BFKL Studies at DØ

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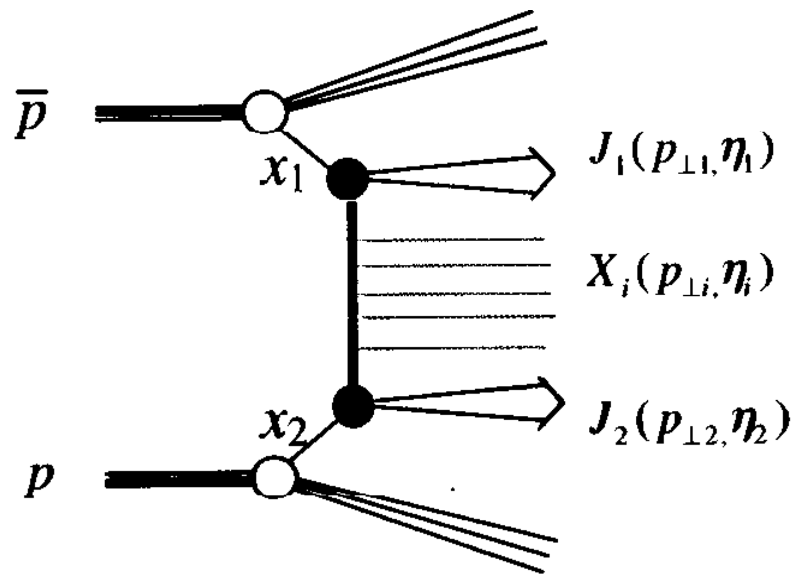
BFKL Dynamics at the Tevatron

- Inclusive dijet production at large rapidities

$$p + \overline{p} \rightarrow J_1(p_{\perp 1}, \eta_1) + J_2(p_{\perp 2}, \eta_2) + X$$

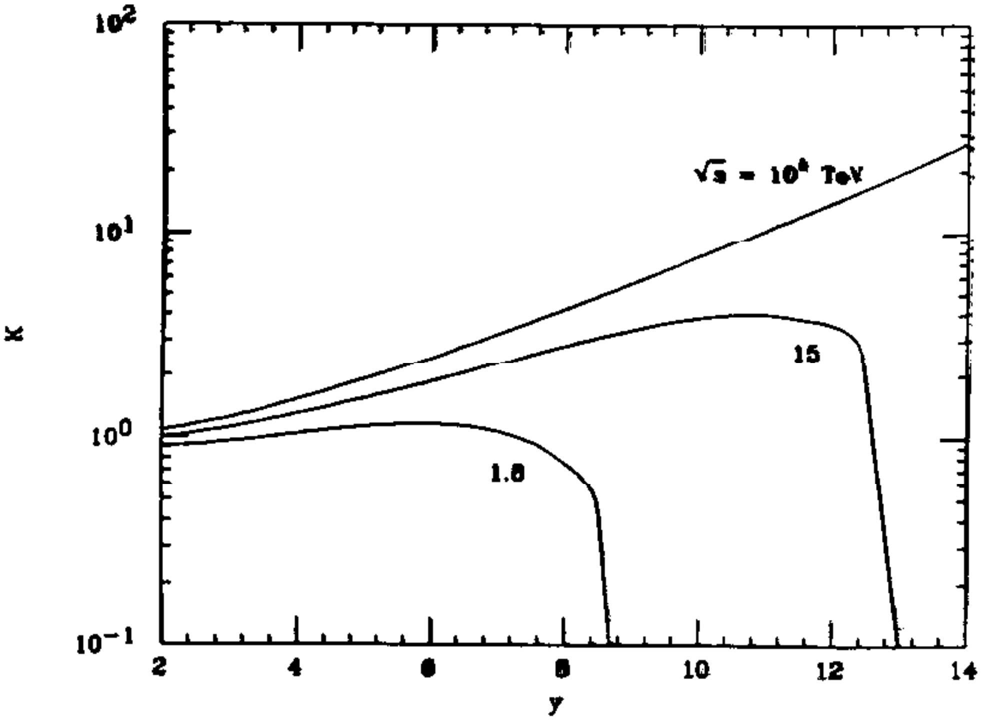
$$\sigma_{dijet} = x_1 P_1(x_1, Q^2) x_2 P_2(x_2, Q^2)\, \hat{\sigma}$$



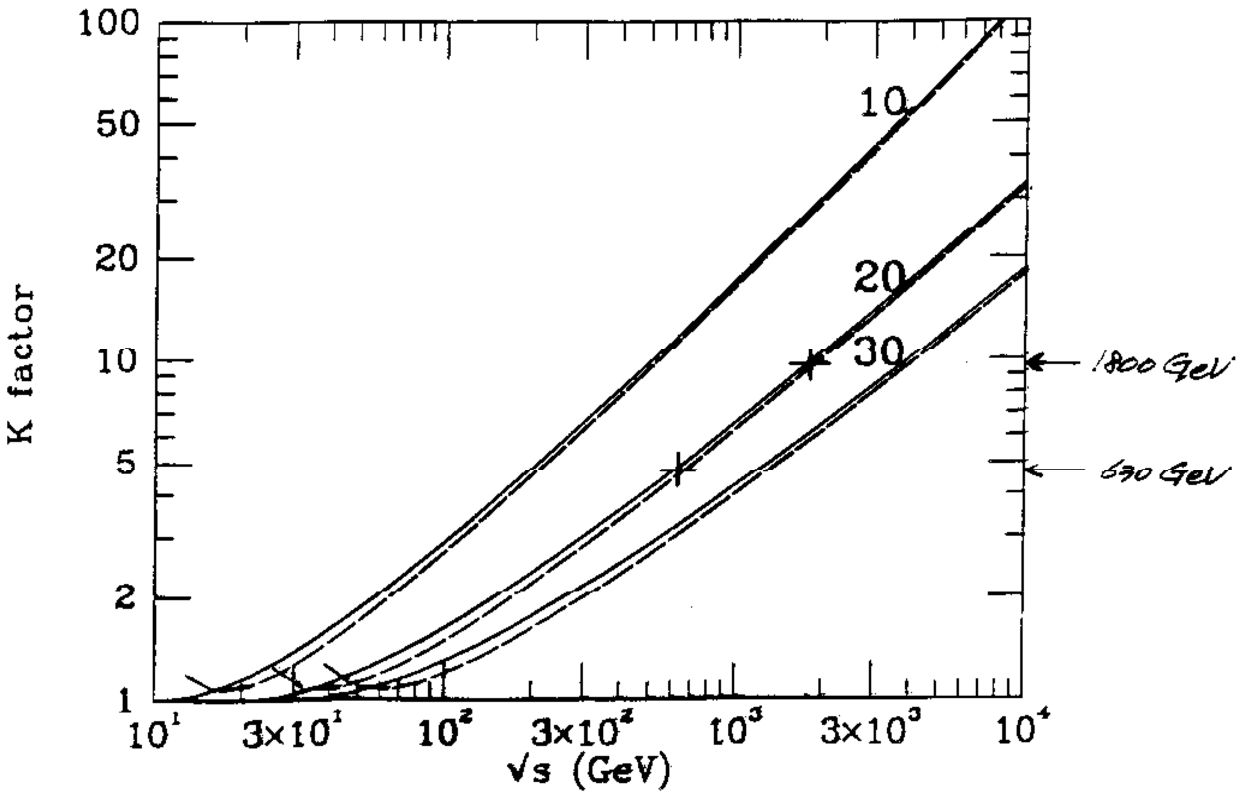
- Semi-hard region: $\Lambda_{QCD} << Q << \sqrt{\hat{s}} = \sqrt{x_1 x_2 s}$

$$\ln \frac{\hat{s}}{Q^2} \approx \eta_1 - \eta_2 = \Delta\eta >> 1$$

- Keeping large x_i allows these logarithms to factorize into the partonic cross section, $\hat{\sigma}$



