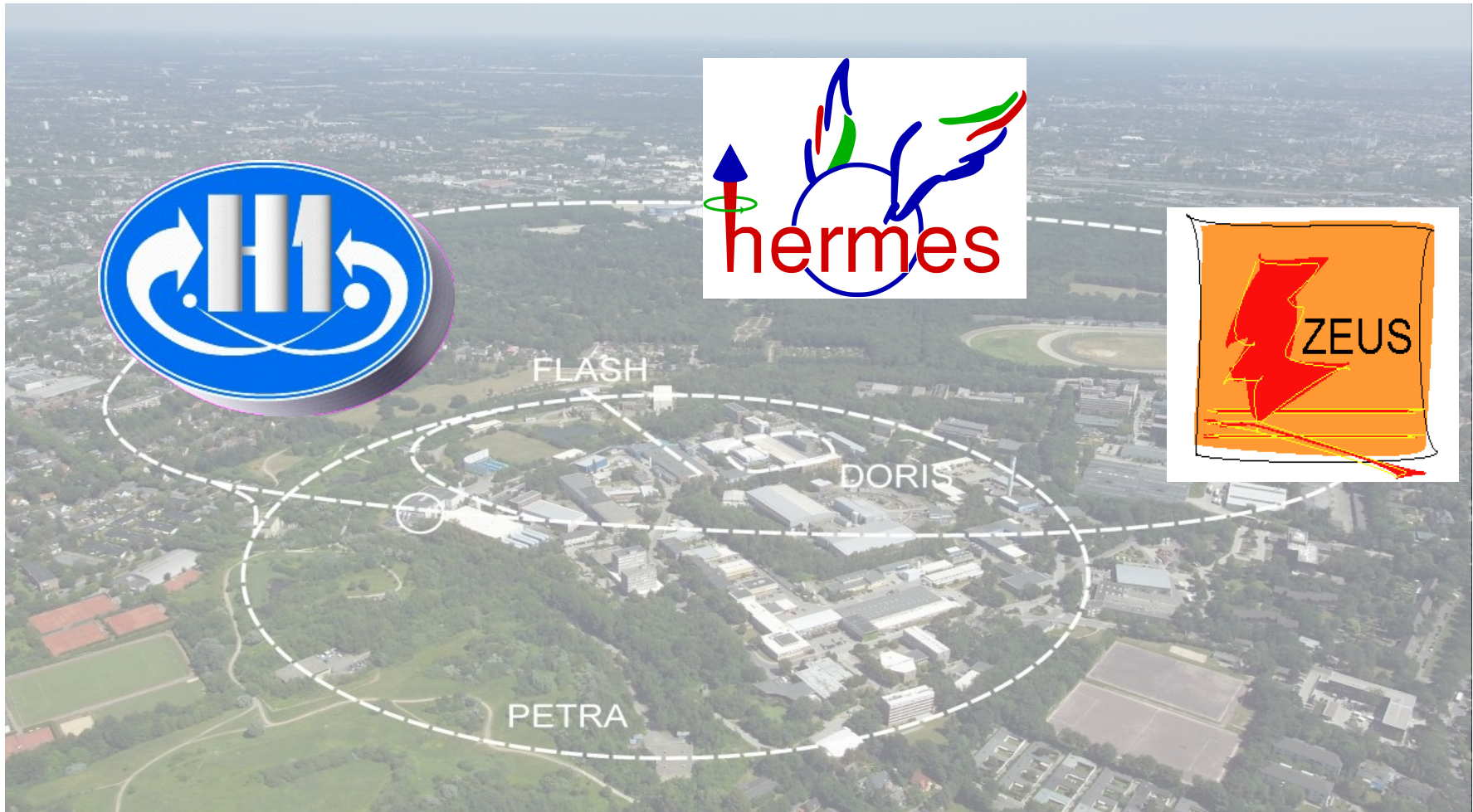


# Report from the HERA experiments



C. Van Hulse (UPV/EHU Bilbao)  
76<sup>th</sup> DESY PRC Meeting  
DESY Hamburg - October 24th, 2013

# collaboration news










- **new ZEUS management**
  - spokesperson: Matthew Wing
  - physics chairwomen: Iris Abt & Katarzyna Wichmann
  - technical coordinator: Janusz Malka
- **new H1-ZEUS combination coordinators**
  - Daniel Britzger (H1) and Achim Geiser (ZEUS)
- **2.5 new PhD students for ZEUS**

# productivity

- 7 publications and 2 submitted papers since last PRC
- 4 released results since last PRC
- 136 HERA physics talks so far at conferences in 2013 similar to last 3 years








# published and submitted papers

## since 75<sup>th</sup> PRC

- **Measurement of charged particle spectra in deep-inelastic ep scattering at HERA**  
Eur. Phys. J. C 73 (2013) 2406 
- **Elastic and proton-dissociative photoproduction of J/psi mesons at HERA**  
Eur. Phys. J. C 73 (2013) 2466 
- **Measurement of D\*± production in deep-inelastic scattering at HERA**  
JHEP 1305 (2013) 097 
- **Measurement of charm fragmentation fractions in photoproduction at HERA**  
JHEP 1309 (2013) 058 
- **Measurement of the luminosity in the ZEUS experiment at HERA II**  
submitted to Nucl. Instrum. Meth. [arXiv. 1306.1391] 
- **Multiplicities of charged pions and kaons from semi-inclusive deep-inelastic scattering by the proton and the deuteron**  
Phys. Rev. D 87 (2013) 074029 
- **The HERMES Recoil Detector**  
JINST 8 (2013) P05012 
- **Transverse target single-spin asymmetry in inclusive electroproduction of charged pions and kaons**  
submitted to Phys. Lett. B [arXiv:1310.5070] 
- **Beam-helicity asymmetry in associated electroproduction of real photons  $ep \rightarrow e\gamma\pi N$  in the  $\Delta$ -resonance region**  
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# new preliminary results since 75<sup>th</sup> PRC

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H1-prelim-13-171, ZEUS-prelim-13-002
- HERAPDF1.5LO PDF set with experimental uncertainties  
H1-prelim-13-141, ZEUS-prelim-13-003
- Transverse-target moments of di-hadron production in semi-inclusive deep-inelastic scattering
- Beam-spin asymmetries in the azimuthal distribution of DIS electroproduction of pions, kaons, and (anti-)protons



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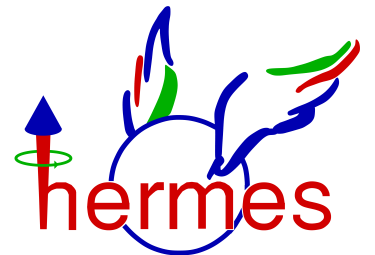


- **Transverse-target moments of di-hadron production in semi-inclusive deep-inelastic scattering**

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Beam-helicity asymmetry in associated  
electroproduction of real photons  $ep \rightarrow e\gamma\pi N$   
in the  $\Delta$ -resonance region

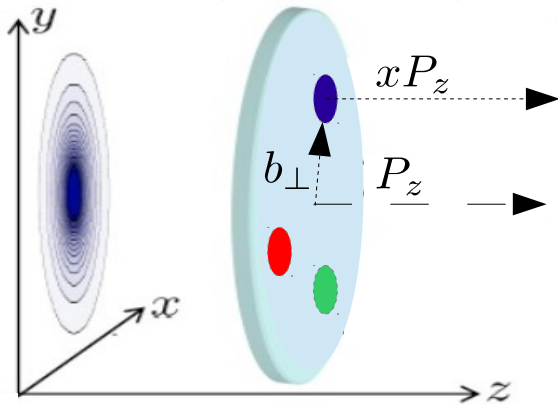




# Beam-helicity asymmetry in $ep \rightarrow e\gamma\pi N$ in $\Delta$ -resonance region

## GPDs

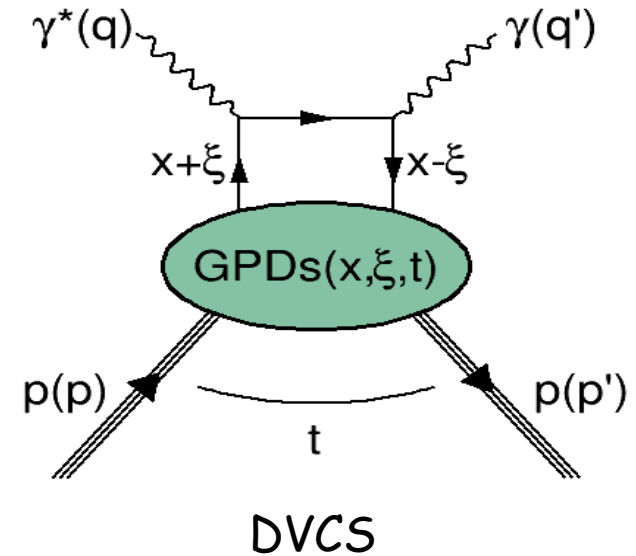
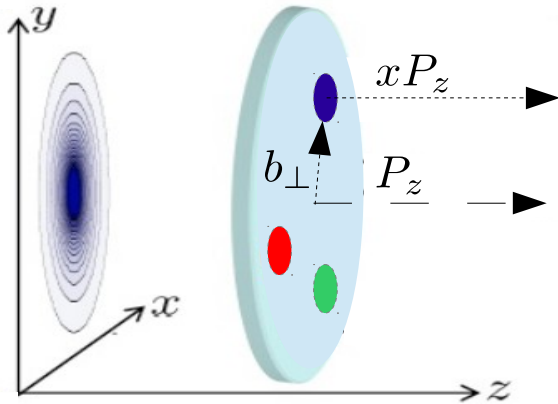
quark distribution in longitudinal-momentum  
and transverse-position space



