BFKL tests at Tevatron and LHC: jet gap jet cross sections

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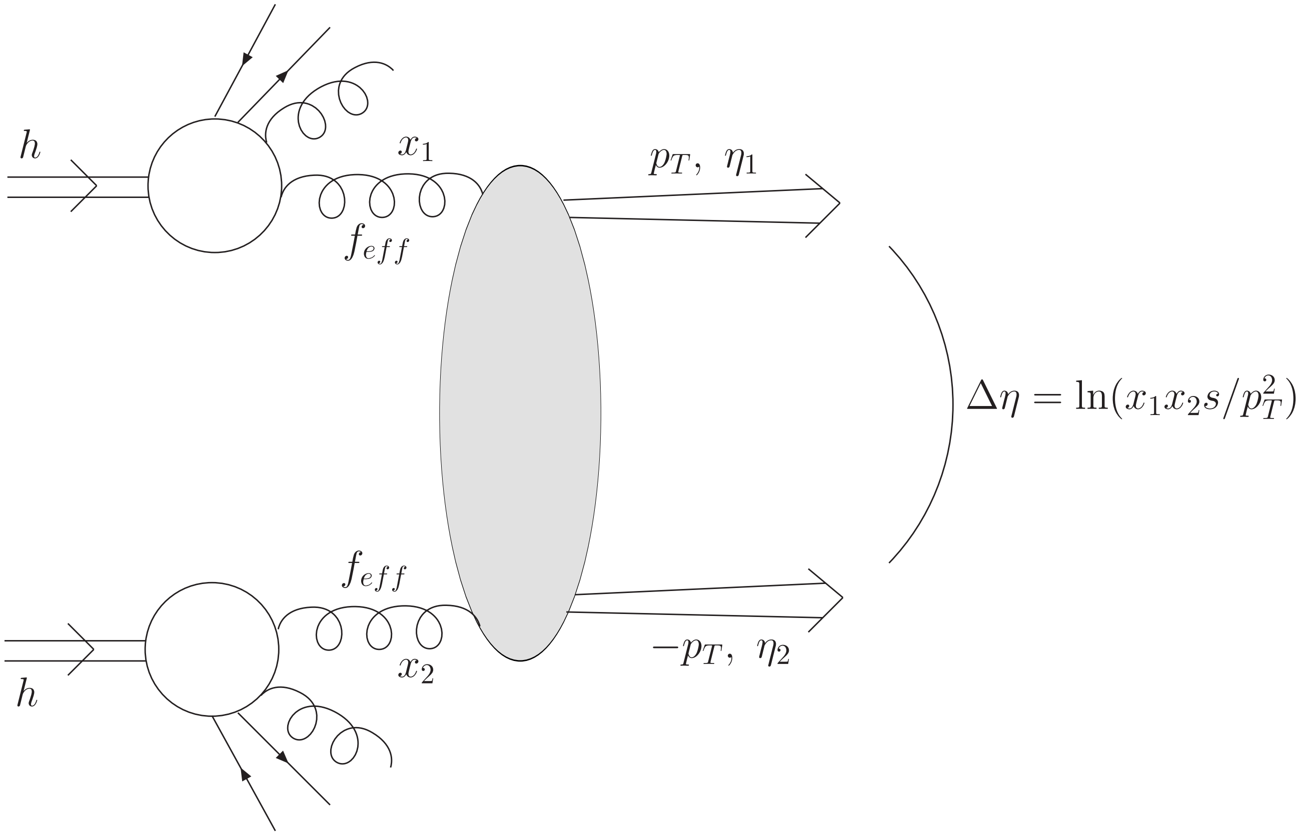
- Jet gap jet and BFKL
- Implementation in Herwig Monte Carlo
- Comparison with D0 and CDF measurements
- Predictions for LHC
- Mueller Navelet jets and effect of energy conservation in BFKL equations

Jet gap jet cross sections



- Test of BFKL evolution: jet gap jet events, large $\Delta\eta$, same p_T for both jets in BFKL calculation
- Principle: Implementation of BFKL NLL formalism in HERWIG Monte Carlo (Measurement sensitive to jet structure and size, gap size smaller than $\Delta\eta$ between jets)

BFKL formalism

- BFKL jet gap jet cross section: integration over ξ, p_T performed in Herwig event generation

$$\frac{d\sigma^{pp\to XJJY}}{dx_1 dx_2 dp_T^2} = \mathcal{S} f_{eff}(x_1, p_T^2) f_{eff}(x_2, p_T^2)$$

