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PHOTOPRODUCTION OF VECTOR MESONS – A REVIEW

KNU KYUNGPOOK NATIONAL UNIVERSITY
APCTP Asia Pacific Center for Theoretical Physics

CONTENTS

INTRODUCTION & MOTIVATION

- Vector meson photoproduction processes
  Missing resonance problem: resonances which couple strongly to, e.g., the VN channel but not to πN

S. Capstick and W. Roberts, Prog. Part. Nucl. Phys. 45 (2000)
V.D. Burkert and T.-S.H. Lee, Int. J. Mod. Phys. E 13 (2004)

- γN→VN is an elementary process for the study of medium modifications of vector mesons in nuclear photoproduction.

F. Riek et al., Phys. Lett. B 677 (2009), Phys. Rev. C 82 (2010)

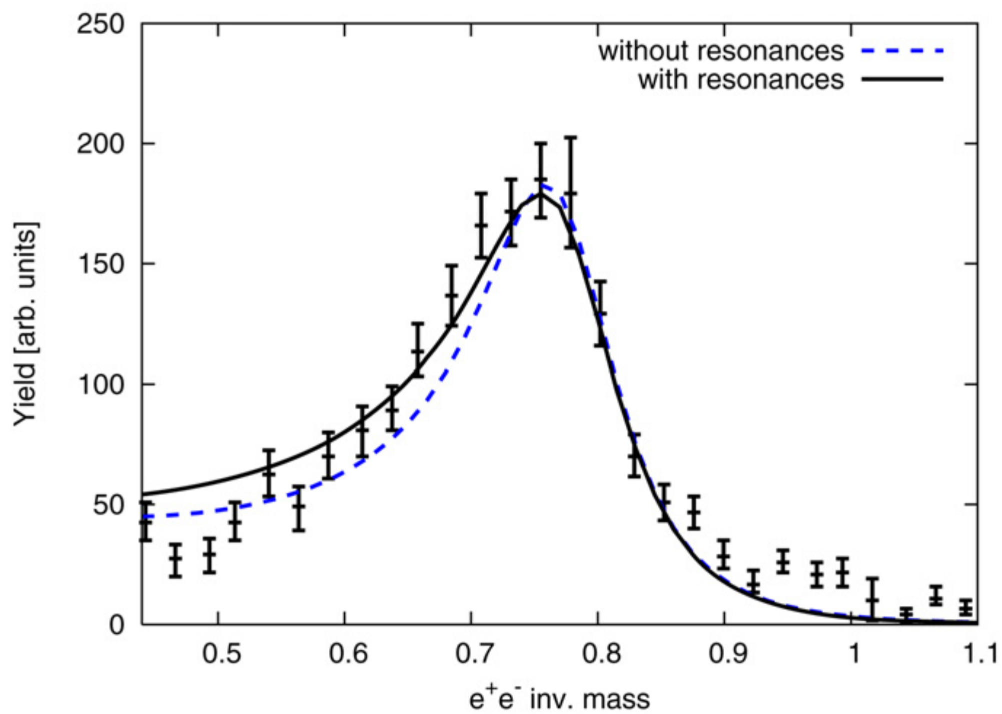
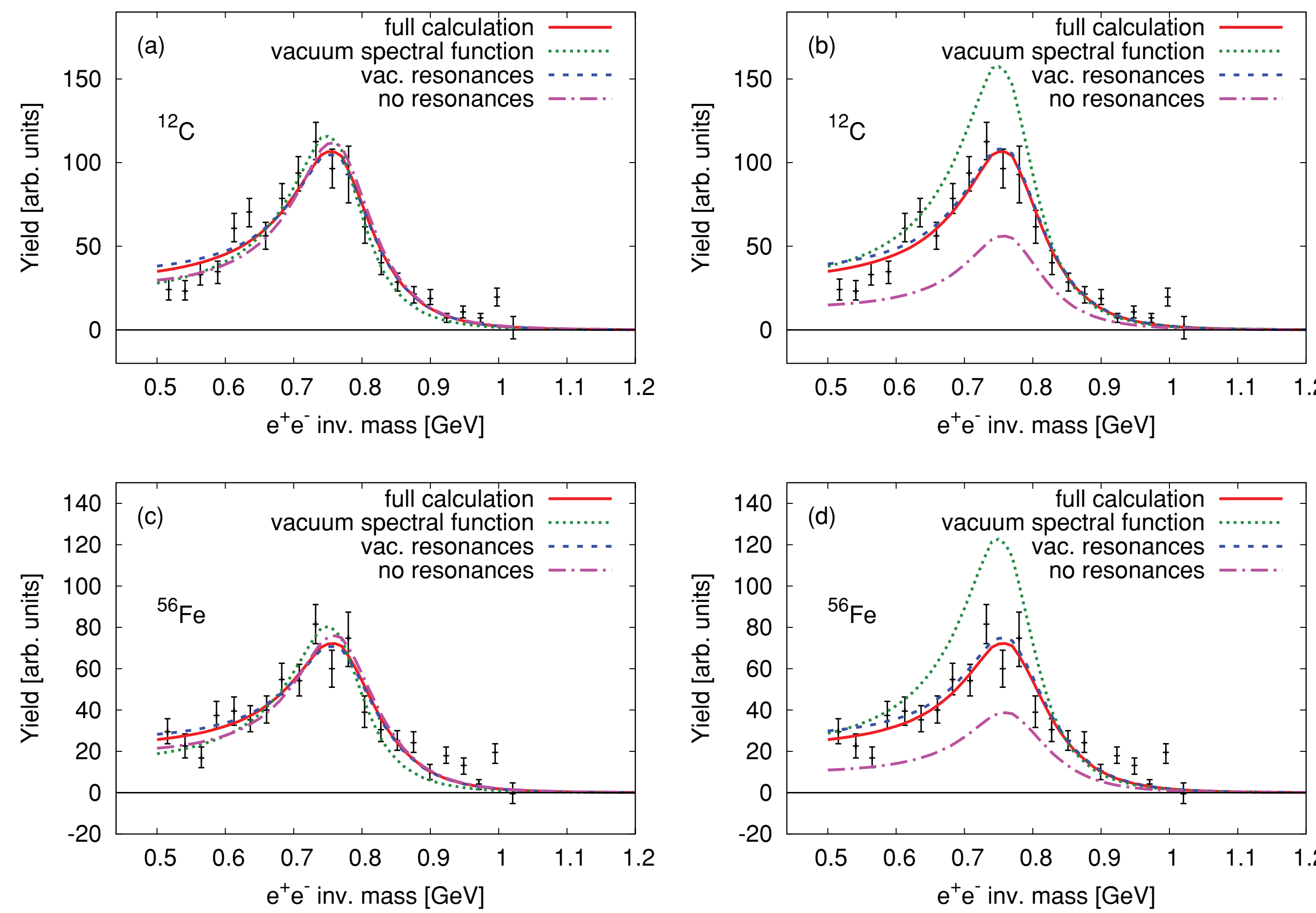
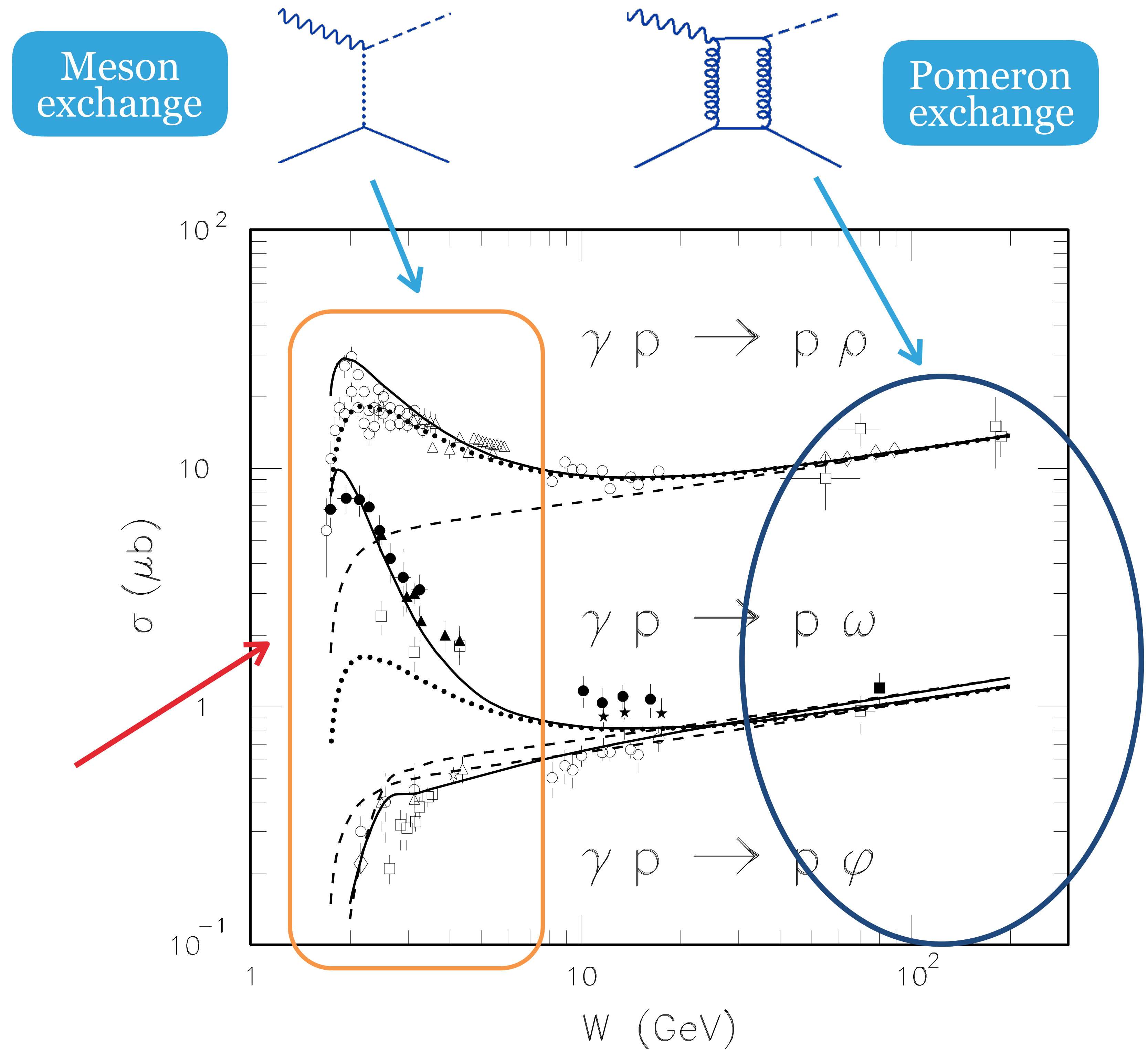


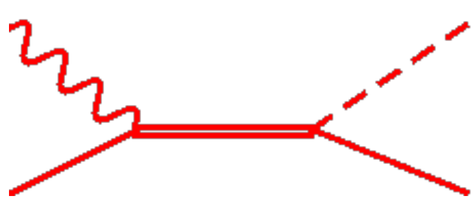
Fig. 3. Dilepton invariant-mass spectrum for ρ photoproduction off deuterium with (solid line) and without (dashed line) baryon resonance contributions, compared to CLAS data after subtraction of ω and ϕ contributions [7,8].



