Jefferson Lab

First Rosenbluth separation of π^0 electroproduction cross section

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The DVCS Hall A collaboration

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Irfu CEA - Saclay

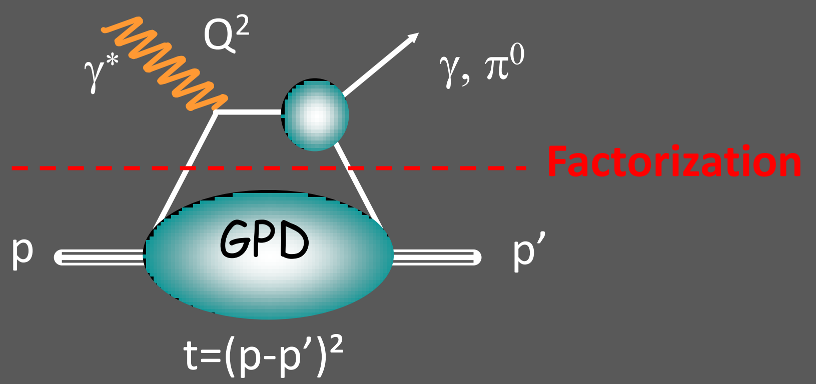
Generalized parton distributions

- GPDs are generalization of form factors and PDF

t_{min} = minimal squared momentum transfer

$t' = t_{min} - t$

$x_B = Q^2/(2M\nu)$

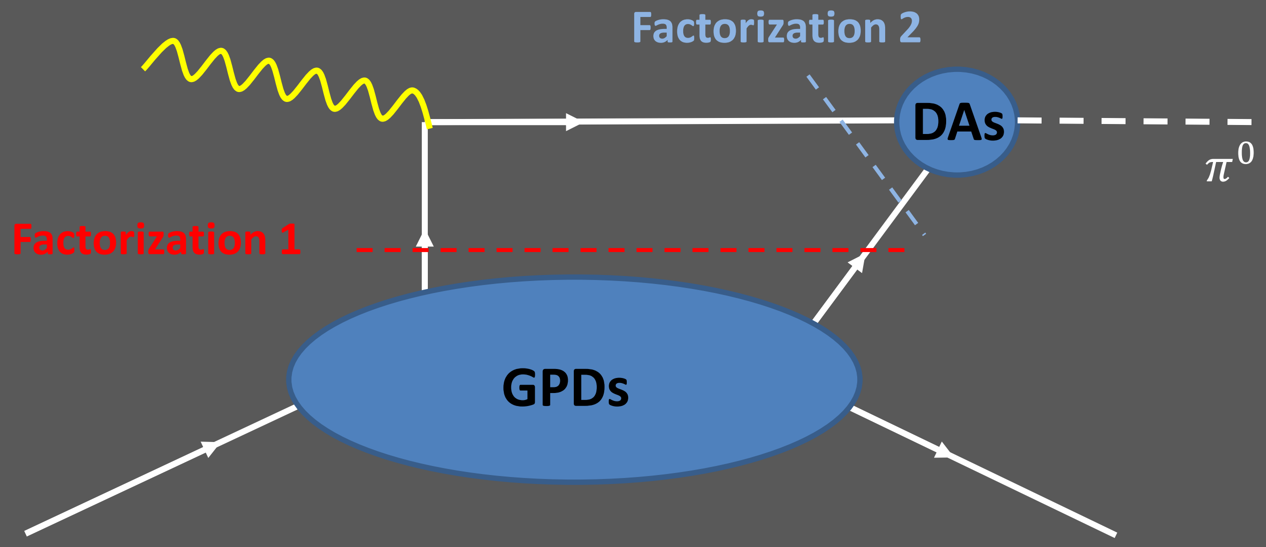


- Applying the factorization to deep exclusive processes:
  - Hard part calculable perturbatively.
  - Soft part encoded in GPDs

(At leading-twist: 4 chiral-odd/ 4 chiral-even)

π^0: another QCD bound state

- Second factorization needed for the pion
  => Distribution amplitude is a second non perturbative object!
  Additional unknown w.r.t. DVCS (Carlos Munoz's talk)



- Product of two twist-expansions!!

GPDs and electroproduction of π^0

For $ep \to ep\pi^0$, with ε degree of longitudinal polarization of the photon:

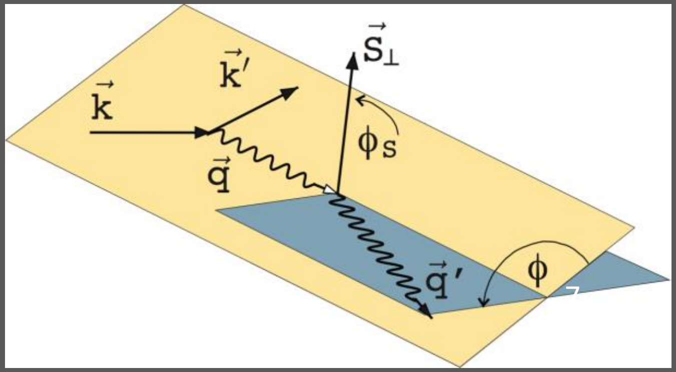
$$\frac{d\sigma}{dt} = \frac{d\sigma_T}{dt} + \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_{TL}}{dt} \sqrt{2\varepsilon\,(1+\varepsilon)}\cos(\Phi) + \frac{d\sigma_{TT}}{dt}\varepsilon\cos(2\Phi)$$

- σ_T and σ_L responses to a transversely/longitudinally polarized virtual photon

- σ_{TT} and σ_{TL} interferences between the responses.

At leading-twist (tw-2 GPDs and tw-2 DA), only longitudinal responses!

σ_L very small (GPD $\tilde{H}$, $\tilde{E}$)