where S is the survival probability (0.1 at Tevatron, 0.03 at LHC) and

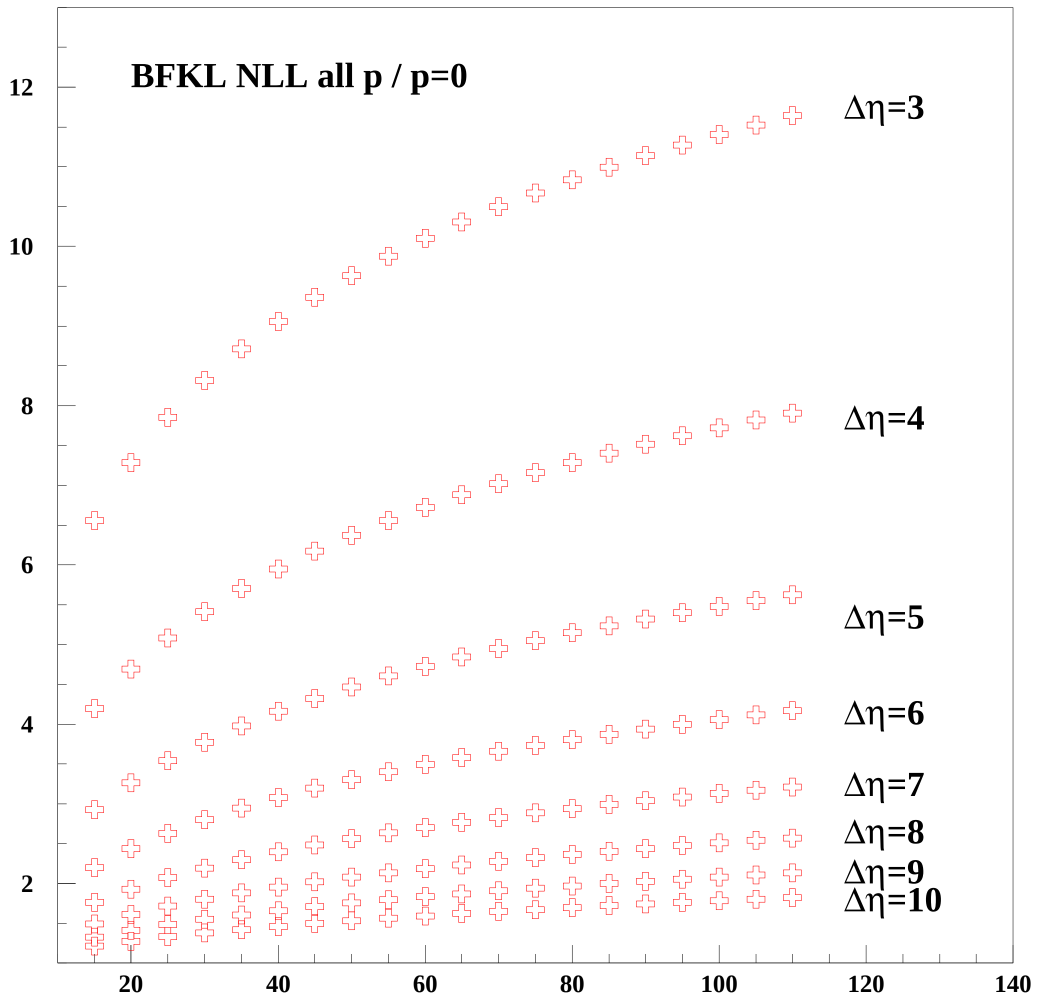
$$\frac{d\sigma^{gg\to gg}}{dp_T^2} = \frac{1}{16\pi} \left| A(\Delta\eta, p_T^2) \right|^2$$

$$A(\Delta\eta, p_T^2) = \frac{16 N_c \pi \alpha_s^2}{C_F p_T^2} \sum_{p=-\infty}^{\infty} \int \frac{d\gamma}{2i\pi} \frac{[p^2 - (\gamma - 1/2)^2]}{[(\gamma - 1/2)^2 - (p - 1/2)^2]} \times \frac{\exp\left\{ \frac{\alpha_S N_C}{\pi} \chi_{eff} \Delta\eta \right\}}{[(\gamma - 1/2)^2 - (p + 1/2)^2]}$$

- α_S: 0.17 at LL (constant), running using RGE at NLL
- BFKL effective kernel χ_{eff}: determined numerically at NLL by solving the implicit equation: $\chi_{eff} = \chi_{NLL}(\gamma, \bar{\alpha}\ \chi_{eff})$
- S4 resummation scheme used to remove spurious singularities in BFKL NLL kernel
- Implementation in Herwig Monte Carlo: Parametrised distribution of $d\sigma/dp_T^2$ fitted to BFKL NLL cross section (2200 points fitted between $10 < p_T < 120$ GeV, $0.1 < \Delta\eta < 10$ with a $\chi^2 \sim 0.1$)

BFKL formalism: resummation over conformal spins

- Study of the ratio $\frac{d\sigma/dp_T(all\ \ p)}{d\sigma/dp_T(p=0)}$
- Resummation over p needed: modifies the p_T and $\Delta\eta$ dependences...:



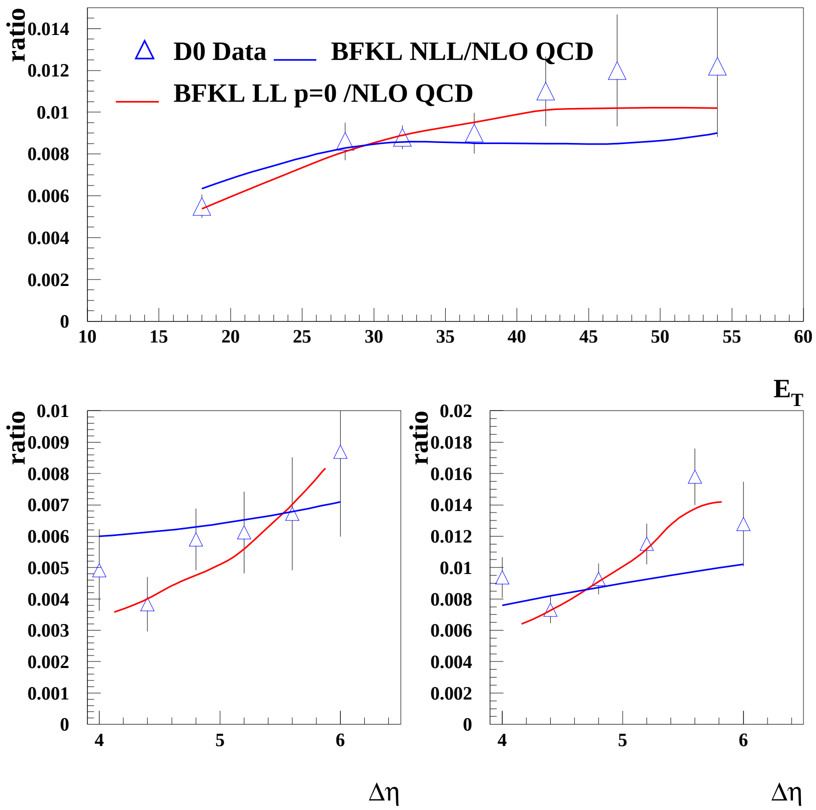
Comparison with D0 data

- D0 measurement: Jet gap jet cross section ratios as a function of second highest E_T jet, or $\Delta\eta$ for the low and high E_T samples, the gap between jets being between -1 and 1 in rapidity
- Comparison with BFKL formalism:

$$Ratio = \frac{BFKL\ NLL\ Herwig}{Dijet\ Herwig} \times \frac{LO\ QCD}{NLO\ QCD}$$

