Flavour of soft drop groomed jets

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[arXiv:2205.01109]

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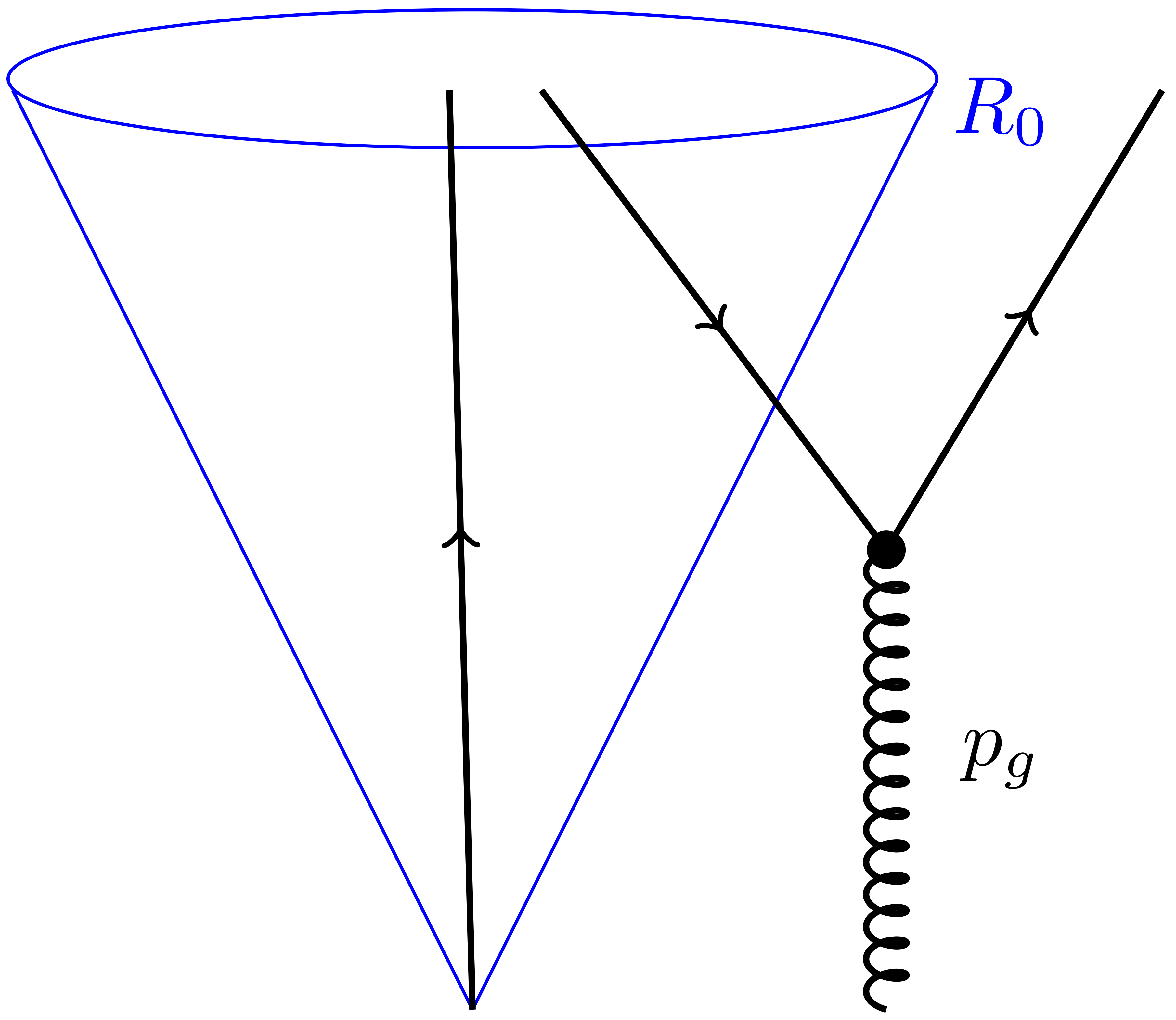
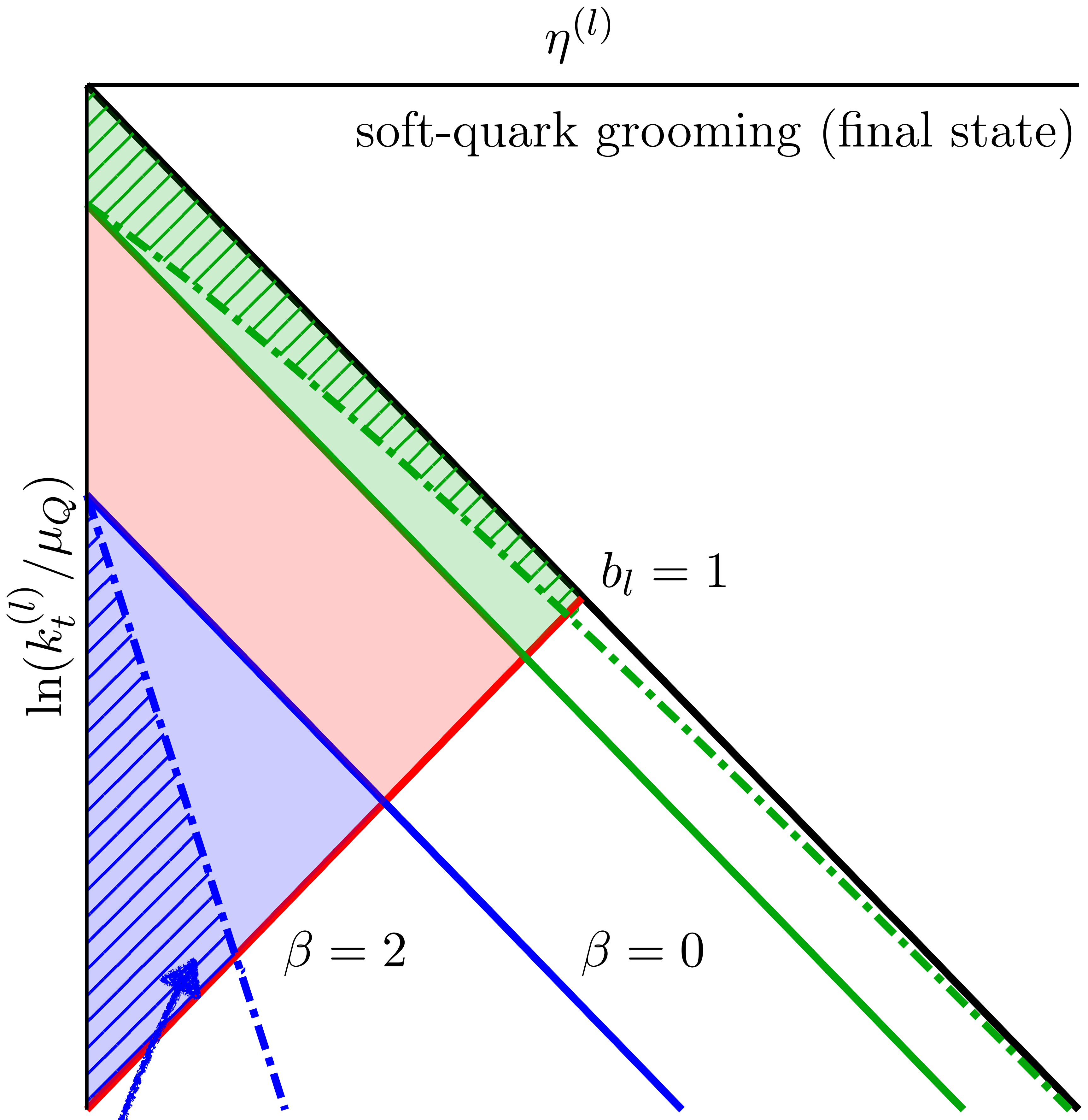
recap: problems in naive flavour definition

