Exclusive vector meson electroproduction @ CLAS6

The 4th Workshop on Exclusive Reactions at High Momentum Transfer
JLab, 20 May 2010

A. Fradi, IPN Orsay

Exclusive ρ^+, ρ^0, ω & ϕ electroproduction on the proton @ CLAS6

A. Fradi, Orsay Univ. PhD thesis (ρ^+@5.75 GeV) } e1-dvcs (2005)

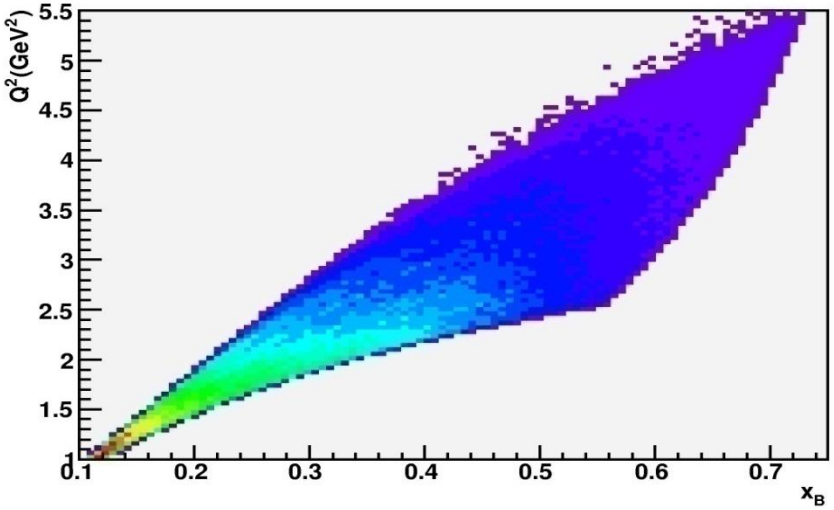
S. Morrow et al., Eur.Phys.J.A39:5-31,2009 (ρ^0@5.75GeV)
J. Santoro et al., Phys.Rev.C78:025210,2008 (ϕ@5.75GeV)
L. Morand et al., Eur.Phys.J.A24:445-458,2005 (ω@5.75GeV) } e1-6 (2001-2002)

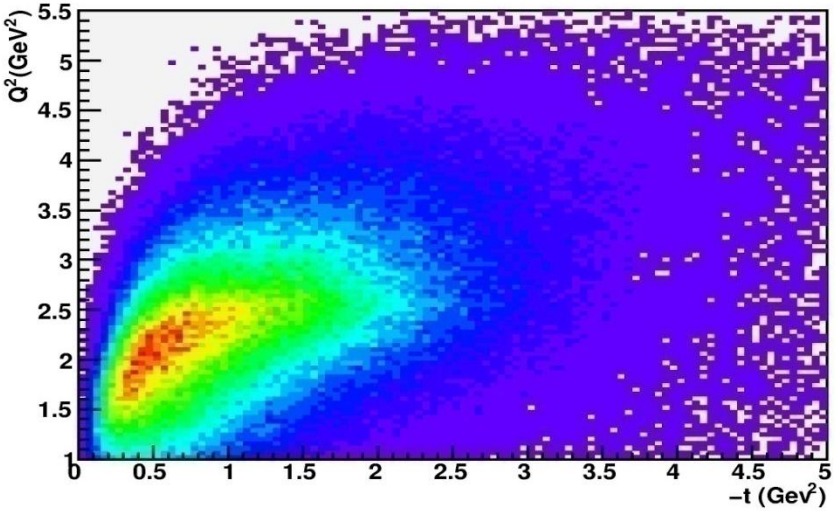
C. Hadjidakis et al., Phys.Lett.B605:256-264,2005 (ρ^0@4.2 GeV)
K. Lukashin et al., Phys.Rev.C63:065205,2001 (ϕ@4.2 GeV) } e1-b (1999)

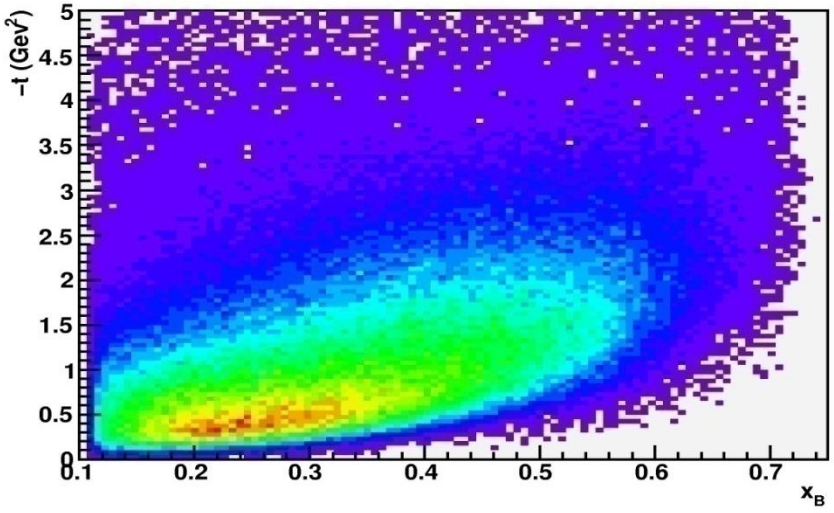
Exclusive ρ^+ electroproduction

The e1-dvcs experiment (March - May 2005)

$e\,p \rightarrow e'\,n\,\rho^{+} \rightarrow e'\,n\,\pi^{+}\pi^{0} \rightarrow e'\,n\,\pi^{+}\,\gamma\,\gamma$







Beam energy = 5.75 GeV

Current: 20-25 nA

Integrated Luminosity ≈ 40fb^{-1}

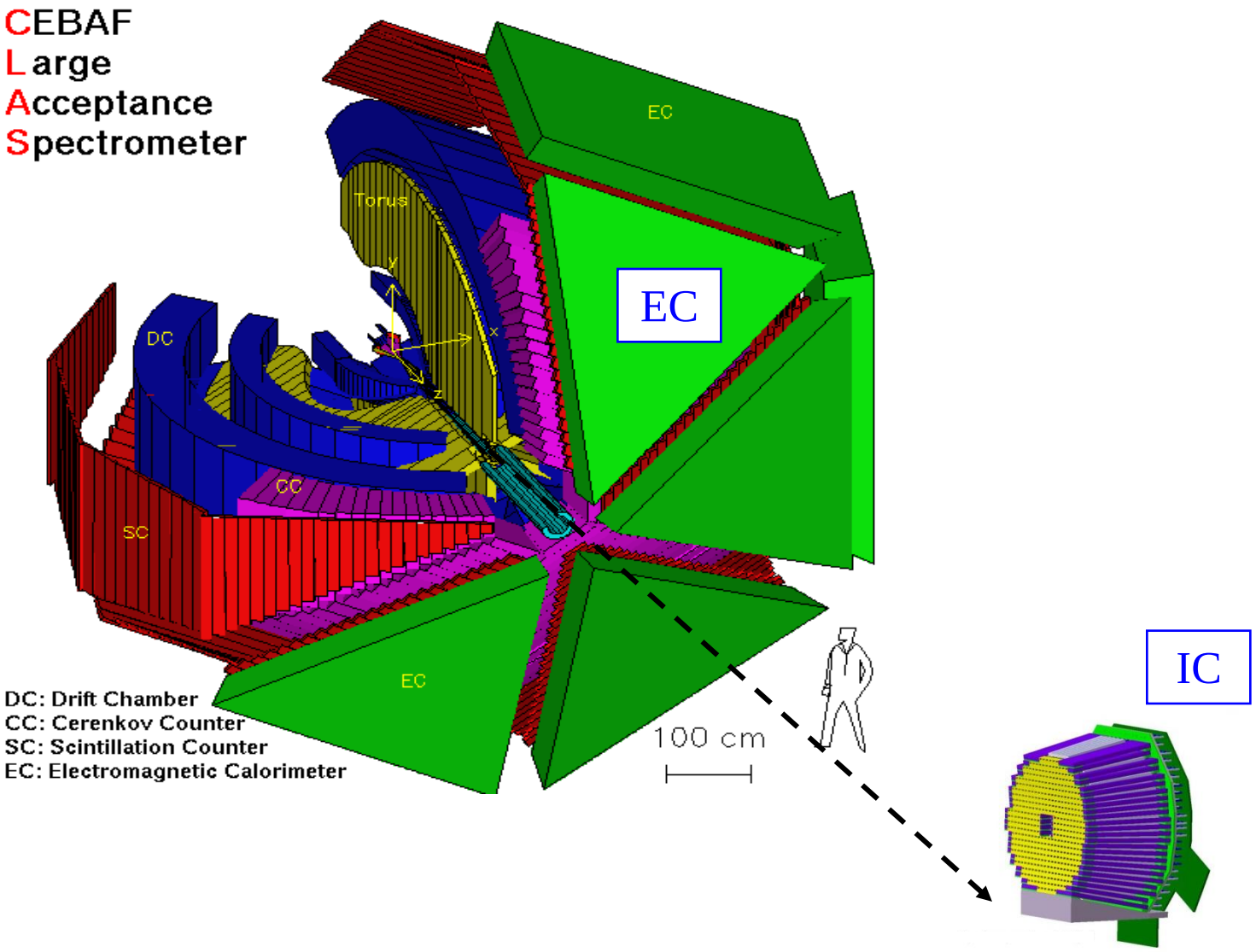
$0.1 < x_B < 0.65$

Q^2 up to 5 GeV^2

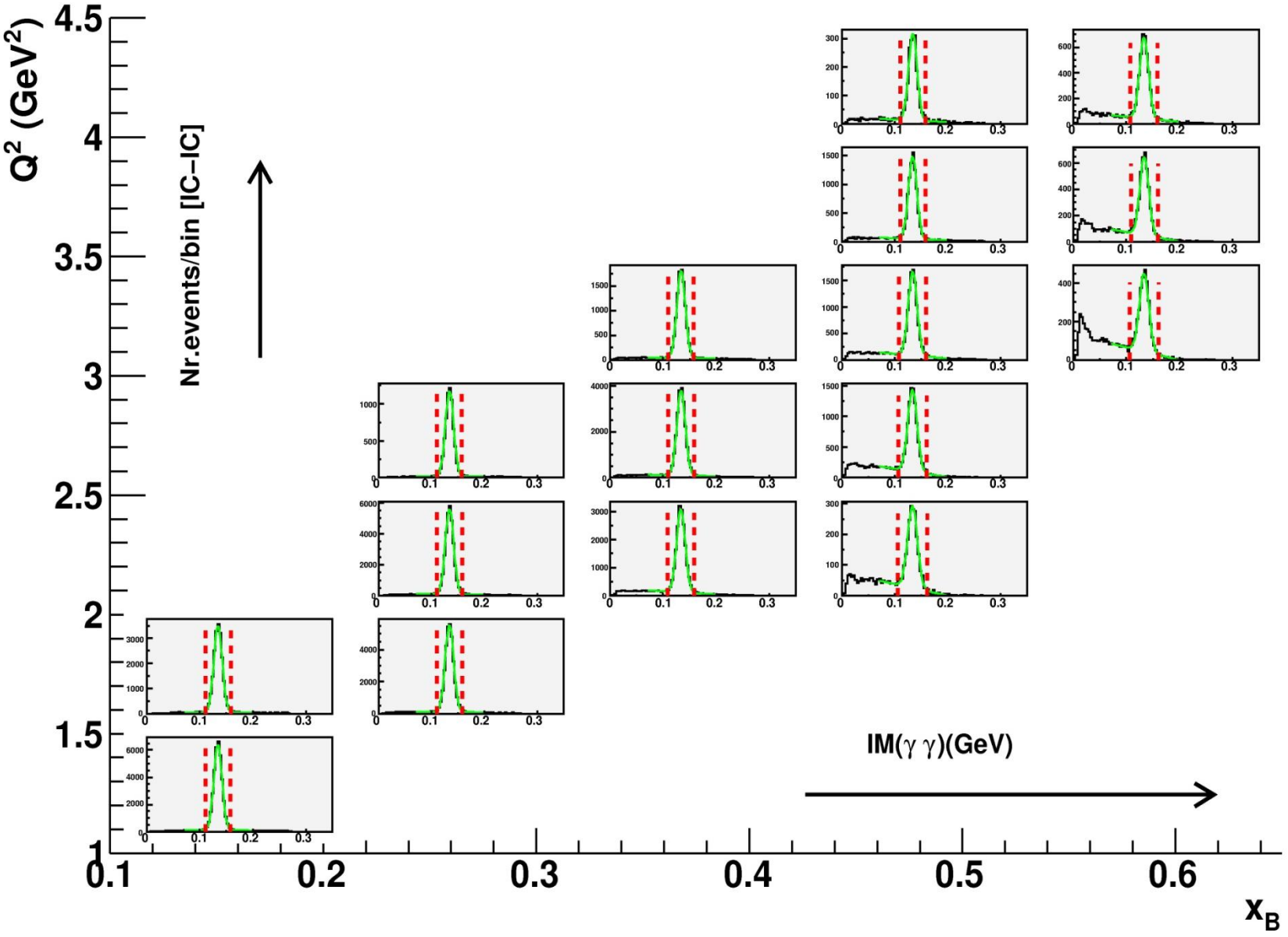
-t up to 3.5 GeV^2

Channel selection

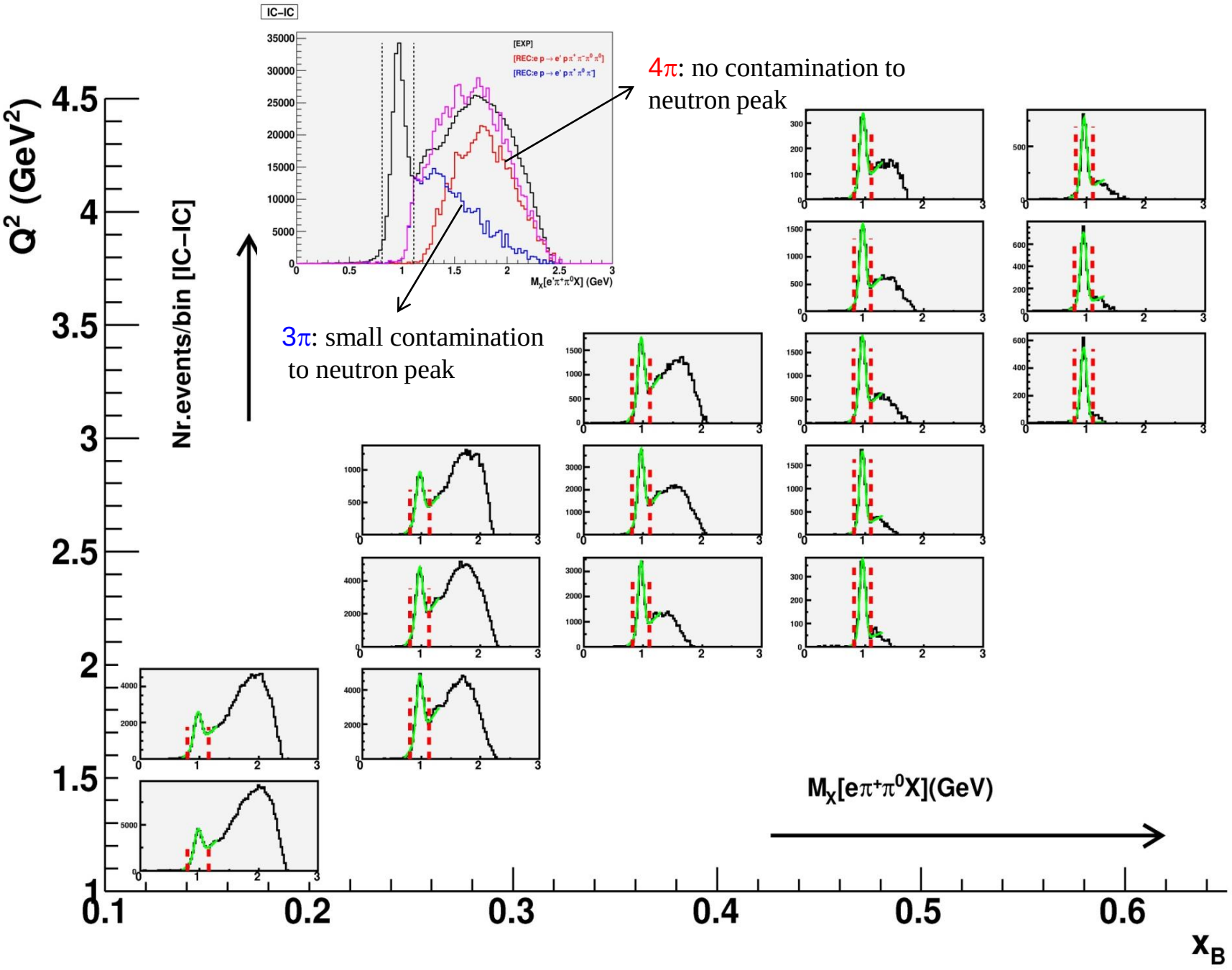
$e\,p \rightarrow e'\,[n]\,\rho^{+} \rightarrow e'\,[n]\,\pi^{+}\pi^{0} \rightarrow e'\,[n]\,\pi^{+}\,\gamma\,\gamma$



