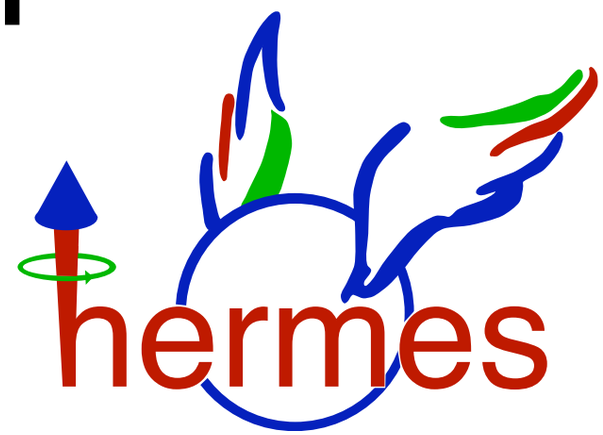
Report from



Caroline Riedl (DESY-Zeuthen)
for the HERMES-Collaboration

Zeuthen, DESY site, October 14, 2010

: Spin- and dynamic structure of the nucleon

I. Spin Puzzle

$$\tfrac{1}{2} = \tfrac{1}{2}\Delta\Sigma + L_q + J_g$$

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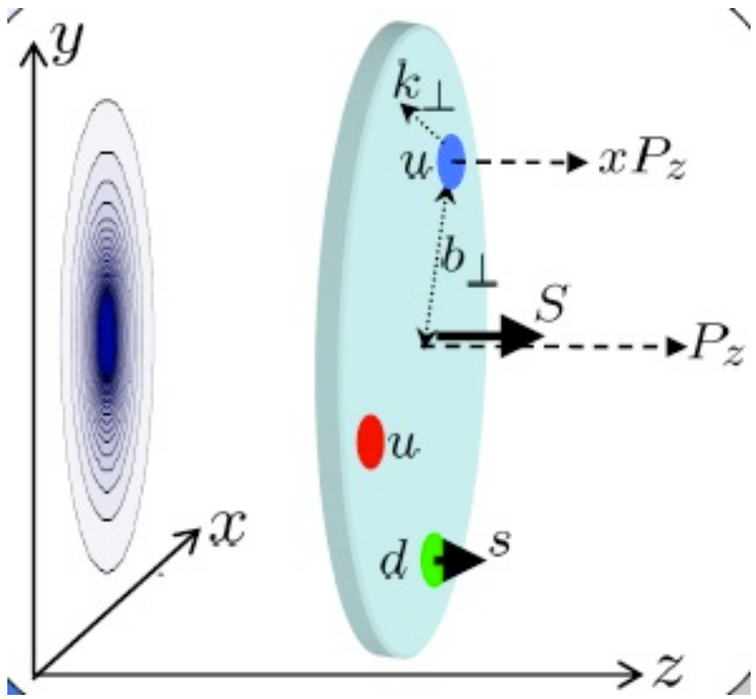
2. Dynamic hologram of the nucleon



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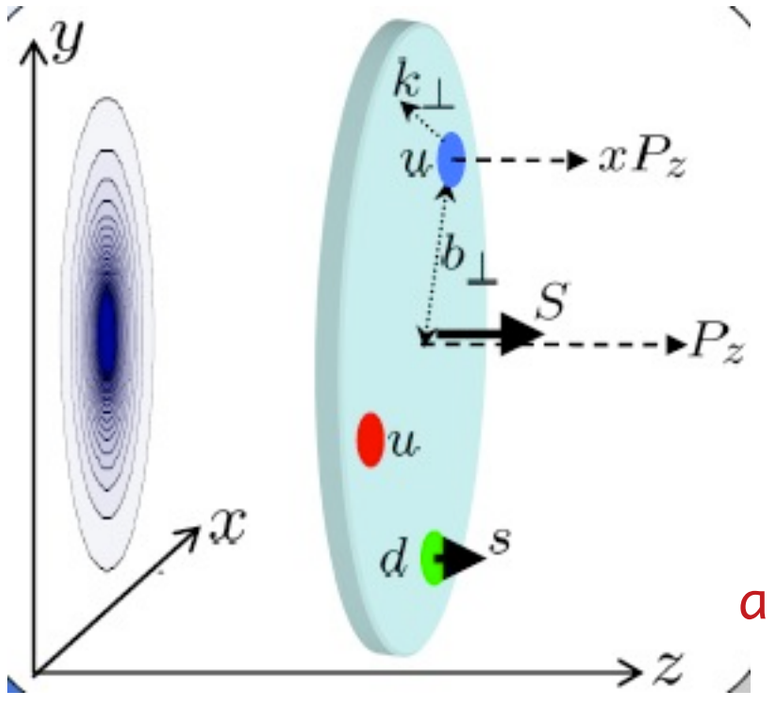

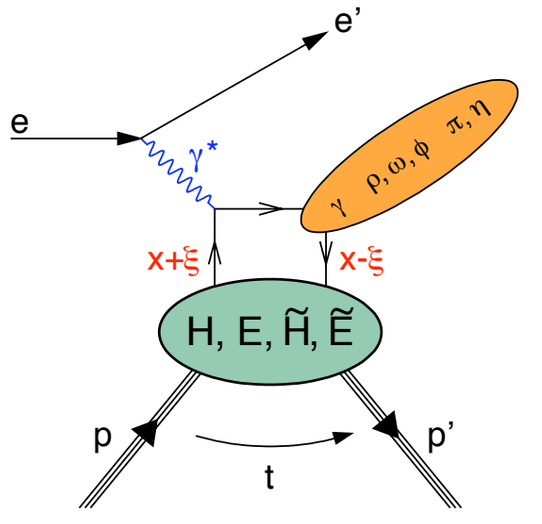

Hard exclusive reactions: access to Generalized Parton Distributions (GPDs)

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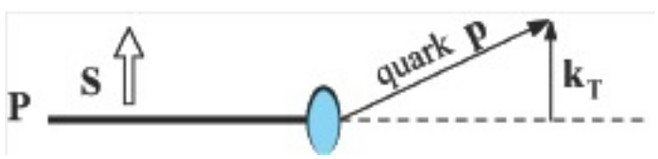

Semi-inclusive reactions: access to Transverse Momentum dependent PDFs (TMDs)

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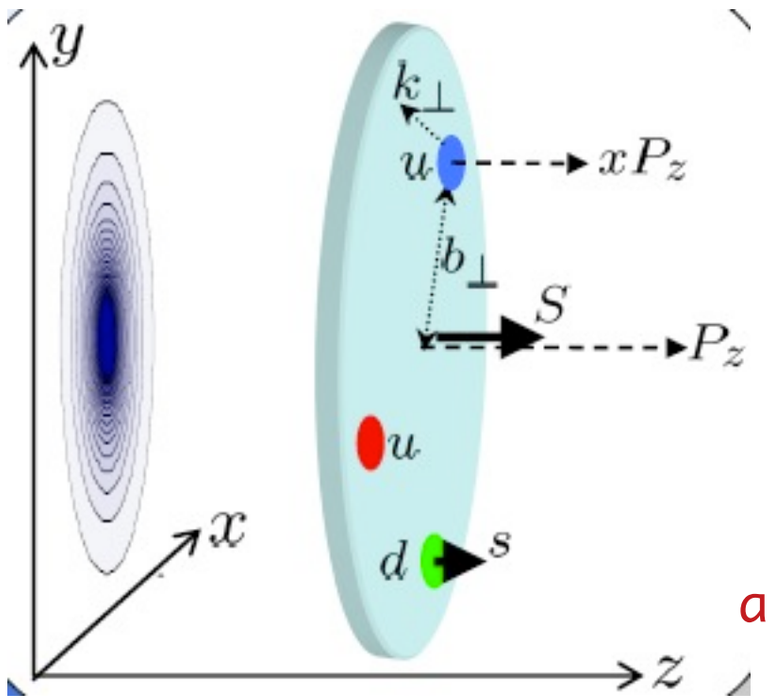

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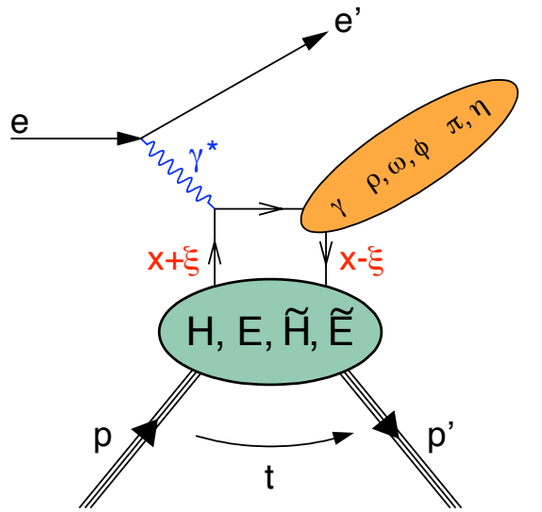

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TMDs

GPDs

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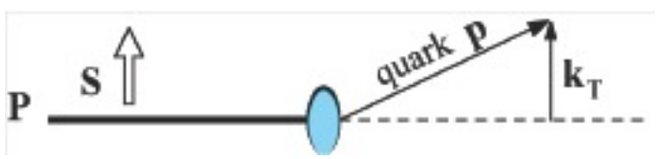

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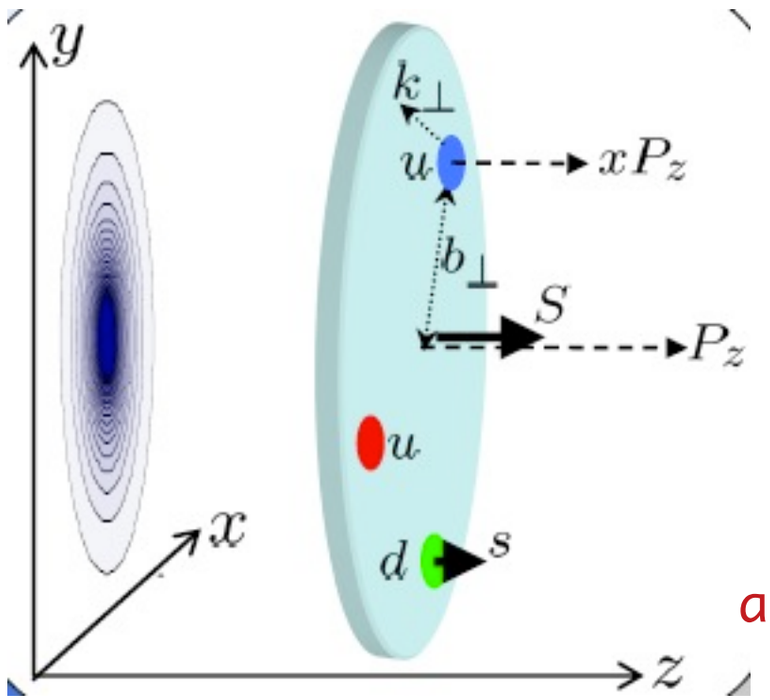

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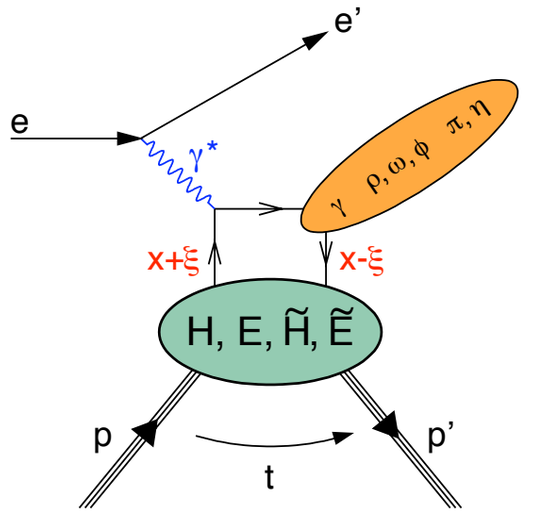

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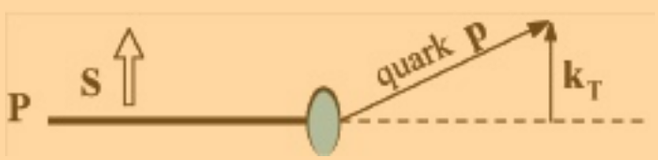

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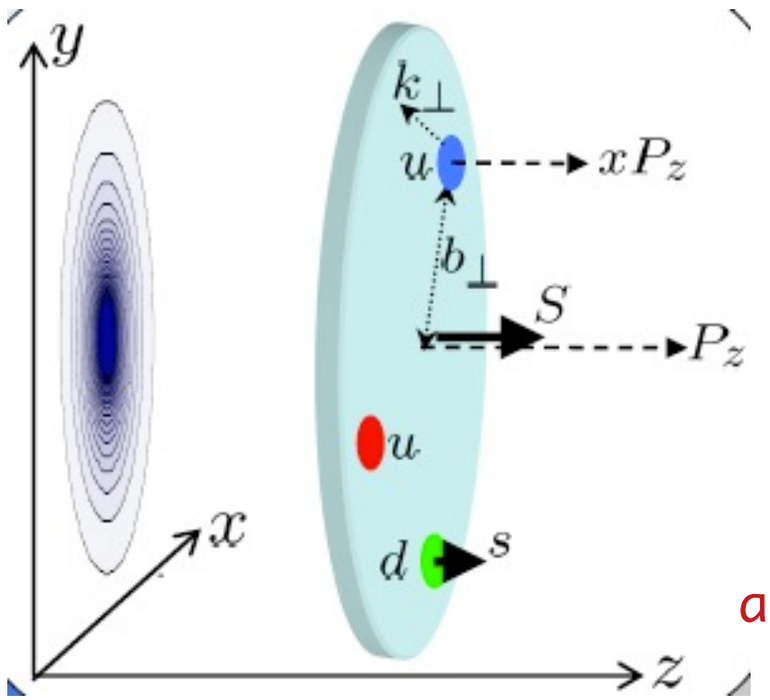

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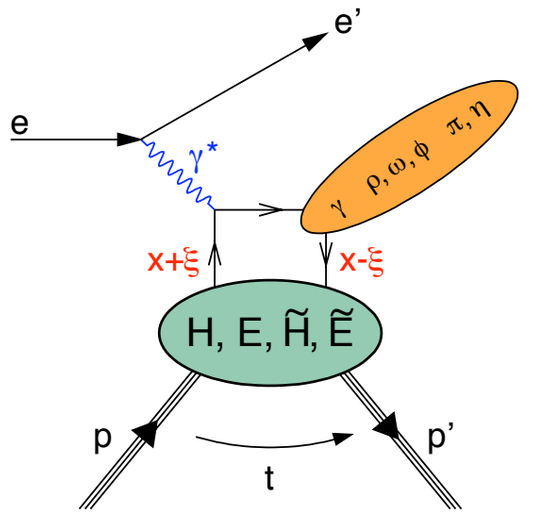