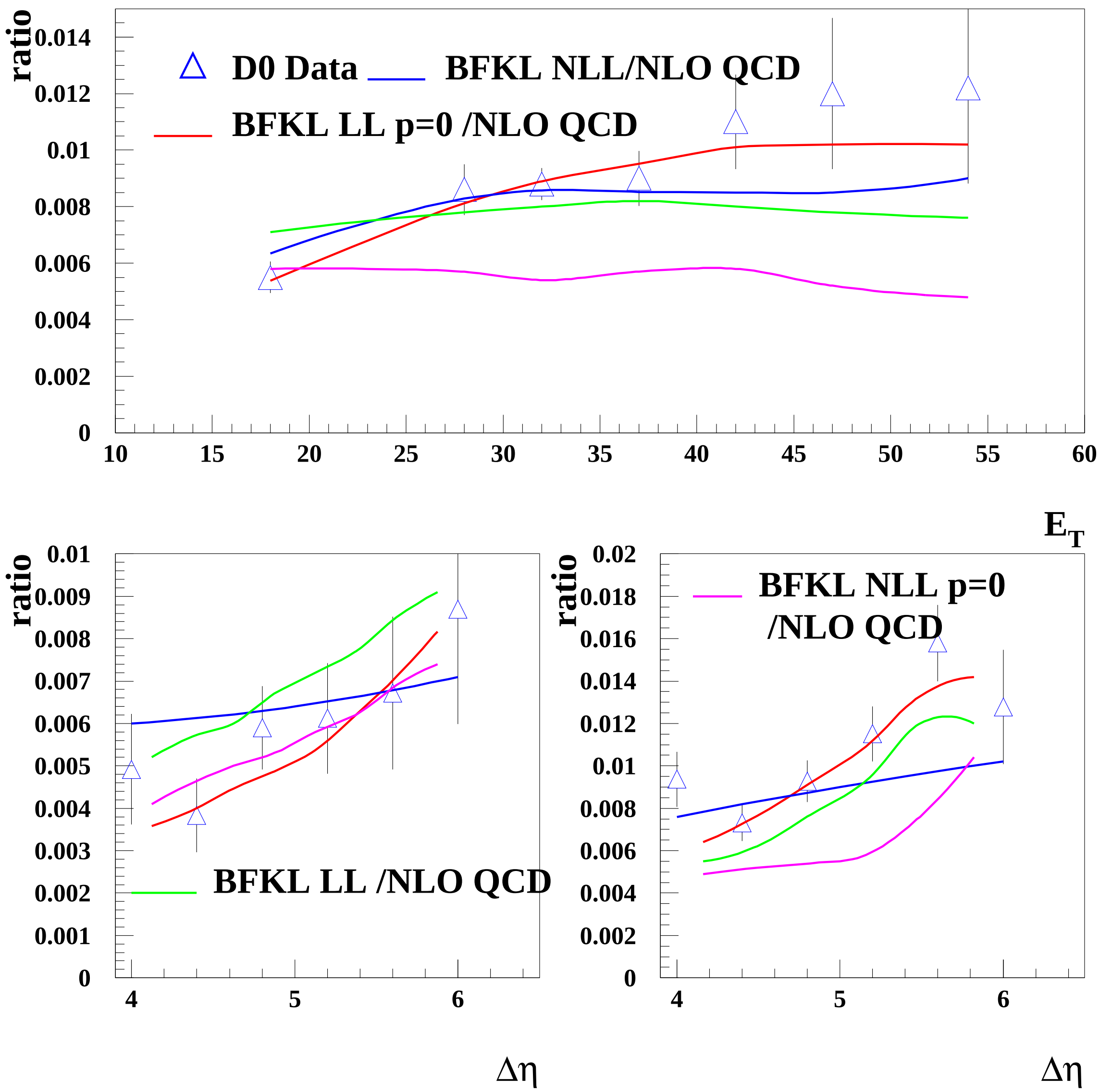
LO and NLO QCD results are obtained using NLOJet++

- Good agreement with LL (p=0) BFKL calculation (better at high p_T than with Lonnblad, Cox, Forshaw due to NLO QCD calculation), reasonable description of BFKL NLL formalism



