Strangeness Electro-photo Production

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Electroproduction of strangeness on nucleons

$$e \; + \; N \; \rightarrow \; e' + \; K \; + \; Y$$

6 channels: $N = p, n$; $Y = \Lambda, \Sigma$; $K = K^+, K^0$

One-photon-exchange approximation -- photoproduction by virtual photons

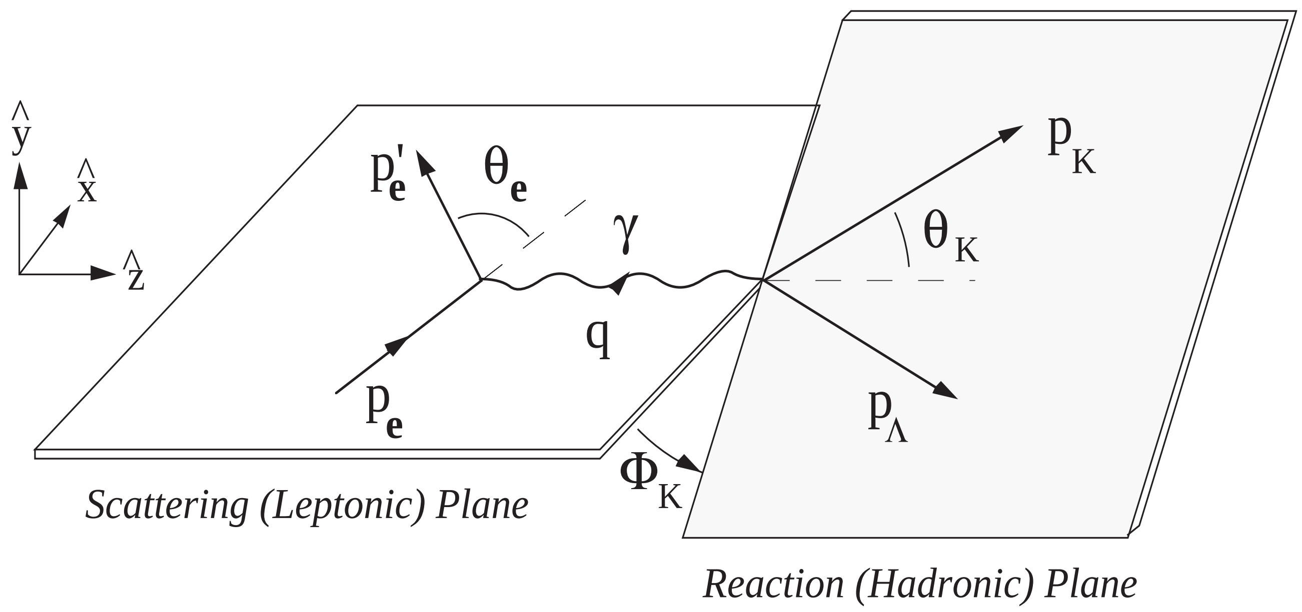
$q^2_\gamma < 0$

Prague, 4 – 6 September, 2010

The unpolarized cross section in laboratory frame

$$\frac{d^3\sigma}{dE'_e\, d\Omega'_e\, d\Omega_K} = \Gamma\left[\frac{d\sigma_T}{d\Omega_K} + \varepsilon\frac{d\sigma_L}{d\Omega_K} + \varepsilon\frac{d\sigma_{TT}}{d\Omega_K}\cos 2\Phi_K + \sqrt{2\varepsilon(\varepsilon+1)}\frac{d\sigma_{TL}}{d\Omega_K}\cos\Phi_K\right]$$

$$\frac{d\sigma}{d\Omega}(q^2, s, t) \qquad s = (q + p_p)^2 \qquad t = (q - p_K)^2$$



New experimental data for the $K^+ \Lambda$ and $K^+ \Sigma^0$ channels

•photoproduction: $d\sigma/d\Omega$, σ^{tot}, P_Y (SAPHIR 2004, CLAS 2006);

$d\sigma/d\Omega$, Σ (LEPS 2006, LEPS 2007 – for $K^+ \Lambda$);

P_Y, Σ (GRAAL 2007)

•electroproduction: σ_T , σ_L, σ_{TT} , σ_{TL} , C_x, C_z, (CLAS 20007)

Photoproduction of $K^0 \Lambda$ and $K^0 \Sigma$ [$d(\gamma,K^0)YN'$]

•inclusive momentum distributions (LNS Tohoku Uni. 2007)

Models for the virtual-photon production

- **Isobar model** (*e.g., Saclay-Lyon, Kaon-MAID, $E_\gamma < 3$ GeV, one-channel approach, effective hadronic Lagrangian, form factors, gauge invariance, SU(3) and crossing symmetry*)
- Multipole analysis (*T. Mart and A. Sulaksono*)
- Regge model (*M. Guidal et al., $E_\gamma > 4$ GeV and small θ_K*)
- **Regge-plus-resonance model** (*T. Corthals et al., resonance and high-energy regions; small θ_K*)
- Unitary approach (*coupled channels, G. Penner, T. Feuster, and U. Mosel; B. Julia-Diaz et al.; A. Usov and O. Scholten*)
- Quark model (*Zhenping Li et al.*)
- Chiral perturbation theory (*S. Steininger and U.-G. Meissner*)
- Chiral unitary framework (*chiral Lagrangian and coupled channels, B. Borasoy et al.*)

