

Particle spectrograph

Wave operator and propagator

| $\sigma_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\sigma_{1+}^{\#2} \alpha\beta$ | $\tau_{1+}^{\#1} \alpha\beta$ | $\sigma_{1-}^{\#1} \alpha$ | $\sigma_{1-}^{\#2} \alpha$ | $\tau_{1-}^{\#1} \alpha$ | $\tau_{1-}^{\#2} \alpha$ |
|---|------------------------------------|--|---|---|--------------------------|--|
| $\sigma_{1+}^{\#1} \dagger^{\alpha\beta}$ | 0 | $-\frac{\sqrt{2}}{t_1+k^2 t_1}$ | 0 | 0 | 0 | 0 |
| $\sigma_{1+}^{\#2} \dagger^{\alpha\beta}$ | $-\frac{\sqrt{2}}{t_1+k^2 t_1}$ | $\frac{-2 i k^3 (2 r_3+r_5)+t_1}{(1+k^2)^2 t_1^2}$ | 0 | 0 | 0 | 0 |
| $\tau_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\frac{i \sqrt{2} k}{t_1+k^2 t_1}$ | $\frac{-2 k^4 (2 r_3+r_5)+k^2 t_1}{(1+k^2)^2 t_1^2}$ | 0 | 0 | 0 | 0 |
| $\sigma_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | $\frac{1}{k^2 (2 r_3+r_5)}$ | $-\frac{1}{\sqrt{2} (k^2+2 k^4) (2 r_3+r_5)}$ | 0 | $-\frac{i}{k (1+2 k^2) (2 r_3+r_5)}$ |
| $\sigma_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | $-\frac{1}{\sqrt{2} (k^2+2 k^4) (2 r_3+r_5)}$ | $\frac{6 k^2 (2 r_3+r_5)+t_1}{2 (k+2 k^3)^2 (2 r_3+r_5) t_1}$ | 0 | $\frac{i (6 k^2 (2 r_3+r_5)+t_1)}{\sqrt{2} k (1+2 k^2)^2 (2 r_3+r_5) t_1}$ |
| $\tau_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $\tau_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | $\frac{i}{k (1+2 k^2) (2 r_3+r_5)}$ | $-\frac{i (6 k^2 (2 r_3+r_5)+t_1)}{\sqrt{2} k (1+2 k^2)^2 (2 r_3+r_5) t_1}$ | 0 | $\frac{6 k^2 (2 r_3+r_5)+t_1}{(1+2 k^2)^2 (2 r_3+r_5) t_1}$ |

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

| $\omega_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\omega_{1+}^{\#2} \alpha\beta$ | $f_{1+}^{\#1} \alpha\beta$ | $\omega_{1-}^{\#1} \alpha$ | $\omega_{1-}^{\#2} \alpha$ | $f_{1-}^{\#1} \alpha$ | $f_{1-}^{\#2} \alpha$ |
|---|-----------------------------------|----------------------------|-----------------------------------|---------------------------------|-----------------------|--------------------------------|
| $\omega_{1+}^{\#1} \dagger^{\alpha\beta}$ | $k^2 (2 r_3+r_5) - \frac{t_1}{2}$ | $-\frac{t_1}{\sqrt{2}}$ | 0 | 0 | 0 | 0 |
| $\omega_{1+}^{\#2} \dagger^{\alpha\beta}$ | $-\frac{t_1}{\sqrt{2}}$ | 0 | 0 | 0 | 0 | 0 |
| $f_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\frac{i k t_1}{\sqrt{2}}$ | 0 | 0 | 0 | 0 | 0 |
| $\omega_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | $k^2 (2 r_3+r_5) + \frac{t_1}{6}$ | $\frac{t_1}{3 \sqrt{2}}$ | 0 | $\frac{i k t_1}{3}$ |
| $\omega_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | $\frac{t_1}{3 \sqrt{2}}$ | $\frac{t_1}{3}$ | 0 | $\frac{1}{3} i \sqrt{2} k t_1$ |
| $f_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $f_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | $-\frac{1}{3} i k t_1$ | $-\frac{1}{3} i \sqrt{2} k t_1$ | 0 | $\frac{2 k^2 t_1}{3}$ |

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

| $\sigma_{0+}^{\#1} \dagger^{\alpha\beta}$ | $\tau_{0+}^{\#1} \alpha\beta$ | $\sigma_{0+}^{\#2} \alpha\beta$ |
|---|-------------------------------|---------------------------------|
| $\sigma_{0+}^{\#1} \dagger^{\alpha\beta}$ | $\frac{1}{6 k^2 r_3}$ | 0 |
| $\tau_{0+}^{\#1} \dagger^{\alpha\beta}$ | 0 | 0 |
| $\tau_{0+}^{\#2} \dagger^{\alpha\beta}$ | 0 | 0 |
| $\sigma_{0-}^{\#1} \dagger^{\alpha\beta}$ | 0 | $-\frac{1}{t_1}$ |

