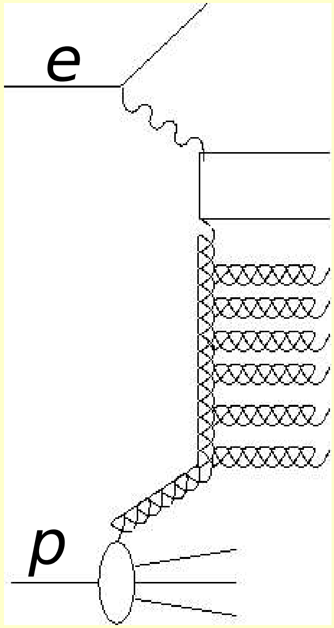
T.Tymieniecka

HERA Today and Tomorow

- HERA-LHC Workshop
- Status report on HERA and the HERA physics
- Hadronic final states

Investigated in Warsaw

  + Azimuthal Asymmetry in $ep \to ehX$
  – Instantons
  – Glueballs
  – Pentaquarks
  – Broken chiral symmetry



HERA – LHC workshop

Meetings:

CERN October 11-13 2004

DESY January 17-21 2005

- Parton density functions
- Multijet final states and energy flow
- Heavy quarks production
- Diffraction
- Monte Carlo tools

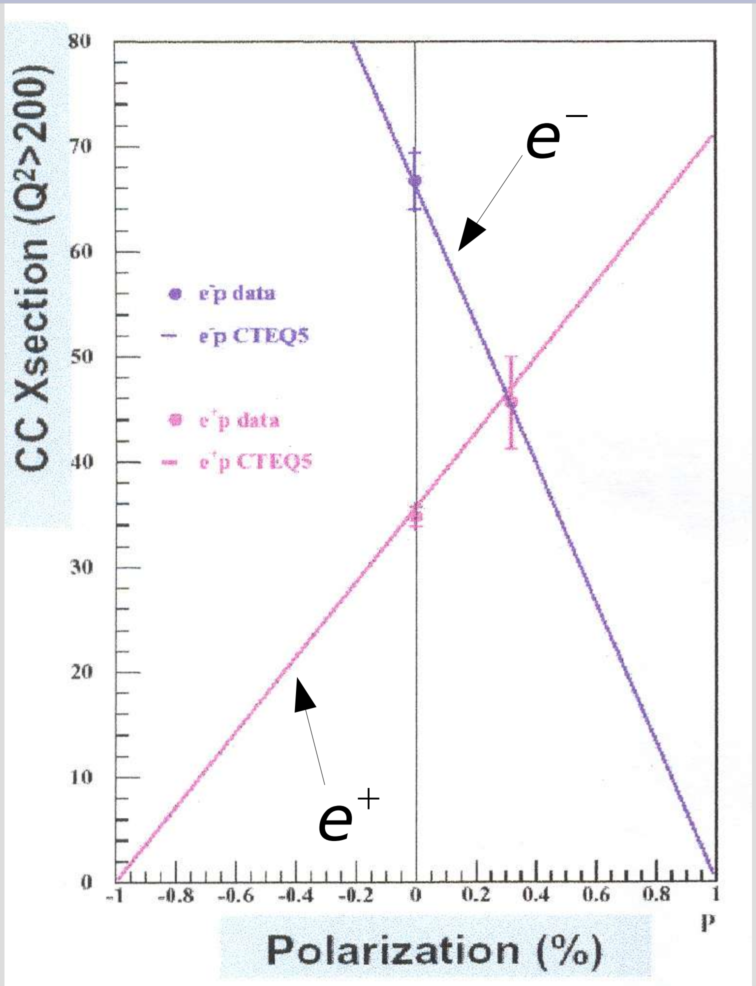
Status report 2003-2004

- Polarized positron beam
  integrated luminosity
  in 2004 20 pb^{-1}

- Problems in 2003
  synchrotron radiation
  detectors 15 years old

- Test of standard model

$$\sigma(e_R^- p \rightarrow \nu p) = 0$$
$$\sigma(e_L^+ p \rightarrow \bar{\nu} p) = 0$$

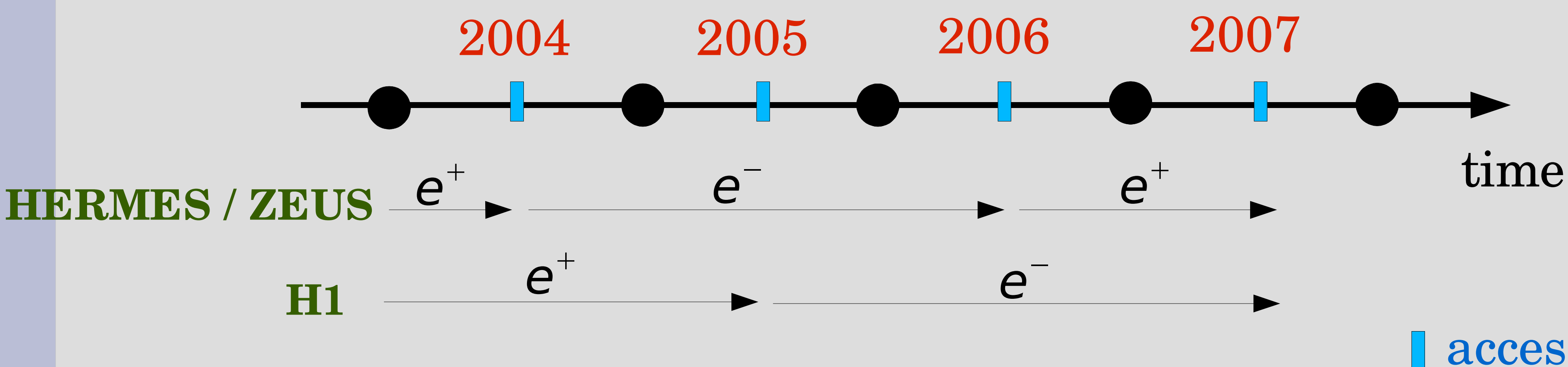


$$\sigma = 38.1 \pm 2.9(stat) \pm 0.8(syst)\, pb$$
$$\int L = 6.6\, \mathrm{pb}^{-1}$$

2004-2007

- Wiązka spolaryzowana
  - leptonowa (e^+e^-) i protonowa
    - polaryzacja docelowe 50 %
      - aktualne 30-40 %

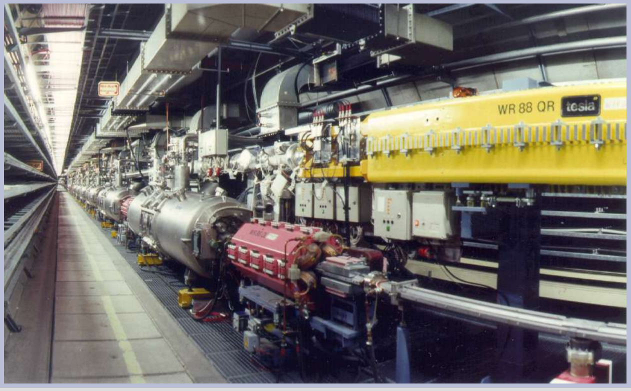
- Planed time table – decision in April 2004



Polarization changes monthly

AIMS (H1, ZEUS)

- F_L
- beyond SM



ARGUMENTS

- HERMES

  recoil detector installed summer 2004

  start summer 2005

- H1

  larger luminosity for e^+

  more multilepton events

- ZEUS

  not enough date for e^-

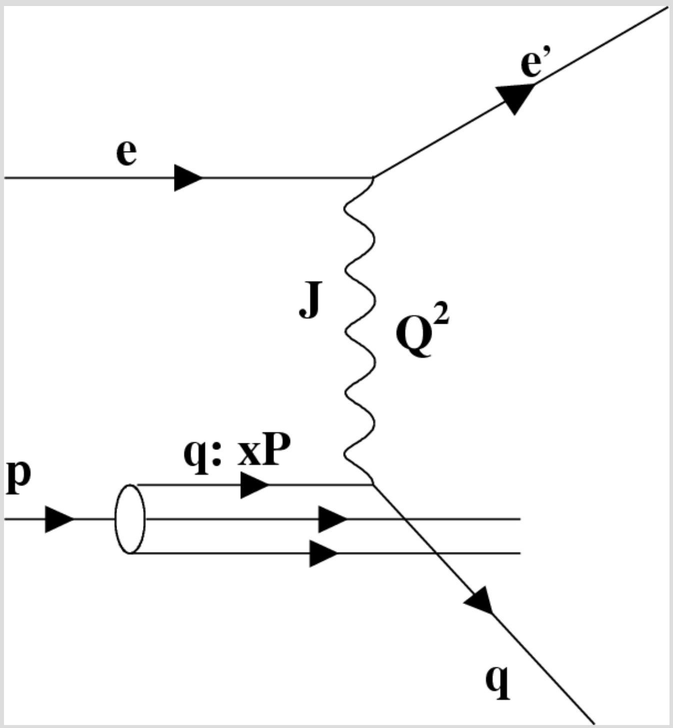
  large sample for e^+

T.Tymieniecka
A.Ukleja

Azimuthal asymmetry using energy flow method

- Azimuthal angle distribution at Q^2>100 GeV^2
- Energy flow method and multiplicity method
- Experimental results
- LEPTO predictions for azimuthal asymmetry
  - BGF+QCDC+QPM
    - without PS
    - with PS
    - with hadronization
- NLO DISENT predictions
- Summary

HERA kinematics

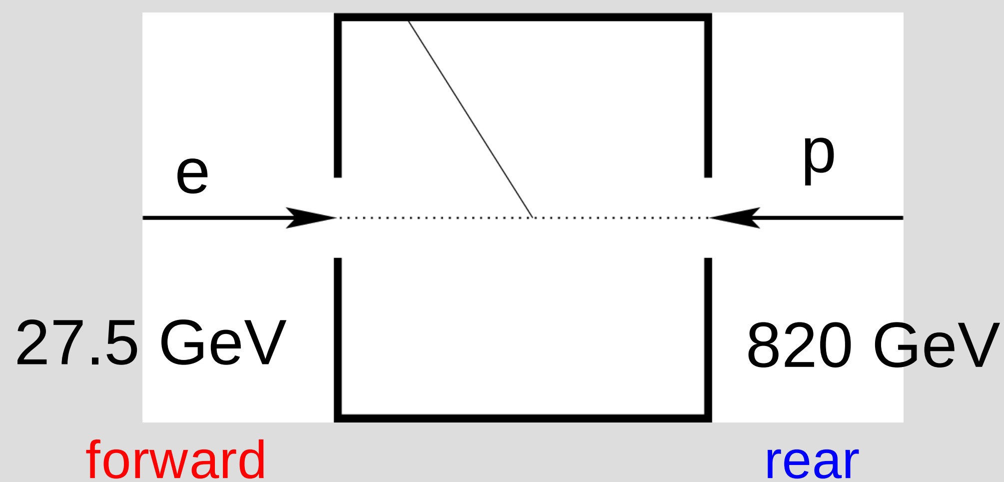


$$Q^2 = -q^2 = -(k_{e'} - k_e)^2$$

$$x = Q^2 / 2\, P \cdot q$$

$$y = P \cdot q / P \cdot k_e$$

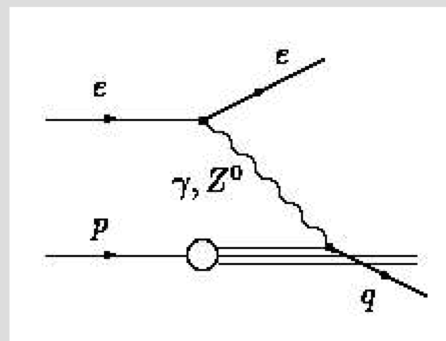
$$J = \begin{Bmatrix} \gamma, Z^0 - NC \\ W - CC \end{Bmatrix}$$



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

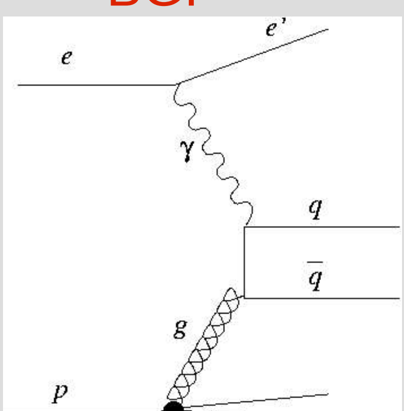
$$\frac{d\sigma^{ep\to ehX}}{dx\,dQ^2\,d\phi} = A + B\cos(\phi) + C\cos(2\phi) + D\sin(\phi) + E\sin(2\phi)$$

Zeroth order QCD process
(Simple DIS, QPM)

