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Strange Decays of Nonstrange Baryons

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Abstract

The strong decays of excited nonstrange baryons into the final states ΛK, ΣK, and for the first time into $\Lambda(1405)K$, $\Lambda(1520)K$, $\Sigma(1385)K$, ΛK^*, and ΣK^*, are examined in a relativized quark pair creation model. The wave functions and parameters of the model are fixed by previous calculations of $N\pi$ and $N\pi\pi$, *etc.*, decays. Our results show that it should be possible to discover several new negative parity excited baryons and confirm the discovery of several others by analyzing these final states in kaon production experiments. We also establish clear predictions for the relative strengths of certain states to decay to $\Lambda(1405)K$ and $\Lambda(1520)K$, which can be tested to determine if a three-quark model of the $\Lambda(1405)$ is valid. Our results compare favorably with the results of partial wave analyses of the limited existing data for the ΛK and ΣK channels. We do not find large ΣK decay amplitudes for a substantial group of predicted and weakly established negative-parity states, in contrast to the only previous work to consider decays of these states into the strange final states ΛK and ΣK.

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I. INTRODUCTION

The strange quark plays a unique role in particle and nuclear physics. It is not quite light enough for expansions based on chiral symmetry to work as well as they do in the case of the up and down quarks, nor is it heavy enough for it to be safely treated in the recently developed heavy quark effective theory. Since its constituent mass is close to the typical scale of soft QCD interactions, expansions in the ratio of its mass to this energy scale may have convergence problems. The strange quark has also been very important in the development of the standard model, as hadrons containing strange quarks were the first to manifest flavor-changing neutral currents and CP violation.

This unique nature makes the strange quark and its hadrons the object of many theoretical and experimental studies. As an example, one can ask whether non-perturbative QCD is flavor-blind. Do hadrons containing strange quarks behave essentially like hadrons containing only non-strange quarks, apart from differences in quark masses? Other important and topical questions include those about the presence of strangeness in the nucleon, the properties of hypernuclei, and strangeness production in relativistic heavy-ion collisions as a signature of the quark-gluon plasma.

A number of experimental facilities are currently engaged in studies of strange hadrons, or will be in the near future. The kaon beam at Brookhaven National Laboratory will clearly provide some impetus, as will the pion beam there, through kaon production experiments. Recent experiments at Bonn and Mainz, and future experiments at GRAAL and especially at TJNAF will also stimulate interest in strange matter. Indeed, the first two experiments to be completed at TJNAF were kaon electroproduction experiments [1].

Understanding how strange hadrons couple to non-strange hadrons is one of the primary goals of the research described above. This understanding will also be required to interpret experiments which search for the presence of strangeness in the nucleon, and which produce strange hadrons in relativistic heavy-ion collisions. Calculations of such couplings are therefore essential to our effort to understand experiments involving strange hadrons.

Kaon electromagnetic production experiments at TJNAF [2,3] can be thought of as producing nonstrange baryons in the s channel, which subsequently decay into a strange baryon and a strange meson. Analysis of kaon production experiments using this model will yield information about the couplings of these resonances to final states like ΛK, ΣK, and through the detection of three body final states [3], to final states involving excited strange baryons and mesons such as ΛK^*, ΣK^*, $\Sigma(1385)K$, *etc.* Because of the relatively high thresholds for these final states compared to $N\pi$ and $N\pi\pi$, it can be expected that these decays are a good way to study the poorly understood excited negative-parity baryons, which in our model have wave functions predominantly in the $N=3$ oscillator band. Few of the many states predicted to be present by symmetric quark models have been seen in $N\pi$ elastic and inelastic scattering, and many of those that have been seen are tentative states. Some of those states already seen have masses significantly lighter than model predictions [4,5]. This is a relatively young aspect of baryon spectroscopy which deserves attention, and we will show that strangeness production experiments should find many of these new states.

Predictions for the amplitudes for nonstrange baryons to decay into strange final states will be useful when planning the analyses of these experiments. Furthermore, through associated production into the final state $\Sigma\pi K$, it may be possible to study the poorly understood

strange baryon $\Lambda(1405)$ and its spin partner $\Lambda(1520)$, which decay to $\Sigma\pi$. The nature of these two states is of fundamental importance to the understanding of the interquark potential. There have been suggestions in the literature (for a brief review see Ref. [6]) that the difficulty encountered in fitting the mass of the $\Lambda(1405)$ in quark potential models [7,5] can be explained if this state is a $\bar{K}N$ bound state. The problem in potential models is that the $J^P=\frac{3}{2}^-$ state $\Lambda(1520)$ is predicted to be essentially degenerate with its $J^P=\frac{1}{2}^-$ spin partner state $\Lambda(1405)$. Spin-orbit interactions can lift this degeneracy, but other aspects of the baryon spectrum rule out spin-orbit interactions of the strength required to fit $\Lambda(1520)-\Lambda(1405)$. A good way to resolve the controversy about the nature of this state is to examine its strong [8,4] and electromagnetic decays [9] with the assumption that it is a conventional three quark state; here we search for one or more decays of a nucleon excited state to $\Lambda(1405)K$ and $\Lambda(1520)K$ which give clear contrasting predictions under this same assumption. If an experiment were to focus on electromagnetic production of $\Lambda(1405)K$ and $\Lambda(1520)K$ through such an intermediate state, comparison with these predictions could play an important role in solving this puzzle. Another possibility, which we will examine in a later paper [10], is to examine the strong decays of higher-lying strange resonances into the $\Lambda(1405)\pi$ and $\Lambda(1520)\pi$ channels.

Predictions for the decays of nonstrange baryons up to the $N=2$ band to the ΛK and ΣK channels have been given by Koniuk and Isgur [8] in an elementary-meson emission model, where a point-like kaon couples directly to the quarks in the initial baryon. Forsyth and Cutkosky [4] have also examined these final state channels in a model based on a decay operator with the structure $\mathbf{S}\cdot(g_1\mathbf{P}_q+g_2\mathbf{P}_{\bar{q}})$, where $\mathbf{P}_q$ and $\mathbf{P}_{\bar{q}}$ are the momenta of the created quark and antiquark, respectively, and S is their combined spin. Our $^3P_0$ model [11] corresponds to $g_1=0$; if g_1 and g_2 are allowed to depend on the state of the spectator quarks their model allows for breaking of the usual spectator approximation. Forsyth and Cutkosky's model predicts that there are a number of reasonably light negative-parity states with wave functions predominantly in the $N=3$ band in a narrow energy range (from 2050-2300 MeV) which have large amplitudes to decay to ΣK. As theirs is the only model of the decays into these final states of $N=3$ band states, it is important to verify this prediction.

In this work we provide predictions for the decay amplitudes into the final states ΛK, ΣK, $\Lambda(1405)K$, $\Lambda(1520)K$, $\Sigma(1385)K$, ΛK^*, and ΣK^* of all states (seen and missing in $N\pi$) with wave functions predominantly in the $N=1$ and $N=2$ bands, and also for several low-lying states in higher bands, using the relativized model of baryon decays based on the $^3P_0$ pair creation model of Refs. [12] and [13]. Models of this kind are generally more predictive than elementary-meson emission models, which usually require a reduced matrix element to be fit to the decay of each type [SU(6) multiplet] of initial baryon. The $^3P_0$ pair creation model also properly takes into account the finite spatial extent of the final meson. Another advantage is that we are able to extend this model to include in the final state the excited strange baryons $\Lambda(1405)$, $\Lambda(1520)$, and $\Sigma(1385)$, as well as the excited meson K^*.

Model parameters are taken from our previous work and not adjusted; wave functions are taken from the relativized model of Ref. [5], which describes all of the states considered here in a consistent picture. In order to be in accord with the Particle Data Group (PDG) [14] conventional definitions of decay widths, we have determined the decay momentum using the central value of the PDG quoted mass for resonances seen in $N\pi$, and the predicted mass from Ref. [5] for missing and undiscovered states. We have also integrated over the line shape of the final state K^*, and $\Sigma(1385)$ and $\Lambda(1405)$ baryons, with the phase space as prescribed in the meson decay calculation of Ref. [15]; for details of this procedure see Eq. (8) of Ref. [13] (note that we do not integrate over the narrow [16 MeV width] $\Lambda(1520)$ line shape). As a consequence there are states below the nominal thresholds which have non-zero decay amplitudes.

In keeping with the convention of Ref. [13], the phases of the amplitudes are determined as follows. We quote the product $A^{X\dagger}_{YK}A^{X}_{N\pi}/|A^{X}_{N\pi}|$ of the predicted decay amplitude for $X \to YK$ (where Y is a ground state or excited state hyperon and K includes the K^*) and the phase of the decay amplitude for $X \to N\pi$, the latter being unobservable in $N\pi$ elastic scattering (note factors of $+i$, conventionally suppressed in quoting amplitudes for decays of negative parity baryons to NM or $N\gamma$, where M has negative parity, do not affect this product). This eliminates problems with (unphysical) sign conventions for wave functions, and the relative signs of these products are then predictions for the (physically significant) relative phases of the contributions of states X in the process $N\pi \to X \to YK$. The *overall* phase of the ΛK decay amplitudes quoted in the Particle Data Group [14] cannot be determined experimentally and so is fixed [16] by choosing the sign of the $N\pi \to S_{11}(1650) \to \Lambda K$ amplitude to be negative, as determined in an $SU(6)_W \times O(3)$ analysis of the strong decays (see, for example, Ref. [17]). Similarly, the overall phase of the $N\pi \to X \to \Sigma K$ decay amplitudes quoted in the Particle Data Group [14] is fixed by comparison to the $\mathrm{SU}(3)_f$ prediction that the sign should be negative when X is a Δ state [18]. Since our calculation explicitly breaks $\mathrm{SU}(3)_f$, we fix the overall sign [19] by choosing the sign of the amplitude for the low-lying state $X = \Delta(1950)F_{37}$, which has a well measured amplitude, to be negative. For the other final state channels dealt with here it may be necessary to fix an unmeasurable overall sign in the same way to compare with upcoming analyses of new data.

For photo and electroproduction experiments at TJNAF and elsewhere it may be useful to know the relative signs of the contributions of states X in the process $N\gamma \to X \to YK$. As the photocouplings of Ref. [20] are also quoted inclusive of the $N\pi$ sign, $A^{X\dagger}_{N\gamma}A^{X}_{N\pi}/|A^{X}_{N\pi}|$, then simply multiplying the quoted photocouplings by the amplitudes quoted here will yield the relative phases of the contributions of states X in $N\gamma \to X \to YK$.

II. RESULTS AND DISCUSSION

Our results for decays into the ΣK, ΣK^* and $\Sigma(1385)K$ channels are given in Tables I and III, and those for the ΛK^*, $\Lambda(1405)K$, and $\Lambda(1520)K$ channels are given in Tables II and IV. We have listed the decay amplitudes into these channels for each model state, which is also identified by its assignment (if any) to a resonance from the analyses. The predictions for the magnitude of the $N\pi$ decay amplitudes for each state [12] and values for these magnitudes extracted from the PDG [14] are also included for ease of identification of missing resonances. All theoretical amplitudes are given with upper and lower limits, along with the central value, in order to convey the uncertainty in our results due to the uncertainty in the resonance's mass. These correspond to our predictions for the amplitudes for a resonance whose mass is set to the upper and lower limits, and to the central value, of the experimentally determined mass. For states as yet unseen in the analyses of the data, we have adopted a 'standard' uncertainty in the mass of 150 MeV and used the model

predictions for the state's mass for the central value. If a state below the effective threshold has been omitted from a table it is because our predictions for all of its amplitudes are zero.

Figures 1 to 8 show the predictions of the model of Ref. [5] for the masses of excited N^* and Δ states below 2200 MeV, along with our predictions for the square roots of the initial channel partial widths and the final channel partial width for each state for the photoproduction reactions $\gamma N \to X \to YK$ and for the pion production reactions $\pi N \to X \to YK$. The final states YK are those listed above, with the exception of ΣK^*, for reasons discussed below. Photon partial widths are calculated using the results of Ref. [20]. When the energy of the initial state in the center of momentum frame coincides with the mass of a given resonance, the strength of the contribution of that resonance will be proportional to the product of the initial and final channel partial widths. We can estimate which states should contribute strongly in a given energy region by comparing the products of our predictions for the square roots of the initial and final channel partial widths of states in that region. In a given production process it should be possible to clearly separate nearby states in the same partial wave when one of these states has this product small and the other large. Model states in the figures which have well established (three or four stars [14]) counterparts from the analyses are distinguished from those which do not, in order to make it simple to assess which new states may be seen in experiments of this kind.

The amplitudes for decays into strange final states are generally smaller than those into lighter nonstrange final states, as shown below. However, it should still be possible to extract useful information about intermediate nonstrange baryon resonances from analyzing specific strange final states. In many strange channels only a few higher mass states contribute with appreciable amplitudes, and in several partial waves one or two states will dominate. This is due in part to the higher thresholds in effect here, which allow these channels to turn on in the mass region where new states are predicted to be present by our model. This is to be contrasted with the situation with nonstrange final states, where often low-lying states with large amplitudes make extraction of information about higher mass states with small amplitudes problematical.

