Jet Evolution Through Multiple In-Medium Soft Gluon Emissions

Fabio Dominguez
IPhT CEA-Saclay CNRS

In collaboration with Jean-Paul Blaizot, Edmond Iancu, and Yacine Mehtar-Tani

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Color Coherence

Jets in vacuum

- Angular ordering implies jets are highly collimated
- Fundamental to understand jet fragmentation

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  - ⋆ Full decoherence: independent emissions

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Understanding decoherence is fundamental to understand modified jet fragmentation

Single medium-induced gluon emission

- BDMPS-Z formalism
  - Emitted gluons acquire transverse momenta through multiple scatterings with the medium

$$\omega \frac{dN}{d\omega} = \frac{C_F \alpha_s}{\pi} \sqrt{\frac{\hat{q} L^2}{\omega}} \propto \alpha_s \frac{L}{t_f} \qquad t_f = \sqrt{\frac{\omega}{\hat{q}}}$$

Soft emissions have short formation times

Multiple emissions become important for: $\alpha_s \frac{L}{t_f} \sim 1$

Formation time

- Medium-induced emission can happen anywhere in the medium
- Medium contribution scales like the length of the medium
- Formation time refers to the time it takes to decorrelate the gluon from the parent parton

- Emitted gluons take time to pick up transverse momentum
- Soft gluons are emitted at large angles
- Soft gluons decorrelate faster

From single emission to multiple branchings

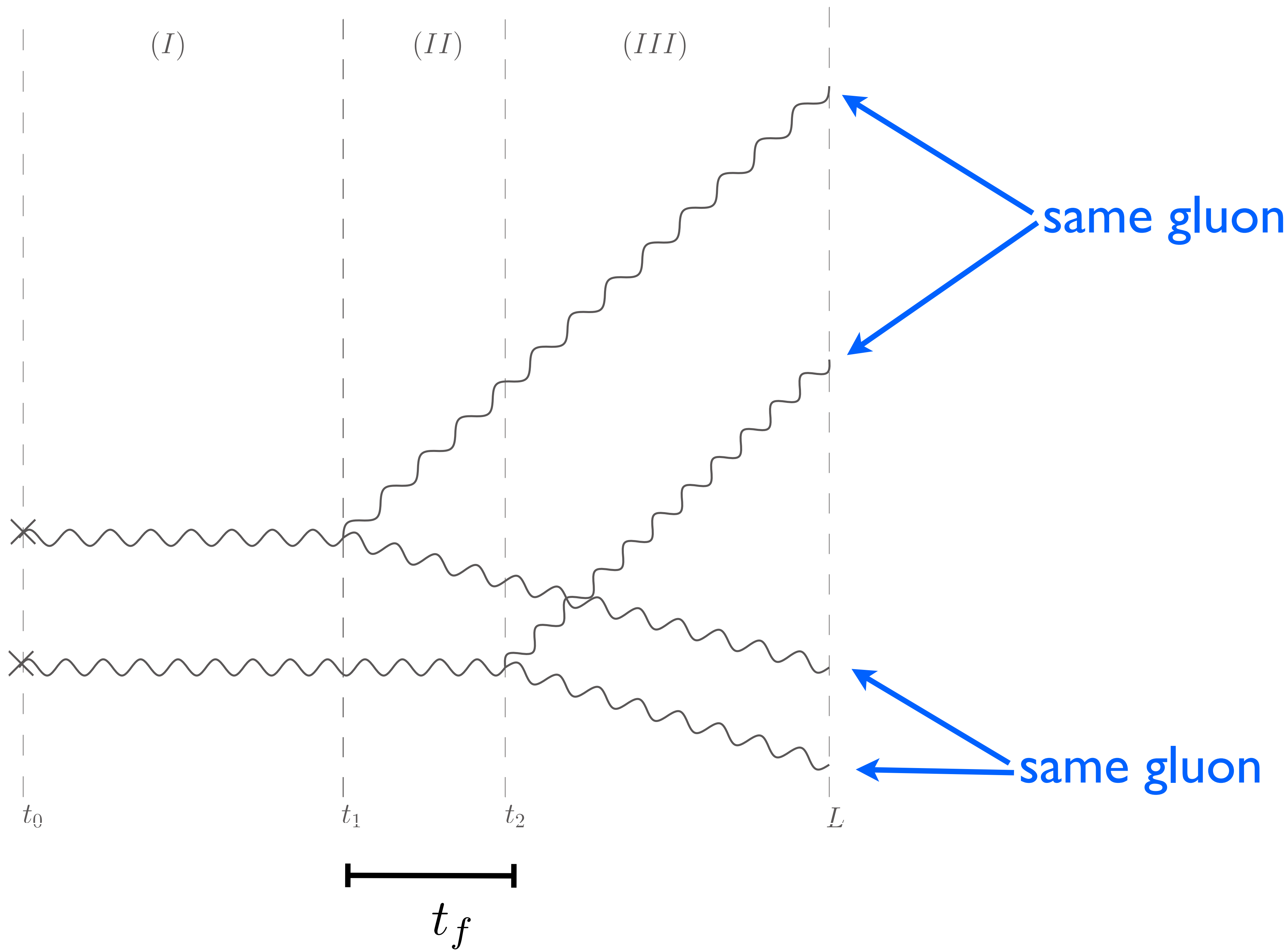
- Soft emissions not necessarily come from leading parton