- starting at NNLO, consider configuration where a soft gluon splits into two quarks
- singularity in limit where $p_q, p_{\bar{q}} \to 0$
- might belong to "gluon-jet" or "quark-jet" phase space depending on clustering
- corresponding virtual correction clearly in "quark-jet" phase space $\Rightarrow$ IRC unsafe



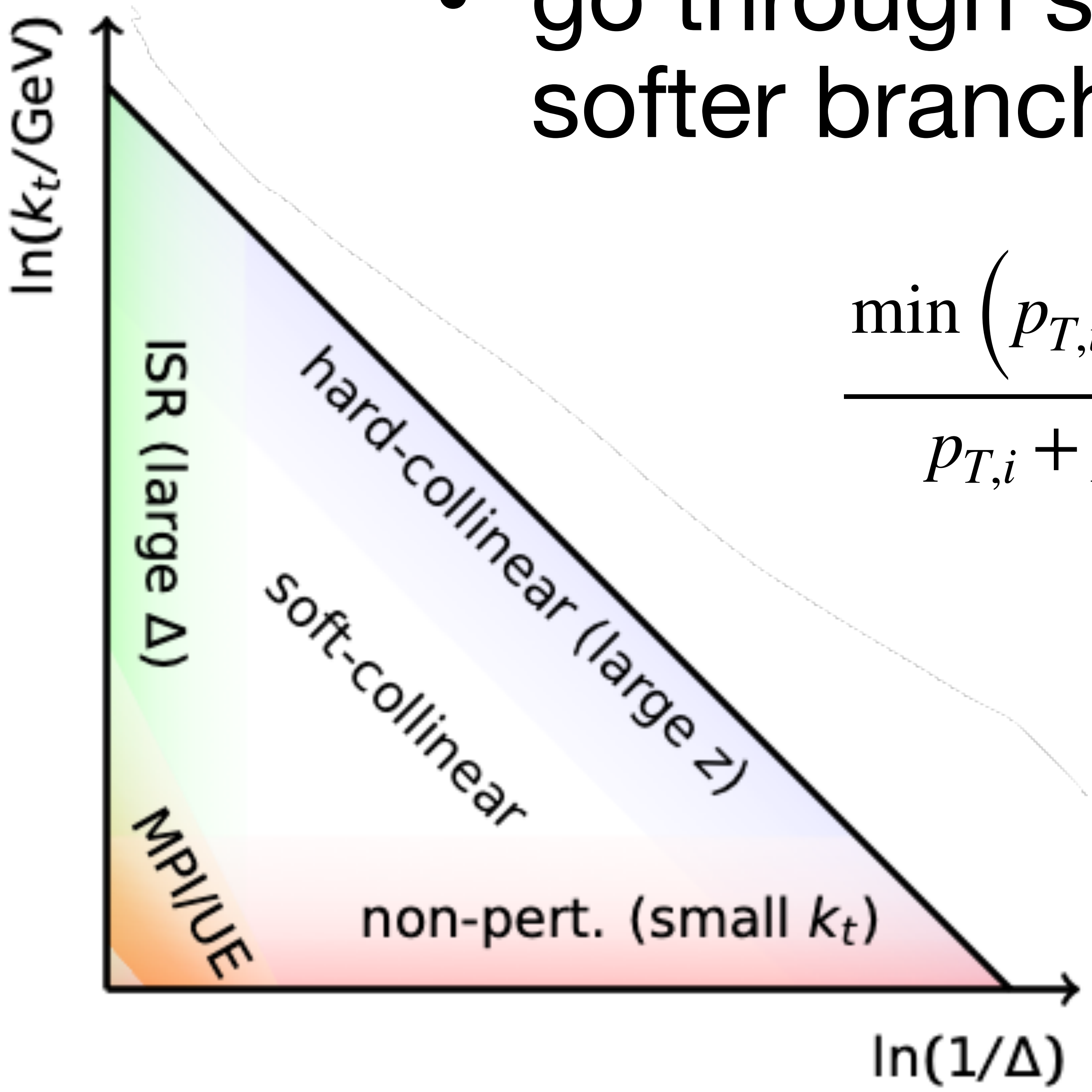
soft drop method



idea: avoid soft wide-angle phase space

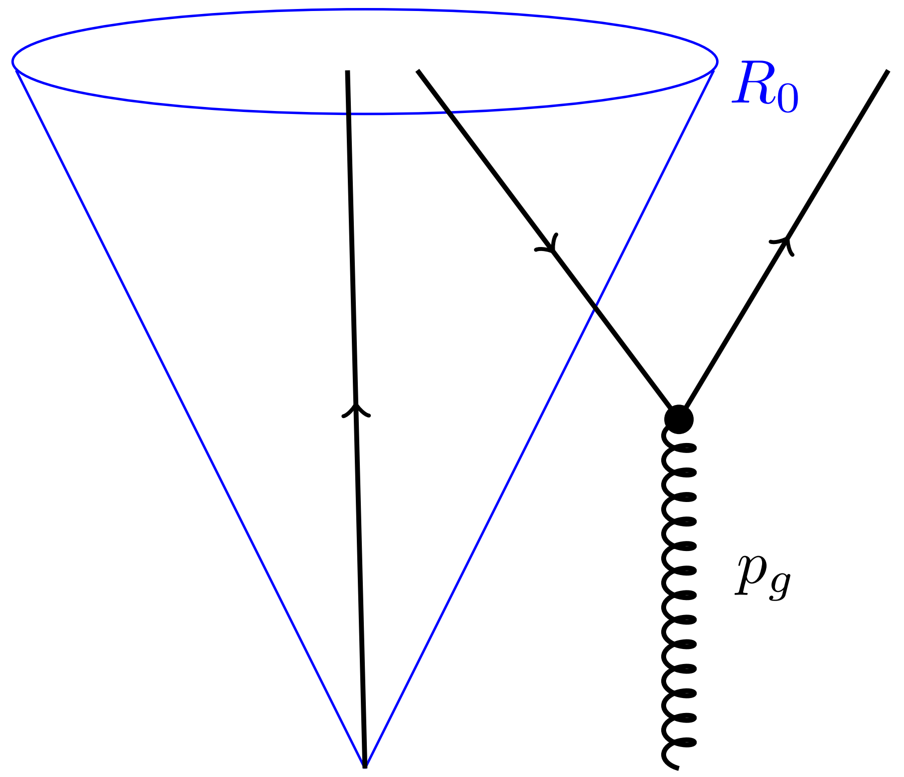
- popular jet substructure technique:
  [Larkoski, Marzani, Soyez, Thaler '14]
  - decluster given jet with Cambridge/Aachen jet measure ⇒ angular ordered splitting sequence
    - go through sequence, remove softer branch if

