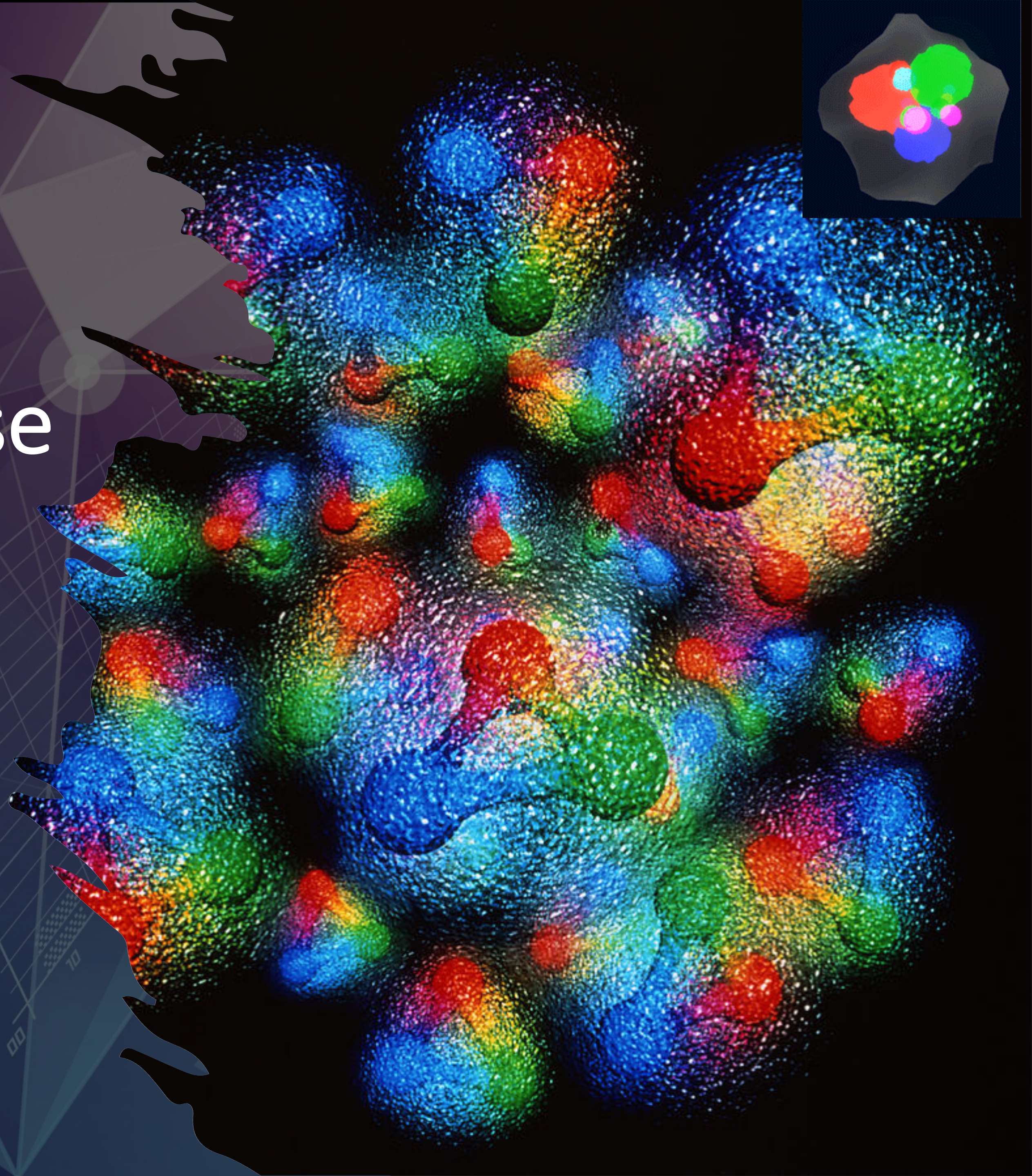
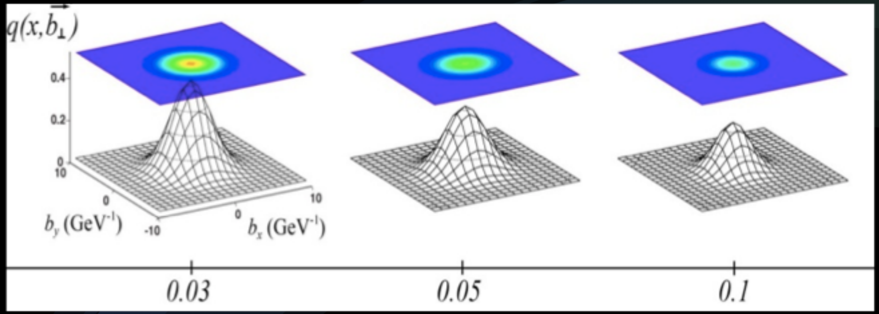
On Longitudinal/Transverse separation in DVES

