Model analysis of meson production reactions

Collaboration:
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Part of a combined analysis of

- $\gamma + N \rightarrow M + N$
- $\pi + N \rightarrow M + N$ ($M = \eta, \eta', \omega, \phi, \ldots$)
- $N + N \rightarrow M + N + N$

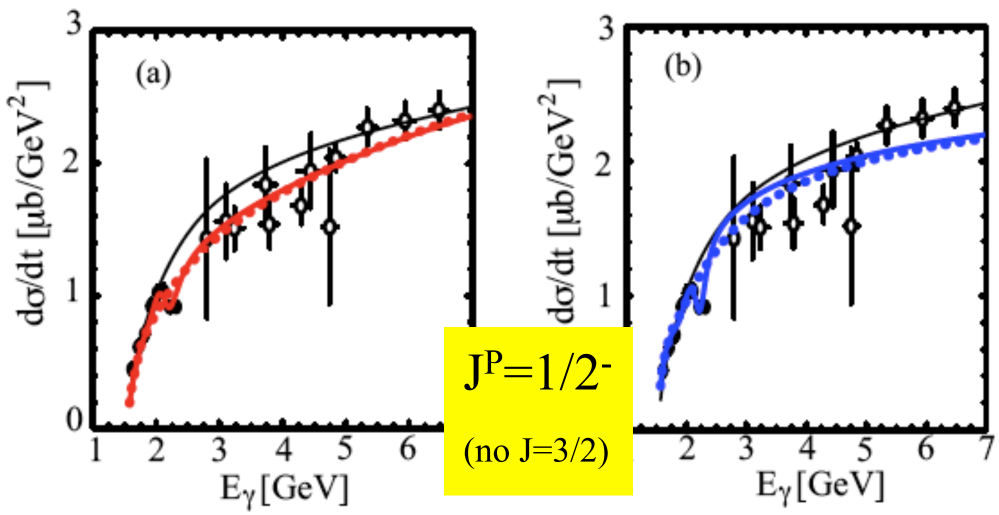
concentrate on the ϕ meson photoproduction

B. Jackson & F. Huang

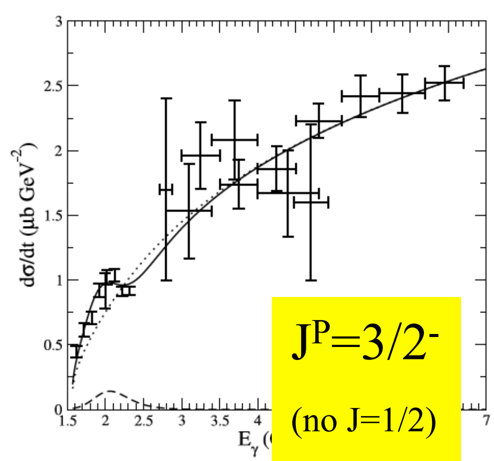
$\gamma p \rightarrow \phi p$: *Bump structure in dσ/dt (LEPS,PRL95'05)*

Ozaki et al., PRC80'09:
coupled-channel approach
(πN, ηN, KΛ, KΣ, KΛ(1520), φN)

Coupled channel effect is not sizable at small t.

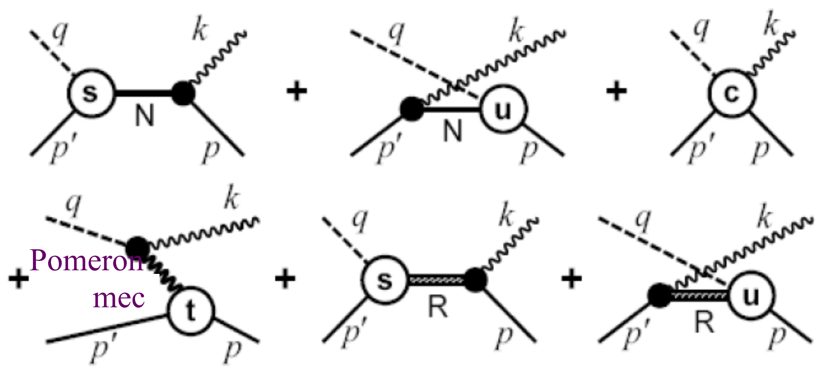


Kiswandhi et al., PLB691'10
(and this meeting) :

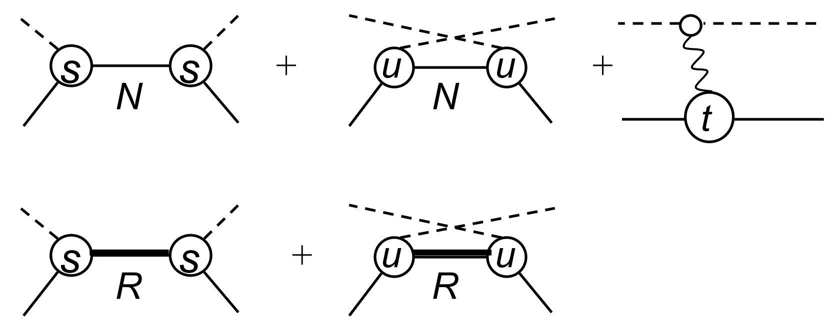


Model: for φ meson production (near threshold)

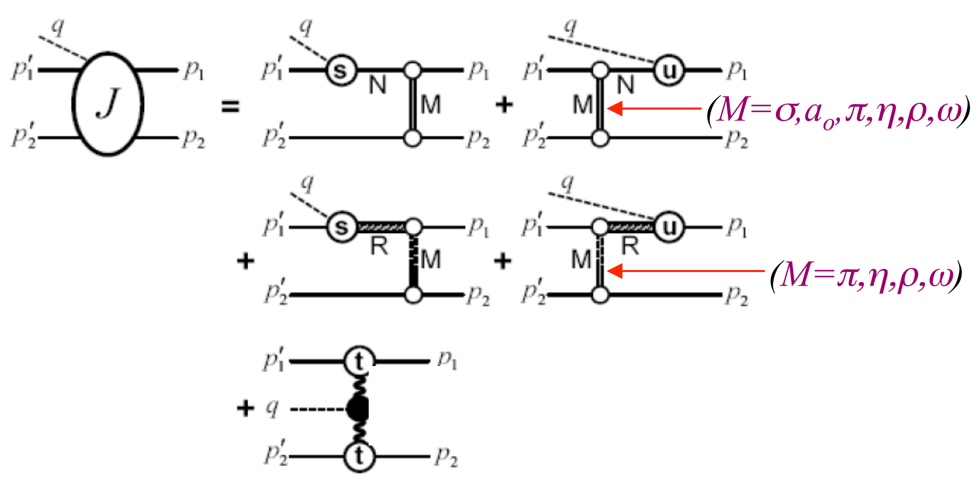
$\gamma + N \rightarrow \phi + N$:



$\pi + N \rightarrow \phi + N$:



$N + N \rightarrow \phi + N + N$:



DWBA:

$$A = (1 + \underbrace{T_f G_f}_{\text{FSI}}) J (1 + \underbrace{G_i T_i}_{\text{ISI}})$$

