Dijet azimuthal correlations in QCD hard processes

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DIS 2007
Munich, 17th April 2007

[1]In collaboration with Andrea Banfi and Mrinal Dasgupta

Introduction
Motivation

Studies of soft gluon radiation and non-perturbative effects are vital for current and future colliders:

- Predictions for future colliders [LHC] (e.g. Higgs Q_t spectrum).
- All-orders analytical resummations.
- Separating non-perturbative effects and underlying event from perturbative physics.
- Extracting non-perturbative parameters (coupling, pdfs).
- (Correct) tuning of Monte Carlos (HERWIG, PYTHIA, etc).

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Examples of where we could go wrong

1. Non-global logs: numerically resummed for two-jet observables in the large N_c limit to single-log accuracy:

M. Dasgupta and G.P. Salam, 2001, 2002

- $\mathcal{O}(1/N_c^2)$ neglected. Could be vital in some cases.
- Three and four-jet observables unaccounted for.

2. Use of a jet algorithm affects resummation of non-global observables:

- Reduces non-global logs.

R. Appleby and M. Seymour, 2002, 2003

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Dijet azimuthal correlation is a valuable observable for these studies:

- Sensitive to jet algorithm and recombination scheme.
- Sensitive to soft and/or collinear gluon radiation and non-perturbative effects.
- Involves three or more jets (challenges our understanding of power corrections, resummation, clustering algorithm effects and non-global logs).
- Similar to dijet Δp_t distribution.
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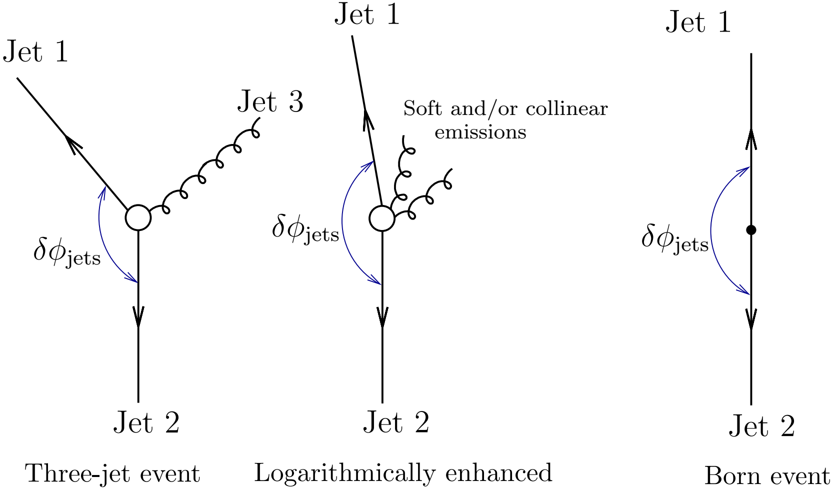
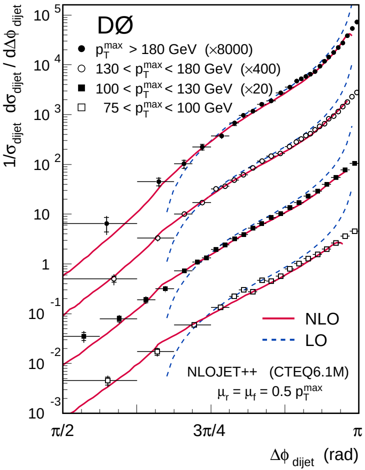
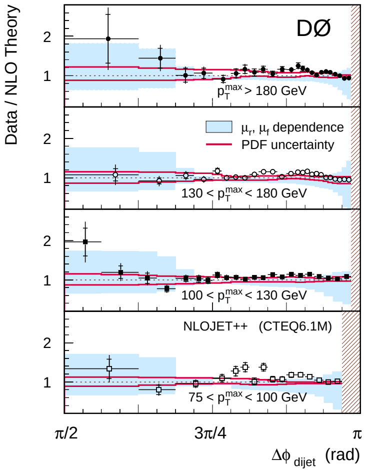


Dijet azimuthal correlation recently measured by DØ





V.M. Abazov, et al [DØ collaboration], 2004

- NLO description is good when $\pi - \delta\phi_{\text{jets}}$ is large.
- Close to Born configuration ($\pi - \delta\phi_{\text{jets}} \to 0$) NLO results diverge.
- Soft and/or collinear logs + non-perturbative effects become enhanced.
- $\Longrightarrow$ Needs resummation, power corrections and NLO matching.
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- Now we have the technology to resum it.

