

Minijets & Mueller-Navelet jets

Mats Kampshoff

25.10.2022

What is BFKL?

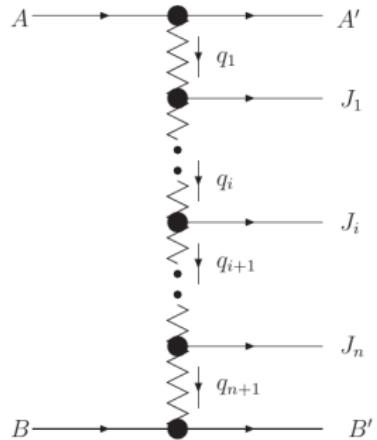


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→ additional radiation ordered in p_\perp

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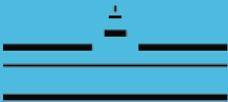


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- large $s \gg |t|$ (actually "Multi-Regge-kinematics"):
 $\alpha_s \ln(s) \approx 1$ and main contribution from terms $(\alpha_s \ln s)^n \Rightarrow$ resum for all n .

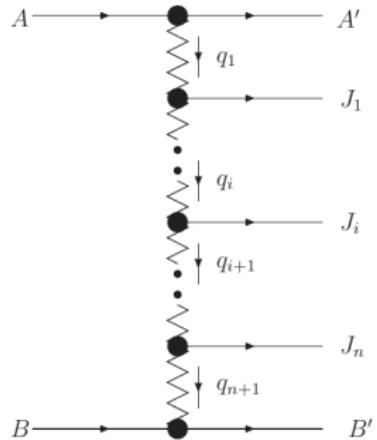


V.S. Fadin, *Acta Physica Polonica B* **39**, 2193 (2008)

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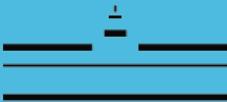


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- BFKL predicts n gluon emissions ordered in rapidity y , unordered in p_{\perp} .

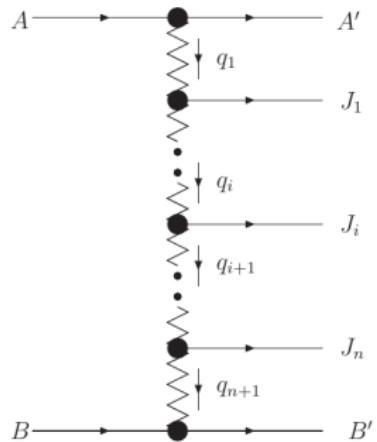


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- $s \gg |t|$: BFKL becomes relevant / dominant at large rapidities!



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The Setup: Mueller-Navelet Jets



- Cuts:

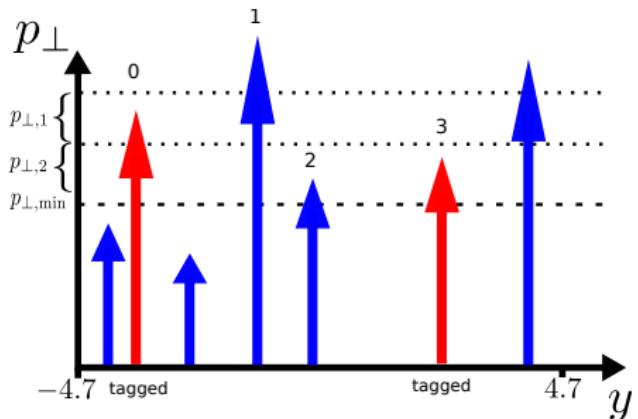
$$p_{\perp 0} \in [30; 40] \text{ GeV}$$

