Helium Compton Form Factor Measurements at CLAS

eg6 @ CLAS.JLab

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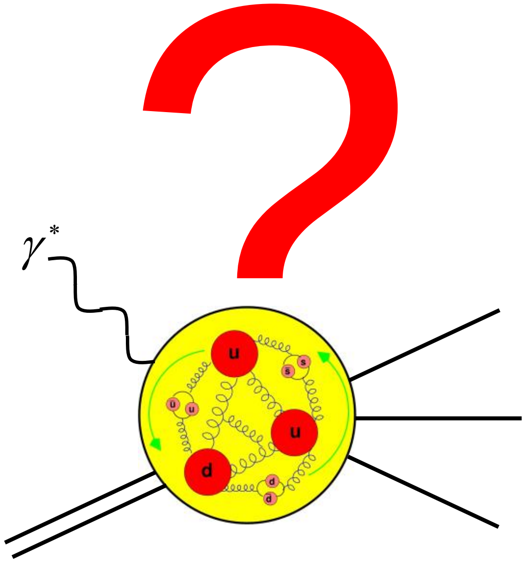
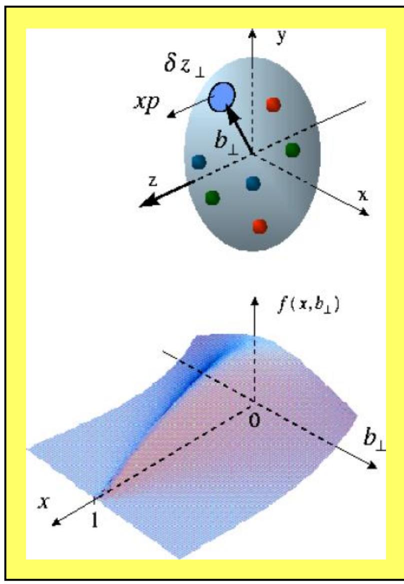


(i) Physics Motivations
(ii) Deeply Virtual Compton Scattering
(iii) Experimental Setup
(iv) ^{4}He(e,e'γ^{4}He) Analysis
(v) ^{4}He Compton Form Factor
(vi) Conclusions

Parton Imaging

- **GPDs** are the **appropriate** framework to deal with the **partonic structure** of hadrons and offer the unprecedented possibility to access the **spatial distribution** of partons.



M. Burkardt, PRD 62 (2000) 071503 M.Diehl, EPJC 25 (2002) 223

- **GPDs** = GPDs(Q^2,x,ξ,t) whose perpendicular component of the momentum transfer to the nucleon is **Fourier conjugate** to the **transverse position** of partons.

- **GPDs** encode the **correlations between partons** and contain information about the dynamics of the system like the **angular momentum** or the **distribution of the strong forces** experienced by quarks and gluons inside hadrons.

X. Ji, PRL 78 (1997) 610 M. Polyakov, PL B555 (2003) 57

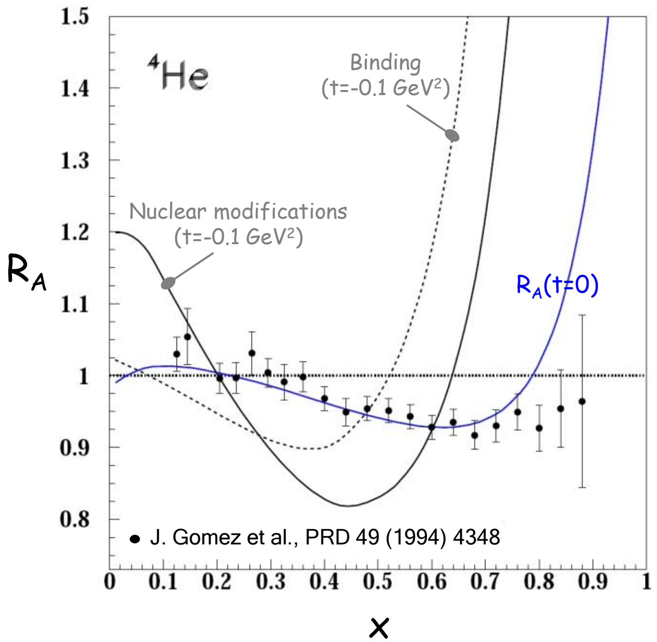
GPDs can be interpreted as a 1/Q resolution **distribution** in the **transverse plane** of partons with **longitudinal momentum** x.

