BFKL NLL phenomenology of forward jets at HERA and Mueller Navelet jets at the Tevatron and the LHC

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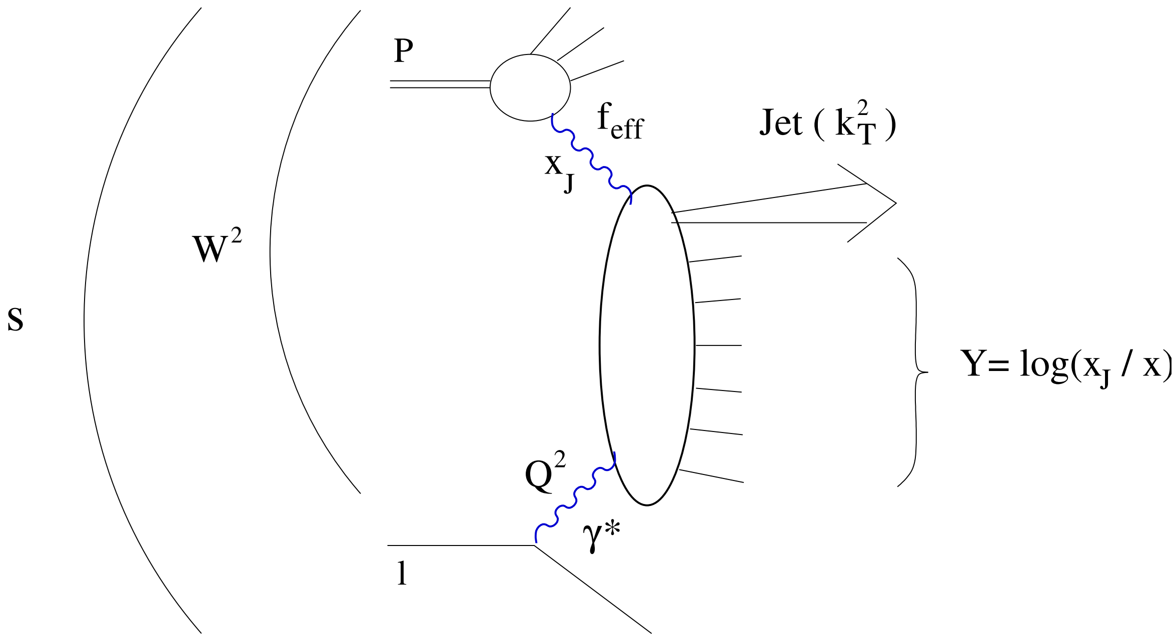
Contents:

- BFKL-NLL formalism
- Fit to H1 $d\sigma/dx$ data
- Prediction for the H1 triple differential cross section
- Prediction for Mueller Navelet jets at the Tevatron/LHC

Work done in collaboration with O. Kepka, C. Marquet, R. Peschanski

arXiv:0704.3409 about Mueller-Navelet jets, forward jets to be submitted

Forward jet measurement at HERA



- Typical kinematical domain where BFKL effects are supposed to appear with respect to DGLAP: $k_T^2 \sim Q^2$, and Q^2 not too large
- LO BFKL forward jet cross section: 2 parameters α_S, normalisation
- NLL BFKL cross section: one single parameter: normalisation (α_S running via RGE)

BFKL NLL and resummation schemes

- NLO BFKL: Corrections were found to be large with respect to LO, and lead to unphysical results
- NLO BFKL kernels need resummation: to remove additional spurious singularities in γ and $(1-\gamma)$
- Resummed NLO BFKL kernel:

$$\chi_{NLO}(\gamma,\omega) = \chi^{(0)}(\gamma,\omega) + \alpha(\chi_1(\gamma) - \chi_1^{(0)}(\gamma))$$

- $\chi_1(\gamma)$: calculated, NLO BFKL eigenvalues (Lipatov, Fadin; Camici, Ciafaloni)
- $\chi^{(0)}$ and $\chi_1(0)$: ambiguity of resummation at higher order than NLO, different ways to remove these singularities, not imposed by BFKL equation, Salam, Ciafaloni, Colferai
- Transformation of the energy scale: $\gamma \to \gamma - \omega/2$ (Salam) needed for F_2 but not for forward jet cross sections (the problem is symmetric contrary to F_2)
- Effective BFKL NLL kernel: full calculation available (no saddle point approximation): resolution of implicit equation performed by numerical methods:

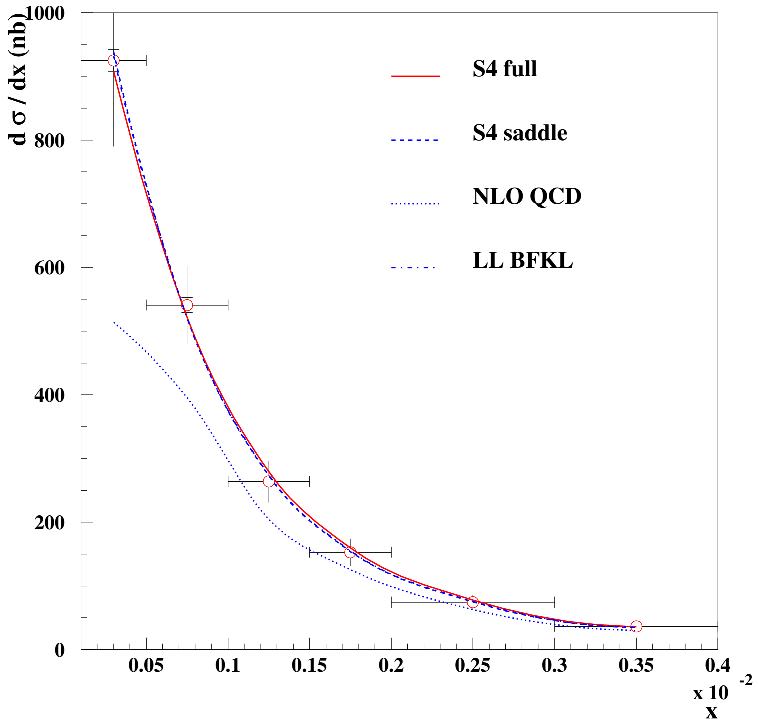
$$\chi_{eff} = \chi_{NLL}(\gamma, \bar{\alpha}\chi_{eff})$$

