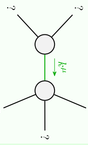
Particle spectrograph

Wave operator and propagator

Massive and massless spectra

Unitarity conditions

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



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

(No massive particles)

Source constraints

SO(3) irreps	Fundamental fields	Multiplicities
$\tau_{0^+}^{\#2} == 0$	$\partial_\beta \partial_\alpha \tau^{\alpha\beta} == 0$	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
$\tau_{1^+}^{\#1\,\alpha\beta} == 0$	$\partial_\chi \partial^\alpha \tau^{\beta\chi} + \partial_\chi \partial^\beta \tau^{\chi\alpha} + \partial_\chi \partial^\chi \tau^{\alpha\beta} == \partial_\chi \partial^\alpha \tau^{\chi\beta} + \partial_\chi \partial^\beta \tau^{\alpha\chi} + \partial_\chi \partial^\chi \tau^{\beta\alpha}$	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^\chi \sigma^{\alpha\delta\beta} + 4\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\chi \sigma^{\alpha\beta\delta} + 2\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\beta\chi\alpha} + 2\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta \sigma^{\alpha\chi\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}}_\delta + 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^\chi \sigma^{\delta\alpha\beta} + 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^\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
$\tau_{2^+}^{\#1\,\alpha\beta} == 0$	$4\,\partial_\delta \partial_\chi \partial^\beta \partial^\alpha \tau^{\chi\delta} + 2\,\partial_\delta \partial^\delta \partial^\beta \partial^\alpha {\tau^\chi}_\chi + 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\alpha\beta} + 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\beta\alpha} + 2\,\eta^{\alpha\beta}\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial_\chi \tau^{\chi\delta} == 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\alpha \tau^{\beta\chi} + 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\beta \tau^{\alpha\chi} + 3\,\partial_\delta \partial^\delta \partial_\chi \partial^\chi \tau^{\alpha\beta} + 2\,\eta^{\alpha\beta}\,\partial_\epsilon \partial^\epsilon \partial_\delta \partial^\delta {\tau^\chi}_\chi$	5
Total constraints/gauge generators:		24

Quadratic (free) action

$$\mathcal{S} ==$$

$$\iiiint \Big(\frac{1}{6}\,(-4\,t_3\,\mathcal{A}^{\alpha\prime}{}_\alpha\,\mathcal{A}_\prime{}^\theta{}_\theta + 6\,f^{\alpha\beta}\,\tau_{\alpha\beta} + 6\,\mathcal{A}^{\alpha\beta\chi}\,\sigma_{\alpha\beta\chi} + 8\,t_3\,\mathcal{A}_\alpha{}^\theta{}_\theta\,\partial_\prime f^{\alpha\prime} - 8\,t_3\,\mathcal{A}_\prime{}^\theta{}_\theta\,\partial^\prime f^\alpha{}_\alpha + 4\,t_3\,\partial_\prime f^\theta{}_\theta\,\partial^\prime f^\alpha{}_\alpha - 3\,r_3\,\partial_\beta \mathcal{A}_\prime{}^\theta{}_\theta\,\partial^\prime \mathcal{A}^{\alpha\beta}{}_\alpha - 3\,r_3\,\partial_\prime \mathcal{A}_\beta{}^\theta{}_\theta\,\partial^\prime \mathcal{A}^{\alpha\beta}{}_\alpha + 4\,t_3\,\partial_\prime f^{\alpha\prime}\,\partial_\theta f_\alpha{}^\theta - 8\,t_3\,\partial^\prime f^\alpha{}_\alpha\,\partial_\theta f_\prime{}^\theta - 3\,r_3\,\partial_\alpha \mathcal{A}^{\alpha\beta\prime}\,\partial_\theta \mathcal{A}_\beta{}^\theta{}_\prime + 6\,r_3\,\partial^\prime \mathcal{A}^{\alpha\beta}{}_\alpha\,\partial_\theta \mathcal{A}_\beta{}^\theta{}_\prime - 3\,r_3\,\partial_\alpha \mathcal{A}^{\alpha\beta\prime}\,\partial_\theta \mathcal{A}_\prime{}^\theta{}_\beta + 6\,r_3\,\partial^\prime \mathcal{A}^{\alpha\beta}{}_\alpha\,\partial_\theta \mathcal{A}_\prime{}^\theta{}_\beta + 8\,r_2\,\partial_\beta \mathcal{A}_{\alpha\prime\theta}\,\partial^\theta \mathcal{A}^{\alpha\beta\prime} - 4\,r_2\,\partial_\beta \mathcal{A}_{\alpha\theta\prime}\,\partial^\theta \mathcal{A}^{\alpha\beta\prime} + 4\,r_2\,\partial_\beta \mathcal{A}_{\prime\theta\alpha}\,\partial^\theta \mathcal{A}^{\alpha\beta\prime} - 24\,r_3\,\partial_\beta \mathcal{A}_{\prime\theta\alpha}\,\partial^\theta \mathcal{A}^{\alpha\beta\prime} - 2\,r_2\,\partial_\prime \mathcal{A}_{\alpha\beta\theta}\,\partial^\theta \mathcal{A}^{\alpha\beta\prime} + 2\,r_2\,\partial_\theta \mathcal{A}_{\alpha\beta\prime}\,\partial^\theta \mathcal{A}^{\alpha\beta\prime} - 4\,r_2\,\partial_\theta \mathcal{A}_{\alpha\prime\beta}\,\partial^\theta \mathcal{A}^{\alpha\beta\prime} + 6\,r_5\,\partial_\prime \mathcal{A}_\theta{}^\kappa{}_\kappa\,\partial^\theta \mathcal{A}^{\alpha\prime}{}_\alpha - 6\,r_5\,\partial_\theta \mathcal{A}_\prime{}^\kappa{}_\kappa\,\partial^\theta \mathcal{A}^{\alpha\prime}{}_\alpha + 6\,r_5\,\partial_\alpha \mathcal{A}^{\alpha\prime\theta}\,\partial_\kappa \mathcal{A}_\prime{}^\kappa{}_\theta - 6\,r_5\,\partial_\alpha \mathcal{A}^{\alpha\prime\theta}\,\partial_\kappa \mathcal{A}_\theta{}^\kappa{}_\prime + 12\,r_5\,\partial^\theta \mathcal{A}^{\alpha\prime}{}_\alpha\,\partial_\kappa \mathcal{A}_\prime{}^\kappa{}_\theta - 12\,r_5\,\partial^\theta \mathcal{A}^{\alpha\prime}{}_\alpha\,\partial_\kappa \mathcal{A}_\theta{}^\kappa{}_\prime)\Big)[t, x, y, z]\,dz\,dy\,dx\,dt$$

