Kinetic equation for QED in external field

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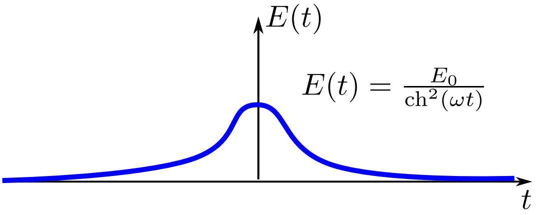
Pair creation in external field

- Tunneling creation of electron-positron pairs in external field (Schwinger effect) has no experimental confirmation yet due to enormous field strength required.
- Critical field strength $E_{cr} = \frac{m^2}{e}$.
- How to enhance the process by other means?
- One of the methods: add initial photons into the system.

E(t) pulse

- We cannot simply use constant field — then we start far from the equilibrium.
- But we can use time-depending field which vanishes in the far past and future.



Points for using $\frac{E_0}{ch^2(\omega t)}$

Possible to solve Klein-Gordon or Dirac equation exactly $\Rightarrow$ find exact tree-level propagators.

Electric field mixes free solutions, so a solution $\phi(t)$ can change its asymptotic

$$e^{-i\omega(p)t} \rightarrow \Phi_- e^{-i\omega'(p)t} + \Phi_+ e^{i\omega'(p)t}$$

Amplitudes in kinetic equation will be affected by

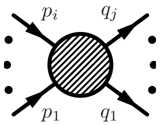
$$\Phi_-\Phi_+ \propto e^{-\rho\frac{m^2}{eE}}$$

Collision integral

- Kinetic equation is written in terms of occupation numbers $n_p = \langle a_p^+ a_p \rangle$ and collision integral $I_p(n_i)$

$$\frac{\partial n_p}{\partial t} = -I_p(n_i)$$

- Collision integral $\Leftrightarrow$ particle interactions:



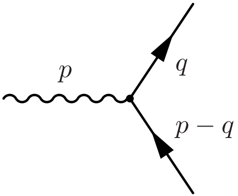
$$\Rightarrow \Delta I_{p_l} = |A|^2 \prod_{a=1}^{i} n_{p_a} \prod_{a=1}^{j} f(n_{p_a}),$$

where $f(n_p)$ is $1 + n_p$ for bosons and $1 - n_p$ for fermions.

Non-vanishing $\langle a_p a_p \rangle$

- Hamiltonian is time-dependent $\Rightarrow$impossible to diagonalize for all times. Must include contribution of $\tilde{n}_p = \langle a_p a_p \rangle$.
- Schwinger–Keldysh diagram technique solves the problem.

Amplitudes



- Vertex $-ie\bar{\psi}(t)\gamma_\mu\psi(t)A_\mu$ with all particles on-shell. On tree level it is proportional to $\Phi_-\Phi_+ \propto e^{-\rho\frac{m^2}{eE}}$.
- Transition probability is exponentialy supressed by dimensionless field parameter $\frac{m^2}{eE}$

One-loop level

- But what happens when we calculate a loop?

- Amplitudes from diagrams like these apart from standard ultraviolet behavior have a peculiar contribution depending on pulse time ω_0^{-1}.
- It comes from poles of loop integrals and has asymptotical form $e^{-2\rho\frac{m^2}{eE}} ln\left(\frac{eE}{m\omega_0}\right)$ as $\omega_0^{-1} \to \infty$

Problems

- The amplitudes are found, but still no solution with appropriate initial conditions
- Some parameters in solution appear to depend on exact form of pulse

Thank you!