Mueller-Navelet jets and Multi-Peripheral emissions

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TÉCNICO LISBOA

Outline

Context

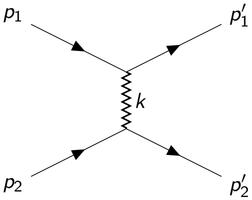
1. Perturbative QCD
2. High Energy scattering
3. BFKL equation (Balitsky-Fadin-Kuraev-Lipatov)
4. Mueller-Navelet jets
5. Multi-Peripheral emissions

High energy QCD

High energy QCD is connected to a multitude of different topics:

- Integrability
- Factorization theorems
- Separation of degrees of freedom (longitudinal and transverse DoF.)
- Transition between soft and hard scale
- Hadronization, colour confinement

The Reggeized Gluon



The gluon propagator

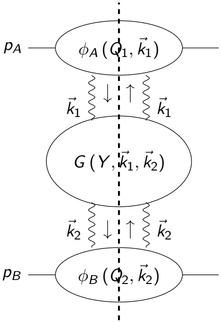
$$D_{\mu\nu} = -\frac{i\eta_{\mu\nu}}{k^2}. \tag{1}$$

The reggeized gluon is a new degree of freedom arising in the high energy limit, with the "dressed" propagator

$$D_{\mu\nu} = -\frac{i\eta_{\mu\nu}}{k^2}\left(\frac{s}{\mathbf{k}^2}\right)^{\epsilon(\mathbf{k})}, \tag{2}$$

where **k** is the hard scale of the process.

BFKL resummation



In BFKL formalism, for the hard scattering part, the cross sections can be expressed as

$$\sigma(Q_1, Q_2, Y) = \int \mathrm{d}^2\vec{k}_1\, \mathrm{d}^2\vec{k}_2\, \phi_A(Q_1, \vec{k}_1)\, \phi_B(Q_2, \vec{k}_2)\, G(\vec{k}_1, \vec{k}_2, Y), \tag{3}$$

where impact factors are process dependent, and the gluon Green's function is universal.

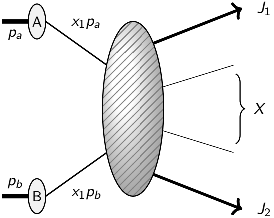
Phenomenological challenges

Detecting a clear BFKL signature is not an easy task:

- Different classes of observables are well described by BFKL dynamics (inclusive DIS, jet azimuthal decorrelation)
- Still, good fits are obtained using different dynamics (DGLAP fit)
- Several observables have been proposed in the literature in order to disentangle the BFKL dynamics (Mueller-Navelet jets, Mueller-Tang jets).
- Important to study differential distributions / more exclusive observables

We will be focusing on Mueller-Navelet jets.

Mueller-Navelet jets



Mueller-Navelet jets were proposed as observable to disentangle the high energy dynamics:

$$p_a + p_b \to j_1 + j_2 + X, \tag{4}$$

- Large rapidity gap (ΔY)
- Similar transverse momenta magnitude (p_T)
- Inclusive cross section
- Azimuthal decorrelation

Fixed-order VS resummation

Comparison between the two approaches:

- PYTHIA8: hard scattering, parton shower, MPI, hadronization (no resummation)
- BFKLex: leading logarithmic approximation (LLA)

BFKLex is a Monte Carlo generator that implements the iterative solution of the BFKL equation at LLA and NLLA.