Simonetta Liuti

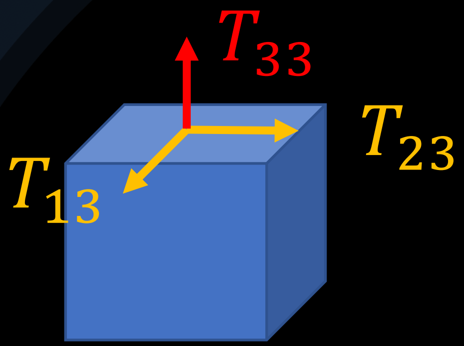


- Quark and Gluon Imaging

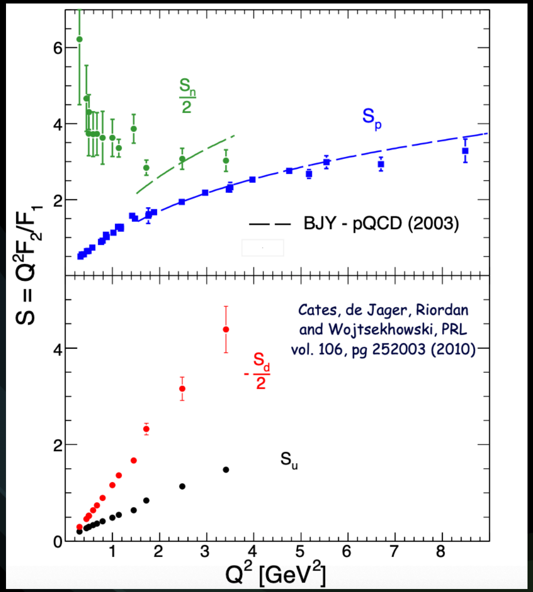


M. Defurne

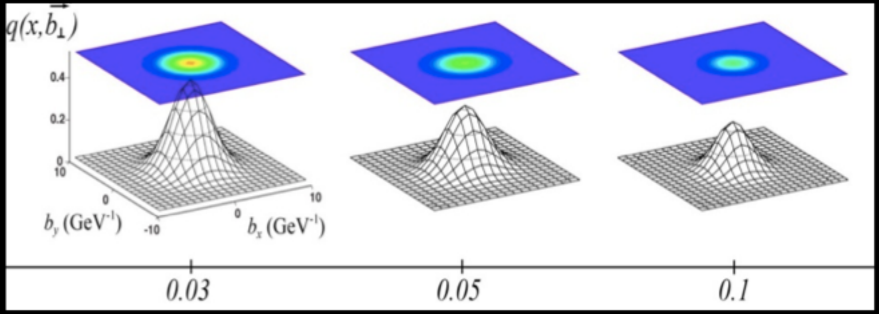
- The proton spin and its internal forces (dynamics)



- Mechanisms of flavor dependence in nucleons and nuclei

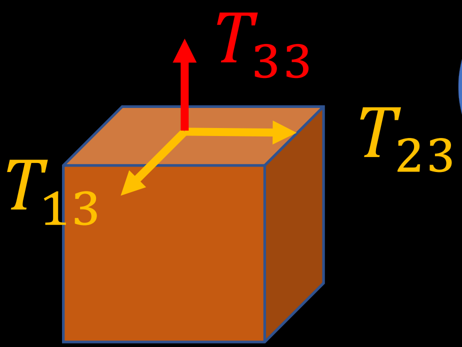


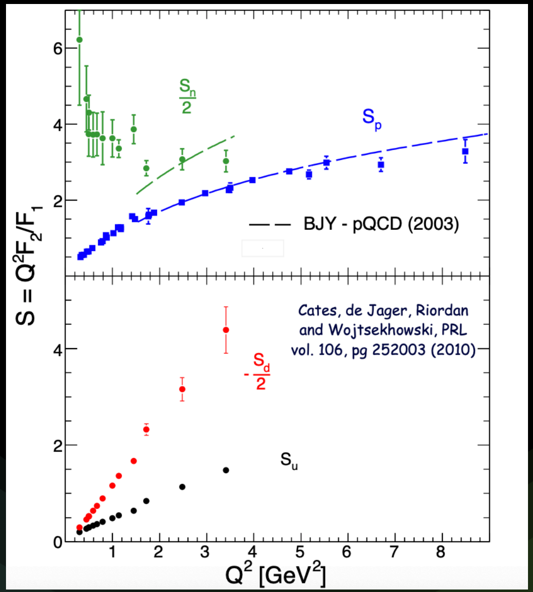
G. Cates et al. (2010)



