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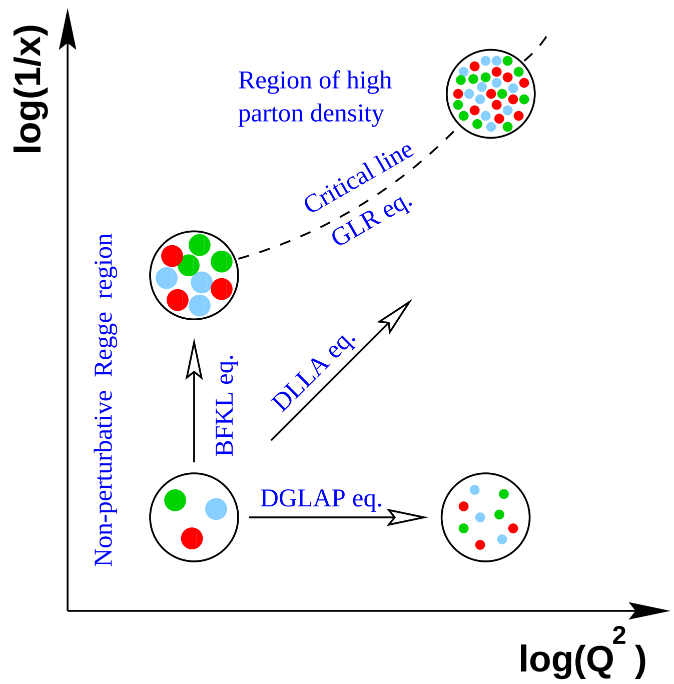
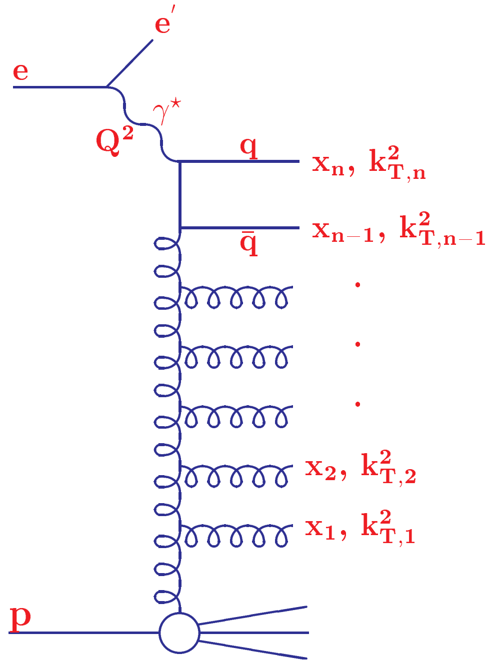
Forward jet production in DIS at HERA

Low x Physics at HERA
Zeuthen, 3–6 June 1998

1. Parton dynamics at small Bjorken–x.
2. Forward jets selection.
3. Properties of the forward jet events.
4. Comparison with theoretical predictions.
5. Conclusions.

DGLAP or BFKL dynamics?





In standard DGLAP evolution scheme (resummation of leading $\ln(Q^2)$), parton cascade follows strong ordering in transverse momenta:

$$Q^2 \equiv k^2_{T,n} \gg k^2_{T,n-1} \gg \cdots \gg k^2_{T,1}$$

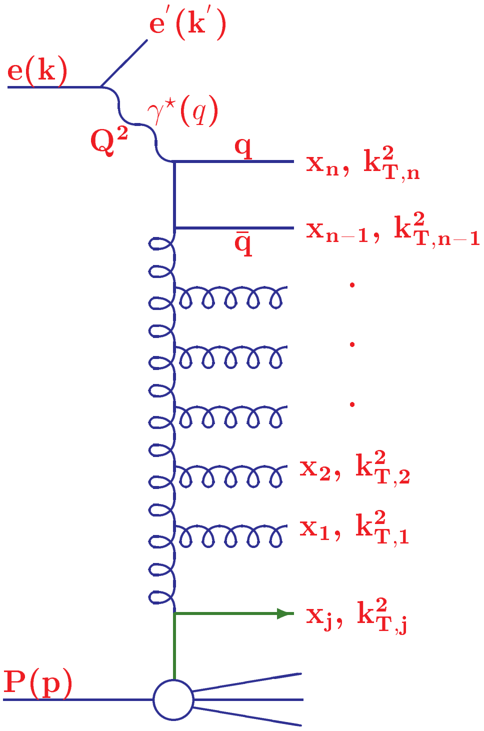
while the ordering in fractional longitudinal momenta is only kinematical.

In the BFKL evolution scheme (resummation of leading $\ln(1/x)$), parton cascade follows strong ordering in fractional longitudinal momenta:

$$x \equiv x_n \ll x_{n-1} \ll \cdots \ll x_1$$

and there is no ordering in transverse momenta ($k^2_{T,1} \approx Q^2$).

