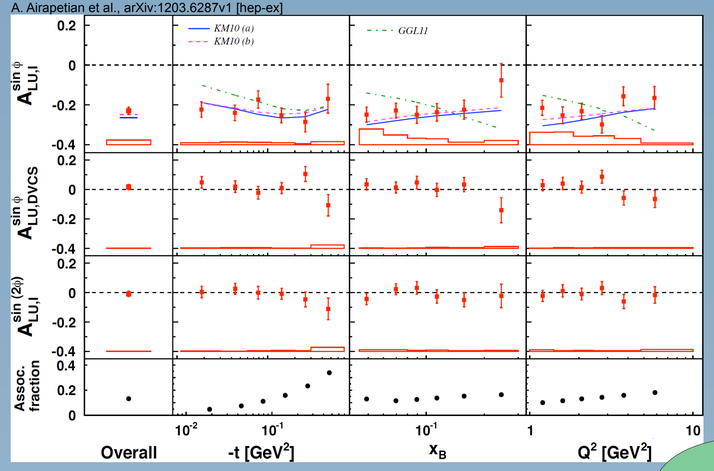
The proton in 3D at HERMES

1995-2007

2006-2007

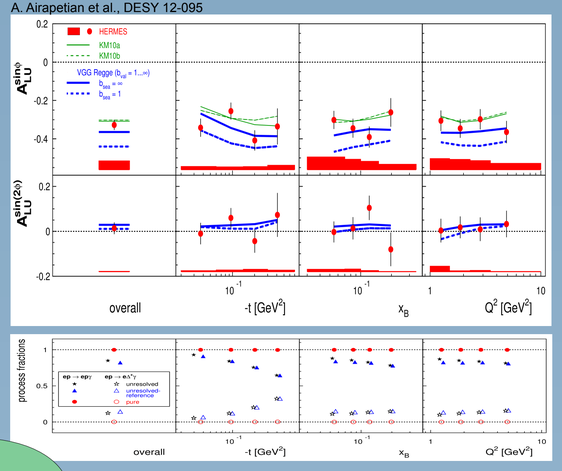
charge-separated beam-helicity asymmetry

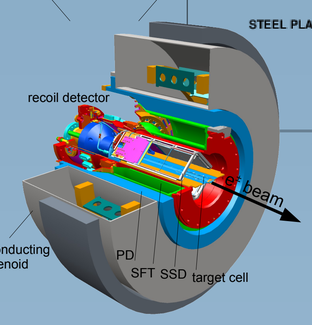
A. Airapetian et al., arXiv:1203.6287v1 [hep-ex]

