

# Particle spectrograph

## Wave operator and propagator

	$\Delta_{1^+ \alpha \beta}^{#1}$	$\Delta_{1^+ \alpha \beta}^{#2}$	$\Delta_{1^+ \alpha \beta}^{#3}$	$\Delta_{1^+ \alpha \beta}^{#1^-}$	$\Delta_{1^+ \alpha \beta}^{#2}$	$\Delta_{1^+ \alpha \beta}^{#3}$	$\Delta_{1^+ \alpha \beta}^{#4}$	$\Delta_{1^+ \alpha \beta}^{#5}$	$\Delta_{1^+ \alpha \beta}^{#6}$	$\mathcal{T}_{1^+ \alpha}^{#1}$
$\Delta_{1^+}^{#1} \dagger^{\alpha \beta}$	0	$-\frac{2\sqrt{2}}{a_0}$	0	0	0	0	0	0	0	0
$\Delta_{1^+}^{#2} \dagger^{\alpha \beta}$	$-\frac{2\sqrt{2}}{a_0}$	$\frac{2}{a_0}$	0	0	0	0	0	0	0	0
$\Delta_{1^+}^{#3} \dagger^{\alpha \beta}$	0	0	$\frac{4}{a_0}$	0	0	0	0	0	0	0
$\Delta_{1^+}^{#1^-} \dagger^{\alpha}$	0	0	0	$\frac{2\sqrt{2}}{a_0}$	0	0	0	0	0	0
$\Delta_{1^+}^{#2^-} \dagger^{\alpha}$	0	0	0	$\frac{2\sqrt{2}}{a_0}$	$\frac{2}{a_0}$	0	0	0	0	0
$\Delta_{1^+}^{#3^-} \dagger^{\alpha}$	0	0	0	0	0	$-\frac{19}{12a_0}$	$\frac{5\sqrt{5}}{12a_0}$	$-\frac{1}{6\sqrt{2}a_0}$	$-\frac{1}{6a_0}$	0
$\Delta_{1^+}^{#4} \dagger^{\alpha}$	0	0	0	0	0	$\frac{5\sqrt{5}}{12a_0}$	$-\frac{1}{12a_0}$	$-\frac{\sqrt{5}}{6a_0}$	$-\frac{\sqrt{5}}{6a_0}$	0
$\Delta_{1^+}^{#5} \dagger^{\alpha}$	0	0	0	0	0	$-\frac{1}{6\sqrt{2}a_0}$	$-\frac{\sqrt{2}}{6a_0}$	$-\frac{17}{6a_0}$	$-\frac{7}{3\sqrt{2}a_0}$	0
$\Delta_{1^+}^{#6} \dagger^{\alpha}$	0	0	0	0	0	$-\frac{1}{6a_0}$	$-\frac{\sqrt{5}}{6a_0}$	$-\frac{7}{3\sqrt{2}a_0}$	$-\frac{5}{3a_0}$	0
$\mathcal{T}_{1^+}^{#1} \dagger^{\alpha}$	0	0	0	0	0	0	0	0	0	0

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

Quadratic (free) action

$$S = \iiint \left( \frac{1}{8} h^{\alpha \beta} \mathcal{T}_{\alpha \beta} - 4 \Gamma^{\alpha \beta \chi} (a_0 \Gamma_{\beta \chi \alpha} - 2 \Delta_{\alpha \beta \chi} + a_0 \partial_{\beta} h_{\alpha \chi}) + 2 a_0 \Gamma_{\alpha}^{\alpha \beta} \partial_{\beta} h^{\chi}{}_{\chi} - 2 a_0 h^{\chi}{}_{\chi} \partial_{\beta} \Gamma_{\alpha}^{\alpha \beta} + 2 a_0 h^{\chi}{}_{\chi} \partial_{\beta} \Gamma_{\alpha}^{\alpha \beta} - 4 a_0 h_{\alpha \chi} \partial_{\beta} \Gamma^{\alpha \beta \chi} + 4 a_0 h^{\alpha \beta} \partial_{\beta} \partial_{\alpha} h^{\chi}{}_{\chi} - a_0 \partial_{\beta} h^{\chi}{}_{\chi} \partial_{\beta} h^{\alpha}{}_{\alpha} - 4 a_0 \partial_{\alpha} h^{\alpha \beta} \partial_{\chi} h_{\beta}^{\chi} + 4 a_0 \partial_{\beta} h_{\alpha}^{\alpha} \partial_{\chi} h_{\beta}^{\chi} + 2 a_0 \Gamma_{\alpha}^{\alpha \beta} (2 \Gamma_{\beta \chi}^{\chi} - \partial_{\beta} h^{\chi}{}_{\chi} + 2 \partial_{\chi} h_{\beta}^{\chi}) - 8 a_0 h^{\alpha \beta} \partial_{\chi} \partial_{\beta} h_{\alpha}^{\chi} + 2 a_0 h_{\alpha}^{\alpha} \partial_{\chi} \partial_{\beta} h^{\beta \chi} + 4 a_0 h^{\alpha \beta} \partial_{\chi} \partial_{\beta} h_{\alpha \chi}^{\chi} - 2 a_0 h_{\alpha}^{\alpha} \partial_{\chi} \partial_{\beta} h^{\beta}{}_{\beta} - 2 a_0 \partial_{\beta} h_{\alpha \chi}^{\chi} \partial^{\chi} h^{\alpha \beta} + 3 a_0 \partial_{\chi} h_{\alpha \beta}^{\alpha} \partial^{\chi} h^{\alpha \beta} + 4 a_0 h_{\beta \chi} \partial^{\chi} \Gamma_{\alpha}^{\alpha \beta} \right) [t, x, y, z] dz dy dx dt$$