The discussion below assumes the availability of polarization data for these processes, so that partial wave analyses are possible. This is automatic for reactions with final state Λ baryons, as their subsequent weak decays are self-analyzing. In addition, there are plans for polarized beams and targets in experiments at Jefferson Laboratory and elsewhere.

A. ΣK decays

In general, channels involving Σ or Σ^* in the final state will be difficult to analyze, as both N and Δ resonances contribute to the cross section. This means that in many instances one will encounter the difficulties associated with broad, overlapping resonances. Nevertheless, our results show that it may still be possible to confirm some weakly established resonances and observe new states by analyzing these final states.

The third columns of Tables I and III give our predictions for the ΣK decay amplitudes for nucleon and Δ resonances with wave functions predominantly in the $N = 1$ and 2 bands, and in higher bands, respectively. Our predictions for the relative contributions of model states below 2200 MeV to photoproduction and pion production of the ΣK final state are illustrated in Figs. 1 and 2. The amplitudes for this channel extracted from analyses are considerably less certain than those for the ΛK channel. However, there are a few examples of states with substantial predicted amplitudes which have also been seen with some certainty with this final state, such as $\Delta(1950)F_{37} = [\Delta\frac{7}{2}^+]_1(1940)$ and $\Delta(1920)P_{33} = [\Delta\frac{3}{2}^+]_3(1915)$ (the notation here and in what follows is that states which have been seen in the analyses are referred to by their PDG masses [14] and $N\pi$ partial wave, accompanied by our model state assignment). An interesting discrepancy between our (substantial) prediction and the extracted amplitudes exists for the state $\Delta(1910)P_{31} = [\Delta\frac{1}{2}^+]_2(1875)$, for which an upper limit only is quoted (see Table I and the PDG [14]), although older experiments admit the possibility of a larger amplitude. This state is predicted to contribute strongly to both $\gamma N \to \Sigma K$ and $\pi N \to \Sigma K$.

From Figs. 1 and 2 we see that we predict that a clear signal for the $N = 2$ band missing positive-parity states $N[\frac{1}{2}^+]_4(1880)$ and $\Delta[\frac{3}{2}^+]_4(1985)$ should be present in the process $\pi N \to \Sigma K$. The $N = 2$ band missing state $N[\frac{3}{2}^+]_3(1910)$ should also be visible in $\gamma N \to \Sigma K$. We also predict that the model states $N[\frac{3}{2}^+]_2(1870)$ and $\Delta[\frac{1}{2}^+]_1(1835)$, evidence for which is found in the multi-channel analysis of Manley and Saleski [21], should contribute strongly to both photo- and pion production of this final state. This suggests that an analysis of these reactions may provide further evidence for these new states.

From Figs. 1 and 2 we see that several low-lying negative-parity nucleon and Δ states with wave functions predominantly in the $N = 3$ band should contribute strongly to photo- or pion production of the ΣK final state. These include the weakly established states $N(2090)S_{11} = [N\frac{1}{2}^-]_3(1945)$, $N(2200)D_{15} = [N\frac{5}{2}^-]_3(2095)$ (pion production), and $\Delta(2150)S_{31} = \Delta[\frac{1}{2}^-]_3(2140)$, as well as the three-star states $\Delta(1900)S_{31} = \Delta[\frac{1}{2}^-]_2(2035)$ (in photoproduction) and $\Delta(1930)D_{35} = \Delta[\frac{5}{2}^-]_1(2155)$. Note that our ΣK amplitudes for these Δ states disagree with the upper limits set by one analysis [18]. Our results predict a clear signal for the model state $N[\frac{1}{2}^-]_4(2030)$ in both photo- and pion production of ΣK. The model state $N[\frac{5}{2}^-]_2(2080)$ should also contribute strongly to $\pi N \to \Sigma K$ and $\gamma N \to \Sigma K$, with a clear separation from its nearby partner $N(2200)D_{15} = [N\frac{5}{2}^-]_3(2095)$ in this partial wave in photoproduction.

Our predictions agree in sign (up to an overall sign which cannot be determined experimentally) and largely in magnitude with those of Koniuk and Isgur [8] for the decays of states with wave functions predominantly in the $N = 1$ and $N = 2$ bands. In two cases [the missing state $N[\frac{3}{2}^+]_2(1870)$ and $\Delta(1910)P_{31} = [\Delta\frac{1}{2}^+]_2(1875)$] our predicted amplitudes are large, and substantially larger than those of Koniuk and Isgur. Our model does not, however, confirm Forsyth and Cutkosky's prediction [4] that there are many light negative-parity states with masses between 2050 and 2300 MeV which have large amplitudes to decay to ΣK. For those $N = 3$ band states for which they predict large (up to 40 MeV) ΣK widths, we have amplitudes which are at most 2.4 MeV$^{\frac{1}{2}}$ in magnitude.

B. ΛK decays

The isospin selectivity of this final state means that only N^* resonances (as opposed to Δ resonances) can be intermediate states, which will simplify the analysis that will be required. Our results for this final state are shown in the first columns of Tables II and IV,

and our predictions for the relative contributions of model states below 2200 MeV to photo- and pion production of this final state are illustrated in Figure 3.

The signs and magnitudes of the predicted ΛK amplitudes are in good agreement with the amplitudes extracted from the analyses (largely in Table II) for well determined states for which there are substantial amplitudes. This gives us confidence that our predictions are reliable. For example, our result for the experimentally well determined ΛK decay amplitude for $N(1650)S_{11} = [N\frac{1}{2}^-]_2(1535)$ essentially agrees with that of Forsyth and Cutkosky [4], and is a little larger than Koniuk and Isgur's prediction [8]; all are within errors of the amplitude extracted from the analyses. Our results for states with wave functions predominantly in the $N = 1$ and $N = 2$ bands largely agree in both sign and in magnitude with those of Koniuk and Isgur [8]; there are just two states where the predicted signs differ, and these have small predicted amplitudes. With the possible exception of the model state $N[\frac{3}{2}^+]_4(1950)$ in pion production, our model predicts that none of the missing positive-parity nucleon states in the $N = 2$ band has a substantial ΛK decay amplitude (see Fig. 3).

From Fig. 3 and Table IV we see that a ΛK experiment should show clear signals for several relatively light negative-parity states with wave functions predominantly in the $N = 3$ band. The two-star state $N(2080)D_{13} = [N\frac{3}{2}^-]_3(1960)$ should be clearly confirmed with a precision $N\gamma$ or $N\pi \to \Lambda K$ experiment as it should dominate its partial wave; the amplitudes quoted in the Particle Data Group (PDG) [14] for this decay are smaller than our prediction, but are without error estimates. The nearby model state $N[\frac{3}{2}^-]_4(2055)$ should also contribute strongly to $N\pi \to \Lambda K$. The model state $N[\frac{5}{2}^-]_2(2080)$ and the nearby weak state $N(2200)D_{15} = N[\frac{5}{2}^-]_3(2095)$ should dominate their partial wave in pion production of this final state, with the former once again being clearly separated from its partner in photoproduction. The weakly established state $N(2090)S_{11} = [N\frac{1}{2}^-]_3(1945)$ should also be visible in both processes. Our predictions for these decays appear to be substantially larger than those of Forsyth and Cutkosky [4], who predict few appreciable ΛK widths for states in the $N = 3$ band.

C. ΛK^*, $\Lambda(1405)K$ and $\Lambda(1520)K$ decays

Our results for these final states are shown in Tables II and IV, and our predictions for the relative contributions of model states below 2200 MeV to photo- and pion production of this final state are illustrated in Figs. 4, 5 and 6. The figures show that, with the possible exception of the missing state $N[\frac{1}{2}^+]_4(1880)$ which may be visible in pion production of $\Lambda(1405)K$, our model predicts no substantial contributions to these channels for any states in the $N = 2$ band.

Our predictions for ΛK^* decays of selected states in higher bands are shown in Table IV and in Figure 4. Several low-lying weakly-established and predicted negative-parity nucleon resonances should contribute strongly to photo- and pion production of this final state; these largely correspond to states mentioned above as important in ΛK production. In addition, our results show it may be possible to see the well established state $N(2190)G_{17} = [N\frac{7}{2}^-]_1(2090)$ in both production experiments. The tentative state $N(2100)P_{11} = [N\frac{1}{2}^+]_6(2065)$ should also contribute strongly to $\pi N \to \Lambda K^*$ (without interference from the nearby model state $N[\frac{1}{2}^+]_7(2210)$, which decouples from both $N\pi$ and $N\gamma$

[see Tables III and IV]).

Our results for the $\Lambda(1405)K$ and $\Lambda(1520)K$ channels are quite interesting, with substantial widths for several low-lying negative-parity and two positive-parity states (see Table IV and Figs. 5 and 6). The weakly established state $N(2090)S_{11} = [N\frac{1}{2}^-]_3(1945)$ and the model state $[N\frac{5}{2}^-]_2(2080)$ should be easily visible in the $\Lambda(1520)K$ channel in both photo- and pion production experiments, and the two-star $N(2080)D_{13} = [N\frac{3}{2}^-]_3(1960)$ state should contribute strongly to $\Lambda(1405)K$ and $\Lambda(1520)K$ final channels in both production processes. The tentative state $N(2100)P_{11} = [N\frac{1}{2}^+]_6(2065)$ has a large predicted effect in $\Lambda(1405)K$ production, and the weak state state $N(2200)D_{15} = N[\frac{5}{2}^-]_3(2095)$ and the model state $N[\frac{7}{2}^+]_2(2390)$ (see Table IV) should be prominent in the pion production of $\Lambda(1520)K$. Once again, only the lighter $[N\frac{5}{2}^-]_2(2080)$ state should be visible in $\gamma N \to \Lambda(1520)K$.

Just as importantly, we see that there are indeed clear predictions of our model for the relative strengths of the decays of the lightest of those states which decay strongly into $\Lambda(1405)K$ and $\Lambda(1520)K$. Both of the weakly established states $N(2090)S_{11} = [N\frac{1}{2}^-]_3(1945)$ and $N(2200)D_{15} = [N\frac{5}{2}^-]_3(2095)$ are predicted to contribute strongly to $\Lambda(1520)K$ production, but not to $\Lambda(1405)K$ production. The opposite is true of the weak P_{11} state $N(2100) = [N\frac{1}{2}^+]_6(2065)$. The D_{13} state $N(2080) = [N\frac{3}{2}^-]_3(1960)$ is predicted to appear with roughly equal strength in both production of $\Lambda(1405)K$ and $\Lambda(1520)K$. In addition, intermediate states in other partial waves are predicted to contribute little to the production of these final states. Furthermore, we predict that none of the well established states in this mass region should couple strongly to $\Lambda(1405)K$ or $\Lambda(1520)K$. A photo- or pion production experiment in the region 2000-2300 MeV which is able to identify the overall spin and parity of the final state and reconstruct these two final baryons, although difficult, would be able to test these predictions of our three-quark model for the relative sizes of these decay amplitudes, and possibly resolve the issue of the nature of the $\Lambda(1405)$.

D. ΣK^* and $\Sigma(1385)K$ decays

From the amplitudes in Table I and from Figs. 7 and 8 we see that it may be possible to discover the $N = 2$ band missing states $N[\frac{5}{2}^+]_2(1980)$ and $\Delta[\frac{3}{2}^+]_4(1985)$ and confirm the state $\Delta(2000)F_{35} = \Delta[\frac{5}{2}^+]_2(1990)$ in a $\Sigma(1385)K$ production experiment. Contributions to ΣK^* production from these light states are weak, which is due in part to the higher nominal threshold.

Our results for decays of higher-lying states into these channels are shown in Table III and Figs. 7 and 8. We have not included a figure for the ΣK^* channel, as from Table III we see that few low-lying negative-parity predicted states should contribute strongly to production of ΣK^*. These include $N[\frac{1}{2}^-]_5(2070)$ (in pion production) and $\Delta[\frac{3}{2}^-]_3(2145)$, and the weakly established state $\Delta(2150)S_{31} = \Delta[\frac{1}{2}^-]_3(2140)$. The first two of these states are predicted to also contribute strongly to $\Sigma(1385)K$ production. From Fig. 7 we see that the dominant contributions to pion production of $\Sigma(1385)K$ in their partial wave should come from the weak state $N(2080)D_{13} = [N\frac{3}{2}^-]_3(1960)$ and the predicted state $N[\frac{3}{2}^-]_4(2055)$, whereas the dominant contribution to photoproduction in this partial wave should come from the nearby state $N[\frac{3}{2}^-]_5(2095)$. It may also be possible to confirm the tentative state

$\Delta(1940)D_{33} = \Delta[\frac{3}{2}^-]_2(2080)$ in a $\Sigma(1385)K$ production experiment.

III. CONCLUSIONS

Our predictions for the ΛK and ΣK decays of low-lying nonstrange baryons are similar to those given by Koniuk and Isgur, who study states with wave functions predominantly in the $N = 1$ and $N = 2$ bands. These results compare favorably in both sign and magnitude with those amplitudes reliably determined from existing data, which are largely to ΛK. There is a clear contrast between our results for negative-parity states with wave functions predominantly in the $N = 3$ band and those of Forsyth and Cutkosky; we predict more substantial ΛK amplitudes, and do not confirm their prediction of a narrow band of states with large amplitudes to decay to ΣK.

