φ meson photoproduction on the nucleon and ^{4}He targets

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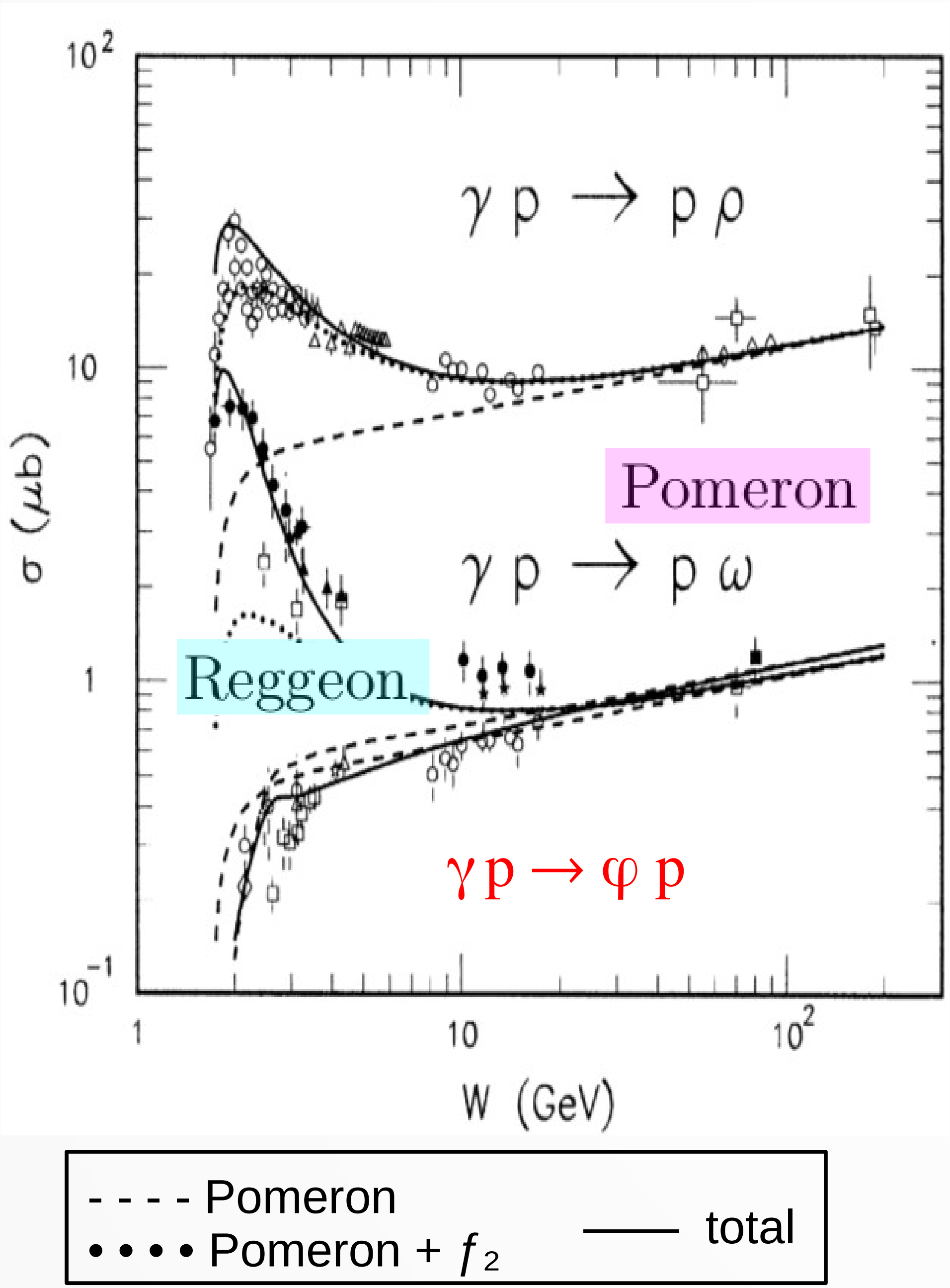
Contents

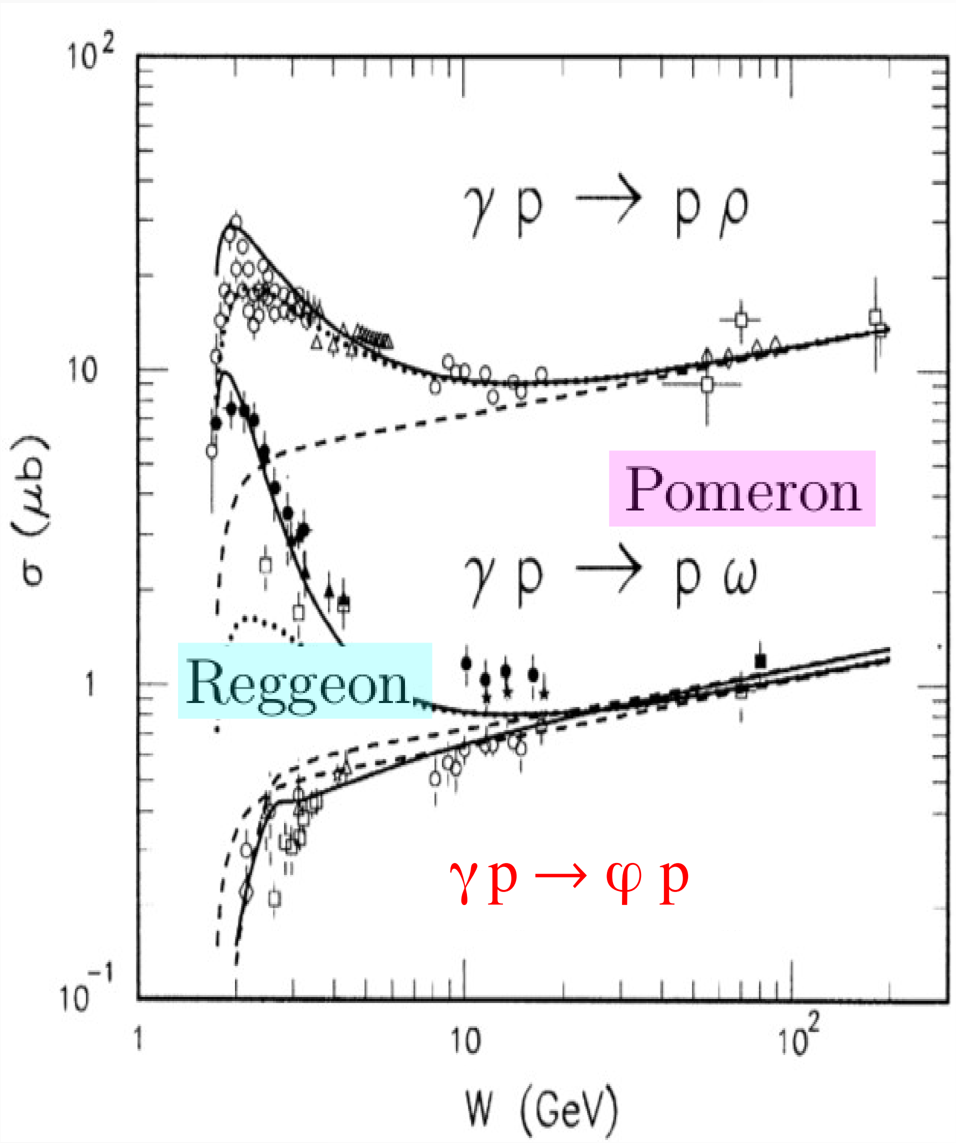
Contents based on

[S.H.Kim, S.i.Nam, PRC.100.065208 (2019)]

[S.H.Kim, T.S.H.Lee, S.i.Nam, Y. Oh, PRC.104.045202 (2021)]



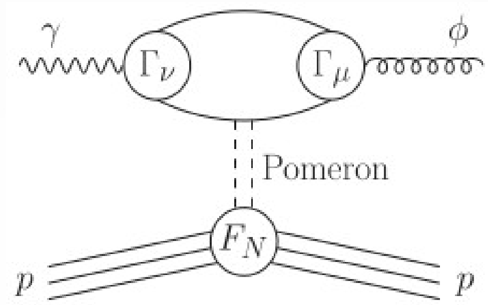
[Laget,PLB.489.313(2000)]



- - - - Pomeron
• • • • Pomeron + f_2
—— total

[Laget,PLB.489.313(2000)]

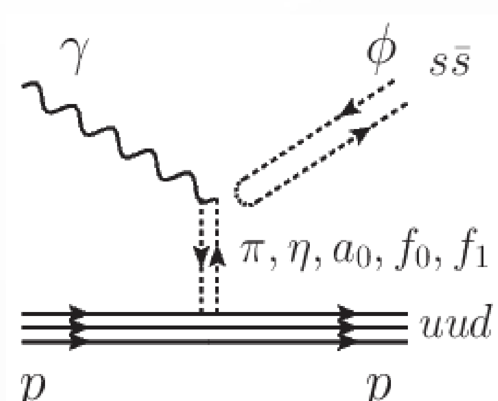
- We focus on γ p → φ p.
- high energy



- □ σ [γp → φp] ≈ σ [γp → ωp]
- □ F_N: isoscalar EM form factor of the nucleon

$$F_N(t) = \frac{4M_N^2 - a_N^2 t}{(4M_N^2 - t)(1 - t/t_0)^2}$$

- low energy



- □ σ[γp → φp] << σ[γp → (ρ,ω)p] due to the OZI rule

❑ high energy:

The two-gluon exchange is simplified by the Donnachie-Landshoff (DL) model which suggests that the Pomeron couples to the nucleon like a C = +1 isoscalar photon and its coupling is described in terms of $F_N(t)$.

[Pomeron Physics and QCD (Cambridge University, 2002)]

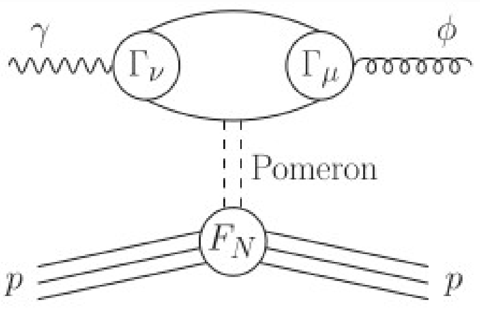
❑ low energy:

We need to clarify the reaction mechanism.

[Exp: Dey, CLAS, PRC.89. 055208 (2014)
Seraydaryan, CLAS, PRC.89.055206 (2014)
Mizutani, LEPS, PRC.96.062201 (2017)]

❑ We focus on $\gamma p \to \varphi p$.

❑ high energy

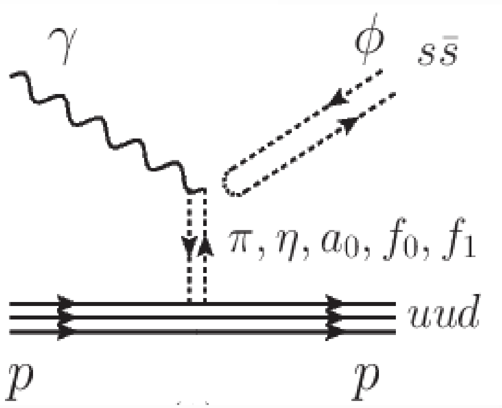


□ $\sigma[\gamma p \to \varphi p] \approx \sigma[\gamma p \to \omega p]$

□ F_N: isoscalar EM form factor of the nucleon

$$F_N(t) = \frac{4M_N^2 - a_N^2 t}{(4M_N^2 - t)(1 - t/t_0)^2}$$

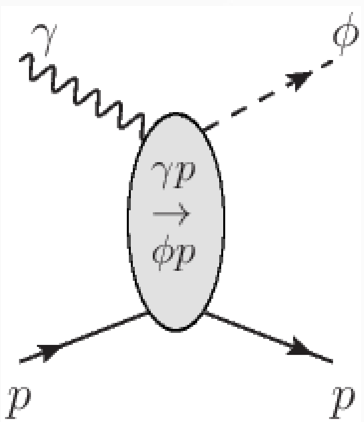
❑ low energy

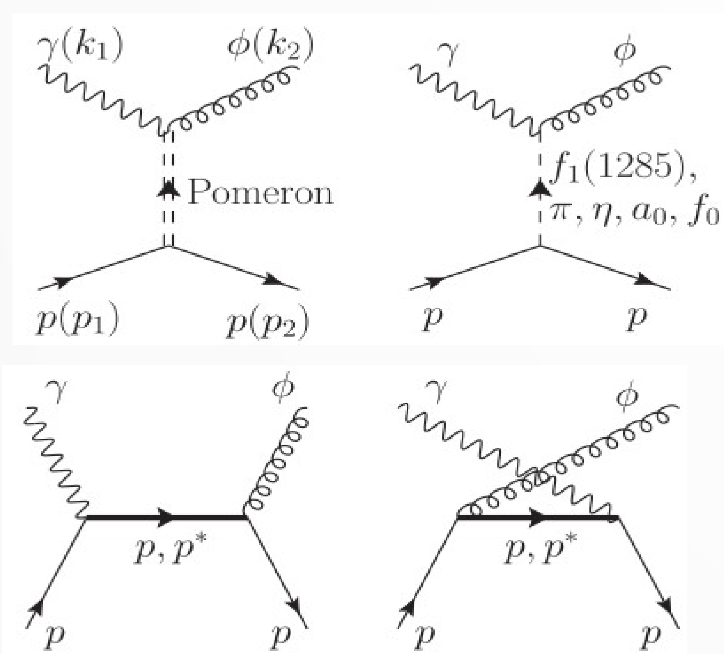


□ $\sigma[\gamma p \to \varphi p] << \sigma[\gamma p \to (\rho,\omega) p]$ due to the OZI rule

