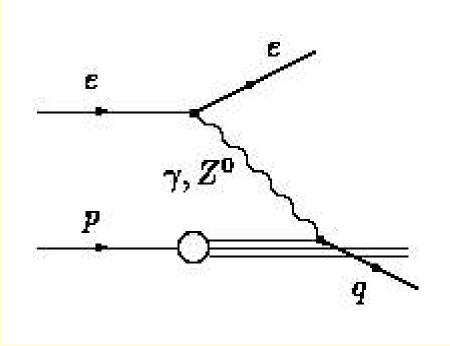
Azimuthal asymmetry using energy flow method

A. Ukleja
on behalf of ZEUS Collaboration

- Azimuthal angle distribution at $Q^2>100$ GeV^2
- Energy flow method
- Experimental results
- LO and NLO predictions
- Summary

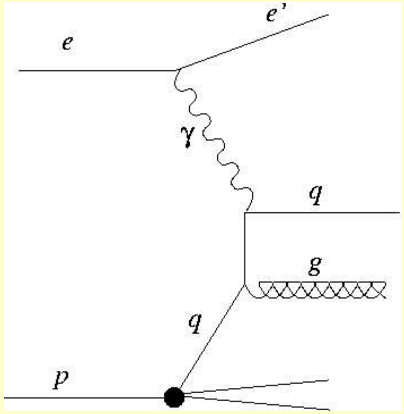
Azimuthal angle definition for the $ep \to ehX$ process

$$\frac{d\sigma^{ep\to ehX}}{d\phi} = 2A\left(\frac{1}{2} + B\cos(\phi) + C\cos(2\phi) + D\sin(\phi) + E\sin(2\phi)\right)$$

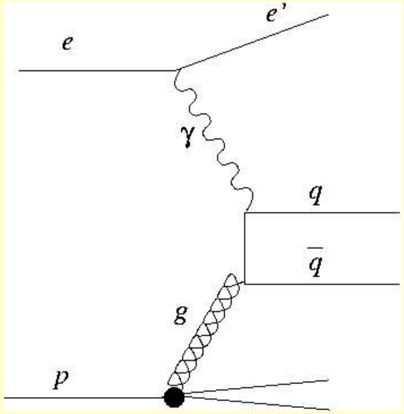


Zeroth order QCD process (Simple DIS, QPM)

