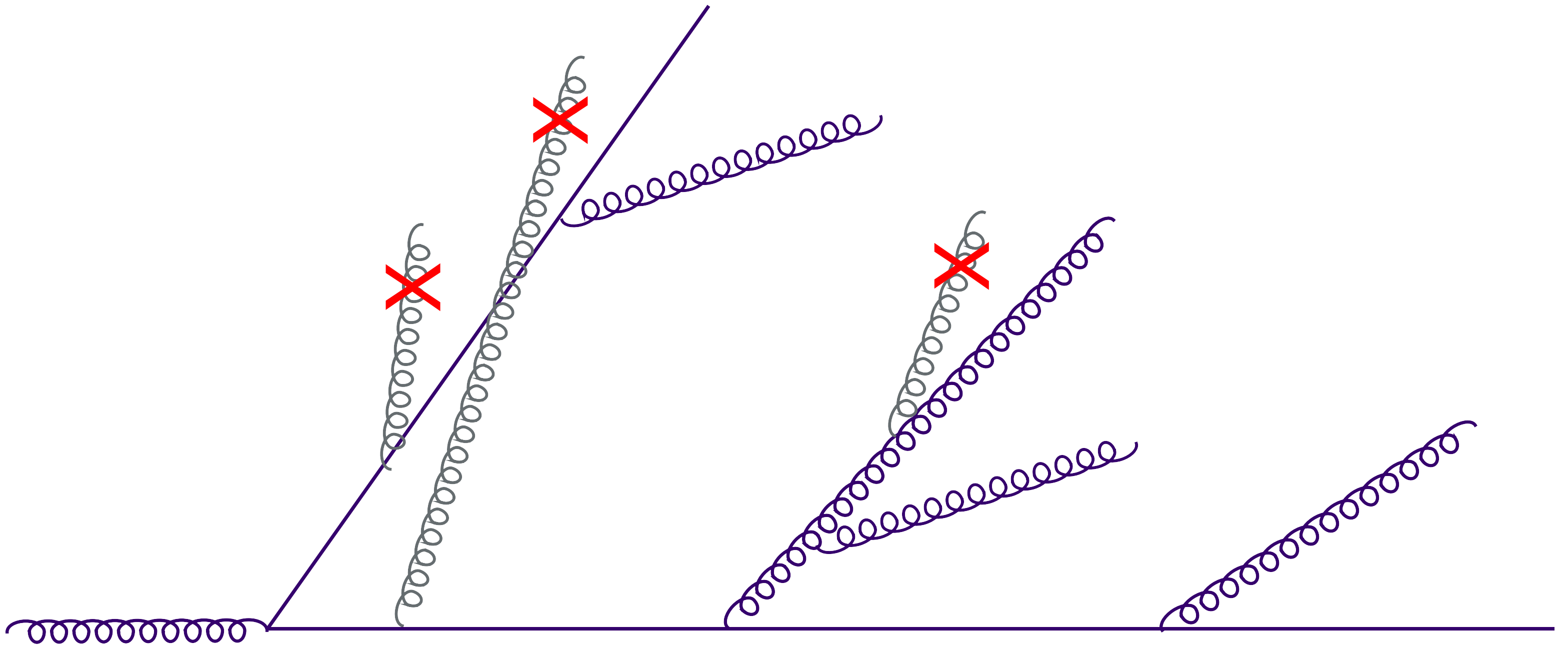
Interference Effects in Medium Induced Gluon Radiation

Jorge Casalderrey Solana
(in collaboration with E. Iancu)

arXiv:1105.1760

Motivation



- When partons propagate through the QGP they radiates gluons.

  What happens when two partons propagate simultaneously?

- Is there interference between more than one propagating source?

  In vacuum, interference is important ⇒ angular ordering

  Are in-medium showers angular ordered?

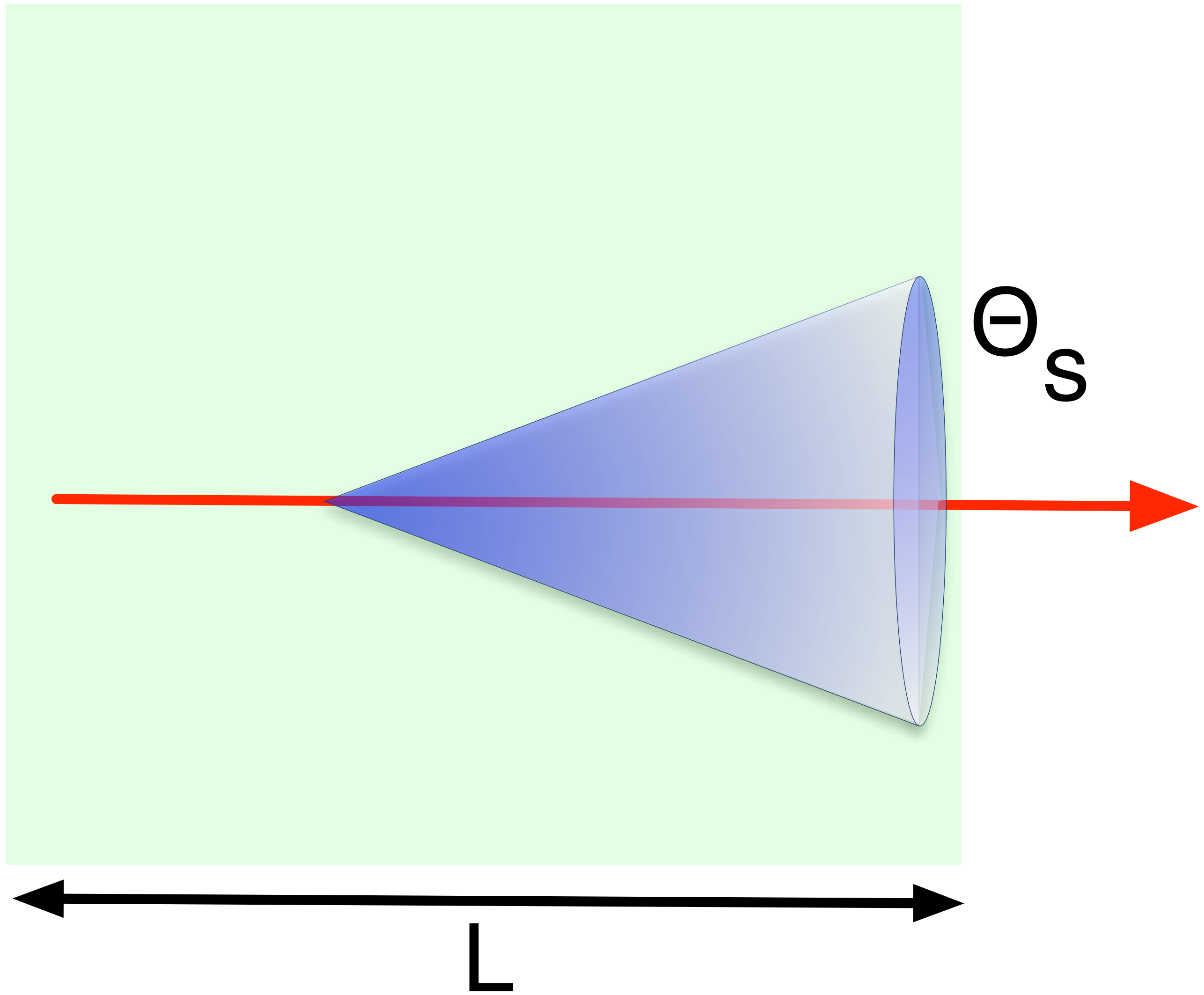
  Interesting angular distribution in N=1 opacity (Mehtar-Tani, Salgado, Tywoniuk 10)

  Is there a restriction on in-medium large angle emissions?

