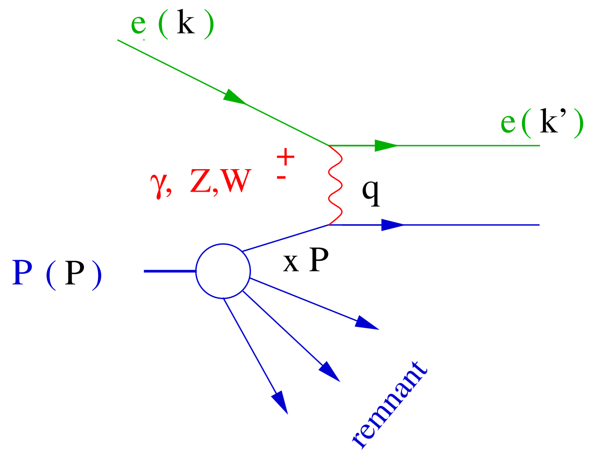
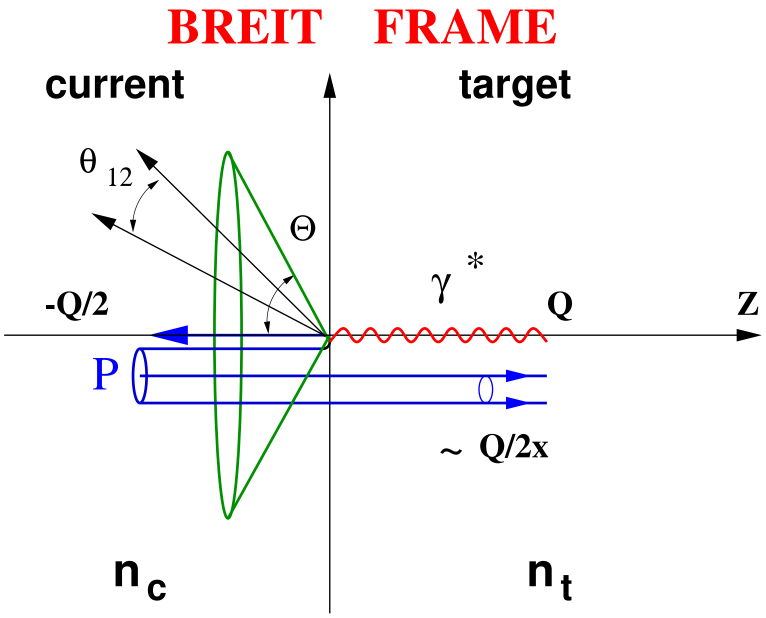
# Short-Range and Long-Range Correlations in DIS at HERA

Sergei Chekanov (ANL)
Int. Symposium on Multiparticle Dynamics, August 1999

- Introduction: NC DIS kinematics;
- Definitions, motivations;
- Angular two-particle correlations;
- Current-Target/Forward-Backward correlations;
- Conclusions.

# Kinematics of NC DIS




$Q^2 = -q^2 = -(k - k')^2$ squared 4-momentum transfer;

$x = \frac{Q^2}{2p \cdot q}$ fractional parton momentum $(0 \le x \le 1)$;

$y = \frac{p \cdot q}{p \cdot k}$ fractional energy transfer $(0 \le y \le 1)$;

$W^2 = (q + p)^2 \simeq \frac{Q^2}{x}(1 - x)$ $\gamma^* P$ Center-of-Mass

# Definitions

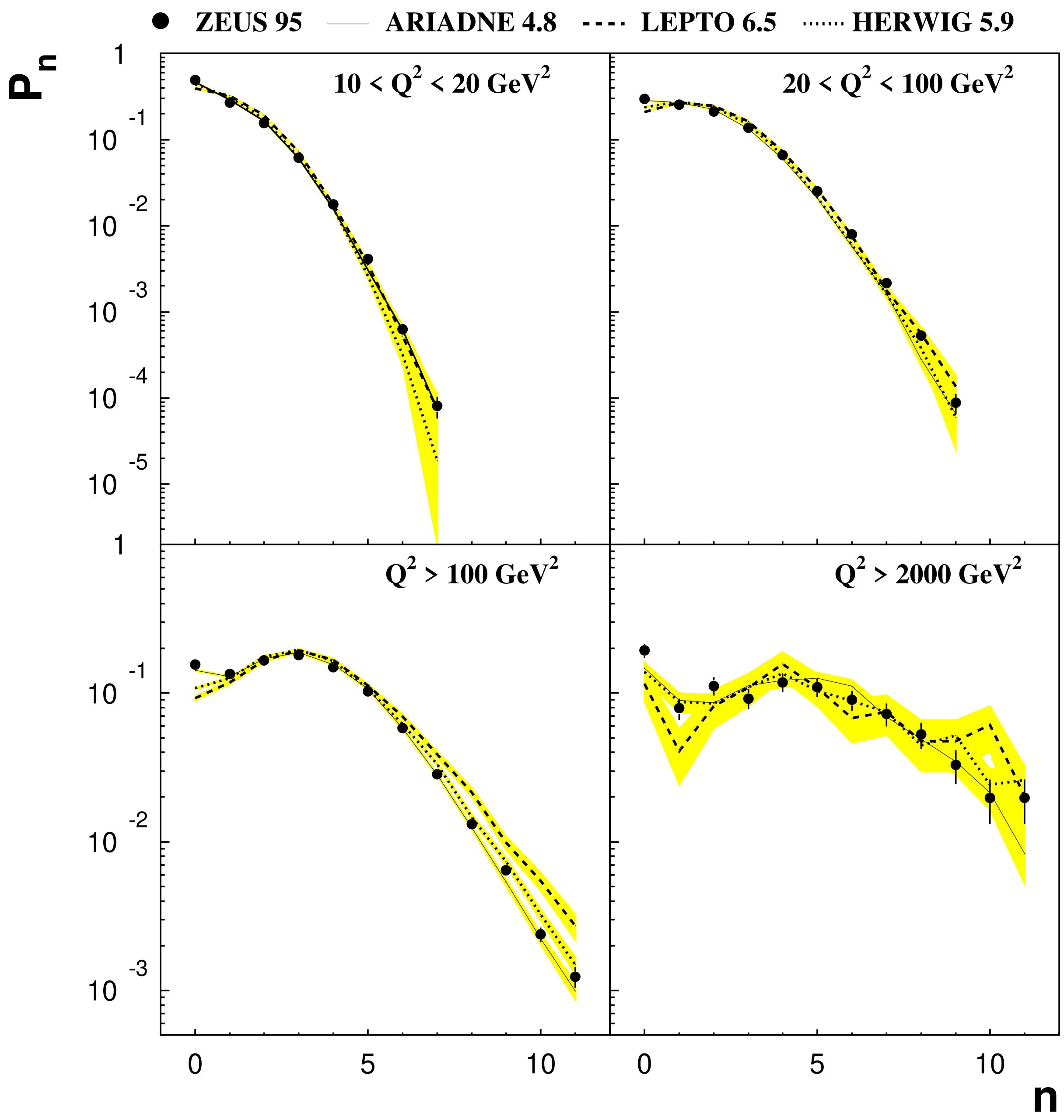
Short-Range (SR) Correlations: interdependence between particles at small phase-space separations;

Long-Range (LR) Correlations: interdependence between well separated particles (phase-space regions).

