Investigations of Non-linear Effects

Krisztian Peters

Deutsches Elektronen-Synchroton DESY

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In collaboration with: Hannes Jung
and lots of discussions with: L. Motyka and K. Kutak

Investigations of Non-linear Effects

Krisztian Peters

- Motivation
- Evolution formalism
- Constraints by HERA
- Heavy quark production
- Conclusions

Motivation

- What is the region of applicability of PDFs and of linear QCD evolution?
- PDFs extracted from HERA will be used in the description of hadronic processes at LHC
- Estimate of non-linear effects which might appear when extrapolating to the kinematical regime of LHC
- For which processes will we expect the breaking of k_t-factorisation?

Towards a unified description

- Kwiecinski et al: Unified BFKL and DGLAP description including saturation effects
- Improvement of BFKL equation by adding non-singular part of DGLAP gluon splitting function
- Resummation of both, leading $\ln Q^2$ and $\ln 1/x$ terms
- Including sub-leading $\ln 1/x$ effects via consistency constraint
- Non-linear part from BK equation to account for gluon recombination

[Kwiecinski, Martin, Stasto, PRD **56 (1997), 3991**]

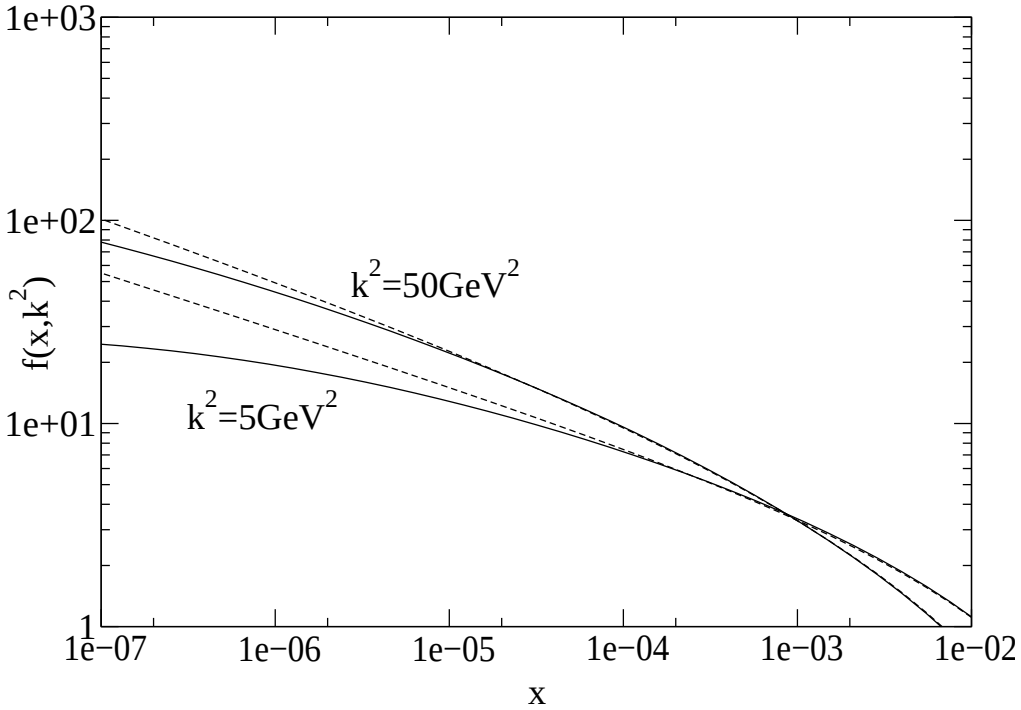
[Kutak, Kwiecinski, EPJ **C29 (2003), 521**]

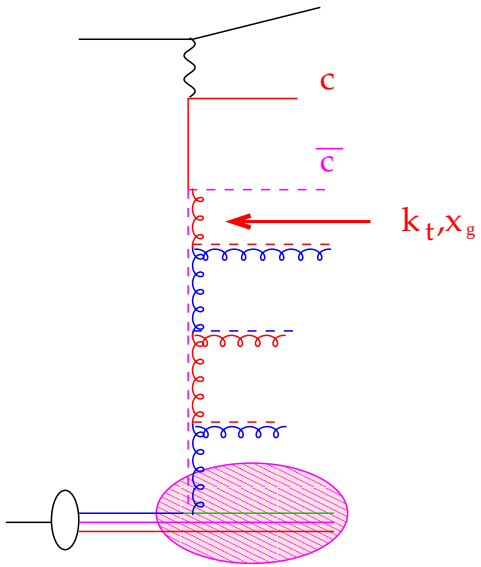
. . .

Towards a unified description cont.

- Non-linear screening contribution $\propto 1/R^2$
- R radius of dense gluon system; $1 < R < 4\,\text{GeV}^{-1}$

