

Reactions of Ξ production
 KN and γN

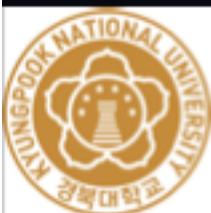
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Collaboration

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2016 JAEA/ASRC Reimei Workshop: New exotic hadron matter at J-PARC
2016. 10. 24 - 10.26, Inha University, Korea

Introduction



- Why Ξ ?
 - A new probe to investigate the strong interactions, in particular, hyperon structure, etc
 - Models for hadron structure have parameters that are determined by the light quark sector and/or $S=-1$ hyperons.
 - Therefore, Ξ hyperons can test various models and may give hints to understand baryon structure.
 - The spectrum of Ξ hyperons is highly model-dependent!



HYPERON SPECTRUM (MODEL DEPENDENCE)

Ground state baryons
are not enough.
We need more data!

Baryon structure and Ξ/Ω spectra

Table 1. Low-lying Ξ and Ω baryon spectrum of spin 1/2 and 3/2 predicted by the non-relativistic quark model of Chao *et al.* (CIK), relativized quark model of Capstick and Isgur (CI), Glozman-Riska model (GR), large N_c analysis, algebraic model (BIL), and QCD sum rules (SR). The recent quark model prediction (QM) and the Skyrme model results (SK) are given as well. The mass is given in the unit of MeV.

State	CIK [4]	CI [5]	GR [6]	Large- N_c [7–11]	BIL [12]	SR [13,14]	QM [15]	SK [1]
$\Xi(\frac{1}{2}^+)$	1325	1305	1320		1334	1320 (1320)	1325	1318
	1695	1840	1798	1825	1727		1891	1932
	1950	2040	1947	1839	1932		2014	
$\Xi(\frac{3}{2}^+)$	1530	1505	1516		1524		1520	1539
	1930	2045	1886	1854	1878		1934	2120
	1965	2065	1947	1859	1979		2020	
$\Xi(\frac{1}{2}^-)$	1785	1755	1758	1780	1869	1550 (1630)	1725	1614
	1890	1810	1849	1922	1932		1811	1660
	1925	1835	1889	1927	2076			
$\Xi(\frac{3}{2}^-)$	1800	1785	1758	1815	1828	1840	1759	1820
	1910	1880	1849	1973	1869		1826	
	1970	1895	1889	1980	1932			
$\Omega(\frac{1}{2}^+)$	2190	2220	2068	2408	2085		2175	2140
	2210	2255	2166		2219		2191	
$\Omega(\frac{3}{2}^+)$	1675	1635	1651		1670		1656	1694
	2065	2165	2020	1922	1998		2170	2282
	2215	2280	2068	2120	2219		2182	
$\Omega(\frac{1}{2}^-)$	2020	1950	1991	2061	1989		1923	1837
$\Omega(\frac{3}{2}^-)$	2020	2000	1991	2100	1989		1953	1978

Exp.

Particle	J^P
$\Xi(1318)$	1/2+
$\Xi(1530)$	3/2+
$\Xi(1620)$	
$\Xi(1690)$	1/2- ?
$\Xi(1820)$	3/2-
$\Xi(1950)$	
$\Xi(2030)$	
$\Xi(2120)$	
$\Xi(2250)$	
$\Xi(2370)$	
$\Xi(2500)$	

 The 3rd lowest state

What Our Ξ Collaboration did:

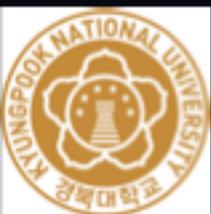
- Theoretical investigation of the reactions for Ξ production
 - $\bar{K}N \rightarrow K\Xi$ (J-PARC)
 - $\gamma N \rightarrow KK\Xi$ (JLab)
 - $\pi N \rightarrow KK\Xi$ (J-PARC)
 - $p\bar{p} \rightarrow \Xi\bar{\Xi}$ (FAIR)
- Build a reliable model to analyze the Ξ spectroscopy data
Start with the ground state $\Xi(1320)$.
- Current status (recent calculations)

- $\bar{K}N \rightarrow K\Xi$: recent calculations:

Sharov, Korotkikh and Lanskoy ([EPJA47, '11](#)),
Shyam, Scholten and Thomas ([PRC84, '11](#)),
Feijoo, Magas and Ramos ([PRC92, '15](#)), U χ PT + high-spin resonances
Kamano, Nakamura, Lee and Sato ([PRC90, '14](#)), DCC approach
they all point to the importance of the S=-1 hyperons

- $\gamma N \rightarrow KK\Xi$: no calculation is available so far, except for:

Liu and Ko ([PRC69, '04](#)), in connection with the Ξ_s production.
Our group ([PRC74, '06; PRC83, '12](#)), analyzing the CLAS data.



$$\bar{K}N \rightarrow K\Sigma$$



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$\bar{K}N \rightarrow K\Xi$ model independent results

- Spin-parity quantum numbers
 - not easy: cf. spin of the Ω^- *BABAR, PRL 97* (2006)
 - parity of $\Xi(1320)$?

Ξ^0

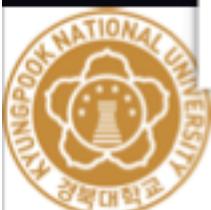
$I(J^P) = \frac{1}{2}(\frac{1}{2}^+)$ Status: ****

The parity has not actually been measured, but + is of course expected.

$\Xi(1530) P_{13}$

$I(J^P) = \frac{1}{2}(\frac{3}{2}^+)$ Status: ****

This is the only Ξ resonance whose properties are all reasonably well known. Assuming that the Λ_c^+ has $J^P = 1/2^+$, AUBERT 08AK, in a study of $\Lambda_c^+ \rightarrow \Xi^-\pi^+K^+$, finds conclusively that the spin of the $\Xi(1530)^0$ is $3/2$. In conjunction with SCHLEIN 63B and BUTTON-SHAFER 66, this proves also that the parity is +.



$\bar{K}N \rightarrow K\Xi$ model independent results

- parity determination

- Difficulty

- Mostly, the decay distribution is used
- Ground state: no strong decay
- Remove model-dependence

- A model-independent method (based on symmetries only)

- Use the anti-kaon beam: larger cross sections
- $\bar{K}(q)N(p) \rightarrow K(q')\Xi(p')$
- define $\hat{\mathbf{n}}_1 \equiv (\mathbf{q} \times \mathbf{q}') \times \mathbf{q} / |(\mathbf{q} \times \mathbf{q}') \times \mathbf{q}|$
 $\hat{\mathbf{n}}_2 \equiv (\mathbf{q} \times \mathbf{q}') / |(\mathbf{q} \times \mathbf{q}')|$
- choose $\hat{\mathbf{q}} = \hat{\mathbf{z}}$, $\hat{\mathbf{n}}_1 = \hat{\mathbf{x}}$, $\hat{\mathbf{n}}_2 = \hat{\mathbf{y}}$

