Description of the ATLAS jet veto measurement and search for BFKL resummation effects at the LHC

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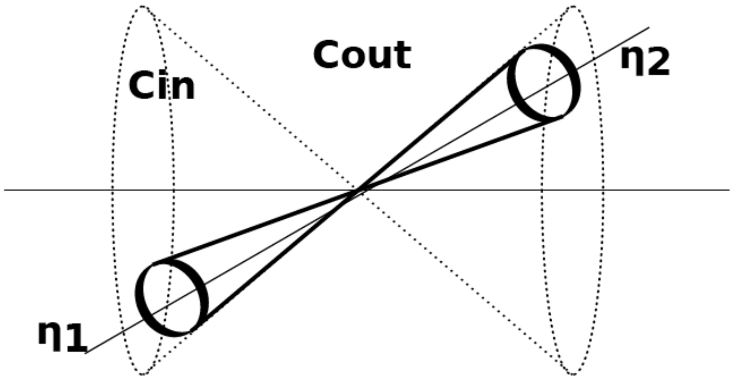
Contents:

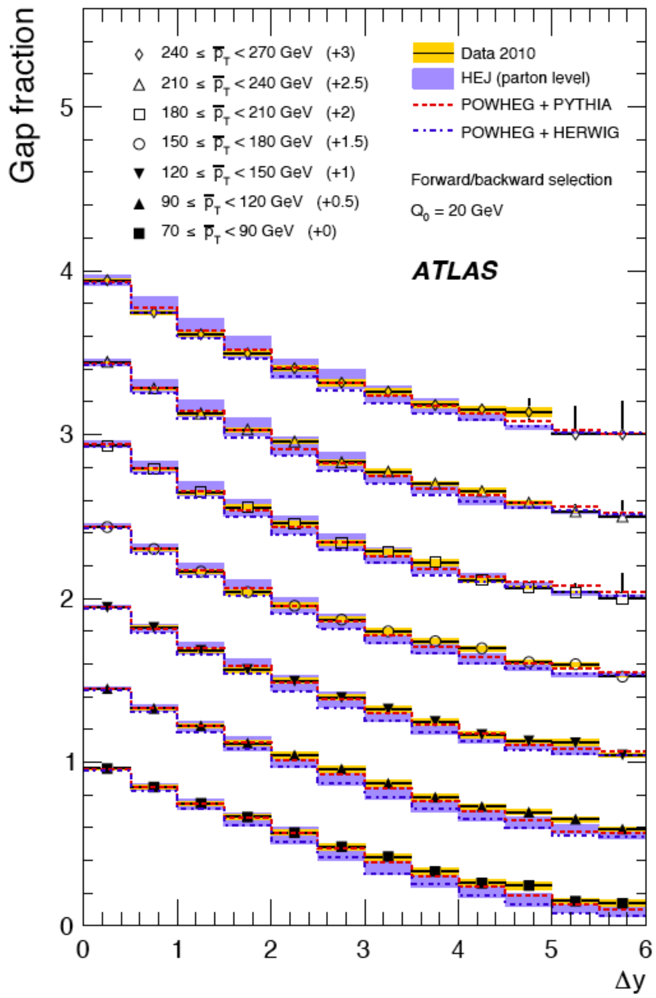
- ATLAS jet veto measurement
- Banfi Smye Marchesini equation
- Description of jet veto measurement
- How to see BFKL resummation effects at the LHC? (Jet gap jet)

References:

- A QCD description of the ATLAS jet veto measurement Y. Hatta, C. Marquet, C. Royon, G. Soyez, T. Ueda, D. Werder, arXiv:1301.1910, accepted in PRD
- Gaps between jets in double-Pomeron-exchange processes at the LHC C. Marquet, C. Royon, M. Trzebinski, R. Zlebcik, arXiv:1212.2059, accepted in PRD
- Gaps between jets in hadronic collisions O. Kepka, C. Marquet, C. Royon, Phys.Rev. D83 (2011) 034036

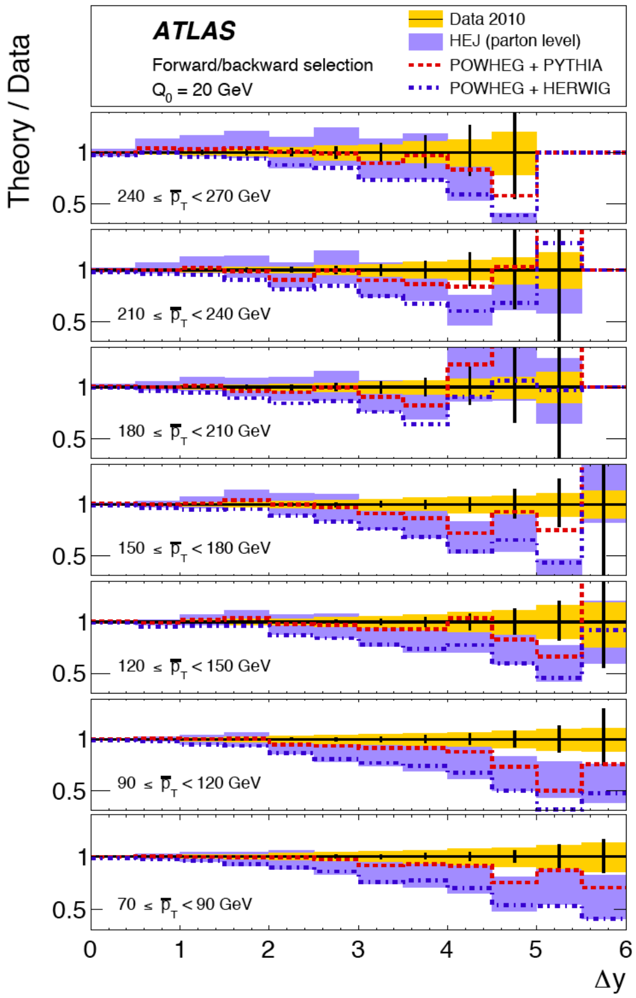
ATLAS measurement





- Select events with two high p_T jets, well separated in rapidity by Δy
- Veto on additional jet activity (with $k_T > Q_0$, with $Q_0 \gg \Lambda_{QCD}$) between the two jets
- Measure the "gap" fraction: dijet events with jet veto / total dijet events