# Beam-helicity asymmetry in $ep \rightarrow e\gamma\pi N$ in $\Delta$ -resonance region

## GPDs

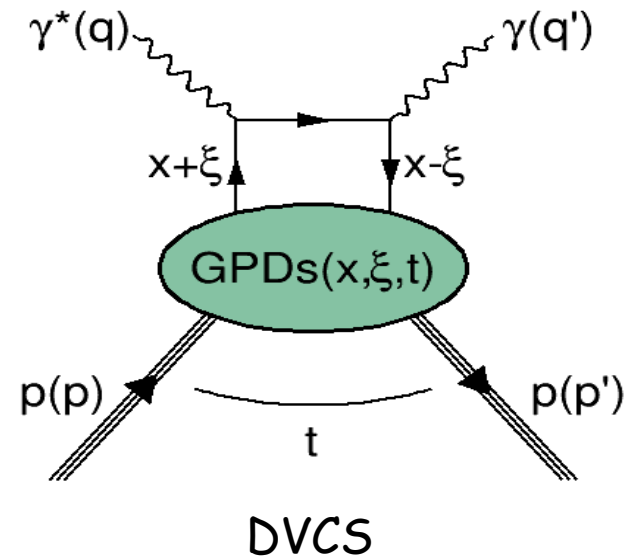
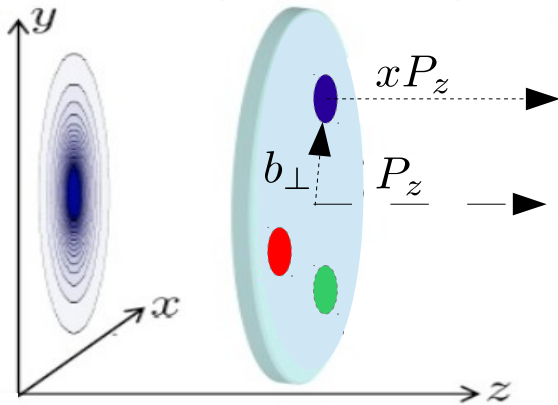
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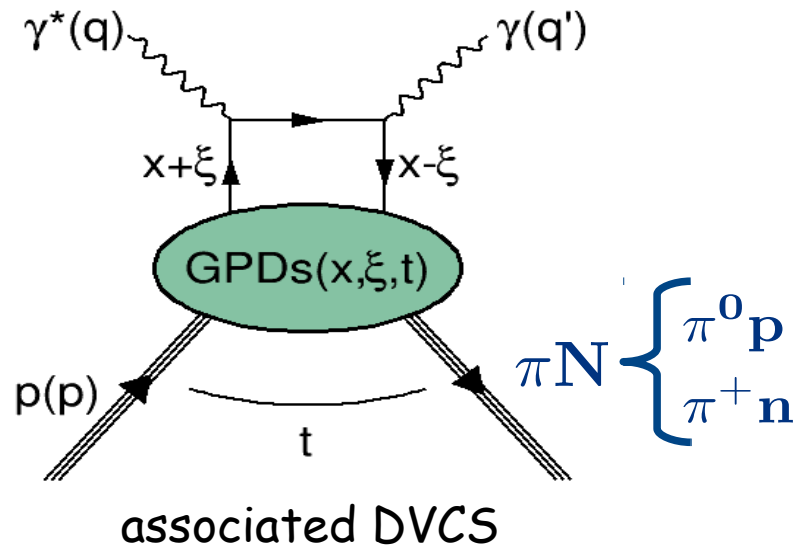
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## GPDs

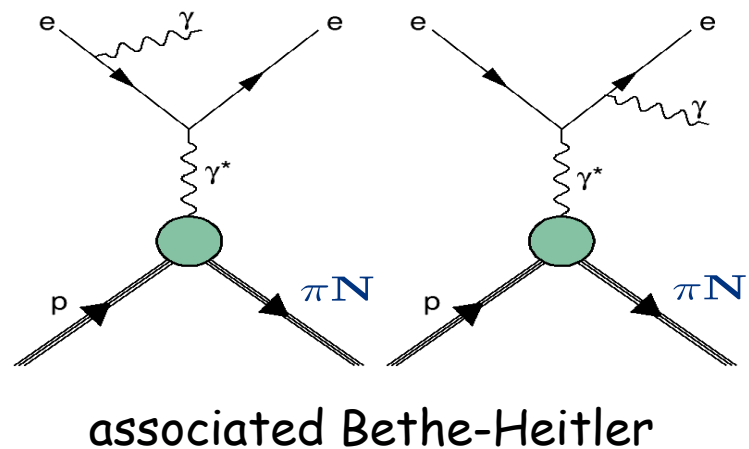
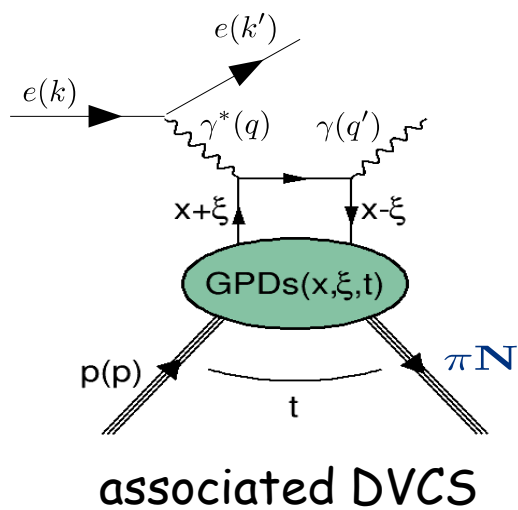
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and transverse-position space



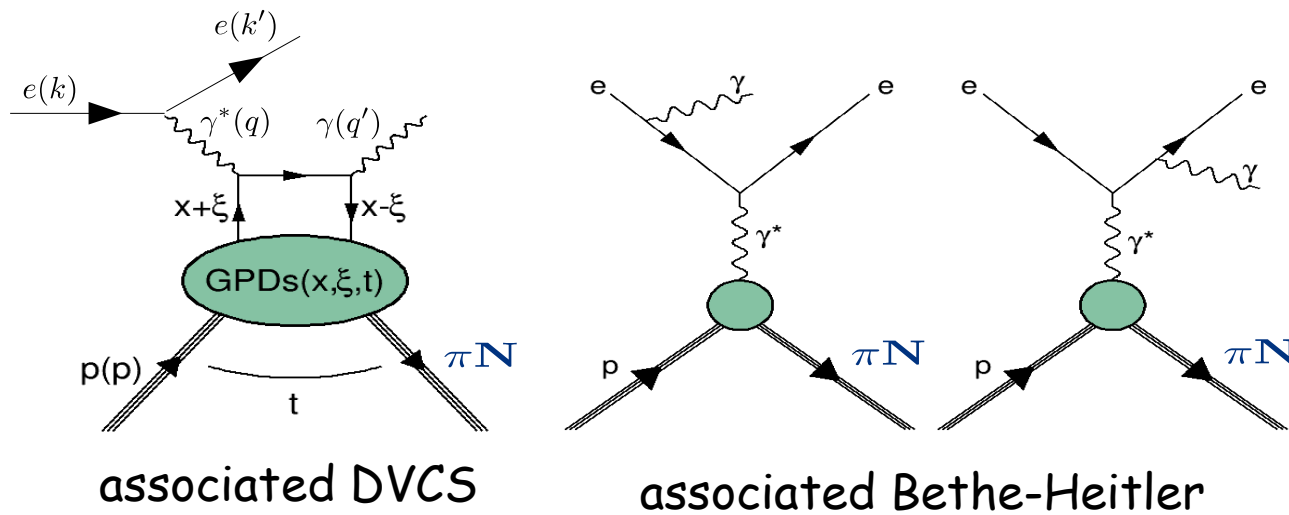
transition GPDs  $p \rightarrow \pi N$



# Beam-helicity asymmetry in $ep \rightarrow e\gamma\pi N$ in $\Delta$ -resonance region

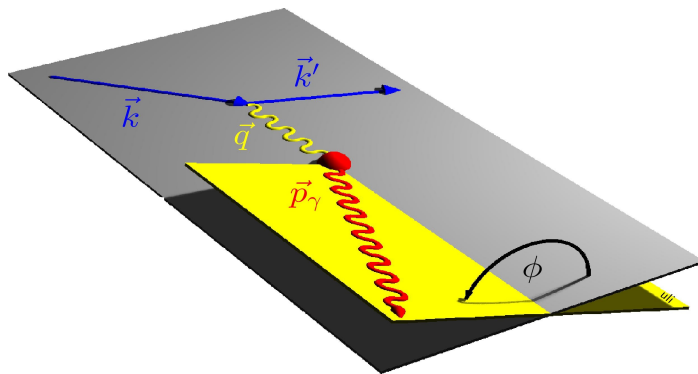


# Beam-helicity asymmetry in $ep \rightarrow e\gamma\pi N$ in $\Delta$ -resonance region

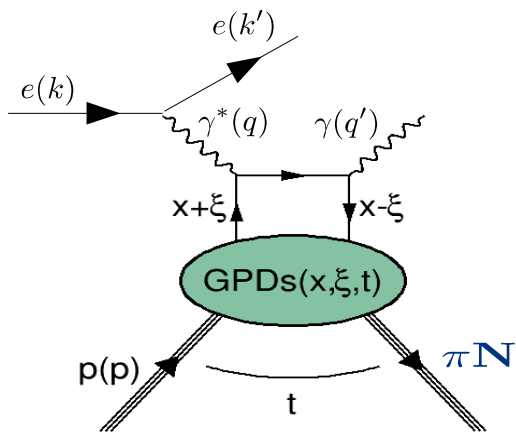


$$d\sigma \propto |\tau_{BH}|^2 + |\tau_{DVCS}|^2 + \tau_{BH} \tau_{DVCS}^* + \tau_{DVCS} \tau_{BH}^*$$

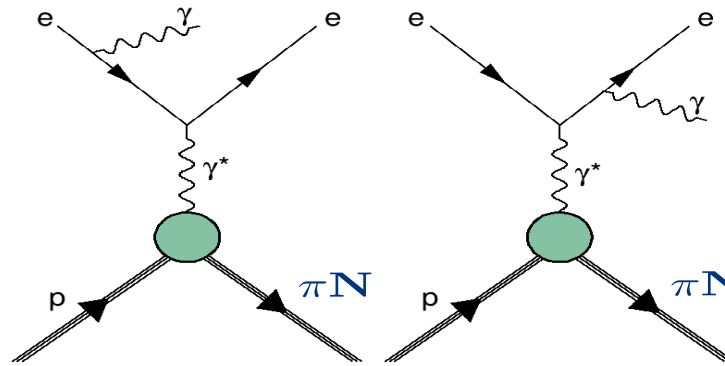
access through azimuthal asymmetries



# Beam-helicity asymmetry in $ep \rightarrow e\gamma\pi N$ in $\Delta$ -resonance region



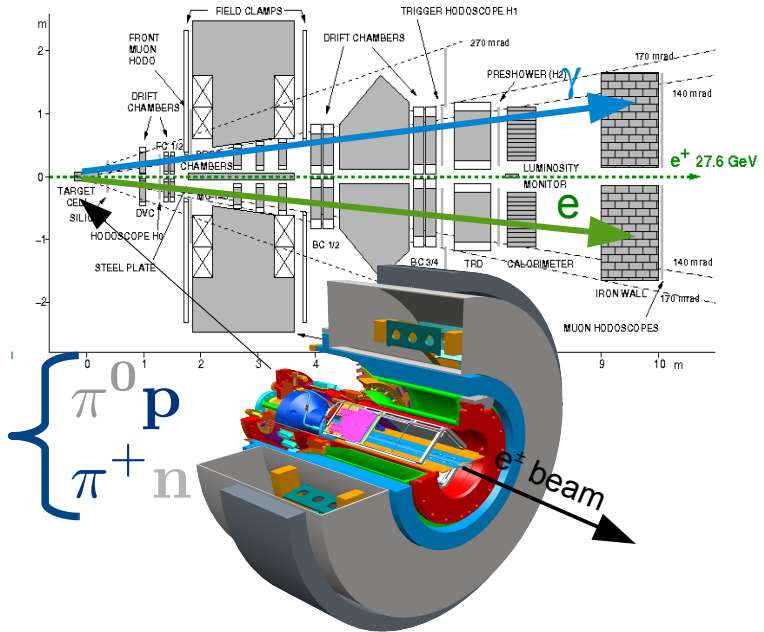
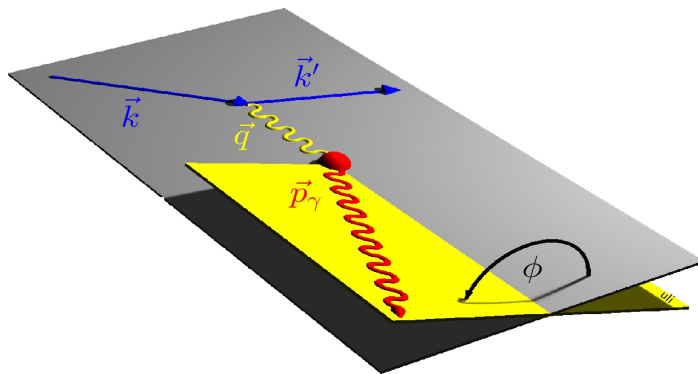
associated DVCS