If we consider an s-channel picture of the pion and electromagnetic production of strange baryons and mesons, and assume a conventional three-quark structure for the $\Lambda(1405)$, we see that the $\Lambda(1405)K$ final state will be produced when $\sqrt{s}$ is of the order of the mass of the intermediate states found here to have appreciable couplings to this channel, roughly 2000–2300 MeV. It is in this mass region also that the final state $\Lambda(1520)K$ will be produced. Although the production amplitude in either case will be a coherent sum of the amplitudes through a few intermediate states, it should be possible to confirm or rule out a three-quark structure for the $\Lambda(1405)$ by studying these channels and comparing to our clear predictions for the relative sizes (and phases) of the amplitudes for decays into these states.

Our results also show that several missing and undiscovered states have substantial amplitudes to decay to strange final states, so that if kaon electromagnetic and pion production experiments were to focus on the region of 1800-2300 MeV, a careful analysis of the results would be likely to discover many new baryon states and provide much needed information about the parameters of states weakly established in other channels. As most of these states are negative-parity states with wave functions predominantly in the $N = 3$ band, partially due to the relatively high thresholds for these final states, the spectrum of many such states may be determined conclusively for the first time in a strangeness production experiment.

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FIGURES

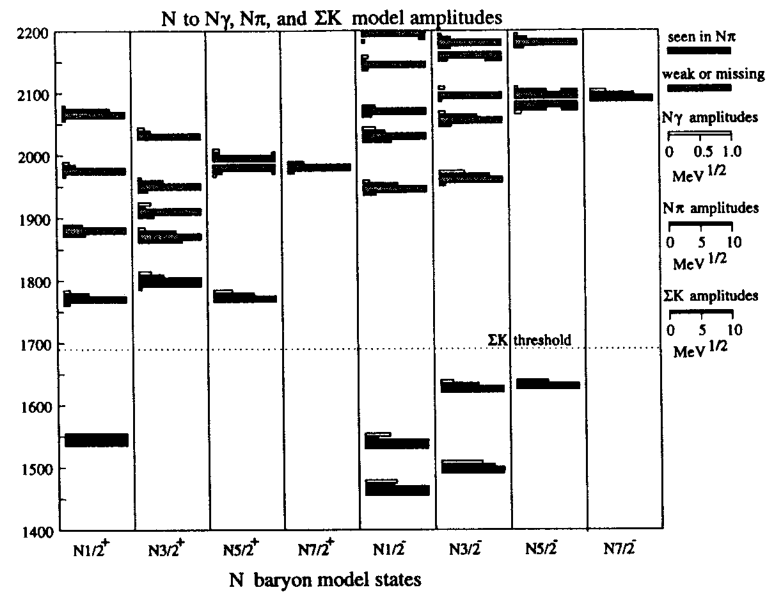

FIG. 1. Mass predictions, $N\gamma$, $N\pi$, and ΣK decay amplitude predictions for nucleon resonances up to 2200 MeV, sorted according to spin and parity. Heavy uniform-width bars show the predicted masses of states with well established counterparts from partial-wave analyses, light bars those of states which are weakly established or missing. The length of the thin white bar gives our prediction for each state's $N\gamma$ decay amplitude, that of the thin grey bar gives our prediction for its $N\pi$ decay amplitude, and that of the thin black bar gives our prediction for its ΣK decay amplitude. States with significant amplitudes for $N\gamma(N\pi)$ and ΣK decays should contribute strongly to the process $\gamma N(\pi N) \to \Sigma K$.

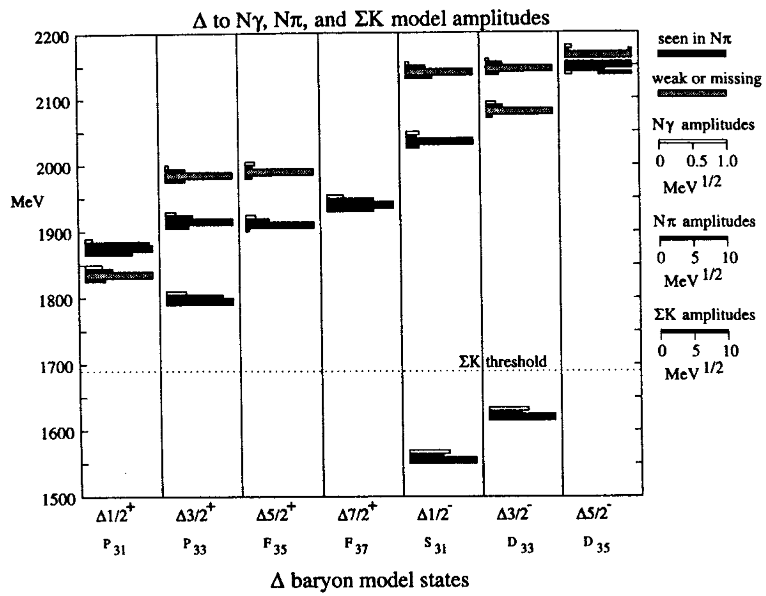

FIG. 2. Mass predictions, $N\gamma$, $N\pi$, and ΣK decay amplitude predictions for Δ resonances up to 2200 MeV. Notation as in Fig. 1. States with significant amplitudes for $N\gamma(N\pi)$ and ΣK decays should contribute strongly to the process $\gamma N(\pi N) \rightarrow \Sigma K$.

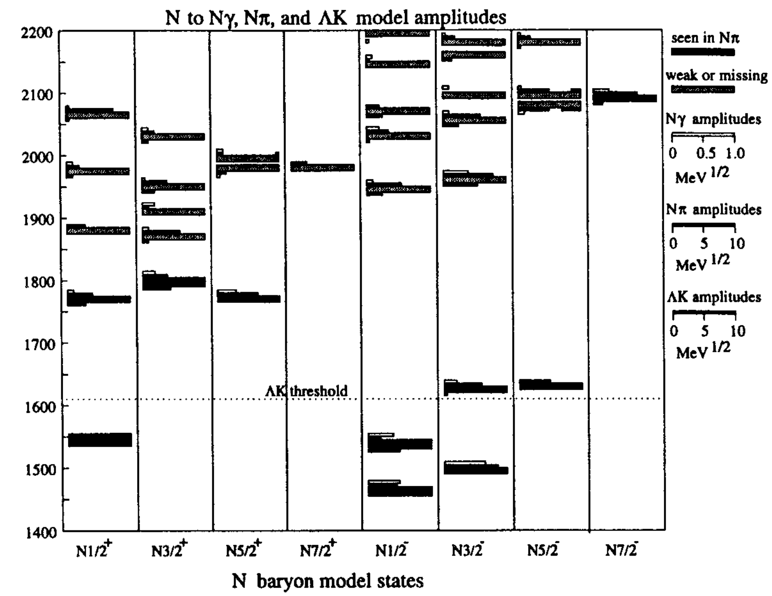

FIG. 3. Mass predictions, $N\gamma$, $N\pi$, and ΛK decay amplitude predictions for nucleon resonances up to 2200 MeV. Notation as in Fig. 1. States with significant amplitudes for $N\gamma(N\pi)$ and ΛK decays should contribute strongly to the process $\gamma N(\pi N) \rightarrow \Lambda K$.

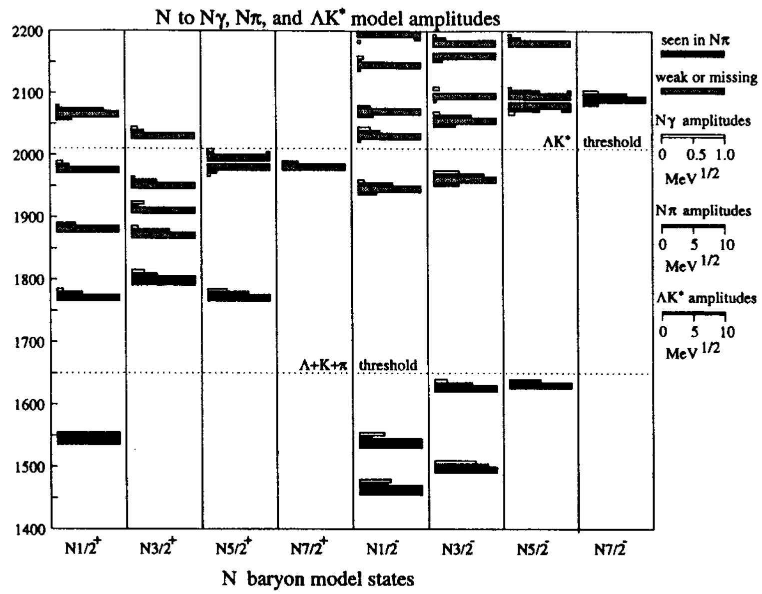

FIG. 4. Mass predictions, $N\gamma$, $N\pi$, and ΛK^* decay amplitude predictions for nucleon resonances up to 2200 MeV. Notation as in Fig. 1. States with significant amplitudes for $N\gamma(N\pi)$ and ΛK^* decays should contribute strongly to the process $\gamma N(\pi N) \to \Lambda K^*$.

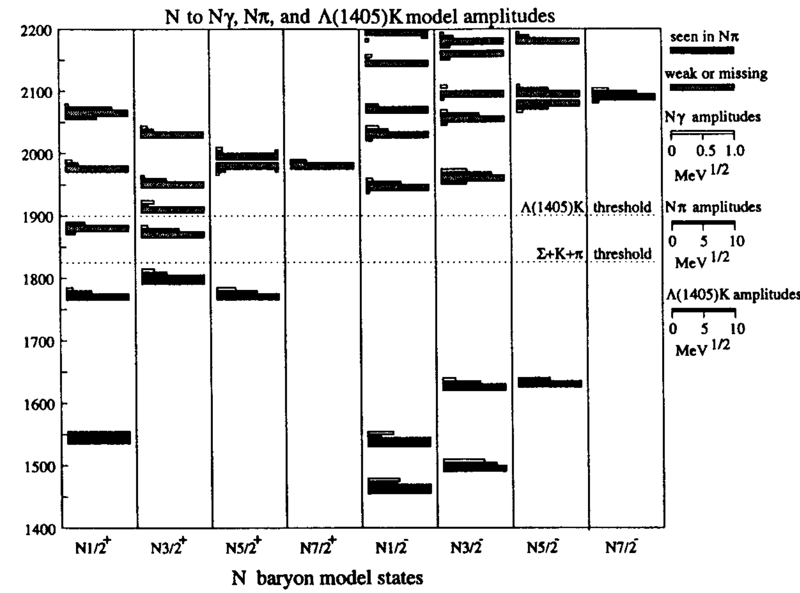

FIG. 5. Mass predictions, $N\gamma$, $N\pi$, and $\Lambda(1405)K$ decay amplitude predictions for nucleon resonances up to 2200 MeV. Notation as in Fig. 1. States with significant amplitudes for $N\gamma(N\pi)$ and $\Lambda(1405)K$ decays should contribute strongly to the process $\gamma N(\pi N) \to \Lambda(1405)K$.

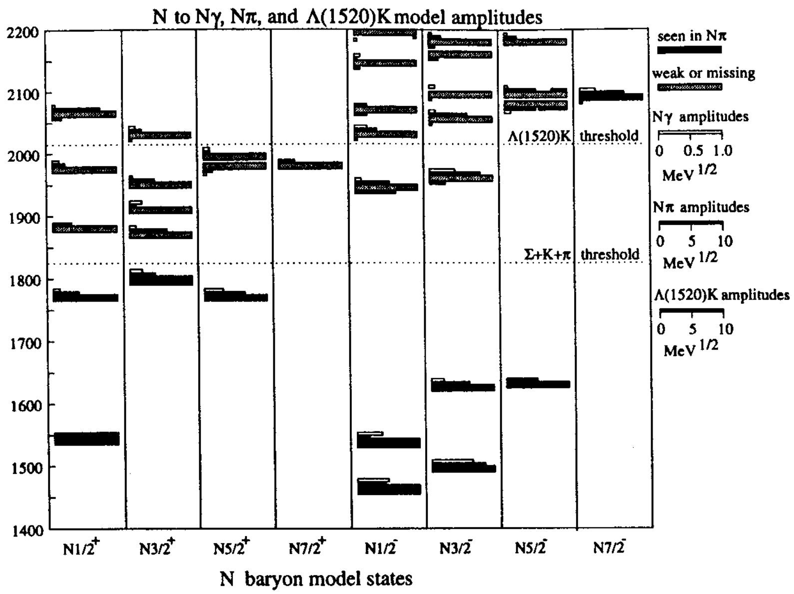

FIG. 6. Mass predictions, $N\gamma$, $N\pi$, and $\Lambda(1520)K$ decay amplitude predictions for nucleon resonances up to 2200 MeV. Notation as in Fig. 1. States with significant amplitudes for $N\gamma(N\pi)$ and $\Lambda(1520)K$ decays should contribute strongly to the process $\gamma N(\pi N) \to \Lambda(1520)K$.

