DVCS with JLab Hall A

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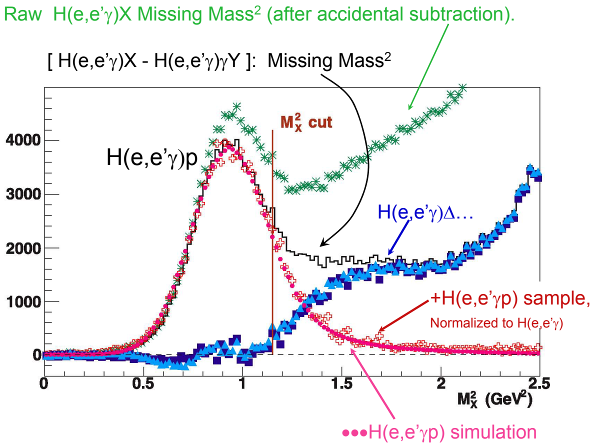
Outline

1. Exclusivity
2. Cross section extraction procedure
3. Opportunities of the beam energy dependence of DVCS

Missing mass

Missing mass squared $ep \to e'\gamma X$

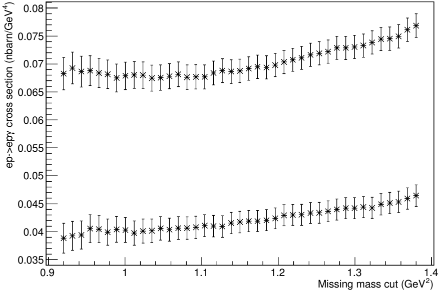
$$M_X^2 = (e + p - e' - \gamma)^2 \qquad M_X^2 \text{ cut} = (M + m_\pi)^2$$

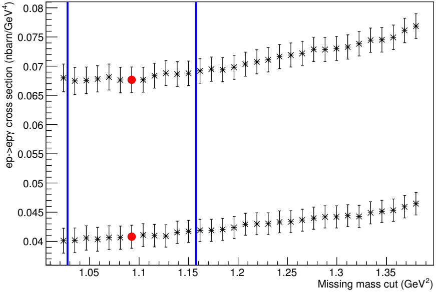


Exclusivity ensured by missing mass technique

Associated systematic error

Varying the M_X^2 cut below the π-production threshold gives an estimate of syst. uncertainty





Systematic error due to the missing mass cut $\lesssim 2\%$

M. Defurne

DVCS cross section: data analysis

Challenge:

Very rapid variation with kinematics (mostly due to BH propagators)

Experimental issues:

- Integration of cross section within experimental bins
- Bin migration

Variables: $\mathbf{x}_v = \{k, x_B, Q^2, t, \varphi_e, \varphi, v_z\}_v$ $\qquad \mathbf{x}_e = \{k, x_B, Q^2, t, \varphi_e, \varphi, v_z\}_e$
Exp. bins: $\mathbf{j}_v = \{j_{x_B}, j_{Q^2}, j_t, j_\varphi\}_v$ $\qquad \mathbf{i}_e = \{i_{x_B}, i_{Q^2}, i_t, i_\varphi\}_e$

$$K(\mathbf{x}_e|\mathbf{x}_v)$$

$$\frac{d\sigma}{d\Omega}(\mathbf{x}_v) = \Gamma^{BH}(\mathbf{x}_v) + \sum_{\Lambda=1}^{3} \Gamma^{\Lambda}(\mathbf{x}_v) X^{\Lambda}_{\mathbf{j}_v} \equiv \sum_{\Lambda=0}^{3} \Gamma^{\Lambda}(\mathbf{x}_v) X^{\Lambda}_{\mathbf{j}_v}$$

Experimental number of counts

$$N(\mathbf{j}_v) = \mathcal{L} \int_{\mathbf{x}_v \in \mathsf{Bin}(\mathbf{j}_v)} \sum_{\Lambda=0}^{3} \Gamma^{\Lambda}(\mathbf{x}_v) X^{\Lambda}_{\mathbf{j}_v} d\mathbf{x}_v =$$

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$$N(\mathbf{i}_e) = \int_{\mathbf{x}_e \in \mathsf{Bin}(\mathbf{i}_e)} d\mathbf{x}_e \sum_{\mathbf{j}_v} N(\mathbf{i}_v) K(\mathbf{x}_e|\mathbf{x}_v) =$$

