

Particle spectrograph

Wave operator and propagator

$\Delta_{1^+}^{\#1}+\alpha\beta$	$\Delta_{1^+}^{\#2}+\alpha\beta$	$\Delta_{1^+}^{\#3}+\alpha\beta$	$\Delta_{1^+}^{\#1}\alpha$	$\Delta_{1^+}^{\#2}\alpha$	$\Delta_{1^+}^{\#3}\alpha$	$\Delta_{1^+}^{\#4}\alpha$	$\Delta_{1^+}^{\#5}\alpha$	$\Delta_{1^+}^{\#6}\alpha$	$\mathcal{T}_{1^+}^{\#1}\alpha$
0	$-\frac{2\sqrt{2}}{a_0}$	0	0	0	0	0	0	0	0
$-\frac{2\sqrt{2}}{a_0}$	$\frac{2}{a_0}$	0	0	0	0	0	0	0	0
0	0	$\frac{4}{a_0}$	0	0	0	0	0	0	0
0	0	0	0	$\frac{\sqrt{2}(4+k^2)}{a_0(2+k^2)}$	$-\frac{2k^2}{\sqrt{3}a_0(2+k^2)}$	0	$\frac{\sqrt{\frac{2}{3}}k^2}{a_0(2+k^2)}$	0	$-\frac{2i\sqrt{2}k}{a_0(2+k^2)}$
0	0	0	$\frac{\sqrt{2}(4+k^2)}{a_0(2+k^2)}$	$\frac{(4+k^2)^2}{2a_0(2+k^2)^2}$	$\frac{k^2(-2+k^2)}{2\sqrt{6}a_0(2+k^2)^2}$	$-\frac{\sqrt{\frac{5}{6}}k^2}{4a_0+2a_0k^2}$	$\frac{k^2(5+2k^2)}{\sqrt{3}a_0(2+k^2)^2}$	$-\frac{k^2}{\sqrt{6}a_0(2+k^2)^2}$	$-\frac{ik(4+k^2)}{a_0(2+k^2)^2}$
0	0	0	$-\frac{2k^2}{\sqrt{3}(2a_0+a_0k^2)}$	$\frac{k^2(-2+k^2)}{2\sqrt{6}a_0(2+k^2)^2}$	$\frac{-76+52k^2+3k^4}{12a_0(2+k^2)^2}$	$\frac{\sqrt{5}(10+3k^2)}{12a_0(2+k^2)}$	$\frac{-2+k^2}{3\sqrt{2}a_0(2+k^2)^2}$	$\frac{1}{-2a_0-2+3k^2}$	$\frac{ik(6+5k^2)}{\sqrt{6}a_0(2+k^2)^2}$
0	0	0	0	$-\frac{\sqrt{5}k^2}{4a_0+2a_0k^2}$	$\frac{\sqrt{5}(10+3k^2)}{12a_0(2+k^2)}$	$\frac{1}{12a_0}$	$-\frac{\sqrt{\frac{5}{2}}}{6a_0+3a_0k^2}$	$-\frac{\sqrt{5}}{6a_0}$	$-\frac{i\sqrt{\frac{5}{6}}k}{a_0(2+k^2)}$
0	0	0	$\frac{\sqrt{\frac{2}{3}}k^2}{2a_0+a_0k^2}$	$\frac{k^2(5+2k^2)}{\sqrt{3}a_0(2+k^2)^2}$	$\frac{-2+k^2}{3\sqrt{2}a_0(2+k^2)^2}$	$-\frac{\sqrt{\frac{5}{2}}}{6a_0+3a_0k^2}$	$\frac{2(17+14k^2+3k^4)}{3a_0(2+k^2)^2}$	$\frac{\sqrt{2}(7+3k^2)}{3a_0(2+k^2)^2}$	$\frac{2ik(3+k^2)}{\sqrt{3}a_0(2+k^2)^2}$
0	0	0	0	$-\frac{k^2}{\sqrt{6}(2a_0+a_0k^2)}$	$\frac{1}{-2a_0-2+3k^2}$	$-\frac{\sqrt{5}}{6a_0}$	$\frac{-\sqrt{2}(7+3k^2)}{3a_0(2+k^2)^2}$	$\frac{5}{3a_0}$	$-\frac{i\sqrt{\frac{2}{3}}k}{a_0(2+k^2)}$
0	0	0	$\frac{2i\sqrt{2}k}{2a_0+a_0k^2}$	$-\frac{ik(4+k^2)}{a_0(2+k^2)^2}$	$-\frac{ik(6+5k^2)}{\sqrt{6}a_0(2+k^2)^2}$	$\frac{i\sqrt{\frac{5}{6}}k}{2a_0+a_0k^2}$	$-\frac{2ik(3+k^2)}{\sqrt{3}a_0(2+k^2)^2}$	$\frac{2k^2}{a_0(2+k^2)^2}$	

