Compton Scattering Experiments at 12 GeV

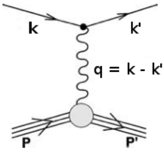
F.-X. Girod

August 20th 2011

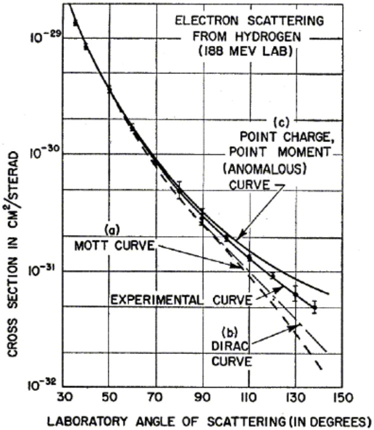
Overview

Introduction

Elastic scattering
Nucleon Form Factors



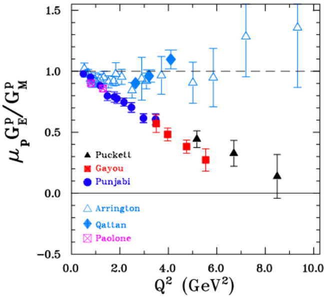
$$
\begin{aligned}
J^{\mu}_{\text{EM}} &= F_1\gamma^{\mu} + \frac{\kappa}{2M}F_2 i\sigma^{\mu\nu}q_{\nu} \\
\frac{d\sigma}{d\Omega} &= \frac{\sigma_{\text{Mott}}}{\epsilon(1+\tau)}\left[\tau G_{\text{M}}^2 + \epsilon G_{\text{E}}^2\right] \\
\tau &= \frac{Q^2}{4M^2} \\
Q^2 &= -\left(k_i - k_f\right)^2 = -m^2_{\gamma *} \\
\frac{1}{\epsilon} &= 1 + 2(1+\tau)\tan^2\frac{\theta_e}{2} \\
G_{\text{E}} &= F_1 - \tau F_2 \\
G_{\text{M}} &= F_1 + F_2
\end{aligned}
$$



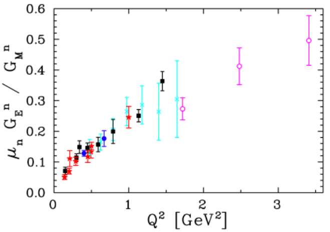
Hofstadter Nobel prize 1961

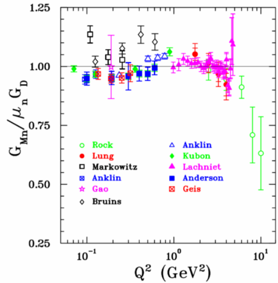
"The best fit in this figure indicates an rms radius close to $0.74 \pm 0.24 \times 10^{-13}$ cm."

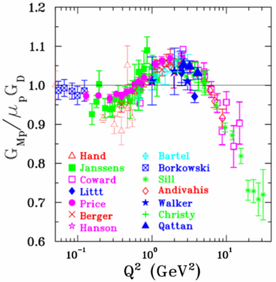
Elastic scattering
Nucleon Form Factors



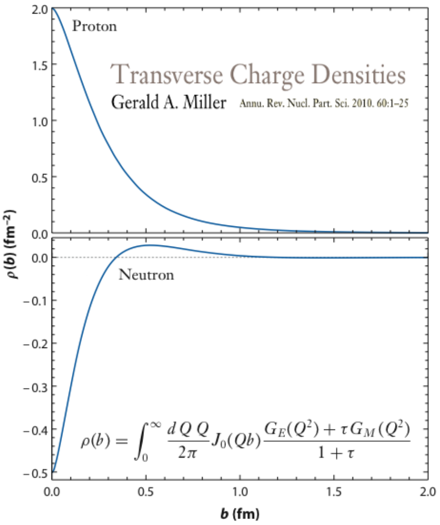
Nucleon Form Factors – A Jefferson Lab Perspective
John Arrington , Kees de Jager and Charles F. Perdrisat
Journal of Physics: Conference Series **299** (2011) 012002







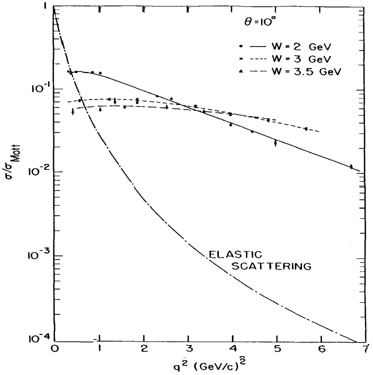
Elastic scattering
Nucleon Form Factors



Deep Inelastic Scattering
Parton Distributions

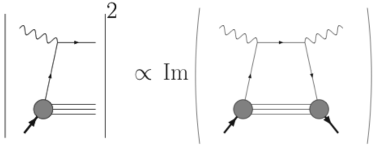
$$\lim_{Q^2\to\infty} \sigma_{\mathrm{DIS}}(x_B) = \int_{x_B}^{1} \frac{d\xi}{\xi} \sum_a f_a(\xi,\mu)\hat{\sigma}^a\left(\frac{x_B}{\xi},\frac{Q}{\mu}\right)$$

SLAC-MIT group, 7-18 GeV electrons on hydrogen



$$x_B = \frac{Q^2}{2M\nu}$$

Optical theorem :
The total cross section is given by
the imaginary part of the forward amplitude



Friedman, Kendall, Taylor, Nobel prize 1990

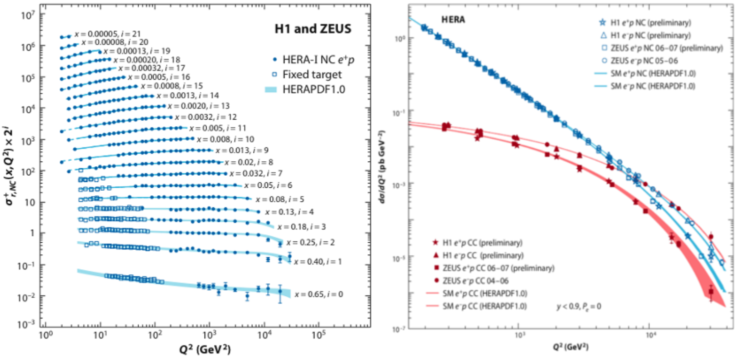
Deep Inelastic Scattering
Parton Distributions

