Channel coupling effects in exclusive meson photo and electroproduction at high momentum transfers

- A good news: it allows to understand long standing problems
- A bad news: quarks are not explicitly needed at JLab6
- JLab12 and higher?
- Semi inclusive reactions?

VCS and DVCS*: Phys. Rev. C76, 052201(R) 2007*

Charged pion*: Phys. Lett. B685, 146 (2010)*

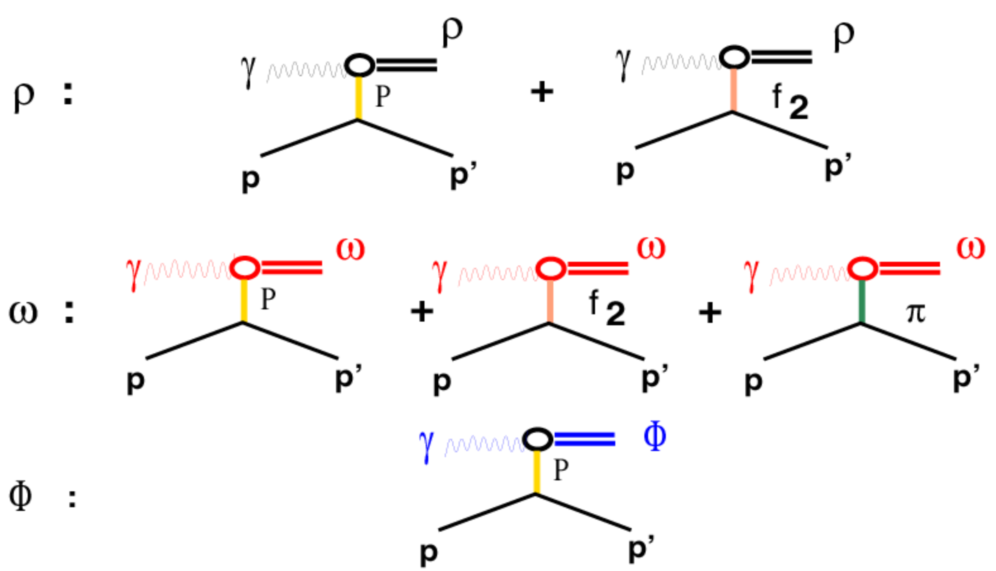
Neutral pion*: arXiv:1004.1949 [hep-ph]*

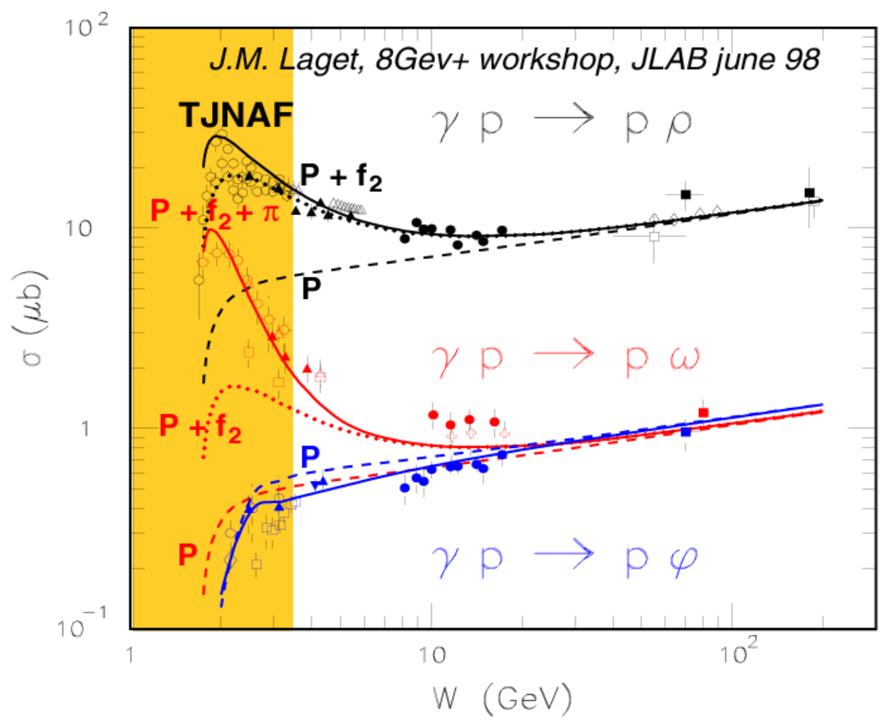
ϕ ***meson****: unpublished yet*

Channel Coupling

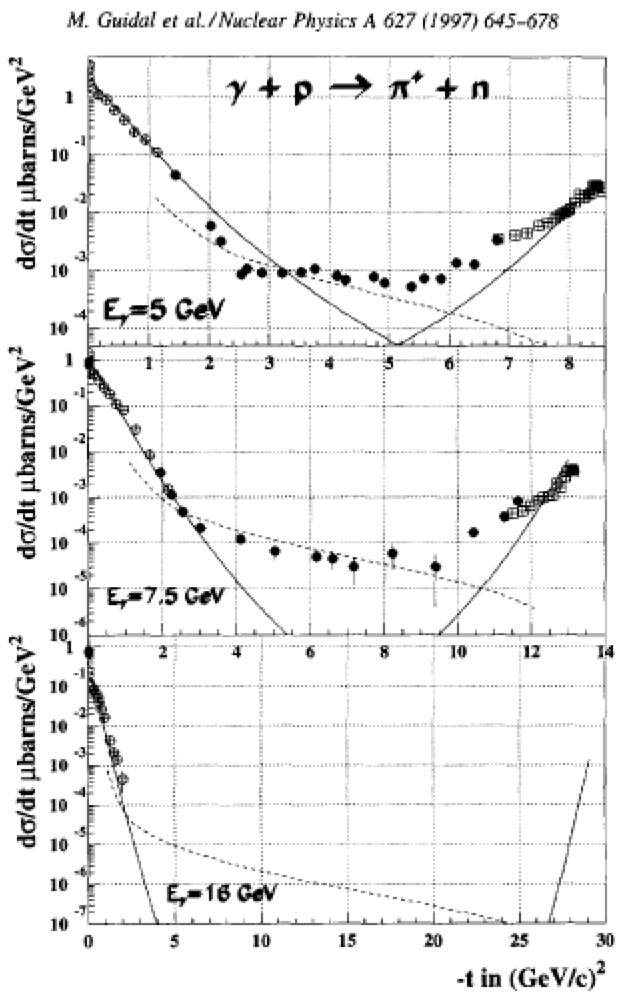
- Consequence of unitarity
- Low energies: many flat channels $\leftrightarrow$ EBAC
- Intermediate energies:
  - one channel dominates: ρ
  - Forward peaked cross section
- High energies?
- Two examples:
  - Large t
  - Large Q^2

