FORWARD JETS AT LOW X

AND

FORWARD E_T FLOW

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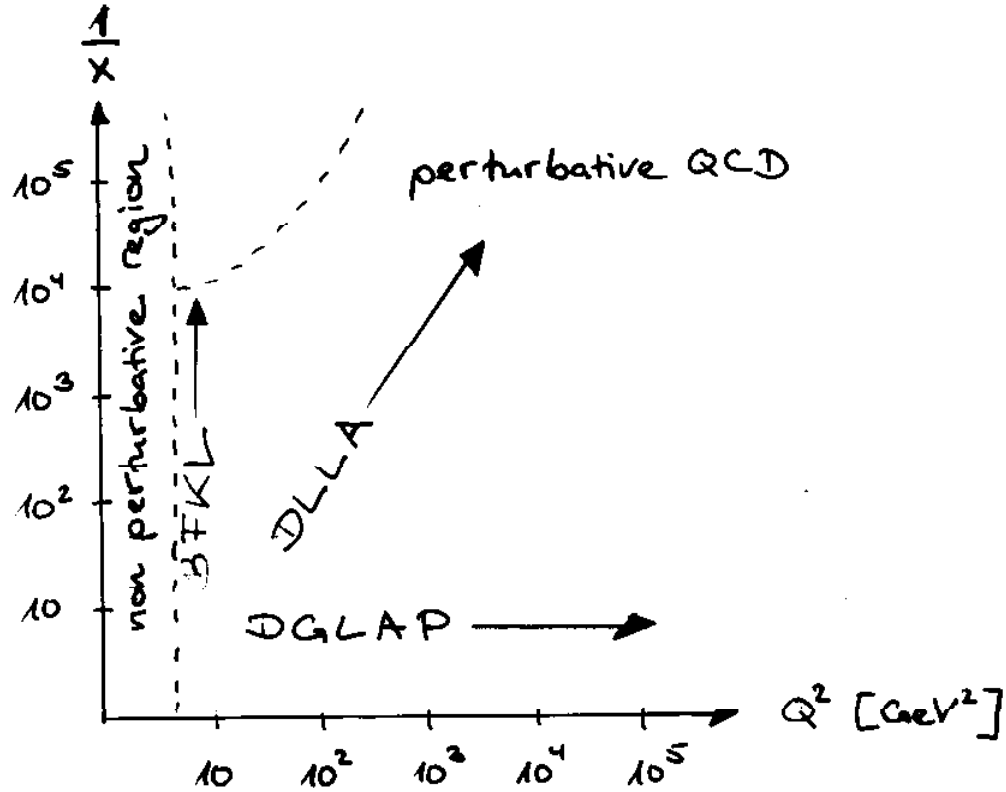
for the

ZEUS Collaboration

Different parton density evolution equations for different regions of $Q^2 - \frac{1}{x}$ - plane

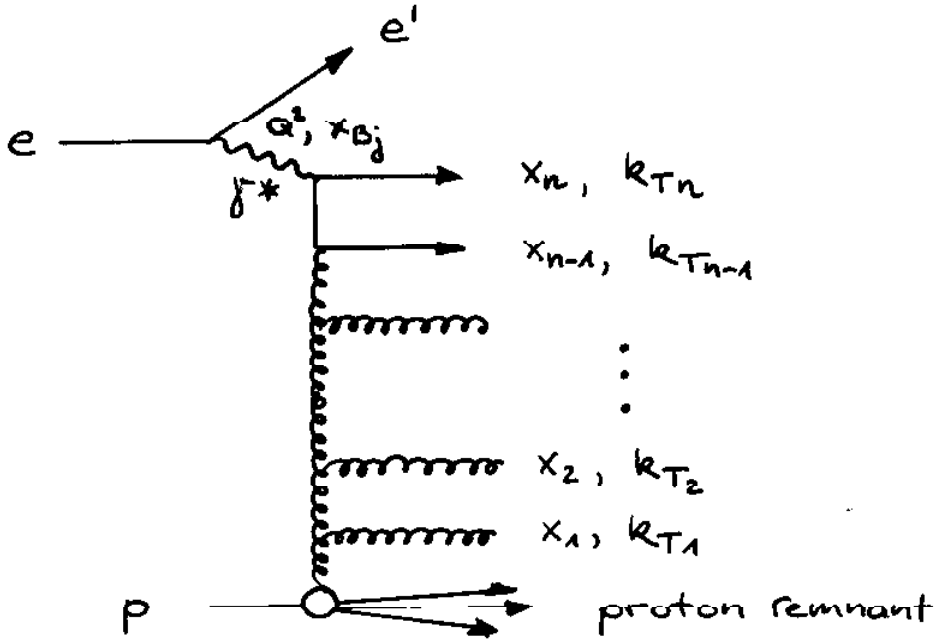


DGLAP : leading $\ln Q^2$ resummation, valid at high x

DLLA (double leading log approximation): leading $\ln \frac{1}{x}$ $\ln Q^2$ resummation, for medium Q^2, x

BFKL: leading $\ln \frac{1}{x}$ resummation, becomes dominant at low x

Gluon ladder diagram



DGLAP: Resummation of $(\alpha_s \ln Q^2)^n$

neglect terms $\alpha_s \ln \frac{1}{x_{Bj}}$

Ordering in x: $x_1 > x_2 > \dots > x_n \approx x_{Bj}$

<u>Strong</u> ordering in k_T: $Q^2 \gg k_{Tn}^2 \gg \dots \gg k_{T1}^2$

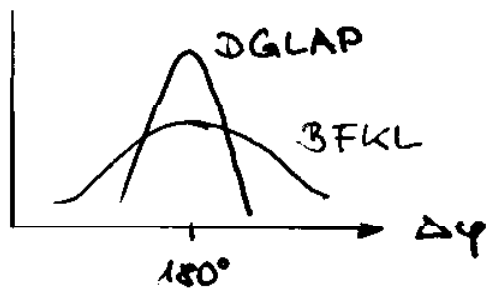
BFKL: Resummation of $\left(\alpha_s \ln \frac{1}{x_{Bj}}\right)^n$

<u>No</u> restriction on transverse momenta,

Strong ordering in x: $x_1 \gg x_2 \gg \dots \gg x_n \approx x_{Bj}$

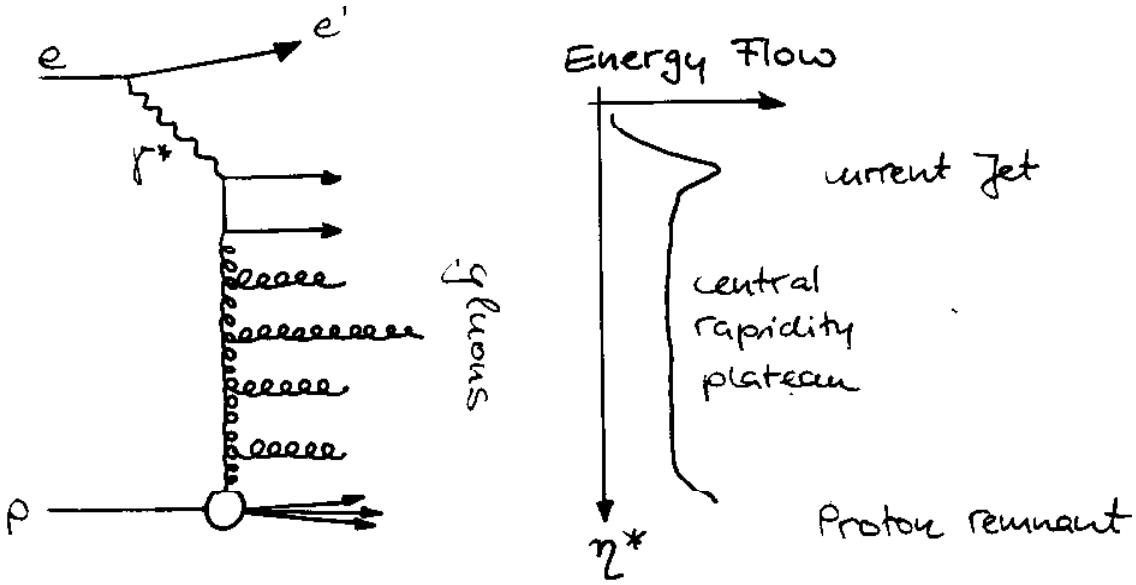
Possible Manifestations of BFKL Dynamics in Hadronic Final States

- Increased transverse energy flow
- Increased forward jet cross section
- Jet angular decorrelation



All these effects are based on the "non ordering" of the transverse momenta.

