Reaction dynamics for photoproductions of baryon resonances

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April 19-22, 2009
NSTAR2009,@IHEP, Beijing

1. Introduction

Exotic structure of baryon resonances

qq and/or $q\bar{q}$ correlations

2. Production reactions

We define the standard mechanism

Λ_{gs}K, Λ(1405), Λ(1520), φ

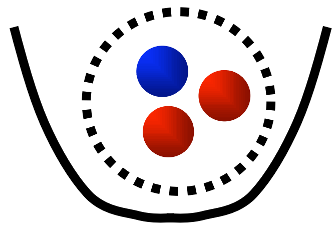
Various cross sections with use of spin

3. Chiral symmetry of baryons

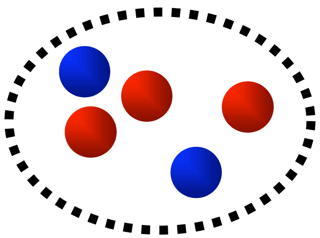
N(940) and *N**(1535)

1. Introduction
Exotic structure of baryon resonances

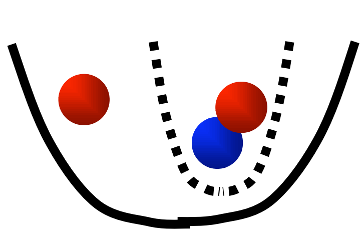
- Quark model (*standard* picture)
  $q\bar{q}$ and qqq of **single particle motion**



