

Report from HERMES

Achim Hillenbrand
(*DESY Zeuthen*)

for the  collaboration

69. DESY PRC Meeting, April 29th, 2010

Longitudinal Spin/
Momentum Structure,
Hadronization

Transverse Spin/
Momentum Structure

DVCS

Transversity
TMDs

GPDs
“Nucleon
Tomography”

hermes

Strange-Baryon
Production

Exclusive Meson
Production

Publications since the last PRC

- 5 papers published (accepted for publication)

- ▶ Nuclear-mass dependence of beam-helicity and beam-charge azimuthal asymmetries in DVCS, *Phys. Rev. C* 81 (2010) 035202, arXiv:0911.0091 (hep-ex) and DESY-09-190

DVCS

- ▶ Measurement of azimuthal asymmetries associated with deeply virtual Compton scattering on an unpolarized deuterium target, *Nucl. Phys. B* 829 (2010) 1-27, arXiv:0911.0095 (hep-ex) and DESY-09-189

DVCS

- ▶ Transverse momentum broadening of hadrons produced in semi-inclusive deep-inelastic scattering on nuclei, *Phys. Lett. B* 684 (2010) 114-118, arXiv:0906.2478 (hep-ex) and DESY-09-082

Hadronization

- ▶ Search for a Two-Photon Exchange Contribution to Inclusive Deep-Inelastic Scattering, *Phys. Lett. B* 682 (2010) 351-354, arXiv:0907.5369 and DESY 09-117

transverse spin

- ▶ Single-spin azimuthal asymmetry in exclusive electroproduction of π^+ mesons on transversely polarized protons, *Phys. Lett. B* 682 (2010) 345-350, arXiv:0907.2596 and DESY 09-106

Exclusive mesons

- 2 papers submitted to journals

- ▶ Leading Order Determination of the Gluon Polarization from high- p_T Hadron Electroproduction, submitted to *JHEP*, arXiv:1002.3921 (hep-ex) and DESY-10-021

longitudinal spin

- ▶ Exclusive Leptoproduction of Real Photons on a Longitudinally Polarised Hydrogen target, submitted to *JHEP*, arXiv:1004.0177 (hep-ex) and DESY-10-046

DVCS

- 5 papers near submission

Preliminary results since last PRC

- 6 preliminary results since November 2009:
 - ▶ 2D dependence of nuclear attenuation
 - ▶ DVCS off a longitudinally polarized deuterium target
 - ▶ DVCS on a hydrogen target (2006/2007 data)
 - ▶ Transverse single-spin asymmetry A_{UT} of inclusive hadrons
 - ▶ Measurement of azimuthal asymmetries in the unpolarized cross-section for pions
 - ▶ Longitudinal spin transfer in semi-inclusive Λ production

Longitudinal Spin/
Momentum Structure,
Hadronization

Transverse Spin/
Momentum Structure

DVCS

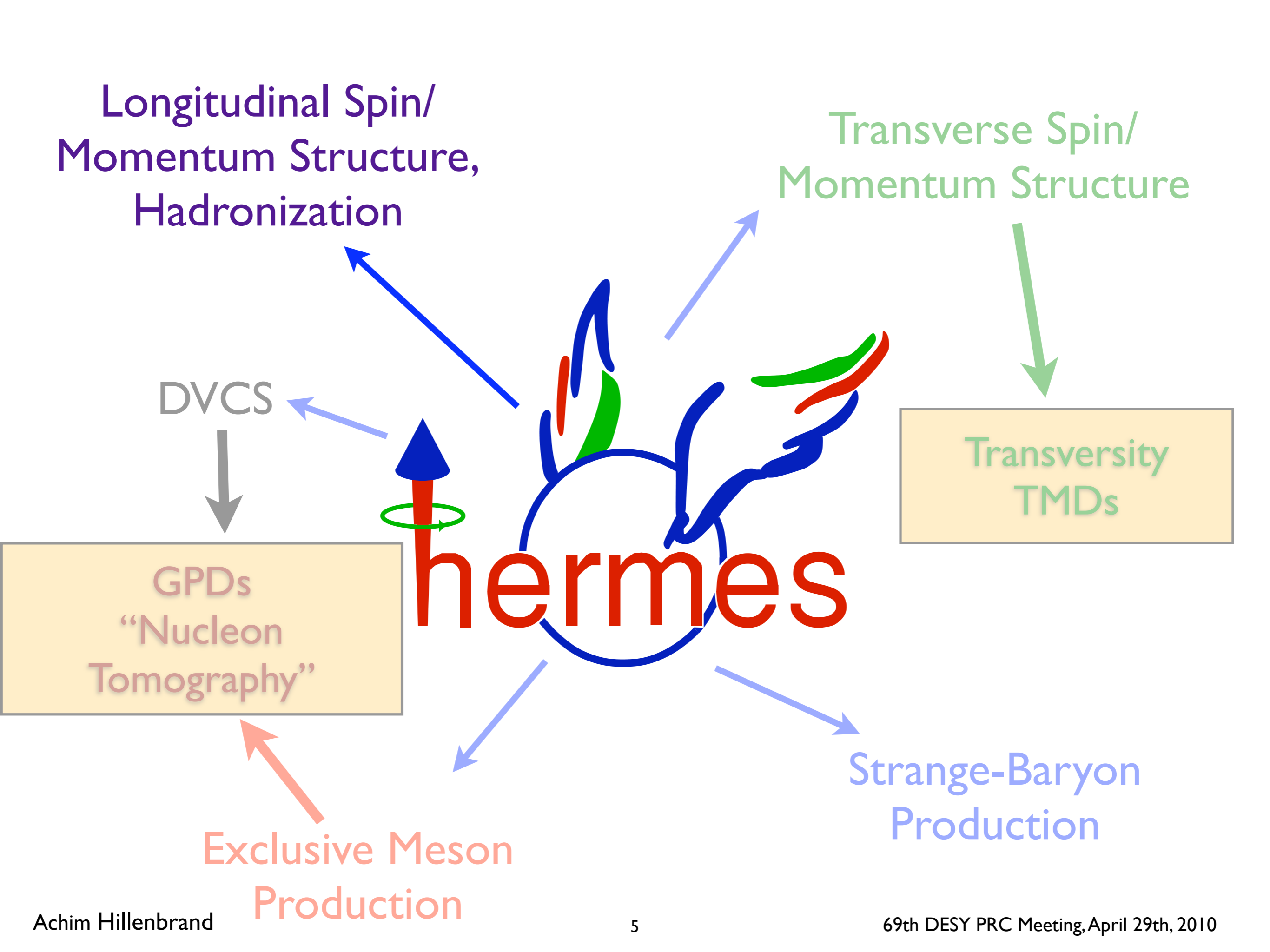
Transversity
TMDs

GPDs
“Nucleon
Tomography”

hermes

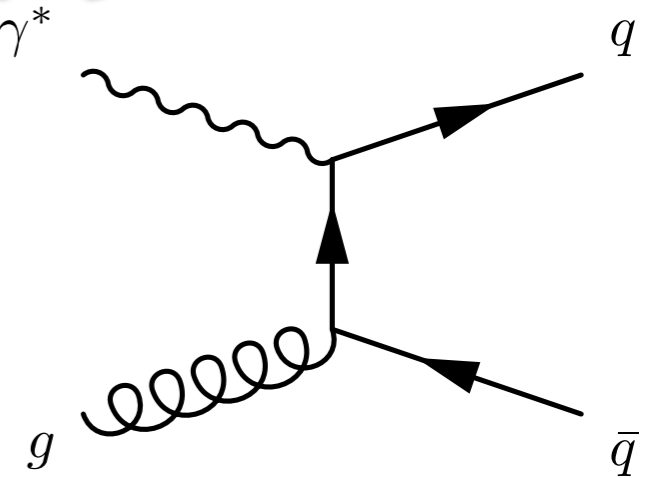
Strange-Baryon
Production

Exclusive Meson
Production

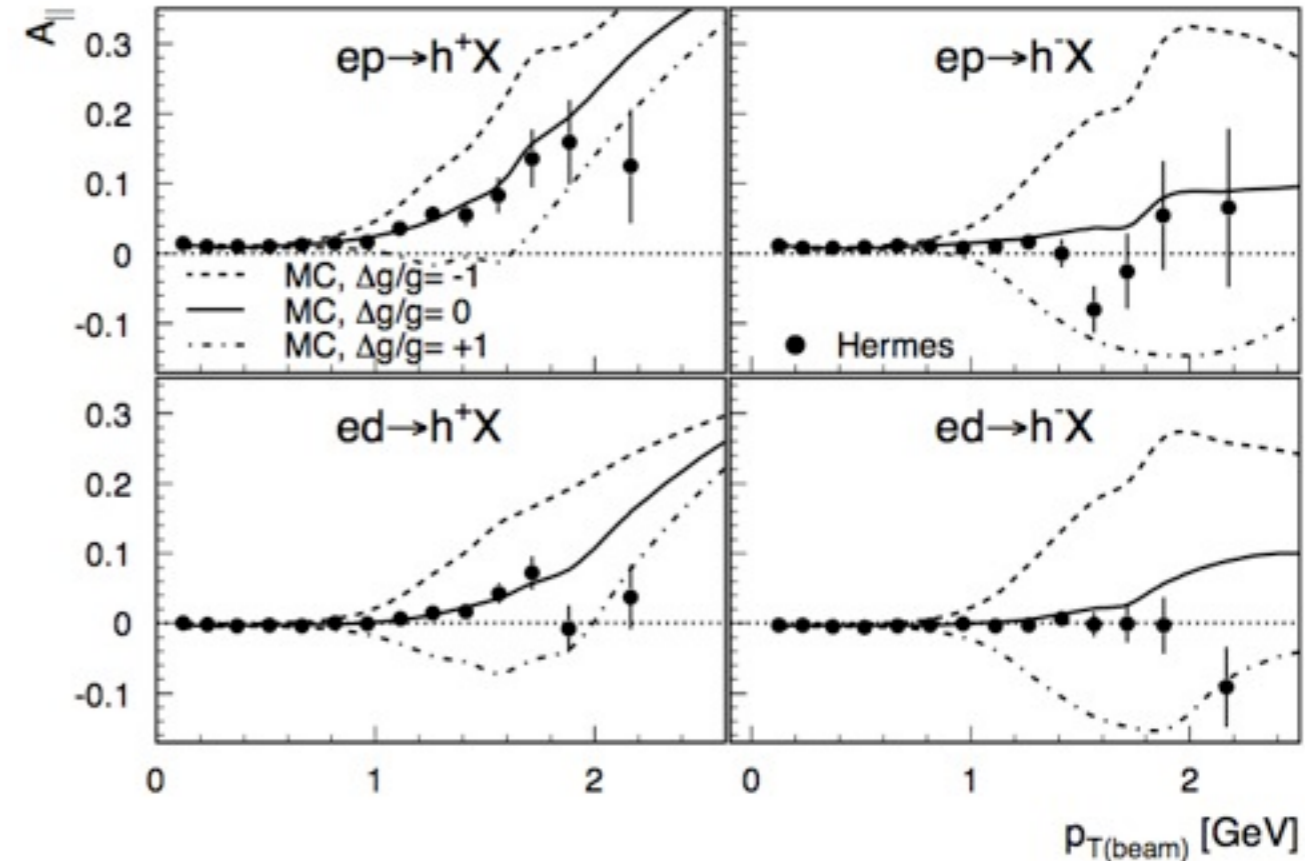


Measurement of $\Delta g/g$ (I)