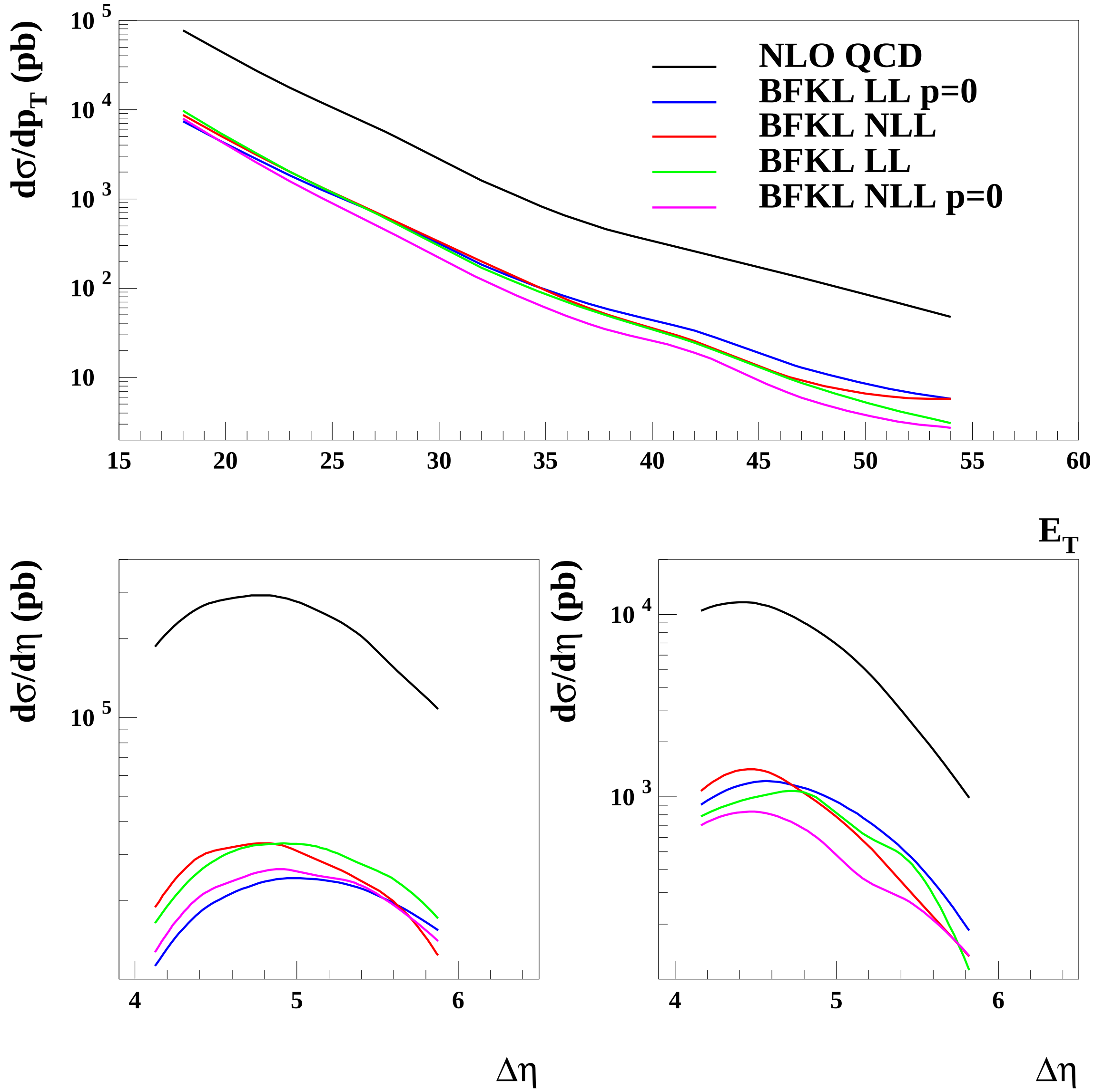
Comparison with D0 data

BFKL NLL leads to a better description than BFKL LL



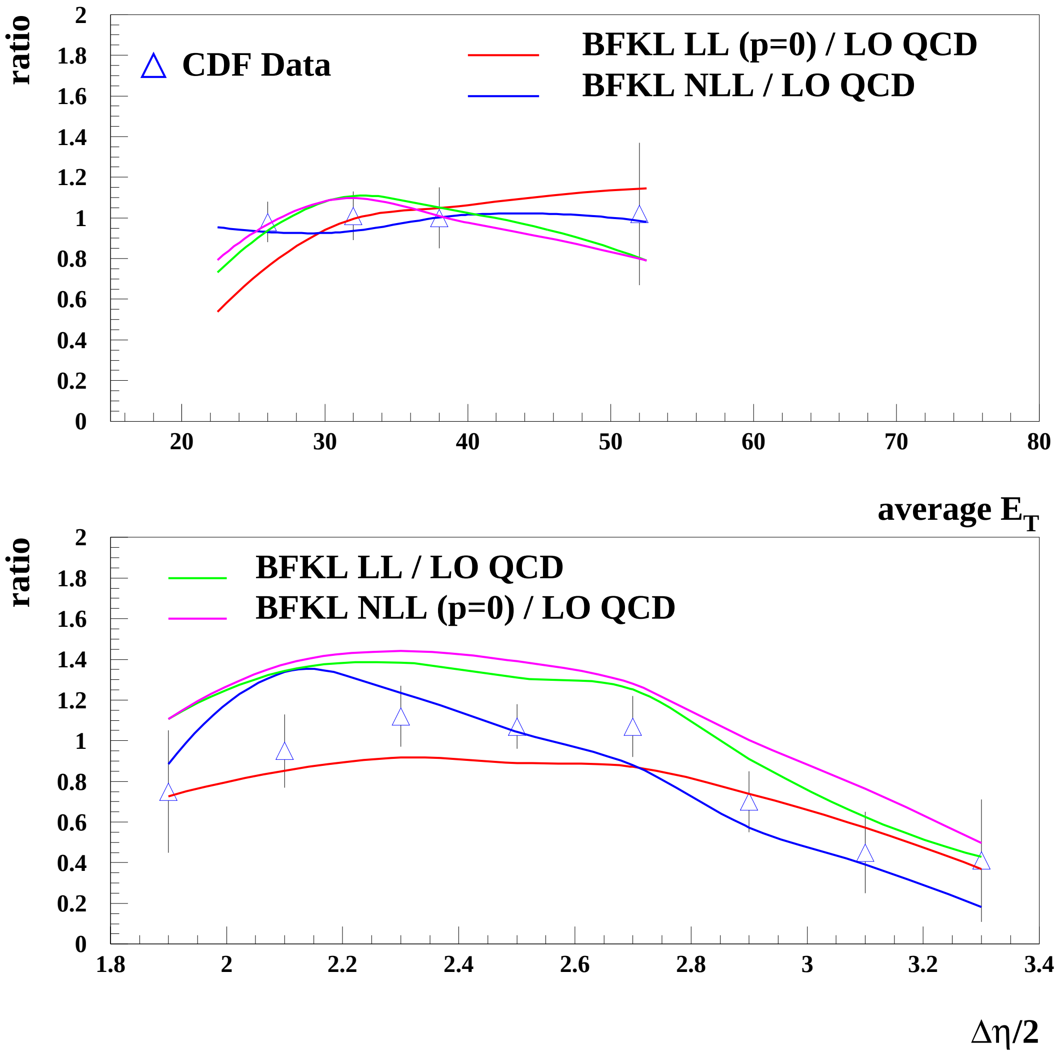
Jet gap jet cross sections

Jet gap jet cross sections at Tevatron (D0 bins): the normalisation comes from the D0 measurement