F. Riek et al., Phys. Lett. B 677 (2009), Phys. Rev. C 82 (2010)

Photoproduction of neutral vector mesons





Searching for missing resonances

J.M. Laget, PLB 489 (2000)

Search for excited baryons in 2-body **channels**

- *data acquired* - *analyzed/published*

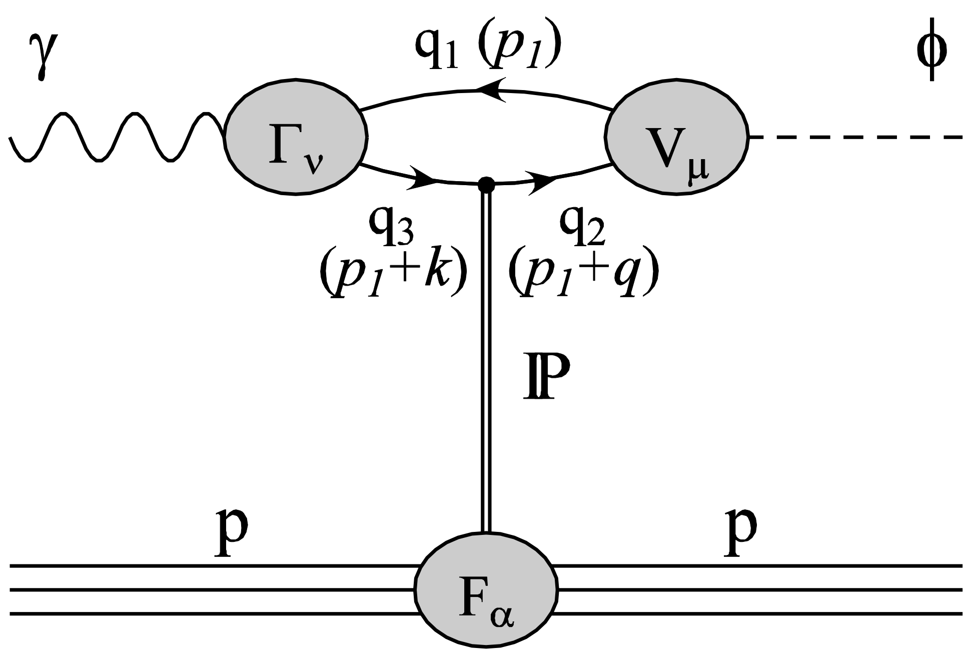
2018

Observable	σ	Σ	T	P	E	F	G	H	T_x	T_z	L_x	L_z	O_x	O_z	C_x	C_z
γp→X																
$p\pi^0$			✓		✓	✓	✓	✓								
$n\pi^+$			✓			✓	✓	✓								
$p\eta$			✓			✓	✓	✓								
$p\eta'$			✓		✓	✓	✓	✓								
$K^+\Lambda$					✓	✓	✓	✓	✓	✓	✓	✓				
$K^+\Sigma^0$					✓	✓	✓	✓	✓	✓	✓	✓				
$p\omega/\phi$						✓	✓	✓	SDME							
$K^{+*}\Lambda$									SDME							
$K^{0*}\Sigma^+$		✓									✓	✓	SDME			
γn→X																
$p\pi^-$						✓	✓									
$p\rho^-$	✓	✓			✓	✓	✓									
$K^-\Sigma^+$		✓			✓	✓	✓									
$K^0\Lambda$		✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
$K^0\Sigma^0$		✓	✓	✓		✓	✓		✓	✓	✓	✓	✓	✓	✓	✓
$K^{0*}\Sigma^0$	✓	✓									✓	✓				

K. Joo

PRODUCTION MECHANISMS

Pomeron Exchange Model



Donnachie-Landshoff

Pomeron: C=+1 isoscalar photon

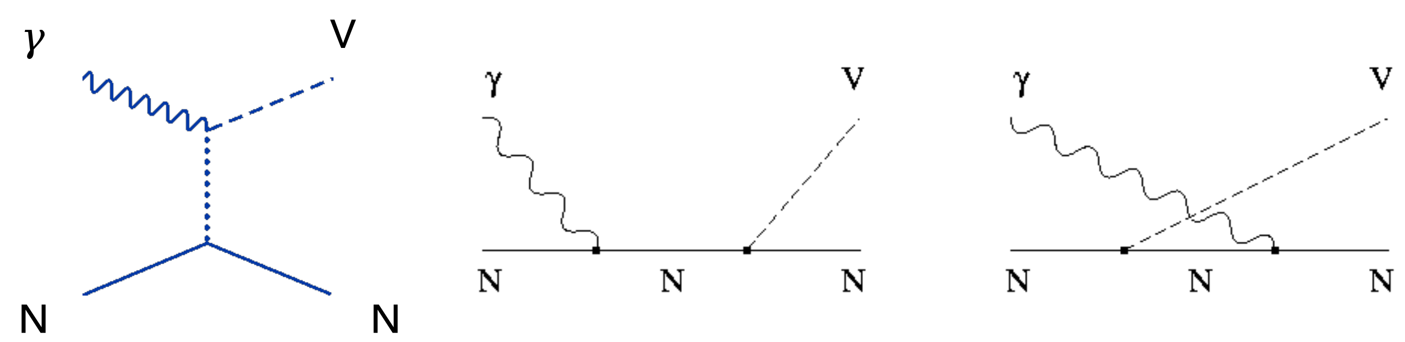
$$\mathcal{M} = \varepsilon_\nu(\gamma)\mathcal{M}^{\mu\nu}\varepsilon^*_\mu(V)$$

$$\mathcal{M}^{\mu\nu} = i12e\frac{M_V^2\beta_q\beta_{q'}}{f_V}\frac{1}{M_V^2-t}\left(\frac{2\mu_0^2}{2\mu_0^2+M_V^2-t}\right)F_1(t)\bar{u}(p')\left\{k\cdot\gamma g^{\mu\nu}-k^\mu\gamma^\nu\right\}u(p)G_P(t)$$

$$G_P(t) = \left(\frac{s}{s_0}\right)^{\alpha(t)-1}\exp\left\{-i\frac{\pi}{2}\left[\alpha(t)-1\right]\right\}, \qquad \alpha(t) = 1.08+0.25t$$

PRODUCTION MECHANISMS

Meson exchange and nucleon pole terms



$$\mathcal{L} = \frac{e g_{V\gamma\varphi}}{M_V}\varepsilon^{\mu\nu\alpha\beta}\partial_\mu V_\nu \partial_\alpha A_\beta \varphi + \frac{g_{\varphi NN}}{2M_N}\bar{N}\gamma^\mu\gamma_5\partial_\mu\varphi N - e\bar{N}\left(A_\mu\gamma^\mu - \frac{\kappa_p}{2M_N}\sigma_{\mu\nu}\partial^\nu A^\mu\right)N + \mathcal{L}_{VNN}$$

Couplings from

and pion photoproduction studies, etc

$g^2_{\pi NN}/4\pi = 14,\ \ g^2_{\eta NN}/4\pi = 1,\ \ g_{\rho NN} = 6.2,\ \ \kappa_\rho = 1.0,\ \ g_{\omega NN} = 10.3,\ \ \kappa_\omega = 0$ $\quad g_{\omega\gamma\pi} = 1.8,$ $\quad g_{\omega\gamma\eta} = 0.4$

ω meson photoproduction

B. Friman and M. Soyeur, Nucl. Phys. A 600 (1996)

- Main non-resonant production mechanism: pion exchange
- Other mechanisms include Pomeron, eta, nucleon exchanges
- Resonant amplitudes

$$I^{N^*}(q,k) = \sum_{J,M_J} \frac{\mathrm{M}_{N^*\to N\omega}(q;J,M_J)\,\mathrm{M}_{\gamma N\to N^*}(k;J,M_J)}{\sqrt{s} - M_R^J + \frac{i}{2}\Gamma^J(s)}$$

- Only N* can contribute. *Δ** contribution is not allowed by isospin.
- Use the N* parameters from the quark model of Capstick and Roberts (PRD46,PRD49)
- 12 positive-parity N*'s and 10 negative-parity N*'s
- N*'s above wN threshold are considered

Y. Oh, A.I. Titov, and T.-S.H. Lee, Phys. Rev. C 63 (2001)

PHYSICAL REVIEW C, VOLUME 63, 025201

Nucleon resonances in ω photoproduction

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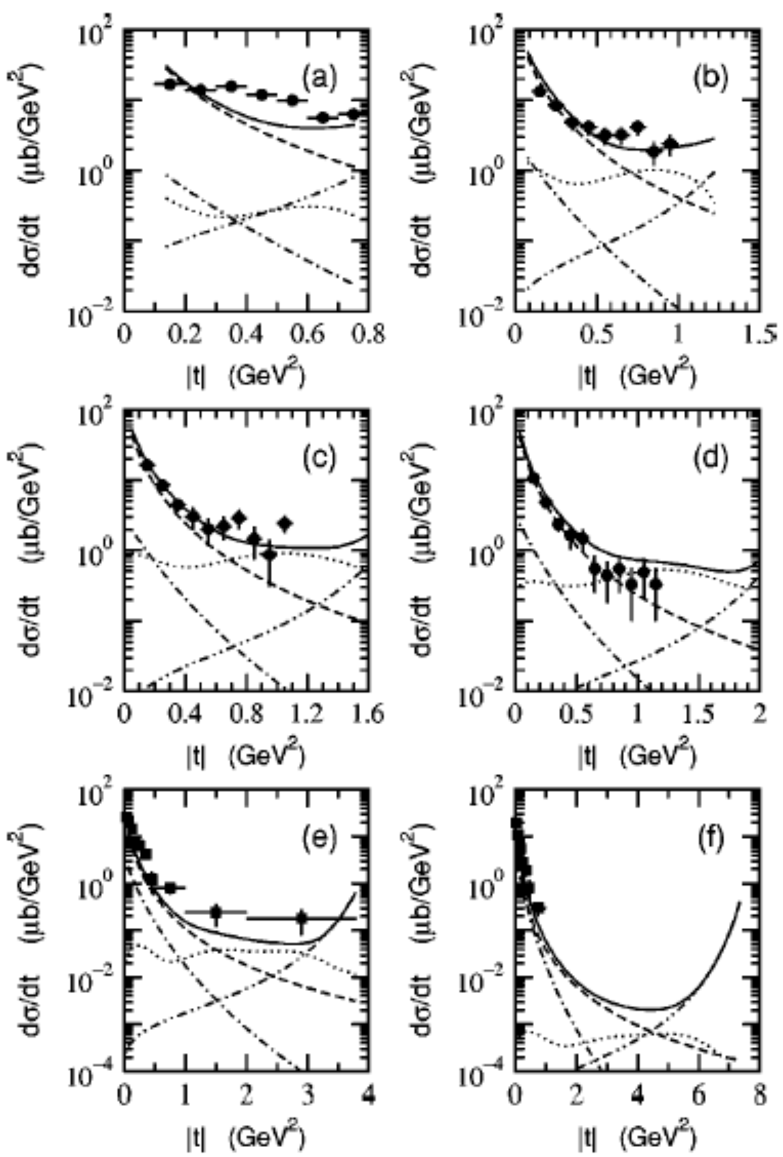
(Received 27 June 2000; published 4 January 2001)

The role of the nucleon resonances (N^*) in ω photoproduction is investigated by using the resonance parameters predicted by Capstick and Roberts [Phys. Rev. D **46**, 2864 (1992); **49**, 4570 (1994)]. In contrast with the previous investigations based on the SU(6)×O(3) limit of the constituent quark model, the employed



Data: SAPHIR 1996 (a-d)
SLAC 1973 (e-f)

E_γ = (a) 1.23 GeV, (b) 1.45 GeV, (c) 1.68 GeV, (d) 1.92 GeV, (e) 2.8 GeV, (f) 4.7 GeV

solid: total
dashed: ps-meson exchange
dot-dashed: Pomeron exchange
dot-dot-dashed: nucleon
dotted: N*

Dominant N*:
N(1910) with $3/2^+$ - missing resonance
N(1960) with $3/2^-$ - D_{13}(2080) in PDG

IMPROVED APPROACHES

- Relativistic treatment including N*'s below threshold:

  A.I. Titov and T.-S.H. Lee, Phys. Rev. C 66 (2002)

- Pion loop corrections

  Y. Oh and T.-S.H. Lee, Phys. Rev. C 66 (2002)

- Coupled channel effects

  G. Penner and U. Mosel, Phys. Rev. C 66 (2002)

- New data from CLAS

  CLAS, Phys. Rev. C 80 (2009), Phys. Lett. B 773 (2017),
  Phys. Rev. C 96 (2017), Phys. Rev. Lett. 122 (2019)

  GRAAL, Phys. Rev. C 91 (2015)

RECENT ANALYSES

Physics Letters B 755 (2016) 97–101

Contents lists available at ScienceDirect

Physics Letters B

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N^* decays to $N\omega$ from new data on $\gamma p \to \omega p$

