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Studies of forward jets and production of Z, W within high energy factorisation approach

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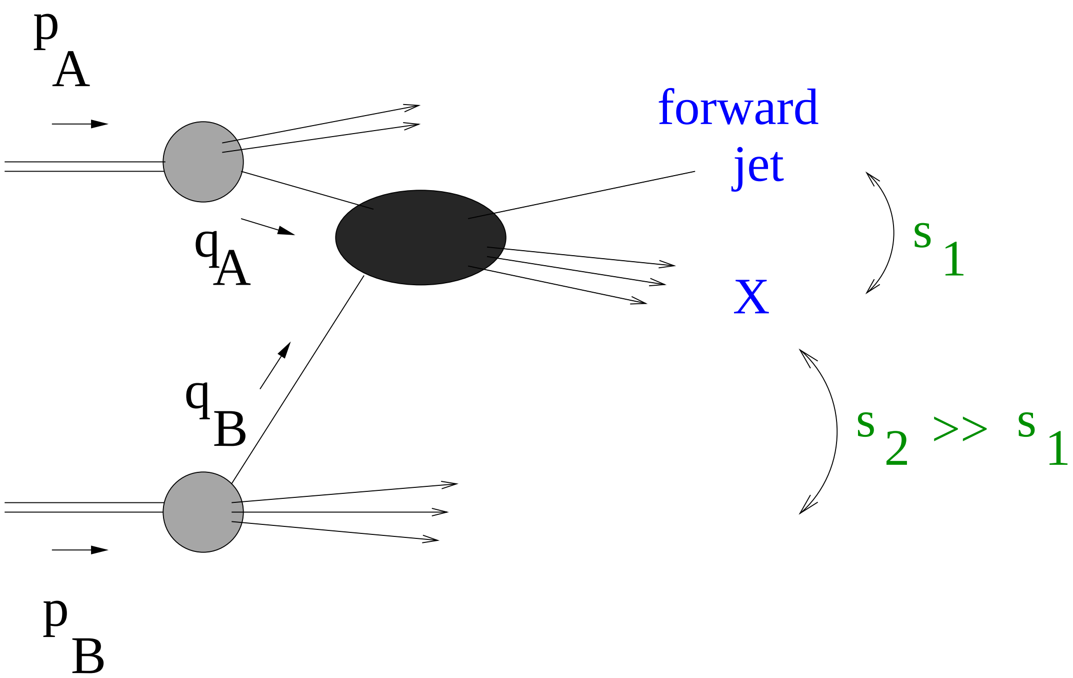
I. INTRODUCTION

High-p_T production at the LHC



▷ phase space opening up for large $\sqrt{s}$

▷ unique coverage of large rapidities (calorimeters+proton taggers)

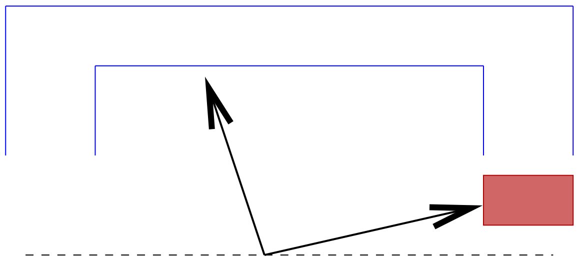
$\Downarrow$

• physics of hard processes with multiple hard scales and highly sensitive to parton dynamics at $x \to 0$

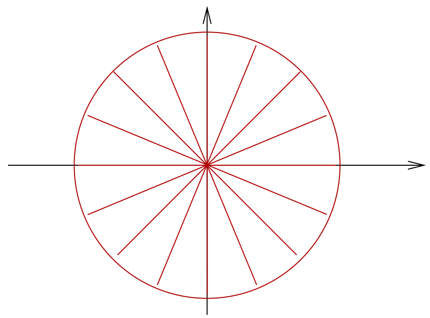
• polar angles small but far enough from beam axis