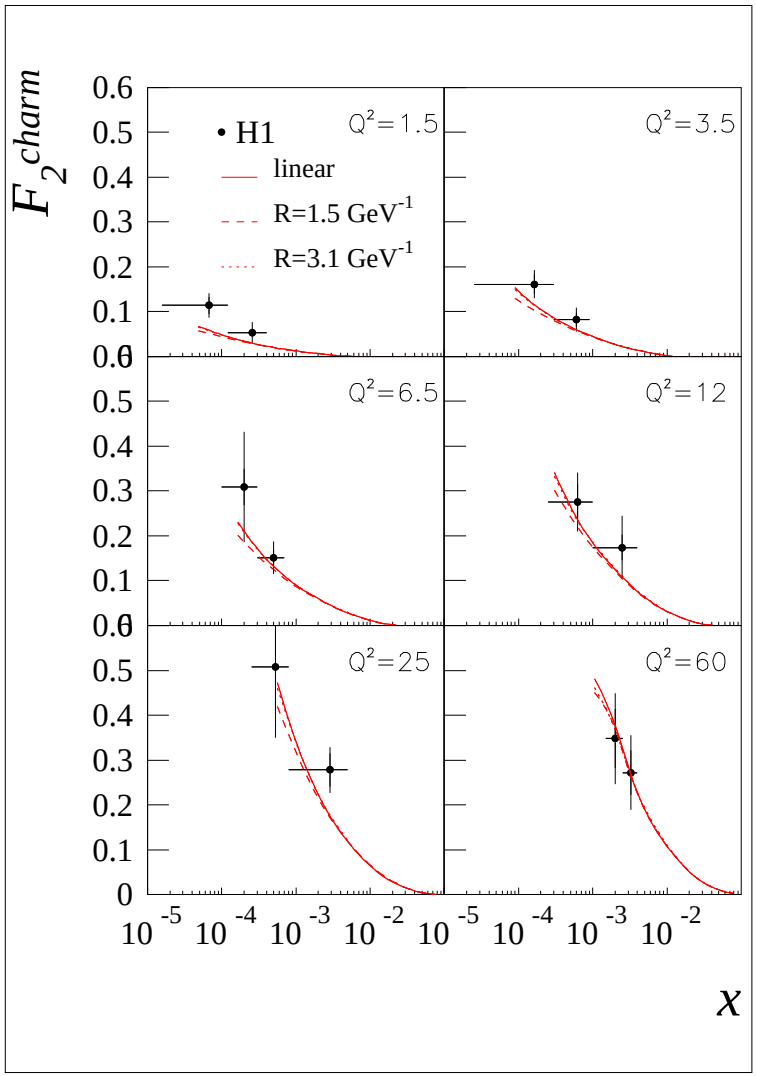
$R = 4\ \text{GeV}^{-1}$





- Saturation effects in the region of small k_t^2 and small x_g
- Do we have to take these into account at LHC for hard scattering processes?

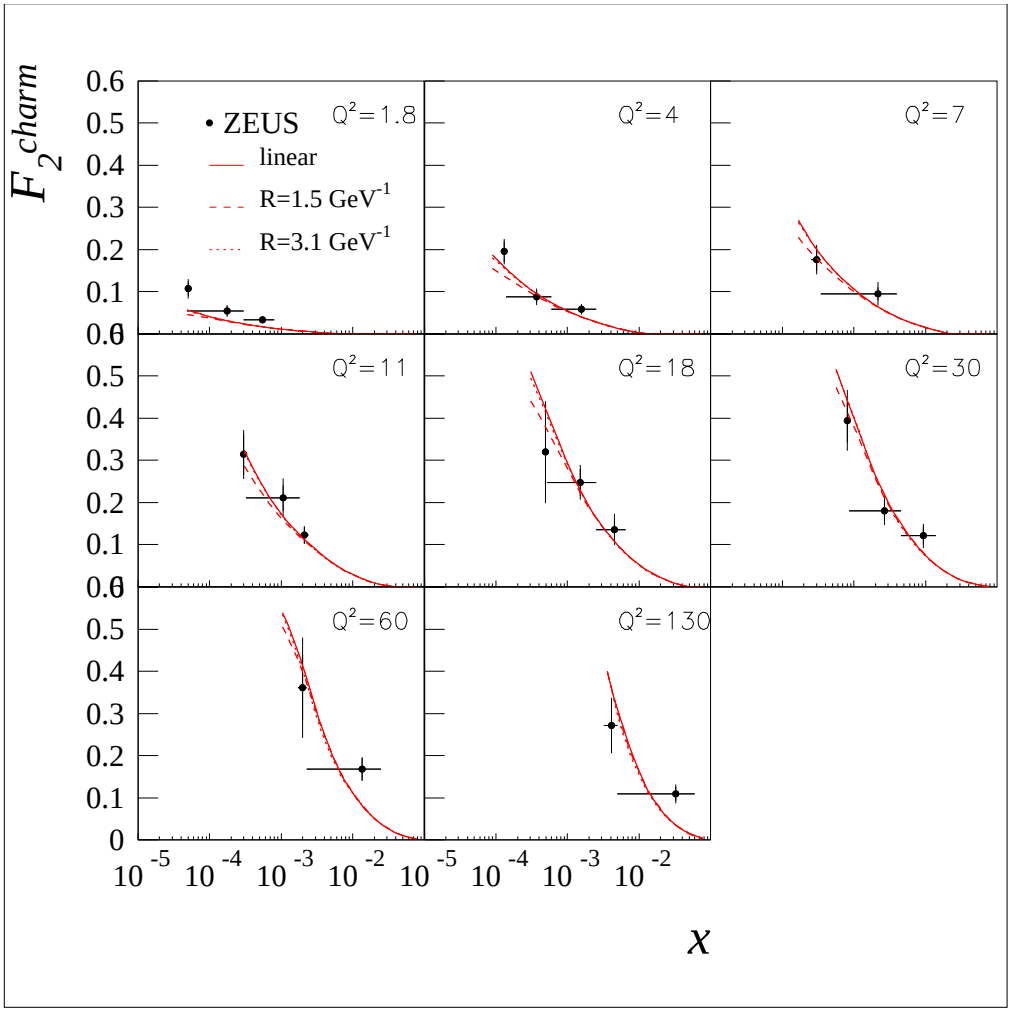
Constraints by HERA - H1



[H1 Coll., PLB **528** (2002) 199]

