Theoretical aspects of strangeness electro-photo production

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Electromagnetic associated production of strangeness on nucleons

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

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

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

Rome, 15 – 16 December, 2009

The unpolarized cross section in laboratory frame

$$\frac{d^3\sigma}{dE_e^{'} d\Omega_e^{'} d\Omega_K} = \mathbf{\Gamma}\left[\frac{d\sigma_T}{d\Omega_K} + \varepsilon\frac{d\sigma_L}{d\Omega_K} + \varepsilon\frac{d\sigma_{TT}}{d\Omega_K}\cos 2\phi + \sqrt{2\varepsilon(\varepsilon+1)}\frac{d\sigma_{TL}}{d\Omega_K}\cos\phi\right]$$

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 – only 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)

Description of the virtual-photon production

- **Isobaric 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., 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.*).

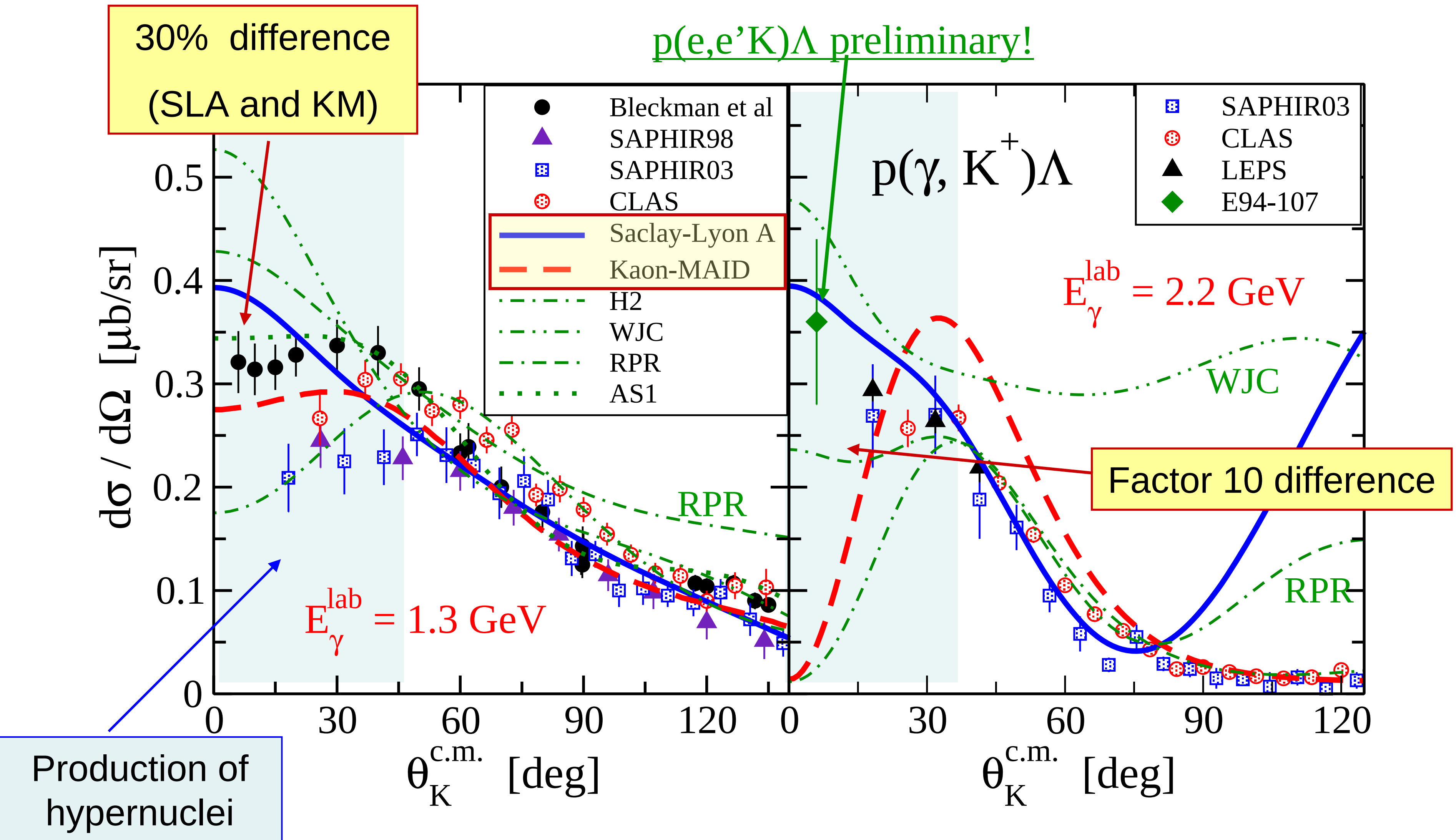
Examples of ISOBARIC MODELS

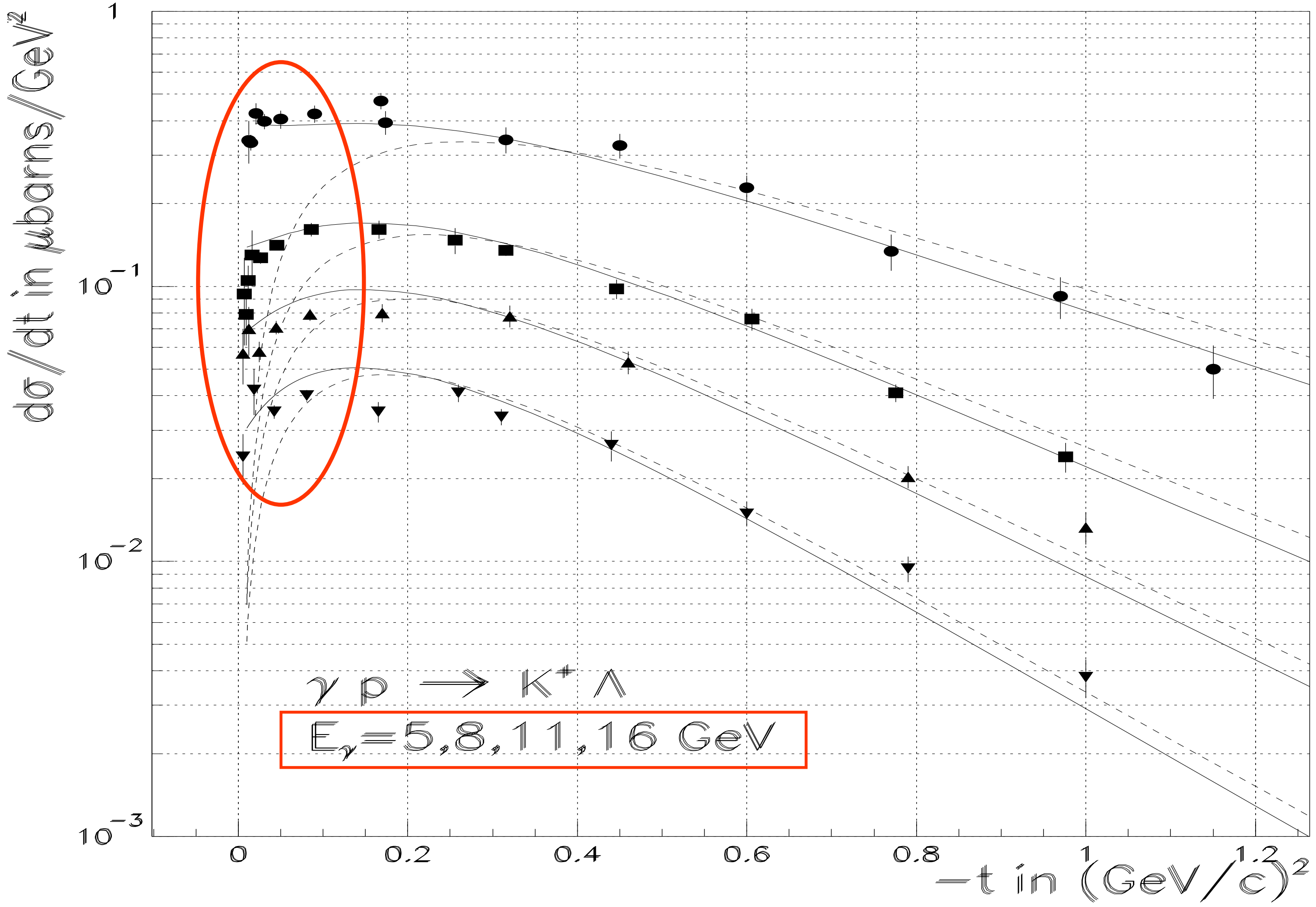
The models include: extended Born terms (p, Λ, Σ, K)

