Particle spectrograph

Wave operator and propagator

Quadratic (free) action

$$S_{\mathrm{F}} ==$$

$$\iiiint\Big(\tfrac{1}{6}\big(4 t_2\, \omega^{\kappa\lambda}{}_{\iota}\, \omega_{\kappa\lambda}{}^{\iota} + 2 t_2\, \omega_{\kappa\lambda}{}^{\iota}\, \omega^{\kappa\lambda}{}_{\iota} + 6 f^{\alpha\beta}\, \tau_{\alpha\beta} + 6\, \omega^{\alpha\beta\chi}\, \sigma_{\alpha\beta\chi} - 6 r_3\, \partial_{\iota}\omega^{\kappa\lambda}{}_{\kappa}$$

$$\partial^{\iota}\omega_{\lambda}{}^{\alpha}{}_{\alpha} + 4 r_2\, \partial^{\beta}\omega^{\theta\alpha}{}_{\kappa}\, \partial_{\theta}\omega_{\alpha\beta}{}^{\kappa} - 2 r_2\, \partial_{\theta}\omega_{\alpha\beta}{}^{\kappa}\, \partial_{\kappa}\omega^{\alpha\beta\theta} - 4 r_2\, \partial_{\theta}\omega_{\alpha\beta}{}^{\kappa}\, \partial_{\kappa}\omega^{\theta\alpha\beta} +$$

$$18 r_3\, \partial_{\alpha}\omega_{\lambda}{}^{\alpha}{}_{\theta}\, \partial_{\kappa}\omega^{\theta\kappa\lambda} - 18 r_3\, \partial_{\theta}\omega_{\lambda}{}^{\alpha}{}_{\alpha}\, \partial_{\kappa}\omega^{\theta\kappa\lambda} - 6 r_3\, \partial_{\alpha}\omega_{\lambda}{}^{\alpha}{}_{\theta}\, \partial_{\kappa}\omega^{\kappa\lambda\theta} +$$

$$12 r_3\, \partial_{\theta}\omega_{\lambda}{}^{\alpha}{}_{\alpha}\, \partial_{\kappa}\omega^{\kappa\lambda\theta} + t_2\, \partial^{\alpha}f_{\theta\kappa}\, \partial^{\kappa}f_{\alpha}{}^{\theta} - t_2\, \partial^{\alpha}f_{\kappa\theta}\, \partial^{\kappa}f_{\alpha}{}^{\theta} + t_2\, \partial^{\alpha}f^{\lambda}{}_{\kappa}\, \partial^{\kappa}f_{\alpha\lambda} +$$

$$2 t_2\, \omega_{\iota\theta\kappa}\, \partial^{\kappa}f^{\iota\theta} - 4 t_2\, \omega_{\iota\kappa\theta}\, \partial^{\kappa}f^{\iota\theta} - 2 t_2\, \omega_{\theta\iota\kappa}\, \partial^{\kappa}f^{\iota\theta} + 4 t_2\, \omega_{\theta\kappa\iota}\, \partial^{\kappa}f^{\iota\theta} -$$

$$t_2\, \partial^{\alpha}f^{\lambda}{}_{\kappa}\, \partial^{\kappa}f_{\lambda\alpha} - t_2\, \partial_{\kappa}f^{\lambda}{}_{\theta}\, \partial^{\theta}f^{\kappa}{}_{\lambda} + t_2\, \partial_{\kappa}f^{\lambda}{}_{\theta}\, \partial^{\kappa}f^{\theta}{}_{\lambda} + 2 r_2\, \partial_{\kappa}\omega^{\alpha\beta\theta}\, \partial^{\kappa}\omega_{\alpha\beta\theta} +$$