Comparison of the isobar models *Saclay-Lyon A* and *Kaon-MAID* for N(γ,K)Λ

The models include the **Born terms** *(N, Λ, Σ^0, K), the t-channel resonances* ***K^*(890), K_1(1270)****, and the s-channel resonance* ***N(1720)***

<u>*Resonances*</u>: **S-L** ***Λ(1407), Λ(1670), Λ(1810), Σ(1660)***
K-M ***N(1650), N(1710), N(1895)*** *– "missing" resonance*

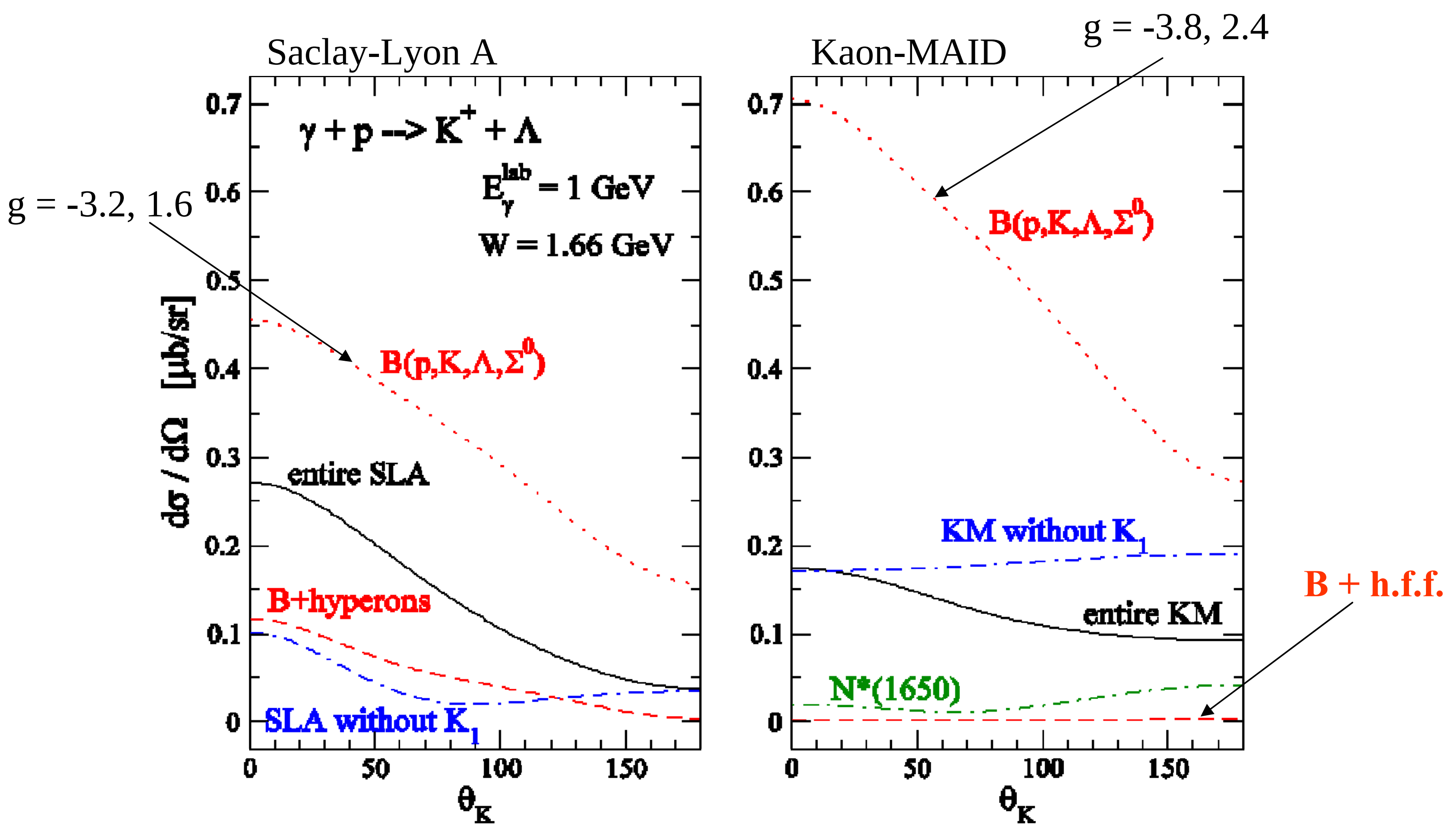
<u>*Hadronic form factors*</u>: **S-L** ***no***
K-M ***yes***

<u>*Symmetries*</u>: **S-L** ***SU(3)*** *for $g_{NK\Lambda}$ and $g_{NK\Sigma}$*, ***crossing*** – p(K^-,γ)Λ
K-M ***SU(3)*** *for $g_{NK\Lambda}$ and $g_{NK\Sigma}$*

