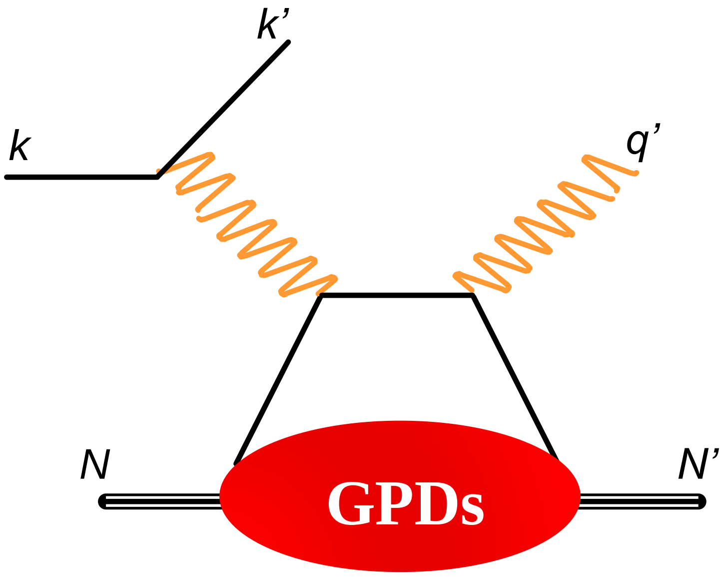
Deeply virtual Compton scattering on longitudinally polarized protons and on ^{4}He

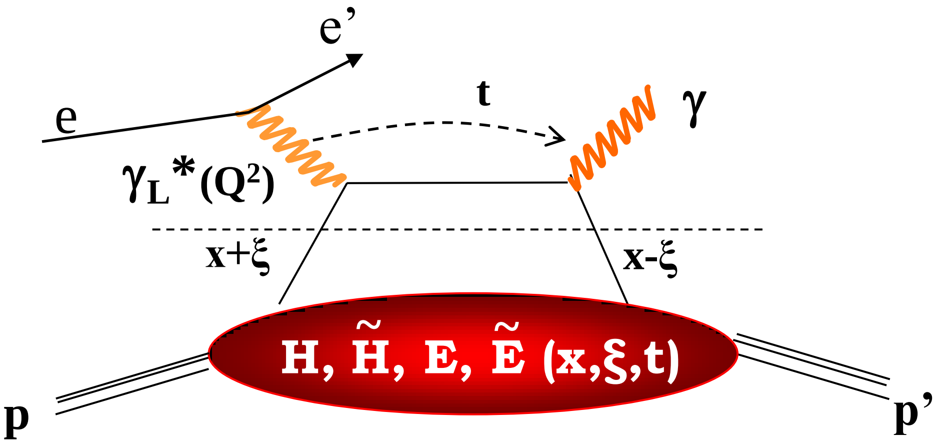


A. Biselli (Fairfield U), S. Niccolai (IPN Orsay), S. Pisano (INFNFR), E. Seder (UConn)

GDR PH-QCD, Saclay, November 27th 2013

IPN ORSAY

Deeply Virtual Compton Scattering and GPDs



- $Q^2 = -(e-e')^2$
- $x_B = Q^2/2M\nu \quad \nu = E_e - E_{e'}$

- x+ξ, x-ξ longitudinal momentum fractions
- $t = (p-p')^2$
- $\xi \cong x_B/(2-x_B)$

4 GPDs for each quark flavor

conserve nucleon helicity

Vector: $H\ (x,\xi,t)$ **Axial-Vector: $\tilde{H}\ (x,\xi,t)$**

Tensor: $E\ (x,\xi,t)$ **Pseudoscalar: $\tilde{E}\ (x,\xi,t)$**

flip nucleon helicity

« Handbag » factorization valid in the Bjorken regime:
high Q^2, ν (fixed x_B), $t \ll Q^2$

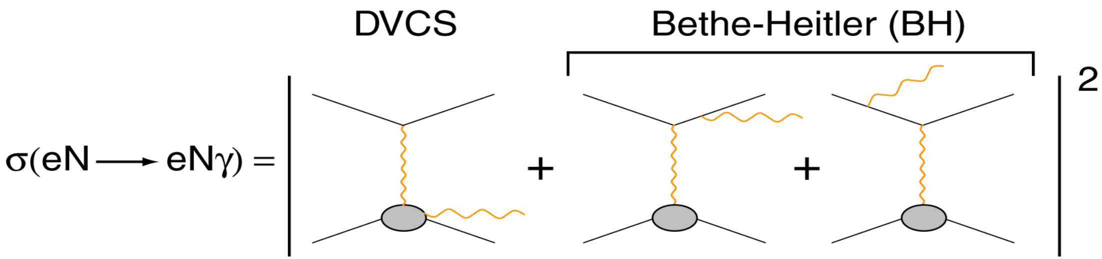
Quark angular momentum (Ji's sum rule)

$$J^q = \frac{1}{2} - J^G = \frac{1}{2}\int_{-1}^{1} x\,dx\left[H^q(x,\xi,0) + E^q(x,\xi,0)\right]$$

X. Ji, Phy.Rev.Lett.78,610(1997)

«3D» quark/gluon image of the nucleon

Accessing GPDs through DVCS

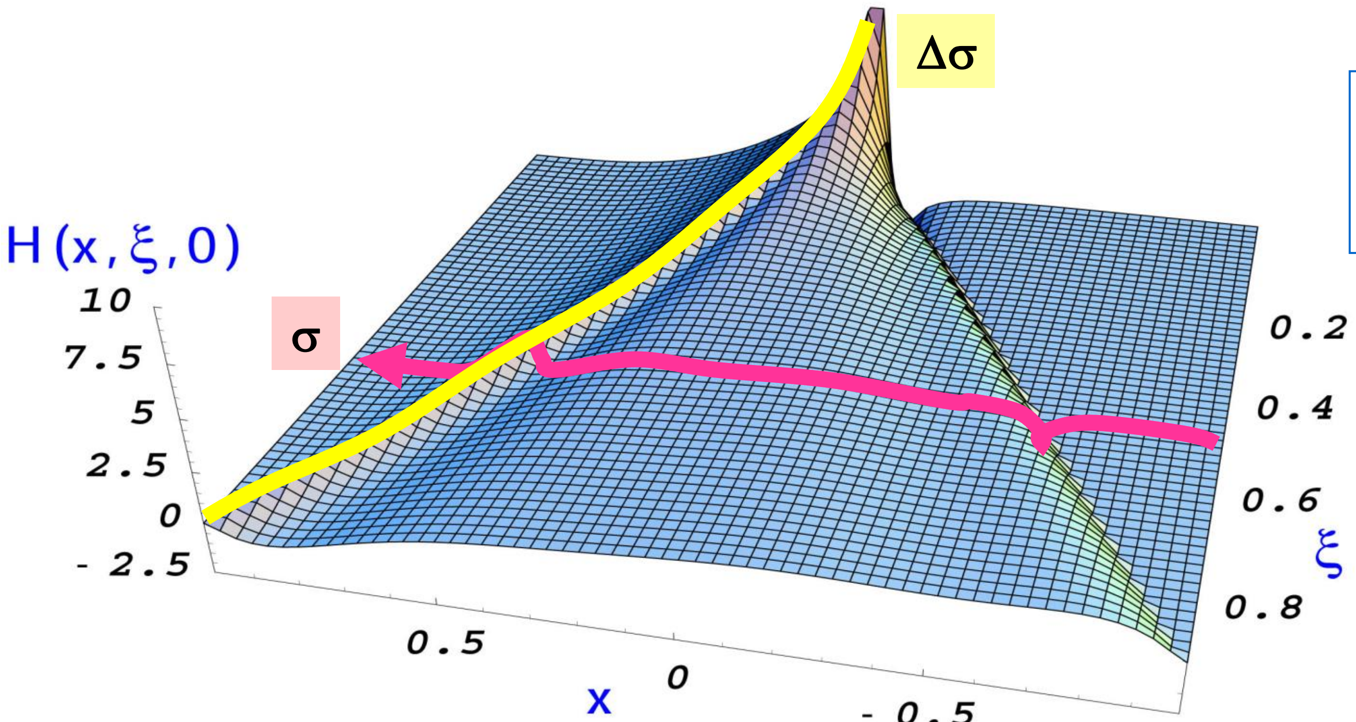


$$\sigma \sim |T^{DVCS} + T^{BH}|^2$$

$$\Delta\sigma = \sigma^{+} - \sigma^{-} \propto I(DVCS \cdot BH)$$

$$A = \frac{\Delta\sigma}{2\sigma} \propto \frac{I(DVCS \cdot BH)}{|BH|^2 + |DVCS|^2 + I}$$

$$T^{DVCS} \sim \int_{-1}^{+1} \frac{GPDs(x,\xi,t)}{x \pm \xi + i\varepsilon} dx + \ldots \sim P\int_{-1}^{+1} \frac{GPDs(x,\xi,t)}{x \pm \xi} dx \pm i\pi GPDs(\pm\xi,\xi,t) + \ldots$$

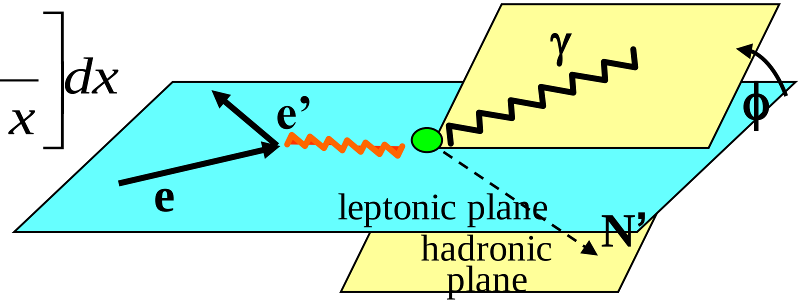


Only x and t are accessible experimentally

Sensitivity to GPDs of DVCS spin observables

$$Re\mathcal{H}_q = e_q^2 P\int_0^{+1}\left(H^q(x,\xi,t)-H^q(-x,\xi,t)\right)\left[\frac{1}{\xi-x}+\frac{1}{\xi+x}\right]dx$$

$$Im\mathcal{H}_q = \pi e_q^2\left[H^q(\xi,\xi,t)-H^q(-\xi,\xi,t)\right]$$



$x = x_B/(2-x_B)$ $k = -t/4M^2$

Proton **Neutron**

Polarized **beam**, unpolarized target:

$\Delta\sigma_{LU}$ ~ $\sin\phi$ **Im**$\{F_1 H + x(F_1+F_2)\tilde{H} - kF_2 E\}d\phi$ ⇒ $Im\{\mathcal{H}_p, \tilde{\mathcal{H}}_p, \mathcal{E}_p\}$ $Im\{\mathcal{H}_n, \tilde{\mathcal{H}}_n, \mathcal{E}_n\}$

Unpolarized beam, **longitudinal** target:

$\Delta\sigma_{UL}$ ~ $\sin\phi$**Im**$\{F_1\tilde{H} + x(F_1+F_2)(H + x_B/2E) - xkF_2\tilde{E} + \ldots\}d\phi$ ⇒ $Im\{\mathcal{H}_p, \tilde{\mathcal{H}}_p\}$ $Im\{\mathcal{H}_n, \mathcal{E}_n, \tilde{\mathcal{E}}_n\}$

Polarized **beam**, **longitudinal** target:

$\Delta\sigma_{LL}$ ~ $(A+B\cos\phi)$**Re**$\{F_1\tilde{H} + x(F_1+F_2)(H + x_B/2E)\ldots\}d\phi$ ⇒ $Re\{\mathcal{H}_p, \tilde{\mathcal{H}}_p\}$ $Re\{\mathcal{H}_n, \mathcal{E}_n, \tilde{\mathcal{E}}_n\}$

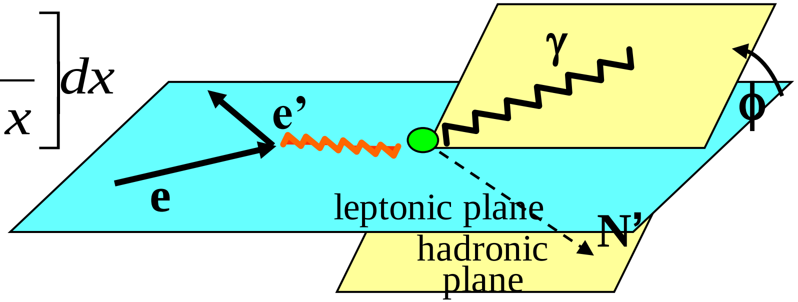
Unpolarized beam, **transverse** target:

$\Delta\sigma_{UT}$ ~ $\sin\phi$**Im**$\{k(F_2 H - F_1 E) + \ldots\}d\phi$ ⇒ $Im\{\mathcal{H}_p, \mathcal{E}_p\}$ $Im\{\mathcal{H}_n\}$

Sensitivity to GPDs of DVCS spin observables

$$Re\mathcal{H}_q = e_q^2 P\int_0^{+1}\left(H^q(x,\xi,t) - H^q(-x,\xi,t)\right)\left[\frac{1}{\xi - x} + \frac{1}{\xi + x}\right]dx$$

$$Im\mathcal{H}_q = \pi e_q^2\left[H^q(\xi,\xi,t) - H^q(-\xi,\xi,t)\right]$$



$x = x_B/(2-x_B)$ $k=-t/4M^2$

Proton   Neutron

Polarized **beam**, unpolarized target:

$\Delta\sigma_{LU} \sim \sin\phi\ \mathbf{Im}\{F_1 H + x(F_1+F_2)\tilde{H} - kF_2 E\}d\phi$ → $Im\{\mathcal{H}_p, \tilde{\mathcal{H}}_p, \mathcal{E}_p\}$, $Im\{\mathcal{H}_n, \tilde{\mathcal{H}}_n, \mathcal{E}_n\}$

Unpolarized beam, **longitudinal** target:

$\Delta\sigma_{UL} \sim \sin\phi\,\mathbf{Im}\{F_1\tilde{H} + x(F_1+F_2)(H + x_B/2E) - xkF_2\tilde{E} + \ldots\}d\phi$ → $Im\{\mathcal{H}_p, \tilde{\mathcal{H}}_p\}$, $Im\{\mathcal{H}_n, \mathcal{E}_n, \tilde{\mathcal{E}}_n\}$

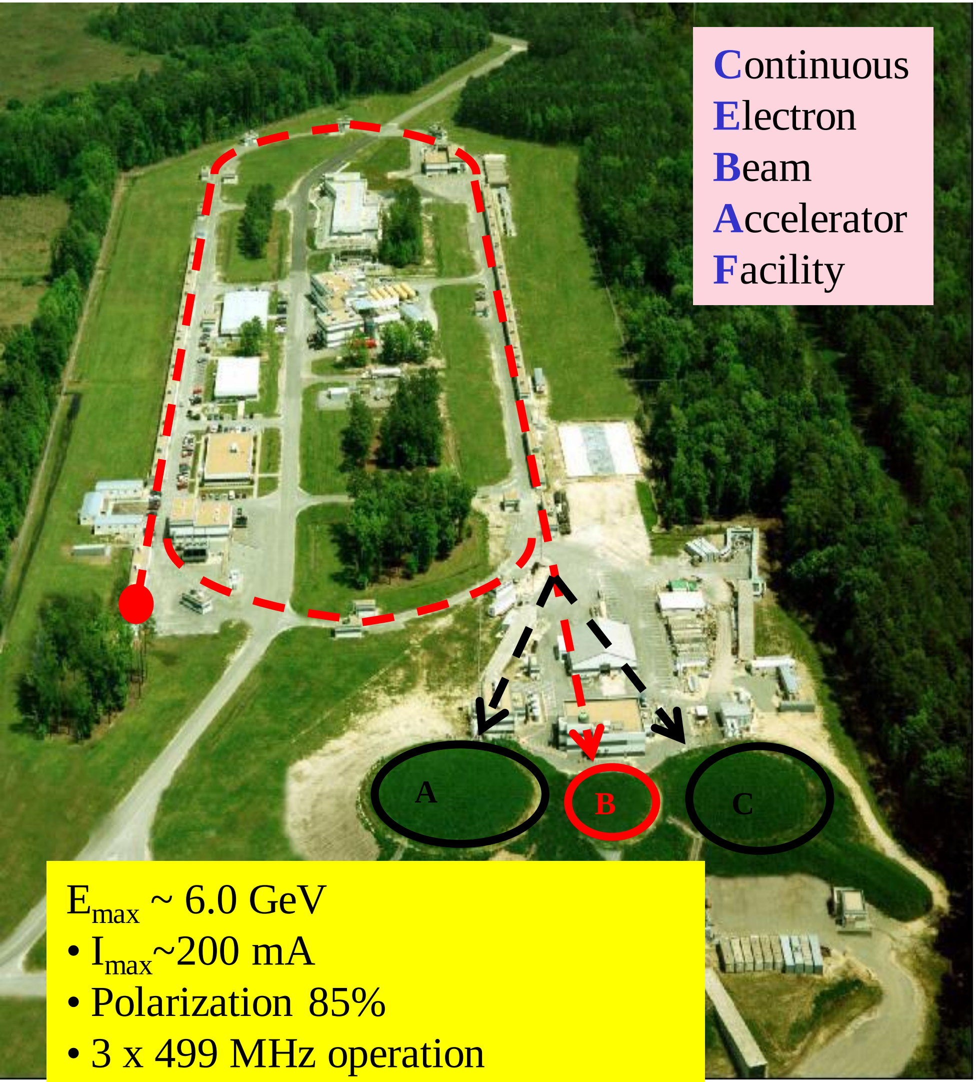
Polarized **beam**, **longitudinal** target:

$\Delta\sigma_{LL} \sim (A+B\cos\phi)\mathbf{Re}\{F_1\tilde{H} + x(F_1+F_2)(H + x_B/2E)\ldots\}d\phi$ → $Re\{\mathcal{H}_p, \tilde{\mathcal{H}}_p\}$, $Re\{\mathcal{H}_n, \mathcal{E}_n, \tilde{\mathcal{E}}_n\}$

Unpolarized beam, **transverse** target:

$\Delta\sigma_{UT} \sim \sin\phi\,\mathbf{Im}\{k(F_2 H - F_1 E) + \ldots\}d\phi$ → $Im\{\mathcal{H}_p, \mathcal{E}_p\}$, $Im\{\mathcal{H}_n\}$

JLab@6 GeV and CLAS



Continuous
Electron
Beam
Accelerator
Facility

E_{max} ~ 6.0 GeV
- I_{max}~200 mA
- Polarization 85%
- 3 x 499 MHz operation
- Simultaneous delivery to 3 halls
- Shutdown in May 2012

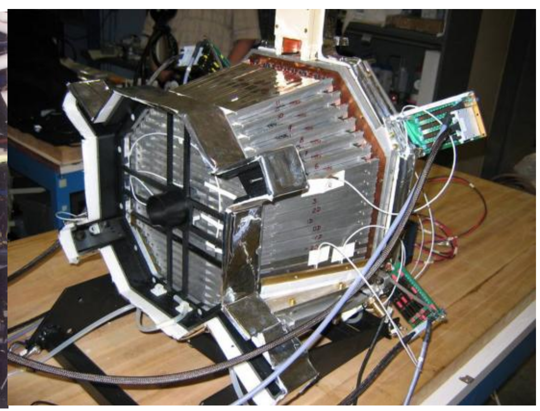
CLAS@Hall B:
- **large acceptance** for charged particles
- $8° < \theta < 142°$, $p_p > 0.3$ GeV/c, $p_p > 0.1$GeV/c
- **good momentum and angular resolution**
- $\Delta p/p \leq 0.5\%$ - 1.5%, $\Delta\theta$, $\Delta\phi \leq 1$ mrad
- suited for **multi-particle final states**
- $L \sim 10^{34}$ cm^{-2} s^{-1}

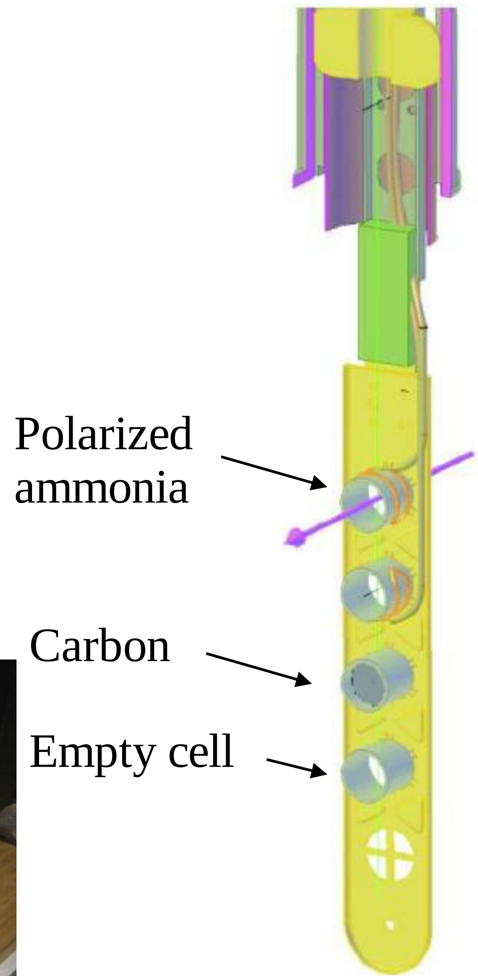
The eg1-dvcs experiment

- Data taken from February to September **2009**
- Beam energies = 4.735, 5.764, 5.892, 5.967 GeV
- Beam polarizaton ~ 85%
- **CLAS+IC** to detect forward photons
- Target: **longitudinally polarized** via DNP (5 Tesla, 1 K, 140 Ghz microwaves) $\mathbf{NH_3}$ (~80%) and $\mathbf{ND_3}$ (~30%) – Luminosity ~ $5\cdot10^{34}$ cm^{-2} s^{-1}
- Target polarization monitored by **NMR**, more precise values via **elastic asymmetry analysis**
- ~75 fb^{-1} on NH3 (parts A, B), ~25 fb^{-1} on ND3 (part C)

The results shown here come from parts A and B

(ongoing nDVCS analysis on part C by Daria Sokhan)





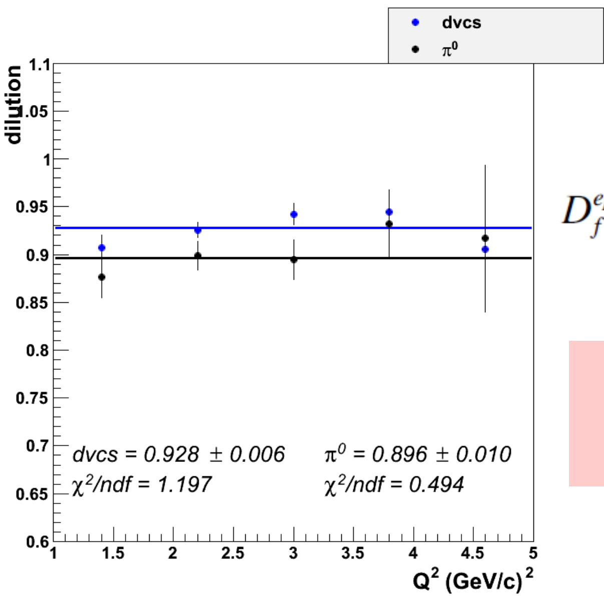
C.D. Keith et al., NIM A 501 (2003) 327

DVCS selection cuts

Events with exactly *1 e, 1 p* and at least *1 γ*

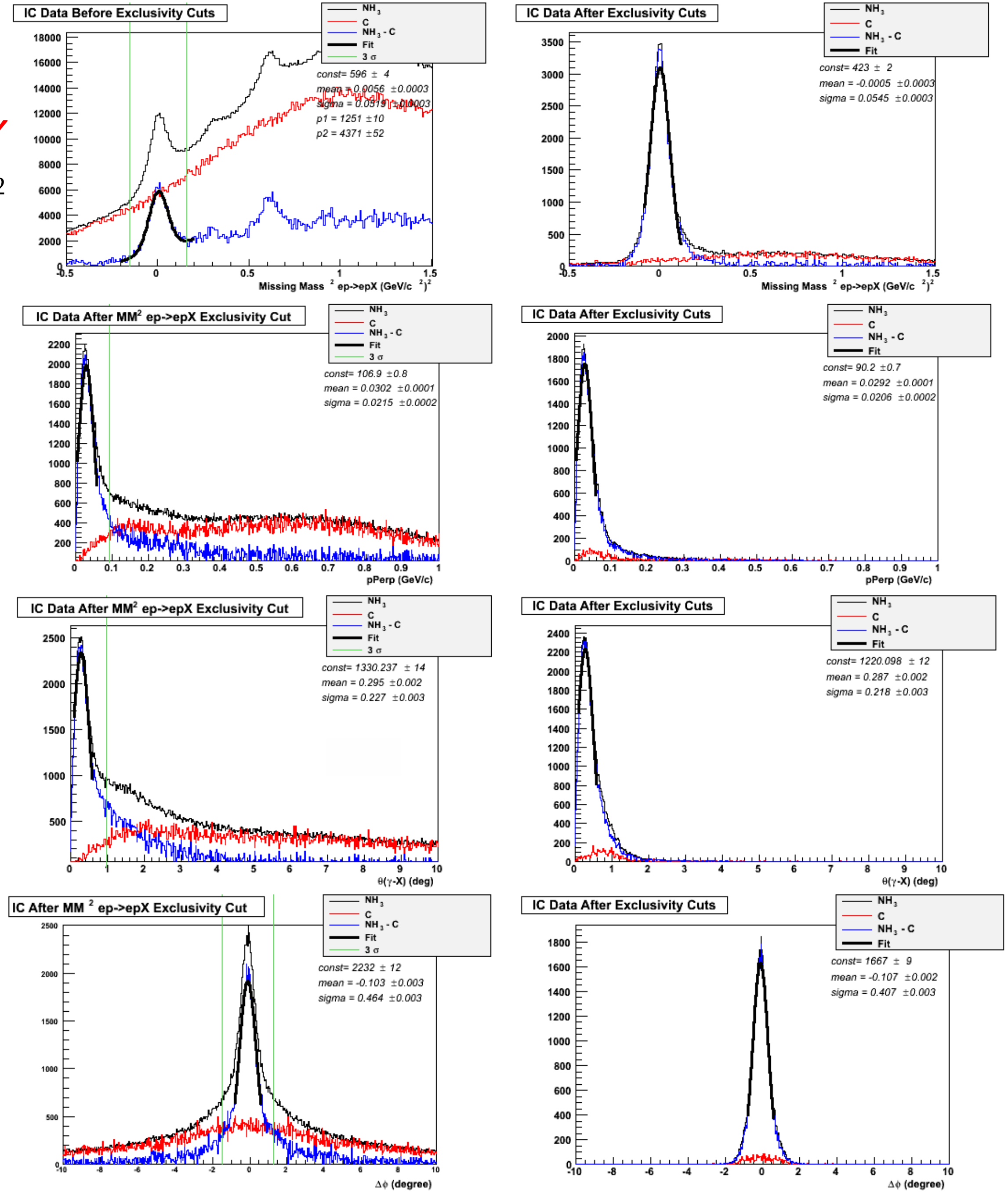
- «Preliminary» cuts: Q^2>1 GeV^2, W>2 GeV, -t>Q^2
- Exclusivity variables: MM^2(ep), p_{perp}, $\Delta\phi$, $\Delta\Theta_{\gamma X}$
- 3σ cuts, from Gaussian fits
- Cuts on p_{perp}, $\Delta\phi$, $\Delta\Theta_{\gamma X}$ determined after cut on MM^2(ep)
- Independent fits for data and MC
- Checked stability of widths before and after cuts

DVCS exclusivity cuts also serve to drastically **reduce the contribution from nuclear background**

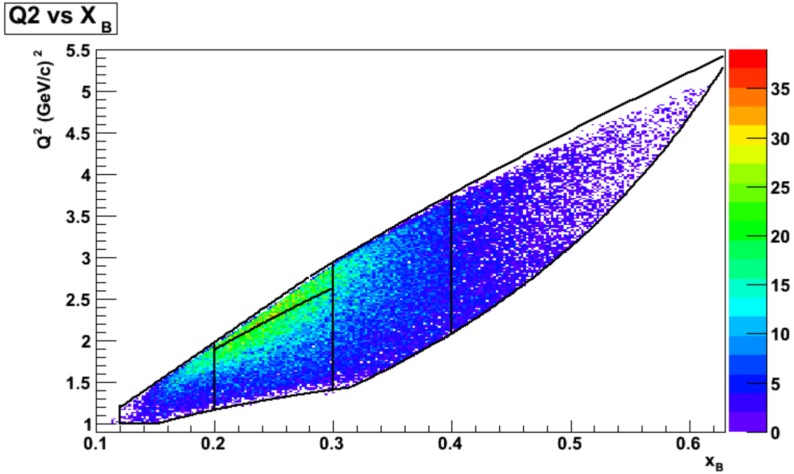


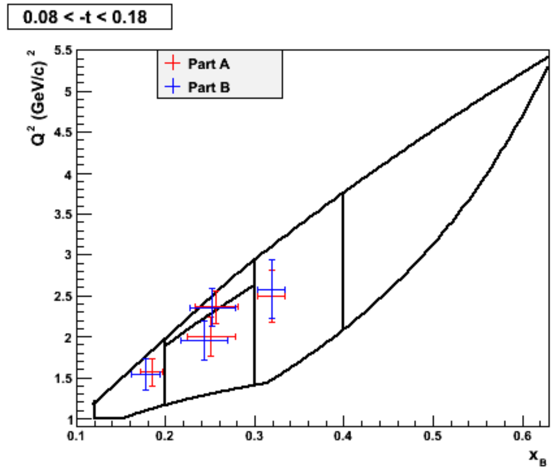
$$D_f^{ep\gamma} = 1 - C\,\frac{N^{C}_{ep\gamma}}{N^{NH_3}_{ep\gamma}}$$

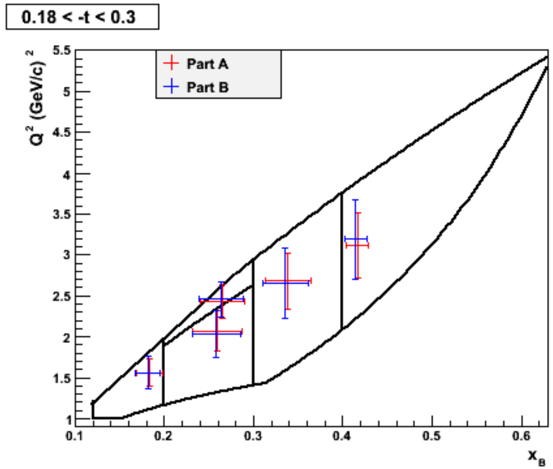
D_f = 0.928
for DVCS
(part B)

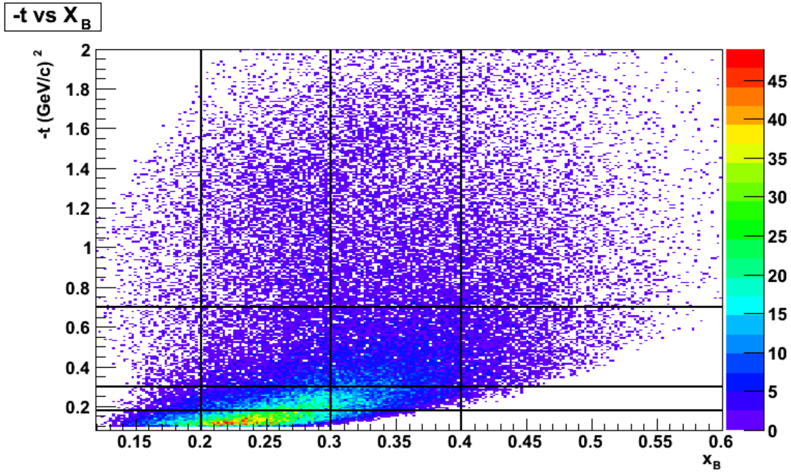


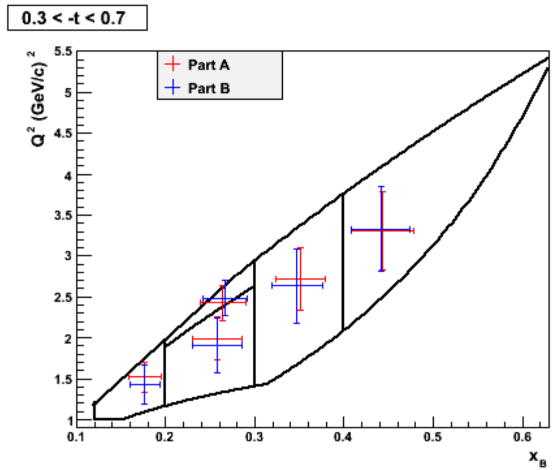
Phase space and binning

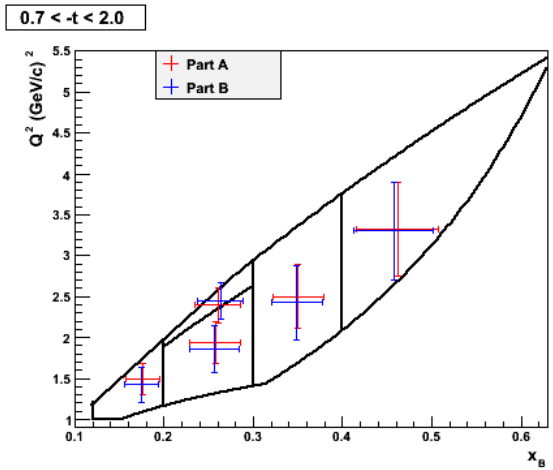












4D binning:

- 4 bins in -t
- 5 bins in Q^2
- 10 bins in ϕ

Beam energies:

