

# Particle spectrograph

## Wave operator and propagator

Quadratic (free) action

$$S_F ==$$
$$\iiint \left( \frac{1}{6} (-2(t_1 - 2t_3) \omega_{\alpha'}^{\alpha'} \omega_{\kappa\alpha}^{\kappa} - 6t_1 \omega_{\kappa\lambda}^{\kappa\lambda} \omega_{\lambda'}^{\lambda'} + 6f^{\alpha\beta} \tau_{\alpha\beta} + 6\omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} + 6r_1 \partial_\mu \omega_{\kappa\lambda}^{\kappa\lambda} \partial'_\mu \omega_{\lambda\alpha}^{\alpha} - 4r_1 \partial^\beta \omega_{\kappa}^{\beta\theta\alpha} \partial_\theta \omega_{\alpha\beta}^{\kappa} - 4r_1 \partial_\theta \omega_{\alpha\beta}^{\kappa} \partial_\kappa \omega_{\alpha\beta}^{\theta\theta} + 4r_1 \partial_\theta \omega_{\alpha\beta}^{\kappa} \partial_\kappa \omega_{\alpha\beta}^{\theta\theta} + 6r_1 \partial_\alpha \omega_{\lambda}^{\alpha} \partial_\kappa \omega_{\lambda}^{\alpha} \partial_\theta \omega_{\lambda}^{\kappa\lambda\theta} - 6r_1 \partial_\theta \omega_{\lambda}^{\alpha} \partial_\kappa \omega_{\lambda}^{\alpha} \partial_\kappa \omega_{\lambda}^{\theta\kappa\lambda} + 6r_1 \partial_\alpha \omega_{\lambda}^{\alpha} \partial_\kappa \omega_{\lambda}^{\kappa\lambda\theta} - 12r_1 \partial_\theta \omega_{\lambda}^{\alpha} \partial_\kappa \omega_{\lambda}^{\alpha} \partial_\kappa \omega_{\theta\kappa}^{\kappa\lambda\theta} - 3t_1 \partial^\alpha f_{\theta\kappa} \partial^\kappa f_{\alpha}^{\theta} - 3t_1 \partial^\alpha f_{\kappa\theta} \partial^\kappa f_{\alpha}^{\theta} - 3t_1 \partial^\alpha f_{\lambda}^{\kappa} \partial^\kappa f_{\alpha\lambda}^{\theta} + 2t_1 \omega_{\kappa\alpha}^{\alpha} \partial^\kappa f_{\lambda'}^{\lambda} - 4t_3 \omega_{\kappa\alpha}^{\alpha} \partial^\kappa f_{\lambda'}^{\lambda} + 2t_1 \omega_{\kappa\lambda}^{\lambda} \partial^\kappa f_{\lambda'}^{\lambda} - 4t_3 \omega_{\kappa\lambda}^{\lambda} \partial^\kappa f_{\lambda'}^{\lambda} + 4t_1 \partial^\alpha f_{\kappa\alpha} \partial^\kappa f_{\lambda'}^{\lambda} - 8t_3 \partial^\alpha f_{\kappa\alpha} \partial^\kappa f_{\lambda'}^{\lambda} - 2t_1 \partial_\kappa f_{\lambda}^{\lambda} \partial^\kappa f_{\lambda'}^{\lambda} + 4t_3 \partial_\kappa f_{\lambda}^{\lambda} \partial^\kappa f_{\lambda'}^{\lambda} + 12t_1 \omega_{\lambda\kappa}^{\lambda} \partial^\kappa f_{\lambda'}^{\theta} - 2t_1 \omega_{\lambda\alpha}^{\alpha} \partial^\kappa f_{\lambda'}^{\theta} + 4t_3 \omega_{\lambda\alpha}^{\alpha} \partial^\kappa f_{\lambda'}^{\theta} + 3t_1 \partial^\alpha f_{\lambda}^{\kappa} \partial^\kappa f_{\lambda\alpha}^{\theta} + 3t_1 \partial_\kappa f_{\lambda}^{\lambda} \partial^\kappa f_{\lambda}^{\theta} + 2t_1 \omega_{\lambda\alpha}^{\alpha} \partial^\kappa f_{\lambda}^{\theta} - 2t_1 \partial^\alpha f_{\lambda}^{\kappa} \partial^\kappa f_{\lambda\kappa}^{\theta} + 4t_3 \partial^\alpha f_{\lambda}^{\kappa} \partial^\kappa f_{\lambda\kappa}^{\theta} + 4r_1 \partial^\beta \omega_{\alpha\beta}^{\alpha\lambda} \partial_\lambda \omega_{\alpha\beta}^{\lambda'} - 16r_1 \partial^\beta \omega_{\alpha\beta}^{\lambda\alpha} \partial_\lambda \omega_{\alpha\beta}^{\lambda'} - 6r_1 \partial_\alpha \omega_{\lambda}^{\alpha} \partial^\lambda \omega_{\lambda}^{\theta\kappa} + 6r_1 \partial_\theta \omega_{\lambda}^{\alpha} \partial^\lambda \omega_{\lambda}^{\theta\kappa} ) [t, x, y, z] dz dy dx dt$$

