Status of the Experimental Studies on DVMP and Transversity GPDs

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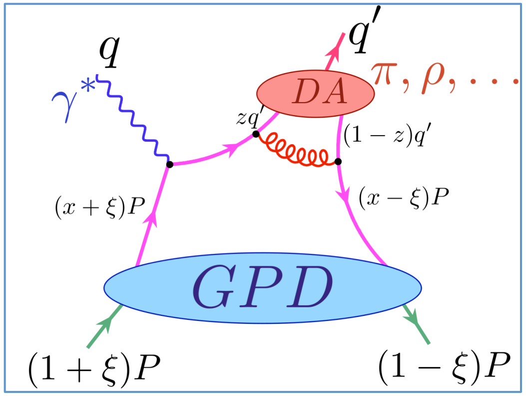
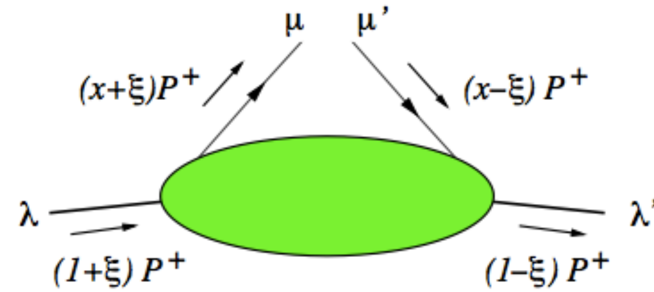
Outline



- CLAS data on pseudoscalar meson electroproduction
- Transversity GPD and structure functions
- Flavor decomposition of the Transversity GPDs
- Impact Parameter Density for u and d-quarks
- CLAS12 – started data taking!
- Conclusion

Generalized Parton Distributions



- GPDs are the functions of three kinematic variables: x, ξ and t
- There are 4 chiral even GPDs where partons do not flip helicity $H, \tilde{H}, E, \tilde{E}$
- 4 chiral odd GPDs flip the parton helicity

  $H_T, \tilde{H}_T, E_T, \tilde{E}_T$
- The chiral-odd GPDs are difficult to access since subprocesses with quark helicity-flip are suppressed

Chiral-odd GPDs

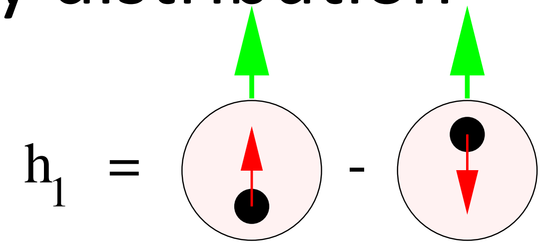
- Very little known about the chiral-odd GPDs
- Anomalous tensor magnetic moment

$$\kappa_T = \int_{-1}^{+1} dx \ \bar{E}_T(x, \xi, t = 0)$$

- (Compare with anomalous magnetic moment)

$$\kappa = \int_{-1}^{+1} dx \ E(x, \xi, t = 0) = F_2(t = 0)$$

- Transversity distribution $H_T^q(x, 0, 0) = h_1^q(x)$



The transversity describes the distribution of transversely polarized quarks in a transversely polarized nucleon

$$ep \to ep\pi^0$$

Structure functions and GPDs

$$\frac{d^4\sigma}{dQ^2 dx_B dt d\phi_\pi} = \Gamma(Q^2, x_B, E)\frac{1}{2\pi}(\sigma_T + \epsilon\sigma_L + \epsilon\cos 2\phi_\pi \sigma_{TT} + \sqrt{2\epsilon(1+\epsilon)}\cos\phi_\pi \sigma_{LT})$$

Leading twist σ_L

$$\sigma_L = \frac{4\pi\alpha_e}{\kappa Q^2}[(1-\xi^2)|\langle\tilde{H}\rangle|^2 - 2\xi^2 Re(\langle\tilde{H}\rangle|\langle\tilde{E}\rangle) - \frac{t}{4m^2}\xi^2|\langle\tilde{E}\rangle|^2]$$

σ_L suppressed by a factor coming from:

$$\tilde{H}^\pi = \frac{1}{3\sqrt{2}}[2\tilde{H}^u + \tilde{H}^d]$$

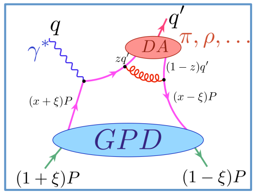
$\tilde{H}^u$ and $\tilde{H}^d$ have opposite signes

S. Goloskokov and P. Kroll
S. Liuti and G. Goldstein

$$\langle\tilde{H}\rangle = \sum_\lambda \int_{-1}^{1} dx M(x,\xi,Q^2,\lambda)\tilde{H}(x,\xi,t)$$

$$\langle\tilde{E}\rangle = \sum_\lambda \int_{-1}^{1} dx M(x,\xi,Q^2,\lambda)\tilde{E}(x,\xi,t)$$

The brackets <F> denote the convolution of the elementary process with the GPD F (generalized form factors)



$$ep \rightarrow ep\pi^0$$

Structure functions and GPDs

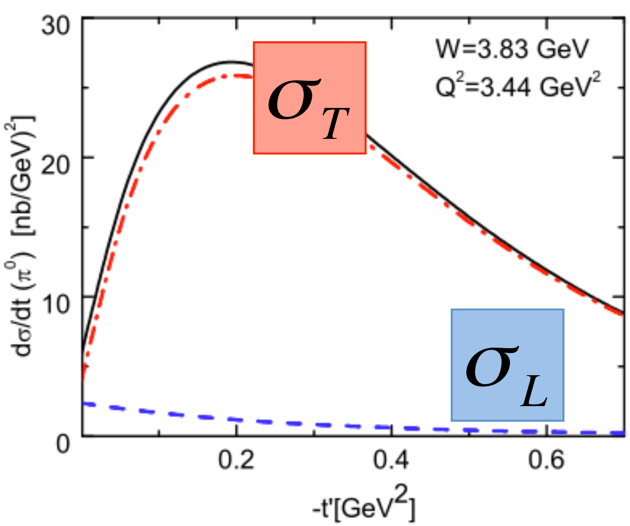
$$\frac{d^4\sigma}{dQ^2 dx_B dt d\phi_\pi} = \Gamma(Q^2, x_B, E)\frac{1}{2\pi}\left(\sigma_T + \epsilon\sigma_L + \epsilon\cos 2\phi_\pi \sigma_{TT} + \sqrt{2\epsilon(1+\epsilon)}\cos\phi_\pi \sigma_{LT}\right)$$

$$\sigma_T = \frac{4\pi\alpha_e}{2\kappa}\frac{\mu_\pi^2}{Q^4}\left[(1-\xi^2)|\langle H_T\rangle|^2 - \frac{t'}{8m^2}|\langle \bar{E}_T\rangle|^2\right]$$

$$\sigma_{TT} = \frac{4\pi\alpha_e}{2\kappa}\frac{\mu_\pi^2}{Q^4}\frac{t'}{8m^2}|\langle \bar{E}_T\rangle|^2$$

$$\left\langle \tilde{H} \right\rangle = \sum_\lambda \int_{-1}^{1} dx M(x,\xi,Q^2,\lambda)\tilde{H}(x,\xi,t)$$

$$\left\langle \tilde{E} \right\rangle = \sum_\lambda \int_{-1}^{1} dx M(x,\xi,Q^2,\lambda)\tilde{E}(x,\xi,t)$$



Transversity GPD model

S. Goloskokov and P. Kroll

S. Liuti and G. Goldstein

- $\sigma_L << \sigma_T$

The brackets <F> denote the convolution of the elementary process with the GPD F (Generalized Form Factors, GFF)

2011-2017

π^0/η Exclusive Electroproduction (Jlab)

- Exclusive neutral pion electroproduction in the deeply virtual regime. Phys .Rev .C **83**, 025201 **(2011)**
- Measurement of Exclusive π^0 electroproduction Structure Functions and their relationship to Transverse Generalized Parton Distribution., PRL **109**, 112001 **(2012)**
- Exclusive π^0 electroproduction at W>2 GeV with CLAS. Phys.Rev. C **90**, 025205 **(2014)**
- Exclusive Rosenbluth Separation of the π^0 Electroproduction Cross Section. PRL **117**, 262001 **(2016)**
- Exclusive η electroproduction at W>2 GeV with CLAS and tranversity generalized parton distributions. Phys. Rev. C **95**, 035202 **(2017)**

PRL 109, 112001 (2012) PHYSICAL REVIEW LETTERS week ending 14 SEPTEMBER 2012

Measurement of Exclusive π^0 Electroproduction Structure Functions and their Relationship to Transverse Generalized Parton Distributions

I. Bedlinskiy,[22] V. Kubarovsky,[35,30] S. Niccolai,[21] P. Stoler,[30] K. P. Adhikari,[29] M. Aghasyan,[18] M. J. Amaryan,[29]

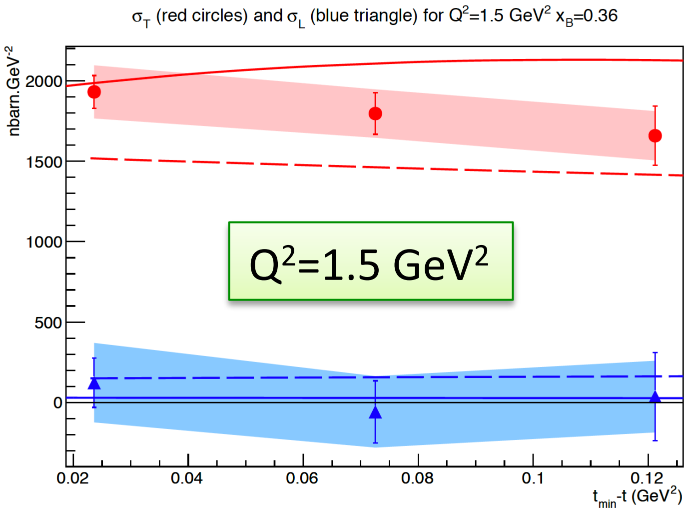
- The measured cross section of π^0 electroproduction is much larger than expected from leading-twist handbag calculation. This means that the contribution of the longitudinal cross section σ_L is small in comparison with σ_T. The same conclusion can be made in a almost model independent way from the comparison of the cross sections σ_U, σ_{TT} and σ_{LT}.

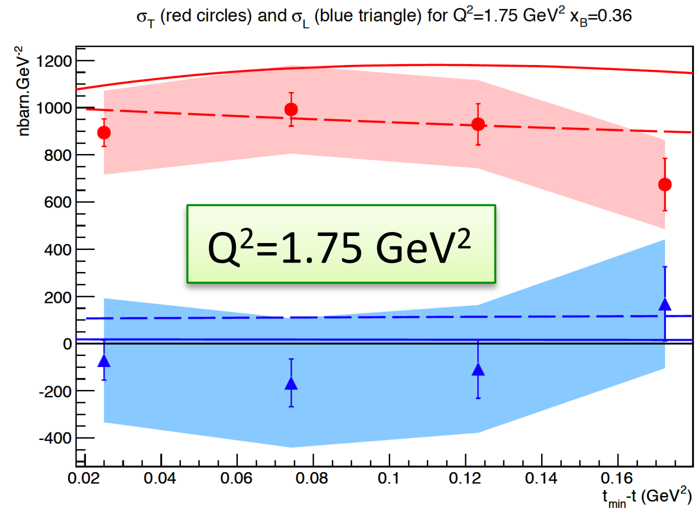
- The data appear to confirm the expectation that pseudoscalar and, in particular, π^0 electroproduction is a uniquely sensitive process to access the transversity GPDs $\bar{E}_T$ and H_T.

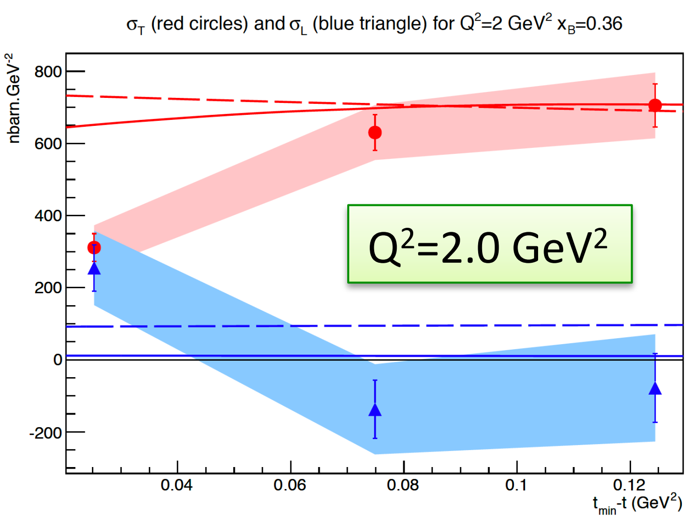
Rosenbluth separation σ_T and σ_L
Hall-A Jefferson Lab

σ_T

σ_L







- Experimental **proof** that the transverse π^0 cross section is dominant!
- It opens the direct way to study the transversity GPDs in pseudoscalar exclusive production

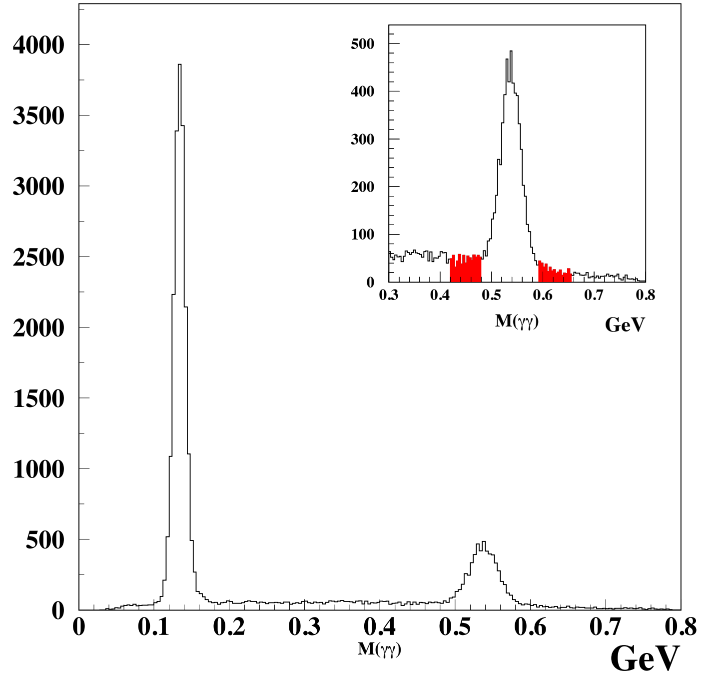
Hall-A, Phys.Rev.Lett. **117**,262001(2016)

4 Dimensional Grid

$$ep \rightarrow ep(\pi^0 / \eta)$$

Rectangular bins are used.