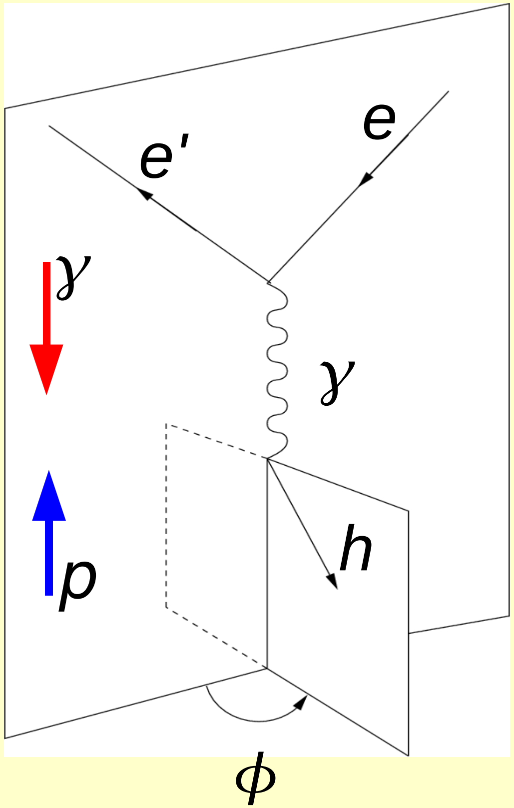
QCDC



BGF



First order QCD processes



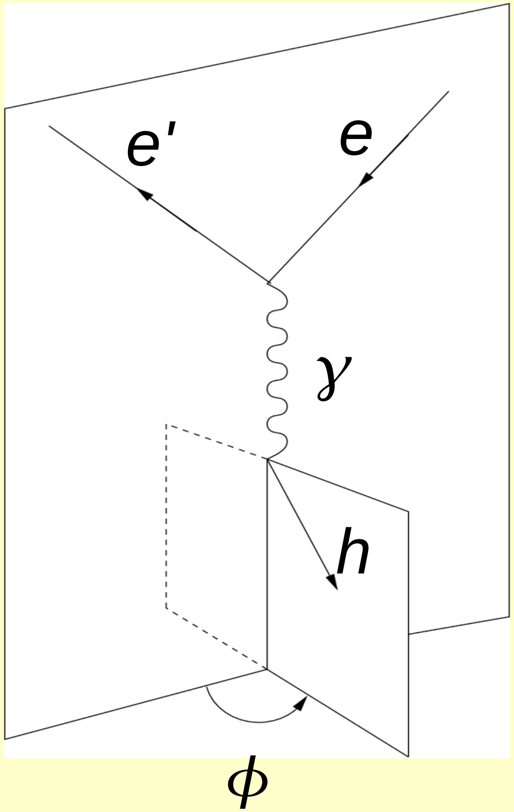
γ^{*}p HCM frame

Azimuthal angle distribution for the $ep \to ehX$ process

$$\frac{d\sigma^{ep\to ehX}}{d\phi} = 2A\left(\frac{1}{2} + B\cos(\phi) + C\cos(2\phi) + D\sin(\phi) + E\sin(2\phi)\right)$$

Azimuthal asymmetry comes from:

- Two-body processes (BGF and QCDC)
- Boson polarization
- Longitudinally polarized electron beam
- Parity violating weak interactions
- Final hadron polarization
- Intrinsic parton momentum in the proton



Future:

asymmetry can be measured for

- longitudinally polarized lepton beam
- CC events

Experimental methods

$$\frac{d\sigma^{ep\to ehX}}{d\phi} = 2A\left(\frac{1}{2} + B\cos(\phi) + C\cos(2\phi) + D\sin(\phi) + E\sin(2\phi)\right)$$

