

Particle spectrograph

Wave operator and propagator

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
$\tau_{1+}^{\#2\alpha} + 2i k \sigma_{1+}^{\#2\alpha} == 0$	$\partial_\chi \partial_\beta \partial^\alpha \tau^{\beta\chi} == \partial_\chi \partial^\chi \partial_\beta \tau^{\alpha\beta} + 2 \partial_\delta \partial^\delta \partial_\chi \partial_\beta \sigma^{\alpha\beta\chi}$	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
$\tau_{1+}^{\#1\alpha\beta} + i k \sigma_{1+}^{\#2\alpha\beta} == 0$	$\partial_\chi \partial^\alpha \tau^{\beta\chi} + \partial_\chi \partial^\beta \tau^{\chi\alpha} + \partial_\chi \partial^\chi \tau^{\alpha\beta} +$ $2 \partial_\delta \partial_\chi \partial^\alpha \sigma^{\beta\chi\delta} + 2 \partial_\delta \partial^\delta \partial_\chi \sigma^{\alpha\beta\chi} ==$ $\partial_\chi \partial^\alpha \tau^{\chi\beta} + \partial_\chi \partial^\beta \tau^{\alpha\chi} +$ $\partial_\chi \partial^\chi \tau^{\beta\alpha} + 2 \partial_\delta \partial_\chi \partial^\beta \sigma^{\alpha\chi\delta}$	3
$\tau_{2+}^{\#1\alpha\beta} - 2i k \sigma_{2+}^{\#1\alpha\beta} == 0$	$-i (4 \partial_\delta \partial_\chi \partial^\beta \partial^\alpha \tau^{\chi\delta} + 2 \partial_\delta \partial^\delta \partial^\beta \partial^\alpha \tau^\chi_\chi -$ $3 \partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\beta\chi} - 3 \partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\chi\beta} -$ $3 \partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\alpha\chi} - 3 \partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\chi\alpha} +$ $3 \partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\alpha\beta} + 3 \partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\beta\alpha} +$ $4 i k^\chi \partial_\epsilon \partial_\chi \partial^\beta \partial^\alpha \sigma^{\delta\epsilon}_\delta -$ $6 i k^\chi \partial_\epsilon \partial_\delta \partial_\chi \partial^\alpha \sigma^{\beta\delta\epsilon} -$ $6 i k^\chi \partial_\epsilon \partial_\delta \partial_\chi \partial^\beta \sigma^{\alpha\delta\epsilon} +$ $2 \eta^{\alpha\beta} \partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \tau^{\chi\delta} +$ $6 i k^\chi \partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \sigma^{\alpha\delta\beta} +$ $6 i k^\chi \partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \sigma^{\beta\delta\alpha} -$ $2 \eta^{\alpha\beta} \partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \tau^\chi_\chi -$ $4 i \eta^{\alpha\beta} k^\chi \partial_\phi \partial^\phi \partial_\epsilon \partial_\chi \sigma^{\delta\epsilon}_\delta) == 0$	5
Total constraints/gauge generators:		17

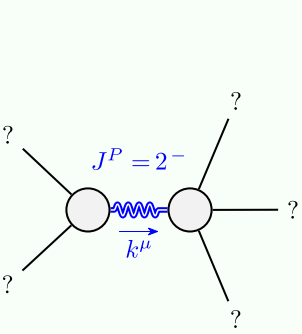
$\sigma_1^1 + \alpha\beta$	$\sigma_1^2 + \alpha\beta$	$\tau_1^1 + \alpha\beta$	$\sigma_1^1 - \alpha$	$\sigma_1^2 - \alpha$	$\tau_1^1 - \alpha$	$\tau_1^2 - \alpha$
0	$-\frac{\sqrt{2}}{t_1 + k^2 t_1}$	$-\frac{i\sqrt{2}k}{t_1 + k^2 t_1}$	0	0	0	0
$-\frac{\sqrt{2}}{t_1 + k^2 t_1}$	$\frac{-2k^2(2r_1 + r_5) + t_1}{(1 + k^2)^2 t_1^2}$	$\frac{-2ik^3(2r_1 + r_5) + ikt_1}{(1 + k^2)^2 t_1^2}$	0	0	0	0
$\frac{i\sqrt{2}k}{t_1 + k^2 t_1}$	$\frac{i(2k^3(2r_1 + r_5) - kt_1)}{(1 + k^2)^2 t_1^2}$	$\frac{-2k^4(2r_1 + r_5) + k^2 t_1}{(1 + k^2)^2 t_1^2}$	0	0	0	0
$\sigma_1^1 + \alpha$	0	0	$\frac{1}{k^2(r_1 + r_5)}$	$-\frac{1}{\sqrt{2}(k^2 + 2k^2)(r_1 + r_5)}$	0	$-\frac{i}{k(1 + 2k^2)(r_1 + r_5)}$
$\sigma_1^2 + \alpha$	0	0	$-\frac{1}{\sqrt{2}(k^2 + 2k^4)(r_1 + r_5)}$	$\frac{6k^2(r_1 + r_5) + t_1}{2(k + 2k^3)^2(r_1 + r_5)t_1}$	0	$\frac{i(6k^2(r_1 + r_5) + t_1)}{\sqrt{2}k(1 + 2k^2)^2(r_1 + r_5)t_1}$
$\tau_1^1 + \alpha$	0	0	0	0	0	0
$\tau_1^2 + \alpha$	0	0	$\frac{i}{k(1 + 2k^2)(r_1 + r_5)}$	$-\frac{i(6k^2(r_1 + r_5) + t_1)}{\sqrt{2}k(1 + 2k^2)^2(r_1 + r_5)t_1}$	0	$\frac{6k^2(r_1 + r_5) + t_1}{(1 + 2k^2)^2(r_1 + r_5)t_1}$

