Non-global logarithms: an overview

Gavin Salam
LPTHE — Univ. Paris VI & VII and CNRS

XXVIIIth Rencontres de Moriond
23–29 March 2003

Outline

This is first of two talks on non-global logarithms:

- ✗ *Non-global? What on earth does that mean?!*
- ✗ Non-global observables
- ✗ Why they are special (non-global logarithms)
- ✗ Theoretical properties of non-global logs:
  - ☛ fixed-order
  - ☛ all-orders

Phenomenology will be in Rob Appleby's talk

Definition

'Non-Global' (NG) observable:

$\equiv$

An observable sensitive to emissions in only a restricted angular region

Examples

- ✗ Properties of *individual jets* (or hemispheres), *e.g.* shapes, # of subjets
- ✗ Definitions of diffraction based on *rapidity gaps* (or energy flow)
- ✗ *Isolation criteria* for photons
- ✗ *Interjet* energy flows
- ✗ Original Sterman-Weinberg jet definition

see also list by Dokshitzer & Marchesini '03

Resummation?

- ✗ Interesting (but also awkward) region is when the observable (y) is constrained to have a small value, $y \ll 1$, restricting emissions.

- ✗ Perturbation theory has logarithmically enhanced terms: *double logs* $(\alpha_s \ln^2 y)^n$ (DL), *single logs* $(\alpha_s \ln y)^n$ (SL), etc.

- ✗ Logs must be *resummed* in order to obtain reliable perturbative predictions.

  SL is current state of the art accuracy.

- ✗ Resummation is also the basis of Monte Carlo event generators (Pythia, Herwig, Ariadne): they guarantee double logs and sometimes some single logs.

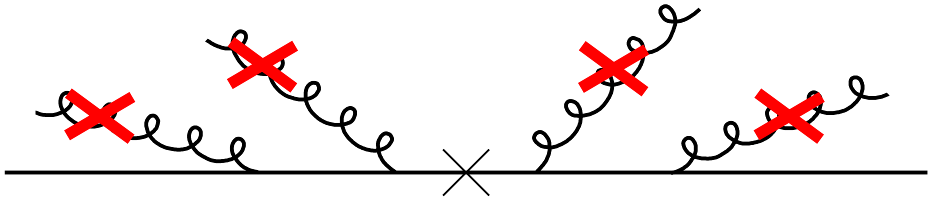
NB: many of the proofs of single-log resummation accuracy were derived for global observables.

Global v. Non-Global?

<u>Global observable:</u>

e.g. total e^+e^- Broadening, B

making $B \ll 1$ restricts emissions everywhere:



Coherence + globalness:

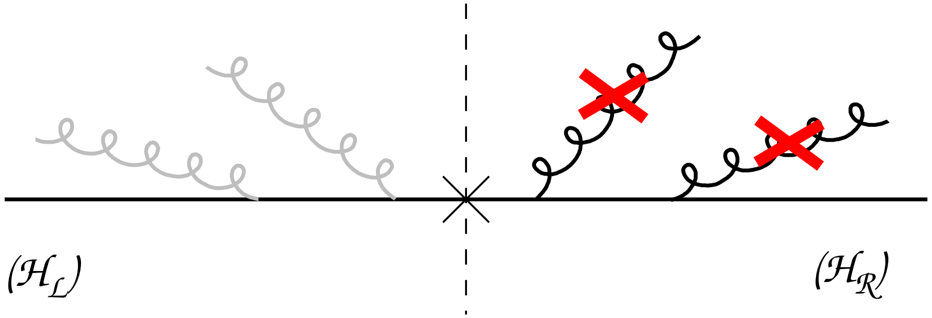
➥ emissions can be resumed as if they were independent *(proved)*

Answers guaranteed to SL accuracy

<u>NG observable:</u>

Right-hemisphere Broadening, B_R

making $B_R \ll 1$ restricts emissions in right-hand hemisphere ($\mathcal{H}_\mathcal{R}$):