- based on measurement of **longitudinal double spin asymmetries** of **charged hadrons** with **high transverse momentum** ($p_t > 1 \text{ GeV}$)

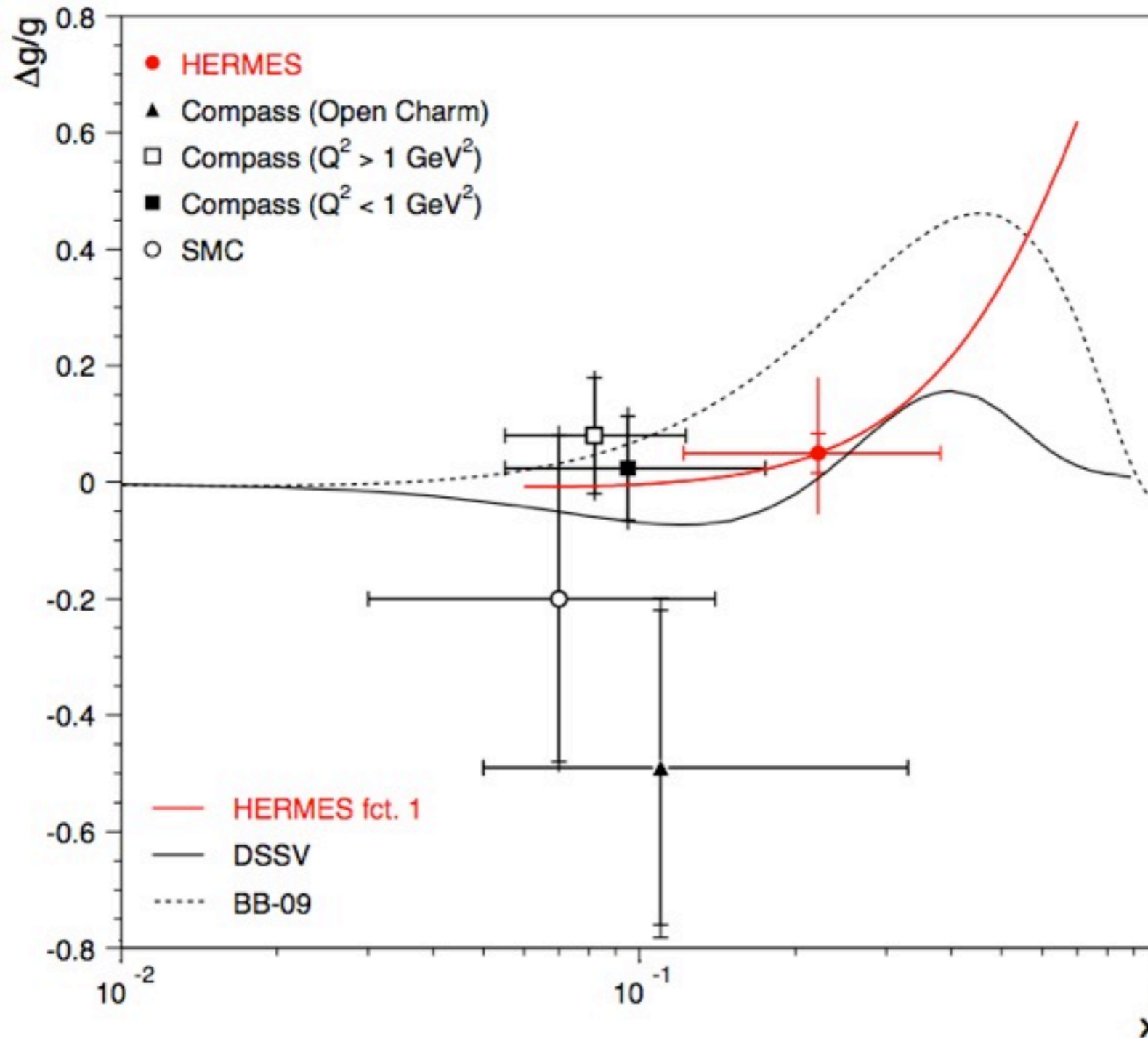


enhances processes with gluons in the initial state (photon-gluon fusion)



- use LO PYTHIA MC model to calculate **subprocess fractions**, **asymmetries and kinematics** for the **signal and background processes**

Measurement of $\Delta g/g$ (II)



- world data on $\Delta g/g$ from leptonprod.
- different scales of Q^2 !

arXiv:1002.3921 (hep-ex)
and DESY-10-021



$$\langle x \rangle = 0.22$$

$$\langle \mu^2 \rangle = 1.35 \text{ GeV}^2$$

$$\Delta g/g(x, \mu^2) = 0.049 \pm 0.034(\text{stat}) \pm 0.010(\text{sys} - \text{exp}) \begin{matrix} +0.126 \\ -0.099 \end{matrix} (\text{sys} - \text{models})$$

Longitudinal Spin/
Momentum Structure,
Hadronization

Transverse Spin/
Momentum Structure

DVCS

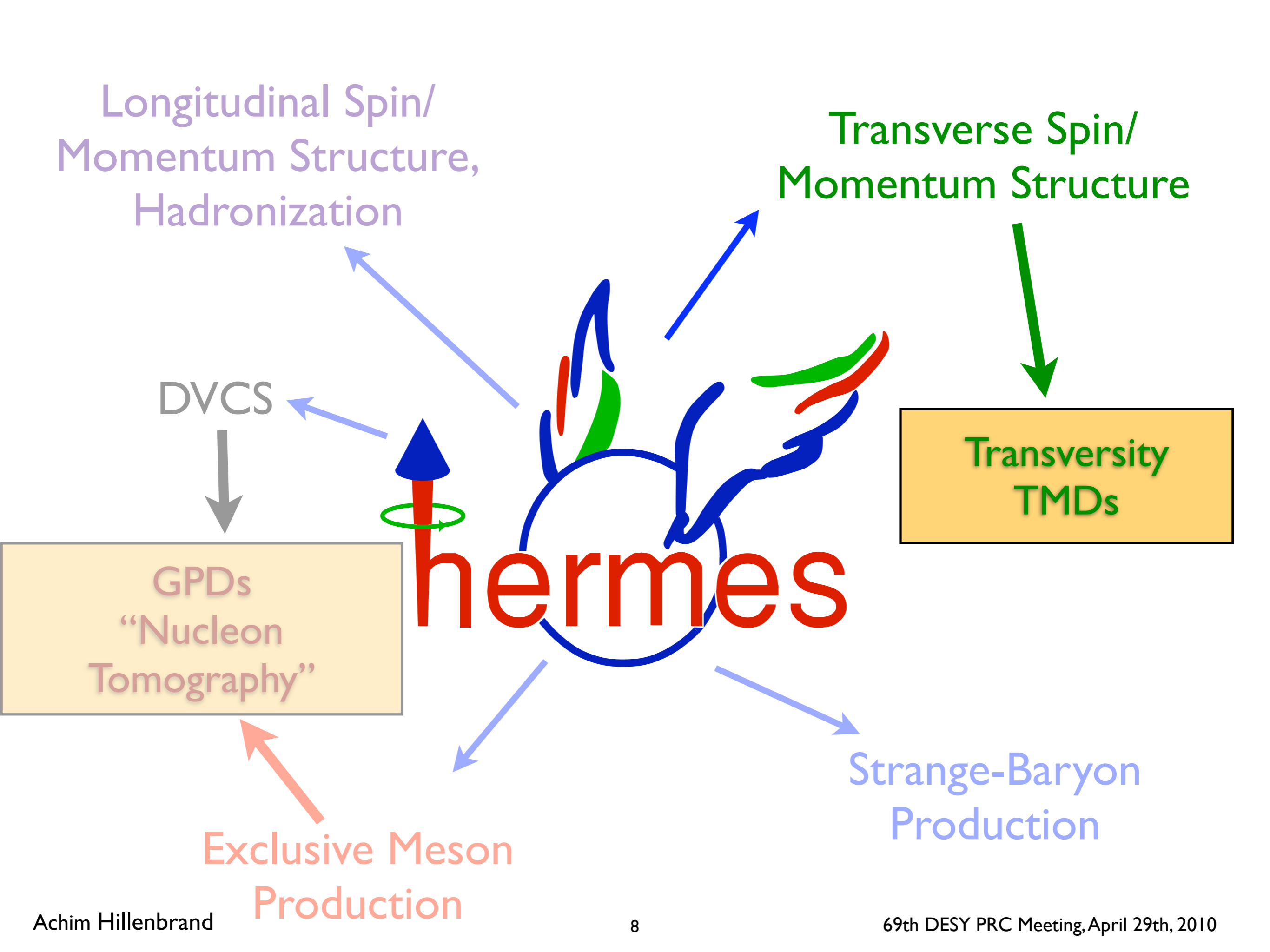
Transversity
TMDs

GPDs
“Nucleon
Tomography”

hermes

Strange-Baryon
Production

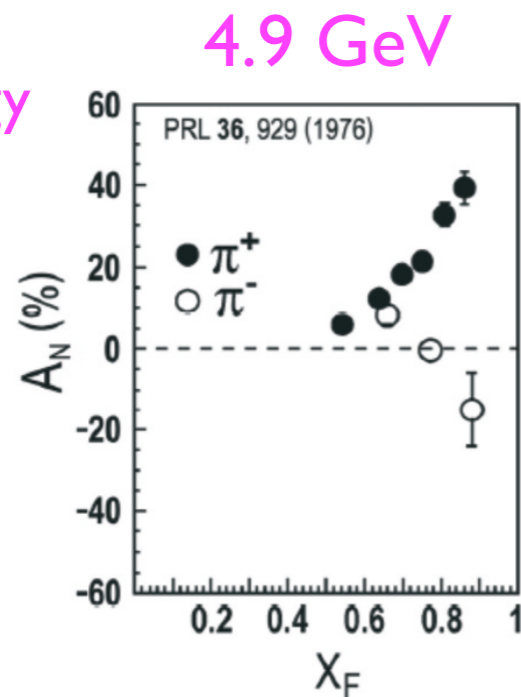
Exclusive Meson
Production



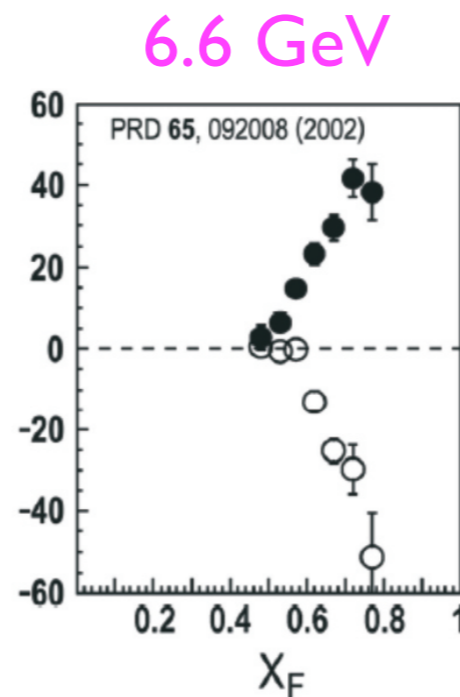
Transverse single-spin asymmetry of inclusive hadrons (I)