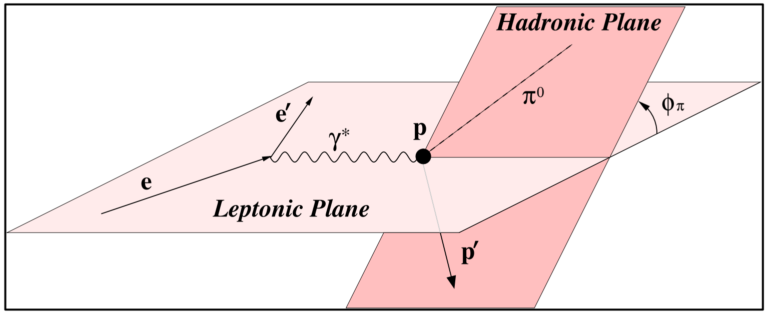
- Q^2 7 bins(1.-4.5GeV^2)
- x_B 7 bins(0.1-0.58)
- t 8 bins(0.09-2.0GeV)
- ϕ 20 bins(0-360°)
- π^0 data ~2000 points
- η data ~1000 points



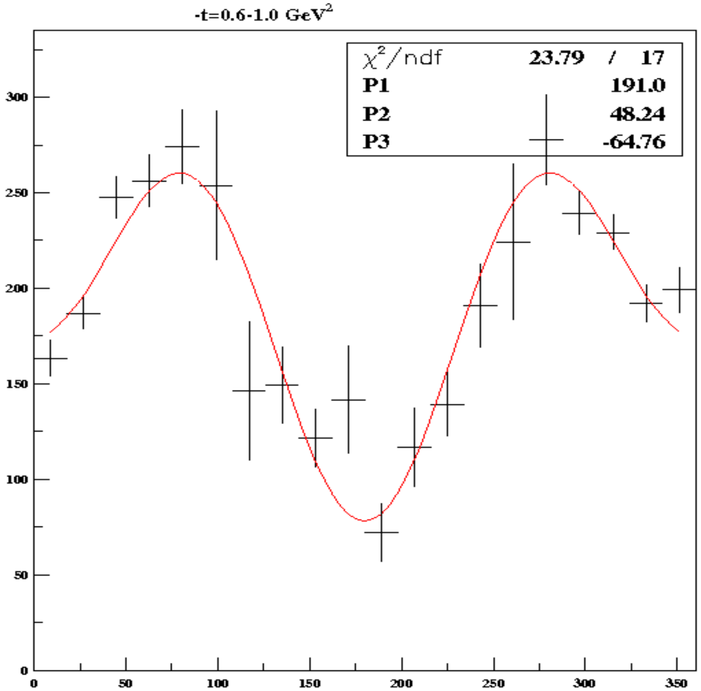
$M_{\gamma\gamma}$

Structure Functions

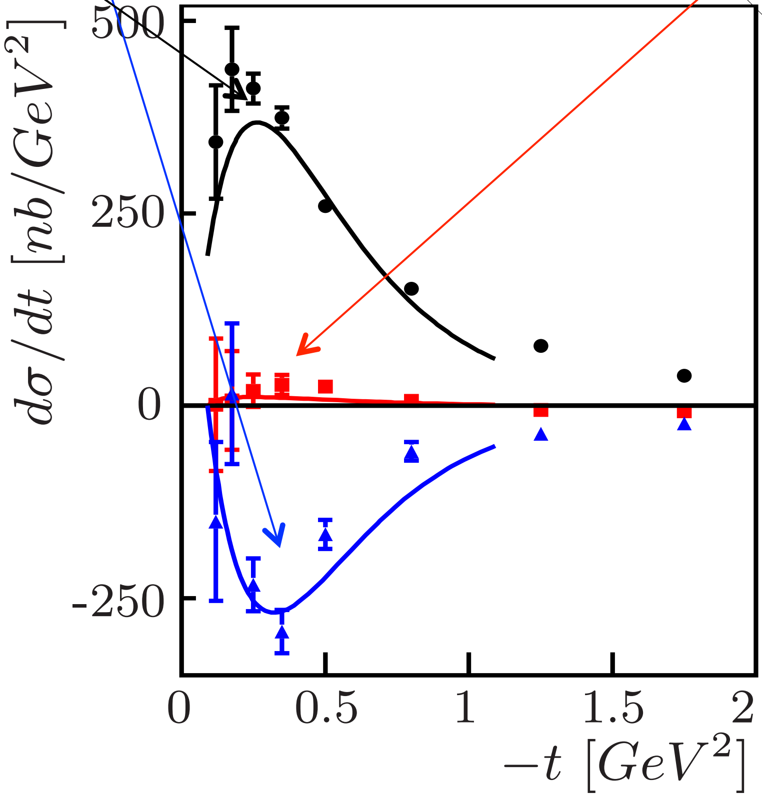
$\sigma_U=\sigma_T+\varepsilon\sigma_L \quad \sigma_{TT} \quad \sigma_{LT}$



$$\frac{d\sigma}{dt\,d\phi}(Q^2,x,t,\phi)=\frac{1}{2\pi}\left(\left(\frac{d\sigma_T}{dt}+\varepsilon\frac{d\sigma_L}{dt}\right)+\varepsilon\frac{d\sigma_{TT}}{dt}\cos 2\phi+\sqrt{2\varepsilon(\varepsilon+1)}\frac{d\sigma_{LT}}{dt}\cos\phi\right)$$



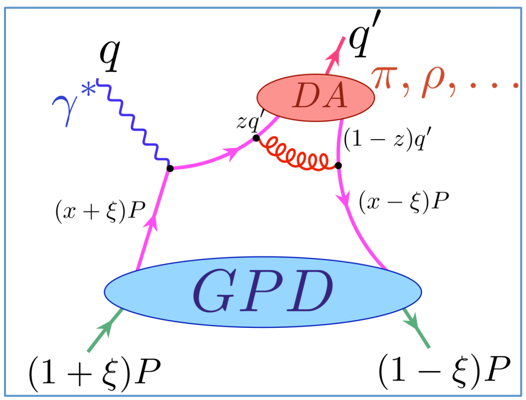
φ distribution

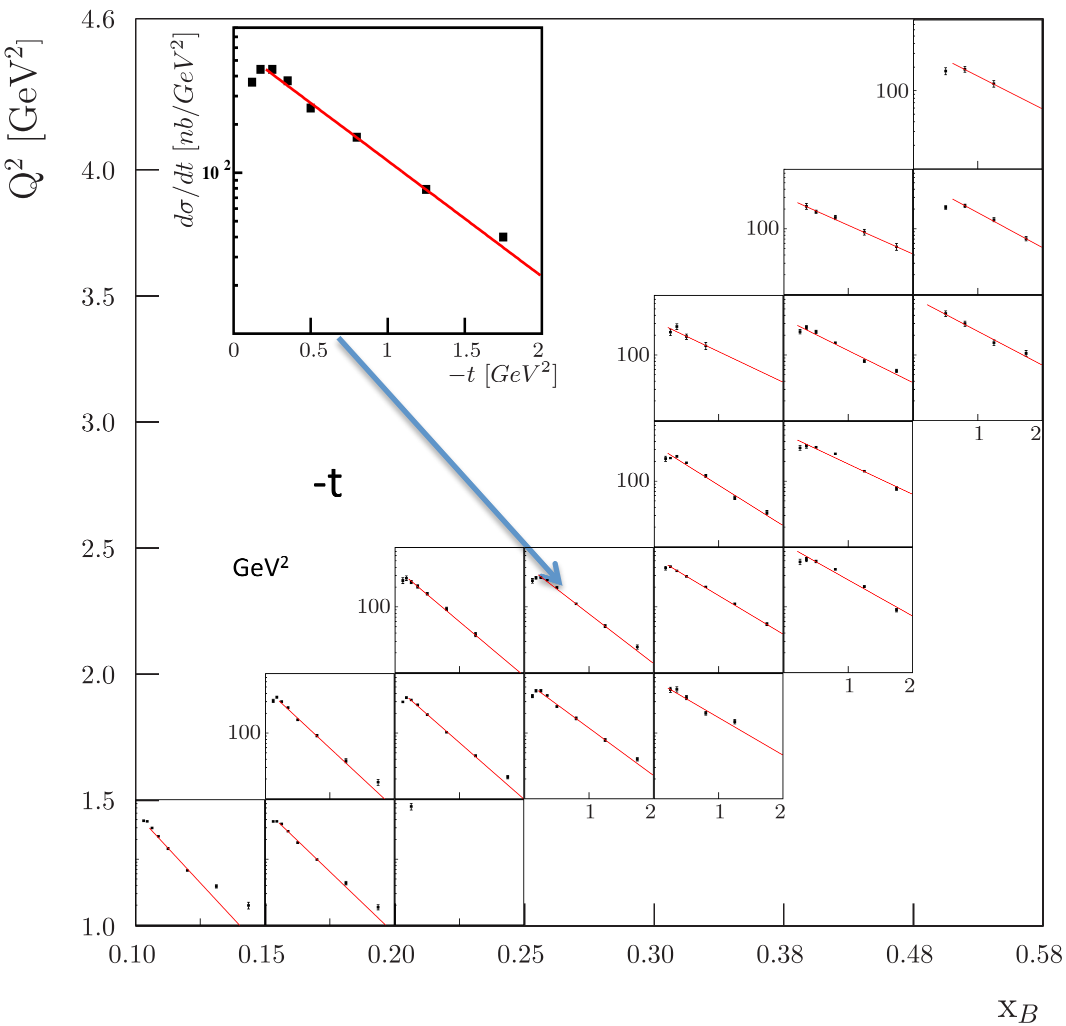


-t

$d\sigma_U/dt$

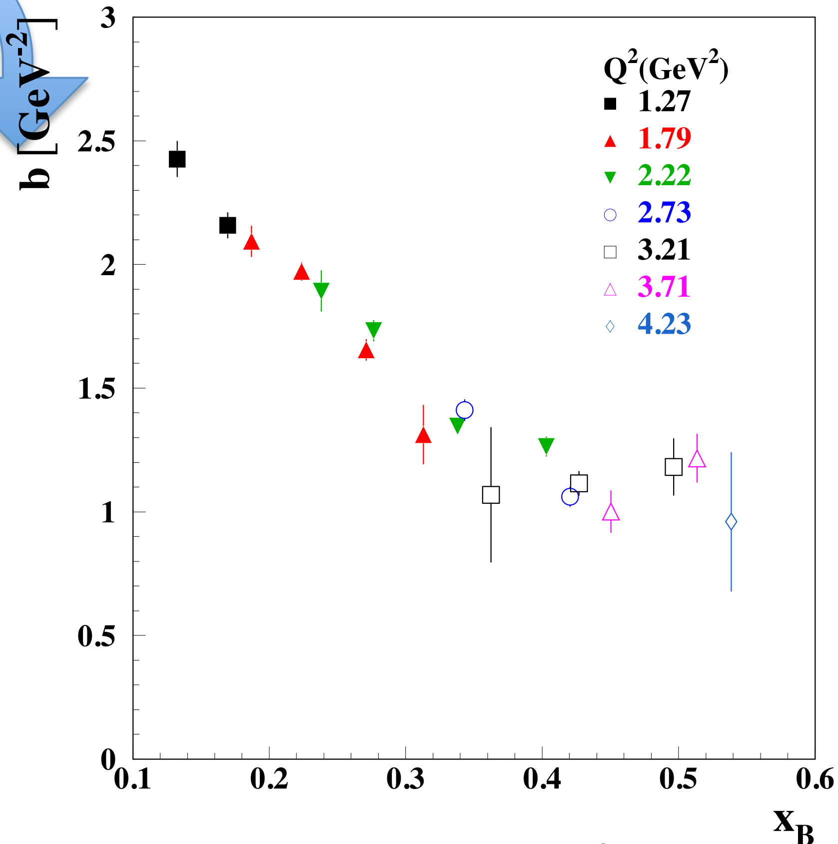
$$\frac{d\sigma}{dt}(\gamma^* p \rightarrow ep\pi^0) \propto e^{bt}$$





t-slope parameter: x_B dependence

$$\frac{d\sigma}{dt} \propto e^{bt}$$

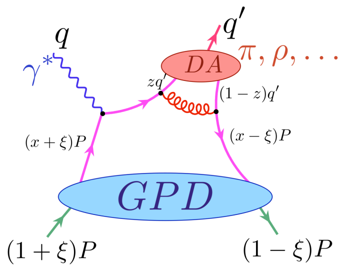


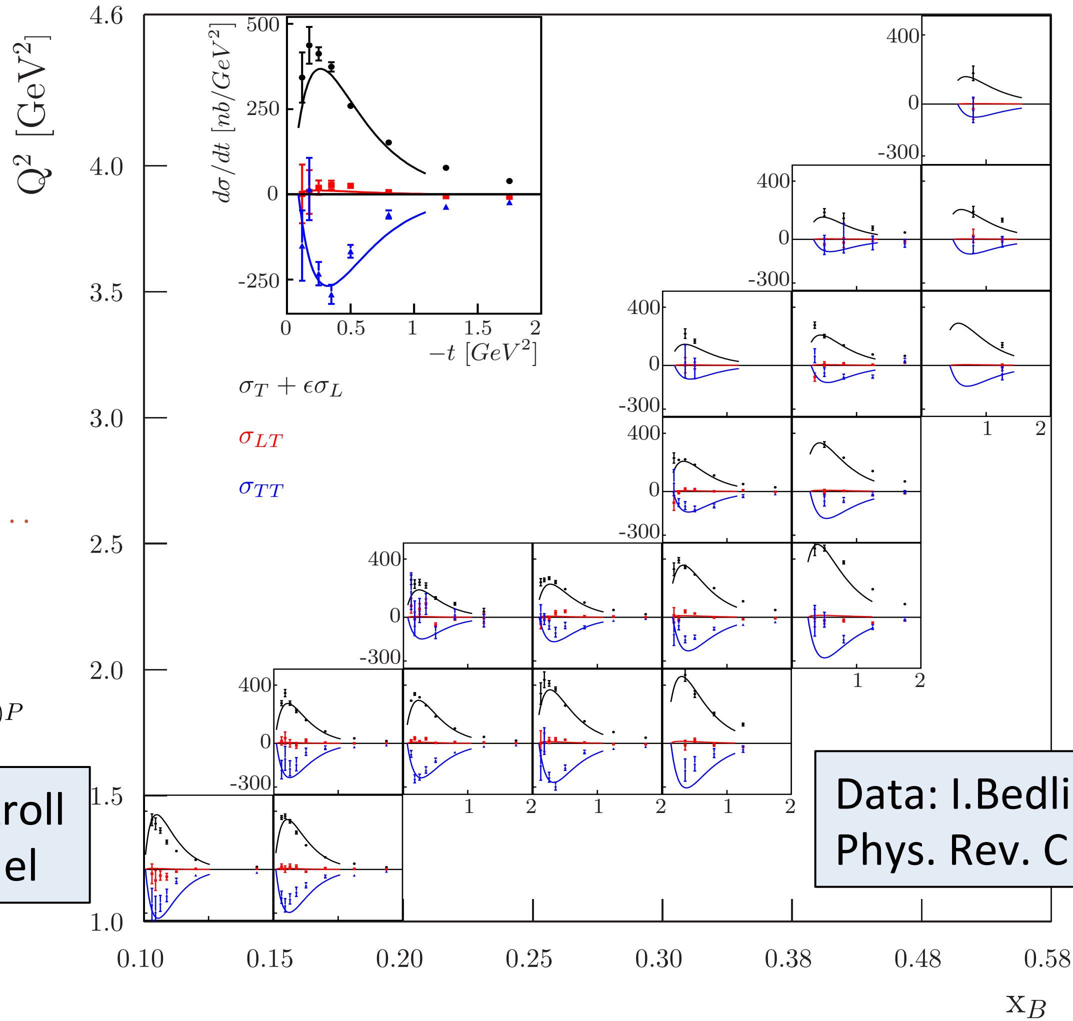
The slope parameter is decreasing with increasing x_B. The Q^2 dependence is weak. Looking to this picture we can say that the perp width of the partons with $x \rightarrow 1$ goes to zero.

Structure Functions

$(\sigma_T + \varepsilon\sigma_L)$ σ_{TT} σ_{LT}

$\gamma^* p \rightarrow p\pi^0$





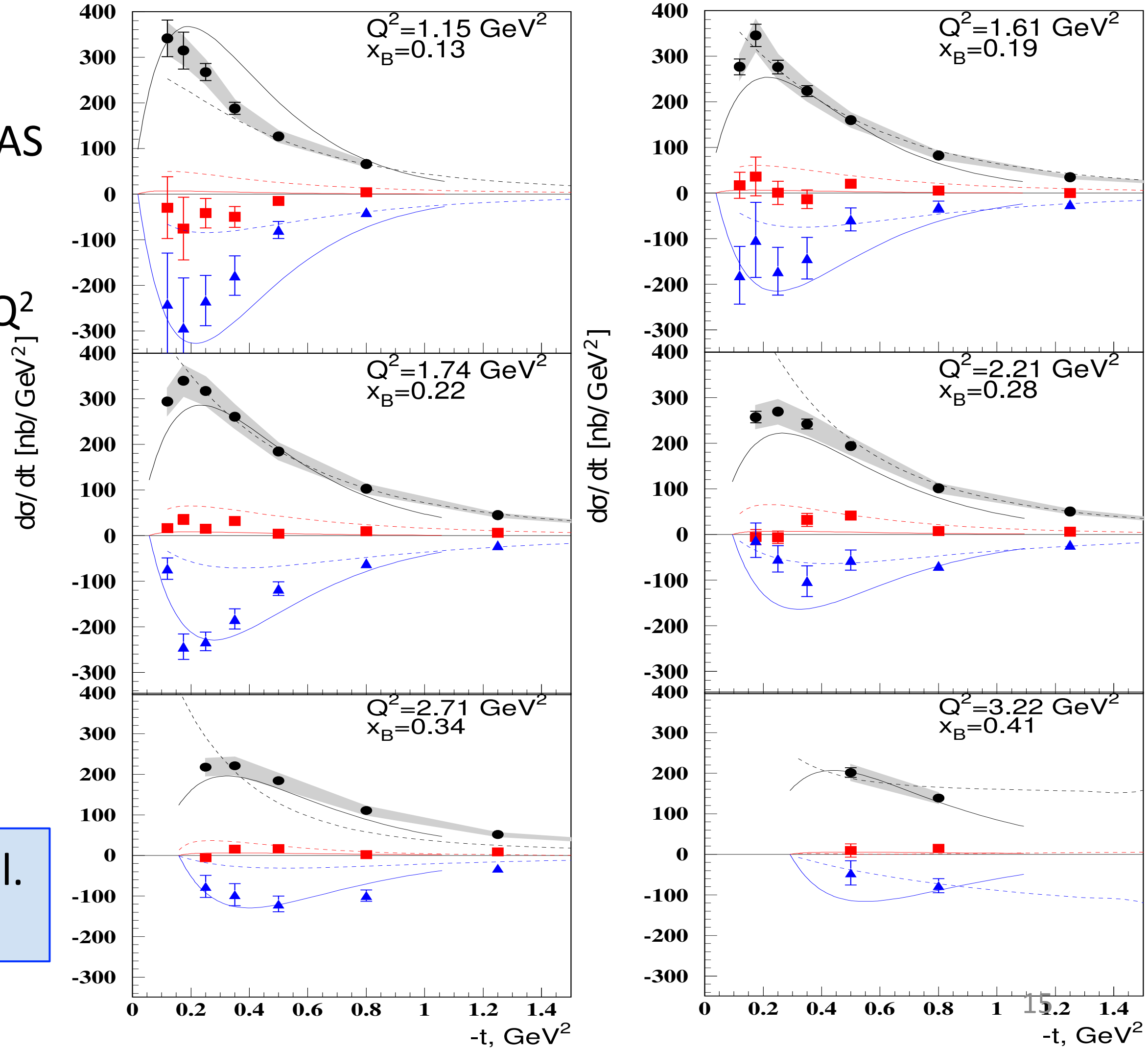
Curves: Goloskokov, Kroll
Transversity GPD model

Data: I.Bedlinskiy et al. (CLAS)
Phys. Rev. C 90, 039901 (2014)

CLAS data and GPD theory predictions

Solid: S. Goloskokov and P. Kroll
Dots: S. Liuti and G. Goldstein

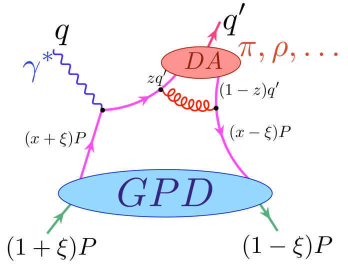
- ***Transversity* GPDs** H_T and $\bar{E}_T = 2\tilde{H}_T + E_T$ dominate in CLAS kinematics.
- The model was optimized for low x_B and high Q^2. The corrections t/Q^2 were omitted
- GPD model successfully describes CLAS data even at low Q^2
- Pseudoscalar meson production provides unique possibility to access the transversity GPDs.

