

Particle spectrograph

Wave operator and propagator

Source constraints			
SO(3) irreps	Fundamental fields	Multiplicities	
$\sigma_0^{\#1} == 0$	$\epsilon \eta_{\alpha\beta\chi\delta} \partial^\delta \sigma^{\alpha\beta\chi} == 0$	1	
$\tau_0^{\#2} == 0$	$\partial_\beta \partial_\alpha \tau^{\alpha\beta} == 0$	1	
$\tau_0^{\#1} - 2 i k \sigma_0^{\#1} == 0$	$\partial_\beta \partial_\alpha \tau^{\alpha\beta} == \partial_\beta \partial^\beta \tau^\alpha_\alpha + 2 \partial_\chi \partial^\chi \partial_\beta \sigma^{\alpha\beta}_\alpha$	1	
$\tau_1^{\#2\alpha} + 2 i k \sigma_1^{\#2\alpha} == 0$	$\partial_\chi \partial_\beta \partial^\alpha \tau^{\beta\chi} == \partial_\chi \partial^\chi \partial_\beta \tau^{\alpha\beta} + 2 \partial_\delta \partial^\delta \partial_\chi \partial_\beta \sigma^{\alpha\beta\chi}$	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	
$\tau_1^{\#1\alpha\beta} == 0$	$\partial_\chi \partial^\alpha \tau^{\beta\chi} + \partial_\chi \partial^\beta \tau^{\chi\alpha} + \partial_\chi \partial^\chi \tau^{\alpha\beta} == \partial_\chi \partial^\beta \tau^{\alpha\chi} + \partial_\chi \partial^\chi \tau^{\beta\alpha}$	3	
$\sigma_1^{\#2\alpha\beta} == 0$	$\partial_\delta \partial_\chi \partial^\alpha \sigma^{\beta\chi\delta} + \partial_\delta \partial^\delta \partial_\chi \sigma^{\alpha\beta\chi} == \partial_\delta \partial_\chi \partial^\beta \sigma^{\alpha\chi\delta}$	3	
$\sigma_2^{\#1\alpha\beta\chi} == 0$	$3 \partial_\epsilon \partial_\delta \partial^\chi \partial^\alpha \sigma^{\beta\delta\epsilon} + 3 \partial_\epsilon \partial^\epsilon \partial^\chi \partial^\alpha \sigma^{\beta\delta}_\delta +$ $2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\beta \sigma^{\alpha\chi\delta} + 4 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\beta \sigma^{\alpha\delta\chi} +$ $2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\beta \sigma^{\chi\delta\alpha} + 4 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\beta \sigma^{\alpha\beta\delta} +$ $2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\chi \sigma^{\alpha\delta\beta} + 2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\beta \sigma^{\beta\chi\alpha} +$ $3 \eta^{\beta\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial^\alpha \sigma^{\delta\epsilon}_\delta +$ $3 \eta^{\alpha\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial_\delta \sigma^{\beta\delta\epsilon} +$ $3 \eta^{\beta\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial^\epsilon \sigma^{\alpha\delta}_\delta ==$ $3 \partial_\epsilon \partial_\delta \partial^\chi \partial^\beta \sigma^{\alpha\delta\epsilon} + 3 \partial_\epsilon \partial^\epsilon \partial^\chi \partial^\beta \sigma^{\alpha\delta}_\delta +$ $2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\alpha \sigma^{\beta\chi\delta} + 4 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\alpha \sigma^{\beta\delta\chi} +$ $2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\alpha \sigma^{\chi\delta\beta} + 2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\alpha \sigma^{\beta\delta\alpha} +$ $4 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\alpha\beta\chi} + 2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\alpha\chi\beta} +$ $3 \eta^{\alpha\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial^\delta \sigma^{\delta\epsilon}_\delta +$ $3 \eta^{\beta\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial_\delta \sigma^{\alpha\delta\epsilon} +$ $3 \eta^{\alpha\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial^\epsilon \sigma^{\beta\delta}_\delta$	5	
$\tau_2^{\#1\alpha\beta} == 0$	$4 \partial_\delta \partial_\chi \partial^\beta \partial^\alpha \tau^{\chi\delta} + 2 \partial_\delta \partial^\delta \partial^\beta \partial^\alpha \tau^\chi_\chi +$ $3 \partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\alpha\beta} + 3 \partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\beta\alpha} +$ $2 \eta^{\alpha\beta} \partial_\epsilon \partial^\epsilon \partial_\delta \tau^{\chi\delta} == 3 \partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\beta\chi} +$ $3 \partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\chi\beta} + 3 \partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\alpha\chi} +$ $3 \partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\chi\alpha} + 2 \eta^{\alpha\beta} \partial_\epsilon \partial^\epsilon \partial_\delta \tau^\chi_\chi$	5	
Total constraints/gauge generators:		25	

