

# Particle spectrograph

## Wave operator and propagator

	$\sigma_{2+}^{\#1}{}_{\alpha\beta}$	$\tau_{2+}^{\#1}{}_{\alpha\beta}$	$\sigma_{2-}^{\#1}{}_{\alpha\beta\chi}$		$\omega_{0+}^{\#1}$	$f_{0+}^{\#1}$	$f_{0+}^{\#2}$	$\omega_{0-}^{\#1}$		$\omega_{2+}^{\#1}{}_{\alpha\beta\chi}$
$\sigma_{2+}^{\#1}{}_{+}^{\alpha\beta}$	$\frac{2}{(1+2k^2)^2t_1}$	$-\frac{2i\sqrt{2}k}{(1+2k^2)^2t_1}$	0	$\omega_{0+}^{\#1}{}_{+}$	$t_3$	$-i\sqrt{2}kt_3$	0	0	$\omega_{2+}^{\#1}{}_{+}^{\alpha\beta}$	0
$\tau_{2+}^{\#1}{}_{+}^{\alpha\beta}$	$\frac{2i\sqrt{2}k}{(1+2k^2)^2t_1}$	$\frac{4k^2}{(1+2k^2)^2t_1}$	0	$f_{0+}^{\#1}{}_{+}$	$i\sqrt{2}kt_3$	$2k^2t_3$	0	0	$f_{2+}^{\#1}{}_{+}^{\alpha\beta}$	$-\frac{ik t_1}{\sqrt{2}}$
$\sigma_{2-}^{\#1}{}_{+}^{\alpha\beta\chi}$	0	0	$\frac{2}{t_1}$	$f_{0+}^{\#2}{}_{+}$	0	0	0	0	$\omega_{2+}^{\#1}{}_{+}^{\alpha\beta\chi}$	$k^2t_1$
				$\omega_{0-}^{\#1}{}_{+}$	0	0	0	$k^2r_2+t_2$	0	0

Quadratic (free) action

$S_F = \int \int \int (\frac{1}{6} (-2(t_1-2t_3) \omega_{\kappa}^{\alpha'} \omega_{\kappa}^{\kappa} - 2(t_1-2t_2) \omega_{\kappa}^{\kappa\lambda} \omega_{\kappa}^{\lambda'} + 2t_1 \omega_{\kappa}^{\kappa\lambda} \omega_{\kappa}^{\lambda'} + 2t_2 \omega_{\kappa}^{\kappa\lambda} \omega_{\kappa}^{\lambda'} + 6 f^{\alpha\beta} \tau_{\alpha\beta} \sigma_{\alpha\beta\chi} + 4 r_2 \partial^{\theta} \omega_{\alpha\beta}^{\kappa} \partial_{\kappa} \omega_{\alpha\beta}^{\theta} - 2 t_1 \partial^{\alpha} f_{\theta\kappa} \partial^{\kappa} f_{\alpha}^{\theta} + 2 r_2 \partial_{\theta} \omega_{\alpha\beta}^{\kappa} \partial_{\kappa} \omega_{\alpha\beta}^{\theta} - 4 r_2 \partial_{\theta} \omega_{\alpha\beta}^{\kappa} \partial_{\kappa} \omega_{\alpha\beta}^{\theta} - 2 t_1 \partial^{\alpha} f_{\theta\kappa} \partial^{\kappa} f_{\alpha}^{\theta} + t_2 \partial^{\alpha} f_{\theta\kappa} \partial^{\kappa} f_{\alpha}^{\theta} - 4 t_1 \partial^{\alpha} f_{\kappa\theta} \partial^{\kappa} f_{\alpha}^{\theta} - t_2 \partial^{\alpha} f_{\kappa\theta} \partial^{\kappa} f_{\alpha}^{\theta} - 