Transverse Energy Flow Distributions in Deep Inelastic Scattering



Expect higher level of central rapidity plateau for BFKL dynamics.

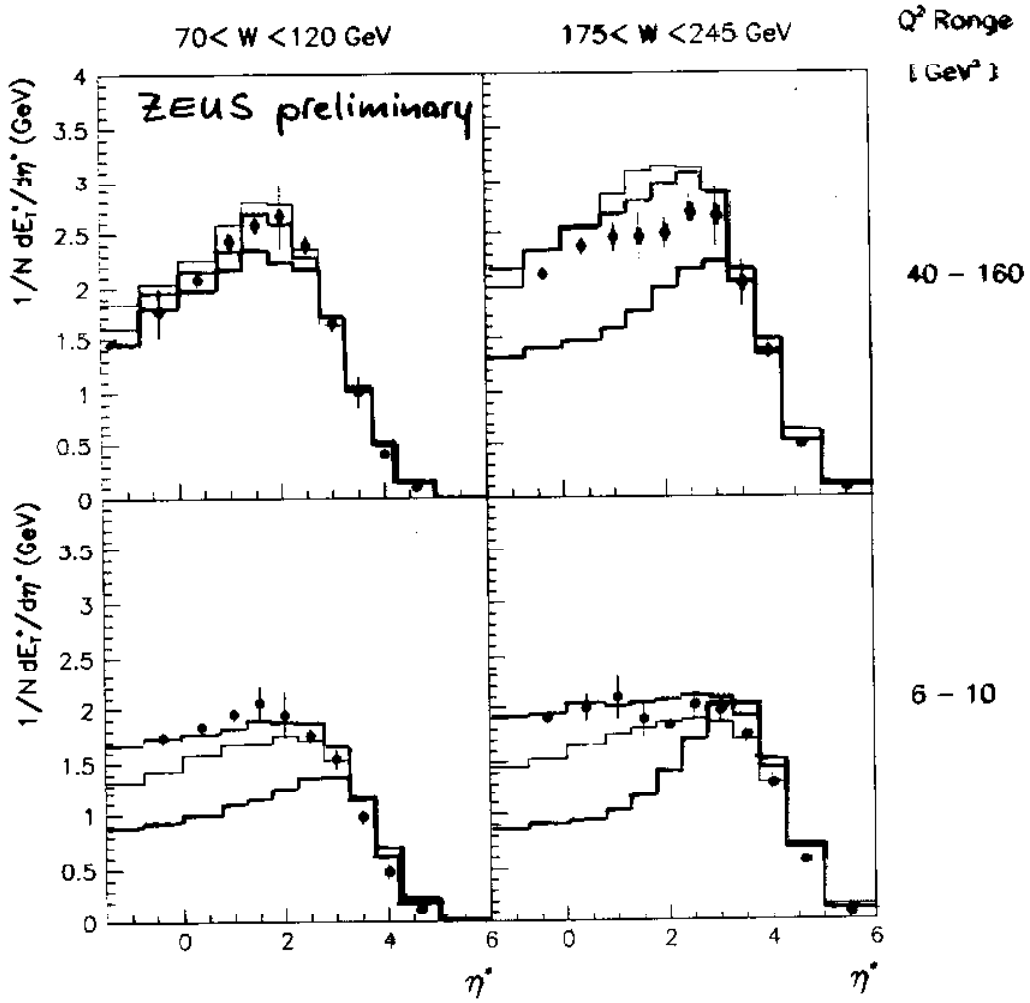
Experimental Results

Event Selection: DIS events,

$E_e > 10$ GeV, $y_{JB} > 0.04$

$\eta_{max} > 1.5$ to suppress large rap. gap events

E_T^* (in hadronic center of mass system) vs η^* for selected W and Q^2 bins



→ γ^* direction

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Lepto 6.5 } Matrix Element + Parton Shower

Lepto 6.1 }

Ariadne 4.08 Color Dipole Model

Comparison with Different Model Calculations

MEPS: Matrix Element
Parton Shower } following DGLAP

↓

strong ordering in k_T

CDM: Colour Dipole Model:

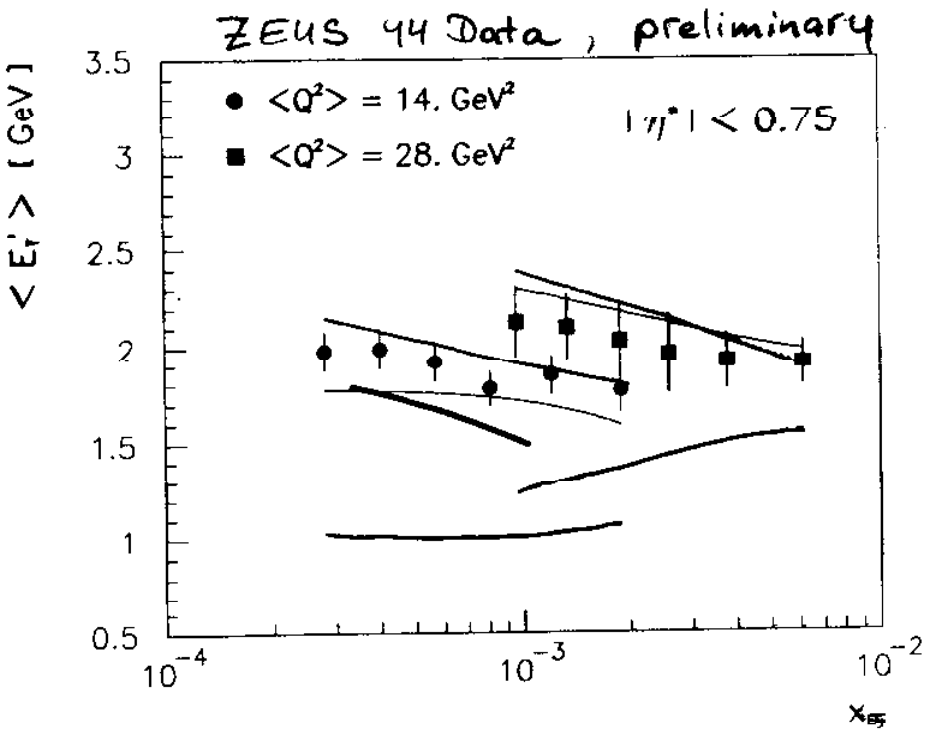
Gluon emission is treated like radiation from a colour dipole

→ no ordering in k_T

"BFKL like"

Averaged E_T^* vs. $x_{Bjorken}$

- LEPTO 6.1 fails to describe data
- Both Ariadne and improved LEPTO 6.5 describe data well.
- Slight decrease in E_T^* for increasing x_{Bj}.