$\sigma_1^{\#1+}\alpha\beta$	$\sigma_1^{\#2+}\alpha\beta$	$\tau_1^{\#1+}\alpha\beta$	$\sigma_1^{\#1-}\alpha$	$\sigma_1^{\#2-}\alpha$	$\tau_1^{\#1-}\alpha$	$\tau_1^{\#2-}\alpha$
$\frac{1}{k^2(2r_3+r_5)}$	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	$\frac{2}{k^2(r_3+2r_5)}$	$\frac{2\sqrt{2}}{k^2(1+2k^2)(r_3+2r_5)}$	0	$\frac{4i}{k(1+2k^2)(r_3+2r_5)}$
0	0	0	$\frac{2\sqrt{2}}{k^2(1+2k^2)(r_3+2r_5)}$	$\frac{3k^2(r_3+2r_5)+4t_3}{(k+2k^3)^2(r_3+2r_5)t_3}$	0	$\frac{i\sqrt{2}(3k^2(r_3+2r_5)+4t_3)}{k(1+2k^2)^2(r_3+2r_5)t_3}$
0	0	0	0	0	0	0
0	0	0	$-\frac{4i}{k(1+2k^2)(r_3+2r_5)}$	$-\frac{i\sqrt{2}(3k^2(r_3+2r_5)+4t_3)}{k(1+2k^2)^2(r_3+2r_5)t_3}$	0	$\frac{6k^2(r_3+2r_5)+8t_3}{(1+2k^2)^2(r_3+2r_5)t_3}$
0	0	0	0	0	0	0

$\omega_1^{\#1+}\alpha\beta$	$\omega_1^{\#2+}\alpha\beta$	$f_1^{\#1+}\alpha\beta$	$\omega_1^{\#1-}\alpha$	$\omega_1^{\#2-}\alpha$	$f_1^{\#1-}\alpha$	$f_1^{\#2-}\alpha$
$k^2(2r_3+r_5)$	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	0	0	0	0
0	0	0	$k^2(\frac{\sqrt{3}}{2}+r_5)+\frac{2t_3}{3}$	$-\frac{\sqrt{2}t_3}{3}$	0	$-\frac{2}{3}i k t_3$
0	0	0	$-\frac{\sqrt{2}t_3}{3}$	$\frac{t_3}{3}$	0	$\frac{1}{3}i\sqrt{2} k t_3$
0	0	0	0	0	0	0
0	0	0	$\frac{2i k t_3}{3}$	$-\frac{1}{3}i\sqrt{2} k t_3$	0	$\frac{2k^2t_3}{3}$

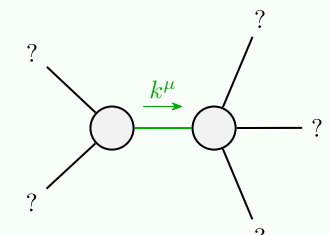
$\omega_2^{\#1+}\alpha\beta$	$f_2^{\#1+}\alpha\beta$	$\omega_2^{\#1-}\alpha\beta\chi$
$-\frac{3k^2r_3}{2}$	0	0
0	0	0
0	0	0

$\sigma_2^{\#1+}\alpha\beta$	$\tau_2^{\#1+}\alpha\beta$	$\sigma_2^{\#1-}\alpha\beta\chi$
$-\frac{2}{3k^2r_3}$	0	0
0	0	0
0	0	0

Quadratic (free) action

$$\begin{aligned} S = & \iiint \iiint (f^{\alpha\beta} \tau_{\alpha\beta} + \omega^{\alpha\beta\chi} \sigma_{\alpha\beta\chi} - \frac{1}{2} r_3 (\partial_\beta \omega_{ \theta}^{ \theta} \partial' \omega^{\alpha\beta}_\alpha + \partial_\gamma \omega_{ \theta}^{ \theta} \partial' \omega^{\alpha\beta}_\alpha + \\ & \partial_\alpha \omega^{\alpha\beta\gamma} \partial_\theta \omega_{ \beta}^{ \theta} - 2 \partial' \omega^{\alpha\beta}_\alpha \partial_\theta \omega_{ \beta}^{ \theta} + \partial_\alpha \omega^{\alpha\beta\gamma} \partial_\theta \omega_{ \beta}^{ \theta} - \\ & 2 \partial' \omega^{\alpha\beta}_\alpha \partial_\theta \omega_{ \beta}^{ \theta} + 8 \partial_\beta \omega_{ \theta}^{ \theta} \partial^\theta \omega^{\alpha\beta\gamma}) - \\ & \frac{2}{3} t_3 (\omega^{\alpha\gamma}_\alpha \omega_{ \kappa}^{ \kappa} - 2 \omega_{ \kappa}^{ \kappa} \partial_\gamma f^{\alpha\gamma} + 2 \omega_{ \kappa}^{ \kappa} \partial' f^\alpha_\alpha - \\ & \partial_\gamma f^\kappa_\kappa \partial' f^\alpha_\alpha - \partial_\gamma f^{\alpha\gamma} \partial_\kappa f^\kappa_\alpha + 2 \partial' f^\alpha_\alpha \partial_\kappa f_{ \gamma}^{ \gamma}) + \\ & r_5 (\partial_\gamma \omega_{ \theta}^{ \theta} \omega_{ \kappa}^{ \kappa} \partial^\theta \omega^{\alpha\gamma}_\alpha - \partial_\theta \omega_{ \kappa}^{ \kappa} \partial^\theta \omega^{\alpha\gamma}_\alpha - (\partial_\alpha \omega^{\alpha\gamma\theta} - 2 \partial^\theta \omega^{\alpha\gamma}_\alpha) \\ & (\partial_\kappa \omega_{ \theta}^{ \theta} - \partial_\kappa \omega_{ \theta}^{ \theta})) [t, x, y, z] dz dy dx dt \end{aligned}$$

Massive and massless spectra



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

(No massive particles)

Unitarity conditions

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