# Backward meson production at CLAS

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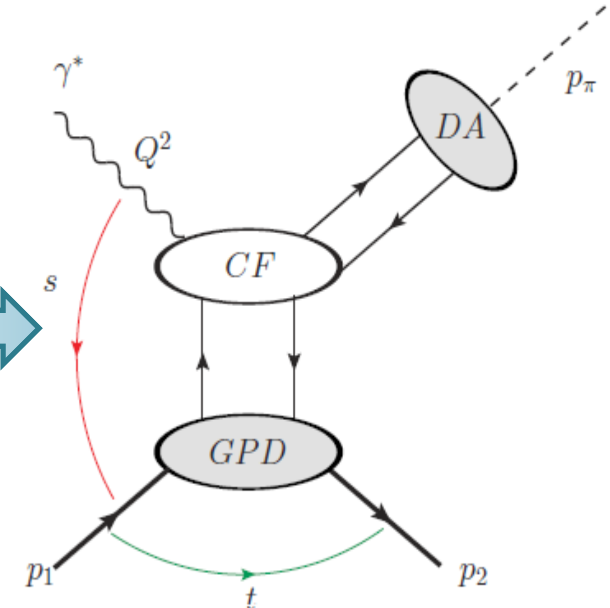
Exclusive Meson Production and Short-Range Hadron Structure
Jefferson Lab, January 22-24, 2015

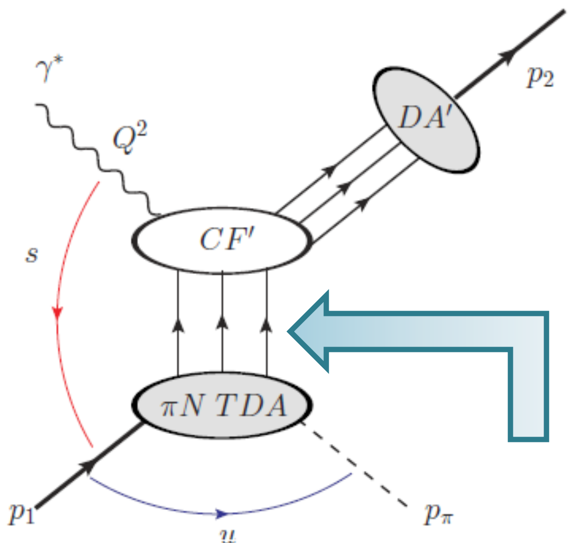
# Outline:

- Physics motivation
- CLAS spectrometer
- Data analysis
- Differential cross sections
- Conclusion

# The transition distribution amplitudes

Generalized Parton Distributions (GPDs) offer a new way to access the quark and gluon nucleon structure.



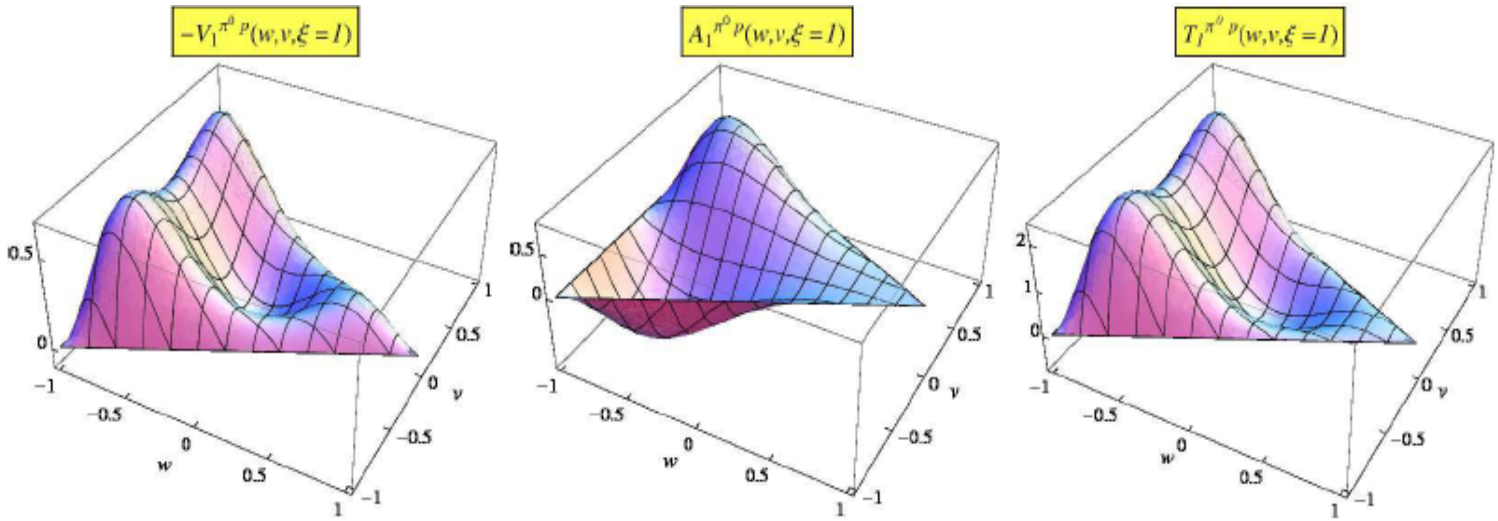




The nucleon to meson transition distribution amplitudes (TDAs) are extension of the GPD concept to three quark operators and the relevance of their nucleon to meson matrix elements which factorize in backward meson electroproduction.