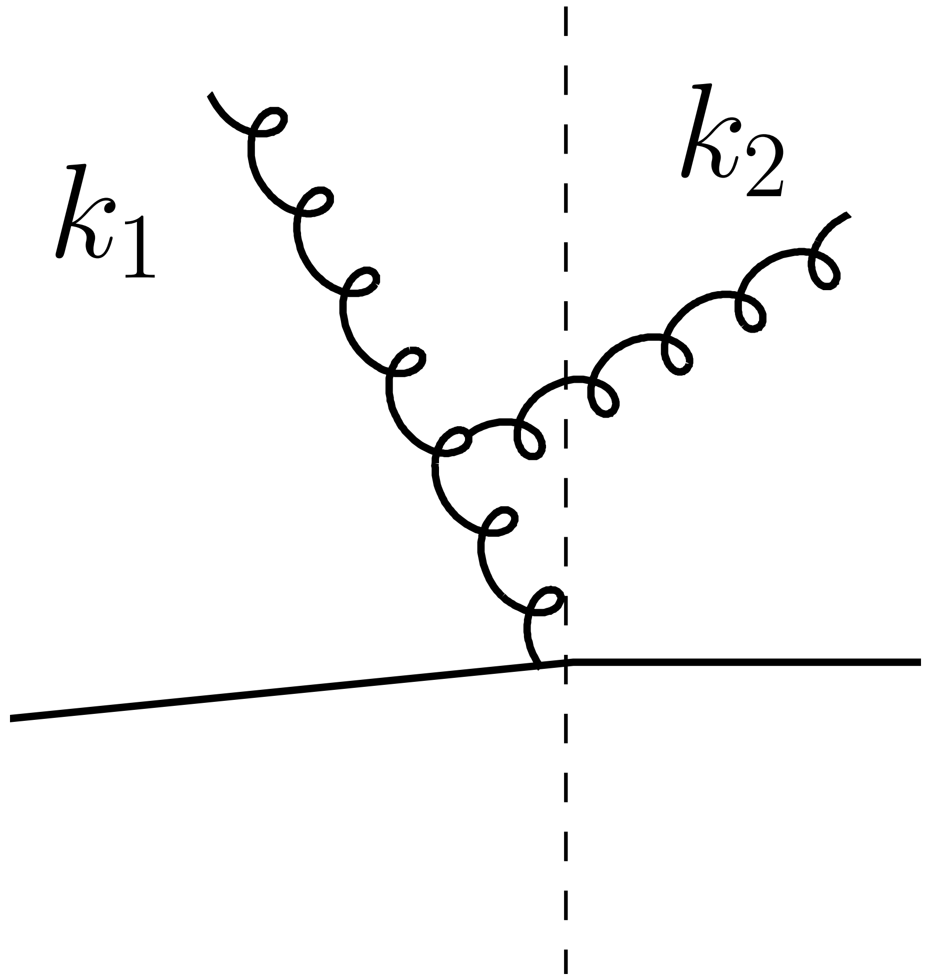
$$\frac{\min\left(p_{T,i}, p_{T,j}\right)}{p_{T,i}+p_{T,j}} > z_{\text{cut}}\left(\frac{\Delta R}{R}\right)^{\beta}$$