Comparison with QCD calculation

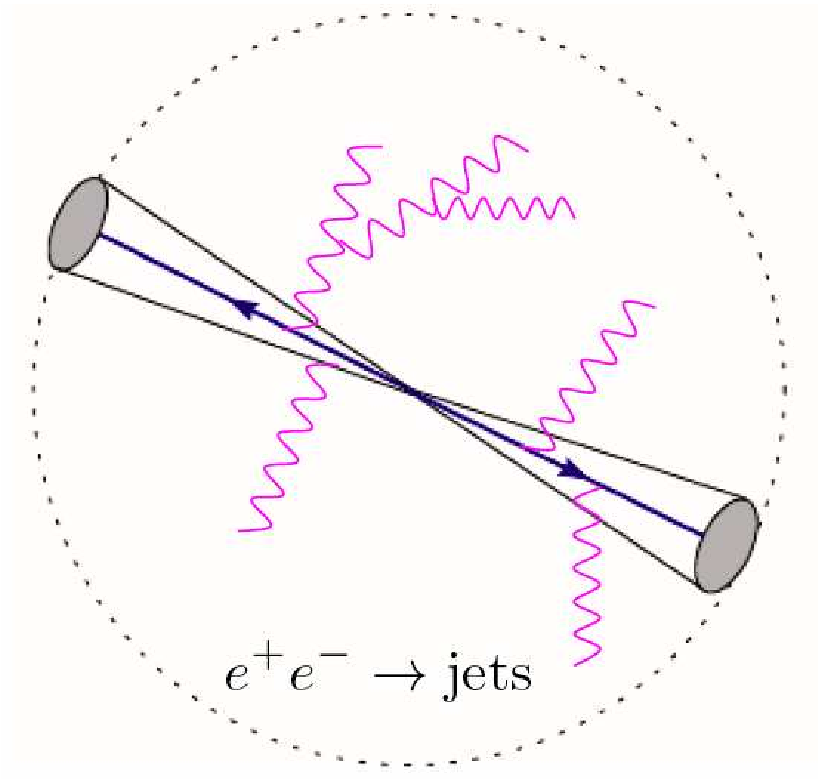


- The standard NLO and parton shower approach (POWHEG + pythia or herwig) fails to describe data

$$\frac{(d\sigma^{2\to 2} + d\sigma^{2\to 3})_{p_{T_3} < E_{out}}}{d\sigma^{2\to 2} + d\sigma^{2\to 3}}$$

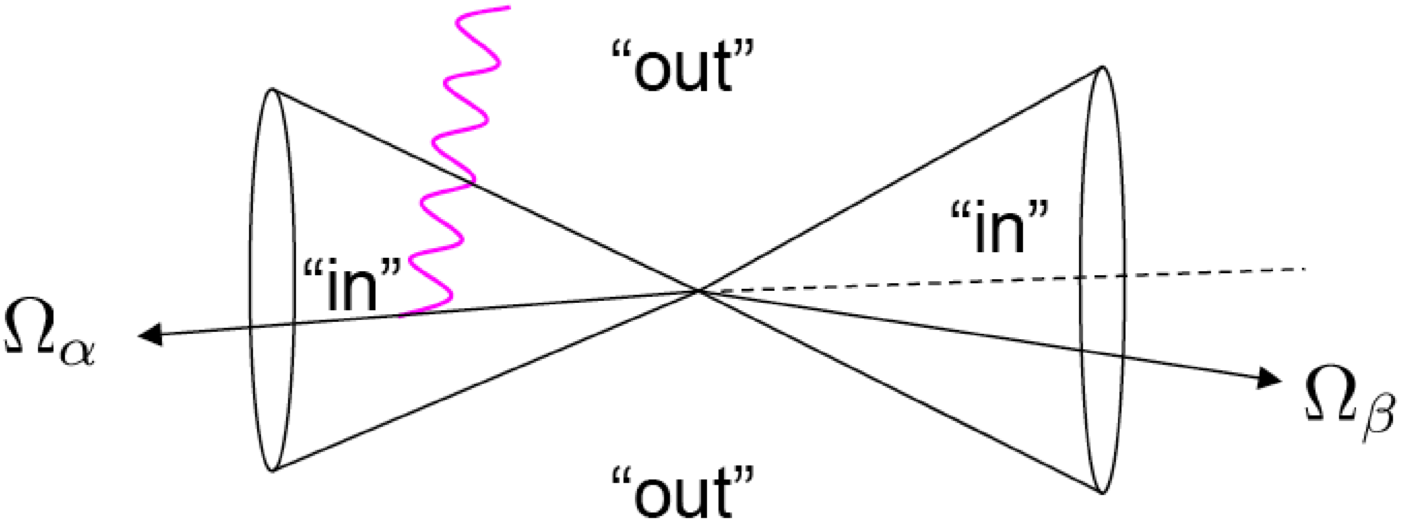
- BFKL resummation (HEJ Monte Carlo) also fails to describe data
- Both approaches miss the resummation of soft gluons at large angles

Gluon emission at large angles



- Resummation of soft gluon emissions at large angle not taken into account in parton showers
- Resummation of soft emissions performed in e^+e^- case: when $p_T \gg E_{out}$, one can resum the soft logarithms $(\alpha_S \log p_T/E_{out})^n$ while requiring that the energy flow into the region between the jets is less than E_{out}

Banfi Marchesini Smye equation



- Compute the probability P_T that the total energy emitted outside the jet cone is less than E_{out}

$$\partial_\tau P_\tau(\Omega_\alpha, \Omega_\beta) = -\int_{C_{out}} \frac{d^2\Omega_\gamma}{4\pi} \frac{1-\cos\theta_{\alpha\beta}}{(1-\cos\theta_{\alpha\gamma})(1-\cos\theta_{\gamma\beta})} P_\tau(\Omega_\alpha, \Omega_\beta)$$
$$+ \int_{C_{in}} \underbrace{\frac{d^2\Omega_\gamma}{4\pi} \frac{1-\cos\theta_{\alpha\beta}}{(1-\cos\theta_{\alpha\gamma})(1-\cos\theta_{\gamma\beta})}} \Big(P_\tau(\Omega_\alpha, \Omega_\gamma) P_\tau(\Omega_\gamma, \Omega_\beta) - P_\tau(\Omega_\alpha, \Omega_\beta) \Big)$$