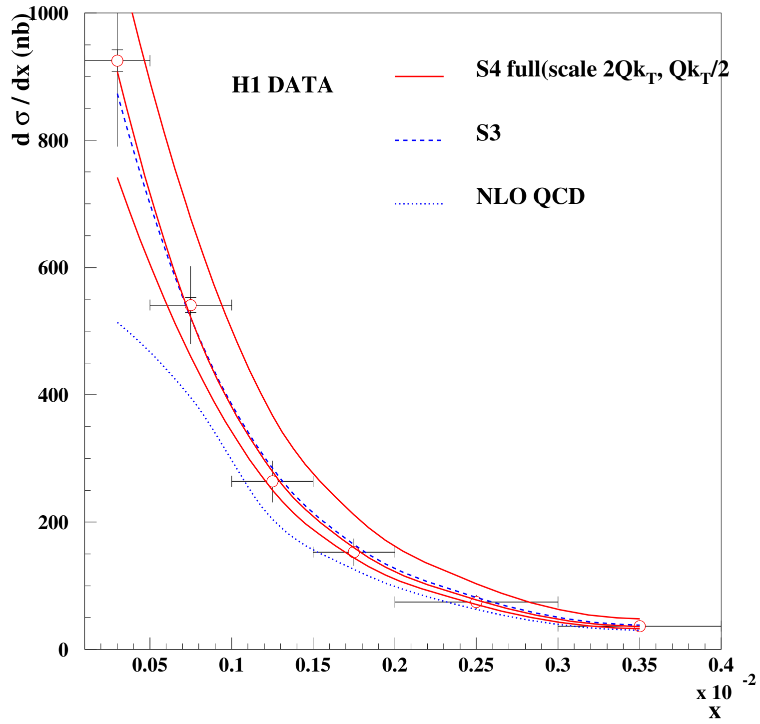
Cross section calculation, comparison with H1

- Two difficulties: We need to integrate over the bin in Q^2, x_{jet}, k_T to compare with the experimental measurement and we need to take into account the experimental cuts (as an example: $E_e > 10$ GeV, $k_T > 3.5$ GeV, $7 \leq \theta_J \leq 20$ degrees....)
- We perform the integration numerically: we chose the variables for which the cross section is as flat as possible to avoid numerical difficulties in precision: k_T^2/Q^2, $1/Q^2$, $log 1/x_{jet}$
- We take into account some of the cuts at the integration level (k_T for instance) and the other ones using a toy Monte Carlo
- Fit of NLL BFKL calculation to the H1 $d\sigma/dx$ data: one single parameter, the cross section normalisation
- Triple differential cross section: Keep the normalisation from the fit to $d\sigma/dx$ and predict the triple differential cross section

