

Progress in Amplitude Evolution and Improved Parton Shower Algorithms

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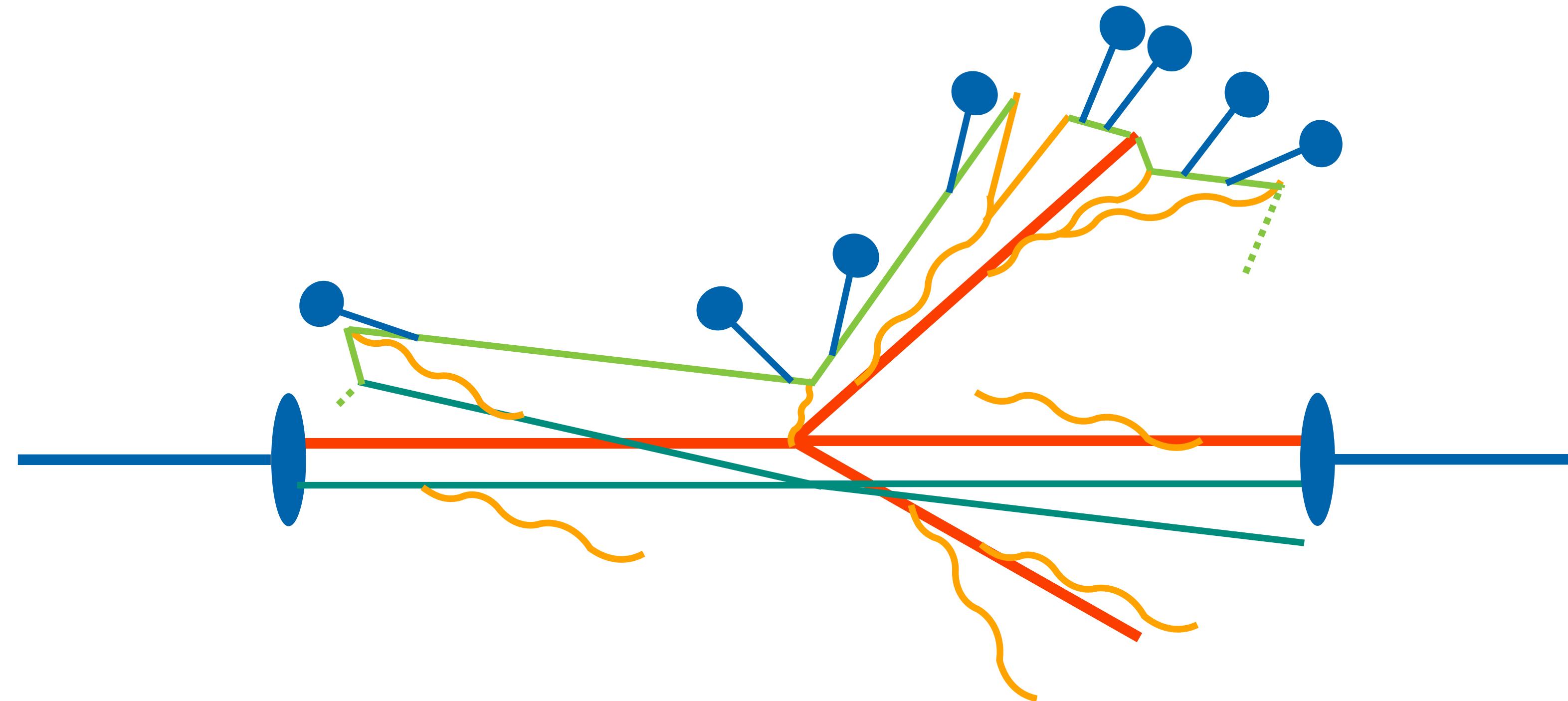
At the
PARTICLEFACE Meeting
Zagreb/Online | 15 July 2021

QCD cross sections

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$$d\sigma \sim L \times d\sigma_H(Q) \times \text{PS}(Q \rightarrow \mu) \times \text{MPI} \times \text{Had}(\mu \rightarrow \Lambda) \times \dots$$

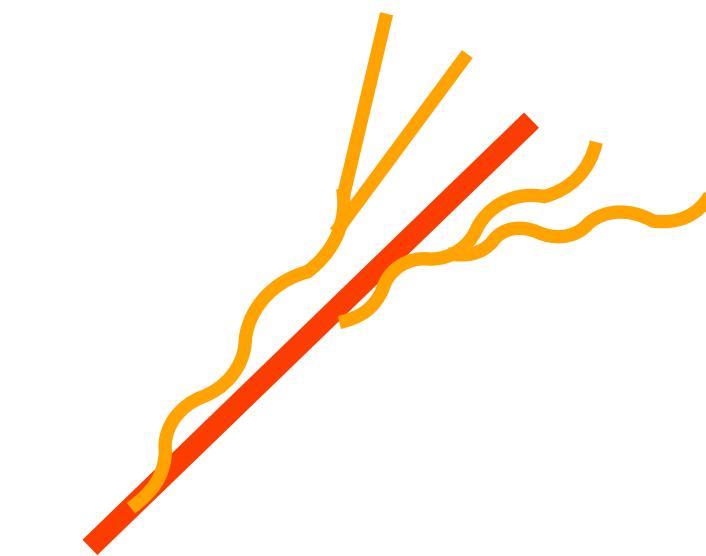
Setting the scene

QCD description of collider reactions:
Complexity challenges precision.

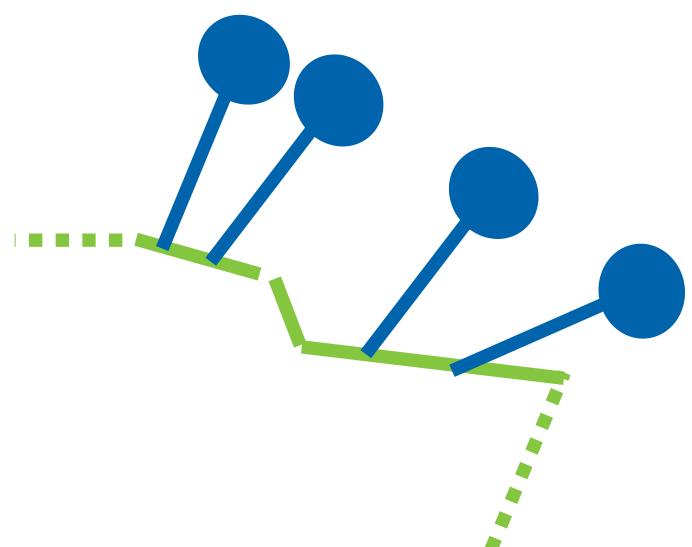
Hard partonic scattering:
NLO QCD routinely

Jet evolution — parton branching:
NLL sometimes, mostly unclear

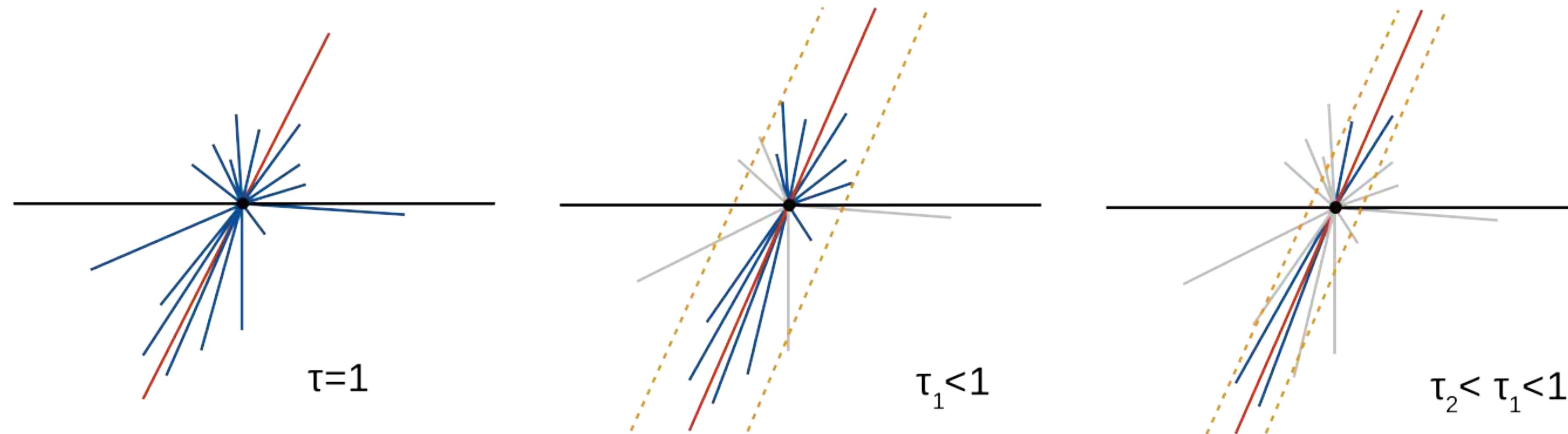
Multi-parton interactions
Hadronization



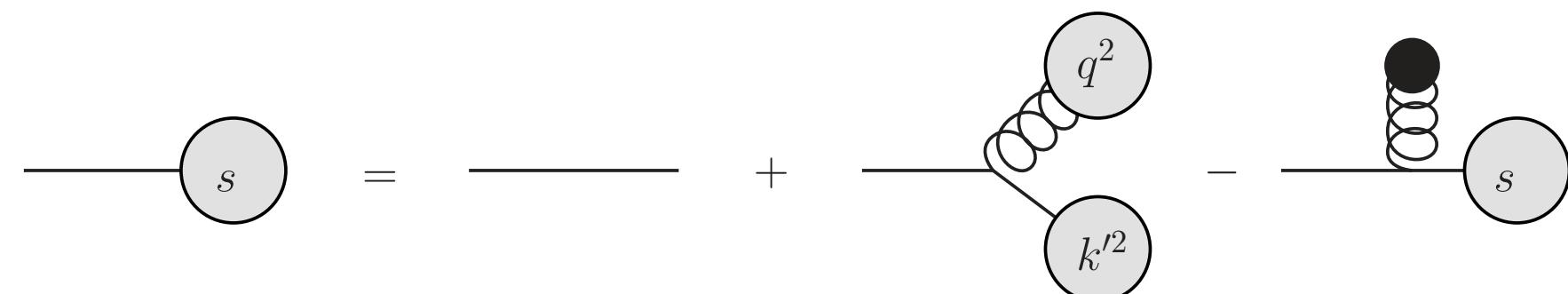
[Salam et al. — JHEP 09 (2018) 033]
[Forshaw, Holguin, Plätzer — JHEP 09 (2020) 014]



$$d\sigma \sim L \times d\sigma_H(Q) \times PS(Q \rightarrow \mu) \times MPI \times Had(\mu \rightarrow \Lambda) \times \dots$$

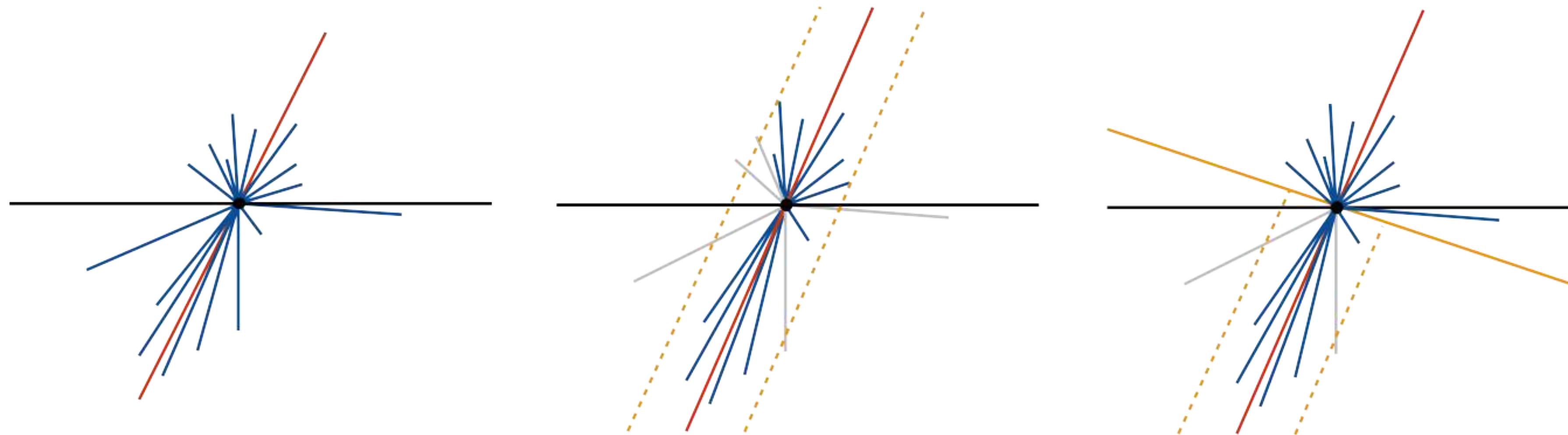


Resummation of observables which globally measure deviations from n-jet limit.
Basis of angular ordered parton showers — highest level of analytic control.



[Catani, Marchesini, Webber — Nucl.Phys.B 407 (1991) 654]
[Hoang, Plätzer, Samitz — JHEP 1810 (2018) 200]

Non-global Observables



Measure deviation from jet topology only in patch of phase space.

Coherent branching breaks down, full complexity of QCD amplitudes strikes back.

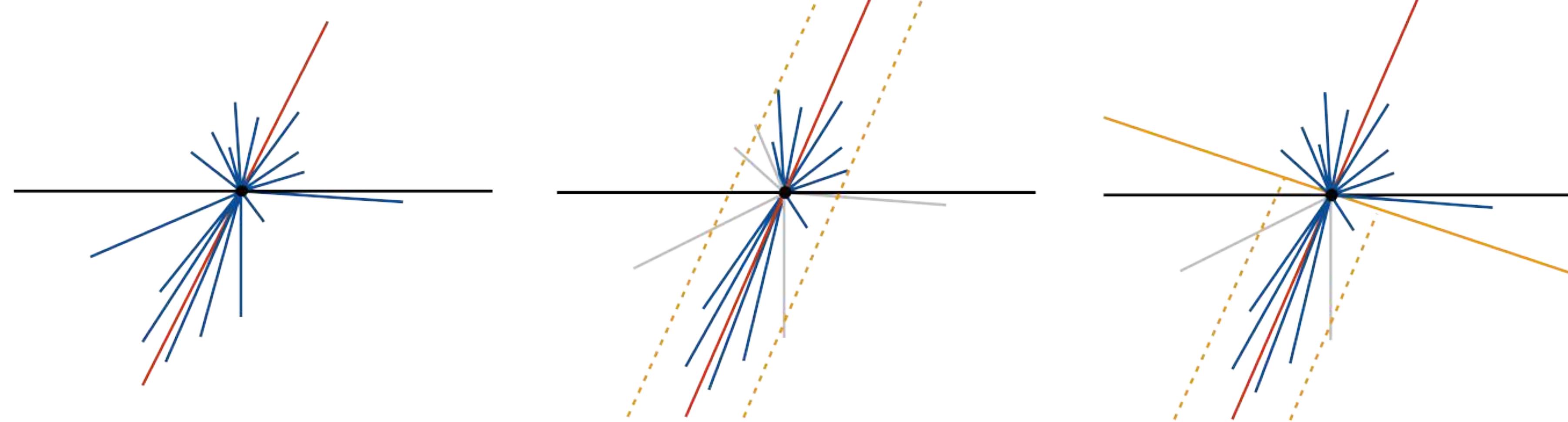
If non-global bit is isolated can use dipole cascades to resum.

Pressing issues in parton showers

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NLO with matching

NLL with coherent branching
Issues in dipole showers

Issues in coherent branching
LL with dipole showers

Understand and decide on accuracy of (existing) parton shower algorithms, take as a starting point for incremental improvements.