t-channel resonances $K^*(890)$, $K_1(1270)$

- *Saclay-Lyon A:* no hadronic f. f., SU(3), crossing, one nucleon (spin 3/2) and four hyperon resonances, *fits to OLD data;*
- *Kaon-MAID:* hadronic f. f., SU(3), four nucleon (spin up to 3/2) resonances ("missing" resonance), *fits to OLD data;*
- *H2:* hadronic f. f., SU(3), four nucleon (spin up to 3/2) and two hyperon resonances, *fits to the preliminary (2003) CLAS data;*
- *Janssen et al: like H2 but* off-mass-shell effects for spin 3/2 resonances;
- *Adelseck-Saghai:* no hadronic f. f., SU(3), one nucleon and one hyperon resonances;
- *Williams-Ji-Cotanch:* no hadronic f. f., no SU(3), duality, two nucleon resonances.

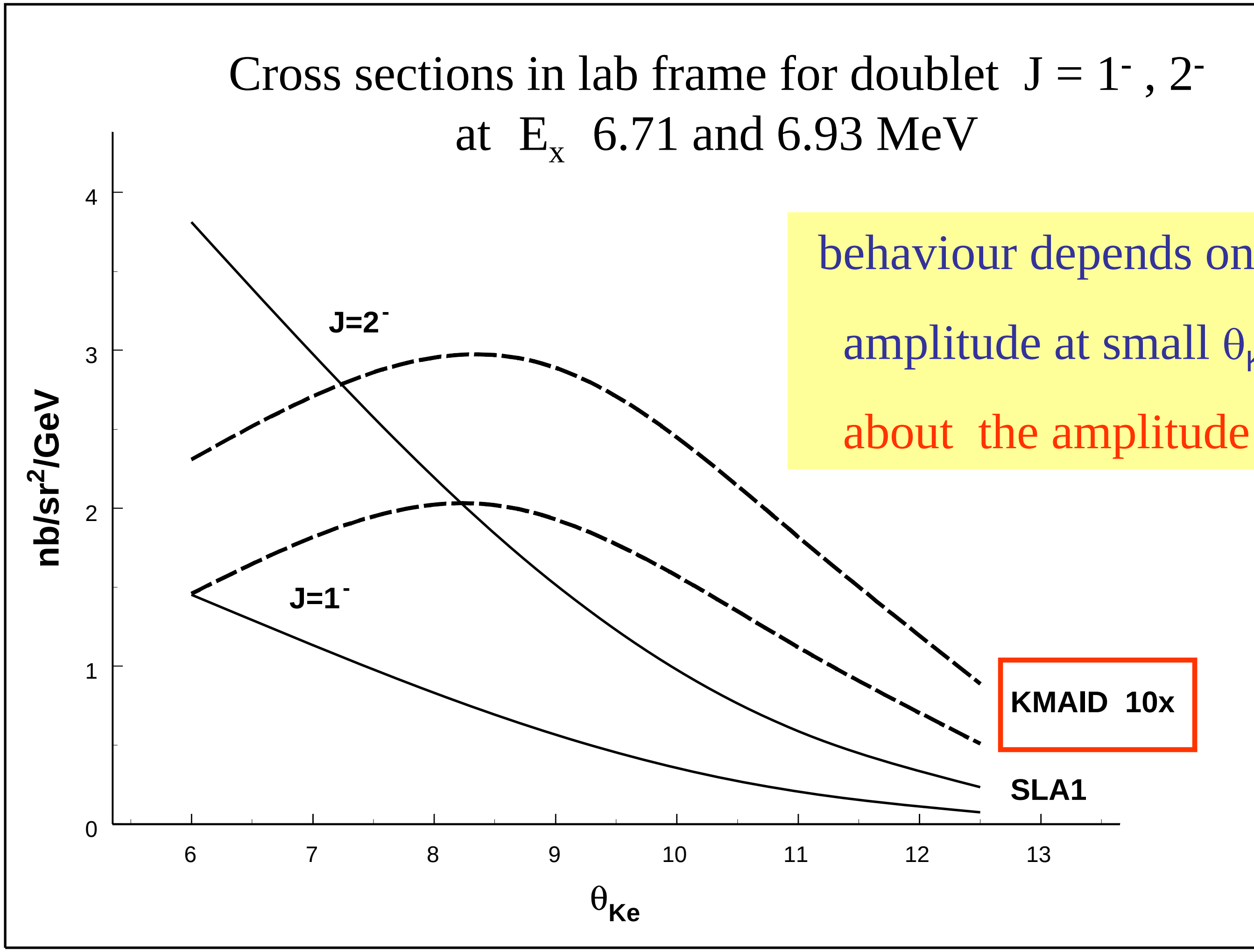
I. Photoproduction at small kaon angles – *important ingredient in calculations of the cross sections for the production of hypernuclei*





