

Particle spectrograph

Wave operator and propagator

| Source constraints | | | |
|---|---|---|----------------|
| SO(3) irreps | Fundamental fields | | Multiplicities |
| $\sigma_0^{\#1} == 0$ | $\partial_\beta \sigma^{\alpha\beta}_\alpha == 0$ | | 1 |
| $\tau_0^{\#1} == 0$ | $\partial_\beta \partial_\alpha \tau^{\alpha\beta} == \partial_\beta \partial^\beta \tau^\alpha_\alpha$ | | 1 |
| $\tau_0^{\#2} == 0$ | $\partial_\beta \partial_\alpha \tau^{\alpha\beta} == 0$ | | 1 |
| $\tau_1^{\#2\alpha} + 2\,i\,k\,\sigma_1^{\#2\alpha} == 0$ | $\partial_\chi \partial_\beta \partial^\alpha \tau^{\beta\chi} == \partial_\chi \partial^\chi \partial_\beta \tau^{\alpha\beta} + 2\,\partial_\delta \partial^\delta \partial_\chi \partial_\beta \sigma^{\alpha\beta\chi}$ | | 3 |
| $\tau_1^{\#1\alpha} == 0$ | $\partial_\chi \partial_\beta \partial^\alpha \tau^{\beta\chi} == \partial_\chi \partial^\chi \partial_\beta \tau^{\beta\alpha}$ | | 3 |
| $\tau_1^{\#1\alpha\beta} + i\,k\,\sigma_1^{\#2\alpha\beta} == 0$ | $\partial_\chi \partial^\alpha \tau^{\beta\chi} + \partial_\chi \partial^\beta \tau^{\chi\alpha} + \partial_\chi \partial^\chi \tau^{\alpha\beta} +$ $2\,\partial_\delta \partial_\chi \partial^\alpha \sigma^{\beta\chi\delta} + 2\,\partial_\delta \partial^\delta \partial_\chi \sigma^{\alpha\beta\chi} ==$ $\partial_\chi \partial^\alpha \tau^{\chi\beta} + \partial_\chi \partial^\beta \tau^{\alpha\chi} +$ $\partial_\chi \partial^\chi \tau^{\beta\alpha} + 2\,\partial_\delta \partial_\chi \partial^\beta \sigma^{\alpha\chi\delta}$ | | 3 |
| $\tau_2^{\#1\alpha\beta} - 2\,i\,k\,\sigma_2^{\#1\alpha\beta} == 0$ | $-i\,(4\,\partial_\delta \partial_\chi \partial^\beta \partial^\alpha \tau^{\chi\delta} + 2\,\partial_\delta \partial^\delta \partial^\beta \partial^\alpha \tau^\chi_\chi -$ $3\,\partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\beta\chi} - 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\chi\beta} -$ $3\,\partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\alpha\chi} - 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\chi\alpha} +$ $3\,\partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\alpha\beta} + 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\beta\alpha} +$ $4\,i\,k^\chi\,\partial_\epsilon \partial_\chi \partial^\beta \partial^\alpha \sigma^{\delta\epsilon}_\delta -$ $6\,i\,k^\chi\,\partial_\epsilon \partial_\delta \partial_\chi \partial^\alpha \sigma^{\beta\delta\epsilon}_\epsilon -$ $6\,i\,k^\chi\,\partial_\epsilon \partial_\delta \partial_\chi \partial^\beta \sigma^{\alpha\delta\epsilon}_\epsilon +$ $2\,\eta^{\alpha\beta}\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \tau^{\chi\delta} +$ $6\,i\,k^\chi\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \sigma^{\alpha\delta\beta}_\beta +$ $6\,i\,k^\chi\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \sigma^{\beta\delta\alpha}_\alpha -$ $2\,\eta^{\alpha\beta}\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \tau^\chi_\chi -$ $4\,i\,\eta^{\alpha\beta}\,k^\chi\,\partial_\phi \partial^\phi \partial_\epsilon \partial_\chi \sigma^{\delta\epsilon}_\delta) == 0$ | 5 | |
| Total constraints/gauge generators: | | | 17 |

