Particle spectrograph

Wave operator and propagator

Source constraints

SO(3) irreps	Fundamental fields	Multiplicities
$\tau^{\#2}_{0^+} == 0$	$\partial_\beta\partial_\alpha\tau^{\alpha\beta} == 0$	1
$\tau^{\#1}_{0^+} - 2\,i\,k\,\sigma^{\#1}_{0^+} == 0$	$\partial_\beta\partial_\alpha\tau^{\alpha\beta} == \partial_\beta\partial^\beta\tau^\alpha{}_\alpha + 2\,\partial_\chi\partial^\chi\partial_\beta\sigma^{\alpha\beta}{}_\alpha$	1
$\tau^{\#2\,\alpha}_{1^-} + 2\,i\,k\,\sigma^{\#2\,\alpha}_{1^-} == 0$	$\partial_\chi\partial_\beta\partial^\alpha\tau^{\beta\chi} == \partial_\chi\partial^\chi\partial_\beta\tau^{\alpha\beta} + 2\,\partial_\delta\partial^\delta\partial_\chi\partial_\beta\sigma^{\alpha\beta\chi}$	3
$\tau^{\#1\,\alpha}_{1^-} == 0$	$\partial_\chi\partial_\beta\partial^\alpha\tau^{\beta\chi} == \partial_\chi\partial^\chi\partial_\beta\tau^{\beta\alpha}$	3
$\tau^{\#1\,\alpha\beta}_{1^+} + i\,k\,\sigma^{\#2\,\alpha\beta}_{1^+} == 0$	$\partial_\chi\partial^\alpha\tau^{\beta\chi} + \partial_\chi\partial^\beta\tau^{\chi\alpha} + \partial_\chi\partial^\chi\tau^{\alpha\beta} +$ $2\,\partial_\delta\partial_\chi\partial^\alpha\sigma^{\beta\chi\delta} + 2\,\partial_\delta\partial^\delta\partial_\chi\sigma^{\alpha\beta\chi} ==$ $\partial_\chi\partial^\alpha\tau^{\chi\beta} + \partial_\chi\partial^\beta\tau^{\alpha\chi} +$ $\partial_\chi\partial^\chi\tau^{\beta\alpha} + 2\,\partial_\delta\partial_\chi\partial^\beta\sigma^{\alpha\chi\delta}$	3
$\tau^{\#1\,\alpha\beta}_{2^+} - 2\,i\,k\,\sigma^{\#1\,\alpha\beta}_{2^+} == 0$	$-i\,(4\,\partial_\delta\partial_\chi\partial^\beta\partial^\alpha\tau^{\chi\delta} + 2\,\partial_\delta\partial^\delta\partial^\beta\partial^\alpha\tau^\chi{}_\chi -$ $3\,\partial_\delta\partial^\delta\partial_\chi\partial^\alpha\tau^{\beta\chi} - 3\,\partial_\delta\partial^\delta\partial_\chi\partial^\alpha\tau^{\chi\beta} -$ $3\,\partial_\delta\partial^\delta\partial_\chi\partial^\beta\tau^{\alpha\chi} - 3\,\partial_\delta\partial^\delta\partial_\chi\partial^\beta\tau^{\chi\alpha} +$ $3\,\partial_\delta\partial^\delta\partial_\chi\partial^\chi\tau^{\alpha\beta} + 3\,\partial_\delta\partial^\delta\partial_\chi\partial^\chi\tau^{\beta\alpha} +$ $4\,i\,k^\chi\,\partial_\epsilon\partial_\chi\partial^\beta\partial^\alpha\sigma^{\delta\epsilon}{}_\delta -$ $6\,i\,k^\chi\,\partial_\epsilon\partial_\delta\partial_\chi\partial^\alpha\sigma^{\beta\delta\epsilon} -$ $6\,i\,k^\chi\,\partial_\epsilon\partial_\delta\partial_\chi\partial^\beta\sigma^{\alpha\delta\epsilon} +$ $2\,\eta^{\alpha\beta}\,\partial_\epsilon\partial^\epsilon\partial_\delta\partial_\chi\tau^{\chi\delta} +$ $6\,i\,k^\chi\,\partial_\epsilon\partial^\epsilon\partial_\delta\partial_\chi\sigma^{\alpha\delta\beta} +$ $6\,i\,k^\chi\,\partial_\epsilon\partial^\epsilon\partial_\delta\partial_\chi\sigma^{\beta\delta\alpha} -$ $2\,\eta^{\alpha\beta}\,\partial_\epsilon\partial^\epsilon\partial_\delta\partial^\delta\tau^\chi{}_\chi -$ $4\,i\,\eta^{\alpha\beta}\,k^\chi\,\partial_\phi\partial^\phi\partial_\epsilon\partial_\chi\sigma^{\delta\epsilon}{}_\delta) == 0$	5
Total constraints/gauge generators:		16