—— MEPS Lepto 6.5

—— CDM Ariadne 4.08

—— MEPS Lepto 6.1

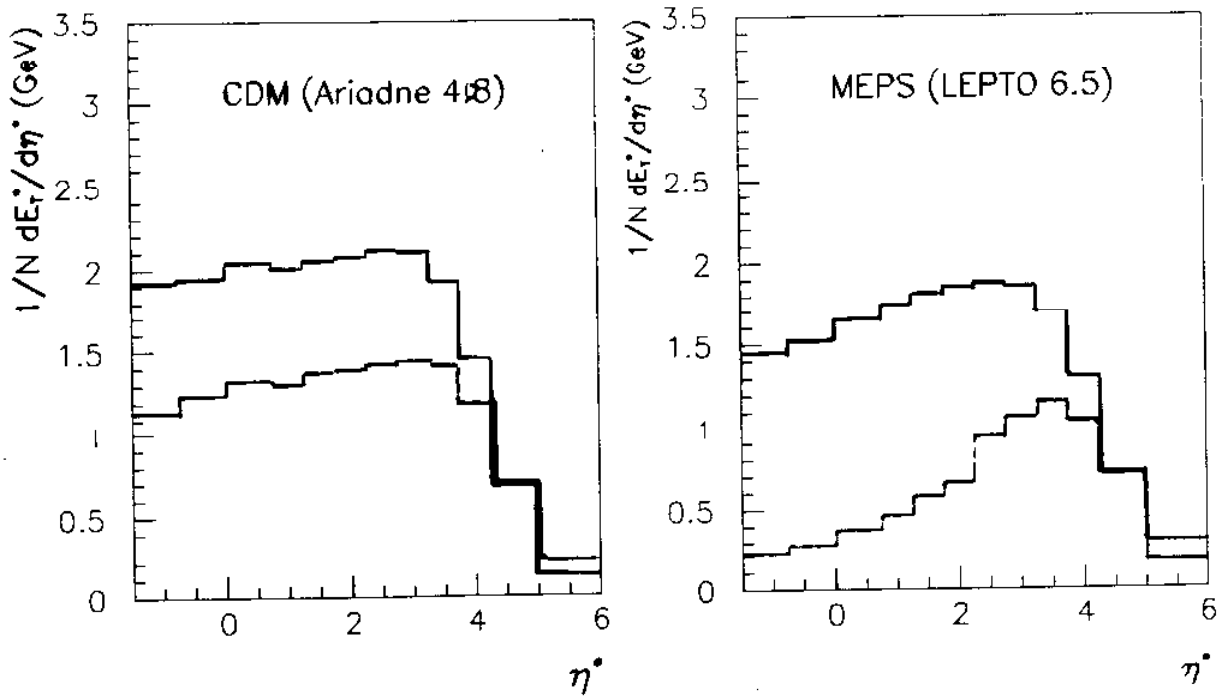
—— BFKL calculation (parton level) (Kwieciński et al.)

Hadronization Effects

Improved description of data by Lepto 6.5 due to modifications in the hadronization scheme

- soft colour interactions
- string reordering

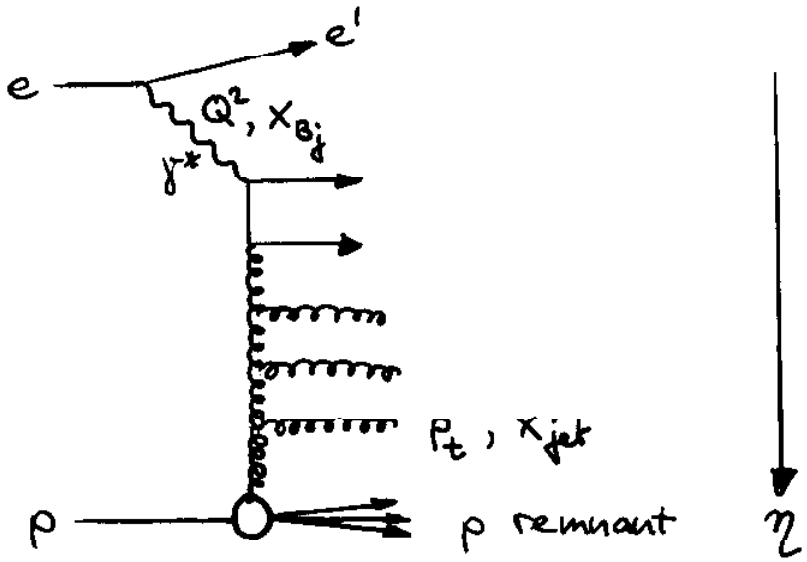
→ Hadronization does not allow to conclude on parton dynamics.



— Parton level

— Hadron level

Forward Jet Cross Section



Select region in phase space, where DGLAP evolution is suppressed:

$$Q^2 \approx p_{t,jet}^2$$

$$x_{jet} \gg x_{Bj} \quad , \quad x_{jet} = \frac{p_{z,jet}}{p_{proton}}$$

Increased jet cross section in forward direction at low x.

Search for Forward Jets at low x

Event Selection:

94 Data : $2.6\ pb^{-1}$

DIS events : $E_e > 10$ GeV

$y_{JB} > 0.1$

Jet finding:

Cone algorithm (PUCELL) in laboratory frame

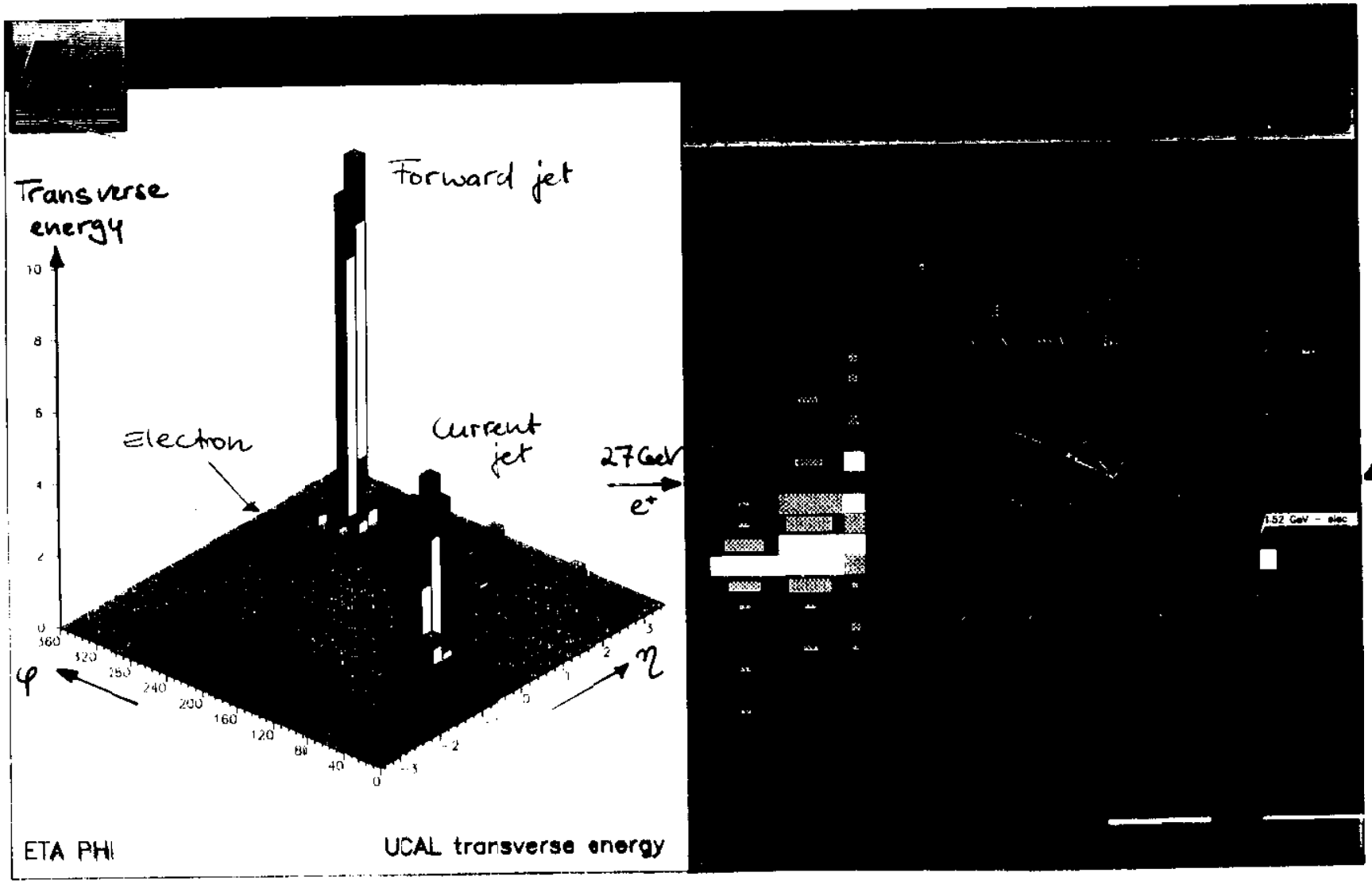
$R = \sqrt{(\Delta\varphi)^2 + (\Delta\eta)^2} = 1$

E_T scheme for recombination , $E_T^{jet} > 5$ GeV

Select most forward jet:

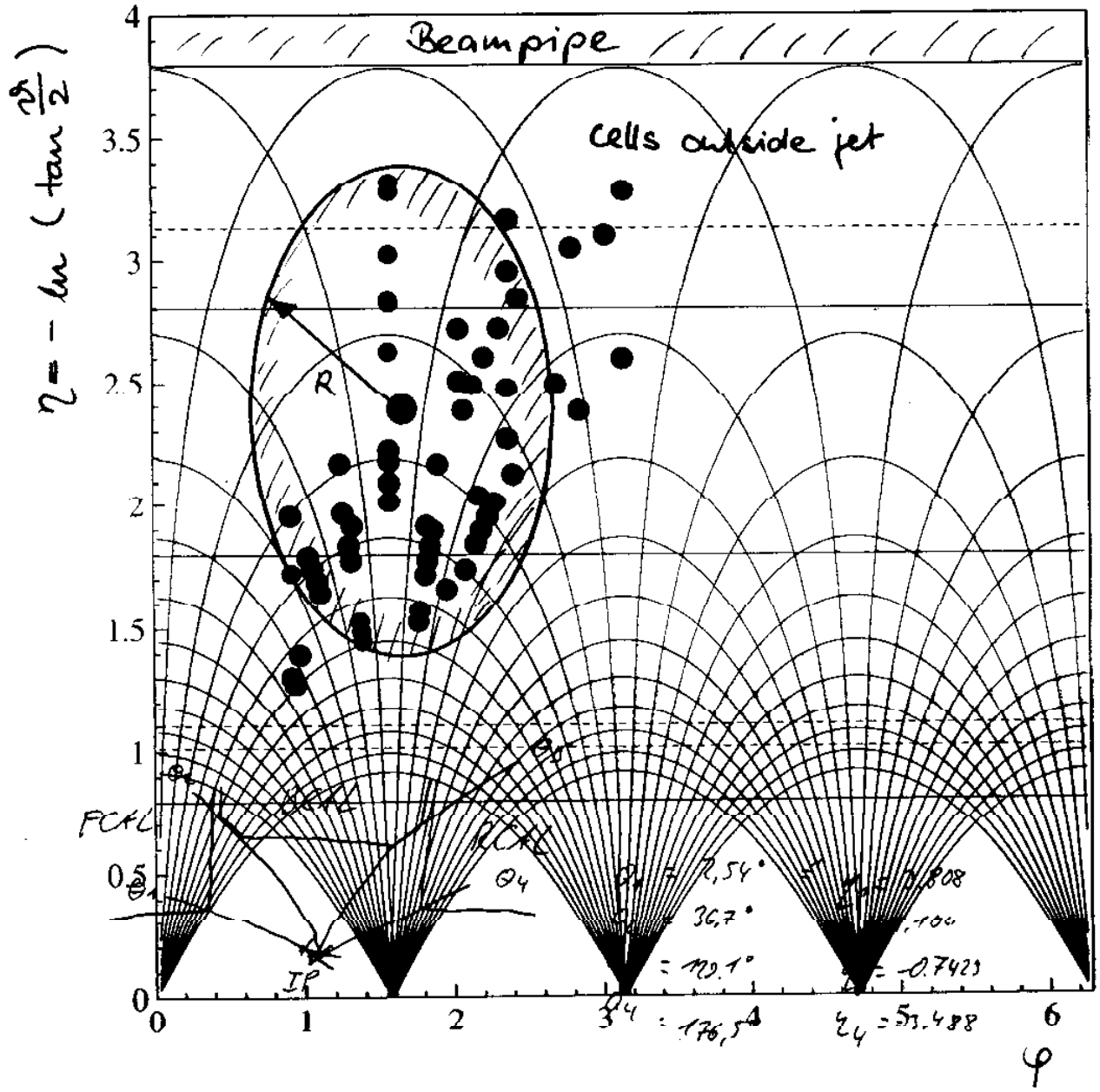
= jet with highest longitudinal momentum

- $x_{jet} > 0.035$ ($x_{jet} \gg x_{Bj}$)
- $0.5 < \frac{p_t^2}{Q^2} < 4$ ($p_t^2 \approx Q^2$)
- $\theta_{jet} > 10°$ ($\eta_{jet} < 2.44$)
- Effective cut on Q^2 : $Q^2 > 0.25$ GeV^2


Transverse energy
Forward jet
Electron
Current jet
27 GeV
e+
φ
η
ETA PHI
UCAL transverse energy
820 G
3.52 GeV - elec