  Relax eikonal approximation

- Determine the role of interferences

  Relation between decoherence time and formation time

Structure of gluon branching



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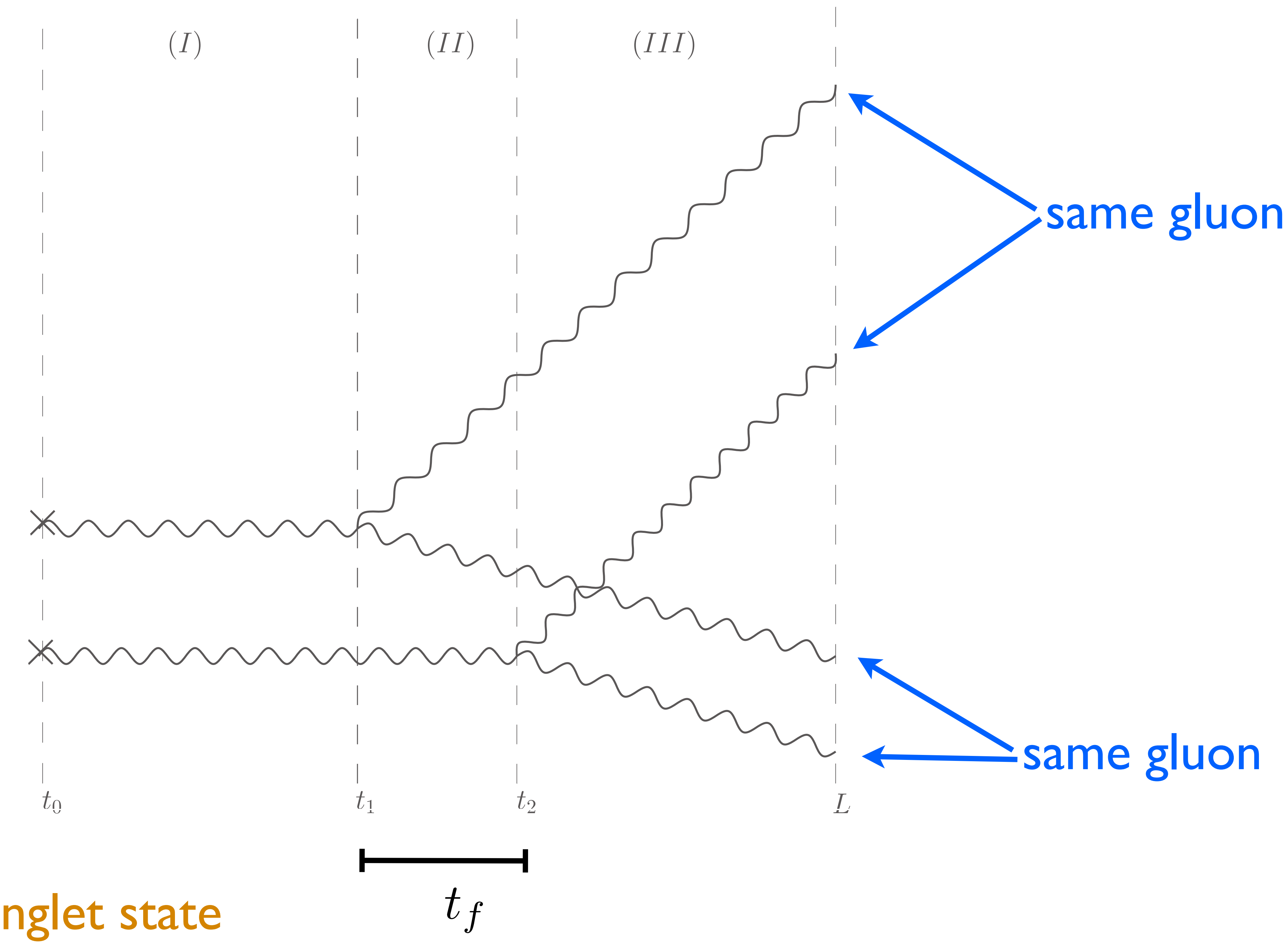