$$\begin{array}{c}
\sigma_{2^+}^{\#1\alpha\beta} \quad \tau_{2^+}^{\#1\alpha\beta} \quad \sigma_{2^+}^{\#1\alpha\beta\chi} \\
\begin{array}{|c|c|c|}
\hline
\sigma_{2^+}^{\#1\alpha\beta} & \tau_{2^+}^{\#1\alpha\beta} & \sigma_{2^+}^{\#1\alpha\beta\chi} \\
\hline
\frac{2}{(1+2k^2)^2 t_1} & -\frac{2i\sqrt{2}k}{(1+2k^2)^2 t_1} & 0 \\
\hline
\tau_{2^+}^{\#1\alpha\beta} & \frac{2i\sqrt{2}k}{(1+2k^2)^2 t_1} & \frac{4k^2}{(1+2k^2)^2 t_1} \\
\hline
\sigma_{2^+}^{\#1\alpha\beta\chi} & 0 & \frac{2}{2k^2 r_1 + t_1} \\
\hline
\end{array}
\end{array}
\begin{array}{c}
\sigma_0^{\#1-} \\
\sigma_0^{\#1+} \tau_0^{\#2} \\
\tau_0^{\#1} \sigma_0^{\#1+} \\
\sigma_0^{\#1+} \tau_0^{\#2} \\
\tau_0^{\#1} \sigma_0^{\#1+}
\end{array}
\begin{array}{|c|c|c|c|}
\hline
\sigma_0^{\#1-} & \sigma_0^{\#1+} \tau_0^{\#2} & \tau_0^{\#1} \sigma_0^{\#1+} & \sigma_0^{\#1+} \tau_0^{\#2} \\
\hline
0 & 0 & 0 & -\frac{1}{t_1} \\
\hline
\sigma_0^{\#1+} \tau_0^{\#2} & \tau_0^{\#1} \sigma_0^{\#1+} & \sigma_0^{\#1+} \tau_0^{\#2} & \tau_0^{\#1} \sigma_0^{\#1+} \\
\hline
0 & 0 & 0 & 0 \\
\hline
\tau_0^{\#1} \sigma_0^{\#1+} & \sigma_0^{\#1+} \tau_0^{\#2} & \tau_0^{\#1} \sigma_0^{\#1+} & \sigma_0^{\#1+} \tau_0^{\#2} \\
\hline
0 & 0 & 0 & 0 \\
\hline
\end{array}$$