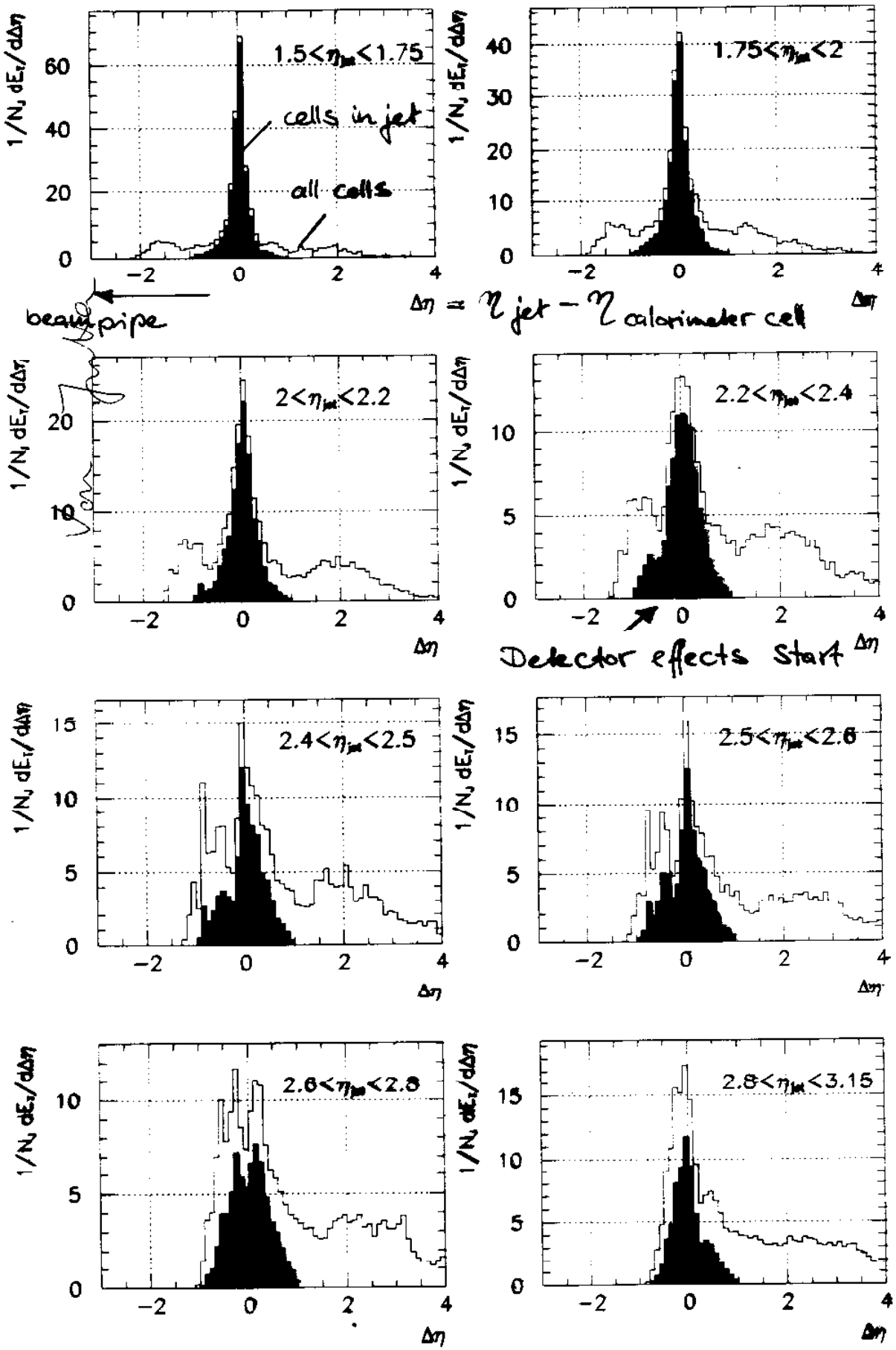
Cone Jet in Forward Calorimeter

Boundaries of calorimeter cells are displayed in $\varphi - \eta$ - coordinates

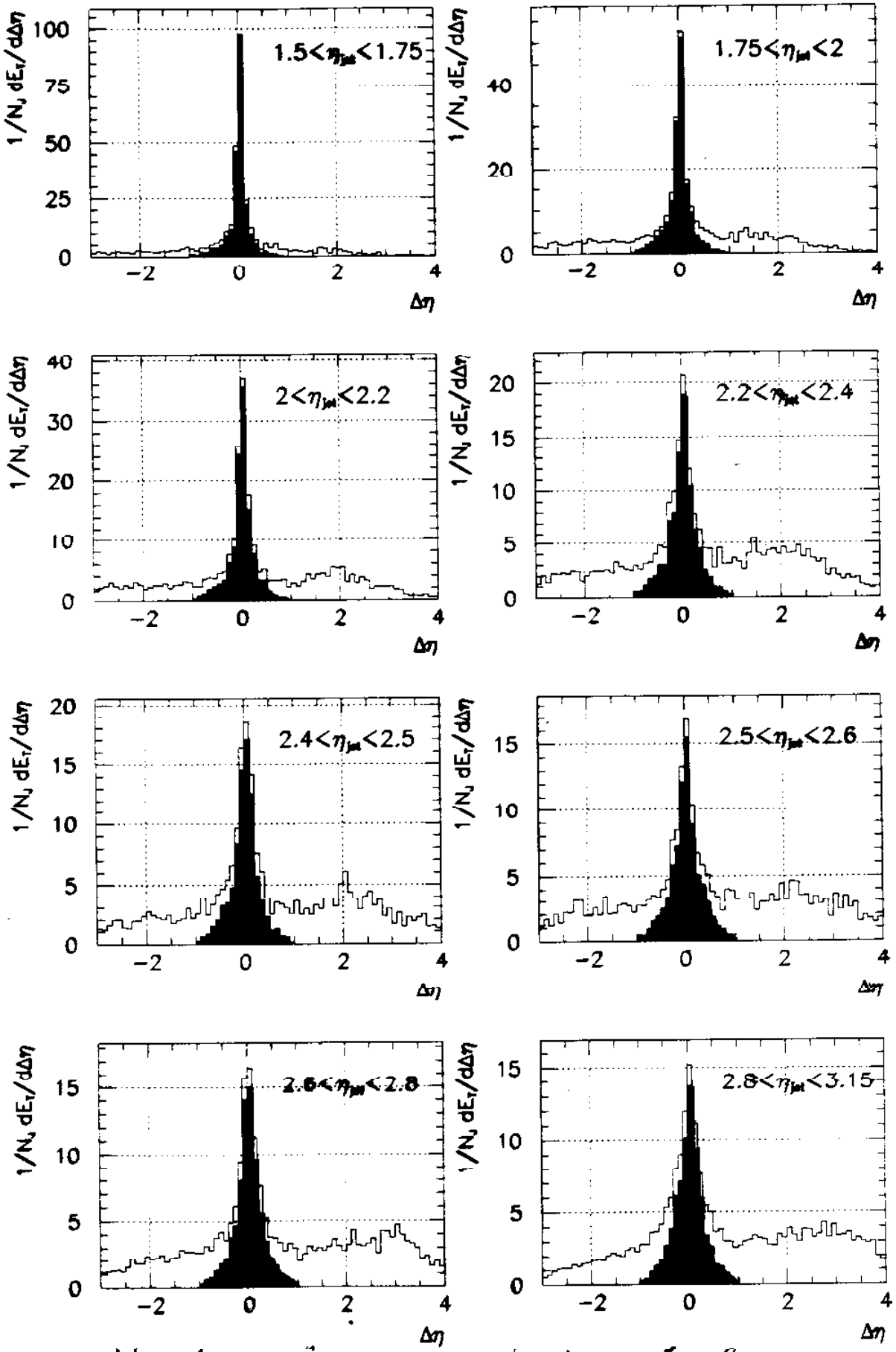


For a jet axis at $\eta = 2.4$ there are still 5 electromagnetic cells before beam pipe starts.

E_t^{jet} detector level, cone algorithm, ARIADNE



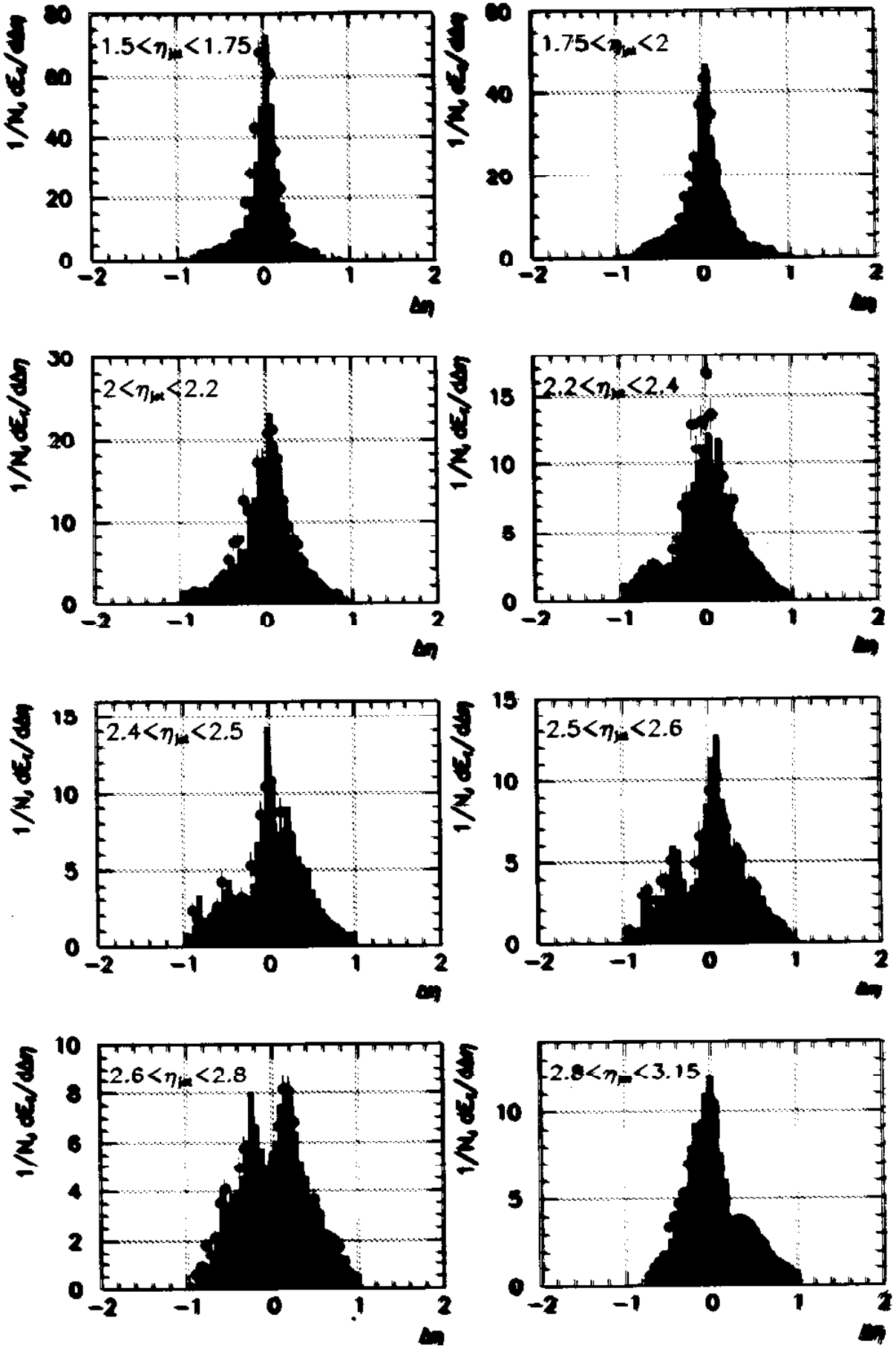
E_t^{jet} hadron level, cone algorithm , ARIADNE