$\Delta_{0^+}^{\#1}$	$\Delta_{0^+}^{\#2}$	$\Delta_{0^+}^{\#3}$	$\Delta_{0^+}^{\#4}$	$\mathcal{T}_{0^+}^{\#1}$	$\mathcal{T}_{0^+}^{\#2}$	$\Delta_{0^+}^{\#1}$
0	$\frac{4\sqrt{6}}{16a_0+3a_0k^2}$	$-\frac{4\sqrt{\frac{2}{3}}}{16a_0+3a_0k^2}$	$-\frac{8}{\sqrt{3}(16a_0+3a_0k^2)}$	$-\frac{2i\sqrt{2}}{a_0k}$	$-\frac{2i\sqrt{6}k}{16a_0+3a_0k^2}$	0
$\Delta_{0^+}^{\#2}+\alpha\beta$	$-\frac{144}{a_0(16+3k^2)^2}$	$-\frac{16(19+3k^2)}{a_0(16+3k^2)^2}$	$-\frac{8\sqrt{2}(10+3k^2)}{a_0(16+3k^2)^2}$	$-\frac{8i\sqrt{3}}{16a_0k+3a_0k^3}$	$\frac{72ik}{a_0(16+3k^2)^2}$	0
$\Delta_{0^+}^{\#3}+\alpha\beta$	$-\frac{4\sqrt{\frac{2}{3}}}{16a_0+3a_0k^2}$	$-\frac{16(19+3k^2)}{a_0(16+3k^2)^2}$	$-\frac{8\sqrt{2}(22+3k^2)}{3a_0(16+3k^2)^2}$	$\frac{8i}{\sqrt{3}(16a_0k+3a_0k^3)}$	$-\frac{8ik(19+3k^2)}{a_0(16+3k^2)^2}$	0
$\Delta_{0^+}^{\#4}+\alpha\beta$	$-\frac{8}{\sqrt{3}(16a_0+3a_0k^2)}$	$-\frac{8\sqrt{2}(10+3k^2)}{a_0(16+3k^2)^2}$	$-\frac{32(13+3k^2)}{3a_0(16+3k^2)^2}$	$\frac{8i\sqrt{\frac{2}{3}}}{16a_0k+3a_0k^3}$	$\frac{4i\sqrt{2}k(10+3k^2)}{a_0(16+3k^2)^2}$	0
$\mathcal{T}_{0^+}^{\#1}+\alpha\beta$	$\frac{2i\sqrt{2}}{a_0k}$	$-\frac{8i\sqrt{3}}{16a_0k+3a_0k^3}$	$-\frac{8i\sqrt{\frac{2}{3}}}{16a_0k+3a_0k^3}$	$\frac{4}{a_0k^2}$	$\frac{4\sqrt{3}}{16a_0+3a_0k^2}$	0
$\mathcal{T}_{0^+}^{\#2}+\alpha\beta$	$\frac{2i\sqrt{6}k}{16a_0+3a_0k^2}$	$-\frac{72ik}{a_0(16+3k^2)^2}$	$-\frac{4i\sqrt{2}k(10+3k^2)}{a_0(16+3k^2)^2}$	$\frac{4\sqrt{3}}{16a_0+3a_0k^2}$	$-\frac{36k^2}{a_0(16+3k^2)^2}$	0
$\Delta_{0^+}^{\#1}+\alpha\beta\chi$	0	0	0	0	0	$-\frac{2}{a_0}$