Common thread

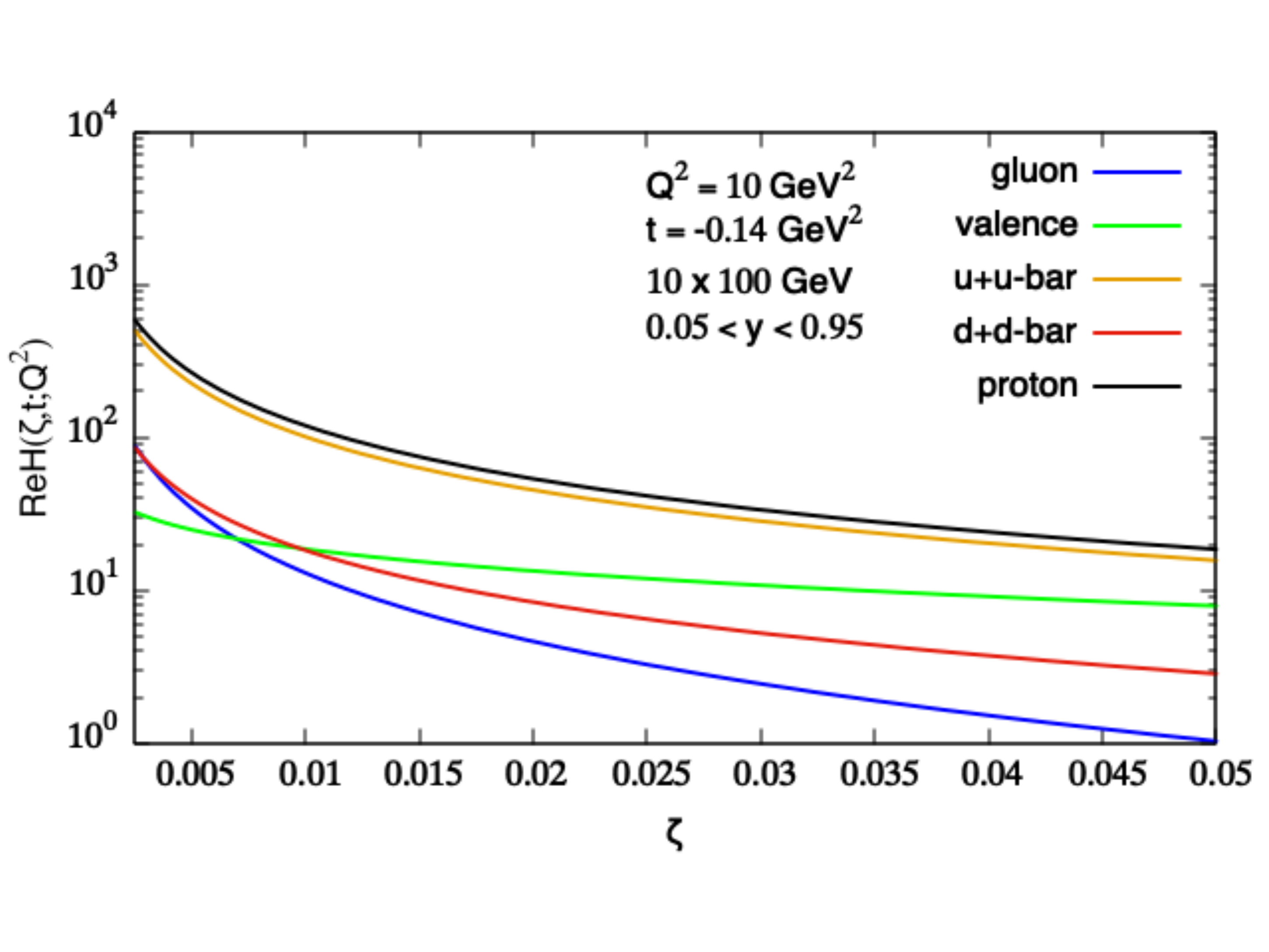
QCD
Scattering
Amplitudes





Outstanding questions

1. How do we separate the various flavor components at leading order (twist)



B. Kriesten and S. Liuti, *in preparation*

Twist -3 GPDs

GPD	$P_q P_p$	TMD	Ref.[1]
$H^{\perp}$	UU	$f^{\perp}$	$2\widetilde{H}_{2T} + E_{2T}$
$\widetilde{H}_L^{\perp}$	LL	$g_L^{\perp}$	$2\widetilde{H}'_{2T} + E'_{2T}$
$H_L^{\perp}$	UL	$f_L^{\perp\,(*)}$	$\widetilde{E}_{2T} - \xi E_{2T}$
$\widetilde{H}^{\perp}$	LU	$g^{\perp\,(*)}$	$\widetilde{E}'_{2T} - \xi E'_{2T}$
$H_T^{(3)}$	UT	$f_T^{(*)}$	$H_{2T} + \tau \widetilde{H}_{2T}$
$\widetilde{H}_T^{(3)}$	LT	g'_T	$H'_{2T} + \tau \widetilde{H}'_{2T}$

(*) T-odd

Outstanding questions

2. How do we separate twist two and twist three components?

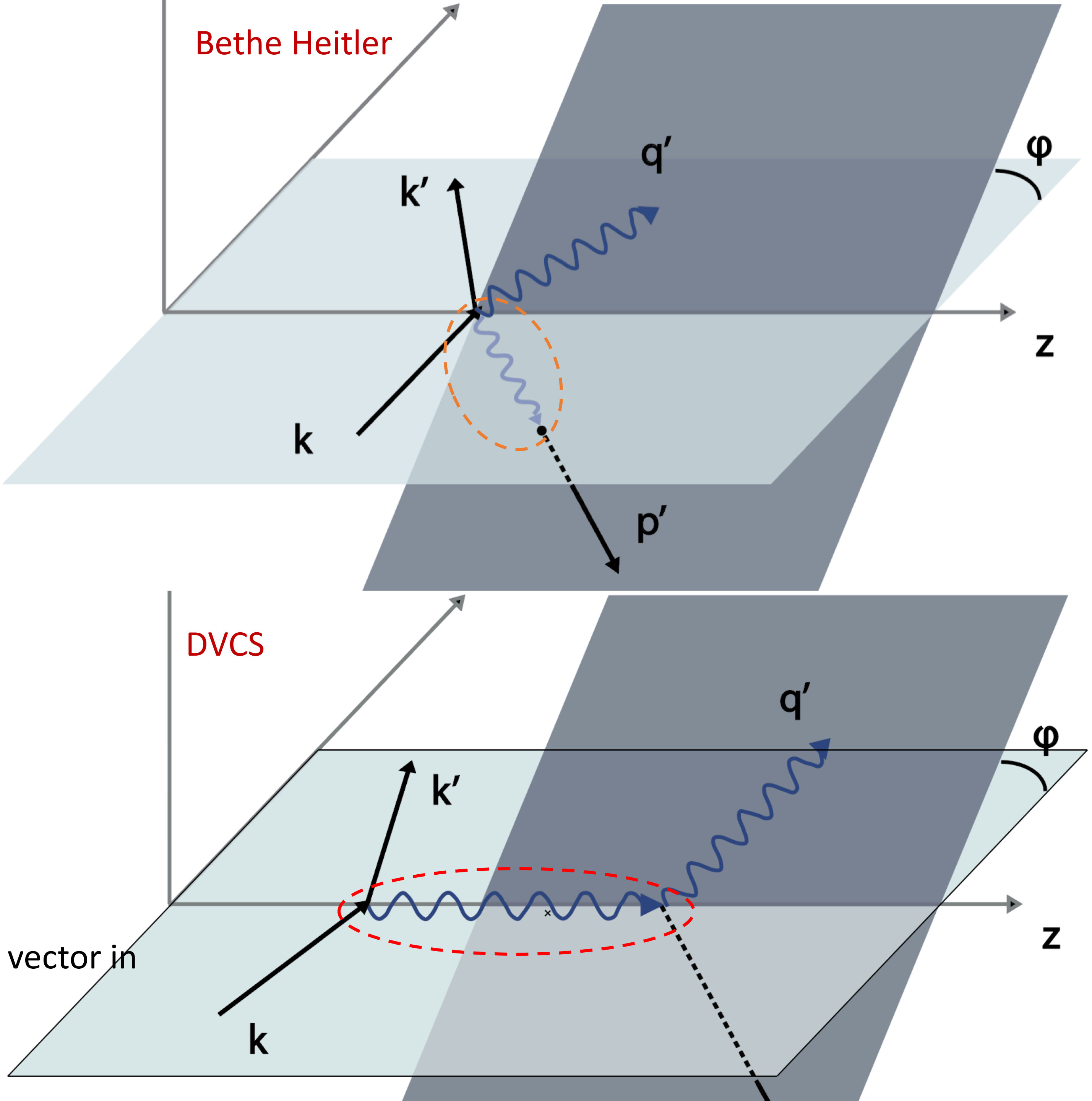
B. Kriesten and S. Liuti, *Phys.Rev. D105 (2022),* arXiv 2004.08890