$\hat{\mathbf{q}}$ and $\hat{\mathbf{n}}_1$ form the reaction plane



$\bar{K}N \rightarrow K\Xi$ model independent results

- The general spin-structure of the reaction amplitude

$$\hat{M}^+ = M_0 + M_2 \boldsymbol{\sigma} \cdot \hat{\mathbf{n}}_2, \quad \text{for positive parity } \Xi$$

$$\hat{M}^- = M_1 \boldsymbol{\sigma} \cdot \hat{\mathbf{n}}_1 + M_3 \boldsymbol{\sigma} \cdot \hat{\mathbf{n}}_3, \quad \text{for negative parity } \Xi$$

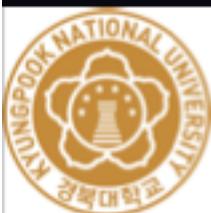
$$\Rightarrow \hat{M} = \sum_{m=0}^3 M_m \sigma_m$$

where $M_1 = M_3 = 0$ for positive parity Ξ

and $M_0 = M_2 = 0$ for negative parity Ξ

- Cross section

$$\frac{d\sigma}{d\Omega} = \frac{1}{2} \operatorname{Tr} (\hat{M} \hat{M}^\dagger) = \sum_{m=0}^3 |M_m|^2$$



Spin-Transfer Coefficient

(Diagonal) spin-transfer coefficient

$$\frac{d\sigma}{d\Omega} K_{ii} = \frac{1}{2} \text{Tr} \left(\hat{M} \sigma_i \hat{M}^\dagger \sigma_i \right) = |M_0|^2 + |M_i|^2 - \sum_{k \neq i} |M_k|^2$$

$$\Rightarrow K_{ii} = \frac{d\sigma_i(++) - d\sigma_i(+-)}{d\sigma_i(++) + d\sigma_i(+-)} \quad d\sigma_i(s_N, s_\Xi)$$

Therefore, when $i=y$, $K_{ii} = \pi_\Xi (= \pm 1)$

Double polarization observable

The Ξ is self-analyzing, so we need polarized nucleon target only
should be possible to measure at J-PARC

Generalization to Ξ^* resonances and to Ξ photoproduction is also
possible

$$\pi_\Xi = \frac{K_{yy}}{\Sigma}$$

Nakayama, YO, Haberzettl, PRC 85 (2012) 042201(R)

Single Spin Asymmetries

Target Nucleon asymmetry

$$\frac{d\sigma}{d\Omega} T_i \equiv \frac{1}{2} \text{Tr} (M \sigma_i M^\dagger) = 2\text{Re}[M_0 M_i^*] + 2\text{Im}[M_j M_k^*]$$

Recoil Cascade asymmetry

$$\frac{d\sigma}{d\Omega} P_i \equiv \frac{1}{2} \text{Tr} (M M^\dagger \sigma_i) = 2\text{Re}[M_0 M_i^*] - 2\text{Im}[M_j M_k^*]$$

Positive parity Cascade

Negative parity Cascade

$$\frac{d\sigma}{d\Omega} (T_y + P_y) = 4\text{Re}[M_0 M_2^*]$$

$$\frac{d\sigma}{d\Omega} (T_y - P_y) = 0$$

$$\frac{d\sigma}{d\Omega} (T_y + P_y) = 0$$

$$\frac{d\sigma}{d\Omega} (T_y - P_y) = 4\text{Im}[M_3 M_1^*]$$

More details for spin-1/2 and 3/2 Ξ baryon production
can be found in [Jackson, YO, Haberzettl, Nakayama, PRC 89 \(2014\) 025206](#)

$$\left. \begin{array}{ll} \Lambda(1116) & \Sigma(1193) \\ \Lambda(1405) & \Sigma(1385) \\ \Lambda(1520) & \end{array} \right\}$$

the model parameters may be fixed from the relevant decay rates(PDG)
and/or quark models and SU(3) symmetry considerations.

Λ states			Σ states				
State	J^P	Γ (MeV)	State	J^P	Γ (MeV)		
Λ(1600)	1/2 ⁺	≈ 150	***	Σ(1660)	1/2 ⁺	≈ 100	***
Λ(1670)	1/2 ⁻	≈ 35	****	Σ(1670)	3/2 ⁻	≈ 60	****
Λ(1690)	3/2 ⁻	≈ 60	****	Σ(1750)	1/2 ⁻	≈ 90	***
Λ(1800)	1/2 ⁻	≈ 300	***	Σ(1775)	5/2 ⁻	≈ 120	****
Λ(1810)	1/2 ⁺	≈ 150	***	Σ(1915)	5/2 ⁺	≈ 120	****
Λ(1820)	5/2 ⁺	≈ 80	****	Σ(1940)	3/2 ⁻	≈ 220	***
Λ(1830)	5/2 ⁻	≈ 95	****	Σ(2030)	7/2 ⁺	≈ 180	****
Λ(1890)	3/2 ⁺	≈ 100	****	Σ(2250)	? [?]	≈ 100	***
Λ(2100)	7/2 ⁻	≈ 200	****				
Λ(2110)	5/2 ⁺	≈ 200	***				
Λ(2350)	9/2 ⁺	≈ 150	***				

no enough information to fix the
parameters of the model.

$$\xleftarrow{\quad} W_{\text{thr}} = 1814 \text{ MeV}$$

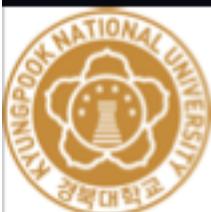
$$\xrightarrow{\quad} \begin{cases} \Sigma_{5/2-}(2250) \rightarrow M = 2270 \pm 50 \text{ MeV} \\ \Sigma_{9/2-}(2250) \rightarrow M = 2210 \pm 30 \text{ MeV} \end{cases}$$

[A. de Bellefon et al., N. Cim. A7(72)]

Strategy: consider all the 3- & 4-star hyperon resonances which affects the fit quality significantly ($\delta\chi^2/N > 0.1$).

$\Lambda_{3/2+}(1890)$ $\Sigma_{5/2-}(2265)$ $\Sigma_{7/2+}(2030)$
 $\Sigma_{3/2+}(1385)$ (g.s. Λ and Σ)

on-shell: $M_{1/2\pm}, M_{5/2\pm} \propto (\varepsilon_N \mp m_N)(\varepsilon_\Xi \mp m_\Xi)$
 $M_{3/2\pm}, M_{7/2\pm} \propto (\varepsilon_N \pm m_N)(\varepsilon_\Xi \pm m_\Xi)$



Interaction Lagrangian

For spin-5/2 hyperons [25, 65],

$$\mathcal{L}_{\Lambda NK}^{5/2(\pm)} = \frac{g_{\Lambda NK}}{m_K^2} \bar{\Lambda}^{\mu\nu} \left\{ D_{\mu\nu}^{5/2(\pm)} \bar{K} \right\} N + H.c. , \quad (\text{A.5a})$$

$$\mathcal{L}_{\Sigma NK}^{5/2(\pm)} = \frac{g_{\Sigma NK}}{m_K^2} \bar{\Sigma}^{\mu\nu} \cdot \left\{ D_{\mu\nu}^{5/2(\pm)} \bar{K} \right\} \tau N + H.c. , \quad (\text{A.5b})$$

$$\mathcal{L}_{\Xi \Lambda K_c}^{5/2(\pm)} = \frac{g_{\Xi \Lambda K_c}}{m_K^2} \bar{\Xi} \left\{ D_{\mu\nu}^{5/2(\pm)} K_c \right\} \Lambda^{\mu\nu} + H.c. , \quad (\text{A.5c})$$

$$\mathcal{L}_{\Xi \Sigma K_c}^{5/2(\pm)} = \frac{g_{\Xi \Sigma K_c}}{m_K^2} \bar{\Xi} \tau \left\{ D_{\mu\nu}^{5/2(\pm)} K_c \right\} \cdot \Sigma^{\mu\nu} + H.c. . \quad (\text{A.5d})$$