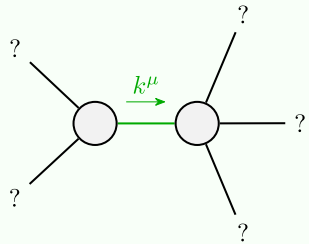
$$\begin{aligned}
\text{Quadratic (free) action} \\
S = & \int \int \int \left(\frac{1}{6} (2 t_1 \omega_{\alpha}^{\alpha i} \omega_{\theta}^{\theta} + 6 f^{\alpha \beta} \tau_{\alpha \beta} + 6 \omega^{\alpha \beta \chi} \sigma_{\alpha \beta \chi} - 4 t_1 \omega_{\alpha}^{\theta} \partial_{\theta} f^{\alpha i} + \right. \\
& 4 t_1 \omega_{\theta}^{\theta} \partial_{\theta} f^{\alpha} - 2 t_1 \partial_{\theta} f^{\theta} \partial_{\theta} f^{\alpha} - 2 t_1 \partial_{\theta} f^{\alpha i} \partial_{\theta} f_{\alpha}^{\theta} + \\
& 4 t_1 \partial_{\theta} f_{\alpha}^{\theta} \partial_{\theta} f_{\theta}^{\theta} - 6 t_1 \partial_{\alpha} f_{\theta}^{\theta} \partial^{\theta} f^{\alpha i} - 3 t_1 \partial_{\alpha} f_{\theta}^{\theta} \partial^{\theta} f^{\alpha i} + \\
& 3 t_1 \partial_{\theta} f_{\alpha \theta}^{\theta} \partial^{\theta} f^{\alpha i} + 3 t_1 \partial_{\theta} f_{\alpha i}^{\theta} \partial^{\theta} f^{\alpha i} + 3 t_1 \partial_{\theta} f_{i \alpha}^{\theta} \partial^{\theta} f^{\alpha i} + \\
& 6 t_1 \omega_{\alpha \theta i} (\omega^{\alpha i \theta} + 2 \partial^{\theta} f^{\alpha i}) - 8 r_1 \partial_{\beta} \omega_{\alpha i \theta} \partial^{\theta} \omega^{\alpha \beta i} + \\
& 4 r_1 \partial_{\beta} \omega_{\alpha \theta i} \partial^{\theta} \omega^{\alpha \beta i} - 16 r_1 \partial_{\beta} \omega_{i \theta \alpha} \partial^{\theta} \omega^{\alpha \beta i} - \\
& 4 r_1 \partial_{\theta} \omega_{\alpha \beta \theta} \partial^{\theta} \omega^{\alpha \beta i} + 4 r_1 \partial_{\theta} \omega_{\alpha \beta i} \partial^{\theta} \omega^{\alpha \beta i} + \\
& 4 r_1 \partial_{\theta} \omega_{\alpha \beta} \partial^{\theta} \omega^{\alpha \beta i} + 6 r_5 \partial_{\theta} \omega_{\alpha}^{\kappa} \partial^{\theta} \omega_{\theta}^{\alpha i \theta} + 6 r_5 \partial_{\theta} \omega_{\theta}^{\alpha i \theta} \partial_{\kappa} \omega_{\theta}^{\kappa} + \\
& 6 r_5 \partial_{\theta} \omega_{\theta}^{\kappa} \partial^{\theta} \omega_{\alpha}^{\alpha} - 6 r_5 \partial_{\alpha} \omega^{\alpha i \theta} \partial_{\kappa} \omega_{\theta}^{\kappa} + \\
& 12 r_5 \partial^{\theta} \omega_{\alpha}^{\alpha} \partial_{\kappa} \omega_{\theta}^{\kappa} + 6 r_5 \partial_{\alpha} \omega^{\alpha i \theta} \partial_{\kappa} \omega_{\theta}^{\kappa} - \\
& \left. 12 r_5 \partial^{\theta} \omega_{\alpha}^{\alpha} \partial_{\kappa} \omega_{\theta}^{\kappa} \right) [t, x, y, z] dz dy dx dt
\end{aligned}$$

	$\omega_1^{\#1} + \alpha\beta$	$\omega_1^{\#2} f_1^{\#1} + \alpha\beta$	$\omega_1^{\#1} \alpha$	$\omega_1^{\#2} \alpha$	$f_1^{\#1} \alpha$	$f_1^{\#2} \alpha$
$\omega_1^{\#1} + \alpha\beta$	$k^2 (2r_1 + r_5) - \frac{t_1}{2}$	$-\frac{t_1}{\sqrt{2}}$	0	0	0	0
$\omega_1^{\#2} + \alpha\beta$	$-\frac{t_1}{\sqrt{2}}$	0	0	0	0	0
$f_1^{\#1} + \alpha\beta$	$\frac{ikt_1}{\sqrt{2}}$	0	0	0	0	0
$\omega_1^{\#1} + \alpha$	0	0	$k^2 (r_1 + r_5) + \frac{t_1}{6}$	$\frac{t_1}{3\sqrt{2}}$	0	$\frac{ikt_1}{3}$
$\omega_1^{\#2} + \alpha$	0	0	$\frac{t_1}{3\sqrt{2}}$	$\frac{t_1}{3}$	0	$\frac{1}{3} i \sqrt{2} k t_1$
$f_1^{\#1} + \alpha$	0	0	0	0	0	0

Massive and massless spectra



Massive particle	
Pole residue:	$-\frac{1}{r_1} > 0$
Polarisations:	5
Square mass:	$-\frac{t_1}{2r_1} > 0$
Spin:	2
Parity:	Odd



Quadratic pole	
Pole residue:	$-\frac{1}{(r_1+r_5)t_1^2} > 0$
Polarisations:	2

Unitarity conditions

$$r_1 < 0 \ \&\& \ r_5 < -r_1 \ \&\& \ t_1 > 0$$