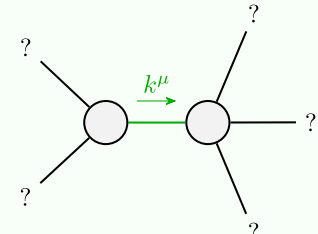
| $\sigma_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\sigma_{1+}^{\#2} \dagger^{\alpha\beta}$ | $\tau_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\sigma_{1-}^{\#1} \dagger^{\alpha}$ | $\sigma_{1-}^{\#2} \dagger^{\alpha}$ | $\tau_{1-}^{\#1} \dagger^{\alpha}$ | $\tau_{1-}^{\#2} \dagger^{\alpha}$ |
|---|---|--|---|---|------------------------------------|--|
| $\sigma_{1+}^{\#1} \dagger^{\alpha\beta}$ | $-\frac{\sqrt{2}}{t_1+k^2\,t_1}$ | $-\frac{i\,\sqrt{2}\,k}{t_1+k^2\,t_1}$ | 0 | 0 | 0 | 0 |
| $\sigma_{1+}^{\#2} \dagger^{\alpha\beta}$ | $-\frac{\sqrt{2}}{t_1+k^2\,t_1}$ | $-\frac{i\,(2\,k^3\,r_5+t_1)}{(1+k^2)^2\,t_1^2}$ | 0 | 0 | 0 | 0 |
| $\tau_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\frac{i\,\sqrt{2}\,k}{t_1+k^2\,t_1}$ | $\frac{-2\,k^4\,r_5+k^2\,t_1}{(1+k^2)^2\,t_1^2}$ | 0 | 0 | 0 | 0 |
| $\sigma_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | $\frac{1}{k^2\,r_5}$ | $-\frac{1}{\sqrt{2}\,(k^2\,r_5+2\,k^4\,r_5)}$ | 0 | $-\frac{i}{k\,r_5+2\,k^3\,r_5}$ |
| $\sigma_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | $-\frac{1}{\sqrt{2}\,(k^2\,r_5+2\,k^4\,r_5)}$ | $\frac{6\,k^2\,r_5+t_1}{2\,(k+2\,k^2)^2\,r_5\,t_1}$ | 0 | $\frac{i\,(6\,k^2\,r_5+t_1)}{\sqrt{2}\,k\,(1+2\,k^2)^2\,r_5\,t_1}$ |
| $\tau_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $\tau_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | $\frac{i}{k\,r_5+2\,k^3\,r_5}$ | $-\frac{i\,(6\,k^2\,r_5+t_1)}{\sqrt{2}\,k\,(1+2\,k^2)^2\,r_5\,t_1}$ | 0 | $\frac{6\,k^2\,r_5+t_1}{(1+2\,k^2)^2\,r_5\,t_1}$ |

Quadratic (free) action

$$S = \iiint \! \! \! \int \! \! \! \int (\! f^{\alpha\beta} \, \tau_{\alpha\beta} + \omega^{\alpha\beta\chi} \, \sigma_{\alpha\beta\chi} +$$
$$\frac{1}{6} \, t_1 (2 \, \omega^{\alpha\iota}_{\alpha} \, \omega^{\theta}_{\iota\,\theta} - 4 \, \omega^{\theta}_{\alpha\,\theta} \, \partial_{\iota} f^{\alpha\iota} + 4 \, \omega^{\theta}_{\iota\,\theta} \, \partial^{\iota} f^{\alpha}_{\alpha} - 2 \, \partial_{\iota} f^{\theta}_{\theta}$$
$$\partial^{\iota} f^{\alpha}_{\alpha} - 2 \, \partial_{\iota} f^{\alpha\iota} \partial_{\theta} f^{\theta}_{\alpha} + 4 \, \partial^{\iota} f^{\alpha}_{\alpha} \, \partial_{\theta} f^{\theta}_{\iota} - 6 \, \partial_{\alpha} f^{\theta}_{\theta} \partial^{\alpha} f^{\alpha\iota} -$$
$$3 \, \partial_{\alpha} f^{\theta}_{\theta\iota} \partial^{\theta} f^{\alpha\iota} + 3 \, \partial_{\iota} f^{\alpha\theta} \partial^{\theta} f^{\alpha\iota} + 3 \, \partial_{\theta} f^{\alpha\iota} \partial^{\theta} f^{\alpha\iota} +$$
$$3 \, \partial_{\theta} f^{\alpha\iota}_{\iota\alpha} \partial^{\theta} f^{\alpha\iota} + 6 \, \omega^{\alpha\theta\iota}_{\alpha} (\omega^{\alpha\iota\theta}_{\iota} + 2 \, \partial^{\theta} f^{\alpha\iota\iota}) +$$
$$r_5 (\partial_{\iota} \omega^{\kappa}_{\theta\,\kappa} \partial^{\theta} \omega^{\alpha\iota}_{\alpha} - \partial_{\theta} \omega^{\kappa}_{\iota\,\kappa} \partial^{\theta} \omega^{\alpha\iota}_{\alpha} - (\partial_{\alpha} \omega^{\alpha\iota\theta}_{\iota} - 2 \, \partial^{\theta} \omega^{\alpha\iota}_{\alpha})$$
$$(\partial_{\kappa} \omega^{\kappa}_{\iota\,\theta} - \partial_{\iota} \omega^{\kappa}_{\theta\,\iota})) [t,\,x,\,y,\,z] dz \, dy \, dx \, dt$$