γ p $\rightarrow$ p V: dominant processes





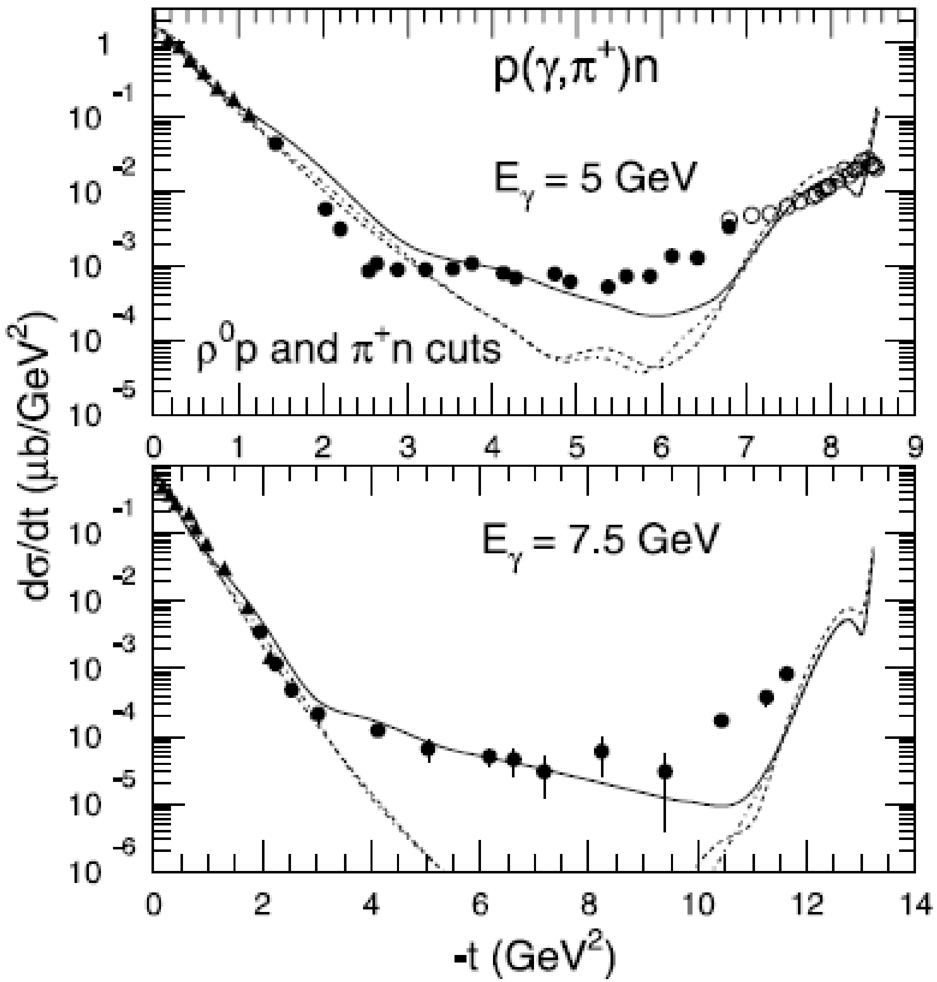
p(γ,π$^+$)n: Regge poles



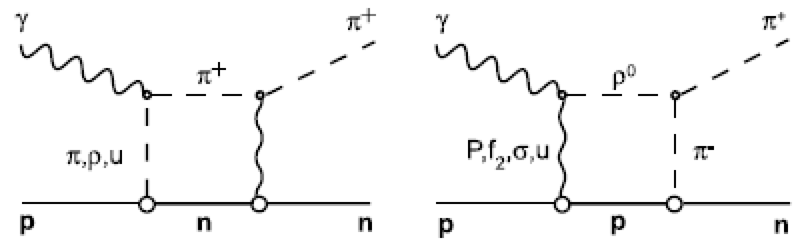
- Regge Pole Approach
- t channel: π, ρ
- u channel: p, Δ

- Linear trajectories:
  forward/backward
- Saturating trajectories:
  intermediate angles
  - *-Poor man quark model!!*
  - *-Consistent with scaling*

p(γ,π⁺)n: cuts

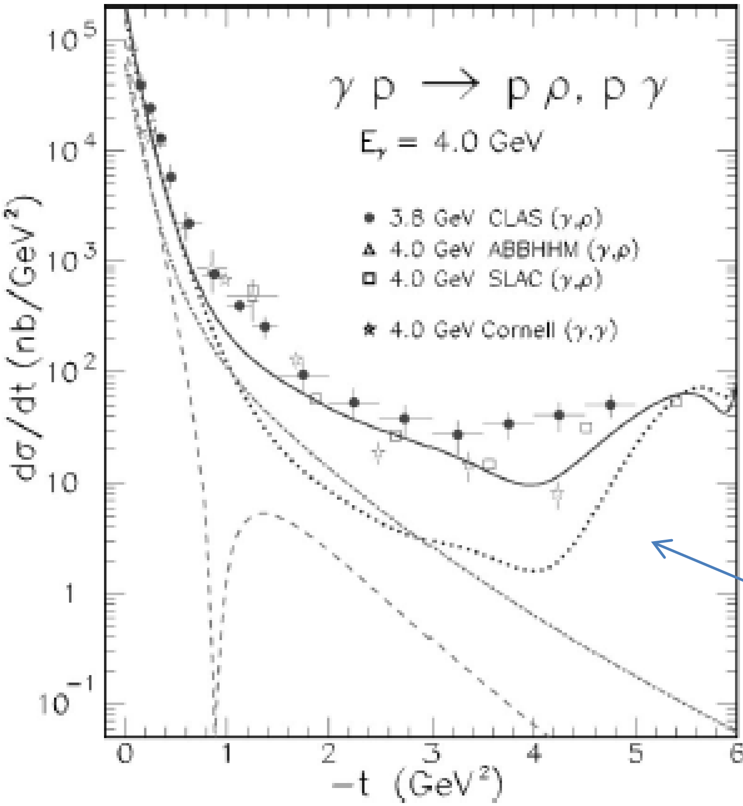


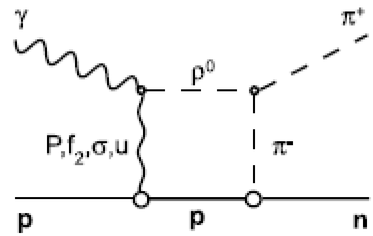
p(γ,π⁺)n
Eγ = 5 GeV
ρ⁰p and π⁺n cuts
Eγ = 7.5 GeV
dσ/dt (μb/GeV²)
-t (GeV²)