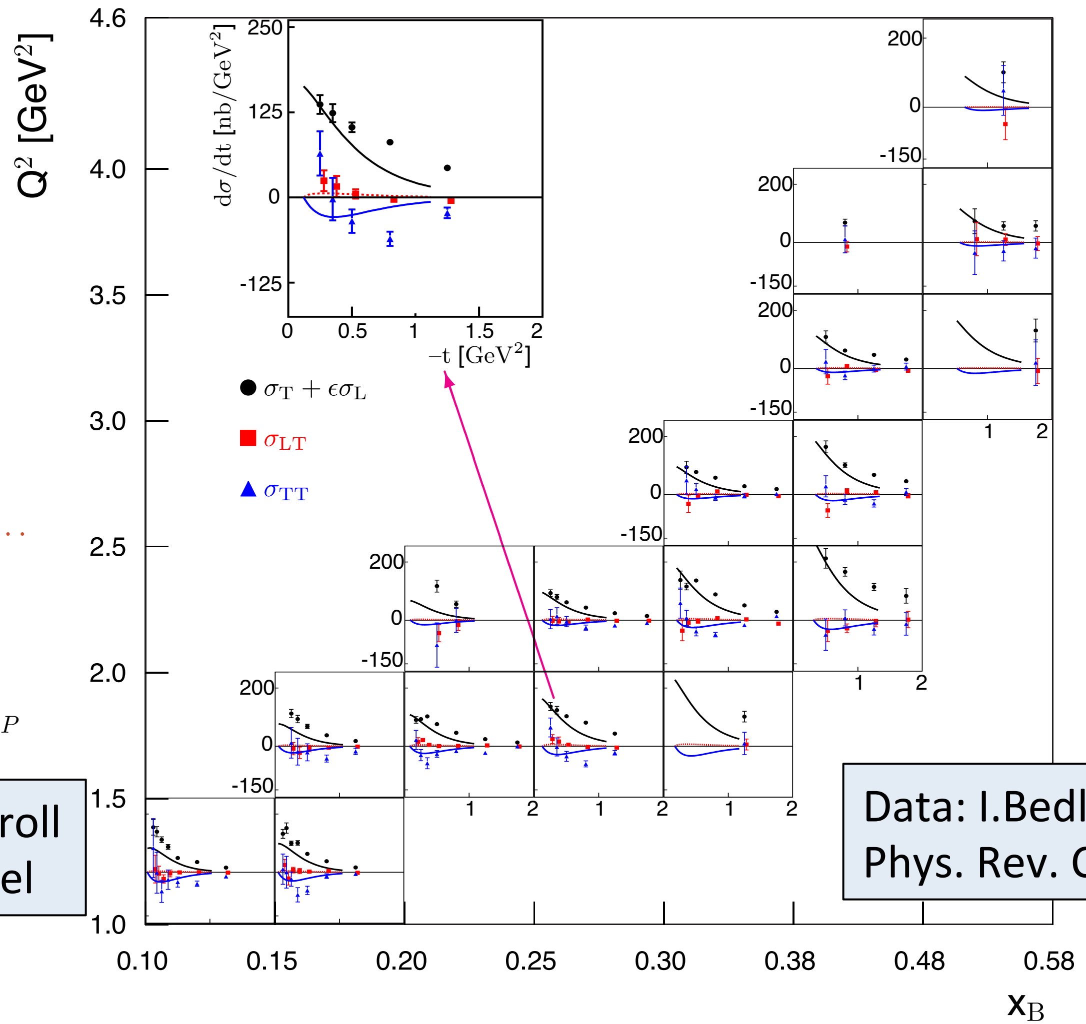


CLAS collaboration. I Bedlinskiy et al. Phys.Rev.Lett. 109 (2012) 112001

η Structure Functions
$(\sigma_T + \varepsilon\sigma_L)$ σ_{TT} σ_{LT}

$\gamma^* p \rightarrow p\eta$

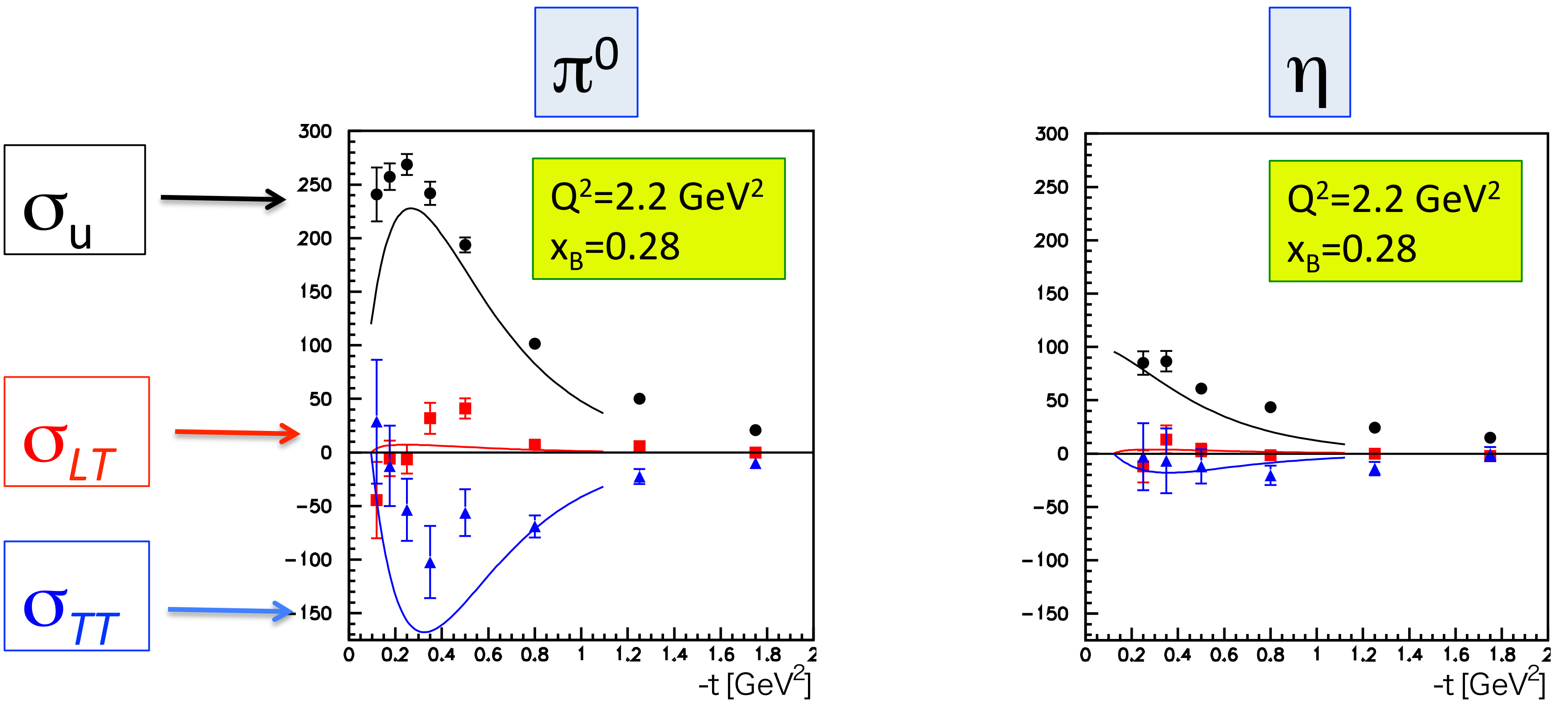




Curves: Goloskokov, Kroll
Transversity GPD model

Data: I.Bedlinskiy et al. (CLAS)
Phys. Rev. C **95**, 035202 (2017)

Comparison π^0/η



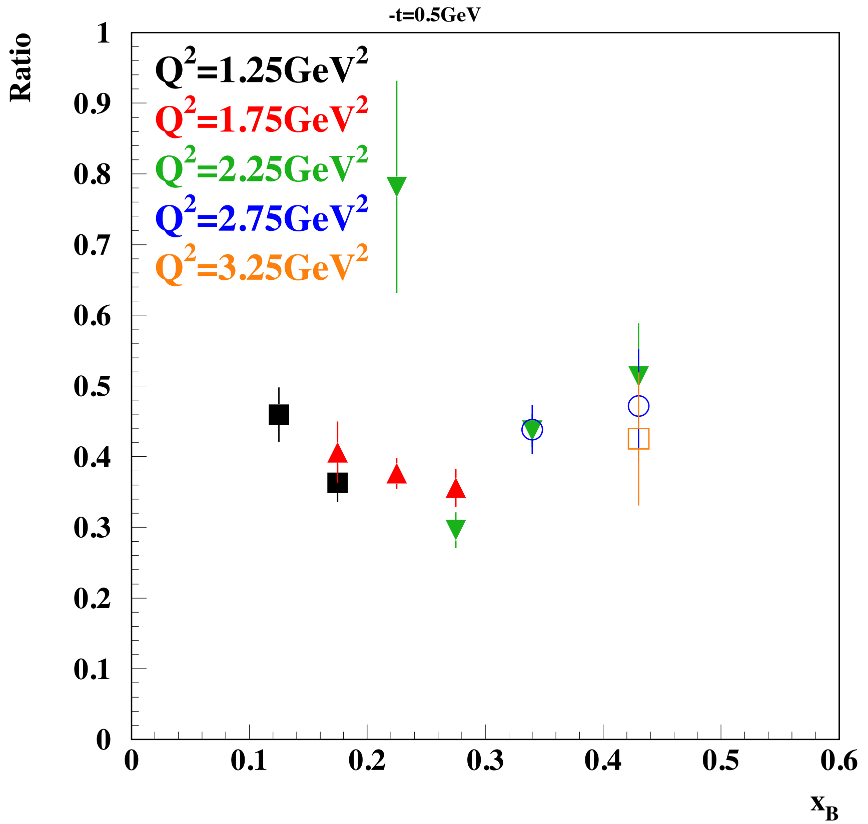
- $\sigma_U=\sigma_T+\varepsilon\sigma_L$ drops by a factor of 2.5 for η
- σ_{TT} drops by a factor of 10
- The GK GPD model (curves) follows the experimental data
- The statement about the ability of transversity GPD model to describe the pseudoscalar electroproduction becomes more solid with the inclusion of η data

CLAS-Phys.Rev.C95(2017)

η/π^0 ratio

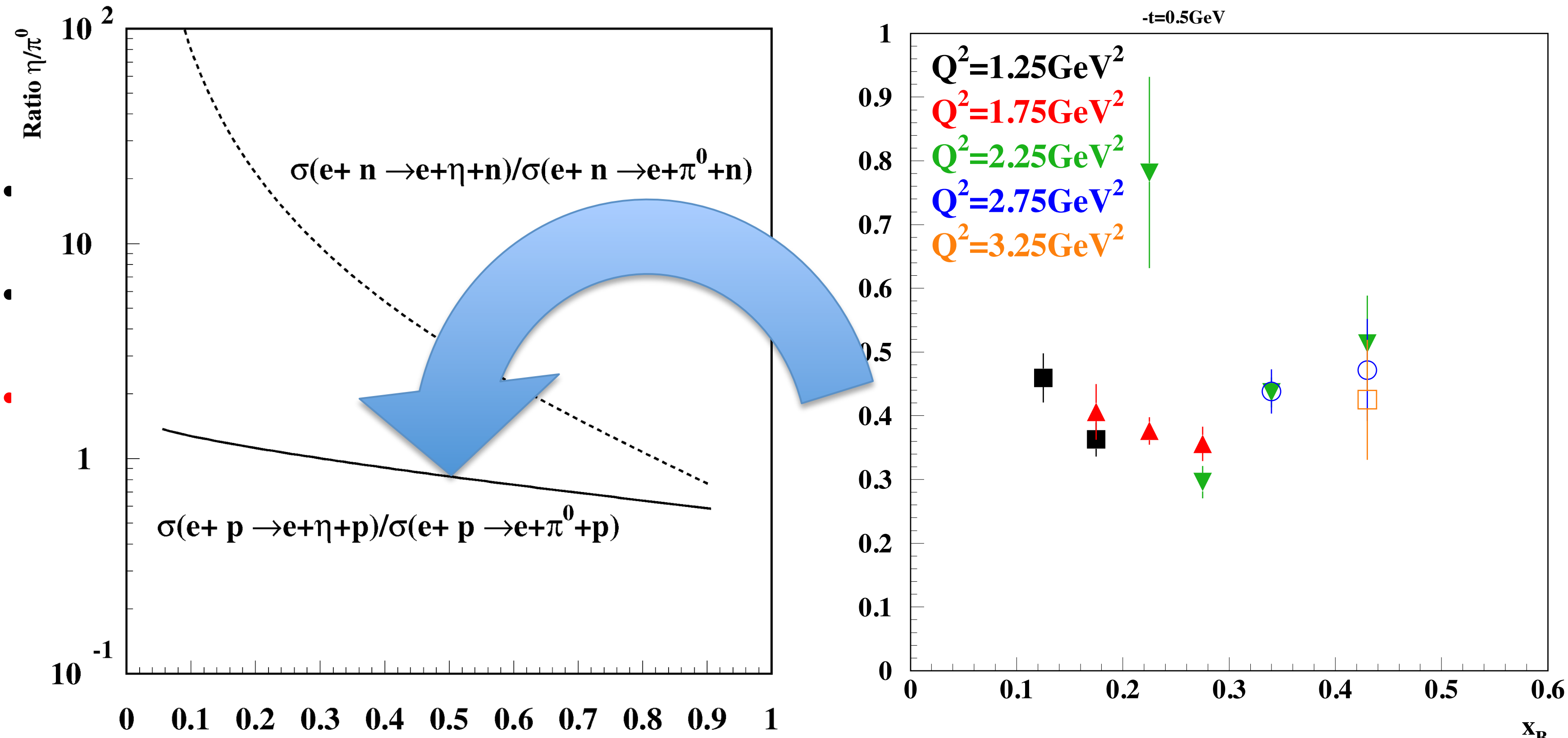
$$\frac{\sigma(ep \rightarrow ep\eta)}{\sigma(ep \rightarrow ep\pi^0)}$$

- The dependence on x_B and Q^2 is very weak.
- Chiral odd GPD models predict this ratio to be ~1/3 at CLAS kinematics
- Chiral even GPD models predict this ratio to be around 1 (at low –t).