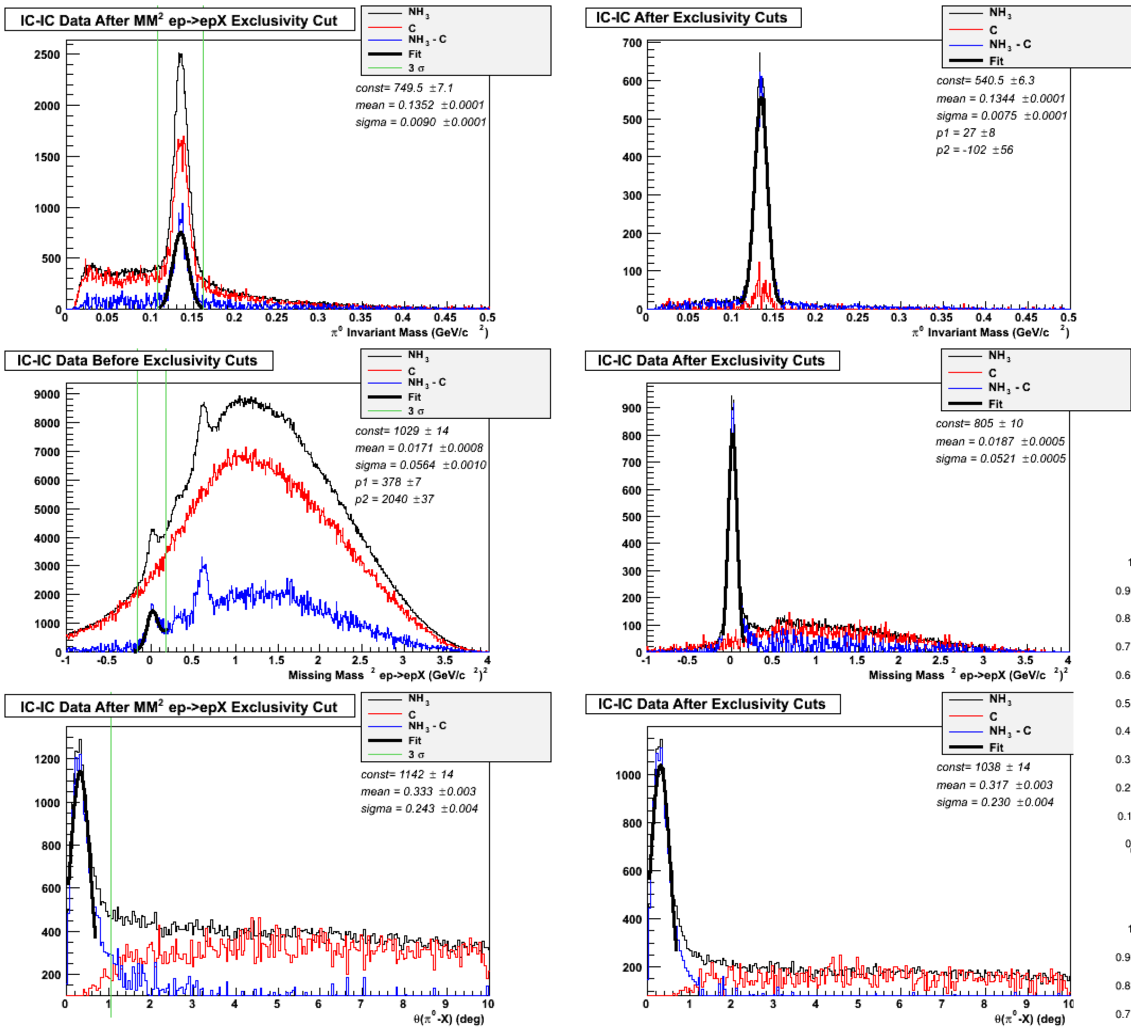
A → 5.892 GeV

B → 5.967 GeV

Average central kinematics for parts A and B compatible within their standard deviations

The asymmetries for the two data sets will be combined

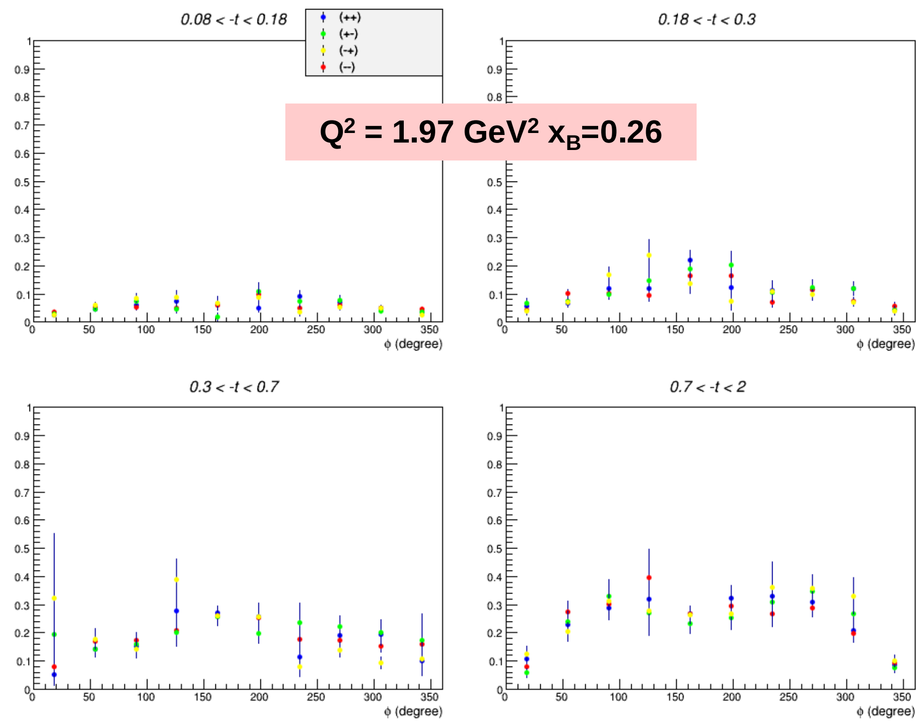
Subtraction of $ep\pi^0$ background



$$N^{bt} = \frac{(1 - B^{bt}_{\pi^0}) \cdot N^{bt}_{ep\gamma}}{FC}$$

$$B^{bt}_{\pi^0} = \frac{N^{MC}_{ep\pi^0(1\gamma)}}{N^{MC}_{ep\pi^0(2\gamma)}} \cdot \frac{N^{Data}_{ep\pi^0}}{N^{Data}_{ep\gamma}} \cdot \frac{D_f^{ep\pi^0}}{D_f^{ep\gamma}}$$

Average background/epγ ~10%
Higher at high $-t$, central ϕ



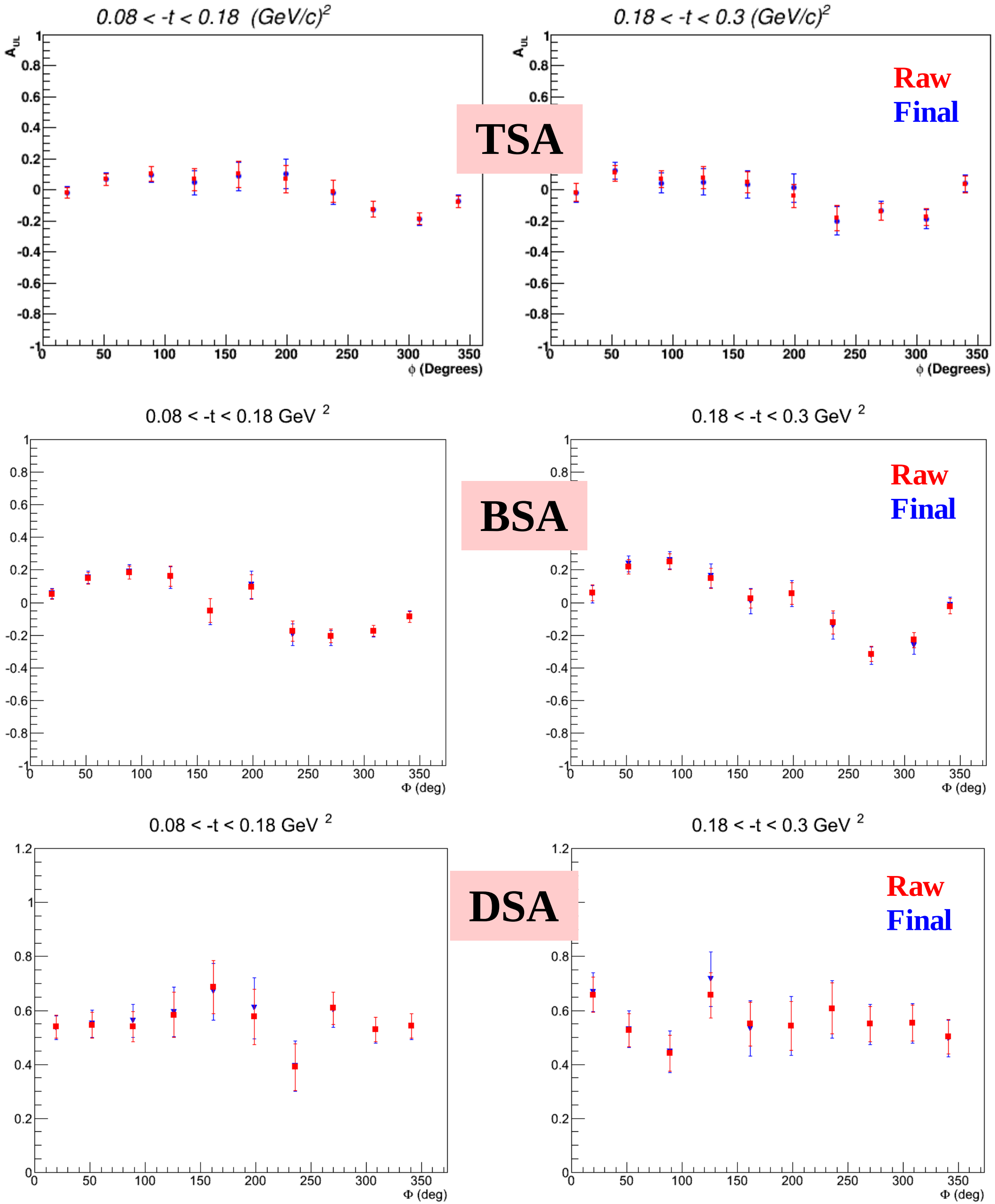
$ep\pi^0$ selection via 3σ cuts on:

- $MM^2(ep)$
- $IM(\gamma\gamma)$
- $\Delta\Theta_{\pi 0X}$

Cut widths determined separately for:

- photon detection topology
- data and MC

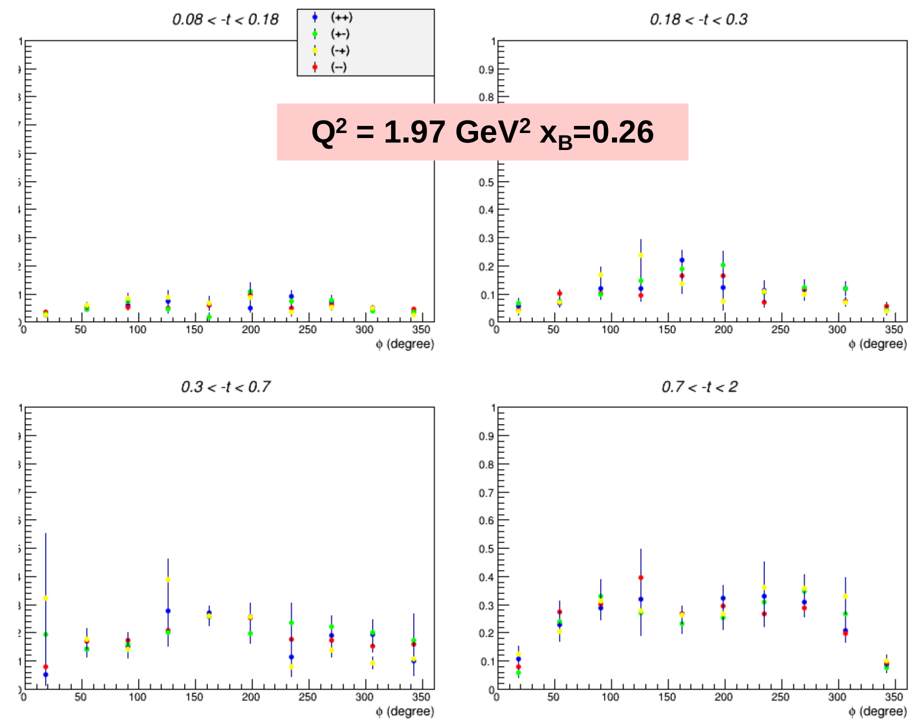
Subtraction of $ep\pi^0$ background



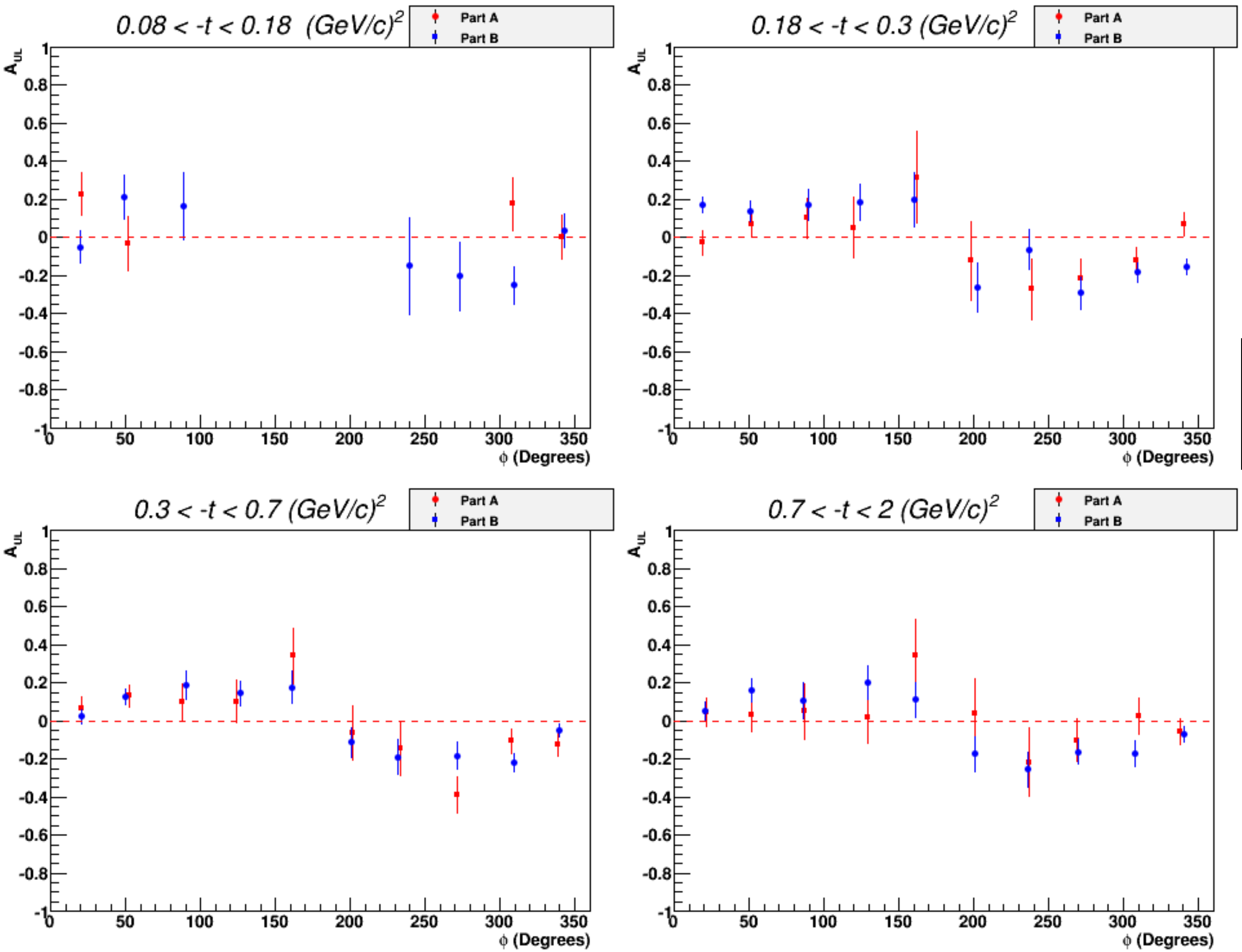
$$N^{bt} = \frac{(1 - B^{bt}_{\pi^0}) \cdot N^{bt}_{ep\gamma}}{FC}$$

$$B^{bt}_{\pi^0} = \frac{N^{MC}_{ep\pi^0(1\gamma)}}{N^{MC}_{ep\pi^0(2\gamma)}} \cdot \frac{N^{Data}_{ep\pi^0}}{N^{Data}_{ep\gamma}} \cdot \frac{D_f^{ep\pi^0}}{D_f^{ep\gamma}}$$

Average background/epγ ~10%
Higher at high –*t*, central ϕ



Merging of parts A and B



Beam energies:
A → 5.892 GeV
B → 5.967 GeV

Statistical compatibility of the two data sets verified via **Student's t test**

Asymmetry	t	Standard deviation	$1/\sqrt{N_{bins}}$
TSA	0.026	1.07	0.08
BSA	-0.027	1.15	0.08
DSA	-0.009	1.00	0.08