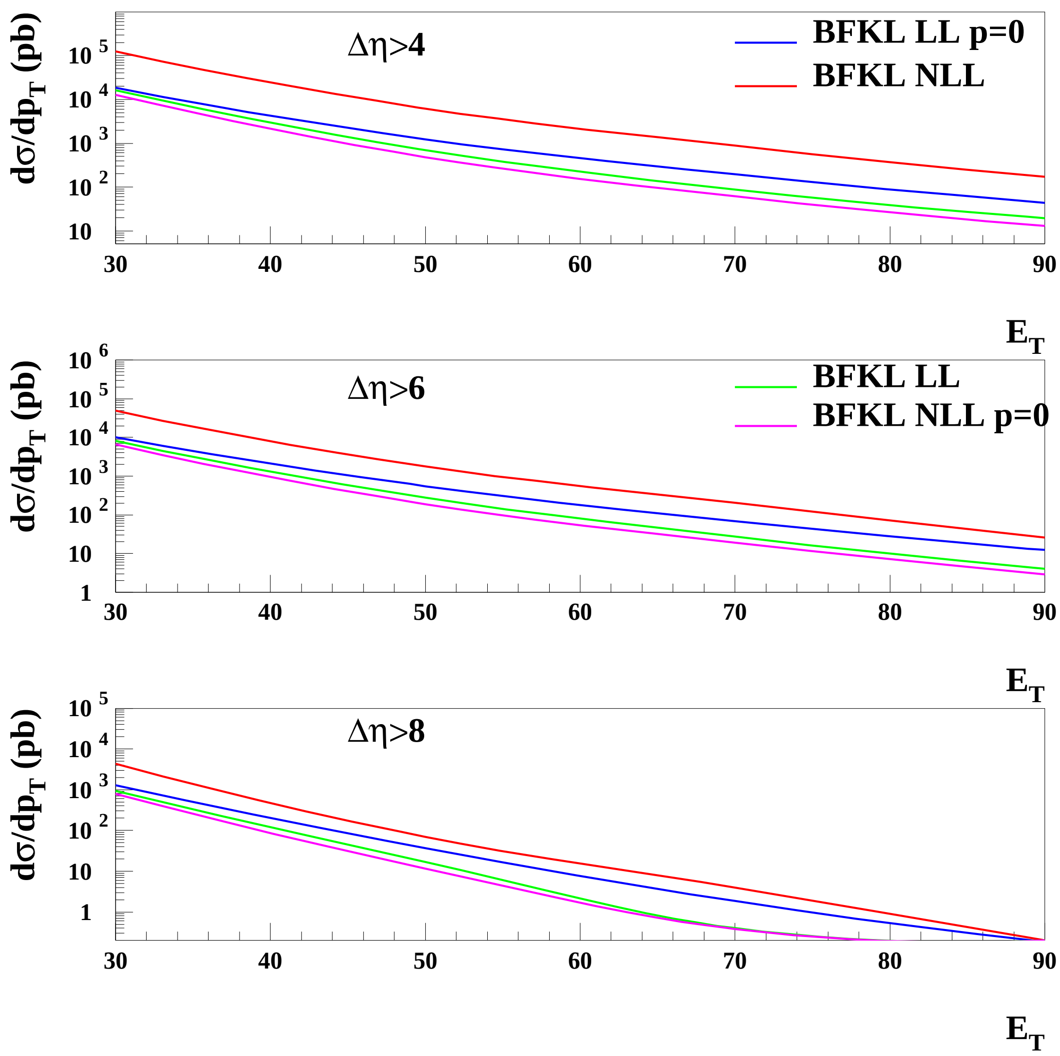
Comparison with CDF data

- Measurement of jet gap jet cross section ratio as a function of average E_T of the two leading jets, and the rapidity interval between the two leading jets divided by 2, the gap between jets being between -1 and 1 in rapidity
- BFKL NLL calculation leads to a better description than LL



