

# Particle spectrograph

## Wave operator and propagator

	$\sigma_{0+}^{\#1}$	$\tau_{0+}^{\#1}$	$\tau_{0+}^{\#2}$	$\sigma_{0-}^{\#1}$
$\sigma_{0+}^{\#1} \dagger$	$\frac{8 \beta_1}{\alpha_0^2 - 4 \alpha_0 \beta_1 + 8 \alpha_6 \beta_1 k^2}$	$-\frac{i \sqrt{2} (\alpha_0 - 4 \beta_1)}{\alpha_0 (\alpha_0 - 4 \beta_1) k + 8 \alpha_6 \beta_1 k^3}$	0	0
$\tau_{0+}^{\#1} \dagger$	$\frac{i \sqrt{2} (\alpha_0 - 4 \beta_1)}{\alpha_0 (\alpha_0 - 4 \beta_1) k + 8 \alpha_6 \beta_1 k^3}$	$-\frac{\alpha_0 - 4 \beta_1 + 2 \alpha_6 k^2}{k^2 (\alpha_0^2 - 4 \alpha_0 \beta_1 + 8 \alpha_6 \beta_1 k^2)}$	0	0
$\tau_{0+}^{\#2} \dagger$	0	0	0	0
$\sigma_{0-}^{\#1} \dagger$	0	0	0	$\frac{2}{\alpha_0 - 4 \beta_1}$

Quadratic (free) action

$$S == \iiint \iiint (-\frac{1}{2} (\alpha_0 - 4 \beta_1) \omega^{\alpha \beta}_{\alpha} \omega^{\chi}_{\beta} \omega^{\chi}_{\chi} + f^{\alpha \beta} \tau_{\alpha \beta} + \omega^{\alpha \beta \chi} \sigma_{\alpha \beta \chi} - 4 \beta_1 \omega^{\chi}_{\alpha} \omega^{\chi}_{\chi} \partial_{\beta} f^{\alpha \beta} - \alpha_0 f^{\alpha \beta} \partial_{\beta} \omega^{\chi}_{\alpha} \omega^{\chi}_{\chi} + \alpha_0 \partial_{\beta} \omega^{\alpha \beta}_{\alpha} + 4 \beta_1 \omega^{\chi}_{\beta} \omega^{\chi}_{\chi} \partial^{\beta} f^{\alpha}_{\alpha} - 2 \beta_1 \partial_{\beta} f^{\chi}_{\chi} \partial^{\beta} f^{\alpha}_{\alpha} - 2 \beta_1 \partial_{\beta} f^{\alpha \beta} \partial_{\chi} f^{\chi}_{\alpha} + 4 \beta_1 \partial^{\beta} f^{\alpha}_{\alpha} \partial_{\chi} f^{\chi}_{\beta} + \alpha_0 f^{\alpha \beta} \partial_{\chi} \omega^{\chi}_{\alpha} \omega^{\chi}_{\beta} - \alpha_0 f^{\alpha}_{\alpha} \partial_{\chi} \omega^{\beta \chi}_{\beta} - 2 \beta_1 \partial_{\alpha} f_{\beta \chi} \partial^{\chi} f^{\alpha \beta} - \beta_1 \partial_{\alpha} f_{\chi \beta} \partial^{\chi} f^{\alpha \beta} + \beta_1 \partial_{\beta} f_{\alpha \chi} \partial^{\chi} f^{\alpha \beta} + \beta_1 \partial_{\chi} f_{\alpha \beta} \partial^{\chi} f^{\alpha \beta} + \beta_1 \partial_{\chi} f_{\beta \alpha} \partial^{\chi} f^{\alpha \beta} - \frac{1}{2} \omega_{\alpha \chi \beta} ((\alpha_0 - 4 \beta_1) \omega^{\alpha \beta \chi} - 8 \beta_1 \partial^{\chi} f^{\alpha \beta}) + \frac{2}{3} \alpha_6 \partial_{\beta} \omega^{\alpha \beta}_{\alpha} \partial_{\delta} \omega^{\chi \delta}_{\chi}) [t, x, y, z] dz dy dx dt$$

Source constraints	Fundamental fields	Multiplicities
SO(3) irreps		
$\tau_{0+}^{\#2} == 0$	$\partial_{\beta} \partial_{\alpha} \tau^{\alpha \beta} == 0$	1
$\tau_{1-}^{\#2 \alpha} + 2 i k \sigma_{1-}^{\#2 \alpha} == 0$	$\partial_{\chi} \partial_{\beta} \partial^{\alpha} \tau^{\beta \chi} == \partial_{\chi} \partial^{\alpha} \partial_{\beta} \tau^{\alpha \beta} + 2 \partial_{\delta} \partial^{\delta} \partial_{\chi} \partial_{\beta} \sigma^{\alpha \beta \chi}$	3
$\tau_{1-}^{\#1 \alpha} == 0$	$\partial_{\chi} \partial_{\beta} \partial^{\alpha} \tau^{\beta \chi} == \partial_{\chi} \partial^{\alpha} \partial_{\beta} \tau^{\beta \alpha}$	3
$\tau_{1+}^{\#1 \alpha \beta} + i k \sigma_{1+}^{\#2 \alpha \beta} == 0$	$\partial_{\chi} \partial^{\alpha} \tau^{\beta \chi} + \partial_{\chi} \partial^{\beta} \tau^{\chi \alpha} + \partial_{\chi} \partial^{\chi} \tau^{\alpha \beta} + 2 \partial_{\delta} \partial^{\delta} \partial_{\chi} \sigma^{\alpha \beta \chi} == \partial_{\chi} \partial^{\alpha} \tau^{\beta \chi} + \partial_{\chi} \partial^{\beta} \tau^{\chi \alpha} + \partial_{\chi} \partial^{\chi} \tau^{\alpha \beta} + 2 \partial_{\delta} \partial^{\delta} \partial_{\chi} \sigma^{\alpha \beta \chi}$	3
Total constraints/gauge generators:		10

