

CLAS Deep Processes Working Group Summary

25 February 2016
CLAS Collaboration Meeting
Jefferson Lab
Keith Griffioen

Deep Processes Working Group Summary

Feb 2016

- 4 Analysis Notes currently under review
- 2 *ad hoc* reviews in progress or to start soon
- 4 submitted or published papers in 2015/16
- Several ongoing thesis analyses
- Several ongoing data-mining projects

Oct 2015

- 3 Analysis Notes currently under review
- 8 *ad hoc* reviews in progress or to start soon
- 4 submitted or published papers in 2015
- Several ongoing thesis analyses
- Several ongoing data-mining projects

Jun 2015

- 7 Analysis Notes currently under review
- 4 *ad hoc* reviews in progress or to start soon
- 4 submitted or published papers in 2015
- Several ongoing thesis analyses
- Several ongoing data-mining projects

Author	Run Group	Title	WGC	ad hoc	Pub
N Saylor <i>et al.</i>	e1-dvcs2	e1-dvcs analysis note	Begin: 150216 K Joo A Kim C Smith		
I Albyrak <i>et al.</i>	g12	Time-Like Compton Scattering	Begin: 150325 S Niccolai R Paremuzyan M Paolone link		
A Fradi <i>et al.</i>	e1-dvcs	Deeply Virtual Production of the ρ^+ Meson on the Proton	Begin: 150316 S Pisano K Giovanetti V Kubarovsky link		
S Koirala S Kuhn <i>et al.</i>	eg1-dvcs	Measurement of Single and Double Spin Asymmetries in Semi-Inclusive Deep Inelastic Scattering on Proton and Deuteron	Begin: 140929 M Mirazita P Bosted M Contalbrigo link End: 151001		
P Bosted <i>et al.</i>	eg1b	Spin Asymmetries in Exclusive π^+ and π^- electro- production from the Eg1b experiment	Begin: 140909 G Dodge X Zheng FX Girod link End: 150815	Begin: 151007 Andrew Puckett Jacques Ball Vitali Baturin End: 150108	
I Bedlinskiy V Kubarovsky <i>et al.</i>	e1-dvcs	Measurement of cross sections of η electroproductio n in e1 dvcs experiment with CLAS	Begin: 140710 R Dupre H Avagyan A Kim link End: 151022		
S Pisano <i>et al.</i>	elf	Di-hadron Beam-Spin Asymmetry in SIDIS electro- production	Begin: 140424 A Biselli B Raue S Kuhn link		
P Bosted <i>et al.</i>	eg1-dvcs	Spin Asymmetries in exclusive π^+ , π^0 , and π^- electro- production from the eg1-dvcs experiment	Begin: 140120 FX Girod S A Pereira P Stoler link End: 150902	Begin: 150903 FX Girod S Bueltmann Jixie Zhang	

Author	Run Group	Title	WGC	ad hoc	Pub
L. Weinstein <i>et al.</i>	TPE/eg5	The Two Photon Exchange Experiment	Begin: 140115 P. Nadel-Turonski Mestayer A. Sandorfi link	Begin: 141031 M Mestayer M Contalbrigo M Wood	Phys. Rev. Lett. 114.062003 (2015)
P. Stoler <i>et al.</i>	elf	Exclusive π^0 electro-production at $W > 2$ GeV with CLAS	Covered by W.Gohn elf analysis	Begin: ~131031 B. Ritchie D. Carman H. Avakian	Phys. Rev. C 90.025205 (2014)
A. Kim <i>et al.</i>	elf	Beam Spin asymmetries of $ep \rightarrow e\eta$ in the deep-inelastic regime	Analysis note unknown	Begin: 140905: Angela Biselli Kijun Park A Celentano	
A. Kim <i>et al.</i>	eg1-dvcs	Single and Double Spin Asymmetries for Deeply Virtual Exclusive π^0 Production on Longitudinally Polarized Proton Target with CLAS	Begin: 130912 M. Guidal S. Pisano A. Biselli link End: 140905	Begin: 150615 E Votier A Biselli M Holtrop End: 151016	
S Pisano <i>et al.</i>	eg1-dvcs	Single and double spin asymmetries for deeply virtual Compton scattering measured with CLAS and a longitudinally polarized proton target	Same as S Niccolai, Measurements of single- and double-spin asymmetries...	Begin: 141027 P Stoler D Sokhan E Voutier End: 141212	Phys. Rev. D 91.052014 (2015)

Author	Run Group	Title	WGC	ad hoc	Pub
S. Niccolai <i>et al.</i>	egI-dvcs	Measurements of single- and double-spin asymmetries for deeply virtual Compton scattering with a polarized electron beam and a longitudinally polarized proton target	Begin: I30722 M. Garcon D. Sokhan A. Puckett link End: I40604	Begin: I40809 D Carman D Sokhan E Voutier	Phys. Rev. Lett. 114.032001 (2015)
S. Kuhn <i>et al.</i>	e8	Measurement of the free neutron structure function using spectator tagging in inelastic d(e, e'p _s)X scattering with CLAS	Covered by previous e8 review	Begin: A. Biselli, A. Deur, Y. Ilieva End: I31121	Phys. Rev. C 89.045206 (2014)
H-S Jo <i>et al.</i>	eI-dvcs	Deeply virtual Compton scattering on the proton: measurement of the unpolarized and polarized cross sections from eI-dvcs	E Voutier K-J Park F Sabatie link Begin: I40307 End I: I40425 Ans I: I40728	Larry Weinstein Kijun Park Silvia Pisano Begin: I50222 End: I51105	Phys. Rev. Lett. 115.212003 (2015)
P. Bosted Y. Prok <i>et al.</i>	egI-dvcs	Inclusive Polarized Structure Functions g ₁ ^P and g ₁ ^d from the egI-dvcs Experiment	Begin: I30430 K. Slifer A. Deur FX Girod link End: I31019	Begin: I31125 K Hicks P. Cole F-X. Girod End: I40115	Phys. Rev. C 90 025212 (2014)
B. Raue <i>et al.</i>	TPE/eg5	Measurement of Two Photon Exchange Effects Using e ⁺ /e ⁻ -Elastic Scattering in CLAS	(P. Rossi) E. Pasyuk D. Carman M. Osipenko link End: I21203	Begin: I30115 V. Mokeev G. Gilfoyle D. Carman	Phys. Rev. C. 88.025210 (2013)
N. Guler <i>et al.</i>	egIb	Measurement of Longitudinal Double Spin Asymmetries and Spin Structure Functions of the Deuteron in the CLAS EG I b Experiment	Begin: I21202 S. Niccolai H. Avagyan R. DeVita link link2 End: I40512	Begin: I41215 H B T Forest Igor Strakovsky End: I50528	arXiv: 1505.07877 Phys. Rev C 92 055201

08:30 Update on status of DVCS analysis from E1-6 data 20'

Speaker: Dr. Aram Movsisyan (INFN-Ferrara)

Material:

Slides



E1-6 experiment:

Data collected in 2001-2002.

Beam energy 5.754 GeV

5cm long liquid hydrogen target

Average beam polarization 70%

1.) *separate analysis of ep , $ep\gamma$, $ep\gamma\gamma$ samples.*

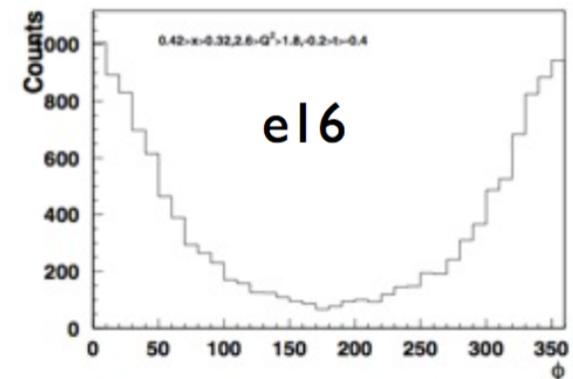
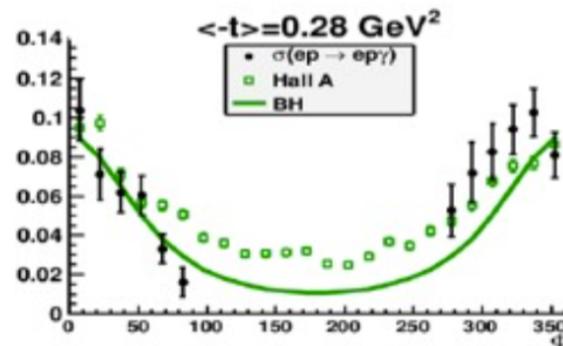
2.) *$ep\gamma\gamma$ - to estimate exclusive pion contribution.*