- Background: clear **non-zero left-right asymmetry** A_N measured in **inclusive pion production in $p^\uparrow p$ collisions**:

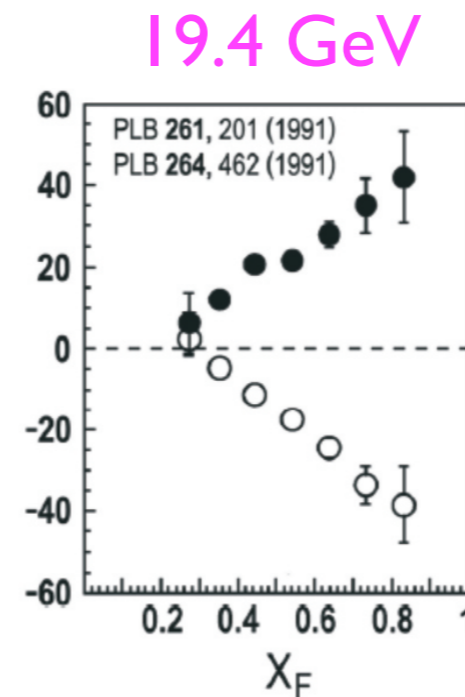
center-of-mass energy



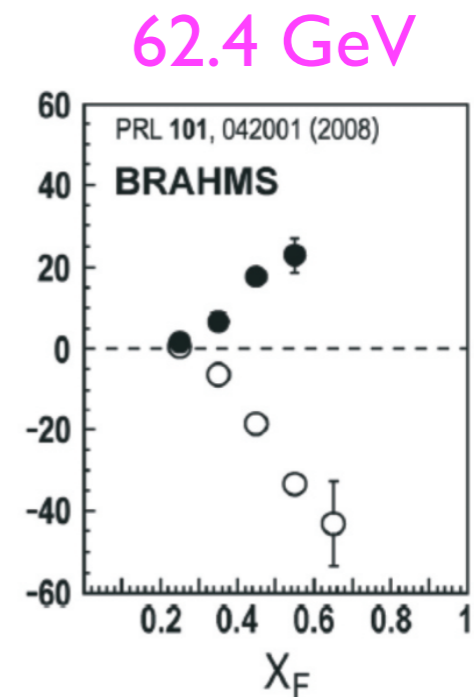
1976



2002



1991

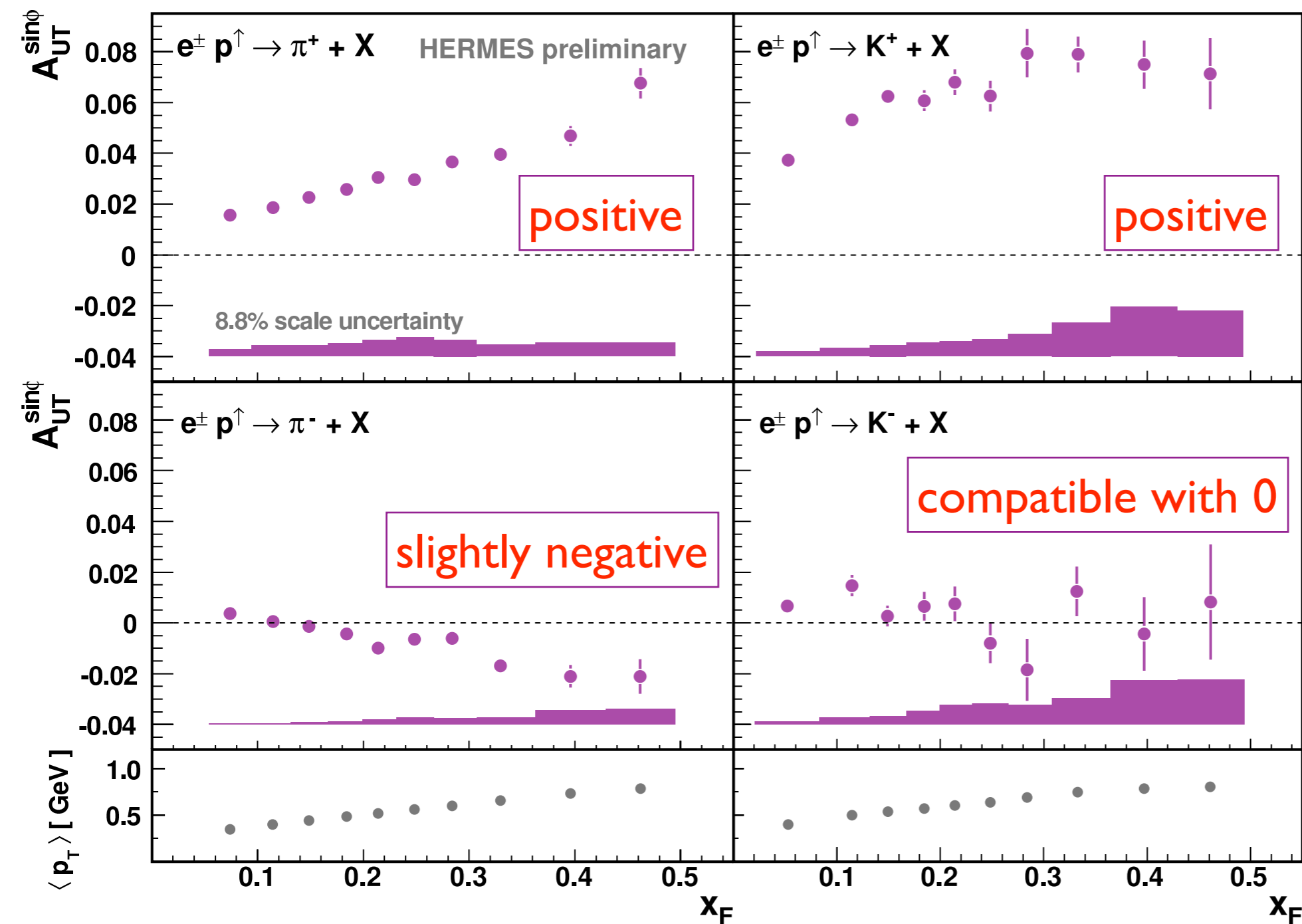


2008

Transverse single-spin asymmetry of inclusive hadrons (I)

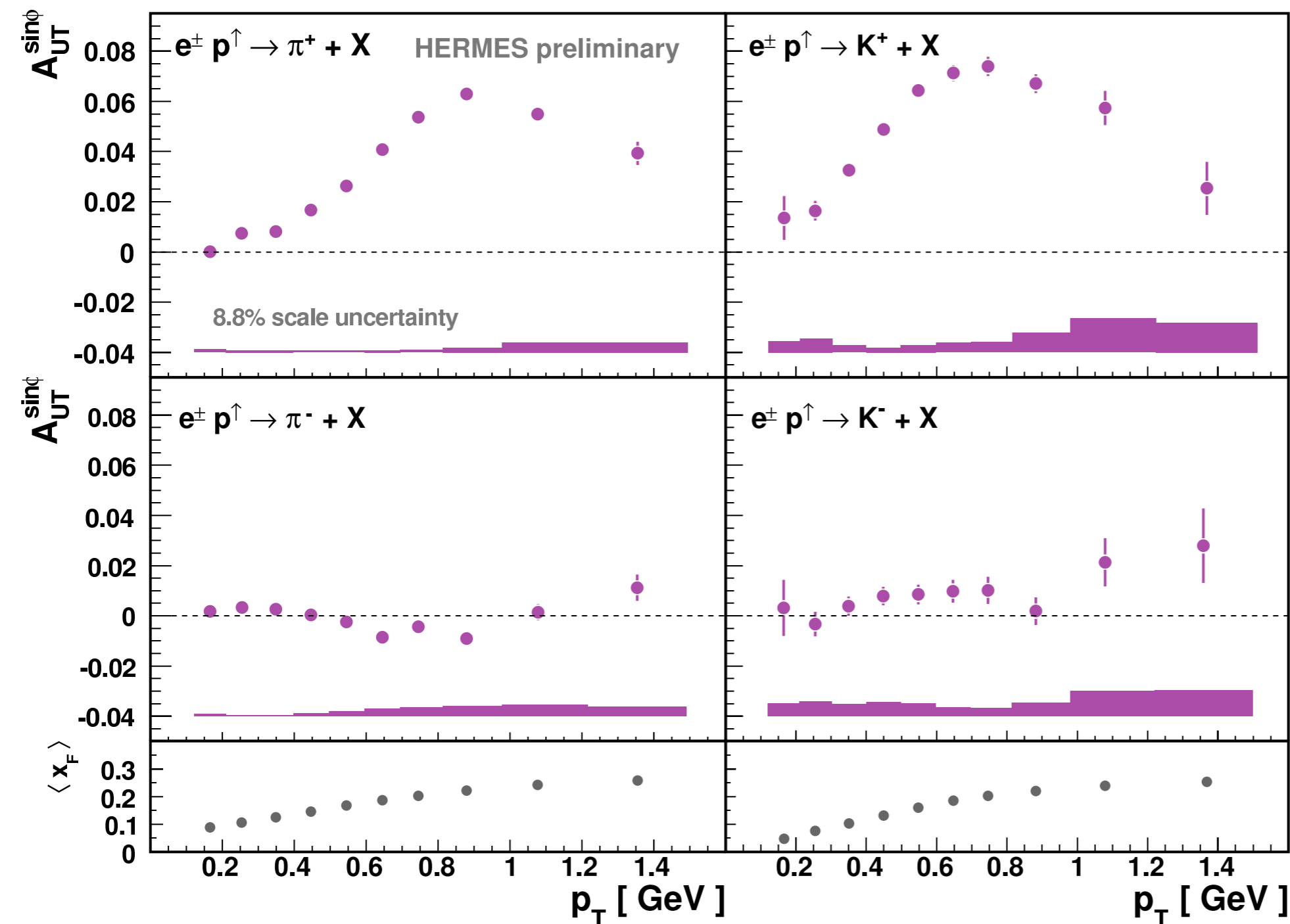
- Production mechanism \Rightarrow 2 models:
 - ▶ TMDs: Sivers effect
correlation between intrinsic k_t and transverse nucleon spin
 - ▶ Collinear approach (higher twist)
- Prediction: $A_N \rightarrow 0$ for high p_t and for $p_t \rightarrow 0$
- so far: all available data from $p^\uparrow p$ collisions
- HERMES data:
 - ▶ first data on lepton production lp^\uparrow
 - ▶ complimentary to $p^\uparrow p$, cleaner channel (one p quark field)
 - ▶ high statistics (~ 50 Million events)