η/π^0 ratio

$$\frac{\sigma(ep \rightarrow ep\eta)}{\sigma(ep \rightarrow ep\pi^0)}$$



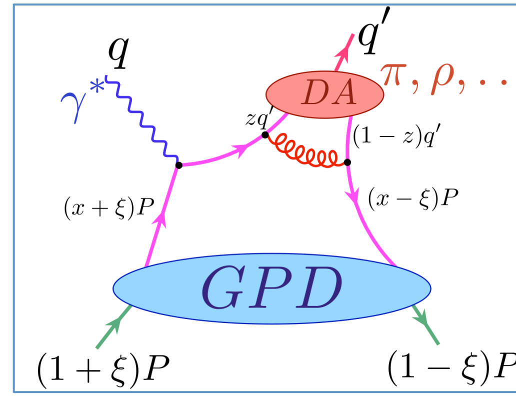
Theoretical prediction R=1 for the Chiral-even GPD models ($\sigma_L >> \sigma_T$)
F, Frankfurt et al,Phys.Rev D59,1999

CLAS-Phys.Rev.C95(2017)

Structure functions and GPDs

$$\frac{d\sigma_T}{dt} = \frac{4\pi\alpha}{2k'}\frac{\mu_P^2}{Q^8}\left[(1-\xi^2)\,|\langle H_T\rangle|^2 - \frac{t'}{8m^2}|\langle \bar{E}_T\rangle|^2\right]$$

$$\frac{d\sigma_{TT}}{dt} = \frac{4\pi\alpha}{k'}\frac{\mu_P^2}{Q^8}\frac{t'}{16m^2}|\langle \bar{E}_T\rangle|^2$$



Goloskokov, Kroll
Transversity GPD model

$$|\langle \bar{E}_T\rangle^{\pi,\eta}|^2 = \frac{k'}{4\pi\alpha}\frac{Q^8}{\mu_P^2}\frac{16m^2}{t'}\frac{d\sigma_{TT}^{\pi,\eta}}{dt}$$

$$|\langle H_T\rangle^{\pi,\eta}|^2 = \frac{2k'}{4\pi\alpha}\frac{Q^8}{\mu_P^2}\frac{1}{1-\xi^2}\left[\frac{d\sigma_T^{\pi,\eta}}{dt} + \frac{d\sigma_{TT}^{\pi,\eta}}{dt}\right]$$

$$\langle H_T\rangle = \Sigma_\lambda \int_{-1}^{1} dx M(x,\xi,Q^2,\lambda) H_T(x,\xi,t)$$

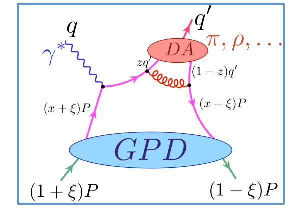
$$\langle \bar{E}_T\rangle = \Sigma_\lambda \int_{-1}^{1} dx M(x,\xi,Q^2,\lambda) \bar{E}_T(x,\xi,t)$$

The brackets <F> denote the convolution of the elementary process with the GPD F (generalized form factors)

- *In the approximation* of the transversity GPDs dominance, that is supported by Jlab data, $\sigma_L \ll \sigma_T$, we have direct access to the generalized form factors for π and η production.

$\bar{E}_T = 2\tilde{H}_T + E_T$

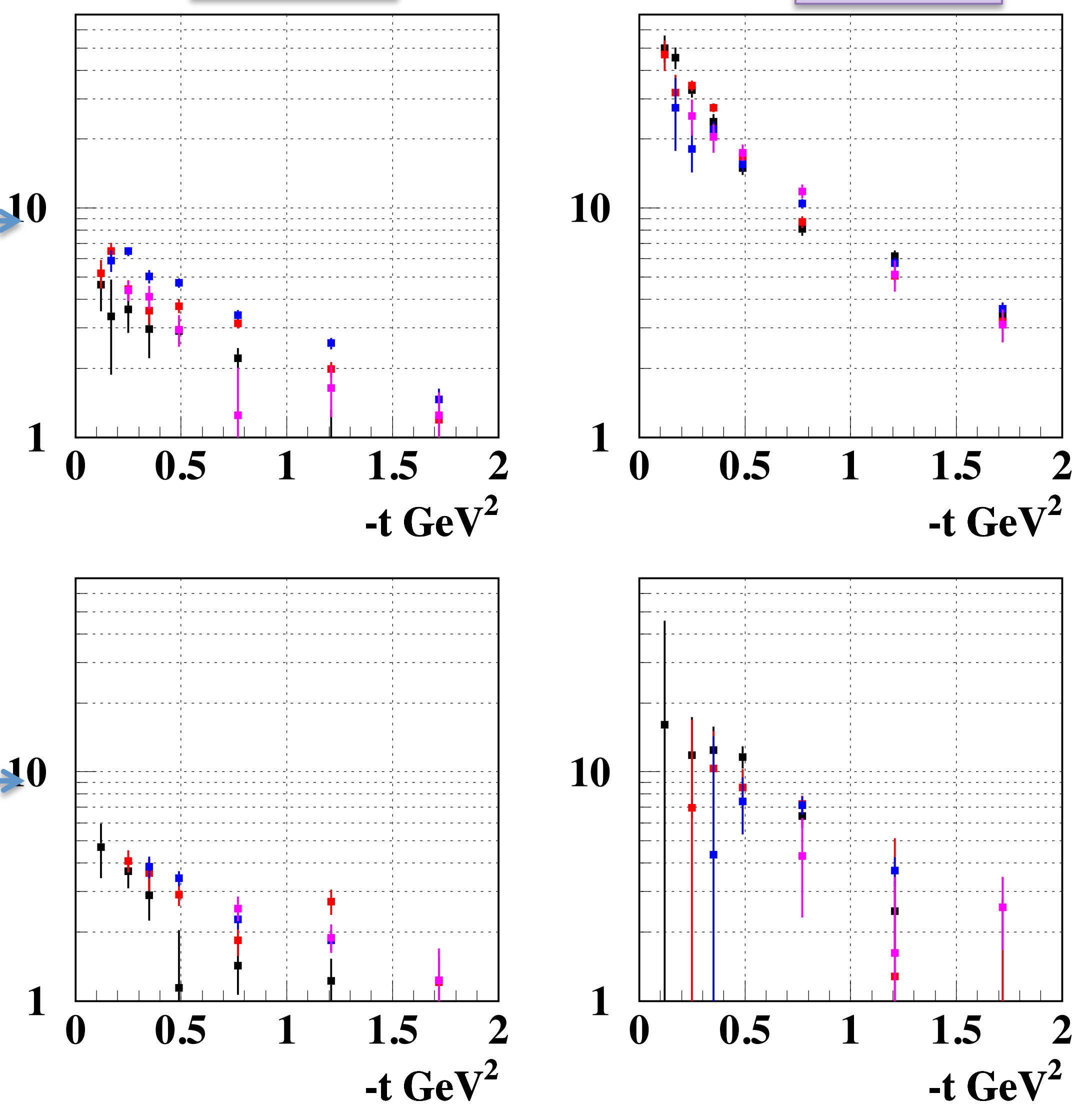
Generalized Form factors



$|\langle H_T \rangle|$ $|\langle \bar{E}_T \rangle|$

π^0

η

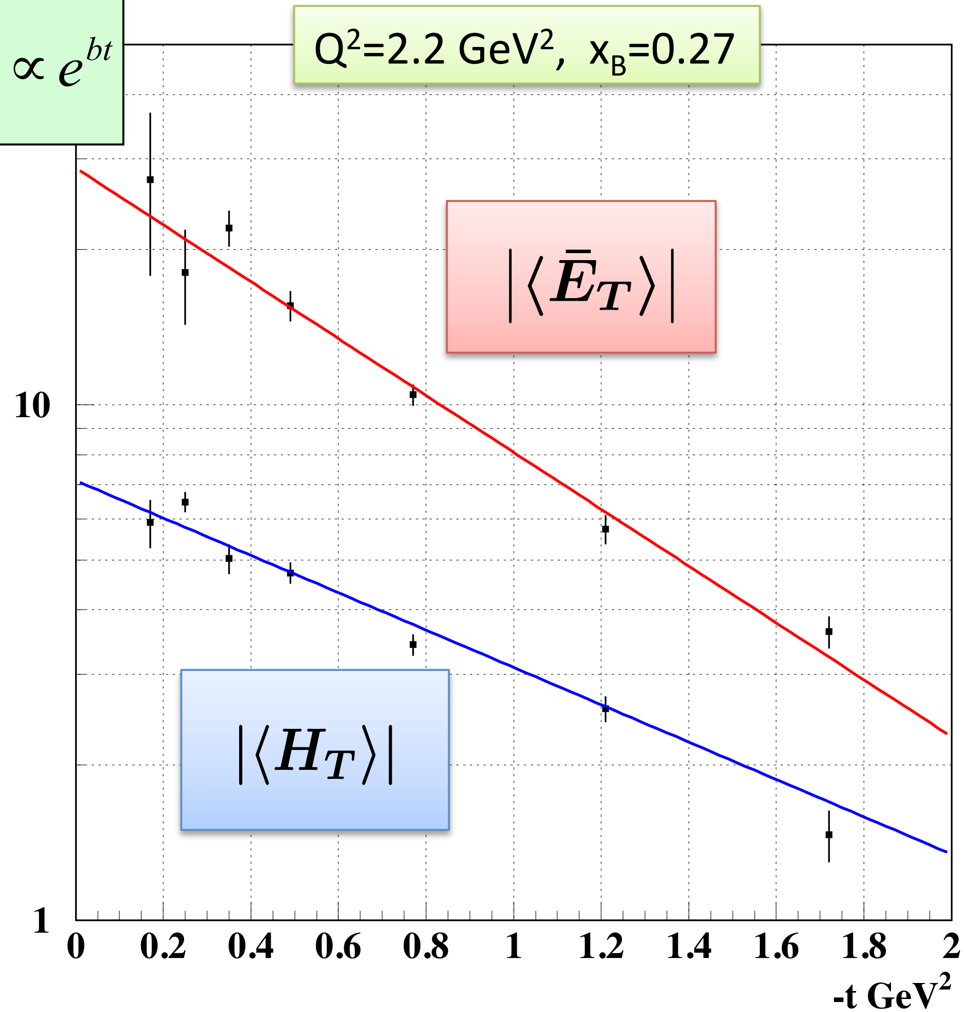


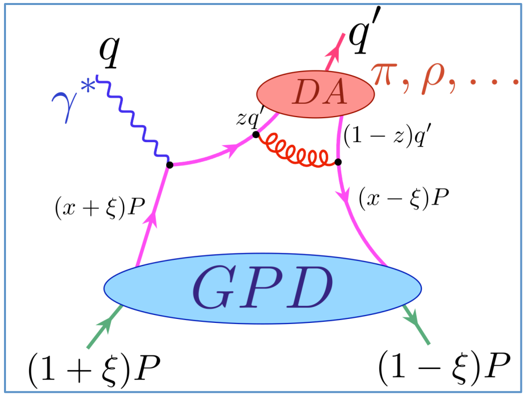
Q^2 GeV^2	x_B
1.2	0.15
1.8	0.22
2.2	0.27
2.7	0.34

- $\bar{E}_T$ > H_T for π^0 and η
- t-dependence is steeper for $\bar{E}_T$ than for H_T
- Estimation of the systematic uncertainties connected with the used approximation is in progress

π^0 Generalized Form Factors

$$\frac{d<F>}{dt} \propto e^{bt}$$





- $\bar{E}_T > H_T$
- t-dependence is steeper for $\bar{E}_T$ than for H_T

- $|<E_T,H_T>| \sim \exp(bt)$
- $b(E_T)=1.27\ GeV^{-2}$
- $b(H_T)=0.98\ GeV^{-2}$

VK, arXiv:1601.04367

GPD Flavor Decomposition

$$H_T^{\pi} = \frac{1}{3\sqrt{2}}[2H_T^u + H_T^d]$$

$$H_T^{\eta} = \frac{1}{\sqrt{6}}[2H_T^u - H_T^d]$$

$$H_T^u = \frac{3}{2\sqrt{2}}[H_T^{\pi} + \sqrt{3}H_T^{\eta}]$$

$$H_T^d = \frac{3}{\sqrt{2}}[H_T^{\pi} - \sqrt{3}H_T^{\eta}]$$

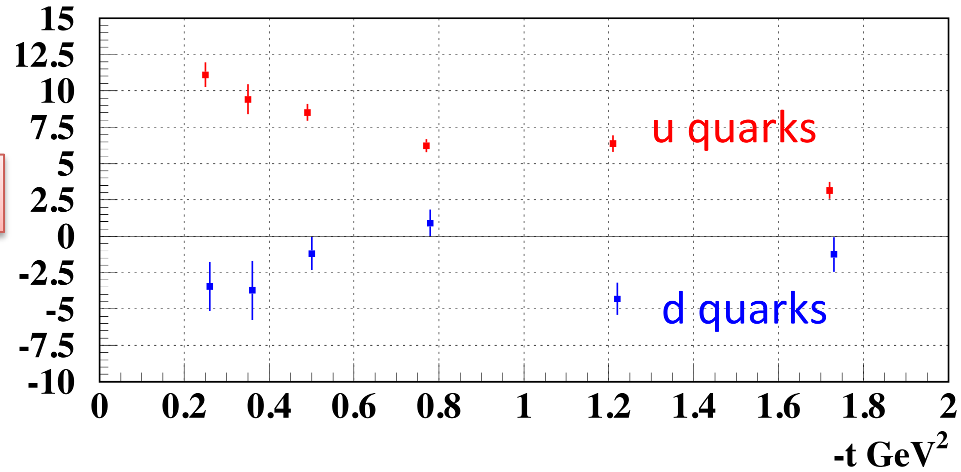
Similar expressions for $\bar{E}_T$

- GPDs appear in different flavor combinations for π^0 and η
- The combined π^0 and η data permit the flavor (u and d) decomposition for GPDs H_T and $\bar{E}_T$
- The u/d decomposition was done under assumption that the relative phase between u and d is 0 or 180 degrees. This assumption confirmed at least for $\bar{E}_T$

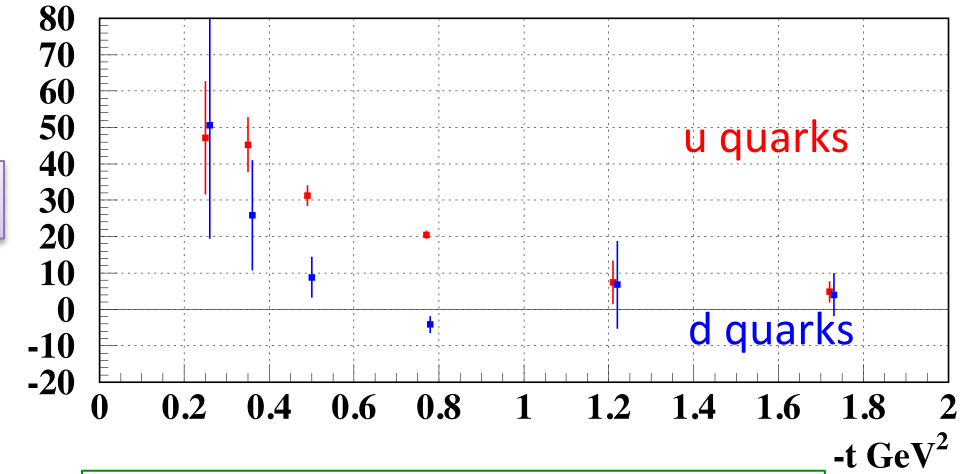
Flavor Decomposition of the Transversity GPDs

Q^2=1.8 GeV^2, x_B=0.22

$\langle H_T \rangle$



$\langle \bar{E}_T \rangle$



VK arXiv: 1601.04367 [hep-ex] 2016

- $\langle H_T \rangle^u$ and $\langle H_T \rangle^d$ have different signs for u and d-quarks in accordance with the transversity function h_1 (Anselmino et al.)
- $\langle \bar{E}_T \rangle^d$ and $\langle \bar{E}_T \rangle^u$ seem to have the same signs
- Decisions shown with positive values of u-quark's GPDs only

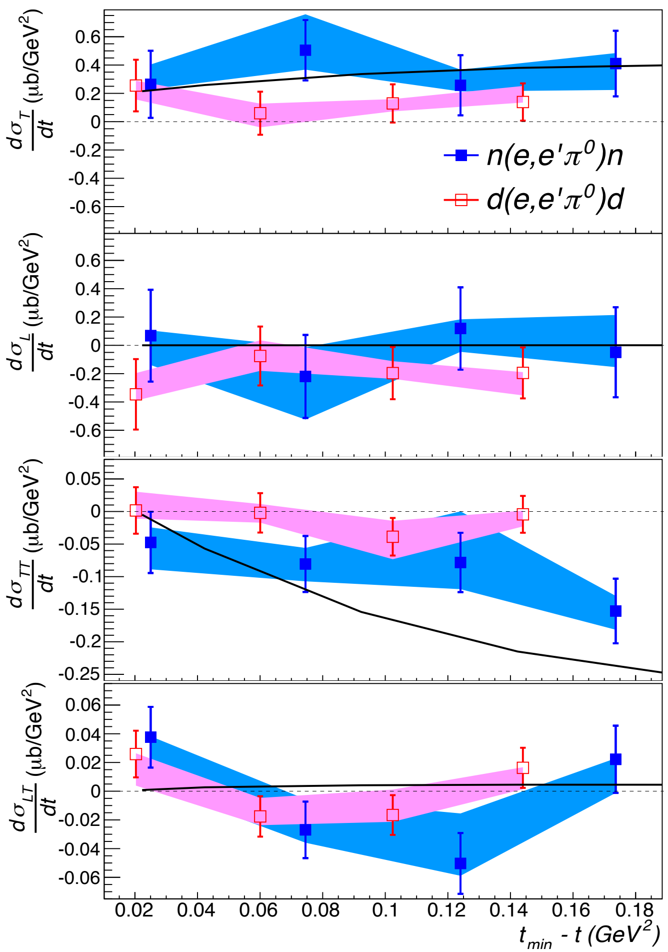
π^0 Electroproduction off *Neutron*

σ_T

σ_L

σ_{TT}

σ_{LT}



Neutron

Deutron

$Q^2 = 1.75$ GeV^2, x_B=0.36

The neutron cross sections

- dominated by σ_T and σ_{TT}
- σ_L and σ_{LT} are compatible with zero
- It is in good agreement with the previous measurement off a proton
- The data are I na a fair agreement with the theoretical expectations based on the helicity-flip (transversity) GPDs