For spin-7/2 hyperons [25, 65],

$$\mathcal{L}_{\Lambda NK}^{7/2(\pm)} = \frac{g_{\Lambda NK}}{m_K^3} \bar{\Lambda}^{\mu\nu\rho} \left\{ D_{\mu\nu\rho}^{7/2(\pm)} \bar{K} \right\} N + H.c. , \quad (\text{A.6a})$$

$$\mathcal{L}_{\Sigma NK}^{7/2(\pm)} = \frac{g_{\Sigma NK}}{m_K^3} \bar{\Sigma}^{\mu\nu\rho} \cdot \left\{ D_{\mu\nu\rho}^{7/2(\pm)} \bar{K} \right\} \tau N + H.c. , \quad (\text{A.6b})$$

$$\mathcal{L}_{\Xi \Lambda K_c}^{7/2(\pm)} = \frac{g_{\Xi \Lambda K_c}}{m_K^3} \bar{\Xi} \left\{ D_{\mu\nu\rho}^{7/2(\pm)} K_c \right\} \Lambda^{\mu\nu\rho} + H.c. , \quad (\text{A.6c})$$

$$\mathcal{L}_{\Xi \Sigma K_c}^{7/2(\pm)} = \frac{g_{\Xi \Sigma K_c}}{m_K^3} \bar{\Xi} \tau \left\{ D_{\mu\nu\rho}^{7/2(\pm)} K_c \right\} \cdot \Sigma^{\mu\nu\rho} + H.c. . \quad (\text{A.6d})$$

$$D_{B'BM}^{1/2(\pm)} \equiv -\Gamma^{(\pm)} \left[\pm i\lambda + \frac{1-\lambda}{m_{B'} \pm m_B} \partial \right] ,$$

$$D_{\nu}^{3/2(\pm)} \equiv \Gamma^{(\mp)} \partial_{\nu} ,$$

$$D_{\mu\nu}^{5/2(\pm)} \equiv -i\Gamma^{(\pm)} \partial_{\mu} \partial_{\nu} ,$$

$$D_{\mu\nu\rho}^{7/2(\pm)} \equiv -\Gamma^{(\mp)} \partial_{\mu} \partial_{\nu} \partial_{\rho} ,$$

$$\hat{S}_r^{5/2}(p_r) = \left[(\not{p}_r - m_r) g - i \frac{\Delta}{2} \Gamma_r \right]^{-1} \Delta,$$

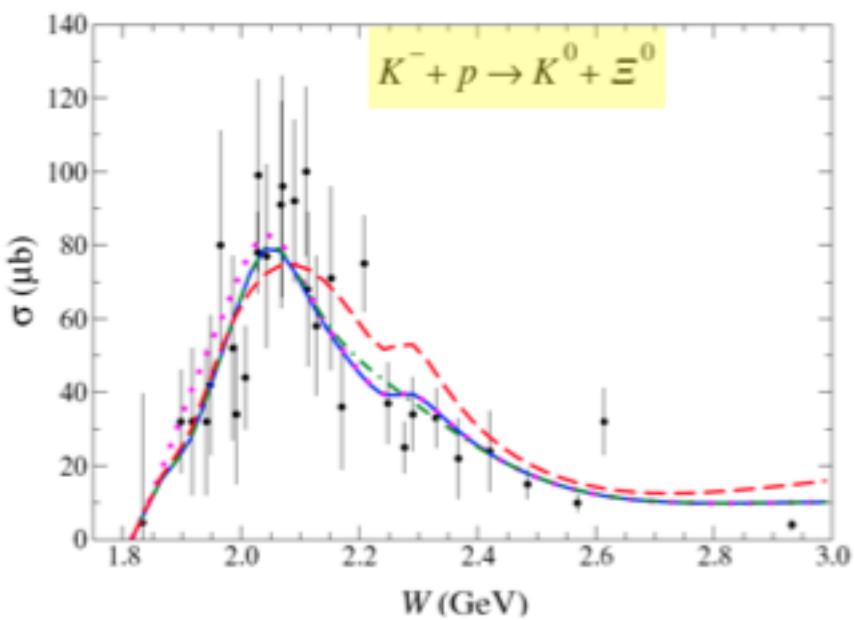
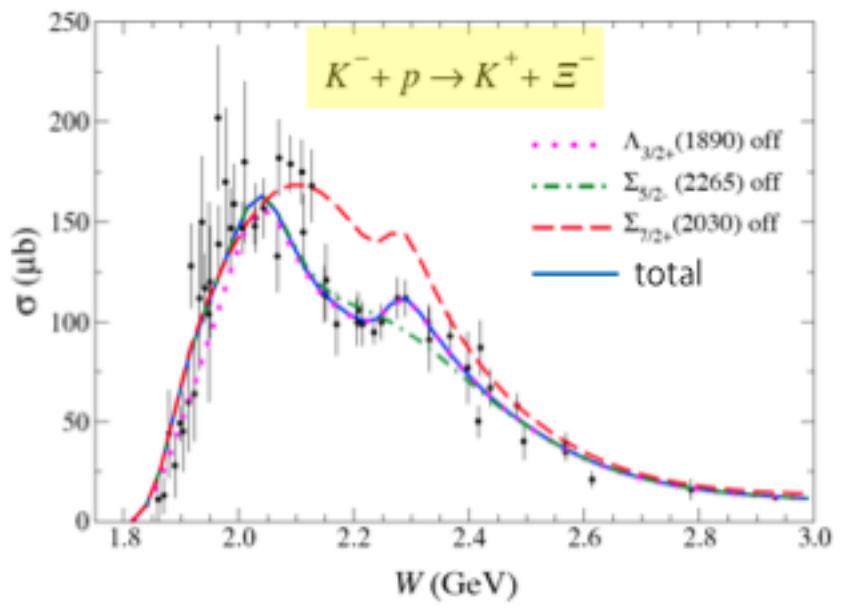
where

$$\begin{aligned} \Delta &\equiv \Delta_{\alpha_1 \alpha_2}^{\beta_1 \beta_2} \\ &= \frac{1}{2} \left(\bar{g}_{\alpha_1}^{\beta_1} \bar{g}_{\alpha_2}^{\beta_2} + \bar{g}_{\alpha_1}^{\beta_2} \bar{g}_{\alpha_2}^{\beta_1} \right) - \frac{1}{5} \bar{g}_{\alpha_1 \alpha_2} \bar{g}^{\beta_1 \beta_2} \\ &\quad - \frac{1}{10} \left(\bar{\gamma}_{\alpha_1} \bar{\gamma}^{\beta_1} \bar{g}_{\alpha_2}^{\beta_2} + \bar{\gamma}_{\alpha_1} \bar{\gamma}^{\beta_2} \bar{g}_{\alpha_2}^{\beta_1} + \bar{\gamma}_{\alpha_2} \bar{\gamma}^{\beta_1} \bar{g}_{\alpha_1}^{\beta_2} \right. \\ &\quad \left. + \bar{\gamma}_{\alpha_2} \bar{\gamma}^{\beta_2} \bar{g}_{\alpha_1}^{\beta_1} \right) \end{aligned}$$

