π^0/η impact on chiral-odd GPD models

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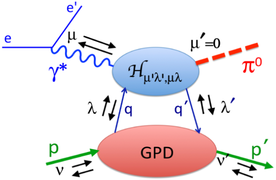
CLAS collaboration
March 7, 2019

GPDs in Deeply Virtual Exclusive Reactions



- $\langle F \rangle = \sum_\lambda \int_{-1}^{1} dx \mathcal{H}_{0\lambda,\mu\lambda}\left(x, \xi, Q^2, t\right) F\left(x, \xi, t\right)$

Generalized Form Factor $\langle F \rangle$ is a convolution of hard subprocess with GPD F

- 4 parton helicity conserving (chiral even) GPDs: H, $\tilde{H}$, E, $\tilde{E}$
- 4 parton helicity flip (chiral odd) GPDs: H_T, $\tilde{H}_T$, E_T, $\tilde{E}_T$
- functions of three kinematic variables: x, ξ and t

Generalized Parton Distributions

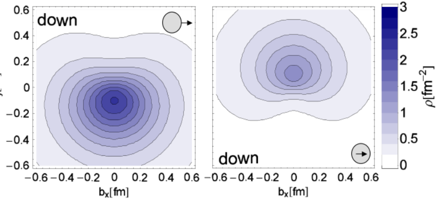
		Quark polarization		
		U	L	T
Nucleon polarization	U	H		$\bar{E}_T$
	L		$\tilde{H}$	
	T	E		$H_T,\ \tilde{H}_T$

Chiral even GPDs:

- DVCS on unpolarized and polarized targets with polarized beam by HERMES, JLAB and COMPASS

Chiral-odd GPD results:

- Deeply virtual meson production
- Lattice QCD by Göckeler *et al*



Tensor charge

- Jaffe and Ji have shown that the first Mellin moment of transversity PDF $h_1^q(x)$ gives us the tensor charge δq

$$\delta q = \int_{-1}^{1} h_1^q(x) dx = \int_0 {}_1(h_1^q(x) - \bar{h}_1^q(x)) dx$$

- We can interpret tensor charge as the absolute magnitude of transversely polarized valence quarks inside a transversely polarized nucleon.
- Given the relations between transversity PDF $h_1^q(x)$ and chiral-odd GPD $H_T(x, \xi, t)$ one can obtain the tensor charge δq through GPD in the forward limit:

$$h_1^q(x) = H_T(x, \xi = 0, t = 0)$$

Goloskokov-Kroll model

Eur. Phys. J. A (2011) **47**: 112
DOI 10.1140/epja/i2011-11112-6

THE EUROPEAN PHYSICAL JOURNAL A

Regular Article – Theoretical Physics

Transversity in hard exclusive electroproduction of pseudoscalar mesons

S.V. Goloskokov[1,a] and P. Kroll[2,3,b]

GPDs parametrization:

H_T

tensor charge: T.Ledwig, A.Silva, H.C. Kim
$\int dx H_T(x,\xi,t)$

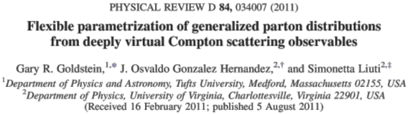
transversity PDF: M.Anselmino
$H_T(x,\xi=0,t=0)=h_1$

$\bar{E}_T = 2\tilde{H}_T + E_T$

Lattice QCD: M.Gockeler
$\bar{E}_T$ moments

- only H_T and $\bar{E}_T$ chiral-odd GPDs have significant contribution to pseudoscalar meson electroproduction
- these two chiral-odd GPDs are data-driven and parameterized using Lattice QCD data and SIDIS data from HERMES and COMPASS collaborations

Goldstein-Gonzalez-Liuti model


PHYSICAL REVIEW D **84**, 034007 (2011)

Flexible parametrization of generalized parton distributions from deeply virtual Compton scattering observables

