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Role of Spin-7/2 Resonances in Strangeness Electromagnetic Production

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In hypernuclear spectroscopy [1], electromagnetic probes provide information complementary to that obtained from purely hadronic reactions. As a first step toward understanding strangeness production on nuclei, one needs to establish a sufficiently realistic description of the elementary process on a nucleon. In recent years there has been an important effort to established the elementary process operator (see Ref. [2] and earlier works quoted therein). The main difficulty in this topic comes from the fact that *a priori* about thirty resonances can contribute to the reaction mechanism. The most developed theoretical frame, based on effective Lagrangian approaches, does not allow a unique determination of the reaction mechanism. It is hence, highly desirable to find criteria which could offer high enough selectivity to shed a light on the relevant exchanged particles required by the available or forthcoming data.

In this purpose, we apply a *model independent* approach [3] which has already provided [4] some interesting information on the strong points, and shortcomings, of various phenomenological formalisms as well as on the sensitivity of polarization observables to resonances in *s*-, *u*-, and *t*-channels.

Using helicity amplitudes, we have considered the general structure [3] of the full set of 15 single and double polarization spin observables for the reaction $\gamma p \to K^+\Lambda$ [4]. Through this method, we deduced general rules about the angular structure of these observables, especially concerning how nodes arise for each observable from the underlying reaction mechanism. These rules are obtained either in a total angular momentum (J) or a multipole truncated basis. Expressions for the observables as a function of multipoles are reported for $l \leq 1$ and $l \leq 2$ in Refs. [3] and [5], respectively. In Table 1, we summarize the maximum number of allowed nodes for $J \leq 7/2$ and $l \leq 2$. The last column of this Table gives the number of nodes for each observable predicted by the most comprehensive available phenomenological model developed by the Saclay-Lyon group [2] and called SL. This model includes *s*-channel nucleonic resonances with spins up to 5/2, as well as *u*-channel hyperonic resonances ($J = 1/2$) and *t*-channel K^* and $K1$ resonances.

The number of nodes for 14 of the 15 spin observables obey the general rules of Ref. [3] concerning the maximum number of nodes permitted within a helicity basis truncated at $J \leq 5/2$. Only the single polarization observable, Σ, with incident linearly polarized photons deviates from these rules and shows the need for a significant spin-7/2 resonances (the special sensitivity of Σ to higher spin amplitudes due to *t*-channel exchange was

Table 1: Maximum number of nodes for single and double polarization observables.

Class	Obs	$\mathcal{H}$ $J \leq 1/2$	$\mathcal{H}$ $J \leq 3/2$	$\mathcal{H}$ $J \leq 5/2$	$\mathcal{H}$ $J \leq 7/2$	*Mult* $l \leq 1$	*Mult* $l \leq 2$	*SL*
$\mathcal{L}_0$								
Beam-Target	$\check{E}$	0	3	5	7	2	4	2
Beam-Recoil	$\hat{C}_{z'}$	1	3	5	7	3	5	3
Target-Recoil	$\hat{L}_{z'}$	1	3	5	7	3	5	3
$\mathcal{L}_{1a}$								
Recoil	$\check{P}$	0	2	4	6	1	3	1
Beam-Target	$\check{H}$	0	2	4	6	1	3	1
Beam-Recoil	$\hat{C}_{x'}$	0	2	4	6	2	4	3
Target-Recoil	$\hat{L}_{x'}$	0	2	4	6	2	4	3
$\mathcal{L}_{1b}$								
Target	$\check{T}$	0	2	4	6	1	3	1
Beam-Target	$\check{F}$	0	2	4	6	1	3	3
Beam-Recoil	$\hat{O}_{x'}$	0	2	4	6	2	4	2
Target-Recoil	$\hat{T}_{z'}$	0	2	4	6	2	4	4
$\mathcal{L}_2$								
Beam	$\check{\Sigma}$	0	1	3	5	0	2	4
Beam-Target	$\check{G}$	0	1	3	5	0	2	1
Beam-Recoil	$\hat{O}_{z'}$	0	1	3	5	1	3	3
Target-Recoil	$\hat{T}_{x'}$	0	1	3	5	1	3	3

emphasized in Ref. [4]). The nodal structure for single polarization observables, whitin the SL model is depicted in Fig. 1. To illustrate further this point, the multipole decomposition of the Σ observable is given in the next page. The expression has a fourth order polynomial structure in $X \equiv cos\theta_{cm}$ and can produce the number of nodes obtained within the SL model. As already discussed [4] in the case of simpler phenomenological models, in fitting data the lack of explicit spin-7/2 resonances in the Saclay-Lyon phenomenological model is compensated by having enhanced t-channel exchanges *via* duality hypothesis.