associated Bethe-Heitler

$$d\sigma \propto |\tau_{BH}|^2 + |\tau_{DVCS}|^2 + \tau_{BH} \tau_{DVCS}^* + \tau_{DVCS} \tau_{BH}^*$$

access through azimuthal asymmetries



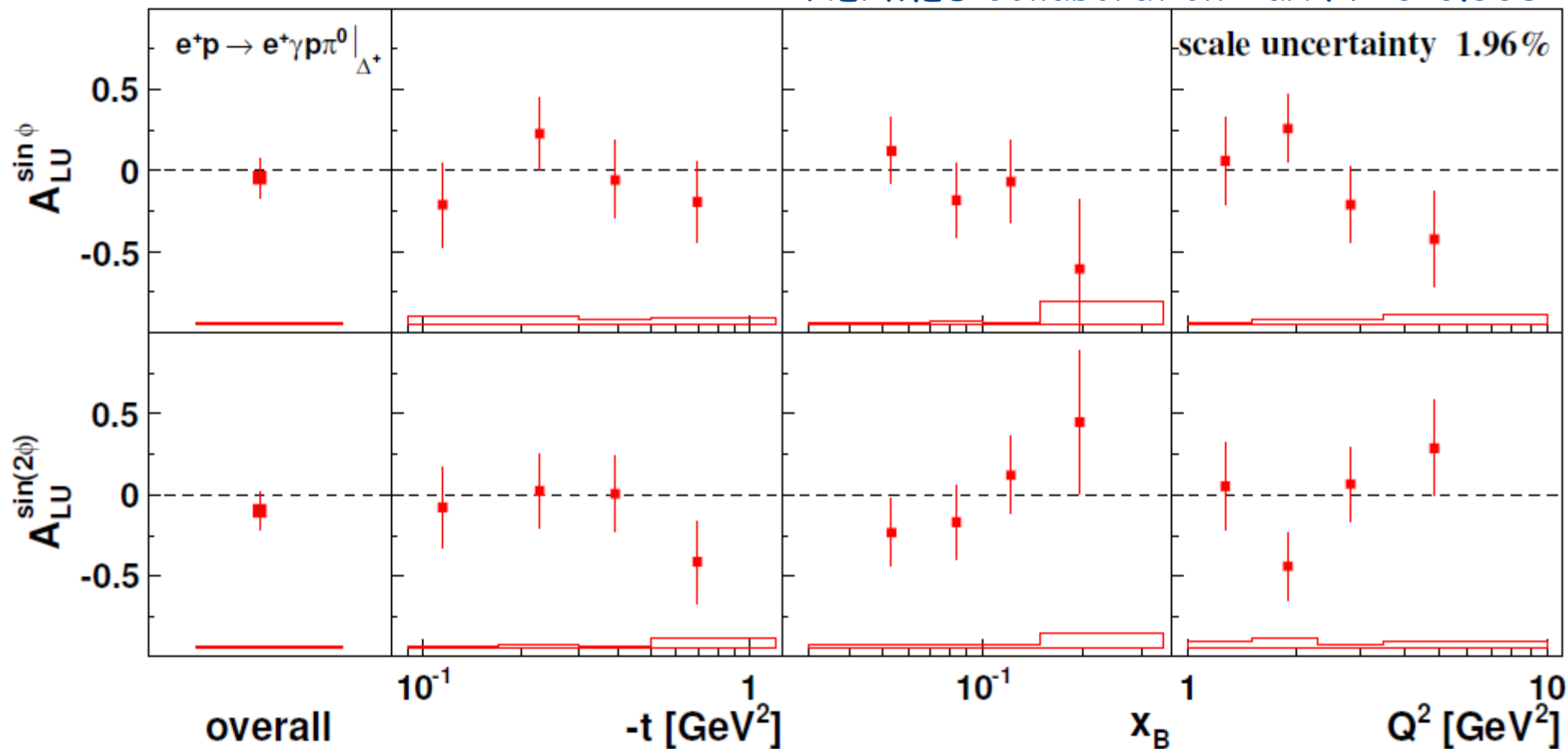
## recoil detector

- p and  $\pi^+$  via PID
- $\pi^0$  and n undetected
- kinematic fitting
- select region around  $\Delta$ -resonance

# Beam-helicity asymmetry in $ep \rightarrow e\gamma\pi N$ in $\Delta$ -resonance region

$ep \rightarrow e\gamma\pi^0 p$

HERMES Collaboration - arXiv:1310.5081

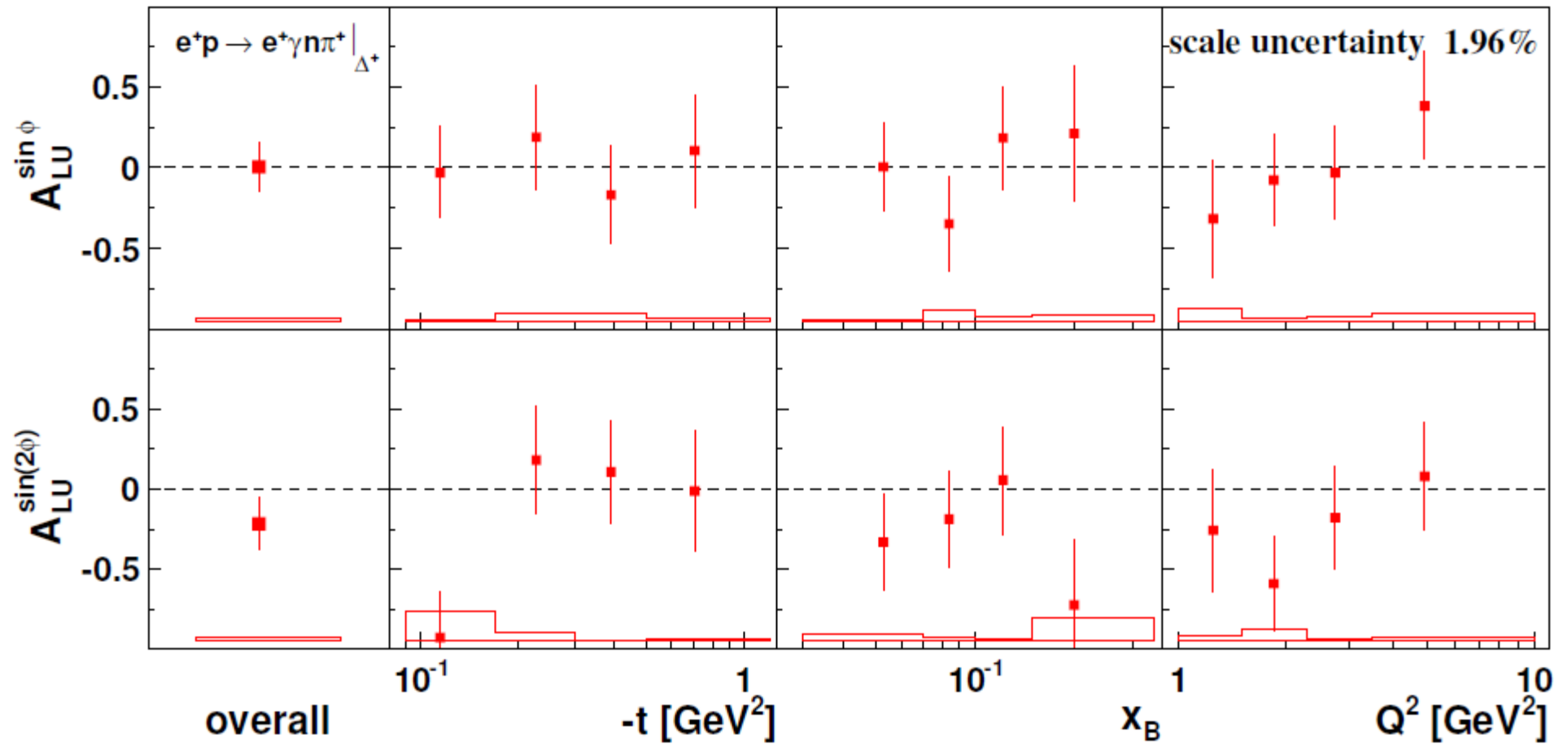


- asymmetry background correction from SIDIS (11%) and  $ep \rightarrow e\gamma p$  (4.6%)
- leading asymmetry consistent with zero

# Beam-helicity asymmetry in $ep \rightarrow e\gamma\pi N$ in $\Delta$ -resonance region

$ep \rightarrow e\gamma\pi^+ n$

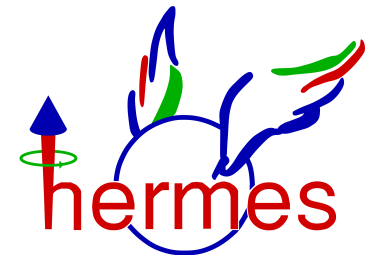
HERMES Collaboration - arXiv:1310.5081



- asymmetry background correction from SIDIS (23%) and  $ep \rightarrow e\gamma p$  (0.2%)
- leading asymmetry consistent with zero

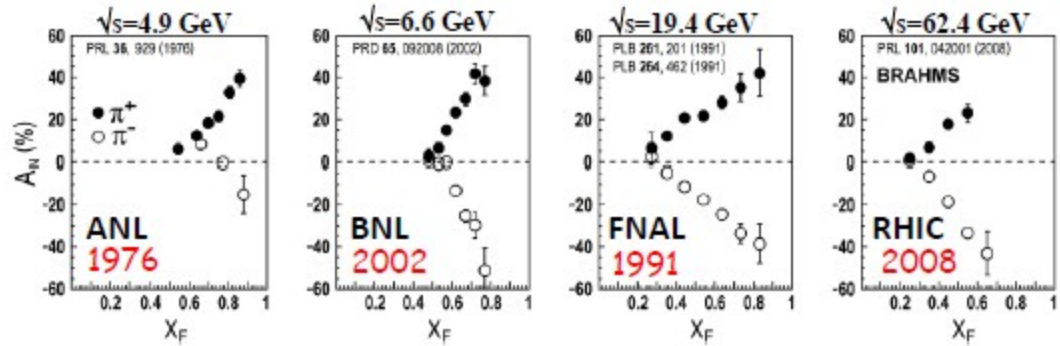
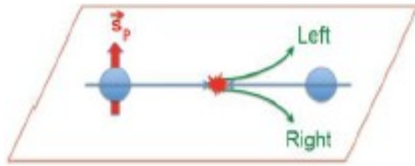


