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Are there three $\Xi(1950)$ states?

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Different experiments on hadron spectroscopy have long suspected the existence of several cascade states in the 1900–2000 MeV region. They are usually labeled under the common name of $\Xi(1950)$. As we argue here, there are also theoretical reasons supporting the idea of several $\Xi(1950)$ resonances. In particular, we propose the existence of three $\Xi(1950)$ states: one of these states would be part of a spin-parity $\frac{1}{2}^-$ decuplet and the other two probably would belong to the $\frac{5}{2}^+$ and $\frac{5}{2}^-$ octets. We also identify which decay channels are more appropriate for the detection of each of the previous states.

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There exists scarce data on cascade (Ξ) resonances. This is because (i) they can only be produced as a part of a final state, (ii) the production cross sections are small, and (iii) the final states are topologically complicated and difficult to study with electronic techniques. Thus, the bulk of information about cascade states comes entirely from old bubble chamber experiments where the numbers of events are small. There are just two four star resonances, $\Xi(1318)$ and $\Xi(1530)$ with spin parity $J^P = \frac{1}{2}^+$ and $\frac{3}{2}^+$, respectively. Those correspond to the lowest-lying S-wave quark model states. Other four cascade states deserve the rating of three stars in the Particle Data Group (PDG) [1]. Among the latter resonances, the chiral structure and spin parity of two of them, $\Xi(1690)$ and $\Xi(1820)$, seem to be theoretically understood [2–6].[1] The other two three star cascade resonances quoted in the PDG are the $\Xi(1950)$ and $\Xi(2030)$ states, which spin parity have not been determined yet. Here we will focus on these two states, in particular, on the $\Xi(1950)$ resonance.

The $\Xi(1950)$ resonance was discovered in 1965 by Badier *et al.* [7] in the decay channels $K^- p \to \Xi^- K^0 \pi^+$ and $K^- p \to \Xi^- K^+ \pi^0$. The Breit-Wigner parametrization fit resulted in a mass and width of $M = 1933 \pm 16$ MeV and $\Gamma = 140 \pm 35$ MeV, respectively. Later, Alitti *et al.* [8] confirmed the existence of a cascade resonance with $M = 1930 \pm 20$ MeV and $\Gamma = 80 \pm 40$ MeV in the $K^- p \to \Xi^- \pi^- \pi^+ K^+$ channel. The authors of Ref. [8] theorized that this resonance may complete the $\frac{5}{2}^-$ octet composed of the $N(1675)$, $\Lambda(1830)$, and $\Sigma(1775)$ resonances. Several experimental searches have since then found evidence for this state [9–12], providing different and sometimes incompatible values for its mass and width, see Table I. However, the $\Xi(1950)$ has not been observed in several works searching for Ξ^* states [14,15], while other experiments see at most a bump [13,16], thus explaining the current three stars status for the $\Xi(1950)$ in the PDG [1].

The possibility that there may be several cascade resonances in the 1900–2000 MeV region was first suggested by Briefel *et al.* [10] who noticed that different values for the $\Xi(1950)$ mass were to be found in different decay channels. This expectation has been commonly discussed in later experimental searches. Indeed, Biagi *et al.* [13] commented that *several bubble chamber experiments have seen indications of a rather broad signal in this region but in general the statistical significance is low and it is not clear if they are all observing the same resonance.*

There are also theoretical/phenomenological reasons to suspect for the existence of several cascade states in the vicinity of 1950 MeV. SU(3)-flavor symmetry was proposed by Gell-Mann [17] and Ne'eman [18] as an ordering principle for hadron spectroscopy [19]. This symmetry allows one to classify baryons and mesons into multiplets of particles with the same spin and parity. Two consequences of SU(3)-flavor symmetry are the Gell-Mann–Okubo (GMO) mass relation [17,20], and the correlation between the decay widths of the different hadrons conforming a multiplet. Here we will use the GMO mass relation to identify possible cascade resonances with masses not far from $M = 1950$ MeV and then try to match the predicted decay widths, assuming the $\Xi(1950)$ belongs to a particular multiplet, to the scarce experimental information available.