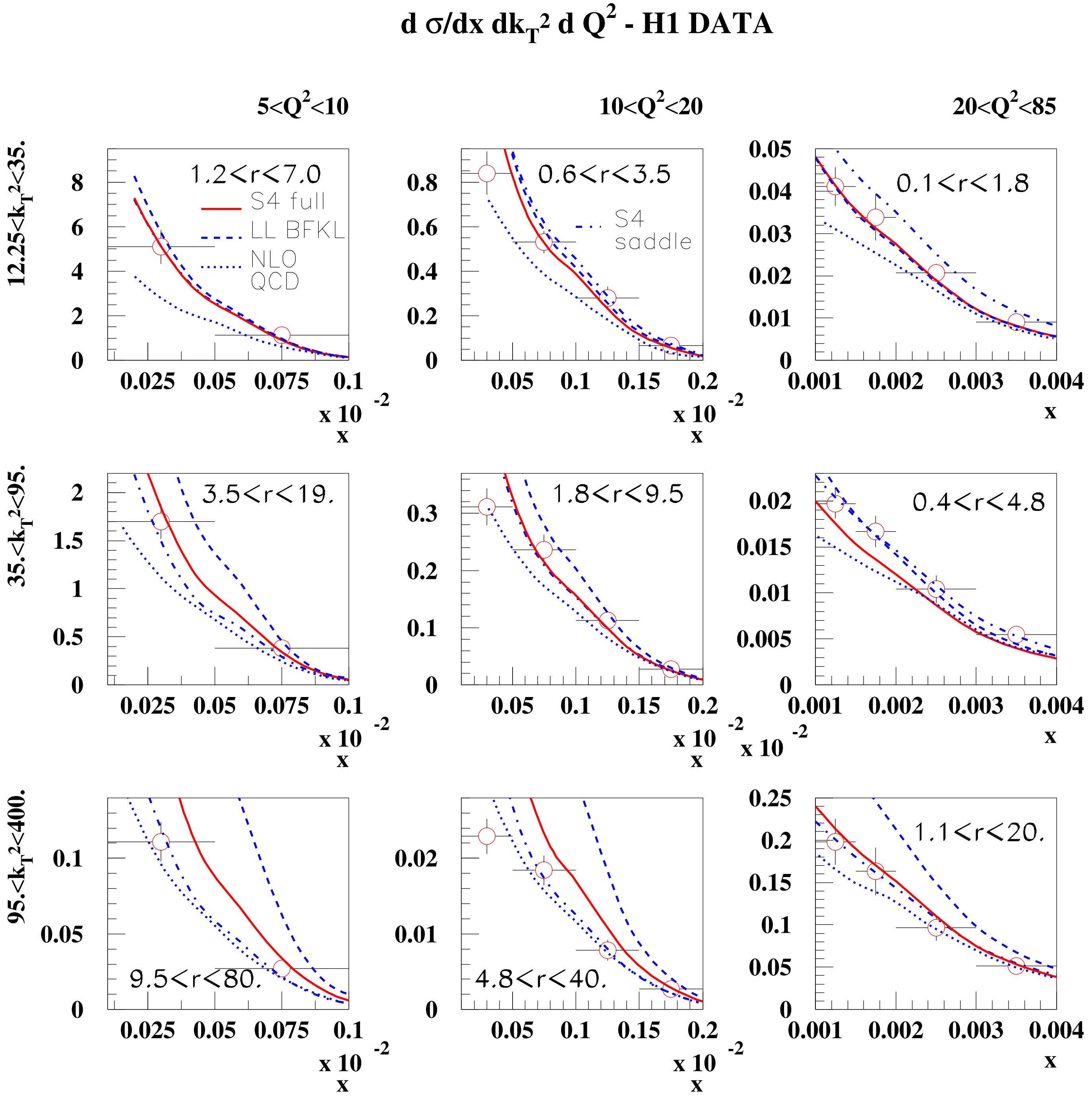
Fit results

- χ^2 for S3: 29.5 (1.15), S4: 10.0 (0.48)
- Good description of H1 data using BFKL LO and BFKL NLL formalism, DGLAP-NLO fails to describe the data
- BFKL higher corrections found to be small (We are in the BFKL-LO region, cut on $0.5 < k_T^2/Q^2 < 5$)