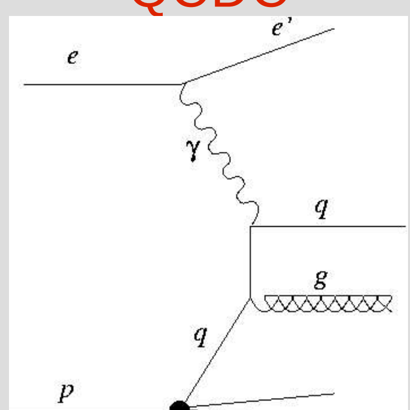


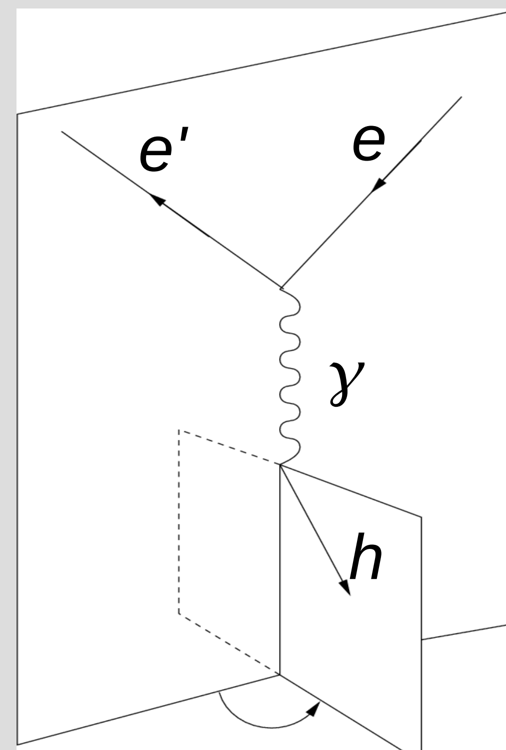
First order QCD processes

BGF



QCDC

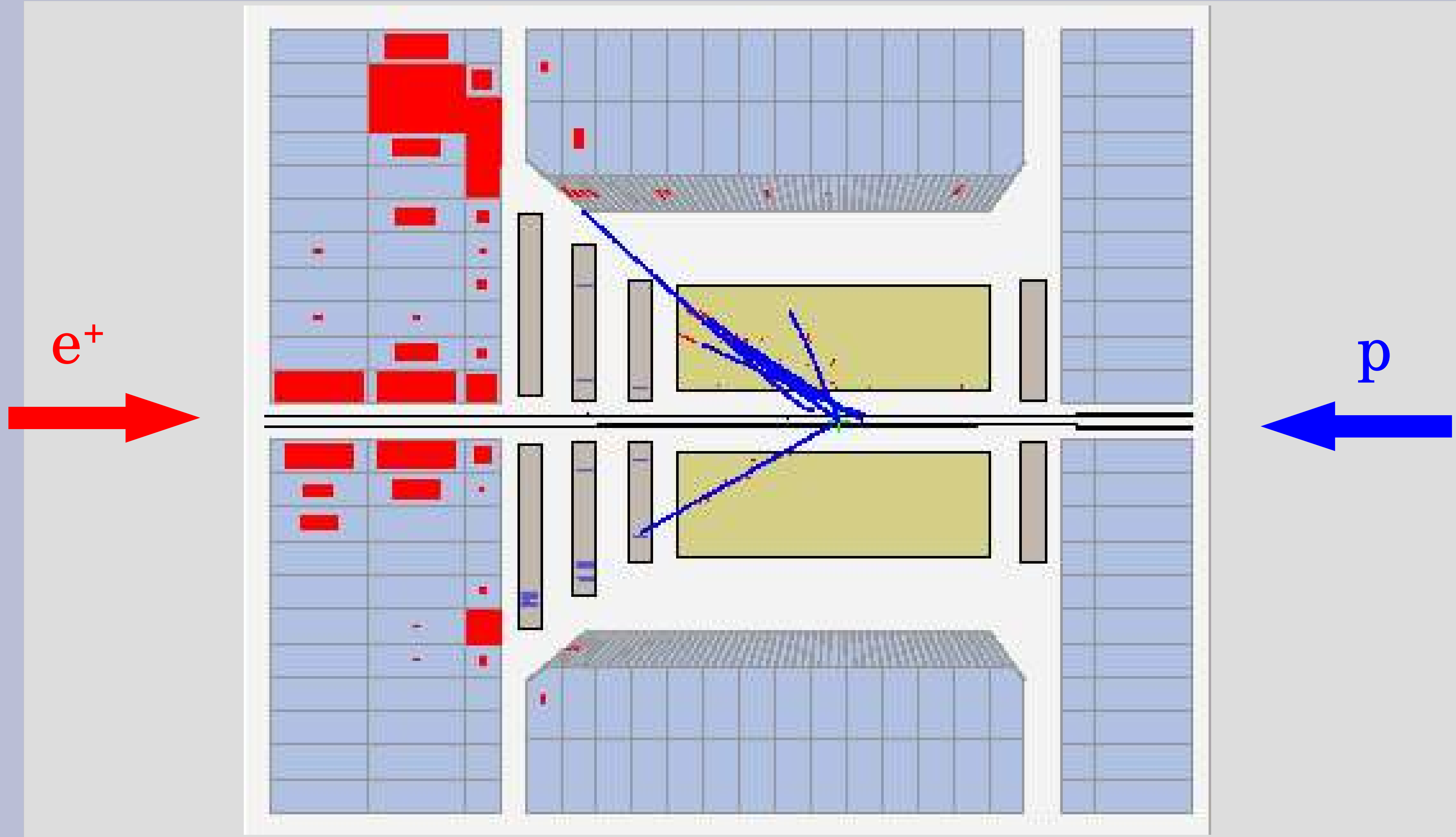




ϕ

$\gamma^* p$ CMS frame

DIS NC

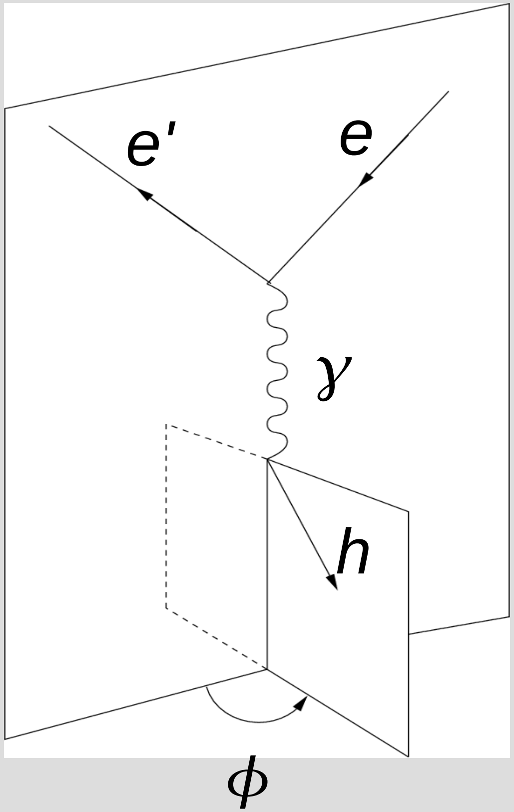


Azimuthal angle distribution for the $ep \to ehX$ process

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

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

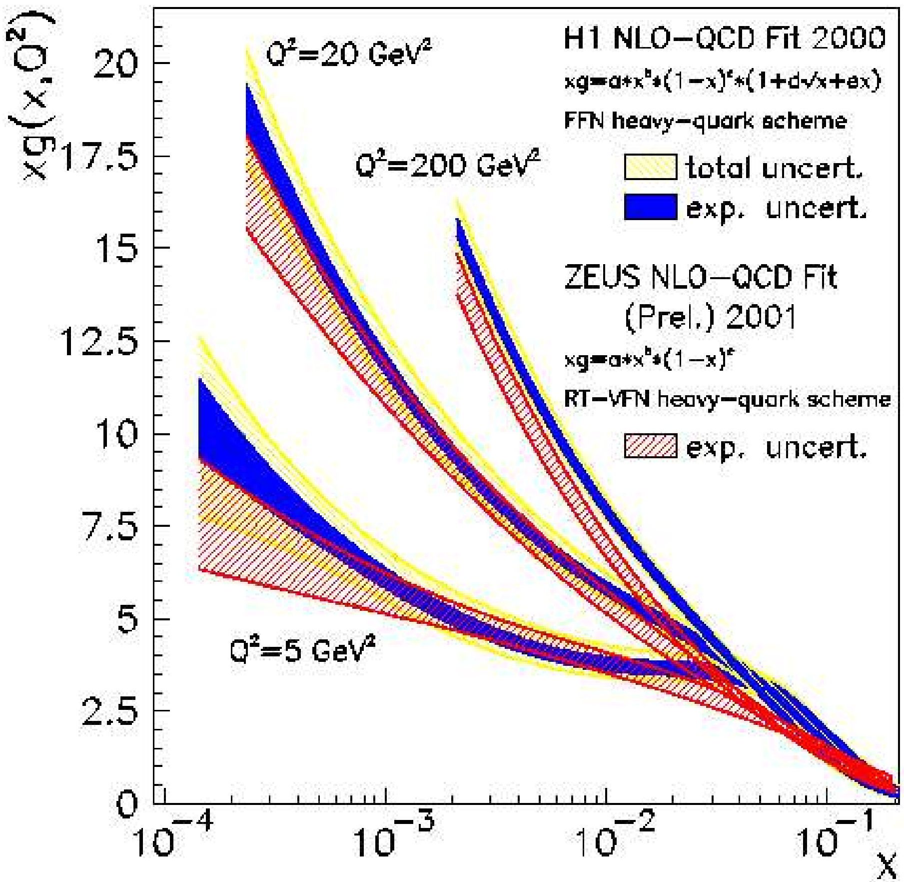


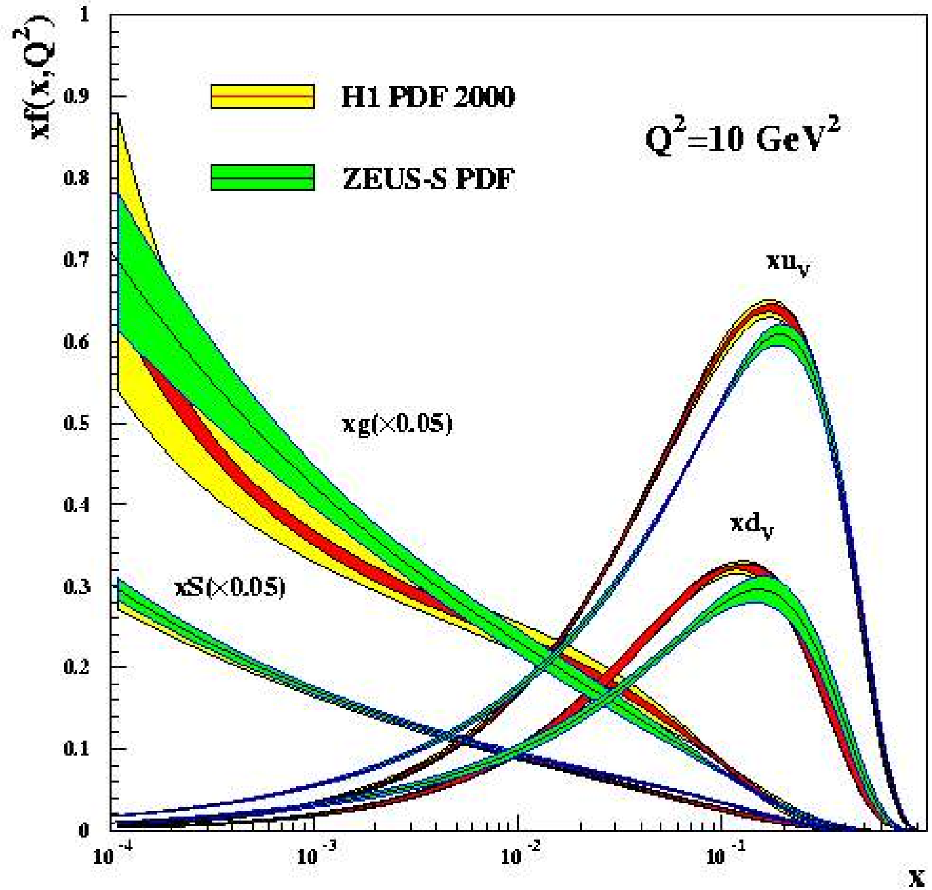
Future:

asymmetry can be measured for

- Longitudinally polarized lepton beam
- CC events

Parton densities





good agreement between quark densities from H1 and ZEUS

some differences betwee gluon densities from H1 and ZEUS

ϕ distribution sensitive to gluon content at $0.01<x<0.1$

Boson polarization

- See J.G.Kőnner, E.Mirkes, G.Schuler, INT.J.Mod.Phys. A4 (1989) 1781
- Bronkorb, Mirkes, Z.Phys. C66 (1995) 141

$$\frac{d\sigma}{d\phi} = d\sigma_T + d\sigma_L + d\tau_{LT} \cdot \cos(\phi) + d\tau_{TT} \cdot \cos(2\phi)$$

Modify p_T distribution

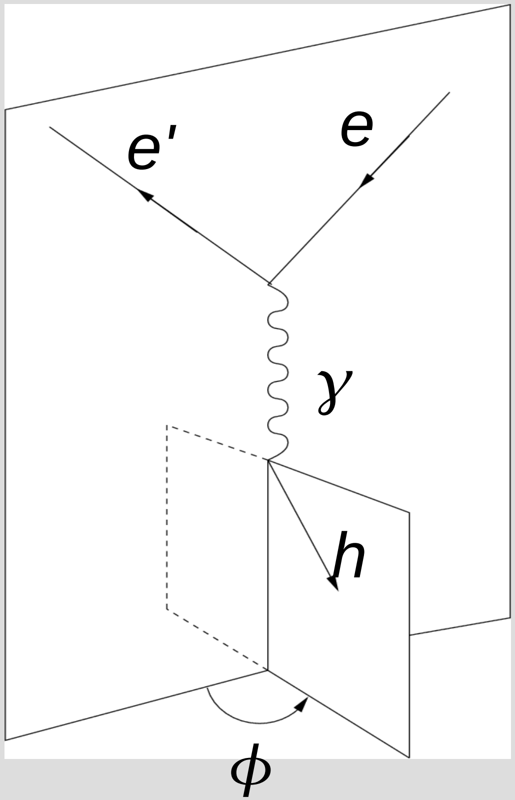
T-odd effects

$$\ldots + D\sin(\phi) + E\sin(2\phi)$$

K.Hagiwara, K.Hikasa, N.Kai, Phys.Rev. D27 (1983) 84

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

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

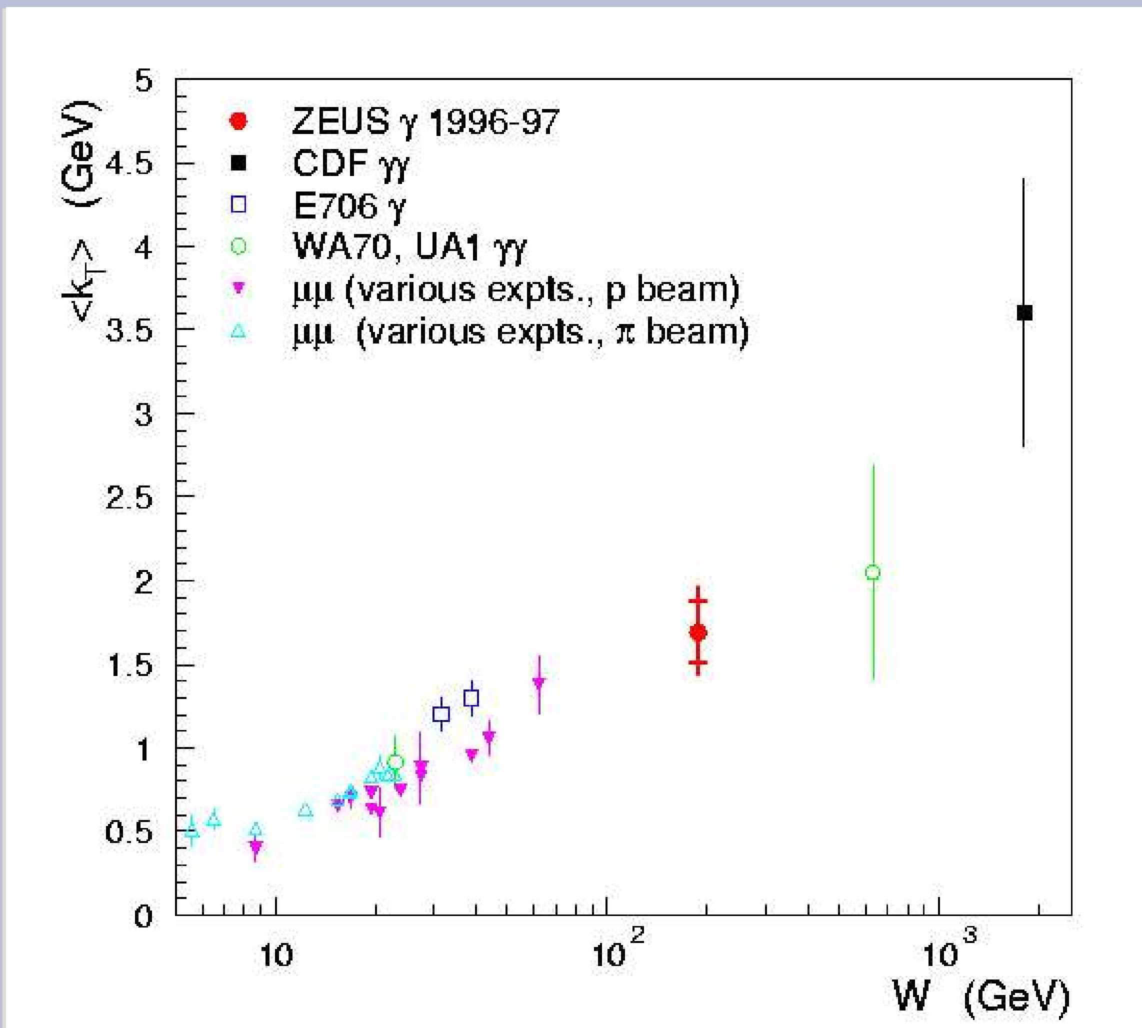


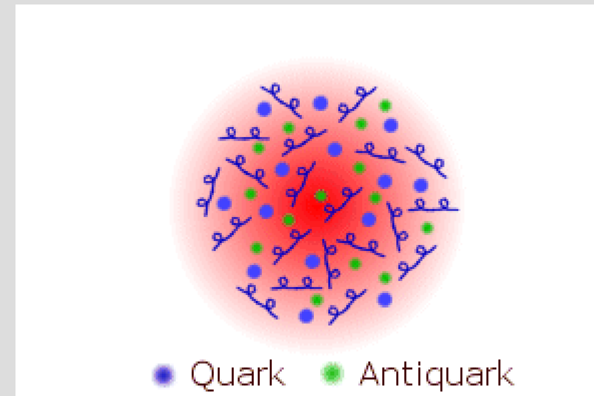
Azimuthal asymmetry comes from:

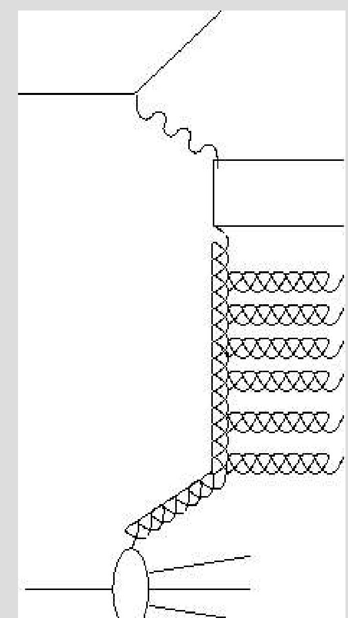
- Two-body processes (BGF and QCDC)
- Boson polarization
- **Longitudinally polarized electron beam**
- **Parity violating weak interactions**
- **Final hadron polarization**
- **Intrinsic parton momentum in the proton**

k_T distribution

Intrinsic parton momentum



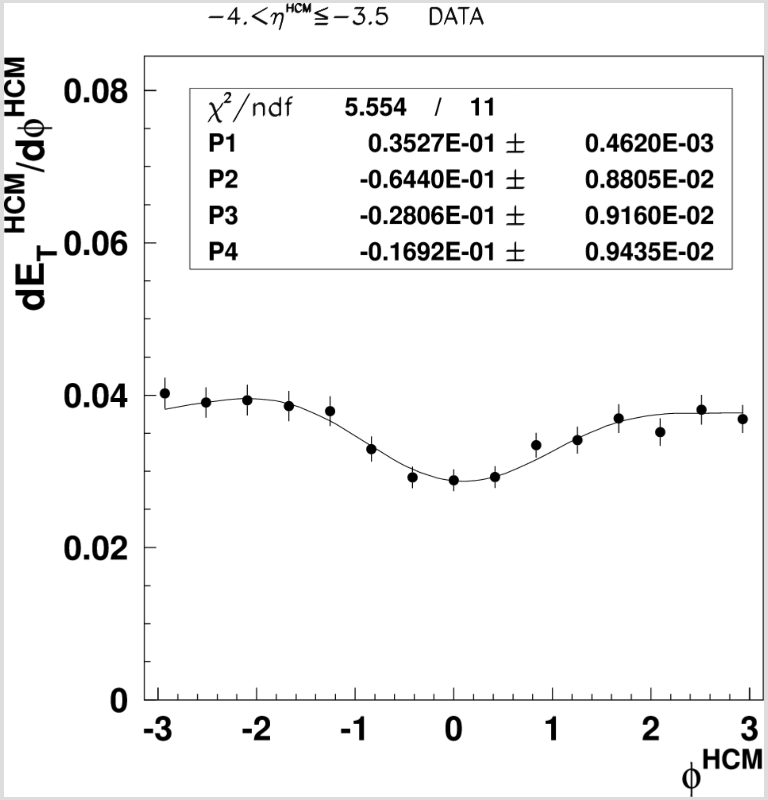




ZEUS: $ep \to e\gamma_{jet} X$

Experimental methods

$$\frac{d\sigma^{ep\rightarrow ehX}}{dx\,dQ^2\,d\phi}=P_1+P_2\cos(\phi)+P_3\cos(2\phi)+P_4\sin(\phi)$$



- Fitted function
- Moments of distributions of trigonometrical functions
  - Mean
  - RMS

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

Moments:

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

Means:

$$\langle\cos(\phi)\rangle = \frac{B}{2A}$$

$$\langle\cos(2\phi)\rangle = \frac{C}{2A}$$

$$\langle\sin(\phi)\rangle = \frac{D}{2A}$$

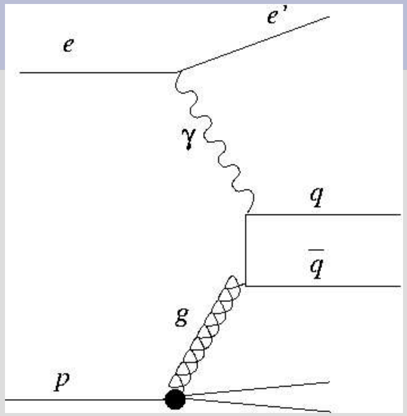
$$\langle\sin(2\phi)\rangle = \frac{E}{2A}$$

