Dijets at Large Rapidity Intervals

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Outline

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- The BFKL Equation
- The Data Set
- Event Selection
- Results
- Conclusions

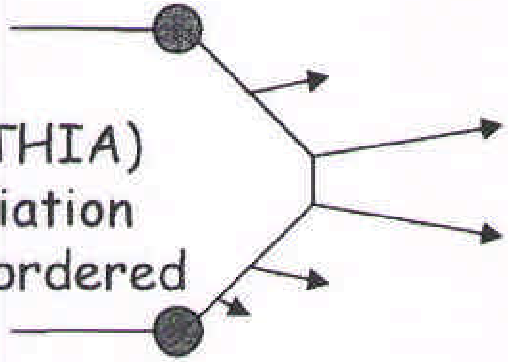
Introduction

- QCD is mostly successful in describing jet production at high energy hadron colliders.
- pQCD at fixed order in α_s is sufficient to describe a wide variety of phenomena; usually tested as a function of Q^2 (DGLAP evolution).
- However for $s \gg Q^2$, large logarithms $\ln(s/Q^2)$ appear. These must be summed to all orders in α_s. This summation is done through the Balitsky-Fadin-Kuraev-Lipatov (BFKL) equation.

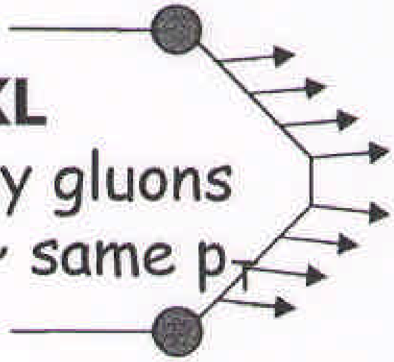
BFKL Dynamics

In hadron-hadron collisions:

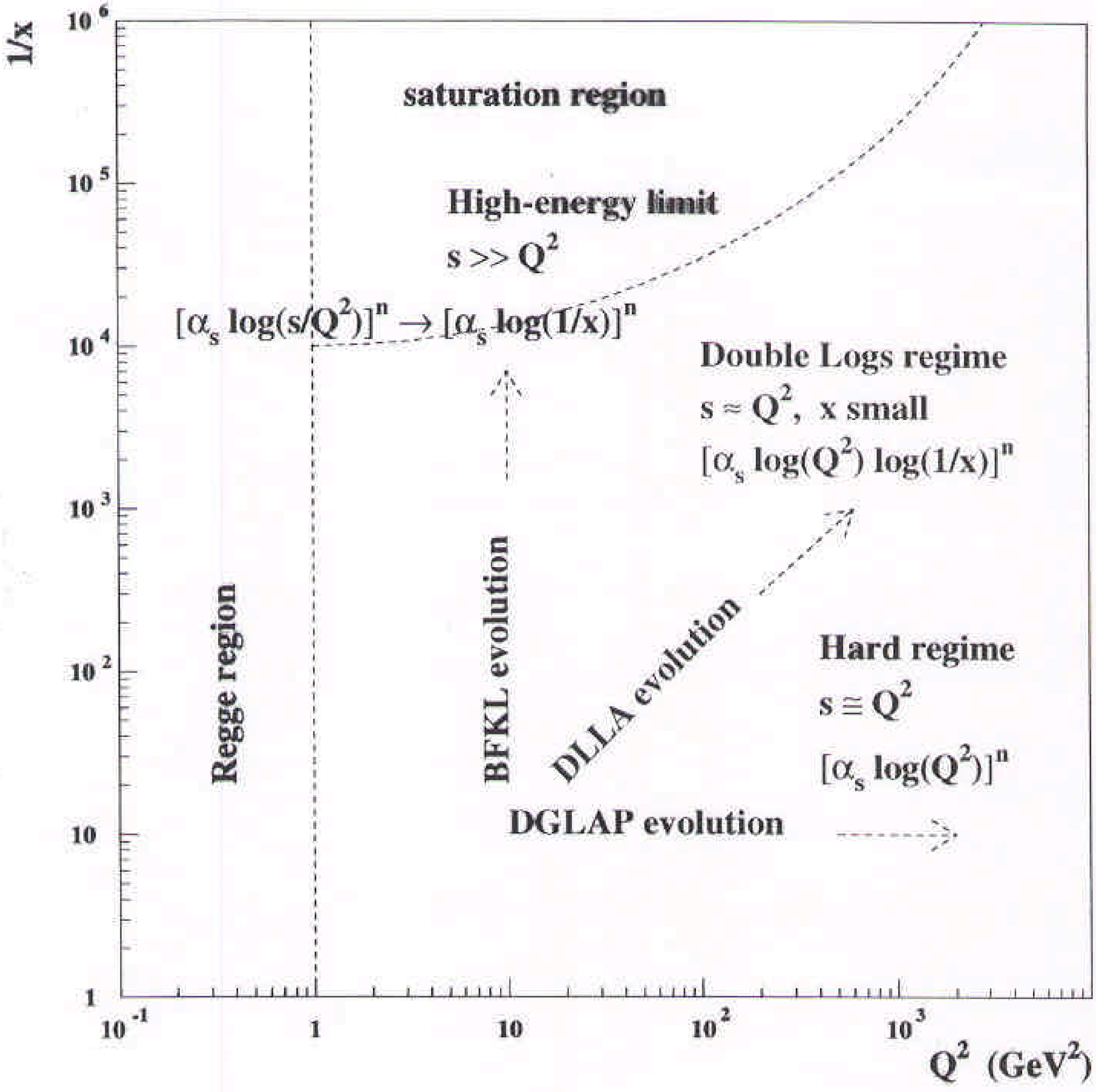
DGLAP
(as in PYTHIA)
gluon radiation
strongly ordered



