New effects in Jet Physics

The Non-global Logs

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QCD and event shapes

7 QCD *is* a special theory in the SM: strongly coupled domain is in the reach of current experiments (and unavoidable)

å wealth of non-trivial phenomena at formally PT scales (divergent PT series, large NP effects, . . .)

7 Main aim of QCD is the full understanding of these phenomena, for their fundamental interest and for studies of new physics

Typically the more exclusive the observable, the more difficult to predict

Interesting compromise between IR sensitivity and PT calculability:

* event shapes

Ideal laboratory to study interface between weakly and strongly coupled regimes of QCD

Event shape variables

7 In collider experiments final states consist of tagged particles and jets

7 Event shapes [thrust, broadening, jet masses] are IR-safe observables which measure the energy and momentum flow of the final state in hard (ee, ep, pp) collisions

7 Mean values and distributions widely used for

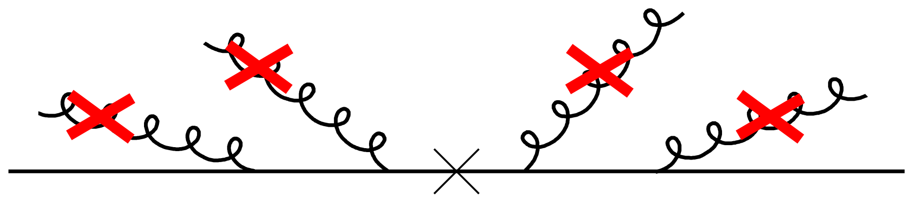
- v measuring α_s and colour factors
- v testing QCD
- v investigating (large) non-perturbative effects

7 Most discriminatory studies make use of event shape *distributions* characterised by two widely different energy scales $VQ \ll Q$

* Here theoretical comparisons require the resummation of large infrared logarithms L = - $Log(V)$

Need for resummation

When observables are close to the Born limit $V \ll 1$, FORBID all except soft and/or collinear emissions, e. g. in e^+e^-:



This leads to soft and/or collinear double (DL) and single (SL) logs:

$$(\alpha_s L^2)^n \qquad (\alpha_s L)^n \qquad L \equiv \text{Log}\frac{1}{V} \gg 1$$

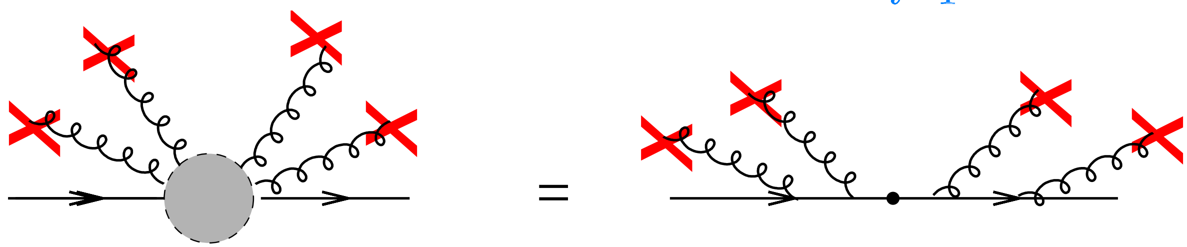
which need to be resummed $\rightsquigarrow 1 - \alpha_s L^2 \Rightarrow e^{-\alpha_s L^2}$