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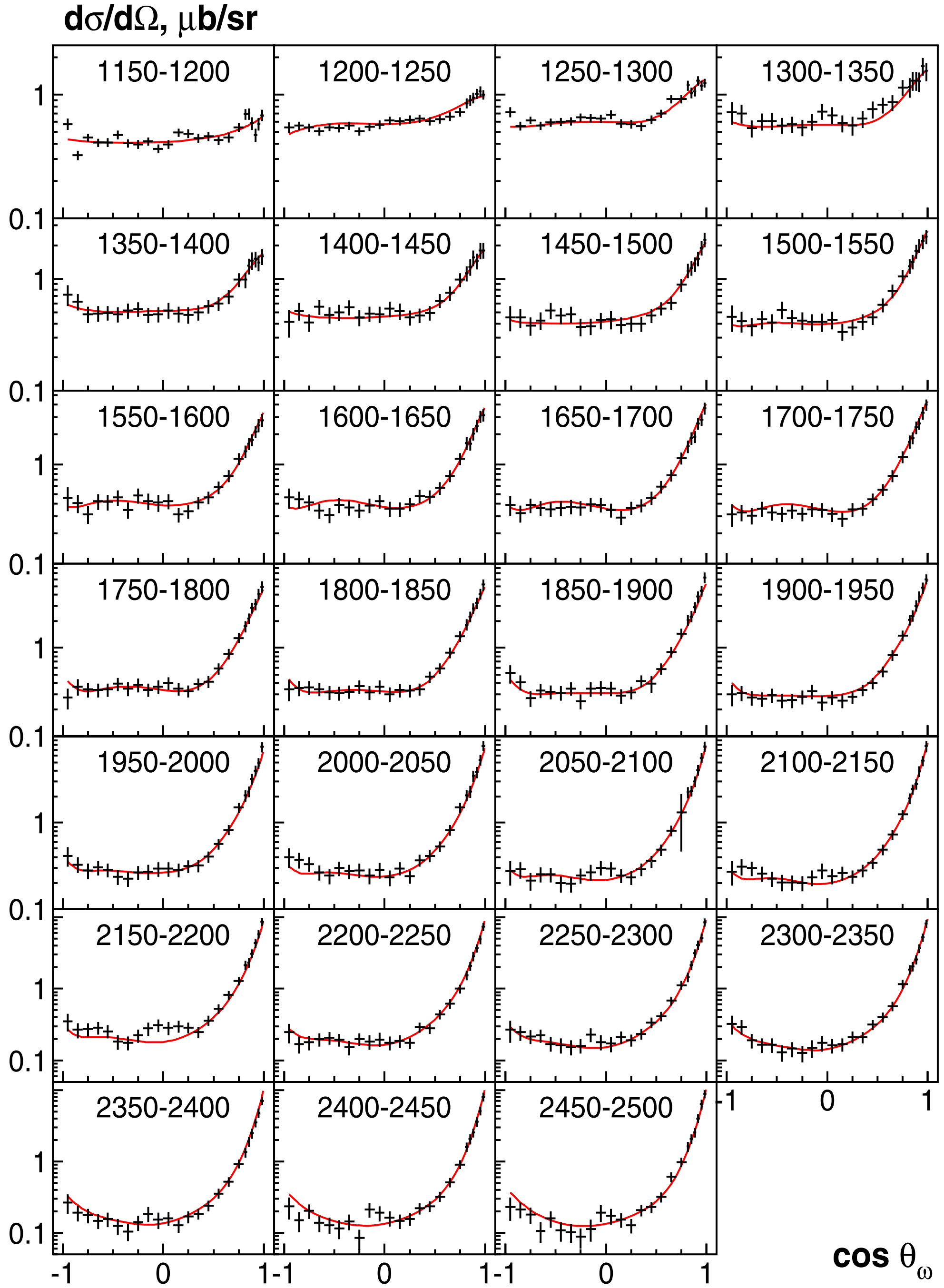
ABSTRACT

Data on the reaction $\gamma p \to \omega p$ with $\omega \to \pi^0\gamma$, taken with unpolarized or polarized beams in combination with an unpolarized or polarized proton-target, were analyzed within the Bonn–Gatchina (BnGa) partial wave analysis. Differential cross sections, several spin density matrix elements, the beam asymmetry Σ, the normalized helicity difference E, and the correlation G between linear photon and longitudinal target polarization were included in a large data base on pion and photo-induced reactions. The data on ω photoproduction are used to determine twelve $N^* \to N\omega$ branching ratios; most of these are determined for the first time.



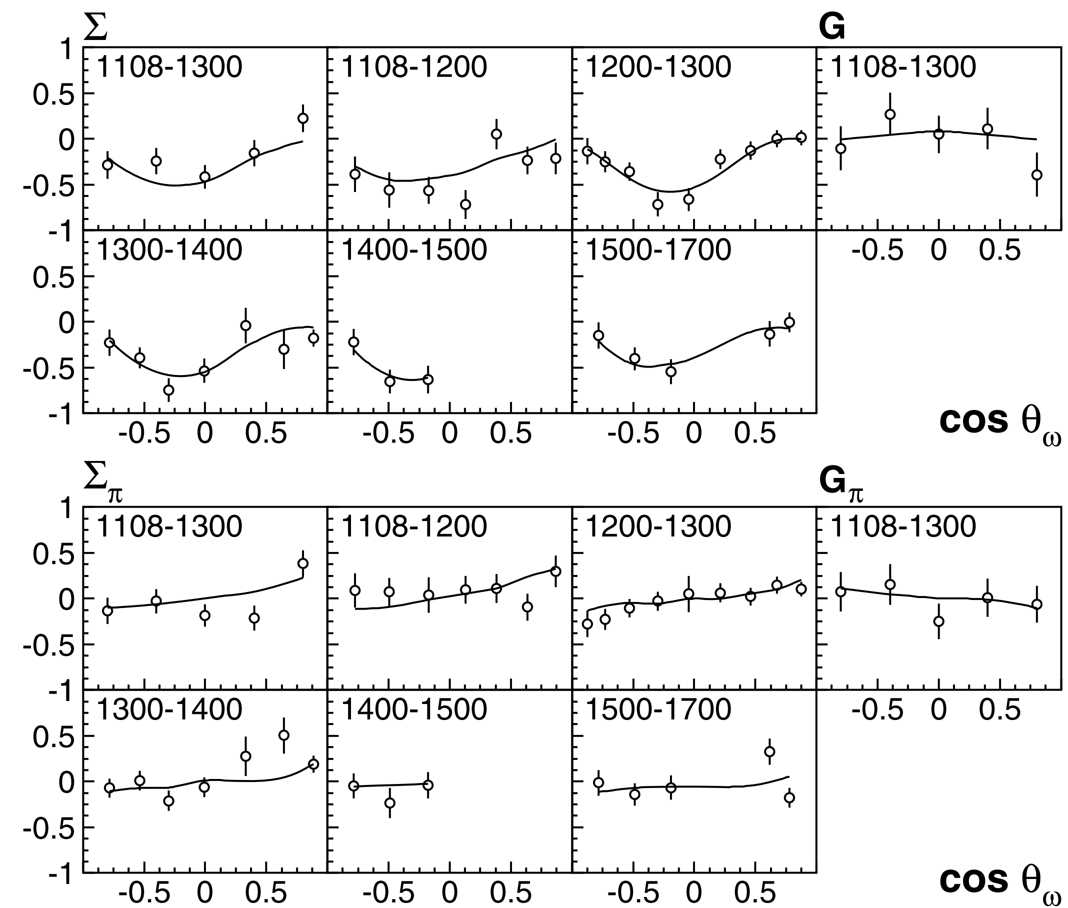


Table 2
Branching ratios (B.R. in %) for N^* decays into $N\omega$. Small numbers were reported in [15]. The $\delta(\chi^2)$ values give the change in χ^2 when the $N\omega$ decay mode is excluded.

Resonance	B.R.	$\delta(\chi^2)$	Resonance	B.R.	$\delta(\chi^2)$
$N(1700)3/2^-$	22 ± 12	100	$N(1900)3/2^+$	15 ± 8	70
				13 ± 9	
$N(1710)1/2^+$	2 ± 2	26	$N(2000)5/2^+$	18 ± 8	42
	8 ± 5			1 ± 1	
$N(1720)3/2^+$	26 ± 14	105	$N(2060)5/2^-$	4 ± 3	37
$N(1875)3/2^-$	13 ± 7	98	$N(2100)1/2^+$	15 ± 10	78
	20 ± 4				
$N(1880)1/2^+$	20 ± 8	33	$N(2150)3/2^-$	12 ± 8	99
$N(1895)1/2^-$	28 ± 12	100	$N(2190)7/2^-$	14 ± 6	131

RECENT ANALYSES

Nucleon resonances in $\gamma p \to \omega p$ reaction

arXiv:1908.01139

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(Dated: August 6, 2019)

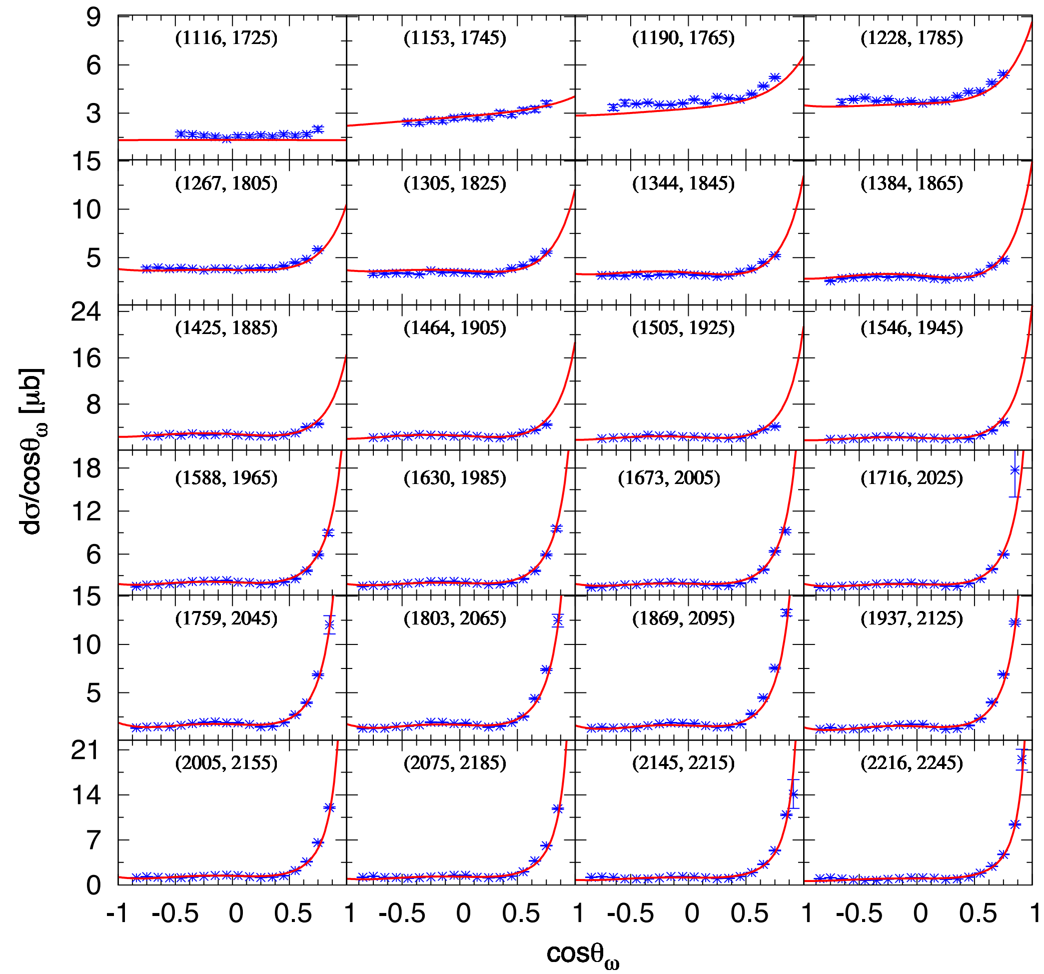
The most recent high-precision data on spin observables Σ, T, P', E, F and H reported by the CLAS Collaboration together with the previous data on differential cross sections and spin-density-matrix elements reported by the CLAS, A2, GRAAL, SAPHIR and CBELSA/TAPS Collaborations for the reaction $\gamma p \to \omega p$ are analyzed within an effective Lagrangian approach. The reaction amplitude is constructed by considering the t-channel π and η exchanges, the s-channel nucleon and nucleon resonances exchanges, the u-channel nucleon exchange and the generalized contact current, with the last one being formulated to ensure that the full photoproduction amplitudes satisfy the generalized Ward-Takahashi identity and thus are fully gauge invariant. It is shown that all the available CLAS data can be satisfactorily described by considering the $N(1520)3/2^-$, $N(1700)3/2^-$, $N(1720)3/2^+$, $N(1860)5/2^+$, $N(1875)3/2^-$, $N(1895)1/2^-$ and $N(2060)5/2^-$ exchanges in the s channel. The parameters of these resonances are extracted and compared with those quoted by PDG.