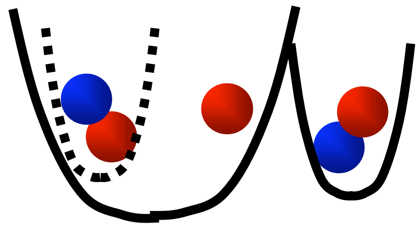
- Exotics are not the *standard*



Multiquarks



Correlated qq
Diquark

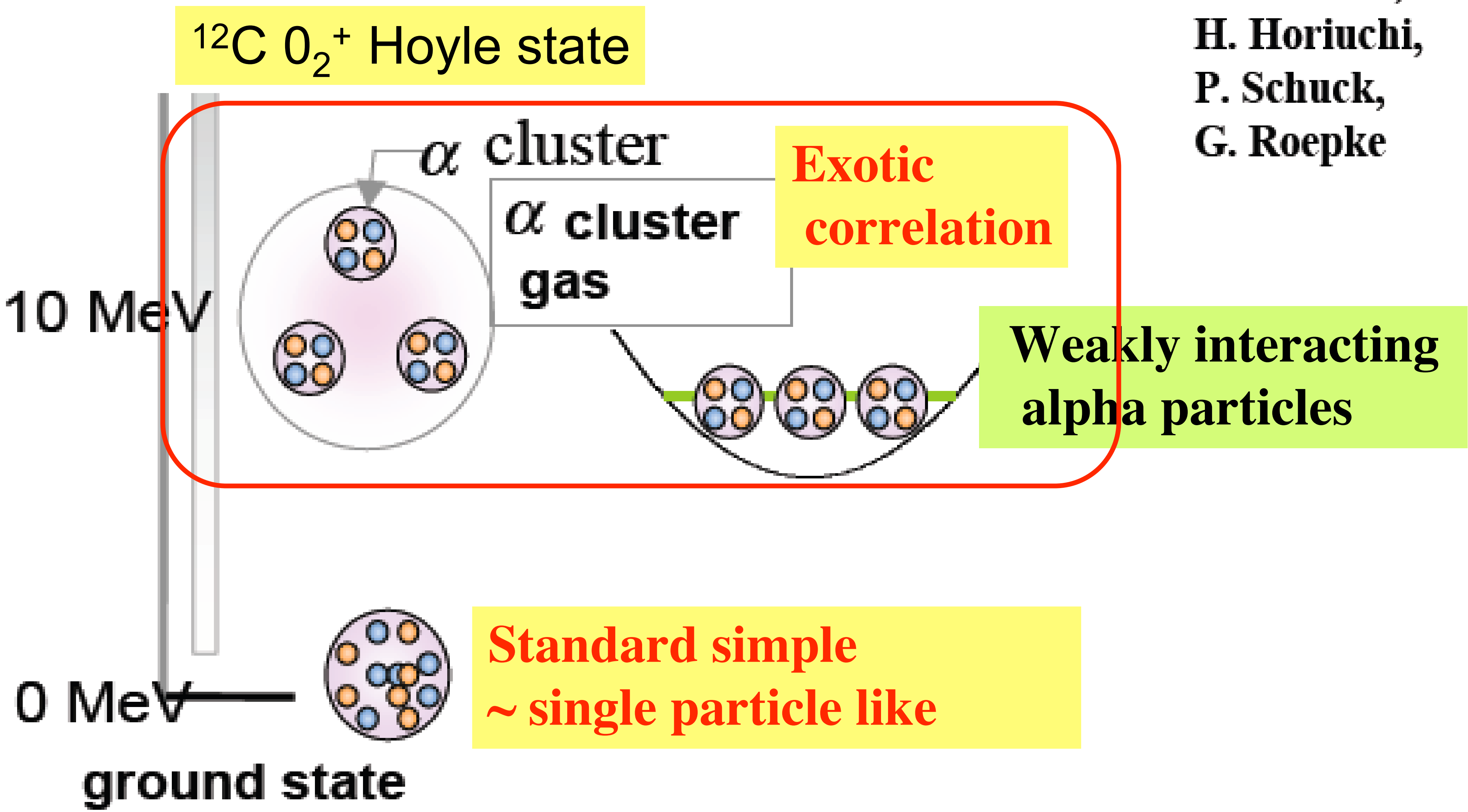


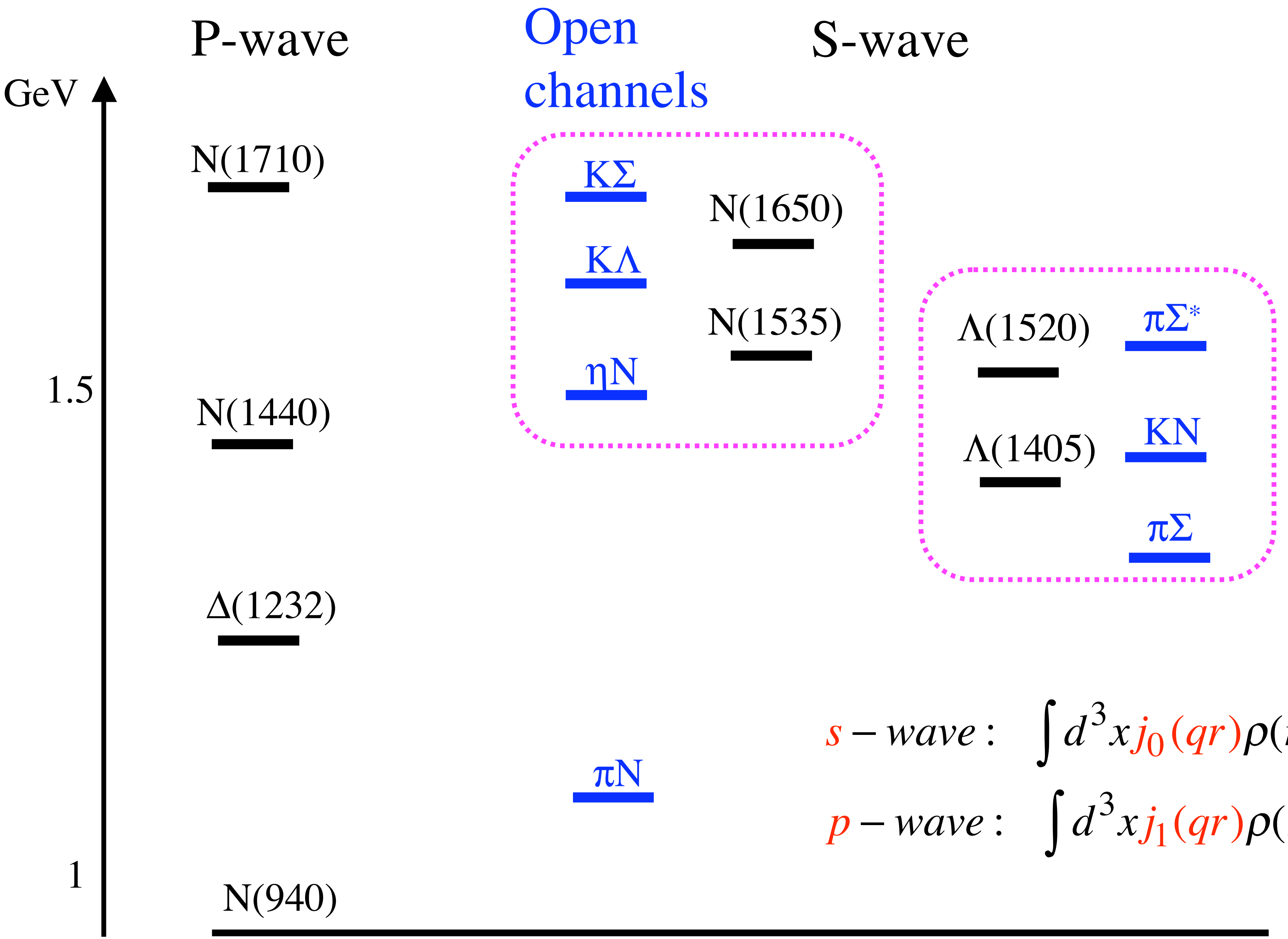
Correlated $q\bar{q}$
Meson

These ***correlations*** can be both ***virtual*** and (almost) ***real***

Example in Nuclear Physics

Y. Funaki,
A. Tohsaki,
H. Horiuchi,
P. Schuck,
G. Roepke





$$s-wave: \int d^3x\, j_0(qr)\rho(r)$$

$$p-wave: \int d^3x\, j_1(qr)\rho(r)$$

2. Production reactions

(1) $K\Lambda_{gs}$

Beam asymmetry, Meson cloud

(2) $K\Lambda(1405)$

Energy dependence

Beam asymmetry

(3) $K\Lambda(1520)$

Energy dependence, Angular (θ) dependence

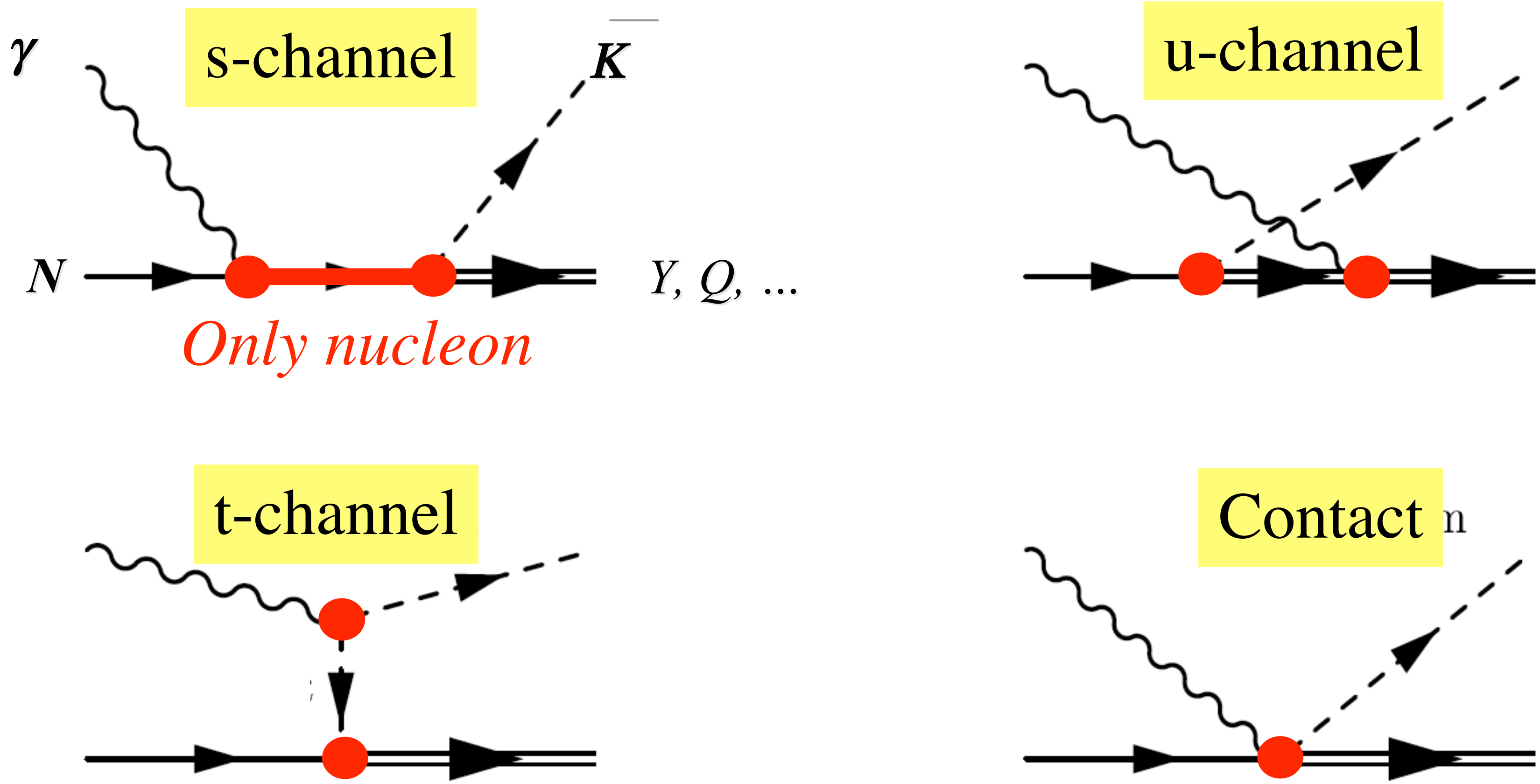
Beam asymmetry, Decay asymmetry

(4) ϕ-production

Pomeron, exotics, resonances??

Effective Lagrangian method
- Photoproductions -

Minimal diagrams

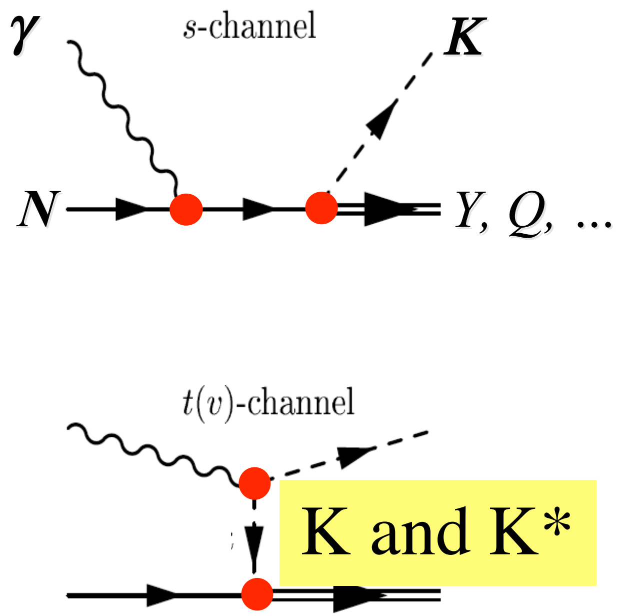


(1) Meson Clouds for K-production

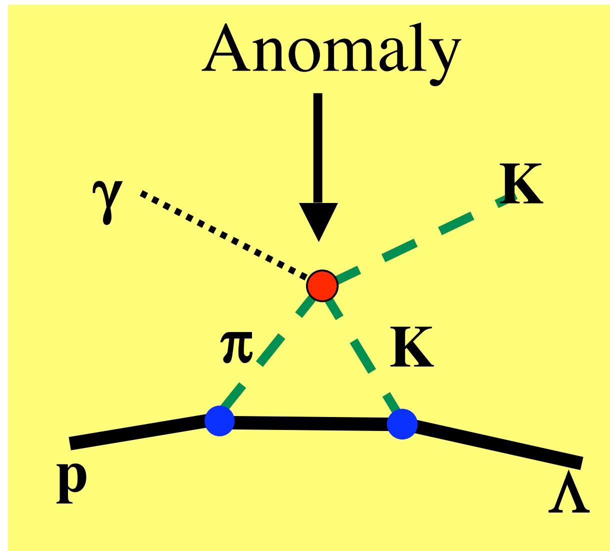
virtual $q\bar{q}$

Ozaki-Nagahiro-Hosaka
Phys.Lett.B665:178-181,2008.

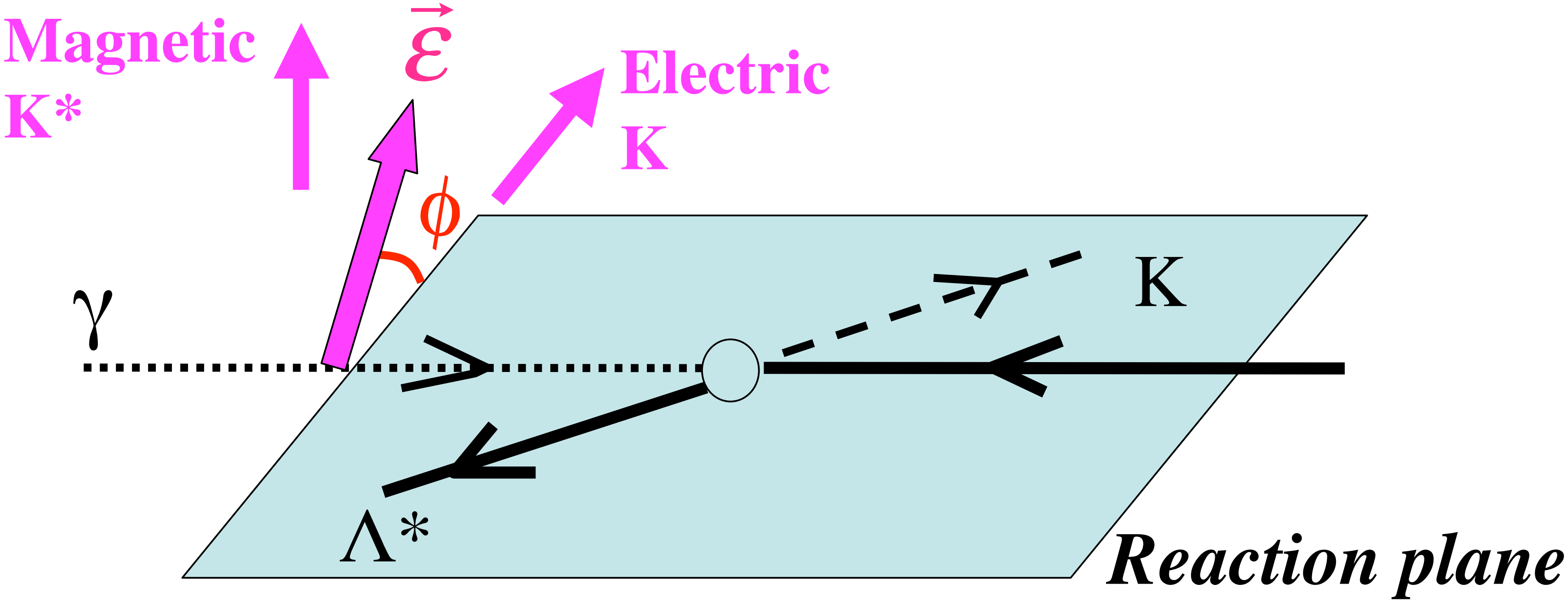
Standard processes



+



Beam asymmetry



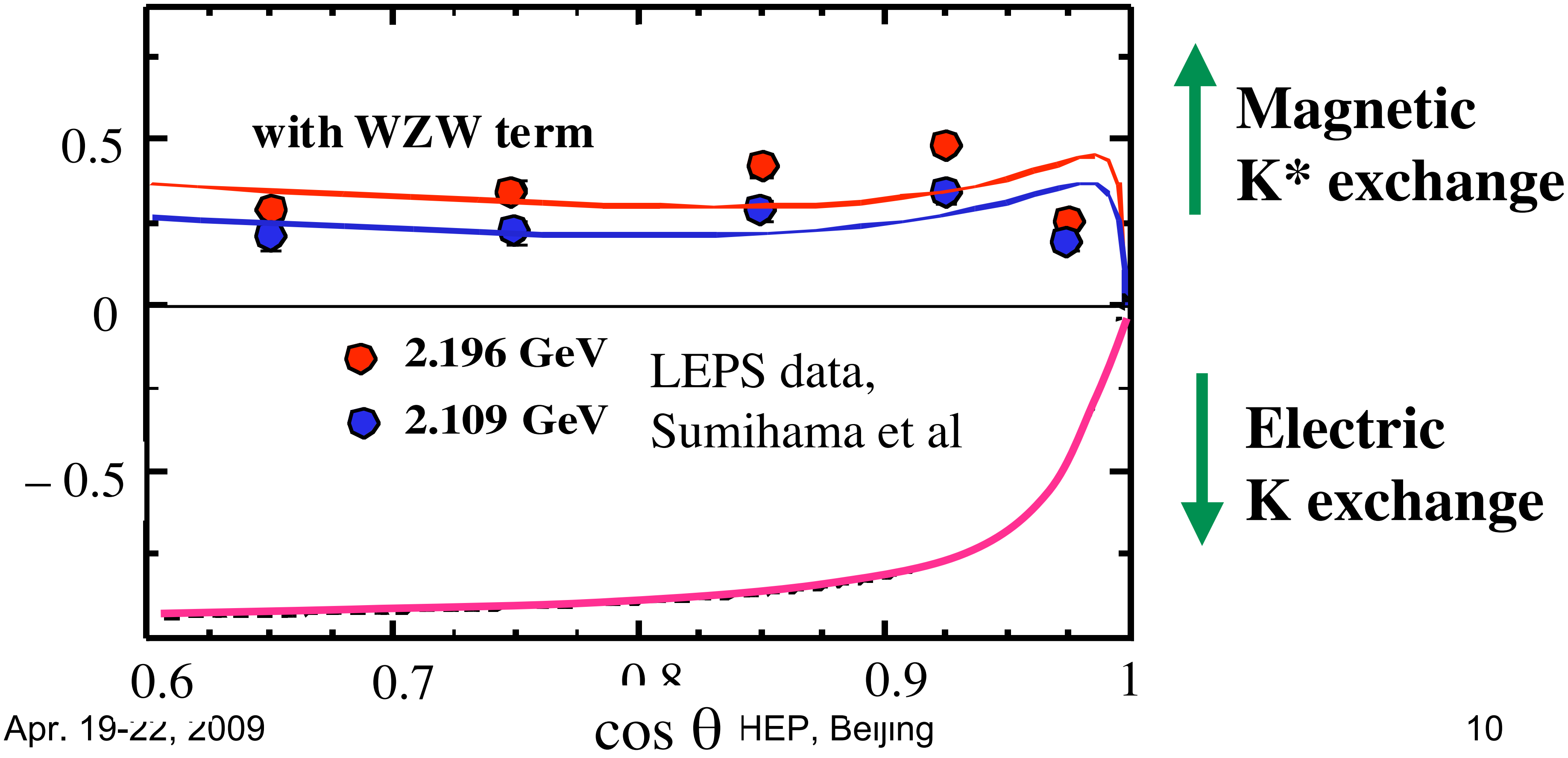
$$\sigma(\phi) \Rightarrow \Sigma = \frac{\sigma(90^\circ) - \sigma(0^\circ)}{\sigma(90^\circ) + \sigma(0^\circ)}$$

