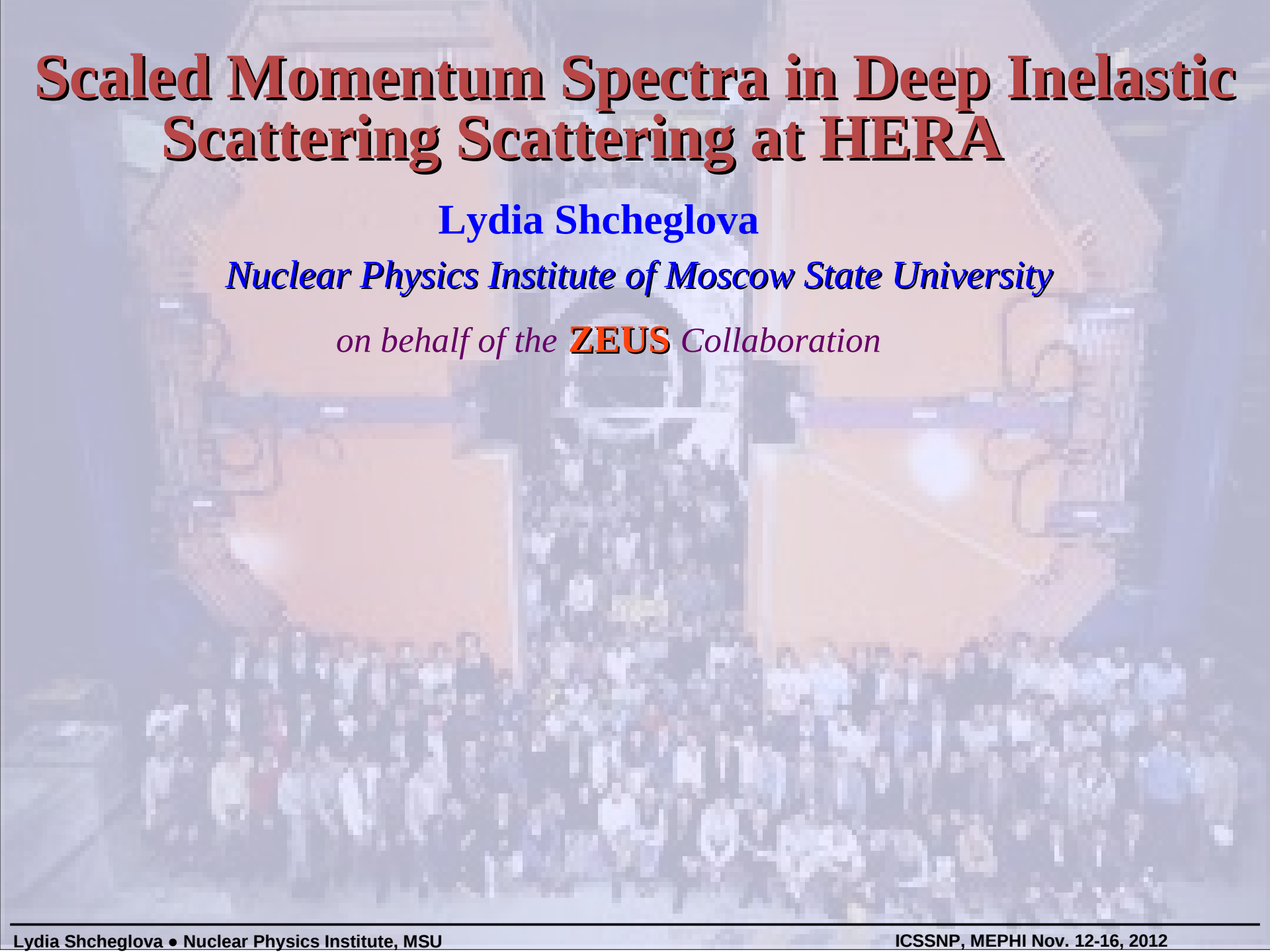
Scaled Momentum Spectra in Deep Inelastic Scattering Scattering at HERA

