Kaon photo and electroproduction

Stijn Janssen and Jan Ryckebusch

Department of Subatomic and Radiation Physics

Ghent University

Introduction

- The *strange* quark opens an additional degree of freedom in studying N^* and the structure of the nucleon

- Theoretical modeling of kaon photoproduction since 1966 [H. Thom]
  - despite 35 years of research, $p(\gamma, K^+)\Lambda$ and $p(\gamma, K)\Sigma$ reaction mechanisms are still elusive

- Amount of $p(\gamma, K)Y$ and $p(e, e'K)Y$ data is growing
  - Jlab, ELSA (SAPHIR), SPring-8, GRAAL ...

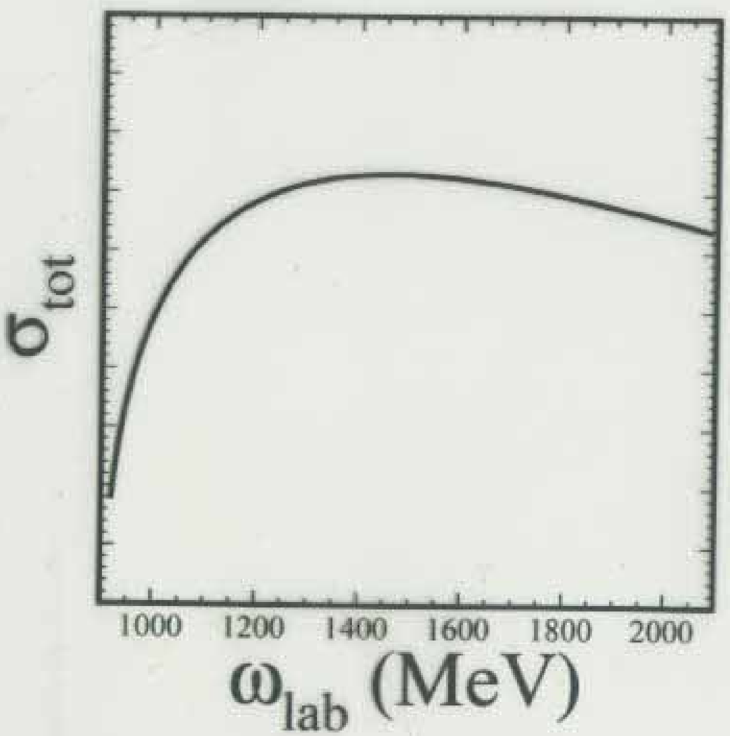
Model for $p(\gamma, K)Y$ and $p(e, e'K)Y$ reactions

- Description of the $p\,(\gamma, K)\,Y$ in terms of hadronic degrees of freedom
- Tree-level Feynman diagrams are calculated with the aid of an effective Lagrangian approach
- Hadronic form factors are inserted to account for the internal structure
- Reaction dynamics:
  - Born terms
  - (axial) vector mesons: $K^*(892)$ and $K_1(1270)$
  - N^* resonances: $S_{11}(1650)$, $P_{11}(1710)$, $P_{13}(1720)$
  - Δ^* resonances: $S_{31}(1900)$, $P_{31}(1910)$ (only for $K\Sigma$)
  - missing resonance: $D_{13}(1895)$, ...?

Model (continued)

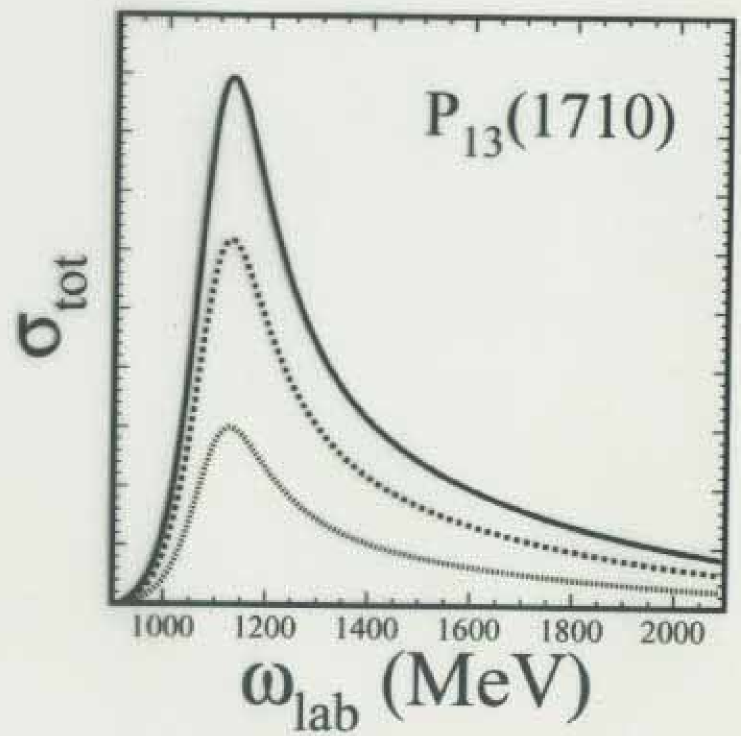
Two sources of $p(\gamma, K)Y$ strength:

The background:



smooth behavior

The resonances:



pole behavior $\rightarrow$ information on N^*/Δ^* parameters

Background contribution

Born terms are fully determined by coupling constants $g_{K^+\Lambda p}$ and $g_{K^+\Sigma^0 p}$

SU(3)-flavor symmetry connects these coupling constants to $g_{\pi NN}$:

$$\left.\begin{array}{c} g_{K^+\Lambda p} \\ g_{K^+\Sigma^0 p} \end{array}\right\} \sim g_{\pi NN}$$

Broken SU(3) sets ranges (e.g. 20%):

$$\begin{array}{rcccl} -4.5 & \leq & \frac{g_{K^+\Lambda p}}{\sqrt{4\pi}} & \leq & -3.0 \\ 0.9 & \leq & \frac{g_{K^+\Sigma^0 p}}{\sqrt{4\pi}} & \leq & 1.3 \end{array}$$

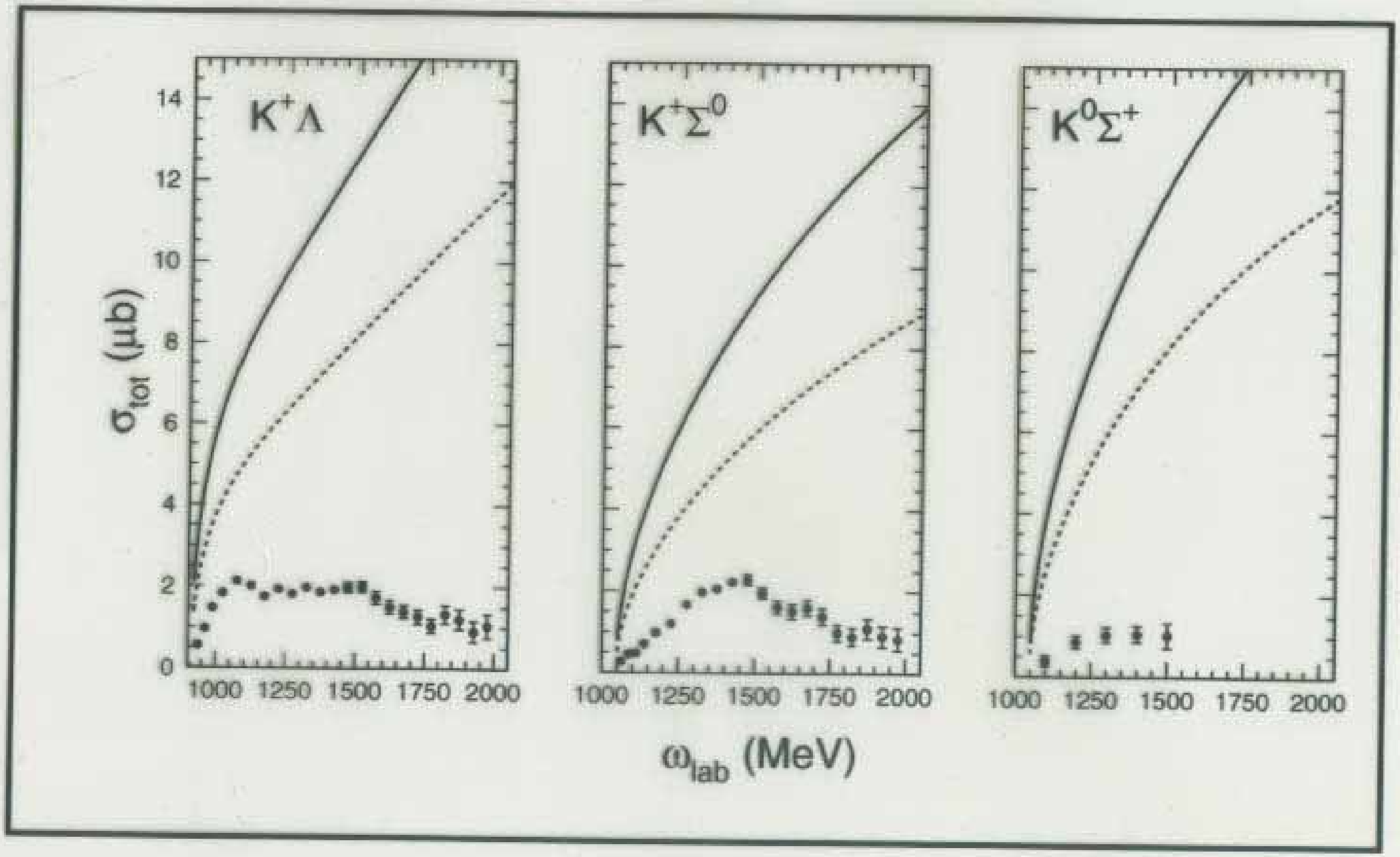
Background contribution (continued I)

