

Particle spectrograph

Wave operator and propagator

Quadratic (free) action

$$\begin{aligned} S = & \iiint \Big(\frac{1}{6} (2 t_1 \omega^{\alpha}{}_{\alpha} \omega^{\theta}{}_{\theta} + 6 f^{\alpha \beta} \tau_{\alpha \beta} + 6 \omega^{\alpha \beta \chi} \sigma_{\alpha \beta \chi} - 4 t_1 \omega_{\alpha \theta} \partial_{\theta} f^{\alpha} + 4 t_1 \omega^{\theta}{}_{\theta} \partial^{\theta} f^{\alpha} - 2 t_1 \partial_{\theta} f^{\alpha} \partial^{\theta} f^{\alpha} - 24 r_3 \partial_{\beta} \omega^{\theta}{}_{\theta} \partial^{\theta} \omega^{\alpha \beta} - 2 t_1 \partial_{\theta} f^{\alpha} \partial_{\theta} f^{\theta}{}_{\alpha} + \\ & 4 t_1 \partial^{\theta} f^{\alpha} \partial_{\alpha} \partial_{\theta} f^{\theta} - 24 r_3 \partial_{\alpha} \omega^{\alpha \beta} \partial_{\theta} \omega^{\theta}{}_{\beta} + 48 r_3 \partial^{\theta} \omega^{\alpha \beta} \partial_{\alpha} \partial_{\theta} \omega^{\theta}{}_{\beta} + 4 t_1 \omega_{\theta \alpha} \partial^{\theta} f^{\alpha} + \\ & 4 t_2 \omega_{\theta \alpha} \partial^{\theta} f^{\alpha} - 4 t_1 \partial_{\alpha} f_{\theta} \partial^{\theta} f^{\alpha} + 2 t_2 \partial_{\alpha} f_{\theta} \partial^{\theta} f^{\alpha} - 4 t_1 \partial_{\alpha} f_{\theta} \partial^{\theta} f^{\alpha} - 4 t_1 \partial_{\alpha} f_{\theta} \partial^{\theta} f^{\alpha} - \\ & t_2 \partial_{\alpha} f_{\theta} \partial^{\theta} f^{\alpha} + 2 t_1 \partial_{\theta} f_{\alpha} \partial^{\theta} f^{\alpha} - t_2 \partial_{\theta} f_{\alpha} \partial^{\theta} f^{\alpha} + 4 t_1 \partial_{\theta} f_{\alpha} \partial^{\theta} f^{\alpha} + t_2 \partial_{\theta} f_{\alpha} \partial^{\theta} f^{\alpha} + \\ & \partial^{\theta} f^{\alpha} + 2 t_1 \partial_{\theta} f_{\alpha} \partial^{\theta} f^{\alpha} - t_2 \partial_{\theta} f_{\alpha} \partial^{\theta} f^{\alpha} + 2 (t_1 + t_2) \omega_{\alpha \theta} (\omega^{\alpha \theta} + 2 \partial^{\theta} f^{\alpha}) + \\ & 2 \omega_{\alpha \theta} ((t_1 - 2 t_2) \omega^{\alpha \theta} + 2 (2 t_1 - t_2) \partial^{\theta} f^{\alpha}) + 8 r_2 \partial_{\beta} \omega_{\alpha \theta} \partial^{\theta} \omega^{\alpha \beta} - 24 r_3 \partial_{\beta} \omega_{\theta \alpha} \partial^{\theta} \omega^{\alpha \beta} - 2 r_2 \partial_{\theta} \omega_{\alpha \beta} \partial^{\theta} \omega^{\alpha \beta} + 2 r_2 \partial_{\theta} \omega_{\alpha \beta} \partial^{\theta} \omega^{\alpha \beta} - 4 r_2 \partial_{\theta} \omega_{\alpha \beta} \partial^{\theta} \omega^{\alpha \beta}) [t, x, y, z] d^3 y d^4 x dt \end{aligned}$$