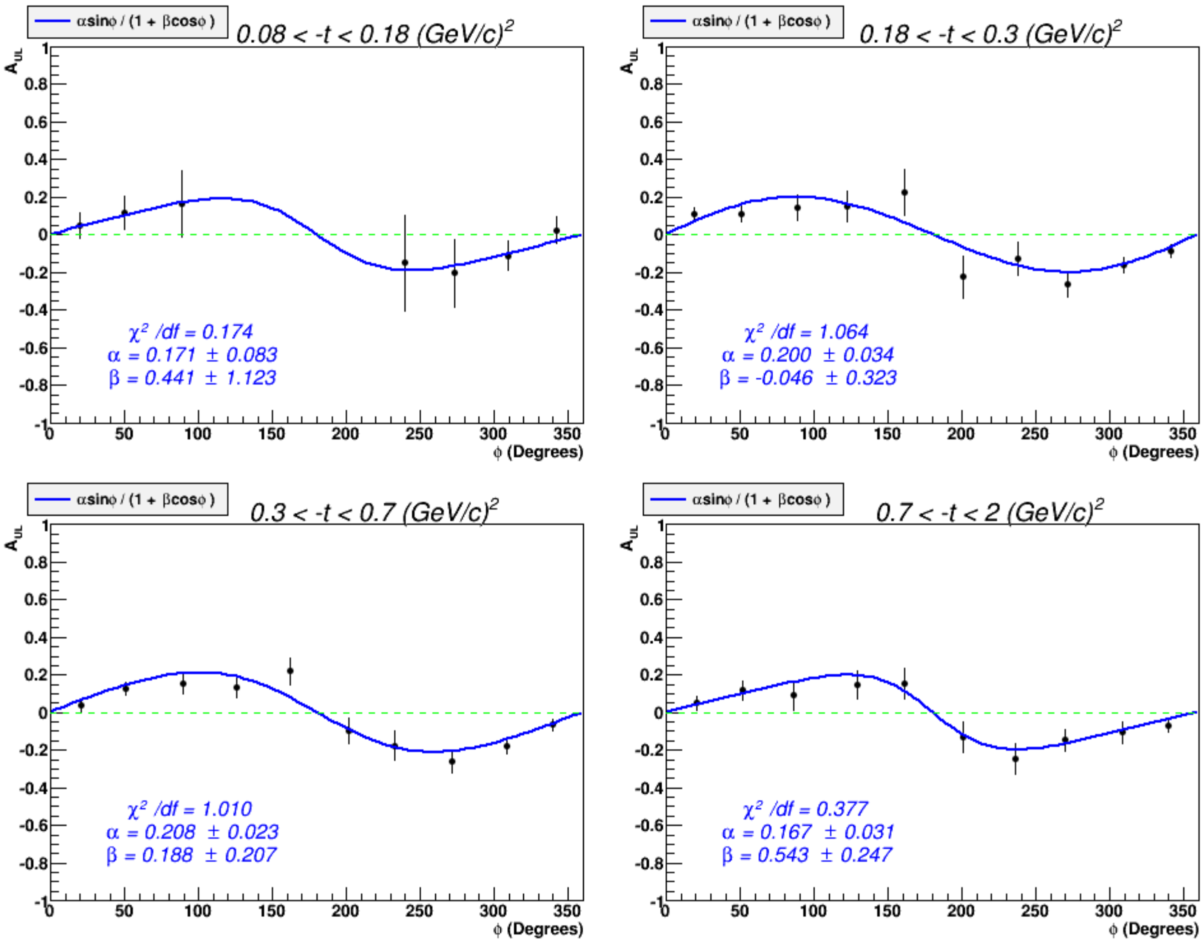
$$A_{comb} = \frac{A_A/\sigma(A_A)^2 + A_B/\sigma(A'_A)^2}{1/\sigma(A_A)^2 + 1/\sigma(A_B)^2}$$

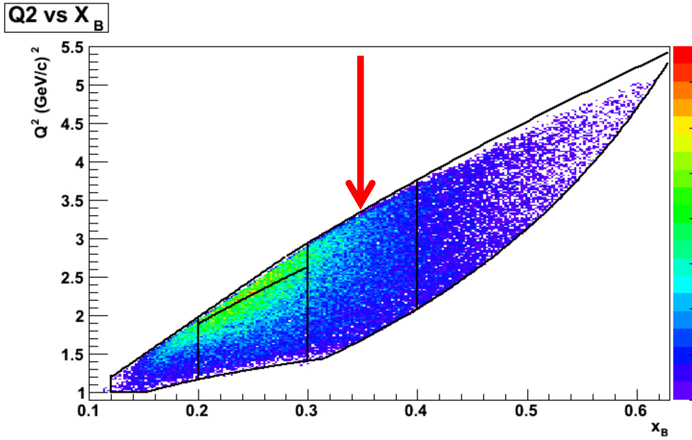
$$\sigma(A_{comb}) = \frac{1}{1/\sigma(A_A)^2 + 1/\sigma(A_B)^2}$$

Q^2 = 2.60 GeV^2 x_B=0.35

Results: TSA

TSA ~ $Im\{\mathcal{H}_p, \widetilde{\mathcal{H}}_p\}$





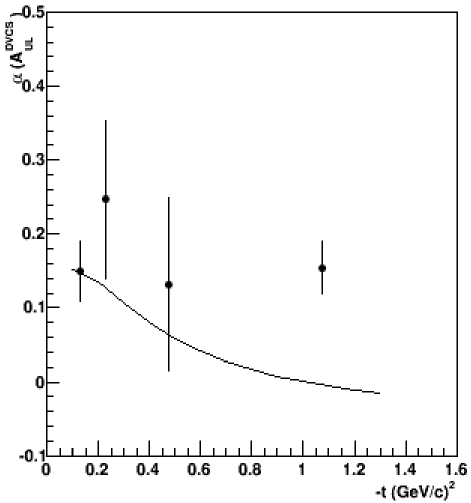
Fitting function:

αsinϕ/(1+βcosϕ)

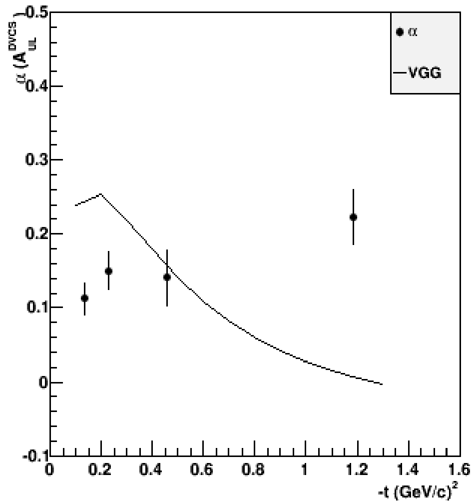
$$A_{UL} = \frac{1}{D_f} \frac{N^{++} + N^{-+} - N^{+-} - N^{--}}{P_T^-(N^{++} + N^{+-}) + P_T^+(N^{-+} + N^{--})}$$

Results: TSA

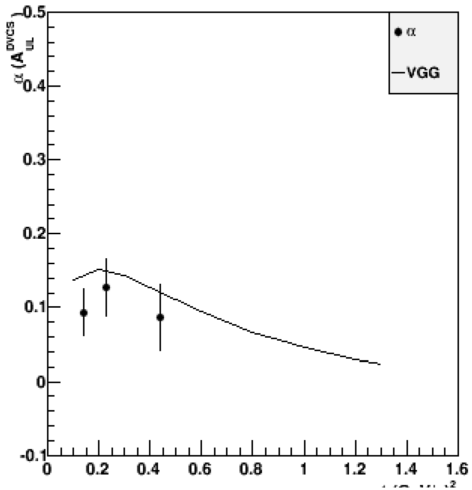
Q^2 = 1.52 GeV^2 x_B=0.18



Q^2 = 1.97 GeV^2 x_B=0.26



Q^2 = 2.41 GeV^2 x_B=0.26



TSA ~ $Im\{\mathcal{H}_p, \widetilde{\mathcal{H}}_p\}$

α term from the fit:

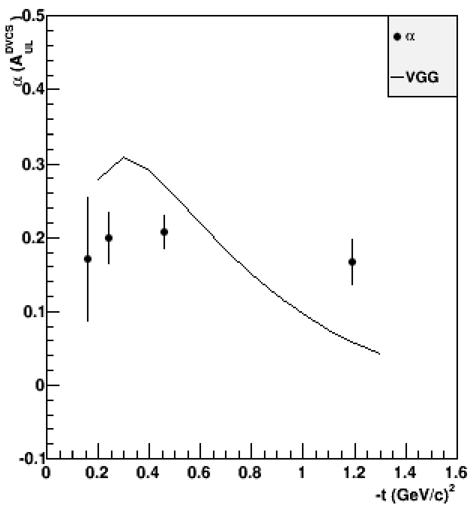
$\alpha\sin\phi/(1+\beta\cos\phi)$

compared to VGG model

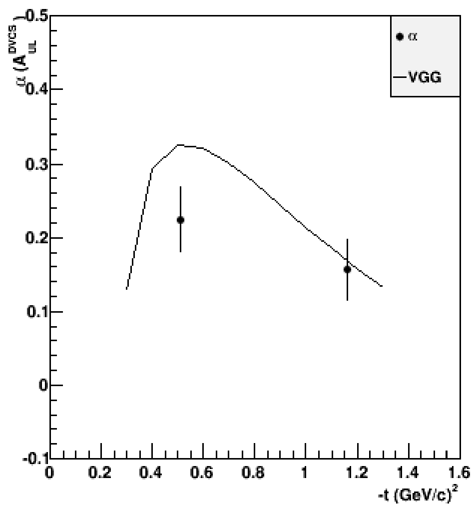
(predictions for the

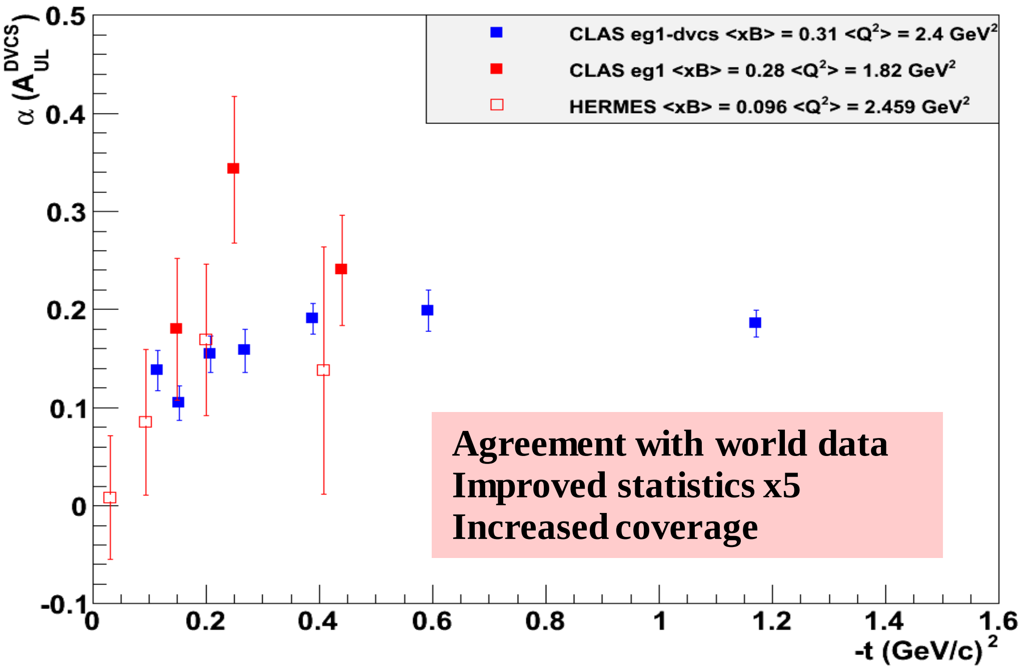
DVCS TSA @ 90°)

Q^2 = 2.60 GeV^2 x_B=0.35

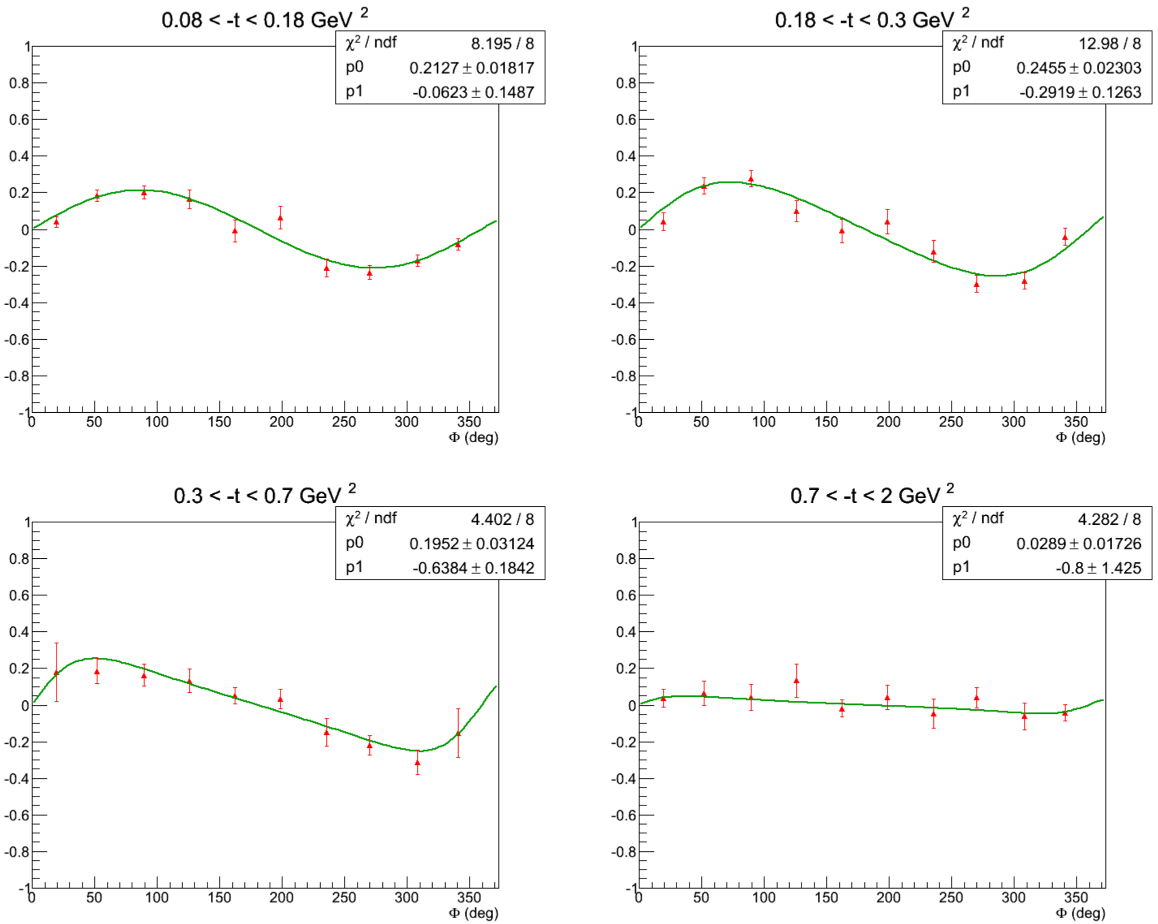


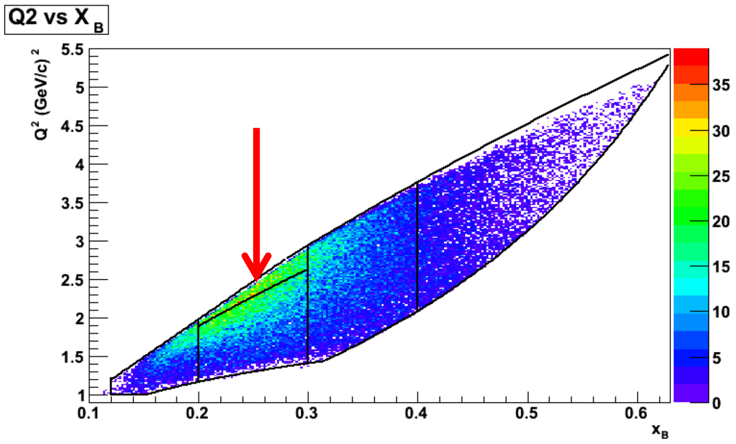
Q^2 = 3.31 GeV^2 x_B=0.45





Results: BSA





BSA ~ $Im\{\mathcal{H}_\mathbf{p}, \tilde{\mathcal{H}}_\mathrm{p}, \mathcal{E}_\mathrm{p}\}$

Fitting function:

$\alpha\sin\phi/(1+\beta\cos\phi)$

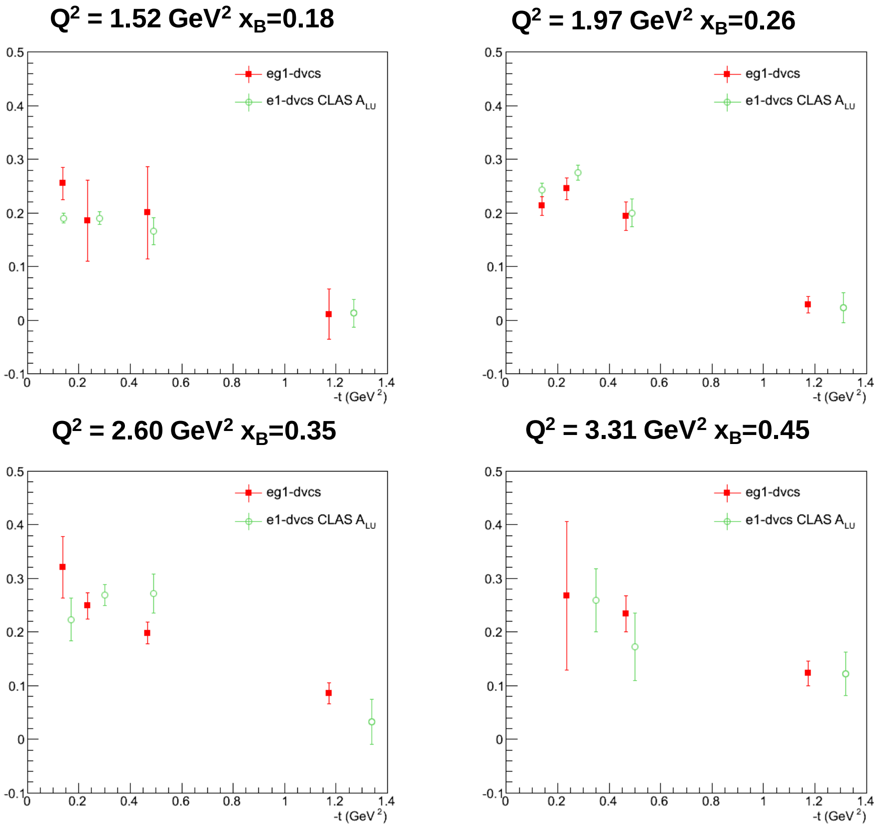
$$A_{LU} = \frac{1}{D_f P_B} \frac{P_T^-(N^{++} - N^{-+}) + P_T^+(N^{+-} - N^{--})}{P_T^-(N^{++} + N^{+-}) + P_T^+(N^{-+} + N^{--})}$$

Results: BSA

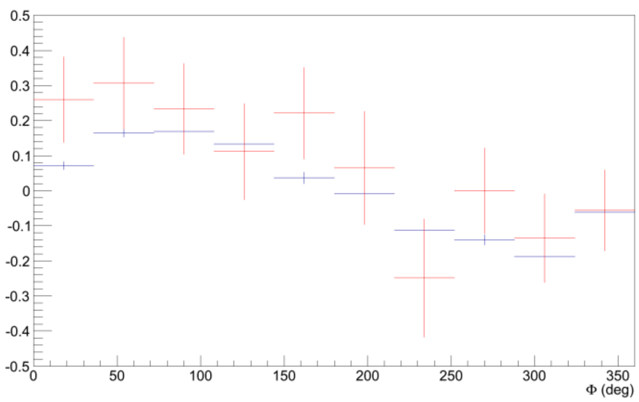
Comparison with published BSA
F.X. Girod et al., PRL. 100 162002 (2008)

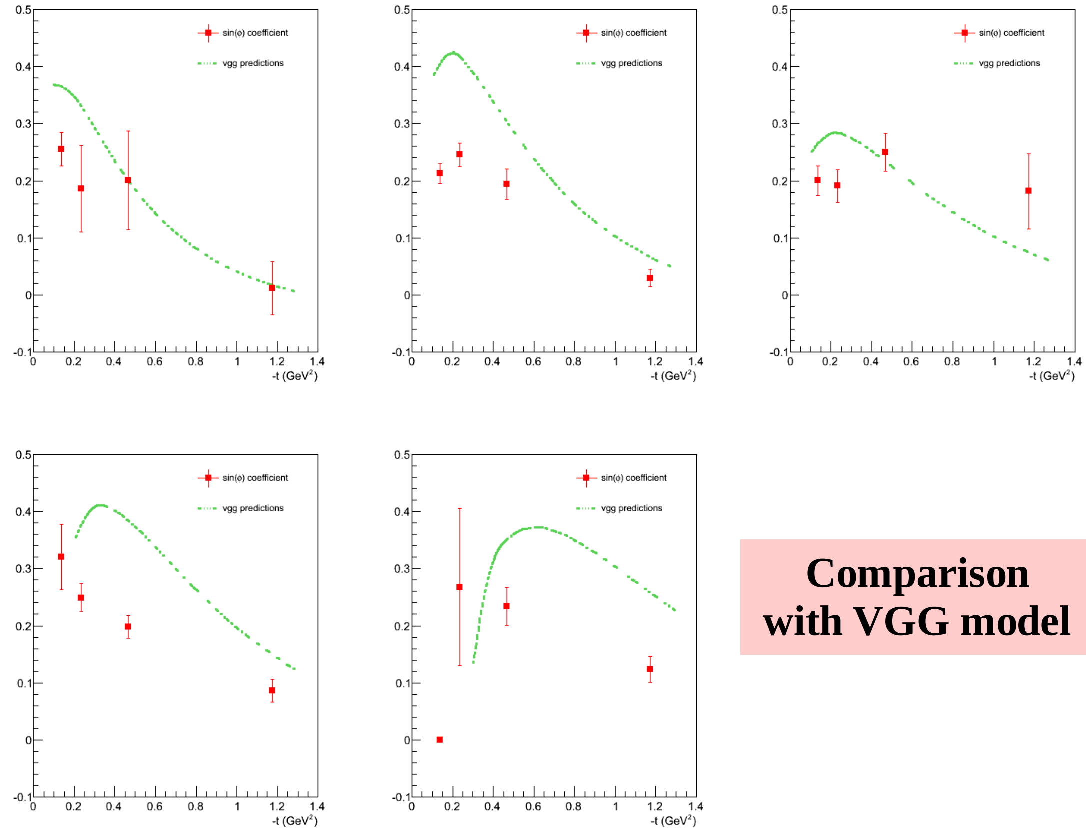
α term from fit:

$$\alpha \sin\phi / (1+\beta\cos\phi)$$



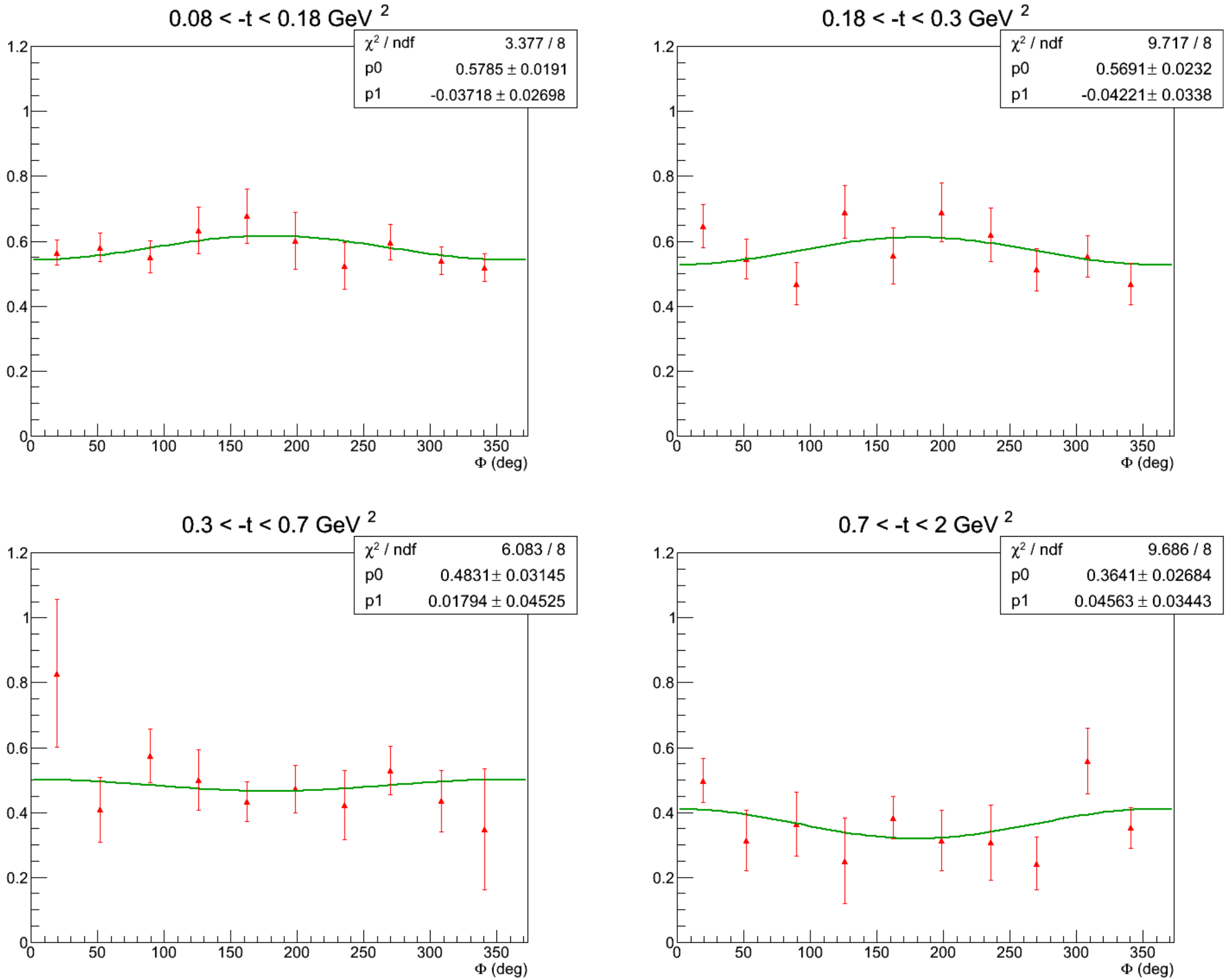
Integrated raw BSA for NH3 and C12

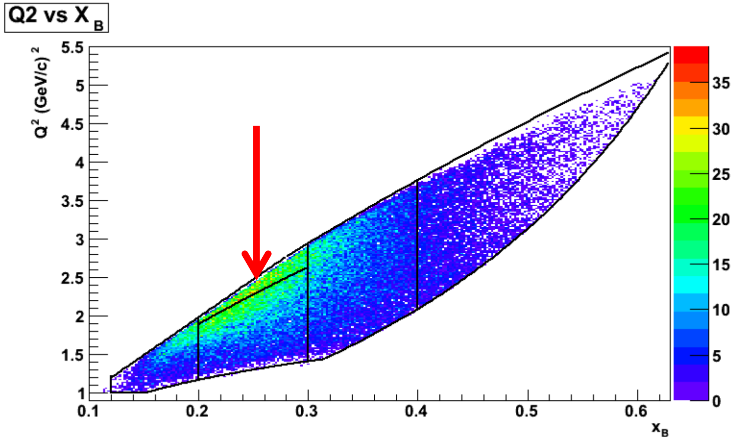




Comparison with VGG model

Results: DSA



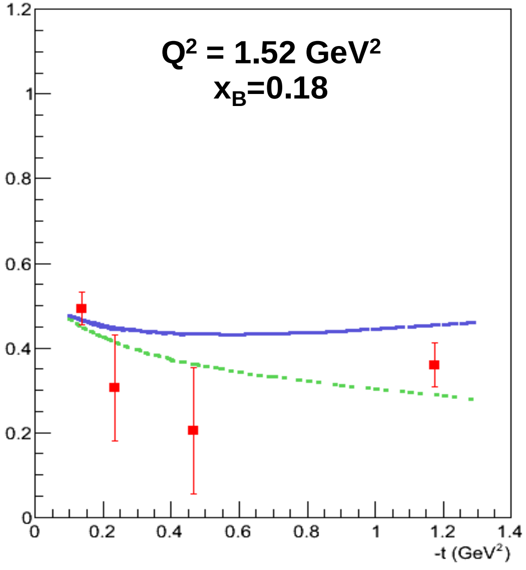


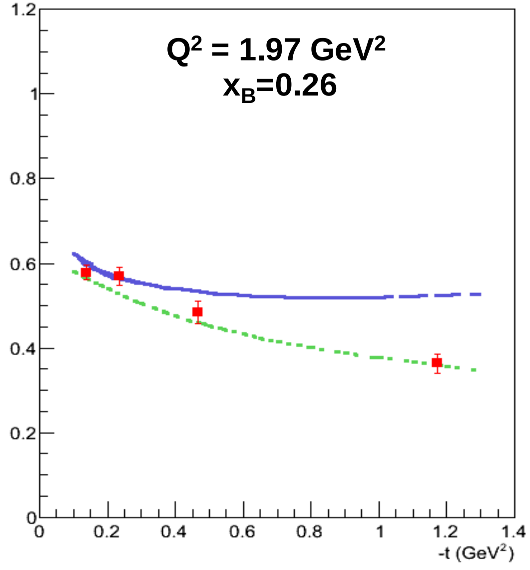
DSA ~ $Re\{\mathcal{H}_p, \widetilde{\mathcal{H}}_p\}$

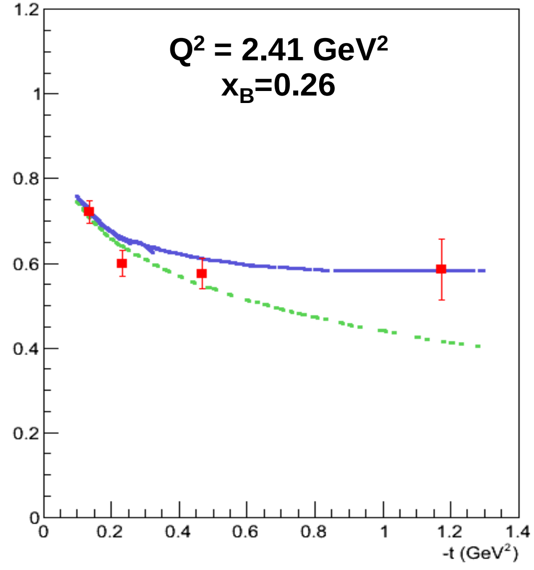
Fitting function:
$p_0+p_1\cos\phi$

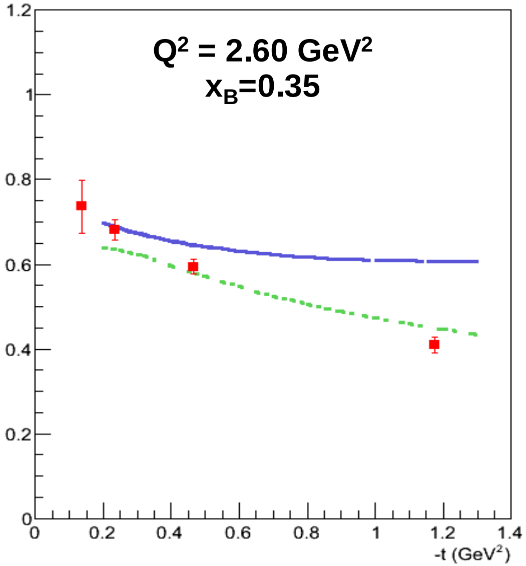
$$A_{LL} = \frac{1}{P_B D_f}\frac{N^{++}+N^{--}-N^{+-}-N^{-+}}{P_T^-(N^{++}+N^{+-})+P_T^+(N^{-+}+N^{--})}$$

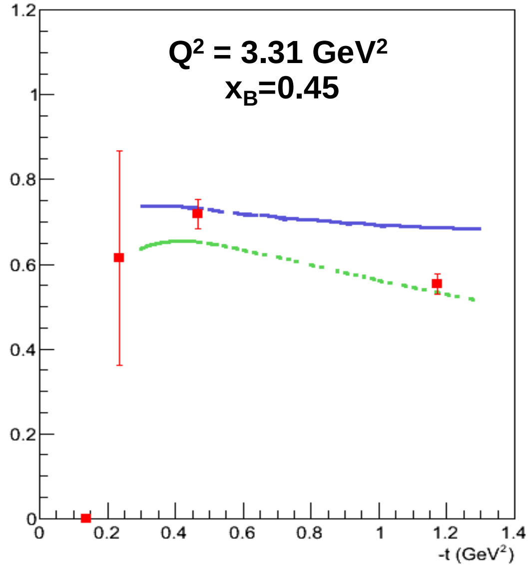
Results: DSA









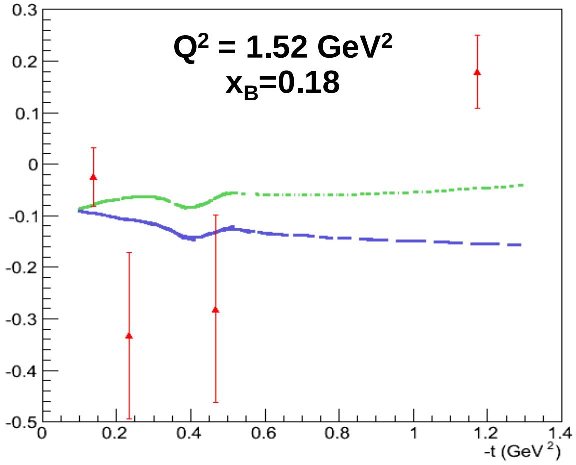


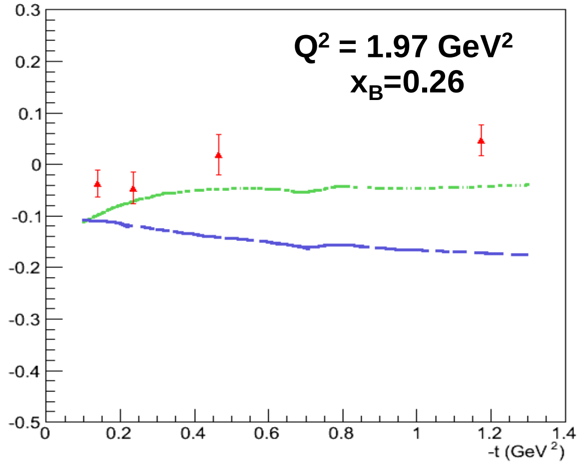
DSA ~ $Re\{\mathcal{H}_p, \widetilde{\mathcal{H}}_p\}$