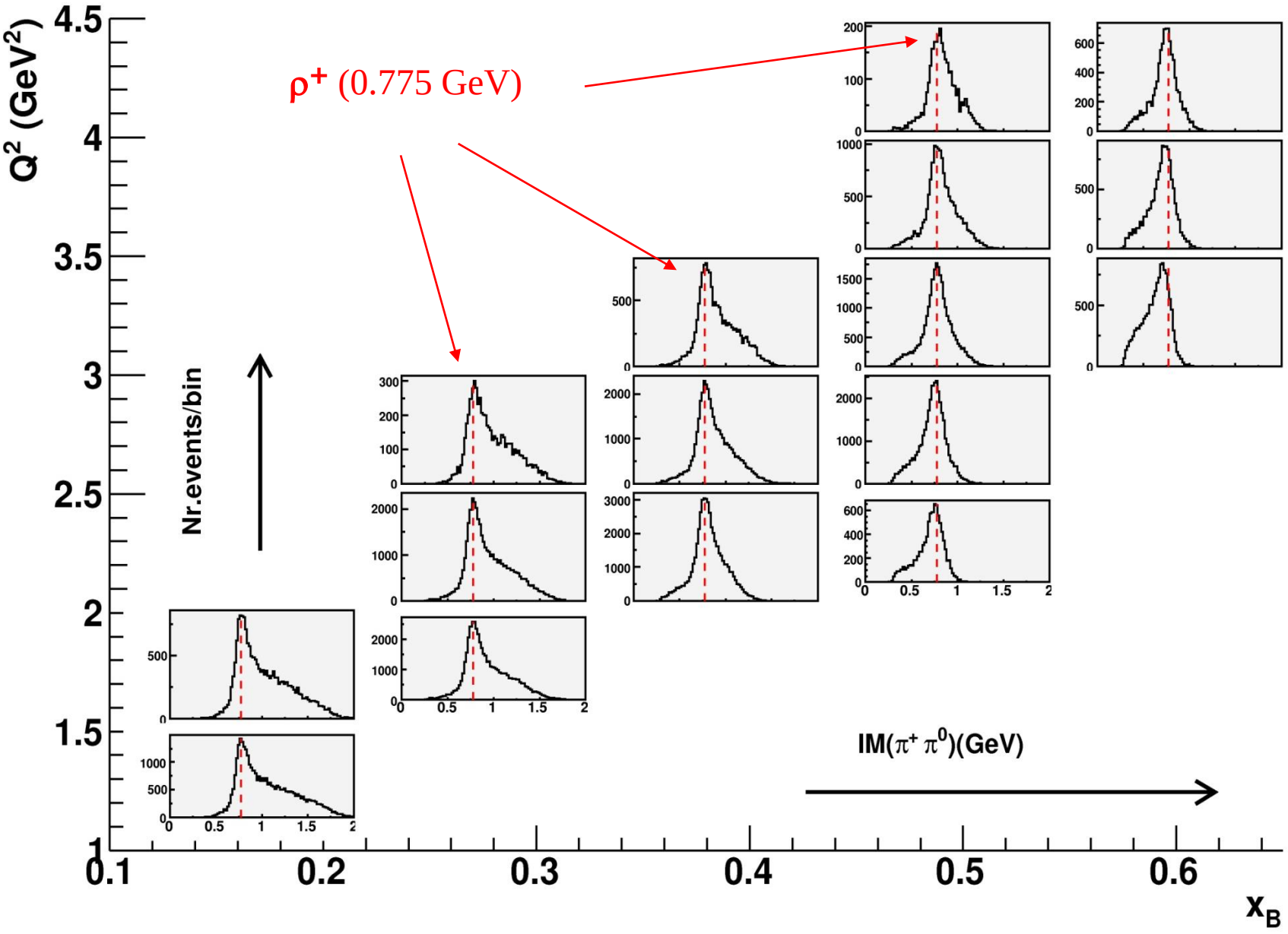
π^0 selection



Neutron selection



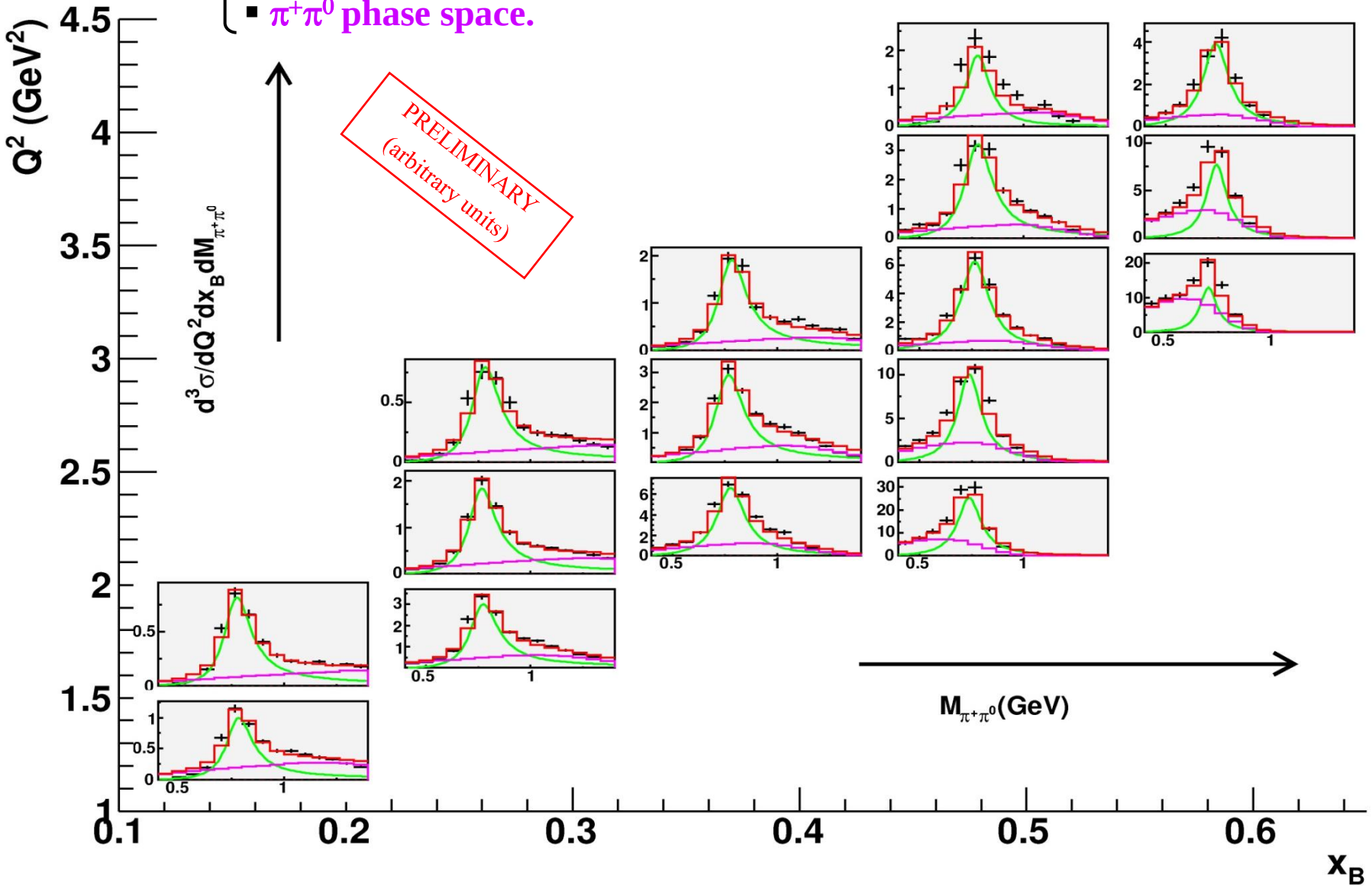
$\pi^+\pi^0$ invariant mass



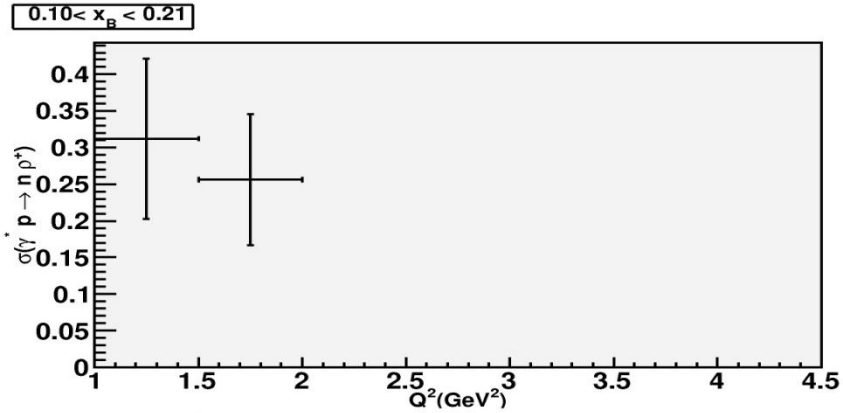
Background subtraction

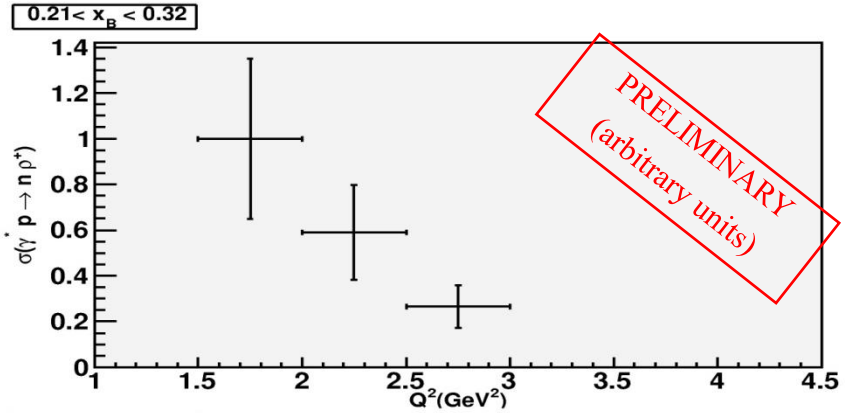
$$\frac{d\sigma_{\gamma^* p\to n\rho^+}}{dQ^2 dx_B d\tau} = \frac{1}{\Gamma_V}\frac{N_{\gamma^* p\to n\rho^+}}{L_{\text{int}}.Acc.\Delta Q^2.\Delta x_B.\Delta\tau} F_{corr}$$

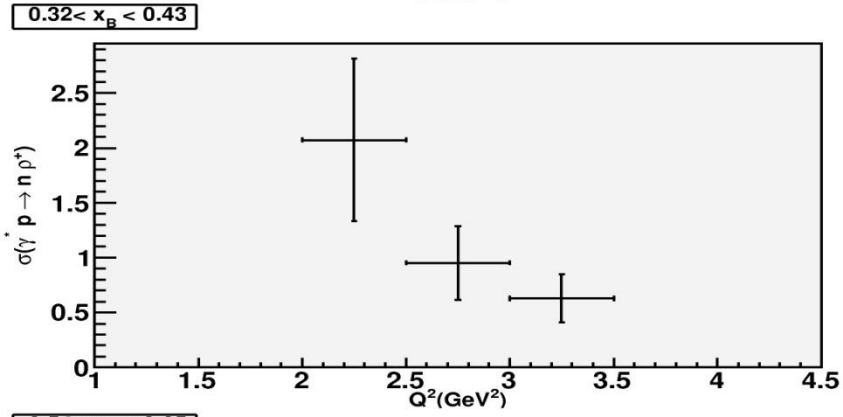
- **Ross-Stodolsky B-W for $\rho^+(770)$ with variable skewedness parameter.**
- **$\pi^+\pi^0$ phase space.**

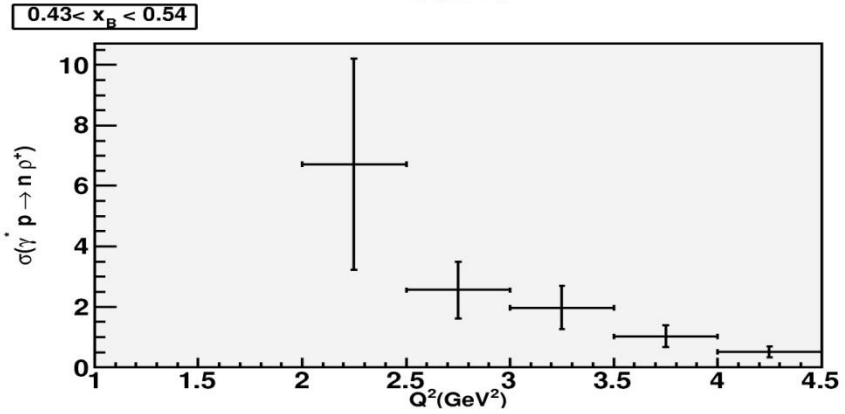


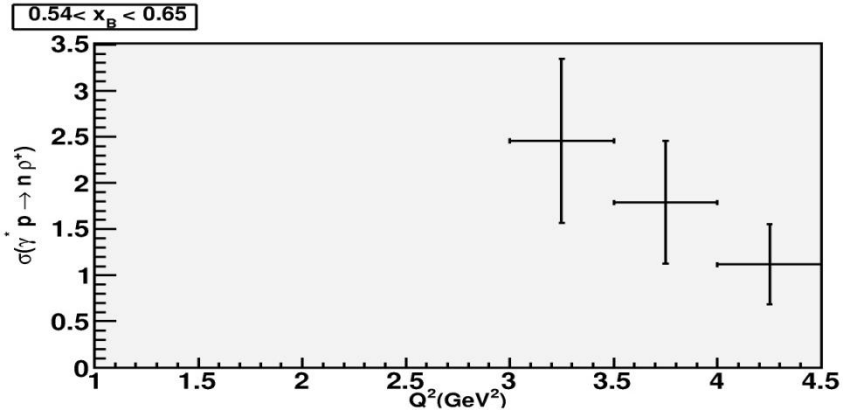
Total cross section $\sigma(\gamma^* p \rightarrow n \rho^+)$