10^2
10^1
10^0
10^{-1}
K
y
2
4
6
8
10
12
14
√s = 10⁴ TeV
15
1.8



100
50
20
10
5
2
1
K factor
10¹
3×10¹
10²
3×10²
10³
3×10³
10⁴
√s (GeV)
10
20
30
1800 GeV
630 GeV

- LLA resums $(\alpha_s \Delta\eta)$ to all orders in α_s

  ⟶ BFKL equation

- The exponential growth of dijet inclusive cross section

$$\hat{\sigma}_{BFKL} \propto \frac{1}{Q^2} \frac{e^{(\alpha_{BFKL}-1)\Delta\eta}}{\sqrt{\alpha_s \Delta\eta}}, \quad \alpha_{BFKL} = \frac{12\alpha_s \ln 2}{\pi} \approx 1.5$$

- The growth rate of the total cross section, K-factor:

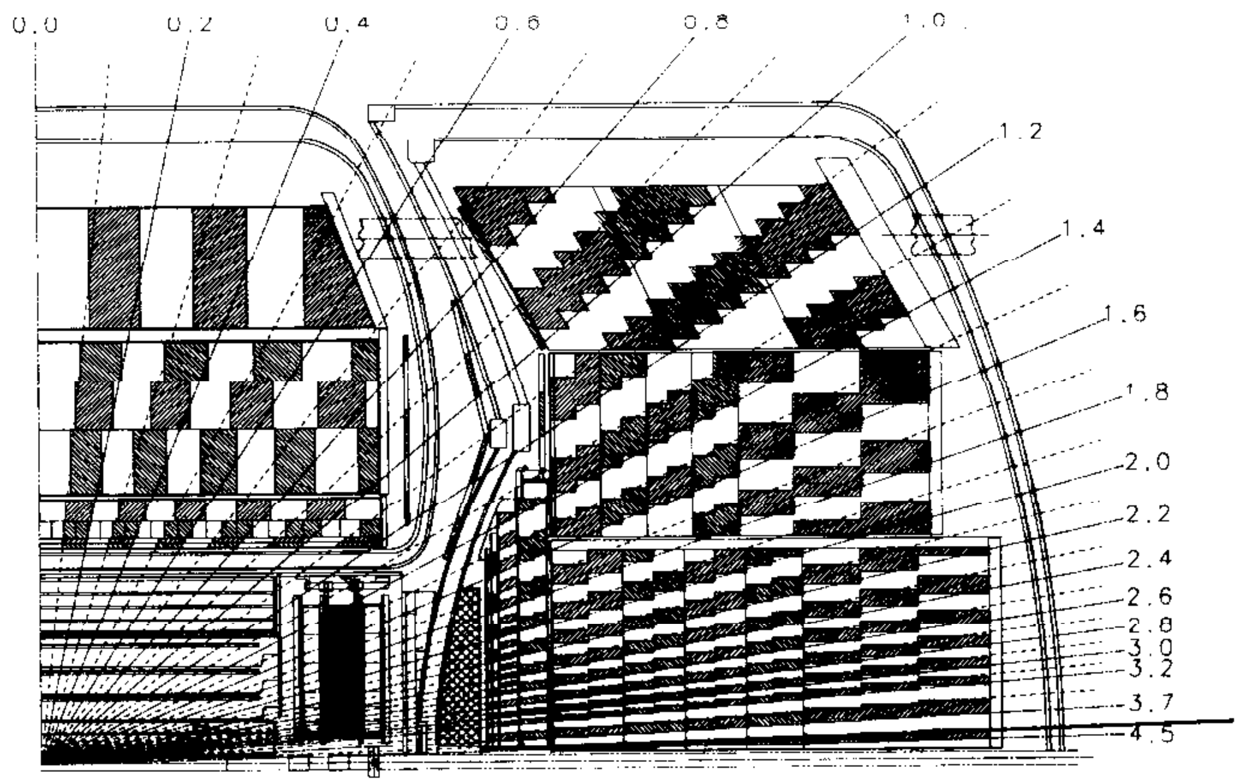
$$K = \frac{\sigma_{BFKL}}{\sigma_{Born}} \approx C \cdot \frac{e^{(\alpha_{BFKL}-1)\Delta\eta}}{\sqrt{\alpha_s \Delta\eta}}, \quad \Delta\eta = \ln \frac{\hat{s}}{p^2_{\perp \min}}, \; C \approx 3.6$$

  - K-factor vs. $\Delta\eta$ at a fixed cms energy
  - K-factor with varying the cms energy

- BFKL studies at DØ
  - Inclusive dijet cross section ratio at large rapidites: α_{BFKL}
  - Dijet decorrelation at large rapidities

The DØ Calorimeter

- Hermetic coverage over large rapidity ($|\eta| < 4.0$)
- Fine transverse segmentation (0.1×0.1 in $\Delta\eta \times \Delta\phi$)
- Excellent jet energy response and resolution



1800/630 GeV Dijet Cross Section Ratio

- Inclusive dijet cross section at large rapidities

$$\sigma \propto x_1 P_1(x_1, Q^2) x_2 P_2(x_2, Q^2) \frac{1}{Q^2} \frac{e^{(\alpha_{BFKL}-1)\Delta\eta}}{\sqrt{\alpha_s \Delta\eta}}$$

- Mueller and Navelet suggested a method to explore BFKL dynamics by describing s dependence (Nucl. Phys. B282 (1987) 727)
- Fix x_1, x_2, Q^2 and take the ratio of the cross sections at two different center of mass energies, s_A and s_B

$$R(s_A, s_B) = \frac{\sigma(x_1, x_2, Q^2, s_A)}{\sigma(x_1, x_2, Q^2, s_B)} = \frac{e^{(\alpha_{BFKL}-1)\ln(s_A/s_B)}}{\sqrt{\Delta\eta_A / \Delta\eta_B}}$$

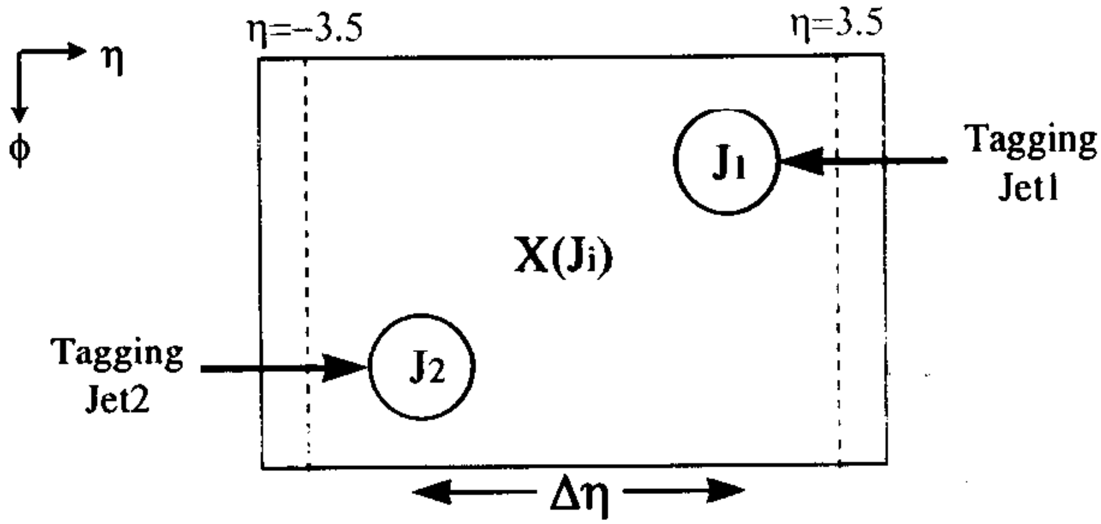
  - Cancellation of the parton distribution functions
  - Elimination of large source of theoretical error
  - Cancellation of many experimental errors