Born term

❑ Scattering amplitude: $T_{\phi N,\gamma N}(E) = [B_{\phi N,\gamma N} \quad]$





□ Ward-Takahashi identity

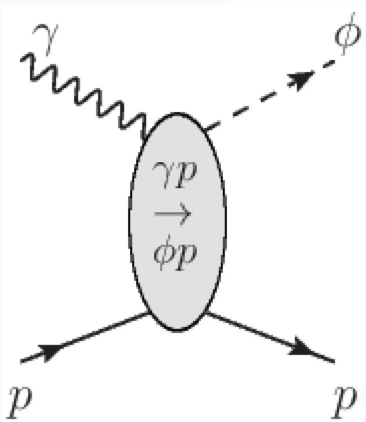
$$\mathcal{M}(k) = \epsilon_\mu(k)\mathcal{M}^\mu(k)$$

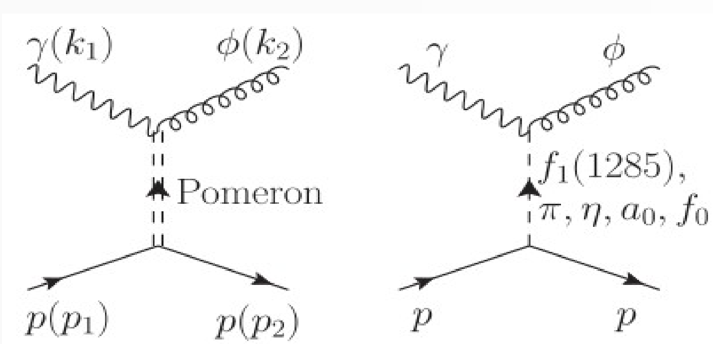
if we replace ϵ_μ with k_μ:

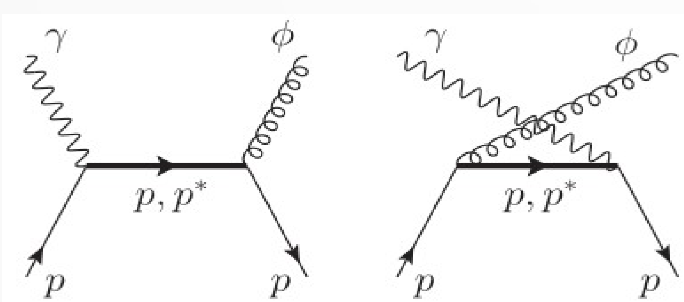
$$k_\mu \mathcal{M}^\mu(k) = 0$$

Born term

❑ Scattering amplitude: $T_{\phi N,\gamma N}(E) = [B_{\phi N,\gamma N}\qquad]$







❑ Effective Lagrangians

□ EM vertex

$$\mathcal{L}_{\gamma\phi f_1} = g_{\gamma\phi f_1}\epsilon^{\mu\nu\alpha\beta}\partial_\mu A_\nu \partial^\lambda \partial_\lambda \phi_\alpha f_{1\beta}$$

$$\mathcal{L}_{\gamma\Phi\phi} = \frac{e g_{\gamma\Phi\phi}}{M_\phi}\epsilon^{\mu\nu\alpha\beta}\partial_\mu A_\nu \partial_\alpha \phi_\beta \Phi$$

$$\mathcal{L}_{\gamma S\phi} = \frac{e g_{\gamma S\phi}}{M_\phi} F^{\mu\nu}\phi_{\mu\nu} S$$

□ strong vertex

$$\mathcal{L}_{f_1 NN} = -g_{f_1 NN}\bar{N}\left[\gamma_\mu - i\frac{\kappa_{f_1 NN}}{2M_N}\gamma_\nu\gamma_\mu\partial^\nu\right] f_1^\mu \gamma_5 N$$

$$\mathcal{L}_{\Phi NN} = -\, i g_{\Phi NN}\bar{N}\Phi\gamma_5 N$$

$$\mathcal{L}_{SNN} = -\, g_{SNN}\bar{N} S N$$

$$\mathcal{L}_{\gamma NN} = -\, e\bar{N}\left[\gamma_\mu - \frac{\kappa_N}{2M_N}\sigma_{\mu\nu}\partial^\nu\right] N A^\mu$$

$$\mathcal{L}_{\phi NN} = -\, g_{\phi NN}\bar{N}\left[\gamma_\mu - \frac{\kappa_{\phi NN}}{2M_N}\sigma_{\mu\nu}\partial^\nu\right] N \phi^\mu$$

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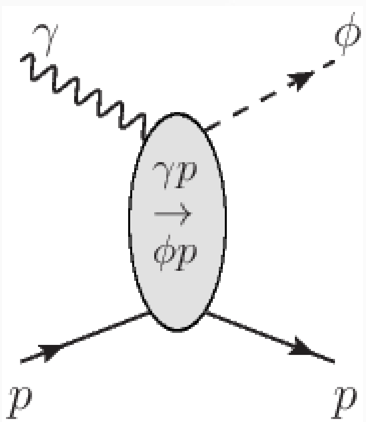

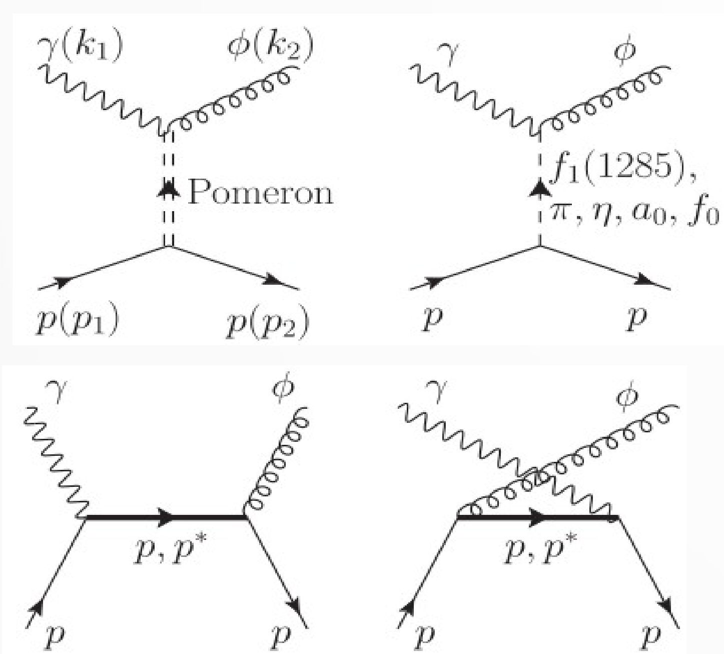

$$\mathcal{M} = \varepsilon^*_\nu \bar{u}_{N'} \mathcal{M}^{\mu\nu} u_N \epsilon_\mu$$

$$\mathcal{M}^{\mu\nu}_{f_1} = i\frac{M^2_\phi g_{\gamma f_1 \phi} g_{f_1 NN}}{t - M^2_{f_1}} \epsilon^{\mu\nu\alpha\beta}\left[-g_{\alpha\lambda} + \frac{q_{t\alpha} q_{t\lambda}}{M^2_{f_1}}\right] \times \left[\gamma^\lambda + \frac{\kappa_{f_1 NN}}{2M_N}\gamma^\sigma\gamma^\lambda q_{t\sigma}\right]\gamma_5 k_{1\beta},$$

$$\mathcal{M}^{\mu\nu}_{\Phi} = i\frac{e}{M_\phi}\frac{g_{\gamma\Phi\phi} g_{\Phi NN}}{t - M^2_\Phi}\epsilon^{\mu\nu\alpha\beta} k_{1\alpha} k_{2\beta}\gamma_5,$$

$$\mathcal{M}^{\mu\nu}_{S} = \frac{e}{M_\phi}\frac{2 g_{\gamma S\phi} g_{SNN}}{t - M^2_S + i\Gamma_S M_S}(k_1 k_2 g^{\mu\nu} - k^\mu_1 k^\nu_2),$$

$$\mathcal{M}^{\mu\nu}_{\phi\,\mathrm{rad},s} = \frac{e g_{\phi NN}}{s - M^2_N}\left(\gamma^\nu - i\frac{\kappa_{\phi NN}}{2M_N}\sigma^{\nu\alpha} k_{2\alpha}\right)(\not{q}_s + M_N) \times \left(\gamma^\mu + i\frac{\kappa_N}{2M_N}\sigma^{\mu\beta} k_{1\beta}\right),$$

$$\mathcal{M}^{\mu\nu}_{\phi\,\mathrm{rad},u} = \frac{e g_{\phi NN}}{u - M^2_N}\left(\gamma^\mu + i\frac{\kappa_N}{2M_N}\sigma^{\mu\alpha} k_{1\alpha}\right)(\not{q}_u + M_N) \times \left(\gamma^\nu - i\frac{\kappa_{\phi NN}}{2M_N}\sigma^{\nu\beta} k_{2\beta}\right),$$

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$$\mathcal{L}_{\gamma\Phi\phi} = \frac{e g_{\gamma\Phi\phi}}{M_\phi}\epsilon^{\mu\nu\alpha\beta}\partial_\mu A_\nu \partial_\alpha \phi_\beta \Phi$$

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□ strong vertex

$$\mathcal{L}_{f_1 NN} = -g_{f_1 NN}\bar{N}\left[\gamma_\mu - i\frac{\kappa_{f_1 NN}}{2M_N}\gamma_\nu\gamma_\mu\partial^\nu\right] f^\mu_1 \gamma_5 N$$

$$\mathcal{L}_{\Phi NN} = -i g_{\Phi NN}\bar{N}\Phi\gamma_5 N$$

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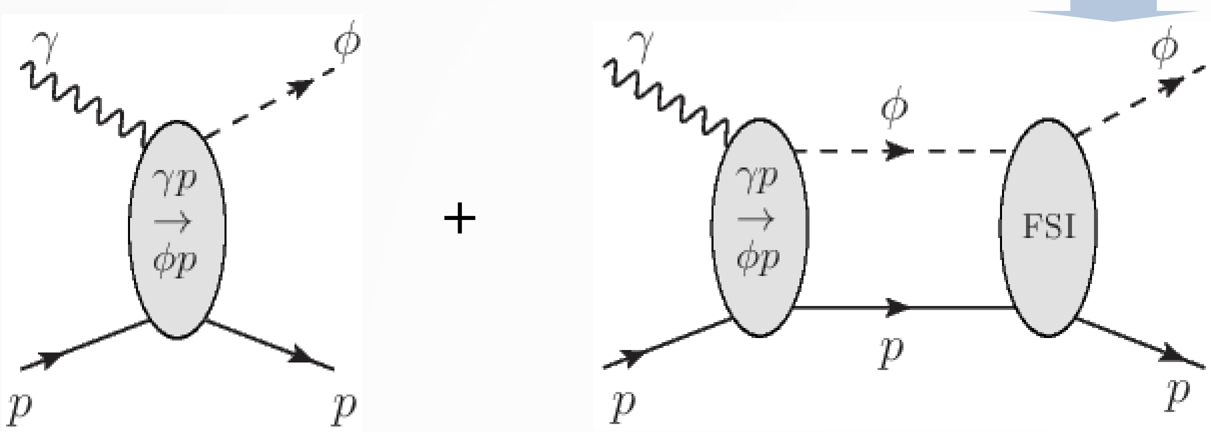
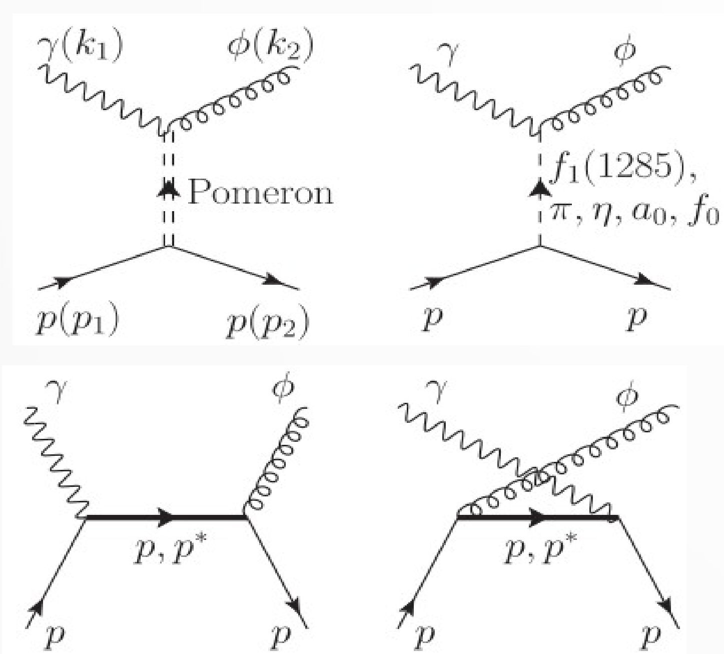
$$\mathcal{L}_{\phi NN} = -g_{\phi NN}\bar{N}\left[\gamma_\mu - \frac{\kappa_{\phi NN}}{2M_N}\sigma_{\mu\nu}\partial^\nu\right] N \phi^\mu$$

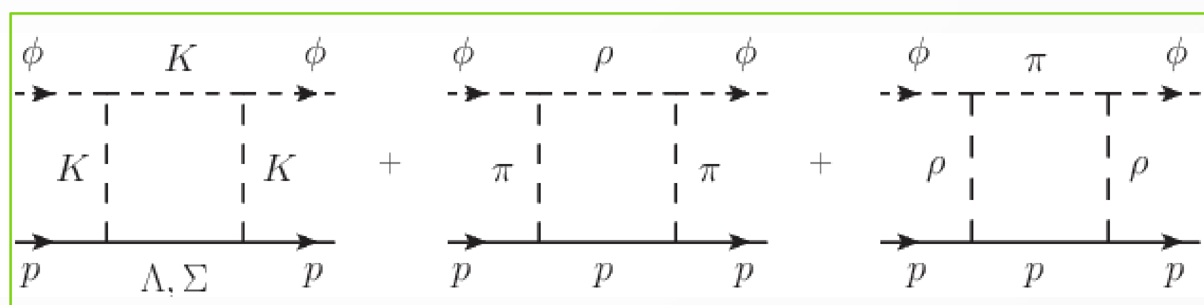
final state interaction (FSI)

❑ Scattering amplitude: $T_{\phi N,\gamma N}(E) = [B_{\phi N,\gamma N} + T^{FSI}_{\phi N,\gamma N}(E)]$