- [Dasgupta, Dreyer, Hamilton, Monni, Salam et al.— JHEP 09 (2018) 033, ...]
- [Hoang, Plätzer, Samitz — JHEP 1810 (2018) 200]
- [Bewick, Ferrario, Richardson, Seymour — JHEP 04 (2020) 019]

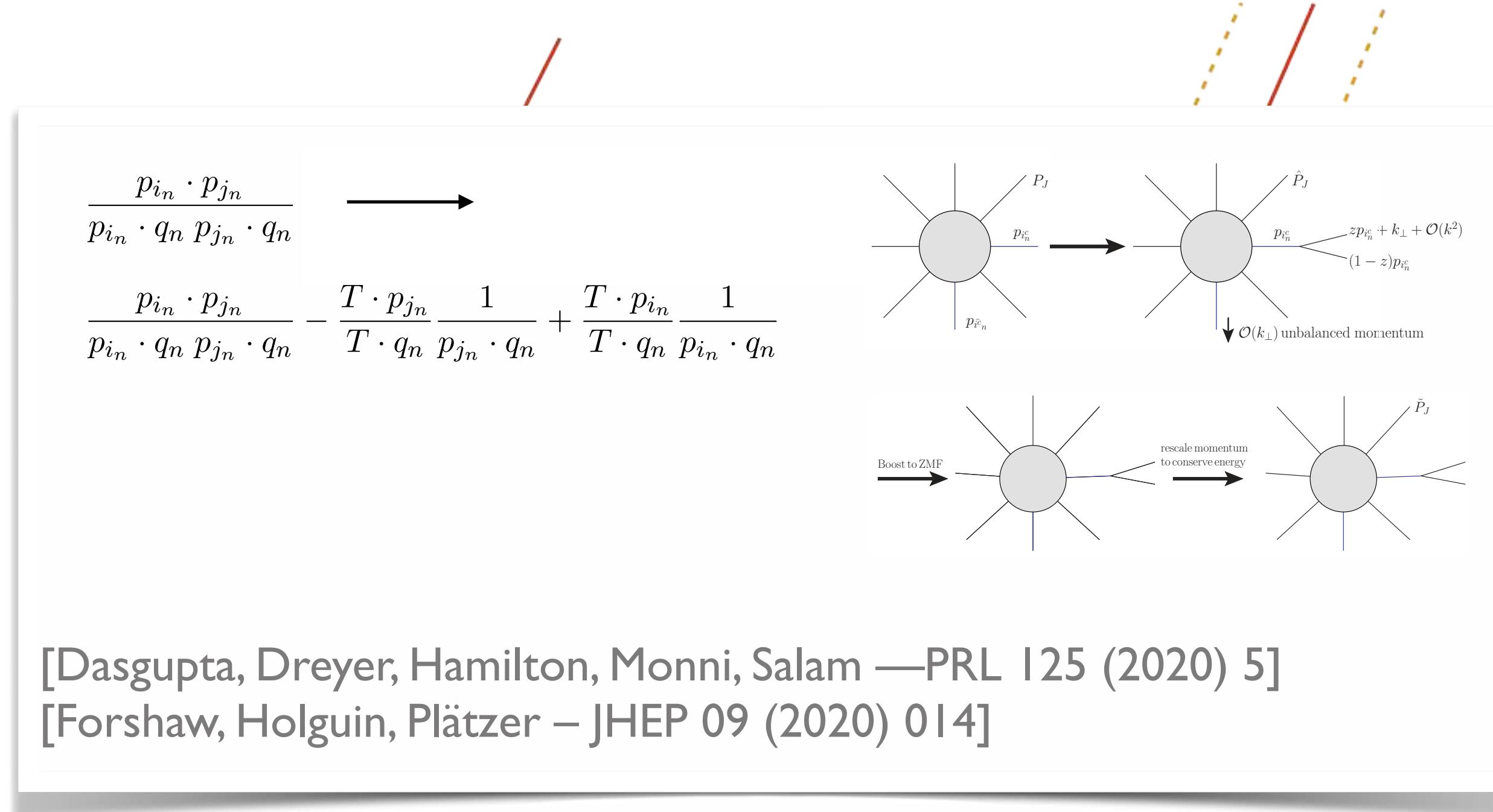
$$\sigma(n \text{ jets}, \tau) \sim \sum_k \sum_{l \leq 2k} c_{nkl} \alpha_s^k(Q) \ln^l \frac{1}{\tau}$$

Pressing issues in parton showers

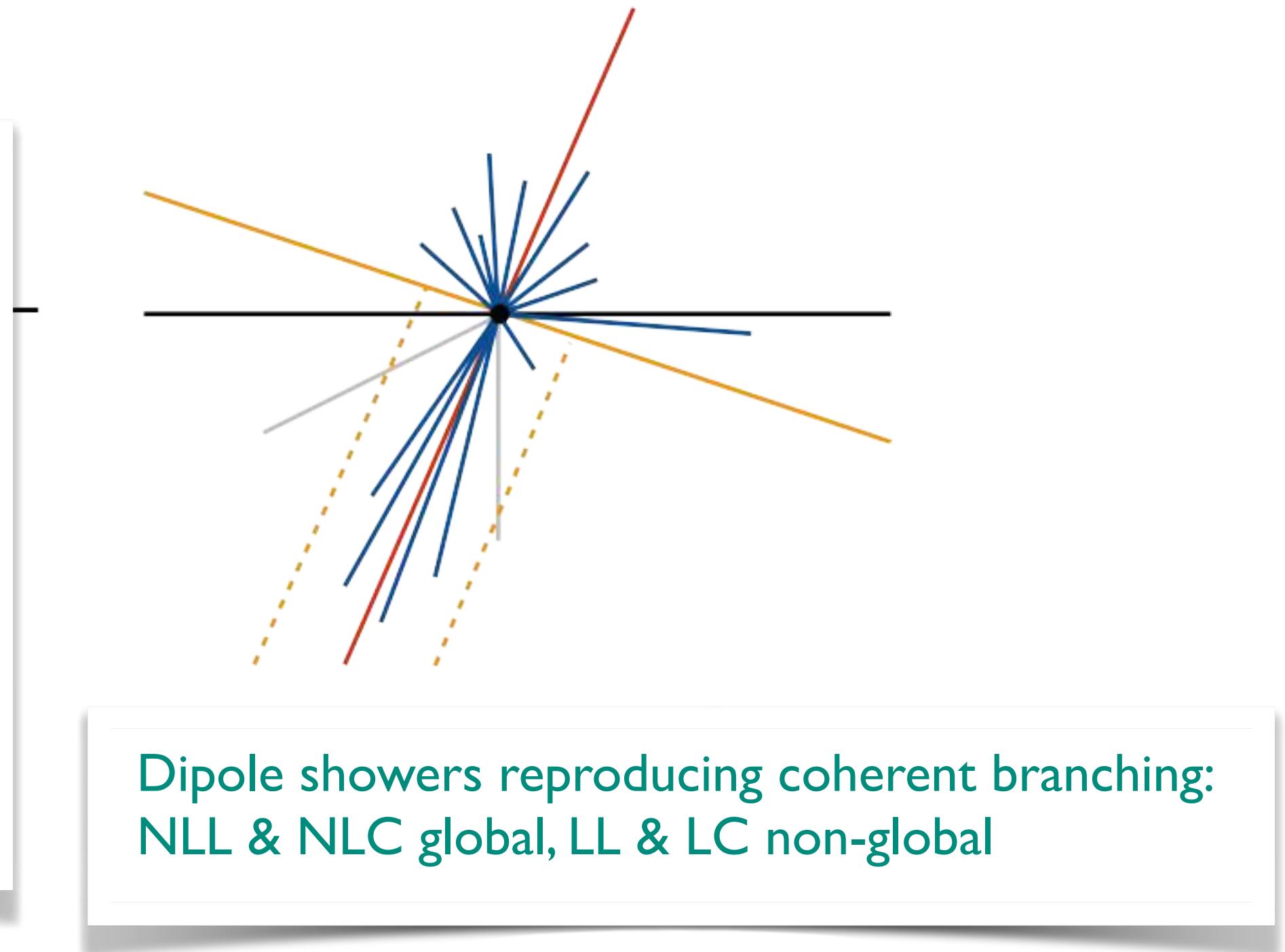
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[Dasgupta, Dreyer, Hamilton, Monni, Salam —PRL 125 (2020) 5]
[Forshaw, Holguin, Plätzer – JHEP 09 (2020) 014]

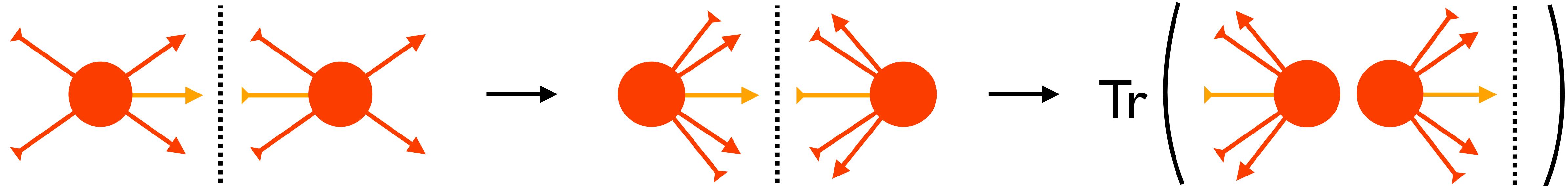


Understand and decide on accuracy of (existing) parton shower algorithms, take as a starting point for incremental improvements.

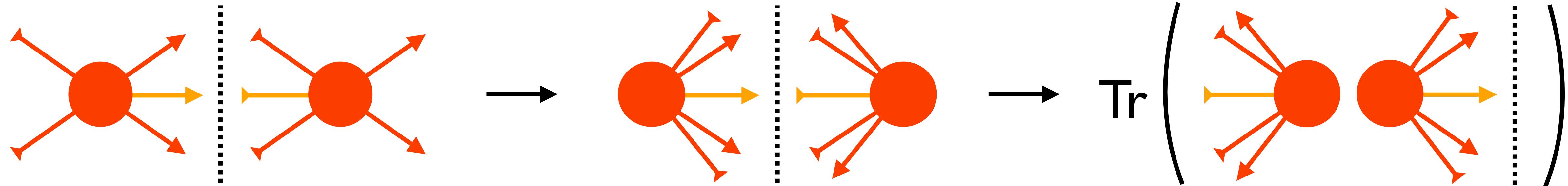
[Dasgupta, Dreyer, Hamilton, Monni, Salam et al.— JHEP 09 (2018) 033, ...]
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$$\sigma(n \text{ jets}, \tau) \sim \sum_k \sum_{l \leq 2k} c_{nkl} \ \alpha_s^k(Q) \ \ln^l \frac{1}{\tau}$$

Cross Sections and Amplitudes



Cross Sections and Amplitudes



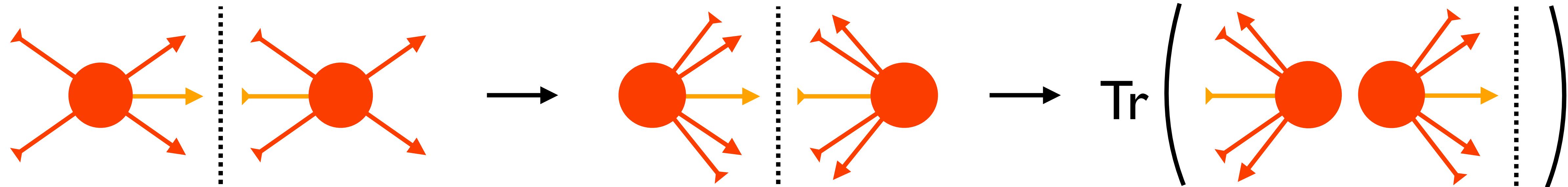
$$\sigma[u] = \sum_n \int \text{Tr} [\mathbf{A}_n] u(q_1, \dots, q_n) d\phi(q_1, \dots, q_n)$$

sum over emissions

'density operator' \sim amplitude amplitude⁺

observable and phase space

Cross Sections and Amplitudes

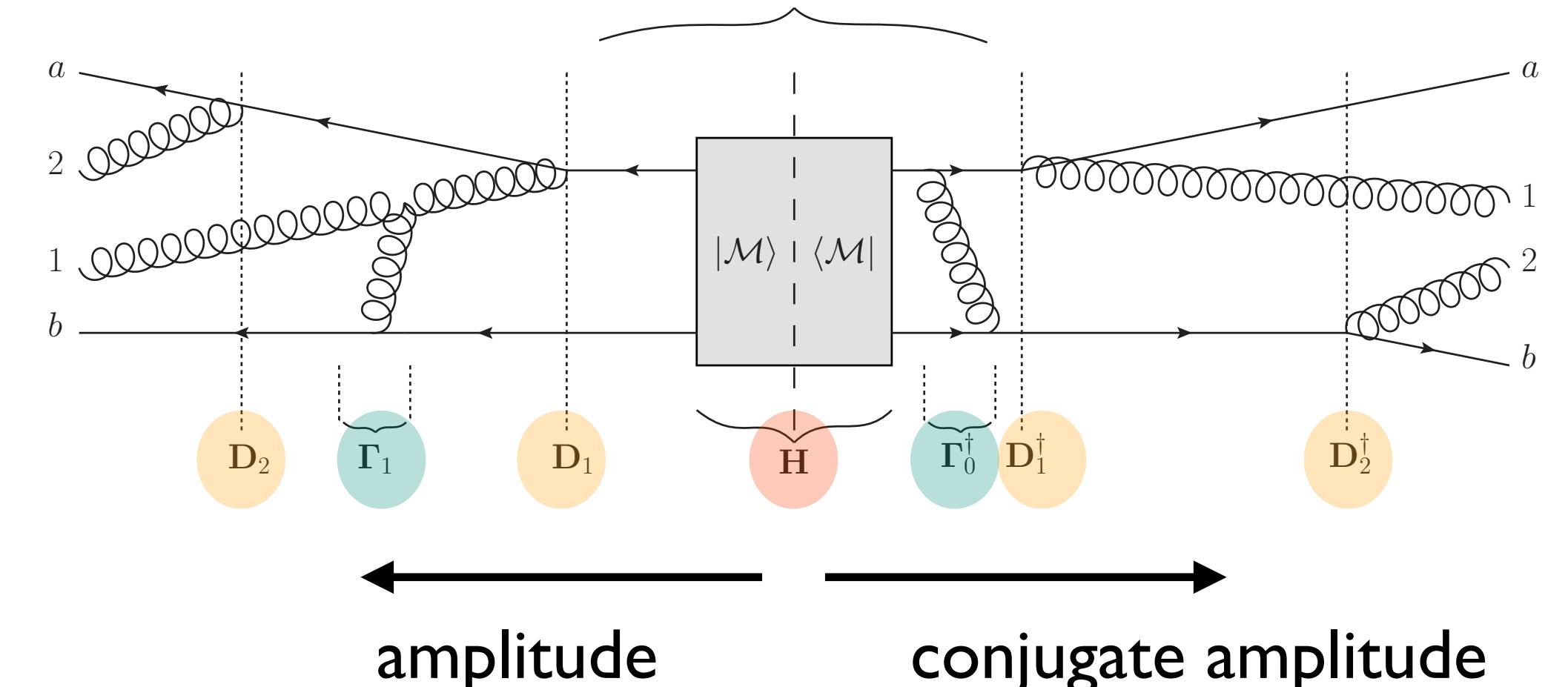


$$A_n(q) = \int_q^Q \frac{dk}{k} P e^{-\int_q^k \frac{dk'}{k'} \Gamma(k')} D_n(k) A_{n-1}(k) D_n^\dagger(k) \bar{P} e^{-\int_q^k \frac{dk'}{k'} \Gamma^\dagger(k')}$$

Markovian algorithm at the amplitude level:
Iterate **gluon exchanges** and **emission**.

Different histories in amplitude and conjugate amplitude needed to include interference.

