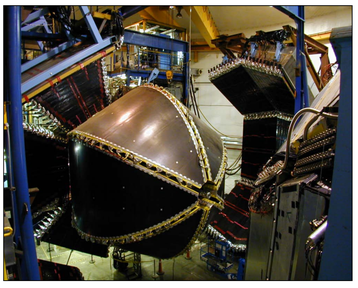
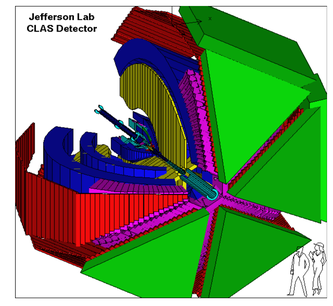


PHYSICAL REVIEW C **83**, 025207 (2011)

Scaling and Resonances in Elementary $K^+\Lambda$ Photoproduction



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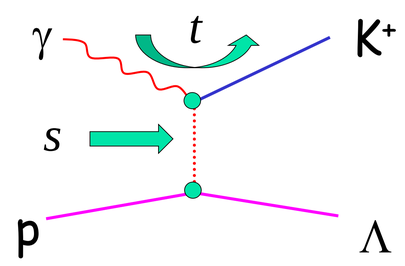
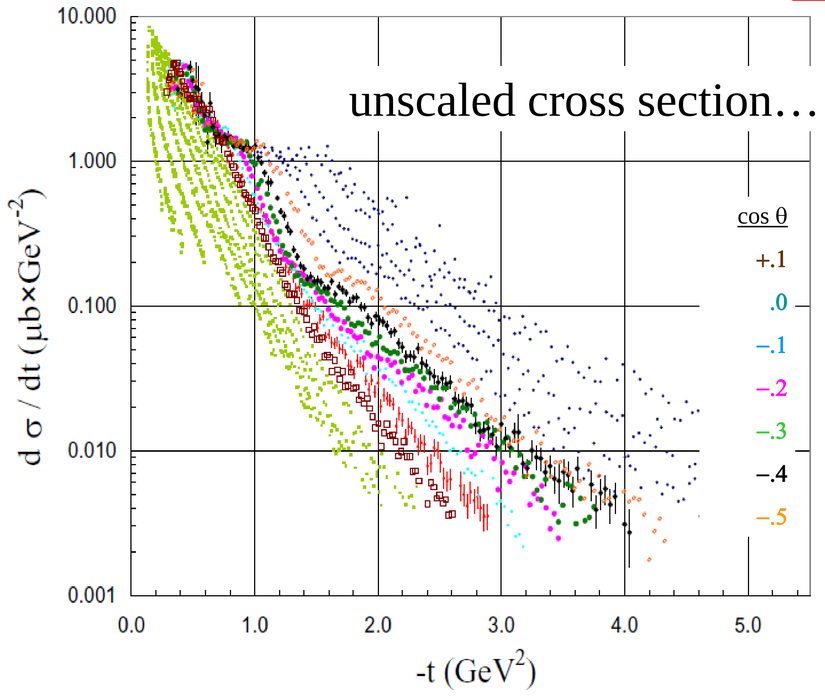
PANIC11 @ MIT

$$\gamma + p \rightarrow K^+ + \Lambda$$

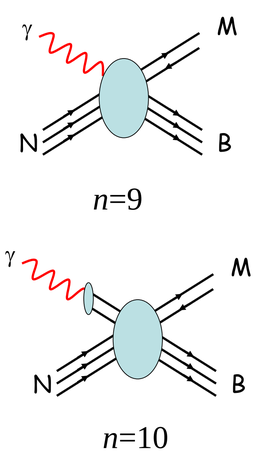
Recent cross-section data for the reaction $\gamma + p \rightarrow K^+ + \Lambda$ are examined for evidence of scaling in both the low-t Regge domain and in the high-$\sqrt{s}$ and $-t$ domain where constituent counting may apply. It is shown that the reaction does scale in both regimes. At large center-of-mass angles, s^{-7} scaling appears to hold at essentially all $-t$ but with angle-dependent oscillations. The scaled data show particularly strong evidence for s-channel resonances for $-t$ below 2 GeV^2 and for W below about 2.3 GeV. The dominant contributions are consistent with an N^*S_{11} resonance at 1690 MeV, a P_{13} resonance at 1920 MeV, and a D_{13} resonance at 2100 MeV, which interfere to give the observed strong angular dependence.



