Gaps and jet vetoes

Grégory Soyez

IPhT, CEA Saclay

with Yoshi Hatta, Cyrille Marquet, Christophe Royon, Takahiro Ueda, Dominik Werder

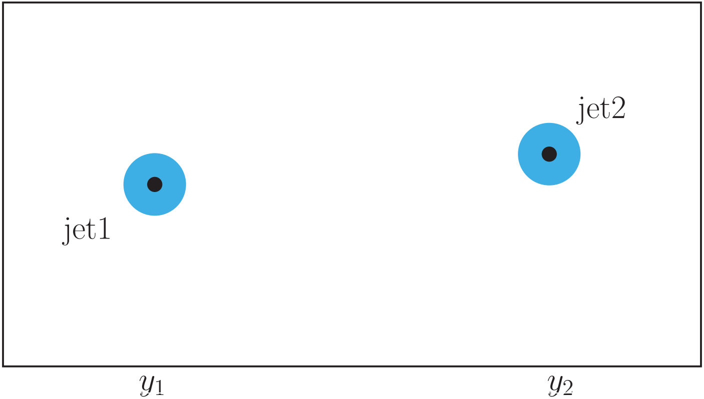
arXiv:1301.1910

April 17 2014

Context and setup

The setup

We'll consider the following situation:



- require 2 jets $(p_{t,1}, y_1, p_{t,2}, y_2)$

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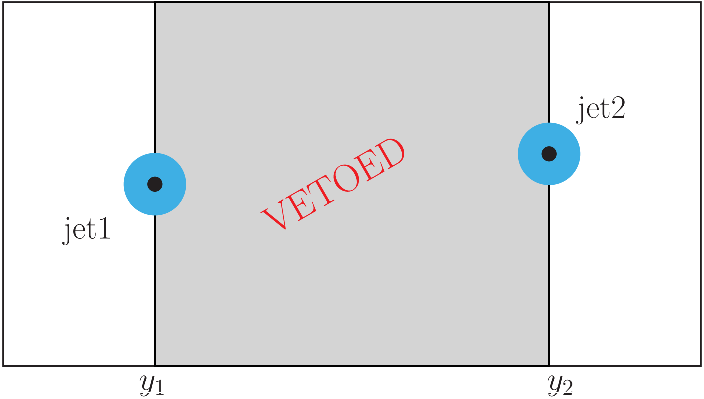
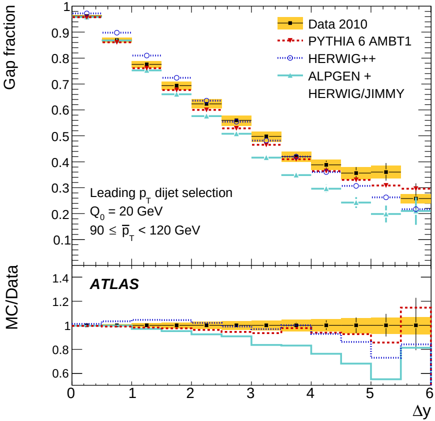


- require 2 jets $(p_{t,1}, y_1, p_{t,2}, y_2)$
- impose a veto: no jet with p_t above Q_0

ATLAS measurements

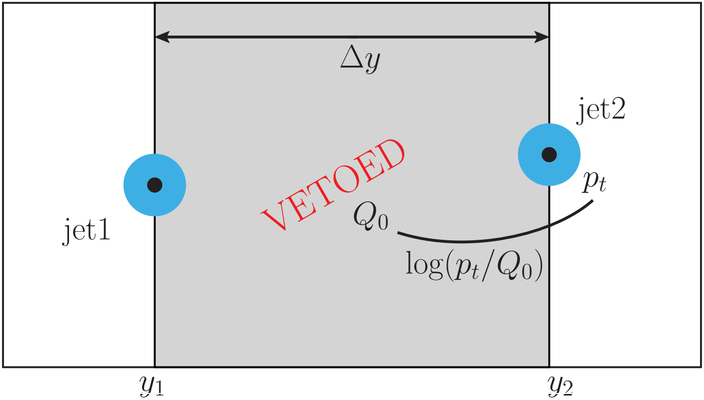
[ATLAS, arXiv:1107.1641]

