DY + forward jet production as a probe of BFKL dynamics

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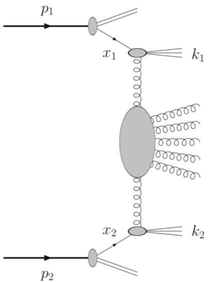
Plan

- Mueller Navelet jets
- Kinematics for DY+jet
- Basic formulas
- Numerical results



- MN dijet cross section

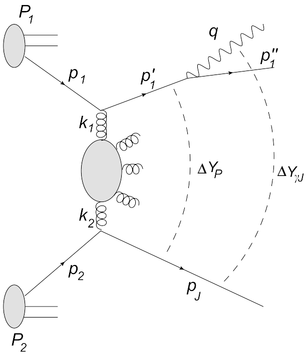
$$\frac{d\sigma}{dJ_1\, dJ_2} = f_1(x_1)\, \phi_J(x_1, k_1) \otimes K(k_1, k_2, \Delta Y_{12}) \otimes \phi_J(x_2, k_2)\, f_2(x_2)$$

where K is the BFKL kernel and ϕ_J is the jet impact factor

- Studies of decorrelation the azimuthal angle between jets.

Stirling, Del Duca, Schmidt, Kwieciński, Motyka, Martin, Bartels, Colferai, Vacca, Sabio Vera, Szymanowski, Walon, Ducloue, D. Yu. Ivanov, Papa, Celiberto,. . .

Kinematics of DY+jet process

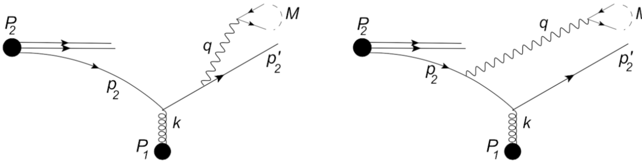


- ΔY_P is an argument of the BFKL kernel while $\Delta Y_{\gamma J}$ is measured

$$\Delta Y_P = \ln\left(\frac{z(1-z)x_1x_2S}{M^2(1-z)+q_T^2+z(k_{1\perp}^2-2\vec{k}_{1\perp}\cdot\vec{q}_T)}\right), \qquad z=\frac{p_{J\perp}\sqrt{M^2+q_T^2}}{x_1x_2S}\,\mathrm{e}^{\Delta Y_{\gamma J}}$$

- ΔY_P depends on $\Delta Y_{\gamma J}$

Standard DY process



- In the photon rest frame, helicity structure functions from angular dependence $\Omega = (\theta, \phi)$

$$\frac{d\sigma^{DY}}{d^4q\, d\Omega} \sim \Big[(1-\cos^2\theta)W_L + (1+\cos^2\theta)W_T + (\sin^2\theta\cos 2\phi)W_{TT} + (\sin 2\theta\cos\phi)W_{LT}\Big]$$

- Integration over full spherical angle Ω gives

$$\frac{d\sigma^{DY}}{d^4q} \sim W_T + \frac{W_L}{2}$$

DY + jet cross section

- For DY+jet helicity structure functions are differential in jet variables

$$W_\lambda \quad \rightarrow \quad \frac{dW_\lambda}{d(\Delta Y_{\gamma J})\, d^2 k_{J\perp}}$$

where $\lambda = T, L, TT, LT$.

- Explicitly

$$\frac{dW_\lambda}{d(\Delta Y_{\gamma J})\, d^2 k_{J\perp}} = \int dx_1 \int dx_2\, f_{q\bar{q}}(x_1, \mu) f_{\rm eff}(x_2, \mu)$$
$$\times \frac{1}{M p_{J\perp}^3} \int \frac{d^2 k_{1\perp}}{k_{1\perp}^3}\, \Phi_{\gamma J}^{(\lambda)}(q_\perp, k_{1\perp}, z)\, K(k_{1\perp}, -p_{J\perp}, \Delta Y_P)$$

where $\Phi_{\gamma J}^{(\lambda)}$ is known photon/jet impact factor and K is the BFKL kernel