Forward Jet Selection



Kinematics:

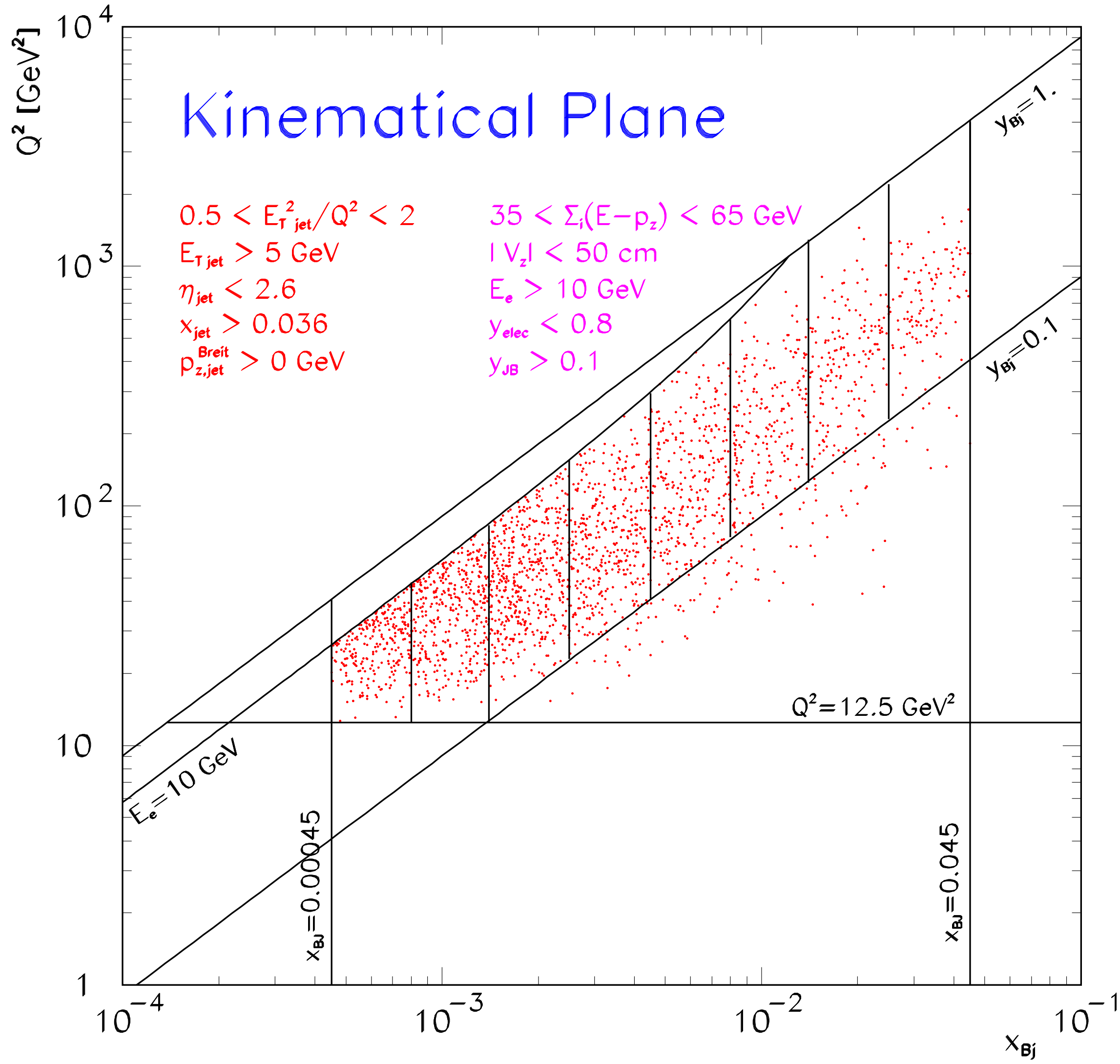
$$
\begin{aligned}
Q^2 &\equiv -q^2 = -(k-k')^2 > 0 \\
x &= Q^2/2p\cdot q \\
y &= p\cdot q/p\cdot k \\
x_{jet} &= p_{z,jet}/p
\end{aligned}
$$

Forward jet cross section was measured in the following kinematical range:

- $E_{T,jet} > 5$ GeV,
- $0.5 < E^2_{T,jet}/Q^2 < 2$,
- $x_{jet} > 0.036$,
- $\eta_{jet} < 2.6$ ($\theta_{jet} > 8.5^o$),
- $p^{Breit}_{z,jet} > 0$ GeV,
- $E_e > 10$ GeV,
- $0.00045 < x_{Bj} < 0.045$,
- $y_{Bj} > 0.1$,