• measure azimuthal plane correlations

$$p_\perp \gtrsim 20 \text{ GeV} , \; \Delta\eta \gtrsim 4 \div 6$$



central + forward detectors



azimuthal plane

[H. Jung et al., HERA-LHC Proc. arXiv:0903.3861;

M. Grothe, arXiv:0901.0998; D. d'Enterria, arXiv:0806.0883;

X. Aslanoglou et al., CERN-CMS-NOTE-2008-022 (2008)]

▷ Multi-scale problem ⇒

⇒ all-order summation of high-energy logarithmic corrections long recognized to be necessary for reliable QCD predictions

Mueller & Navelet, 1987; Del Duca, Peskin & Tang, 1993; Stirling, 1994

⇒ efforts toward improved Monte Carlos / semi-analytic approaches

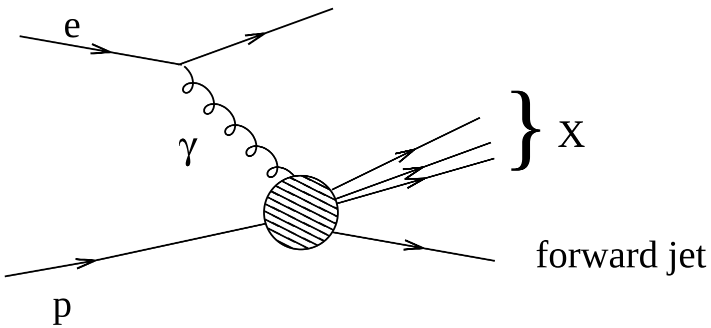
Andersen, arXiv:0906.1965; Andersen and Sabio Vera, 2003;

Andersen, Del Duca, Frixione, Schmidt and Stirling, 2001;

Schwennsen, hep-ph/0703198; Bartels, Sabio Vera and Schwennsen, 2006;

Ewerz, Orr, Stirling and Webber, 2000; Orr and Stirling, 1998

• DIS case ⇒



• neither PYTHIA Monte Carlo nor NLO calculations are able to describe forward jet ep data

[A. Knutsson, LUNFD6-NFFL-7225-2007 (2007); L. Jönsson, AIP Conf. Proc. 828 (2006) 175]

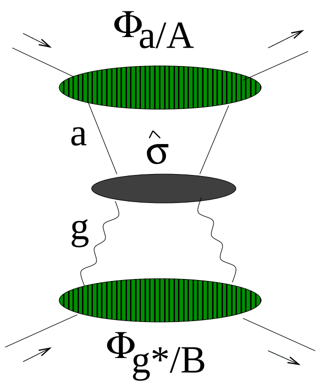
- High-energy factorization at fixed transverse momentum

$$\frac{d\sigma}{dQ_T^2 d\varphi} = \sum_a \int \phi_{a/A} \otimes \frac{d\widehat{\sigma}}{dQ_T^2 d\varphi} \otimes \phi_{g^*/B}$$

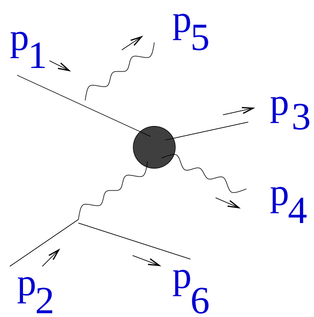
▷ needed to resum consistently both logs of rapidity and logs of hard scale

Catani et al., 1991; Ciafaloni, 1998

Deák, Jung, Hautmann & K, in progress



(a)

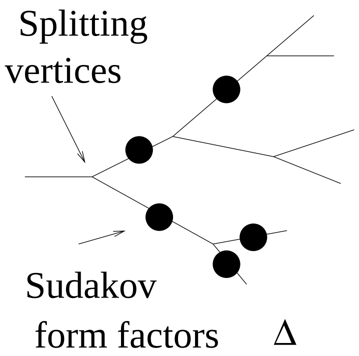


(b)

Figure 1: (a) Factorized structure of the cross section; (b) a typical contribution to the qg channel matrix element.