- By measuring R(1800,630) at the Tevatron, we can probe the perturbative BFKL dynamics and extract the effective coupling of the BFKL pomeron, α_{BFKL}

	BFKL	LO	HERWIG
R	~1.7	1.0	~1.4

Event topology and Analysis variables

- Inclusive dijet: $p+\bar{p} \rightarrow J_1(\eta_1,\phi_1)+J_2(\eta_2,\phi_2)+X(J_i)$



Rapidity ordering: $\eta_1 > \eta_i > \eta_2$

- Analysis variables:

$$\Delta\eta = \eta_1 - \eta_2$$

$$Q^2 = E_{T1}\,E_{T2}$$

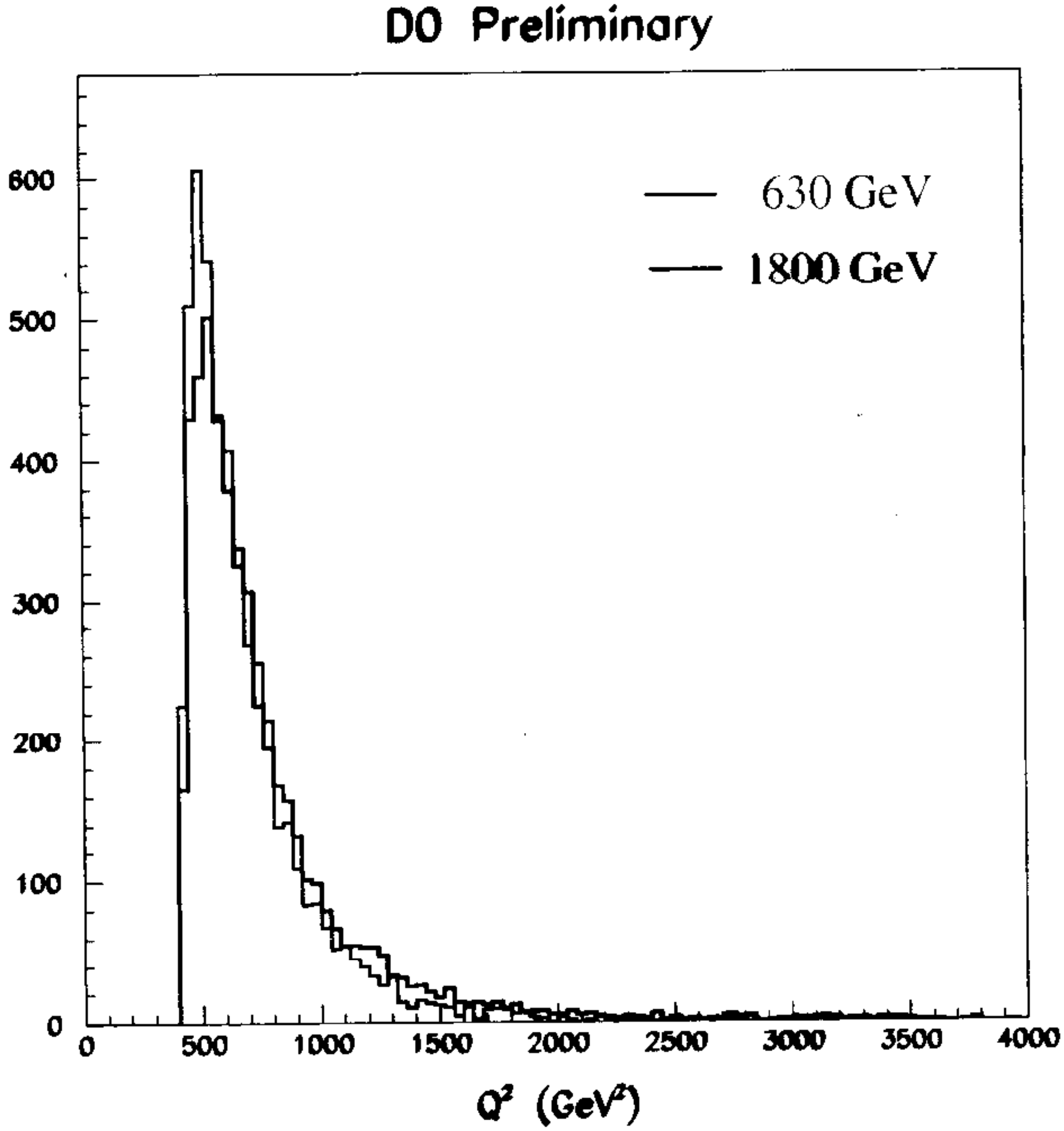
$$x_{1,2} = \frac{2E_{T1,2}}{\sqrt{s}}\,e^{\pm\bar{\eta}}\cosh\Delta\eta$$

