

Status of HERA experiments



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78th DESY PRC Meeting, Zeuthen, 16.10.2014

Publications since last PRC



Transverse polarisation of Λ hyperons from quasi-real photoproduction on nuclei

Phys. Rev. D (in press), DESY-14-097



Spin density matrix elements in exclusive ω electroproduction on ^1H and ^2H targets at 27.6 GeV beam energy

EPJC (in press), DESY-14-116



Reevaluation of the parton distribution of strange quarks in the nucleon

Phys. Rev. D 89 (2014) 097101, DESY-13-246



Measurement of D^ photoproduction at three different centre-of-mass energies at HERA*

JHEP10 (2014) 003, DESY-14-082



Further studies of the photoproduction of isolated photons with a jet at HERA

JHEP08 (2014) 023, DESY-14-086



Measurement of multijet production in ep collisions at high Q^2 and determination of the strong coupling α_s

DESY-14-089

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Preliminary results since last PRC



Single- and double-spin asymmetries in semi-inclusive lepto-production of charged pions and kaons from transversely polarized protons



Beam-spin asymmetries in semi-inclusive lepto-production of charged pions and kaons



Trijet production in deep inelastic scattering at HERA

ZEUS-prel-14-008

Updates on:

Combined Measurement of Inclusive e^+p Scattering

Cross Sections at HERA

H1prelim-14-042, ZEUS-prel-14-007



QCD Analysis of the Inclusive e^+p Scattering

Cross Sections at HERA

H1prelim-14-041, ZEUS-prel-14-005

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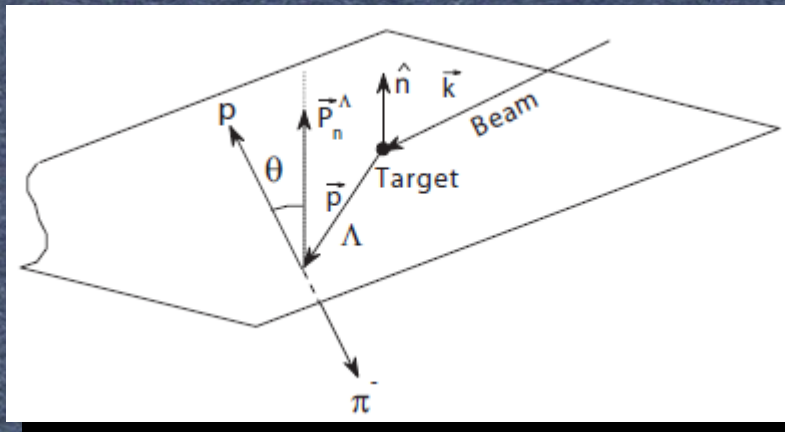
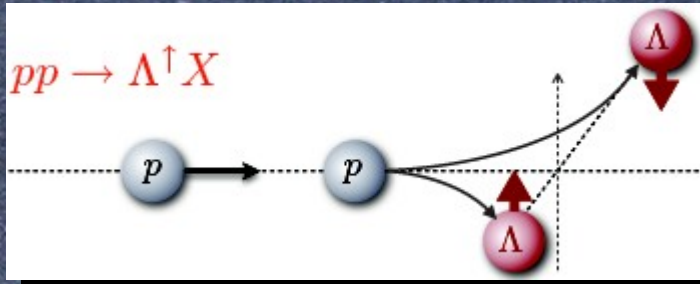
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H1prelim-14-041, ZEUS-prel-14-005

*Transverse polarisation of Λ hyperons from quasi-real
photoproduction on nuclei*

Transverse polarisation of Λ in photoproduction

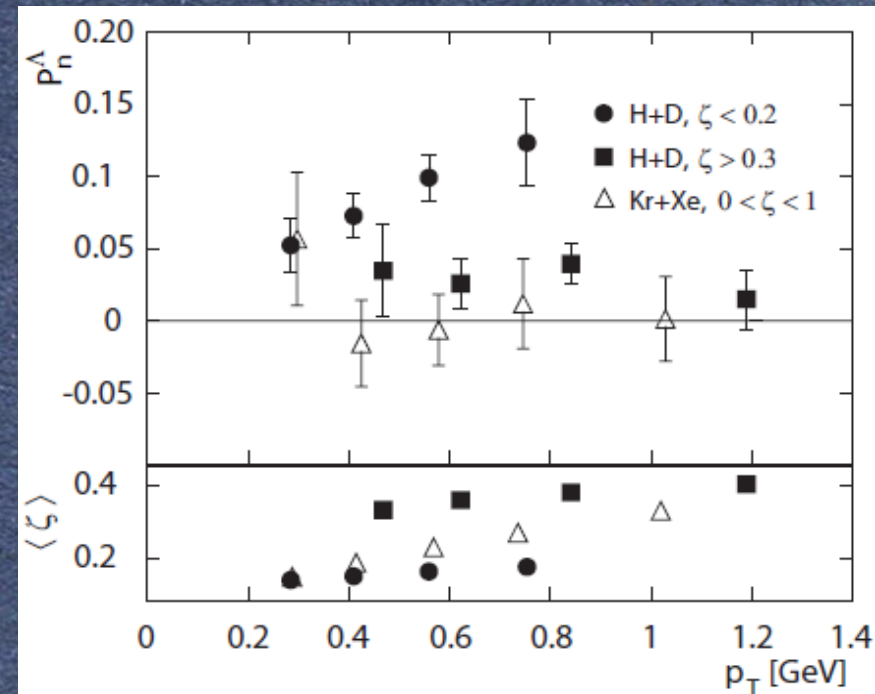


- ◆ In hadron-hadron collisions Λ hyperons are produced transversely polarised \rightarrow well established phenomenon.
- ◆ Very little information on Λ polarisation from photo- and electro-production.
- ◆ Polarisation vector \vec{P} is directed along the normal \hat{n} to the Λ production plane.
- ◆ Reaction studied using various nuclear targets: H, D, ^4He , Ne, Kr, and Xe.