Lydia Shcheglova

Nuclear Physics Institute of Moscow State University

on behalf of the **ZEUS** *Collaboration*



Scaled Momentum Spectra in Deep Inelastic Scattering Scattering at HERA

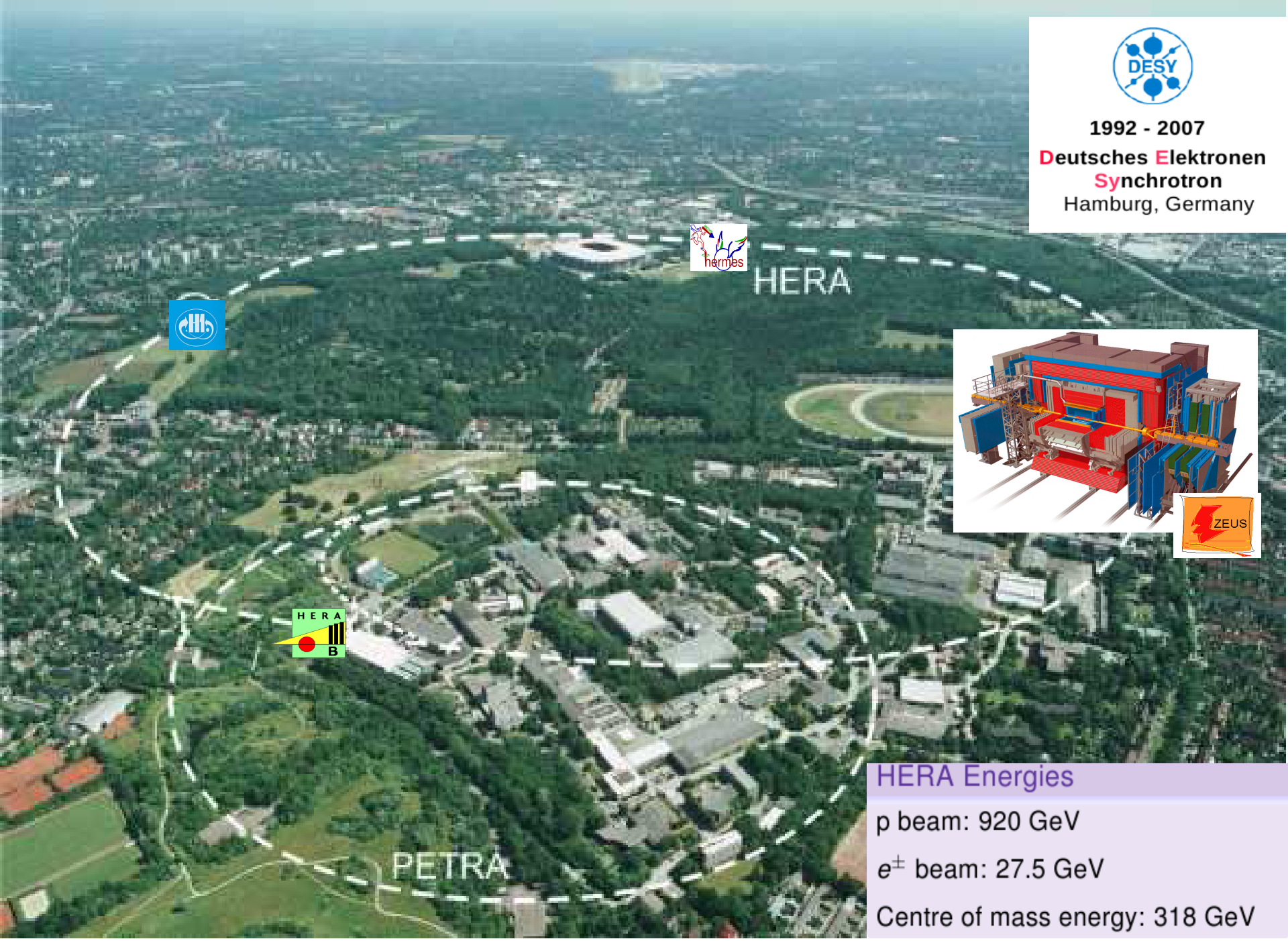
Lydia Shcheglova

Nuclear Physics Institute of MoscowStateUniversity

on behalf of the ZEUS Collaboration

Outline :

- Introduction.
  HERA Collider and the ZEUS detector
- Motivation
- Scaled momentum spectra:
  - charged particles
  - K/Λ particles
- Summary



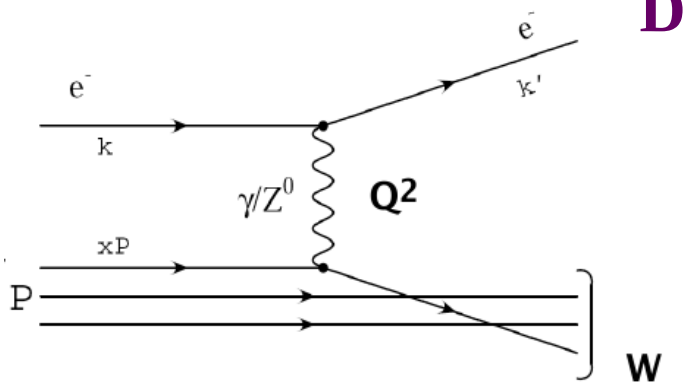
HERA Energies

p beam: 920 GeV

$e^{\pm}$ beam: 27.5 GeV

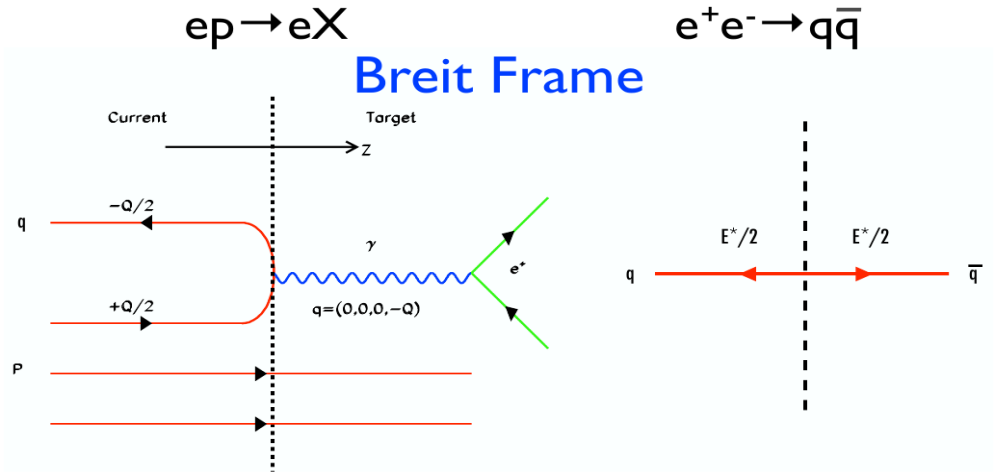
Centre of mass energy: 318 GeV

DIS kinematics



$$Q^2 = -q^2 = -(k - k')^2$$

$$x = \frac{Q^2}{2q \cdot P}$$



Breit Frame definition:

$$2xP + q = 0$$

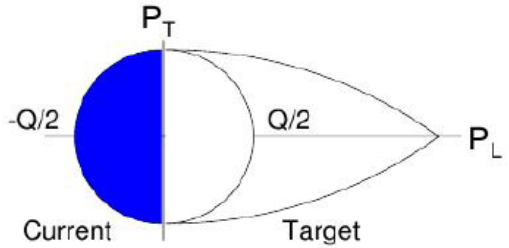
"Brick wall frame" incoming quark scatters off photon and returns along same axis.

Scaled momentum

$x_p = p/E$

E = Q/2 maximum available momentum

Easy direct comparison to the hadronisation in one hemisphere of e^+e^- annihilation



Momentum space in the Breit frame

Motivation

Fragmentation functions $D(z,Q^2)$

Hadron spectra in ep hard scattering

$$d\sigma/dx_p = f(x,Q^2) \otimes \sigma(Q^2) \otimes D(x_p,Q^2)$$

$f(x,Q^2)$: Parton density

$\sigma(Q^2)$: parton cross section (NLO,..)

$D(x_p,Q^2)$: fragmentation function - probability for a parton to fragment into a hadron carrying a given fraction x_p of the parton energy

- Evolution of FF given by DGLAP
- FF are universal (from factorisation theorem)

- NLO QCD calculations that combine full NLO matrix elements with fragmentation functions (FF) obtained from fits to e^+e^- annihilation data,
  - NLO fragmentation functions obtained from fits to e^+e^- data;
  - The predictions were obtained using the CYCLOPS program.
- Modified leading-log-approximation (MLLA) + local parton-hadron duality assumption (LPHD).

Scaled momentum $x_p = \frac{(2\ P_h)}{Q} = \frac{P_h}{E_{beam}}$

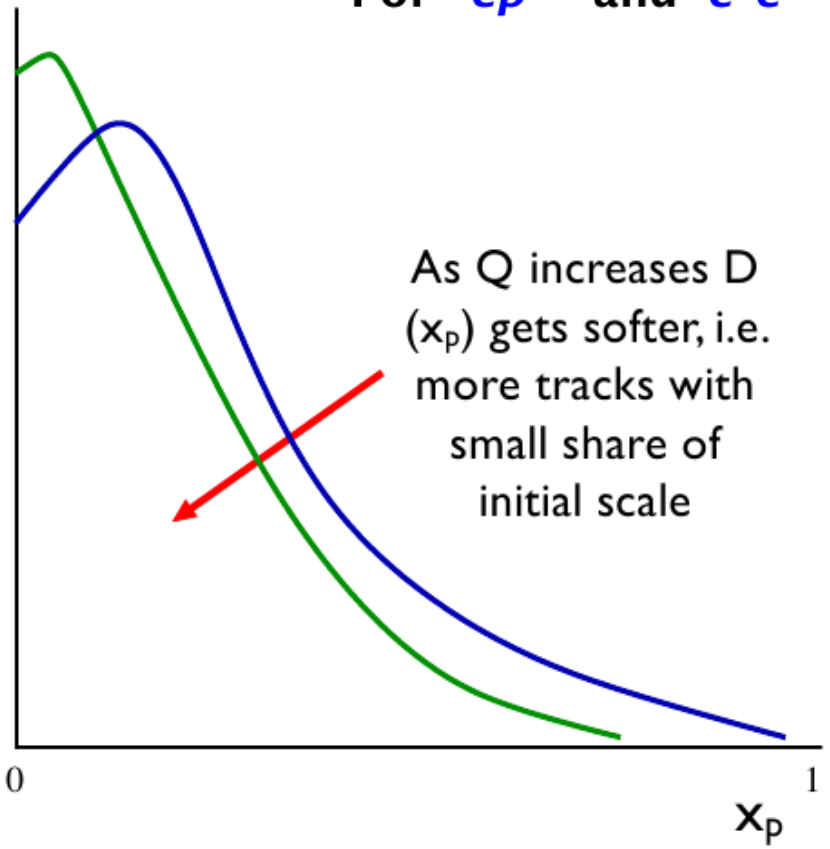
For *ep* and e^+e^-

$$D(x_p) = \frac{1}{N_{event}} dn/dx_p$$

x_p = scaled momentum variable

Q/2 = Scale in current region of Breit Frame

p_h = momentum of charged particle in current region of Breit frame



$D(x_p)$ = event normalised, charged particle, scaled momentum distribution

Scaled momentum spectra : charged particles

Data & details of the analysis

Data: $Q^2 > 160\ GeV^2$

collected in 1996 - 2007 (0.5 fb−1)

- 820 GeV: 75 pb−1;
- 920 GeV: 402 pb−1
- Standard selection of well reconstructed DIS events
- central tracking detector used,
- $p_t > 0.15$ GeV , $|\eta| < 1.75$
- well reconstructed tracks from primary vertex.