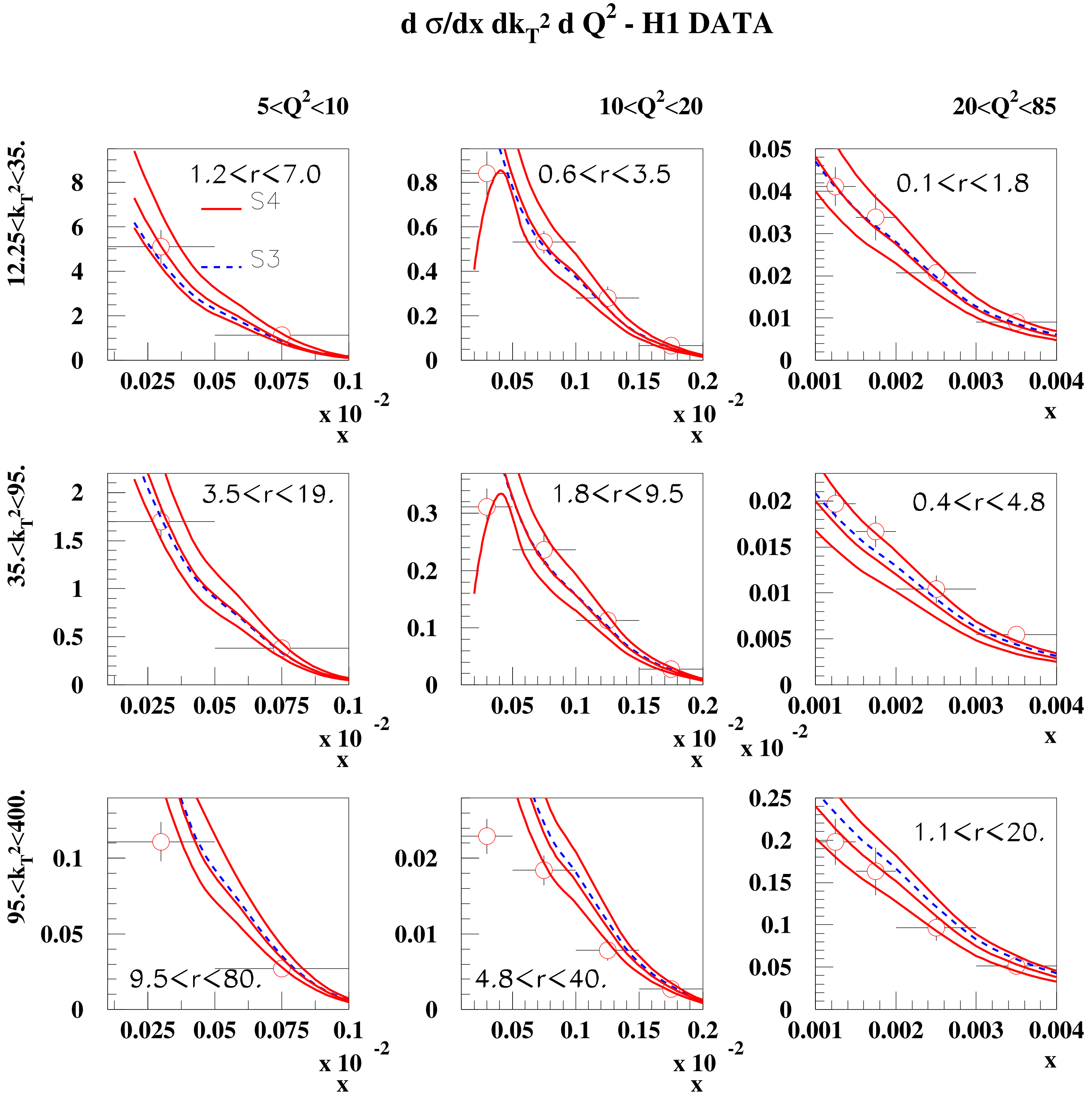




Comparison with H1 triple differential data



Comparison with H1 triple differential data

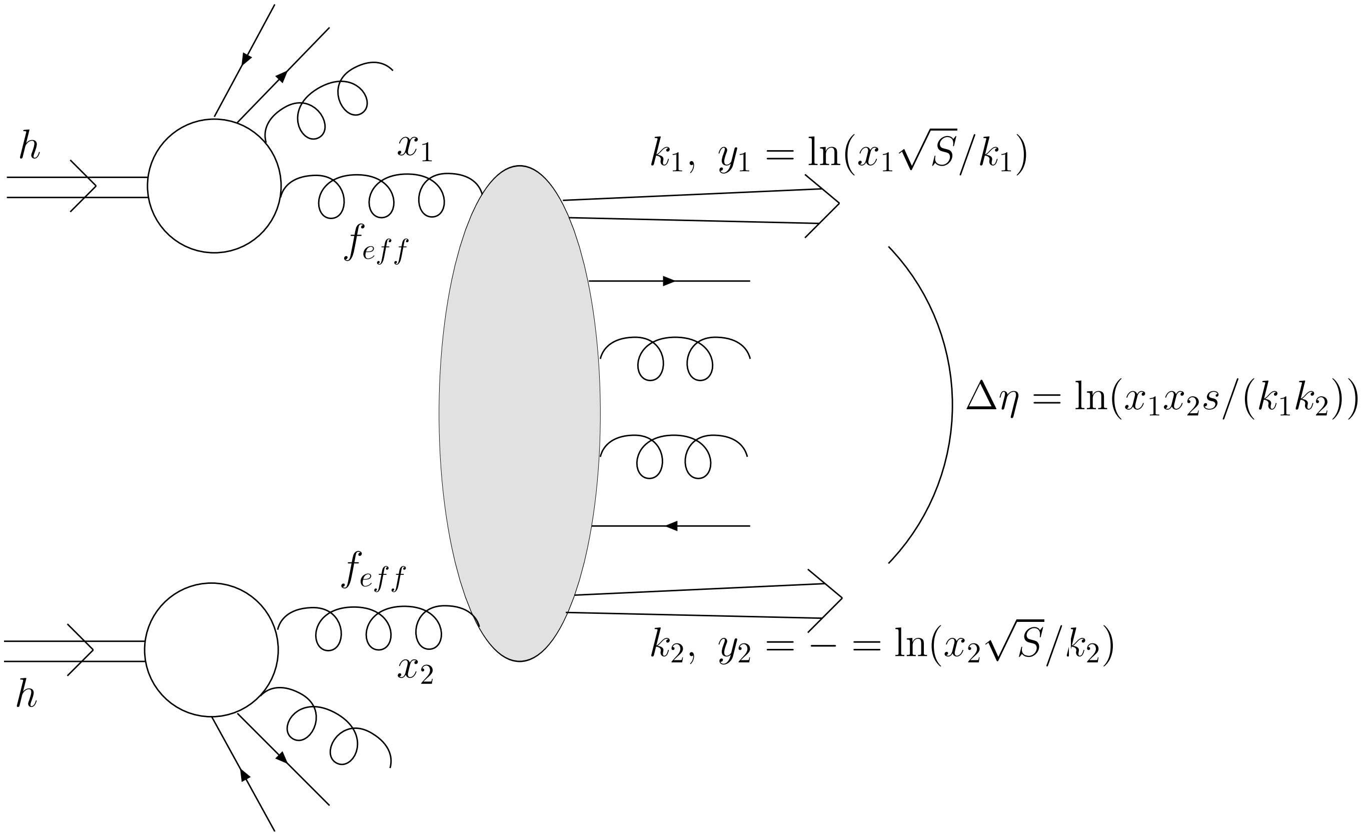


Remarks about BFKL NLL calculations

- DGLAP NLO predictions cannot describe H1 data in the full range, and large difference between DGLAP NLO and DGLAP LO results are also obtained, large difference expected at NNLO as well (DGLAP NLO includes part of the small x resummation effects)
- BFKL LO describes the H1 data when $r = k_T^2/Q^2$ is close to 1 and BFKL LO fails outside the region $r \sim 1$ specially at high Q^2
- Nice description of data on the full range using BFKL-NLL formalism (S4 slightly favoured)
- BFKL higher order corrections found to be small (as expected) when $r \sim 1$
- Higher order BFKL corrections larger when r further away from 1, where the BFKL NLL prediction is closer to the DGLAP one (Q^2 resummation effects are starting to be large)
- Systematic additional studies: Check the effect of varying scale in α_S ($2Qk_T$, $Qk_T/2$, Q^2, k_T^2)
- Side remark: Comparison with saddle point approximation: not as bad approximation as people thought originally, leads to a slightly worse description though