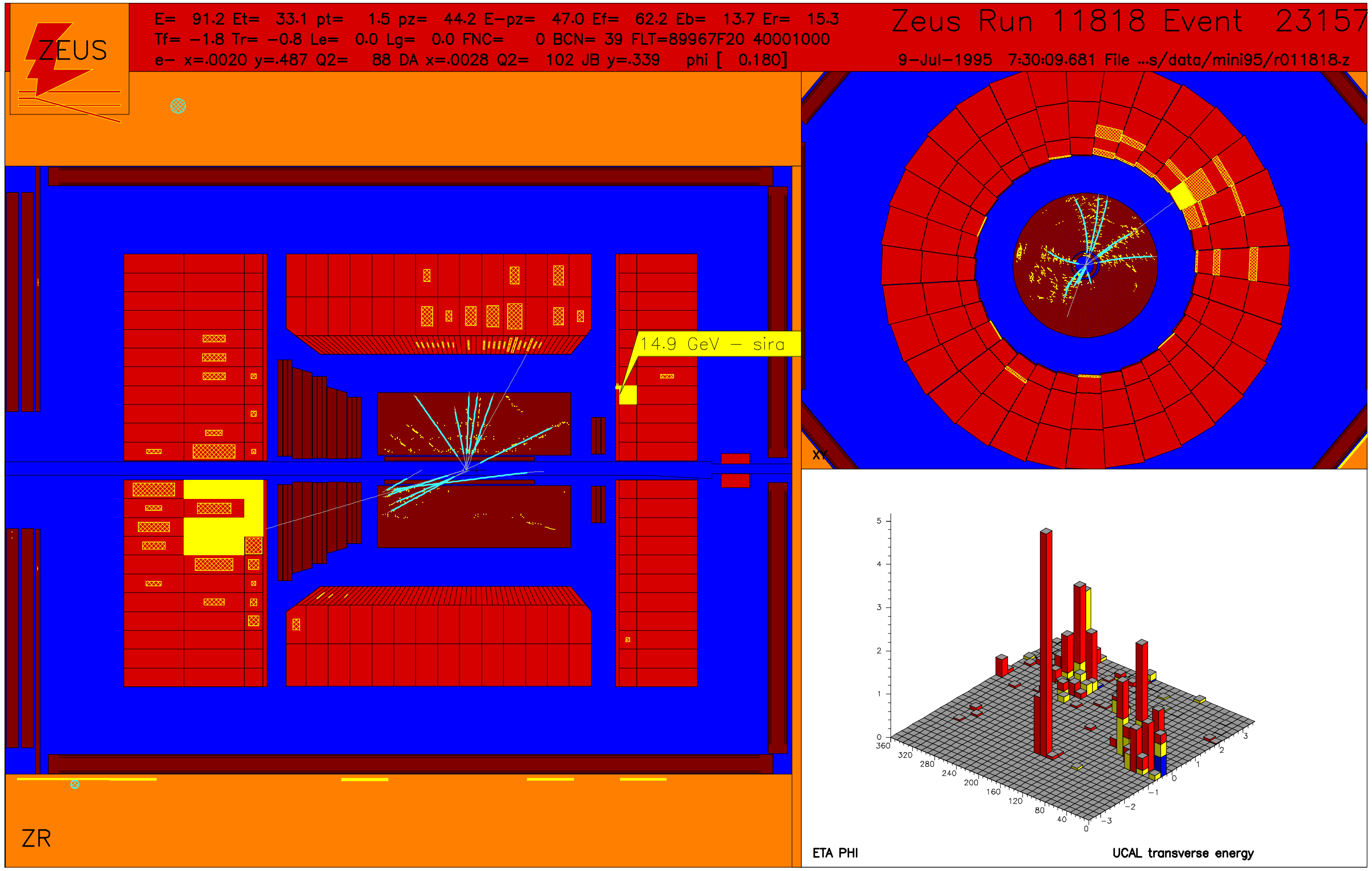
To find jets the cone algorithm in η–ϕ space in E_T scheme was used with R=1 and seed energy equal to 0.5 GeV.

