Jets and resummation

Mrinal Dasgupta

University of Manchester

HERA LHC Workshop, CERN, May 27, 2008

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Outline

- Motivation.
- Issues and challenges in jet resummations.
- The dijet azimuthal decorrelation.
- Future developments.

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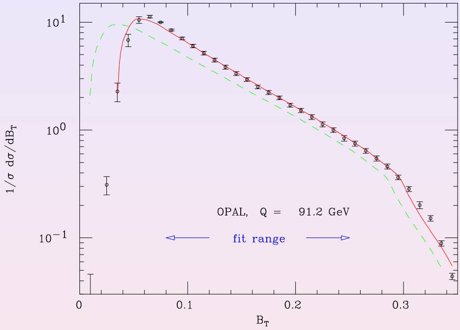
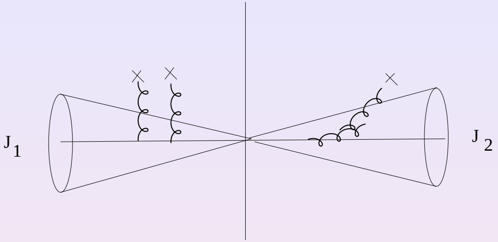
Motivation



Striking success of event shapes – general lessons or a one off ? Dokshitzer, Lucenti, Marchesini, Salam 1998

A history of surprises



- Apply e^+e^- ideas blindly to e.g. single hemisphere DIS event shapes – breakdown of techniques , need for non-global logarithms , large N_c approximation.

  Salam and MD 2002

- Look for non-global logarithms in gaps between jet studies in hadron -collisions using "well-known standard techniques" – find breakdown of naive coherence (super leading logarithm $\alpha_s^4 \ln^5 Q/Q_0$).

  Forshaw Kyrieleis and Seymour 2006

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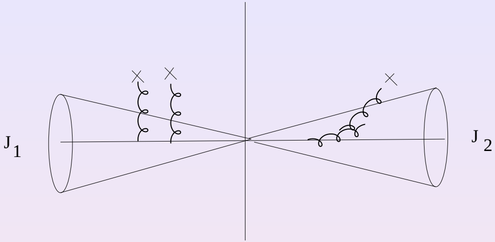

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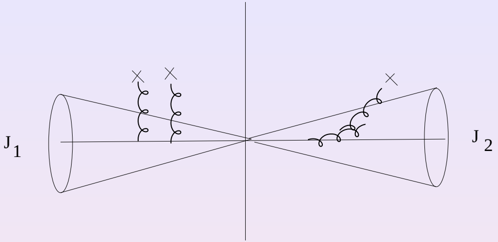

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- Use well accepted resummation formulae in situations involving running of a jet algorithm – find extra logarithms that depend on algorithm parameters. Banfi and M.D. 2004, Banfi Delenda and M.D. 2006

Lesson – Important to keep testing “established” ideas in different contexts. Helps design better observables for future phenomenology - e.g. event shapes at hadron colliders. Banfi, Salam, Zanderighi 2005

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Jet defined multi-scale observables

Include

- Dijet rates with symmetric E_t cuts. Banfi and MD 2004
- Dijet invariant mass near threshold $x = \frac{M_{jj}^2}{\sqrt{\hat{s}}} \to 1$. Kidonakis, Oderda, Sterman 1998
- Inclusive jet spectra $x_t = \frac{2p_t}{\sqrt{\hat{s}}} \to 1$. Kidonakis Oderda and Sterman 1998, De Florian and Vogelsang 2007
- Dijet azimuthal decorrelations $\Delta\phi_{jj} \to \pi$.
- Energy flow between jets with a clustered or jet defined final state. Appleby and Seymour 2002, Banfi and MD 2005, Banfi, Delenda and MD 2006

All offer the opportunity to study and verify rich PT and NP QCD dynamics of multi-parton ensembles. Also present new challenges to resummation techniques.

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Main problems common to all the above resummations

- Potential non globalness – all study energy flow between jets.
- Running the jet algorithm complicates resummation – affects final state non-trivially. Can we use jet definitions to our advantage ?

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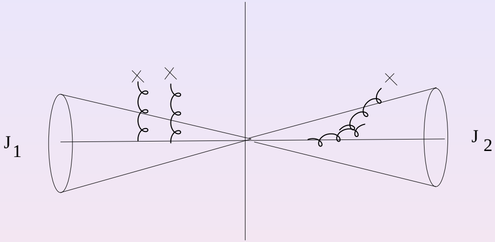
Dijet azimuthal decorrelation



Take dijets produced in DIS or hadron collisions. In plane perpendicular to the beam/Breit-axis jets are back-to–back, $\Delta\phi = \pi$. Small deviations from $\Delta\phi = \pi$ caused by soft and/or collinear emissions. May expect only soft gluons not recombined with jets to contribute to decorrelation – looks non global. However exact recombination scheme plays a vital role.