M. Guidal et al , Nucl. Phys. A 627 (1997) 645.

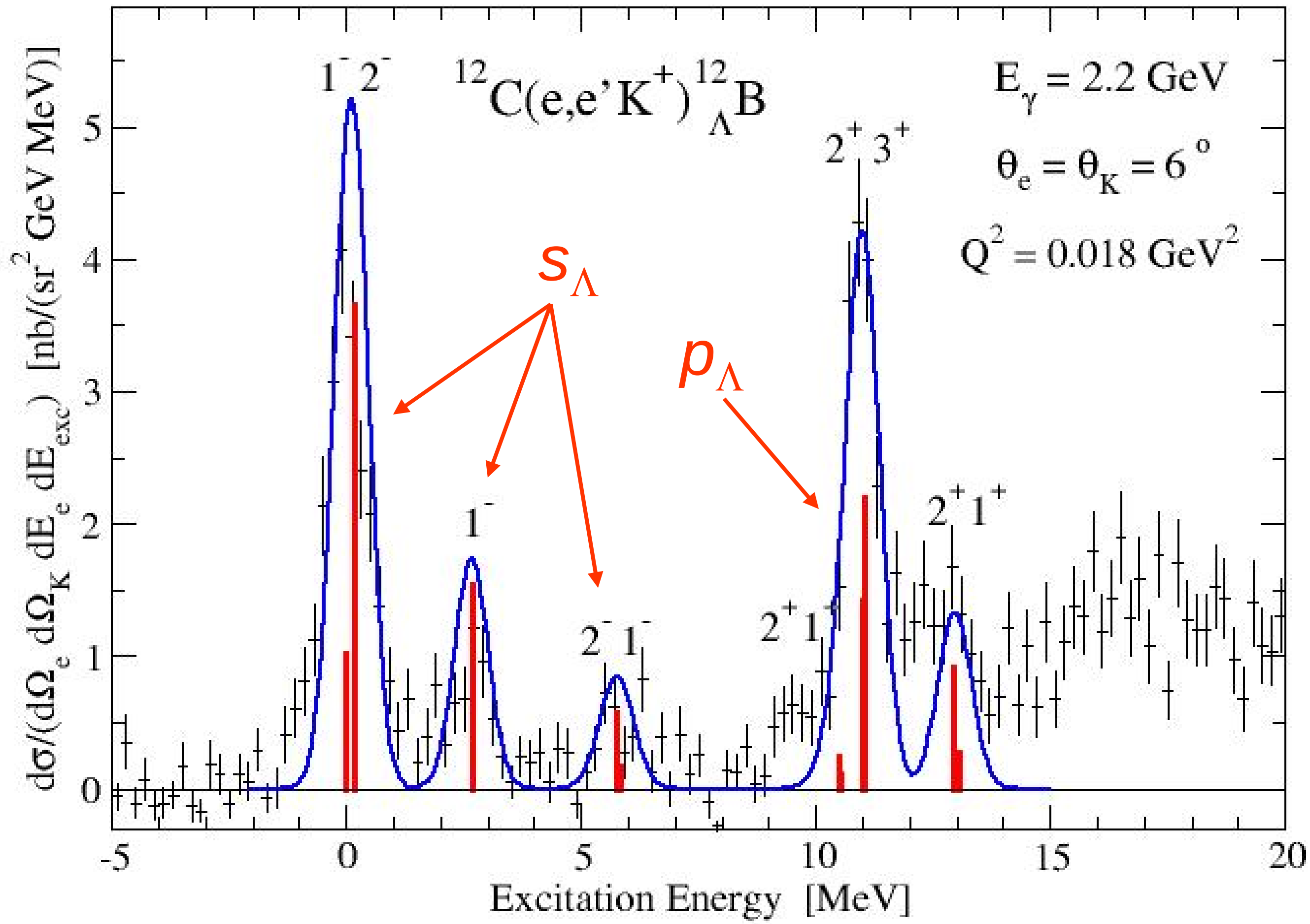
Angular dependence of the cross section for electroproduction of $^{16}N_\Lambda$ at $E_\gamma = 2.21$ GeV and $\theta_e = 6^o$, DWIA calculations with SLA and KM



behaviour depends on the elementary amplitude at small θ_K – information about the amplitude at small angles.