27.6 GeV lepton colliding with 820 GeV proton, $\int \mathcal{L} \sim 180.6 \text{ fb}^{-1}$

Physics Accomplishments of HERA

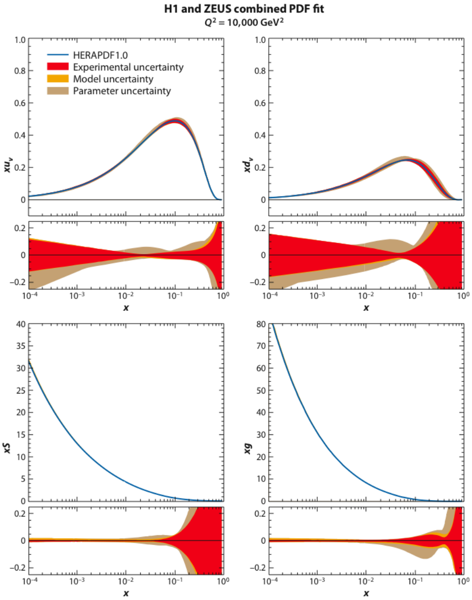
C. Diaconu, T. Haas, M. Medinnis, K. Rith, and A. Wagner

Annu. Rev. Nucl. Part. Sci. 2010. 60:101–28



Deep Inelastic Scattering

Parton Distributions



Deep Exclusive Processes
Generalized Parton Distributions

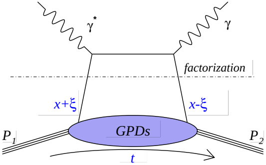
$$\gamma^* p \to \gamma p'$$

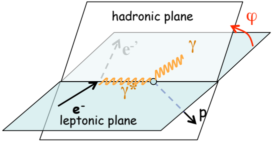
Bjorken regime :

$$Q^2 \to \infty, \quad \nu \to \infty,$$

$$x_B = Q^2/2M\nu \text{ fixed}$$

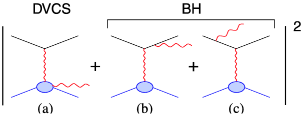
$$\left(\xi \to \frac{x_B}{2-x_B}\right)$$





$$ep \to ep\gamma$$

$\sigma(ep \to ep\gamma) \propto \left| \text{DVCS} + \text{BH} \right|^2$



Diehl, Gousset, Pire, Ralston (1997)
Belitsky, Müller, Kirchner (2002, 2010)

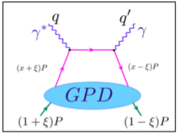
$$A_{LU} = \frac{d^4\sigma^{\rightarrow} - d^4\sigma^{\leftarrow}}{d^4\sigma^{\rightarrow} + d^4\sigma^{\leftarrow}} \overset{\text{twist-2}}{\approx} \frac{\alpha \sin\phi}{1+\beta\cos\phi}$$

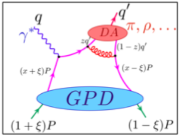
$$\alpha \propto \left(F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - \frac{t}{4M^2}F_2\mathcal{E}\right)$$

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

$$A_{UL} \propto \left(F_1\tilde{\mathcal{H}} + \xi G_M\mathcal{H} + G_M\frac{\xi}{1+\xi}\mathcal{E} + \cdots\right)\sin\phi$$

Observables sensitivities to GPD





	$\mathcal{I}m$	$\mathcal{R}e$
$\mathcal{H}$	A_{LU}	σ , A_{LL}
$\tilde{\mathcal{H}}$	A_{UL}	
$\mathcal{E}$	A_{UT} , A_{LT}	

DVCS

	Meson	Flavor
$\tilde{\mathcal{H}}$,$\tilde{\mathcal{E}}$	π^+	$\Delta u - \Delta d$
	π^0	$2\Delta u + \Delta d$
	η	$2\Delta u - \Delta d + 2\Delta s$
$\mathcal{H}$,$\mathcal{E}$	ρ^+	$u - d$
	ρ^0	$2u + d$
	ω	$2u - d$
	ϕ	s

DVMP

Only a global analysis of all observables can disentangle GPDs

Interplay between spin and flavor decompositions

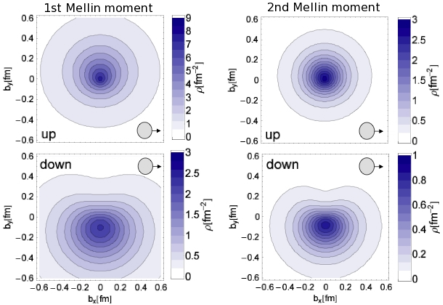
	Process	Flavor	$q/\bar{q}/g$	
$\mathcal{H},\mathcal{E},\tilde{\mathcal{H}},\tilde{\mathcal{E}}$	pDVCS	$4u+d+s$	$q+\bar{q}$, $\alpha_S g$	
	nDVCS	$4d+u+s$	$q+\bar{q}$, $\alpha_S g$	(polarized) deuteron
$\mathcal{H},\mathcal{E}$	ρ^+	$u-d$	$q+\bar{q}$, g	Im($\mathcal{H}E^*$) in A_{UT}
	ρ^0	$2u+d$	$q+\bar{q}$, g	
	ω	$2u-d$	$q+\bar{q}$, g	
	ϕ	s	$q+\bar{q}$, g	
	J/ψ , Υ		g	
	$(\pi^+\pi^-)_{L=0}$	$2u-d$	$q-\bar{q}$	interfere with $(\pi^+\pi^-)_{L=1}$
	$K^{*0}\Sigma^+$, $K^{*+}\Sigma^0$	$d-s$	$2q-\bar{q}$	SU(3)
	$K^{*+}\Lambda$	$2u-d-s$	$2q-\bar{q}$	SU(3)
$\tilde{\mathcal{H}},\tilde{\mathcal{E}}$	π^+	$\Delta u-\Delta d$	$2q-\bar{q}$	
	π^0	$2\Delta u+\Delta d$	$q-\bar{q}$	
	η	$2\Delta u-\Delta d+2\Delta s$	$q-\bar{q}$	
	$K^{*0}\Sigma^+$, $K^{*+}\Sigma^0$	$d-s$	$2q+\bar{q}$	SU(3)
	$K^{*+}\Lambda$	$2u-d-s$	$2q+\bar{q}$	SU(3)

Physical content of GPDs :

Momentum distributions in the transverse plane

$$q_X(x, \vec{b}_\perp) = \int \frac{d^2\vec{\Delta}_\perp}{(2\pi)^2} H(x,0,t) e^{-i\vec{\Delta}_\perp \cdot \vec{b}_\perp} - \frac{1}{2M}\frac{\partial}{\partial b_y} \int \frac{d^2\vec{\Delta}_\perp}{(2\pi)^2} E(x,0,t) e^{-i\vec{\Delta}_\perp \cdot \vec{b}_\perp}$$

