Particle spectrograph

Wave operator and propagator

Quadratic (free) action

$$S_F == \int\int\int\int (\frac{1}{6}(4\,t_2\,\omega_{\iota}{}^{\kappa\lambda}\,\omega_{\kappa\lambda}{}'+2\,t_2\,\omega_{\kappa\lambda}{}'\,\omega^{\kappa\lambda}{}_{\iota}+6\,f^{\alpha\beta}{}_{\tau}\,\tau_{\alpha\beta}+6\,\omega^{\alpha\beta\chi}\,\sigma_{\alpha\beta\chi}-3\,r_3\,\partial_{\iota}\omega^{\kappa\lambda}{}_{\kappa}\,\partial'\omega_{\lambda}{}^{\alpha}{}_{\alpha}-6\,r_5\,\partial_{\iota}\omega^{\kappa\lambda}{}_{\kappa}\,\partial'\omega_{\lambda}{}^{\alpha}{}_{\alpha}+4\,r_2\,\partial^{\beta}\omega^{\theta\alpha}{}_{\kappa}\,\partial_{\theta}\omega_{\alpha\beta}{}^{\kappa}-2\,r_2\,\partial_{\theta}\omega_{\alpha\beta}{}^{\kappa}\,\partial_{\kappa}\omega^{\alpha\beta\theta}-4\,r_2\,\partial_{\theta}\omega^{\kappa}{}_{\alpha\beta}\,\partial_{\kappa}\omega^{\theta\alpha\beta}+3\,r_3\,\partial_{\alpha}\omega_{\lambda}{}^{\alpha}{}_{\theta}\,\partial_{\kappa}\omega^{\theta\kappa\lambda}-6\,r_5\,\partial_{\alpha}\omega_{\lambda}{}^{\alpha}{}_{\theta}\,\partial_{\kappa}\omega^{\theta\kappa\lambda}+6\,r_5\,\partial_{\theta}\omega_{\lambda}{}^{\alpha}{}_{\alpha}\,\partial_{\kappa}\omega^{\theta\kappa\lambda}-3\,r_3\,\partial_{\alpha}\omega_{\lambda}{}^{\alpha}{}_{\theta}\,\partial_{\kappa}\omega^{\kappa\lambda\theta}-6\,r_5\,\partial_{\alpha}\omega_{\lambda}{}^{\alpha}{}_{\theta}\,\partial_{\kappa}\omega^{\kappa\lambda\theta}+12\,r_5\,\partial_{\theta}\omega_{\lambda}{}^{\alpha}{}_{\alpha}\,\partial_{\kappa}\omega^{\kappa\lambda\theta}+t_2\,\partial^{\alpha}f_{\alpha}{}^{\theta}\,\partial^{\kappa}f_{\kappa}{}^{\lambda}\,\partial_{\lambda}\omega^{\kappa\lambda\theta}+2\,t_2\,\partial^{\alpha}f_{\alpha}{}^{\theta}\,\partial^{\kappa}f_{\kappa\theta}\,\partial^{\lambda}f_{\lambda}{}^{\iota\theta}-4\,t_2\,\omega_{\iota\kappa\theta}\,\partial^{\kappa}f^{\iota\theta}+4\,t_2\,\omega_{\theta\kappa\iota}\,\partial^{\kappa}f^{\iota\theta}-t_2\,\partial^{\alpha}f^{\lambda}{}_{\kappa}\,\partial^{\kappa}f_{\lambda\alpha}-t_2\,\partial_{\kappa}f_{\theta}{}^{\lambda}\,\partial^{\kappa}f_{\lambda}{}^{\theta}+2\,r_2\,\partial_{\kappa}\omega^{\alpha\beta\theta}\,\partial^{\kappa}\omega_{\alpha\beta\theta}+4\,r_2\,\partial_{\kappa}\omega^{\theta\alpha\beta}\,\partial^{\kappa}\omega_{\alpha\beta\theta}-4\,r_2\,\partial^{\beta}\omega_{\iota}{}^{\alpha\lambda}\,\partial_{\lambda}\omega_{\alpha\beta}{}'+4\,r_2\,\partial^{\beta}\omega_{\iota}{}^{\alpha\lambda}\,\partial_{\lambda}\omega_{\alpha\beta}{}'-24\,r_3\,\partial^{\beta}\omega_{\iota}{}^{\lambda\alpha}\,\partial_{\lambda}\omega_{\alpha\beta}{}'-3\,r_3\,\partial_{\alpha}\omega_{\lambda}{}^{\alpha}{}_{\theta}\,\partial^{\lambda}\omega^{\theta\kappa}{}_{\kappa}+6\,r_5\,\partial_{\alpha}\omega_{\lambda}{}^{\alpha}{}_{\theta}\,\partial_{\theta}\omega_{\lambda}{}^{\alpha}{}_{\alpha}\,\partial^{\lambda}\omega^{\theta\kappa}{}_{\kappa}-6\,r_5\,\partial_{\theta}\omega_{\lambda}{}^{\alpha}{}_{\alpha}\,\partial^{\lambda}\omega^{\theta\kappa}{}_{\kappa})[t,x,y,z]\,dt\,dx\,dy\,dz$$

