Deeply Virtual Compton Scattering off ^{4}He

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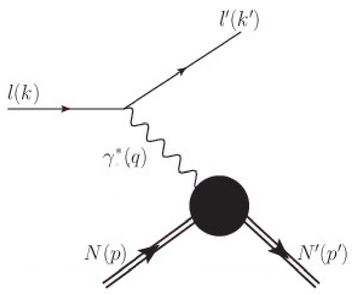
Elastic Scattering (ES)



Measuring the elastic Form Factors (FFs) gives the spatial charge distributions of nucleon's constituents.

FFs

$$\int_{-1}^{+1} dx H^q(x,\xi,t) = F_1^q(t) \quad \text{Dirac F.F.}$$
$$\int_{-1}^{+1} dx E^q(x,\xi,t) = F_2^q(t) \quad \text{Pauli F.F.}$$

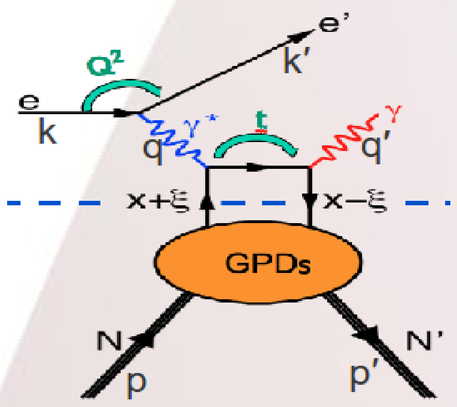
GPDs

Deeply Virtual Compton Scattering (DVCS)

More information about nucleon structure is embedded within the correlation between momentum and spatial coordinates.

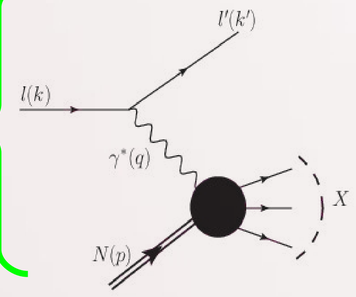
Hard part: perturbative (calculable in PQCD)

Soft part: non perturbative (parameterized in terms of GPDs)



GPDs(x,ξ,t): give a three dimensional image of both longitudinal momentum and transverse coordinates of nucleon's constituents.

Deep Inelastic Scattering (DIS)



Measuring the Parton Distribution Functions (PDFs) gives access to the momentum distributions of the nucleon's constituents.

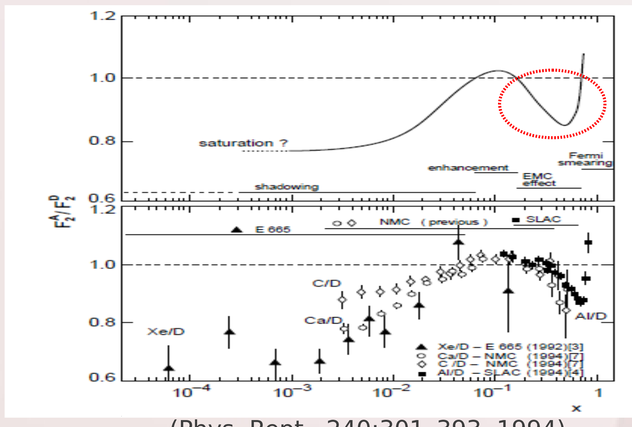
PDFs

GPDs

If ξ = t = 0:
$H^q(x,0,0) = q(x)$ unpolarized quark density.
$\tilde{H}^q(x,0,0) = \Delta q(x)$ polarized quark density.

EMC Effect

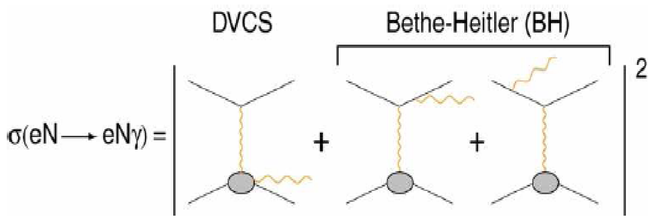
The structure function of the free nucleon ≠ the structure function of the nucleon inside a nucleus.



(Phys. Rept., 240:301–393, 1994)

Experimental access to DVCS process

DVCS amplitude interferes with Bethe-Heitler amplitude, but they have different sensitivities to the polarization of the beam. This enhances the DVCS signal in the beam-spin asymmetry.