M. Burkardt, Phys. Rev. **D62**, (2000) 071503
$\xi \neq 0$ in M. Diehl, Eur. Phys. J. **C25** (2002) 223



QCDSF-UKQCD collaboration, Nucl. Phys. Proc. Suppl. **153** (2006) 146
($n = 1$ and 2 Mellin moment w.r.t. x of distributions)

u and *d* quarks have opposite orbital motions in a transversly polarized proton

Physical content of GPDs :

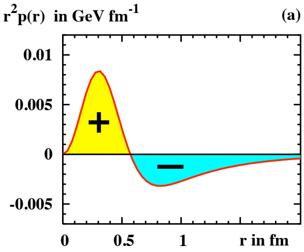
Energy-momentum tensor of q flavored quarks

$$\langle p_2 | \hat{T}^q_{\mu\nu} | p_1 \rangle = \bar{U}(p_2) \left[M_2^q(t) \frac{P_\mu P_\nu}{M} + J^q(t) \frac{\imath (P_\mu \sigma_{\nu\rho} + P_\nu \sigma_{\mu\rho}) \Delta^\rho}{2M} + d_1^q(t) \frac{\Delta_\mu \Delta_\nu - g_{\mu\nu} \Delta^2}{5M} \right] U(p_1)$$

To measure gravitational FFs : graviton scattering or GPDs identities :

$$J^q(t) = \frac{1}{2} \int_{-1}^{1} dx\, x \left[H^q(x,\xi,t) + E^q(x,\xi,t) \right] \;, \quad M_2^q(t) + \frac{4}{5} d_1(t) \xi^2 = \frac{1}{2} \int_{-1}^{1} dx\, x H^q(x,\xi,t)$$

(Ji's sum rule)



Stability $\Rightarrow \int_0^\infty dr\, r^2 p(r) = 0$

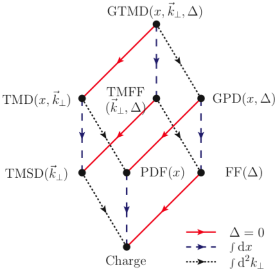
$r < 0.57$ fm $\Rightarrow p(r) > 0 \leftrightarrow$ repulsion (quark core)

$r > 0.57$ fm $\Rightarrow p(r) < 0 \leftrightarrow$ attraction (pion cloud)

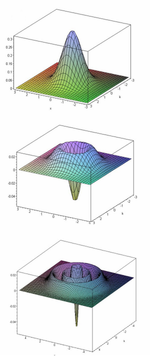
K.Goeke,*& al*, Phys. Rev. **D75** (2007) 094021

Unified view of hadron structure
Wigner Distributions

FFs, PDFs, GPDs, TMDs, inflation of acronyms all related to the same Wigner distribution



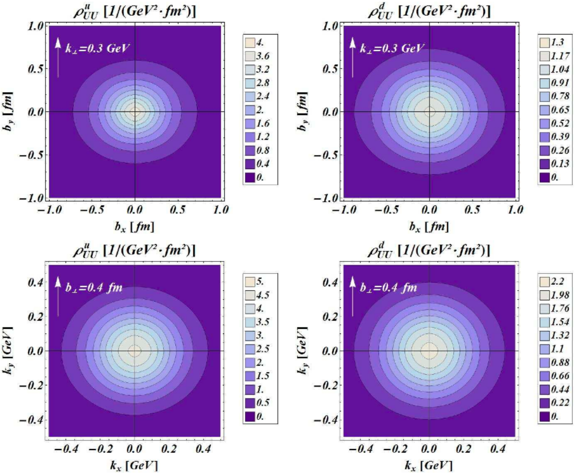
- Most general one-parton density matrix
- Not known how to measure
- Provides a unifying description
- Constraints for model building



Unified framework for GPDs and TMDs within a 3Q LC picture of the nucleon

C. Lorcé *et al*, arXiv:1102.4704, JHEP 1105:041,2011

Overview of the nucleon structure
Unpolarized quark in unpolarized nucleon



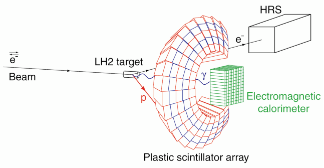
Quadrupole deformation of transverse position for quarks at large transverse momentum
Intuitive from a semi-classical picture of confinement

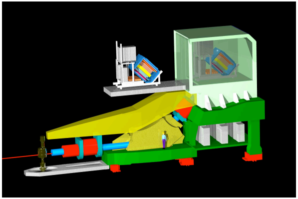
C. Lorcé *et al*, arXiv:1106.0139

6 GeV dedicated experiments

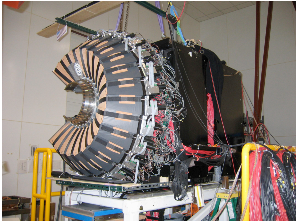
Hall-A E00-110, Scaling tests of σ_{DVCS}, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$
C. Muñoz *et al.*, Phys. Rev. Lett. 97 (2006) 262002

$E_b = 5.75$ GeV, $\mathcal{P}_b = 75.3\%$, $\mathcal{L} = 10 \times 10^{37}$ cm^{-2}s^{-1}, $\int dt\mathcal{L} = 13294$ fb^{-1} (3.26 C)

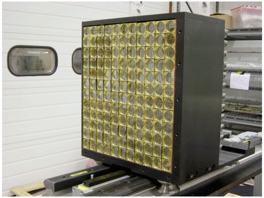




100-channel scintillator array



132-block PbF_2 electromagnetic calorimeter



Kin	k' (GeV/c)	θ_e (°)	Q^2 (GeV^2)	x_{Bj}	θ_q (°)	W (GeV)	E_γ (GeV)
1	3.53	15.6	1.5	0.36	−22.3	1.9	2.14
2	2.94	19.3	1.9	0.36	−18.3	2.0	2.73
3	2.34	23.8	2.3	0.36	−14.8	2.2	3.33

Hall-A E00-110, Scaling tests of σ_{DVCS}, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$