FSI ISI

J: transition current

Dynamical content: for ϕ meson photoproduction

Pomeron (Titov&Lee, PRC67'03):

$$I^P_{fi} = -M_P(s,t)\Gamma^P_{fi}$$

$$\Gamma^P_{fi} = \varepsilon^*_\mu(\lambda_V)\bar{u}_f h^{\mu\nu}_P u_i \varepsilon_\nu(\lambda_\gamma)$$

$$h^{\mu\nu}_P = \not k\left(g^{\mu\nu} - \frac{q^\mu q^\nu}{q^2}\right) - \gamma^\nu\left(k^\mu - \frac{q^\mu k\cdot q}{q^2}\right) - q^\nu\left(\gamma^\mu - \frac{\not q q^\mu}{q^2}\right)$$

$$M_P(s,t) = C_P F_1(t) F_V(t) \frac{1}{s}\left(\frac{s}{s_P}\right)^{\alpha_P(t)} \exp\left[-\frac{i\pi}{2}\alpha_P(t)\right]$$

$$F_1(t) = \frac{4M_N^2 - 2.8t}{(4M_N^2 - t)(1 - t/t_0)^2} \qquad t_0 = 0.7\ \mathrm{GeV}^2$$

$$F_V(t) = \frac{2\mu_0^2}{(1 - t/M_V^2)(2\mu_0^2 + M_V^2 - t)}$$

$$\mu_0^2 = 1.1\ \mathrm{GeV}^2$$

$$C_P = \frac{6g^2\sqrt{4\pi\alpha_{\mathrm{em}}}}{\gamma_V}$$

$$\alpha_P(t) = 1.08 + 0.25t$$

$$2\gamma_\phi = 13.13$$

$$g^2 \equiv g_{Pss} g_{Pqq}$$

$$g_{Pqq} = 4.1 \text{ and } g_{Pss} = 3.22.$$

mec :

πϕγ, ηϕγ−vertex: cut off parameter in the formfactor is a fit param.

res : $(M_R, \Gamma_R, g_{RN\phi}g_{RN\gamma}) \rightarrow$ fit param.

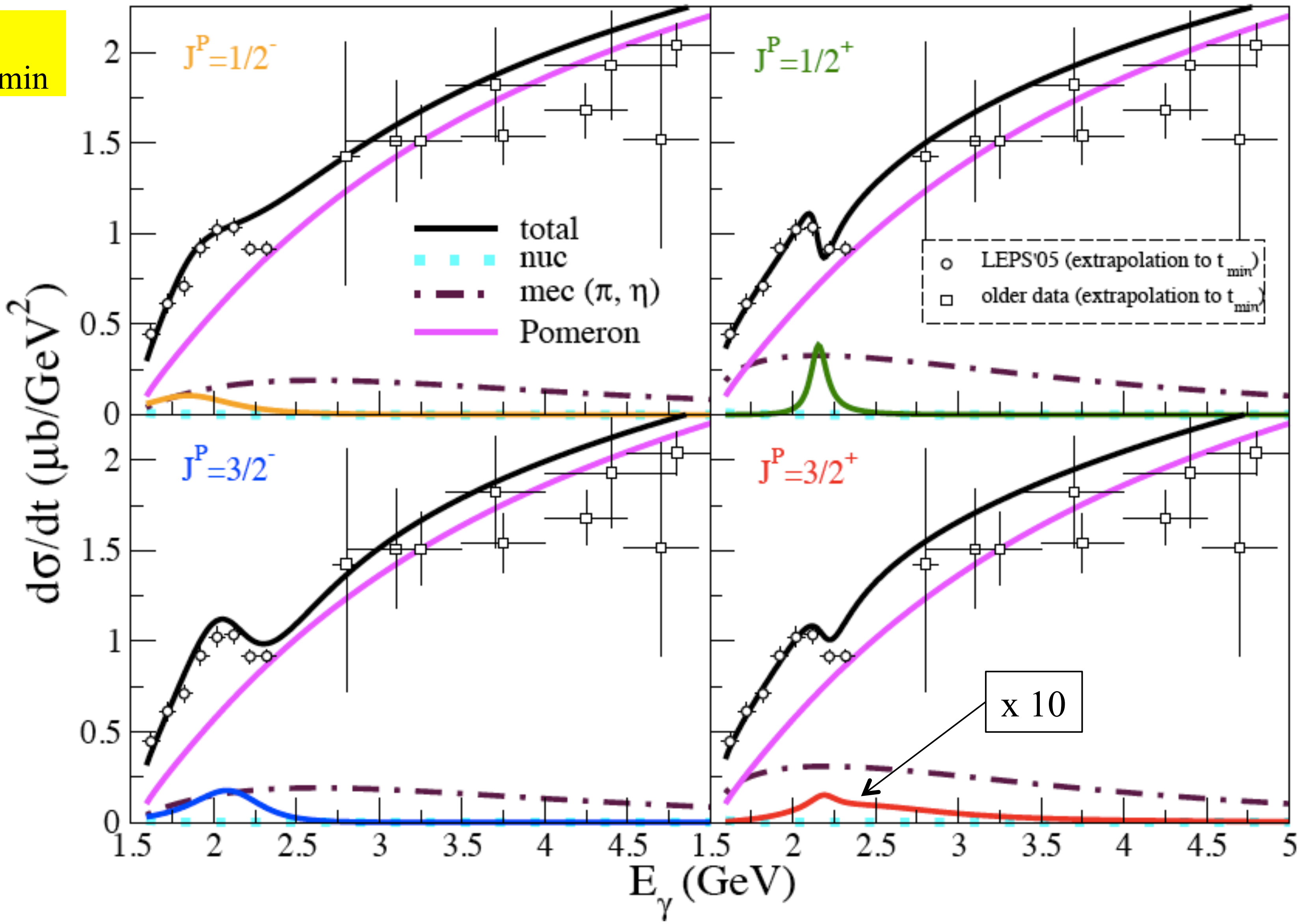
nuc/res :

BNϕ−vertex: cut off parameter in the formfactor is a fit param.

$\gamma p \to \phi p$: energy dependence of $d\sigma/dt$ at $t = t_{min}$

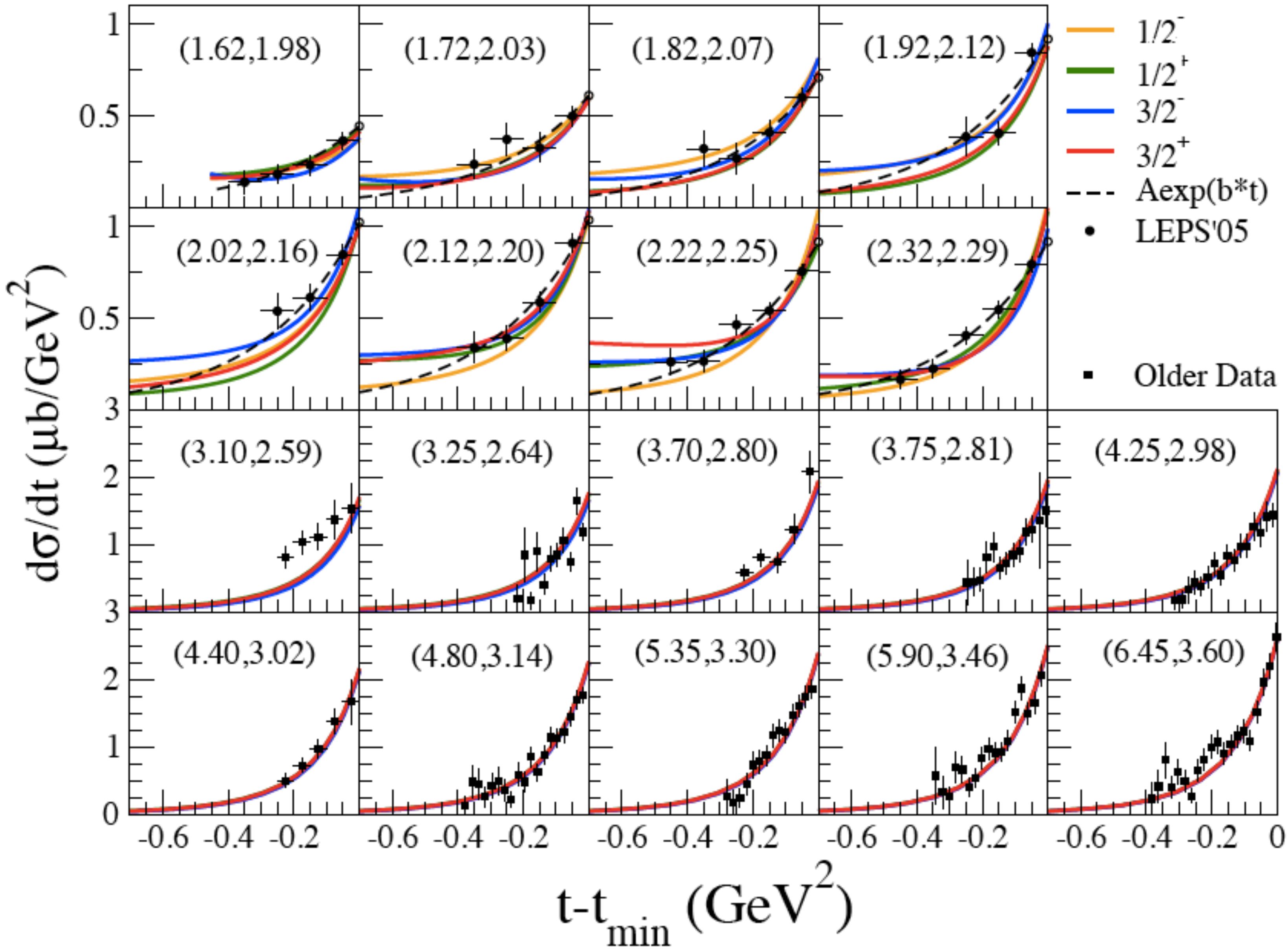
[data: LEPS, PRL95'05; SLAC'73; BONN'74; DEISY'78; DARESBURY'82]

