Mueller-Navelet jets Phenomenology

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FCT
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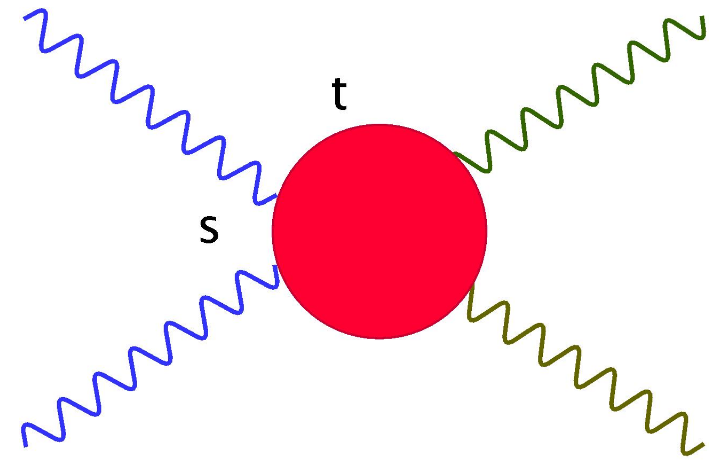
LIP

Some remarks

- This talk is about perturbative QCD in the forward region (high scattering energies)
- We need a good understanding since lots of very energetic muons and neutrinos at the Forward Physics Facility (FPF)
- Use a case study to review where we stand and question ourselves whether the already studies observables are enough to allow for a better understanding of QCD.
- Extrapolate to the FPF: we need to understand better what is the dynamics that governs what goes down the tube in the forward region (in terms of pQCD). Also, what is the dynamics that governs what happens once the flux reaches the FPF.

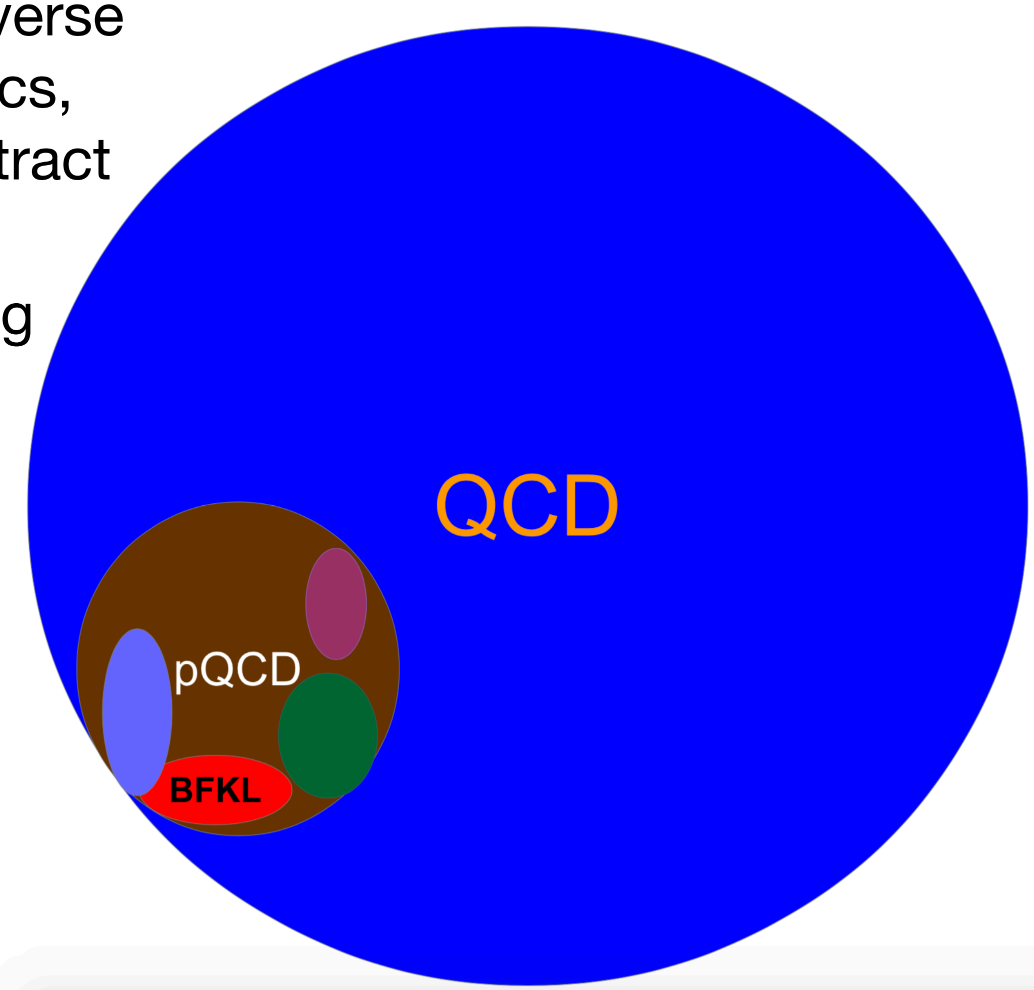
The high energy or *Regge* limit

$$s \gg -t \gg m^2$$



There is a plethora or things we access by studying that limit: **Theory**: Integrability, gravity, black holes, AdS/CFT, Bern-Dixon-Smirnov amplitudes, factorization, separation between transverse and longitudinal d.o.f, transition from hard to soft scale physics, glueballs. Furthermore, in **Mathematics**: number theory, abstract algebra, special functions, …

We are here interested in **Phenomenology** and understanding **QCD** better.