2 t_1 \partial^{\alpha} f_{\kappa}^{\lambda} \partial^{\kappa} f_{\alpha}^{\lambda} + t_2 \partial^{\alpha} f_{\kappa}^{\lambda} \partial^{\kappa} f_{\alpha}^{\lambda} + 2 t_1 \omega_{\kappa}^{\alpha} \partial^{\kappa} f_{\kappa}^{\lambda} - 4 t_3 \omega_{\kappa}^{\alpha} \partial^{\kappa} f_{\kappa}^{\lambda} + 2 t_1 \omega_{\kappa}^{\lambda} \partial^{\kappa} f_{\kappa}^{\lambda} - 4 t_3 \omega_{\kappa}^{\lambda} \partial^{\kappa} f_{\kappa}^{\lambda} + 4 t_1 \partial^{\alpha} f_{\kappa\alpha} \partial^{\kappa} f_{\lambda}^{\theta} - 8 t_3 \partial^{\alpha} f_{\kappa\alpha} \partial^{\kappa} f_{\lambda}^{\theta} - 2 t_1 \partial_{\kappa} f_{\lambda}^{\alpha} \partial^{\kappa} f_{\alpha}^{\lambda} + 4 t_3 \partial_{\kappa} f_{\lambda}^{\alpha} \partial^{\kappa} f_{\alpha}^{\lambda} + 2 t_1 \omega_{\theta\kappa} \partial^{\kappa} f_{\theta}^{\lambda} - 2 t_2 \omega_{\theta\kappa} \partial^{\kappa} f_{\theta}^{\lambda} + 8 t_1 \omega_{\theta\kappa} \partial^{\kappa} f_{\theta}^{\lambda} - 4 t_2 \omega_{\theta\kappa} \partial^{\kappa} f_{\theta}^{\lambda} - 2 t_1 \omega_{\theta\kappa} \partial^{\kappa} f_{\theta}^{\lambda} + 4 t_3 \omega_{\theta\kappa} \partial^{\kappa} f_{\theta}^{\lambda} + 4 t_3 \omega_{\kappa}^{\lambda} \partial^{\kappa} f_{\lambda}^{\theta} + 2 t_1 \partial^{\alpha} f_{\lambda}^{\theta} \partial^{\kappa} f_{\alpha}^{\lambda} - t_2 \partial^{\alpha} f_{\lambda}^{\theta} \partial^{\kappa} f_{\alpha}^{\lambda} + 2 t_1 \partial_{\kappa} f_{\lambda}^{\theta} \partial^{\kappa} f_{\alpha}^{\lambda} - t_2 \partial_{\kappa} f_{\lambda}^{\theta} \partial^{\kappa} f_{\alpha}^{\lambda} + 4 t_1 \partial_{\kappa} f_{\lambda}^{\theta} \partial^{\kappa} f_{\alpha}^{\lambda} + 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^{\theta} \omega_{\lambda}^{\alpha\lambda} \partial_{\lambda} \omega_{\alpha\beta}^{\kappa} + 4 r_2 \partial^{\theta} \omega_{\lambda}^{\lambda\alpha} \partial_{\lambda} \omega_{\alpha\beta}^{\kappa}) [t, x, y, z] dz dy dx dt$