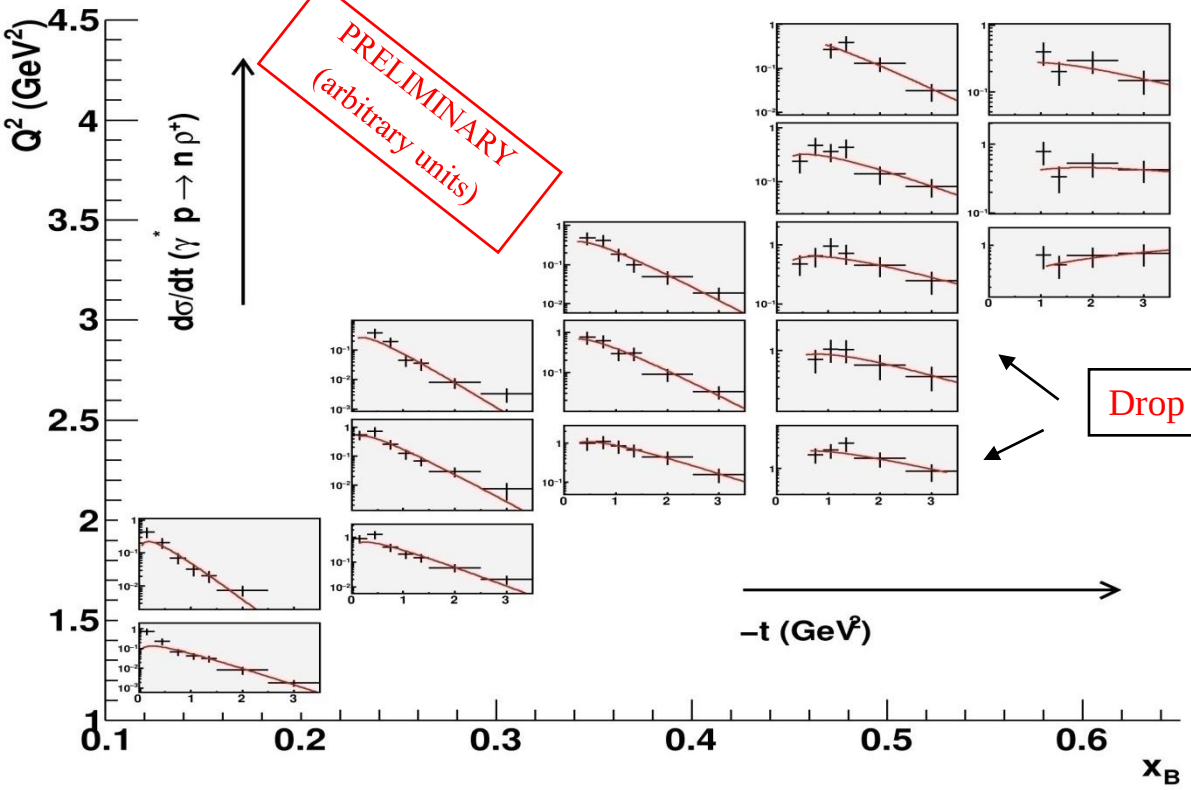






World's first-ever measurement

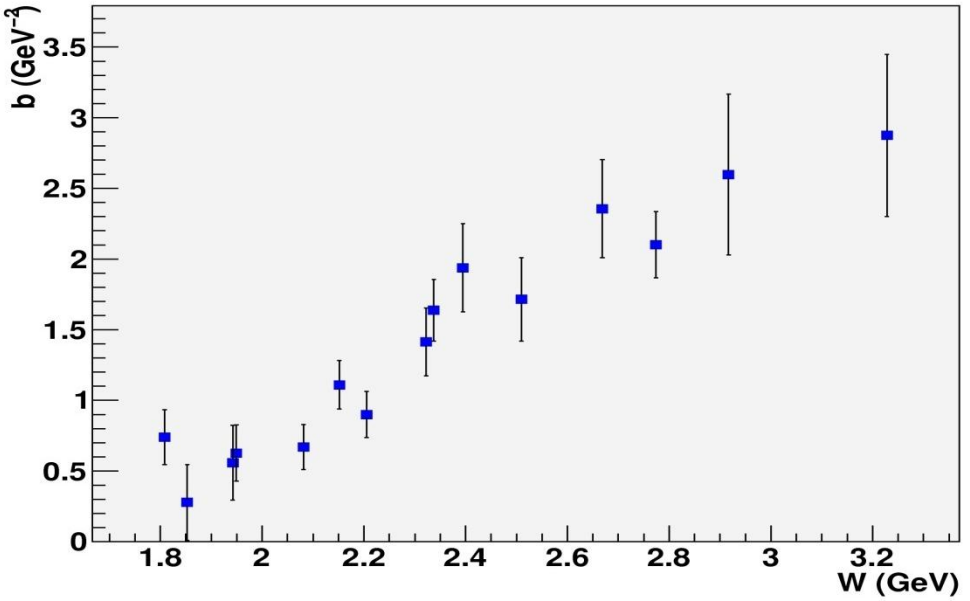
$d\sigma/dt\ (\gamma^* p \rightarrow n \rho^+)$



Drop of $d\sigma/dt$ for $t \rightarrow 0$

Fit function:

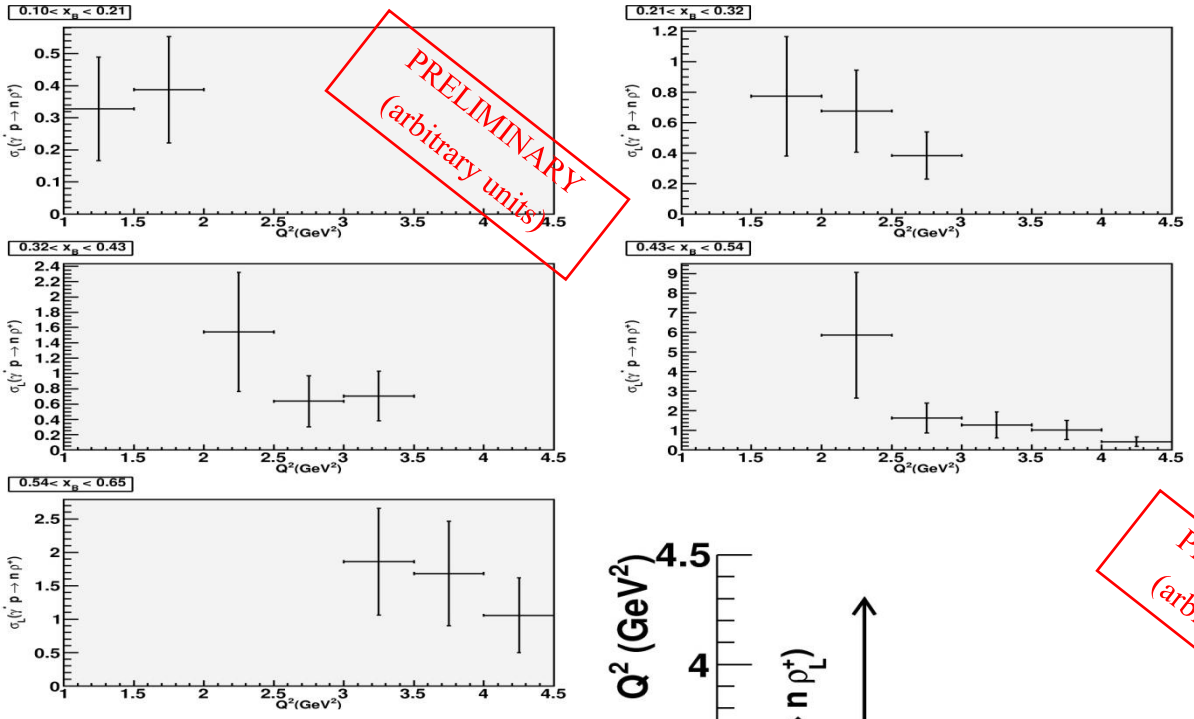
$$A\sqrt{-t}e^{-bt}$$



Longitudinal cross sections

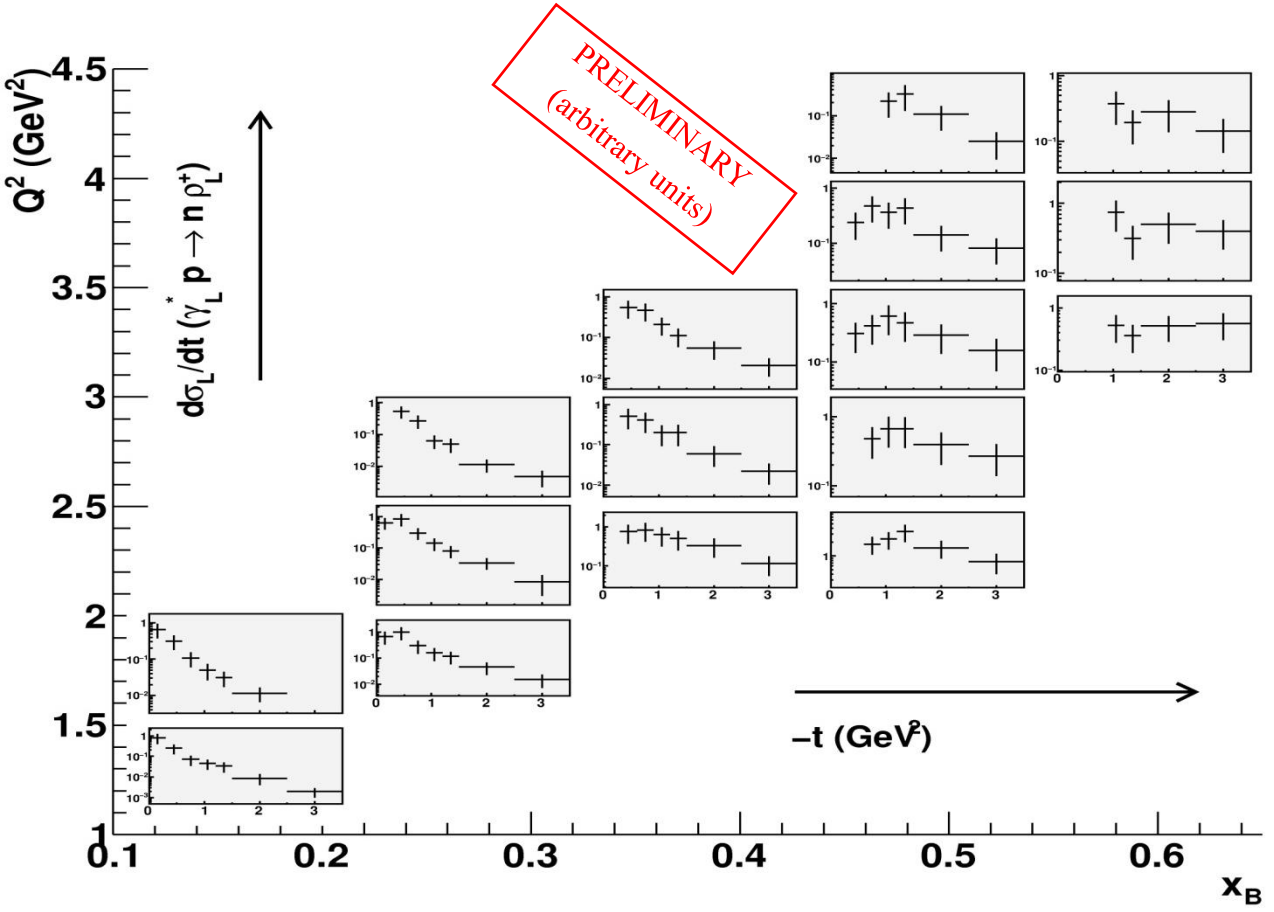
Longitudinal/Transverse separation:

- Analysis of the pion decay angles of the ρ^+ ($\cos\theta_{HS}$)
- SCHC



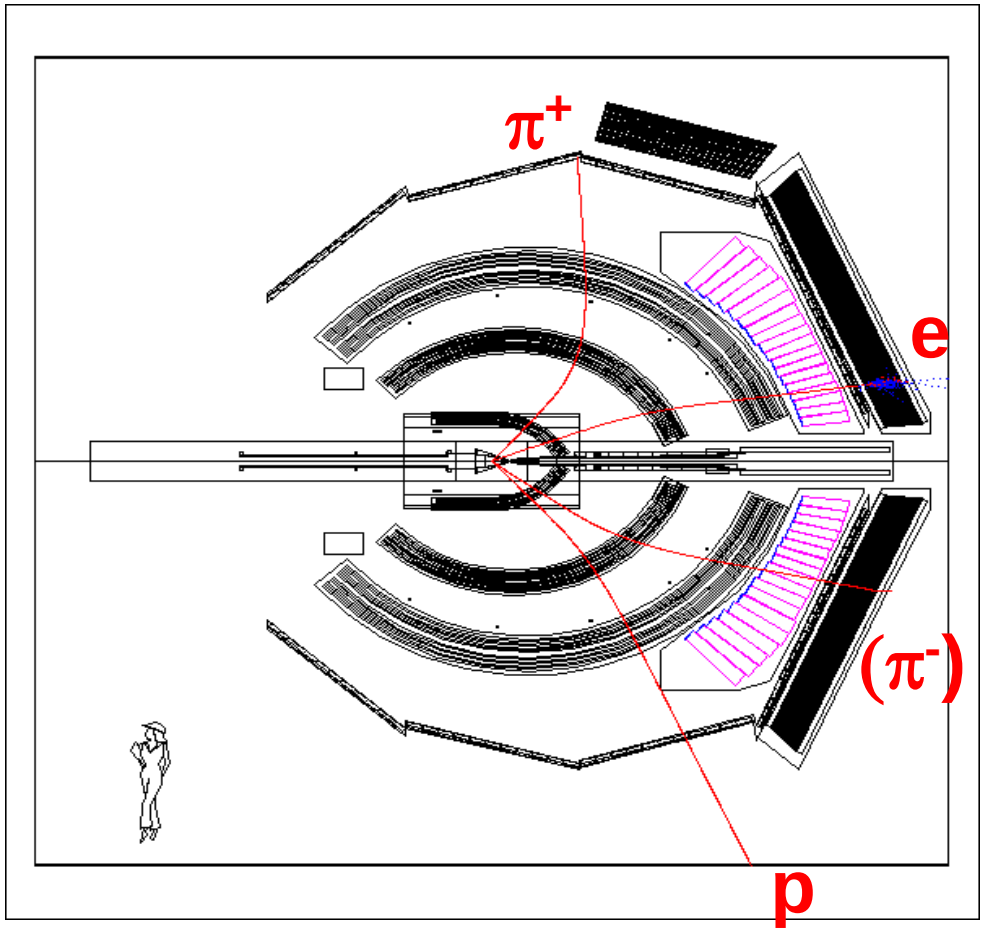
$\sigma_L(\gamma^* p \rightarrow n \rho^+)$

$d\sigma_L/dt\ (\gamma^* p \rightarrow n \rho^+)$

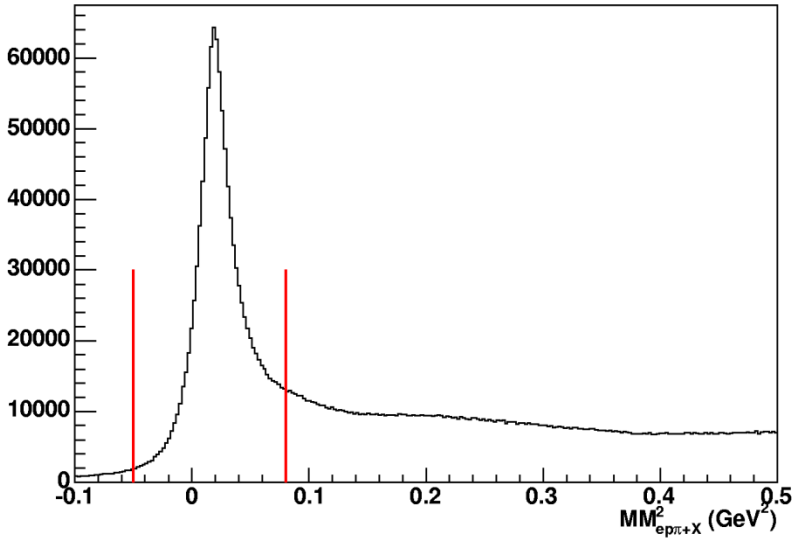


Exclusive ρ^0 electroproduction

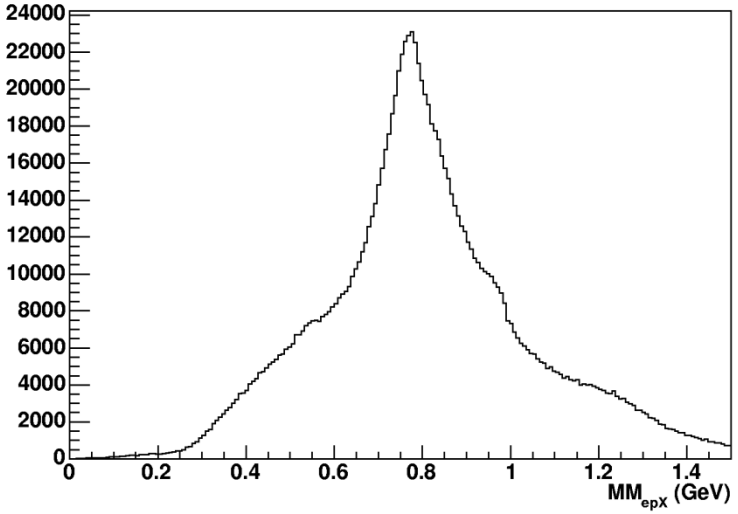
$e\ p \rightarrow e\ p\ \rho^0 \rightarrow e'\ p\ \pi^+(\pi^-)$