Tempting to *assume* one can:

✗ ignore left hemisphere ($\mathcal{H}_\mathcal{L}$)

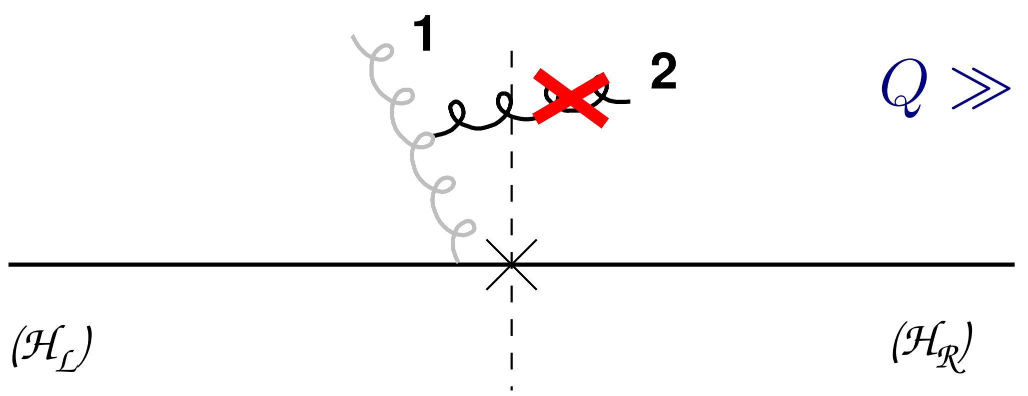
✗ use independent emission approximation in $\mathcal{H}_\mathcal{R}$.

THIS IS WRONG AT SL ACCURACY

Dasgupta & GPS '01

Extra ingredient for NG observables

suppress energy-ordered large-angle secondary emissions:

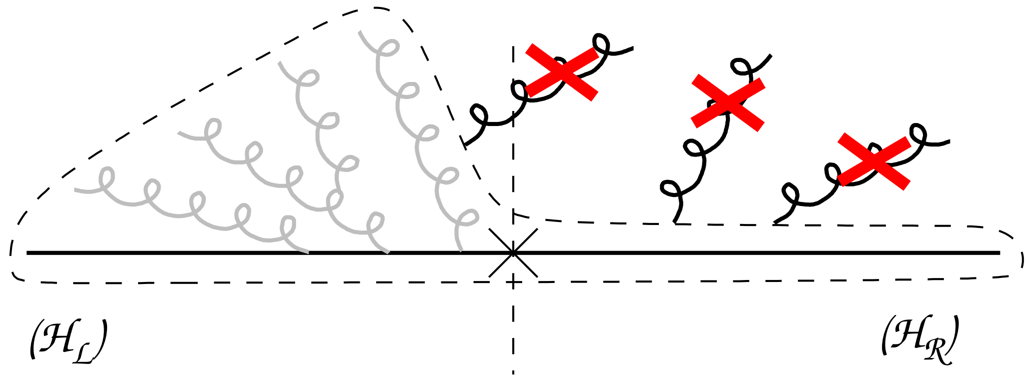


$Q \gg E_1 \gg E_2 \gg B_R Q$

$\hookrightarrow \alpha_s^2 \ln^2 B_R$

All-orders:

Forbid coherent radiation from energy-ordered ensembles of large-angle gluons



$\hookrightarrow \alpha_s^n \ln^n B_R$

Correcting ‘independent-emission’

Predictions for NG observables can be obtained by

- ✗ taking resummed result for distributions based on independent-emission approximation

- ✗ multiplying it by a factor $\mathcal{N}$ containing all *non-global logarithms:*

$$\mathcal{N}(t) = \sum_{i=2}^{\infty} \mathcal{N}_i \, t^i \,, \qquad t(y) = \int_{yQ}^{Q} \frac{dk_t}{k_t} \frac{\alpha_s(k_t)}{2\pi}$$