where $\bar{\eta} = (\eta_1 + \eta_2)/2$

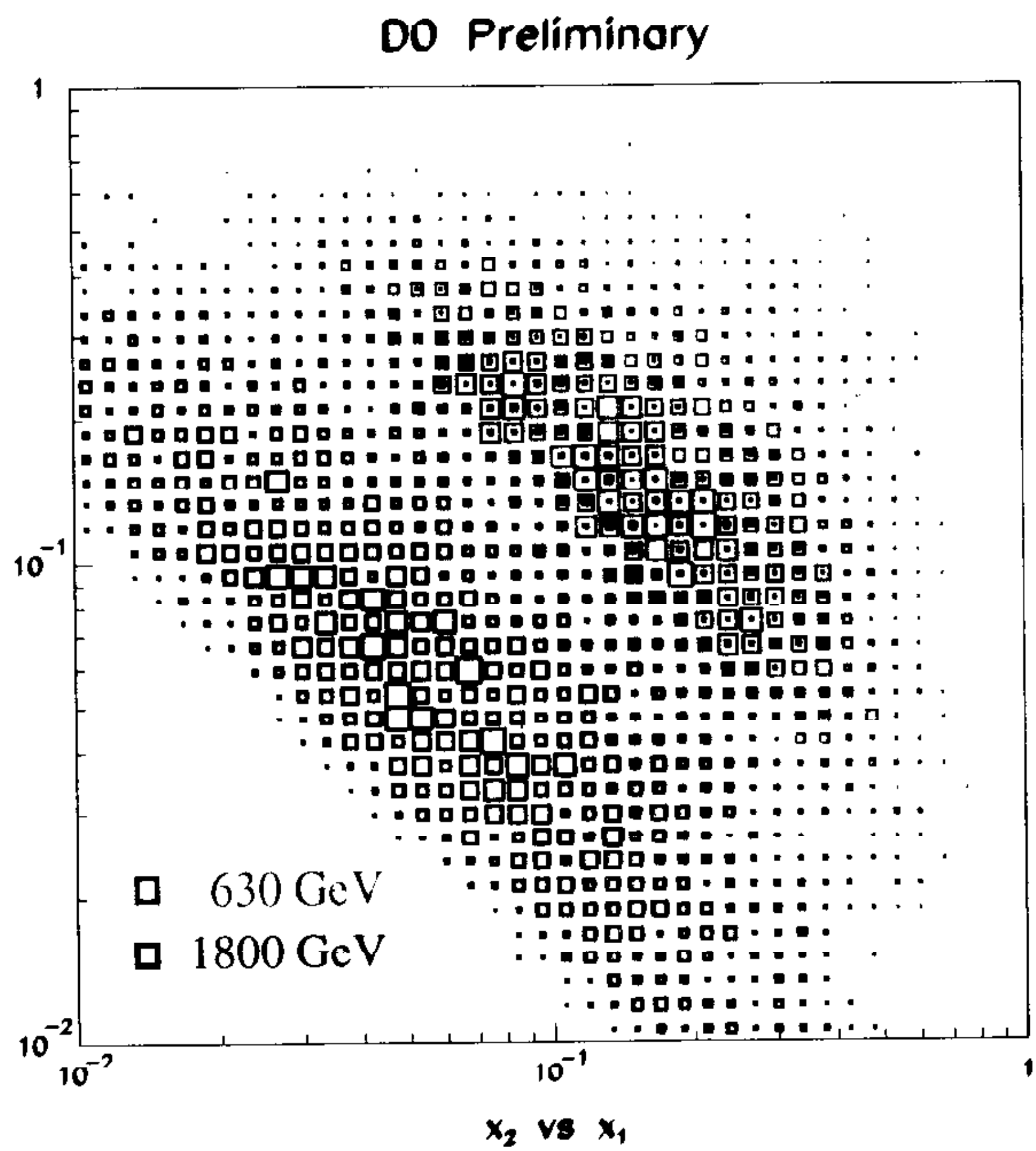
Q^2 and x

- Data set
  - 1800 GeV: 50 hour special runs during 1994-1995
  - 630 GeV: 3 weeks runs in Dec. 1995
- Offline cuts
  - Single interaction only
  - Spurious jets removed
  - $E_T > 20$ GeV, $|\eta| < 3.5$
  - tagging two jets at extremes of rapidity
  - $\Delta\eta > 2.0$
- Q^2 bin : 400 - 1000 GeV^2
- 9 (x_1, x_2) bins: multiple measurements of R

Q^2 Distributions



$x_1\ x_2$ Distributions



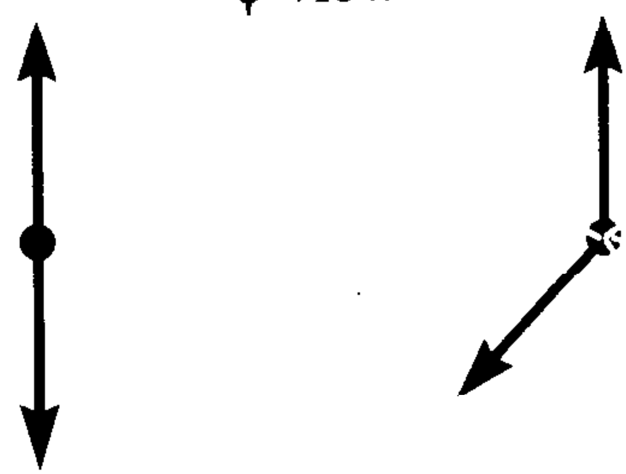
Status

- Work in progress to measure cross sections
  - energy scale and resolution effects
    at low E_T over all rapidities
- Directly sensitive to BFKL dynamics

Dijet decorrelation at large rapidities

- Tevatron at the fixed cms energy
  - At large $\Delta\eta$ ($x \rightarrow 1$), the total dijet cross section is suppressed by parton distribution functions
  - Difficult to see the growth of cross section with $\Delta\eta$
  - Look for evidence of additional radiation as $\Delta\eta$ increases
- Azimuthal Angle Decorrelation

ϕ-view



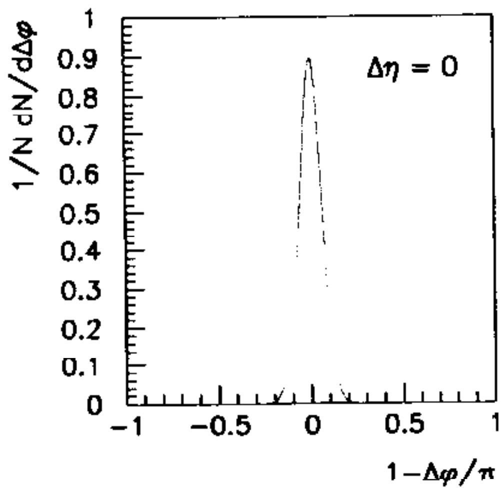
LO: $\Delta\phi=\pi$
$\Delta\eta = 0$

More radiation
$\Delta\eta >> 0$

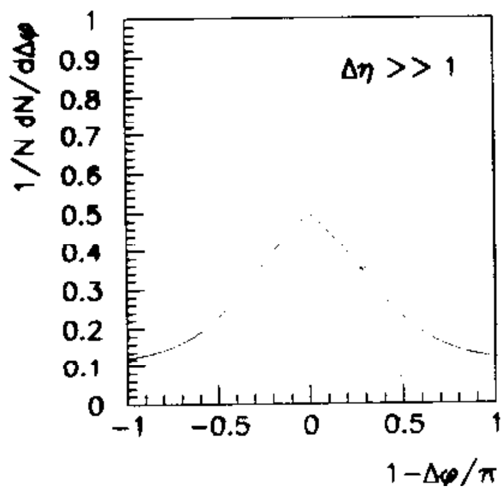
- **Measuring Azimuthal Decorrelation**

  Qualitative: broadening $1/N\, dN/d\Delta\phi$ as $\Delta\eta$

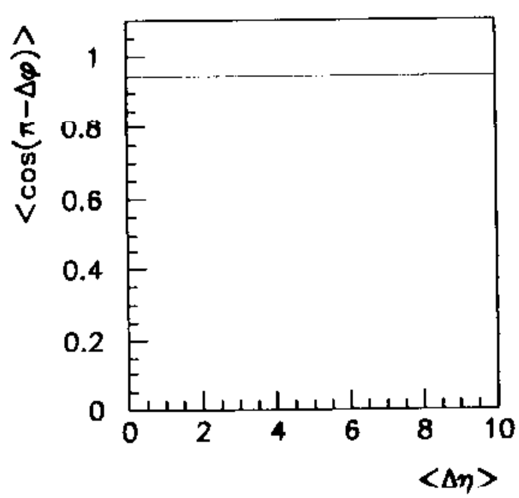
  Quantitative: falling off $<\cos(\pi-\Delta\phi)>$ as $\Delta\eta$