* The standard accuracy guarantees correctness of all DL and SL logs

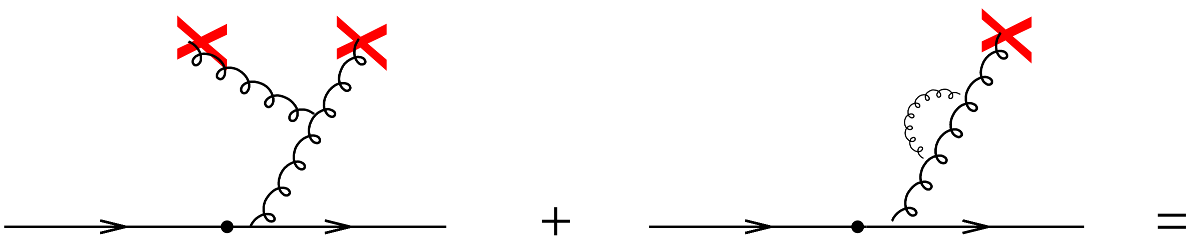
Soft emission at large angles

Resummation of infrared logarithms is based on *angular ordering* which reduces to soft *independent emissions* ($\Rightarrow$ QED)

$$e^+e^- \to 2\,\text{jets} \Rightarrow w_{p\bar{p}}(k_1,\ldots,k_n) = \prod_{i=1}^{n} w_{p\bar{p}}(k_i)$$



The basis of independent emission is the cancellation of non-abelian contributions, i.e. neglect secondary gluon branching (only account for running of α_s)



$$VQ \ll E_2 \sim E_1 \ll Q$$

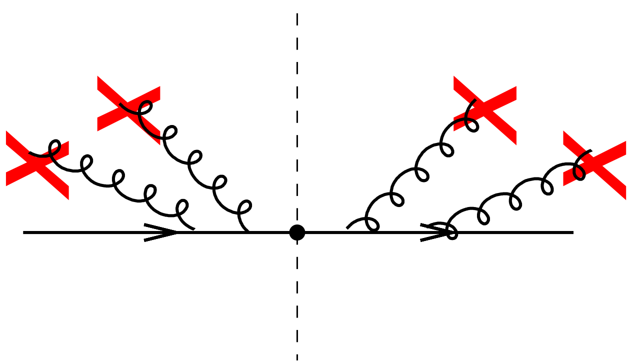
$$\mathcal{O}\left(\alpha_s^2 L\right)$$

å beyond SL!

Two kind of observables

Global observables:	sensitive to emissions in the whole phase space (eventually through recoil)
Non-global observables:	sensitive to emissions only in a restricted phase space region (for instance in one hemisphere)

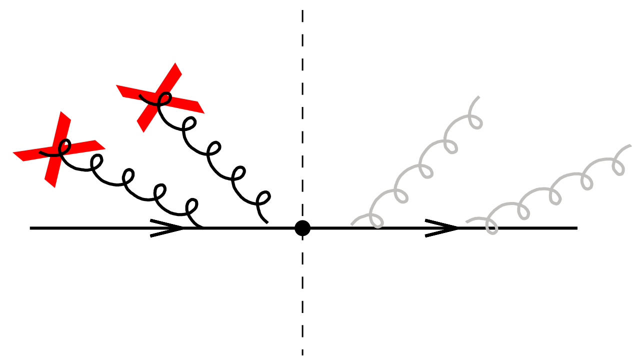
Global:



observed region *observed region*

$\Longrightarrow$

Non-global:



observed region *not observed region*

* Approximation of *independent emissions* requires suppression of QCD radiation *only in the selected region*

