

# Particle spectrograph

## Wave operator and propagator

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

$$\begin{aligned} S_F = & \iiint (\frac{1}{6} (-6t_1 \omega_{\kappa\alpha}^{\alpha'} \omega_{\kappa\alpha}^{\kappa} - 6t_1 \omega_{\kappa\lambda}^{\lambda} \omega_{\kappa\lambda}^{\kappa\lambda} + 6 f^{\alpha\beta} \tau_{\alpha\beta} + 6 \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} + \\ & 4 r_2 \partial^\beta \omega_{\kappa}^{\alpha} \partial_\theta \omega_{\alpha\beta}^{\kappa} - 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^{\theta\alpha\beta} - \\ & 3 t_1 \partial^\alpha f_{\theta\kappa} \partial^\kappa f_{\alpha}^{\theta} - 3 t_1 \partial^\alpha f_{\kappa\theta} \partial^\kappa f_{\alpha}^{\theta} - 3 t_1 \partial^\alpha f_{\alpha}^{\kappa} \partial^\kappa f_{\lambda}^{\theta} - 3 t_1 \partial^\alpha f_{\lambda}^{\kappa} \partial^\kappa f_{\alpha}^{\theta} + 6 t_1 \omega_{\kappa\alpha}^{\alpha} \partial^\kappa f_{\lambda}^{\theta} + \\ & 6 t_1 \omega_{\kappa\lambda}^{\lambda} \partial^\kappa f_{\lambda}^{\theta} + 12 t_1 \partial^\alpha f_{\kappa\alpha} \partial^\kappa f_{\lambda}^{\theta} - 6 t_1 \partial^\alpha f_{\lambda}^{\kappa} \partial^\kappa f_{\alpha}^{\theta} + 12 t_1 \omega_{\kappa\theta} \partial^\kappa f_{\theta}^{\lambda} - \\ & 6 t_1 \omega_{\lambda\alpha}^{\alpha} \partial^\kappa f_{\kappa}^{\theta} - 6 t_1 \omega_{\lambda\lambda}^{\lambda} \partial^\kappa f_{\kappa}^{\theta} + 3 t_1 \partial^\alpha f_{\lambda}^{\kappa} \partial^\kappa f_{\alpha}^{\theta} + 3 t_1 \partial^\alpha f_{\alpha}^{\kappa} \partial^\kappa f_{\lambda}^{\theta} + \\ & 3 t_1 \partial^\alpha f_{\theta}^{\kappa} \partial^\kappa f_{\lambda}^{\theta} - 6 t_1 \partial^\alpha f_{\alpha}^{\kappa} \partial^\kappa f_{\lambda}^{\theta} + 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^\beta \omega_{\lambda}^{\alpha\lambda} \partial_\lambda \omega_{\alpha\beta}^{\kappa} + 4 r_2 \partial^\beta \omega_{\lambda}^{\lambda\alpha} \partial_\lambda \omega_{\alpha\beta}^{\kappa}) [t, x, y, z] dz dy dx dt \end{aligned}$$

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

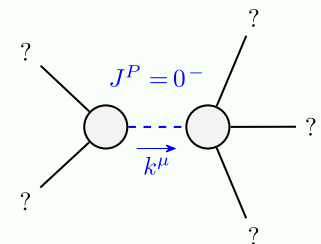
	$\omega_{2+}^{\#1} \alpha\beta$	$f_{2+}^{\#1} \alpha\beta$	$\omega_{2-}^{\#1} \alpha\beta\chi$
$\omega_{2+}^{\#1} \dagger^{\alpha\beta}$	$\frac{t_1}{2}$	$-\frac{i k t_1}{\sqrt{2}}$	0
$f_{2+}^{\#1} \dagger^{\alpha\beta}$	$\frac{i k t_1}{\sqrt{2}}$	$k^2 t_1$	0
$\omega_{2-}^{\#1} \dagger^{\alpha\beta\chi}$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

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

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

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