- ◆ Measured transverse polarisation of Λ is observed to be positive.
- ◆ Polarisation for light target increases linearly as a function of p_T for the region of $\zeta < 0.2$ and is independent of p_T for $\zeta > 0.3$.

$$\zeta \equiv (E_\Lambda + p_{z\Lambda}) / (E_e + p_e)$$

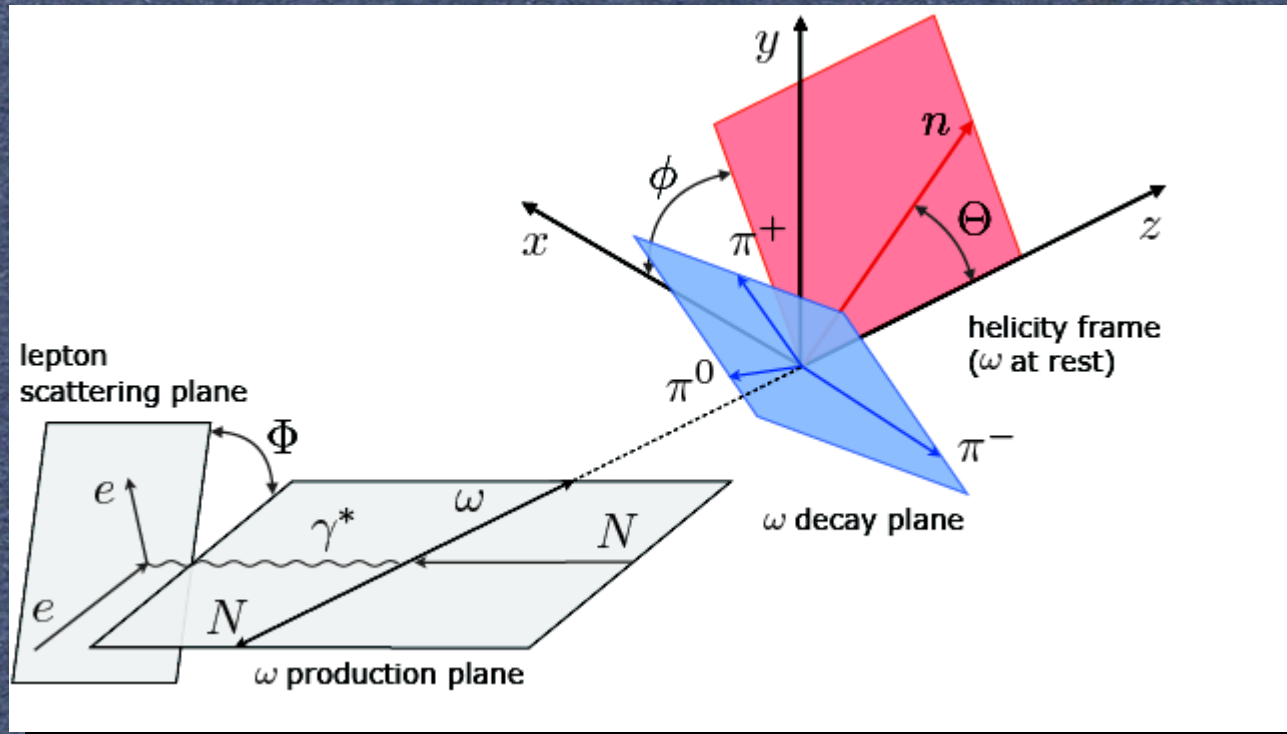
- ◆ For heavy targets polarisation is consistent with 0.



*Spin density matrix elements in exclusive ω
electroproduction on ^1H and ^2H targets at 27.6 GeV
beam energy*

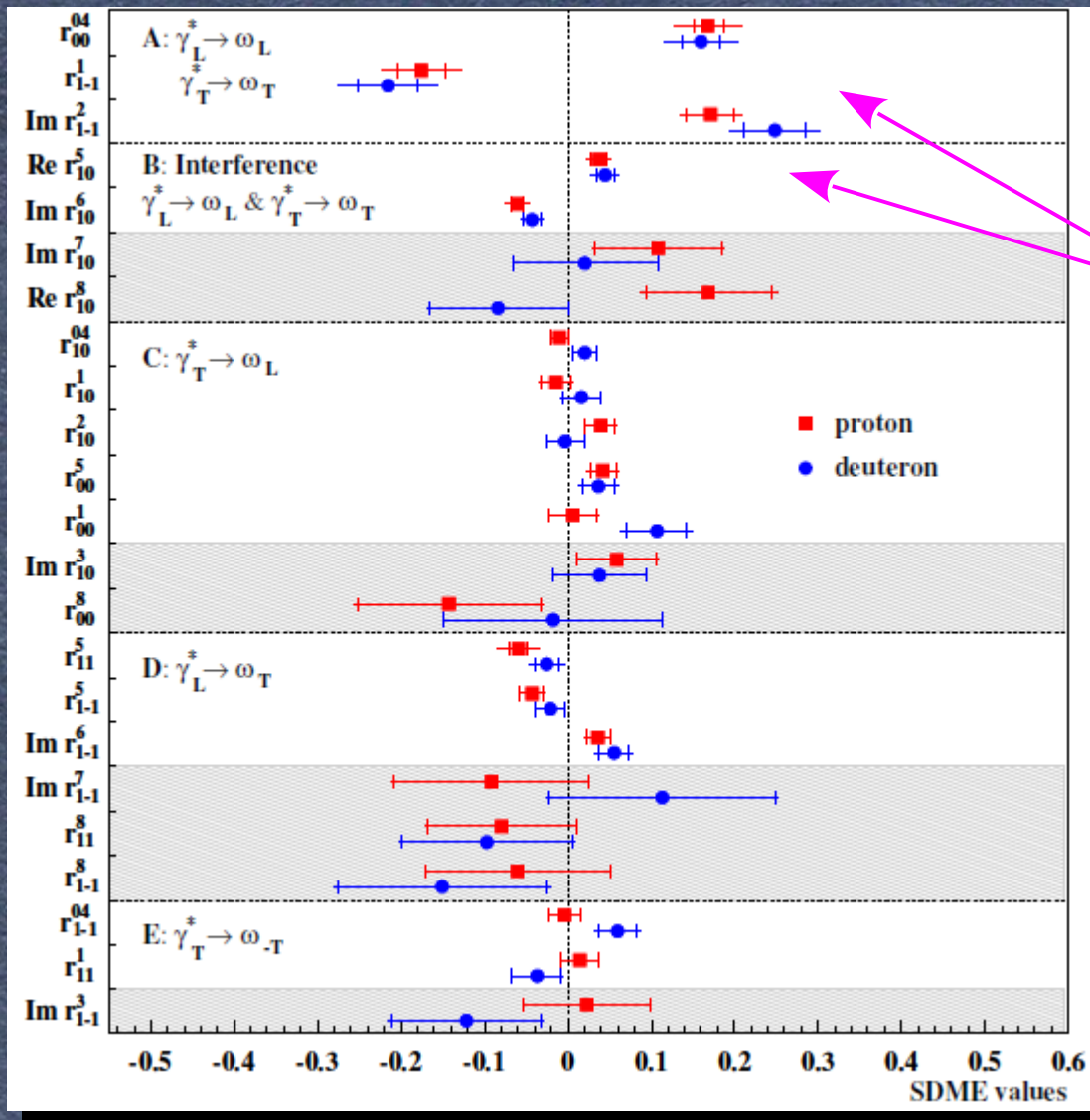
SDMEs of ω

- ◆ Spin density matrix elements (SDMEs) describe the final spin states of the produced vector meson.
- ◆ SDMEs are parametrised by combination of helicity amplitudes.