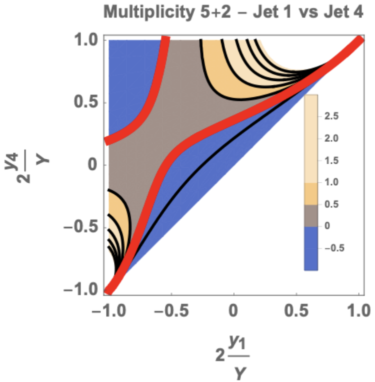
Multi-peripheral emissions - 1

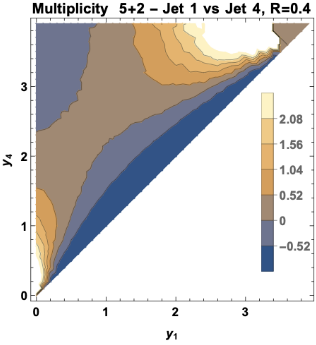
What multi-peripheral emissions are?´

- In a multi-peripheral-type collision, the incoming hadrons exchange only a small amount of momentum, effectively "glancing" off one another.
- The colliding process can be visualized as a sequence of interactions where each produced particle is linked to the next by a soft momentum exchange – concept of "clusters".
- Energy is shared among many particles, so individual transverse momenta are small, and the rapidity distribution is approximately flat (rapidity plateau)
- Phenomenological models in 1960-1970 (ex. ex. Chew-Pignotti, Amati-Fubini-Stanghellini-Tonin)
- Similarity with BFKL dynamics (strong rapidity ordering, no transverse momentum ordering)

Multi-peripheral emissions - 2

Two-particle rapidity correlations with Chew-Pignotti model (left) and BFKLex (right).





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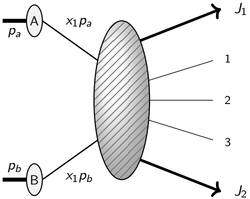
Proton-proton scattering: kinematical cuts



Multi-peripheral emissions were described during 1960s using phenomenological models. We focus on the following configuration:

- Proton-proton scattering, energy {8,13} TeV
- Large rapidity Mueller-Navelet jets (forward, backward), minijet activity between them
- Rapidity window (-4.7, 4.7)
- Minimum jet p_T cut, (2,10,20) GeV, Anti-k_T algorithm (radius = 0.4 for 13Tev, 0.5 for 8Tev)

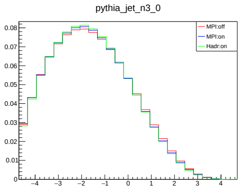
Observables

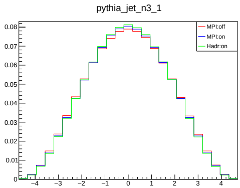
Important observables:

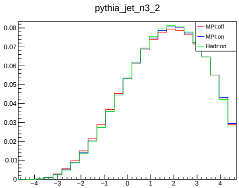
1. Fixed-multiplicity single-jet rapidity distribution
2. Rapidity distribution of the most backward (forward) jet and second most backward (forward) jet (all multiplicities)
3. All jets rapidity distribution (all multiplicities)
4. Jet rapidity-rapidity correlation

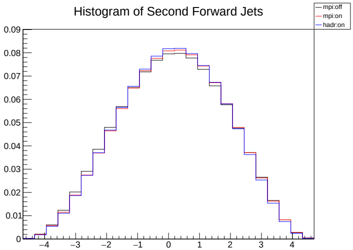
In the following, we focus on observables 1 and 2.

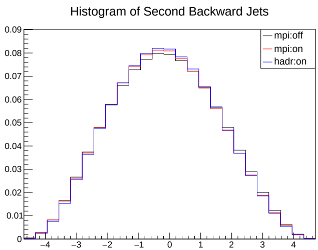
PYTHIA8 13TeV, MPI & Hadronization, PRELIMINARY







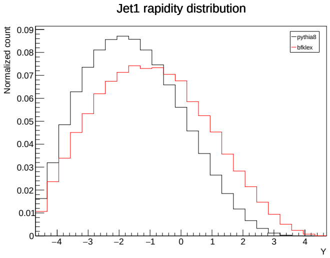


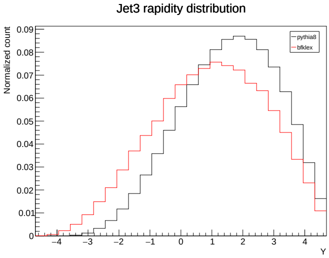


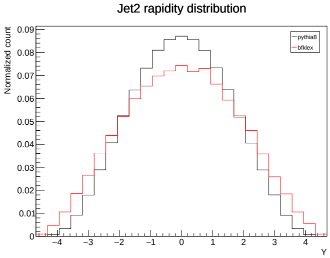
MPI:off VS MPI:on VS Hadr:on, 13 TeV, p_T min = 20 GeV.