◇ ϕ_a near-collinear, large-x; ϕ_{g^*} $k_\perp$-dependent, small-x
◇ $\widehat{\sigma}$ off-shell continuation of hard-scattering matrix elements

II. PARTON DISTRIBUTIONS BY SHOWERING METHODS

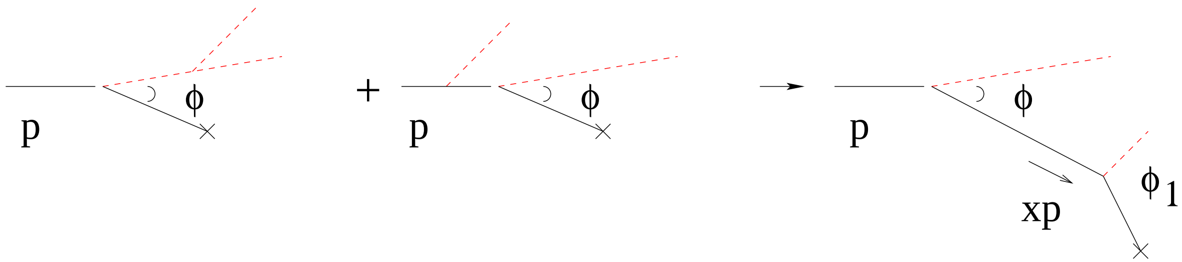


$$d\mathcal{P} = \int \frac{dq^2}{q^2} \int dz \; \alpha_S(q^2) \; P(z) \; \Delta(q^2, q_0^2)$$

$\hookrightarrow$ collinear, incoherent emission

◇ Soft emission $\longrightarrow$ interferences $\longrightarrow$ ordering in decay angles

$\hookrightarrow$ gluon coherence for $x \sim 1$



- ex.: HERWIG, new PYTHIA

◇ Gluon coherence for $x \ll 1 \Rightarrow$ corrections to angular ordering:

$\hookrightarrow$ MC based on $k_\perp$-dependent unintegrated pdfs and MEs

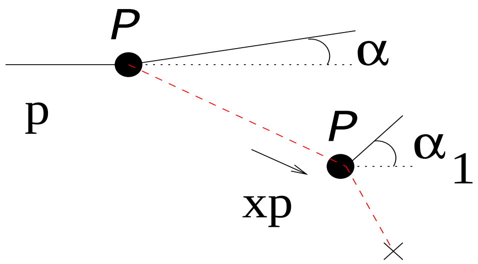
K$_\perp$-DEPENDENT PARTON BRANCHING

- MC for NLO QCD evolution at unintegrated level

  proposed in Jadach & Skrzypek, arXiv:0905.1399 [hep-ph]

- CCFM gluon branching eq. (leading-logarithmic)

$$\begin{aligned}\mathcal{G}(x, k_T, \mu) &= \mathcal{G}_0(x, k_T, \mu) + \int \frac{dz}{z} \int \frac{dq^2}{q^2}\, \Theta(\mu - zq) \\ &\times \underbrace{\Delta(\mu, zq)}_{\text{Sudakov}} \; \underbrace{\mathcal{P}(z, q, k_T)}_{\text{unintegr. splitting}} \; \mathcal{G}\left(\frac{x}{z}, k_T + (1-z)q, q\right)\end{aligned}$$



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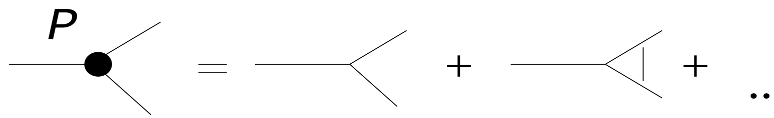


▷ implemented in CASCADE MC (H. Jung)