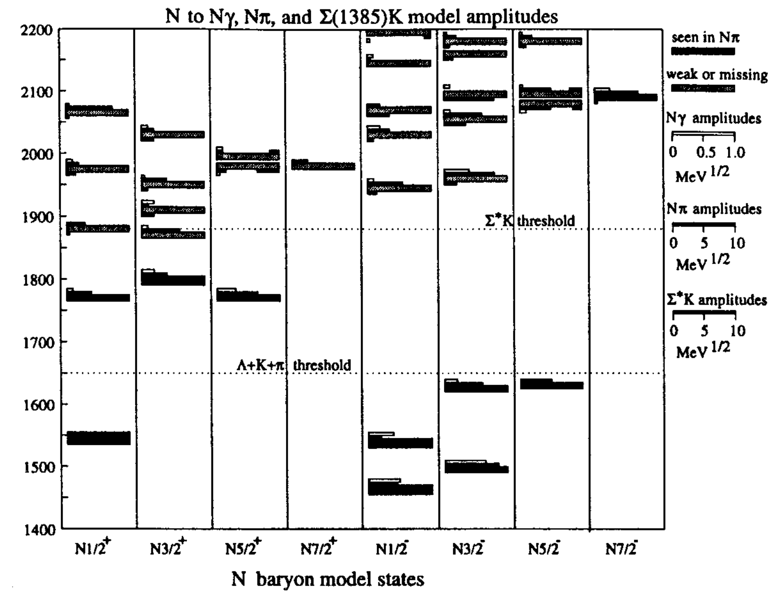

FIG. 7. Mass predictions, $N\gamma$, $N\pi$, and $\Sigma(1385)K$ decay amplitude predictions for nucleon resonances up to 2200 MeV. Notation as in Fig. 1. States with significant amplitudes for $N\gamma(N\pi)$ and $\Sigma(1385)K$ decays should contribute strongly to the process $\gamma N(\pi N) \to \Sigma(1385)K$.

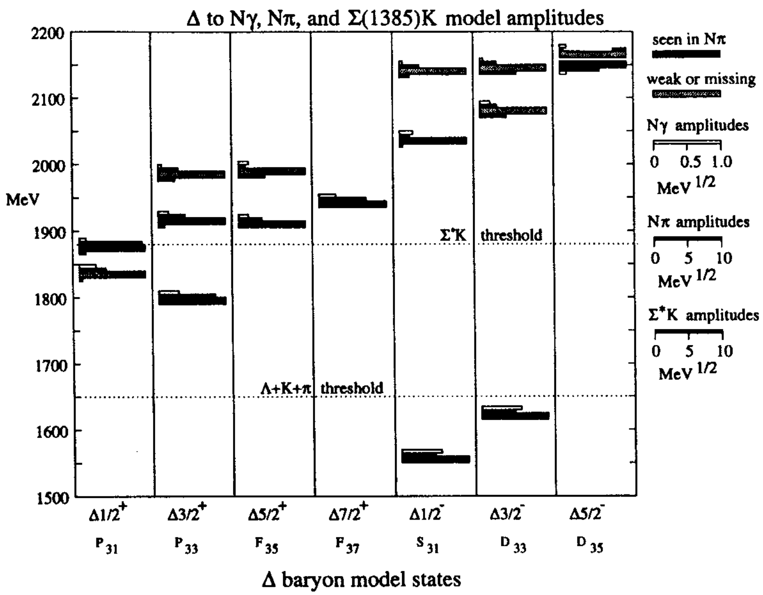

FIG. 8. Mass predictions, $N\gamma$, $N\pi$, and $\Sigma(1385)K$ decay amplitude predictions for Δ resonances up to 2200 MeV. Notation as in Fig. 1. States with significant amplitudes for $N\gamma(N\pi)$ and $\Sigma(1385)K$ decays should contribute strongly to the process $\gamma N(\pi N) \to \Sigma(1385)K$.

TABLES

TABLE I. Results for N and Δ states in the $N = 1$ and $N = 2$ bands in the ΣK, ΣK^*, and $\Sigma(1385)K$ channels. $N\pi$ amplitudes from Ref. [12] are included to explain our assignments of the model states to resonances. Notation for model states is $[J^P]_n$(mass[MeV]), where J^P is the spin/parity of the state and n its principal quantum number. The first row gives our model results, while the second row lists the available $N\pi$ and ΣK amplitudes from the partial-wave analyses, as well as the Particle Data Group (PDG) name for the state, its $N\pi$ partial wave, and its PDG star rating. Light states with zero amplitudes are omitted from the table. Signs are omitted from experimental amplitudes where they are not determined; with the exception of the $N\pi$ amplitudes (where we do not quote predicted signs) we omit positive signs from amplitudes predicted to be positive.

State	$N\pi$	ΣK	ΣK^*	ΣK^*	ΣK^*	$\sqrt{\Gamma_{\Sigma K^*}}$	$\Sigma(1385)K$	$\Sigma(1385)K$	$\sqrt{\Gamma_{\Sigma(1385)K}}$
$[N\frac{1}{2}^-]_2(1535)$	12.2 ± 0.8								
$N(1650)S_{11}$****	11.5 ± 1.3	$\simeq 2.7 \pm 1.8$							
$[N\frac{3}{2}^-]_2(1625)$	5.8 ± 0.6	$0.0\,^{+0.3}_{-0.0}$							
$N(1700)D_{13}$***	3.2 ± 1.1	< 0.5							
$[N\frac{5}{2}^-]_1(1630)$	5.3 ± 0.1								
$N(1675)D_{15}$****	8.2 ± 0.9	< 0.1							
$[\Delta\frac{3}{2}^-]_1(1620)$	4.9 ± 0.7	$0.1\,^{+0.6}_{-0.1}$							
$\Delta(1700)D_{33}$****	6.7 ± 1.6	$\simeq 0.2 \pm 0.1$							
			$p_{\frac{1}{2}}$	$p_{\frac{3}{2}}$			p		
$[N\frac{1}{2}^+]_3(1770)$	4.2 ± 0.1	$-1.1^{+1.1}_{-0.9}$							
$N(1710)P_{11}$***	4.7 ± 1.8	$\simeq -1.1 \pm 1.4$							
$[N\frac{1}{2}^+]_4(1880)$	$2.7\,^{+0.6}_{-0.9}$	$3.7\,^{+1.2}_{-2.4}$	$0.0\,^{+0.4}_{-0.0}$	0.0 ± 0.1		$0.0\,^{+0.4}_{-0.0}$	$0.4\,^{+2.8}_{-0.4}$		$0.4\,^{+2.8}_{-0.4}$
$[N\frac{1}{2}^+]_5(1975)$	$2.0\,^{+0.2}_{-0.3}$	0.6 ± 0.1	$0.1\,^{+1.0}_{-0.1}$	$0.0\,^{+0.0}_{-0.2}$		$0.1\,^{+1.0}_{-0.1}$	$1.3\,^{+1.1}_{-1.3}$		$1.3\,^{+1.1}_{-1.3}$
			$p_{\frac{1}{2}}$	$p_{\frac{3}{2}}$	$f_{\frac{3}{2}}$		p	f	
$[N\frac{3}{2}^+]_1(1795)$	14.1 ± 0.1	-0.3 ± 0.3							
$N(1720)P_{13}$****	4.7 ± 1.1	$\simeq 2.2 \pm 1.1$							
$[N\frac{3}{2}^+]_2(1870)$	$6.1\,^{+0.6}_{-1.2}$	$7.0\,^{+2.5}_{-4.9}$	0.0 ± 0.0	$0.0\,^{+0.0}_{-0.4}$	0.0 ± 0.0	$0.0\,^{+0.4}_{-0.0}$	$-0.2^{+0.2}_{-2.0}$	$0.0\,^{+0.2}_{-0.0}$	$0.2\,^{+2.0}_{-0.2}$
	11.4 ± 1.6[a]								
$[N\frac{3}{2}^+]_3(1910)$	1.0 ± 0.1	$2.5\,^{+0.8}_{-1.3}$	$0.1\,^{+0.8}_{-0.1}$	$-0.1^{+0.1}_{-0.9}$	0.0 ± 0.0	$0.1\,^{+1.2}_{-0.1}$	$-1.9^{+1.9}_{-7.3}$	$0.0\,^{+0.0}_{-0.4}$	$1.9\,^{+7.3}_{-1.9}$
$[N\frac{3}{2}^+]_4(1950)$	$4.1\,^{+0.4}_{-0.7}$	$1.4\,^{+0.3}_{-0.6}$	$0.1\,^{+1.0}_{-0.1}$	$0.1\,^{+1.0}_{-0.1}$	0.0 ± 0.0	$0.1\,^{+1.4}_{-0.1}$	$1.1\,^{+1.6}_{-1.0}$	$-0.1^{+0.1}_{-0.7}$	$1.1\,^{+1.7}_{-1.0}$
$[N\frac{3}{2}^+]_5(2030)$	1.8 ± 0.2	0.0 ± 0.0	$0.1\,^{+0.6}_{-0.1}$	$0.3\,^{+2.1}_{-0.3}$	0.0 ± 0.0	$0.3\,^{+2.1}_{-0.3}$	$2.2\,^{+1.0}_{-1.9}$	$-0.2^{+0.1}_{-0.3}$	$2.2\,^{+1.0}_{-1.9}$
			$f_{\frac{1}{2}}$	$p_{\frac{3}{2}}$	$f_{\frac{3}{2}}$		p	f	
$[N\frac{5}{2}^+]_2(1980)$	1.3 ± 0.2	0.4 ± 0.3	0.0 ± 0.0	$0.1\,^{+0.3}_{-0.1}$	0.0 ± 0.1	$0.1\,^{+0.3}_{-0.1}$	$-3.6^{+2.5}_{-3.0}$	$-0.1^{+0.1}_{-0.3}$	$3.6\,^{+3.0}_{-2.5}$
$[N\frac{5}{2}^+]_3(1995)$	0.9 ± 0.2	$-0.6^{+0.4}_{-0.6}$	0.0 ± 0.0	$-0.2^{+0.2}_{-2.4}$	$0.0\,^{+0.1}_{-0.0}$	$0.2\,^{+2.4}_{-0.2}$	$-1.7^{+1.6}_{-1.3}$	$0.2\,^{+0.7}_{-0.2}$	$1.7\,^{+1.4}_{-1.6}$
$N(2000)F_{15}$**	4.2 ± 1.8	$\simeq 2.5 \pm 2.2$							
							f	h	
$[N\frac{7}{2}^+]_1(2000)$	2.4 ± 0.4	$1.1\,^{+0.7}_{-0.5}$				0.0 ± 0.0	$-0.2^{+0.2}_{-0.5}$	0.0 ± 0.0	$0.2\,^{+0.5}_{-0.2}$
$N(1990)F_{17}$**	4.6 ± 1.2	$\simeq 2.9 \pm 2.2$							
			$p_{\frac{1}{2}}$	$p_{\frac{3}{2}}$			p		
$[\Delta\frac{1}{2}^+]_1(1835)$	$3.9\,^{+0.4}_{-0.7}$	$2.9\,^{+1.4}_{-2.9}$	$0.0\,^{+0.0}_{-0.4}$	$0.0\,^{+0.3}_{-0.0}$		$0.0\,^{+0.5}_{-0.0}$	$-0.3^{+0.3}_{-5.5}$		$0.3\,^{+5.5}_{-0.3}$
$\Delta(1740)P_{31}$[b]	4.9 ± 1.3								
$[\Delta\frac{1}{2}^+]_2(1875)$	9.4 ± 0.4	$6.9\,^{+0.6}_{-0.7}$	0.0 ± 0.1	0.0 ± 0.0		0.1 ± 0.1	$1.0\,^{+0.9}_{-0.7}$		$1.0\,^{+0.9}_{-0.7}$
$\Delta(1910)P_{31}$****	7.5 ± 1.5	< 1.0							
			$p_{\frac{1}{2}}$	$p_{\frac{3}{2}}$	$f_{\frac{3}{2}}$		p	f	
$[\Delta\frac{3}{2}^+]_2(1795)$	8.7 ± 0.2	$0.0\,^{+1.1}_{-0.0}$							
$\Delta(1600)P_{33}$***	7.8 ± 2.0	$\simeq 1.1 \pm 0.9$							
$[\Delta\frac{3}{2}^+]_3(1915)$	4.2 ± 0.3	3.3 ± 0.3	0.1 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.2	$1.2\,^{+1.3}_{-0.9}$	-0.1 ± 0.0	$1.2\,^{+1.3}_{-0.9}$
$\Delta(1920)P_{33}$***	5.3 ± 1.8	$\simeq +2.2 \pm 1.2$							
$[\Delta\frac{3}{2}^+]_4(1985)$	$3.3\,^{+0.8}_{-1.1}$	$3.2\,^{+0.3}_{-0.9}$	$-0.2^{+0.2}_{-1.8}$	$0.1\,^{+1.0}_{-0.1}$	$0.0\,^{+0.0}_{-0.2}$	$0.2\,^{+2.1}_{-0.2}$	$2.6\,^{+2.1}_{-2.5}$	$0.1\,^{+0.5}_{-0.1}$	$2.6\,^{+2.1}_{-2.5}$
			$f_{\frac{1}{2}}$	$p_{\frac{3}{2}}$	$f_{\frac{3}{2}}$		p	f	
$[\Delta\frac{5}{2}^+]_1(1910)$	3.4 ± 0.2	0.4 ± 0.1	0.0 ± 0.0	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	0.2 ± 0.1
$\Delta(1750)F_{35}$[c]	2.0 ± 0.8								
$\Delta(1905)F_{35}$****	5.7 ± 1.6	$\simeq -0.9 \pm 0.3$							

$[\Delta\frac{5}{2}^+]_2(1990)$	1.2 ± 0.4	$0.2^{+0.3}_{-0.2}$	$0.0^{+0.4}_{-0.0}$	$0.1^{+1.9}_{-0.1}$	$0.0^{+0.0}_{-0.5}$	$0.1^{+2.0}_{-0.1}$	$4.0^{+4.5}_{-4.0}$	$-0.1^{+0.1}_{-0.4}$	$4.0^{+4.5}_{-4.0}$
$\Delta(2000)F_{35}$**	5.3 ± 2.3								
			$f_{\frac{1}{2}}$	$f_{\frac{3}{2}}$	$h_{\frac{3}{2}}$		f	h	
$[\Delta\frac{7}{2}^+]_1(1940)$	7.1 ± 0.1	1.2 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	-0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0
$\Delta(1950)F_{37}$****	10.4 ± 1.1	$\simeq +1.5 \pm 0.4$							

a Second P_{13} found in Ref. [21].
b First P_{31} state found in Ref. [21].
c Ref. [21] finds two F_{35} states; this one and $\Delta(1905)F_{35}$.