ZEUS 1995 Data

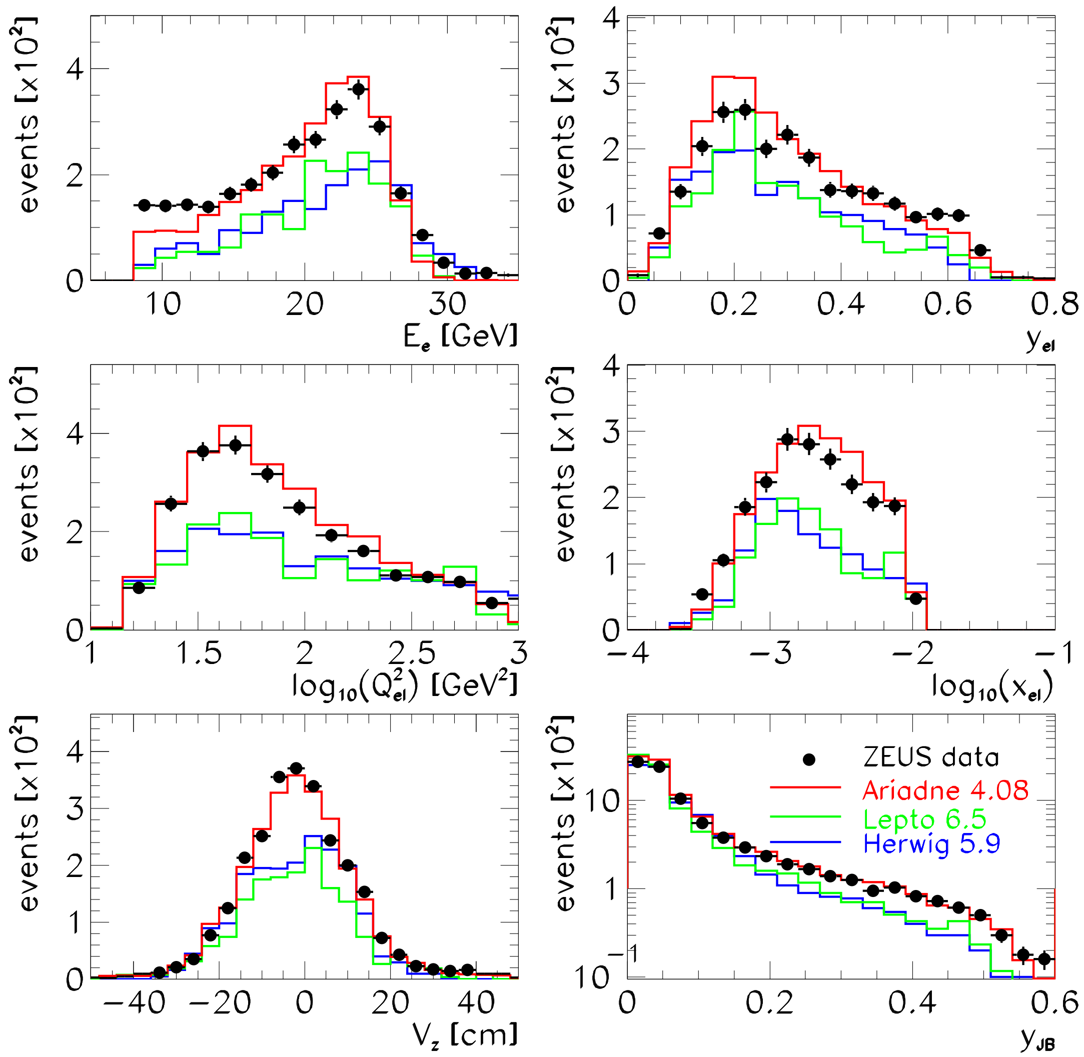


Total luminosity used in the analysis: 6.36 pb^{-1}.
Number of surviving events: 2918.