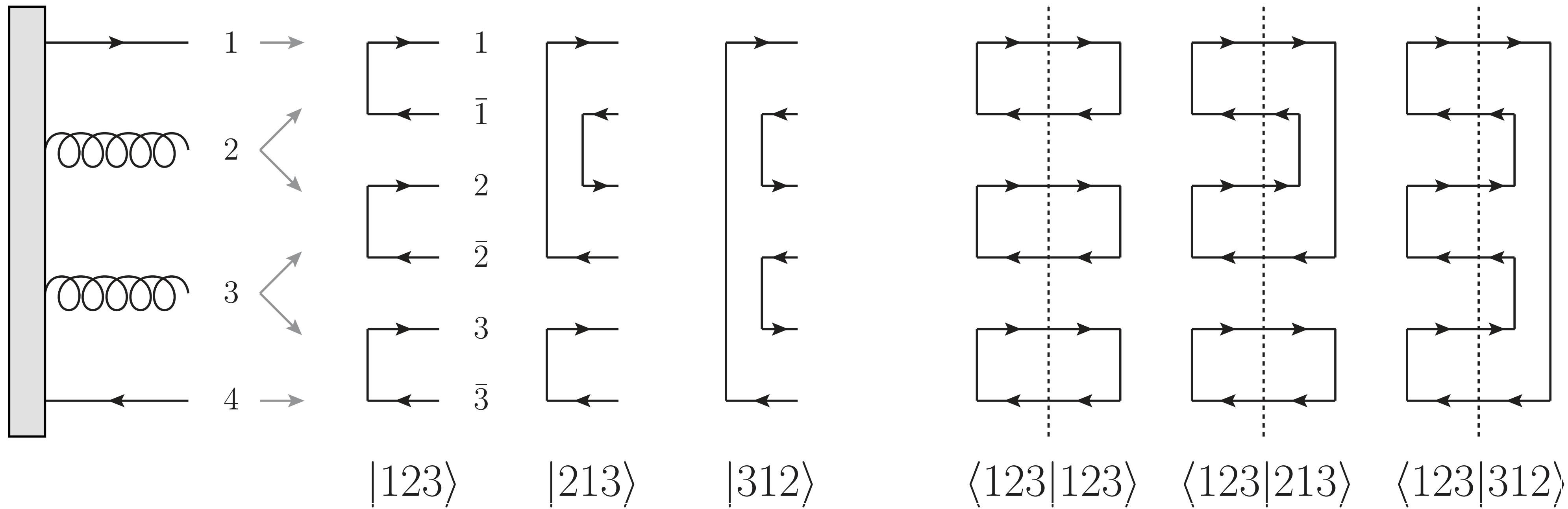
[Angeles, De Angelis, Forshaw, Plätzer, Seymour – JHEP 05 (2018) 044]
[Forshaw, Holguin, Plätzer – JHEP 1908 (2019) 145]



Tracking colour

Decompose amplitudes in flow of colour charge.

$$\text{Tr} [\mathbf{A}_n] = \sum_{\sigma, \tau} A_{\tau \sigma} \langle \sigma | \tau \rangle$$



N^3

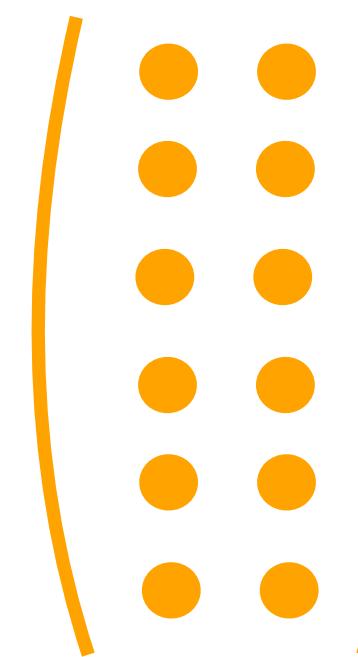
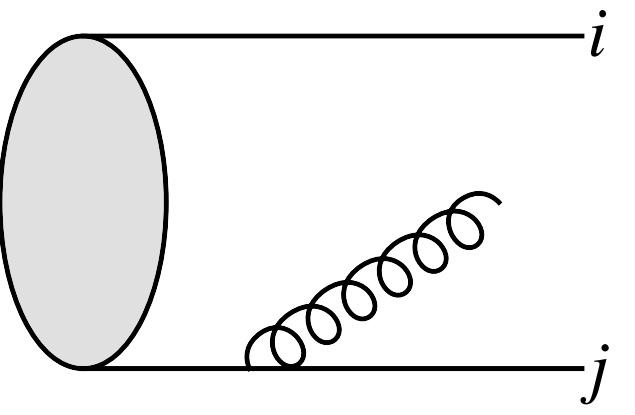
N^2

N

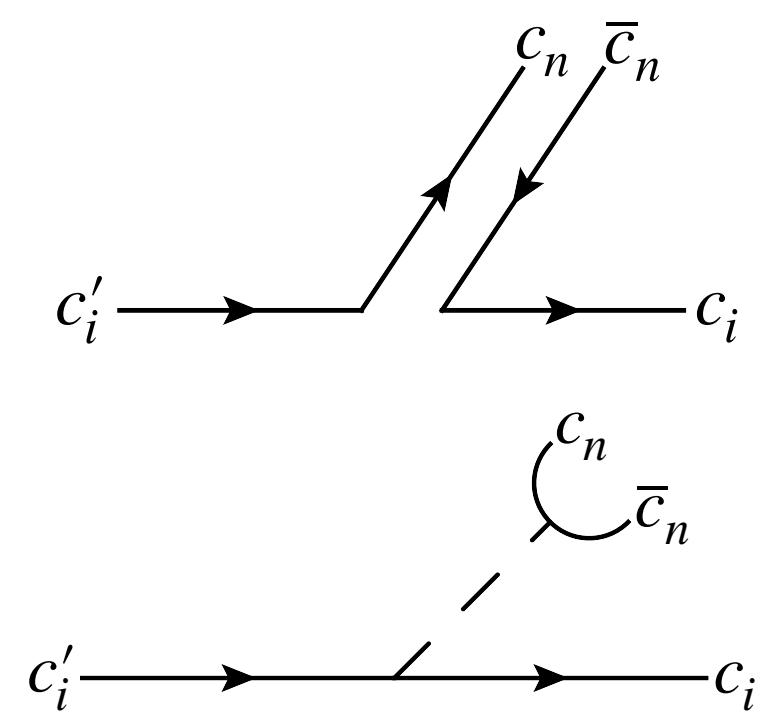
Tracking colour

Gluon emission

$$D_n(k)$$



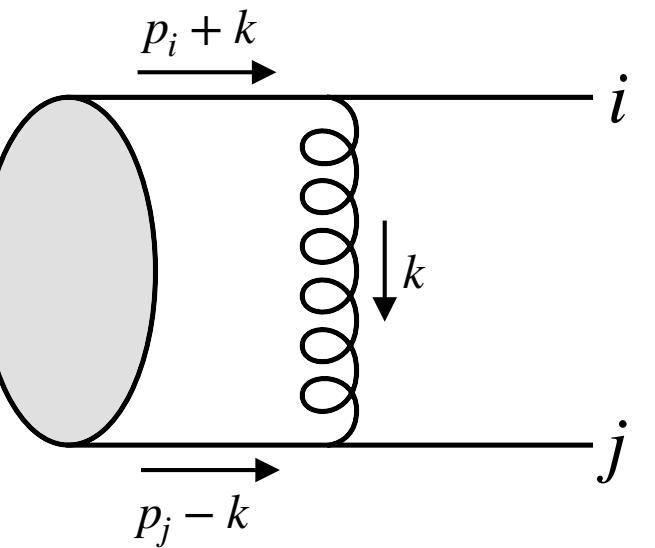
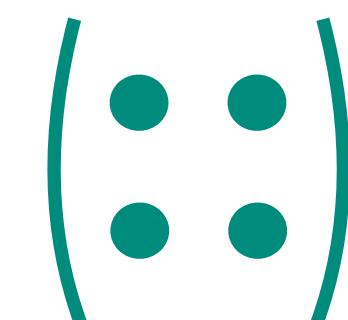
Explicit suppression in I/N



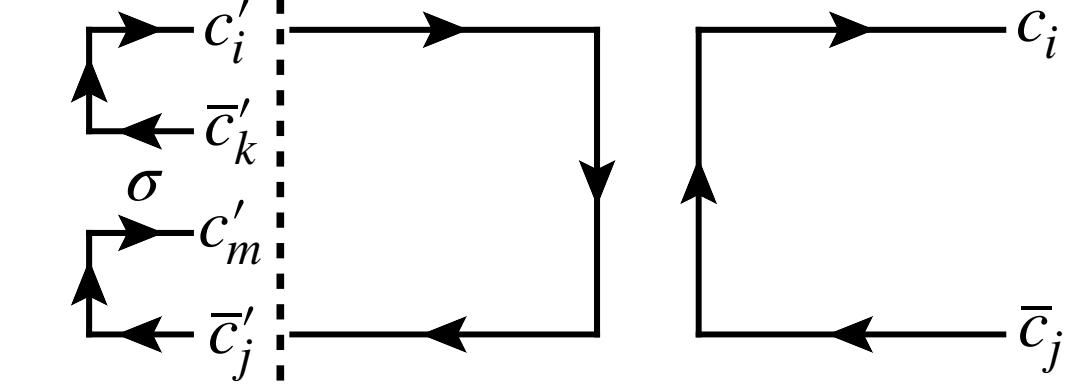
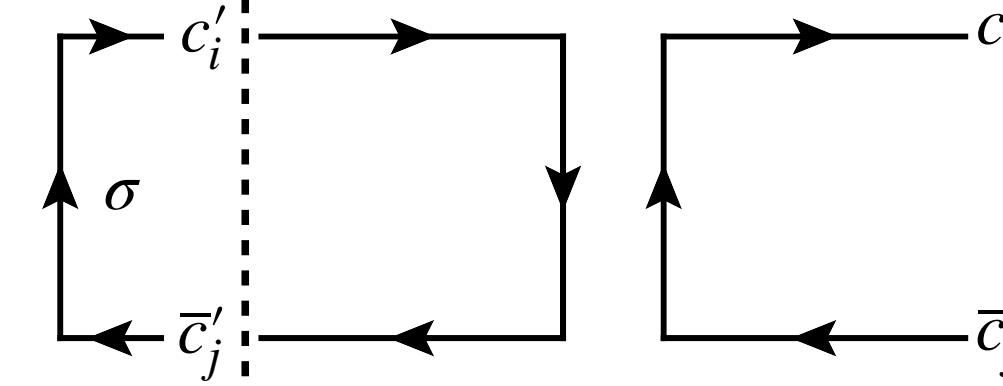
Systematically expand around large-N limit
summing towers of terms enhanced by $\alpha_S N$

Gluon exchange

$$Pe^{-\int_q^k \frac{dk'}{k'} \Gamma(k')}$$



$$[\tau | \Gamma | \sigma \rangle = (\alpha_s N) [\tau | \Gamma^{(1)} | \sigma \rangle + (\alpha_s N)^2 [\tau | \Gamma^{(2)} | \sigma \rangle + \dots]$$



$$[\tau | \Gamma^{(1)} | \sigma \rangle = \left(\Gamma_{\sigma}^{(1)} + \frac{1}{N^2} \rho^{(1)} \right) \delta_{\sigma\tau} + \frac{1}{N} \Sigma_{\sigma\tau}^{(1)}$$



dipole flips — implicit suppression in I/N

Non-global Observables and Large-N

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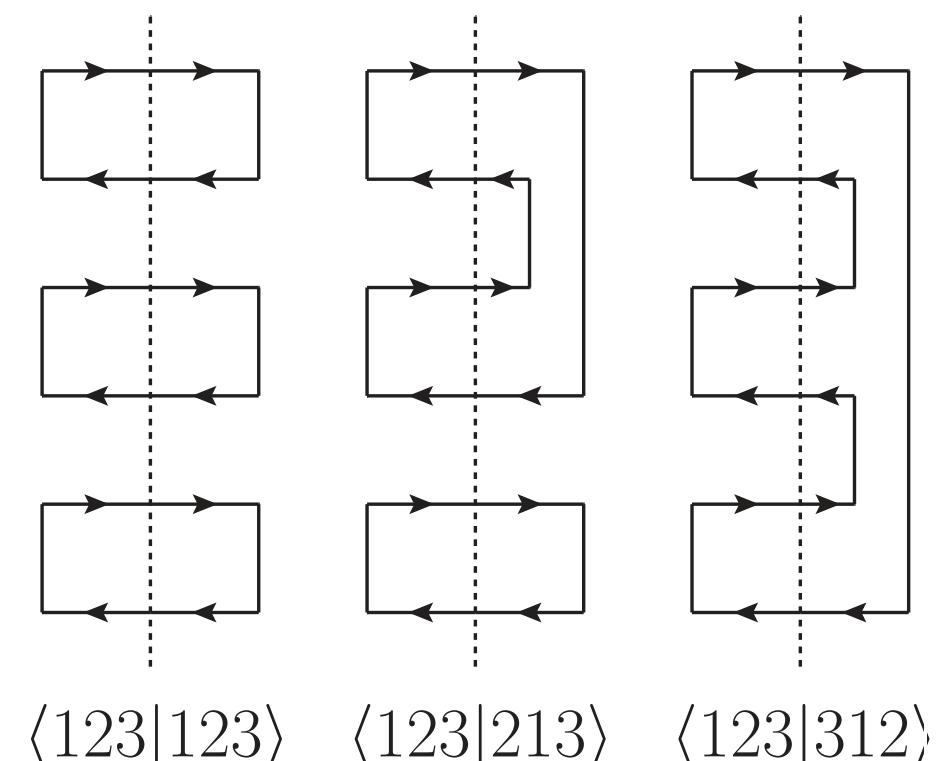
[Angeles, De Angelis, Forshaw, Plätzer, Seymour – JHEP 05 (2018) 044]

Primary application: Non-global observables

$$E \frac{\partial \mathbf{G}_n(E)}{\partial E} = -\Gamma \mathbf{G}_n(E) - \mathbf{G}_n(E) \Gamma^\dagger + \mathbf{D}_n^\mu \mathbf{G}_{n-1}(E) \mathbf{D}_{n\mu}^\dagger u(E, \hat{k}_n)$$

Utilise colour flow basis, and expand around large-N:

$$\text{Leading}_{\tau\sigma}^{(l)} [\mathbf{A}] = \sum_{k=0}^l \mathcal{A}_{\tau\sigma} \Big|_{1/N^k} \delta_{\#\text{transpositions}(\tau,\sigma), l-k}$$



Re-derive BMS equation: Prototype of constructing a dipole shower

$$\text{Leading}_{\tau\sigma}^{(0)} \left[\mathbf{V}_n \mathbf{A}_n \mathbf{V}_n^\dagger \right] = \delta_{\tau\sigma} \left| V_\sigma^{(n)} \right|^2 \text{Leading}_{\tau\sigma}^{(0)} [\mathbf{A}_n]$$

$$V_\sigma^{(n)} = \exp \left(-N \sum_{i,j \text{ c.c. in } \sigma} \lambda_i \bar{\lambda}_j W_{ij}^{(n)} \right)$$

$$\text{Leading}_{\tau\sigma}^{(0)} \left[\mathbf{D}_n \mathbf{A}_{n-1} \mathbf{D}_n^\dagger \right] = \delta_{\tau\sigma} \sum_{i,j \text{ c.c. in } \sigma \setminus n} \lambda_i \bar{\lambda}_j R_{ij}^{(n)} \text{Leading}_{\tau \setminus n, \sigma \setminus n}^{(0)} [\mathbf{A}_{n-1}]$$

↑
colour connected dipoles

Colour Evolution Beyond Leading Order

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[Plätzer, Ruffa — JHEP 06 (2021) 007 & work in progress]

Include simultaneously unresolved emissions and higher loop structures

$$E \frac{\partial}{\partial E} \mathbf{A}_n(E) = \Gamma_n(E) \mathbf{A}_n(E) + \mathbf{A}_n(E) \Gamma_n^\dagger(E) - \sum_k \mathbf{R}_n^{(k)}(E) \mathbf{A}_{n-k}(E) \mathbf{R}_n^{(k),\dagger}(E)$$



combination of purely virtual and unresolved real corrections, point-by-point in phase space



resolved real emissions and virtual/unresolved corrections to emissions

Similar in origin to a fixed-order calculation with the subtraction method:

Subtract (unresolved) real emissions — cast virtual corrections into phase-space type integrals instead of integrating subtraction terms.