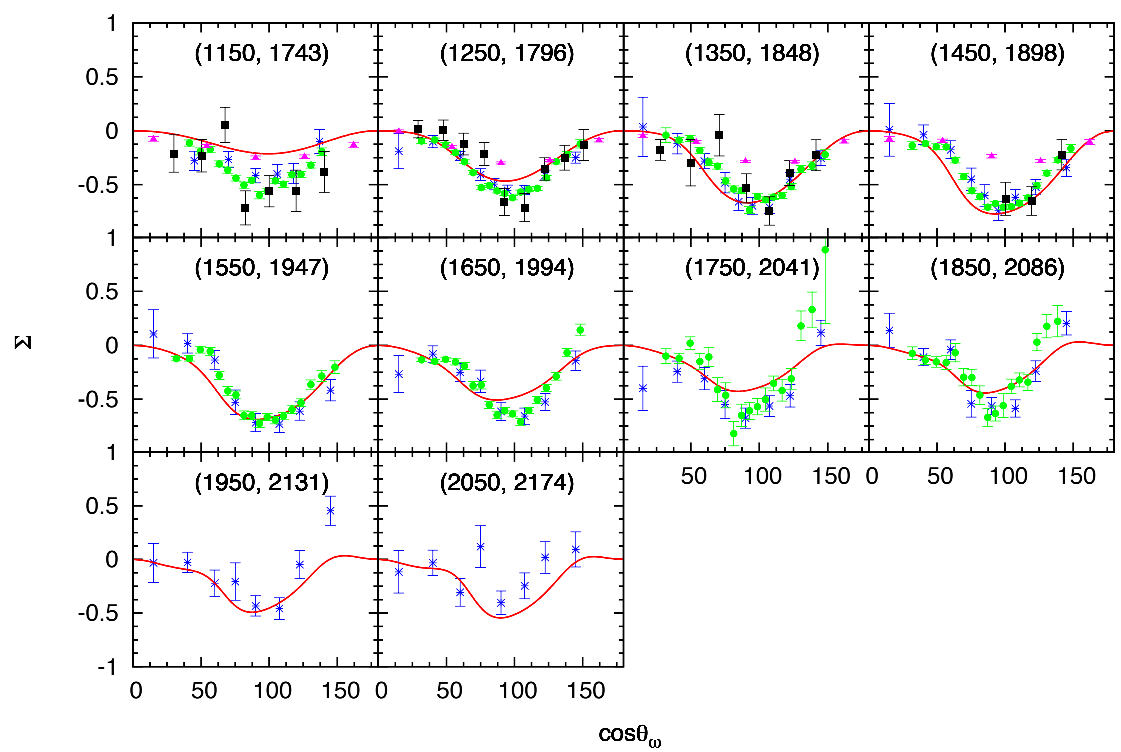
$$\mathcal{L}^{1/2\pm}_{RN\omega} = -\frac{g_{RN\omega}}{2M_N}\bar{R}\Gamma^{(\mp)}\left\{\left[\left(\frac{\gamma_\mu\partial^2}{M_R \mp M_N} \pm i\partial_\mu\right) - \frac{f_{RN\omega}}{g_{RN\omega}}\sigma_{\mu\nu}\partial^\nu\right]\omega^\mu\right\} N + \text{H.c.}, \quad (19)$$

$$\mathcal{L}^{3/2\pm}_{RN\omega} = -i\frac{g^{(1)}_{RN\omega}}{2M_N}\bar{R}_\mu\gamma_\nu\Gamma^{(\pm)}\omega^{\mu\nu}N + \frac{g^{(2)}_{RN\omega}}{(2M_N)^2}\bar{R}_\mu\Gamma^{(\pm)}\omega^{\mu\nu}\partial_\nu N \mp \frac{g^{(3)}_{RN\omega}}{(2M_N)^2}\bar{R}_\mu\Gamma^{(\pm)}\left(\partial_\nu\omega^{\mu\nu}\right)N + \text{H.c.}, \quad (20)$$

$$\mathcal{L}^{5/2\pm}_{RN\omega} = \frac{g^{(1)}_{RN\omega}}{(2M_N)^2}\bar{R}_{\mu\alpha}\gamma_\nu\Gamma^{(\mp)}\left(\partial^\alpha\omega^{\mu\nu}\right)N \pm i\frac{g^{(2)}_{RN\omega}}{(2M_N)^3}\bar{R}_{\mu\alpha}\Gamma^{(\mp)}\left(\partial^\alpha\omega^{\mu\nu}\right)\partial_\nu N \mp i\frac{g^{(3)}_{RN\omega}}{(2M_N)^3}\bar{R}_{\mu\alpha}\Gamma^{(\mp)}\left(\partial^\alpha\partial_\nu\omega^{\mu\nu}\right)N + \text{H.c.}, \quad (21)$$

$$\mathcal{L}^{7/2\pm}_{RN\omega} = i\frac{g^{(1)}_{RN\omega}}{(2M_N)^3}\bar{R}_{\mu\alpha\beta}\gamma_\nu\Gamma^{(\pm)}\left(\partial^\alpha\partial^\beta\omega^{\mu\nu}\right)N - \frac{g^{(2)}_{RN\omega}}{(2M_N)^4}\bar{R}_{\mu\alpha\beta}\Gamma^{(\pm)}\left(\partial^\alpha\partial^\beta\omega^{\mu\nu}\right)\partial_\nu N \pm \frac{g^{(3)}_{RN\omega}}{(2M_N)^4}\bar{R}_{\mu\alpha\beta}\Gamma^{(\pm)}\left(\partial^\alpha\partial^\beta\partial_\nu\omega^{\mu\nu}\right)N + \text{H.c.}, \quad (22)$$





ρ meson photoproduction

- σ meson exchange model B. Friman and M. Soyeur, Nucl. Phys. A 600 (1996) to describe the low energy region
  ⇨ one pion exchange is suppressed due to small $\Gamma(\rho \to \pi\gamma)$
  ⇨ $\Gamma(\rho \to \pi\pi\gamma)$ is large instead, so its effect should be taken into account. The 2π is then modeled by the σ meson.

$\rho(770)^0$ decays

Γ_6	$\pi^+\pi^-$		$\sim$ 100	%	
Γ_7	$\pi^+\pi^-\gamma$		(9.9 ±1.6)	$\times 10^{-3}$	
Γ_8	$\pi^0\gamma$		(6.2 ±1.3)	$\times 10^{-4}$	S=1.1
Γ_9	$\eta\gamma$		(3.1 ±0.4)	$\times 10^{-4}$	S=1.4
Γ_{10}	$\pi^0\pi^0\gamma$		(4.1 ±1.0)	$\times 10^{-5}$	
Γ_{11}	$\mu^+\mu^-$	[a]	(4.60±0.28)	$\times 10^{-5}$	
Γ_{12}	e^+e^-	[a]	(4.48±0.21)	$\times 10^{-5}$	
Γ_{13}	$\pi^+\pi^-\pi^0$		$<$ 1.2	$\times 10^{-4}$	CL=90%
Γ_{14}	$\pi^+\pi^-\pi^+\pi^-$		(1.8 ±0.9)	$\times 10^{-5}$	
Γ_{15}	$\pi^+\pi^-\pi^0\pi^0$		$<$ 4	$\times 10^{-5}$	CL=90%

σ MESON EXCHANGE

$$\mathcal{L} = \frac{e g_{\sigma\rho\gamma}}{M_\rho} \partial^\mu \rho^\nu F_{\mu\nu} \sigma + g_{\sigma NN} \bar{N} \sigma N$$

- Friman, Soyeur, NPA 600, 477 (1996)
  determine the parameters to fit the ρ photoproduction data

$$M_\sigma = 0.5 \text{ GeV}, \quad g_{\sigma NN}^2 / 4\pi = 8.0, \quad g_{\sigma\rho\gamma} = 3.0$$

⇨ This will constitute our model (A)

- Bonn potential – Machleidt et al, Phys. Rep. 149, 1 (1987)

$$M_\sigma = 0.55 \sim 0.66 \text{ GeV}, \quad g_{\sigma NN}^2 / 4\pi = 8.3 \sim 10$$

- QCD sum rules

$$g_{\sigma\rho\gamma} = \begin{cases} 3.2 \pm 0.6 \\ 2.2 \pm 0.4 \end{cases}$$

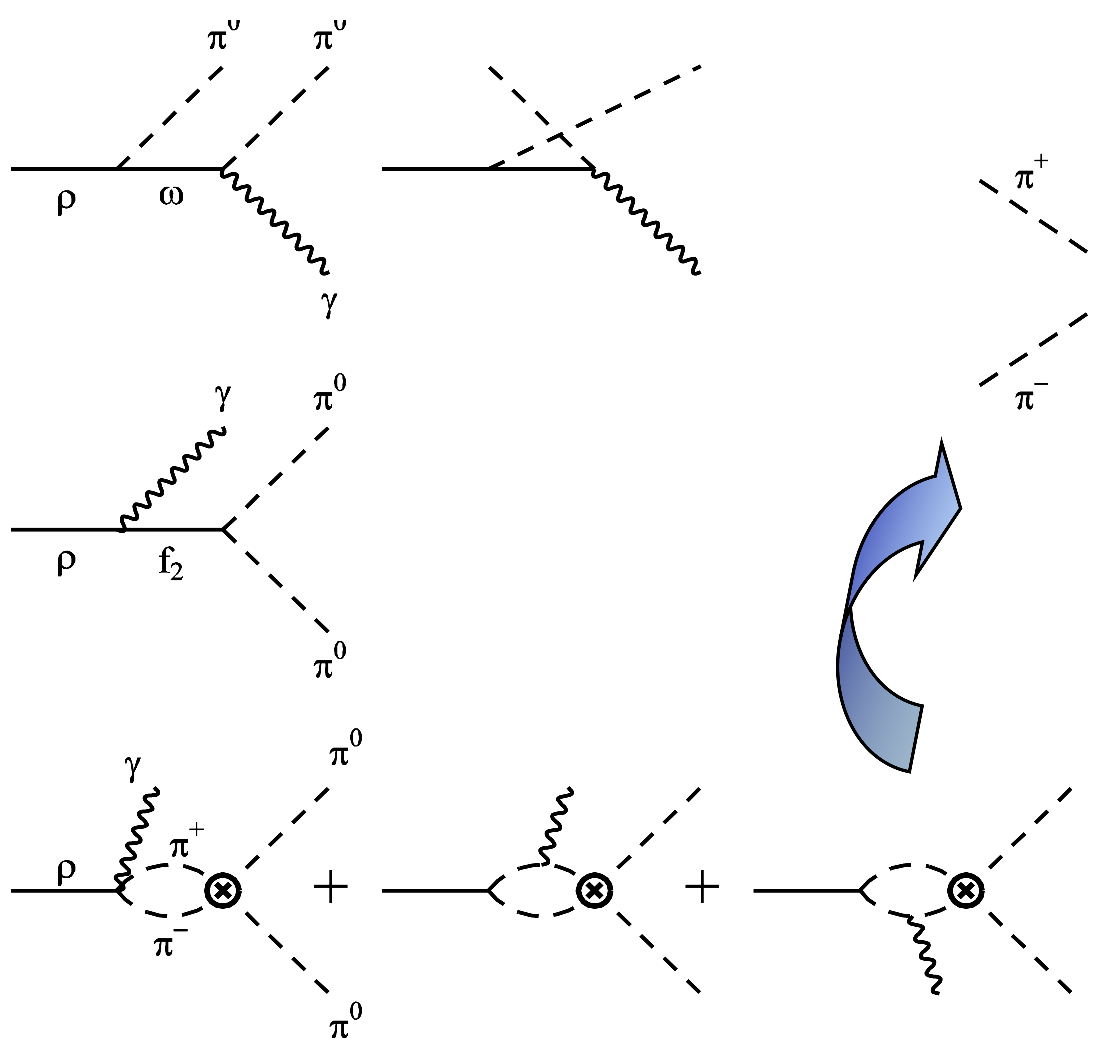
Goklap, Yilmaz, PRD 64 (2001)