BFKL kernel

- Fourier expansion of the BFKL kernel

$$K(k_{1\perp}, k_{2\perp}, \Delta Y_P) = l_0 + \sum_{m=0}^{\infty} 2\cos(m\phi) \int_{-\infty}^{\infty} d\nu\, R_m(\nu)\, e^{\omega_m(\nu)\Delta Y_P} \cos(\nu\rho)$$

- The LL approximation solution

$$\omega_m(\nu) = \overline{\alpha}_s \left[2\psi(1) - \psi\left(\frac{m+1}{2} + i\nu\right) - \psi\left(\frac{m+1}{2} - i\nu\right)\right]$$

- The BFKL with consistency constraint (CC) solution

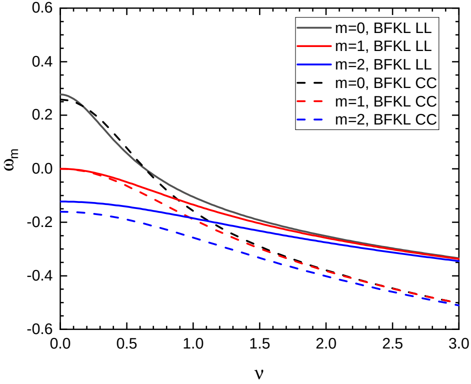
$$\omega_m(\nu) = \overline{\alpha}_s \left[2\psi(1) - \psi\left(\frac{m+\omega_m(\nu)+1}{2} + i\nu\right) - \psi\left(\frac{m+\omega_m(\nu)+1}{2} - i\nu\right)\right]$$

- The LO-Born approximation (two gluon exchange) kernel

$$K(k_{1\perp}, k_{2\perp}) = |k_{1\perp}|\,|k_{2\perp}|\,\delta^2(k_{1\perp} + k_{2\perp})$$

(G. P. Salam, hep-ph/9910492)

BFKL solutions - $\omega_m(\nu)$



- For $\bar{\alpha}_s = 0.1$ for LL and $\bar{\alpha}_s = 0.15$ for CC, $\omega_0(0) \approx 0.27$
- Similar results for LL and CC solutions

- The ratio of the cross sections with differential helicity functions

$$\frac{\sigma(\phi_{\gamma J})}{\sigma(0)} \equiv \frac{dW_T(\phi_{\gamma J}) + dW_L(\phi_{\gamma J})/2}{dW_T(0) + dW_L(0)/2}$$

as a function of γ^*–jet angle

$$\phi_{\gamma J} = \pi - (\phi_\gamma - \phi_J)$$

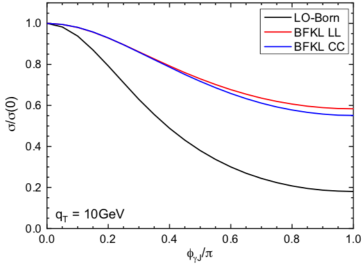
and the LHC energy

$$\sqrt{s} = 13 \text{ TeV}$$

- Strong decorrelation found - stronger than for MN jets

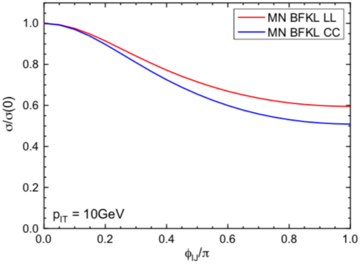
Decorrelation - comparison with MN jets

DY+jet



photon $q_T = 10$ GeV

MN jets

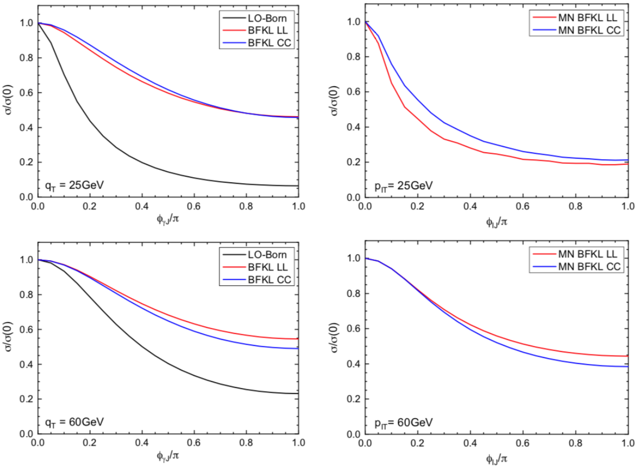


jet $p_T = 10$ GeV

$$p_{J\perp} = 30 \text{ GeV}\,, \quad \Delta Y_{\gamma J} = 7\,, \quad M = 35 \text{ GeV}$$