A_{UT} of incl pions vs x_F



- smaller than for $p^\uparrow p$

A_{UT} of incl pions vs p_t

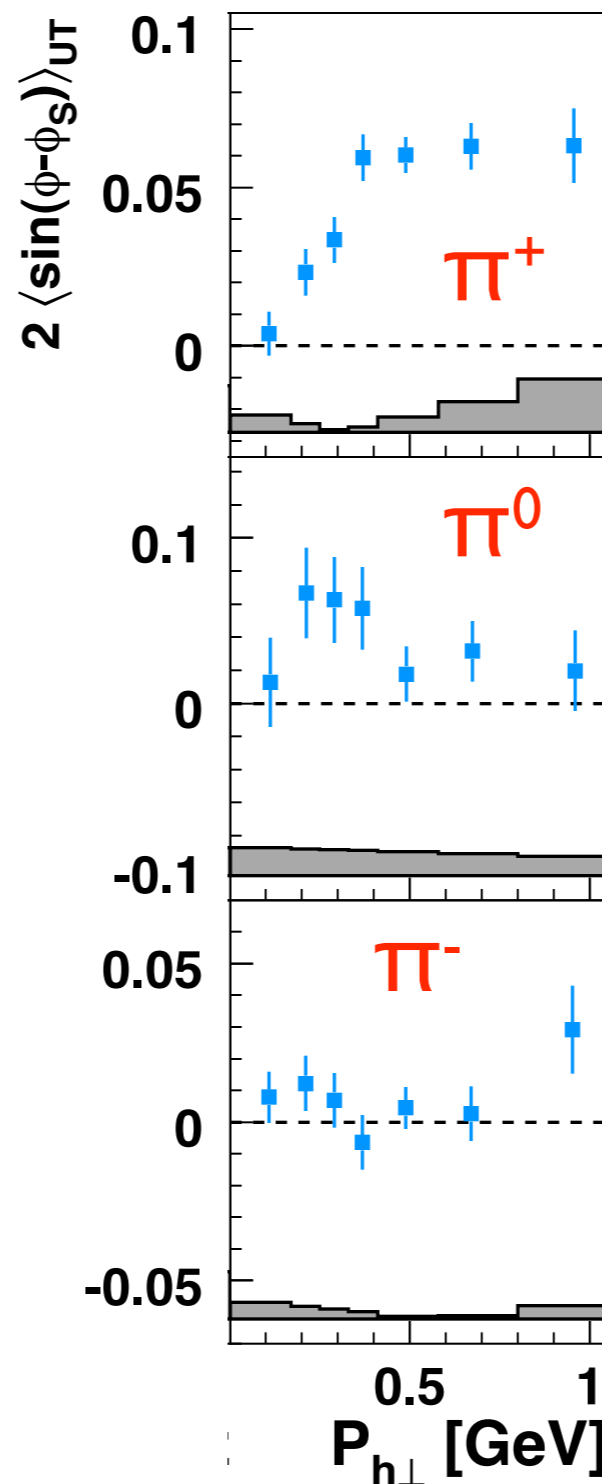
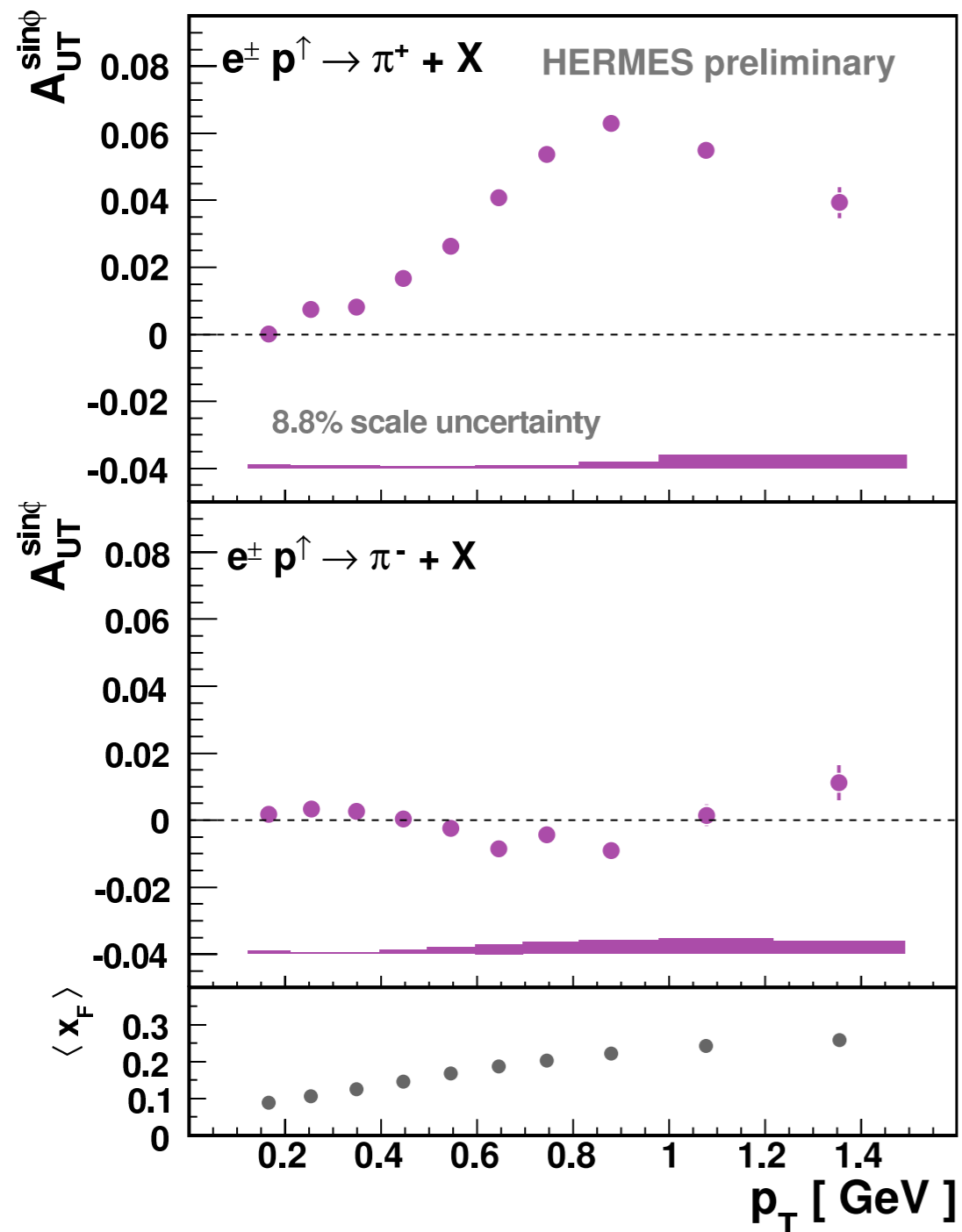


- positive for π^+ and K^+
- small/zero for negative hadrons
- decrease at high p_t

A_{UT} of incl pions vs p_t

A_N

Sivers

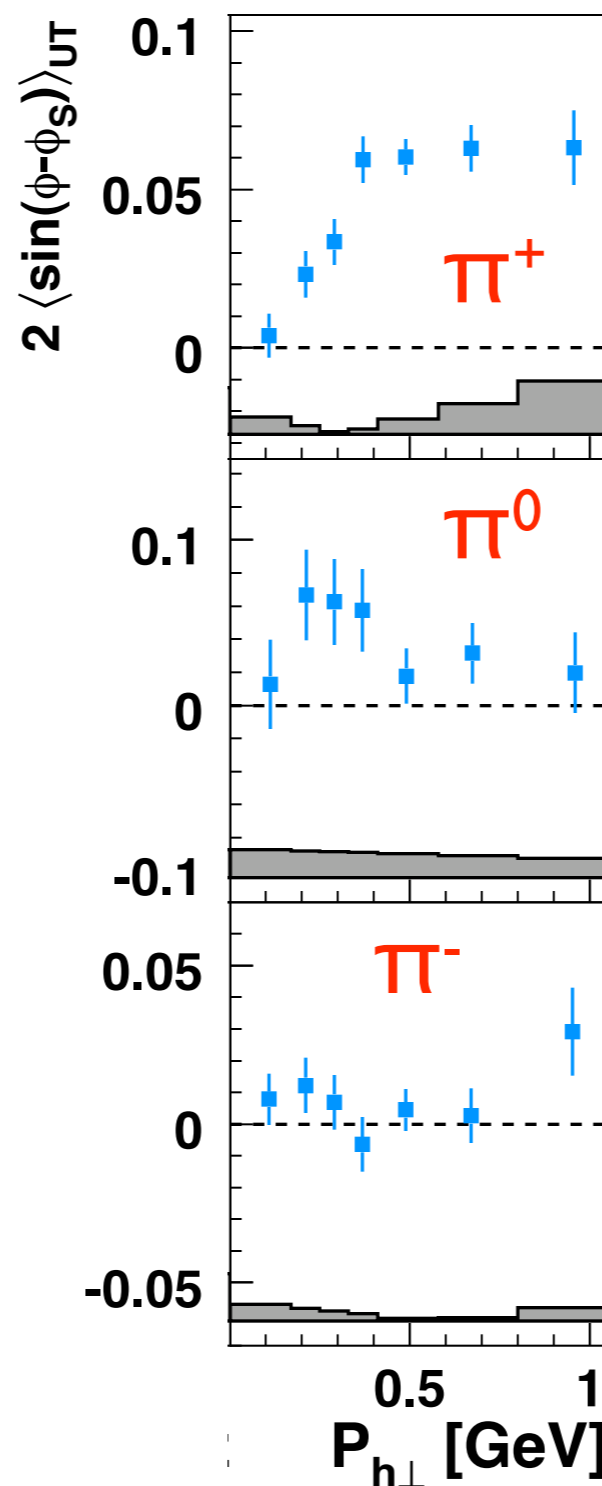
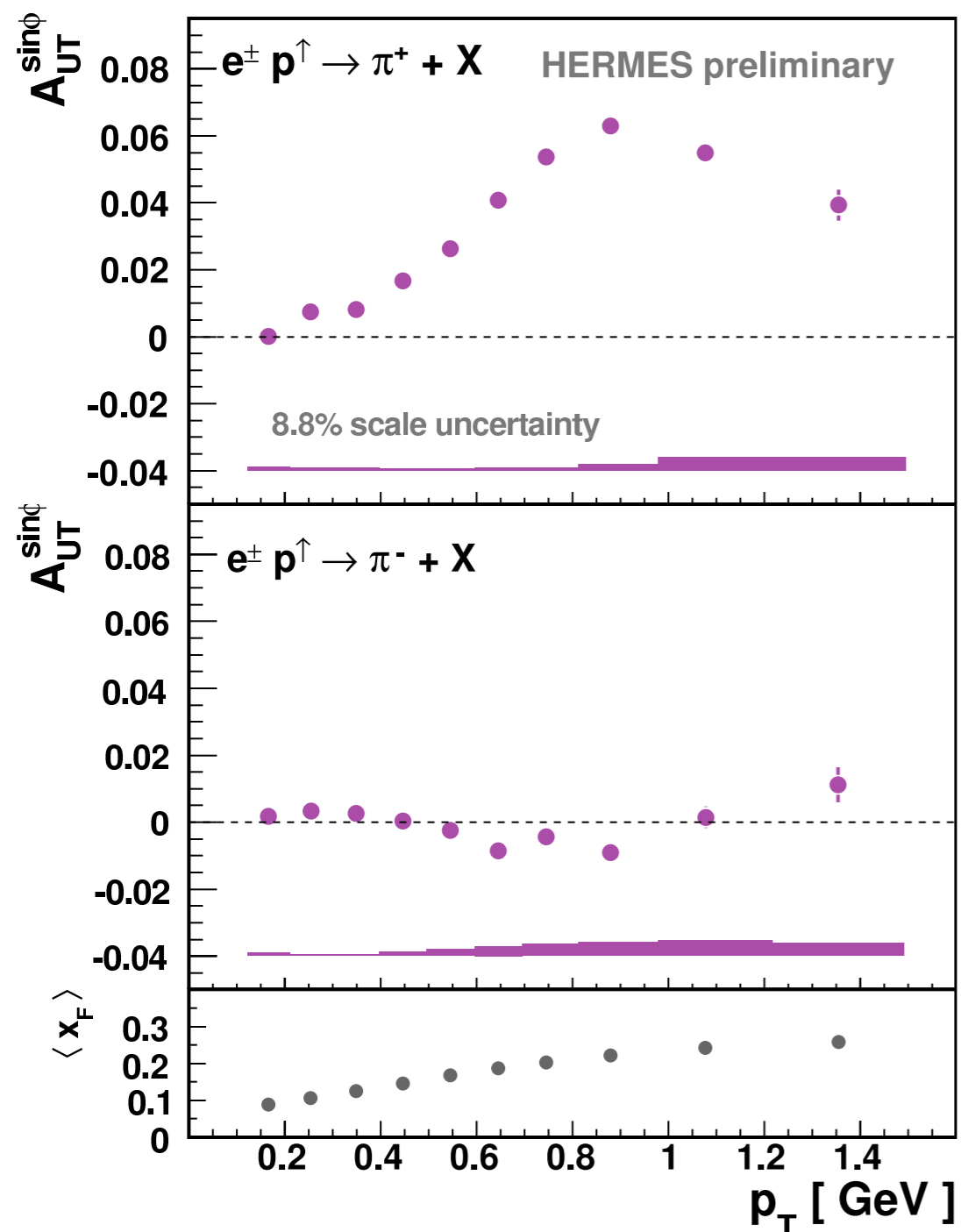