  NB: for fixed coupling $t \equiv \dfrac{\alpha_s \ln 1/y}{2\pi}$

- ✗ Series starts from $\mathcal{N}_2$

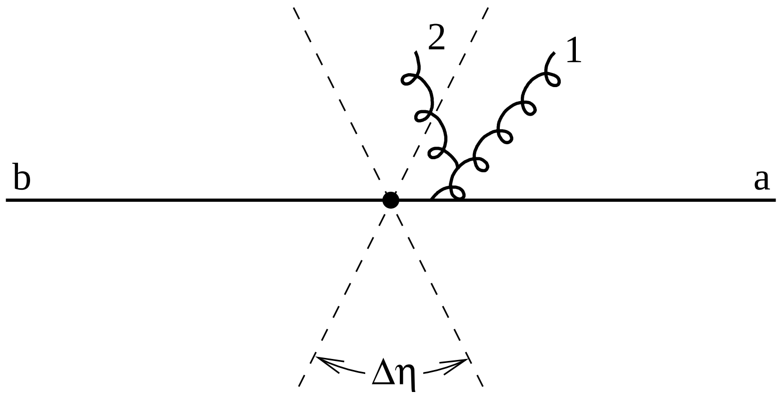
$\mathcal{O}\left(\alpha_s^2 L^2\right)$ calculations

SL 'two-gluon' term can be calculated exactly:

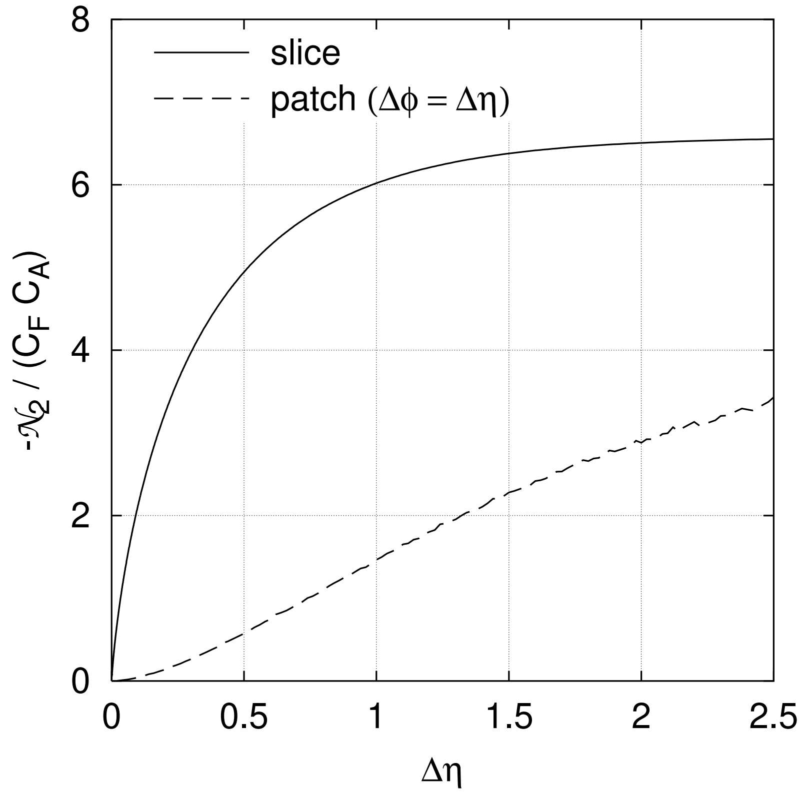
- ✗ Single-hemisphere observables: $\mathcal{N}_2 \cdot t^2 = \frac{\pi^2}{3} C_F C_A \left(\frac{\alpha_s \ln B_R}{2\pi}\right)^2$