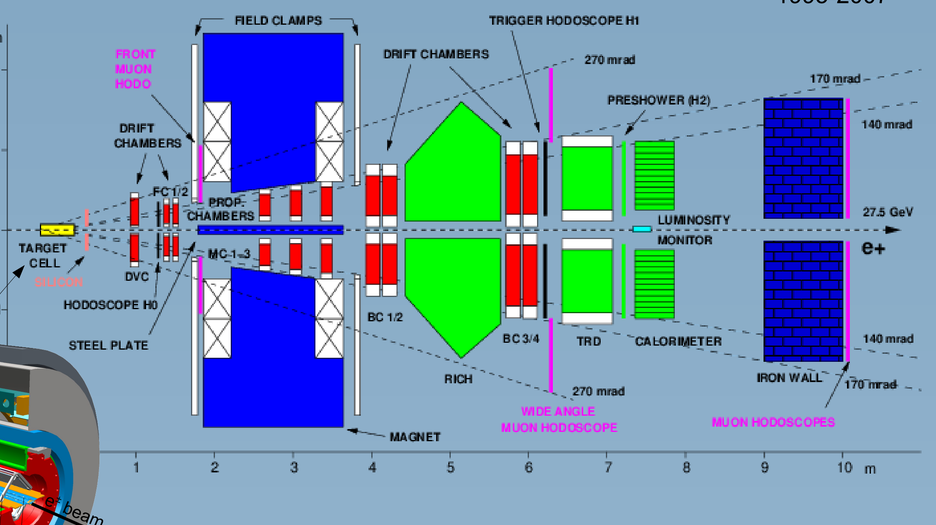


single-charge beam-helicity asymmetry

A. Airapetian et al., DESY 12-095



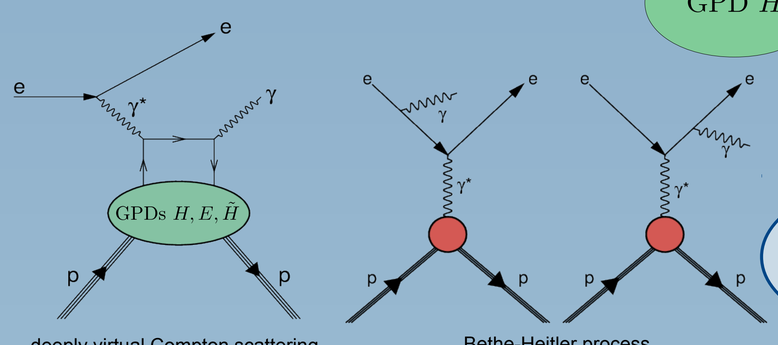




GPD H

spin-independent probability distribution of quarks as a function of their longitudinal fractional momentum and transverse position

M. Burkardt, Phys. Rev. D **62** (2000) 071503



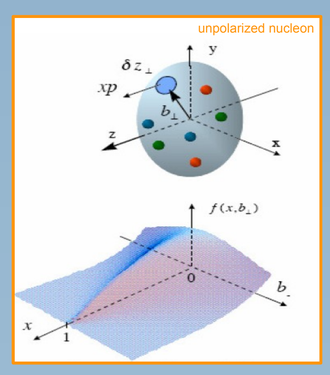
deeply virtual Compton scattering

Bethe-Heitler process

$$d\sigma \sim |T_{DVCS}|^2 + |T_{BH}|^2 + \underbrace{T_{BH}T^*_{DVCS} + T^*_{BH}T_{DVCS}}_{\text{interference term } I}$$

access to quark orbital angular momentum L_z^q

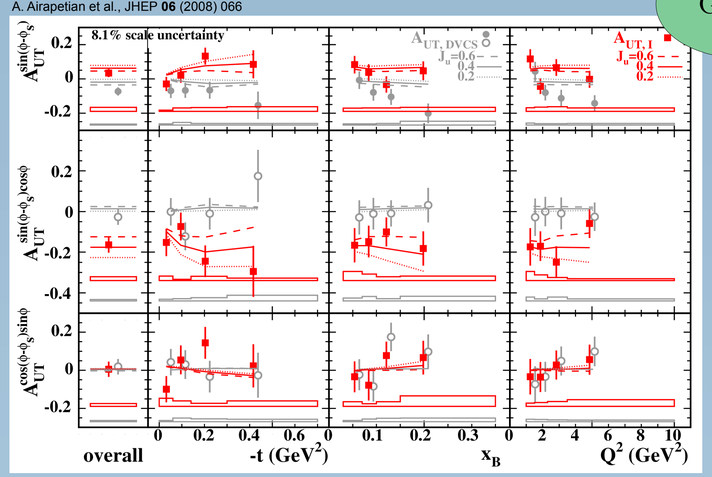
X. Ji, Phys. Rev. Lett. **78** (1997) 610



GPD E

charge-separated transverse-target-spin asymmetry

A. Airapetian et al., JHEP **06** (2008) 066



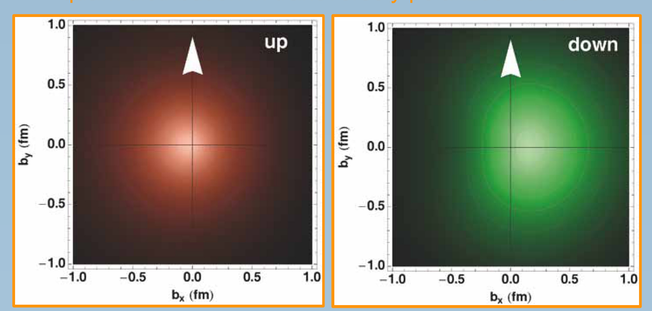
distortion of quark probability distribution compared to unpolarized nucleon

M. Burkardt, Phys. Rev. D **66** (2002) 114005

helicity-dependent probability distribution of quarks as a function of their longitudinal fractional momentum and transverse position

