

Particle spectrograph

Wave operator and propagator

Quadratic (free) Lagrangian density

$$\begin{aligned} & \frac{2}{3} t_2 \omega_{\lambda}^{\kappa\lambda} \omega_{\kappa\lambda}^{\prime} + \frac{1}{3} t_2 \omega_{\kappa\lambda}^{\prime} \omega_{\kappa\lambda}^{\kappa\lambda} + f^{\alpha\beta} \tau_{\alpha\beta} + \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} - \frac{1}{2} r_3 \partial_{\lambda} \omega_{\kappa}^{\kappa\lambda} \partial_{\lambda} \omega_{\alpha}^{\alpha} - \\ & r_5 \partial_{\lambda} \omega_{\kappa}^{\kappa\lambda} \partial_{\lambda} \omega_{\alpha}^{\alpha} + \frac{2}{3} r_2 \partial^{\beta} \omega_{\kappa}^{\theta\alpha} \partial_{\theta} \omega_{\alpha\beta} - \frac{1}{3} r_2 \partial_{\theta} \omega_{\alpha\beta}^{\kappa} \partial_{\kappa} \omega^{\alpha\beta\theta} - \\ & \frac{2}{3} r_2 \partial_{\theta} \omega_{\alpha\beta}^{\kappa} \partial_{\kappa} \omega^{\theta\alpha\beta} + \frac{1}{2} r_3 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega^{\theta\kappa\lambda} - r_5 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \partial_{\kappa} \omega^{\theta\kappa\lambda} - \\ & \frac{1}{2} r_3 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega^{\theta\kappa\lambda} + r_5 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega^{\theta\kappa\lambda} - \frac{1}{2} r_3 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \partial_{\kappa} \omega^{\kappa\lambda\theta} - \\ & r_5 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \partial_{\kappa} \omega^{\kappa\lambda\theta} + r_3 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega^{\kappa\lambda\theta} + 2 r_5 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial_{\kappa} \omega^{\kappa\lambda\theta} + \frac{1}{6} t_2 \partial^{\alpha} f_{\theta\kappa} \partial^{\kappa} f_{\alpha}^{\theta} - \\ & \frac{1}{6} t_2 \partial^{\alpha} f_{\kappa\theta} \partial^{\kappa} f_{\alpha}^{\theta} + \frac{1}{6} t_2 \partial^{\alpha} f_{\lambda}^{\kappa} \partial^{\kappa} f_{\alpha\lambda} + \frac{1}{3} t_2 \omega_{\theta\kappa} \partial^{\kappa} f^{\theta\lambda} - \frac{1}{3} t_2 \partial^{\alpha} f_{\lambda}^{\kappa} \partial^{\kappa} f_{\alpha\lambda} - \frac{2}{3} t_2 \omega_{\theta\kappa} \partial^{\kappa} f^{\theta\lambda} + \frac{2}{3} t_2 \omega_{\theta\kappa} \partial^{\kappa} f^{\theta\lambda} - \frac{1}{6} t_2 \partial^{\alpha} f_{\lambda}^{\kappa} \partial^{\kappa} f_{\alpha\lambda} - \\ & \frac{1}{3} t_2 \omega_{\theta\kappa} \partial^{\kappa} f^{\theta\lambda} + \frac{2}{3} t_2 \omega_{\theta\kappa} \partial^{\kappa} f^{\theta\lambda} - \frac{1}{6} t_2 \partial^{\alpha} f_{\lambda}^{\kappa} \partial^{\kappa} f_{\alpha\lambda} + \frac{1}{3} t_2 \omega_{\theta\kappa} \partial^{\kappa} f^{\theta\lambda} - \frac{1}{6} t_2 \partial^{\alpha} f_{\lambda}^{\kappa} \partial^{\kappa} f_{\alpha\lambda} - \\ & \frac{1}{6} t_2 \partial_{\kappa} f^{\lambda} \partial^{\kappa} f_{\theta}^{\theta} + \frac{1}{3} r_2 \partial_{\kappa} \omega^{\alpha\beta\theta} \partial^{\kappa} \omega_{\alpha\beta\theta} + \frac{2}{3} r_2 \partial_{\kappa} \omega^{\theta\alpha\beta} \partial^{\kappa} \omega_{\alpha\beta\theta} - \\ & \frac{2}{3} r_2 \partial^{\beta} \omega_{\lambda}^{\alpha\lambda} \partial_{\lambda} \omega_{\alpha\beta}^{\prime} + \frac{2}{3} r_2 \partial^{\beta} \omega_{\lambda}^{\prime\lambda} \partial_{\lambda} \omega_{\alpha\beta}^{\prime} - 4 r_3 \partial^{\beta} \omega_{\lambda}^{\prime\lambda} \partial_{\lambda} \omega_{\alpha\beta}^{\prime} - \\ & \frac{1}{2} r_3 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \omega^{\theta\kappa} + r_5 \partial_{\alpha} \omega_{\lambda}^{\alpha} \partial_{\theta} \omega^{\theta\kappa} + \frac{1}{2} r_3 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial^{\lambda} \omega_{\alpha}^{\theta\kappa} - r_5 \partial_{\theta} \omega_{\lambda}^{\alpha} \partial^{\lambda} \omega_{\alpha}^{\theta\kappa} \end{aligned}$$