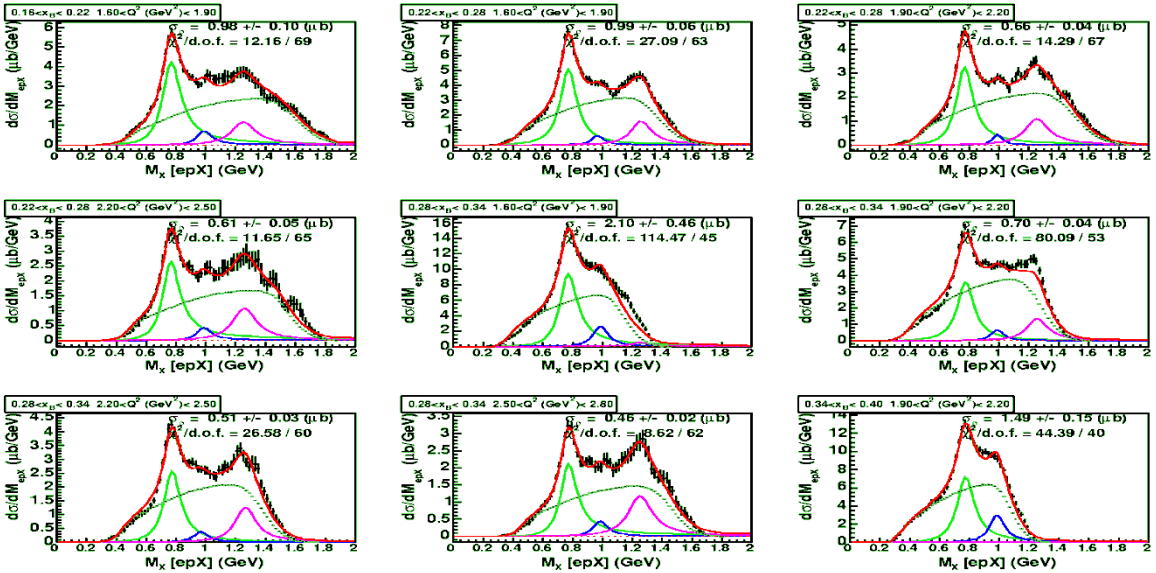


Mm(epπ+ X)



Mm(epX)



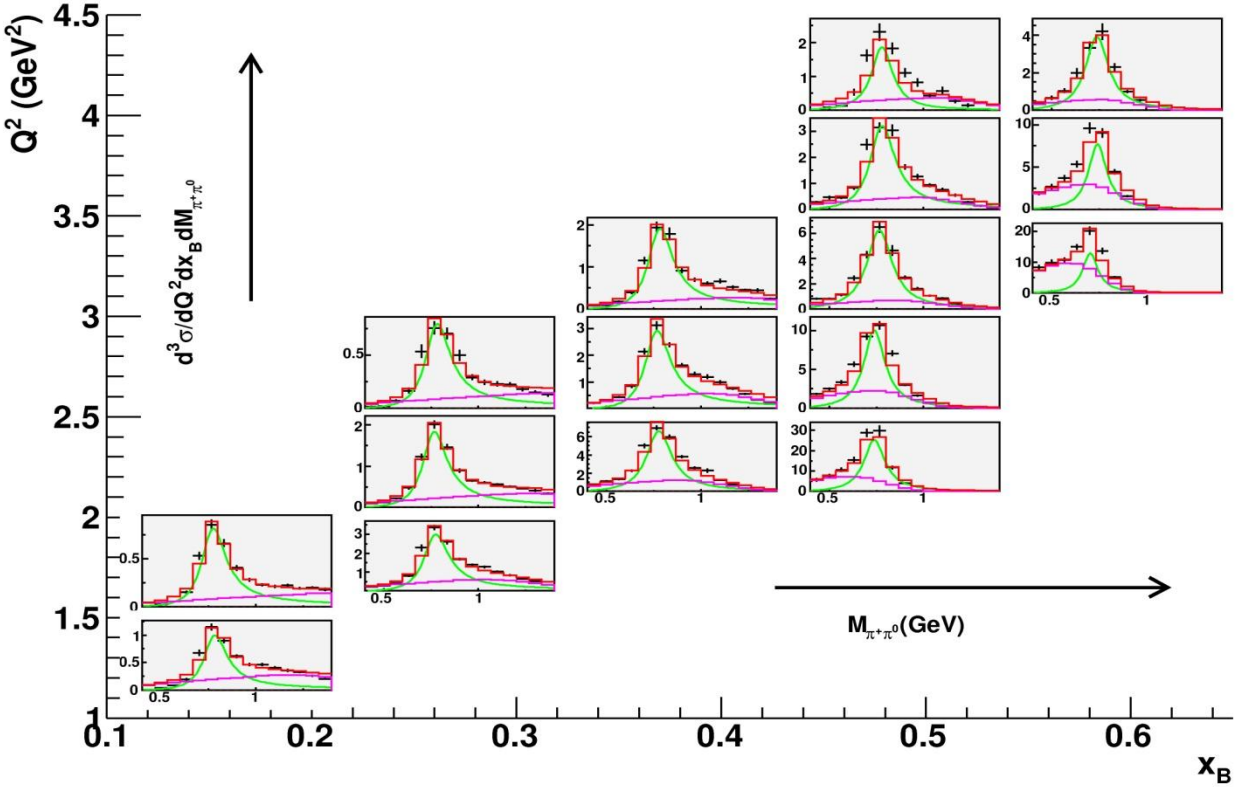


ρ^0

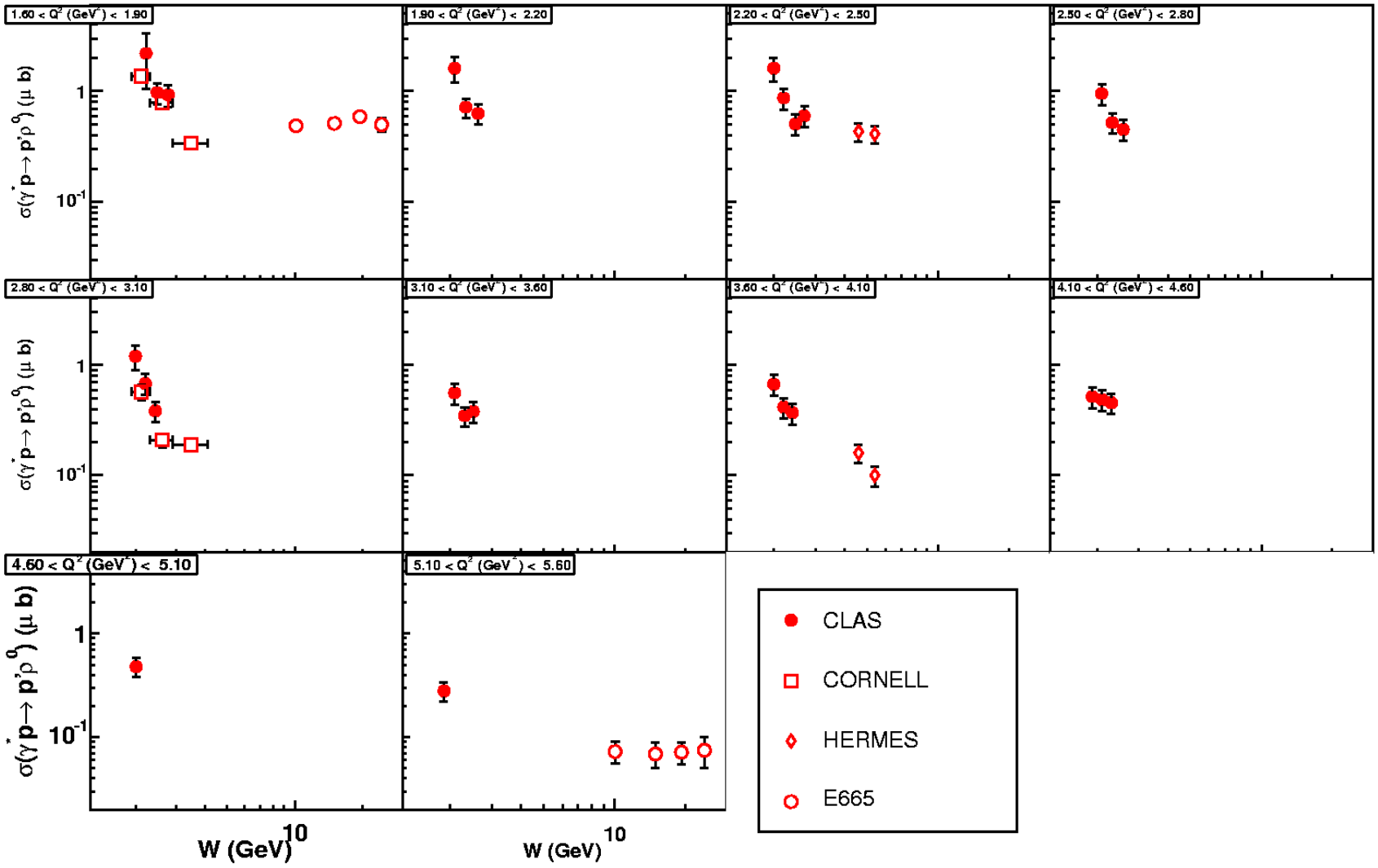
Background: non resonant $\pi^+ \pi^-$, f_0, f_2

ρ^+

Background:non resonant $\pi^+\pi^0$

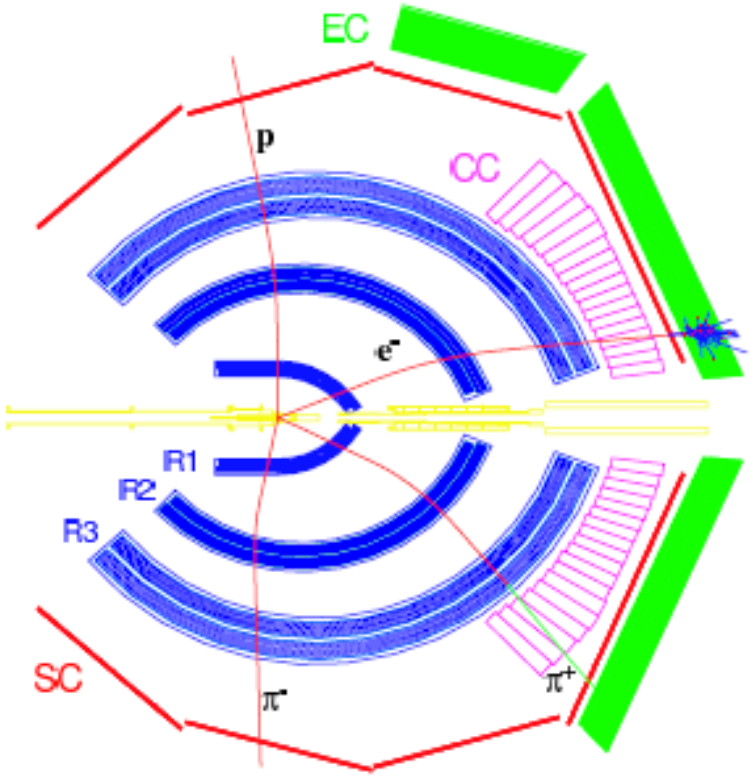


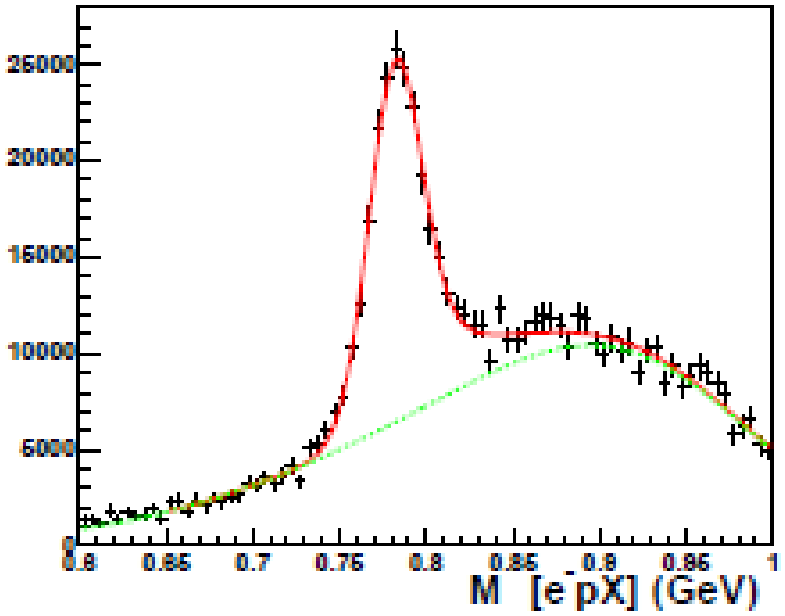
$\sigma_\rho (\gamma^* p \to p\rho^0)$ vs W



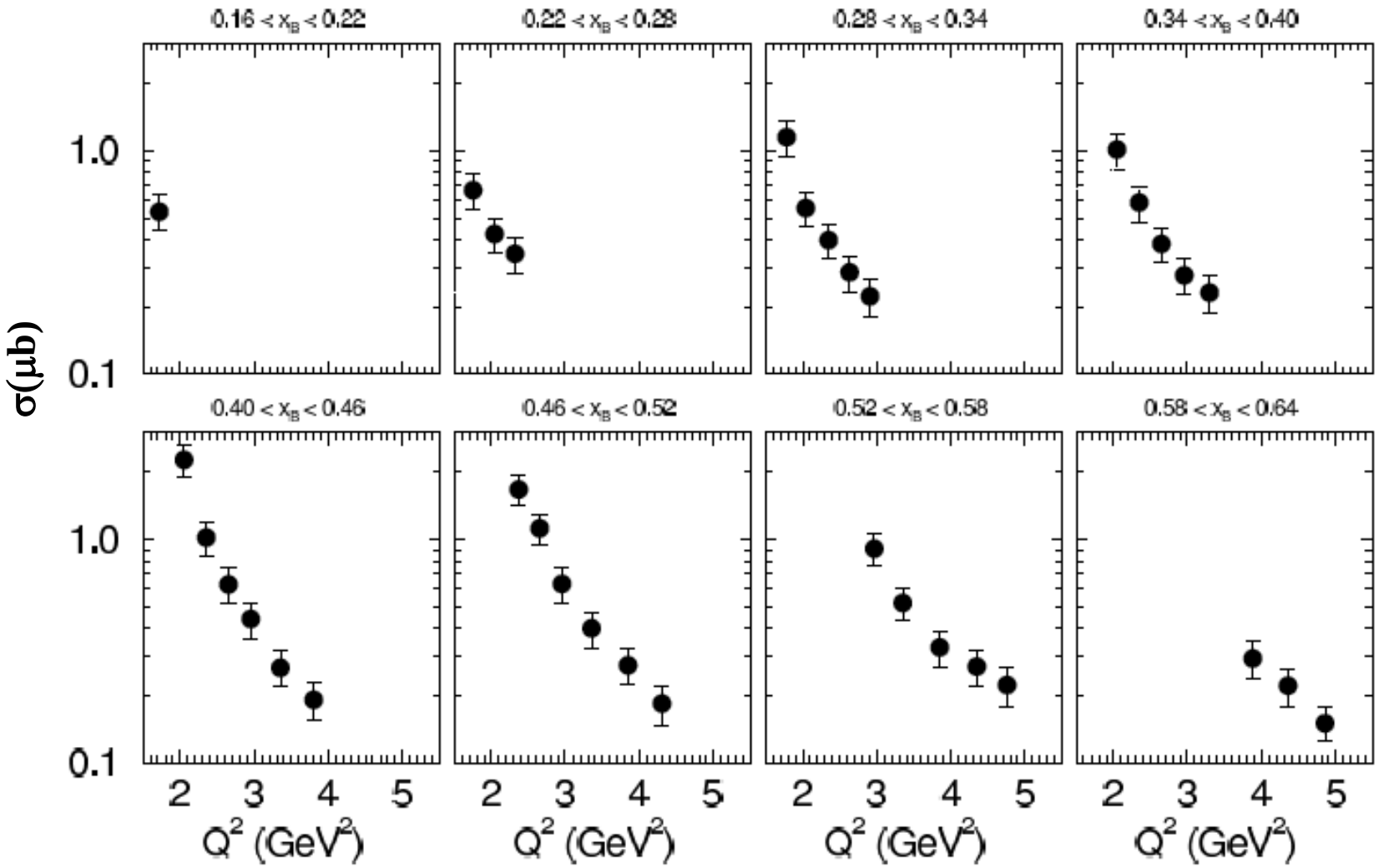
Exclusive ω electroproduction

ep->epω (↳ $\pi^+\pi^-[\pi^0]$)