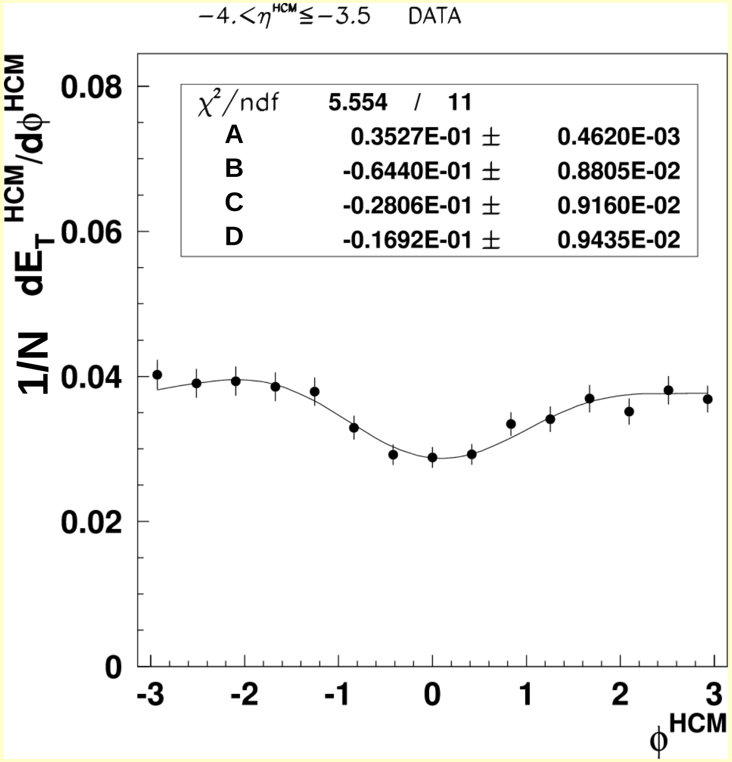
- **Fit**
- **Moments:**

$$\langle\cos(n\phi)\rangle = \frac{\int d\sigma\cos(n\phi)}{\int d\sigma}$$

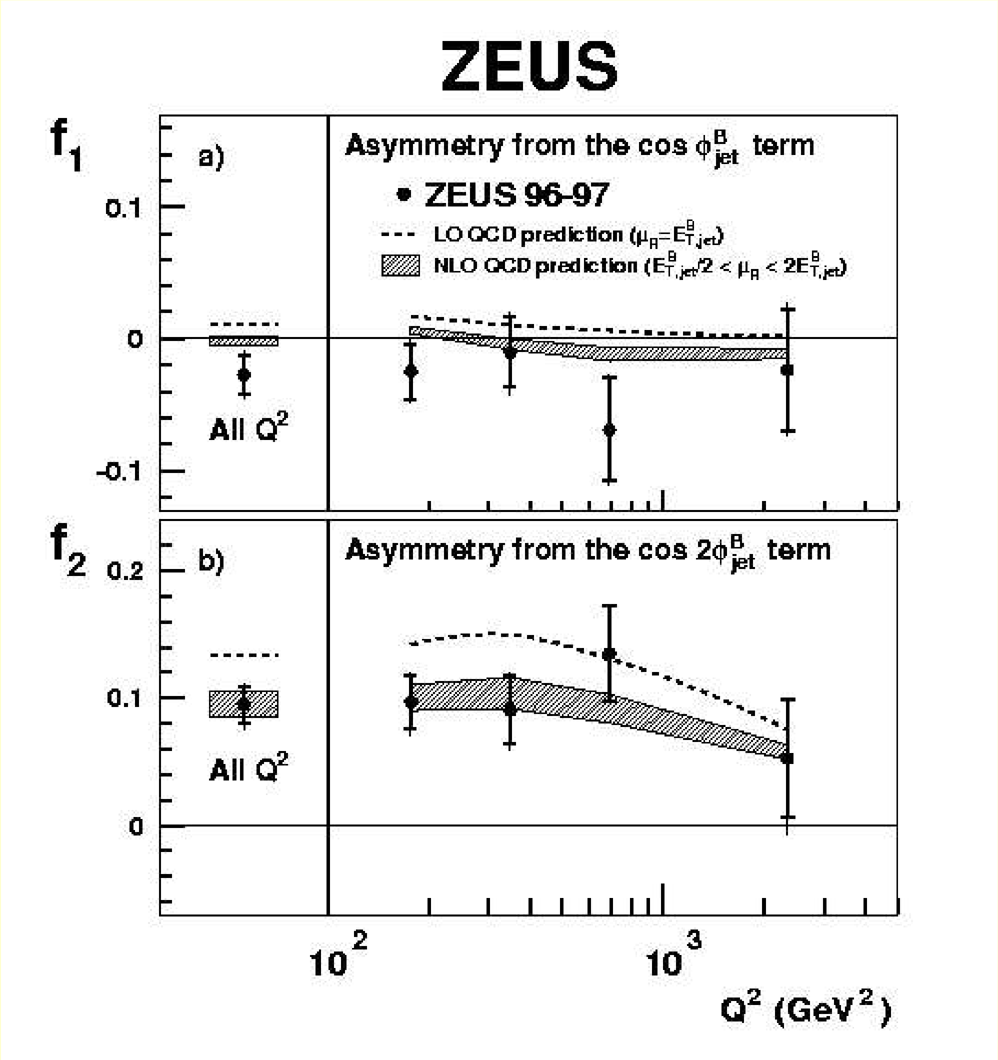
Means:

$$\langle\cos(\phi)\rangle = B \qquad \langle\sin(\phi)\rangle = D$$

$$\langle\cos(2\phi)\rangle = C \qquad \langle\sin(2\phi)\rangle = E$$

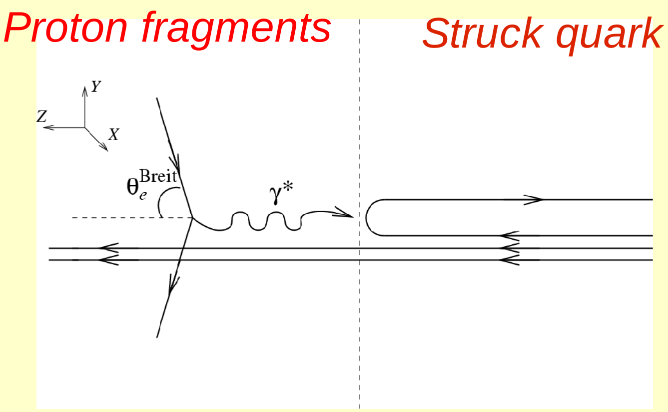


Distribution of the azimuthal angle – ZEUS paper 2002



Jet analysis

Breit frame



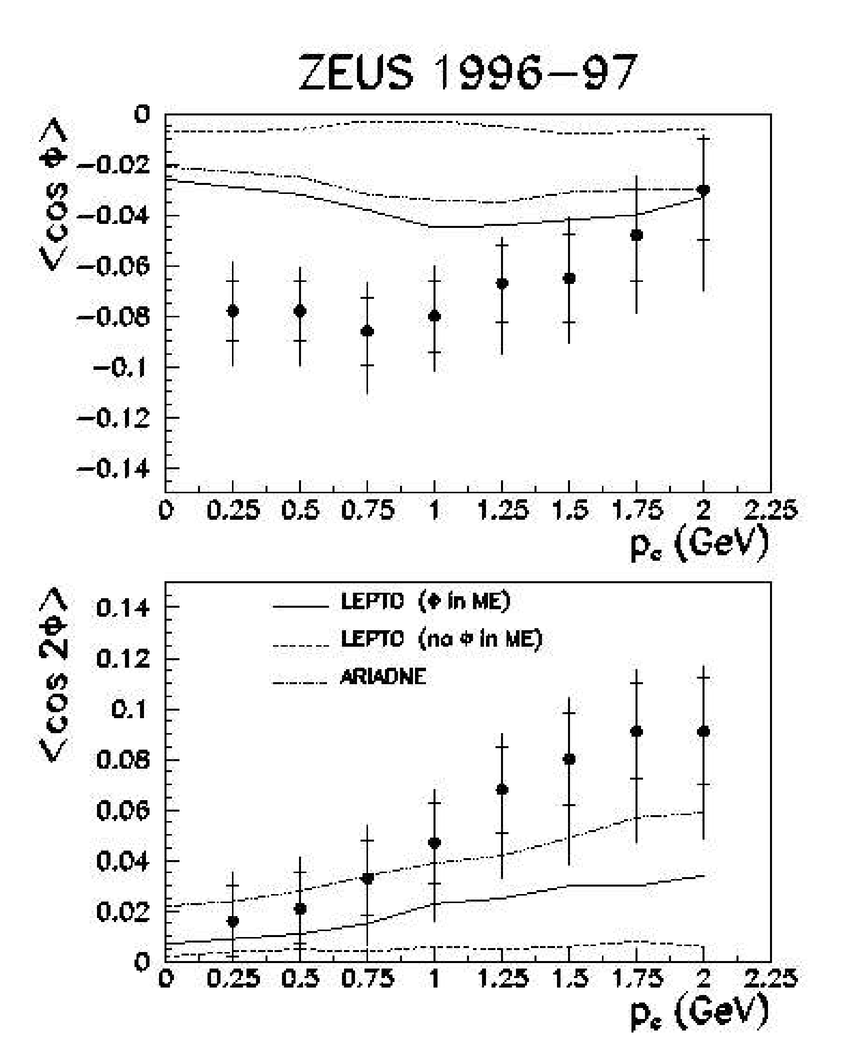
Fitted to experimental data

$$\frac{1}{\sigma}\frac{d\sigma}{d|\phi^B_{jet}|}=\frac{1}{\pi}[1+f_1\cos(\phi^B_{jet})+f_2\cos(2\phi^B_{jet})]$$