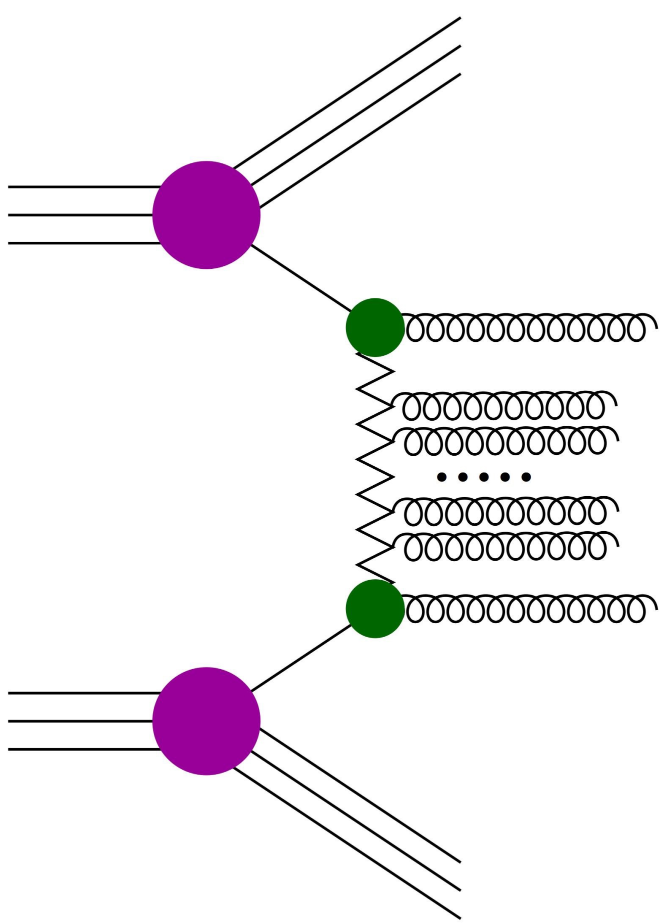


A crucial tool to study the *Regge* limit in QCD is ***Balitsky-Fadin-Kuraev-Lipatov* (BFKL)** dynamics. In its essence, BFKL resums to all orders diagrams that carry **large logarithms** in energy.
It goes beyond fixed order.

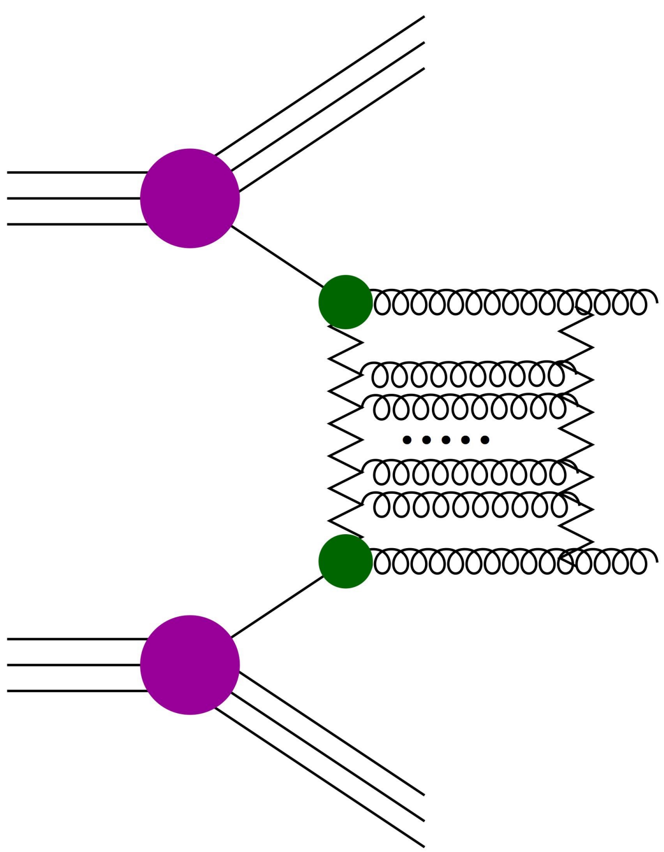
High energy scattering QCD

Rich phenomenology, e.g.