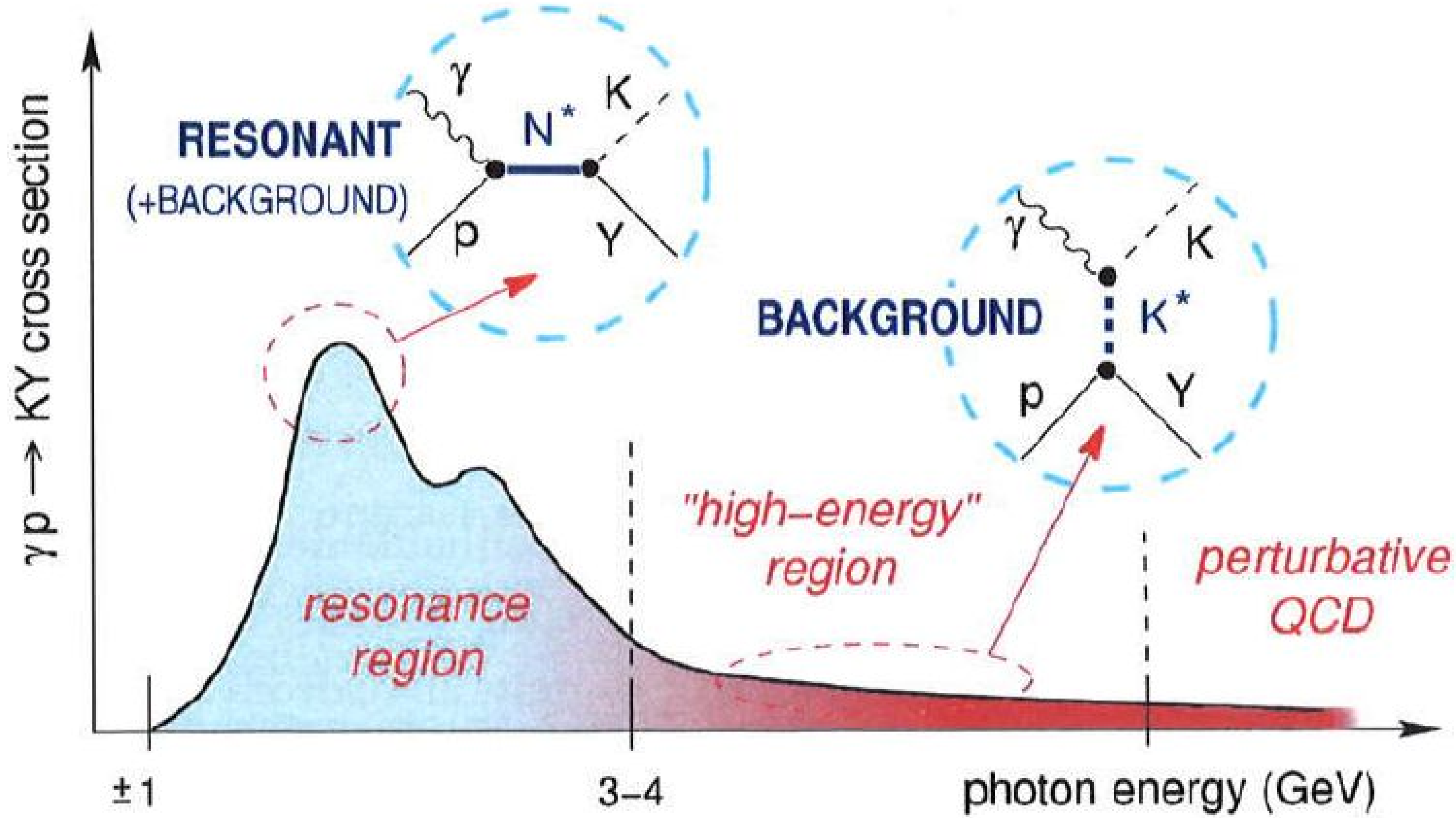
<u>*Coupling constants fitted to data:*</u>

	NKΛ	Σ^0	$K^*_{V/T}$	$K_1^{V/T}$	N(1720)
S-L	-3.2	1.6	-0.04 / 0.2	-0.2 / -0.4	-0.04 / -0.1
K-M	-3.8	2.4	<u>-0.8 / -2.6</u>	<u>3.8 / -2.4</u>	0.05 / 0.6

Different dynamics of the Saclay-Lyon and Kaon-MAID models.
Contributions to the cross sections.



Regge-plus-resonance model – a hybrid Regge – isobar model



Tamara Corthals, PhD. Thesis, Uni. Gent, 2007

Dynamics of the RPR model

<u>*Invariant amplitude*</u>*:* $\mathcal{M} = \mathcal{M}_{\text{background}}$ (*Regge*) + $\mathcal{M}_{\text{resonant}}$ (*isobar*)

$$\mathcal{M}_{\text{background}} \sim P_{Regge}(s,t) = \frac{(s/s_0)^{\alpha(t)}}{\sin \pi\alpha(t)} \frac{\pi\alpha'}{\Gamma(1+\alpha(t))} \begin{Bmatrix} 1 \\ e^{-i\pi\alpha(t)} \end{Bmatrix}$$

where $\alpha(t) = \alpha_0 + \alpha'(t - m^2)$, for the trajectories **K** and **K***

<u>the resonant part</u> - *exchanges of s-channel resonances: N(1650), N(1710), N(1720) and two "missing" resonances N(1900), P_{13} and D_{13}*

$$\mathcal{M}_{\text{resonant}} \sim P_{Feyn}(s) = \frac{1}{s - m^2 + i\, m\Gamma}$$