The GMO mass relation [17,20] relates the masses of the baryons composing a particular multiplet. For the octet case we have $2(m_N + m_\Xi) = 3m_\Lambda + m_\Sigma$, while for the decuplets the GMO relation predicts $m_\Omega - m_\Xi = m_\Xi - m_\Sigma = m_\Sigma - m_\Delta$. In the fundamental octet and decuplet, these relations are satisfied at the 1% level.

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[1]The $\Xi(1820)$ is dynamically generated from the Δ decuplet-pion octet chiral interaction [4,5], and it could be the partner of the $N(1520)$ in a $\frac{3}{2}^-$ octet. The $\Xi(1690)$ and the one star $\Xi(1620)$ appear in unitary chiral approaches to the scattering of Goldstone bosons off baryons of the nucleon octet [2,3,6], and they would be partners [3,6] of the $N(1535)$, $N(1650)$, $\Lambda(1405)$, and $\Lambda(1670)$ in two $\frac{1}{2}^-$ octets.

TABLE I. Different $\Xi(1950)$ mass and width experimental determinations. Works with an $*$ only see a bump.

Experiment	$M_{\Xi(1950)}$ [MeV]	$\Gamma_{\Xi(1950)}$ [MeV]	Channel
Badier 65 [7]	1933 ± 16	140 ± 35	$K^- p \to \Xi^- K^0 \pi^+$, $\Xi^- K^+ \pi^0$
Alitti 68 [8]	1930 ± 20	80 ± 40	$K^- p \to \Xi^- \pi^- \pi^+ K^+$
DiBianca 75 [9]	1900 ± 12	63 ± 78	$K^- d$ ($\Xi^- \pi^+$ mass distribution)
Briefel 77 [10]	1936 ± 22	87 ± 26	$K^- p \to \Xi^0 \pi^- K^+$
	1961 ± 18	159 ± 57	$K^- p \to \Xi^- \pi^+ K^0$
	1964 ± 10	60 ± 39	$K^- p \to \Xi(1530) \pi K$
Biagi 81 $*$ [13]	1937 ± 7	60 ± 8	$\Xi^- \mathrm{N} \to \Xi^- \pi^+ X$
Biagi 87a $*$ [11]	1944 ± 9	100 ± 31	$\Xi^- \mathrm{Be} \to \Xi^- \pi^+ \pi^- X$
Biagi 87b [11]	$1963 \pm 5 \pm 2$	$25 \pm 15 \pm 1$	$\Xi^- \mathrm{Be} \to \Lambda \bar{K}^0 X$
Adamovich 99 [12]	1955 ± 6	68 ± 22	Σ^-Nucleus ($\Xi^- \pi^+$ mass distribution)

We will consider three multiplets (two $\frac{5}{2}^{\pm}$ octets and a $\frac{1}{2}^-$ decuplet) for which the cascade state will possibly lie in the 1900–2000 MeV region. The $\frac{5}{2}^-$ octet would be composed of the $N(1675)$, $\Lambda(1830)$, and $\Sigma(1775)$ resonances leading to a GMO prediction of $m_\Xi[J^P = \frac{5}{2}^-] = 1958 \pm 30$ MeV. The error includes, added in quadratures, a 1% theoretical uncertainty for the GMO mass relation. Conversely for the $\frac{5}{2}^+$ octet [$N(1680)$, $\Lambda(1820)$, $\Sigma(1915)$] the cascade should lie around $m_\Xi[J^P = \frac{5}{2}^+] = 2003 \pm 24$ MeV.

One can firmly believe in the existence of the two cascade states above with $J^P = \frac{5}{2}^{\pm}$, since flavor SU(3) symmetry is reasonable realized in hadron spectroscopy and the existence of the rest of their partners is experimentally well established (four stars in the PDG [1]). These two multiplets are also derived in [21–23], where excited baryon states were studied in the large N_C limit.