	$\sigma_{1+}^{\#1} \dagger \alpha\beta$	$\sigma_{1+}^{\#2} \dagger \alpha\beta$	$\tau_{1+}^{\#1} \dagger \alpha\beta$	$\sigma_{1-}^{\#1} \dagger \alpha$	$\sigma_{1-}^{\#2} \dagger \alpha$	$\tau_{1-}^{\#1} \dagger \alpha$	$\tau_{1-}^{\#2} \dagger \alpha$
$\sigma_{1+}^{\#1} \dagger \alpha\beta$	$\frac{1}{k^2 (2r_3+r_5)}$	$-\frac{\sqrt{2}}{k^2 (1+k^2) (2r_3+r_5)}$	$-\frac{i\sqrt{2}}{k (1+k^2) (2r_3+r_5)}$	0	0	0	0
$\sigma_{1+}^{\#2} \dagger \alpha\beta$	$-\frac{\sqrt{2}}{k^2 (1+k^2) (2r_3+r_5)}$	$\frac{3k^2 (2r_3+r_5)+2t_2}{(k+k^3)^2 (2r_3+r_5)t_2}$	$\frac{i(3k^2 (2r_3+r_5)+2t_2)}{k (1+k^2)^2 (2r_3+r_5)t_2}$	0	0	0	0
$\tau_{1+}^{\#1} \dagger \alpha\beta$	$\frac{i\sqrt{2}}{k (1+k^2) (2r_3+r_5)}$	$-\frac{i(3k^2 (2r_3+r_5)+2t_2)}{k (1+k^2)^2 (2r_3+r_5)t_2}$	$\frac{3k^2 (2r_3+r_5)+2t_2}{(1+k^2)^2 (2r_3+r_5)t_2}$	0	0	0	0
$\sigma_{1-}^{\#1} \dagger \alpha$	0	0	0	$\frac{2}{k^2 (r_3+2r_5)}$	0	0	0
$\sigma_{1-}^{\#2} \dagger \alpha$	0	0	0	0	0	0	0
$\tau_{1-}^{\#1} \dagger \alpha$	0	0	0	0	0	0	0
$\tau_{1-}^{\#2} \dagger \alpha$	0	0	0	0	0	0	0