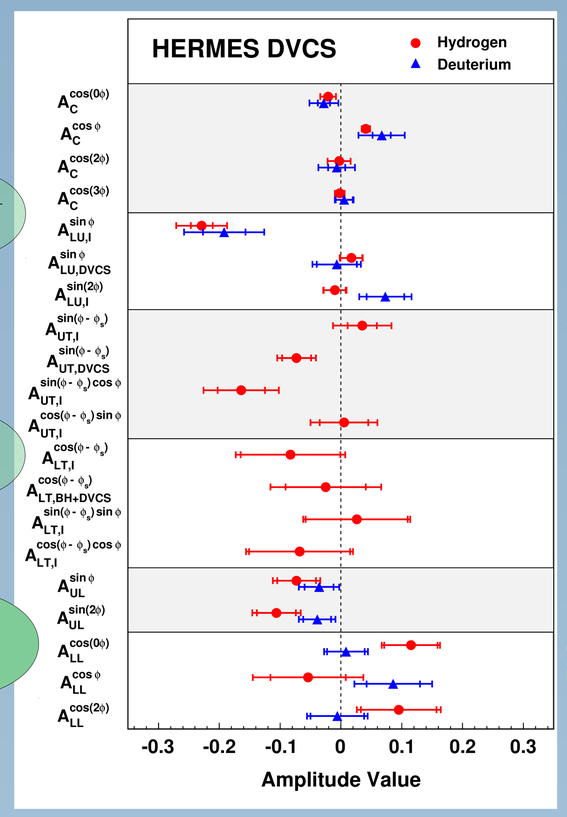
M. Burkardt, Phys. Rev. D **62** (2000) 071503

quark distribution in transversely polarized nucleon



pictures taken from A. Bacchetta and M. Contalbrigo, Il Nuovo Saggiatore **28** (2012) 1-2

GPD $\tilde{H}$



beam-charge asymmetry
arXiv:1203.6287v1 [hep-ex]
Nucl. Phys. B 829 (2010) 1

beam-helicity asymmetry
arXiv:1203.6287v1 [hep-ex]
Nucl. Phys. B 829 (2010) 1

transverse target-spin asymmetry
JHEP **06** (2008) 066

double spin (LT) asymmetry
Phys. Lett. B **704** (2011) 15

longitudinal target-spin asymmetry
JHEP **06** (2010) 019
Nucl. Phys. B 842 (2011) 265

double spin (LL) asymmetry
JHEP **06** (2010) 019
Nucl. Phys. B 842 (2011) 265

Generalized parton distributions

$$\int d^2\vec{k}_T\, W(x,\vec{k}_T,\vec{r}) = \text{GPDs}\ (x,\xi,t)$$

Wigner distributions $W(x,\vec{k}_T,\vec{r})$

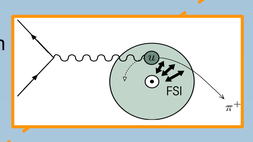
describe distribution of partons inside nucleon in six dimensions, i.e., momentum space (longitudinal x and transverse $\vec{k}_T$) and position space $\vec{r}$

Transverse-momentum-dependent parton distribution functions

$$\int d^3\vec{r}\, W(x,\vec{k}_T,\vec{r}) = \text{TMD PDFs}\ (x,\vec{k}_T)$$

qualitative link through distortion in position distribution and final-state interactions

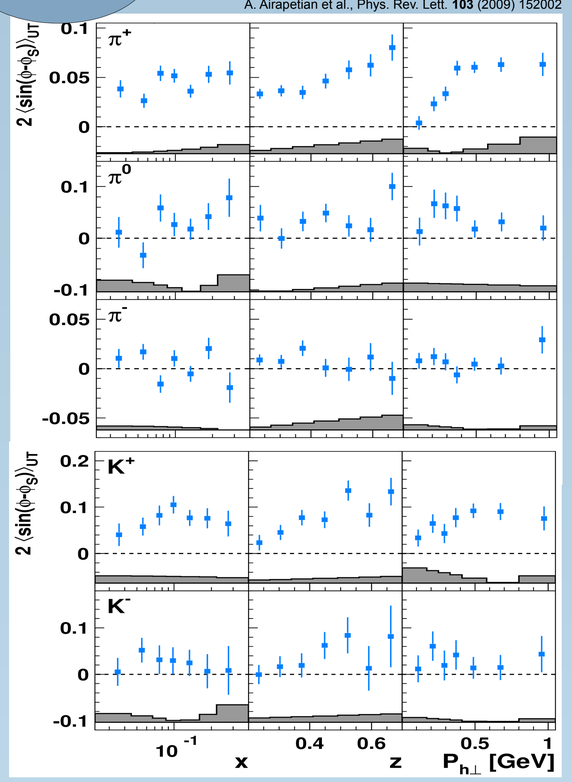
M. Burkardt, Phys. Rev. D **66** (2002) 114005, arXiv:hep-ph/0309269v1

