

Particle spectrograph

Wave operator and propagator

$\sigma_{1+}^{\#1} \dagger^{\alpha\beta}$	$\sigma_{1+}^{\#2} \dagger^{\alpha\beta}$	$\tau_{1+}^{\#1} \dagger^{\alpha\beta}$	$\sigma_{1-}^{\#1} \dagger^{\alpha}$	$\sigma_{1-}^{\#2} \dagger^{\alpha}$	$\tau_{1-}^{\#1} \dagger^{\alpha}$	$\tau_{1-}^{\#2} \dagger^{\alpha}$
$\frac{2\left(t_1+t_2\right)}{3 t_1 t_2+2 k^2 r_5\left(t_1+t_2\right)}$	$\frac{\sqrt{2}\left(t_1-2 t_2\right)}{\left(1+k^2\right)\left(3 t_1 t_2+2 k^2 r_5\left(t_1+t_2\right)\right)}$	$\frac{i \sqrt{2} k\left(t_1-2 t_2\right)}{\left(1+k^2\right)\left(3 t_1 t_2+2 k^2 r_5\left(t_1+t_2\right)\right)}$	0	0	0	0
$\frac{\sqrt{2}\left(t_1-2 t_2\right)}{\left(1+k^2\right)\left(3 t_1 t_2+2 k^2 r_5\left(t_1+t_2\right)\right)}$	$\frac{6 k^2 r_5+t_1+4 t_2}{\left(1+k^2\right)^2\left(3 t_1 t_2+2 k^2 r_5\left(t_1+t_2\right)\right)}$	$\frac{i k\left(6 k^2 r_5+t_1+4 t_2\right)}{\left(1+k^2\right)^2\left(3 t_1 t_2+2 k^2 r_5\left(t_1+t_2\right)\right)}$	0	0	0	0
$-\frac{i \sqrt{2} k\left(t_1-2 t_2\right)}{\left(1+k^2\right)\left(3 t_1 t_2+2 k^2 r_5\left(t_1+t_2\right)\right)}$	$-\frac{i k\left(6 k^2 r_5+t_1+4 t_2\right)}{\left(1+k^2\right)^2\left(3 t_1 t_2+2 k^2 r_5\left(t_1+t_2\right)\right)}$	$-\frac{k^2\left(6 k^2 r_5+t_1+4 t_2\right)}{\left(1+k^2\right)^2\left(3 t_1 t_2+2 k^2 r_5\left(t_1+t_2\right)\right)}$	0	0	0	0
0	0	0	0	$\frac{\sqrt{2}}{t_1+2 k^2 t_1}$	0	$\frac{2 i k}{t_1+2 k^2 t_1}$
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	$-\frac{\sqrt{2}}{t_1+2 k^2 t_1}$	0	$-\frac{i \sqrt{2} k\left(2 k^2 r_5 t_1\right)}{\left(t_1+2 k^2 t_1\right)^2}$
0	0	0	0	0	0	0
0	0	0	$-\frac{2 i k}{t_1+2 k^2 t_1}$	$-\frac{i \sqrt{2} k\left(2 k^2 r_5 t_1\right)}{\left(t_1+2 k^2 t_1\right)^2}$	0	$\frac{-4 k^4 r_5+2 k^2 t_1}{\left(t_1+2 k^2 t_1\right)^2}$