All measured distributions were corrected to hadron level

Monte Carlo Generators

ARIADNE 4.12 – color dipole model (CDM)

LEPTO 6.5 – matrix elements+parton shower (MEPS)

All generated events were passed trough ZEUS detector

Scaled momentum spectra : charged particles

ZEUS

The normalized spectrum:

$1/N\ dn^{\pm}/d\ln(1/x_p)$

N – number of events

$N^{\pm}$ – number of charged particles

in different (x,Q^2) bins

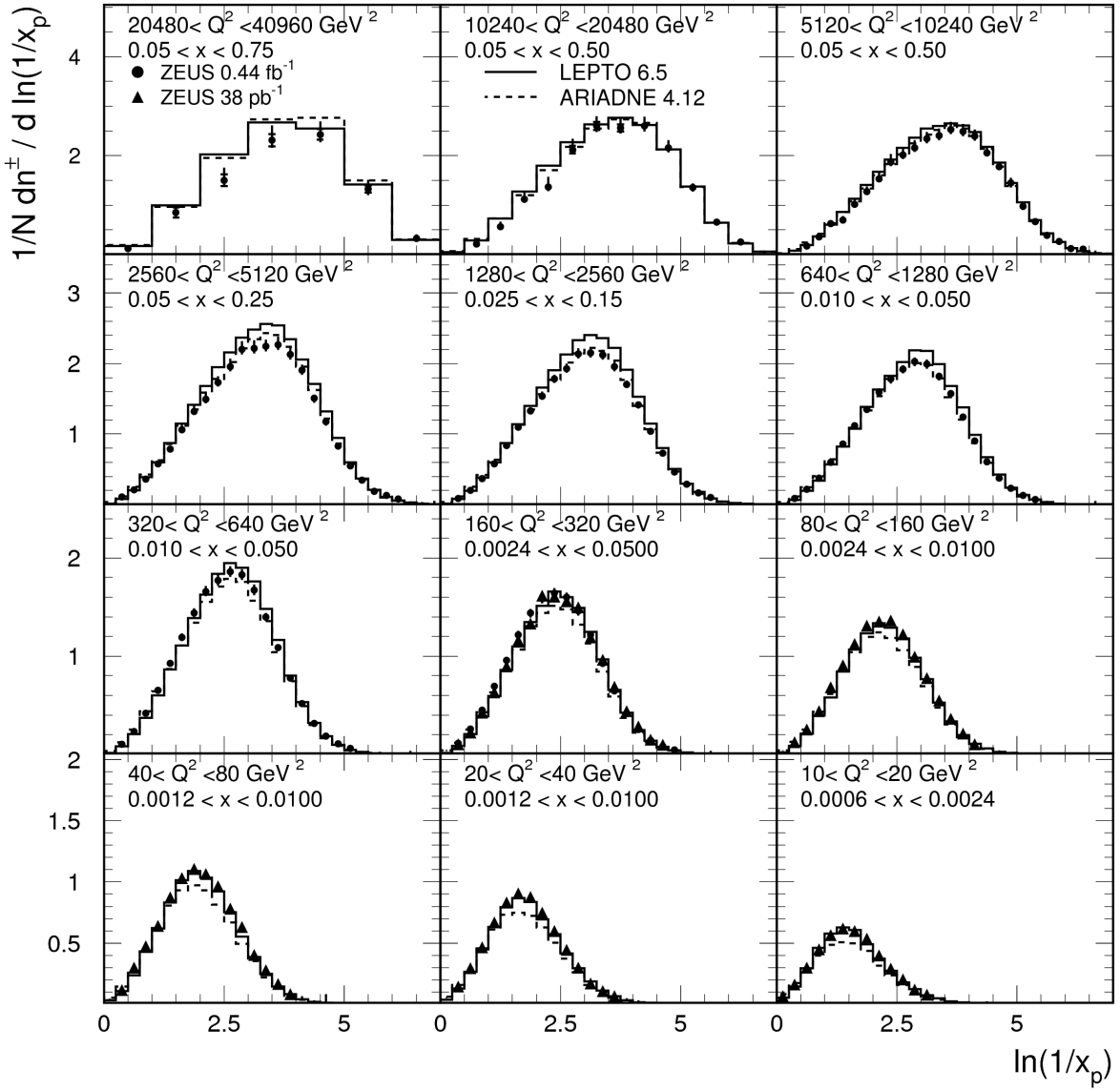
$10 < Q^2 < 40960\ \text{GeV}^2$

$0.002 < x < 0.75$

(data from earlier ZEUS publication included)

Predictions of ARIADNE and LEPTO compared to the data.

- Main features reproduced;
- Some disagreement in details.