Value of $g_{K^+\Lambda p}$: long standing problem...

$g_{K^+\Lambda p}$	Reference
-4.5 $\leftrightarrow$ -3.0	SU(3) $\pm$ 20%
-2.38 $\leftrightarrow$ -1.16	Williams *et al.* (1992)
0.51	Mart *et al.* (1995)
-3.2	David *et al.* (1996)
-1.72	Feuster *et al.* (1999)
-2.41 $\leftrightarrow$ -1.24	Hsiao *et al.* (2000)
-3.80	Lee *et al.* (2001)
-3.44	Penner *et al.* (2002)
...	

Background contribution (continued II)

Born terms with coupling constants in the (broken) SU(3) range produce far too much strength:



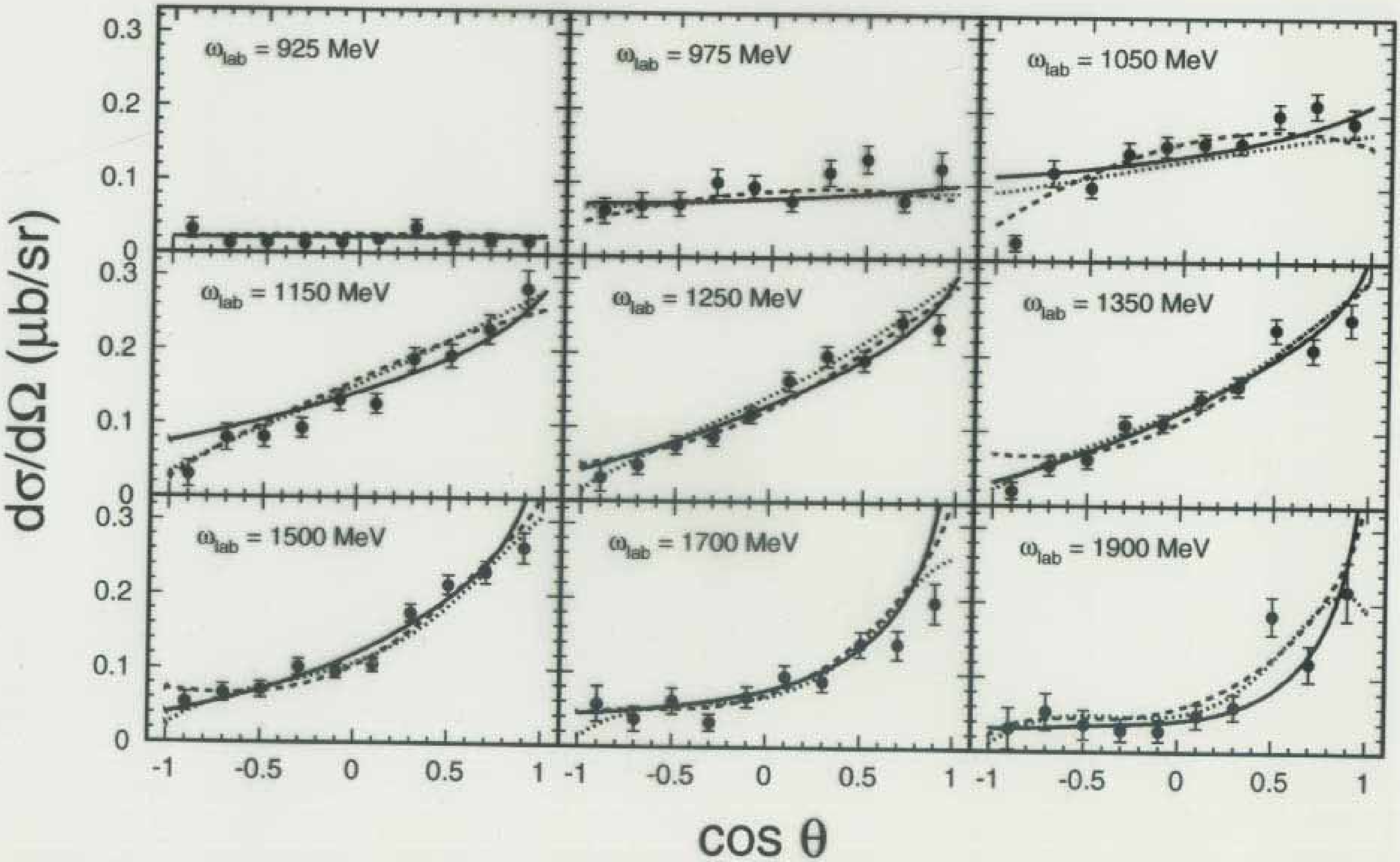
solid line: g_{KYp} with exact SU(3) symmetry
dashed line: g_{KYp} with broken (20%) SU(3) symmetry