BFKL
many gluons
all ~ same p_T



Gluons are strongly ordered in η or, equivalently, their longitudinal momentum fractions, x_i. Thus BFKL describes the evolution in x of the gluon momentum distribution.

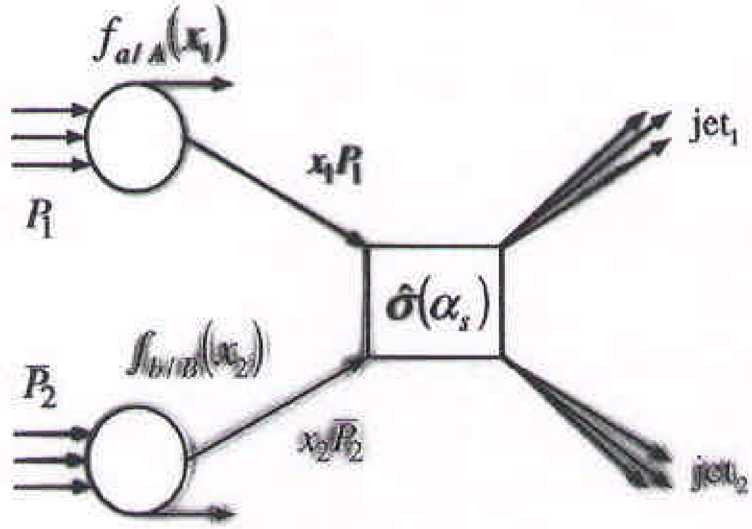


s: center-of-mass energy squared

x: longitudinal momentum fraction of proton

Q: momentum transfer during hard scattering

- In high energy $p\bar{p}$ collisions, inclusive dijet production at large pseudorapidity intervals, $\Delta\eta$, between the two jets provides an excellent testing ground for BFKL dynamics.



$$\sigma_{dijet} = x_1 f_1(x_1, Q^2)\, x_2 f_2(x_2, Q^2)\hat{\sigma}$$

- The dijet cross section is factorized into the partonic cross section, $\hat{\sigma}$, and the parton distribution functions, $f(x, Q^2)$.