$\Delta_{3^+}^{\#1}+\alpha\beta\chi$

$\Delta_{3^+}^{\#1}-\alpha\beta\chi$

$\Delta_{3^+}^{\#1}+\alpha\beta\chi$

$\Delta_{3^+}^{\#1}-\alpha\beta\chi$

$\Gamma_{1^+}^{\#1}+\alpha\beta$	$\Gamma_{1^+}^{\#2}+\alpha\beta$	$\Gamma_{1^+}^{\#3}+\alpha\beta$	$\Gamma_{1^+}^{\#1}\alpha$	$\Gamma_{1^+}^{\#2}\alpha$	$\Gamma_{1^+}^{\#3}\alpha$	$\Gamma_{1^+}^{\#4}\alpha$	$\Gamma_{1^+}^{\#5}\alpha$	$\Gamma_{1^+}^{\#6}\alpha$	$h_{1^+}^{\#1}\alpha$
$-\frac{a_0}{4}$	$-\frac{a_0}{2\sqrt{2}}$	0	0	0	0	0	0	0	0
$-\frac{a_0}{2\sqrt{2}}$	0	0	0	0	0	0	0	0	0
0	0	$\frac{a_0}{4}$	0	0	0	0	0	0	0
0	0	$-\frac{a_0}{4}$	$-\frac{a_0}{2\sqrt{2}}$	$-\frac{a_0}{2\sqrt{2}}$	0	0	0	0	$-\frac{ia_0k}{4\sqrt{2}}$
0	0	0	$\frac{a_0}{2\sqrt{2}}$	0	0	0	0	0	0
0	0	0	0	0	$-\frac{a_0}{3}$	$\frac{\sqrt{5}a_0}{6}$	$-\frac{a_0}{6\sqrt{2}}$	$-\frac{a_0}{6}$	$\frac{ia_0k}{4\sqrt{6}}$
0	0	0	0	0	$\frac{\sqrt{5}a_0}{6}$	$\frac{a_0}{3}$	$-\frac{\sqrt{5}a_0}{6}$	$-\frac{1}{6}\sqrt{\frac{5}{2}}a_0$	$-\frac{1}{4}i\sqrt{\frac{5}{6}}a_0k$
0	0	0	0	0	$-\frac{a_0}{6\sqrt{2}}$	$-\frac{1}{6}\sqrt{\frac{5}{2}}a_0$	$\frac{a_0}{3}$	$\frac{a_0}{6\sqrt{2}}$	$\frac{ia_0k}{4\sqrt{3}}$
0	0	0	0	0	$-\frac{a_0}{6}$	$-\frac{\sqrt{5}a_0}{6}$	$\frac{a_0}{6\sqrt{2}}$	$\frac{5a_0}{12}$	$\frac{ia_0k}{4\sqrt{6}}$
0	0	0	$\frac{ia_0k}{4\sqrt{2}}$	$\frac{ia_0k}{4\sqrt{2}}$	0	$-\frac{ia_0k}{4\sqrt{6}}$	$-\frac{ia_0k}{4\sqrt{3}}$	$-\frac{ia_0k}{4\sqrt{6}}$	0
$h_{1^+}^{\#1}+\alpha\beta$	0	0	0	0	0	0	0	0	0

$\Gamma_{2^+}^{\#1}+\alpha\beta$	$\Gamma_{2^+}^{\#2}+\alpha\beta$	$\Gamma_{2^+}^{\#3}+\alpha\beta$	$h_{2^+}^{\#1}+\alpha\beta$	$\Gamma_{2^+}^{\#1}\alpha\beta\chi$	$\Gamma_{2^+}^{\#2}\alpha\beta\chi$
$\frac{a_0}{4}$	0	0	$\frac{ia_0k}{4\sqrt{2}}$	0	0
0	$-\frac{a_0}{2}$	0	$\frac{ia_0k}{4\sqrt{3}}$	0	0
0	0	$\frac{a_0}{4}$	$-\frac{ia_0k}{4\sqrt{6}}$	0	0
$-\frac{ia_0k}{4\sqrt{2}}$	$-\frac{ia_0k}{4\sqrt{3}}$	$\frac{ia_0k}{4\sqrt{6}}$	0	$\frac{a_0}{4}$	0
0	0	0	0	0	$\frac{a_0}{4}$

Source constraints/gauge generators

SO(3) irreps	Multiplicities
$2\mathcal{T}_{0^+}^{\#2}-ik\Delta_{0^+}^{\#2}==0$	1
$\Delta_{0^+}^{\#3}+2\Delta_{0^+}^{\#4}+3\Delta_{0^+}^{\#2}==0$	1
$6\mathcal{T}_{1^+}^{\#1\alpha}-ik(3\Delta_{1^+}^{\#2\alpha}-\Delta_{1^+}^{\#5\alpha}+\Delta_{1^+}^{\#3\alpha})==0$	3
$2\Delta_{1^+}^{\#6\alpha}+\Delta_{1^+}^{\#4\alpha}+2\Delta_{1^+}^{\#5\alpha}+\Delta_{1^+}^{\#3\alpha}==0$	3
Total constraints:	8