# Transverse target single-spin asymmetry in inclusive electroproduction of charged pions and kaons



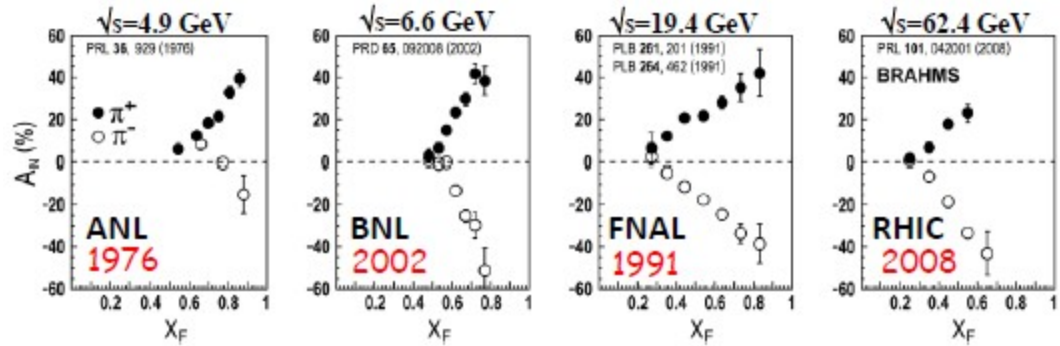
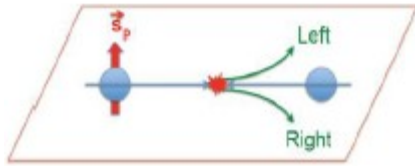
# Transverse target single-spin asymmetry in inclusive electroproduction of pions and kaons

- various polarized pp scattering experiments consistently observe since 35 years large  $A_N$  asymmetries, with  $\sqrt{s}$  from 5 to 200 GeV



# Transverse target single-spin asymmetry in inclusive electroproduction of pions and kaons

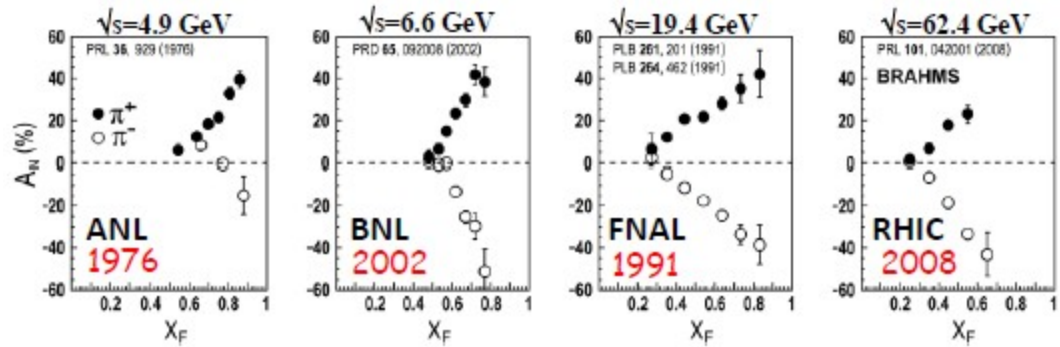
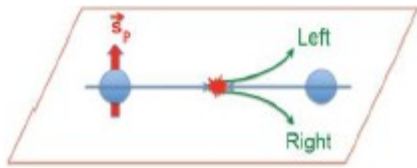
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- not interpretable in leading-twist based on collinear factorization

# Transverse target single-spin asymmetry in inclusive electroproduction of pions and kaons

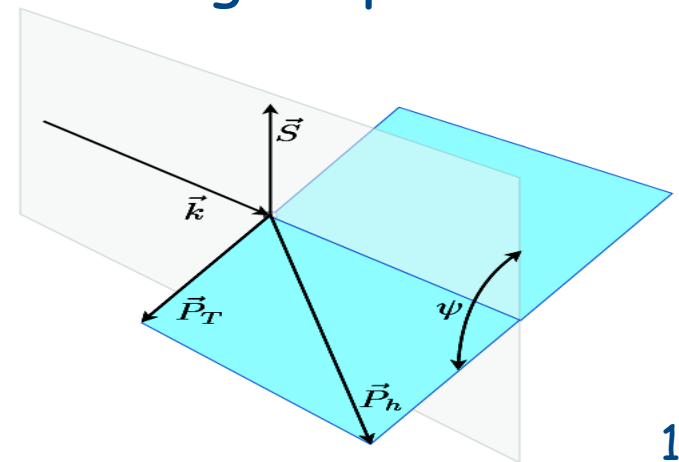
- various polarized pp scattering experiments consistently observe since 35 years large  $A_N$  asymmetries, with  $\sqrt{s}$  from 5 to 200 GeV



- not interpretable in leading-twist based on collinear factorization
- HERMES measurement of inclusive transverse target spin asymmetry  $A_{UT}^{\sin(\psi)}$ :

$$d\sigma = d\sigma_{UU} [1 + S_{\perp} A_{UT}^{\sin(\psi)} \sin(\psi)]$$

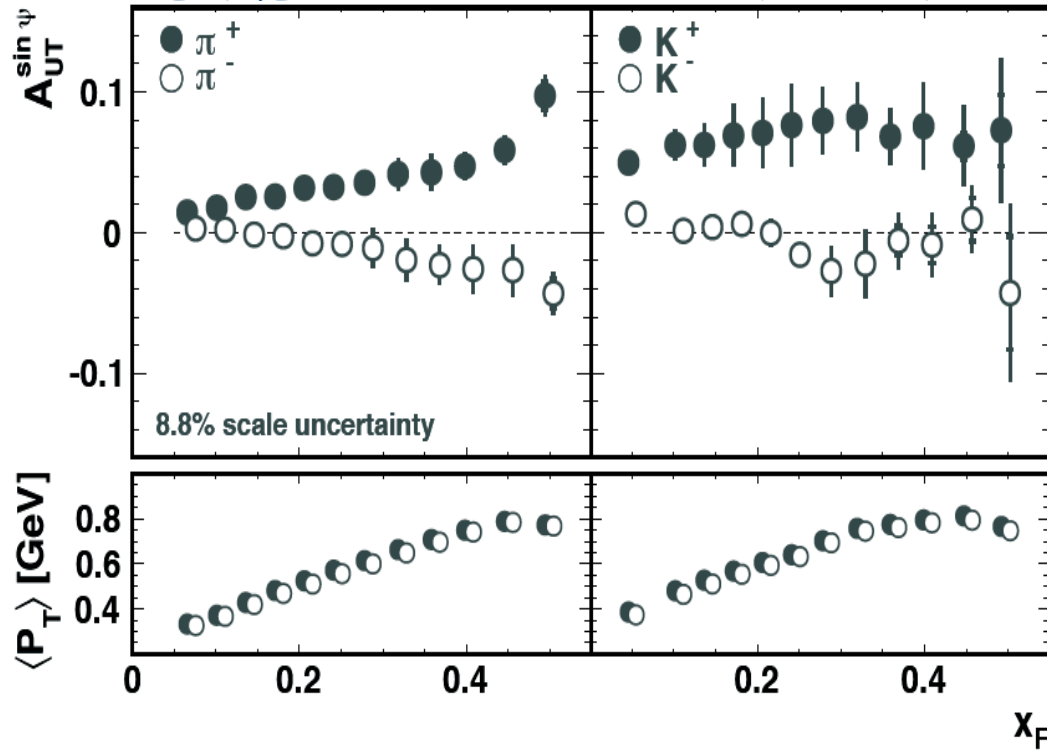
- $A_{UT}^{\sin(\psi)} = \frac{\pi}{2} A_N$