  important for the description of di-jet asymmetries

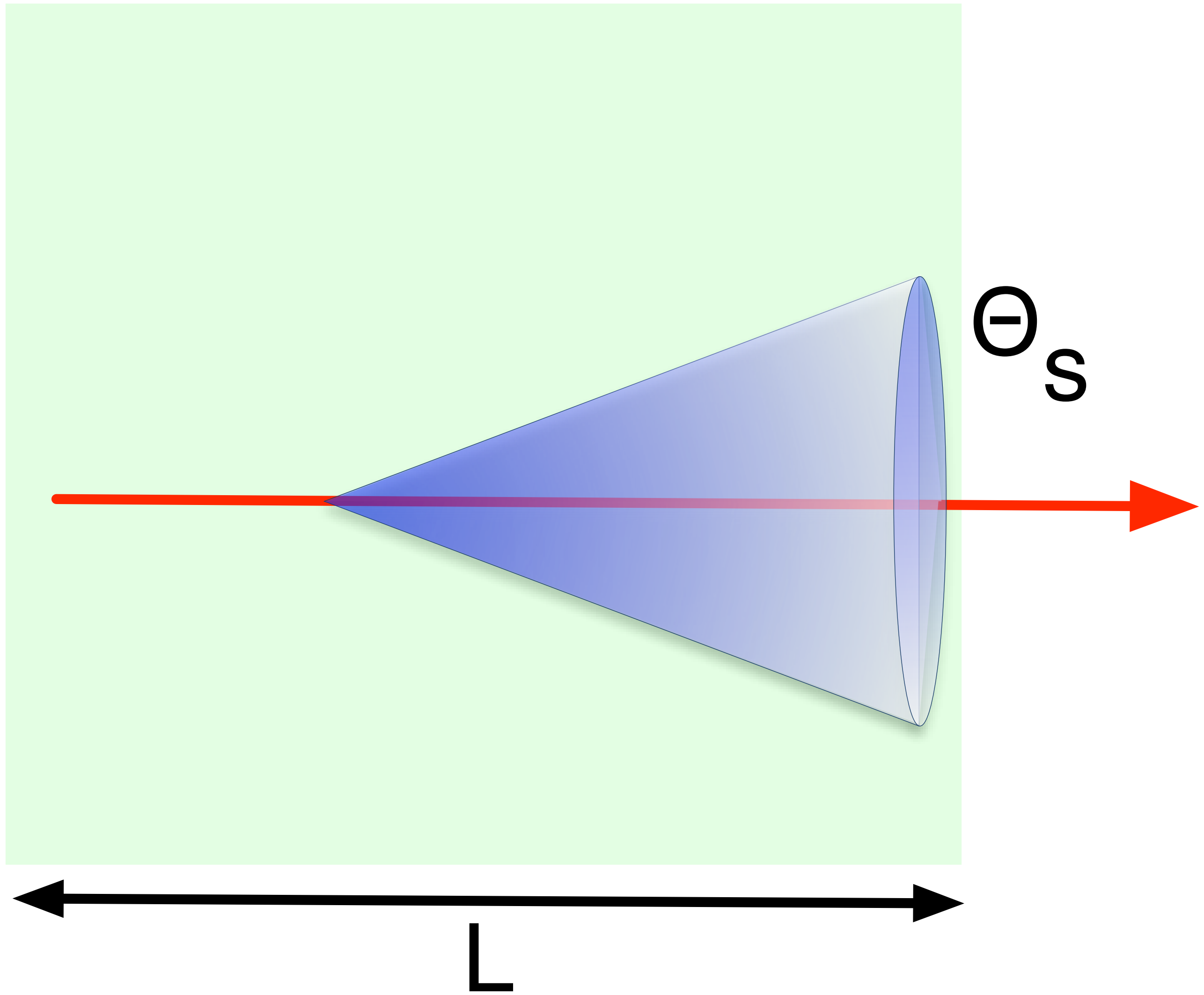
BDMPS-Z Radiation

$$\theta_s^2 = \frac{\hat{q}L}{\omega^2}$$



- Gluons are emitted with a typical angle Θ_s

BDMPS-Z Radiation



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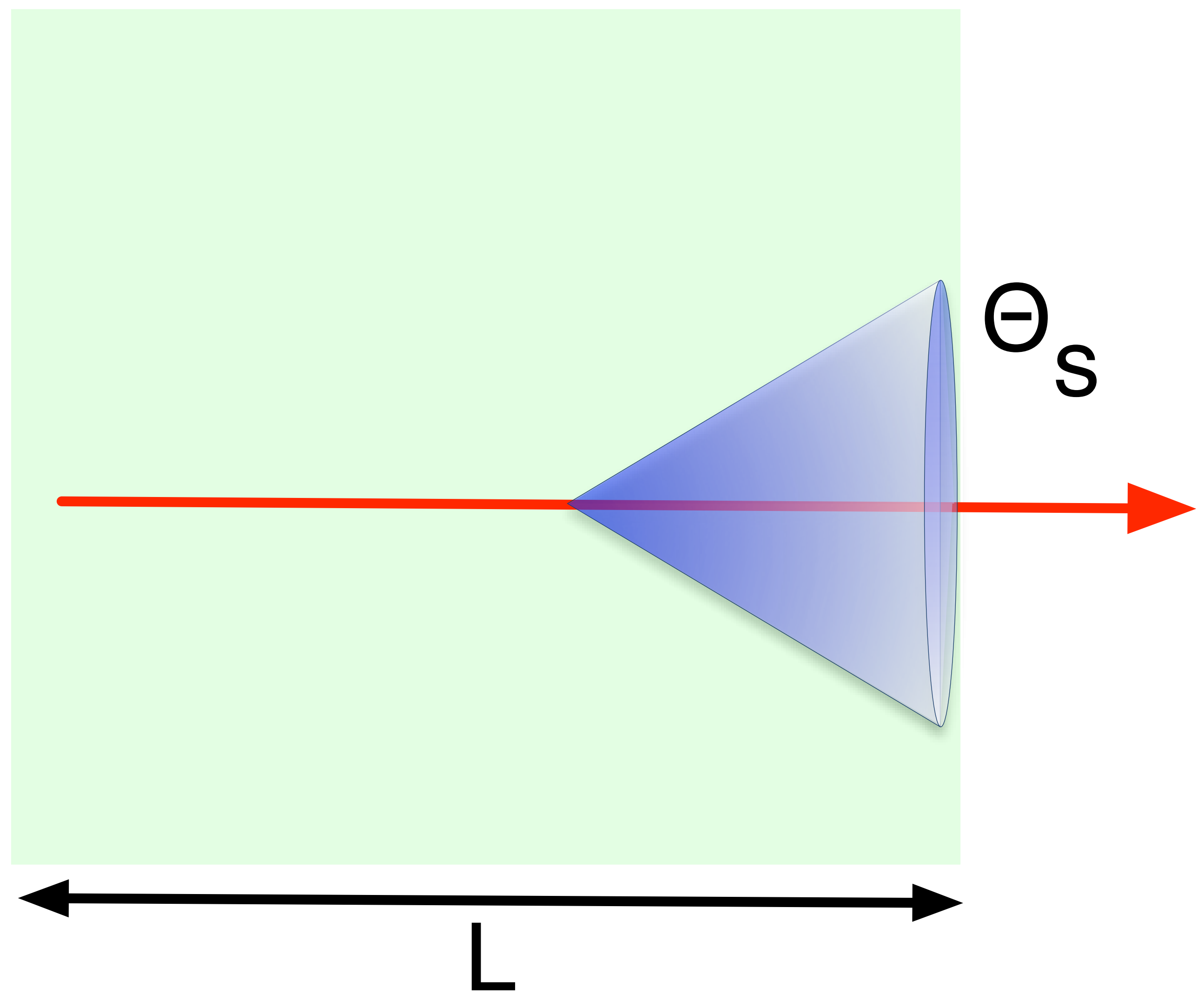

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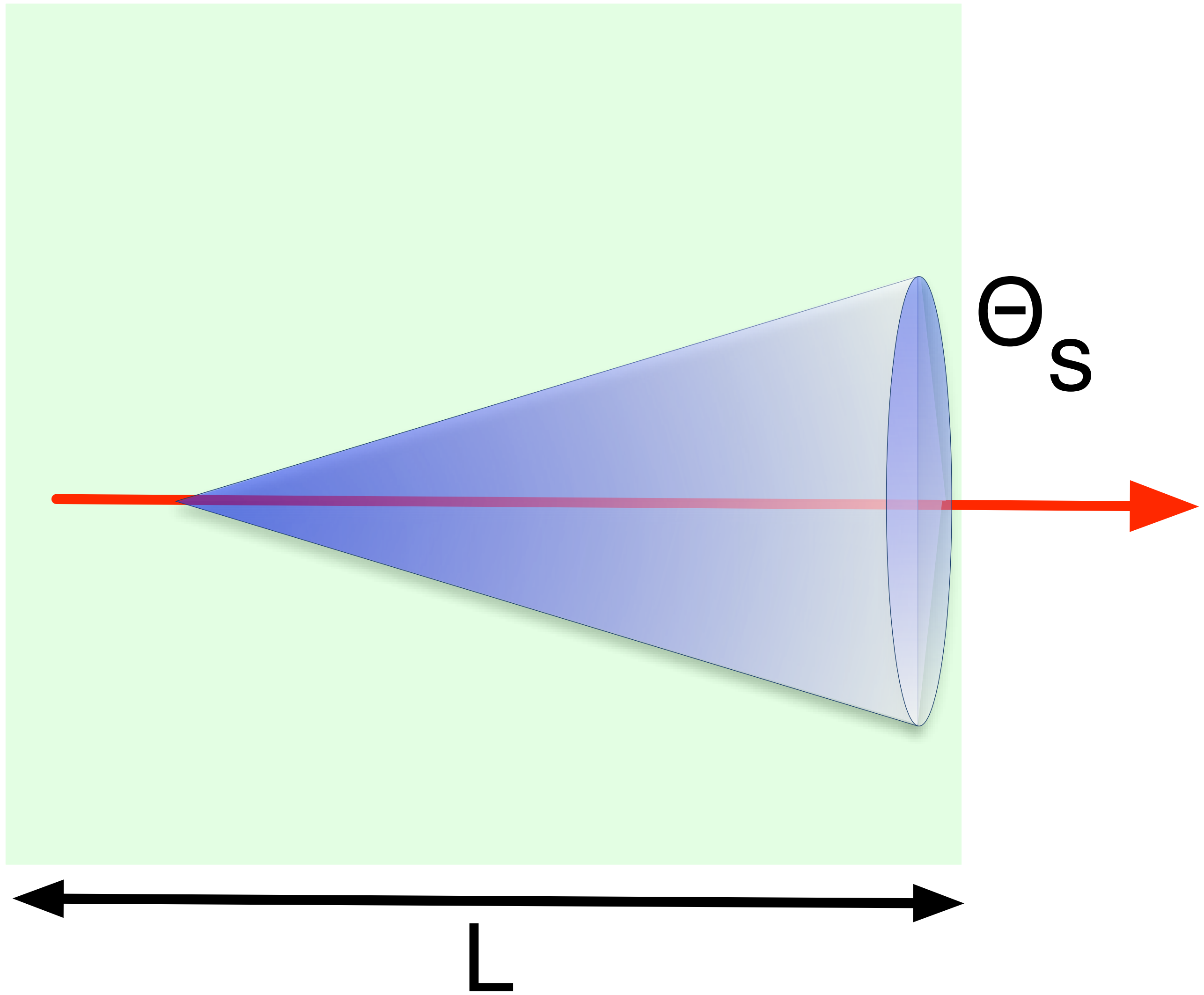