Decorrelation - comparison with MN jets

DY+jet　　　　MN jets



$q_T = 25, 60$ GeV　　　　$p_T = 25, 60$ GeV

Mean cosines

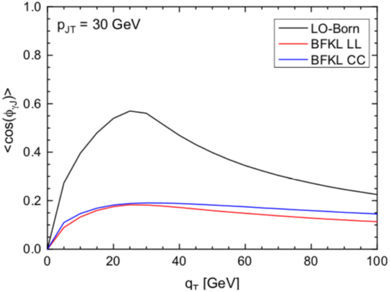
- Experimentally measured

$$\langle \cos(n\phi_{\gamma J}) \rangle = \frac{\int_0^{2\pi} d\phi_{\gamma J} \, \cos(n\phi_{\gamma J}) \, \frac{d\sigma}{dM d\Delta Y_{\gamma J} dq_T \, dp_{J\perp} \, d\phi_{\gamma J}}}{\int_0^{2\pi} d\phi_{\gamma J} \, \frac{d\sigma}{dM d\Delta Y_{\gamma J} dq_T \, dp_{J\perp} \, d\phi_{\gamma J}}}$$

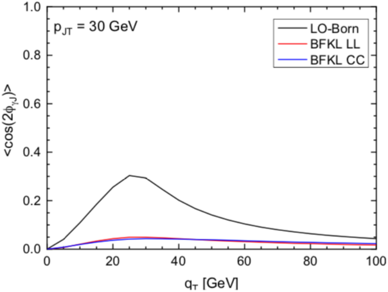
- Shown for $n = 1$ and $n = 2$ as a function of photon q_T and $\Delta Y_{\gamma J}$

Mean cosines for DY+jet as a function of photon q_T

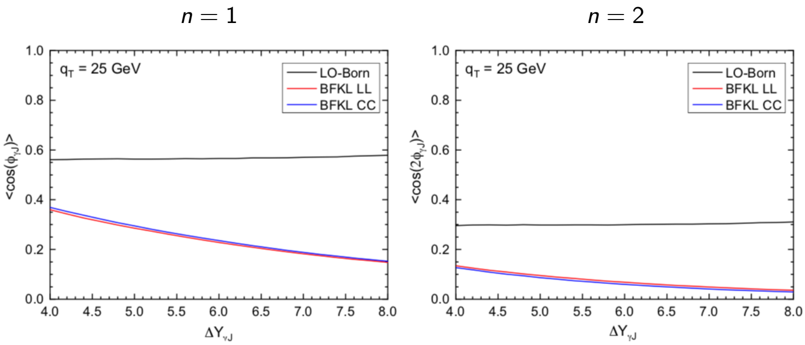
$n = 1$



$n = 2$



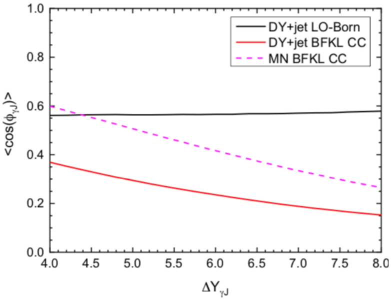
$$p_{J\perp} = 30\ \mathrm{GeV}\,, \quad \Delta Y_{\gamma J} = 7\,, \quad M = 35\ \mathrm{GeV}$$