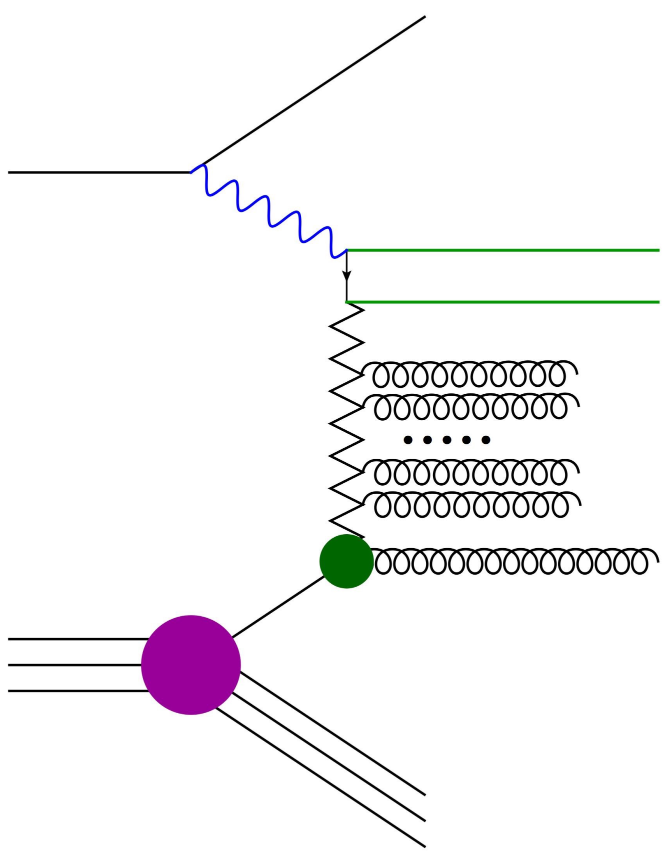
Mueller-Navelet jets



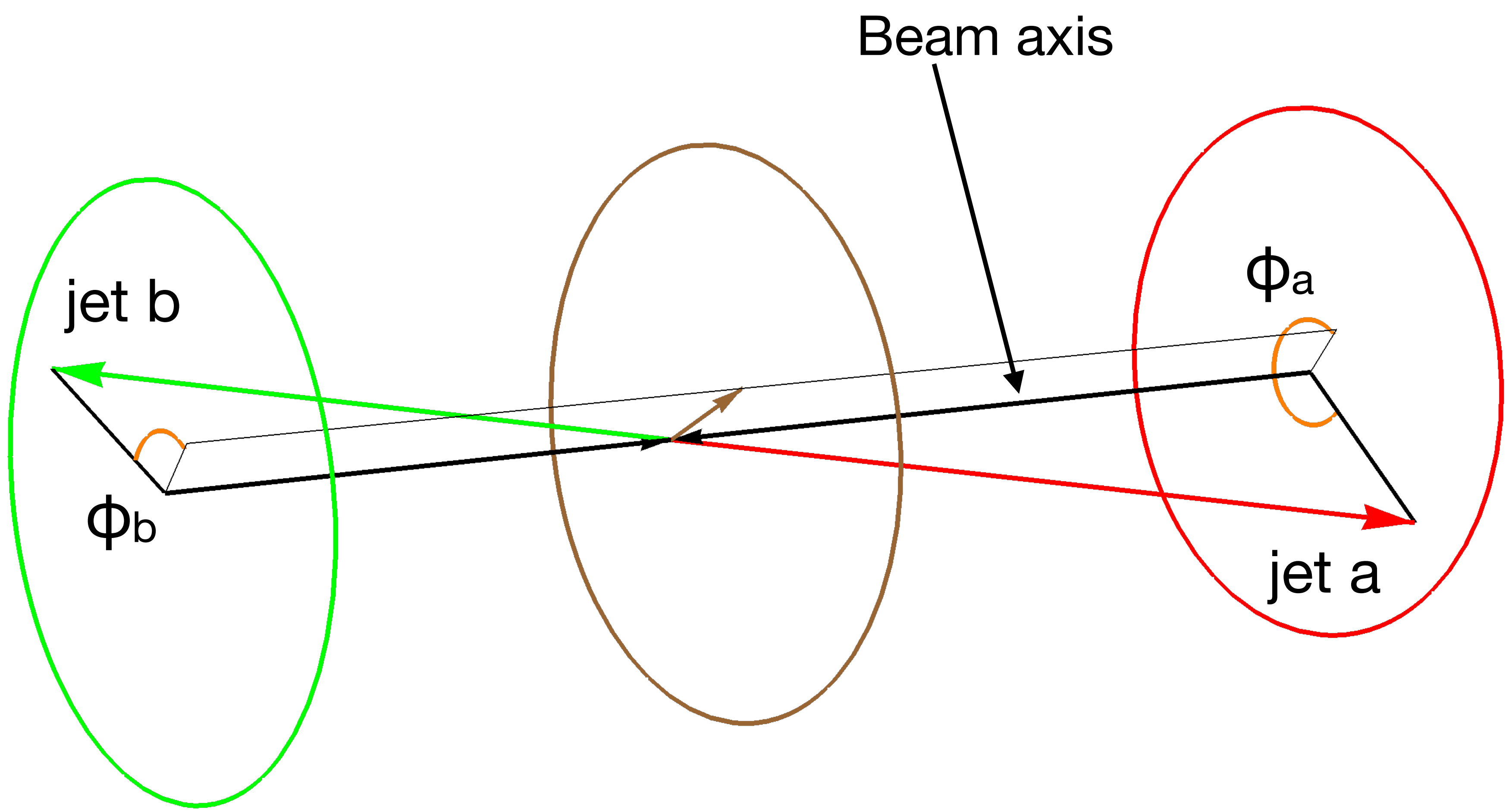
rapidity gaps



DIS



A MN jets example



CMS-FSQ-12-002

CERN-PH-EP/2015-309
2016/01/26

Azimuthal decorrelation of jets widely separated in rapidity in pp collisions at $\sqrt{s} = 7\,\mathrm{TeV}$

The CMS Collaboration*

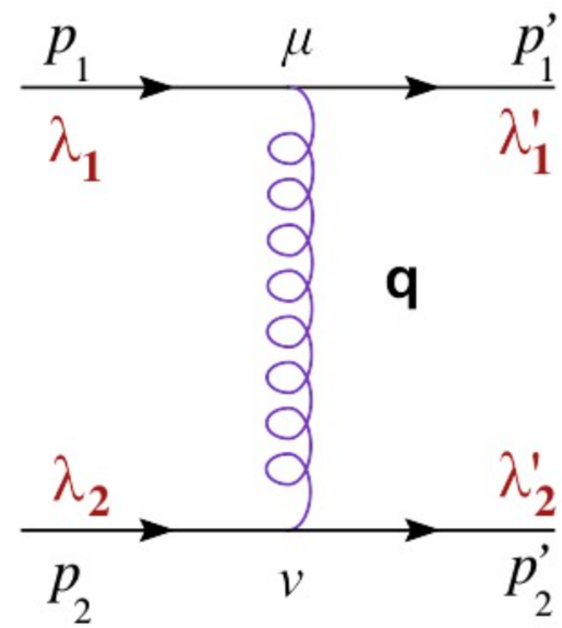
Key question: What is the applicability energy window for BFKL? Is it at LHC energies?

In the Conclusions of that paper, it reads:

The observed sensitivity to the implementation of the colour-coherence effects in the DGLAP MC generators and the reasonable data-theory agreement shown by the NLL BFKL analytical calculations at large Δy, may be considered as indications that the kinematical domain of the present study lies in between the regions described by the DGLAP and BFKL approaches. Possible manifestations of BFKL signatures are expected to be more pronounced at increasing collision energies.