J. P. Lansberg, B. Pire, L. Szymanowski
Phys.Rev. D75 (2007) 074004, Erratum-ibid. D77 (2008) 019902

# The leading-twist TDAs for the p → π° transition is defined as:

$$4\mathcal{F}\left(\langle \pi^0(p_\pi)|\,\epsilon^{ijk}u^i_\alpha(z_1 n)u^j_\beta(z_2 n)d^k_\gamma(z_3 n)\,|P(p_1)\rangle\right) =$$

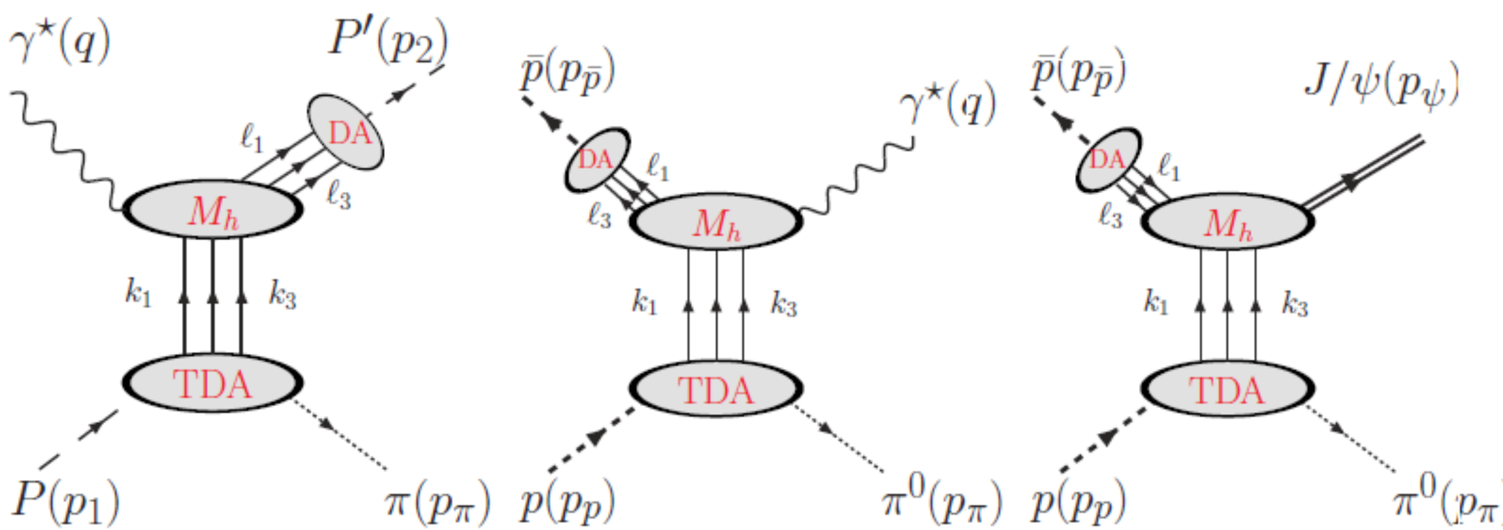



$$i\frac{f_N}{f_\pi}\Big[V_1^{p\pi^0}(\not p C)_{\alpha\beta}(N^+)_\gamma + A_1^{p\pi^0}(\not p\gamma^5 C)_{\alpha\beta}(\gamma^5 N^+)_\gamma + T_1^{p\pi^0}(\sigma_{p\mu}C)_{\alpha\beta}(\gamma^\mu N^+)_\gamma$$
$$+ M^{-1}V_2^{p\pi^0}(\not p C)_{\alpha\beta}(\not\Delta_T N^+)_\gamma + M^{-1}A_2^{p\pi^0}(\not p\gamma^5 C)_{\alpha\beta}(\gamma^5\not\Delta_T N^+)_\gamma + M^{-1}T_2^{p\pi^0}(\sigma_{p\Delta_T}C)_{\alpha\beta}(N^+)_\gamma$$
$$+ M^{-1}T_3^{p\pi^0}(\sigma_{p\mu}C)_{\alpha\beta}(\sigma^{\mu\Delta_T}N^+)_\gamma + M^{-2}T_4^{p\pi^0}(\sigma_{p\Delta_T}C)_{\alpha\beta}(\not\Delta_T N^+)_\gamma\Big]$$

J. P. Lansberg, B. Pire, K. Semenov-Tian-Shansky, L. Szymanowski
arXiv:1112.3570 [hep-ph] Phys.Rev. D85(2012) 054021

# Processes involving the TDAs

*$\gamma^* p \rightarrow p\pi^\circ$ at high $-t$* $\quad$ $p\bar{p} \rightarrow \gamma^\star \pi^0$ $\quad$ $p\bar{p} \rightarrow J/\psi \pi^0$