- ✗ 2-jet interjet energy flow: NG logs are an edge effect

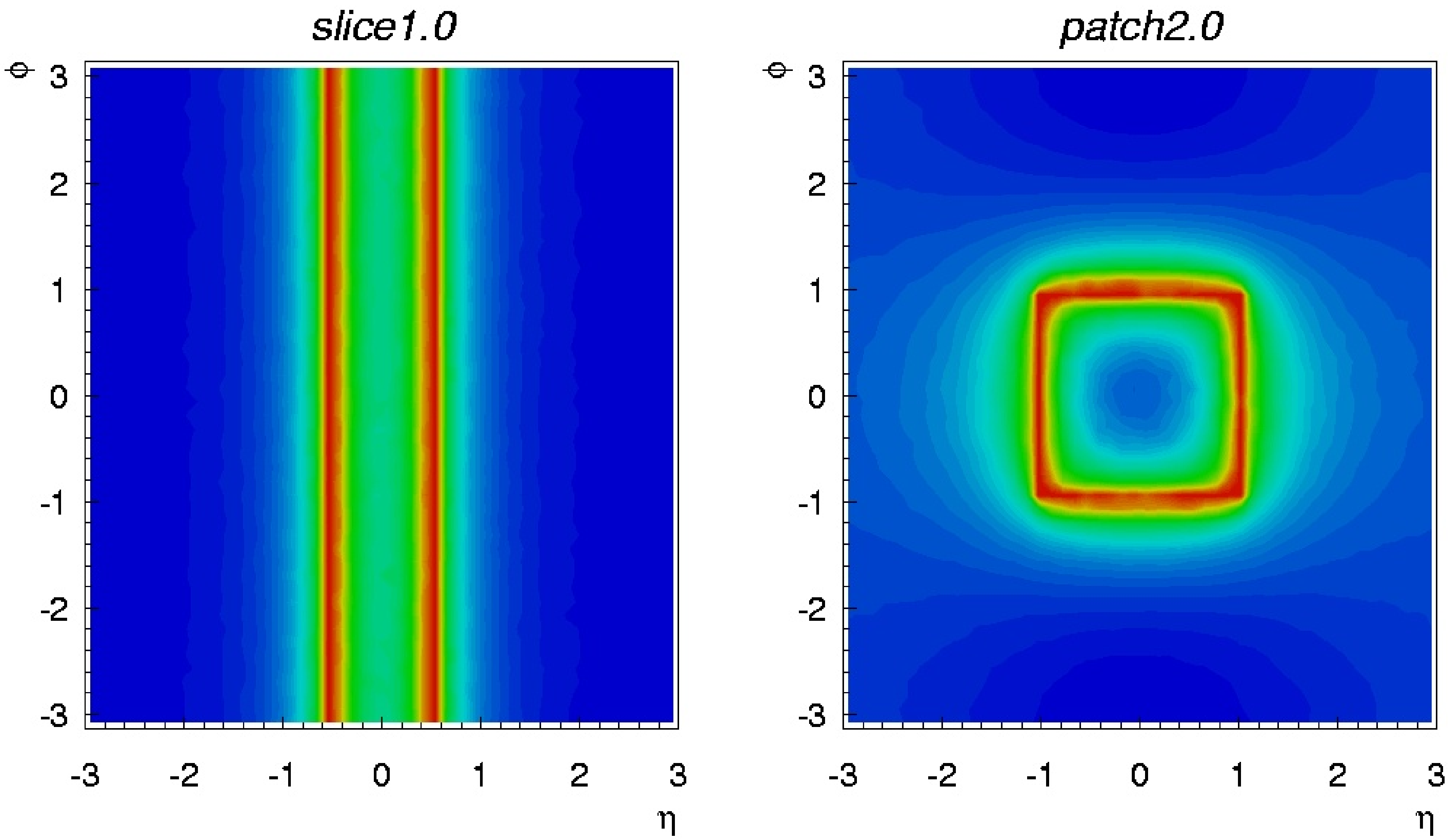
  - ☛ in *slices* of rapidity (as a function of slice size, $\Delta\eta$)



  - ☛ in square *patches* of rapidity ($\Delta\eta$) and azimuth ($\Delta\phi = \Delta\eta$)



