

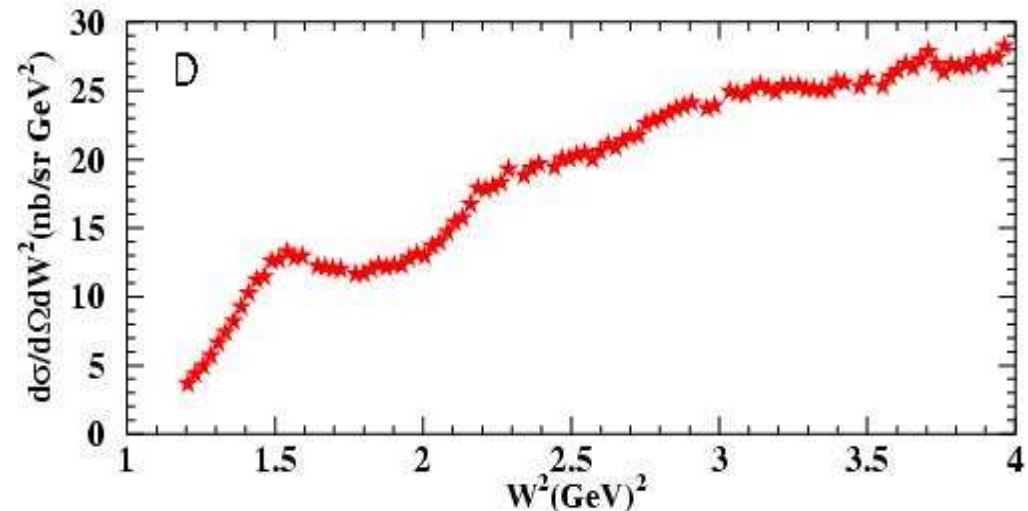
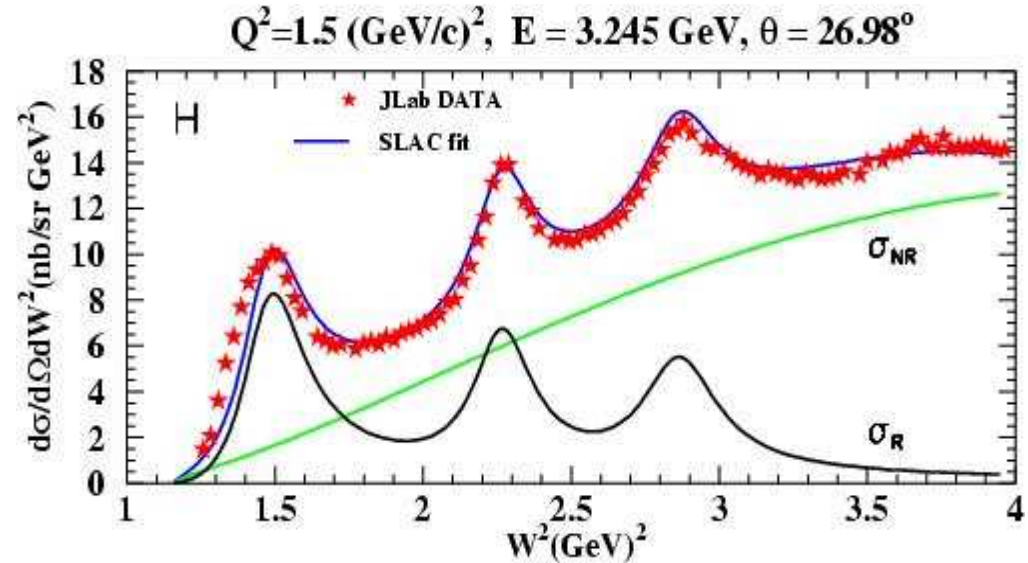
Differential Cross Section for the Reaction $\gamma^* n \rightarrow \pi^- p$ from Deuterium

Jixie Zhang (JLab), Gail Dodge (ODU),
Sebastian Kuhn (ODU), Igor Strakovsky (GW)

for the CLAS Collaboration
Nov. 4th, Santa Fe (NM), DNP 2010

Inclusive Cross Section in the Resonance Region

- Motivation: understand the structure of the neutron.
- Difficulty: no free neutron target, use deuteron instead.
- Data on the Proton: Clear resonant structure, separation from the non-resonant background is possible
- Data on the deuteron: Kinematically smeared due to binding, off-shell, final state interactions (FSI), etc.



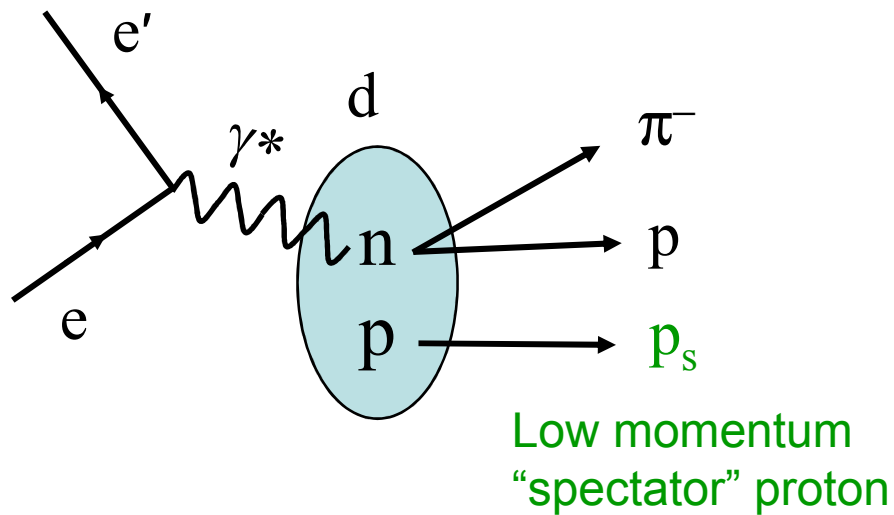
L.W. Whitlow *et al.*, Phys. Lett. B282, 475 (1992).