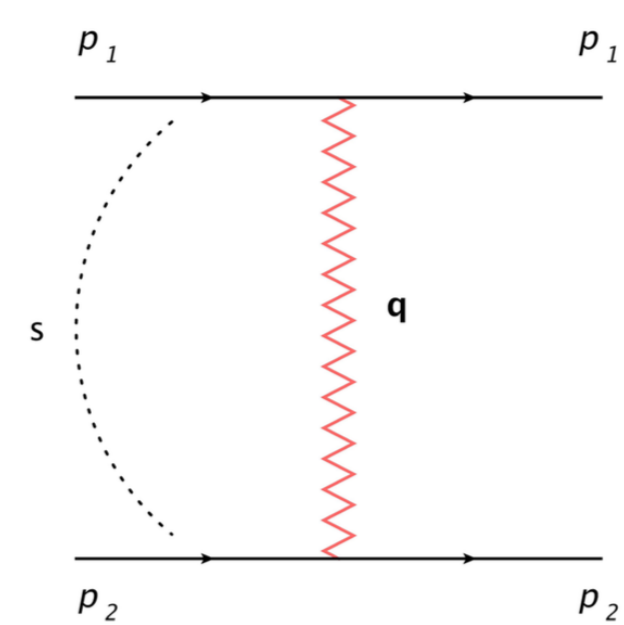
Large logs from virtual corrections

A normal gluon propagator: $D_{\mu\nu}(s,q^2) = -i\frac{g_{\mu\nu}}{q^2}$

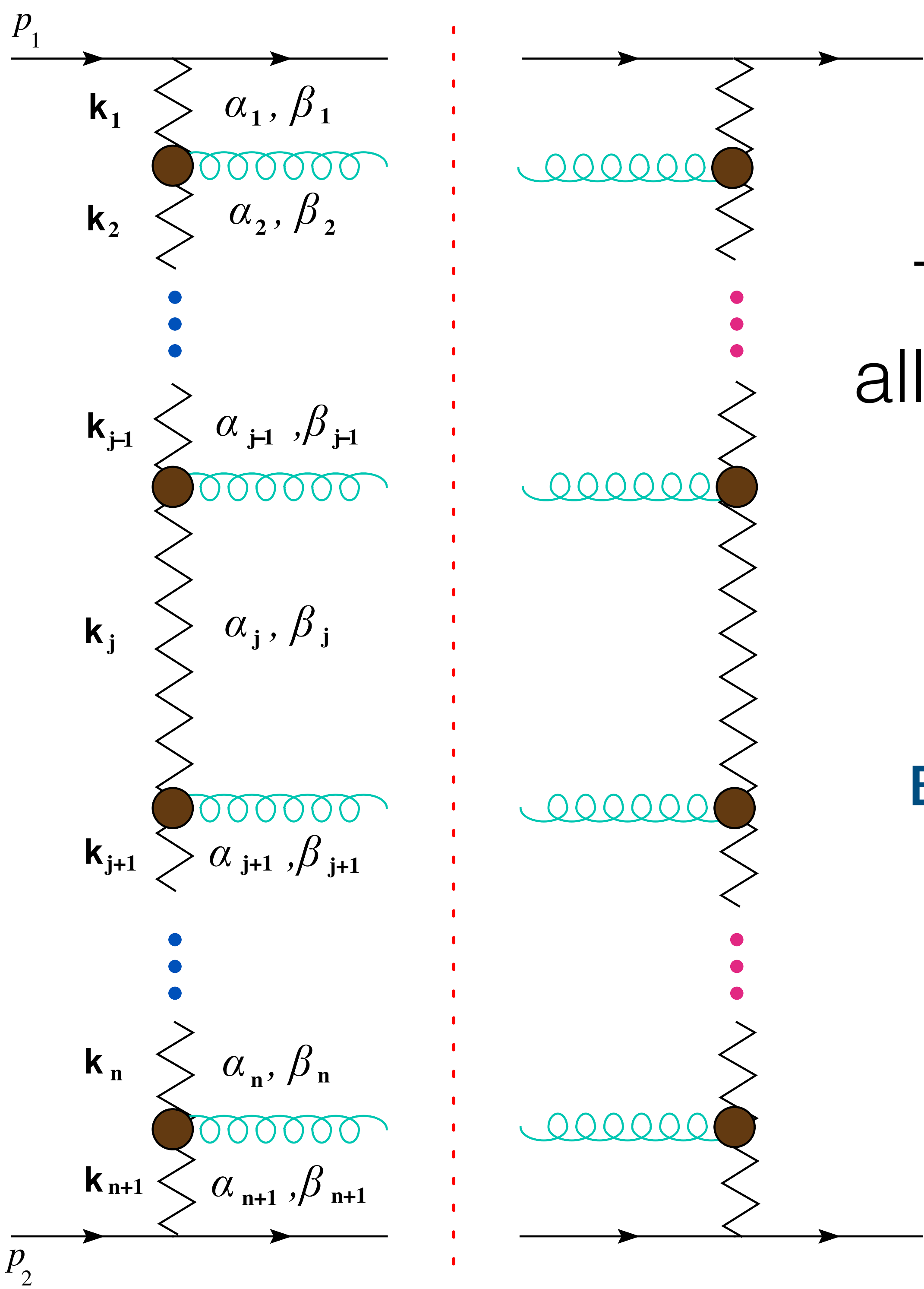


The reggeized gluon is a gluon with modified propagator:

$$D_{\mu\nu}(s,q^2) = -i\frac{g_{\mu\nu}}{q^2}\left(\frac{s}{\mathbf{k}^2}\right)^{\omega(q^2)}$$