The BFKL Equation

Using the BFKL prescription to sum the leading logarithm terms, $\alpha_s \ln(s/Q^2)$ to all orders in α_s, it has been shown (Mueller and Navelet) that $\hat{\sigma}$ rises exponentially with $\Delta\eta$.

$$\hat{\sigma}_{BFKL} \sim \frac{1}{Q^2} \frac{e^{(\alpha_{BFKL} - 1)\Delta\eta}}{\sqrt{\alpha_s \Delta\eta}}$$

α_{BFKL} is the BFKL intercept which governs the growth of the gluon distribution at small x.

In the LLA:

$$\alpha_{BFKL} - 1 = \frac{\alpha_s(Q) 12 \ln 2}{\pi} = 0.5$$

- The predicted rise of the partonic cross section with $\Delta\eta$ is difficult to observe experimentally due to the steeply falling behavior of the PDFs with x.

==> measure σ at two c.m. energies, $\sqrt{s}$ = 1800 GeV and $\sqrt{s}$ = 630 GeV and take their ratio for the same values of x_1, x_2, and Q^2.

- This eliminates the dependence on the PDF.

$$R = \frac{\sigma(x_1, x_2, Q^2, s_A)}{\sigma(x_1, x_2, Q^2, s_B)} = \frac{\hat{\sigma}(\Delta\eta_A)}{\hat{\sigma}(\Delta\eta_B)}$$

$$R = \frac{e^{(\alpha_{BFKL} - 1)(\Delta\eta_A - \Delta\eta_B)}}{\sqrt{\Delta\eta_A / \Delta\eta_B}}$$

Data Set

- Tevatron Run 1c @ $\sqrt{s}$ = 1800 GeV and $\sqrt{s}$ = 630 GeV
- 3-level trigger system requiring 1 jet with $E_T > 12$ GeV
- Trigger efficiency:- 85/95/100 %

  @ 20/25/30 GeV
- Luminosity:- 0.7 nb^{-1} @ 1800 GeV

  30.3 nb^{-1} @ 630 GeV
- Jet Definition: Fixed-cone algorithm

  with R = 0.7 in (η,ϕ) space
- Energy scale corrections:-

  noise, pileup

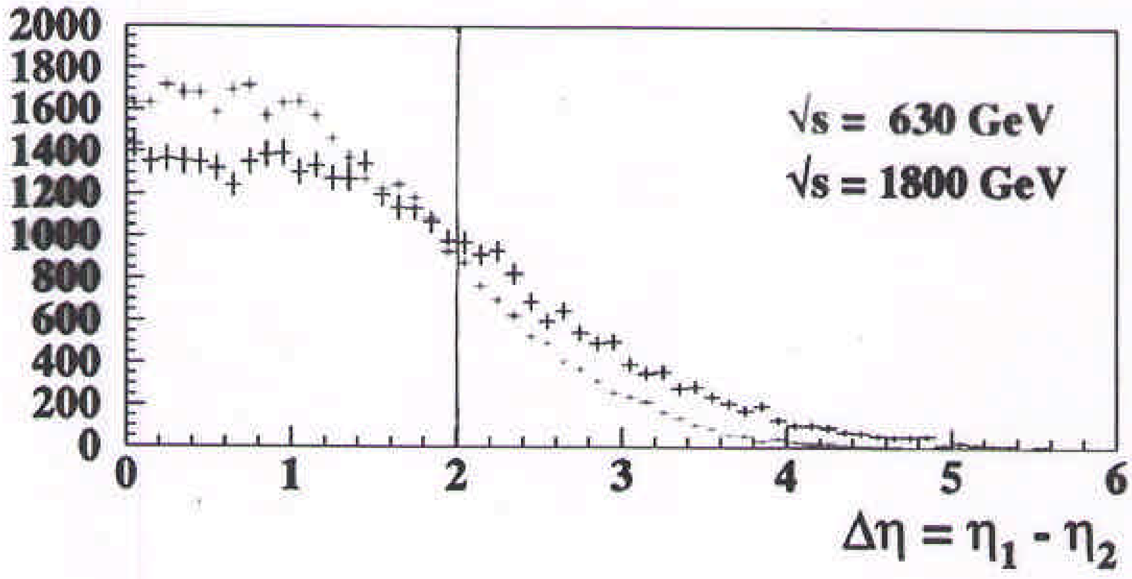
  hadronic response

  showering losses

Event and Jet Selection

- $|Z_{vert}| < 50$ cm $\Rightarrow$ **93/86% eff. at 1800/630 GeV**
- **eliminate events w/ large $\not{E}_T$ $\Rightarrow$ >98% eff.**
- **jet quality criteria $\Rightarrow$ 96-98% eff.**
- **jet $E_T > 20$ GeV, jet $|\eta| < 3$**
- **keep all events w/ at least 2 good jets**