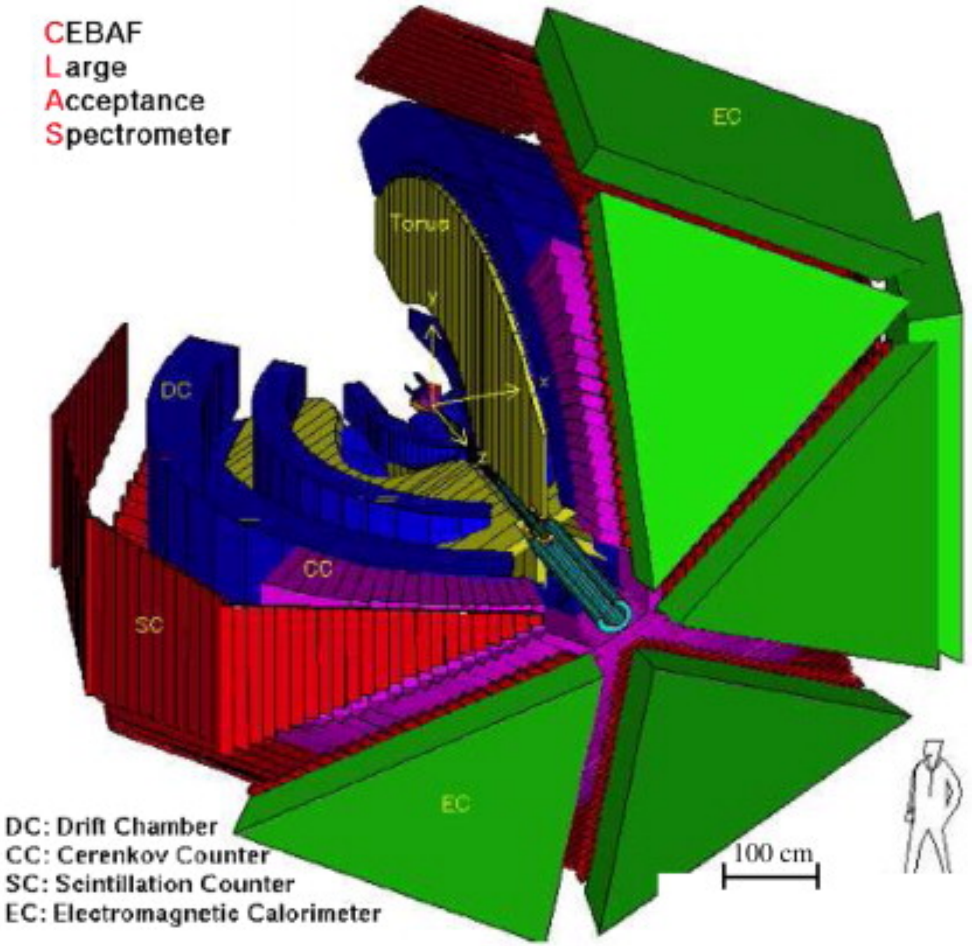


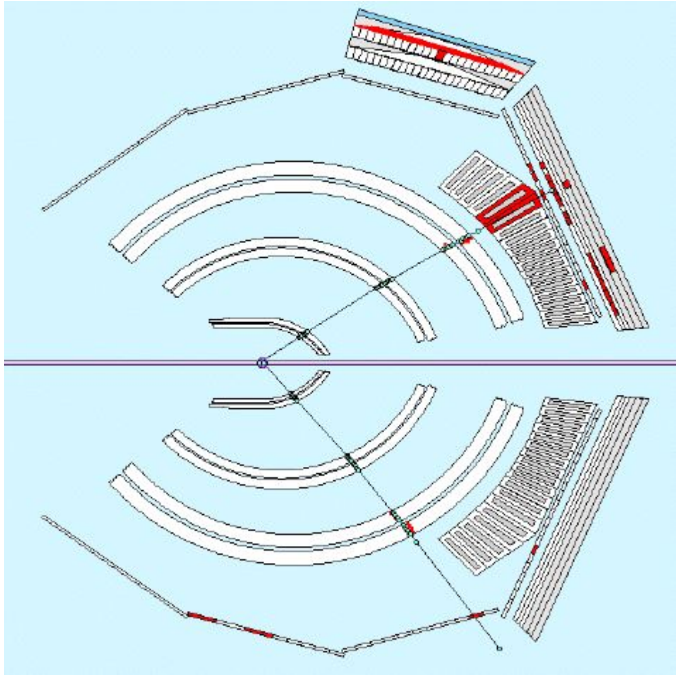

$p \rightarrow \pi^\circ$ baryonic TDAs appear in the description of backward electroproduction of a $\pi^\circ$ on a proton target.