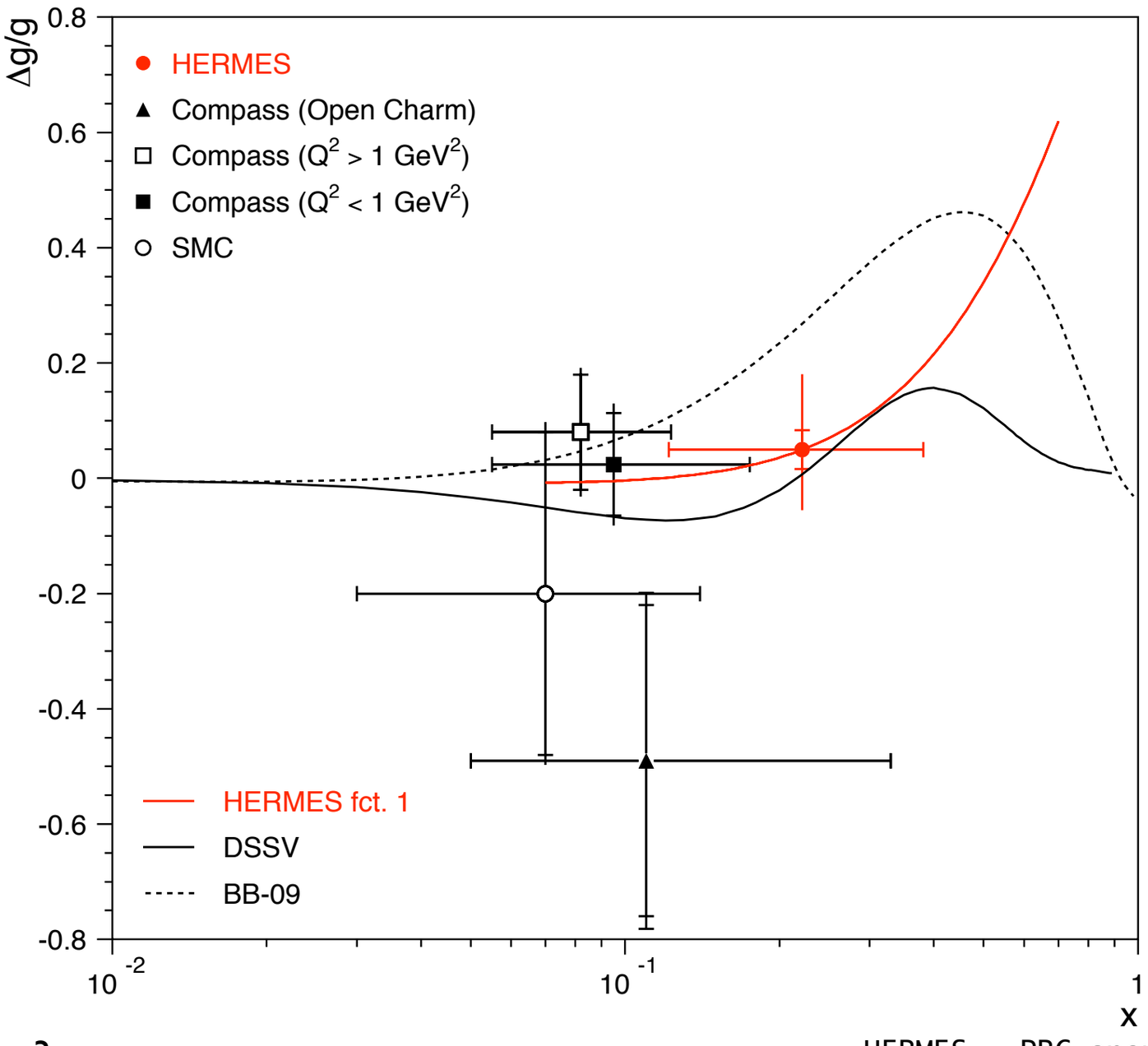
Hard exclusive reactions: access to Generalized Parton Distributions (GPDs)

Gluon Polarization

$\Delta g/g(x,\mu^2)=0.049\pm0.034(stat)\pm0.010(sys\text{-}exp)^{+0.126}_{-0.099}(sys\text{-}models)$

at $\langle x\rangle=0.22$ and $\langle\mu^2\rangle=1.35$ GeV^2

Publication:
JHEP 08 (2010) 130
Leading order Determination of the Gluon Polarization from high-p_T Hadron Electroproduction



- Based on measurement of longitudinal double-spin asymmetries of charged hadrons with high p_T (1-2.5 GeV)
- Enhancement of processes with gluons in the initial state (photon-gluon fusion)
- Compilation of world data of lepto-production data (different Q^2-scales)

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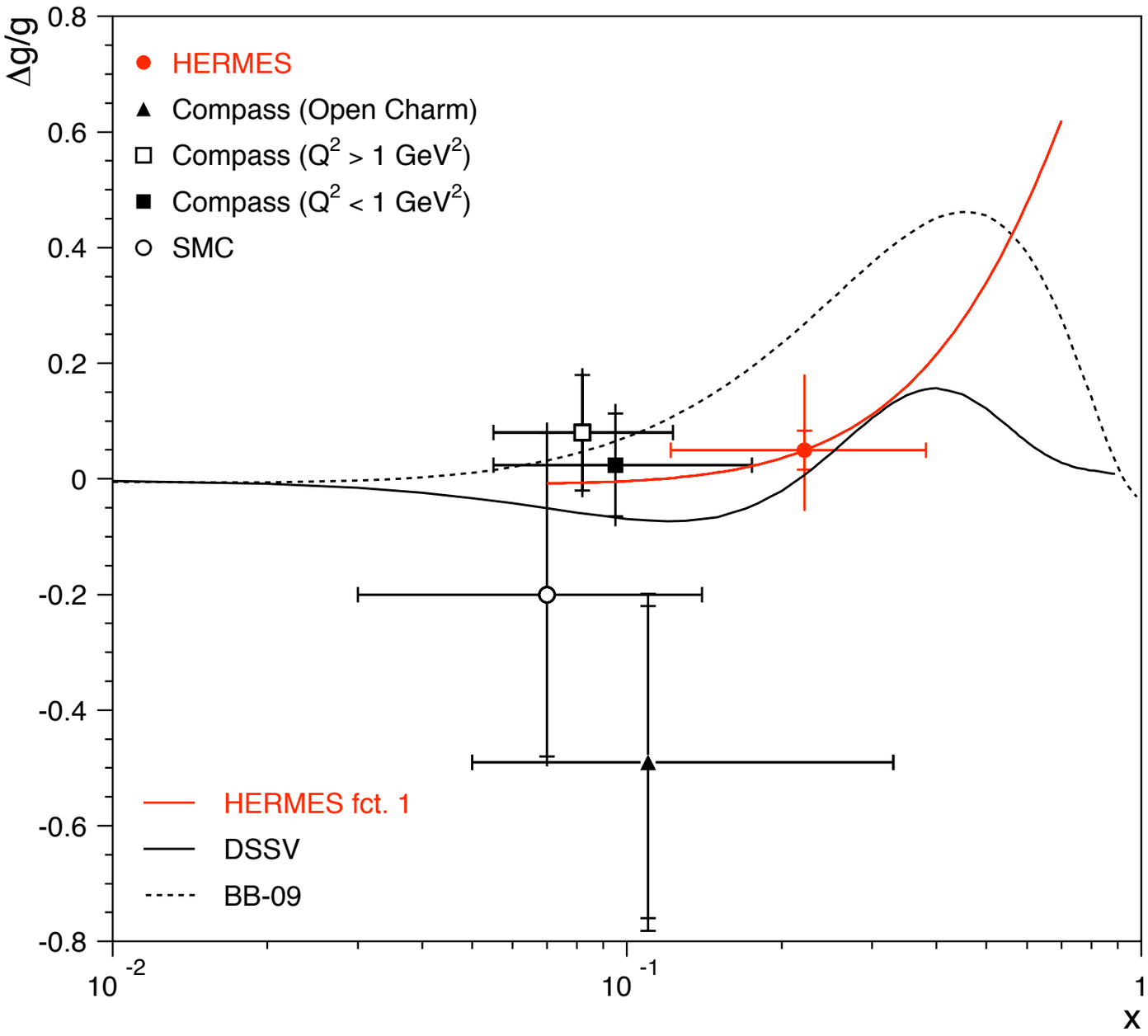

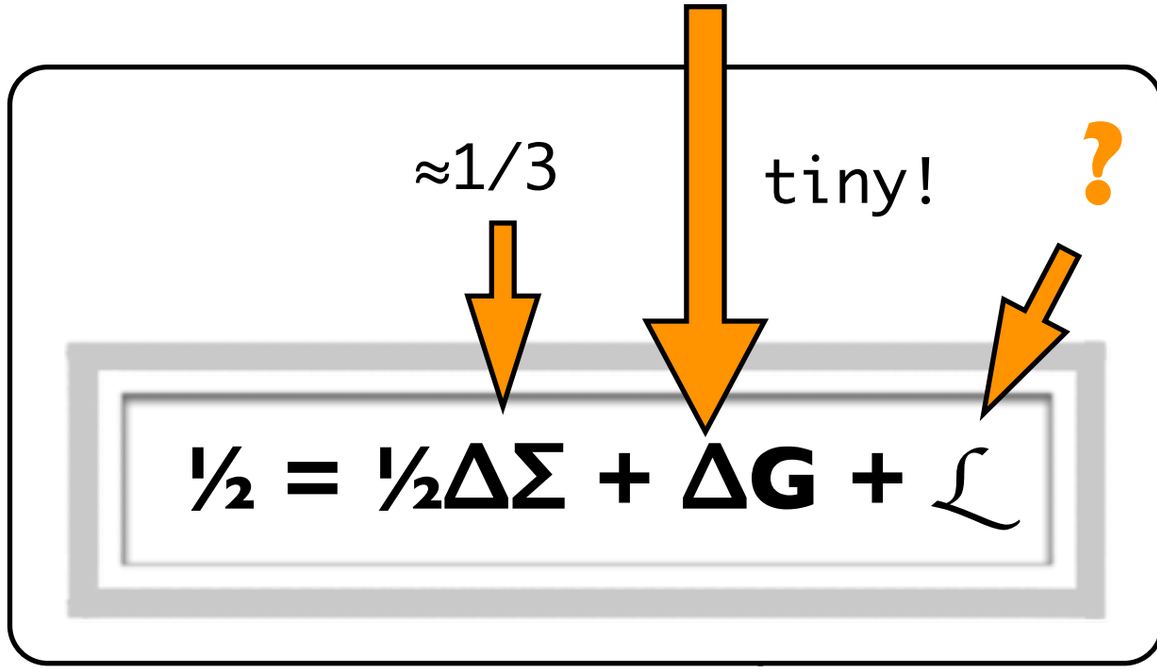

with gluons
in the initial state
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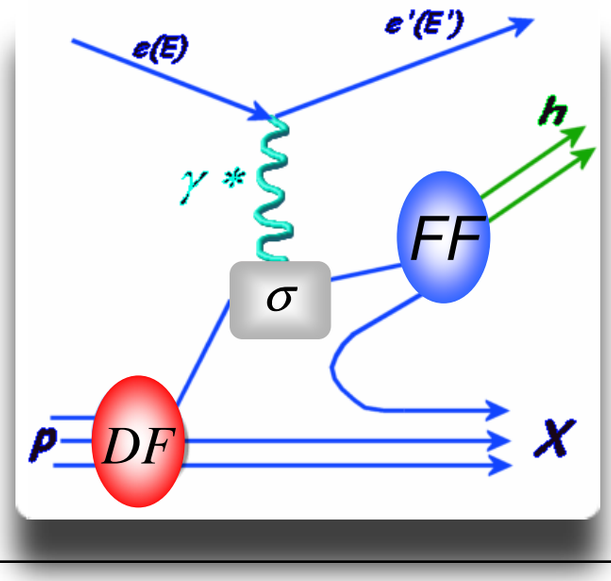
- Compilation of world data of lepto-production data (different Q^2-scales)

Azimuthal asymmetries in the semi-inclusive cross-section

Distribution Functions (DF)				
	quark polarization			
nucleon		U	L	T
	U	f_1		$h_1^\perp$
	L		g_{1L}	$h_{1L}^\perp$
	T	$f_{1T}^\perp$	g_{1T}	h_1, $h_{1T}^\perp$

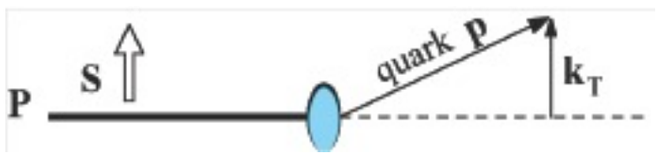
- main diagonal: TMDs ‘surviving’ integration over k_T
- “$\perp$”: TMDs depending explicitly on k_T