- Hall-A, PRL, 118, 222002 (2017)
- Theory, S. Goloskokov and P. Kroll, Eur. Phys. J. A47, 112 (2011)

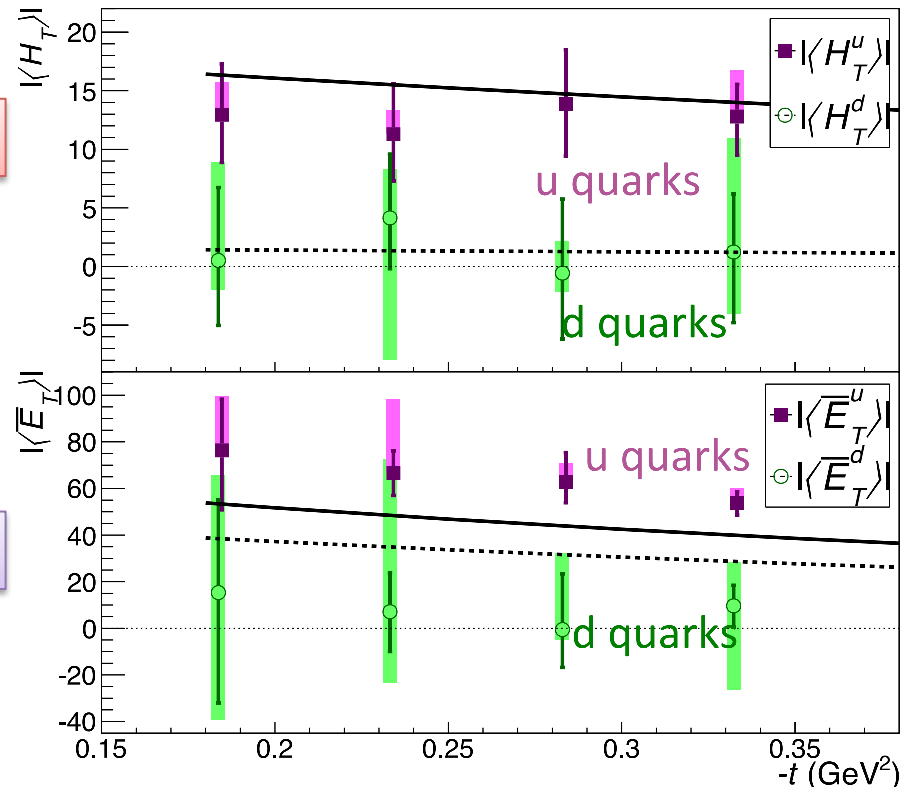
Flavor decomposition:n and p

$$H_T^p = \frac{1}{3\sqrt{2}}(2H_T^u + H_T^d)$$

$$H_T^n = \frac{1}{3\sqrt{2}}(H_T^u + 2H_T^d)$$

|<H$_T$>|

|<E$_T$>|



$$H_T^p = \frac{1}{3\sqrt{2}}(2H_T^u + H_T^d)$$

$$H_T^n = \frac{1}{3\sqrt{2}}(H_T^u + 2H_T^d)$$

$$H_T^\eta = \frac{1}{\sqrt{6}}(2H_T^u - H_T^d)$$

Proton, neutron and η data
Will solve the problem of
unknown phase between u
and d GFF

- $< E_T^u >$ is larger than $< H_T^u >$
- Good agreement with GK model

Q^2=1.75 GeV^2
x_B=0.36

From GFF to GPD

- The access to GPDs through DVMP is indirect because cross section depends on Generalized Form Factors (GFFs), i.e. convolution of GPDs with sub processes.
- GFFs (or CFF in DVCS) form factors are an intermediate step towards GPD extraction
- The way to go is the global fit of experimental observables using GPD models with parameters. It may include DVCS and DVMP experimental data set.
- The DVCS community made an impressive steps in this direction. We can do similar attempts for the transversity GPDs.
- There are several models on the market that provide such a parameterization (PK,SL,SG,GG,CW…)
- The Jlab pseudoscalar electroproduction data(cross section on different targets, asymmetries etc) gives the unique opportunity to access the critical parameters of the transversity GPDs.

The Fourier Transform of Generalized Parton Distribution

- The Fourier transforms of GPDs at $\xi = 0$ describe the distribution of partons in the transverse plane (M. Burkardt, 2002)
- It was shown that they satisfy positivity constraints which justify their physical interpretation as a probability density
- **H** is related to the impact parameter distribution of unpolarized quarks in an unpolarized nucleon
- **$\tilde{H}$** is related to the distribution of longitudinally polarized quarks in a longitudinally polarized nucleon
- **E** is related to the distortion of the unpolarized quark distribution in the transverse plane when the nucleon has transverse polarization.
- **$\bar{E}_T$** is related to the distortion of the polarized quark distribution in the transverse plane for an unpolarized nucleon

$$\mathcal{K}(x,\vec{b}) = \int \frac{d^2\vec{\Delta}}{(2\pi)^2} \exp^{-i\vec{b}\cdot\vec{\Delta}} K(x, t=-\Delta^2)$$

GPD Parameterization and Fourier Transform

$$\mathcal{K}(x,\vec{b}) = \int \frac{d^2\vec{\Delta}}{(2\pi)^2} \exp^{-i\vec{b}\cdot\vec{\Delta}} K(x, t = -\Delta^2)$$

GPD Parameterization (Diehl, Kroll 2013)

$$K(x,t) = k(x) \cdot \exp^{t \cdot f(x)}$$

forward limit k(x) and the profile function f(x)

$$\mathcal{K}(x,\vec{b}) = \frac{1}{4\pi} \frac{k(x)}{f(x)} \exp^{-b^2/4f(x)}$$

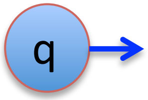
$$f(x) = (B + \alpha' \ln 1/x) \cdot (1-x)^3 + A \cdot x \cdot (1-x)^2$$

A,B,α' are the model parameters

The Density of Transversely Polarized Quarks (in x-direction) in an Unpolarized Proton

$\bar{E}_T$ is related to the distortion of the polarized quark distribution in the transverse plane for an unpolarized nucleon

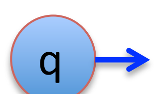
$$\delta(x,\vec{b}) = \frac{1}{2}[H(x,\vec{b}) - \frac{b_y}{m}\frac{\partial}{\partial b^2}\bar{E}_T(x,\vec{b})]$$



The Density of Transversely Polarized Quarks (in x-direction) in an Unpolarized Proton

$\bar{E}$ is related to the distortion of the polarized quark distribution in the transverse plane for an unpolarized nucleon

$$\delta(x,\vec{b}) = \frac{1}{2}\left[H(x,\vec{b}) - \frac{b_y}{m}\frac{\partial}{\partial b^2}\bar{E}_T(x,\vec{b})\right]$$

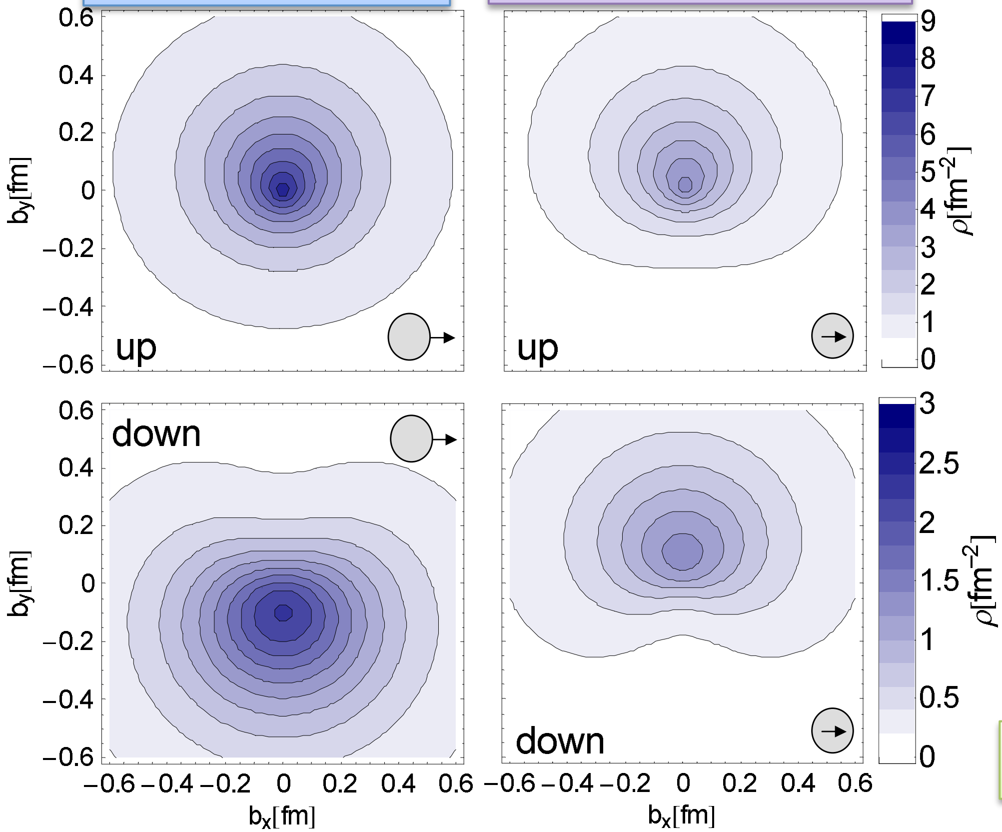


Integrated Over x Transverse Densities for u and d Quarks in the Proton

Polarized proton | Unpolarized proton

u quarks

d quarks



Strong distortions for unpolarized quarks in transversely polarized proton

Strong distortions for transversely polarized quarks in an unpolarized proton

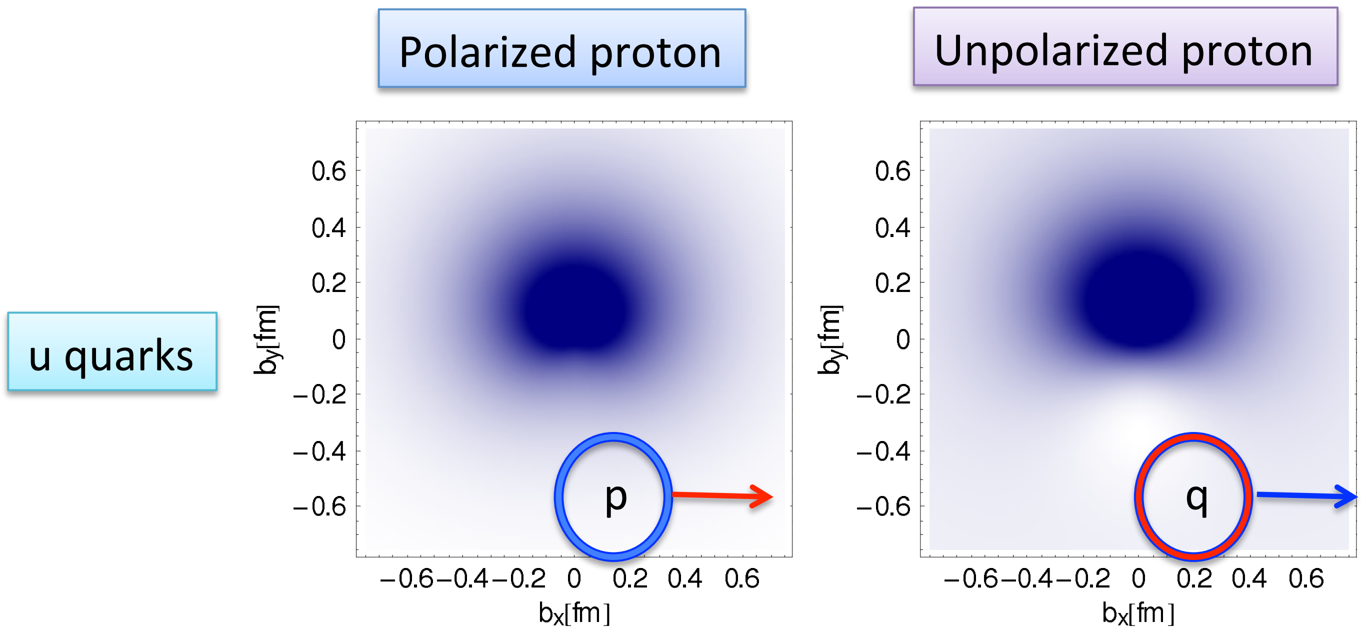
Controlled by E

Controlled by $\bar{E}_T = 2\tilde{H}_T + E_T$

Lattice calculations

Gockeler et al, Phys. Rev. Lett. 98, 222001 (2007), lattice

GPD model: integrated over *x* Impact Parameter Density for u-quarks



- **Left:** unpolarized u-quarks in a proton with transverse spin vector.
- **Right**: the distribution of u-quarks with transverse spin vector in an unpolarized proton.

M. Diehl and Ph Hagler (2005) GPD model with "some reasonable " parameters.

CLAS data and Proton Spin Density Distributions for u and quarks

- CLAS data on π^0/η electroproduction gives direct access to the Etbar GPD

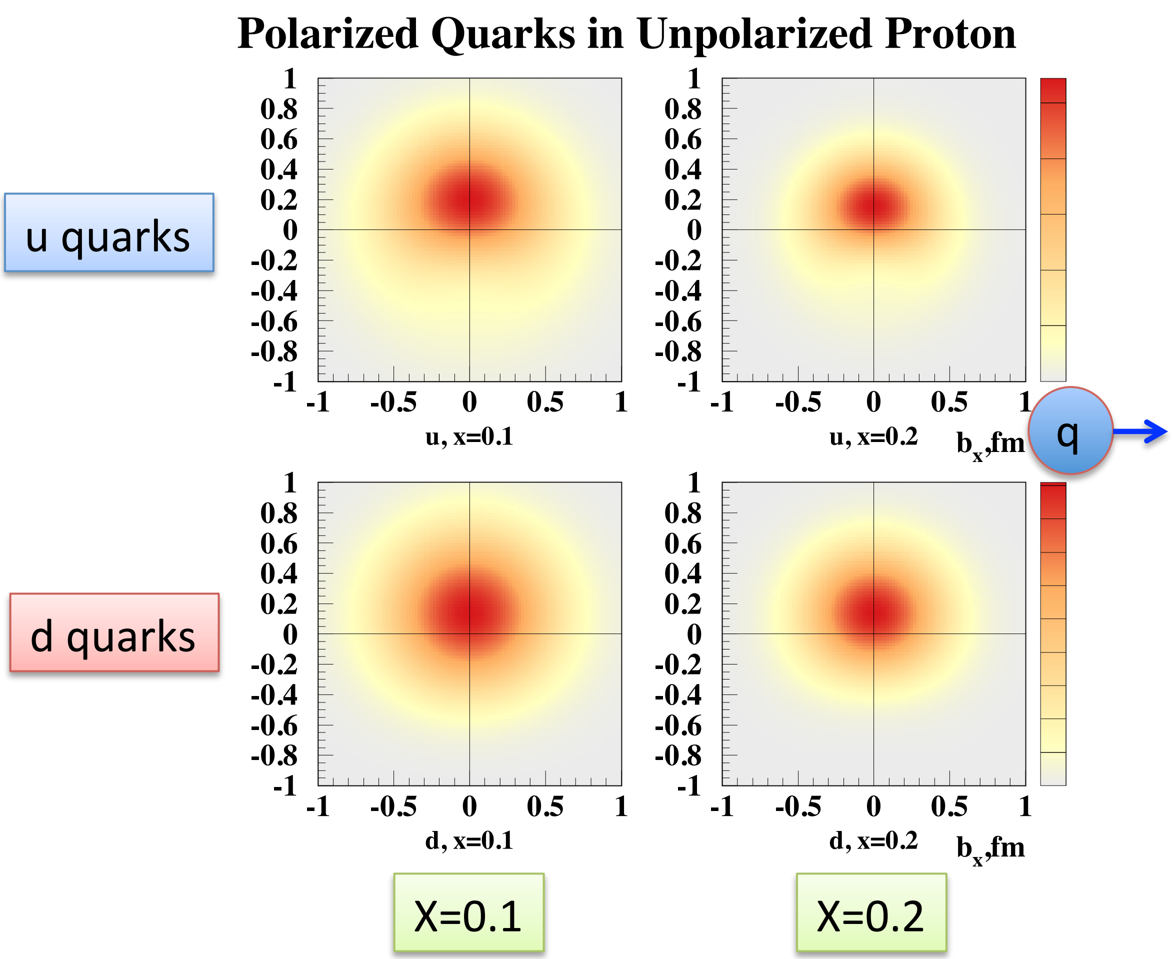
$$\frac{d\sigma_T}{dt} = \frac{4\pi\alpha}{2k'}\frac{\mu_P^2}{Q^8}\left[\left(1-\xi^2\right)\left|\langle H_T\rangle\right|^2 - \frac{t'}{8m^2}\left|\langle \bar{E}_T\rangle\right|^2\right]$$

$$\frac{d\sigma_{TT}}{dt} = \frac{4\pi\alpha}{k'}\frac{\mu_P^2}{Q^8}\frac{t'}{16m^2}\left|\langle \bar{E}_T\rangle\right|^2$$