The situation is less robust in the case of the $\frac{1}{2}^-$ decuplet. The existence of this multiplet is proposed in [6] and in the aforesaid Ref. [21]. In [6], $J^P = \frac{1}{2}^-$ Δ, Σ, Ξ, and Ω poles are found from a SU(6) spin–flavor extension [24] of the leading order SU(3) chiral Weinberg-Tomozawa meson-baryon interaction. They are grouped in a decuplet belonging to a SU(6) spin-flavor 70 multiplet of odd parity resonances,[2] as happens in [21]. In the case of the $\frac{1}{2}^-$ decuplet, there are only two known members, the $\Delta(1620)$ and the $\Sigma(1750)$ resonances. From the masses quoted in the PDG for them, we estimate $m_\Xi[J^P = \frac{1}{2}^-] = 1900 \pm 100$ MeV, which is also compatible with a Ξ resonance in the 1900–2000 MeV region.

According to SU(3)-flavor symmetry, the decay of a baryon a into a baryon b and a meson c takes the form [19]

$$\Gamma(a \to bc) = \frac{g^2}{8\pi} |C^a_{bc}|^2 M_b \frac{p}{M_a} \left(\frac{p}{M_s}\right)^{2l}, \tag{1}$$

where g is a constant, $M_{a(b)}$ is the mass of baryon $a(b)$, p is the center of mass momentum of the outgoing meson c, l is the angular momentum related with the decay, and M_s is a scaling mass, which we set to $M_s = 1$ GeV for simplicity. g depends on the particular multiplet assignment of the baryons a and b. We have only considered decays into a baryon belonging either to the $N(940)$ octet or the $\Delta(1232)$ decuplet and a meson of the pion octet. Thus, g will stand for $g_{\mu_b}(J^P|_a)$, with $\mu_b = 8$, 10 depending on whether baryon b is placed in an octet or a decuplet and $J^P|_a$ the spin-parity assignment of the initial baryon a. Besides, C^a_{bc} is the corresponding SU(3) Clebsch-Gordan coefficient, for which we follow de Swart's convention [25], that is, for the $8 \to 8 \otimes 8$ decays we write the coefficients in terms of the ratio[3] $\alpha = F/(D + F)$.

In Table II we compile experimentally known partial decay widths of the different baryons of the $\frac{5}{2}^{\pm}$ octets and $\frac{1}{2}^-$ decuplet. Results from best fits to Eq. (1) are shown in Table II where in addition, the values of χ^2/d.o.f., Gaussian correlation coefficients, and the fitted partial decay widths are given as well.[4] We observe that, given the experimental accuracy of the data, the SU(3) flavor symmetry picture advocated here looks consistent with data, since it provides reasonably small values of χ^2/d.o.f. To obtain the central values and the first set of errors in Table II all uncertainties in the masses have been ignored. However, the experimental masses of the members of the $\frac{5}{2}^{\pm}$ octets and the $\frac{1}{2}^-$ decuplet are certainly poorer determined than that of each of the decay products, and one might think that these uncertainties might have some influence both on the determination of the SU(3) couplings and on the accuracy of the predicted partial

[2]The Weinberg-Tomozawa extended interaction is strongly attractive in this spin-flavor sector [6], and most of the members of the 70 SU(6) multiplet can be identified with three and four star resonances.

[3]For instance, for the $\Xi(1950)$ partial decays we have $C(\Xi_{1950} \to \Xi\pi) = \sqrt{3}(2\alpha - 1)$, $C(\Xi_{1950} \to \Lambda\bar{K}) = \frac{4\alpha-1}{\sqrt{3}}$, $C(\Xi_{1950} \to \Sigma\bar{K}) = \sqrt{3}$, and $C(\Xi_{1950} \to \Xi\eta) = -\frac{2\alpha+1}{\sqrt{3}}$.

[4]We use a Monte Carlo simulation to propagate the correlated errors of the fitted SU(3) couplings, shown in the fifth column of Table II (first set of errors), to the partial decay widths (first set of errors in the fourth column).