TABLE II. Results for N states in the $N = 1$ and $N = 2$ bands for decays into the ΛK, ΛK^*, $\Lambda(1405)K$ and $\Lambda(1520)K$ channels. Notation as in Table I.

State	ΛK	ΛK^*	ΛK^*	ΛK^*	$\sqrt{\Gamma_{\Lambda K^*}}$	$\Lambda(1405)K$	$\Lambda(1520)K$	$\Lambda(1520)K$	$\sqrt{\Gamma_{\Lambda(1520)K}}$
$[N\frac{1}{2}^-]_2(1535)$	$-5.2^{+1.4}_{-0.5}$								
$N(1650)S_{11}$****	$+3.3 \pm 1.0$								
$[N\frac{3}{2}^-]_1(1495)$	$0.0^{+0.0}_{-0.9}$								
$N(1520)D_{13}$****	0.0 ± 0.0								
$[N\frac{3}{2}^-]_2(1625)$	-0.4 ± 0.2								
$N(1700)D_{13}$***	-0.4 ± 0.3								
$[N\frac{5}{2}^-]_1(1630)$	0.0 ± 0.0								
$N(1675)D_{15}$****	0.4 ± 0.3								
$[N\frac{1}{2}^+]_3(1770)$	-2.8 ± 0.6								
$N(1710)P_{11}$***	$+4.7 \pm 3.7$								
		$p_{\frac{1}{2}}$	$p_{\frac{3}{2}}$				d		
$[N\frac{1}{2}^+]_4(1880)$	-0.1 ± 0.1	0.0 ± 0.0	$0.0^{+0.2}_{-0.0}$		$0.0^{+0.2}_{-0.0}$	$1.4^{+4.9}_{-1.4}$			
$[N\frac{1}{2}^+]_5(1975)$	$-1.1^{+0.3}_{-0.2}$	$0.1^{+0.3}_{-0.1}$	$0.2^{+0.9}_{-0.2}$		$0.2^{+0.9}_{-0.2}$	-0.1 ± 0.1	$0.0^{+0.0}_{-0.2}$		$0.0^{+0.2}_{-0.0}$
		$p_{\frac{1}{2}}$	$p_{\frac{3}{2}}$	$f_{\frac{3}{2}}$			s	d	
$[N\frac{3}{2}^+]_1(1795)$	$-4.3^{+0.8}_{-0.7}$								
$N(1720)P_{13}$****	$+3.2 \pm 1.8$								
$[N\frac{3}{2}^+]_2(1870)$	$-0.9^{+0.4}_{-0.1}$	$0.0^{+0.2}_{-0.0}$	$0.0^{+0.0}_{-0.2}$	0.0 ± 0.0	$0.0^{+0.2}_{-0.0}$	$0.0^{+0.0}_{-0.4}$	$0.0^{+0.0}_{-0.8}$	0.0 ± 0.0	$0.0^{+0.8}_{-0.0}$
$[N\frac{3}{2}^+]_3(1910)$	0.0 ± 0.0	$0.0^{+0.1}_{-0.0}$	$0.0^{+0.0}_{-0.2}$	0.0 ± 0.0	$0.0^{+0.3}_{-0.0}$	$0.0^{+0.0}_{-0.2}$	0.0 ± 0.1	$0.0^{+0.0}_{-0.2}$	$0.0^{+0.2}_{-0.0}$
$[N\frac{3}{2}^+]_4(1950)$	$-1.9^{+0.5}_{-0.2}$	$0.1^{+0.5}_{-0.1}$	$-0.1^{+0.1}_{-0.4}$	$0.0^{+0.0}_{-0.1}$	$0.1^{+0.6}_{-0.1}$	$-0.1^{+0.1}_{-0.4}$	$0.0^{+0.0}_{-2.2}$	$0.0^{+0.3}_{-0.0}$	$0.0^{+2.2}_{-0.0}$
$[N\frac{3}{2}^+]_5(2030)$	-0.9 ± 0.2	$0.1^{+0.3}_{-0.1}$	$-0.1^{+0.1}_{-0.3}$	$0.0^{+0.0}_{-0.2}$	$0.1^{+0.4}_{-0.1}$	0.1 ± 0.1	$-0.6^{+0.6}_{-0.3}$	0.0 ± 0.0	$0.6^{+0.3}_{-0.6}$
		$f_{\frac{1}{2}}$	$p_{\frac{3}{2}}$	$f_{\frac{3}{2}}$			d	g	
$[N\frac{5}{2}^+]_1(1770)$	-0.1 ± 0.0								
$N(1680)F_{15}$****	$\simeq 0.1 \pm 0.1$								
$[N\frac{5}{2}^+]_2(1980)$	0.0 ± 0.0				0.0 ± 0.0	$-0.3^{+0.2}_{-0.4}$			0.0 ± 0.0
$[N\frac{5}{2}^+]_3(1995)$	-0.5 ± 0.3	0.0 ± 0.1	$0.3^{+1.2}_{-0.2}$	$0.0^{+0.2}_{-0.0}$	$0.3^{+1.3}_{-0.2}$	$-0.6^{+0.6}_{-1.6}$	$0.0^{+0.0}_{-0.5}$	0.0 ± 0.0	$0.0^{+0.5}_{-0.0}$
							d	g	
$[N\frac{7}{2}^+]_1(2000)$	0.0 ± 0.0				0.0 ± 0.0	0.0 ± 0.0	$0.0^{+0.0}_{-0.5}$	0.0 ± 0.0	$0.0^{+0.5}_{-0.0}$
	$\simeq 1.5 \pm 2.4$								

TABLE III. Results in the ΣK, ΣK^*, and $\Sigma(1385)K$ channels for the lightest few negative-parity N and Δ resonances of each J in the N=3 band, and for the lightest few N and Δ resonances for J^P values which first appear in the N=4, 5 and 6 bands. Notation as in Table I.