P. Amaudruz *et al.*, Phys. Lett. B295, 159 (1992).

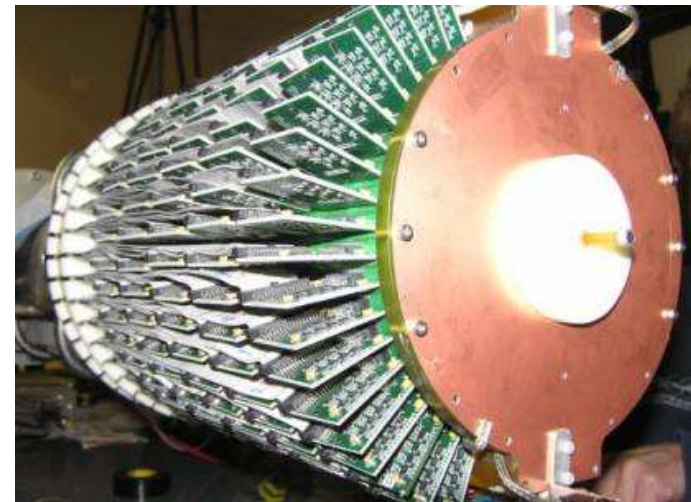
Exclusive π^- electro-production

$$D(e, e' \pi^- p) p$$

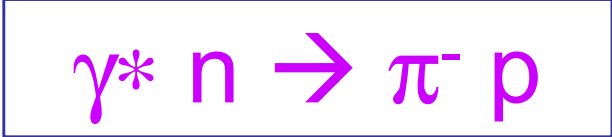
Detect e' , π^- and at least **ONE** of the two final state **protons** in $D(e, e' \pi^- p) p$ to ensure exclusivity and select events where the “spectator” proton has low, backwards momentum. Conservation of energy and momentum allows to determine the initial state of the neutron.



Novel approach by the BoNuS collaboration:
detect the spectator proton directly.

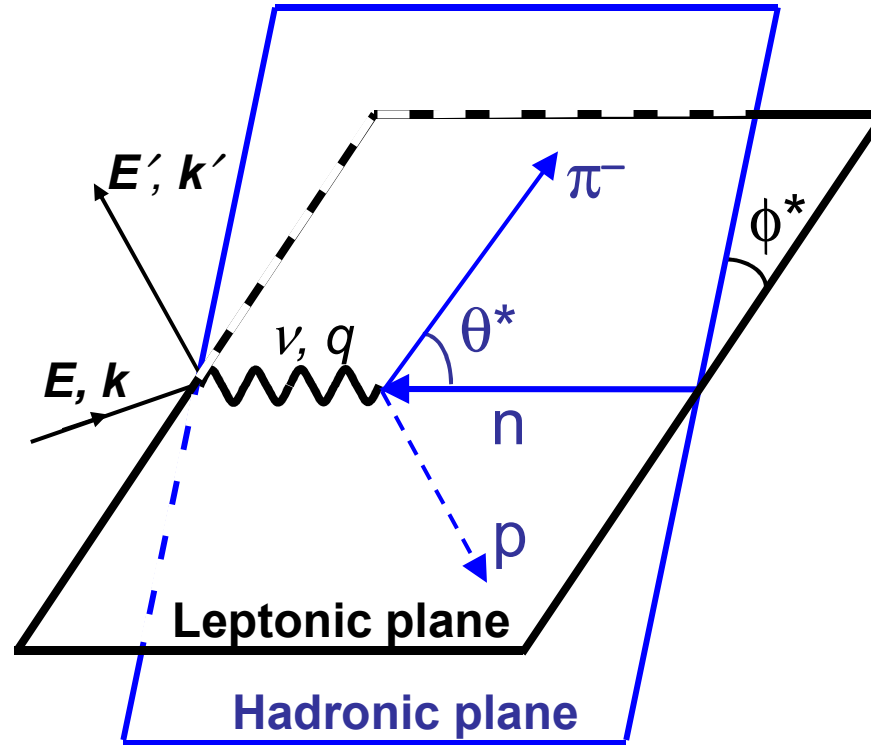


π^- Production Kinematics



$$Q^2 = -(q^\mu)^2 = 4EE' \sin^2(\theta_e/2)$$

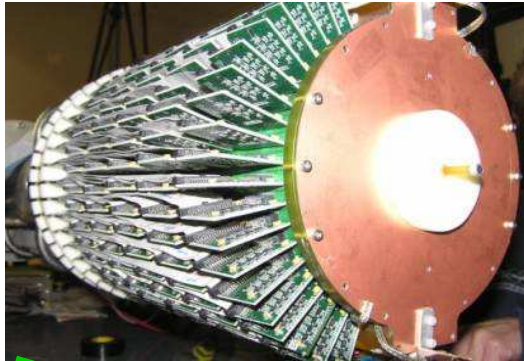
$$W'^2 = (q^\mu + n^\mu)^2 = (q^\mu + d^\mu - p_s^\mu)^2 = (\pi^\mu + p^\mu)^2$$