TABLE II. Experimental partial decay widths (second and third columns) and results from different fits of Eq. (1): widths and best fit SU(3) decay parameters are displayed in the fourth and fifth columns, respectively. In these two latter columns, the first (second) set of errors stands for statistical (systematic) uncertainties (see text). In the last column, we also give the obtained χ^2/d.o.f. values for each fit, and the corresponding Gaussian correlation coefficients in the case of two parameter fits. In the first column, we give the SU(3) model details of each type of decays, including the value of l used in Eq. (1). For the masses of the different decaying resonances, we have used (i) $M = 1675 \pm 5$, 1830 ± 10, and 1775 ± 5 MeV for the $\frac{5}{2}^-$ octet, (ii) $M = 1685 \pm 5$, 1820 ± 5, and 1915 ± 20 MeV for the $\frac{5}{2}^+$ octet, and (iii) $M = 1630 \pm 30$ and 1765 ± 35 MeV for the $\frac{1}{2}^-$ decuplet.

SU(3) Decay		Decay channel	Data Γ_i (MeV) [1]	Fitted Γ_i (MeV)	Best fit parameters
$\frac{5}{2}^-$ $8 \to 8 \otimes 8$	$l = 2$	$N(1675) \to N\pi$	59 ± 10	$49 \pm 7 \pm 0.0$	$g_8 = 3.6 \pm 0.3 \pm 0.1$
		$\Lambda(1830) \to N\bar{K}$	5.5 ± 3.4	$2.7 \pm 1.2 \pm 0.1$	$\alpha = -0.23 \pm 0.06 \pm 0.00$
		$\Lambda(1830) \to \Sigma\pi$	47 ± 22	$72 \pm 7 \pm 2$	$r_{g_8,\alpha} = 0.75$
		$\Sigma(1775) \to N\bar{K}$	48 ± 7	$39 \pm 5 \pm 0$	χ^2/d.o.f $= 1.8$
		$\Sigma(1775) \to \Lambda\pi$	20 ± 4	$26 \pm 3 \pm 0$	
		$\Sigma(1775) \to \Sigma\pi$	4.2 ± 1.9	$3.5 \pm 1.5 \pm 0.0$	
$\frac{5}{2}^-$ $8 \to 10 \otimes 8$	$l = 2$	$N(1675) \to \Delta\pi$	81 ± 12	$86 \pm 2 \pm 0$	$g_{10} = 24 \pm 2 \pm 1$
		$\Sigma(1775) \to \Sigma(1385)\pi$	12 ± 3	$8.5 \pm 0.4 \pm 0.1$	χ^2/d.o.f $= 1.5$
$\frac{5}{2}^+$ $8 \to 8 \otimes 8$	$l = 3$	$N(1680) \to N\pi$	88 ± 8	$81 \pm 6 \pm 0$	$g_8 = 7.9 \pm 0.3 \pm 0.2$
		$\Lambda(1820) \to N\bar{K}$	48 ± 7	$55 \pm 6 \pm 0$	$\alpha = 0.58 \pm 0.05 \pm 0.00$
		$\Lambda(1820) \to \Sigma\pi$	8.8 ± 2.6	$9.6 \pm 2.8 \pm 0.0$	$r_{g_8,\alpha} = -0.18$
		$\Sigma(1915) \to N\bar{K}$	12 ± 7.2	$3.0 \pm 2.8 \pm 0.3$	χ^2/d.o.f $= 1.9$
$\frac{5}{2}^+$ $8 \to 10 \otimes 8$	$l = 1$	$N(1680) \to \Delta\pi$	13 ± 5	$9.5 \pm 2.6 \pm 0.0$	$g_{10} = 2.8 \pm 0.4 \pm 0.0$
		$\Lambda(1820) \to \Sigma(1385)\pi$	6.0 ± 2.1	$6.8 \pm 1.9 \pm 0.0$	χ^2/d.o.f $= 0.6$
$\frac{1}{2}^-$ $10 \to 8 \otimes 8$	$l = 0$	$\Delta(1620) \to N\pi$	36 ± 7	$37 \pm 7 \pm 0.0$	$g'_8 = 2.5 \pm 0.2 \pm 0.0$
		$\Sigma(1750) \to N\bar{K}$	28 ± 21	$11 \pm 2 \pm 0$	χ^2/d.o.f $= 1.1$
		$\Sigma(1750) \to \Sigma\eta$	39 ± 28	$5.5 \pm 1.1 \pm 3.8$	
$\frac{1}{2}^-$ $10 \to 10 \otimes 8$	$l = 2$	$\Delta(1620) \to \Delta\pi$	64 ± 22	$64 \pm 22 \pm 0$	$g'_{10} = 30 \pm 5 \pm 6$