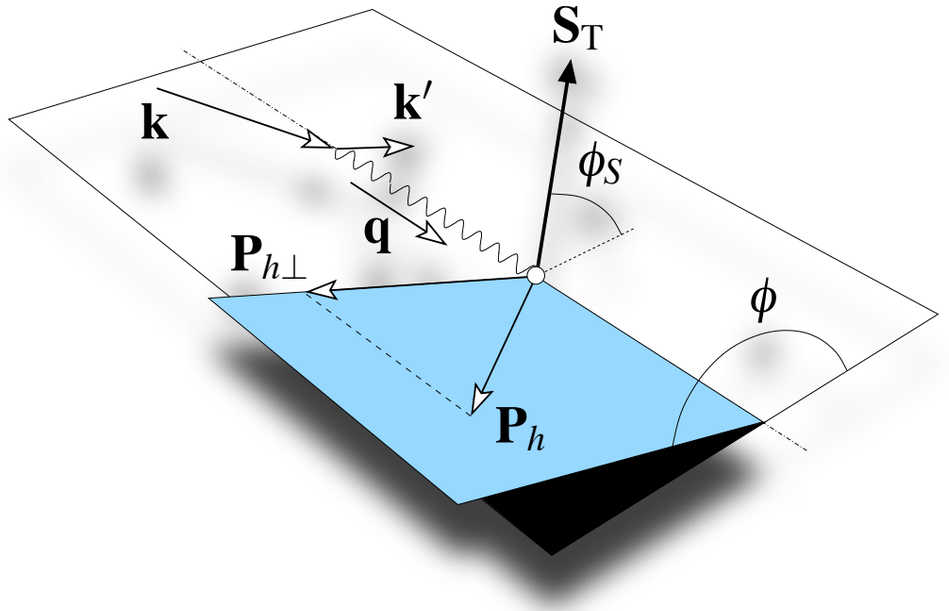


$$\sigma^{ep\to ehX} = \sum_q (DF \otimes \sigma^{eq\to eq} \otimes FF)$$

Fragmentation Functions (FF)	
q \ h	U
U	D_1
T	$H_1^\perp$

Partonic spin-orbit effects cause azimuthal modulations in the cross-section

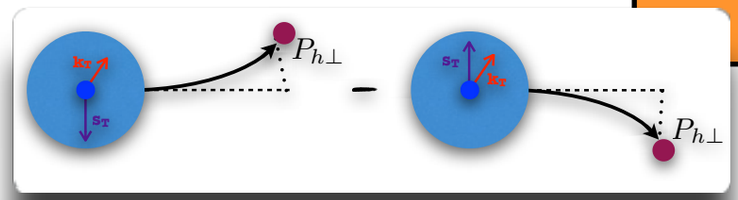




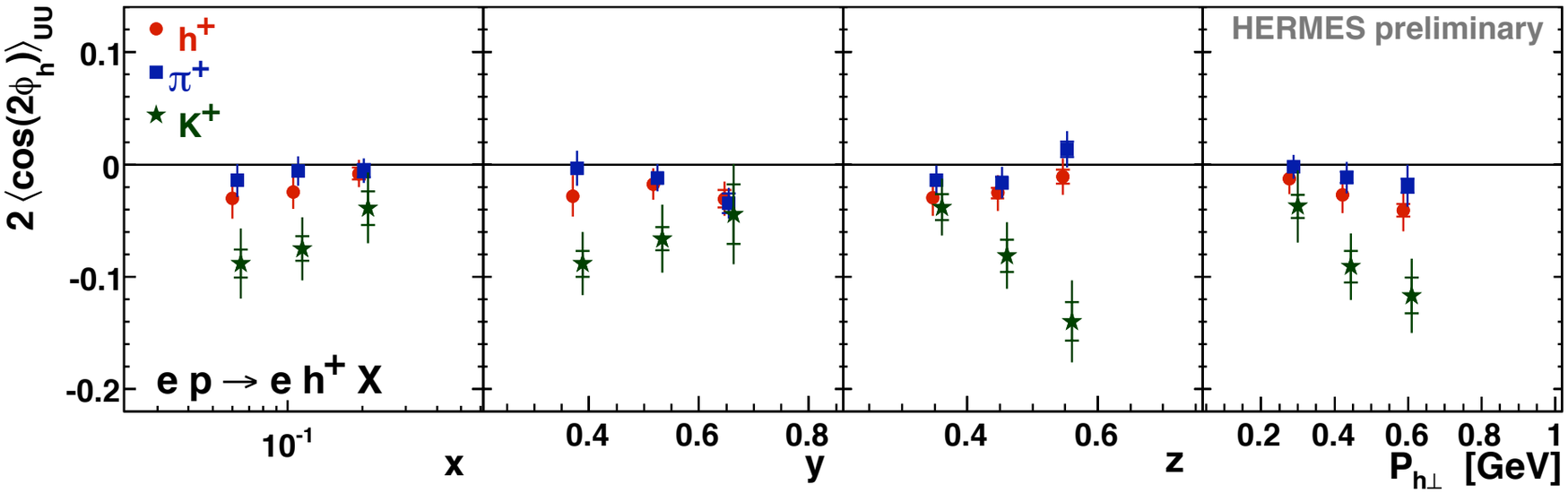
Boer-Mulders TMD

Preliminary: Measurement of azimuthal asymmetries of the unpolarized cross-section for hadrons and kaons

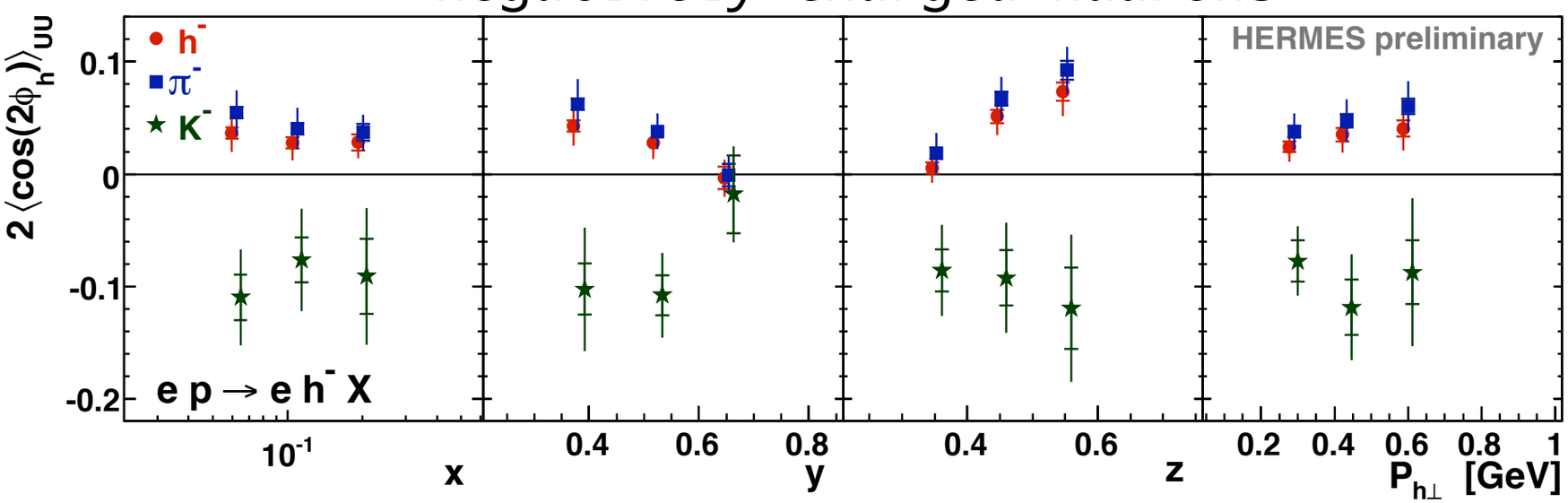
$h_1^\perp \otimes H_1^\perp$: cos(2ϕ) modulation



positively charged hadrons



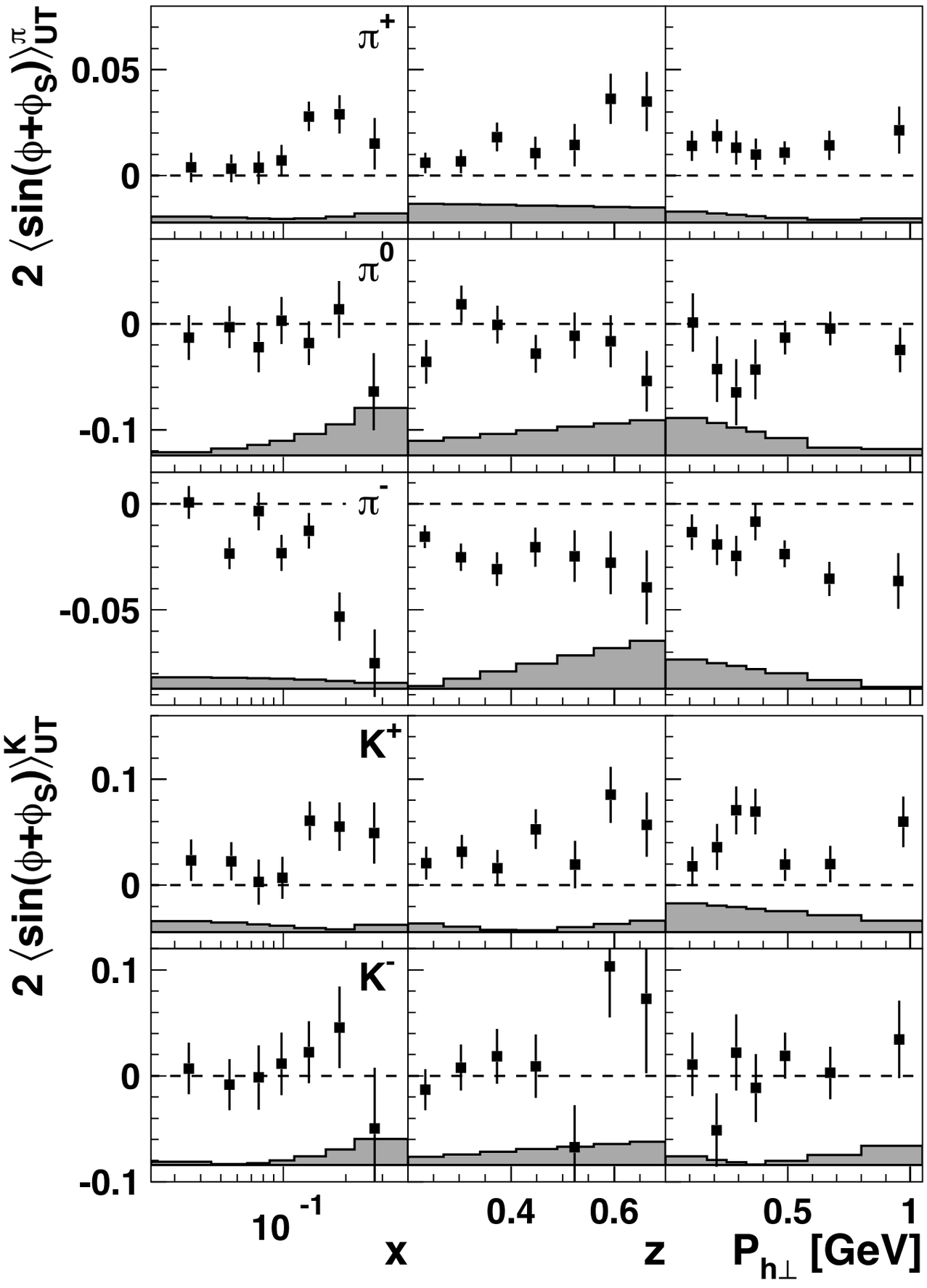
negatively charged hadrons



- Flavor-dependent extraction of cos-modulation of unpolarized SIDIS x-section
- Opposite sign for π+/π- ⇒ non-zero Boer-Mulders function
- Striking difference: K > π, role of sea quarks?
- Similar results for H and D target ⇒ Boer-Mulders function with same sign for u- and d-quarks

Collins Effect

Publication:
Phys. Lett. B 693 (2010) 11-16
Effects of transversity in deep-inelastic scattering by polarized protons



$h_1 \otimes H_1^{\perp}$: $\sin(\phi+\phi_S)$ modulation of polarized cross-section

- Convolution of transversity DF and Collins fragmentation function
- "Polarimeter" measuring correlation between transverse polarization of fragmenting quark and its k_T
- Charged pions non-zero and of opposite sign
- $K^+ > \pi^+$ once more
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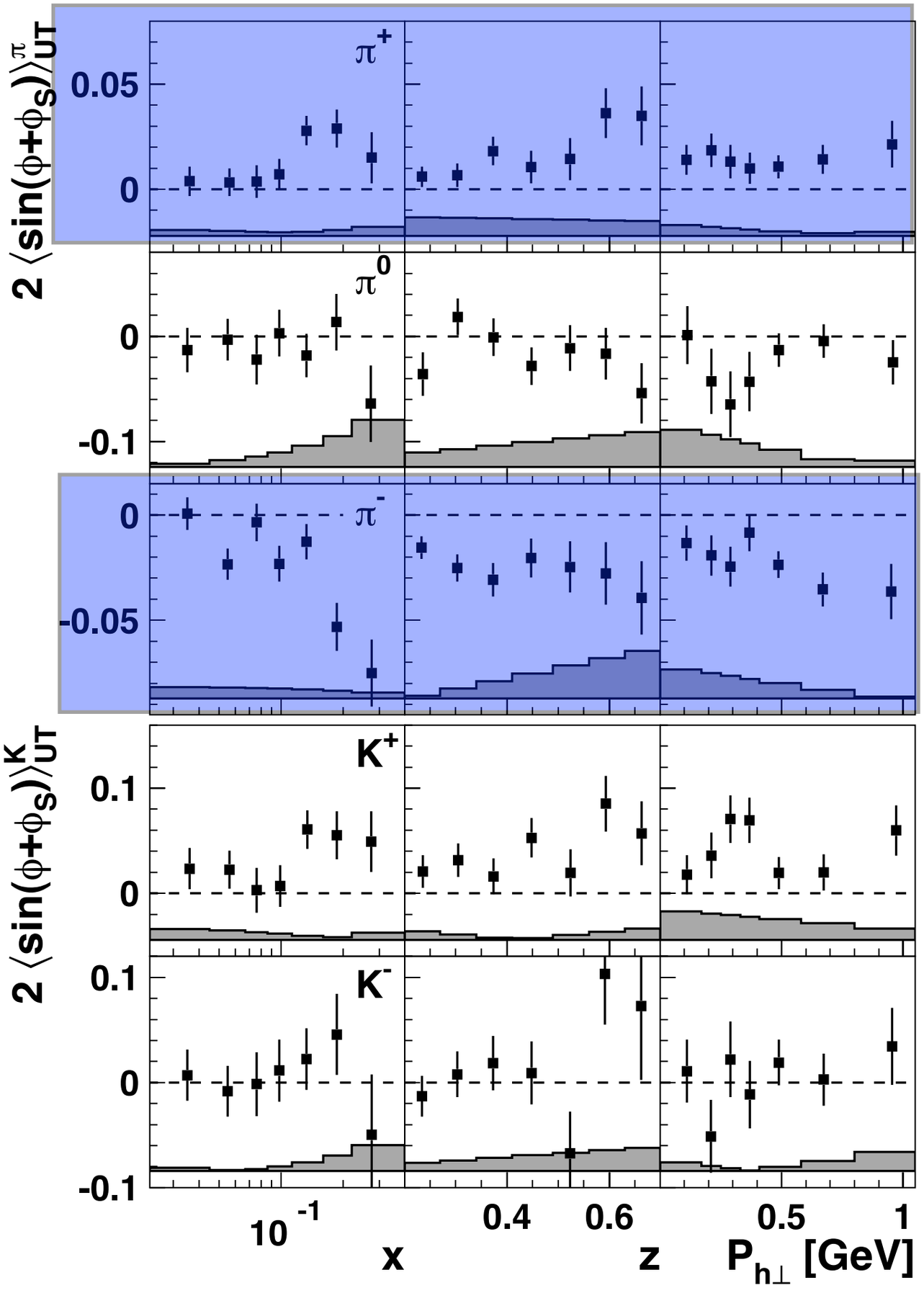