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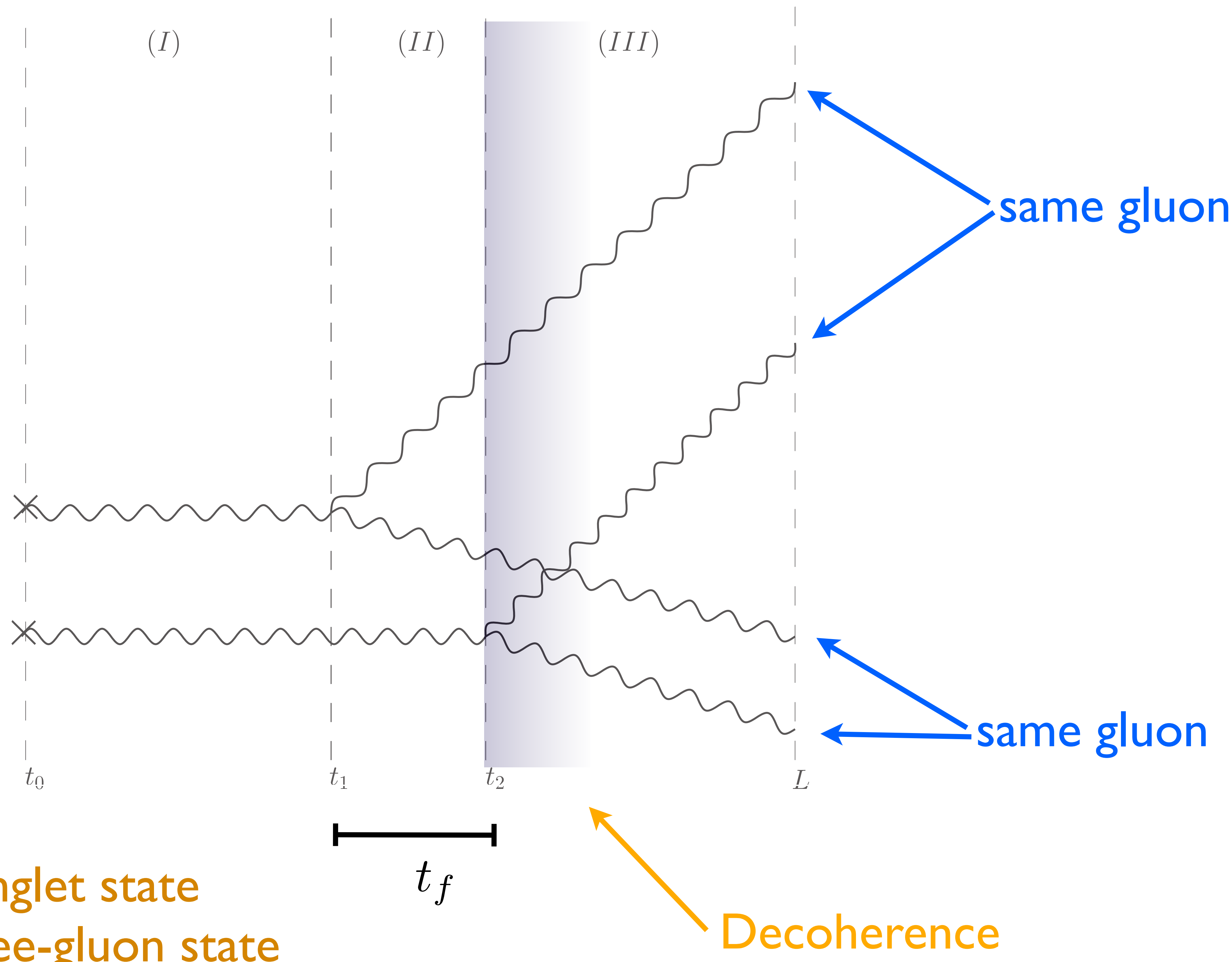