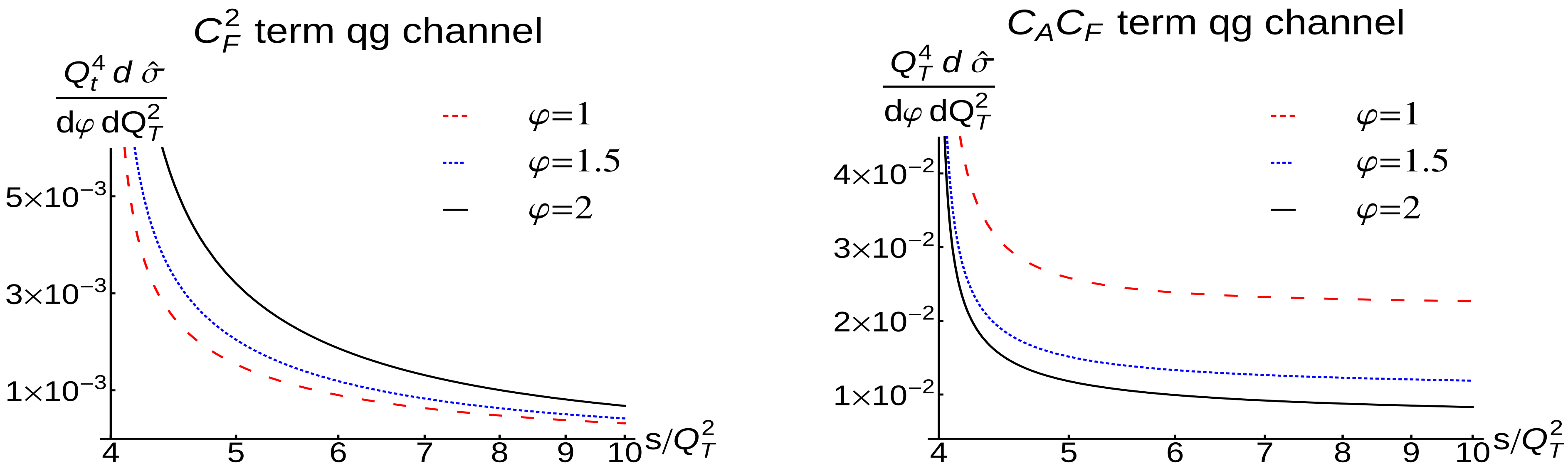
III. HARD SCATTERING CROSS SECTIONS

- Matrix elements for fully exclusive events with forward jets

[Deák, Hautmann, Jung, & K, 2009]

- Both quark and gluon channels found to be important for realistic phenomenology

$Q_T =$ final-state transverse energy (in terms of two leading jets p_t's)