	$\sigma_{1^+}^{\#1}{}_{\alpha\beta}$	$\sigma_{1^+}^{\#2}{}_{\alpha\beta}$	$\tau_{1^+}^{\#1}{}_{\alpha\beta}$	$\sigma_{1^-}^{\#1}{}_{\alpha}$	$\sigma_{1^-}^{\#2}{}_{\alpha}$	$\tau_{1^-}^{\#1}{}_{\alpha}$	$\tau_{1^-}^{\#2}{}_{\alpha}$
$\sigma_{1^+}^{\#1\,\dagger\,\alpha\beta}$	$\frac{1}{k^2\,(2\,r_3+r_5)}$	0	0	0	0	0	0
$\sigma_{1^+}^{\#2\,\dagger\,\alpha\beta}$	0	0	0	0	0	0	0
$\tau_{1^+}^{\#1\,\dagger\,\alpha\beta}$	0	0	0	0	0	0	0
$\sigma_{1^-}^{\#1\,\dagger\,\alpha}$	0	0	0	$\frac{2}{k^2\,(r_3+2\,r_5)}$	$\frac{2\,\sqrt{2}}{k^2\,(1+2\,k^2)\,(r_3+2\,r_5)}$	0	$\frac{4\,i}{k\,(1+2\,k^2)\,(r_3+2\,r_5)}$
$\sigma_{1^-}^{\#2\,\dagger\,\alpha}$	0	0	0	$\frac{2\,\sqrt{2}}{k^2\,(1+2\,k^2)\,(r_3+2\,r_5)}$	$\frac{3\,k^2\,(r_3+2\,r_5)+4\,t_3}{(k+2\,k^3)^2\,(r_3+2\,r_5)\,t_3}$	0	$\frac{i\,\sqrt{2}\,(3\,k^2\,(r_3+2\,r_5)+4\,t_3)}{k\,(1+2\,k^2)^2\,(r_3+2\,r_5)\,t_3}$
$\tau_{1^-}^{\#1\,\dagger\,\alpha}$	0	0	0	0	0	0	0
$\tau_{1^-}^{\#2\,\dagger\,\alpha}$	0	0	0	$-\frac{4\,i}{k\,(1+2\,k^2)\,(r_3+2\,r_5)}$	$-\frac{i\,\sqrt{2}\,(3\,k^2\,(r_3+2\,r_5)+4\,t_3)}{k\,(1+2\,k^2)^2\,(r_3+2\,r_5)\,t_3}$	0	$\frac{6\,k^2\,(r_3+2\,r_5)+8\,t_3}{(1+2\,k^2)^2\,(r_3+2\,r_5)\,t_3}$