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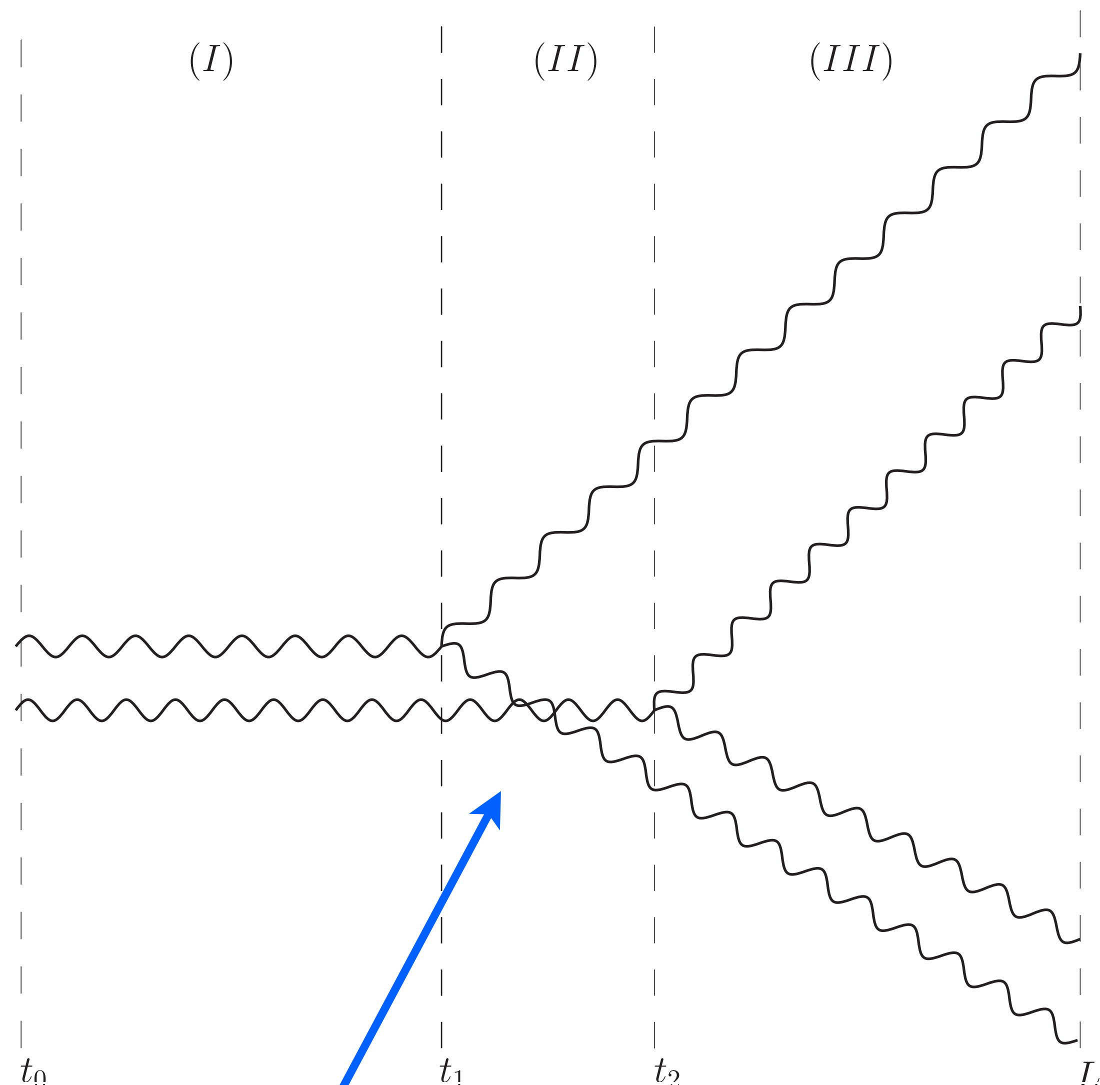