Mueller Navelet jets

Same kind of processes at the Tevatron and the LHC



- 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:

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

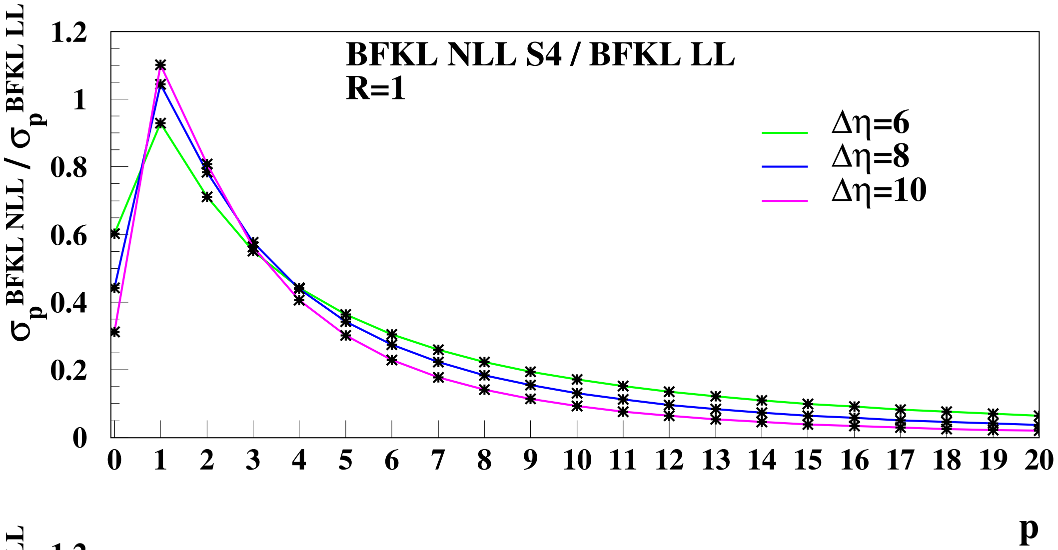
where

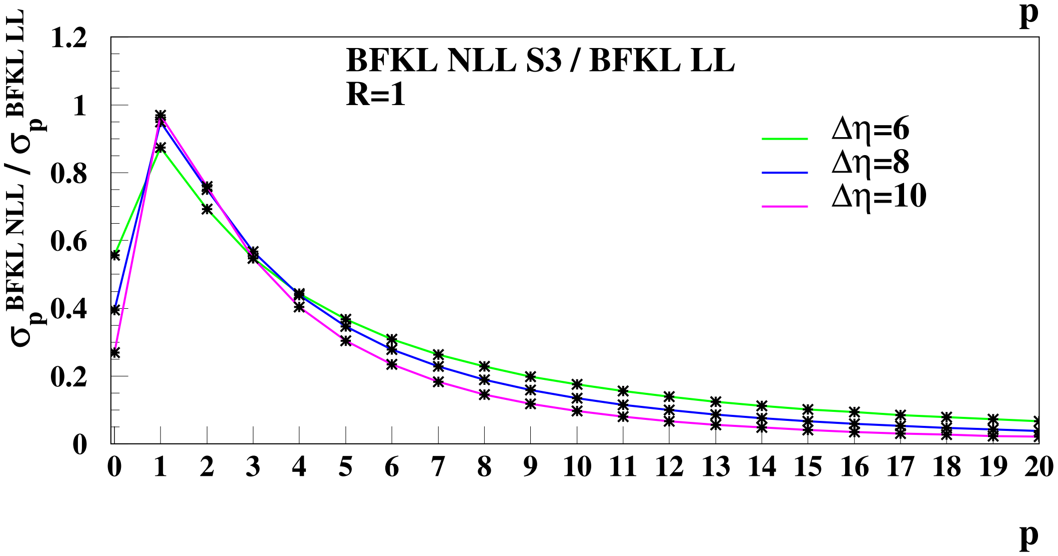
$$\sigma_p = \int_{E_T}^{\infty} \frac{dQ}{Q^3} \alpha_s(Q^2/R) \alpha_s(Q^2 R) \left(\int_{y_<}^{y_>} dy x_1 f_{eff}(x_1, Q^2/R) x_2 f_{eff}(x_2, Q^2 R) \right) \int_{1/2-\infty}^{1/2+\infty} \frac{d\gamma}{2i\pi} R^{-2\gamma} \; e^{\bar{\alpha}(Q^2)\chi_{eff}^{(p)} \Delta\eta}$$

- BFKL NLL available for all components (different conformal spins p), $\Delta\Phi$ dependence comes from p different from 0