Typical forward jet event

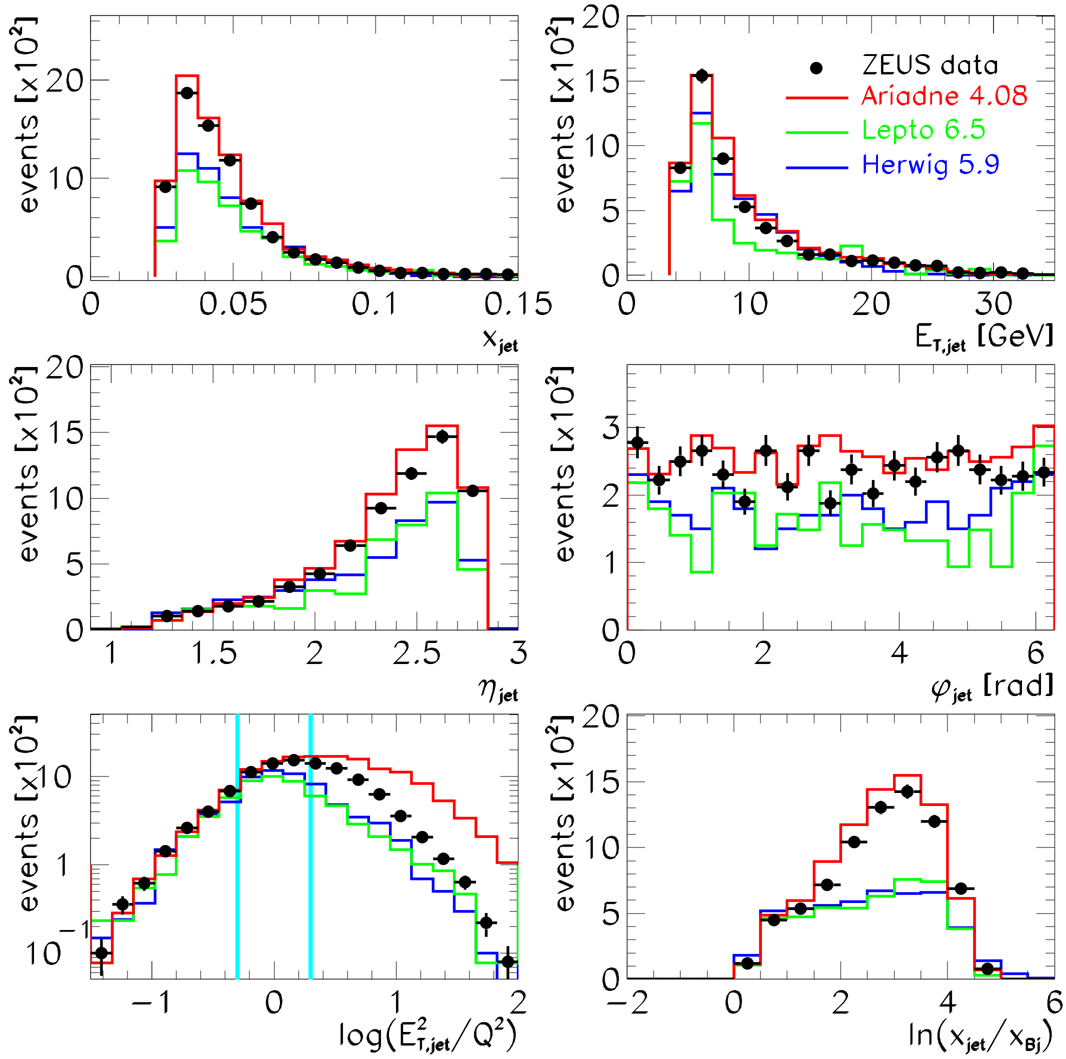


Properties of the forward jet events



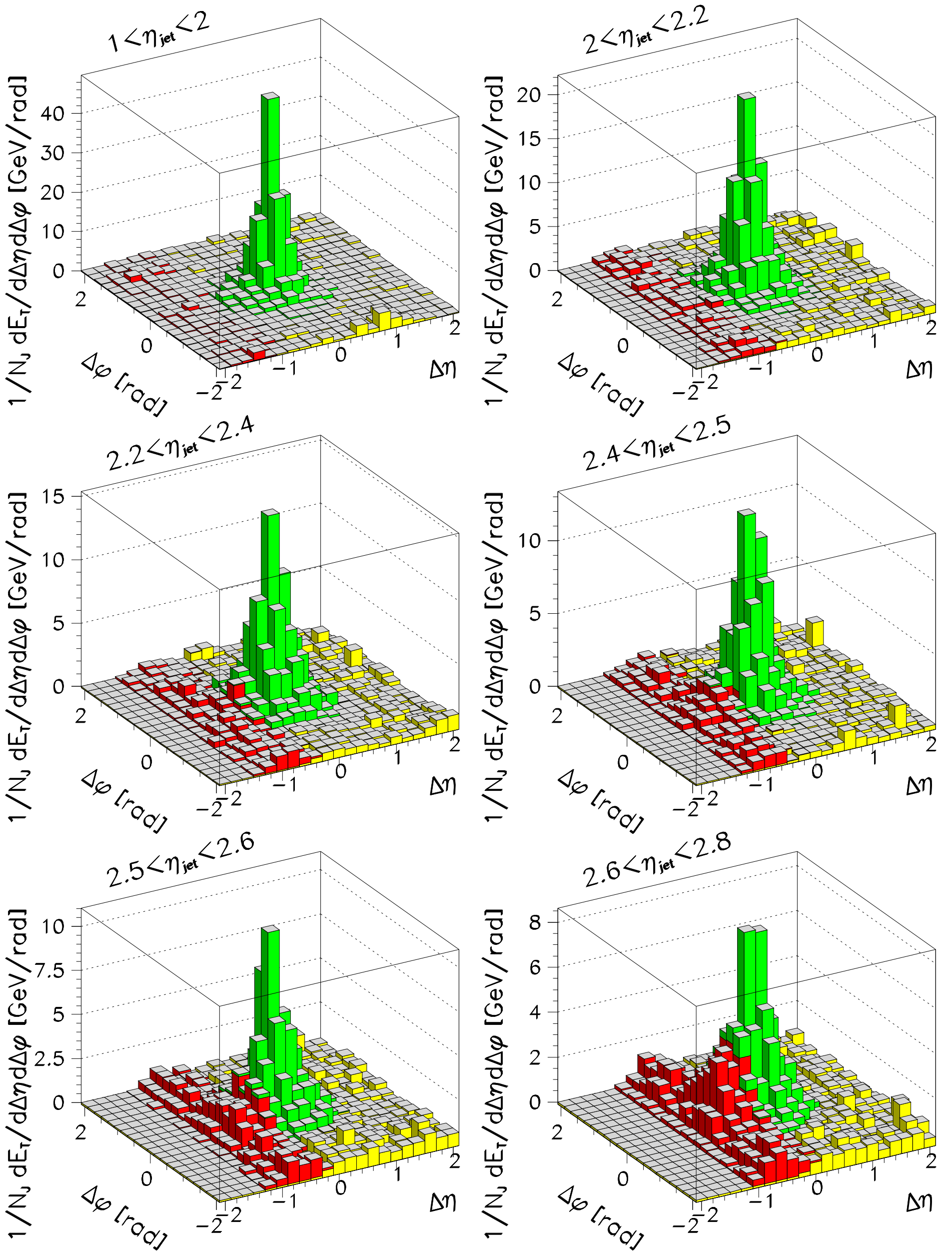
- **Ariadne 4.08:** Color Dipole Model + fragmentation through the Lund String model
- **Lepto 6.5:** MEPS, parton evolution based on DGLAP equations + fragmentation through the Lund String model
- **Herwig 5.9:** MEPS, parton evolution based on DGLAP equations + fragmentation through the cluster model

Properties of the forward jet events



- For $E^2_{T,jet} \ll Q^2$ all models agree with each other and with the data,
- For $E^2_{T,jet} \approx Q^2$ Ariadne describes the data whereas DGLAP based models start to deviate,
- For $E^2_{T,jet} \gg Q^2$ none of the models describe the data.