$\sigma_{1+}^{\#1} \dagger^{\alpha\beta}$	$\sigma_{1+}^{\#2} \sigma_{1+}^{\alpha\beta}$	$\tau_{1+}^{\#1} \dagger^{\alpha\beta}$	$\sigma_{1+}^{\#1} \sigma_{1+}^{\alpha}$	$\tau_{1+}^{\#1} \sigma_{1+}^{\alpha}$	$\tau_{1+}^{\#2} \sigma_{1+}^{\alpha}$
0	$-\frac{\sqrt{2}}{t_1+k^2 t_1}$	$-\frac{i\sqrt{2}k}{t_1+k^2 t_1}$	0	0	0
$-\frac{\sqrt{2}}{t_1+k^2 t_1}$	$\frac{-2k^2 r_1+t_1}{(1+k^2)^2 t_1^2}$	$-\frac{i(2k^3 r_1-kt_1)}{(1+k^2)^2 t_1^2}$	0	0	0
$\frac{i\sqrt{2}k}{t_1+k^2 t_1}$	$\frac{i(2k^3 r_1-kt_1)}{(1+k^2)^2 t_1^2}$	$\frac{-2k^4 r_1+k^2 t_1}{(1+k^2)^2 t_1^2}$	0	0	0
0	0	0	$\frac{2(t_1+t_3)}{3t_1 t_3}$	$-\frac{\sqrt{2}(t_1-2t_3)}{3(1+2k^2)t_1 t_3}$	$-\frac{2ikt_1-4ikt_3}{3t_1 t_3+6k^2 t_1 t_3}$
0	0	0	0	$-\frac{\sqrt{2}(t_1-2t_3)}{3(1+2k^2)^2 t_1 t_3}$	$\frac{i\sqrt{2}k(t_1+4t_3)}{3(1+2k^2)^2 t_1 t_3}$
0	0	0	0	0	0
0	0	0	$\frac{2ik(t_1-2t_3)}{3t_1 t_3+6k^2 t_1 t_3}$	$-\frac{i\sqrt{2}k(t_1+4t_3)}{3(1+2k^2)^2 t_1 t_3}$	$\frac{2k^2(t_1+4t_3)}{3(1+2k^2)^2 t_1 t_3}$

$\omega_{1+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{1+}^{\#2} \omega_{1+}^{\alpha\beta}$	$f_{1+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{1+}^{\#1} \omega_{1+}^{\alpha}$	$f_{1+}^{\#1} \sigma_{1+}^{\alpha}$	$f_{1+}^{\#2} \sigma_{1+}^{\alpha}$
$k^2 r_1 - \frac{t_1}{2}$	$-\frac{t_1}{\sqrt{2}}$	$-\frac{ikt_1}{\sqrt{2}}$	0	0	0
$-\frac{t_1}{\sqrt{2}}$	0	0	0	0	0
$\frac{ikt_1}{\sqrt{2}}$	0	0	0	0	0
0	0	0	$\frac{1}{6}(t_1+4t_3)$	0	$\frac{1}{3}ik(t_1-2t_3)$
0	0	0	$\frac{t_1-2t_3}{3\sqrt{2}}$	0	$\frac{1}{3}i\sqrt{2}k(t_1+t_3)$
0	0	0	0	0	0
0	0	0	$-\frac{1}{3}ik(t_1-2t_3)$	$-\frac{1}{3}i\sqrt{2}k(t_1+t_3)$	$\frac{2}{3}k^2(t_1+t_3)$

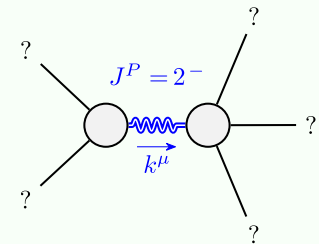
Source constraints/gauge generators	
SO(3) irreps	Multiplicities
$\tau_{0+}^{\#2} == 0$	1
$\tau_{0+}^{\#1} - 2ik\sigma_{0+}^{\#1} == 0$	1
$\tau_{1-}^{\#2\alpha} + 2ik\sigma_{1+}^{\#2\alpha} == 0$	3
$\tau_{1-}^{\#1\alpha} == 0$	3
$\tau_{1+}^{\#1\alpha\beta} + ik\sigma_{1+}^{\#2\alpha\beta} == 0$	3
$\tau_{2+}^{\#1\alpha\beta} - 2ik\sigma_{2+}^{\#1\alpha\beta} == 0$	5
Total constraints:	16

$\omega_{2+}^{\#1} \dagger^{\alpha\beta}$	$f_{2+}^{\#1} \dagger^{\alpha\beta}$	$\omega_{2-}^{\#1} \alpha\beta\chi$
$\frac{t_1}{2}$	$-\frac{ikt_1}{\sqrt{2}}$	0
$\frac{ikt_1}{\sqrt{2}}$	$k^2 t_1$	0
0	0	$k^2 r_1 + \frac{t_1}{2}$

$\sigma_{0+}^{\#1} \dagger$	$\tau_{0+}^{\#1} \dagger$	$\tau_{0+}^{\#2} \dagger$	$\sigma_{0-}^{\#1} \dagger$
$\frac{1}{(1+2k^2)^2 t_3}$	$-\frac{i\sqrt{2}k}{(1+2k^2)^2 t_3}$	0	0
$\frac{i\sqrt{2}k}{(1+2k^2)^2 t_3}$	$\frac{2k^2}{(1+2k^2)^2 t_3}$	0	0
0	0	0	0
0	0	0	$-\frac{1}{t_1}$

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

## 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

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