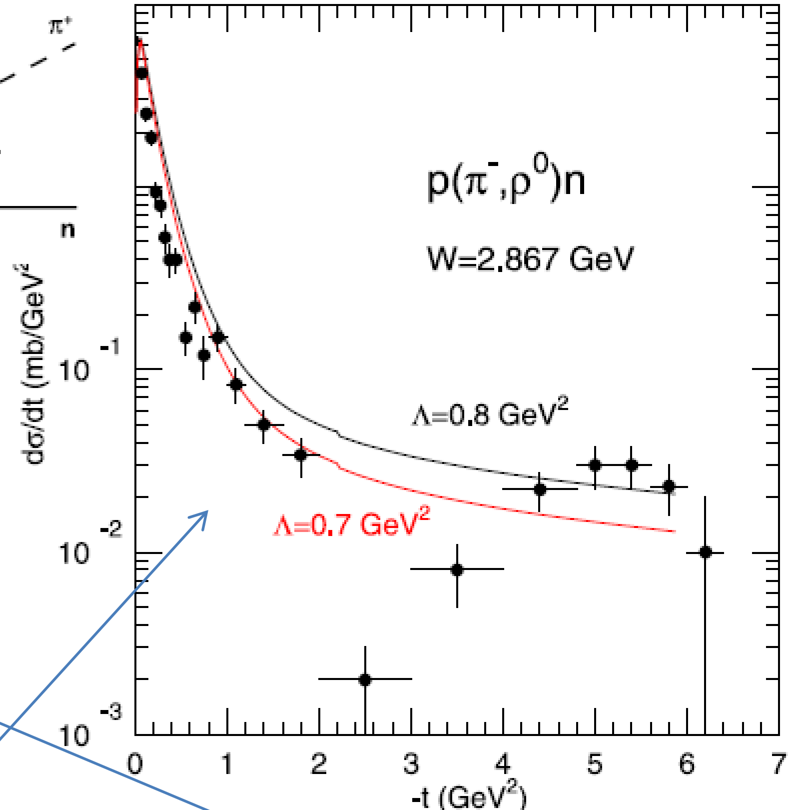


γ
π⁺
π⁺
π,ρ,u
p
n
n
γ
ρ⁰
π⁺
P,f₂,σ,u
π⁻
p
p
n

p(γ,π⁺)n: ρ⁰p cut





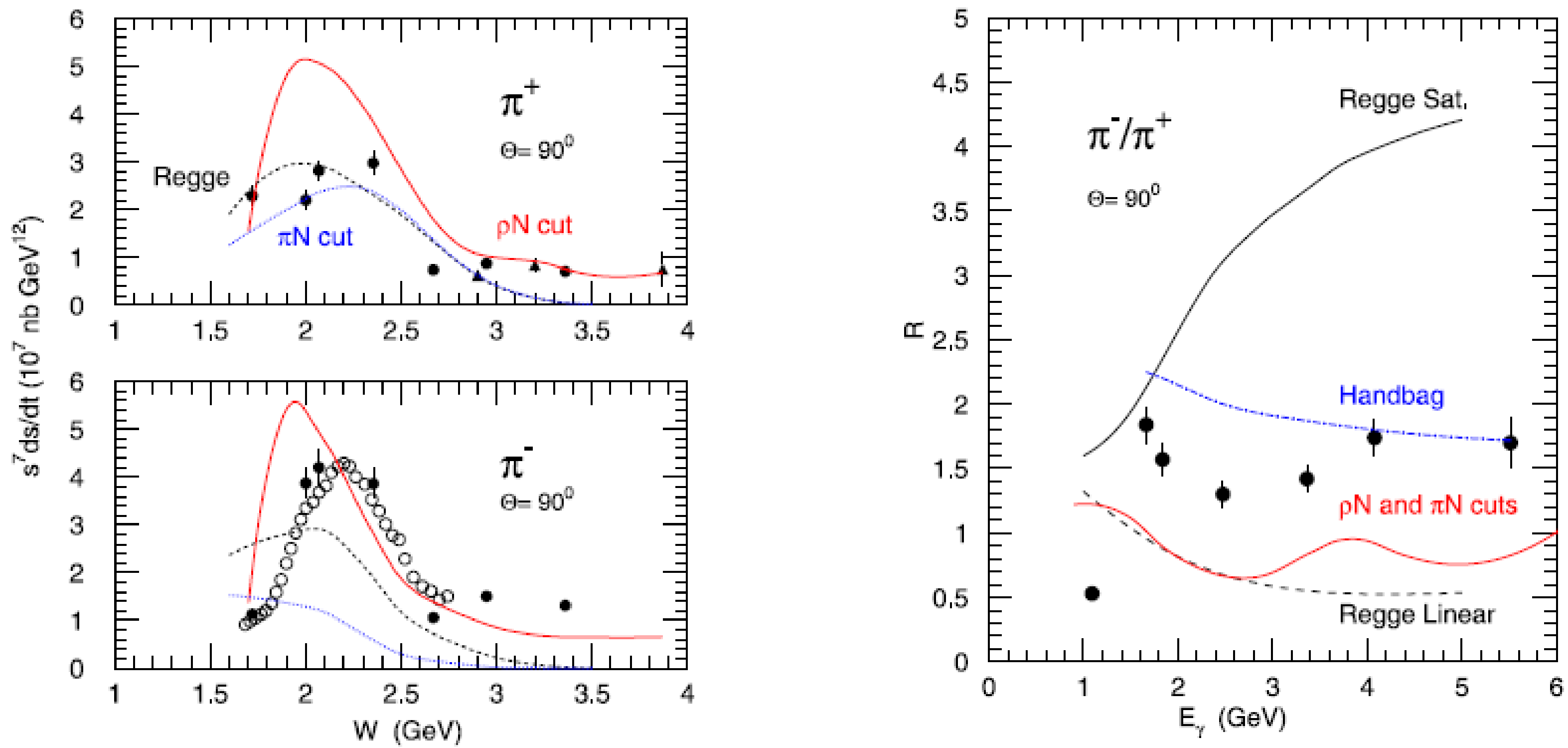


Regge

$$T_{loop} = -i\frac{mp_{c.m.}}{16\pi^2\sqrt{s}}\int d\Omega_p \sum_{m_p,m_\rho} (m_f|T_{\rho\pi}(t_\pi)|m_p,m_\rho)(m_p,m_\rho|T_{\gamma\rho}(t_\gamma)|m_i)$$

Parameter free!

p(γ,π⁺)n: scaling

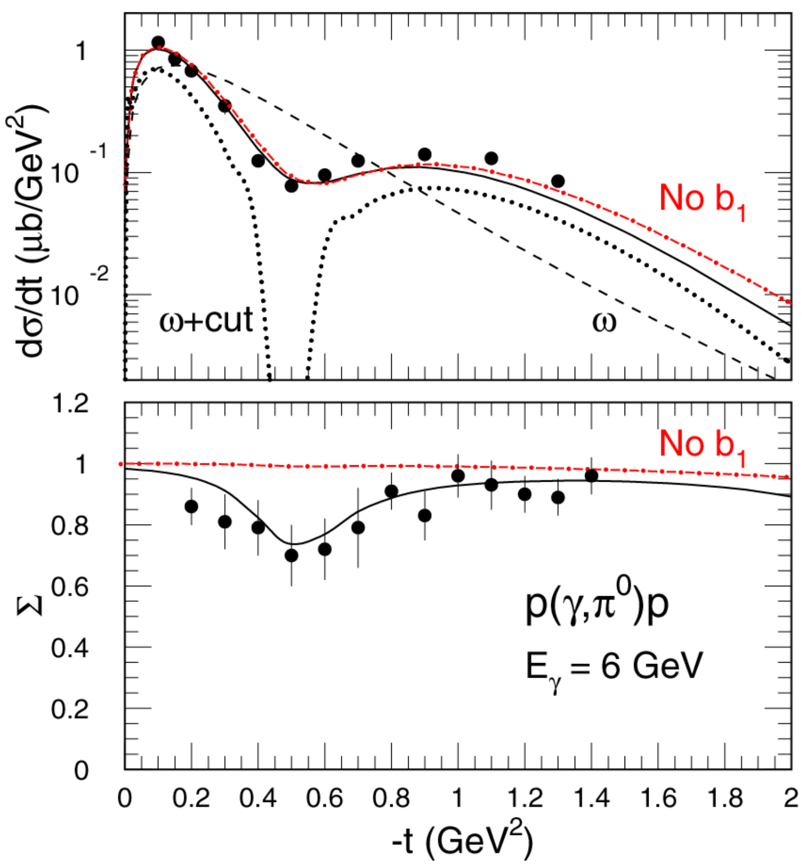


- No quarks explicitly needed!
- Natural explanation of scaling and deviations at low energies

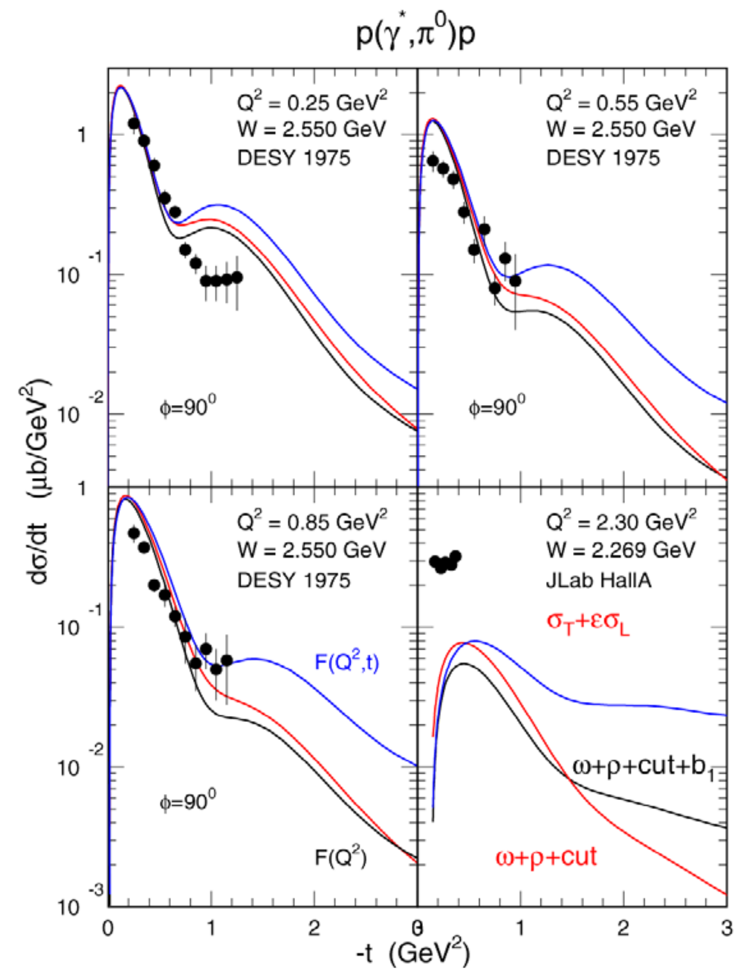
$p(e,e'\pi^0)p$: issues

- Node around t=0.5 GeV^2 at Q^2=0
- This node disappears when Q2≠0
- Around Q^2= 2—3 Gev^2, the measured cross section exceeds by a factor 5 the Regge pole extrapolation
- Solution: coupling to the charged ρ production channels