Quadratic (free) action

$$
\begin{aligned}
\mathcal{S} == & \\
\iiiint\Big(\tfrac{1}{6}\big(&6\,t_1\,\mathcal{A}^{\alpha\iota}{}_\alpha\,\mathcal{A}_\iota{}^\theta{}_\theta + 6\,f^{\alpha\beta}\,\tau_{\alpha\beta} + 6\,\mathcal{A}^{\alpha\beta\chi}\,\sigma_{\alpha\beta\chi} - 12\,t_1\,\mathcal{A}_\alpha{}^\theta{}_\theta\,\partial_\iota f^{\alpha\iota} + 12\\
&t_1\,\mathcal{A}_\iota{}^\theta{}_\theta\,\partial^\iota f^\alpha{}_\alpha - 6\,t_1\,\partial_\iota f^\theta{}_\theta\,\partial^\iota f^\alpha{}_\alpha -\\
&12\,r_1\,\partial_\beta\mathcal{A}_\iota{}^\theta{}_\theta\,\partial^\iota\mathcal{A}^{\alpha\beta}{}_\alpha + 12\,r_1\,\partial_\iota\mathcal{A}_\beta{}^\theta{}_\theta\,\partial^\iota\mathcal{A}^{\alpha\beta}{}_\alpha -\\
&6\,t_1\,\partial_\iota f^{\alpha\iota}\,\partial_\theta f_\alpha{}^\theta + 12\,t_1\,\partial^\iota f^\alpha{}_\alpha\,\partial_\theta f_\iota{}^\theta +\\
&12\,r_1\,\partial_\alpha\mathcal{A}^{\alpha\beta\iota}\,\partial_\theta\mathcal{A}_\beta{}^\theta{}_\iota - 24\,r_1\,\partial^\iota\mathcal{A}^{\alpha\beta}{}_\alpha\,\partial_\theta\mathcal{A}_\beta{}^\theta{}_\iota -\\
&12\,r_1\,\partial_\alpha\mathcal{A}^{\alpha\beta\iota}\,\partial_\theta\mathcal{A}_\iota{}^\theta{}_\beta + 24\,r_1\,\partial^\iota\mathcal{A}^{\alpha\beta}{}_\alpha\,\partial_\theta\mathcal{A}_\iota{}^\theta{}_\beta +\\
&4\,t_1\,\mathcal{A}_{\iota\theta\alpha}\,\partial^\theta f^{\alpha\iota} + 4\,t_2\,\mathcal{A}_{\iota\theta\alpha}\,\partial^\theta f^{\alpha\iota} - 4\,t_1\,\partial_\alpha f_{\iota\theta}\,\partial^\theta f^{\alpha\iota} +\\
&2\,t_2\,\partial_\alpha f_{\iota\theta}\,\partial^\theta f^{\alpha\iota} - 4\,t_1\,\partial_\alpha f_{\theta\iota}\,\partial^\theta f^{\alpha\iota} - t_2\,\partial_\alpha f_{\theta\iota}\,\partial^\theta f^{\alpha\iota} +\\
&2\,t_1\,\partial_\iota f_{\alpha\theta}\,\partial^\theta f^{\alpha\iota} - t_2\,\partial_\iota f_{\alpha\theta}\,\partial^\theta f^{\alpha\iota} + 4\,t_1\,\partial_\theta f_{\alpha\iota}\,\partial^\theta f^{\alpha\iota} +\\
&t_2\,\partial_\theta f_{\alpha\iota}\,\partial^\theta f^{\alpha\iota} + 2\,t_1\,\partial_\theta f_{\iota\alpha}\,\partial^\theta f^{\alpha\iota} - t_2\,\partial_\theta f_{\iota\alpha}\,\partial^\theta f^{\alpha\iota} +\\
&2\,(t_1 + t_2)\,\mathcal{A}_{\alpha\iota\theta}\,(\mathcal{A}^{\alpha\iota\theta} + 2\,\partial^\theta f^{\alpha\iota}) +\\
&2\,\mathcal{A}_{\alpha\theta\iota}\,((t_1 - 2\,t_2)\,\mathcal{A}^{\alpha\iota\theta} + 2\,(2\,t_1 - t_2)\,\partial^\theta f^{\alpha\iota}) -\\
&8\,r_1\,\partial_\beta\mathcal{A}_{\alpha\iota\theta}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota} + 8\,r_2\,\partial_\beta\mathcal{A}_{\alpha\iota\theta}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota} +\\
&4\,r_1\,\partial_\beta\mathcal{A}_{\alpha\theta\iota}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota} - 4\,r_2\,\partial_\beta\mathcal{A}_{\alpha\theta\iota}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota} - 16\,r_1\,\partial_\beta\mathcal{A}_{\iota\theta\alpha}\\
&\partial^\theta\mathcal{A}^{\alpha\beta\iota} + 4\,r_2\,\partial_\beta\mathcal{A}_{\iota\theta\alpha}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota} - 4\,r_1\,\partial_\iota\mathcal{A}_{\alpha\beta\theta}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota} -\\
&2\,r_2\,\partial_\iota\mathcal{A}_{\alpha\beta\theta}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota} + 4\,r_1\,\partial_\theta\mathcal{A}_{\alpha\beta\iota}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota} +\\
&2\,r_2\,\partial_\theta\mathcal{A}_{\alpha\beta\iota}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota} + 4\,r_1\,\partial_\theta\mathcal{A}_{\alpha\iota\beta}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota} -\\
&4\,r_2\,\partial_\theta\mathcal{A}_{\alpha\iota\beta}\,\partial^\theta\mathcal{A}^{\alpha\beta\iota}\big)\Big)[t, x, y, z]\,dz\,dy\,dx\,dt
\end{aligned}
$$