Transverse energy flow around jet axis



– transverse energy deposited in cells around the beam hole,

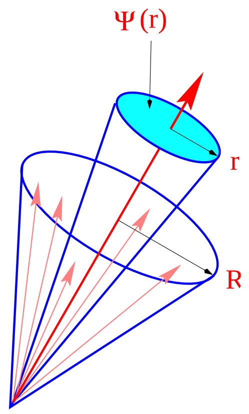
– transverse energy of the cells belonging to the forward jet, (aside from those already plotted in red, $R < 1$),

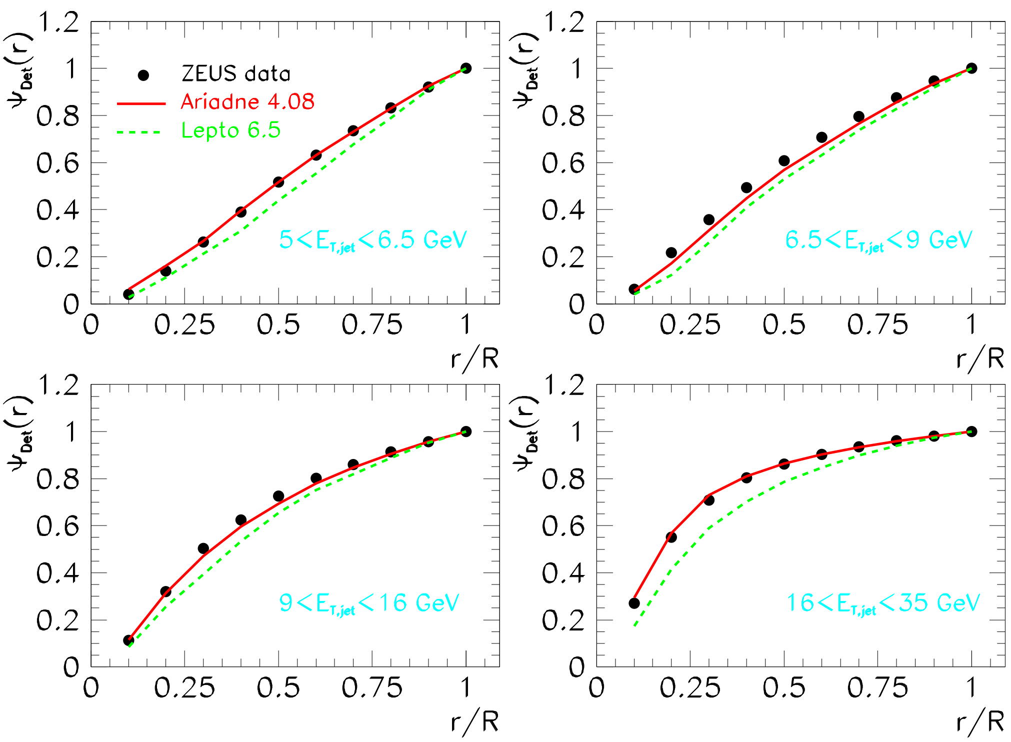
– all remaining transverse energy deposits in the event.

Forward jet shapes

Definition of the jet shape:

$$\Psi_{Det}(r) = \frac{1}{N_{jets}} \sum_{jets} \frac{E_T(r)}{E_T(r=R)}$$



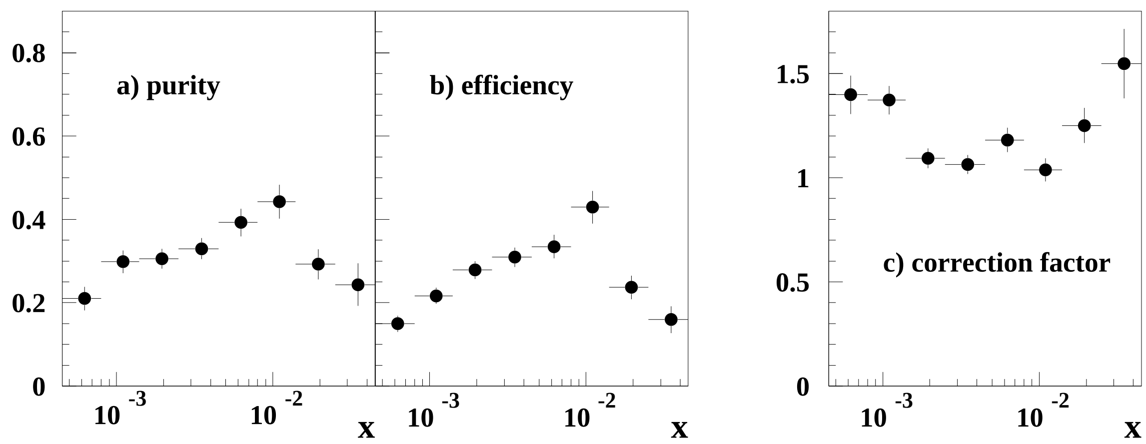


Jets become narrower as $E_{T,jet}$ increases.
Jets also become narrower when η_{jet} decreases.

Data correction methods

The data were corrected to the hadron level using two different methods and Ariadne for the acceptance correction:

- Bin-to-bin correction method in which each bin of the data is independently multiplied by the correction factor.