FSI=



□ decay mode of φ-meson

Γ_1	K^+K^-	$(49.2 \pm 0.5)\%$
Γ_2	$K^0_L K^0_S$	$(34.0 \pm 0.4)\%$
Γ_3	$\rho\pi + \pi^+\pi^-\pi^0$	$(15.24 \pm 0.33)\%$
Γ_4	$\rho\pi$	
Γ_5	$\pi^+\pi^-\pi^0$	
Γ_6	$\eta\gamma$	$(1.303 \pm 0.025)\%$
Γ_7	$\pi^0\gamma$	$(1.32 \pm 0.06) \times 10^{-3}$
Γ_8	$\ell^+\ell^-$	
Γ_9	e^+e^-	$(2.974 \pm 0.034) \times 10^{-4}$
Γ_{10}	$\mu^+\mu^-$	$(2.86 \pm 0.19) \times 10^{-4}$
Γ_{11}	ηe^+e^-	$(1.08 \pm 0.04) \times 10^{-4}$
Γ_{12}	$\pi^+\pi^-$	$(7.3 \pm 1.3) \times 10^{-5}$
Γ_{13}	$\omega\pi^0$	$(4.7 \pm 0.5) \times 10^{-5}$
Γ_{14}	$\omega\gamma$	$< 5\%$
Γ_{15}	$\rho\gamma$	$< 1.2 \times 10^{-5}$

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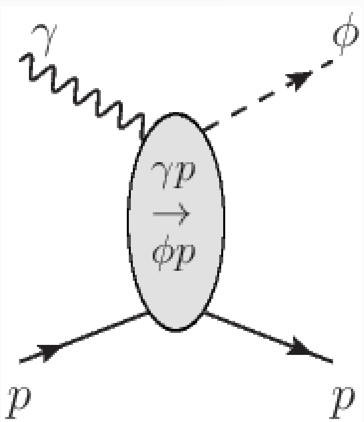

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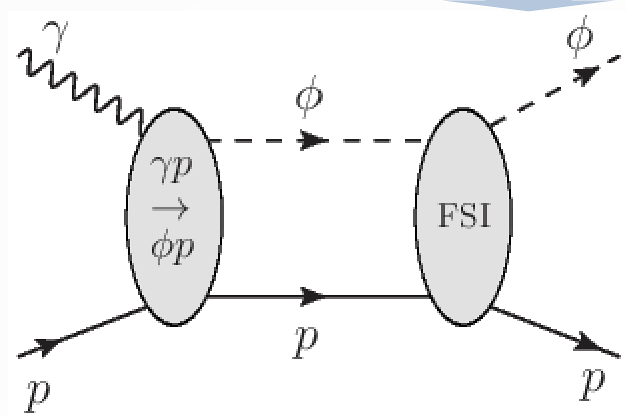

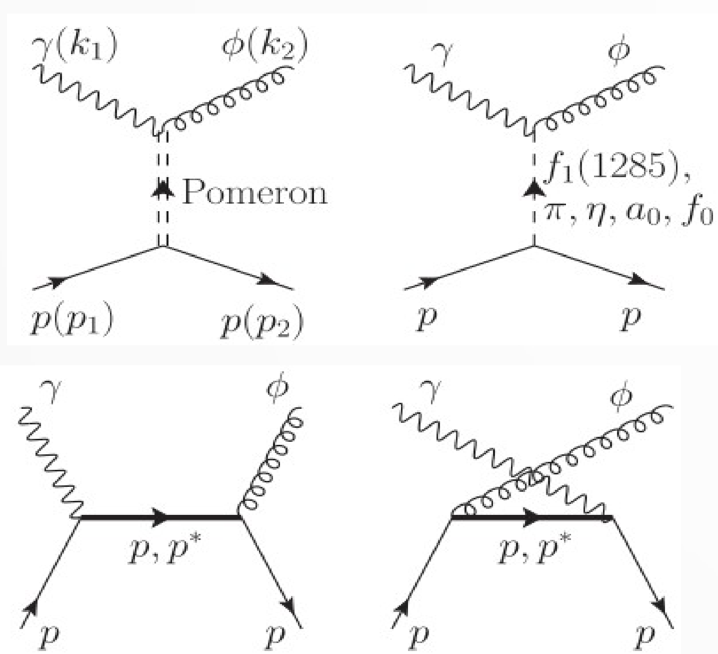

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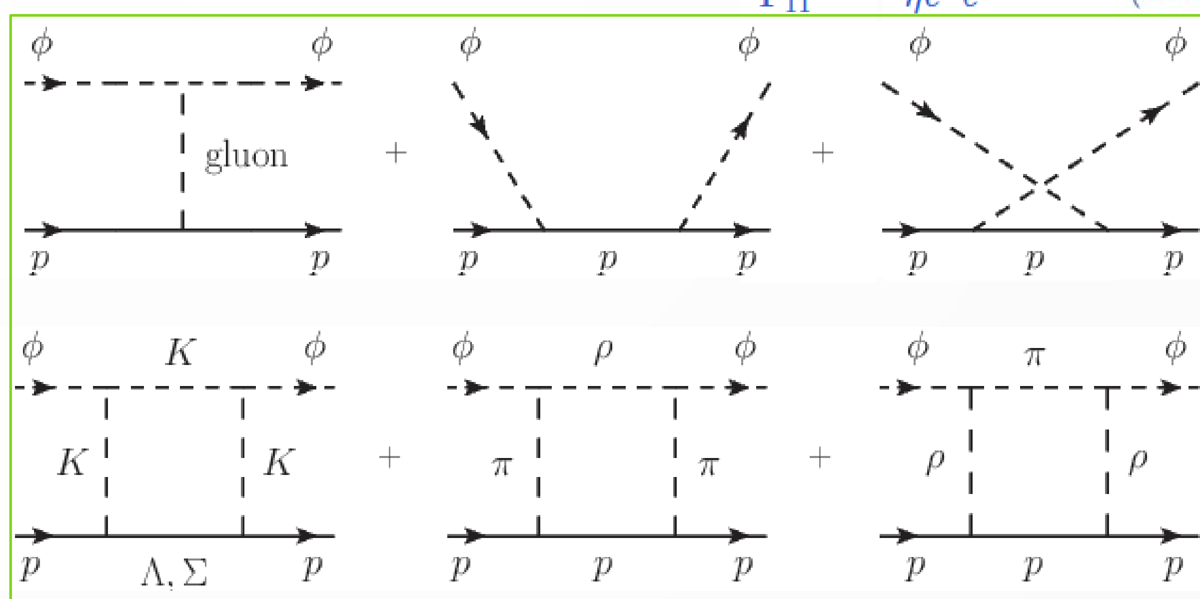

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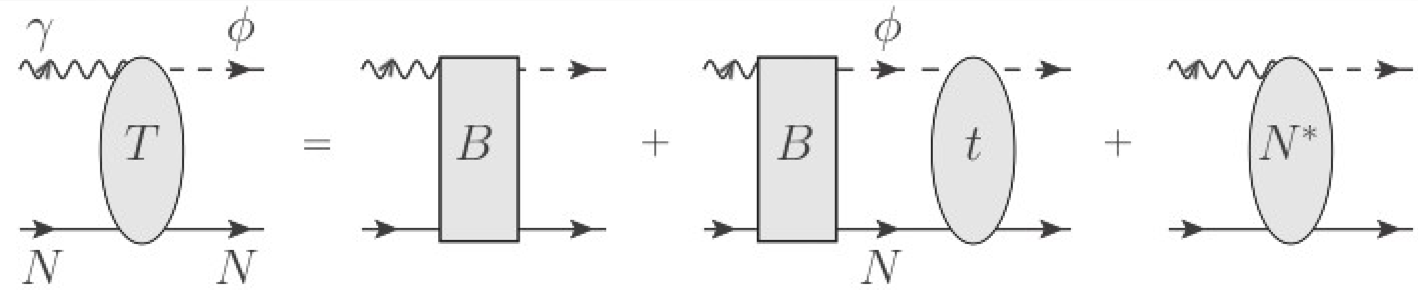
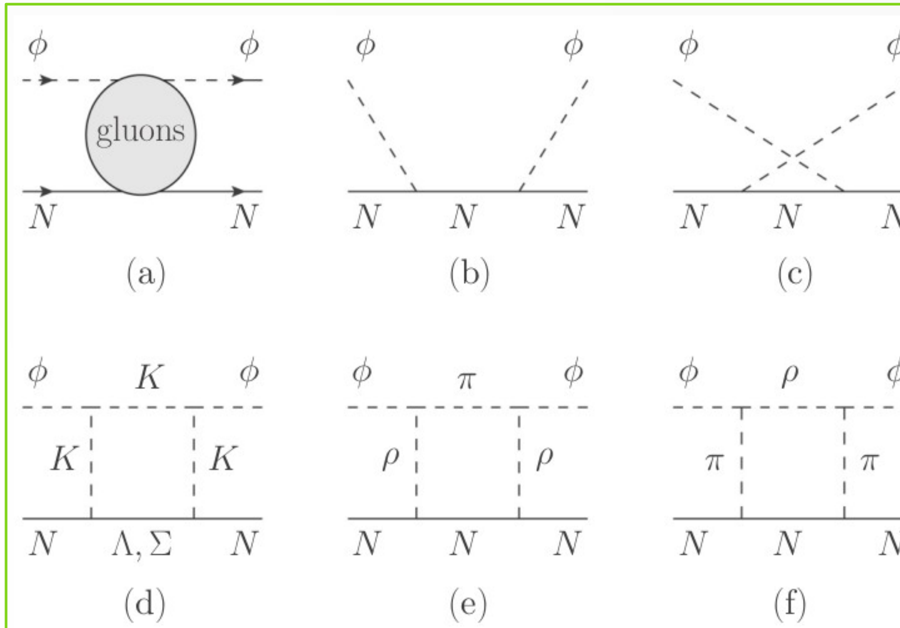
		$1.3) \times 10^{-5}$
		$0.5) \times 10^{-5}$
		$\times 10^{-5}$

final state interaction (FSI)



$$T_{\phi N,\gamma N}(E) = B_{\phi N,\gamma N} + T^{\mathrm{FSI}}_{\phi N,\gamma N}(E) + T^{N^*}_{\phi N,\gamma N}(E)$$

$t_{\phi N,\phi N}(E)$



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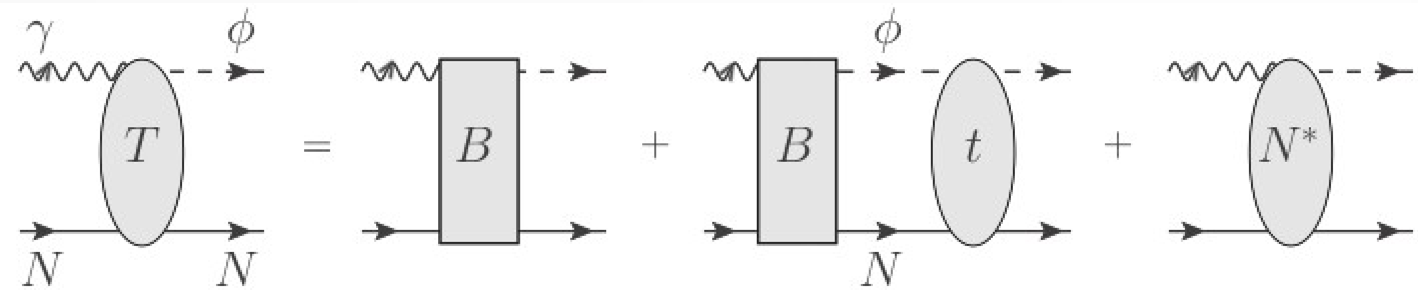
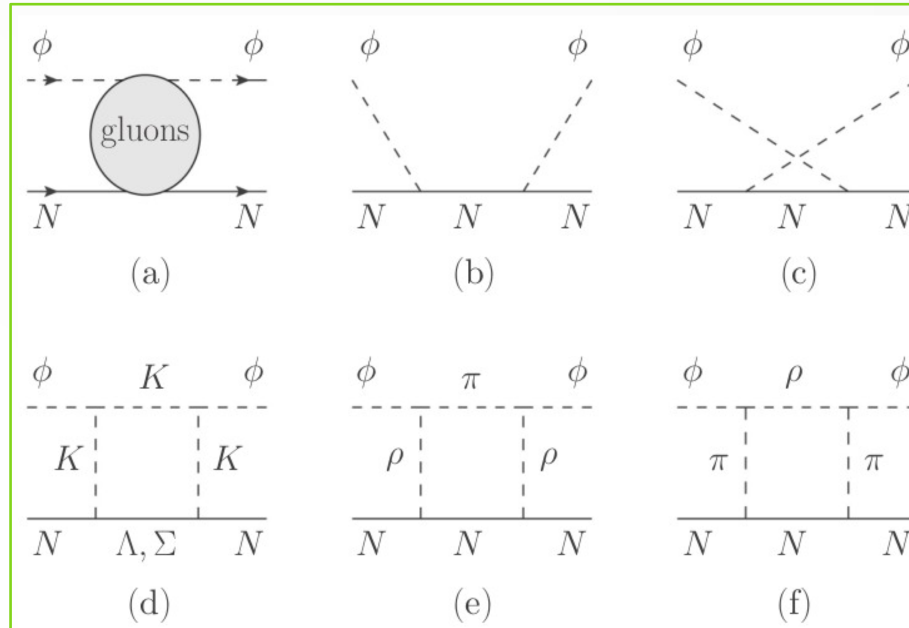


