

Particle spectrograph

Wave operator and propagator

| Source constraints | | | Fundamental fields | | Multiplicities | |
|--|--|--|---|--|----------------|--|
| SO(3) irreps | | | | | | |
| $\sigma_0^{\#1} == 0$ | | | $\partial_\beta \sigma^{\alpha\beta}_\alpha == 0$ | | 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 | |
| $\tau_1^{\#2\alpha} == 0$ | | | $\partial_\chi \partial_\beta \partial^\alpha \tau^{\beta\chi} == \partial_\chi \partial^\chi \partial_\beta \tau^{\alpha\beta}$ | | 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 | |
| $\sigma_1^{\#2\alpha} == 0$ | | | $\partial_\chi \partial_\beta \sigma^{\alpha\beta\chi} == 0$ | | 3 | |
| $\tau_1^{\#1\alpha\beta} + i k \sigma_1^{\#2\alpha\beta} == 0$ | | | $\partial_\chi \partial^\alpha \tau^{\beta\chi} + \partial_\chi \partial^\beta \tau^{\alpha\chi} + \partial_\chi \partial^\chi \tau^{\alpha\beta} + 2 \partial_\beta \partial^\delta \partial_\chi \sigma^{\alpha\beta\chi} ==$ $\partial_\chi \partial^\alpha \tau^{\chi\beta} + \partial_\chi \partial^\beta \tau^{\alpha\chi} + \partial_\chi \partial^\chi \tau^{\beta\alpha} + 2 \partial_\beta \partial^\delta \partial_\chi \sigma^{\alpha\delta\beta} + 2 \partial_\beta \partial^\epsilon \partial_\chi \sigma^{\alpha\delta\epsilon} + 3 \eta^{\beta\chi} \partial_\phi \partial^\phi \partial_\epsilon \sigma^{\alpha\delta\epsilon} + 3 \eta^{\alpha\chi} \partial_\phi \partial^\phi \partial_\epsilon \sigma^{\alpha\delta\epsilon} + 3 \eta^{\beta\chi} \partial_\phi \partial^\phi \partial_\epsilon \sigma^{\alpha\delta} =$ $3 \partial_\epsilon \partial_\phi \partial^\chi \partial^\phi \sigma^{\alpha\delta\epsilon} + 3 \partial_\epsilon \partial^\epsilon \partial^\chi \partial^\phi \sigma^{\alpha\delta} + 2 \partial_\epsilon \partial^\epsilon \partial_\phi \partial^\phi \sigma^{\alpha\chi\delta} + 4 \partial_\epsilon \partial^\epsilon \partial_\phi \partial^\phi \sigma^{\alpha\delta\chi} + 2 \partial_\epsilon \partial^\epsilon \partial_\phi \partial^\phi \sigma^{\chi\delta\alpha} + 4 \partial_\epsilon \partial^\epsilon \partial_\phi \partial^\phi \sigma^{\alpha\beta\delta} + 2 \partial_\epsilon \partial^\epsilon \partial_\phi \partial^\phi \sigma^{\alpha\delta\beta} + 2 \partial_\epsilon \partial^\epsilon \partial_\phi \partial^\phi \sigma^{\alpha\chi\beta} + 3 \eta^{\alpha\chi} \partial_\phi \partial^\phi \partial_\epsilon \sigma^{\delta\epsilon} + 3 \eta^{\beta\chi} \partial_\phi \partial^\phi \partial_\epsilon \sigma^{\alpha\delta\epsilon} + 3 \eta^{\alpha\chi} \partial_\phi \partial^\phi \partial_\epsilon \sigma^{\alpha\delta} =$ | | 5 | |
| $\tau_2^{\#1\alpha\beta} == 0$ | | | $3 \partial_\epsilon \partial_\phi \partial^\chi \partial^\phi \tau^{\alpha\chi\delta} + 2 \partial_\beta \partial^\delta \partial^\beta \partial^\alpha \tau^\chi_\chi + 3 \partial_\beta \partial^\delta \partial_\chi \partial^\alpha \tau^{\beta\chi} + 3 \partial_\beta \partial^\delta \partial_\chi \partial^\alpha \tau^{\beta\chi} + 2 \eta^{\alpha\beta} \partial_\epsilon \partial^\epsilon \partial_\phi \partial_\chi \tau^{\chi\delta} ==$ $3 \partial_\phi \partial^\delta \partial_\chi \partial^\alpha \tau^{\beta\chi} + 3 \partial_\beta \partial^\delta \partial_\chi \partial^\alpha \tau^{\chi\beta} + 3 \partial_\beta \partial^\delta \partial_\chi \partial^\beta \tau^{\alpha\chi} + 3 \partial_\beta \partial^\delta \partial_\chi \partial^\beta \tau^{\chi\alpha} + 2 \eta^{\alpha\beta} \partial_\epsilon \partial^\epsilon \partial_\phi \partial^\delta \tau^\chi_\chi$ | | 5 | |
| Total constraints/gauge generators: | | | | | 25 | |