# Motivations:

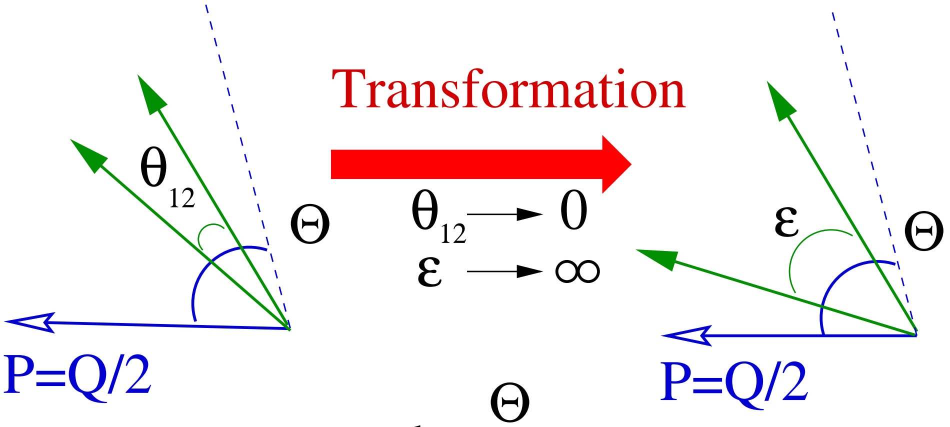
- A step beyond single-particle spectra ($p_t$, $\eta$ and $x_p$ spectra);
- SR Correlations:
  How particles depend on each other as the parton cascade evolves ?
  LR Correlations:
  Do inclusive events contain distinct event subclasses ?
- Can pQCD describe the correlations?
  At what energy scale? Does LPHD hold ?
- Can MC models reproduce the correlations?
- Does universality exist between $ep$ and $e^+e^-$ collisions for correlations?

# Multiplicity Distributions in the Current Region (uncorrected data)




MC models reasonably agree with the distributions

# Two-Particle Density in the Current Region




$$\varepsilon = \frac{\ln \frac{\Theta}{\theta_{12}}}{\ln \frac{P\sin\Theta}{\Lambda}}$$

$$\rho(\varepsilon) = \frac{1}{N_{\mathrm{ev}}} \frac{dn_{\mathrm{pair}}}{d\varepsilon} \qquad \hat{Y} \equiv -\frac{\ln[\rho(\varepsilon)/(b\langle n(\Theta)\rangle^2)]}{2\sqrt{\ln[P\sin\Theta/\Lambda]}}$$

pQCD in DLA + LPHD predicts:

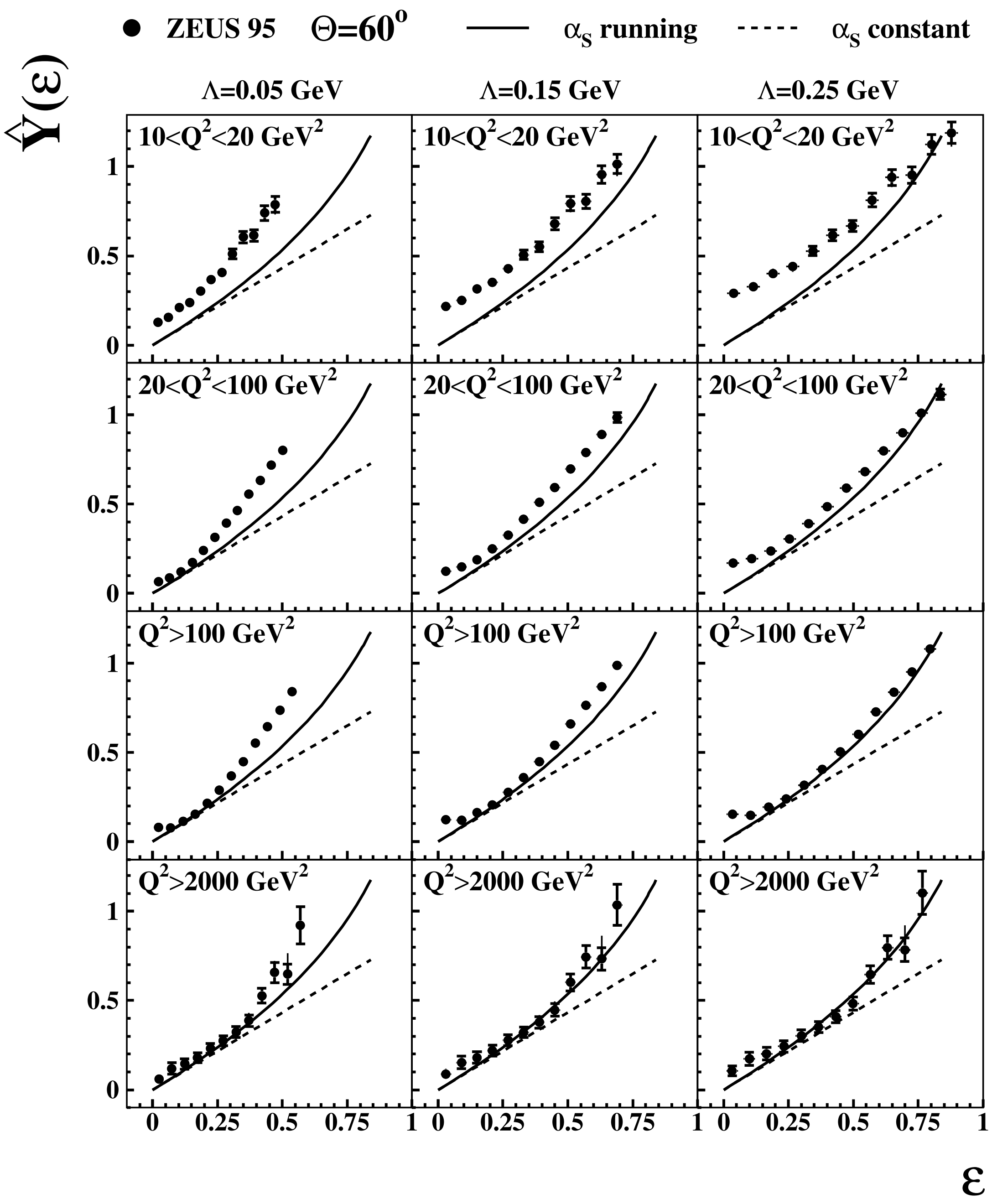
$$\hat{Y} \simeq 2\beta(1 - 0.5\omega(\varepsilon))$$