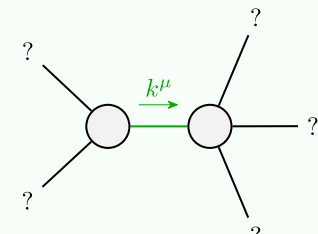
Quadratic (free) action

$$S= \iiint\int(\frac{1}{4}$$
$$(2a_0\Gamma_{\alpha}^{\alpha\beta}\Gamma_{\beta\chi}^{\chi}+4h^{\alpha\beta}\mathcal{T}_{\alpha\beta}+\Gamma^{\alpha\beta\chi}(-2a_0\Gamma_{\beta\chi\alpha}+4\Delta_{\alpha\beta\chi})-a_0h^{\chi}_{\chi}\partial_{\beta}\Gamma_{\alpha}^{\alpha\beta}+$$
$$a_0h^{\chi}_{\chi}\partial_{\beta}\Gamma^{\alpha\beta}_{\alpha}-2a_0h_{\alpha\chi}\partial_{\beta}\Gamma^{\alpha\beta\chi}+2a_0h_{\beta\chi}\partial^{\chi}\Gamma^{\alpha\beta}_{\alpha})) [t,x,y,z]dzdydxdt$$

$\Gamma_{0^+}^{\#1}$	$\Gamma_{0^+}^{\#2}$	$\Gamma_{0^+}^{\#3}$	$\Gamma_{0^+}^{\#4}$	$h_{0^+}^{\#1}$	$h_{0^+}^{\#2}$	$\Gamma_{0^+}^{\#1}$
$-\frac{a_0}{2}$	0	0	0	$-\frac{ia_0k}{2\sqrt{2}}$	0	0
0	0	$\frac{a_0}{2}$	$-\frac{a_0}{2\sqrt{2}}$	$\frac{ia_0k}{4\sqrt{3}}$	$-\frac{1}{4}ia_0k$	0
0	0	$-\frac{a_0}{2}$	$\frac{a_0}{2\sqrt{2}}$	$-\frac{ia_0k}{4\sqrt{6}}$	$\frac{ia_0k}{4\sqrt{2}}$	0
$\frac{ia_0k}{2\sqrt{2}}$	0	$-\frac{ia_0k}{4\sqrt{3}}$	$\frac{ia_0k}{4\sqrt{6}}$	0	0	0
0	0	$\frac{ia_0k}{4}$	$-\frac{ia_0k}{4\sqrt{2}}$	0	0	0
0	0	0	0	0	0	$-\frac{a_0}{2}$

$\Delta_{2^+}^{\#1}+\alpha\beta$	$\Delta_{2^+}^{\#2}+\alpha\beta$	$\Delta_{2^+}^{\#3}+\alpha\beta$	$\mathcal{T}_{2^+}^{\#1}+\alpha\beta$	$\Delta_{2^+}^{\#1}\alpha\beta\chi$	$\Delta_{2^+}^{\#2}\alpha\beta\chi$
0	$\frac{2\sqrt{\frac{2}{3}}}{a_0}$	$\frac{4}{\sqrt{3}a_0}$	$\frac{4i\sqrt{2}}{a_0k}$	0	0
$\frac{2\sqrt{\frac{2}{3}}}{a_0}$	$-\frac{8}{3a_0}$	$-\frac{2\sqrt{2}}{3a_0}$	$-\frac{4i}{\sqrt{3}a_0k}$	0	0
$\frac{4}{\sqrt{3}a_0}$	$-\frac{2\sqrt{2}}{3a_0}$	$\frac{8}{3a_0}$	$-\frac{4i\sqrt{\frac{2}{3}}}{a_0k}$	0	0
$-\frac{4i\sqrt{2}}{a_0k}$	$\frac{4i}{\sqrt{3}a_0k}$	$\frac{4i\sqrt{\frac{2}{3}}}{a_0k}$	$-\frac{8}{a_0k^2}$	0	0
0	0	0	0	$\frac{4}{a_0}$	0
0	0	0	0	0	$\frac{4}{a_0}$

Massive and massless spectra



Quadratic pole

Pole residue: $-\frac{1}{s_0} > 0$

Polarisations: 2

(No massive particles)

Unitarity conditions

$a_0 < 0$