A new light on hadron structure

Coherent Nuclear DVCS

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

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



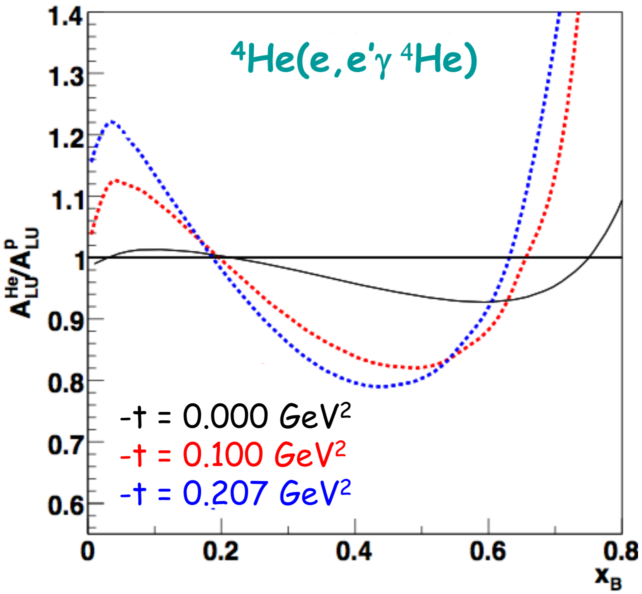
Generalized EMC Ratio

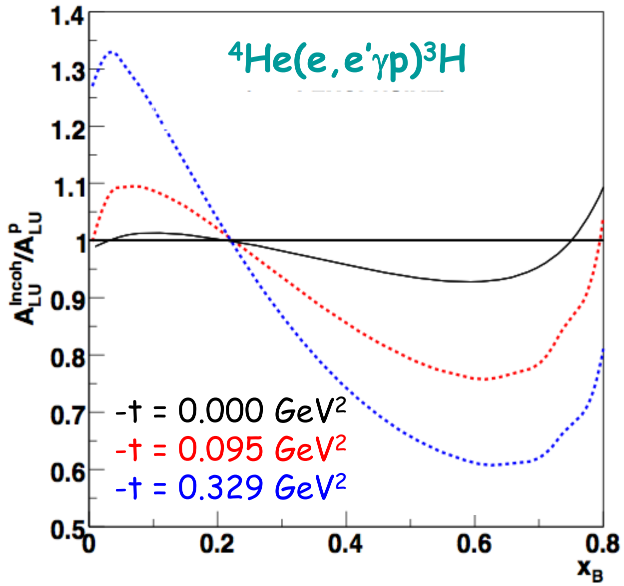
$$R_A(x,\xi,t)=\frac{A_{LU}^{A}(x,\xi,t)}{A_{LU}^{p}(x,\xi,t)}\approx\frac{H_A(x,\xi,t)}{F_A(t)}\,\frac{F_N(t)}{H_N(x,\xi,t)}$$

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

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.

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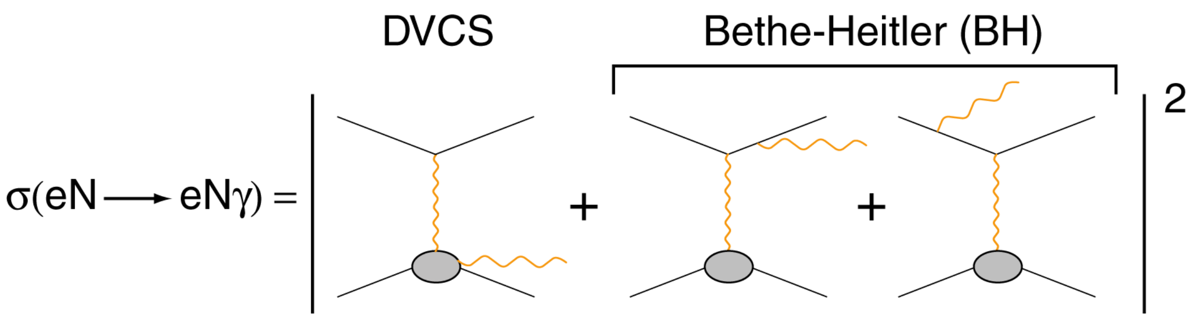
Spinless Nucleus

A. Belitsky, D. Müller, A. Kirchner, A. Schäfer, PR D64 (2001) 116002 V. Guzey, M. Strikman, PRC 68 (2003) 015204



➢ At leading order of the coupling constant, the partonic structure of **spin 0** nuclei is characterized by **one twist-2** (H_A) and two twist-3 quark GPDs (+ gluon ones).

Spatial Distribution of Strong Forces

$$\int_{-1}^{1} dx\, x\, H_A^f\left(x,\xi,t,Q^2\right) = M_2^{f/A}(t) + \frac{4}{5}\xi^2 d_A^f(t)$$

Momentum fraction of the target carried by the quark

Nuclear D-term accessible via the real part of the DVCS amplitude.
M. Polyakov, PLB 555 (2003) 57

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**.

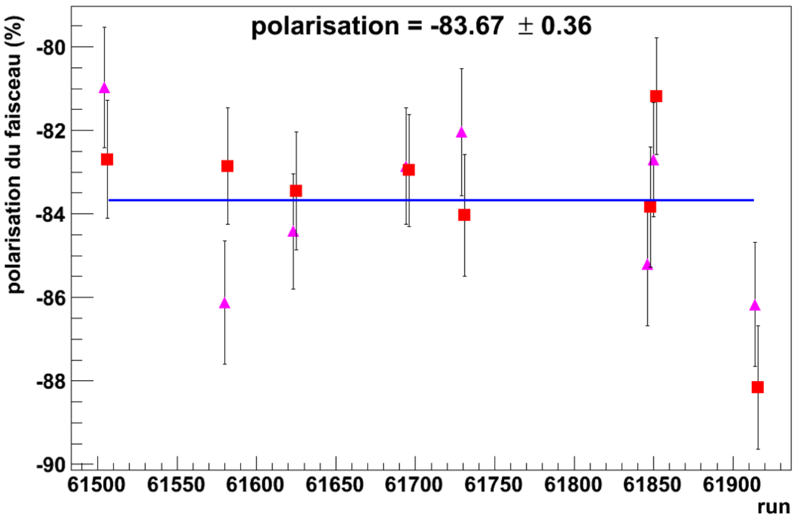
$$A_{LU}^{^4He}(\varphi) = \frac{\alpha_0(\varphi)\, F_A(t)\, \Im\mathrm{m}[\mathcal{H}_A]}{\alpha_1(\varphi)\, F_A^2(t) + \alpha_2(\varphi)\, F_A(t)\, \Re\mathrm{e}[\mathcal{H}_A] + \alpha_3(\varphi)\, \Re\mathrm{e}[\mathcal{H}_A]^2 + \alpha_3(\varphi)\, \Im\mathrm{m}[\mathcal{H}_A]^2}$$

- In the region of the minimum of the helium form factor (**~0.4 GeV^2**), the beam spin asymmetry provides some control on the **twist-3 effects**.