Scaling Using Constituent-Counting



M. E. McCracken *et al*. (CLAS), Phys. Rev. **C81**, 025201 (2010)



Constituent counting rule for exclusive scattering

$$\frac{d\sigma}{dt} = f\left(\frac{t}{s}\right) s^{2-n}$$

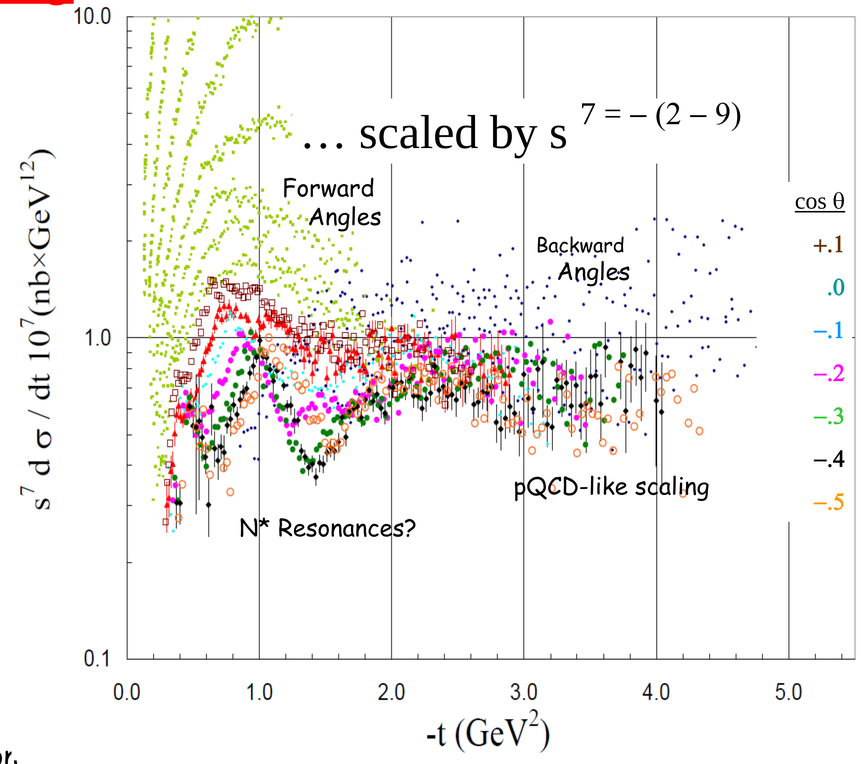
"Valid" for $s \rightarrow \infty$ and t/s fixed
$t/s \sim \cos(\theta_{cm})$ as $s \rightarrow \infty$

n = number of point-like constituents

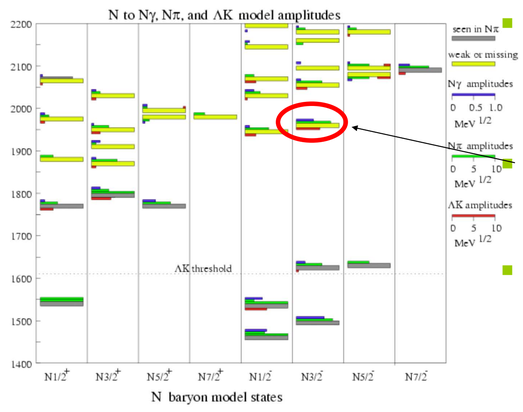
Follows from perturbative QCD (and some other models)

Analysis finds: n-2 = 7.1 ± 0.1

pQCD-like constituent scaling is confirmed for hyperon photoproduction.