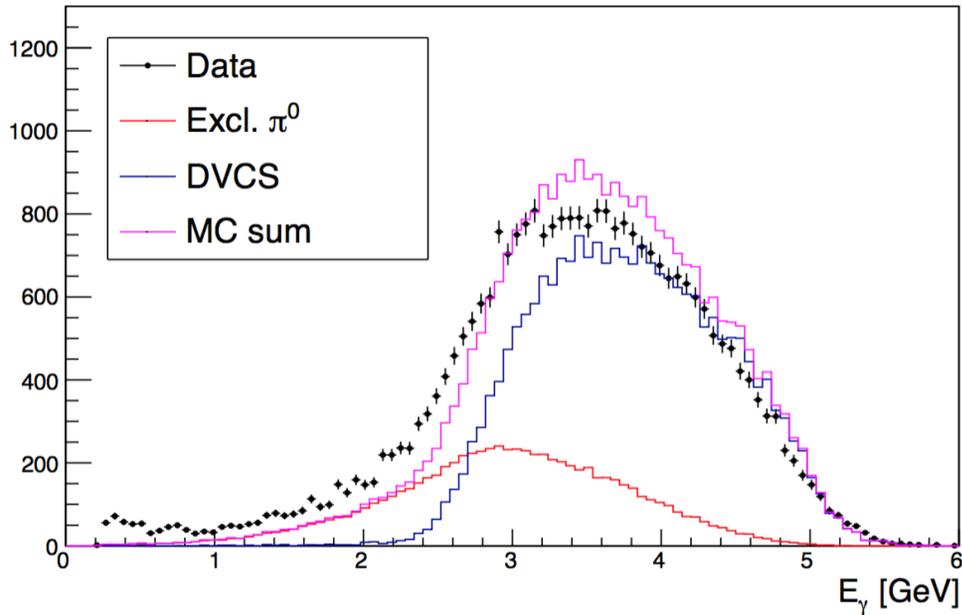
3.) *$ep\gamma$ - to validate the analysis procedure.*

4.) *ep - cross-check of MC normalization*

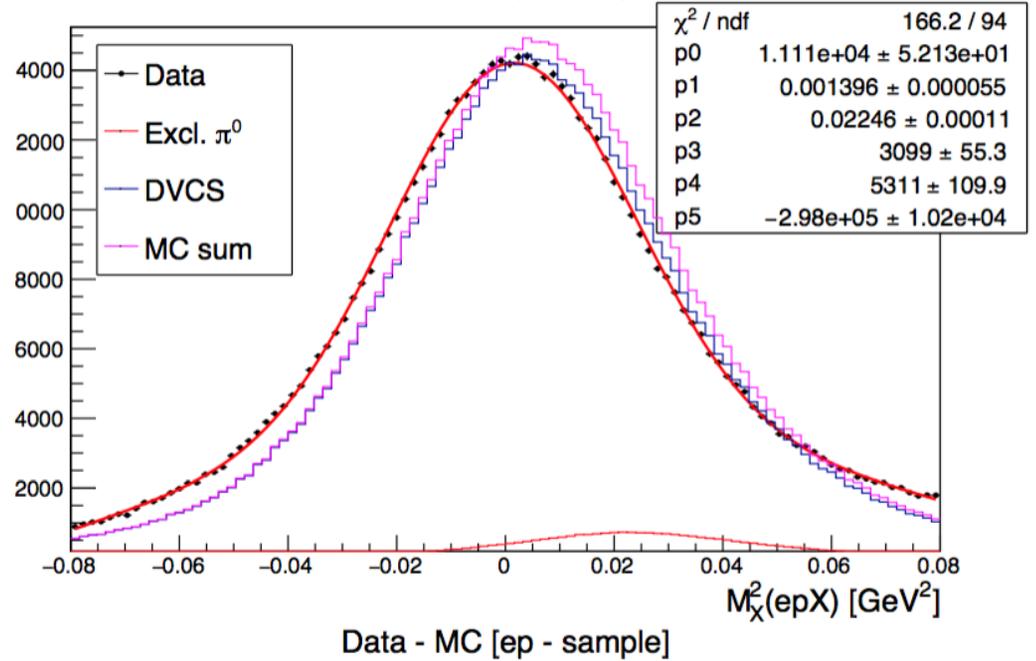
Measurement of DVCS Cross Section, via detection of final state proton p' and lepton e' .

Large statistics & broad kinematic coverage => large coverage of Φ acceptance.



Data - MC [ep γ - sample]

Data - MC [ep - sample]



a. Sufficiently good description of data by MC simulation allows to measure DVCS via detection of only electron and proton.

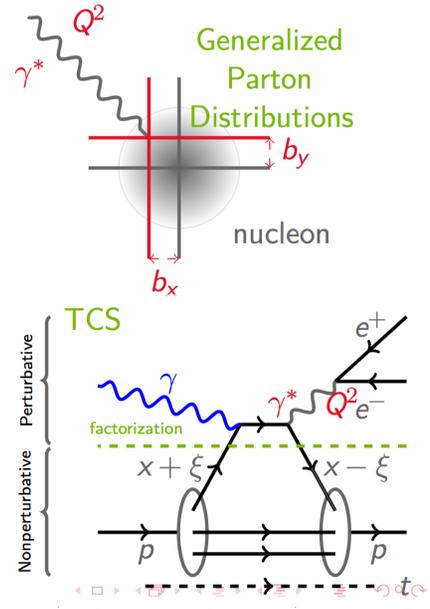
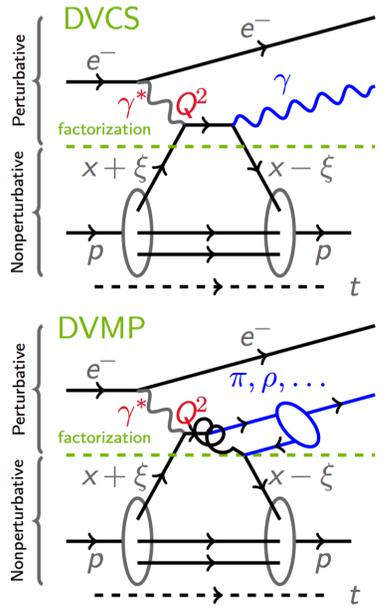
08:50

The PARTONS platform: status and prospects 20'