[1] Meissner, Metz and Schlegel, JHEP(2009)

The ability to perform L/T separations is important

Demystification of harmonics formalism:

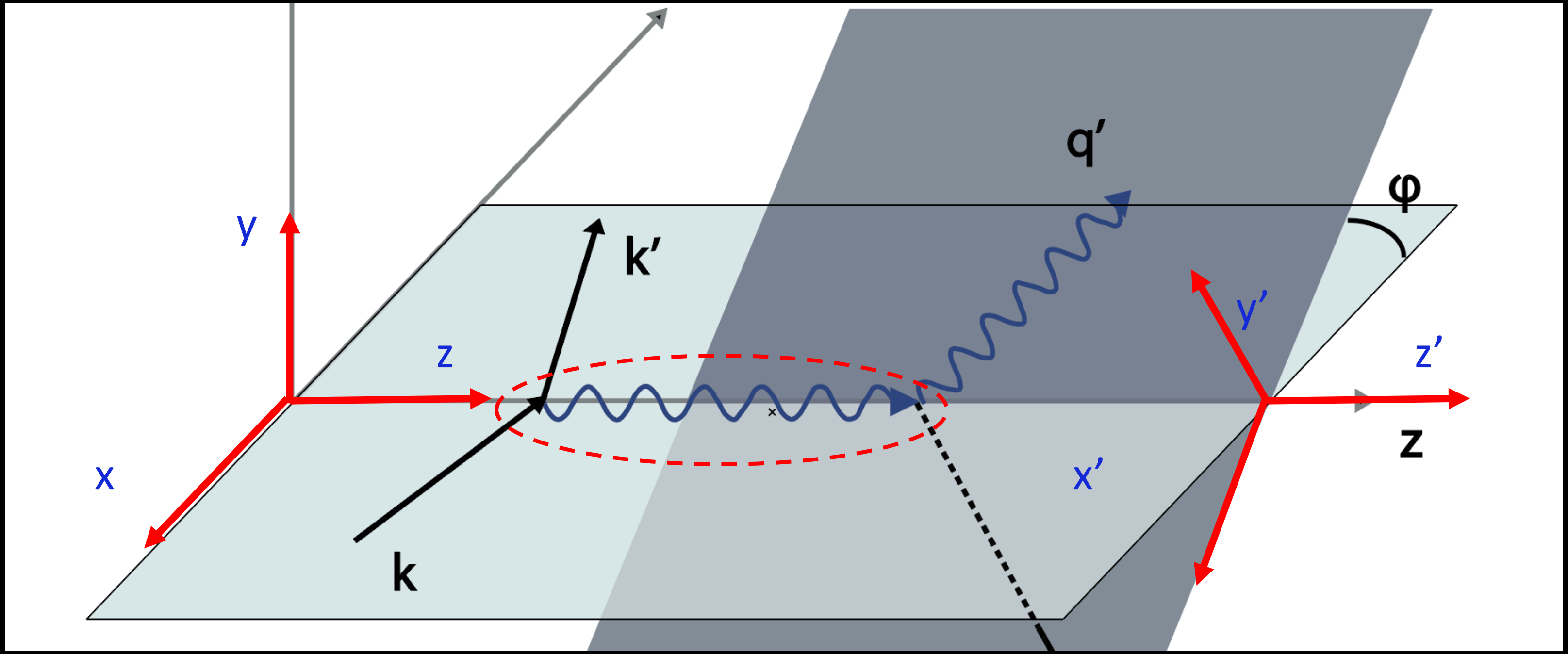
Phase is the keyword



- In DVCS the virtual photon is along the z axis: φ dependence from usual rotation of polarization vector in helicity amp