$$\omega(\varepsilon) = 2\sqrt{1-\varepsilon}\,(1 - \ln(1-\varepsilon)/8)$$

$$\beta = 6(11\,N_c - 2n_f)^{-1/2}, \qquad b = 2\beta\sqrt{\ln(P\sin\Theta/\Lambda)}$$

W.Ochs, J.Wosiek, PL B289 (1992) 159,B304 (1993) 144

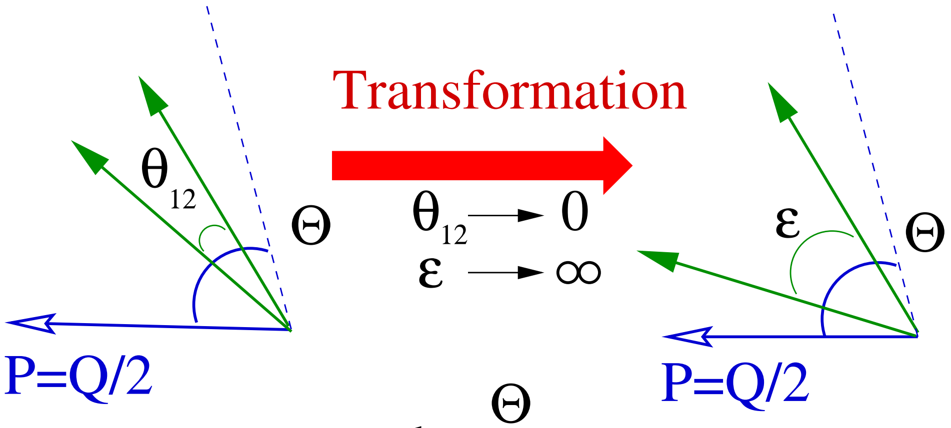
# Two-Particle Density in the Current Region




Good description at high $Q^2$ and $\Lambda > 0.15$ GeV

Sergei Chekanov (ANL), ISMD99, August 1999

# Two-Particle Correlations in the Current Region




$$\varepsilon = \frac{\ln \frac{\Theta}{\theta_{12}}}{\ln \frac{P \sin\Theta}{\Lambda}}$$

$$\rho(\varepsilon) = \frac{1}{N_{\mathrm{ev}}} \frac{dn_{\mathrm{pair}}}{d\varepsilon} \qquad Y \equiv \frac{\ln[\rho(\varepsilon)/\rho_{\mathrm{mix}}(\varepsilon)]}{\sqrt{\ln(P \sin\Theta/\Lambda)}}$$

pQCD in DLA + LPHD predicts:

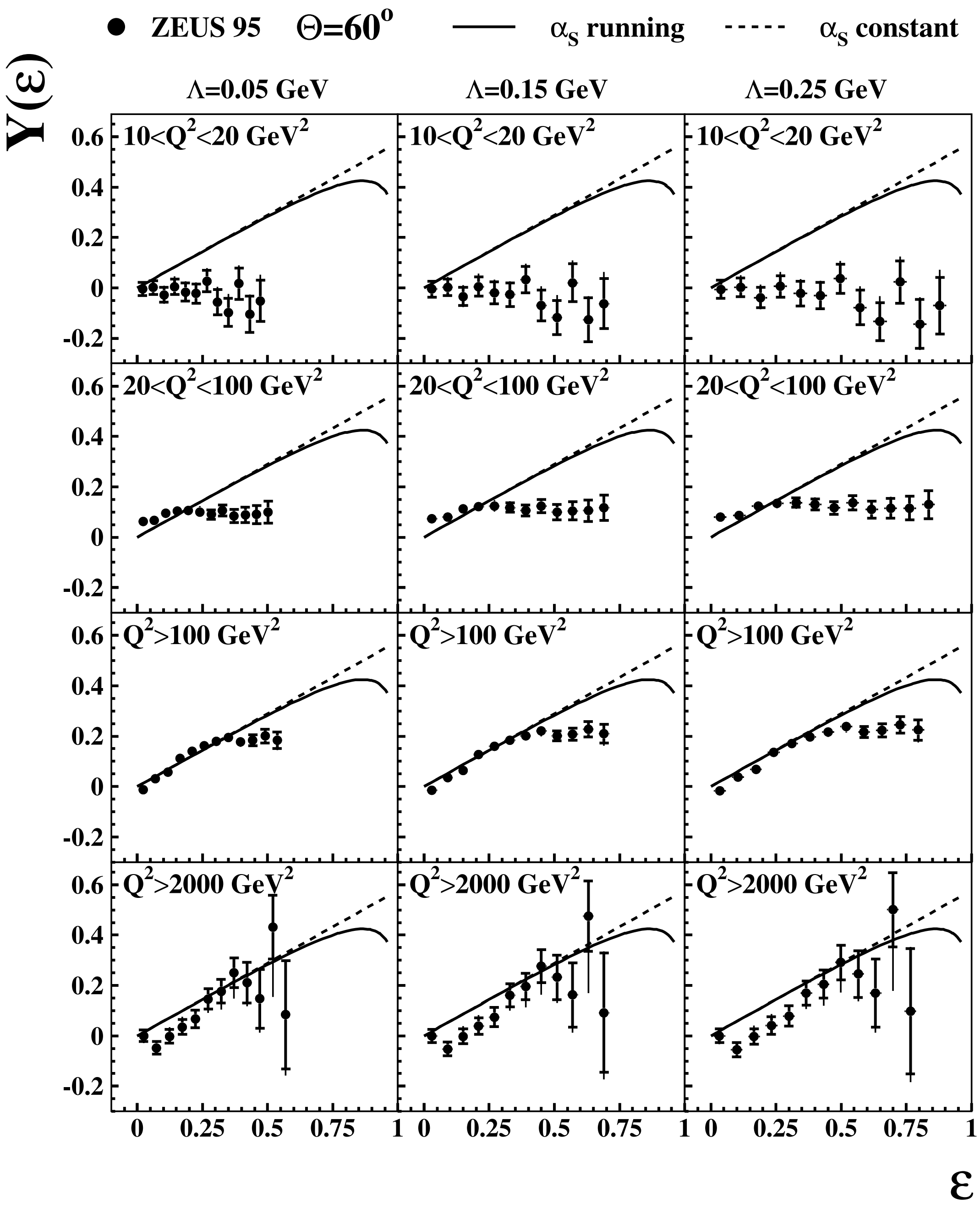
$$Y \simeq 2\beta(\omega(\varepsilon) - 2\sqrt{1-\varepsilon})$$