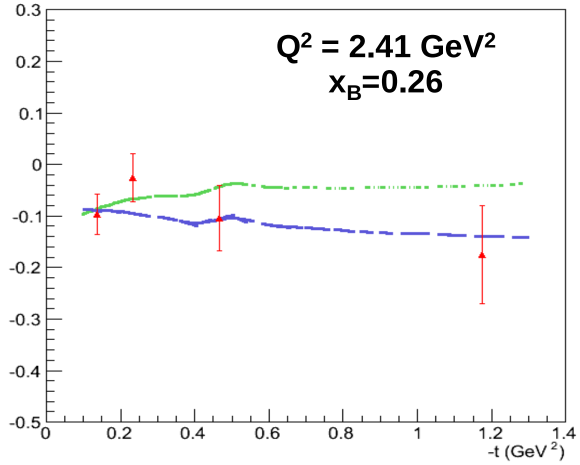
Fit: $p_0 + p_1 \cos\phi$
Bethe Heitler
BH+DVCS (VGG)

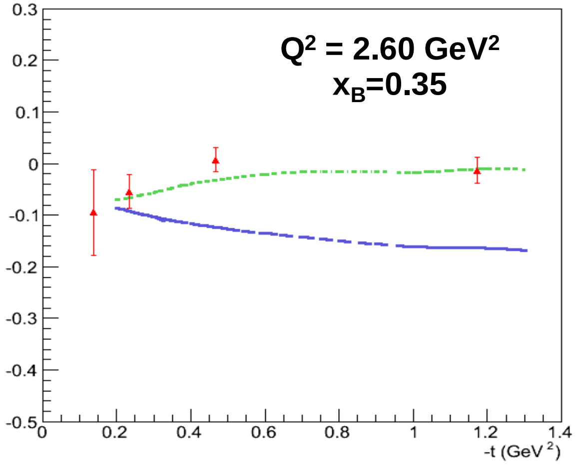
Constant term dominated by **BH** at low t

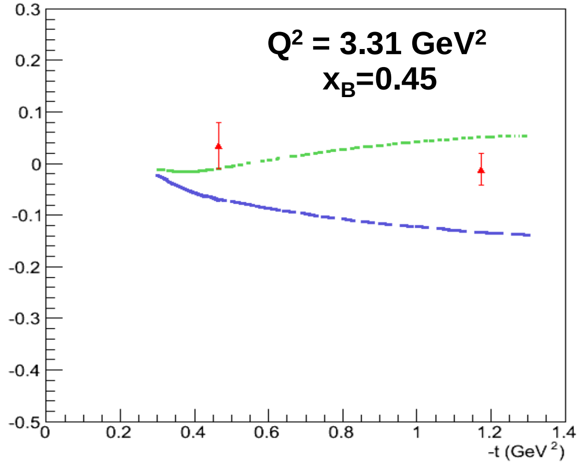
Results: DSA











DSA ~ $Re\{\mathcal{H}_p, \tilde{\mathcal{H}}_p\}$

Fit: $p_0 + p_1 \cos\phi$

Bethe Heitler

BH+DVCS (VGG)

$\cos\phi$ term:
more sensitivity to DVCS
but precision is limited

Extraction of Compton Form Factors from DVCS observables

8 CFF

$$\mathrm{Re}(\mathcal{H}) = P\int_0^1 dx\left[H(x,\xi,t) - H(-x,\xi,t)\right]C^+(x,\xi)$$

$$\mathrm{Re}(\mathcal{E}) = P\int_0^1 dx\left[E(x,\xi,t) - E(-x,\xi,t)\right]C^+(x,\xi)$$

$$\mathrm{Re}(\tilde{\mathcal{H}}) = P\int_0^1 dx\left[\tilde{H}(x,\xi,t) + \tilde{H}(-x,\xi,t)\right]C^-(x,\xi)$$

$$\mathrm{Re}(\tilde{\mathcal{E}}) = P\int_0^1 dx\left[\tilde{E}(x,\xi,t) + \tilde{E}(-x,\xi,t)\right]C^-(x,\xi)$$

$$\mathrm{Im}(\mathcal{H}) = H(\xi,\xi,t) - H(-\xi,\xi,t)$$

$$\mathrm{Im}(\mathcal{E}) = E(\xi,\xi,t) - E(-\xi,\xi,t)$$

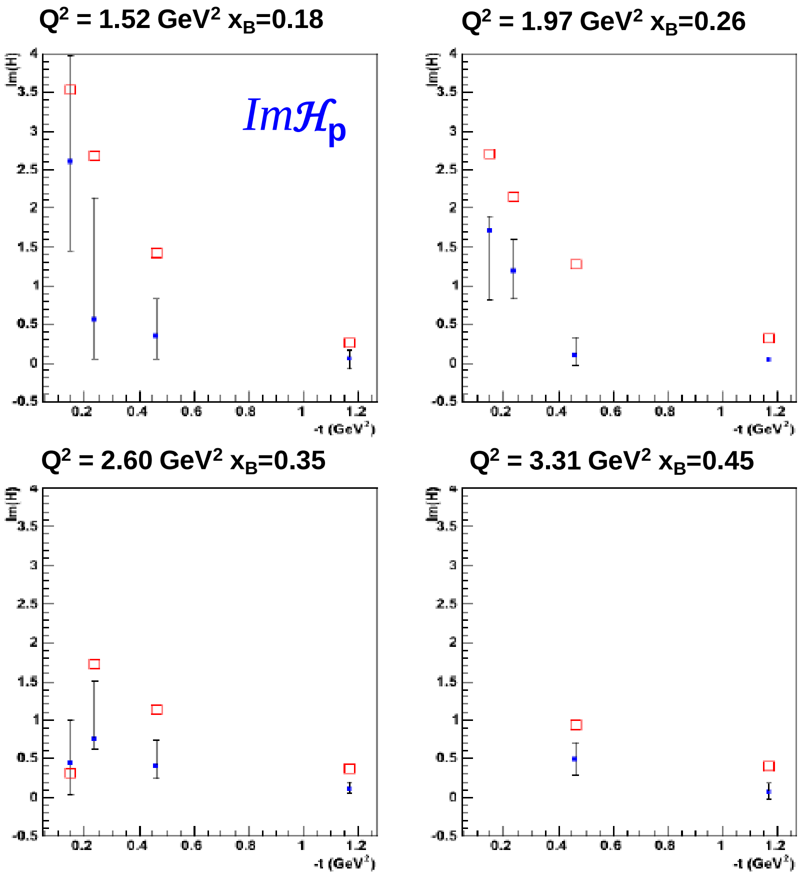
$$\mathrm{Im}(\tilde{\mathcal{H}}) = \tilde{H}(\xi,\xi,t) - \tilde{H}(-\xi,\xi,t)$$

$$\mathrm{Im}(\tilde{\mathcal{E}}) = \tilde{E}(\xi,\xi,t) - \tilde{E}(-\xi,\xi,t)$$

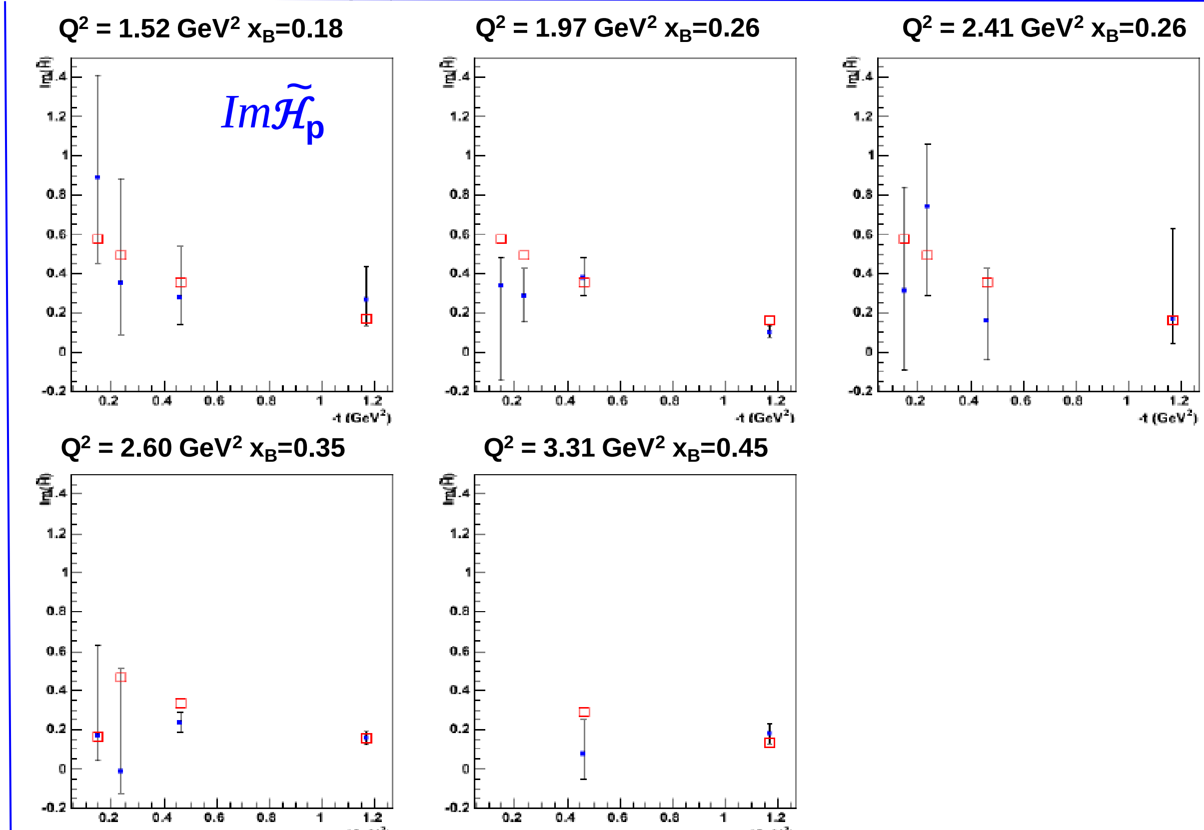
with $C^{\pm}(x,\xi) = \frac{1}{x-\xi} \pm \frac{1}{x+\xi}$

M. Guidal: **Model-independent fit**, at fixed Q^2, x_B and t of DVCS observables
8 unknowns (the CFFs), non-linear problem, strong correlations
Bounding the domain of variation of the CFFs with model (5xVGG)
M. Guidal, Eur. Phys. J. A 37 (2008) 319

Extraction of CFF from DVCS TSA, BSA, DSA



- • Fitted values (*M. Guidal*)
- ❑ VGG prediction



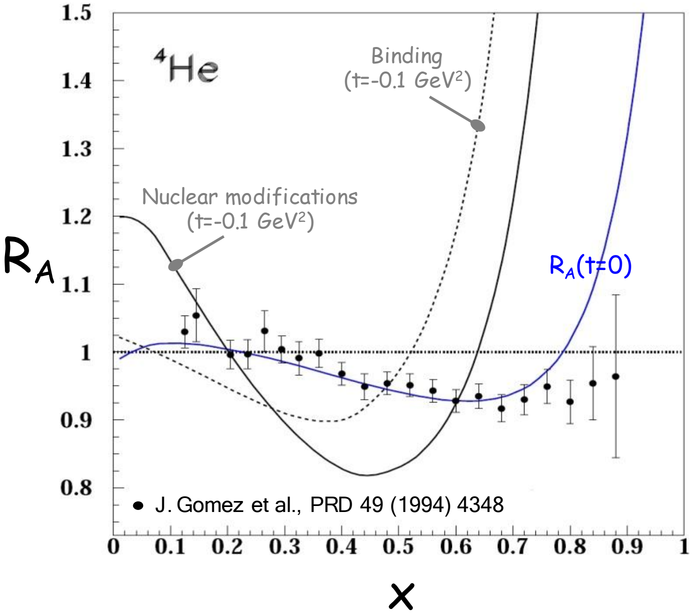
$Im\mathcal{H}$ has steeper t-slope than $Im\widetilde{\mathcal{H}}$: is axial charge more "concentrated" than the electromagnetic charge?

Some sensitivity to $Re\widetilde{\mathcal{H}}$, $Im\mathcal{E}$ with big uncertainties

Coherent Nuclear DVCS

- **Nuclear DVCS** probes the **partonic structure of nuclei** and offers the opportunity to investigate the role of **transverse degrees** of freedom in the **modifications** of the **nuclear parton distributions,** as compared to free nucleons.

S. Scopetta, PRC 70 (2004) 015204 ; 79 (2009) 025207
S. Liuti, K.Taneja, PRC 72 (2005) 032201 ; 034902



Generalized EMC Ratio

$$R_A(x,\xi,t) = \frac{A_{LU}^{A}(x,\xi,t)}{A_{LU}^{p}(x,\xi,t)} \approx \frac{H_A(x,\xi,t)}{F_A(t)} \frac{F_N(t)}{H_N(x,\xi,t)}$$

The ratio of **beam-spin asymmetries** (**BSA**) on the nucleus and on the nucleon is predicted to be **sensitive** to peculiar features of the **EMC effect** modeling.

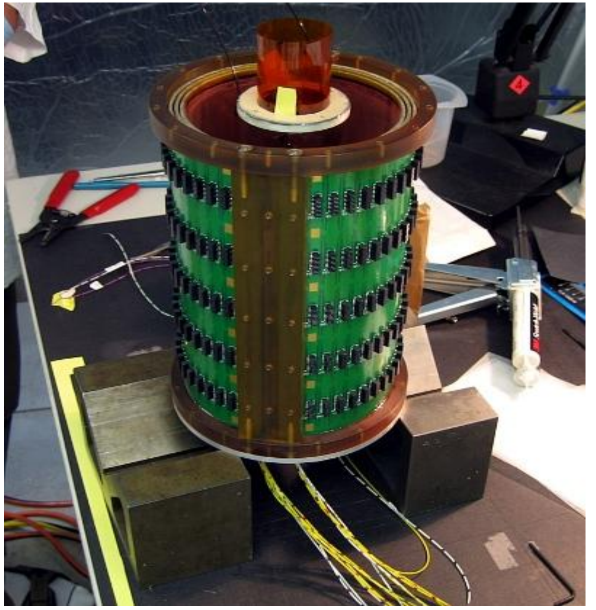
- Because of the simple GPD structure of spin 0 nuclei, the twist-2 beam spin asymmetry allows for a **model-independent** simultaneous **extraction** of the **real** and the **imaginary parts** of the **twist-2 Compton form factor**.

$$A_{LU}^{^4He}(\varphi) = \frac{\alpha_0(\varphi) F_A(t) \Im m[\mathcal{H}_A]}{\alpha_1(\varphi) F_A^2(t) + \alpha_2(\varphi) F_A(t) \Re e[\mathcal{H}_A] + \alpha_3(\varphi) \Re e[\mathcal{H}_A]^2 + \alpha_3(\varphi) \Im m[\mathcal{H}_A]^2}$$

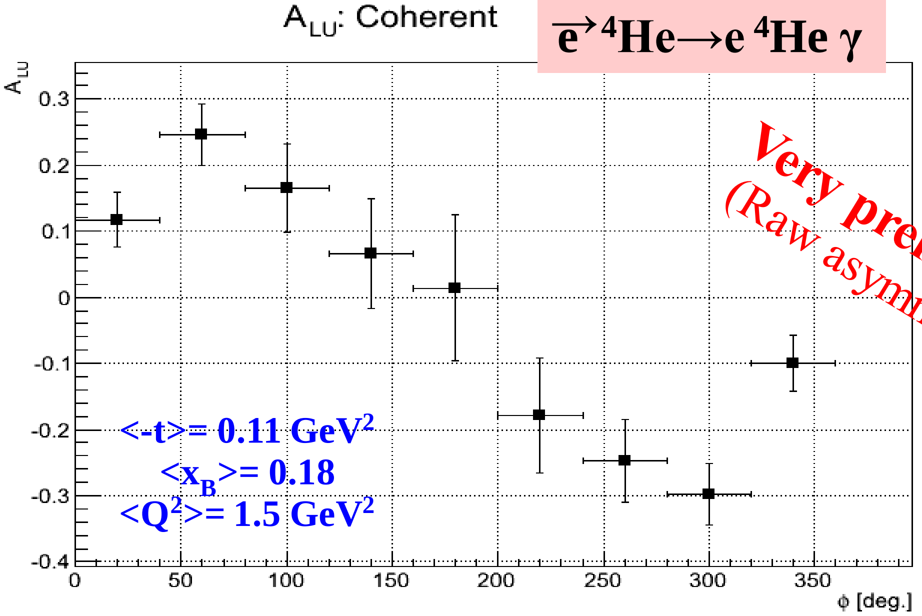
DVCS on ^{4}He: the CLAS eg6 experiment

- Data taken in the fall 2009
- Setup: CLAS+IC+**RTPC**+^{4}He target
- Beam energy **~6.065 GeV**
- Goals: coherent and incoherent DVCS
- Nuclear GPDs, EMC effect
- Calibrations (RTPC, IC) ongoing