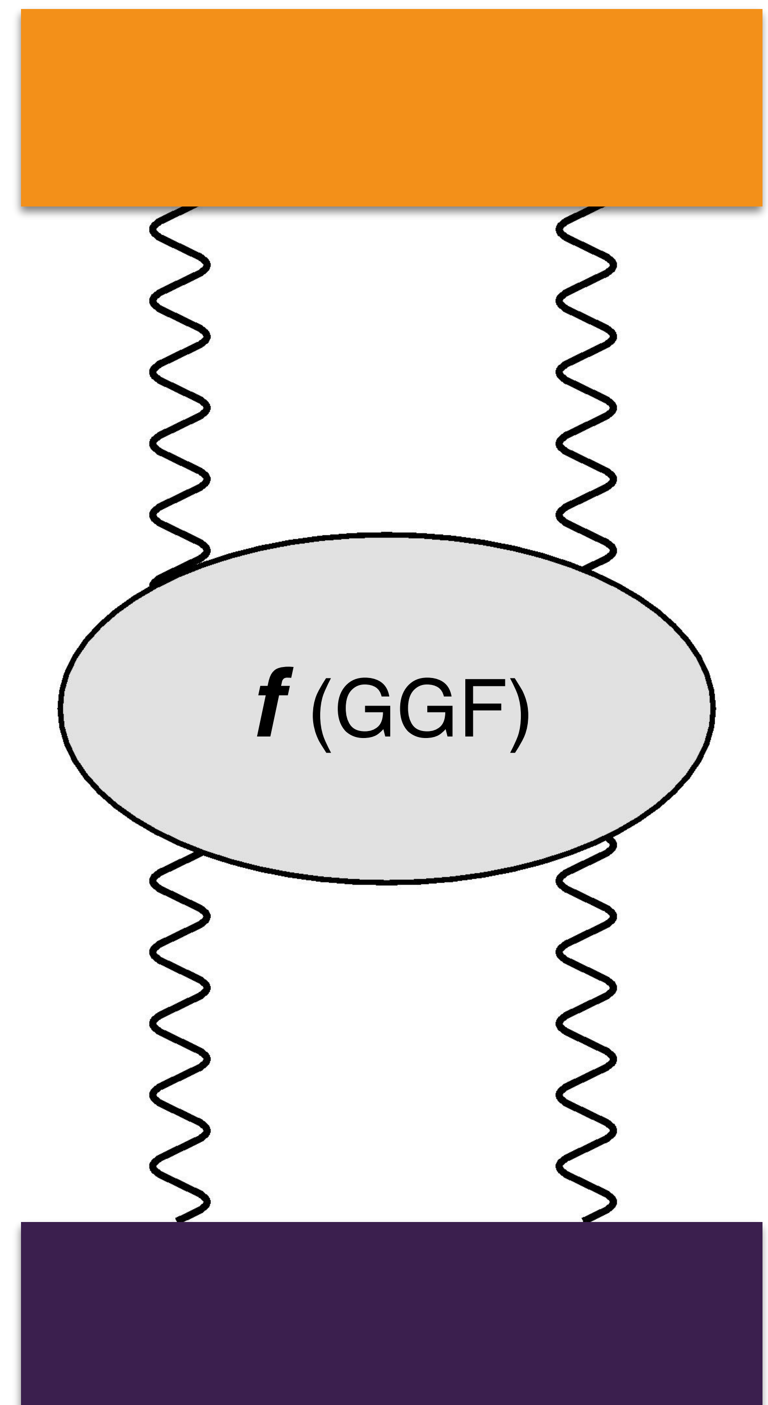


Large logs from real emission corrections



To resum to all n, use BFKL

BFKL Pomeron



Average rapidity ratio

Multi-Regge kinematics

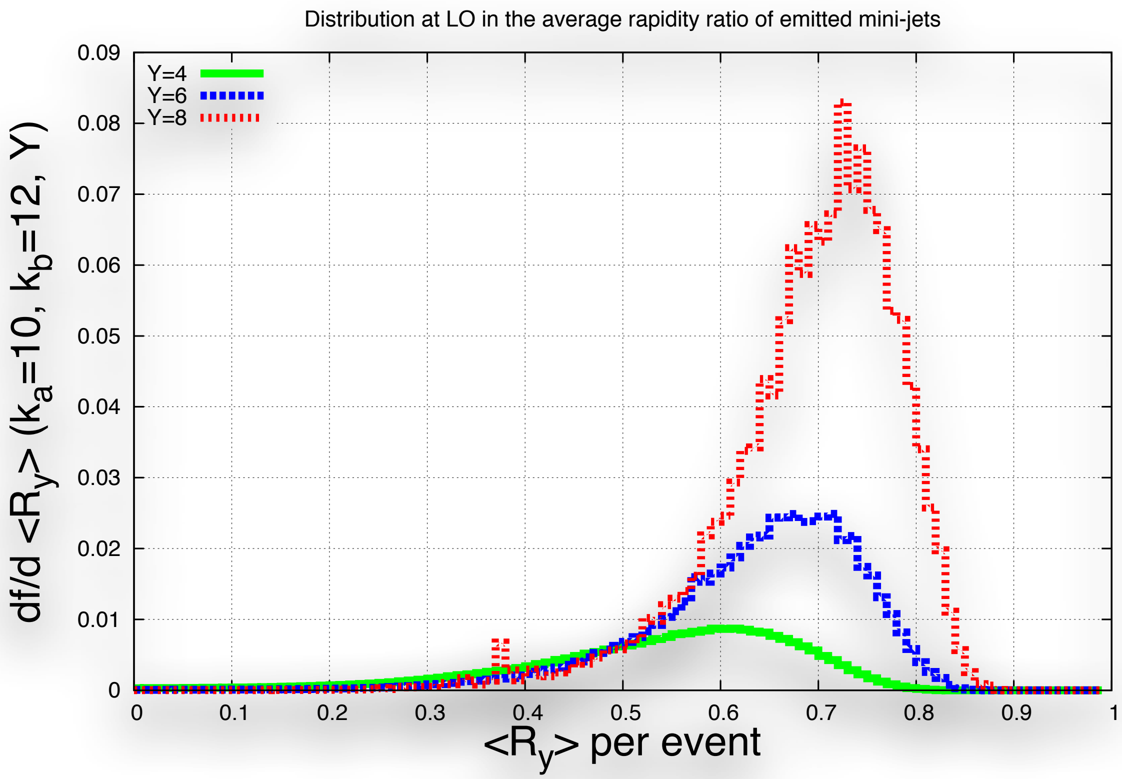
$$y_b(=0) \ll y_n \ll \cdots \ll y_2 \ll y_1 \ll y_a$$

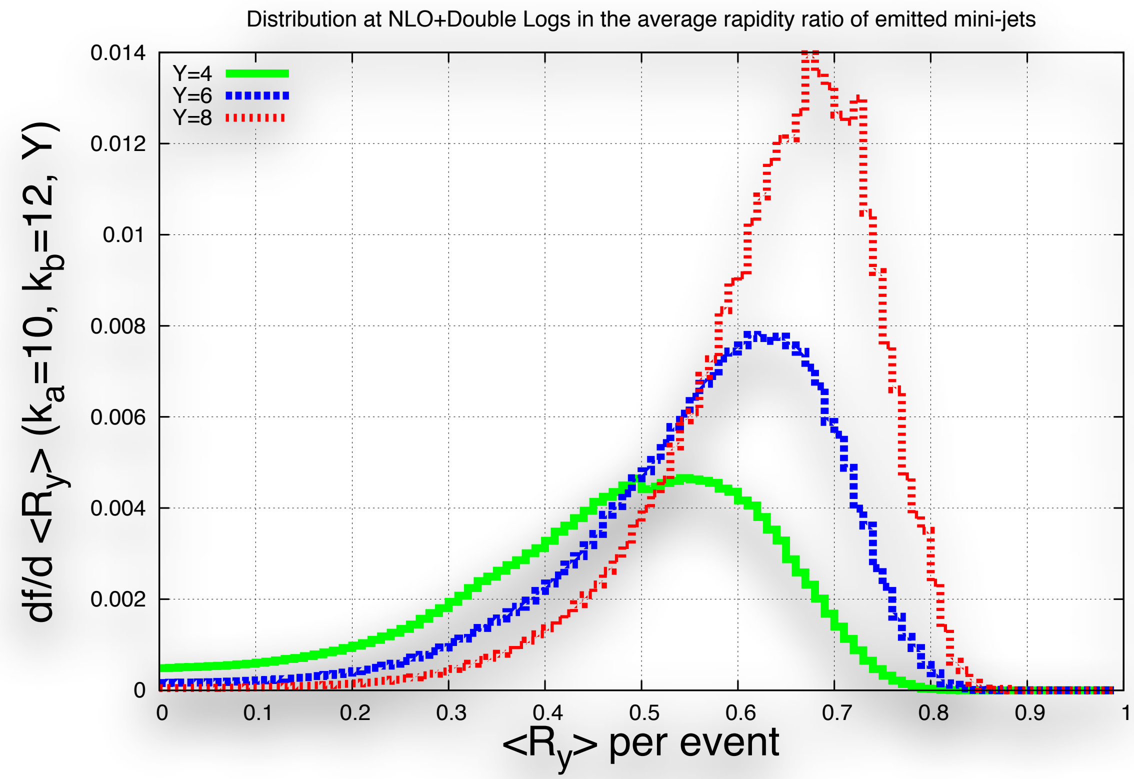
$$|\boldsymbol{k}_{b\perp}| \simeq |\boldsymbol{k}_{n\perp}| \simeq \cdots \simeq |\boldsymbol{k}_{2\perp}| \simeq |\boldsymbol{k}_{1\perp}| \simeq |\boldsymbol{k}_{a\perp}|$$