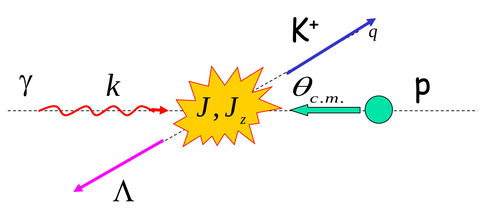
N* Baryons: Seen & "Missing"



- Relativised CQM: Classify oscillator-model states by I, J, P
- Possible observation of a "missing" N* state in $K^+\Lambda$
- There is a PDG "**" state N(2080) D_{13}

S. Capstick and W. Roberts, Phys. Rev. **D58**, (1998).

Physics Model



- Quantize along beam axis
- $\alpha_{\frac{1}{2},\pm\frac{1}{2}}$ nucleon spinors
- Y_{LM} spherical harmonic of final state

Example: J=3/2 resonance formed in J_z=+1/2 substate, decaying to P-wave

$$\psi_{L=1}\left(J=\tfrac{3}{2}, J_z=\tfrac{1}{2}\right) = \left\{\frac{1}{\sqrt{3}} Y_{1,1}\, \alpha_{\frac{1}{2},-\frac{1}{2}} + \frac{2}{\sqrt{3}} Y_{1,0}\, \alpha_{\frac{1}{2},+\frac{1}{2}}\right\} BW_{1/2}(m)$$

Similar expressions for

$$\psi_P\left(\tfrac{3}{2},\tfrac{3}{2}\right),\ \psi_D\left(\tfrac{3}{2},\tfrac{3}{2}\right),\ \psi_D\left(\tfrac{3}{2},\tfrac{1}{2}\right),\ \psi_S\left(\tfrac{1}{2},\tfrac{1}{2}\right)$$

$$BW_{J_z}(m) = \frac{\sqrt{m m_0 \Gamma_{J_z,\gamma p\rightarrow N^*} \Gamma_{N^*\rightarrow K\Lambda}(q)}}{m^2 - m_0^2 - i m_0 \Gamma_{tot}(q)}$$

$$\Gamma_{tot}(q) = \Gamma_{N^*\rightarrow K\Lambda}(q) + \Gamma_S(q)$$

$$\Gamma_{N^*\rightarrow K\Lambda}(q) = \Gamma_0 \left(\frac{q}{q_0}\right)^{2L+1} \qquad (L \in 0,1,2)$$

$$\Gamma_S(q) = \Gamma_{S_0} \left(\frac{q}{q_S}\right)^7$$

- Each resonance represented as a relativistic Breit-Wigner
- Phenomenological damping of high-mass tail to achieve s^{-7} scaling

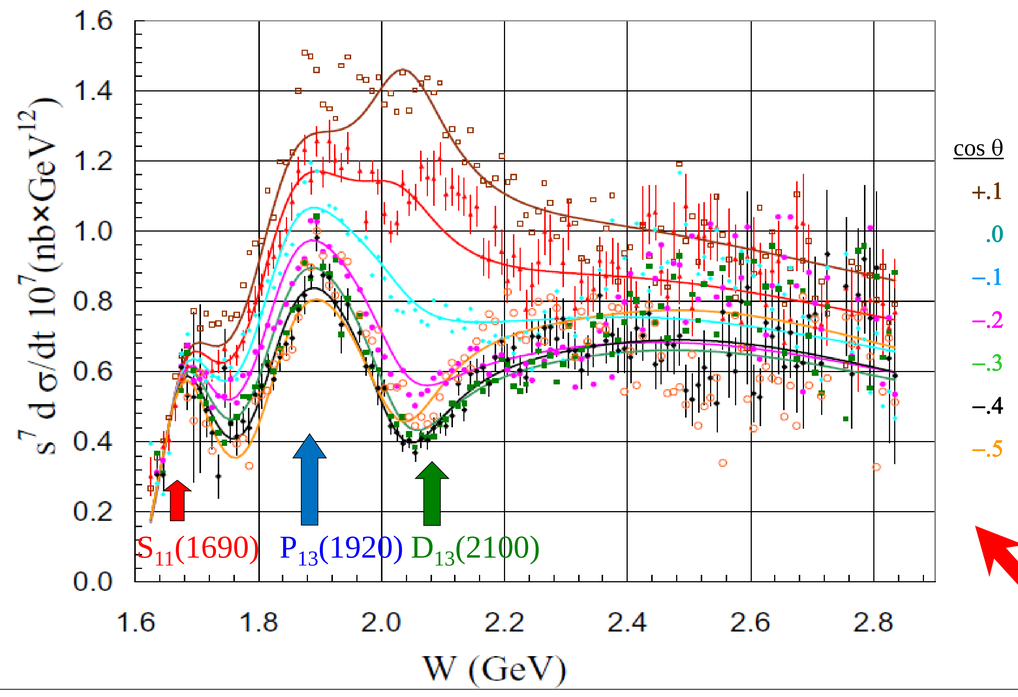
- Compute coherent total amplitude
- Scale cross section
- Fit to optimize observed angular distributions
- Use S, P, and D wave decay distributions

