Parton showers for non-global QCD observables

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University of Manchester

Work in collaboration with A. Banfi and G. Corcella

DIS 2007, Munich, 18 April

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Outline

- How good is a given parton shower ?
- Non-global observables and loss of angular-ordering (AO).
- Mismatch between AO and full leading-logarithmic calculations.
- HERWIG vs PYTHIA vs resummed perturbation theory.
- Concluding remarks.

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Monte-Carlo simulations of QCD perhaps the most vital physics tool at LHC. Crucial to critically the examine the different components :

- Perturbative aspects - parton shower (PS), ME corrections and matching.
- Non-perturbative aspects - hadronisation and underlying event models.
- Tuning of event generators.

A lot of attention being paid to all aspects but are some details slipping the net ? We shall address the first issue ....

See also plenary talk by Z. Nagy, this meeting

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- Developments in all-order resummations have challenged understanding of soft radiation at large angles (angular ordering) even at leading (logarithmic) accuracy. MD and Salam 2001,2002. Banfi, Marchesini, Smye 2002
- Observables sensitive to soft emission in limited regions include energy flow distributions, event shapes, jet distributions and many others.
- Must re-examine the accuracy of the shower in these instances. Do we tune leading logs into the MC parameters ? Should we worry about this.....? In principle ? Numerically ?

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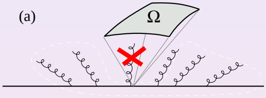

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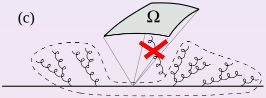

Examine differential E_t flow

$$\frac{1}{\sigma}\frac{d\sigma}{dE_t}$$

Here $E_t = \sum_{i\in\Omega} E_{t,i}$ and Ω is interjet region e.g rapidity slice.

Leading logs are $\alpha_s^n L^n$ where $L = \ln Q/E_t$. Originate from $\omega_1 \gg \omega_2 \gg \omega_3 \cdots$ without angular-ordering. But AO a feature of MC's e.g HERWIG and old PYTHIA (before v 6.3).

Non global observables and loss of AO

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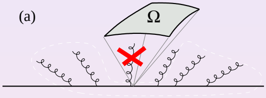

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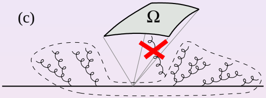

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Resummation and angular ordering

We take two approaches to the problem.

- Take resummation program and force angular ordering – toy model of AO.
- Take real parton showers from HERWIG and PYTHIA and compare to non-global resummation.

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Modified resummation with angular ordering

The leading logarithms resummed in large N_c limit by a dipole evolution Monte-Carlo.

Dasgupta and Salam 2001

Add soft gluon at scale $L' = \ln Q/\omega$ to dipole configuration C at scale L to get C'

$$P_{C'}(L') = \bar{\alpha}_s(L')\Delta_C(L,L')F_C(\theta',\phi')P_C(L)$$

$$F_C(\theta_k,\phi_k) = \sum_{\text{dipoles}-\text{ij}} \frac{2C_A\left(1-\cos\theta_{ij}\right)}{\left(1-\cos\theta_{ik}\right)\left(1-\cos\theta_{jk}\right)}$$

The single-log form factor obtained as

$$\Sigma(\alpha_s L) = \sum_{C|\Omega_{\text{empty}}} P_C(L), L = \ln Q/E_t\,.$$

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AO modification

To force only configurations with AO :

$$F(\theta_k, \phi_k) \to \frac{\theta\left(\cos\theta_{ik} - \cos\theta_{ij}\right)}{(1-\cos\theta_{ik})} + \frac{\theta\left(\cos\theta_{jk} - \cos\theta_{ij}\right)}{(1-\cos\theta_{jk})}$$

Then one gets $\Sigma_{\mathrm{AO}}(\alpha_S L)$ as before.

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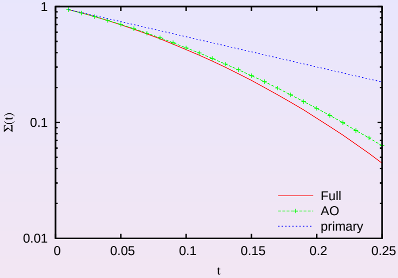

For unit rapidity slice in e^+e^- annihilation with

$$t \sim \frac{\alpha_s}{2\pi} \ln \frac{Q}{E_t}$$

10 % effect at $t = 0.15$. Corresponds to 1 GeV in the gap and 100 GeV jets. Similar results for other geometries Ω. Bulk of leading-log effects come from inside azimuthally averaged cones – not accidental.