- ◆ Angular distribution of pions from ω decay depends on SDMEs and beam polarisation.
- ◆ Angular distributions are decomposed into polarised and unpolarised parts, depending on the longitudinal polarisation of the beam.
- ◆ SDMEs are extracted from measured angular distributions.

SDMEs of ω

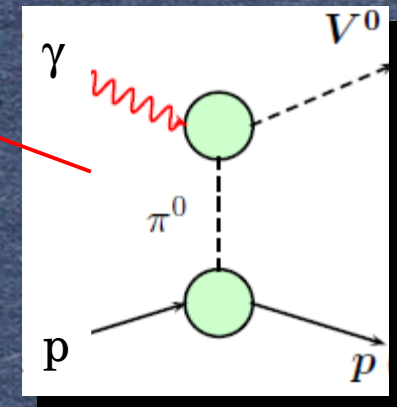
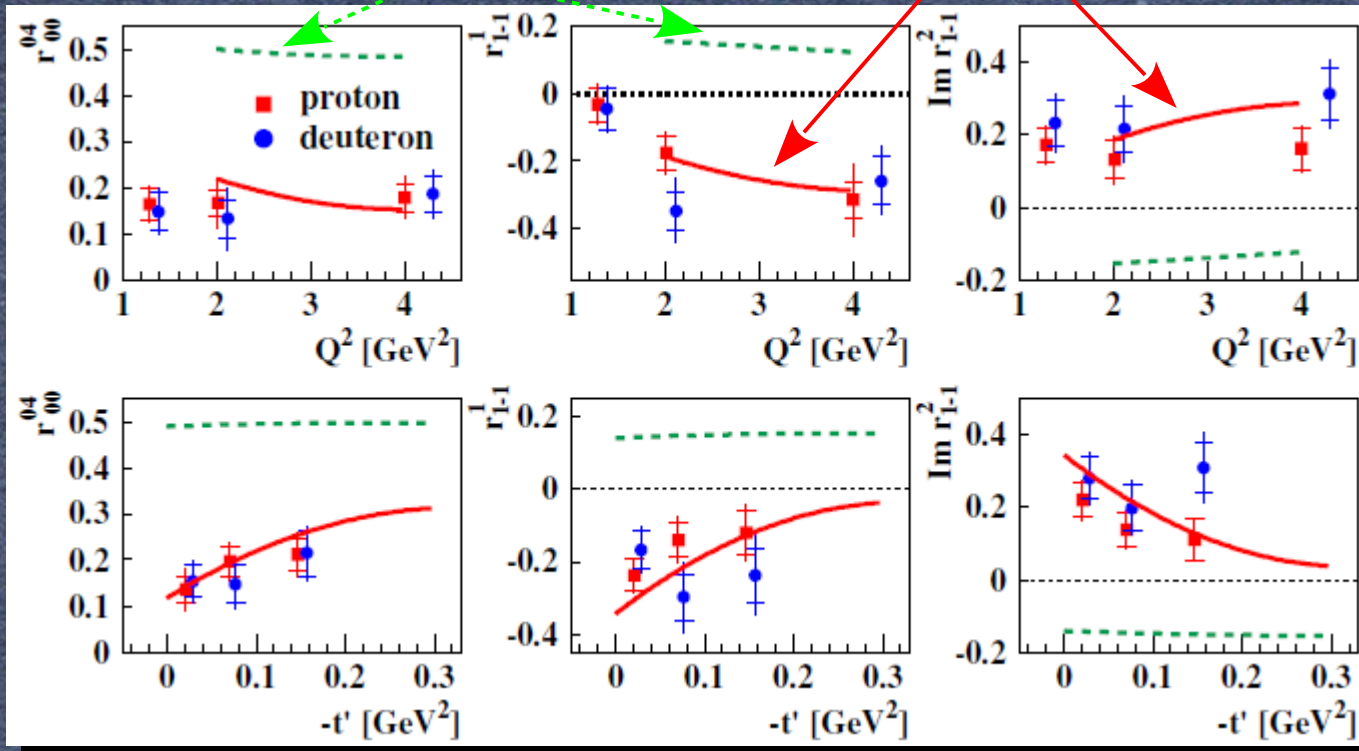


- ◆ Extracted SDMEs are divided into five classes according to the helicity transition.
- ◆ SDMEs are expected to be non-zero for $\gamma_T^* \rightarrow \omega_T$ and $\gamma_L^* \rightarrow \omega_L$, i.e for processes without helicity flip.
- ◆ In case of s-channel helicity conservation, the SDME terms with helicity flip are expected to be 0.
- ◆ Polarised SDMEs are displayed in shaded areas.
- ◆ Proton and deuteron data are seen to have similar behaviour.

SDMEs of ω

No contribution
from pion exchange

Including pion
exchange



The pion-
exchange graph
in vector-meson
leptonproduction

- ◆ Extracted SDMEs allow to the testing of different phenomenological models.
- ◆ SDMEs are compared to theoretical predictions with and without contribution from pion exchange.
- ◆ Prediction including pion exchange contribution shows a good description of the data, while model without this contribution fails to describe the measurement.