Beam asymmetry

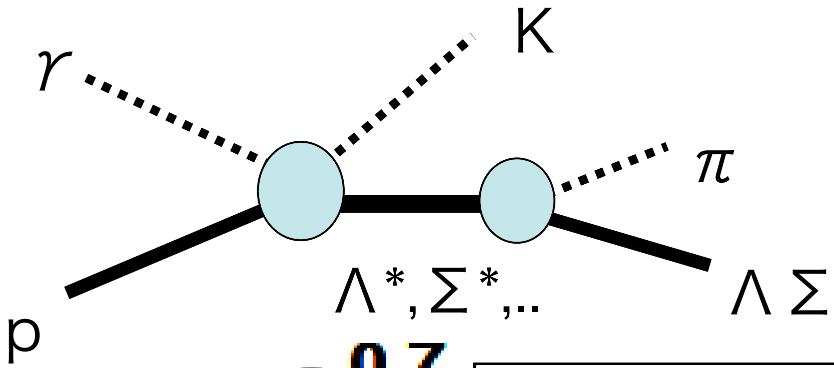
$\gamma p \rightarrow K^{-}\Lambda$

LEPS data
Sumihama et al.
PRC73,035214 (2006)

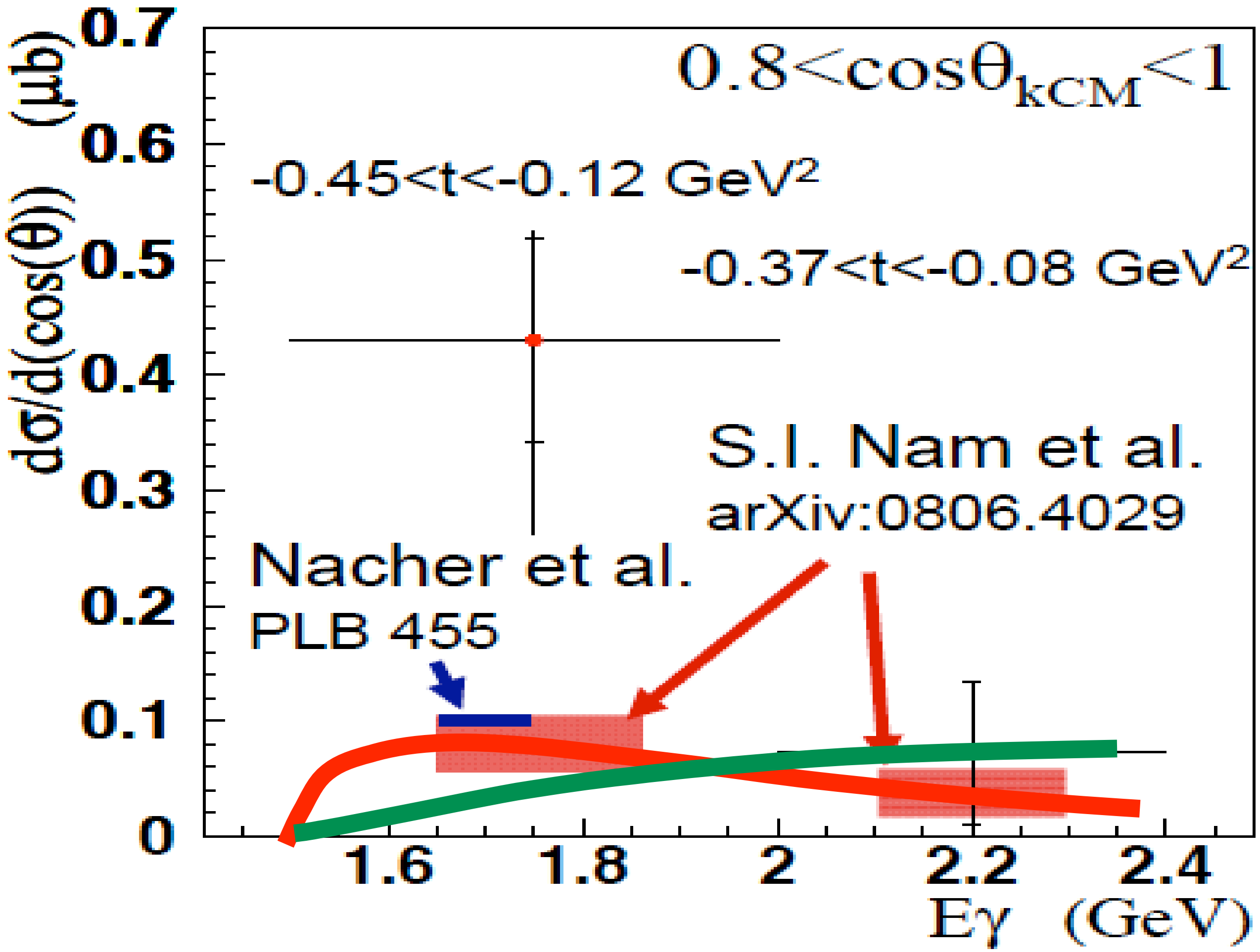
Also talk by
Schumacher
Jlab data



(2) Λ(1405) ~ Λ*



Niiyama et al, Phys.Rev.C78: 035202,2008

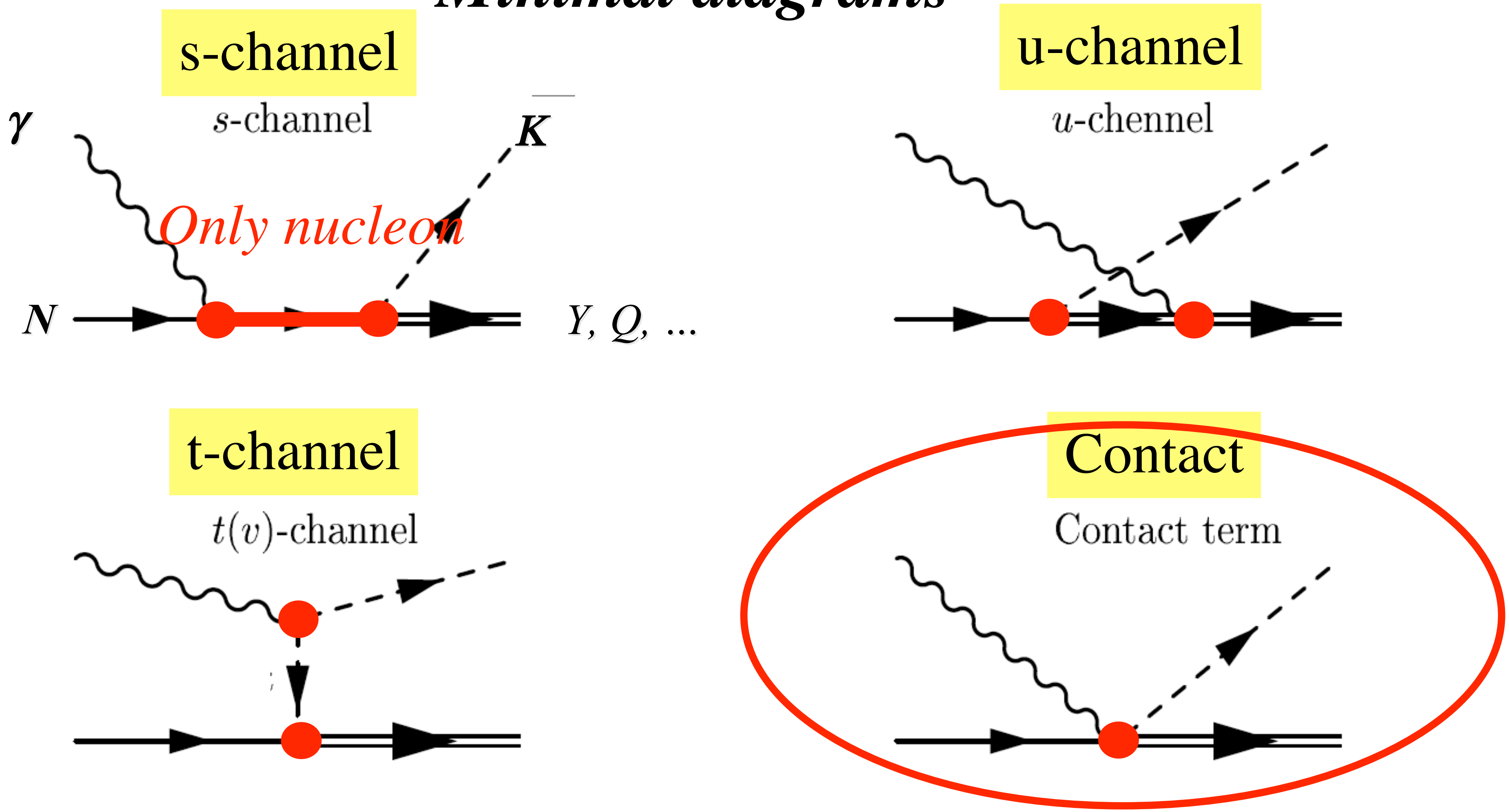


(3) Λ(1520)

γp -> K^+ Λ(1520) and γn -> K^0 Λ(1520)

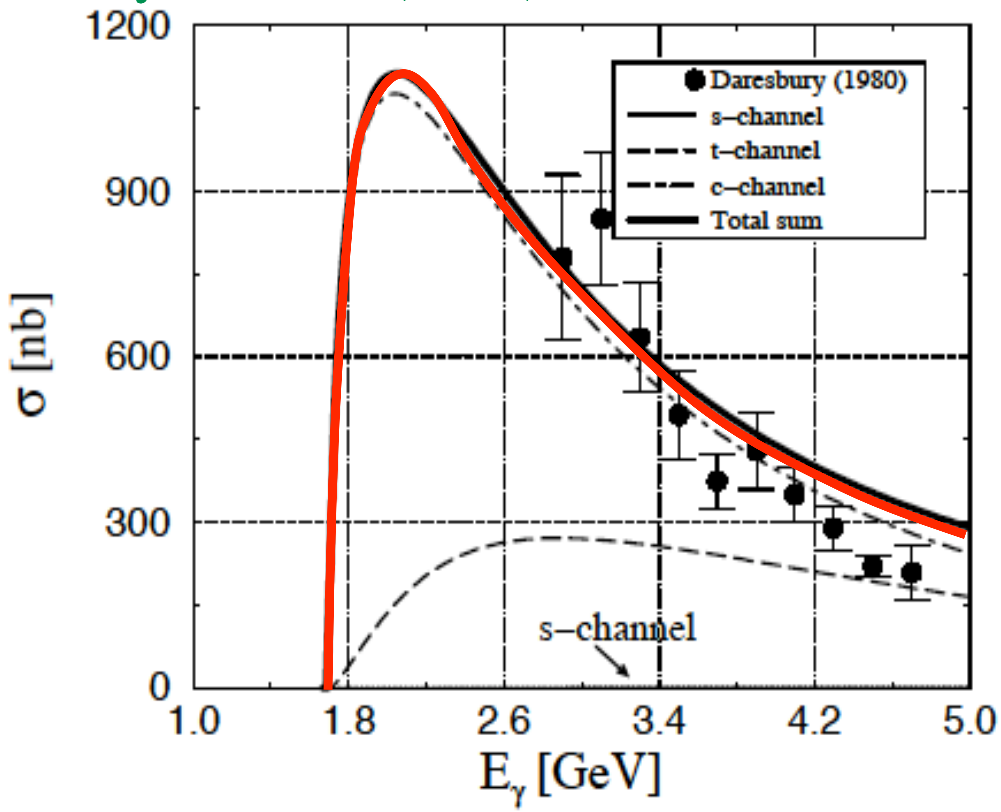
Nam, Hosaka, Kim, PRD71, 114012 (2005)

