

# Particle spectrograph

## Wave operator and propagator

Quadratic (free) action

$$S_F =$$

$$\iiint (\frac{1}{6} (4 t_3 \omega_{\lambda'}^{\alpha'} \omega_{\kappa\alpha}^{\kappa} + 6 f^{\alpha\beta} \tau_{\alpha\beta} + 6 \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} - 3 r_3 \partial_{\lambda'} \omega_{\kappa}^{\kappa\lambda} \partial_{\lambda} \omega_{\alpha}^{\alpha} - 6 r_5 \partial_{\lambda} \omega_{\kappa}^{\kappa\lambda} \partial_{\lambda'} \omega_{\alpha}^{\alpha} + 4 r_2 \partial^{\beta} \omega_{\alpha}^{\alpha} \partial_{\theta} \omega_{\alpha\beta}^{\alpha} - 2 r_2 \partial_{\theta} \omega_{\alpha\beta}^{\alpha} \partial_{\theta} \omega_{\alpha}^{\alpha} - 4 r_2 \partial_{\theta} \omega_{\alpha\beta}^{\alpha} \partial_{\theta} \omega_{\alpha}^{\alpha} + 3 r_3 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \omega_{\lambda}^{\theta\kappa\lambda} - 6 r_5 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \omega_{\lambda}^{\theta\kappa\lambda} - 3 r_3 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega_{\alpha}^{\theta\kappa\lambda} + 6 r_5 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega_{\alpha}^{\theta\kappa\lambda} - 3 r_3 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \omega_{\lambda}^{\kappa\lambda\theta} - 6 r_5 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \omega_{\lambda}^{\kappa\lambda\theta} + 6 r_3 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega_{\alpha}^{\kappa\lambda\theta} + 12 r_5 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega_{\lambda}^{\kappa\lambda\theta} - 4 t_3 \omega_{\kappa\alpha}^{\alpha} \partial^{\kappa} f_{\lambda'} - 4 t_3 \omega_{\kappa\lambda}^{\lambda} \partial^{\kappa} f_{\lambda'} - 8 t_3 \partial^{\alpha} f_{\kappa\alpha} \partial^{\kappa} f_{\lambda'} + 4 t_3 \partial_{\kappa} f_{\lambda}^{\lambda} \partial^{\kappa} f_{\lambda'} + 4 t_3 \omega_{\lambda\alpha}^{\alpha} \partial^{\kappa} f_{\kappa} + 4 t_3 \omega_{\lambda\lambda}^{\lambda} \partial^{\kappa} f_{\lambda'} + 4 t_3 \partial^{\alpha} f_{\lambda}^{\lambda} \partial^{\kappa} f_{\alpha} + 2 r_2 \partial_{\kappa} \omega^{\alpha\beta\theta} \partial^{\kappa} \omega_{\alpha\beta\theta} + 4 r_2 \partial_{\kappa} \omega^{\theta\alpha\beta} \partial^{\kappa} \omega_{\alpha\beta\theta} - 4 r_2 \partial^{\beta} \omega_{\lambda'}^{\alpha\lambda} \partial_{\lambda} \omega_{\alpha\beta}^{\alpha} + 4 r_2 \partial^{\beta} \omega_{\lambda'}^{\lambda\alpha} \partial_{\lambda} \omega_{\alpha\beta}^{\alpha} - 24 r_3 \partial^{\beta} \omega_{\lambda'}^{\lambda\alpha} \partial_{\lambda} \omega_{\alpha\beta}^{\alpha} - 3 r_3 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \omega_{\lambda}^{\theta\kappa} + 6 r_5 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \omega_{\lambda}^{\theta\kappa} + 3 r_3 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial^{\lambda} \omega_{\kappa}^{\theta\kappa} - 6 r_5 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial^{\lambda} \omega_{\kappa}^{\theta\kappa})) [t, x, y, z] dz dy dx dt$$

$\sigma_{1+}^{\#1} \dagger^{\alpha\beta}$	$\sigma_{1+}^{\#2} \sigma_{1+}^{\#1} \dagger^{\alpha\beta}$	$\sigma_{1-}^{\#1} \alpha$	$\sigma_{1-}^{\#2} \alpha$	$\tau_{1-}^{\#1} \alpha$	$\tau_{1-}^{\#2} \alpha$
$\frac{1}{k^2 (2r_3+r_5)}$	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	$\frac{2}{k^2 (r_3+2r_5)}$	$\frac{2\sqrt{2}}{k^2 (1+2k^2) (r_3+2r_5)}$	0	$\frac{4i}{k (1+2k^2) (r_3+2r_5)}$
0	0	$\frac{2\sqrt{2}}{k^2 (1+2k^2) (r_3+2r_5)}$	$\frac{3k^2 (r_3+2r_5)+4t_3}{(k+2k^3)^2 (r_3+2r_5) t_3}$	0	$\frac{i\sqrt{2} (3k^2 (r_3+2r_5)+4t_3)}{k (1+2k^2)^2 (r_3+2r_5) t_3}$
0	0	0	0	0	0
0	0	$-\frac{4i}{k (1+2k^2) (r_3+2r_5)}$	$-\frac{i\sqrt{2} (3k^2 (r_3+2r_5)+4t_3)}{k (1+2k^2)^2 (r_3+2r_5) t_3}$	0	$\frac{6k^2 (r_3+2r_5)+8t_3}{(1+2k^2)^2 (r_3+2r_5) t_3}$