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We define a bin mapping function:

$$K^{\Lambda}_{\mathbf{i}_e,\mathbf{j}_v} = \int_{\mathbf{x}_e \in \mathsf{Bin}(\mathbf{i}_e)} \int_{\mathbf{x}_v \in \mathsf{Bin}(\mathbf{j}_v)} d\mathbf{x}_e \, d\mathbf{x}_v \; K(\mathbf{x}_e|\mathbf{x}_v) \Gamma^{\Lambda}(\mathbf{x}_v)$$

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Fit of experimental counts: linear system

$$N^{\mathsf{MC}}(\mathbf{i}_e) = \mathcal{L} \sum_{\mathbf{j}_v, \Lambda} K^{\Lambda}_{\mathbf{i}_e, \mathbf{j}_v} X^{\Lambda}_{\mathbf{j}_v} \,.$$

$$\chi^2 = \sum_{\mathbf{i}_e} \frac{[N^{\mathsf{Exp}}(\mathbf{i}_e) - N^{\mathsf{MC}}(\mathbf{i}_e)]^2}{[\sigma^{\mathsf{Exp}}(\mathbf{i}_e)]^2} \,,$$

$$0 \;=\; -\frac{1}{2} \frac{\partial \chi^2}{\partial X^{\Lambda}_{\mathbf{j}_v}} \bigg|_{\overline{\mathbf{X}}_{\mathbf{j}_v}} = \sum_{\mathbf{i}_e} \mathcal{L} K^{\Lambda}_{\mathbf{i}_e, \mathbf{j}_v} \frac{\mathcal{L} \sum_{\mathbf{j}'_v, \Lambda'} K^{\Lambda'}_{\mathbf{i}_e, \mathbf{j}'_v} \overline{X}^{\Lambda'}_{\mathbf{j}'_v} - N^{\mathsf{Exp}}(\mathbf{i}_e)}{[\sigma^{\mathsf{Exp}}(\mathbf{i}_e)]^2}$$

$$0 \;=\; \sum_{\mathbf{j}'_v, \Lambda'} \alpha^{\Lambda, \Lambda'}_{\mathbf{j}_v, \mathbf{j}'_v} \overline{X}^{\Lambda'}_{\mathbf{j}'_v} - \beta^{\Lambda}_{\mathbf{j}_v} \qquad \forall\, \mathbf{j}_v,\, \Lambda \,.$$

The linear system is defined by:

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Cross-section results

The fit parameters are:

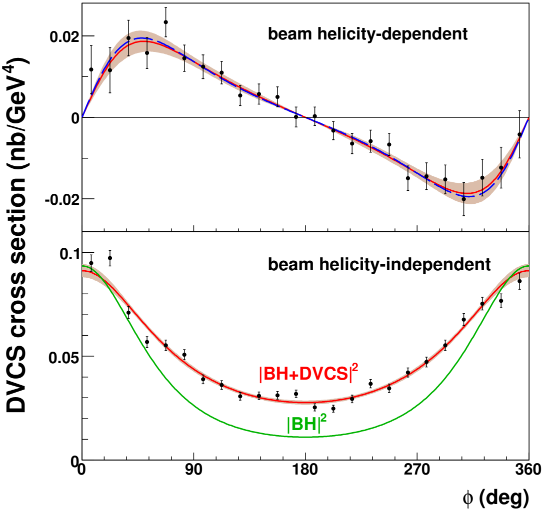
$$\overline{X}^{\Lambda}_{\mathbf{j}_v} = \sum_{\mathbf{j}'_v,\,\Lambda'} [\alpha^{-1}]^{\Lambda,\,\Lambda'}_{\mathbf{j}_v,\mathbf{j}'_v}\, \beta^{\Lambda'}_{\mathbf{j}'_v}\,.$$

The covariance matrix of the fitted parameters is:

$$V^{\Lambda,\,\Lambda'}_{\mathbf{j}_v,\mathbf{j}'_v} = [\alpha^{-1}]^{\Lambda,\,\Lambda'}_{\mathbf{j}_v,\mathbf{j}'_v}\,.$$

$$\frac{d^5\sigma^{\mathrm{Exp}}(i)}{d^5\Phi} = \frac{d^5\sigma^{\mathrm{Fit}}(i)}{d^5\Phi} N_i^{\mathrm{Exp}}/N_i^{\mathrm{Fit}},$$