To understand the cross section we need to understand the ϕ dependence

DVCS



The hadronic tensor is evaluated in the rotated frame

BH

$$\frac{d^5\sigma^{BH}_{unpol}}{dx_{Bj}dQ^2d|t|d\phi d\phi_S} \equiv \frac{\Gamma}{t}F^{BH}_{UU} = \frac{\Gamma}{t}\left[A(y,x_{Bj},t,Q^2,\phi)\boxed{\left(F_1^2+\tau F_2^2\right)} + B(y,x_{Bj},t,Q^2,\phi)\tau \boxed{G_M^2(t)}\right]$$

$$A = \frac{16\,M^2}{t(k\,q')(k'\,q')}\left[4\tau\left((k\,P)^2+(k'\,P)^2\right)-(\tau+1)\left((k\,\Delta)^2+(k'\,\Delta)^2\right)\right]$$

$$B = \frac{32\,M^2}{t(k\,q')(k'\,q')}\left[(k\,\Delta)^2+(k'\,\Delta)^2\right],$$

$$\epsilon_{BH} = \left(1+\frac{B}{A}(1+\tau)\right)^{-1}$$

…compared to ELASTIC SCATTERING

$$\left(\frac{d\sigma}{d\Omega}\right)_0 = \left(\frac{d\sigma}{d\Omega}\right)_{\text{Mott}} \frac{\epsilon (G_E^N)^2 + \tau (G_M^N)^2}{\epsilon(1+\tau)},$$

where $N = p$ for a proton and $N = n$ for a neutron, (
the recoil-corrected relativistic point-particle (Mott)
and τ, ϵ are dimensionless kinematic variables:

$$\tau = \frac{Q^2}{4m_N^2}, \quad \epsilon = \left[1 + 2(1+\tau)\tan^2\frac{\theta}{2}\right]^{-1},$$

[1] Meissner, Metz and Schlegel, JHEP(2009)

…dan, Z. Ye, B. Wojsetowski, A. Puckett …

10/21/21

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…compared to BKM, NPB (2001)

$$|\mathcal{T}_{\mathrm{BH}}|^2 = \frac{e^6}{x_{\mathrm{B}}^2 y^2 (1+\epsilon^2)^2 \Delta^2 \mathcal{P}_1(\phi)\mathcal{P}_2(\phi)} \times \left\{ c_0^{\mathrm{BH}} + \sum_{n=1}^{2} c_n^{\mathrm{BH}} \cos(n\phi) + s_1^{\mathrm{BH}} \sin(\phi) \right\},$$

$$\begin{aligned}
c_{0,\mathrm{unp}}^{\mathrm{BH}} = 8K^2 \Big\{ & (2+3\epsilon^2)\frac{Q^2}{\Delta^2}\left(F_1^2 - \frac{\Delta^2}{4M^2}F_2^2\right) + 2x_{\mathrm{B}}^2 (F_1+F_2)^2 \Big\} \\
& + (2-y)^2 \Big\{ (2+\epsilon^2)\bigg[\frac{4x_{\mathrm{B}}^2 M^2}{\Delta^2}\left(1+\frac{\Delta^2}{Q^2}\right)^2 \\
& \qquad + 4(1-x_{\mathrm{B}})\left(1+x_{\mathrm{B}}\frac{\Delta^2}{Q^2}\right)\bigg]\left(F_1^2 - \frac{\Delta^2}{4M^2}F_2^2\right) \\
& \qquad + 4x_{\mathrm{B}}^2\bigg[x_{\mathrm{B}} + \left(1 - x_{\mathrm{B}} + \frac{\epsilon^2}{2}\right)\left(1-\frac{\Delta^2}{Q^2}\right)^2 \\
& \qquad - x_{\mathrm{B}}(1-2x_{\mathrm{B}})\frac{\Delta^4}{Q^4}\bigg](F_1+F_2)^2 \Big\} \\
& + 8(1+\epsilon^2)\left(1 - y - \frac{\epsilon^2 y^2}{4}\right) \\
& \times \left\{ 2\epsilon^2\left(1-\frac{\Delta^2}{4M^2}\right)\left(F_1^2 - \frac{\Delta^2}{4M^2}F_2^2\right) - x_{\mathrm{B}}^2\left(1-\frac{\Delta^2}{Q^2}\right)^2 (F_1+F_2)^2 \right\},
\end{aligned}$$

$$\begin{aligned}
c_{1,\mathrm{unp}}^{\mathrm{BH}} = 8K(2-y)\Big\{ & \left(\frac{4x_{\mathrm{B}}^2 M^2}{\Delta^2} - 2x_{\mathrm{B}} - \epsilon^2\right)\left(F_1^2 - \frac{\Delta^2}{4M^2}F_2^2\right) \\
& + 2x_{\mathrm{B}}^2\left(1 - (1-2x_{\mathrm{B}})\frac{\Delta^2}{Q^2}\right)(F_1+F_2)^2 \Big\},
\end{aligned}$$

$$c_{2,\mathrm{unp}}^{\mathrm{BH}} = 8x_{\mathrm{B}}^2 K^2 \left\{ \frac{4M^2}{\Delta^2}\left(F_1^2 - \frac{\Delta^2}{4M^2}F_2^2\right) + 2(F_1+F_2)^2 \right\}.$$

BH-DVCS interference

$$F_{UU}^{\mathcal{I},tw2} = A_{UU}^{\mathcal{I}} \Re e \boxed{\left(F_1 \mathcal{H} + \tau F_2 \mathcal{E}\right)} + B_{UU}^{\mathcal{I}} \boxed{G_M \Re e \left(\mathcal{H} + \mathcal{E}\right)} + C_{UU}^{\mathcal{I}} \boxed{G_M \Re e \widetilde{\mathcal{H}}}$$