	$\sigma_{1^{+} \alpha \beta}^{\#1}$	$\sigma_{1^{+} \alpha \beta}^{\#2}$	$\tau_{1^{+} \alpha \beta}^{\#1}$	$\sigma_{1^{-} \alpha}^{\#1}$	$\sigma_{1^{-} \alpha}^{\#2}$	$\tau_{1^{-} \alpha}^{\#1}$	$\tau_{1^{-} \alpha}^{\#2}$
$\sigma_{1^{+}}^{\#1} \dagger^{\alpha \beta}$	$\frac{2 (t_1 + t_2)}{3 t_1 t_2}$	$\frac{\sqrt{2} (t_1 - 2 t_2)}{3 (1 + k^2) t_1 t_2}$	$\frac{i \sqrt{2} k (t_1 - 2 t_2)}{3 (1 + k^2) t_1 t_2}$	0	0	0	0
$\sigma_{1^{+}}^{\#2} \dagger^{\alpha \beta}$	$\frac{\sqrt{2} (t_1 - 2 t_2)}{3 (1 + k^2) t_1 t_2}$	$\frac{t_1 + 4 t_2}{3 (1 + k^2)^2 t_1 t_2}$	$\frac{i k (t_1 + 4 t_2)}{3 (1 + k^2)^2 t_1 t_2}$	0	0	0	0
$\tau_{1^{+}}^{\#1} \dagger^{\alpha \beta}$	$-\frac{i \sqrt{2} k (t_1 - 2 t_2)}{3 (1 + k^2) t_1 t_2}$	$-\frac{i k (t_1 + 4 t_2)}{3 (1 + k^2)^2 t_1 t_2}$	$\frac{k^2 (t_1 + 4 t_2)}{3 (1 + k^2)^2 t_1 t_2}$	0	0	0	0
$\sigma_{1^{-}}^{\#1} \dagger^{\alpha}$	0	0	0	$\frac{6}{(3 + 4 k^2)^2 t_1}$	$\frac{6 \sqrt{2}}{(3 + 4 k^2)^2 t_1}$	0	$\frac{12 i k}{(3 + 4 k^2)^2 t_1}$
$\sigma_{1^{-}}^{\#2} \dagger^{\alpha}$	0	0	0	$\frac{6 \sqrt{2}}{(3 + 4 k^2)^2 t_1}$	$\frac{12}{(3 + 4 k^2)^2 t_1}$	0	$\frac{12 i \sqrt{2} k}{(3 + 4 k^2)^2 t_1}$
$\tau_{1^{-}}^{\#1} \dagger^{\alpha}$	0	0	0	0	0	0	0
$\tau_{1^{-}}^{\#2} \dagger^{\alpha}$	0	0	0	$-\frac{12 i k}{(3 + 4 k^2)^2 t_1}$	$-\frac{12 i \sqrt{2} k}{(3 + 4 k^2)^2 t_1}$	0	$\frac{24 k^2}{(3 + 4 k^2)^2 t_1}$