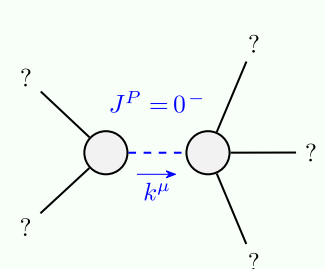
	$\sigma_{0+}^{\#1}$	$\tau_{0+}^{\#1}$	$\tau_{0+}^{\#2}$	$\sigma_{0-}^{\#1}$
$\sigma_{0+}^{\#1}{}_{+}$	$\frac{1}{(1+2k^2)^2t_3}$	$-\frac{i\sqrt{2}k}{(1+2k^2)^2t_3}$	0	0
$\tau_{0+}^{\#1}{}_{+}$	$\frac{i\sqrt{2}k}{(1+2k^2)^2t_3}$	$\frac{2k^2}{(1+2k^2)^2t_3}$	0	0
$\tau_{0+}^{\#2}{}_{+}$	0	0	0	0
$\sigma_{0-}^{\#1}{}_{+}$	0	0	0	$\frac{1}{k^2r_2+t_2}$

	$\omega_{1+}^{\#1}{}_{\alpha\beta}$	$\omega_{1+}^{\#2}{}_{\alpha\beta}$	$f_{1+}^{\#1}{}_{\alpha\beta}$	$\omega_{1-}^{\#1}{}_{\alpha}$	$\omega_{1-}^{\#2}{}_{\alpha}$	$f_{1-}^{\#1}{}_{\alpha}$	$f_{1-}^{\#2}{}_{\alpha}$
$\omega_{1+}^{\#1}{}_{+}^{\alpha\beta}$	$\frac{1}{6}(t_1+4t_2)$	$-\frac{t_1-2t_2}{3\sqrt{2}}$	$-\frac{ik(t_1-2t_2)}{3\sqrt{2}}$	0	0	0	0
$\omega_{1+}^{\#2}{}_{+}^{\alpha\beta}$	$-\frac{t_1-2t_2}{3\sqrt{2}}$	$\frac{t_1+t_2}{3}$	$\frac{1}{3}ik(t_1+t_2)$	0	0	0	0
$f_{1+}^{\#1}{}_{+}^{\alpha\beta}$	$\frac{ik(t_1-2t_2)}{3\sqrt{2}}$	$-\frac{1}{3}ik(t_1+t_2)$	$\frac{1}{3}k^2(t_1+t_2)$	0	0	0	0
$\omega_{1-}^{\#1}{}_{+}^{\alpha}$	0	0	0	$\frac{1}{6}(t_1+4t_3)$	$\frac{t_1-2t_3}{3\sqrt{2}}$	0	$\frac{1}{3}ik(t_1-2t_3)$
$\omega_{1-}^{\#2}{}_{+}^{\alpha}$	0	0	0	$\frac{t_1-2t_3}{3\sqrt{2}}$	$\frac{t_1+t_3}{3}$	0	$\frac{1}{3}i\sqrt{2}k(t_1+t_3)$
$f_{1-}^{\#1}{}_{+}^{\alpha}$	0	0	0	0	0	0	0
$f_{1-}^{\#2}{}_{+}^{\alpha}$	0	0	0	$-\frac{1}{3}ik(t_1-2t_3)$	$-\frac{1}{3}i\sqrt{2}k(t_1+t_3)$	0	$\frac{2}{3}k^2(t_1+t_3)$

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

	$\sigma_{1+}^{\#1}{}_{\alpha\beta}$	$\sigma_{1+}^{\#2}{}_{\alpha\beta}$	$\tau_{1+}^{\#1}{}_{\alpha\beta}$	$\sigma_{1-}^{\#1}{}_{\alpha}$	$\sigma_{1-}^{\#2}{}_{\alpha}$	$\tau_{1-}^{\#1}{}_{\alpha}$	$\tau_{1-}^{\#2}{}_{\alpha}$
$\sigma_{1+}^{\#1}{}_{+}^{\alpha\beta}$	$\frac{2(t_1+t_2)}{3t_1t_2}$	$\frac{\sqrt{2}(t_1-2t_2)}{3(1+k^2)t_1t_2}$	$\frac{i\sqrt{2}k(t_1-2t_2)}{3(1+k^2)t_1t_2}$	0	0	0	0
$\sigma_{1+}^{\#2}{}_{+}^{\alpha\beta}$	$\frac{\sqrt{2}(t_1-2t_2)}{3(1+k^2)t_1t_2}$	$\frac{t_1+4t_2}{3(1+k^2)^2t_1t_2}$	$\frac{ik(t_1+4t_2)}{3(1+k^2)^2t_1t_2}$	0	0	0	0
$\tau_{1+}^{\#1}{}_{+}^{\alpha\beta}$	$-\frac{i\sqrt{2}k(t_1-2t_2)}{3(1+k^2)t_1t_2}$	$-\frac{ik(t_1+4t_2)}{3(1+k^2)^2t_1t_2}$	$\frac{k^2(t_1+4t_2)}{3(1+k^2)^2t_1t_2}$	0	0	0	0
$\sigma_{1-}^{\#1}{}_{+}^{\alpha}$	0	0	0	$\frac{2(t_1+t_3)}{3t_1t_3}$	$-\frac{\sqrt{2}(t_1-2t_3)}{3(1+2k^2)t_1t_3}$	$-\frac{2ikt_1-4ikt_3}{3t_1t_3+6k^2t_1t_3}$	$-\frac{2ikt_1-4ikt_3}{3t_1t_3+6k^2t_1t_3}$
$\sigma_{1-}^{\#2}{}_{+}^{\alpha}$	0	0	0	0	0	0	0
$\tau_{1-}^{\#1}{}_{+}^{\alpha}$	0	0	0	0	0	0	0
$\tau_{1-}^{\#2}{}_{+}^{\alpha}$	0	0	0	$\frac{2ikt_1-4ikt_3}{3t_1t_3+6k^2t_1t_3}$	$-\frac{i\sqrt{2}k(t_1+4t_3)}{3(1+2k^2)^2t_1t_3}$	$\frac{2k^2(t_1+4t_3)}{3(1+2k^2)^2t_1t_3}$	$\frac{2k^2(t_1+4t_3)}{3(1+2k^2)^2t_1t_3}$

## Massive and massless spectra



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

$r_2 < 0 \ \&\& \ t_2 > 0$