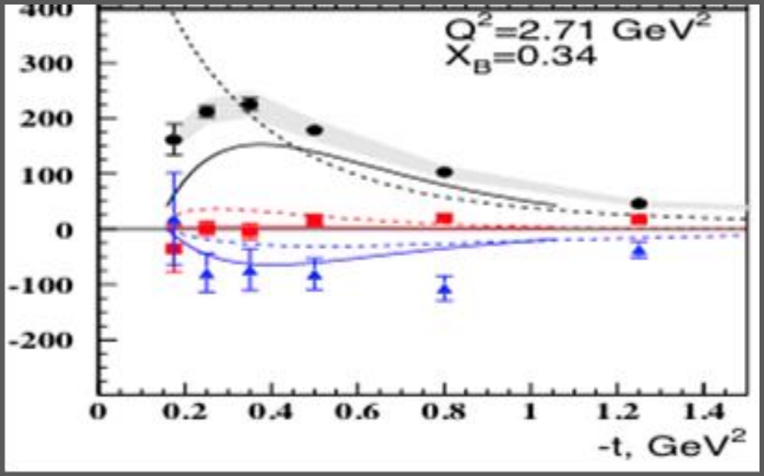
Results of π^0 electroproduction

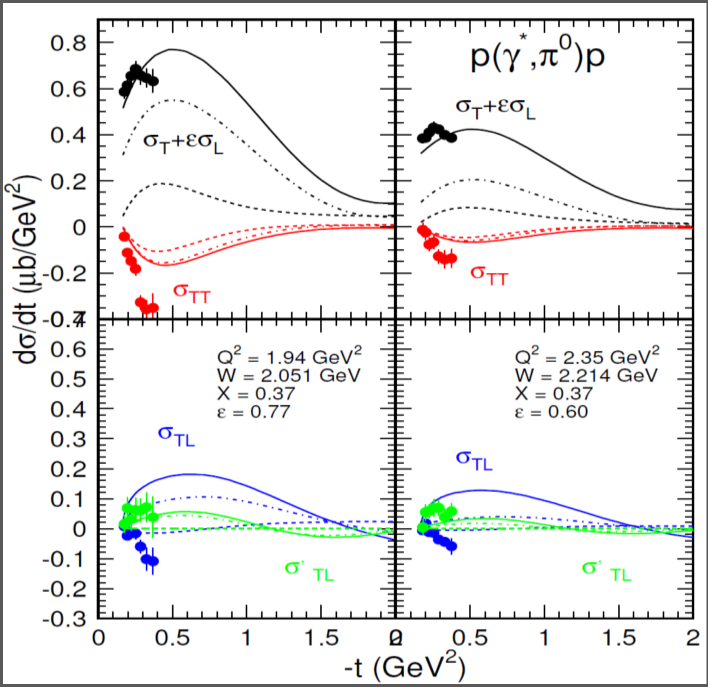
For $ep \rightarrow ep\pi^0$

$$\frac{d\sigma}{dt} = \frac{d\sigma_T}{dt} + \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_{TL}}{dt}\sqrt{2\varepsilon\,(1+\varepsilon)}\cos(\Phi) + \frac{d\sigma_{TT}}{dt}\varepsilon\cos(2\Phi)$$

Surprising results from Hall A and CLAS:

Very significant contribution $\frac{d\sigma_T}{dt} + \varepsilon \frac{d\sigma_L}{dt}$





[1]: CLAS Collaboration, Bedlinskiy et al., Phys.Rev.C.90 (2014)

[2]: Fuchey et al., Phys.Rev.C.83 (2011)

Transversity GPDs at twist 3

- Twist-2 Chiral odd GPDs must couple to chiral odd DAs which are twist-3 DAs.

Ahmad, et al. PRD79,(2009); Goldstein, Osvaldo Gonzalez Hernandez, Liuti arXiv:1401.0438

- Although kinematically suppressed w.r.t. to twist-2, twist-3 DA contributions enhanced by:

$$\frac{m_\pi^2}{m_u + m_d}$$

According to Goloskokov and Kroll model, we have:

$$\frac{d\sigma_{TT}}{dt} \propto |\langle \bar{E}_T \rangle|^2$$

$$\frac{d\sigma_{T}}{dt} \propto (1-\xi^2)|\langle H_T \rangle|^2 - \frac{t'}{8M^2}|\langle \bar{E}_T \rangle|^2$$

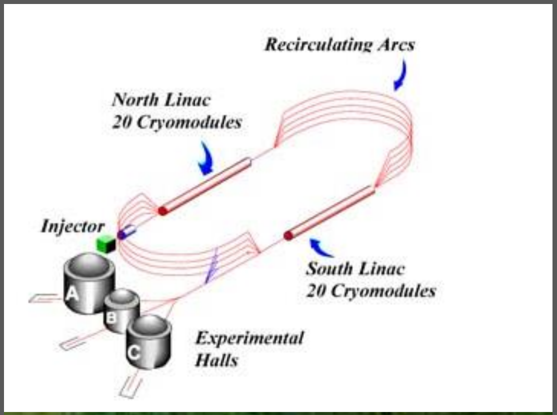
$\Rightarrow$ **Direct access to transversity GPDs (H_T, H_T, E_T)**

- Rosenbluth separation to evaluate L/T contributions

Goloskokov, Kroll, Transversity in hard exclusive electroproduction of pseudoscalar mesons, Eur. Phys. J. A, **47**:112 (2011)

Thomas Jefferson National Accelerator Facility

- The E07-007 experiment ran from October to December 2010 at JLab – Hall A
- Provides a continuous polarized electron beam to three (soon four) experimental halls.
- Maximum beam current: 200 μA
- All the halls are running experiments on fixed targets (Here it is liquid hydrogen).
- Spring 2014, first electrons at 10 GeV sent in CEBAF.



Experiment design

$$e\,p \rightarrow e\,(p)\;\gamma\gamma$$

Pion identification with invariant mass $m_{\gamma\gamma}$

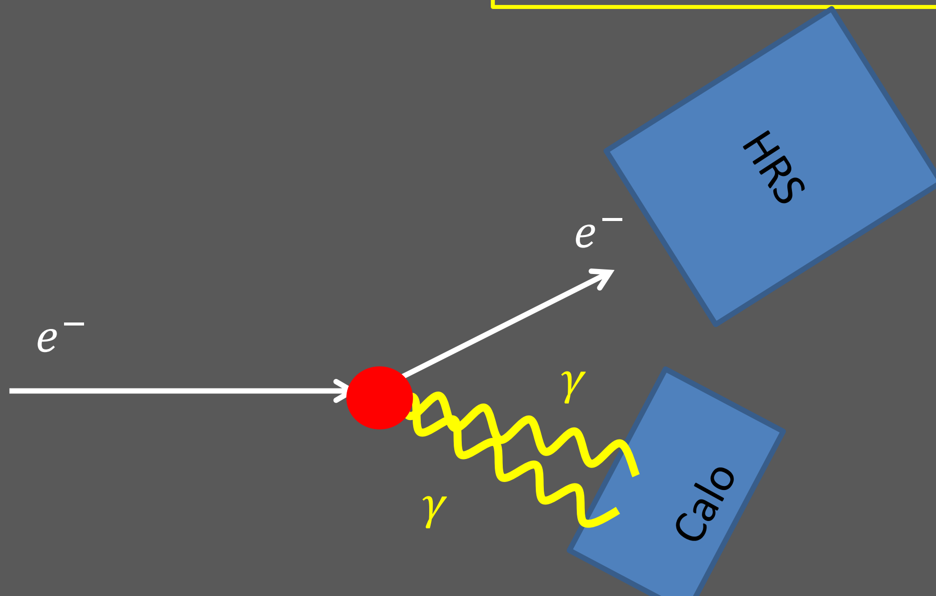
Accuracy on the 4-momentum of the virtual photon