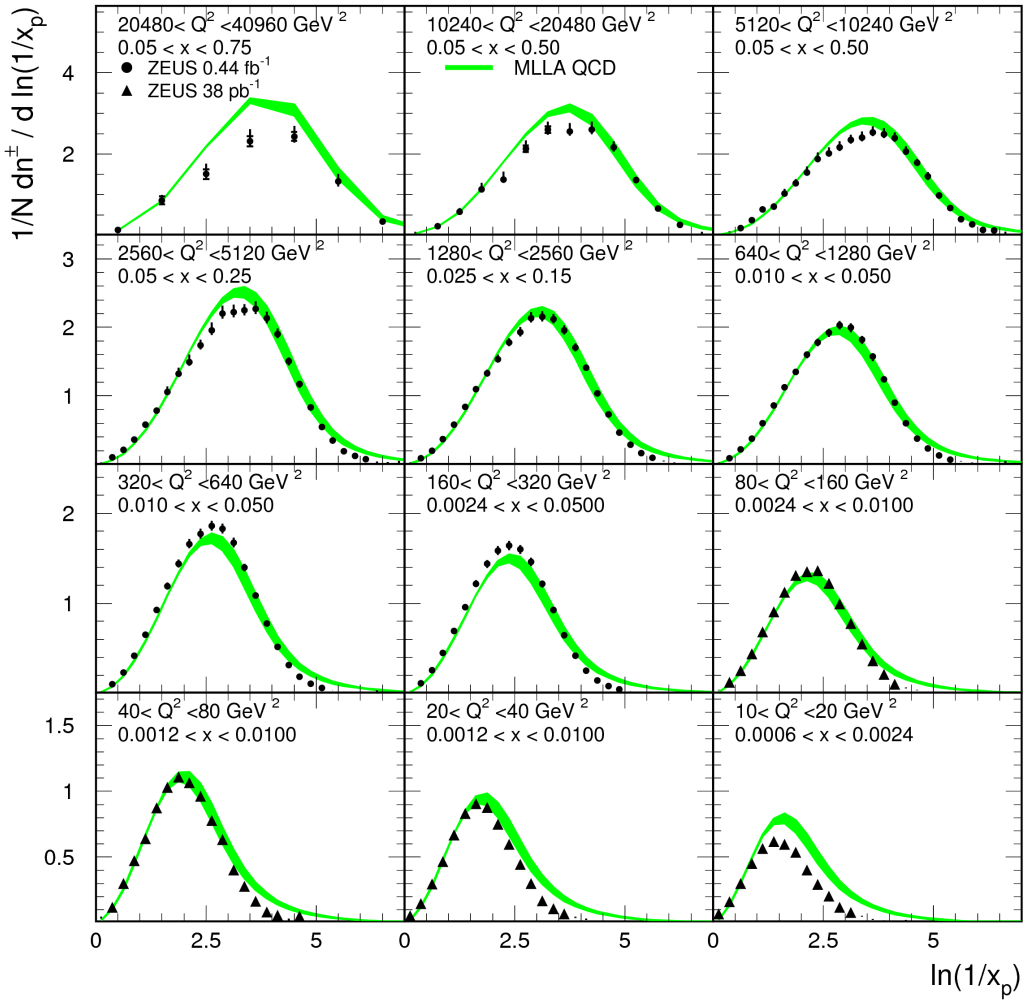


Scaled momentum spectra : charged particles

ZEUS

The MLLA+LPHD predictions compared to the data:

- Too many particles are predicted for the highest- and lowest-Q^2 bins;
- Medium Q^2 reasonably well described;
- At low Q^2 difference explained as a significant migration of particles to the target region of the Breit Frame.



Scaled momentum spectra _ : charged particles

Data together with four NLO+FF QCD predictions:
Kretzer (with error band)

Fit of the Z-pole data from ALEPH , fix boundary conditions for FF at the low resolution scale of GRV parton model