$A_{UU}{}^{I}$ $B_{UU}{}^{I}$ $C_{UU}{}^{I}$ are φ dependent coefficients

Twist 3 BH-DVCS interference

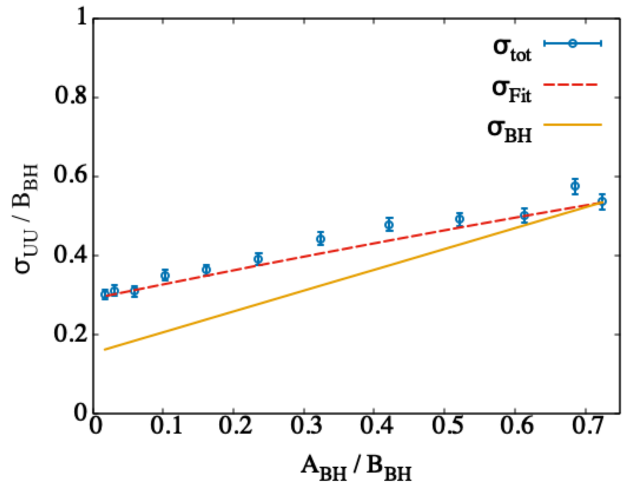
$$F^{\mathcal{I}}_{UU} = F^{\mathcal{I},tw2}_{UU} + \frac{K}{\sqrt{Q^2}} F^{\mathcal{I},tw3}_{UU}$$

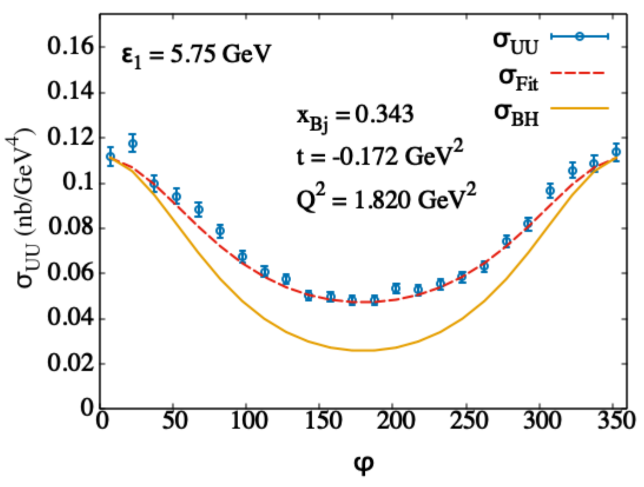
$$F^{\mathcal{I},tw3}_{UU} = A^{(3)\mathcal{I}}_{UU}\left[F_1\left(\Re e(2\widetilde{\mathcal{H}}_{2T} + \mathcal{E}_{2T}) - \Re e(2\widetilde{\mathcal{H}}'_{2T} + \mathcal{E}'_{2T})\right) + F_2\left(\Re e(\mathcal{H}_{2T} + \tau\widetilde{\mathcal{H}}_{2T}) - \Re e(\mathcal{H}'_{2T} + \tau\widetilde{\mathcal{H}}'_{2T})\right)\right]$$
$$+ \boxed{B^{(3)\mathcal{I}}_{UU} G_M \left(\Re e\widetilde{\mathcal{E}}_{2T} - \Re e\widetilde{\mathcal{E}}'_{2T}\right)}$$
$$+ C^{(3)\mathcal{I}}_{UU} G_M \left[2\xi(\Re e\mathcal{H}_{2T} - \Re e\mathcal{H}'_{2T}) - \tau\left(\Re e(\widetilde{\mathcal{E}}_{2T} - \xi\mathcal{E}_{2T}) - \Re e\left(\widetilde{\mathcal{E}}'_{2T} - \xi\mathcal{E}'_{2T}\right)\right)\right]$$

Orbital Angular Momentum

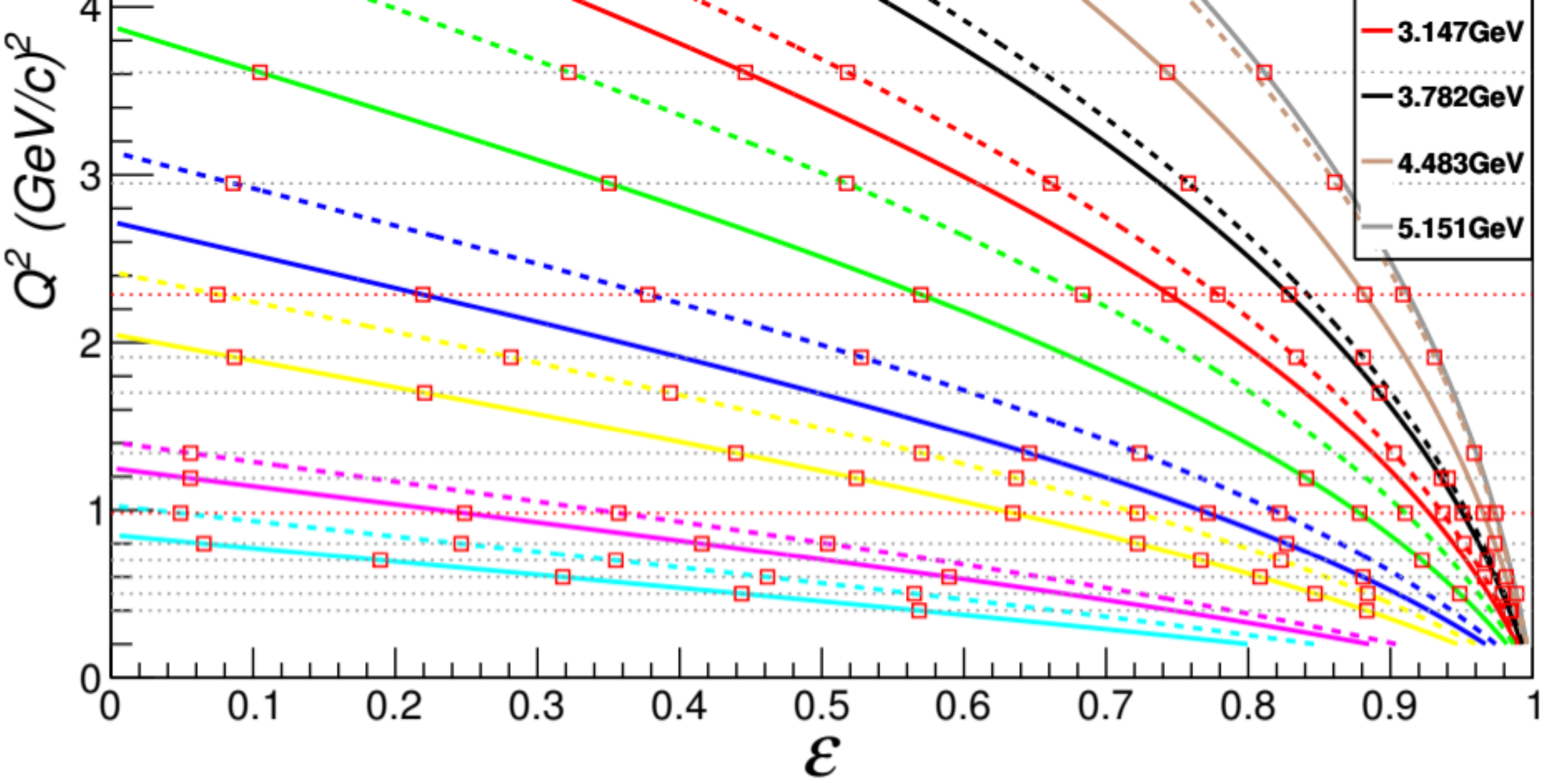
Streamlined description of cross section