	$\sigma^{\#1}_{1^+\,\alpha\beta}$	$\sigma^{\#2}_{1^+\,\alpha\beta}$	$\tau^{\#1}_{1^+\,\alpha\beta}$	$\sigma^{\#1}_{1^-\,\alpha}$	$\sigma^{\#2}_{1^-\,\alpha}$	$\tau^{\#1}_{1^-\,\alpha}$	$\tau^{\#2}_{1^-\,\alpha}$
$\sigma^{\#1}_{1^+}\dagger^{\alpha\beta}$	$\frac{2\,(t_1+t_2)}{3\,t_1\,t_2}$	$\frac{\sqrt{2}\,(t_1-2\,t_2)}{3\,(1+k^2)\,t_1\,t_2}$	$\frac{i\,\sqrt{2}\,k\,(t_1-2\,t_2)}{3\,(1+k^2)\,t_1\,t_2}$	0	0	0	0
$\sigma^{\#2}_{1^+}\dagger^{\alpha\beta}$	$\frac{\sqrt{2}\,(t_1-2\,t_2)}{3\,(1+k^2)\,t_1\,t_2}$	$\frac{t_1+4\,t_2}{3\,(1+k^2)^2\,t_1\,t_2}$	$\frac{i\,k\,(t_1+4\,t_2)}{3\,(1+k^2)^2\,t_1\,t_2}$	0	0	0	0
$\tau^{\#1}_{1^+}\dagger^{\alpha\beta}$	$-\frac{i\,\sqrt{2}\,k\,(t_1-2\,t_2)}{3\,(1+k^2)\,t_1\,t_2}$	$-\frac{i\,k\,(t_1+4\,t_2)}{3\,(1+k^2)^2\,t_1\,t_2}$	$\frac{k^2\,(t_1+4\,t_2)}{3\,(1+k^2)^2\,t_1\,t_2}$	0	0	0	0
$\sigma^{\#1}_{1^-}\dagger^{\alpha}$	0	0	0	0	$\frac{\sqrt{2}}{t_1+2\,k^2\,t_1}$	0	$\frac{2\,i\,k}{t_1+2\,k^2\,t_1}$
$\sigma^{\#2}_{1^-}\dagger^{\alpha}$	0	0	0	$\frac{\sqrt{2}}{t_1+2\,k^2\,t_1}$	$\frac{2\,k^2\,r_1+t_1}{(t_1+2\,k^2\,t_1)^2}$	0	$\frac{i\,\sqrt{2}\,k\,(2\,k^2\,r_1+t_1)}{(t_1+2\,k^2\,t_1)^2}$
$\tau^{\#1}_{1^-}\dagger^{\alpha}$	0	0	0	0	0	0	0
$\tau^{\#2}_{1^-}\dagger^{\alpha}$	0	0	0	$-\frac{2\,i\,k}{t_1+2\,k^2\,t_1}$	$-\frac{i\,\sqrt{2}\,k\,(2\,k^2\,r_1+t_1)}{(t_1+2\,k^2\,t_1)^2}$	0	$\frac{2\,k^2\,(2\,k^2\,r_1+t_1)}{(t_1+2\,k^2\,t_1)^2}$