Small Large

Phys.Lett. B551 (2003) 226-240

Distribution of the azimuthal angle – ZEUS paper 2000



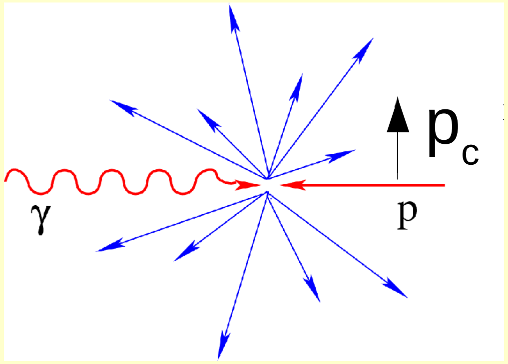
HCM frame

z, p_T method

Multiplicity method
Charged hadrons

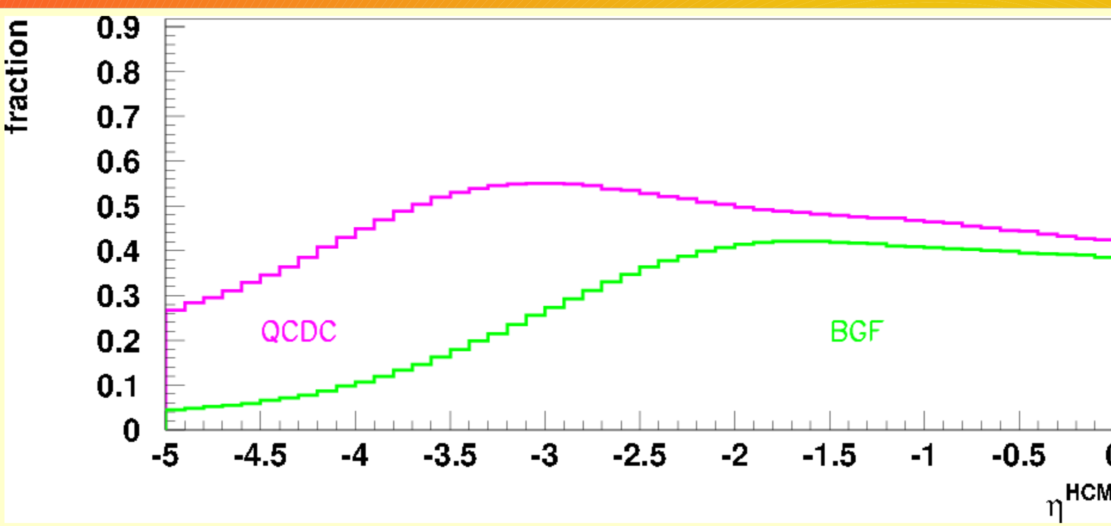
For hadrons with $p_T > p_c$

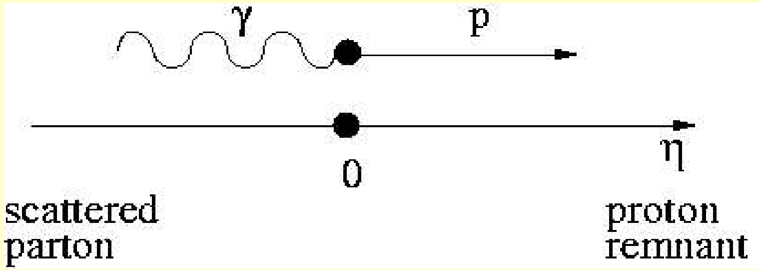
$$0.2 < z_h = \frac{P \cdot p_h}{P \cdot q} < 1$$