$$4 r_2\, \partial_{\kappa}\omega^{\theta\alpha\beta}\, \partial^{\kappa}\omega_{\alpha\beta\theta} - 4 r_2\, \partial^{\beta}\omega^{\alpha\lambda}{}_{\iota}\, \partial_{\lambda}\omega_{\alpha\beta}{}^{\iota} + 4 r_2\, \partial^{\beta}\omega^{\lambda\alpha}{}_{\iota}\, \partial_{\lambda}\omega_{\alpha\beta}{}^{\iota} - 24 r_3\, \partial^{\beta}\omega^{\lambda\alpha}{}_{\iota}$$

$$\partial_{\lambda}\omega_{\alpha\beta}{}^{\iota} - 18 r_3\, \partial_{\alpha}\omega_{\lambda}{}^{\alpha}{}_{\theta}\, \partial^{\lambda}\omega^{\theta\kappa}{}_{\kappa} + 18 r_3\, \partial_{\theta}\omega_{\lambda}{}^{\alpha}{}_{\alpha}\, \partial^{\lambda}\omega^{\theta\kappa}{}_{\kappa}\big)\Big)[t, x, y, z]\, dz\, dy\, dx\, dt$$

	$\sigma^{\#1}_{1^+\alpha\beta}$	$\sigma^{\#2}_{1^+\alpha\beta}$	$\tau^{\#1}_{1^+\alpha\beta}$	$\sigma^{\#1}_{1^-\alpha}$	$\sigma^{\#2}_{1^-\alpha}$	$\tau^{\#1}_{1^-\alpha}$	$\tau^{\#2}_{1^-\alpha}$
$\sigma^{\#1}_{1^+}\dagger^{\alpha\beta}$	$\frac{1}{k^2 r_3}$	$-\frac{\sqrt{2}}{k^2 r_3+k^4 r_3}$	$-\frac{i\sqrt{2}}{k r_3+k^3 r_3}$	0	0	0	0
$\sigma^{\#2}_{1^+}\dagger^{\alpha\beta}$	$-\frac{\sqrt{2}}{k^2 r_3+k^4 r_3}$	$\frac{3k^2 r_3+2t_2}{(k+k^3)^2 r_3 t_2}$	$\frac{i(3k^2 r_3+2t_2)}{k(1+k^2)^2 r_3 t_2}$	0	0	0	0
$\tau^{\#1}_{1^+}\dagger^{\alpha\beta}$	$\frac{i\sqrt{2}}{k r_3+k^3 r_3}$	$-\frac{i(3k^2 r_3+2t_2)}{k(1+k^2)^2 r_3 t_2}$	$\frac{3k^2 r_3+2t_2}{(1+k^2)^2 r_3 t_2}$	0	0	0	0
$\sigma^{\#1}_{1^-}\dagger^{\alpha}$	0	0	0	$\frac{1}{k^2 r_3}$	0	0	0
$\sigma^{\#2}_{1^-}\dagger^{\alpha}$	0	0	0	0	0	0	0
$\tau^{\#1}_{1^-}\dagger^{\alpha}$	0	0	0	0	0	0	0
$\tau^{\#2}_{1^-}\dagger^{\alpha}$	0	0	0	0	0	0	0

	$\omega^{\#1}_{1^+\alpha\beta}$	$\omega^{\#2}_{1^+\alpha\beta}$	$f^{\#1}_{1^+\alpha\beta}$	$\omega^{\#1}_{1^-\alpha}$	$\omega^{\#2}_{1^-\alpha}$	$f^{\#1}_{1^-\alpha}$	$f^{\#2}_{1^-\alpha}$
$\omega^{\#1}_{1^+}\dagger^{\alpha\beta}$	$k^2 r_3+\frac{2t_2}{3}$	$\frac{\sqrt{2}\,t_2}{3}$	$\frac{1}{3} i \sqrt{2}\, k t_2$	0	0	0	0
$\omega^{\#2}_{1^+}\dagger^{\alpha\beta}$	$\frac{\sqrt{2}\,t_2}{3}$	$\frac{t_2}{3}$	$\frac{i k t_2}{3}$	0	0	0	0
$f^{\#1}_{1^+}\dagger^{\alpha\beta}$	$-\frac{1}{3} i \sqrt{2}\, k t_2$	$-\frac{1}{3} i k t_2$	$\frac{k^2 t_2}{3}$	0	0	0	0
$\omega^{\#1}_{1^-}\dagger^{\alpha}$	0	0	0	$k^2 r_3$	0	0	0
$\omega^{\#2}_{1^-}\dagger^{\alpha}$	0	0	0	0	0	0	0
$f^{\#1}_{1^-}\dagger^{\alpha}$	0	0	0	0	0	0	0
$f^{\#2}_{1^-}\dagger^{\alpha}$	0	0	0	0	0	0	0