Quadratic (free) action

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$$\iiint (\frac{1}{6} f^{\alpha\beta} \tau_{\alpha\beta} + 6 \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} - 3 r_3 \partial_\beta \omega_{,\theta}^\theta \partial' \omega^{\alpha\beta}_\alpha - 3 r_3 \partial_\beta \omega_{\beta,\theta}^\theta \partial' \omega^{\alpha\beta}_\alpha - 3 r_3 \partial_\alpha \omega^{\alpha\beta\gamma} \partial_\theta \omega_{\beta,\gamma}^\theta + 6 r_3 \partial' \omega^{\alpha\beta}_\alpha \partial_\theta \omega_{\beta,\gamma}^\theta - 3 r_3 \partial_\alpha \omega^{\alpha\beta\gamma} \partial_\theta \omega_{\beta,\gamma}^\theta + 6 r_3 \partial' \omega^{\alpha\beta}_\alpha \partial_\theta \omega_{\beta,\gamma}^\theta + 4 t_2 \omega_{,\theta\alpha} \partial^\theta f^{\alpha\gamma} + 2 t_2 \partial_\alpha f_{,\theta}^\theta \partial^\theta f^{\alpha\gamma} - t_2 \partial_\alpha f_{,\theta}^\theta \partial^\theta f^{\alpha\gamma} - t_2 \partial_\alpha f_{,\theta}^\theta \partial^\theta f^{\alpha\gamma} - 4 t_2 \omega_{,\alpha\theta\gamma} (\omega^{\alpha\theta\gamma} + \partial^\theta f^{\alpha\gamma}) + 2 t_2 \omega_{\alpha\theta\beta} (\omega^{\alpha\theta\beta} + 2 \partial^\theta f^{\alpha\gamma}) - 24 r_3 \partial_\beta \omega_{,\theta\alpha} \partial^\theta \omega_{\alpha}^{\beta\gamma} + 6 r_5 \partial_\alpha \omega_{,\theta}^\kappa \partial^\theta \omega_{\alpha}^{\beta\gamma} - 6 r_5 \partial_\theta \omega_{,\kappa}^\kappa \partial^\theta \omega_{\alpha}^{\beta\gamma} - 6 r_5 \partial_\theta \omega_{,\kappa}^\kappa \partial^\theta \omega_{\alpha}^{\beta\gamma} - 12 r_5 \partial^\theta \omega_{\alpha}^{\beta\gamma} \partial_\kappa \omega_{,\theta}^\kappa + 6 r_5 \partial_\alpha \omega^{\alpha\theta\beta} \partial_\kappa \omega_{\theta,\gamma}^\kappa - 12 r_5 \partial^\theta \omega_{\alpha}^{\beta\gamma} \partial_\kappa \omega_{\theta,\gamma}^\kappa) [t, x, y, z] dz dy dx dt$$