C. Muñoz *et al.*, Phys. Rev. Lett. 97 (2006) 262002

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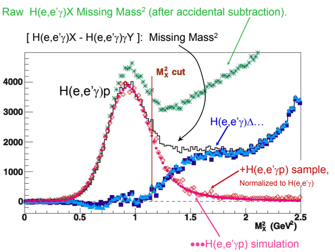
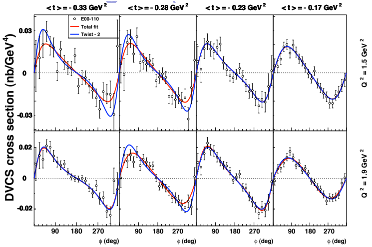
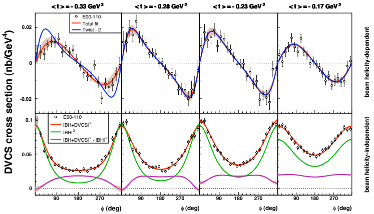
Missing mass squared $ep \to e\gamma X$ (E00-110)







Exclusivity ensured by missing mass technique

Hall-A E00-110, Scaling tests of σ_{DVCS}, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$

C. Muñoz *et al.*, Phys. Rev. Lett. 97 (2006) 262002

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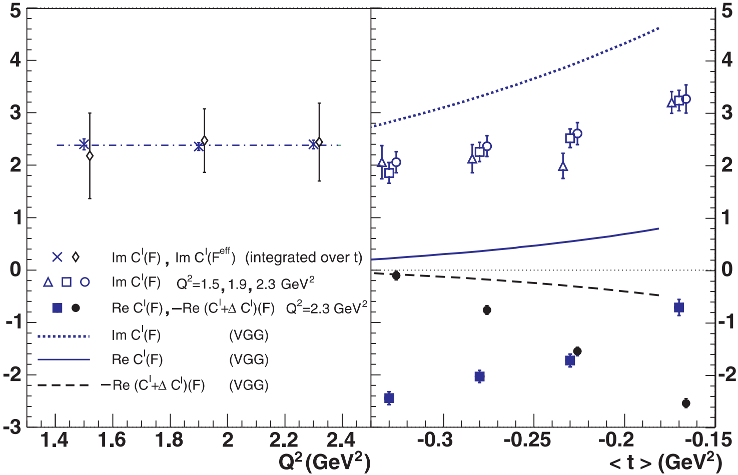
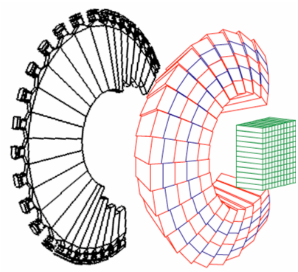
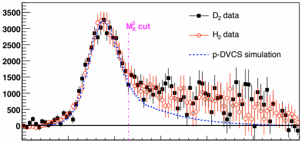
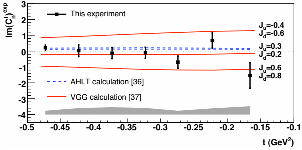


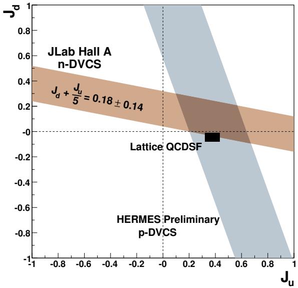
Hall-A E03-106, DVCS off the Neutron, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$

M. Mazouz *et al.*, Phys. Rev. Lett. 99 (2007) 242501





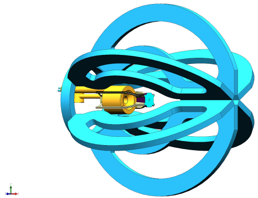


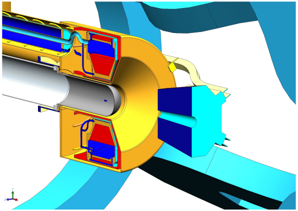


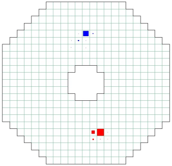
Hall-B E01-113, DVCS BSA, $F_1\mathcal{H} + \xi G_M \tilde{\mathcal{H}} - F_2 \frac{t}{4M^2}\mathcal{E} + \cdots$

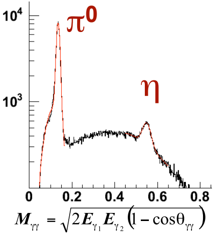
Solenoid and calorimeter

Hydrogen target, beam polarisation $\approx 80\%$, $\int \mathcal{L} \approx 45\ \text{fb}^{-1}$





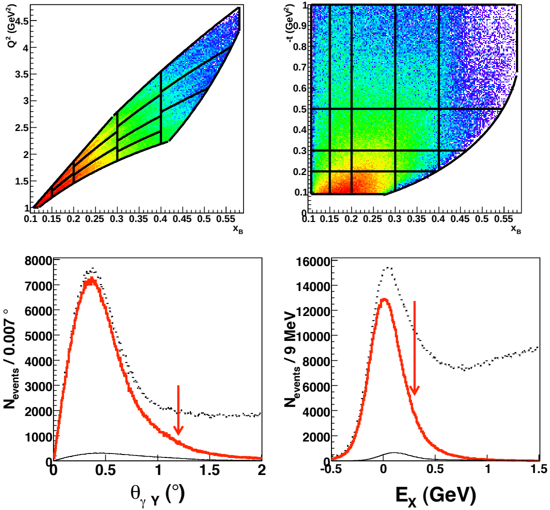




Hall-B E01-113, DVCS BSA, $F_1\mathcal{H} + \xi G_M \tilde{\mathcal{H}} - F_2 \frac{t}{4M^2}\mathcal{E} + \cdots$