J. P. Lansberg, B. Pire, K. Semenov-Tian-Shansky, L. Szymanowski
Phys.Rev. D84 (2011) 074014

# CLAS e1-6a experiment

- Data taken 2001-2002 years
- Electron beam energy - 5.754 GeV
- Beam current -7nA
- 5cm long liquid hydrogen target
- Total accumulated charge - 21 mC
- Torus current – 3375 A



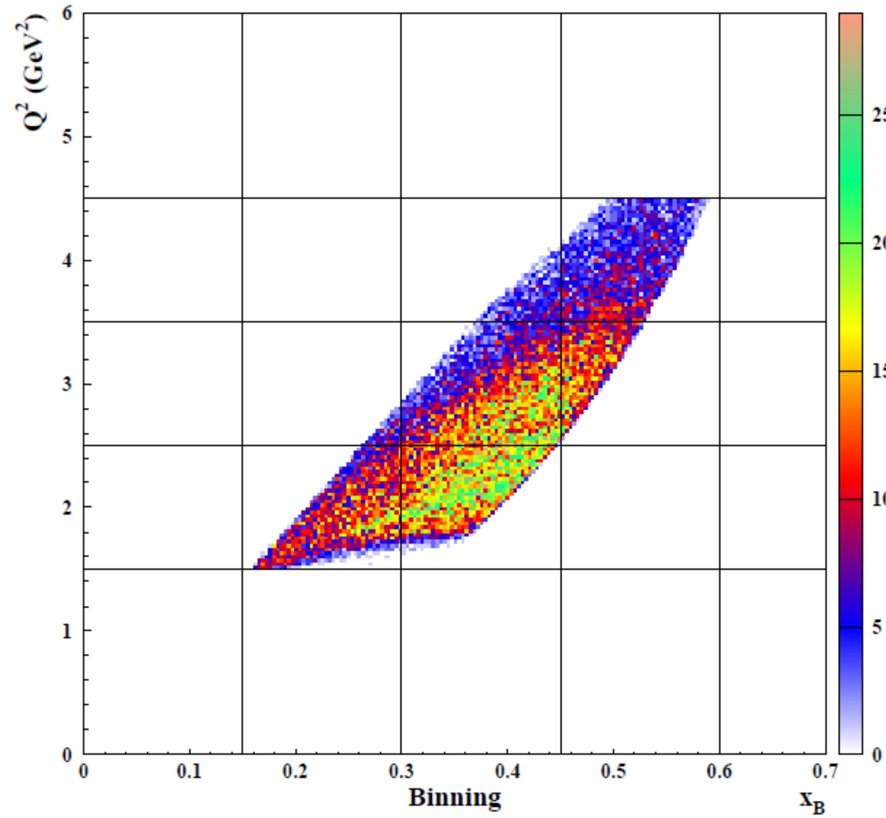



Visualization of the typical ep → e'pπ° event on CLAS Event Display

# Binning and kinematic region

Rectangular ($Q^2$,$x_B$) bins are used

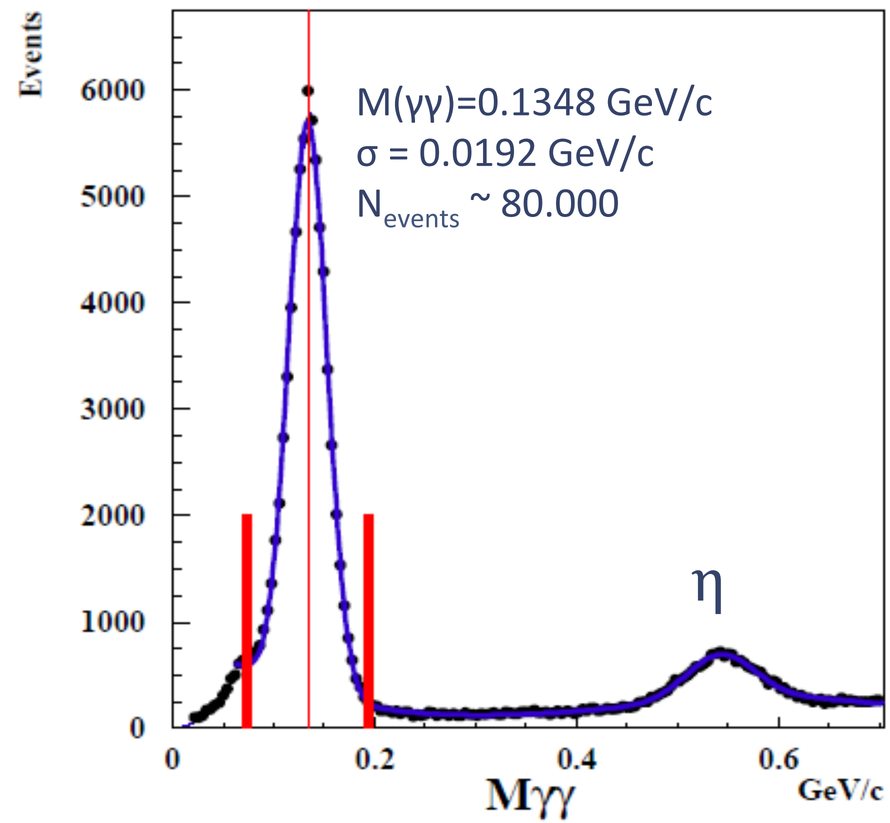
- $Q^2$: 3 bins from 1.5 to 4.5 GeV$^2$
- $x_B$: 3 bins from 0.15 to 0.60
- -t: 5 bins from up to 6.0 GeV$^2$
- W > 2.0 GeV (non-resonant region)