Quadratic (free) action

$$S=$$

$$\iiint\left(\frac{1}{6}\left(6 t_1 \omega_{\alpha}^{\alpha i} \omega_{\theta}^{\theta} \omega_{\theta}^{\theta} \tau_{\alpha \beta}^{\alpha \beta} \sigma_{\alpha \beta \chi}^{\alpha \beta \chi}-12 t_1 \omega_{\alpha}^{\theta} \partial_{\theta} f^{\alpha i}+12 t_1 \omega_{\theta}^{\theta} \partial_{\theta} f_{\alpha}^{\alpha}-6 t_1 \partial_{\theta} f_{\alpha}^{\alpha} \partial_{\theta} f_{\theta}^{\theta} \partial_{\theta} f_{\alpha}^{\alpha i}+12 t_1 \partial_{\theta} f_{\alpha}^{\alpha i} \partial_{\theta} f_{\theta}^{\theta} \partial_{\theta} f_{\alpha}^{\alpha}-4 t_1 \omega_{\theta \alpha} \partial_{\theta} f^{\alpha i}+4 t_2 \omega_{\theta \alpha} \partial_{\theta} f_{\theta}^{\theta} \partial_{\theta} f_{\alpha}^{\alpha i}-4 t_1 \partial_{\alpha} f_{\theta i} \partial_{\theta} f^{\alpha i}-t_2 \partial_{\alpha} f_{\theta i} \partial_{\theta} f_{\alpha}^{\alpha i}+2 t_1 \partial_{\theta} f_{\alpha i} \partial_{\theta} f^{\alpha i}-t_2 \partial_{\theta} f_{\alpha i} \partial_{\theta} f_{\alpha}^{\alpha i}+4 t_1 \partial_{\theta} f_{\alpha i} \partial_{\theta} f_{\alpha}^{\alpha i}+t_2 \partial_{\theta} f_{\alpha i} \partial_{\theta} f_{\alpha}^{\alpha i}+2 t_1 \partial_{\theta} f_{\alpha i} \partial_{\theta} f_{\alpha}^{\alpha i}-t_2 \partial_{\theta} f_{\alpha i} \partial_{\theta} f_{\alpha}^{\alpha i}+2\left(t_1+t_2\right) \omega_{\alpha i \theta}\left(\omega^{\alpha i \theta}+2 \partial^{\theta} f^{\alpha i}\right)+2 \omega_{\alpha \theta i}\left(\left(t_1-2 t_2\right) \omega^{\alpha i \theta}+2\left(2 t_1-t_2\right) \partial^{\theta} f^{\alpha i}\right)+8 r_2 \partial_{\beta} \omega_{\alpha i \theta} \partial^{\theta} \omega^{\alpha \beta i}-4 r_2 \partial_{\beta} \omega_{\alpha \theta i} \partial^{\theta} \omega^{\alpha \beta i}+4 r_2 \partial_{\beta} \omega_{\theta \alpha} \partial^{\theta} \omega^{\alpha \beta i}-2 r_2 \partial_{\theta} \omega_{\alpha \beta \theta} \partial^{\theta} \omega^{\alpha \beta i}+2 r_2 \partial_{\theta} \omega_{\alpha \beta i} \partial^{\theta} \omega^{\alpha \beta i}-4 r_2 \partial_{\theta} \omega_{\alpha i \beta} \partial^{\theta} \omega^{\alpha \beta i}+6 r_5 \partial_{\theta} \omega_{\theta \kappa} \partial^{\theta} \omega_{\alpha}^{\alpha i}-6 r_5 \partial_{\alpha} \omega_{\alpha}^{\alpha i} \partial_{\kappa} \omega_{\theta}^{\alpha i \theta}+12 r_5 \partial_{\theta} \omega_{\theta}^{\alpha i} \partial_{\kappa} \omega_{\alpha}^{\alpha i}-6 r_5 \partial_{\alpha} \omega^{\alpha i \theta} \partial_{\kappa} \omega_{\theta}^{\kappa}-12 r_5 \partial^{\theta} \omega_{\alpha}^{\alpha i} \partial_{\kappa} \omega_{\theta}^{\kappa}\right)[t, x, y, z] d z d y d x d t$$