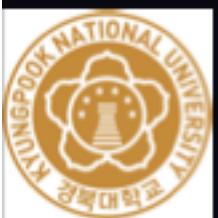
with

$$\bar{g}^{\mu\nu} \equiv g^{\mu\nu} - \frac{p^{\mu} p^{\nu}}{m_r^2}, \quad \bar{\gamma}^{\mu} \equiv \gamma^{\mu} - \frac{p^{\mu} \not{p}}{m_r^2}.$$

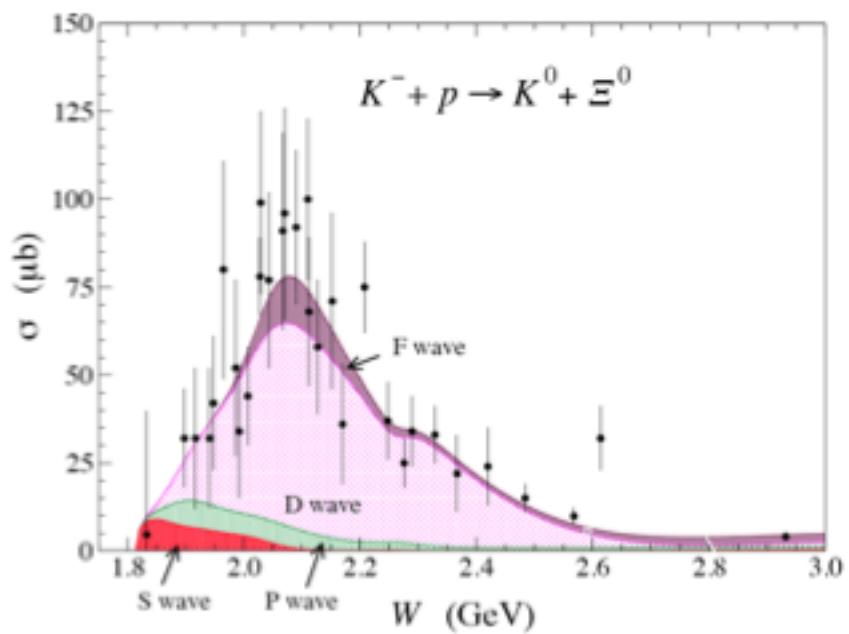
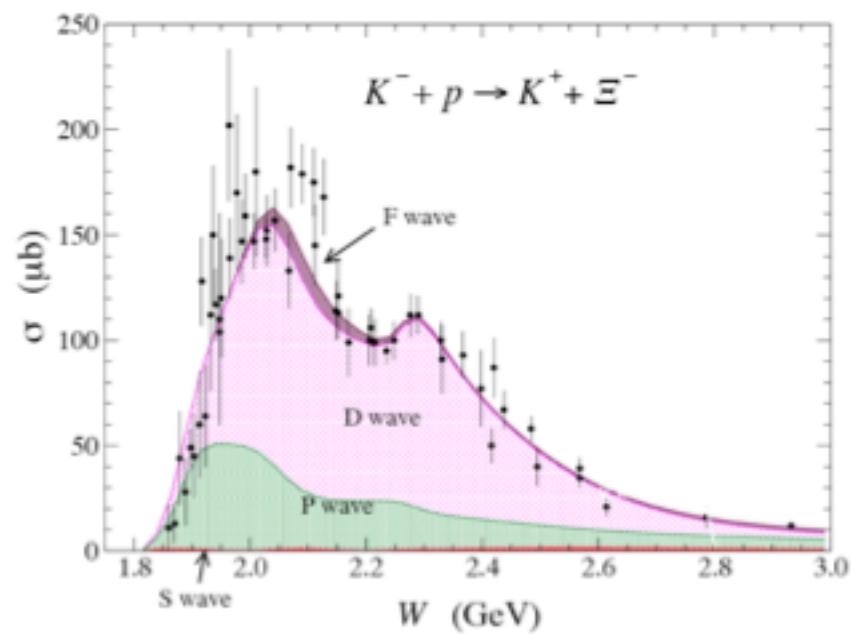




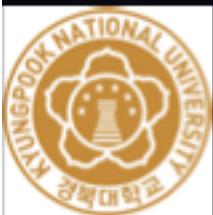
Total cross sections



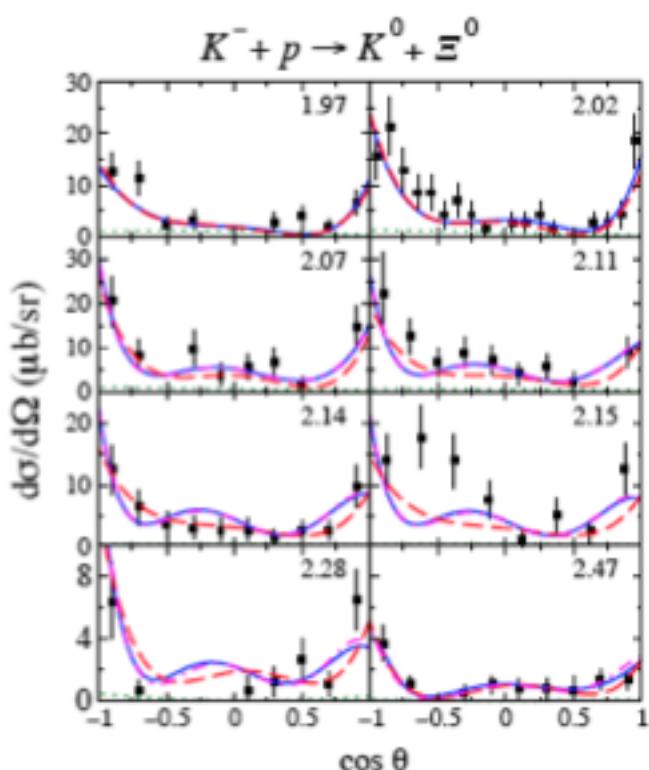
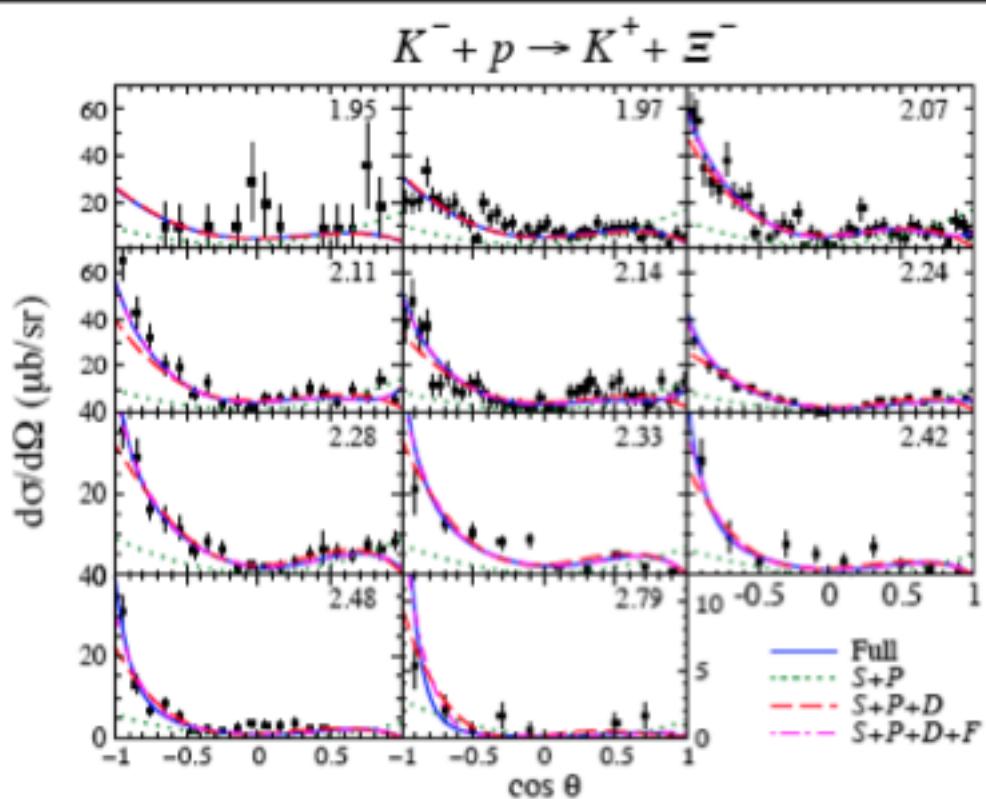
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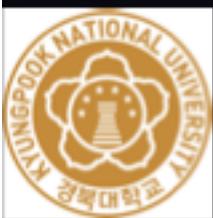
Total cross sections