$$\omega(\varepsilon) = 2\sqrt{1-\varepsilon}\ (1 - \ln(1-\varepsilon)/8)$$

$$\beta = 6(11\,N_c - 2n_f)^{-1/2}, \qquad b = 2\beta\sqrt{\ln(P \sin\Theta/\Lambda)}$$

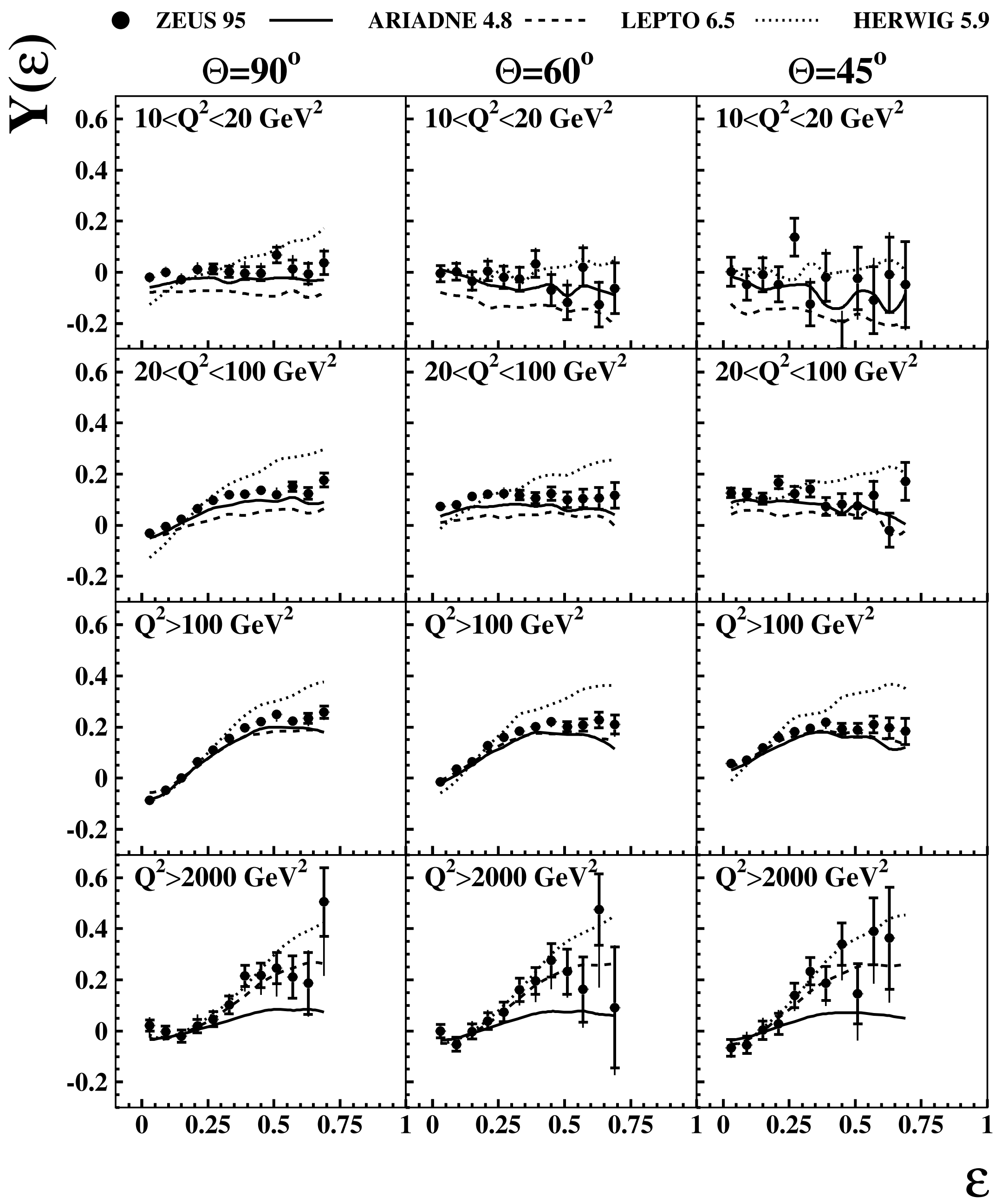
W.Ochs, J.Wosiek, PL B289 (1992) 159,B304 (1993) 144