$t_{\phi N,\phi N}(E)$



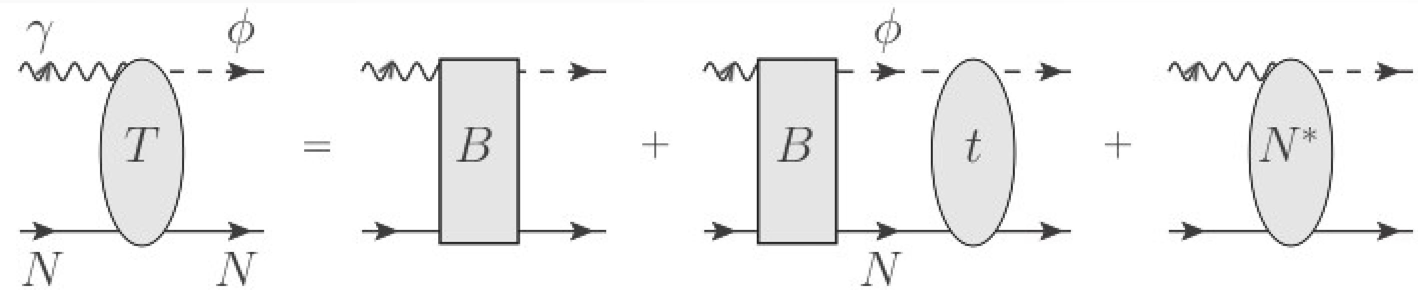
$$T_{\phi N,\gamma N}(E) = B_{\phi N,\gamma N} + \underline{T^{\mathrm{FSI}}_{\phi N,\gamma N}(E)} + T^{N^*}_{\phi N,\gamma N}(E)$$

$$t_{\phi N,\phi N}(E) G_{\phi N}(E) B_{\phi N,\gamma N}$$

$$G_{MB}(E) = \frac{|MB\rangle\langle MB|}{E - H_0 + i\epsilon}$$: meson-baryon propagator

$$t_{\phi N,\phi N}(E) = V_{\phi N,\phi N}(E) + V_{\phi N,\phi N} G_{\phi N}(E) t_{\phi N,\phi N}(E)$$

final state interaction (FSI)



$$T_{\phi N,\gamma N}(E) = B_{\phi N,\gamma N} + \underline{T^{\text{FSI}}_{\phi N,\gamma N}}(E) + T^{N^*}_{\phi N,\gamma N}(E)$$

$$t_{\phi N,\phi N}(E) G_{\phi N}(E) B_{\phi N,\gamma N}$$

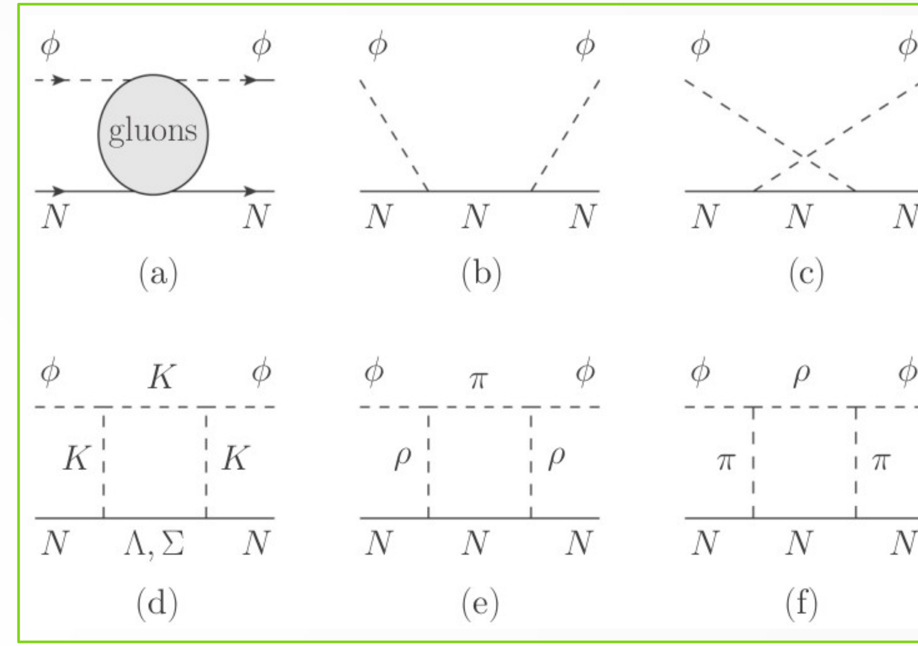
$$G_{MB}(E) = \frac{|MB\rangle\langle MB|}{E - H_0 + i\epsilon}$$: meson-baryon propagator

$$t_{\phi N,\phi N}(E) = \underline{V_{\phi N,\phi N}(E)} + V_{\phi N,\phi N} G_{\phi N}(E) t_{\phi N,\phi N}(E)$$

$$v^{\text{Gluon}}_{\phi N,\phi N} + v^{\text{Direct}}_{\phi N,\phi N} + \sum_{MB} v_{\phi N,MB} G_{MB}(E) v_{MB,\phi N}$$

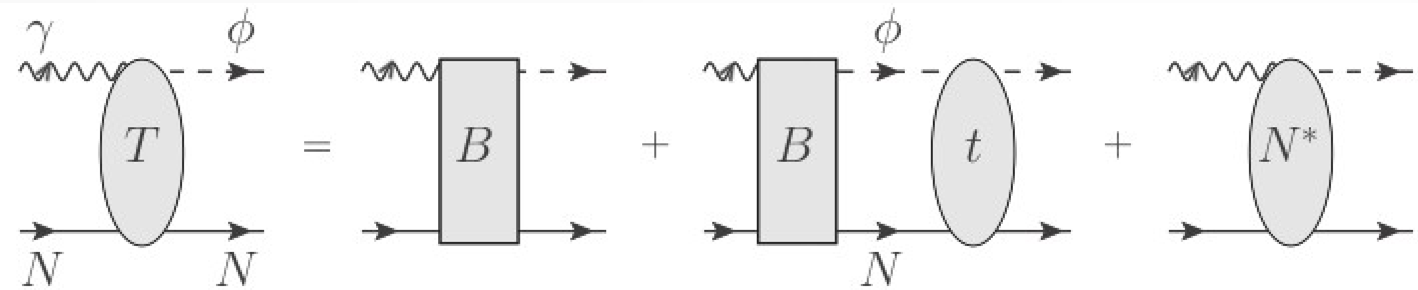
(a) (b,c) (d,e,f) MB = (KΛ, KΣ, πN, ρN)

$t_{\phi N,\phi N}(E)$



□ To leading order,
we obtain these FSI diagrams.

final state interaction (FSI)



$$T_{\phi N,\gamma N}(E) = B_{\phi N,\gamma N} + T^{\rm FSI}_{\phi N,\gamma N}(E) + T^{N^*}_{\phi N,\gamma N}(E)$$

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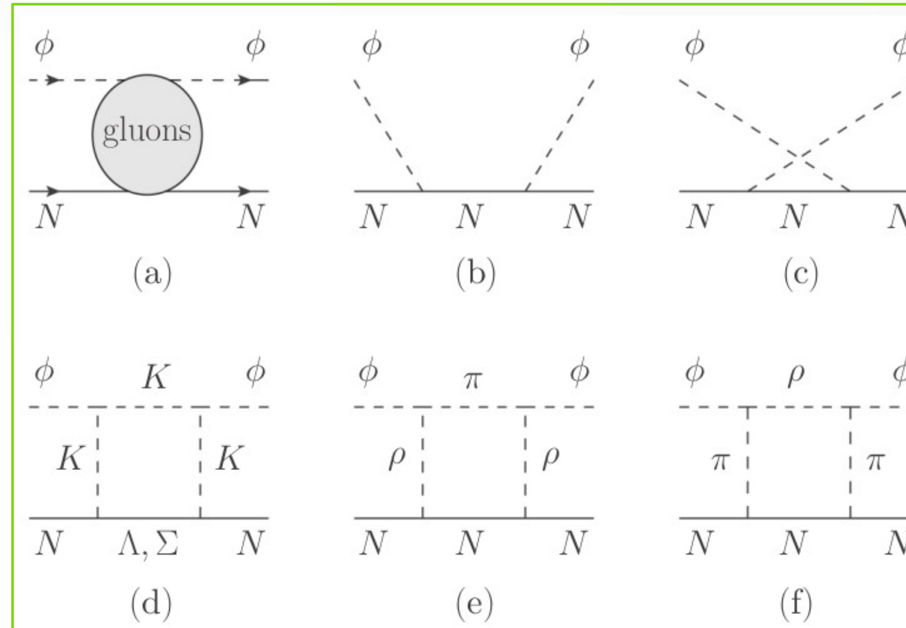
$$t_{\phi N,\phi N}(E) = V_{\phi N,\phi N}(E) + V_{\phi N,\phi N}G_{\phi N}(E)t_{\phi N,\phi N}(E)$$

$$v^{\rm Gluon}_{\phi N,\phi N} + v^{\rm Direct}_{\phi N,\phi N} + \sum_{MB} v_{\phi N,MB}G_{MB}(E)v_{MB,\phi N}$$

(a) (b,c) (d,e,f) MB = (KΛ, KΣ, πN, ρN)

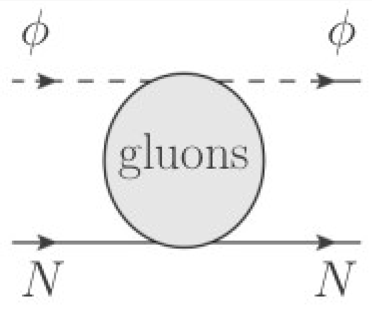
$t_{\phi N,\phi N}(E)$



$$\frac{1}{E - H_0 + i\epsilon} = P\frac{1}{E - H_0} - i\pi\delta(E - H_0)$$

□ We consider both parts numerically.

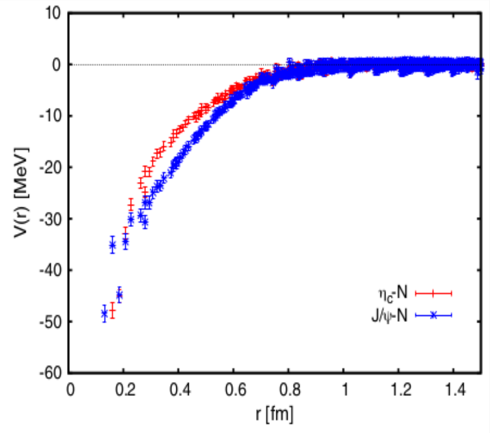
final state interaction (FSI)



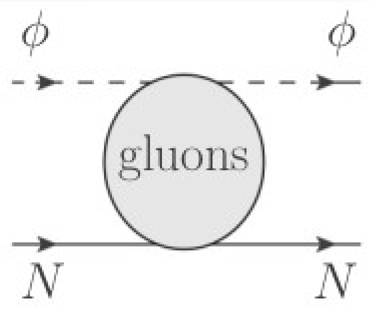
❑ The J/ψ-N potential from the LQCD data
~ Yukawa form (υ_0 = 0.1, α = 0.3 GeV)
[Kawanai, Sasaki, PRD.82.091501(R) (2010)]

$$\mathcal{V}_{\text{gluon}} = -\upsilon_0 \frac{e^{-\alpha r}}{r}$$

❑ which is assumed in our work, φ-N potential
The best fit was obtained by (υ_0 = 0.2, α = 0.5 GeV).



final state interaction (FSI)



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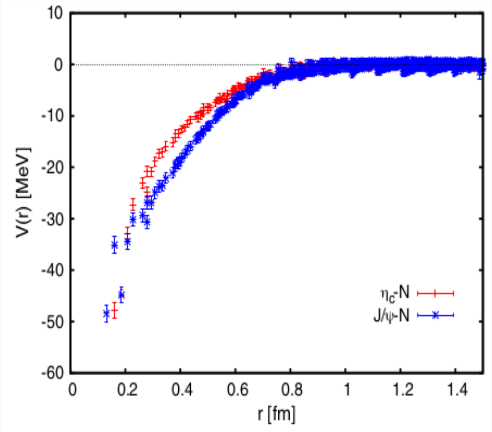

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The best fit was obtained by (υ_0 = 0.2, α = 0.5 GeV).

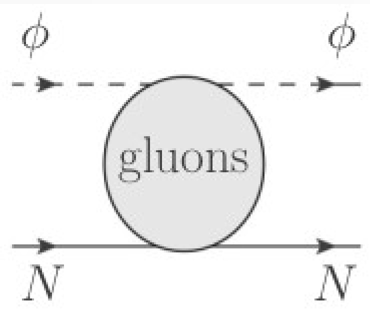
❑ The potential is obtained by taking the nonrelativistic limit of the scalar-meson exchange amplitude calculated from the Lagrangian:

$$\mathscr{L}_\sigma = V_0(\bar{\psi}_N \psi_N \Phi_\sigma + \phi^\mu \phi_\mu \Phi_\sigma)$$

Φ_σ is a scalar field with mass α ($V_0 = -8\upsilon_0 \pi M_\varphi$).

❑ $$\mathcal{V}_{\rm gluon}(k\lambda_\phi, pm_s; k'\lambda'_\phi, p'm'_s) = \frac{V_0}{(p-p')^2 - \alpha^2} [\bar{u}_N(p, m_s) u_N(p', m'_s)][\epsilon^*_\mu(k, \lambda_\phi)\epsilon^\mu(k', \lambda'_\phi)]$$

final state interaction (FSI)



- The J/ψ-N potential from the LQCD data ~ Yukawa form (υ_0 = 0.1, α = 0.3 GeV)
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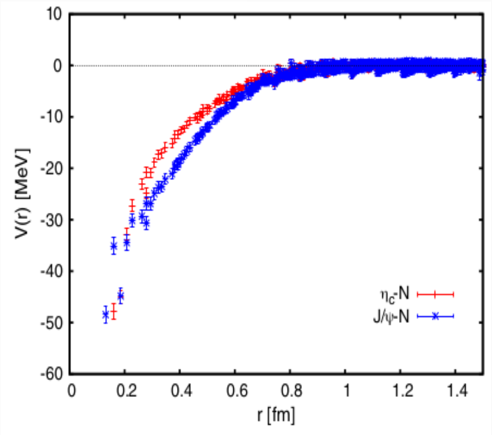
  The best fit was obtained by (υ_0 = 0.2, α = 0.5 GeV).



- The φ-N potential from the LQCD [PRD.106.074507 (2022)]

Attractive N-ϕ Interaction and Two-Pion Tail from Lattice QCD near Physical Point

Yan Lyu,[1,2,*] Takumi Doi,[2,†] Tetsuo Hatsuda,[2,‡] Yoichi Ikeda,[3,§]
Jie Meng,[1,4,¶] Kenji Sasaki,[3,**] and Takuya Sugiura[2,††]

- The simple fitting functions such as "the Yukawa form" and "the van der Waals form ~ $1/r^k$ with k=6(7)" cannot reproduce the lattice data.