θ^* = polar angle of the outgoing π^- in C.M. frame

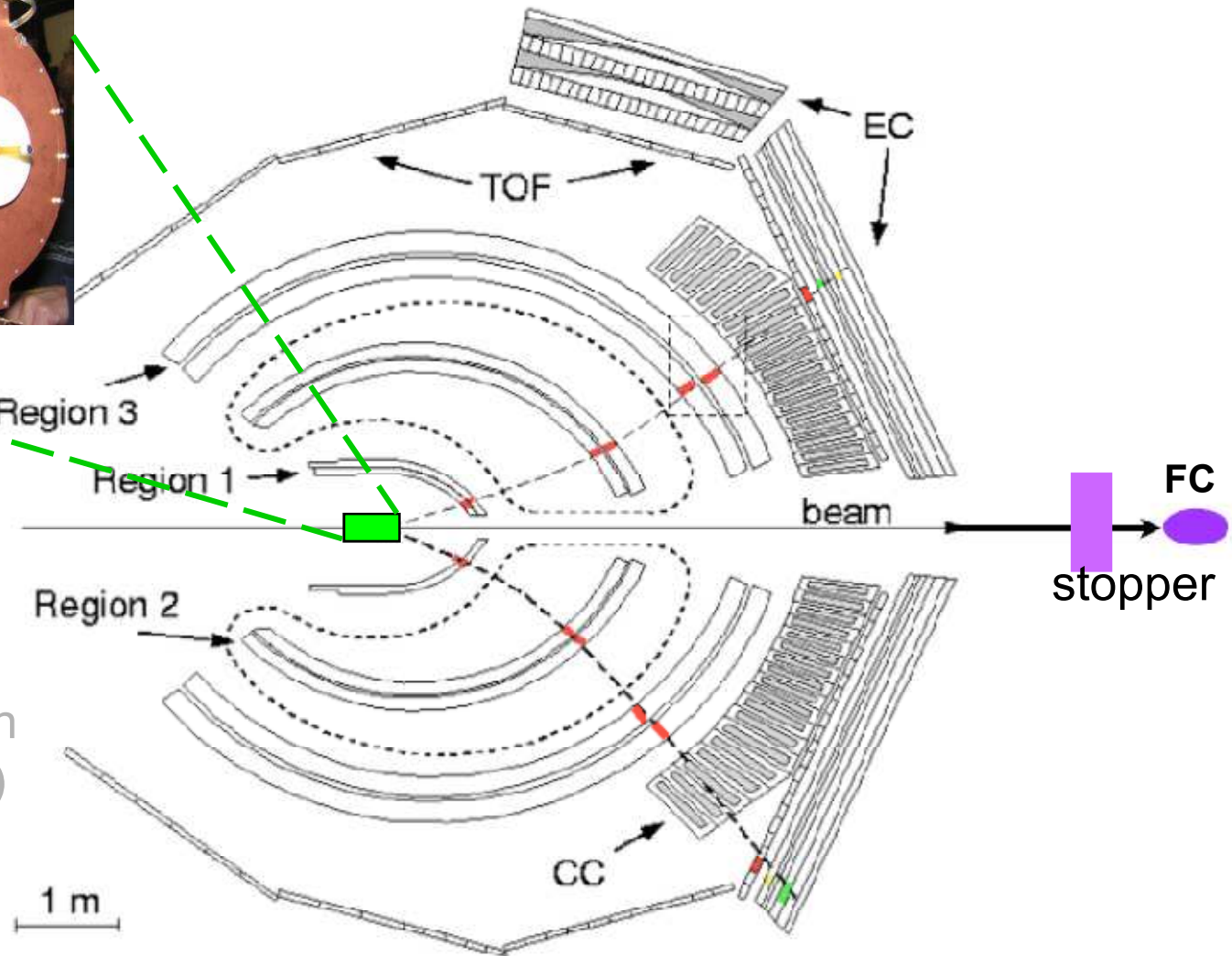
ϕ^* = Azimuthal angle of the outgoing π^- in C.M. frame

Barely off-shell Nucleon Structure (BoNuS)



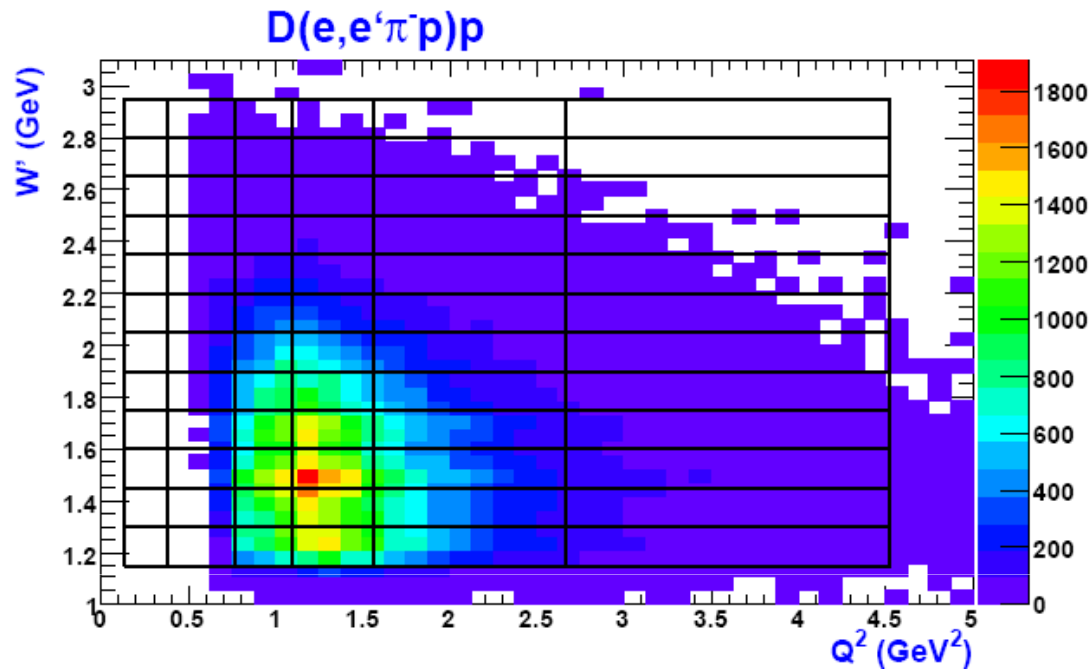
Radial Time
Projection
Chamber
(RTPC)