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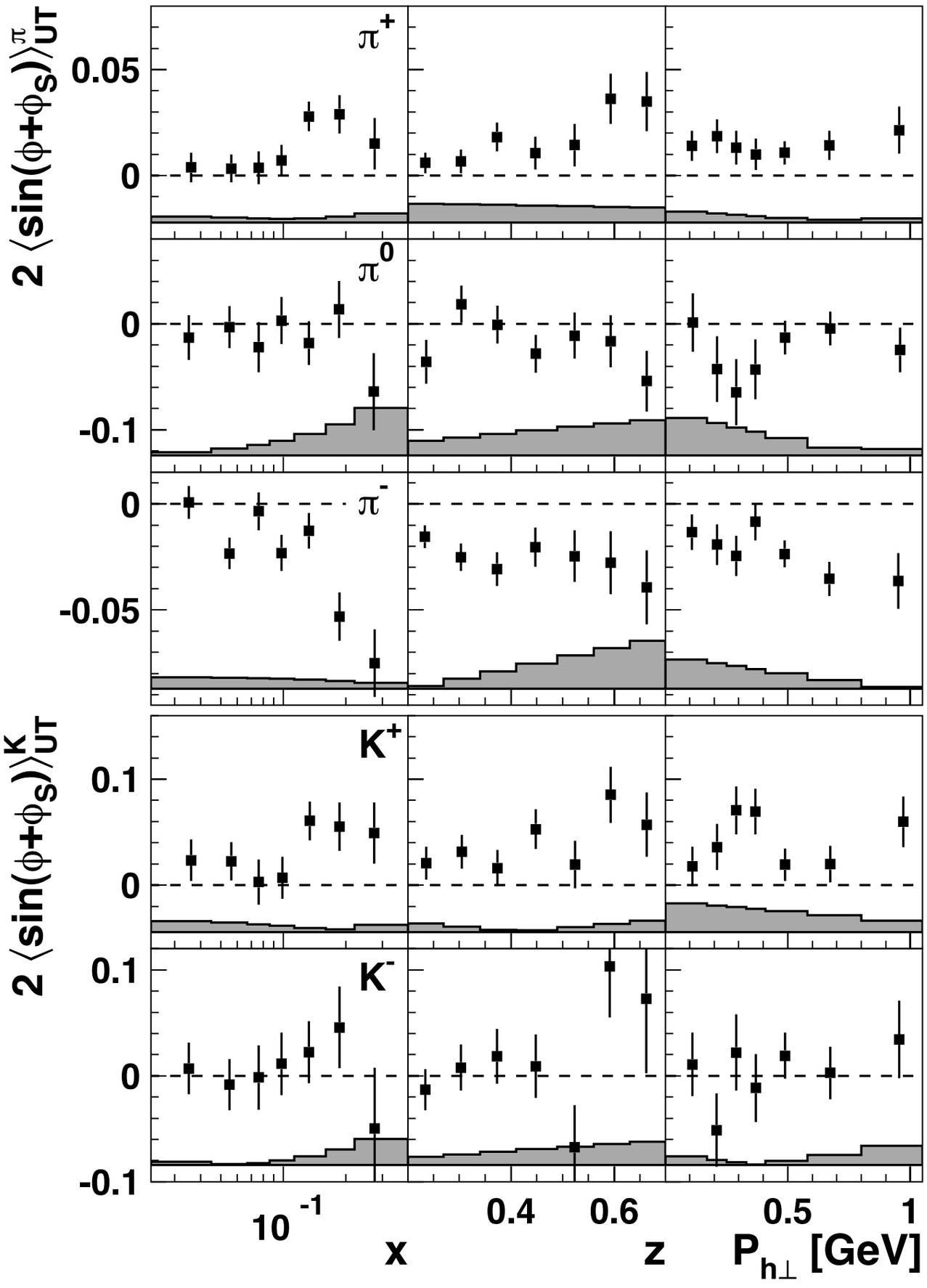

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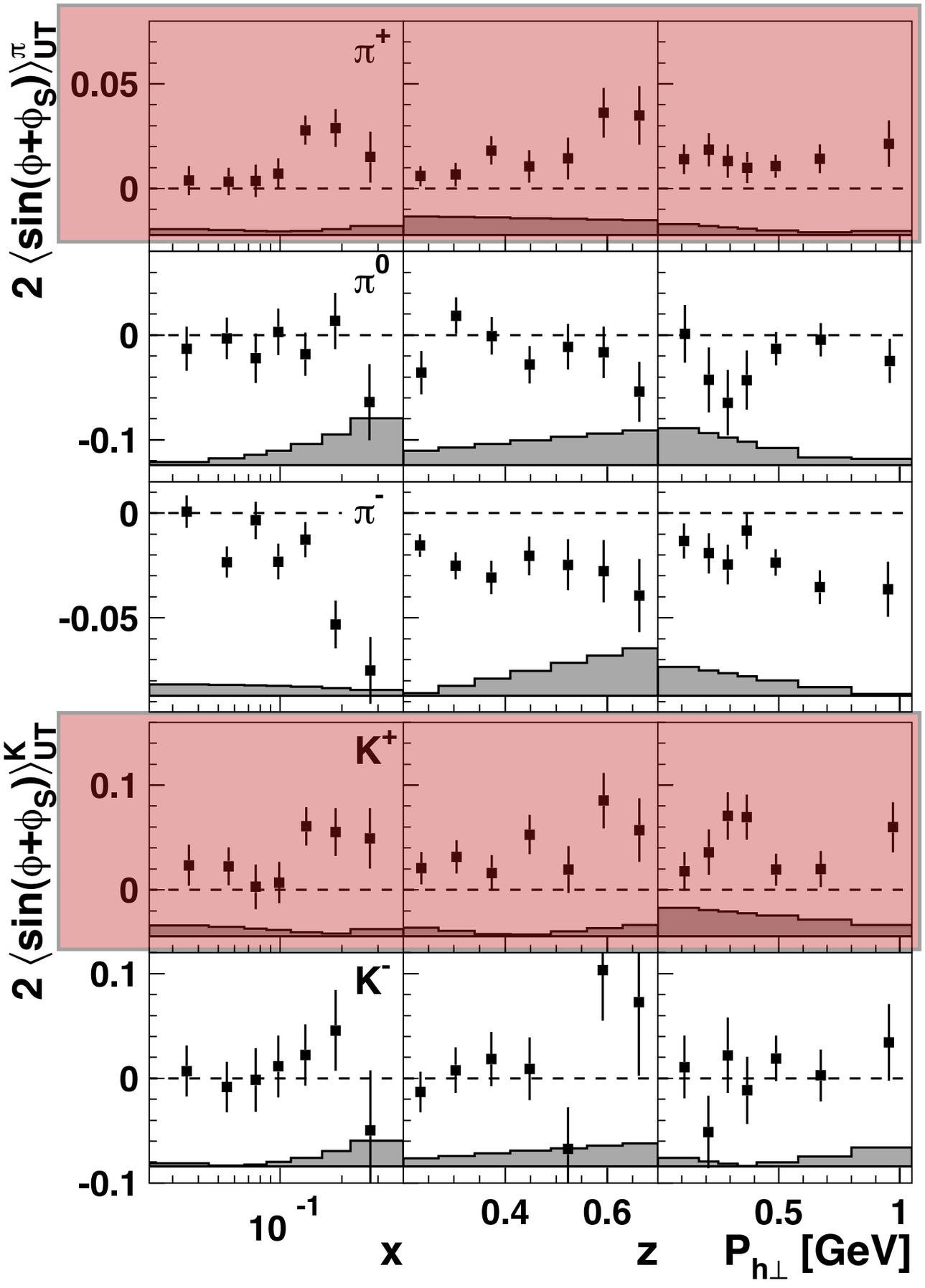

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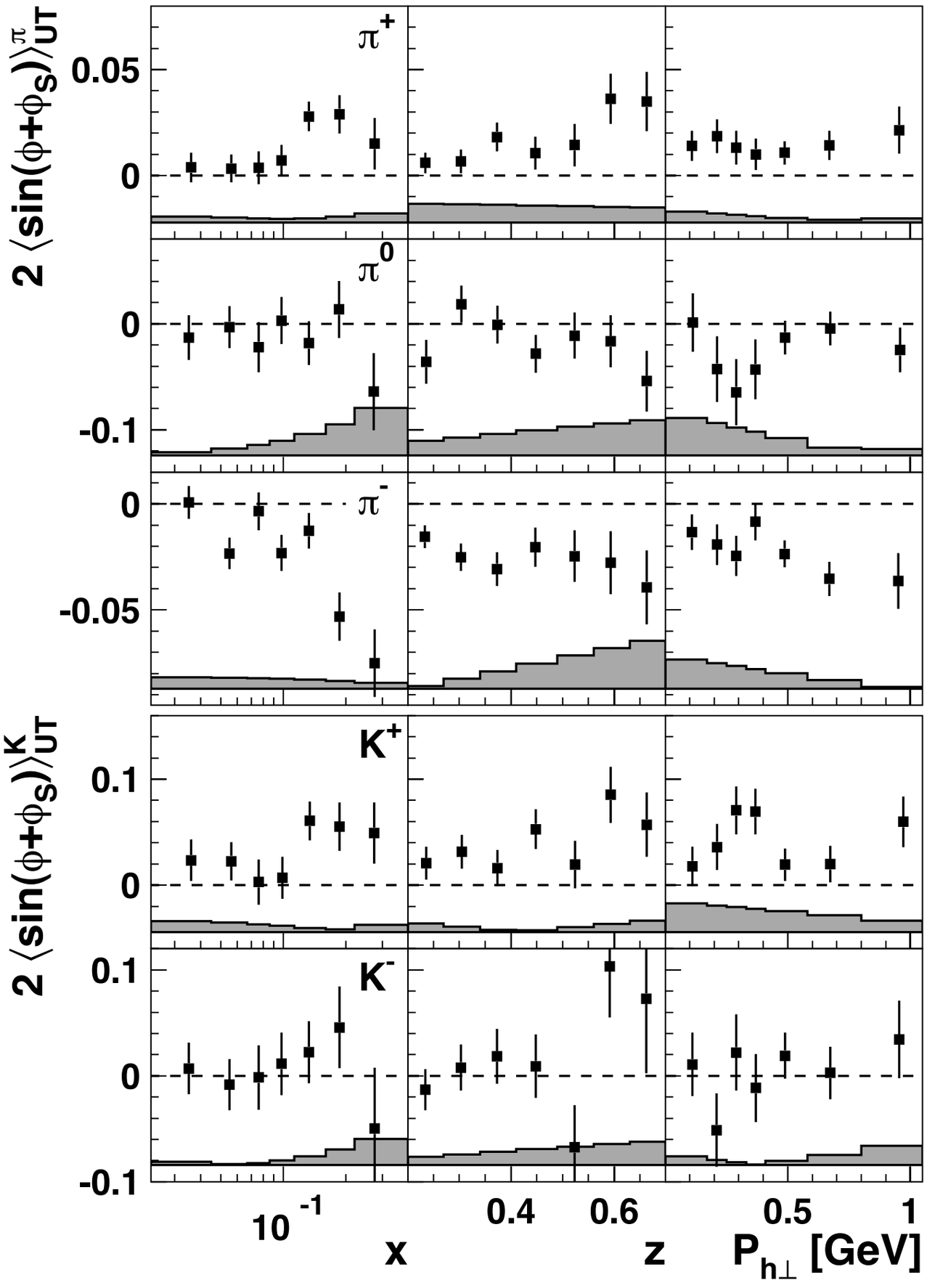

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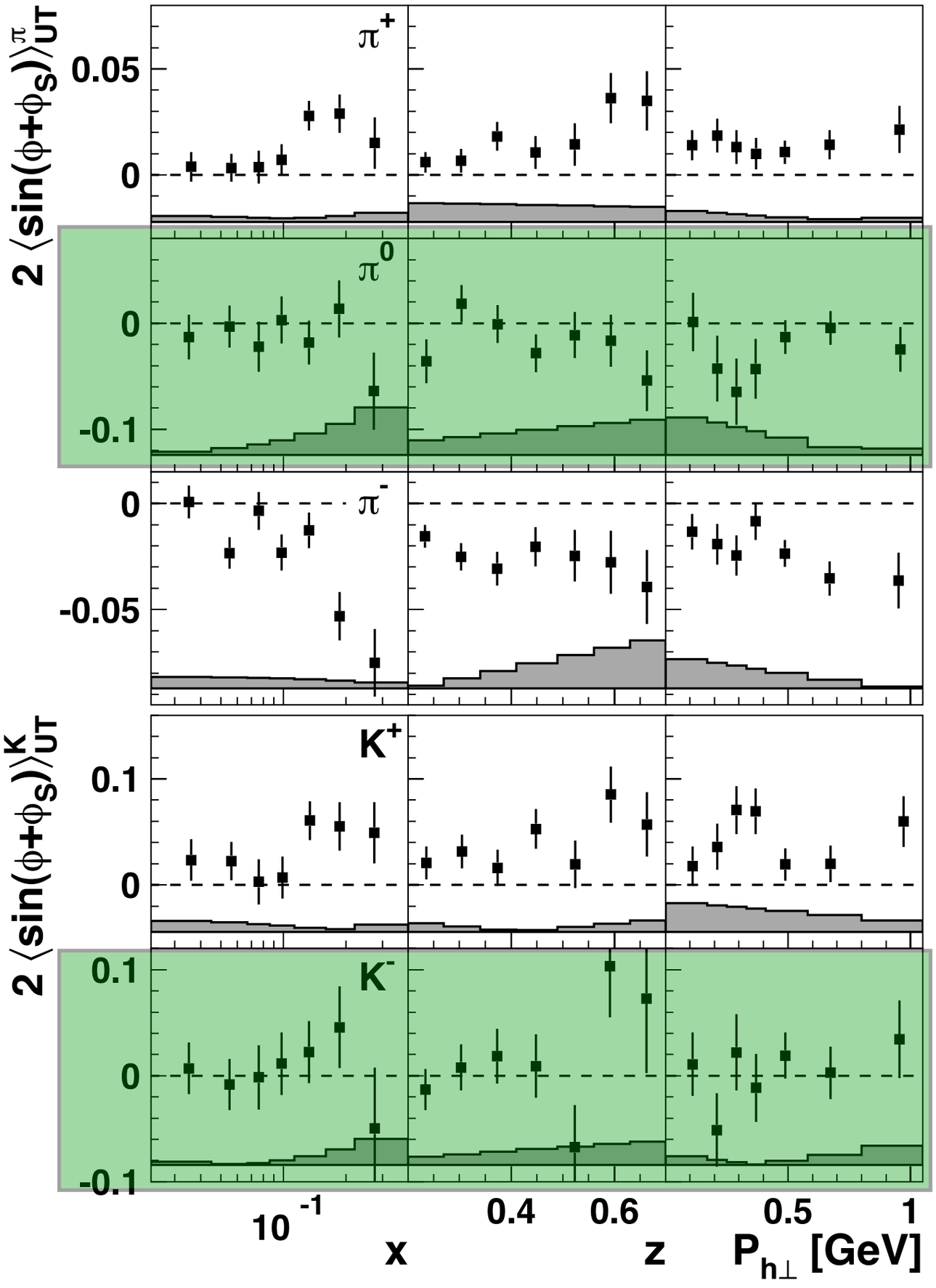

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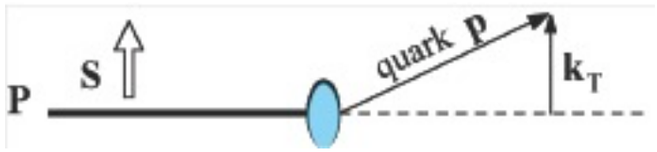

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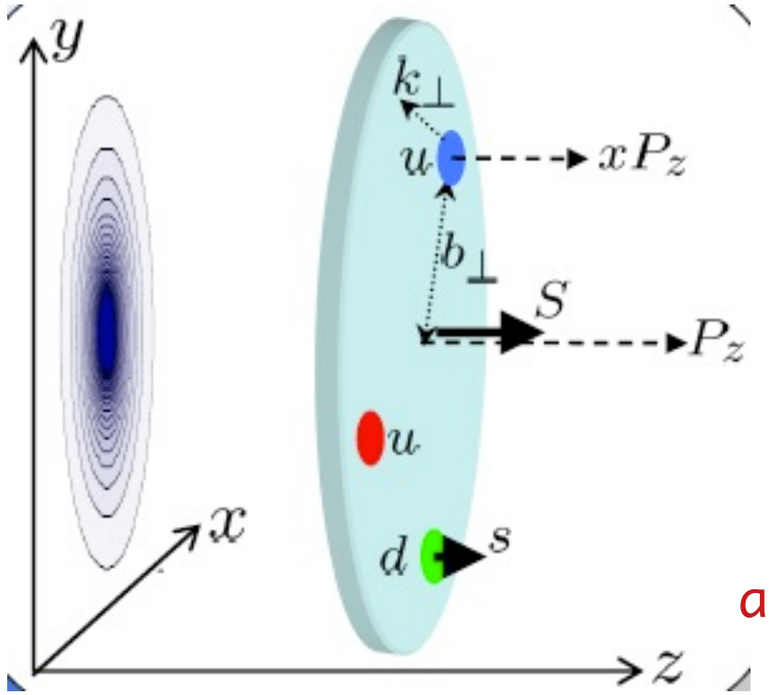