Experimental results



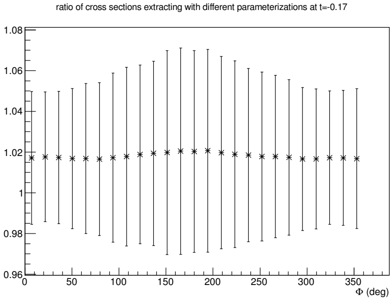
Analysis with BKM-2002:

Belitsky, Müller, Kirchner, Nucl. Phys. **B629**, 323 (2002)

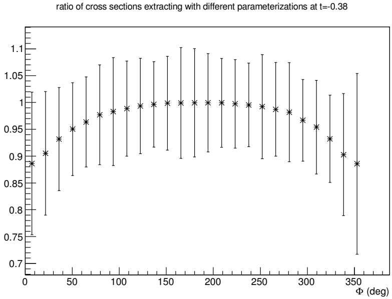
Results with different parametrizations

- Reanalysis with BMK-2010 and comparison

Low $-t$



High $-t$



- Stable within statistical uncertainties
- Especially at low $-t$ where the acceptance is best known

M. Defurne

Rosenbluth-like separation of the DVCS cross section

$$\sigma(ep \to ep\gamma) = \underbrace{|BH|^2}_{\text{Known to} \sim 1\%} + \underbrace{\mathcal{I}(BH \cdot DVCS)}_{\text{Linear combination of GPDs}} + \underbrace{|DVCS|^2}_{\text{Bilinear combination of GPDs}}$$

$$\mathcal{I} \propto 1/y^3 = (k/\nu)^3,$$
$$\left|\mathcal{T}^{DVCS}\right|^2 \propto 1/y^2 = (k/\nu)^2$$

BKM-2010 – at leading twist $\rightarrow$ 7 independent GPD terms:

$$\left\{\Re\text{e}, \Im\text{m}\left[\mathcal{C}^{\mathcal{I}}, \mathcal{C}^{\mathcal{I},V}, \mathcal{C}^{\mathcal{I},A}\right](\mathcal{F})\right\}, \qquad \text{and} \qquad \mathcal{C}^{DVCS}(\mathcal{F}, \mathcal{F}*).$$

φ-dependence provides 5 independent observables:

$$\sim 1, \sim \cos\varphi, \sim \sin\varphi, \sim \cos(2\varphi), \sim \sin(2\varphi)$$

The measurement of the cross section at two or more beam energies for exactly the same Q^2, x_B, t kinematics, provides the additional information in order to extract all leading twist observables independently.

DVCS cross-section: φ & Q^2

$$\begin{aligned} \mathcal{I} &= \frac{i_0/Q^2 + i_1\cos\varphi/Q + i_2\cos 2\varphi/Q^2 + i_3\cos 3\varphi/Q}{\mathcal{P}_1\mathcal{P}_2} \\ \text{DVCS}^2 &= d_0/Q^2 + d_1\cos\varphi/Q^3 + d_2\cos 2\varphi/Q^4 \,. \end{aligned}$$

The product of the BH propagators reads:

$$\mathcal{P}_1\mathcal{P}_2 = 1 + \frac{p_1}{Q}\cos\varphi + \frac{p_2}{Q^2}\cos 2\varphi \,.$$

Reducing to a common denominator ($\times\mathcal{P}_1\mathcal{P}_2$), one obtains:

$$\begin{aligned} \mathcal{P}_1\mathcal{P}_2\mathcal{I} + \mathcal{P}_1\mathcal{P}_2\text{DVCS}^2 = &\boxed{(i_0 + d_0)/Q^2} + d_1 p_1/2/Q^4 + p_2 d_2/2/Q^6 \\ &+ [i_1/Q + (p_1 d_0 + d_1)/Q^3 + (p_1 d_2 + p_2 d_1)/2/Q^5]\cos\varphi \\ &+ [i_2/Q^2 + (p_2 d_0 + p_1 d_1/2 + d_2)/Q^4]\cos 2\varphi \\ &+ [i_3/Q + (p_1 d_2 + p_2 d_1)/2/Q^5]\cos 3\varphi \\ &+ [p_2 d_2/4/Q^6]\cos 4\varphi \,. \end{aligned}$$

The $\mathcal{I}$ and DVCS^2 terms **mix at leading order in 1/Q** in the φ expansion

Thank you!