$\sigma_{1^+}^{\#1\,\alpha\beta}$

$\frac{1}{k^2\,(2\,r_3+r_5)}$	$-\frac{\sqrt{2}}{k^2\,(1+k^2)\,(2\,r_3+r_5)}$	$\frac{\sqrt{2}}{(1+k^2)\,(2\,r_3+r_5)}$	$\frac{i\,\sqrt{2}}{k\,(1+k^2)\,(2\,r_3+r_5)}$
0	0	0	0
0	0	0	0
0	0	0	0

$\sigma_{1^+}^{\#2\,\alpha\beta}$

$-\frac{\sqrt{2}}{k^2\,(1+k^2)\,(2\,r_3+r_5)}$	$\frac{3\,k^2\,(2\,r_3+r_5)+2\,t_2}{(k+k^3)^2\,(2\,r_3+r_5)\,t_2}$	$-\frac{i\,(3\,k^2\,(2\,r_3+r_5)+2\,t_2)}{k\,(1+k^2)^2\,(2\,r_3+r_5)\,t_2}$	0
0	0	0	0
0	0	0	0
0	0	0	0

$\tau_{1^+}^{\#1\,\alpha\beta}$

$-\frac{i\,\sqrt{2}}{k\,(1+k^2)\,(2\,r_3+r_5)}$	$\frac{i\,(3\,k^2\,(2\,r_3+r_5)+2\,t_2)}{k\,(1+k^2)^2\,(2\,r_3+r_5)\,t_2}$	$-\frac{3\,k^2\,(2\,r_3+r_5)+2\,t_2}{(1+k^2)^2\,(2\,r_3+r_5)\,t_2}$	0
0	0	0	0
0	0	0	0
0	0	0	0

$\sigma_{1^-}^{\#1\,\alpha}$

0	0	0	0
0	0	0	$\frac{2}{k^2\,(r_3+2\,r_5)}$
0	0	0	0
0	0	0	0

$\sigma_{1^-}^{\#2\,\alpha}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\tau_{1^-}^{\#1\,\alpha}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\tau_{1^-}^{\#2\,\alpha}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\omega_{1^+}^{\#1\,\alpha\beta}$

$\frac{1}{3}\,k^2\,(2\,r_3+r_5)+\frac{2\,t_2}{3}$	$\frac{\sqrt{2}\,t_2}{3}$	$\frac{1}{3}\,i\,\sqrt{2}\,k\,t_2$	0
$\frac{\sqrt{2}\,t_2}{3}$	$\frac{t_2}{3}$	$\frac{i\,k\,t_2}{3}$	0
$-\frac{1}{3}\,i\,\sqrt{2}\,k\,t_2$	$-\frac{1}{3}\,i\,k\,t_2$	$\frac{k^2\,t_2}{3}$	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\omega_{1^+}^{\#2\,\alpha\beta}$