A_N resembles Sivers effect

A_{UT} of incl pions vs p_t

A_N

Sivers



A_N resembles Sivers effect

- Presented at DIS 2010
- First result on lepton production
- Paper drafting in progress

Longitudinal Spin/
Momentum Structure,
Hadronization

Transverse Spin/
Momentum Structure

DVCS

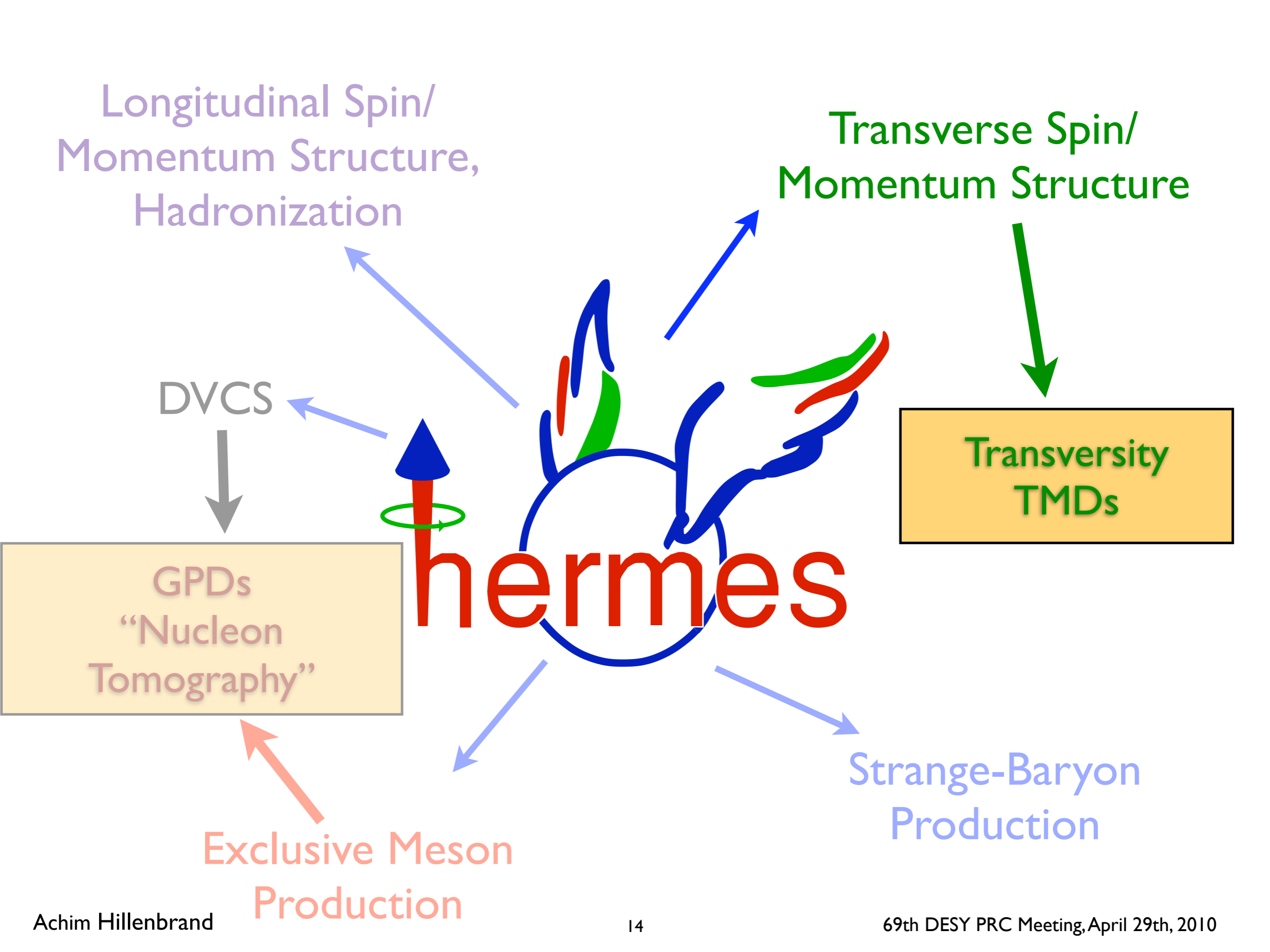
Transversity
TMDs

GPDs
“Nucleon
Tomography”

hermes

Strange-Baryon
Production

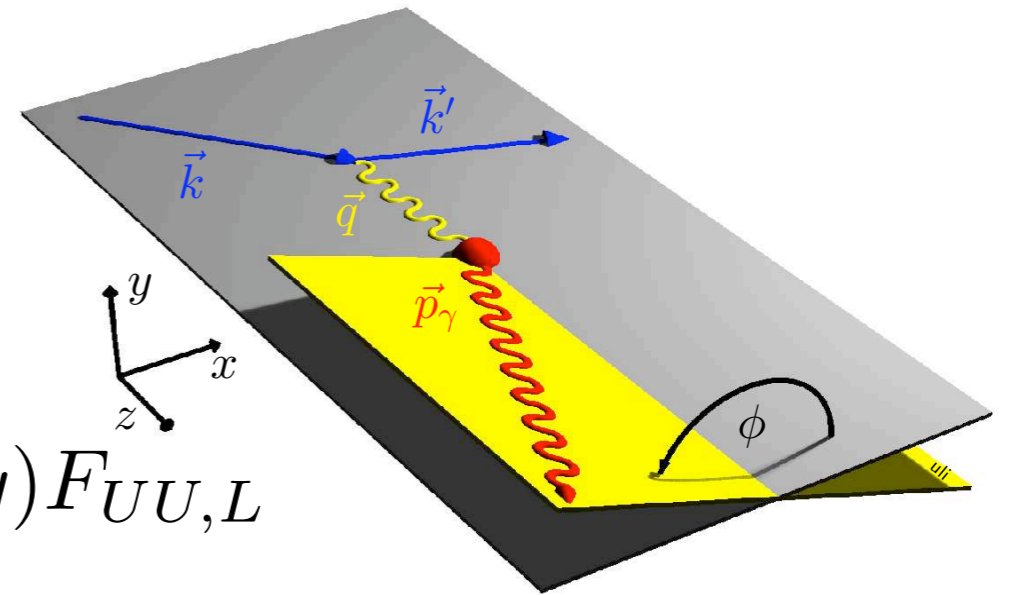
Exclusive Meson
Production



Azimuthal asymmetries in the unpolarized cross section for pions

- Unpolarized semi-inclusive DIS cross section:

$$\frac{d\sigma}{dx dy dz dP_{h\perp}^2 d\phi_h} \propto A(y)F_{UU,T} + B(y)F_{UU,L} + C(y) \cos \phi_h F_{UU}^{\cos \phi_h} + D(y) \cos 2\phi_h F_{UU}^{\cos 2\phi_h}$$



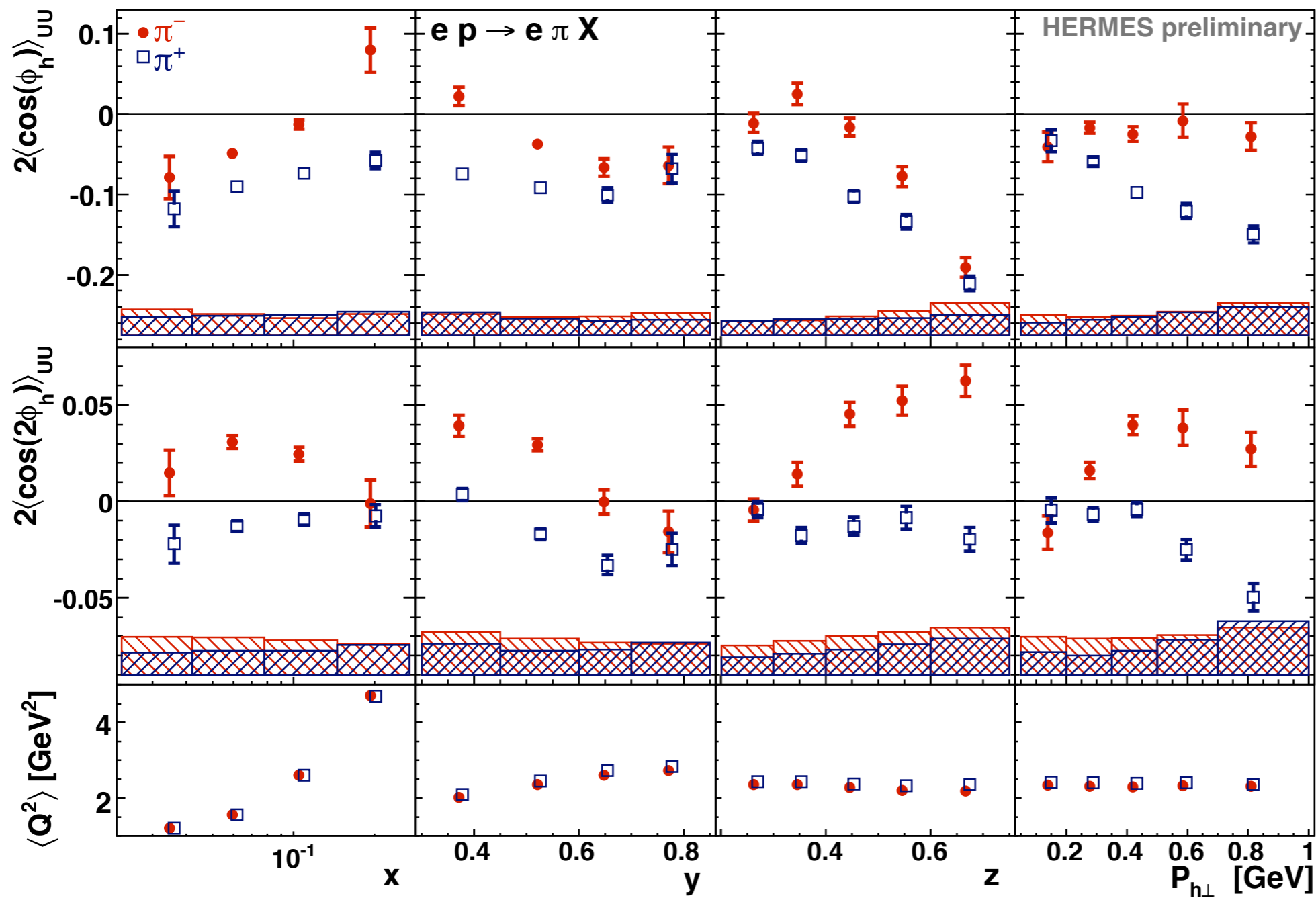
$$F_{UU}^{\cos 2\phi_h}$$

- leading twist
- Boer-Mulders DF \otimes Collins-FF
- generated by coupling of the quark transverse spin to the quark transverse momentum