	$\mathcal{A}^{\#1}_{1^+\,\alpha\beta}$	$\mathcal{A}^{\#2}_{1^+\,\alpha\beta}$	$f^{\#1}_{1^+\,\alpha\beta}$	$\mathcal{A}^{\#1}_{1^-\,\alpha}$	$\mathcal{A}^{\#2}_{1^-\,\alpha}$	$f^{\#1}_{1^-\,\alpha}$	$f^{\#2}_{1^-\,\alpha}$
$\mathcal{A}^{\#1}_{1^+}\dagger^{\alpha\beta}$	$\frac{1}{6}\,(t_1 + 4\,t_2)$	$-\frac{t_1-2\,t_2}{3\,\sqrt{2}}$	$-\frac{i\,k\,(t_1-2\,t_2)}{3\,\sqrt{2}}$	0	0	0	0
$\mathcal{A}^{\#2}_{1^+}\dagger^{\alpha\beta}$	$-\frac{t_1-2\,t_2}{3\,\sqrt{2}}$	$\frac{t_1+t_2}{3}$	$\frac{1}{3}\,i\,k\,(t_1 + t_2)$	0	0	0	0
$f^{\#1}_{1^+}\dagger^{\alpha\beta}$	$\frac{i\,k\,(t_1-2\,t_2)}{3\,\sqrt{2}}$	$-\frac{1}{3}\,i\,k\,(t_1 + t_2)$	$\frac{1}{3}\,k^2\,(t_1 + t_2)$	0	0	0	0
$\mathcal{A}^{\#1}_{1^-}\dagger^{\alpha}$	0	0	0	$-k^2\,r_1 - \frac{t_1}{2}$	$\frac{t_1}{\sqrt{2}}$	0	$i\,k\,t_1$
$\mathcal{A}^{\#2}_{1^-}\dagger^{\alpha}$	0	0	0	$\frac{t_1}{\sqrt{2}}$	0	0	0
$f^{\#1}_{1^-}\dagger^{\alpha}$	0	0	0	0	0	0	0
$f^{\#2}_{1^-}\dagger^{\alpha}$	0	0	0	$-i\,k\,t_1$	0	0	0