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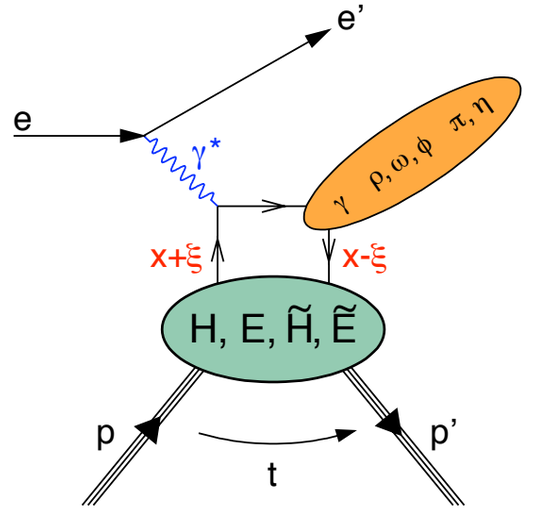

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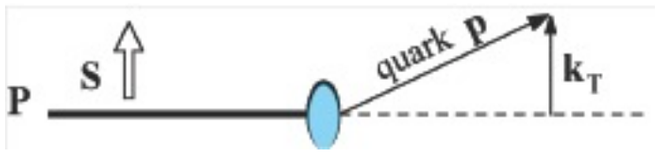

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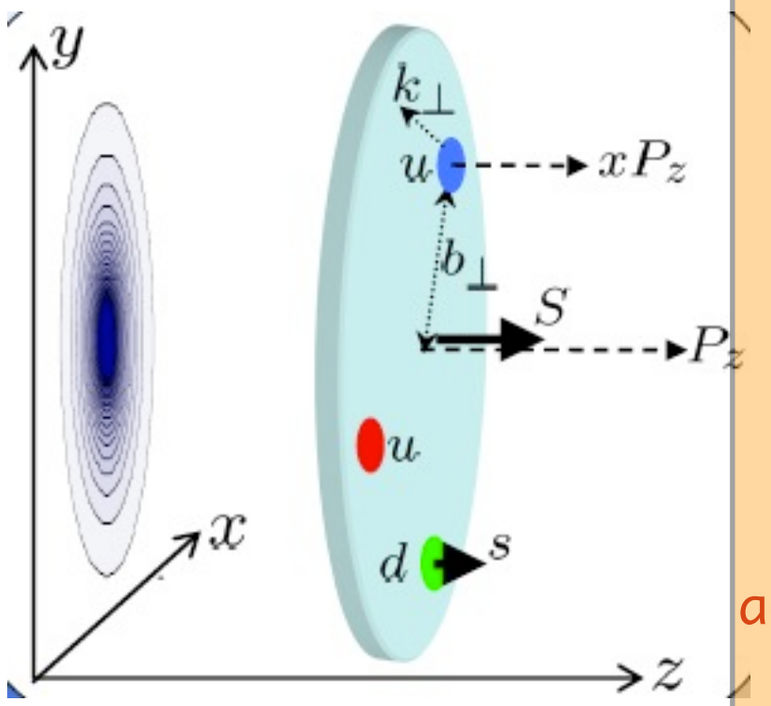

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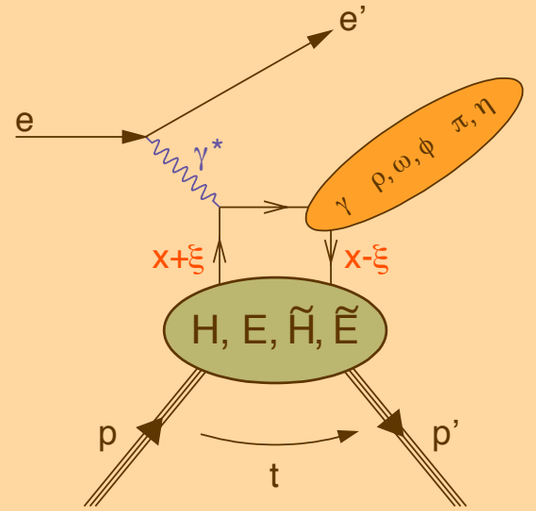

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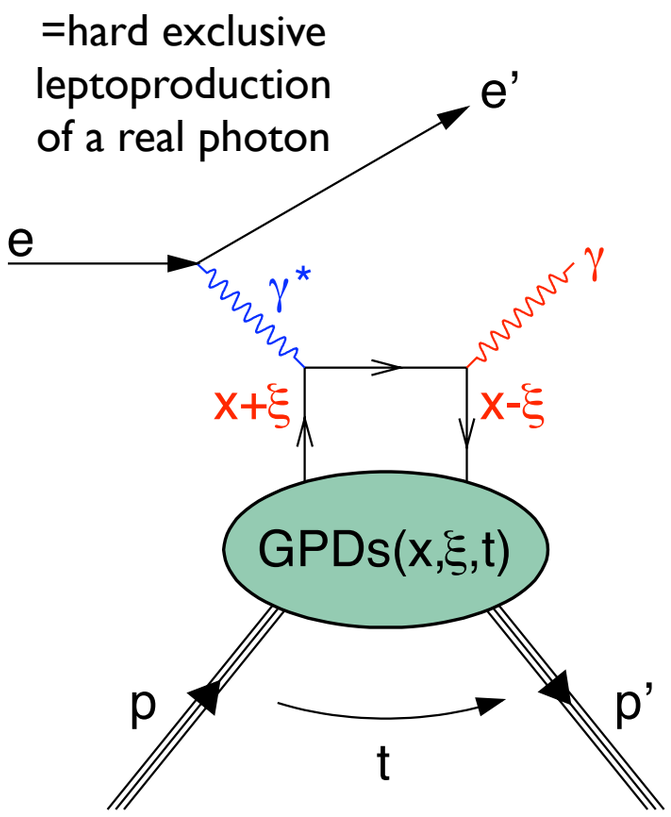
Deeply Virtual Compton Scattering



Spin-1/2	flips nucleon helicity	conserves nucleon helicity
does not depend on quark helicity	E	H
depends on quark helicity	$\tilde{E}$	$\tilde{H}$

forward limit $\xi \to 0, t \to 0$

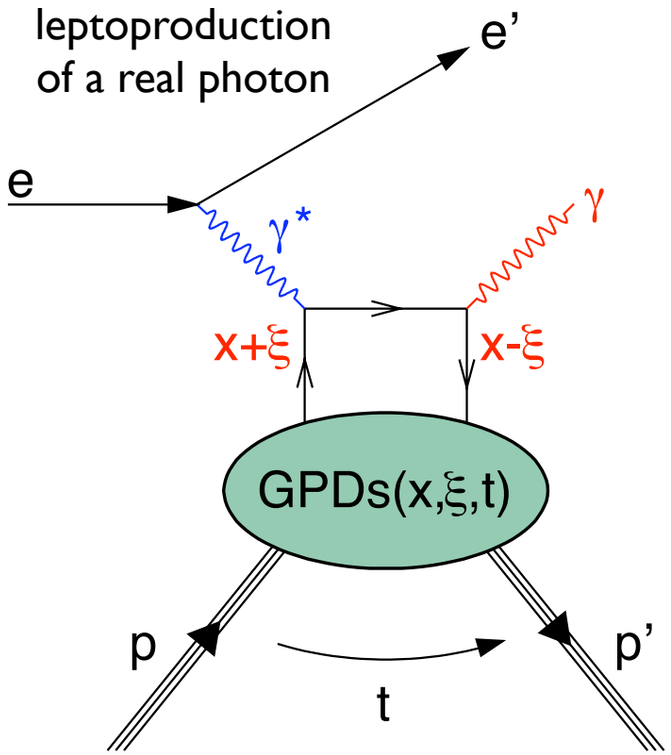
$H \to q(x)$

$\tilde{H} \to \Delta q(x)$

4 chiral-even quark GPDs
at leading twist

Deeply Virtual Compton Scattering

=hard exclusive leptoproduction of a real photon



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does not depend on quark helicity	E	H → q(x)
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forward limit $\xi \to 0, t \to 0$

4 chiral-even quark GPDs at leading twist

tensor structure function $b_1(x)$

Spin-1	$H_1, H_2, H_3, H_4, H_5, \tilde{H}_1, \tilde{H}_2, \tilde{H}_3, \tilde{H}_4$

9 chiral-even quark GPDs at leading twist

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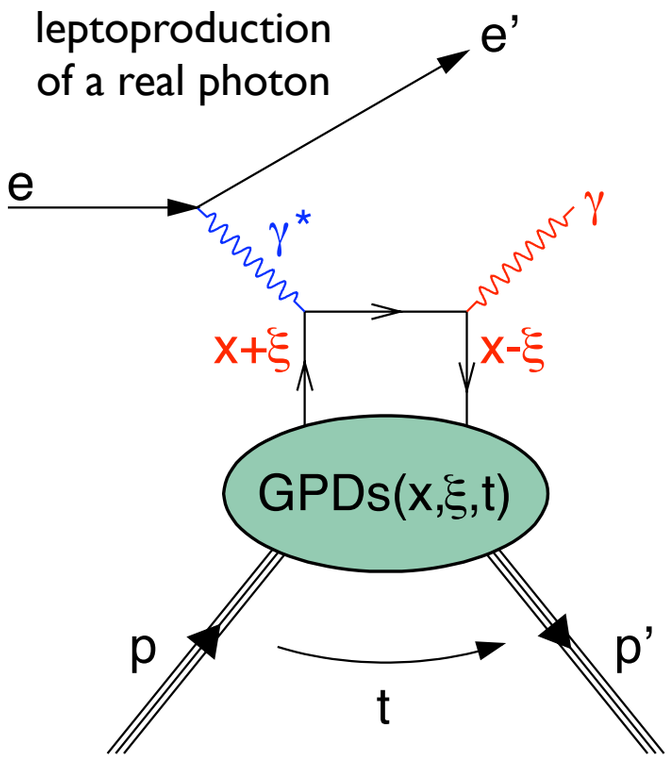

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proton vs. deuteron target

tensor structure function $b_1(x)$

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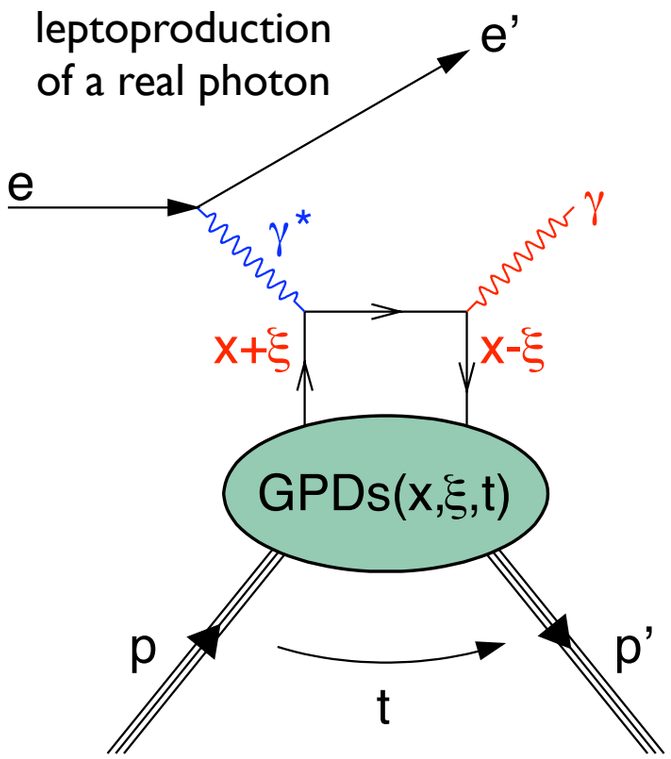

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Cross-section of $ep \to ep\gamma$

$$\sigma_{\gamma^* \gamma N} \sim \left| \text{DVCS} + \text{Bethe–Heitler (BH)} \right|^2$$

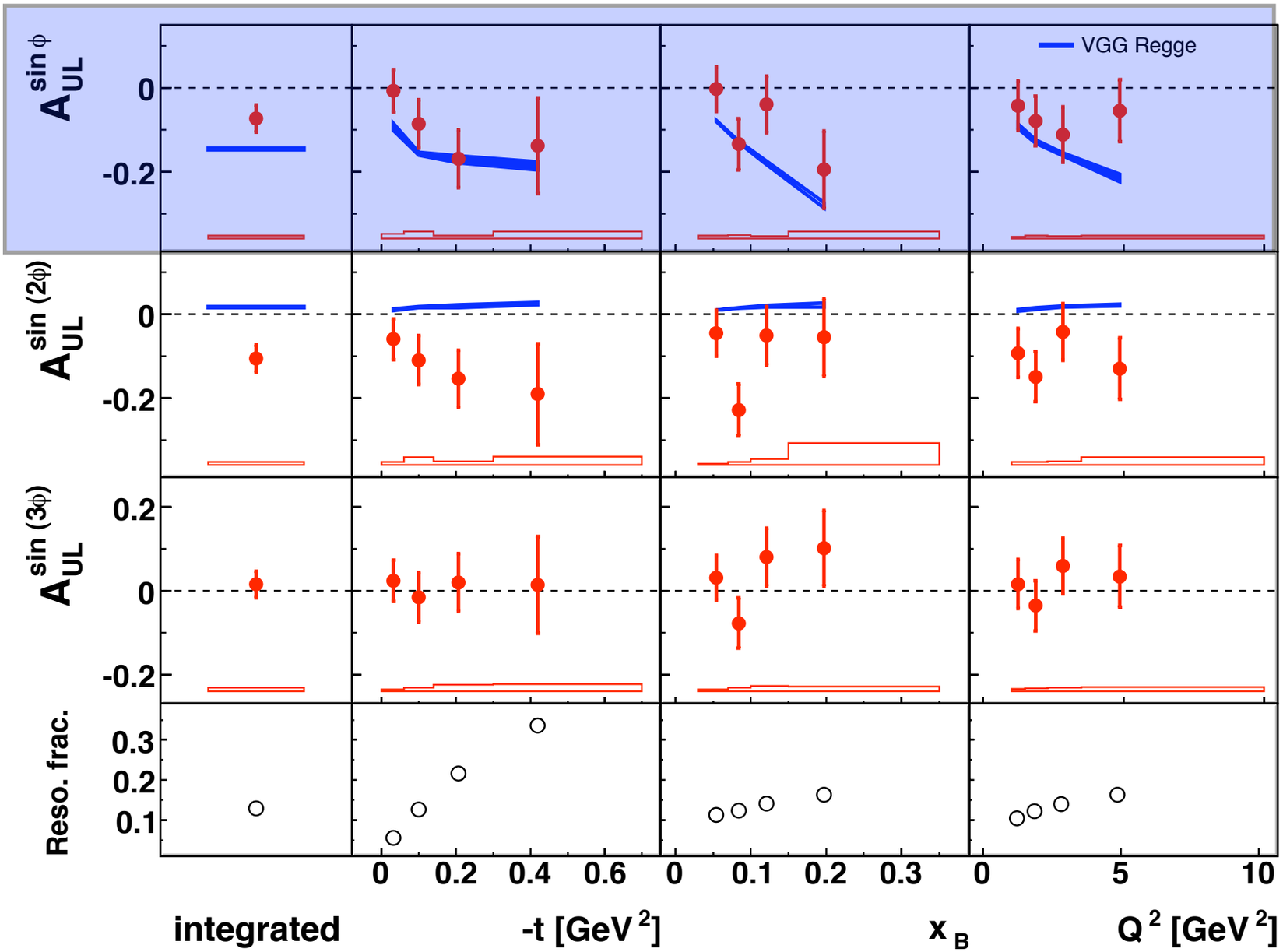
$$= |\tau_{DVCS}|^2 + |\tau_{BH}|^2 + (\tau_{DVCS}\tau_{BH}^* + \tau_{DVCS}^*\tau_{BH})$$