KKP Kniehl,Kramer,Pötter

fit LEP1 and SLC data, MS renormalization and factorizatiion sheme

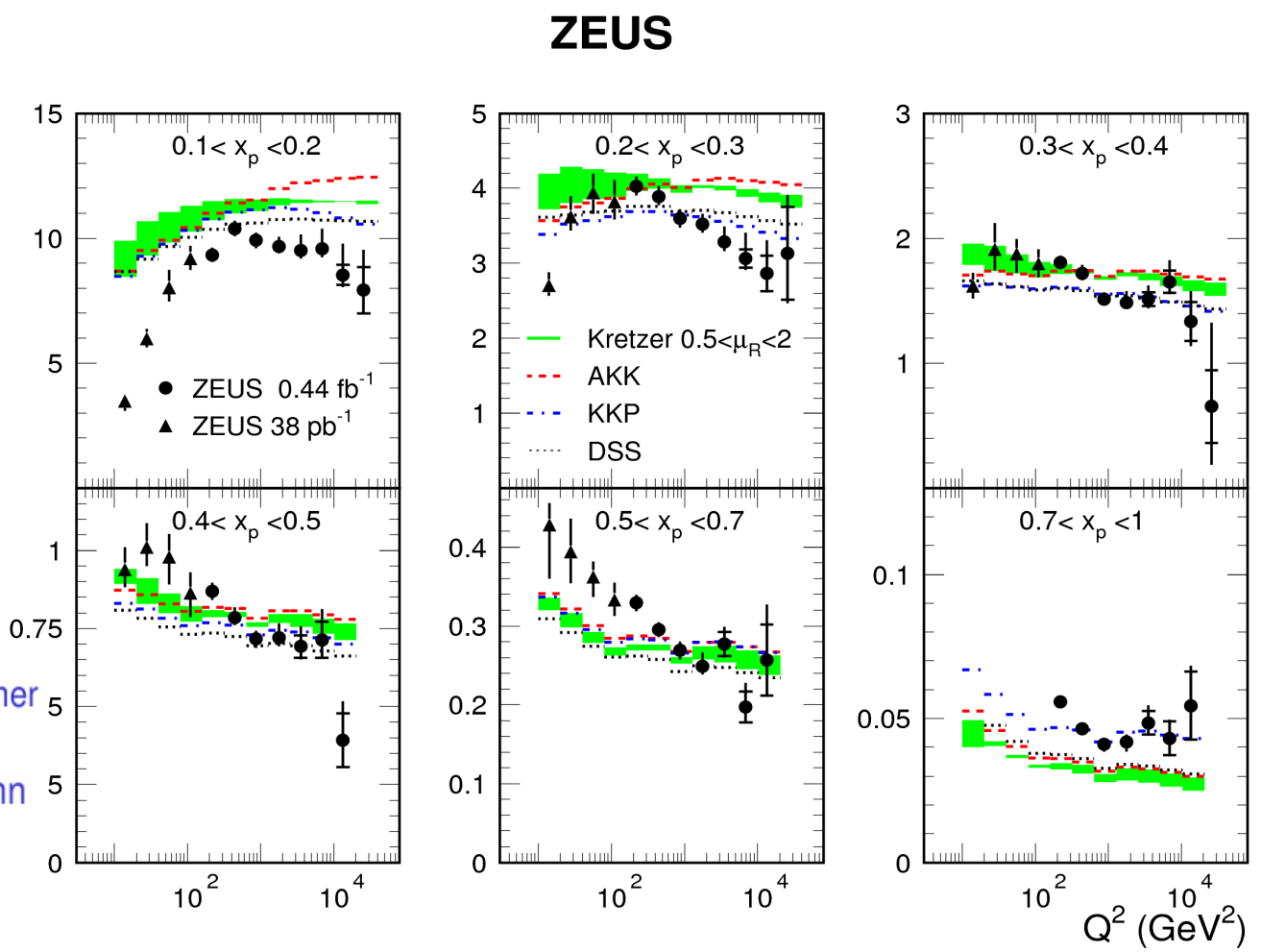
AKK Albino,Kniehl,Kramer

AKK + CYCLOPS : Albino, Kniehl, Kramer
PDF : CTEQ6M

DSS : De Florian, Sassot , Stratmann
PDF: MRST

FF: fit to e^+e^- + pp + ep data

The NLO calculations do not provide a good description of the data. Predicted scaling violations not too strong.