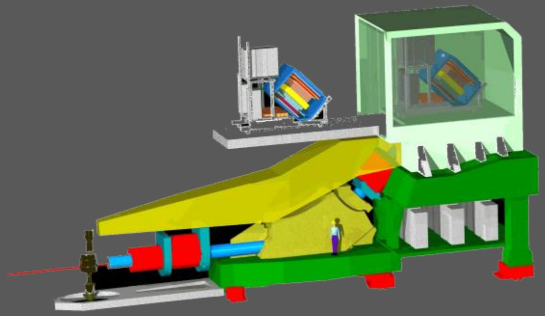
Q^2 , x_B

The direction of the pion is well determined

t , ϕ

Ensure the exclusivity with $M^2_{ep\rightarrow e\pi^0 X}$





E07-007 kinematical settings

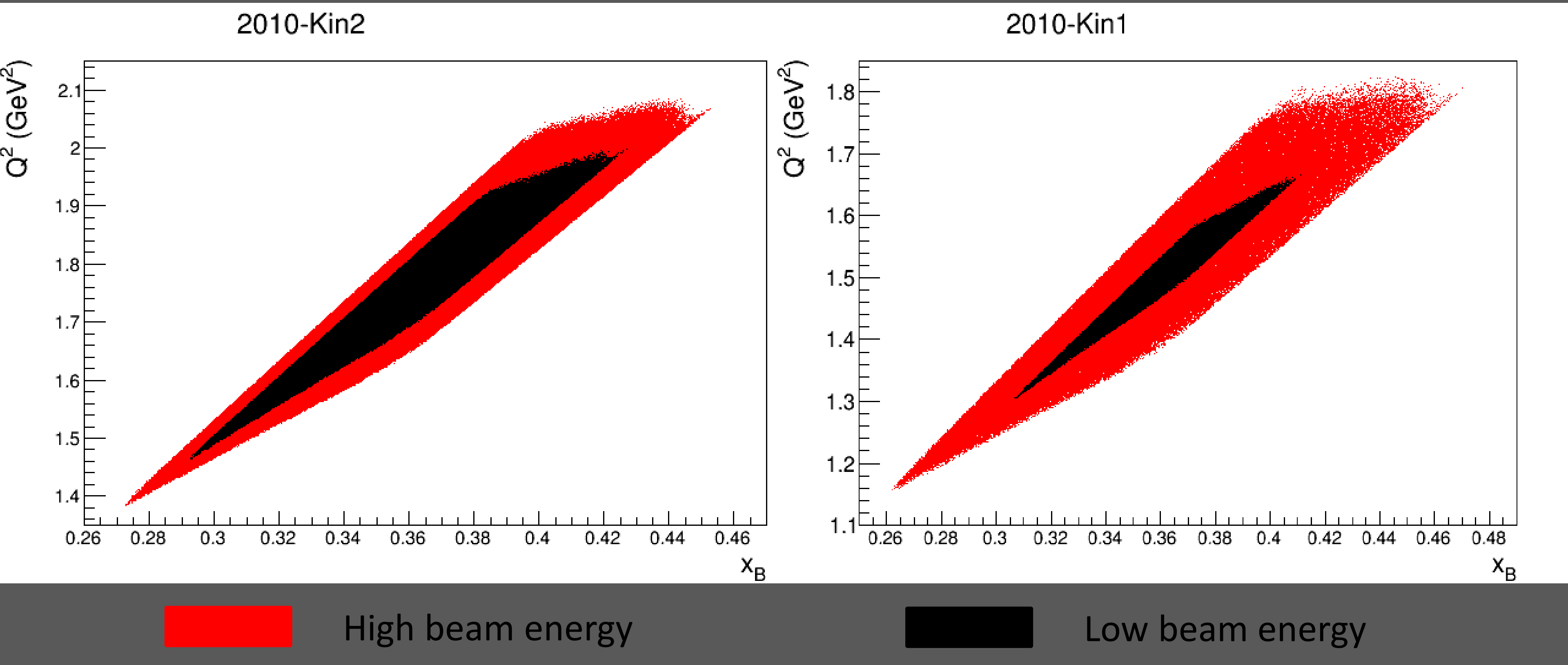
- Rosenbluth separation: Change only ε to perform L/T separation
  Need to extract cross sections at two different beam energies.

$$\frac{d\sigma}{dt} = \frac{d\sigma_T}{dt} + \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_{TL}}{dt}\sqrt{2\varepsilon\,(1+\varepsilon)}\cos(\Phi) + \frac{d\sigma_{TT}}{dt}\varepsilon\cos(2\Phi)$$

x_B	$Q^2\ (GeV^2)$	***beam Energy*** (GeV)	$\boldsymbol{\varepsilon}$
0.36	1.5	(3.355 ; 5.55)	(0.52 ; 0.84)
0.36	1.75	(4.455 ; 5.55)	(0.65 ; 0.79)
0.36	2	(4.455 ; 5.55)	(0.53 ; 0.72)

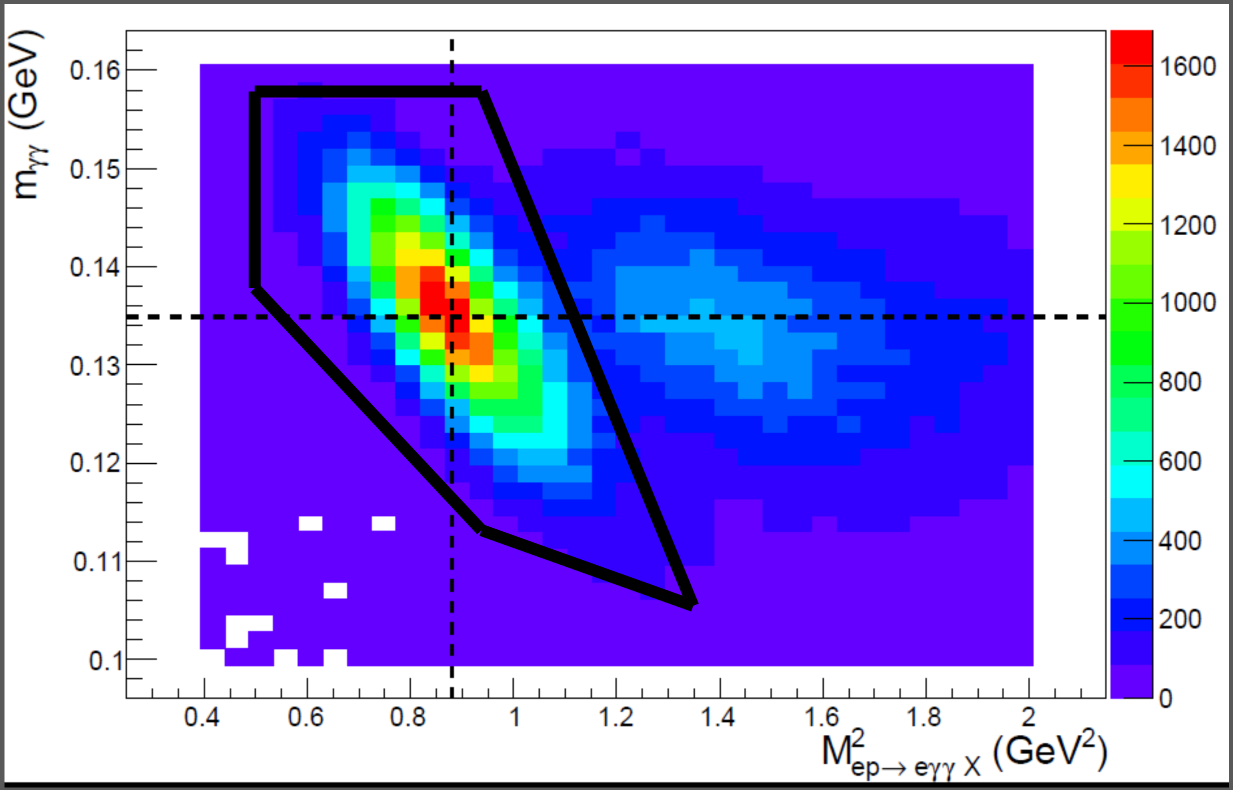
Cuts to select events

- Strong Q^2 dependence of the different responses from Hall A and CLAS results. Need to match low beam energy and high beam energy acceptances of the spectrometer.



Cuts to select events

- Two dimensional cuts on squared missing-mass and invariant mass of the two photons for exclusivity and particle identification.