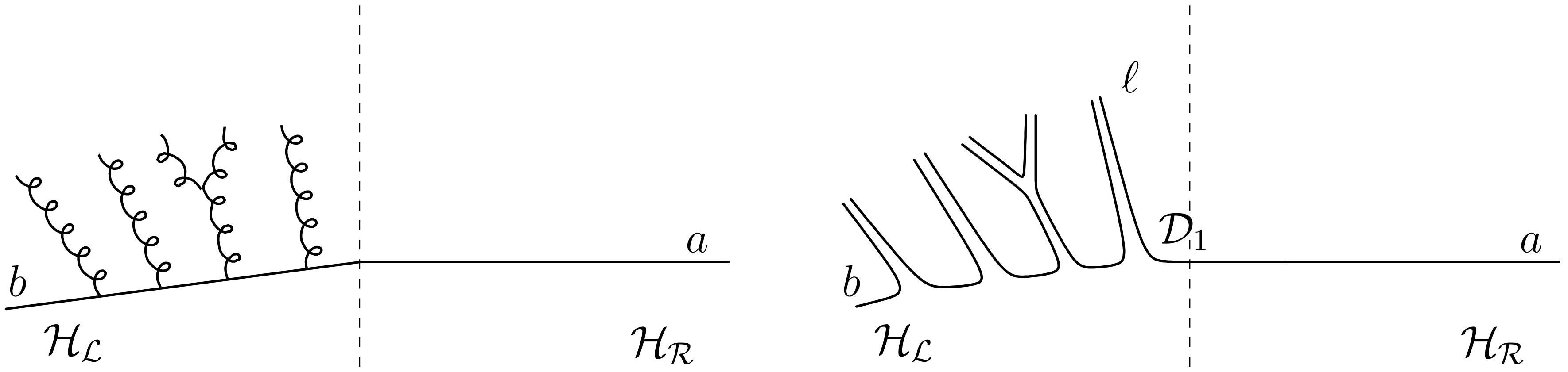
$\eta - \phi$ distribution of the two gluons



All-orders calculations

Exact results do not yet exist: complicated colour structure

➥ use large-N_C limit $\equiv$ structure of independent colour dipoles. Branching pattern is known (since 1980's) and simple.