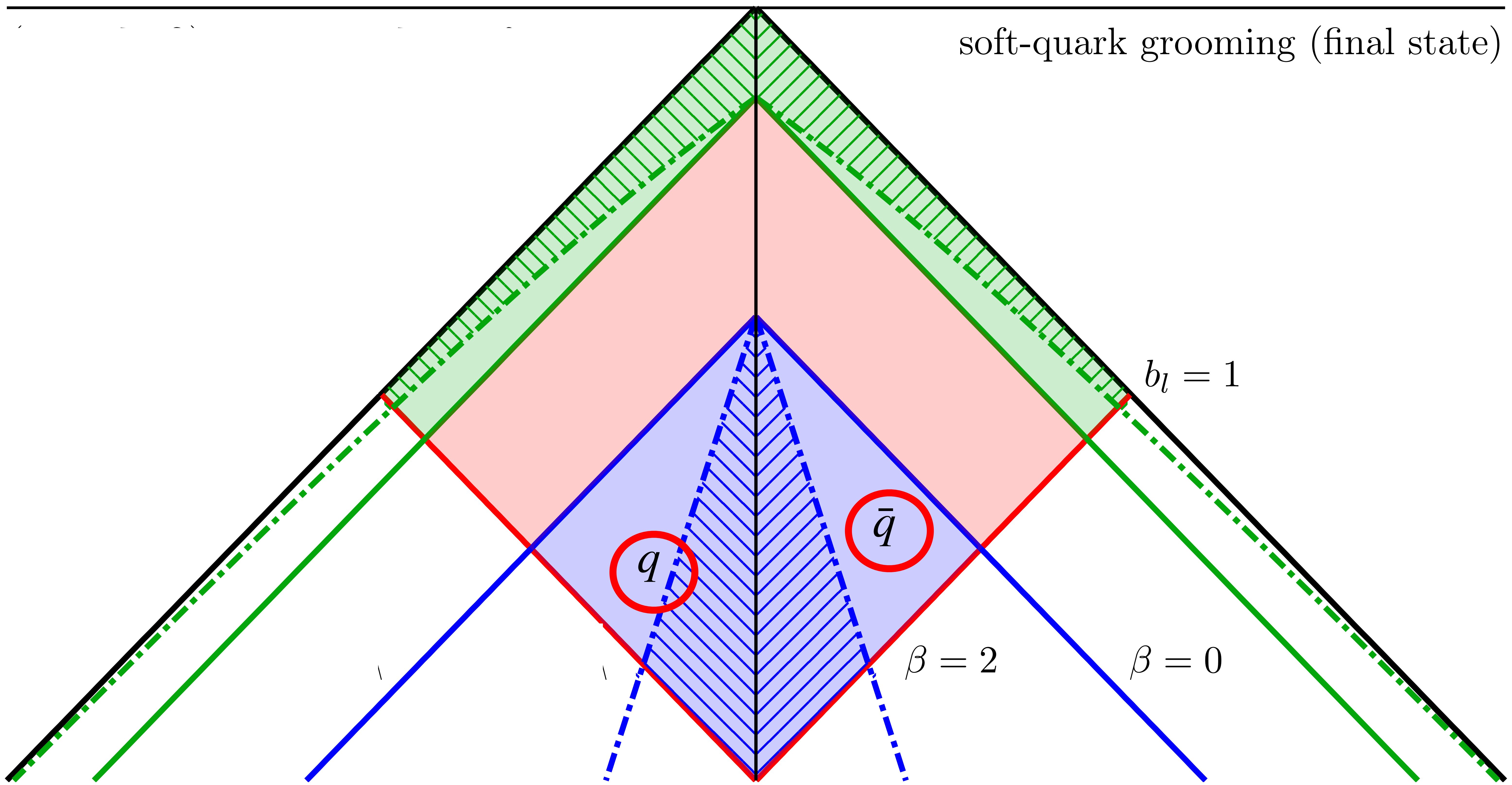
motivation

- Idea: groom jet/hemisphere/object → take flavour from remaining partons
- Why would this work:
    - Intuitively: soft particles should not enter tagging → just need a clean definition excluding soft particles
    - Formally: soft divergencies in “naive” flavour definitions are associated with configurations similar to non-global logs → SD removes non-global logs, should also help here