Minimal diagrams

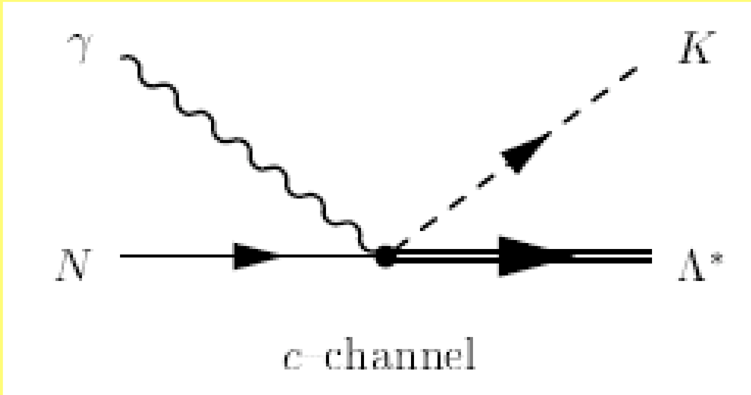


Total σ

Data: D.P. Baber et al,
Z. Phys. C7, 17 (1980)



Contact term dominant



σ(p) >> σ(n)

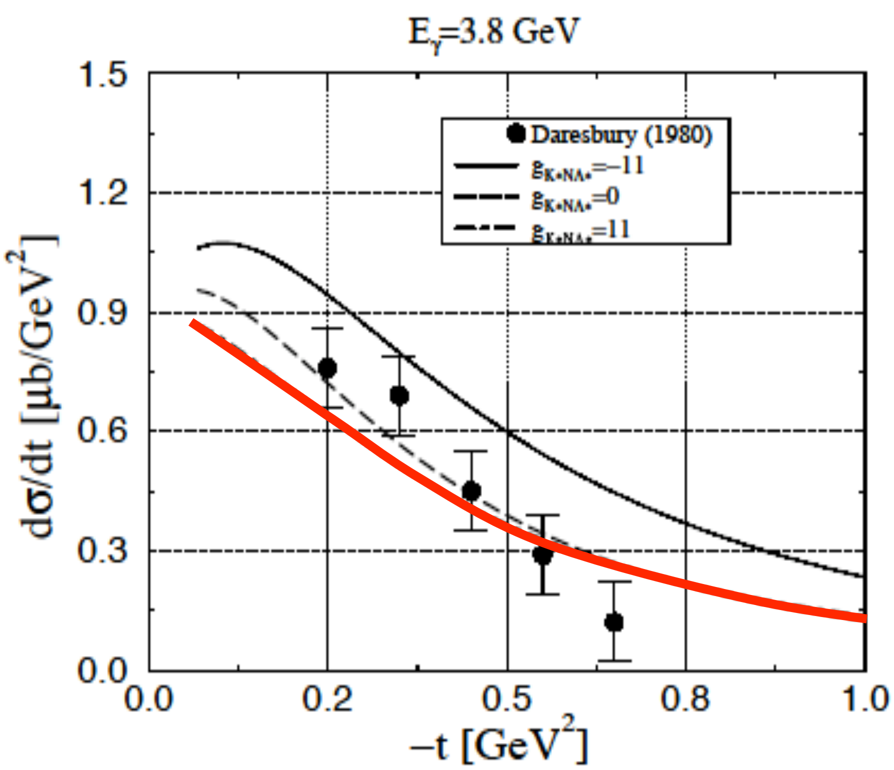
Consistent with the new data by Muramatsu et al 0904.2034[nucl-ex]

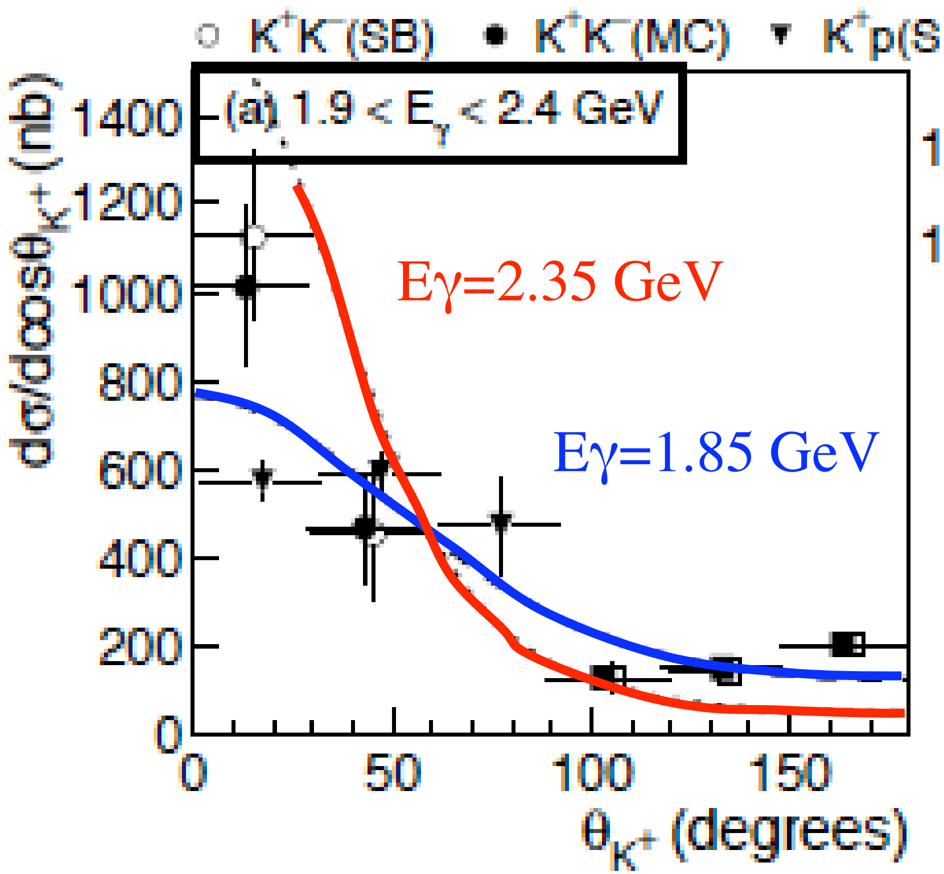
t/θ dependence

Forward peak

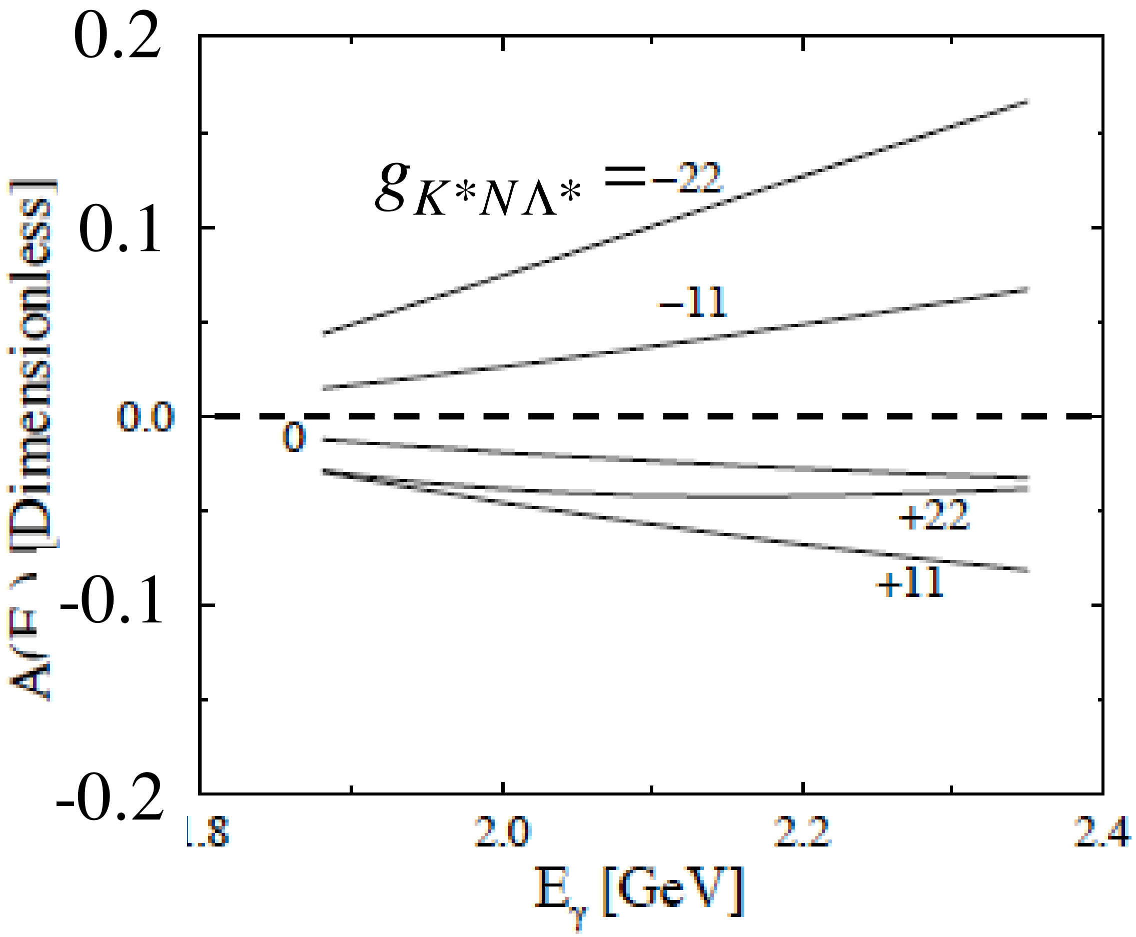
Data: D.P. Baber et al,
Z. Phys. C7, 17 (1980)

Muramatsu et al
0904.2034[nucl-ex]





