# Photon production by a quark-gluon plasma

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<u>References</u>:

Phys. Rev. D <u>61</u>, 116001 (1999)

Phys. Rev. D <u>62</u>, 096012 (2000)

Phys. Lett. B <u>493</u>, 182 (2000)

## Model:

- $T \gg$ masses
- $g \ll 1$
- equilibrium

At $T = 300$ MeV

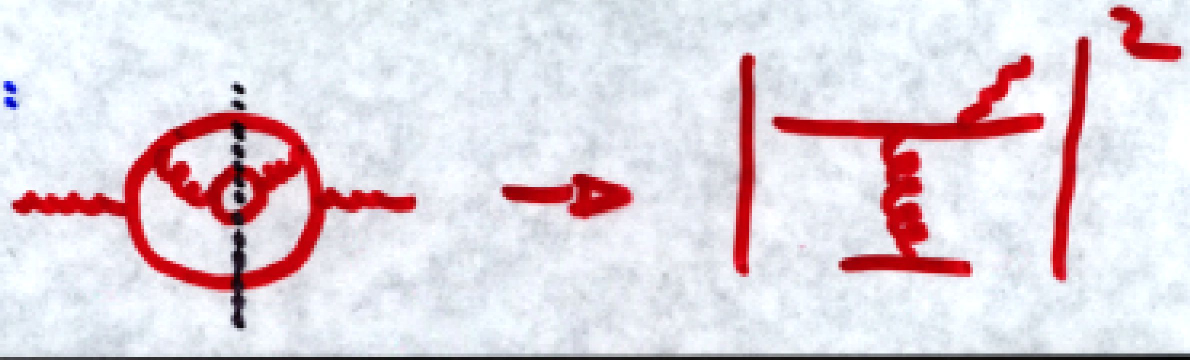
$g \sim 3$

## Tool: Thermal Field Theory

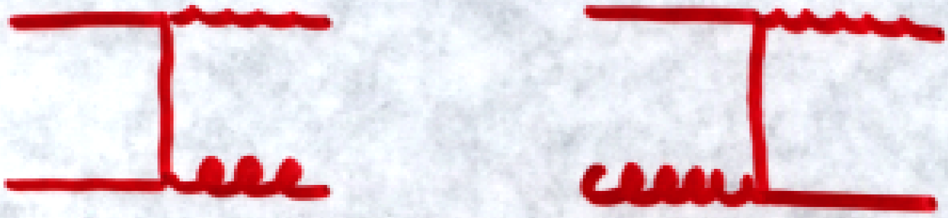
$$\frac{dN^{\gamma}}{dt\,dV\,d^3\vec{q}\,d\omega} \propto \mathrm{Im}\, \Pi_{Ret}{}^{\mu}{}_{\mu}(\omega,\vec{q})$$

photon pol. tensor calculated in the thermal bath.

ex:



# Lowest order :



$$\mathrm{Im}\,\Pi_{Ret}{}^{\mu}{}_{\mu}(\omega,\vec{q}) \sim e^2 g^2\, T^2 \ln\frac{\omega T}{m_{th}^2}$$

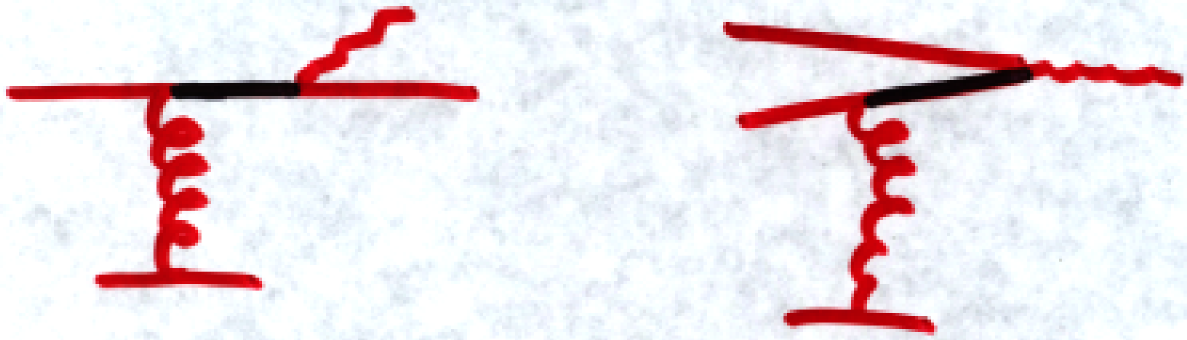
with $m_{th} \sim$ thermal mass $\sim gT$