Local fit procedure and extraction

- Least square fitting procedure: $\chi^2 = \sum_{k=0}^{N_{bin}} \left(\frac{N_k^{exp} - N_k^{sim}}{\sigma_k^{exp}} \right)^2$

$$N_k^{sim} = L \int_{\Phi_k} \frac{d^4\sigma}{d^4\Phi}\, d^4\Phi$$

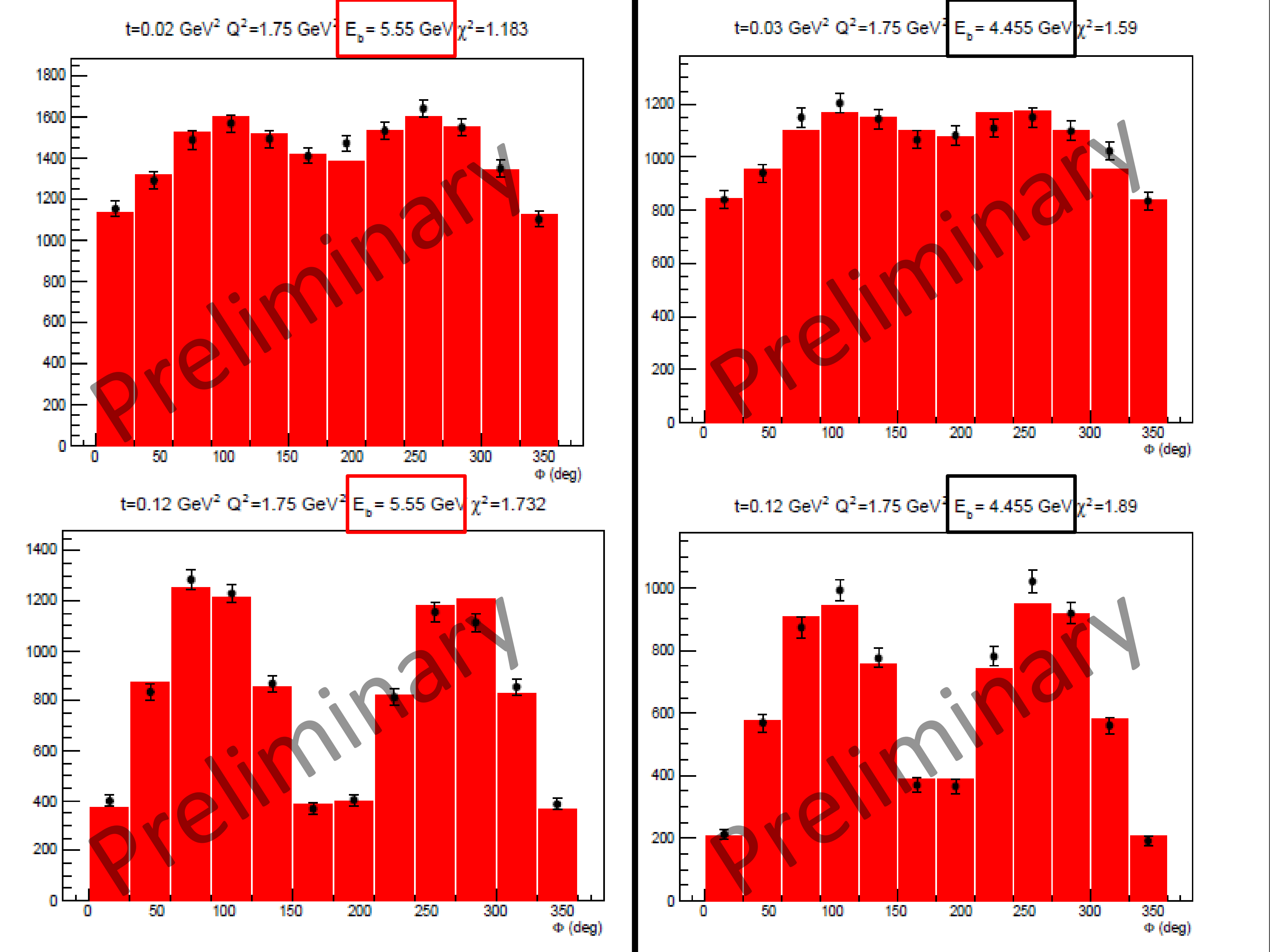
$$d^4\Phi = dQ^2\, dt\, dx_B d\varphi$$

Fit number of counts for both beam energies data set AT THE SAME TIME.

- Using the natural parametrization:

$$\frac{d^4\sigma}{d^4\Phi} = \Gamma(x_B, Q^2, E) \times \left[\frac{d\sigma_T}{dt} + \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_{TL}}{dt} \sqrt{2\varepsilon\,(1+\varepsilon)} \cos(\Phi) + \frac{d\sigma_{TT}}{dt} \varepsilon \cos(2\Phi) \right]$$

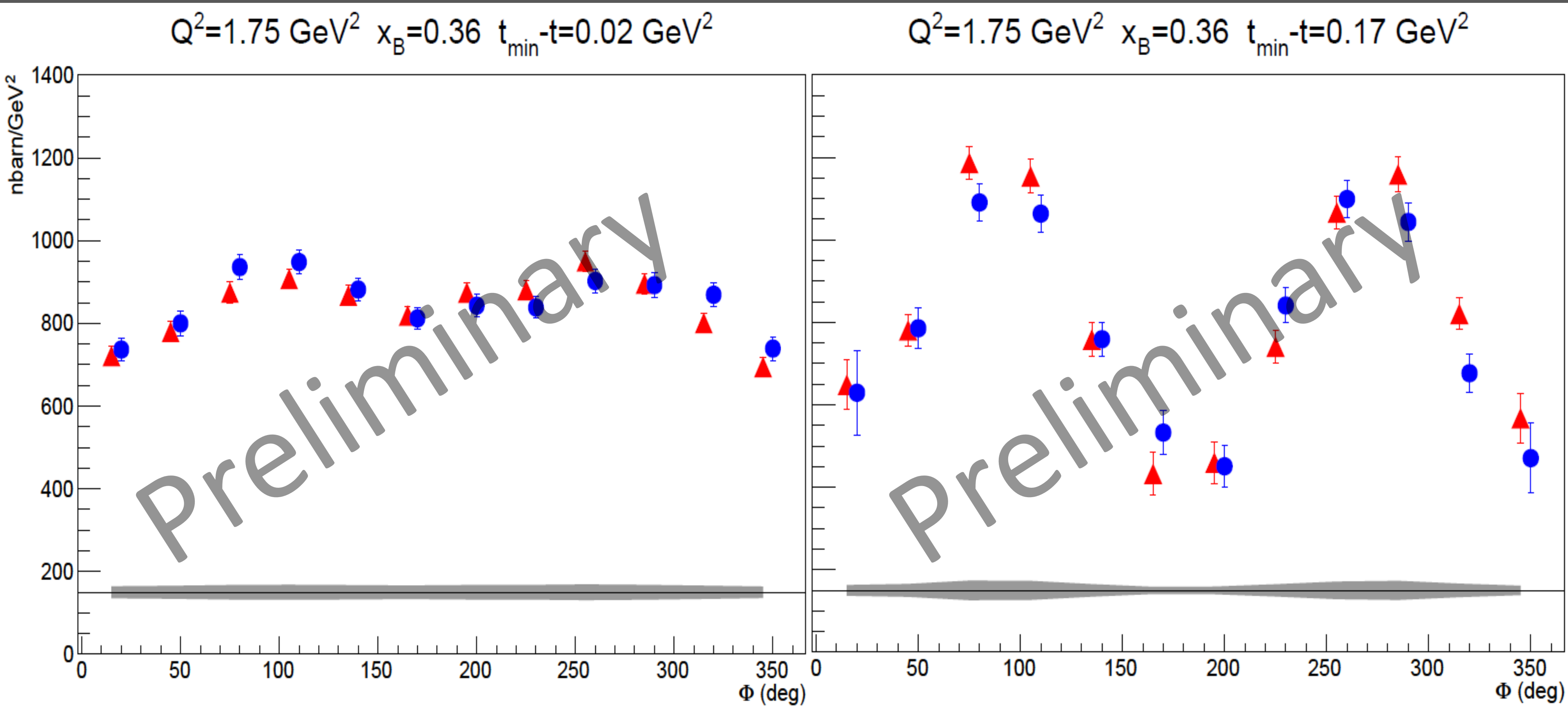
- Use the Monte-Carlo to integrate $\Gamma(x_B, Q^2, E)$ and ε over the spectrometer acceptance



t=0.02 GeV² Q²=1.75 GeV² E_b = 5.55 GeV χ²=1.183
t=0.03 GeV² Q²=1.75 GeV² E_b = 4.455 GeV χ²=1.59
t=0.12 GeV² Q²=1.75 GeV² E_b = 5.55 GeV χ²=1.732
t=0.12 GeV² Q²=1.75 GeV² E_b = 4.455 GeV χ²=1.89
Φ (deg)
Preliminary