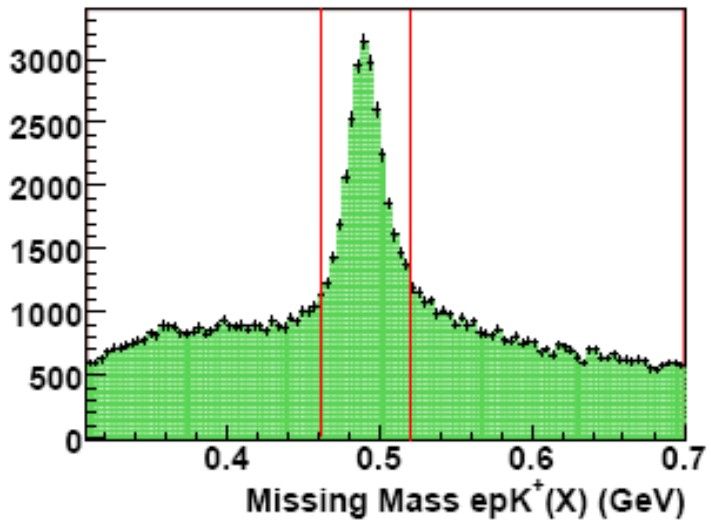


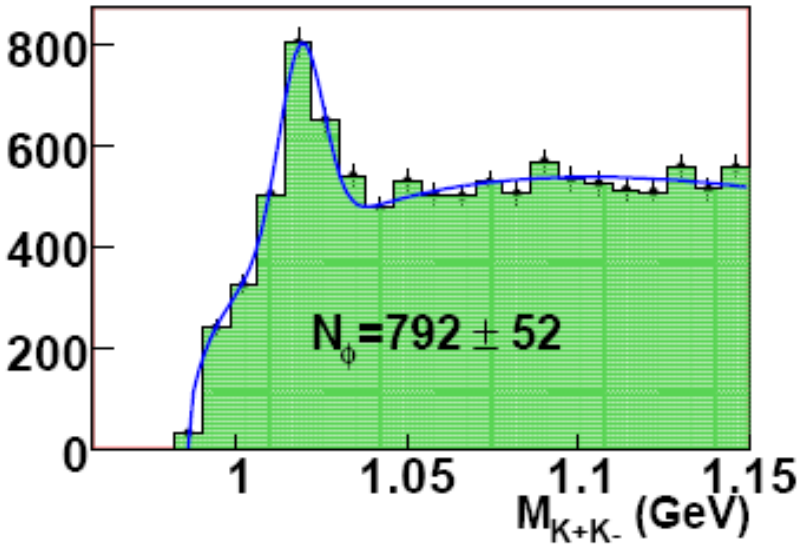
Total cross section σ (γ^* p → p ω)

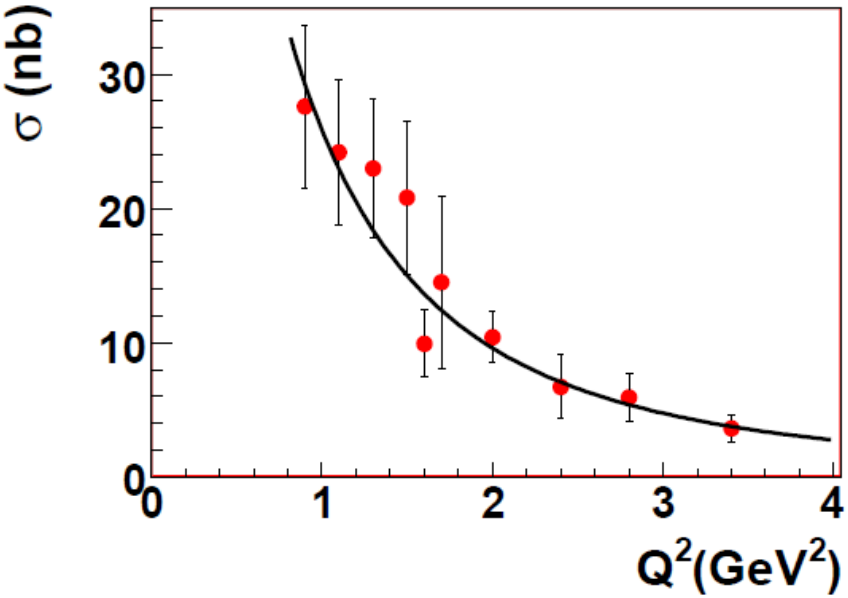


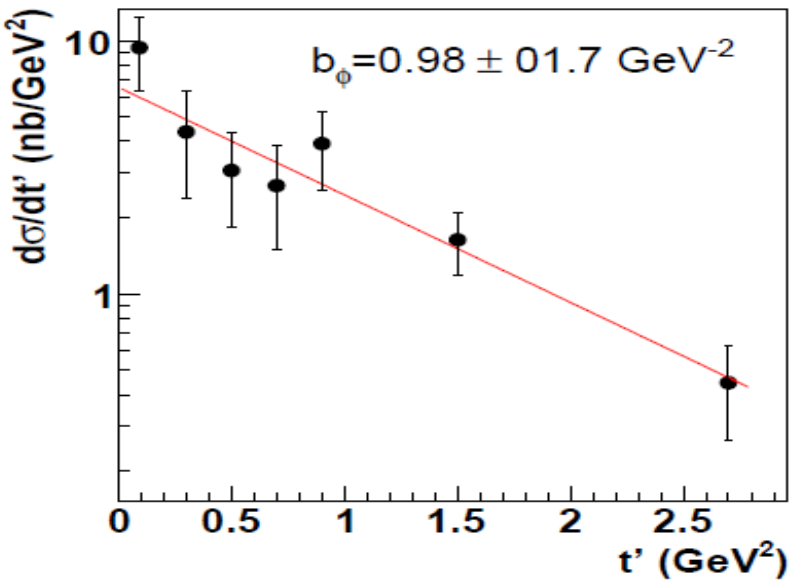
Exclusive ϕ electroproduction

ep->epϕ (↳ $K^+[K^-]$)

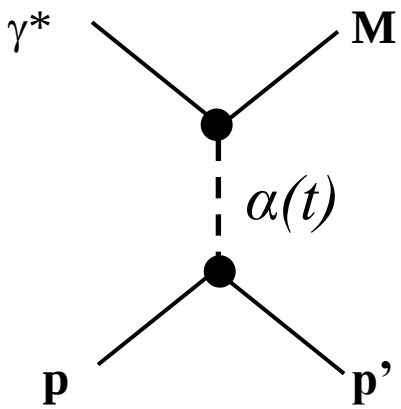

3000
2500
2000
1500
1000
500
0
0.4
0.5
0.6
0.7
Missing Mass epK+(X) (GeV)

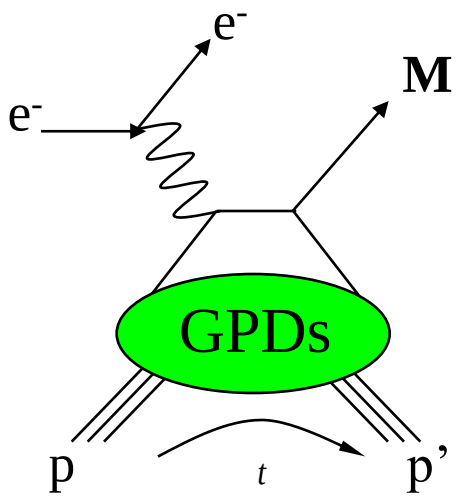

800
600
400
200
0
1
1.05
1.1
1.15
Nϕ=792 ± 52
MK+K- (GeV)


σ (nb)
30
20
10
0
0
1
2
3
4
Q2(GeV2)


bϕ=0.98 ± 01.7 GeV-2
dσ/dt' (nb/GeV2)
10
1
0
0.5
1
1.5
2
2.5
t' (GeV2)

Theoretical interpretation





Hadronic approach:

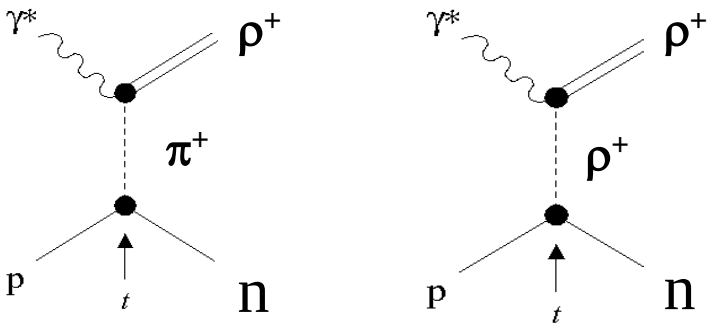
Regge theory and meson trajectory exchanges

Partonic approach:

Handbag diagram and GPDs

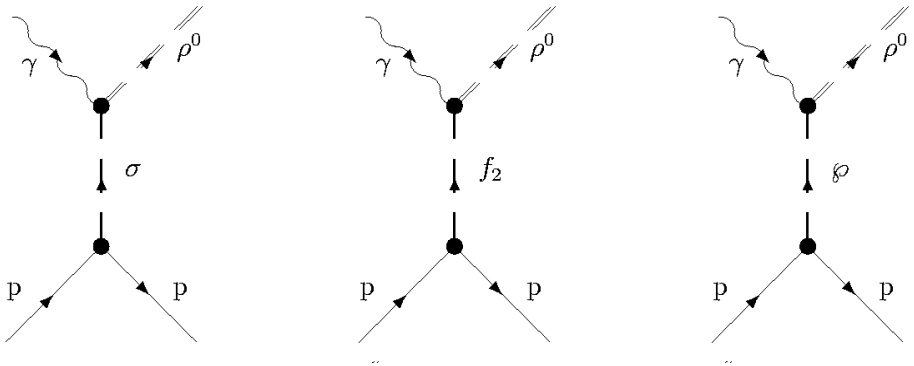
Hadronic approach: Laget model

$\gamma^* p \to n\rho^+$

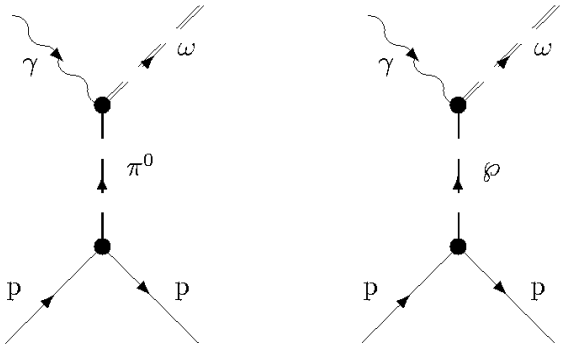


Free parameters:
*Hadronic coupling constants: g_{MNN}
*Mass scales of EM FFs: $(1+Q^2/\Lambda^2)^{-2}$