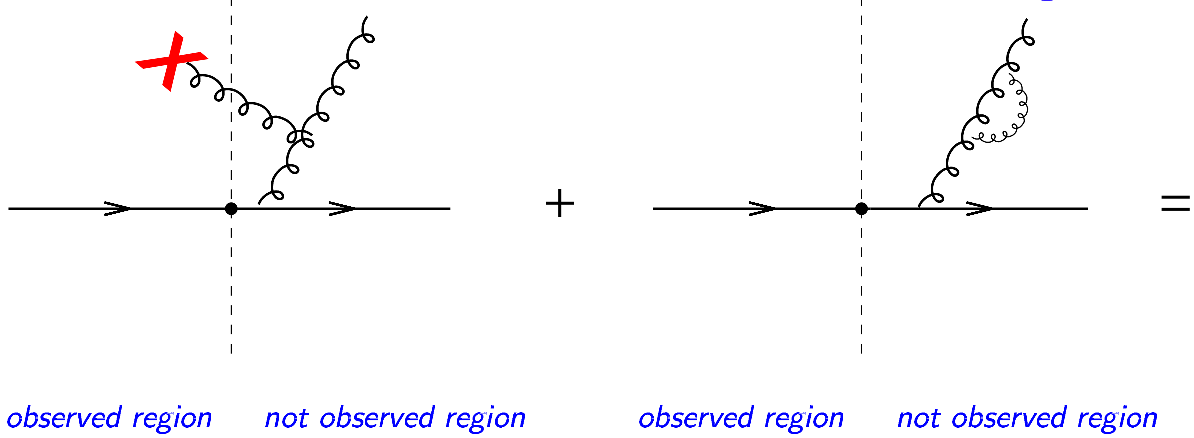
⚠ This is *WRONG FOR SINGLE LOGS OF NON-GLOBAL OBSERVABLES*, one must also to forbid energy-ordered large-angles secondary emissions in the observed region from *EVERYWHERE*

Dasgupta & Salam, hep-ph/0104277

Soft emission at large angles

* For non-global observables real-virtual cancellation does not work any more

SL contributions arise when only the softest gluon is emitted in the measure region



$VQ \ll E_2 \sim E_1 \ll Q$

$\mathcal{O}\left(\alpha_s^2 L^2\right)$

å affect SL answer!

Neglecting this effect has left many victims on its way

- G. Oderda and G. Sterman PRL 81 (1998) 3591
  "Energy and color flow in dijet rapidity gaps"
- G. Oderda, PRD 61 (2000) 014004
  "Dijet rapidity gaps in photoproduction from perturbative QCD"
- V. Antonelli, M. Dasgupta and G. P. Salam JHEP 02 (2000) 001
  "Resummation of thrust distributions in DIS," only τ_{zE} which is discountinously global
- A. Banfi, G. Marchesini, Yu. L. Dokshitzer and G. Zanderighi JHEP 07 (2000) 002
  "QCD analysis of near-to-planar three-jet events" only $K_{\rm out}$ right
- S.J. Burby and E.W. Glover JHEP 04 (2001) 029
  "Resumming the light hemisphere mass and narrow jet broadening distributions in e^+e^- annihilation," only v1
- C. F. Berger, T. Kucs and G. Sterman PRD 65 (2002) 094031
  "Energy flow in interjet radiation"