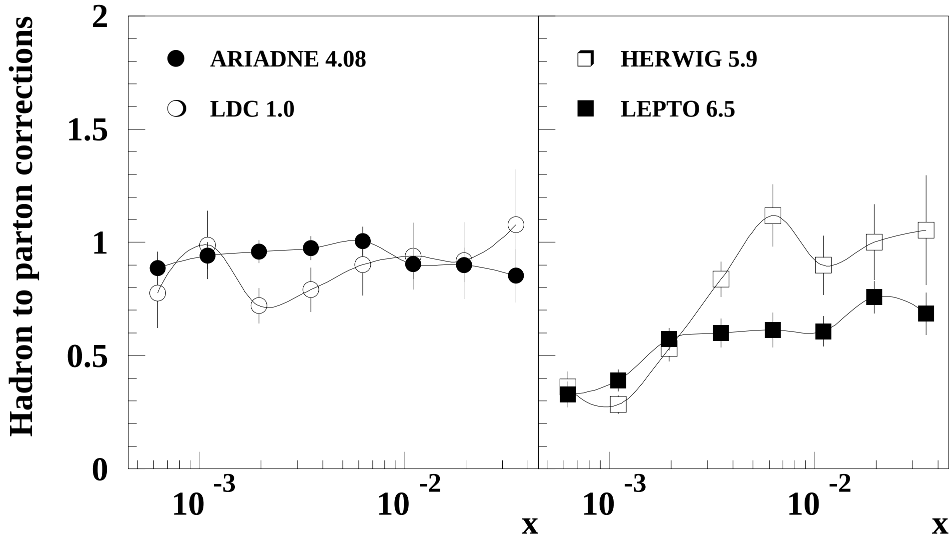


$$\mathrm{eff} = \frac{N_{\mathrm{jets}}^{\mathrm{Det}\oplus\mathrm{Had}}}{N_{\mathrm{jets}}^{\mathrm{Had}}} \qquad \mathrm{pur} = \frac{N_{\mathrm{jets}}^{\mathrm{Det}\oplus\mathrm{Had}}}{N_{\mathrm{jets}}^{\mathrm{Det}}}$$

- The unfolding method based on Bayes' theorem, which takes into account migration effects between the bins.

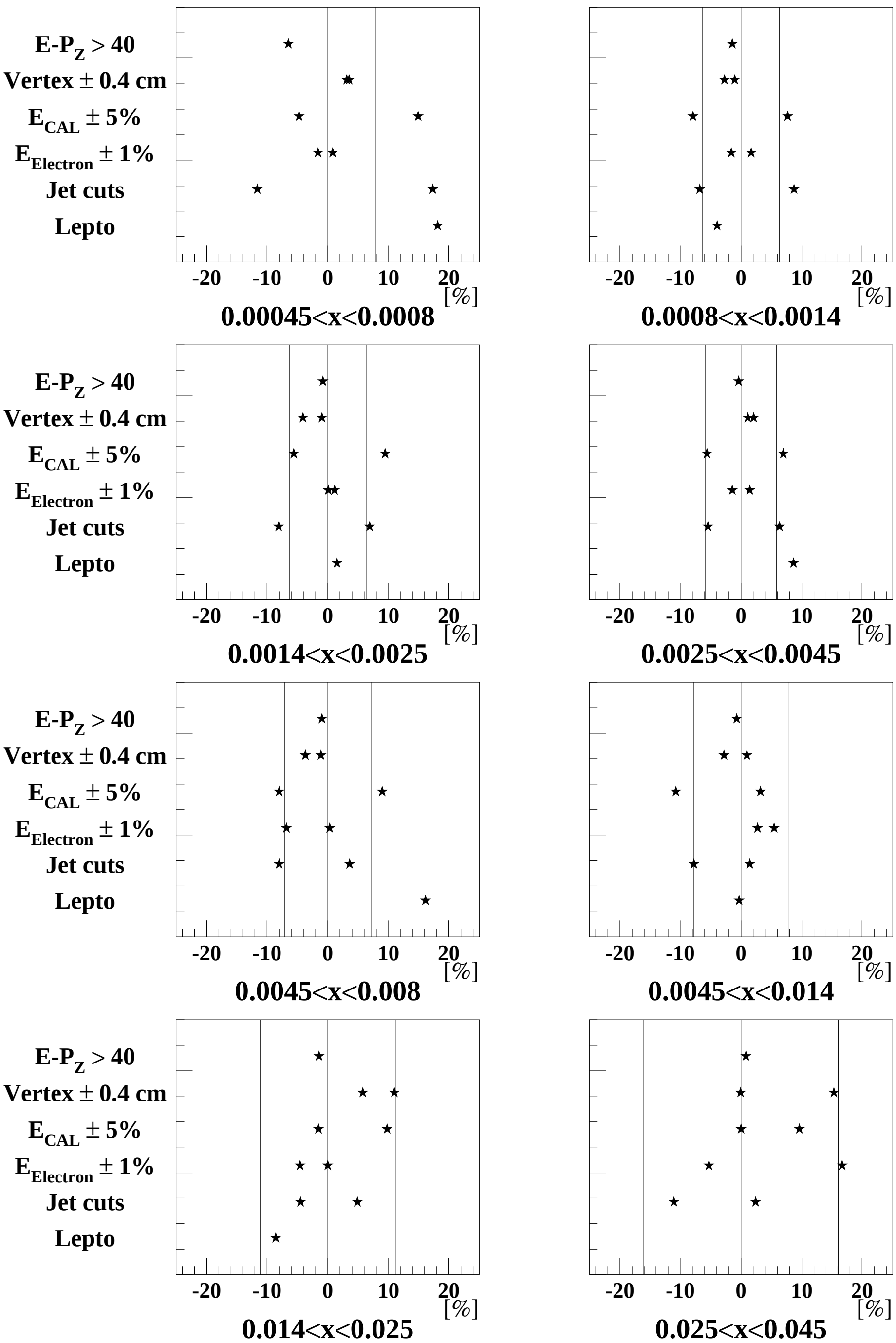
The extracted forward jet cross sections agree well between the two methods.