State	$N\pi$	ΣK	ΣK^*	ΣK^*	ΣK^*	$\sqrt{\Gamma_{\Sigma K^*}}$	$\Sigma(1385)K$	$\Sigma(1385)K$	$\sqrt{\Gamma_{\Sigma(1385)K}}$
			$s_{\frac{1}{2}}$	$d_{\frac{1}{2}}$			d		
$[N\frac{1}{2}^-]_3(1945)$	$5.7^{+0.5}_{-1.6}$	$2.1^{+1.3}_{-1.4}$	$-0.9^{+0.8}_{-0.7}$	$-0.2^{+0.2}_{-1.3}$		$0.9^{+1.2}_{-0.8}$	$1.7^{+2.0}_{-1.4}$		$1.7^{+2.0}_{-1.4}$
$N(2090)S_{11}$*	7.9 ± 3.8								
$[N\frac{1}{2}^-]_4(2030)$	$3.7^{+0.5}_{-1.1}$	$-4.5^{+2.8}_{-2.4}$	$-0.7^{+0.6}_{-2.7}$	$0.1^{+0.6}_{-0.1}$		$0.7^{+2.8}_{-0.6}$	$1.0^{+1.0}_{-0.9}$		$1.0^{+1.0}_{-0.9}$
$[N\frac{1}{2}^-]_5(2070)$	$2.1^{+0.8}_{-1.5}$	-1.5 ± 0.6	$2.9^{+5.7}_{-2.6}$	$0.1^{+1.1}_{-0.1}$		$2.9^{+5.7}_{-2.6}$	$-3.3^{+2.9}_{-2.7}$		$3.3^{+2.7}_{-2.9}$
$[N\frac{1}{2}^-]_6(2145)$	0.4 ± 0.0	-1.1 ± 0.7	0.0 ± 0.0	$0.3^{+0.8}_{-0.3}$		$0.3^{+0.8}_{-0.3}$	$-0.2^{+0.1}_{-0.5}$		$0.2^{+0.5}_{-0.1}$
$[N\frac{1}{2}^-]_7(2195)$	0.1 ± 0.1	-0.7 ± 0.9	0.5 ± 0.3	$0.5^{+0.8}_{-0.4}$		$0.7^{+0.8}_{-0.5}$	$-0.8^{+0.3}_{-0.9}$		$0.8^{+0.9}_{-0.3}$
$[N\frac{3}{2}^-]_3(1960)$	$8.2^{+0.7}_{-1.7}$	-0.7 ± 0.3	$0.1^{+0.9}_{-0.1}$	-0.5 ± 0.5	$0.0^{+0.0}_{-0.3}$	$0.6^{+1.0}_{-0.5}$	1.3 ± 0.4	1.4 ± 1.3	$1.9^{+1.3}_{-1.0}$
$N(2080)D_{13}$**	6.2 ± 2.0	$\simeq 1.2 \pm 0.0$							
			$d_{\frac{1}{2}}$	$s_{\frac{3}{2}}$	$d_{\frac{3}{2}}$		s	d	
$[N\frac{3}{2}^-]_4(2055)$	$6.2^{+0.1}_{-0.6}$	$1.8^{+0.7}_{-0.8}$	$-0.2^{+0.2}_{-1.3}$	$1.2^{+2.0}_{-1.1}$	0.0 ± 0.1	$1.2^{+3.2}_{-1.1}$	-2.5 ± 1.0	$-2.5^{+2.3}_{-1.9}$	3.5 ± 2.1
$[N\frac{3}{2}^-]_5(2095)$	0.2 ± 0.2	0.4 ± 0.1	$0.3^{+1.9}_{-0.3}$	$1.7^{+1.2}_{-1.5}$	$-0.4^{+0.3}_{-2.3}$	$1.7^{+2.8}_{-1.6}$	7.7 ± 1.2	$-0.8^{+0.7}_{-1.0}$	$7.8^{+1.3}_{-1.2}$
$[N\frac{3}{2}^-]_6(2165)$	$1.5^{+0.1}_{-0.2}$	$2.4^{+0.5}_{-0.7}$	$0.2^{+0.4}_{-0.2}$	-0.1 ± 0.0	$0.2^{+0.4}_{-0.2}$	$0.3^{+0.6}_{-0.3}$	0.0 ± 0.1	$0.4^{+0.8}_{-0.3}$	$0.4^{+0.8}_{-0.3}$
$[N\frac{3}{2}^-]_7(2180)$	$1.7^{+0.1}_{-0.2}$	$1.8^{+0.3}_{-0.5}$	$0.4^{+0.6}_{-0.3}$	0.0 ± 0.0	$0.4^{+0.7}_{-0.4}$	$0.5^{+1.0}_{-0.5}$	-0.1 ± 0.0	$1.0^{+1.6}_{-0.5}$	$1.0^{+1.6}_{-0.5}$
			$d_{\frac{1}{2}}$	$d_{\frac{3}{2}}$	$g_{\frac{3}{2}}$		d	g	
$[N\frac{5}{2}^-]_2(2080)$	$5.1^{+0.2}_{-0.8}$	$-2.4^{+0.9}_{-0.5}$	$-0.1^{+0.1}_{-0.2}$	$0.8^{+2.3}_{-0.8}$	0.0 ± 0.1	$0.8^{+2.3}_{-0.8}$	$1.7^{+1.5}_{-1.2}$	$-0.1^{+0.1}_{-0.3}$	$1.7^{+1.5}_{-1.2}$
$[N\frac{5}{2}^-]_3(2095)$	$5.2^{+0.4}_{-1.0}$	$2.5^{+0.6}_{-0.9}$	$0.2^{+1.2}_{-0.2}$	$-0.2^{+0.2}_{-1.5}$	0.0 ± 0.0	$0.3^{+1.9}_{-0.3}$	$-2.0^{+1.6}_{-2.5}$	$0.0^{+0.0}_{-0.1}$	$2.0^{+2.5}_{-1.6}$
$N(2200)D_{15}$**	4.7 ± 1.0								
$[N\frac{5}{2}^-]_4(2180)$	$1.9^{+0.1}_{-0.3}$	$1.5^{+0.3}_{-0.4}$	$0.2^{+0.3}_{-0.2}$	$0.5^{+0.8}_{-0.4}$	$0.0^{+0.0}_{-0.1}$	$0.5^{+0.9}_{-0.4}$	$1.1^{+1.7}_{-0.5}$	$-0.1^{+0.1}_{-0.4}$	$1.1^{+1.7}_{-0.5}$
$[N\frac{5}{2}^-]_5(2235)$	$2.0^{+0.1}_{-0.3}$	0.4 ± 0.1	$-1.1^{+1.0}_{-1.2}$	$-1.0^{+0.9}_{-1.1}$	0.0 ± 0.0	$1.5^{+1.7}_{-1.3}$	-0.6 ± 0.3	$0.6^{+0.7}_{-0.5}$	$0.9^{+0.7}_{-0.5}$
$[N\frac{5}{2}^-]_6(2260)$	0.4 ± 0.1	-0.2 ± 0.1	$-1.1^{+1.0}_{-1.3}$	$1.0^{+1.1}_{-0.8}$	$-0.1^{+0.1}_{-0.3}$	$1.5^{+1.7}_{-1.3}$	$2.8^{+0.2}_{-1.7}$	0.3 ± 0.2	$2.8^{+0.2}_{-1.7}$
$[N\frac{5}{2}^-]_7(2295)$	0.2 ± 0.0	$1.8^{+0.2}_{-0.3}$	$0.2^{+0.3}_{-0.1}$	$0.4^{+0.6}_{-0.3}$	$-0.1^{+0.1}_{-0.4}$	$0.4^{+0.7}_{-0.3}$	1.0 ± 0.5	-0.1 ± 0.1	1.1 ± 0.5
$[N\frac{5}{2}^-]_8(2305)$	0.3 ± 0.1	0.7 ± 0.0	$-0.7^{+0.5}_{-1.2}$	$0.3^{+0.4}_{-0.2}$	$-0.1^{+0.1}_{-0.4}$	$0.8^{+1.3}_{-0.6}$	1.2 ± 0.6	$0.4^{+0.1}_{-0.3}$	1.3 ± 0.6
			$g_{\frac{1}{2}}$	$d_{\frac{3}{2}}$	$g_{\frac{3}{2}}$		d	g	
$[N\frac{7}{2}^-]_1(2090)$	6.9 ± 1.3	-0.2 ± 0.1	0.0 ± 0.1	$-0.3^{+0.2}_{-0.4}$	0.0 ± 0.0	$0.3^{+0.4}_{-0.2}$	$0.3^{+0.3}_{-0.1}$	$0.2^{+0.4}_{-0.1}$	$0.3^{+0.5}_{-0.1}$
$N(2190)G_{17}$****	7.0 ± 3.0								
$[N\frac{7}{2}^-]_2(2305)$	0.4 ± 0.1	0.4 ± 0.2	$-0.1^{+0.1}_{-0.2}$	$0.8^{+1.2}_{-0.6}$	$-0.1^{+0.1}_{-0.2}$	$0.8^{+1.3}_{-0.6}$	0.0 ± 0.0	$-0.6^{+0.5}_{-0.1}$	$0.6^{+0.1}_{-0.5}$
$[N\frac{7}{2}^-]_3(2355)$	1.1 ± 0.3	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.1	0.1 ± 0.1	-0.3 ± 0.1	0.0 ± 0.0	0.3 ± 0.1
			$g_{\frac{1}{2}}$	$g_{\frac{3}{2}}$	$i_{\frac{3}{2}}$		g	i	
$[N\frac{9}{2}^-]_1(2215)$	2.5 ± 0.4	1.1 ± 0.4	0.1 ± 0.1	-0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.2	-0.7 ± 0.4	0.0 ± 0.0	0.7 ± 0.5
$N(2250)G_{19}$****	6.1 ± 1.0								
			$i_{\frac{1}{2}}$	$g_{\frac{3}{2}}$	$i_{\frac{3}{2}}$		g	i	
$[N\frac{11}{2}^-]_1(2600)$	$3.3^{+1.1}_{-0.9}$	0.0 ± 0.0	0.0 ± 0.0	-0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.1	0.1 ± 0.1
$N(2600)I_{1\ 11}$***	4.5 ± 1.5								
$[N\frac{11}{2}^-]_2(2670)$	1.8 ± 0.5	0.2 ± 0.1	0.0 ± 0.0	$0.5^{+0.7}_{-0.2}$	$-0.1^{+0.1}_{-0.2}$	$0.5^{+0.7}_{-0.2}$	0.1 ± 0.1	$-0.2^{+0.1}_{-0.5}$	$0.3^{+0.5}_{-0.1}$
$[N\frac{11}{2}^-]_3(2700)$	0.3 ± 0.1	0.0 ± 0.0	$-0.2^{+0.1}_{-0.5}$	0.0 ± 0.0	$0.2^{+0.4}_{-0.1}$	$0.3^{+0.6}_{-0.2}$	$-0.9^{+0.4}_{-1.0}$	0.0 ± 0.0	$0.9^{+1.0}_{-0.4}$
$[N\frac{11}{2}^-]_4(2770)$	0.2 ± 0.0	0.2 ± 0.1	-0.1 ± 0.1	$0.5^{+0.4}_{-0.3}$	-0.1 ± 0.1	$0.5^{+0.5}_{-0.3}$	-0.1 ± 0.1	$-0.3^{+0.2}_{-0.5}$	$0.3^{+0.5}_{-0.2}$
$[N\frac{11}{2}^-]_5(2855)$	0.6 ± 0.1	0.0 ± 0.0	-0.1 ± 0.1	0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	-0.2 ± 0.1	-0.1 ± 0.0	0.2 ± 0.1
			$i_{\frac{1}{2}}$	$i_{\frac{3}{2}}$	$k_{\frac{3}{2}}$		i	k	
$[N\frac{13}{2}^-]_1(2715)$	1.1 ± 0.3	0.4 ± 0.2	$0.1^{+0.3}_{-0.1}$	$-0.2^{+0.1}_{-0.4}$	0.0 ± 0.0	$0.2^{+0.5}_{-0.2}$	$-0.3^{+0.2}_{-0.6}$	0.0 ± 0.0	$0.3^{+0.6}_{-0.2}$
$[N\frac{13}{2}^-]_2(2845)$	0.2 ± 0.1	0.1 ± 0.1	0.1 ± 0.1	-0.1 ± 0.1	0.0 ± 0.0	0.2 ± 0.1	$-0.2^{+0.1}_{-0.2}$	0.0 ± 0.0	$0.2^{+0.2}_{-0.1}$
			$s_{\frac{1}{2}}$	$d_{\frac{1}{2}}$			d		
$[\Delta\frac{1}{2}^-]_2(2035)$	1.2 ± 0.2	-1.9 ± 0.3	0.1 ± 0.2	0.0 ± 0.0		0.1 ± 0.2	$-0.3^{+0.2}_{-0.6}$		$0.3^{+0.6}_{-0.2}$
$\Delta(1900)S_{31}$***	6.3 ± 1.0	< 0.9							
$[\Delta\frac{1}{2}^-]_3(2140)$	$3.1^{+0.4}_{-1.1}$	-4.1 ± 2.4	$-4.8^{+4.2}_{-0.7}$	$0.4^{+1.0}_{-0.4}$		$4.8^{+0.9}_{-4.2}$	$1.4^{+2.9}_{-0.9}$		$1.4^{+2.9}_{-0.9}$
$\Delta(2150)S_{31}$*	6.6 ± 2.0	< 0.7							
			$d_{\frac{1}{2}}$	$s_{\frac{3}{2}}$	$d_{\frac{3}{2}}$		s	d	
$[\Delta\frac{3}{2}^-]_2(2080)$	2.1 ± 0.1	1.1 ± 0.7	$0.0^{+0.0}_{-0.4}$	$0.1^{+1.0}_{-0.1}$	$0.0^{+0.1}_{-0.0}$	$0.1^{+1.1}_{-0.1}$	$-4.1^{+4.0}_{-1.5}$	$-0.5^{+0.5}_{-2.2}$	$4.2^{+2.1}_{-4.0}$
$\Delta(1940)D_{33}$*	6.5 ± 2.0	< 0.7							
$[\Delta\frac{3}{2}^-]_3(2145)$	$2.2^{+0.1}_{-0.3}$	$1.9^{+0.5}_{-0.6}$	0.1 ± 0.1	$5.7^{+1.2}_{-5.0}$	$-0.6^{+0.6}_{-1.7}$	$5.7^{+1.5}_{-5.0}$	5.2 ± 0.4	$-1.9^{+1.2}_{-4.0}$	$5.5^{+2.6}_{-0.7}$
			$d_{\frac{1}{2}}$	$d_{\frac{3}{2}}$	$g_{\frac{3}{2}}$		d	g	
$[\Delta\frac{5}{2}^-]_1(2155)$	5.2 ± 0.0	2.1 ± 0.4				0.0 ± 0.0	$-0.2^{+0.2}_{-0.3}$	0.0 ± 0.0	$0.2^{+0.3}_{-0.2}$