	$\omega_{1+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{1+}^{\#2} \dagger^{\alpha\beta}$	$f_{1+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{1-}^{\#1} \dagger^{\alpha}$	$\omega_{1-}^{\#2} \dagger^{\alpha}$	$f_{1-}^{\#1} \dagger^{\alpha}$	$f_{1-}^{\#2} \dagger^{\alpha}$
$\omega_{1+}^{\#1} \dagger^{\alpha\beta}$	$\frac{1}{6}\left(6 k^2 r_5+t_1+4 t_2\right)$	$-\frac{t_1-2 t_2}{3 \sqrt{2}}$	$-\frac{i k\left(t_1-2 t_2\right)}{3 \sqrt{2}}$	0	0	0	0
$\omega_{1+}^{\#2} \dagger^{\alpha\beta}$	$-\frac{t_1-2 t_2}{3 \sqrt{2}}$	$\frac{t_1+t_2}{3}$	$\frac{1}{3} i k\left(t_1+t_2\right)$	0	0	0	0
$f_{1+}^{\#1} \dagger^{\alpha\beta}$	$\frac{i k\left(t_1-2 t_2\right)}{3 \sqrt{2}}$	$-\frac{1}{3} i k\left(t_1+t_2\right)$	$\frac{1}{3} k^2\left(t_1+t_2\right)$	0	0	0	0
$\omega_{1-}^{\#1} \dagger^{\alpha}$	0	0	0	$k^2 r_5-\frac{t_1}{2}$	$\frac{t_1}{\sqrt{2}}$	0	$i k t_1$
$\omega_{1-}^{\#2} \dagger^{\alpha}$	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	$-i k t_1$	0	0	0

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

	$\sigma_{0+}^{\#1} \dagger$	$\tau_{0+}^{\#1} \dagger$	$\tau_{0+}^{\#2} \dagger$	$\sigma_{0-}^{\#1} \dagger$
$\sigma_{0+}^{\#1} \dagger$	$-\frac{1}{\left(1+2 k^2\right)^2 t_1}$	$\frac{i \sqrt{2} k}{\left(1+2 k^2\right)^2 t_1}$	0	0
$\tau_{0+}^{\#1} \dagger$	$-\frac{i \sqrt{2} k}{\left(1+2 k^2\right)^2 t_1}$	$-\frac{2 k^2}{\left(1+2 k^2\right)^2 t_1}$	0	0
$\tau_{0+}^{\#2} \dagger$	0	0	0	0
$\sigma_{0-}^{\#1} \dagger$	0	0	0	$\frac{1}{k^2 r_2+t_2}$

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
$\tau_{1+}^{\#1 \alpha \beta}+i k \sigma_{1+}^{\#2 \alpha \beta} == 0$	3
$\tau_{2+}^{\#1 \alpha \beta}-2 i k \sigma_{2+}^{\#1 \alpha \beta} == 0$	5
Total constraints:	16

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

$\omega_0^{\#1} \dagger$	$f_0^{\#1} \dagger$	$f_0^{\#2} \dagger$	$\omega_0^{\#1} \dagger$
$\omega_0^{\#1} \dagger$	$-t_1$	$i \sqrt{2} k t_1$	0
$f_0^{\#1} \dagger$	$-i \sqrt{2} k t_1$	$-2 k^2 t_1$	0
$f_0^{\#2} \dagger$	0	0	0
$\omega_0^{\#1} \dagger$	0	0	$k^2 r_2+t_2$

Massive and massless spectra

Massive particle	
Pole residue:	$\frac{-3 t_1 t_2\left(t_1+t_2\right)+3 r_5\left(t_1^2+2 t_2^2\right)}{r_5\left(t_1+t_2\right)\left(-3 t_1 t_2+2 r_5\left(t_1+t_2\right)\right)} > 0$
Polarisations:	3
Square mass:	$-\frac{3 t_1 t_2}{2 r_5 t_1+2 r_5 t_2} > 0$
Spin:	1
Parity:	Even

Massive particle	
Pole residue:	$-\frac{1}{r_2} > 0$
Polarisations:	1
Square mass:	$-\frac{t_2}{r_2} > 0$
Spin:	0
Parity:	Odd

(No massless particles)

Unitarity conditions

$r_2 < 0 \ \&\& \ r_5 > 0 \ \&\& \ t_1 < 0 \ \&\& \ t_2 > -t_1$