**Note** : for soft photons :

$$\mathrm{Im}\,\Pi_{Ret}{}^{\mu}{}_{\mu}(\omega,\vec{q}) \sim e^2 g^2\, \frac{m_{th}^2\, T}{\omega}$$

phase-space suppression

# Bremsstrahlung ...



$$\mathrm{Im}\,\Pi_{\mathrm{Ret}\,\mu}^{\mu} \sim e^2 g^4 \frac{T^2}{m_{th}^2}\left[\frac{T^3}{\omega} \oplus T\omega\right]$$

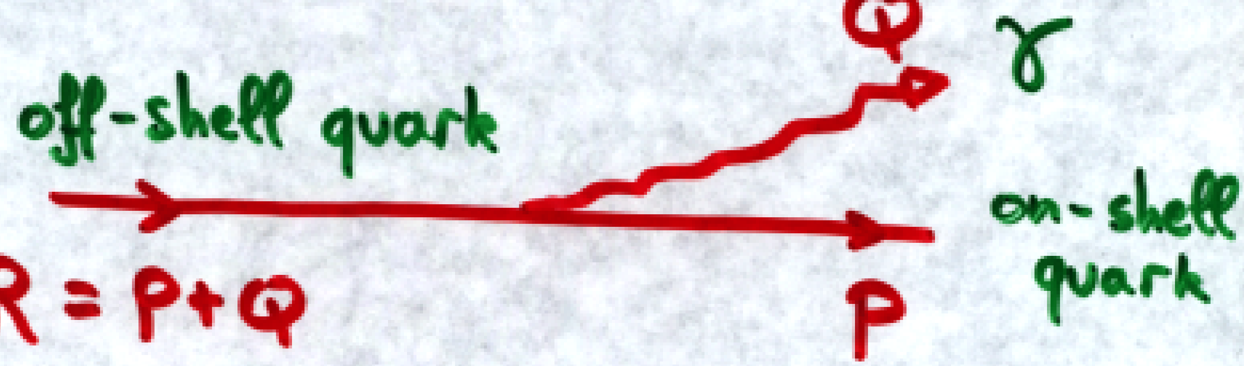
vertices

enhancement $\sim \frac{1}{g^2}$
due to collinear singularities

**Problem**: what happens in higher orders ?

# Photon formation time

- Collinear singularities are controlled by the <u>virtuality</u> of the quarks:




$$R^2 - M^2 \approx \frac{\omega}{p}\left[p_\perp^2 + M_{eff}^2\right]$$

with $$M_{eff}^2 = M^2 + \frac{Q^2}{\omega^2} p_0 r_0$$

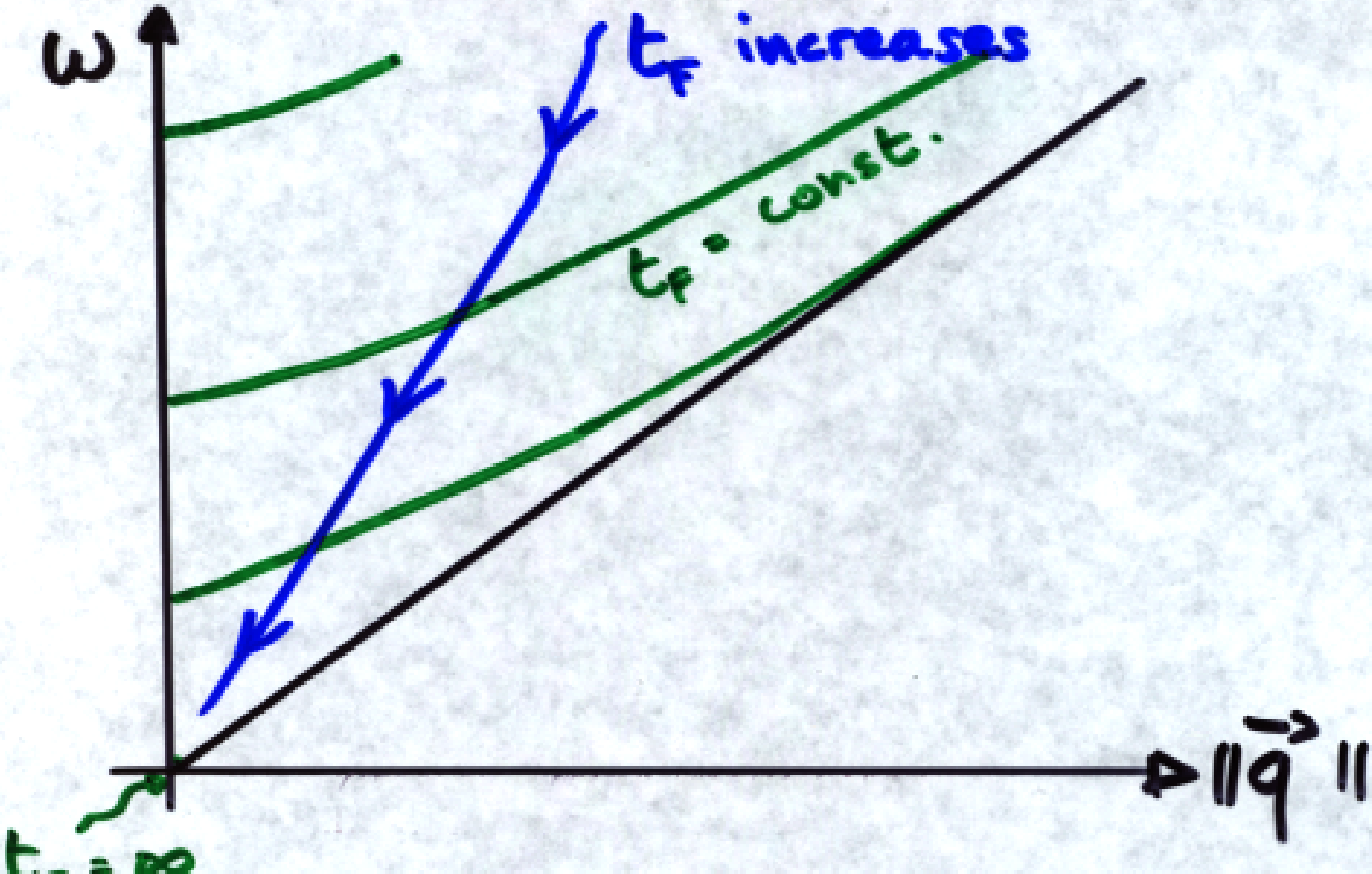
- uncertainty principle:

$$t_F^{-1} \sim \Delta E \sim \frac{R^2 - M^2}{2 r_0} \sim \frac{\omega}{p_0 r_0}\left[p_\perp^2 + M_{eff}^2\right]$$

Collinear enhancement

$\Longleftrightarrow$ Small virtualities

$\Longleftrightarrow$ large formation time




**Question** :

$t_F$ larger than what ?