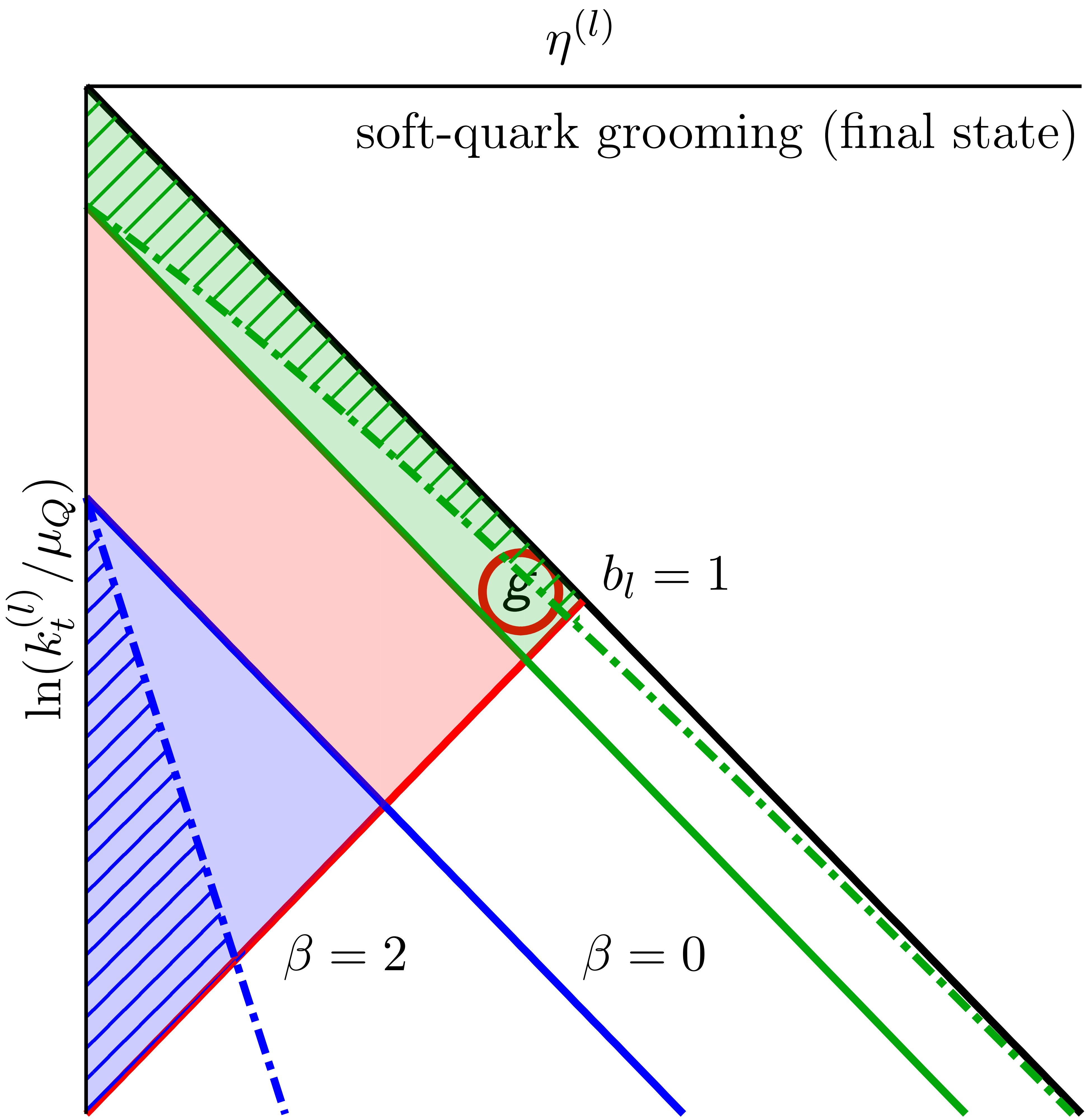




how it should work

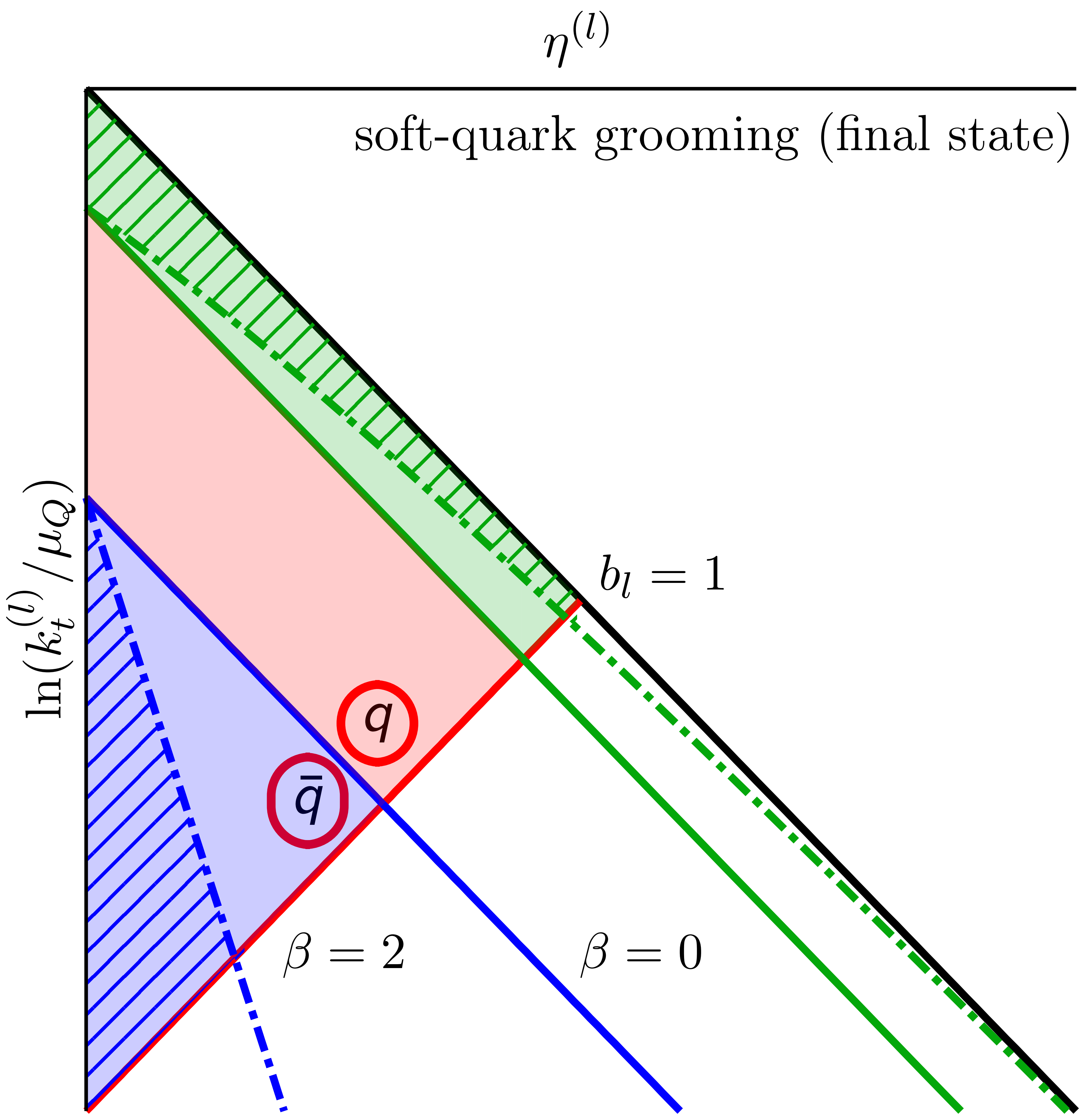


caveats - at $\mathcal{O}(\alpha_s)$



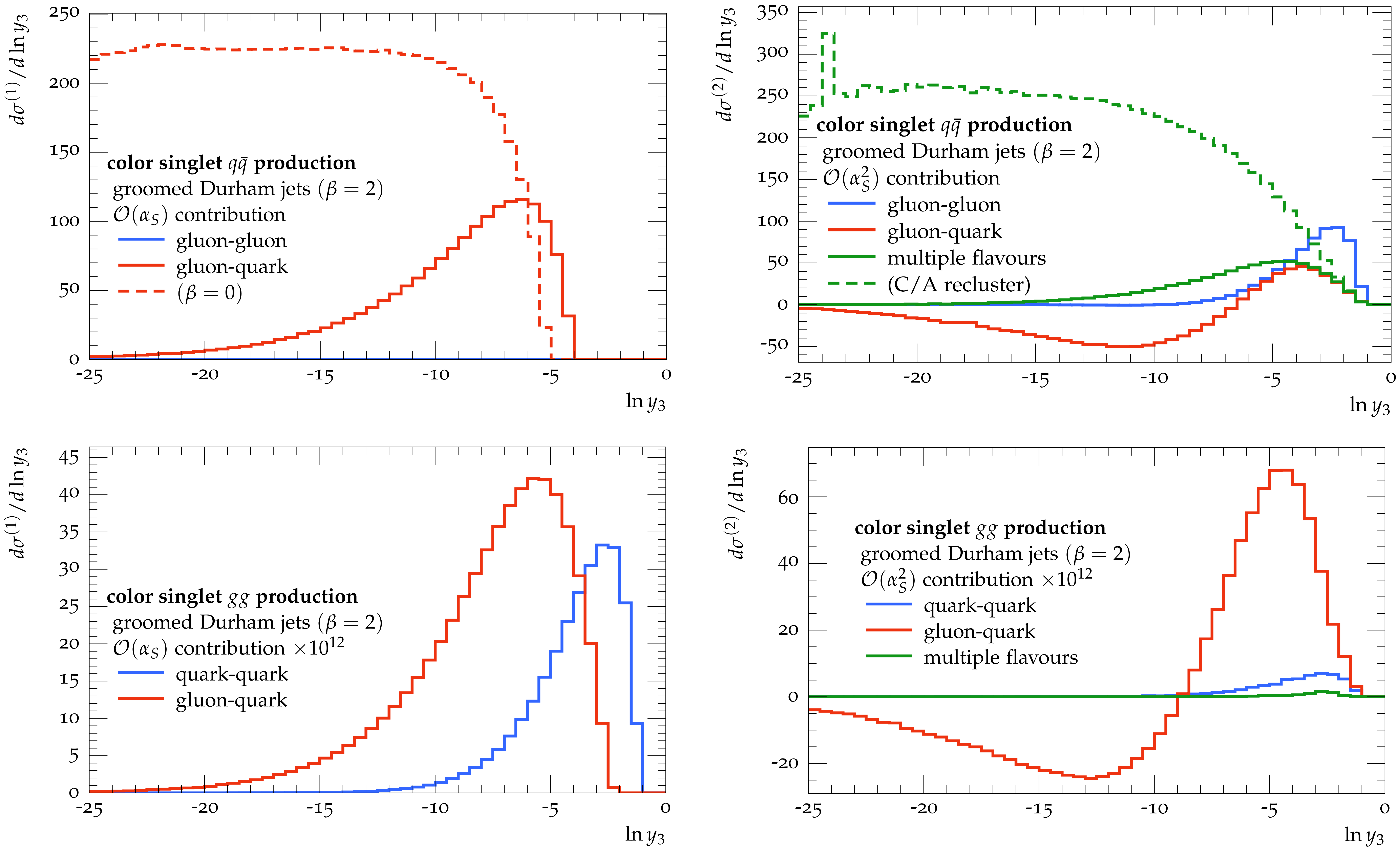
- close to collinear region, might groom away “hard” quark instead of gluon
- logarithmic region for $\beta = 0$, spoils flavour definition already at LO!
- power suppressed for $\beta > 0$, thus requirement for IRC safe soft drop flavour

caveats - at $\mathcal{O}(\alpha_s^2)$



- soft drop involves re-clustering step to establish "splitting sequence"
- traditional: Cambridge/Aachen (angular ordered)
- but: consider jet with 3 particles $(g, q, \bar{q}) \rightarrow$ potentially assign as quark jet, even if both quarks are soft
- need to make sure $q\bar{q}$ pair clustered together first in this case $\rightarrow$ can be achieved by using JADE (virtuality ordered)

tests of IRC safety to $\mathcal{O}(\alpha_s^2)$