$\Rightarrow$ **rapidity ordering:** $\eta_1 > \eta_i > \eta_2$

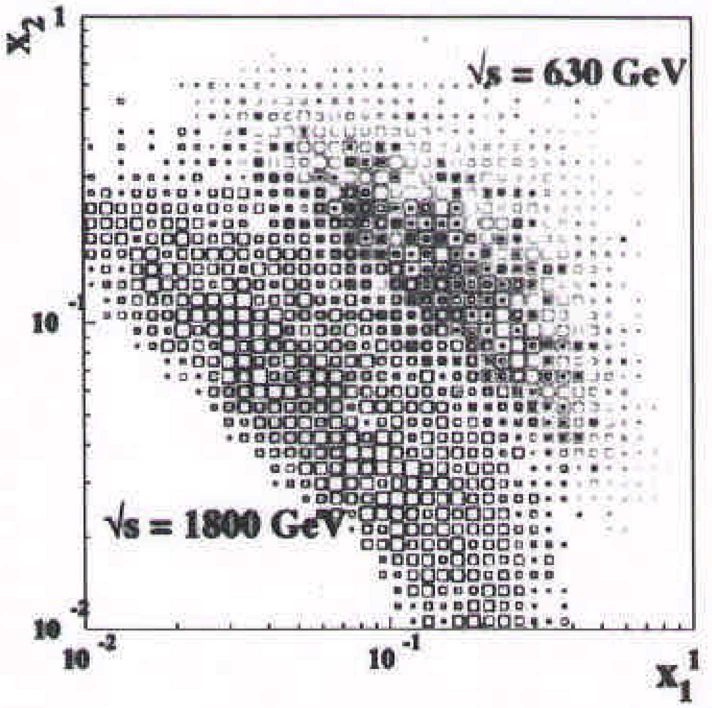


$\Rightarrow$ **require** $\Delta\eta = \eta_1 - \eta_2 > 2$

Reconstruction of Kinematics

$$400 < Q^2 = E_{T_1} \cdot E_{T_2} < 1000 \text{ GeV}^2$$

$$x_{1,2} = \frac{2E_{T_i}}{\sqrt{s}} \; e^{\pm|\bar{\eta}|} \; \cosh(\Delta\eta/2)$$



- **measure dijet cross section in (x_1, x_2, Q^2) bins**
- **unsmear σ for jet E_T resolution effects**
- **take ratio $R = \sigma_{1800}/\sigma_{630}$ in overlapping bins**
- **extract a value for $\alpha_{\rm BFKL}$ for each R_{bin}**