Refer to Sebastion
Kuhn's talk (CB 4)
for detail



CEBAF Large Acceptance Spectrometer (CLAS)

Kinematic coverage and binning, 5 GeV

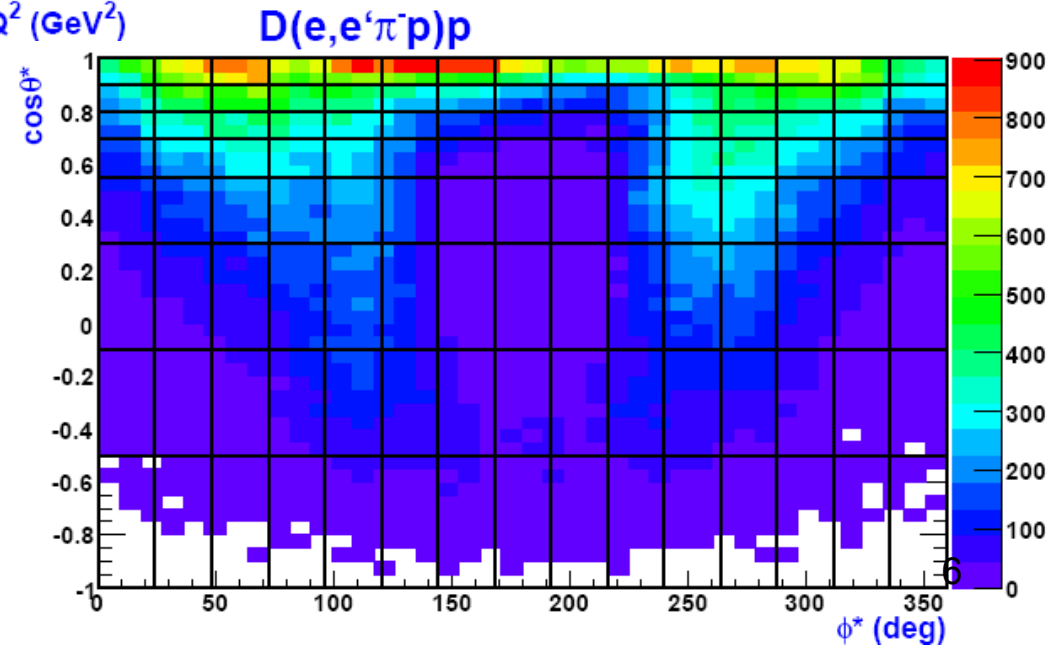


W' : 150 MeV each bin, [1.15,2.95)

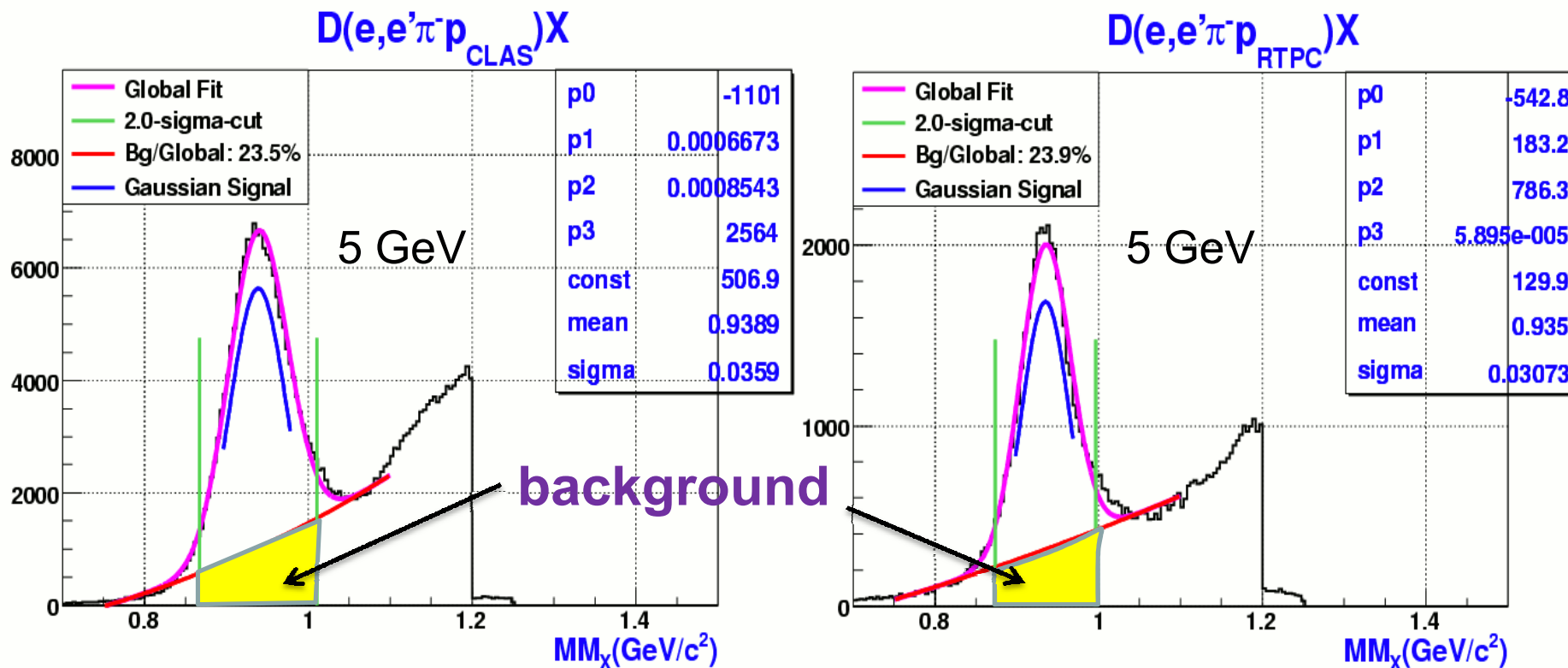
Q^2 : 6 bins with boundaries at
0.1309, 0.3790, 0.7697, 1.0969,
1.5632, 2.6594, 4.5243