Speaker: Herve Moutarde

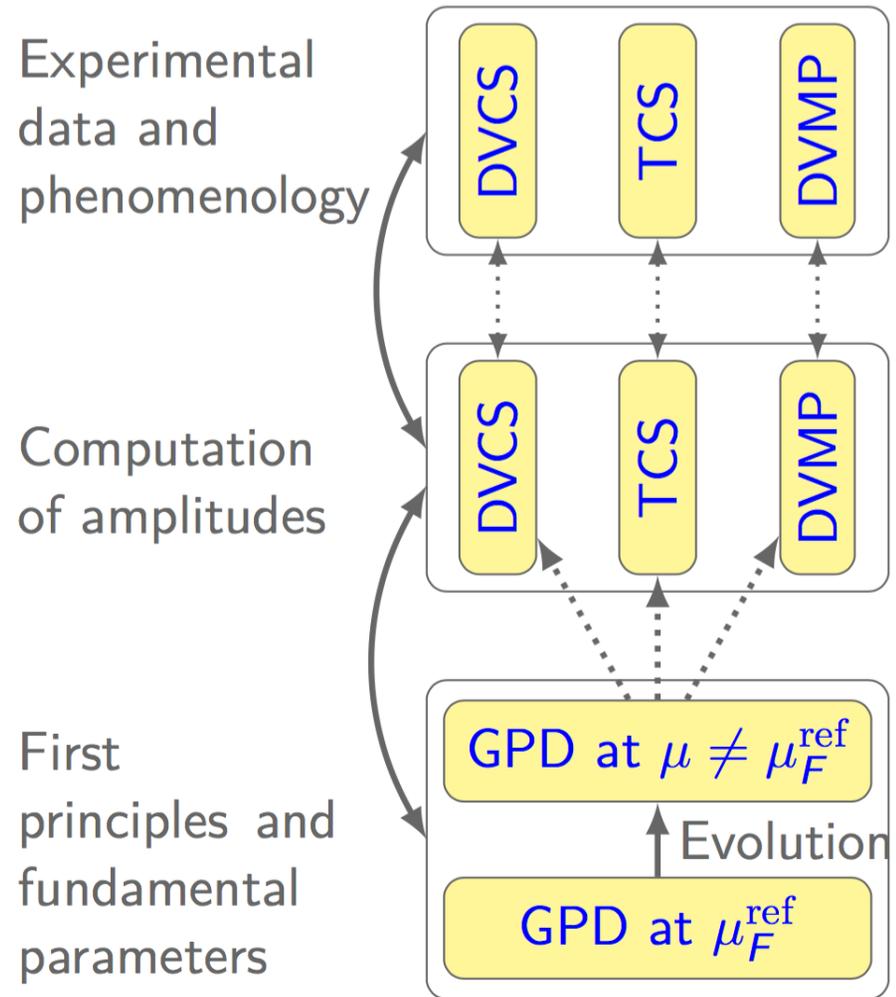


The PARTONS Platform: Status and Prospects



- Perturbative AND nonperturbative QCD at work**
- Define **universal** objects describing 3D nucleon structure: **Generalized Parton Distributions (GPD)**.
 - Relate GPDs to measurements using **factorization**: **Virtual Compton Scattering (DVCS, TCS), Deeply Virtual Meson production (DVMP)**.
 - Get **experimental knowledge** of nucleon structure.

- PARTONS software Platform for GPD phenomenology near completion for DVCS channel.
- Designed to simplify:
 - Integration of new modules.
 - Systematic differential studies.
- Expected production in 2016
 - Local and global fits of CFFs.
 - Evaluation of DVCS observables.
 - Computation of Light Front Wave Function



Beam-Spin Asymmetry for back-to-back di-hadron electroproduction with CLAS6 and CLAS12 20'

Speaker: Dr. Silvia Pisano (Frascati)

Material: [Slides](#) 

back2back electro-production



Contents lists available at SciVerse ScienceDirect

Physics Letters B

www.elsevier.com/locate/physletb



A novel beam-spin asymmetry in double-hadron inclusive lepto-production

M. Anselmino^{a,*}, V. Barone^b, A. Kotzinian^{a,c}

^a Dipartimento di Fisica Teorica, Università di Torino, INFN, Sezione di Torino, 10125 Torino, Italy
^b Di.S.T.A., Università del Piemonte Orientale "A. Avogadro", INFN, Gruppo Collegato di Alessandria, 15121 Alessandria, Italy
^c Yerevan Physics Institute, 375036 Yerevan, Armenia

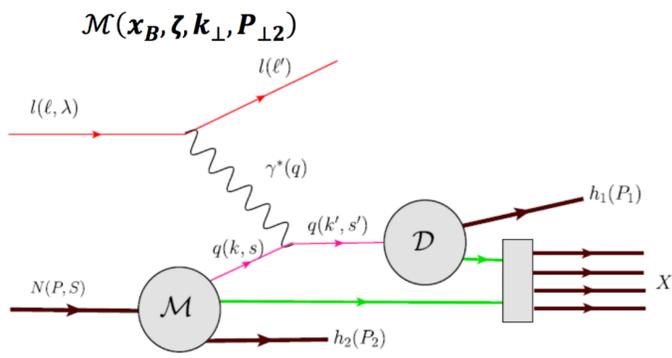
$$\mathcal{F}_{LU}, \mathcal{F}_{UU} \propto \mathcal{C}[\mathcal{M}\mathcal{D}]$$

Fracture Functions:

probability of finding a parton i with fractional momentum x_B and a hadron h with fractional momentum ζ

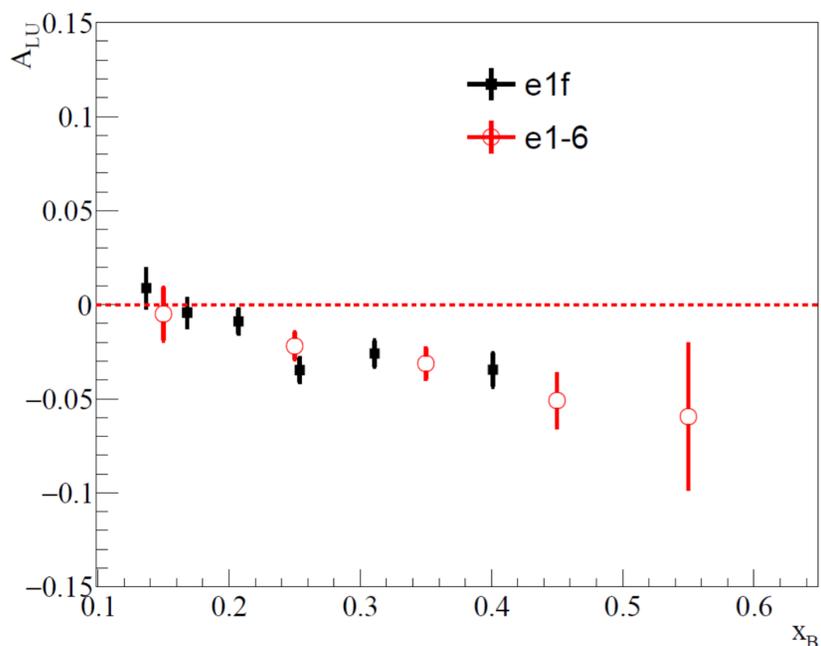
Fragmentation Functions:

$$\mathcal{D}(z_1, \mathbf{k}_\perp)$$

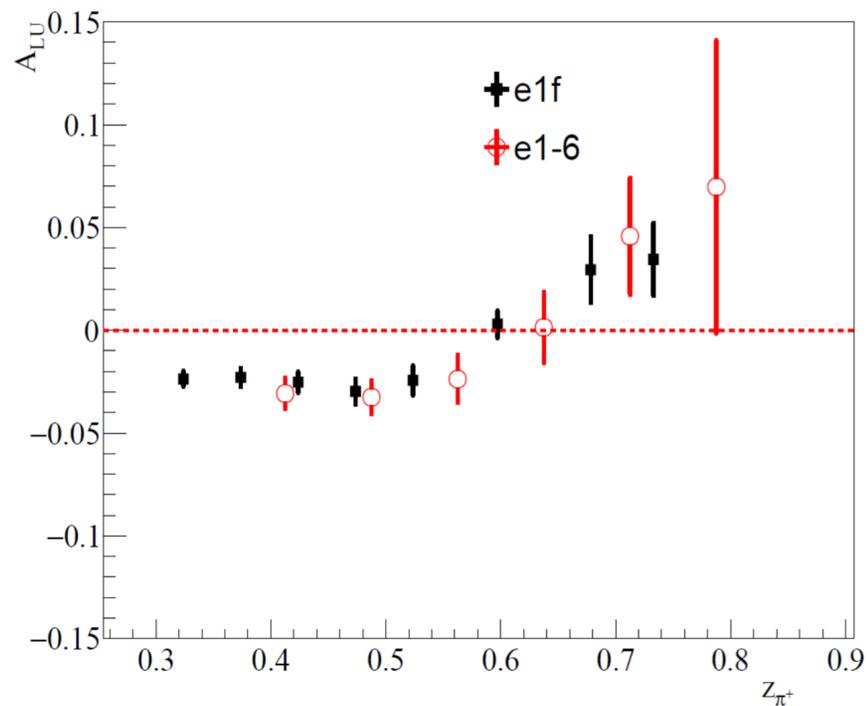


$$\mathcal{M}(x_B, \zeta, \mathbf{k}_\perp, P_{\perp 2})$$

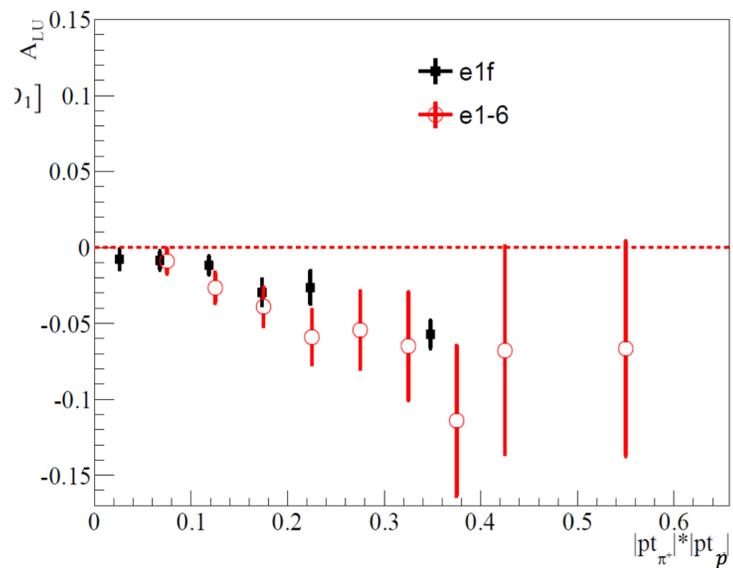
Back-to-back $ep \rightarrow ep\pi^+X$: x_B on e16 and e1f