RMS:

e.g.

$$RMS_{\langle\cos(2\phi)\rangle} = \sqrt{\frac{1}{2} + \frac{C}{2A}}$$

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



$$\langle\cos(\phi)\rangle=\frac{B}{2A}$$

$$\frac{d\sigma}{dxdydzdp_T^2}=\sum_i str.func.\cdot\frac{d\sigma_{\gamma i\to j}}{dx_h dydz_h dp_T^2}\cdot D_j(\xi',Q^2)$$

$$D_j=PS+hadronization$$

$$x_h=\frac{x}{\xi}=\frac{Q^2}{2p_i q}$$

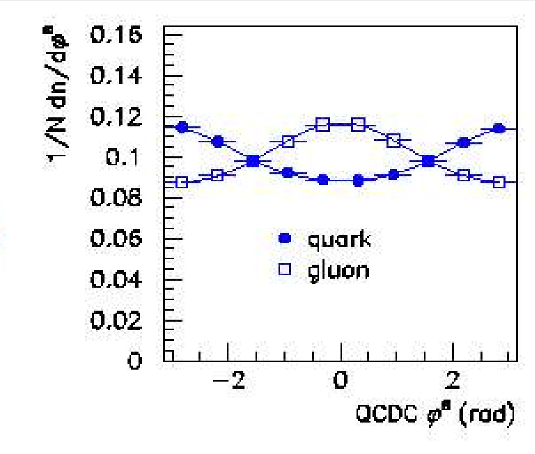
$$z_h=\frac{z}{\xi'}=\frac{p_i p_j}{p_i q}$$

$$\frac{\alpha^2 Q_q^2}{16\;\pi Q^2}\,y\,\delta(\ldots)L_{\mu\nu}M_{ij}^{\mu\nu}$$

For pure photon exchange the currents can be written:

QCDC

$$L_{\mu\nu}M^{\mu\nu}_{qg} = \frac{64\pi}{3}\alpha_s Q^2 \frac{1}{y^2}\Big[(1+(1-y)^2(\frac{x_h^2+z_h^2}{(1-x_h)(1-z_h)} + 2(x_h z_h+1))$$
$$-4(2-y)\sqrt{1-y}\sqrt{\frac{x_h z_h}{(1-x_h)(1-z_h)}}(x_h z_h + (1-x_h)(1-z_h))\cos\phi$$
$$+4x_h(1-y)z_h\cos 2\phi\Big]$$

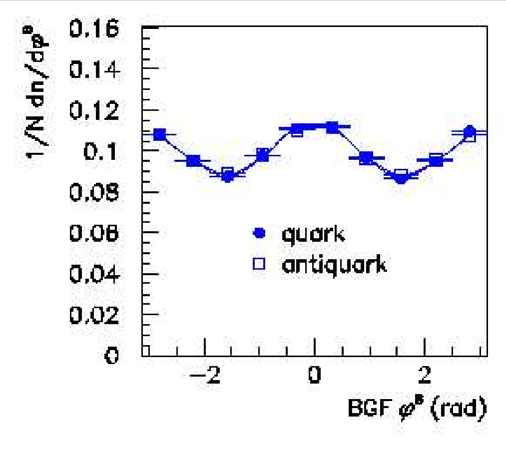


e^{η}

η pseudorapidity

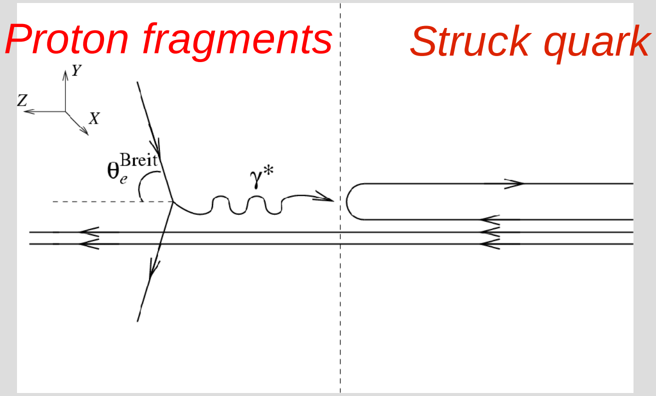
BGF

$$L_{\mu\nu}M^{\mu\nu}_{q\bar{q}} = 8\pi\alpha_s Q^2 \frac{1}{y^2}\Big[(1+(1-y)^2)(x_h^2+(1-x_h)^2)\frac{z_h^2+(1-z_h)^2}{z_h(1-z_h)}$$
$$-4(2-y)\sqrt{1-y}\sqrt{\frac{x_h(1-x_h)}{z_h(1-z_h)}}(1-2x_h)(1-2z_h)\cos\phi$$
$$+8x_h(1-x_h)(1-y)\cos 2\phi\Big]$$



Previous Measurement

The HCM / Breit frame

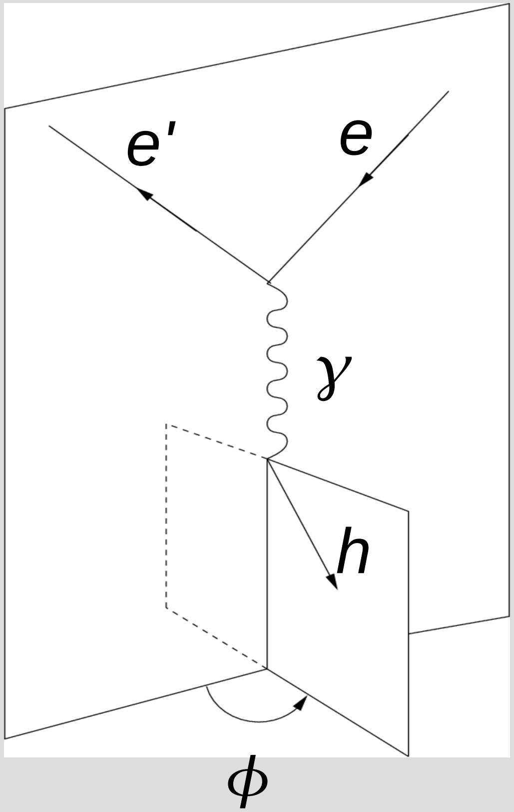


$$E_T^{BR} = E_T^{HCM}$$

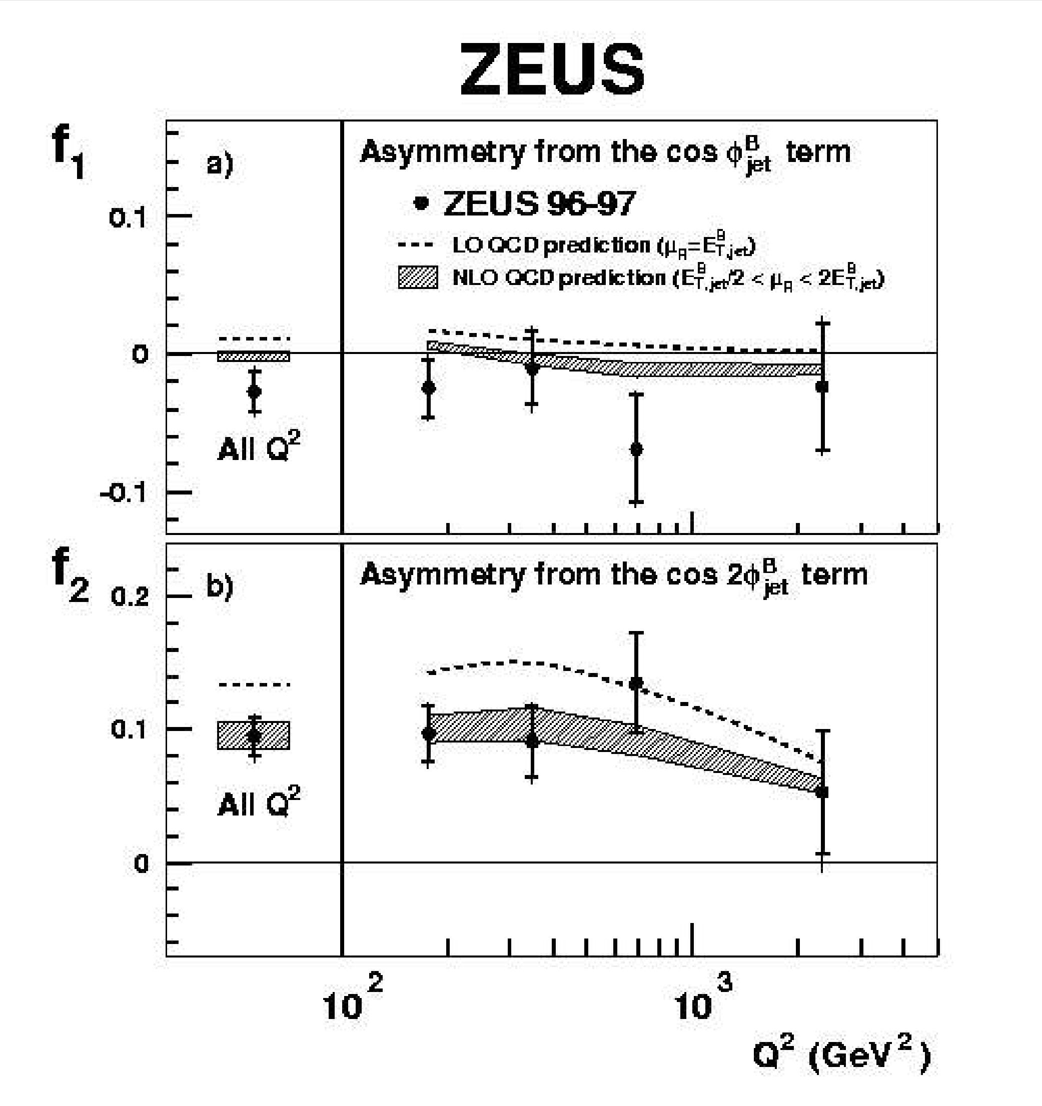
$$\phi^{BR} = \phi^{HCM}$$

For massless partons or particles

$$\eta^{BR} \approx \eta^{HCM} + 0.5 \cdot \ln\left(\frac{1-x}{x}\right)$$



Distribution of the azimuthal angle – ZEUS paper 2002



Breit frame

Jet analysis

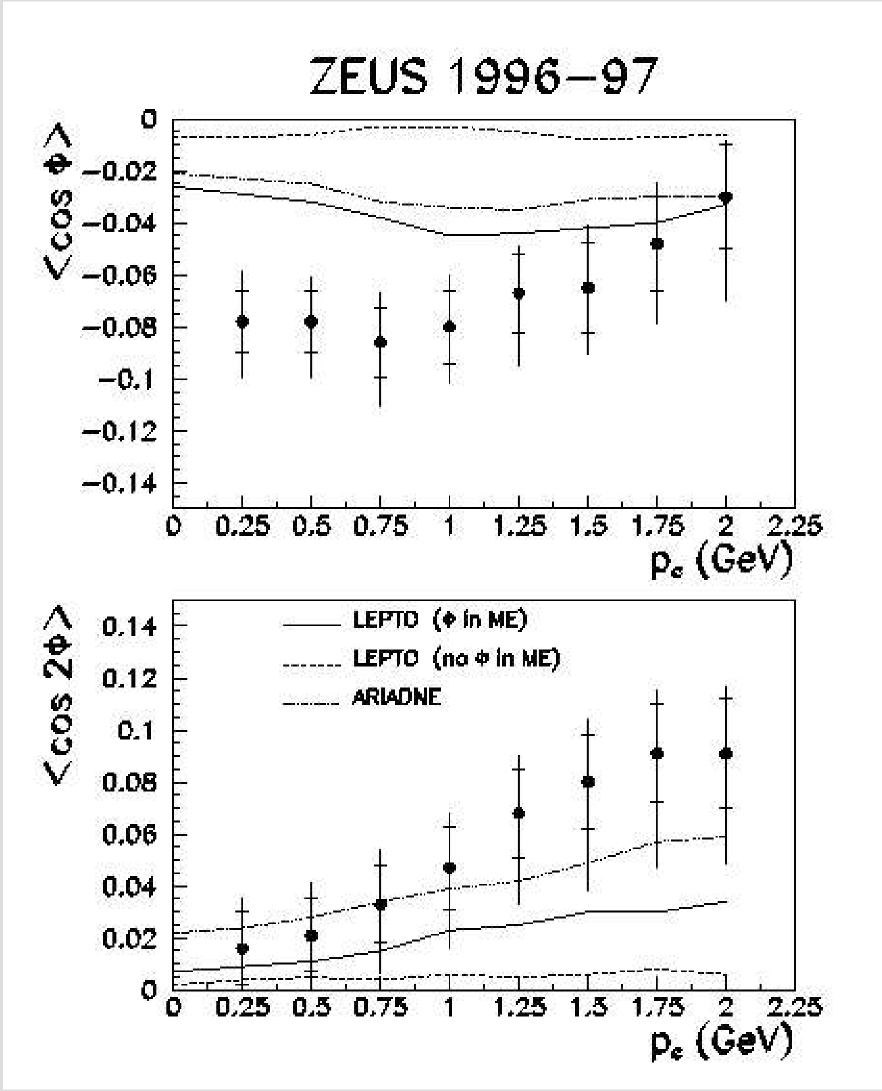
Fitted to experimental data

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

Small Large

See Oscar Gonzalez thesis and
DESY-02-171, Phys.Lett. B551 (2003) 226-240

Distribution of the azimuthal angle – ZEUS paper 2000



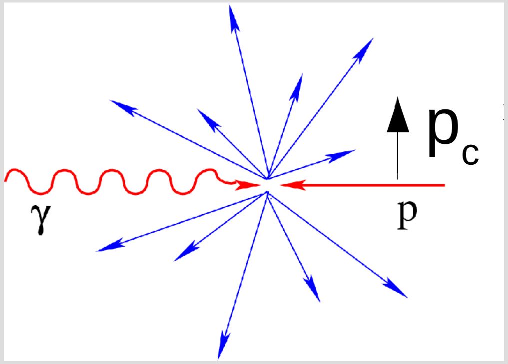
HCM frame

z, p_T method

Multiplicity method
Charged hadrons

For hadrons with $p_T > p_c$

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



See Eduardo Rodriguez thesis and DESY-00-040, Phys.Lett. B481 (2000) 199-212

Why pseudorapidity?

$$E_T^{BR} = E_T^{HCM} = E_T^{*}$$

$$\phi^{BR} = \phi^{HCM}$$

For massless partons or particles

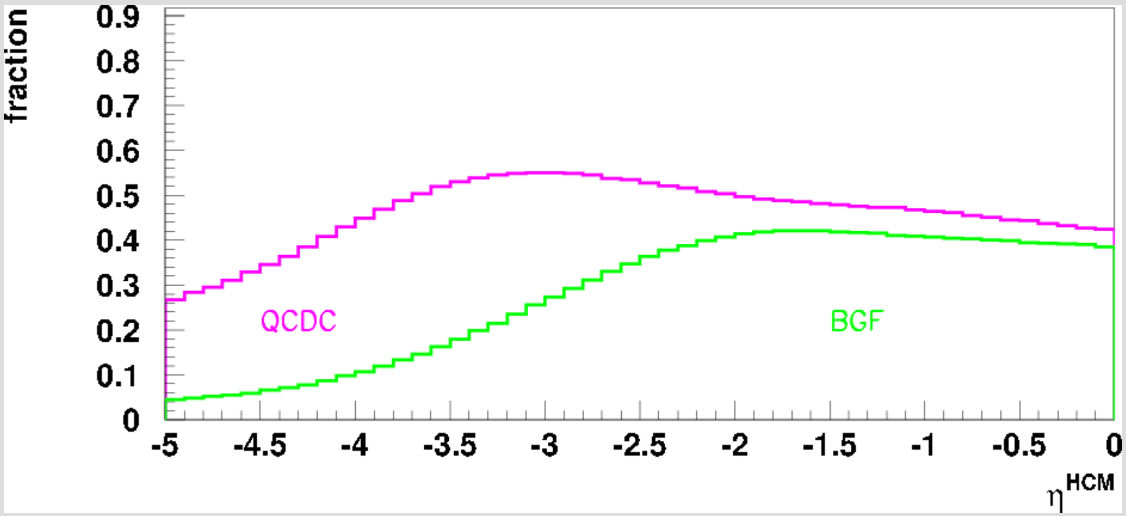
$$\eta^{BR} \approx \eta^{HCM} + 0.5 \cdot \ln\left(\frac{1-x}{x}\right)$$

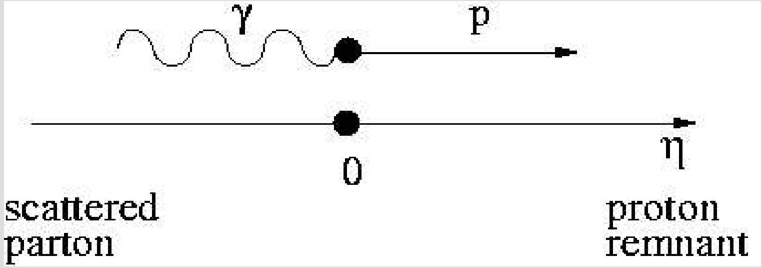
$$z_h = \frac{E_T^{*}}{Q} \cdot e^{-\eta^{BR}}$$

$$\frac{E_T^{*}}{Q} = \sqrt{\frac{z_h(1-x_h)(1-z_h)}{x_h}}$$

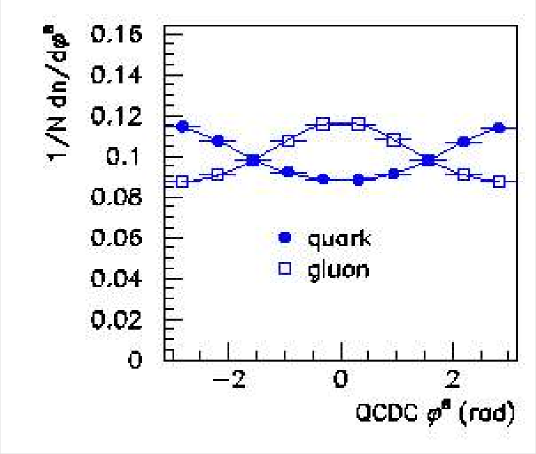
$$\sqrt{\frac{x_h z_h}{(1-x_h)(1-z_h)}} = e^{\eta^{BR}}$$