at $t = t_{min}$



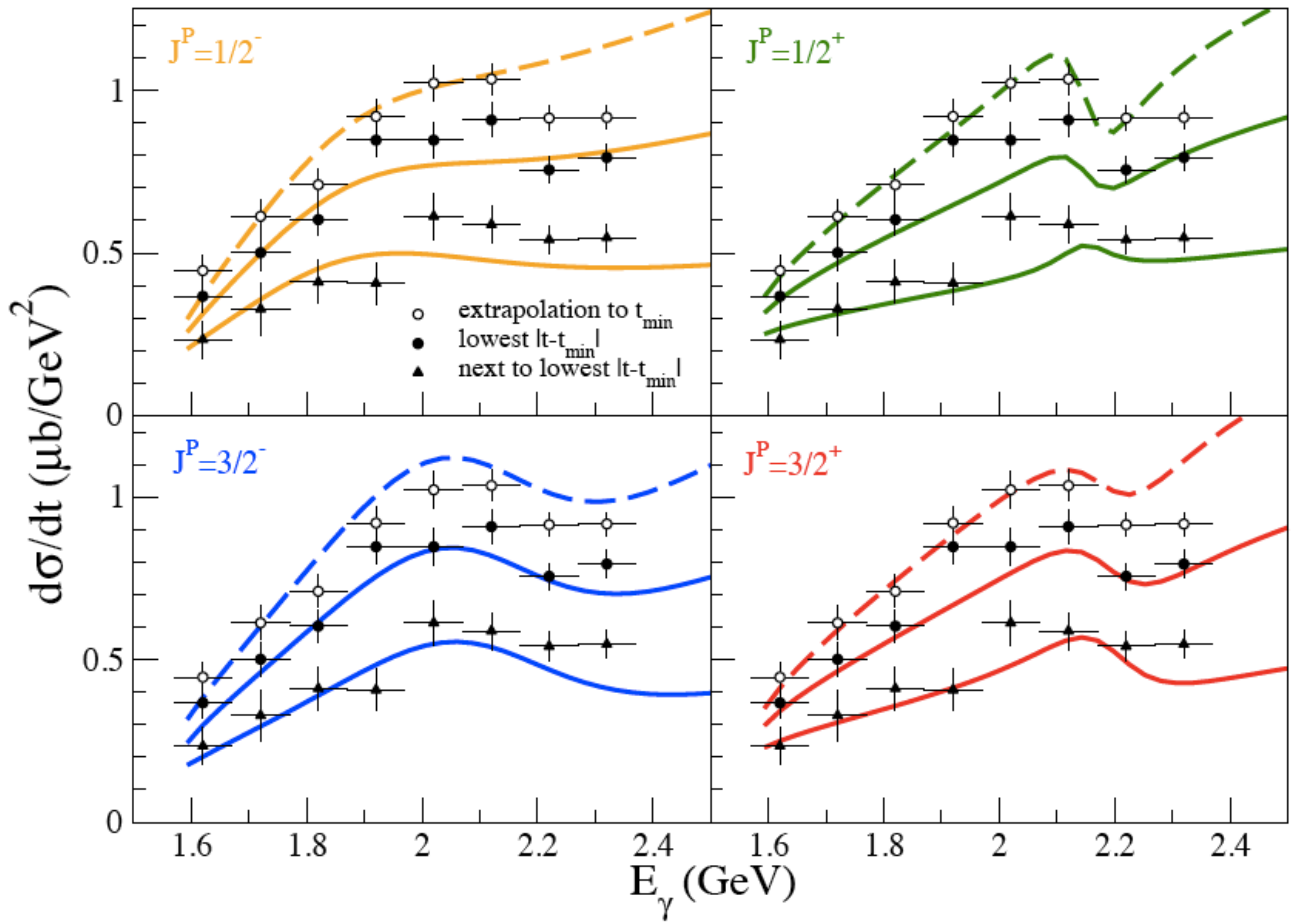
$\gamma p \rightarrow \phi p$: $d\sigma/dt$

[data: LEPS, PRL95'05; BONN'74; DEISY'78; DARESBURY'82]

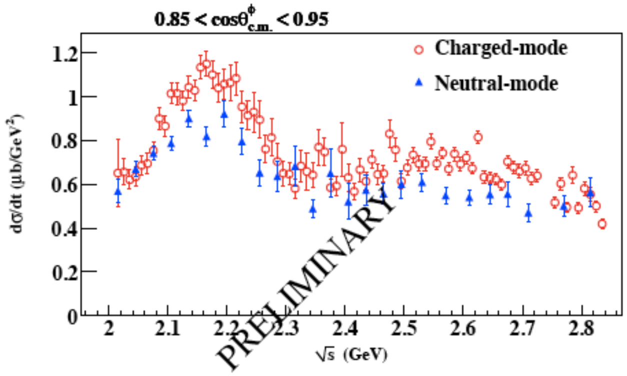


$\gamma p \to \phi p$: *energy dependence of dσ/dt at low t*

[data: LEPS, PRL95'05]