Gary R. Goldstein,[1,*] J. Osvaldo Gonzalez Hernandez,[2,†] and Simonetta Liuti[2,‡]

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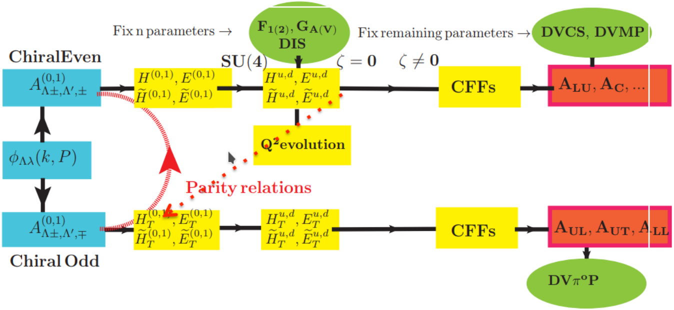
(Received 16 February 2011; published 5 August 2011)

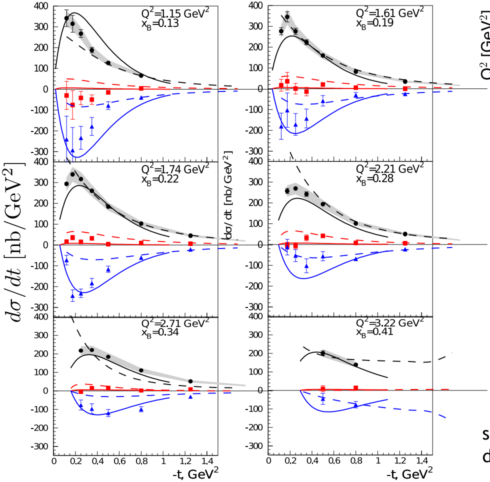
- In 2011 Goldstein, Hernandez and Liuti came up with a new model which allows flexible parameterization of GPDs.
- **Recursive fit**: DIS data, nucleon form factors, DVCS data.
- Relations between chiral-even and chiral-odd sectors through parity relations among helicity amplitudes.



CLAS measurements of pseudoscalar meson production

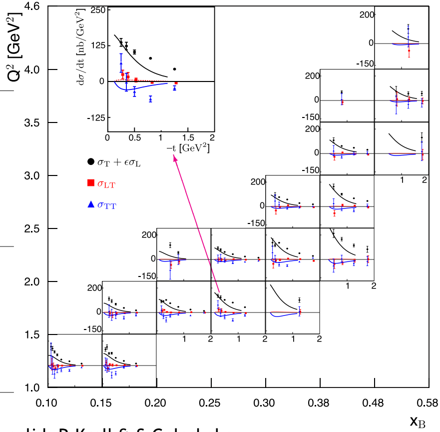
π^0 measurements

PRL109:112001 (2012) I. Bedlinskiy et al. (CLAS collaboration)



η measurements

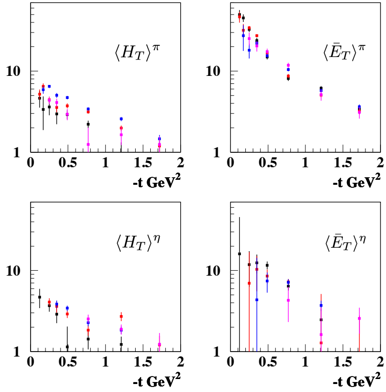
PRL95: 035202 (2017) I. Bedlinsky et al. (CLAS)



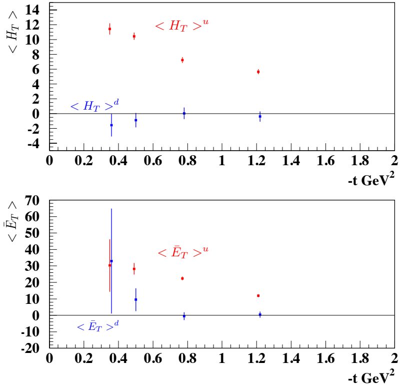
solid: P.Kroll & S.Goloskokov
dashed: G.R. Goldstein, J.O. Gonzalez & S.Liuti