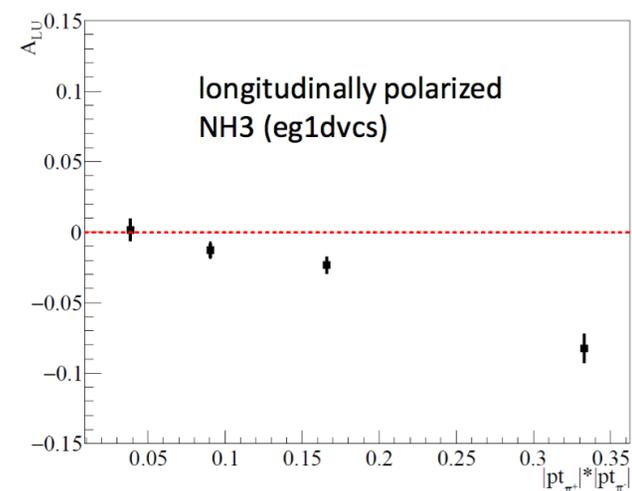
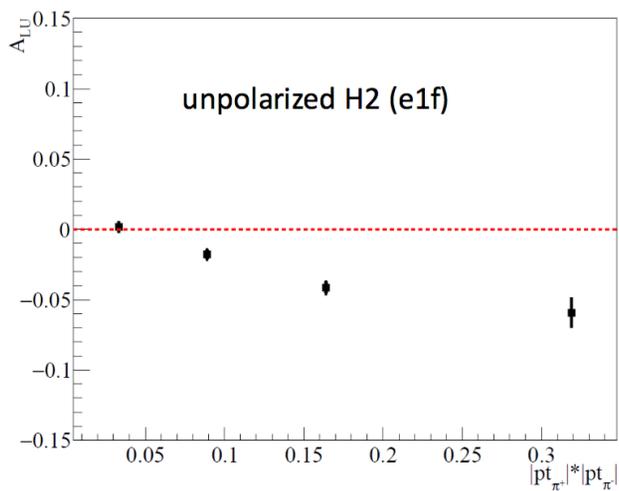
Back-to-back $ep \rightarrow ep\pi^+X$: z on e16 and e1f



Back-to-back $ep \rightarrow ep\pi^+X$: $|p_{T1}||p_{T2}|$ on e16 and e1f



Longitudinal observables - A_{UL} with the NH3 target



Speaker: Sergio Anefalos

Material: [Slides](#) 

$$ep \rightarrow e' \pi^+ \pi^- X$$

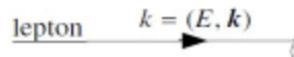
Presented by Harut

$$F_{LU}^{\sin \phi_R} = -x \frac{|R| \sin \theta}{Q} \left[\frac{M}{M_h} x e^q(x) H_1^{\leftarrow q}(z, \cos \theta, M_h) + \frac{1}{z} f_1^q(x) \tilde{G}^{\leftarrow q}(z, \cos \theta, M_h) \right]$$

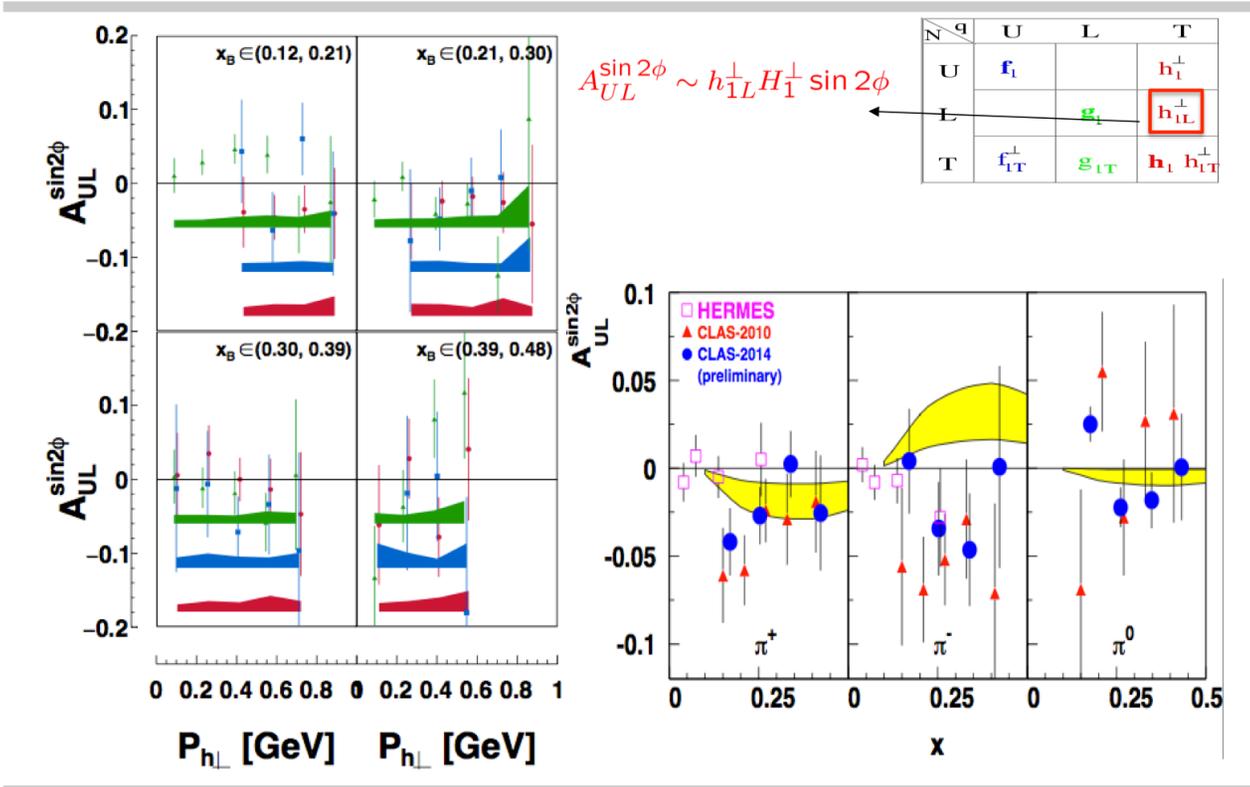
$$F_{UL}^{\sin \phi_R} = -x \frac{|R| \sin \theta}{Q} \left[\frac{M}{M_h} x h_L^q(x) H_1^{\leftarrow q}(z, \cos \theta, M_h) + \frac{1}{z} g_1^q(x) \tilde{G}^{\leftarrow q}(z, \cos \theta, M_h) \right]$$