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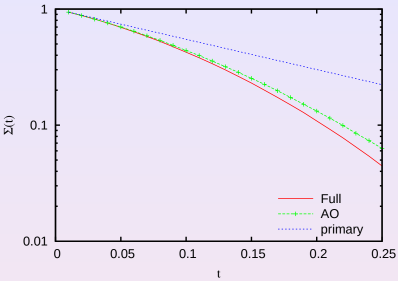
Results



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Comparison to HERWIG and PYTHIA

- HERWIG based on angular ordering, shd be close to full (large N_c) result.
- PYTHIA (old) ordering in m^2 and reject non AO configs, shd do worse.
- ARIADNE – dipole phase space, shd have the full LL.
- PYTHIA (new) like ARIADNE ?

Trick go to very high $(10^5$ GeV) to kill subleading effects. Only interested in $t \sim \frac{\alpha_s}{2\pi} \ln \frac{Q}{E_t}$.

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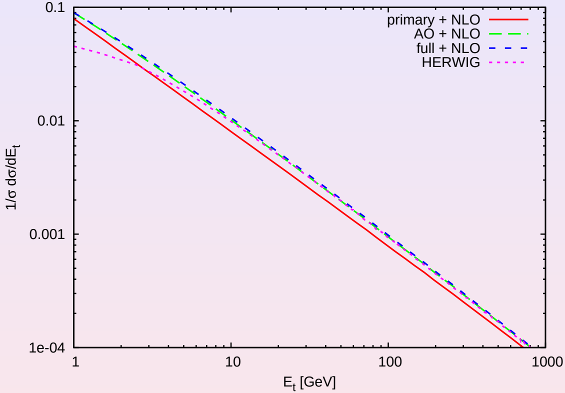
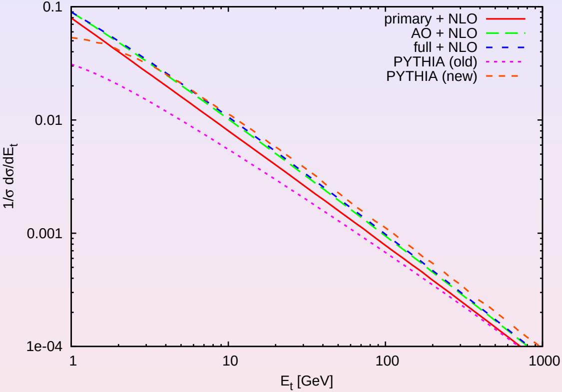


Numerically 10% effect at $t = 0.15$, $E_t = 10$ GeV.

Comparison to PYTHIA



At $t = 0.15$

PYTHIA old deviates by 50 % from full. PYTHIA new only 7.5% off.

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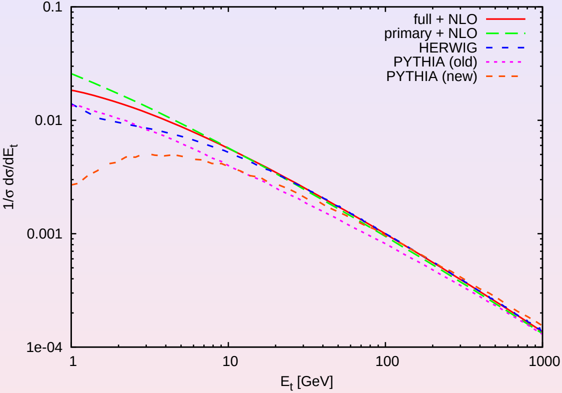
But for large gaps....



Problems seen with new PYTHIA at large rapidity intervals.....

Concluding Remarks

- Angular ordering (implemented as in HERWIG) numerically includes a bulk of leading-log effects.
- The old PYTHIA versions (before 6.3) do not account for a large part of the leading perturbative logarithms for a number of observables.
- The new PYTHIA model works much better but we note problems at large rapidity intervals for energy flow between jets.
- Further studies are needed to understand the behaviour of the various parton showers in a quantitative fashion. Wherever possible compare HERWIG and PYTHIA.......

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