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In the soft and/or collinear regime

$$\Delta = \pi - \delta\phi_{\rm jets},$$

$\delta\phi_{\rm jets}$: difference in azimuth of outgoing jets.

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$$\Delta \simeq \frac{1}{p_t}\left|\sum_{i\notin \mathrm{outgoing\,jets}} k_{t,i}\sin\phi_i\right|,$$

p_t: transverse momentum of outgoing jets.
$k_{t,i}$: transverse momentum of i^{th} gluon.

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  $\Longrightarrow$ non-global observable.

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$$\Delta = \pi - \delta\phi_{\rm jets},$$

$\delta\phi_{\rm jets}$: difference in azimuth of outgoing jets.

Depends on jet recombination method:

- Average E_t-weighted azimuth - used at HERA:
  $\phi_{jet} = \sum_{i\in \rm jet} E_{t,i}\phi_i / \sum_{i\in \rm jet} E_{t,i}$

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  $\theta_{ij} = 1$ if particle i belongs to jet j.
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  $\Longrightarrow$ Continuously global observable.

Dijet azimuthal correlation in DIS

The resummed result

- Use average E_t-weighted azimuth method.
- Measure Δ between outgoing legs in hadronic CoM.

$$\sigma(\Delta) = \int \sigma_{\mathcal{B}} d\mathcal{B} \frac{2}{\pi} \int_0^\infty \frac{db}{b} \sin(b\,\Delta) e^{-R(b)},$$

$\sigma_{\mathcal{B}}$: Born weight.
$R(b)$: Radiator, $R(b) = l g_1(\alpha_s l) + g_2(\alpha_s l)$.
$l = \ln(b e^{\gamma_E})$.

- $l g_1(\alpha_s l)$ resums leading logs. Originate from soft-collinear emissions to all legs.
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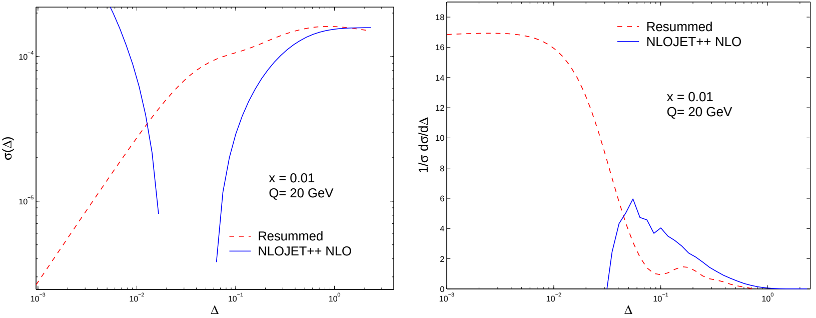

Comparison to NLOJET++

MC vs resummation at $\mathcal{O}(\alpha_s)$

Expansion of resummed result to $\mathcal{O}(\alpha_s)$:

$$\frac{d\sigma^{(1)}(\Delta)}{dL} = h_{11} + 2h_{12}L,$$

$L = \ln(1/\Delta)$, h_{ij}: constants.

All logs controllable. Must fully agree with NLOJET++ in the logarithmically enhanced region.

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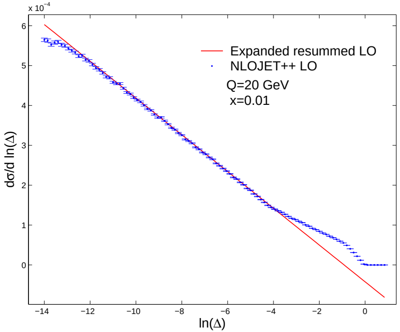

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$$\frac{d\sigma^{(2)}(\Delta)}{dL} = 2h'_{22}L + 3h_{23}L^2 + 4h_{24}L^3,$$

NLOJET++ result at $\mathcal{O}(\alpha_s^2)$:

$$\frac{d\sigma^{(2)}_{\mathrm{MC}}(\Delta)}{dL} = h_{21} + 2h_{22}L + 3h_{23}L^2 + 4h_{24}L^3 + \mathcal{O}(\Delta).$$

h'_{22} and h_{22} not the same (contain uncontrollable sub-leading logs).