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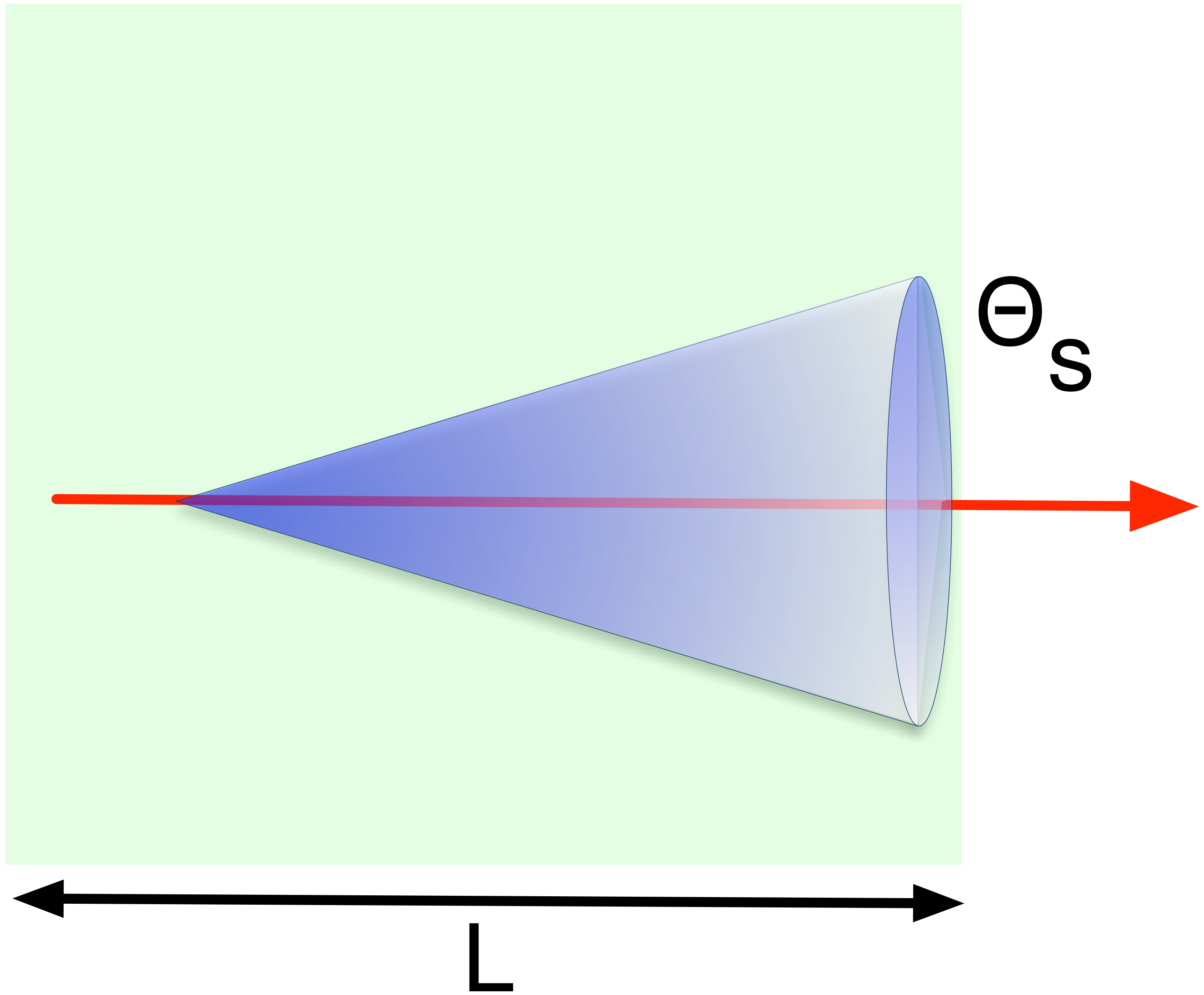

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- Emissions occur all along the medium: $dN \propto L$

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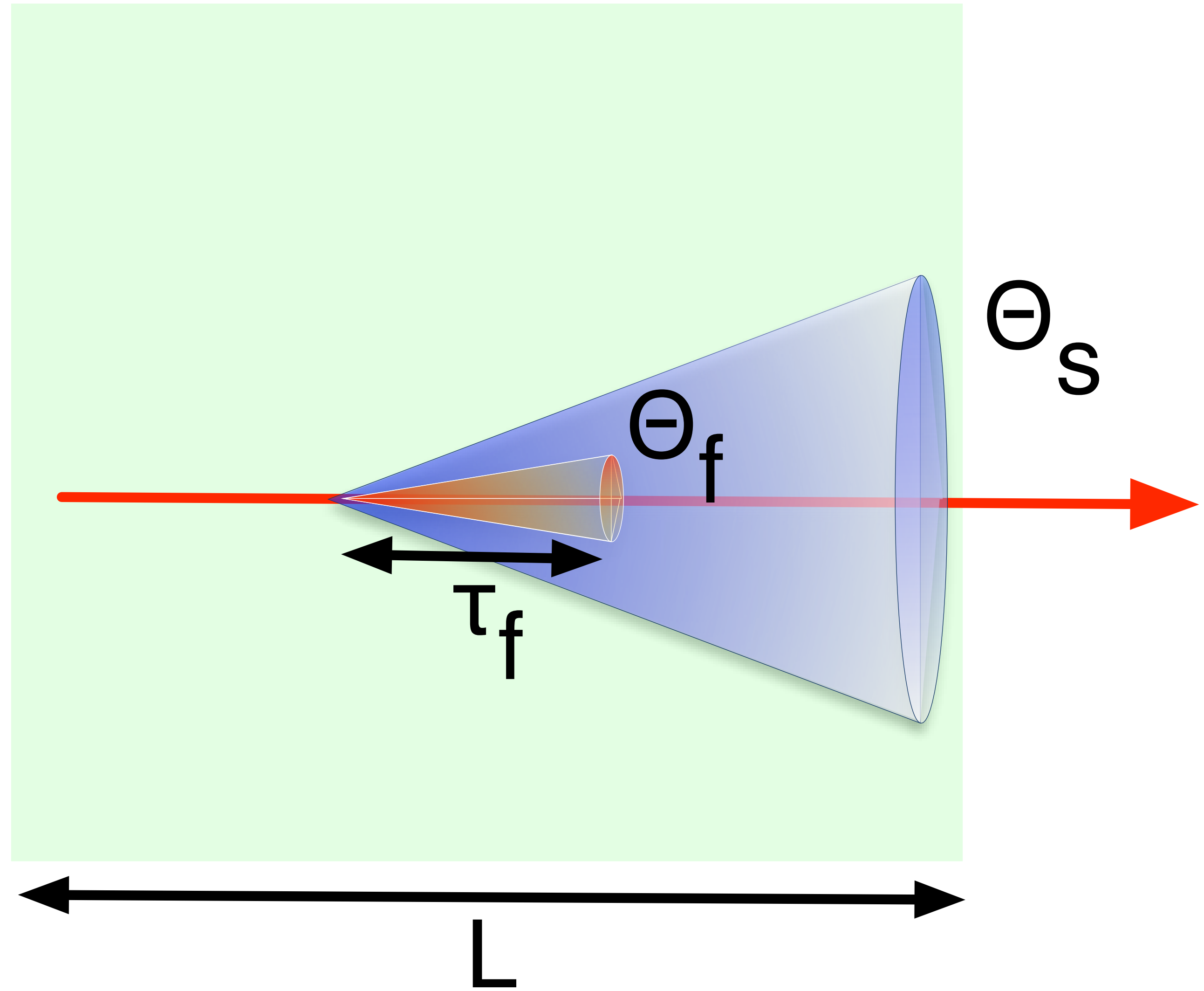

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- Soft gluons are formed (decohered) at a short time τ_f

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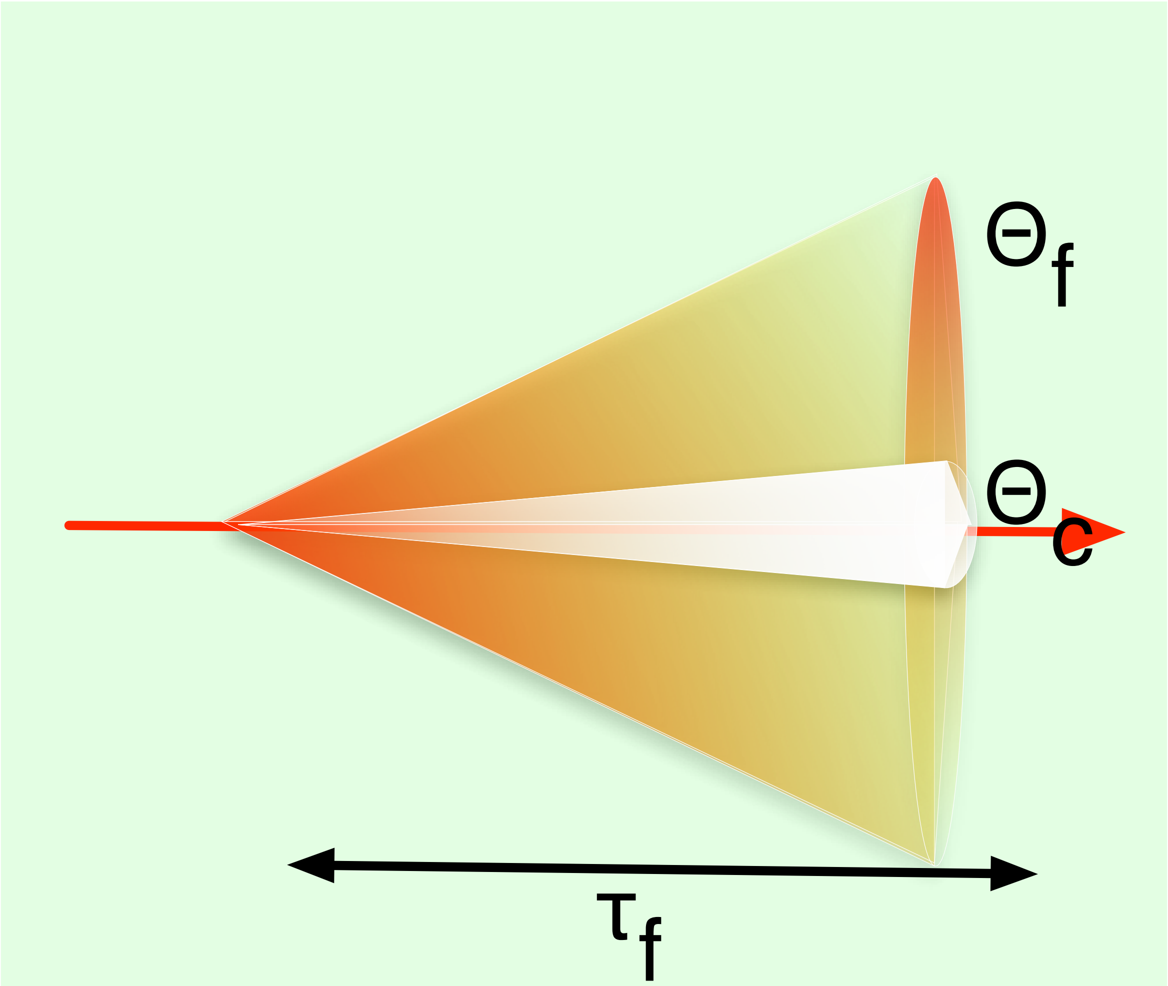