# Transverse target single-spin asymmetry in inclusive electroproduction of pions and kaons

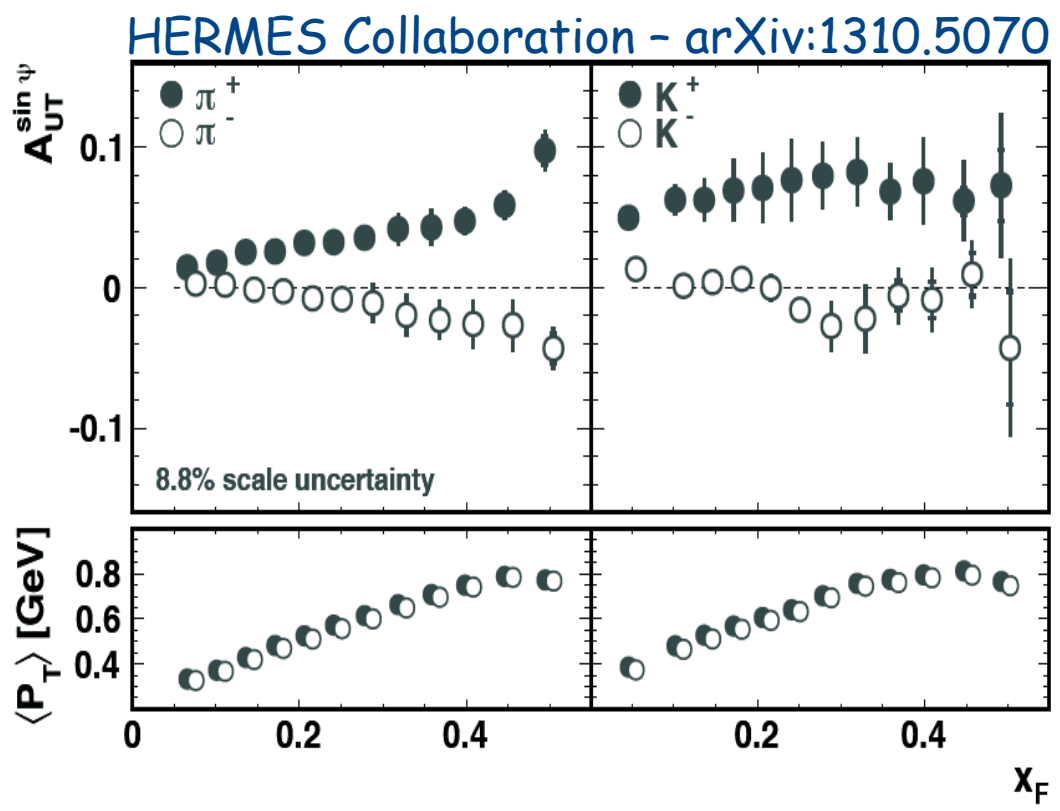
$x_F = 2P_L/\sqrt{s}$  dependence

HERMES Collaboration - arXiv:1310.5070



# Transverse target single-spin asymmetry in inclusive electroproduction of pions and kaons

$x_F = 2P_L/\sqrt{s}$  dependence



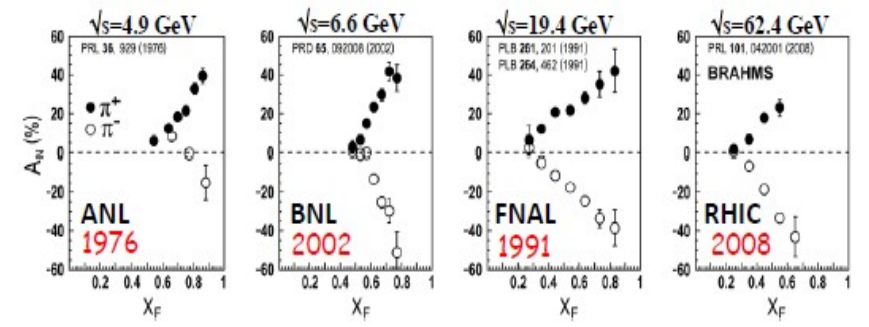
$\pi^+$

- positive, increase linearly with  $x_F$

$\pi^-$

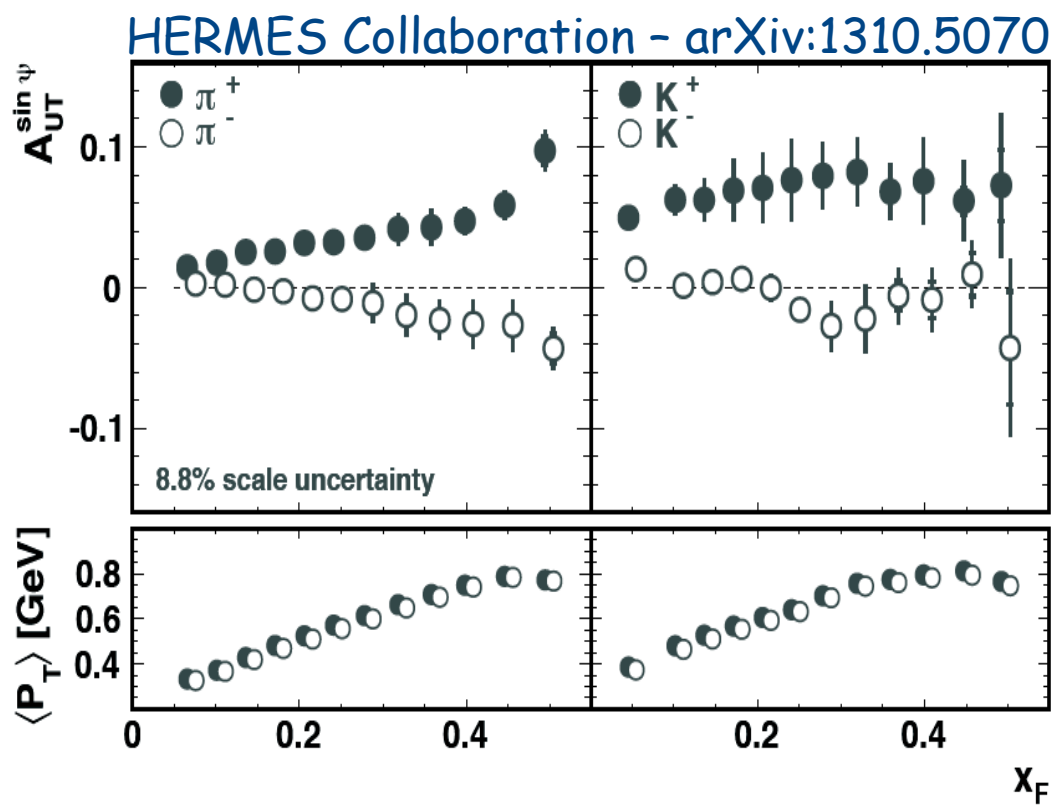
- negative, decrease linearly with  $x_F$

$x_F$  behavior of pions similar to what observed in hadron-hadron collisions



# Transverse target single-spin asymmetry in inclusive electroproduction of pions and kaons

$x_F = 2P_L/\sqrt{s}$  dependence



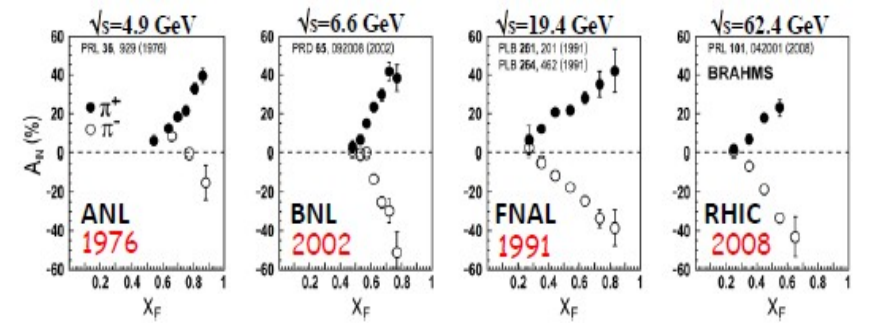
$\pi^+$

- positive, increase linearly with  $x_F$

$\pi^-$

- negative, decrease linearly with  $x_F$

$x_F$  behavior of pions similar to what observed in hadron-hadron collisions



$K^+$

- positive, ~constant with  $x_F$

$K^-$

- compatible with zero, with small variation over  $x_F$

# Transverse target single-spin asymmetry in inclusive electroproduction of pions and kaons

disentangle  $x_F$  and  $P_T$  dependence

$\pi^+$

- increase with  $P_T$  up to  $P_T \approx 0.8$  GeV
- $P_T$  dependence independent of  $x_F$
- $x_F$  increase from  $P_T$  dependence

$\pi^-$

- small amplitudes, varyingly positive and negative with  $P_T$
- decrease with increasing  $x_F$

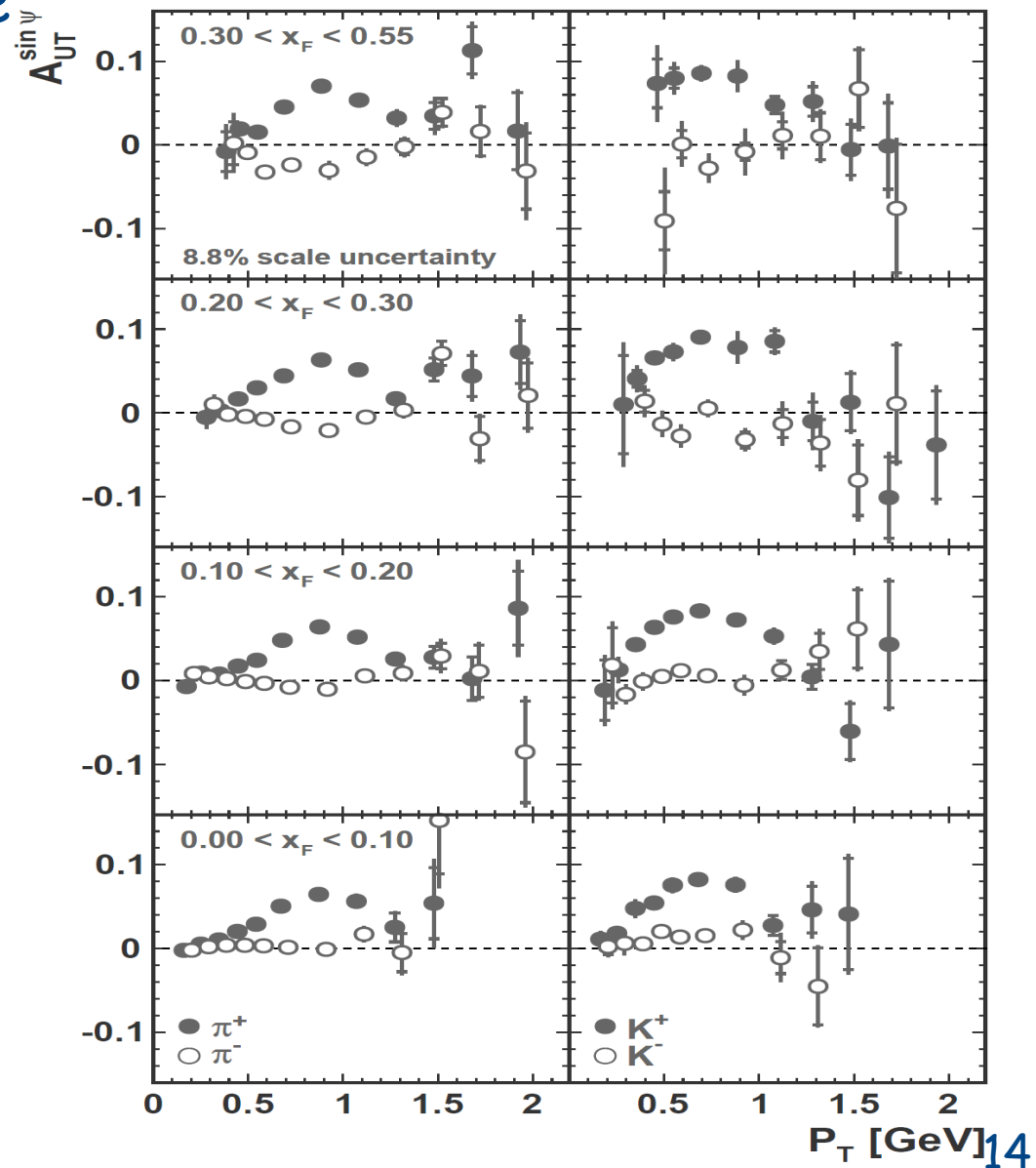
$K^+$

- increase with  $P_T$  up to  $P_T \approx 0.8$  GeV
- increase with increasing  $x_F$

$K^-$

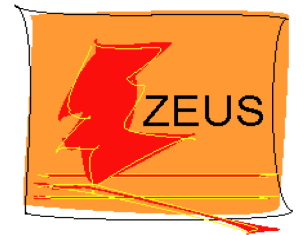
- small amplitudes
- decrease with increasing  $x_F$