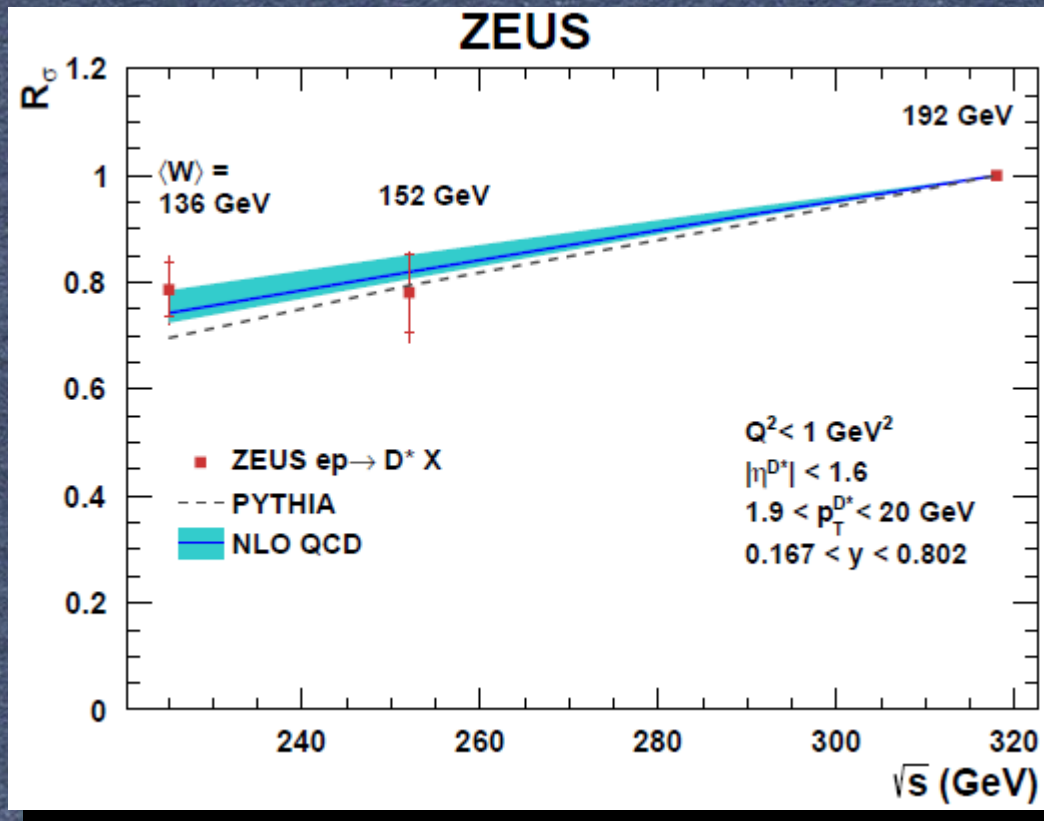


Measurement of D^ photoproduction at three
different centre-of-mass energies at HERA*

D* at different centre-of-mass energies

Heavy quark production provides an opportunity to study perturbative QCD.

The dependence of D* photoproduction on the ep centre-of-mass energy is measured for the first time at HERA.



Normalised D* total cross section:

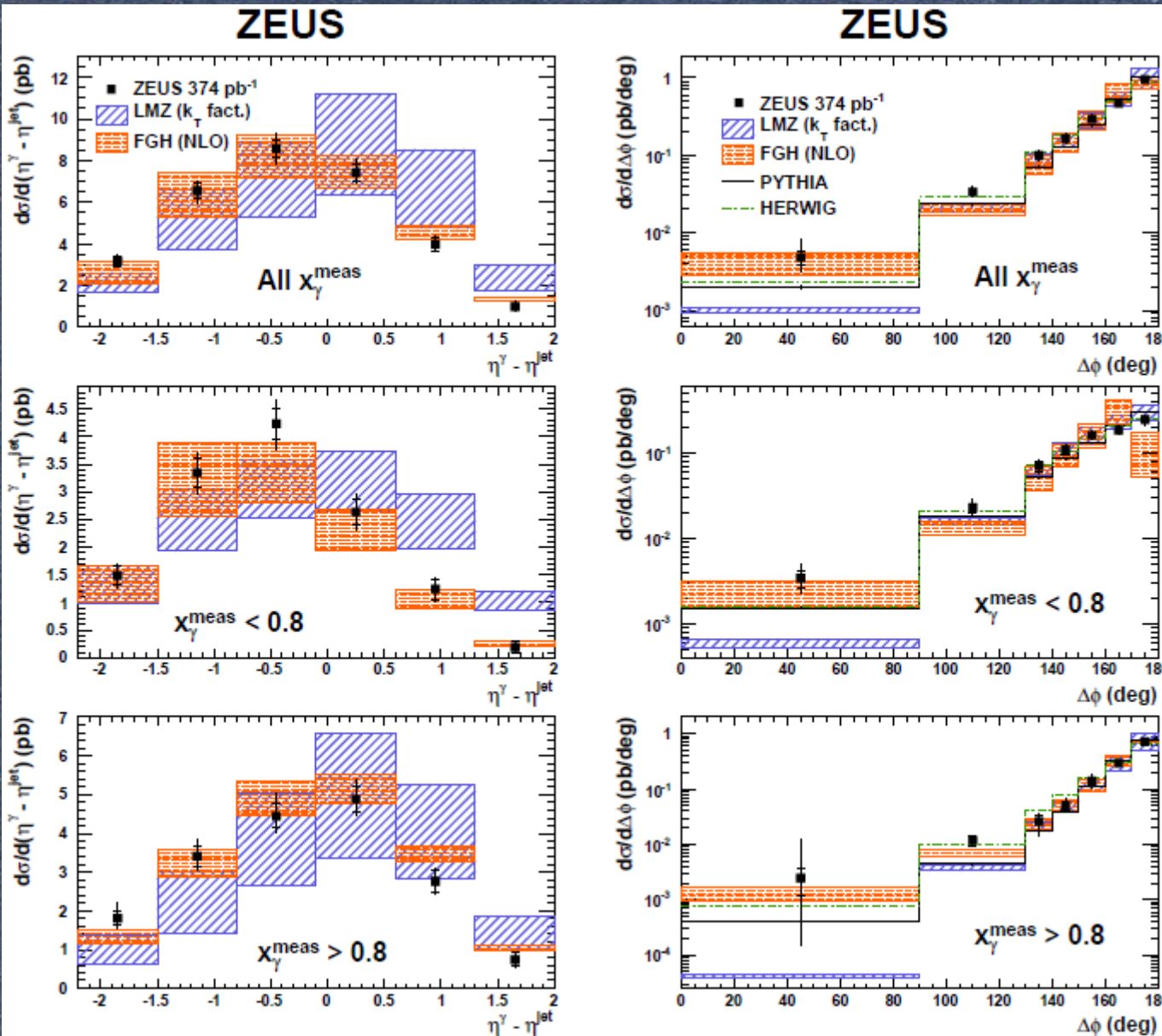
- ♦ \sqrt{s} = ep centre-of-mass energy.
- ♦ W = centre-of-mass energy of photon-proton system.
- ♦ Cancellation of experimental and theoretical uncertainties correlated between measurements.
- ♦ The data increases with increasing centre-of-mass energy.
- ♦ This behaviour is predicted well by NLO QCD.



follow up of *Phys. Lett. B* 730 (2014) 293

Further studies of the photoproduction of isolated photons with a jet at HERA

Photoproduction of isolated photons with a jet



- Cross section as a function of
- ♦ $(\eta_\gamma - \eta_{\text{jet}}) \rightarrow$ sensitive to the details of hard scattering process.
 - ♦ $\Delta\phi \rightarrow$ sensitive to the higher-order gluon radiation.
 - ♦ x_γ – fraction of photon energy, contributing to the photon-jet final state.