decay widths. To check this, we have generated uncorrelated Monte Carlo samples for the decaying baryon masses and have repeated the best fits for each set of mass values and calculated, with the new fitted parameters, the corresponding partial decay widths. From the obtained distributions of best fit parameters and predicted partial widths, we have read off the 68% confidence level intervals, which give rise to the second set of errors displayed in Table II. In most cases, systematic errors are much smaller than the statistical ones induced from the errors of the decay widths used in the χ^2 fits. In general, systematic errors are around 10 times smaller than statistical uncertainties.

Next, we consider the Ξ states of the $\frac{5}{2}^\pm$ octets and the $\frac{1}{2}^-$ decuplet, and their SU(3) $8 \otimes 8$ and $10 \otimes 8$ decays. We use the fitted parameters of Table II to compute the partial decay widths, which are shown in Table III. As can be seen, the $\frac{5}{2}^-$ octet assignment for the $\Xi(1950)$ implies a relatively broad resonance ($\Gamma > 100$ MeV) that should be mostly evident in the $\Xi\pi$ invariant mass distribution. This pattern is consistent with most of the observations of the $\Xi(1950)$, which is usually detected in the $\Xi\pi$ channel.

On the contrary, the identification with a $\frac{5}{2}^+$ octet translates into a narrow resonance visible in the $\Lambda\bar{K}$ and $\Sigma\bar{K}$ mass distributions. These features coincide with those of the cascade resonance found in [11], where a relatively narrow cascade ($\Gamma = 25 \pm 15$ MeV) was found at a mass of $M = 1963 \pm 5$ MeV in the $\Lambda\bar{K}^0$ mass distribution (with a statistical significance of 3.6σ). This experimental work was unable to find this cascade signal in the $\Sigma^0\bar{K}^0$ mass distribution, in apparent contradiction with the results of Table III. However, isospin invariance implies that the decay width into the $\Sigma^0\bar{K}^0$ channel is $1/3$ of the complete decay width into $\Sigma\bar{K}$, an observation which led the authors of Ref. [11] to the set up the upper limit

$$\frac{\Gamma(\Xi(1950) \to \Sigma\bar{K})}{\Gamma(\Xi(1950) \to \Lambda\bar{K})} < 2.3, \tag{2}$$

at the 90% confidence level. By using the numbers of Table II, we obtain a branching ratio of $2.2 \pm 0.6 \pm 0.1$ for $M = 1965$ MeV, saturating (but still compatible with) the experimental bound. According to Ref. [11], the spin parity of this resonance should most probably be $\frac{5}{2}^+, \frac{7}{2}^-, \frac{9}{2}^+, \cdots$, in agreement with our assignment.

We should comment that the $\frac{5}{2}^+$ identification for the $\Xi(1963)$ state observed in [11] is not entirely free of ambiguities. Indeed, the GMO mass expectation for the $\frac{5}{2}^+$ cascade, $m_\Xi = 2003 \pm 24$ MeV, looks a bit more compatible with the $\Xi(2030)$ than with the $\Xi(1963)$. The $\Xi(2030)$ was first observed in [26] and definitively confirmed (at the 8σ level) in [27] in the channel $K^- p \to (\Sigma\bar{K})^- K^+$. In this reference a mass $M = 2024 \pm 2$ MeV and a width $\Gamma = 16 \pm 5$ MeV are determined, and apart from the $\Sigma\bar{K}$ channel, the only other visible decay mode was the $\Lambda\bar{K}$. In fact the PDG values, $M = 2025 \pm 5$ MeV

TABLE III. Partial and total decay widths (in MeV) of the $\Xi(1950)$ assuming it belongs to different multiplets. The SU(3) decay parameters are taken from Table II. The meaning of the two error sets given in this table is the same as in Table II. For the mass of the $\Xi(1950)$ we have chosen different values in each multiplet: in the $\frac{5}{2}^+$ octet we have considered the canonical 1950 MeV value together with 1965 MeV (for a better comparison with Ref. [11]) and 2025 MeV [for evaluating the alternative completion of the $\frac{5}{2}^+$ octet with the $\Xi(2030)$]. In the $\frac{1}{2}^-$ decuplet we have also considered the GMO-relation inspired value of the mass $M = 1900$ MeV.