Phys.Lett. B481 (2000) 199-212

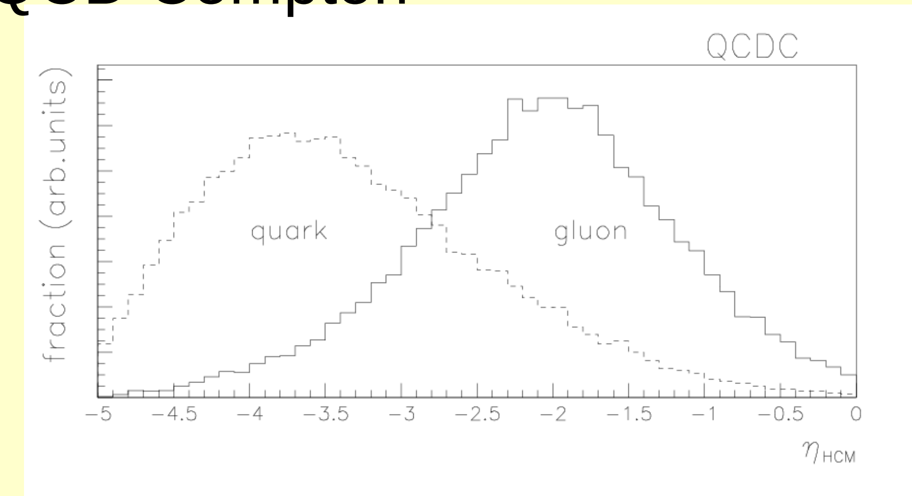
Look into pseudorapidity

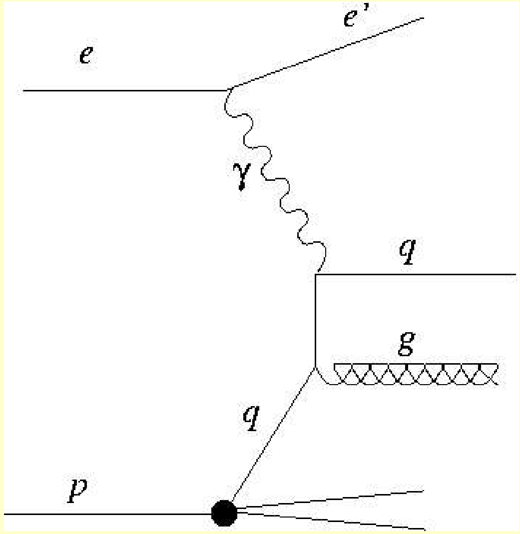




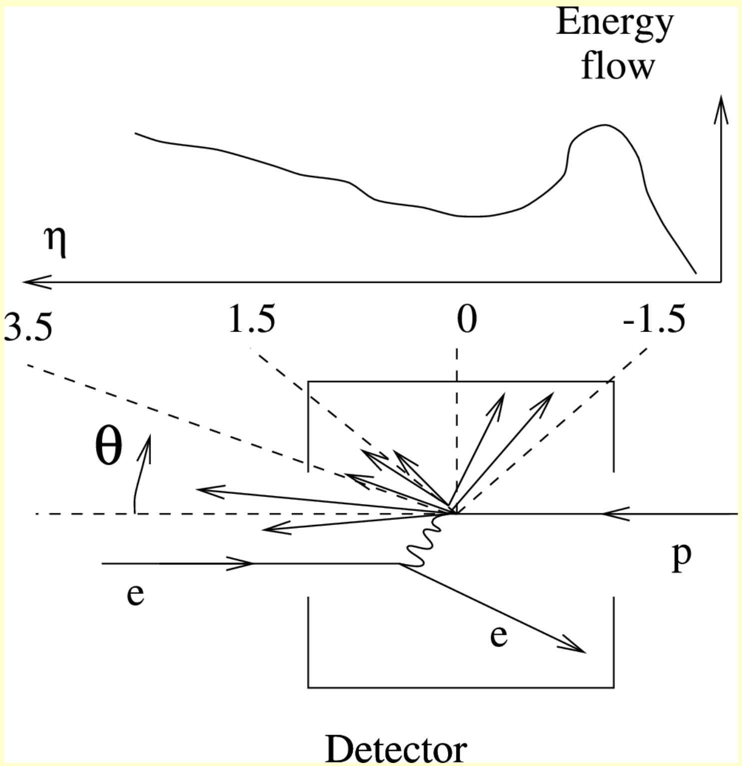
- Different contribution of BGF and QCDC
- separation of hadrons from *q* and *g*

QCD Compton





Energy flow method in the laboratory frame



Each particle direction is weighted with its energy

- charged and neutral hadrons included
- hard partons (E^{*}_{T} larger) provides a larger contribution
- calorimeter energy scale uncertainties is cancelled for i.e. $\langle\cos(\phi)\rangle$
- wider region of phace space

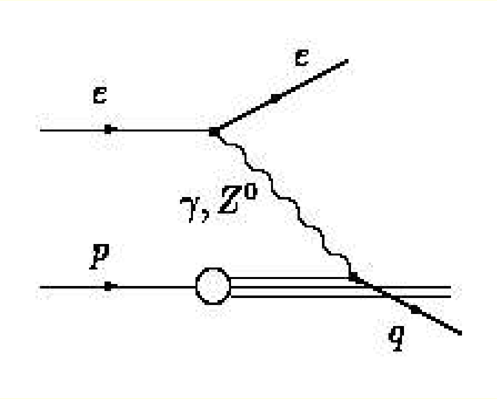
Global selection criteria

$E_{e'}^{LAB} > 10\ GeV$

$100 < Q^2 < 8000\ GeV^2$

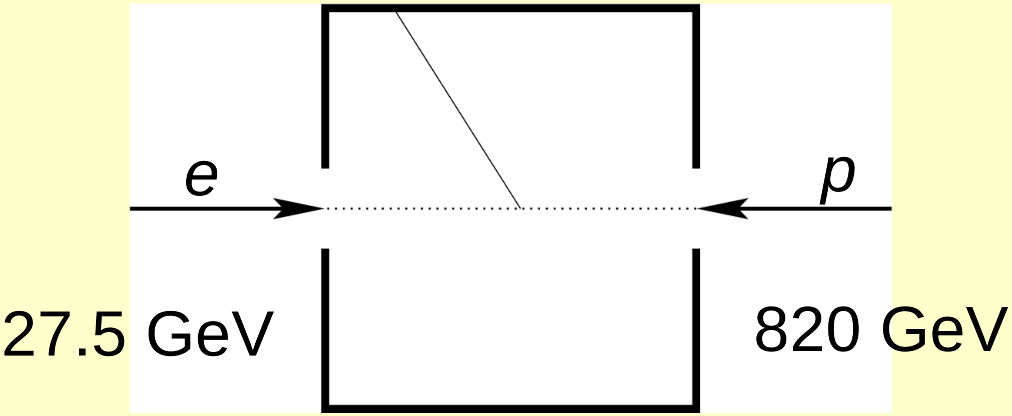
$0.2 < y < 0.8$

$0.01 < x < 0.1$



$\theta_{particle}^{LAB} > 8^0$

$p_T^{LAB} > 150\ MeV$



Luminosity:

$45.21\, pb^{-1}$

Monte Carlo Models

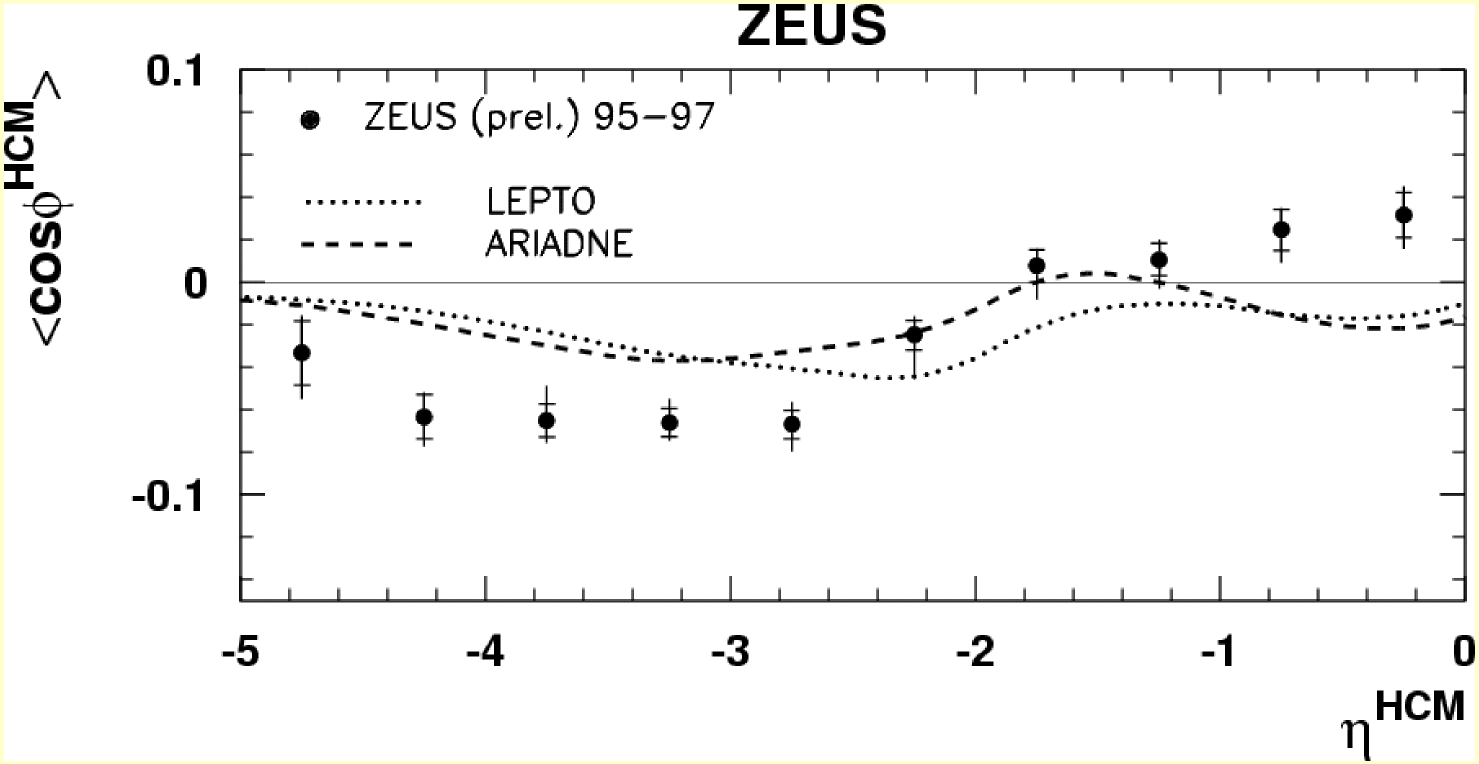
LEPTO 6.5.1 – matrix element and parton shower
+ JETSET hadron level