Measured data are compared to different QCD-based theory models:

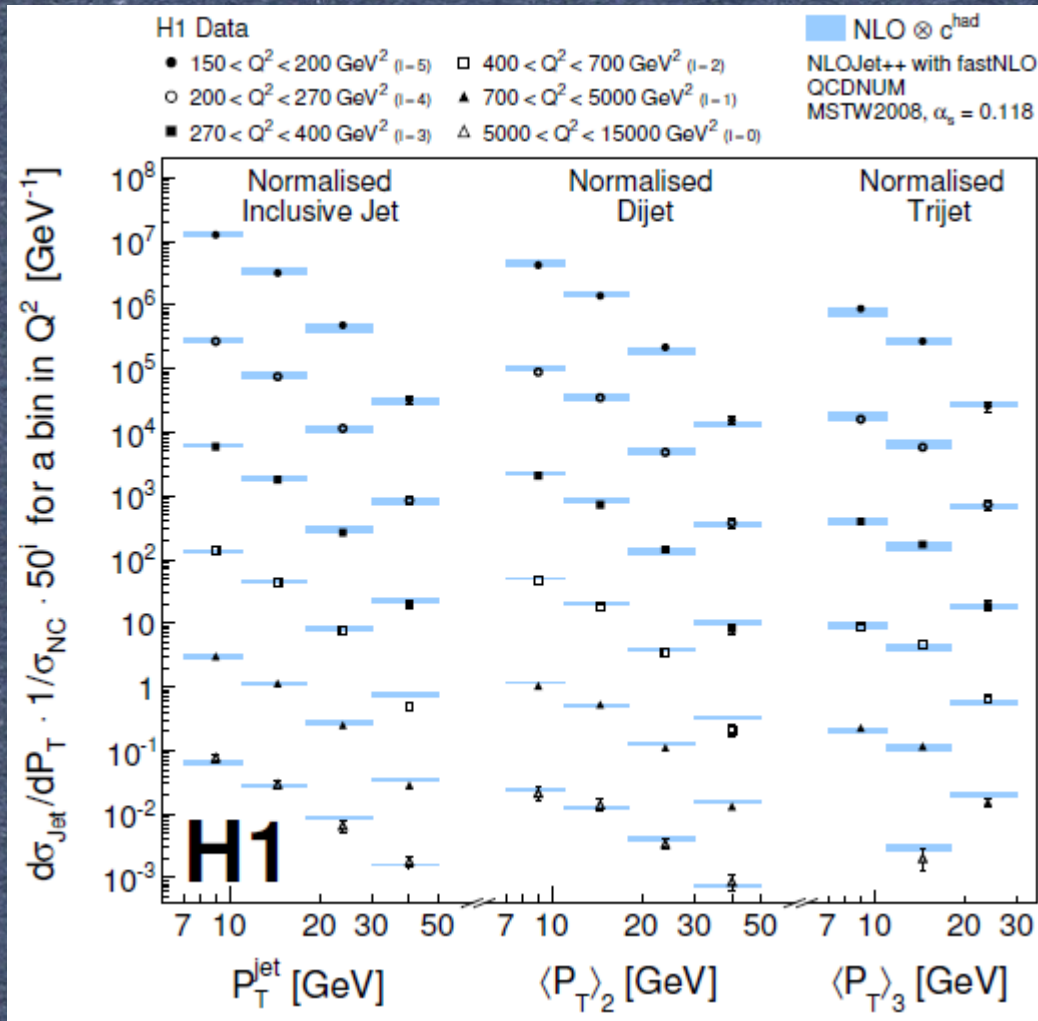
- ♦ FGH \rightarrow NLO calculation,
- ♦ LMZ \rightarrow k_T -factorisation approach.

LMZ \rightarrow generally ok,
FGH \rightarrow good agreement.

Measurement of multijet production in ep collisions at high Q^2 and determination of the strong coupling α_s

Multijet production in DIS at high Q^2

- Jet production is an important process for studying strong interactions and is directly sensitive to α_s .
- Double-differential inclusive jet, dijet and trijet cross sections are measured by the H1 experiment using regularised unfolding.



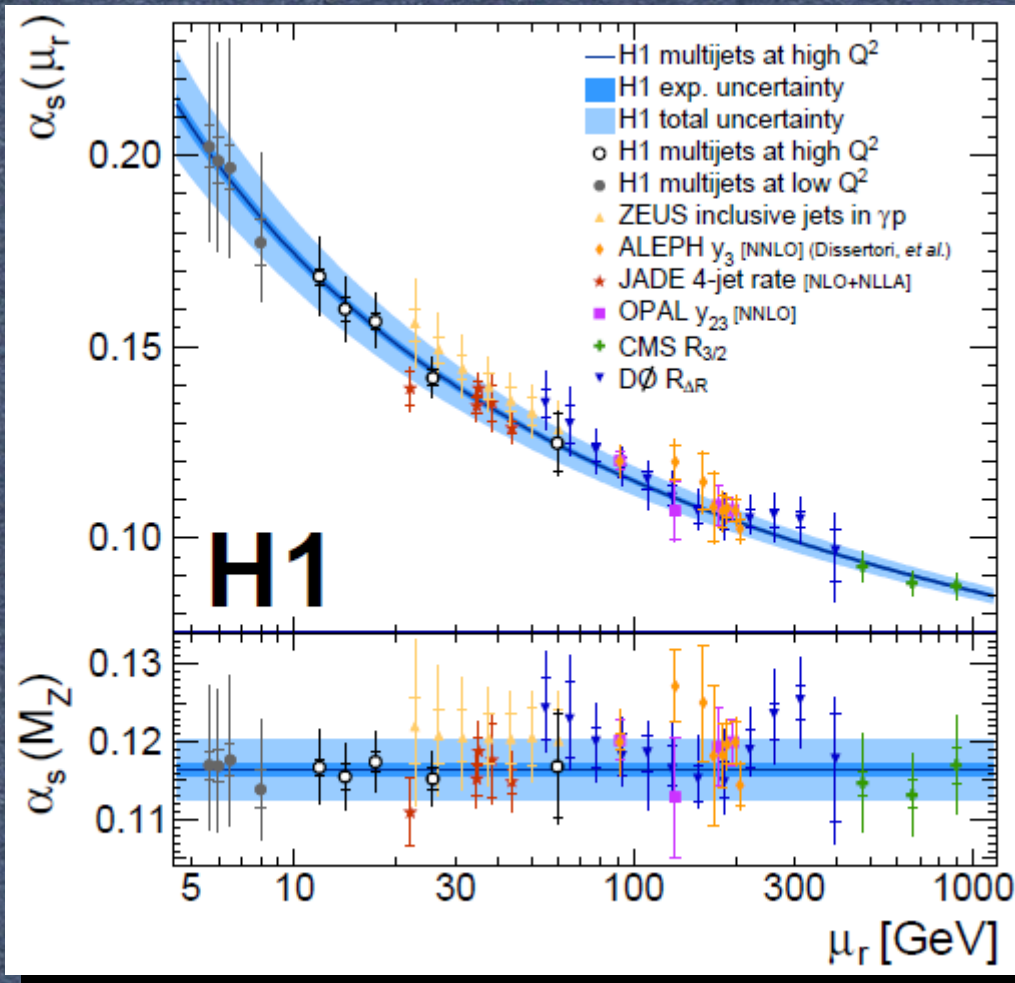
- Measured absolute cross sections are then normalised to the NC DIS cross section to benefit from cancellation of systematic uncertainties correlated between the measurements.
- New calibration reduces jet energy scale uncertainty down to 1% !
- Blue band corresponds to NLO uncertainty, obtained by varying renormalisation scale $\mu = (Q^2 + P_T^2) / 2$.