- strong form factors – a smooth transition into the high-energy region

$$F(s) = \exp\left\{ -\frac{(s-m^2)^2}{\Lambda^4} \right\}$$

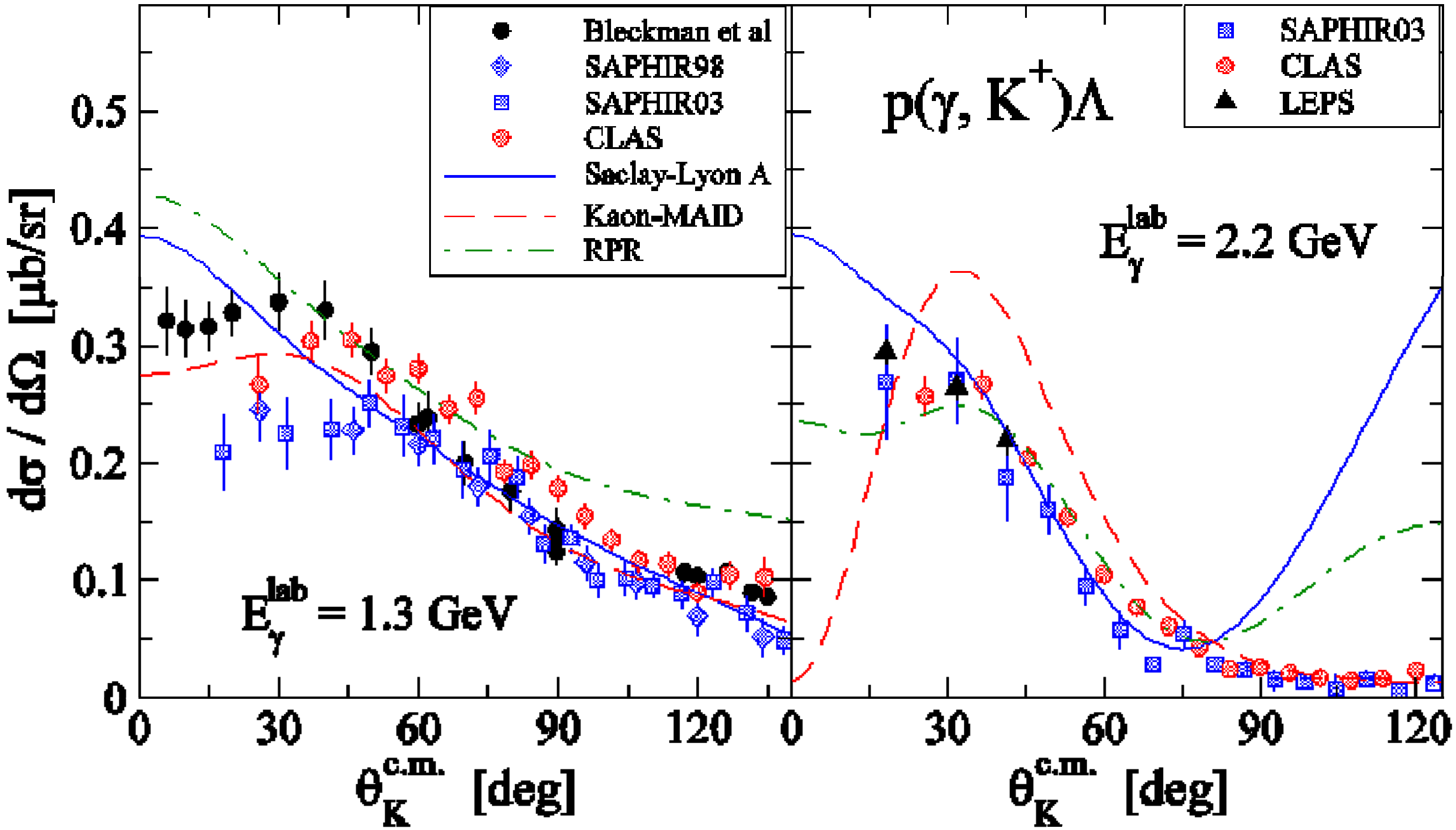
Advantages of the RPR model:

- large energy region described: from the threshold up to 20 GeV (*for small t*);
- the background part is described with a smaller number of parameters than in the isobar models;
- the background parameters are fixed by high-energy data (E > 5 GeV);
- no problem with the unreasonably large contribution of the Born terms to the background part as in the isobar models;
- no strong form factors for the background part;

Problems:

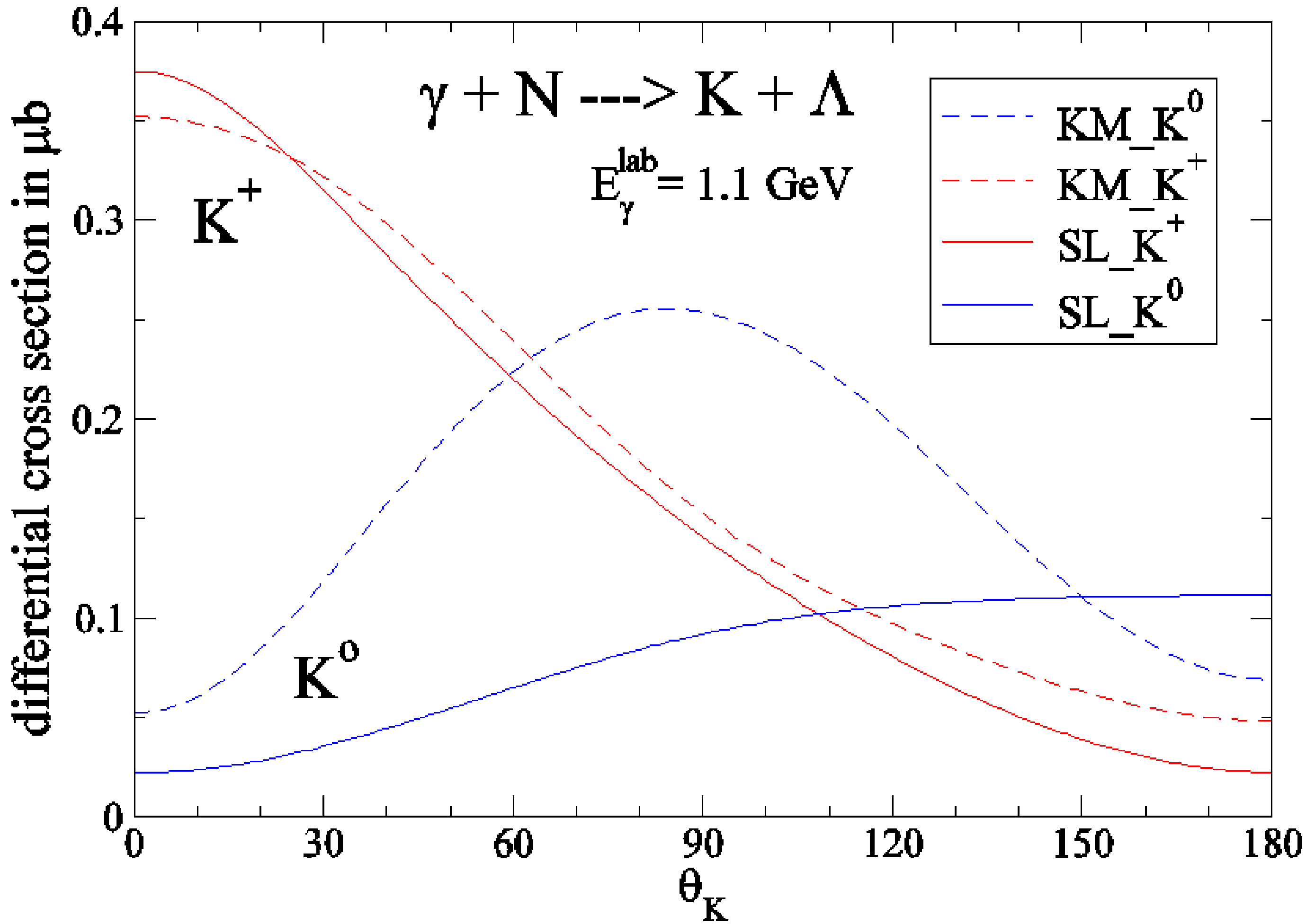
- double counting (*duality hypothesis*) in the resonance region – *the number of included resonances is small;*
- uncertainty due to rotating/constant trajectories – *careful analysis of new data* (*L .De Cruz et al*);

Comparison of model predictions. The cross sections for the photoproduction of K^+ on proton