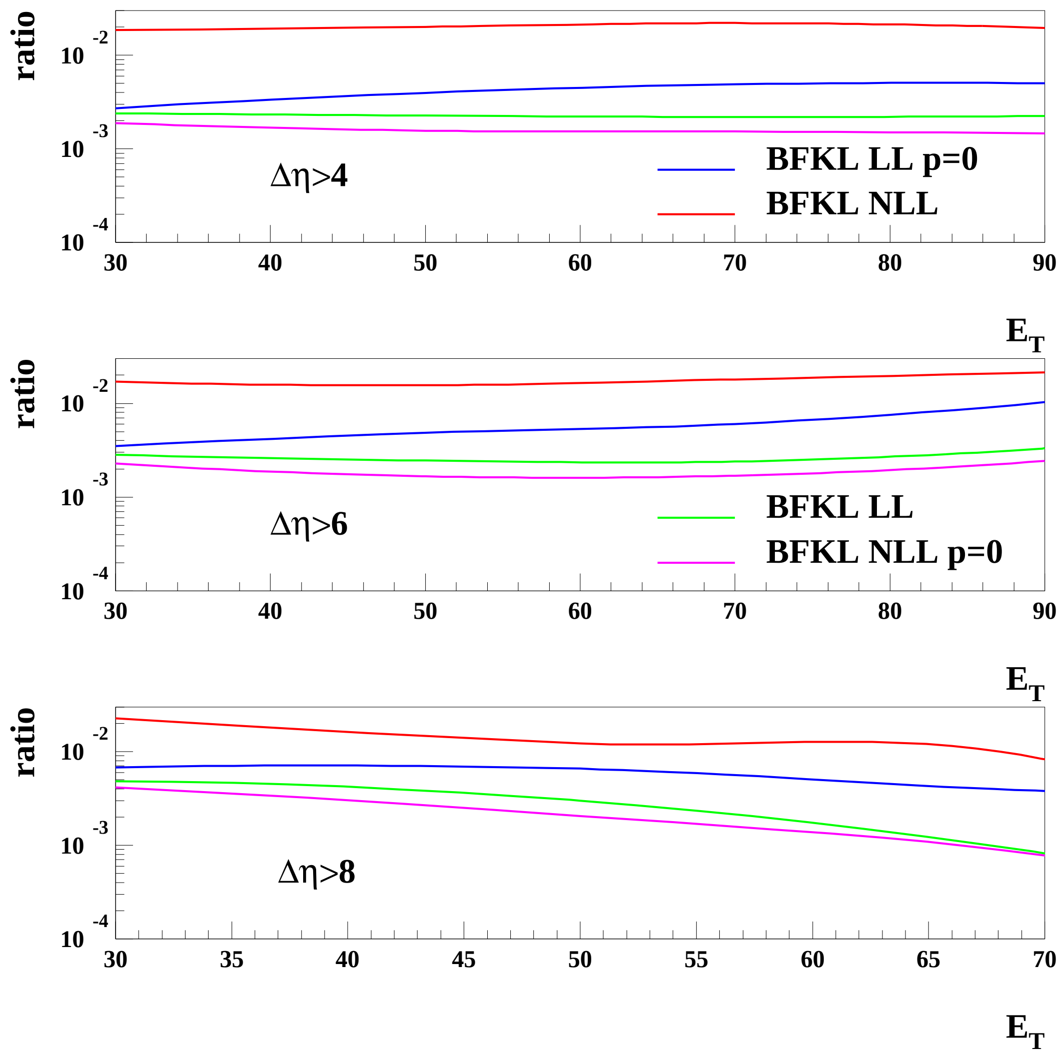
Predictions for the LHC

- Use the same BFKL NLL formalism implemented in Herwig at LHC energies
- Normalisation: apply differences of gap survival between LHC and Tevatron (0.1 and 0.03 assumed)
- Gap between -1 and 1 in rapidity assumed



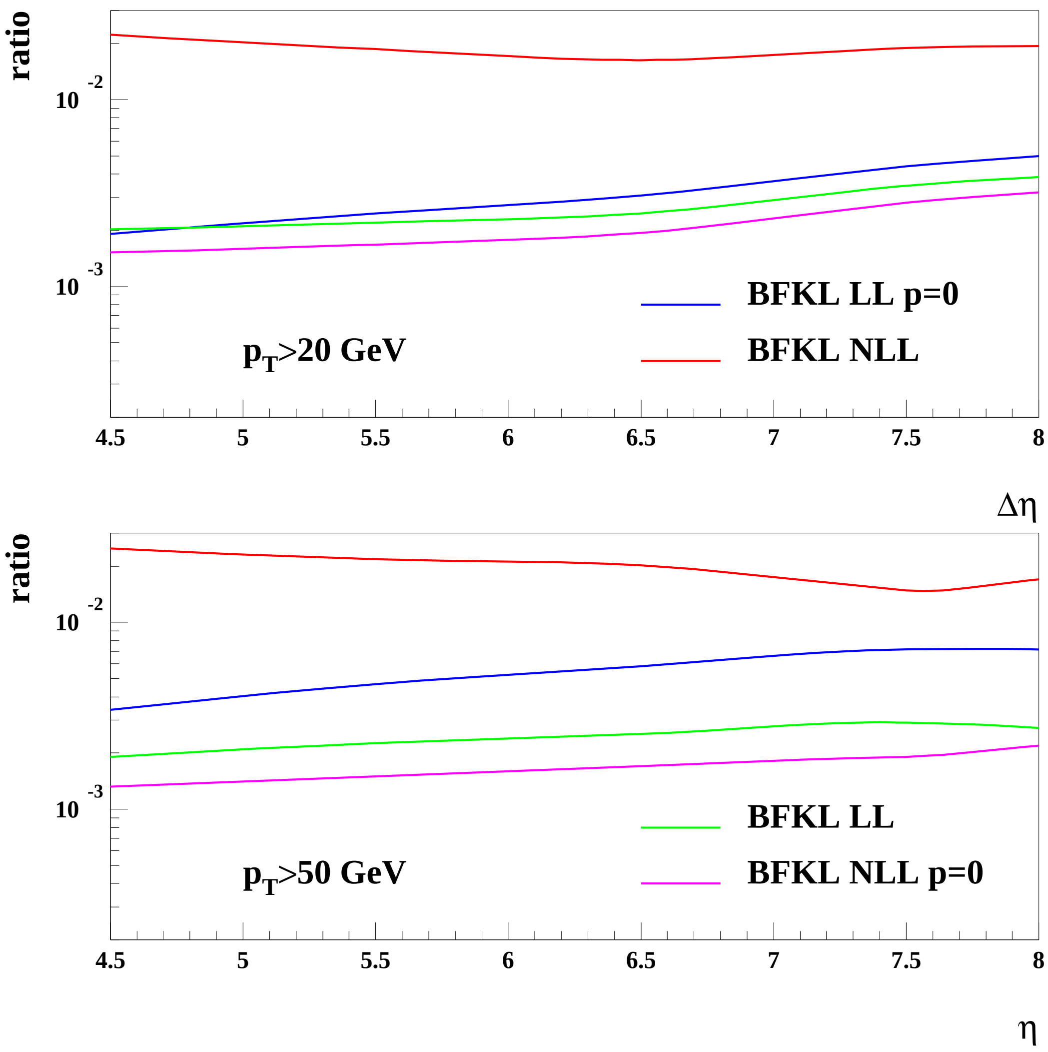
Predictions for the LHC

- Weak E_T dependence
- Large differences in normalisation between BFKL LL and NLL predictions