Leading Order Evolution

CF vs CA/2

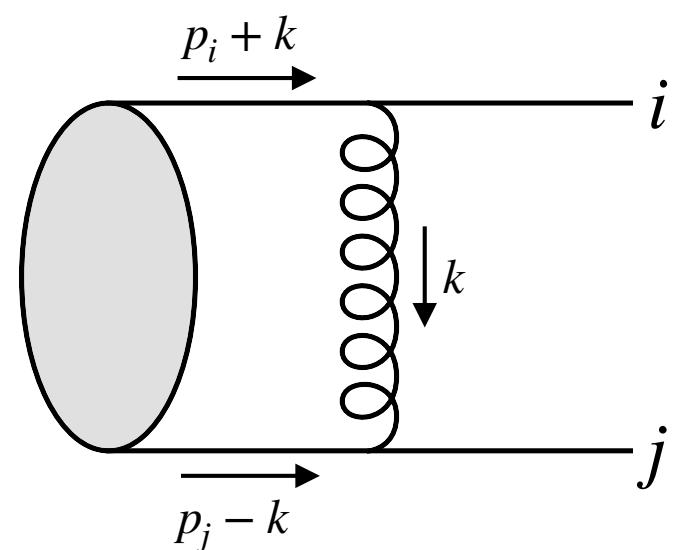
dipole flips

$$\Gamma^{(1)} = \frac{1}{2} \sum_{i,j} \Omega_{ij}^{(1)} \frac{1}{N} \mathbf{T}_i \cdot \mathbf{T}_j$$

$$[\tau | \Gamma^{(1)} | \sigma \rangle = \left(\Gamma_\sigma^{(1)} + \frac{1}{N^2} \rho^{(1)} \right) \delta_{\sigma\tau} + \frac{1}{N} \Sigma_{\sigma\tau}^{(1)}$$

Expand around colour diagonal limit

Cast e.g. into form of energy ordered observables by doing a contour integral



$$\Omega_{ij}^{(1)} = i\mu^{2\epsilon} \int \frac{d^d k}{i\pi^{d/2}} \frac{p_i \cdot p_j}{(k^2 + i0)(p_i \cdot k + i0)(p_j \cdot k - i0)} = \int_0^\infty \frac{dE}{E} \left(\frac{\mu^2}{E^2} \right)^\epsilon \omega^{(ij)}$$

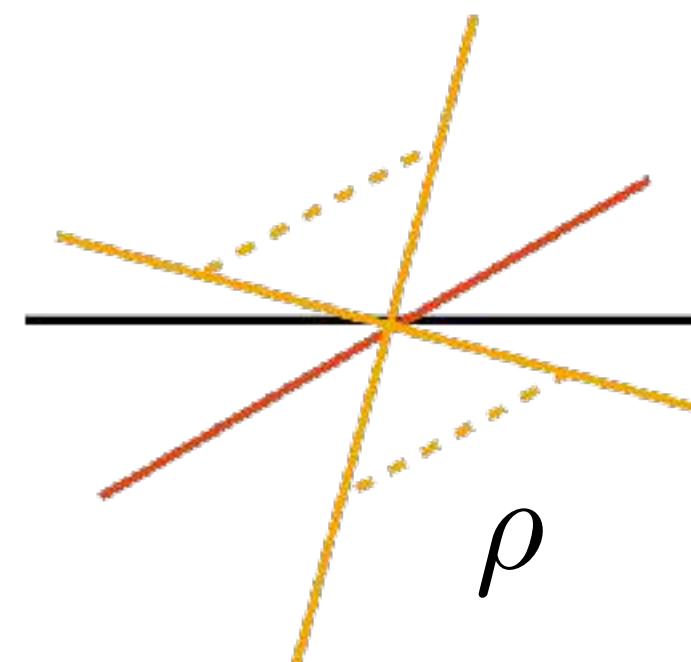
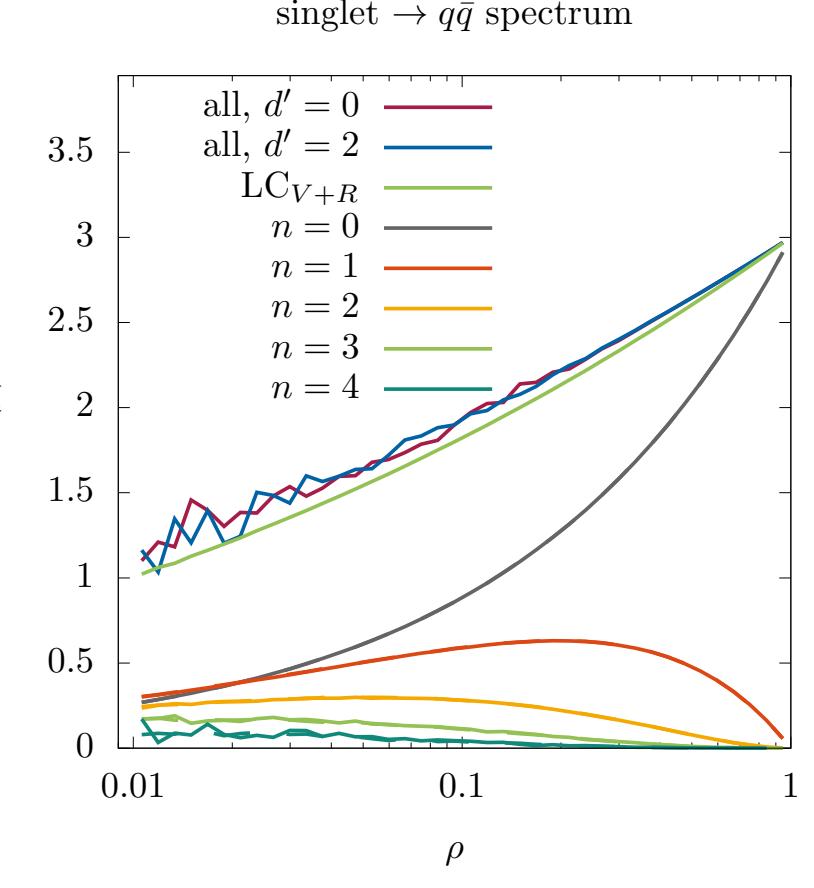
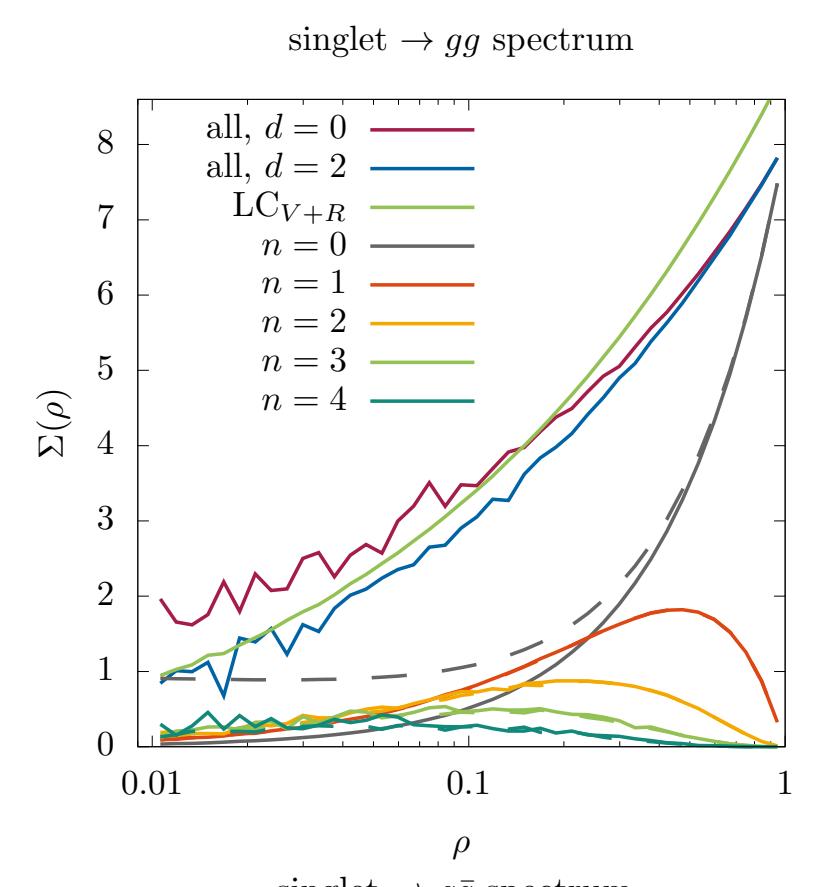
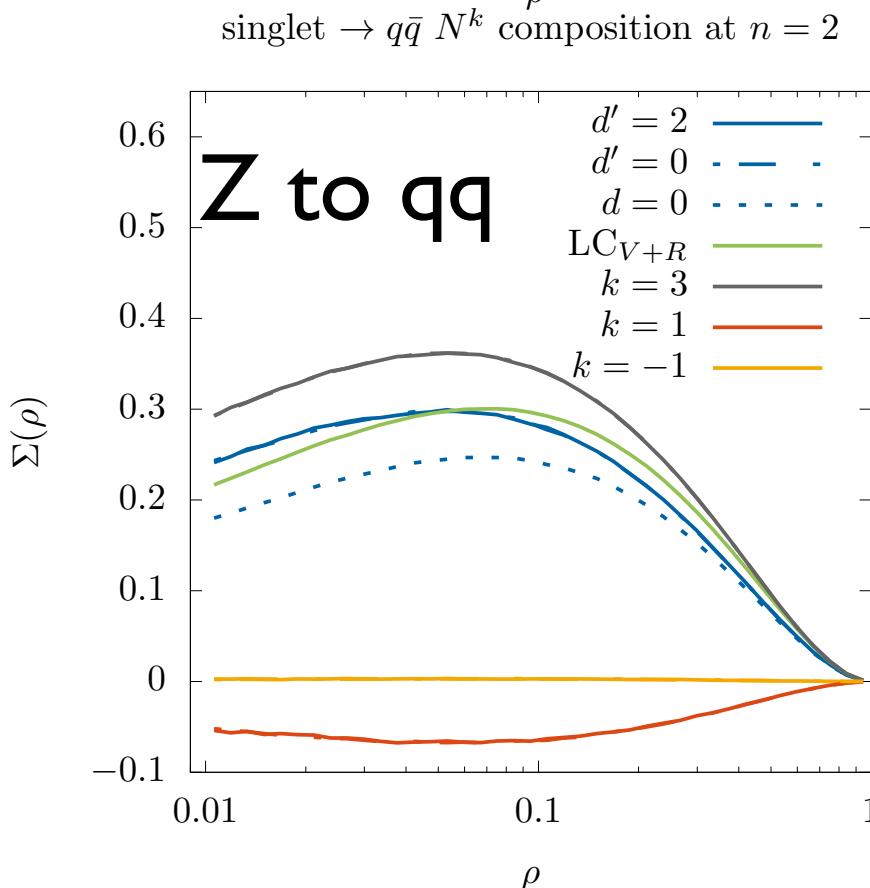
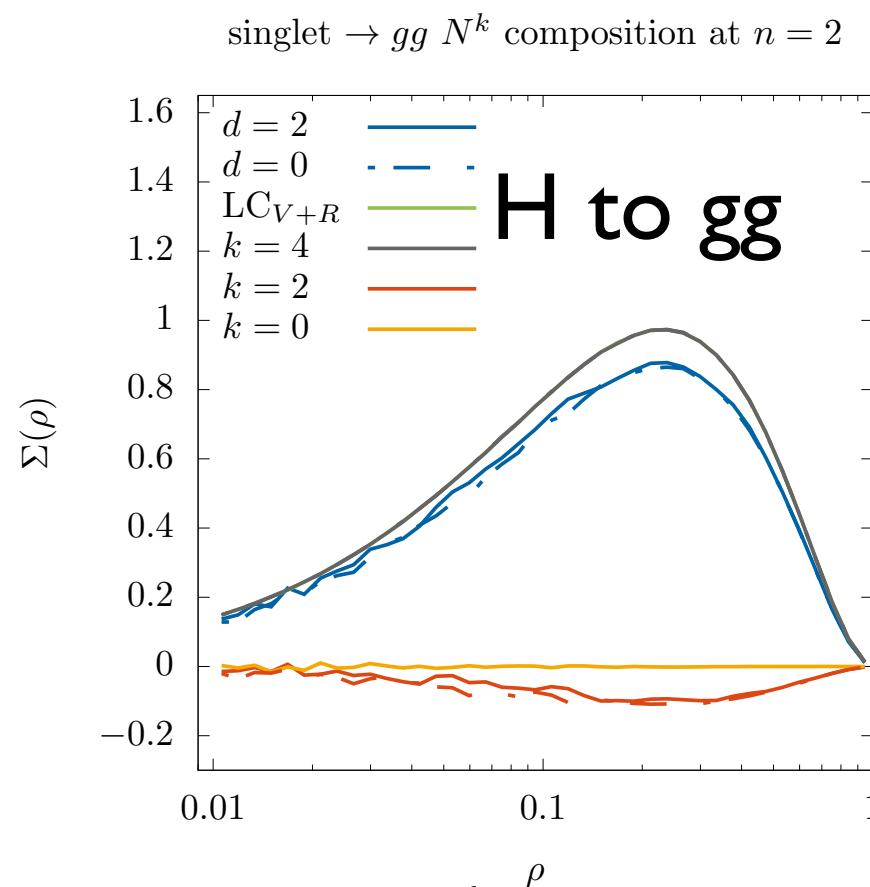
$$\omega^{(ij)} = \frac{(2\pi)^{2\epsilon}}{\pi} \left[\int \frac{d\Omega^{(d-2)}}{4\pi} \frac{n_i \cdot n_j}{n_i \cdot n \ n \cdot n_j} - i\pi \int \frac{d\Omega^{(d-3)}}{2\pi} \right]$$

Beyond Leading Colour

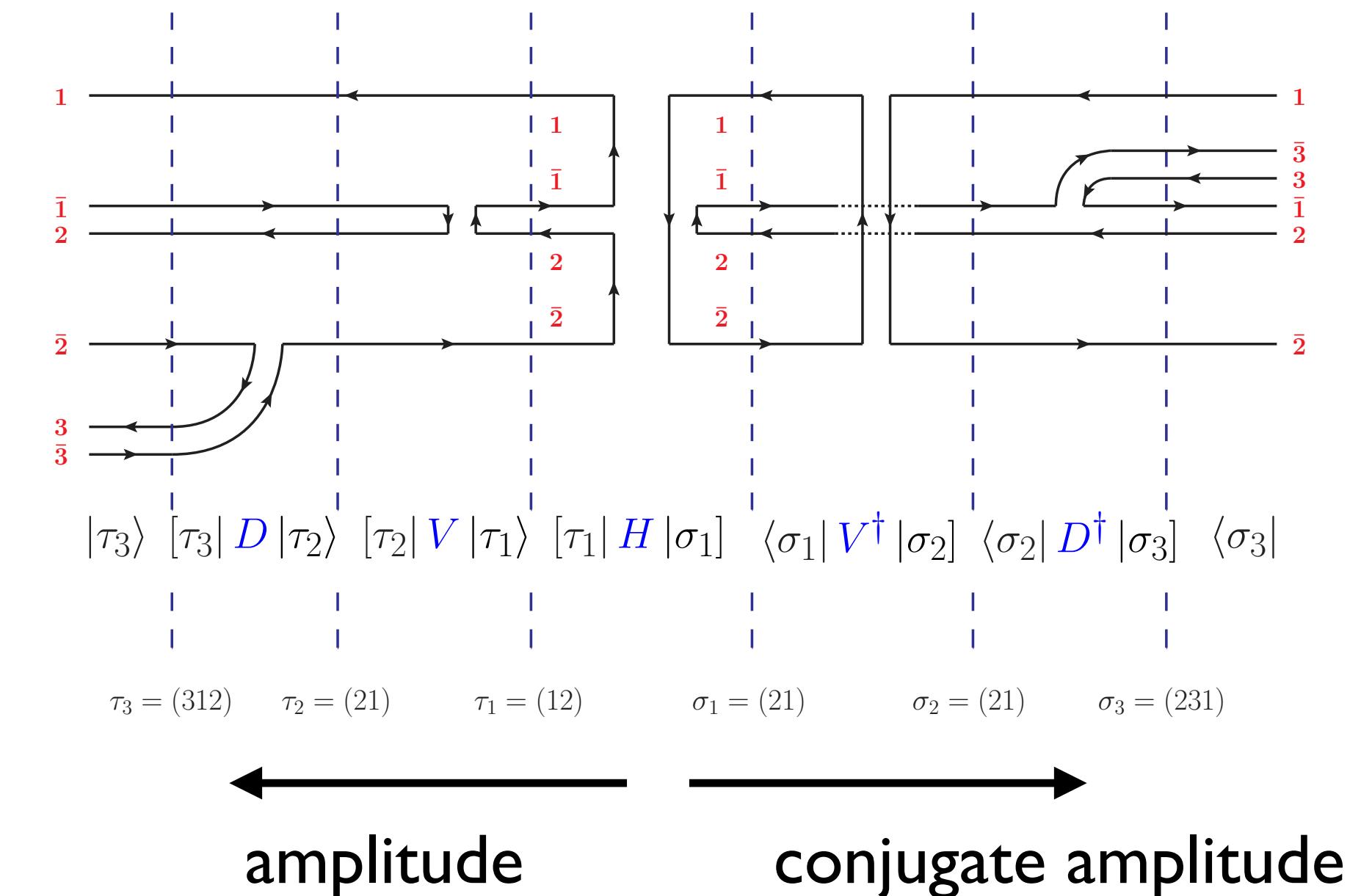
CVolver library implements numerical evolution in colour space.

origins in
[Plätzer – EPJ C 74 (2014) 2907]

Resummation of non-global logarithms at full colour:



[De Angelis, Forshaw, Plätzer — PRL 126 (2021) 11]



Avoid complexity which grows with colour space dimensionality:

$$\Sigma(\rho) = \sum_n \int d\sigma(\{p_i\}) \prod_i \theta_{in}(\rho - E_i)$$

- Monte Carlo over colour flows,
- events at intermediate steps carry complex weights.