$(d\sigma^{(2)}/dL)/L$ should give agreement for large values of L.

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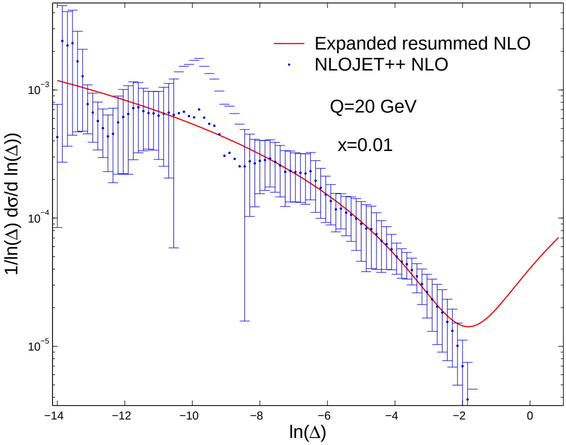

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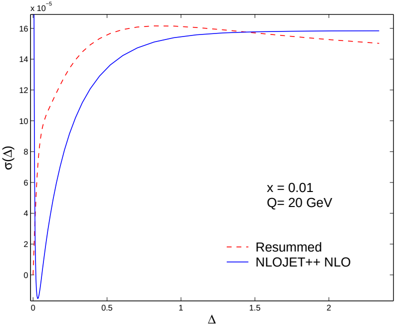

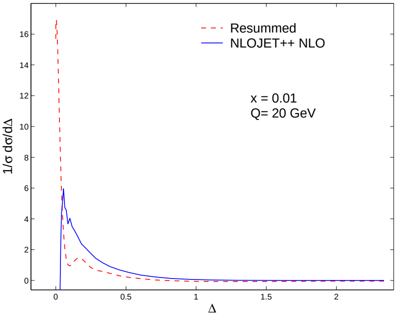

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IN PROGRESS!

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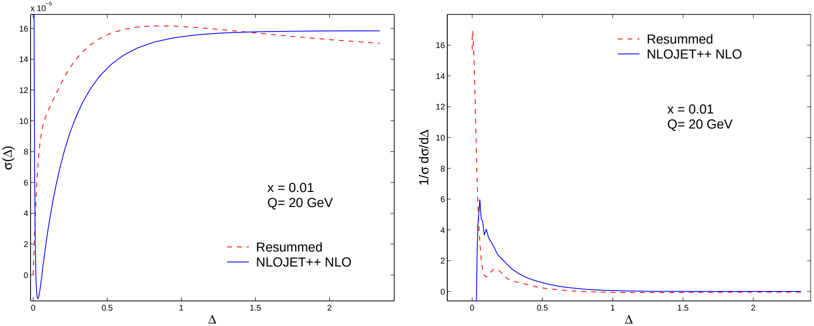

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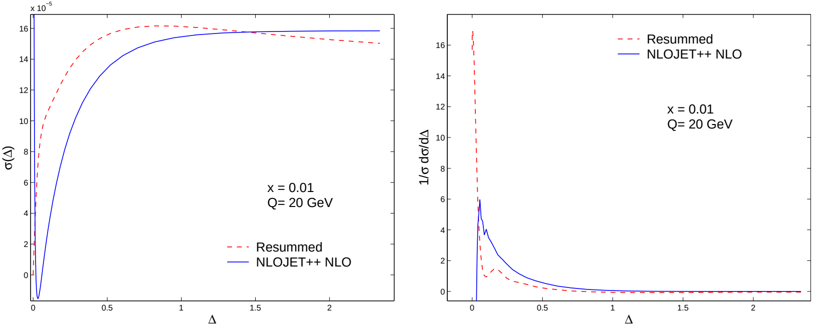

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Non-perturbative effects (hadronisation) enter the distribution through running of α_s below some scale μ_I ($\sim 2\mathrm{GeV}$):

- Replace α_s with α_{eff} below μ.
- Use

$$\frac{1}{\mu}\int_0^{\mu} \alpha_{\mathrm{eff}}(k_t)dk_t = \alpha_0(\mu),$$

α_0: non-perturbative parameter. $\alpha_0(2\mathrm{GeV}) \approx 0.52 \pm 0.04$

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Future directions and conclusions

- Perform a NLO matching to NLOJET++ and calculate power corrections.
- Study the hadron-hadron case (DØ) [Result analytically available for E_t-weighted recombination scheme].
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