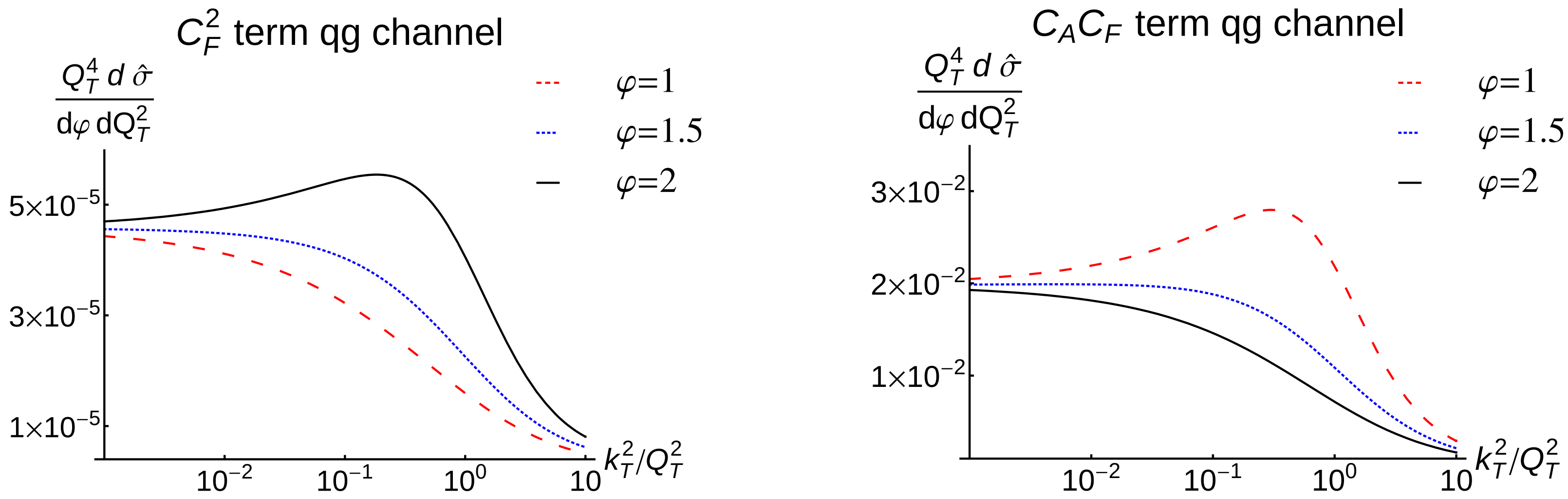


▷ $C_F C_A$ contribution to qg dominates large s/Q_T^2 (constant at large energy)

BEHAVIOR AT LARGE $k_\perp$

$k_T =$ transverse momentum carried away by extra jets

$k_T/Q_T \to 0$ leading order process



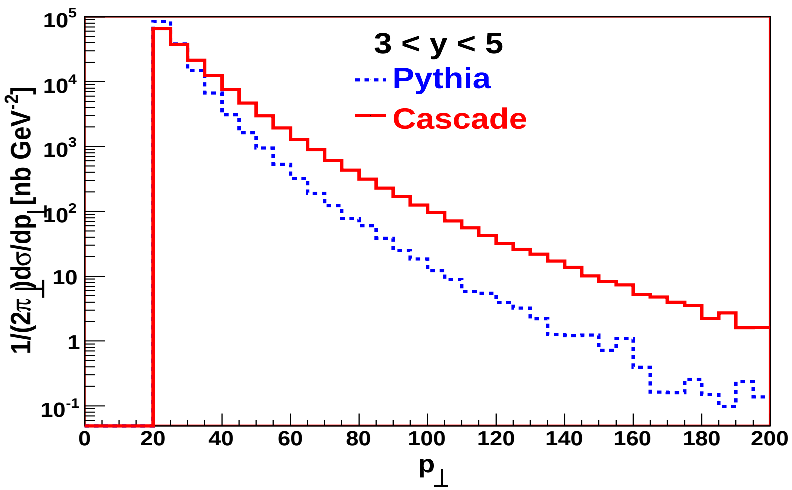
[Deák, Hautmann, Jung, & K, in progress]

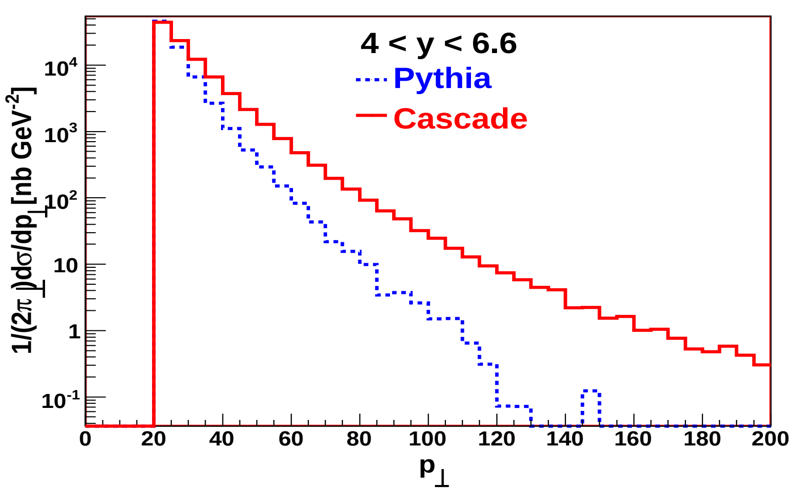
- dynamical cut-off at $k_T \sim Q_T$ set by coherence effects
- non-negligible terms from finite k_T tail