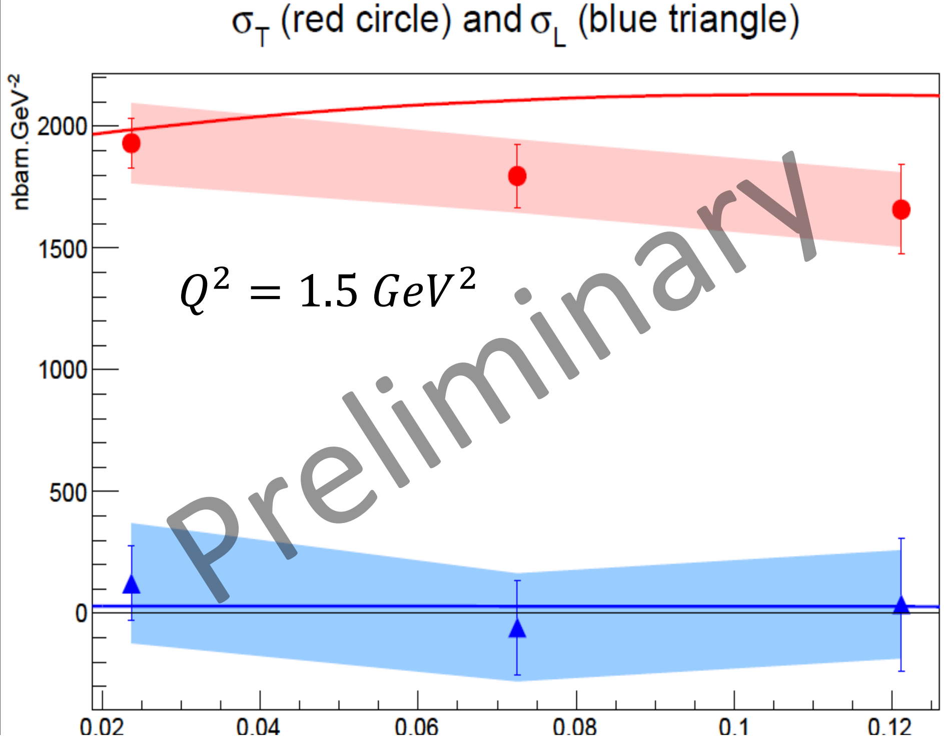
Differential cross sections in t and Φ

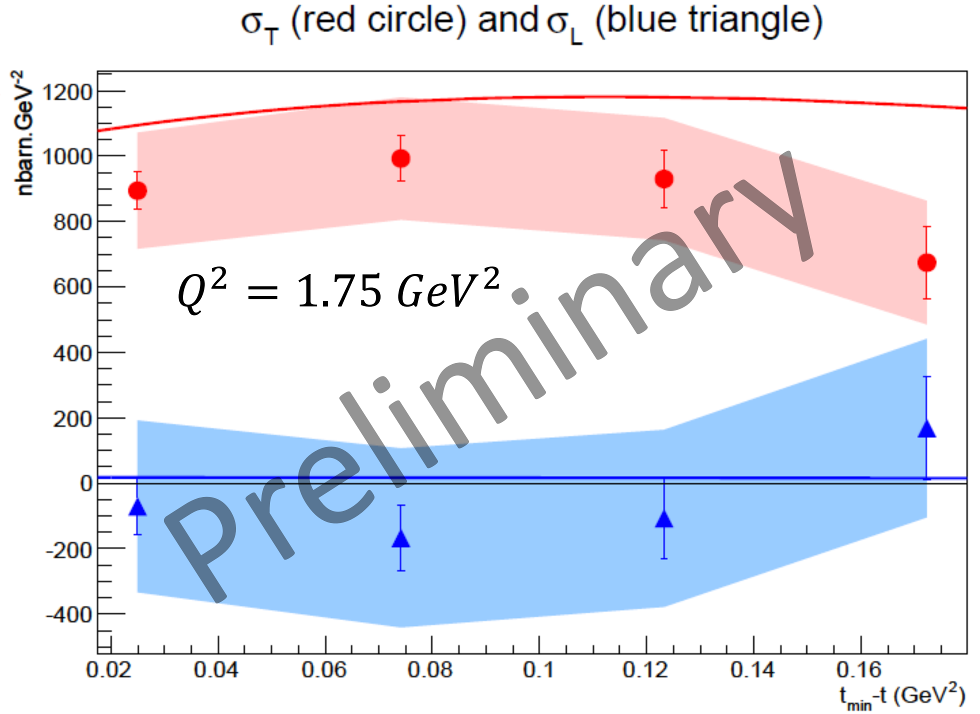
$$\frac{d\sigma}{dt} = \frac{d\sigma_T}{dt} + \varepsilon \frac{d\sigma_L}{dt} + \frac{d\sigma_{TL}}{dt}\sqrt{2\varepsilon\,(1+\varepsilon)}\cos(\Phi) + \frac{d\sigma_{TT}}{dt}\varepsilon\cos(2\Phi)$$