$k^2\,(2\,r_3+r_5)$	$-\frac{\sqrt{2}\,t_2}{3}$	$-\frac{1}{3}\,i\,\sqrt{2}\,k\,t_2$	0
$-\frac{\sqrt{2}\,t_2}{3}$	$\frac{t_2}{3}$	$\frac{i\,k\,t_2}{3}$	0
$\frac{1}{3}\,i\,\sqrt{2}\,k\,t_2$	$-\frac{i\,k\,t_2}{3}$	$\frac{k^2\,t_2}{3}$	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$f_{1^+}^{\#1\,\alpha\beta}$

$\frac{1}{3}\,i\,\sqrt{2}\,k\,t_2$	$\frac{i\,k\,t_2}{3}$	$\frac{k^2\,t_2}{3}$	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\omega_{1^-}^{\#1\,\alpha}$

0	0	0	0
0	0	0	0
0	0	0	0
$\frac{1}{2}\,k^2\,(r_3+2\,r_5)$	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\omega_{1^-}^{\#2\,\alpha}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$f_{1^-}^{\#1\,\alpha}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$f_{1^-}^{\#2\,\alpha}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\omega_{2^+}^{\#1\,\alpha\beta}$

$-\frac{3\,k^2\,r_3}{2}$	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$f_{2^+}^{\#1\,\alpha\beta}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\omega_{2^-}^{\#1\,\alpha\beta\chi}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\omega_{0^+}^{\#1}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	$k^2\,r_2+t_2$

$f_{0^+}^{\#1}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$f_{0^+}^{\#2}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\sigma_{0^-}^{\#1}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	$\frac{1}{k^2\,r_2+t_2}$

$\tau_{0^+}^{\#1}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\tau_{0^+}^{\#2}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\sigma_{2^+}^{\#1\,\alpha\beta}$

$-\frac{2}{3\,k^2\,r_3}$	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

$\tau_{2^+}^{\#1\,\alpha\beta}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

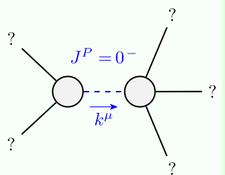
$\sigma_{2^-}^{\#1\,\alpha\beta\chi}$

0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0
0	0	0	0

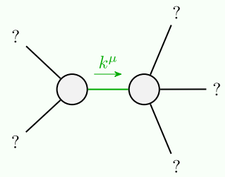
Source constraints/gauge generators

SO(3) irreps	Multiplicities
$\tau_{0^+}^{\#2} == 0$	1
$\tau_{0^+}^{\#1} == 0$	1
$\sigma_{0^+}^{\#1} == 0$	1
$\tau_{1^-}^{\#2\,\alpha} == 0$	3
$\tau_{1^-}^{\#1\,\alpha} == 0$	3
$\sigma_{1^-}^{\#2\,\alpha} == 0$	3
$\tau_{1^+}^{\#1\,\alpha\beta} + i\,k\,\sigma_{1^+}^{\#2\,\alpha\beta} == 0$	3
$\sigma_{2^-}^{\#1\,\alpha\beta\chi} == 0$	5
$\tau_{2^+}^{\#1\,\alpha\beta} == 0$	5
Total constraints:	25

Massive and massless spectra



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



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

Unitarity conditions

$$r_2 < 0 \,\&\&\, r_3 < 0 \,\&\&\, r_5 < -\frac{r_3}{2} \,\&\&\, t_2 > 0 \,\|\, r_2 < 0 \,\&\&\, r_3 < 0 \,\&\&\, r_5 > -2\,r_3 \,\&\&\, t_2 > 0 \,\|\, r_2 < 0 \,\&\&\, r_3 > 0 \,\&\&\, -2\,r_3 < r_5 < -\frac{r_3}{2} \,\&\&\, t_2 > 0$$