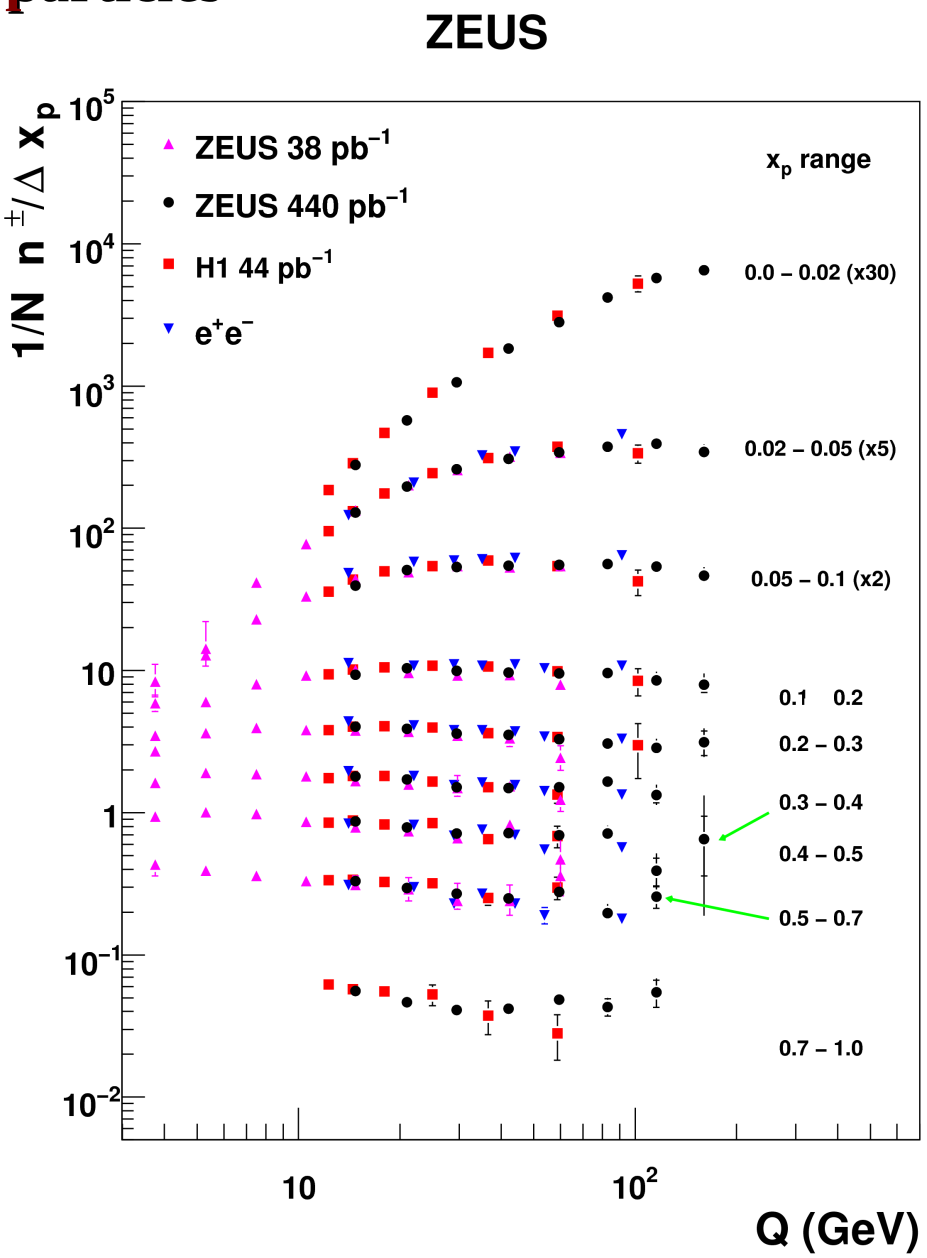


Scaled momentum spectra : charged particles

The same data as in previous plots together with:

- H1 experiment Phys.Lett. **B 654**, 148 (2007),
- e^+e^- data scaled to half of the center-of-mass energy: $Q = 2E_{beam}$.

The overall agreement between the different data sets supports fragmentation universality.



Scaled momentum spectra :K^0_S and Λ

Details of the analysis

Data

$e^{\pm}$ (27.5 GeV) p(820 GeV) collisions, $\sqrt{s} \sim 318$ GeV
standard NC DIS events selection : 330 pb^{-1}
$10 < Q^2 < 40000$ GeV^2 , $0.001 < x < 0.75$

K^0_S , Λ, $\bar{\Lambda}$ candidates:
two oppositely charged tracks
associated with a secondary vertex.
with cuts on:
dca, effective mass distributions, collinearity angles, distances between candidates decay vertex and primary vertex, P_t variable (Armenteros-Podolanski).

(JHEP 03 (2012) 020)

Analysis: current region of the Breit frame (BF)
(BF: exchanged virtual boson is purely space-like with 3-momentum q = (0,0,-Q))

Distributions presented in $x_p = 2P^{Breit} / \sqrt{Q2}$ $\rightarrow$
an estimator for z : the fraction of parton momentum carried by hadron after fragmentation

Monte Carlo

ARIADNE - CDM color dipole mode or
LEPTO – MEPS model PDF: CTEQ5D

JETSET: Lund string model

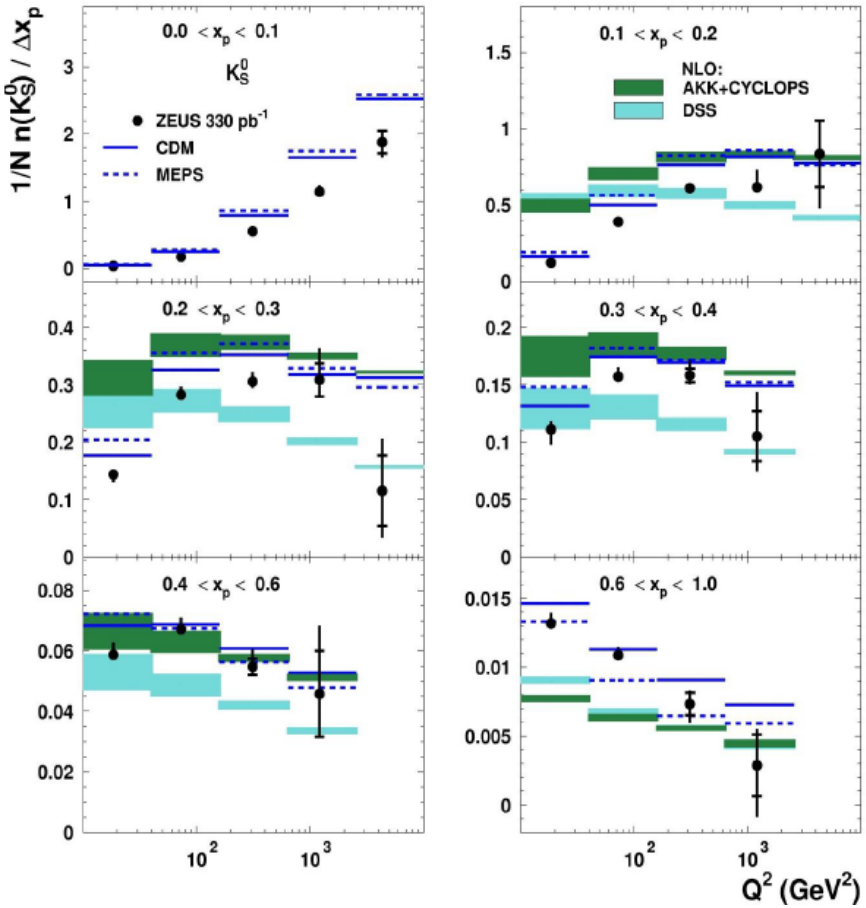
NLO QCD

AKK + CYCLOPS : Albino, Kniehl, Kramer
PDF : CTEQ6M
FF : fit to e^+e^- data
hadron mass effect was included