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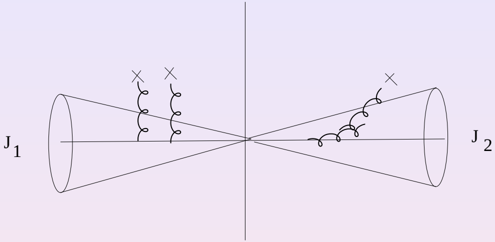

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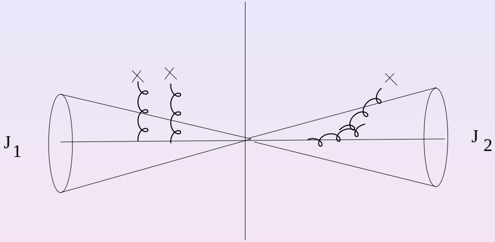

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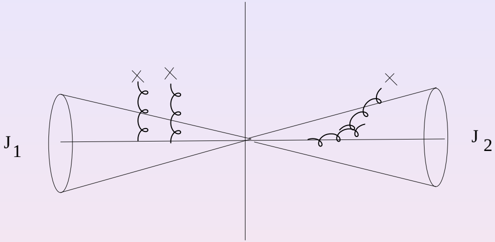

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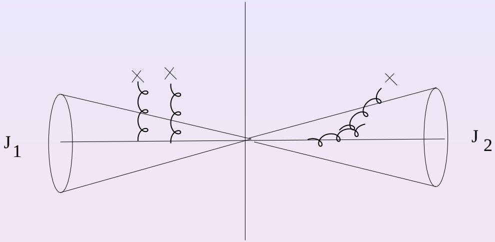

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Kinematics in the transverse plane :

$$
\begin{aligned}
\vec{p}_{t,1} &= p_{t,1}(1,0), \\
\vec{p}_{t,2} &= p_{t,2}(\cos(\pi-\epsilon), \sin(\pi-\epsilon)), \\
&= p_{t,2}(-\cos\epsilon, \sin\epsilon), \\
\vec{k}_{t,i} &= k_{t,i}(\cos\phi_i, \sin\phi_i)
\end{aligned}
$$

From momentum conservation $\epsilon = -\sum_i \frac{k_{t,i}}{p_t}\sin\phi_i$

Use an E_t weighted recombination scheme (H1 collaboration)

$$\phi_j = \frac{\sum_{i\in j} E_{t,i}\phi_i}{\sum_{i\in j} E_{t,i}}$$

Then

$$\phi_{j1} = \frac{\sum_{i\in j1} k_{t,i}\,\phi_i}{p_{t,1} + \sum_{i\in j1} k_{t,i}} \approx \frac{\sum_{i\in j1} k_{t,i}\phi_i}{p_t},$$

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Making the $\Delta\phi$ global

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Finally we have

$$|\pi - \Delta\phi| = \left|\sum_i \frac{k_{t,i}}{p_t}\left(\sin\phi_i - \theta_{i1}\phi_i - \theta_{i2}(\pi-\phi_i)\right)\right| + \mathcal{O}\left(k_t^2\right),$$

Both gluons inside and out of jets contribute. Observable in fact continuously global and resummable to NLL accuracy.

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$$\tan\phi_j = \frac{p_{t,y}}{p_{t,x}}$$

with $p_j^\mu = \sum_{i\in j} p_i^\mu$.

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Resummed results for global definition

Resummation in b space leads to (for dijets in DIS)

$$\Sigma_a(\{p\}, \Delta) = \frac{1}{\pi} \int_{-\infty}^{\infty} \frac{db}{b} \sin(b\Delta) e^{-R_a(b)} f_a(x, \mu_f^2/b^2).$$

$\Delta \equiv |\pi - \Delta\phi|$ Similar result with two pdfs for hadron collisions

$\sin(b\Delta)$ function reflects phase space constraint while $R(b)$ contains the QCD dynamics. Result of their convolution - no Sudakov peak. Distribution in Δ goes smoothly to non-zero value as $\Delta \to 0$.