- Initial distribution: $xg(x, k_0^2) = N(1-x)^\rho$
- Fitted to H1 data with MC CASCADE
- $\chi^2/ndf = 1.05$
- Evolution describes F_2^c
- Non-linear part has no impact in the kinematical region of HERA

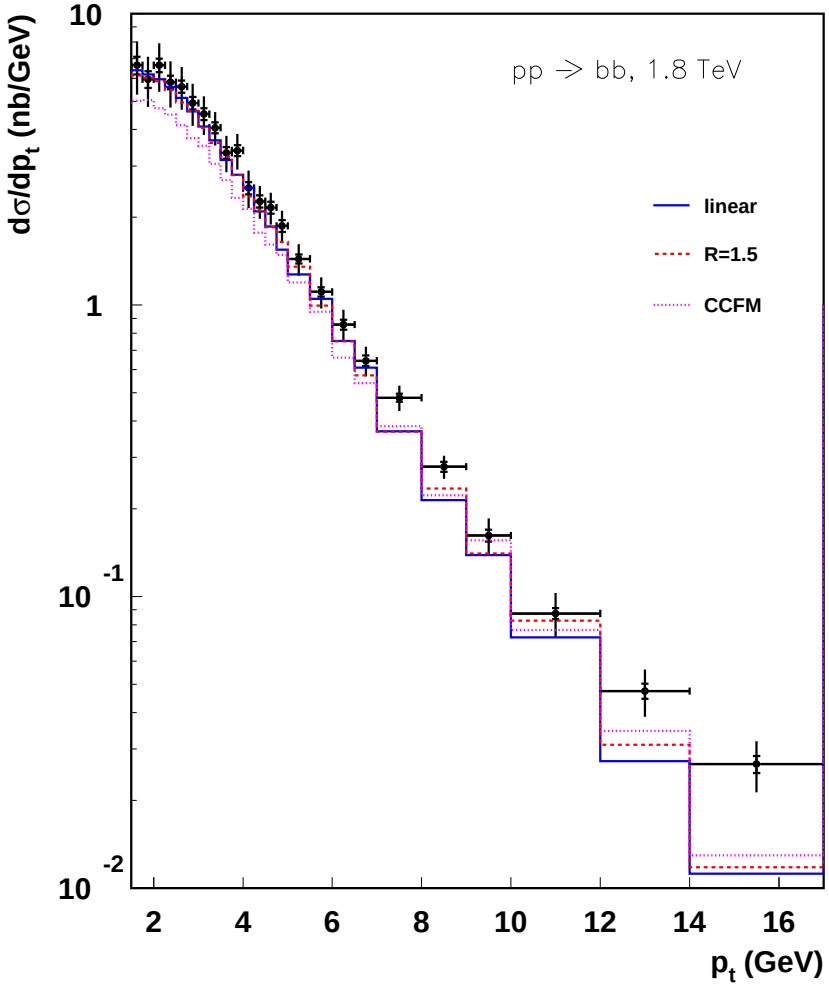
Constraints by HERA - Zeus



[ZEUS Coll., EPJ **C12** (2000) 35]

- Fit to Zeus data
- $\chi^2/ndf = 1.23$
- Again, non-linear part has no impact
- Cross-check: calculate $b\bar{b}$ production at CDF
- Predict $b\bar{b}$ production at LHC