$\cos\theta^*$: 8 bins with boundaries
at 1.0, 0.5, -0.1, 0.3, 0.55,
0.7, 0.8, 0.9, 1.0

ϕ^* : 15 bins, 24 degrees each
bin, [0.0,360.0)

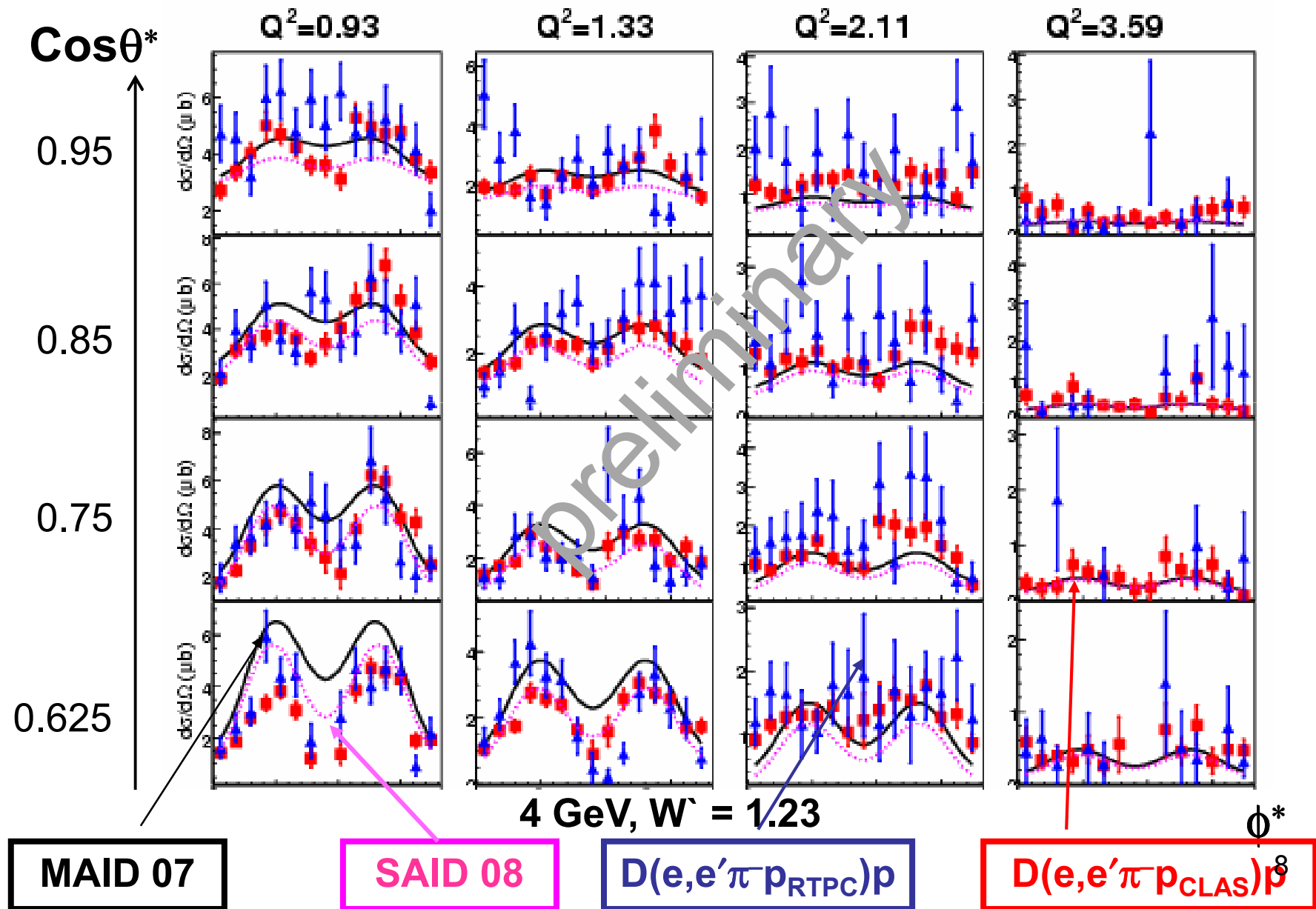


Missing Mass Cut: 2σ from the Center