Small at HERMES

Exactly calculable in QED given the nucleon elastic form factors F_1 and F_2

DVCS-BH interference term

DVCS on $\vec{H}$



Publication:
JHEP 06 (2010) 019
Exclusive Leptoproduction of Real Photons on a Longitudinally Polarised Hydrogen target

- Target-spin asymmetry sensitive to GPD $\tilde{H}$
- Resonant processes, like $ep \to e\Delta^+\gamma$, could not be resolved from elastic one, $ep \to ep\gamma$

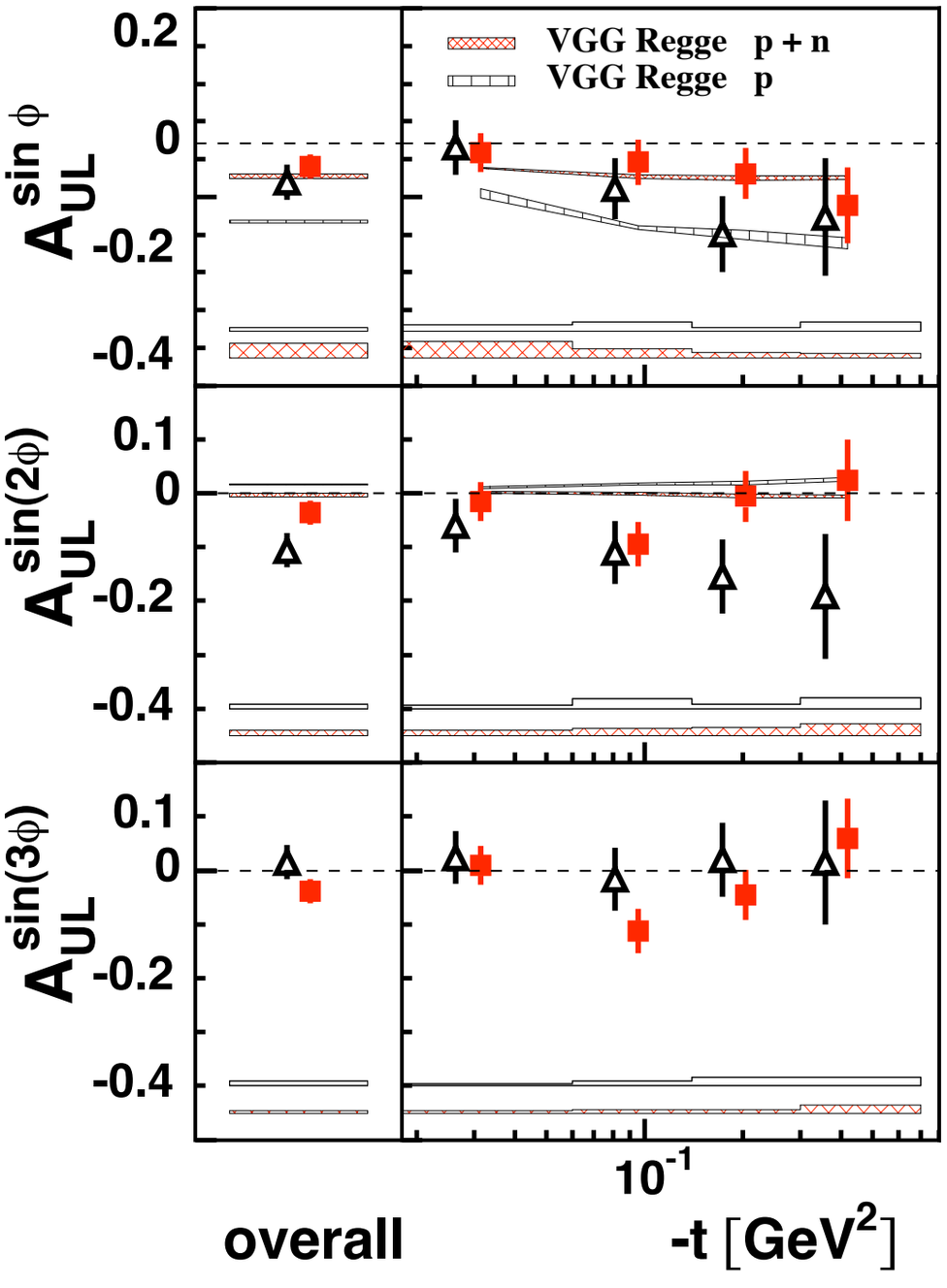
DVCS on $\vec{D}$

(compared to $\vec{H}$)

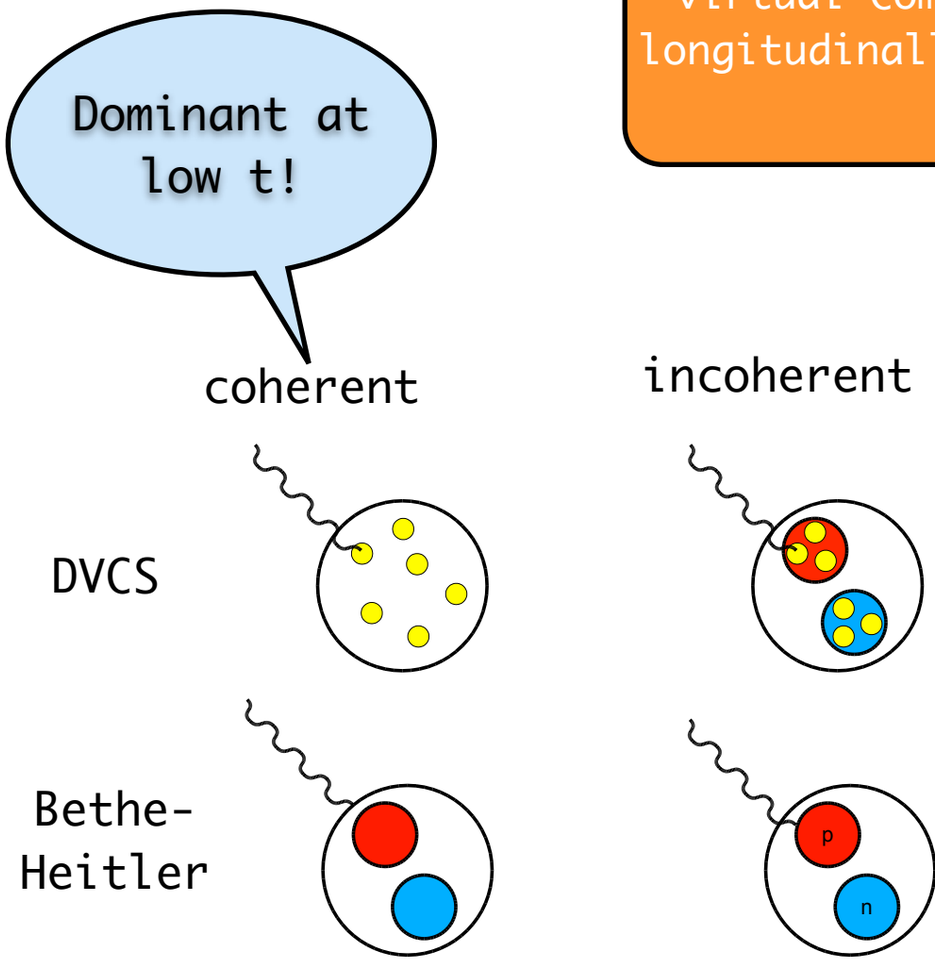
Search for coherent signature

in press

Publication:
accepted by Nucl. Phys. B
Measurement of azimuthal asymmetries associated with deeply virtual Compton scattering on a longitudinally polarized deuterium target



Dominant at low t!



Deuteron: probe spin-1 object

$\tilde{H}_1$

Nucleon: probe spin-1/2 object

$\tilde{H}$

DVCS on $\vec{D}$

(compared to $\vec{H}$)

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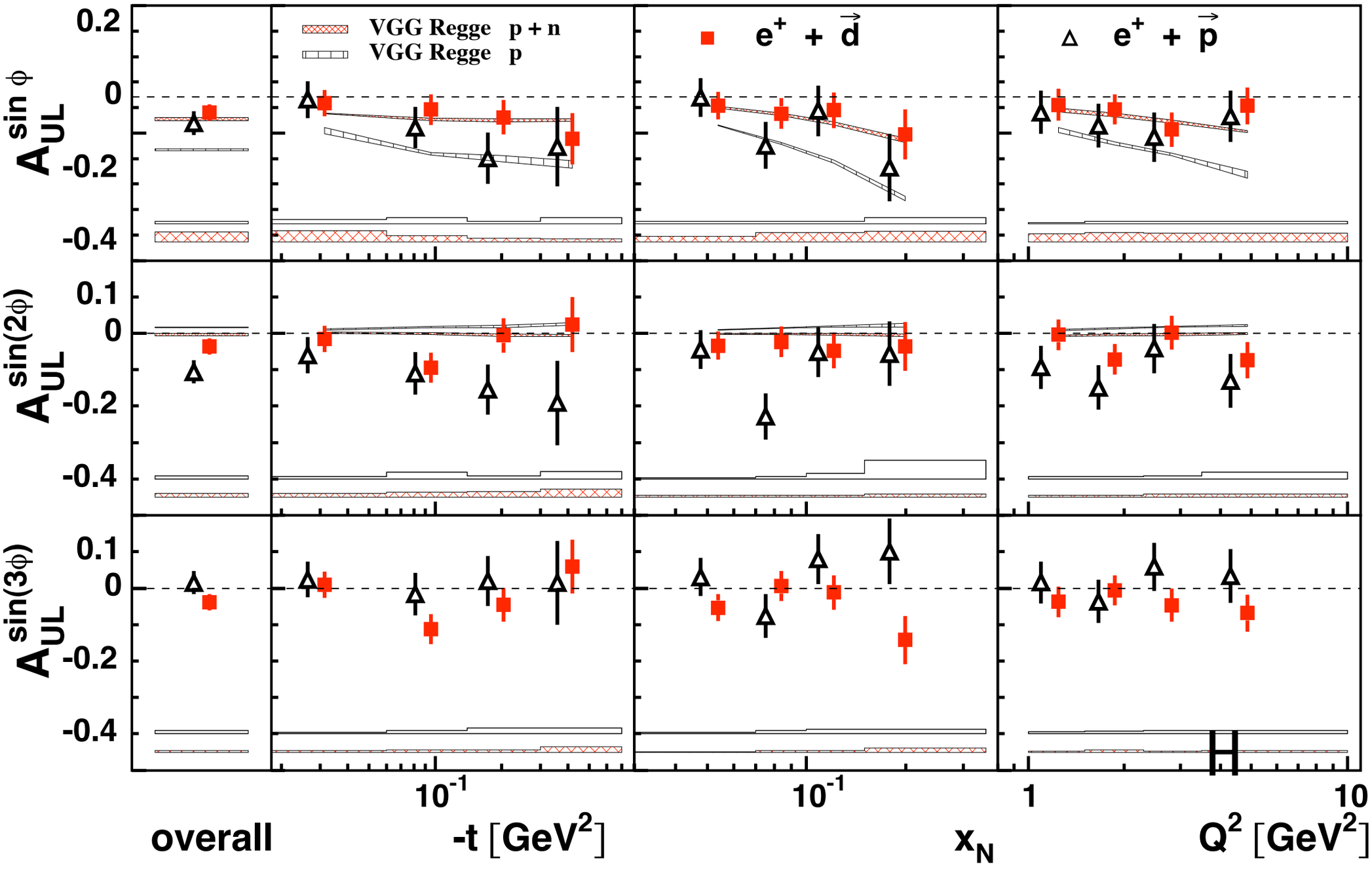
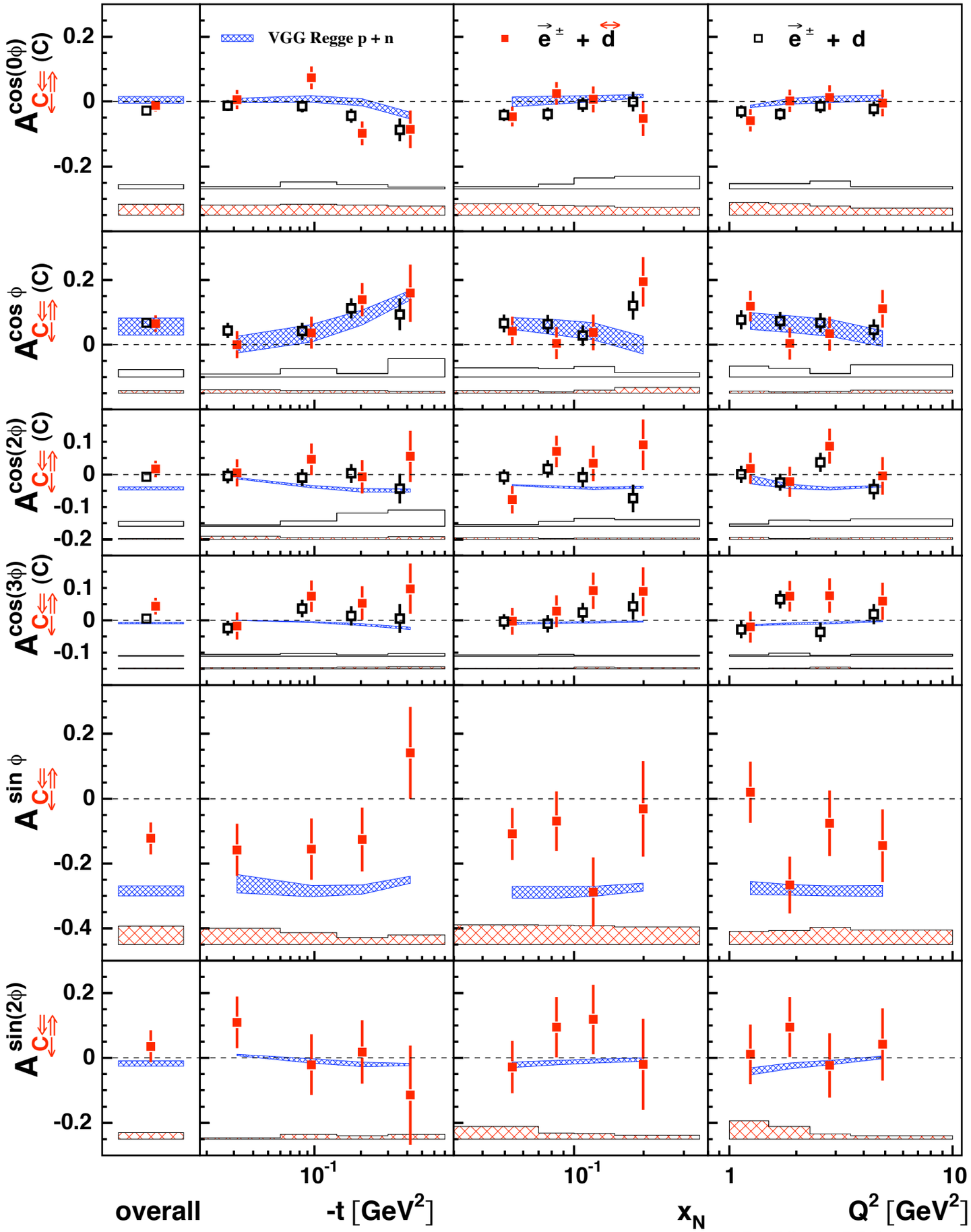