- GPD model successfully described our data
- The spin density of the proton was extracted using the Kroll’s model
- We can map the u and d –quarks spin density distributions as a function of x

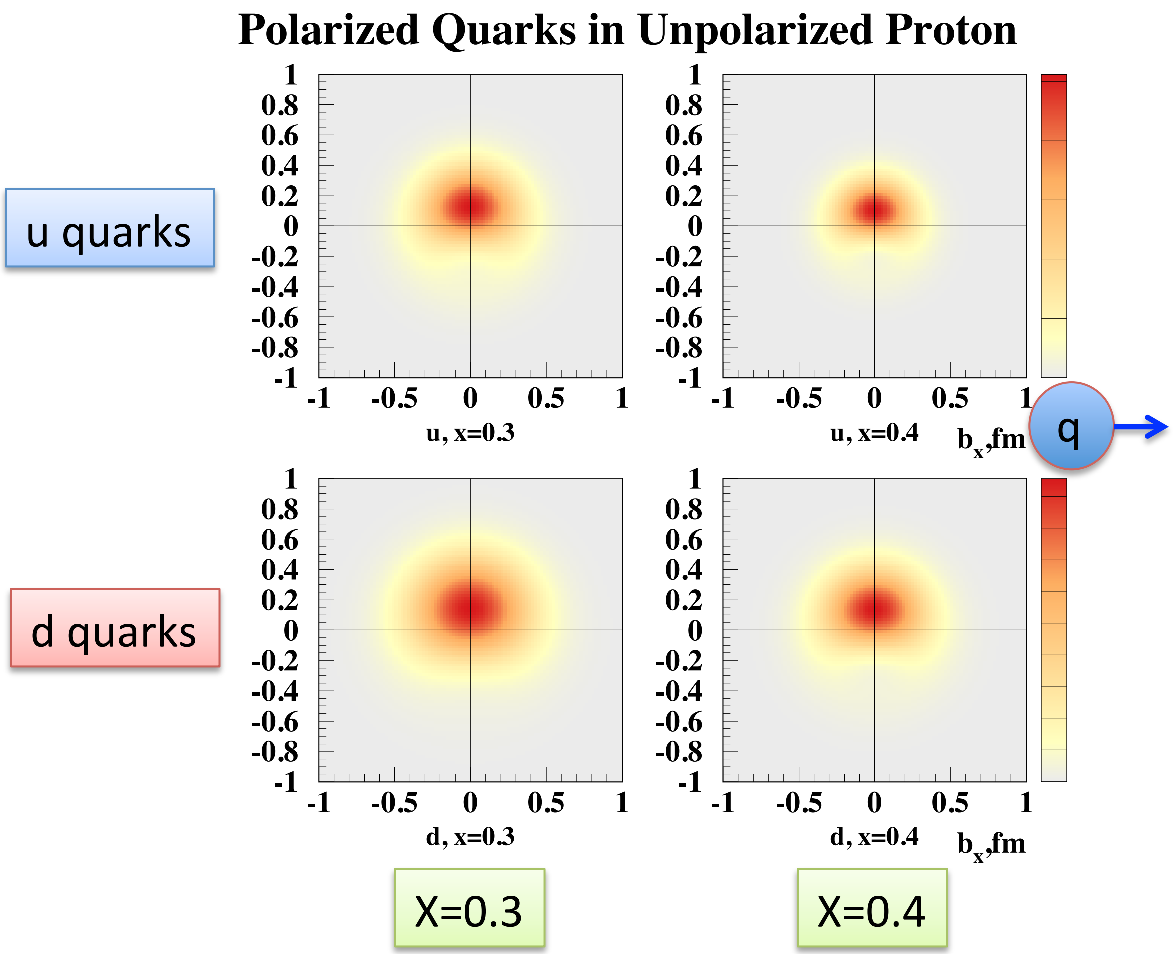
M. Diehl and P. Kroll, Eur. Phys. J. C 73, no. 4, 2397 (2013)

Transverse Densities for u and d Quarks in the Proton

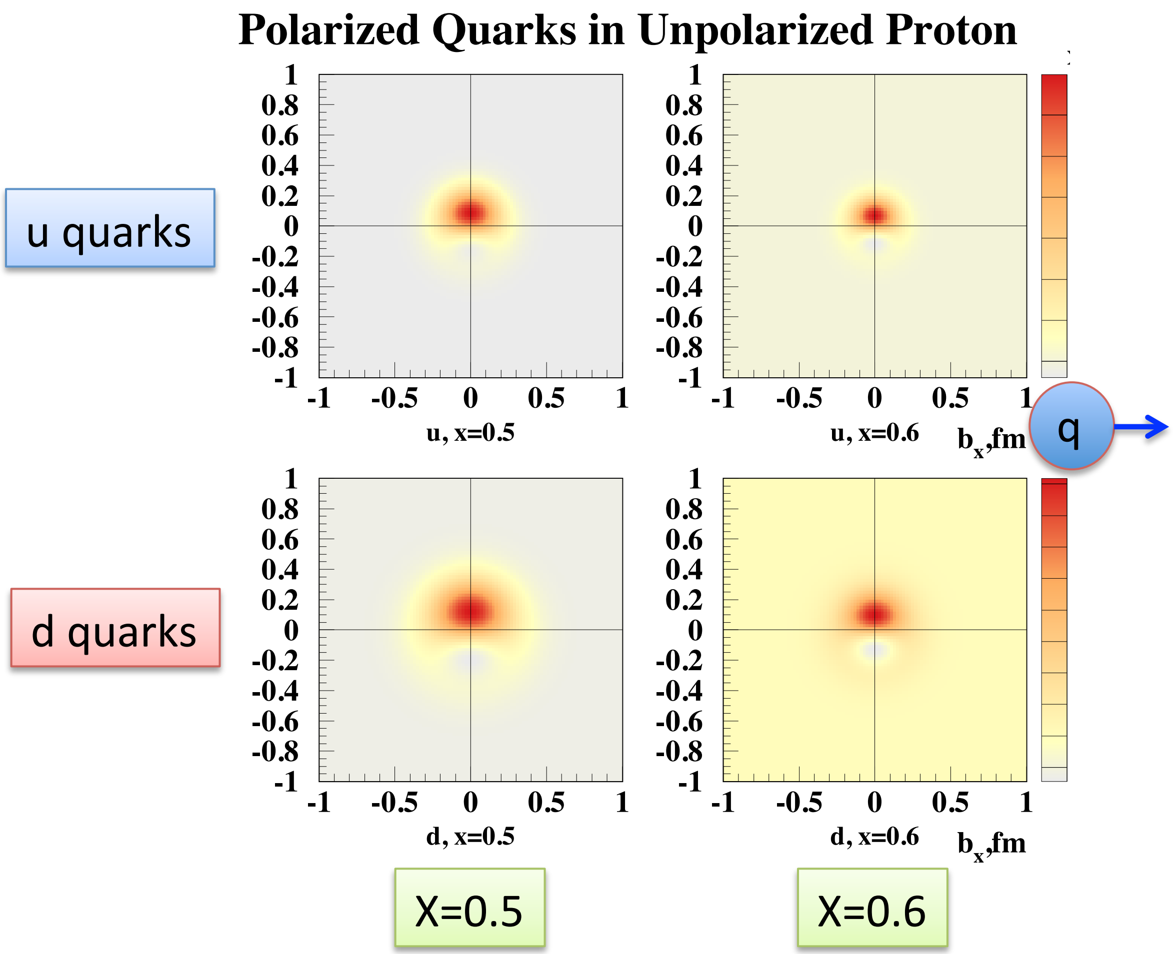


Note distortions for transversely polarized u and d quarks.

Transverse Densities for u and d Quarks in the Proton



Transverse Densities for u and d Quarks in the Proton

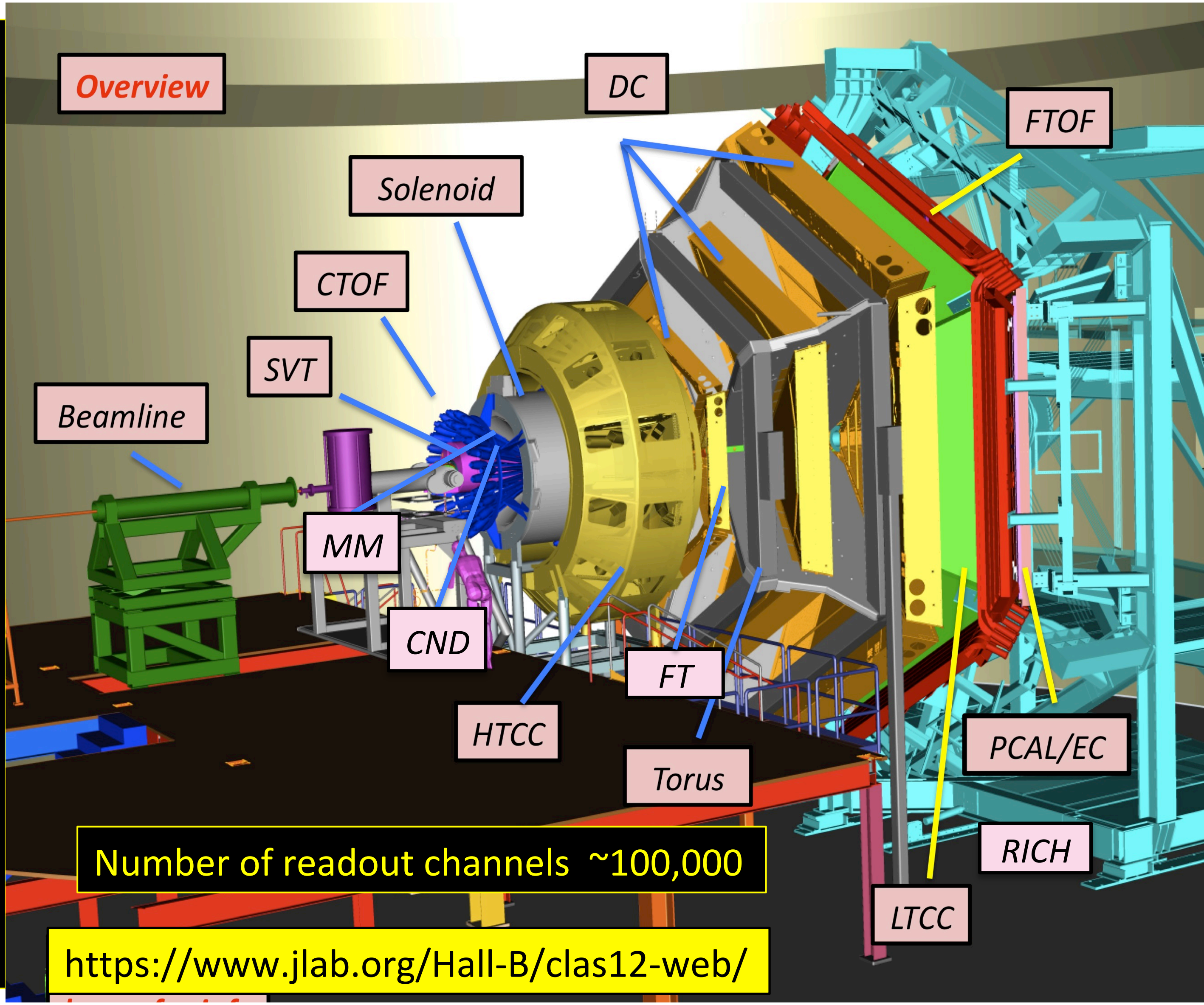


CLAS12 Started to take data!

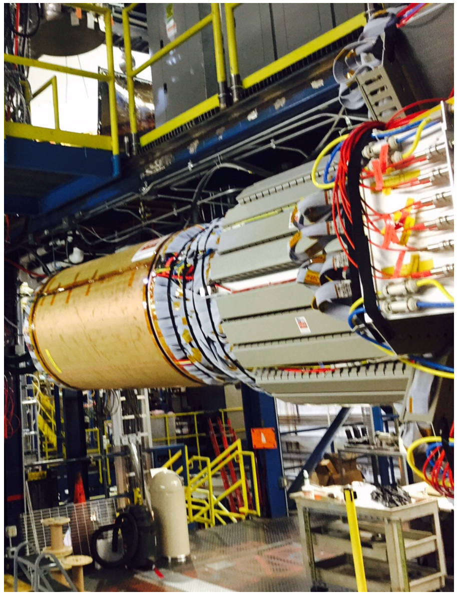
Forward Detector (FD)
- TORUS magnet
- HT Cherenkov Counter
- Drift chamber system
- LT Cherenkov Counter
- Forward ToF System
- Pre-shower calorimeter
- E.M. calorimeter
- Forward Tagger
- RICH detector

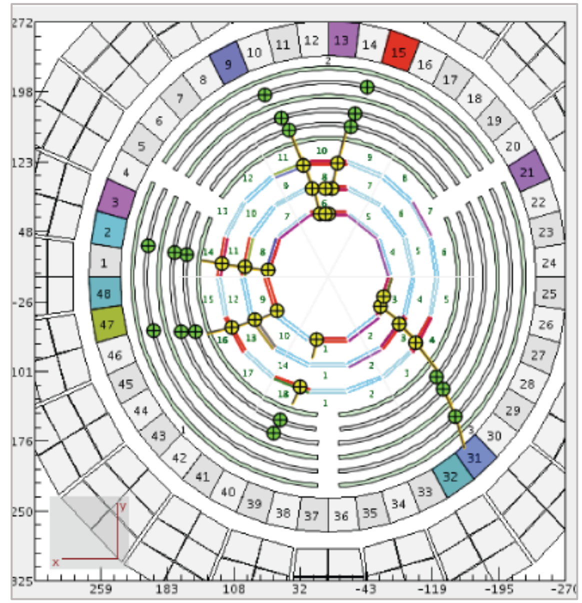
Central Detector (CD)
- Solenoid magnet
- Silicon Vertex Tracker
- Central Time-of-Flight
- Central Neutron Detector
- MicroMegas tracker

Beamline
- Photon Tagger Dump
- Shielding
- Targets
- Moller Polarimeter
- Faraday Cup