p$_\perp$ DISTRIBUTION OF PRODUCED JETS

Jet Nr.1:$-2 < y < 2$ p$_\perp$ > 20GeV

Jet Nr.2: $3 < y < 5$ and $4 < y < 6.6$ p$_\perp > 20$GeV

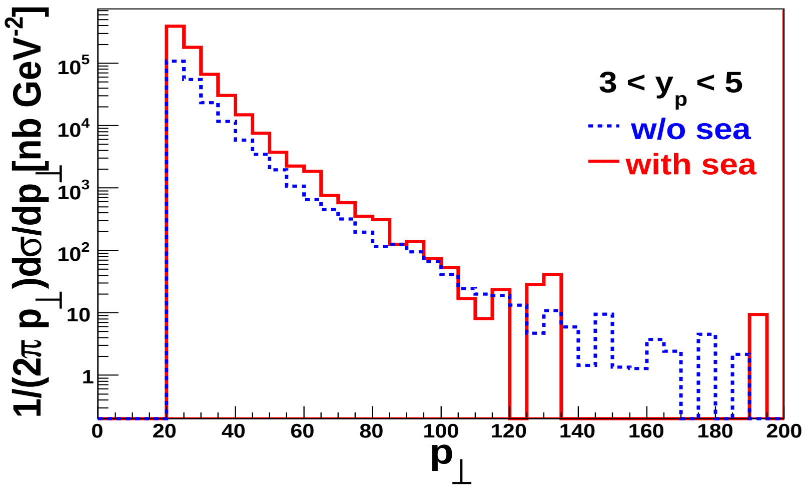


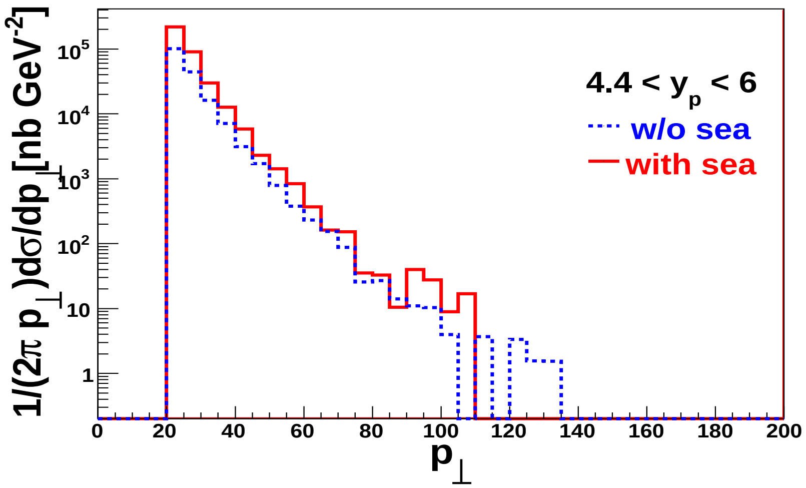


[Deák, Hautmann, Jung, & K, in progress]

- k_T of incoming gluon allows for harder spectrum
  - non-negligible terms from finite k_T tail

FORWARD JETS - PYTHIA PROOF OF THE CONCEPT

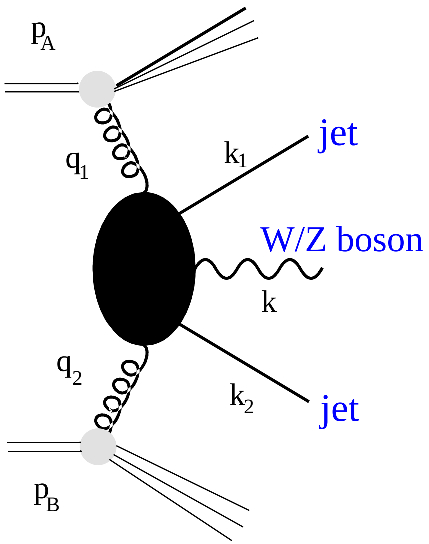




- in our approach we consider only flavour nonsinglet
  - PYTHIA cross checks that flavour singlet contribute less in a forward region