Radial
Time
Projection
Chamber



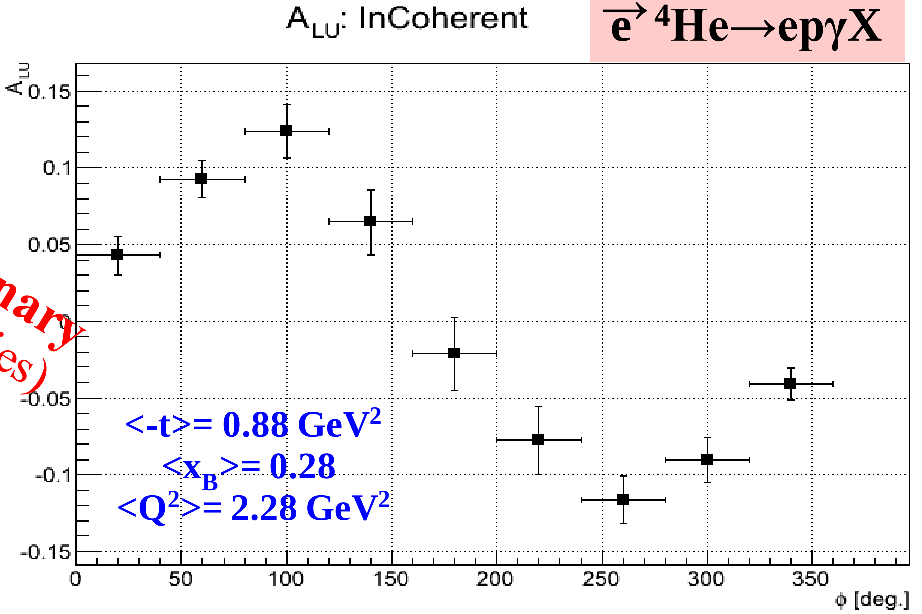
Work by M. Hattawy, IPNO



$\vec{e}\,{}^4He \rightarrow e\,{}^4He\,\gamma$

$<-t>$= 0.11 GeV^2
$<x_B>$= 0.18
$<Q^2>$= 1.5 GeV^2

Very preliminary
(Raw asymmetries)



$\vec{e}\,{}^4He \rightarrow ep\gamma X$

$<-t>$= 0.88 GeV^2
$<x_B>$= 0.28
$<Q^2>$= 2.28 GeV^2

DVCS on ^{4}He: the CLAS eg6 experiment

- Data taken in the fall 2009
- Setup: CLAS+IC+**RTPC**+^{4}He target
- Beam energy **~6.065 GeV**
- Goals: coherent and incoherent DVCS
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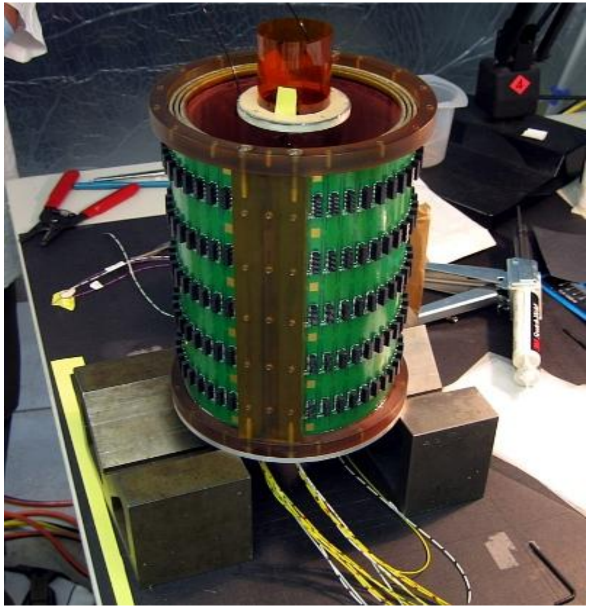
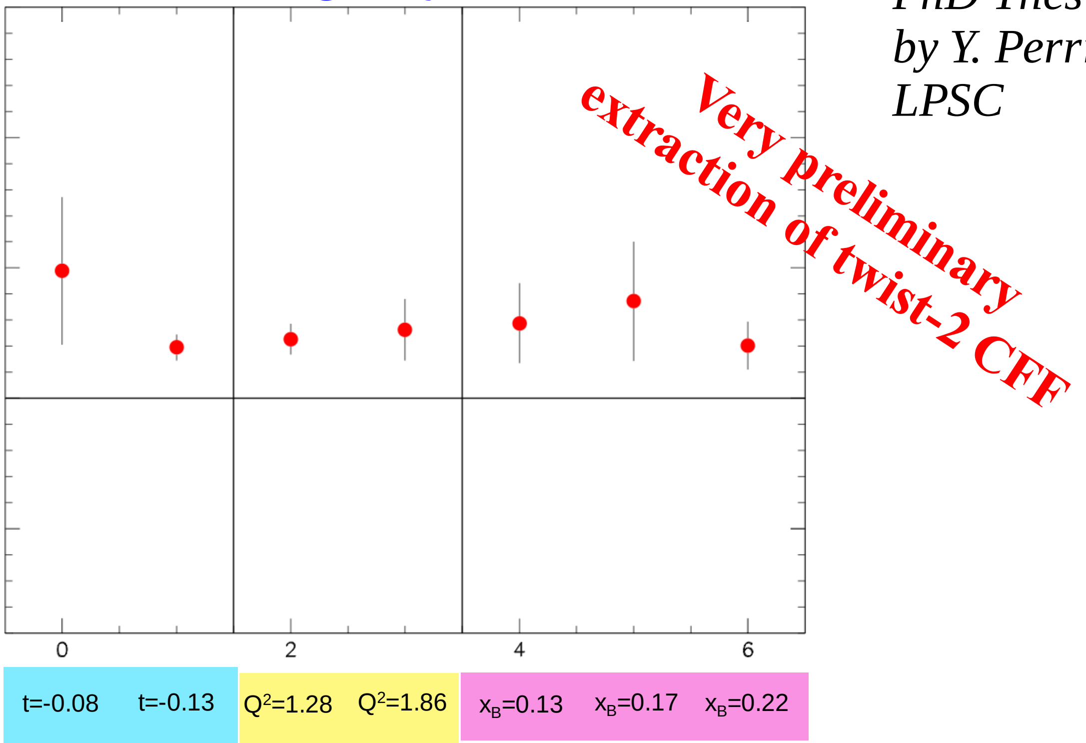
Radial
Time
Projection
Chamber



Imaginary Part



PhD Thesis by Y. Perrin, LPSC

- The **imaginary part** is **better determined** than the real part.
- Within the current statistics, the **real part** is consistent with **0**.

Summary and outlook

• Combining various **DVCS spin observables** is necessary to provide constraints for the **extraction of Compton Form Factors** (→GPDs)

• The CLAS**-eg1-dvcs** experiment combined the CLAS-DVCS setup (**CLAS+IC**) with a **polarized NH3 target,** and allows the **simultaneous measurement of BSA, TSA, DSA** for DVCS

• Results for **TSA and BSA for pDVCS** are in good agreement with existing data, and the statistics of the TSA with respect to previous CLAS and HERMES data has been improved by more than a **factor 5**

• Results for **double-spin asymmetries** show dominance of the **constant term,** and of **BH**

• Constraints on ***Im(H)*** and ***Im($\widetilde{H}$)*** from CFF fits, some sensitivity to other CFFs, with lower statistical precision

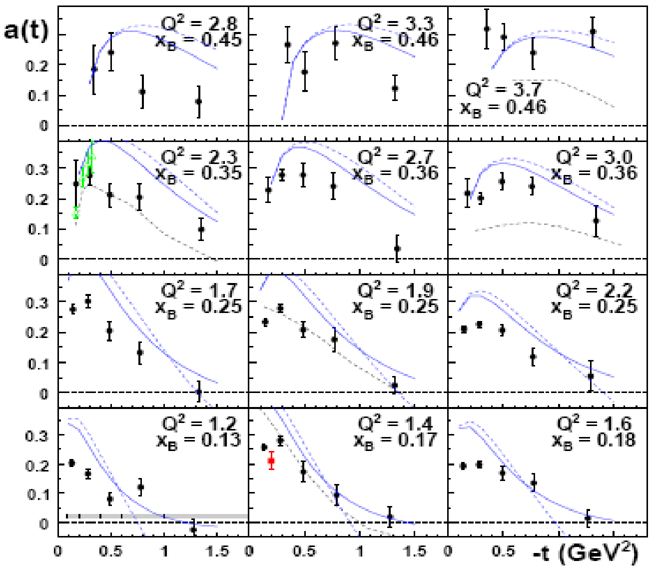
• The analysis note is **under CLAS review** – paper(s) to come in spring!

• The **CLAS-eg6** experiment ran with the goal of measuring **coherent and incoherent BSA for DVCS on ^{4}He**; data still under calibration

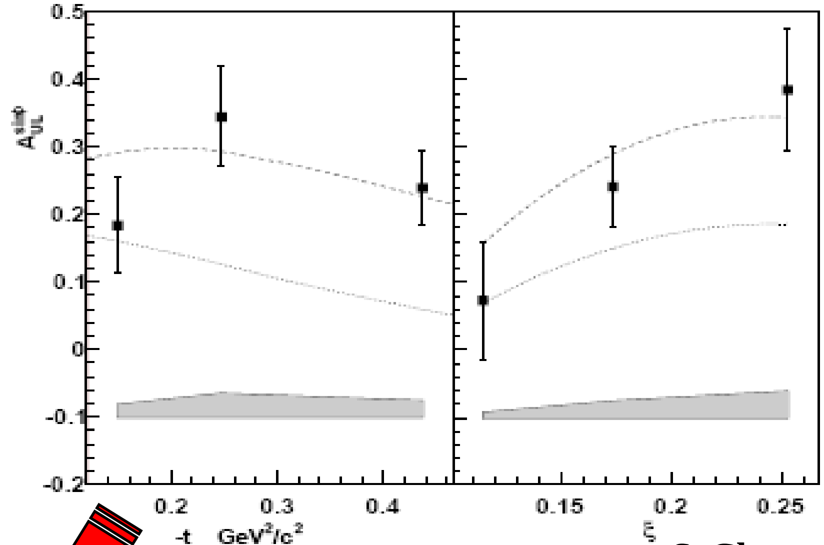
• First very preliminary data show the possibility to extract $Im(\mathcal{H}_A)$; **no sizeable medium effects** can be observed from the comparison of the BSA for the incoherent channel and the free proton one

What we have learned from the published CLAS asymmetries

CLAS
pDVCS
BSAs



F.-X. Girod et al, PRL. 100 162002 (2008)



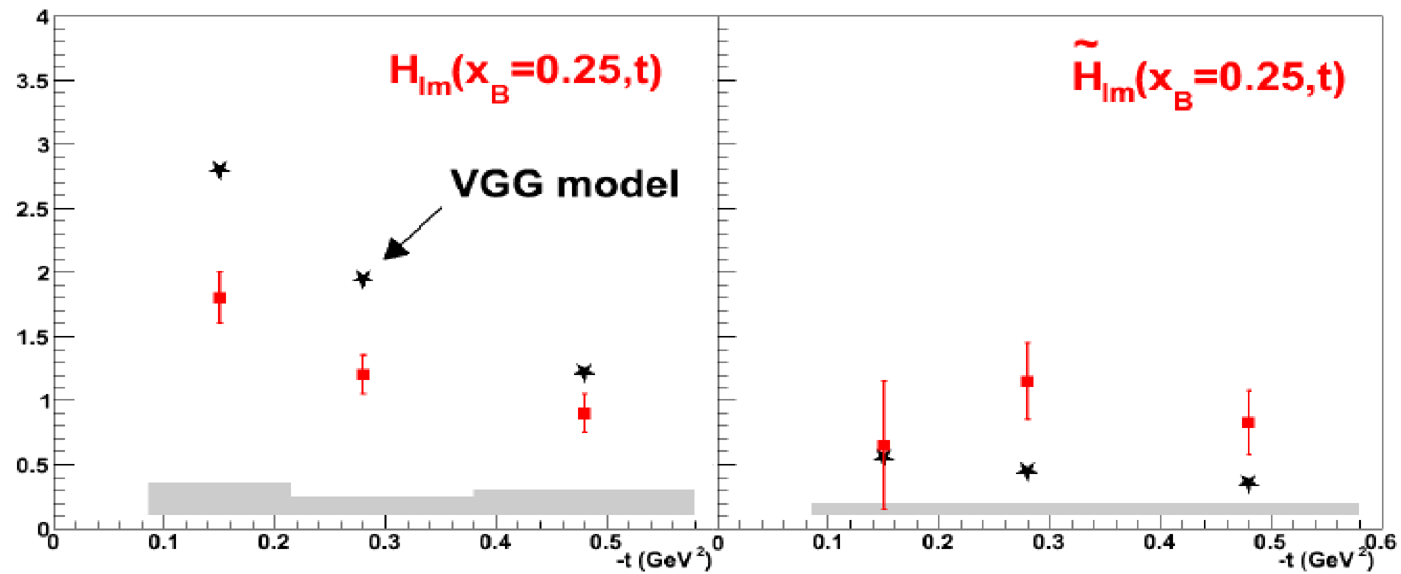
CLAS
pDVCS
TSAs

eg1 (2000), not a DVCS-dedicated experiment

S. Chen *et al*, PRL 97, 072002 (2006)

Model-independent fit at fixed x_B, t, Q^2 of DVCS observables

ImH has steeper t-slope than Im$\tilde{H}$: is axial charge more concentrated than the electromagnetic charge?



M. Guidal, Phys. Lett. B 689, 156-162 (2010)

ep→epγX event selection

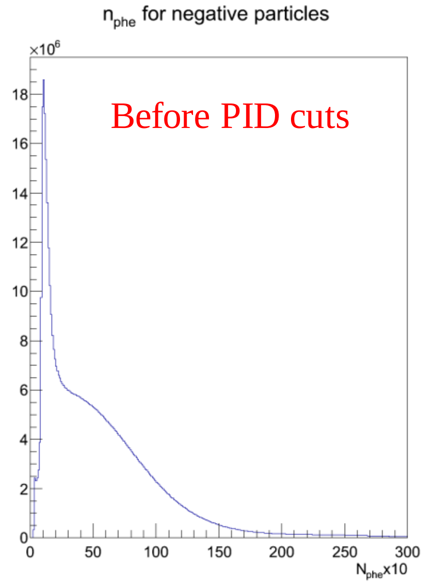
Events with *exactly 1 e, 1 p* and *at least 1 γ*

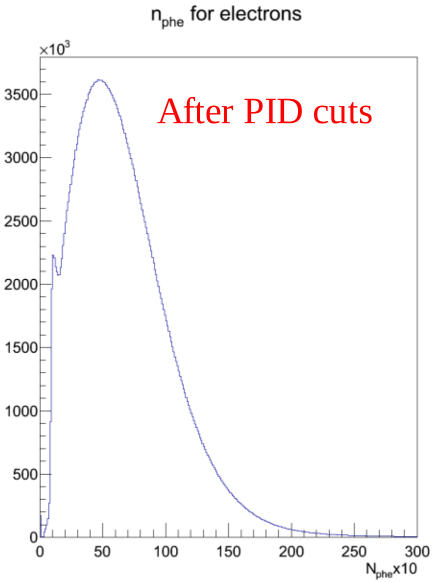
Electron PID cuts
- Negative charge
- EC inner deposited energy > 0.06 GeV
- Etot/p > 0.12 GeV
- Vertex within 3 cm from the nominal target position
- P > 0.8 GeV
- $|t_{SC} - t_{CC}| < 2$ ns
- cc_c2 < 0.15
- EC fiducial cuts
- IC frame fiducial cuts

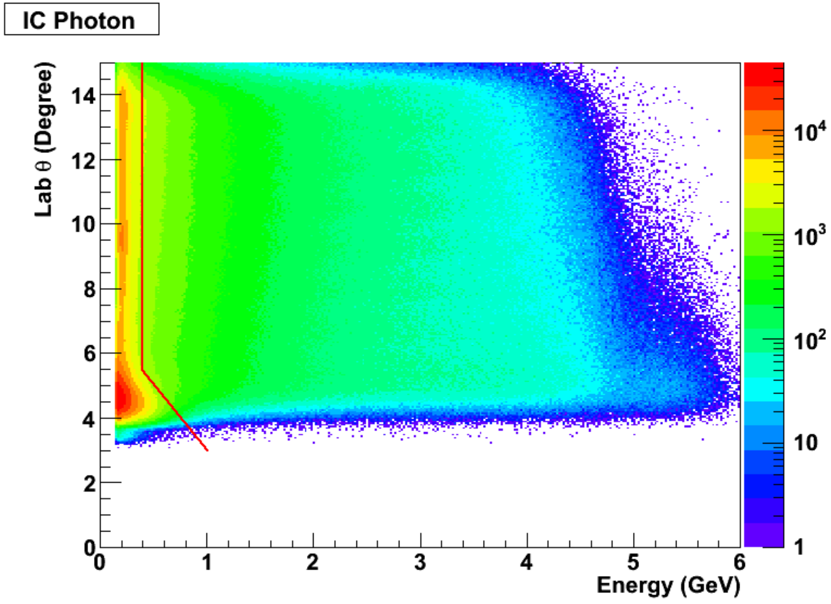
Proton PID cuts
- Positive charge
- Vertex within 4 cm from the nominal target position
- p-dependent β cut
- IC frame fiducial cuts

