QCD description of ATLAS jet veto data

Based on: Y. Hatta, C. Marquet, C. Royon, G. Soyez, T. Ueda, DW, arxiv:1301.1910

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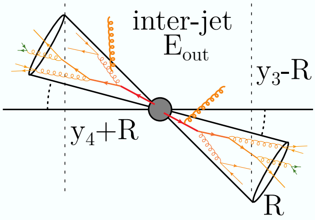
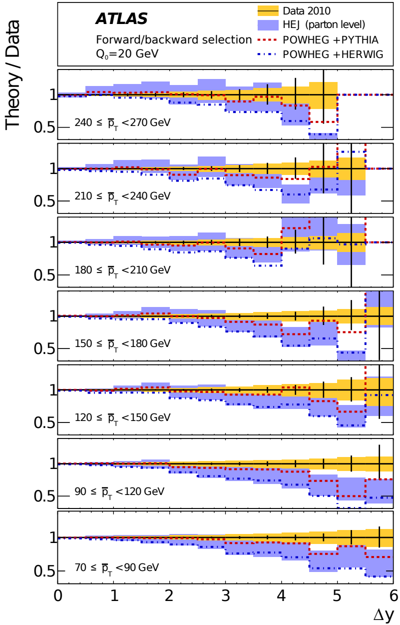
Jets with veto on inter-jet radiation

- Di-jet events, high-$p_\perp$, $\Delta y = y_3 - y_4$
- Veto on extra activity between these primary jets:
  Perturbative threshold e.g. $E_{\text{out}} \simeq 20$ GeV
- $\mathcal{R}(\Delta y, p_\perp) = \frac{d\sigma^{\text{veto}}}{d\Delta y\, d^2 p_\perp} / \frac{d\sigma^{\text{incl}}}{d\Delta y\, d^2 p_\perp}$
- Contributing to additional activity between tagged jets:
  Wide angle emissions of gluons from primary, secondary ...



$y = \ln \cot(\theta/2)$

Jets with veto on inter-jet radiation



Description very good for smaller Δy.

Theory below data for larger Δy.

Pythia with $p_\perp$ ordered showers much closer.

HEJ w/o showers very close as well.

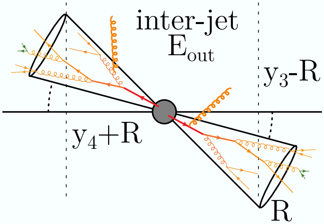
Herwig: angular ordered showers seem to deviate most.

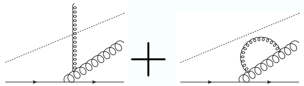
Soft emissions ordered in $p_\perp$.

ATLAS arxiv:1107.1641

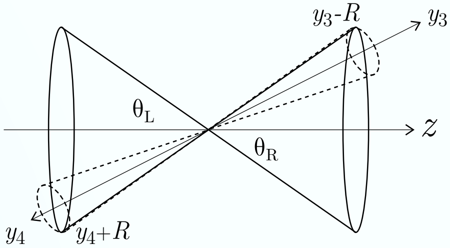
Wide angle emissions

- Applying veto: Cancellation spoiled $(\alpha_s\, \Delta y\, \ln p_\perp / E_{\text{out}})^n$
- For $p_\perp \gg E_{\text{out}}$ or large Δy sensitivity to resummation of large-angle gluon emissions
- Two types of logarithms appear:
  Sudakov (from primary partons)
  Non-global (2nd, 3rd ...)
- For wide angle gluon emissions from primary parton:
  Global logs $\rightarrow e^{-c_0 \alpha_s \Delta y \ln(p_\perp / E_{\text{out}})}$
- Emissions from the secondary (and other) partons:
  More difficult, e.g. [hep-ph/0104277] ...
  We use: Banfi, Marchesini, Smye, 2002 [hep-ph/0206076]





BMS approach for non-global resummation



- LO matrix element
- Primary jets, given by (y_3, φ), (y_4, φ)
- Cones enclose tagged jets: Veto region between the cones
- Kinematical cuts:
  $p_\perp = (p_{3\perp} + p_{4\perp})/2 \geq 70$ GeV
  $|y| \leq 4.4$
  Jet reconstruction: anti-$k_\perp$, $R = 0.6$
- For σ^{veto} require $E_\perp^{\text{inter-jet}} \leq E_{\text{out}} \sim 20$ GeV