$p(e,e'\pi^0)p$

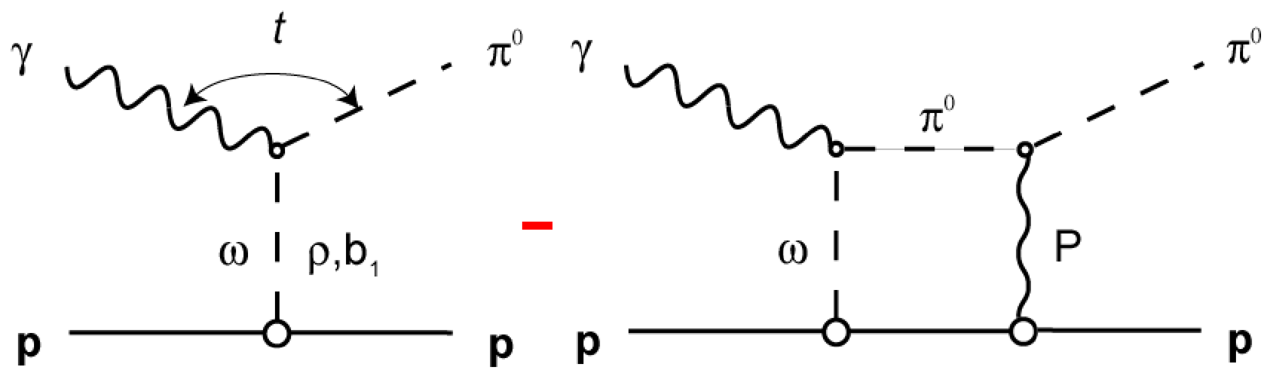


dσ/dt (μb/GeV²)
No b₁
ω+cut
ω
Σ
p(γ,π⁰)p
E_γ = 6 GeV
-t (GeV²)



p(γ*,π⁰)p
Q² = 0.25 GeV²
W = 2.550 GeV
DESY 1975
Q² = 0.55 GeV²
W = 2.550 GeV
DESY 1975
Q² = 0.85 GeV²
W = 2.550 GeV
DESY 1975
Q² = 2.30 GeV²
W = 2.269 GeV
JLab HallA
φ=90⁰
σ_T+εσ_L
F(Q²,t)
F(Q²)
ω+ρ+cut+b₁
ω+ρ+cut
dσ/dt (μb/GeV²)
-t (GeV²)

p(e,e'π^0)p: Regge cut



Degenerate Scheme + Cut

$$e^{-i\pi\alpha_\omega(t)}\left(\frac{s}{s_0}\right)^{\alpha_\omega(t)-1} F_{em}(Q^2)$$

$$\begin{aligned}\alpha_\omega(t) &= \alpha_\omega(0) + \alpha'_\omega t \\ &= 0.44 + 0.9t\end{aligned}$$

$$e^{-i\pi\alpha_c(t)}\left(\frac{s}{s_0}\right)^{\alpha_c(t)-1} G(Q^2, t)$$

$$\begin{aligned}\alpha_c(0) &= \alpha_\omega(0) + \alpha_P(0) - 1 &= 0.44 \\ \alpha'_c &= (\alpha'_\omega \times \alpha'_P)/(\alpha'_\omega + \alpha'_P) &= 0.2\end{aligned}$$

Non Degenerate ωTrajectory (GLV scheme)

$$\frac{-1 + e^{-i\pi\alpha_\omega(t)}}{2}\left(\frac{s}{s_0}\right)^{\alpha_\omega(t)-1} F_{em}(Q^2)$$