First attempts at GPDs extraction

Generalized Form Factors

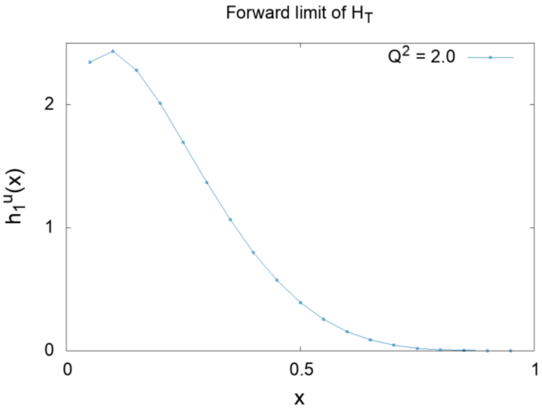


Quark flavor decomposition



HepGen

- HEPGen++ is an event generator for high energy exclusive meson / photon production:link
- Goloskokov-Kroll model has been implemented in HEPGen for π^0 and η electroproduction by C. Regali in his thesis.
- HEPGen is capable to compute unpolarized cross sections of π^0 and η electroproduction.
- In the forward limit for u quarks we get:



GPD parameterizations

$$H_T(x,\xi,t) = N\ \exp[b\,t] \sum_{j=0}^{5} c_j \cdot \mathcal{D}\left(\frac{j}{2}, x, \xi\right) \qquad E_T^u(x,\xi,t) = N^u \exp[b\,t] \sum_{j=0}^{2} c_j^u \cdot \mathcal{D}\left(\frac{j}{2}, x, \xi\right)$$

Table 6.3: Used parameters for H_T [95].

Parameter	**u**	**d**
c_0	3.653	1.924
c_1	-0.583	0.179
c_2	19.807	-7.775
c_3	-23.487	3.504
c_4	-23.46	5.851
c_5	24.07	-3.683

Table 6.4: Power expansion coefficients used for $\bar{E}_T$ [95].

Parameter	**u**	**d**
c_0	1	1
c_1	0	0
c_2	-1	-2
c_3	0	0
c_4	0	1

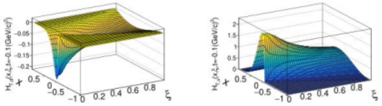


Figure 6.3: The transversity GPD H_T for d quarks on the left and u quarks on the right.

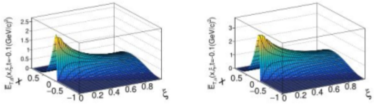


Figure 6.4: The transversity GPD combination $\bar{E}_T$ for d quarks on the left and u quarks on the right.

Technical details

The agreement between experimental data and GK model results can be improved using CLAS experimental measurements to revise GPD parameterizations. However HEPGen is slow, calculation of one kinematic point takes a few minutes. Common gradient-based optimization is not going to work if approached head-on.

Possible solutions:

- Derivative free optimization methods: genetic algorithms, cross entropy method.
- Pre-calculated grid for subprocess amplitudes and interpolation for any kinematic point.

Fitting $\bar{E}_T$ GPD with CLAS unpolarized π^0 data

$$E_T^u(x,\xi,t) = N^u \exp[b\,t] \sum_{j=0}^{2} c_j^u \cdot \mathcal{D}\left(\frac{j}{2}, x, \xi\right)$$

Table 6.4: Power expansion coefficients used for $\bar{E}_T$ [95].