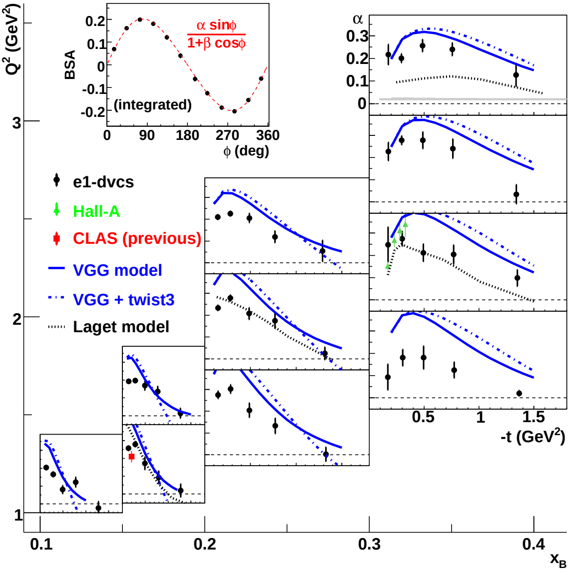
Flavor of analysis

- kinematical coverage
- exclusivity cuts
- π^0 subtraction



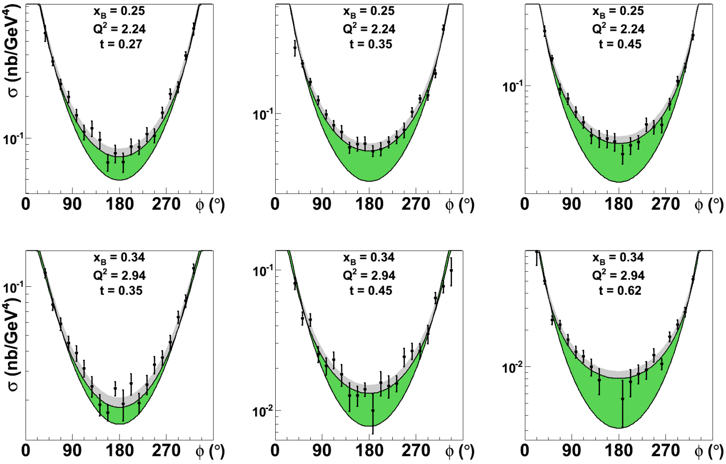
Hall-B E01-113, DVCS BSA, $F_1\mathcal{H} + \xi G_M \tilde{\mathcal{H}} - F_2 \frac{t}{4M^2}\mathcal{E} + \cdots$

FXG *et al.*, Phys. Rev. Lett. 100 (2008) 162002



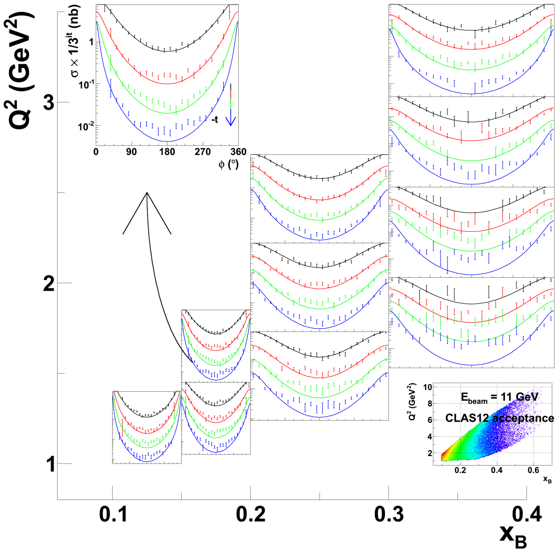
Hall-B E01-113, $\sigma_{\mathbf{DVCS}}$, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$

Preliminary



Hall-B E01-113, σ_{DVCS}, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$

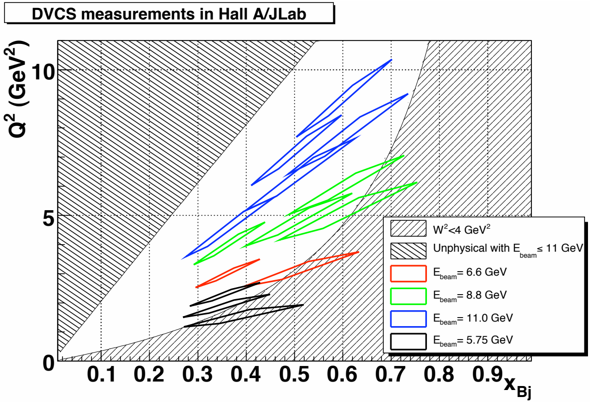
Preliminary



12 GeV upgrade

Hall-A E12-06-114, $\sigma_{\mathbf{DVCS}}$, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$

Upagraded equipment has already run (E07-007) and is ready to take beam
"Rosenbluth" separation of inteference and DVCS squared



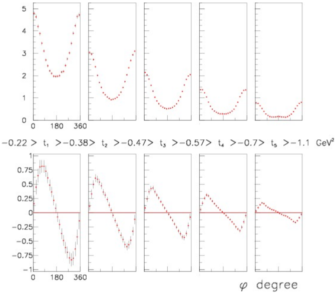
Hall-A E12-06-114, σ_{DVCS}, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$

Upagraded equipment has already run (E07-007) and is ready to take beam
"Rosenbluth" separation of inteference and DVCS squared

Luminosity: from $4 \cdot 10^{37}$ to $1 \cdot 10^{38}$ Hz/cm^2

$E_b = 8.8$ GeV, $Q^2 = 4.8$ GeV^2, $x_B = 0.50$

Helicity-independent cross sections (pb/GeV4)



Helicity-dependent cross sections (pb/GeV4)

Statistical uncertainty: from 3 % to 5 %

Beamtime request (days)

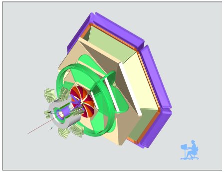
Q^2 (GeV)	$x_B = 0.36$	$x_B = 0.5$	$x_B = 0.6$
3.0	3		
4.0	2		
4.6	1		
3.1		5	
4.8		4	
6.3		4	
7.2		7	
5.1			13
6.0			16
7.7			13
9.0			20

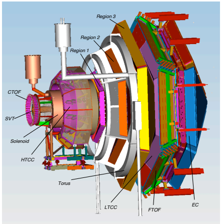
Total: 88 + 12 (overhead) = 100 days

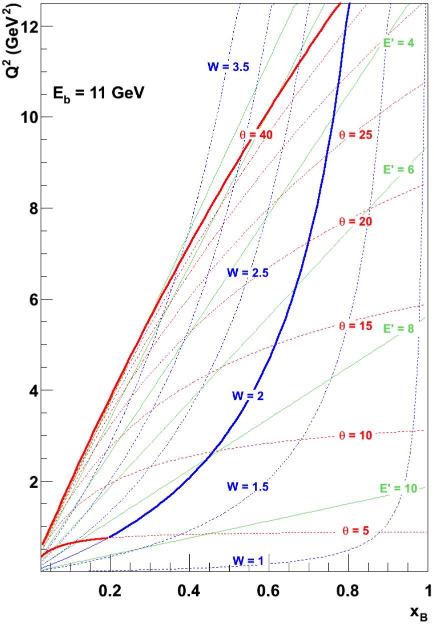
Systematic uncertainty: 4 %

- 2.5% acceptance
- 3% π^0 contamination

CLAS12 (11 GeV)