	$\omega_{2+}^{\#1} \dagger^{\alpha \beta}$	$f_{2+}^{\#1} \dagger^{\alpha \beta}$	$\omega_{2-}^{\#1} \dagger^{\alpha \beta \chi}$
$\omega_{2+}^{\#1} \dagger^{\alpha \beta}$	$-\frac{\alpha_0}{4} + \beta_1$	$\frac{i (\alpha_0 - 4 \beta_1) k}{2 \sqrt{2}}$	0
$f_{2+}^{\#1} \dagger^{\alpha \beta}$	$-\frac{i (\alpha_0 - 4 \beta_1) k}{2 \sqrt{2}}$	$2 \beta_1 k^2$	0
$\omega_{2-}^{\#1} \dagger^{\alpha \beta \chi}$	0	0	$-\frac{\alpha_0}{4} + \beta_1$

	$\omega_{1+}^{\#1} \dagger^{\alpha \beta}$	$\omega_{1+}^{\#2} \dagger^{\alpha \beta}$	$f_{1+}^{\#1} \dagger^{\alpha \beta}$	$\omega_{1-}^{\#1} \dagger^{\alpha}$	$\omega_{1-}^{\#2} \dagger^{\alpha}$	$f_{1-}^{\#1} \dagger^{\alpha}$	$f_{1-}^{\#2} \dagger^{\alpha}$
$\omega_{1+}^{\#1} \dagger^{\alpha \beta}$	$\frac{1}{4} (\alpha_0 - 4 \beta_1)$	$\frac{\alpha_0 - 4 \beta_1}{2 \sqrt{2}}$	$\frac{i (\alpha_0 - 4 \beta_1) k}{2 \sqrt{2}}$	0	0	0	0
$\omega_{1+}^{\#2} \dagger^{\alpha \beta}$	$\frac{\alpha_0 - 4 \beta_1}{2 \sqrt{2}}$	0	0	0	0	0	0
$f_{1+}^{\#1} \dagger^{\alpha \beta}$	$-\frac{i (\alpha_0 - 4 \beta_1) k}{2 \sqrt{2}}$	0	0	0	0	0	0
$\omega_{1-}^{\#1} \dagger^{\alpha}$	0	0	0	$\frac{1}{4} (\alpha_0 - 4 \beta_1)$	$-\frac{\alpha_0 - 4 \beta_1}{2 \sqrt{2}}$	0	$-\frac{1}{2} i (\alpha_0 - 4 \beta_1) k$
$\omega_{1-}^{\#2} \dagger^{\alpha}$	0	0	0	$-\frac{\alpha_0 - 4 \beta_1}{2 \sqrt{2}}$	0	0	0
$f_{1-}^{\#1} \dagger^{\alpha}$	0	0	0	0	0	0	0
$f_{1-}^{\#2} \dagger^{\alpha}$	0	0	0	$\frac{1}{2} i (\alpha_0 - 4 \beta_1) k$	0	0	0

	$\omega_0^{\#1} \dagger$	$f_0^{\#1} \dagger$	$f_0^{\#2} \dagger$	$\omega_0^{\#1}$
$\omega_0^{\#1} \dagger$	$\frac{\alpha_0}{2} - 2 \beta_1 + \alpha_6 k^2$	$-\frac{i (\alpha_0 - 4 \beta_1) k}{\sqrt{2}}$	0	0
$f_0^{\#1} \dagger$	$\frac{i (\alpha_0 - 4 \beta_1) k}{\sqrt{2}}$	$-4 \beta_1 k^2$	0	0
$f_0^{\#2} \dagger$	0	0	0	0
$\omega_0^{\#1} \dagger$	0	0	0	$\frac{1}{2} (\alpha_0 - 4 \beta_1)$

	$\sigma_{2+}^{\#1} \dagger^{\alpha \beta}$	$\tau_{2+}^{\#1} \dagger^{\alpha \beta}$	$\sigma_{2-}^{\#1} \dagger^{\alpha \beta \chi}$
$\sigma_{2+}^{\#1} \dagger^{\alpha \beta}$	$-\frac{16 \beta_1}{\alpha_0^2 - 4 \alpha_0 \beta_1}$	$\frac{2 i \sqrt{2}}{\alpha_0 k}$	0
$\tau_{2+}^{\#1} \dagger^{\alpha \beta}$	$-\frac{2 i \sqrt{2}}{\alpha_0 k}$	$\frac{2}{\alpha_0 k^2}$	0
$\sigma_{2-}^{\#1} \dagger^{\alpha \beta \chi}$	0	0	$\frac{1}{-\frac{\alpha_0}{4} + \beta_1}$



Massive particle	
Pole residue:	$\frac{1}{\alpha_0} + \frac{1}{\alpha_6} - \frac{1}{4 \beta_1} > 0$
Polarisations:	1
Square mass:	$-\frac{\alpha_0 (\alpha_0 - 4 \beta_1)}{8 \alpha_6 \beta_1} > 0$
Spin:	0
Parity:	Even



Quadratic pole	
Pole residue:	$\frac{1}{\alpha_0} > 0$
Polarisations:	2

$\alpha_0 > 0 \ \&\& \ \alpha_6 > 0 \ \&\& \ \beta_1 < 0 \ || \ \beta_1 > \frac{\alpha_0}{4}$

## Massive and massless spectra

## Unitarity conditions