Multijet production in DIS at high Q^2

- ◆ α_s is extracted by fitting each jet cross section separately and also all 3 simultaneously taking into account the covariance matrix from unfolding.

$$\alpha_s = 0.1165 \pm 0.0008_{exp} \pm 0.0038_{theo}$$

Theoretical uncertainty 3.3%
experimental only 0.7%!

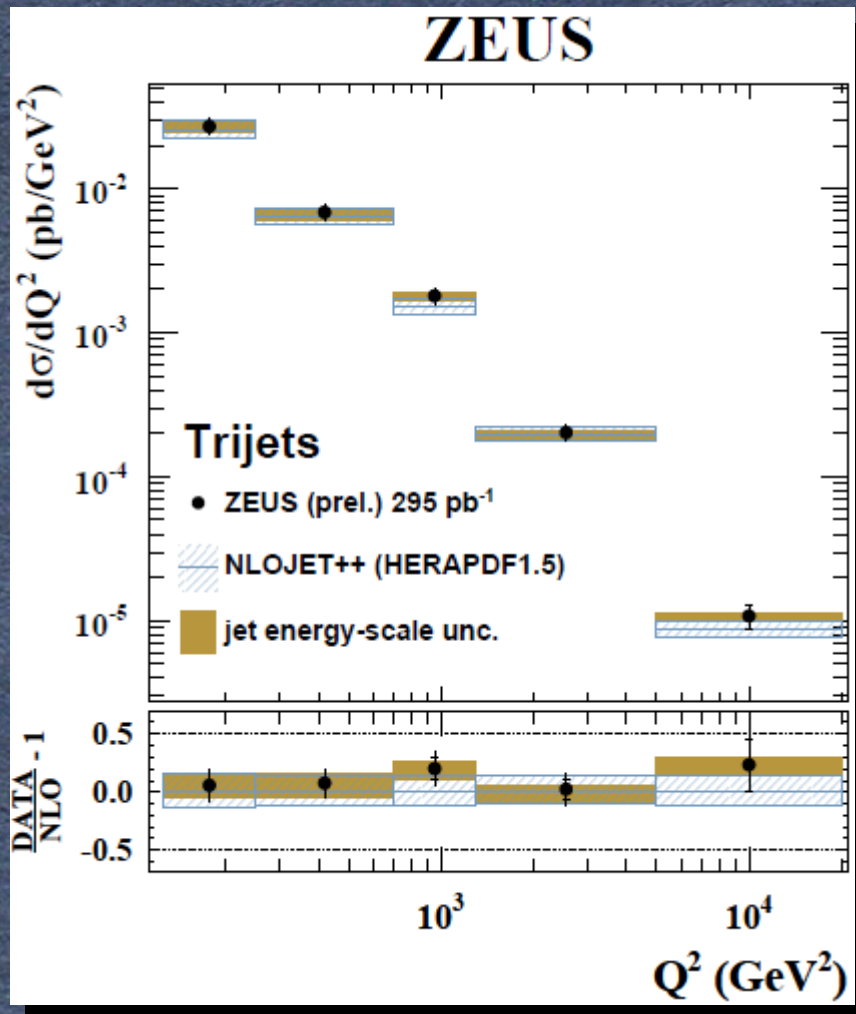


- ◆ The running of the strong coupling α_s as a function of the scale μ_r as well as the corresponding values of $\alpha_s(M_Z)$.
- ◆ Shown also are α_s values measured by ZEUS, DØ and CMS experiments.



*Trijet production in deep inelastic
scattering at HERA*

Trijet production in DIS



Differential trijet production cross section is measured as a function of various kinematic observables.

- ◆ Measured cross section as a function of Q^2 compared to the NLO predictions.
- ◆ Also shown is relative difference between data and theory.

Good agreement between data and prediction is observed.

Kinematic range:

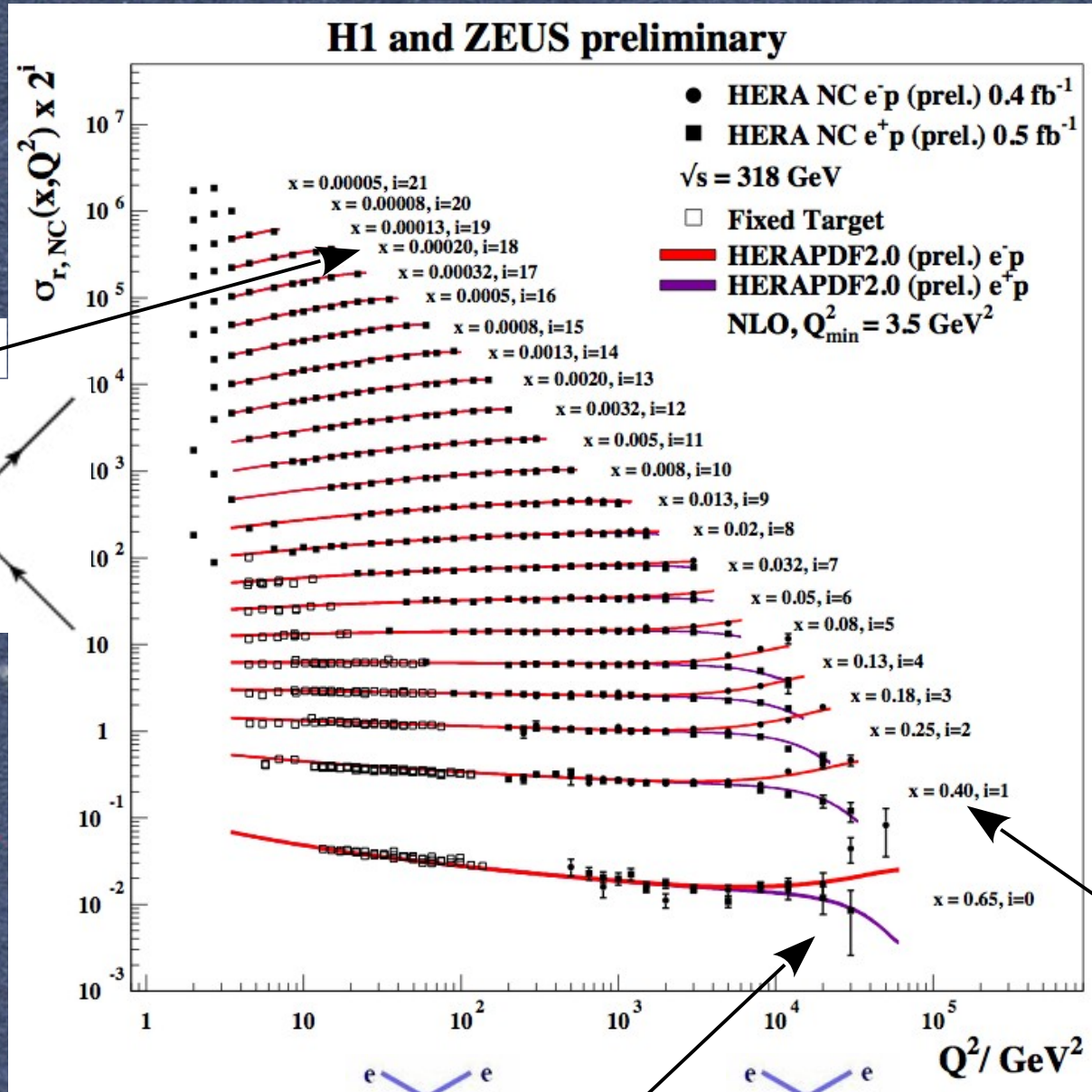
- ◆ $-1 < \eta_{\text{lab}}^{\text{jet}} < 2.5$; pseudorapidity in lab frame,
- ◆ $E_{\text{T,B}}^{\text{jet}} > 8 \text{ GeV}$; jet transverse momentum in Breit frame.



Combined measurement of inclusive $e^\pm p$ scattering cross sections at HERA

QCD analysis of the inclusive $e^\pm p$ scattering cross sections at HERA

Combination of inclusive DIS data



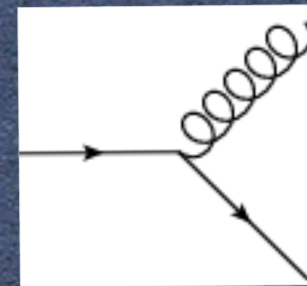
@ low x



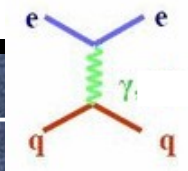
Combined NC DIS cross sections compared to NLO QCD fit HERAPDF 2.0.

Nice illustration of:

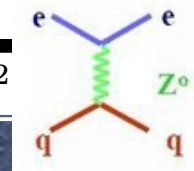
- ◆ Scaling violation,
- ◆ Electroweak effects at high Q^2 .