HERMES Collaboration - arXiv:1310.5070

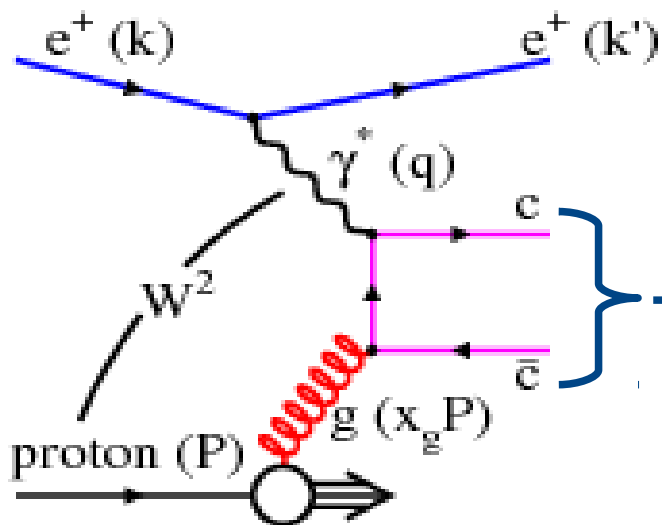




# Combination of $D^*$ differential cross section measurements in DIS at HERA



# Combination of $D^*$ differential cross section measurements in DIS at HERA

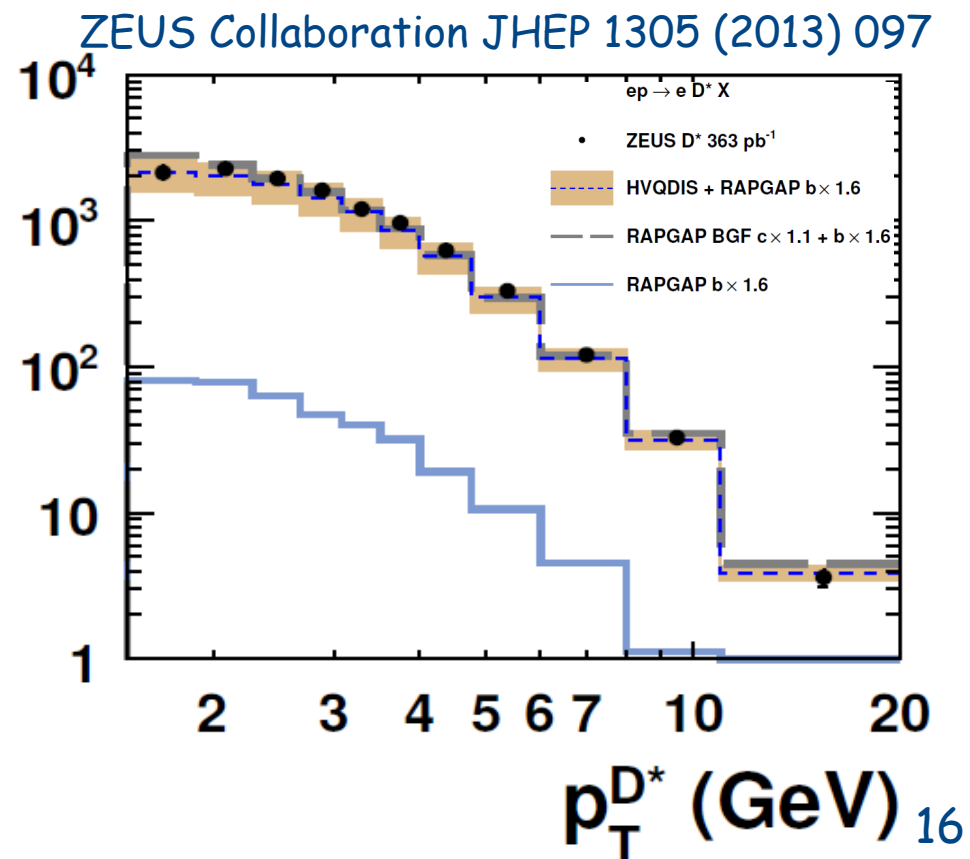


golden channel

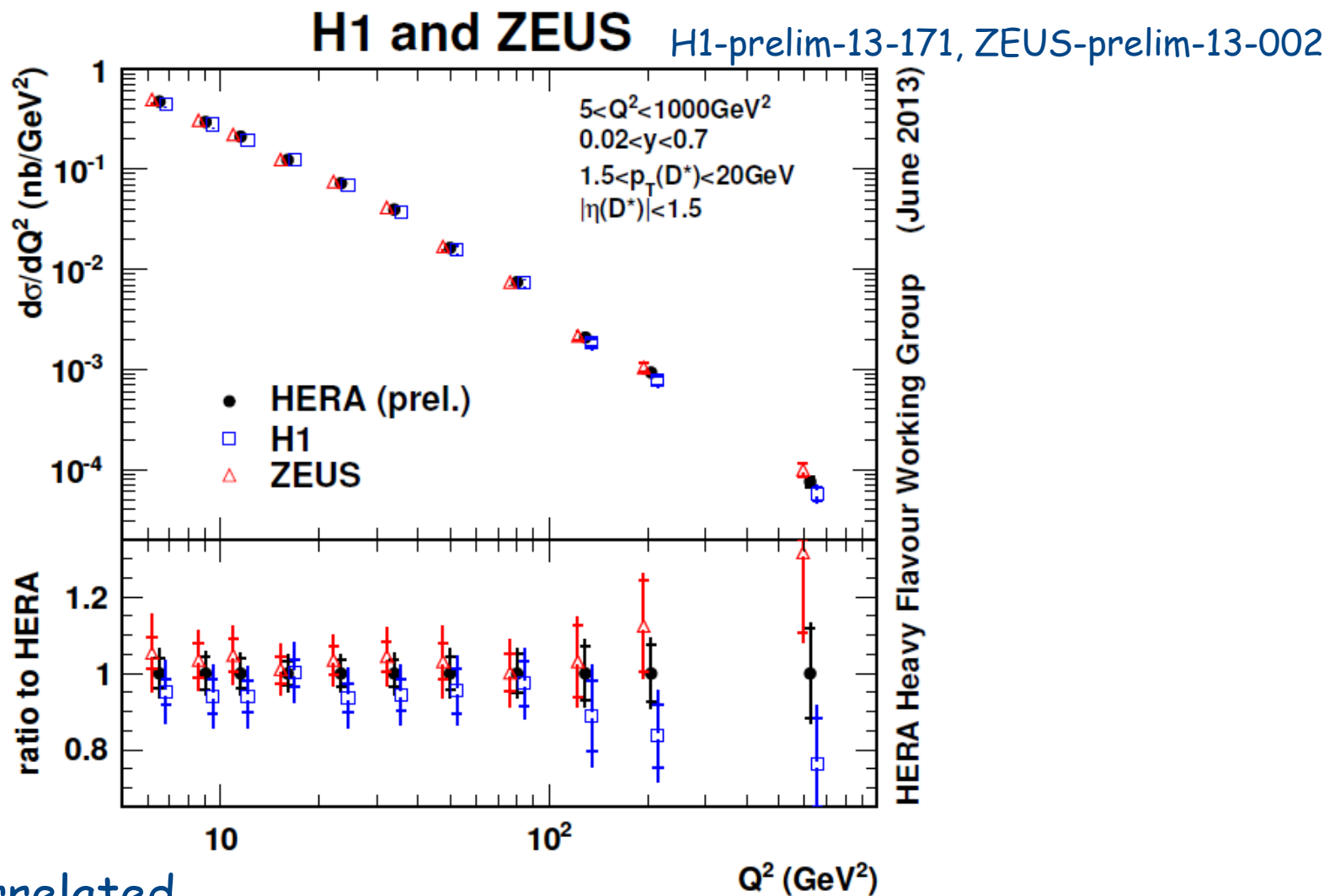
$$D^{*\pm} \rightarrow D^0 \pi_{slow}^{\pm} \rightarrow (K^{\mp} \pi^{\pm}) \pi_{slow}^{\pm}$$

- well-defined phase-space
- combined experimental data
  - H1: Phys. Lett. B 686 (2010) 91  
Eur. Phys. J. C 71 (2011) 1769
  - ZEUS: JHEP 1305 (2013) 097

$d\sigma/dp_T^{D^*}$  (pb/GeV)



# Combination of $D^*$ differential cross section measurements in DIS at HERA



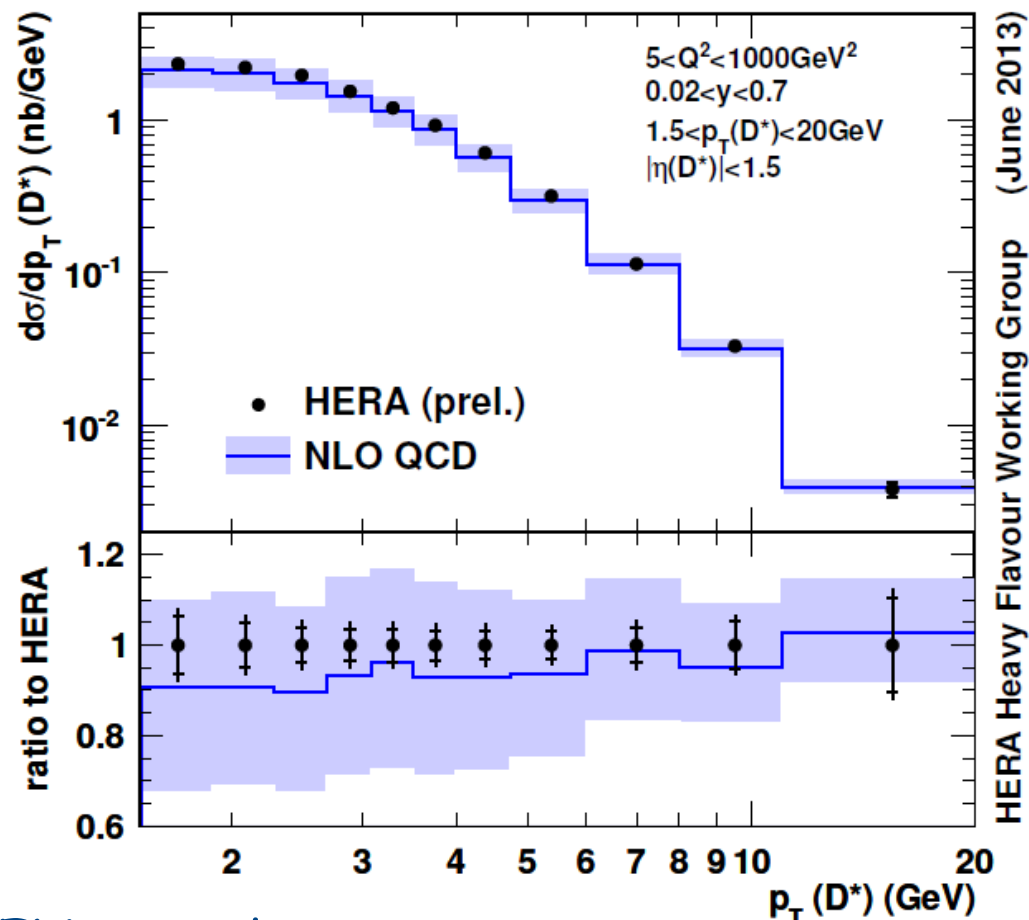
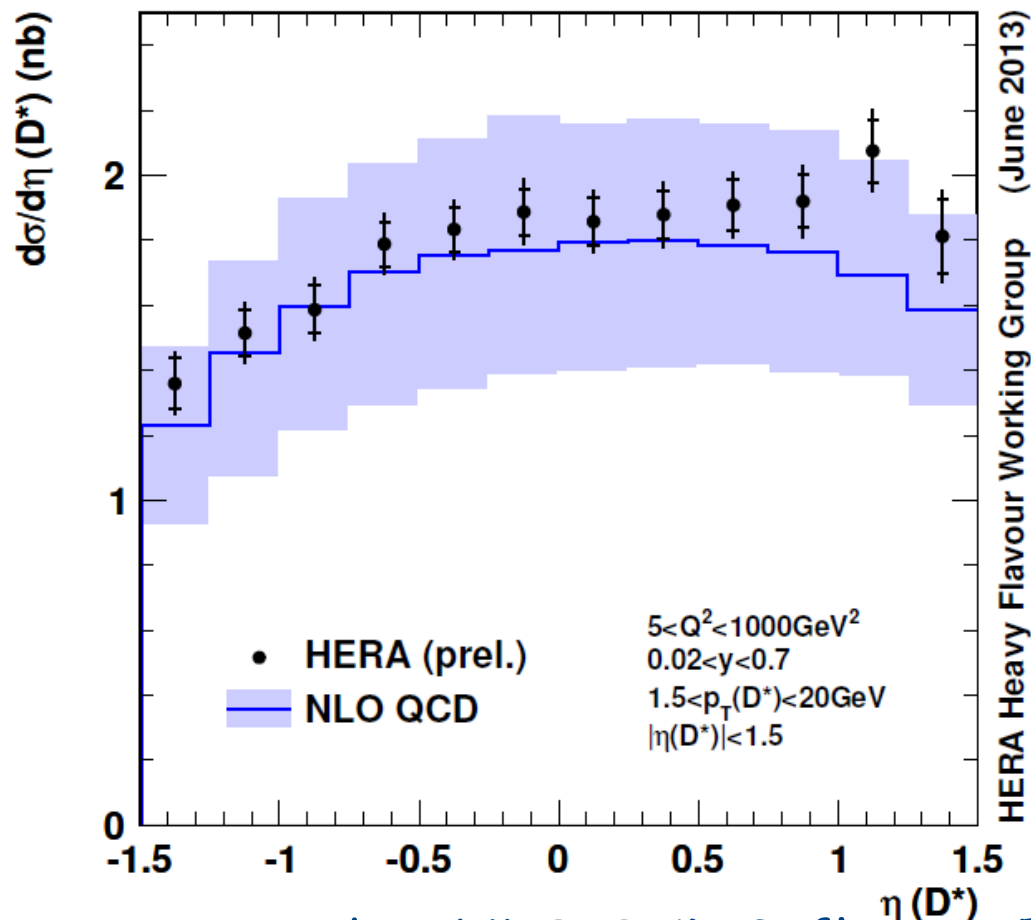
- stat. unc.: uncorrelated
- sys. unc.: point-to-point correlated
- ZEUS-H1 sys. unc.: uncorrelated, except BR unc.