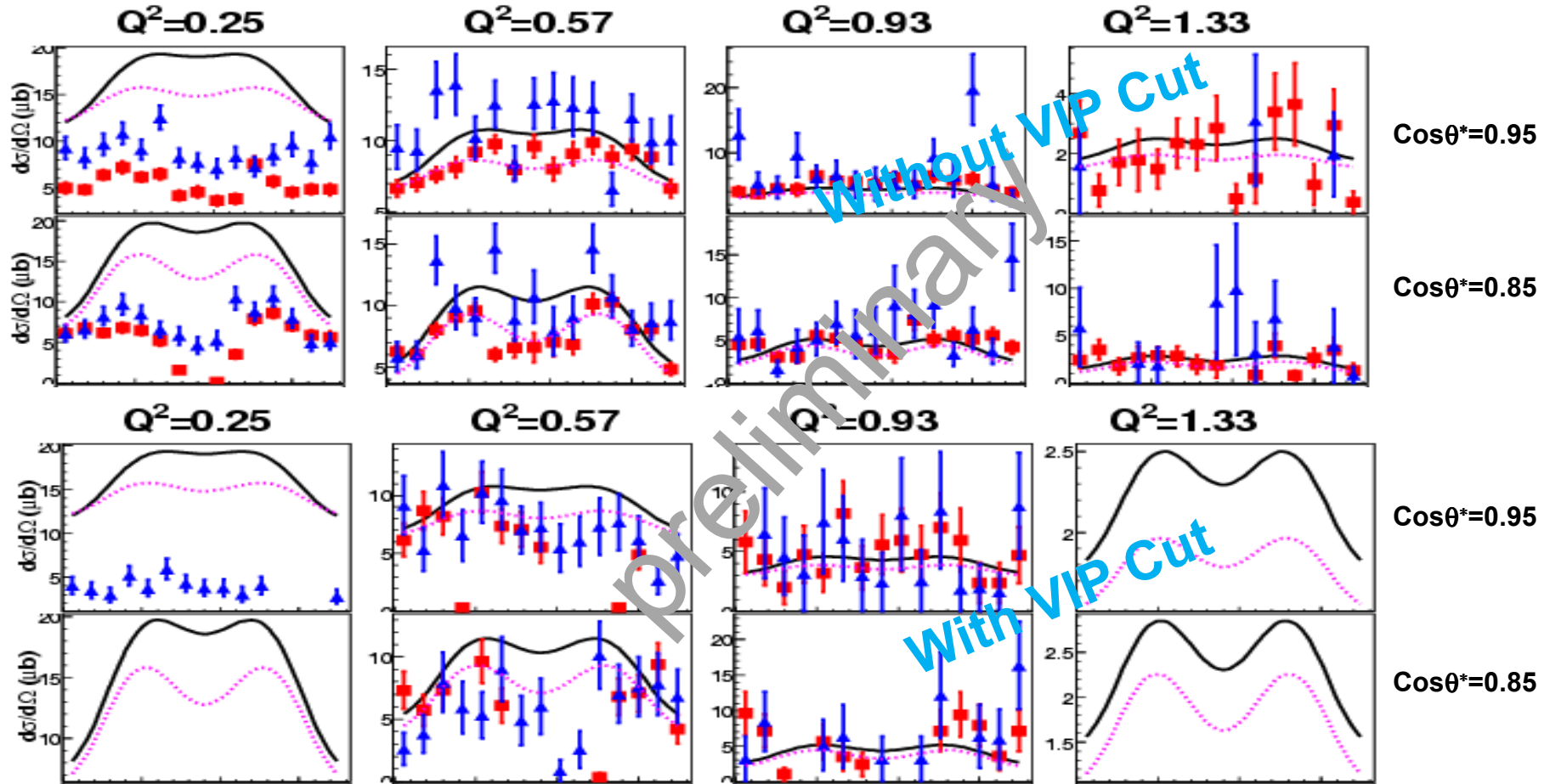
Beam Energy	MM Cut of $D(e,e'\pi^-p_{\text{CLAS}})p$	MM Cut of $D(e,e'\pi^-p_{\text{RTPC}})p$
2.x	0.9436 +/- 0.0509	0.9374 +/- 0.0400
4.x	0.9401 +/- 0.0605	0.9356 +/- 0.0501
5.x	0.9389 +/- 0.0718	0.9350 +/- 0.0615