$\Delta(1930)D_{35}$***	7.2 ± 1.0	< 0.7							
$[\Delta\frac{5}{2}^-]_2(2165)$	0.6 ± 0.1	1.0 ± 0.3	$0.9^{+1.8}_{-0.9}$	$-0.4^{+0.3}_{-0.8}$	$0.0^{+0.1}_{-0.0}$	$1.0^{+2.0}_{-0.9}$	$-1.9^{+1.1}_{-3.7}$	$-0.3^{+0.2}_{-1.0}$	$2.0^{+3.8}_{-1.1}$
$[\Delta\frac{5}{2}^-]_3(2265)$	2.4 ± 0.4	2.5 ± 0.1	$0.8^{+0.9}_{-0.2}$	$1.0^{+1.1}_{-0.3}$	$-0.2^{+0.1}_{-0.4}$	$1.3^{+1.4}_{-0.3}$	1.9 ± 0.3	$-0.6^{+0.2}_{-0.1}$	2.0 ± 0.3
$\Delta(2350)D_{35}$*	5.1 ± 2.0	< 0.9							
$[\Delta\frac{5}{2}^-]_4(2325)$	0.1 ± 0.0	-0.3 ± 0.1	$0.3^{+0.4}_{-0.2}$	$1.5^{+2.4}_{-1.0}$	$-0.1^{+0.1}_{-0.2}$	$1.6^{+2.4}_{-1.0}$	1.8 ± 0.8	$-0.5^{+0.4}_{-0.1}$	1.9 ± 0.8
			$g_{\frac{1}{2}}$	$d_{\frac{3}{2}}$	$g_{\frac{3}{2}}$		d	g	
$[\Delta\frac{7}{2}^-]_1(2230)$	2.1 ± 0.6	$0.4^{+0.3}_{-0.2}$	$-0.1^{+0.1}_{-0.4}$	$0.5^{+0.8}_{-0.5}$	0.0 ± 0.1	$0.5^{+0.9}_{-0.5}$	$-2.0^{+0.8}_{-2.1}$	$-0.3^{+0.2}_{-0.8}$	$2.0^{+2.2}_{-0.9}$
$\Delta(2200)G_{37}$*	5.4 ± 1.0	$\simeq - 1.1 \pm 0.0$							
$[\Delta\frac{7}{2}^-] - 2(2295)$	1.8 ± 0.4	0.5 ± 0.3	$0.1^{+0.3}_{-0.1}$	$1.3^{+2.0}_{-1.0}$	$-0.2^{+0.2}_{-0.8}$	$1.4^{+2.1}_{-1.0}$	2.5 ± 1.3	$-0.7^{+0.6}_{-0.2}$	2.6 ± 1.3
			$g_{\frac{1}{2}}$	$g_{\frac{3}{2}}$	$i_{\frac{3}{2}}$		g	i	
$[\Delta\frac{9}{2}^-]_1(2295)$	4.8 ± 1.3	$1.4^{+1.0}_{-0.8}$	$0.4^{+0.5}_{-0.3}$	$-0.6^{+0.5}_{-0.8}$	0.0 ± 0.0	$0.7^{+0.9}_{-0.6}$	-0.9 ± 0.7	0.0 ± 0.0	0.9 ± 0.7
$\Delta(2400)G_{39}$**	5.4 ± 1.0	< 1.2							
			$i_{\frac{1}{2}}$	$i_{\frac{3}{2}}$	$k_{\frac{3}{2}}$		i	k	
$[\Delta\frac{13}{2}^-]_1(2750)$	2.2 ± 0.4	0.4 ± 0.1	$0.2^{+0.2}_{-0.1}$	$-0.3^{+0.1}_{-0.3}$	0.0 ± 0.0	$0.3^{+0.4}_{-0.2}$	$-0.4^{+0.2}_{-0.4}$	0.0 ± 0.0	$0.4^{+0.4}_{-0.2}$
$\Delta(2750)I_{3\ 13}$**	3.7 ± 1.5								
			$p_{\frac{1}{2}}$	$p_{\frac{3}{2}}$			p		
$[N\frac{1}{2}^+]_6(2065)$	$7.7^{+2.4}_{-2.9}$	0.3 ± 0.3	0.1 ± 0.0	-0.1 ± 0.0		0.1 ± 0.0	0.6 ± 0.2		0.6 ± 0.2
$N(2100)P_{11}$*	5.0 ± 2.0								
$[N\frac{1}{2}^+]_7(2210)$	$0.3^{+0.2}_{-0.1}$	$0.0^{+0.7}_{-0.5}$	$0.5^{+0.1}_{-0.3}$	-0.3 ± 0.2		$0.5^{+0.2}_{-0.4}$	$1.1^{+0.6}_{-0.4}$		$1.1^{+0.6}_{-0.4}$
			$f_{\frac{1}{2}}$	$f_{\frac{3}{2}}$	$h_{\frac{3}{2}}$		f	h	
$[N\frac{7}{2}^+]_2(2390)$	$4.9^{+0.0}_{-0.4}$	0.1 ± 0.0	-0.2 ± 0.1	-0.2 ± 0.1	0.0 ± 0.0	0.3 ± 0.2	0.0 ± 0.0	0.1 ± 0.1	0.1 ± 0.1
$[N\frac{7}{2}^+]_3(2410)$	$0.4^{+0.2}_{-0.4}$	$1.7^{+0.3}_{-0.4}$	$0.7^{+0.3}_{-0.4}$	$-1.2^{+0.8}_{-0.5}$	0.0 ± 0.0	$1.4^{+0.6}_{-0.9}$	-1.6 ± 0.3	0.0 ± 0.0	1.6 ± 0.3
$[N\frac{7}{2}^+]_4(2455)$	0.5 ± 0.0	0.5 ± 0.1	$-1.1^{+0.8}_{-0.1}$	$0.3^{+0.0}_{-0.2}$	-0.2 ± 0.1	$1.1^{+0.1}_{-0.8}$	1.1 ± 0.1	$0.2^{+0.2}_{-0.1}$	1.1 ± 0.2
			$h_{\frac{1}{2}}$	$f_{\frac{3}{2}}$	$h_{\frac{3}{2}}$		f	h	
$[N\frac{9}{2}^+]_1(2345)$	$3.6^{+1.0}_{-0.8}$	0.0 ± 0.0				0.0 ± 0.0	-0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.1
$N(2220)H_{19}$****	8.1 ± 1.0								
$[N\frac{9}{2}^+]_2(2500)$	0.4 ± 0.1	-0.4 ± 0.2	0.2 ± 0.1	$-1.3^{+0.8}_{-0.2}$	0.1 ± 0.1	$1.3^{+0.3}_{-0.8}$	0.2 ± 0.0	$0.4^{+0.5}_{-0.1}$	$0.5^{+0.4}_{-0.1}$
$[N\frac{9}{2}^+]_3(2490)$	0.6 ± 0.2	0.0 ± 0.0	-0.3 ± 0.2	-0.1 ± 0.1	0.2 ± 0.2	0.4 ± 0.3	-1.7 ± 0.3	0.0 ± 0.0	1.7 ± 0.3
			$h_{\frac{1}{2}}$	$h_{\frac{3}{2}}$	$j_{\frac{3}{2}}$		h	j	
$[N\frac{11}{2}^+]_1(2490)$	1.3 ± 0.4	0.6 ± 0.4	0.1 ± 0.1	-0.2 ± 0.2	0.0 ± 0.0	0.3 ± 0.2	$-0.3^{+0.1}_{-0.3}$	0.0 ± 0.0	$0.3^{+0.3}_{-0.1}$
$[N\frac{11}{2}^+]_2(2600)$	0.7 ± 0.1	0.3 ± 0.1	0.1 ± 0.1	$-0.1^{+0.0}_{-0.2}$	0.0 ± 0.0	$0.1^{+0.2}_{-0.1}$	$-0.2^{+0.1}_{-0.2}$	0.0 ± 0.0	$0.2^{+0.2}_{-0.1}$
			$j_{\frac{1}{2}}$	$h_{\frac{3}{2}}$	$j_{\frac{3}{2}}$		h	j	
$[N\frac{13}{2}^+]_1(2820)$	$2.0^{+0.8}_{-0.6}$	0.0 ± 0.0				0.0 ± 0.0			0.0 ± 0.0
$N(2700)K_{1\ 13}$**	3.7 ± 1.2								
$[N\frac{13}{2}^+]_2(2930)$	0.2 ± 0.1	-0.1 ± 0.1	0.1 ± 0.0	$-0.6^{+0.3}_{-0.1}$	0.1 ± 0.1	$0.7^{+0.1}_{-0.3}$	0.0 ± 0.0	0.5 ± 0.4	0.5 ± 0.4
$[N\frac{13}{2}^+]_3(2955)$	0.2 ± 0.1	0.0 ± 0.0	-0.3 ± 0.2	0.1 ± 0.0	0.2 ± 0.1	0.4 ± 0.2	$-1.2^{+0.6}_{-0.4}$	-0.1 ± 0.1	$1.2^{+0.4}_{-0.6}$
			$j_{\frac{1}{2}}$	$j_{\frac{3}{2}}$	$l_{\frac{3}{2}}$		j	l	
$[N\frac{15}{2}^+]_1(2940)$	0.7 ± 0.2	0.2 ± 0.1	0.1 ± 0.1	-0.2 ± 0.1	0.0 ± 0.0	0.3 ± 0.1	-0.4 ± 0.3	0.0 ± 0.0	0.4 ± 0.3
$[N\frac{15}{2}^+]_2(3005)$	0.4 ± 0.1	0.1 ± 0.1	0.1 ± 0.0	-0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	-0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.1
			$f_{\frac{1}{2}}$	$f_{\frac{3}{2}}$	$h_{\frac{3}{2}}$		f	h	
$[\Delta\frac{7}{2}^+]_2(2370)$	$1.5^{+0.6}_{-0.9}$	$1.9^{+0.4}_{-0.5}$	$0.6^{+0.6}_{-0.4}$	$-1.0^{+0.7}_{-1.1}$	0.0 ± 0.0	$1.1^{+1.3}_{-0.8}$	$-2.1^{+1.1}_{-0.1}$	0.0 ± 0.0	$2.1^{+0.1}_{-1.1}$
$\Delta(2390)F_{37}$*	4.7 ± 1.0	< 0.9							
$[\Delta\frac{7}{2}^+]_3(2460)$	$1.1^{+0.0}_{-0.1}$	0.5 ± 0.1	0.5 ± 0.4	0.8 ± 0.6	-0.1 ± 0.1	$0.9^{+0.7}_{-0.6}$	$0.8^{+0.1}_{-0.3}$	-0.3 ± 0.2	$0.8^{+0.2}_{-0.3}$
			$h_{\frac{1}{2}}$	$f_{\frac{3}{2}}$	$h_{\frac{3}{2}}$		f	h	
$[\Delta\frac{9}{2}^+]_1(2420)$	1.2 ± 0.4	0.2 ± 0.1	0.0 ± 0.0	$0.3^{+0.8}_{-0.3}$	0.0 ± 0.0	$0.3^{+0.8}_{-0.3}$	0.0 ± 0.0	-0.2 ± 0.2	0.2 ± 0.1
$\Delta(2300)H_{39}$**	4.8 ± 1.0	$\simeq + 1.4 \pm 0.0$							
$[\Delta\frac{9}{2}^+]_2(2505)$	0.4 ± 0.1	0.1 ± 0.1	0.3 ± 0.3	$0.4^{+0.1}_{-0.2}$	-0.3 ± 0.2	0.6 ± 0.3	$1.4^{+0.6}_{-0.0}$	-0.1 ± 0.0	$1.4^{+0.6}_{-0.0}$
			$h_{\frac{1}{2}}$	$h_{\frac{3}{2}}$	$j_{\frac{3}{2}}$		h	j	
$[\Delta\frac{11}{2}^+]_1(2450)$	2.9 ± 0.7	0.5 ± 0.3	0.1 ± 0.1	-0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.2	-0.3 ± 0.1	0.0 ± 0.0	0.3 ± 0.1
$\Delta(2420)H_{3\ 11}$****	6.3 ± 1.0	$\simeq - 1.0 \pm 0.0$							
			$j_{\frac{1}{2}}$	$h_{\frac{3}{2}}$	$j_{\frac{3}{2}}$		h	j	
$[\Delta\frac{13}{2}^+]_1(2880)$	0.8 ± 0.2	0.1 ± 0.1	-0.1 ± 0.1	$0.5^{+0.1}_{-0.3}$	-0.1 ± 0.1	$0.5^{+0.1}_{-0.3}$	0.0 ± 0.0	$-0.3^{+0.2}_{-0.4}$	$0.3^{+0.4}_{-0.2}$
$[\Delta\frac{13}{2}^+]_2(2955)$	0.2 ± 0.1	0.0 ± 0.0	0.3 ± 0.1	0.2 ± 0.0	-0.3 ± 0.2	0.4 ± 0.2	$1.1^{+0.3}_{-0.6}$	-0.1 ± 0.1	$1.1^{+0.3}_{-0.6}$
			$j_{\frac{1}{2}}$	$j_{\frac{3}{2}}$	$l_{\frac{3}{2}}$		j	l	
$[\Delta\frac{15}{2}^+]_1(2920)$	1.6 ± 0.3	0.2 ± 0.1	0.2 ± 0.0	-0.3 ± 0.1	0.0 ± 0.0	0.3 ± 0.1	-0.4 ± 0.2	0.0 ± 0.0	0.4 ± 0.2
$\Delta(2950)K_{3\ 15}$**	3.6 ± 1.5								
$[\Delta\frac{15}{2}^+]_2(3085)$	0.4 ± 0.1	0.1 ± 0.0	0.0 ± 0.0	-0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0	-0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.0

TABLE IV. Results in the ΛK, ΛK^*, $\Lambda(1405)K$ and $\Lambda(1520)K$ channels for the lightest few negative-parity N resonances of each J in the N=3 band, and for the lightest few N resonances for J^P values which first appear in the N=4, 5 and 6 bands. Notation as in Table I.