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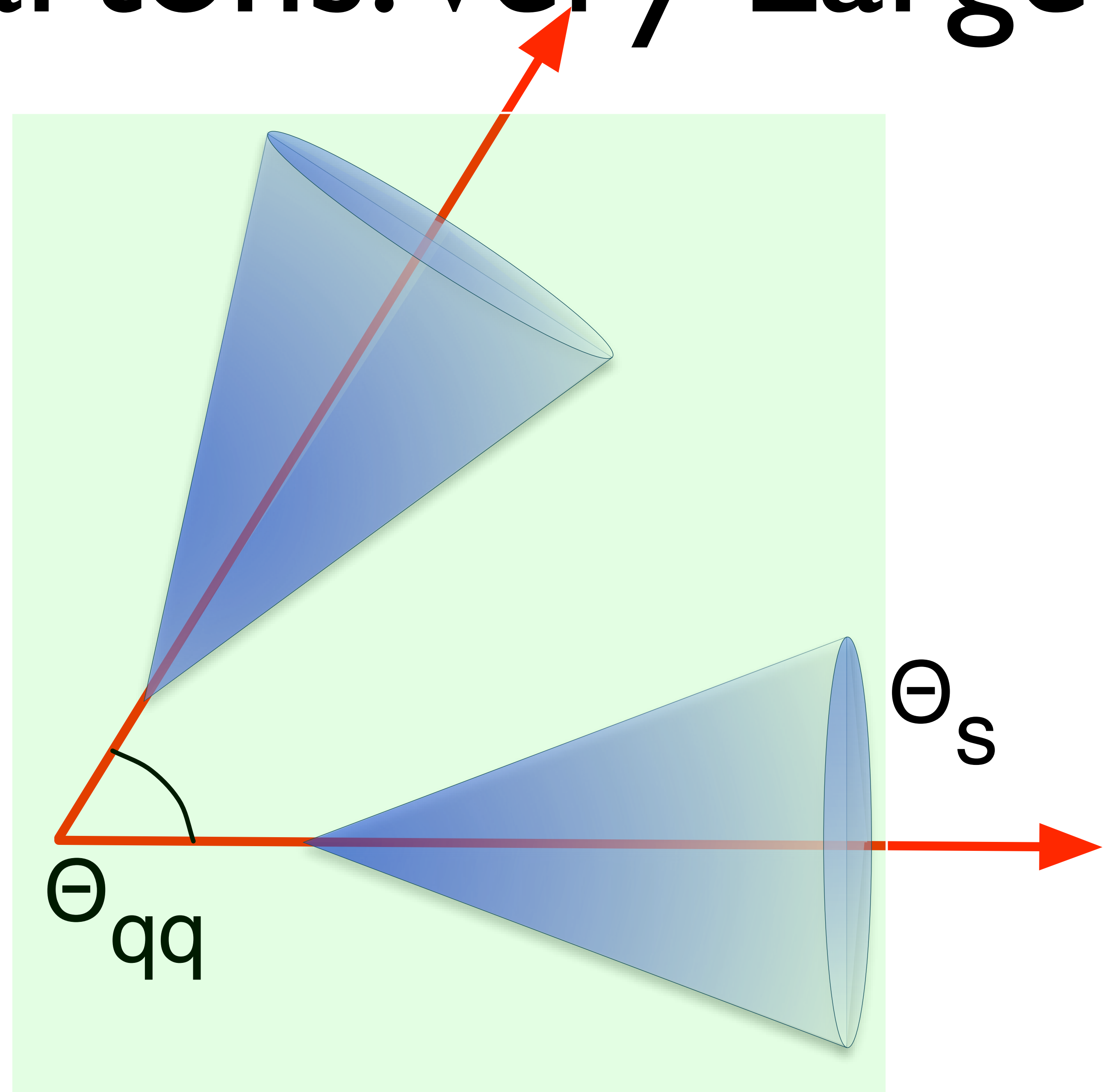
$$\theta_c^2 = \frac{1}{\hat{q}L^3}$$

- Gluons are emitted with a typical angle Θ_s
- Emissions occur all along the medium: $dN \propto L$
- Soft gluons are formed (decohered) at a short time τ_f
- There is a minimum value for emissions Θ_C

Two Partons: Very Large Angles



- Radiation from two sources propagating in plasma.
- $\Theta_{qq} >> \Theta_s$ the two fronts do not overlap

  No interference between BDMPS gluons

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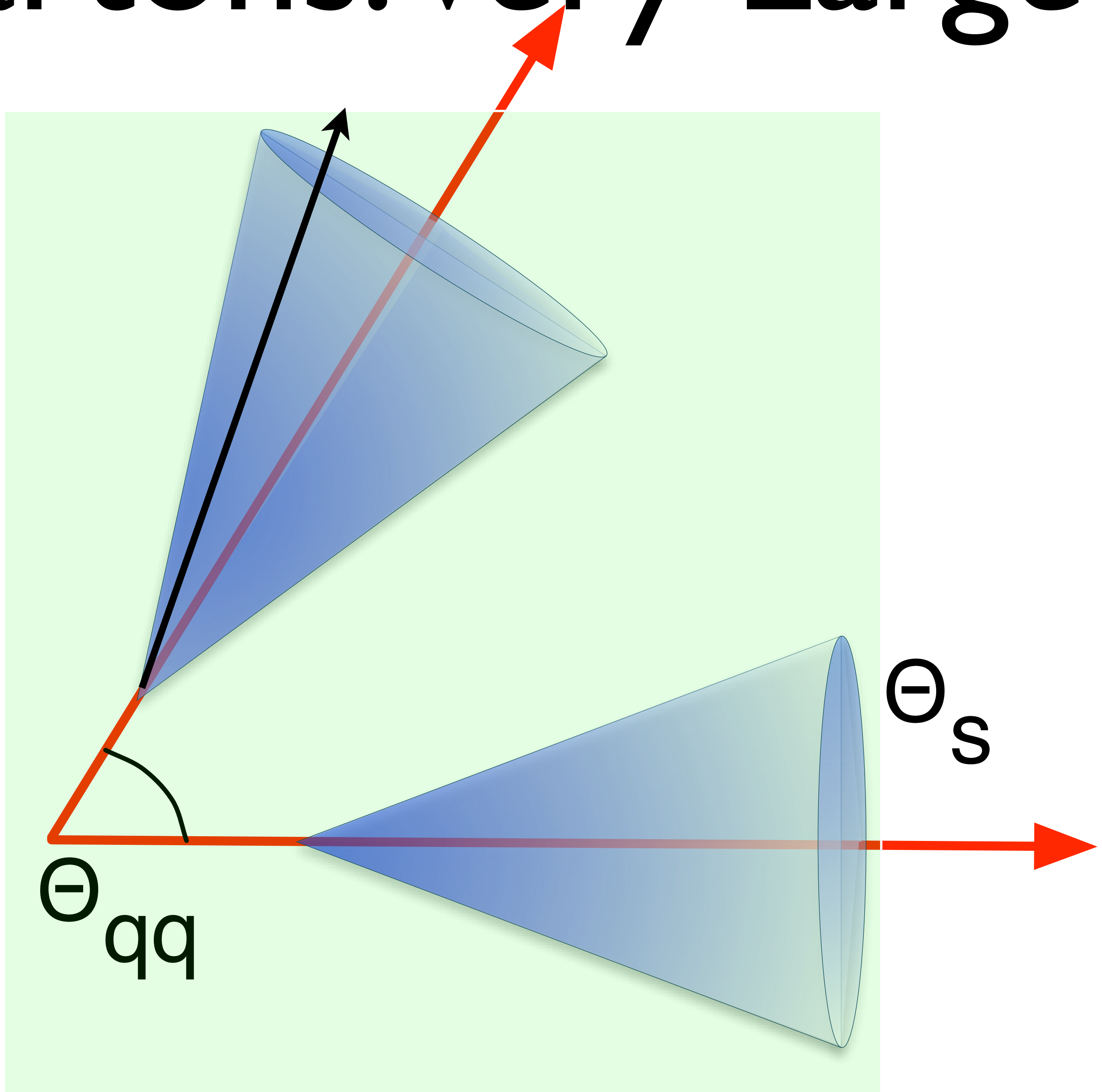