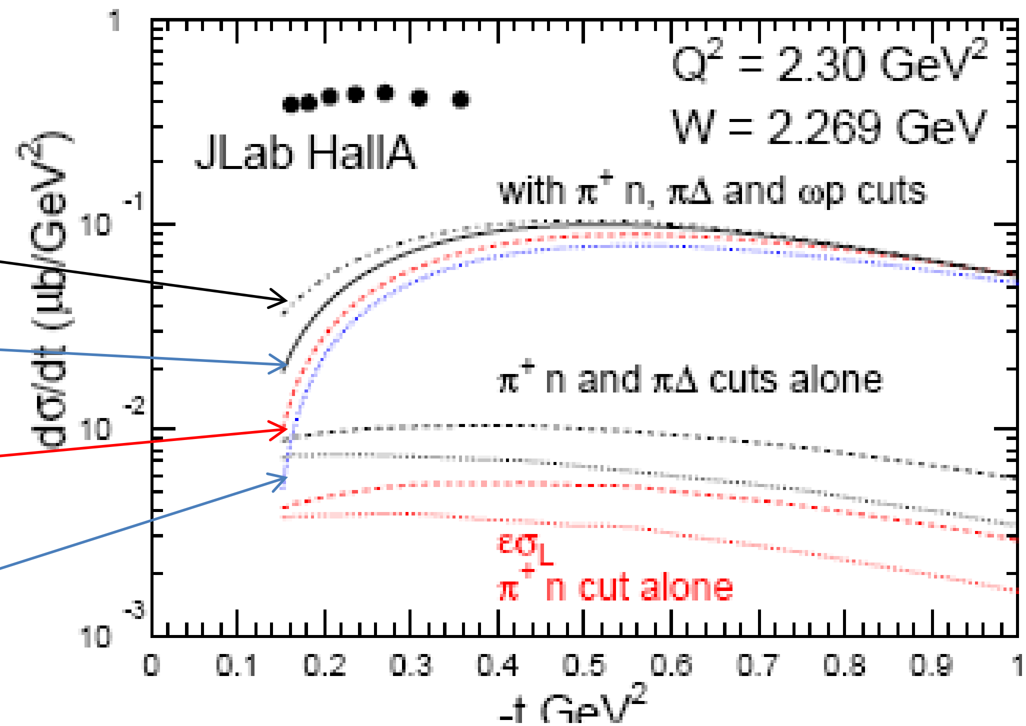
$p(e,e'\pi^0)p$: CEX and ωp cuts

+ ωp cut

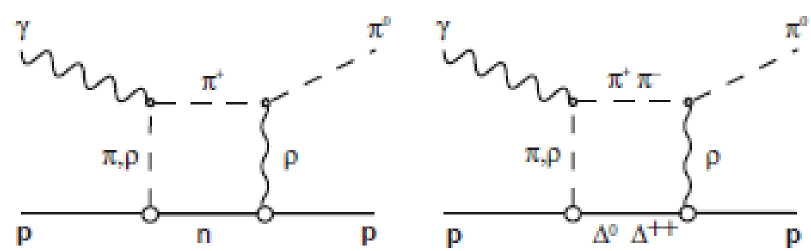
πN, πΔ CEX cuts

πN CEX cut

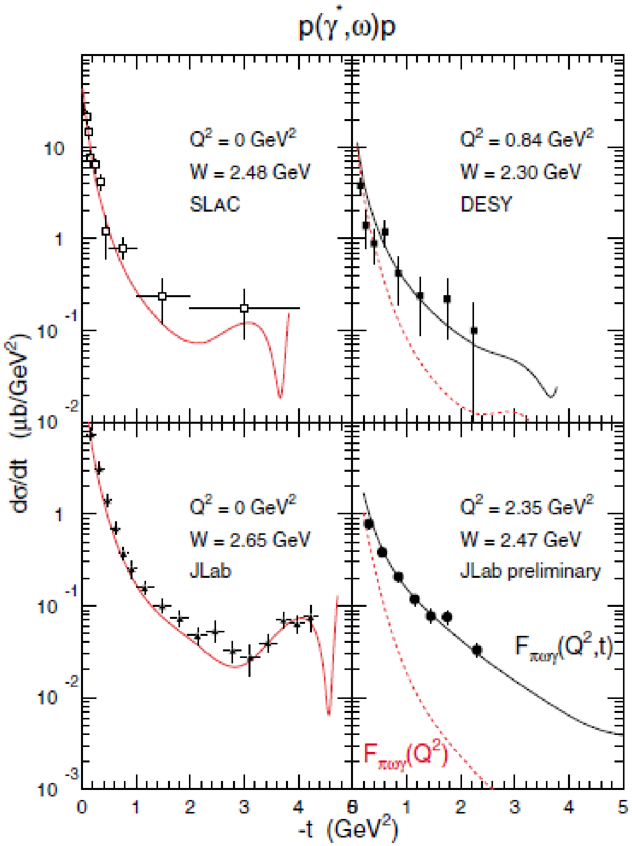
Regge Poles

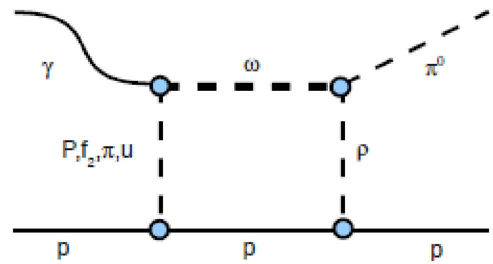


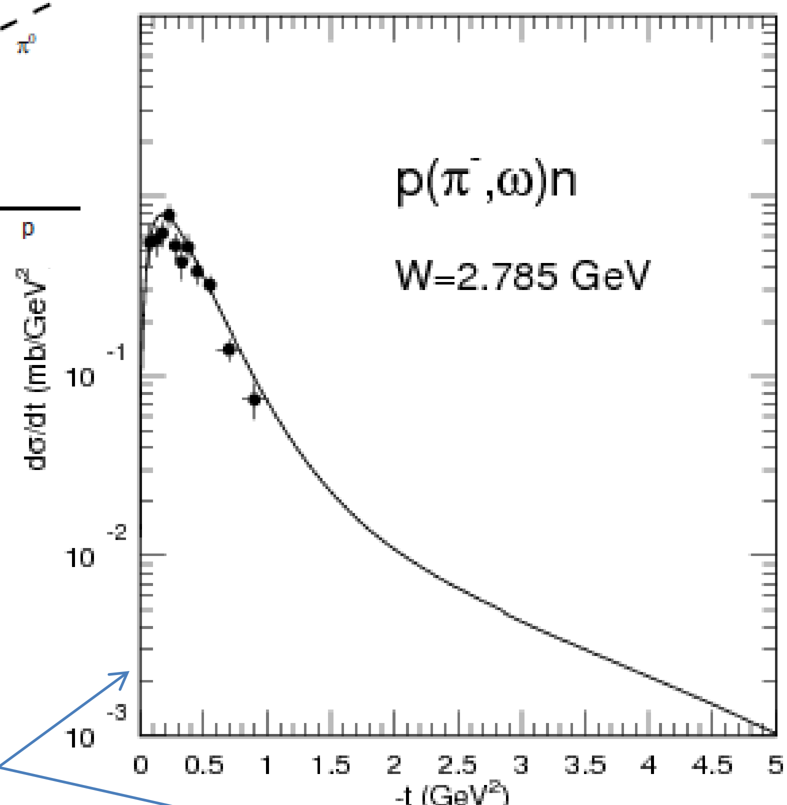
Not enough!



p(e,e'π^0)p: ωp cut



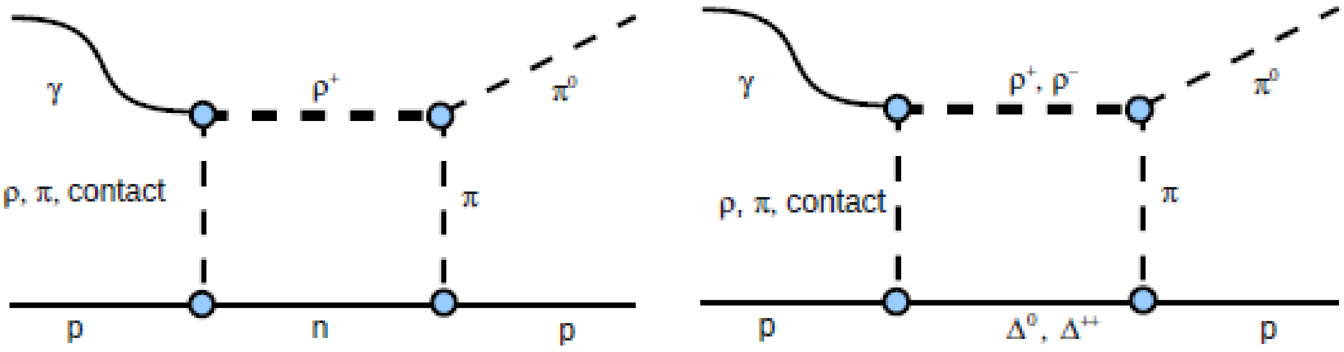




$$T_{loop} = -i\frac{m p_{c.m.}}{16\pi^2\sqrt{s}} \int d\Omega_p \sum_{m_p,m_\omega} (m_f|T_{\omega\pi}(t_\rho)|m_p,m_\omega)(m_p,m_\omega|T_{\gamma\omega}(t_\gamma)|m_i)$$

No freedom as long as the elementary reactions are reproduced

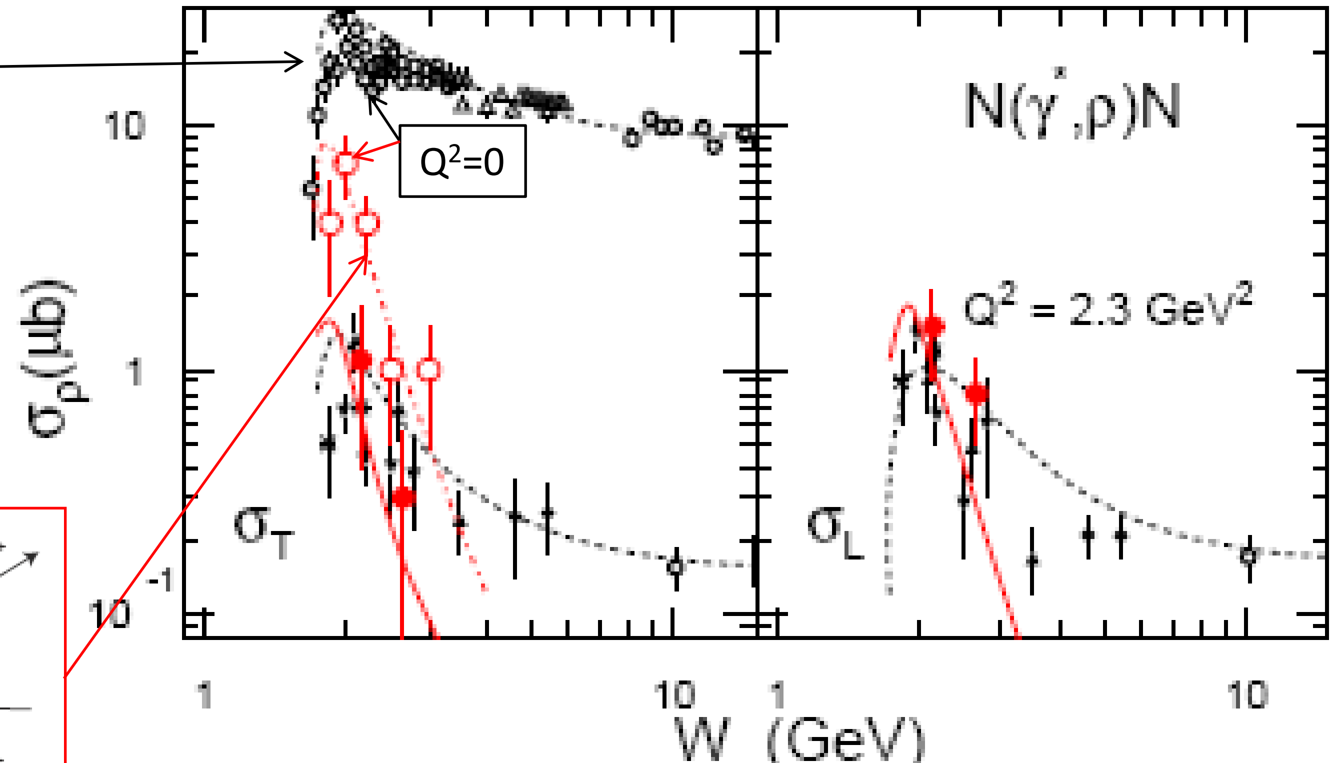
$p(e,e'\pi^0)p$: ρ^+n and $\rho^{+-}\Delta$ cuts