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

CEBAF

➢ The eg6 experiment is intended as an **exploratory study** of the **He-DVCS** reaction within a **fully exclusive** experimental method.



E_0 = 6.065 GeV   λ = -83.7 ± 0.4 %   P(^{4}He) = 5.1 atm

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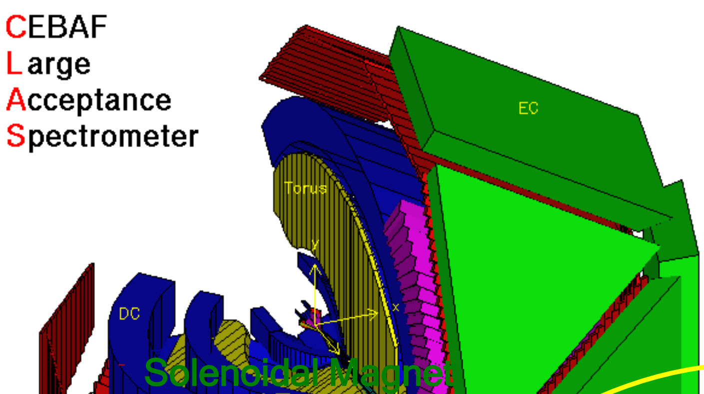
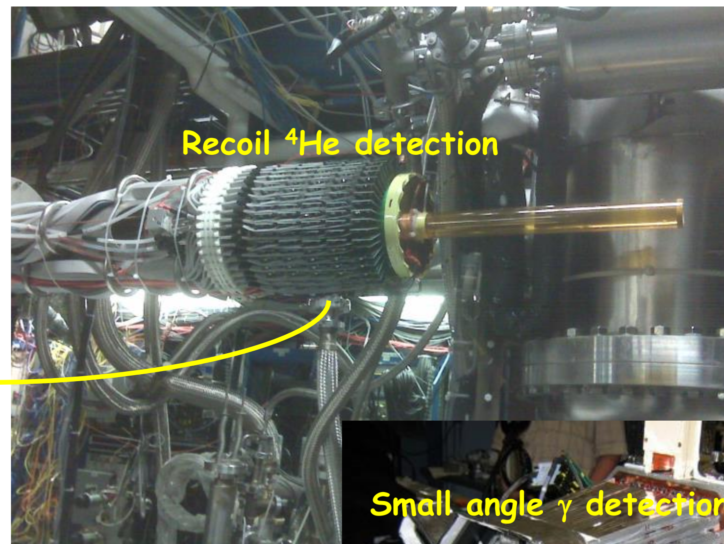
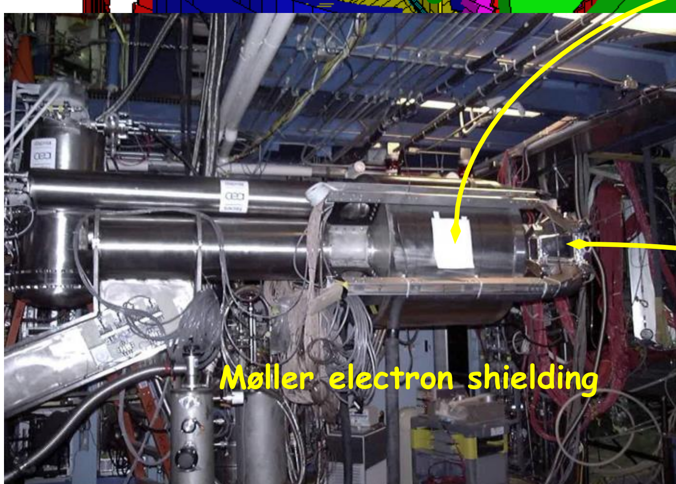
Instrumentation

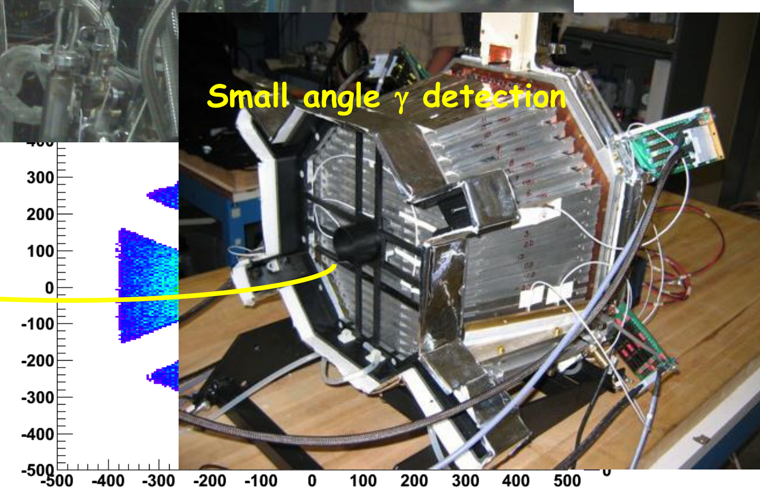
- The CLAS detector is a 4π toroidal ... Chambers, ... romagnetic ... rs. ... viding the ... ctron and ... one single