Computing non-global logs

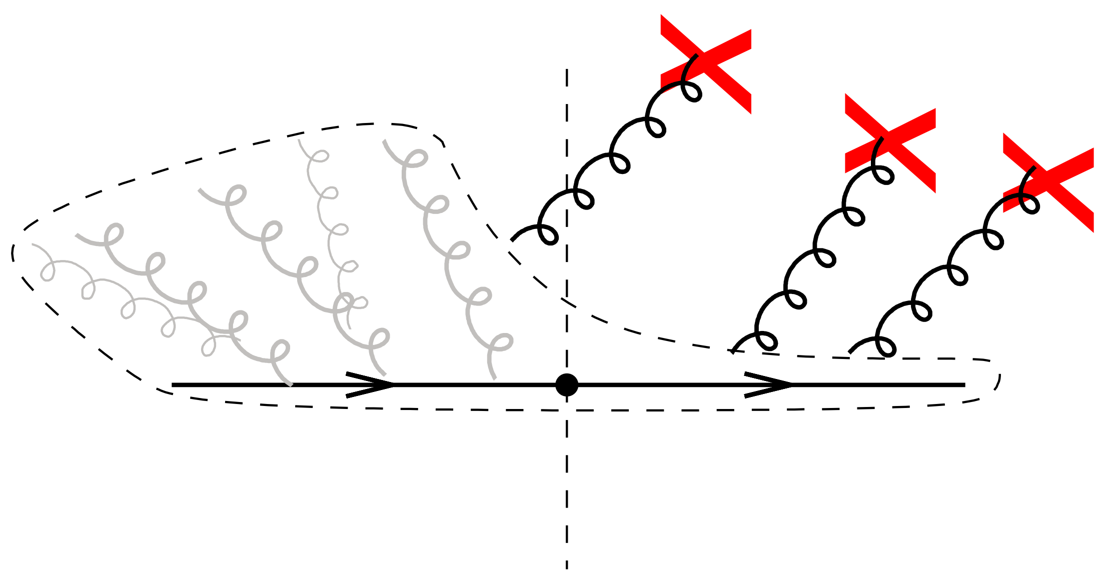
Define

$$\Sigma_{\text{non glob.}}(v) \equiv \mathcal{S}(v)\Sigma_{\text{glob.}}(v)$$

All new effects embodied in $\mathcal{S}(\alpha_s L) = 1 + \sum_{n=2}^{\infty} \mathcal{S}_n \cdot (\alpha_s L)^n$

$\mathcal{S}_2$ can be computed exactly (involves emission of 2 secondary partons)

Computation of $\mathcal{S}$ involves considering an *ensemble of an arbitrary number of large-angle energy-ordered gluons which coherently emit an additional gluon*



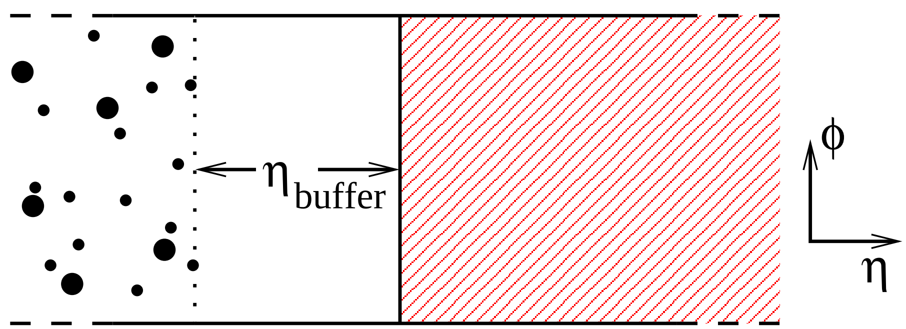
All orders in $\alpha_s L$??

Forbid coherent radiation from an *ensemble* of energy ordered large-angle gluons

7 Complex colour-structure as the number of gluons increases $\Rightarrow$ large N_c-limit

7 Complex 3D-geometry due to many large-angle gluons $\Rightarrow$ two different approaches Monte Carlo simulation (Dasgupta & Salam) or *non-linear* evolution equation (Banfi et al.)