+ analytic check against singularity structure from double soft/ tripple collinear splitting functions

summary - pros and cons

- pros
  - actually defines flavour of a given jet (not a new jet with a flavour), without reference to the overall event topology
  - simple steps in principle
    1. construct anti-kt jets
    2. groom
    3. tag
    - separately all routine part of analyses

- cons
  - not IRC safe beyond NNLO
  - need to recluster with JADE
    - at best not standard, does it create problems?
    - maybe don’t need exactly JADE?

bonus - WTA flavour

- companion paper [arXiv:2205.01117] suggesting to measure flavour of particle(s) along WTA axis
- soft- but not collinear safe
- similar to fragmentation functions, linear evolution equation ~ DGLAP
- not trivially applicable to fixed order calculation, but could use this as benchmark for MC analyses

1. Cluster and find jets in your collision event with any desired jet algorithm.
2. On a given jet, recluster its constituents with a pairwise, IRC safe, algorithm, using the WTA recombination scheme [50–52]. Specifically:
   (a) For all pairs i, j of particles in your jet, calculate the pairwise metric d_{ij}.
   (b) For the pair i, j that corresponds to the smallest d_{ij}, recombine their momenta into a new massless particle $\widetilde{ij}$ such that $E_{\widetilde{ij}} = E_i + E_j$, and the direction of $\widetilde{ij}$ is along the direction of the harder of i and j.[2]
   (c) Replace particles i and j with their combination $\widetilde{ij}$ in the collection of particles in the jet.
   (d) Repeat clustering until there is a single, combined particle that remains. The direction of this particle corresponds to the direction of the WTA axis of the jet.
3. The sum of the flavors of all particles in the jet whose momenta lie exactly along the WTA axis is defined to be the flavor of the jet.