$b\bar{b}$ production at CDF: $b \longrightarrow J/\psi$

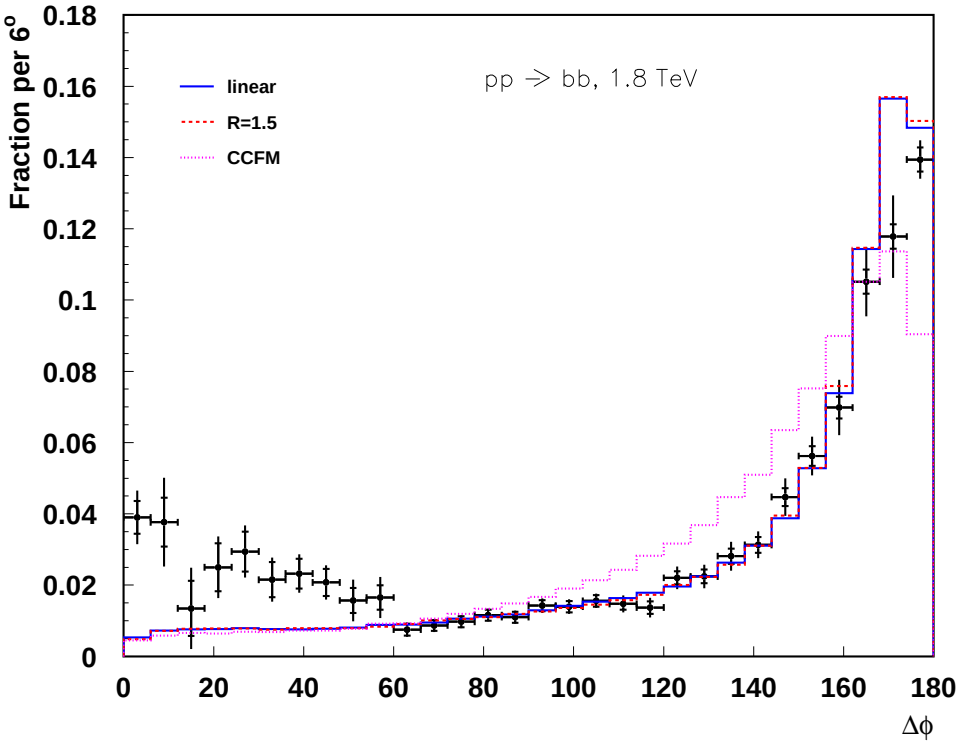


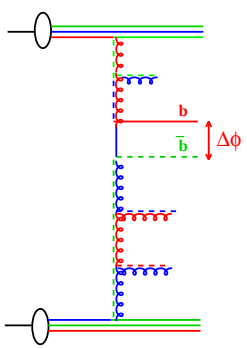
[CDF Coll., hep-ex/0412071]

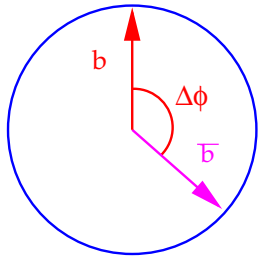
- Use gluon densities constrained by HERA
- $m_b = 4.75$ GeV
- Scale for α_s: $4m_q^2 + p_t^2$
- KMS gluon density has no factorisation scale

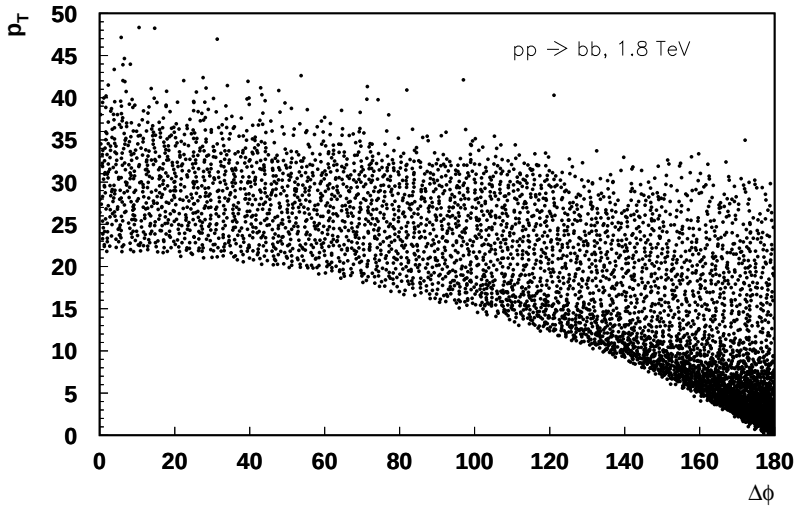
- KMS gluon density fits to the data well
- Again, non-linear part has no impact
- Good agreement between CCFM and KMS results