> We need to update our results based on the LQCD data.

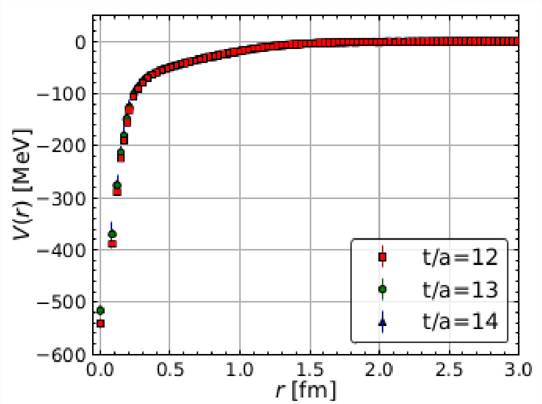
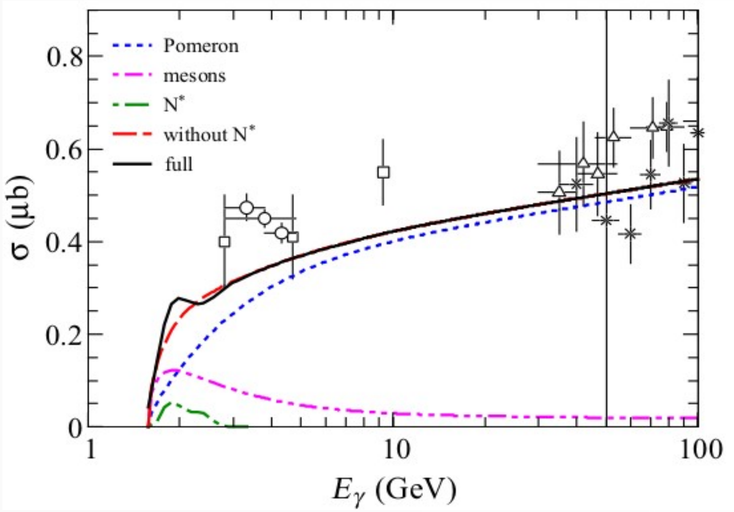


FIG. 1. (Color online). The N-ϕ potential $V(r)$ in the $^4S_{3/2}$ channel as a function of separation r at Euclidean time t/a = 12 (red squares), 13 (green circles) and 14 (blue triangles).

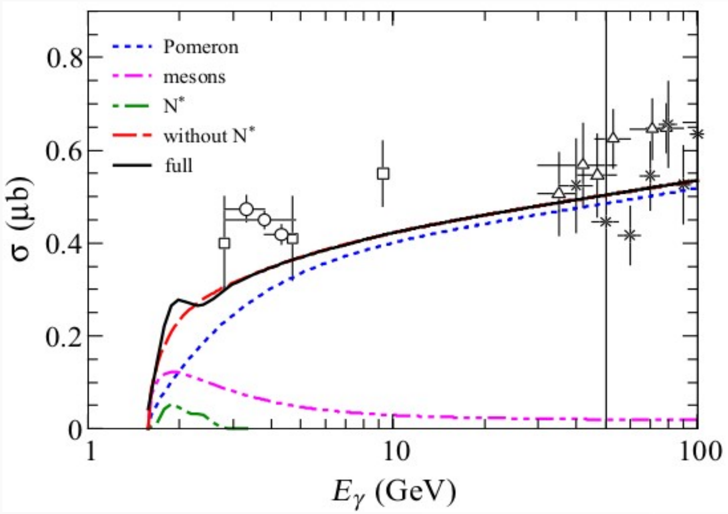
Born term

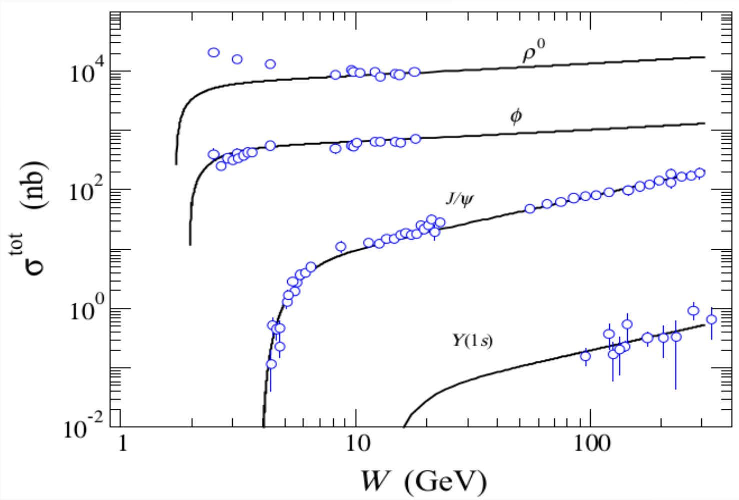
total cross section [$\gamma\ p \to \varphi\ p$]



Born term

total cross section [$\gamma\, p \to \varphi\, p$]





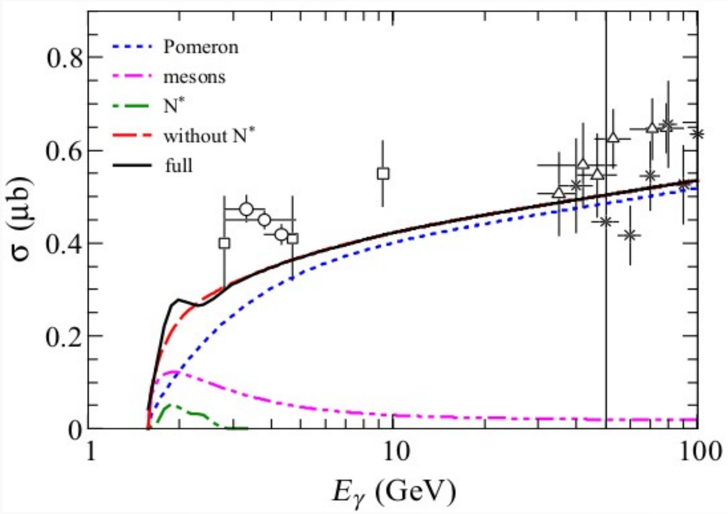
$\gamma\, p \to$
ρ^0
ω
φ
J/ψ
$\Upsilon(1s)$

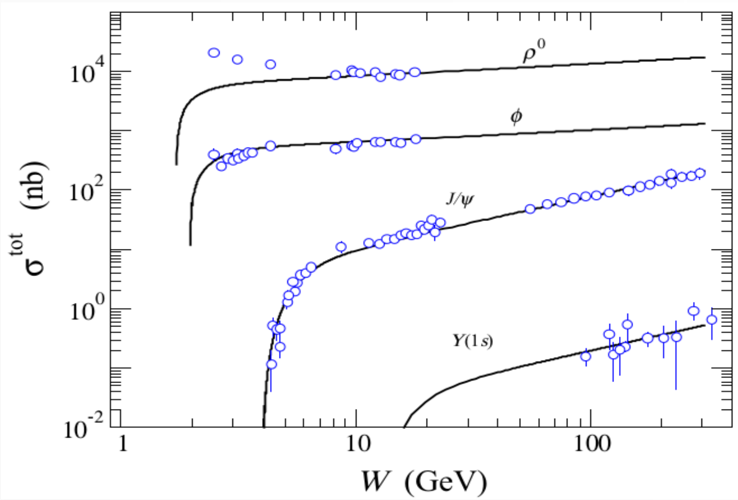
□ Our Pomeron model describes the high energy regions quite well.

Born term

total cross section [$\gamma\, p \rightarrow \varphi\, p$]

with FSI





$\gamma\, p \rightarrow$
ρ^0
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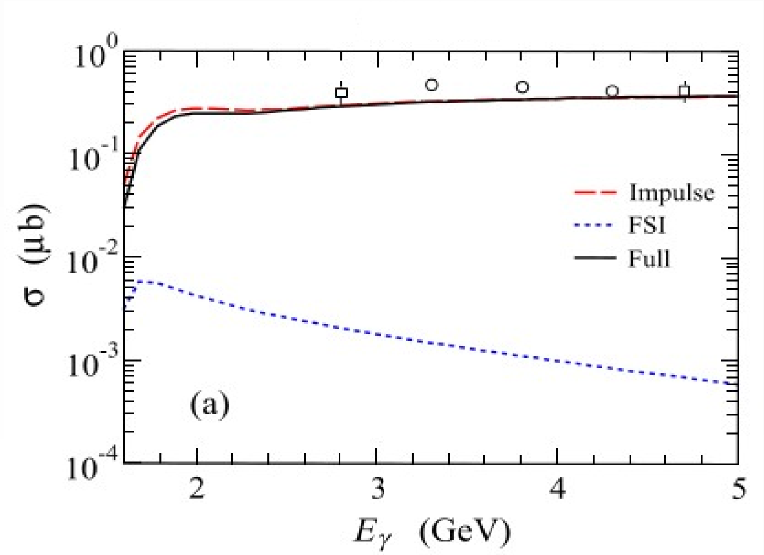
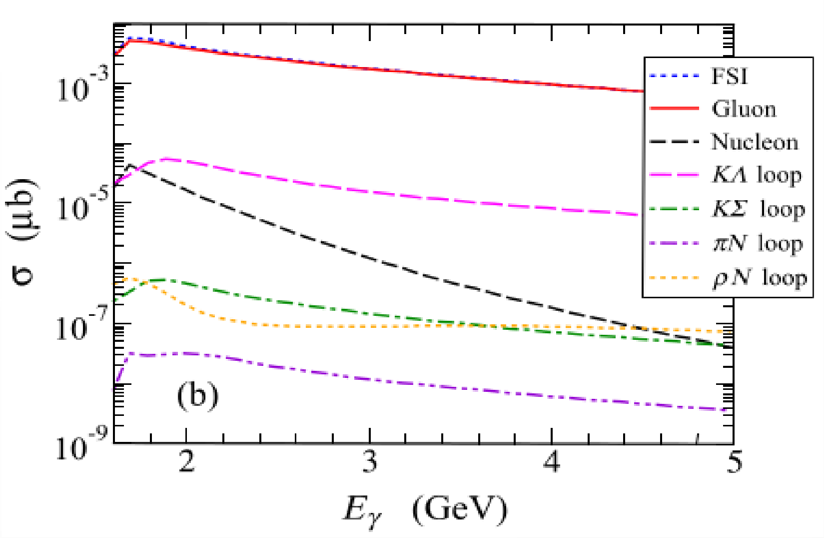
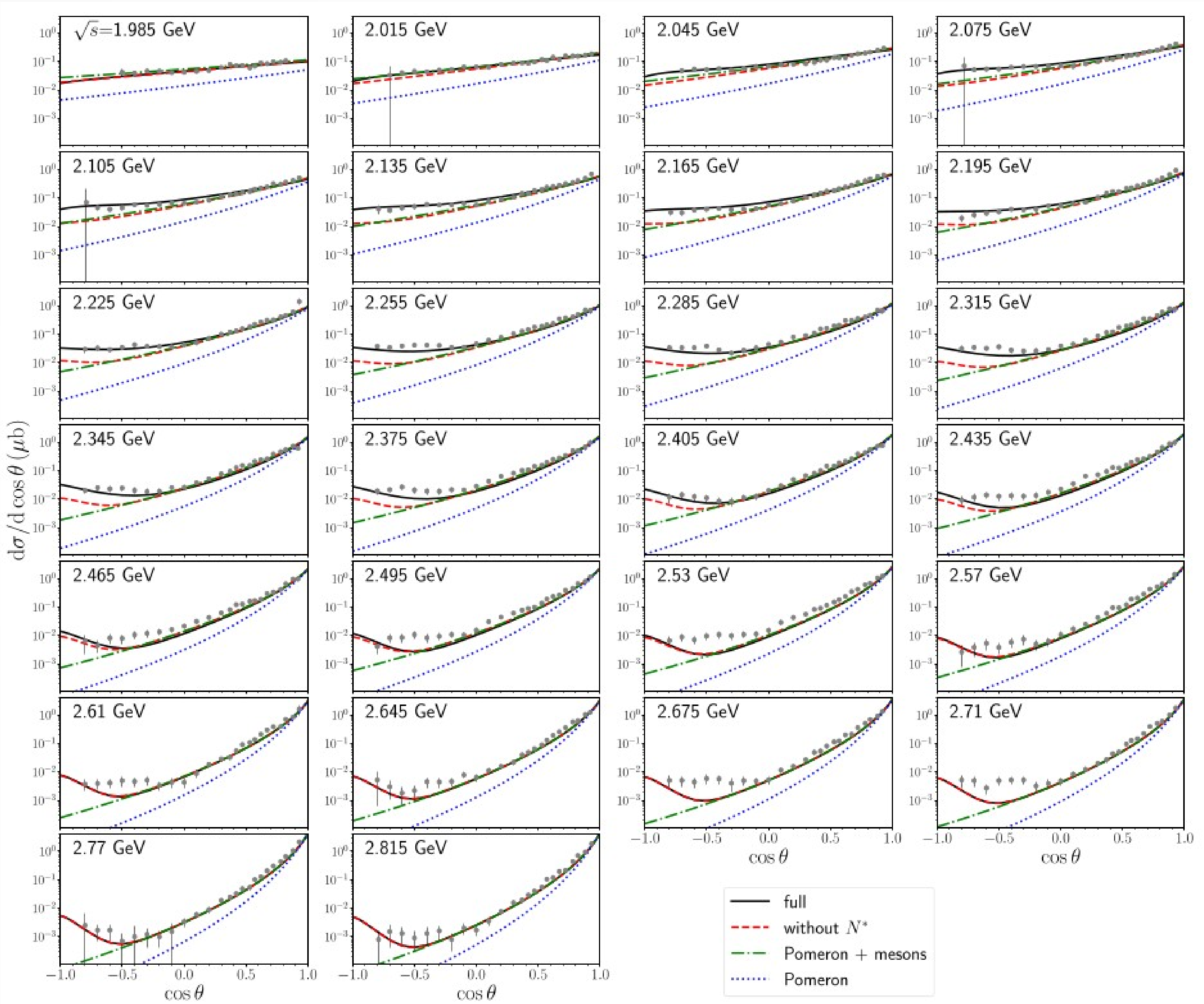
$\Upsilon(1s)$





□ Our Pomeron model describes the high energy regions quite well.