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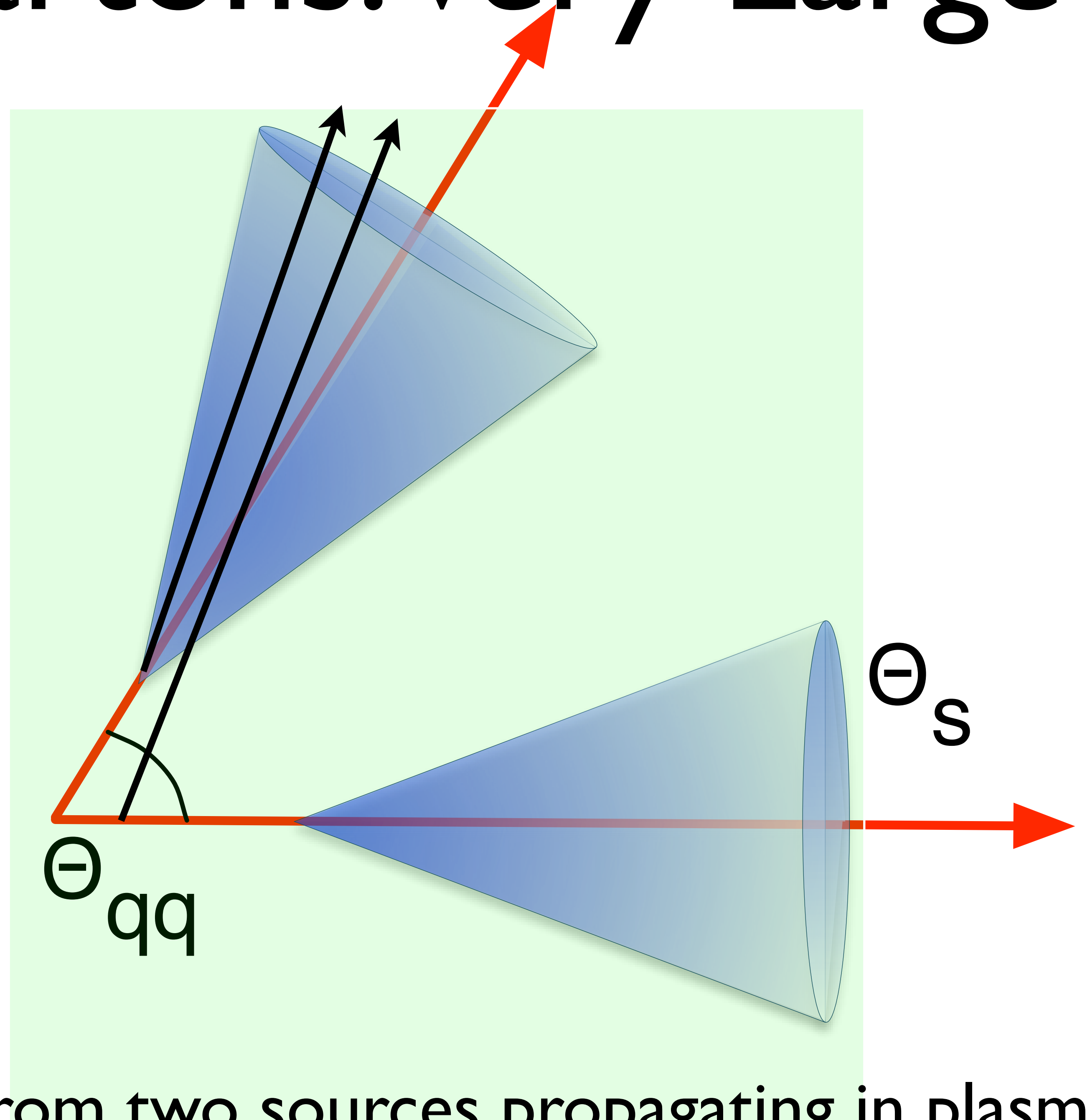

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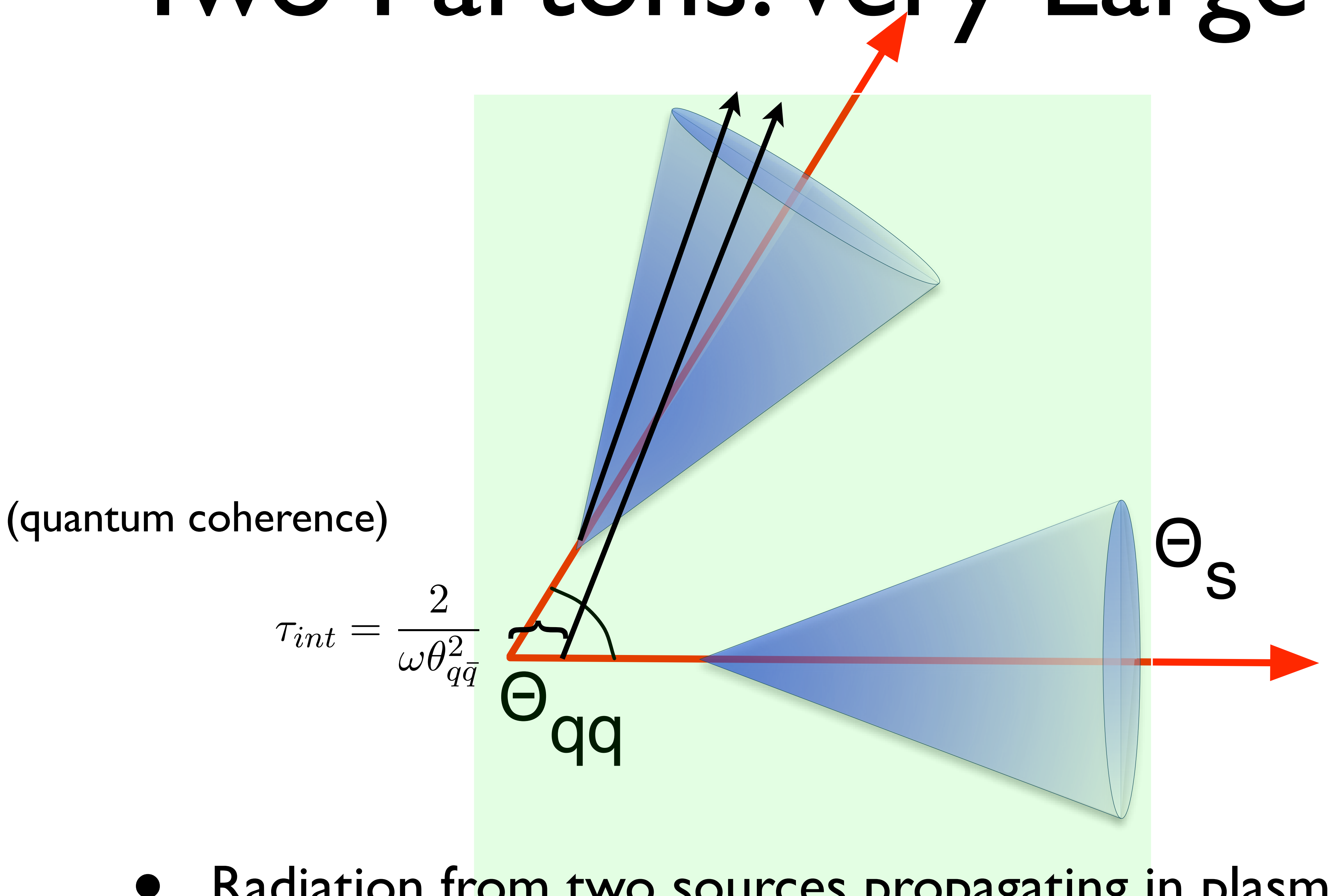

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- Interference contribution scales with $dI \propto \tau_{int}$