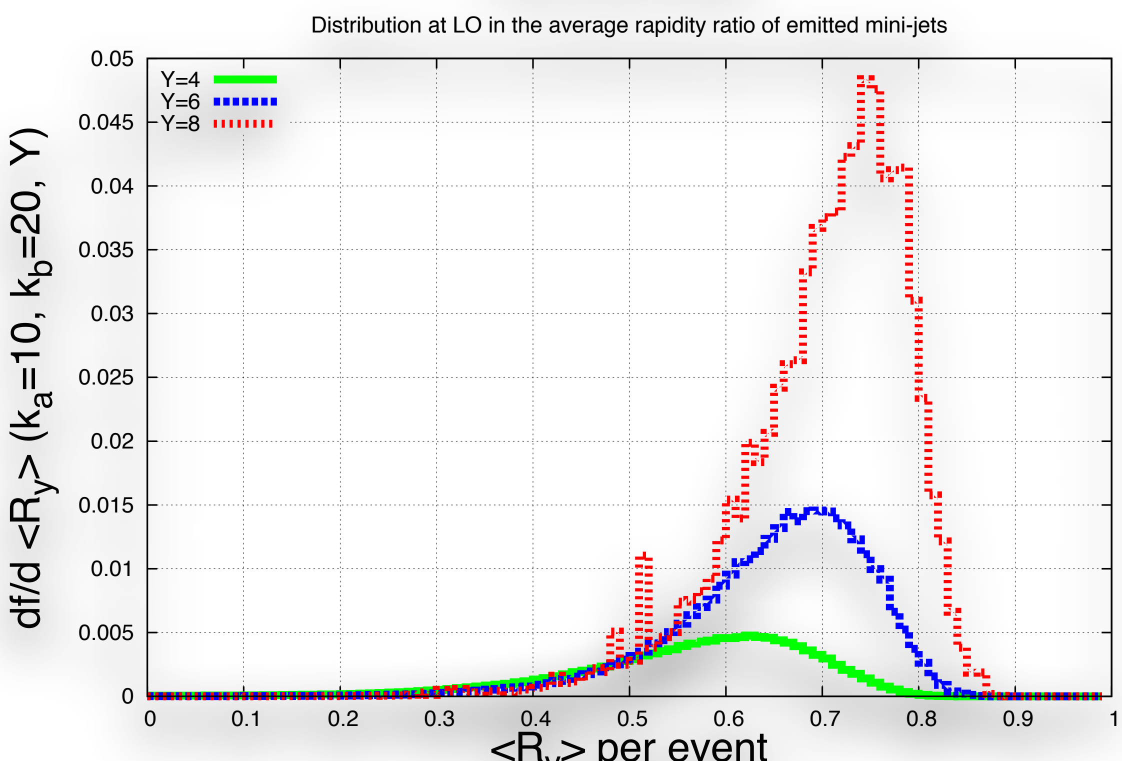
$$\langle \mathcal{R}_y \rangle = \frac{1}{N+1} \sum_{i=1}^{N+1} \frac{y_i}{y_{i-1}}$$

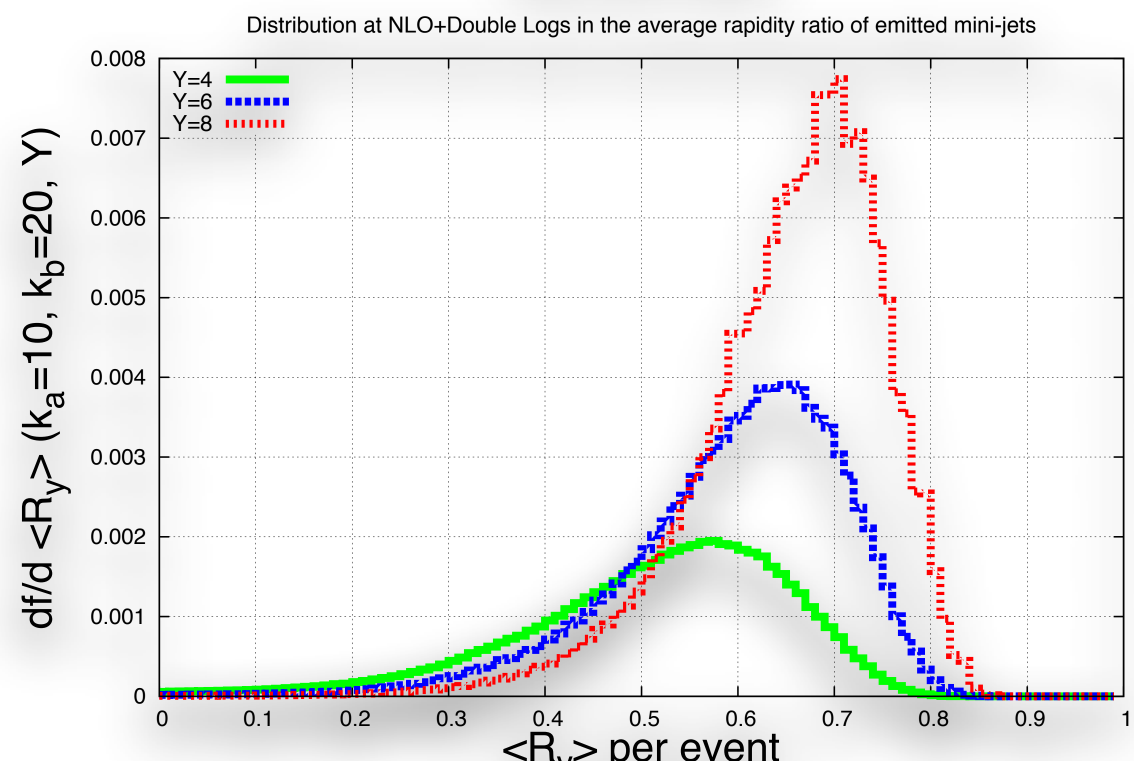
The average rapidity ratio probes the rapidity ordering in Multi-Regge kinematics.