$$F_{LL} = x g_1^q(x) D_1^q(z, \cos \theta, M_h),$$

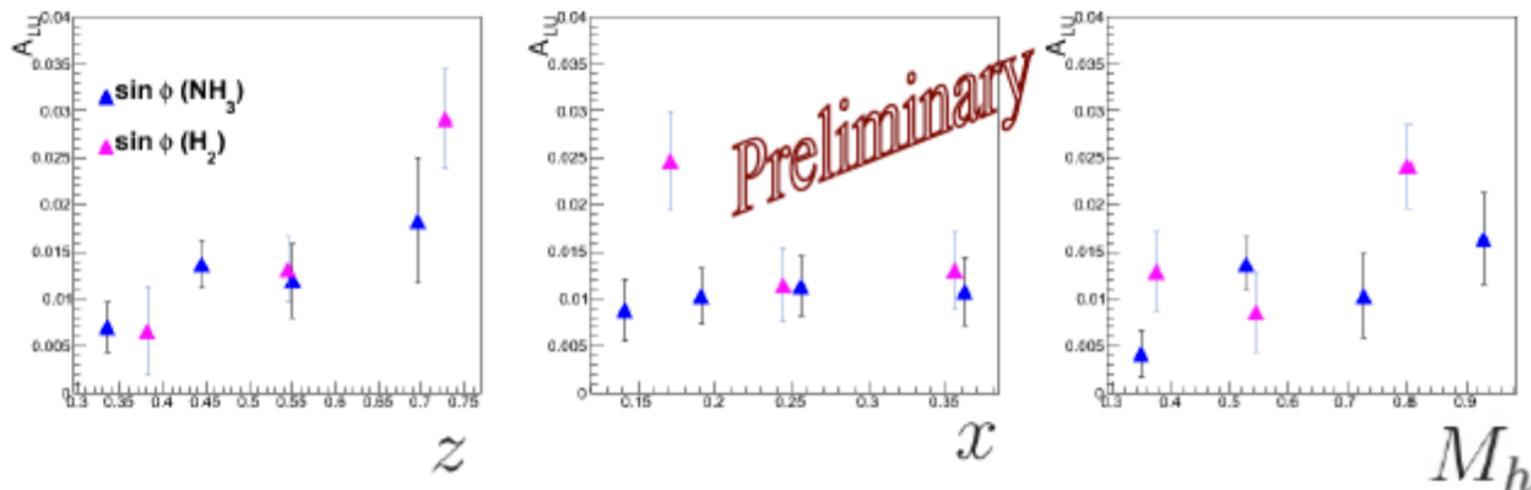
$$F_{LL}^{\cos \phi_R} = -x \frac{|R| \sin \theta}{Q} \frac{1}{z} g_1^q(x) \tilde{D}^{\leftarrow q}(z, \cos \theta, M_h).$$



Comparing eg1dvcs with eg1

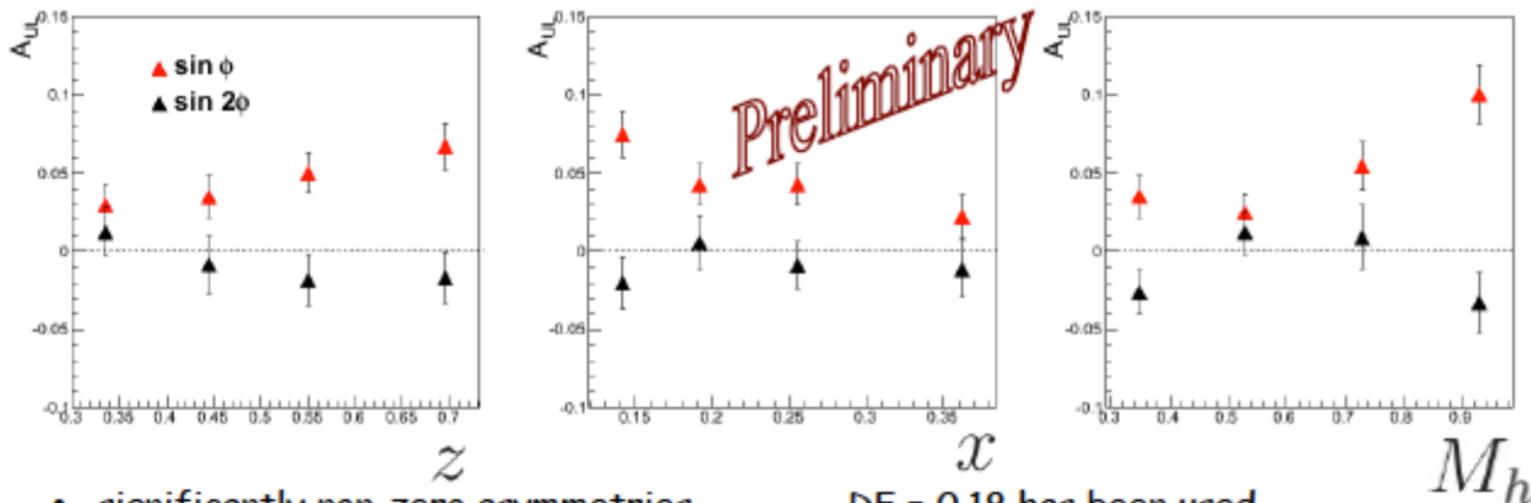


Beam-Spin Asymmetry (BSA) $A_{LU} \propto e(x) H_1^{\star q}(z, \cos \theta, M_h)$



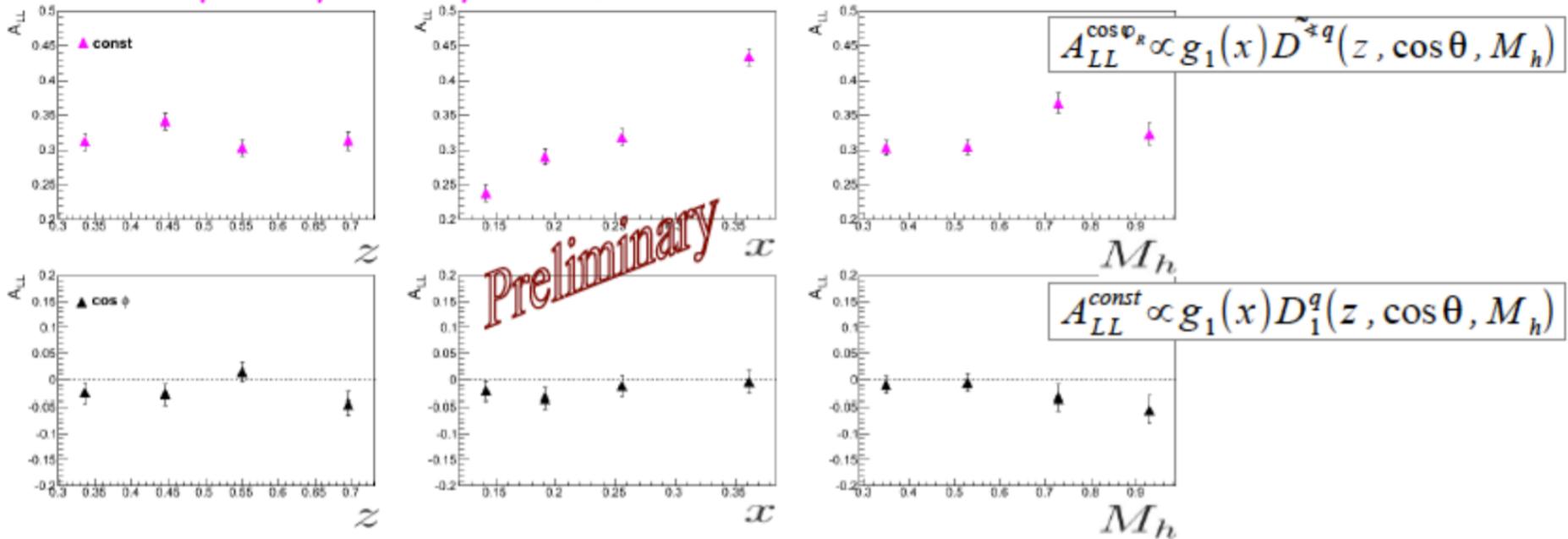
- Two independent analysis
- Two different experiments (unpolarized H₂ target (e1f) and longitudinally polarized NH₃ target (eg1-dvcs))
- Good agreement between the two analysis and no nuclear effects observed

Target-Spin Asymmetry (TSA) $A_{UL} \propto h_L(x) H_1^{\star q}(z, \cos \theta, M_h)$



- significantly non-zero asymmetries
- $\sin 2\phi$ compatible with zero
- DF = 0.18 has been used
- gives access to the sub-leading twist PDF $h_L(x)$

Double-Spin Asymmetry (DSA)



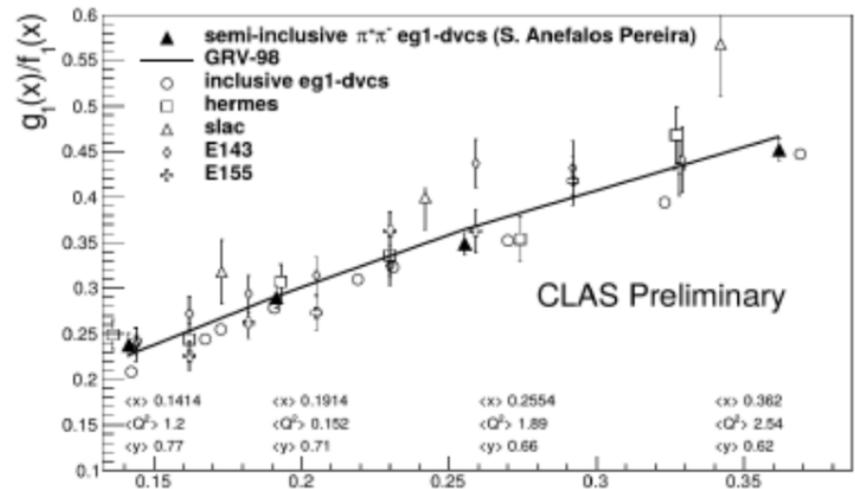
- Significantly non-zero A_{LL}^{const} asymmetries