7 Some features understandable with intuitive, simple arguments: the *buffer mechanism*

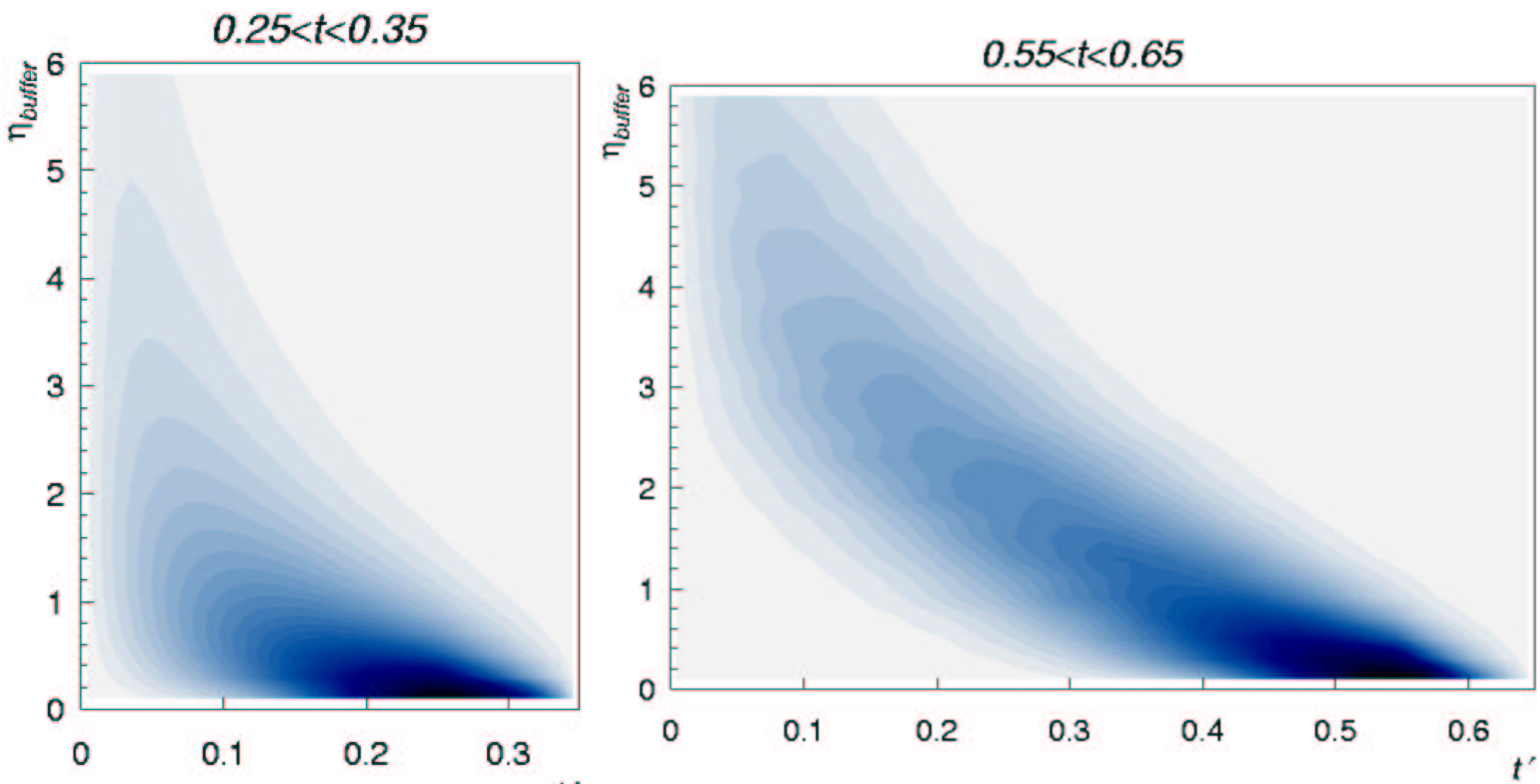


Evolution of the buffer

Evolution variable:

$$t \sim \int \frac{dk_t}{k_t} \alpha_s(k_t)$$

Ask the region Ω to be empty down to some scale t, then at the scale t' an empty buffer exist between Ω and the emission closest to Ω.