BMS approach for non-global resummation

- Probability P for $E_\perp^{\text{inter-jet}} < E_{\text{out}}$
  boost invariance, $y_R = y_3 - R$, $y_L = y_4 + R$
  $P_\tau(y_R, y_L, y_3, y_4) = P_\tau(\frac{y_R - y_L}{2}, -\frac{y_R - y_L}{2}, y_3 - \frac{y_R + y_L}{2}, y_4 - \frac{y_R + y_L}{2})$
- Evolution variable, for running α_s
  $\tau = \int_{E_{\text{out}}}^{p_\perp} \frac{dk_\perp}{k_\perp} \frac{\alpha_s(k_\perp) N_c}{\pi} = \frac{1}{2b} \ln(\alpha_s(E_{\text{out}})/\alpha_s(p_\perp)) = \frac{1}{2b} \ln \frac{\ln(p_\perp/\Lambda_{\text{QCD}})}{\ln(E_{\text{out}}/\Lambda_{\text{QCD}})}$
- Evolution equation, large-N_c

$$\partial_\tau P_\tau(\Omega_\alpha, \Omega_\beta) = -\int_{C_{\text{out}}} \frac{d^2\Omega_\gamma}{4\pi} \frac{1 - \cos\theta_{\alpha\beta}}{(1 - \cos\theta_{\alpha\gamma})(1 - \cos\theta_{\gamma\beta})} P_\tau(\Omega_\alpha, \Omega_\beta)$$

$$+ \int_{C_{\text{in}}} \frac{d^2\Omega_\gamma}{4\pi} \frac{1 - \cos\theta_{\alpha\beta}}{(1 - \cos\theta_{\alpha\gamma})(1 - \cos\theta_{\gamma\beta})} (P_\tau(\Omega_\alpha, \Omega_\gamma) P_\tau(\Omega_\gamma, \Omega_\beta) - P_\tau(\Omega_\alpha, \Omega_\beta))$$

- Numerically solved (Y. Hatta, T. Ueda, 2009)

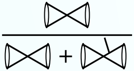
LO ME + single leading log resummed

- Contributing processes: Leading order QCD $2 \to 2$

  $qq' \to qq'$, $qq \to qq$, $q\bar{q} \to q\bar{q}$, $q\bar{q} \to q'\bar{q}'$, $q\bar{q} \to gg$ ...

  $$\frac{d\sigma}{dp_\perp \, d\Delta Y} = \sum_{ij} \int_Y dY \, x_1 f_i(x_1) \, x_2 f_j(x_2) \frac{1}{\pi} \frac{d\sigma_{ij}}{d\hat{t}}$$

- Weighted QCD cross section with BMS veto factor
- Standard proton PDF
- Running α_s with $\alpha_s(m_Z = 91.2\,\text{GeV}) = 0.12$
- Take ratio with inclusive cross section ($P = 1$):



Estimation of uncertainties

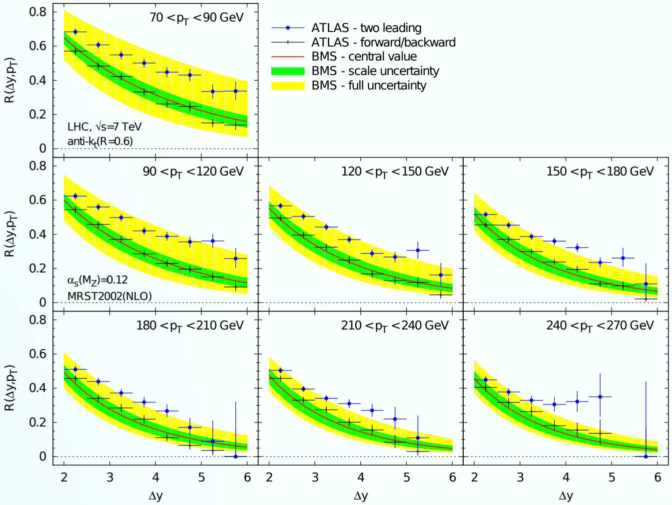
- Uncertainties: Variation of α_s-scale ($\times 2$)
  - in ME
  - in τ