	$\omega^{\#1}_{2^+\alpha\beta}$	$f^{\#1}_{2^+\alpha\beta}$	$\omega^{\#1}_{2^-\alpha\beta\chi}$
$\omega^{\#1}_{2^+}\dagger^{\alpha\beta}$	0	0	0
$f^{\#1}_{2^+}\dagger^{\alpha\beta}$	0	0	0
$\omega^{\#1}_{2^-}\dagger^{\alpha\beta\chi}$	0	0	0

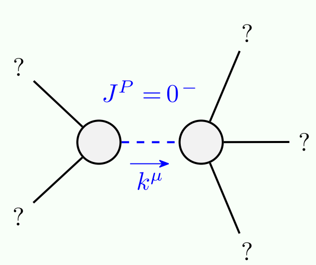
	$\sigma^{\#1}_{2^+\alpha\beta}$	$\tau^{\#1}_{2^+\alpha\beta}$	$\sigma^{\#1}_{2^-\alpha\beta\chi}$
$\sigma^{\#1}_{2^+}\dagger^{\alpha\beta}$	0	0	0
$\tau^{\#1}_{2^+}\dagger^{\alpha\beta}$	0	0	0
$\sigma^{\#1}_{2^-}\dagger^{\alpha\beta\chi}$	0	0	0

	$\omega^{\#1}_{0^+}$	$f^{\#1}_{0^+}$	$f^{\#2}_{0^+}$	$\omega^{\#1}_{0^-}$
$\omega^{\#1}_{0^+}\dagger$	$6k^2 r_3$	0	0	0
$f^{\#1}_{0^+}\dagger$	0	0	0	0
$f^{\#2}_{0^+}\dagger$	0	0	0	0
$\omega^{\#1}_{0^-}\dagger$	0	0	0	$k^2 r_2+t_2$

Source constraints/gauge generators	
SO(3) irreps	Multiplicities
$\tau^{\#2}_{0^+} == 0$	1
$\tau^{\#1}_{0^+} == 0$	1
$\tau^{\#2}_{1^-}{}^{\alpha} == 0$	3
$\tau^{\#1}_{1^-}{}^{\alpha} == 0$	3
$\sigma^{\#2}_{1^-}{}^{\alpha} == 0$	3
$\tau^{\#1}_{1^+}{}^{\alpha\beta} + i k\, \sigma^{\#2}_{1^+}{}^{\alpha\beta} == 0$	3
$\sigma^{\#1}_{2^-}{}^{\alpha\beta\chi} == 0$	5
$\tau^{\#1}_{2^+}{}^{\alpha\beta} == 0$	5
$\sigma^{\#1}_{2^+}{}^{\alpha\beta} == 0$	5
Total constraints:	29

	$\sigma^{\#1}_{0^+}$	$\tau^{\#1}_{0^+}$	$\tau^{\#2}_{0^+}$	$\sigma^{\#1}_{0^-}$
$\sigma^{\#1}_{0^+}\dagger$	$\frac{1}{6k^2 r_3}$	0	0	0
$\tau^{\#1}_{0^+}\dagger$	0	0	0	0
$\tau^{\#2}_{0^+}\dagger$	0	0	0	0
$\sigma^{\#1}_{0^-}\dagger$	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

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