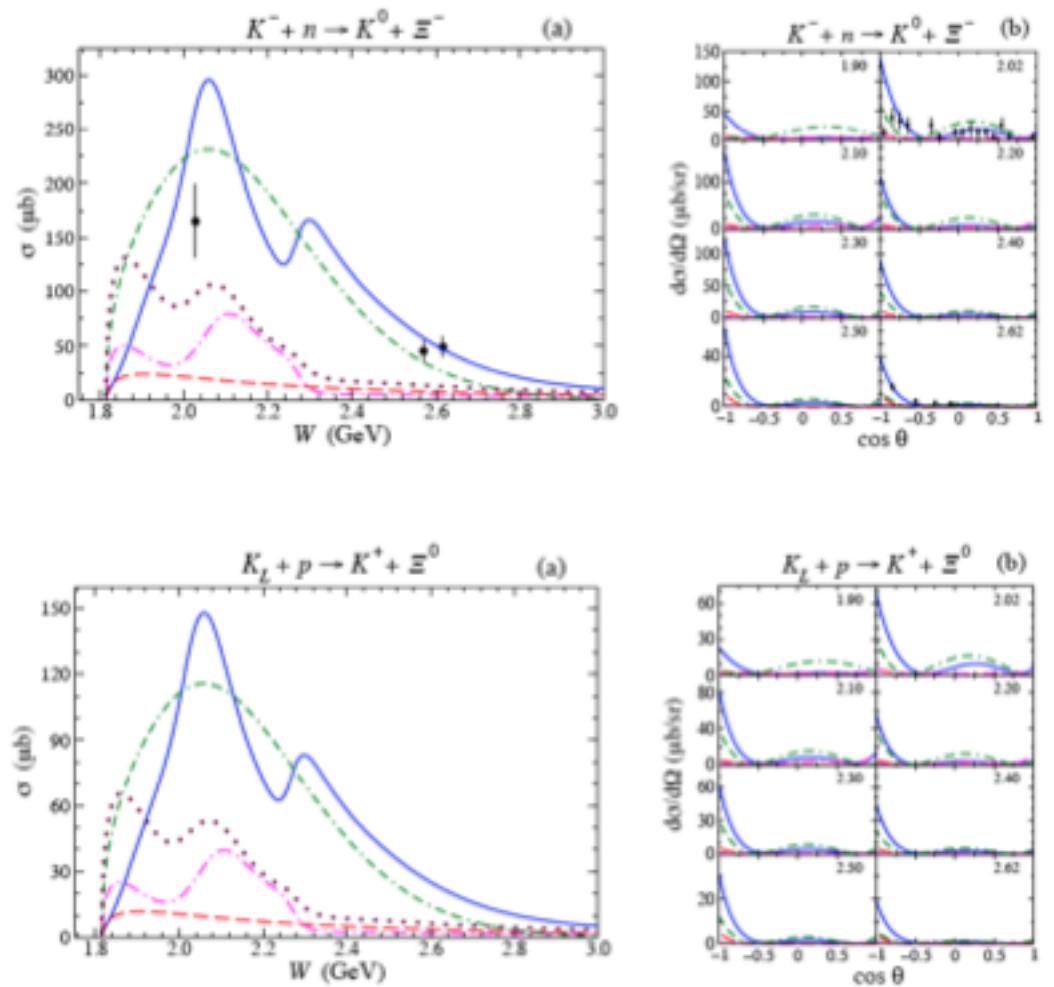
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Differential cross sections



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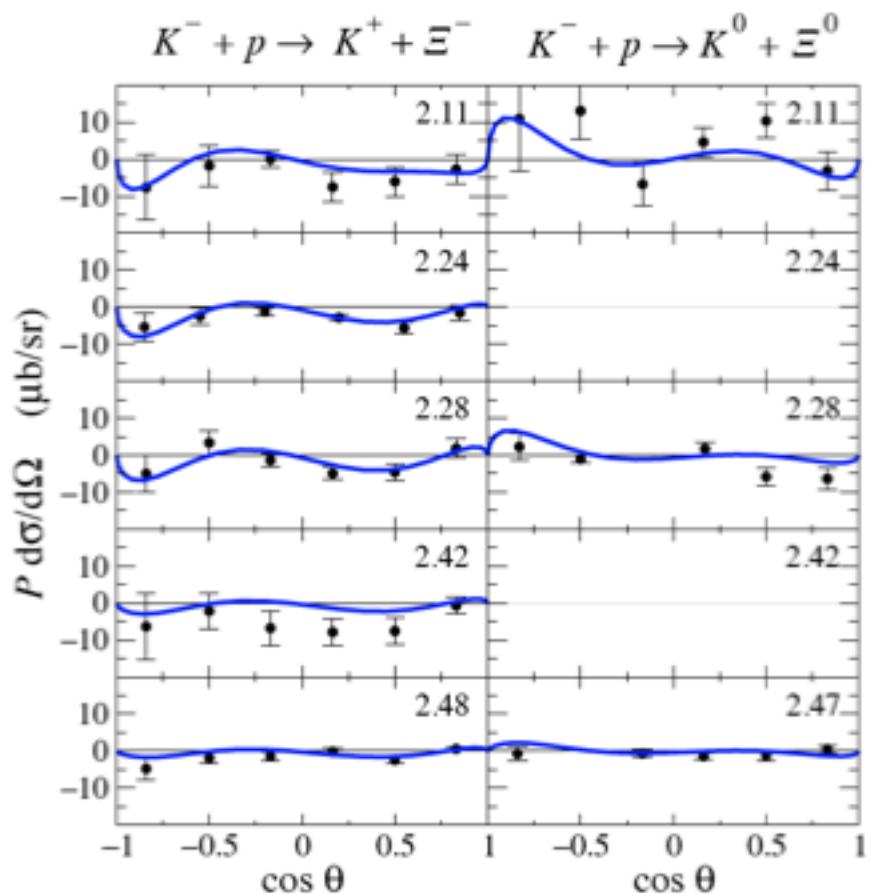