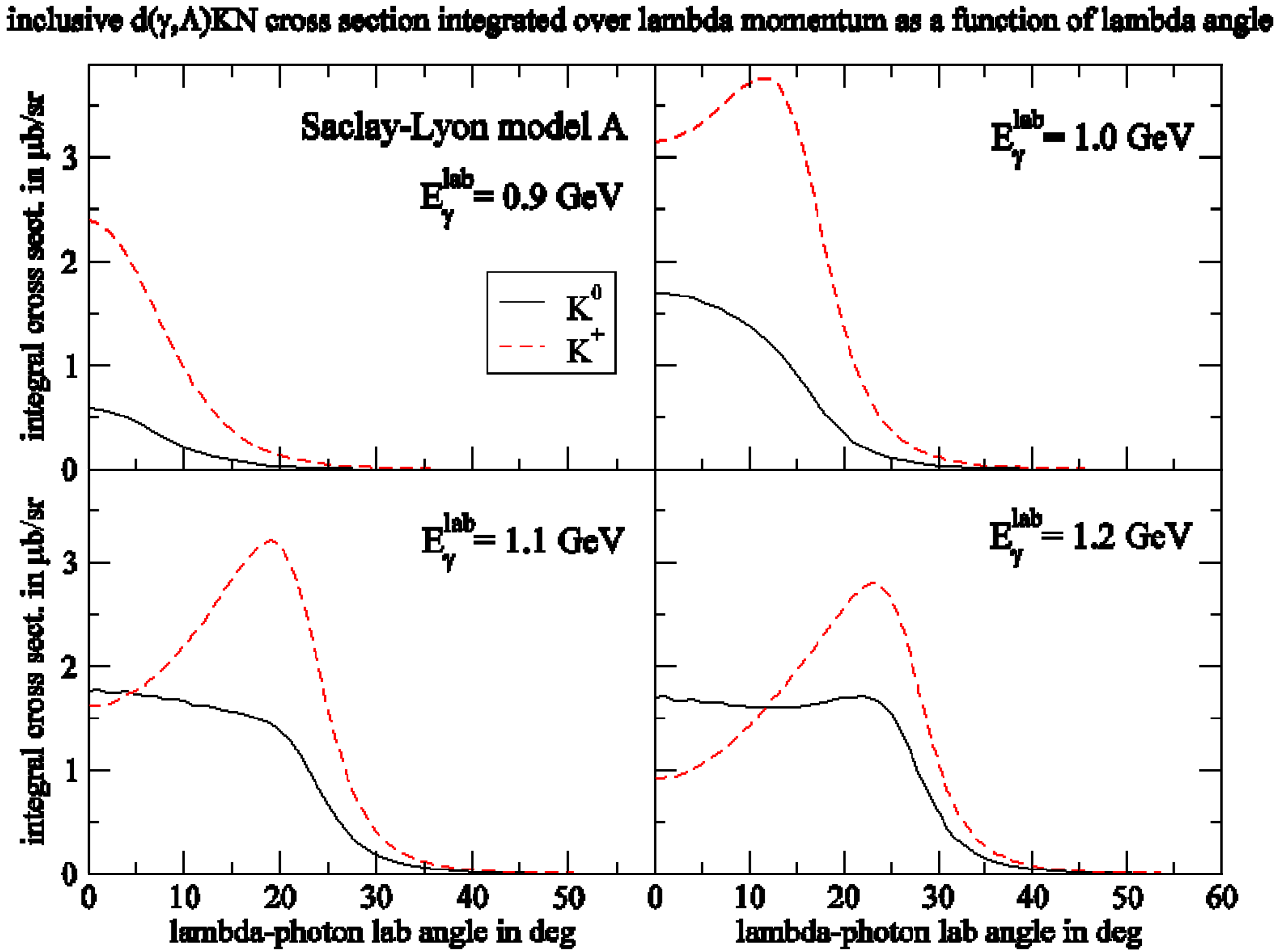


Selection of models using the $K^0\ \Lambda$ channel

Relation of the K^+ and K^0 amplitudes: *SU(2) symmetry* for the strong coupling constants, *helicity amplitudes* and *decay widths* for the electromagnetic coupling constants – the only free parameter is $r_{KK1} = g_{KK1\gamma}{}^0 / g_{KK1\gamma}{}^+$

