

# Particle spectrograph

## Wave operator and propagator

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

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

Quadratic (free) action

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

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

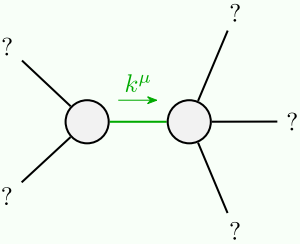
$\omega_{0+}^{\#1} \dagger$	$f_{0+}^{\#1} \dagger$	$\omega_{0+}^{\#2} \dagger$	$\omega_{0-}^{\#1} \dagger$
$\frac{\alpha_0}{2}$	$-\frac{i \alpha_0 k}{\sqrt{2}}$	0	0
$\frac{i \alpha_0 k}{\sqrt{2}}$	0	0	0
0	0	0	0
0	0	0	$\frac{\alpha_0}{2}$

$\sigma_{0+}^{\#1} \dagger$	$\tau_{0+}^{\#1} \dagger$	$\tau_{0+}^{\#2} \dagger$	$\sigma_{0-}^{\#1} \dagger$
0	$\frac{i \sqrt{2}}{\alpha_0 k}$	0	0
$\frac{i \sqrt{2}}{\alpha_0 k}$	$-\frac{1}{\alpha_0 k^2}$	0	0
0	0	0	0
0	0	0	$\frac{2}{\alpha_0}$

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

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

## Massive and massless spectra



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

(No massive particles)

## Unitarity conditions

$$\alpha_0 > 0$$