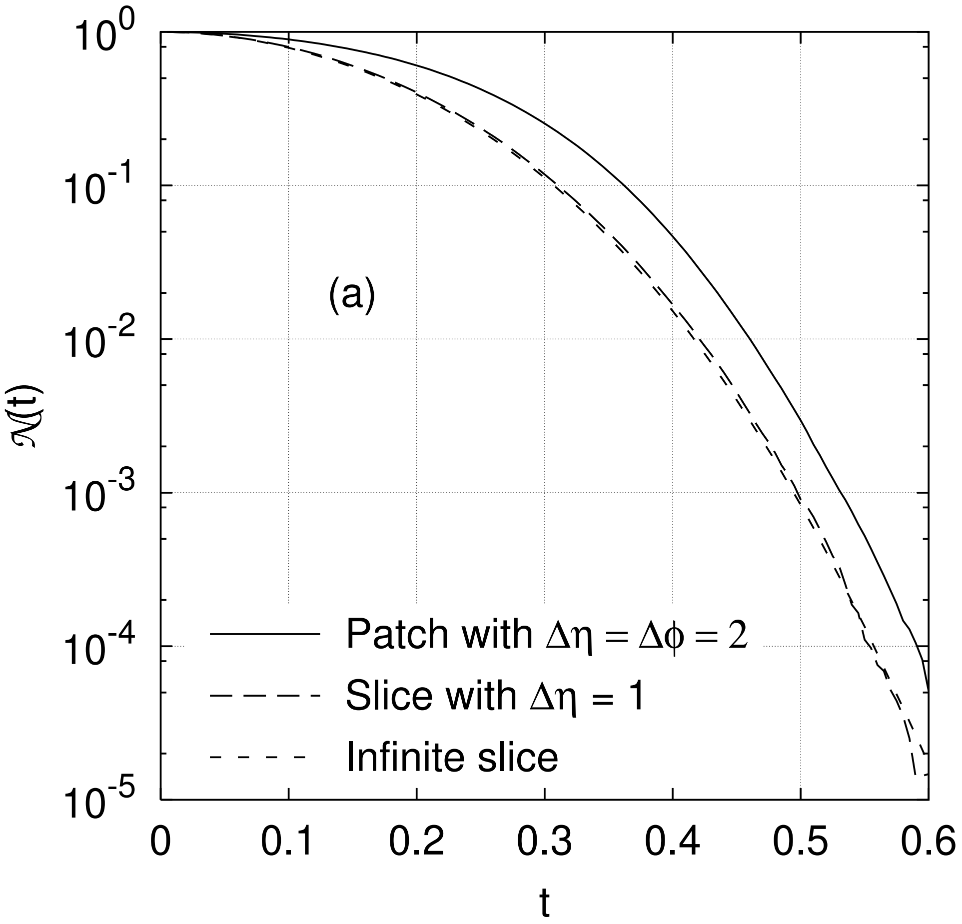


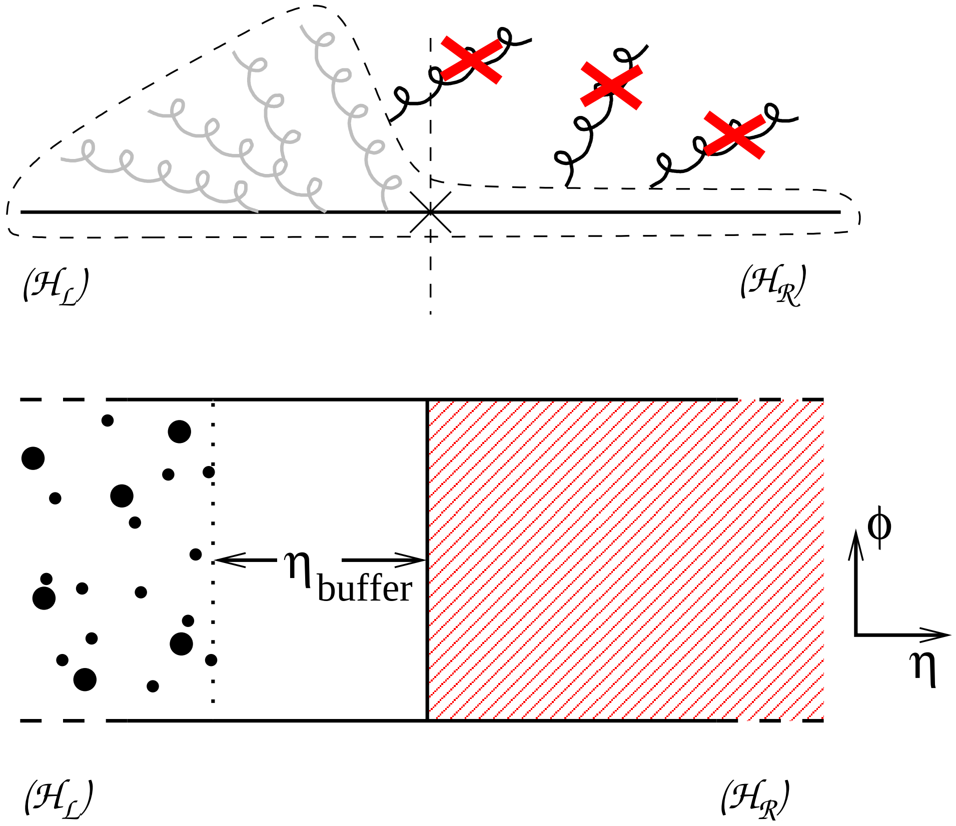
Geometry is also complex: need numerical methods to get full solution even with large-N_C approx.