t_f

Kernel

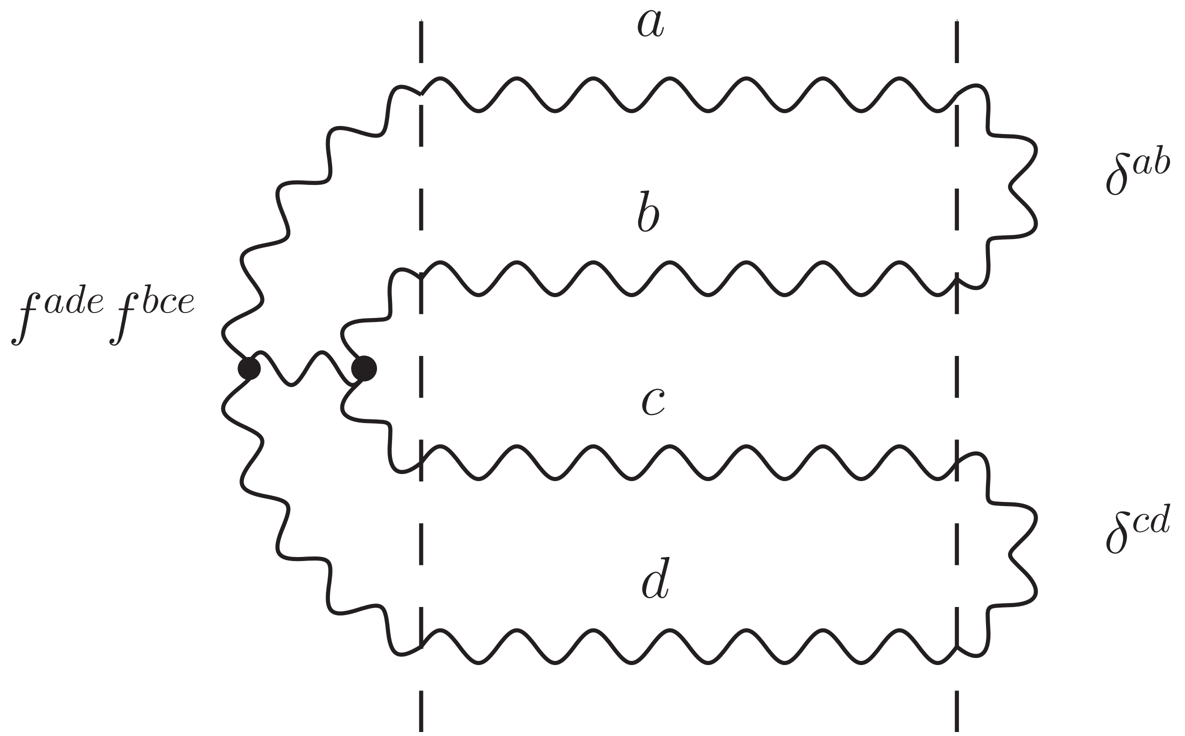
$\mathcal{K}$

Factorized propagation

$$S^{(4)} \equiv \left\langle \mathcal{G}_1 \mathcal{G}_2 \mathcal{G}_1^\dagger \mathcal{G}_2^\dagger \right\rangle$$

$$= \left\langle \mathcal{G}_1 \mathcal{G}_1^\dagger \right\rangle \left\langle \mathcal{G}_1 \mathcal{G}_1^\dagger \right\rangle + \mathcal{O}\left(\frac{t_f}{L}\right)$$

Factorization of two-gluon propagation



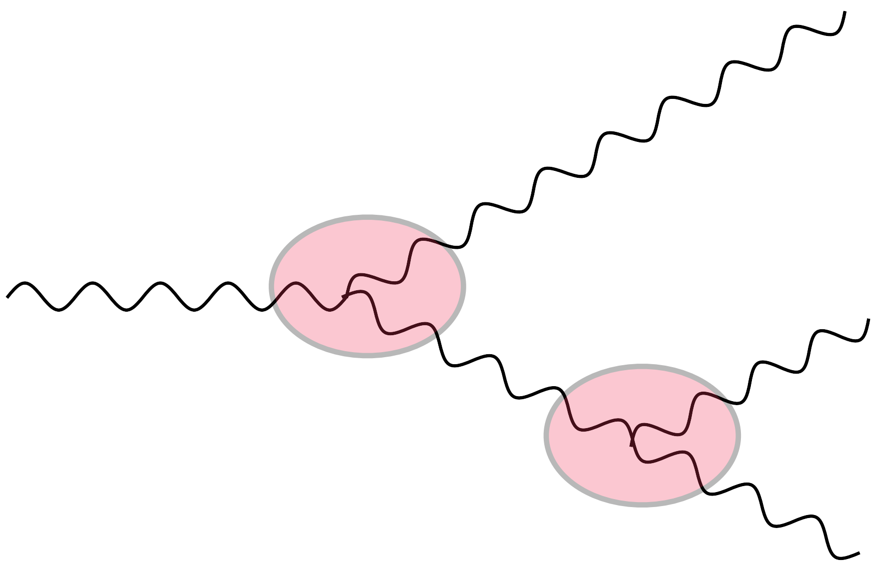
- For large number of colors, the medium average can be explicitly performed and the point of the transition singled out