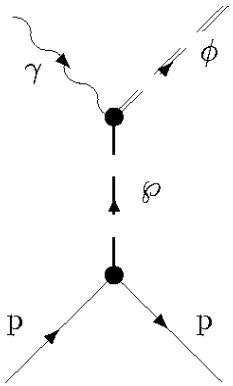
$\gamma^* p \to p\rho^0$

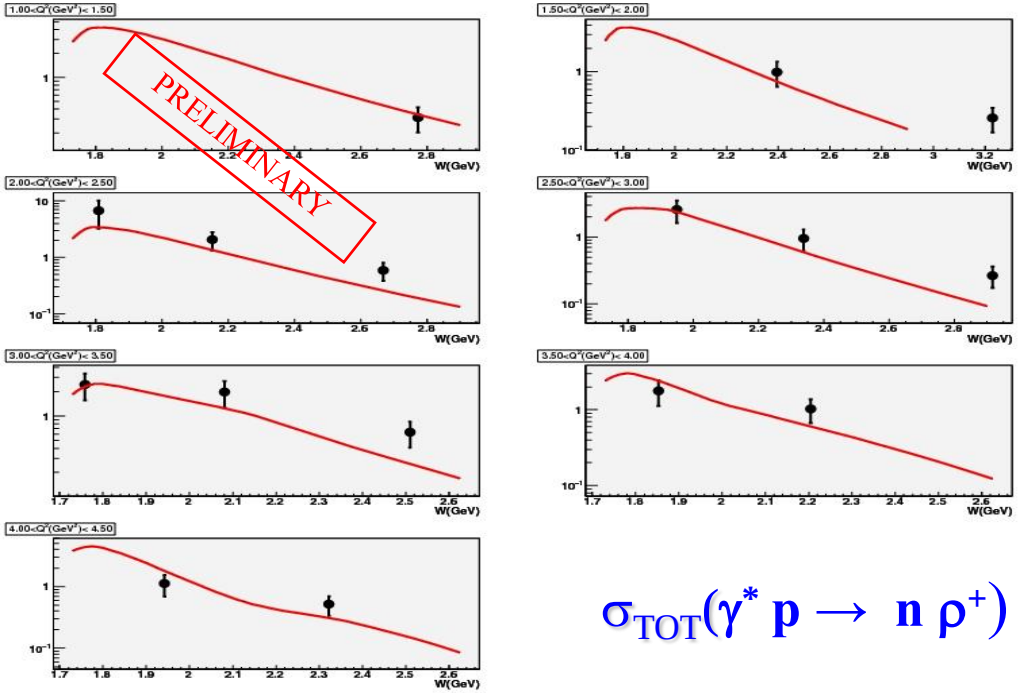


$\gamma^* p \to p\omega$



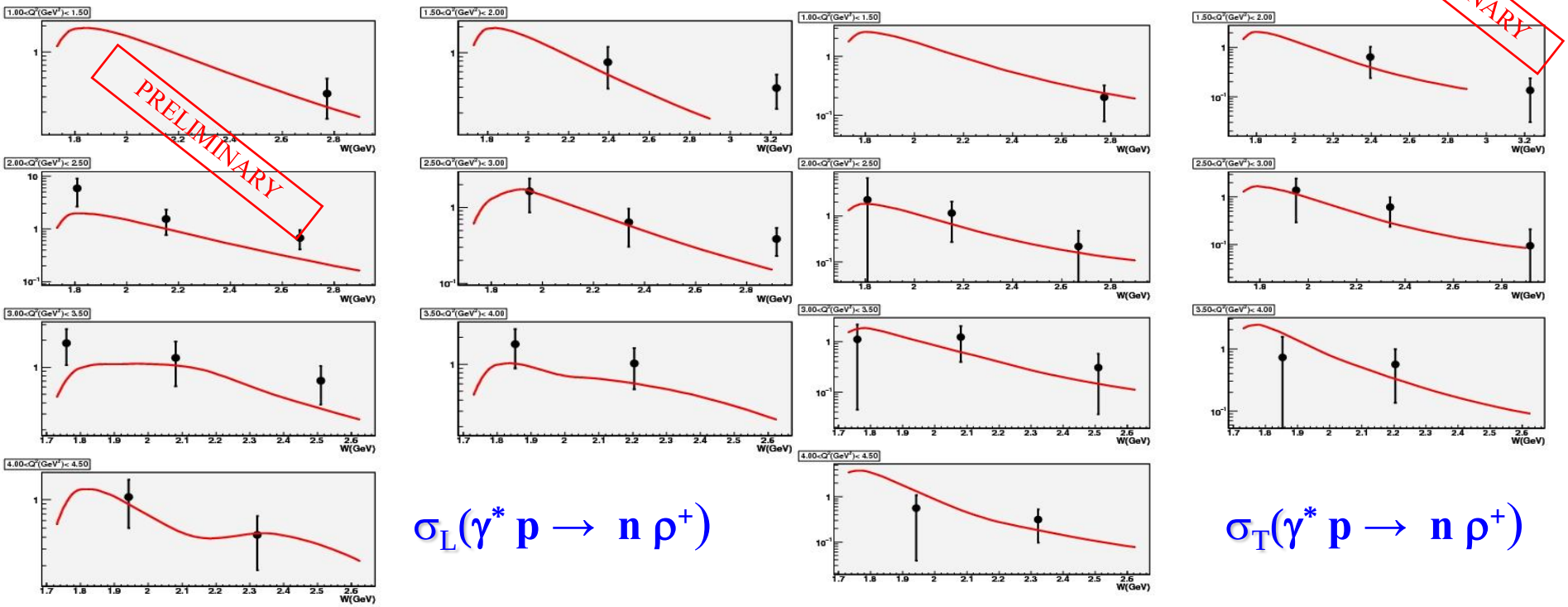
$\gamma^* p \to p\phi$





Laget model for $\gamma^* p \rightarrow n\rho^+$

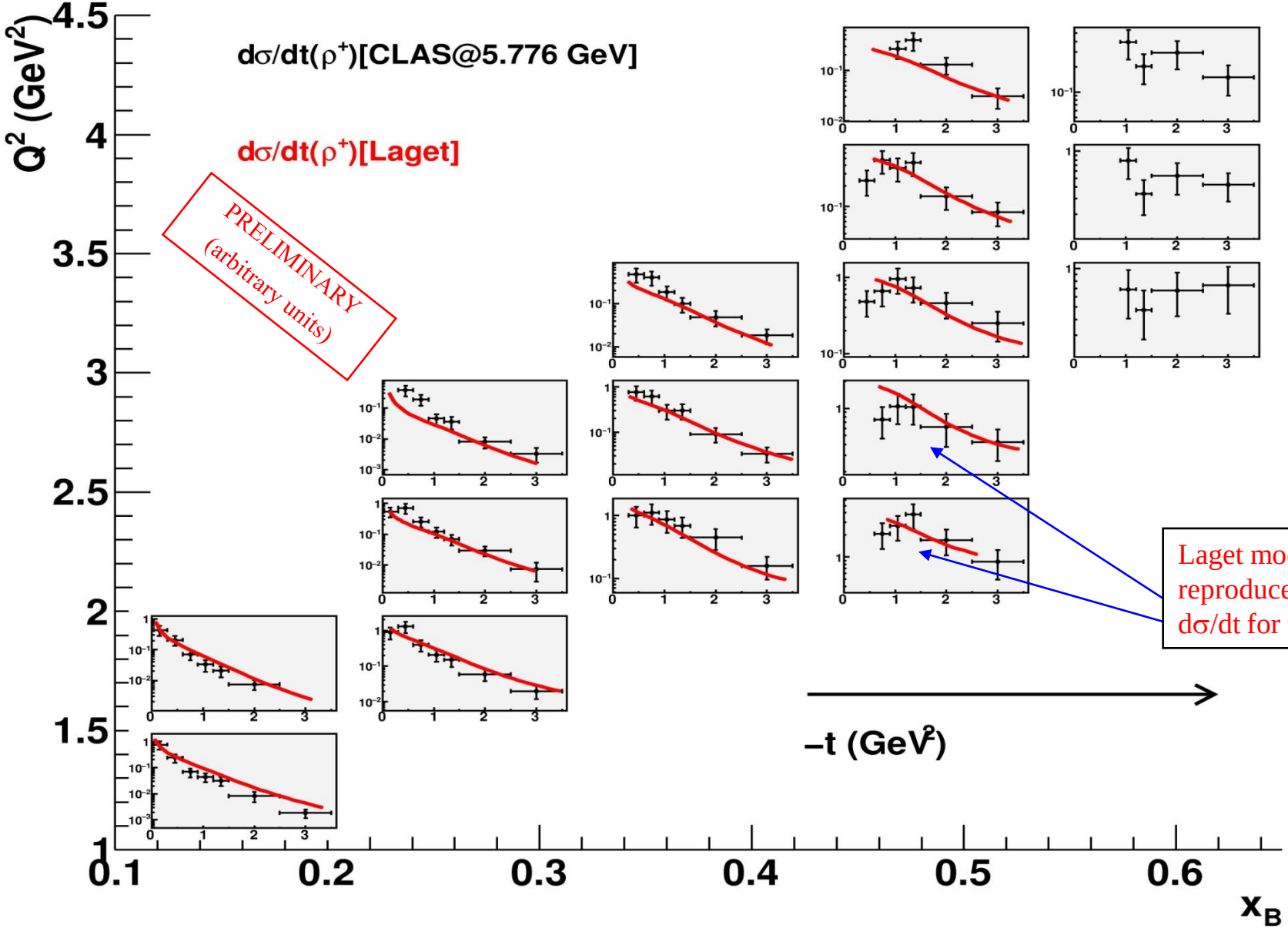
$\sigma_{TOT}(\gamma^* \mathbf{p} \rightarrow \mathbf{n}\,\rho^+)$



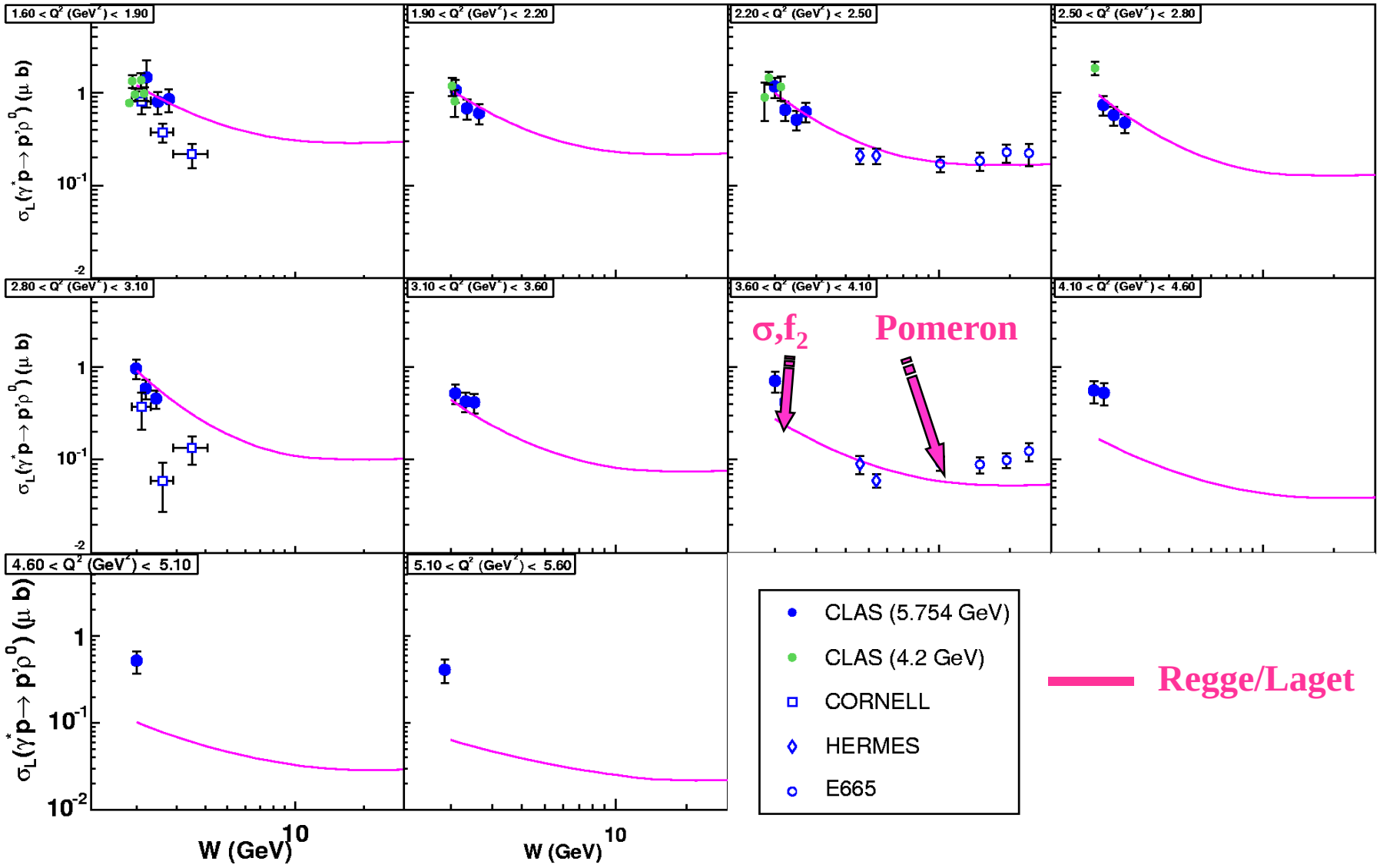
$\sigma_L(\gamma^* \mathbf{p} \rightarrow \mathbf{n}\,\rho^+)$

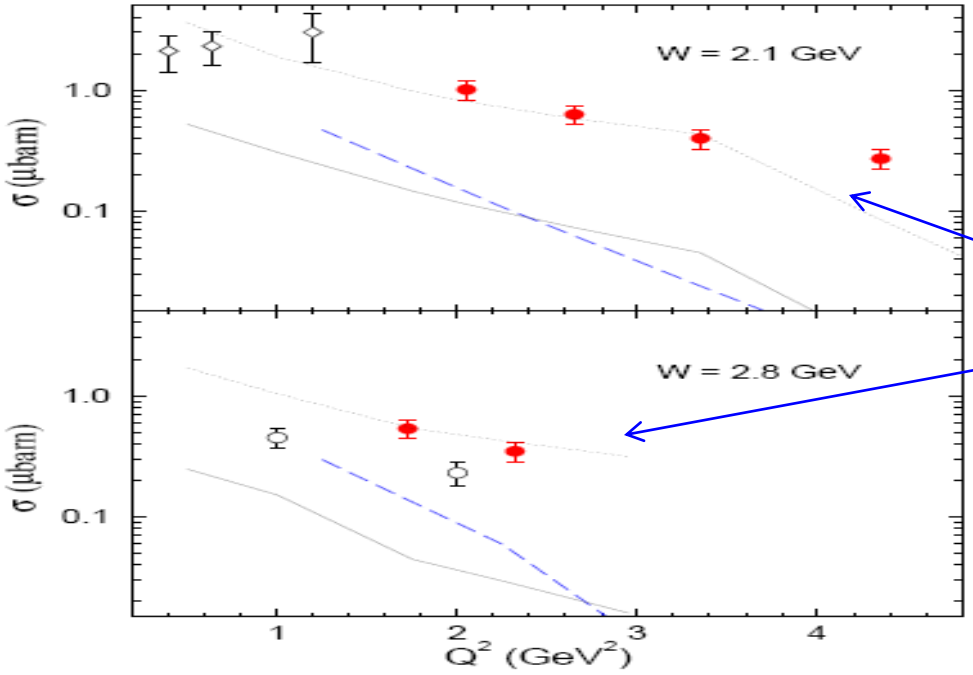
$\sigma_T(\gamma^* \mathbf{p} \rightarrow \mathbf{n}\,\rho^+)$

Laget model for $\gamma^* p \rightarrow n\rho^+$



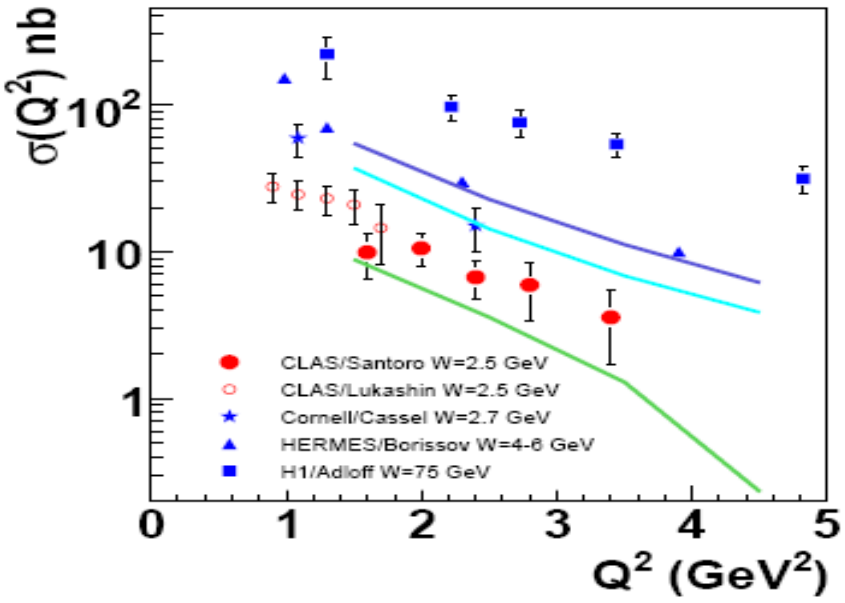
$\sigma_L\ (\gamma^*_L p \rightarrow p\rho^0_L)$





Laget Regge model

for $\gamma^* p \rightarrow p\omega$



Laget Regge model

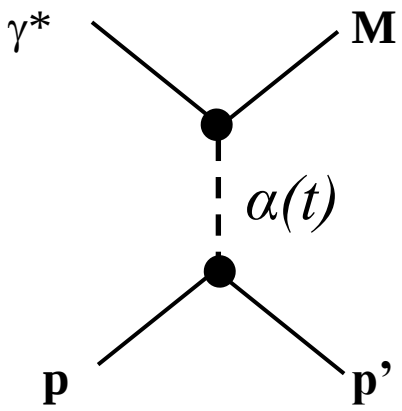
for $\gamma^* p \rightarrow p\phi$

W=2.9 GeV

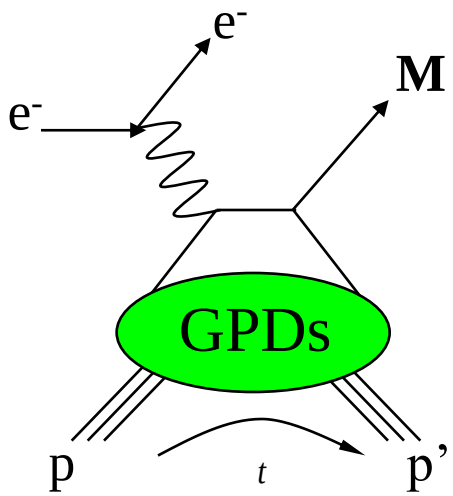
W=2.45 GeV

W=2.1 GeV

Theoretical interpretation



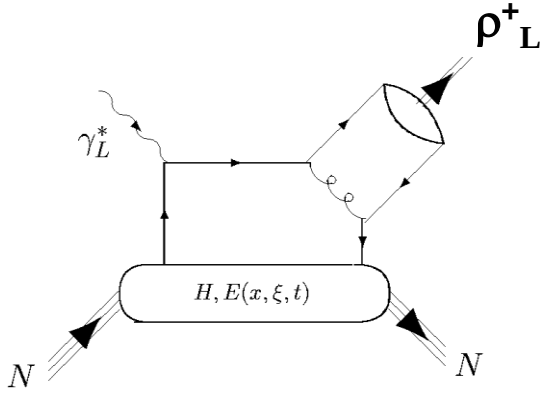
Laget Regge model describes well most of the features of (ρ^+, ρ^0, ω, ϕ) cross sections (total and diff., L and T) up to Q^2~4 GeV^2.



What about the GPDs approach ?