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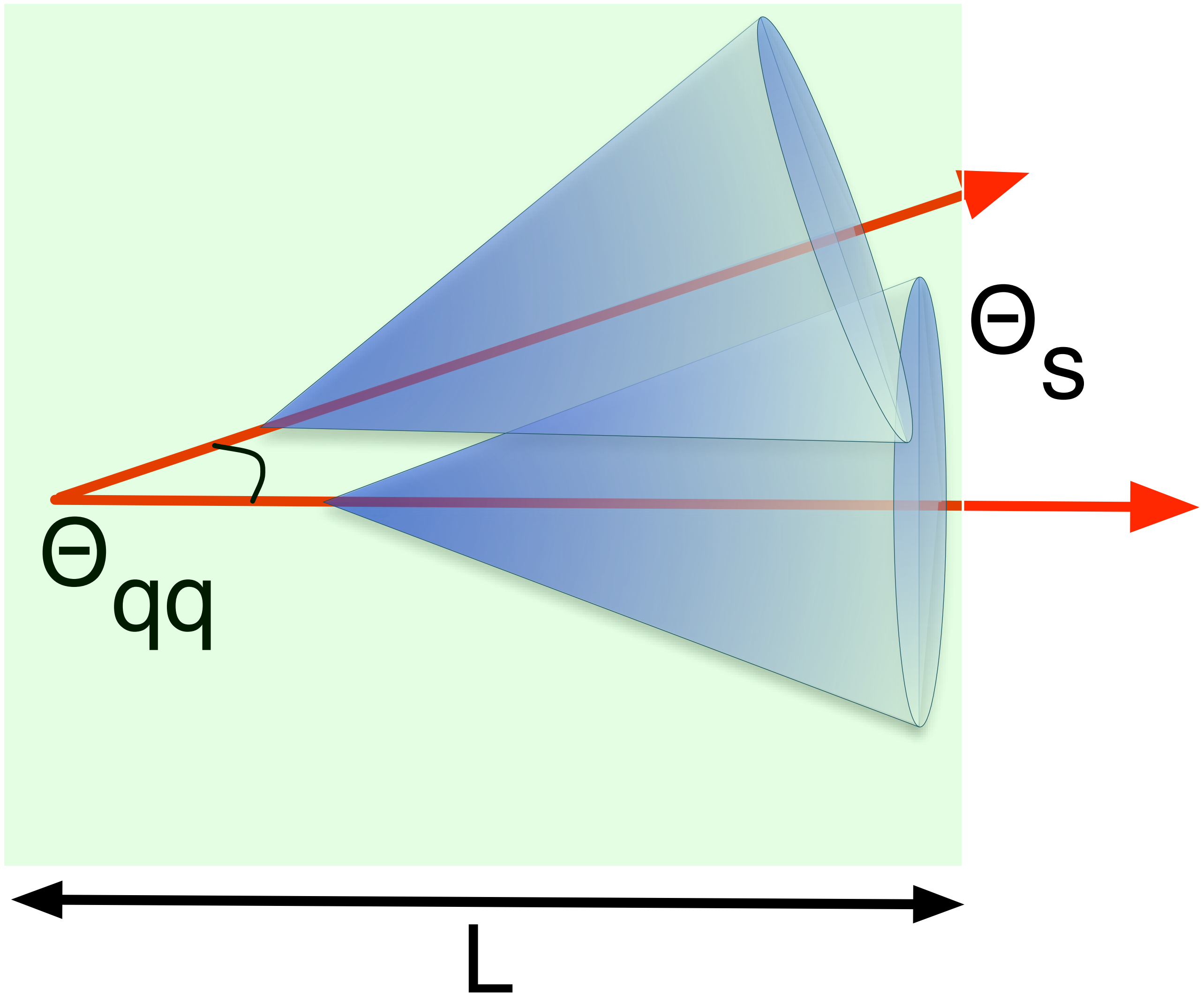

- The two fronts overlap when $\Theta_{qq} \leq \Theta_s$. Can they interfere?

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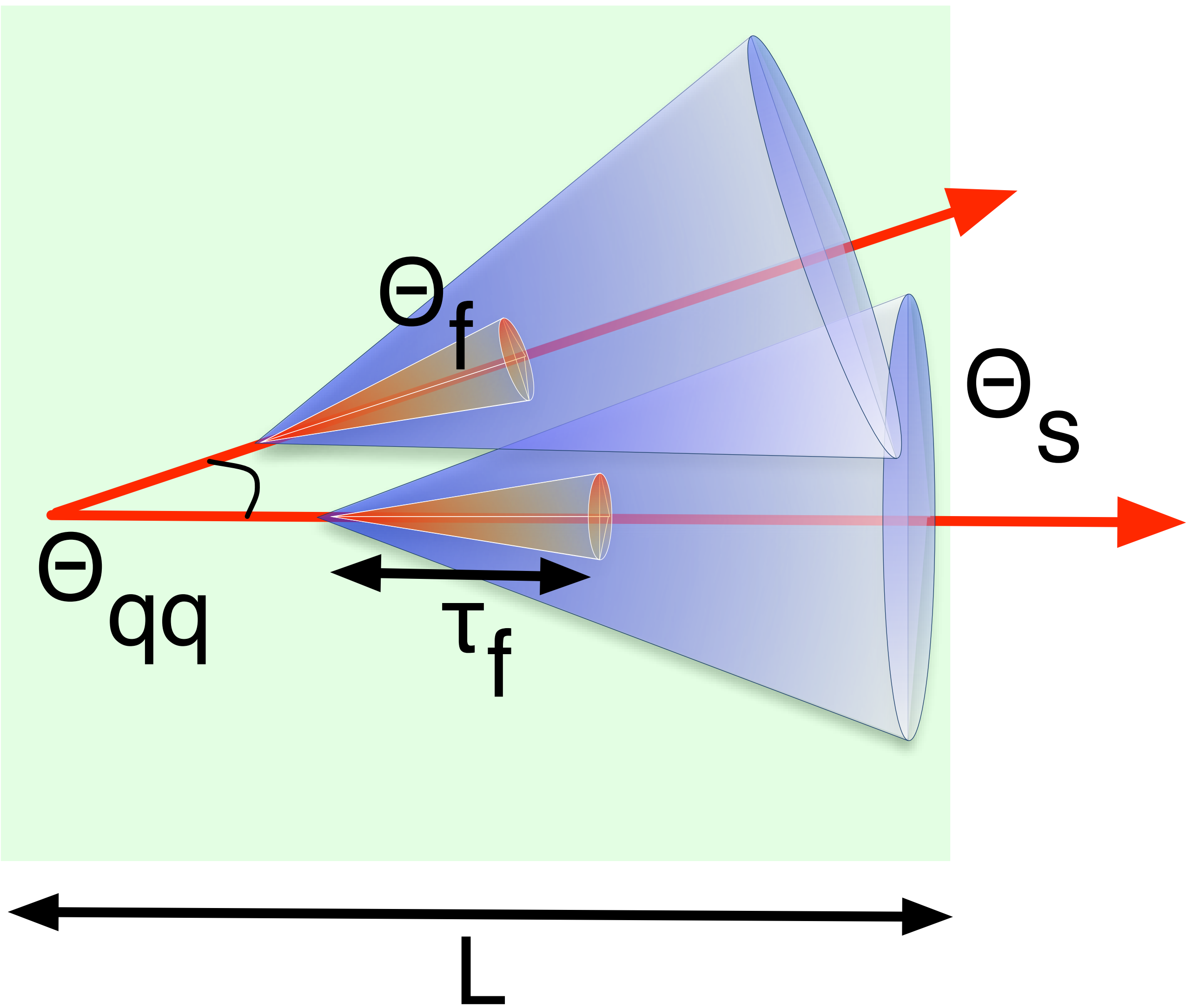

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No! at formation the fronts do not overlap

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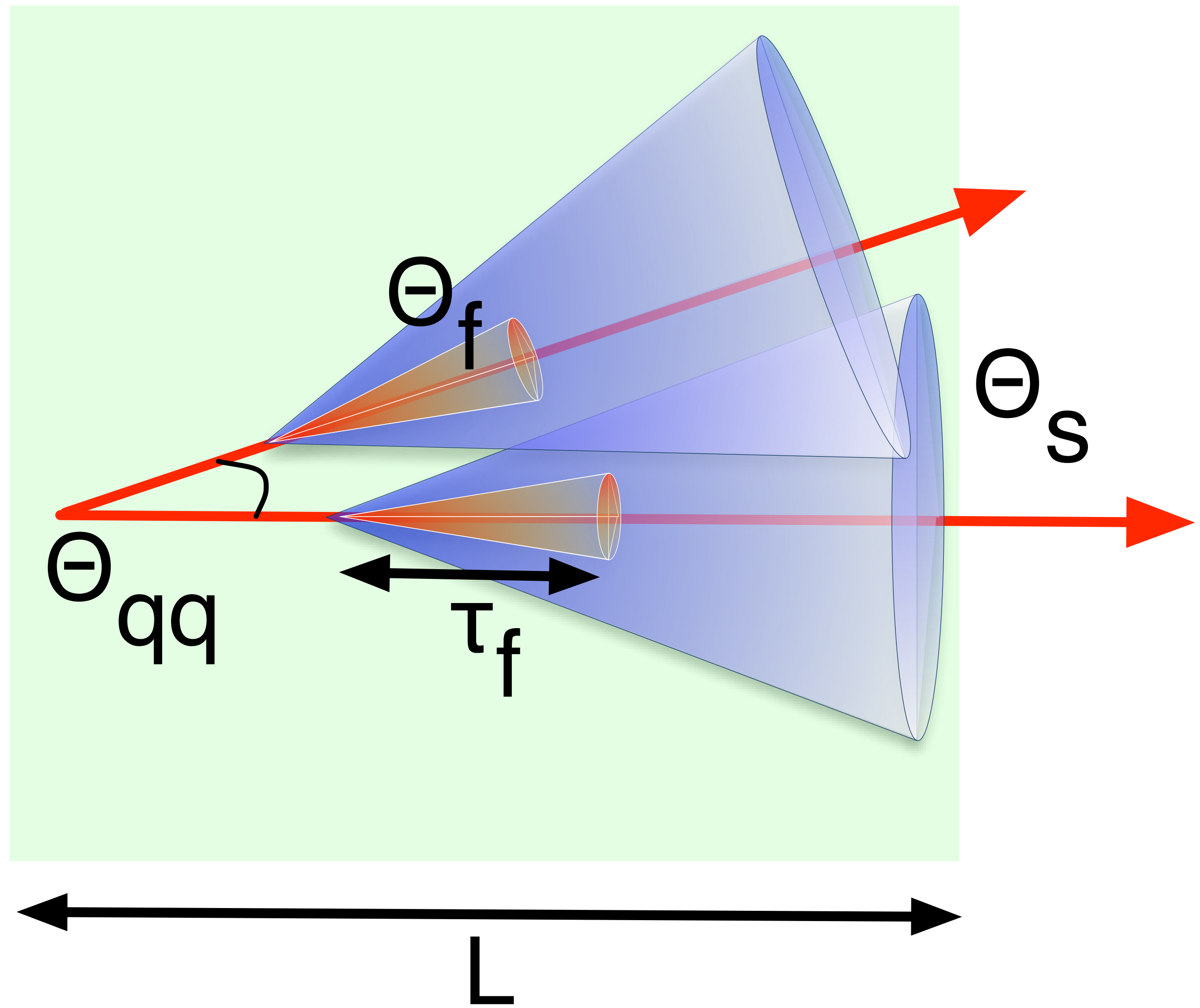