Radial Time Projection Chamber



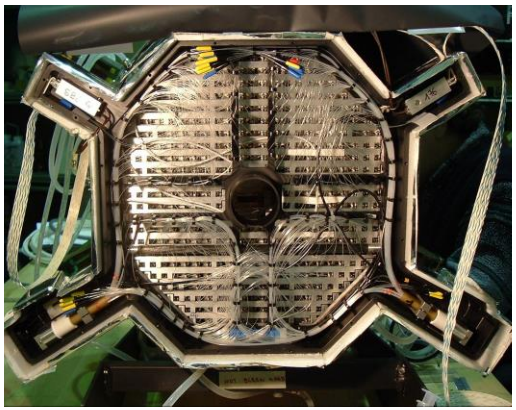




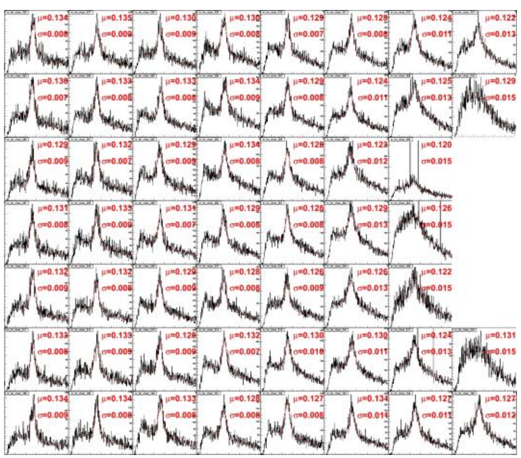


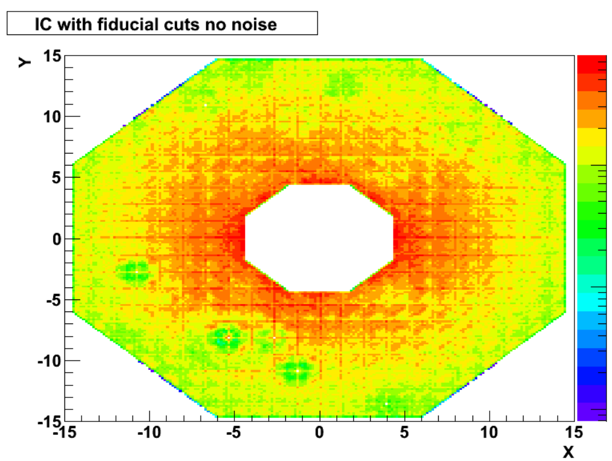
Inner Calorimeter

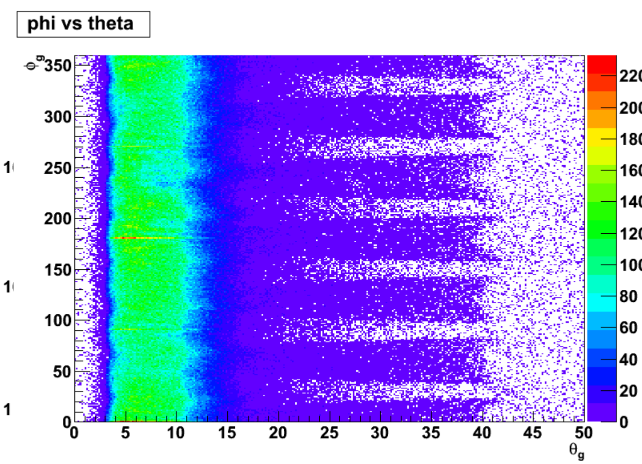
IC (γ)



- The invariant mass of **2γ-events** in **IC** is used for the calorimeter **calibration**, taking into account the interaction **vertex** as given by **CLAS**.
- The final resolution is **7.1%** at the pion mass.



