

Particle spectrograph

Wave operator and propagator

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

Quadratic (free) action

$$S_F = \iiint (\frac{1}{6} (-2t_1 \omega_{\mu}^{\alpha\mu} \omega_{\kappa\alpha}^{\kappa} - 6t_1 \omega_{\mu}^{\kappa\lambda} \omega_{\kappa\lambda}^{\mu} + 6f^{\alpha\beta} \tau_{\alpha\beta} + 6\omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} + 4r_2 \partial^\beta \omega_{\kappa}^{\theta\alpha} \partial_\theta \omega_{\alpha\beta}^{\kappa} - 2r_2 \partial_\theta \omega_{\alpha\beta}^{\kappa} \partial_\kappa \omega^{\alpha\beta\theta} - 4r_2 \partial_\theta \omega_{\alpha\beta}^{\kappa} \partial_\kappa \omega^{\theta\alpha\beta} - 3t_1 \partial^\alpha f_{\theta\kappa} \partial^\kappa f_{\alpha}^{\theta} - 3t_1 \partial^\alpha f_{\kappa\theta} \partial^\kappa f_{\alpha}^{\theta} - 3t_1 \partial^\alpha f_{\lambda}^{\theta} \partial^\kappa f_{\alpha}^{\theta} - 3t_1 \partial^\alpha f_{\lambda}^{\theta} \partial^\kappa f_{\alpha}^{\theta} - 2t_1 \omega_{\kappa\lambda}^{\lambda} \partial^\kappa f_{\mu}^{\lambda} + 4t_1 \partial^\alpha f_{\kappa\alpha} \partial^\kappa f_{\mu}^{\lambda} - 2t_1 \partial_\kappa f_{\lambda}^{\lambda} \partial^\kappa f_{\mu}^{\lambda} + 12t_1 \omega_{\mu\kappa\theta} \partial^\kappa f_{\mu}^{\theta} - 2t_1 \omega_{\mu\alpha}^{\alpha} \partial^\kappa f_{\mu}^{\lambda} - 2t_1 \omega_{\mu\alpha}^{\lambda} \partial^\kappa f_{\mu}^{\lambda} + 3t_1 \partial^\alpha f_{\lambda}^{\alpha} \partial^\kappa f_{\mu}^{\lambda} + 3t_1 \partial_\kappa f_{\lambda}^{\lambda} \partial^\kappa f_{\mu}^{\theta} + 3t_1 \partial_\kappa f_{\theta}^{\lambda} \partial^\kappa f_{\lambda}^{\theta} - 2t_1 \partial_\kappa f_{\lambda}^{\theta} \partial^\kappa f_{\mu}^{\lambda} + 2r_2 \partial_\kappa \omega^{\alpha\beta\theta} \partial^\kappa \omega_{\alpha\beta\theta} + 4r_2 \partial_\kappa \omega^{\theta\alpha\beta} \partial^\kappa \omega_{\alpha\beta\theta} - 4r_2 \partial^\beta \omega_{\mu}^{\alpha\lambda} \partial_\lambda \omega_{\alpha\beta}^{\mu} + 4r_2 \partial^\beta \omega_{\mu}^{\lambda\alpha} \partial_\lambda \omega_{\alpha\beta}^{\mu})) [t, x, y, z] dz dy dx dt$$

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

$\sigma_{2+}^{\#1} \dagger^{\alpha\beta}$ $\tau_{2+}^{\#1} \dagger^{\alpha\beta}$ $\sigma_{2+}^{\#1} \alpha\beta\chi$

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

Source constraints/gauge generators

| SO(3) irreps | Multiplicities |
|--|----------------|
| $\tau_{0+}^{\#2} == 0$ | 1 |
| $\tau_{0+}^{\#1} == 0$ | 1 |
| $\sigma_{0+}^{\#1} == 0$ | 1 |
| $\tau_{1-}^{\#2\alpha} + 2ik \sigma_{1-}^{\#1\alpha} == 0$ | 3 |
| $\tau_{1-}^{\#1\alpha} == 0$ | 3 |
| $\sigma_{1-}^{\#1\alpha} == \sigma_{1-}^{\#2\alpha}$ | 3 |
| $\tau_{1+}^{\#1\alpha\beta} + ik \sigma_{1+}^{\#2\alpha\beta} == 0$ | 3 |
| $\tau_{2+}^{\#1\alpha\beta} - 2ik \sigma_{2+}^{\#1\alpha\beta} == 0$ | 5 |
| Total constraints: | 20 |

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

| $\sigma_{0+}^{\#1} \dagger$ | $\tau_{0+}^{\#1} \dagger$ | $\tau_{0+}^{\#2} \dagger$ | $\sigma_{0-}^{\#1} \dagger$ |
|-----------------------------|---------------------------|---------------------------|-----------------------------|
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | $\frac{1}{k^2 r_2 t_1}$ |

| $\omega_{0+}^{\#1} \dagger$ | $f_{0+}^{\#1} \dagger$ | $f_{0+}^{\#2} \dagger$ | $\omega_{0-}^{\#1} \dagger$ |
|-----------------------------|------------------------|------------------------|-----------------------------|
| 0 | 0 | 0 | $k^2 r_2 - t_1$ |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |

Massive and massless spectra

Massive particle

| | |
|----------------|-----------------------|
| Pole residue: | $-\frac{1}{r_2} > 0$ |
| Polarisations: | 1 |
| Square mass: | $\frac{t_1}{r_2} > 0$ |
| Spin: | 0 |
| Parity: | Odd |

(No massless particles)

Unitarity conditions

$r_2 < 0 \ \&\& \ t_1 < 0$