Compton Form Factors

Beam-spin asymmetry (A_{LU}) is an observable of the DVCS process, which is sensitive to the real and imaginary part of the Compton Form Factors. For the case of the coherent DVCS off ^{4}He, it becomes :

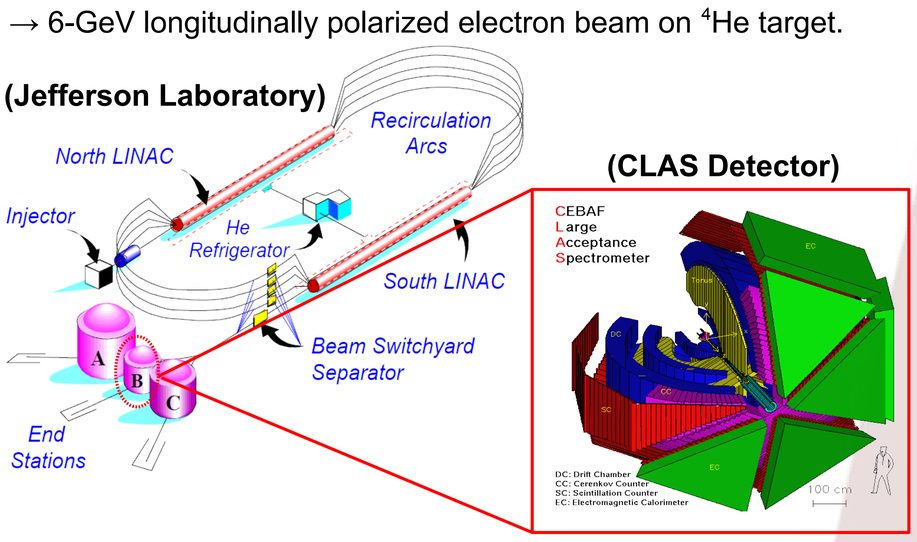
$$A_{LU} = \frac{\alpha_0(\phi)\Im_A}{\alpha_1(\phi) + \alpha_2(\phi)\Re_A + \alpha_3(\phi)(\Re_A^2 + \Im_A^2)} = \frac{1}{P_B}\frac{N^+ - N^-}{N^+ + N^-}$$

$$\mathcal{I}_A \propto [H_A(\xi,\xi,t) - H_A(-\xi,\xi,t)] \qquad \mathcal{R}_A \propto \int_{-1}^{+1} dx \left(\frac{1}{x-\xi} - \frac{1}{x+\xi}\right) H_A(x,\xi,t)$$

N^+,N^-: Number of events with (+) and (-) helicity of electrons.
P_B : Beam polarization.

Experimental Setup

CLAS experiment in the Hall-B of Jefferson Laboratory (Virginia, USA).
→ 6-GeV longitudinally polarized electron beam on ^{4}He target.



The exclusivity of DVCS off ^{4}He @Jlab is ensured by measuring all produced particles

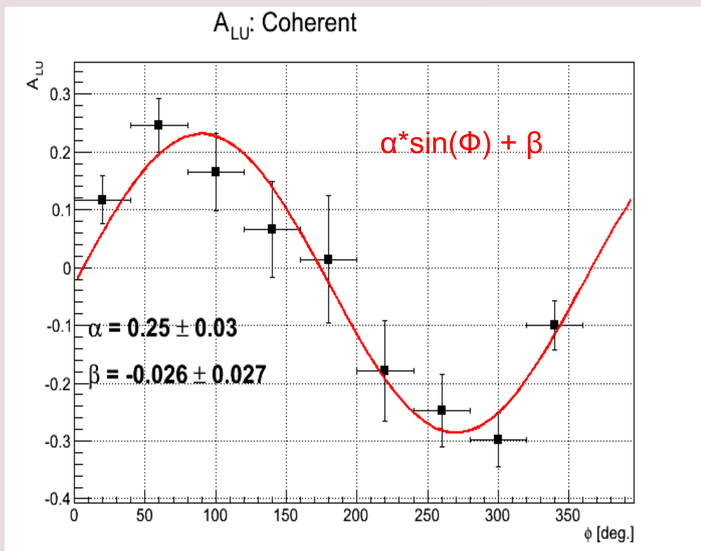
→ The scattered electron (CLAS)
→ The real photon (Inner Calorimeter (IC) + CLAS (EC))
→ The proton (CLAS)
→ The recoil helium nucleus (RTPC)

Nuclear DVCS

The spin zero of ^{4}He allows for simple parametrization of its partonic structure.