The specific configuration used in Pythia is not expected to significantly affect the result.

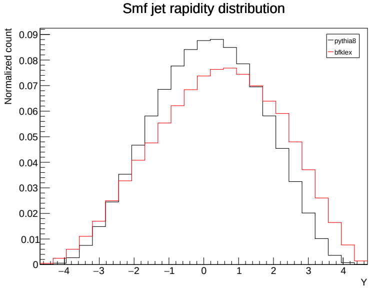
8TeV, multiplicity fixed jet distribution, PRELIMINARY

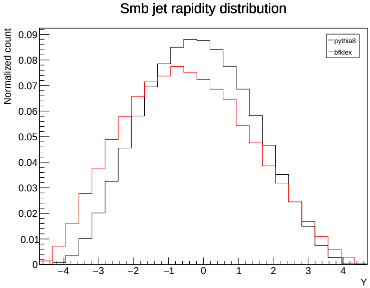






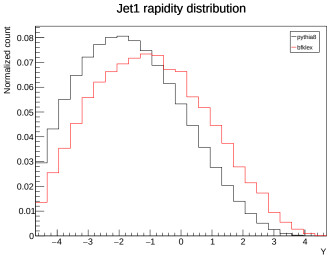
BFKLex VS PYTHIA8: Multiplicity=3, jet distribution, 8 TeV, p_T min = 20 GeV

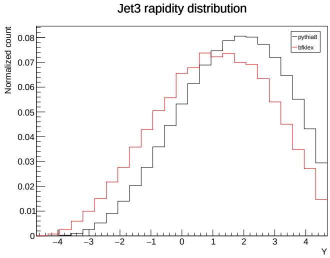


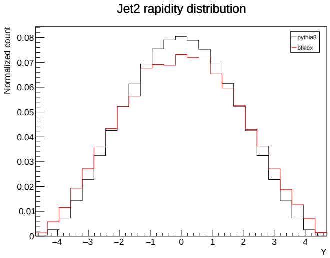


BFKLex VS PYTHIA8: SMF and SMB, jet distribution, 8 TeV, p_T min = 20 GeV

13TeV, multiplicity fixed jet distribution, PRELIMINARY

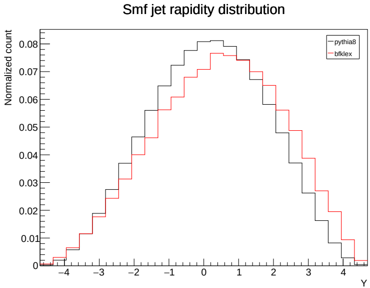


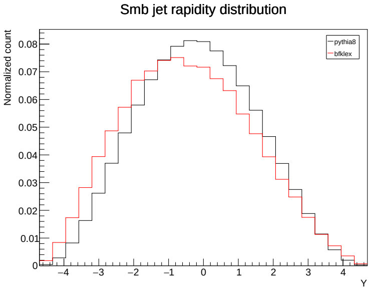




BFKLex VS PYTHIA8: Multiplicity=3, jet distribution, 13 TeV, p_T min = 20 GeV

13TeV, SMF and SMB rapidity distribution, PRELIMINARY





BFKLex VS PYTHIA8: SMF and SMB, jet distribution, 13 TeV, p_T min = 20 GeV

Conclusion

In conclusion:

- Jet rapidity distributions in multi-peripheral events are analysed in order to disentangle the BFKL dynamics
- Promising results are obtained focusing on the differences between BFKL (BFKLex) and fixed-order (PYTHIA8) dynamics
- This is work in progress, more checks are needed and with different kinematical cuts and ultimately, comparison against experimental data.