# Two-Particle Correlations in the Current Region



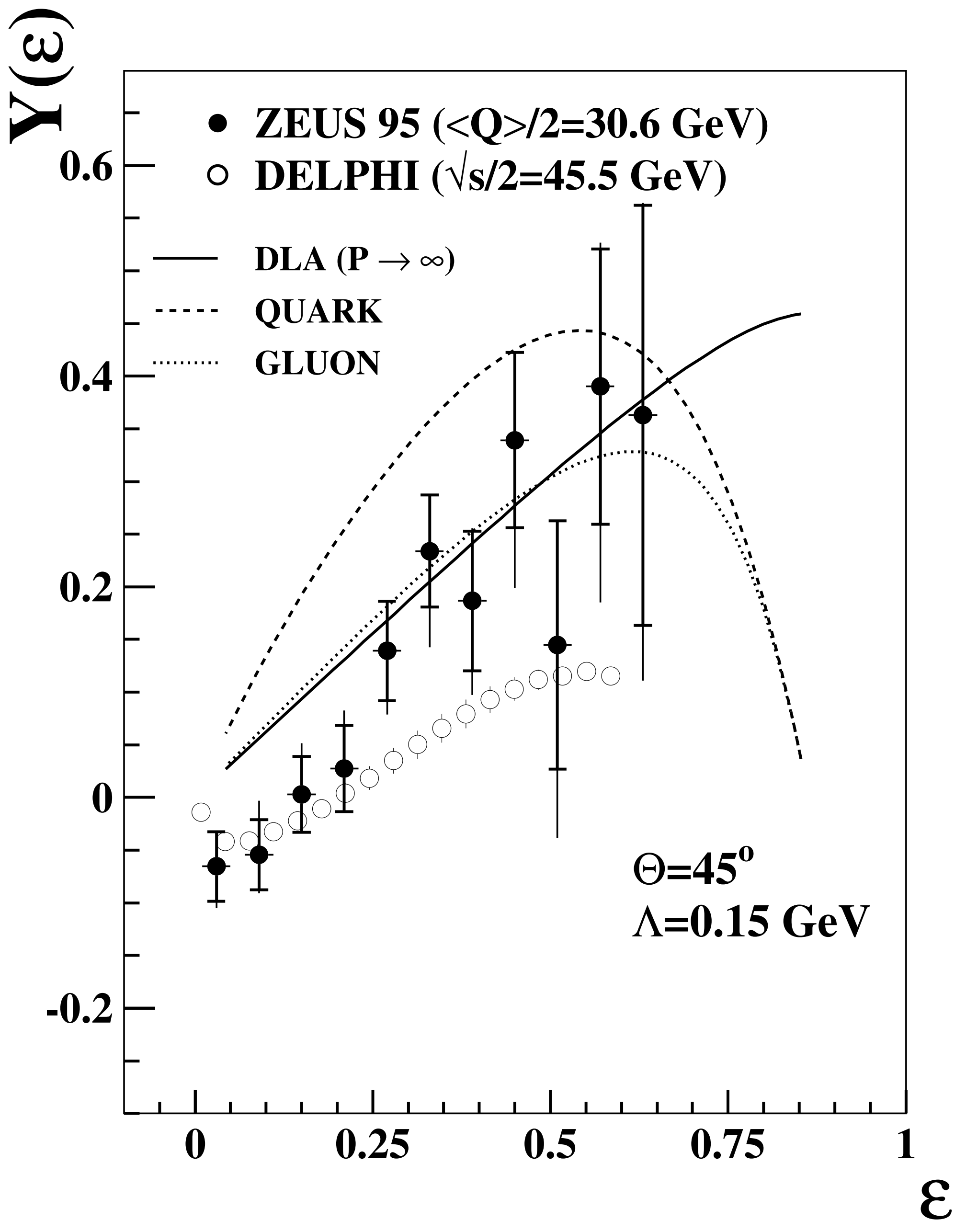

No satisfactory description by DLA;
Better agreement at high $Q^2$

# Two-Particle Correlations in the Current Region (data vs MC)




All MC models show discrepancies

# Two-Particle Correlations in the Current Region ($ep$ vs $e^+e^-$)




Short-Range correlations in $ep$ are slightly larger

# Long-Range Correlations

Sensitive to the presence of distinct event sub-classes in an inclusive event sample

Methods:

1) To determine the average number $\langle n_1 \rangle$ of particles in one hemisphere as a function of the particle multiplicity $n_2$ in the opposite hemisphere.

$$\langle n_1 \rangle = a + b \cdot n_2$$

2) For small detector acceptances one can measure the coefficient of correlations:

$$\kappa = s_1^{-1} s_2^{-1} \mathrm{cov}(n_1, n_2),$$

$$\mathrm{cov}(n_1, n_2) = \langle n_1 n_2 \rangle - \langle n_1 \rangle \langle n_2 \rangle,$$

$s_1$ and $s_2$ are the standard deviations

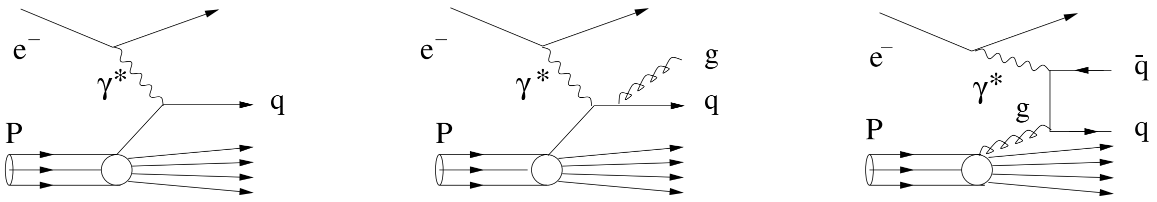
# Current-Target Correlations

QCD expectations (SC, J.Phys. G25 (1999) 59):

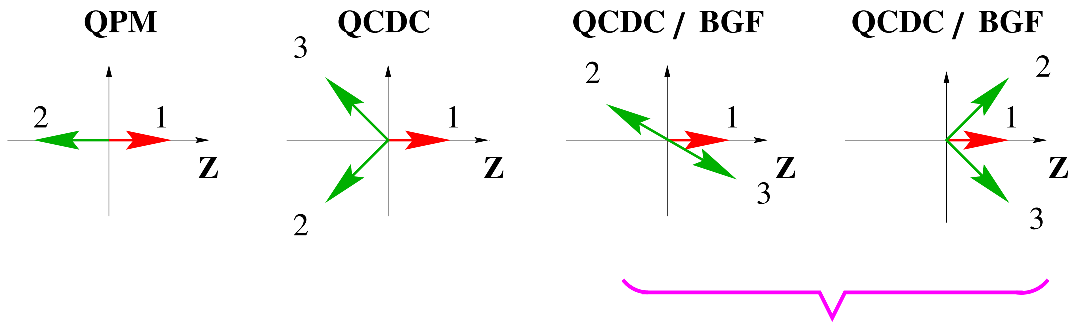
$$\text{cov}(n_{\text{c}}, n_{\text{t}}) \simeq -A_1(Q^2)R_1(Q^2,x) - A_2(Q^2)R_2(Q^2,x)$$