State	ΛK	ΛK^*	ΛK^*	ΛK^*	$\sqrt{\Gamma_{\Lambda K^*}}$	$\Lambda(1405)K$	$\Lambda(1520)K$	$\Lambda(1520)K$	$\sqrt{\Gamma_{\Lambda(1520)K}}$
		$s_{1/2}$	$d_{3/2}$				p		
$[N\frac{1}{2}^-]_3(1945)$	2.3 ± 2.7	-2.2 ± 1.7	$2.2^{+4.2}_{-2.0}$		$3.1^{+4.3}_{-2.5}$	$0.5^{+1.0}_{-0.4}$	$6.4^{+5.7}_{-6.4}$		$6.4^{+5.7}_{-6.4}$
$N(2090)S_{11}{}^*$									
$[N\frac{1}{2}^-]_4(2030)$	0.3 ± 0.5	$-0.4^{+0.3}_{-0.2}$	$0.1^{+0.8}_{-0.1}$		$0.4^{+0.7}_{-0.4}$	$1.2^{+0.9}_{-1.1}$	$0.5^{+2.2}_{-0.5}$		$0.5^{+2.2}_{-0.5}$
$[N\frac{1}{2}^-]_5(2070)$	2.7 ± 1.3	$-2.3^{+2.0}_{-0.5}$	$0.9^{+2.4}_{-0.8}$		$2.4^{+1.8}_{-2.1}$	0.1 ± 0.1	$1.9^{+2.3}_{-1.9}$		$1.9^{+2.3}_{-1.9}$
$[N\frac{1}{2}^-]_6(2145)$	-0.1 ± 0.1	0.0 ± 0.0	$-0.3^{+0.2}_{-0.4}$		$0.3^{+0.4}_{-0.2}$	0.0 ± 0.0	$1.1^{+0.6}_{-1.1}$		$1.1^{+0.6}_{-1.1}$
$[N\frac{1}{2}^-]_7(2195)$	-0.1 ± 0.3	0.8 ± 0.2	$-0.8^{+0.7}_{-1.1}$		$1.1^{+1.0}_{-0.5}$	$-1.0^{+0.4}_{-0.0}$	$-0.7^{+0.5}_{-0.1}$		$0.7^{+0.1}_{-0.5}$
		$d_{1/2}$	$s_{3/2}$	$d_{3/2}$			p	f	
$[N\frac{3}{2}^-]_3(1960)$	$-5.6^{+1.7}_{-1.3}$	$0.7^{+1.5}_{-0.6}$	3.8 ± 2.9	$1.3^{+2.9}_{-1.2}$	$4.0^{+4.1}_{-3.1}$	$3.9^{+1.3}_{-2.7}$	$-2.6^{+2.6}_{-2.8}$	$-0.2^{+0.2}_{-1.3}$	$2.6^{+2.9}_{-2.6}$
$N(2080)D_{13}{}^{**}$	$\simeq +1.7 \pm 1.0$								
$[N\frac{3}{2}^-]_4(2055)$	$-2.7^{+0.9}_{-0.8}$	$0.2^{+0.8}_{-0.2}$	$3.3^{+1.7}_{-2.9}$	$0.4^{+1.6}_{-0.4}$	$3.3^{+2.1}_{-3.0}$	$1.2^{+0.5}_{-0.9}$	$-0.5^{+0.5}_{-0.9}$	$0.0^{+0.0}_{-0.5}$	$0.6^{+1.0}_{-0.6}$
$[N\frac{3}{2}^-]_5(2095)$	-0.1 ± 0.0	0.0 ± 0.0	$-0.6^{+0.5}_{-0.2}$	0.0 ± 0.0	$0.6^{+0.2}_{-0.5}$	$0.7^{+0.2}_{-0.4}$	0.4 ± 0.4	0.0 ± 0.0	0.4 ± 0.4
$[N\frac{3}{2}^-]_6(2165)$	0.2 ± 0.1	-0.1 ± 0.1	-0.1 ± 0.0	-0.1 ± 0.1	0.2 ± 0.2	-0.1 ± 0.1	$0.4^{+0.2}_{-0.4}$	0.0 ± 0.1	$0.4^{+0.2}_{-0.4}$
$[N\frac{3}{2}^-]_7(2180)$	-0.1 ± 0.0	0.1 ± 0.1	-0.1 ± 0.0	-0.1 ± 0.0	0.2 ± 0.2	$1.5^{+0.3}_{-0.7}$	$-1.1^{+0.9}_{-0.4}$	-0.1 ± 0.1	$1.1^{+0.5}_{-0.9}$
		$d_{1/2}$	$d_{3/2}$	$g_{3/2}$			p	f	
$[N\frac{5}{2}^-]_2(2080)$	$-2.9^{+0.8}_{-0.4}$	$0.9^{+1.6}_{-0.9}$	$-1.0^{+0.9}_{-1.6}$	$-0.3^{+0.3}_{-1.6}$	$1.4^{+2.7}_{-1.3}$	$0.1^{+0.4}_{-0.1}$	$-4.7^{+4.7}_{-1.2}$	$-0.3^{+0.3}_{-0.8}$	$4.7^{+1.3}_{-4.7}$
$[N\frac{5}{2}^-]_3(2095)$	$-1.7^{+0.5}_{-0.4}$	$0.2^{+0.4}_{-0.2}$	$-0.2^{+0.2}_{-0.4}$	$0.0^{+0.0}_{-0.2}$	$0.3^{+0.6}_{-0.3}$	0.0 ± 0.0	$-2.4^{+2.4}_{-2.0}$	$-0.1^{+0.1}_{-0.3}$	$2.4^{+2.0}_{-2.4}$
$N(2200)D_{15}{}^{**}$	$\simeq -2.2 \pm 1.0$								
$[N\frac{5}{2}^-]_4(2180)$	-0.3 ± 0.1	0.1 ± 0.1	-0.2 ± 0.2	0.0 ± 0.0	0.2 ± 0.3	-0.2 ± 0.2	0.0 ± 0.1	0.0 ± 0.0	0.0 ± 0.1
$[N\frac{5}{2}^-]_5(2235)$	-0.9 ± 0.2	$0.3^{+0.4}_{-0.2}$	$-0.3^{+0.2}_{-0.5}$	$-0.1^{+0.1}_{-0.4}$	$0.4^{+0.7}_{-0.3}$	-0.1 ± 0.1	0.0 ± 0.1	$-0.2^{+0.2}_{-0.3}$	$0.2^{+0.3}_{-0.2}$
$[N\frac{5}{2}^-]_6(2260)$	-0.2 ± 0.0	0.1 ± 0.1	-0.1 ± 0.1	0.0 ± 0.0	$0.2^{+0.2}_{-0.1}$	$0.4^{+0.5}_{-0.2}$	$-2.1^{+0.9}_{-0.4}$	$0.2^{+0.3}_{-0.2}$	$2.1^{+0.5}_{-0.9}$
$[N\frac{5}{2}^-]_7(2295)$	0.4 ± 0.0	-0.3 ± 0.1	0.3 ± 0.2	$0.1^{+0.2}_{-0.1}$	$0.4^{+0.4}_{-0.2}$	0.1 ± 0.1	$0.4^{+0.0}_{-0.1}$	-0.1 ± 0.1	0.4 ± 0.0
$[N\frac{5}{2}^-]_8(2305)$	0.0 ± 0.0				0.0 ± 0.0	$-0.3^{+0.2}_{-0.4}$	-0.3 ± 0.1	0.0 ± 0.0	0.3 ± 0.0
		$g_{1/2}$	$d_{3/2}$	$g_{3/2}$			f	h	
$[N\frac{7}{2}^-]_1(2090)$	$-1.3^{+0.4}_{-0.6}$	0.1 ± 0.2	$2.5^{+1.0}_{-1.6}$	$0.2^{+0.3}_{-0.2}$	$2.5^{+1.0}_{-1.6}$	1.2 ± 0.7	$-0.5^{+0.4}_{-0.6}$	0.0 ± 0.0	$0.5^{+0.6}_{-0.4}$
$N(2190)G_{17}{}^{****}$	$\simeq +1.1 \pm 0.0$								
$[N\frac{7}{2}^-]_2(2205)$	-0.5 ± 0.2	$0.1^{+0.2}_{-0.1}$	$1.0^{+1.3}_{-0.8}$	$0.1^{+0.3}_{-0.1}$	$1.0^{+1.3}_{-0.8}$	$0.7^{+0.7}_{-0.5}$	$-0.2^{+0.2}_{-0.4}$	0.0 ± 0.0	$0.2^{+0.4}_{-0.2}$
$[N\frac{7}{2}^-]_3(2255)$	-0.1 ± 0.1	0.0 ± 0.1	$0.3^{+0.4}_{-0.2}$	0.0 ± 0.1	$0.3^{+0.4}_{-0.2}$	0.0 ± 0.0	-0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1
$[N\frac{7}{2}^-]_4(2305)$	0.1 ± 0.0	0.0 ± 0.0	-0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	$-0.2^{+0.1}_{-0.3}$	0.2 ± 0.2	0.0 ± 0.0	0.2 ± 0.2
$[N\frac{7}{2}^-]_5(2355)$	-0.3 ± 0.1	0.1 ± 0.0	$0.8^{+0.0}_{-0.5}$	0.1 ± 0.1	$0.8^{+0.0}_{-0.5}$	$0.9^{+1.0}_{-0.5}$	$0.5^{+0.4}_{-0.3}$	0.0 ± 0.0	$0.5^{+0.4}_{-0.3}$
							f	h	
$[N\frac{9}{2}^-](2215)$	0.0 ± 0.0				0.0 ± 0.0	0.0 ± 0.0	-0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.1
$N(2250)G_{19}{}^{****}$	$\simeq -1.2 \pm 0.0$								
		$p_{1/2}$	$p_{3/2}$				d		
$[N\frac{1}{2}^+]_6(2065)$	$0.4^{+1.1}_{-1.6}$	$-0.8^{+0.7}_{-0.1}$	$-2.2^{+1.9}_{-0.4}$		$2.3^{+0.4}_{-2.0}$	5.2 ± 0.8	$-1.3^{+1.3}_{-2.9}$		$1.3^{+2.9}_{-1.3}$
$N(2100)P_{11}{}^*$									
$[N\frac{1}{2}^+]_7(2210)$	$-0.9^{+0.3}_{-0.2}$	$0.7^{+0.3}_{-0.4}$	$2.1^{+0.8}_{-1.3}$		$2.2^{+0.9}_{-1.3}$	-0.6 ± 0.3	1.0 ± 0.7		1.0 ± 0.7
		$f_{1/2}$	$f_{3/2}$	$h_{3/2}$			d	g	
$[N\frac{7}{2}^+]_2(2390)$	-1.7 ± 0.4	$0.9^{+0.1}_{-0.6}$	$-1.0^{+0.7}_{-0.1}$	-0.5 ± 0.4	$1.4^{+0.2}_{-1.0}$	0.1 ± 0.0	$3.1^{+0.8}_{-1.2}$	$0.3^{+0.3}_{-0.2}$	$3.1^{+0.8}_{-1.2}$
$[N\frac{7}{2}^+]_3(2410)$	0.1 ± 0.0				0.0 ± 0.0	-0.1 ± 0.1	$-0.7^{+0.2}_{-0.1}$	-0.1 ± 0.0	$0.7^{+0.1}_{-0.2}$
$[N\frac{7}{2}^+]_4(2455)$	0.0 ± 0.0				0.0 ± 0.0	-0.2 ± 0.1	-0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.1
		$h_{1/2}$	$f_{3/2}$	$h_{3/2}$			g	i	
$[N\frac{9}{2}^+]_1(2345)$	-0.4 ± 0.1	0.0 ± 0.1	$0.6^{+0.7}_{-0.4}$	0.0 ± 0.1	$0.6^{+0.7}_{-0.4}$	$-0.3^{+0.2}_{-0.3}$	0.1 ± 0.2	0.0 ± 0.0	0.1 ± 0.2
$N(2220)H_{19}{}^{****}$	$\simeq 0.0 \pm 0.0$								
$[N\frac{9}{2}^+]_2(2500)$	-0.2 ± 0.1	0.1 ± 0.1	$0.5^{+0.3}_{-0.1}$	$0.1^{+0.2}_{-0.0}$	$0.5^{+0.3}_{-0.1}$	-0.6 ± 0.4	0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.2
$[N\frac{9}{2}^+]_3(2490)$	-0.1 ± 0.0	0.0 ± 0.0	0.2 ± 0.1	0.0 ± 0.1	0.2 ± 0.1	-0.4 ± 0.2	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1
							g	i	
$[N\frac{11}{2}^+]_1(2490)$	0.0 ± 0.0				0.0 ± 0.0	0.0 ± 0.0	-0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.2
$[N\frac{11}{2}^+]_2(2600)$	0.0 ± 0.0				0.0 ± 0.0	0.0 ± 0.0	0.4 ± 0.3	0.0 ± 0.0	0.4 ± 0.3
		$i_{1/2}$	$g_{3/2}$	$i_{3/2}$			h	j	
$[N\frac{11}{2}^-]_1(2600)$	-0.4 ± 0.2	$0.1^{+0.3}_{-0.1}$	$0.9^{+1.2}_{-0.3}$	$0.2^{+0.4}_{-0.1}$	$0.9^{+1.3}_{-0.3}$	1.0 ± 0.6	$-0.4^{+0.2}_{-0.4}$	0.0 ± 0.0	$0.4^{+0.4}_{-0.2}$
$N(2600)I_{1\,11}{}^{***}$									
$[N\frac{11}{2}^-]_2(2670)$	-0.2 ± 0.1	0.1 ± 0.1	$0.4^{+0.5}_{-0.2}$	$0.1^{+0.2}_{-0.1}$	$0.4^{+0.5}_{-0.2}$	0.5 ± 0.3	-0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.1
$[N\frac{11}{2}^-]_3(2700)$	0.0 ± 0.0	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0	0.0 ± 0.0
$[N\frac{11}{2}^-]_4(2770)$	0.0 ± 0.0	0.0 ± 0.0	-0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.0	-0.2 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1
$[N\frac{11}{2}^-]_5(2855)$	-0.1 ± 0.0	0.1 ± 0.0	$0.3^{+0.0}_{-0.1}$	0.1 ± 0.0	$0.3^{+0.0}_{-0.2}$	0.5 ± 0.2	0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.1
		$j_{1/2}$	$h_{3/2}$	$j_{3/2}$			i	k	
$[N\frac{13}{2}^+]_1(2820)$	-0.2 ± 0.1	0.1 ± 0.1	$0.5^{+0.6}_{-0.3}$	$0.1^{+0.2}_{-0.1}$	$0.5^{+0.6}_{-0.3}$	-0.5 ± 0.2	0.2 ± 0.2	0.0 ± 0.0	0.2 ± 0.2
$N(2700)K_{1\,13}{}^{**}$									
$[N\frac{13}{2}^+]_2(2930)$	-0.1 ± 0.0	0.1 ± 0.0	0.3 ± 0.0	0.1 ± 0.0	0.3 ± 0.0	-0.3 ± 0.1	0.1 ± 0.1	0.0 ± 0.0	0.1 ± 0.1
$[N\frac{13}{2}^+]_3(2955)$	0.0 ± 0.0				0.0 ± 0.0	-0.1 ± 0.0			0.0 ± 0.0
							h	j	
$[N\frac{13}{2}^-]_1(2715)$	0.0 ± 0.0				0.0 ± 0.0	0.0 ± 0.0	-0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.1
$[N\frac{13}{2}^-]_2(2845)$	0.0 ± 0.0				0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.1
							i	k	
$[N\frac{15}{2}^+]_1(2940)$	0.0 ± 0.0				0.0 ± 0.0	0.0 ± 0.0	-0.1 ± 0.0	0.0 ± 0.0	0.1 ± 0.0
$[N\frac{15}{2}^+]_2(3005)$	0.0 ± 0.0				0.0 ± 0.0	0.0 ± 0.0	0.2 ± 0.1	0.0 ± 0.0	0.2 ± 0.1