# Massive spin-1 particles

$$\boxed{\mathcal{L} = -\frac{1}{4} F_{\mu\nu} F^{\mu\nu} + \frac{m^2}{2} A_\mu A^\mu, \qquad F_{\mu\nu} = \partial_\mu A_\nu - \partial_\nu A_\mu}$$

- equations of motion:

$$\partial_\mu \frac{\partial \mathcal{L}}{\partial(\partial_\mu A_\nu)} - \frac{\partial \mathcal{L}}{\partial A_\nu} = 0$$

show: $\left[ g^{\mu\nu}(\Box + m^2) - \partial^\mu \partial^\nu \right] A_\nu = 0$

and $\partial_\mu A^\mu = 0$

- plane-wave solutions:

$$A^\nu = \varepsilon^\nu e^{\pm ipx}$$

a) what is the condition on polarization vector $\varepsilon^\nu$?

b) given: $(p^\mu) = (E, 0, 0, p)$, $\quad p = |\vec{p}|$

construct 3 orthogonal $\varepsilon^\nu$ with $\varepsilon^2 = -1$

c) show that $\varepsilon_3^\nu \equiv \varepsilon_L^\nu \simeq \frac{p^\nu}{m}$ for $p \gg m$

- propagator:

verify that $D_{\rho\nu}(k) = \left( -g_{\nu\rho} + \frac{k_\nu k_\rho}{m^2} \right) \frac{1}{k^2 - m^2 + i\varepsilon}$

is the solution of

$$\left[ (-k^2 + m^2) g^{\mu\rho} + k^\mu k^\rho \right] D_{\rho\nu}(k) = g^\mu{}_\nu$$

DESY

# Scalar QED

a) Construct Lagrangian $\mathcal{L}$ for scalar QED, with a scalar field $\phi(x)$, $\phi(x) \neq \phi^+(x)$ and a photon field $A_\mu(x)$.

b) Identify interaction terms and derive the Feynman rules