| | | | | | | | | | | | |
|---|------------------------------|-------------------------------|-------------------------------|---|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|--------------------------------------|
| $\omega_{1+}^{\#1} \dagger^{\alpha\beta}$ | $k^2\,r_5 - \frac{t_1}{2}$ | $-\frac{t_1}{\sqrt{2}}$ | $-\frac{i\,k\,t_1}{\sqrt{2}}$ | $\omega_{1+}^{\#1} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | $\omega_{1-}^{\#1} \dagger^{\alpha}$ | $\omega_{1-}^{\#2} \dagger^{\alpha}$ | $f_{1-}^{\#1} \dagger^{\alpha}$ | $f_{1-}^{\#2} \dagger^{\alpha}$ |
| $\omega_{1+}^{\#2} \dagger^{\alpha\beta}$ | $-\frac{t_1}{\sqrt{2}}$ | 0 | 0 | $\omega_{1+}^{\#2} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | $\omega_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | 0 |
| $f_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\frac{i\,k\,t_1}{\sqrt{2}}$ | 0 | 0 | $f_{1+}^{\#1} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | $\omega_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | 0 |
| $\omega_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | 0 | $\omega_{1-}^{\#1} \dagger^{\alpha}$ | $k^2\,r_5 + \frac{t_1}{6}$ | $\frac{t_1}{3\sqrt{2}}$ | 0 | $\omega_{1-}^{\#2} \dagger^{\alpha}$ | $\frac{i\,k\,t_1}{3}$ | 0 | 0 |
| $\omega_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | 0 | $\omega_{1-}^{\#2} \dagger^{\alpha}$ | $\frac{t_1}{3\sqrt{2}}$ | $\frac{t_1}{3}$ | 0 | $\omega_{1-}^{\#2} \dagger^{\alpha}$ | $\frac{1}{3}\,i\,\sqrt{2}\,k\,t_1$ | 0 | 0 |
| $f_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | 0 | $f_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | 0 | $\omega_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | 0 |
| $f_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | 0 | $f_{1-}^{\#2} \dagger^{\alpha}$ | $-\frac{1}{3}\,i\,k\,t_1$ | $-\frac{1}{3}\,i\,\sqrt{2}\,k\,t_1$ | 0 | $\omega_{1-}^{\#2} \dagger^{\alpha}$ | $\frac{2\,k^2\,t_1}{3}$ | 0 | 0 |
| $\omega_{2+}^{\#1} \dagger^{\alpha\beta}$ | $\frac{t_1}{2}$ | $-\frac{i\,k\,t_1}{\sqrt{2}}$ | 0 | $\omega_{2+}^{\#1} \dagger^{\alpha\beta\chi}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ |
| $\omega_{2+}^{\#1} \dagger^{\alpha\beta}$ | $\frac{t_1}{2}$ | $-\frac{i\,k\,t_1}{\sqrt{2}}$ | 0 | $\omega_{2+}^{\#1} \dagger^{\alpha\beta\chi}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $\omega_{0+}^{\#1} \dagger^{\alpha}$ |
| $f_{2+}^{\#1} \dagger^{\alpha\beta}$ | $\frac{i\,k\,t_1}{\sqrt{2}}$ | $k^2\,t_1$ | 0 | $f_{2+}^{\#1} \dagger^{\alpha\beta\chi}$ | $f_{0+}^{\#1} \dagger^{\alpha}$ | $f_{0+}^{\#1} \dagger^{\alpha}$ | $f_{0+}^{\#1} \dagger^{\alpha}$ | $f_{0+}^{\#1} \dagger^{\alpha}$ | $f_{0+}^{\#1} \dagger^{\alpha}$ | $f_{0+}^{\#1} \dagger^{\alpha}$ | $f_{0+}^{\#1} \dagger^{\alpha}$ |
| $\omega_{2-}^{\#1} \dagger^{\alpha\beta\chi}$ | 0 | 0 | $\frac{t_1}{2}$ | $\omega_{2-}^{\#1} \dagger^{\alpha\beta\chi}$ | $\omega_{0-}^{\#1} \dagger^{\alpha}$ | $\omega_{0-}^{\#1} \dagger^{\alpha}$ | $\omega_{0-}^{\#1} \dagger^{\alpha}$ | $\omega_{0-}^{\#1} \dagger^{\alpha}$ | $\omega_{0-}^{\#1} \dagger^{\alpha}$ | $\omega_{0-}^{\#1} \dagger^{\alpha}$ | $\omega_{0-}^{\#1} \dagger^{\alpha}$ |

Massive and massless spectra



| | |
|----------------|-----------------------------|
| Quadratic pole | |
| Pole residue: | $-\frac{1}{r_5\,t_1^2} > 0$ |
| Polarisations: | 2 |

(No massive particles)

Unitarity conditions

$$r_5 < 0 \,\&\& \, t_1 < 0 \, || \, t_1 > 0$$