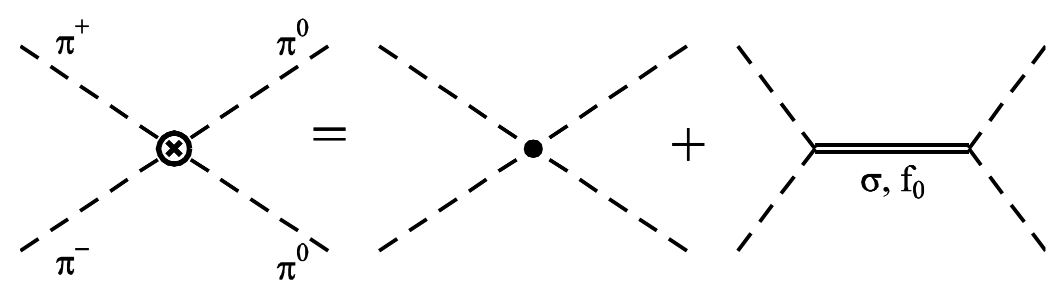
Aliev et al., PRD 65 (2002)

σ MESON EXCHANGE

- But large $g_{\sigma\rho\gamma}$ gives too large decay width of $\rho \to \pi\pi\gamma$ by two orders of magnitude
- Estimate of SND experiment M.N. Achasov et al. PLB 537, 201 (2002)

BR ($\rho \to \pi^0\pi^0\gamma$) ~ 4.1 x 10^{-5} and BR ($\omega \to \pi^0\pi^0\gamma$) ~ 6.6 x 10^{-5}





$$\Gamma(\rho \to \sigma\gamma) \approx 2.83 \text{ keV},$$

which gives $g_{\sigma\rho\gamma} \approx 0.25$

Bramon et al., PLB283, PLB289, PLB517
Palomar et al., NPA707
YO, H. Kim, PRD68

f_2 exchange model

- f_2 meson: tensor meson with $I^G(J^{PC}) = 0^+(2^{++})$
- We need f_2NN and $f_2\rho\gamma$ couplings
- Strategy
  $f\pi\pi$ coupling: from the decay of f_2 into 2-pion
  tensor meson dominance: relates $f\pi\pi$ and fVV, fNN
  vector meson dominance: relates fVV and $fV\gamma$, $f\gamma\gamma$
- $f\pi\pi$ coupling Pilkuhn et al., NPB 65, 460 (1973)

$f_2(1270)$ MASS

VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
1275.4± 1.2 OUR AVERAGE				

$f_2(1270)$ WIDTH

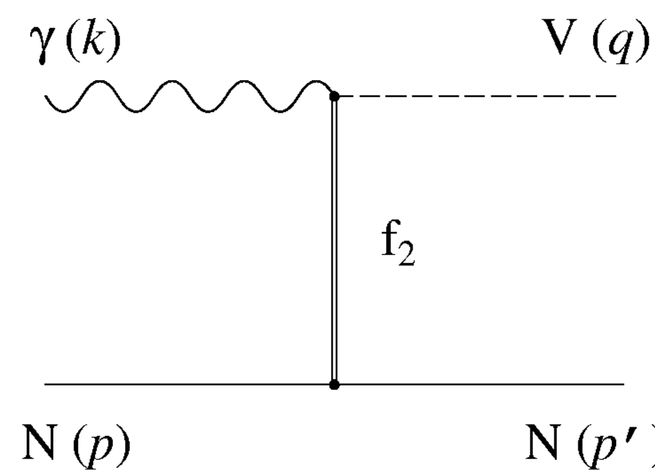
VALUE (MeV)	EVTS	DOCUMENT ID	TECN	COMMENT
$185.1^{+3.5}_{-2.6}$ OUR NEW UNCHECKED FIT				Error includes scale factor of 1.5.

$f_2(1270)$ DECAY MODES

	Mode	Fraction (Γ_i/Γ)	Scale factor/ Confidence level
Γ_1	$\pi\pi$	$(84.8\ ^{+2.5}_{-1.3})\ \%$	S=1.3
Γ_2	$\pi^+\pi^-2\pi^0$	$(\ 7.1\ ^{+1.5}_{-2.7})\ \%$	S=1.3
Γ_3	$K\overline{K}$	$(\ 4.6\ \pm 0.4\ )\ \%$	S=2.7
Γ_4	$2\pi^+2\pi^-$	$(\ 2.8\ \pm 0.4\ )\ \%$	S=1.2
Γ_5	$\eta\eta$	$(\ 4.5\ \pm 1.0\ ) \times 10^{-3}$	S=2.4
Γ_6	$4\pi^0$	$(\ 3.0\ \pm 1.0\ ) \times 10^{-3}$	
Γ_7	$\gamma\gamma$	$(\ 1.41 \pm 0.13) \times 10^{-5}$	
Γ_8	$\eta\pi\pi$	$< 8 \times 10^{-3}$	
Γ_9	$K^0K^-\pi^+ +$ c.c.	$< 3.4 \times 10^{-3}$	
Γ_{10}	e^+e^-	$< 6 \times 10^{-10}$	

f_2 meson exchange model

$$T_{f_2}^{\mu\nu} = -\bar{u}(p')\Gamma^{\alpha\beta}(p,p')u(p)\frac{P_{\alpha\beta;\rho\sigma}}{(p-p')^2 - M_f^2} V^{\rho\sigma;\nu\mu}(k,q)$$



where

$$\Gamma_{\alpha\beta}(p,p') = \frac{G_{fNN}}{M_N}\left[(p+p')_\alpha \gamma_\beta + (p+p')_\beta \gamma_\alpha\right] + \frac{F_{fNN}}{M_N^2}(p+p')_\alpha (p+p')_\beta$$

$$P_{\alpha\beta;\rho\sigma} = \frac{1}{2}\left(\bar{g}_{\alpha\rho}\bar{g}_{\beta\sigma} + \bar{g}_{\alpha\sigma}\bar{g}_{\beta\rho}\right) - \frac{1}{3}\bar{g}_{\alpha\beta}\bar{g}_{\rho\sigma}$$

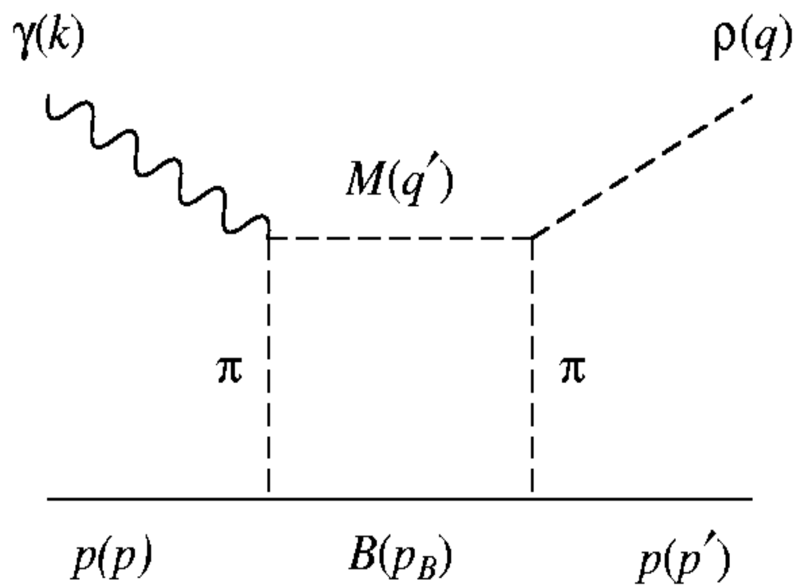
$$V^{\rho\sigma;\nu\mu}(k,q) = \frac{f_{fV\gamma}}{M_f^4}\left[-g_{\mu\nu}(k\cdot q) + q_\nu k_\mu\right](k+q)_\rho (k+q)_\sigma$$
$$+ \frac{g_{fV\gamma}}{M_f}\Big[g_{\mu\nu}(k+q)_\rho (k+q)_\sigma - g_{\mu\rho}q_\nu (k+q)_\sigma - g_{\mu\sigma}q_\nu (k+q)_\rho$$
$$-g_{\nu\rho}k_\mu (k+q)_\sigma - g_{\nu\sigma}k_\mu (k+q)_\rho + 2k\cdot q\left(g_{\nu\rho}g_{\mu\sigma} + g_{\nu\sigma}g_{\mu\rho}\right)\Big]$$

We use $F_{fNN} = f_{fV\gamma} = 0, \quad g_{fV\gamma} = \frac{eG_{fVV}}{f_\rho},$ with $G_{fVV} = G_{f\pi\pi} = 5.76, \quad G_{fNN}^2 / 4\pi = 2.2$

two-pion exchange model

Two-pion exchange model (M=**π** and B=N: B=**Δ** will not be considered as M=**ω**)

(M=**η**,**ρ** are not allowed by G parity)



$$L = e\left(\partial^{\mu}\vec{\pi}\times\vec{\pi}\right)_z A_{\mu} + g_{\rho\pi\pi}\overrightarrow{\rho_{\mu}}\cdot\left(\vec{\pi}\times\partial^{\mu}\vec{\pi}\right) + \frac{g_{\pi NN}}{2M_N}\overline{N}\gamma^{\mu}\gamma_5\vec{\tau}\cdot\partial_{\mu}\vec{\pi}N$$

Sato-Lee method to compute the loop integral Sato, Lee, PRC54, 2660 (1996)

$$T_{\mathrm{loop}} = \int d^3\mathbf{q}' B_{\gamma N,MN}(\mathbf{k},\mathbf{q}';W) G_{MN}(\mathbf{q}',W)\, V_{MN,\rho N}(\mathbf{q}',\mathbf{q};W)$$

where

$$G_{MN}(\mathbf{q}',W) = \frac{1}{W - E_N(q') - E_M(q') + i\varepsilon}$$

RESULTS

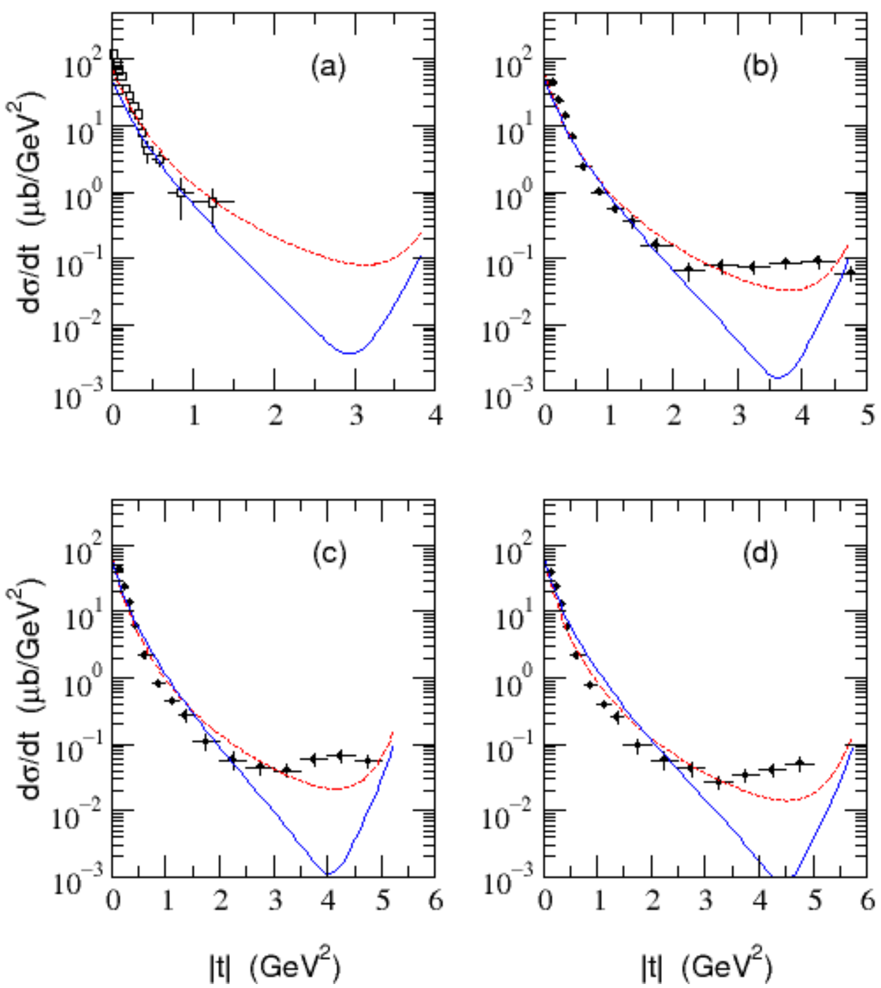
Y. Oh and T.-S.H. Lee, Phys. Rev. C 69 (2004)