Evolution at the Next Order

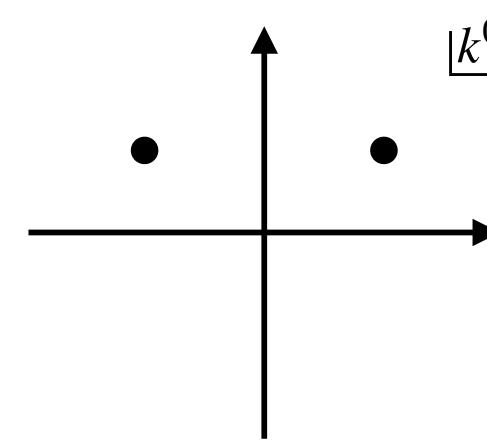
[Plätzer, Ruffa — JHEP 06 (2021) 007]

Coefficient	Diagram	Colour-factor
$\Omega_{ij}^{(2)}$		$(\mathbf{T}_i \cdot \mathbf{T}_j)(\mathbf{T}_i \cdot \mathbf{T}_j)$
$\tilde{\Omega}_{ij}^{(2)}$		$\mathbf{T}_i^a \mathbf{T}_i^b \mathbf{T}_j^b \mathbf{T}_j^a$
$\Omega_{ijl}^{(2)}$		$(\mathbf{T}_i \cdot \mathbf{T}_l)(\mathbf{T}_i \cdot \mathbf{T}_j)$
$\hat{\Omega}_{ijl}^{(2)}$		$i f^{abc} \mathbf{T}_i^a \mathbf{T}_j^b \mathbf{T}_l^c$
$\Omega_{ij,\text{self-en.}}^{(2)}$		$T_R(\mathbf{T}_i \cdot \mathbf{T}_j)$
$\Omega_{ij,\text{vertex-corr.}}^{(2)}$		$T_R(\mathbf{T}_i \cdot \mathbf{T}_j)$
$\hat{\Omega}_{ij}^{(2)}$		$\mathbf{T}_i^b \mathbf{T}_i^a \mathbf{T}_i^b \mathbf{T}_j^a$

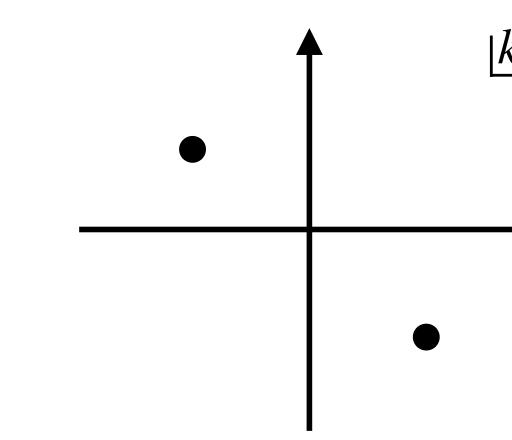
Coefficient	Diagram	Colour-factor
$\Omega_{ij}^{(1,1)}$		$\mathbf{T}_i^a (\mathbf{T}_i \cdot \mathbf{T}_j)$
$\tilde{\Omega}_{ij}^{(1,1)}$		$(\mathbf{T}_i \cdot \mathbf{T}_j) \mathbf{T}_i^a$
$\bar{\Omega}_{ij}^{(1,1)}$		$i f^{abc} \mathbf{T}_i^b \mathbf{T}_j^c$
$\Omega_{ijl}^{(1,1)}$		$\mathbf{T}_l^a (\mathbf{T}_i \cdot \mathbf{T}_j)$
$\Omega_{i,\text{self-en.}}^{(1,1)}$		$T_R \mathbf{T}_i^a$
$\Omega_{i,\text{vertex-corr.}}^{(1,1)}$		$T_R \mathbf{T}_i^a$
$\hat{\Omega}_{ij}^{(1,1)}$		$\mathbf{T}_i^b \mathbf{T}_i^a \mathbf{T}_i^b$

[Plätzer, Ruffa — JHEP 06 (2021) 007]

Algorithmic treatment of virtual corrections needed



Advanced



Feynman

Feynman tree theorem:

$$\frac{1}{k^2 + i0(T \cdot k)^2} = \frac{1}{(k^0)^2 - \vec{k}^2 + 2i0(k^0)^2}$$

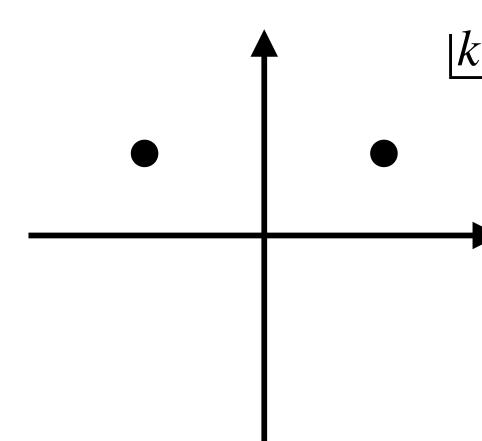
$(T^\mu) = (\sqrt{2}, \vec{0})$

$$\frac{1}{[q^2 - i0(T \cdot q)|T \cdot q|]} = \frac{1}{[q^2 + i0(T \cdot q)^2]} + 2\pi i\delta(q^2)\theta(T \cdot q)$$

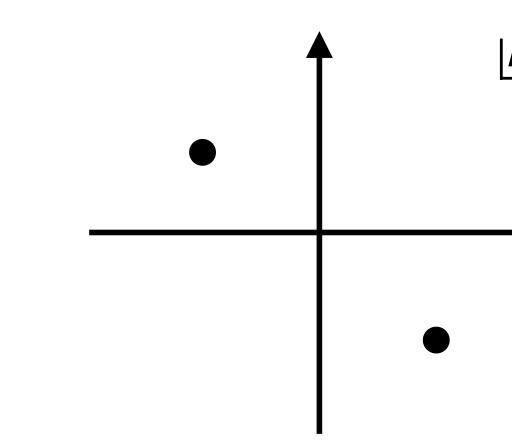
Cutting rules

[Plätzer, Ruffa — JHEP 06 (2021) 007]

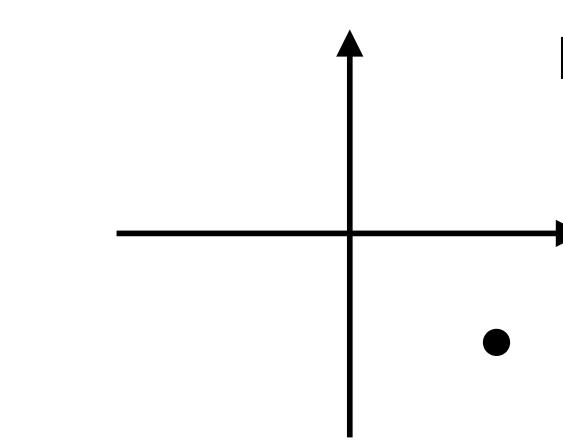
Algorithmic treatment of virtual corrections needed



Advanced



Feynman



Eikonal

Feynman tree theorem:

$$\frac{1}{k^2 + i0(T \cdot k)^2} = \frac{1}{(k^0)^2 - \vec{k}^2 + 2i0(k^0)^2}$$

$(T^\mu) = (\sqrt{2}, \vec{0})$

$$\frac{1}{[q^2 - i0(T \cdot q)|T \cdot q|]} = \frac{1}{[q^2 + i0(T \cdot q)^2]} + 2\pi i \delta(q^2) \theta(T \cdot q)$$

$$\text{Diagram: } \text{Advanced propagator} = - \left[\text{Feynman propagator} + \text{Eikonal propagator} + \text{Eikonal propagator} \right]$$

Extend to Eikonal and higher-power propagators:

$$\frac{1}{2p_i \cdot k - i0(T \cdot p_i)^2} = \frac{1}{2p_i \cdot k + i0(T \cdot p_i)^2} + 2\pi i \delta(2p_i \cdot k)$$

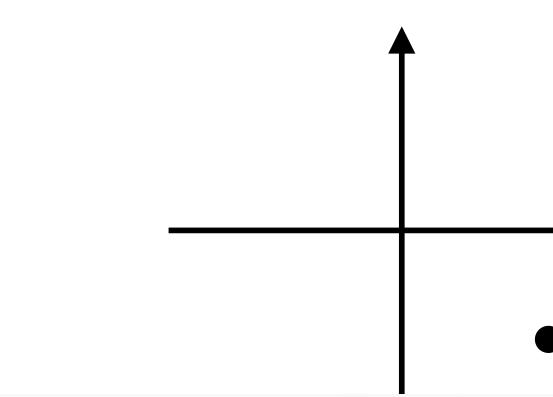
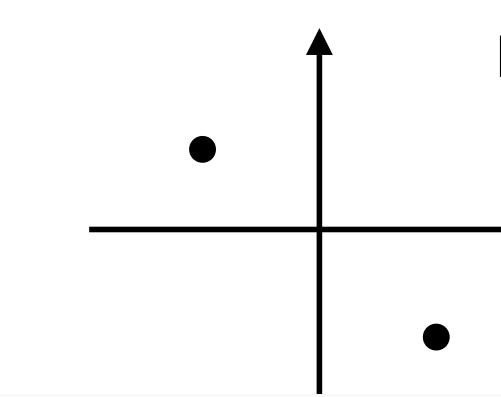
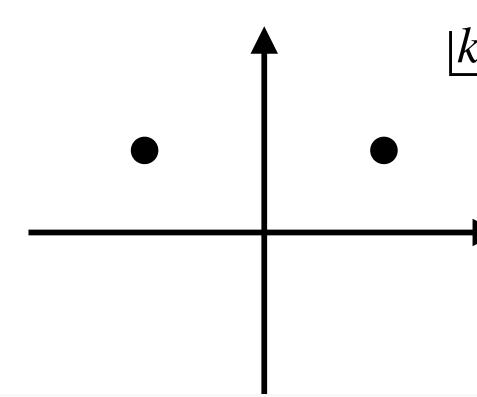
$$\omega^{(ij)} = \frac{(2\pi)^{2\epsilon}}{\pi} \left[\int \frac{d\Omega^{(d-2)}}{4\pi} \frac{n_i \cdot n_j}{n_i \cdot n \ n \cdot n_j} - i\pi \int \frac{d\Omega^{(d-3)}}{2\pi} \right]$$

$$\frac{1}{[q^2 - i0(T \cdot q)|T \cdot q|]^2} - \frac{1}{[q^2 + i0(T \cdot q)^2]^2} = -2i\pi\theta(T \cdot q)\delta'(q^2)$$

Cutting rules

[Plätzer, Ruffa — JHEP 06 (2021) 007]

Algorithmic treatment of virtual corrections needed



Feynman tree theorem:

$$\frac{1}{k^2 + i0(T \cdot k)^2} = \frac{1}{(k^0)^2 - \vec{k}^2 + 2i0(k^0)^2}$$

$(T^\mu) = (\sqrt{2}, \vec{0})$

$$\frac{1}{[q^2 + i0(T \cdot q)^2]} = \frac{1}{[q^2 + i0(T \cdot q)^2]} + 2\pi i \delta(q^2) \theta(T \cdot q)$$

$$\begin{aligned} \text{Diagram with a shaded loop and arrows } i \text{ and } j &= - \left[\text{Diagram with a shaded loop and } i \text{ arrow} + \text{Diagram with a shaded loop and } j \text{ arrow} + \text{Diagram with a shaded loop and } i \text{ arrow} + \text{Diagram with a shaded loop and } j \text{ arrow} \right. \\ &\quad \left. + \text{Diagram with a shaded loop and } i \text{ arrow} + \text{Diagram with a shaded loop and } j \text{ arrow} \right]. \end{aligned}$$

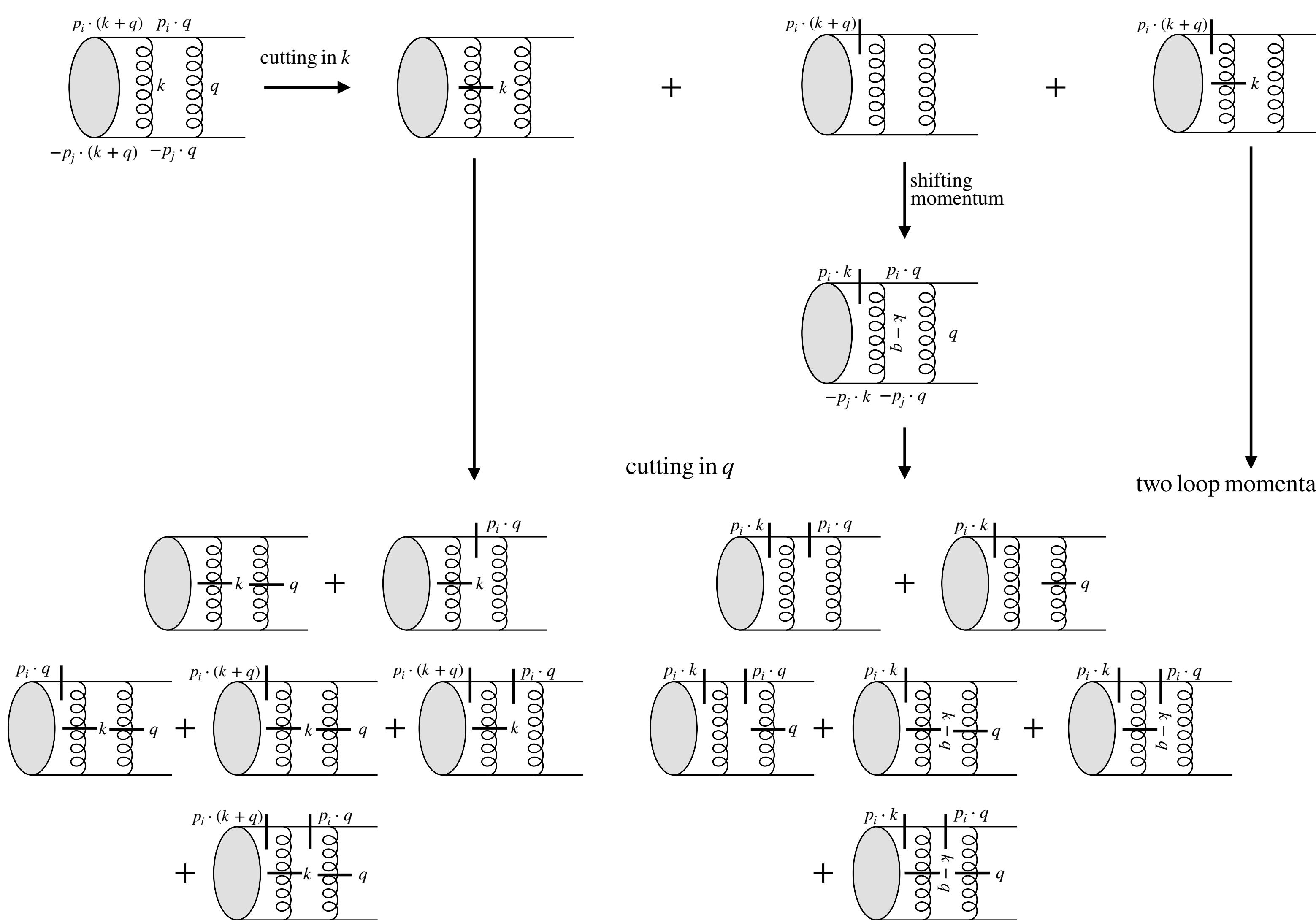
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I higher-power propagators:

$$\frac{1}{(p_i)^2} = \frac{1}{2p_i \cdot k + i0(T \cdot p_i)^2} + 2\pi i \delta(2p_i \cdot k)$$

$$\frac{1}{[q^2 + i0(T \cdot q)^2]^2} = -2i\pi\theta(T \cdot q)\delta'(q^2)$$

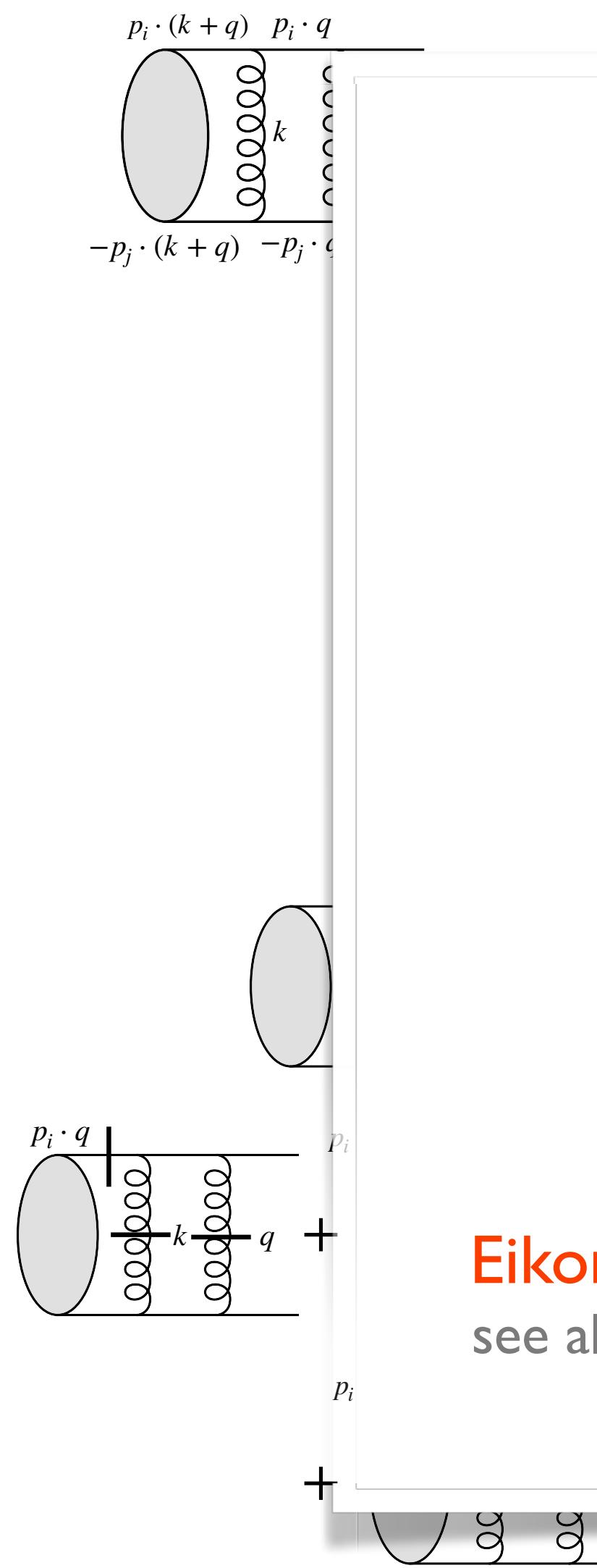
Cutting rules



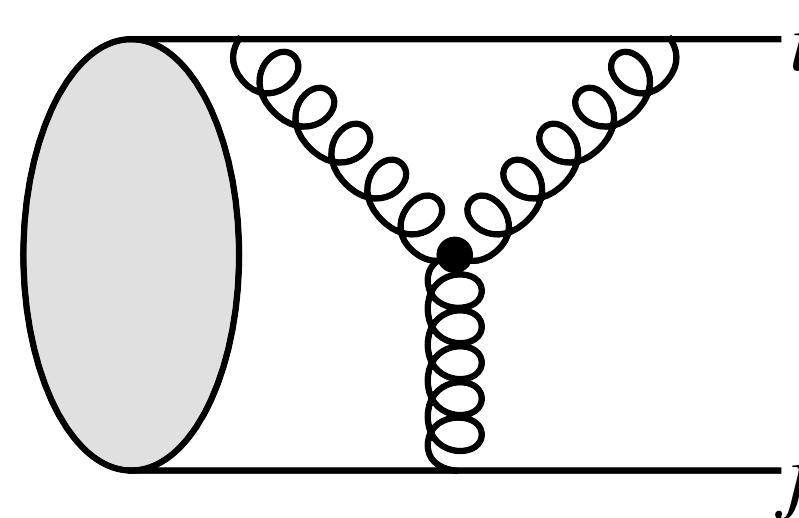
[Plätzer, Ruffa — JHEP 06 (2021) 007]

Cutting rules

[Plätzer, Ruffa — JHEP 06 (2021) 007]



$$\mu^{4\varepsilon} \int \frac{d^d k}{i\pi^{d/2}} \frac{d^d q}{i\pi^{d/2}} \frac{1}{[p_i \cdot k + i0][-p_j \cdot (k + q) + i0][k^2 + i0][q^2 + i0][(k + q)^2 + i0]}$$



Eikonal coupling only to hard lines!

see also [Angeles, Forshaw, Seymour — JHEP 12 (2015) 091]

$$\begin{aligned} & \mu^{4\varepsilon} \int \frac{d^d k}{i\pi^{d/2}} \frac{d^d q}{i\pi^{d/2}} \left\{ \frac{(2\pi i)^2 \tilde{\delta}(k) \tilde{\delta}(q)}{[p_i \cdot k + i0][(k + q)^2 + i0][-p_j \cdot (k + q) + i0]} \right. \\ & + \frac{(2\pi i)^2 \tilde{\delta}(q) \delta(p_i \cdot k)}{[k^2 + i0][(k + q)^2 + i0][-p_j \cdot (k + q) + i0]} \\ & + \frac{(2\pi i)^2 \tilde{\delta}(k) \tilde{\delta}(q)}{[p_i \cdot k + i0][(q - k)^2 + i0][-p_j \cdot q + i0]} \\ & + \frac{(2\pi i)^2 \tilde{\delta}(q) \delta(p_i \cdot k)}{[k^2 + i0][(q - k)^2 + i0][-p_j \cdot q + i0]} \\ & - \frac{(2\pi i)^2 \tilde{\delta}(q) \tilde{\delta}(k)}{[p_i \cdot (k - q) + i0][(k - q)^2 + i0][-p_j \cdot k + i0]} \\ & + \frac{(2\pi i)^3 \tilde{\delta}(k) \tilde{\delta}(q) \tilde{\delta}(k + q)}{[p_i \cdot k + i0][-p_j \cdot (k + q) + i0]} \\ & + \frac{(2\pi i)^3 \tilde{\delta}(q) \tilde{\delta}(k + q) \delta(p_i \cdot k)}{[k^2 + i0][-p_j \cdot (k + q) + i0]} + \frac{(2\pi i)^3 \tilde{\delta}(q) \tilde{\delta}(k) \tilde{\delta}(q - k)}{[p_i \cdot k + i0][-p_j \cdot q + i0]} \\ & \left. + \frac{(2\pi i)^3 \tilde{\delta}(q - k) \tilde{\delta}(q) \delta(p_i \cdot k)}{[k^2 + i0][-p_j \cdot q + i0]} \right\}. \end{aligned}$$

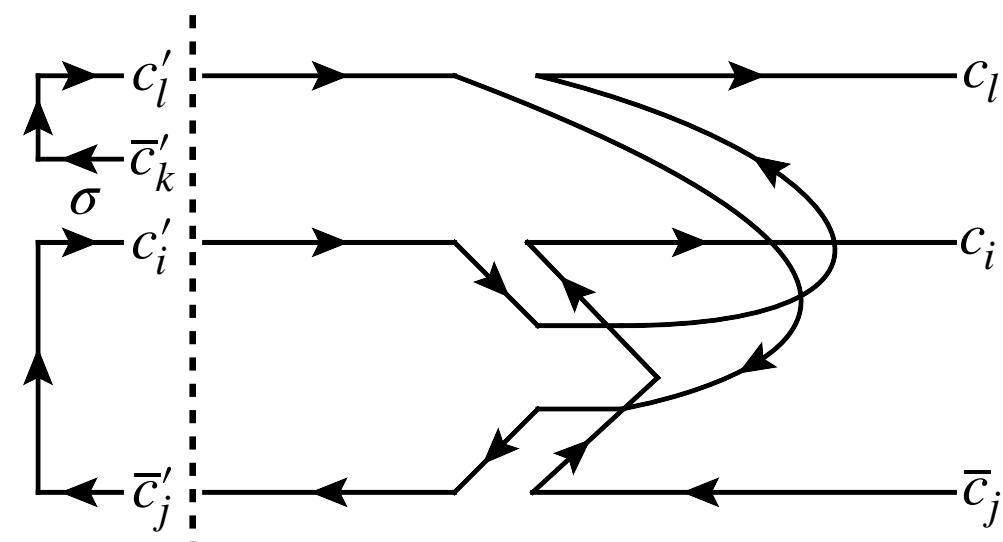
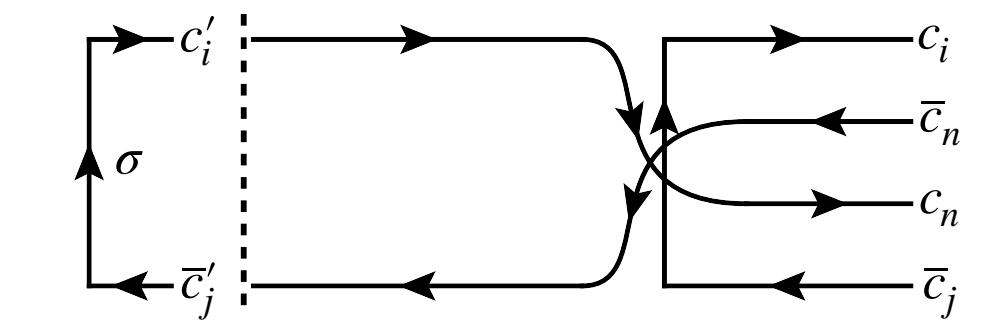
Colour structures at two loops

[Plätzer, Ruffa — JHEP 06 (2021) 007]

Analyze two-loop and one-loop/one-emission structures in colour flow basis.

$$[\tau|\Gamma|\sigma\rangle = (\alpha_s N)[\tau|\Gamma^{(1)}|\sigma\rangle + (\alpha_s N)^2[\tau|\Gamma^{(2)}|\sigma\rangle + \dots$$

$$\begin{aligned} [\tau|\Gamma^{(1,1)}|\sigma\rangle &= \left(\frac{1}{N^2}\rho_{\sigma\tau} + \frac{1}{N^4}\rho_\tau \right) \delta_{\sigma\tau\setminus n} \\ &+ \frac{1}{N}\hat{\Sigma}_{\sigma\tau}^{(1,1)} + \frac{1}{N^3} \left(\tilde{\Sigma}_{\sigma\tau}^{(1,1)} + \hat{\tilde{\Sigma}}_{\sigma\tau} \right) + \frac{1}{N^2} \left(\Sigma'_{\sigma\tau}^{(1,1)} + \Sigma''_{\sigma\tau}^{(1,1)} \right) \end{aligned}$$



$$\begin{aligned} [\tau|\Gamma^{(2)}|\sigma\rangle &= \left(\Gamma_\sigma^{(2)} + \frac{1}{N^2} (\rho_\sigma + \tilde{\rho}) + \frac{1}{N^4}\rho^{(2)} \right) \delta_{\sigma\tau} \quad \text{no swaps} \\ &+ \frac{1}{N} \left(\Sigma_{\sigma\tau}^{(2)} + \hat{\Sigma}_{\sigma\tau}^{(2)} \right) + \frac{1}{N^3}\tilde{\Sigma}_{\sigma\tau}^{(2)} + \frac{1}{N^2} \left(\Sigma'_{\sigma\tau}^{(2)} + \Sigma''_{\sigma\tau}^{(2)} \right) \end{aligned}$$

Colour structures imply colour-diagonal **three parton correlations**: Dipoles are not enough.

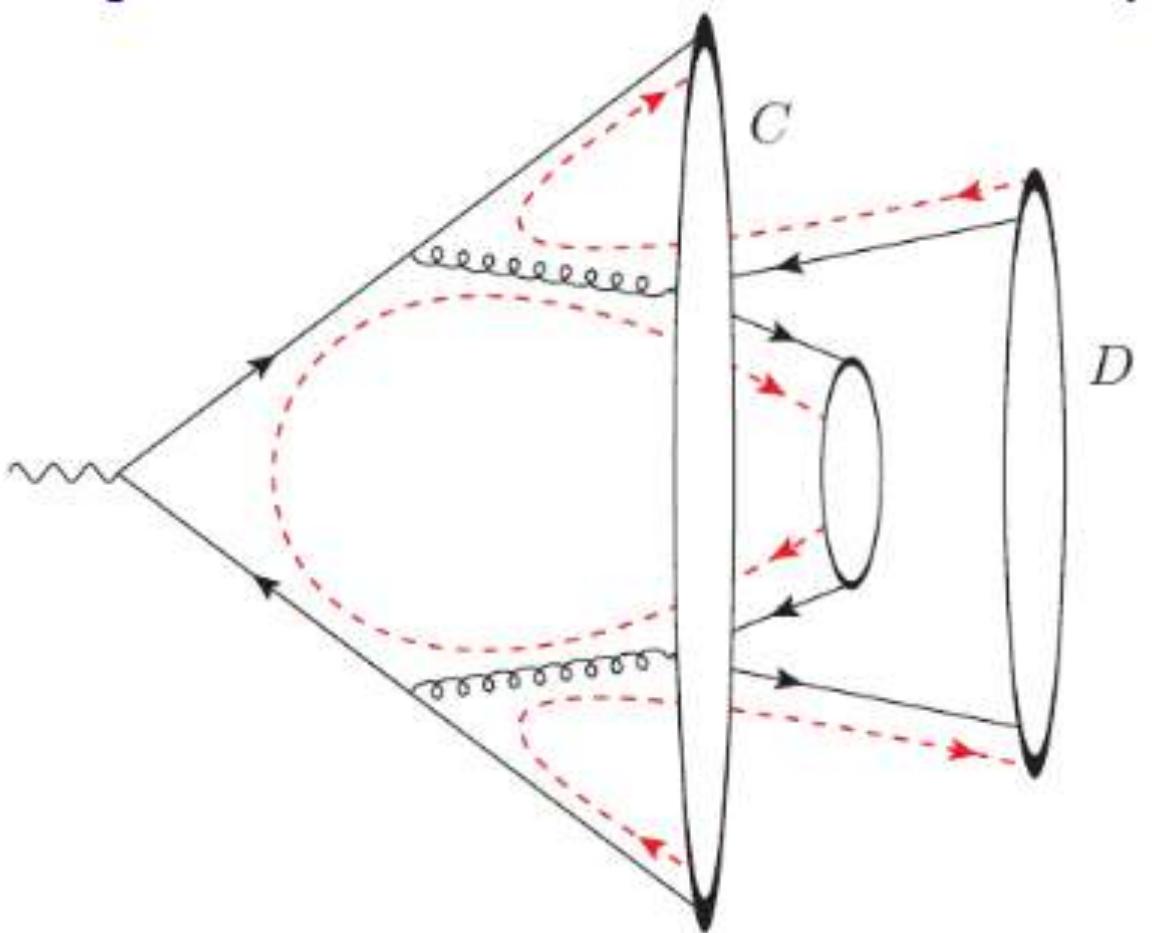
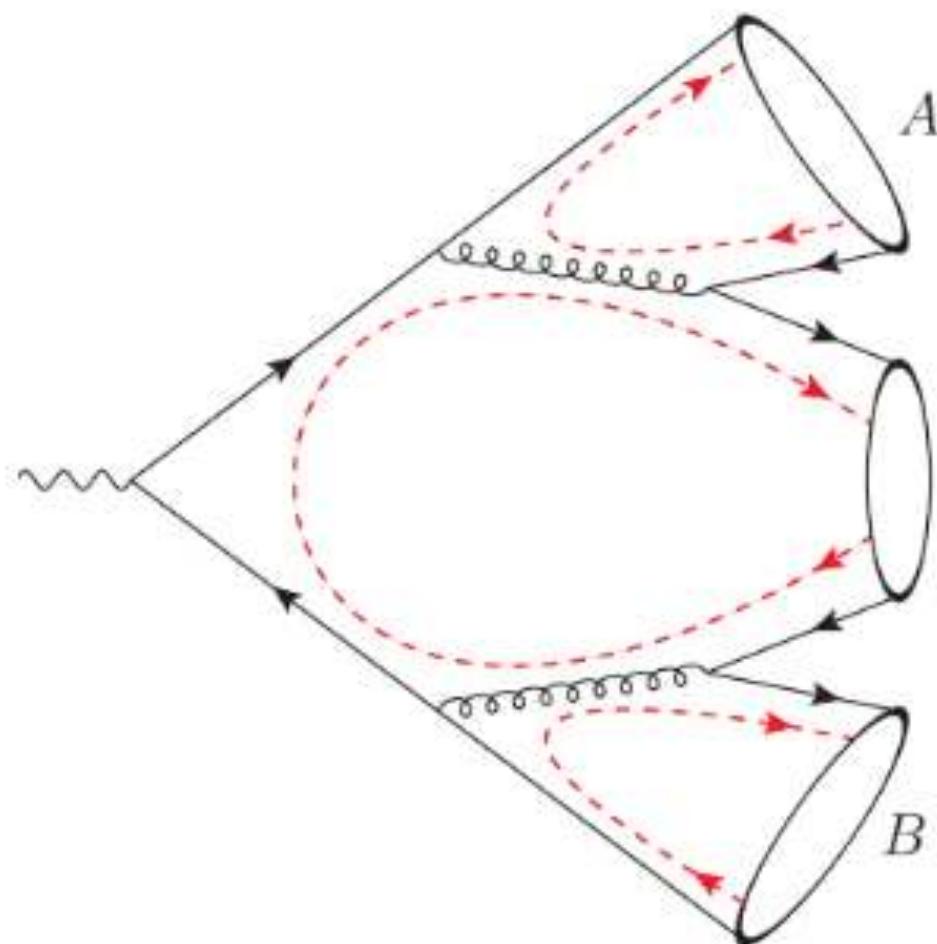
New approaches need to take this into account.