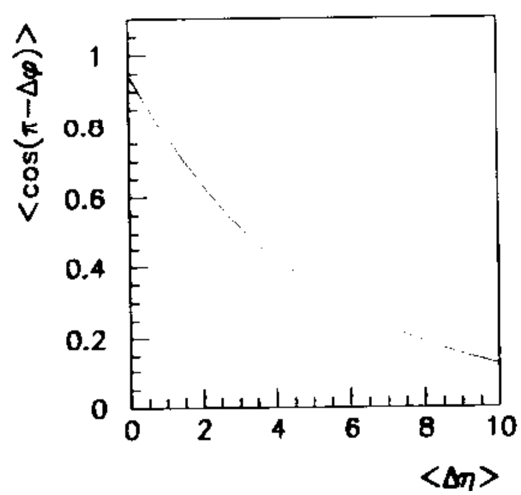
Back-to-back in azimuth



Rondom in azimuth



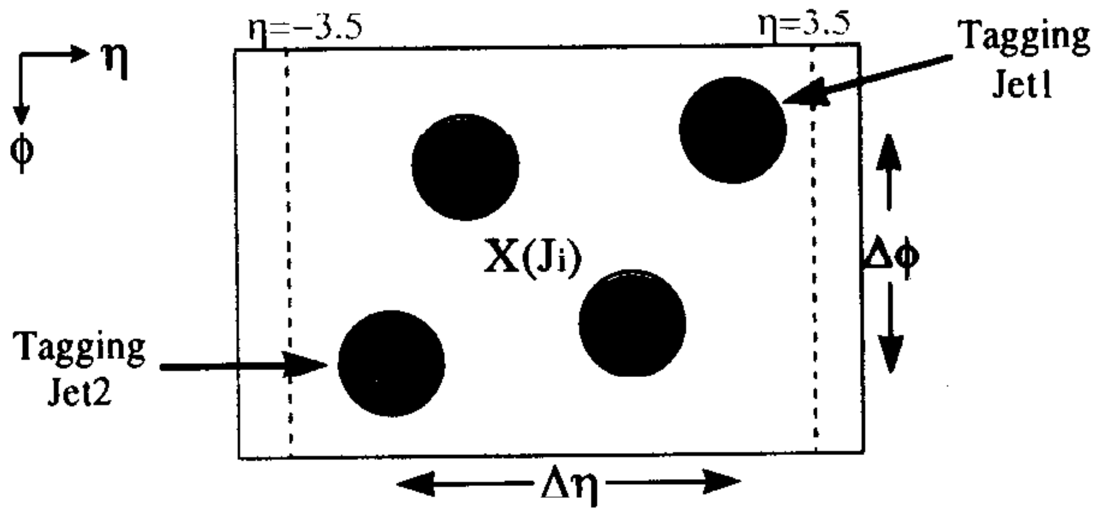
Born-Level



Multi-porton Dynamics

Event topology and Analysis variables

- Inclusive dijet: $p+\bar{p} \rightarrow J_1(\eta_1,\phi_1)+J_2(\eta_2,\phi_2)+X(J_i)$



Rapidity ordering: $\eta_1 > \eta_i > \eta_2$

- Analysis variables:

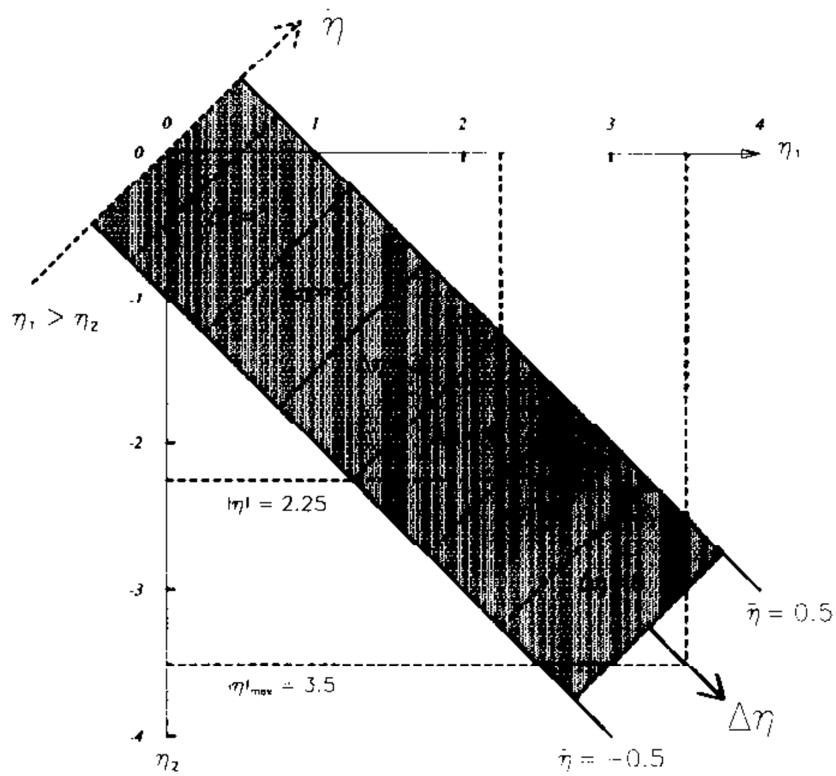
$\Delta\eta = \eta_1 - \eta_2$ Rapidity interval

$\Delta\phi = \phi_1 - \phi_2$ Separation in azimuth

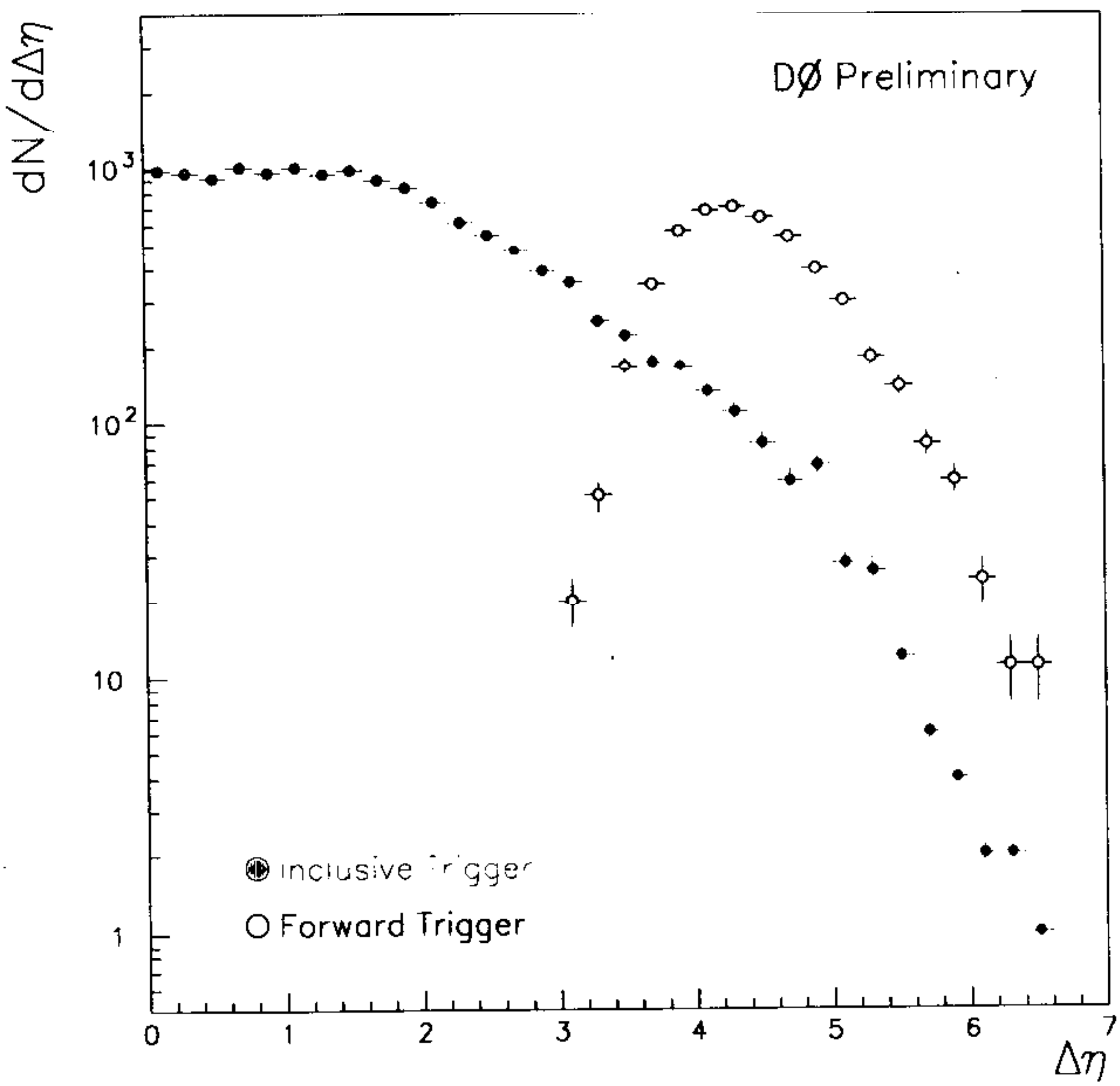
$\bar{\eta} = (\eta_1 + \eta_2)/2$ Rapidity boost