1) Negative due to the LO kinematics

2) Driven by the BGF at low $x$

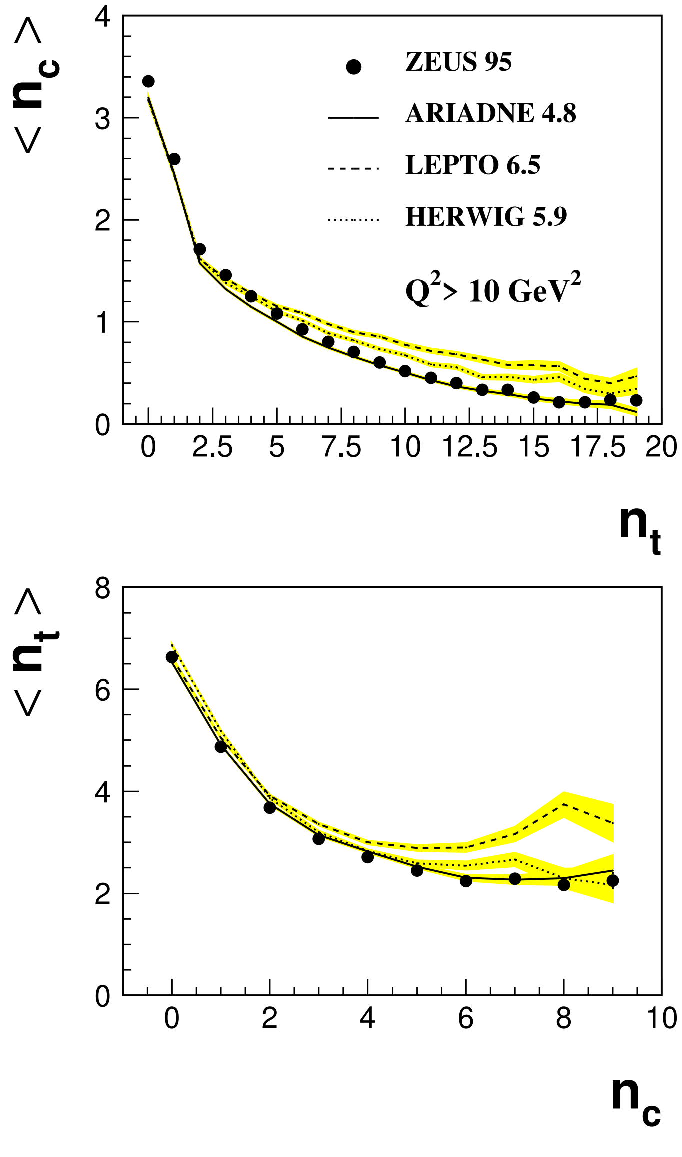



a) QPM b) QCDC c) BGF




source for anticorrelations

# Current-Target Correlations
# (uncorrected data)

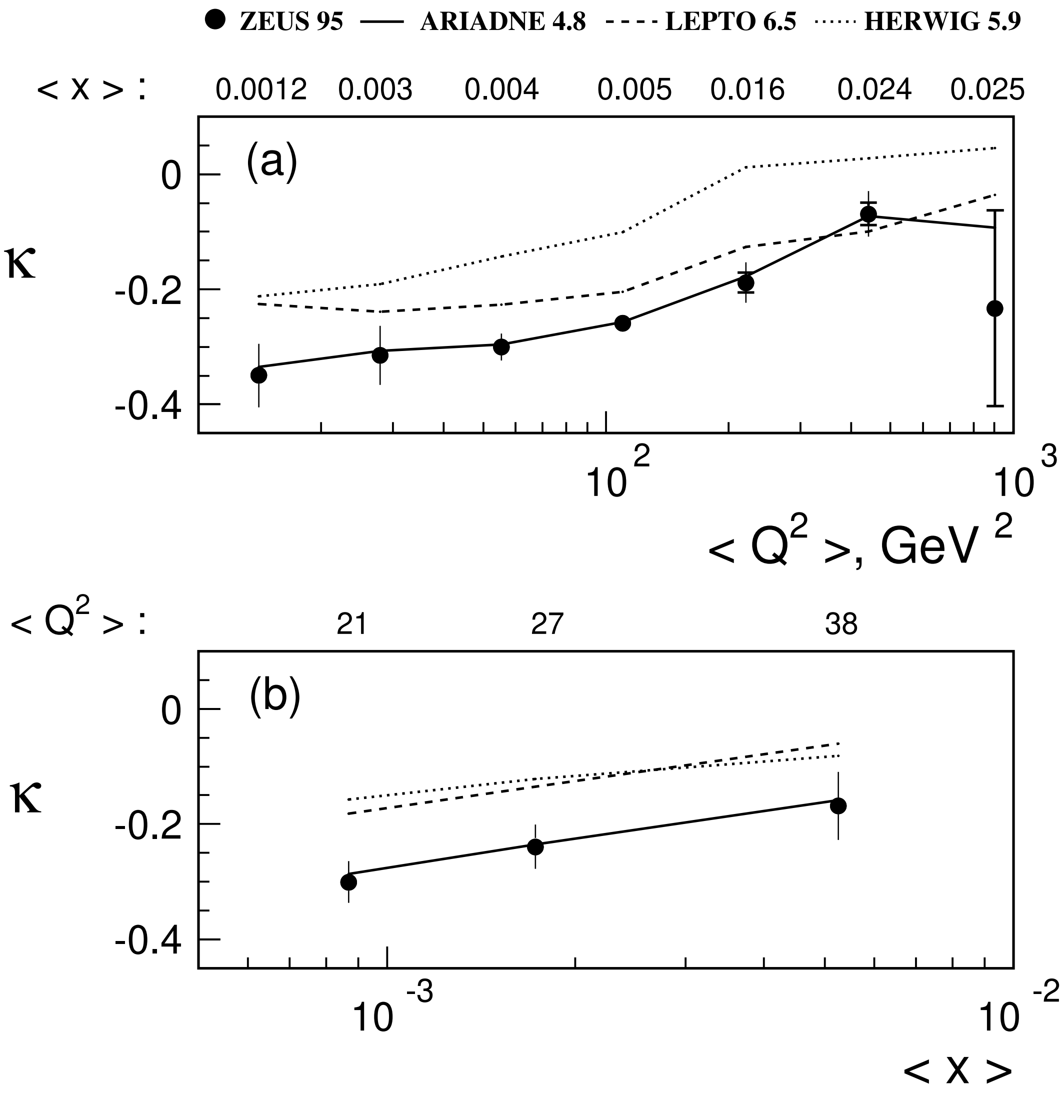



$n_c$ ($n_t$) : multiplicity in the current (target) regions

# Current-Target Correlations (corrected data)

$$\kappa = \sigma_c^{-1}\sigma_t^{-1}\mathrm{cov}(n_c, n_t),$$

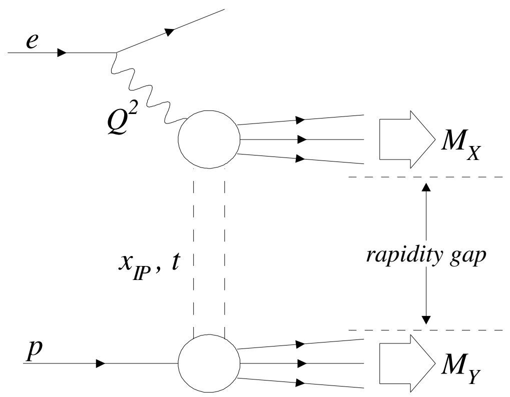
$\sigma_c$ and $\sigma_t$ are the standard deviations