Mueller Navelet jets: $\Delta\Phi$ dependence

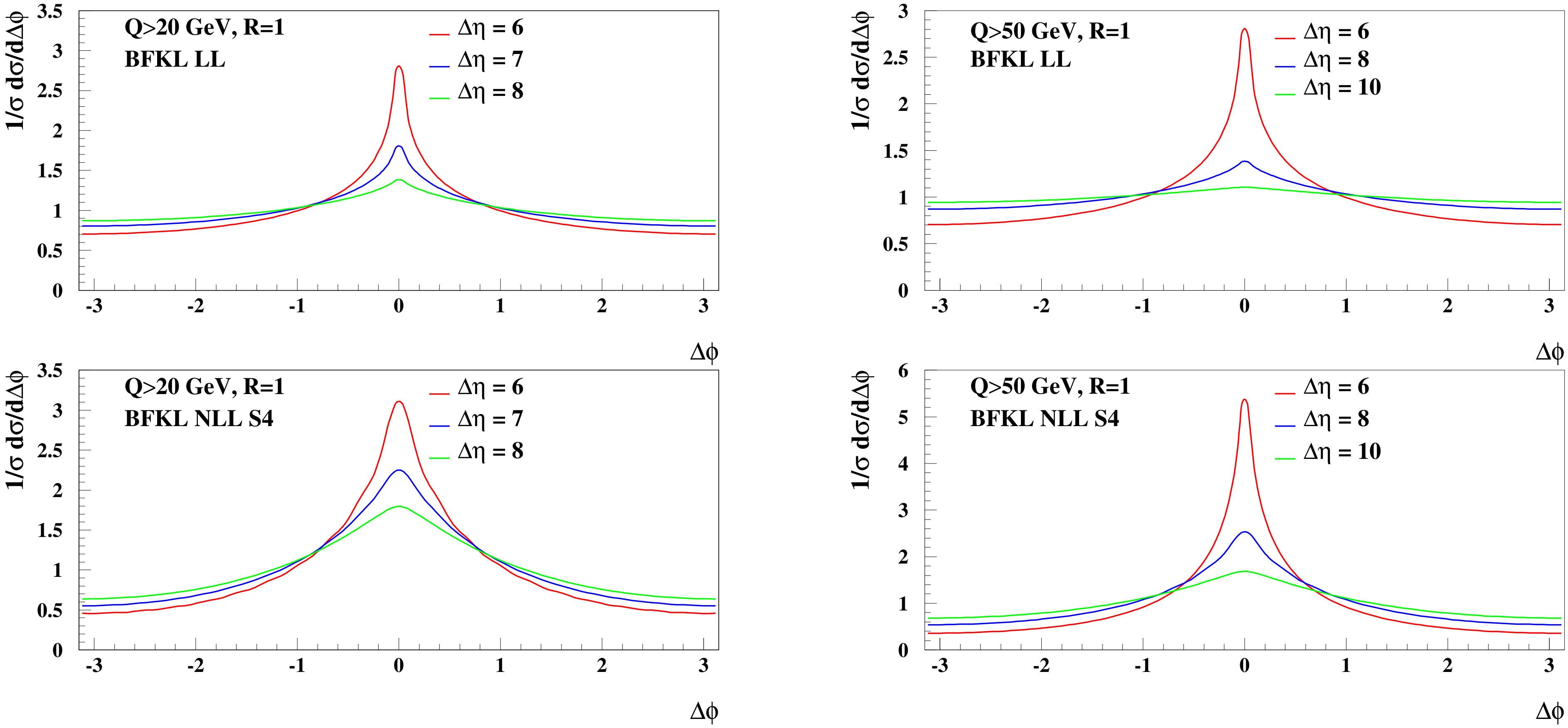
Ratio of the values of σ_i entering into the $\Delta\Phi$ spectrum between BFKL NLL and BFKL LL for different intervals in rapidity





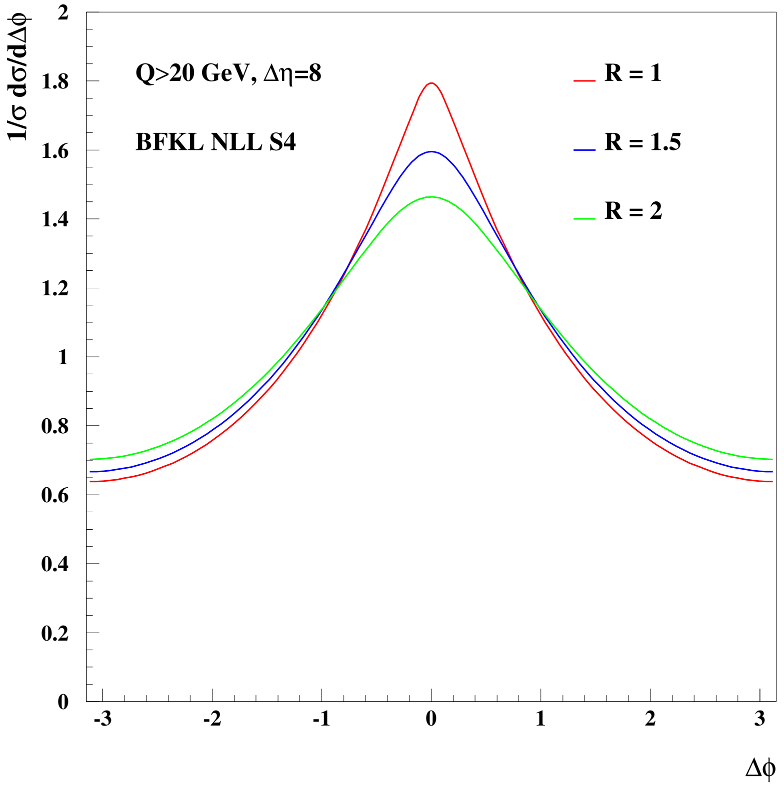
Mueller Navelet jets: $\Delta\Phi$ dependence