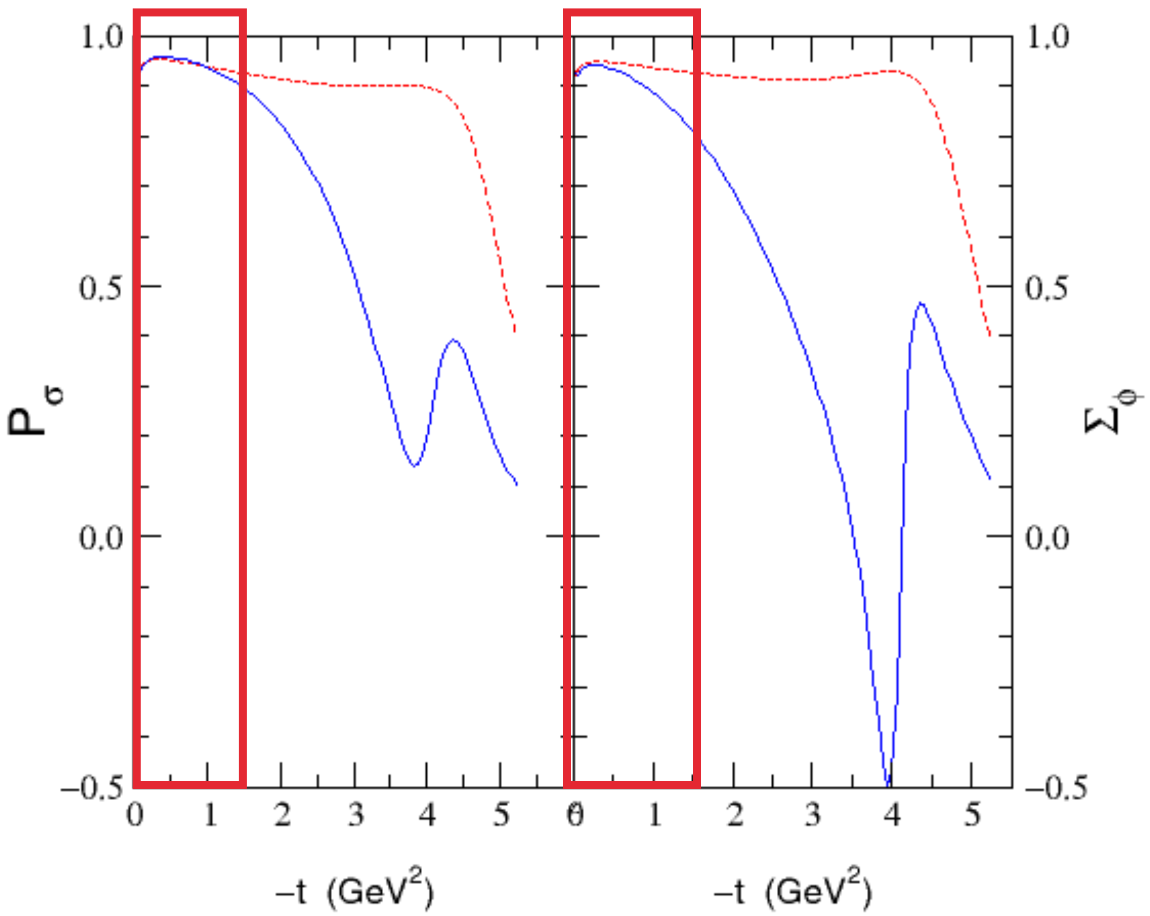
Model A : $\mathrm{P} + N + \pi + \eta + \sigma$

Model B : $\mathrm{P} + N + \pi + \eta + f_2 + 2\pi + \sigma$

σ parameters are fitted by **ρ** photoproduction

σ and f_2 parameters are fixed by other reactions





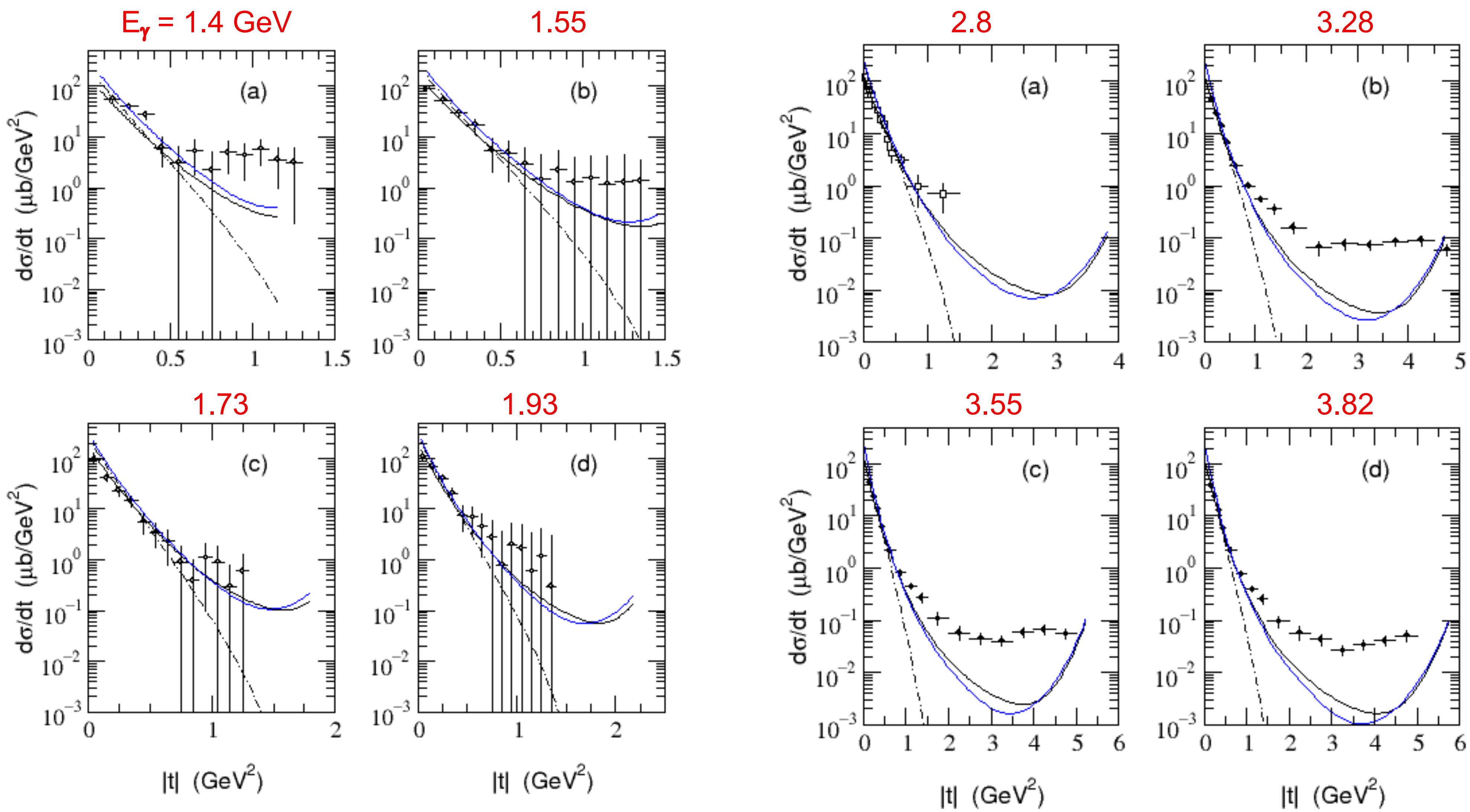
red dashed lines: model (A)

blue solid lines: model (B)

P_σ = +1 for natural-parity exchange ($P=(-1)^J$)

P_σ = −1 for unnatural-parity exchange

RESULTS: f_2–trajectory exchange



dot-dashed: f_2-trajectory alone
solid: full with the other backgrounds
blue solid: f_2-trajectory model of Laget with other background

Left: SAPHIR 1996
Right: SLAC & CLAS

K* PHOTOPRODUCTION

- Photoproduction of strange vector mesons

PHYSICAL REVIEW C **73**, 065202 (2006)

K^* photoproduction off the nucleon: $\gamma N \to K^* \Lambda$

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Department of Physics and Astronomy, University of Georgia, Athens, Georgia 30602, USA

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(Received 16 February 2006; published 19 June 2006)

PHYSICAL REVIEW C **74**, 015208 (2006)

Scalar κ meson in K^* photoproduction

Yongseok Oh[1,*] and Hungchong Kim[2,†]
[1]*Department of Physics and Astronomy, University of Georgia, Athens, Georgia 30602, USA*
[2]*Department of Physics, Pohang University of Science and Technology, Pohang 790-784, Korea*

(Received 4 May 2006; published 28 July 2006)

- Production mechanisms: different from those of neutral VMs.
- background t-channel exchanges and hyperon resonances

K* PHOTOPRODUCTION

K* → Kγ decays gives

$$g^0_{K^*K\gamma} = -0.388 \text{ GeV}^{-1} \text{ for neutral case}$$
$$g^c_{K^*K\gamma} = 0.254 \text{ GeV}^{-1} \text{ for charged case}$$

Flavor SU(3) gives $g_{KN\Lambda} = -13.24 \qquad g_{KN\Sigma} = 3.58$

$$R \equiv \frac{\sigma(\gamma p \to K^{*+}\Lambda)}{\sigma(\gamma p \to K^{*0}\Sigma)} \simeq \left(\frac{g^c_{K^*\tilde{K}\gamma} g_{\tilde{K}N\Lambda}}{\sqrt{2} g^0_{K^*\tilde{K}\gamma} g_{\tilde{K}N\Sigma}} \right)^2 \sim 3 \text{ when } \tilde{K} = K$$

Experimental data from CLAS give R ~ 1

We need another mechanism for strange VM photoproduction. - κ meson exchange

$$\left| g^c_{\kappa K^*\gamma} g_{\kappa N\Lambda} \right| = 1.1 \text{ GeV}^{-1},$$
$$\left| g^c_{\kappa K^*\gamma} g_{\kappa N\Sigma} \right| = 0.7 \text{ GeV}^{-1},$$