# Other scales of the problem

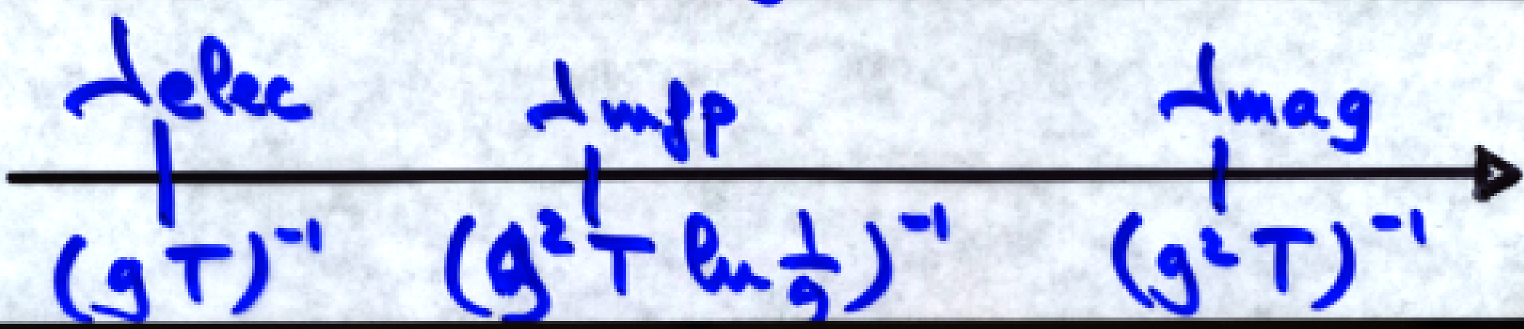
- **mean free path** of the quarks

$$\lambda_{mfp} \sim \frac{1}{g^2 T \ln \frac{1}{g}}$$

- **Range of the interactions in the medium**:

$$\lambda_{elec} \sim \frac{1}{gT} \quad \left(\text{Debye screening}\right)$$

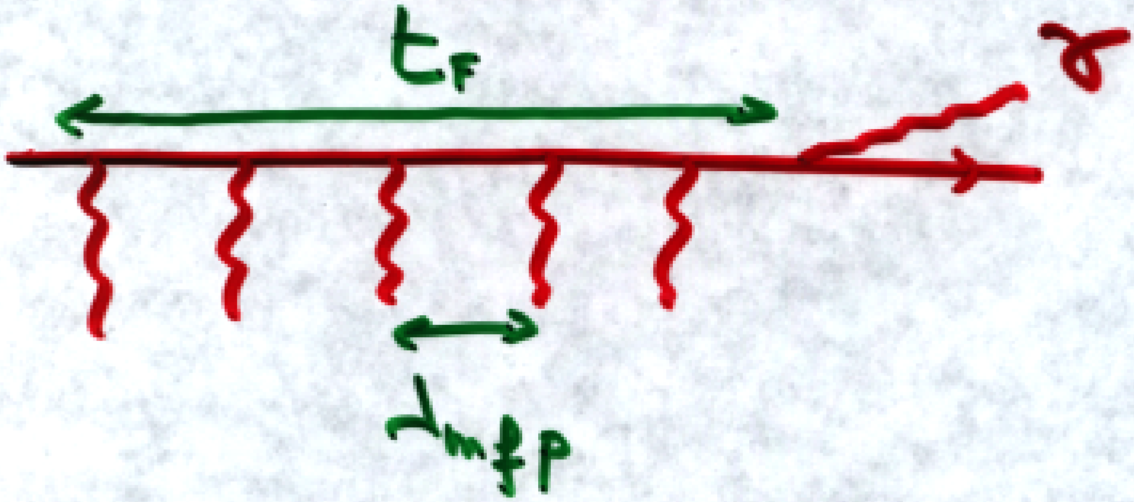
$$\lambda_{mag} \sim \frac{1}{g^2 T}$$



• Multiple scatterings

are important if:

$$\boxed{t_F \gtrsim \lambda_{mfp}}$$




• If this condition is satisfied, higher order diagrams are important.