□ The contributions of the FSI terms are almost very small.



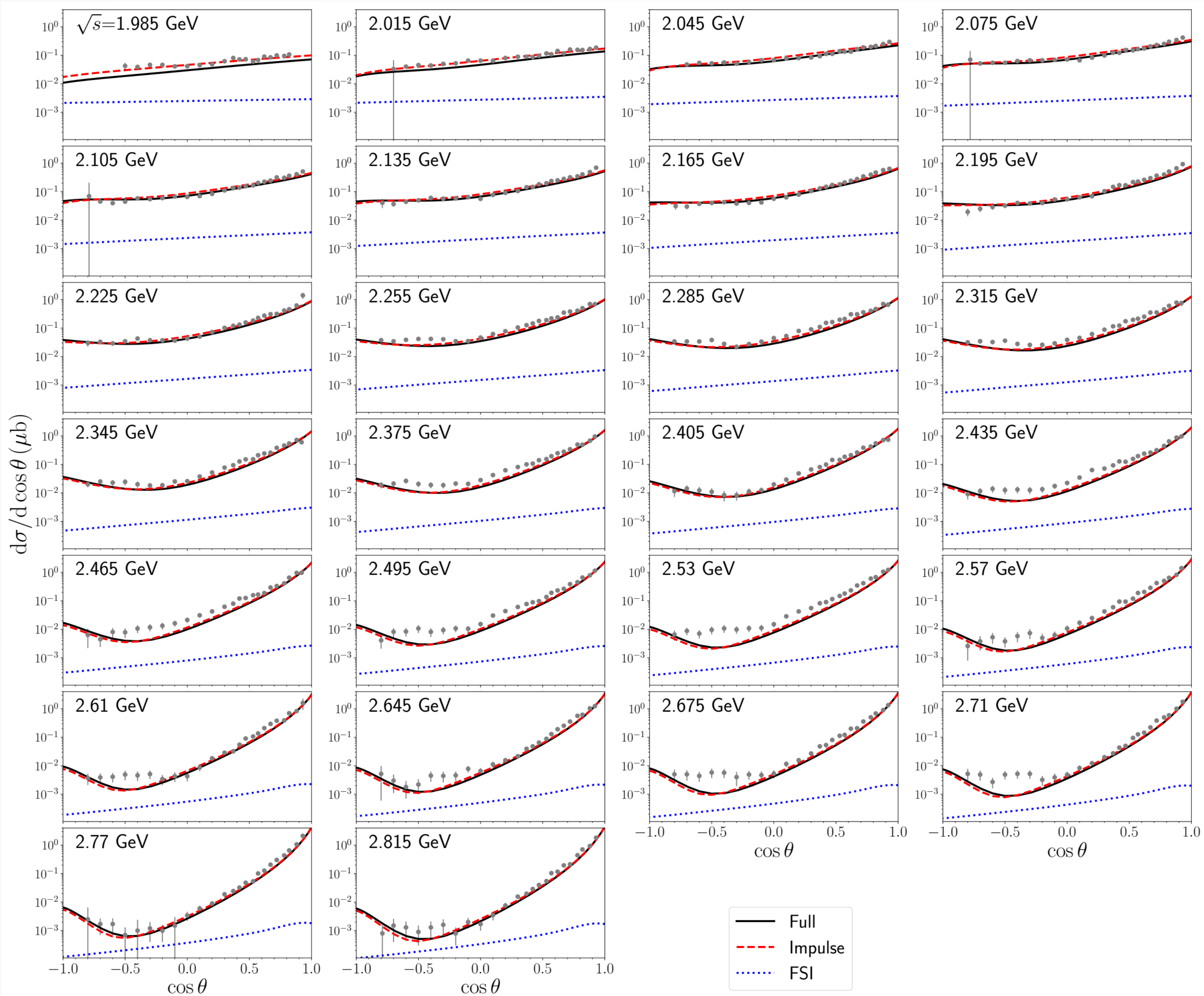
differential cross sections
[γ p → φ p]

Born term

- □ Forward: Pomeron exchange
- □ Backward: mesons, nucleon, N^* exchanges

play crucial roles.

[Exp: Dey (CLAS), PRC.89. 055208 (2014)]



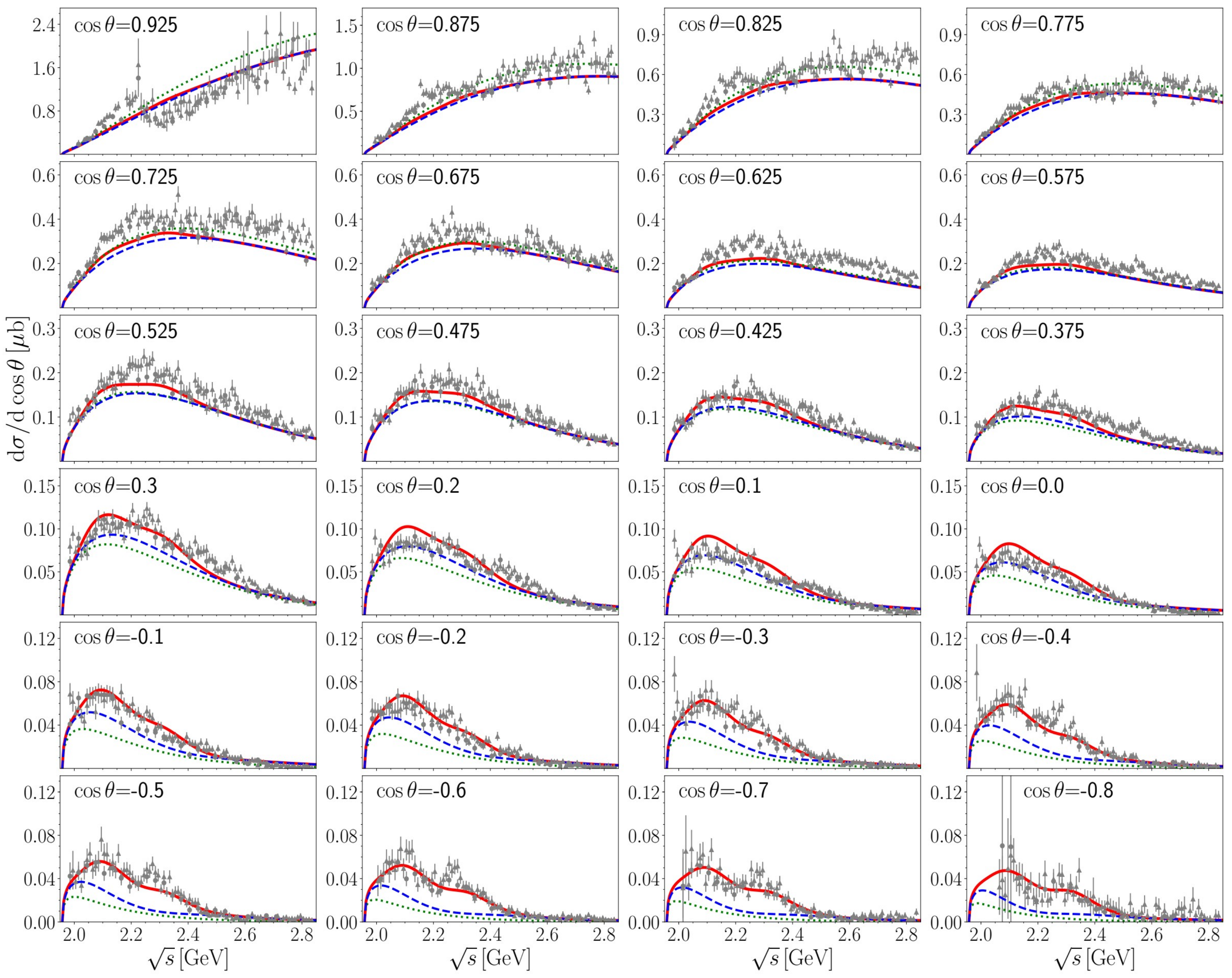
differential cross sections
[γ p → φ p]

with FSI

- ☐ The contributions of the FSI terms are very small.

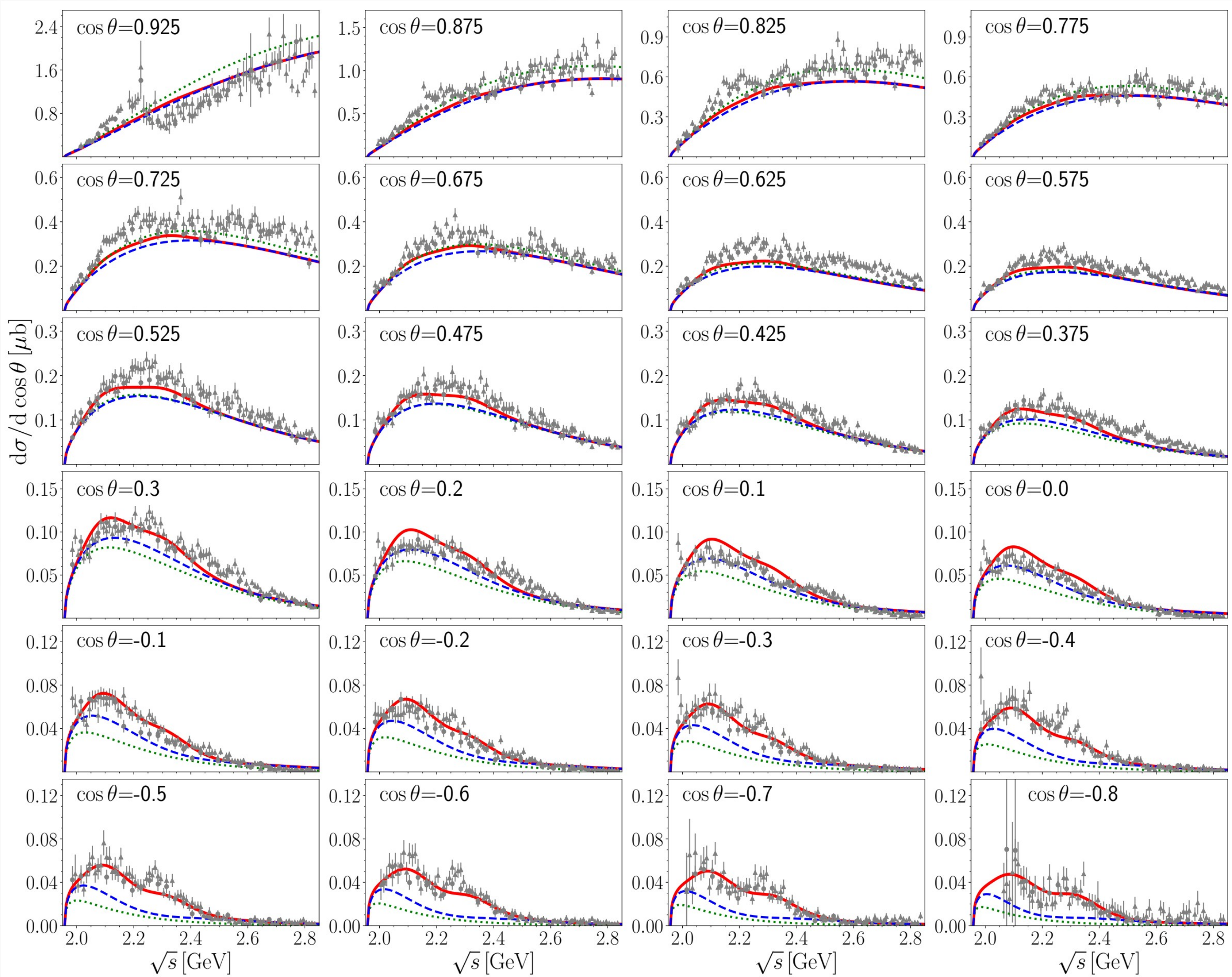
[Exp: Dey (CLAS), PRC.89. 055208 (2014)]

differential cross sections
[$\gamma\ p \rightarrow \varphi\ p$]



Pomeron
Born
total

[Exp: Dey (CLAS), PRC.89. 055208 (2014)]



differential cross sections
[γ p → φ p]

- □ The strong peak at $\sqrt{s} \simeq 2.2$ GeV persists only in cosθ = 0.925 & vanishes around cosθ = 0.8.
- □ The two peaks at $\sqrt{s} \simeq 2.1$ & 2.3 GeV are due to the two N^* contributions, although the magnitudes are far more suppressed.