ARIADNE 4.12 – colour dipol model (LO)
+ JETSET hadron level

DISENT – NLO colour dipol model, parton level

$$\text{correction} = \frac{\text{hadron}_{\text{ZEUS}}}{\text{parton}}$$

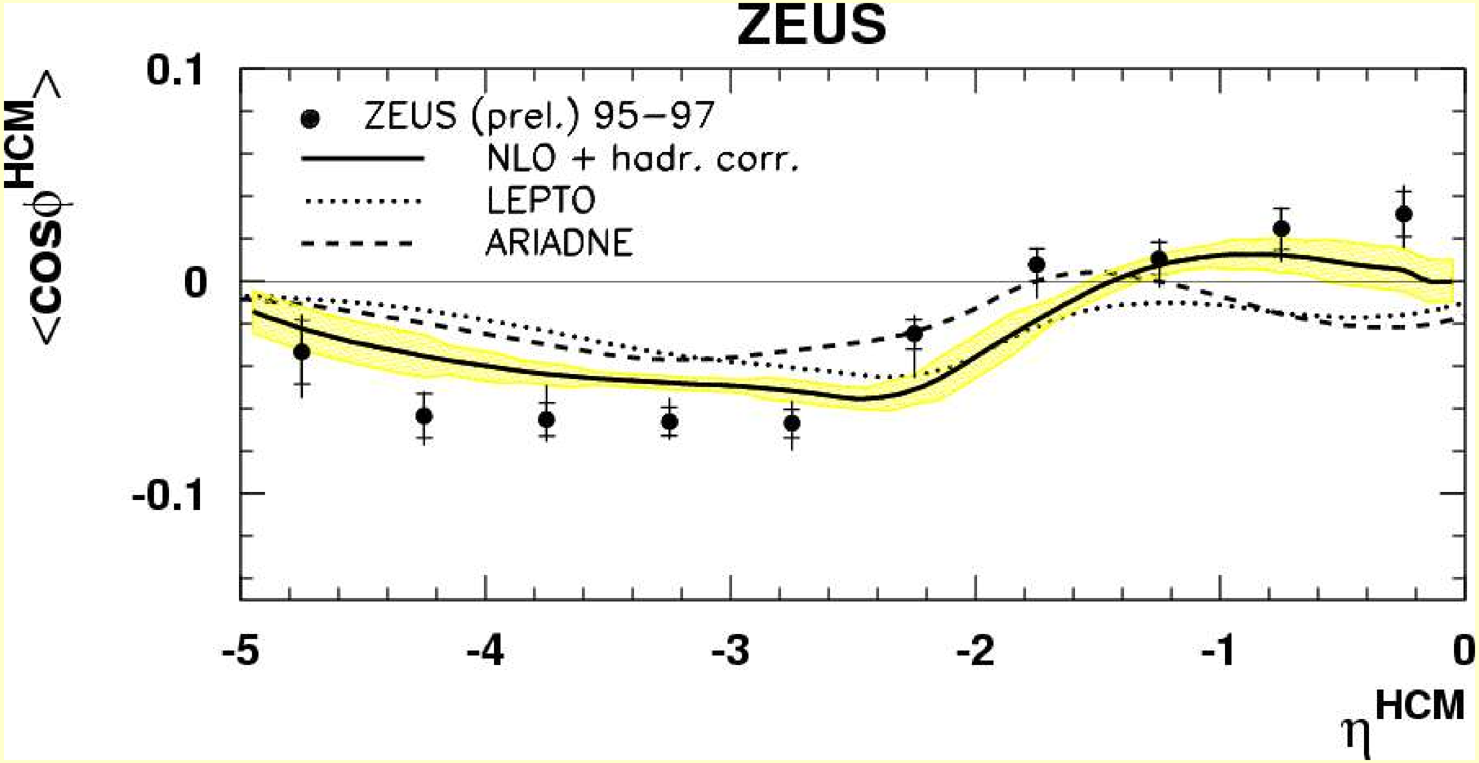
Azimuthal asymmetry energy flow method



$\langle \cos(\phi) \rangle$ are signifficant

Some discrepancies between data and LO Monte Carlo

Azimuthal asymmetry energy flow method



NLO provides better agreement with experimental data

Summary and conclusions

A novel approach to azim. asym. is proposed which provides precise measurements and small systematical errors in the wider interval of phase space

The method permits to:

- include charged and neutral hadrons
- wider pseudorapidity region

The main results are:

- the NLO effects give non-negligible contribution
- they provide better agreement with experimental data
- some small discrepancies are visible which cannot be explained by experimental and theoretical uncertainties