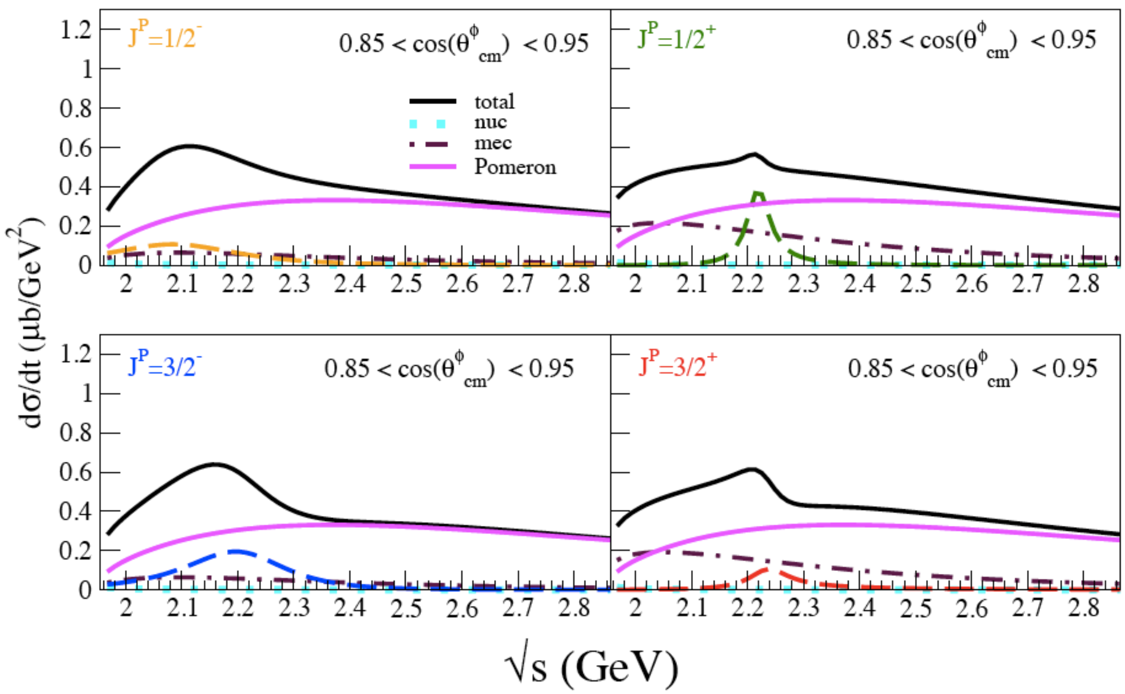
$\gamma\, p \to \phi\, p$: *energy dependence of dσ/dt at larger θ_ϕ*



CLAS'11

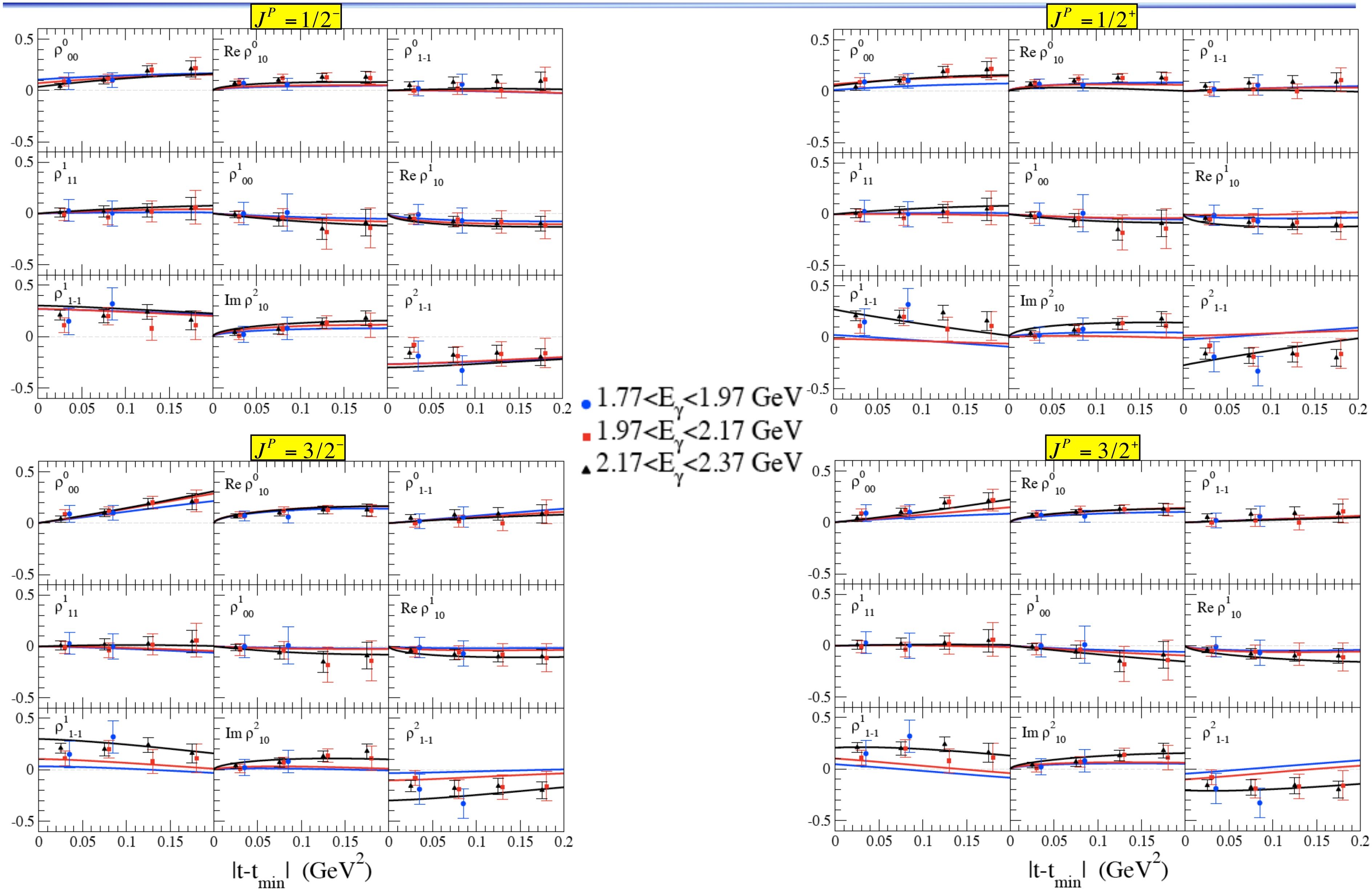
arXiv:1103.3821[nucl-exp]

FIGURE 1. (Color online) Preliminary ϕ differential cross sections in a forward-angle bin shown for both the charged- and neutral-mode topologies. The "bump" around $\sqrt{s} \sim 2.1$ GeV, seen in previous LEPS data [3] is clearly visible here.



$\gamma p \rightarrow \phi p$: *spin density matrices* ρ^k_{ij}

[data: LEPS, PRC82'10]



$\gamma p \rightarrow \phi p$: $\rho^1_{1,-1}$ *(resonance contributions only)*

[data; LEPS, PC82'10]

Titov&Lee, PRC67'03:

Spin Density Matrix $\rho^1_{1,-1}$

for pure helicity-conserving processes:

$$\rho^1_{1\text{-}1} = \frac{1}{2}\frac{|I_0^{\rm N}|^2 - |I_0^{\rm U}|^2}{|I_0^{\rm N}|^2 + |I_0^{\rm U}|^2}$$

for spin-flip processes:

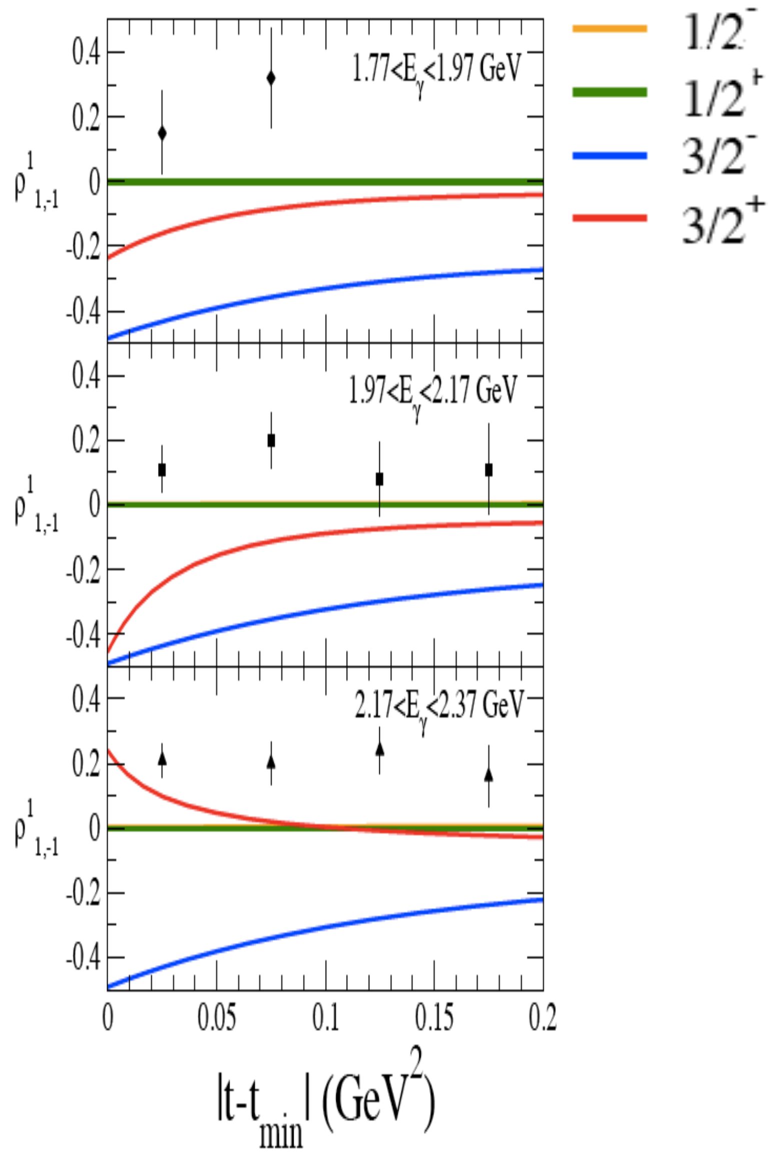
$$\rho^1_{1\text{-}1} = \frac{1}{2}\frac{|I_0^{\rm N}|^2 - |I_0^{\rm U}|^2 + |I_1^{1-1}|^2}{|I_0^{\rm N}|^2 + |I_0^{\rm U}|^2 + |I^{10}|^2 + |I_2^{1-1}|^2}$$

$$\lambda_\gamma \rightarrow \lambda_\phi = 0 \qquad |I^{10}|^2 = {\rm Tr}[I_{\alpha;10} I^\dagger_{\alpha;10}]$$

$$\lambda_\gamma \rightarrow \lambda_\phi = -\lambda_\gamma \begin{cases} |I_1^{\alpha;1-1}|^2 = {\rm Tr}[I_{\alpha;1\text{-}1} I^\dagger_{\alpha;-11}] \\ |I_2^{\alpha;1-1}|^2 = {\rm Tr}[I_{\alpha;1\text{-}1} I^\dagger_{\alpha;1\text{-}1}] \end{cases}$$

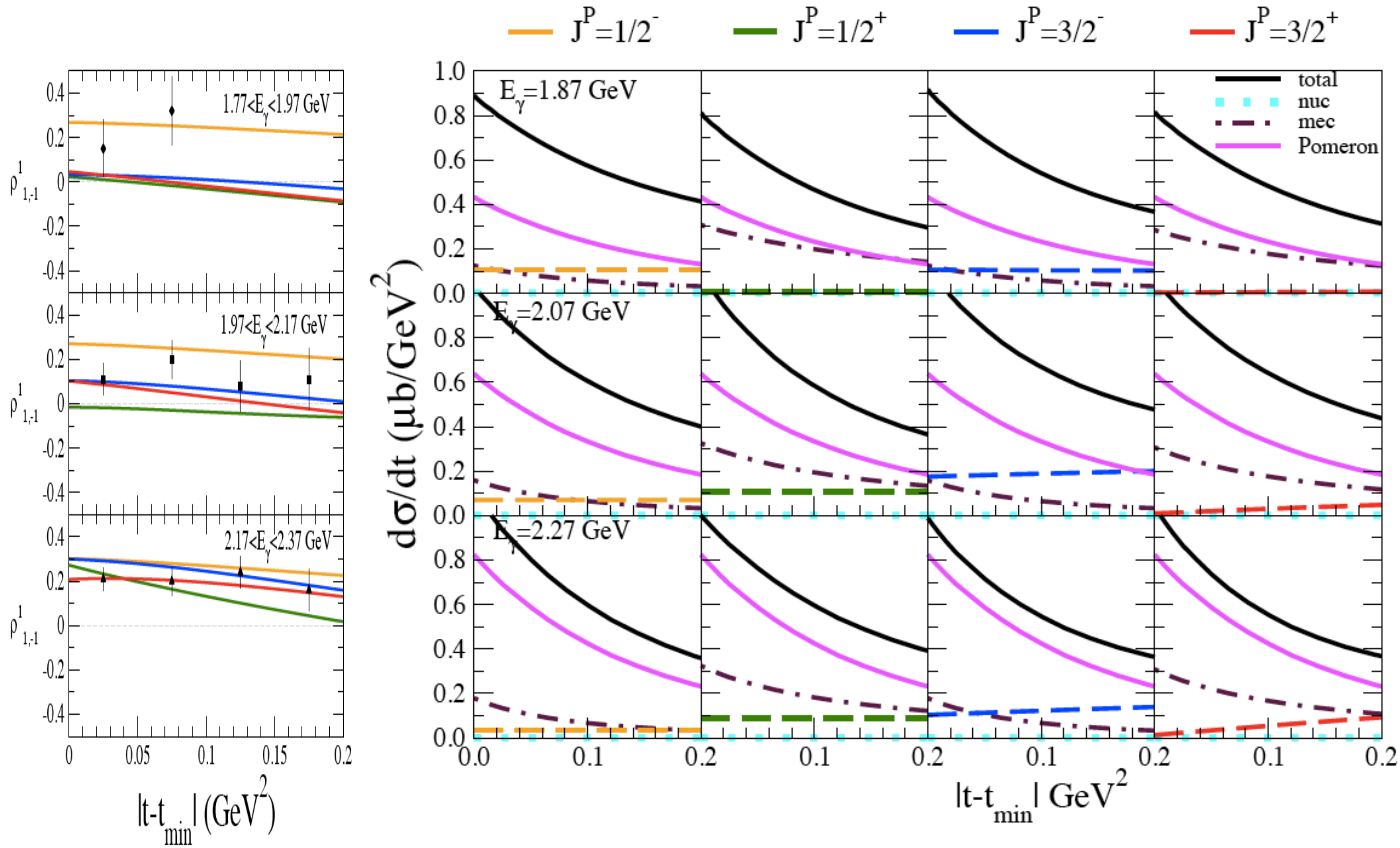
For Pomeron exchange: $\rho^1_{1,-1} \cong +1/2$