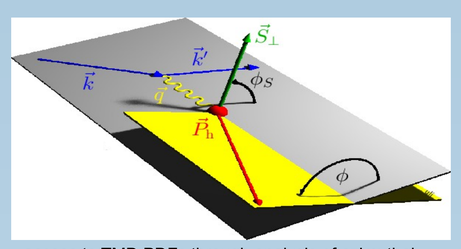


$\propto f_{1T}^{\perp,q} \otimes D_1^q$

Sivers amplitudes

A. Airapetian et al., Phys. Rev. Lett. **103** (2009) 152002





- access to TMD PDFs through analysis of azimuthal modulations of hadrons produced in SIDIS off polarized (longitudinal or transverse) and unpolarized nucleons
- the magnitude of a specific azimuthal modulation relates in the quark-parton model to a convolution of a specific TMD PDF and fragmentation function, describing the fragmentation of a quark into a hadron, e.g., the spin-independent (transverse-spin-dependent) quark fragmentation into an unpolarized hadron D_1^q ($H_1^{\perp,q}$)

name	TMD PDFs	description
spin-independent	$f_1^q(x,k_T^2)$	spin-independent quark distribution in unpolarized nucleon
helicity-difference	$g_{1L}^q(x,k_T^2)$	helicity-dependent quark distribution in longitudinally polarized nucleon
transversity	$h_{1T}^q(x,k_T^2)$	transverse-spin-dependent quark distribution in transversely polarized nucleon
Sivers	$f_{1T}^{\perp,q}(x,k_T^2)$	spin-independent quark distribution in transversely polarized nucleon, describing quark transverse momentum and nucleon spin correlation
Boer-Mulders	$h_1^{\perp,q}(x,k_T^2)$	transverse-spin-dependent quark distribution in unpolarized nucleon, describing quark transverse momentum and spin correlation
pretzelosity	$h_{1T}^{\perp,q}(x,k_T^2)$	transverse-spin-dependent quark distribution in transversely polarized nucleon, describing quark transverse momentum and spin correlation
worm-gear (I)	$h_{1L}^{\perp,q}(x,k_T^2)$	transverse-spin-dependent quark distribution in longitudinally polarized nucleon, describing quark transverse momentum and spin correlation
worm-gear (II)	$g_{1T}^{\perp,q}(x,k_T^2)$	helicity-dependent quark distribution in transversely polarized nucleon, describing quark transverse momentum and spin correlation

The eight leading-twist TMD PDFs describing the DIS cross section for hadron production.
The TMD PDFs in the first three rows are the only TMD PDFs that survive integration over k_T.

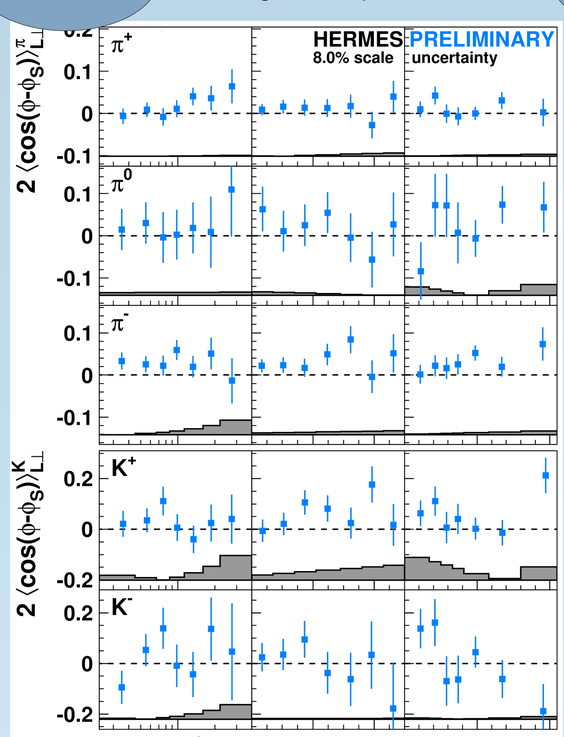
strong evidence for quark orbital angular momentum