Pomeron

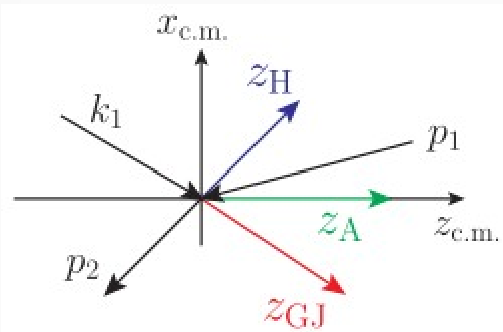
Born

total

[Exp: Dey (CLAS), PRC.89. 055208 (2014)]

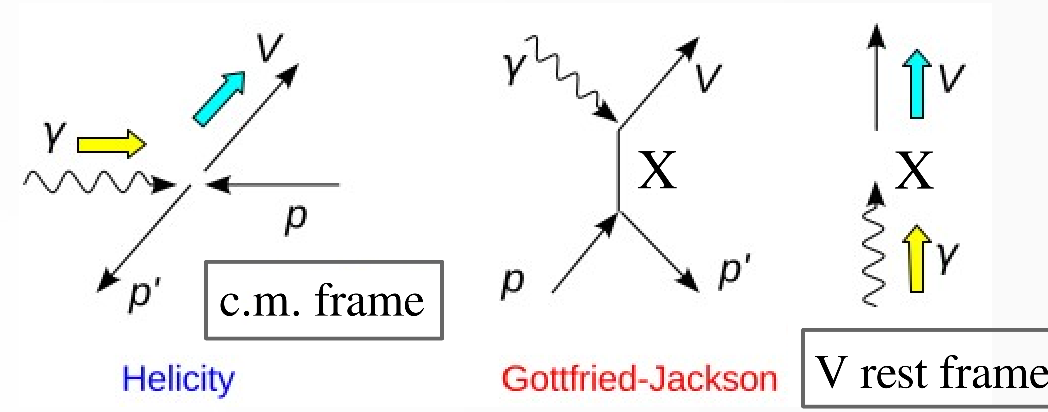
spin-density matrices

❑ Decay frame



V rest frame

Adair frame
Helicty frame
Gottfried-Jackson frame



Definition

$$\rho^0_{\lambda\lambda'} = \frac{1}{N}\sum_{\lambda_\gamma,\lambda_i,\lambda_f} \mathcal{M}_{\lambda_f\lambda;\lambda_i\lambda_\gamma}\mathcal{M}^*_{\lambda_f\lambda';\lambda_i\lambda_\gamma},$$

$$\rho^1_{\lambda\lambda'} = \frac{1}{N}\sum_{\lambda_\gamma,\lambda_i,\lambda_f} \mathcal{M}_{\lambda_f\lambda;\lambda_i-\lambda_\gamma}\mathcal{M}^*_{\lambda_f\lambda';\lambda_i\lambda_\gamma},$$

$$\rho^2_{\lambda\lambda'} = \frac{i}{N}\sum_{\lambda_\gamma,\lambda_i,\lambda_f} \lambda_\gamma\mathcal{M}_{\lambda_f\lambda;\lambda_i-\lambda_\gamma}\mathcal{M}^*_{\lambda_f\lambda';\lambda_i\lambda_\gamma},$$

$$\rho^3_{\lambda\lambda'} = \frac{1}{N}\sum_{\lambda_\gamma,\lambda_i,\lambda_f} \lambda_\gamma\mathcal{M}_{\lambda_f\lambda;\lambda_i\lambda_\gamma}\mathcal{M}^*_{\lambda_f\lambda';\lambda_i\lambda_\gamma},$$

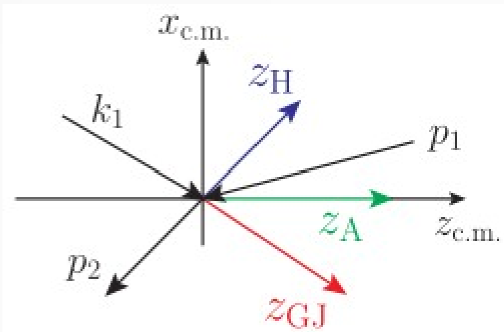
□ λ, λ' : Helicity states of the vector-meson

□ For a *t*-channel exchange of X,
the momentum of γ and V is collinear in the GJ frame.

Thus, the ρ_{ij}^k elements measure the degree of helicity flip due to the *t*-channel exchange of X in the GJ frame.

spin-density matrices

❑ Decay frame

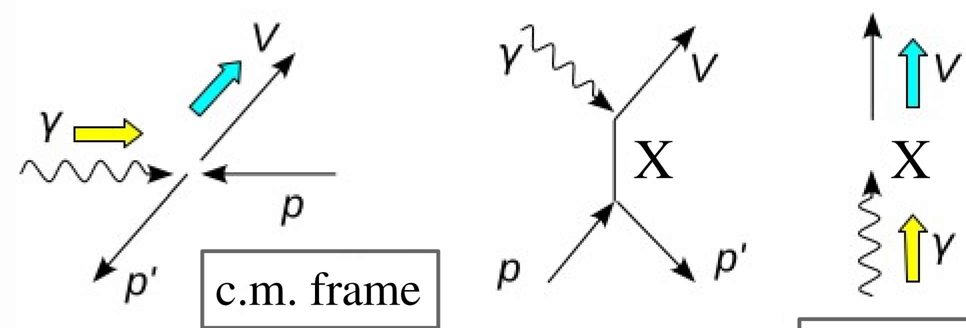


V rest frame

Adair frame

Helicty frame

Gottfried-Jackson frame



Helicity Gottfried-Jackson V rest frame

Definition

$$\rho^0_{\lambda\lambda'} = \frac{1}{N}\sum_{\lambda_\gamma,\lambda_i,\lambda_f} \mathcal{M}_{\lambda_f\lambda;\lambda_i\lambda_\gamma}\mathcal{M}^*_{\lambda_f\lambda';\lambda_i\lambda_\gamma},$$

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$$\rho^0_{00} \propto \left|\mathcal{M}_{\lambda_\gamma=1,\lambda_\phi=0}\right|^2 + \left|\mathcal{M}_{\lambda_\gamma=-1,\lambda_\phi=0}\right|^2$$

- Single helicity-flip transition between γ & V

$$-\text{Im}[\rho^2_{1-1}] \approx \rho^1_{1-1} = \frac{1}{2}\frac{\sigma^N - \sigma^U}{\sigma^N + \sigma^U}$$

- Relative contribution between Natural & Unnatural parity exchanges

□ Convert into other frames by applying Wigner rotations:

$$\alpha_{\text{A}\to\text{H}} = \theta_{\text{c.m.}},$$

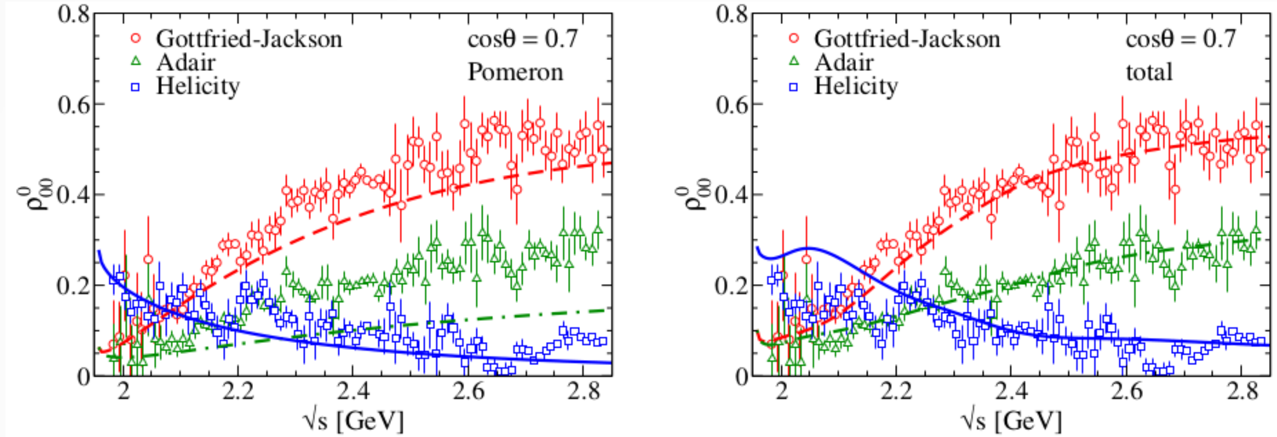
$$\alpha_{\text{H}\to\text{GJ}} = -\cos^{-1}\left(\frac{v - \cos\theta_{\text{c.m.}}}{v\cos\theta_{\text{c.m.}} - 1}\right)$$

$$\alpha_{\text{A}\to\text{GJ}} = \alpha_{\text{A}\to\text{H}} + \alpha_{\text{H}\to\text{GJ}}$$

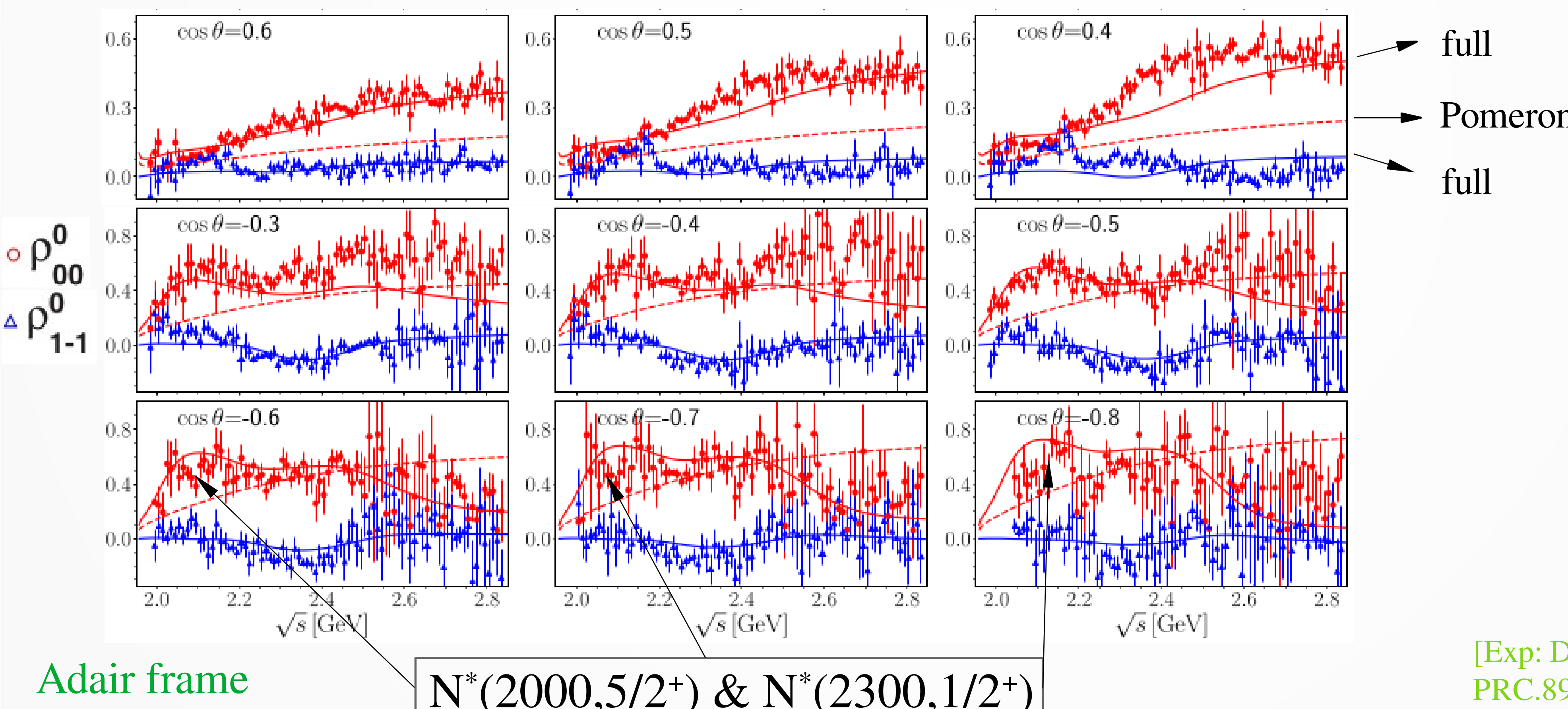
v : The velocity of the K meson in the φ rest frame (φ → $K\bar{K}$ decay)

spin-density matrices

$\gamma\, p \rightarrow \varphi\, p$



- TCHC & SCHC are broken.



Adair frame

[Exp: Dey (CLAS), PRC.89. 055208 (2014)]

- We employ a distorted-wave impulse approximation.

- The contribution from the impulse term for spin J=0 nuclei:

$$\frac{d\sigma^{\text{IMP}}}{d\Omega_{\text{Lab}}} = \frac{(2\pi)^4 |\mathbf{k}|^2 E_V(\mathbf{k}) E_A(\mathbf{q}-\mathbf{k})}{|E_A(\mathbf{q}-\mathbf{k})|\mathbf{k}| + E_V(\mathbf{k})(|\mathbf{k}| - |\mathbf{q}|\cos\theta_{\text{Lab}})|} |A F_T(t) \bar{t}(\mathbf{k},\mathbf{q})|^2$$