- We measure

$$A_{LL}^{const} \approx \frac{F_{UU}}{F_{LL}}$$

$$\approx \frac{g_1^q(x) D_1^q(z, \cos \theta, M_h)}{f_1^q(x) D_1^q(z, \cos \theta, M_h)}$$

- This comparison shows that the present A_{LL}^{const} results are very consistent



09:50 **CLAS12 beamline background studies and a new shielding design 20'**
Speaker: David Riser (University of Connecticut)

Copy of Talk Missing

10:10

Low energy DVCS studies with CLAS12 20'

Speaker: Latifa Elouadrhiri (Jefferson Lab)

Material:

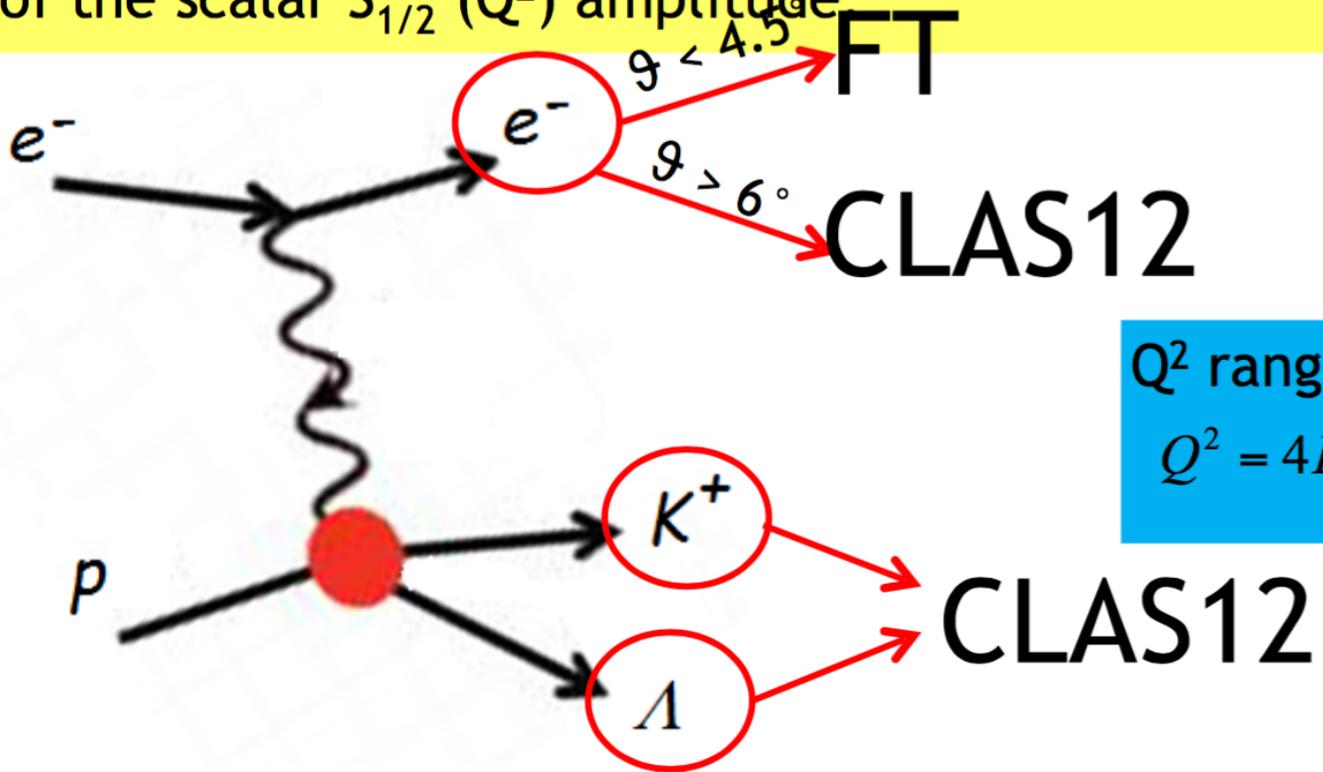
Slides



- To use the beam energy dependence of the BH and DVCS amplitudes to isolate the BH-DVCS interference term from the pure DVCS² contribution (as a function of Q^2):
 - Extraction Combinations of GPDs
 - Additional test of DVCS scaling
- To measure response functions of the deep virtual π_0 channel, in particular $d\sigma_L$ and $d\sigma_T$ by a Rosenbluth separation (as a function of Q^2):
 - valuable complementary (flavor) information on GPDs
- Complementary measurements to Hall A experiments

Scattered electrons will be detected in Forward Tagger for angles from 2.5° to 4.5° .

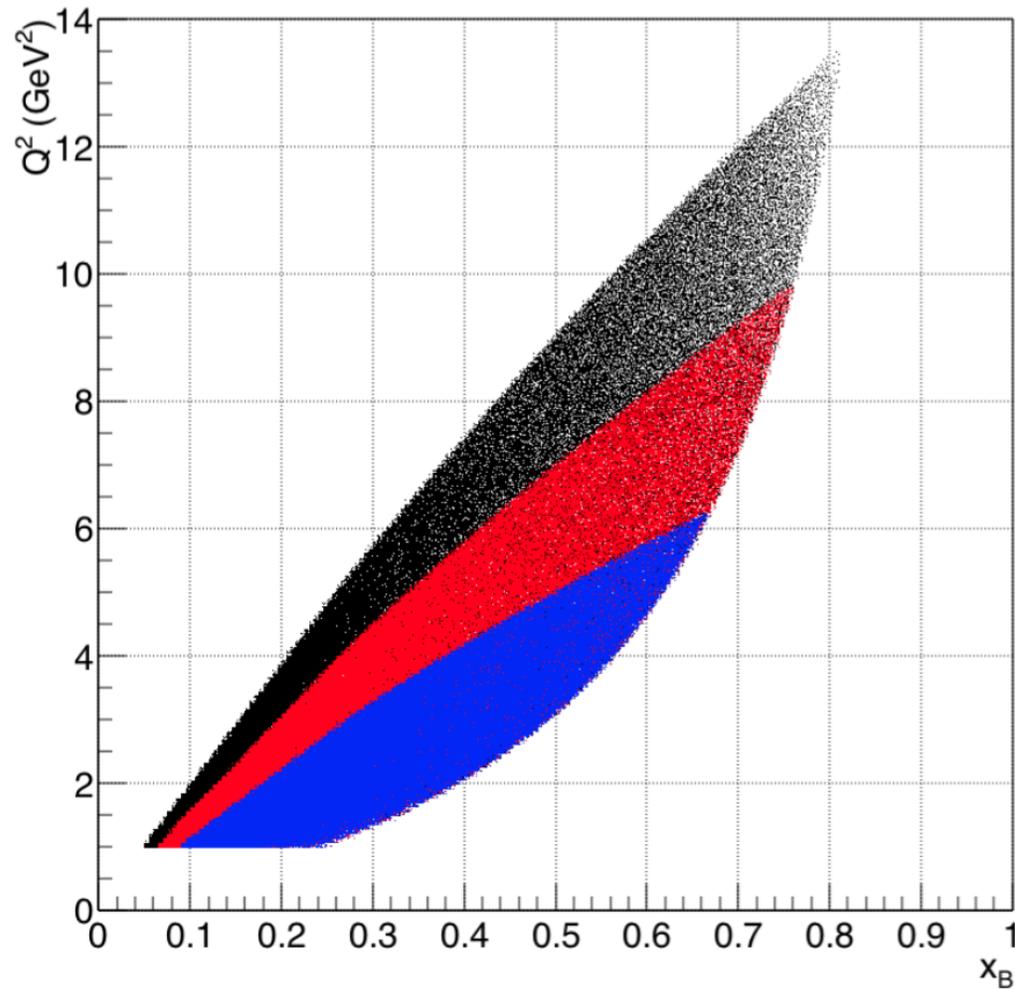
FT allows to probe the crucial Q^2 range where hybrid baryons may be identified due to their fast dropping $A_{1/2}(Q^2)$ amplitude and the suppression of the scalar $S_{1/2}(Q^2)$ amplitude.