$$p_{\perp N_{\text{jets}}-1} \in [20; 30] \text{ GeV}$$

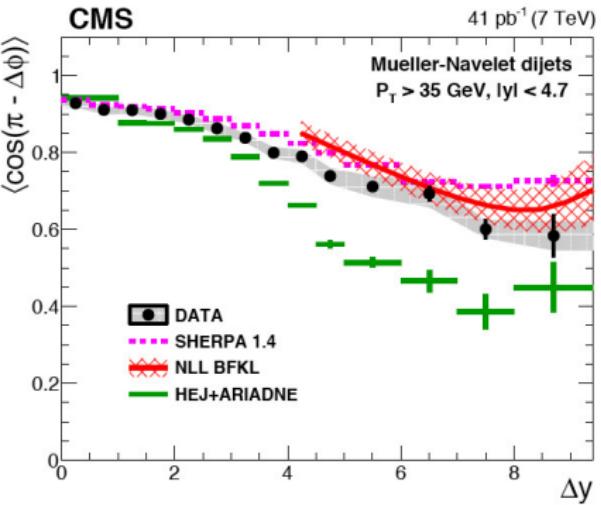
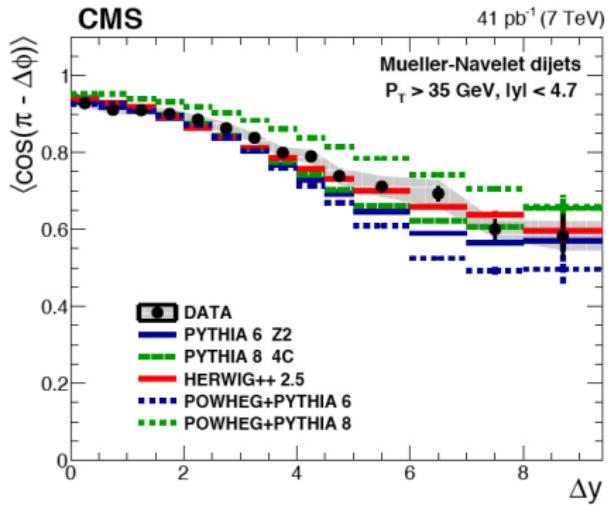
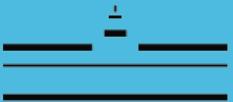
$$p_{\perp \min} \geq 20 \text{ GeV}$$

$$y \in [-4.7; 4.7]$$

- Maximize $|y_{N_{\text{jets}}-1} - y_0|$ in tagging

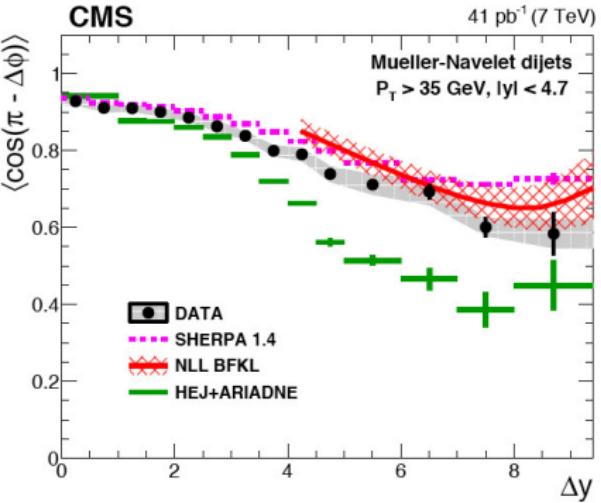
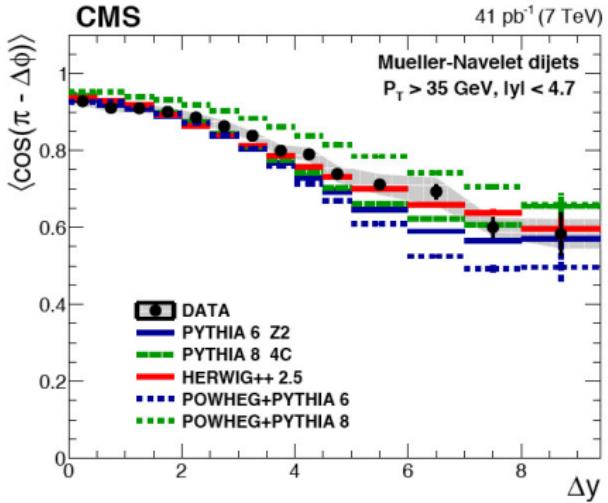
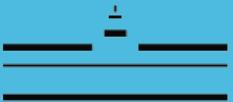


Motivation



- Previous CMS study: Inclusive dijet observables, $\langle \cos(\Delta\Phi) \rangle$

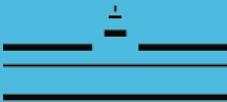
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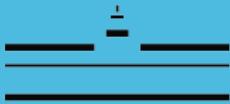
- Previous CMS study: Inclusive dijet observables, $\langle \cos(\Delta\Phi) \rangle$
⇒ Hints of BFKL dynamics, further studies required ⇒ look for less inclusive variables, "minijets"



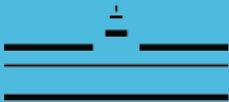
- Goal: Can we pin down BFKL effects at current energies in multijet production at the LHC? Also understand the structure of multi-guon emission!