For pseudoscalar mec: $\rho^1_{1,-1} = -1/2$



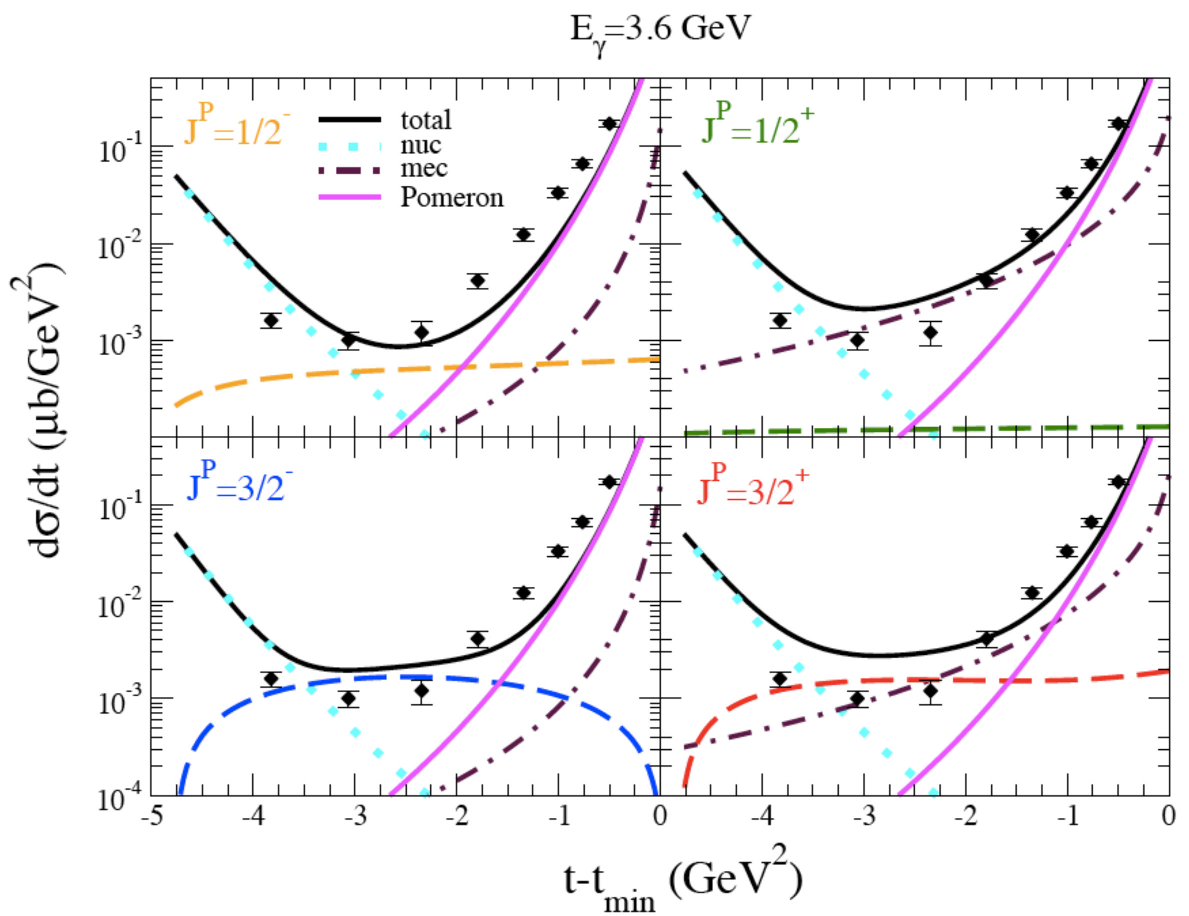
$\gamma p \rightarrow \phi p$: ρ^1_{1-1} *versus* $d\sigma/dt$

[data: LEPS, PRC82'10]



$\gamma p \rightarrow \phi p$: $d\sigma/dt$ at large t

[data: CLAS, PRL85'00]

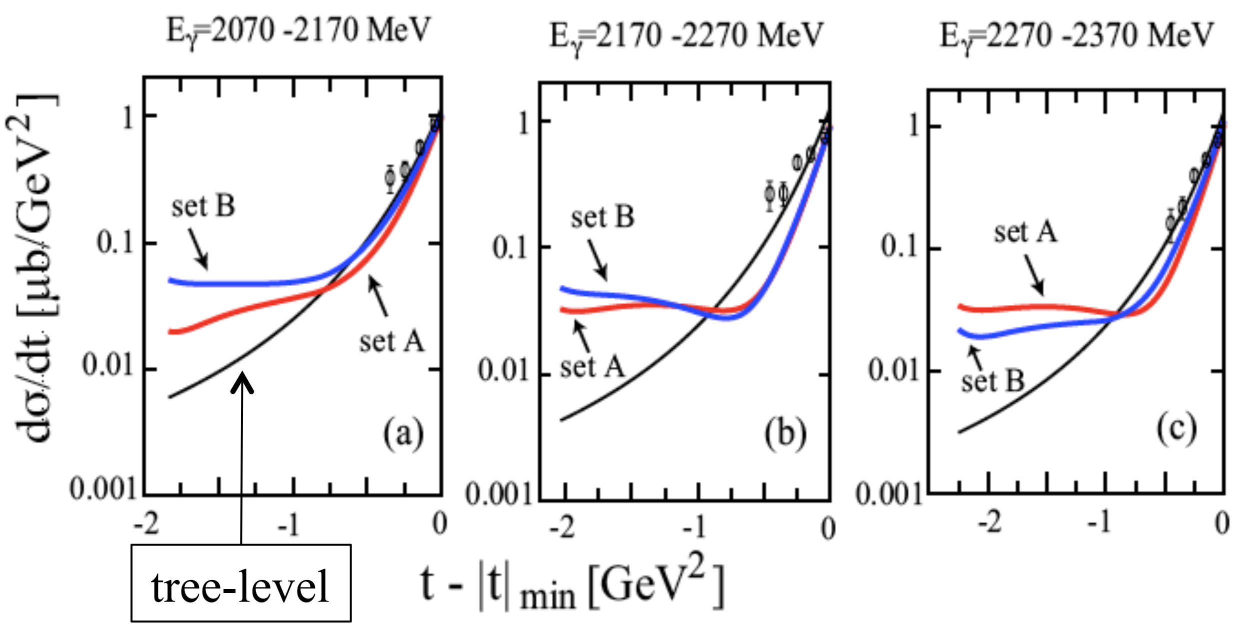


$g_{NN\phi} = -0.6$
SU(3)+OZI

information on $g_{NN\phi}$?

$\gamma p \rightarrow \phi p$: *coupled channel effects at larger t*

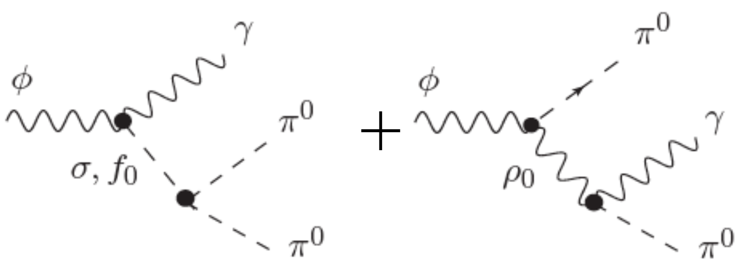
Ozaki et al., PRC80'09:
coupled-channel approach
(πN, ηN, KΛ, KΣ, KΛ(1520), φN)



Estimate of the σφγ , a_0φγ, f_0φγ coupling strengths

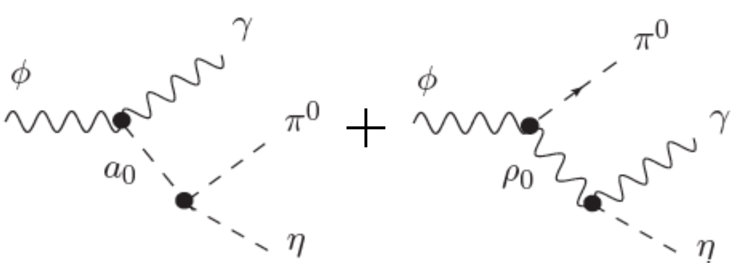
Estimate from the measured radiative decays (invariant MM mass distributions) $\phi \to \pi^0\pi^0\gamma$ & $\phi \to \eta\pi^0\gamma$:

(KLOE, PLB536/537'02; CMD-2, PLB462'99)



$g_{\sigma\phi\gamma} = 0.03$

$g_{f0\phi\gamma} = 3.23$

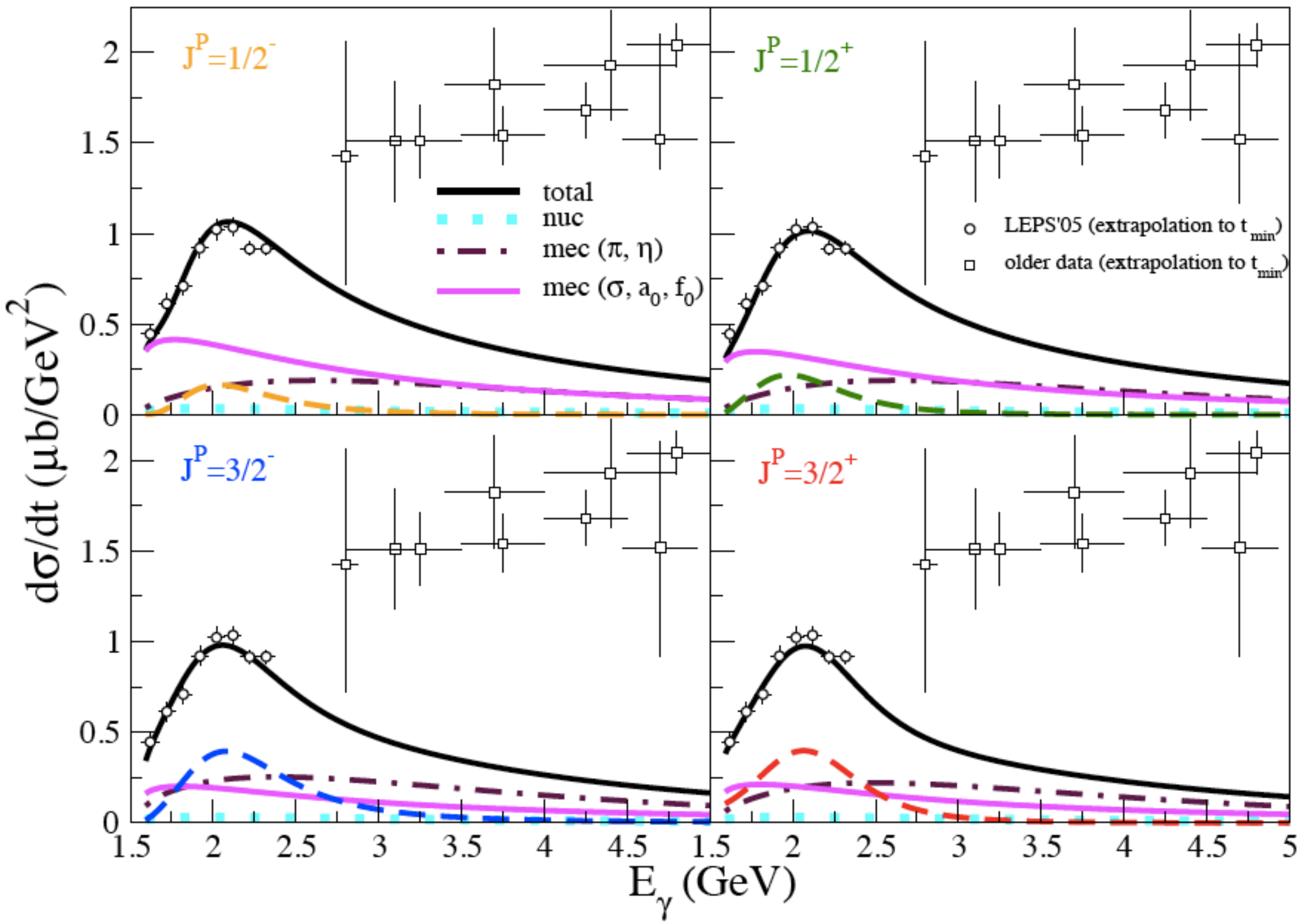


$g_{a0\phi\gamma} = 1.78$

$\gamma p \rightarrow \phi p$: $\sigma, a_0, f_0 - mec$

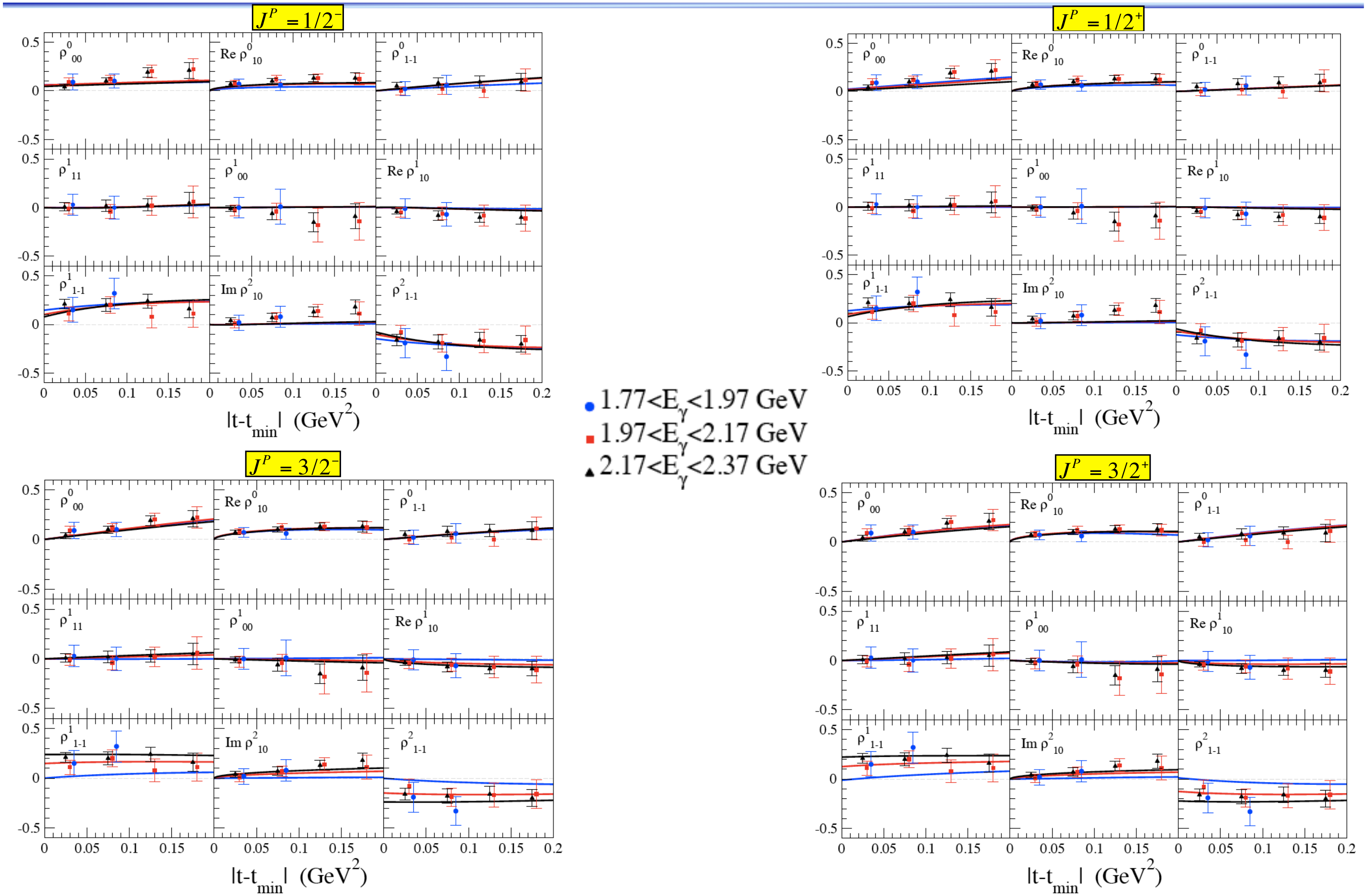
[data: LEPS, PRL95'05; SLAC'73; BONN'74; DEISY'78; DARESBURY'82]

at $t = t_{min}$



$\gamma p \rightarrow \phi p$: σ, a_0 , f_0 - *mec*

[data: LEPS, PRC82'10]