Consistent with the Nijmegen potential

This leads to R ~ 0.3

K* PHOTOPRODUCTION

Results by combining K and κ exchanges

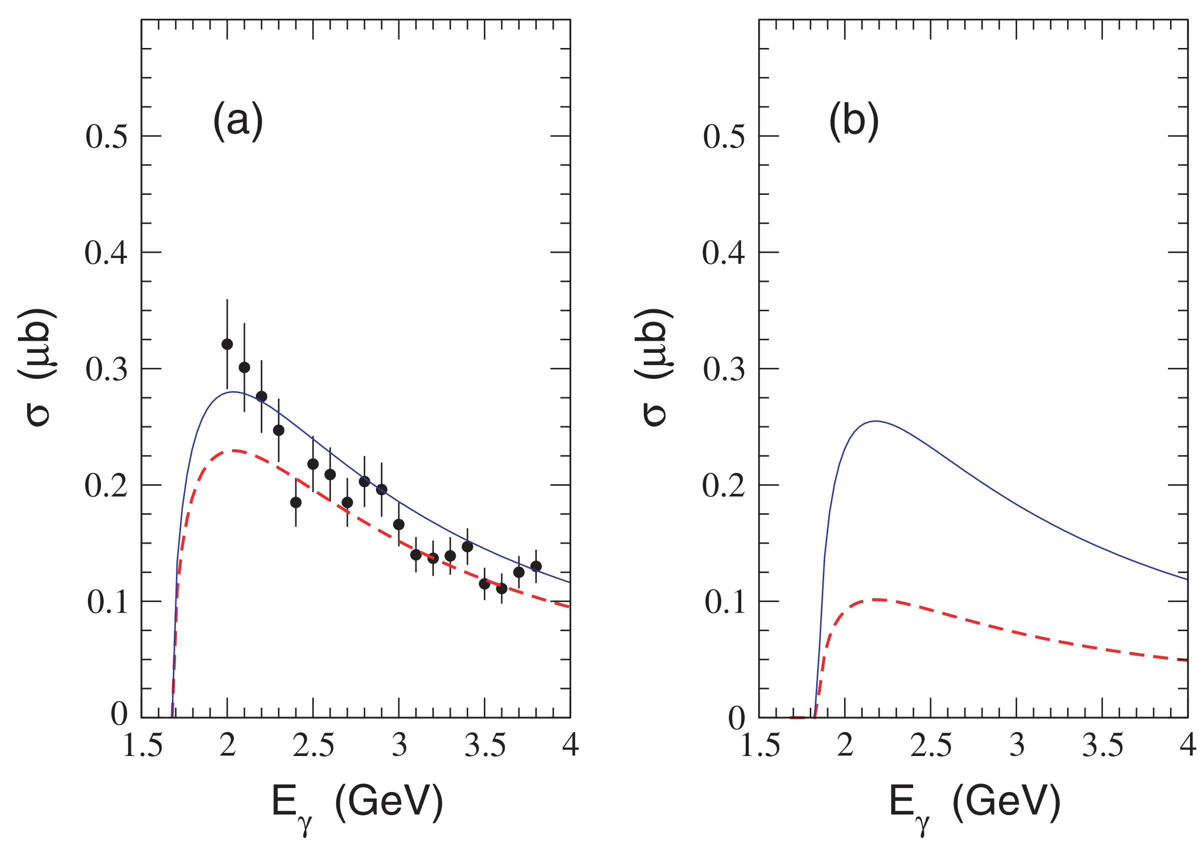

FIG. 3. (Color online) Total cross sections for (a) $\gamma p \to K^{*+}\Lambda$ and for (b) $\gamma p \to K^{*0}\Sigma^+$. The dashed and solid lines are the results for models (I) and (II), respectively. The data are from Ref. [2].

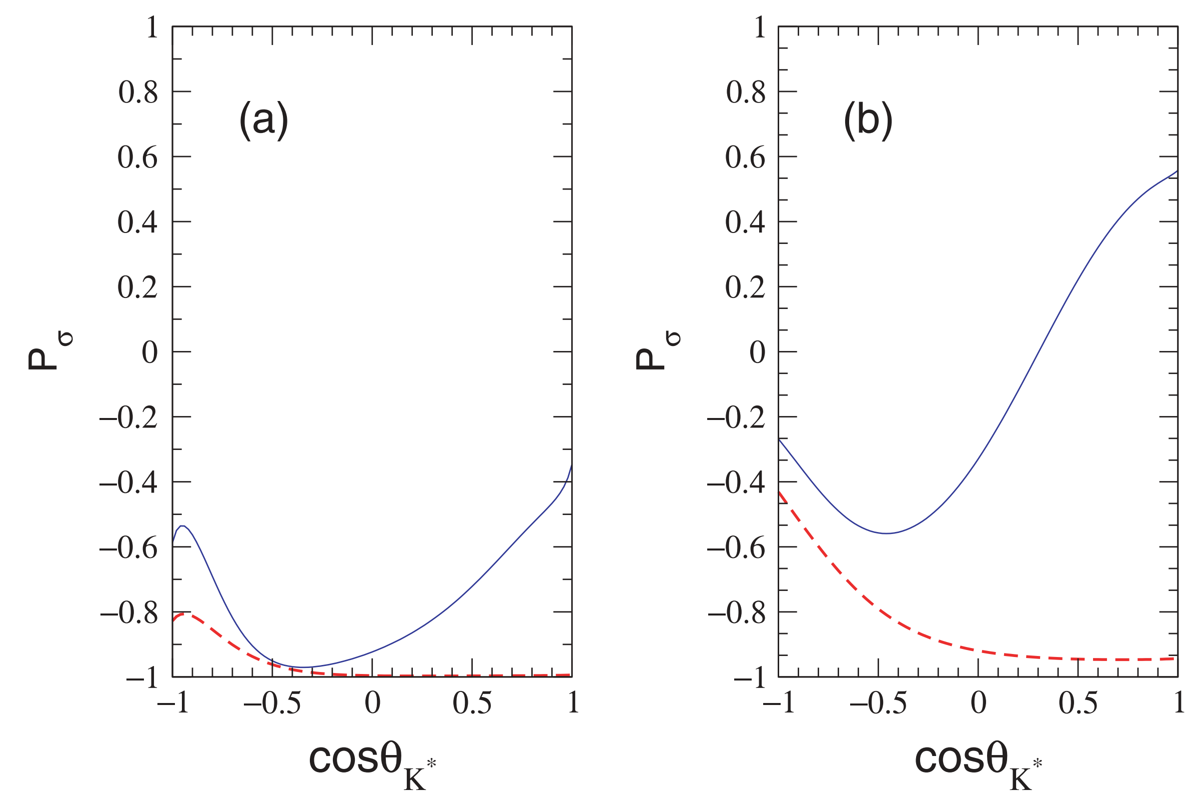

FIG. 4. (Color online) Parity spin asymmetry P_σ for (a) $\gamma p \to K^{*+}\Lambda$ and for (b) $\gamma p \to K^{*0}\Sigma^+$ at $E_\gamma = 3.0$ GeV. Notations are the same as in Fig. 3.

K* PHOTOPRODUCTION

PRL 108, 092001 (2012) PHYSICAL REVIEW LETTERS week ending 2 MARCH 2012

Spin-Density Matrix Elements for $\gamma p \to K^{*0}\Sigma^+$ at $E_\gamma = 1.85$–3.0 GeV with Evidence for the $\kappa(800)$ Meson Exchange

S. H. Hwang,[1] K. Hicks,[2] J. K. Ahn,[1] T. Nakano,[3] D. S. Ahn,[3] W. C. Chang,[4] J. Y. Chen,[4] S. Daté,[5] H. Ejiri,[3,5] H. Fujimura,[6] M. Fujiwara,[3] S. Fukui,[3] W. Gohn,[7] T. Hotta,[3] K. Imai,[8] T. Ishikawa,[9] K. Joo,[7] Y. Kato,[3] H. Kohri,[3] Y. Kon,[3] H. S. Lee,[10] Y. Maeda,[11] M. Miyabe,[9] T. Mibe,[12] Y. Morino,[5] N. Muramatsu,[3] Y. Nakatsugawa,[13] M. Niiyama,[14] H. Noumi,[3] Y. Oh,[15] Y. Ohashi,[5] T. Ohta,[3] M. Oka,[3] J. Parker,[14] C. Rangacharyulu,[16] S. Y. Ryu,[3,13] T. Sawada,[3] Y. Sugaya,[17] M. Sumihama,[18] T. Tsunemi,[3] M. Uchida,[19] M. Ungaro,[7] and M. Yosoi[3]

(LEPS Collaboration)

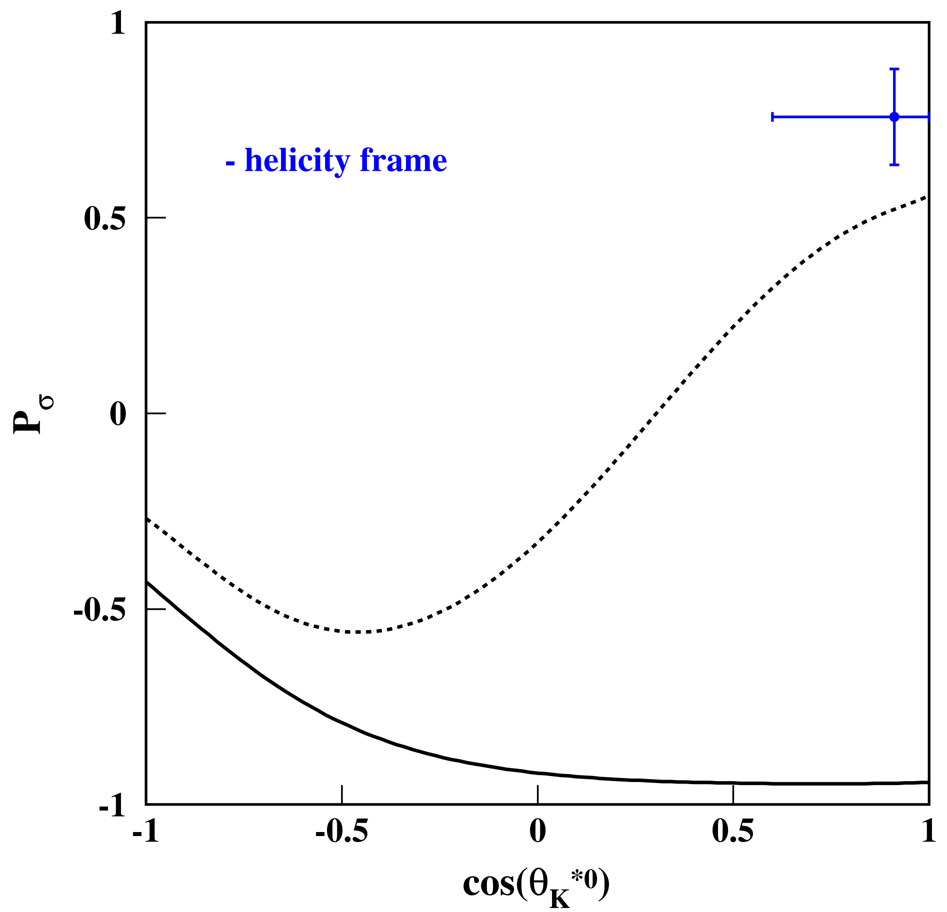

FIG. 4 (color online). Parity spin asymmetry ($P_\sigma = 2\rho^1_{1-1} - \rho^1_{00}$) in the helicity frame. The data point is averaged over photon energies from 1.85 to 2.96 GeV. The solid (dashed) line is the result of model I (model II) of Ref. [15] at $E_\gamma = 2.5$ GeV. Model I has almost no contribution from κ exchange, whereas model II includes substantial κ exchange.