EC photons
- Null charge
- b > 0.92
- Etot/0.27 > 0.25 GeV
- EC fiducial cuts
- IC frame fiducial cuts

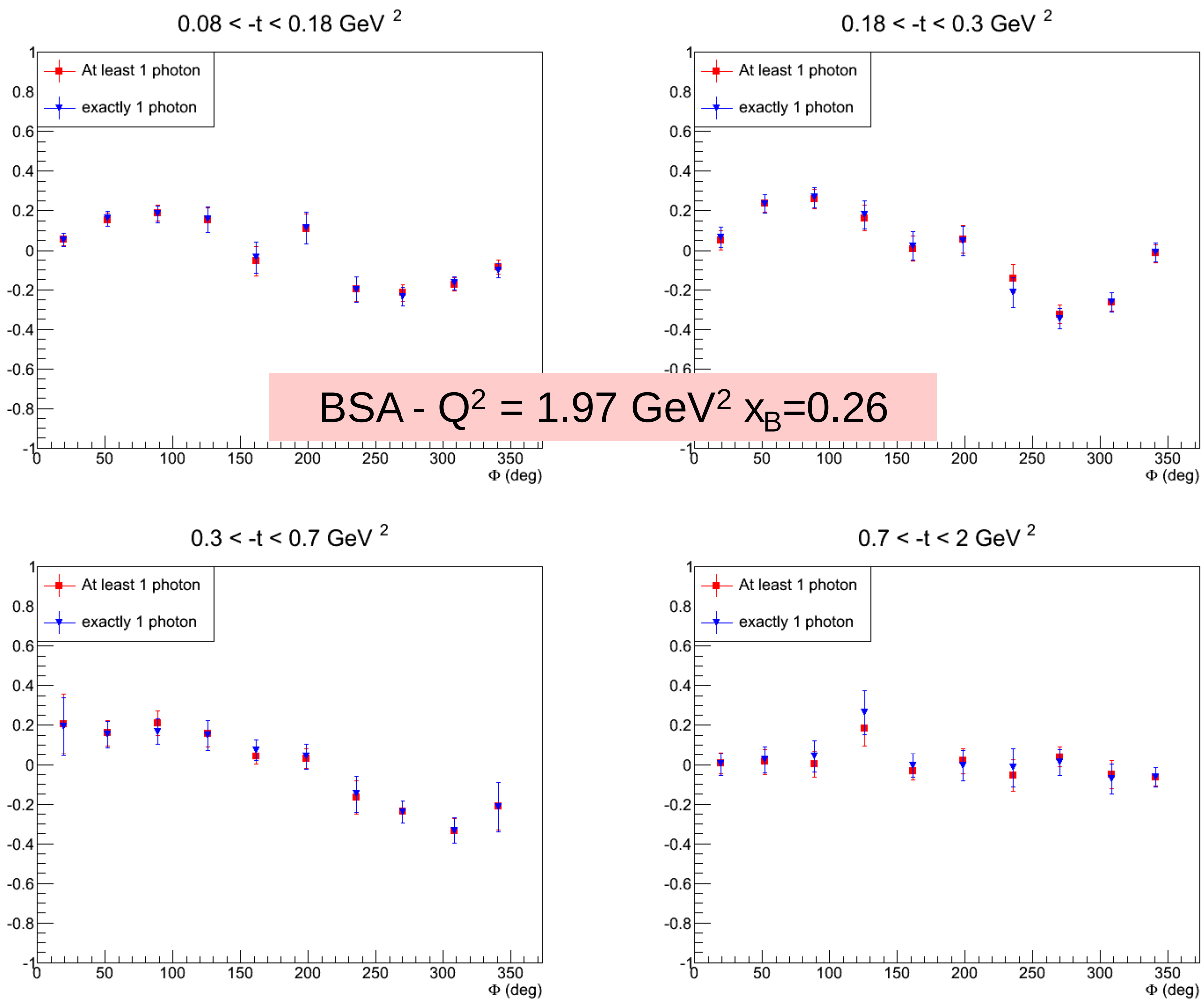
IC photons
- Null charge
- Cluster energy > 0.15 GeV
- E_γ vs Θ_γ cut
- IC fiducial cuts







Checks and systematics



Systematics evaluated for:

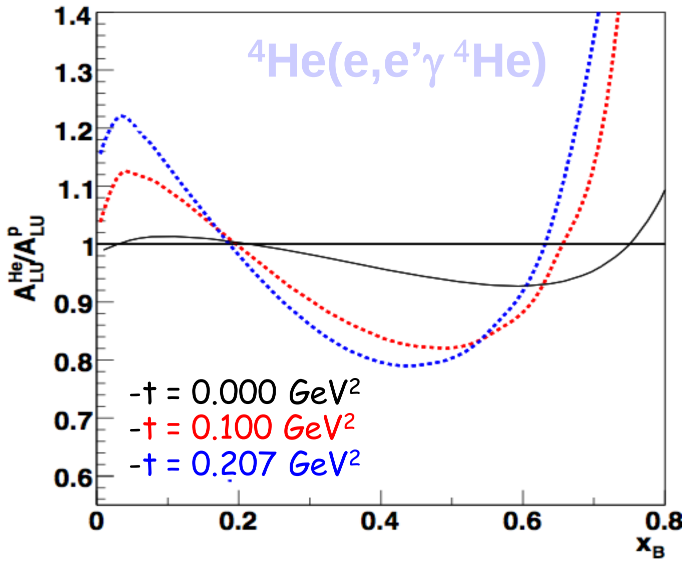
- Exclusivity cuts
- Pb, Pt, PbPt
- Background subtraction
- Dilution factor

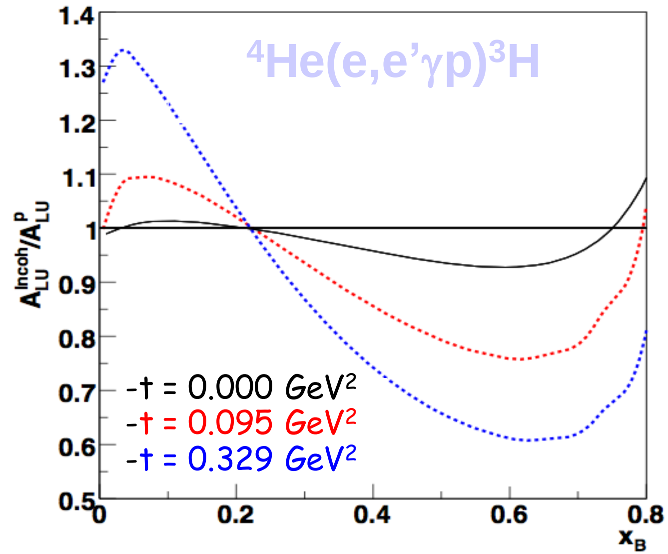
Overall systematics smaller than statistical uncertainties (work in progress for final values)

Various checks requested by DPWG review committee (example: **at least/at most 1γ**)

Incoherent Nuclear DVCS

S. Liuti, K.Taneja, PRC 72 (2005) 032201 ; 034902





❖ Within the SLT dynamical approach, the **incoherent ratio** is predicted to be **more sensitive to nuclear medium effects** than the coherent ratio.

Importance of reaction mechanisms beyond impulse approximation has still to be investigated.

Beam Spin Asymmetry

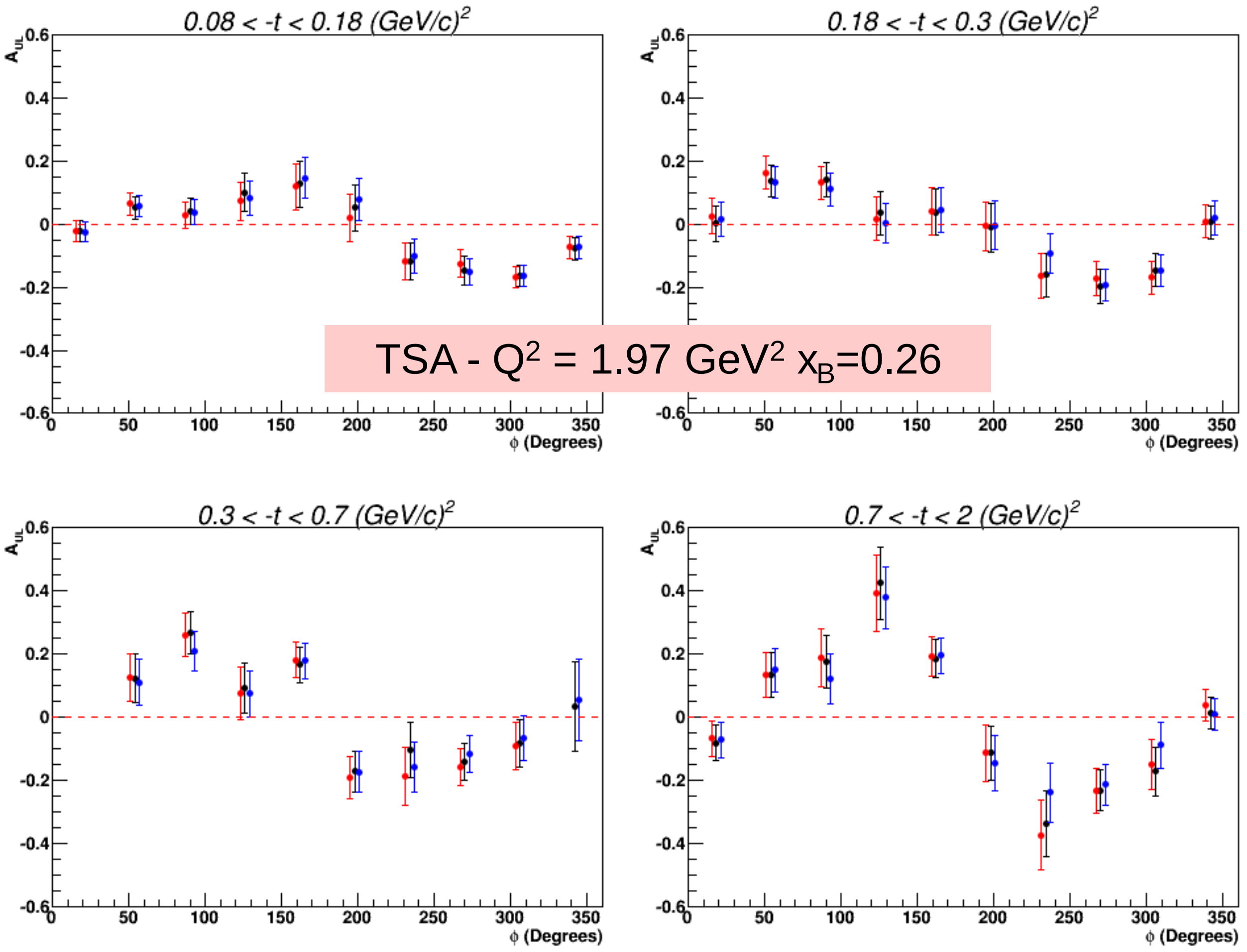
- Because of the simple GPD structure of spin 0 nuclei, the twist-2 beam spin asymmetry (**BSA**) allows for a **model-independent** simultaneous **extraction** of the **real** and the **imaginary parts** of the **twist-2 Compton form factor**.

$$A_{LU}^{^4He}(\varphi) = \frac{\alpha_0(\varphi)\, F_A(t)\, \Im m\left[\mathcal{H}_A\right]}{\alpha_1(\varphi)\, F_A^2(t) + \alpha_2(\varphi)\, F_A(t)\, \Re e\left[\mathcal{H}_A\right] + \alpha_3(\varphi)\, \Re e\left[\mathcal{H}_A\right]^2 + \alpha_3(\varphi)\, \Im m\left[\mathcal{H}_A\right]^2}$$

- In the region of the minimum of the helium form factor (**~0.4 GeV²**), the beam spin asymmetry provides **some control** on the **twist-3 effects**.

$$A_{LU}^{^4He}(\phi) = \frac{\alpha_4(\phi)\, \Im m\left[\mathcal{H}_A^{eff}\right]}{\alpha_3(\phi)\, \Re e\left[\mathcal{H}_A\right]^2 + \alpha_3(\phi)\, \Im m\left[\mathcal{H}_A\right]^2}$$

Checks and systematics



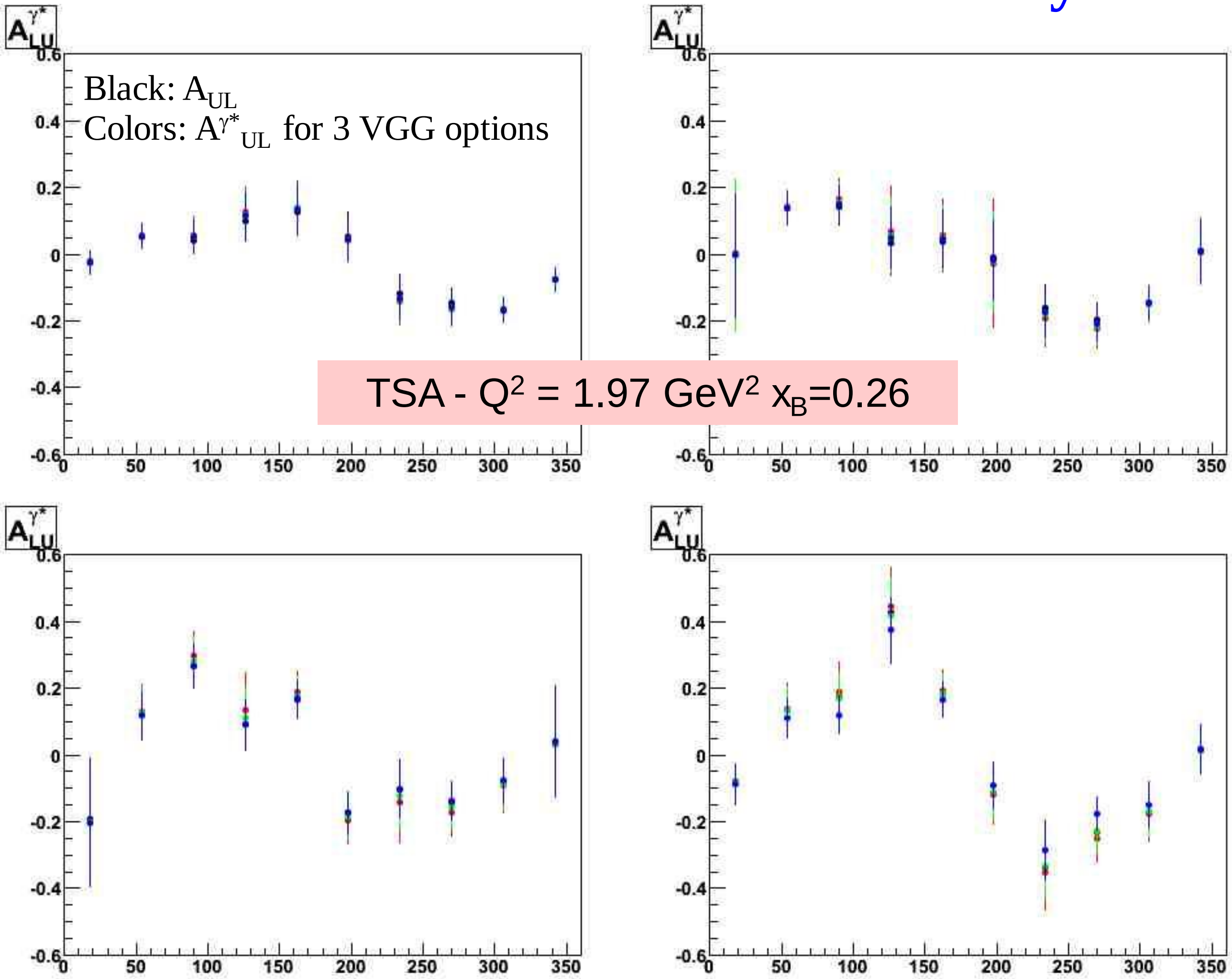
Systematics evaluated for:

- Exclusivity cuts
- Pb, Pt, PbPt
- Background subtraction
- Dilution factor

Overall systematics smaller than statistical uncertainties (work in progress for final values)

Systematic check on exclusivity cuts: **2.5σ**, **3σ**, **3.5σ**

Checks and systematics



TSA - Q^2 = 1.97 GeV^2 x_B=0.26

Systematics evaluated for:

- Exclusivity cuts
- Pb, Pt, PbPt
- Background subtraction
- Dilution factor

Overall systematics smaller than statistical uncertainties (work in progress for final values)

Ongoing work:

- Bin-centering corrections
- Simultaneaous fits of the 3 asymmetries with common denominator
- Transverse asymmetry correction

$$A_{UL} = \cos\theta^{\gamma*}\, \mathbf{A^{\gamma*}_{UL}} - \sin\theta^{\gamma*}\, \mathbf{A^{\gamma*}_{UT}(0)}$$

measured — average per bin — our goal — VGG model

M. Diehl, S. Sapeta, Eur.Phys.J.C41:515-533,2005