

Particle spectrograph

Wave operator and propagator

| Source constraints | | | Fundamental fields | | Multiplicities |
|---|--|--|---|--|----------------|
| SO(3) irreps | | | | | |
| $\tau_{0+}^{\#2} == 0$ | | | $\partial_\beta \partial_\alpha \tau^{\alpha\beta} == 0$ | | 1 |
| $\tau_{0+}^{\#1} == 0$ | | | $\partial_\beta \partial_\alpha \tau^{\alpha\beta} == \partial_\beta \partial^\beta \tau^\alpha_\alpha$ | | 1 |
| $\tau_1^{\#2\alpha} + 2\,i\,k\,\sigma_1^{\#1\alpha} == 0$ | | | $\partial_\chi \partial_\beta \partial^\alpha \tau^{\beta\chi} +$ $2\,(\partial_\theta \partial^\theta \partial_\chi \partial^\alpha \sigma^{\beta\chi}_\beta - \partial_\theta \partial^\theta \partial_\chi \partial_\beta \sigma^{\alpha\beta\chi} +$ $\partial_\theta \partial^\theta \partial_\chi \partial^\chi \sigma^{\alpha\beta}_\beta) == \partial_\chi \partial^\chi \partial_\beta \tau^{\alpha\beta}$ | | 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 |
| $\sigma_1^{\#1\alpha} == \sigma_1^{\#2\alpha}$ | | | $\partial_\chi \partial^\alpha \sigma^{\beta\chi}_\beta + \partial_\chi \partial^\chi \sigma^{\alpha\beta}_\beta == 0$ | | 3 |
| $\tau_1^{\#1\alpha\beta} + i\,k\,\sigma_1^{\#2\alpha\beta} == 0$ | | | $\partial_\chi \partial^\alpha \tau^{\beta\chi} + \partial_\chi \partial^\beta \tau^\chi_\alpha + \partial_\chi \partial^\chi \tau^\alpha_\beta +$ $2\,\partial_\theta \partial_\chi \partial^\alpha \sigma^{\beta\chi\delta} + 2\,\partial_\theta \partial^\theta \partial_\chi \sigma^{\alpha\beta\chi} ==$ $\partial_\chi \partial^\alpha \tau^\chi_\beta + \partial_\chi \partial^\beta \tau^\alpha\chi +$ $\partial_\chi \partial^\chi \tau^{\beta\alpha} + 2\,\partial_\theta \partial_\chi \partial^\beta \sigma^{\alpha\chi\delta}$ | | 3 |
| $\tau_2^{\#1\alpha\beta} - 2\,i\,k\,\sigma_2^{\#1\alpha\beta} == 0$ | | | $-i\,(4\,\partial_\theta \partial_\chi \partial^\beta \partial^\alpha \tau^\chi_\delta + 2\,\partial_\theta \partial^\theta \partial_\beta \partial^\alpha \tau^\chi_\chi -$ $3\,\partial_\theta \partial^\theta \partial_\chi \partial^\alpha \tau^{\beta\chi} - 3\,\partial_\theta \partial^\theta \partial_\chi \partial^\alpha \tau^\chi_\beta -$ $3\,\partial_\theta \partial^\theta \partial_\chi \partial^\beta \tau^{\alpha\chi} - 3\,\partial_\theta \partial^\theta \partial_\chi \partial^\beta \tau^\chi_\alpha +$ $3\,\partial_\theta \partial^\theta \partial_\chi \partial^\chi \tau^{\alpha\beta} + 3\,\partial_\theta \partial^\theta \partial_\chi \partial^\chi \tau^{\beta\alpha} +$ $4\,i\,k^\chi\,\partial_\epsilon \partial_\chi \partial^\beta \partial^\alpha \sigma^{\delta\epsilon}_\delta -$ $6\,i\,k^\chi\,\partial_\epsilon \partial_\theta \partial_\chi \partial^\alpha \sigma^{\beta\delta\epsilon}_\delta -$ $6\,i\,k^\chi\,\partial_\epsilon \partial_\theta \partial_\chi \partial^\beta \sigma^{\alpha\delta\epsilon} +$ $2\,\eta^{\alpha\beta}\,\partial_\epsilon \partial^\epsilon \partial_\theta \partial_\chi \tau^\chi_\delta +$ $6\,i\,k^\chi\,\partial_\epsilon \partial^\epsilon \partial_\theta \partial_\chi \sigma^{\alpha\delta\beta} +$ $6\,i\,k^\chi\,\partial_\epsilon \partial^\epsilon \partial_\theta \partial_\chi \sigma^{\beta\delta\alpha} -$ $2\,\eta^{\alpha\beta}\,\partial_\epsilon \partial^\epsilon \partial_\theta \partial^\delta \tau^\chi_\chi -$ $4\,i\,\eta^{\alpha\beta}\,k^\chi\,\partial_\theta \partial^\theta \partial_\epsilon \partial_\chi \sigma^{\delta\epsilon}_\delta) == 0$ | | 5 |
| Total constraints/gauge generators: | | | | | |
| | | | | | 19 |