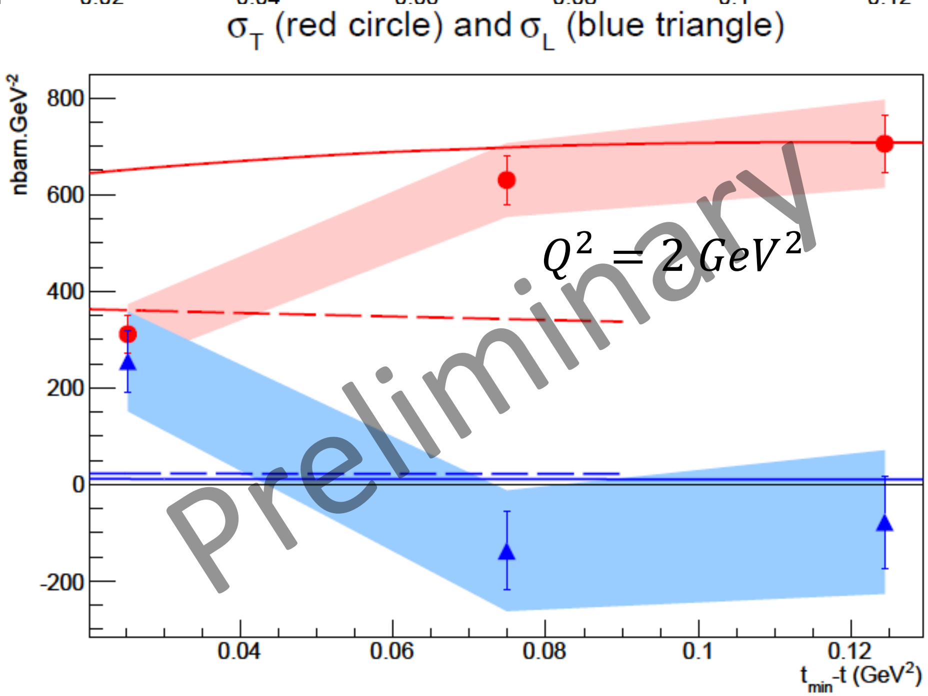


$\varepsilon = 0.65$

$\varepsilon = 0.79$



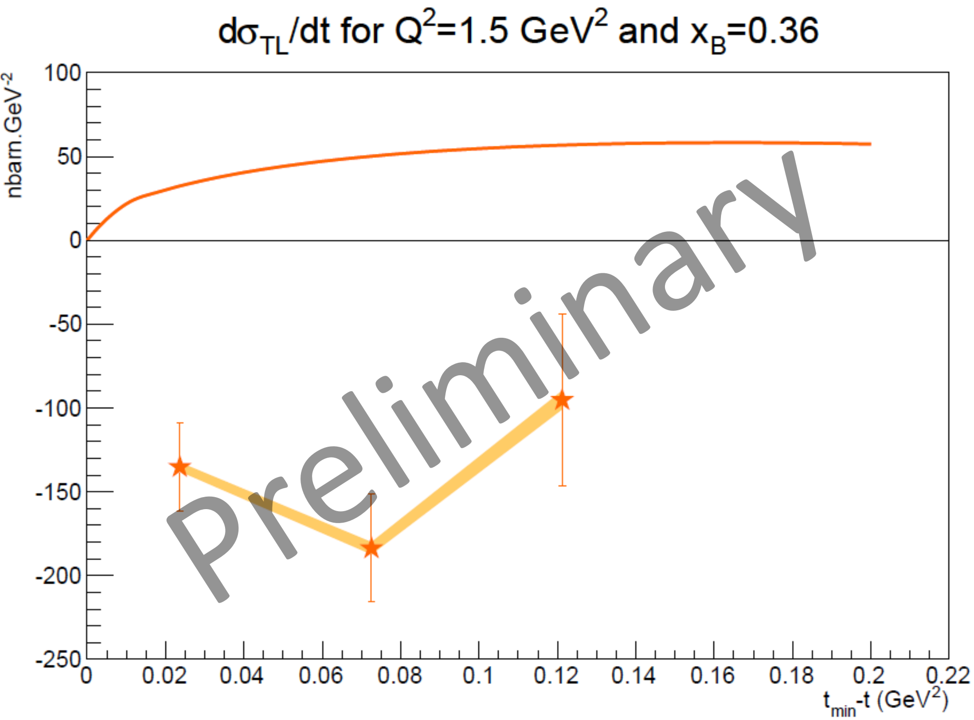


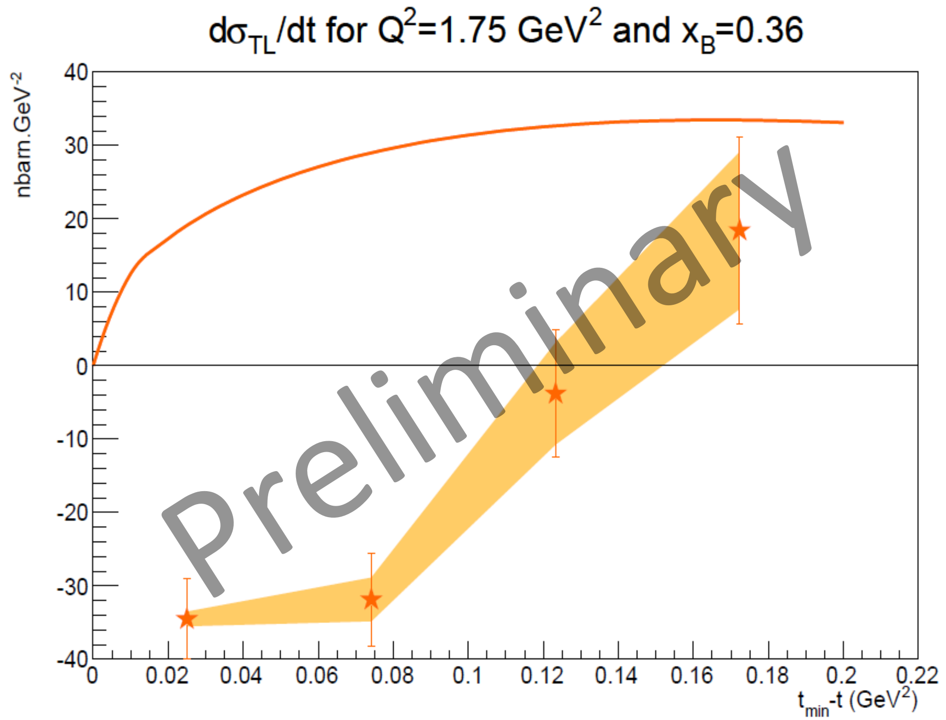


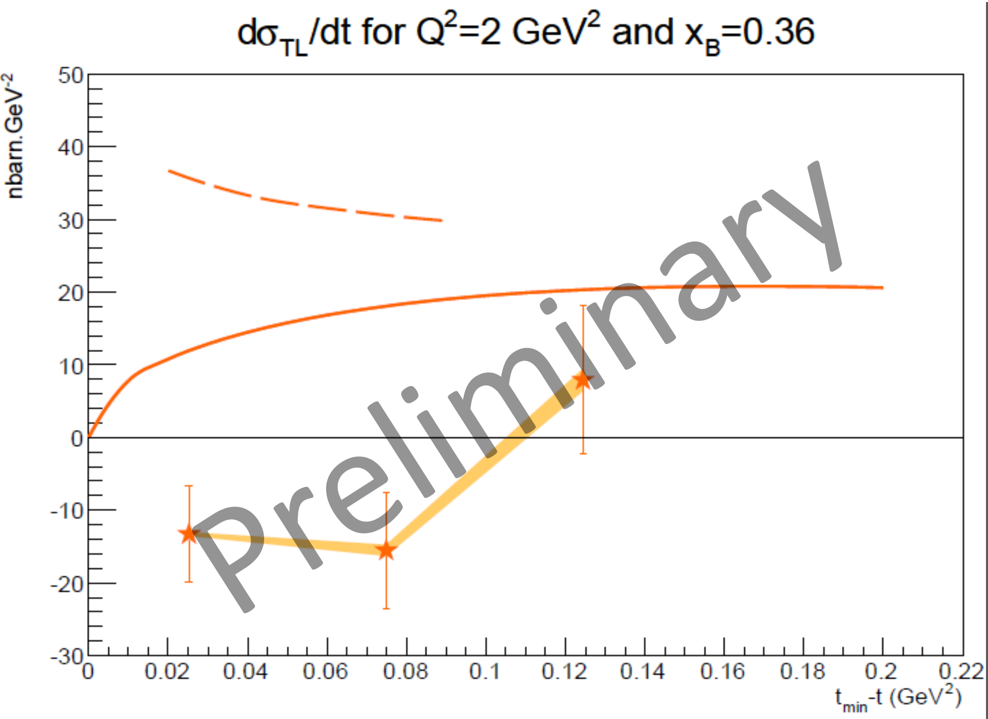
Error band represents 2% normalization error