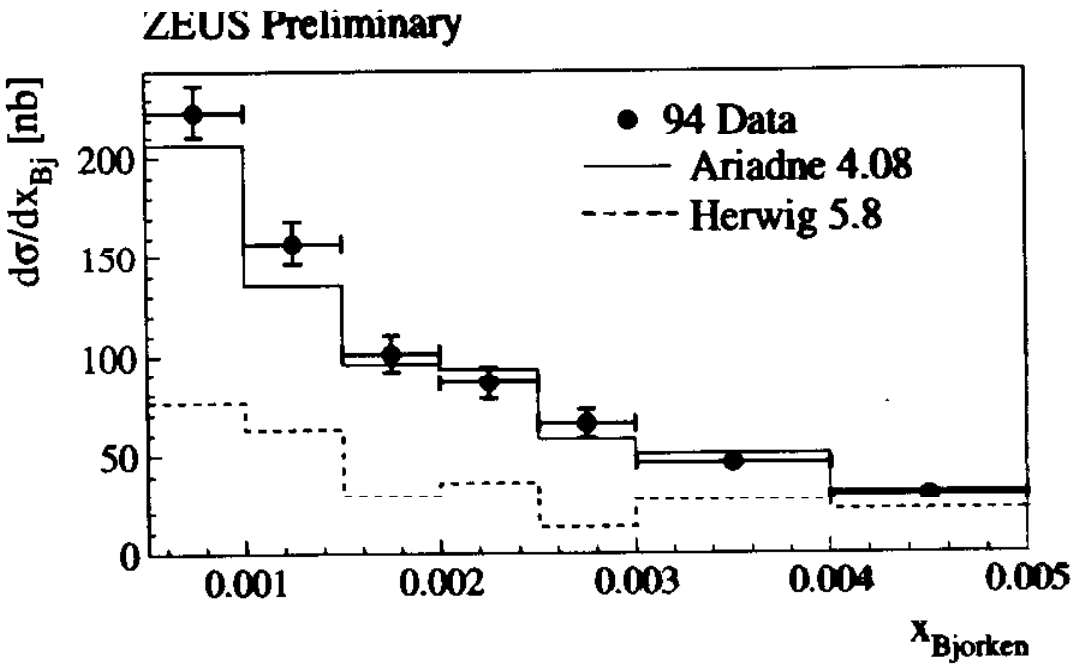
No "bump" seen on hadron level

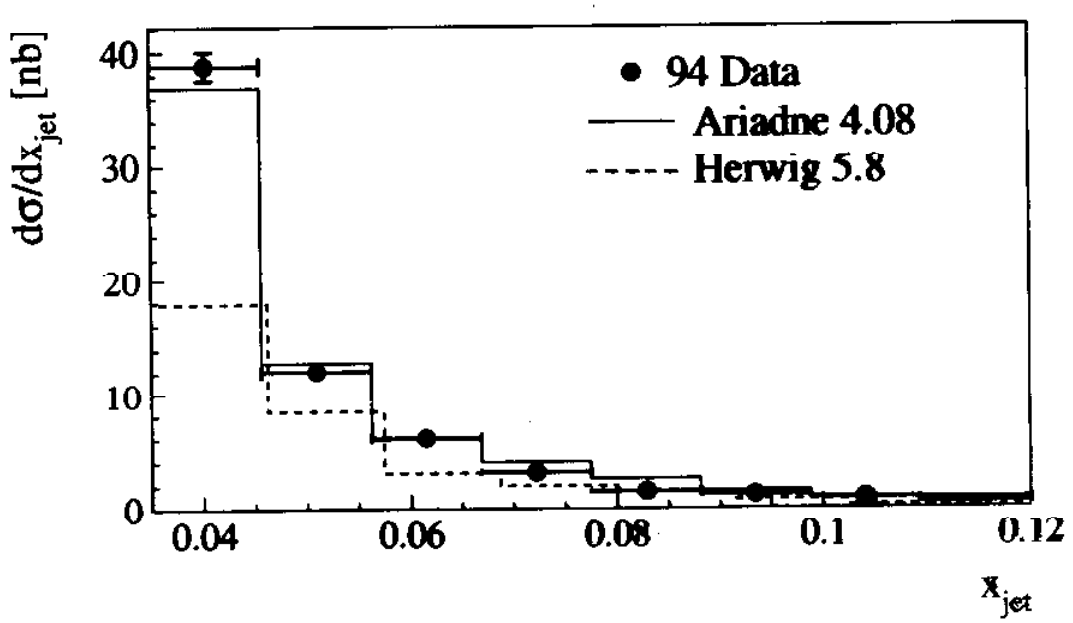
■ ARIADNE
● ZEUS 94

E_t^{jet} detector level, cone algorithm



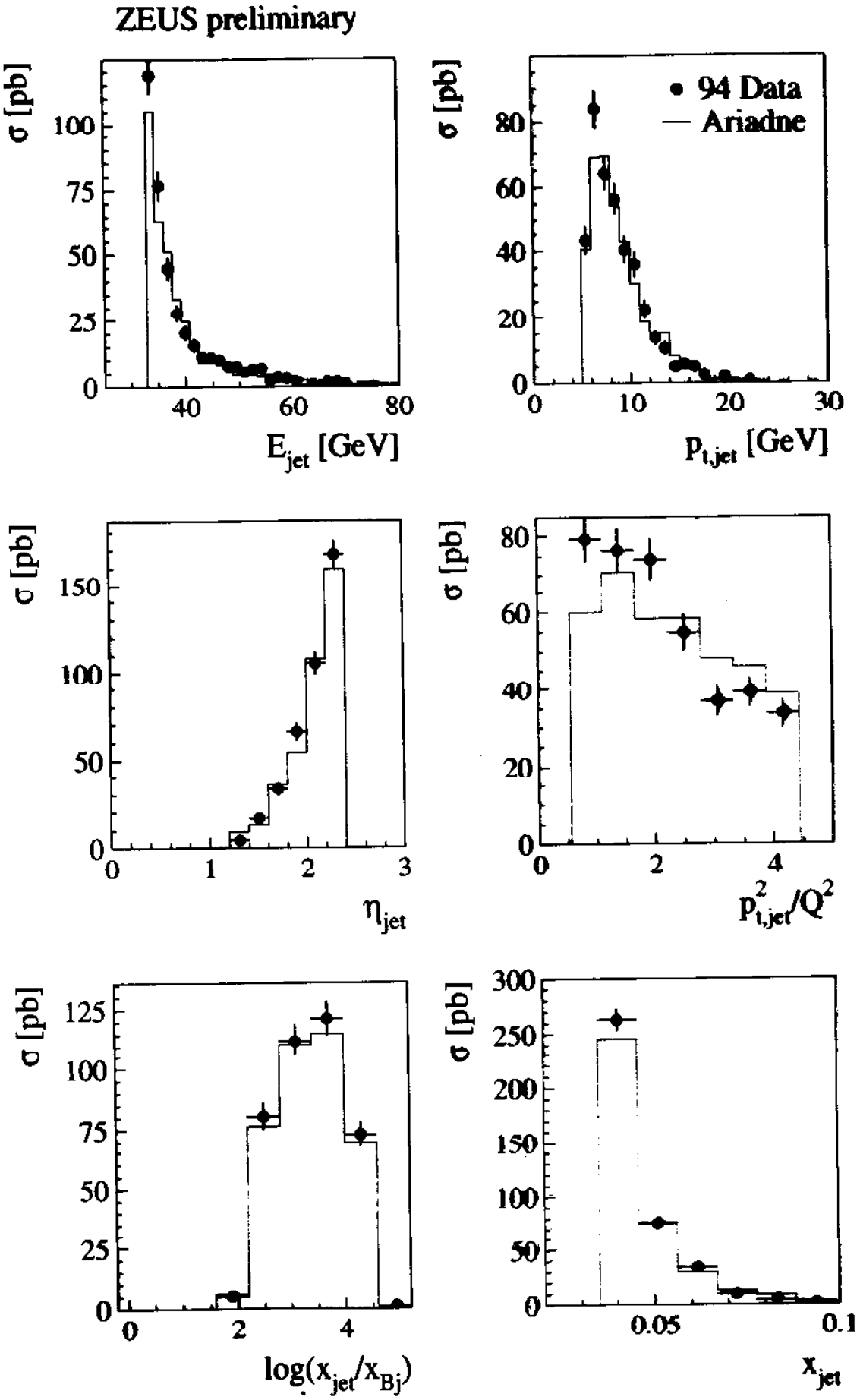
Uncorrected Data in Comparison
with different Monte Carlo Simulations