Beam-charge asymmetry on (un)polarized D



- H_1
- $H_1 - \frac{1}{3}H_5$

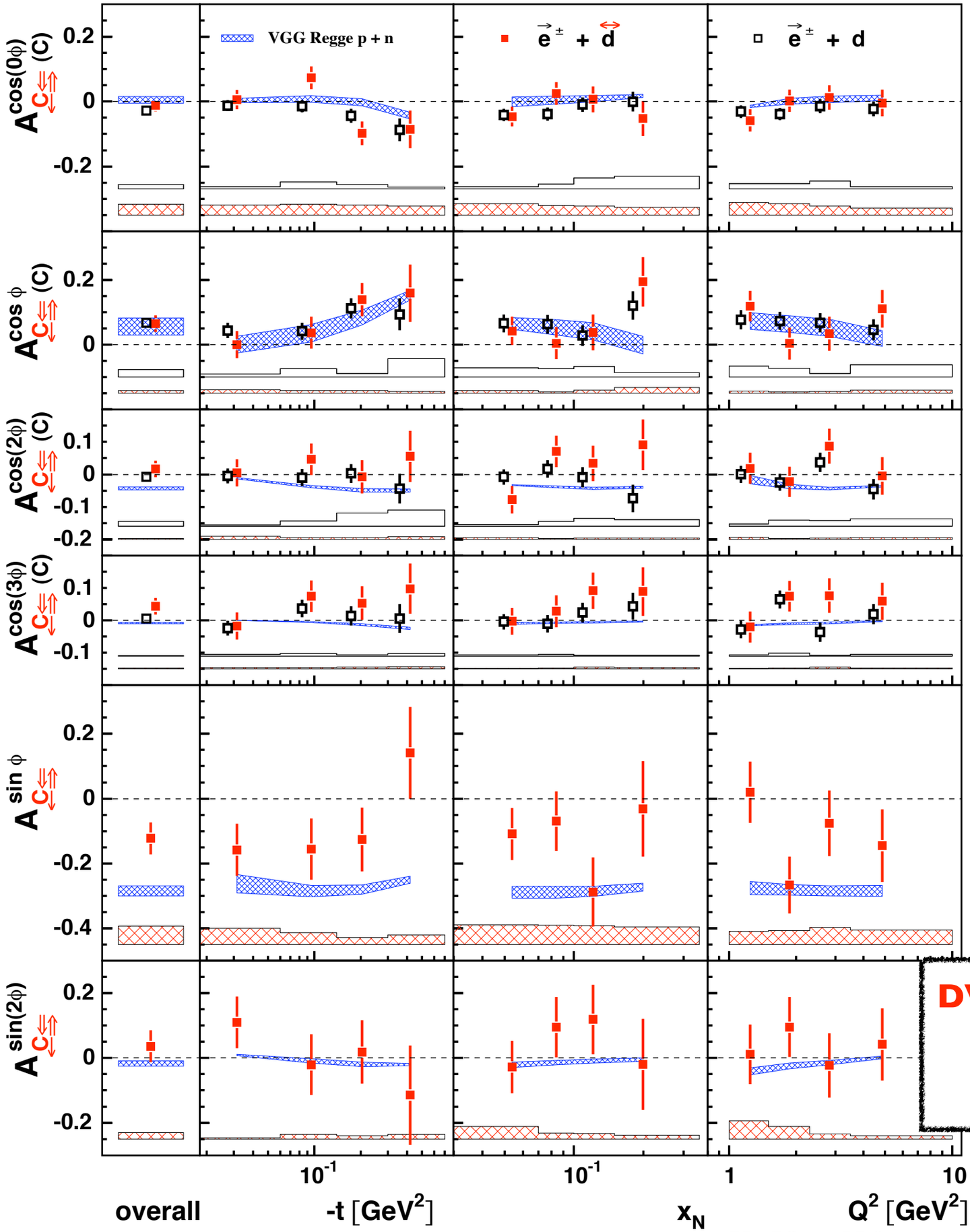
for coherent scattering

Search for tensor signature

Publication: accepted by Nucl. Phys. B

Measurement of azimuthal asymmetries associated with deeply virtual Compton scattering on a longitudinally polarized deuterium target

Beam-charge asymmetry on (un)polarized D



- H_1
- $H_1 - \frac{1}{3}H_5$

for coherent scattering

Search for tensor signature

DVCS $\mathcal{A}_{LZZ}$ sinϕ amplitude:

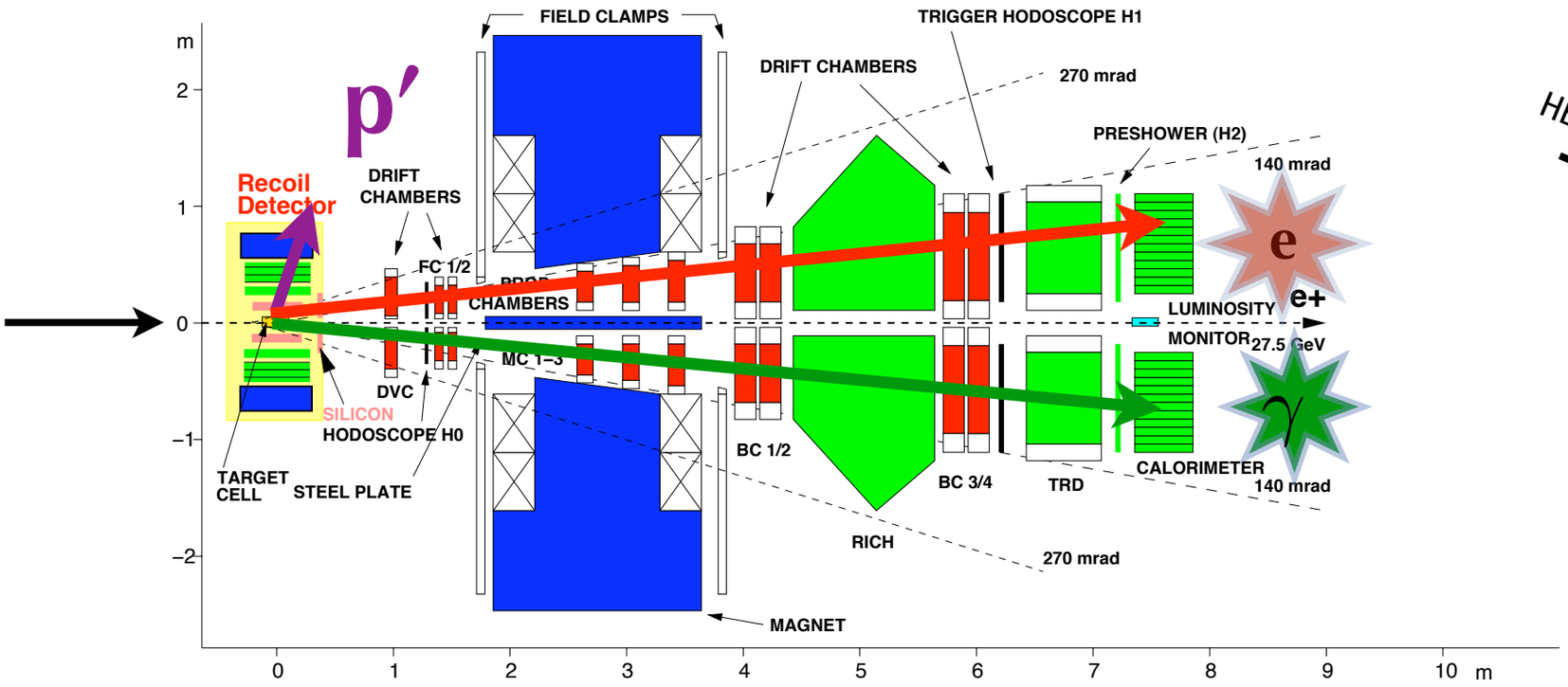
0.074 ± 0.196 ± 0.022

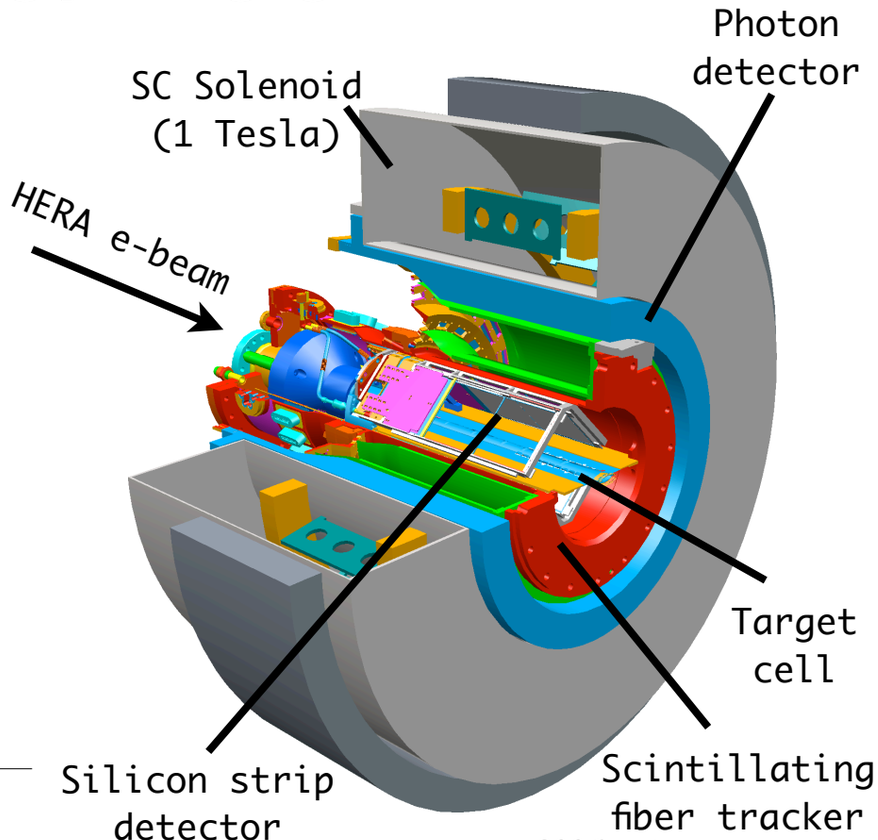
(-t<0.06 GeV², 40% coherent)

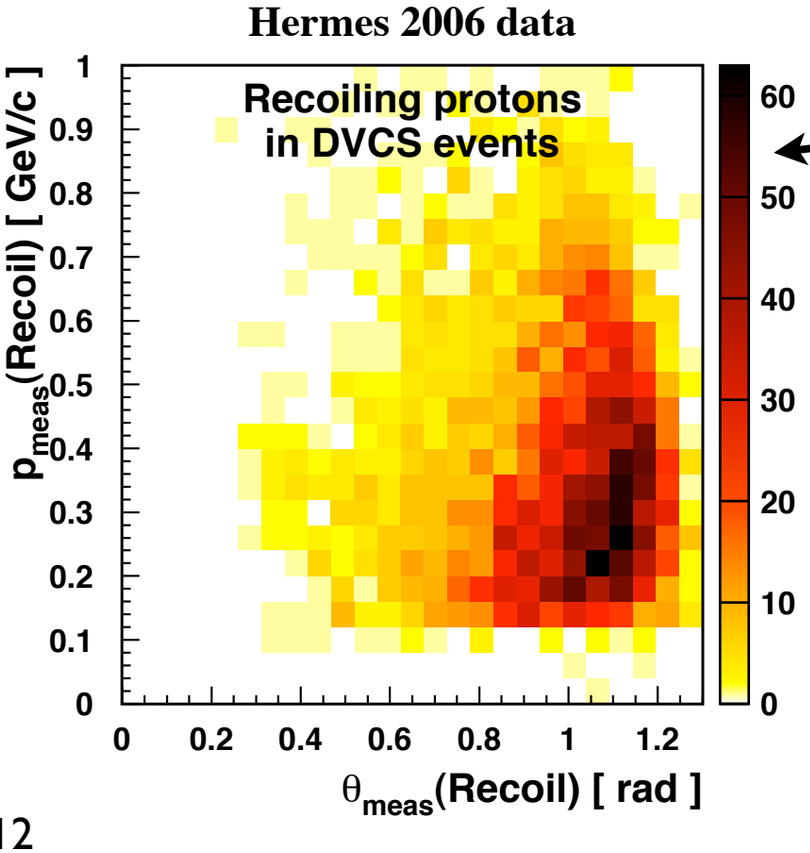
Publication: accepted by Nucl. Phys. B

Measurement of azimuthal asymmetries associated with deeply virtual Compton scattering on a longitudinally polarized deuterium target

