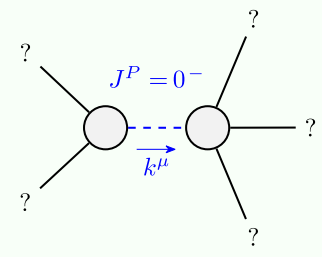


Particle spectrograph

Wave operator and propagator

| Source constraints | | |
|--|--|----------------|
| SO(3) irreps | Fundamental fields | Multiplicities |
| $\tau_{0+}^{\#2} == 0$ | $\partial_\beta \partial_\alpha \tau^{\alpha\beta} == 0$ | 1 |
| $\tau_{0+}^{\#1} - 2 i i k \sigma_{0+}^{\#1} == 0$ | $\partial_\beta \partial_\alpha \tau^{\alpha\beta} == \partial_\beta \partial^\beta \tau^\alpha_\alpha + 2 \partial_\chi \partial^\chi \partial_\beta \sigma^{\alpha\beta}_\alpha$ | 1 |
| $\tau_{1-}^{\#2\alpha} + 2 i i k \sigma_{1-}^{\#2\alpha} == 0$ | $\partial_\chi \partial_\beta \partial^\alpha \tau^{\beta\chi} == \partial_\chi \partial^\chi \partial_\beta \tau^{\alpha\beta} + 2 \partial_\delta \partial^\delta \partial_\chi \partial_\beta \sigma^{\alpha\beta\chi}$ | 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 |
| $\tau_{1+}^{\#1\alpha\beta} + i i k \sigma_{1+}^{\#2\alpha\beta} == 0$ | $\partial_\chi \partial^\alpha \tau^{\beta\chi} + \partial_\chi \partial^\beta \tau^{\alpha\chi} + \partial_\chi \partial^\alpha \tau^{\beta\alpha} + 2 \partial_\delta \partial^\delta \partial_\chi \partial^\alpha \sigma^{\alpha\beta\chi} ==$ $\partial_\chi \partial^\alpha \tau^{\chi\beta} + \partial_\chi \partial^\beta \tau^{\alpha\chi} + \partial_\chi \partial^\alpha \tau^{\beta\alpha} + 2 \partial_\delta \partial^\delta \partial_\chi \partial^\beta \sigma^{\alpha\chi\delta}$ | 3 |
| $\tau_{2+}^{\#1\alpha\beta} - 2 i i k \sigma_{2+}^{\#1\alpha\beta} == 0$ | $-i i (4 \partial_\delta \partial_\chi \partial^\beta \partial^\alpha \tau^{\chi\delta} + 2 \partial_\delta \partial^\delta \partial^\beta \partial^\alpha \tau^\chi_\chi -$ $3 \partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\beta\chi} - 3 \partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\chi\beta} -$ $3 \partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\alpha\chi} - 3 \partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\chi\alpha} +$ $3 \partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\alpha\beta} + 3 \partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\beta\alpha} +$ $4 i i k^X \partial_\epsilon \partial_\chi \partial^\beta \partial^\alpha \sigma^{\delta\epsilon}_\delta -$ $6 i i k^X \partial_\epsilon \partial_\delta \partial_\chi \partial^\alpha \sigma^{\beta\delta\epsilon} -$ $6 i i k^X \partial_\epsilon \partial_\delta \partial_\chi \partial^\beta \sigma^{\alpha\delta\epsilon} +$ $2 \eta^{\alpha\beta} \partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \tau^{\chi\delta} +$ $6 i i k^X \partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \sigma^{\alpha\delta\beta} +$ $6 i i k^X \partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \sigma^{\beta\delta\alpha} -$ $2 \eta^{\alpha\beta} \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \tau^\chi_\chi -$ $4 i i \eta^{\alpha\beta} k^X \partial_\phi \partial^\phi \partial_\epsilon \partial_\chi \sigma^{\delta\epsilon}_\delta) == 0$ | 5 |
| Total constraints/gauge generators: | | 16 |

Massive and massless spectra



| Massive particle | |
|------------------|------------------------|
| Pole residue: | $-\frac{1}{r_2} > 0$ |
| Polarisations: | 1 |
| Square mass: | $-\frac{t_2}{r_2} > 0$ |
| Spin: | 0 |
| Parity: | Odd |

(No massless particles)