Coherent channel

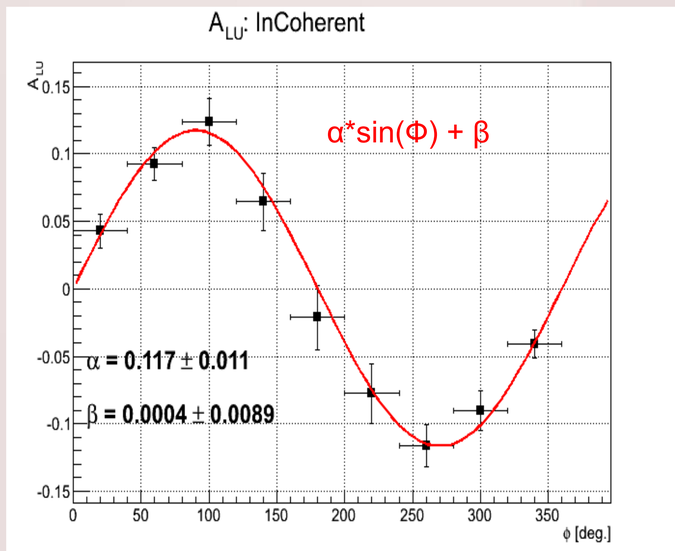
→ $e^-\ {}^4He \to e^-\ \gamma\ {}^4He$.
→ soft part parameterized by one GPD (H_A).
→ study partonic structure of ^{4}He as a whole.



<-t>= 0.11 GeV²
<x_B>= 0.18
<Q²>= 1.5 GeV²

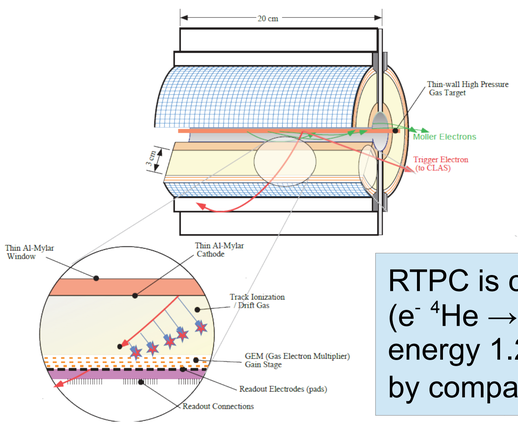
Incoherent channel

→ $e^-\ {}^4He \to e^-\ \gamma\ p$ (nuclear fragments).
→ soft part parameterized by 4 GPDs {H, E, H̃, Ẽ}.
→ study medium modifications (EMC).



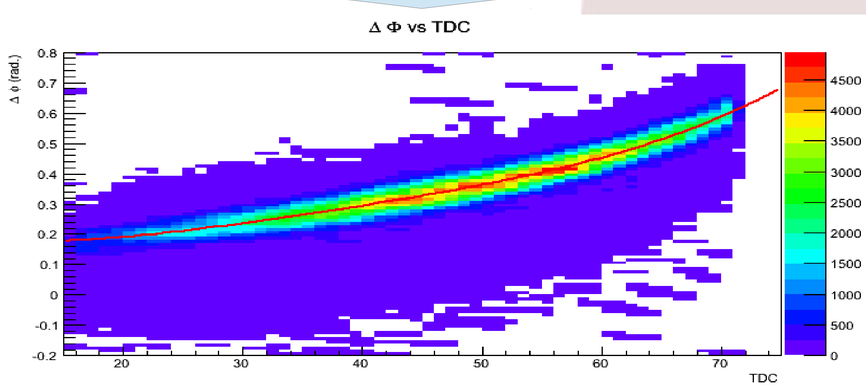
<-t>= 0.88 GeV²
<x_B>= 0.28
<Q²>= 2.28 GeV²

Radial Time Projection Chamber (RTPC)



- ^{4}He low momentum detector.
- Target : ^{4}He gas @ 7atm.
- Drift region: DME/Ne gas @1atm.
- 3200 readout pads.

RTPC is calibrated by using the elastic process ($e^-\ {}^4He \to e^-\ {}^4He$) with an electron beam of energy 1.2 GeV, then drift paths are reconstructed by comparing Geant4 simulation with data.



Conclusions and Perspectives

- Our experiment @ JLab explores DVCS off ^{4}He by using a 6-GeV polarized electron beam [1].
- DVCS events for both coherent and incoherent channels have been identified.
- We have preliminary measurements for the beam-spin asymmetries of DVCS off ^{4}He.
- Good agreement was found between the incoherent channel and the results for free proton @ CLAS [3].

To do:

- More work is needed on RTPC to improve momentum corrections, gain calibration and Monte Carlo simulation of the detector.
- Physics interpretation and comparison to theoretical models.

References

[1] K.Hafidi et al., Deeply Virtual Comton Scattering off ^{4}He, JLab proposal to PAC33, 2007.
[2] V. Burkert, L. Elouadrhiri, M. Garcon and S. Stepanyan. Deeply Virtual Compton Scattering with CLAS at 6 GeV. JLab Experiment E01-113, 2001.
[3] F.X. Girod et al., Deeply Virtual Comton Scattering Beam-Spin Asymmetries, arXiv:0711.4805v3, 2008.