$$F_{UU}^{\cos \phi_h}$$

- sub-leading twist
- Boer-Mulders DF \otimes Collins-FF + unpol DF \otimes unpol FF (Cahn effect)
- kinematic effect due to non-zero intrinsic quark k_t

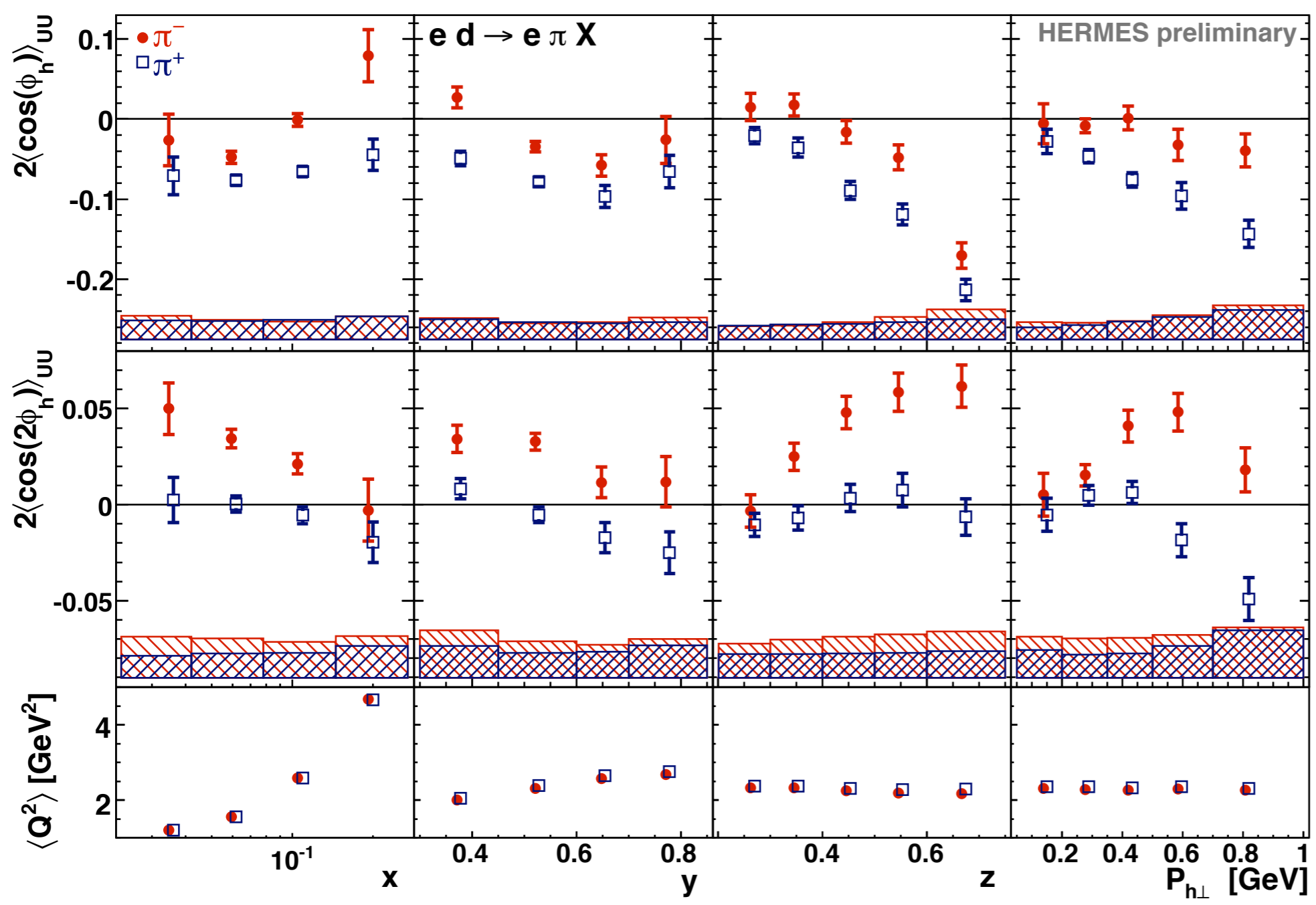
Pion asymmetries (Proton target)



Expands previously (2008) released results by including

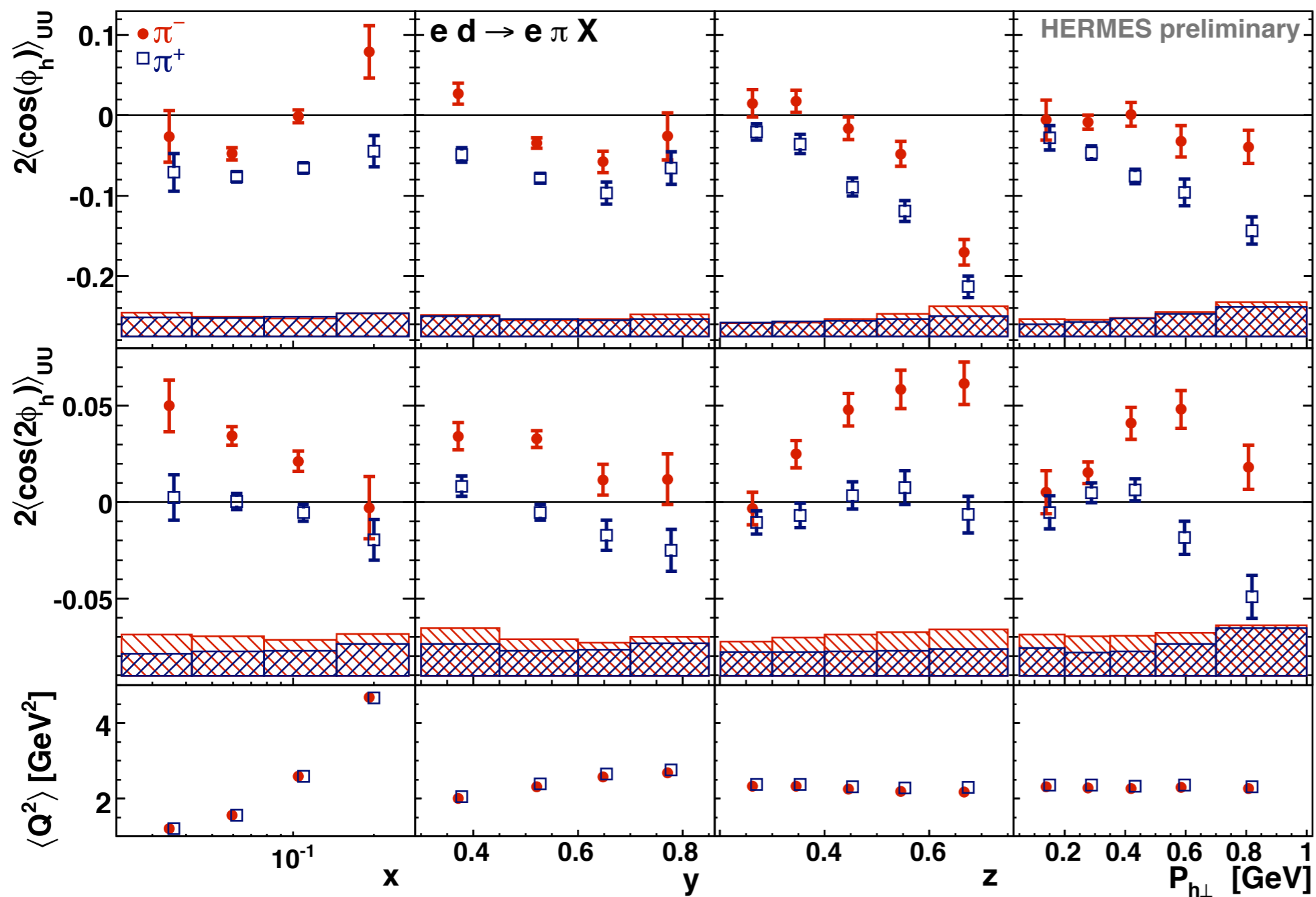
- 2006/2007 data (lots of statistics)
- pion identification

Pion asymmetries (Deuteron target)



- Expands previously (2008) released results by including
- 2006/2007 data (lots of statistics)
 - pion identification

Pion asymmetries (Deuteron target)



