

# Particle spectrograph

## Wave operator and propagator

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

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

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

Source constraints/gauge generators	
SO(3) irreps	Multiplicities
$\sigma_{0+}^{\#1} == 0$	1
$\tau_{0+}^{\#1} == 0$	1
$\tau_{0+}^{\#2} == 0$	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:	17

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

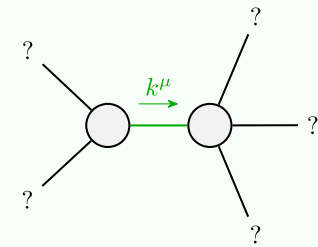
	$\sigma_{0+}^{\#1}$	$\tau_{0+}^{\#1}$	$\tau_{0+}^{\#2}$	$\sigma_{0-}^{\#1}$
$\sigma_{0+}^{\#1} \dagger$	0	0	0	0
$\tau_{0+}^{\#1} \dagger$	0	0	0	0
$\tau_{0+}^{\#2} \dagger$	0	0	0	0
$\sigma_{0-}^{\#1} \dagger$	0	0	0	$-\frac{1}{t_1}$

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

Quadratic (free) action

$$S = \iiint (f^{\alpha\beta} \tau_{\alpha\beta} + \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} + \frac{1}{6} t_1 (2 \omega^{\alpha i}{}_{\alpha} \omega_{, \theta}^{\theta} - 4 \omega_{\alpha}^{\theta}{}_{\theta} \partial_i f^{\alpha i} + 4 \omega_{, \theta}^{\theta} \partial' f^{\alpha}{}_{\alpha} - 2 \partial_i f_{\theta}^{\theta} \partial' f^{\alpha}{}_{\alpha} - 2 \partial_i f^{\alpha i} \partial_{\theta} f_{\alpha}^{\theta} + 4 \partial' f^{\alpha}{}_{\alpha} \partial_{\theta} f_{, \theta}^{\theta} - 6 \partial_{\alpha} f_{, \theta} \partial^{\theta} f^{\alpha i} - 3 \partial_{\alpha} f_{\theta i} \partial^{\theta} f^{\alpha i} + 3 \partial_i f_{\alpha \theta} \partial^{\theta} f^{\alpha i} + 3 \partial_{\theta} f_{\alpha i} \partial^{\theta} f^{\alpha i} + 3 \partial_{\theta} f_{, i \alpha} \partial^{\theta} f^{\alpha i} + 6 \omega_{\alpha \theta i} ( \omega^{\alpha i \theta} + 2 \partial^{\theta} f^{\alpha i} )) + r_5 ( \partial_i \omega_{\theta}^{\kappa}{}_{\kappa} \partial^{\theta} \omega^{\alpha i}{}_{\alpha} - \partial_{\theta} \omega_{, \kappa}^{\kappa} \partial^{\theta} \omega^{\alpha i}{}_{\alpha} - ( \partial_{\alpha} \omega^{\alpha i \theta} - 2 \partial^{\theta} \omega^{\alpha i}{}_{\alpha} ) ( \partial_{\kappa} \omega_{, \theta}^{\kappa} - \partial_{\kappa} \omega_{\theta}^{\kappa}{}_{, i} )) ) [ t, x, y, z] dz dy dx dt$$

## Massive and massless spectra



Quadratic pole	
Pole residue:	$-\frac{1}{r_5 t_1^2} > 0$
Polarisations:	2

(No massive particles)

## Unitarity conditions

$$r_5 < 0 \&\& t_1 < 0 || t_1 > 0$$