$b\bar{b}$ production at CDF - $\Delta\Phi$ distribution





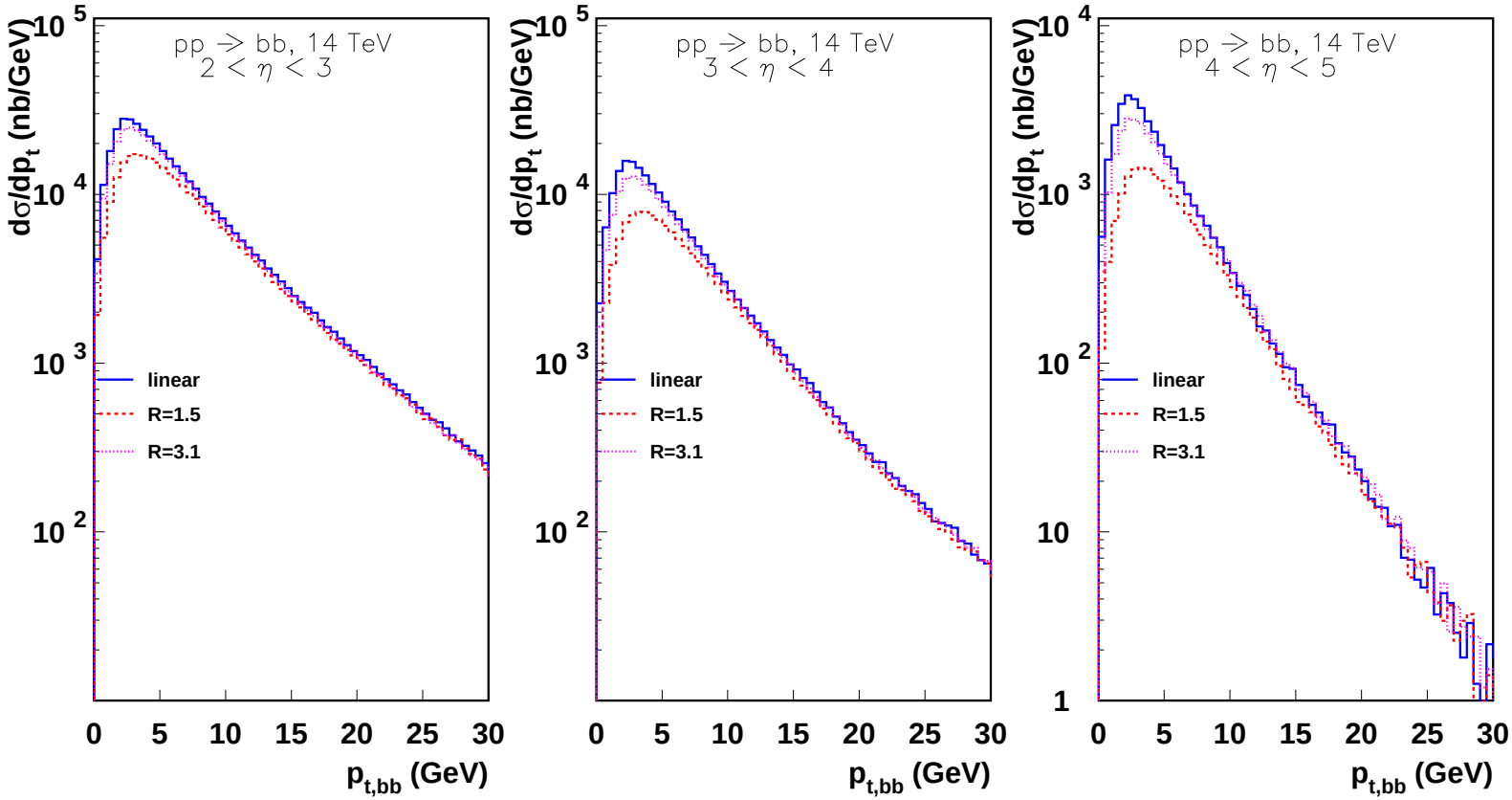




[CDF Coll., hep-ex/0412006]

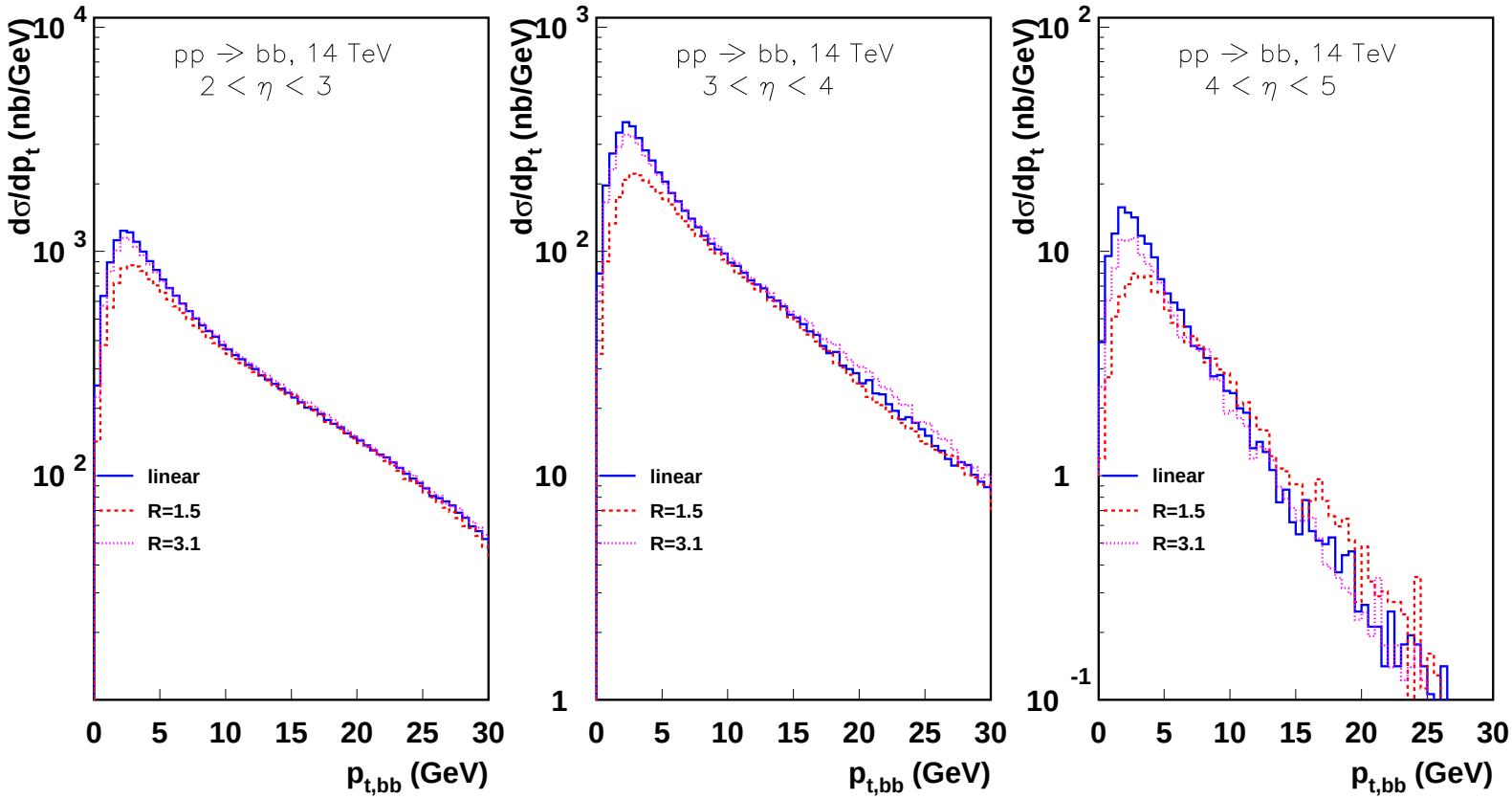
- KMS gluon density describes the $\Delta\phi$ distribution very well for high $\Delta\phi$ / low p_t values
- Smearing effects included