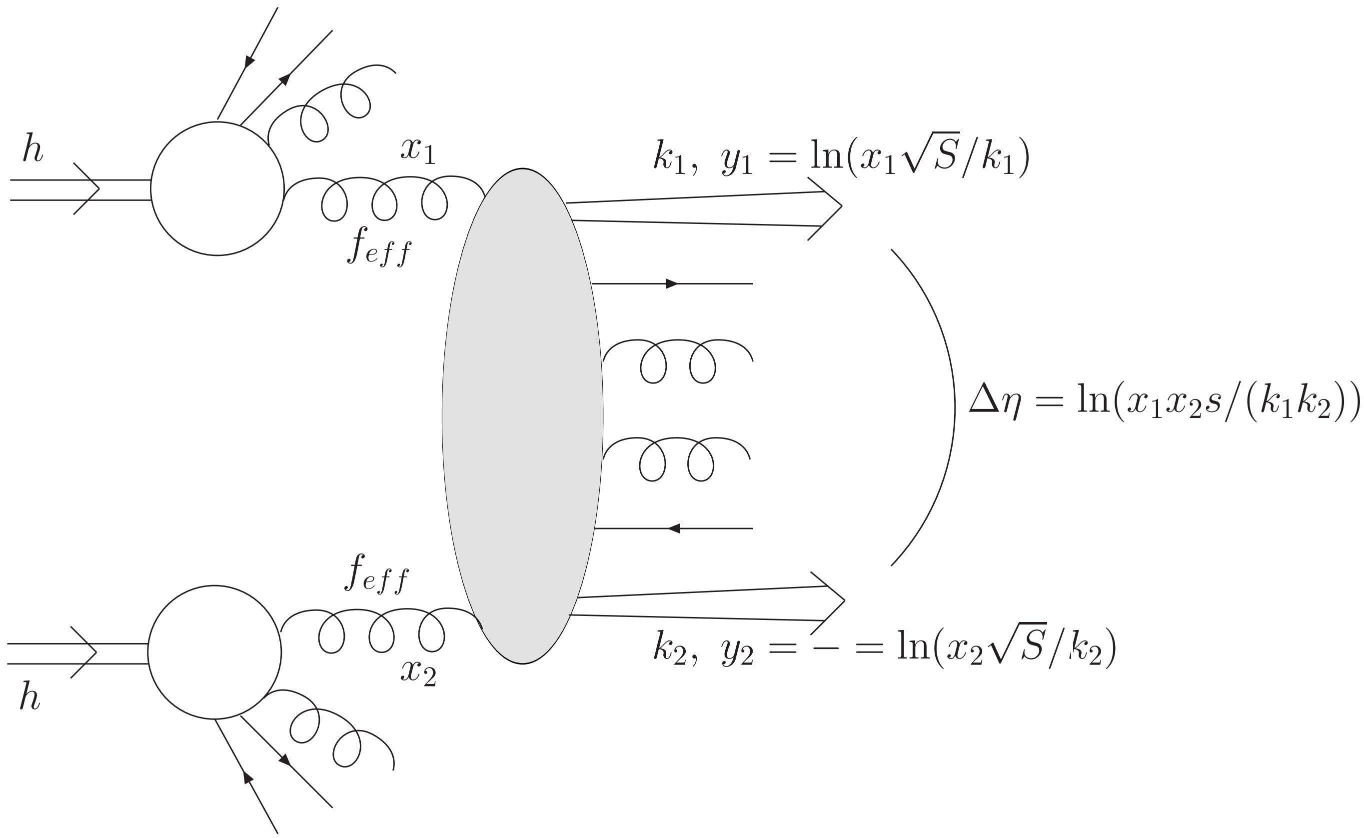


Predictions for the LHC

- Weak $\Delta\eta$ dependence
- Large differences in normalisation between BFKL LL and NLL predictions



Another observable for BFKL effects: Mueller Navelet jets



- Same kind of processes at the Tevatron and the LHC: Mueller Navelet jets
- Study the $\Delta\Phi$ between jets dependence of the cross section:

Mueller Navelet jets: $\Delta\Phi$ dependence

- Study the $\Delta\Phi$ dependence of the relative cross section
- Relevant variables:

$$\begin{aligned}\Delta\eta &= y_1 - y_2\\ y &= (y_1 + y_2)/2\\ Q &= \sqrt{k_1 k_2}\\ R &= k_2/k_1\end{aligned}$$

- Azimuthal correlation of dijets:

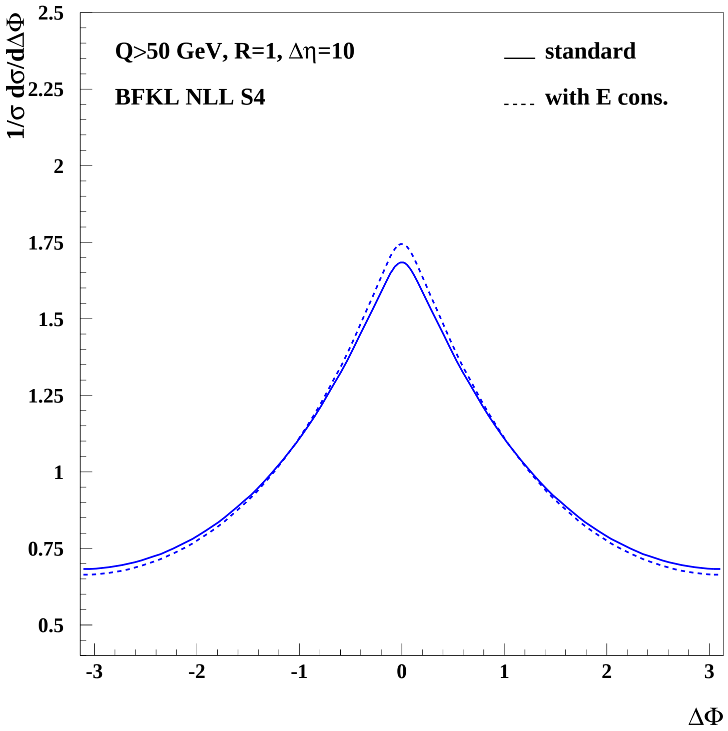
$$2\pi \frac{d\sigma}{d\Delta\eta dR d\Delta\Phi} \Big/ \frac{d\sigma}{d\Delta\eta dR} = 1 + \frac{2}{\sigma_0(\Delta\eta, R)} \sum_{p=1}^{\infty} \sigma_p(\Delta\eta, R) \cos(p\Delta\Phi)$$