- The time scale for such a transition is given by the formation time

Consequences of short formation times

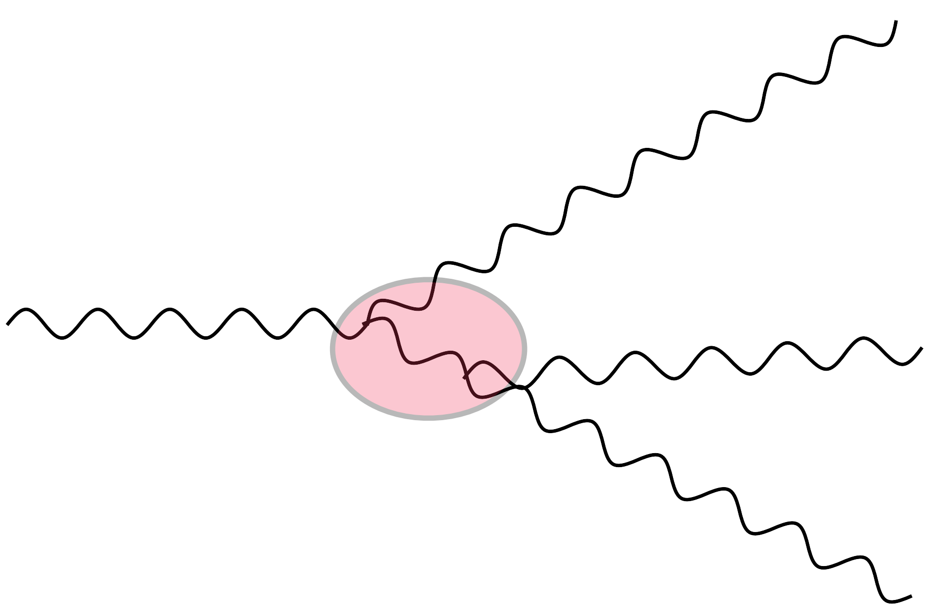
- Splitting process is semi-local
- Propagation of two-gluon system factorizes into independent propagation
- Overlapping emissions are suppressed by factors of $\frac{t_f}{L}$
- Interferences are a subleading effect

Interferences



$$\sim \left(\alpha_s \frac{L}{t_f}\right)^2$$

Independent emissions are enhanced by the medium length



$$\sim \alpha_s^2 \frac{L}{t_f}$$

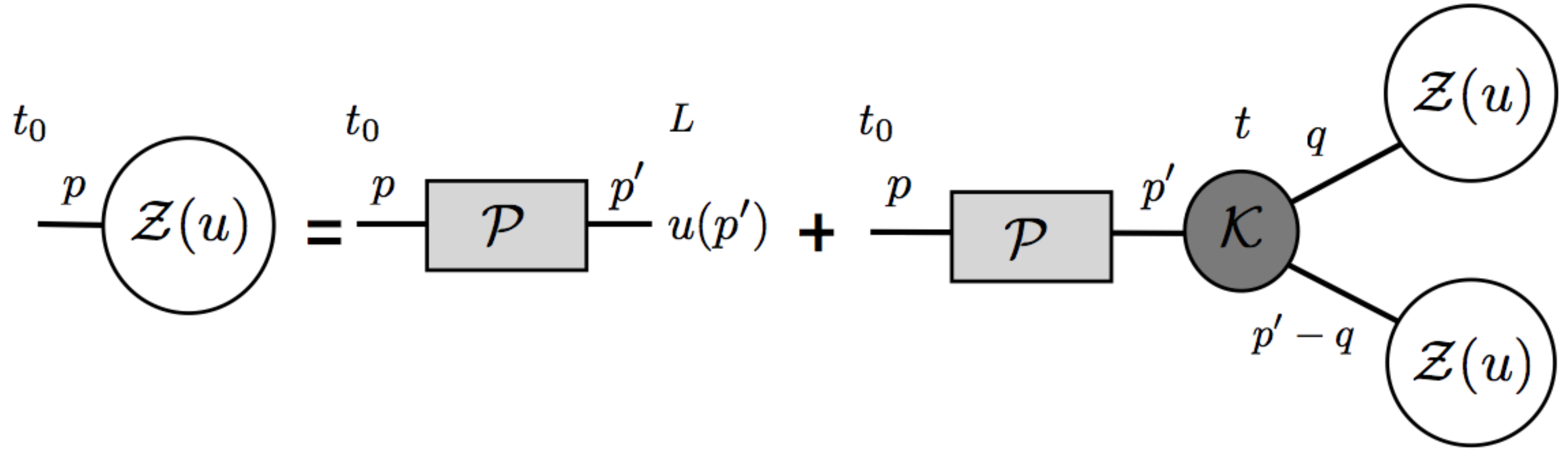
Interferences II

- Interferences between emissions from different sources are important only if they occur sufficiently close to previous splitting

- For dynamical case,

  decoherence time = formation time

Probabilistic picture



$$\mathcal{Z}(\mathbf{p}, L-t_0|u) = \Delta(p^+, L-t_0)\int\frac{d\mathbf{p}'}{(2\pi)^2}\,\mathcal{P}(\mathbf{p}'-\mathbf{p}, L-t_0)\,u(\mathbf{p}') + \alpha_s\int_{t_0}^{L} dt\,\Delta(p^+, t-t_0)$$

$$\times\int_0^1\frac{dz}{z}\int\frac{d\mathbf{p}'}{(2\pi)^2}\mathcal{P}(\mathbf{p}'-\mathbf{p}, L-t_0)\int\frac{d\mathbf{q}}{(2\pi)^2}\,\mathcal{K}(\mathbf{q}-z\mathbf{p}'|z)\,\mathcal{Z}(\mathbf{q}, L-t|u)\,\mathcal{Z}(\mathbf{p}'-\mathbf{q}, L-t|u)$$