Expands previously (2008) released results by including

- 2006/2007 data (lots of statistics)
- pion identification

- Presented at DIS 2010
- Paper drafting in progress

Longitudinal Spin/
Momentum Structure,
Hadronization

Transverse Spin/
Momenitum Structure

DVCS

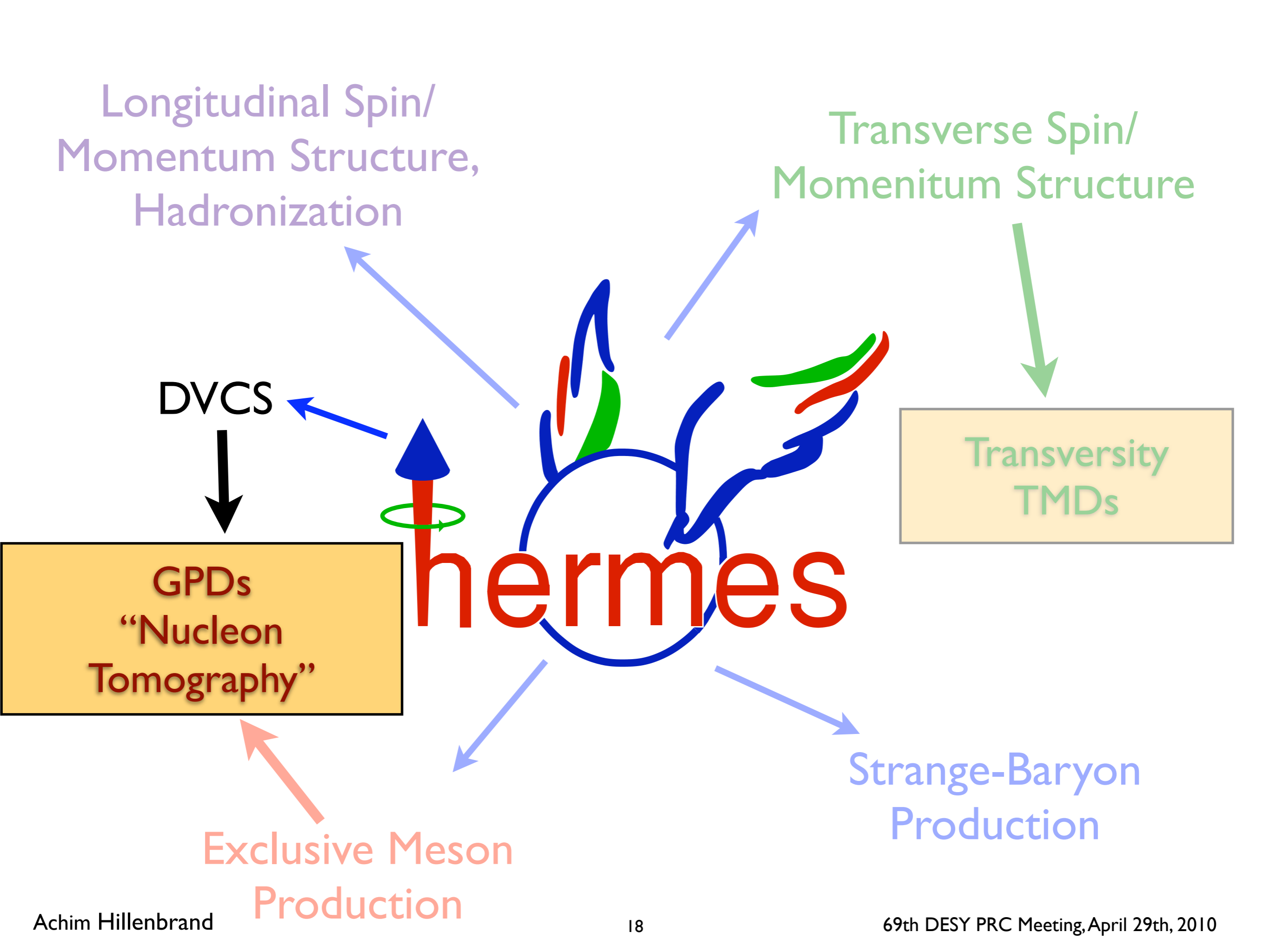
Transversity
TMDs

GPDs
“Nucleon
Tomography”

hermes

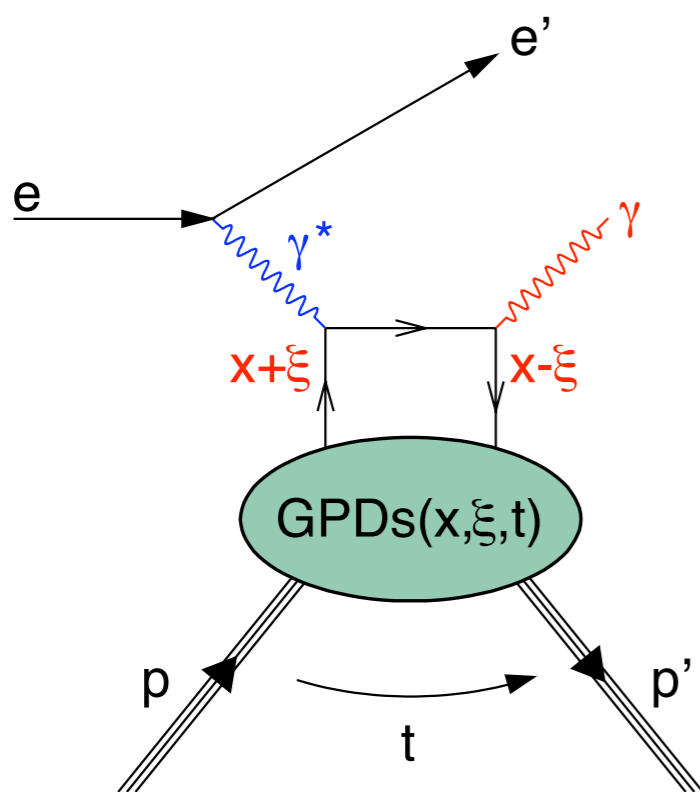
Strange-Baryon
Production

Exclusive Meson
Production

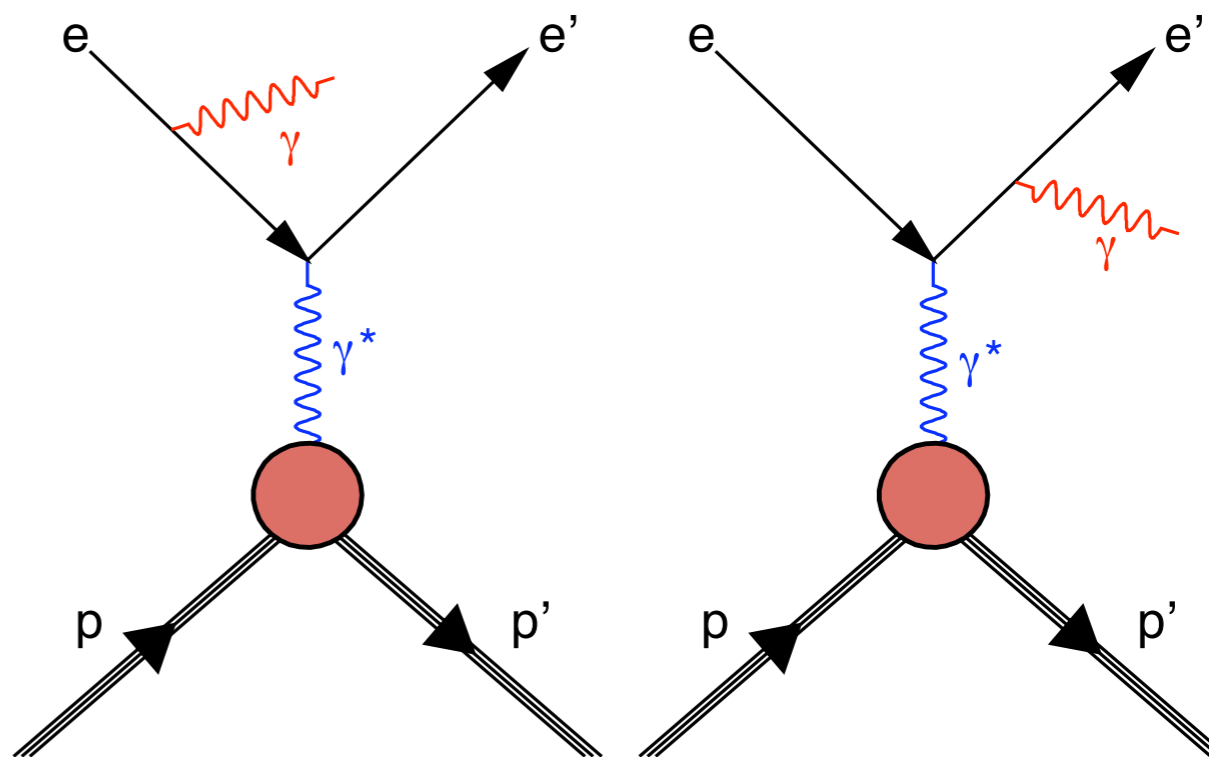


Access to Generalized Parton Distributions (GPDs) via Deeply Virtual Compton Scattering (DVCS)

$$\begin{aligned} \sigma_{LU}(\phi, P_B, C_B) &\propto |\mathcal{T}_{\text{DVCS}}|^2 + |\mathcal{T}_{\text{BH}}|^2 + \mathcal{I} \\ &= \sigma_{\text{UU}} \left[1 + P_B A_{\text{LU}}^{\text{DVCS}} + C_B P_B A_{\text{LU}}^{\text{I}} + C_B A_C \right] \end{aligned}$$

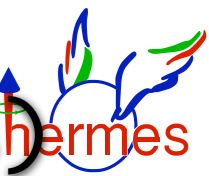


DVCS



Bethe-Heitler

Access to Generalized Parton Distributions (GPDs) via Deeply Virtual Compton Scattering (DVCS)



$$\begin{aligned}\sigma_{\text{LU}}(\phi, P_B, C_B) &\propto |\mathcal{T}_{\text{DVCS}}|^2 + |\mathcal{T}_{\text{BH}}|^2 + \mathcal{I} \\ &= \sigma_{\text{UU}} \left[1 + P_B A_{\text{LU}}^{\text{DVCS}} + C_B P_B A_{\text{LU}}^{\text{I}} + C_B A_C \right]\end{aligned}$$

Beam-charge asymmetry

$$A_C(\phi) = \frac{(\sigma^{+\rightarrow} + \sigma^{+\leftarrow}) - (\sigma^{-\rightarrow} + \sigma^{-\leftarrow})}{(\sigma^{+\rightarrow} + \sigma^{+\leftarrow}) + (\sigma^{-\rightarrow} + \sigma^{-\leftarrow})}$$

Charge-difference beam-helicity asymmetry

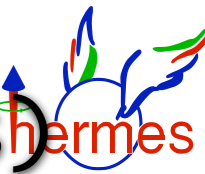
$$A_{\text{LU}}^{\text{I}}(\phi) = \frac{(\sigma^{+\rightarrow} - \sigma^{+\leftarrow}) - (\sigma^{-\rightarrow} - \sigma^{-\leftarrow})}{(\sigma^{+\rightarrow} + \sigma^{+\leftarrow}) + (\sigma^{-\rightarrow} + \sigma^{-\leftarrow})}$$

Charge-averaged beam-helicity asymmetry

$$A_{\text{LU}}^{\text{DVCS}}(\phi) = \frac{(\sigma^{+\rightarrow} - \sigma^{+\leftarrow}) + (\sigma^{-\rightarrow} - \sigma^{-\leftarrow})}{(\sigma^{+\rightarrow} + \sigma^{+\leftarrow}) + (\sigma^{-\rightarrow} + \sigma^{-\leftarrow})}$$

Moments of these asymmetries in $n\phi$ related to GPDs

Access to Generalized Parton Distributions (GPDs) via Deeply Virtual Compton Scattering (DVCS)



$$\begin{aligned} \sigma_{\text{LU}}(\phi, P_B, C_B) &\propto |\mathcal{T}_{\text{DVCS}}|^2 + |\mathcal{T}_{\text{BH}}|^2 + \mathcal{I} \\ &= \sigma_{\text{UU}} \left[1 + P_B A_{\text{LU}}^{\text{DVCS}} + C_B P_B A_{\text{LU}}^{\text{I}} + C_B A_C \right] \end{aligned}$$

Results on DVCS on unpolarized targets published recently:

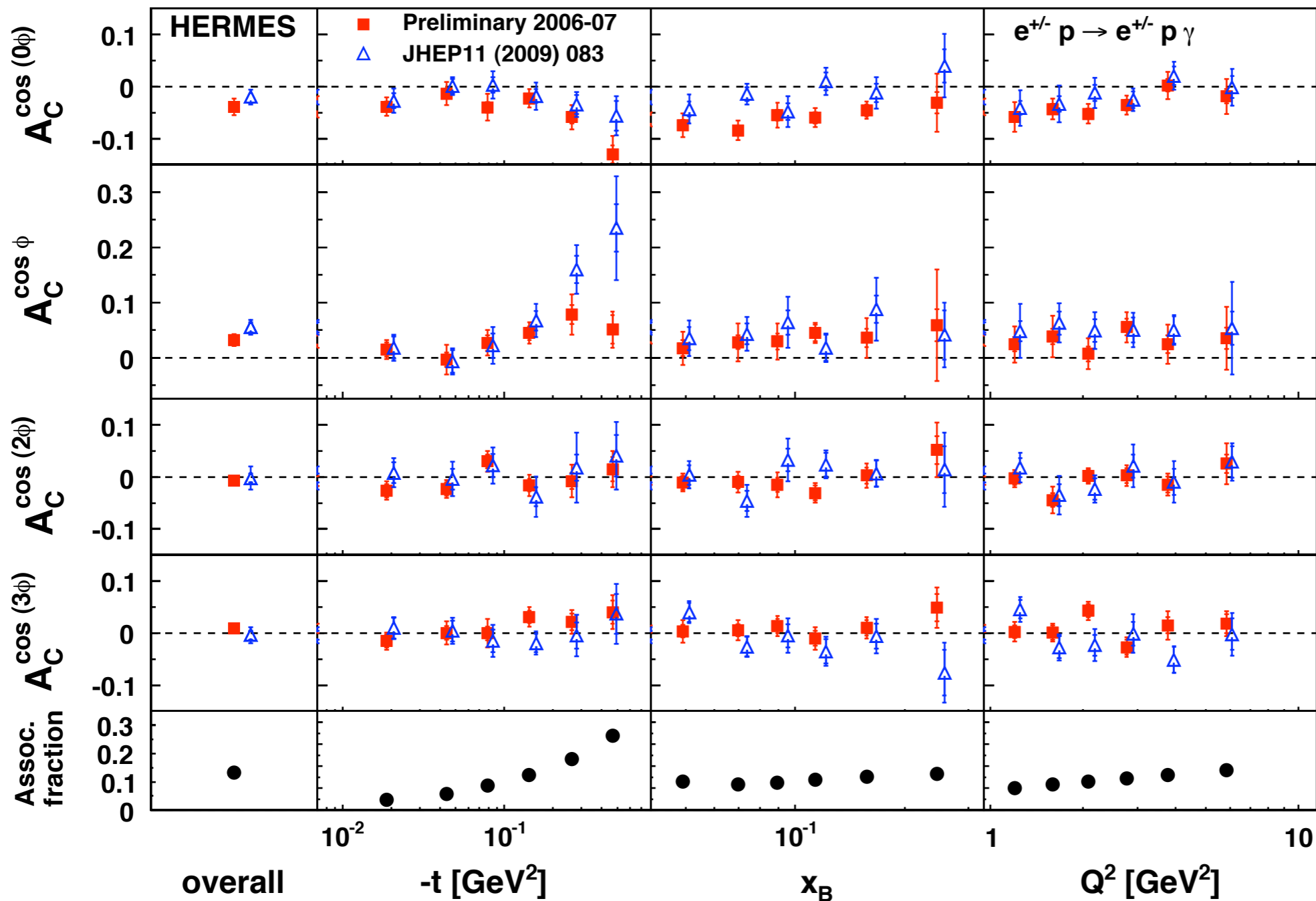
- Hydrogen: *JHEP 11 (2009) 083*
- Deuterium: *Nucl. Phys. B 829 (2010) 1-27*
- Nuclear mass dependence: *Phys. Rev. C 81 (2010) 035202*

Charge-averaged
beam-helicity
asymmetry

$$A_{\text{LU}}^{\text{DVCS}}(\phi) = \frac{(\sigma^{+\rightarrow} - \sigma^{+\leftarrow}) + (\sigma^{-\rightarrow} - \sigma^{-\leftarrow})}{(\sigma^{+\rightarrow} + \sigma^{+\leftarrow}) + (\sigma^{-\rightarrow} + \sigma^{-\leftarrow})}$$

Moments of these asymmetries in $n\phi$ related to GPDs

DVCS from 2006/2007 data: beam-charge asymmetries



- 2006/2007 data contains ~2.4x the statistics of 1996-2005
- good agreement of different data taking periods

Longitudinal Spin/
Momentum Structure,
Hadronization

Transverse Spin/
Momentum Structure

DVCS

Transversity
TMDs

GPDs
“Nucleon
Tomography”

hermes



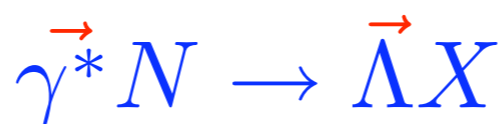
Strange-Baryon
Production

Exclusive Meson
Production

Longitudinal Λ polarization

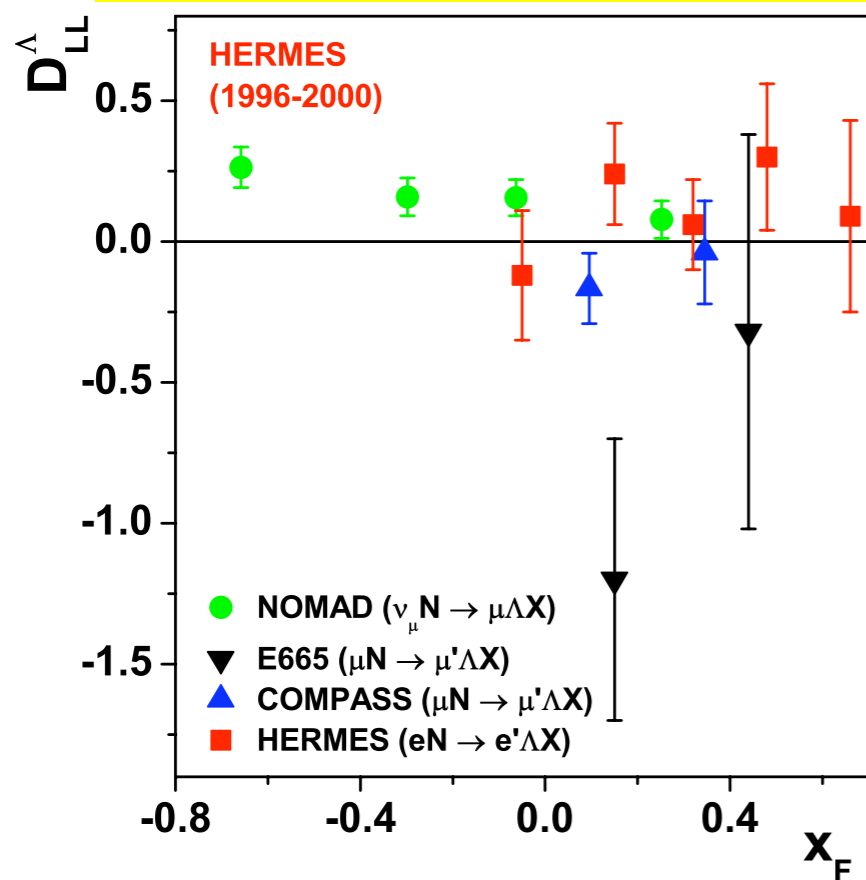
Parity violating decay $\Lambda \rightarrow \pi^- p$: p preferentially emitted along Λ spin

in Λ CMS:
$$\frac{dN}{d\Omega_p} = \frac{dN_0}{d\Omega_p} (1 + \alpha P_\Lambda \cos \theta_p) \quad \alpha = 0.642 \pm 0.013$$

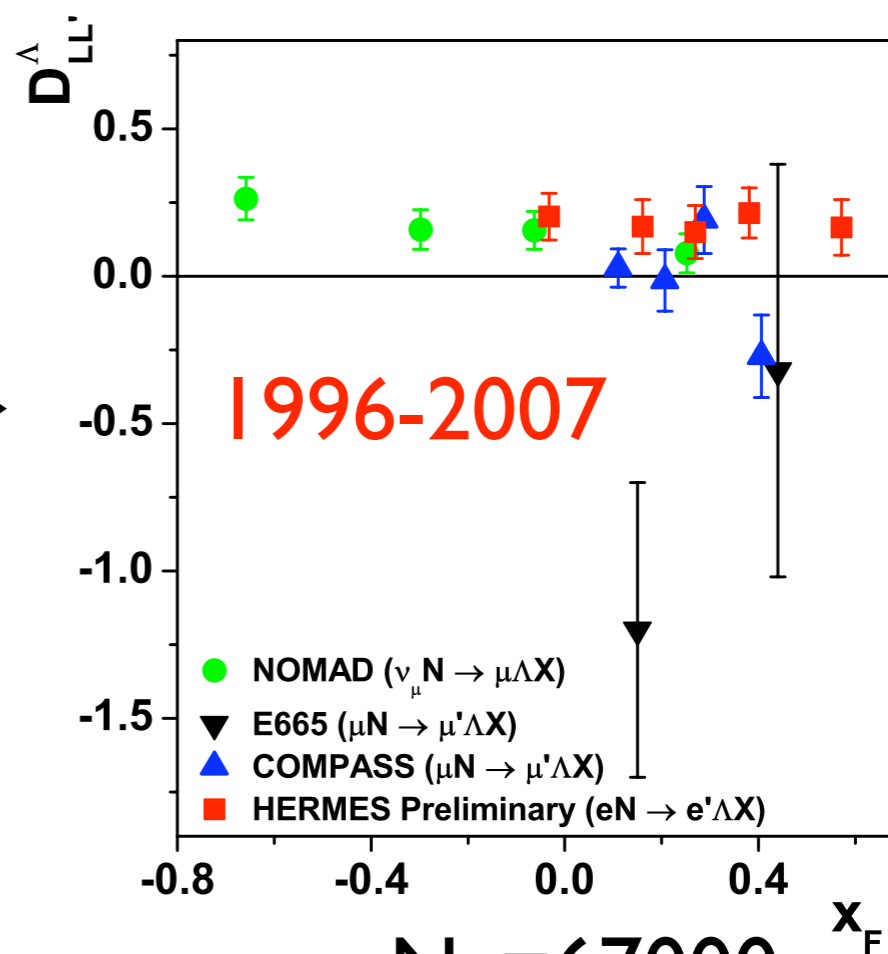
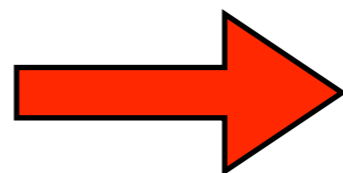


$$D_{LL'}^\Lambda = 0.19 \pm 0.04$$

Phys. Rev. D 74 (2006) 072004



$N_\Lambda = 8200$



$N_\Lambda = 67000$

Summary

- Since the last PRC meeting
 - ▶ Five papers published
 - ▶ Two papers submitted
 - ▶ Six new physics results released and presented at conferences
- Results cover all areas of physics studied at HERMES
- First results covering the 2006/2007 data taking years (dramatically enhancing statistics)
- Recoil detector physics analysis progressing