Gap fraction $$R(\Delta y, \bar{p}_t) = \frac{\sigma^{\text{veto}}}{\sigma^{\text{incl}}}$$



- $\Delta y \equiv$ rapidity separation; $\bar{p}_t \equiv (p_{t1} + p_{t2})/2$
- hard selections: leading jets *or* most forward/backward jets above 20 GeV
- study of Δy, $\bar{p}_t$ and Q_0 dependence

QCD logs

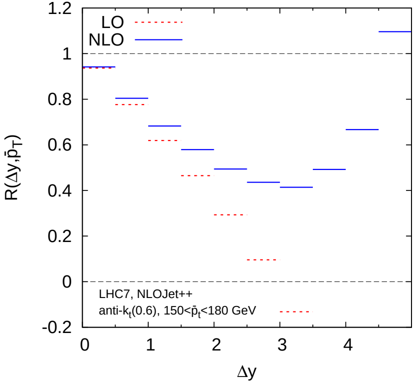


This talk in a nutshell

Soft QCD logs: Δy and $\log(\bar{p}_t/Q_0)$

Can we understand R from a QCD perturbative computation?

Breakup of order-by-order expansion



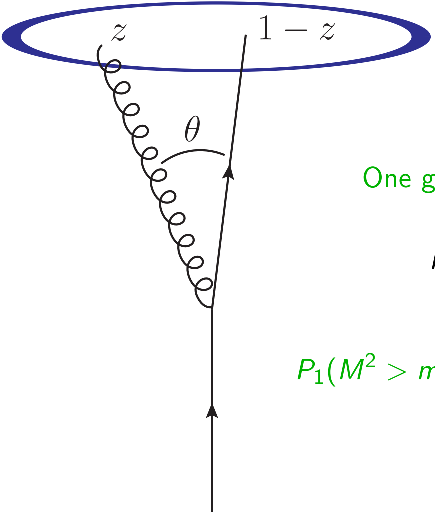
- LO: $R = 1 - C_1\alpha_s$
- NLO: $R = 1 - C_1\alpha_s + C_2\alpha_s^2$

- At large Δy:
  $1 - C_1'\alpha_s\Delta y + C_2'(\alpha_s\Delta y)^2 - \dots$

- Obvious need for resummation

Jet mass as an example

Example: the jet mass



One gluon emission:

$$M^2 = z(1-z)\theta^2 p_t^2, \quad \rho = \frac{p_t^2 R^2}{m^2}$$

$$P_1(M^2 > m^2) = \frac{\alpha_s C_F}{\pi}\left[\underbrace{\frac{1}{2}\log^2(\rho)}_{\text{soft\&col}} - \underbrace{\frac{3}{4}\log(\rho)}_{\text{collinear}}\right]$$

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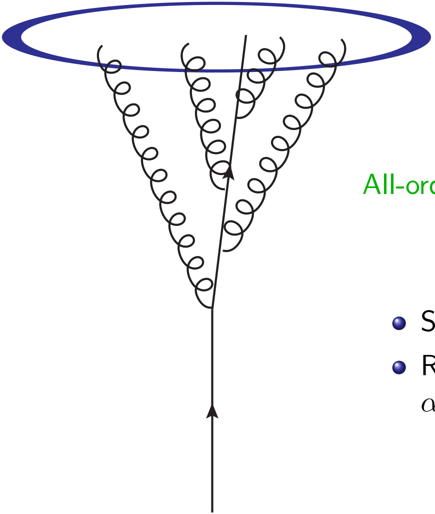
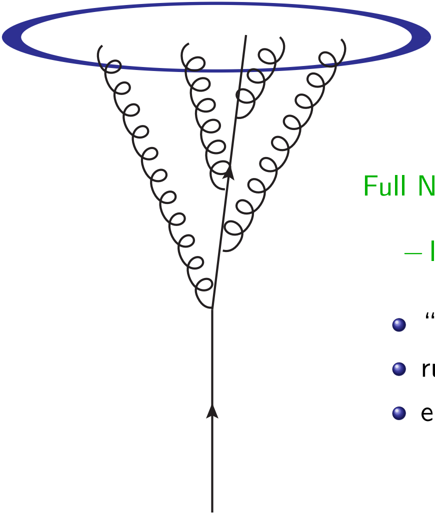