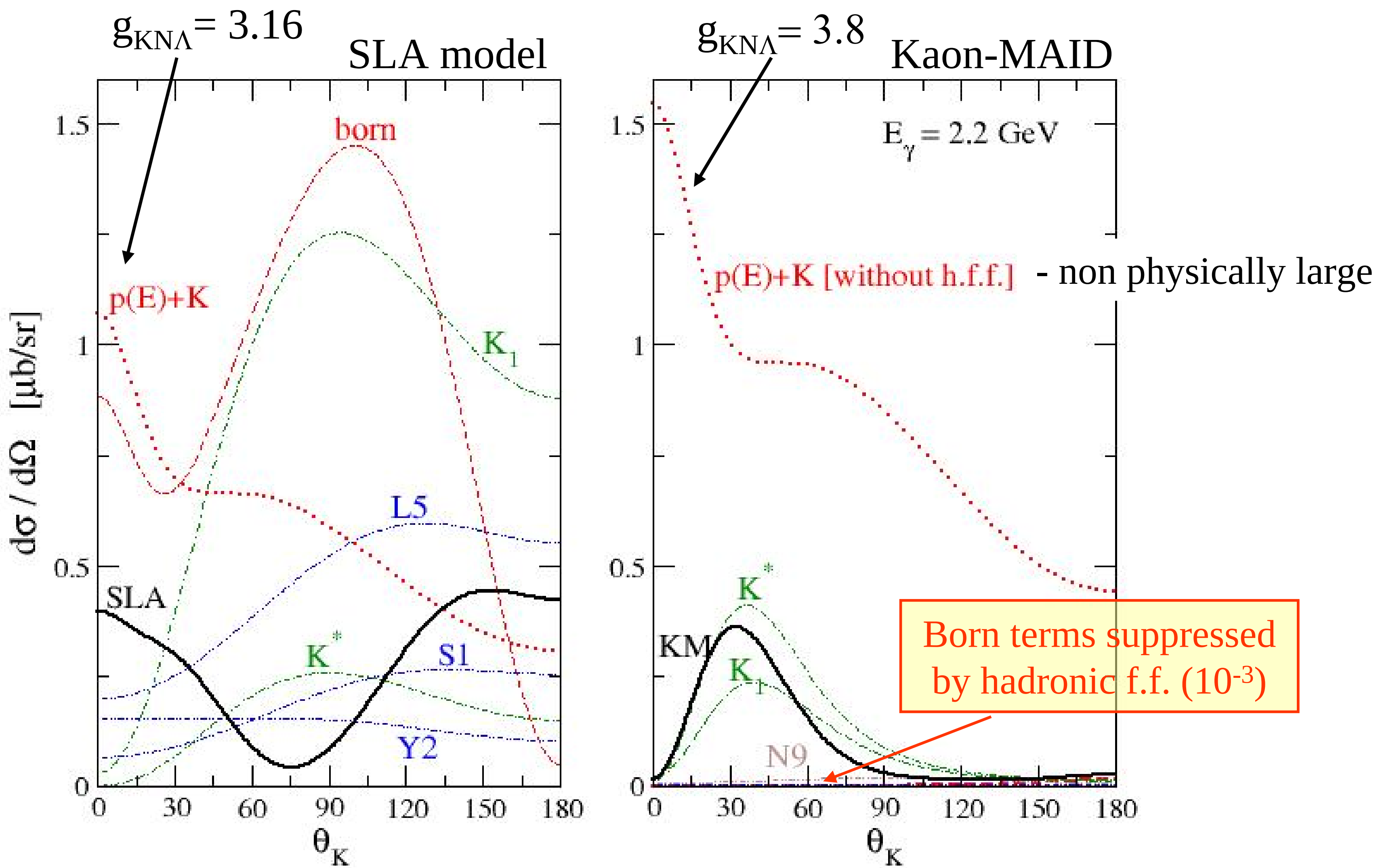
θ_{Ke} is kaon lab angle with respect to beam

Quite a good agreement of the calculated cross sections with data for the Saclay-Lyon model – *good description of the elementary process*