GPD "partonic" approach

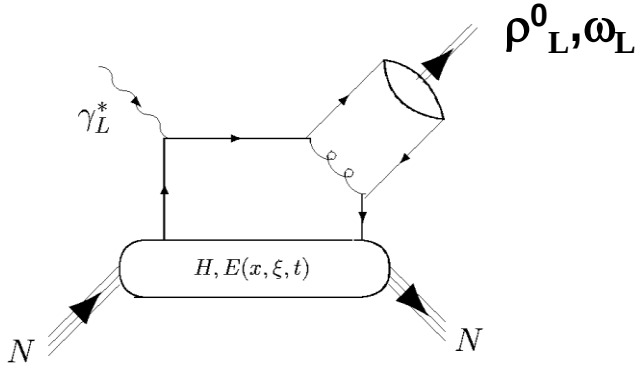
$\gamma^* p \to n\rho^+$



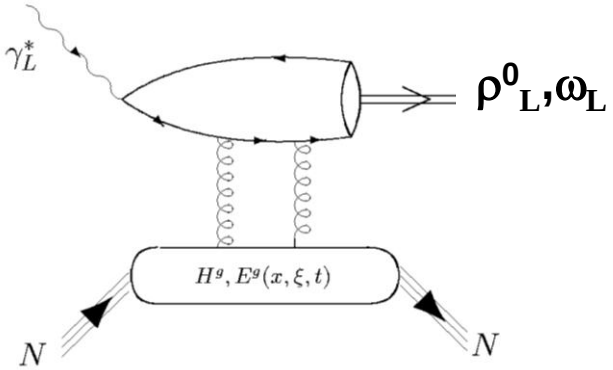
ρ^0	$e_u H^u - e_d H^d$ $e_u E^u - e_d E^d$
ω	$e_u H^u + e_d H^d$ $e_u E^u + e_d E^d$
ρ^+	$H^u - H^d$ $E^u - E^d$

$\gamma^* p \to p\rho^0$

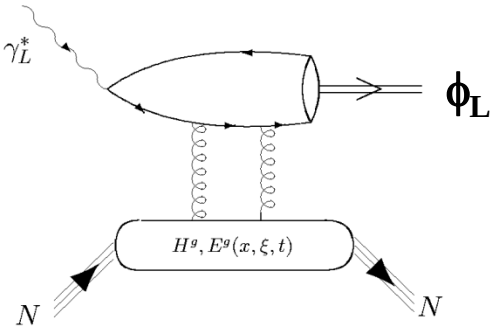
$\gamma^* p \to p\omega$



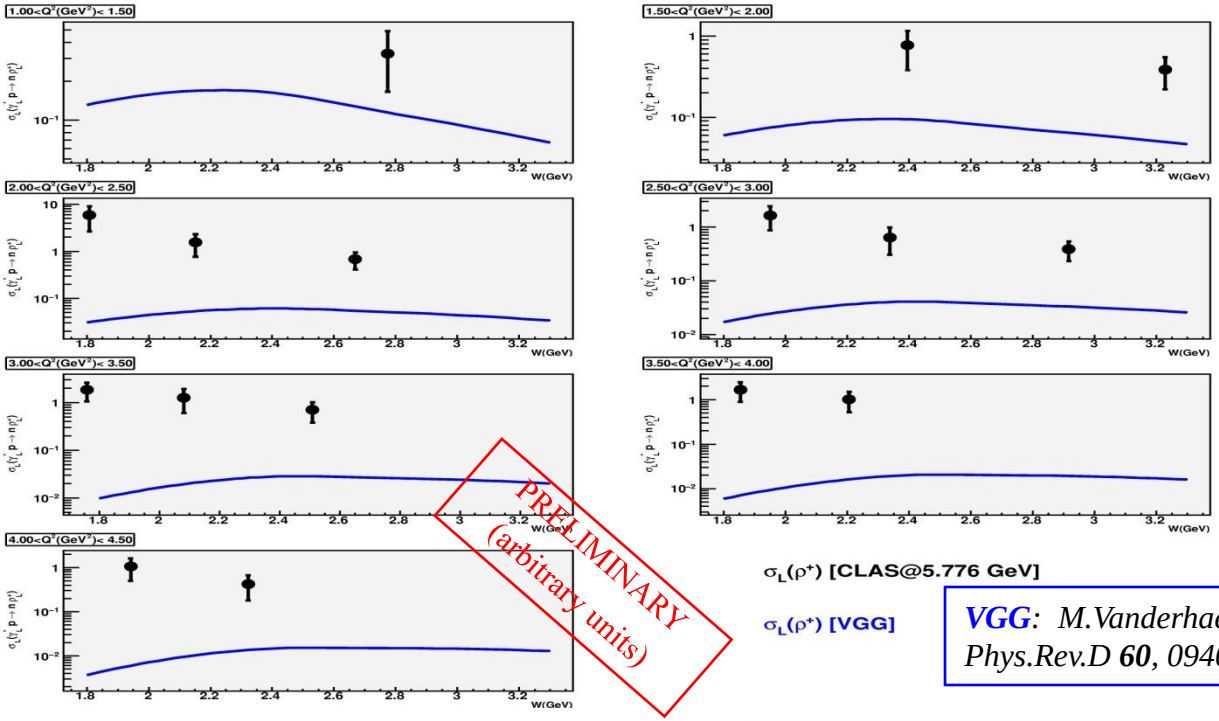
+



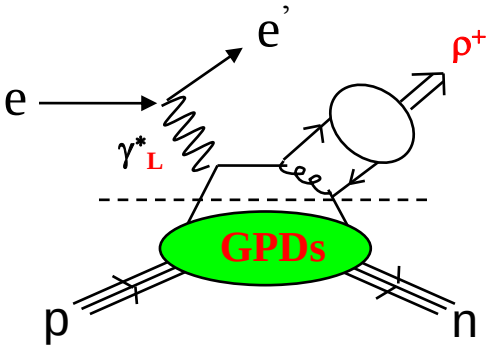
$\gamma^* p \to p\phi$



"Partonic approach"



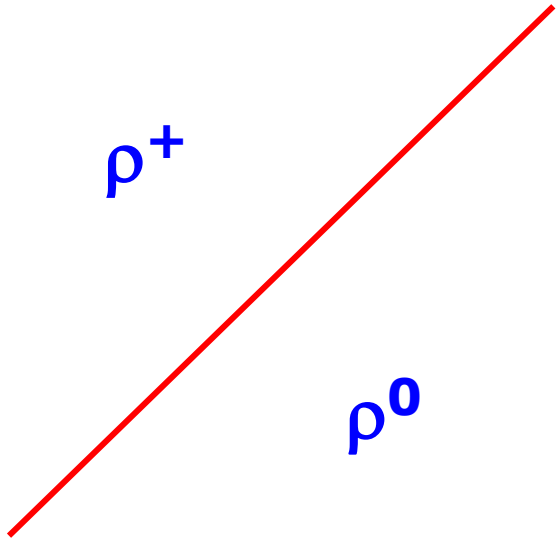
PRELIMINARY (arbitrary units)

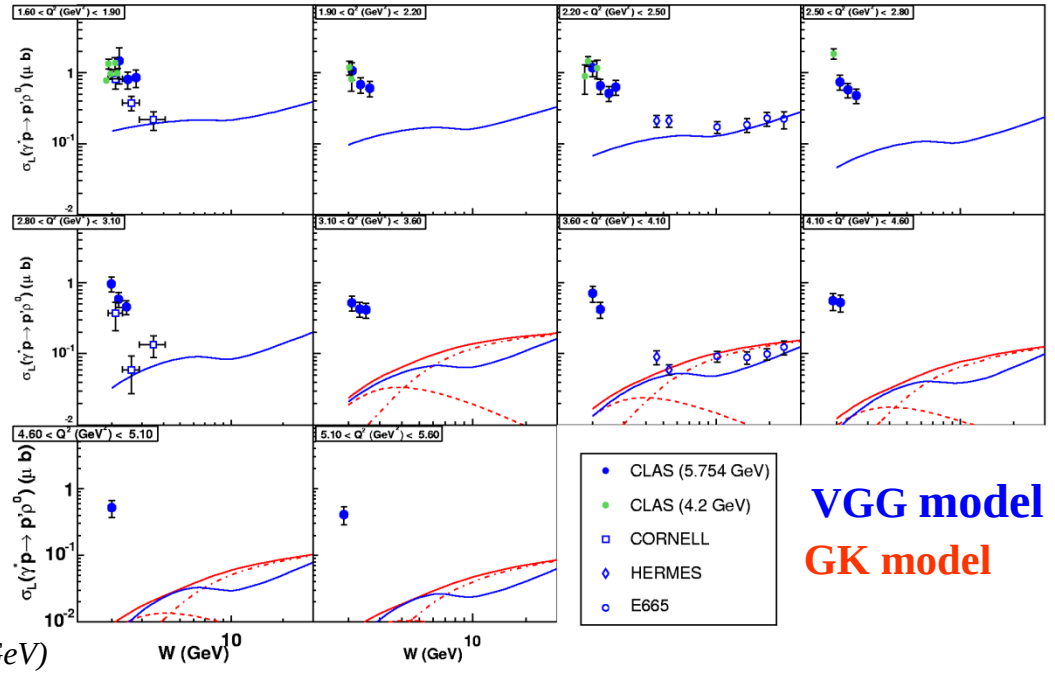


$\sigma_L(\rho^+)$ [CLAS@5.776 GeV]

$\sigma_L(\rho^+)$ [VGG]

VGG: *M.Vanderhaeghen, P.A..M Guichon, and M.Guidal, Phys.Rev.D* ***60****, 094017 (1999).*



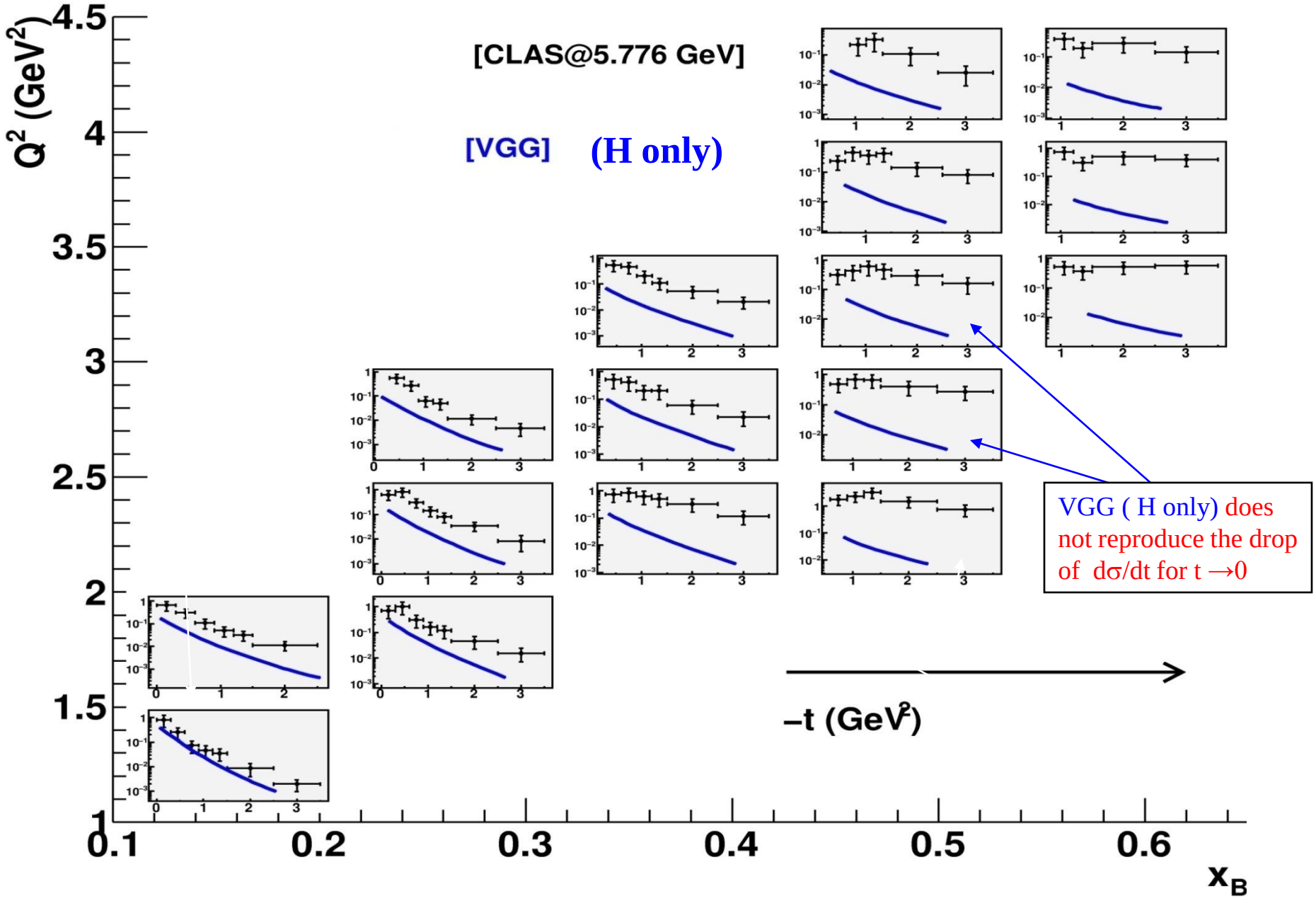


VGG model

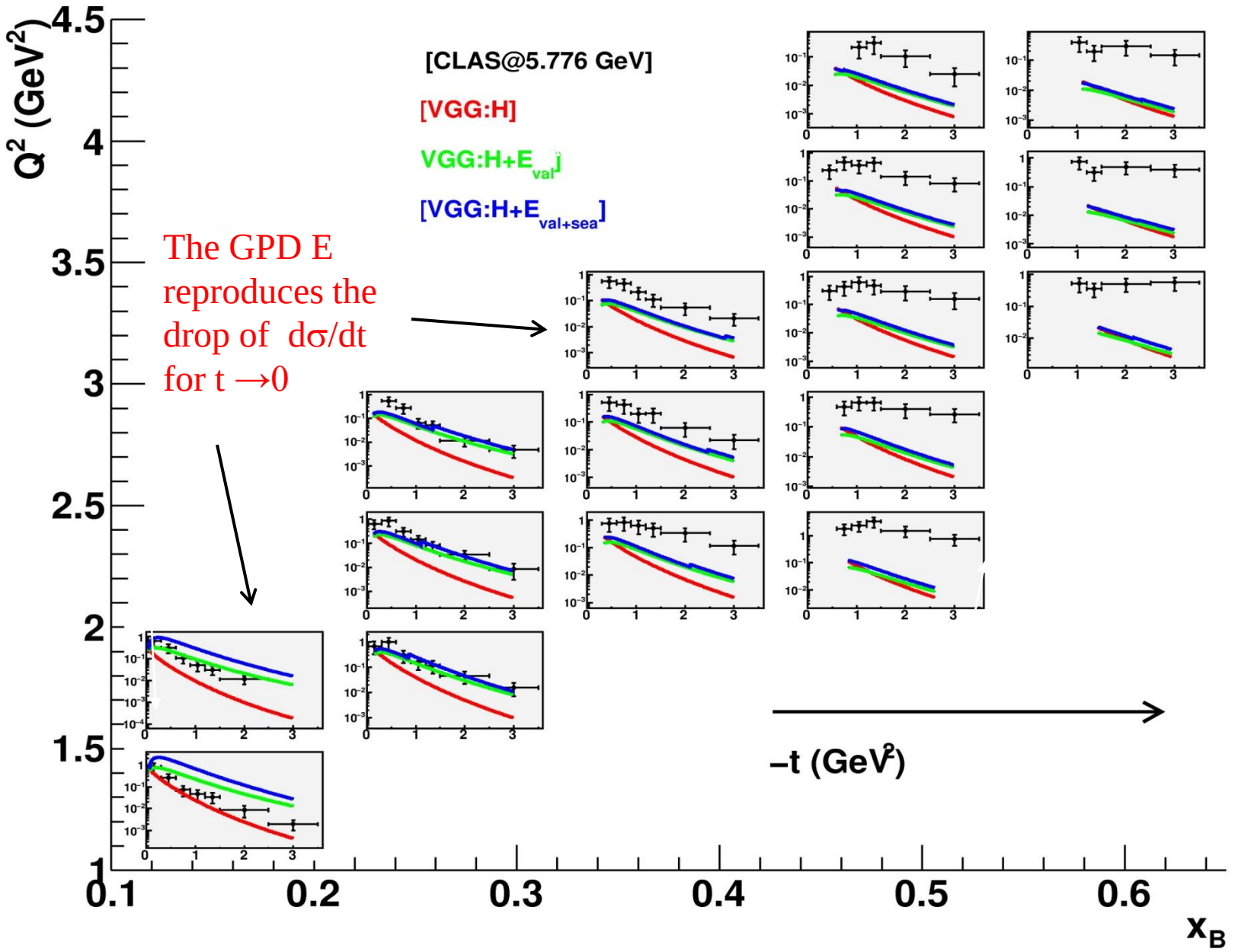
GK model

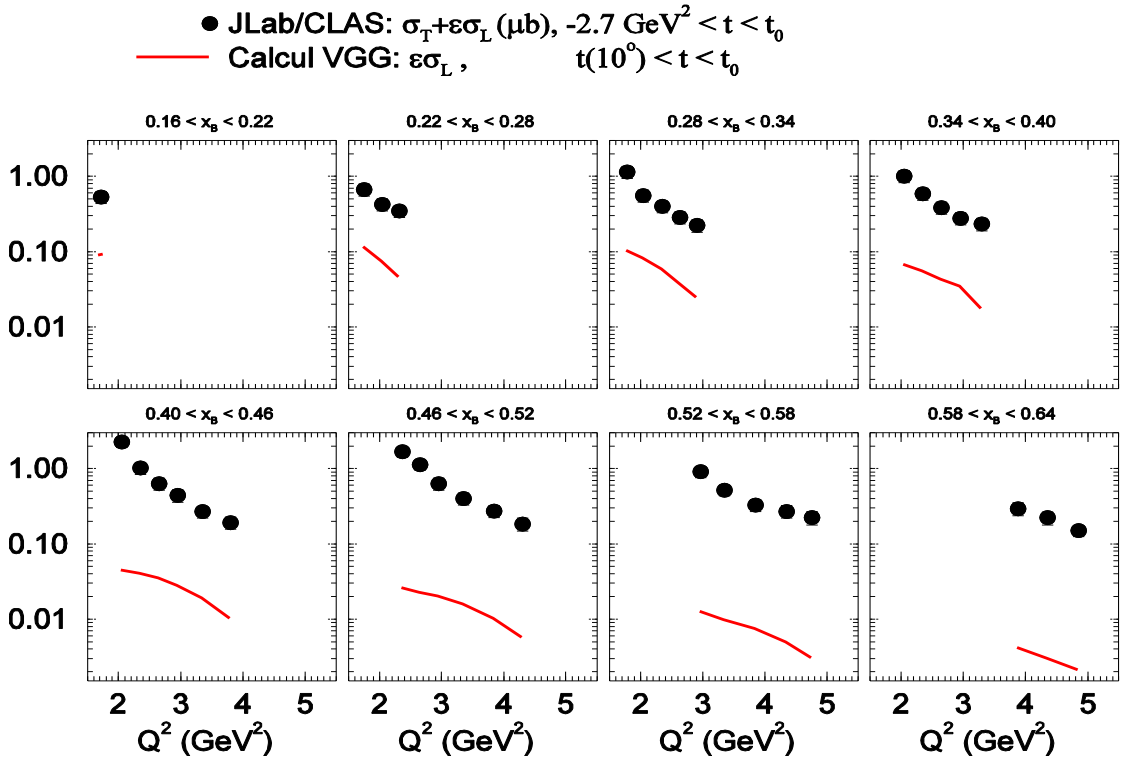
S. Morrow et al., Eur.Phys.J.A39:5-31,2009 (ρ^0@5.75GeV)