Unitarity conditions

$r_2 < 0 \&\& t_2 > 0$

Quadratic (free) action

S ==
$$\int \int \int \int (\frac{1}{6} (6 t_1 \omega_{\alpha}^{\alpha i} \omega_{\theta}^{\theta} + 6 f^{\alpha\beta} \tau_{\alpha\beta} + 6 \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} - 12 t_1 \omega_{\alpha}^{\theta} \partial_i f^{\alpha i} + 12 t_1 \omega_{\theta}^{\alpha} \partial_i f^{\alpha i} - 6 t_1 \partial_i f_{\alpha}^{\theta} \partial^{\theta} f_{\theta}^{\alpha} - 6 t_1 \partial_i f^{\alpha i} \partial_{\theta} f_{\alpha}^{\theta} + 12 t_1 \partial_i f_{\alpha}^{\alpha} \partial_{\theta} f_{\theta}^{\theta} + 4 t_1 \omega_{\theta\alpha} \partial^{\theta} f^{\alpha i} + 4 t_2 \omega_{\theta\alpha} \partial^{\theta} f^{\alpha i} - 4 t_1 \partial_{\alpha} f_{\theta} \partial^{\theta} f^{\alpha i} + 2 t_2 \partial_{\alpha} f_{\theta} \partial^{\theta} f^{\alpha i} - 4 t_1 \partial_{\alpha} f_{\theta i} \partial^{\theta} f^{\alpha i} - t_2 \partial_{\alpha} f_{\theta i} \partial^{\theta} f^{\alpha i} + 2 t_1 \partial_i f_{\alpha\theta} \partial^{\theta} f^{\alpha i} - t_2 \partial_i f_{\alpha\theta} \partial^{\theta} f^{\alpha i} + 4 t_1 \partial_{\theta} f_{\alpha i} \partial^{\theta} f^{\alpha i} + 2 t_2 \partial_{\theta} f_{\alpha i} \partial^{\theta} f^{\alpha i} + 2 t_1 \partial_{\theta} f_{\alpha} \partial^{\theta} f^{\alpha i} - t_2 \partial_{\theta} f_{\alpha} \partial^{\theta} f^{\alpha i} + 2 (t_1 + t_2) \omega_{\alpha i\theta} (\omega^{\alpha i\theta} + 2 \partial^{\theta} f^{\alpha i}) + 2 \omega_{\alpha\theta i} ((t_1 - 2 t_2) \omega^{\alpha i\theta} + 2 (2 t_1 - t_2) \partial^{\theta} f^{\alpha i}) + 8 r_2 \partial_\beta \omega_{\alpha i\theta} \partial^\theta \omega^{\alpha\beta i} - 4 r_2 \partial_\beta \omega_{\alpha\theta i} \partial^\theta \omega^{\alpha\beta i} + 4 r_2 \partial_\beta \omega_{\theta\alpha i} \partial^\theta \omega^{\alpha\beta i} - 2 r_2 \partial_i \omega_{\alpha\beta\theta} \partial^\theta \omega^{\alpha\beta i} + 2 r_2 \partial_\theta \omega_{\alpha\beta i} \partial^\theta \omega^{\alpha\beta i} - \partial^\theta \omega^{\alpha\beta i} - 2 r_2 \partial_i \omega_{\alpha\beta\theta} \partial^\theta \omega^{\alpha\beta i}) [t, x, y, z] dz dy dx dt$$

| $\sigma_{1+}^{\#1} \uparrow^{\alpha\beta}$ | $\sigma_{1+}^{\#2} \uparrow^{\alpha\beta}$ | $\tau_{1+}^{\#1} \uparrow^{\alpha\beta}$ | $\sigma_{1-}^{\#1} \uparrow^{\alpha}$ | $\sigma_{1-}^{\#2} \uparrow^{\alpha}$ | $\tau_{1-}^{\#1} \uparrow^{\alpha}$ | $\tau_{1-}^{\#2} \uparrow^{\alpha}$ |
|--|---|---|---------------------------------------|---------------------------------------|-------------------------------------|-------------------------------------|
| $\frac{2(t_1+t_2)}{3t_1t_2}$ | $\frac{\sqrt{2}(t_1-2t_2)}{3(1+k^2)t_1t_2}$ | $\frac{i\sqrt{2}k(t_1-2t_2)}{3(1+k^2)t_1t_2}$ | 0 | 0 | 0 | 0 |
| $\frac{\sqrt{2}(t_1-2t_2)}{3(1+k^2)t_1t_2}$ | $\frac{t_1+4t_2}{3(1+k^2)^2t_1t_2}$ | $\frac{ik(t_1+4t_2)}{3(1+k^2)^2t_1t_2}$ | 0 | 0 | 0 | 0 |
| $\frac{-i\sqrt{2}k(t_1-2t_2)}{3(1+k^2)t_1t_2}$ | $\frac{-ik(t_1+4t_2)}{3(1+k^2)^2t_1t_2}$ | $\frac{k^2(t_1+4t_2)}{3(1+k^2)^2t_1t_2}$ | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | $-\frac{\sqrt{2}}{t_1+2k^2t_1}$ | 0 | $-\frac{2ik}{t_1+2k^2t_1}$ |
| 0 | 0 | 0 | $\frac{\sqrt{2}}{t_1+2k^2t_1}$ | $-\frac{1}{(1+2k^2)^2t_1}$ | 0 | $\frac{i\sqrt{2}k}{(1+2k^2)^2t_1}$ |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | $-\frac{2ik}{t_1+2k^2t_1}$ | $-\frac{i\sqrt{2}k}{(1+2k^2)^2t_1}$ | 0 | $-\frac{2k^2}{(1+2k^2)^2t_1}$ |