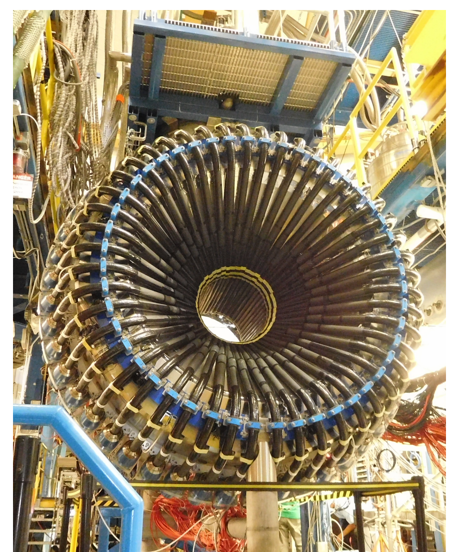
Central Vertex Detector





Central Neutron Detector

Central TOF



CLAS12

HT Cherenkov Counter

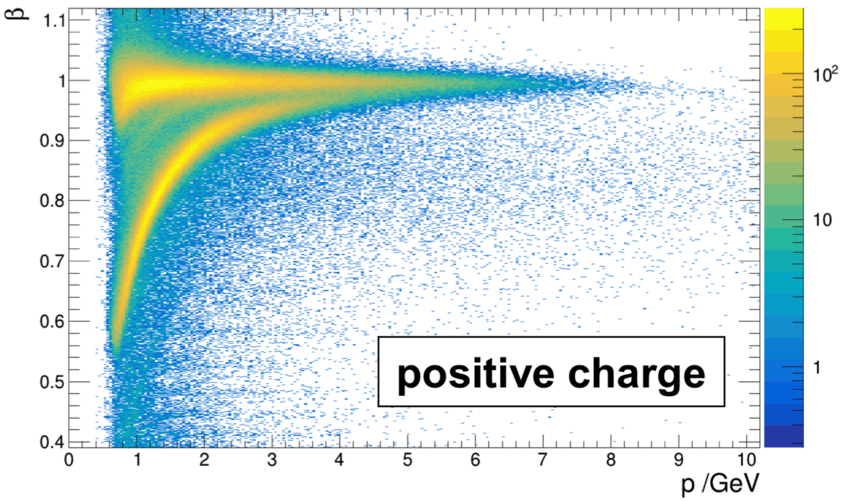
- Particle ID
- Electron trigger

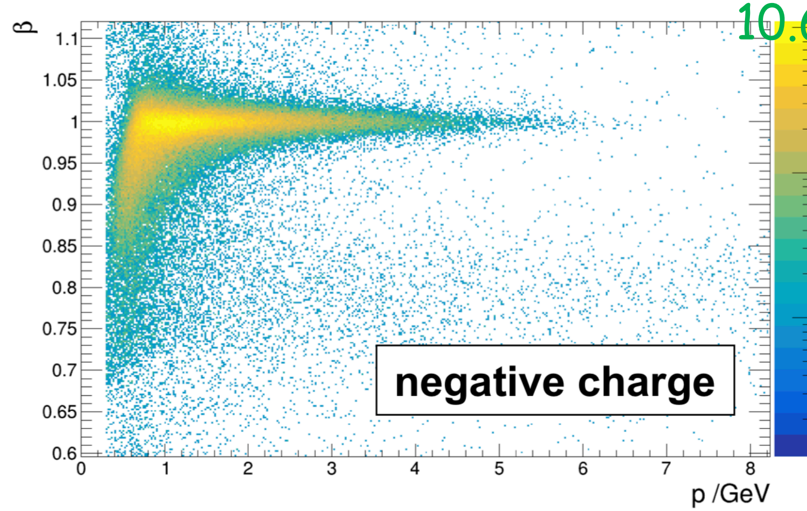
360° seamless coverage in azimuth
Radiator Gas: CO_2

CLAS12

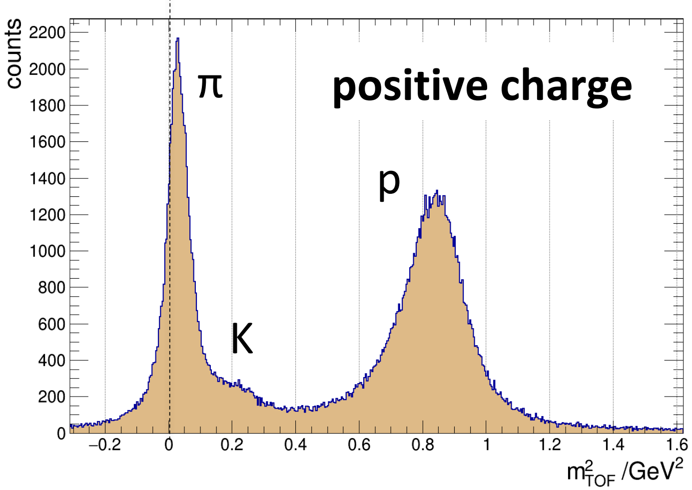
Forward TOF

10.6 GeV

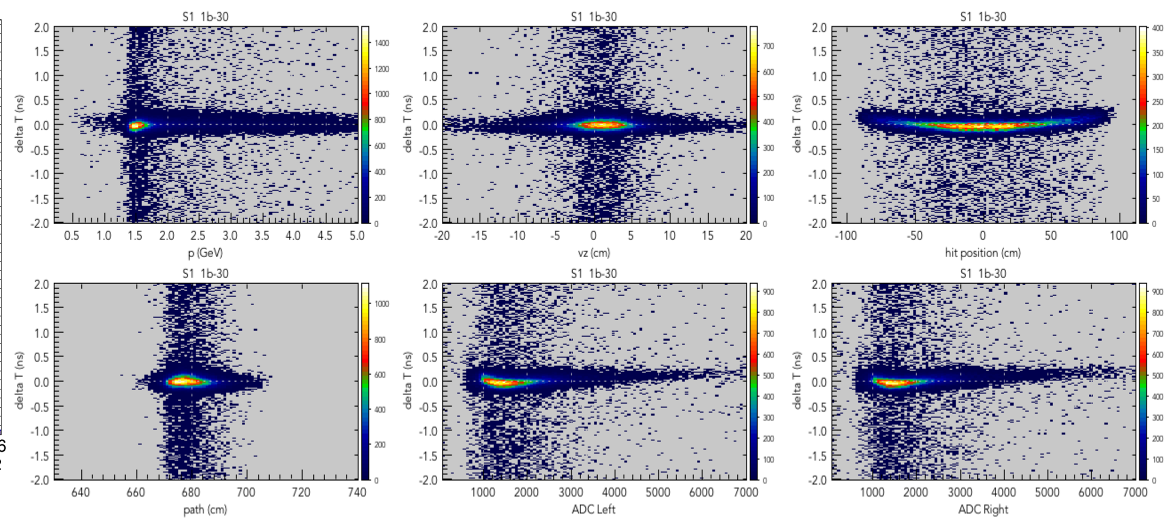




δT within 20% of specs



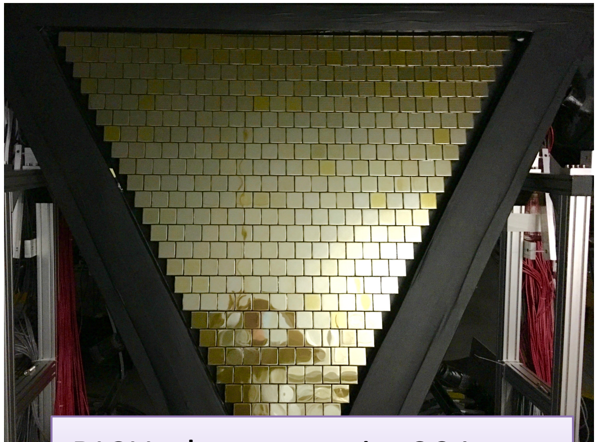
Timing Calibration "Checkplots" for one counter



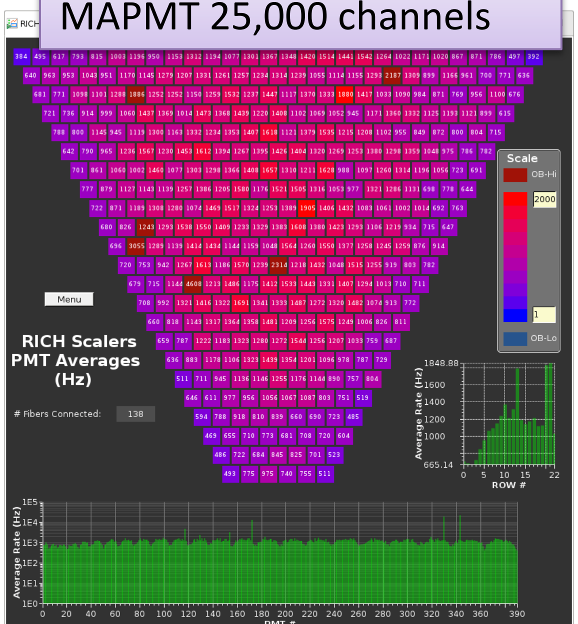
CLAS12 RICH Detector

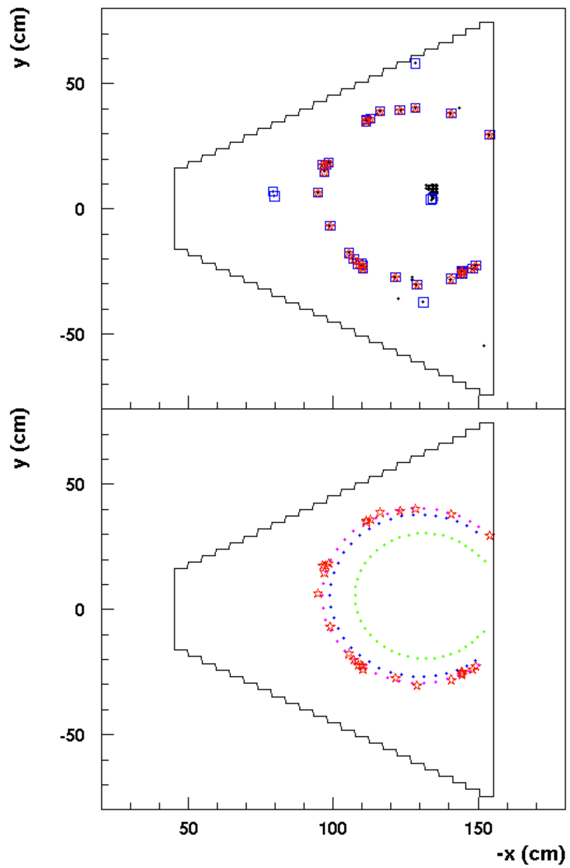
Radiator: Aerogel tiles, Photon detectors: MAPMTs

- RICH took data during entire RGA production runs
- 25,000 channels were calibrated using laser stand
- RICH is using equalized gains for each pixel at 1000V