predictions for different channels



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recoil polarization P



recoil asymmetry



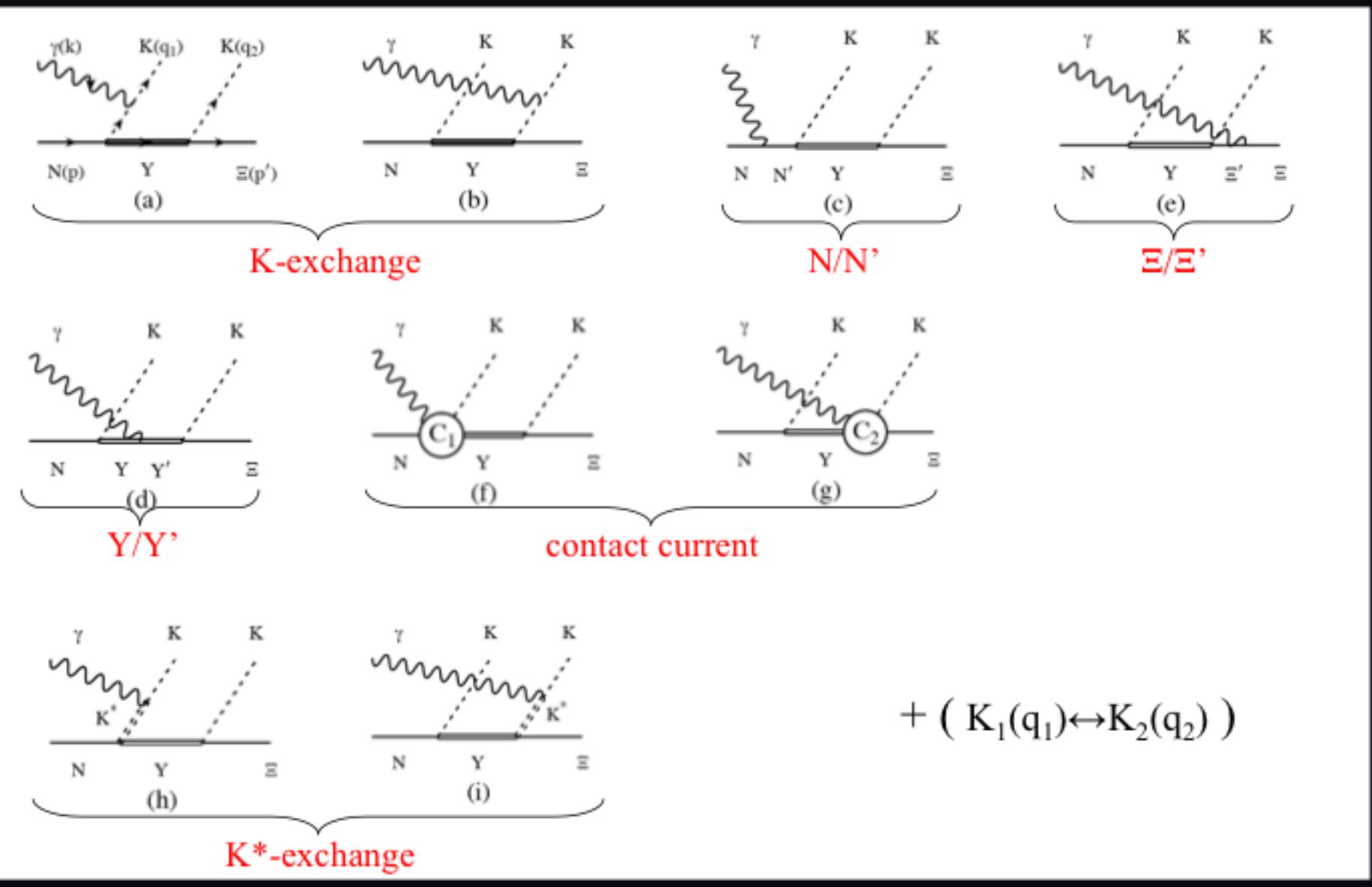
$\gamma N \rightarrow KK\Xi$



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$\gamma N \rightarrow KK\Xi$ a model

Nakayama, YO, Haberzettl, PRC 74 (2006) 035205



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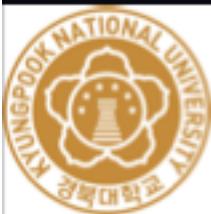
$\gamma N \rightarrow KK\Xi$ a model

Nakayama, YO, Haberzettl, PRC 74 (2006) 035205

Λ states					Σ states				
State	J^P	Γ (MeV)	Rating	$ g_{NAK} $	State	J^P	Γ (MeV)	Rating	$ g_{N\Xi K} $
Λ(1116)	1/2 ⁺		****		Σ(1193)	1/2 ⁺		****	
Λ(1405)	1/2 ⁻	≈ 50	****		Σ(1385)	3/2 ⁺	≈ 37	****	
Λ(1520)	3/2 ⁻	≈ 16	****						
Λ(1600)	1/2 ⁺	≈ 150	***	4.2	Σ(1660)	1/2 ⁺	≈ 100	***	2.5
Λ(1670)	1/2 ⁻	≈ 35	****	0.3	Σ(1670)	3/2 ⁻	≈ 60	****	2.8
Λ(1690)	3/2 ⁻	≈ 60	****	4.0	Σ(1750)	1/2 ⁻	≈ 90	***	0.5
Λ(1800)	1/2 ⁻	≈ 300	***	1.0	Σ(1775)	5/2 ⁻	≈ 120	****	
Λ(1810)	1/2 ⁺	≈ 150	***	2.8	Σ(1915)	5/2 ⁺	≈ 120	****	
Λ(1820)	5/2 ⁺	≈ 80	****		Σ(1940)	3/2 ⁻	≈ 220	***	< 2.8
Λ(1830)	5/2 ⁻	≈ 95	****		Σ(2030)	7/2 ⁺	≈ 180	****	
Λ(1890)	3/2 ⁺	≈ 100	****	0.8	Σ(2250)	? [?]	≈ 100	***	
Λ(2100)	7/2 ⁻	≈ 200	****						
Λ(2110)	5/2 ⁺	≈ 200	***						
Λ(2350)	9/2 ⁺	≈ 150	***						

$$\left|M_{1/2^\pm}\right|^2, \left|M_{5/2^\pm}\right|^2 \propto (E_N \mp M_N)(E_\Xi \mp M_\Xi)$$

$$\left|M_{3/2^\pm}\right|^2, \left|M_{7/2^\pm}\right|^2 \propto (E_N \pm M_N)(E_\Xi \pm M_\Xi)$$