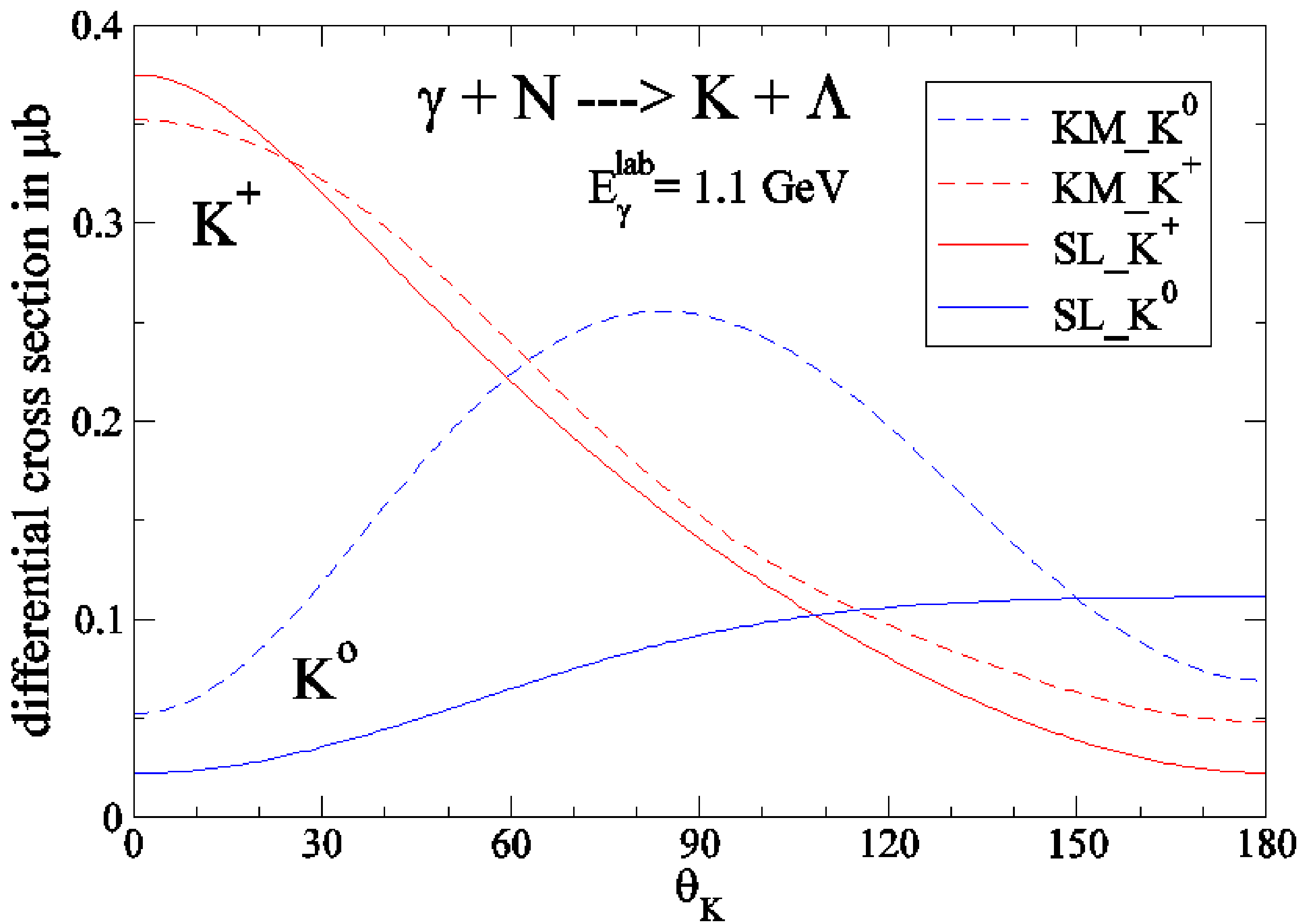
M. Iodice et al, Phys. Rev. Lett. 99 (2007) 052501.

Different dynamics of the Saclay-Lyon and Kaon-MAID models at forward angles. Contributions to the cross section:



II. 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

Data on inclusive cross section $d(\gamma,K^0)YN$ $Y=\Lambda$, Σ^0 and Σ^+

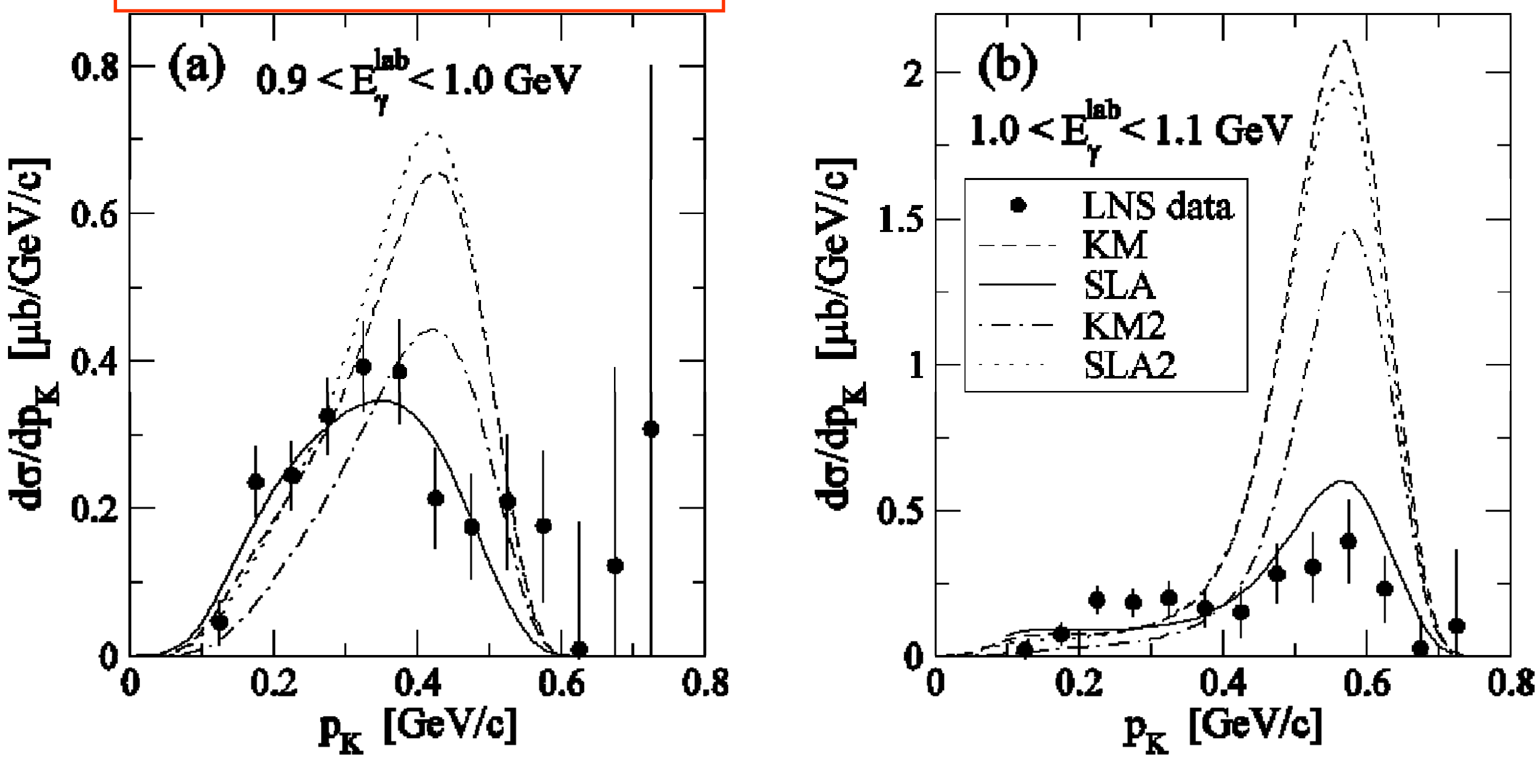
LNS, Tohoku Uni. *K. Tsukada et al, Phys.Rev. C 78 (2008) 014001*

Energy-averaged and kaon-angle-integrated momentum distributions, calculations for the $K^0\Lambda$ channel

Fit SLA: $r_{K1K\gamma}$= -2.09, χ^2_{ndf}= 0.88; KM: $r_{K1K\gamma}$= -0.45; SLA2: $r_{K1K\gamma}$= -3.4;

KM2 – re-fitted Kaon-MAID: $r_{K1K\gamma}$= -2.34, χ^2_{ndf}= 3.64

$K^0\Sigma^0$ and $K^0\Sigma^+$ negligible **$K^0\Sigma^0$ and $K^0\Sigma^+$ important**



Summary

- *good data at very small kaon angles are needed to fix the models for the K^+ production at forward angles which is necessary for reliable hypernuclear calculations;*

- *the Saclay-Lyon model gives reasonable cross sections for the hypernucleus production – good description of the elementary process at small θ_K (?);*

- *the first data on the K^0 photoproduction from deuteron near threshold set constraints on the models for the elementary process;*