Beam asymmetry



Quark model

$g_{K^*N\Lambda^*} \sim 10$

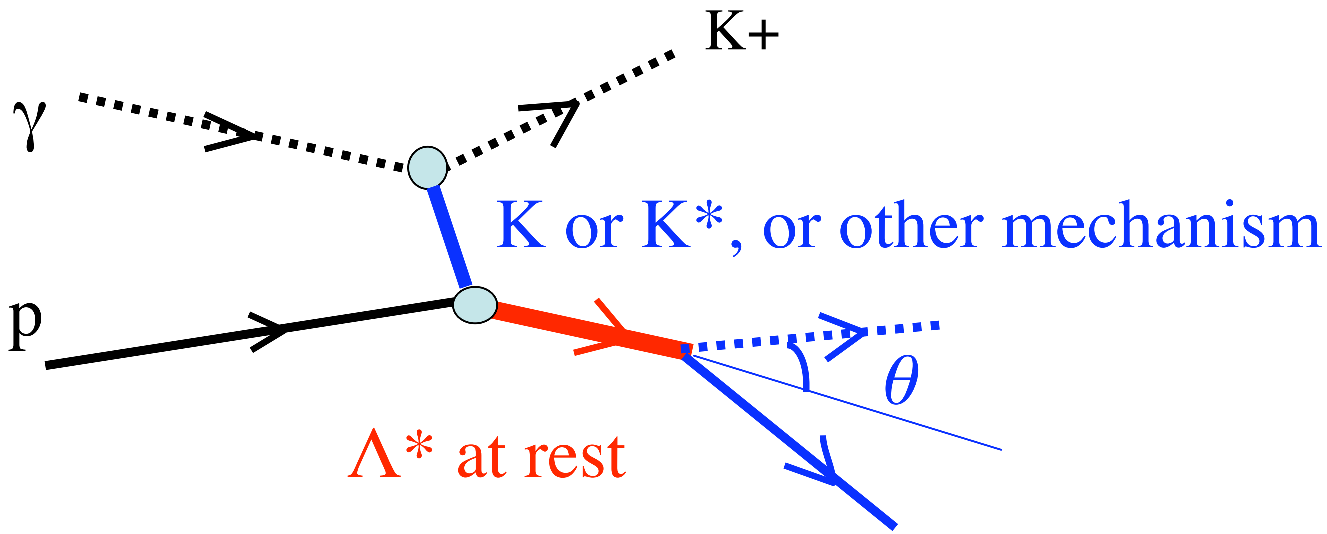
Chiral unitary

$g_{K^*N\Lambda^*} \sim 1.5$

−0.01±0.07

Muramatsu et al

Decay asymmetry



If $h(\Lambda^*) = 1/2$: $\cos^2\theta + \frac{1}{3}$

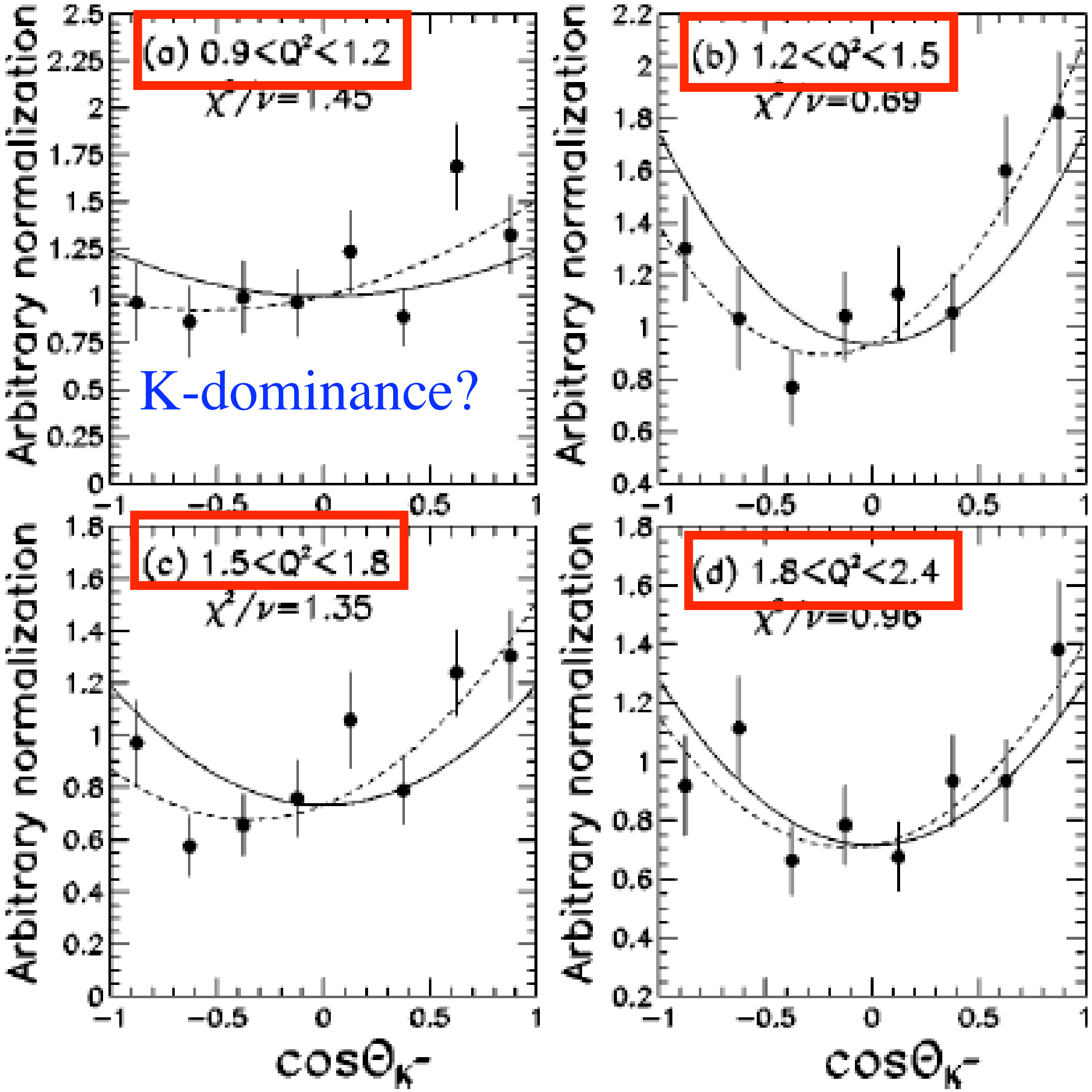
If $h(\Lambda^*) = 3/2$: $\sin^2\theta$

K-exch: $\cos^2\theta + \frac{1}{3}$

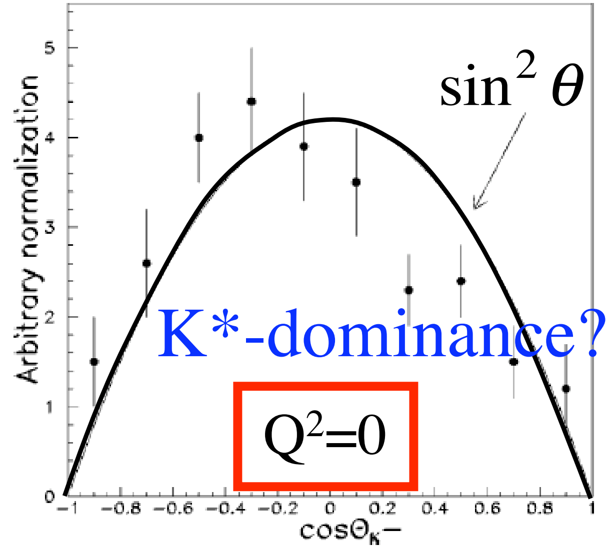
K*-exch: $\frac{2}{3}\sin^2\theta + \frac{4}{9}$

Contact: const

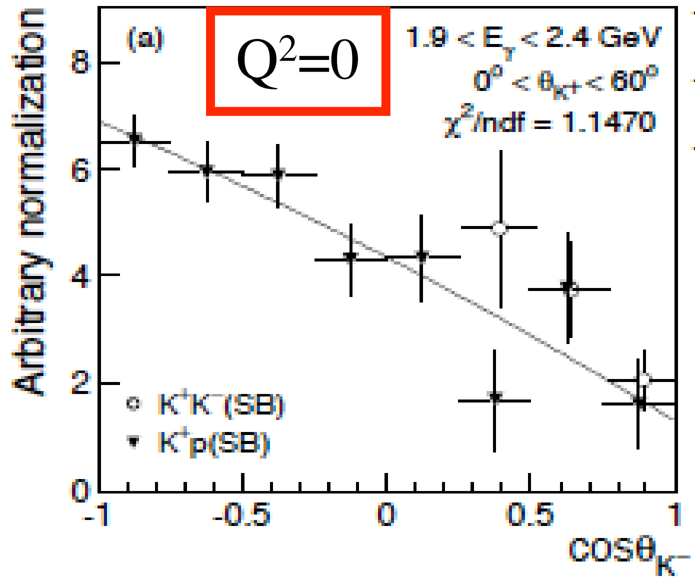
S. P. Barrow et al@JLab
PRC64, 044601 (2001)



D. Barber et al.,
Z. Phys. C7, 17 (1980)



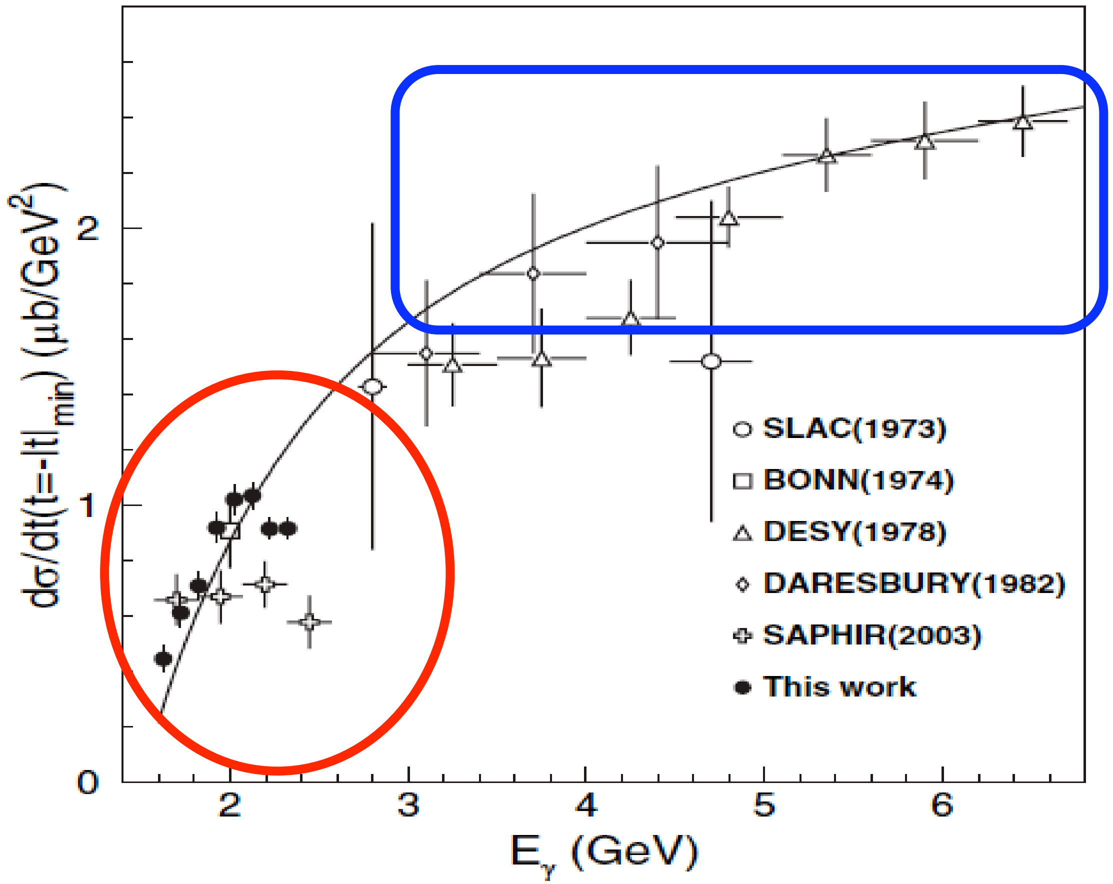
Muramatsu et al
0904.2034[nucl-ex]



