8.11 Some effects of HTLs

We saw that HTL functions give rise to thermal masses. For scalars this is the only effect of HTLs. For fermions there is a thermal mass, which, however does not appear in the same way as a Dirac mass:

with Dirac mass $S(k) = \frac{-1}{\not{k} - m} = -\frac{\not{k} + m}{k^2 - m^2}$

$\langle \bar{\psi} \psi \rangle = \mathrm{tr}(S(0)) \propto m$

$\uparrow$ coordinate space

HTL resummed, zero Dirac mass: $S(k) = \frac{-1}{\not{k} - \Sigma(k)}$

$$\Sigma_{HTL}(k) = m^2 \int \frac{d\Omega}{4\pi} \frac{\not{v}}{v \cdot k}$$

$\uparrow$ plasmino mass

$\mathrm{tr}\,\Sigma_{HTL} = 0 \quad \Rightarrow \quad \langle \bar{\psi} \psi \rangle = 0$

chiral symmetry unbroken

photon / gluon polarization tensor in HTL approximation:

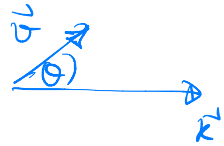
$$\Pi_{\mu\nu}(k) = m_D^2 \left\{ -u_\mu u_\nu + k_0 \int \frac{d\Omega}{4\pi} \frac{v_\mu v_\nu}{v \cdot k} \right\}$$

$k_0 = 0$: Debye mass m_D

$(k^\mu) \gg m_D$: asymptotic mass $\neq m_D$

But $\Pi_{\mu\nu}$ also has an imaginary part:

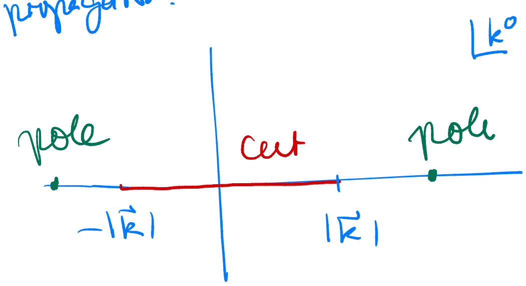
$$\frac{1}{v\cdot k} = \frac{1}{k^0 - |\vec k|\cos\theta}$$



$$\mathrm{Im}\int\frac{d\Omega}{4\pi}\underbrace{\frac{1}{k^0+i0^+-|\vec k|\cos\theta}}_{=\,-i\pi\,\delta(k^0-|\vec k|\cos\theta)} = -\frac{i}{2}\frac{1}{|\vec k|}\,\theta(\vec k^2-k_0^2)$$

non-zero for space-like k^μ

HTL propagator:

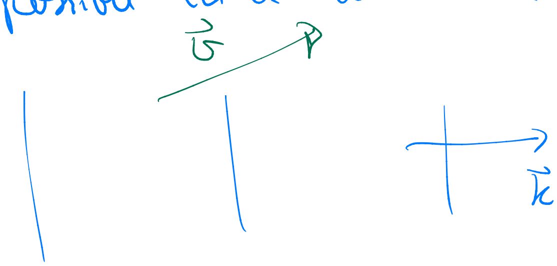


Interpretation of the imaginary part:

HTLs describe classical charged particles interacting with classical fields. Imaginary parts in wave equations → damping or growing amplitudes.

The imaginary part of $\Pi_{\mu\nu}$ is from particles with $v_\parallel = k^0/|\vec k|$ $(v_\parallel = \hat k\cdot\vec v)$

Suppose we have an electromagnetic wave with $|k^0|/|\vec k|<1$, which is possible in a medium.



A particle moving with $v_{\parallel} = k^0/|\vec{k}|$ sees a constant electric field and is accelerated or slowed down continuously. This leads to a net energy transfer between particle and waves. Landau damping