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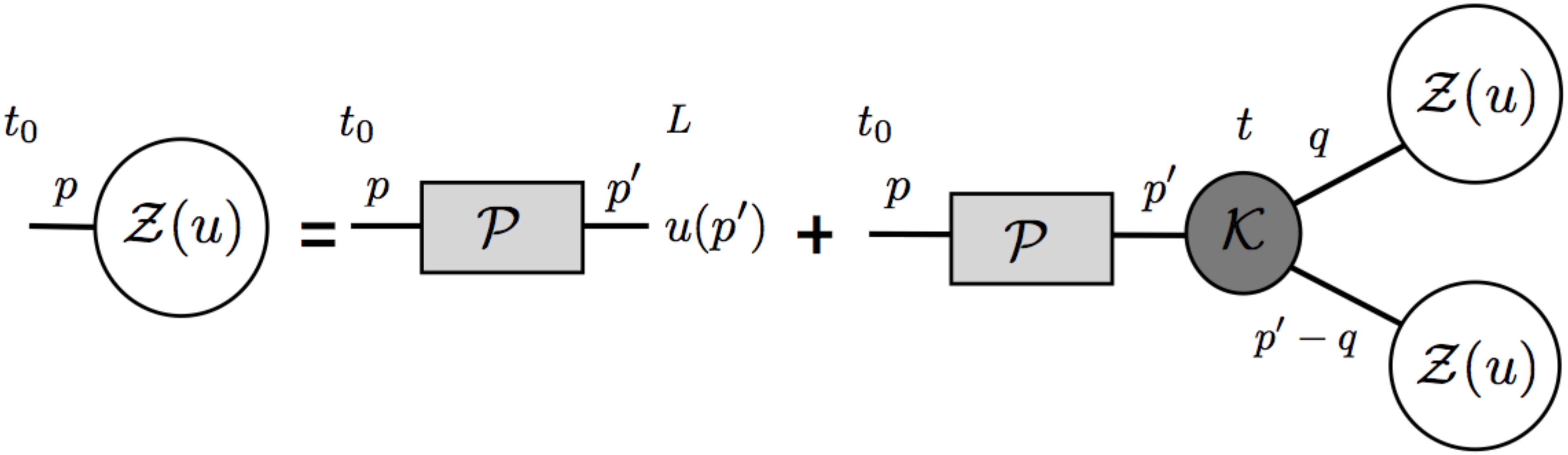

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Transverse momentum broadening

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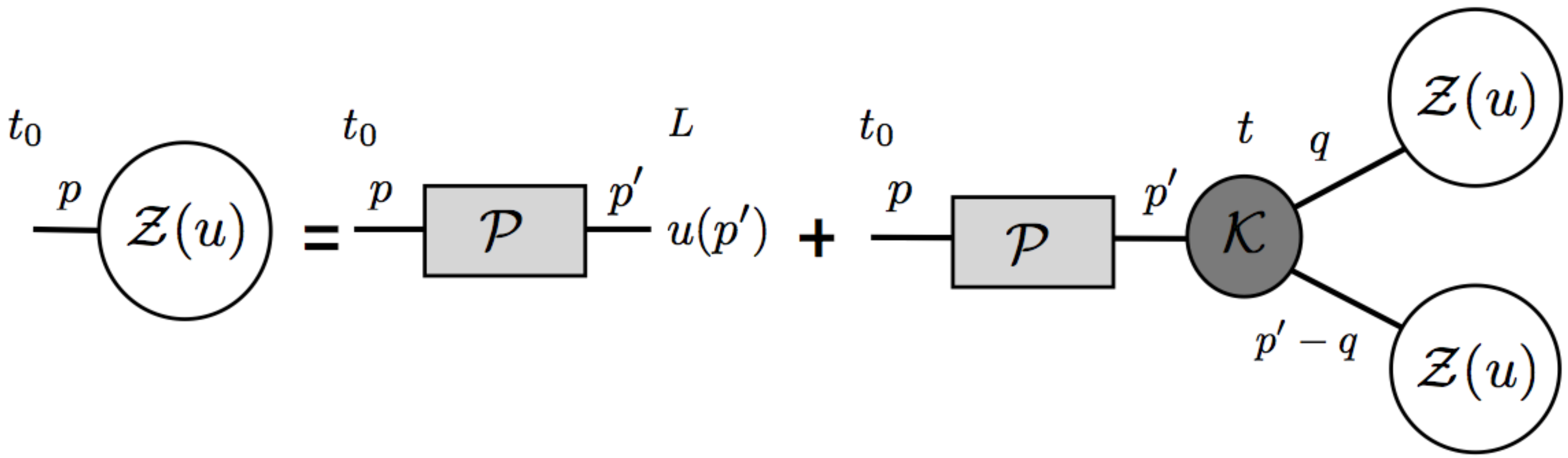