Q^2 range of interest: $0.05 - 2 \text{ GeV}^2$
 $Q^2 = 4E_{\text{Beam}}E_e \sin^2 \frac{\vartheta}{2} \Rightarrow \vartheta < 5^\circ$

Scattered electrons will be detected in the Forward Detector of CLAS12 for scattering angles greater than about 6° . Charged hadrons will be measured in the full range from 6° to 130° .

Deep Process Kinematics with 6.6 , 8.8, and 12 GeV



- Increase and optimize kinematical coverage with 6.6, 8.8, and 11 GeV
- “Rosenbluth” type separation between DVCS /Bethe-Heitler interference term and DVCS square term
- Clean extraction of Imaginary and Real parts of Compton Form Factors
- Use dispersion relations to access the elusive D-term and open physics reach of exclusive processes beyond Imaging in the transverse plane

11:00

Helicity amplitude formulation of hard exclusive processes 20'

Speaker: Prof. simonetta liuti (university of virginia)

Material:

Slides



In order to understand how twist three GPDs can be measured one needs to develop the appropriate formalism

We are developing the **framework** for extracting OAM and the 3D Structure of the nucleon from experimental data

1st practical problem: Finding a parametric functional form given the enhanced complexity

From DIS

$$q(x, Q_o^2) = A_q x^{-\alpha_q} (1-x)^{\beta_q} F(x, c_q, d_q, \dots)$$



to DVCS, DVMP

$$H_q(x, \xi, t, Q_o^2) = ?$$

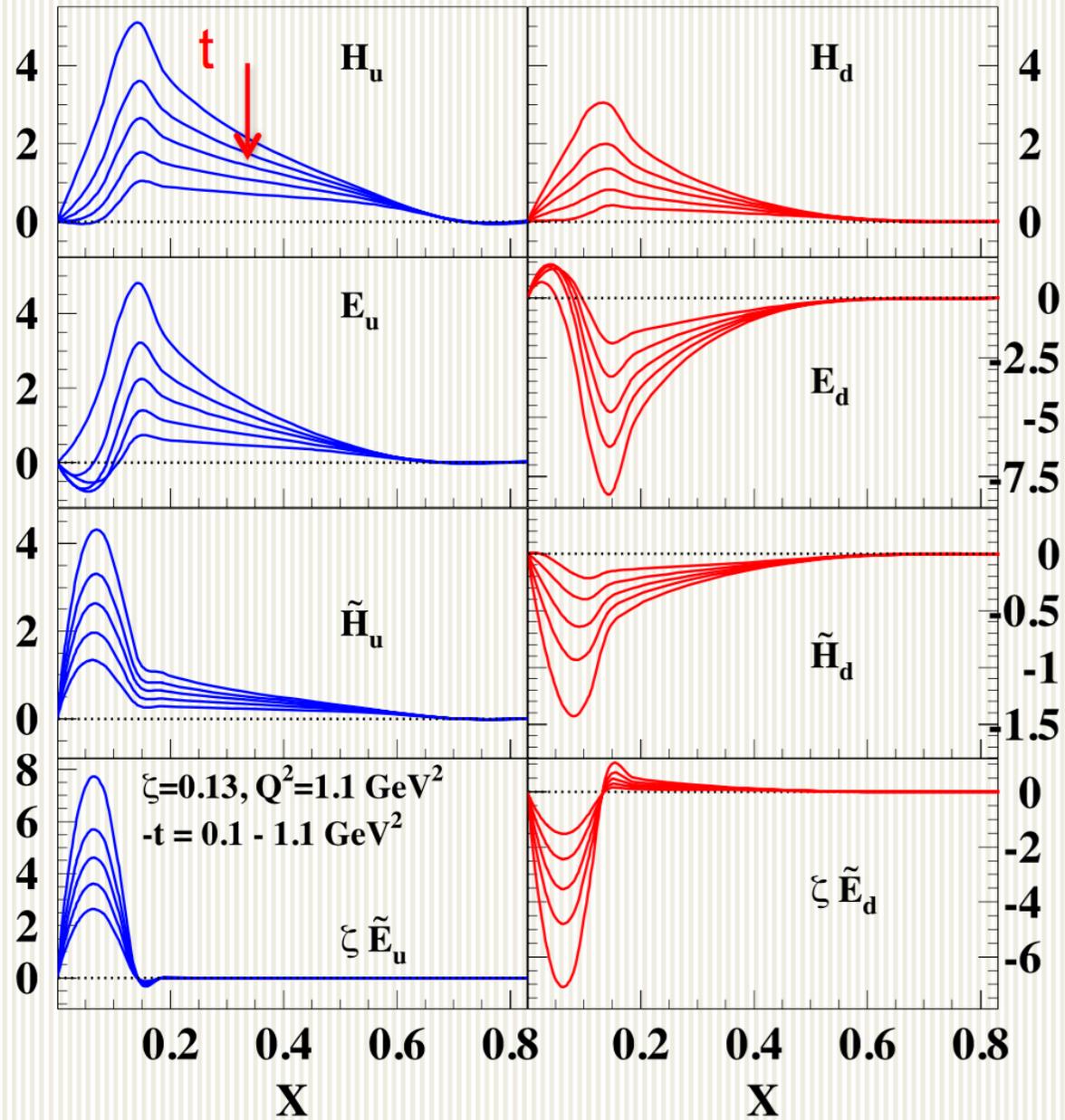
to DVCS, DVMP

Covariant Scattering Matrix Framework

$$H_q(x, \xi, t, Q_o^2) = N_q x^{-[\alpha_q + \alpha'_q (1-x)^p t + f(\beta\xi)]} G(x, \xi, t, m_q, M_X^q, M_\Lambda^q)$$

Reggeized diquark model

GPDs (with error, Hessian, not shown)



11:20 Discussion of the ND3 run group extension proposal 40'

Speaker: Silvia Nicolai (IPN Orsay)

Material:



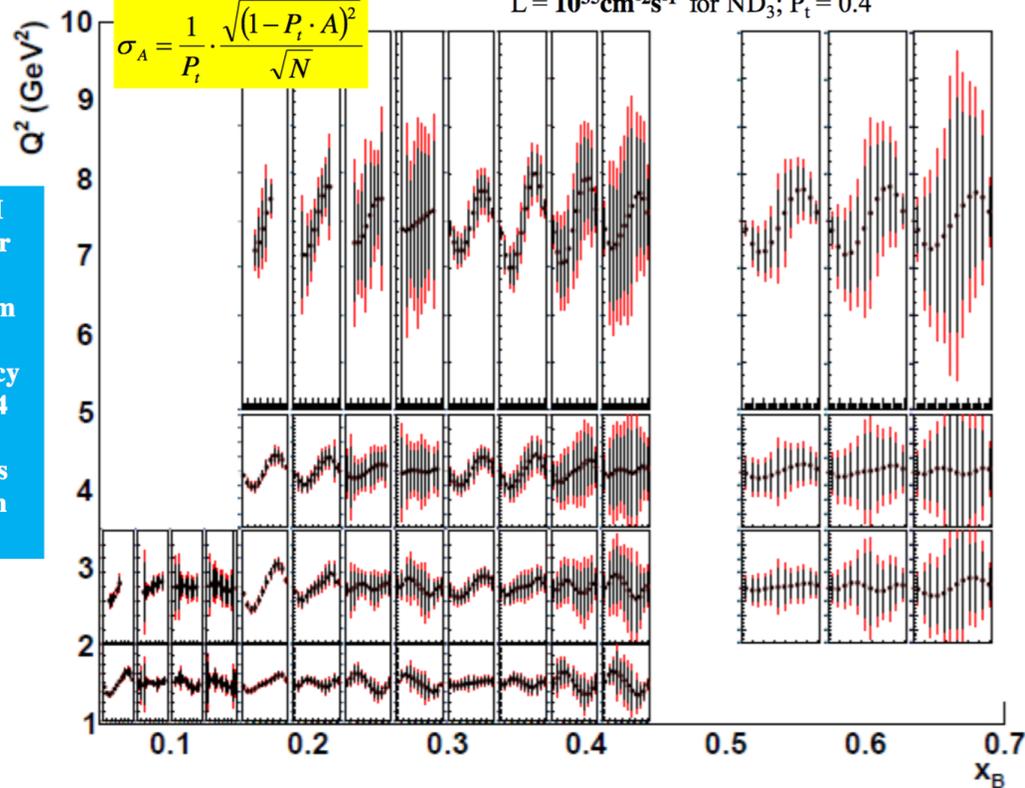
nDVCS: projected target-spin asymmetry

100 days

50 days

$L = 10^{35} \text{cm}^{-2} \text{s}^{-1}$ for ND3; $P_t = 0.4$

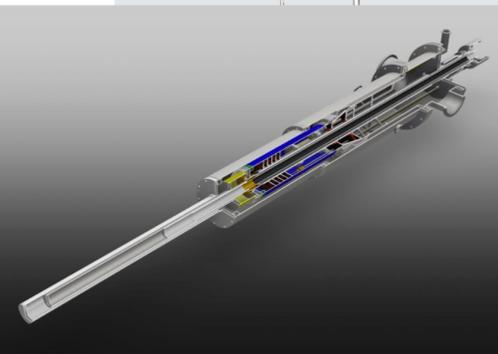
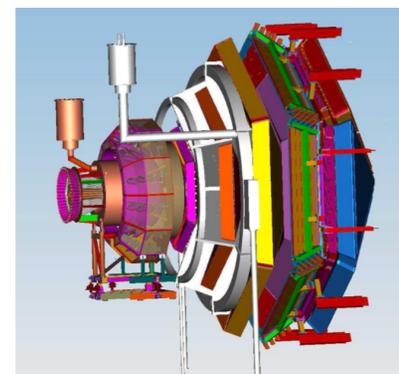
$$\sigma_A = \frac{1}{P_t} \cdot \frac{\sqrt{(1 - P_t \cdot A)^2}}{\sqrt{N}}$$



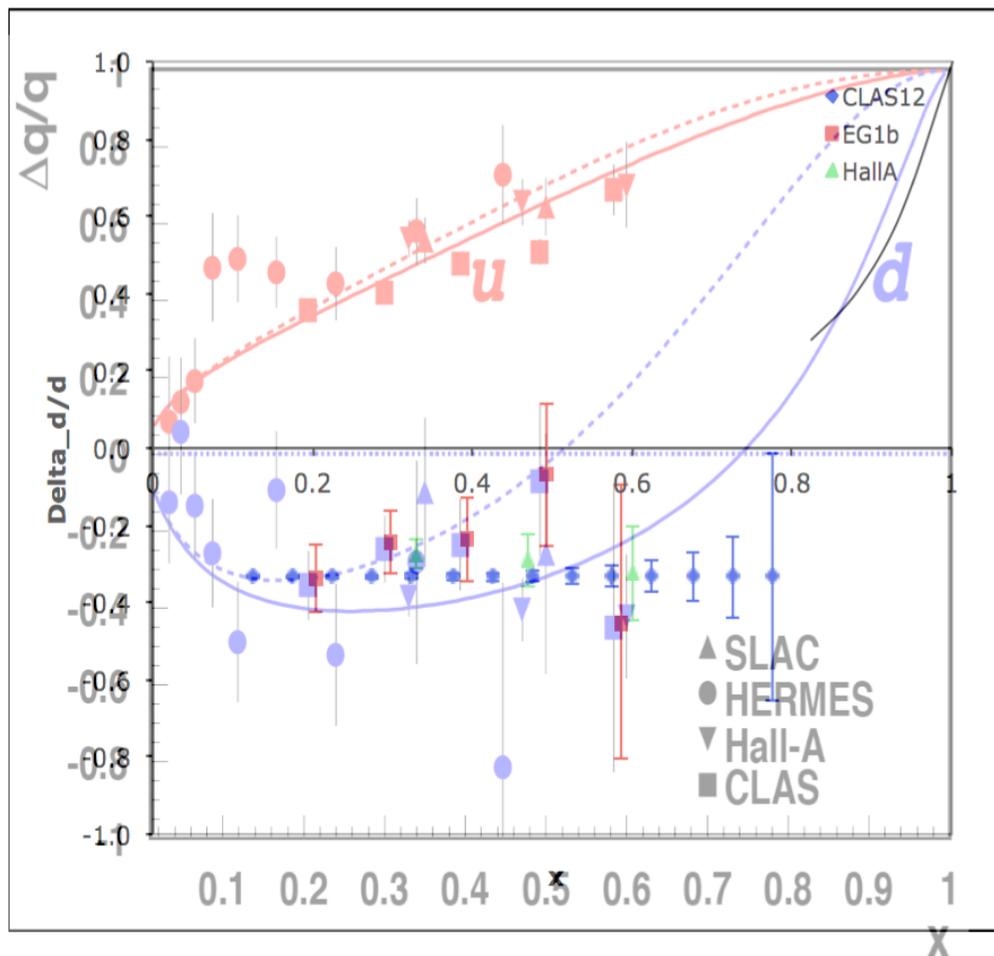
Minisession on the extension of the polarized ND3 CLAS12 run group

Silvia Nicolai 

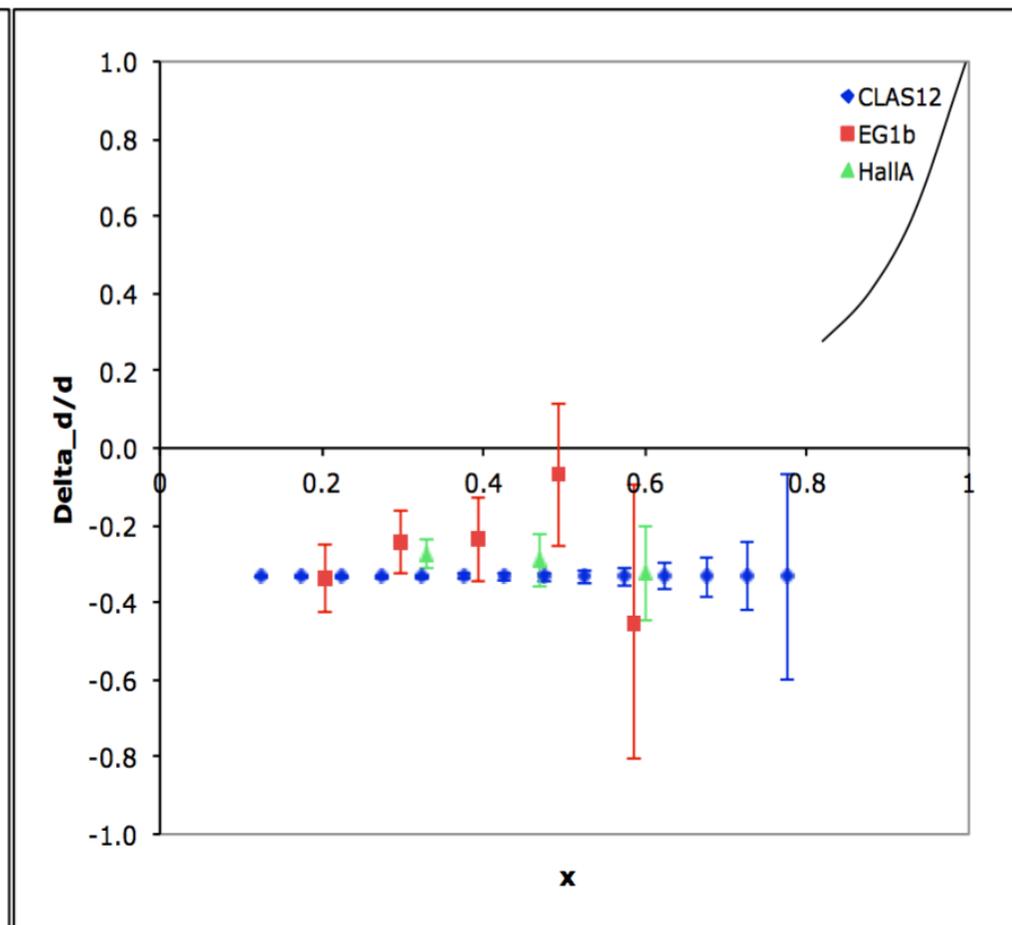
CLAS Collaboration meeting, 2/25/2015



DELTA-D / D



50 days on ND3



100 days on ND3

- DPWG analyses are working their way through the system
- Analysis/extraction frameworks are needed for SIDIS and DVCS
- There will likely be a request for more polarized deuterium running.