single dipole swaps

double dipole swaps

Phenomenological Impact?

Project colour state on low-mass colour singlet systems.
Clusters = highly excited hadrons.



Colour reconnection: cluster swaps.

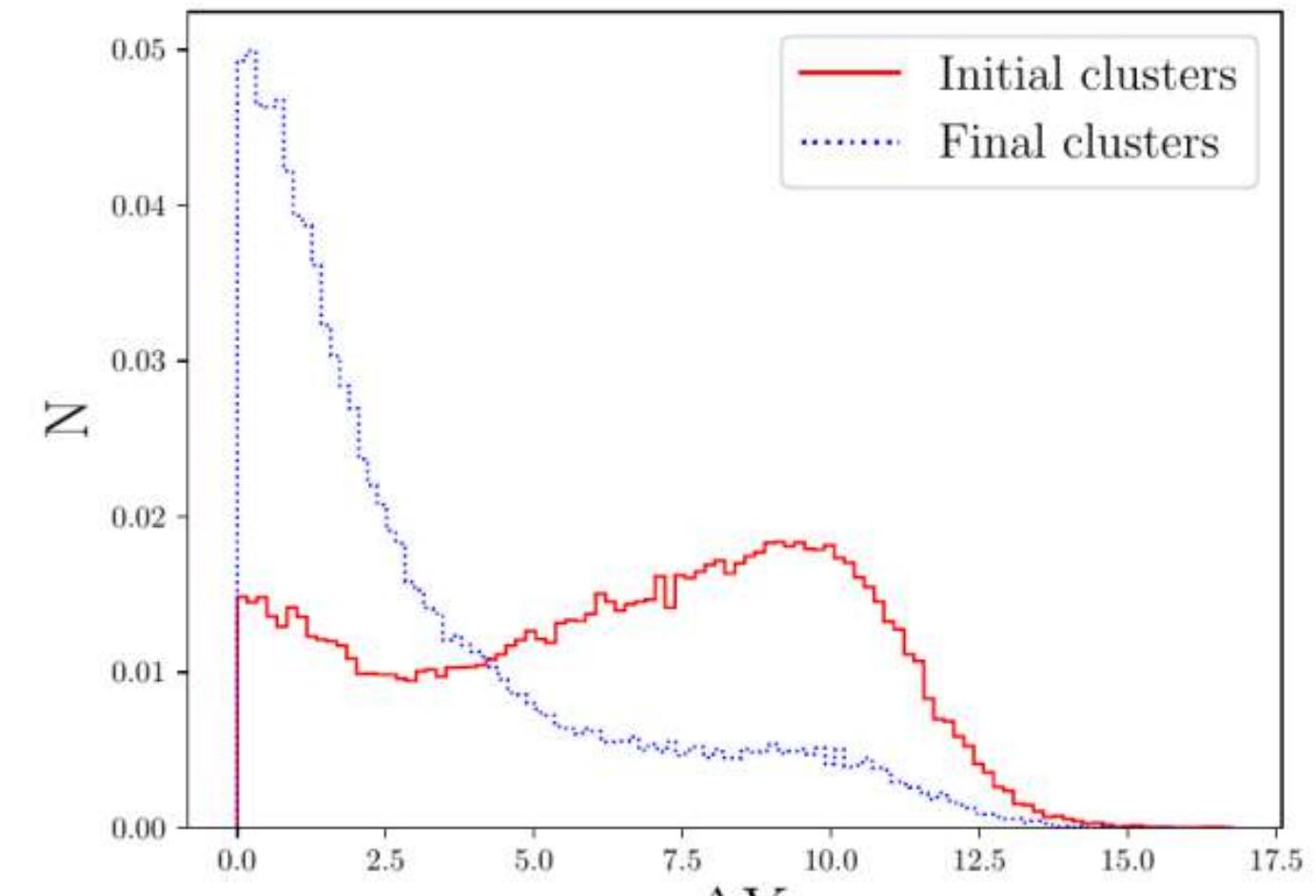
[Gieseke, Kirchgaesser, Plätzer – EPJ C 78 (2018) 99]

Approach colour reconnection from colour evolution: perturbative component?

Reconnection amplitude

$$A_{\tau \rightarrow \sigma} = \langle \sigma | \mathbf{U} (\{p\}, \mu^2, \{M_{ij}^2\}) | \tau \rangle$$

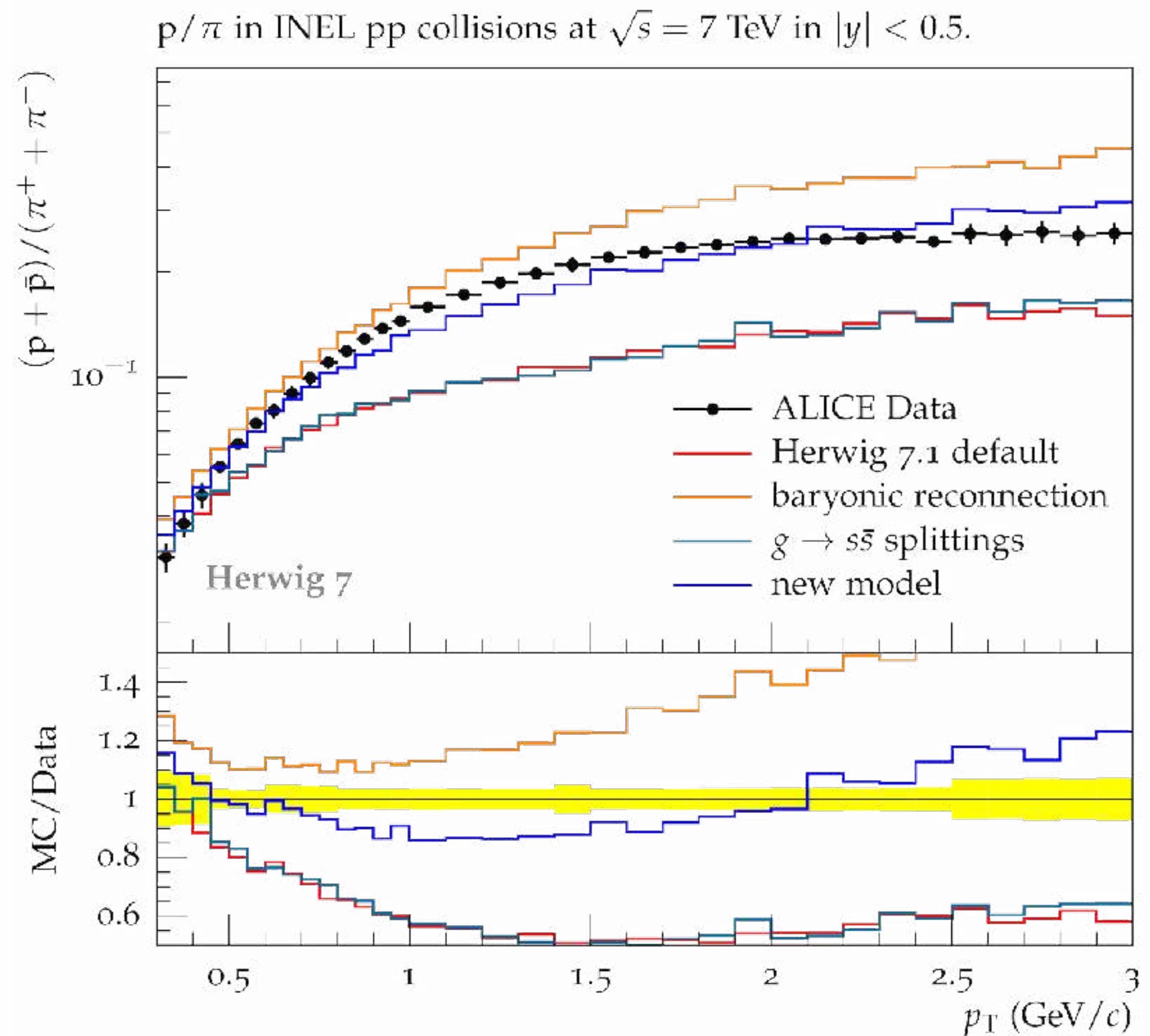
Strong support for geometric models from colour evolution.



[Gieseke, Kirchgaesser, Plätzer, Siadmok – JHEP 11 (2018) 149]

Phenomenological Impact?

Project colour state on low-mass colour singlet systems.

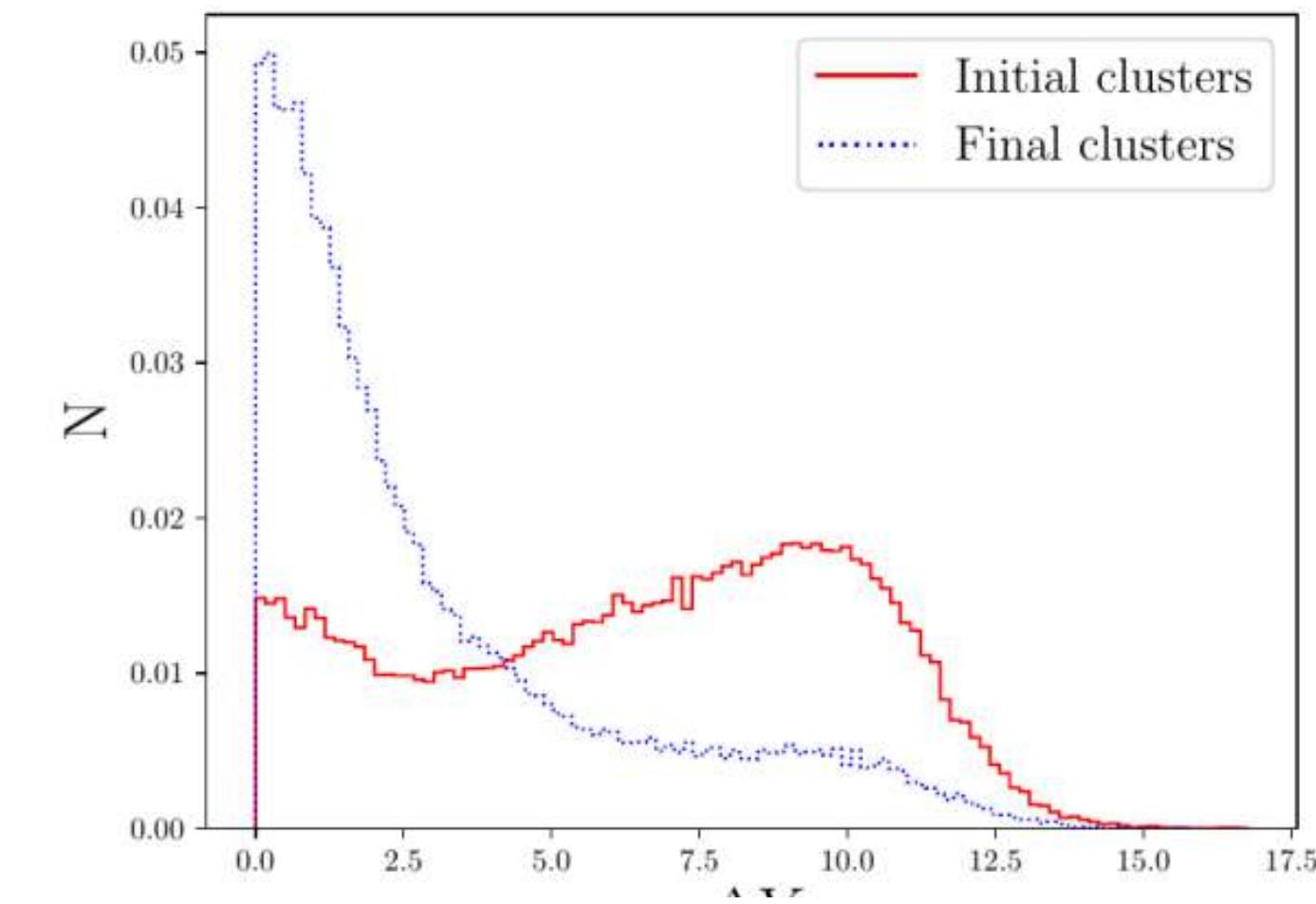


Approach colour reconnection from colour evolution: perturbative component?

Reconnection
amplitude

$$\mathcal{A}_{\tau \rightarrow \sigma} = \langle \sigma | \mathbf{U} (\{p\}, \mu^2, \{M_{ij}^2\}) | \tau \rangle$$

Strong support
for geometric
models from
colour evolution.



Sudakov-type densities central to Showers

$$\frac{dS_P(q|Q, z, x)}{dq dz} = \Delta_P(Q_0|Q, x)\delta(q - Q_0)\delta(z - z_0)$$

$$+ \Delta_P(q|Q, x)P(q, z, x)\theta(Q - q)\theta(q - Q_0)$$

emission

no emission

Negative P or unknown overestimate
requires weighted veto algorithm, with
in principle arbitrary proposal kernel
and veto probability.

[Olsson, Plätzer, Sjödahl — EPJC 80 (2020) 10]

[Plätzer, Sjödahl — EPJ Plus 127 (2012) 26]

Also cf. shower variations e.g.