Quadratic (free) action

$$S == \int \int \int \int (f^{\alpha\beta} \tau_{\alpha\beta} + \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} +$$
$$\frac{1}{6} t_1 (2 \omega^{\alpha\iota}_\alpha \omega_{\iota\theta}^\theta - 4 \omega_\alpha^\theta \partial_{\iota f}^{\alpha\iota} + 4 \omega_{\iota\theta}^\theta \partial_{\iota f}^{\alpha\iota} - 2 \partial_{\iota f}^\theta \partial_\theta$$
$$\partial_{\iota f}^\alpha - 2 \partial_{\iota f}^{\alpha\iota} \partial_\theta f_\alpha^\theta + 4 \partial_{\iota f}^\alpha \partial_\theta f_\alpha^\theta - 6 \partial_{\alpha f}^\theta \partial_{\iota\theta} \partial^\theta f^{\alpha\iota} -$$
$$3 \partial_{\alpha f} \partial_{\theta\iota} \partial^\theta f^{\alpha\iota} + 3 \partial_{\iota f} \partial_\theta \partial^\theta f^{\alpha\iota} + 3 \partial_\theta f_{\alpha\iota} \partial^\theta f^{\alpha\iota} +$$
$$3 \partial_\theta f_{\iota\alpha} \partial^\theta f^{\alpha\iota} + 6 \omega_{\alpha\theta\iota} (\omega^{\alpha\iota\theta} + 2 \partial^\theta f^{\alpha\iota})) -$$
$$4 r_3 (\partial_\beta \omega_{\iota\theta} \partial_{\iota\theta} \omega^{\alpha\beta}_\alpha + \partial_\alpha \omega^{\alpha\beta\iota} \partial_\theta \omega_{\iota\beta}^\theta -$$
$$2 \partial_{\iota} \omega^{\alpha\beta}_\alpha \partial_\theta \omega_{\iota\beta}^\theta + \partial_\beta \omega_{\iota\theta\alpha} \partial^\theta \omega^{\alpha\beta\iota}) +$$
$$\frac{1}{3} r_1 (9 \partial_\beta \omega_{\iota\theta}^\theta \partial_{\iota\theta} \omega^{\alpha\beta}_\alpha + 3 \partial_{\iota} \omega_{\beta\theta}^{\alpha\beta} \partial_{\iota\theta} \omega^{\alpha\beta}_\alpha +$$
$$3 \partial_\alpha \omega^{\alpha\beta\iota} \partial_\theta \omega_{\beta\iota}^\theta - 6 \partial_{\iota} \omega^{\alpha\beta}_\alpha \partial_\theta \omega_{\beta\iota}^\theta + 9 \partial_\alpha \omega^{\alpha\beta\iota} \partial_\theta \omega_{\beta\iota}^\theta -$$
$$18 \partial_{\iota} \omega^{\alpha\beta}_\alpha \partial_\theta \omega_{\iota\beta}^\theta - 4 \partial_\beta \omega_{\alpha\iota\theta} \partial^\theta \omega^{\alpha\beta\iota} +$$
$$2 \partial_\beta \omega_{\alpha\theta\iota} \partial^\theta \omega^{\alpha\beta\iota} + 4 \partial_\beta \omega_{\iota\theta\alpha} \partial^\theta \omega^{\alpha\beta\iota} -$$
$$2 \partial_{\iota} \omega_{\alpha\beta\theta} \partial^\theta \omega^{\alpha\beta\iota} + 2 \partial_\theta \omega_{\alpha\beta\iota} \partial^\theta \omega^{\alpha\beta\iota} +$$
$$2 \partial_\theta \omega_{\alpha\iota\beta} \partial^\theta \omega^{\alpha\beta\iota})) [t, x, y, z] dz dy dx dt$$