$\omega_{1+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{1+}^{\#2} \omega_{1+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{1-}^{\#1} \alpha$	$\omega_{1-}^{\#2} \alpha$	$f_{1-}^{\#1} \alpha$	$f_{1-}^{\#2} \alpha$
$k^2 (2r_3+r_5)$	0	0	0	0	0
0	0	0	0	0	0
0	0	0	0	0	0
0	0	$k^2 (\frac{r_3}{2} + r_5) + \frac{2t_3}{3}$	$-\frac{\sqrt{2} t_3}{3}$	0	$-\frac{2}{3} i k t_3$
0	0	$-\frac{\sqrt{2} t_3}{3}$	$\frac{t_3}{3}$	0	$\frac{1}{3} i \sqrt{2} k t_3$
0	0	0	0	0	0
0	0	$\frac{2 i k t_3}{3}$	$-\frac{1}{3} i \sqrt{2} k t_3$	0	$\frac{2 k^2 t_3}{3}$

Source constraints/gauge generators

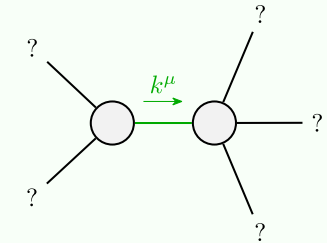
SO(3) irreps	Multiplicities
$\tau_{0+}^{\#2} == 0$	1
$\tau_{0+}^{\#1} - 2 i k \sigma_{0+}^{\#1} == 0$	1
$\tau_{1-}^{\#2\alpha} + 2 i k \sigma_{1-}^{\#2\alpha} == 0$	3
$\tau_{1-}^{\#1\alpha} == 0$	3
$\tau_{1+}^{\#1\alpha\beta} == 0$	3
$\sigma_{1+}^{\#2\alpha\beta} == 0$	3
$\sigma_{2-}^{\#1\alpha\beta\chi} == 0$	5
$\tau_{2+}^{\#1\alpha\beta} == 0$	5
Total constraints:	24

	$\sigma_{0+}^{\#1}$	$\tau_{0+}^{\#1}$	$\tau_{0+}^{\#2}$	$\sigma_{0+}^{\#1}$
$\sigma_{0+}^{\#1} \dagger$	$\frac{1}{(1+2k^2)^2 t_3}$	$-\frac{i\sqrt{2} k}{(1+2k^2)^2 t_3}$	0	0
$\tau_{0+}^{\#1} \dagger$	$\frac{i\sqrt{2} k}{(1+2k^2)^2 t_3}$	$\frac{2k^2}{(1+2k^2)^2 t_3}$	0	0
$\tau_{0+}^{\#2} \dagger$	0	0	0	0
$\sigma_{0+}^{\#1} \dagger$	0	0	0	$\frac{1}{k^2 r_2}$

	$\sigma_{2+}^{\#1} \dagger^{\alpha\beta}$	$\tau_{2+}^{\#1} \dagger^{\alpha\beta}$	$\sigma_{2-}^{\#1} \dagger^{\alpha\beta\chi}$
$\sigma_{2+}^{\#1} \dagger^{\alpha\beta}$	$-\frac{2}{3k^2 r_3}$	0	0
$\tau_{2+}^{\#1} \dagger^{\alpha\beta}$	0	0	0
$\sigma_{2-}^{\#1} \dagger^{\alpha\beta\chi}$	0	0	0

	$\omega_{2+}^{\#1} \dagger^{\alpha\beta}$	$f_{2+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{2-}^{\#1} \dagger^{\alpha\beta\chi}$
$\omega_{2+}^{\#1} \dagger^{\alpha\beta}$	$-\frac{3k^2 r_3}{2}$	0	0
$f_{2+}^{\#1} \dagger^{\alpha\beta}$	0	0	0
$\omega_{2-}^{\#1} \dagger^{\alpha\beta\chi}$	0	0	0

## Massive and massless spectra



Quadratic pole

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

(No massive particles)

## Unitarity conditions

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