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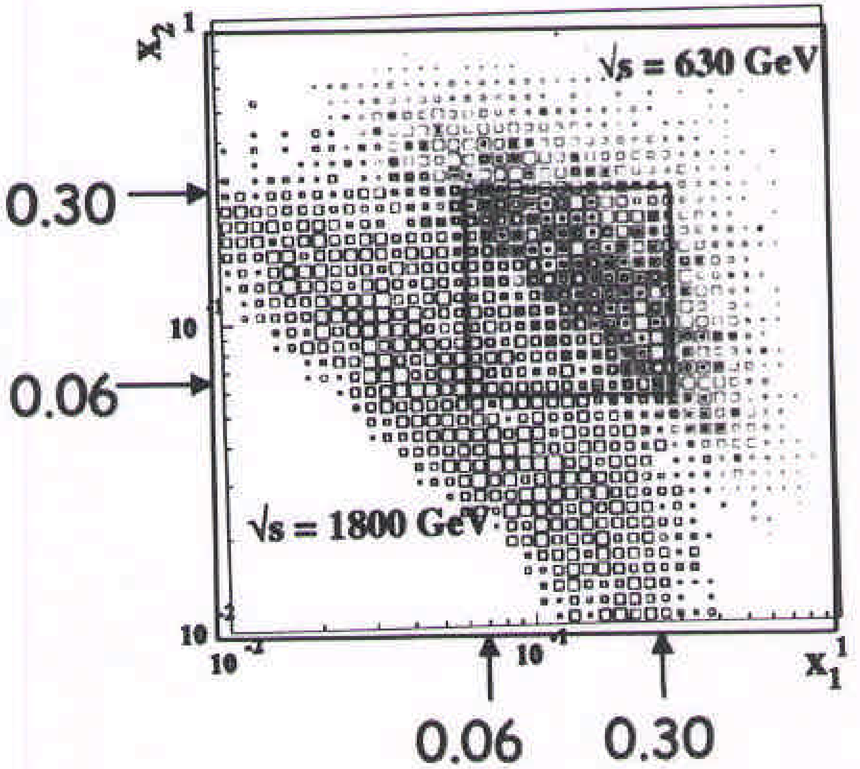

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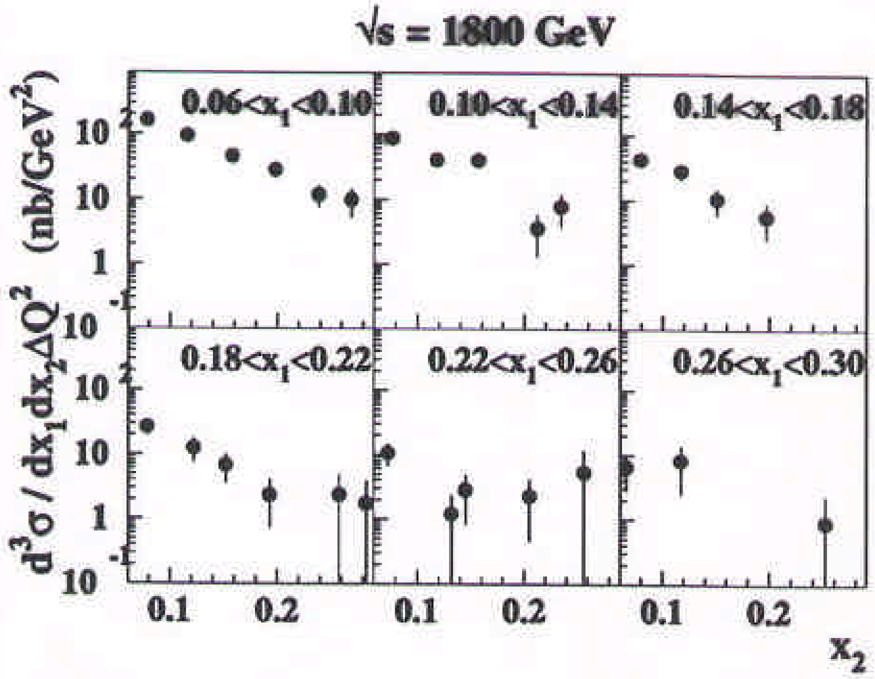
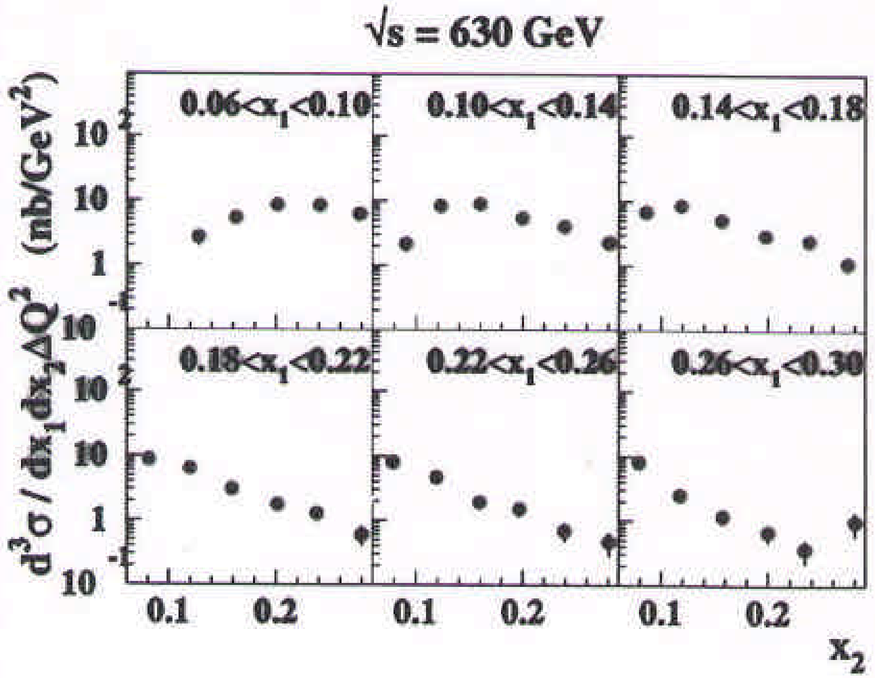
Unsmeared Dijet Cross Sections

