Particle spectrograph

Wave operator and propagator

Massive and massless spectra

Source constraints

SO(3) irreps	Fundamental fields	Multiplicities
$\sigma_{0^+}^{\#1} == 0$	$\partial_\beta \sigma^{\alpha\beta}{}_\alpha == 0$	1
$\tau_{0^+}^{\#1} == 0$	$\partial_\beta \partial_\alpha \tau^{\alpha\beta} == \partial_\beta \partial^\beta \tau^\alpha{}_\alpha$	1
$\tau_{0^+}^{\#2} == 0$	$\partial_\beta \partial_\alpha \tau^{\alpha\beta} == 0$	1
$\tau_{1^-}^{\#2\,\alpha} == 0$	$\partial_\chi \partial_\beta \partial^\alpha \tau^{\beta\chi} == \partial_\chi \partial^\chi \partial_\beta \tau^{\alpha\beta}$	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
$\sigma_{1^-}^{\#2\,\alpha} == 0$	$\partial_\chi \partial_\beta \sigma^{\alpha\beta\chi} == 0$	3
$\tau_{1^+}^{\#1\,\alpha\beta} + i\,k\,\sigma_{1^+}^{\#2\,\alpha\beta} == 0$	$\partial_\chi \partial^\alpha \tau^{\beta\chi} + \partial_\chi \partial^\beta \tau^{\chi\alpha} + \partial_\chi \partial^\chi \tau^{\alpha\beta} + 2\,\partial_\delta \partial_\chi \partial^\alpha \sigma^{\beta\chi\delta} + 2\,\partial_\delta \partial_\chi \partial^\beta \sigma^{\alpha\chi\delta} == \partial_\chi \partial^\alpha \tau^{\chi\beta} + \partial_\chi \partial^\beta \tau^{\alpha\chi} + \partial_\chi \partial^\chi \tau^{\beta\alpha} + 2\,\partial_\delta \partial_\chi \partial^\beta \sigma^{\alpha\chi\delta}$	3
$\sigma_{2^-}^{\#1\,\alpha\beta\chi} == 0$	$3\,\partial_\epsilon \partial_\delta \partial^\chi \partial^\alpha \sigma^{\beta\delta\epsilon} + 3\,\partial_\epsilon \partial^\epsilon \partial^\chi \partial^\alpha \sigma^{\beta\delta}{}_\delta + 2\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\beta \sigma^{\alpha\chi\delta} + 4\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\alpha\delta\chi} + 2\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\chi \sigma^{\alpha\delta\beta} + 4\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\beta\chi\alpha} + 2\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\alpha\delta\beta} + 3\,\eta^{\beta\chi}\,\partial_\phi \partial^\phi \partial_\epsilon \partial^\alpha \sigma^{\delta\epsilon}{}_\delta + 3\,\eta^{\alpha\chi}\,\partial_\phi \partial^\phi \partial_\epsilon \partial_\delta \sigma^{\beta\delta\epsilon} + 3\,\eta^{\beta\chi}\,\partial_\phi \partial^\phi \partial_\epsilon \partial^\epsilon \sigma^{\alpha\delta}{}_\delta == 3\,\partial_\epsilon \partial_\delta \partial^\chi \partial^\beta \sigma^{\alpha\delta\epsilon} + 3\,\partial_\epsilon \partial^\epsilon \partial^\chi \partial^\beta \sigma^{\alpha\delta}{}_\delta + 2\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\alpha \sigma^{\beta\chi\delta} + 4\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\alpha \sigma^{\beta\delta\chi} + 2\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\chi \sigma^{\beta\delta\alpha} + 2\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\beta\chi\alpha} + 4\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\alpha\chi\beta} + 2\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\alpha\chi\beta} + 3\,\eta^{\alpha\chi}\,\partial_\phi \partial^\phi \partial_\epsilon \partial^\beta \sigma^{\delta\epsilon}{}_\delta + 3\,\eta^{\beta\chi}\,\partial_\phi \partial^\phi \partial_\epsilon \partial_\delta \sigma^{\alpha\delta\epsilon} + 3\,\eta^{\alpha\chi}\,\partial_\phi \partial^\phi \partial_\epsilon \partial^\epsilon \sigma^{\beta\delta}{}_\delta$	5
$\tau_{2^+}^{\#1\,\alpha\beta} == 0$	$4\,\partial_\delta \partial_\chi \partial^\beta \partial^\alpha \tau^{\chi\delta} + 2\,\partial_\delta \partial^\delta \partial^\beta \partial^\alpha \tau^\chi{}_\chi + 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\alpha\beta} + 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\beta\alpha} + 2\,\eta^{\alpha\beta}\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \tau^{\chi\delta} == 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\beta\chi} + 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\chi\alpha} + 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\alpha\chi} + 2\,\eta^{\alpha\beta}\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \tau^\chi{}_\chi$	5
Total constraints/gauge generators:		25