Summary:

- The observed structure in the LEPS'05 data has to be confirmed.
  (CLAS'11 preliminary data seem to corroborate this finding)
  It would be interesting also to look in other ϕ production processes such as the $NN \rightarrow NN\phi$ reaction (COSY).

- The spin density matrix $\rho^1_{1,-1}$ imposes some constraints on the reaction mechanism at low energies.

- Cross sections at larger t is more sensitive to the spin of the possible resonance. Coupled channel effects may become more significant, however (Ozaki et al., PRC80'09).

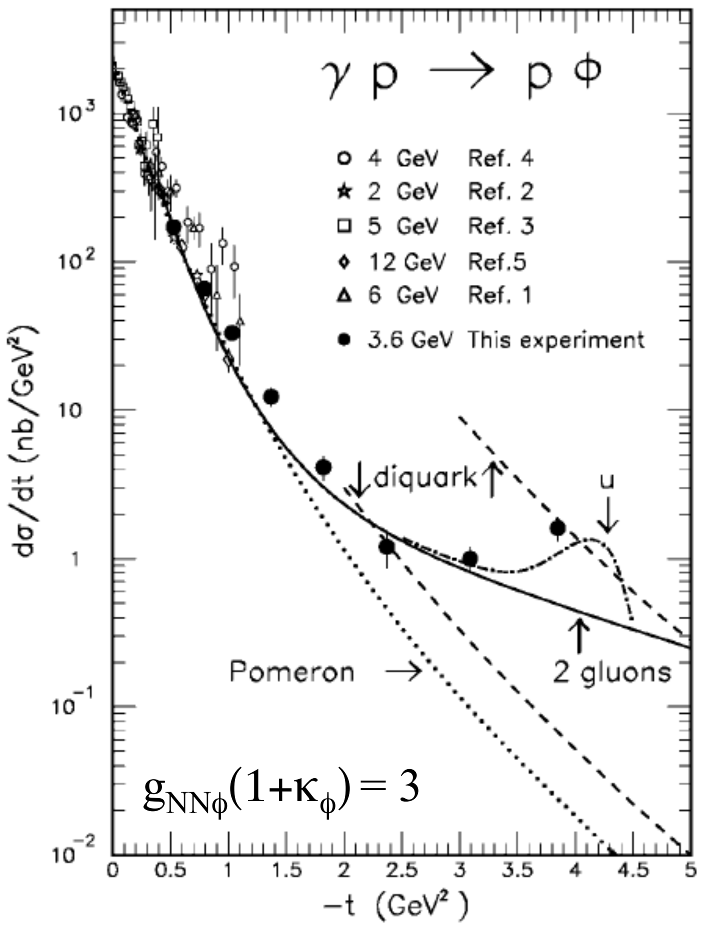
- Cross sections at higher energies and larger t might impose some constraints on the $NN\phi$ coupling strength.

- Near threshold, Pomeron versus scalar mec should be investigated .

The End

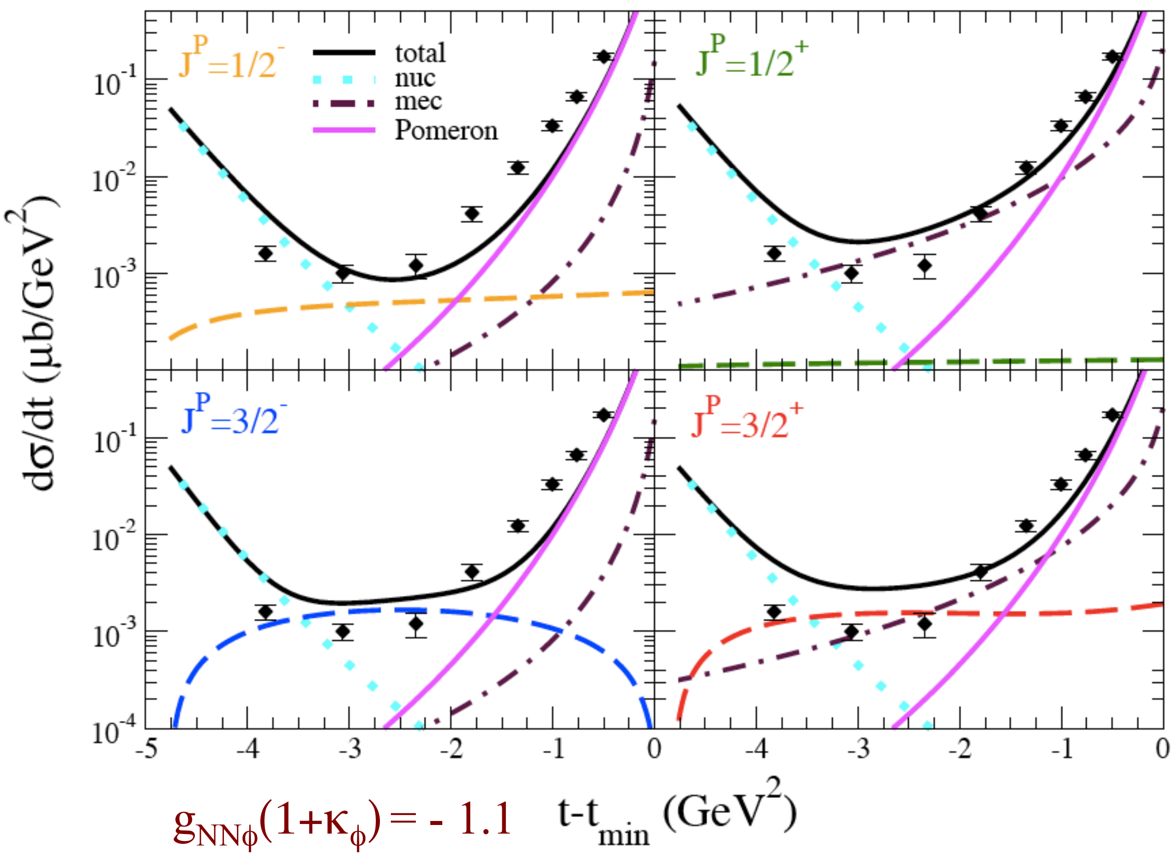
$\gamma\, p \rightarrow \phi\, p$: $d\sigma/dt$ at large t

[data: CLAS, PRL85'00]



$g_{NN\phi}(1+\kappa_\phi) = 3$

E$_\gamma$=3.6 GeV



$g_{NN\phi}(1+\kappa_\phi) = -\ 1.1$

SU(3)+OZI

information on $g_{NN\phi}$?