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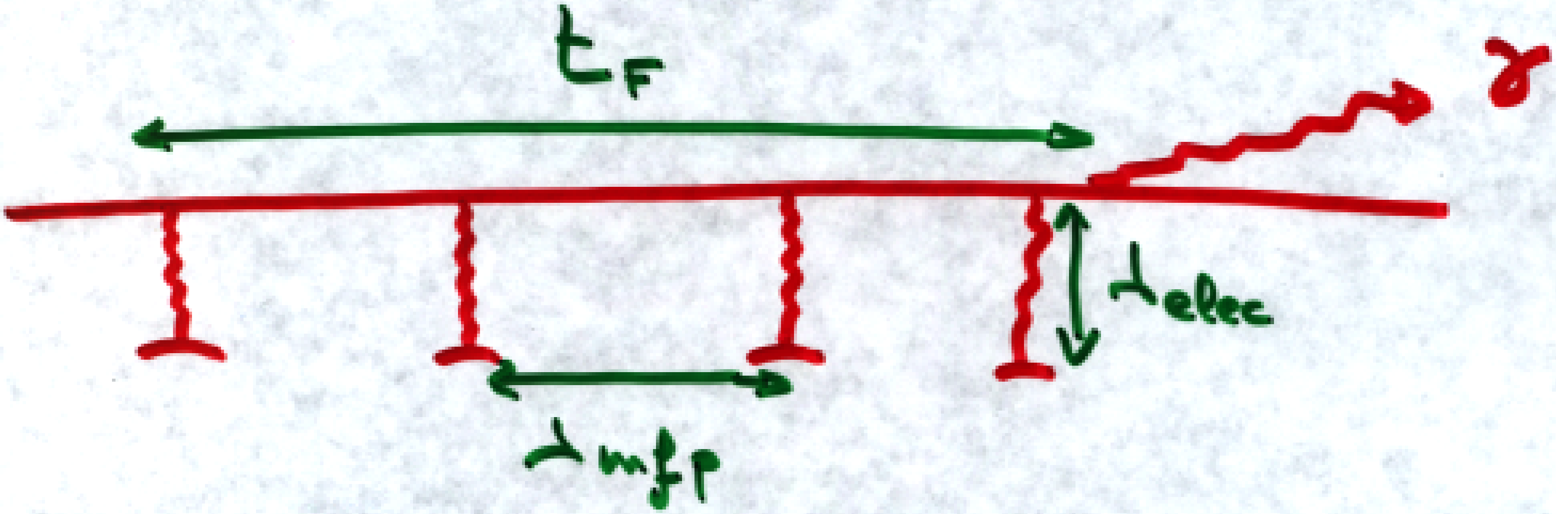
Question: How complicated are the topologies we must consider?

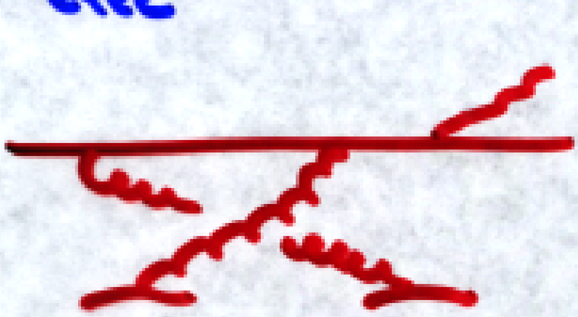
**Answer**: It depends on the range of the interactions.

**Short-ranged interactions**:

$$\boxed{\lambda_{elec} \ll \lambda_{mfp}}$$




Since $\lambda_{elec}$ is small:

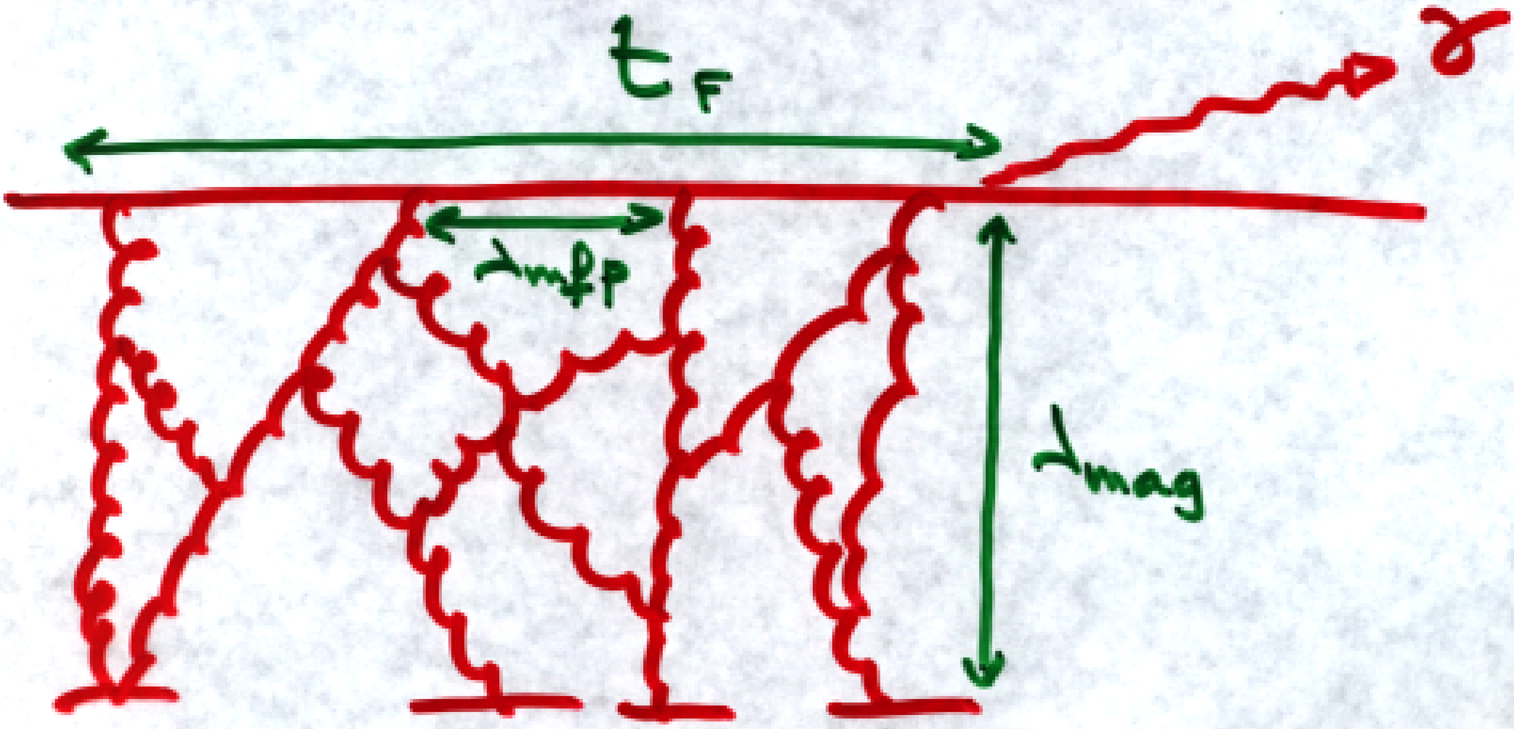


is suppressed

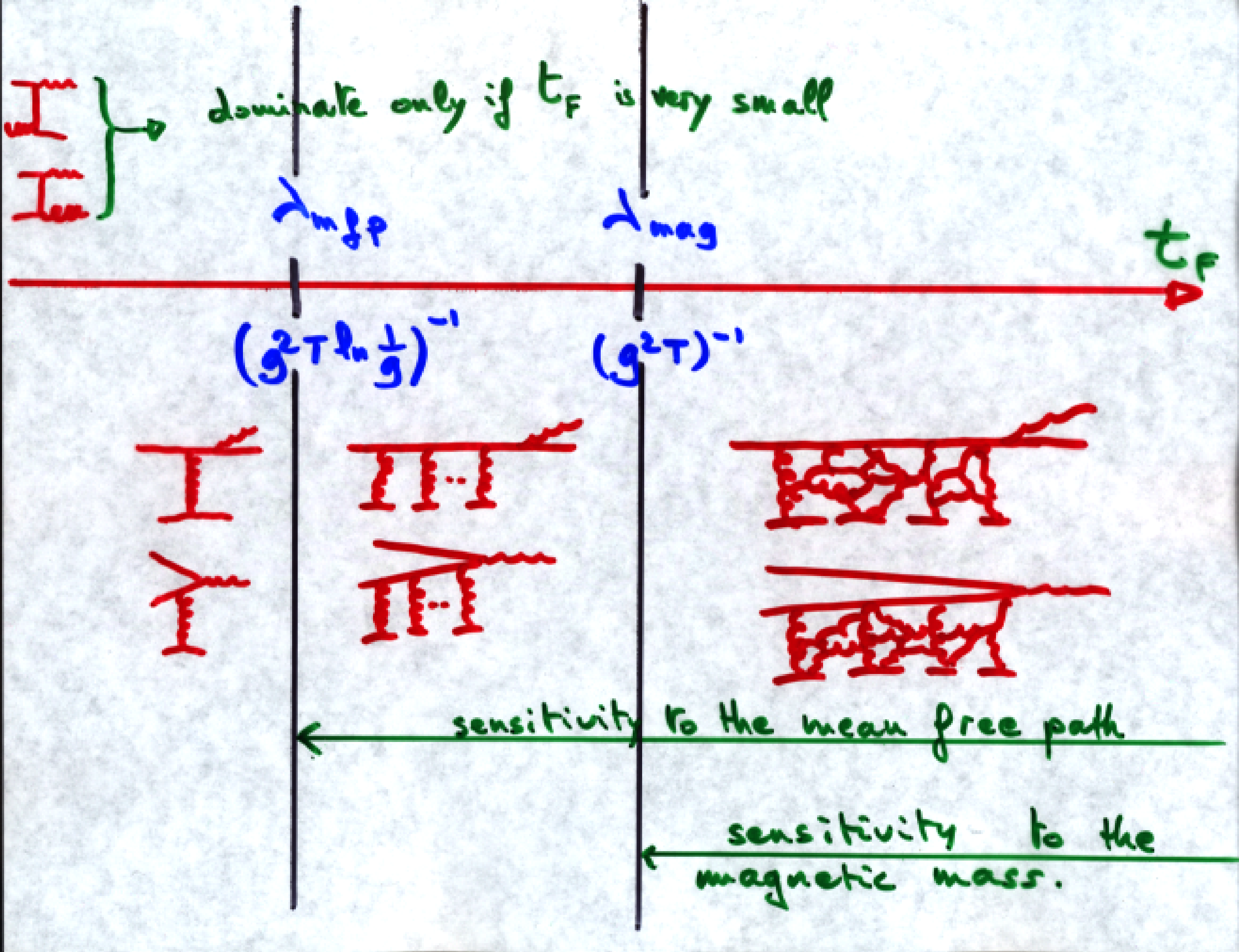
$\Rightarrow$ only "ladder" topologies

# Long-ranged interactions:

$$\boxed{\lambda_{mag} \gg \lambda_{mfp}}$$

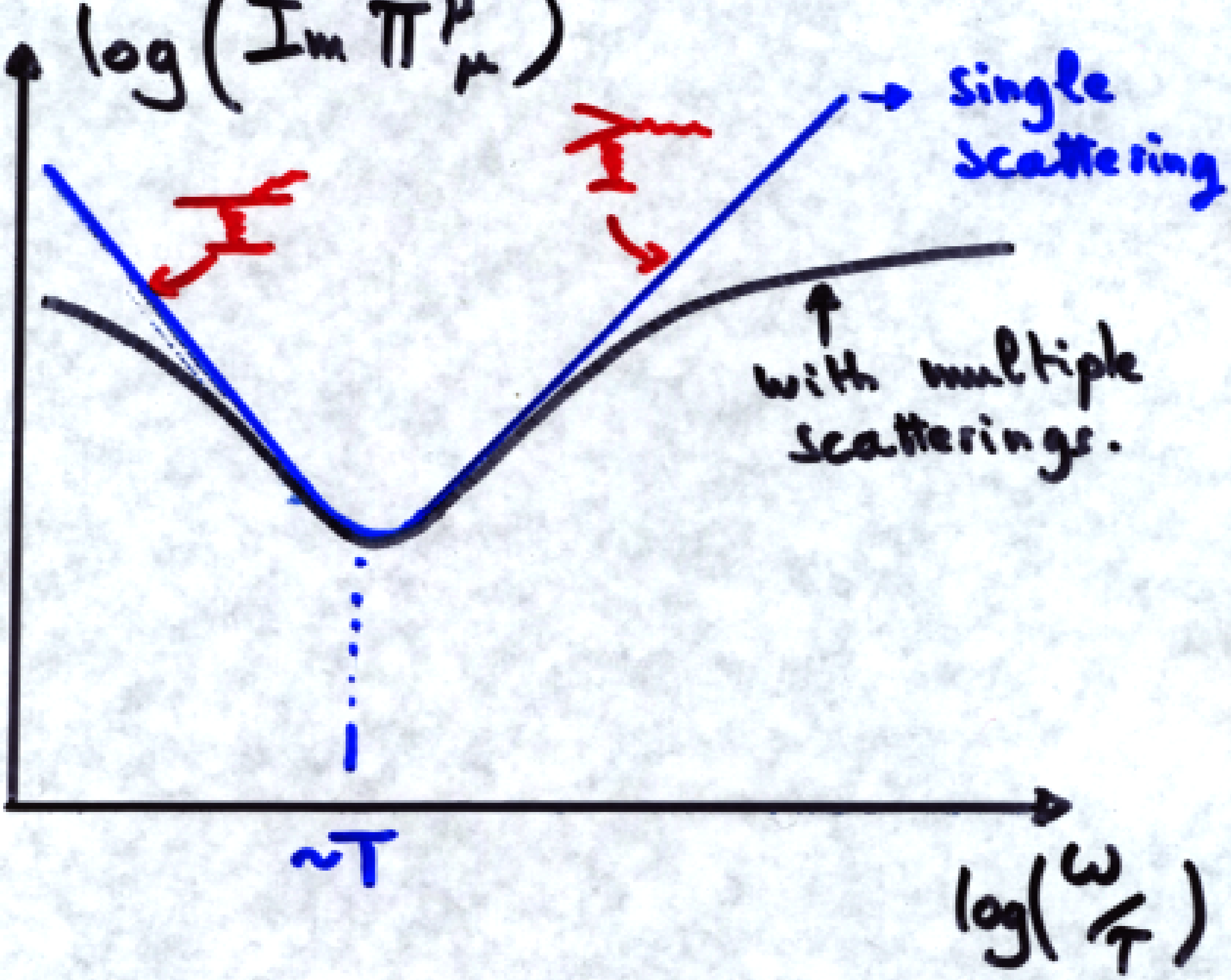



$\Rightarrow$ successive collisions are not independent: all topologies can contribute.



dominate only if $t_F$ is very small
$\lambda_{mfp}$
$\lambda_{mag}$
$t_F$
$(g^2 T \ln \frac{1}{g})^{-1}$
$(g^2 T)^{-1}$
sensitivity to the mean free path
sensitivity to the magnetic mass.

# How do multiple scatterings change the photon rate? ( qualitative )



# What can we calculate analytically ?

- Dileptons :

  (i.e. virtual photons for which
  $t_F \ll \lambda_{mfp}$ ).

- Photons at leading log :

  (the sensitivity to the magnetic scale seems to enter only in the subleading logs. )

- Anything beyond that is non-perturbative ...