Cross Section: BoNuS Vs MAID and SAID



Minimizing Final State Interactions

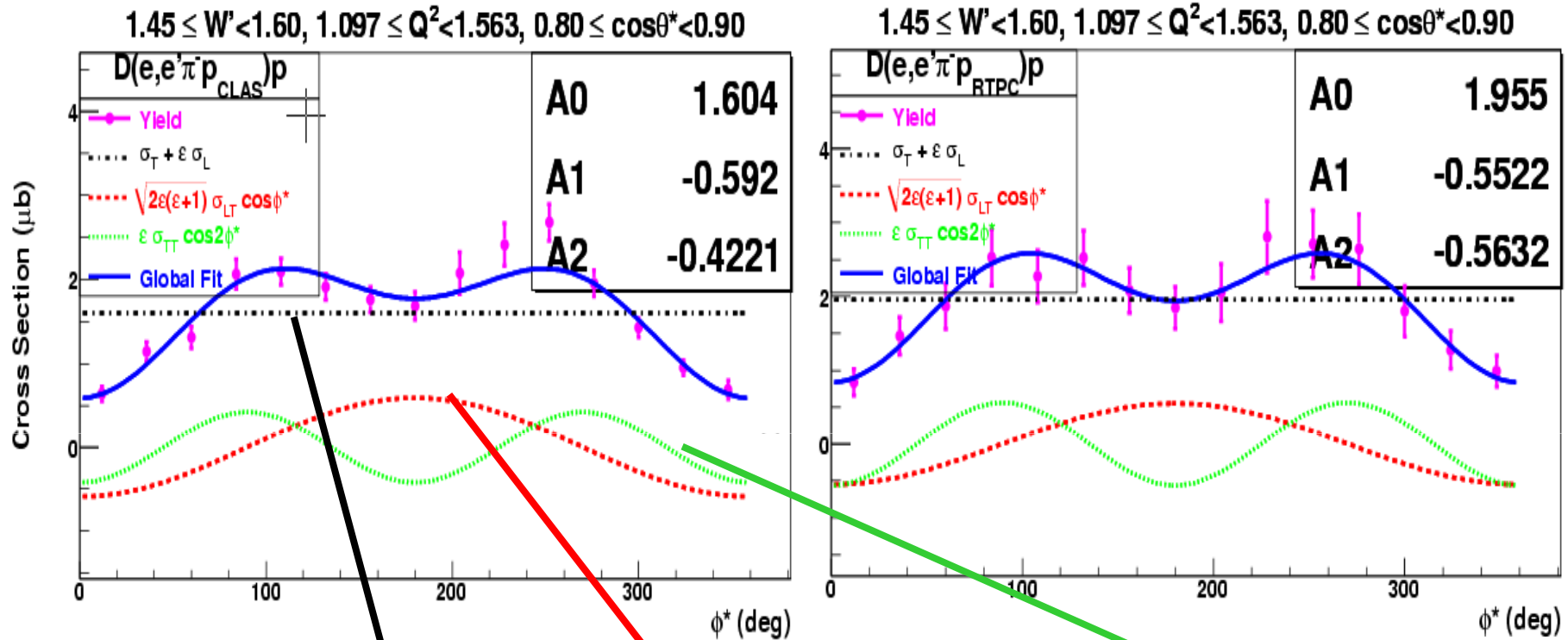
2 GeV, $W' = 1.23$



VIP = $\theta_{pq} > 100^\circ$ and $70 < p_s < 120$ MeV/c

Prediction: FSI + Binding < 20% under VIP cut
Data: 1) Better agreement between CLAS and RTPC channel for low Q^2 ; 2) No obvious change other than removing data points to the results with larger Q^2

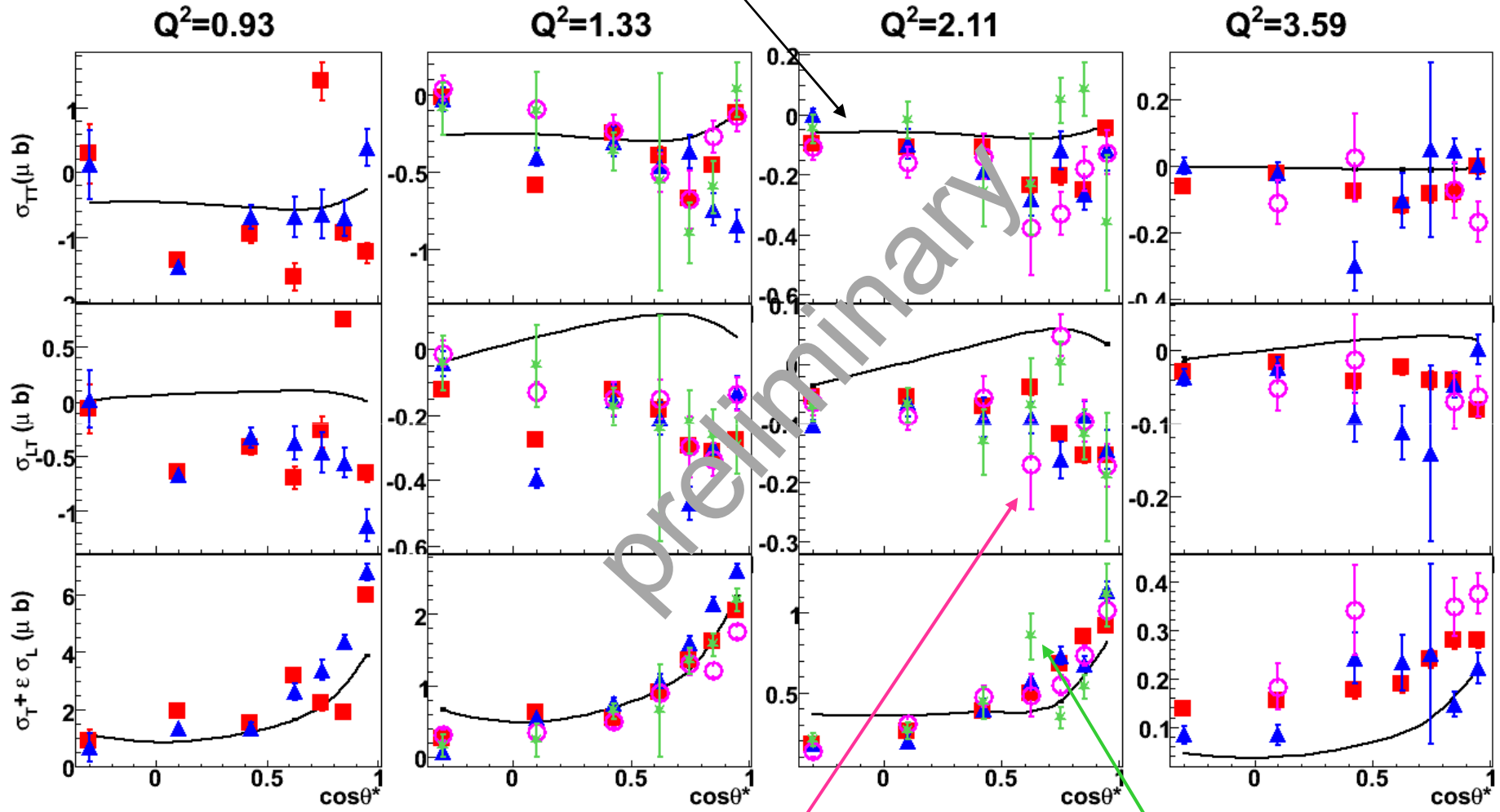
Fit for Structure Functions



$$\frac{\partial^2 \sigma}{\partial \Omega_\pi^*} = \boxed{\sigma_T + \varepsilon \sigma_L} + \boxed{\sqrt{2\varepsilon(1+\varepsilon)}\sigma_{LT}\cos\phi_\pi^*} + \boxed{\varepsilon\sigma_{TT}\cos 2\phi_\pi^*}$$

