

# Particle spectrograph

## Wave operator and propagator

## Quadratic (free) action

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$$\begin{aligned} & \iiint \left( \frac{1}{6} (6 f^{\alpha\beta} \tau_{\alpha\beta} + 6 \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} - 15 r_3 \partial_\beta \omega_{,\theta}^\theta \partial' \omega_{,\alpha}^{\alpha\beta} + 9 r_3 \partial_1 \omega_\beta^\theta \partial' \omega_{,\alpha}^{\alpha\beta} + \right. \\ & 9 r_3 \partial_\alpha \omega^{\alpha\beta} \partial_\theta \omega_{\beta,}^\theta - 18 r_3 \partial' \omega_{,\alpha}^{\alpha\beta} \partial_\theta \omega_{\beta,}^\theta - 15 r_3 \partial_\alpha \omega^{\alpha\beta} \partial_\theta \omega_{,\beta}^\theta + \\ & 30 r_3 \partial' \omega_{,\alpha}^{\alpha\beta} \partial_\theta \omega_{,\beta}^\theta + 4 t_2 \omega_{,\theta\alpha}^\theta \partial^\theta f^{\alpha 1} + 2 t_2 \partial_\alpha f_{,\theta}^\theta \partial^\theta f^{\alpha 1} - t_2 \partial_\alpha f_{,\theta 1}^\theta \partial^\theta f^{\alpha 1} - \\ & t_2 \partial_1 f_{,\alpha\theta}^\theta \partial^\theta f^{\alpha 1} + t_2 \partial_\theta f_{,\alpha 1}^\theta \partial^\theta f^{\alpha 1} - t_2 \partial_\theta f_{,\alpha}^\theta \partial^\theta f^{\alpha 1} - 4 t_2 \omega_{\alpha\theta 1} (\omega^{\alpha 1\theta} + \partial^\theta f^{\alpha 1}) + \\ & 2 t_2 \omega_{\alpha\theta} (\omega^{\alpha 1\theta} + 2 \partial^\theta f^{\alpha 1}) + 8 r_2 \partial_\beta \omega_{\alpha 1\theta}^\theta \partial^\theta \omega^{\alpha\beta 1} - 4 r_2 \partial_\beta \omega_{\alpha\theta 1}^\theta \partial^\theta \omega^{\alpha\beta 1} + \\ & 4 r_2 \partial_\beta \omega_{,\theta\alpha}^\theta \partial^\theta \omega^{\alpha\beta 1} - 24 r_3 \partial_\beta \omega_{,\theta\alpha}^\theta \partial^\theta \omega^{\alpha\beta 1} - 2 r_2 \partial_1 \omega_{\alpha\beta\theta}^\theta \partial^\theta \omega^{\alpha\beta 1} + \\ & \left. 2 r_2 \partial_\theta \omega_{,\alpha\beta}^\theta \partial^\theta \omega^{\alpha\beta 1} - 4 r_2 \partial_\theta \omega_{,\alpha\beta}^\theta \partial^\theta \omega^{\alpha\beta 1} \right) [t, x, y, z] dz dy dx dt \end{aligned}$$

	$\omega_1^{\#1} \dagger \alpha\beta$	$\omega_1^{\#2} \dagger \alpha\beta$	$f_1^{\#1} \dagger \alpha\beta$	$\omega_1^{\#1} \alpha$	$\omega_1^{\#2} \alpha$	$f_1^{\#1} \alpha$	$f_1^{\#2} \alpha$
$\omega_1^{\#1} \dagger \alpha\beta$	$\frac{2t_2}{3}$	$\frac{\sqrt{2}t_2}{3}$	$\frac{1}{3}i\sqrt{2}kt_2$	0	0	0	0
$\omega_1^{\#2} \dagger \alpha\beta$	$\frac{\sqrt{2}t_2}{3}$	$\frac{t_2}{3}$	$\frac{ikt_2}{3}$	0	0	0	0
$f_1^{\#1} \dagger \alpha\beta$	$-\frac{1}{3}i\sqrt{2}kt_2$	$-\frac{1}{3}ikt_2$	$\frac{k^2t_2}{3}$	0	0	0	0
$\omega_1^{\#1} \dagger \alpha$	0	0	0	$-\frac{3k^2r_3}{2}$	0	0	0
$\omega_1^{\#2} \dagger \alpha$	0	0	0	0	0	0	0
$f_1^{\#1} \dagger \alpha$	0	0	0	0	0	0	0
$f_1^{\#2} \dagger \alpha$	0	0	0	0	0	0	0

	$\omega_{2+}^{\#1} \alpha \beta$	$f_{2+}^{\#1} \alpha \beta$	$\omega_{2-}^{\#1} \alpha \beta \chi$
$\omega_{2+}^{\#1} \dagger \alpha \beta$	$-\frac{3k^2 r_3}{2}$	0	0
$f_{2+}^{\#1} \dagger \alpha \beta$	0	0	0
$\omega_{2-}^{\#1} \dagger \alpha \beta \chi$	0	0	0

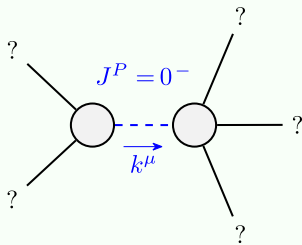
	$\sigma_{2^+}^{\#1} \alpha\beta$	$\tau_{2^+}^{\#1} \alpha\beta$	$\sigma_{2^-}^{\#1} \alpha\beta\chi$
$\sigma_{2^+}^{\#1} \dagger \alpha\beta$	$-\frac{2}{3k^2 r_3}$	0	0
$\tau_{2^+}^{\#1} \dagger \alpha\beta$	0	0	0
$\sigma_{2^-}^{\#1} \dagger \alpha\beta\chi$	0	0	0

	$\omega_{0+}^{\#1}$	$f_{0+}^{\#1}$	$f_{0+}^{\#2}$	$\omega_{0-}^{\#1}$
$\omega_{0+}^{\#1} \uparrow$	0	0	0	0
$f_{0+}^{\#1} \uparrow$	0	0	0	0
$f_{0+}^{\#2} \uparrow$	0	0	0	0
$\omega_{0-}^{\#1} \uparrow$	0	0	0	$k^2 r_2 + t_2$

Source constraints/gauge generators	
SO(3) irreps	Multiplicities
$\tau_{0+}^{\#2} == 0$	1
$\tau_{0+}^{\#1} == 0$	1
$\sigma_{0+}^{\#1} == 0$	1
$\tau_{1-}^{\#2\alpha} == 0$	3
$\tau_{1-}^{\#1\alpha} == 0$	3
$\sigma_{1-}^{\#2\alpha} == 0$	3
$\tau_{1+}^{\#1\alpha\beta} + i k \sigma_{1+}^{\#1\alpha\beta} == 0$	3
$\sigma_{1+}^{\#1\alpha\beta} == \sigma_{1+}^{\#2\alpha\beta}$	3
$\sigma_{2-}^{\#1\alpha\beta\chi} == 0$	5
$\tau_{2+}^{\#1\alpha\beta} == 0$	5
Total constraints:	28

	$\sigma_{0+}^{\#1}$	$\tau_{0+}^{\#1}$	$\tau_{0+}^{\#2}$	$\sigma_{0-}^{\#1}$
$\sigma_{0+}^{\#1} \vdash$	0	0	0	0
$\tau_{0+}^{\#1} \vdash$	0	0	0	0
$\tau_{0+}^{\#2} \vdash$	0	0	0	0
$\sigma_{0-}^{\#1} \vdash$	0	0	0	$\frac{1}{k^2 r_2 + t_2}$

# 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

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