Full line: Goloskokov et al. model

Dashed line: Liuti et al. model







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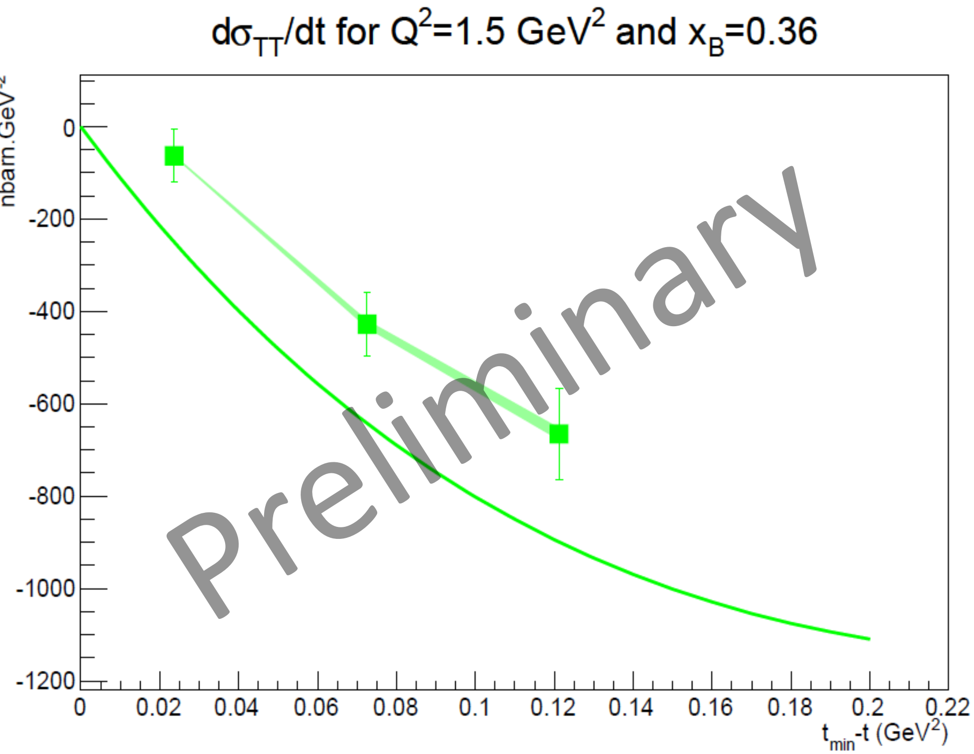