Average rapidity ratio (BFKLex)

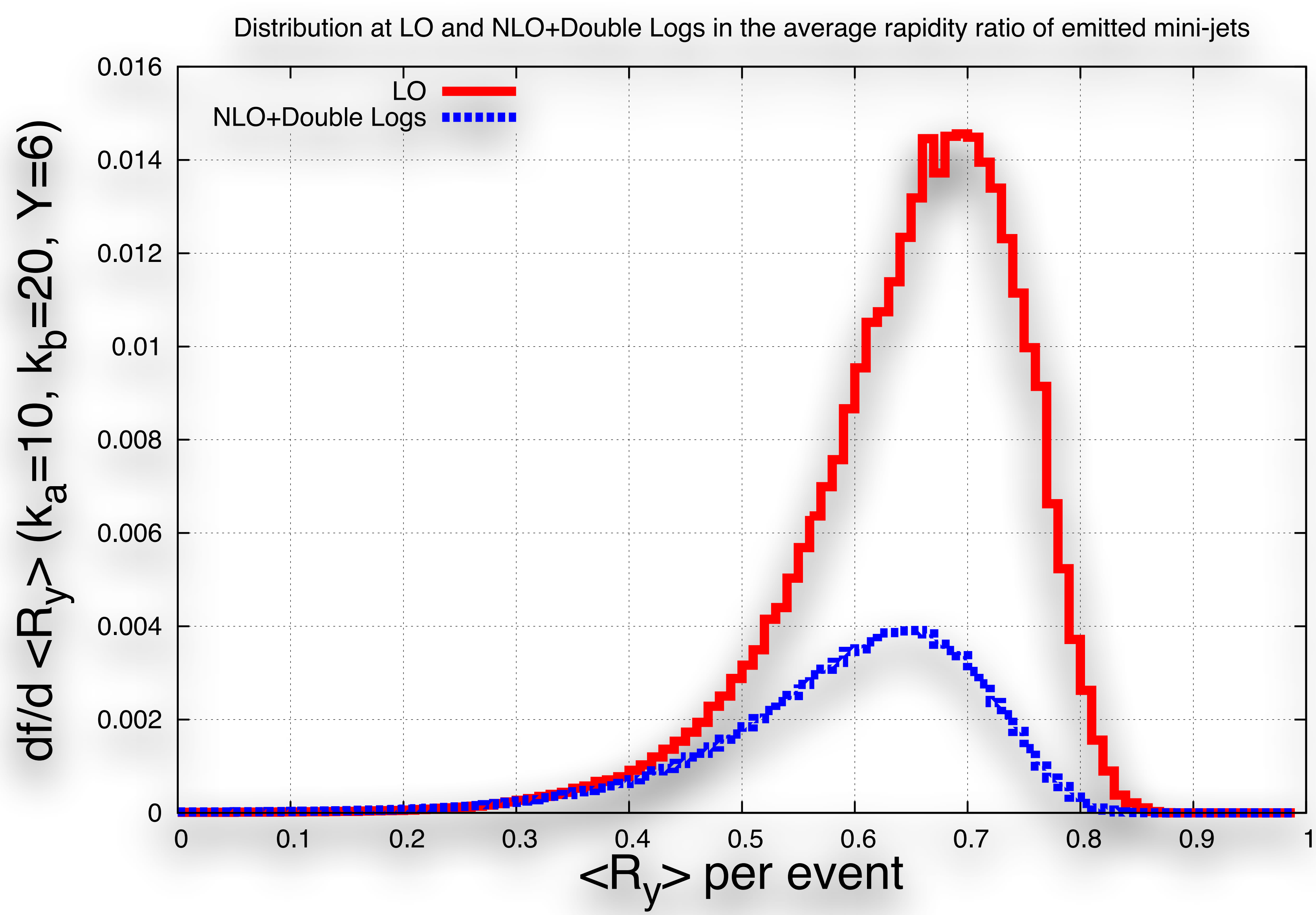








Average rapidity ratio (BFKLex)



A new observable

Multi-Regge kinematics

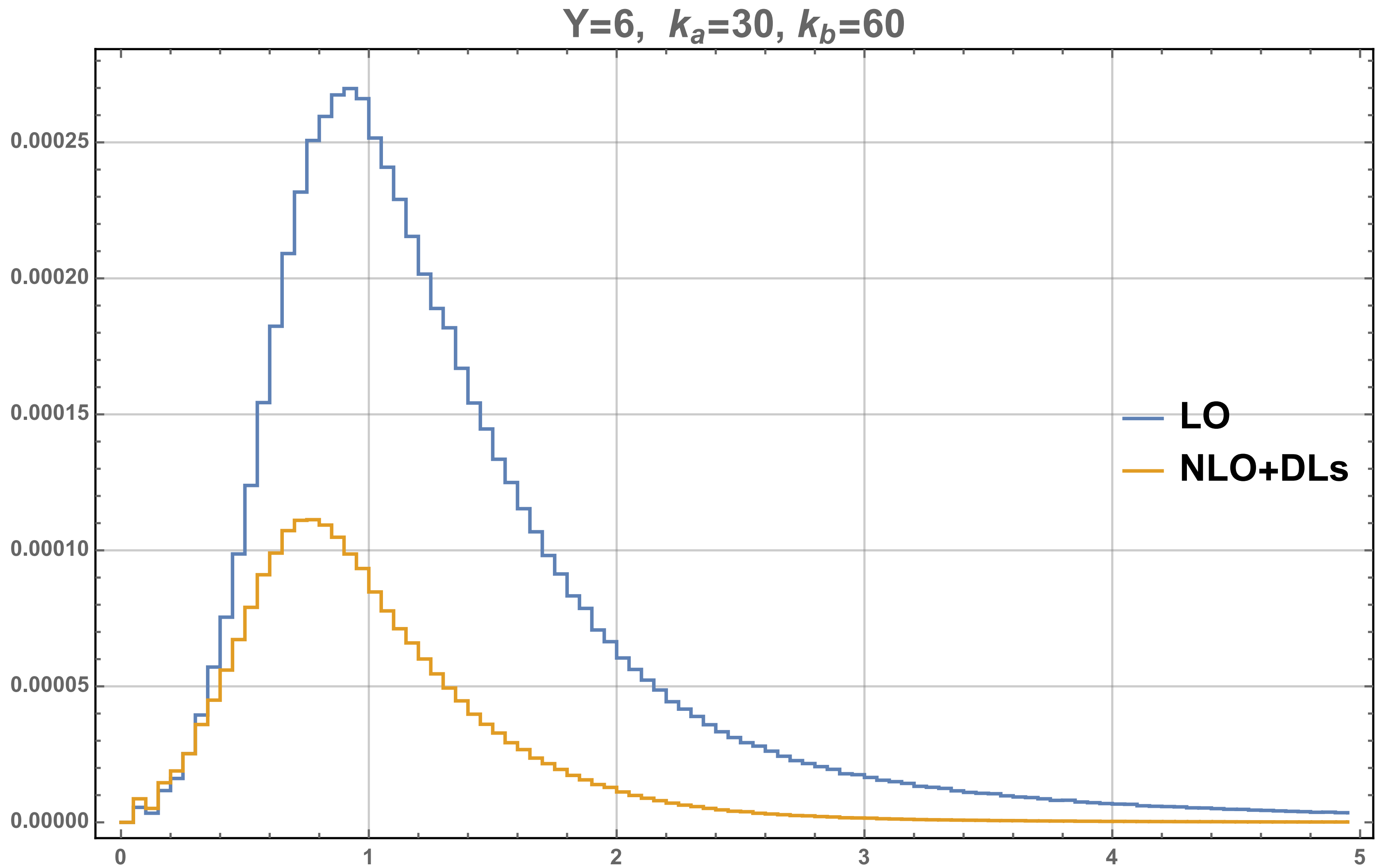
$$y_b(=0) \ll y_n \ll \cdots \ll y_2 \ll y_1 \ll y_a$$

