

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	
$\sigma_2^{\#1\alpha\beta\chi} = 0$	$3 \partial_\epsilon \partial_\delta \partial^\chi \partial^\alpha \sigma^{\beta\delta\epsilon} + 3 \partial_\epsilon \partial^\epsilon \partial^\chi \partial^\alpha \sigma^{\beta\delta}_\delta +$ $2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\beta \sigma^{\alpha\chi\delta} + 4 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\beta \sigma^{\alpha\delta\chi} +$ $2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\beta \sigma^{\chi\delta\alpha} + 4 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\beta \sigma^{\alpha\beta\delta} +$ $2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\chi \sigma^{\alpha\delta\beta} + 2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\beta\chi\alpha} +$ $3 \eta^{\beta\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial^\alpha \sigma^{\delta\epsilon}_\delta +$ $3 \eta^{\alpha\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial_\delta \sigma^{\beta\delta\epsilon} +$ $3 \eta^{\beta\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial^\epsilon \sigma^{\alpha\delta}_\delta =$ $3 \partial_\epsilon \partial_\delta \partial^\chi \partial^\beta \sigma^{\alpha\delta\epsilon} + 3 \partial_\epsilon \partial^\epsilon \partial^\chi \partial^\beta \sigma^{\alpha\delta}_\delta +$ $2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\alpha \sigma^{\beta\chi\delta} + 4 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\alpha \sigma^{\beta\delta\chi} +$ $2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\alpha \sigma^{\chi\delta\beta} + 2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\chi \sigma^{\beta\delta\alpha} +$ $4 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\alpha\beta\chi} + 2 \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\alpha\chi\beta} +$ $3 \eta^{\alpha\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial^\delta \sigma^{\delta\epsilon}_\delta +$ $3 \eta^{\beta\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial_\delta \sigma^{\alpha\delta\epsilon} +$ $3 \eta^{\alpha\chi} \partial_\phi \partial^\phi \partial_\epsilon \partial^\epsilon \sigma^{\beta\delta}_\delta$	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	$k^2 (\frac{r_3}{2} + r_5) + \frac{2t_3}{3}$	$-\frac{\sqrt{2} t_3}{3}$	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	$\frac{2 i k t_3}{3}$	$-\frac{1}{3} i \sqrt{2} k t_3$	0	$\frac{2 k^2 t_3}{3}$

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

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

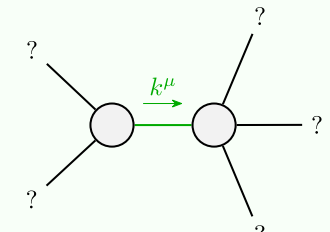
$\sigma_0^{\#1} +$	$\tau_0^{\#2} +$	$\sigma_0^{\#1} \alpha$
$\frac{1}{(1+2k^2)^2 t_3}$	0	0
$\frac{i\sqrt{2} k}{(1+2k^2)^2 t_3}$	0	0
0	0	0
0	0	0

$\omega_0^{\#1} +$	$f_0^{\#2} +$	$\omega_0^{\#1} \alpha$
t_3	$-i\sqrt{2} k t_3$	0
$i\sqrt{2} k t_3$	$2k^2 t_3$	0
0	0	0
0	0	0

Quadratic (free) action

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

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

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