$b\bar{b}$ production at LHC - without cuts



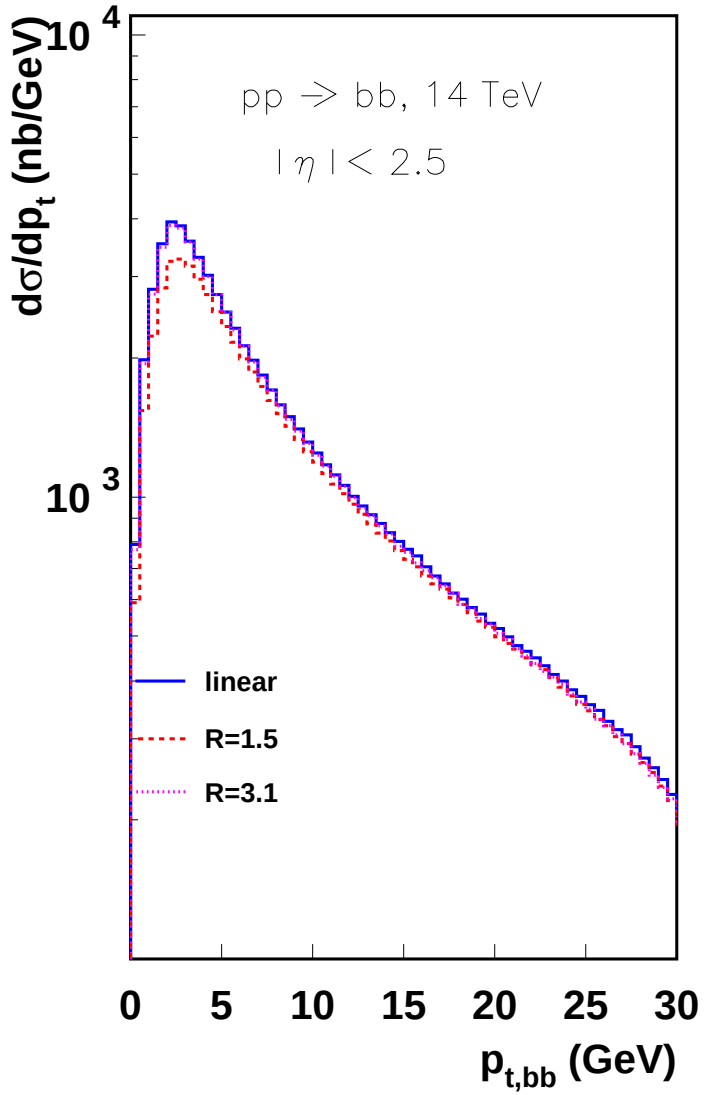
- For small R: saturation effects in the small p_t region
- Effects grow with rapidity (up to a factor 4)

$b\bar{b}$ production at ATLAS/CMS - $p_{t,b}$ cuts included



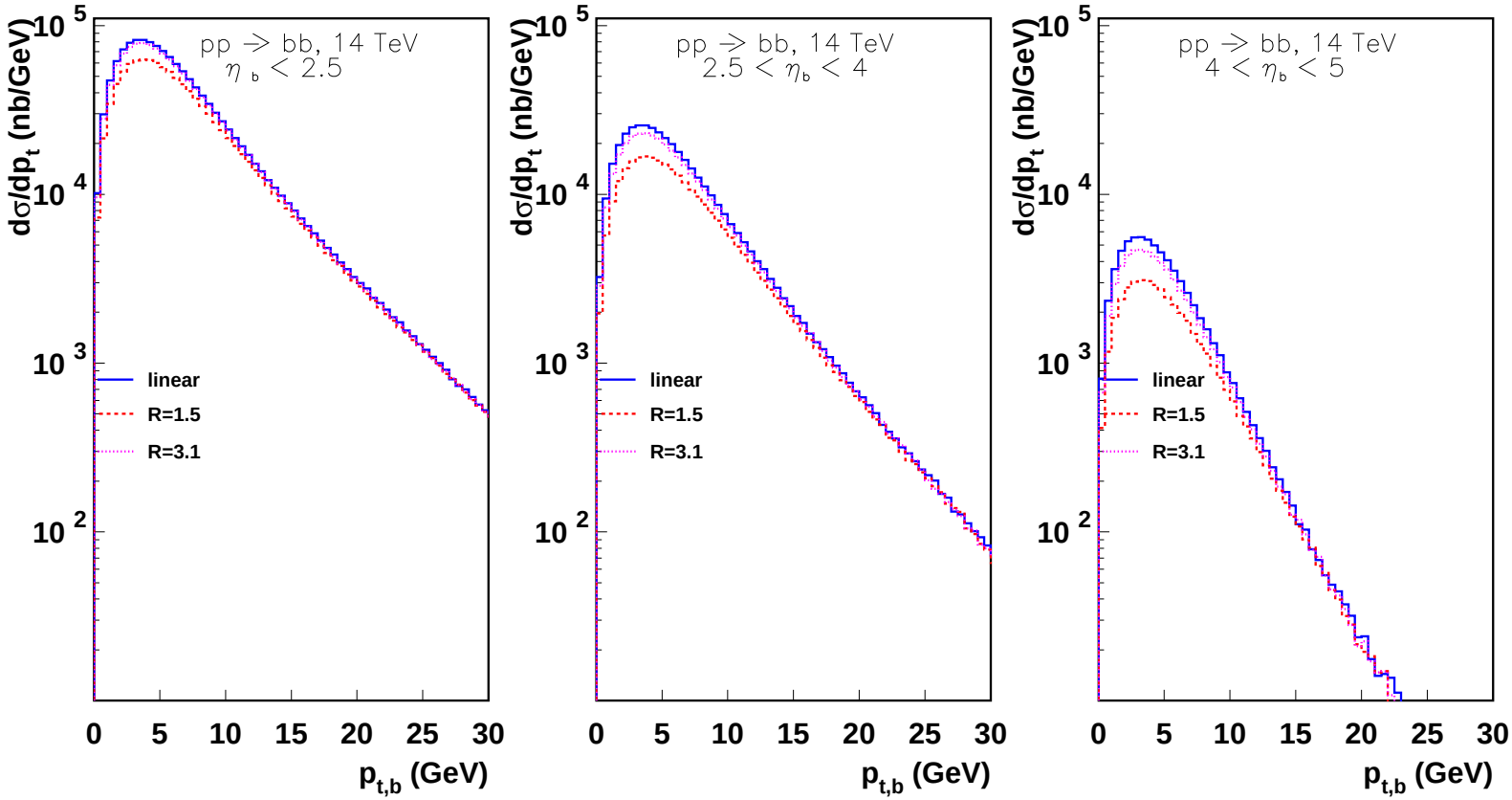
- $p_{t,b}$ and $p_{t,\bar{b}} > 10$ GeV
- Saturation effects could be still visible for small p_t values