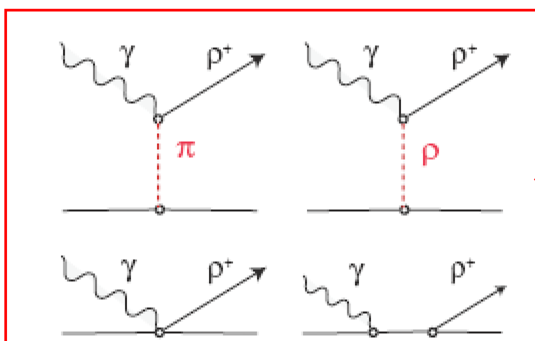


- ρ^+ cross section: large at $Q^2 \approx 3$ GeV^2 (CLAS)
  small at $Q^2=0$
- $\rho \rightarrow \pi$ cross section larger than $\omega \rightarrow \pi$ cross section
- Δ intermediate states as important as neutron one

P(e,e'ρ^+)N

ρ^0: diffractive

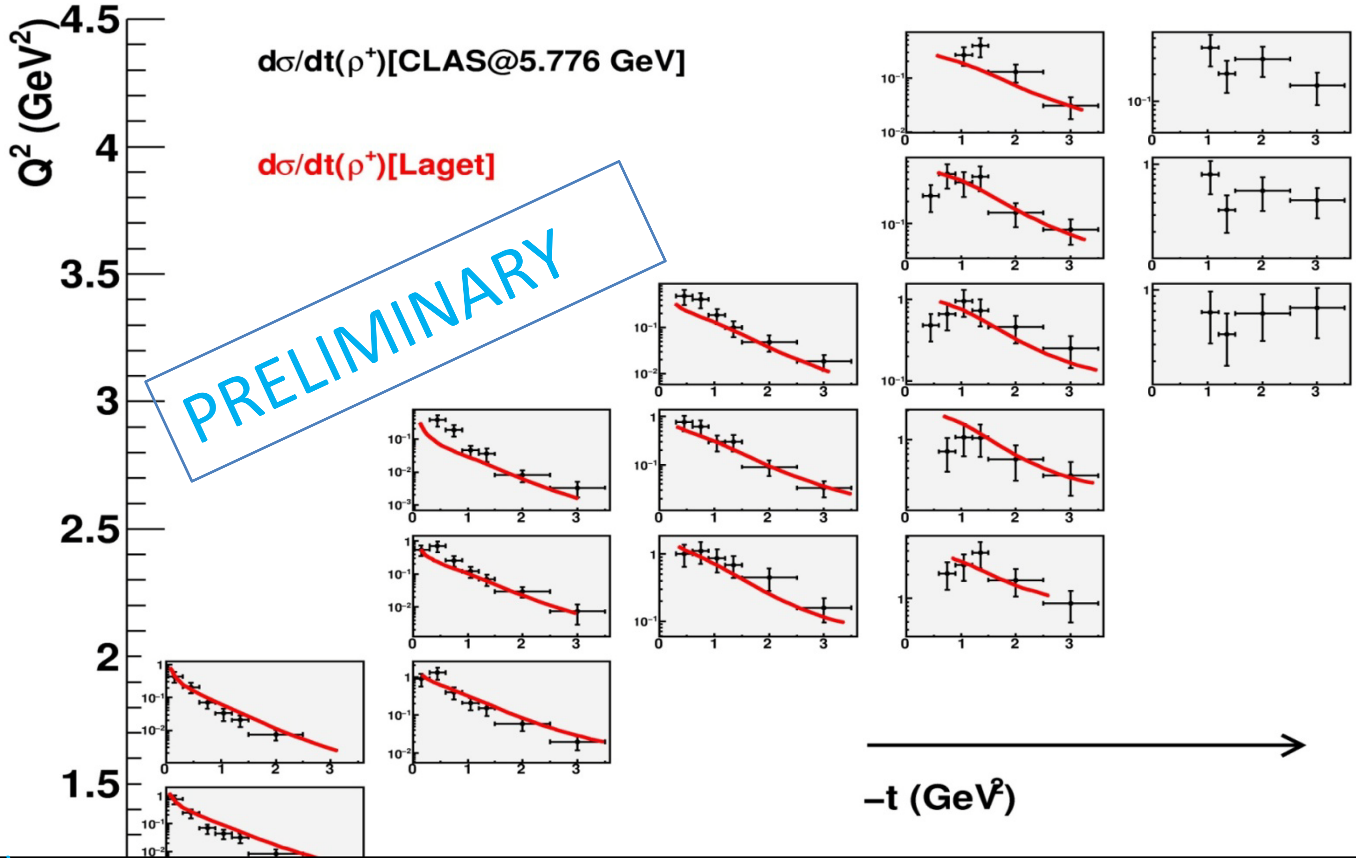




Gauge invariant

p(e,e’ ρ⁺)n

- Regge
- t-channel ρ and π
- Contact term
- s-channel nucleon
- Gauge invariant

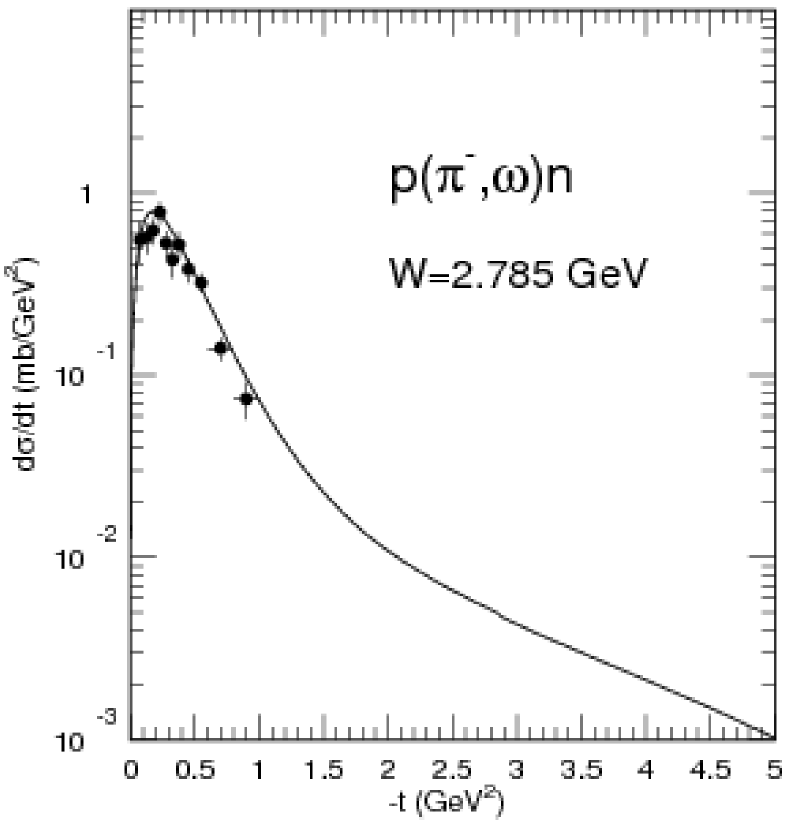


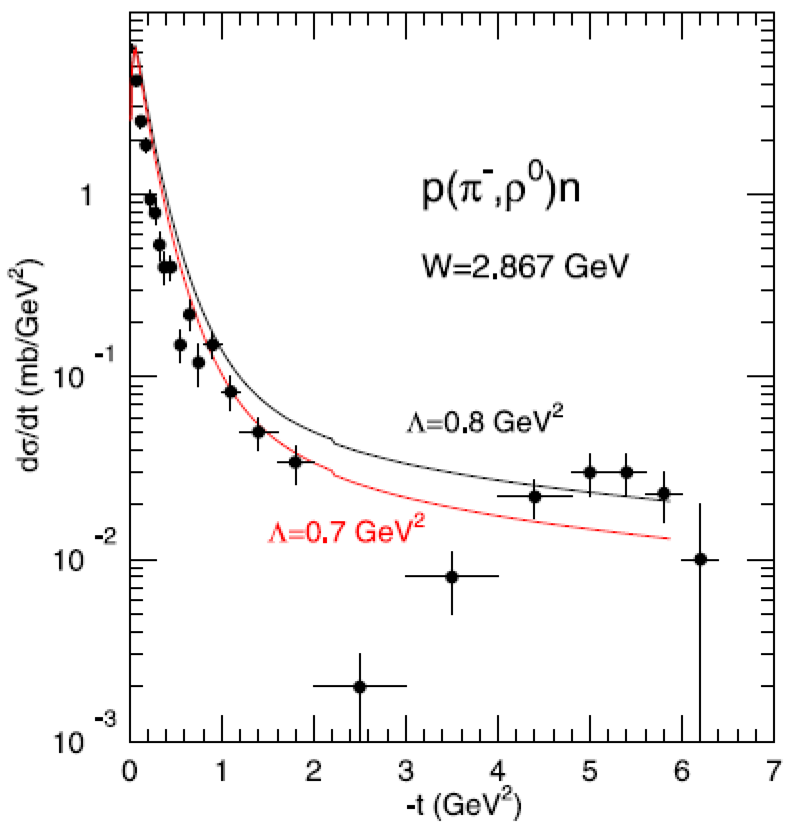
A. Fradi (Milos2009)