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- "Vacuum-medium" interference is still possible

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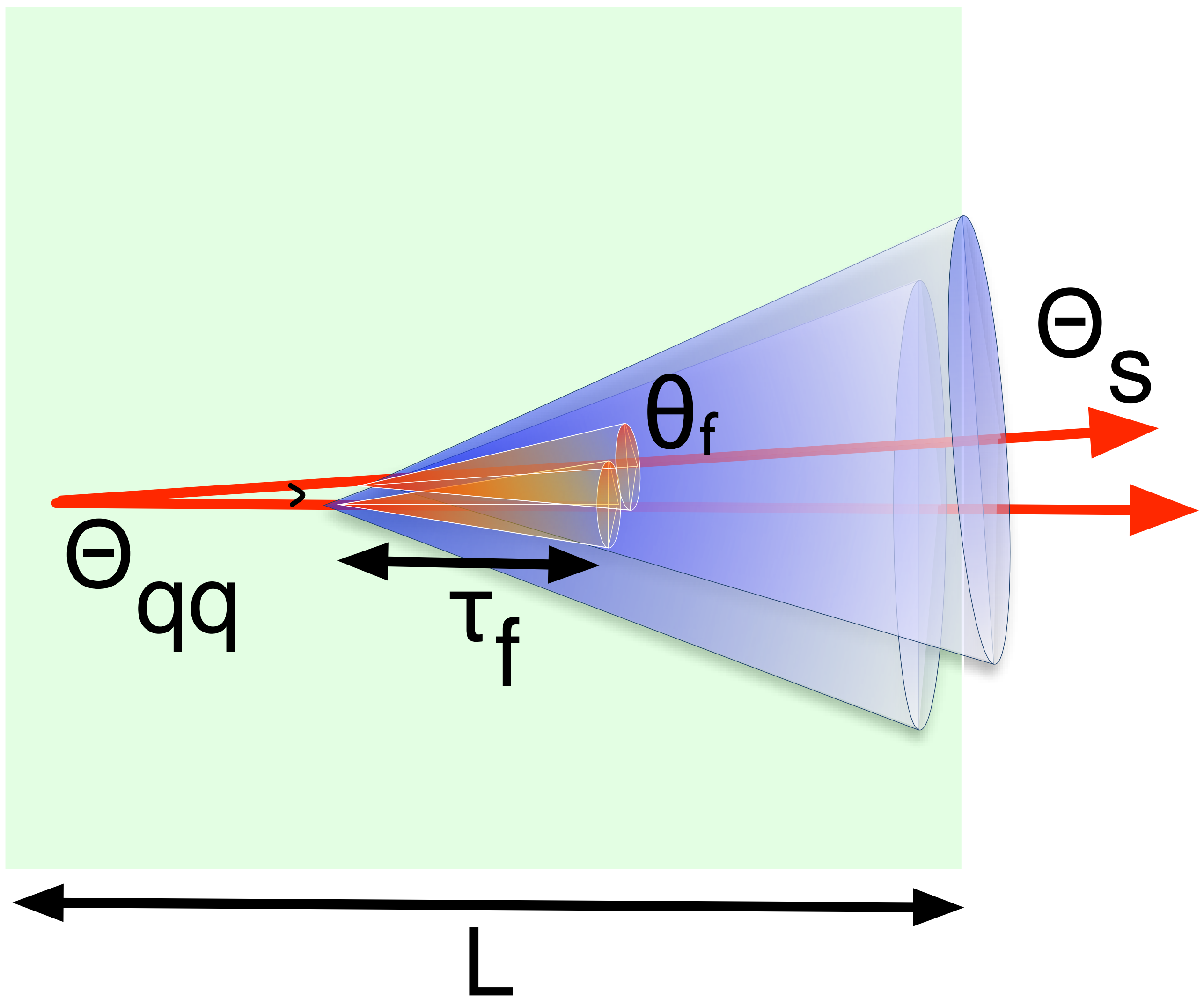
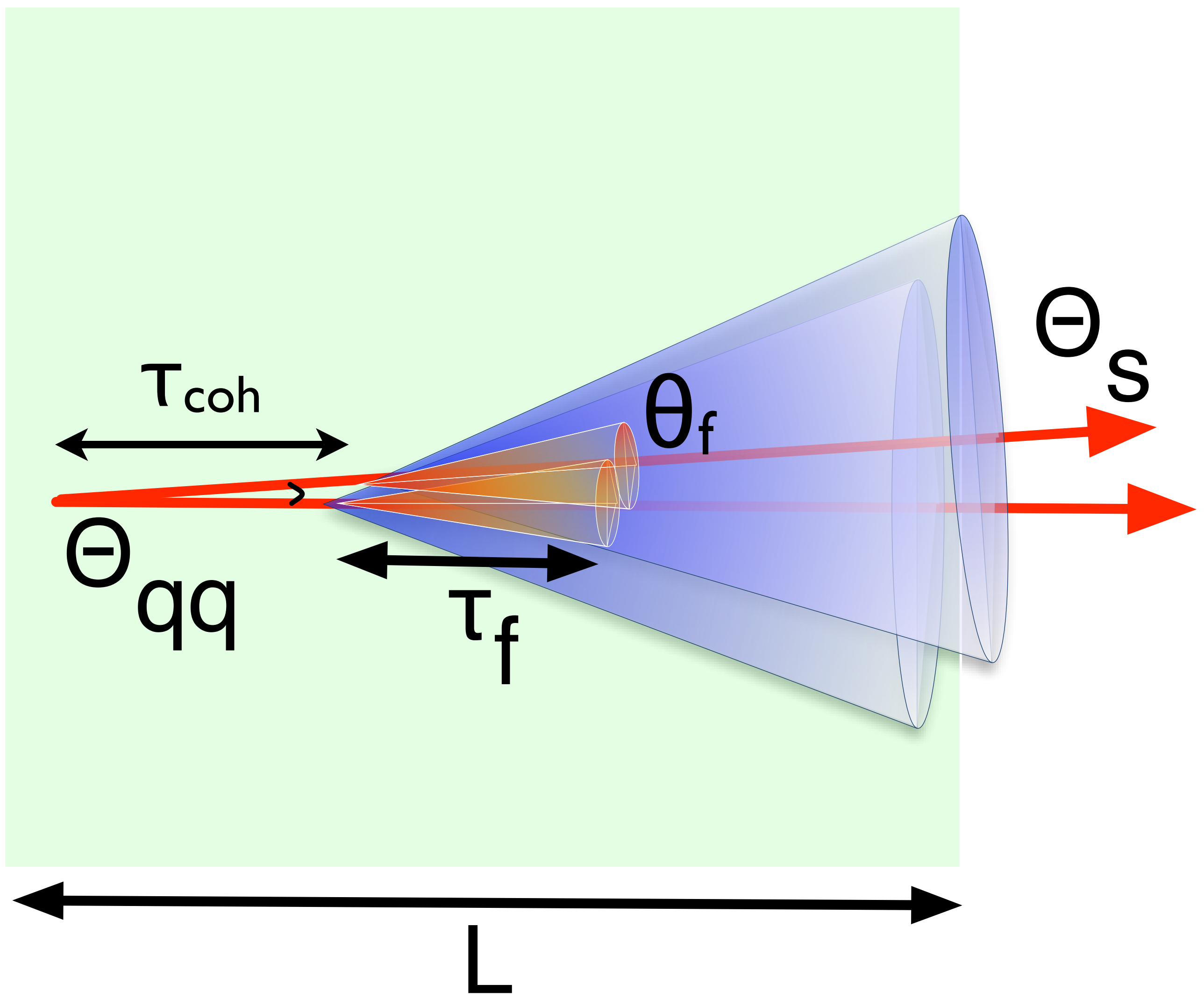
Two Partons: Small Angles



- The two fronts overlap at formation: they can interfere.

Two Partons: Small Angles

(color coherence)