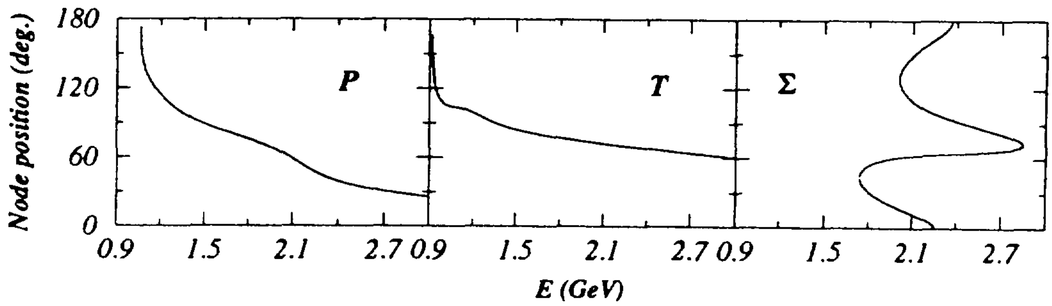

Fig. 1. Nodal structure of the single polarization observables as a function of incident photon lab. energy: recoil hyperon (P), target (T), and beam (Σ).

Our results show clearly that the existing data imply contributions from spin-7/2 nucleonic resonances. We look forward to upcoming data to learn if such resonances are

$$
\begin{aligned}
\hat{\Sigma} \equiv \quad \Sigma\, \mathcal{I} = \tfrac{-\sin^2\theta}{2}\, Re\Big(& 3\,|E_2^-|^2 + 9\,|E_3^-|^2 + 9\,|E_1^+|^2 + 18\,|E_2^+|^2 + \tfrac{225}{4}|E_3^+|^2 - 9\,|M_2^-|^2 \\
& -18\,|M_3^-|^2 - 3\,|M_1^+|^2 - 9\,|M_2^+|^2 - \tfrac{135}{4}|M_3^+|^2 + 6\,E_0^+\,[M_2^+ - E_2^- - E_2^+ - M_2^-]^* \\
& +E_1^+[18E_3^- - 45E_3^+ + 6M_1^- - 9\,M_3^- - 6\,M_3^+]^* + 3E_2^+[3M_2^- + 7E_2^- - 3M_2^+]^* \\
& +3\,M_1^-[2M_3^- - 5E_3^+ - 2E_3^- - 2M_1^+ + 5M_3^+]^* + 9E_3^-[M_3^+ - M_3^- - 5E_3^+]^* \\
& +6\,E_2^-[M_2^+ - M_2^-]^* + 18\,M_2^{+*}\,M_2^- + 3M_1^+[7M_3^- - 2E_3^- + 5E_3^+ + \tfrac{7}{2}M_3^+]^* \\
& +\tfrac{45}{2}E_3^{-*}[M_3^- - M_3^+]^* - \tfrac{117}{2}M_3^{-*}M_3^+ + \mathbf{X} \;\;\big(30E_0^+[M_3^+ - E_3^- - E_3^+ - M_3^-]^* \\
& +18E_1^+[3E_2^+ - 2E_2^-]^* + 189\,E_2^{+*}\,E_3^- - 6M_1^+[6M_2^- + 5E_2^+ + 4M_2^+]^* \\
& +30M_1^-[E_2^+ - M_2^+]^* + 6E_2^-[5M_3^+ - 4E_3^- + 20E_3^+ - 5M_3^-]^* + 189\,M_3^{-*}\,M_2^+ \\
& +9M_2^-[20M_3^+ + 6M_3^-]^* \;\big) + \mathbf{X}^2 \;\big(\; 45\,|E_3^-|^2 + 90\,|E_2^+|^2 - \tfrac{225}{2}|E_3^+|^2 - 90\,|M_3^-|^2 \\
& -45|M_2^+|^2 + \tfrac{135}{2}|M_3^+|^2 + 45E_1^+[M_3^+ - 4E_3^- + 3E_3^+ - M_3^-]^* + 105M_1^-[E_3^+ - M_3^+]^* \\
& -15M_1^+[9M_3^- + 7E_3^+ + 5M_3^+]^* - 45M_3^-[E_3^- - 25M_3^+]^* - 180\,M_2^{-*}M_2^+ \\
& +5E_2^+[9M_2^- - 27E_2^- - 9M_2^+]^* + 45\,M_3^{+*}\,E_3^+ + 45E_3^+[M_3^+ - M_3^- - 21E_3^-]^* \;\big) \\
& + \mathbf{X}^3 \;\big(\; -420\,E_3^{+*}E_2^- - 15E_2^+[45E_3^- - 32E_3^+]^* + 210E_3^+[M_2^- - M_2^+]^* \\
& -45M_2^+[15M_3^- - 6M_3^+]^* - 630\,M_2^{-*}\,M_3^+ \;\big) + \mathbf{X}^4 \;\big(\; \tfrac{2625}{4}|E_3^+|^2 \\
& -\tfrac{1575}{4}|M_3^+|^2 - E_3^+[2100E_3^- - \tfrac{525}{2}M_3^- + \tfrac{525}{2}M_3^+]^* - \tfrac{4725}{2}M_3^{-*}M_3^+ \;\big)\Big)
\end{aligned}
$$

indeed required by the reaction mechanism or, as discussed in Ref. [6], the manifestations of such high spin resonances in this energy range are induced by inconsistencies within the present data base.

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