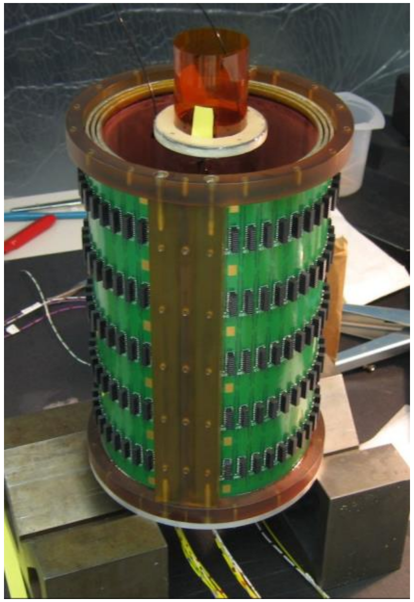




F.-X. Girod

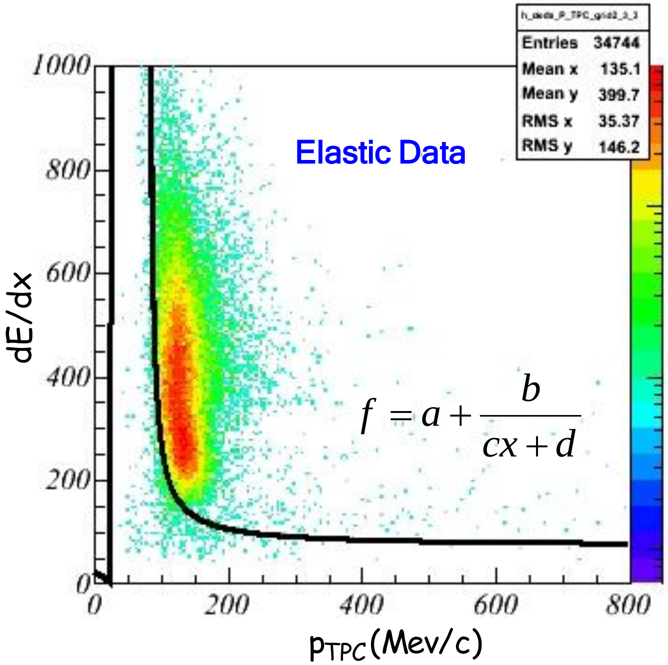
Radial time Projection Chamber

H. Fenker et al. NIM A592 (2008) 273



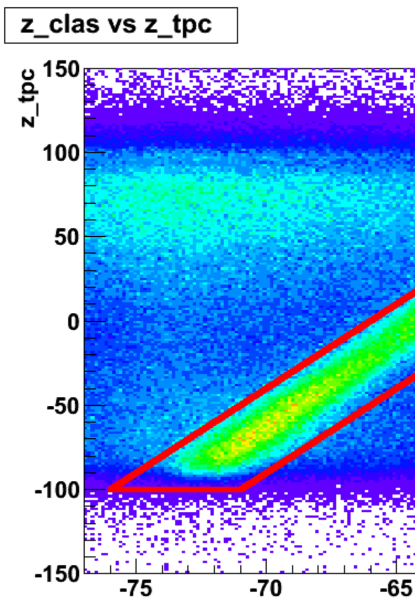
- The **eg6 RTPC** is a mechanically modified version of the **BoNuS** TPC, and operates with a Ne (80%) + DME (20%) gas mixture.

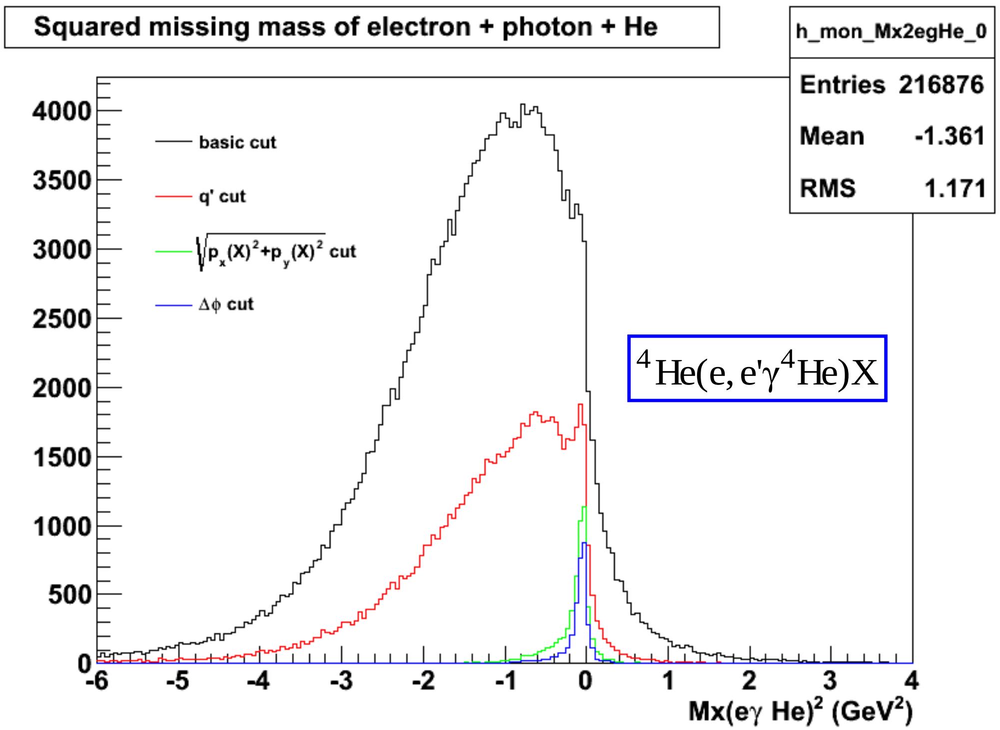
- **First Pass Calibration** of the **RTPC** is obtained from **elastic** electron scattering data off helium at **1.2 GeV**, tagging the recoil ^4He with the scattered e^- measured in CLAS.