# Combination of $D^*$ differential cross section measurements in DIS at HERA

H1-prelim-13-171, ZEUS-prelim-13-002

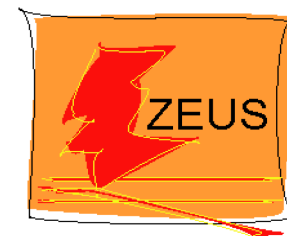
H1 and ZEUS

H1 and ZEUS



- compared to NLO QCD 3-flavour FFNS predictions
- theoretical unc.: 10% (high  $Q^2$ ) to 30% (low  $Q^2$ )
- experimental unc.: 5%

# HERAPDF1.5LO PDF set with experimental uncertainties



# HERAPDF1.5LO PDF set with experimental uncertainties

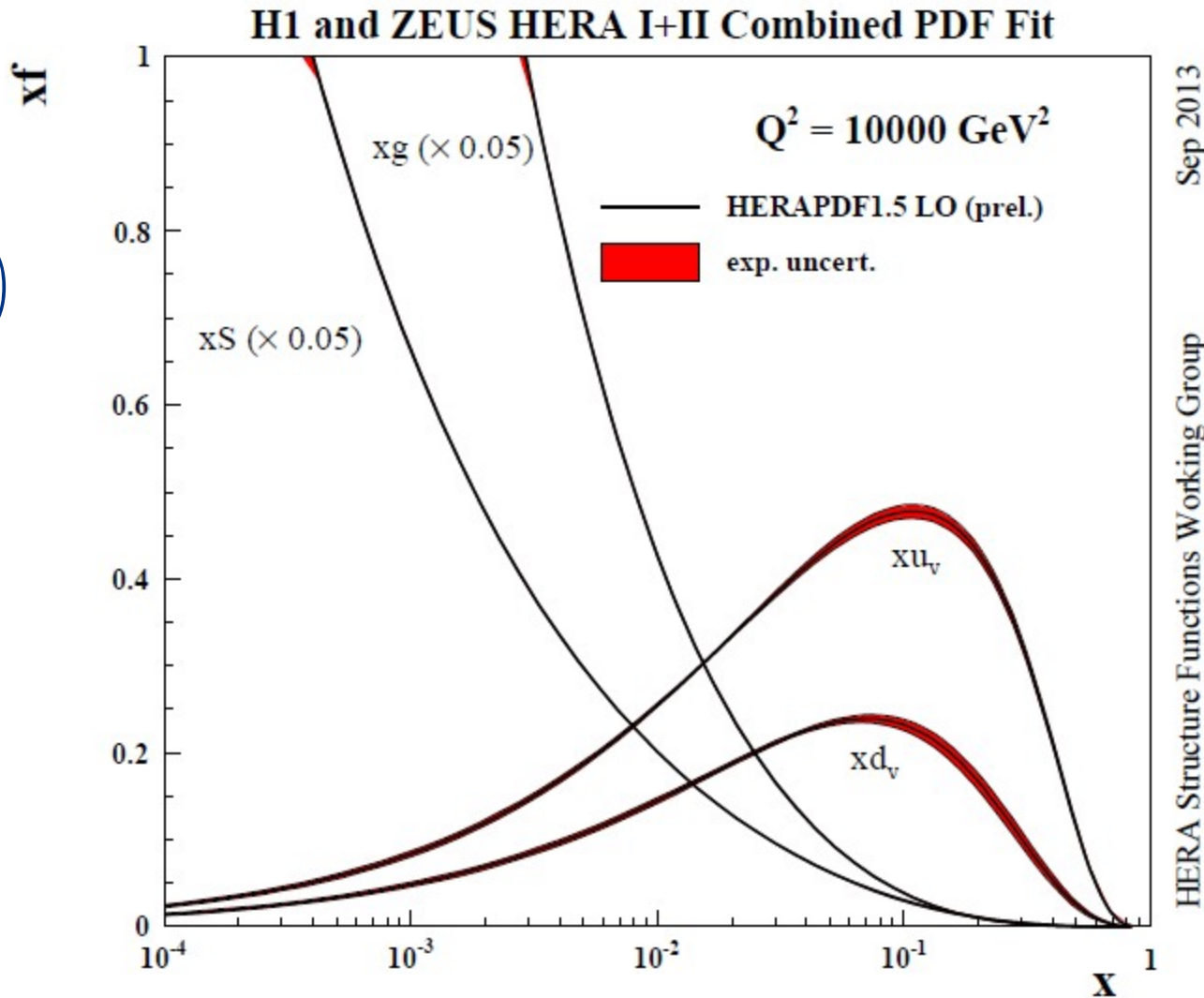
- LO PDFs needed for Monte-Carlo tuning, useful also for LHC, HERMES
- LO PDF set from preliminary HERA I+II inclusive NC+CC DIS data
- framework based on HERAFitter project
- same settings used as for HERAPDF1.5NLO (except LO DGLAP)
  - $\chi^2$  fit accounting for stat., correlated and uncorrelated sys. uncertainties
  - 13 free parameters for  $u_v(x)$ ,  $d_v(x)$ ,  $\bar{u}(x)$ ,  $\bar{d}(x)+\bar{s}(x)$ ,  $g(x)$
  - starting scale  $Q^2=1.9 \text{ GeV}^2$   
evolution LO DGLAP with  $\mu_r^2 = \mu_f^2 = Q^2$  and  $\alpha_s(M_Z)=0.13$
  - charm and beauty quark masses in RT VFNS
- released to LHAPDF library