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$\gamma N \rightarrow KK\Xi$ a model

Nakayama, YO, Haberzettl, PRC 74 (2006) 035205

$$\begin{aligned}\Delta_{\alpha_1 \alpha_2}^{\beta_1 \beta_2} \left(\frac{5}{2}\right) &= \frac{1}{2} (\theta_{\alpha_1}^{\beta_1} \theta_{\alpha_2}^{\beta_2} + \theta_{\alpha_1}^{\beta_2} \theta_{\alpha_2}^{\beta_1}) - \frac{1}{5} \theta_{\alpha_1 \alpha_2} \theta^{\beta_1 \beta_2} - \frac{1}{10} (\bar{\gamma}_{\alpha_1} \bar{\gamma}^{\beta_1} \theta_{\alpha_2}^{\beta_2} + \bar{\gamma}_{\alpha_1} \bar{\gamma}^{\beta_2} \theta_{\alpha_2}^{\beta_1} + \bar{\gamma}_{\alpha_2} \bar{\gamma}^{\beta_1} \theta_{\alpha_1}^{\beta_2} + \bar{\gamma}_{\alpha_2} \bar{\gamma}^{\beta_2} \theta_{\alpha_1}^{\beta_1}), \\ \Delta_{\alpha_1 \alpha_2 \alpha_3}^{\beta_1 \beta_2 \beta_3} \left(\frac{7}{2}\right) &= \frac{1}{36} \sum_{P(\alpha), P(\beta)} (\theta_{\alpha_1}^{\beta_1} \theta_{\alpha_2}^{\beta_2} \theta_{\alpha_3}^{\beta_3} - \frac{3}{7} \theta_{\alpha_1}^{\beta_1} \theta_{\alpha_2 \alpha_3}^{\beta_2 \beta_3} - \frac{3}{7} \bar{\gamma}_{\alpha_1} \bar{\gamma}^{\beta_1} \theta_{\alpha_2}^{\beta_2} \theta_{\alpha_3}^{\beta_3} + \frac{3}{35} \bar{\gamma}_{\alpha_1} \bar{\gamma}^{\beta_1} \theta_{\alpha_2 \alpha_3}^{\beta_2 \beta_3}),\end{aligned}\tag{A3}$$

where

$$\theta_\mu^\nu = g_\mu^\nu - \frac{p_\mu p^\nu}{M^2}, \quad \bar{\gamma}_\mu = \gamma_\mu - \frac{p_\mu \not{p}}{M^2}, \tag{A4}$$

with M being the resonance mass. In Eq. (A3), the propagator for the spin-7/2 field contains summation over all possible permutations of $\{\alpha_1, \alpha_2, \alpha_3\}$ and $\{\beta_1, \beta_2, \beta_3\}$.

B. Effective Lagrangian

By considering parity and angular momentum conservation, one can easily confirm that there is only one form factor in the interaction of a hyperon of arbitrary spin with the nucleon-kaon channel or with the Ξ -kaon channel. By introducing

$$\Gamma^{(\pm)} = \begin{pmatrix} \gamma_5 \\ 1 \end{pmatrix}, \tag{A5}$$

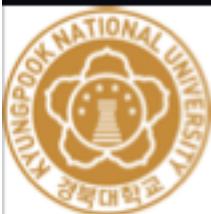
and dropping the isospin dependence, the interaction Lagrangian of spin-5/2 hyperon field $Y_{\mu\nu}$ reads

$$\begin{aligned}\mathcal{L}_{BYK}^{5/2\pm} &= i \frac{g_{BYK}}{m_K^2} \bar{B} \Gamma^{(\pm)} Y^{\mu\nu} \partial_\mu \partial_\nu K + \text{H.c.}, \\ \mathcal{L}_{BYK\gamma}^{5/2\pm} &= - \frac{g_{BYK}}{m_K^2} \hat{e}_K \bar{B} \Gamma^{(\pm)} Y^{\mu\nu} (A_\mu \partial_\nu + \partial_\mu A_\nu) K + \text{H.c.},\end{aligned}\tag{A6}$$

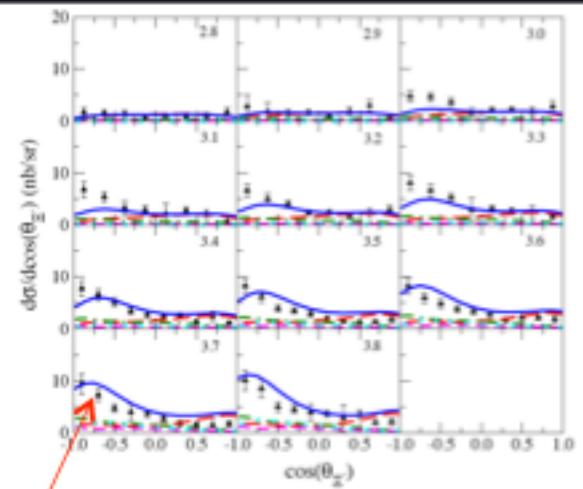
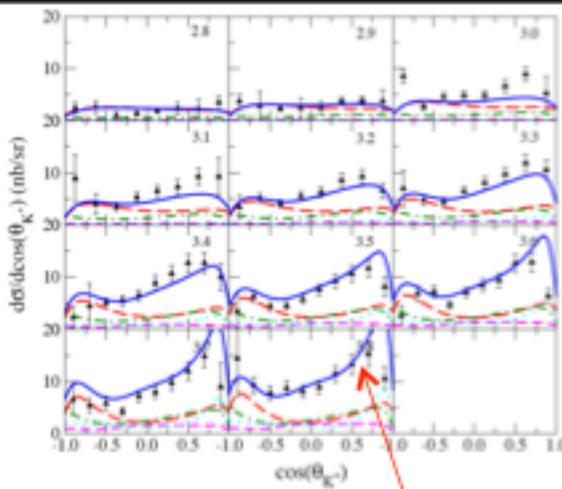
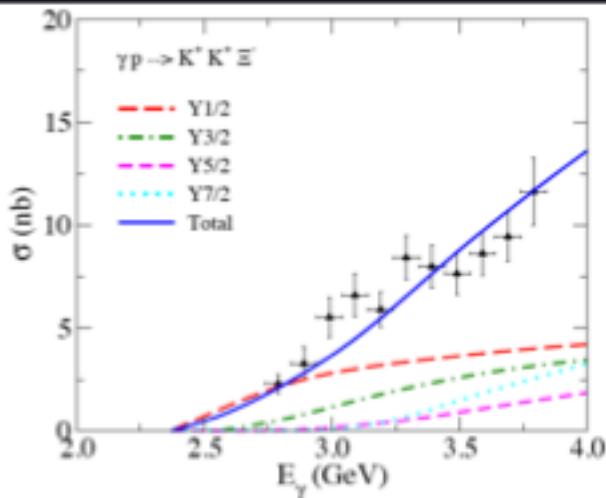
where the latter is obtained from the former by minimal substitution. Here, \hat{e}_K is the charge of the K meson.