	$\mathcal{A}_{1^+}^{\#1}{}_{\alpha\beta}$	$\mathcal{A}_{1^+}^{\#2}{}_{\alpha\beta}$	$f_{1^+}^{\#1}{}_{\alpha\beta}$	$\mathcal{A}_{1^-}^{\#1}{}_{\alpha}$	$\mathcal{A}_{1^-}^{\#2}{}_{\alpha}$	$f_{1^-}^{\#1}{}_{\alpha}$	$f_{1^-}^{\#2}{}_{\alpha}$
$\mathcal{A}_{1^+}^{\#1\,\dagger\,\alpha\beta}$	$k^2\,(2\,r_3+r_5)$	0	0	0	0	0	0
$\mathcal{A}_{1^+}^{\#2\,\dagger\,\alpha\beta}$	0	0	0	0	0	0	0
$f_{1^+}^{\#1\,\dagger\,\alpha\beta}$	0	0	0	0	0	0	0
$\mathcal{A}_{1^-}^{\#1\,\dagger\,\alpha}$	0	0	0	$k^2\,(\frac{r_3}{2}+r_5)+\frac{2\,t_3}{3}$	$-\frac{\sqrt{2}\,t_3}{3}$	0	$-\frac{2}{3}\,i\,k\,t_3$
$\mathcal{A}_{1^-}^{\#2\,\dagger\,\alpha}$	0	0	0	$-\frac{\sqrt{2}\,t_3}{3}$	$\frac{t_3}{3}$	0	$\frac{1}{3}\,i\,\sqrt{2}\,k\,t_3$
$f_{1^-}^{\#1\,\dagger\,\alpha}$	0	0	0	0	0	0	0
$f_{1^-}^{\#2\,\dagger\,\alpha}$	0	0	0	$\frac{2\,i\,k\,t_3}{3}$	$-\frac{1}{3}\,i\,\sqrt{2}\,k\,t_3$	0	$\frac{2\,k^2\,t_3}{3}$

	$\sigma_{0^+}^{\#1}$	$\tau_{0^+}^{\#2}$	$\tau_{0^+}^{\#1}$	$\sigma_{0^+}^{\#2}$
$\sigma_{0^+}^{\#1\,\dagger}$	0	0	$\frac{1}{(1+2\,k^2)^2\,r_3}$	$-\frac{i\,\sqrt{2}\,k}{(1+2\,k^2)^2\,r_3}$
$\tau_{0^+}^{\#2\,\dagger}$	0	0	$\frac{i\,\sqrt{2}\,k}{(1+2\,k^2)^2\,r_3}$	$\frac{2\,k^2}{(1+2\,k^2)^2\,r_3\,t_3}$
$\tau_{0^+}^{\#1\,\dagger}$	0	0	0	0
$\sigma_{0^+}^{\#2\,\dagger}$	0	0	0	$\frac{1}{k^2\,r_2}$

	$\mathcal{A}_{2^+}^{\#1}{}_{\alpha\beta\chi}$	$f_{2^+}^{\#1}{}_{\alpha\beta}$	$\mathcal{A}_{2^+}^{\#1}{}_{\alpha\beta}$
$\mathcal{A}_{2^+}^{\#1\,\dagger\,\alpha\beta\chi}$	0	0	$-\frac{3\,k^2\,r_3}{2}$
$f_{2^+}^{\#1\,\dagger\,\alpha\beta}$	0	0	0
$\mathcal{A}_{2^+}^{\#1\,\dagger\,\alpha\beta}$	0	0	0

	$\mathcal{A}_{0^+}^{\#1}$	$f_{0^+}^{\#1}$	$f_{0^+}^{\#2}$	$\mathcal{A}_{0^-}^{\#1}$
$\mathcal{A}_{0^+}^{\#1\,\dagger}$	t_3	$-i\,\sqrt{2}\,k\,t_3$	0	0
$f_{0^+}^{\#1\,\dagger}$	$i\,\sqrt{2}\,k\,t_3$	$2\,k^2\,t_3$	0	0
$f_{0^+}^{\#2\,\dagger}$	0	0	0	0
$\mathcal{A}_{0^-}^{\#1\,\dagger}$	0	0	0	$k^2\,r_2$

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