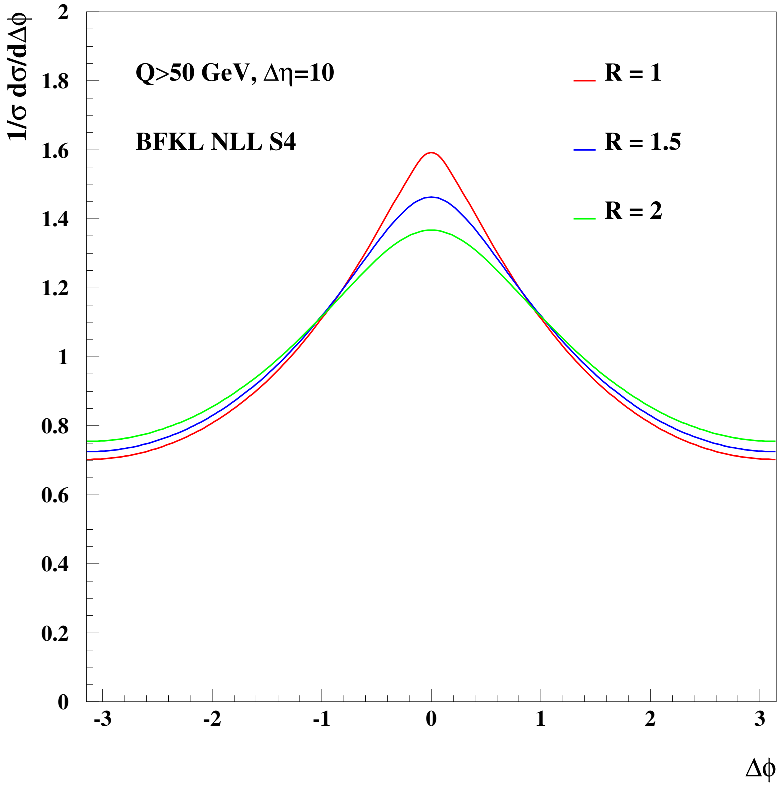
- $1/\sigma d\sigma/d\Delta\Phi$ spectrum for BFKL LL and BFKL NLL as a function of $\Delta\Phi$ for different values of $\Delta\eta$
- Measurement to be performed at the Tevatron/LHC



Mueller Navelet jets: R dependence

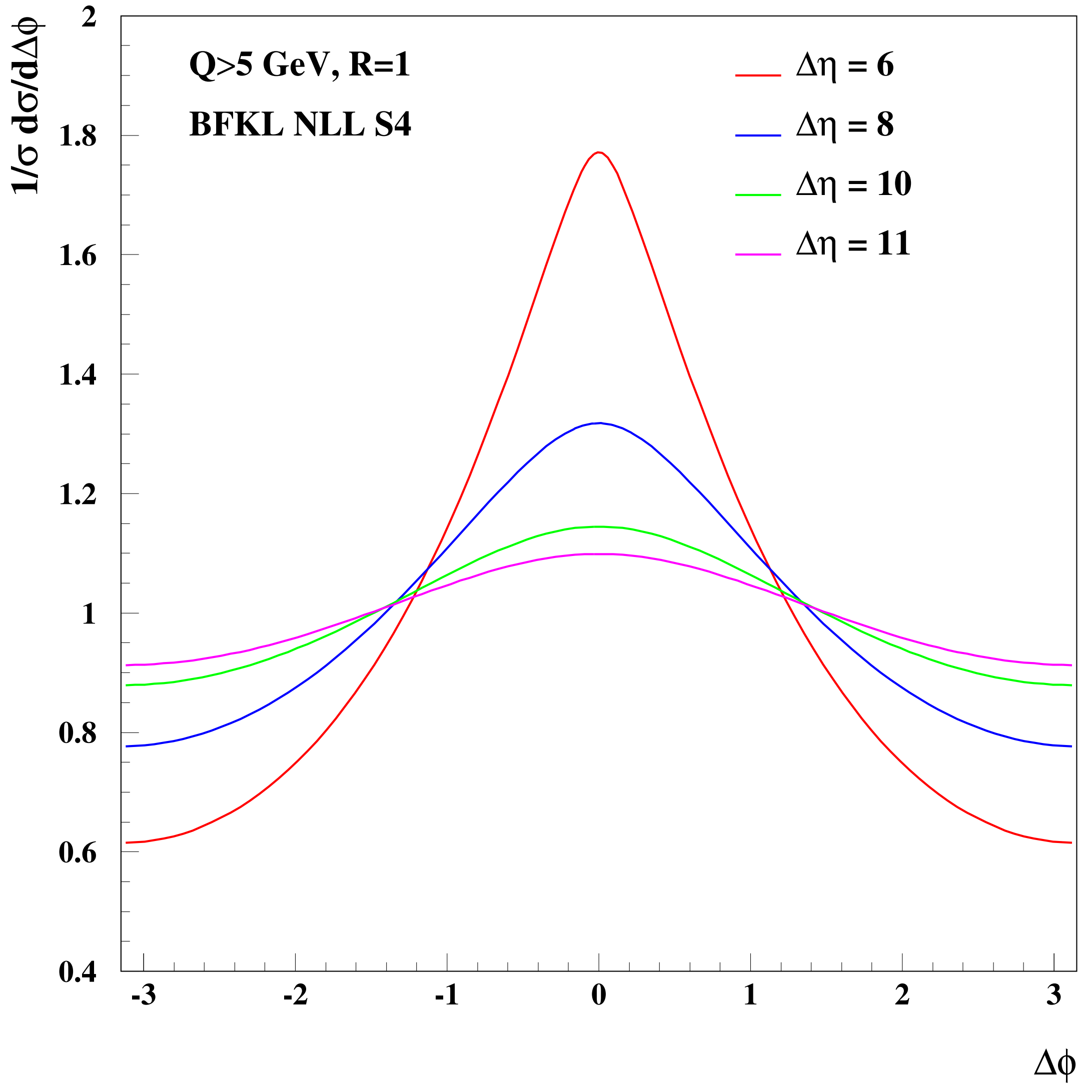
Weak $R = k_2/k_1$ dependence, BFKL/DGLAP enhanced if R close to 1