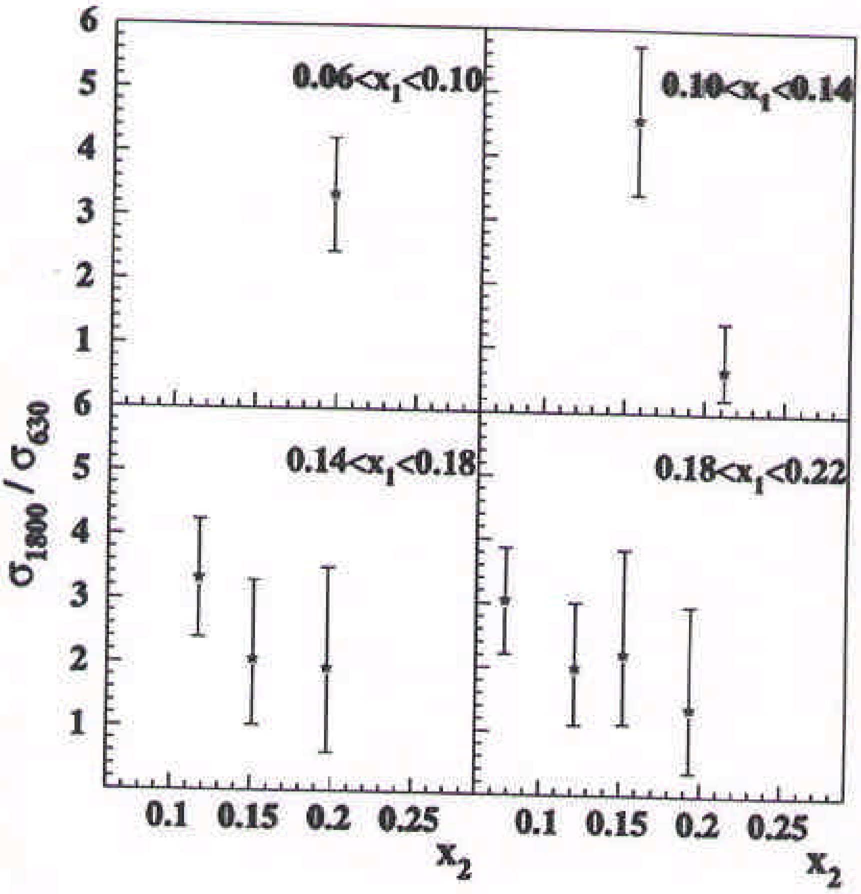




$$|\eta| < 3 \Rightarrow x_{1,2} < 0.22$$

$$E_T > 20\text{ GeV and } \Delta\eta > 2 \Rightarrow x_1 \cdot x_2 > 0.0096$$

Ratio $\sigma_{1800}/\sigma_{630}$



$$R = \sigma_{1800}/\sigma_{630} = 2.8 \pm 0.3\,(\text{stat})$$

for $<\Delta\eta_{630}>= 2.4$ and $<\Delta\eta_{1800}>= 4.6$

Systematic uncertainties:

▷ **jet energy scale**

▷ **jet energy resolutions**

▷ **unsmearing of the cross section**

▷ **luminosity**

→ $\mathrm{R} = \sigma_{1800}/\sigma_{630} = 2.8 \pm 0.3\,(\text{stat}) \pm 0.3\,(\text{syst})$

Comparison with Predictions

- Our measurement:

  $R = 2.8 \pm 0.3(stat) \pm 0.3(syst)$

- Asymptotic LO QCD ($\Delta\eta$ very large)

  $R = 1.0$

- Exact LO QCD (Orr/Stirling)

  $R = 1.2$

- HERWIG Monte Carlo

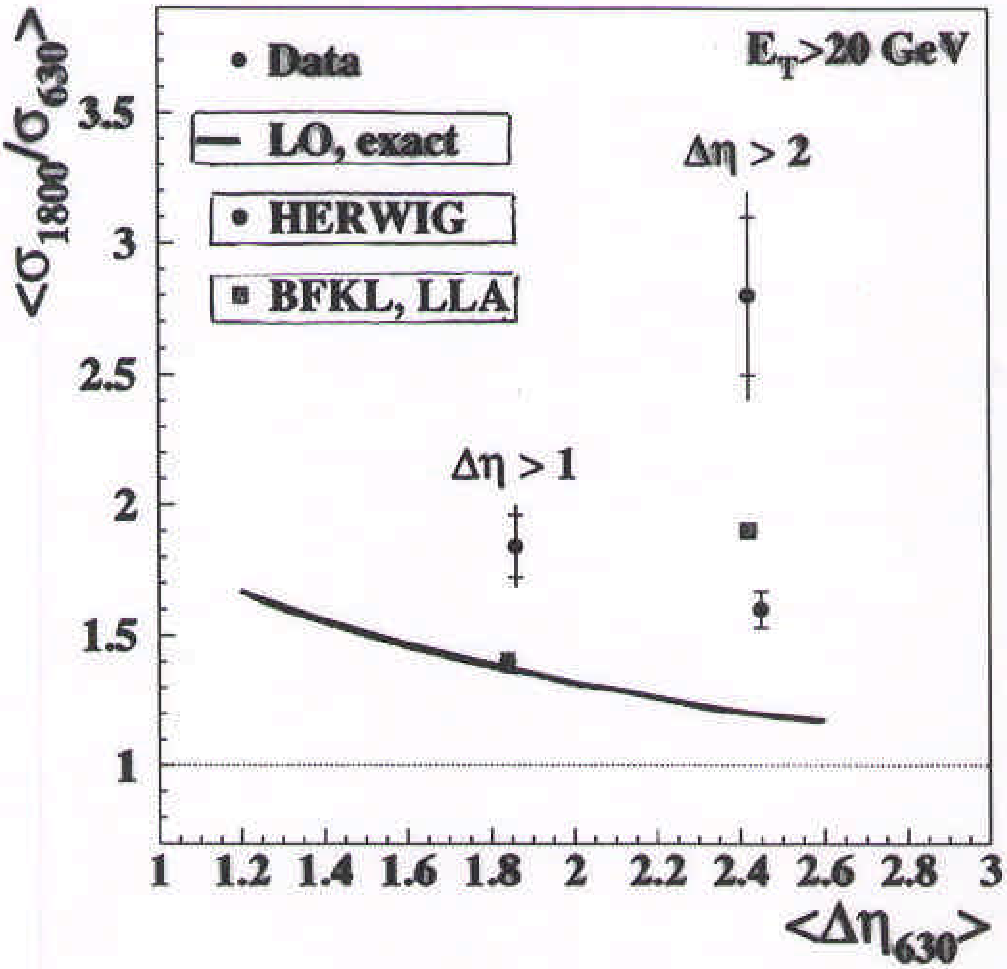
  $R = 1.6 \pm 0.1(stat)$

- LLA **BFKL** (Mueller/Navelet)