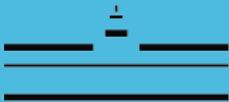
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- Ultimately: Search for observables with linearly independent distributions
⇒ Fit to data



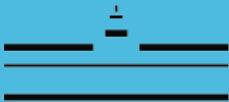
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- NLO QCD: POWHEG dijet $2 \rightarrow 3$ hard process + Pythia showering
⇒ 3 independent hard partons multiply by collinear emission

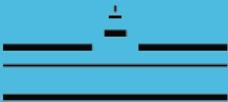


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- Jet finder: slowJet, anti- k_T , $R = 0.5$

Observables



! Only take into account minijets $\Rightarrow N_{\text{jets}} \geq 4$

tagged jets are not part of the observables, sort $y_0 = 0, y_i < y_{i+1}$

$$\langle p_\perp \rangle_{\text{mini}} = \frac{1}{N_{\text{jets}} - 2} \sum_{i \in \text{minij.}} p_{\perp,i},$$

$$\text{random: } \frac{d\sigma}{d\langle p_\perp \rangle_{\text{mini}}} \sim \langle p_\perp \rangle_{\text{mini}}^{N_{\text{jets}} - 3}$$

$$\langle \Delta y \rangle_{\text{mini}} = \frac{1}{N_{\text{jets}} - 2} \sum_{i \in \text{minij.}} y_{i+1} - y_i = y_{N_{\text{jets}} - 1} - y_1,$$

$$\text{random: } \frac{d\sigma}{d\langle \Delta y \rangle_{\text{mini}}} \sim \begin{cases} \langle \Delta y \rangle_{\text{mini}}^{N_{\text{jets}} - 3} & \langle \Delta y \rangle_{\text{mini}} < \Delta Y \\ \langle \Delta y \rangle_{\text{mini}}^{N_{\text{jets}} - 2} & \langle \Delta y \rangle_{\text{mini}} > \Delta Y \end{cases}$$



Observables

$$R_y = \frac{1}{N_{\text{jets}} - 3} \sum_{i, i+1 \in \text{mj}} \frac{y_i}{y_{i+1}}$$

Shifts to higher values with N_{jets} increasing, unchanged with ΔY .

Strict BFKL 5-jet event would have $R_y \sim \frac{2}{3}$.

foQCD: All over the place!

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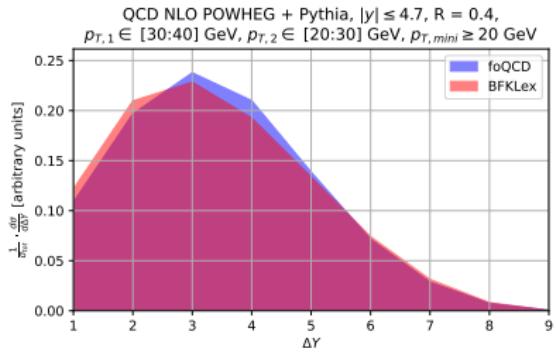
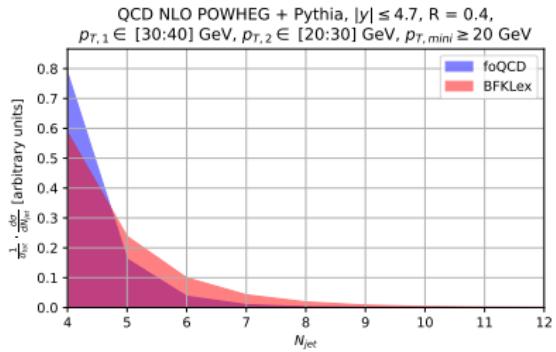
foQCD: All over the place!

$$R_{ky} = \frac{1}{N_{\text{jets}} - 3} \sum_{i,i+1 \in \text{mj}} \frac{p_{\perp,i}}{p_{\perp,i+1}} \exp(y_i - y_{i+1})$$

BFKL: $p_{\perp,i} \sim p_{\perp,i+1}$, $y_{i+1} \gg y_i \Rightarrow R_{ky}$ small.