The contact term
has weak θ-dependence

(4) ϕ production

γ N -> ϕ N

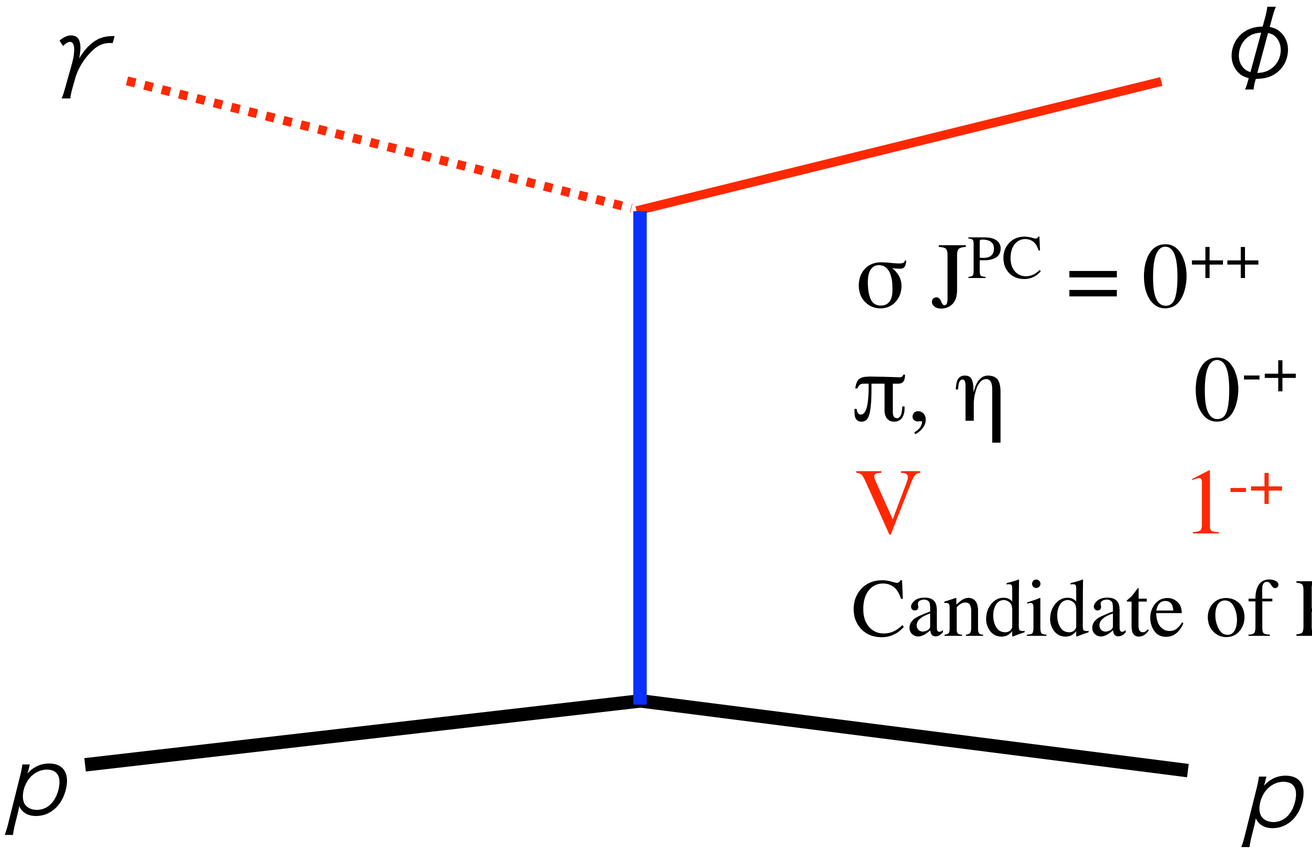


Increase as *E*

Bump at 2 GeV
or
Dip at 2.2 GeV

Mibe et al
PRL95,182001
(2005)

Increase via meson exchanges

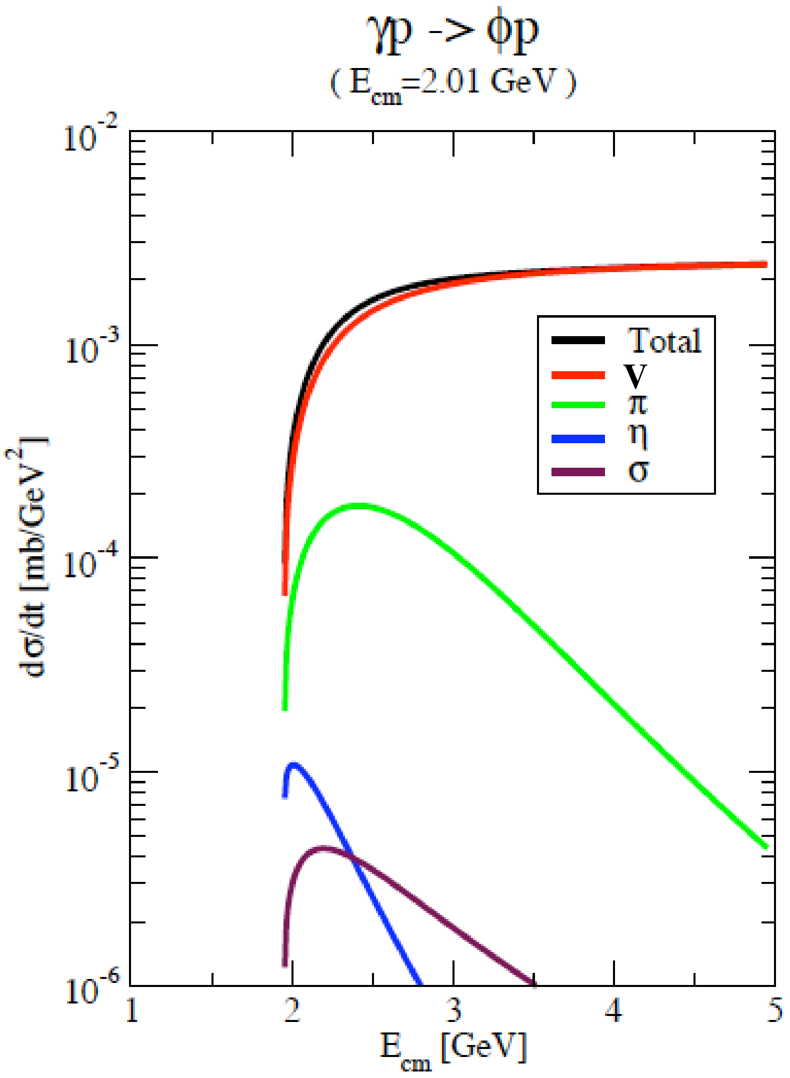


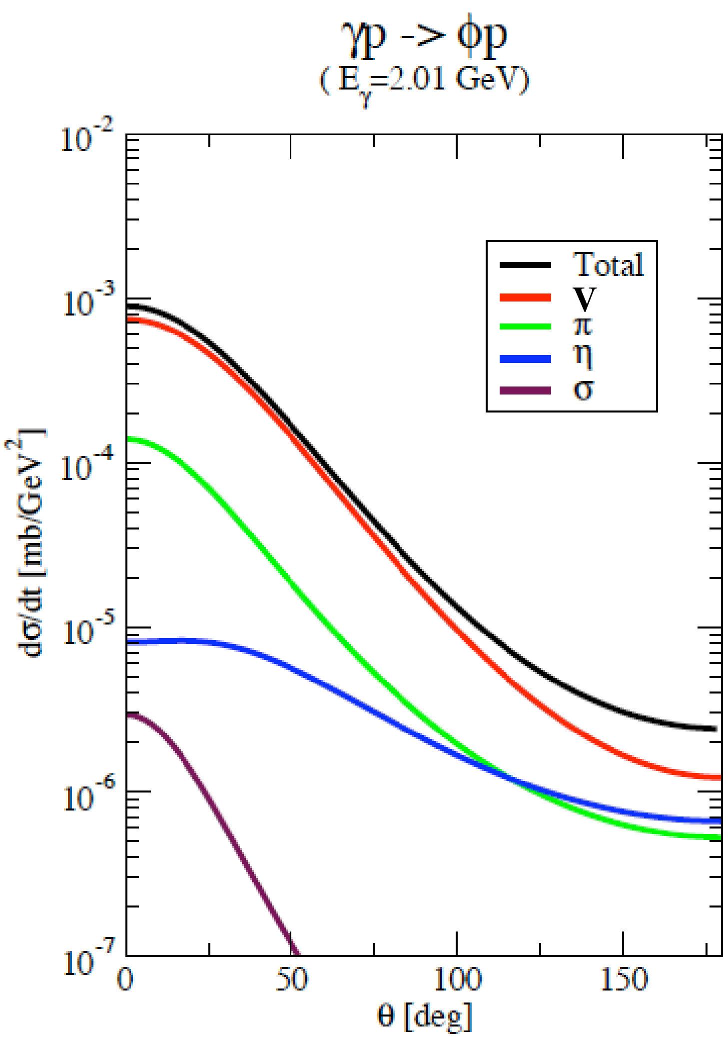
σ $J^{PC} = 0^{++}$

π, η 0^{-+}

V 1^{-+} $\sim \pi_1$?

Candidate of Pomeron





$g_{\omega NN}$=15.85 (Bonn Potential)

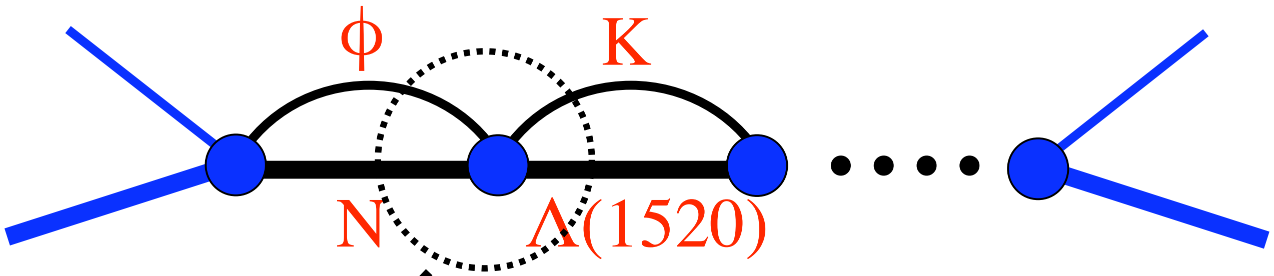
$g_{\omega\eta\phi}$=0.76 (Γ_ι=0.008)

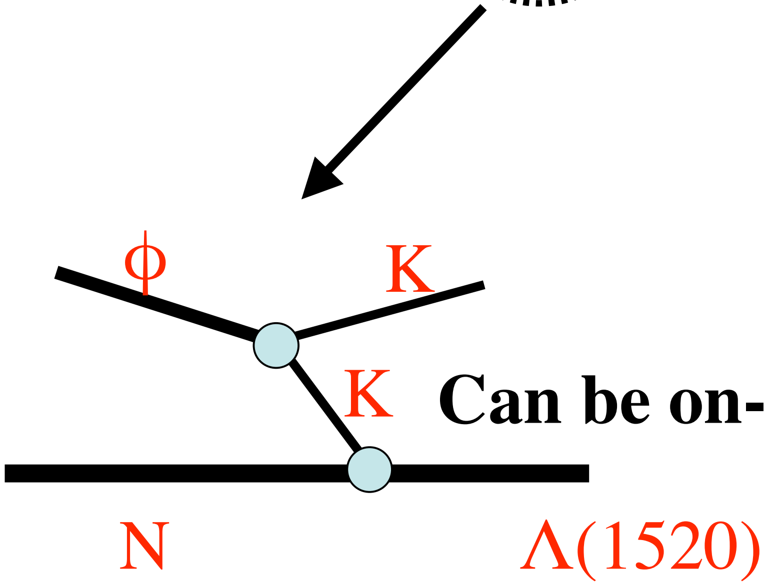
- Increasing as energy is increased
- Forward peak

Coupled channels for the bump?