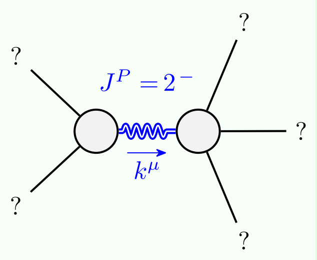
	$\mathcal{A}^{\#1}_{0^+}$	$f^{\#1}_{0^+}$	$f^{\#2}_{0^+}$	$\mathcal{A}^{\#1}_{0^-}$
$\mathcal{A}^{\#1}_{0^+}\dagger$	$-t_1$	$i\,\sqrt{2}\,k\,t_1$	0	0
$f^{\#1}_{0^+}\dagger$	$-i\,\sqrt{2}\,k\,t_1$	$-2\,k^2\,t_1$	0	0
$f^{\#2}_{0^+}\dagger$	0	0	0	0
$\mathcal{A}^{\#1}_{0^-}\dagger$	0	0	0	$k^2\,r_2 + t_2$

	$\sigma^{\#1}_{0^+}$	$\tau^{\#1}_{0^+}$	$\tau^{\#2}_{0^+}$	$\sigma^{\#1}_{0^-}$
$\sigma^{\#1}_{0^+}\dagger$	$-\frac{1}{(1+2\,k^2)^2\,t_1}$	$\frac{i\,\sqrt{2}\,k}{(1+2\,k^2)^2\,t_1}$	0	0
$\tau^{\#1}_{0^+}\dagger$	$-\frac{i\,\sqrt{2}\,k}{(1+2\,k^2)^2\,t_1}$	$-\frac{2\,k^2}{(1+2\,k^2)^2\,t_1}$	0	0
$\tau^{\#2}_{0^+}\dagger$	0	0	0	0
$\sigma^{\#1}_{0^-}\dagger$	0	0	0	$\frac{1}{k^2\,r_2+t_2}$

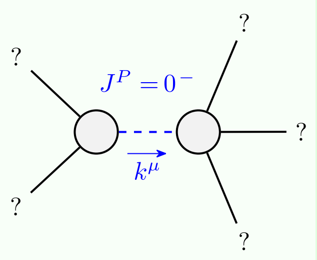
	$\mathcal{A}^{\#1}_{2^+\,\alpha\beta}$	$f^{\#1}_{2^+\,\alpha\beta}$	$\mathcal{A}^{\#1}_{2^-\,\alpha\beta\chi}$
$\mathcal{A}^{\#1}_{2^+}\dagger^{\alpha\beta}$	$\frac{t_1}{2}$	$-\frac{i\,k\,t_1}{\sqrt{2}}$	0
$f^{\#1}_{2^+}\dagger^{\alpha\beta}$	$\frac{i\,k\,t_1}{\sqrt{2}}$	$k^2\,t_1$	0
$\mathcal{A}^{\#1}_{2^-}\dagger^{\alpha\beta\chi}$	0	0	$k^2\,r_1 + \frac{t_1}{2}$

	$\sigma^{\#1}_{2^+\,\alpha\beta}$	$\tau^{\#1}_{2^+\,\alpha\beta}$	$\sigma^{\#1}_{2^-\,\alpha\beta\chi}$
$\sigma^{\#1}_{2^+}\dagger^{\alpha\beta}$	$\frac{2}{(1+2\,k^2)^2\,t_1}$	$-\frac{2\,i\,\sqrt{2}\,k}{(1+2\,k^2)^2\,t_1}$	0
$\tau^{\#1}_{2^+}\dagger^{\alpha\beta}$	$\frac{2\,i\,\sqrt{2}\,k}{(1+2\,k^2)^2\,t_1}$	$\frac{4\,k^2}{(1+2\,k^2)^2\,t_1}$	0
$\sigma^{\#1}_{2^-}\dagger^{\alpha\beta\chi}$	0	0	$\frac{2}{2\,k^2\,r_1+t_1}$

Massive and massless spectra



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



Massive particle	
Pole residue:	$-\frac{1}{r_2} > 0$
Polarisations:	1
Square mass:	$-\frac{t_2}{r_2} > 0$
Spin:	0
Parity:	Odd

(No massless particles)

Unitarity conditions

$r_1 < 0\ \&\&\ r_2 < 0\ \&\&\ t_1 > 0\ \&\&\ t_2 > 0$