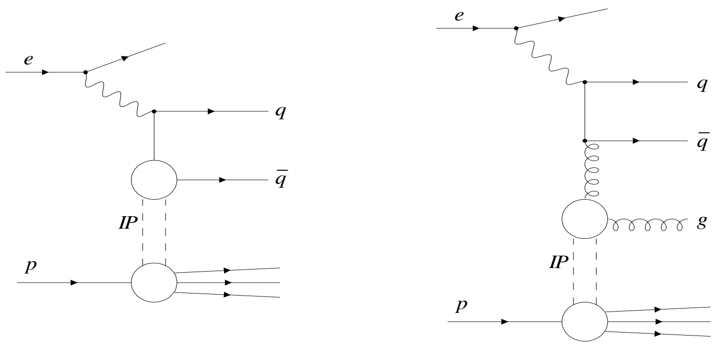


# Diffractive DIS

$ep \to eXY$ with well separated $X$ and $Y$

$Y$ = intact proton/excited to a low-mass system



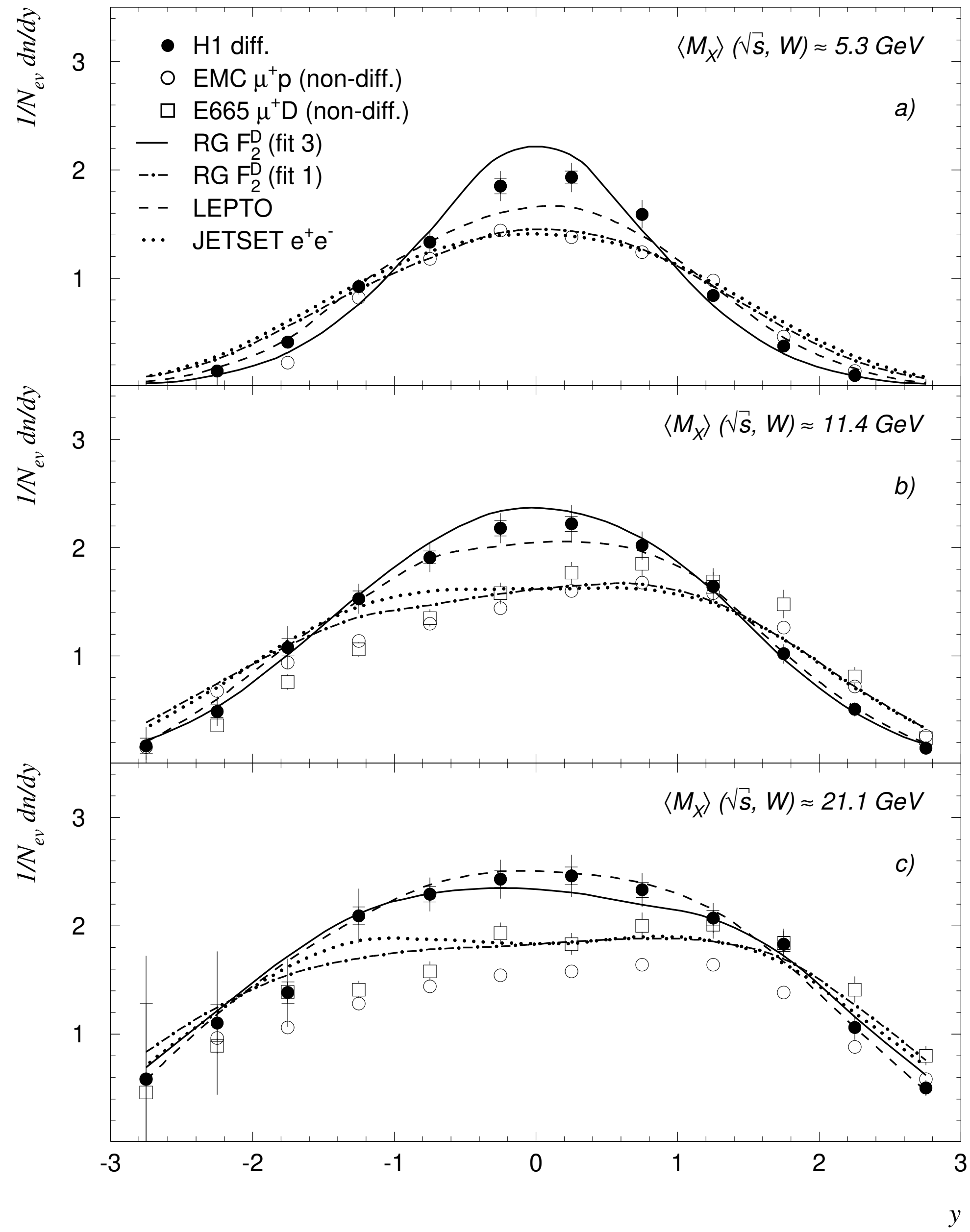

Gluon dominated $\mathbb{P}$:

- Complex parton configuration
- Complex string topology
- Large variations in the number of strings