Event Selection and Analysis Cuts

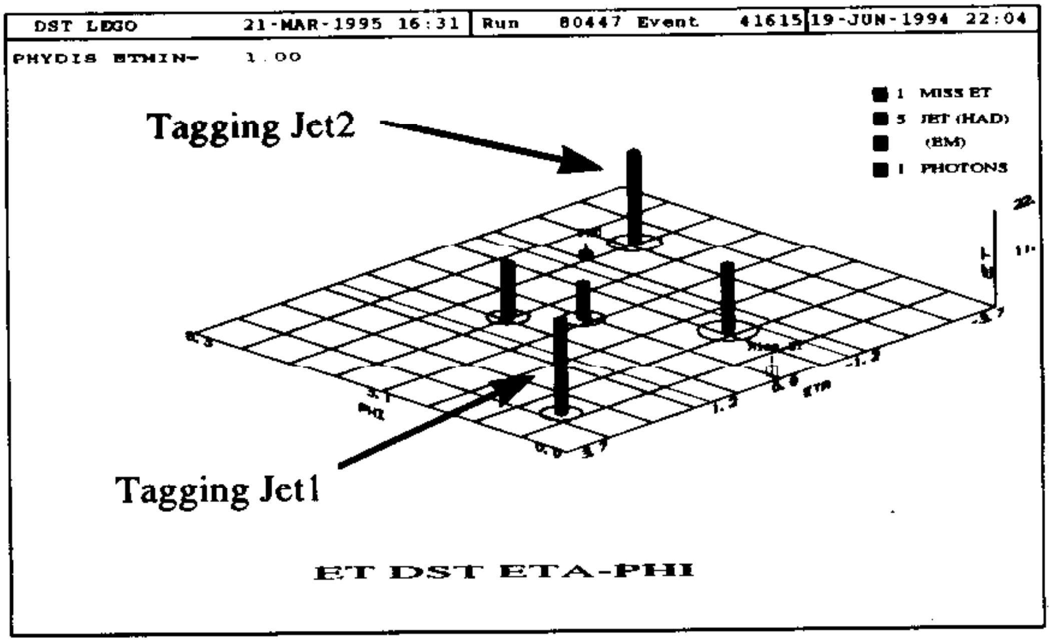
- Single jet triggers: Inclusive: Et > 12 GeV
  Forward: Et > 12 GeV and $|\eta| > 1.6$
- Multiple $p\bar{p}$ interaction events and spurious jets removed
- Select analysis jets: Et > 20 GeV and $|\eta| < 3.5$
- Tagging jets at the extreme rapidities: $(\eta_1,\phi_1),(\eta_2,\phi_2)$
- Boost cut: $|\bar{\eta}| < 0.5$
- Forward trigger η efficiency cut: $\mathrm{Max}(|\eta_1|,|\eta_2|) > 2.25$