$b\bar{b}$ production at ATLAS/CMS - η and p_t cuts included



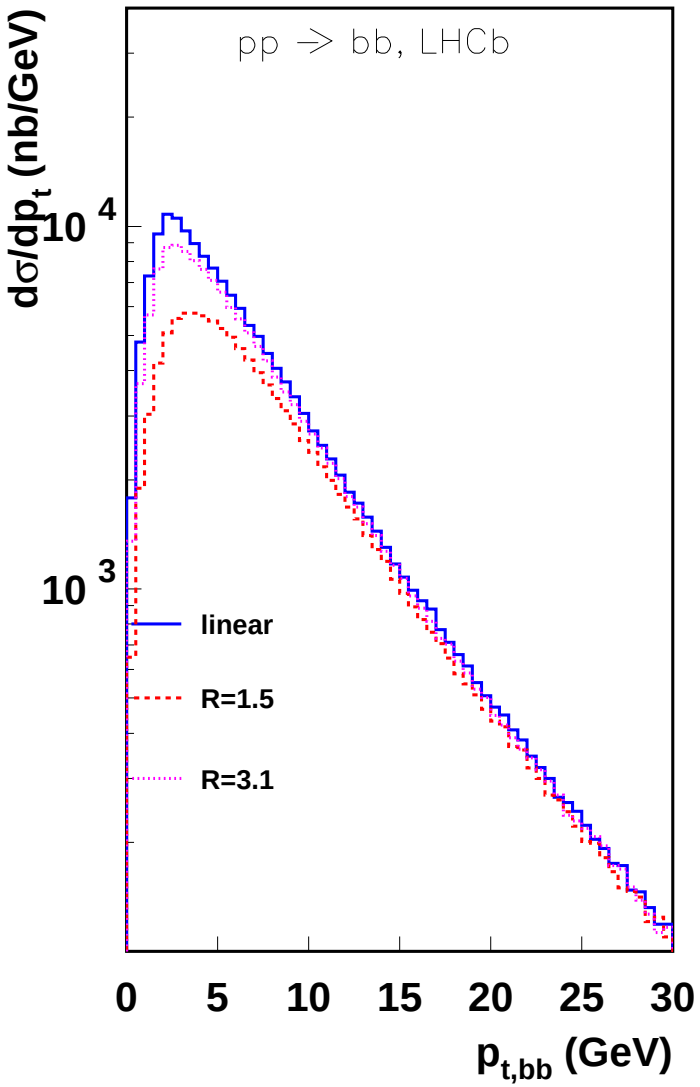
- $|\eta_b|$ and $|\eta_{\bar{b}}| < 2.5$
- $p_{t,b}$ and $p_{t,\bar{b}} > 10$ GeV
- Small saturation effects for $b\bar{b}$ production at the proposed cuts, only for $R = 1.5$ GeV^{-1}
- Effective k_t-factorisation can be safely used in this kinematical region