K* PHOTOPRODUCTION

- Role of hyperon resonances and more investigation on the production mechanisms
- New data

PRL 108, 092001 (2012) PHYSICAL REVIEW LETTERS week ending 2 MARCH 2012

Spin-Density Matrix Elements for $\gamma p \to K^{*0}\Sigma^+$ at $E_\gamma = 1.85$–3.0 GeV with Evidence for the $\kappa(800)$ Meson Exchange

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(LEPS Collaboration)

Eur. Phys. J. A **35**, 333–342 (2008)
DOI 10.1140/epja/i2007-10552-9

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Experimental Physics

$K^0\pi^0\Sigma^+$ and $K^{*0}\Sigma^+$ photoproduction off the proton

The CBELSA/TAPS Collaboration

M. Nanova[1,a], J.C.S. Bacelar[2], B. Bantes[3], O. Bartholomy[4], D. Bayadilov[4,5], R. Beck[4], Y.A. Beloglazov[5], R. Castelijns[2,b], V. Crede[6], H. Dutz[3], A. Ehmanns[4], D. Elsner[3], K. Essig[4], R. Ewald[3], I. Fabry[4], K. Fornet-Ponse[3], M. Fuchs[4], Ch. Funke[4], R. Gothe[3,c], R. Gregor[1], A.B. Gridnev[5], E. Gutz[4], P. Hoffmeister[4], I. Horn[4], I. Jaegle[7], J. Junkersfeld[4], H. Kalinowsky[4], S. Kammer[3], V. Kleber[3], Frank Klein[3], Friedrich Klein[3], E. Klempt[4], M. Konrad[3], M. Kotulla[1], B. Krusche[7], M. Lang[4], J. Langheinrich[3,c], H. Löhner[2], I.V. Lopatin[5], J. Lotz[4], S. Lugert[1], D. Menze[3], J.G. Messchendorp[2], T. Mertens[7], V. Metag[1], C. Morales[3], D.V. Novinski[5], R. Novotny[1], M. Ostrick[3,d], L.M. Pant[1,e], H. van Pee[4], M. Pfeiffer[1], A. Radkov[5], A. Roy[1,f], S. Schadmand[1,b], Ch. Schmidt[4], H. Schmieden[3], B. Schoch[3], S.V. Shende[2], V. Sokhoyan[4], A. Süle[3], V.V. Sumachev[5], T. Szczepanek[4], U. Thoma[1,4], D. Trnka[1], R. Varma[1,f], D. Walther[3,4], Ch. Weinheimer[4,g], and Ch. Wendel[4]

K* PHOTOPRODUCTION

RAPID COMMUNICATIONS

PHYSICAL REVIEW C **75**, 042201(R) (2007)

Cross sections for the $\gamma p \to K^{*0}\Sigma^{+}$ reaction at $E_{\gamma} = 1.7$–3.0 GeV

I. Hleiqawi,[1] K. Hicks,[1] D. S. Carman,[1,32] T. Mibe,[1] G. Niculescu,[20] A. Tkabladze,[13] M. Amarian,[26] P. Ambrozewicz,[11] M. Anghinolfi,[17] G. Asryan,[37] H. Avakian,[32] H. Bagdasaryan,[26] N. Baillie,[36] J. P. Ball,[2] N. A. Baltzell,[31] V. Batourin[21] M. Battaglieri,[17] K. Beard,[20] I. Bedlinskiy,[19] M. Bellis,[4] N. Benmouna,[13] B. L. Berman,[13] A. S. Biselli,[4] S. Bouchigny,[18] S. Boiarinov,[32] R. Bradford,[4,*] D. Branford,[10] W. J. Briscoe,[13] W. K. Brooks,[32] S. Bültmann,[26] V. D. Burkert,[32]

PHYSICAL REVIEW C **87**, 065204 (2013)

Cross sections for the $\gamma p \to K^{*+}\Lambda$ and $\gamma p \to K^{*+}\Sigma^{0}$ reactions measured at CLAS

W. Tang,[1] K. Hicks,[1] D. Keller,[1,*] S. H. Kim,[40,†] H. C. Kim,[40] K. P. Adhikari,[28] M. Aghasyan,[18] M. J. Amaryan,[28] M. D. Anderson,[36] S. Anefalos Pereira,[18] N. A. Baltzell,[2,33] M. Battaglieri,[19] I. Bedlinskiy,[22] A. S. Biselli,[6,12] J. Bono,[13]

Physics Letters B 771 (2017) 142–150

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ELSEVIER

Differential cross sections and polarization observables from CLAS K^* photoproduction and the search for new N^* states

CrossMark

The CLAS Collaboration

Table 1
Branching ratios for $N^* \to K^*\Lambda$ decays. For the states denoted with $*$ we assume $\Gamma_{\gamma p} = 0.1$ MeV.

$N(1880)1/2^+$	$0.8 \pm 0.3\%$	$N(1895)1/2^-$	$6.3 \pm 2.5\%$
$N(2100)1/2^+$	$7.0 \pm 4\%$	$N(1875)3/2^-$	$< 0.2\%$
$N(2120)3/2^-$	$< 0.2\%$	$N(2060)5/2^-$	$0.8 \pm 0.5\%$
$N(2000)5/2^+$	$2.2 \pm 1.0\%$	$N(1900)3/2^+$	$< 0.2\%$
$N(2190)7/2^-$	$0.5 \pm 0.3\%$	$N(2355)^*1/2^-$	$6 \pm 1.5\%$
$N(2250)^*3/2^-$	$10 \pm 5\%$	$N(2300)^*5/2^-$	$4.5 \pm 1.4\%$

Table 2
Masses and widths of tentative additional resonances contributing to the reaction $\gamma p \to K^{*+}\Lambda$.

Resonance	Mass	Width
$N(2355)1/2^-$	2355 ± 20 MeV	235 ± 30 MeV
$N(2250)3/2^-$	2250 ± 35 MeV	240 ± 40 MeV
$N(2300)5/2^-$	2300^{+30}_{-60} MeV	205 ± 65 MeV

K* PHOTOPRODUCTION

Theoretical works and more elaborated model studies

K* Λ production

S. Ozaki et al., Rhys. Rev. C 81, 035206 (2010) - Regge approach
S.H. Kim et al., Phys. Rev. D 84, 114023 (2011), Phys. Rev. D 90, 014021 (2014) - resonances
A.C. Wang et al., Phys. Rev. C 96, 035206 (2017) - resonances
B.G. Yu et al., Phys. Rev. D 95, 074034 (2017) - Regge approach
X.-Y. Wang and J. He, Phys. Rev. C 93, 035202 (2016) - neutron target

K* Σ production

S.H. Kim et al., Phys. Rev. D 88, 054012 (2013) - resonances
A.C. Wang et al., Phys. Rev. C 98, 045209 (2018) - resonances

CONCLUSIONS & OUTLOOK

- Vector meson photoproduction processes
  - Neutral VM & strange VM
  - Various analyses have been done
  - New precise and ample data for various polarization observables
    - require more sophisticated and careful analyses
    - constraints on N* and Y* properties as well as on production mechanisms
- Extension to electropoduction processes
  - More stringent constraints
  - May rule out several models and assumptions
- Nuclear targets

ANNOUNCEMENTS

- Hadron physics workshops in Korea
  - Light Cone Conference 2020
    June 29 - July 4, 2020
    Booyoung Hotel & Resort, Jeju Island, Korea
  - APCTP Focus Program in Nuclear Physics 2020
    - Electroweak scatterings with nuclear targets
    July 6 - July 11, 2020
    APCTP, Pohang, Korea

LIGHT CONE CONFERENCE 2020

LIGHT CONE CONFERENCE 2020

29 June - 4 July, 2020 https://indico.cern.ch/event/849578/ OR https://indico.cern.ch/e/LC2020

LC2020 - Physics of Hadrons on the Light Front

29 June 2020 to 4 July 2020
Jeju Booyoung Hotel
Asia/Seoul timezone

Search...

- Overview
- Timetable
- Accommodation
- Conference venue
- International Advisory Committee
- Local Organizing Committee
- ILCAC
- Previous meetings
- McCartor Fellowship and APCTP Fellowship
- Visa
- Social Event

Organizers

lightcone2020@gmail.com

Light Cone 2020 is the latest in the series of conferences that, beginning in 1991, have played an important role in promoting research towards a rigorous description of hadrons and nuclei based on quantisation methods in the front form.

As with earlier conferences in the series, the aim of this meeting will be to create a scientific program that will stimulate developments at the forefront of nuclear, hadron and particle physics research. In particular, Light Cone 2020 will focus on the following physics topics and approaches:

Physics Topics

- hadron structure and parton physics
- meson and baryon (N*) resonances
- XYZ and exotic hadrons
- quarkonia
- the physics of B factories
- finite temperature and density QCD
- nuclear structure and nuclear matter
- hypernuclei
- few- and many-body physics

LIGHT CONE CONFERENCE 2020

Physics Topics

- hadron structure and parton physics
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- few- and many-body physics
- electroweak scatterings with nuclear targets
- neutrino physics
- spin physics
- physics of electron-ion colliders

Theoretical and Experimental Tools

- light-front field theories
- lattice field theory
- effective field theories
- phenomenological models
- coupled channels models
- present and future facilities

Starts 29 Jun 2020, 08:30
Ends 4 Jul 2020, 18:30
Asia/Seoul

Yongseok Oh
Chueng Ji
Ho-Meoyng Choi
Hyon-Suk Jo
Kyungseon Joo

We look forward to welcoming you at Jeju island in Korea in the summer of 2020 (29 June - 4 July, 2020) !

LIGHT CONE CONFERENCE 2020

LIGHT CONE CONFERENCE 2020

29 June - 4 July, 2020

APCTP FOCUS PROGRAM IN NUCLEAR PHYSICS

Launched in 2019 at Asia Pacific Center for Theoretical Physics (APCTP)

Nuclear Many-Body Theories: Beyond the mean field approaches

July 01 (Mon), 2019 ~ July 10 (Wed), 2019

Main Page

APCTP Focus Program in Nuclear Physics 2019

Venue

APCTP Headquarters, Pohang

Period

July 01 (Mon), 2019 ~ July 10 (Wed), 2019

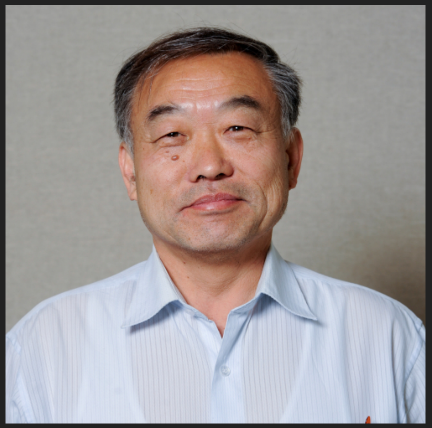
Overview

Nuclear many-body theory is a major key to understand the structure of nucleus and nuclear matter. It has a key role in investigating the structure of compact stellar objects like neutron stars. In most cases, the mean field approximation is widely used as the first approximation to the strongly interacting nuclear systems. However, for more profound understanding of nuclear matter requires theoretical tools beyond the mean field treatment. Therefore, investigation in this direction is very crucial to develop more powerful and consistent theory for nuclear structure and nuclear matter. In this Focus Program, we will summarize the attempts made up to present and discuss the directions of future research. To establish close collaboration among participants is another goal of this program. We will start by addressing the topic of nucleon-nucleon correlations in nuclear-response theory and related subjects. The main issue is to go beyond the mean-field picture in dynamic situations not just the ground state. We will start to discuss on extended-RPA theories with a correlated ground state. This has been developed by many authors including the speakers of this Focus Program, who are experts in this field pursuing various approaches beyond the mean-field approximation. For microscopic input for many-body theory, we have to understand fundamental nucleon interactions and many-body theories based directly on the nucleon interactions. These *ab initio* models are important to fully understand the nuclear structure and nuclear response. In this program, we invite experts of the in-medium renormalization group. By inviting these world-leading experts in nuclear many-body theories, we will develop strong collaborations with them and will make chances to young

APCTP FOCUS PROGRAM IN NUCLEAR PHYSICS

- The program in 2020 will be held with the title of "Electroweak Scatterings with Nuclear Targets"
- Dates: July 6 - 11, 2020
- Place: APCTP, Pohang, Korea
- Organizers

  Yongseok Oh
  Cheung Ji
  Ho-Meoyng Choi
  Hyun-Suk Jo
  Kyungseon Joo



APCTP FOCUS PROGRAM IN NUCLEAR PHYSICS

- About 15 invited speakers: 1.5 hour talks
  Experimentalists + Theorists
- One-day mini-workshop for contributed talks

We hope to see you in Jeju and in Pohang, Korea.

(LC 2020 and AFPNP 2020)