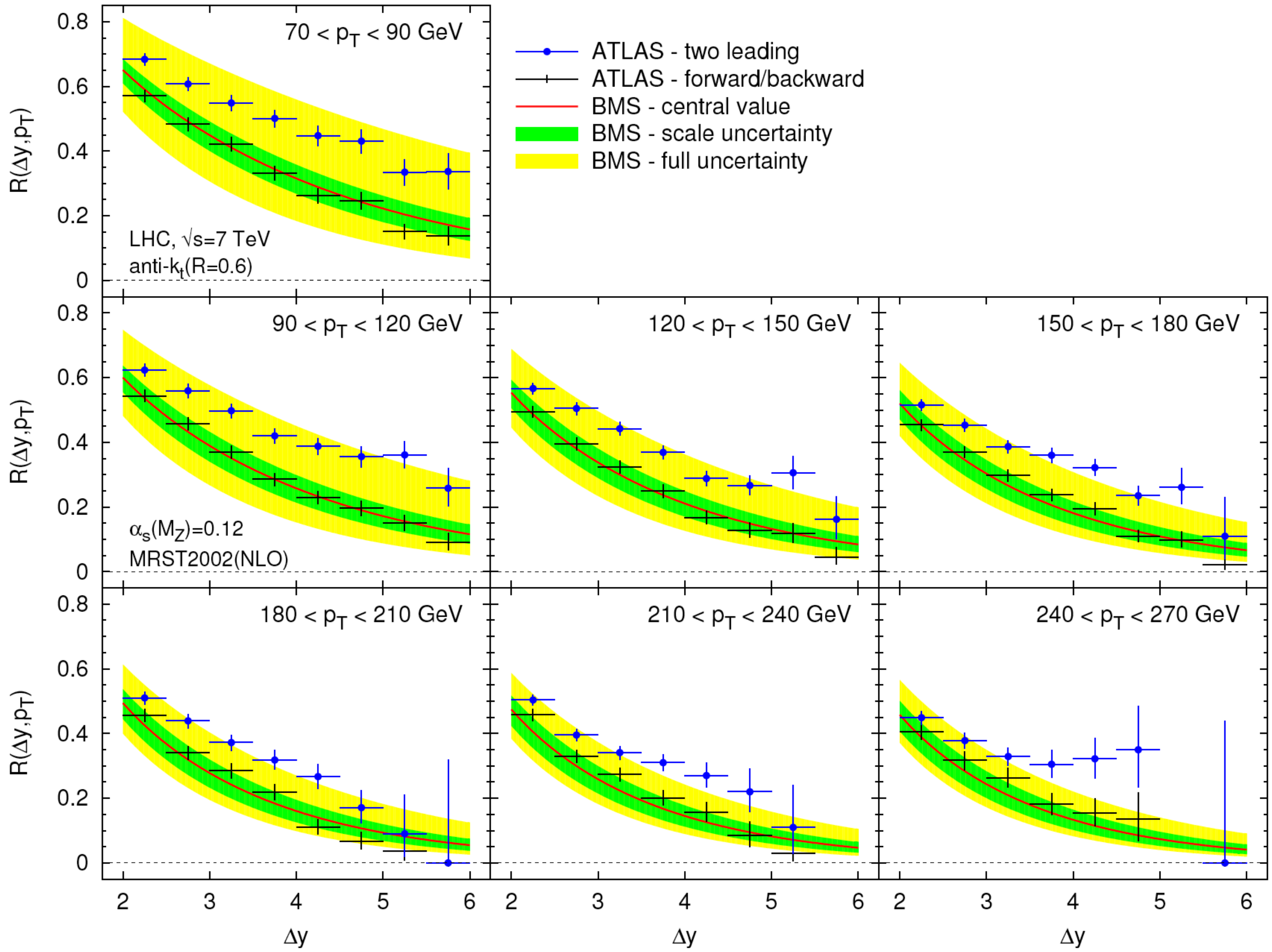
Sudakov logs

non-global logs

differential probability for the soft gluon emission

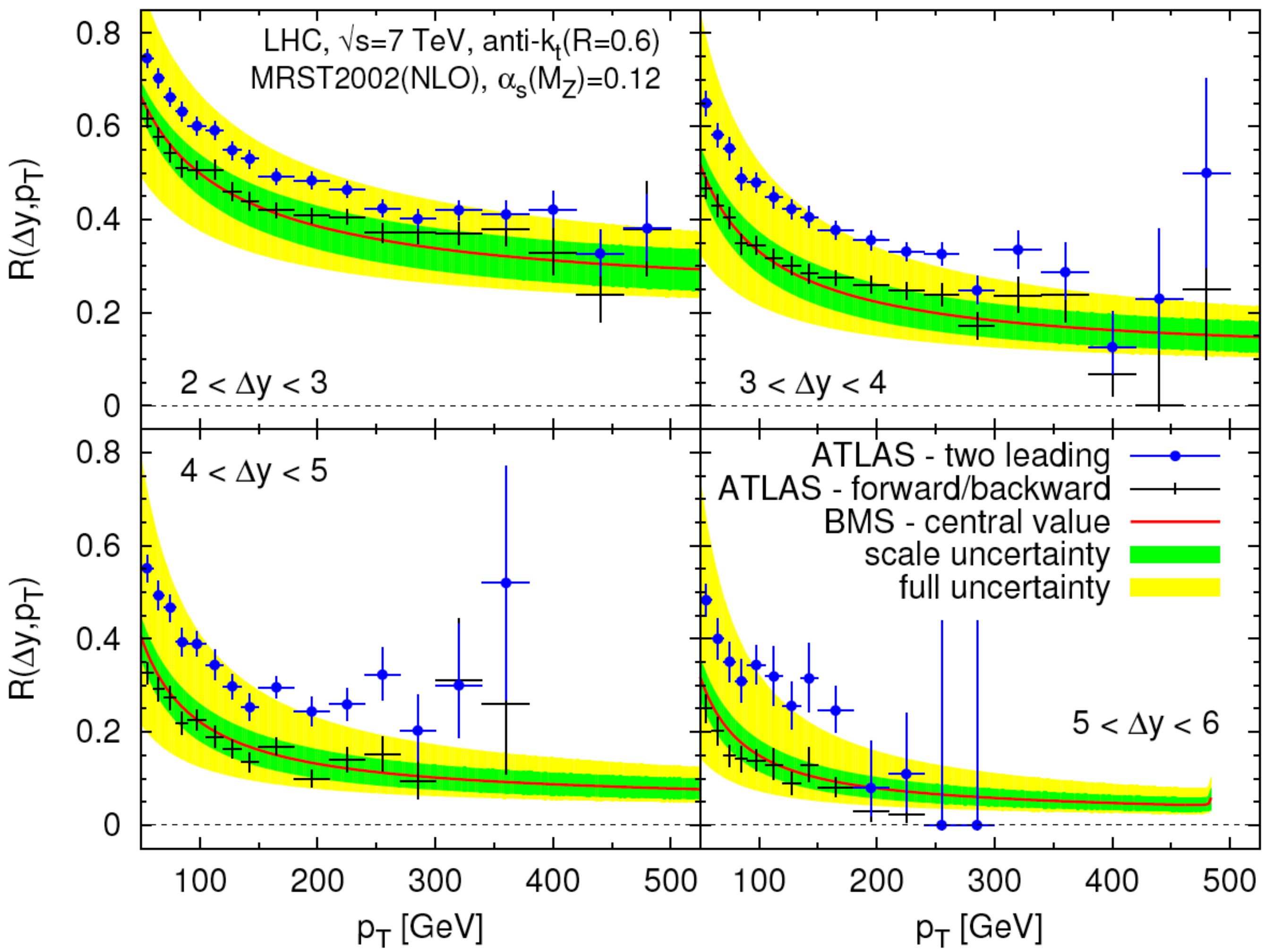
- Numerical solutions are available (Hatta and Ueda, 2009)

Comparison with ATLAS data



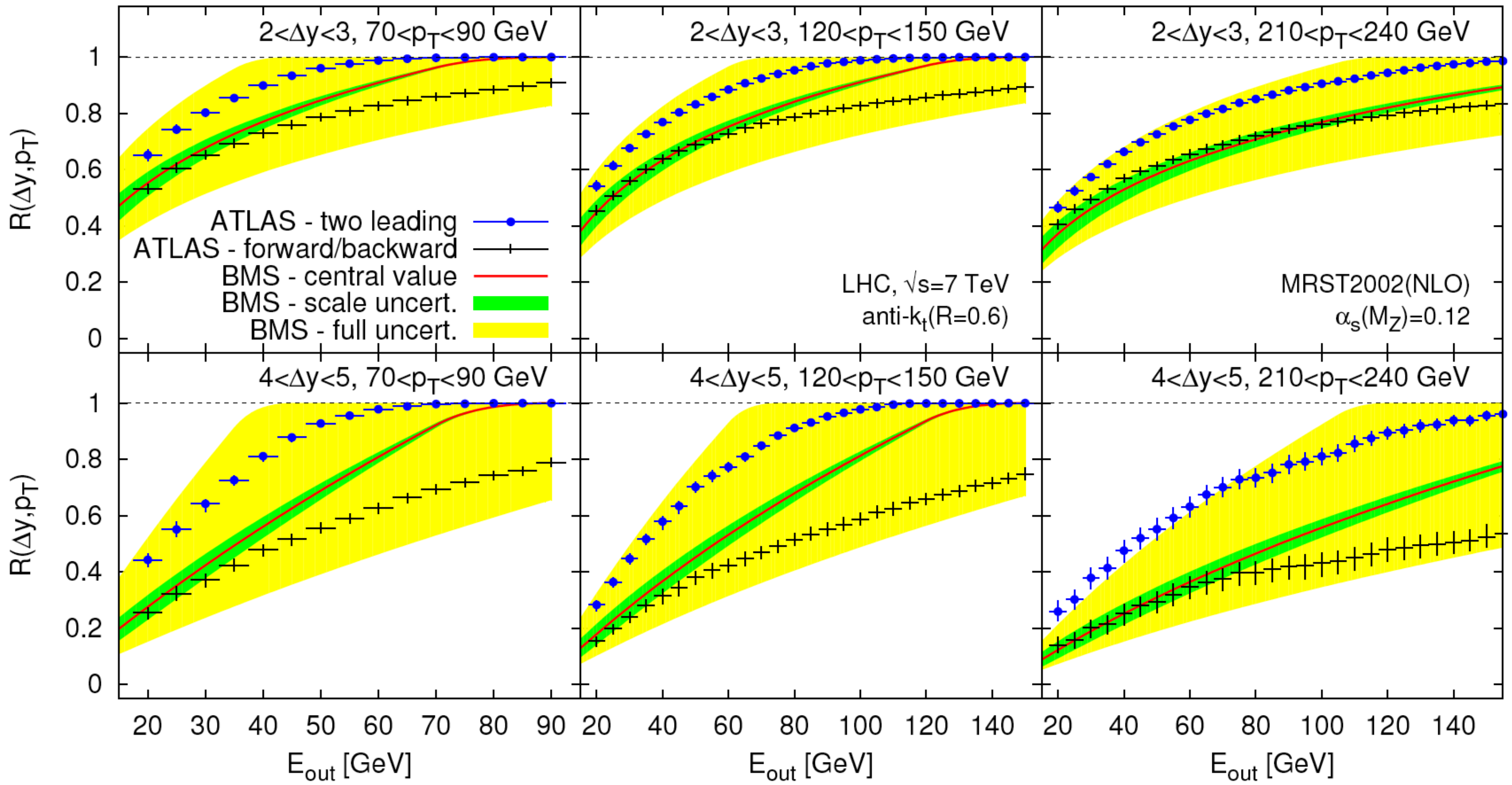
- Good agreement between prediction and ATLAS data (black points when the most forward and backward jets are selected and E_{out}=20 GeV)
- Plot as a function of Δy between jets in different jet p_T bins
- Green band: renormalisation and factorisation scale uncertainties (between $2p_T$ and $p_T/2$); yellow band: uncertainties related to sub-leading logs