$\Xi(1950)$	M [MeV]	$\to \Xi\pi$	$\to \Lambda\bar{K}$	$\to \Sigma\bar{K}$	$\to \Xi\eta$	$\to \Xi(1535)\pi$	$\to \Sigma(1385)\bar{K}$	$\Gamma_{\rm Total}$
$\frac{5}{2}^-$ octet	1950	$83 \pm 10 \pm 3$	$14 \pm 2 \pm 1$	$19 \pm 3 \pm 1$	<0.5	$19 \pm 2 \pm 1$	$2.1 \pm 0.4 \pm 0.2$	$137 \pm 15 \pm 5$
$\frac{5}{2}^+$ octet	1950	$1.8 \pm 1.7 \pm 0.0$	$8.8 \pm 2.6 \pm 0.3$	$18 \pm 1 \pm 1$	<0.5	$2.1 \pm 0.6 \pm 0.0$	$0.5 \pm 0.1 \pm 0.0$	$31 \pm 6 \pm 1$
	1965	$2.0 \pm 1.9 \pm 0.0$	$10 \pm 3 \pm 0$	$23 \pm 2 \pm 1$	<0.5	$2.3 \pm 0.6 \pm 0.0$	$0.7 \pm 0.2 \pm 0.0$	$38 \pm 7 \pm 1$
	2025	$3.5 \pm 3.3 \pm 0.0$	$19 \pm 6 \pm 1$	$48 \pm 4 \pm 2$	$2.1 \pm 0.2 \pm 0.1$	$3.4 \pm 0.9 \pm 0.0$	$1.6 \pm 0.4 \pm 0.0$	$76 \pm 14 \pm 3$
$\frac{1}{2}^-$ decuplet	1900	$20 \pm 4 \pm 0$	$17 \pm 3 \pm 0$	$15 \pm 3 \pm 0$	$6.8 \pm 1.4 \pm 0.1$	$10 \pm 3 \pm 4$	<0.5	$69 \pm 12 \pm 4$
	1950	$21 \pm 4 \pm 0$	$18 \pm 4 \pm 0$	$17 \pm 3 \pm 0$	$11 \pm 2 \pm 0$	$19 \pm 6 \pm 8$	$8.0 \pm 3.0 \pm 3.3$	$94 \pm 16 \pm 11$

and $\Gamma = 21 \pm 6$ MeV, are mostly based on Ref. [27]. The momentum analysis of Ref. [27] suggested, at the 3σ level, that the spin must be $J \geq (\frac{5}{2})$ for the $\Xi(2030)$. However, the identification of the $\Xi(2030)$ as a member of the $\frac{5}{2}^+$ octet translates into a total decay width much larger than the expected one on the basis of Ref. [27] ($\Gamma_{\rm th} = 76 \pm 14$ MeV from Table III versus $\Gamma_{\rm exp} = 16 \pm 5$ MeV quoted in [27]). The authors of Ref. [27] also determined

$$\frac{\Gamma(\Xi(2030) \to \Lambda\bar{K})}{\Gamma(\Xi(2030) \to \Sigma\bar{K})} = 0.22 \pm 0.09, \tag{3}$$

which may be incompatible with the $\Xi(2030)$ being part of the $\frac{5}{2}^+$ octet, as this identification leads to the ratio 0.4 ± 0.1, a 2σ discrepancy. Thus, we support the identification of the $\Xi(2030)$ as part of a different multiplet, in contrast with [19], where this state is assigned to be the partner of the $\frac{5}{2}^+$ $N(1680)$, $\Lambda(1820)$, $\Sigma(1915)$ resonances.

Finally, the $\frac{1}{2}^-$ decuplet assignment is quite unspecific regarding the decays, see Table III. In general this identification will lead to a broad state that does not have a preferred decay channel. However, if its mass is in the vicinity of 1950 MeV, the $\frac{1}{2}^-$ decuplet state would be the only cascade with a sizable $\Sigma(1385)\bar{K}$ branching ratio above 5%, providing thus a clear signature for an eventual unambiguous identification.