  Factor α_s in ME cancels in ratio

$$\tau = \int_{E_{\text{out}}}^{p_\perp} \frac{dk_\perp}{k_\perp} \frac{\alpha_s(k_\perp) N_c}{\pi}$$
$$= \frac{1}{2b} \ln(\alpha_s(E_{\text{out}})/\alpha_s(p_\perp))$$

- Variation of scale in PDF ($\times 2$)
- Cross-check PDFs (CT10, MRST2002, ...)
- Subleading logs not accounted for in $(\alpha_s \ln(p_\perp/E_{\text{out}}))^n$
  Vary boundary in τ integral

Results



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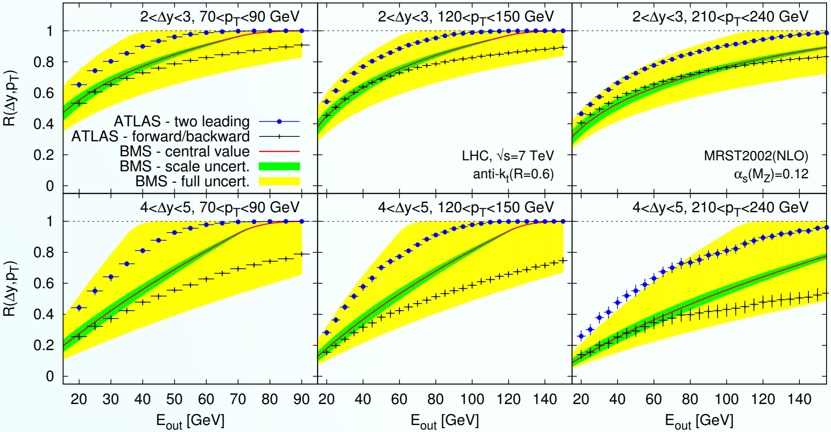
- Very nice agreement with forward/backward jet selection
- Larger uncertainties from estimation of subleading logs

Results



- Best description for large scale difference
  Large scale needed for formalism

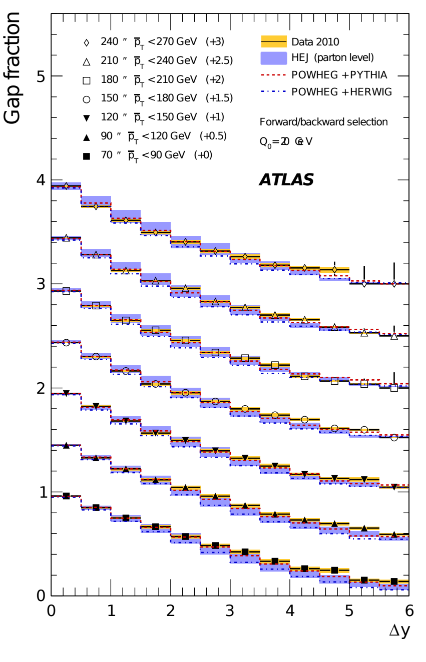
Conclusions

- Jets with veto on inter-jet region
- Emissions from primaries (Sudakov) vs. secondaries
- Resummation possible for first case, numerical solution via BMS for second
- Compared to ATLAS jet veto data:
  Very good agreement with the forward/backward dijet selection

Comment on BFKL

- Choice of veto E_{out} too large for sensitivity to BFKL
- Would increase P
  Scattered quarks form dipoles most dominantly with their remnants
  $\Rightarrow$ Less radiative activity between the boundary jets
- Need for BFKL not evident for the choice of E_{out}


ENSIS
GRAT



Gap fraction
Δy
240 ≤ p̄T < 270 GeV (+3)
210 ≤ p̄T < 240 GeV (+2.5)
180 ≤ p̄T < 210 GeV (+2)
150 ≤ p̄T < 180 GeV (+1.5)
120 ≤ p̄T < 150 GeV (+1)
90 ≤ p̄T < 120 GeV (+0.5)
70 ≤ p̄T < 90 GeV (+0)
Data 2010
HEJ (parton level)
POWHEG +PYTHIA
POWHEG +HERWIG
Forward/backward selection
Q0=20 GeV
ATLAS