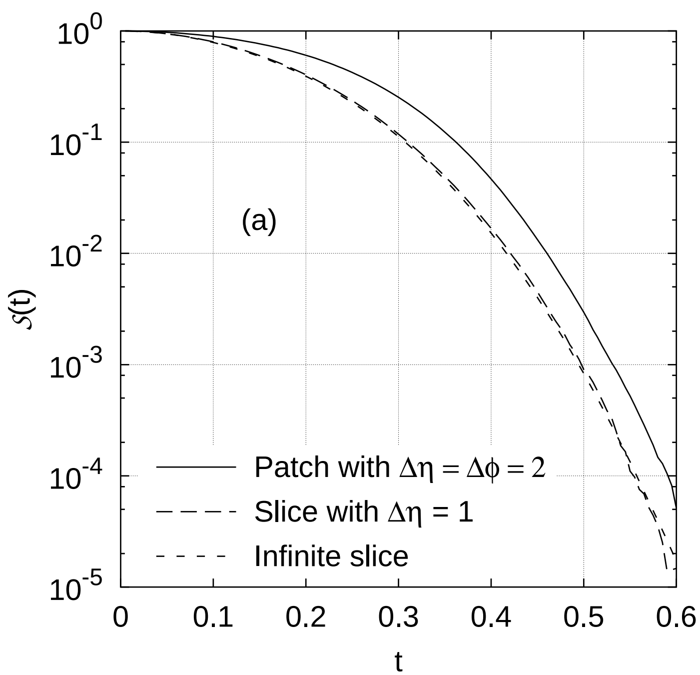


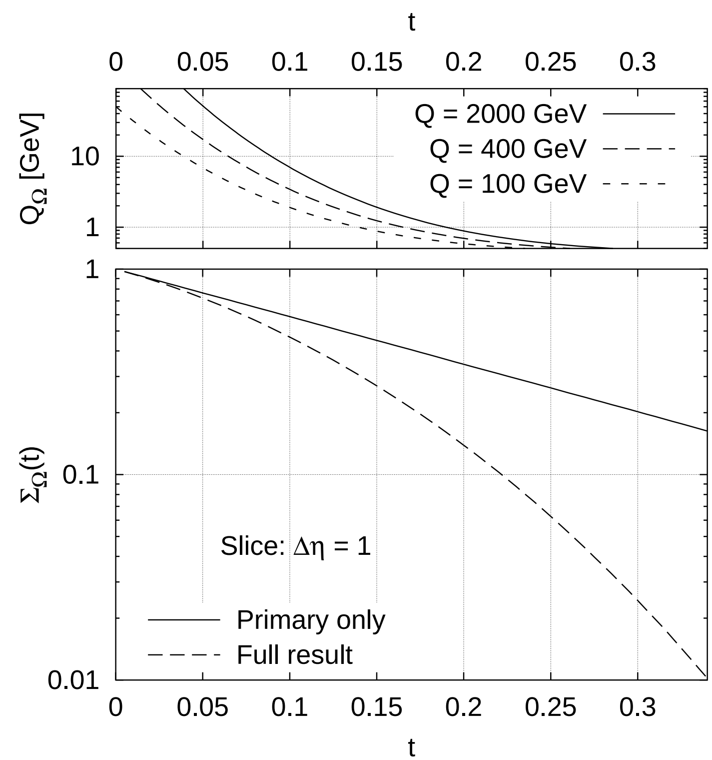
* buffer increses with $t \Rightarrow$ with large t the behaviour of $\mathcal{S}$ is expected to be independent of the size and shape of Ω

Monte Carlo simulation

$$\Sigma_{\text{non glob.}}(v) \equiv \mathcal{S}(t)\Sigma_{\text{glob.}}(v) \qquad t \sim \int \frac{dk_t}{k_t}\alpha_s(k_t)$$