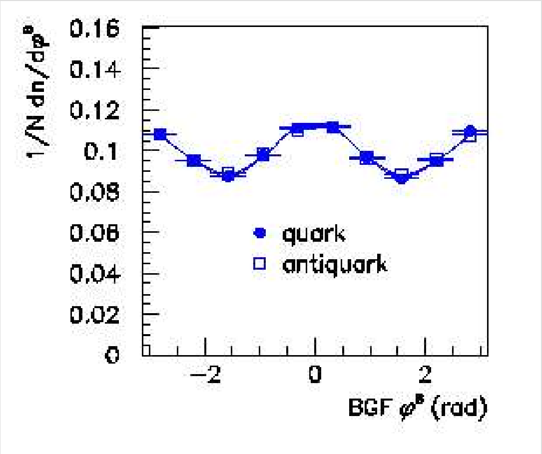
Look into pseudorapidity





If integrated over





the dominant contribution:

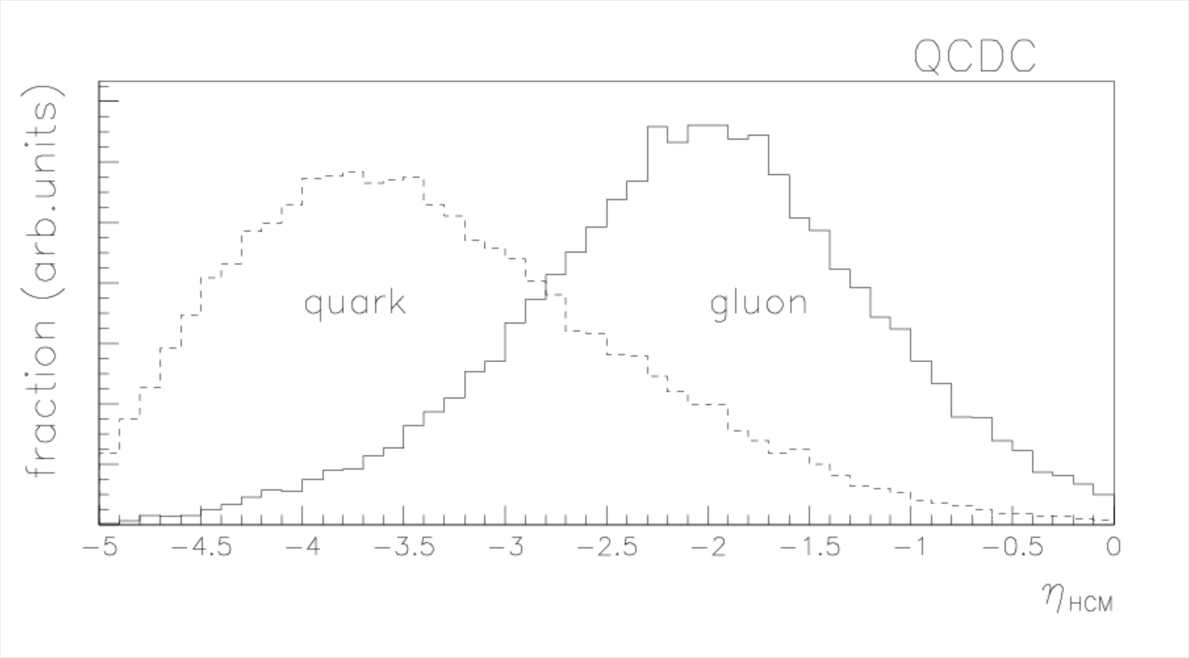
from QCDC $\gamma^* q \to q g$

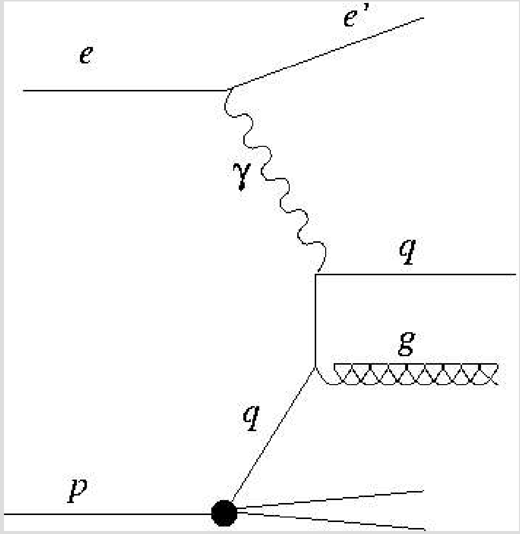
to $\cos(\phi)$

from BGF $\gamma^* g \to q \bar{q}$

to $\cos(2\phi)$

QCD Compton


QCDC
fraction (arb.units)
quark
gluon
−5
−4.5
−4
−3.5
−3
−2.5
−2
−1.5
−1
−0.5
0
η_{HCM}


e
e'
γ
q
g
q
p

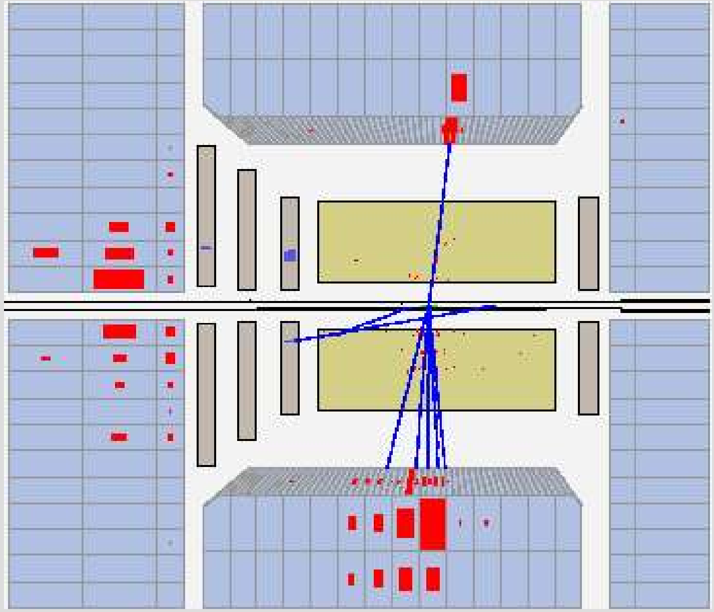
Pseudorapidity because:

- separation of BGF and QCDC
- separation of hadrons from q and g

Important because:

- BGF → gluonic structure function of proton

Why energy flow method instead of multiplicity method?



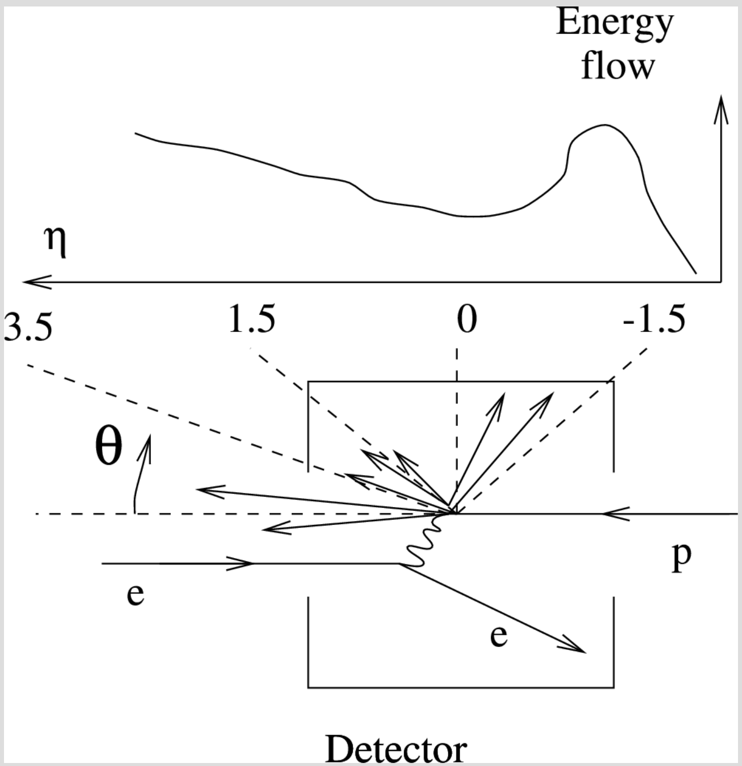
Tracking detector

$$-1.75 < \eta^{\mathrm{LAB}} < 1.75$$

Calorimeter

$$-3 < \eta^{\mathrm{LAB}} < 4$$

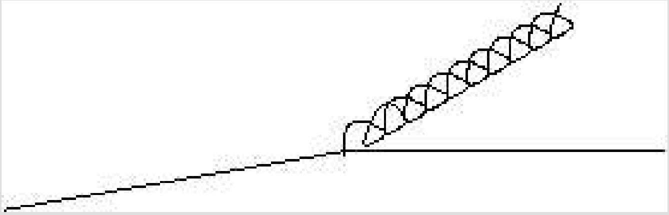
Energy flow method in the laboratory frame



Energy flow objects EFO
EFO used as pseudohadrons

pQCD
infrared and collinear singularities out

Peccei, Rückl (1978)



Each particle direction is weighet with its energy

Comments on the energy flow method and pseudorapidity

Advantages

- charged and neutral hadrons included
- hard partons (E^*_T larger) provides a larger contribution
- hadrons nearby in the HCM frame $\longrightarrow$ nearby in LAB
- sensitive to parton fragmentation $\longrightarrow$ no dependence on jet algorithms
- multiplicity method with charged hadrons $\longrightarrow$ sensitive to hadronization
- calorimeter energy scale is cancelled for i.e. $\langle \cos(\phi) \rangle$

Disadventages

- no hadrons but clusters of energy
  the quantities like $z = Pp_h / Pq$ are not well measured

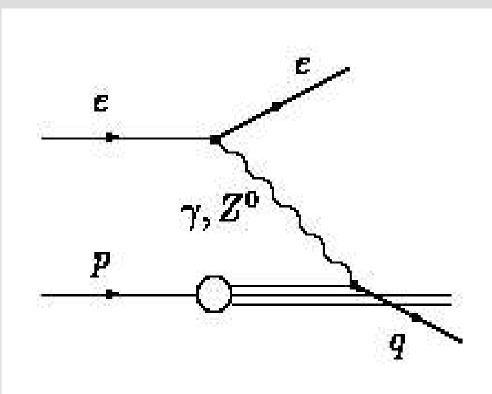
Global selection criteria

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

$$100 < Q^2 < 8000 \text{ GeV}^2$$

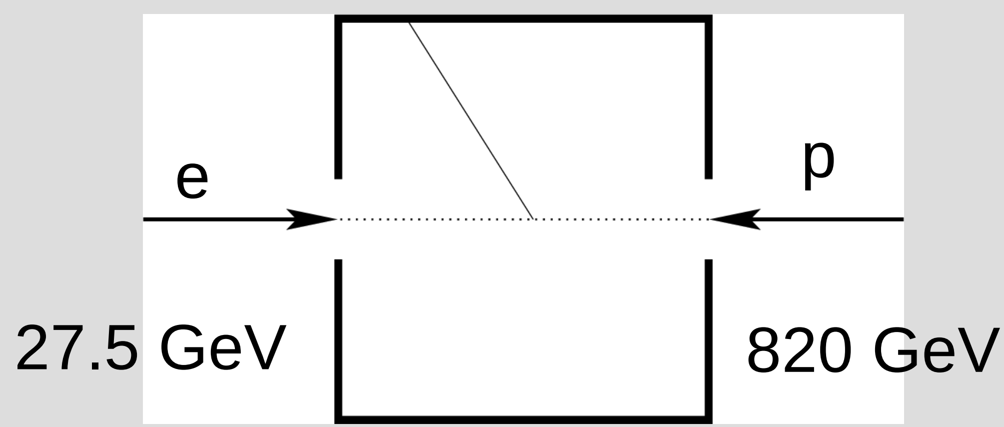
$$0.2 < y < 0.8$$

$$0.01 < x < 0.1$$



$$\theta_{particle}^{LAB} > 8^0 \text{ (First ring)}$$

$$p_T^{LAB} > 150 \text{ MeV}$$



$$Q^2 = -q^2 = -(k_{e'} - k_e)^2$$

$$x = Q^2 / 2 P \cdot q$$

$$y = P \cdot q / P \cdot k_e$$

Monte Carlo Models

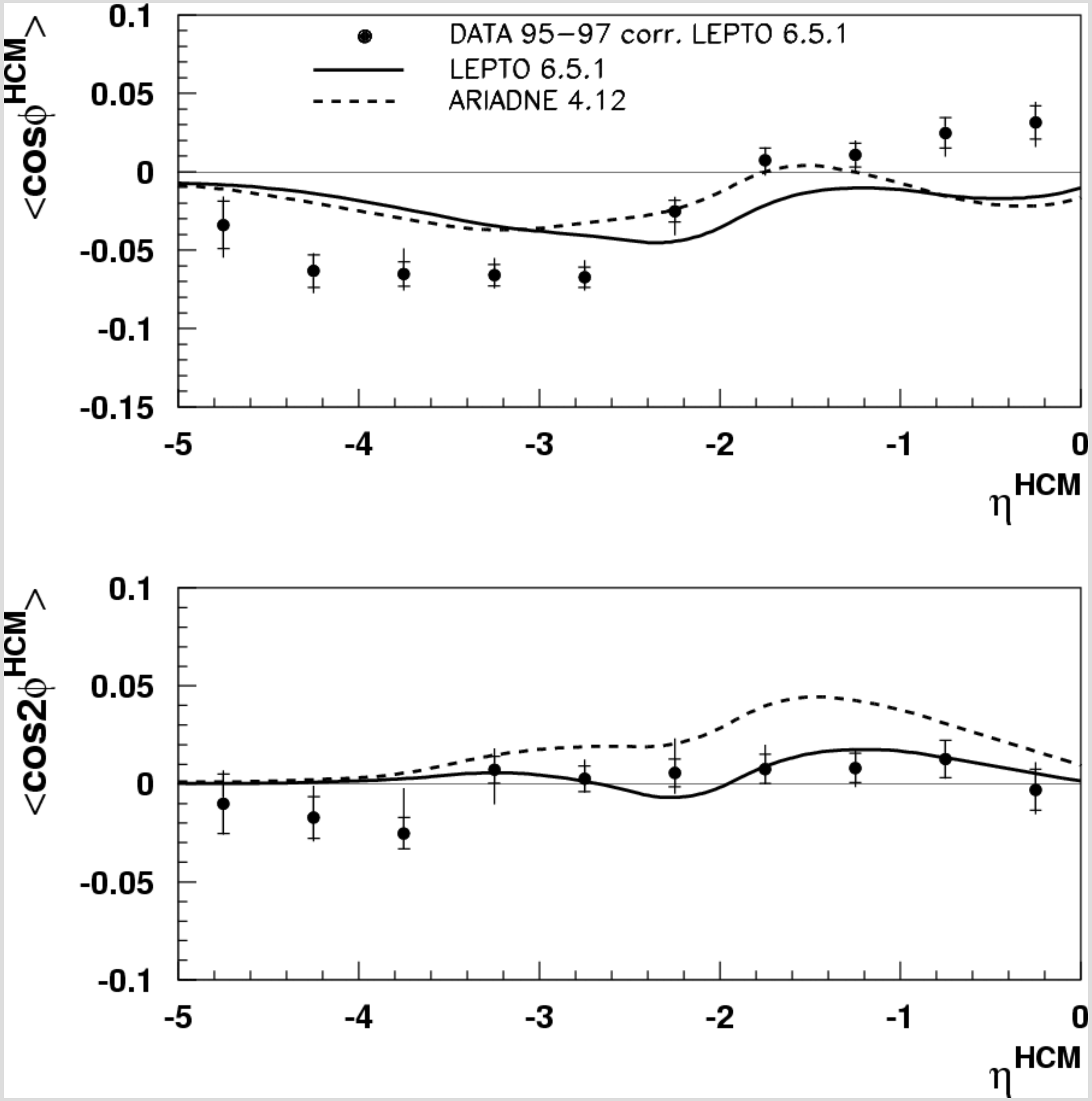
LEPTO 6.5.1 – matrix element and parton shower

ARIADNE 4.12 – colour dipol model (LO)