# Events selection

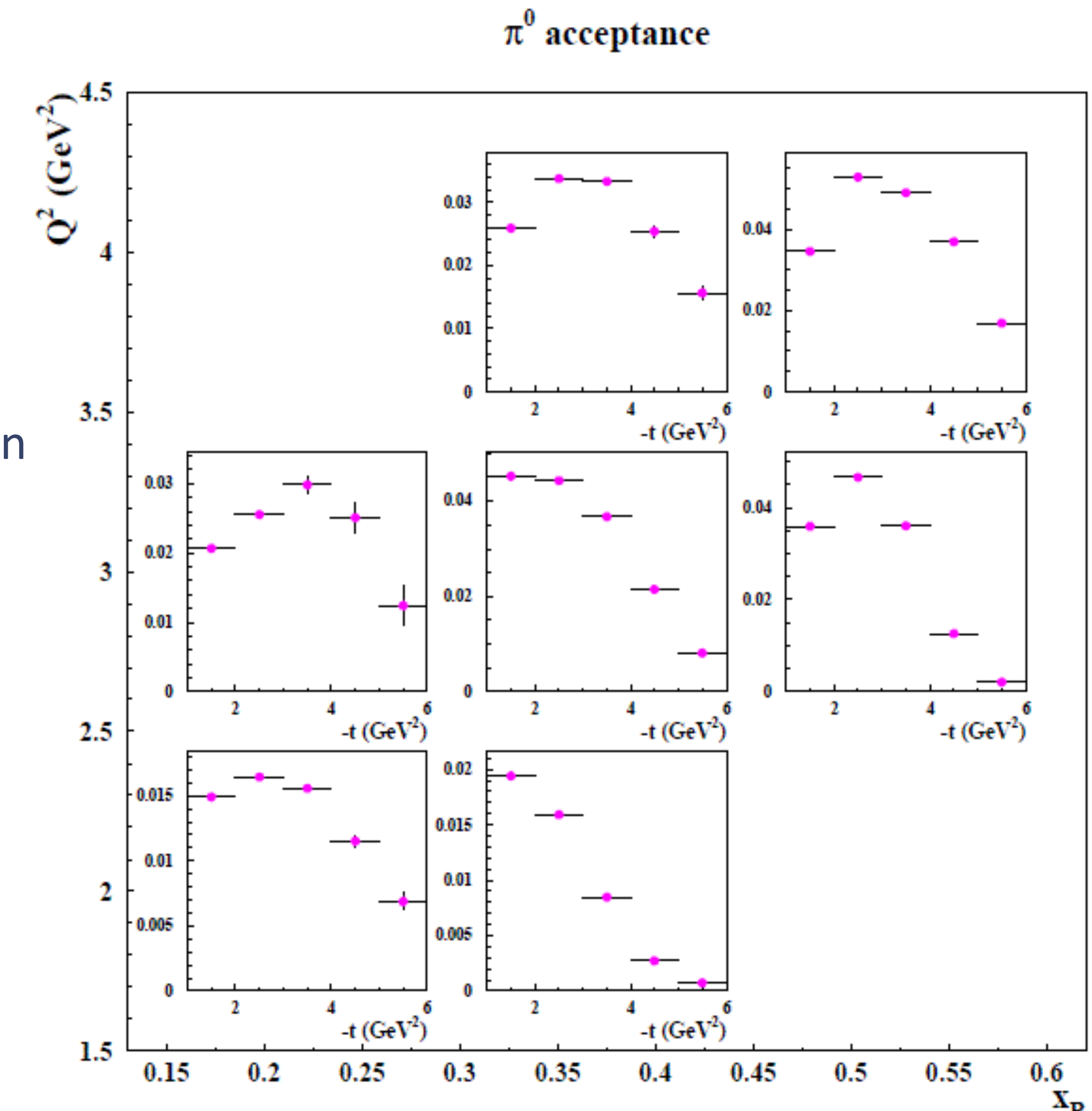
$ep \rightarrow e'p\pi^\circ$
$\searrow \gamma\gamma$

- Events with 1 electron, 1 proton and 2 photons
- Electron – hardware trigger, CC, EC, DC
- Proton – TOF, DC
- Two photons – EC, $E_\gamma > 0.5$ GeV
- W > 2 GeV
- Exclusivity cuts:
  - ✓ Angle between X(ep) and π° cut
  - ✓ $M_x^2$ (ep) missing mass cut (3σ)
  - ✓ Missing energy cut (3σ)
  - ✓ $M_{inv}(\gamma\gamma)$ invariant mass cut (3σ)