  $R = 1.9$

- (Next-to-leading log BFKL predictions are not yet available)

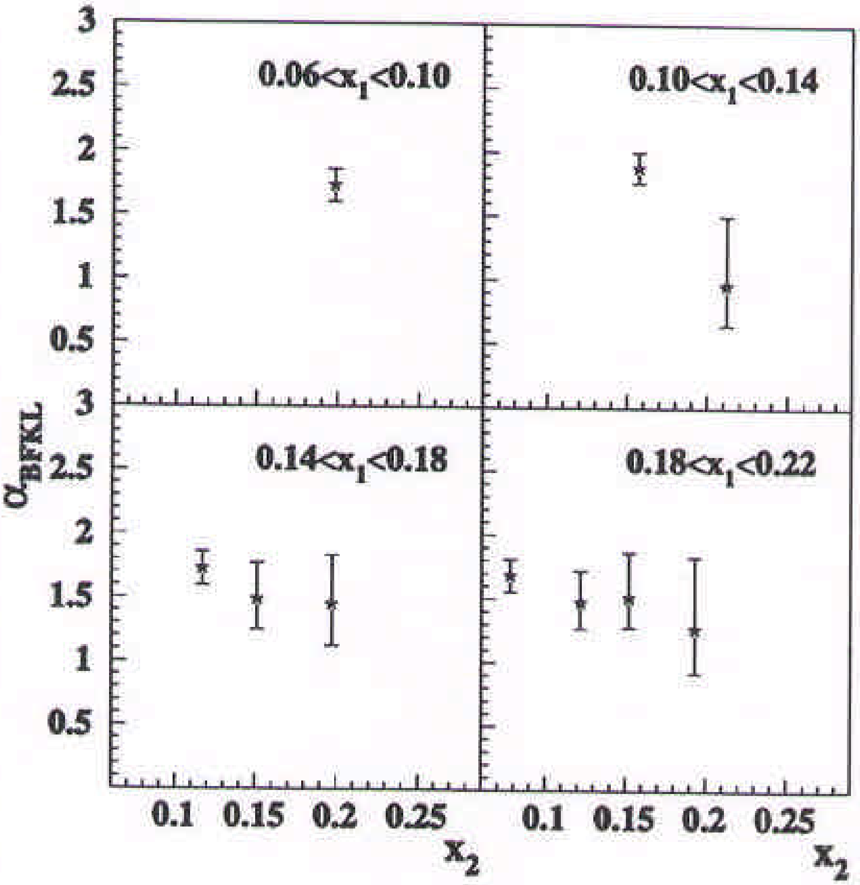
R vs. $\Delta\eta$



$\Longrightarrow$ **R increases with $\Delta\eta$**

$\Longrightarrow$ **difference in σ between different $\sqrt{s}$ ($\Delta\eta$)**
increases with $\Delta\eta$
in contrast to LO QCD

BFKL Intercept



$\alpha_{\mathrm{BFKL}} = \mathbf{1.65} \pm \mathbf{0.05}$ (stat.) $\pm$ $\mathbf{0.05}$ (syst.)

In LLA BFKL (for $\alpha_s(20\,\mathrm{GeV}) = 0.17$):

$\alpha_{\mathrm{BFKL}} = 1.45$

Conclusions

- **Dijet cross section for $\Delta\eta > 2$** measured @ $\sqrt{s}$ = 1800 GeV and 630 GeV
- Strong rise of the dijet cross section seen as a function of $\sqrt{s} \Leftrightarrow \Delta\eta$
- Energy increase (R) is qualitatively consistent with BFKL predictions
- However R is larger than all quantitative predictions
- The BFKL intercept has been extracted at **Q=20 GeV**:

  $\alpha_{BFKL} = 1.65 \pm .05(stat) \pm .05(syst)$
- These results have recently been published: PRL 84,5722(2000)