$\Rightarrow$ Large fluctuations/LR correlations

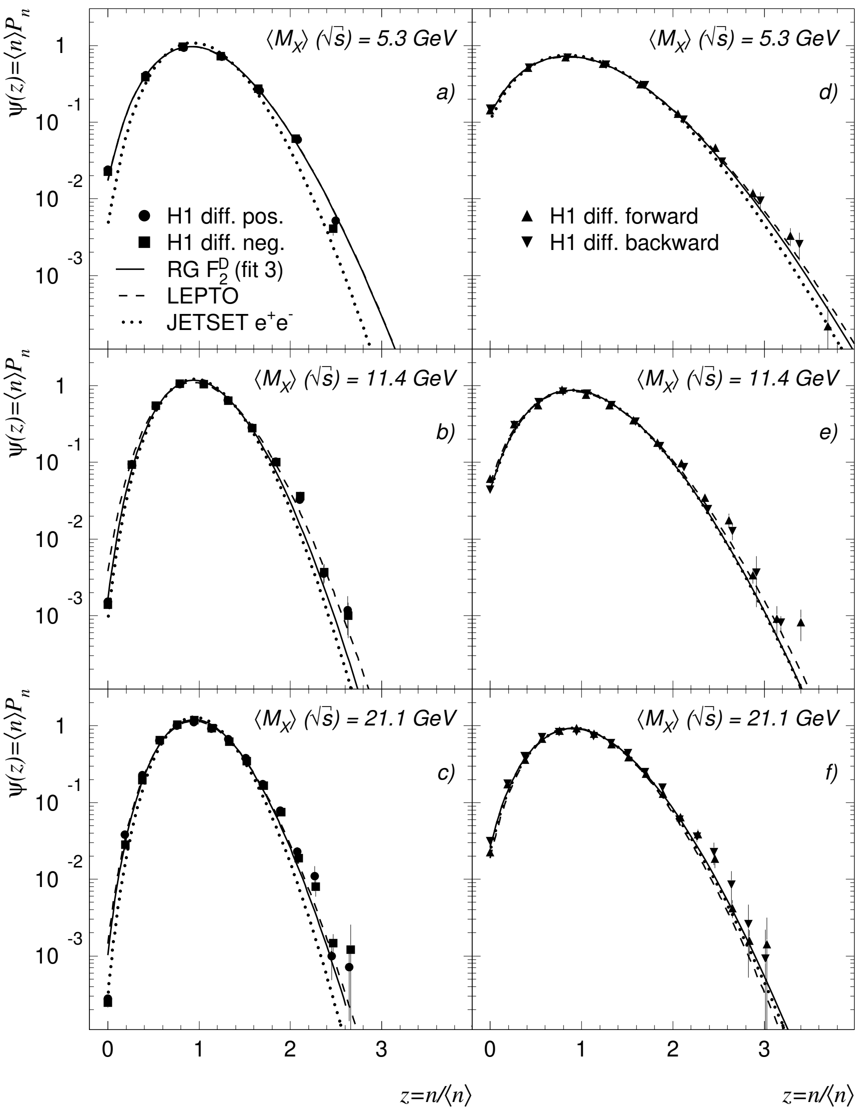
# Diffractive DIS

## Rapidity Distribution in the Rest-Frame of $X$




High particle density

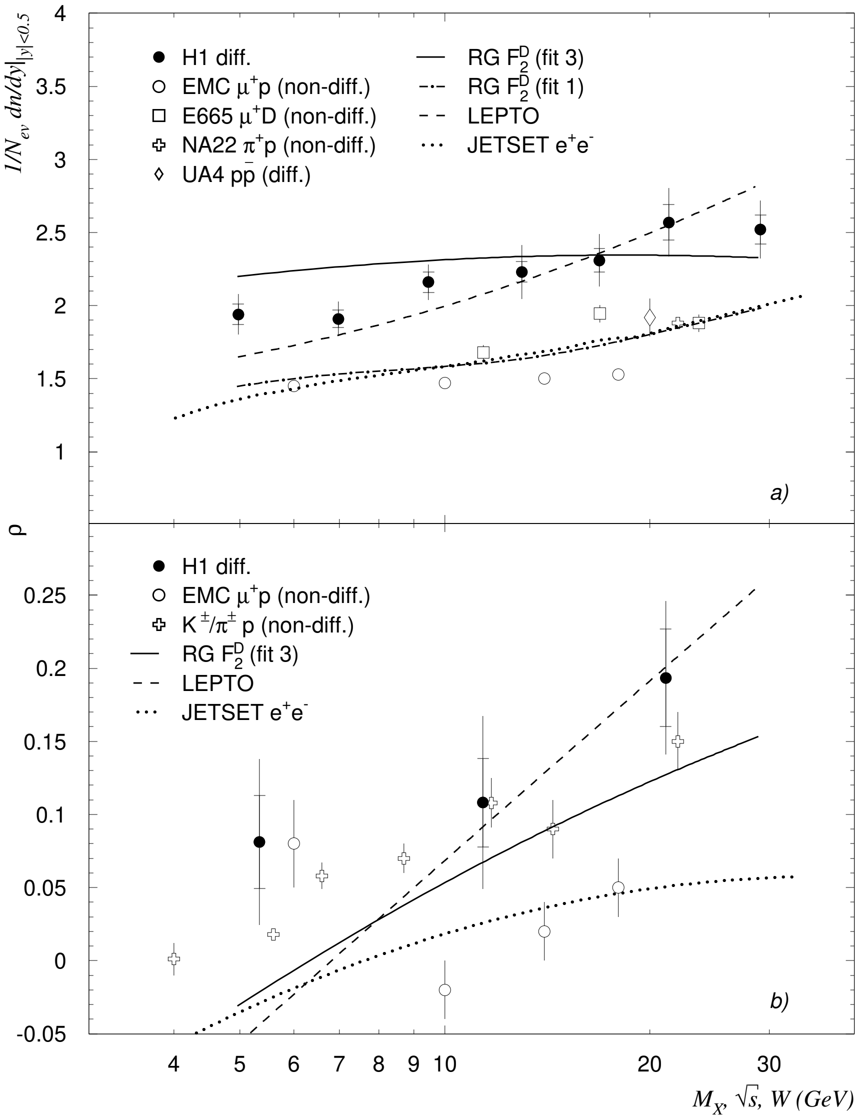
# Multiplicity Distributions in Forward and Backward Hemispheres




no evidence for an asymmetry between forward and backward hemispheres

# Forward-Backward Correlations in Diffractive DIS

$$\langle n_F \rangle = a + b n_B \qquad \rho = b = \frac{\mathrm{cov}(n_F, n_B)}{\sigma_F^2}$$




Favor models with high gluonic content

# Conclusions

## Angular Correlations

- DLA and MCs do not describe the data;
  ...wait for MLLA. No conclusion on LPHD yet.
- best description at $Q^2 > 100$ GeV$^2$;
- stronger for $ep$ than for $e^+e^-$. No universality.
  ...LO kinematics in the Breit frame ?

## Long-Range Correlations

- Current-Target in DIS:
  1) large and negative;
  2) understood in terms of the LO kinematics
- Forward-Backward in Diffractive DIS:
  1) small and positive;
  2) favor gluon-dominated pomeron;
  3) suggest a mixture of states with distinct properties in the LRG sample.
  ...more differential studies are needed