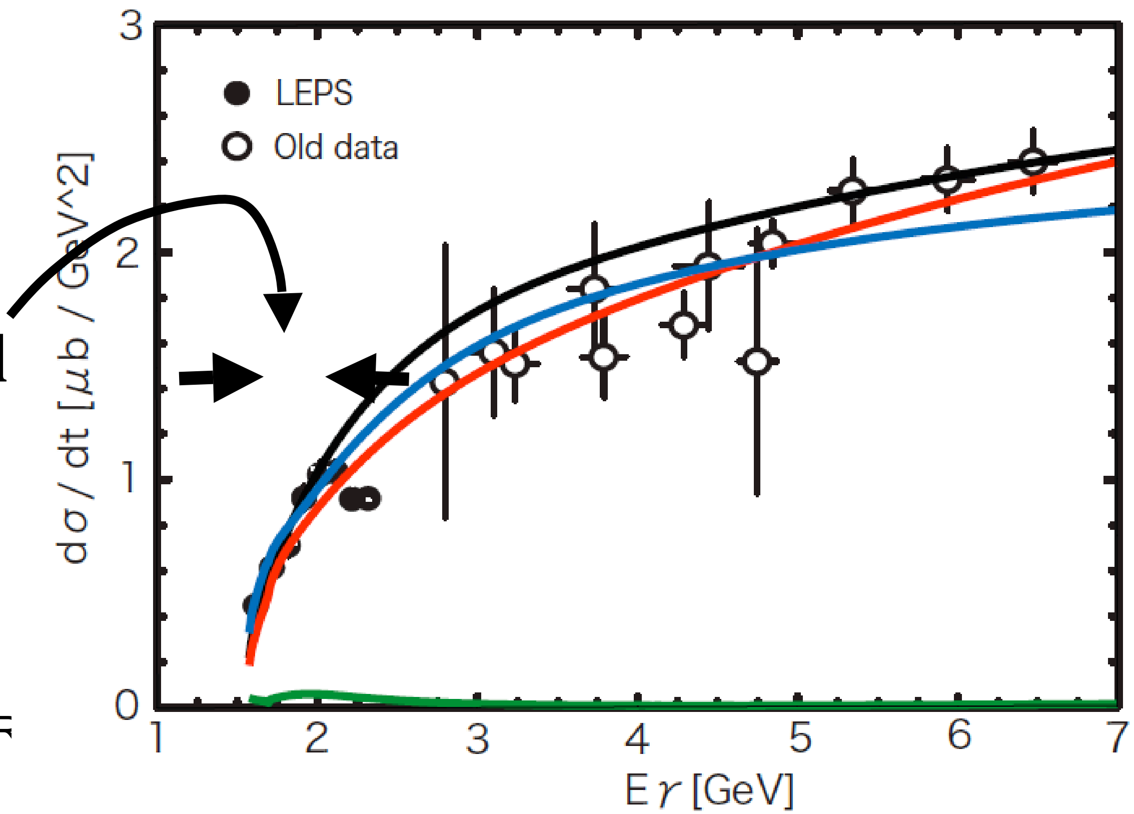
$\gamma N \to [\phi N, K\Lambda(1520), (K\Lambda, K\Sigma)] \to \phi N$

Ozaki-Nagahiro-Hosaka-Scholten



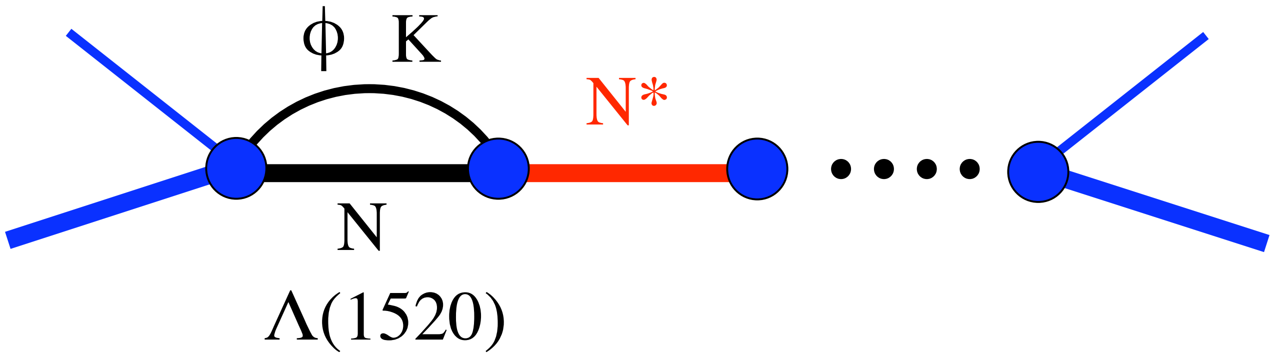


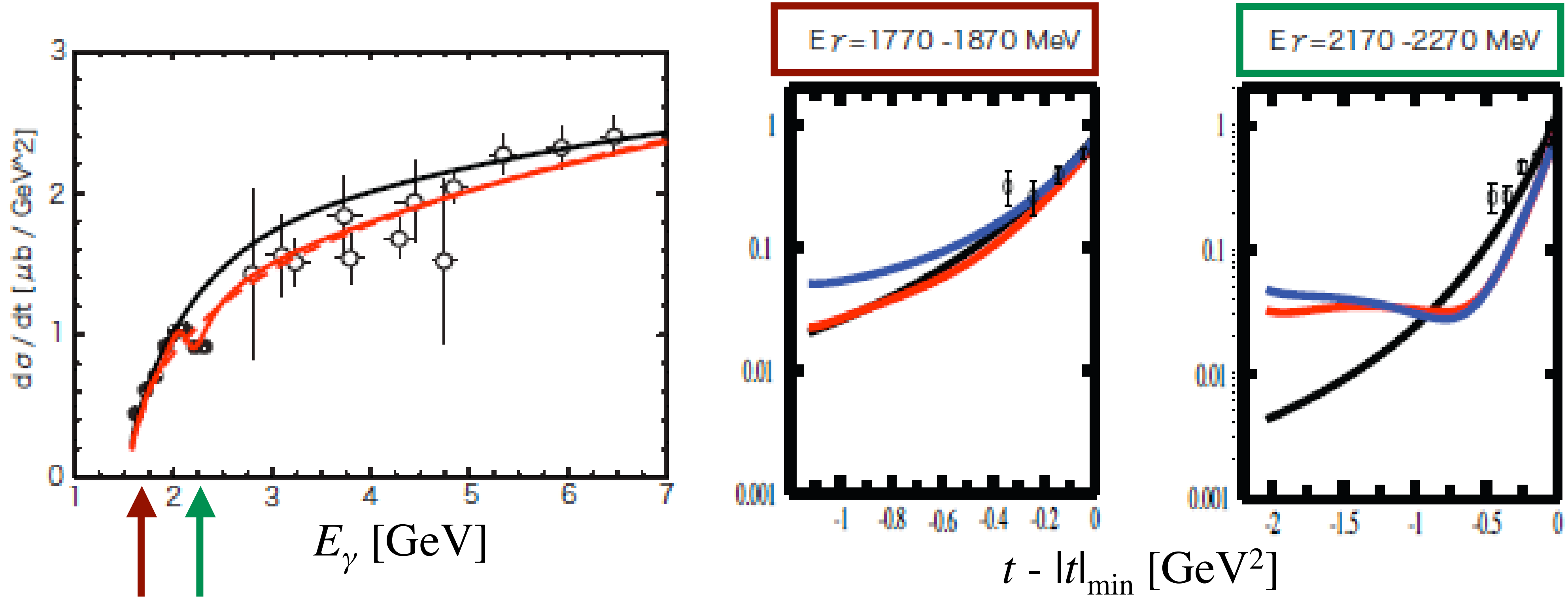
Can be on-shell



Resonance?

Titov, Lee, PRC, 065205 (2003)





3. Chiral symmetry of baryons

D. Jido, M. Oka, A. Hosaka,
Prog. Theor. Phys. 106 (2001) 823-834
Prog. Theor. Phys. 106 (2001) 873-908,
K. Nagata, A. Hosaka, V. Dmitrasinovic,
Phys. Rev. Lett. 101: 092001, 2008,
Eur. Phys. J, C57: 557-567, 2008

Does it make sense to talk about
linear representations *in the broken world?*
Asked by Weinberg, and the probable answer is YES
S. Weinberg, Phys. Rev. Lett. 65, 1177 (1990)
S. Weinberg, Phys. Rev. 177 (1969) 2604

Chiral representations

$\pi \sim qq^* \sim (1/2, 1/2) \sim \sigma$ $\qquad$ $\varrho, a_1 \sim (1,0)+(0,1)$

SU(2) x SU(2)

Parity pair

What are chiral representations of baryons?

qqq can accommodate only (1/2, 0)+(0, 1/2)

K. Nagata, A. Hosaka, V. Dmitrasinovic,
Eur. Phys. J, C57: 557-567, 2008

Complex structure allows any representations
$(A, B) + (B, A)$

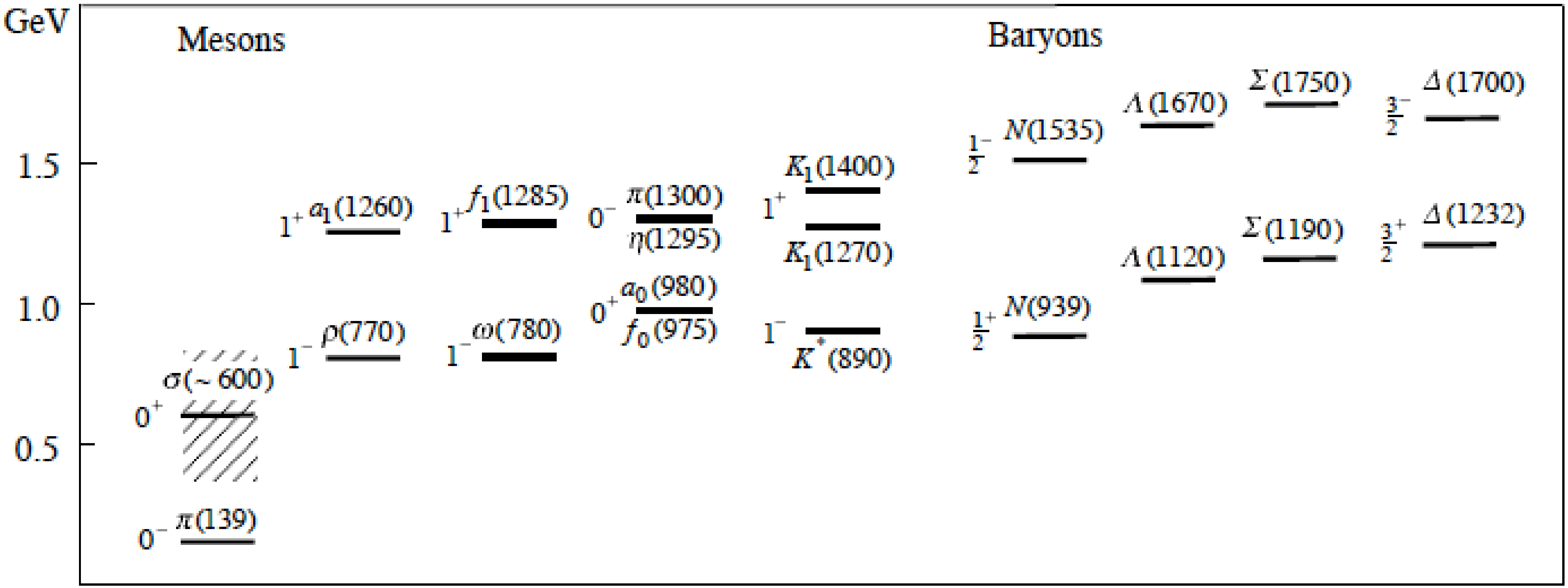


Fig. 1. Mass splittings of positive and negative parity hadrons in various channels. Data are taken from the Particle Data Booklet [11]. The uncertain mass of sigma (σ) is hatched.