The corresponding Lagrangians for a spin-7/2 resonance are given by

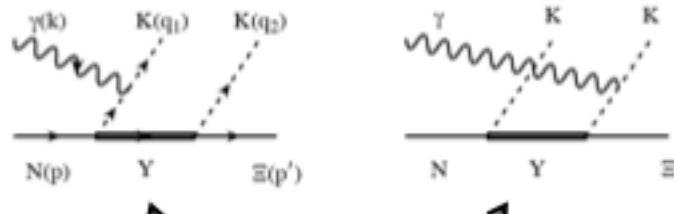
$$\begin{aligned}\mathcal{L}_{BYK}^{7/2\pm} &= - \frac{g_{BYK}}{m_K^3} \bar{B} \Gamma^{(\mp)} Y^{\mu\nu\rho} \partial_\mu \partial_\nu \partial_\rho K + \text{H.c.}, \\ \mathcal{L}_{BYK\gamma}^{7/2\pm} &= i \frac{g_{BYK}}{m_K^3} \bar{B} \Gamma^{(\pm)} Y^{\mu\nu} \hat{e}_K A_{\mu\nu} K + \text{H.c.}\end{aligned}\tag{A7}$$



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Kaon-exchange: responsible for the forward (backward) angle peaking of the K^+ (Ξ^-) distribution



S=-1 resonances needed

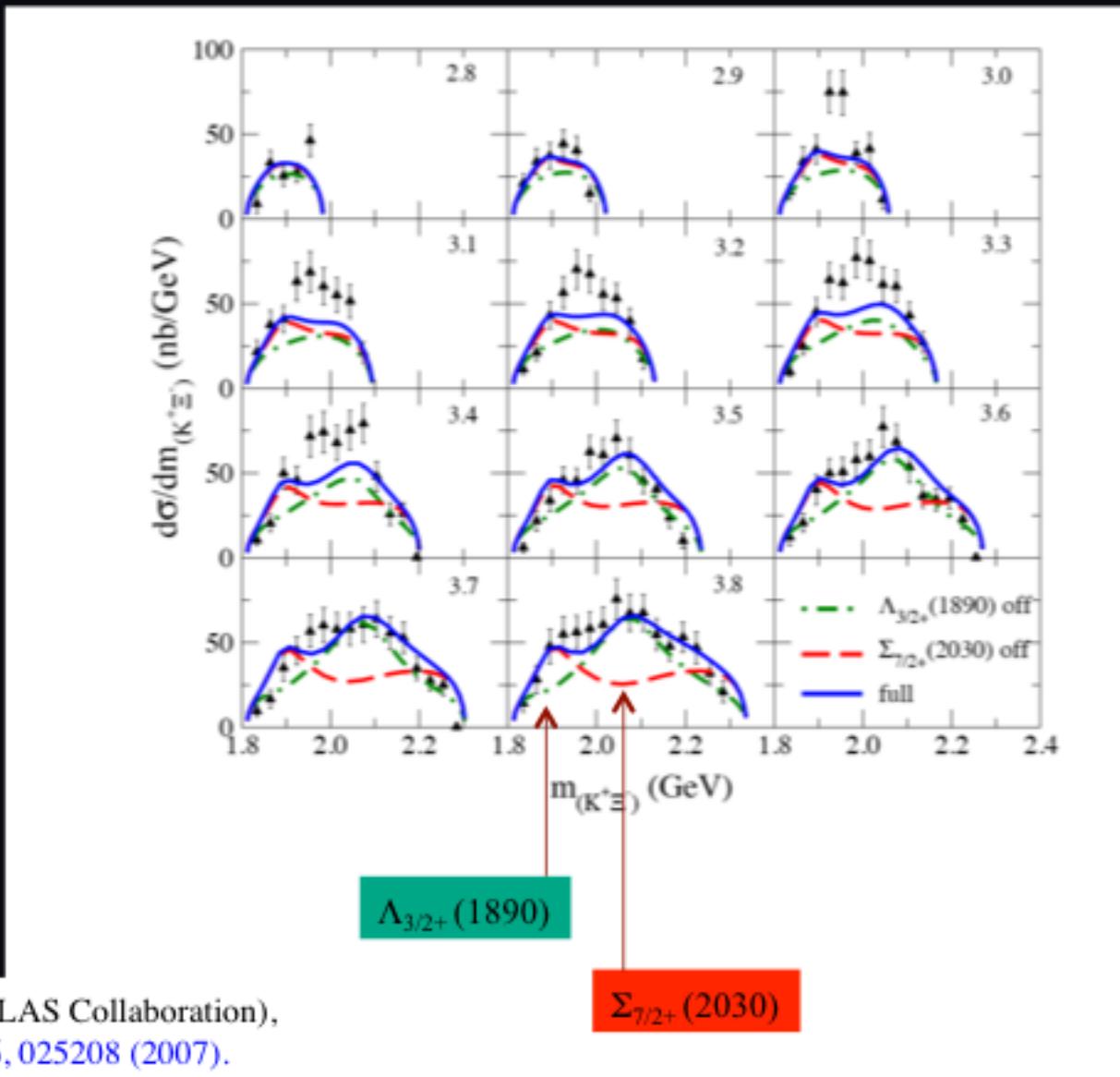
Data: L. Guo *et al.* (CLAS Collaboration),
Phys. Rev. C 76, 025208 (2007).



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$\gamma N \rightarrow KK\Xi$ a model

Man, YO, Nakayama, PRC 83 (2011) 055201



Data: L. Guo *et al.* (CLAS Collaboration),
[Phys. Rev. C 76, 025208 \(2007\)](#).



Summary :

➤ $\bar{K}N \rightarrow K\Xi(1320)$:

- a) overall, existing data are described well.
- b) suited for learning about S=-1 hyperon resonances in the 2 GeV mass region:
 - Hints for the coupling to $\Sigma_{7/2+}(2030)$, $\Sigma_{5/2-}(2265)$, $\Lambda_{3/2+}(1890)$: more accurate data required for a definite confirmation and more complete model.
- c) P-wave dominance even close to threshold in $K^- + p \rightarrow K^+ + \Xi^-$.
total and differential cross section data are consistent with each other.
- d) for further detailed analysis : more accurate data required.

➤ $\gamma p \rightarrow K\bar{K}\Xi(1320)$:

- a) basic features of $\gamma p \rightarrow K^+ K^- \Xi(1318)$ understood:
 - K-exchange currents : essential for describing the $d\sigma/d\Omega$ data.
(above the threshold S=-1 resonances needed)
- b) suited for learning about S=-1 hyperon resonances in the 2 GeV mass region:
 - Hints for the coupling to $\Lambda_{3/2+}(1890)$, $\Sigma_{7/2+}(2030)$: required to describe $m_{K\Xi}$ data.
- c) more data needed, especially, the spin observables:
 - beam-asymmetry : sensitive to the K-exchange currents ($\Sigma = -1$).
 - target-asymmetry : sensitive to the ps-pv mixing in the KNY couplings.