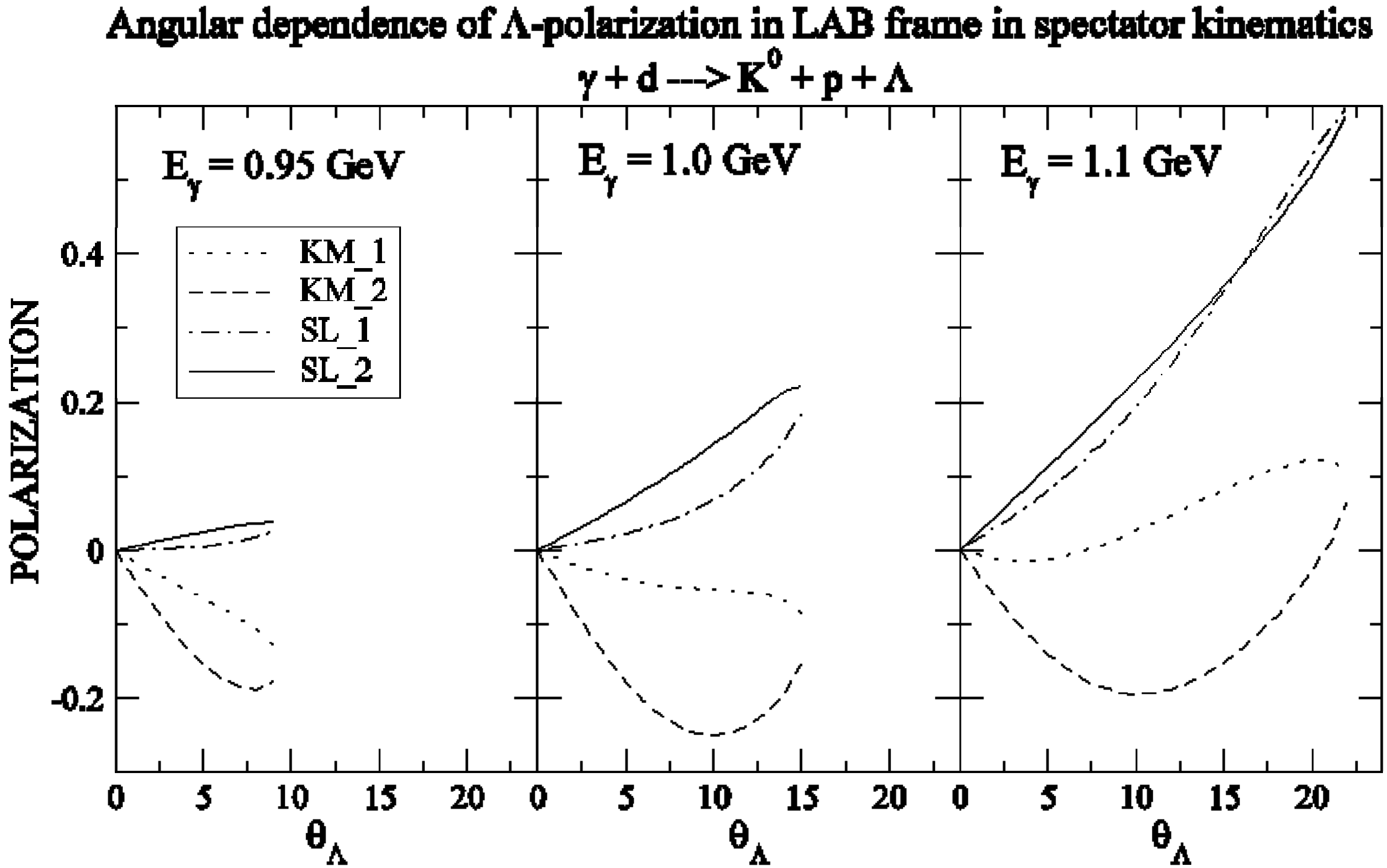


	r_{KK1}
KM	-0.45
SLA	-2.09



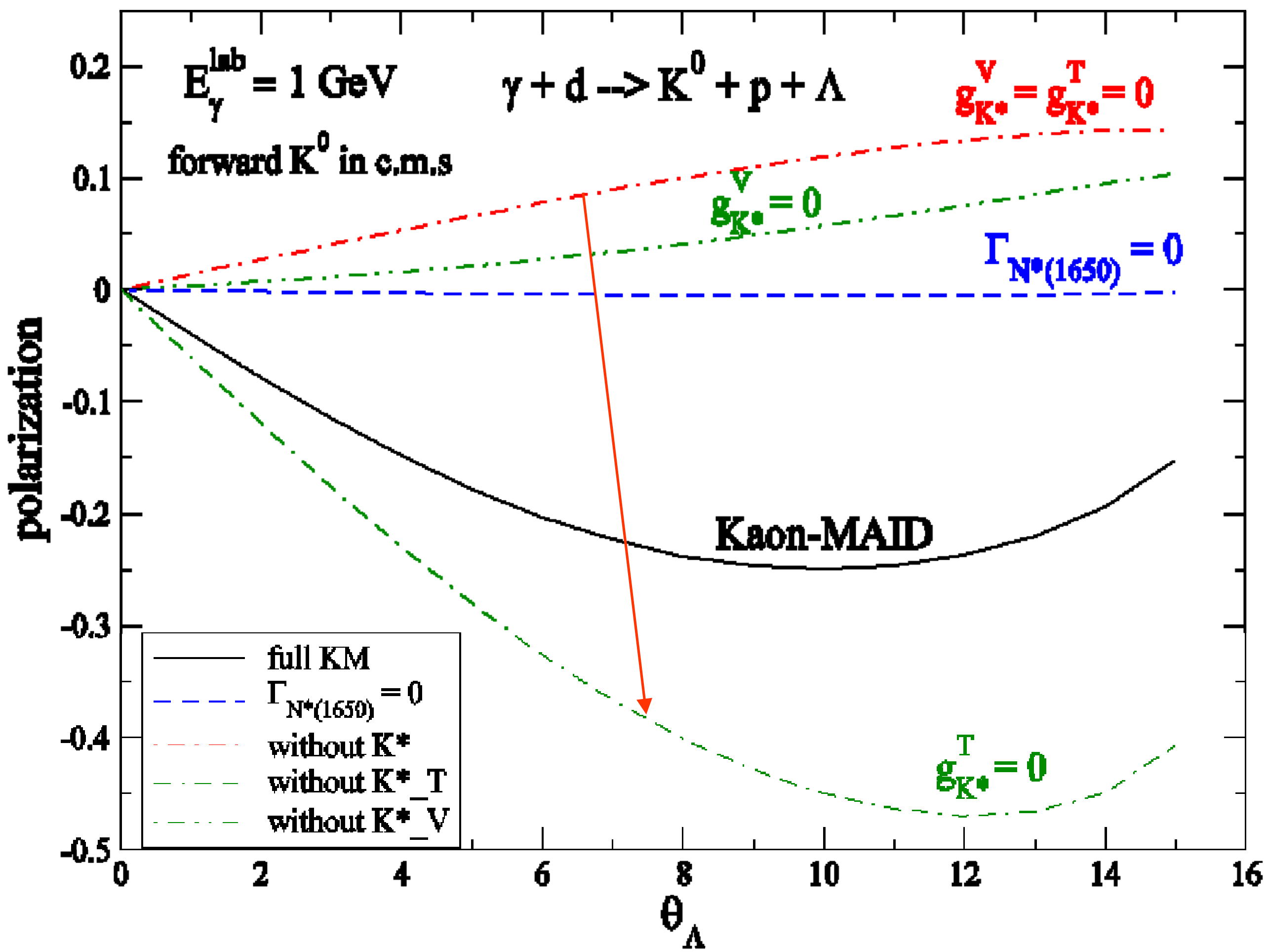
inclusive d(γ,Λ)KN cross section integrated over lambda momentum as a function of lambda angle
Saclay-Lyon model A
E_γ^{lab}= 0.9 GeV
E_γ^{lab}= 1.0 GeV
E_γ^{lab}= 1.1 GeV
E_γ^{lab}= 1.2 GeV
K^0
K^+
integral cross sect. in μb/sr
lambda-photon lab angle in deg
0
1
2
3
10
20
30
40
50
60

$p_p = 0$


Angular dependence of Λ-polarization in LAB frame in spectator kinematics
γ + d ---> K⁰ + p + Λ
E_γ = 0.95 GeV
E_γ = 1.0 GeV
E_γ = 1.1 GeV
KM_1
KM_2
SL_1
SL_2
POLARIZATION
0.4
0.2
0
-0.2
0
5
10
15
20
θ_Λ