Mirror representation

One of the simplest but nontrivial representation

Naive: (1/2, 0)+(0, 1/2)

$\psi_{\mathrm{L}} \quad + \quad \psi_{\mathrm{R}}$

qqq

$g_A = +1 \qquad g_{\pi BB} = +1$

Mirror representation

One of the simplest but nontrivial representation

Naive: (1/2, 0)+(0, 1/2)

$\psi_{\mathrm{L}} + \psi_{\mathrm{R}}$

qqq

$g_A = +1 \quad g_{\pi BB} = +1$

Mirror: (0, 1/2)+(1/2, 0)

$\psi_{\mathrm{L}} + \psi_{\mathrm{R}}$

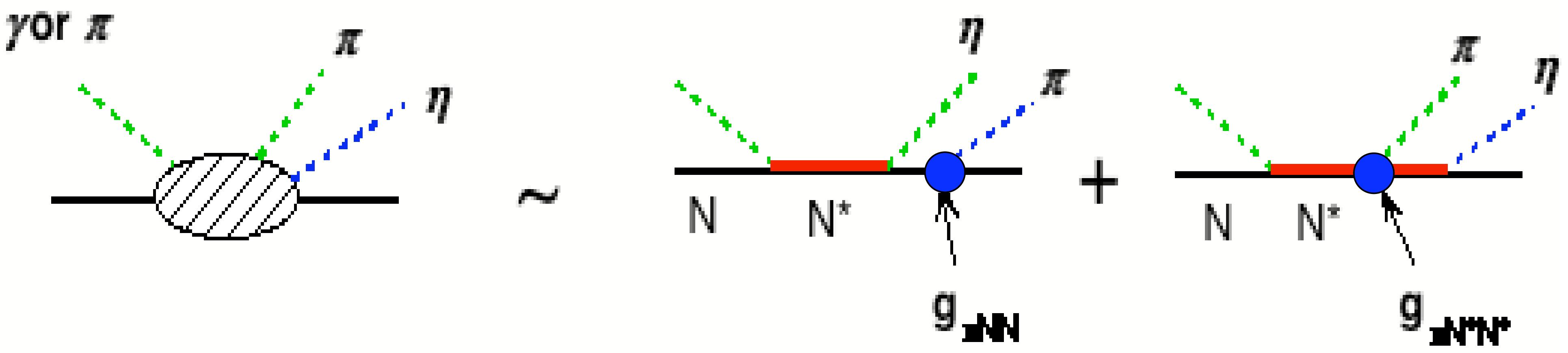
$qqqq\bar{q}$

$g_A = -1 \quad g_{\pi BB} = -1$

Axial-charge carry information on internal structure

Observe the sign of g_A

Assume minimal processes with N and $N(1535)$



\+ ….

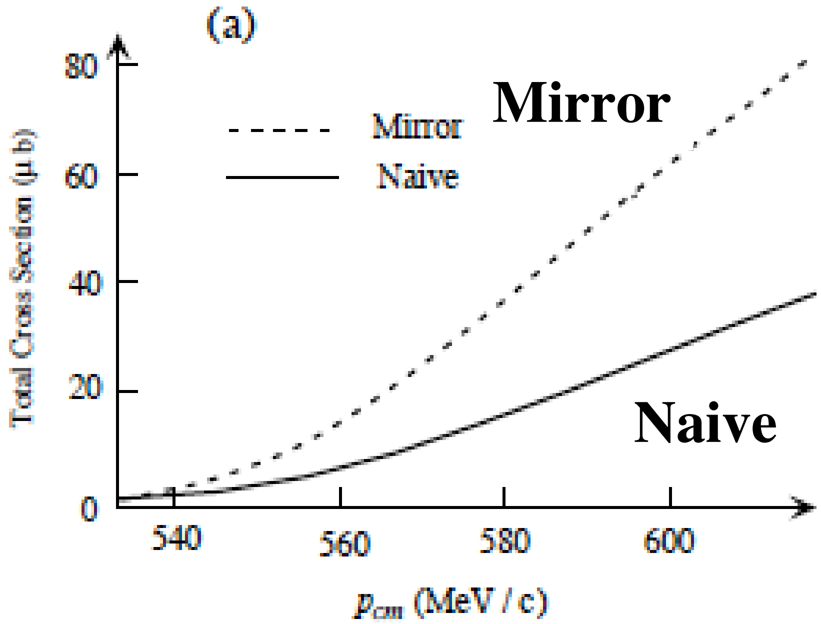
Naive: $g_{\pi N^* N^*} = g_{\pi NN}$ -> constructive

Mirror: $g_{\pi N^* N^*} = -g_{\pi NN}$ -> destructive

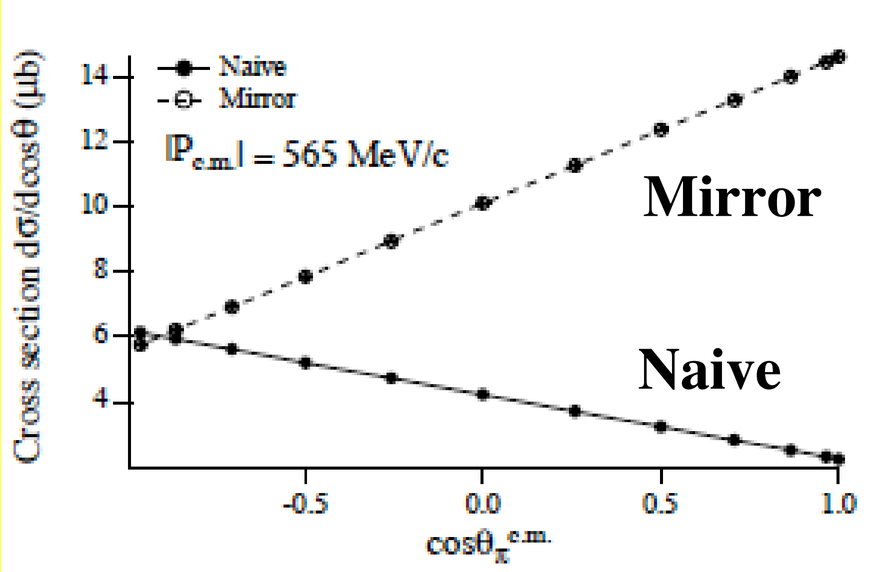
Pion-induced production

Jido, Oka, Hosaka
Prog. Theor. Phys. 106, 873, 2001

Total cross section



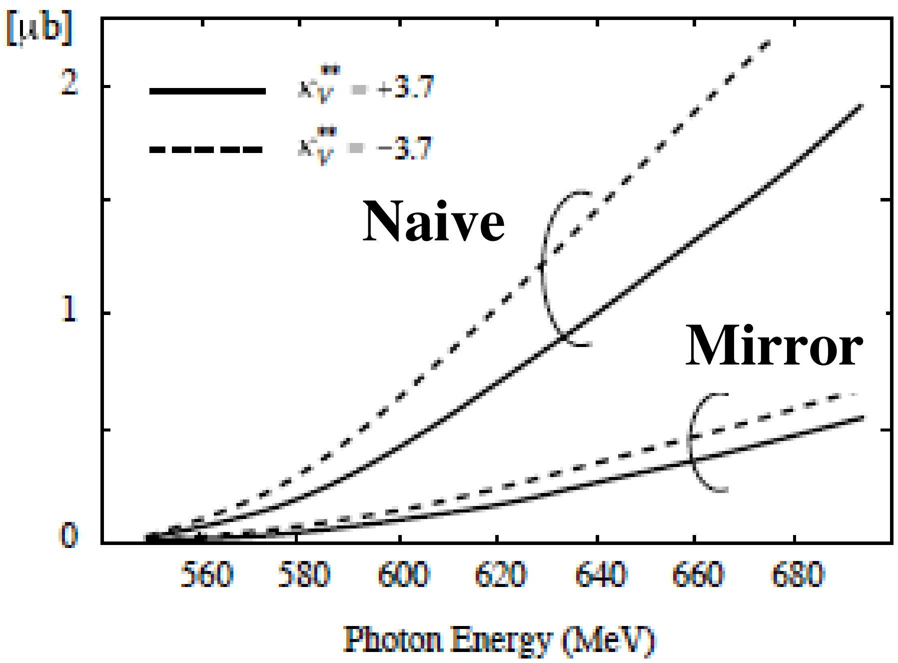
Angular distributions



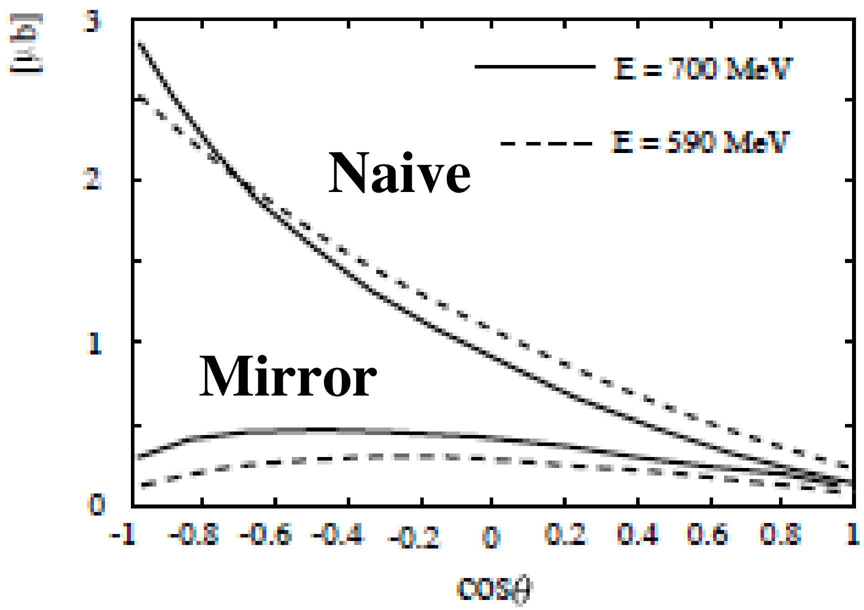
Photoproduction

Jido, Oka, Hosaka
Prog. Theor. Phys. 106, 873, 2001

Total cross section



Angular distributions



Summary

- Exotics may have *correlations*

  $q\bar{q}$, qq, qqq

  Question remains; how are they realized and observed

- Importance of the virtual meson clouds in KΛ prod.
- Λ(1405) seems very unusual
- Λ(1520) can be explained by standard react. mechanism

  Structure information is in various coupling constants

- Possible explanation of φ production: $N^* \sim 2100$ MeV

- Chiral symmetry repr. can be a measure of structure

  Mirror g_A is a good signal