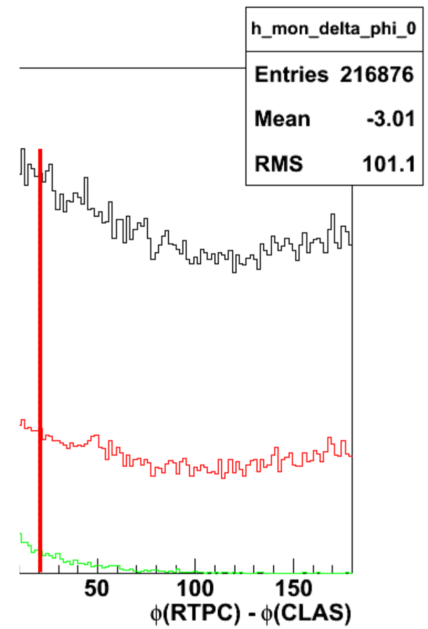


N. Baltzell, R. Dupré, R. Paremuzyan, Y. Perrin

Event Selection





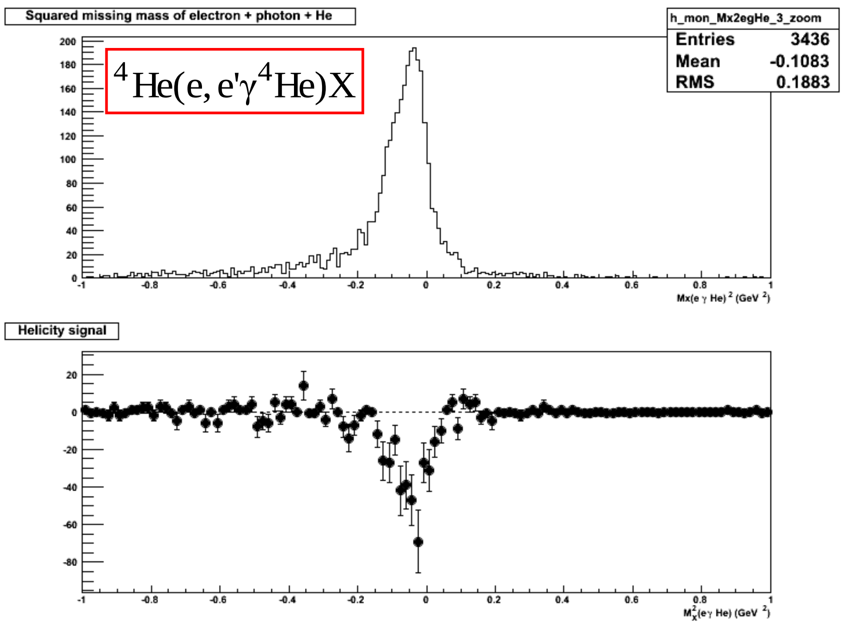


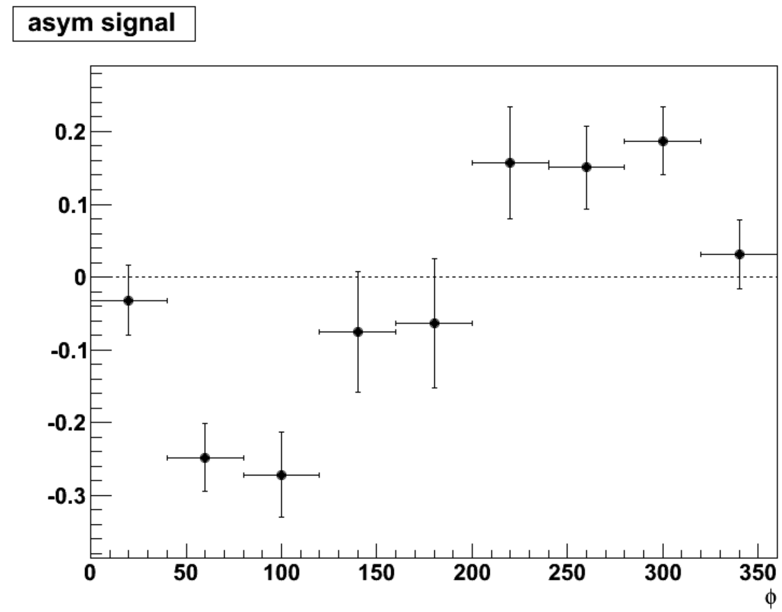
- The **CLAS(+IC)/RTPC correlations** with respect to the **interaction vertex** location and the **out-of-plane angle** provide a good rejection of background.

- Additional **physics correlations** (**q'(θ)** and **perpendicular missing momentum**) provide the final selection of **candidate He-DVCS events**.

Helicity Signal

$$S_h = \int_0^{\pi} (N^+ - N^-)d\varphi - \int_{\pi}^{2\pi} (N^+ - N^-)d\varphi$$

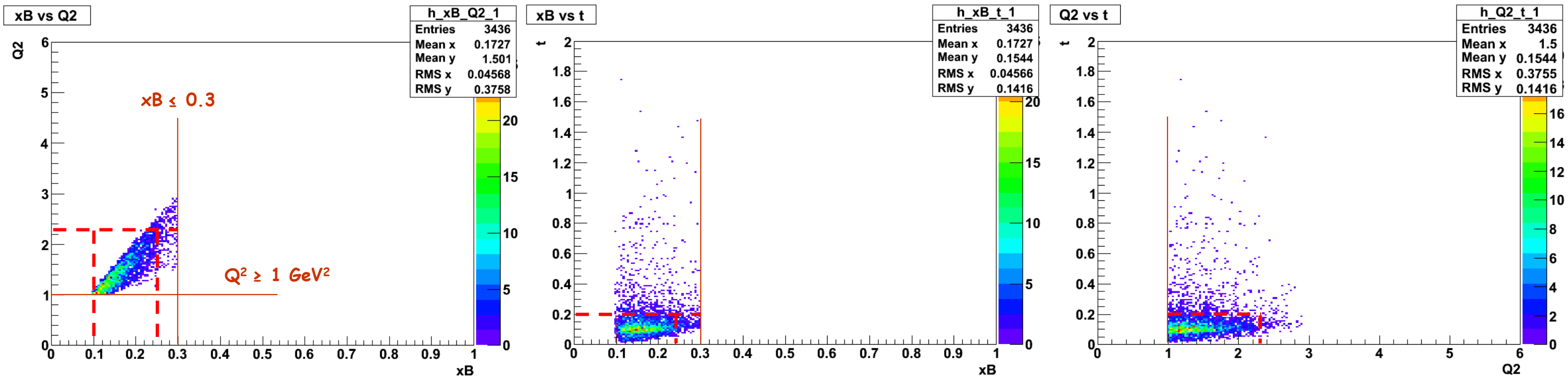




A clear **helicity signal** is observed for **coherent DVCS** candidate events, and confirmed by the **out-of-plane angle distribution** of events **integrated** over **(t, Q^2, x_B)**.