| $\sigma_1^{\#1+} \dagger^{\alpha\beta}$ | $\sigma_1^{\#2+} \alpha\beta$ | $\tau_1^{\#1+} \alpha\beta$ | $\sigma_1^{\#1-} \alpha$ | $\sigma_1^{\#2-} \alpha$ | $\tau_1^{\#1-} \alpha$ | $\tau_1^{\#2-} \alpha$ |
|---|---------------------------------|---|---------------------------|-----------------------------------|------------------------|--------------------------------------|
| 0 | $-\frac{\sqrt{2}}{t_1+k^2}t_1$ | $-\frac{i\sqrt{2}k}{t_1+k^2}t_1$ | 0 | 0 | 0 | 0 |
| $\sigma_1^{\#2+} \dagger^{\alpha\beta}$ | $-\frac{\sqrt{2}}{t_1+k^2}t_1$ | $-\frac{i(2k^3r_1+kt_1)}{(1+k^2)^2t_1^2}$ | 0 | 0 | 0 | 0 |
| $\tau_1^{\#1+} \dagger^{\alpha\beta}$ | $\frac{i\sqrt{2}k}{t_1+k^2}t_1$ | $\frac{-2k^4r_1+k^2t_1}{(1+k^2)^2t_1^2}$ | 0 | 0 | 0 | 0 |
| $\sigma_1^{\#1+} \dagger^\alpha$ | 0 | 0 | $\frac{6}{(3+4k^2)^2t_1}$ | $\frac{6\sqrt{2}}{(3+4k^2)^2t_1}$ | 0 | $\frac{12ik}{(3+4k^2)^2t_1}$ |
| $\sigma_1^{\#2+} \dagger^\alpha$ | 0 | 0 | 0 | $\frac{12}{(3+4k^2)^2t_1}$ | 0 | $\frac{12i\sqrt{2}k}{(3+4k^2)^2t_1}$ |
| $\tau_1^{\#1-} \dagger^\alpha$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $\tau_1^{\#2+} \dagger^\alpha$ | 0 | 0 | 0 | $-\frac{12ik}{(3+4k^2)^2t_1}$ | 0 | $\frac{24k^2}{(3+4k^2)^2t_1}$ |

| $\omega_1^{\#1+} \alpha\beta$ | $\omega_1^{\#2+} \alpha\beta$ | $f_1^{\#1+} \alpha\beta$ | $\omega_1^{\#1-} \alpha$ | $\omega_1^{\#2-} \alpha$ | $f_1^{\#1-} \alpha$ | $f_1^{\#2-} \alpha$ |
|---|-------------------------------|---------------------------|-----------------------------|-----------------------------|---------------------|----------------------------|
| $k^2r_1-\frac{t_1}{2}$ | $-\frac{t_1}{\sqrt{2}}$ | $-\frac{ikt_1}{\sqrt{2}}$ | 0 | 0 | 0 | 0 |
| $\omega_1^{\#2+} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $f_1^{\#1+} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $\omega_1^{\#1+} \dagger^\alpha$ | 0 | 0 | $\frac{t_1}{6}$ | $\frac{t_1}{3\sqrt{2}}$ | 0 | $\frac{ikt_1}{3}$ |
| $\omega_1^{\#2+} \dagger^\alpha$ | 0 | 0 | $\frac{t_1}{3\sqrt{2}}$ | $\frac{t_1}{3}$ | 0 | $\frac{1}{3}i\sqrt{2}kt_1$ |
| $f_1^{\#1+} \dagger^\alpha$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $f_1^{\#2+} \dagger^\alpha$ | 0 | 0 | $-\frac{1}{3}i\sqrt{2}kt_1$ | $-\frac{1}{3}i\sqrt{2}kt_1$ | 0 | $\frac{2k^2t_1}{3}$ |