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Transverse momentum broadening

In-medium splitting kernel: $\mathcal{K}_g(\mathbf{q}, z) \approx \frac{2}{p^+} P_{gg}(z) \ \sin\left[\frac{\mathbf{q}^2}{2\mathbf{k}_\mathrm{f}^2}\right] \exp\left[-\frac{\mathbf{q}^2}{2\mathbf{k}_\mathrm{f}^2}\right]$

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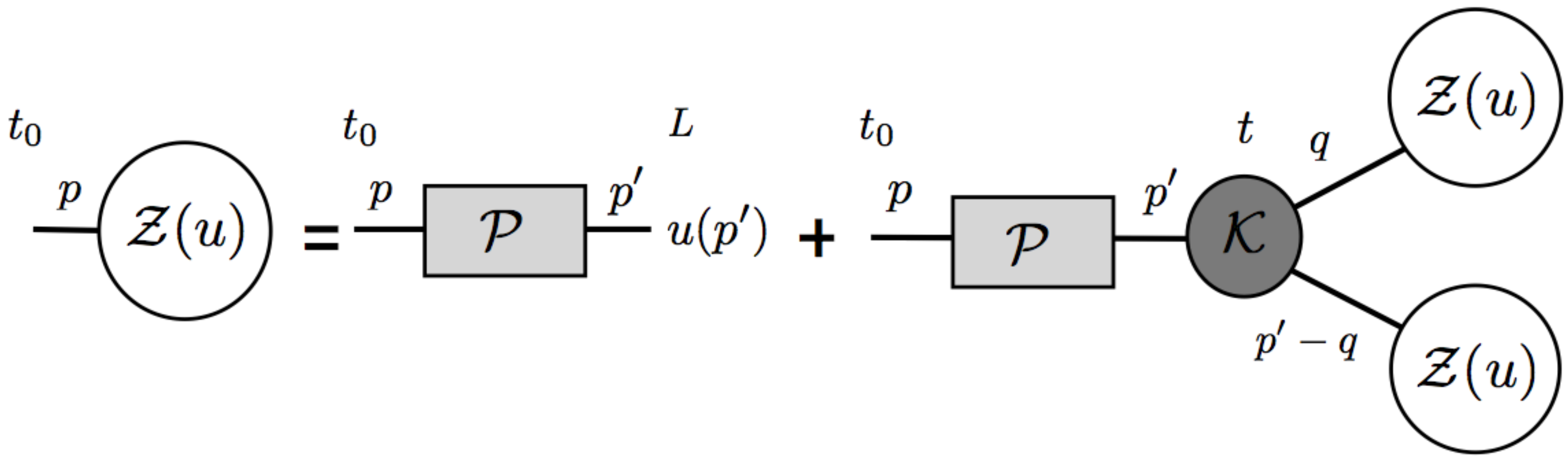

$$\mathcal{Z}(\mathbf{p}, L - t_0|u) = \Delta(p^+, L - t_0) \int \frac{d\mathbf{p}'}{(2\pi)^2} \mathcal{P}(\mathbf{p}' - \mathbf{p}, L - t_0) u(\mathbf{p}') + \alpha_s \int_{t_0}^{L} dt\, \Delta(p^+, t - t_0)$$

$$\times \int_0^1 \frac{dz}{z} \int \frac{d\mathbf{p}'}{(2\pi)^2} \mathcal{P}(\mathbf{p}' - \mathbf{p}, L - t_0) \int \frac{d\mathbf{q}}{(2\pi)^2} \mathcal{K}(\mathbf{q} - z\mathbf{p}'|z)\, \mathcal{Z}(\mathbf{q}, L - t|u)\, \mathcal{Z}(\mathbf{p}' - \mathbf{q}, L - t|u)$$

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Sudakov form factor $$\Delta(p^+, L - t_0) = \exp\left[-\alpha_s (L - t_0) \int_0^1 \frac{dz}{z} \mathcal{K}(z)\right]$$

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- Resums powers of $\alpha_s \frac{L}{t_f}$
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Only valid for soft sector in the full decoherence regime

Conclusion

- Two-gluon production factorizes in the limit of short formation times
- Interferences are unimportant for soft emissions
- Full medium-induced branching process can be set in a suitable way for MC implementation (generating functional)