# Acceptance calculation

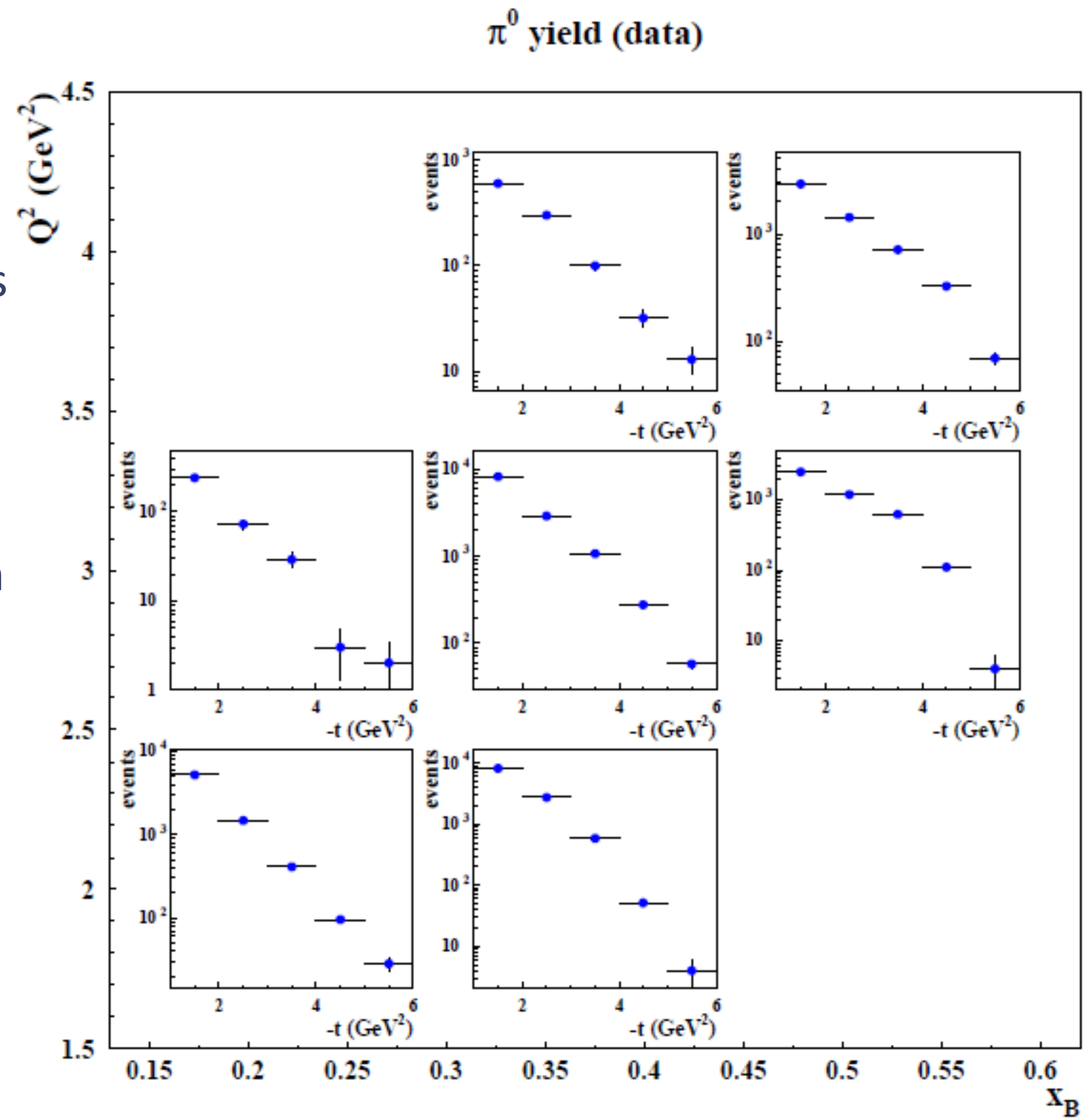
- Radiative generator aao_rad , ~ $10^8$ events
- GSIM   Geant-3 simulation
- RECSIS  events reconstruction
- Analysis code



# Data yield

The following corrections were applied:

- Electron momentum and angular corrections
- Proton angular correction
- Proton energy loss correction
- Fiducial cuts