Contributions to the polarization of Λ – model Kaon-MAID

spectator kinematics ($p_p = 0$), K^0 moves forwards in c.m.s. (the smaller value of p_Λ)



$P \sim \mathrm{Im} \sum a_{ij} \, A^*_i \, A_j$

$P \sim \sum a_{ij} \left[\mathrm{Re}A_i \, \mathrm{Im}A_j - \mathrm{Im}A_i \, \mathrm{Re}A_j \right]$

- exchanges of resonances

  $A_i \sim (s - m^2 + i\, m\, \Gamma)^{-1}$

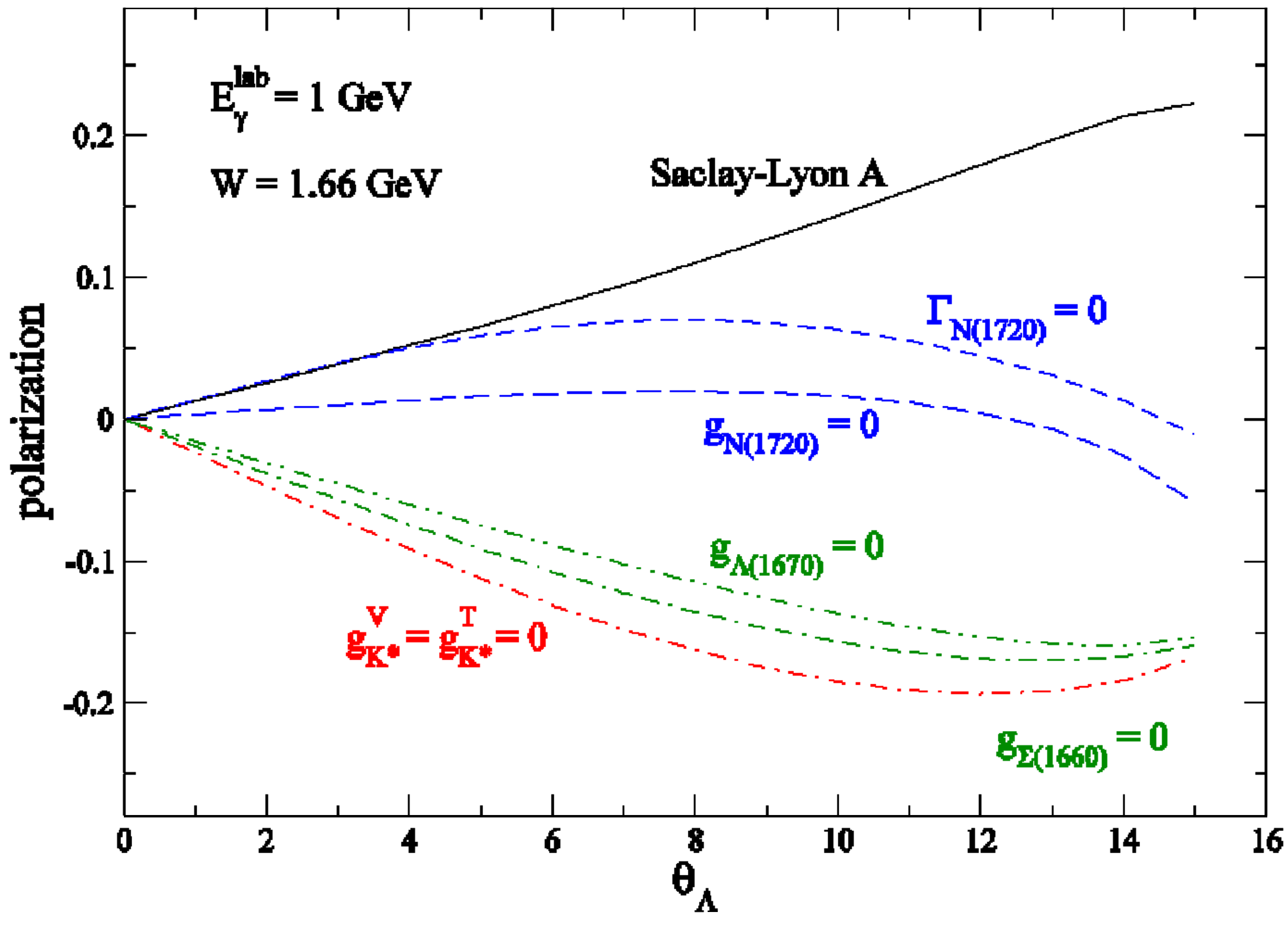
- dominant contribution to $\mathrm{Im}A_i$ at W=1.66 GeV is from N(1650)

  $\sim m\Gamma/[(s-m^2)^2 + m^2\Gamma^2]$

  $s = W^2$

Contributions to the polarization of Λ – model Saclay-Lyon A

K^0 moves forwards in c.m.s. => the smaller value of Λ momentum



Summary

• the dynamical content of the isobar models is different => any analysis is model-dependent

• K^0 channels provide another strict test of the isobar models

• Isobar models should be compared with the quark model – importance of assumed resonances, coupling constants, strong form factors

• Regge-plus-resonance model appears to be suitable for hypernuclear calculations