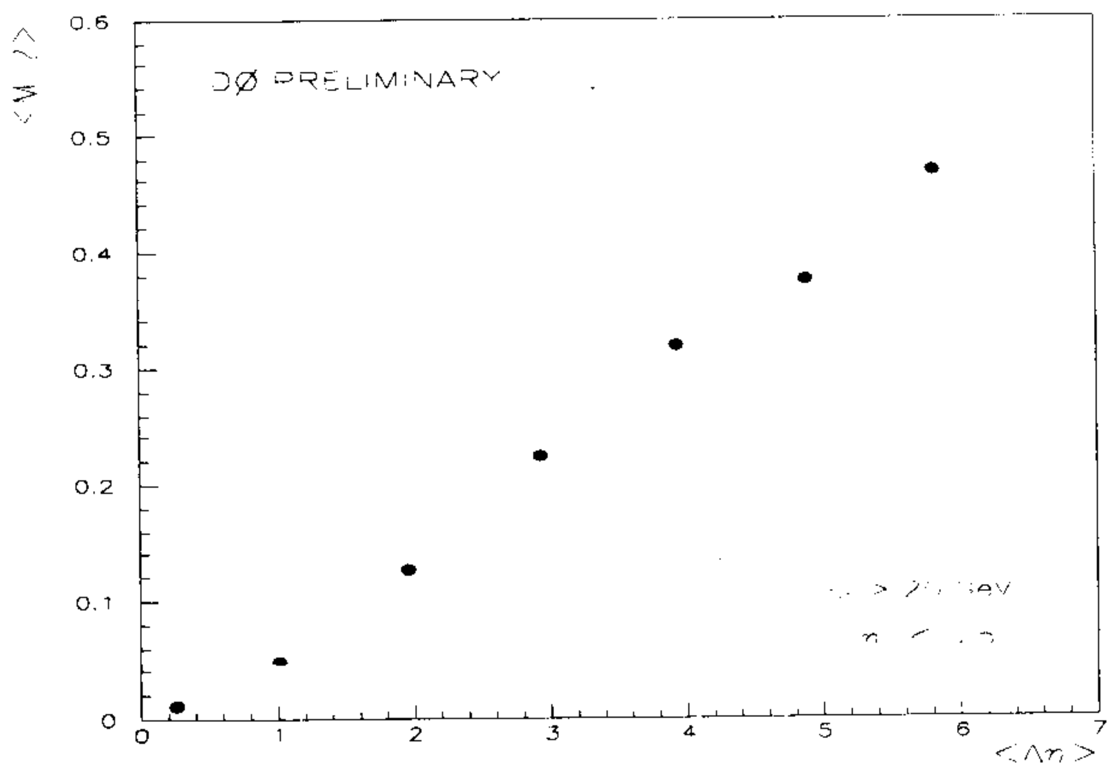


Δη Distribution

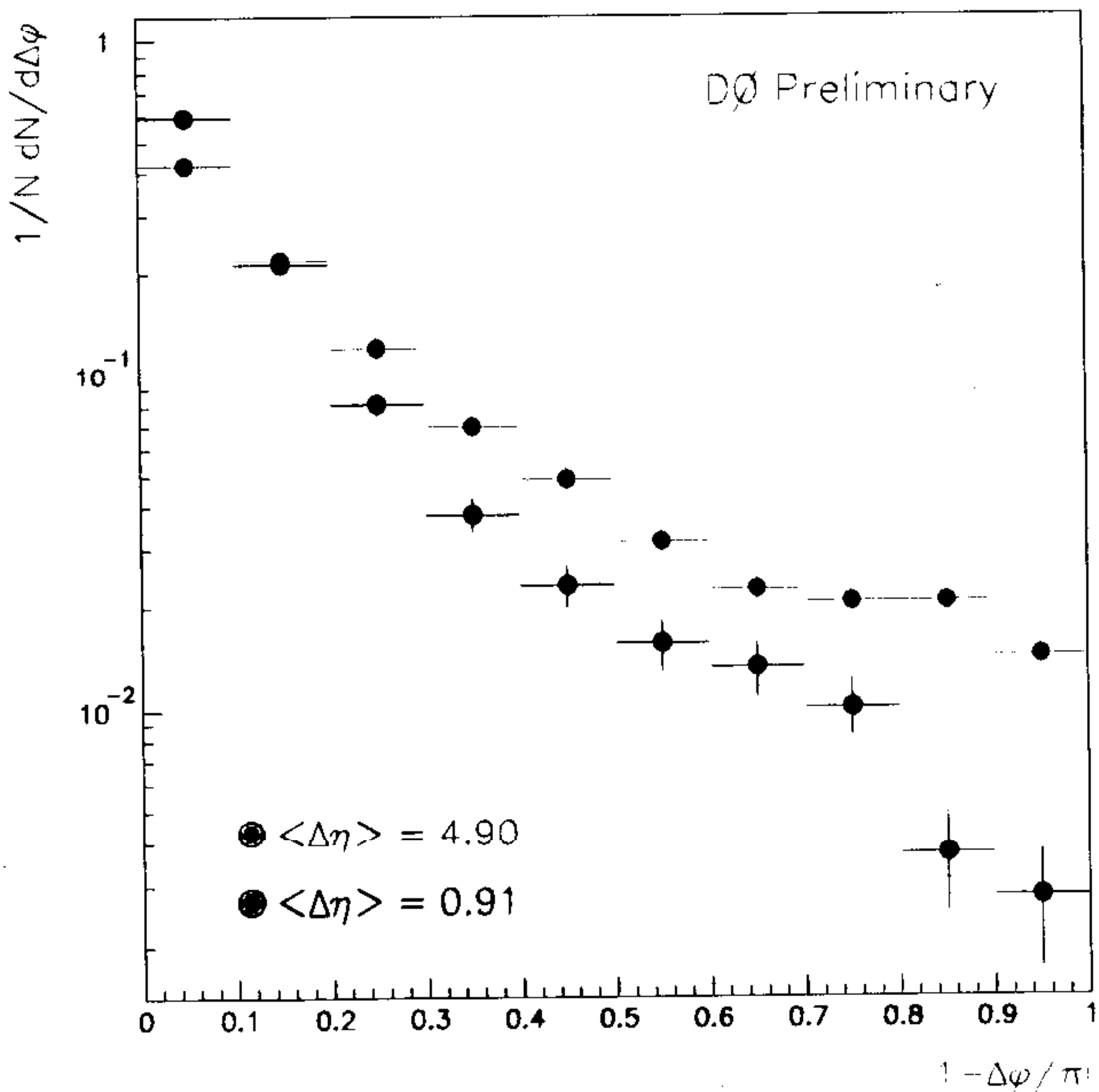


Multi-jet Event and Average Jet Multiplicity

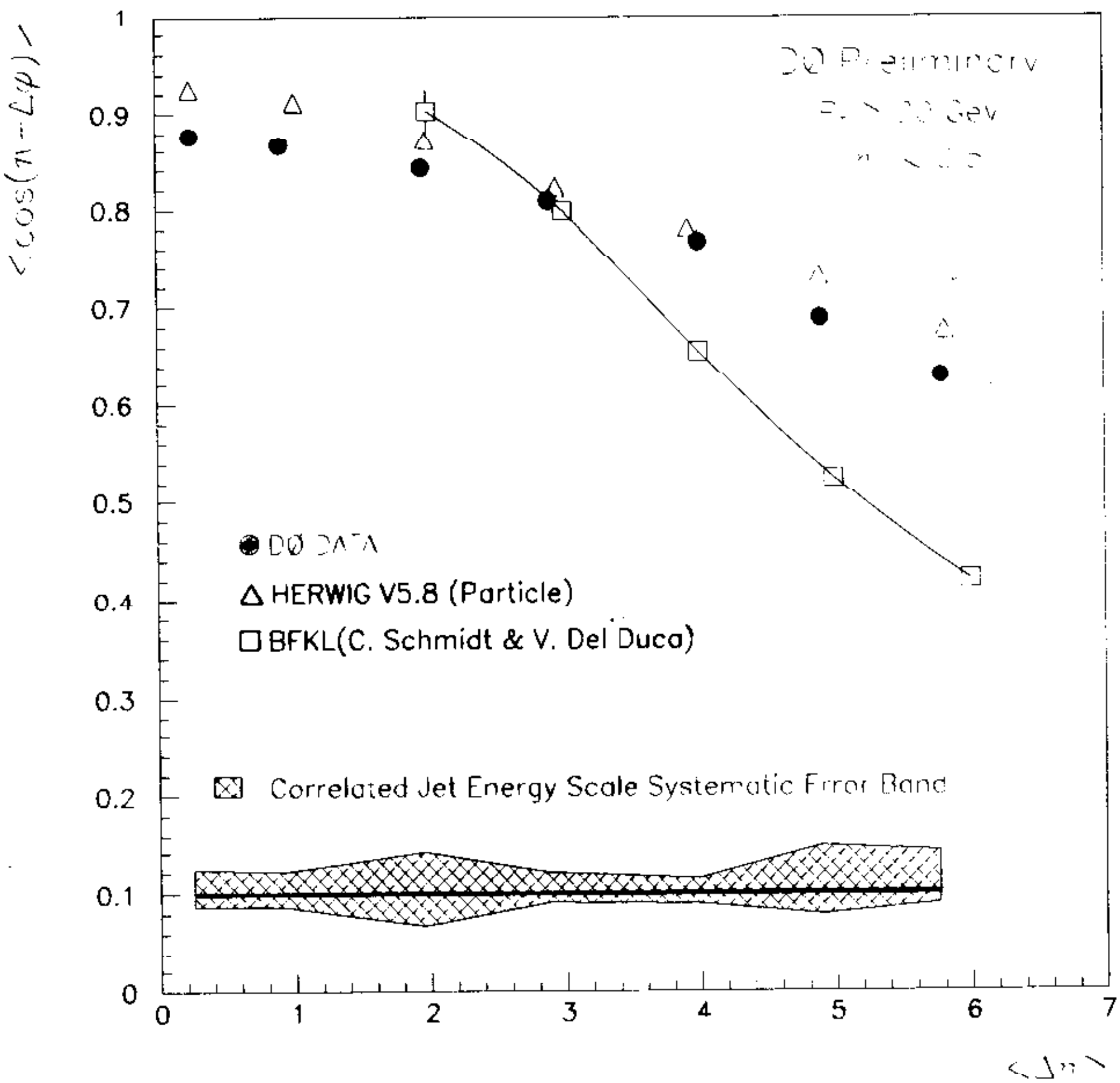




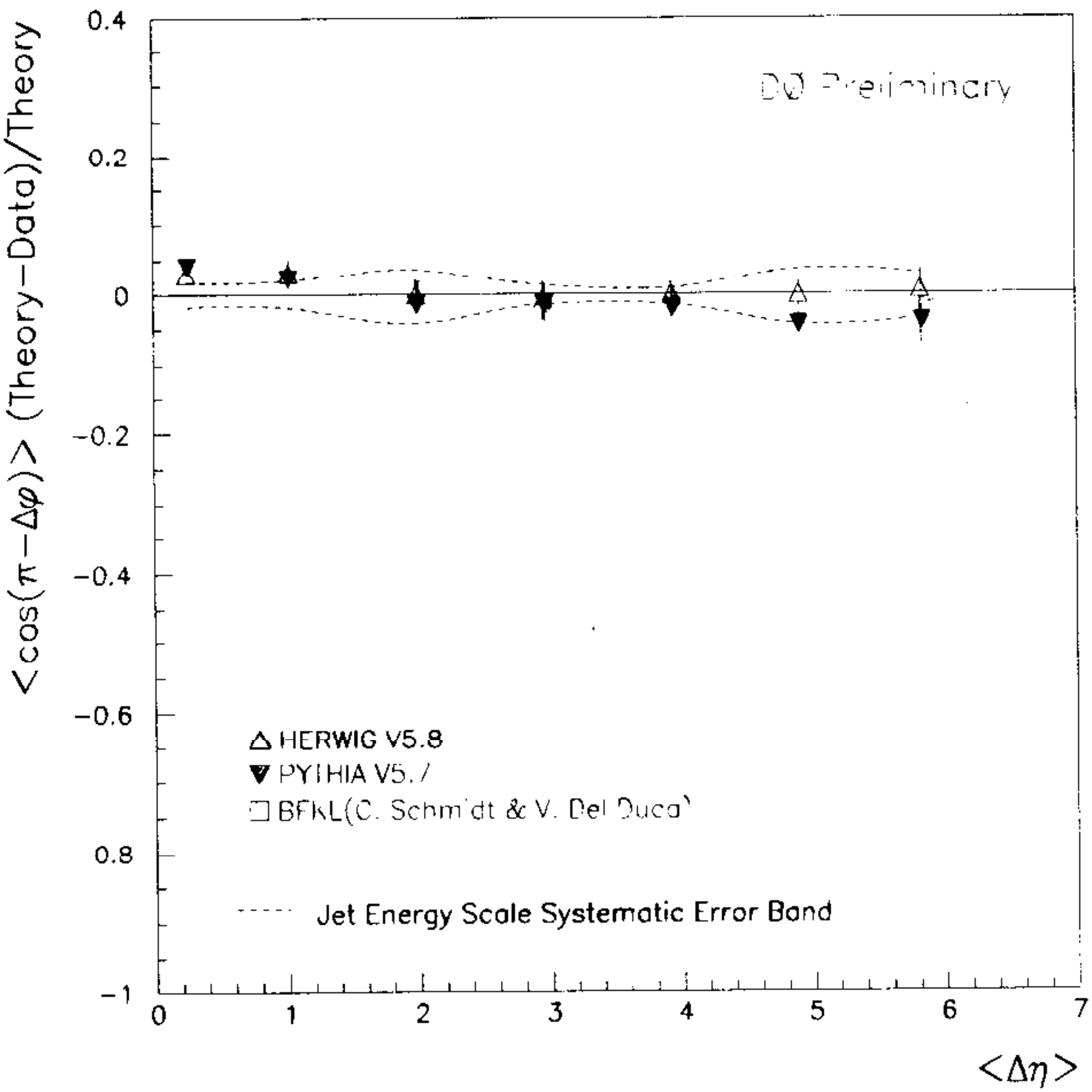
1/N dN/dΔφ vs. Δη



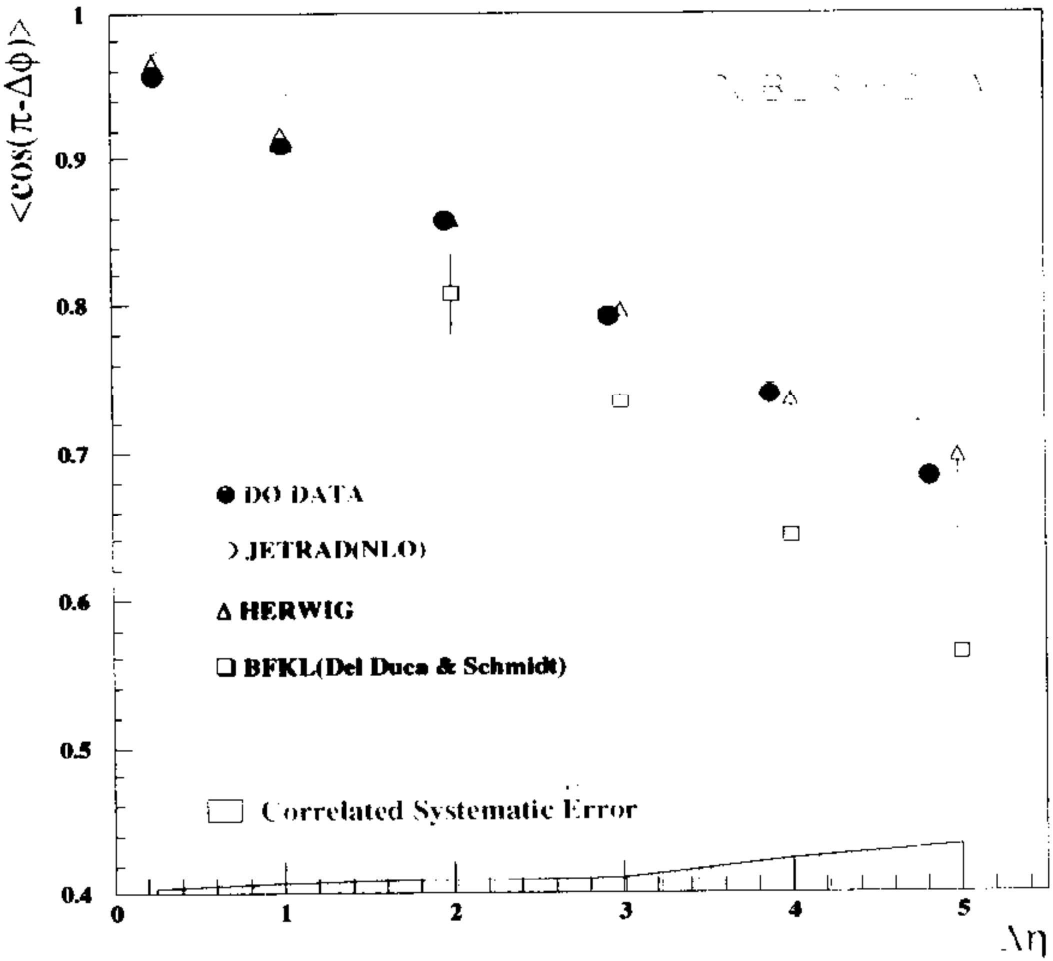
$<\cos(\pi-\Delta\phi)>$ vs. $\Delta\eta$



(Theory - Data) / Theory



Published 1A Result: PRL, 77, 595 (1996)



	1A	1B	COMMENT
ET THRESHOLD CUT	Asymmetric Max(Et1,Et2) > 50 Min(Et1,Et2) > 20	Symmetric Min(Et1,Et2) > 20	Lower Symmetric Et cut
MAX Δη	5	6	Extended

Conclusions and Remarks in Decorrelation

- **The decorrelation in azimuth increases with the rapidity interval.** $(P_{\perp min} = 20\ GeV, \Delta\eta \leq 6)$
- **Parton shower Monte Carlos, HERWIG and PYTHIA describe the effect well over the region that we studied.**
- **The prediction based on the leading logarithmic BFKL theory does not agree with data as the rapidity interval increases.**

- Is the azimuthal decorrelation sensitive to BFKL dynamics?
- Is the kinematical region that we studied adequate to see BFKL dynamics ?
- Are next-to-leading logarithmic corrections to BFKL matrix elements significant ?

Conclusions and Comments

- Decorrelation study using symmetric and asymmetric E_T cuts show no strong BFKL signature
- Dijet cross section ratio at 630/1800 GeV study under way

- **NLL BFKL calculations in progress**
- **ΣE_T in a central rapidity bin between two widely separated jets (C. Schmidt)**