See his talk this week

[redacted]

ω vs ρ absorption cross sections



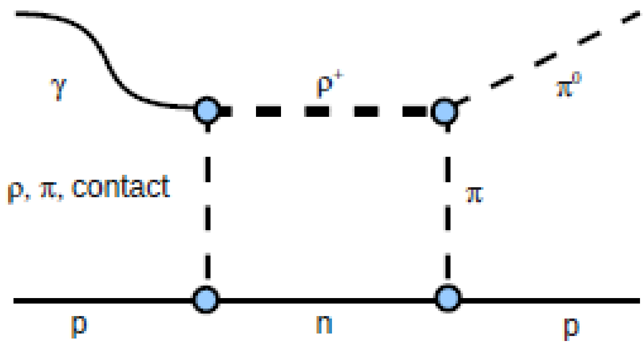


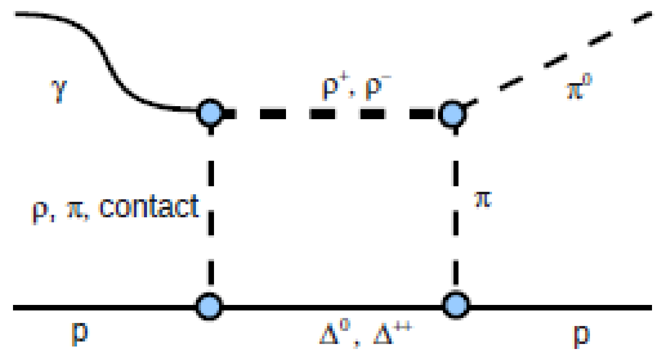
Regge ρ exchange

σ(π,ω) < σ(π,ρ)

Regge π exchange

p(e,e'π⁰)p: ρ⁺n and ρ⁺⁻Δ cuts





$$g_\rho g_\pi \ \vec{\sigma} \cdot \vec{k_\rho} \vec{\sigma} \cdot \vec{k_\pi}$$

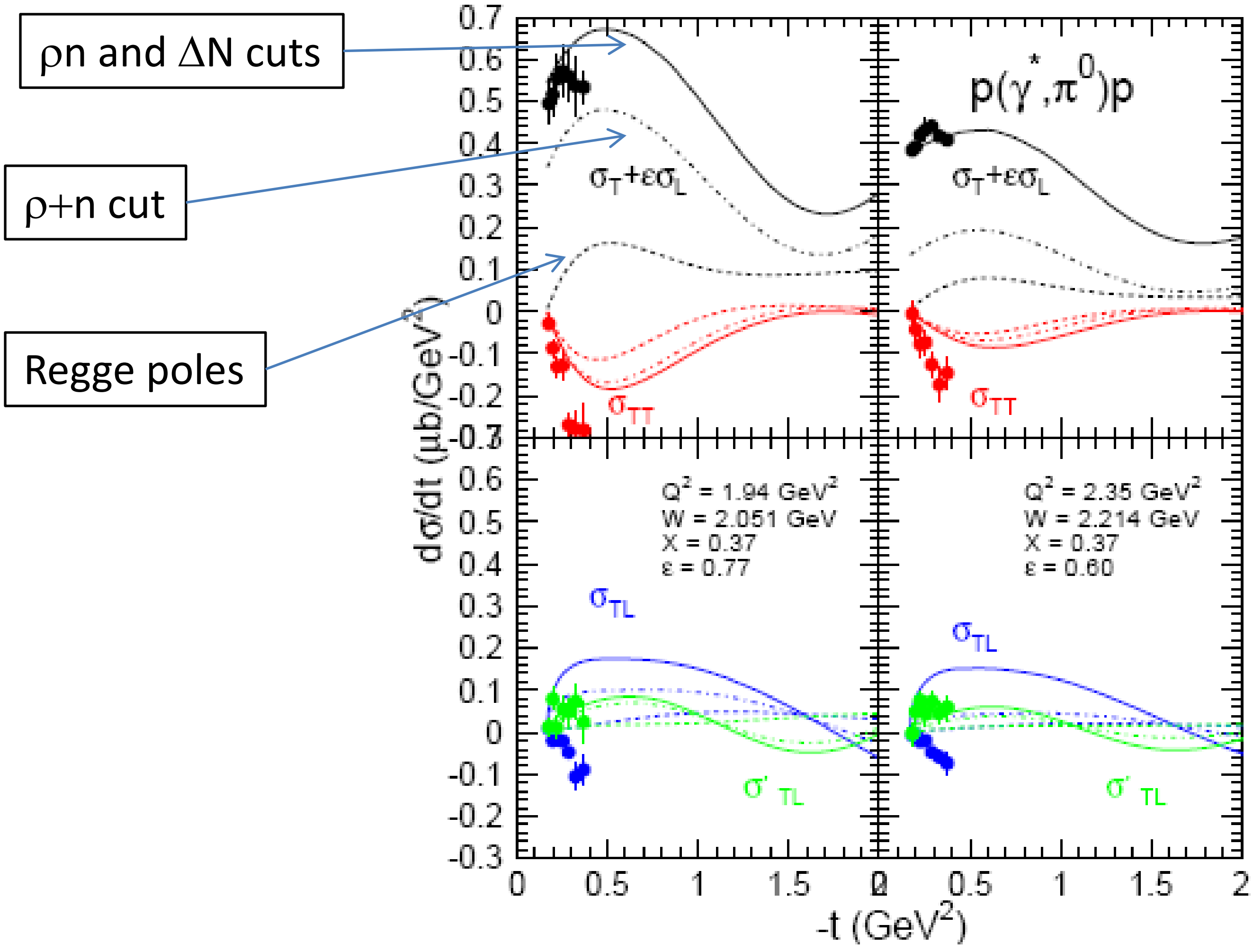
$$G_\rho G_\pi \ \vec{S} \cdot \vec{k_\rho} \vec{S} \cdot \vec{k_\pi}$$

$$\vec{k_\rho} \cdot \vec{k_\pi} + i\vec{\sigma} \cdot \vec{k_\rho} \times \vec{k_\pi}$$

$$\tfrac{2}{3}\vec{k_\rho} \cdot \vec{k_\pi} + i\tfrac{1}{3}\vec{\sigma} \cdot \vec{k_\rho} \times \vec{k_\pi}$$

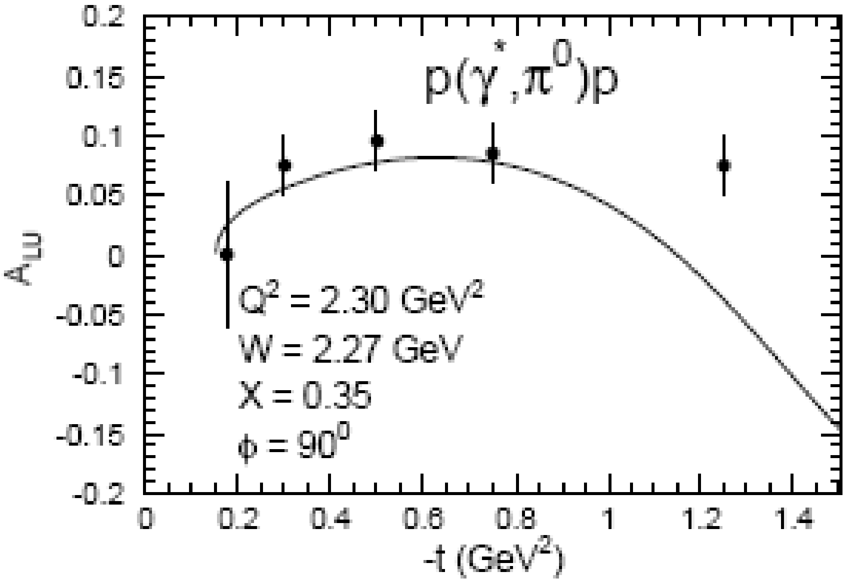
$$T_n + T_{\Delta^0} + T_{\Delta^{++}} \sim 1.75 \div 2.1 \ T_n$$