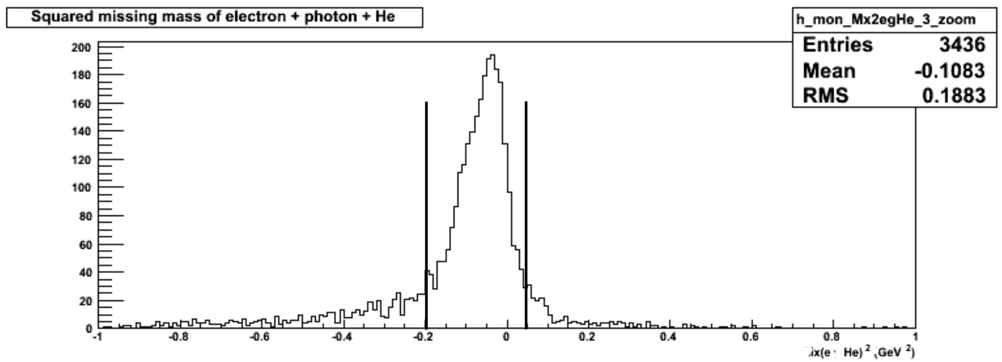
Y. Perrin, Doctorat Thesis, Grenoble (2012)

Experimental Phase Space



The candidate **experimental phase space** for **coherent DVCS** is limited but **allow** for a study of the **t**, **x_B**, and **Q^2** dependence while integrating other variables.

$$-t \leq 0.2\ GeV^2 \qquad 0.1 \leq x_B \leq 0.25 \qquad 1\ GeV^2 \leq Q^2 \leq 2.3\ GeV^2$$



- **First pass** analysis of eg6-data yields up to **3000** candidate **He-DVCS** events.

- bin 0 : $-0.1 < t$
- bin 1 : $-0.2 < t < -0.1$ (GeV^2)
- bin 2 : $1.0 < Q^2 < 1.6$ (GeV^2)
- bin 3 : $1.6 < Q^2 < 2.3$ (GeV^2)
- bin 4 : $0.10 < x_B < 0.15$
- bin 5 : $0.15 < x_B < 0.20$
- bin 6 : $0.20 < x_B < 0.25$

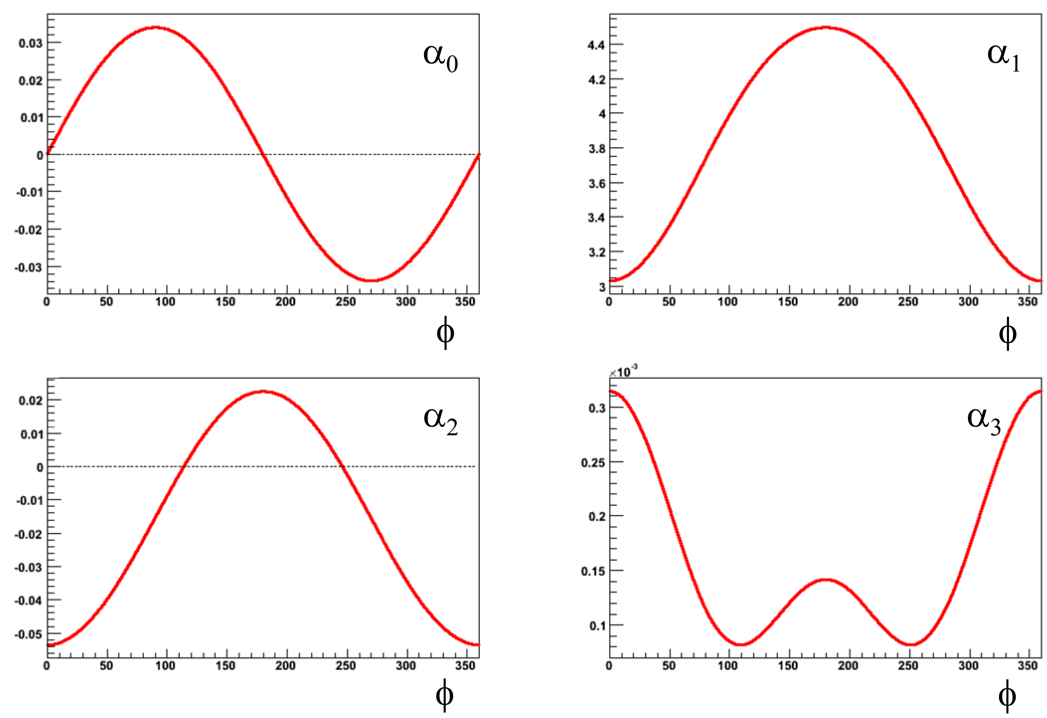
bin	x_B	Q^2	$-t$
0	0.160	1.383	0.080
1	0.172	1.501	0.133
2	0.151	1.281	0.107
3	0.208	1.859	0.119
4	0.130	1.173	0.104
5	0.173	1.479	0.110
6	0.221	1.807	0.121

Harmonic Analysis

$$A_{LU}^{\lambda}(\phi) = \lambda \frac{\alpha_0(\phi)\,\Im m(\mathcal{H}_A)}{\alpha_1(\phi) + \alpha_2(\phi)\,\Re e(\mathcal{H}_A) + \alpha_3(\phi)\left(\Re e(\mathcal{H}_A)^2 + \Im m(\mathcal{H}_A)^2\right)}$$

- α_0 is a simple **sin(ϕ)** function while α_1, α_2 and α_3 are **cos(nϕ)** developments up to n=2.

$$\alpha_0(\phi) \sim 10^{-2}$$
$$\alpha_1(\phi) \sim 10^{0}$$
$$\alpha_2(\phi) \sim 10^{-2}$$
$$\alpha_3(\phi) \sim 10^{-4}$$



Experimental Asymmetries

CLAS-eg6
PRELIMINARY

- **Q^2-dependence** : study of the scaling of the Compton form factor.
- **x_B-dependence** : study of deviations with respect to PDF.
- **t-dependence** : study of deviations with respect to the form factor dependence.