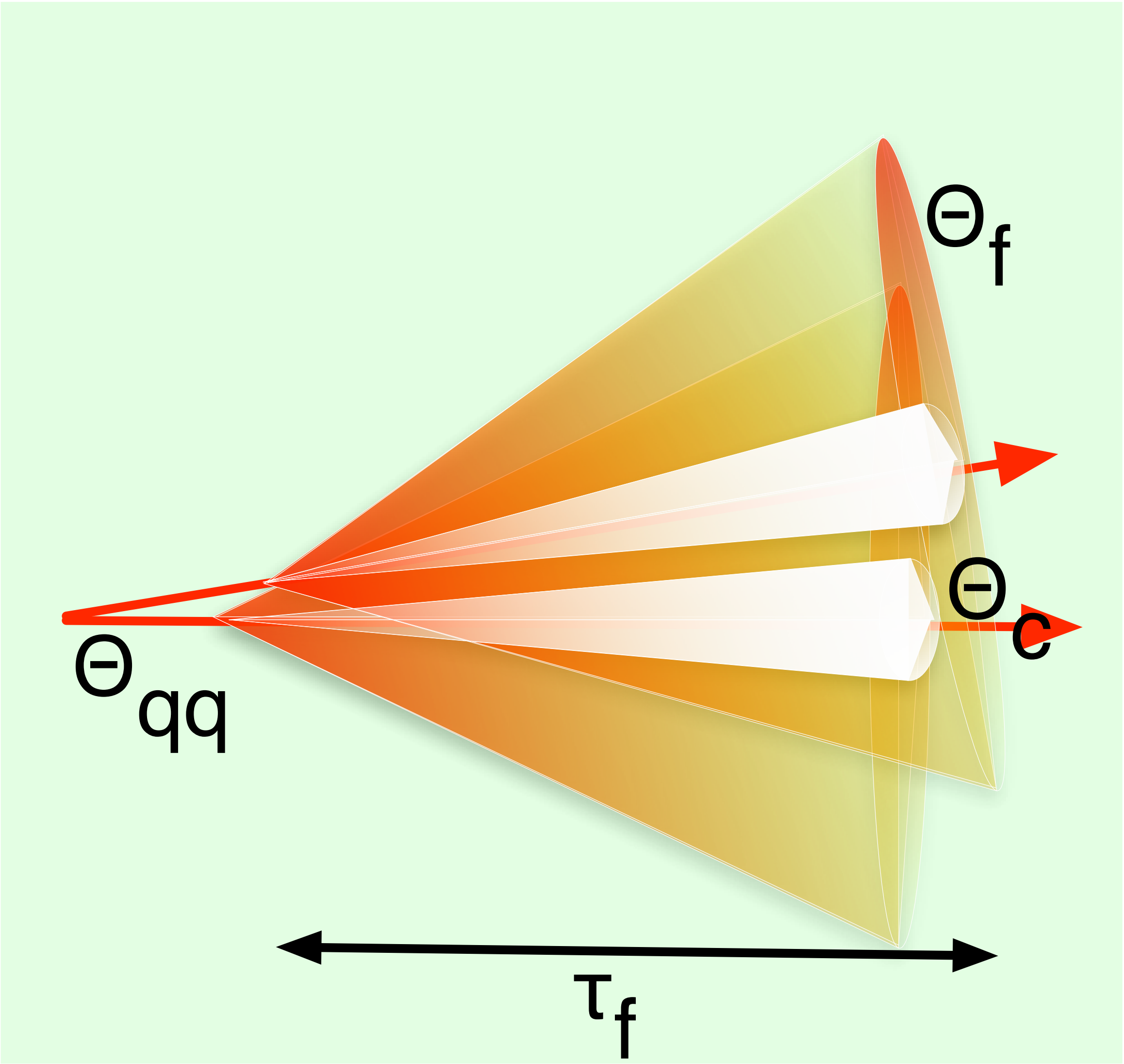
- The two fronts overlap at formation: they can interfere.
- The qq pair rotates color before emission. At

$$\tau_{coh} = \left(\frac{\theta_c}{\theta_{q\bar{q}}}\right)^{2/3} L$$

The color of each quark is randomized ⇒ No interference

- Interference contribution scales with $dI \propto \tau_{coh}$

Two Partons: Very Small Angles



- Interference is possible. Antenna color remains almost constant
- Interference occurs as in vacuum up to corrections Θ^2_{qq}/Θ^2_C

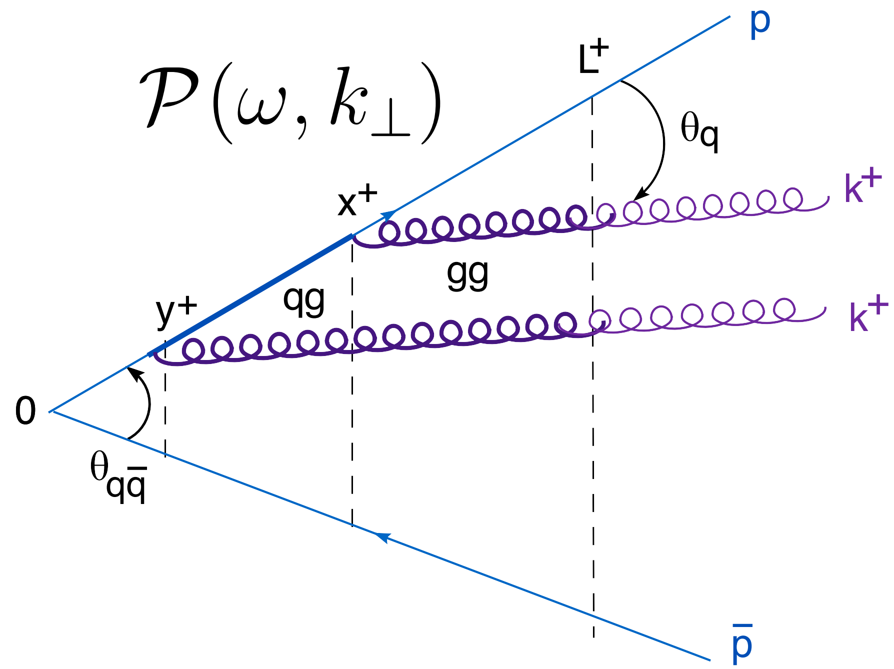
The dipole interacts as a single charge

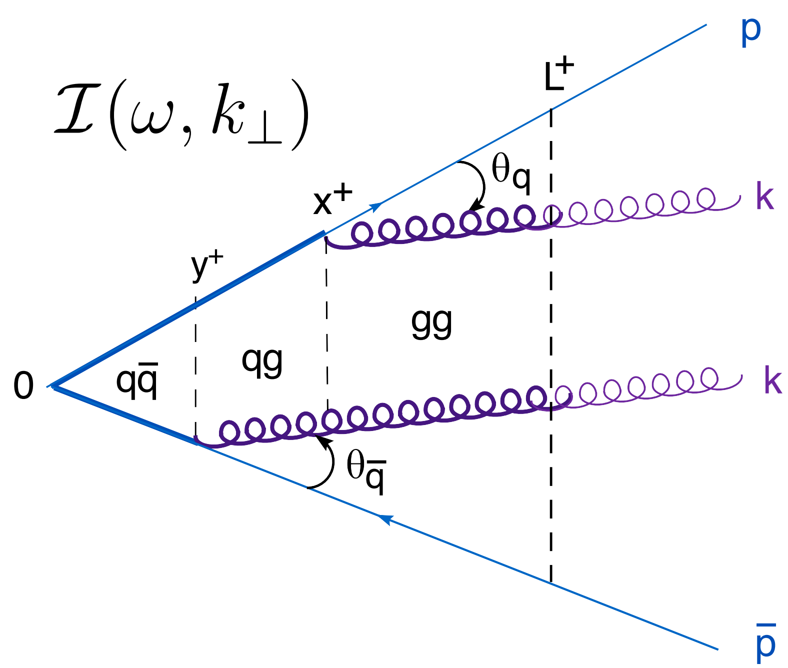
- The corrections Θ^2_{qq}/Θ^2_C may lead to non-trivial distribution

Natural limit for connecting to N=1 opacity

(Mehtar-Tani, Salgado, Tywoniuk 10, see Hao Ma's talk)

Summary





- Medium induced radiation scales with the medium L

$$\mathcal{P}(\omega, k_\perp) \propto \alpha_s C_F\, \theta_f^2\, L^+ \frac{\omega}{Q_s^2} \exp\left\{ -\frac{(k_\perp - k^+ \boldsymbol{u}_L)^2}{Q_s^2} \right\}$$

- Large angles $\Theta_f < \Theta_{qq}$ "vacuum medium" interference leads to:

(quantum coherence) $$\mathcal{R} = \frac{|\mathcal{I}|}{\mathcal{P}} = \frac{\tau_{int}}{L} < \left(\frac{\omega}{\omega_c}\right)^{1/2}$$ Interference is suppressed

- Small angles $\Theta_c << \Theta_{qq} < \Theta_f$ "medium-medium" interference :

(color coherence) $$\mathcal{R} = \frac{|\mathcal{I}|}{\mathcal{P}} = \frac{\tau_{coh}}{L} \ll 1$$ Interference is suppressed

- Very small angles $\Theta_{qq} < \Theta_c$ the medium interacts with the whole dipole charge

Conclusions

- Unless Θ_{qq} is very small

  Each source induces gluons independently from each other

- Typical sources for in-medium antennas

  In-medium radiations $\Rightarrow \theta_{qq} \sim \theta_f$

  Vacuum splittings (QCD evolution) $\Rightarrow \theta_{qq}$ takes any value

but

$$\left(\begin{array}{c} \hat{q} \sim 10\,\mathrm{GeV}^2/\mathrm{fm} \\ L \sim 6\,\mathrm{fm} \end{array} \quad \Rightarrow \quad \begin{array}{c} \theta_c \sim 0.005 \\ \omega_c \sim 900\,\mathrm{GeV} \end{array} \right)$$

BDMPS-Z gluons are NOT angular ordered

- In addition to BDMPS-Z gluons, color decoherence of the antenna leads to additional gluon radiation! (see Y. Mehtar-Tani's talk)

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(but vacuum-like ones are)

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Back-up

Parameter	Definition	Parametric estimate	Physical meaning
τ_q	$\frac{2\omega}{k_\perp^2}$	$\tau_f \left(\frac{\theta_f}{\theta_q}\right)^2$	vacuum formation time
τ_f	$\sqrt{\frac{2\omega}{\hat{q}}}$	$\sqrt{\frac{\omega}{\omega_c}}\, L$	in–medium formation time
θ_f	$\left(\frac{2\hat{q}}{\omega^3}\right)^{1/4}$	$\theta_c \left(\frac{\omega_c}{\omega}\right)^{3/4}$	formation angle
θ_s	$\frac{\sqrt{\hat{q}L}}{\omega}$	$\theta_c \frac{\omega_c}{\omega}$	saturation angle
τ_{int}	$\frac{2}{\omega\theta_{q\bar{q}}^2}$	$\tau_f \left(\frac{\theta_f}{\theta_{q\bar{q}}}\right)^2$	interference time
τ_λ	$\frac{1}{\theta_{q\bar{q}}(\omega\hat{q})^{1/4}}$	$\tau_f \frac{\theta_f}{\theta_{q\bar{q}}}$	transverse resolution time
τ_{coh}	$\frac{2}{(\hat{q}\theta_{q\bar{q}}^2)^{1/3}}$	$\tau_f \left(\frac{\theta_f}{\theta_{q\bar{q}}}\right)^{2/3}$	color decoherence time