Parameter	u	d
c_0	1	1
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c_3	0	0
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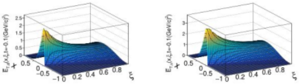
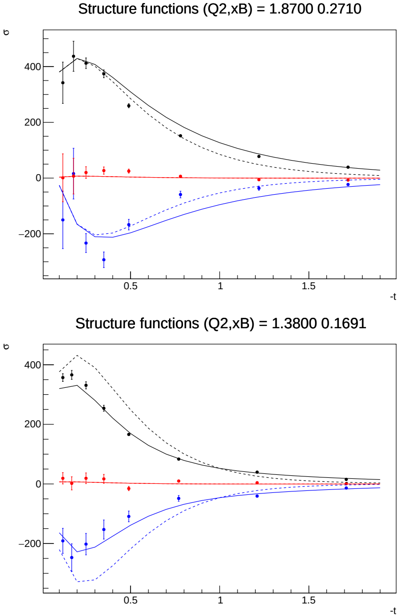


Figure 6.4: The transversity GPD combination $\bar{E}_T$ for d quarks on the left and u quarks on the right.

- H_T is constrained using SIDIS data from HERMES and COMPASS
- $\bar{E}_T$ is only constrained by Lattice QCD results
- As a preliminary step: we use only unpolarized π^0 data to constrain $\bar{E}_T$ parameterizations of u and d quarks
- Free 10 coefficients, 5 per each quark

Fitting $\bar{E}_T$ GPD with CLAS unpolarized π^0 data



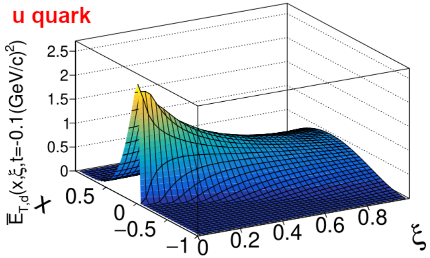
- Unpolarized π^0 structure function measurements
- σ_0, σ_{TT}, σ_{LT} at 96 $Q^2, xB, -t$ kinematic bins, 18 Q^2, xB bins
- Free 10 coefficients in $\bar{E}_T$ parameterization
- Minimization of $$\chi^2 = \sum \frac{(\sigma_{GK} - \sigma_{CLAS})^2}{\Delta\sigma^2}$$
- Initial $\chi^2 = 8560$ after the fit $\chi^2 = 2085$

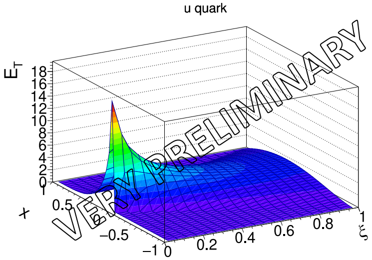
σ_0, σ_{TT}, σ_{LT}
Solid line - after the fit
Dashed - before the fit

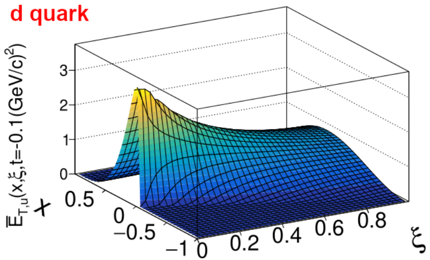
Very preliminary impact on GPD $\bar{E}_T$

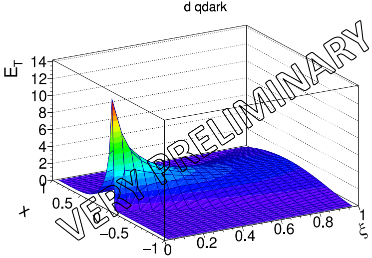
constrained by Lattice QCD

constrained by CLAS data









Near-future plans

- Develop the procedure to fit GPDs parameterizations using π^0 and η data from CLAS and CLAS12, as well as data on neutron from Hall A
- CLAS12 pass0 cook is finished and we are starting to look at π^0/η channel from CLAS12 data
- Adopt HEPGen cross section calculations for π^0/η generators
- Chiral-odd GPD extractions using CLAS/CLAS12 data