sensitive to non-spherical shape of proton

G. A. Miller, Phys. Rev. C **76** (2007) 065209

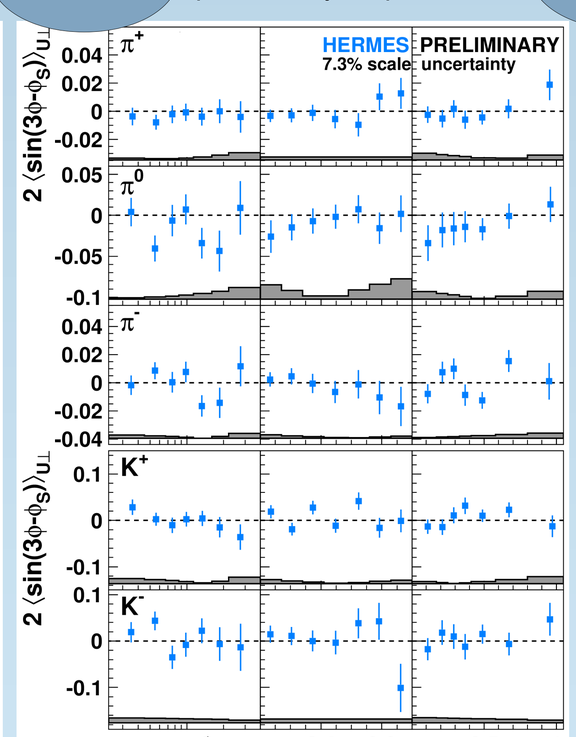
$\propto g_{1T}^{\perp,q} \otimes D_1^q$

worm-gear amplitudes



$\propto h_{1T}^{\perp,q} \otimes H_1^{\perp,q}$

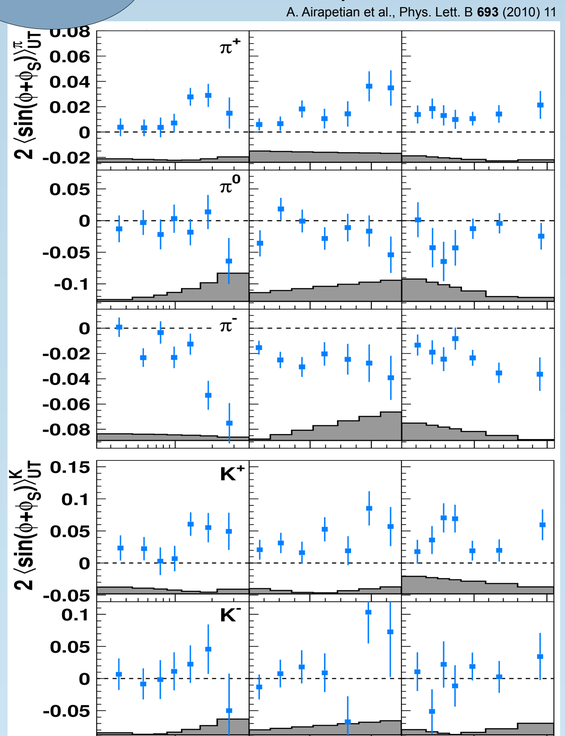
pretzelosity amplitudes



$\propto h_{1T}^q \otimes H_1^{\perp,q}$

Collins amplitudes

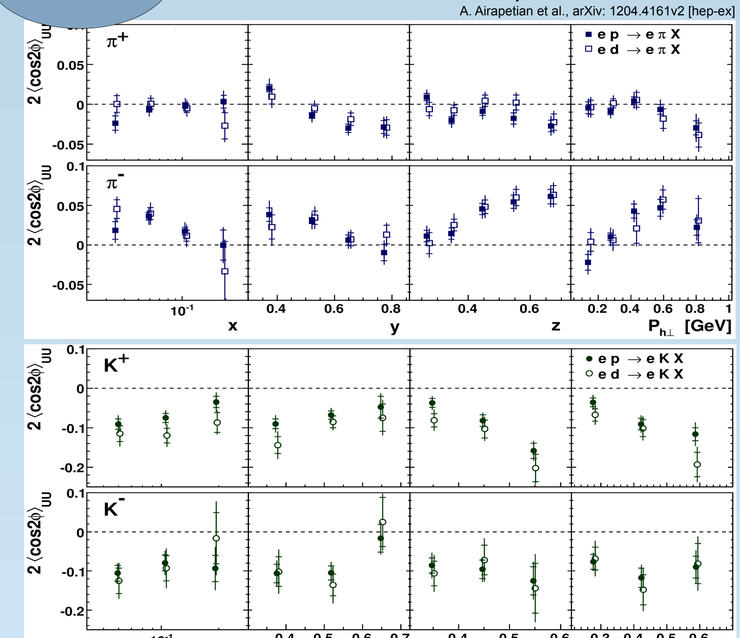
A. Airapetian et al., Phys. Lett. B **693** (2010) 11



$\propto h_1^{\perp,q} \otimes H_1^{\perp,q}$

Boer-Mulders-Collins amplitudes

A. Airapetian et al., arXiv: 1204.4161v2 [hep-ex]



Charlotte Van Hulse, on behalf of the HERMES collaboration, University of the Basque Country – UPV/EHU