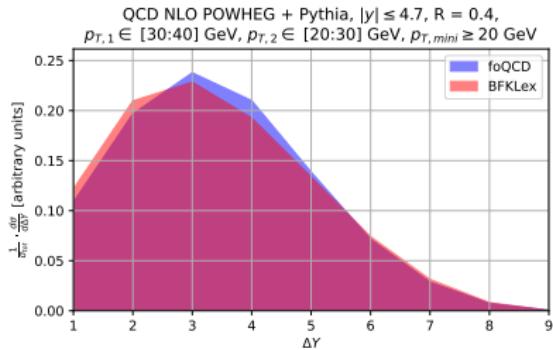
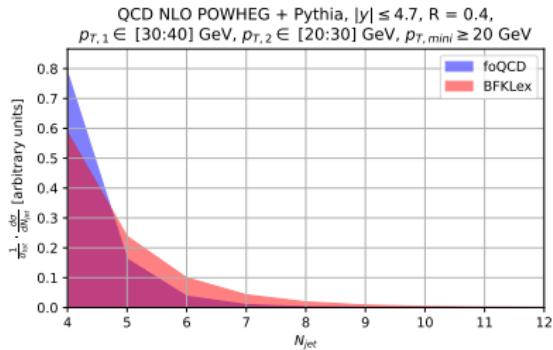
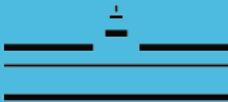
foQCD: $p_{\perp,i} \gg p_{\perp,i+1}$, $y_{i+1} \sim y_i \Rightarrow R_{ky}$ larger...in some constellations!

Inclusive cross-sections



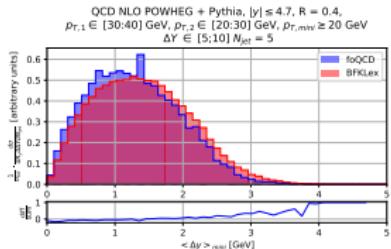
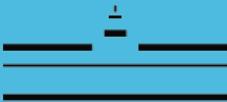
- $\frac{d\sigma}{dN_{\text{jets}}}$ (left): Require 4 hard jets! foQCD at max 3 hard partons, showering eventually runs out of options. BFKL does not need collinearity for hard emissions, more likely.

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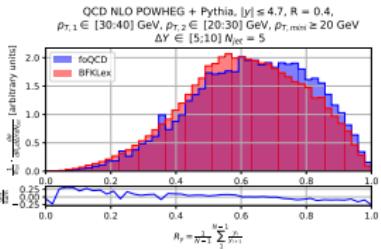


- $\frac{d\sigma}{dN_{\text{jets}}}$ (left): Require 4 hard jets! foQCD at max 3 hard partons, showering eventually runs out of options. BFKL does not need collinearity for hard emissions, more likely.
- $\frac{d\sigma}{d\Delta Y}$ (right): Low- Y has more boosted possibilities, suppressed by PDF. Less problematic for BFKL, no 4-momentum conservation. Also low- Y for foQCD means 3rd partonic jet might end up outside.

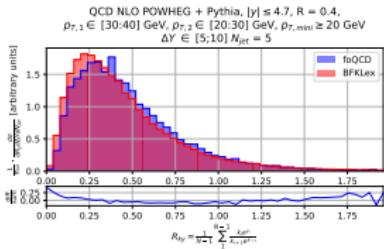
Rapidity-related observables



$\langle \Delta y \rangle_{\min}$



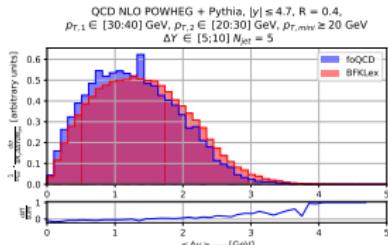
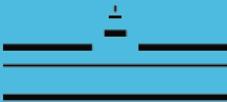
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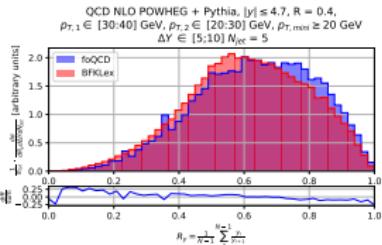
R_{ky}