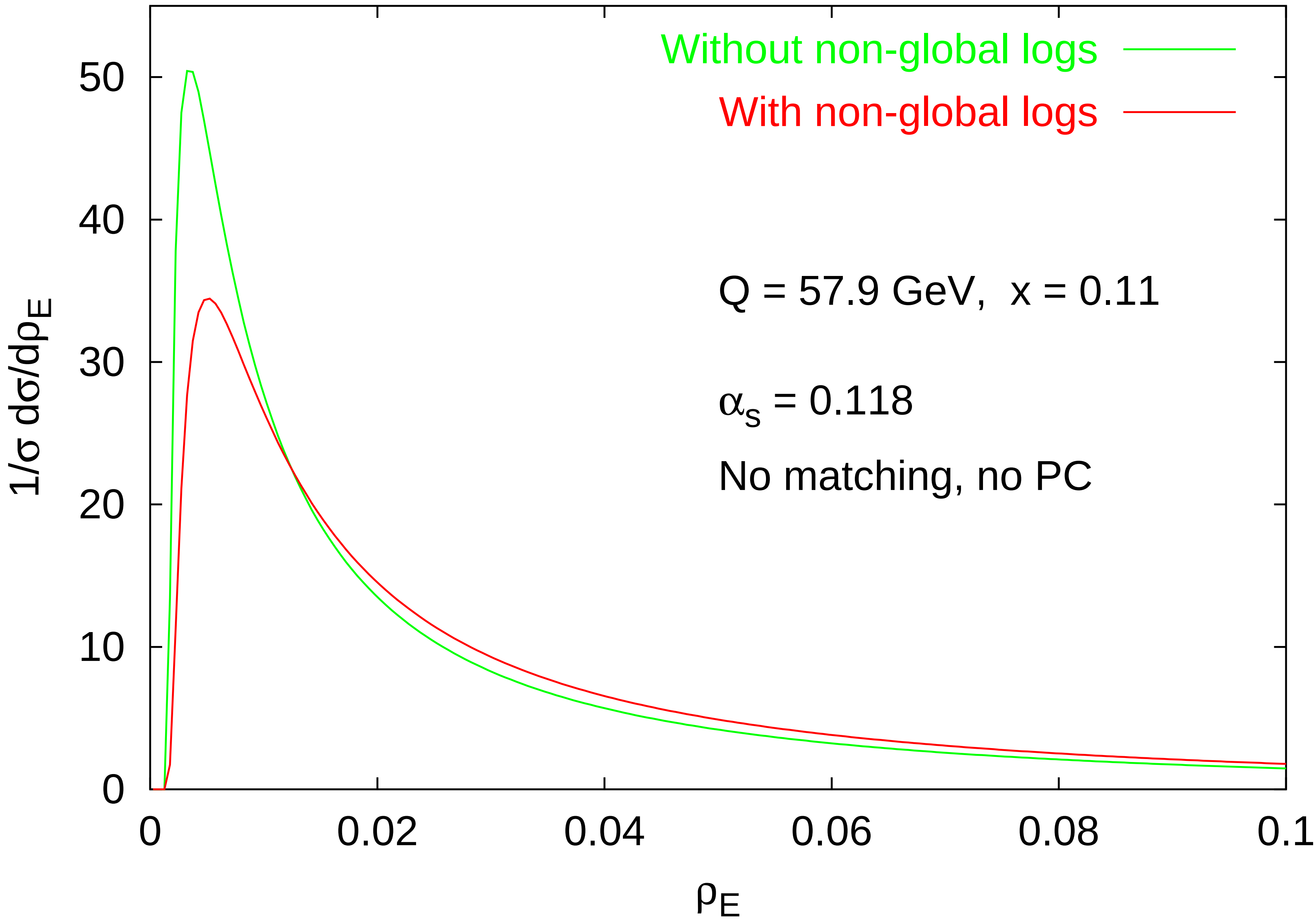
$\mathcal{S}$ accounts for secondary gluon branchings. Can be computed in the large N_c-limit with a MC procedure which produces weighted events.





* *shape* of $\mathcal{S}$ independent of the geometry for large t

Phenomenological relevance of non-global logs



Conclusions

7 A new class of observables: non-global observables

7 These are affected by new genuine non-abelian effects: the non-global logs

7 They can be resummed in the large N_c limit via Monte Carlo simulations or solving a *non-linear* evolution equation

7 Be aware that non-global effects affect many final state observables in hh-collisions (rapidity cuts, jet cones . . .)

* alternatively understand tricks to define “fake-global” observables (global through recoil ⇒ DIS)

7 Accounting for these effects needs a *change of philosophy:*

* *independent emissions/angular ordering is not sufficient!*