

# Particle spectrograph

## Wave operator and propagator

$\sigma_{1+}^{\#1} \dagger^{\alpha\beta}$	$\sigma_{1+}^{\#2} \alpha\beta$	$\tau_{1+}^{\#1} \alpha\beta$	$\sigma_{1-}^{\#1} \alpha$	$\sigma_{1-}^{\#2} \alpha$	$\tau_{1-}^{\#1} \alpha$	$\tau_{1-}^{\#2} \alpha$
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
$-\frac{\sqrt{2}}{t_1+k^2}t_1$	$\frac{-2k^2r_1+t_1}{(1+k^2)^2}t_1^2$	$-\frac{i(2k^3r_1-kt_1)}{(1+k^2)^2}t_1^2$	0	0	0	0
$\frac{i\sqrt{2}k}{t_1+k^2}t_1$	$\frac{i(2k^3r_1-kt_1)}{(1+k^2)^2}t_1^2$	$\frac{-2k^4r_1+k^2t_1}{(1+k^2)^2}t_1^2$	0	0	0	0
0	0	0	0	$\frac{\sqrt{2}}{t_1+2k^2}t_1$	0	$\frac{2ik}{t_1+2k^2}t_1$
0	0	0	0	$\frac{1}{(1+2k^2)^2}t_1$	0	$\frac{i\sqrt{2}k}{(1+2k^2)^2}t_1$
0	0	0	0	0	0	0
0	0	0	$-\frac{2ik}{t_1+2k^2}t_1$	$-\frac{i\sqrt{2}k}{(1+2k^2)^2}t_1$	0	$\frac{2k^2}{(1+2k^2)^2}t_1$

Quadratic (free) action

$$S=$$

$$\iiint\iiint[(f^{\alpha\beta} \tau_{\alpha\beta} + \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} + \frac{1}{2}t_1(2\omega^{\alpha\iota}_{\alpha} \omega^{\theta}_{\iota\theta} - 4\omega^{\theta}_{\alpha}{}^{\theta} \partial_{\iota}f^{\alpha\iota} + 4\omega^{\theta}_{\iota}{}^{\theta} \partial_{\iota}f^{\alpha\alpha} -$$

$$2\partial_{\iota}f^{\theta}_{\theta} \partial_{\iota}f^{\alpha}_{\alpha} - 2\partial_{\iota}f^{\alpha\iota} \partial_{\theta}f^{\theta}_{\alpha} + 4\partial_{\iota}f^{\alpha}_{\alpha} \partial_{\theta}f^{\theta}_{\iota} - 2\partial_{\alpha}f_{\iota\theta} \partial^{\theta}f^{\alpha\iota} - \partial_{\alpha}f_{\theta\iota} \partial^{\theta}f^{\alpha\iota} +$$

$$\partial_{\iota}f_{\alpha\theta} \partial^{\theta}f^{\alpha\iota} + \partial_{\theta}f_{\alpha\iota} \partial^{\theta}f^{\alpha\iota} + \partial_{\theta}f_{\iota\alpha} \partial^{\theta}f^{\alpha\iota} + 2\omega_{\alpha\theta\iota}(\omega^{\alpha\iota\theta} + 2\partial^{\theta}f^{\alpha\iota})) -$$

$$\frac{1}{3}r_1(3\partial_{\beta}\omega^{\theta}_{\iota} \partial^{\iota}\omega^{\alpha\beta}_{\alpha} - 3\partial_{\iota}\omega^{\theta}_{\beta} \partial^{\iota}\omega^{\alpha\beta}_{\alpha} - 3\partial_{\alpha}\omega^{\alpha\beta\iota}_{\iota} \partial_{\theta}\omega^{\theta}_{\beta} +$$

$$6\partial^{\iota}\omega^{\alpha\beta}_{\alpha} \partial_{\theta}\omega^{\theta}_{\beta} + 3\partial_{\alpha}\omega^{\alpha\beta\iota}_{\iota} \partial_{\theta}\omega^{\theta}_{\beta} - 6\partial^{\iota}\omega^{\alpha\beta}_{\alpha} \partial_{\theta}\omega^{\theta}_{\iota} +$$

$$4\partial_{\beta}\omega_{\alpha\iota\theta} \partial^{\theta}\omega^{\alpha\beta\iota}_{\iota} - 2\partial_{\beta}\omega_{\alpha\theta\iota} \partial^{\theta}\omega^{\alpha\beta\iota}_{\iota} + 8\partial_{\beta}\omega_{\iota\theta\alpha} \partial^{\theta}\omega^{\alpha\beta\iota}_{\iota} + 2\partial_{\iota}\omega_{\alpha\beta\theta} \partial^{\theta}\omega^{\alpha\beta\iota}_{\iota} -$$

$$2\partial_{\theta}\omega_{\alpha\beta\iota} \partial^{\theta}\omega^{\alpha\beta\iota}_{\iota} - 2\partial_{\theta}\omega_{\alpha\iota\beta} \partial^{\theta}\omega^{\alpha\beta\iota}_{\iota}))[t,x,y,z]dzdydxdt$$

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

	$\sigma_{2+}^{\#1} \alpha\beta$	$\tau_{2+}^{\#1} \alpha\beta$	$\sigma_{2-}^{\#1} \alpha\beta\chi$
$\sigma_{2+}^{\#1} \dagger^{\alpha\beta}$	$\frac{2}{(1+2k^2)^2}t_1$	$-\frac{2i\sqrt{2}k}{(1+2k^2)^2}t_1$	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	$\frac{2}{2k^2r_1+t_1}$

	$\omega_{2+}^{\#1} \alpha\beta$	$f_{2+}^{\#1} \alpha\beta$	$\omega_{2-}^{\#1} \alpha\beta\chi$
$\omega_{2+}^{\#1} \dagger^{\alpha\beta}$	$\frac{t_1}{2}$	$-\frac{ikt_1}{\sqrt{2}}$	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	$k^2r_1 + \frac{t_1}{2}$

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

## Massive and massless spectra

Massive particle	
Pole residue:	$-\frac{1}{r_1} > 0$
Polarisations:	5
Square mass:	$-\frac{t_1}{2r_1} > 0$
Spin:	2
Parity:	Odd

(No massless particles)

## Unitarity conditions

$$r_1 < 0 \&\& t_1 > 0$$

### 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