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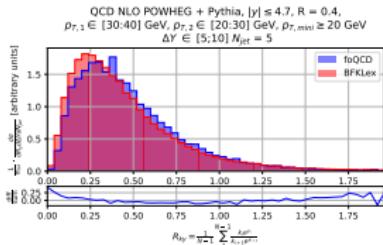
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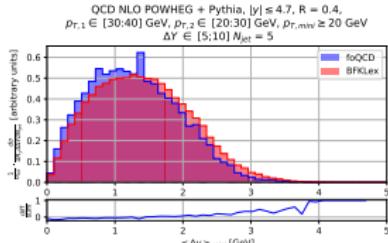
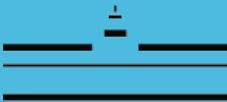
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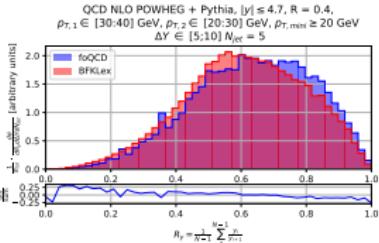
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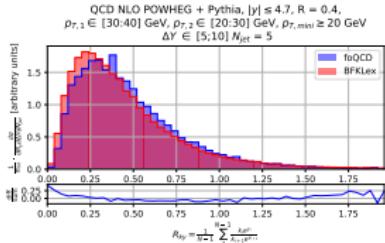
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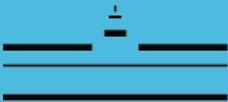


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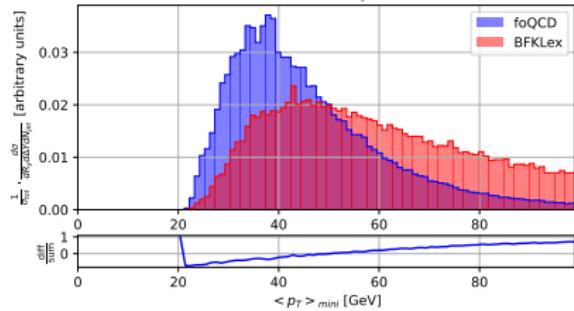


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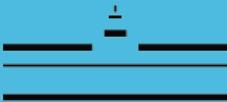
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- $Y > 5$: Should be favorable for BFKL physics, maybe not forward enough?



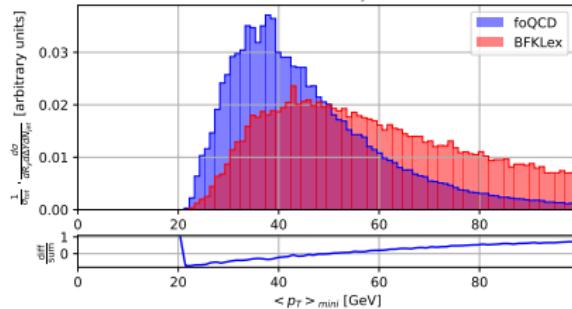
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 $p_{T,1} \in [30:40] \text{ GeV}$, $p_{T,2} \in [20:30] \text{ GeV}$, $p_{T,\text{mini}} \geq 20 \text{ GeV}$
 $\Delta Y \in [1:10]$ $N_{\text{jet}} = 7$



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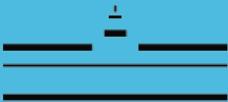
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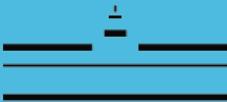
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- BFKLex: only transverse momentum conservation, no showering
⇒ wider tail

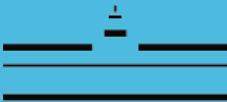
Conclusion & Outlook



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- ! Need to implement hadronization to compare to measurement