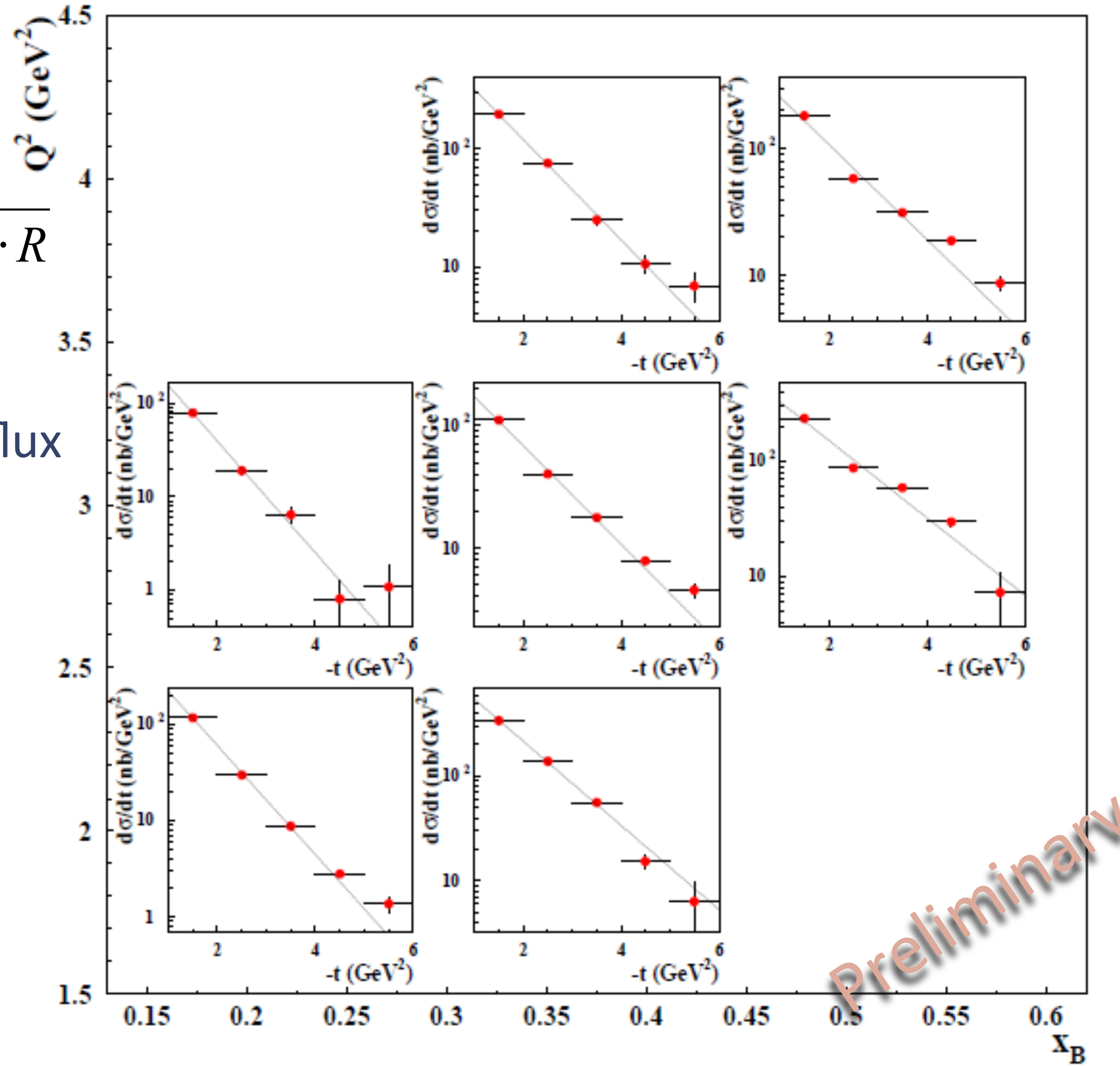
# dσ/dt (γ*p → pπ°) differential cross section

$$\frac{d\sigma}{dt} = \frac{\Delta N}{\Gamma(Q^2, x_B)\cdot \Delta Q^2 \Delta x_B \Delta t \cdot L \cdot \varepsilon \cdot R}$$

*where*

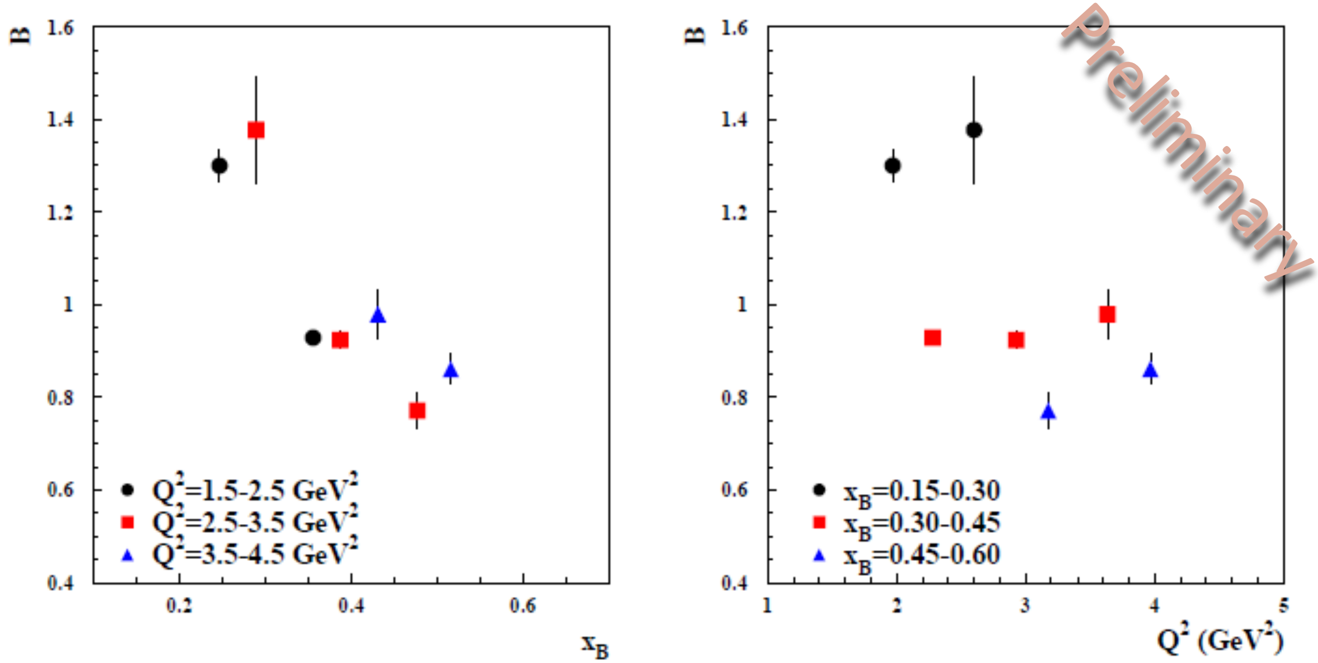
- Γ (Q2,xB) – virtual photon flux
- L – integrated luminosity
- ε – acceptance
- R – bin volume correction