Why do we not quote the parton level cross section?

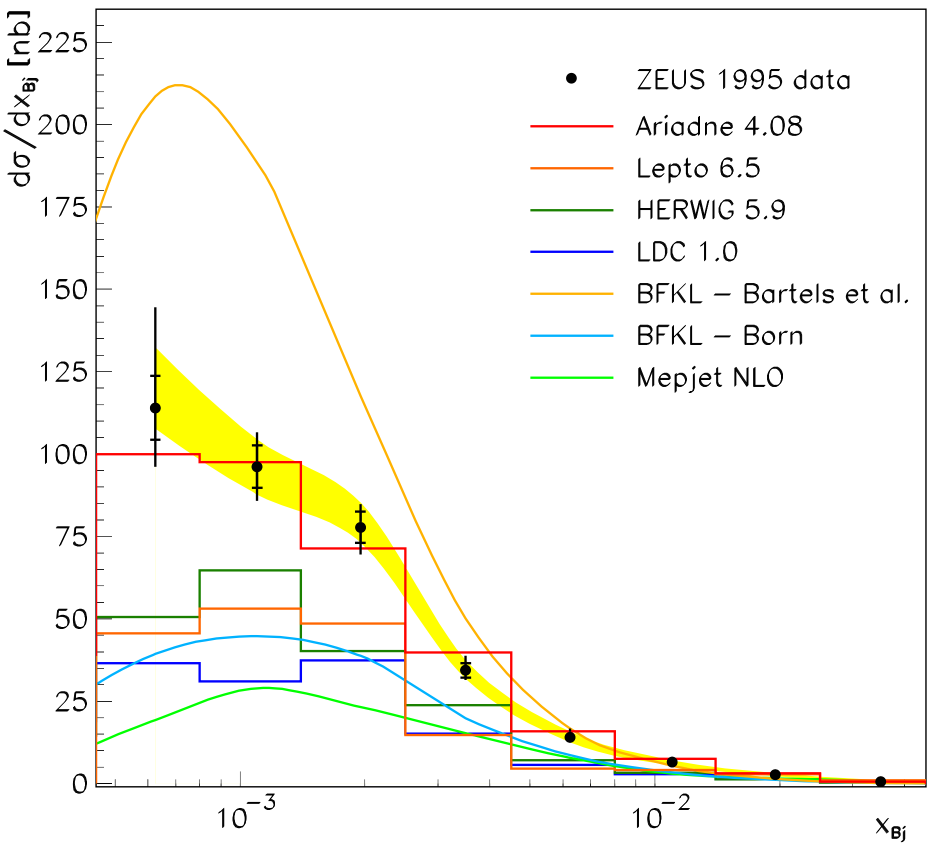


The size of the corrections from hadron to parton level depend strongly on the model. Also the relation between the parton level in parton shower Monte Carlo programs and partons in exect NLO calculations is not obvious. Therefore we refrain from quoting mesurements corrected to the parton level.

Systematic uncertainties – hadron level



Forward jet cross section



Forward jet cross section at hadron level as a function of x_{Bj} in the kinematic region of $0.00045 < x_{Bj} < 0.045$, $y_{Bj} > 0.1$, $E_e > 10$ GeV, $\eta_{jet} < 2.6$, $0.5 < E^2_{T,jet}/Q^2 < 2$, $x_{jet} > 0.036$ and $E_{T,jet} > 5$ GeV.

Inner error bars represent statistical errors and outer error bars represent statistical and systematic errors added in quadrature. The errors due to the uncertainty of the jet energy scale are shown as the yellow band.
The measured cross section is compared to different Monte Carlo models and to the theoretical calculations.

Conclusions

1. Forward jet cross section in DIS events has been measured in kinematic range of $0.00045 < x_{Bj} < 0.045$, $y_{Bj} > 0.1$ and $E_e > 10$ GeV at the hadron level. It has been compared to several Monte Carlo models and theoretical calculations.

2. Both the shape and absolute normalization of the measured cross section are very well described by the CDM as implemented in Ariadne.

3. Three regions are identified in $E^2_{T,jet}/Q^2$ distribution:
   - $E^2_{T,jet} \ll Q^2$ – the standard DGLAP region where all Monte Carlo models are in agreement with the data,
   - $E^2_{T,jet} \approx Q^2$ – the region where BFKL dynamics is expected to contribute significantly; only CDM describes the data well,
   - $E^2_{T,jet} \gg Q^2$ – where none of the models describe the data.

4. An excess of the measured cross section above DGLAP predictions suggests that we observe in the data new, hard interactions, which can not be explained either by standard parton dynamics nor by non-perturbative effects like hadronization or Soft Color Interactions model recently introduced in Lepto.

5. No correction to the parton level because of the model dependence.