$\gamma\, ^4\text{He} \to \phi\, ^4\text{He}$ $\qquad$ $\gamma\, p \to \phi\, p$

$$F_c(q^2) = F_N(q^2) F_T(q^2 = t)$$

F_c (F_N) :
nuclear (nucleon) charge FF

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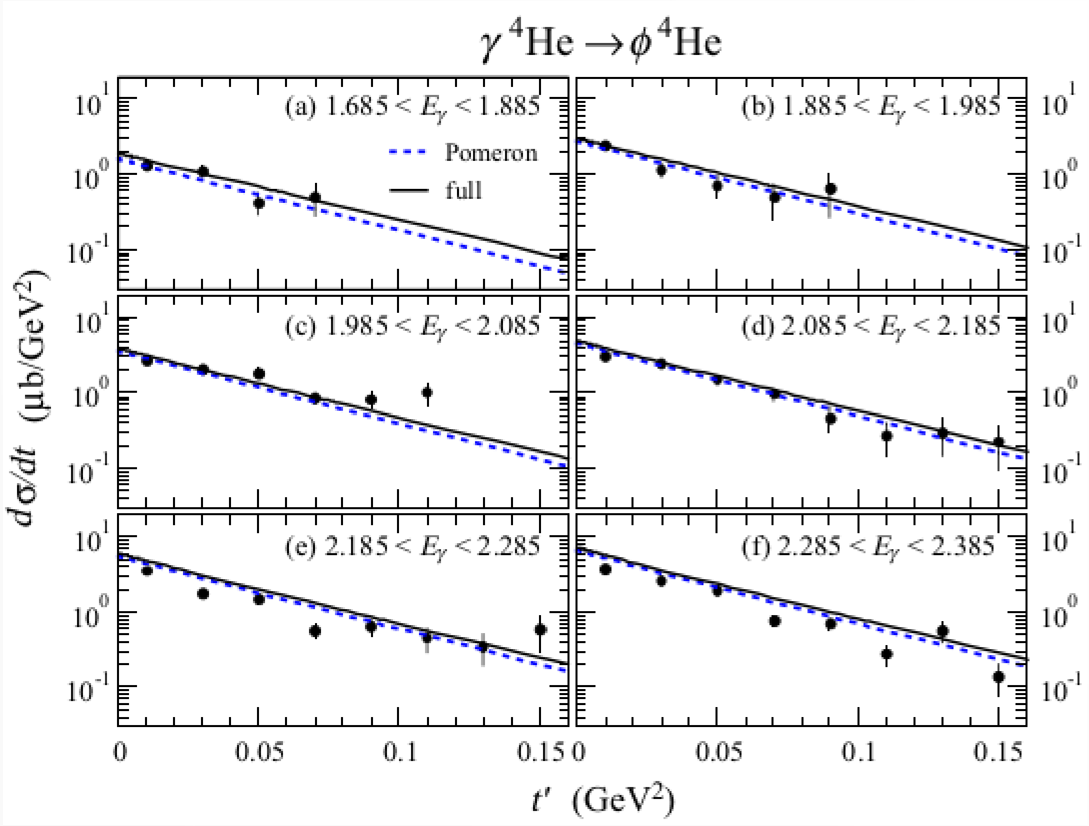
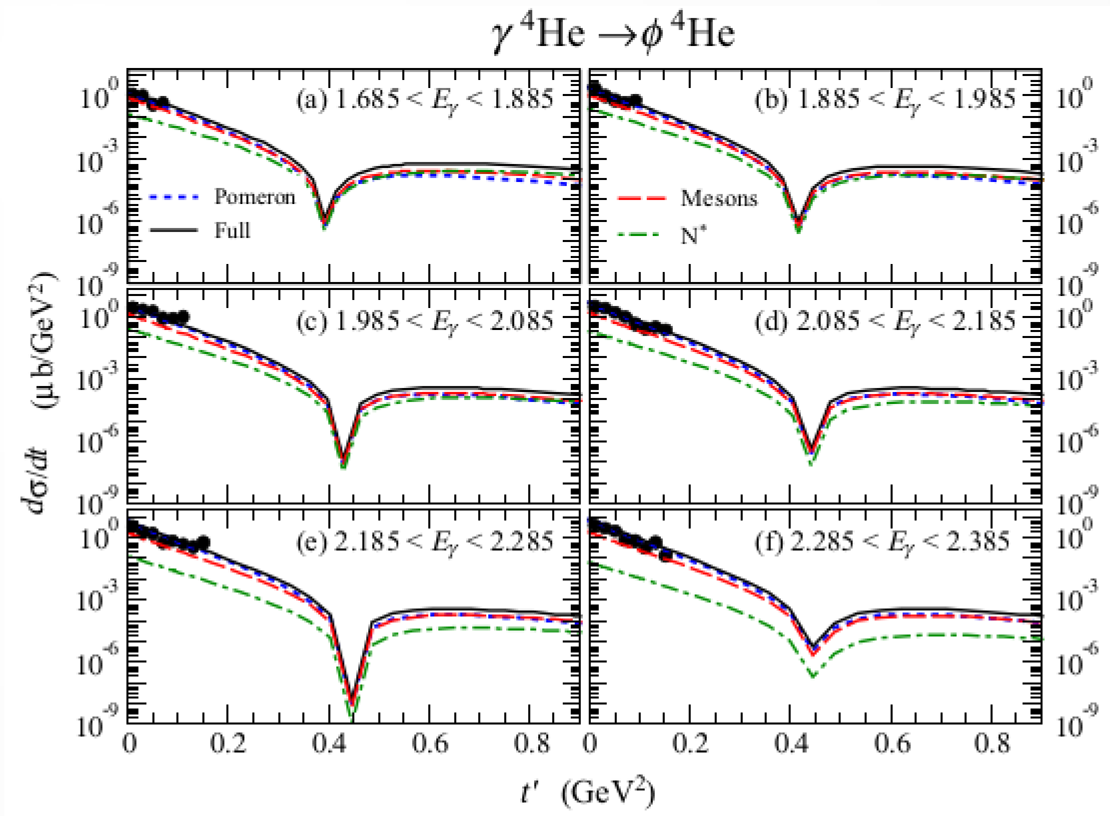
Fc (FN) :
nuclear (nucleon) charge FF

γ ^{4}He → φ ^{4}He   γ p → φ p





[Exp: Hiraiwa (LEPS), PRC.035208.5 (2017)]

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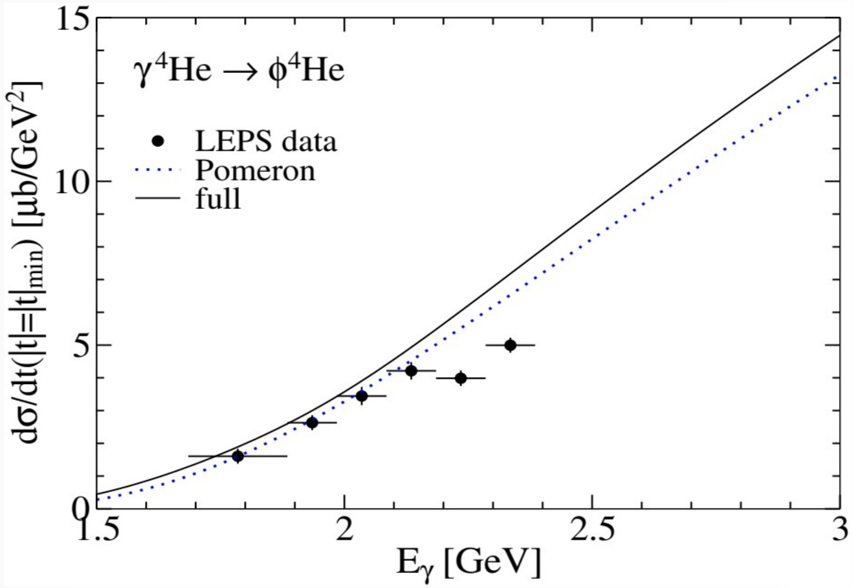
$\gamma\ ^4He \rightarrow \varphi\ ^4He$



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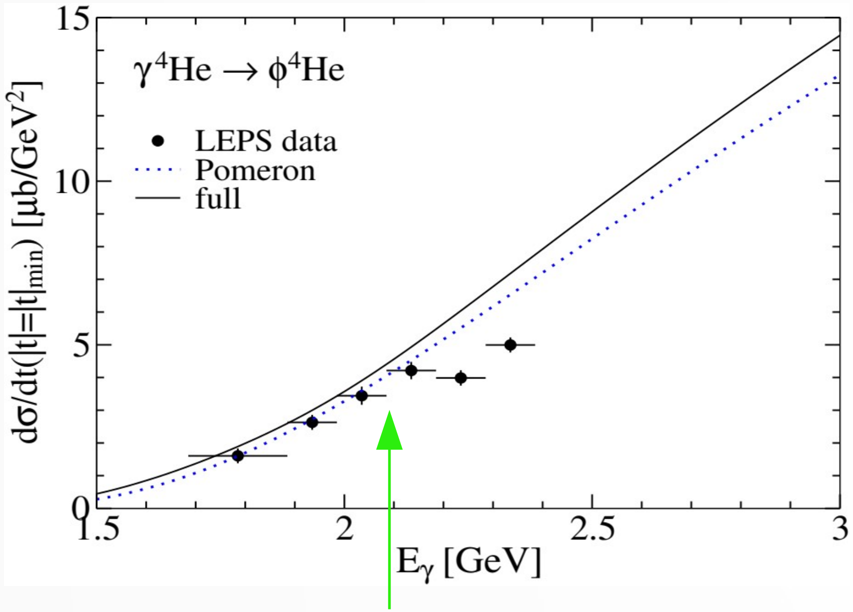

[Exp: Hiraiwa (LEPS), PRC.035208.5 (2017)]

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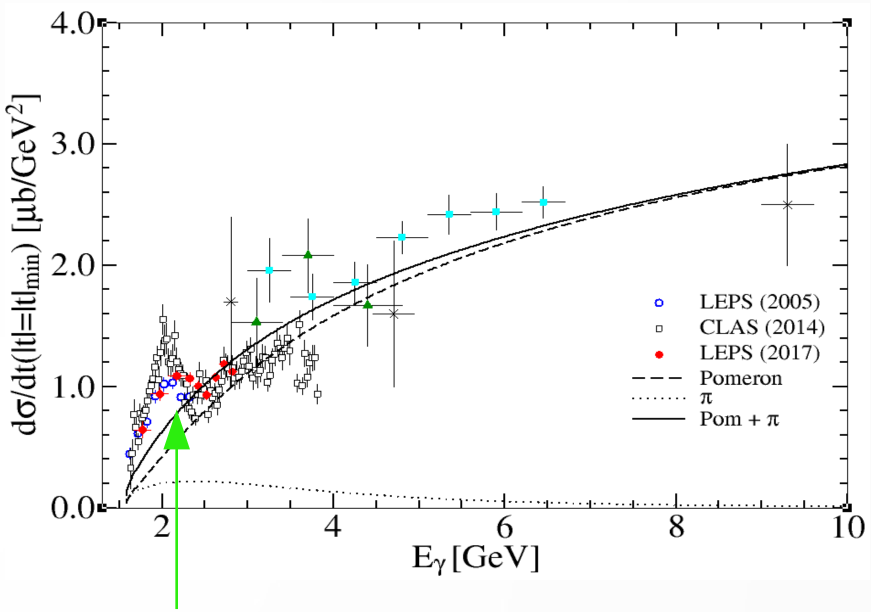

- is not due to the N* contribution.
- may arise from another mechanism.

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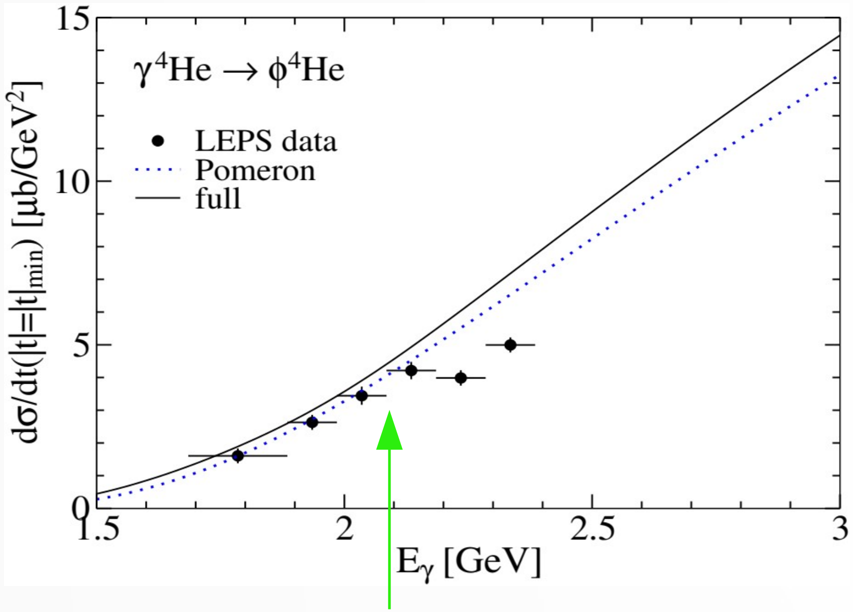

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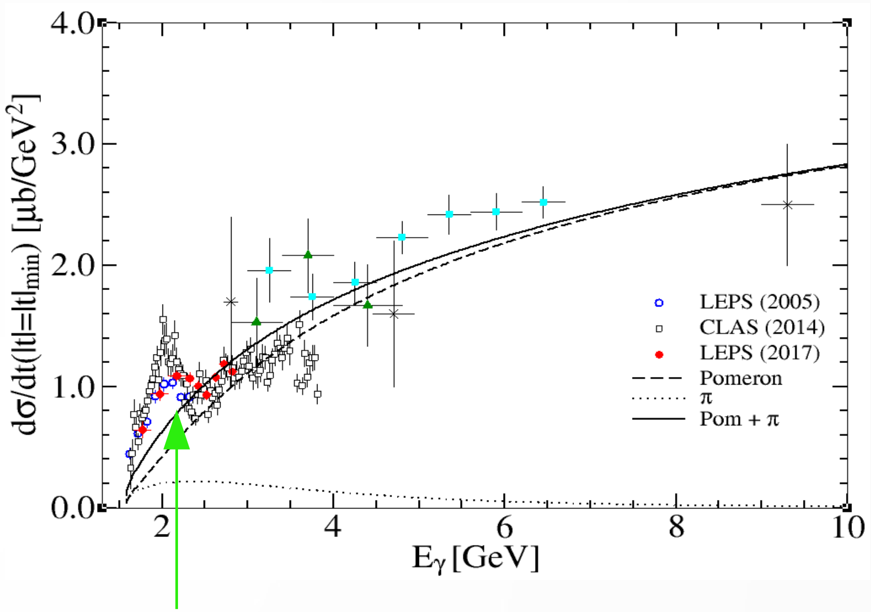

- is not due to the N^* contribution.
- may arise from another mechanism.

□ The peak position is similar to each other.
Any relation between them?

◇ For $\gamma\, p \rightarrow \varphi\, p$,
we studied relative contributions between the Pomeson and various meson exchanges.
> The light-meson (π, η, a_0, f_0,...) contribution is crucial to describe the data at low energies.

◇ The final φN interactions are described by the gluon-exchange, direct φN couplings,
and the box diagrams arising from the couplings with πN, ρN, $K\Lambda$, and $K\Sigma$ channels.
> The FSI effects are small.

◇ For $\gamma\, {}^4He \rightarrow \varphi\, {}^4He$,
a distorted-wave impulse approximation is employed within the multiple scattering formulation.

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◇ Planning to extend to $\gamma^{(*)}\, A \rightarrow V[\varphi, J/\psi, \Upsilon(1S)]\, A$, [$A = {}^2\mathrm{H}, {}^4\mathrm{He}, {}^{12}\mathrm{C},\ldots$]

◇ Approved 12 GeV era experiments to date at Jafferson Labarotory:
[E12-09-003] Nucleon Resonances Studies with CLAS
[E12-11-005] Meson spectroscopy with low Q^2 electron scattering in CLAS12
[E12-12-006] Near Threshold Electroproduction of J/ψ at 11 GeV
[E12-12-007] Exclusive Phi Meson Electroproduction with CLAS12

◇ Electron-Ion Collider (EIC) will carry out the relevant experiments in the future.

Thank you very much for your attention