JLab HallA kinematics

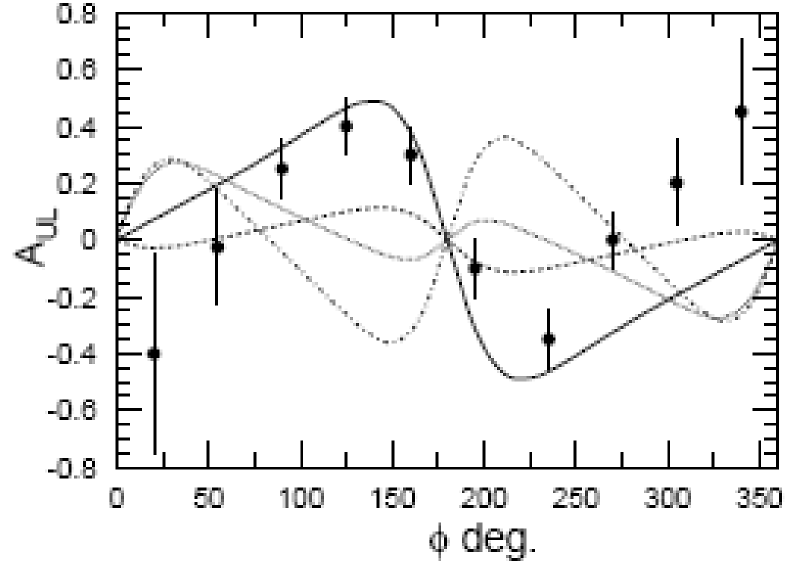


JLab HallB

- Unpolarized Xsections: → Talk by V. Kubarovsky
- Single Spin Asymmetries (SSA)

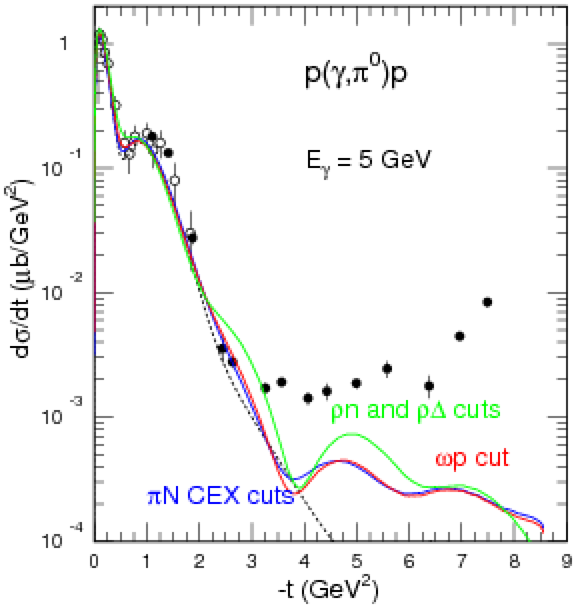


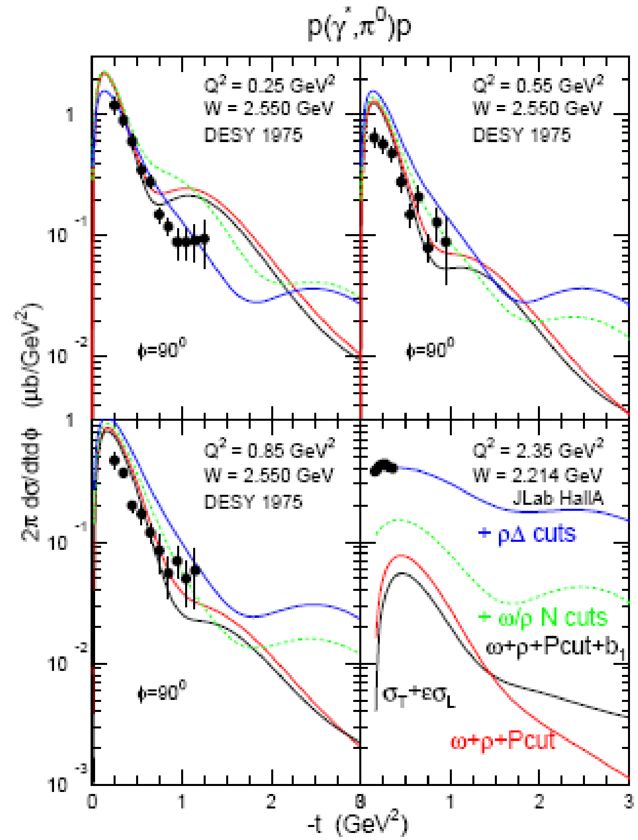
Beam



Target

p(e,e'π^0)p: low Q^2



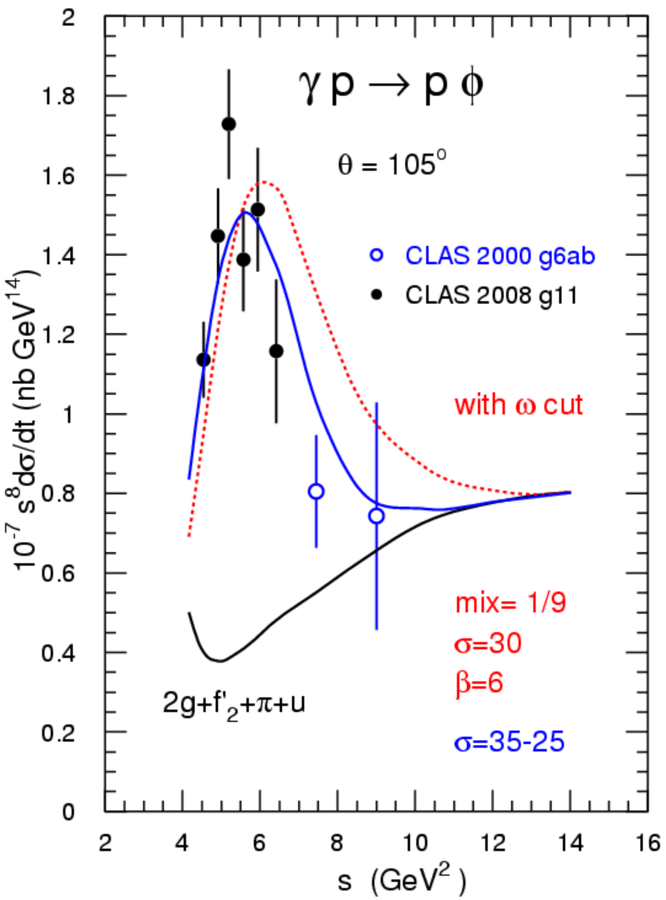


- Does not compromise the good agreement at Q2=0
- Helps to get rid of the node, for Q2<1 GeV^2
- A fine tuning of the EM form factors may improve the picture

Conclusion

- Hadronic picture of the light quark sector:
  - large t (scaling)
  - large Q^2 (DVCS, π^0,...)
  - No quark explicitly needed
- Consistent links between various channels
- Comes from the large production and absorption cross sections of the ρ
- Coupling to the ρ^0 survives at high energy
- Coupling to the ω and $\rho^{\pm}$ suppressed at high energy
- → Heavy quark sector at JLab12 (ϕ, J/ψ,....)
  - Weak channel coupling ?
  - Quark/gluon picture makes more sense ?

Approach to scaling



- 2 gluon exchange scales for s> 12 GeV^2
- The oscillation around scaling comes from coupling to the ω channel
- No data above Eγ= 4.5 GeV
- Coupled channel effects suppressed at high energies
- → 12 GeV+ ? → p(e,e'ϕ)p

Channel coupling effects in exclusive meson photo and electroproduction at high momentum transfers

VCS and DVCS: Phys. Rev. C76, 052201(R) 2007

Charged pion: Phys. Lett. B685, 146 (2010)

Neutral pion: arXiv:1004.1949 [hep-ph]

ϕ meson: unpublished yet