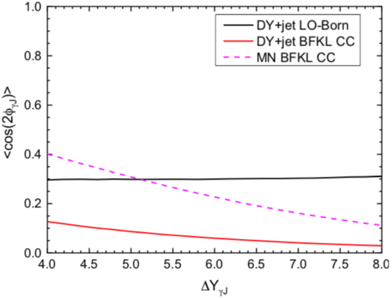


$p_{J\perp} = 30\ \mathrm{GeV}\,, \quad q_T = 25\ \mathrm{GeV}\,, \quad M = 35\ \mathrm{GeV}$

Mean cosines - comparison with MN jets

$n = 1$ $n = 2$





$q_T = p_T = 25\ \mathrm{GeV},\ M = 35\ \mathrm{GeV},\ p_{JT} = 30\ \mathrm{GeV}$

Angular coefficients of DY leptons

- Experimental opportunity to measure angular coefficients of DY leptons

$$A_0 = \frac{dW^{(L)}}{dW^{(T)} + dW^{(L)}/2}, \quad A_1 = \frac{dW^{(LT)}}{dW^{(T)} + dW^{(L)}/2}, \quad A_2 = \frac{2dW^{(TT)}}{dW^{(T)} + dW^{(L)}/2}$$

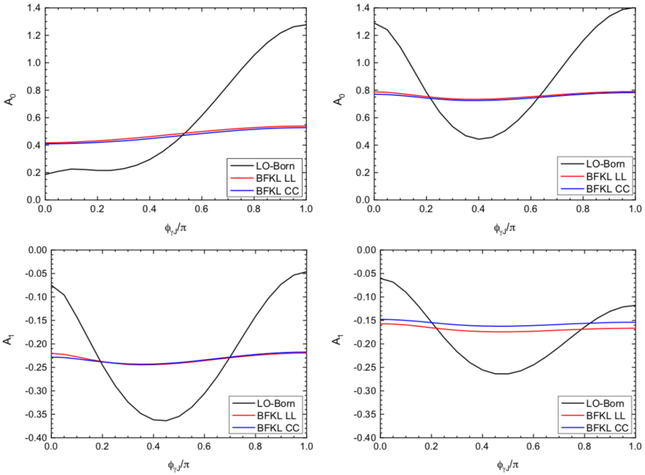
- Lam-Tung relation

$$dW^{(L)} - 2dW^{(TT)} = 0 \qquad => \qquad A_0 - A_2 = 0$$

- Additional information about BFKL predictions.
- Strong difference with respect to LO-Born BFKL kernel prediction.

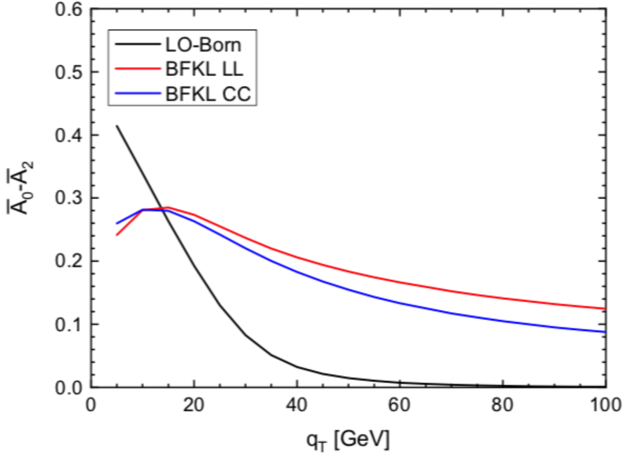
Angular coefficients A_0 and A_1

$q_T = 25$ GeV $\qquad$ $q_T = 60$ GeV



$p_{J\perp} = 30$ GeV , $\Delta Y_{\gamma J} = 7$, $M = 35$ GeV

Lam-Tung relation $\langle A_0 \rangle - \langle A_2 \rangle$



Summary and outlook

- We propose to study forward DY+ jet process to test BFKL dynamics
- More observables than for MN jets and cleaner experimental signature
- Angular decorrelation in γ^*–jet angle found stronger than for MN jets
- Angular coefficients of DY lepton pair strongly sensitive to BFKL dynamics
- Outlook:

  full NLO/NLL analysis