Recoil Detector 2006/2007



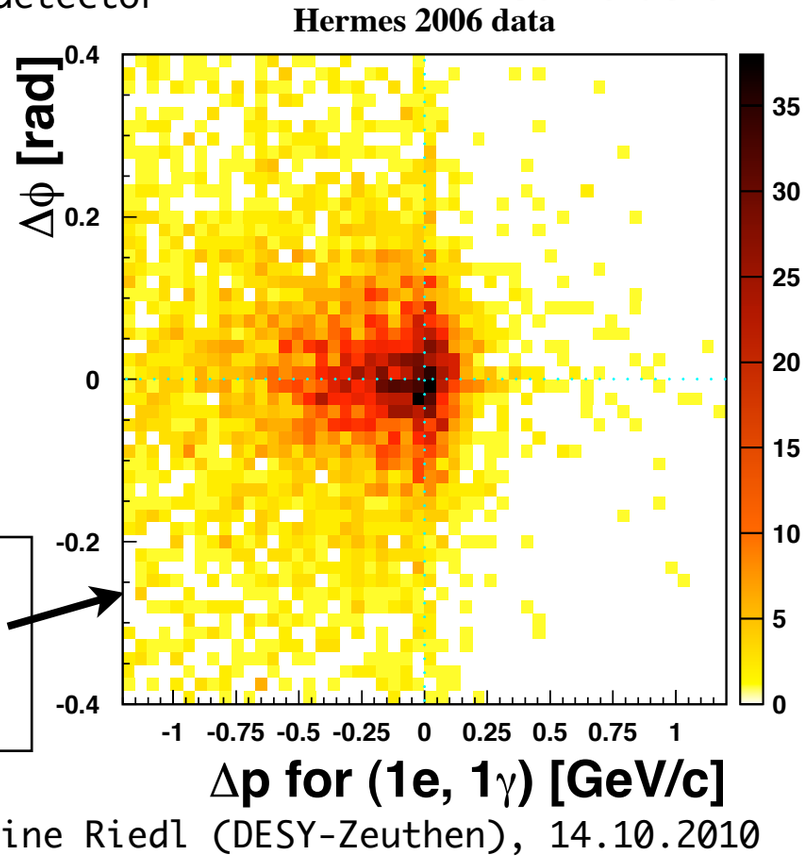




p-θ-distribution of recoiling protons

2006 data

Correlation between measured and expected momentum and ϕ-angle

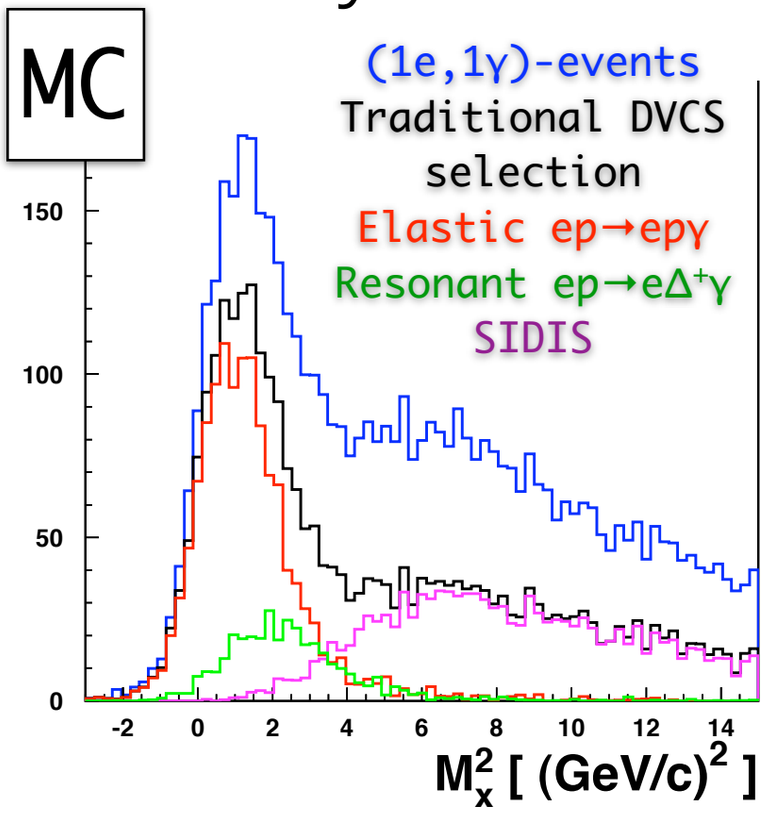


Kinematic Fitting for DVCS

- Event reconstruction: all 3 particles detected
- Test hypothesis by χ^2-analysis
  - n=9 kinematic parameters
  - 4 constraints C_j: 4-momentum conservation assuming proton mass
  - Measurement errors σ_i from Monte Carlo

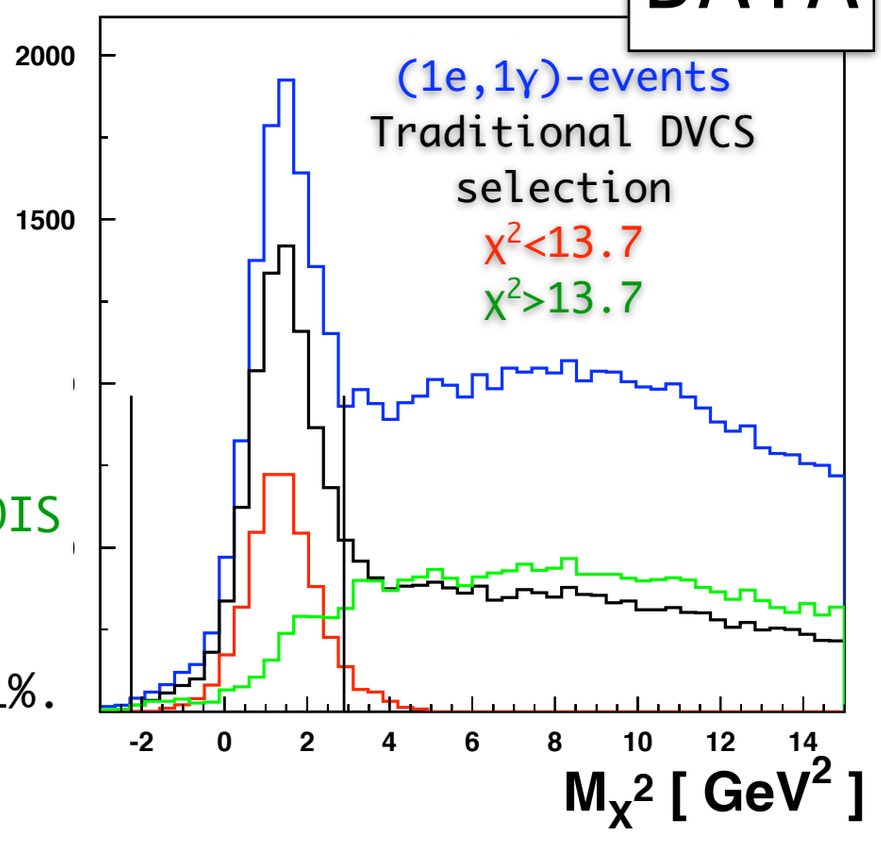
$$\chi^2 = \sum_{i=0}^{n-1} (par_i^{fit} - par_i^{meas})^2 / \sigma_i^2 + T \cdot \sum_{j=0}^{m-1} C_j^2 / \sigma_{cj}^2$$

- If hypothesis correct, improve accuracy of kinematic reconstruction



elastic: purity >99%,
efficiency 84%
"background" =
resonant ⊗ elastic ⊗ SIDIS

χ^2=13.7 ≡
fit probability of 1%.
Cut optimized to
select elastic



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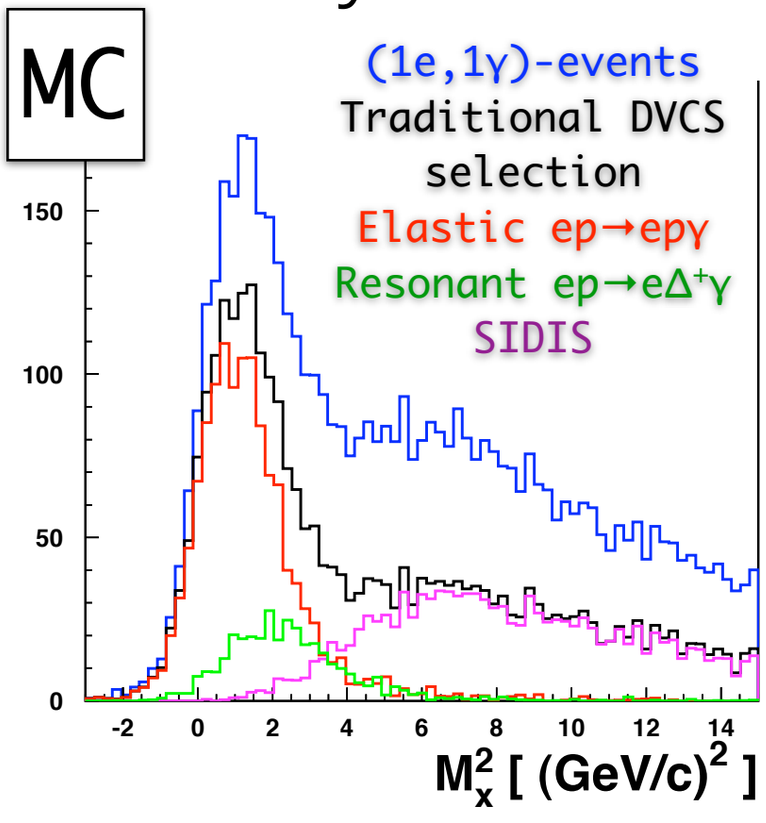

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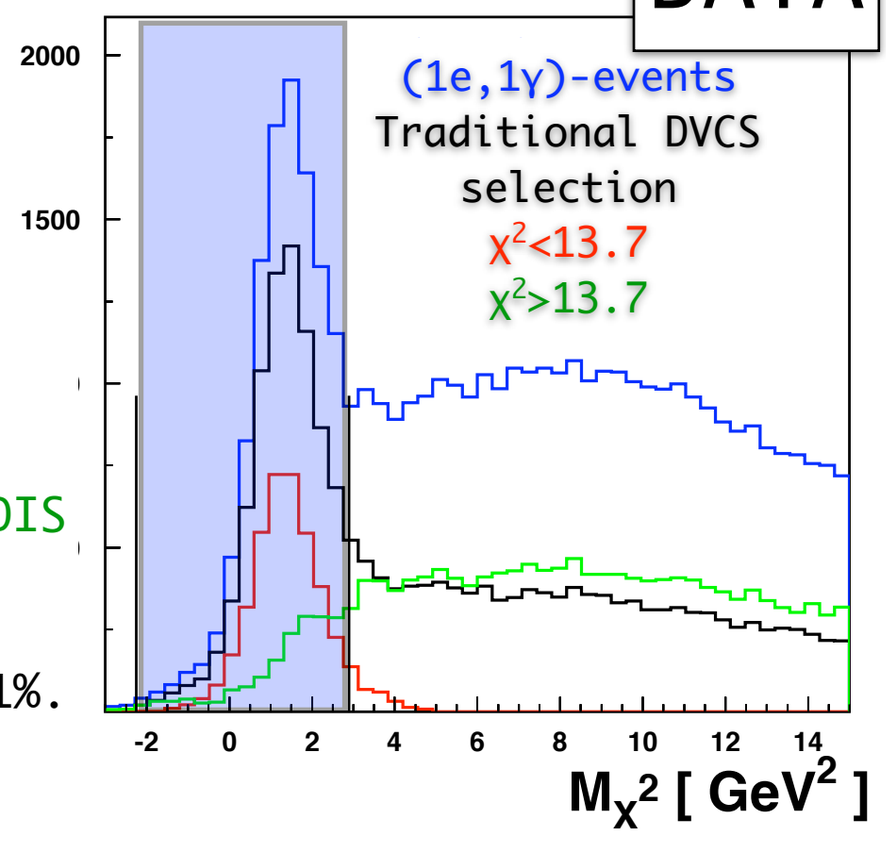


Separation of elastic and background beam-spin asymmetry

- Presently: focus on extracting clean elastic asymmetry

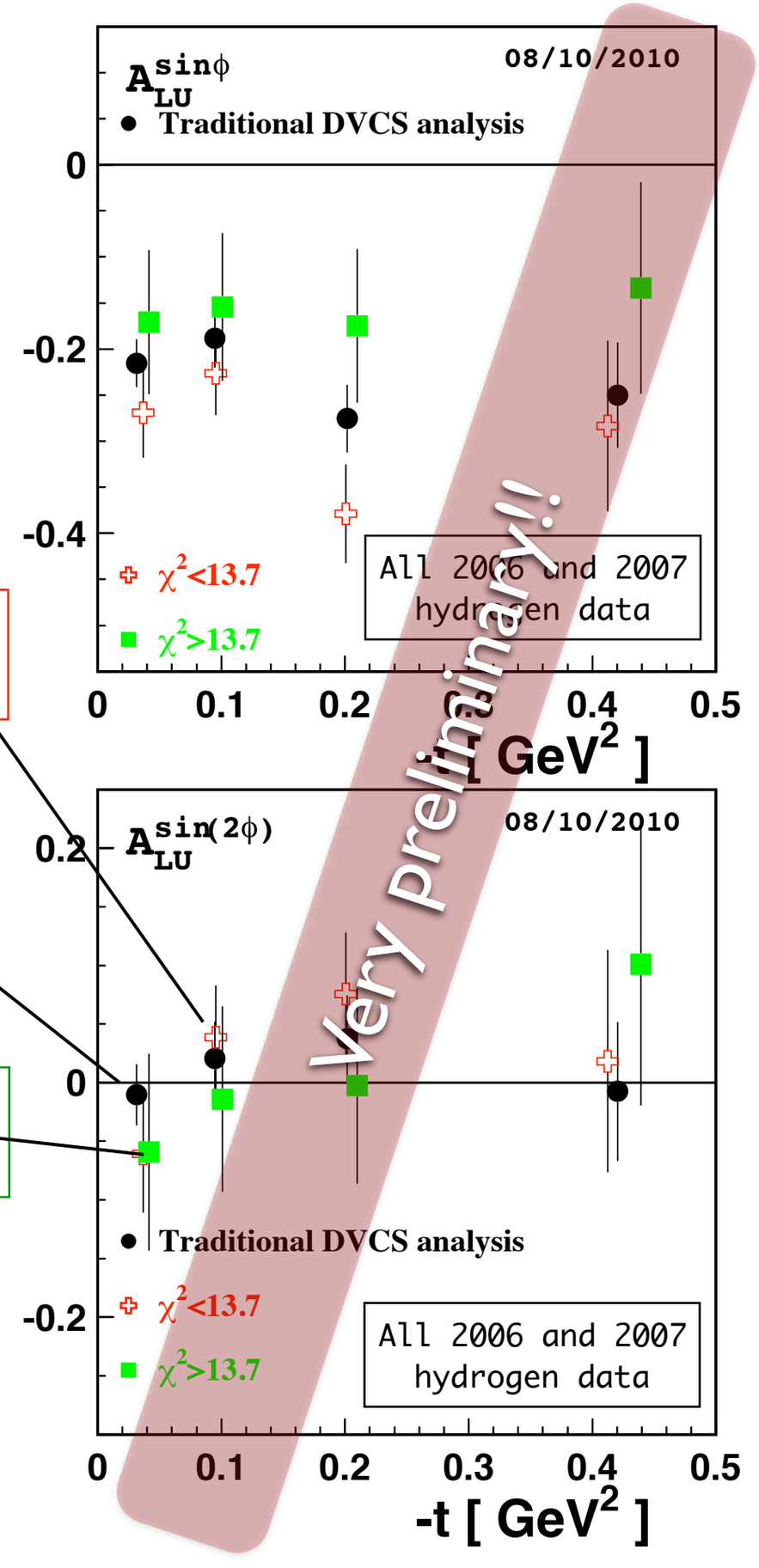
- In parallel, try to understand background asymmetry

- Possible systematic uncertainties:
  Recoil inefficiencies, time dependence of DVCS yield, misalignment of sub-detectors, plus uncertainties from traditional analysis

elastic DVCS amplitude extracted with upper χ^2-cut

DVCS amplitude extracted with all traditional cuts

background amplitude extracted with lower χ^2-cut



Summary: HERMES

- In 2010:
  9 publications in journals + 5 new preliminary results.
  4 papers in circulation of the collaboration,
  10 papers in advanced drafting stage.
  11 talks at DIS, 14 talks at SPIN,
  12 invited talks at other major conferences.

- First Recoil detector physics result: beam-spin asymmetry
  More Recoil results planned: SDMEs for vector mesons, tagged structure functions, beam-charge asymmetry, ...

- Collaboration still actively meeting in Hamburg,
  2-3 collaboration meetings / year,
  3-4 analysis- + drafting weeks / year

- Main focus of scientific effort slowly moves towards paper writing

- Data Preservation: see talk by David South