

# Particle spectrograph

## Wave operator and propagator

	$\sigma_{1^+}^{\#1} \dagger^{\alpha\beta}$	$\sigma_{1^+}^{\#2} \dagger^{\alpha\beta}$	$\tau_{1^+}^{\#1} \dagger^{\alpha\beta}$	$\sigma_{1^+}^{\#1} \dagger^{\alpha}$	$\sigma_{1^+}^{\#2} \dagger^{\alpha}$	$\tau_{1^+}^{\#1} \dagger^{\alpha}$	$\tau_{1^+}^{\#2} \dagger^{\alpha}$
$\sigma_{1^+}^{\#1} \dagger^{\alpha\beta}$	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
$\sigma_{1^+}^{\#2} \dagger^{\alpha\beta}$	$-\frac{\sqrt{2}}{t_1+k^2}t_1$	$\frac{-2k^2r_5+t_1}{(1+k^2)^2t_1^2}$	$-\frac{i(2k^3r_5-kt_1)}{(1+k^2)^2t_1^2}$	0	0	0	0
$\tau_{1^+}^{\#1} \dagger^{\alpha\beta}$	$\frac{i\sqrt{2}k}{t_1+k^2}t_1$	$\frac{i(2k^3r_5-kt_1)}{(1+k^2)^2t_1^2}$	$\frac{-2k^4r_5+k^2t_1}{(1+k^2)^2t_1^2}$	0	0	0	0
$\sigma_{1^+}^{\#1} \dagger^{\alpha}$	0	0	0	0	$\frac{\sqrt{2}}{t_1+2k^2}t_1$	0	$\frac{2ik}{t_1+2k^2}t_1$
$\sigma_{1^+}^{\#2} \dagger^{\alpha}$	0	0	0	$\frac{\sqrt{2}}{t_1+2k^2}t_1$	$\frac{-2k^2r_5+t_1}{(t_1+2k^2t_1)^2}$	0	$-\frac{i\sqrt{2}k(2k^2r_5-t_1)}{(t_1+2k^2t_1)^2}$
$\tau_{1^+}^{\#1} \dagger^{\alpha}$	0	0	0	0	0	0	0
$\tau_{1^+}^{\#2} \dagger^{\alpha}$	0	0	0	$-\frac{2ik}{t_1+2k^2}t_1$	$\frac{i\sqrt{2}k(2k^2r_5-t_1)}{(t_1+2k^2t_1)^2}$	0	$\frac{-4k^4r_5+2k^2t_1}{(t_1+2k^2t_1)^2}$

Quadratic (free) action

$$S = \int \int \int \int [ (f^{\alpha\beta} \tau_{\alpha\beta} + \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} + \frac{1}{2} t_1 (2 \omega^{\alpha i} \omega_{\alpha}{}^{\theta} \omega_{\theta}{}^{\prime} \omega_{\theta}{}^{\prime} f_{\alpha}^{\prime \prime} + 4 \omega_{\theta}{}^{\theta} \partial_{\theta} f_{\alpha}^{\prime \prime} - 2 \partial_{\theta} f_{\theta}^{\prime \prime} \partial_{\theta} f_{\alpha}^{\prime \prime} - 2 \partial_{\theta} f_{\alpha}^{\prime \prime} \partial_{\theta} f_{\theta}^{\prime \prime} - 2 \partial_{\alpha} f_{\theta}^{\prime \prime} \partial_{\theta} f_{\alpha}^{\prime \prime} - \partial_{\alpha} f_{\theta}^{\prime \prime} \partial_{\theta} f_{\theta}^{\prime \prime} + \partial_{\theta} f_{\alpha\theta} \partial^{\theta} f^{\alpha i} + \partial_{\theta} f_{\alpha i} \partial^{\theta} f^{\alpha i} + \partial_{\theta} f_{\alpha}^{\prime \prime} \partial^{\theta} f^{\alpha i} + 2 \omega_{\alpha\theta i} (\omega^{\alpha i\theta} + 2 \partial^{\theta} f^{\alpha i})) + \frac{1}{3} r_2 (4 \partial_{\beta} \omega_{\alpha i \theta} - 2 \partial_{\beta} \omega_{\alpha \theta i} + 2 \partial_{\beta} \omega_{\theta \alpha i} - \partial_{\theta} \omega_{\alpha \beta i} + \partial_{\theta} \omega_{\alpha i \beta} - 2 \partial_{\theta} \omega_{\alpha i \beta}) \partial^{\theta} \omega^{\alpha \beta i} + r_5 (\partial_{\theta} \omega_{\theta}{}^{\kappa} \partial^{\theta} \omega_{\alpha}{}^{\kappa} - \partial_{\theta} \omega_{\alpha}{}^{\kappa} \partial^{\theta} \omega_{\theta}{}^{\kappa} - (\partial_{\alpha} \omega^{\alpha i \theta} - 2 \partial^{\theta} \omega_{\alpha}{}^{\kappa}) (\partial_{\kappa} \omega_{\theta}{}^{\kappa} - \partial_{\kappa} \omega_{\theta}{}^{\kappa})) ] dt dx dy dz$$