To summarize, we have provided theoretical arguments in favor of the experimental observation [10] that the $\Xi(1950)$ probably consists of several states of similar masses. In particular we have identified the missing cascade members of a $\frac{1}{2}^-$ decuplet and the $\frac{5}{2}^\pm$ octets as possible candidates for explaining different appearances of the $\Xi(1950)$. While the $\frac{1}{2}^-$ decuplet signal would be quite indistinct, the $\frac{5}{2}^-$ octet identification fits into the experimental observations of broad structures in the $\Xi\pi$ invariant mass distribution (e.g. the old Ref. [7] or the more recent work of Ref. [12]), while the $\frac{5}{2}^+$ assignment is compatible with the observation of a narrower state in the $\Lambda\bar{K}$ decay channel and with a mass of about 1965 MeV [11]. We disfavor, however, the identification [19] of the $\Xi(2030)$ as the missing member of the $\frac{5}{2}^+$ octet. We find it worth mentioning that Refs. [21–23] lead to the same multiplet assignments as this work from a different theoretical background, and suggest, in addition, the existence of even more cascades in the 1900–2000 MeV region.

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[1] K. Nakamura *et al.*, J. Phys. G **37**, 075021 (2010).
[2] A. Ramos, E. Oset, and C. Bennhold, Phys. Rev. Lett. **89**, 252001 (2002).
[3] C. Garcia-Recio, M. F. M. Lutz, and J. Nieves, Phys. Lett. B **582**, 49 (2004).
[4] E. E. Kolomeitsev and M. F. M. Lutz, Phys. Lett. B **585**, 243 (2004).
[5] S. Sarkar, E. Oset, and M. J. Vicente Vacas, Nucl. Phys. **A750**, 294 (2005).
[6] D. Gamermann, C. Garcia-Recio, J. Nieves, and L. L. Salcedo, Phys. Rev. D **84**, 056017 (2011).
[7] J. Badier, M. Demoulin, and J. Goldberg, Phys. Lett. **16**, 171 (1965).
[8] J. Alitti *et al.*, Phys. Rev. Lett. **21**, 1119 (1968).
[9] F. A. DiBianca and R. J. Endorf, Nucl. Phys. **B98**, 137 (1975).
[10] E. Briefel *et al.*, Phys. Rev. D **16**, 2706 (1977).
[11] S. F. Biagi *et al.*, Z. Phys. C **34**, 175 (1987).

[12] M. I. Adamovich *et al.*, Eur. Phys. J. C **11**, 271 (1999).
[13] S. F. Biagi *et al.*, Z. Phys. C **9**, 305 (1981).
[14] J. K. Hassall *et al.*, Nucl. Phys. **B189**, 397 (1981).
[15] D. Aston *et al.*, Phys. Rev. D **32**, 2270 (1985).
[16] S. F. Biagi *et al.*, Z. Phys. C **34**, 15 (1987).
[17] M. Gell-Mann, Phys. Rev. **125**, 1067 (1962).
[18] Y. Ne'eman, Nucl. Phys. **26**, 222 (1961).
[19] N. P. Samios, M. Goldberg, and B. T. Meadows, Rev. Mod. Phys. **46**, 49 (1974).
[20] S. Okubo, Prog. Theor. Phys. **27**, 949 (1962).
[21] C. L. Schat, J. L. Goity, and N. N. Scoccola, Phys. Rev. Lett. **88**, 102002 (2002).
[22] J. L. Goity, C. L. Schat, and N. N. Scoccola, Phys. Rev. D **66**, 114014 (2002).
[23] J. L. Goity, C. Schat, and N. N. Scoccola, Phys. Lett. B **564**, 83 (2003).
[24] C. Garcia-Recio, J. Nieves, and L. L. Salcedo, Phys. Rev. D **74**, 034025 (2006).
[25] J. J. de Swart, Rev. Mod. Phys. **35**, 916 (1963).
[26] J. Alitti *et al.*, Phys. Rev. Lett. **22**, 79 (1969).
[27] R. J. Hemingway *et al.*, Phys. Lett. B **68**, 197 (1977).