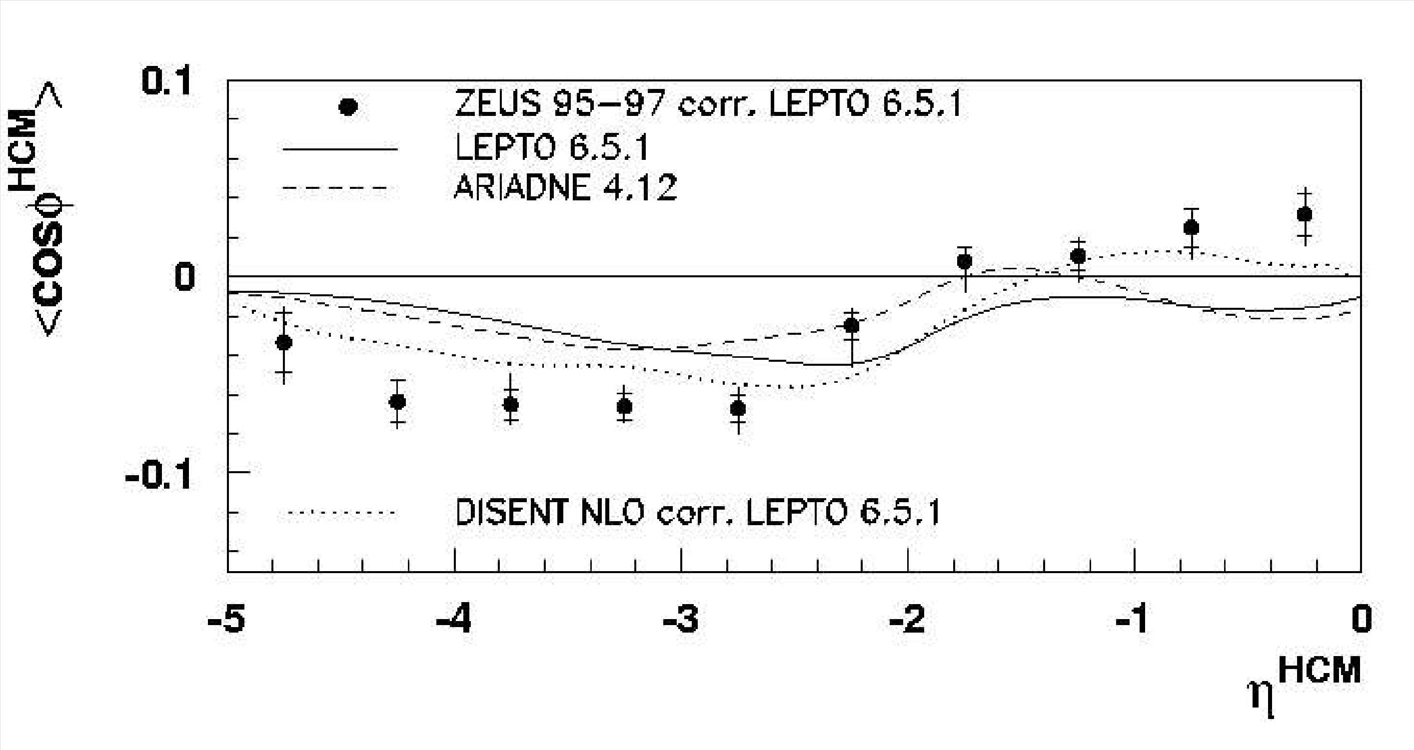
DISENT – NLO colour dipol model

DATA versus LO models

Energy flow method



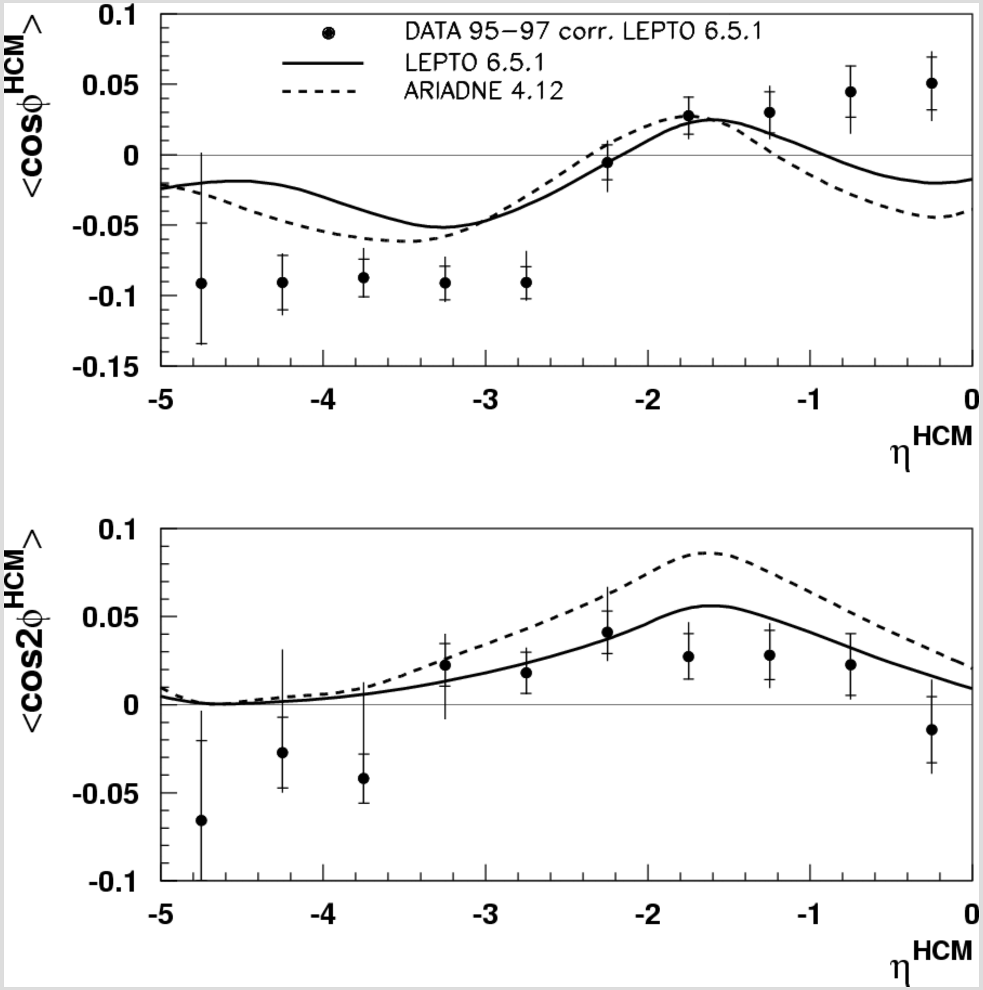
Azimuthal asymmetry energy flow method

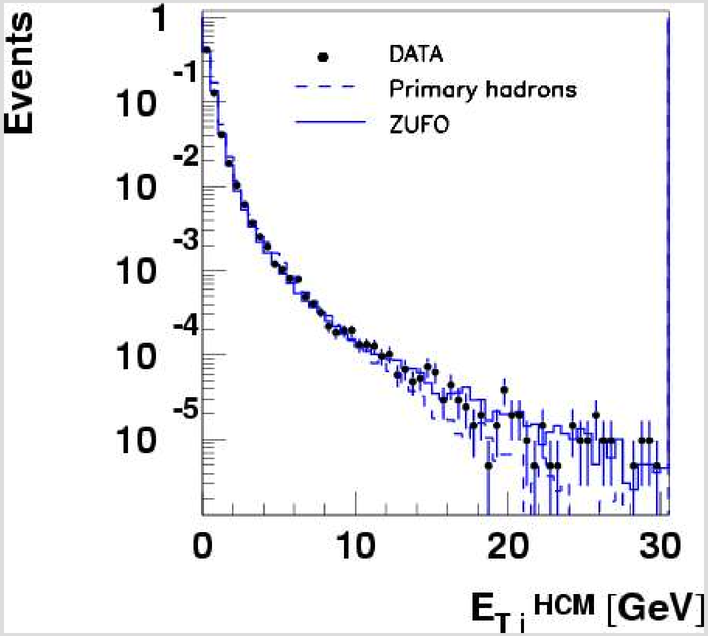


Compared ZEUS DATA 95-97 with predictions

Energy flow method

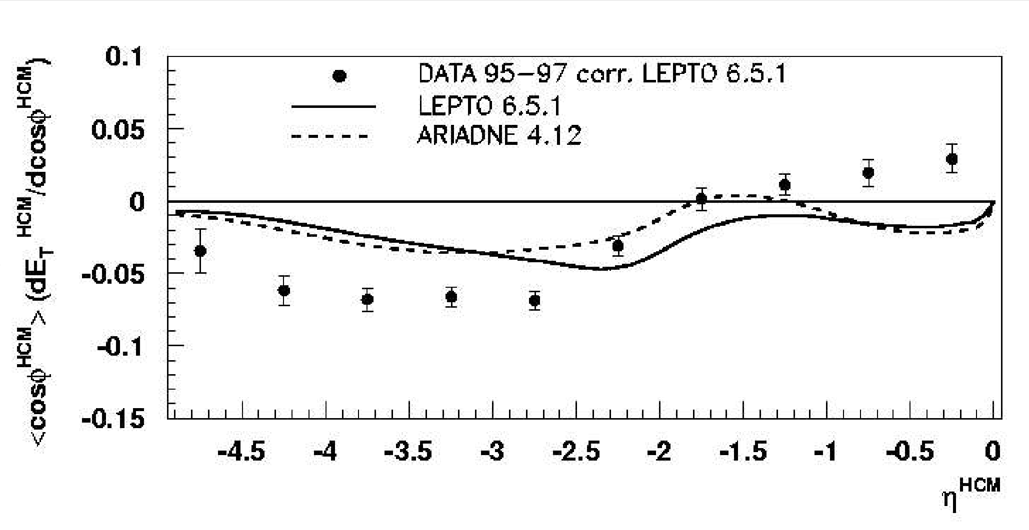
$E_T^{HCM} > 1$ GeV



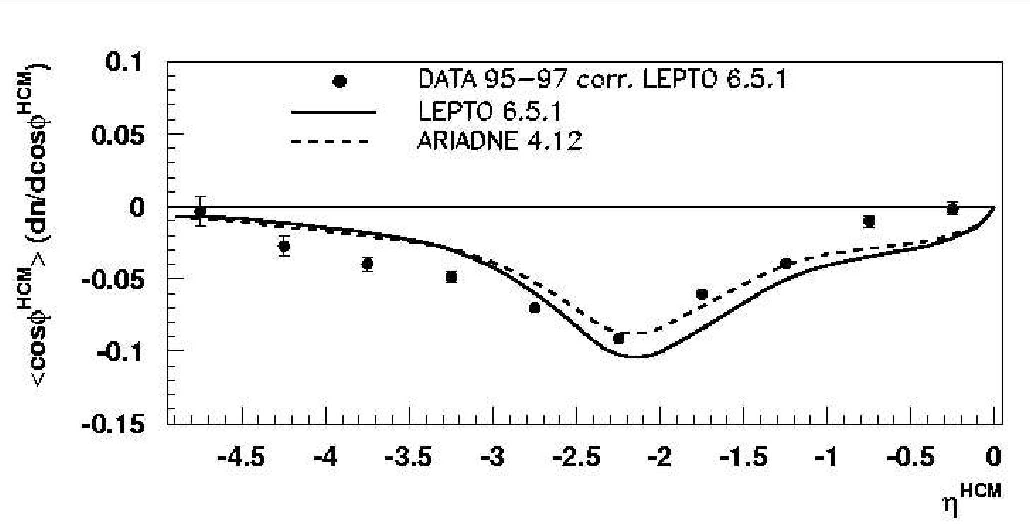


Energy flow and multiplicity

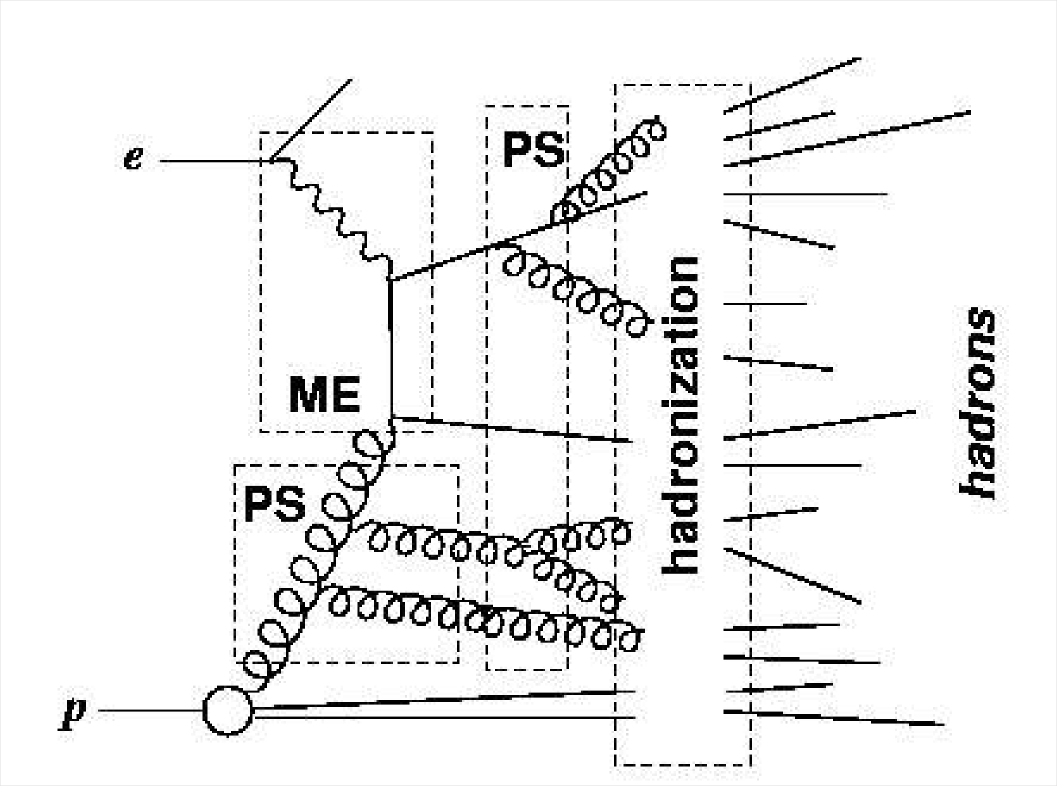
Energy flow method



Multiplicity method



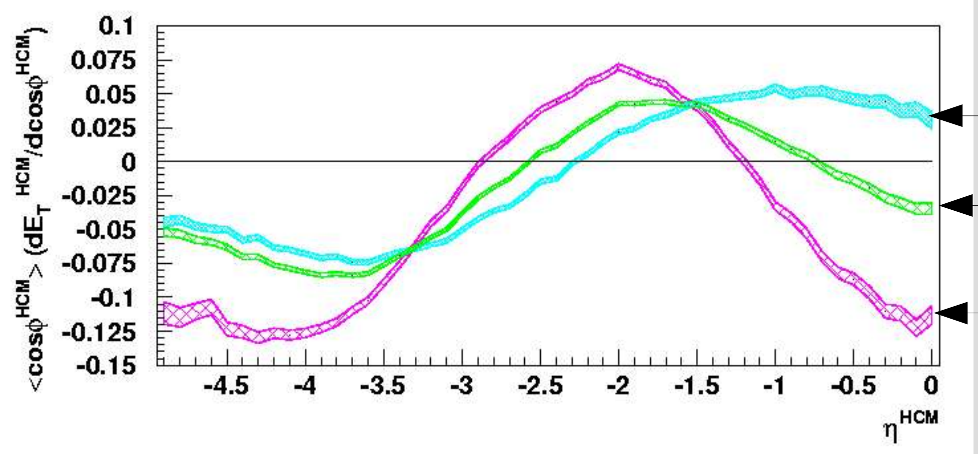
Sequence of subprocesses in DIS



Contribution to asymmetries from: BGF + QCDC

ME prediction:
parton level without PS

Energy flow method



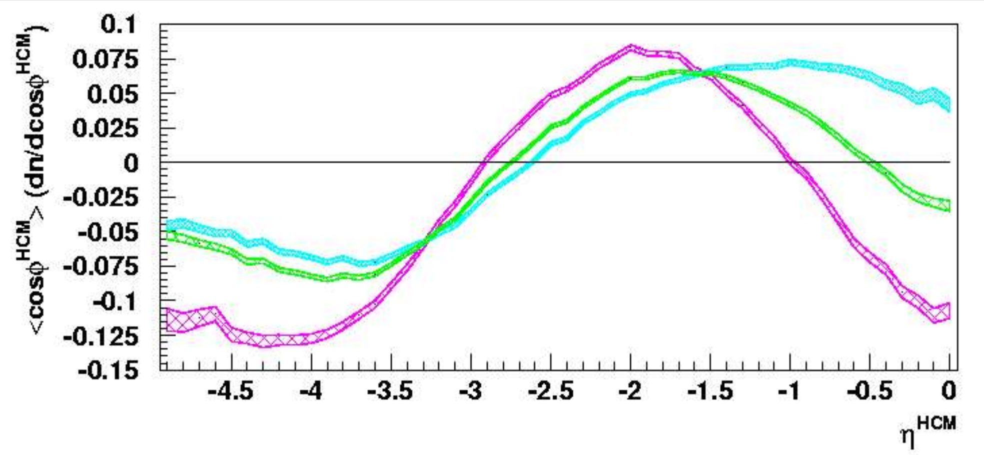
LEPTO 6.5.1

QCDC

BGF + QCDC + QPM

BGF

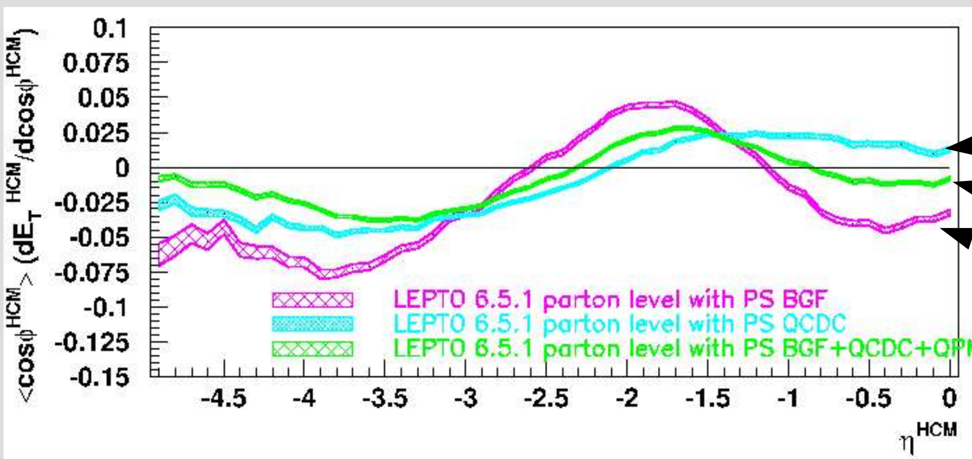
Multiplicity method



ME + PS prediction:

parton level with PS

Energy flow method



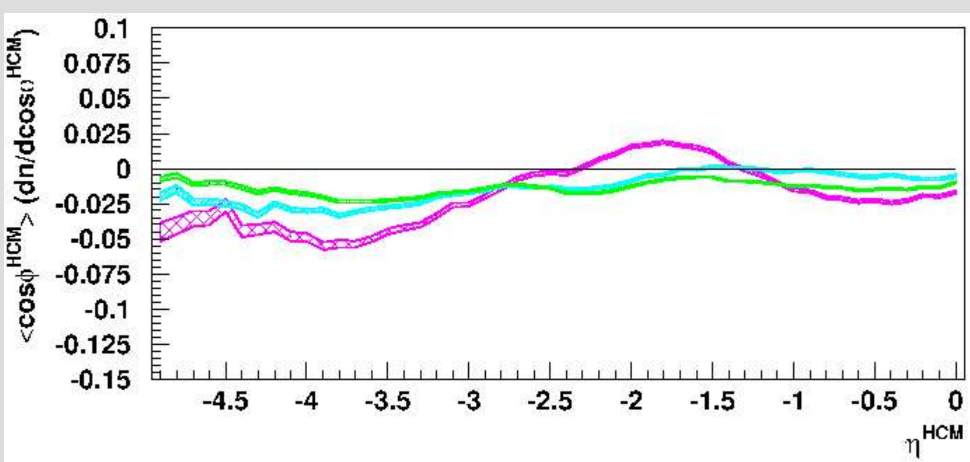
LEPTO 6.5.1

QCDC

BGF + QCDC + QPM

BGF

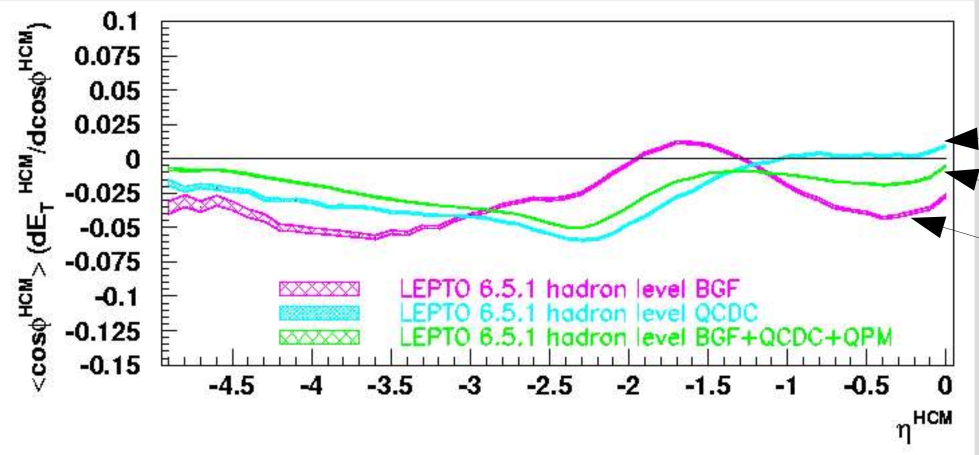
Multiplicity method



Prediction:

hadron level + detection

Energy flow method



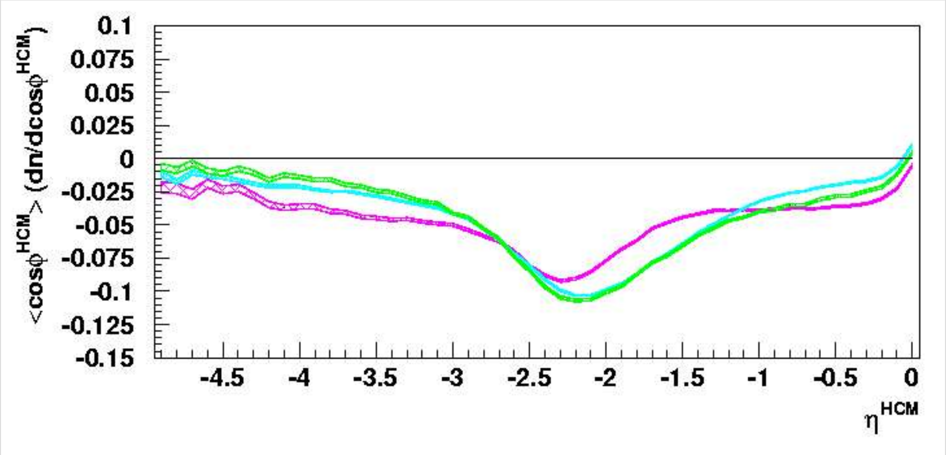
LEPTO 6.5.1

QCDC

BGF + QCDC + QPM

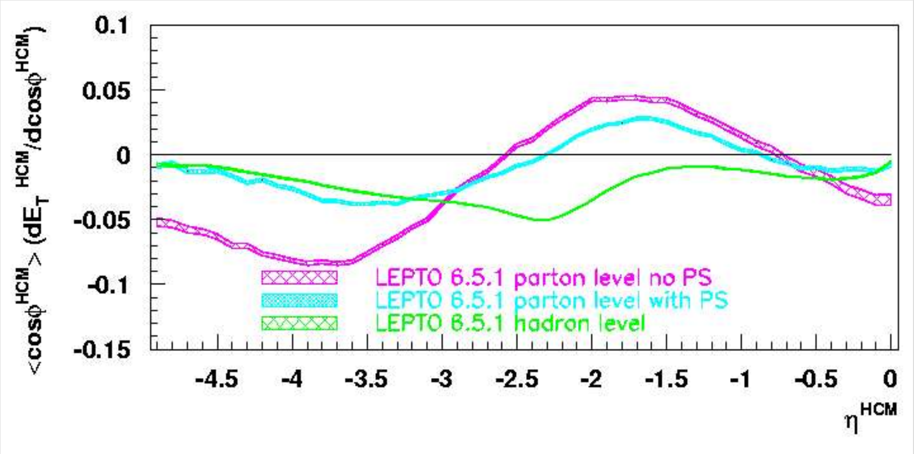
BGF

Multiplicity method



Prediction:
parton level vs. hadron level

Energy flow method



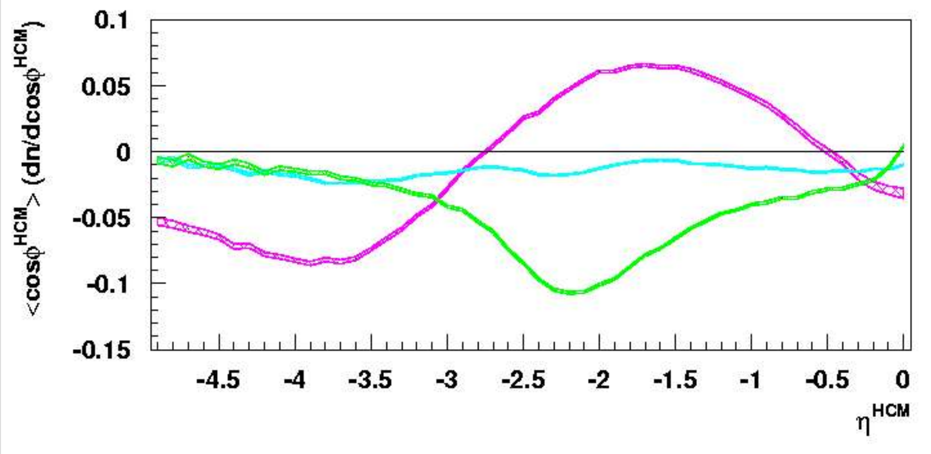
LEPTO 6.5.1

Parton level no PS

Parton level with PS

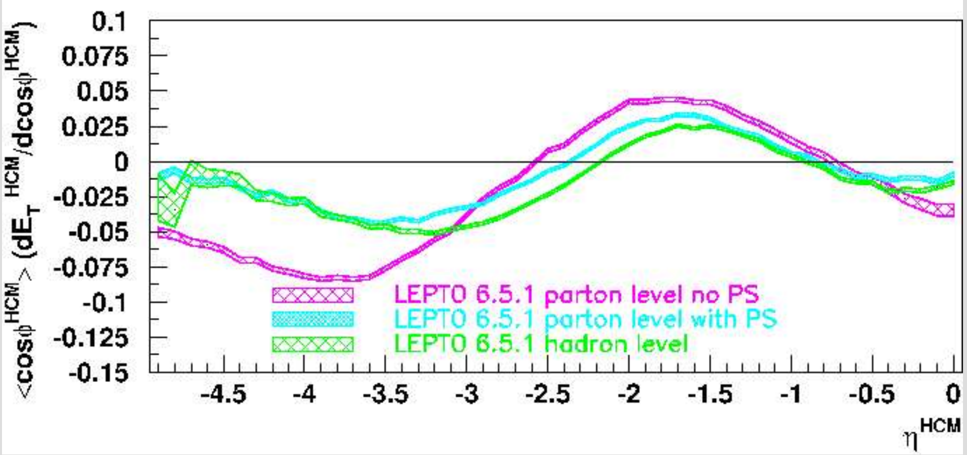
Hadron level

Multiplicity method



Prediction:
parton level vs. hadron level

Energy flow method



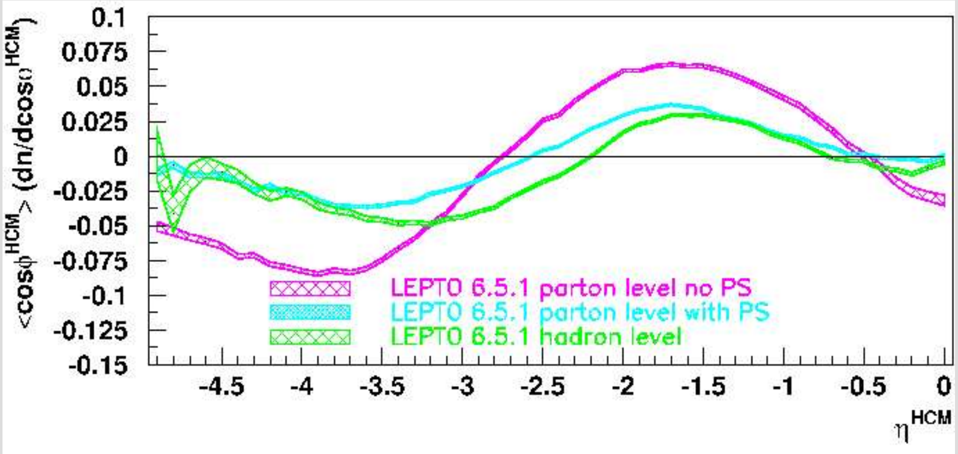
LEPTO 6.5.1

Parton level no PS

Parton level with PS

Hadron level

Multiplicity method



$E_T^{HCM} > 1\ \mathrm{GeV}$

Conclusions (part I)

- The multiplicity method is very sensitive to detection inefficiencies
- Therefore the obtained azimuthal asymmetries are dominated by hadronization effects
- Azimuthal asymmetries for 0.01<x<0.1 with energy flow the dominant contribution depends on the η interval

  $-5. < \eta^{HCM} \leqslant -3.$ is dominated by QCDC and NLO

  $-3. < \eta^{HCM} \leqslant -1.$ is sensitive to BGF content

  $-1. < \eta^{HCM} \leqslant -0.$ by both QCDC + BGF and NLO

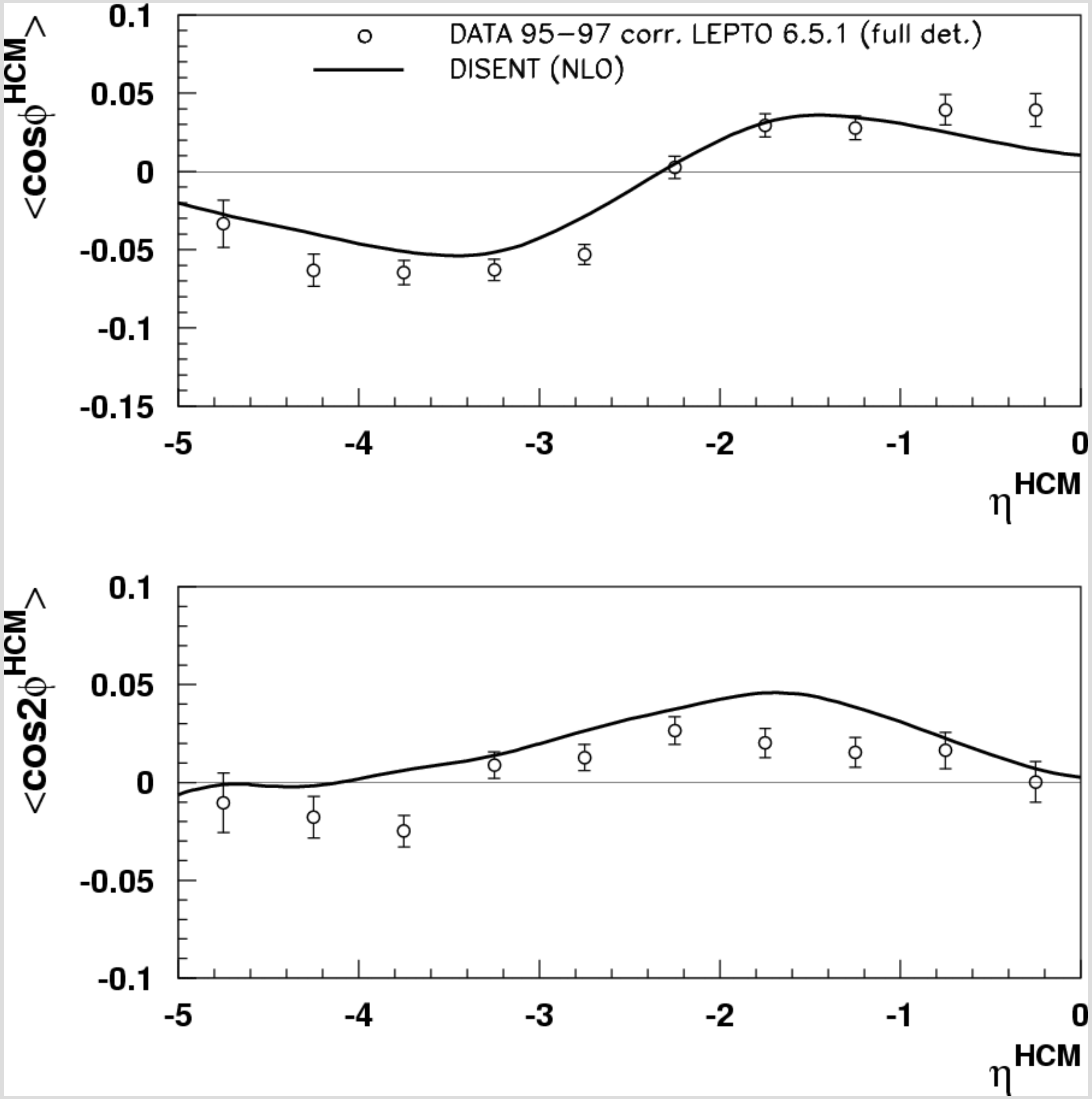
DATA versus NLO

Energy flow method

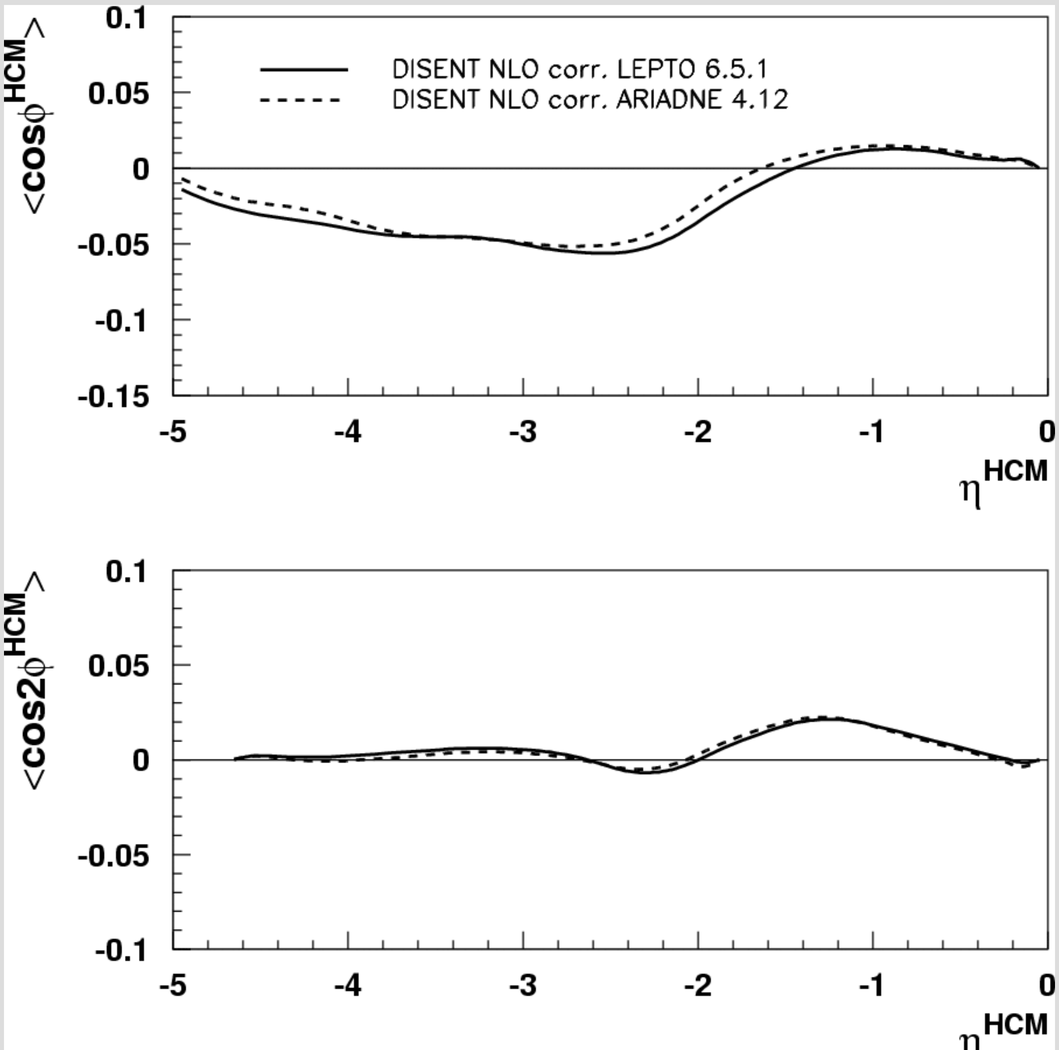
DATA corrected
for losses
in the HERA beampipe

(Against rules!)