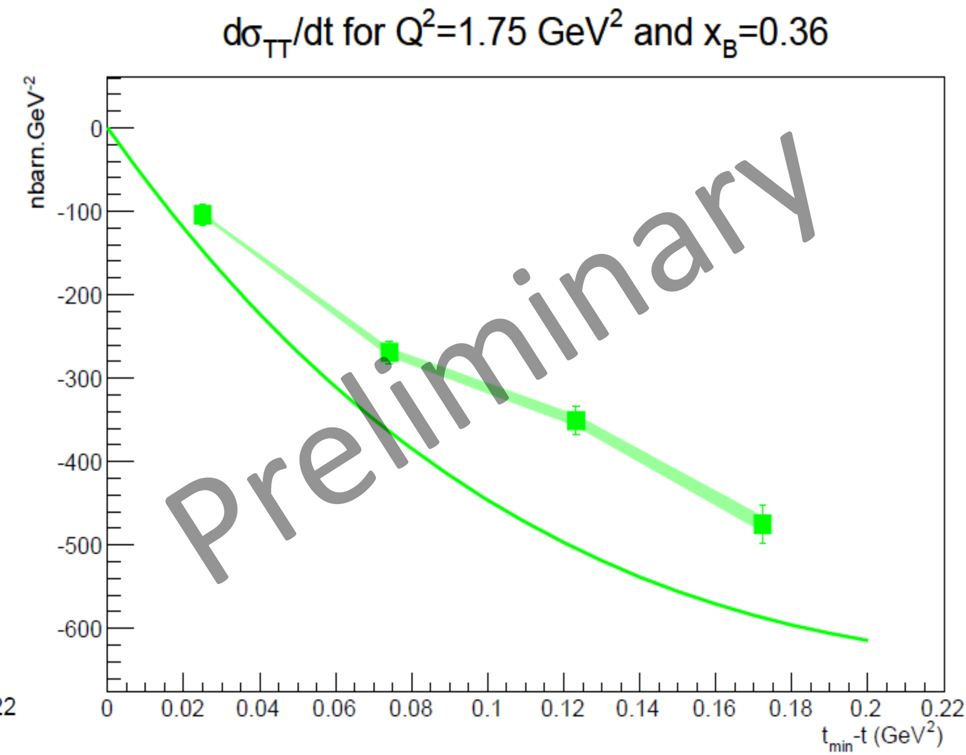

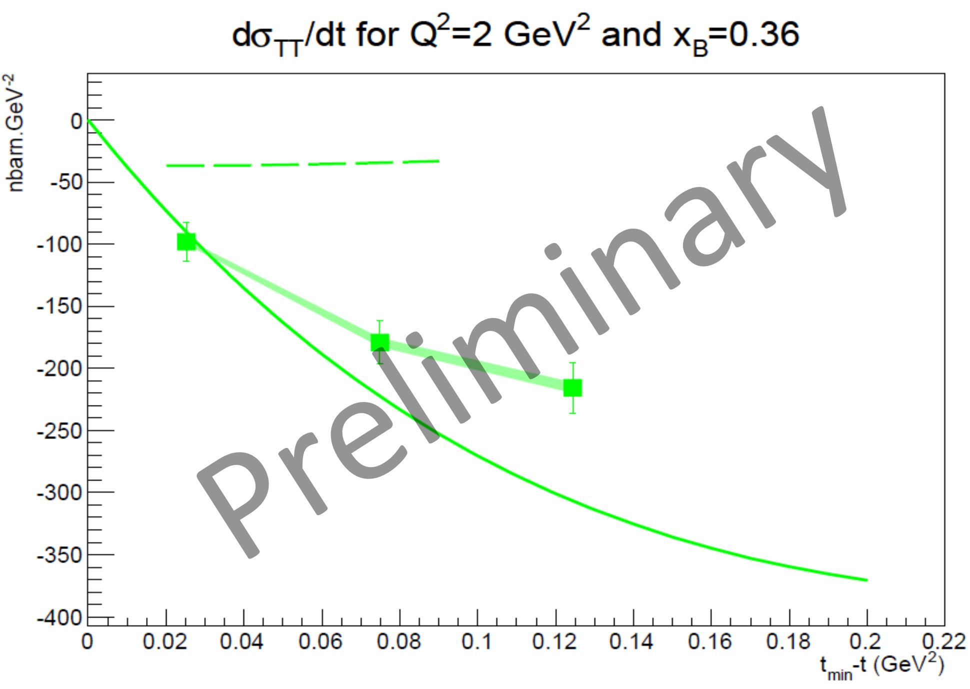

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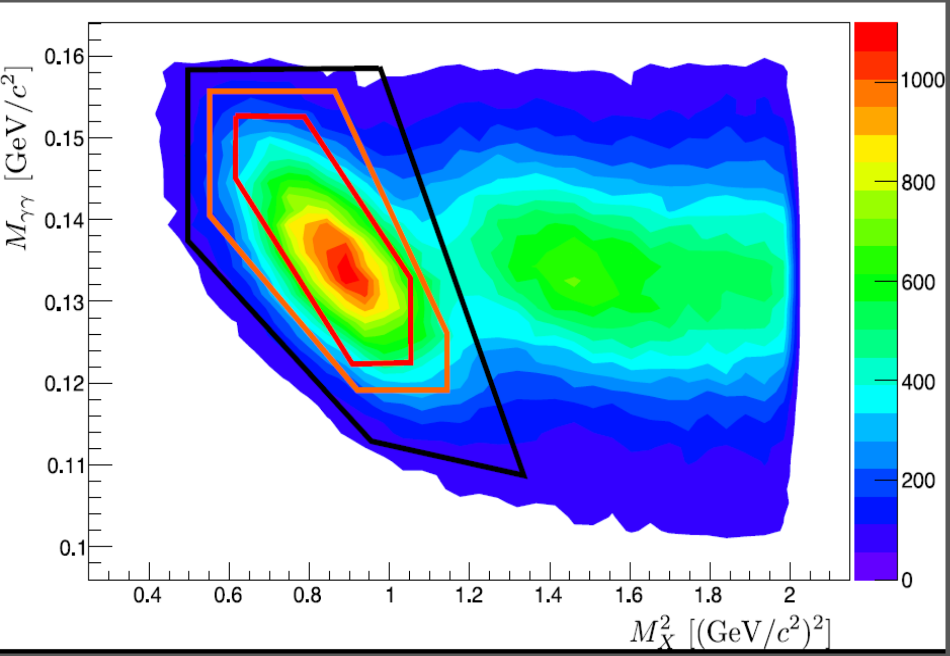
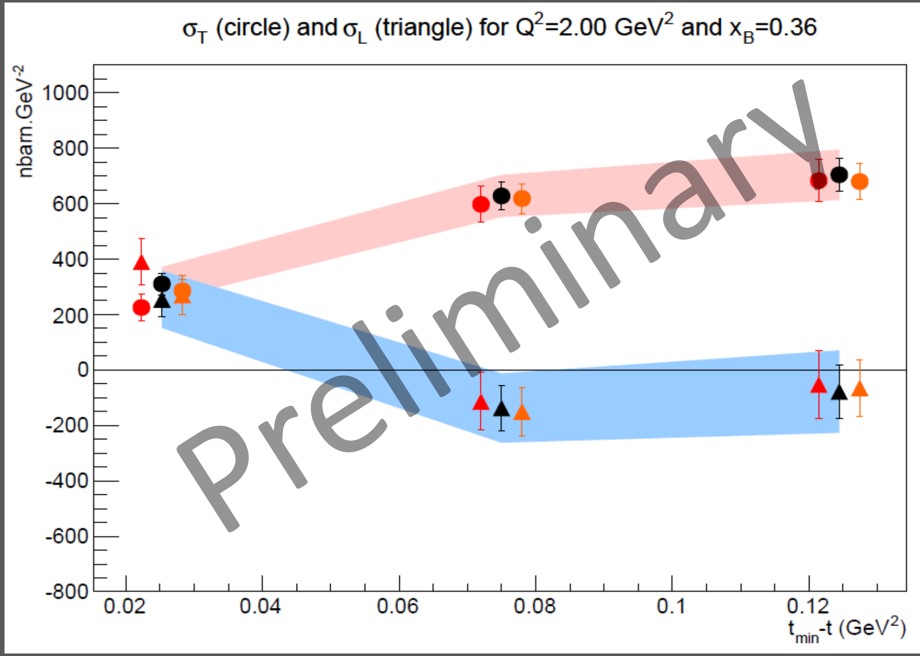
Systematic error evaluation

- No significant systematic error from exclusivity cut.

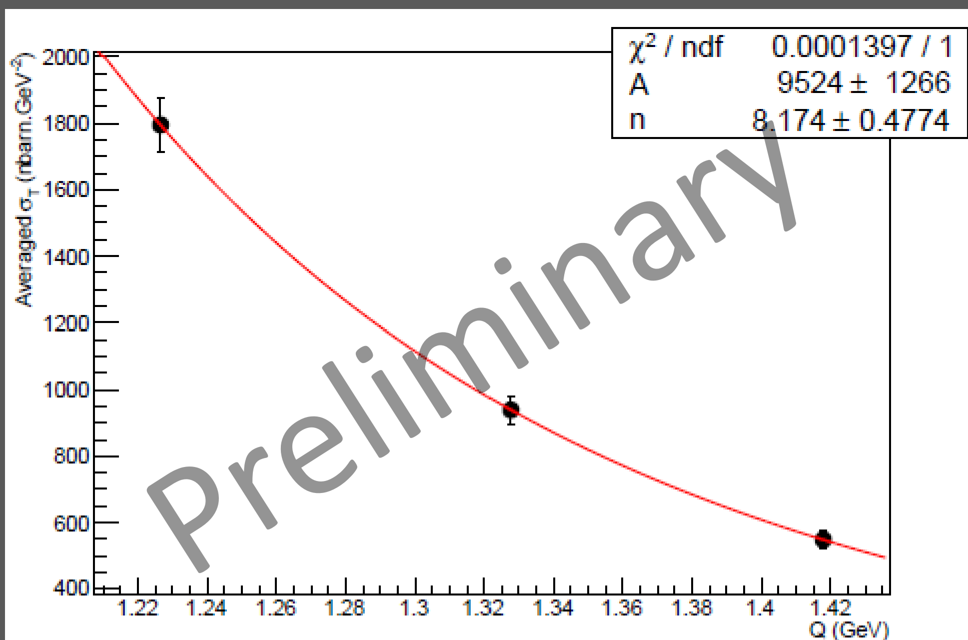


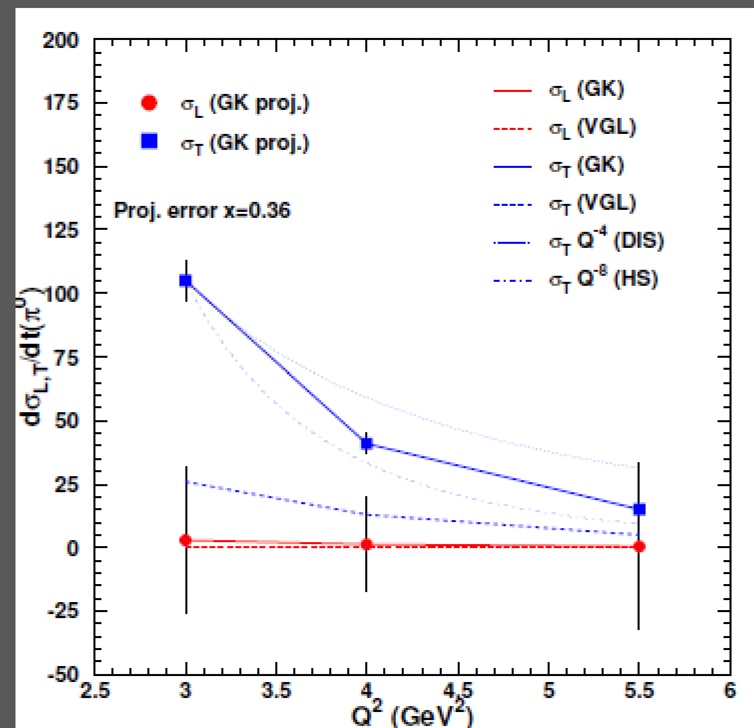


- Interference terms are also very stable with exclusivity cut.

Q^2-dependence of σ_T

- Fitting a function $\frac{A}{Q^n}$ to the averaged results over t'





- Seems to indicate the handbag diagram dominance

Conclusions

- The main contribution is the transverse response.
- Fair agreement with Goloskokov-Kroll predictions.
- Longitudinal response is found to very small: upper bound for $\widetilde{H}$ and $\tilde{E}$.
- Hints of non-zero longitudinal contribution at small t’ and $Q^2 = 2\ GeV^2$:
  Interesting to study higher Q^2 with higher R=$\frac{\sigma_L}{\sigma_T}$

Outlook

- Proposal for Rosenbluth separation in Hall C approved.
- The High Momentum Spectrometer with 11-GeV beam allow to access higher Q^2.
- Better energy and position resolution with the $PbWO_4$ calorimeter