| $\omega_{1+}^{\#1} \uparrow^{\alpha\beta}$ | $\omega_{1+}^{\#2} \uparrow^{\alpha\beta}$ | $f_{1+}^{\#1} \uparrow^{\alpha\beta}$ | $\omega_{1-}^{\#1} \uparrow^{\alpha}$ | $\omega_{1-}^{\#2} \uparrow^{\alpha}$ | $f_{1-}^{\#1} \uparrow^{\alpha}$ | $f_{1-}^{\#2} \uparrow^{\alpha}$ |
|--|--|---------------------------------------|---------------------------------------|---------------------------------------|----------------------------------|----------------------------------|
| $\frac{1}{6}(t_1+4t_2)$ | $-\frac{t_1-2t_2}{3\sqrt{2}}$ | $-\frac{ik(t_1-2t_2)}{3\sqrt{2}}$ | 0 | 0 | 0 | 0 |
| $-\frac{t_1-2t_2}{3\sqrt{2}}$ | $\frac{t_1+t_2}{3}$ | $\frac{1}{3}ik(t_1+t_2)$ | 0 | 0 | 0 | 0 |
| $\frac{ik(t_1-2t_2)}{3\sqrt{2}}$ | $-\frac{1}{3}ik(t_1+t_2)$ | $\frac{1}{3}k^2(t_1+t_2)$ | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | $-\frac{t_1}{2}$ | $\frac{t_1}{\sqrt{2}}$ | 0 | $ik t_1$ |
| 0 | 0 | 0 | $\frac{t_1}{\sqrt{2}}$ | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | $-ik t_1$ | 0 | 0 | 0 |

| $\sigma_{0+}^{\#1} \uparrow^{\alpha\beta}$ | $\tau_{0+}^{\#1} \uparrow^{\alpha\beta}$ | $\tau_{0+}^{\#2} \uparrow^{\alpha\beta}$ | $\sigma_{0-}^{\#1} \uparrow^{\alpha\beta}$ | $\sigma_{2+}^{\#1} \uparrow^{\alpha\beta}$ | $\tau_{2+}^{\#1} \uparrow^{\alpha\beta}$ | $\sigma_{2-}^{\#1} \uparrow^{\alpha\beta\chi}$ |
|--|--|--|--|--|--|--|
| $-\frac{1}{(1+2k^2)^2t_1}$ | $\frac{i\sqrt{2}k}{(1+2k^2)^2t_1}$ | 0 | 0 | $\frac{2}{(1+2k^2)^2t_1}$ | $-\frac{2i\sqrt{2}k}{(1+2k^2)^2t_1}$ | 0 |
| $-\frac{i\sqrt{2}k}{(1+2k^2)^2t_1}$ | $-\frac{2k^2}{(1+2k^2)^2t_1}$ | 0 | 0 | $\frac{2i\sqrt{2}k}{(1+2k^2)^2t_1}$ | $-\frac{4k^2}{(1+2k^2)^2t_1}$ | 0 |
| 0 | 0 | 0 | 0 | $\sigma_{2-}^{\#1} \uparrow^{\alpha\beta\chi}$ | 0 | $\frac{2}{t_1}$ |
| 0 | 0 | 0 | $\frac{1}{k^2r_2+t_2}$ | $\omega_{0+}^{\#1}$ | $f_{0+}^{\#1}$ | $\omega_{0-}^{\#1}$ |

| $\omega_{2+}^{\#1} \uparrow^{\alpha\beta}$ | $f_{2+}^{\#1} \uparrow^{\alpha\beta}$ | $\omega_{2-}^{\#1} \uparrow^{\alpha\beta\chi}$ |
|--|---------------------------------------|--|
| $\frac{t_1}{2}$ | $-\frac{ikt_1}{\sqrt{2}}$ | 0 |
| $\frac{ikt_1}{\sqrt{2}}$ | k^2t_1 | 0 |
| 0 | 0 | $\frac{t_1}{2}$ |

| $\omega_0^{\#1} \uparrow^{\alpha\beta}$ | $f_0^{\#1} \uparrow^{\alpha\beta}$ | $\omega_0^{\#2} \uparrow^{\alpha\beta}$ |
|---|------------------------------------|---|
| $\omega_0^{\#1} \uparrow^{\alpha\beta}$ | $i\sqrt{2}kt_1$ | 0 |
| $f_0^{\#1} \uparrow^{\alpha\beta}$ | $-i\sqrt{2}kt_1$ | 0 |
| $f_0^{\#2} \uparrow^{\alpha\beta}$ | 0 | 0 |
| $\omega_0^{\#1} \uparrow^{\alpha\beta\chi}$ | 0 | $k^2r_2+t_2$ |