Quadratic (free) action

$$\mathcal{S} == \iiiint \Big(\frac{1}{6}\,(6\,f^{\alpha\beta}\,\tau_{\alpha\beta} + 6\,\omega^{\alpha\beta\chi}\,\sigma_{\alpha\beta\chi} - 3\,r_3\,\partial_\beta \omega_\iota{}^\theta{}_\theta\,\partial^\iota \omega^{\alpha\beta}{}_\alpha - 3\,r_3\,\partial_\iota \omega_\beta{}^\theta{}_\theta\,\partial^\iota \omega^{\alpha\beta}{}_\alpha - 3\,r_3\,\partial_\alpha \omega^{\alpha\beta\iota}\,\partial_\theta \omega_\beta{}^\theta{}_\iota - 6\,r_3\,\partial^\iota \omega^{\alpha\beta}{}_\alpha\,\partial_\theta \omega_\beta{}^\theta{}_\iota - 3\,r_3\,\partial_\alpha \omega^{\alpha\beta\iota}\,\partial_\theta \omega_\iota{}^\theta{}_\beta + 6\,r_3\,\partial^\iota \omega^{\alpha\beta}{}_\alpha\,\partial_\theta \omega_\iota{}^\theta{}_\beta + 4\,t_2\,\omega_{\iota\theta\alpha}\,\partial^\theta f^{\alpha\iota} + 2\,t_2\,\partial_\alpha f_{\iota\theta}\,\partial^\theta f^{\alpha\iota} - t_2\,\partial_\alpha f_{\theta\iota}\,\partial^\theta f^{\alpha\iota} - t_2\,\partial_\iota f_{\alpha\theta}\,\partial^\theta f^{\alpha\iota} + t_2\,\partial_\theta f_{\alpha\iota}\,\partial^\theta f^{\alpha\iota} - t_2\,\partial_\theta f_{\iota\alpha}\,\partial^\theta f^{\alpha\iota} - 4\,t_2\,\omega_{\alpha\theta\iota}\,(\omega^{\alpha\iota\theta} + \partial^\theta f^{\alpha\iota}) + 2\,t_2\,\omega_{\alpha\iota\theta}\,(\omega^{\alpha\iota\theta} + 2\,\partial^\theta f^{\alpha\iota}) - 24\,r_3\,\partial_\beta \omega_{\iota\theta\alpha}\,\partial^\theta \omega^{\alpha\beta\iota} + 6\,r_5\,\partial_\iota \omega_\theta{}^\kappa{}_\kappa\,\partial^\theta \omega^{\alpha\iota}{}_\alpha - 6\,r_5\,\partial_\theta \omega_\iota{}^\kappa{}_\kappa\,\partial^\theta \omega^{\alpha\iota}{}_\alpha - 6\,r_5\,\partial_\alpha \omega^{\alpha\iota\theta}\,\partial_\kappa \omega_\iota{}^\kappa{}_\theta + 12\,r_5\,\partial^\theta \omega^{\alpha\iota}{}_\alpha\,\partial_\kappa \omega_\iota{}^\kappa{}_\theta + 6\,r_5\,\partial_\alpha \omega^{\alpha\iota\theta}\,\partial_\kappa \omega_\theta{}^\kappa{}_\iota - 12\,r_5\,\partial^\theta \omega^{\alpha\iota}{}_\alpha\,\partial_\kappa \omega_\theta{}^\kappa{}_\iota)\Big)[t, x, y, z]\,dz\,dy\,dx\,dt$$

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

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

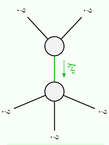
	$\omega_{2^+}^{\#1\,\alpha\beta\chi}$	$f_{2^+}^{\#1\,\alpha\beta}$	$\omega_{2^+}^{\#1\,\alpha\beta}$
$\omega_{2^+}^{\#1\,\dagger\,\alpha\beta\chi}$	0	0	0
$f_{2^+}^{\#1\,\dagger\,\alpha\beta}$	0	0	0
$\omega_{2^+}^{\#1\,\dagger\,\alpha\beta}$	0	0	$-\frac{3\,k^2\,t_2}{2}$

	$\omega_{0^+}^{\#1}$	$f_{0^+}^{\#2}$	$f_{0^+}^{\#1}$	$\omega_{0^+}^{\#1}$
$\omega_{0^+}^{\#1\,\dagger}$	0	0	0	0
$f_{0^+}^{\#2\,\dagger}$	0	0	0	0
$f_{0^+}^{\#1\,\dagger}$	0	0	0	0
$\omega_{0^+}^{\#1\,\dagger}$	0	0	0	t_2

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

	$\sigma_{0^-}^{\#1}$	$\tau_{0^+}^{\#2}$	$\tau_{0^+}^{\#1}$	$\sigma_{0^+}^{\#1}$
$\sigma_{0^-}^{\#1\,\dagger}$	0	0	0	0
$\tau_{0^+}^{\#2\,\dagger}$	0	0	0	0
$\tau_{0^+}^{\#1\,\dagger}$	0	0	0	0
$\sigma_{0^+}^{\#1\,\dagger}$	0	0	0	t_2

Unitarity conditions



Quadratic pole

Pole residue: $\frac{1}{r_3\,(2\,r_3+r_5)\,(r_3+2\,r_5)\,p^2} > 0$

Polarisations: 2

$r_3 < 0 \&\& (r_5 < -\frac{r_3}{2} \,||\, r_5 > -2\,r_3) \,||\, r_3 > 0 \&\& -2\,r_3 < r_5 < -\frac{r_3}{2}$

(No massive particles)