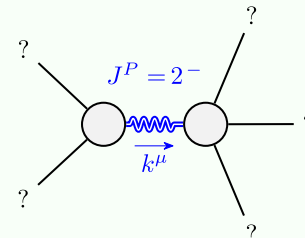
| $\omega_2^{\#1+} \alpha\beta$ | $f_2^{\#1+} \alpha\beta$ | $\omega_2^{\#1-} \alpha\beta\chi$ | |
|---|--------------------------|-----------------------------------|---------------------------|
| $\omega_2^{\#1+} \dagger^{\alpha\beta}$ | $\frac{t_1}{2}$ | $-\frac{ikt_1}{\sqrt{2}}$ | 0 |
| $f_2^{\#1+} \dagger^{\alpha\beta}$ | $\frac{ikt_1}{\sqrt{2}}$ | $k^2 t_1$ | 0 |
| $\omega_2^{\#1+} \alpha\beta\chi$ | 0 | 0 | $k^2 r_1 + \frac{t_1}{2}$ |

| $\omega_0^{\#1+}$ | $f_0^{\#1+}$ | $f_0^{\#2+}$ | $\omega_0^{\#1-}$ | |
|---|----------------------|--------------|-------------------|--------|
| $\omega_0^{\#1+} \dagger^{\alpha\beta}$ | $6 k^2 (-r_1 + r_3)$ | 0 | 0 | 0 |
| $f_0^{\#1+} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | 0 |
| $f_0^{\#2+} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | 0 |
| $\omega_0^{\#1+} \dagger^{\alpha\beta\chi}$ | 0 | 0 | 0 | $-t_1$ |

| $\sigma_2^{\#1+} \alpha\beta$ | $\tau_2^{\#1+} \alpha\beta$ | $\sigma_2^{\#1-} \alpha\beta\chi$ | |
|---|--------------------------------------|---------------------------------------|----------------------------|
| $\sigma_2^{\#1+} \dagger^{\alpha\beta}$ | $\frac{2}{(1+2k^2)^2 t_1}$ | $-\frac{2i\sqrt{2}k}{(1+2k^2)^2 t_1}$ | 0 |
| $\tau_2^{\#1+} \dagger^{\alpha\beta}$ | $\frac{2i\sqrt{2}k}{(1+2k^2)^2 t_1}$ | $\frac{4k^2}{(1+2k^2)^2 t_1}$ | 0 |
| $\sigma_2^{\#1+} \alpha\beta\chi$ | 0 | 0 | $\frac{2}{2k^2 r_1 + t_1}$ |

| $\sigma_0^{\#1+}$ | $\tau_0^{\#1+}$ | $\tau_0^{\#2+}$ | $\sigma_0^{\#1-}$ | |
|---|----------------------------|-----------------|-------------------|------------------|
| $\sigma_0^{\#1+} \dagger^{\alpha\beta}$ | $\frac{1}{6k^2(-r_1+r_3)}$ | 0 | 0 | 0 |
| $\tau_0^{\#1+} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | 0 |
| $\tau_0^{\#2+} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | 0 |
| $\sigma_0^{\#1+} \dagger^{\alpha\beta\chi}$ | 0 | 0 | 0 | $-\frac{1}{t_1}$ |

Massive and massless spectra



| Massive particle | |
|------------------|-------------------------|
| Pole residue: | $-\frac{1}{r_1} > 0$ |
| Polarisations: | 5 |
| Square mass: | $-\frac{t_1}{2r_1} > 0$ |
| Spin: | 2 |
| Parity: | Odd |

(No massless particles)

Unitarity conditions

$r_1 < 0 \&\& t_1 > 0$