- Rosenbluth Separated BH-DVCS interference data





2.B. Kriesten, S. Liuti and A. Meyer, *Phys. Lett. B**829**, (2022)*

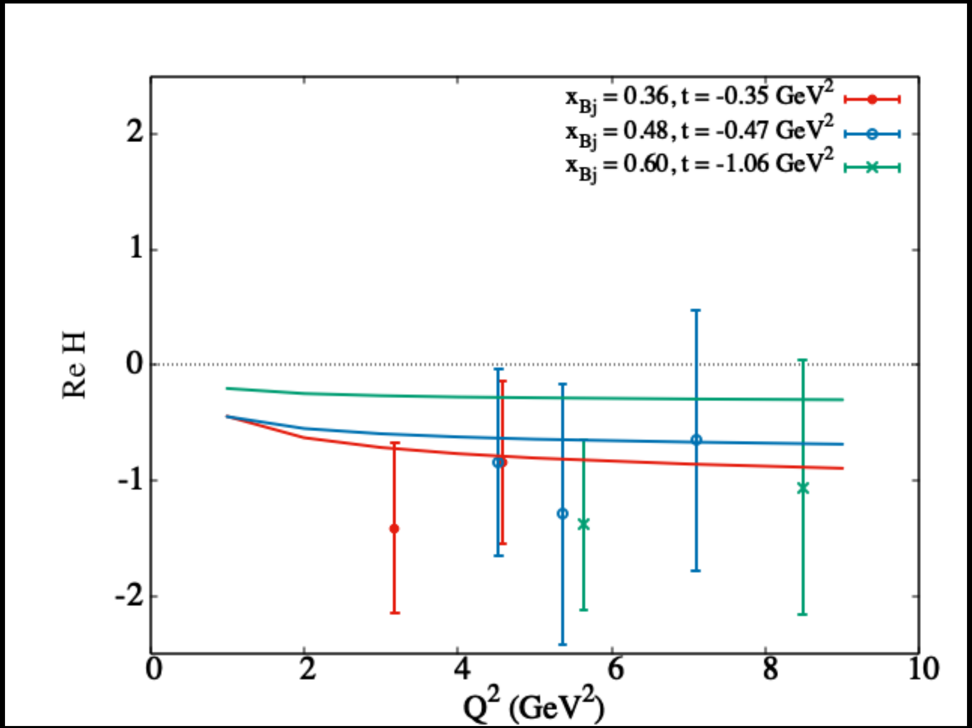


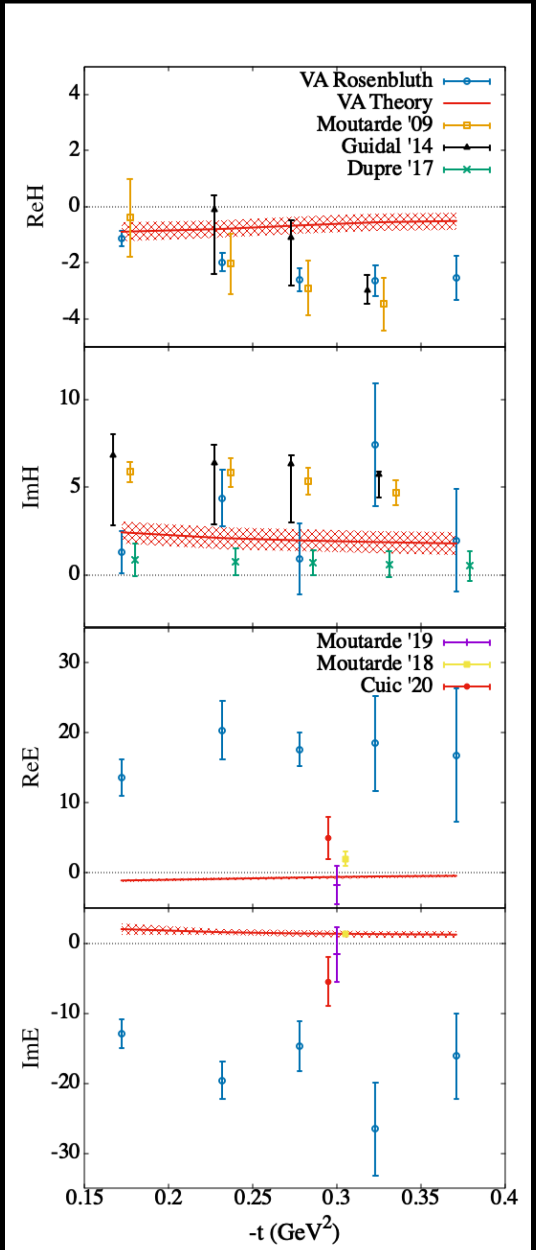
ure 3.2: The E05-017 nominal kinematic coverage. The solid and dashed lines are constan