Comparison with ATLAS data



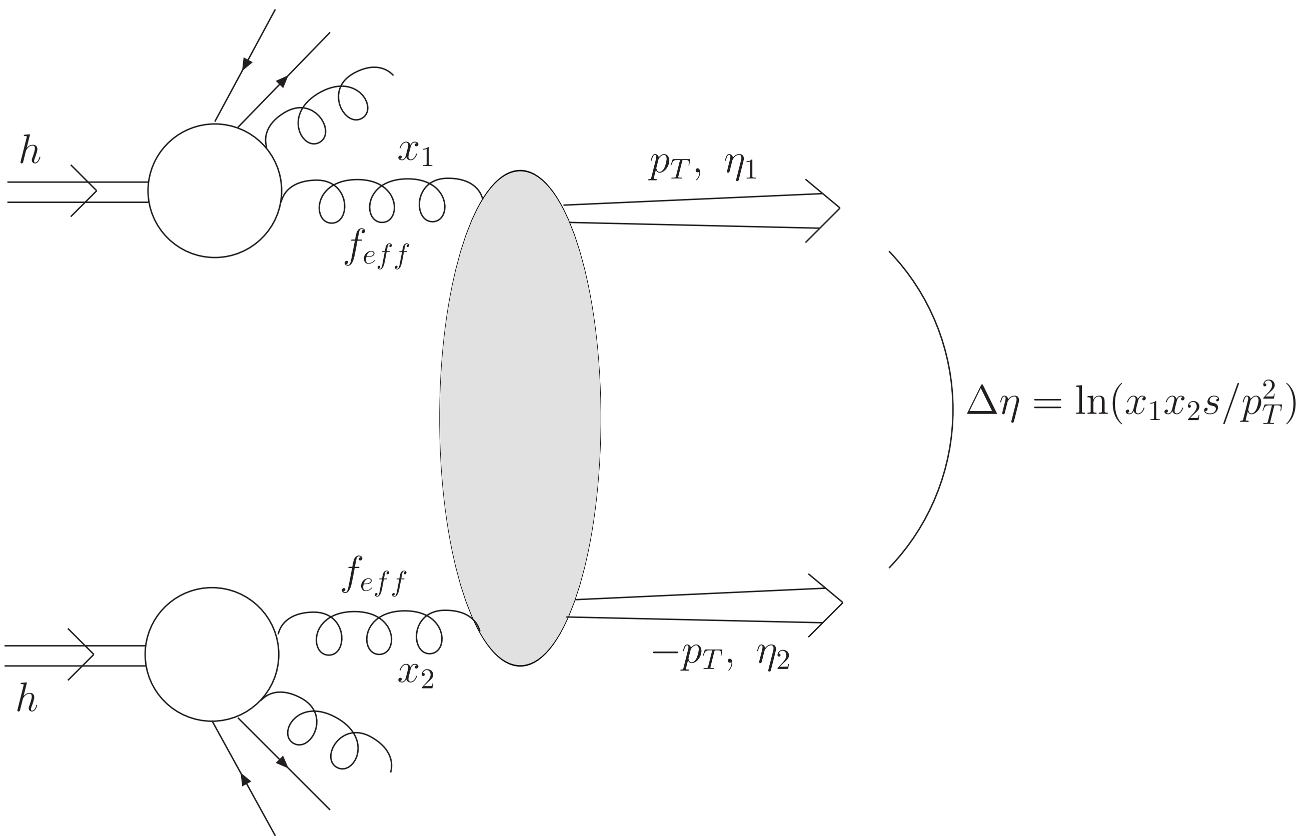
- Good agreement between prediction and ATLAS data (black points when the most forward and backward jets are selected and E_{out}=20 GeV)
- Plot as a function of jet p_T in different Δy bins

Comparison with ATLAS data



- Plot as a function of the energy between the two jets in different jet p_T and Δy bins
- Description not so good when $E_{out} \sim p_T$ as expected
- No need of BFKL resummation: other observables

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

$$\frac{d\sigma^{pp\to XJJY}}{dx_1 dx_2 dp_T^2} = \mathcal{S}\frac{f_{eff}(x_1,p_T^2)f_{eff}(x_2,p_T^2)}{16\pi}\left|A(\Delta\eta,p_T^2)\right|^2$$