@ high x

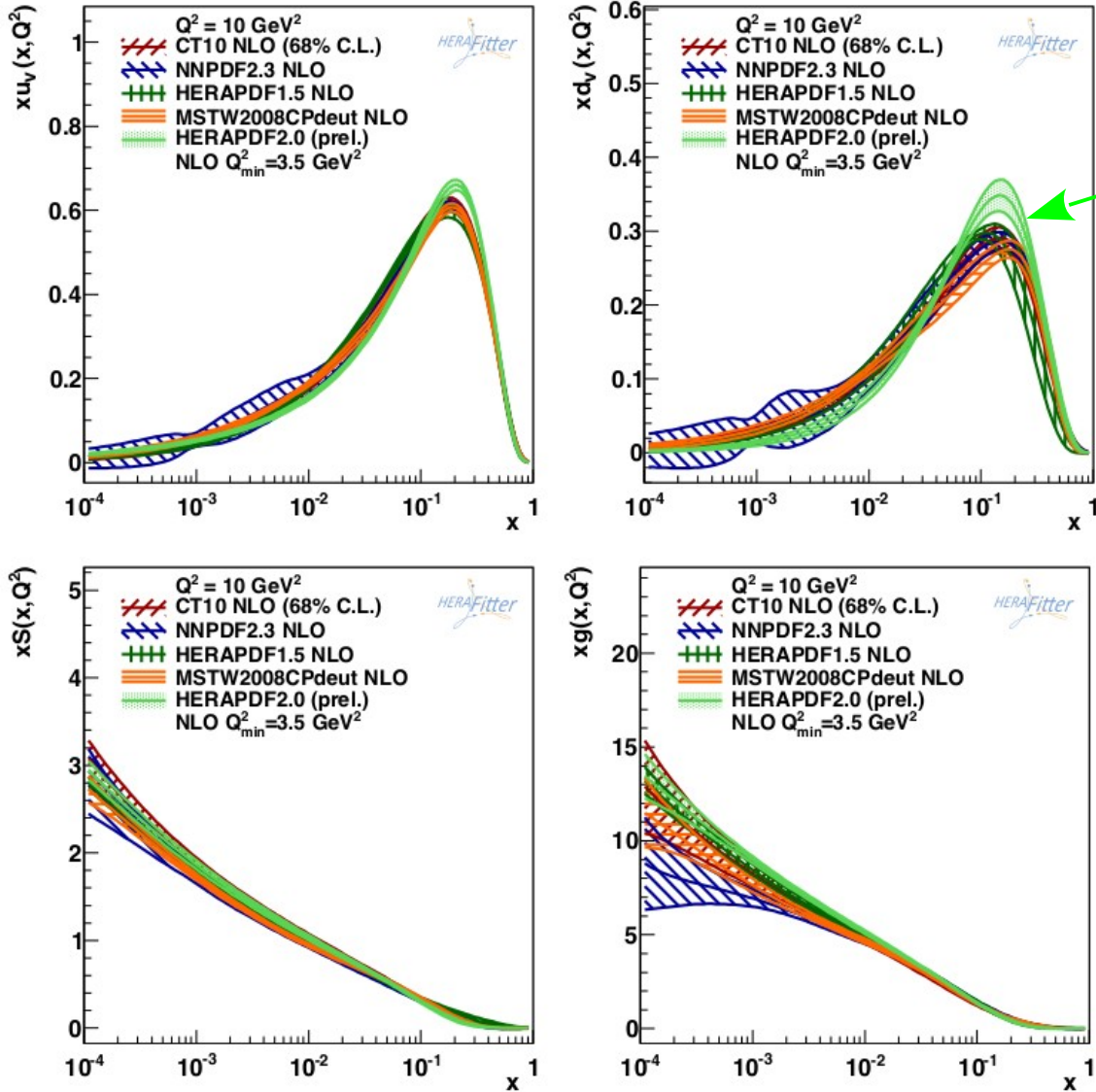


@ high Q^2



HERAPDF 2.0

H1 and ZEUS preliminary



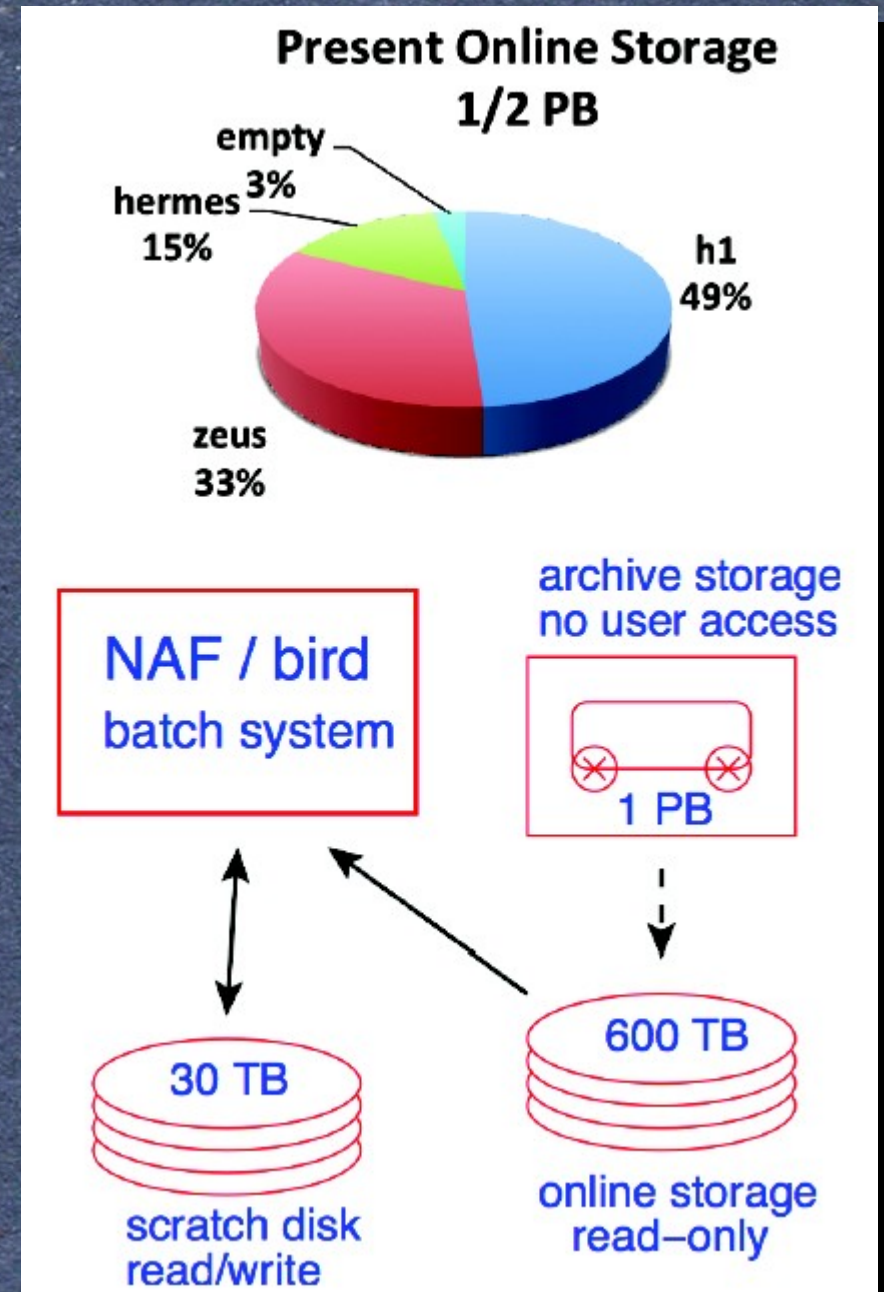
HERAPDF 2.0 (prel.) compared to different PDFs

- ◆ Difference in valence quarks,
- ◆ d-valence better constrained by new data.

HERA data preservation at DESY

Status of DP for the HERA experiments

- ◆ DPHEP Collaboration is now officially installed
 - MoU Signed by: CERN, DESY, IN2P3, MPI Munich, HIP, IHEP, KEK.
- ◆ Legacy dataset
 - Defined
 - About 80% of the data and Monte Carlo is transferred to long term storage.
- ◆ Moving to central IT services
 - Successfully using NAF / bird batch system,
 - Archive web server available for all experiments,
 - New software preservation system in preparation.



HERA Workshop on November 11-13th

Future Physics with HERA Data for Current and Planned Experiments

11-13 November 2014

DESY, Hamburg, Germany

The workshop addresses the question:
Which measurements could/should be still carried out with
the unique HERA data collected by the H1, ZEUS and HERMES
experiments and what is their relevance/impact on current or
future experiments at the LHC, ILC, LHeC, EIC or other facilities?

Local Organising Committee:
Matthew Wing (Chair), Olaf Behnke, Markus Diehl, Achim Geiser, Sergey Levonian,
Ani Rostomyan, Gunar Schnell, Stefan Schmitt

<https://indico.desy.de/event/futurehera>



- ◆ Measurements still to be carried out with unique HERA data collected by the H1, ZEUS and HERMES.
- ◆ Relevance and impact on current and future experiments.
- ◆ Various topics:
 - Proton structure and PDFs,
 - Nucleon spin,
 - 3D nucleon structure,
 - Diffraction and low x ,
 - Hadronic final states,
 - Jets and heavy flavours,
 - Monte Carlo development and tuning.

Summary

- ◆ HERA results still very interesting and visible in the community
 - Conference contributions: ~120 physics talks in 2014.
- ◆ New results since last PRC
 - 5 publications,
 - 4 preliminary results.
- ◆ Significant results and progress in data preservation
 - DPHEP Collaboration is now officially installed.
- ◆ Dedicated workshop on HERA data, relevance and impact on current and future experiments on November 11-13th.