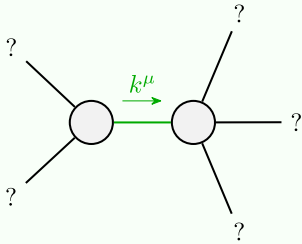
Quadratic (free) action

$$S = \iiint ((f^{\alpha\beta} \tau_{\alpha\beta} + \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} + \frac{1}{6} t_1 (2 \omega^{\alpha\iota} \omega_{\alpha}{}^{\theta}{}_{,\theta} - 4 \omega_{\alpha}{}^{\theta}{}_{,\theta} \omega^{\alpha\iota} f^{\alpha}{}_{,\theta} + 4 \omega_{,\theta}{}^{\theta} \partial^{\iota} f^{\alpha}{}_{,\theta} - 2 \partial_{,\theta} f^{\theta}{}_{,\alpha} \partial^{\alpha} f^{\alpha}{}_{,\theta} - 2 \partial_{,\theta} f^{\alpha\iota} \partial_{\theta} f^{\theta}{}_{,\alpha} + 4 \partial^{\iota} f^{\alpha}{}_{,\alpha} \partial_{\theta} f^{\theta}{}_{,\theta} - 6 \partial_{\alpha} f^{\theta}{}_{,\theta} \partial^{\theta} f^{\alpha\iota} - 3 \partial_{\alpha} f^{\theta}{}_{,\theta} \partial^{\theta} f^{\alpha\iota} + 3 \partial_{\theta} f^{\alpha\iota} \partial^{\theta} f^{\alpha\iota} + 3 \partial_{\theta} f^{\alpha\iota} \partial^{\theta} f^{\alpha\iota} + 3 \partial_{\theta} f^{\alpha\iota} \partial^{\theta} f^{\alpha\iota} + 6 \omega_{\alpha\theta\iota} (\omega^{\alpha\iota\theta} + 2 \partial^{\theta} f^{\alpha\iota})) - 2 r_3 (\partial_{\beta} \omega_{,\theta} \partial^{\iota} \omega_{\alpha}{}^{\beta} + \partial_{,\iota} \omega_{\beta}{}^{\theta} \partial^{\iota} \omega_{\theta}{}^{\alpha\beta} + \partial_{\alpha} \omega^{\alpha\beta\iota} \partial_{\theta} \omega_{\beta}{}^{\theta} - 2 \partial^{\iota} \omega_{\alpha}{}^{\beta} \partial_{\theta} \omega_{\beta}{}^{\theta} + \partial_{\alpha} \omega^{\alpha\beta\iota} \partial_{\theta} \omega_{,\beta}{}^{\theta} - 2 \partial^{\iota} \omega_{\alpha}{}^{\beta} \partial_{\theta} \omega_{,\beta}{}^{\theta} + 2 \partial_{\beta} \omega_{,\theta\alpha} \partial^{\theta} \omega^{\alpha\beta\iota}) + r_5 (\partial_{,\iota} \omega_{\theta}{}^{\kappa} \partial^{\theta} \omega_{\alpha}{}^{\iota} - \partial_{\theta} \omega_{,\kappa}{}^{\iota} \partial^{\theta} \omega_{\alpha}{}^{\iota} - (\partial_{\alpha} \omega^{\alpha\iota\theta} - 2 \partial^{\theta} \omega^{\alpha\iota}{}_{,\alpha}) (\partial_{\kappa} \omega_{,\theta}{}^{\kappa} - \partial_{\kappa} \omega_{\theta}{}^{\kappa})))[t, x, y, z] dz dy dx dt$$

| $\omega_{0+}^{\#1} \dagger^{\alpha\beta}$ | $f_{0+}^{\#1} \alpha\beta$ | $f_{0+}^{\#2} \alpha\beta$ | $\omega_{0-}^{\#1} \alpha\beta$ |
|---|----------------------------|----------------------------|---------------------------------|
| $\omega_{0+}^{\#1} \dagger^{\alpha\beta}$ | $6 k^2 r_3$ | 0 | 0 |
| $f_{0+}^{\#1} \dagger^{\alpha\beta}$ | 0 | 0 | 0 |
| $f_{0+}^{\#2} \dagger^{\alpha\beta}$ | 0 | 0 | 0 |
| $\omega_{0-}^{\#1} \dagger^{\alpha\beta}$ | 0 | 0 | $-t_1$ |

| Source constraints/gauge generators | |
|--|----------------|
| SO(3) irreps | Multiplicities |
| $\tau_{0+}^{\#2} == 0$ | 1 |
| $\tau_{0+}^{\#1} == 0$ | 1 |
| $\tau_{1-}^{\#2\alpha} + 2 i k \sigma_{1-}^{\#2\alpha} == 0$ | 3 |
| $\tau_{1-}^{\#1\alpha} == 0$ | 3 |
| $\tau_{1+}^{\#1\alpha\beta} + i k \sigma_{1+}^{\#2\alpha\beta} == 0$ | 3 |
| $\tau_{2+}^{\#1\alpha\beta} - 2 i k \sigma_{2+}^{\#1\alpha\beta} == 0$ | 5 |
| Total constraints: | 16 |

Massive and massless spectra



| Quadratic pole | |
|----------------|------------------------------------|
| Pole residue: | $-\frac{1}{(2 r_3+r_5) t_1^2} > 0$ |
| Polarisations: | 2 |

(No massive particles)

Unitarity conditions

$$r_5 < -2 r_3 \ \& \ t_1 < 0 \ || \ t_1 > 0$$