# HERAPDF1.5LO PDF set with experimental uncertainties

H1-prelim-13-141, ZEUS-prelim-13-003

$$\frac{\chi^2}{\text{ndf}} = \frac{762}{664}$$

$$\left( \text{NLO: } \frac{\chi^2}{\text{ndf}} = \frac{736}{664} \right)$$

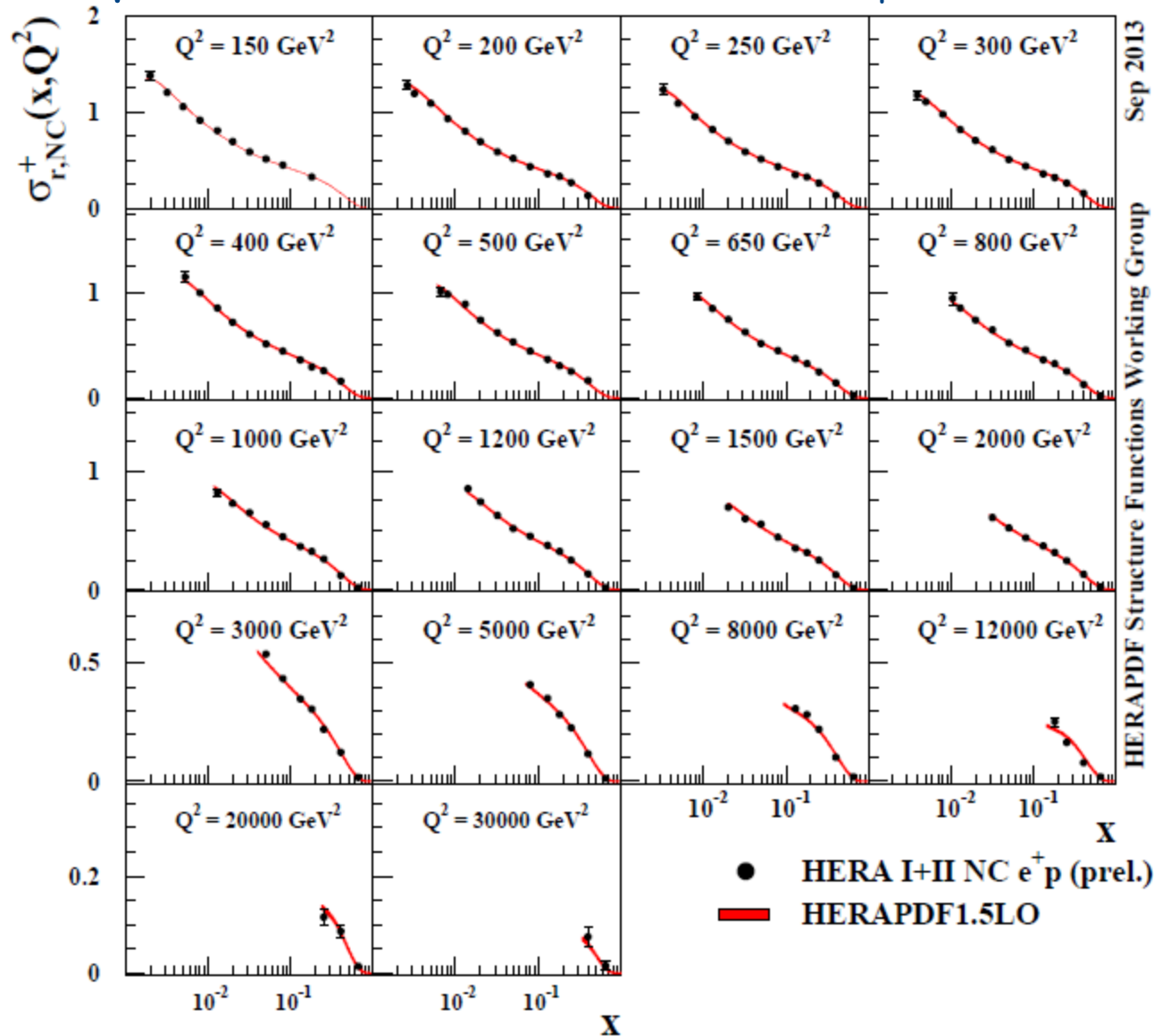


# HERAPDF1.5LO PDF set with experimental uncertainties

LO cross-section predictions vs. data

H1 and ZEUS

H1-prelim-13-141, ZEUS-prelim-13-003

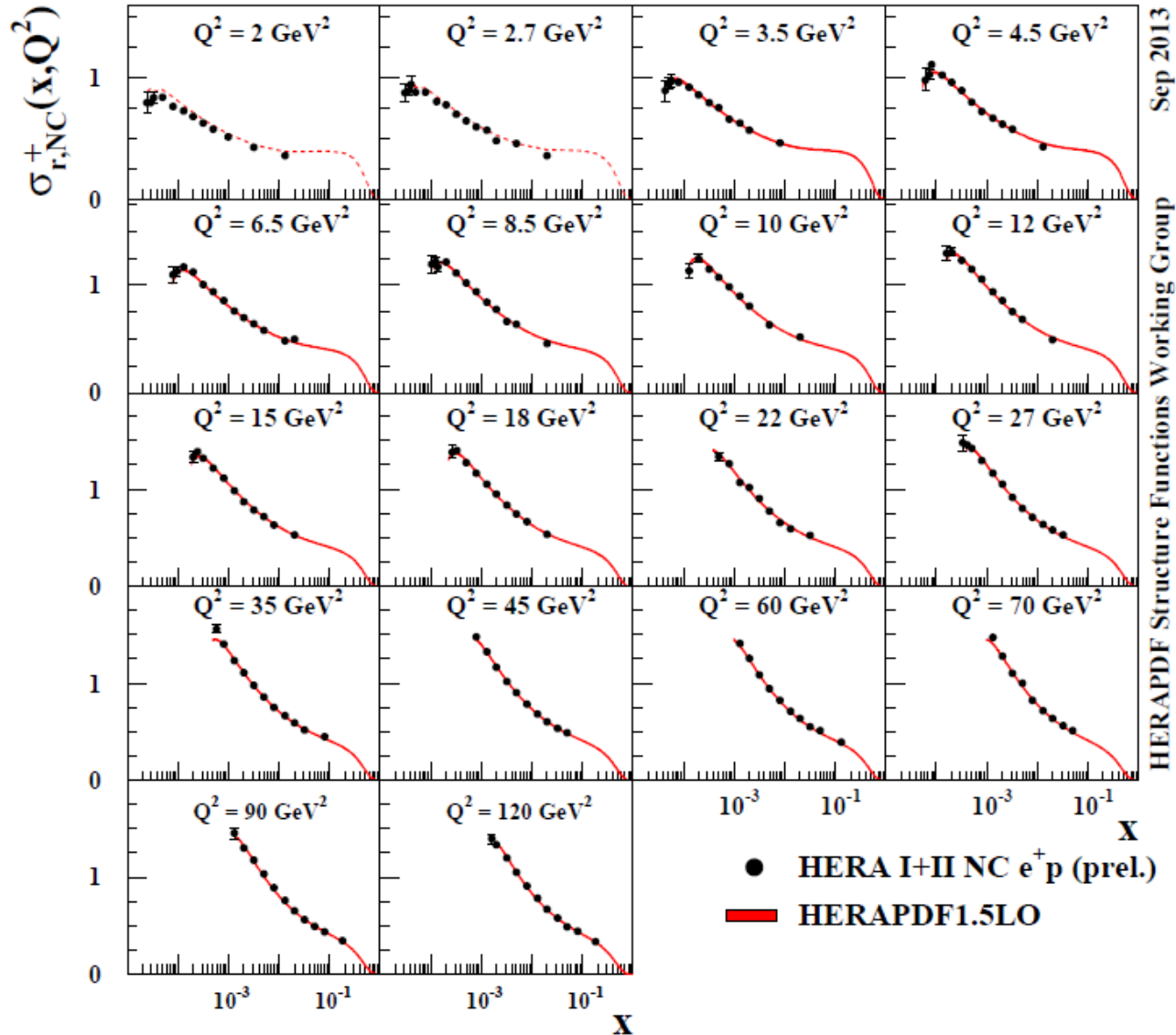




# HERAPDF1.5LO PDF set with experimental uncertainties

LO cross-section predictions vs. data

H1 and ZEUS H1-prelim-13-141, ZEUS-prelim-13-003



# HERAPDF1.5LO PDF set with experimental uncertainties

- HERAPDF1.5 now released in LO, NLO, and NNLO
- main activity of H1-ZEUS inclusive combination group:
  - final combination of inclusive CC+NC HERA II data
  - release of HERAPDF2.0 PDF set based on inclusive data
  - release of HERAPDF2.0 PDF set based on inclusive, charm and jet data

# Data preservation at DESY

## DESY-DPHEP group

# data preservation at DESY

## DESY-DPHEP group

- DPHEP data sets defined and produced by all HERA experiments
  - transition to NAF2/BIRD by H1 (planned for 2014), ZEUS (in progress), HERMES (finalized)
  - ZEUS' common ntuple production finalized, according to plan
- DESY-IT is now in the process of defining and migrating the data to a new long-term storage model
- work on validation system continues, significant interest and praise at CHEP by other experiments and collaborations
- many contributions to conferences by DESY DPHEP group this year, including among others DIS, EPS and CHEP
- DPHEP study group is now moving to a new collaboration structure  
DESY should continue to play a key role, essential for future production of HERA physics results

# Summary

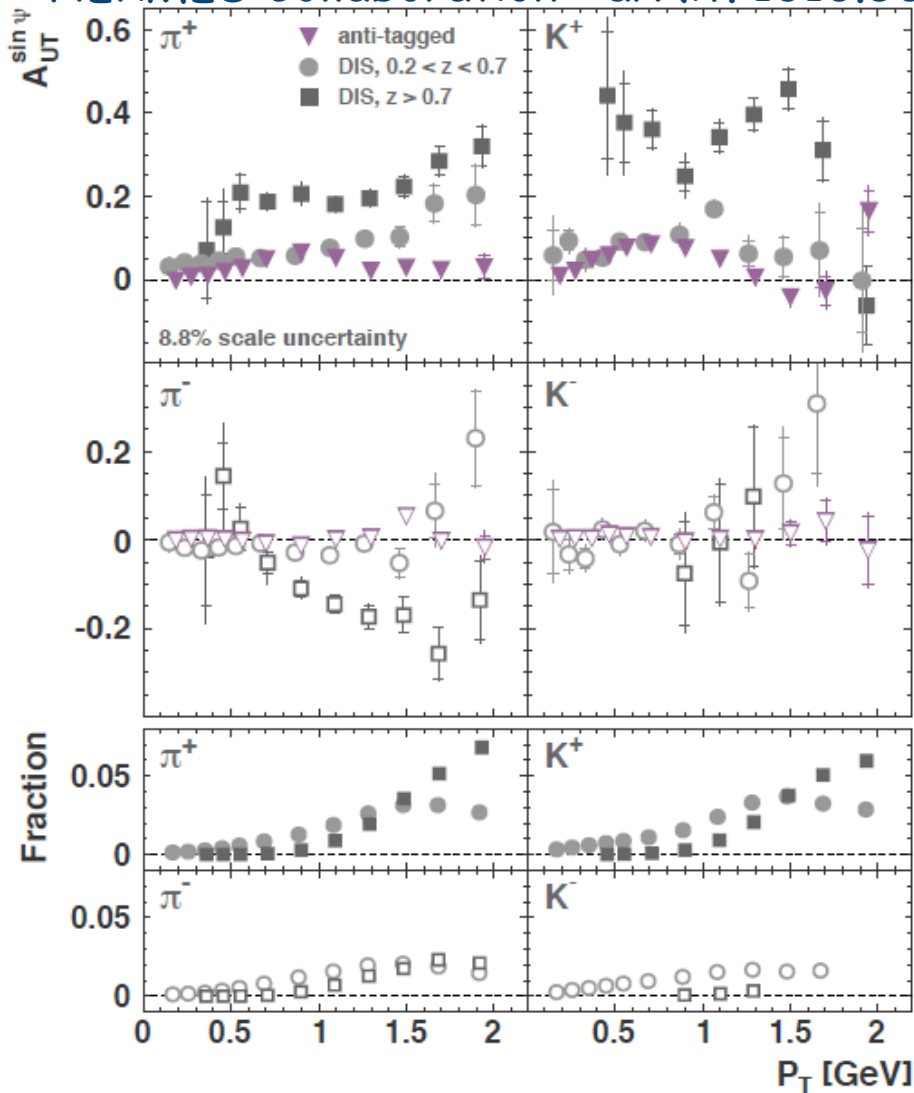
- continuing interest in HERA results, with active conference contributions: 136 physics talks in 2013
- 7 published and 2 submitted papers since last PRC
- 4 released results since last PRC
- significant progress and interest in data preservation

Back up

# Transverse target single-spin asymmetry in inclusive electroproduction of pions and kaons

disentanglement of sub samples

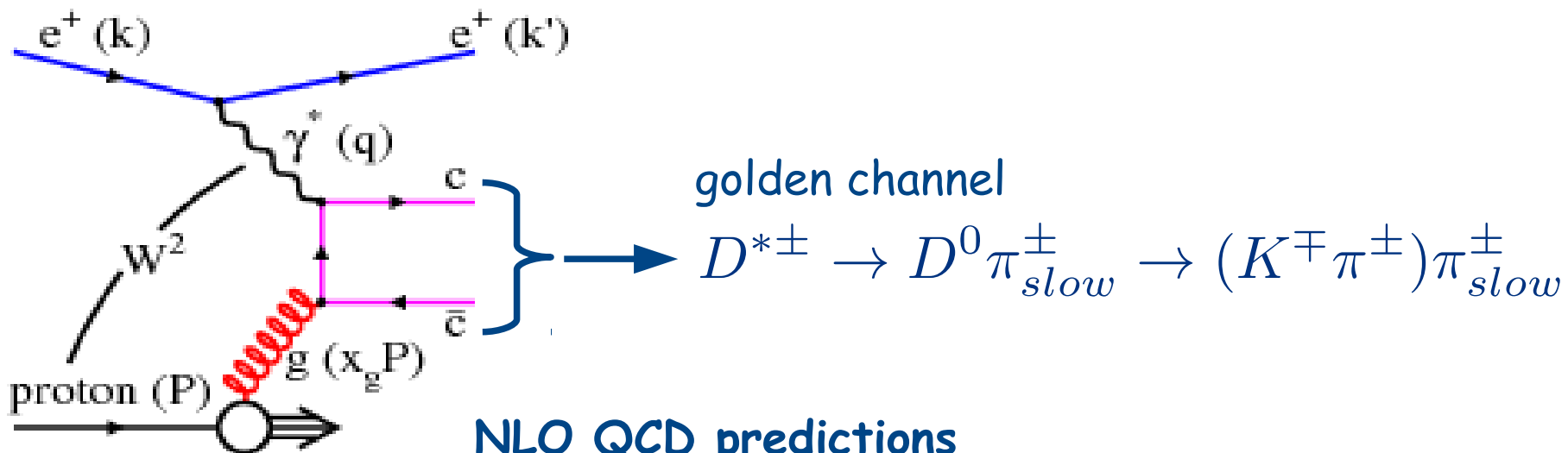
HERMES Collaboration - arXiv. 1310.5070



disentangling of different sub samples:

- anti-tagged region
- DIS region  $0.2 < z < 0.7$
- DIS region  $z > 0.7$

# Combination of $D^*$ differential cross section measurements in DIS at HERA



## NLO QCD predictions

- NLO QCD HVQDIS 3-flavour FFNS
- $m_c = 1.5 \pm 0.15 \text{ GeV}$
- $\alpha_s(M_Z) = 0.105 \pm 0.002$
- $\mu_r, \mu_f$  :  

$$\mu_r = \mu_f = \mu_0 = \sqrt{Q^2 + 4m_c^2}$$
 varied independently:  $1/2 \mu_0 < \mu_r, \mu_f < 2 \mu_0$
- PDF: HERAPDF1.0 FFNS
- fragmentation: Kartvelishvili  
 Eur. Phys. J. C 73 (2013) 2311