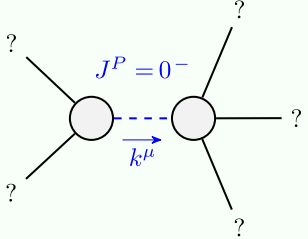
	$\omega_{1^{+} \alpha \beta}^{\#1}$	$\omega_{1^{+} \alpha \beta}^{\#2}$	$f_{1^{+} \alpha \beta}^{\#1}$	$\omega_{1^{-} \alpha}^{\#1}$	$\omega_{1^{-} \alpha}^{\#2}$	$f_{1^{-} \alpha}^{\#1}$	$f_{1^{-} \alpha}^{\#2}$
$\omega_{1^{+}}^{\#1} \dagger^{\alpha \beta}$	$\frac{1}{6} (t_1 + 4 t_2)$	$-\frac{t_1 - 2 t_2}{3 \sqrt{2}}$	$-\frac{i k (t_1 - 2 t_2)}{3 \sqrt{2}}$	0	0	0	0
$\omega_{1^{+}}^{\#2} \dagger^{\alpha \beta}$	$-\frac{t_1 - 2 t_2}{3 \sqrt{2}}$	$\frac{t_1 + t_2}{3}$	$\frac{1}{3} i k (t_1 + t_2)$	0	0	0	0
$f_{1^{+}}^{\#1} \dagger^{\alpha \beta}$	$\frac{i k (t_1 - 2 t_2)}{3 \sqrt{2}}$	$-\frac{1}{3} i k (t_1 + t_2)$	$\frac{1}{3} k^2 (t_1 + t_2)$	0	0	0	0
$\omega_{1^{-}}^{\#1} \dagger^{\alpha}$	0	0	0	$\frac{t_1}{6}$	$\frac{t_1}{3 \sqrt{2}}$	0	$\frac{i k t_1}{3}$
$\omega_{1^{-}}^{\#2} \dagger^{\alpha}$	0	0	0	$\frac{t_1}{3 \sqrt{2}}$	$\frac{t_1}{3}$	0	$\frac{1}{3} i \sqrt{2} k t_1$
$f_{1^{-}}^{\#1} \dagger^{\alpha}$	0	0	0	0	0	0	0
$f_{1^{-}}^{\#2} \dagger^{\alpha}$	0	0	0	$-\frac{1}{3} i k t_1$	$-\frac{1}{3} i \sqrt{2} k t_1$	0	$\frac{2 k^2 t_1}{3}$

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

	$\omega_{0^{+}}^{\#1}$	$f_{0^{+}}^{\#1}$	$f_{0^{+}}^{\#2}$	$\omega_{0^{-}}^{\#1}$
$\omega_{0^{+}}^{\#1} \dagger$	$6 k^2 r_3$	0	0	0
$f_{0^{+}}^{\#1} \dagger$	0	0	0	0
$f_{0^{+}}^{\#2} \dagger$	0	0	0	0
$\omega_{0^{-}}^{\#1} \dagger$	0	0	0	$k^2 r_2 + t_2$

Source constraints/gauge generators	Multiplicities
$\tau_{0^{+}}^{\#2} == 0$	1
$\tau_{0^{+}}^{\#1} == 0$	1
$\tau_{1^{-}}^{\#2 \alpha} + 2 i k \sigma_{1^{-}}^{\#1 \alpha} == 0$	3
$\tau_{1^{-}}^{\#1 \alpha} == 0$	3
$\sigma_{1^{-}}^{\#1 \alpha} == \sigma_{1^{-}}^{\#2 \alpha}$	3
$\tau_{1^{+}}^{\#1 \alpha \beta} + i k \sigma_{1^{+}}^{\#2 \alpha \beta} == 0$	3
$\tau_{2^{+}}^{\#1 \alpha \beta} - 2 i k \sigma_{2^{+}}^{\#1 \alpha \beta} == 0$	5
Total constraints:	19

	$\sigma_{2^{+} \alpha \beta}^{\#1}$	$\tau_{2^{+} \alpha \beta}^{\#1}$	$\sigma_{2^{-} \alpha \beta \chi}^{\#1}$	$\sigma_{0^{-}}^{\#1}$
$\sigma_{2^{+}}^{\#1} \dagger^{\alpha \beta}$	$\frac{2}{(1 + 2 k^2)^2 t_1}$	$-\frac{2 i \sqrt{2} k}{(1 + 2 k^2)^2 t_1}$	0	0
$\tau_{2^{+}}^{\#1} \dagger^{\alpha \beta}$	$\frac{2 i \sqrt{2} k}{(1 + 2 k^2)^2 t_1}$	$\frac{4 k^2}{(1 + 2 k^2)^2 t_1}$	0	0
$\sigma_{2^{-}}^{\#1} \dagger^{\alpha \beta \chi}$	0	0	$\frac{2}{t_1}$	$\frac{1}{k^2 r_2 + t_2}$



Massive particle	
Pole residue:	$-\frac{1}{r_2} > 0$
Polarisations:	1
Square mass:	$-\frac{t_2}{r_2} > 0$
Spin:	0
Parity:	Odd

(squared mass is negative)

Massive and massless spectra

Unitarity conditions

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