All-order resummation:

$$P(<\rho) = \exp\left[-P_1(>\rho)\right]$$

- Simple Sudakov-type exponentiation
- Resums $\alpha_s^n \log^{2n}(\rho)$ (double logs) and $\alpha_s^n \log^{2n-1}(\rho)$ (subleading logs)

Example: the jet mass



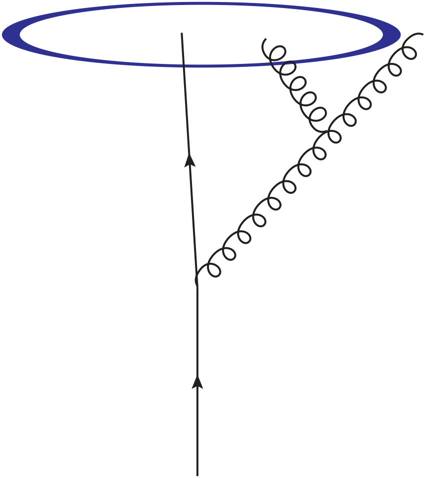
Full NLO calculation (single logs):

$$-\log(P(<\rho)) = g_1(\alpha_s L)L + g_2(\alpha_s L)$$

- “hard” collinear (as above)
- running coupling
- emission no longer independent

Example : the jet mass

[M.Dasgupta,G.Salam, hep-ph/0104277]



also Non-global logs:

- delicate single-logs (soft)
- do not trivially exponentiate
- appear for observables sensitive to a reduced geometrical region

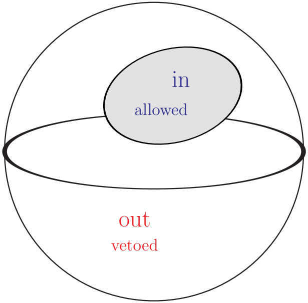
Resummation for energy flow with veto

Non-global logs resummation (e^+e^- collisions)

[A.Banfi, G.Marchesini, G.Smye, hep-ph/0206076]

Energy-flow (in the large-N_c approximation):

$$E\partial_E G_{ab}(E,E_0) = -\int_{\text{out}} \frac{d^2\Omega_k}{4\pi}\bar{\alpha}_s w_{ab}(k)\, G_{ab}(E,E_0) + \int_{\text{in}} \frac{d^2\Omega_k}{4\pi}\bar{\alpha}_s w_{ab}(k)\,[G_{ak}(E,E_0)G_{kb}(E,E_0) - G_{ab}(E,E_0)]$$



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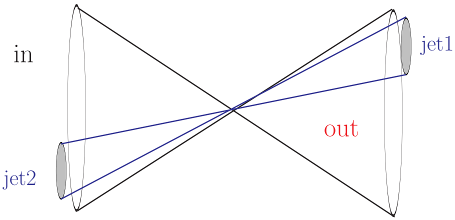
Non-linear evolution equation including non-global logs

- ab are quark and anti-quark (dipole) directions
- $G \simeq$ probability P
- $R^{(0)} \equiv$ single-log radiator (global observables)
- $w_{ab}(k) \equiv$ kernel for soft-gluon emission (antenna formula)
- resums $\alpha_s^n \log^n(E/E_0)$ for non-global observables

For our jet veto setup

$$\sigma_{\text{incl}} = \sum_{q,g \text{ channels}} \sigma_{\text{channel}} = \sum_{q,g \text{ channels}} \sum_{\text{colour flows}} \sigma^{\text{flow}}_{\text{channel}}$$