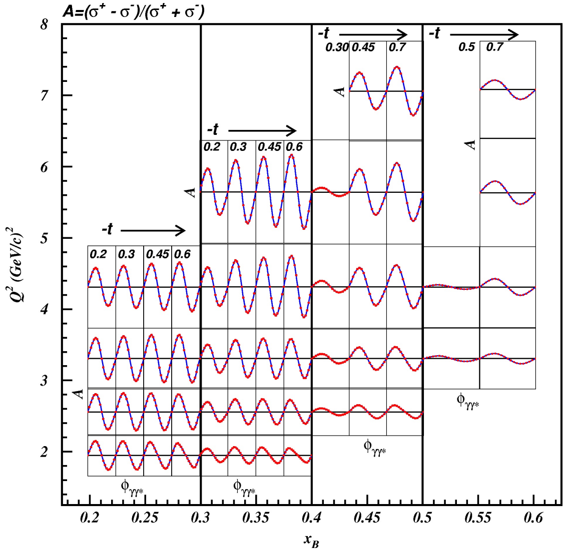






Hall-B E12-06-119, proton DVCS, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$

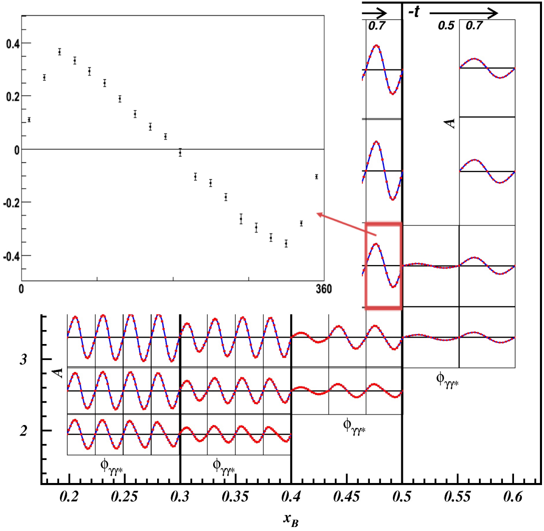
80 days @ $\mathcal{L} = 10^{35}$ cm^{-2}s^{-1} with 85% polarized beam



Statistical uncertainties from 1 % (low Q^2) to 10 % (high Q^2)

Hall-B E12-06-119, proton DVCS, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$

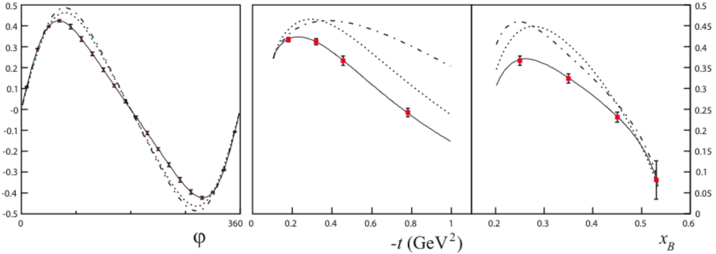
80 days @ $\mathcal{L} = 10^{35}$ cm^{-2}s^{-1} with 85% polarized beam



Statistical uncertainties from 1 % (low Q^2) to 10 % (high Q^2)

Hall-B E12-06-119, proton DVCS, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$

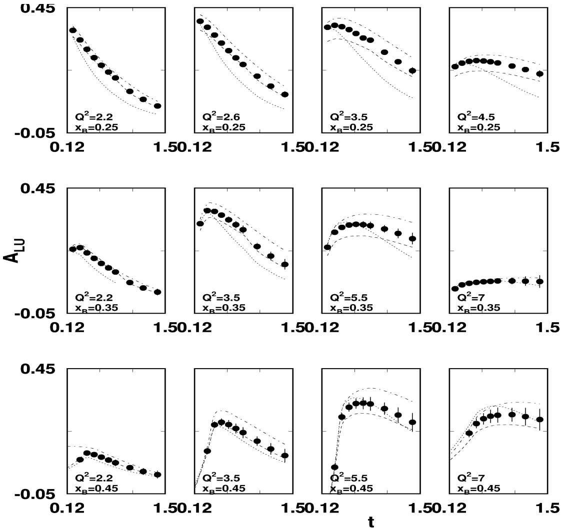
80 days @ $\mathcal{L} = 10^{35}$ cm^{-2}s^{-1} with 85% polarized beam



Dotted curve : no D-term, dashed-dotted : factorized t-dependence

$Q^2 = 3.3$ GeV^2, $x_B = 0.2$ (left and middle), $-t = 0.45$ GeV^2 (left and right)

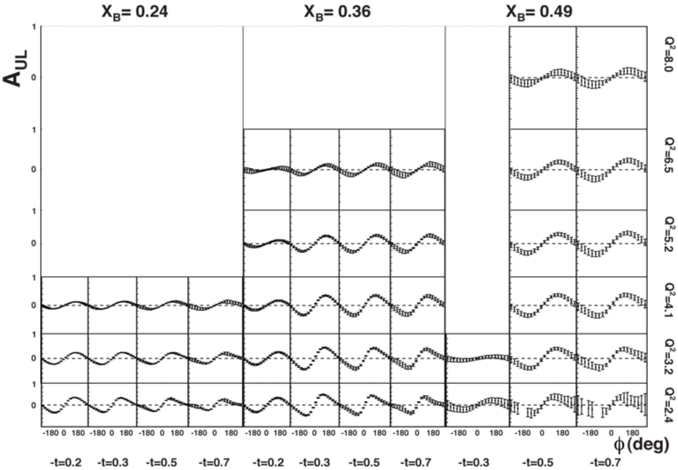
Hall-B E12-06-119, proton DVCS, $F_1\mathcal{H} + \xi G_M\tilde{\mathcal{H}} - F_2\frac{t}{4M^2}\mathcal{E} + \cdots$



Hall-B E12-06-119, longitudinally polarized proton DVCS A_{UL}

$F_1\tilde{\mathcal{H}} + \xi G_M \mathcal{H} + G_M \frac{\xi}{1+\xi}\mathcal{E} + \cdots$

120 days @ $\mathcal{L} = 2 \times 10^{35}$ cm^{-2}s^{-1} with 80% polarized NH_3