$d\sigma_L/dt\ (\gamma^* p \rightarrow n \rho^+)$

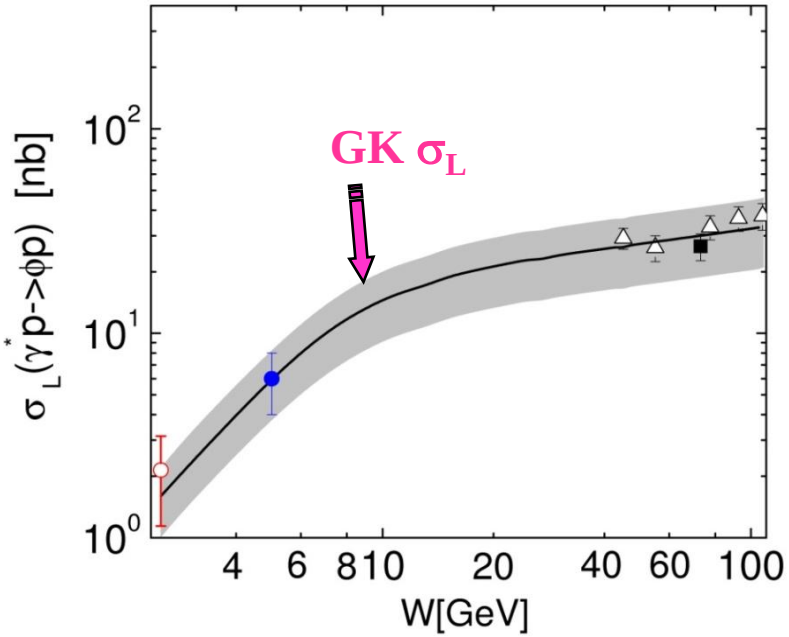


$d\sigma_L/dt\ (\gamma^* p \rightarrow n \rho^+)$: Hint of GPD E dominance ?



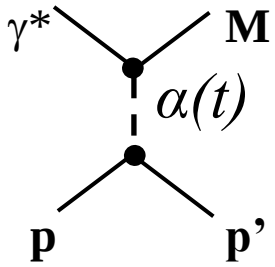


Cross section $\sigma(\gamma^* p \rightarrow p\omega)$ –Comparison with GPD calculation (VGG)-



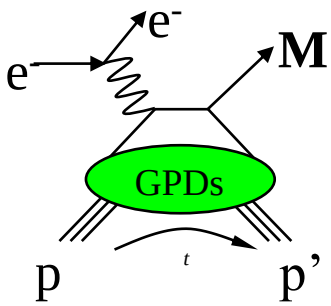
Cross section $\sigma(\gamma^* p \rightarrow p\phi)$ –Comparison with GPD calculation (GK)-

Theoretical interpretation



➢Laget Regge model describes well most of the features of (ρ^0,ω,ϕ,ρ^+) cross sections (total and diff., L and T) up to Q^2~4 GeV^2.

➢ GPD approach describes well data for W>~5 GeV for the (ρ^0,ϕ) channels: handbag for sea quarks and/or gluons is dominant.



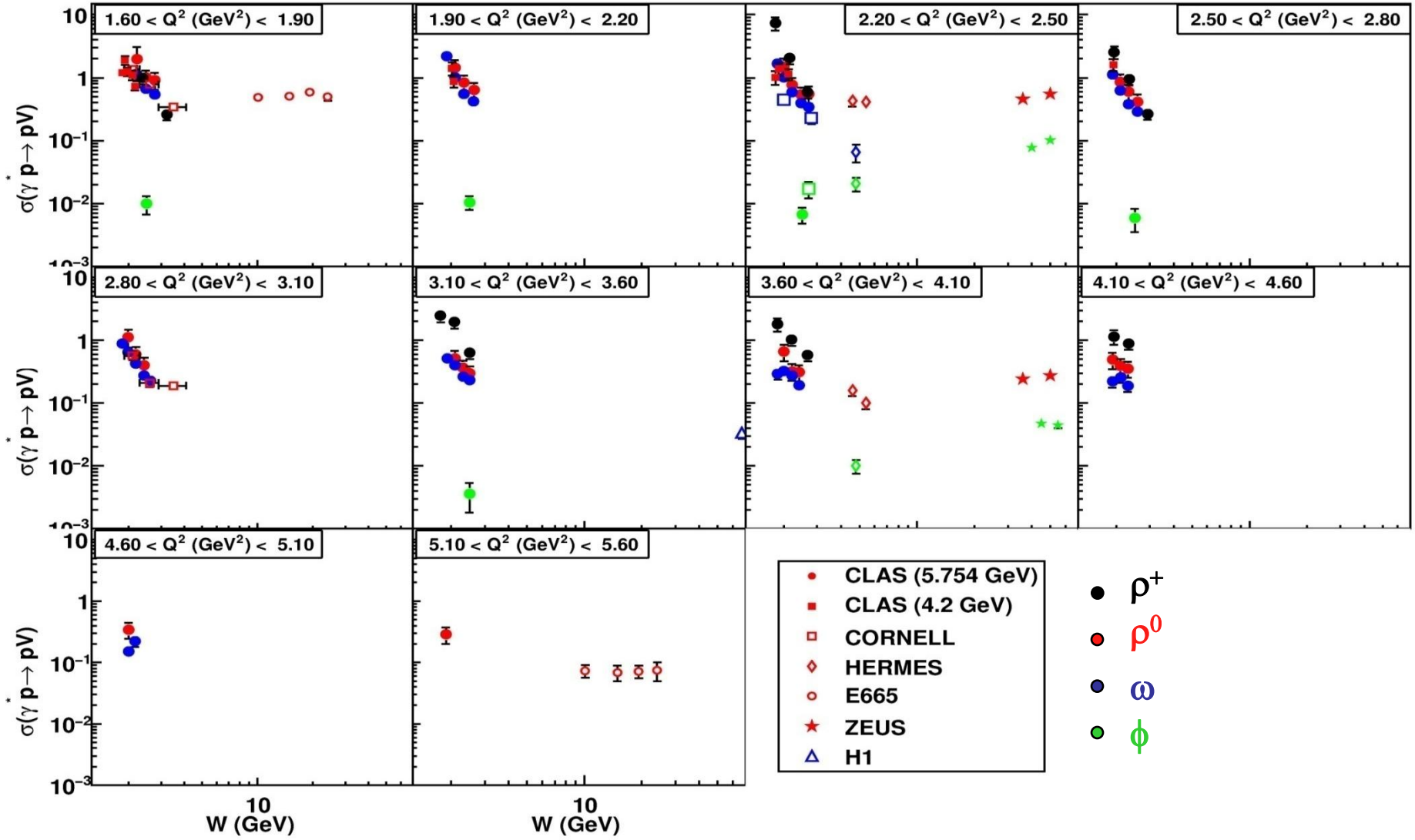
➢For ϕ channel: continues to work for W<~5 GeV (Gluons GPDs are dominant because of the strangeness composition of ϕ).

➢For ρ^0 channel: fails by large for W<~5 GeV

➢ For ω channel: fails by large for W<~5 GeV

➢For ρ^+ channel: fails by large for W<~5 GeV

Comparison between $(\rho^+, \rho^0, \omega, \phi)$



C. Hadjidakis et al., Phys.Lett.B605:256-264,2005 (ρ^0@4.2 GeV)

L. Morand et al., Eur.Phys.J.A24:445-458,2005 (ω@5.75GeV)

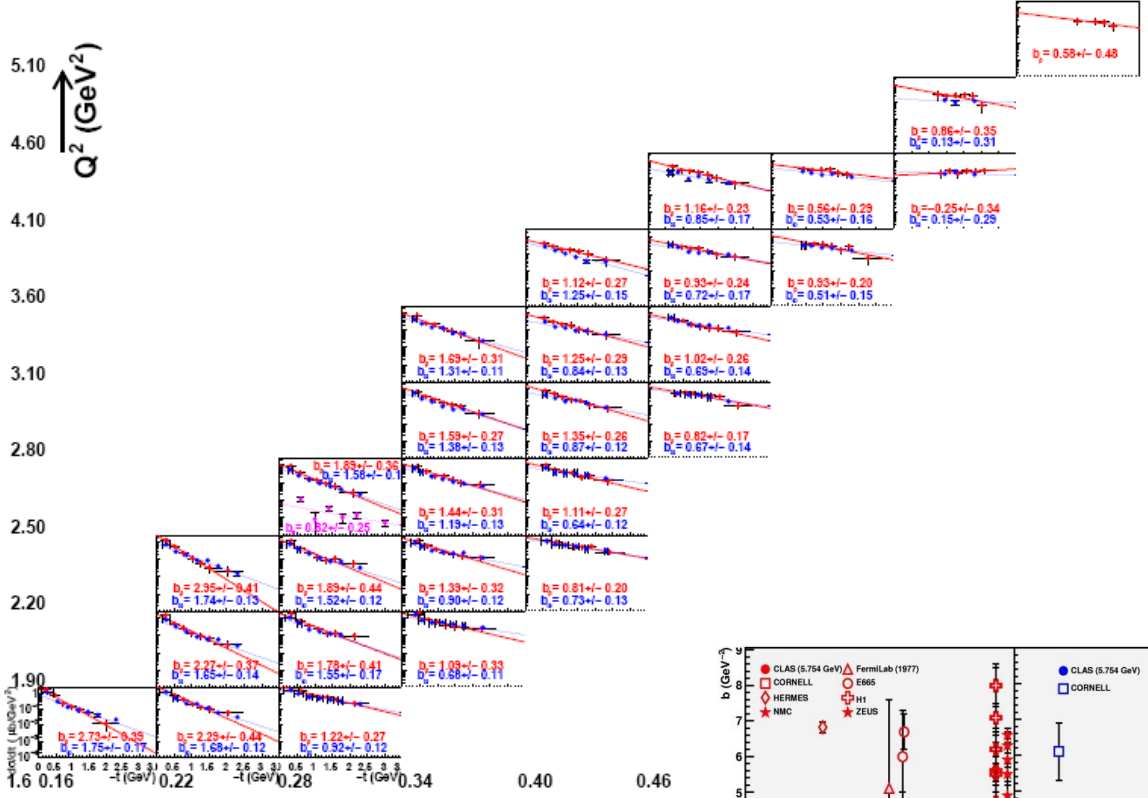
K. Lukashin, Phys.Rev.C63:065205,2001 (ϕ@4.2 GeV)

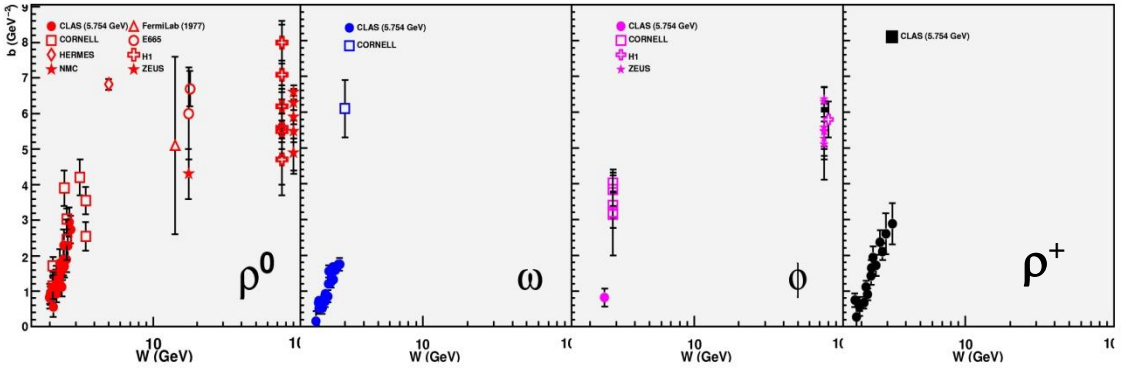
S. Morrow et al., Eur.Phys.J.A39:5-31,2009 (ρ^0@5.75GeV)

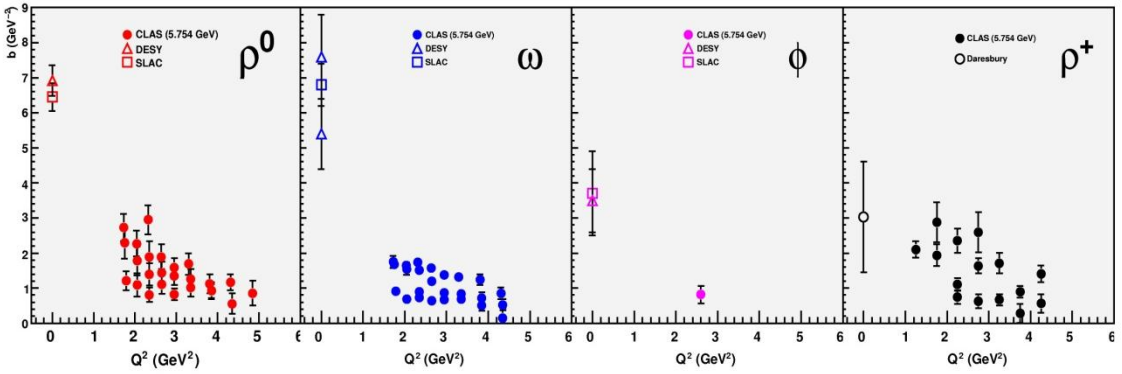
J. Santoro et al., Phys.Rev.C78:025210,2008 (ϕ@5.75GeV)

A. Fradi, Orsay Univ. PhD thesis, 2009 (ρ^+@5.75GeV)

$d\sigma/dt$ for ρ^0, ω, ϕ







Fit function: Ae^{-bt}

b reflects the size of the meson-nucleon system

Conclusions

- World's first-ever measurement of exclusive ρ^+ electroproduction.

- Largest set ever of data for VM $(\rho^+, \rho^0, \omega, \phi)$ production in the valence region $(\sigma_{L,T}\ ,\ d\sigma/dt, \ldots)$.

- "Hadronic approach" : Laget Regge model describes well most of the features of $(\rho^+, \rho^0, \omega, \phi)$ cross sections (total and diff., L and T) up to Q^2~4 GeV^2.

- "Partonic approach": GPDs models describe well data for W>~5 GeV (sea quarks and/or gluons) BUT fail by large for W<~5 GeV (valence region). We have to go to higher Q^2 (but stay in valence region).

- Comparison between $(\rho^+, \rho^0, \omega, \phi)$ in progress:
common features, ratios (cancel higher twists ?),…