Stat. uncertainties only



Corrections for DISENT NLO



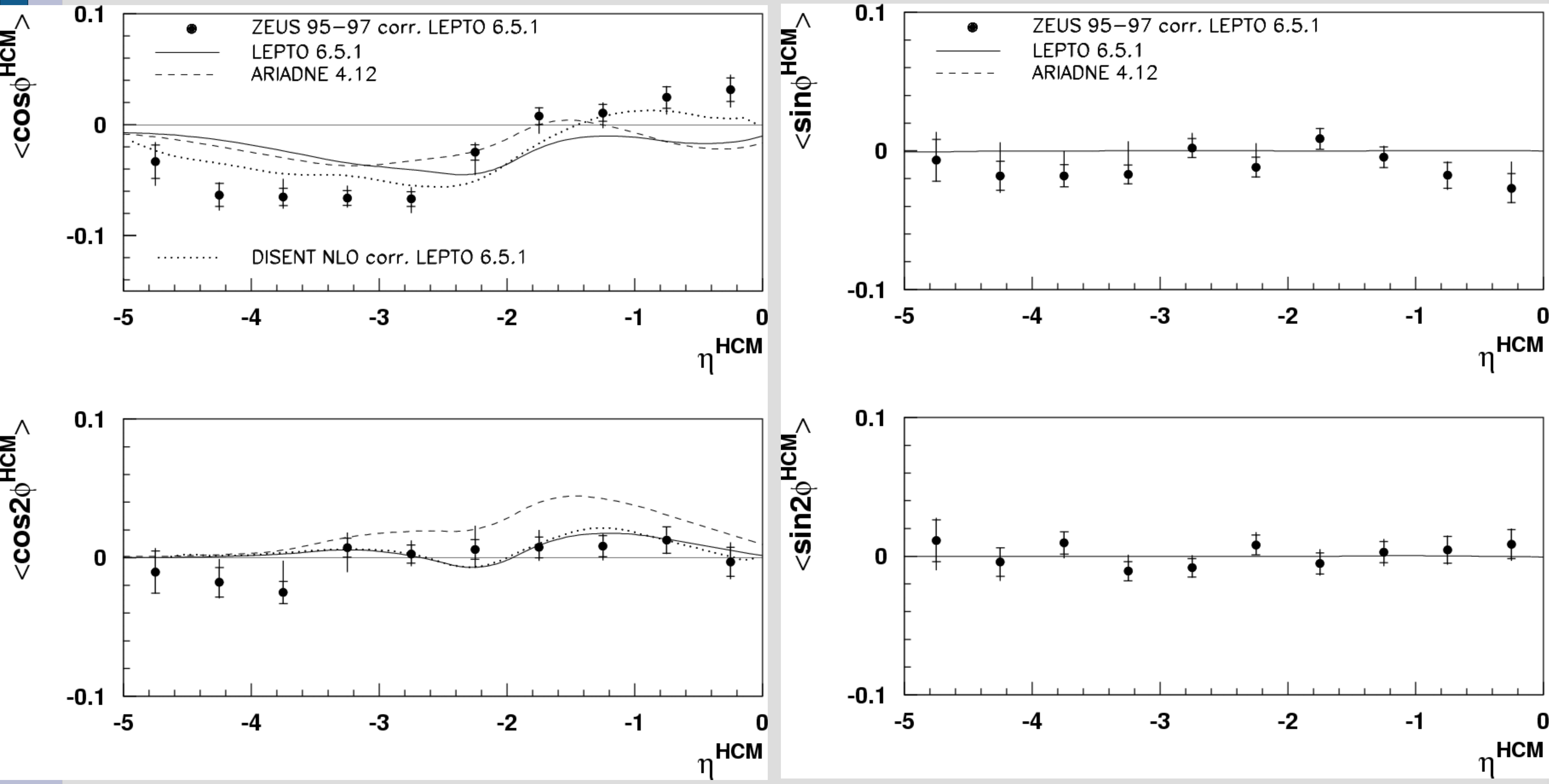
No model dependence

Uncertainties due
to factorization
and renormalization scales
were calculated by changing

$\mu_{F,R} = Q$ *to* $0.5 \cdot Q$ *and* $2 \cdot Q$

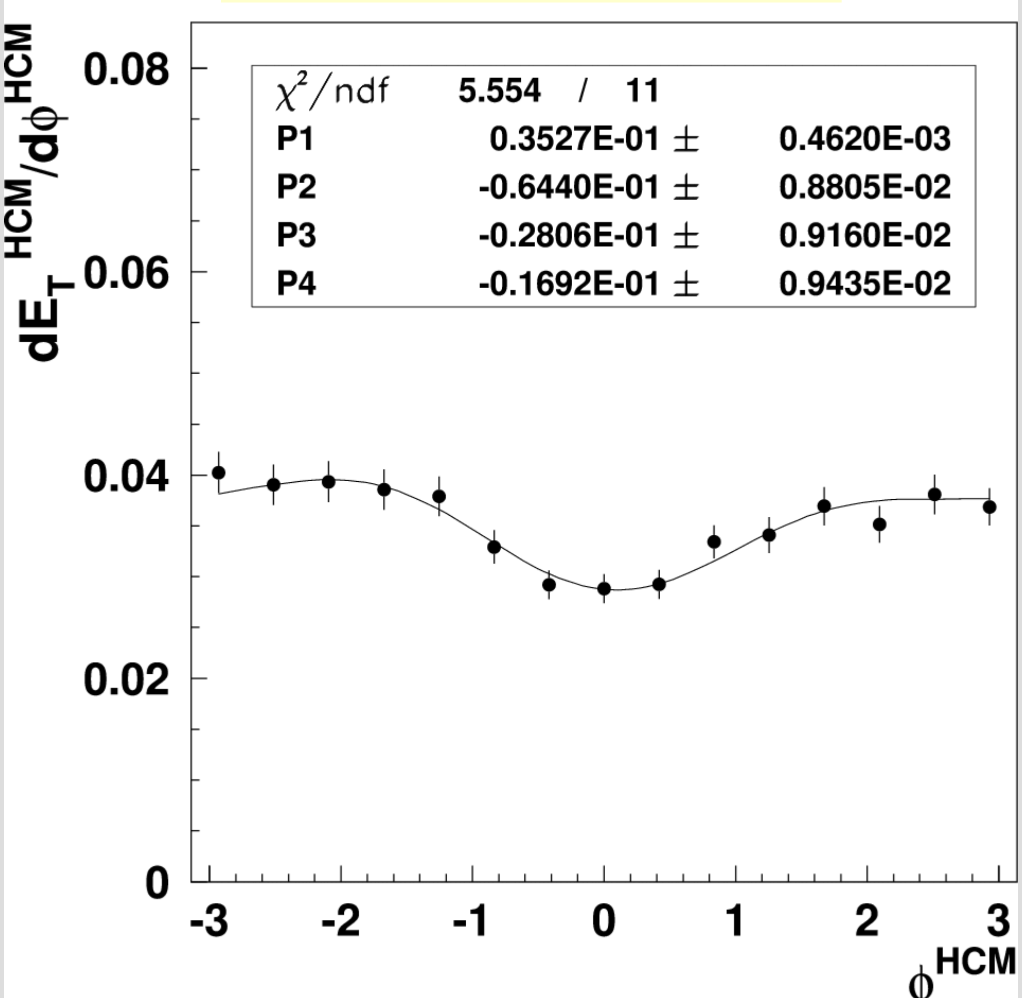
The asymmetries fluctuated
within a band of ±0.005

Azimuthal asymmetry energy flow method



Azimuthal angle distribution energy flow method

$-4. < \eta^{HCM} \leqslant -3.5$



DATA 95-97 corr. LEPTO 6.5.1

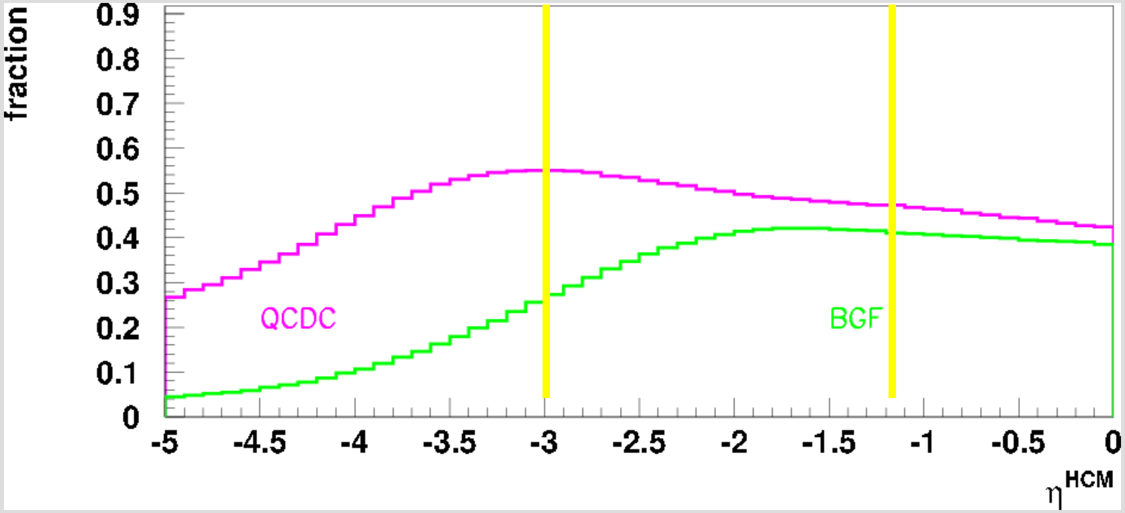
$$\frac{d\sigma}{d\phi} = P_1 + P_2 \cos(\phi) + P_3 \cos(2\phi) + P_4 \sin(\phi)$$

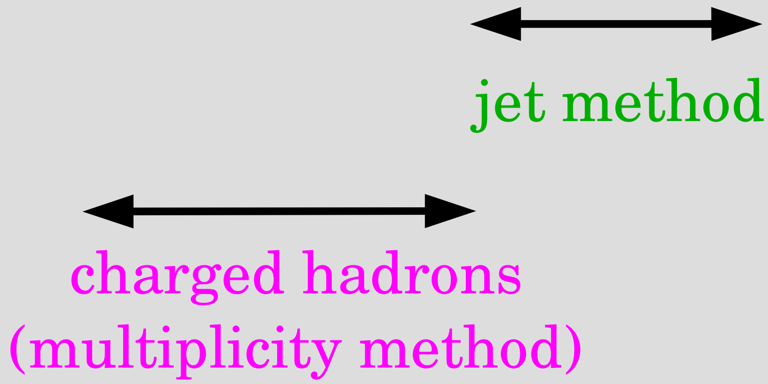
The second independent analysis
Fitted values P_2, P_3, P_4
are consistent with mean ones

$$\langle \cos(\phi^{HCM}) \rangle, \ \langle \cos(2\phi^{HCM}) \rangle, \ \langle \sin(\phi^{HCM}) \rangle$$

BGF versus QCDC for energy flow method

LEPTO 6.5.1





charged hadrons
(multiplicity method)
Eduardo Rodrigues
DESY-00-040
Phys.Lett. B481 (2000) 199-212

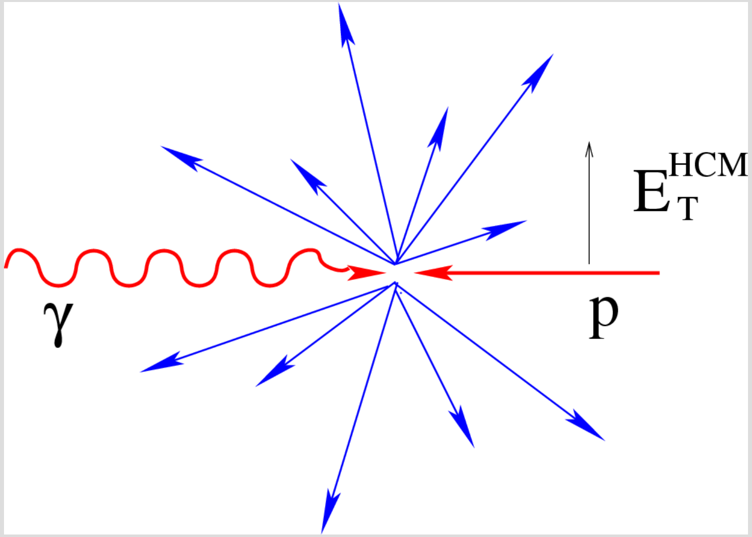
jet method
Oscar Gonzalez
DESY-02-171
Phys.Lett. B551 (2003) 226-240

Azimuthal asymmetry as $f(E_T^{HCM}(min))$

$$-5. < \eta^{HCM} \leqslant -2.5$$

$$-2.5 < \eta^{HCM} \leqslant -1.$$

$$-1. < \eta^{HCM} \leqslant 0.$$



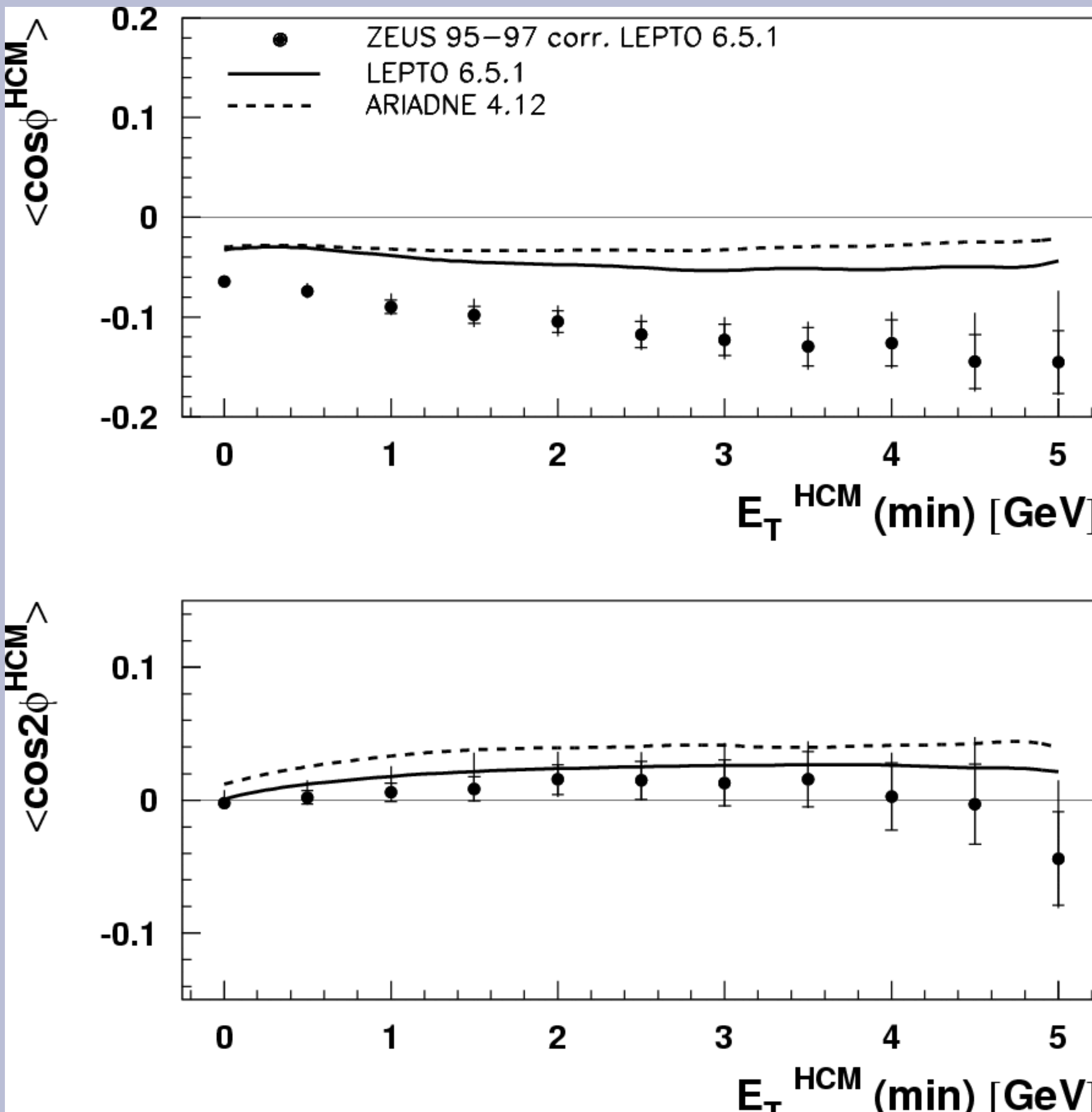
$E_T^{HCM}(min)$ large $\longrightarrow$ pQCD