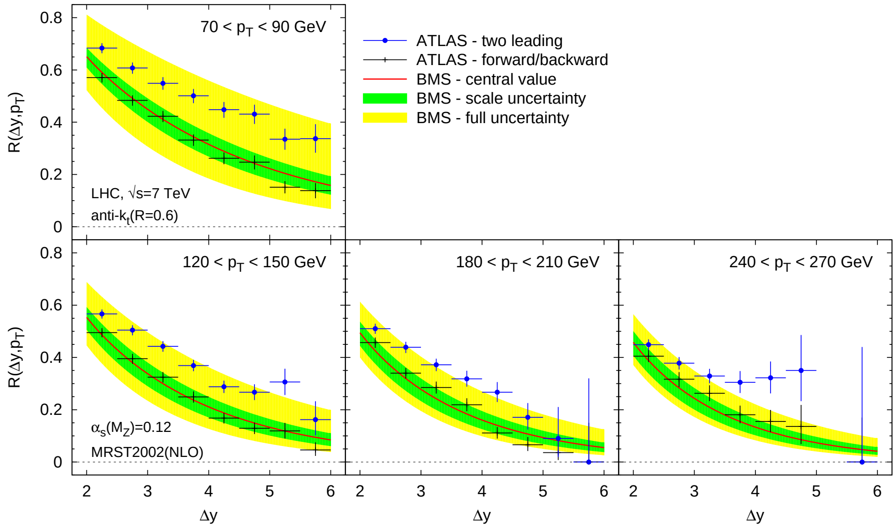
$$\sigma_{\text{veto}} = \sum_{q,g \text{ channels}} \sum_{\text{colour flows}} \sigma^{\text{flow}}_{\text{channel}} \prod_{\text{dipoles}} G_{\text{dipole}}(p_T, E_0)$$



For the purpose of jet vetos

- One G factor for each "dipole" in our $2 \to 2$ process (depends on parton types and channels)
- Numerical solution from Y.Hatta, T.Ueda, arXiv:0909.0056

Results: rapidity dependence



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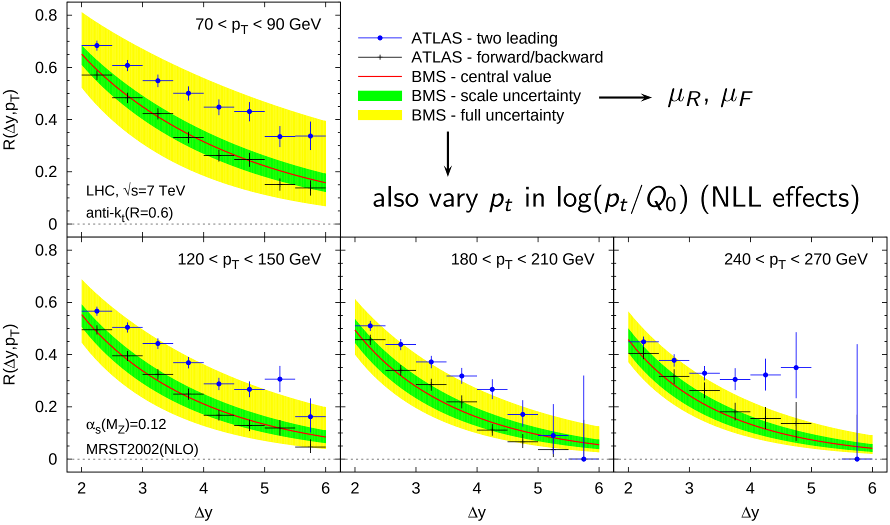
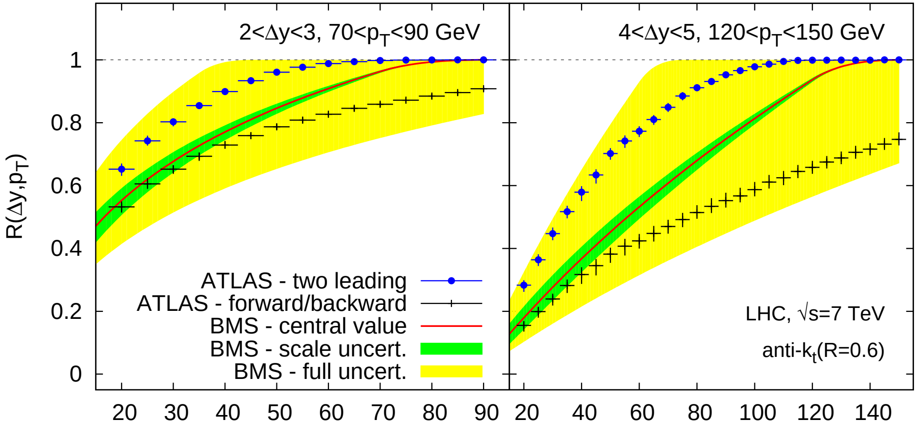