$$= \boxed{A0} + \boxed{A1 \cos\phi^*} + \boxed{A2 \cos 2\phi^*}$$

BoNuS Vs MAID, 5 GeV, $W' = 1.525$



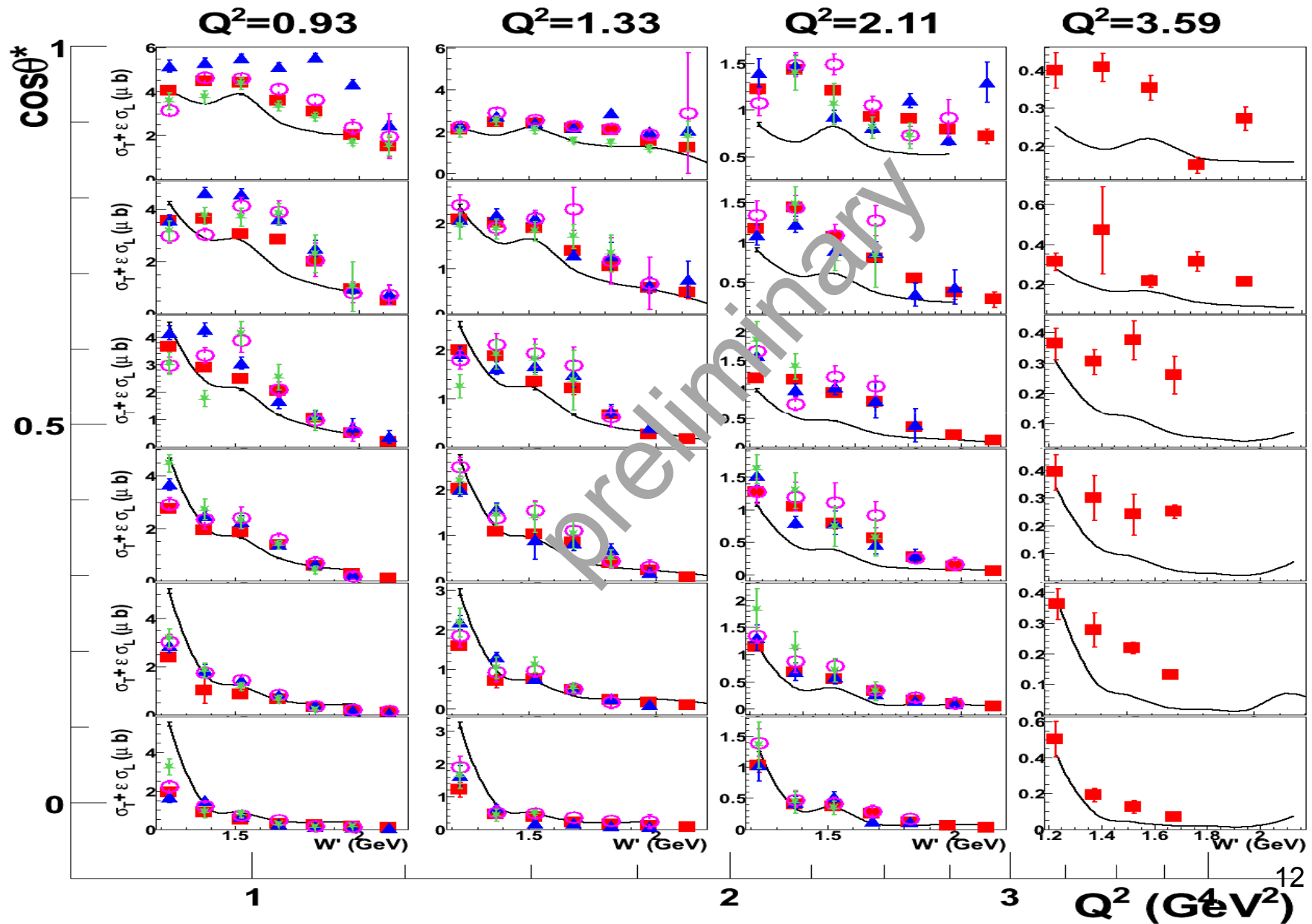
VIP = $70 < p_s < 120$
 MeV/c, and $\theta_{pq} > 100^\circ$

$D(e, e' \pi) p_{\text{CLAS}} + \text{VIP}$

$D(e, e' \pi) p_{\text{RTPC}} + \text{VIP}$

FSI + Binding < 20% under VIP cut

A_0 : BoNuS Vs MAID, 4 GeV with VIP cut



Summary and Outlook

- Measured absolute cross sections for $D(e, e' \pi^- p)p$ reaction over a wide kinematic range.
- We see qualitative consistency in most bins between our results and model predictions.
- In most bins, the p_{RTPC} and p_{CLAS} channels are consistent.
- Huge increase in available data points (about 2000) for $\gamma^* n \rightarrow \pi^- p$. These data will be used to improve our understanding of neutron structure, as part of fits to world data (SAID, MAID...)
- Include the FSI correction in future.
- We may repeat this analysis using other deuteron data, i.e. CLAS E6 data.