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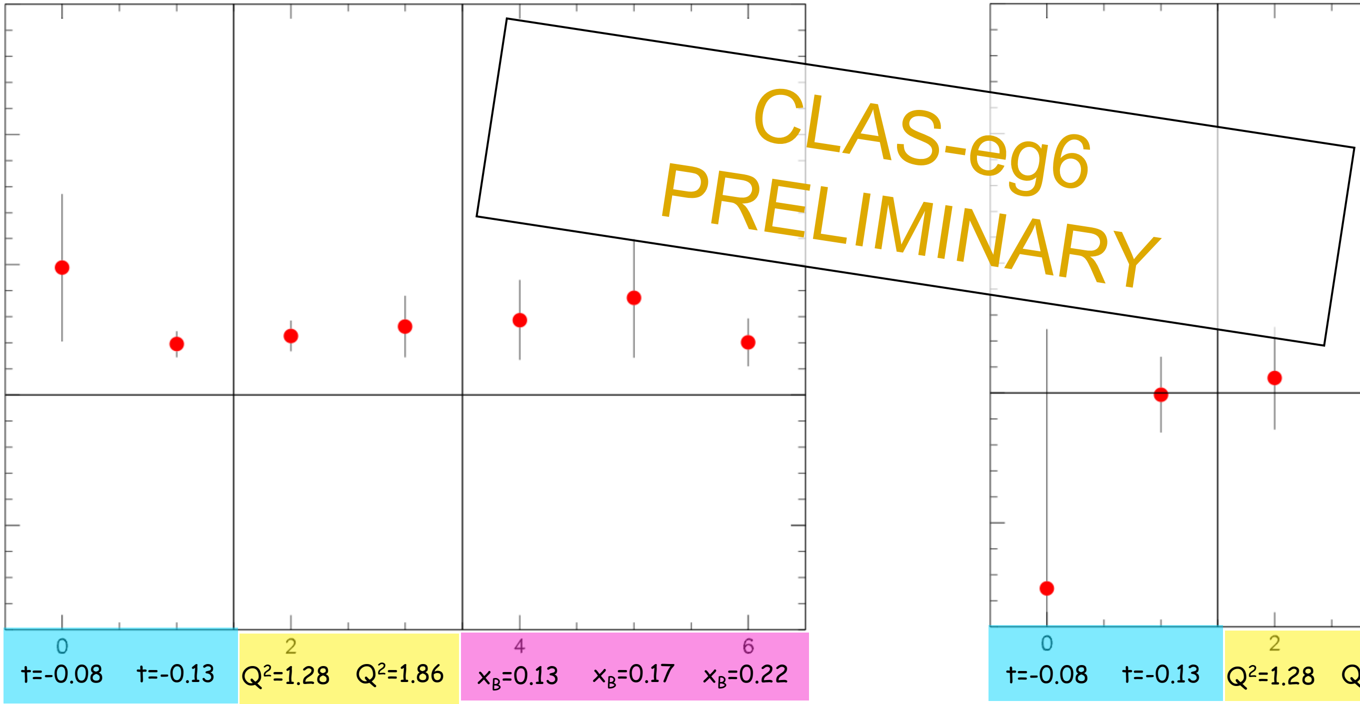
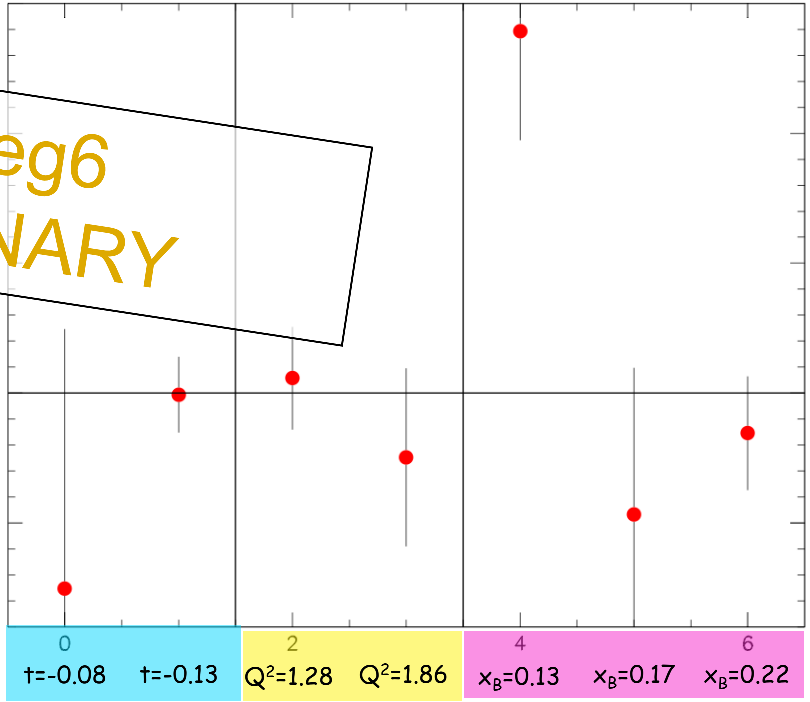
First Pass Analysis Results

Imaginary Part



Real Part



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

Y. Perrin, Doctorat Thesis, Grenoble (2012)

Summary

A significant **helicity signal**
for **coherent DVCS off ^{4}He** has been observed at **CLAS**
within an **exclusive** detection scheme
of the **He-DVCS** process.

Final calibration of the **RTPC** (energy loss, drift path)
Refinement of **CLAS detectors calibration**
Determination of the potential **physics background** (π^0,^{3}He,^{3}H)
Refined **extraction** of the Compton form factor

Final **results** are expected by the **end** of **2013**.