RICH photo matrix, 391 MAPMT 25,000 channels



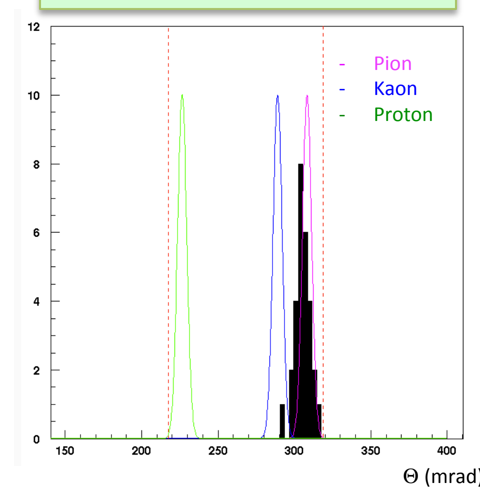


CLAS12 event

P=4.3 GeV/c

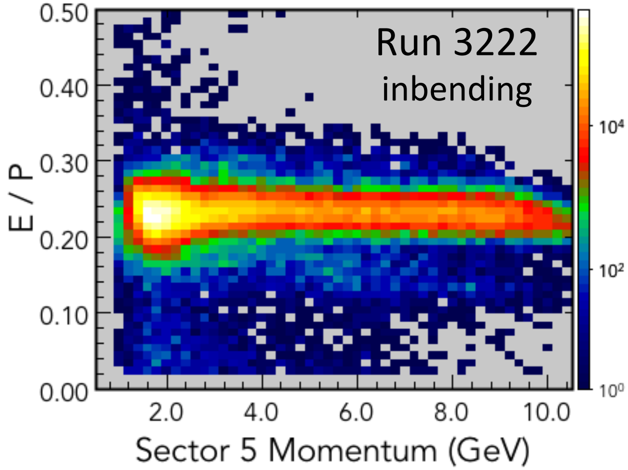
FTOF PID - π

RICH PID - π

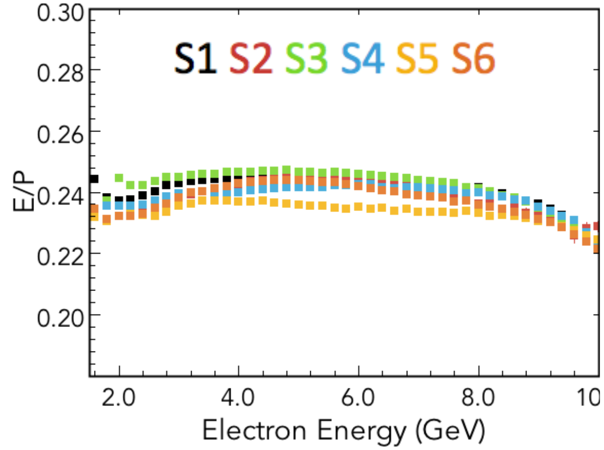


CLAS12 Electromagnetic Calorimeter

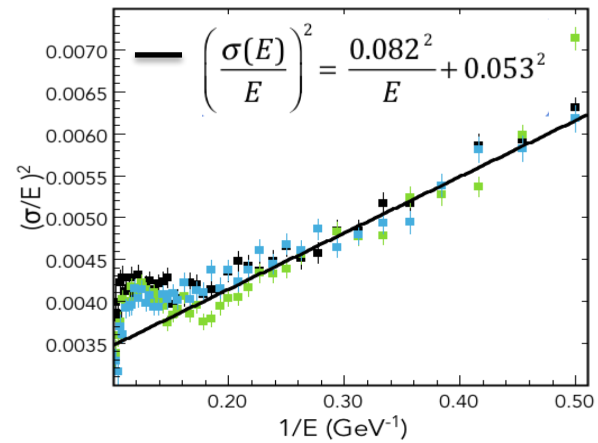
Electron Identification



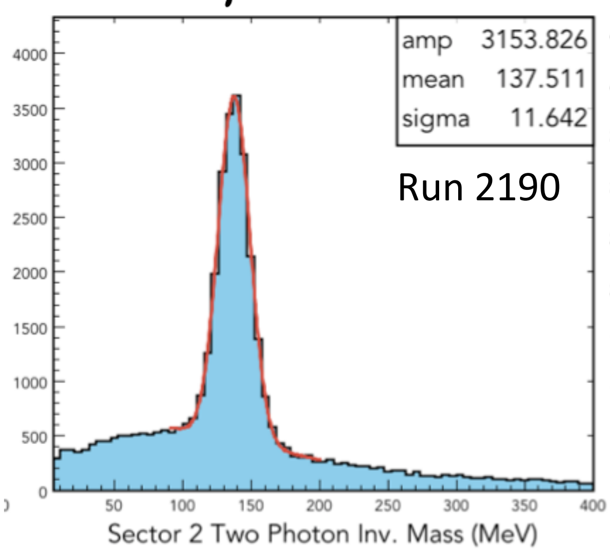
Calibration



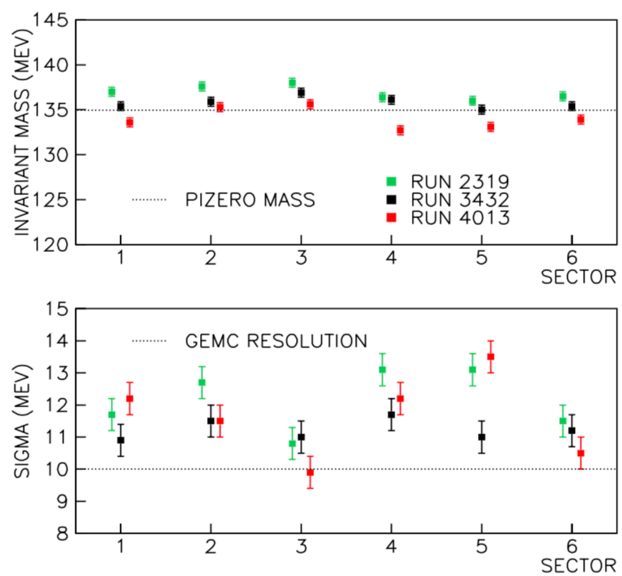
Resolution



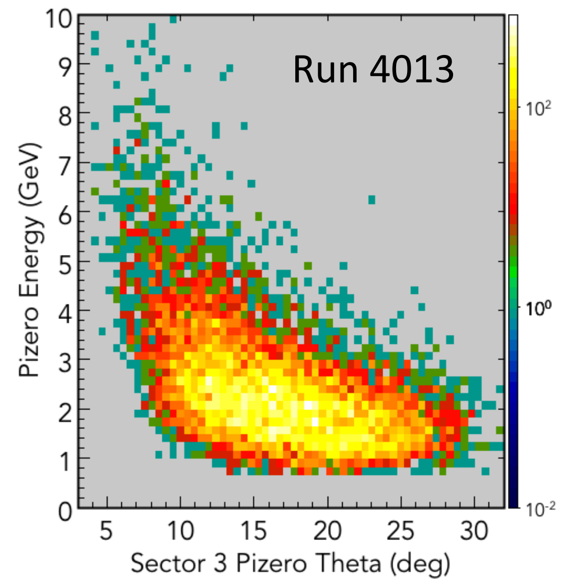
$\pi^0 \to 2\gamma$ Reconstruction



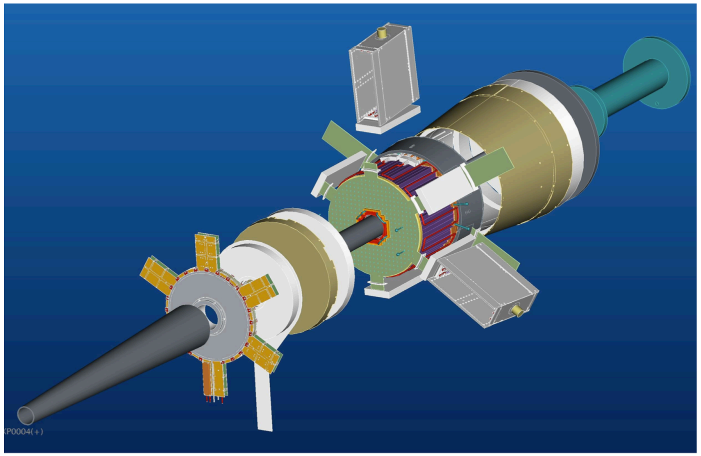
Fits to Invariant Mass Peaks



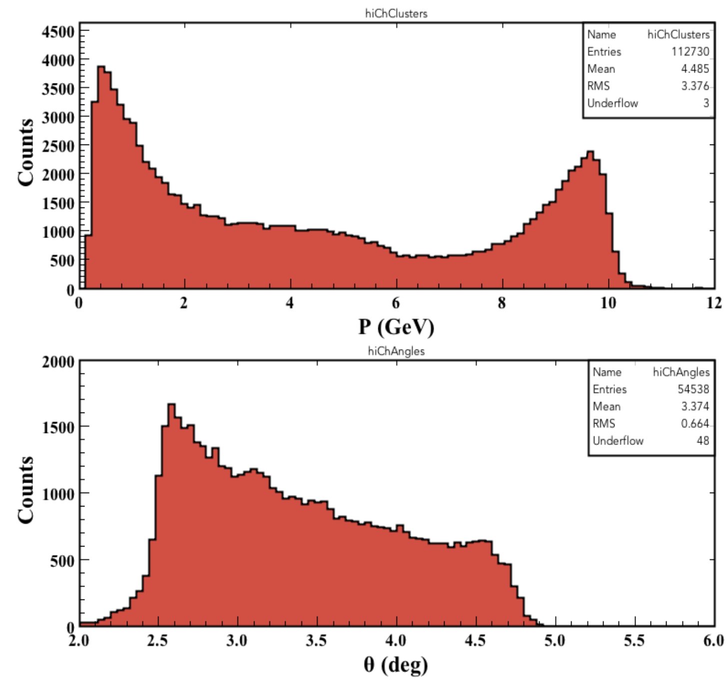
Kinematics



Forward Tagger



Charged Cluster E and θ ranges



Performance	Expected Value	Measured Value
Azimuthal angular coverage	2.5° to 4.5°	2.6° to 4.6°
EM shower energy range	(0.5-8) GeV	(0.3 – 9.5) GeV
Energy resolution	$\sigma_E/E \leq 2\%/\sqrt{E} \oplus 1\%$	3.3% @ 2 GeV
Angular resolution	$\sigma_\theta/\theta \leq 1.5\%$, $\sigma_\phi \leq 2°$	tbd
Time resolution	≤ 300 ps	<200 ps

- Energy and angular acceptance match or exceed design ranges

- Extends capability to detect electrons and photons at small angles down to 2.5°
- Lead tungstate $PbWO_4$ electromagnetic calorimeter, provide fast trigger decision
- Scintillator hodoscope to separate electrons/photons
- Tracker to measure the scattering electron angle

CLAS12 trigger

- ***Inclusive electron scattering trigger***

High Threshold Cherenkov Counter

Drift Chambers track reconstruction

Electromagnetic calorimeter

- ***Photoproduction trigger (FT trigger)***

Forward Tagger (FT) and Hodoscope, cluster funding is used to determine the electron energy and coordinate

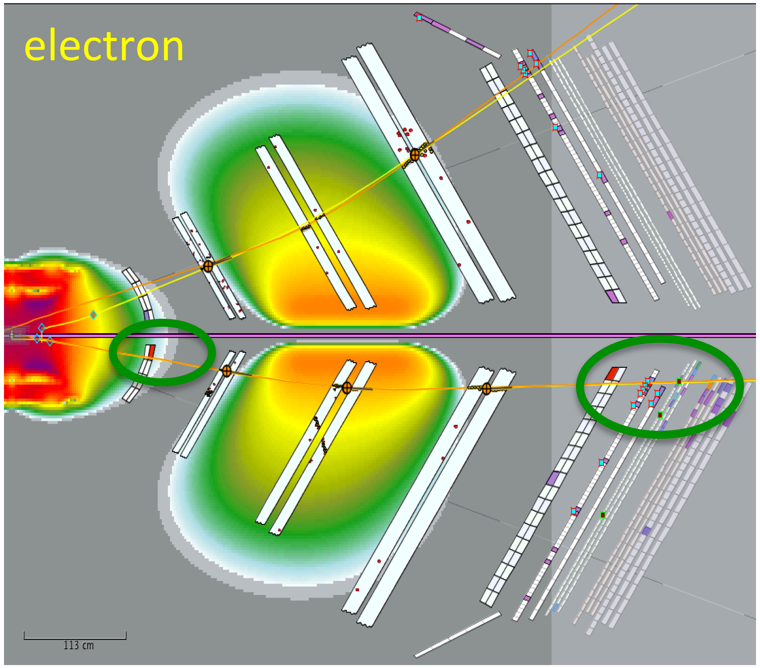
Charge particles in the Forward and Central Detectors.

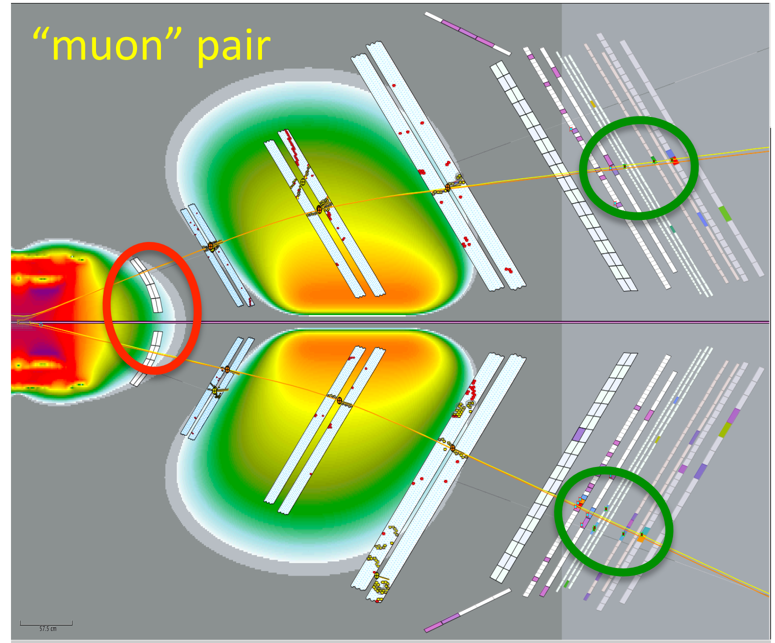
- ***"Muon" trigger***

Select events with two muons detected in the Forward Detectors ONLY. This trigger does not require to detect scattered electron.

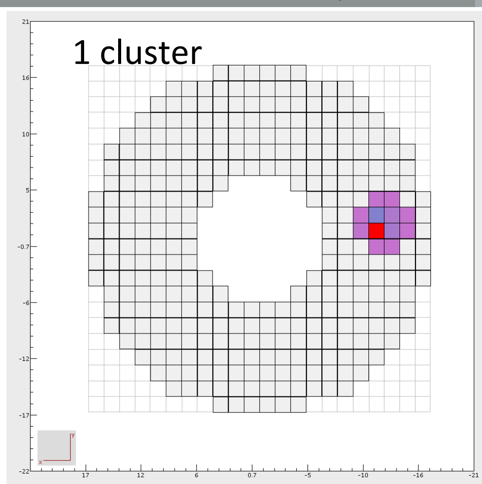
CLAS12

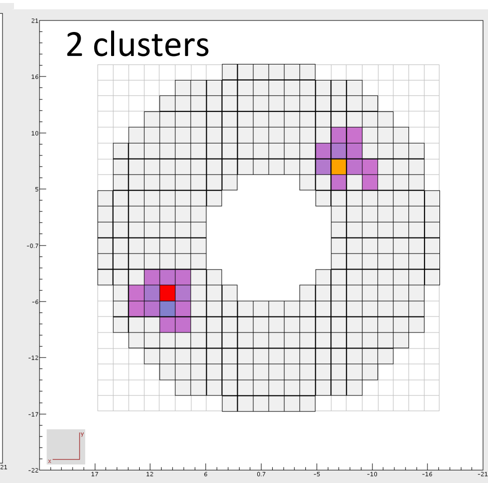
Event based triggers



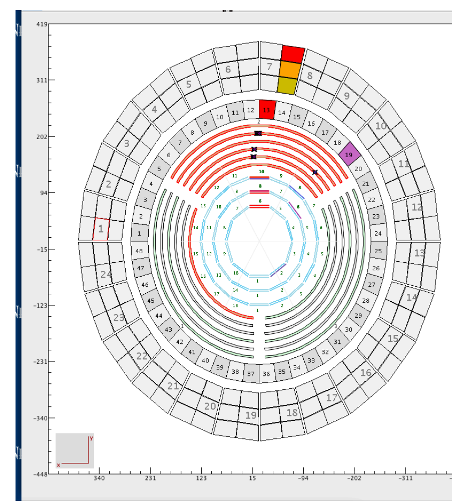


FT-CAL Trigger





CD - CTOF

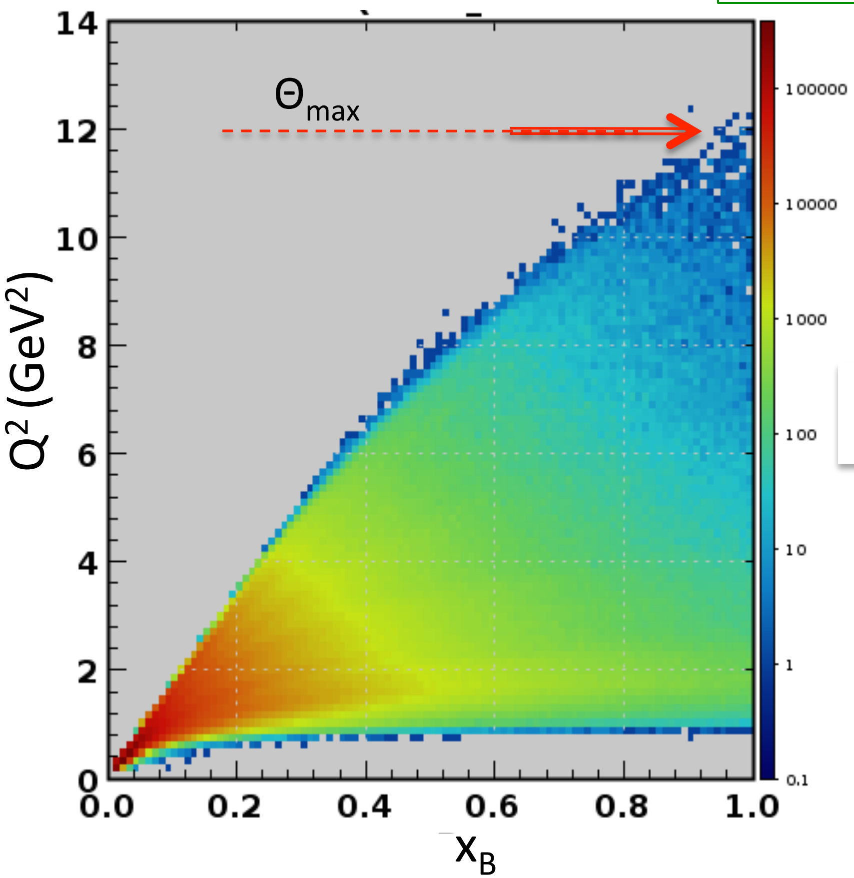


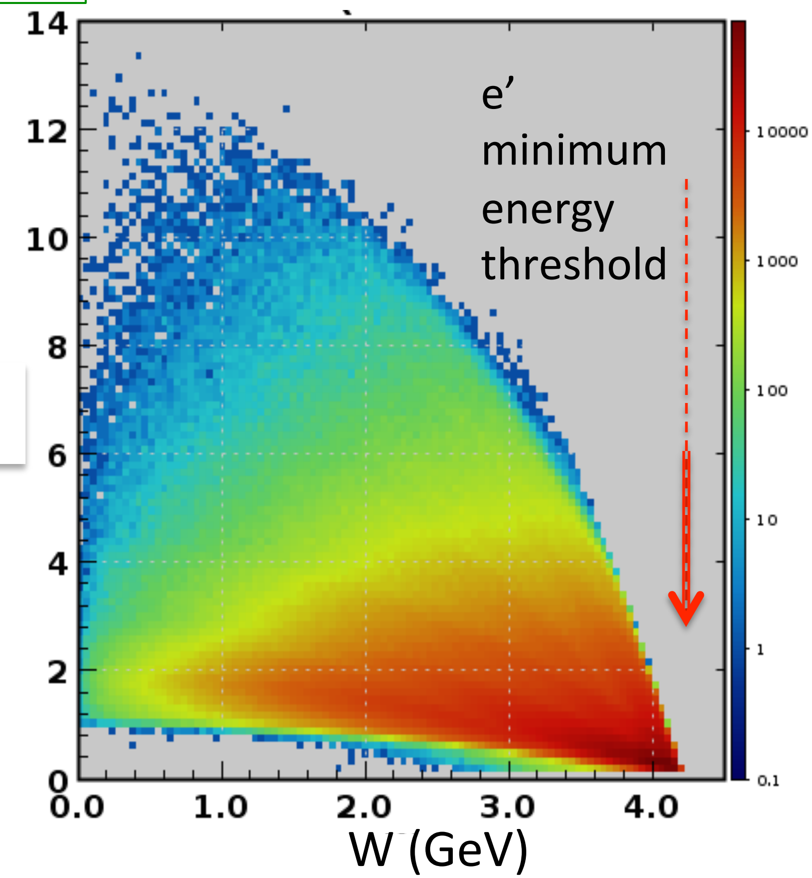
Kinematic reach

CLAS12

Beam energy at 10.6 GeV Torus current 3770 A, electrons out-bending, Solenoid magnet at 2416 A.

p(e,e')X





Future developments

- CLAS12 took data this year with proton target and will continue taking data in the same configuration this fall. Next in a queue – deuteron target.

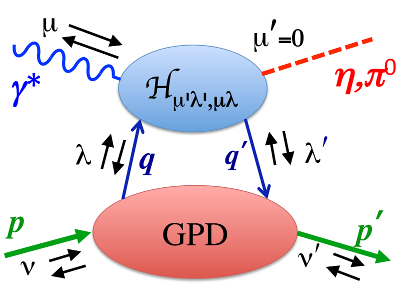
- Cross sections:
  - $ep \to ep(\pi^0, \eta)$
  - $en \to en(\pi^0, \eta)$
  - $ep \to e\pi^+ n$
  - $ep \to eK^+ \Lambda$

- Asymmetries:
  - A_{LU} – *beam spin*
  - A_{UL} – *target spin*
  - A_{LL} – *beam target*

Summary

- Jlab π^0 and η data supports the dominance of the transversity GPDs H_T and $\bar{E}_T$ in the processes of the pseudoscalar meson electroproduction
- The combined π^0 and η, proton and neutron data provide the way for the flavor decomposition of transversity GPD
- The density distributions of the polarized u and d quarks in an unpolarized proton were extracted with the GPD model parameters that describes CLAS π^0 and η data
- The measurement of deeply virtual exclusive pseudoscalar meson production uniquely measures transversity GPDs, and has already begun to access their underlying polarization distributions of quarks in the nucleon.
- The brand new CLAS12 detector began to take data with 10.6 GeV electron beam. The data analysis is in progress. Stay tuned!

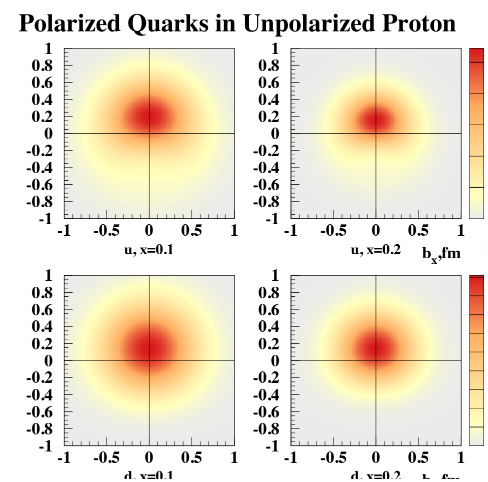
The End



μ
μ′=0
γ*
η,π0
Hμ'λ',μλ
λ
q
q′
λ′
p
GPD
p′
ν
ν′

+

=



Polarized Quarks in Unpolarized Proton
u, x=0.1
u, x=0.2
bx,fm