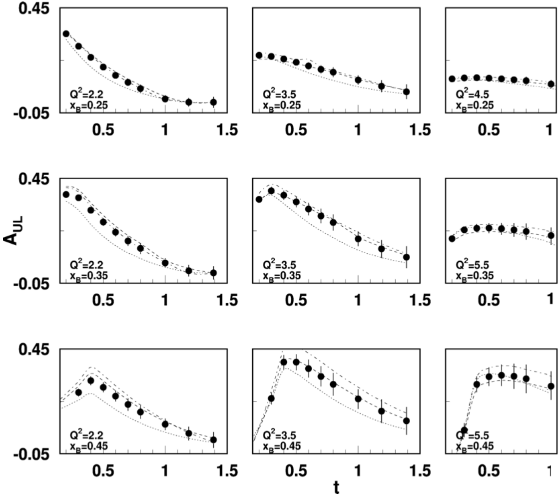


Statistical uncertainties from 2 % (low Q^2) to 10 % (high Q^2)

Hall-B E12-06-119, longitudinally polarized proton DVCS A_{UL}

$F_1 \tilde{\mathcal{H}} + \xi G_M \mathcal{H} + G_M \frac{\xi}{1+\xi} \mathcal{E} + \cdots$

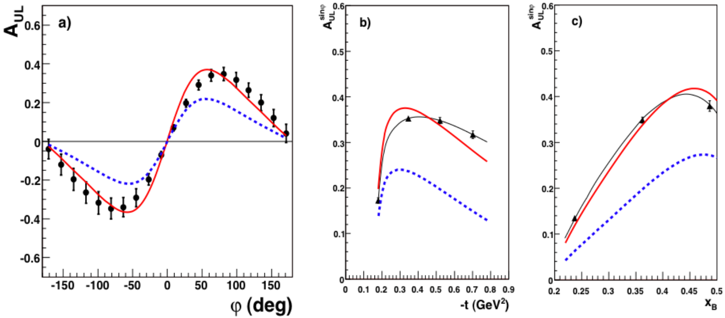
120 days @ $\mathcal{L} = 2 \times 10^{35}$ cm^{-2}s^{-1} with 80% polarized NH_3



Hall-B E12-06-119, longitudinally polarized proton DVCS A_{UL}

$F_1 \tilde{\mathcal{H}} + \xi G_M \mathcal{H} + G_M \frac{\xi}{1+\xi} \mathcal{E} + \cdots$

120 days @ $\mathcal{L} = 2 \times 10^{35}$ cm^{-2}s^{-1} with 80% polarized NH_3

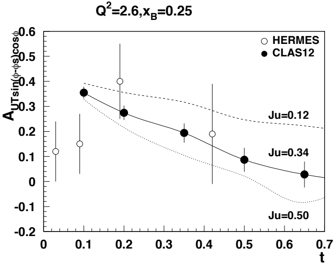


Red solid line : $E = \tilde{E} = 0$, blue dashed line : $\tilde{H} = 0$
$Q^2 = 4.1$ GeV^2, $x_B = 0.36$ (left and middle), $-t = 0.52$ GeV^2 (left and right)

Hall-B LOI11-105, transversly polarized target DVCS A_{UT}

More on angular momentum

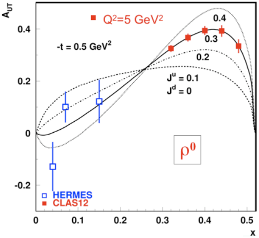
DVCS with frozen HD-ice

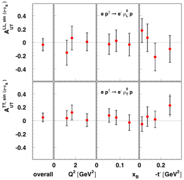


$x_B \approx 0.25$

$Q^2 \approx 2.6$ GeV^2

Exclusive ρ^0 production (hydrogen target)





$A_{UT} \sim \Delta_\perp \mathrm{Im} AB^*$

$A \sim 2H^u + H^d$

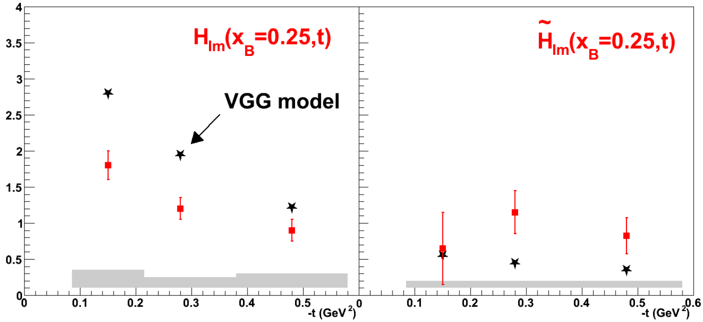
$B \sim 2E^u + E^d$

GPD extraction procedures

Model independent extraction

Using only A_{LU} and A_{UL} with sensitivity to $\mathcal{H}$ and $\tilde{\mathcal{H}}$

- CFFs varied within VGG model range
- Independence on Q^2
- $\tilde{\mathcal{H}}(t)$ more flat than $\mathcal{H}(t)$
- Stable results
- Large uncertainties



M. Guidal, arXiv:1003.0307

Global approach, holographic principle

D. Müller *et al* strategy to fit data

$$\left\{\begin{matrix}\mathcal{H}\\ \mathcal{E}\end{matrix}\right\}(x_{\rm Bj},t,\mathcal{Q}^2) \stackrel{\rm LO}{=} \int_{-1}^{1} dx\, \frac{2x}{\xi^2-x^2-i\epsilon}\left\{\begin{matrix}H\\ E\end{matrix}\right\}(x,\eta=\xi,t,\mathcal{Q}^2)$$

$$\Im{\rm m}\mathcal{F}(x_{\rm Bj},t,\mathcal{Q}^2) \stackrel{\rm LO}{=} \pi F(\xi,\xi,t,\mathcal{Q}^2)\,, \quad F=\{H,E,\widetilde{H},\widetilde{E}\}$$

$$\Re{\rm e}\left\{\begin{matrix}\mathcal{H}\\ \mathcal{E}\end{matrix}\right\}(x_{\rm Bj},t,\mathcal{Q}^2) \stackrel{\rm LO}{=} {\rm PV}\int_{0}^{1} dx\, \frac{2x}{\xi^2-x^2}\left\{\begin{matrix}H\\ E\end{matrix}\right\}(x,x,t,\mathcal{Q}^2) \pm \mathcal{D}(t,\mathcal{Q}^2)$$