Simplest numerical approach is to encode branching with a *Monte Carlo algorithm.* ➥phenomenological results in talk by Appleby

Qu.: can one understand *physical mechanisms* behind all-orders behaviour?

Clues



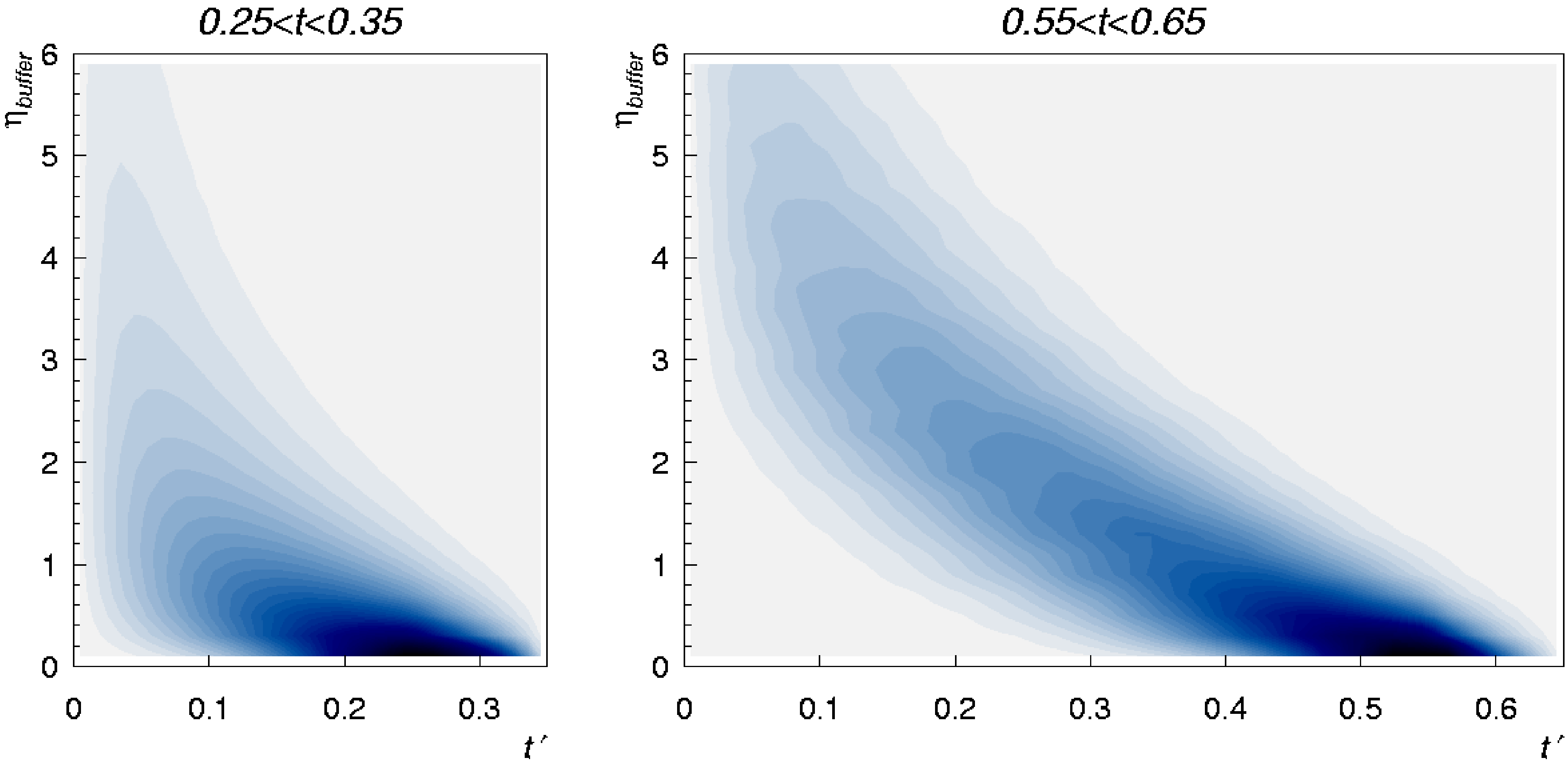


Asymptotic behaviour of $\mathcal{N}$ is geometry-independent

Buffer mechanism

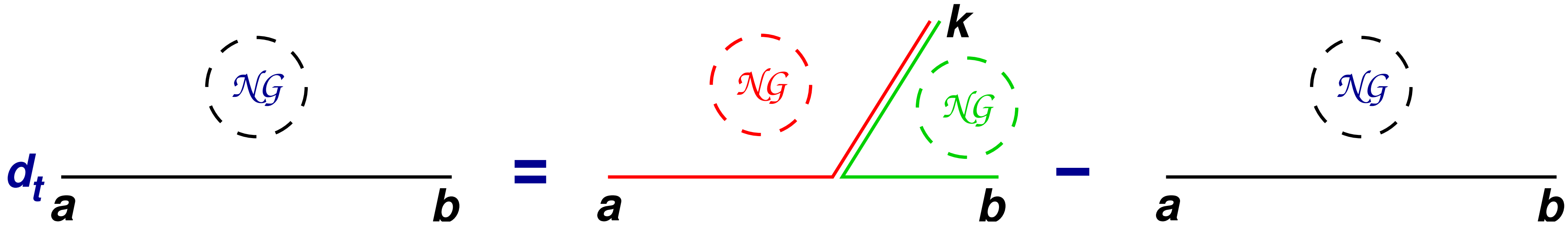
Dasgupta & GPS ’02

Buffer pictures



Banfi-Marchesini-Smye equation & asymptotic solution

Elegant, compact formulation of problem as a non-linear integral equation:



$$\partial_t \mathcal{N}_{ab}(t) = \int_{\text{unmeasured}} \frac{d^2\Omega_k}{4\pi}\, w_{ab}(k) \left(U^{(0)}_{abk}\, \mathcal{N}_{ak}(t)\, \mathcal{N}_{kb}(t) - \mathcal{N}_{ab}(t) \right)$$

Solution is identical to that of Monte Carlo approach.

In very asymptotic region ($t \gtrsim 0.75$) they derived analytical behaviour of solution

$$\mathcal{N}(t) \sim e^{-c\, N_J\, C_A^2\, t^2}, \qquad c \simeq 2.5 \pm 0.2$$

($N_J =$ # of unmeasured jets)

Zoology: related classes of observables

- ✗ 'Not measuring everywhere' *NOT EQUIVALENT* to 'non-global'