$$\frac{d\sigma}{dt} = A \cdot e^{Bt}$$



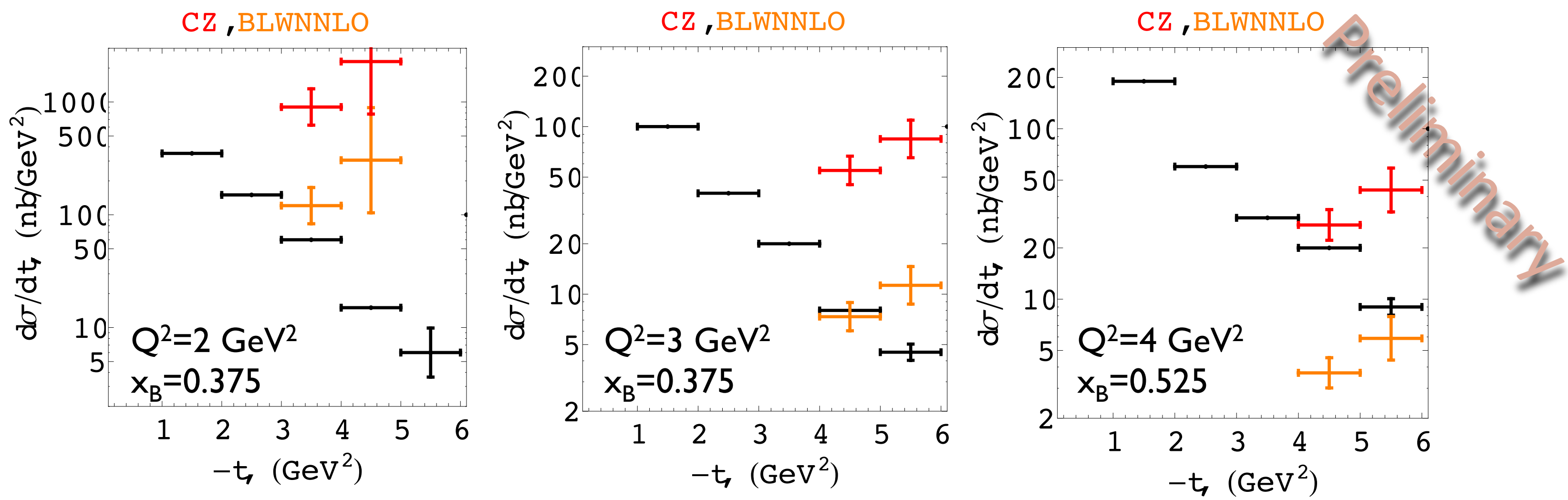
# t slope parameter B vs $Q^2$ and $x_B$

$$\frac{d\sigma}{dt} = A \cdot e^{Bt}$$




- t-slope parameter B is around 1GeV$^2$
- B $\rightarrow$0 when $x_B$ $\rightarrow$1
- B is almost independent of $Q^2$ that is the indication of scaling onset.

# Comparison with theoretical predisctions




Black – CLAS data

Red – TDA model with Chernyak-Zhitinsky nucleon DAs as input

Orange – TDA model with Braun-Lenz-Wittmann nucleon DAs as input

- Comparison with theoretical calculations (K. Semenov-Tyan-Shansky) shows that magnitude seems to be correct.
- However data does not follow predicted dependence at high values of *t*.

V.L. Chernyak and I.R. Zhitinsky (IYF) Nucl.Phys. B246(1984) 52-74
V.M. Braun, A. Lenz and M. Wittmann (Regensburg U.) Phys.Rev. D73(2006) 094019

# Conclusion

- CLAS has potential to probe nucleon to meson transition distribution amplitudes (TDAs) in backward meson electroproduction.
- Independence of the t-slope parameter as a function of $Q^2$ is the indication of scaling onset.
- Theoretical models show reasonable order of magnitude cross section
- Cross section is small. More data needed in the region of high *t*. We can add e1f and e1-dvcs data sets to this analysis.

*Thank you*