$\longrightarrow \mu_R, \mu_F$

also vary p_t in $\log(p_t/Q_0)$ (NLL effects)

Results: E_0 dependence



Improvements

Room for improvement: work in progress

- Use exact exclusion region
  Currently we use a rectangle from $y_{\mathrm{jet1}} + R$ to $y_{\mathrm{jet2}} - R$

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- Include NLL effects
  Doable but complicated colour structures
- Understand "2 leading jets" v. "most forward/backward

Beyond large-N_c

[H. Weigert, arXiv:hep-ph/0312050]

Generalises to a Fokker-Planck type of equation

$$E\partial_E \hat{Z}_E[U] = -H_{\rm ng}\hat{Z}_E[U]$$

$$H_{\rm ng} = -\frac{\alpha_s}{2\pi} w_{uv}(k)\left[f^{(1)}(k)\left(i\nabla^a_u i\nabla^a_v + i\bar{\nabla}^a_u i\bar{\nabla}^a_v\right) + f^{(2)}[U_k]^{ab}\left(i\bar{\nabla}^a_u i\nabla^b_v + i\bar{\nabla}^a_v i\nabla^b_u\right)\right]$$

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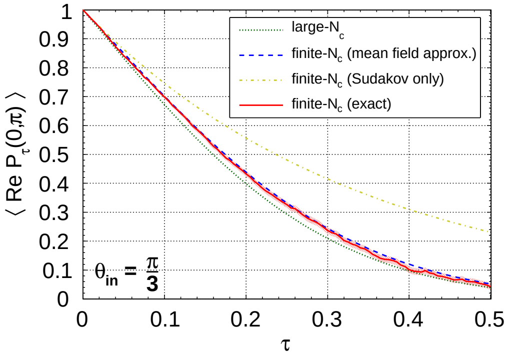
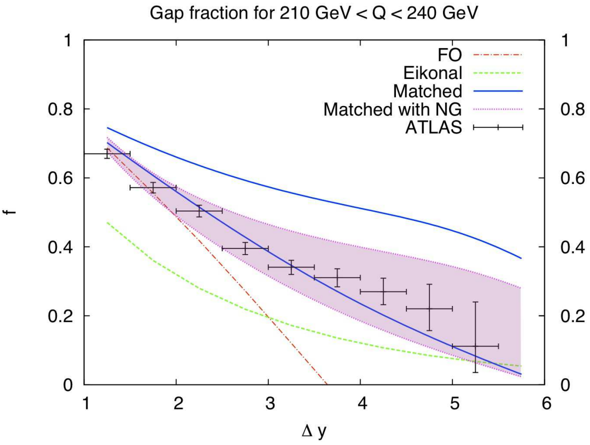


[Y.Hatta, T.Ueda, arXiv:1304.6930]

small (few %) effect

Matching with fixed-order

[R Delgado, J. Forshaw, S. Marzani, M. Seymour, arXiv:1107.2084]



Matched to LO

Could be generalised to NLO

Other processes

Jet vetos appear in other contexts:

- A similar calculation could be extended to $H + 2$ jets + veto
- H+0/1 jet with additional jet veto

[A.Banfi, G.Gavin, G.Zanderighi, arXiv:1203.5773]

[A.Banfi, P-F.Monni, G.Zanderighi, arXiv:1206.4998]

[I.Stewart, F.Tackman, J.Walsh, S.Zuberi, arXiv:1307.1808]

Conclusions

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- Jet vetos can be calculated in perturbative QCD
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Future plans

- Room for improvement at various places
- Possible extension to Hjj+veto (relevant for gg-fusion v. VBF)