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DIS dijets

$$
\begin{aligned}
R^a_{\rm out}(\bar{b}) &= (C_1^a + C_2^a)\frac{\alpha_s}{2\pi}\left(\frac{2}{3}L^2 + \frac{4}{3}L\left(-\ln 3 - 4\ln 2 + 3\ln\frac{Q}{p_t}\right)\right) \\
&\quad + \frac{4}{3}\frac{\alpha_s}{2\pi}\left(C_1^a B_1^a + C_2^a B_2^a\right)L, \\
R^a_{\rm in} &= C_i^a\frac{\alpha_s}{2\pi}\left(2L^2 + 4L\left(-\ln 2 + \ln\frac{Q}{p_t}\right)\right) + 4C_i^a\frac{\alpha_s}{2\pi}B_i^a L, \\
\ln S(\bar{b},\{p\}) &= -4L\left(2C_F\frac{\alpha_s}{2\pi}\ln\frac{Q_{qq'}}{Q} + C_A\frac{\alpha_s}{2\pi}\ln\frac{Q_{qg}Q_{gq'}}{Q_{qq'}Q}\right),
\end{aligned}
$$

with $L = \ln\bar{b}$

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Results(Hadron Collisions)

$$
\begin{aligned}
R_{\text{out}}(\bar{b}) &= (C_1 + C_2)\frac{\alpha_s}{2\pi}\left(\frac{2}{3}L^2 + \frac{4}{3}L\left(-\ln 3 - 4\ln 2 + 3\ln\frac{Q_{12}}{p_t}\right)\right) + \\
&\quad + \frac{4}{3}(C_1B_1 + C_2B_2)\frac{\alpha_s}{2\pi}L, \\
R_{\text{in}} &= (C_{i1} + C_{i2})\frac{\alpha_s}{2\pi}\left(2L^2 + 4L\left(-\ln 2 + \ln\frac{Q_{12}}{p_t}\right)\right) + \\
&\quad + 4(C_{i1}B_{i1} + C_{i2}B_{i2})\frac{\alpha_s}{2\pi}L, \\
\ln S &= \ln\frac{\mathrm{Tr}\left(He^{-t\Gamma^\dagger/2}Me^{-t\Gamma/2}\right)}{\mathrm{Tr}(HM)}
\end{aligned}
$$

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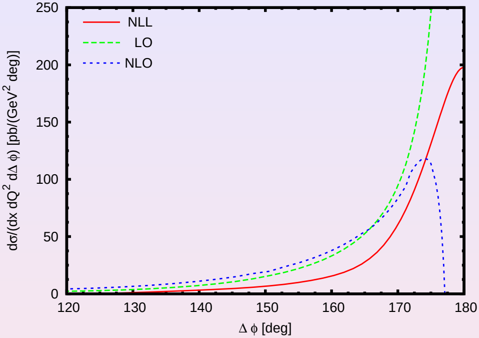
Results and extensions



Banfi, Delenda and MD 2008

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- Comparisons with data from HERA and Tevatron.

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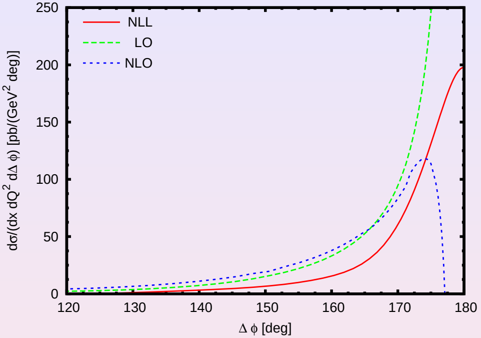

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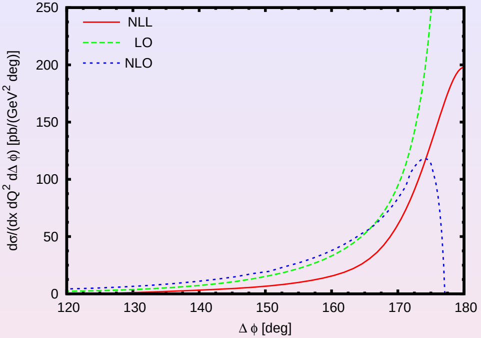

Banfi, Delenda and MD 2008

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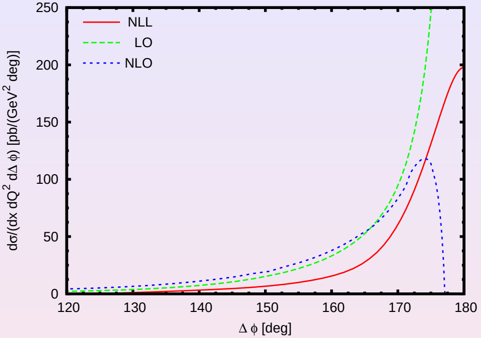

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