ings.

M. Yurov, Ph.D. thesis

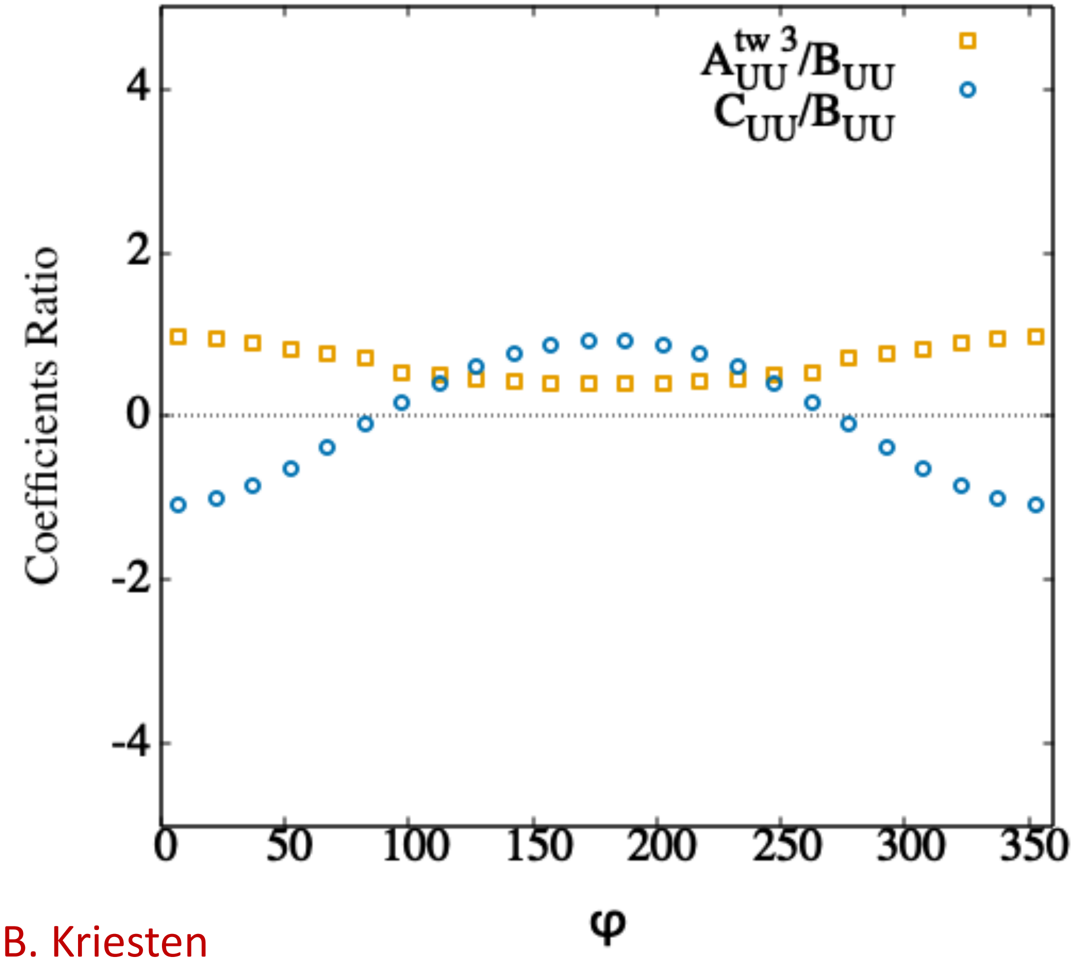
Compton Form Factor Extraction





Q^2 dependence

First estimate: Twist 3 seems small



B. Kriesten

Bringing this further: ML based approach merging and organizing information from experiment and lattice with a faithful uncertainty representation (uncertainty quantification)
B. Kriesten’s talk

- statistical analysis for extraction of form factors
- Extraction of GPDs

DVCS formalism

- B. Kriesten et al, *Phys.Rev. D* 101 (2020)
- B. Kriesten and S. Liuti, *Phys.Rev. D105 (2022),* arXiv 2004.08890
- B. Kriesten and S. Liuti, Phys. Lett. B829 (2022), arXiv:2011.04484

ML

- J. Grigsby, B. Kriesten, J. Hoskins, S. Liuti, P. Alonzi and M. Burkardt, Phys. Rev. D104 (2021)

GPD Parametrization for global analysis

- B. Kriesten, P. Velie, E. Yeats, F. Y. Lopez and S. Liuti,

Phys. Rev D 105 (2022), arXiv:2101.01826