$b\bar{b}$ production at LHC



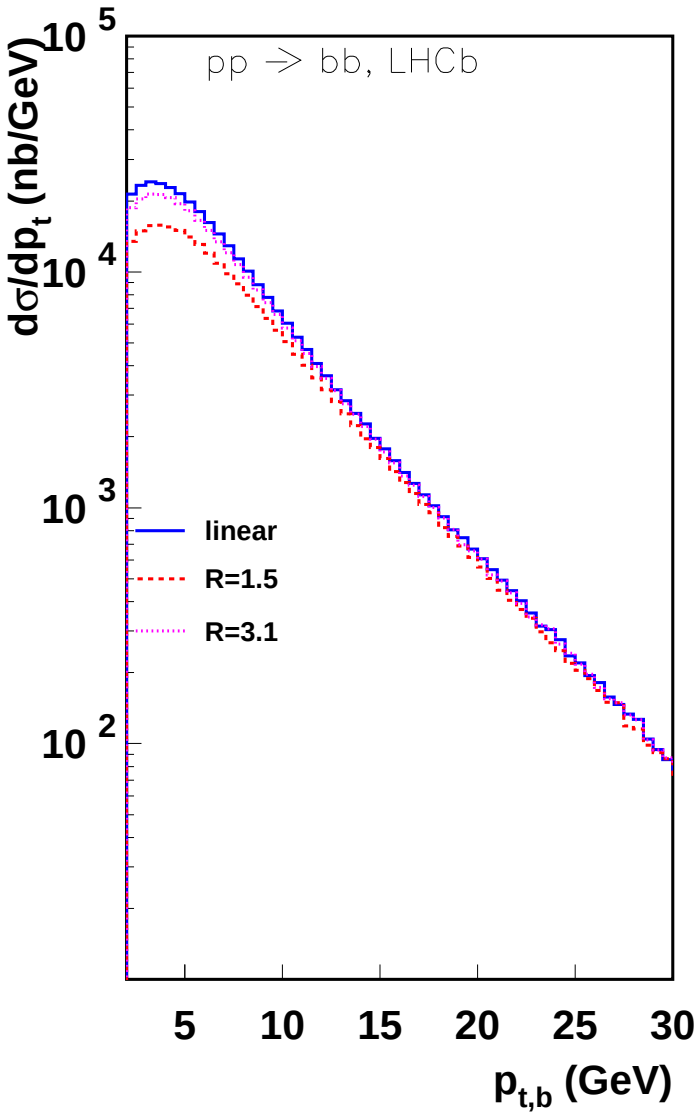
- Saturation effects for $p_{t,b} < 10$ GeV
- Only for the 'Hot-Spot scenario'

$b\bar{b}$ production at LHCb



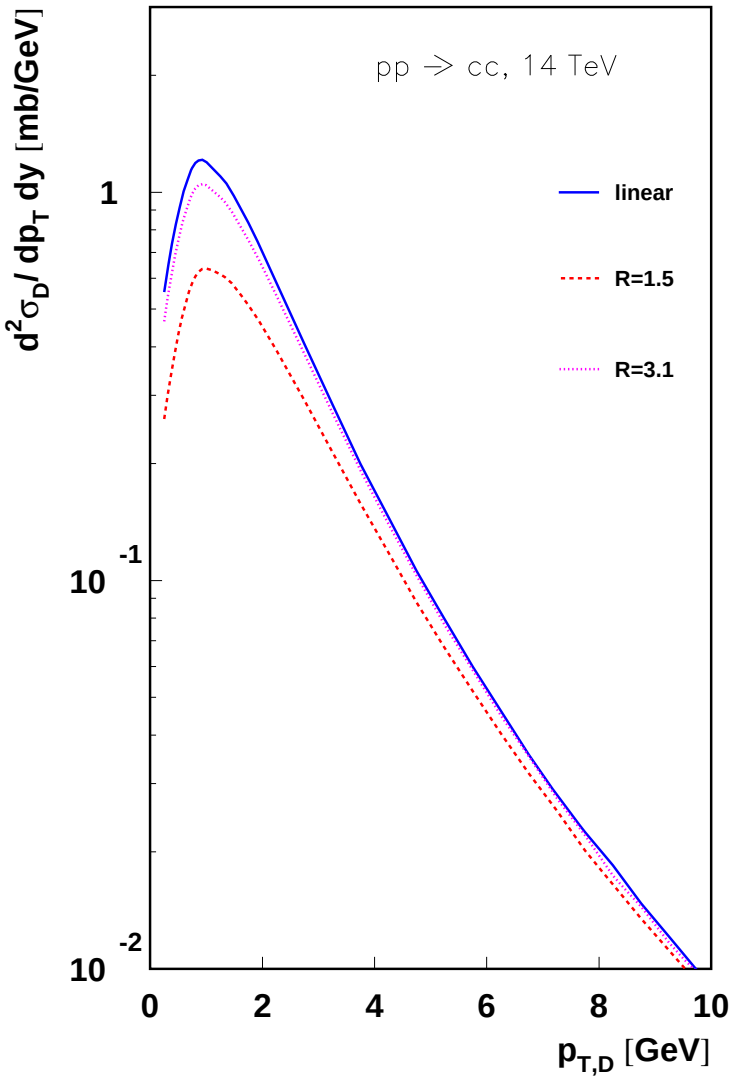
- p_t of $b\bar{b}$ system
- $p_{t,b}$ and $p_{t,\bar{b}} > 2$ GeV
- $1.9 < \eta_b\,,\ \eta_{\bar{b}} < 4.9$
- MC CASCADE
- At $p_t < 10$ GeV saturation effects for small R observable at LHCb

$b\bar{b}$ production at LHCb



- Tag only one quark
- $p_{t,b} > 2$ GeV
- $1.9 < \eta_b < 4.9$
- At $p_t < 10$ GeV saturation effects for small R still observable

$c\bar{c}$ production at ALICE: $c \longrightarrow D^0$



- $m_c = 1.5$ GeV
- Scale for α_s: $4m_q^2 + p_t^2$
- $|\eta| < 1$
- $p_{t,D} > 0.5$ GeV
- Saturation effects only at very low $p_{t,D}$ in this η range

Conclusions

- KMS gluon density fitted to HERA data describes $b\bar{b}$ production at CDF well
- At the kinematical region of HERA and CDF no saturation effects visible for heavy quark production
- Perturbative saturation effects at $b\bar{b}$ production at LHC for $p_t < 10$ GeV
- These effects do not survive cuts from ATLAS/CMS for $b\bar{b}$ production but could be visible at LHCb and at ALICE for $c\bar{c}$ production
- Saturation effects in the presented kinematical regions mainly for small values of the Saturation Radius relevant 'Hot-Spot scenario'