$$|k_{b\perp}| \simeq |k_{n\perp}| \simeq \cdots \simeq |k_{2\perp}| \simeq |k_{1\perp}| \simeq |k_{a\perp}|$$

$$\langle \mathcal{R}_{kY} \rangle = \frac{1}{n+1} \sum_{i=1}^{n+1} \frac{k_i \, e^{y_i}}{k_{i-1} \, e^{y_{i-1}}}$$

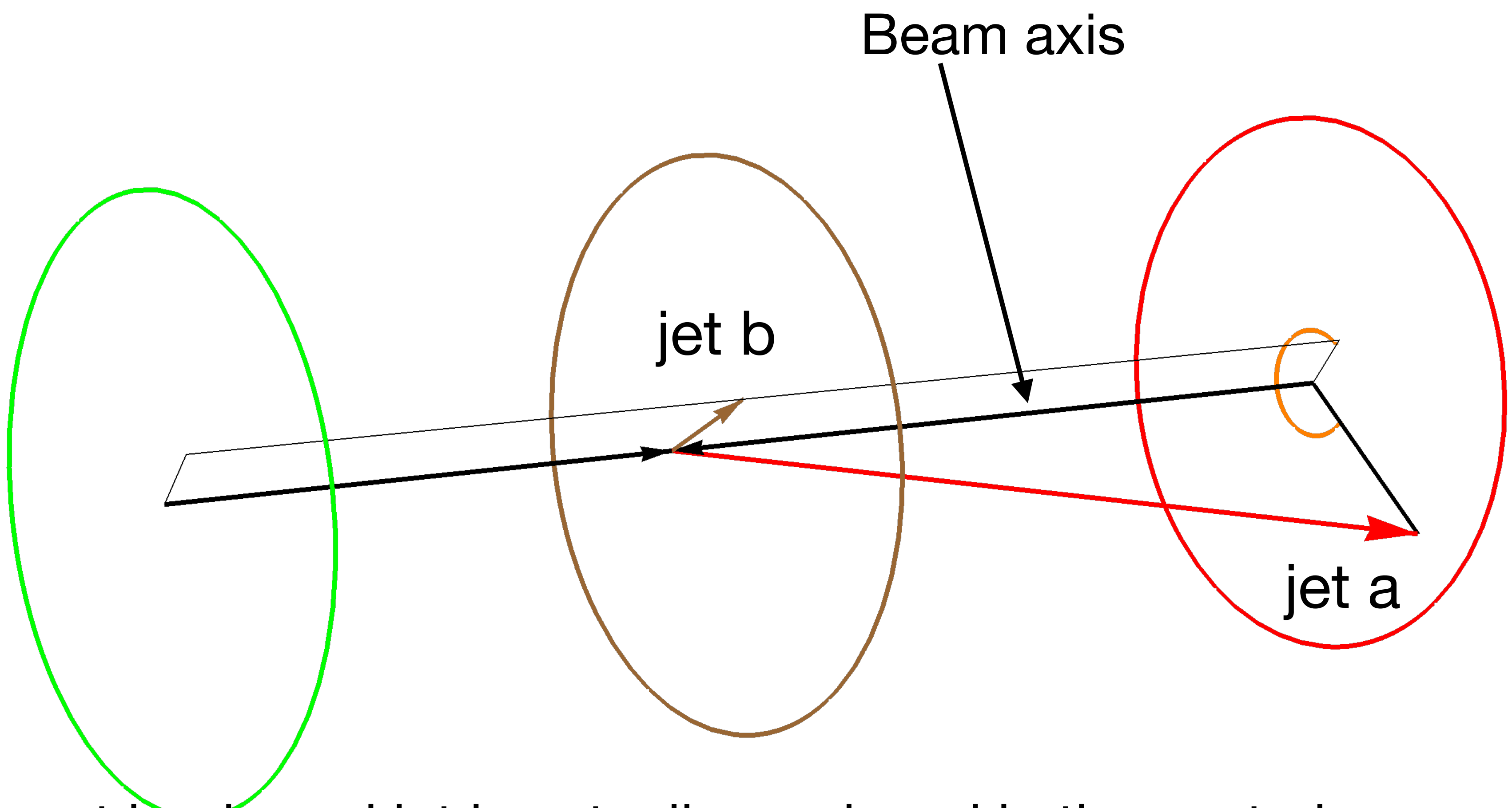
The new observable still probes the rapidity ordering in Multi-Regge kinematics but with the added feature that it also encodes the dependence on the transverse size of the emitted jets.

A new observable (BFKLex)



<$\mathcal{R}_{kY}$> per event

A new MN example



- What if the most backward jet is actually produced in the central rapidity region and the most forward in the very forward region?
- How do we transition from a two-similar-hard-scale problem (ka, kb) to one-hard-scale configuration (kb) — similar to DIS?
- Neutrino DIS?
- Are there observables that probe the topology of the multi-Regge kinematics in such scenarios?
- Limiting factors (large pile-up, onset of soft physics)

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