Background contribution (continued III)

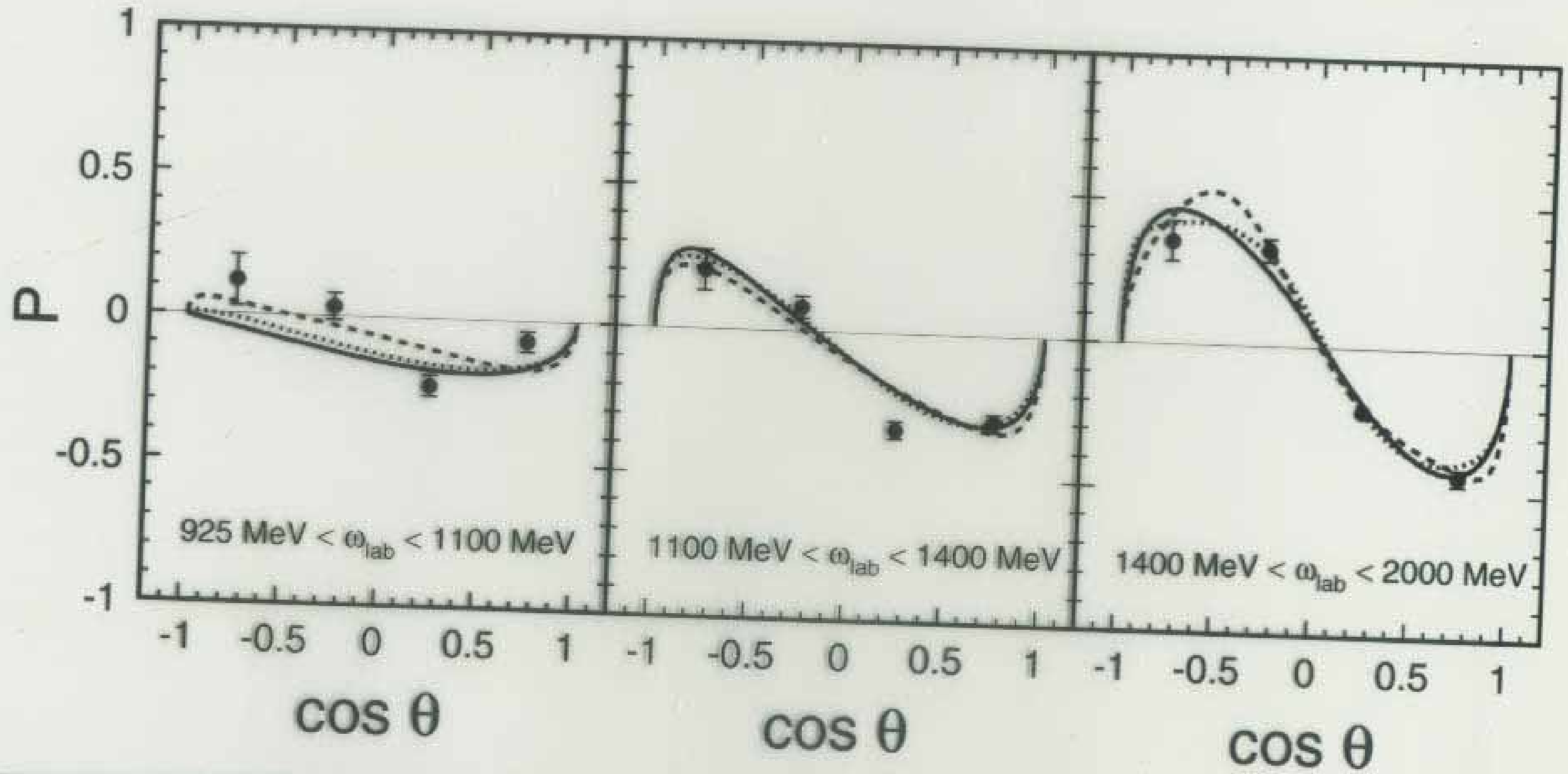
Schemes to reduce strength from the Born terms:

- Violation of the SU(3) ranges
  - ➡ $g_{KYp} \approx 20\%$ of the SU(3) prediction!
- Introduction of "soft" hadronic form factors
  - ➡ cutoff parameter $\Lambda_c \sim 0.5$ GeV
  - ➡ relevant quantity: $g_{KYp} \cdot F_{\text{had}}(\Lambda_c)$
- Introduction of hyperon resonances in the u-channel
  - ➡ Λ^* and Σ^* interfere destructively with Born terms
  - ➡ Y^* coupling constants are (relatively) big

Results for $\gamma p \to K^+\Lambda$



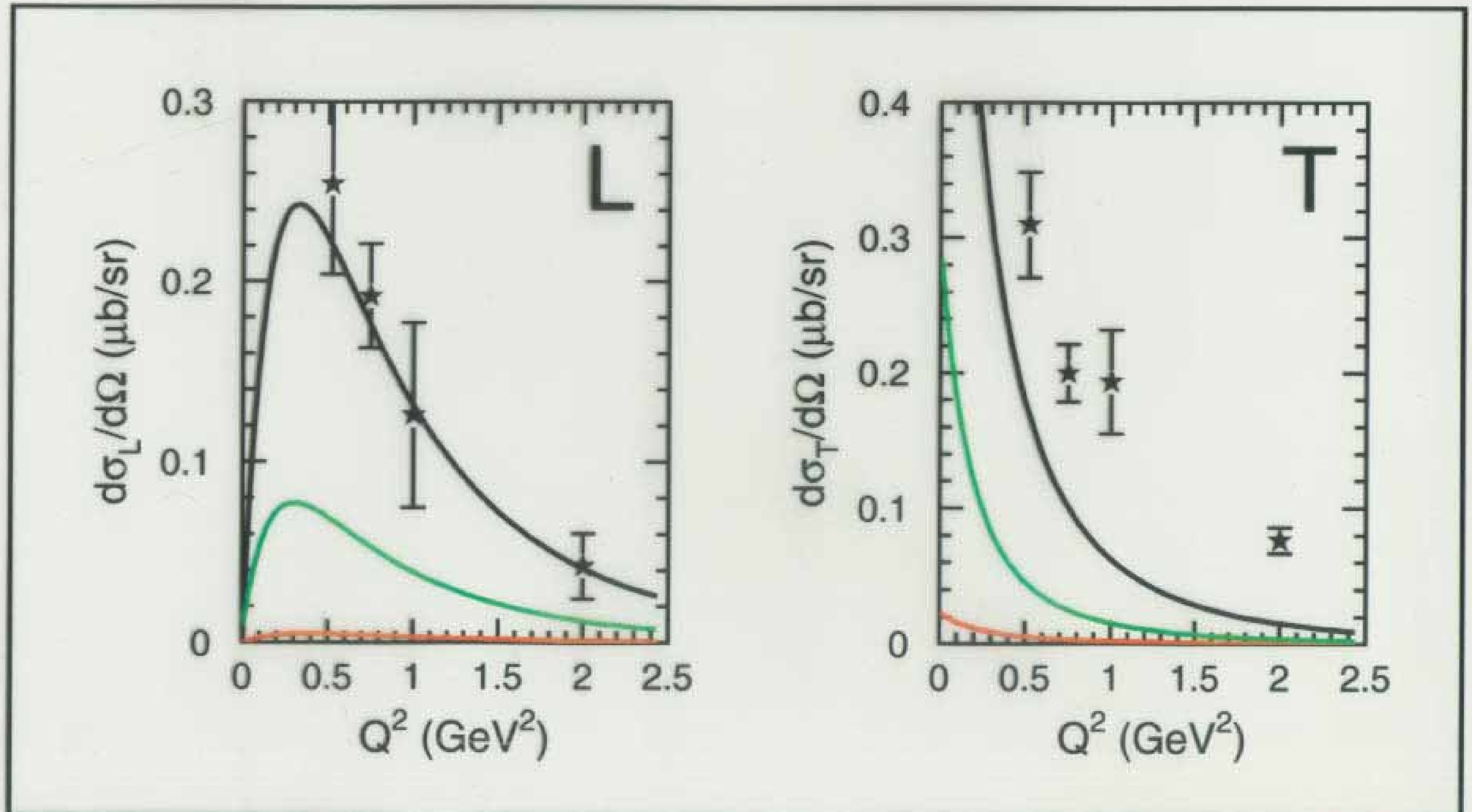
Results for $\gamma p \rightarrow K^+ \vec{\Lambda}$