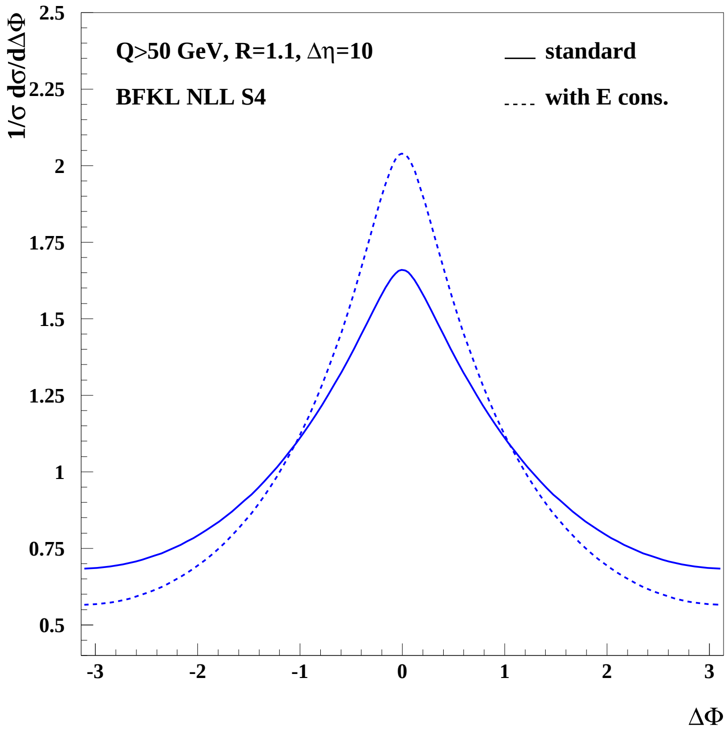
where

$$\sigma_p = \int_{E_T}^{\infty} \frac{dQ}{Q^3} \alpha_s(Q^2/R) \alpha_s(Q^2 R) \left(\int_{y_<}^{y_>} dy x_1 f_{eff}(x_1, Q^2/R) x_2 f_{eff}(x_2, Q^2 R) \right) \int_{1/2-\infty}^{1/2+\infty} \frac{d\gamma}{2i\pi} R^{-2\gamma} \; e^{\bar{\alpha}(Q^2)\chi_{eff}(p)\Delta\eta}$$

Mueller Navelet jets: energy conservation

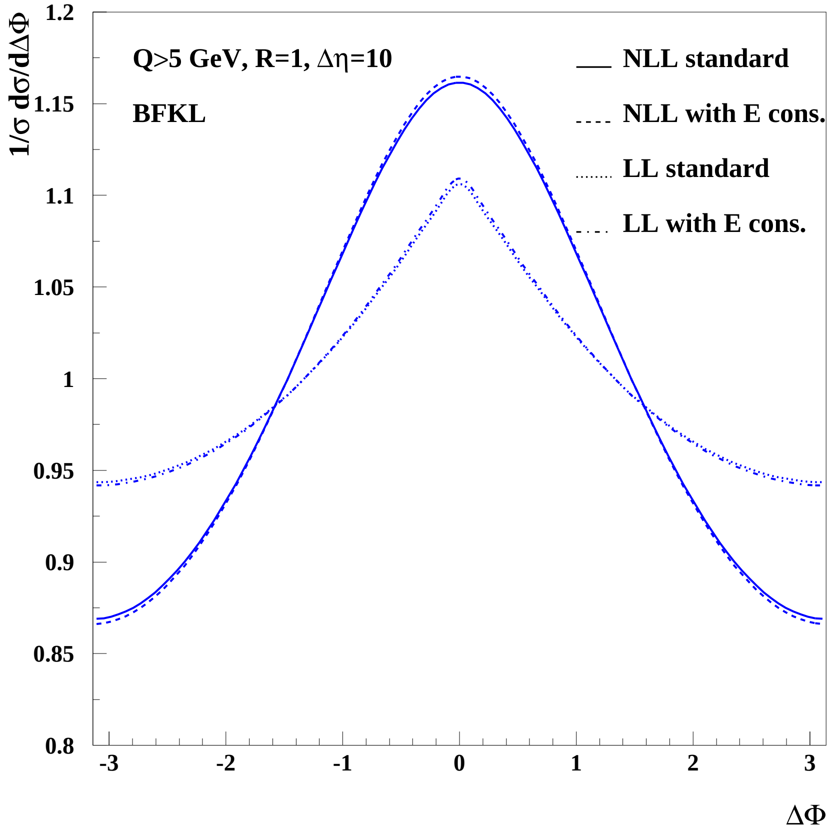
- Easy measurement to test BFKL dynamics (angular measurement)
- Issue: Effect of energy conservation in BFKL equations: large if E_T of jets not close, BFKL prediction close to DGLAP in that case





Mueller Navelet jets: CDF measurement

Possibility of measurement in CDF in mini-plug detectors in forward rapiditues: inconvenient, difficult to cut precisely on jet p_T



Conclusion

- BFKL NLL formalism fully implemented in HERWIG: fundamental to compare with data (sensitivity on the finite jet size, differences between $\Delta\eta$ between jets and size of rapidity gap
- Important to resum all conformal spins, large effect
- Comparison with D0/CDF data: Good agreement, better agreement with NLL calculation than with full LL
- Predictions for LHC: differences in normalisation/shape between LL and NLL
- Mueller Navelet jets: Another test of BFKL resummation, sensitive to ratio of jets p_T