DSS : De Florian, Sassot , Stratmann
PDF: MRST
FF: fit to e^+e^- + pp + ep data
hadron mass effect was not included

Scaled momentum spectra :K^0_S and Λ

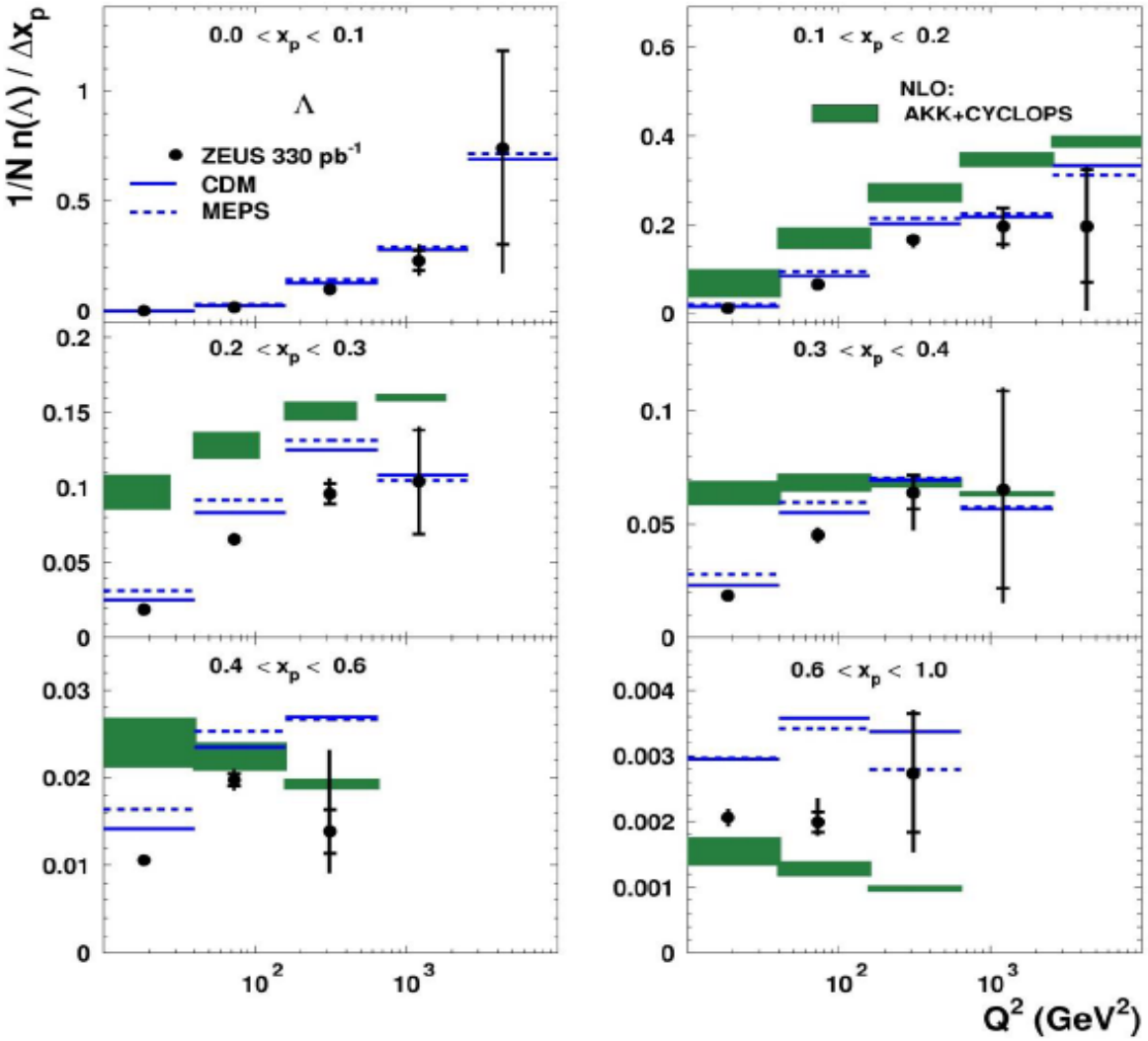
Scaled Momentum Distribution: K^0_S and QCD predictions



- Scaling violation is observed: with increasing Q more soft gluons are radiated → more particles with low x_p are produced
- Calculations with the Fragmentation Functions based on e^+e^- (AKK+CYCLOPS) or on e^+e^- + pp + ep data (DSS) cannot describe x_p distributions. DSS do it a little better in mid-range of x_p
- MCs descriptions are reasonable

Scaled momentum spectra :K^0_S and Λ

Scaled Momentum Distribution: Λ and QCD predictions



- No DSS calculations are available
- Scaling violation is observed
- AKK+CYCLOPS prediction with FF based only on e^+e^- data fail in data description
- Monte Carlo are still reasonable
- Poor statistics for the highest x_p bin

Summary and Conclusions

- Scaled momentum distributions for K^0_s and Λ were measured for the first time in ep DIS
- Scaled momentum distributions show scaling violattions
- NLO QCD predictions for different fragmentation functions describe the data only in certain regions of the phase space
- LO Monte Carlo (ARIADNE, LEPTO) predictions supply better agreement with data over full phase space
- High precision measurements of K^0_s and Λ obtained in this analysis have the potential to constrain the fragmentation functions further if they will be included as input in global fits

Thank you for your attention!