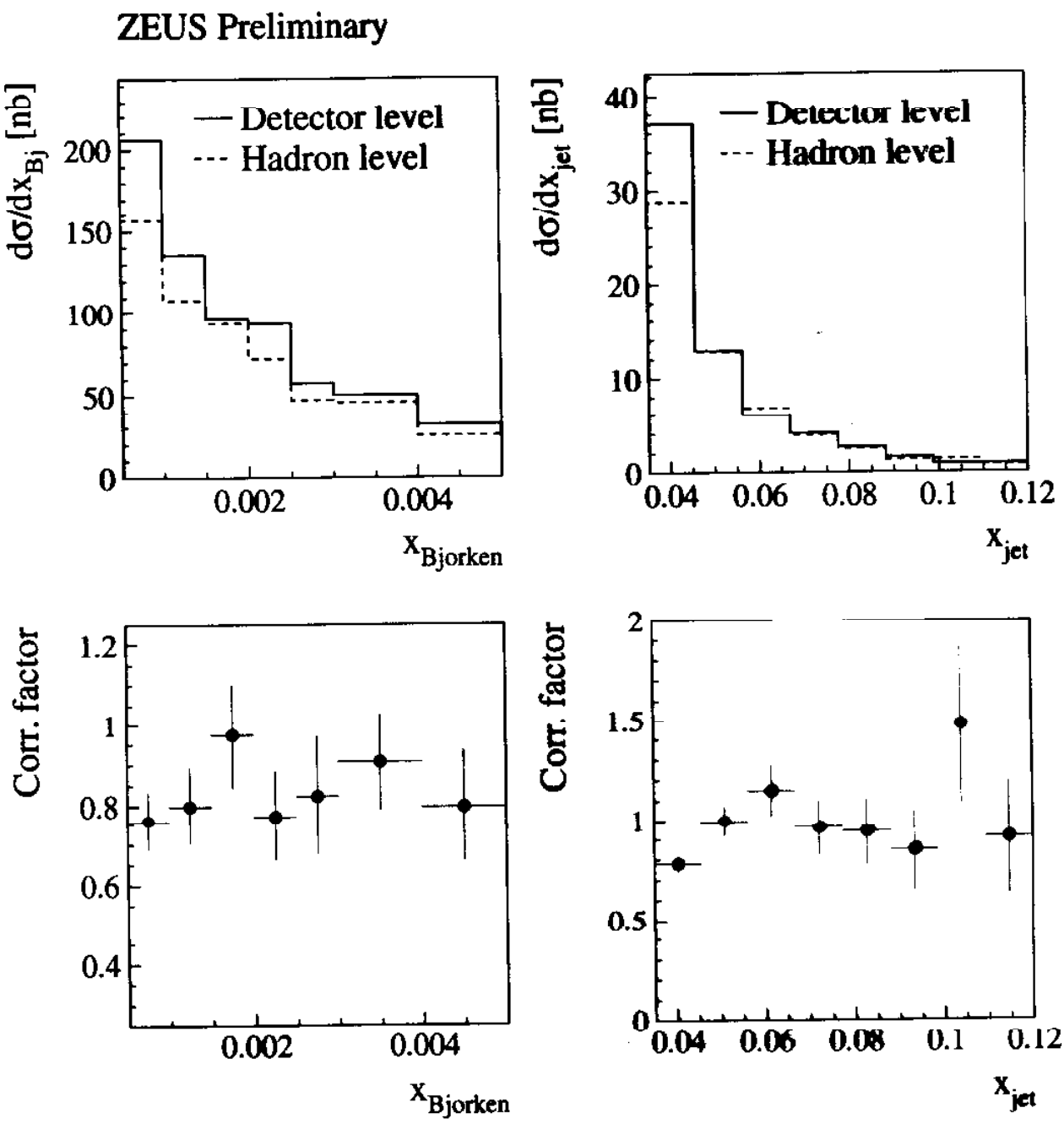
Ariadne describes data well.

Variables of selected forward jets



Correction Factors Hadron/Detector level

from Ariadne 4.08

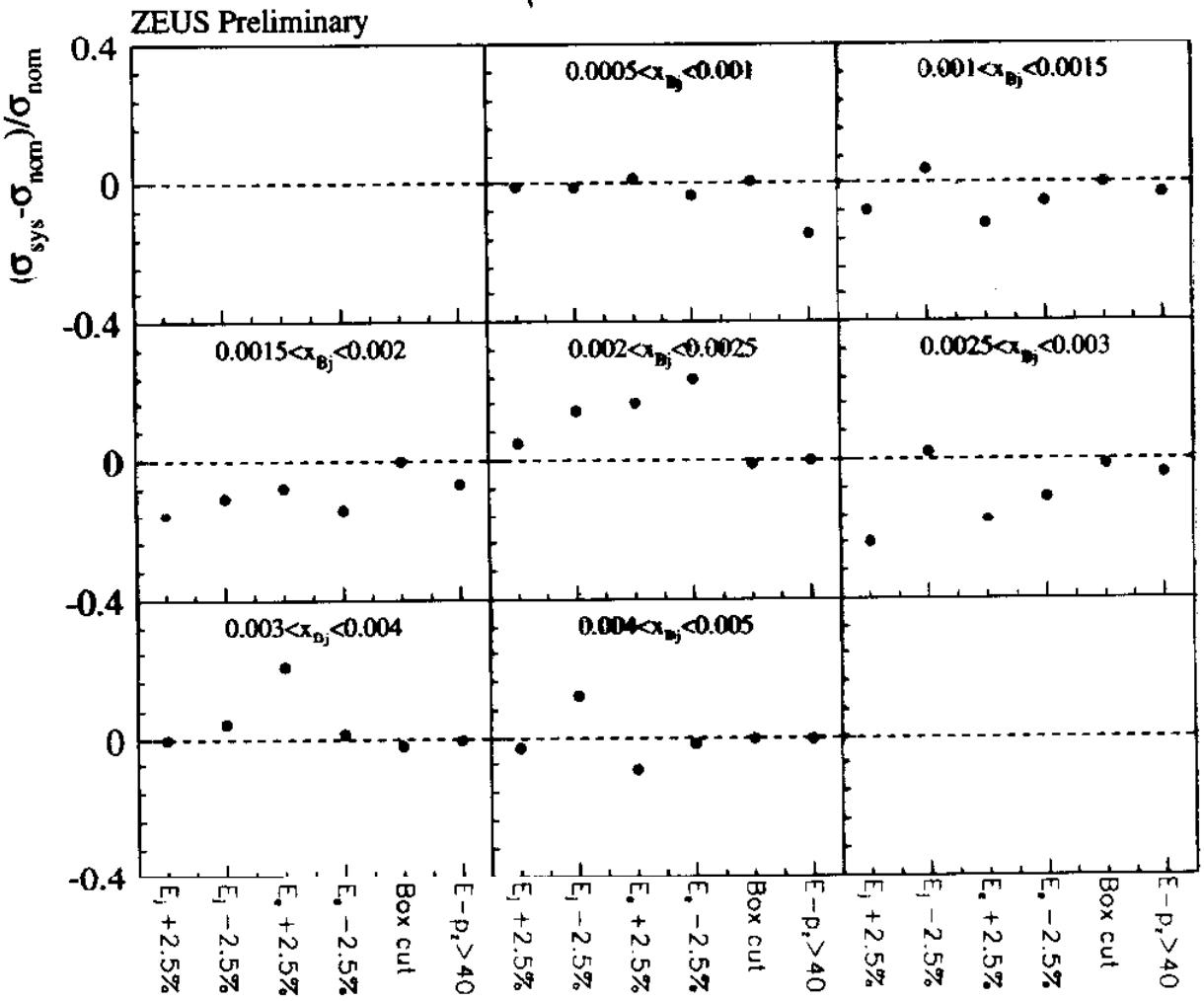


→ Correction factors between 0.7 and 1.0

Systematic Checks

- Vary (hadronic) calorimeter energy scale by ± 2.5%
- Vary electron energy by ± 2.5 %
- change "box cut" }
- Change $E-p_z$ cut }

Relative Deviation from nominal cross section



More systematic checks are needed:

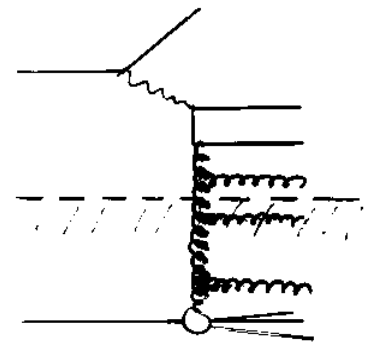
- hadronization scheme
- parton density functions