[Bellm, Plätzer, et al. — Phys.Rev.D 94 (2016) 3, 034028]

$Q' \leftarrow Q, w \leftarrow w_0$
loop

A trial splitting scale and variables, q, z , are generated according to $S_R(q|Q', z, x)$, for example using Alg. 1.

if $q = Q_0$ then

There is no emission and the cut-off scale Q_0 is returned while the event weight is kept at w .

else

if $\text{rnd} \leq \epsilon$ then

The trial splitting variables q, z are accepted, and

$$w \leftarrow w \times \frac{1}{\epsilon} \times \frac{P(Q', z, x)}{R(Q', z, x)}. \quad (3)$$

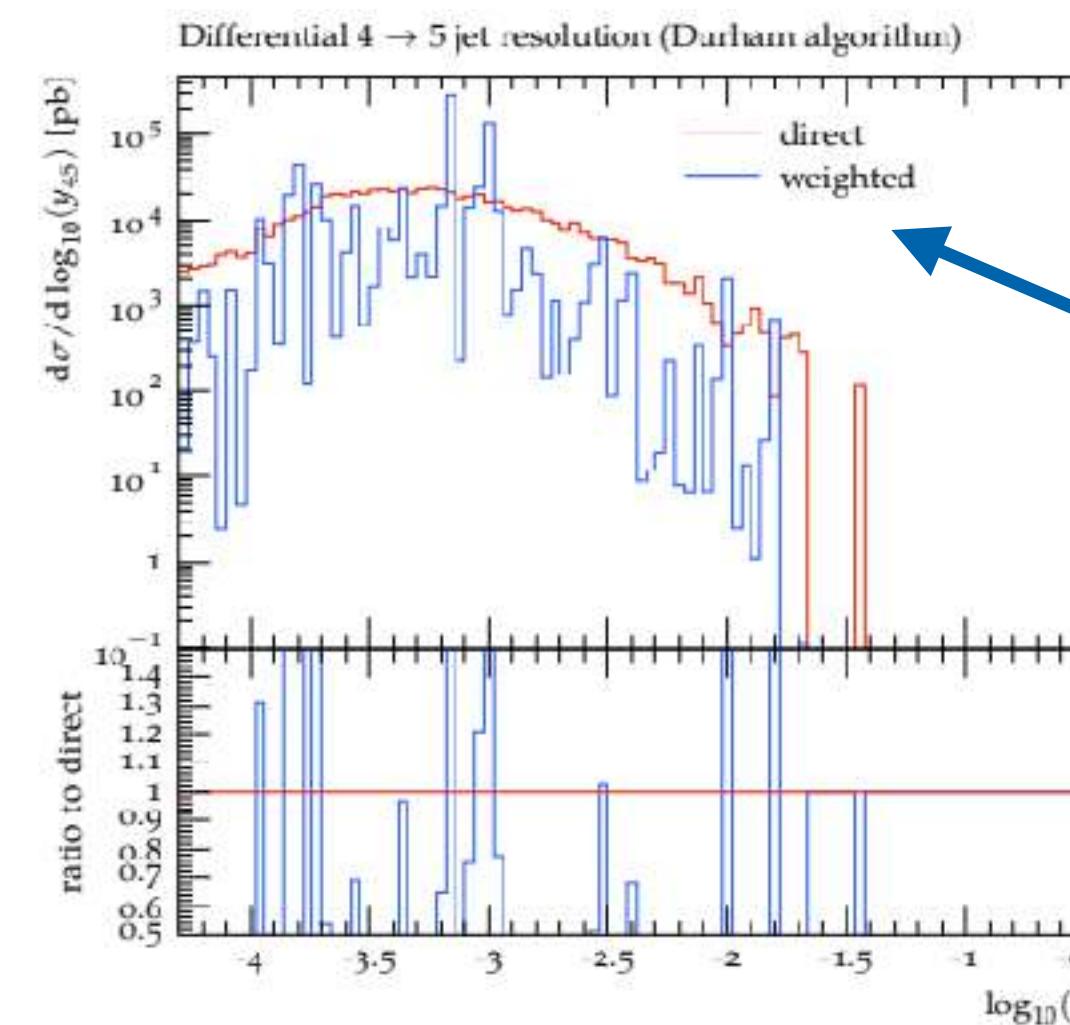
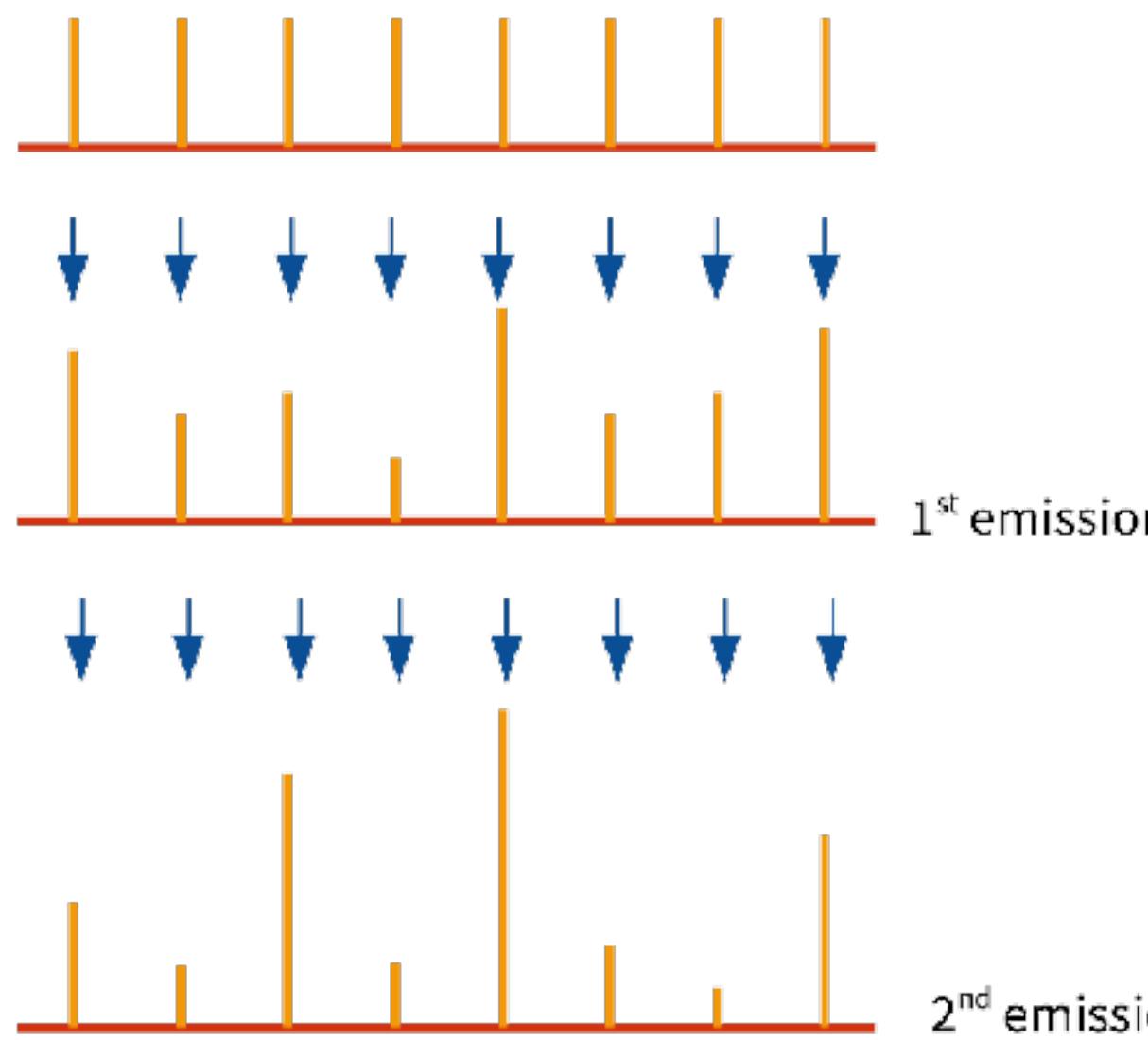
else

The emission is rejected, and the algorithm continues with

$$w \leftarrow w \times \frac{1}{1 - \epsilon} \times \left(1 - \frac{P(q, z, x)}{R(q, z, x)}\right) \\ Q' \leftarrow q. \quad (4)$$

end if
end if
end loop

Weighted Veto Algorithms & Resampling



[Olsson, Plätzer, Sjödahl — EPJ C80 (2020) 10, 934]

Weighted branching algorithms exhibit prohibitive weight distributions & convergence issues.

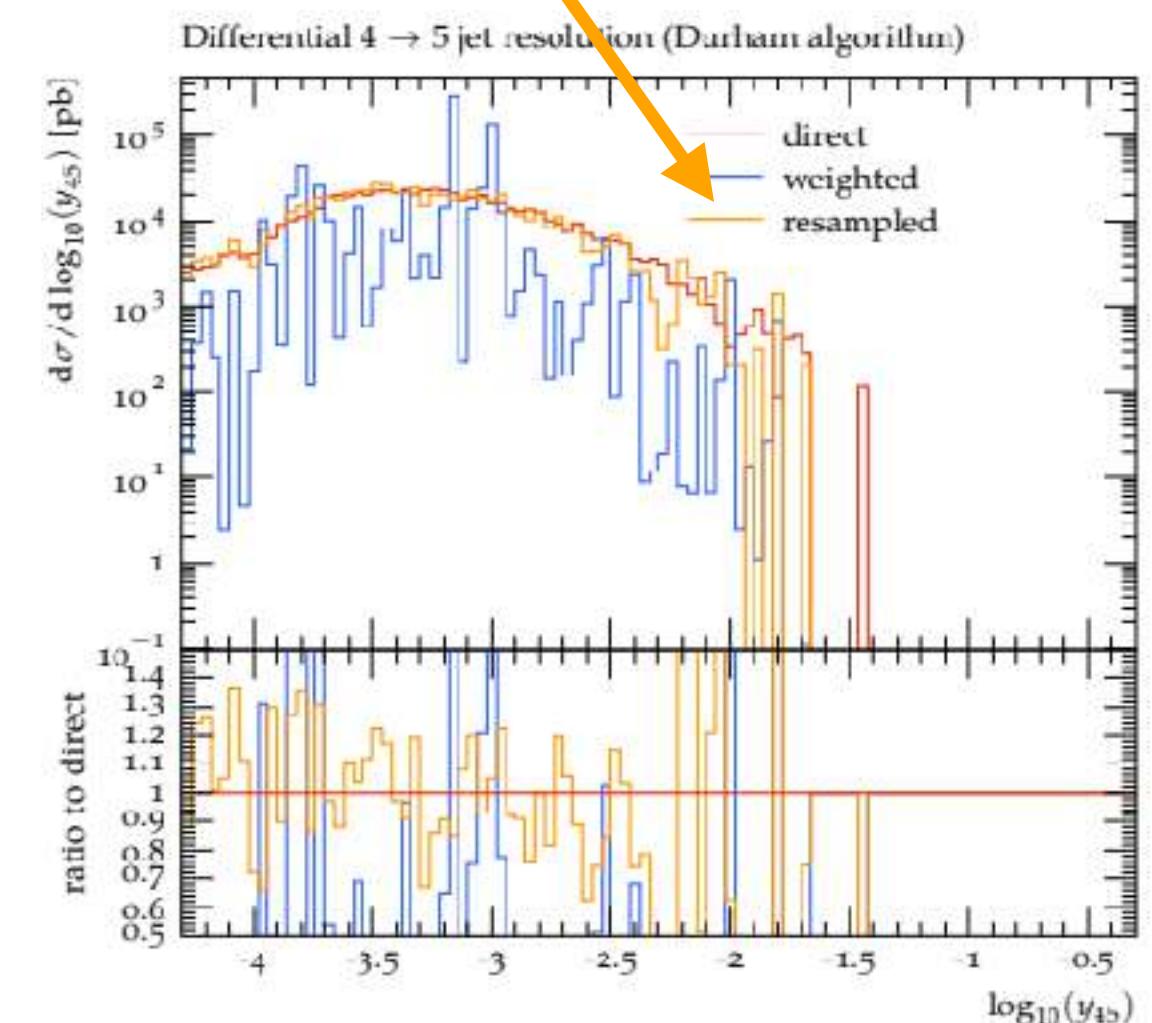
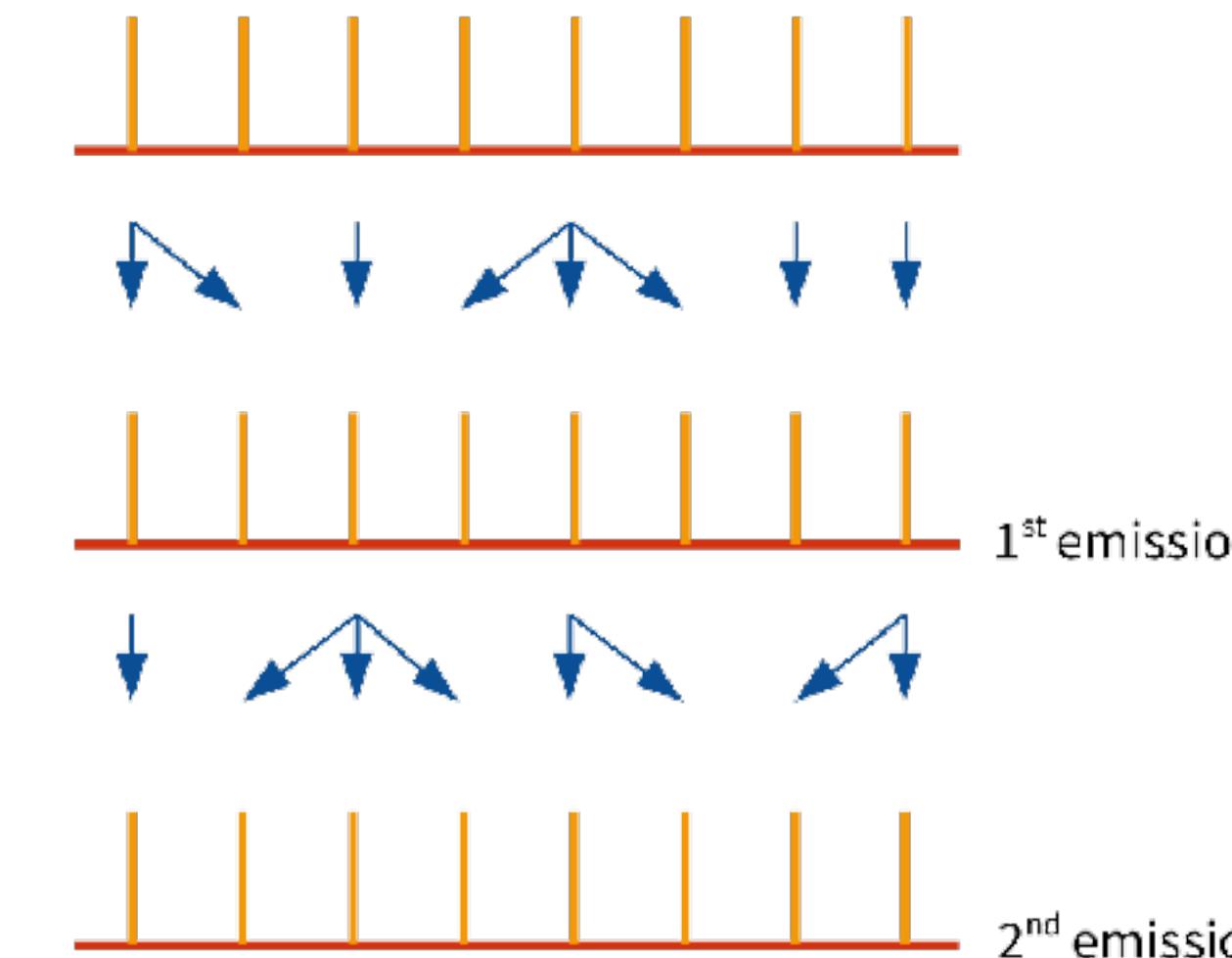
Result without resampling

Result with resampling

Resampling algorithms can compress weight distributions at intermediate steps.

Different resampling method developed as event generator after-burner.

[Andersen, Gütschow, Maier, Prestel — EPJ C 80 (2020) 11]



Amplitude level evolution sets level of complexity to understand and design parton shower and resummation algorithms: both for incremental improvements and in its own right.

Crucial to address effects of Coulomb/Glauber phases, factorisation violation, super-leading logarithms, ... — otherwise out of reach.

Investigate soft gluon effects at two loops (and related):

- Understand colour structures for many external legs and systematically expand around large- N limit.
- Design resummation of non-global observables beyond leading log and leading- N , investigate phases.
- Key ingredient for decisive statements about most flexible parton showers beyond leading order.

Thank you!

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