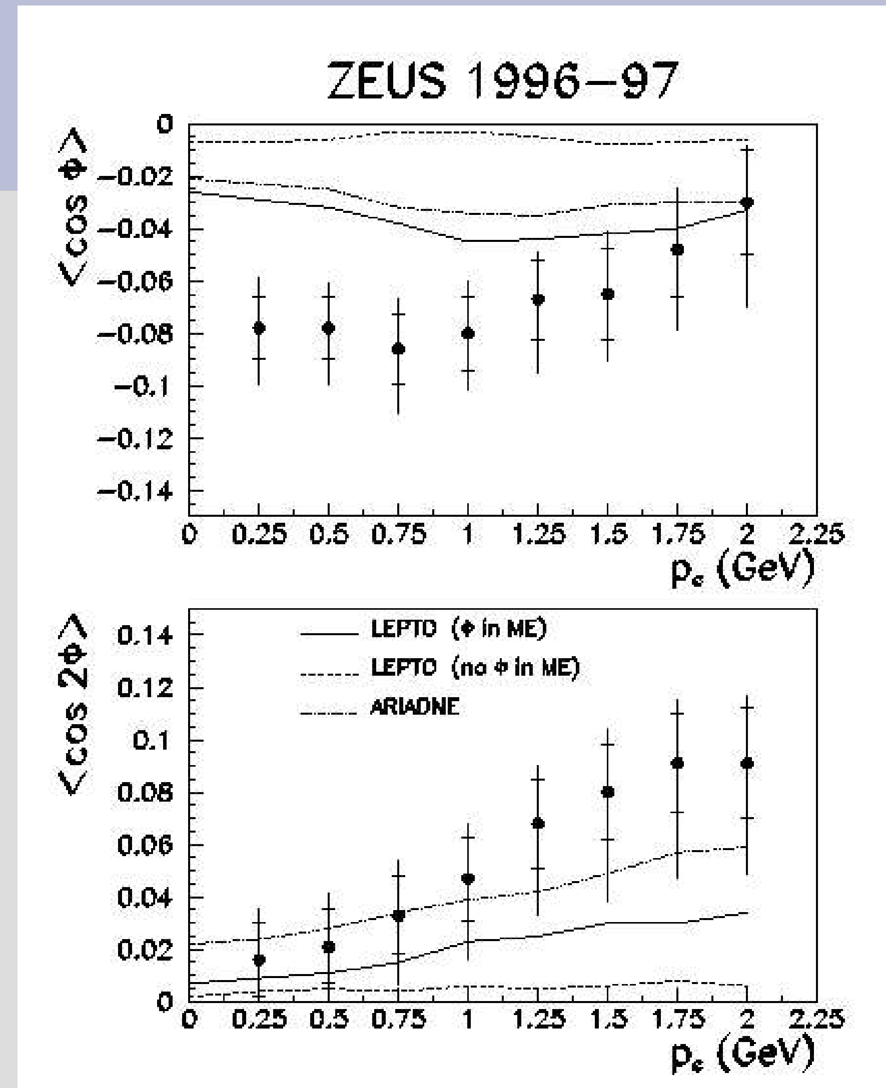
Theorists claim that cut on E_T^{HCM} 2 GeV
is sufficient to removed nonperturbative effects

Method p_T – cut:
Chay et al. Phys.Rev. D45 (1992) 46

Phys.Lett. B481 (2000) 199-212

$-5. < \eta^{\mathrm{HCM}} \leqslant -2.5$



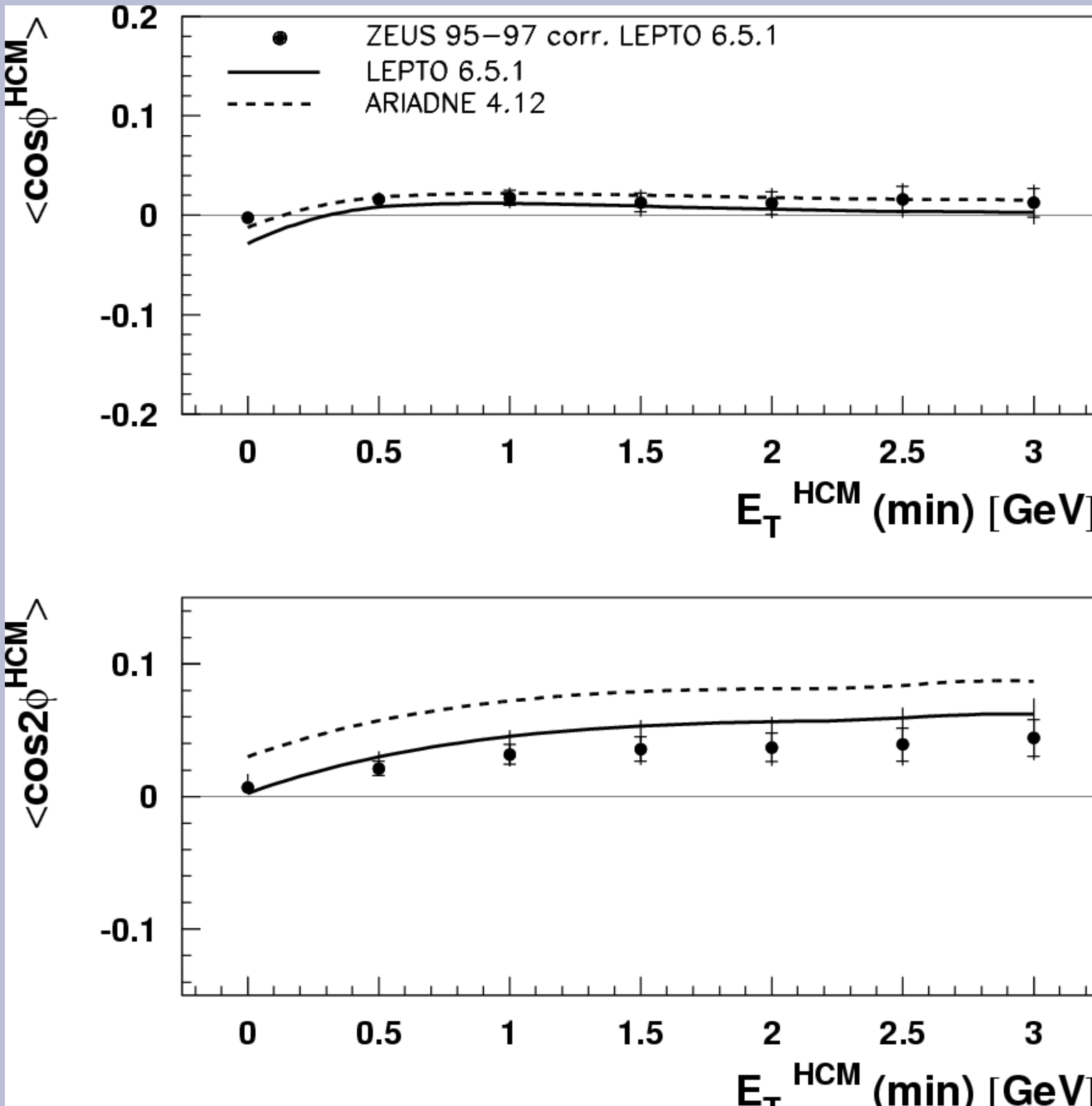


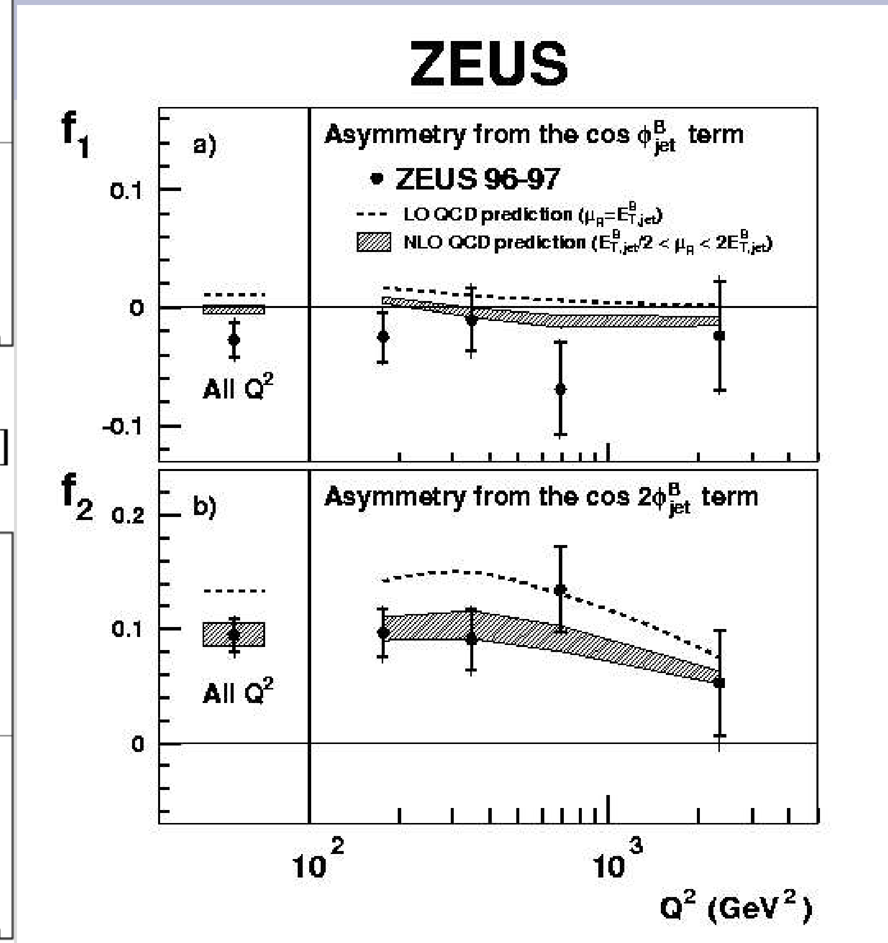
$$0.2 < z_h = \frac{P \cdot p_h}{P \cdot q} < 1$$

$$|\eta^{\mathrm{LAB}}| < 1.75$$

Phys.Lett. B551 (2003) 226-240

$-2.5 < \eta^{\mathrm{HCM}} \leqslant -1.$



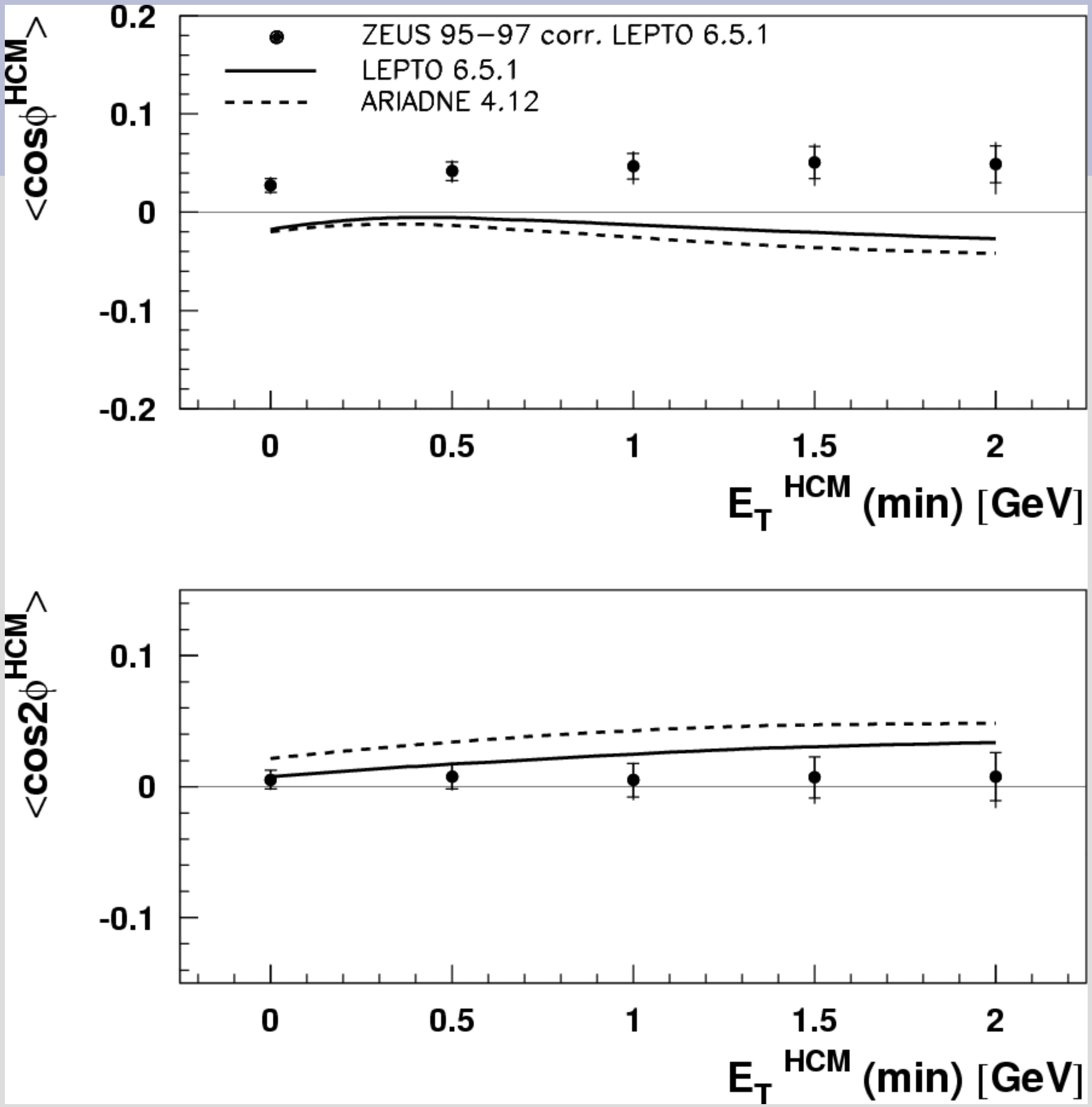


$$\frac{1}{\sigma}\frac{\mathrm{d}\sigma}{\mathrm{d}|\phi_{\mathrm{jet}}^{\mathrm{B}}|} = \frac{1}{\pi}\left[1 + \mathrm{f}_1 \cos(\phi_{\mathrm{jet}}^{\mathrm{B}}) + \mathrm{f}_2 \cos(2\phi_{\mathrm{jet}}^{\mathrm{B}})\right]$$

$$\mathrm{f}_1 \Leftrightarrow \langle \cos(\phi^{\mathrm{HCM}}) \rangle; \quad \mathrm{f}_2 \Leftrightarrow \langle \cos(2\phi^{\mathrm{HCM}}) \rangle$$

$-1. < \eta^{HCM} \leqslant 0.$

First measurements in this region of phace space



NLO prediction expects:

- the positive values for $\langle \cos(\phi^{HCM}) \rangle$
- the smaller positive ones for $\langle \cos(2\phi^{HCM}) \rangle$

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
- enhance contributions of hard partons by weighting with energy, i.e. energy flow
- investigate contributions of BGF w.r.t QCDC
- compare these results with the previous ZEUS measurements

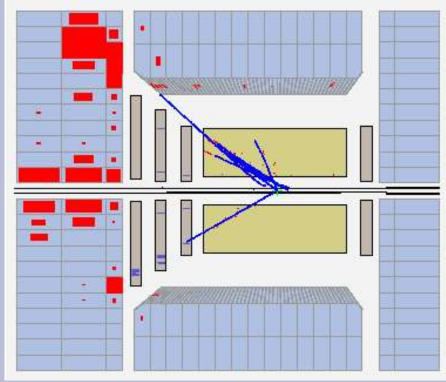
Disadvantage:

- cuts on individual hadrons – unreliable

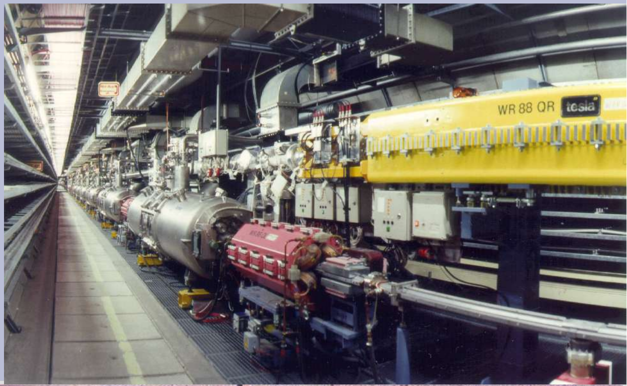
Summary and conclusions

The main results are:

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



New look at HERA



HERA jest polską marką odzieżową powszechnie rozpoznawalną i cenioną. Dzięki wysoko wykwalifikowanej kadrze oraz nowoczesnym liniom produkcyjnym, HERA oferuje produkty na najwyższym światowym poziomie. Wieloletnie doświadczenie poparte obserwacją aktualnych światowych trendów mody, pozwoliły Pani Halinie Widlińskiej na tworzenie kolekcji spójnych wzorniczo i kolorystycznie z obowiązującymi liniami największych domów mody. Współpraca z wiodącymi producentami tkanin i dodatków nadaje wyrobom oryginalny i lekki charakter. Kolekcje łączą w sobie zarówno elementy awangardowe, tworzone z nowatorskich oryginalnych materiałów jak i klasyczne całodzienne kostiumy dla kobiet aktywnych zawodowo. Dwa razy do roku HERA wprowadza na rynek nowe kolekcje obejmujące sezony: jesienno-zimowy oraz wiosenno-letni. Bardzo krótkie serie poszczególnych modeli połączone z szeroką gamą wzorniczą pozwalają klientkom firmy na kreowanie własnego, niepowtarzalnego wizerunku, zgodnego ze światowymi trendami.

Myślą przewodnią tworzonych przez firmę HERA kolekcji jest nadanie klientkom charakteru nowoczesności, lekkości, oryginalności a przede wszystkim poczucia wiecznej młodości.