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

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

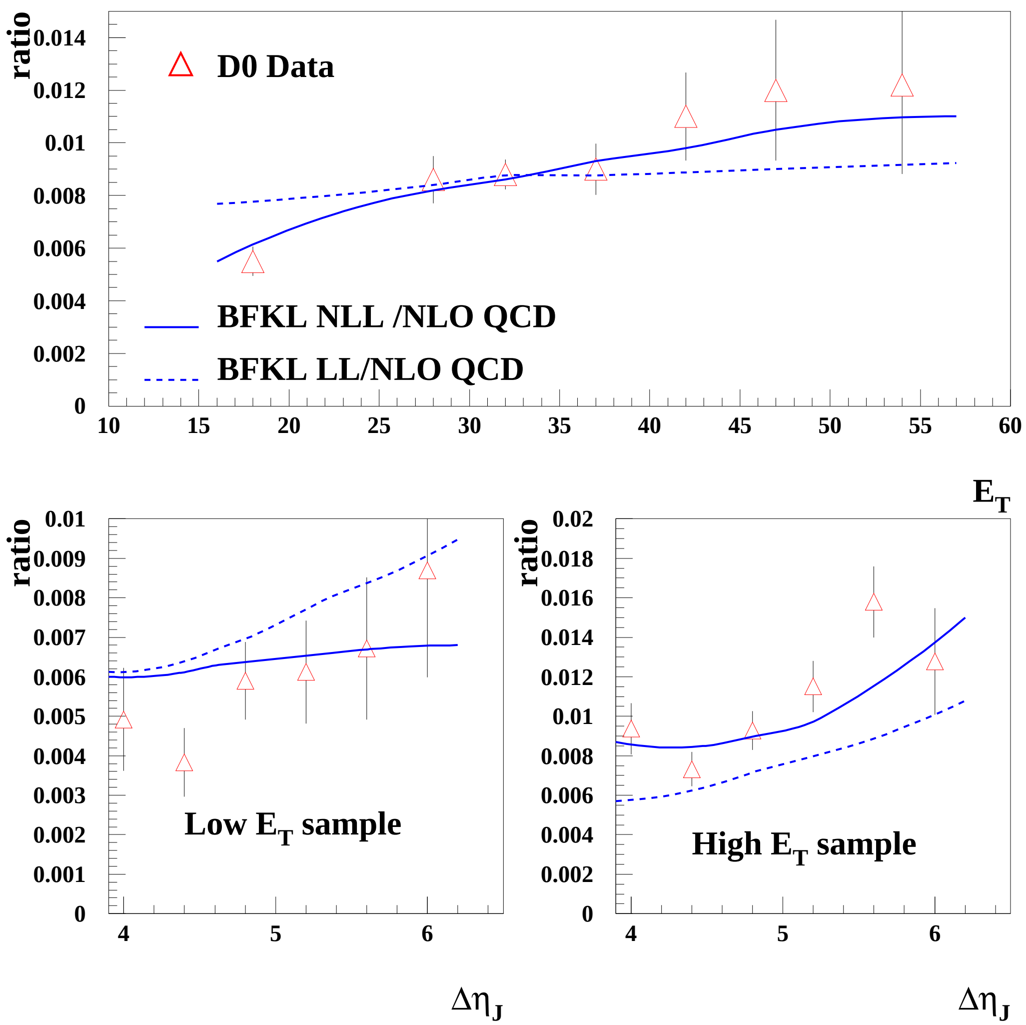
- α_S: 0.17 at LL (constant), running using RGE at NLL
- BFKL effective kernel χ_{eff}: determined numerically, solving the implicit equation: $\chi_{eff} = \chi_{NLL}(\gamma, \bar{\alpha}\ \chi_{eff})$
- S4 resummation scheme used to remove spurious singularities in BFKL NLL kernel
- Implementation in Herwig Monte Carlo: needed to take into account jet size and at parton level the gap size is equal to $\Delta\eta$ between jets
- Herwig MC: 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 $\chi^2 \sim 0.1$)

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:

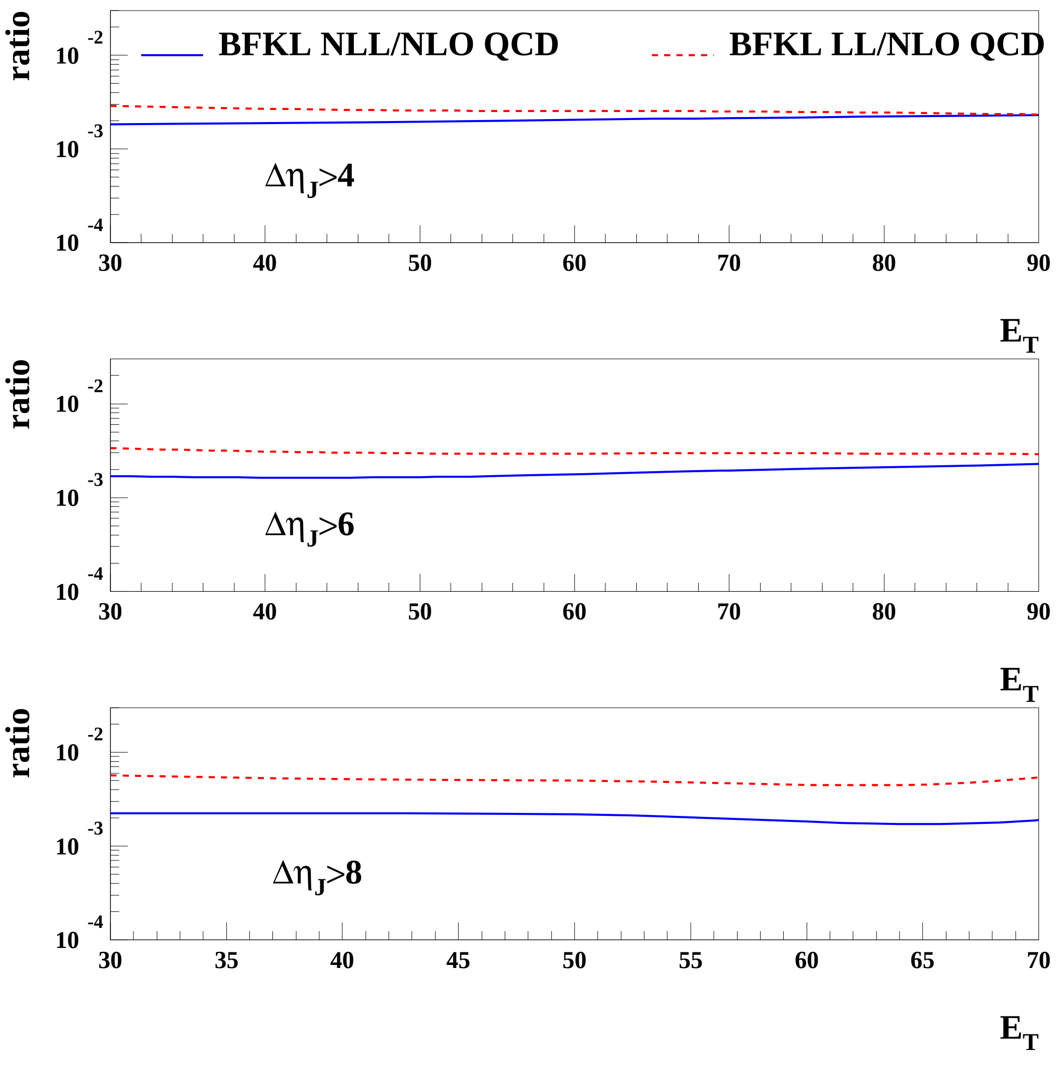
$$Ratio = \frac{BFKL\ NLL\ Herwig}{Dijet\ Herwig} \times \frac{LO\ QCD\ NLOJet++}{NLO\ QCD\ NLOJet++}$$