PRODUCTION OF Z/W BOSONS

- background for BSM processes
  - luminosity measurements , calibration of detectors

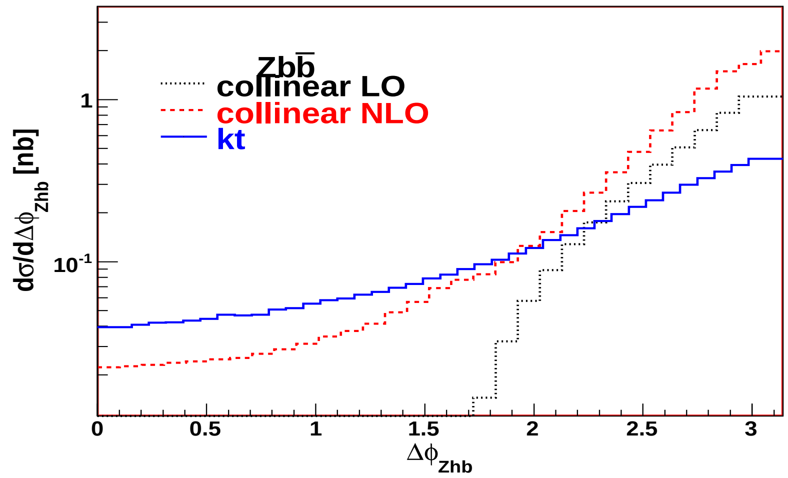


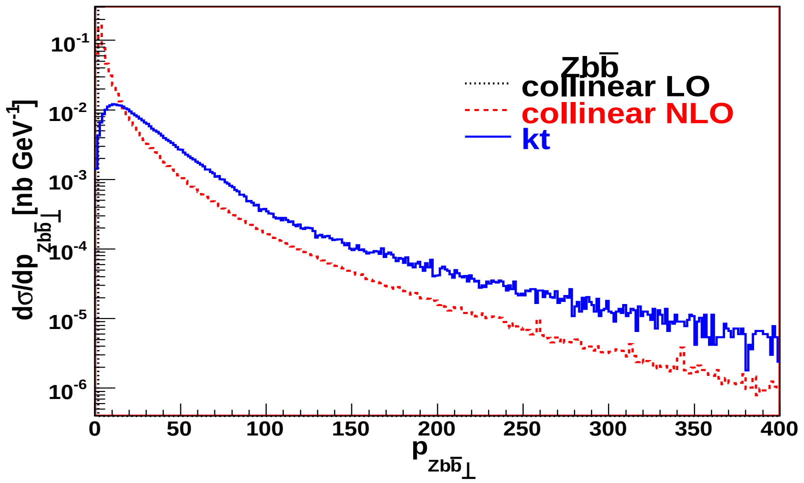
[Deák, Schwennsen; Baranov, Lipatov, Zotov]

- hard scale provided by mass of Z/W
  - k_T of incoming gluons might be relevant for W/Z $p_\perp$ spectra

ANGULAR CORRELATIONS AND $p_\perp$ SPECTRUM

$$\Delta\phi_{Zhb} = ang(p_{Z\perp}, max(p_{b\perp}, p_{\bar{b}\perp}))$$





- forbiden at LO region in collinear factorisation
  can be evaded in LO high energy factorisation
  - difference in $p_\perp$ spectrum due to missing
    higher order terms in collinear calculation

Conclusions

- Correlations of high-p_T probes across large rapidity intervals will be explored with forward detectors at the LHC to unique level

- Branching methods based on u-pdfs and $k_\perp$-MEs useful to
  - ▷ simulate high-energy parton showers
  - ▷ investigate possibly new effects from QCD physics
  - ▷ calculate background for BSM physics