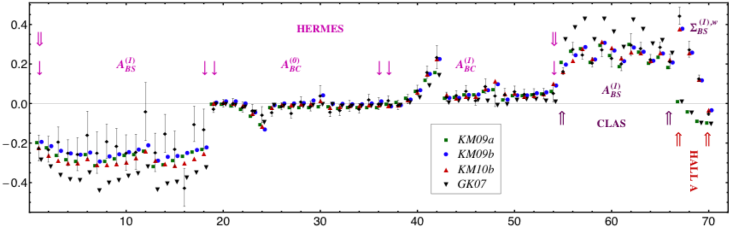
$$H^{\rm val}(x,x,t) = \frac{1.35\,r}{1+x}\left(\frac{2x}{1+x}\right)^{-\alpha(t)}\left(\frac{1-x}{1+x}\right)^{b}\left(1-\frac{1-x}{1+x}\frac{t}{M^{\rm val}}\right)^{-1}$$

$$\mathcal{D}(t) = d\left(1-\frac{t}{M_d^2}\right)^{-2} \qquad r = \lim_{x\to 0} H(x,x)/H(x,0)$$

$$\alpha(t) = 0.43 + 0.85\,t/{\rm GeV}^2$$

Global approach, holographic principle

D. Müller *et al* global fit



$$KM09a: \quad b^{\rm sea} = 3.09\,, \quad r^{\rm val} = 0.95\,, \quad b^{\rm val} = 0.45\,, \quad d = -0.24\,, \quad M_d = 0.5\,{\rm GeV}\,,$$

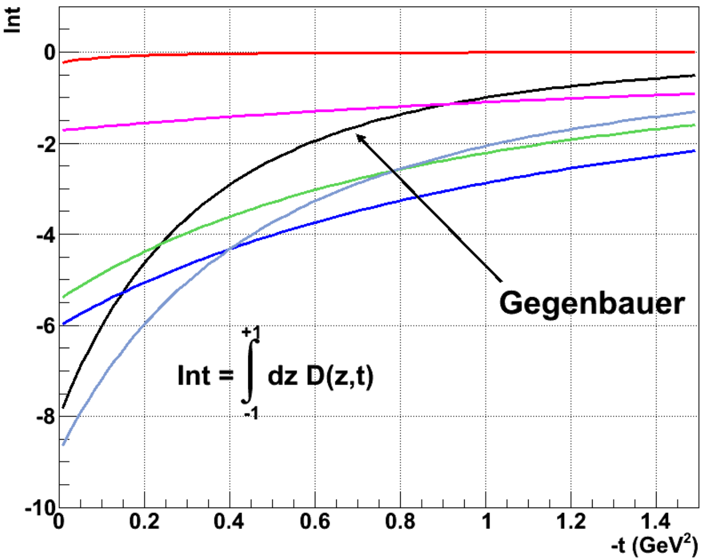
$$KM09b: \quad b^{\rm sea} = 4.60\,, \quad r^{\rm val} = 1.11\,, \quad b^{\rm val} = 2.40\,, \quad d = -6.00\,, \quad M_d = 1.5\,{\rm GeV}\,,$$

$$KM10a: \quad r^{\rm val} = 0.88\,, \quad M^{\rm val} = 1.5\,{\rm GeV}\,, \quad b^{\rm val} = 0.40\,, \quad d = -1.72\,, \quad M_d = 2.0\,{\rm GeV}\,,$$

$$KM10b: \quad r^{\rm val} = 0.81\,, \quad M^{\rm val} = 0.8\,{\rm GeV}\,, \quad b^{\rm val} = 0.77\,, \quad d = -5.43\,, \quad M_d = 1.33\,{\rm GeV}\,,$$

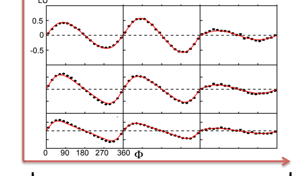
$$KM10: \quad r^{\rm val} = 0.62\,, \quad M^{\rm val} = 4.0\,{\rm GeV}\,, \quad b^{\rm val} = 0.40\,, \quad d = -8.78\,, \quad M_d = 0.97\,{\rm GeV}\,.$$

Global approach, holographic principle



Hybrid fits of GPDs

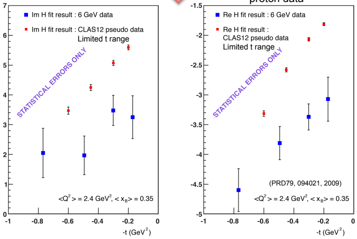
CLAS12 pseudo-data sample in :
$0.2 < x_B < 0.5$, $2 < Q^2 < 5$ GeV^2
$0.25 < -t < 0.35$ GeV^2



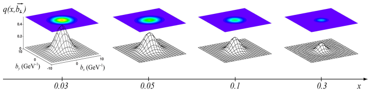
Fit to CLAS6 or **CLAS12** A_{LU}

x10 accuracy improvement from CLAS6 to CLAS12

H and $\tilde{H}$ separation needs unpolarized and polarized proton data



$$q(x,\vec{b}_\perp) = \int \frac{d^2\vec{\Delta}_\perp}{(2\pi)^2} e^{i\vec{b}_\perp\cdot\vec{\Delta}_\perp} H(x,\xi=0,-\Delta_\perp^2)$$

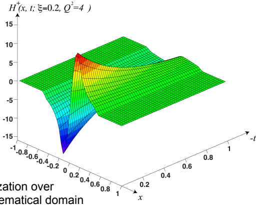


$\xi = 0$

GPD parametrization needed for ξ=0 or t=0 extrapolations

Parametrized GPDs

Lots of new developments in the next 5 years



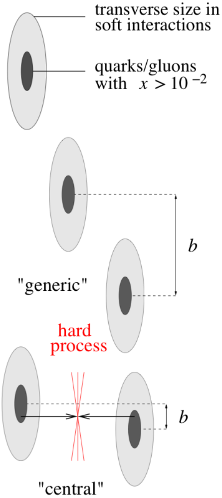
Global fits:

- Parametrization over the full kinematical domain
- Use all kinds of data from several experiments
- Include Q^2 evolution

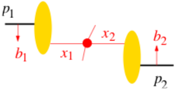
H. Moutarde, F. Sabatié

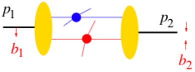
Beyond JLab

Nucleon structure for hadron-hadron colliders



- Multiple hard processes in *pp* indicate substantial correlations
- CDF 3 jet + γ consistent with $\rho \sim 0.3$ fm
- Forward dipion production at RHIC
- Crucial at LHC
- Very hard to tune MC generators (many parameters)
- Also underlying event physics





C. Weiss, L. Frankfurt, M. Strikman, Ann.Rev.Nucl.Part.Sci. 55 (2005) 403-465

Conclusion

Conclusion

- Unified framework for nucleon tomography
- First dedicated results on Compton Scattering
- Essential component of a long range plan to extract GPDs
- Interplay between spin and flavor decompositions requires also other reactions
- Also crucial for QCD backgrounds at LHC and beyond