⋮

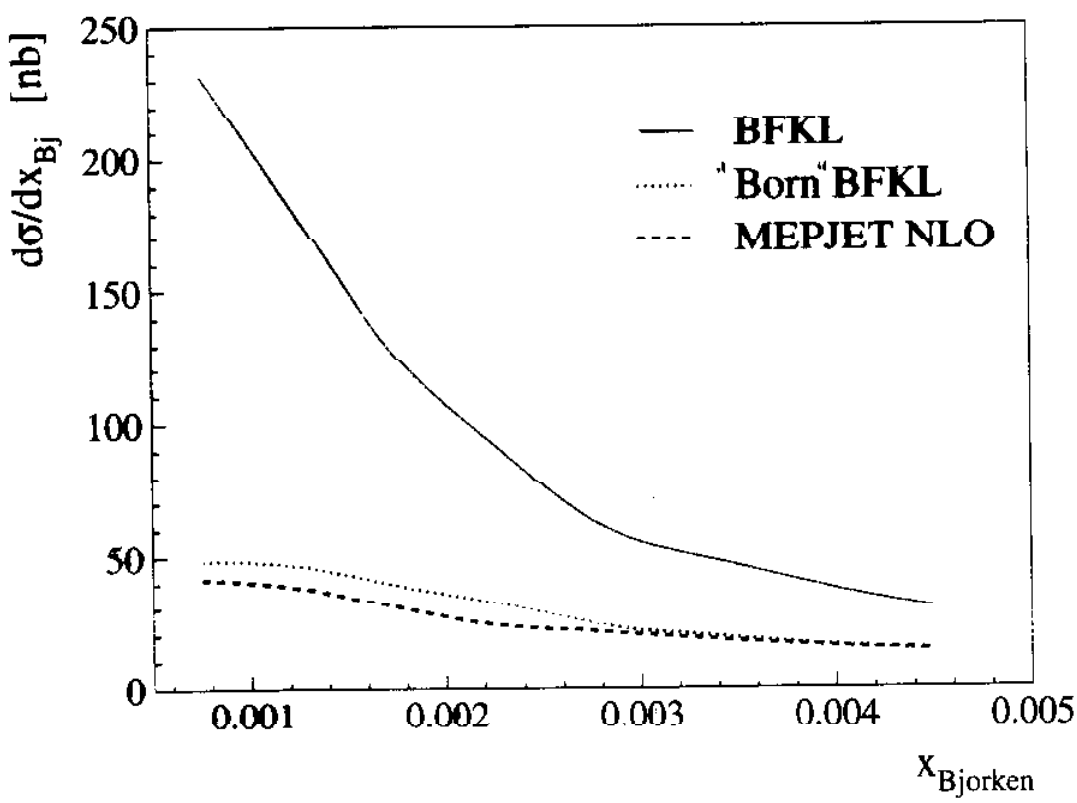
Theoretical Calculations

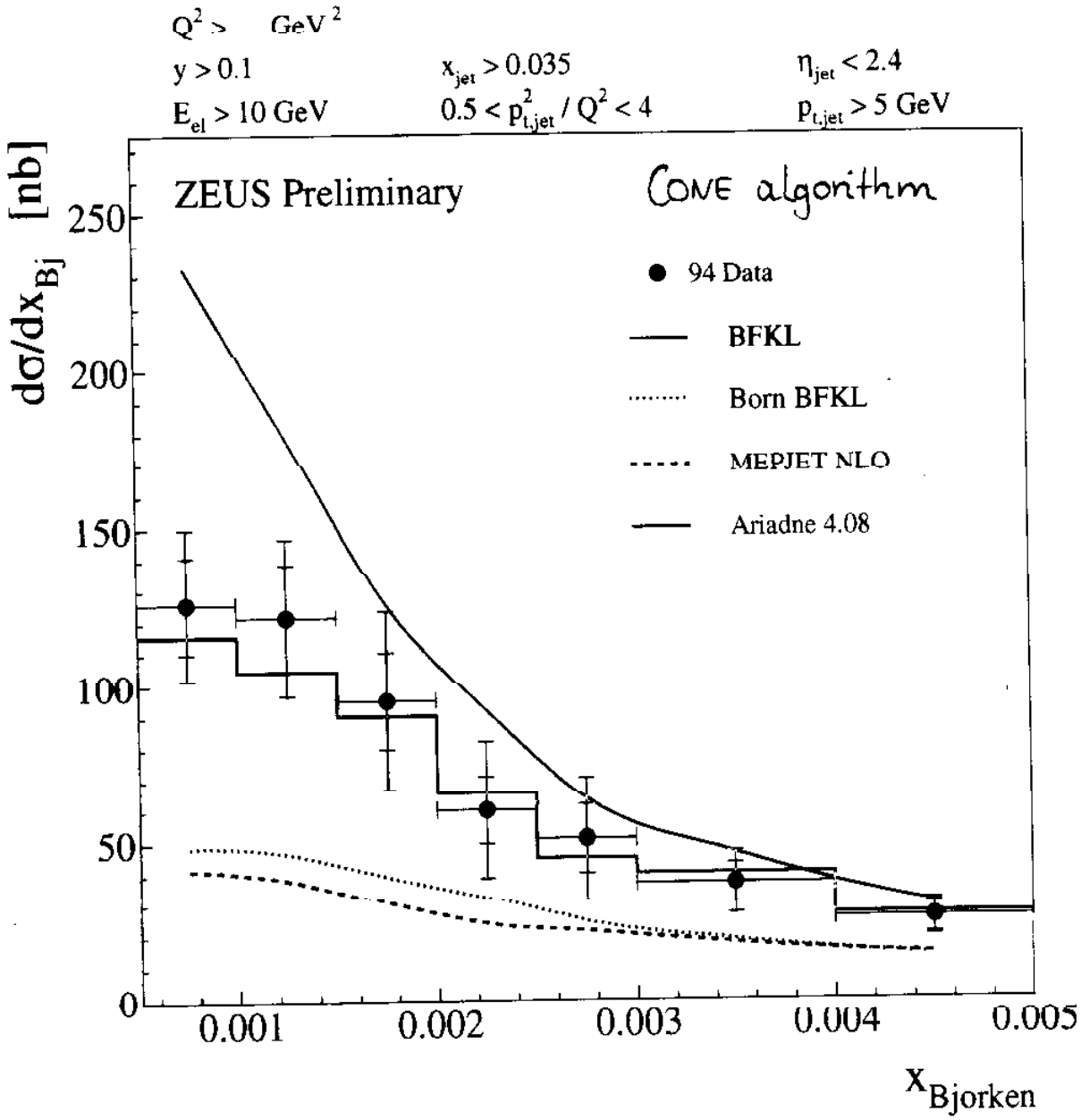
BFKL: Calculation by Bartels and Wüsthoff
No jet algorithm implemented.

"Born" BFKL: lowest order BFKL
→ should correspond
to NLO DGLAP



MEPJET: Next-to-leading QCD calculation
(Mirkes, Zeppenfeld)
Cone algorithm implemented,
but no E_T recombination scheme.




$Q^2 >$ GeV^2
$y > 0.1$
$E_{el} > 10$ GeV
$x_{jet} > 0.035$
$0.5 < p^2_{t,jet} / Q^2 < 4$
$\eta_{jet} < 2.4$
$p_{t,jet} > 5$ GeV
ZEUS Preliminary
Cone algorithm
94 Data
BFKL
Born BFKL
MEPJET NLO
Ariadne 4.08
$d\sigma/dx_{Bj}$ [nb]
250
200
150
100
50
0
0.001
0.002
0.003
0.004
0.005
$x_{Bjorken}$

Differential Cross Section for Forward Jets

Qualitative comparison with BFKL and NLO QCD calculation.

6 (effective)

- Data are corrected to parton level
- Systematic and statistical errors are added quadratically.

Summary

Transverse Energy Flow

- Transverse energy flow of DIS events has been measured in the hadronic center of mass system.

- A comparison with different model calculations gave good agreement for CDM (ARIADNE) and improved LEPTO 6.5

- Hadronization effects make it very difficult to conclude on parton dynamics

Forward Jets

- The differential cross section $\frac{d\sigma}{dx_{Bj}}$ of forward jets has been measured for $5 \cdot 10^{-4} < x_{Bj} < 5 \cdot 10^{-3}$.

- ARIADNE describes cross section and jet variables very well.

- Data lie for low x between BFKL prediction and NLO QCD calculation, agreement gets better for higher x. (Qualitative comparison)