	$\sigma_{0^+}^{\#1} \dagger$	$\tau_{0^+}^{\#1} \dagger$	$\tau_{0^+}^{\#2} \dagger$	$\sigma_{0^+}^{\#1} \dagger$
$\sigma_{0^+}^{\#1} \dagger$	$-\frac{1}{(1+2k^2)^2t_1}$	$\frac{i\sqrt{2}k}{(1+2k^2)^2t_1}$	0	0
$\tau_{0^+}^{\#1} \dagger$	$\frac{i\sqrt{2}k}{(1+2k^2)^2t_1}$	$-\frac{2k^2}{(1+2k^2)^2t_1}$	0	0
$\tau_{0^+}^{\#2} \dagger$	0	0	0	0
$\sigma_{0^+}^{\#1} \dagger$	0	0	0	$\frac{1}{k^2r_2-t_1}$

	$\omega_{1^+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{1^+}^{\#2} \dagger^{\alpha\beta}$	$f_{1^+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{1^+}^{\#1} \dagger^{\alpha}$	$\omega_{1^+}^{\#2} \dagger^{\alpha}$	$f_{1^+}^{\#1} \dagger^{\alpha}$	$f_{1^+}^{\#2} \dagger^{\alpha}$
$\omega_{1^+}^{\#1} \dagger^{\alpha\beta}$	$k^2r_5-\frac{t_1}{2}$	$-\frac{t_1}{\sqrt{2}}$	$-\frac{ikt_1}{\sqrt{2}}$	0	$k^2r_5-\frac{t_1}{2}$	0	$i\sqrt{2}kt_1$
$\omega_{1^+}^{\#2} \dagger^{\alpha\beta}$	$-\frac{t_1}{\sqrt{2}}$	0	0	0	$\frac{t_1}{\sqrt{2}}$	0	0
$f_{1^+}^{\#1} \dagger^{\alpha\beta}$	$\frac{ikt_1}{\sqrt{2}}$	0	0	0	0	0	0
$\omega_{1^+}^{\#1} \dagger^{\alpha}$	0	0	0	$k^2r_5-\frac{t_1}{2}$	0	0	0
$\omega_{1^+}^{\#2} \dagger^{\alpha}$	0	0	0	$\frac{t_1}{\sqrt{2}}$	0	0	0
$f_{1^+}^{\#1} \dagger^{\alpha}$	0	0	0	0	0	0	0
$f_{1^+}^{\#2} \dagger^{\alpha}$	0	0	0	$-i\sqrt{2}kt_1$	0	0	0

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

	$\omega_{2^+}^{\#1} \dagger^{\alpha\beta}$	$f_{2^+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{2^+}^{\#1} \dagger^{\alpha\beta\chi}$
$\omega_{2^+}^{\#1} \dagger^{\alpha\beta}$	$\frac{t_1}{2}$	$-\frac{ikt_1}{\sqrt{2}}$	0
$f_{2^+}^{\#1} \dagger^{\alpha\beta}$	$\frac{ikt_1}{\sqrt{2}}$	$k^2t_1$	0
$\omega_{2^+}^{\#1} \dagger^{\alpha\beta\chi}$	0	0	$\frac{t_1}{2}$

	$\omega_{0^+}^{\#1} \dagger$	$f_{0^+}^{\#1} \dagger$	$f_{0^+}^{\#2} \dagger$	$\omega_{0^+}^{\#1} \dagger$
$\omega_{0^+}^{\#1} \dagger$	$-t_1$	$i\sqrt{2}kt_1$	0	0
$f_{0^+}^{\#1} \dagger$	$-i\sqrt{2}kt_1$	$-2k^2t_1$	0	0
$f_{0^+}^{\#2} \dagger$	0	0	0	0
$\omega_{0^+}^{\#1} \dagger$	0	0	0	$k^2r_2-t_1$

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

## 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

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