- Reasonable description using BFKL NLL formalism



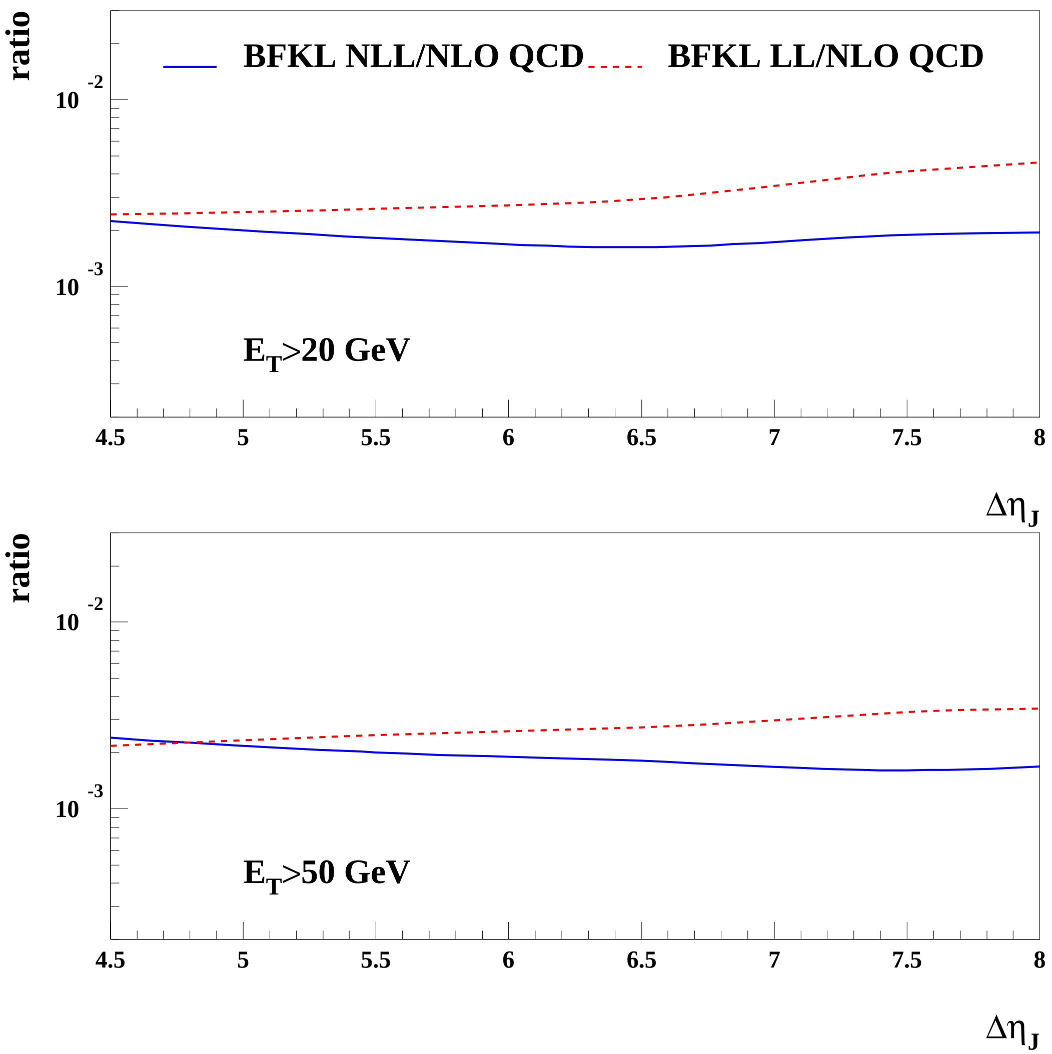
Predictions for the LHC

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



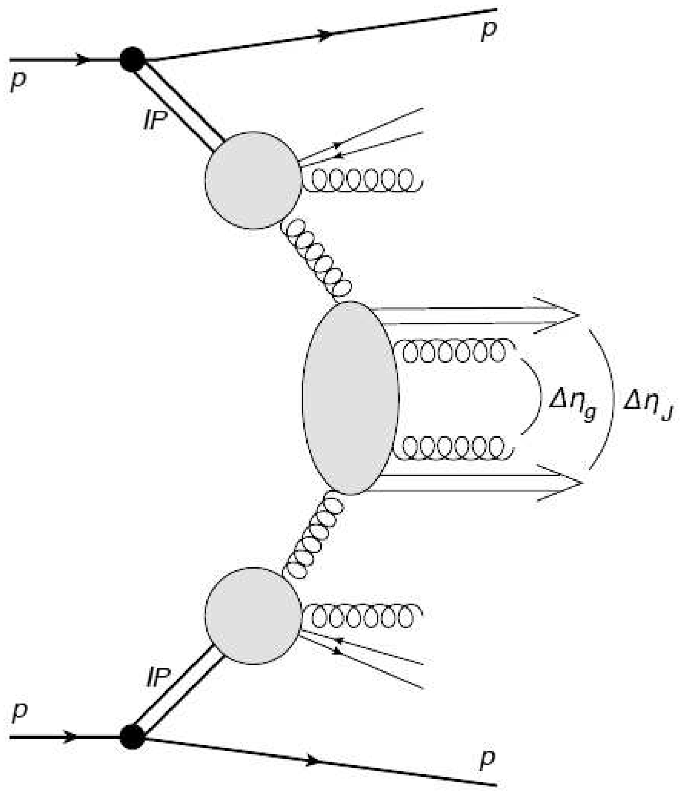
Predictions for the LHC

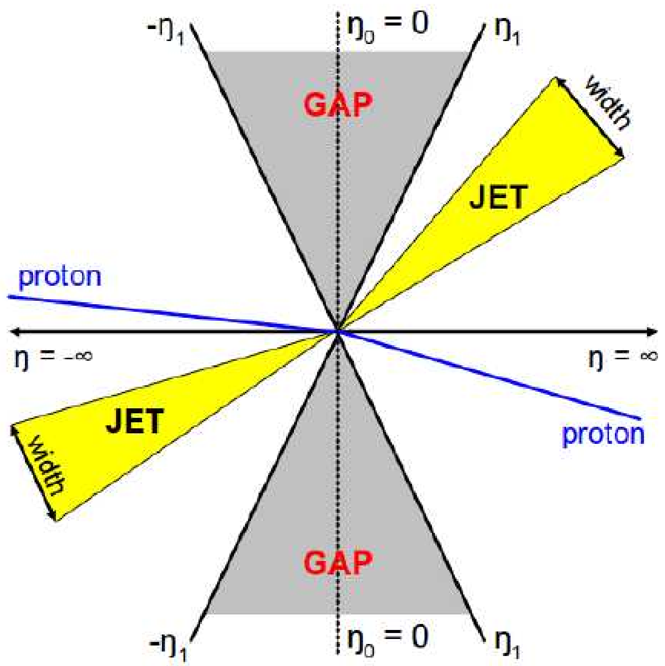
- Weak $\Delta\eta$ dependence
- Large differences in normalisation between BFKL LL and NLL predictions



Jet gap jet events in diffraction

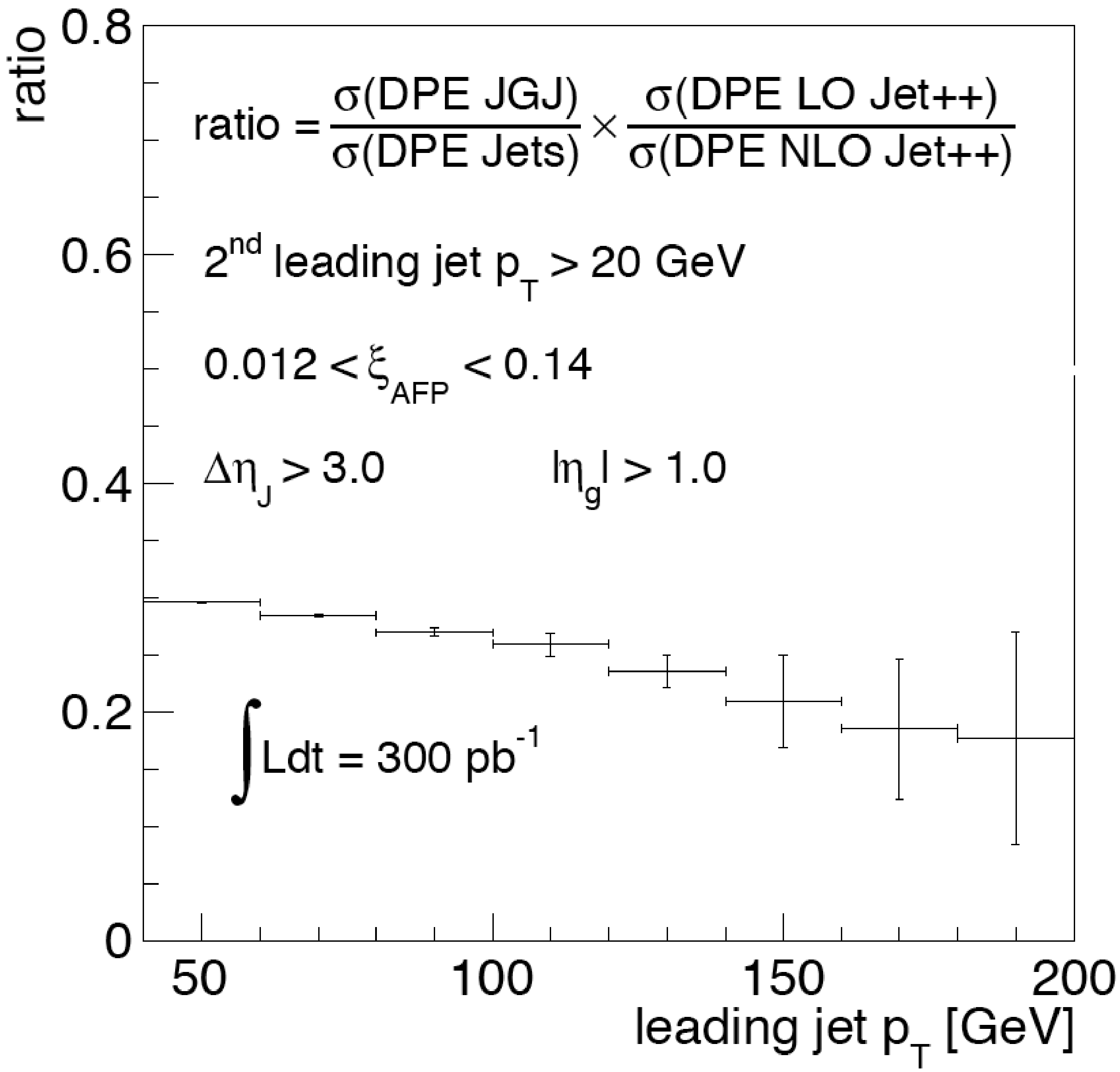
- Study BFKL dynamics using jet gap jet events
- Jet gap jet events in DPE processes: clean process, allows to go to larger $\Delta\eta$ between jets
- See: Gaps between jets in double-Pomeron-exchange processes at the LHC, C. Marquet, C. Royon, M. Trzebinski, R. Zlebcik, ArXiv:1212:2059, accepted by Phys. Rev. D





Jet gap jet events in diffraction

- Measure the ratio of the jet gap jet to the dijet cross sections: sensitivity to BFKL dynamics
- As an example, study as a function of leading jet p_T



Conclusion

- ATLAS measurement of jet veto cross section: good description of data using resummation of gluon emission at large angles (traditional QCD or BFKL formalism fail to describe data)
- Full implementation of BFKL NLL kernel for many jet proceeses at HERA, Tevatron and LHC
- Jet gap jets events to look for BFKL resummation effects:
  - NLL BFKL cross section implemented in HERWIG
  - Fair description of D0 and CDF data, decrease at higher rapidity of jet gap jet ratio to dijet data not expected by theory
  - Jet gap jet events in diffraction