	$\omega_{1+}^{\#1} \dagger \alpha\beta$	$\omega_{1+}^{\#2} \dagger \alpha\beta$	$f_{1+}^{\#1} \dagger \alpha\beta$	$\omega_{1-}^{\#1} \dagger \alpha$	$\omega_{1-}^{\#2} \dagger \alpha$	$f_{1-}^{\#1} \dagger \alpha$	$f_{1-}^{\#2} \dagger \alpha$
$\omega_{1+}^{\#1} \dagger \alpha\beta$	$k^2 (2r_3+r_5) + \frac{2t_2}{3}$	$\frac{\sqrt{2}t_2}{3}$	$\frac{1}{3} i \sqrt{2} k t_2$	0	0	0	0
$\omega_{1+}^{\#2} \dagger \alpha\beta$	$\frac{\sqrt{2}t_2}{3}$	$\frac{t_2}{3}$	$\frac{i k t_2}{3}$	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	$\frac{1}{2} k^2 (r_3+2r_5)$	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

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

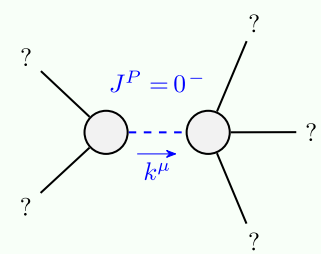
	$\omega_{0+}^{\#1} \dagger$	$f_{0+}^{\#1} \dagger$	$f_{0+}^{\#2} \dagger$	$\omega_{0-}^{\#1} \dagger$
$\omega_{0+}^{\#1} \dagger$	0	0	0	0
$f_{0+}^{\#1} \dagger$	0	0	0	0
$f_{0+}^{\#2} \dagger$	0	0	0	0
$\omega_{0-}^{\#1} \dagger$	0	0	0	$k^2 r_2 + t_2$

Source constraints/gauge generators	
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
$\tau_{1+}^{\#1\alpha\beta} + i k \sigma_{1+}^{\#2\alpha\beta} == 0$	3
$\sigma_{2-}^{\#1\alpha\beta\chi} == 0$	5
$\tau_{2+}^{\#1\alpha\beta} == 0$	5
Total constraints:	25

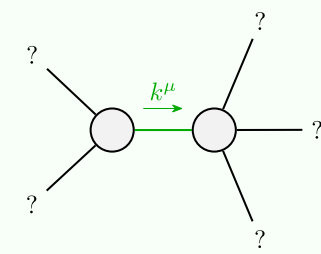
	$\sigma_{2+}^{\#1} \dagger \alpha\beta$	$\tau_{2+}^{\#1} \dagger \alpha\beta$	$\sigma_{2-}^{\#1} \dagger \alpha\beta\chi$
$\sigma_{2+}^{\#1} \dagger \alpha\beta$	$-\frac{2}{3k^2 r_3}$	0	0
$\tau_{2+}^{\#1} \dagger \alpha\beta$	0	0	0
$\sigma_{2-}^{\#1} \dagger \alpha\beta\chi$	0	0	0

	$\sigma_0^{\#1} \dagger$	$\tau_0^{\#1} \dagger$	$\tau_0^{\#2} \dagger$	$\sigma_0^{\#1} \dagger$
$\sigma_0^{\#1} \dagger$	0	0	0	0
$\tau_0^{\#1} \dagger$	0	0	0	0
$\tau_0^{\#2} \dagger$	0	0	0	0
$\sigma_0^{\#1} \dagger$	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



Quadratic pole	
Pole residue:	$-\frac{1}{r_3 (2r_3+r_5) (r_3+2r_5) p^2} > 0$
Polarisations:	2

Unitarity conditions

$$r_2 < 0 \&\& r_3 < 0 \&\& r_5 < -\frac{r_3}{2} \&\& t_2 > 0 \parallel r_2 < 0 \&\& r_3 < 0 \&\& r_5 > -2r_3 \&\& t_2 > 0 \parallel r_2 < 0 \&\& r_3 > 0 \&\& -2r_3 < r_5 < -\frac{r_3}{2} \&\& t_2 > 0$$