➡ No room to discriminate between "background models"!

Electroproduction: $ep \to e'K^+\Lambda$

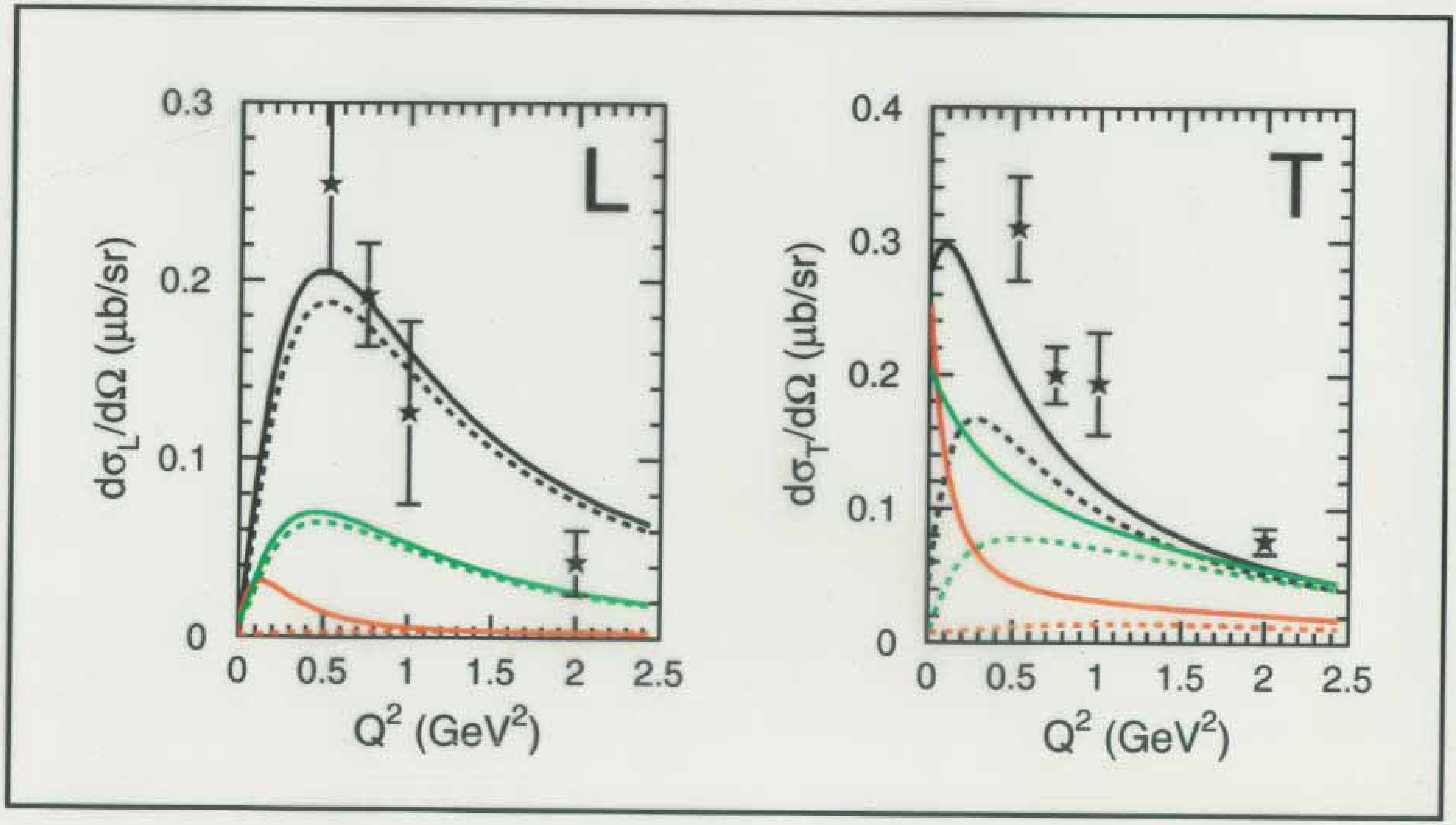
Born term contributions:



SU(3) SU(3)/2 SU(3)/8

Electroproduction: $ep \to e'K^+\Lambda$

Background (dashed) + N^* contributions (solid)



SU(3) SU(3)/2 SU(3)/8

Electroproduction: Conclusion

$p(e, e'K)Y$: possibility to discriminate between background models $\rightarrow$ handle on $g_{KYp} \cdot F_{\text{had}}(\Lambda_c)$

Failing...

- Strong SU(3) breaking $\rightarrow g_{KYp} << g_{KYp}^{SU(3)}$
- Soft hadronic form factor $\rightarrow \Lambda_c \approx 0.5$ GeV

Seemingly working...

- $g_{KYp} \cdot F_{\text{had}}(\Lambda_c) \sim g_{K\Lambda p}^{SU(3)} \cdot 1$
- Important role for u-channel Y^* resonances

Missing resonance

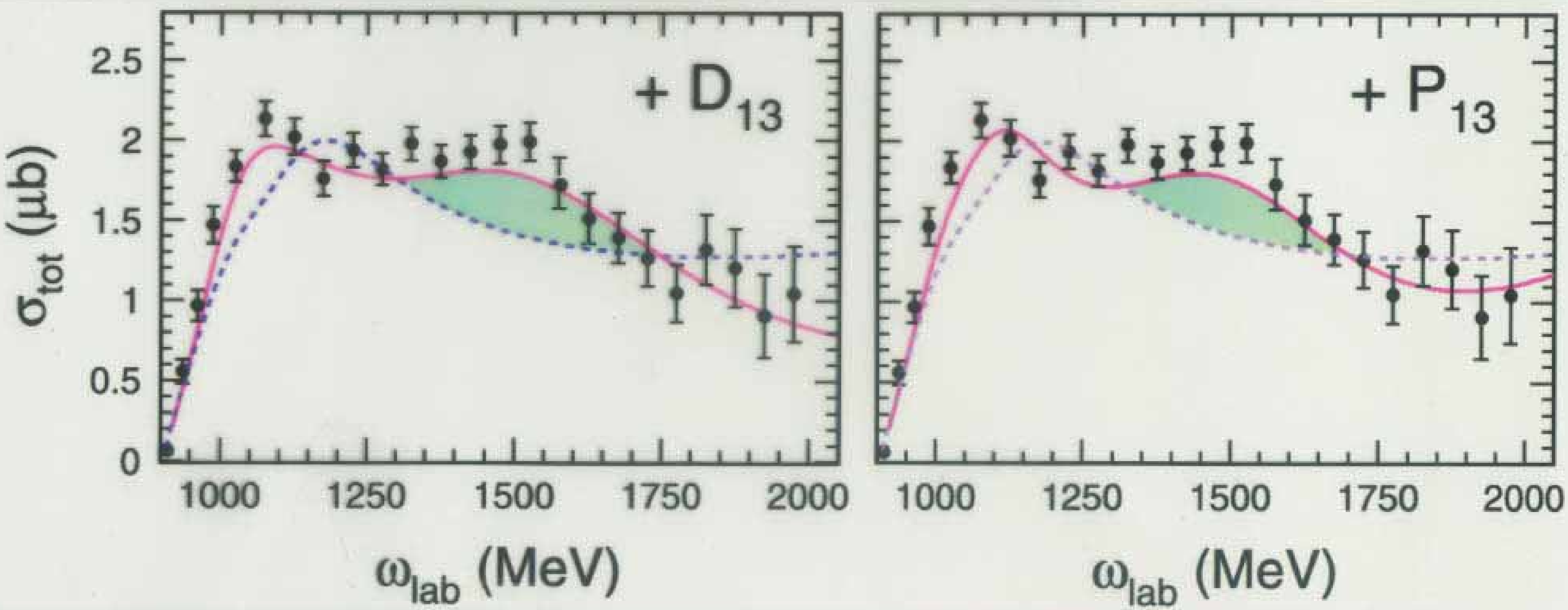
Introduction of "missing" $D_{13}(1895)$ resonance [1] can improve the description of the data:

χ^2	without D_{13}	with D_{13}	Improvement
$K\Lambda$	3.4 - 4.4	2.9	24% - 40%
$K\Sigma$	1.9	1.8	5%

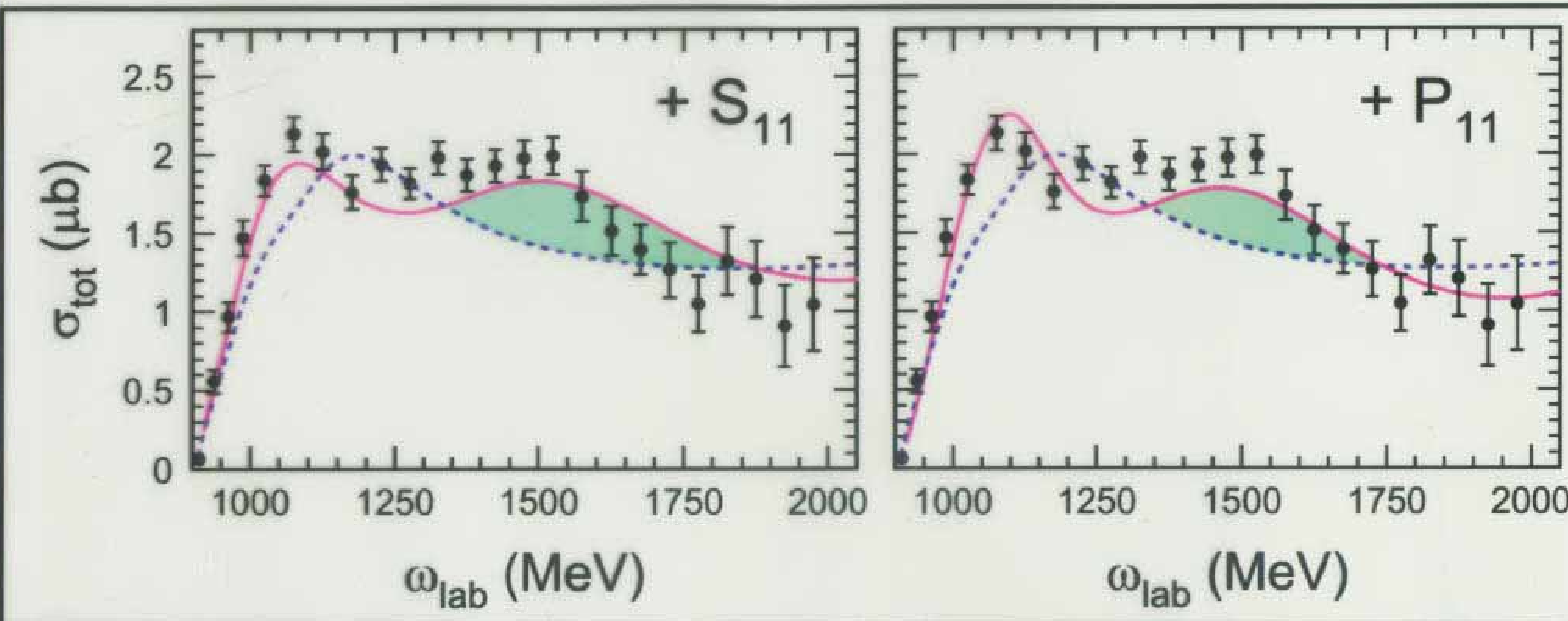
[1] T. Mart and C. Bennhold, PRC 61, R012201 (2000)

Missing resonance (continued I)

But... introduction of an other resonance can do the same job!



Missing resonance (continued II)



Missing resonance (continued II)

Other explanations for "structure" in literature:

- *Saghai* (nucl-th/0105001): u-channel $\Lambda^*(1890)$ hyperon resonance
- *Penner and Mosel* (nucl-th/020769): K^*-nucleon interference effect in $1/2^+$ partial wave

Both are background processes!

Conclusion

- Background is studied for $\gamma(p, K^+)\Lambda$ and $p(\gamma, K)\Sigma$ reaction
  - ➡ Various possibilities seem to produce similar $p(\gamma, K)Y$ results
- Special attention to pinning down g_{KY_p} coupling constants
  - ➡ $p(\gamma, K)Y$ not conclusive … depends on background!
- $p(e, e'K)Y$ data seem to exclude introduction of strong SU(3) breaking for g_{KY_p} and/or "soft" hadronic form factors
- Great care must be exercised in identifying the quantum numbers of missing resonances!