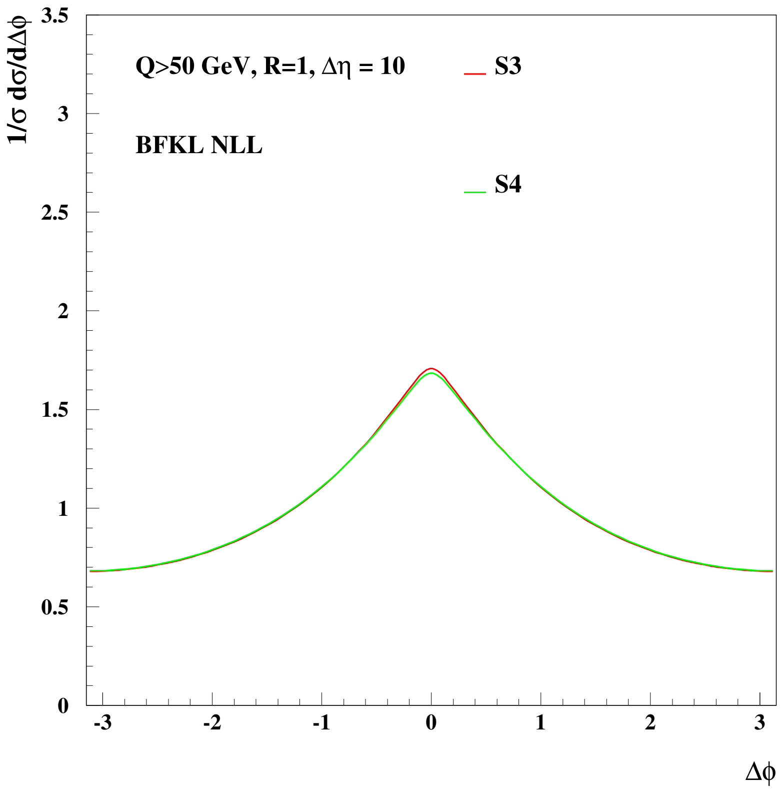
Mueller Navelet jets in CDF

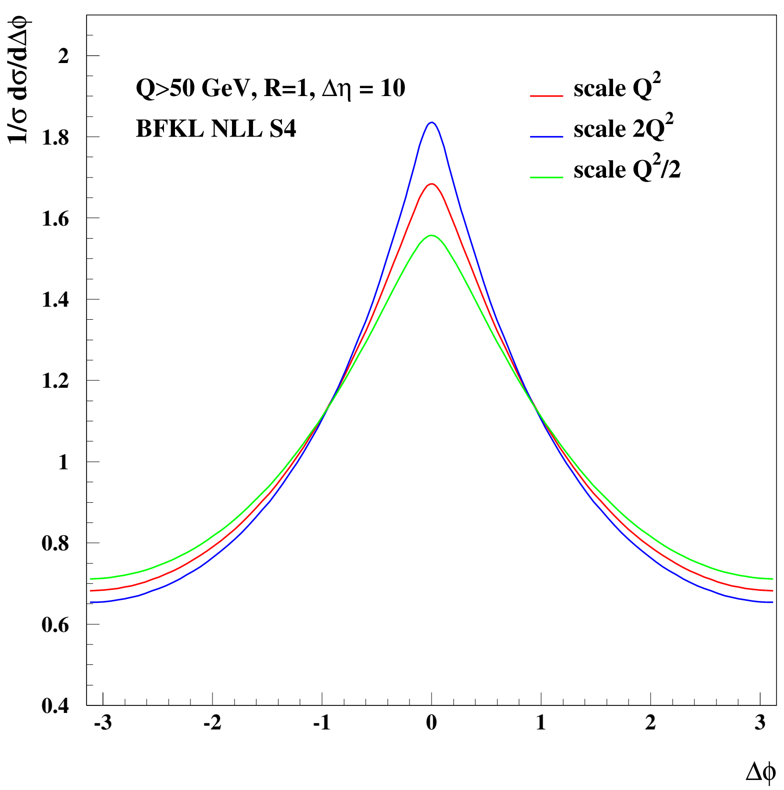
Possibility to measure $\Delta\Phi$ distribution in CDF for large $\Delta\eta$ and low jet p_T ($p_T > 5$ GeV) using the CDF miniPLUG calorimeter



Mueller Navelet jets: S3 and S4, scale dependence

- No difference between S3 and S4 schemes (as an example for LHC)
- Weak scale dependence (given as an example for the LHC): $Q^2/2$, Q^2, $2Q^2$





Conclusion

- DGLAP NLO fails to describe forward jet data
- First BFKL NLL description of H1 and ZEUS forward jet data: very good description using full BFKL-NLL kernel and LO impact factors
- Mueller Navelet jets: Full calculation available using S3 and S4 schemes (without saddle point approximation)
- Mueller Navelet jets $\Delta\Phi$ dependence: weak dependence even after NLL corrections, little sensitivity to chosen scale
- Mueller Navelet jets: Very nice measurement to be performed at the Tevatron/LHC, special use of CDF forward miniPLUG calorimeter which gives a good acceptance at large η and small p_T for jets