent mixture of the \(\Sigma(1385)\) resonance component in the observed spectrum. The best-fit mass and width after considering the \(\Sigma(1385)\) mixture yield \(M_{\text{pole}} = 1370^{+6.2}_{-5.1}\) MeV/\(c^2\) and \(\Gamma = 67 \pm 5\) MeV (0% \(\Sigma(1385)\) gives the best result), as shown in Fig. 13. The present results contradict Magas et al.’s two-pole postulation\(^{20}\) in which the Thomas et al.’s peak structure corresponds to the 2nd-pole effect that appears in the \(T_{22}\) spectrum. Finally, for a better conclusion concerning the mass and width of the \(\Lambda^*\) resonance we look forward to near-future experiments with high statistics.

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