  e.g. DIS current hemisphere jet-broadening (B_{zQ}) measures particles only in one hemisphere. But it is *sensitive* to emissions everywhere (through recoil): *indirectly global*

- ✗ Observables that use clustering algorithms to select measurement region

  ➥ Appleby & Seymour '02

- ✗ Discontinuously global observables

  sensitivity in different angular regions is parametrically different

  - ☞ within a single observable (*e.g.* in DIS)
  - ☞ dynamical discontinuity — Dasgupta & GPS '02
  - ☞ multivariate distributions (allows *suppression* of NG effects)

    Berger, Kucs & Sterman '02, '03

    Marchesini & Dokshitzer '03

Summary & Outlook

- ✗ Non-global logs are *everywhere* (almost)!
  - ☞ single-hemispheres; rapidity gaps; energy flows; . . .
  - ☞ clustering observables
  - ☞ range of discontinuously global observables
- ✗ MUCH has been learnt since their discovery in ’01:
  - ☞ Geometry dependence at $\mathcal{O}\left(\alpha_s^2 L^2\right)$
  - ☞ All-orders solution in *large-N_c limit*
  - ☞ asymptotic behaviour *(buffer, BMS solution)*
- ✗ Scope for going further
  - ☞ Understanding extent to which NG logs simulated by Pythia & Herwig
  - ☞ Beyond large-N_c limit

Phenomenology in next talk