| $\sigma_1^{\#1+ \alpha\beta}$ | $\sigma_1^{\#2+ \alpha\beta}$ | $\tau_1^{\#1+ \alpha\beta}$ | $\sigma_1^{\#1- \alpha}$ | $\sigma_1^{\#2- \alpha}$ | $\tau_1^{\#1- \alpha}$ | $\tau_1^{\#2- \alpha}$ |
|---|--|---|-------------------------------|--------------------------|------------------------|------------------------|
| $\frac{1}{k^2 (2 r_3 + r_5)}$ | $-\frac{\sqrt{2}}{k^2 (1 + k^2) (2 r_3 + r_5)}$ | $-\frac{i \sqrt{2}}{k (1 + k^2) (2 r_3 + r_5)}$ | 0 | 0 | 0 | 0 |
| $-\frac{\sqrt{2}}{k^2 (1 + k^2) (2 r_3 + r_5)}$ | $\frac{3 k^2 (2 r_3 + r_5) + 2 t_2}{(k + k^3)^2 (2 r_3 + r_5) t_2}$ | $\frac{i (3 k^2 (2 r_3 + r_5) + 2 t_2)}{k (1 + k^2)^2 (2 r_3 + r_5) t_2}$ | 0 | 0 | 0 | 0 |
| $-\frac{i \sqrt{2}}{k (1 + k^2) (2 r_3 + r_5)}$ | $-\frac{i (3 k^2 (2 r_3 + r_5) + 2 t_2)}{k (1 + k^2)^2 (2 r_3 + r_5) t_2}$ | $\frac{3 k^2 (2 r_3 + r_5) + 2 t_2}{(1 + k^2)^2 (2 r_3 + r_5) t_2}$ | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | $\frac{2}{k^2 (r_3 + 2 r_5)}$ | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |

| $\omega_1^{\#1+ \alpha\beta}$ | $\omega_1^{\#2+ \alpha\beta}$ | $f_1^{\#1+ \alpha\beta}$ | $\omega_1^{\#1- \alpha}$ | $\omega_1^{\#2- \alpha}$ | $f_1^{\#1- \alpha}$ | $f_1^{\#2- \alpha}$ |
|---------------------------------------|-------------------------------|--------------------------------|---------------------------------|--------------------------|---------------------|---------------------|
| $k^2 (2 r_3 + r_5) + \frac{2 t_2}{3}$ | $\frac{\sqrt{2} t_2}{3}$ | $\frac{1}{3} i \sqrt{2} k t_2$ | 0 | 0 | 0 | 0 |
| $\frac{\sqrt{2} t_2}{3}$ | $\frac{t_2}{3}$ | $\frac{i k t_2}{3}$ | 0 | 0 | 0 | 0 |
| $-\frac{1}{3} i \sqrt{2} k t_2$ | $-\frac{1}{3} i k t_2$ | $\frac{k^2 t_2}{3}$ | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | $\frac{1}{2} k^2 (r_3 + 2 r_5)$ | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 | 0 | 0 | 0 |

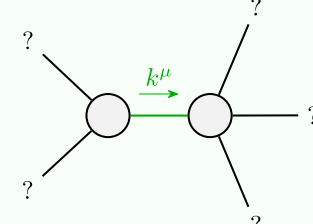
| | | | |
|-------------------|--------------|--------------|-------------------|
| $\omega_0^{\#1+}$ | $f_0^{\#1+}$ | $f_0^{\#2+}$ | $\omega_0^{\#1-}$ |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | t_2 |

| | | |
|-------------------------------|--------------------------|-----------------------------------|
| $\omega_2^{\#1+ \alpha\beta}$ | $f_2^{\#1+ \alpha\beta}$ | $\omega_2^{\#1- \alpha\beta\chi}$ |
| $-\frac{3 k^2 r_3}{2}$ | 0 | 0 |
| 0 | 0 | 0 |
| 0 | 0 | 0 |

| | | | |
|-------------------|-----------------|-----------------|-------------------|
| $\sigma_0^{\#1+}$ | $\tau_0^{\#1+}$ | $\tau_0^{\#2+}$ | $\sigma_0^{\#1-}$ |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | 0 |
| 0 | 0 | 0 | $\frac{1}{t_2}$ |

| | | |
|-------------------------------|-----------------------------|-----------------------------------|
| $\sigma_2^{\#1+ \alpha\beta}$ | $\tau_2^{\#1+ \alpha\beta}$ | $\sigma_2^{\#1- \alpha\beta\chi}$ |
| $-\frac{2}{3 k^2 r_3}$ | 0 | 0 |
| 0 | 0 | 0 |
| 0 | 0 | 0 |

Massive and massless spectra



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

(No massive particles)

Unitarity conditions

$r_3 < 0 \&\& (r_5 < -\frac{r_3}{2} \parallel r_5 > -2 r_3) \parallel r_3 > 0 \&\& -2 r_3 < r_5 < -\frac{r_3}{2}$