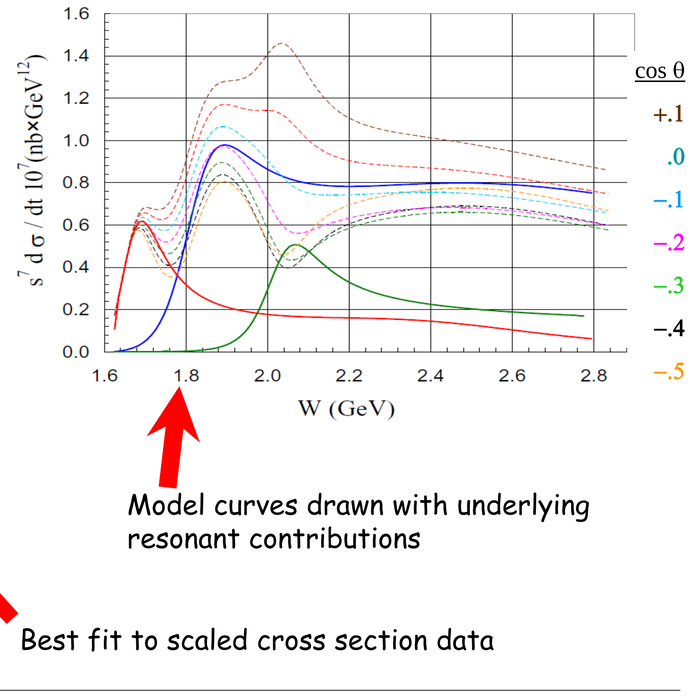
Total amplitude:

$$\left|A(m,\cos\theta_{c.m.})\right|^2 = \left|\psi_S\left(\tfrac{1}{2},\tfrac{1}{2}\right) + \psi_P\left(\tfrac{3}{2},\tfrac{1}{2}\right) + \psi_P\left(\tfrac{3}{2},\tfrac{3}{2}\right) + \psi_D\left(\tfrac{3}{2},\tfrac{1}{2}\right) + \psi_D\left(\tfrac{3}{2},\tfrac{3}{2}\right)\right|^2$$

Scaled cross section to fit:

$$s^7 \frac{d\sigma}{dt} = s^7 \frac{(\hbar c)^2}{64\pi} \frac{1}{s} \frac{1}{k^2} \left|A(m,\cos\theta_{c.m.})\right|^2$$





Model curves drawn with underlying resonant contributions

Best fit to scaled cross section data

Model Results

$$\begin{cases} \Gamma_{S_0} = 0.50 \quad \text{GeV} \\ q_S = 0.77 \ \text{GeV/c} \end{cases}$$

Resonance &Decay	m_0 (GeV)	Γ_0 (MeV)	$\sqrt{\Gamma_{1/2,\gamma p\rightarrow N^*}}$ $(\text{GeV})^{1/2}$ Phase	$\sqrt{\Gamma_{3/2,\gamma p\rightarrow N^*}}$ $(\text{GeV})^{1/2}$ Phase
S_{11}	1690 ± 10	80 ± 20	$1.83 \pm .10$ $(-142 \pm 5)^\circ$	
P_{13}	1920 ± 10	440 ± 100	$1.93 \pm .10$ –	$1.67 \pm .07$ –
New D_{13}	2100 ± 20	200 ± 50	$0.61 \pm .10$ $(45 \pm 5)^\circ$	$1.19 \pm .10$ $(45 \pm 5)^\circ$

Conclusions

High statistics recent data from CLAS at Jefferson Lab allowed two physics processes to be investigated:

1) Scaling of the cross section dσ/dt as s^{-7} is seen clearly for the first time in hyperon photoproduction. This phenomenon follows from "constituent counting" in QCD.
2) For W less than ~2.4 GeV, excitation of nucleon resonances is seen. We find evidence for a "new" resonance at 2100 MeV that is consistent with quantum numbers I=1/2, J=3/2, and decay to $K^+\Lambda$ via L = 2. This resonance has been described as a "missing " quark model state; we may have pinpointed this predicted state in the hyperon photoproduction channel.