Source constraints	Fundamental fields	Multiplicities
$\mathcal{T}_{0^+}^{#2} == 0$	$\partial_{\beta} \partial_{\alpha} \mathcal{T}^{\alpha \beta} == 0$	1
$\Delta_{0^+}^{#3} + 2 \Delta_{0^+}^{#4} + 3 \Delta_{0^+}^{#2} == 0$	$\partial_{\alpha} \Delta^{\alpha \beta}{}_{\beta} == 0$	1
$\mathcal{T}_{1^+}^{#1 \alpha} == 0$	$\partial_{\chi} \partial_{\beta} \partial^{\alpha} \mathcal{T}^{\alpha \beta \chi} == \partial_{\chi} \partial^{\chi} \partial_{\beta} \mathcal{T}^{\alpha \beta}$	3
$2 \Delta_{1^+}^{#6 \alpha} + \Delta_{1^+}^{#4 \alpha} + 2 \Delta_{1^+}^{#5 \alpha} + \Delta_{1^+}^{#3 \alpha} == 0$	$\partial_{\beta} \partial^{\alpha} \Delta^{\beta \chi}{}_{\chi} == \partial_{\chi} \partial^{\chi} \Delta^{\alpha \beta}{}_{\beta}$	3
Total constraints/gauge generators:		
		8

	$\Delta_{0^+}^{#1}$	$\Delta_{0^+}^{#2}$	$\Delta_{0^+}^{#3}$	$\Delta_{0^+}^{#4}$	$\mathcal{T}_{0^+}^{#1}$	$\mathcal{T}_{0^+}^{#2}$	$\Delta_{0^+}^{#1}$
$\Delta_{0^+}^{#1} \dagger$	$-\frac{2}{a_0}$	0	0	0	0	0	0
$\Delta_{0^+}^{#2} \dagger$	0	$-\frac{3}{4a_0}$	$\frac{5}{4a_0}$	$-\frac{1}{2\sqrt{2}a_0}$	0	0	0
$\Delta_{0^+}^{#3} \dagger$	0	$\frac{5}{4a_0}$	$-\frac{3}{4a_0}$	$-\frac{1}{2\sqrt{2}a_0}$	0	0	0
$\Delta_{0^+}^{#4} \dagger$	0	$-\frac{1}{2\sqrt{2}a_0}$	$\frac{1}{2a_0}$	$\frac{1}{2a_0}$	0	0	0
$\mathcal{T}_{0^+}^{#1} \dagger$	0	0	0	0	$\frac{4}{a_0 k^2}$	0	0
$\mathcal{T}_{0^+}^{#2} \dagger$	0	0	0	0	0	0	0
$\Delta_{0^+}^{#1} \dagger$	0	0	0	0	0	$-\frac{2}{a_0}$	0

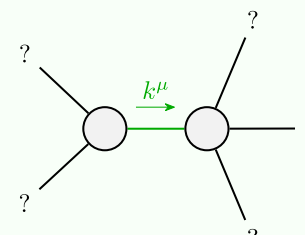
$\omega_{\alpha \beta \chi}^{#1} \dagger^{\alpha \beta \chi}$  $\Delta_{3^+}^{#1} \dagger^{\alpha \beta \chi}$  $-\frac{2}{a_0}$  $\Gamma_{3^+}^{#1} \dagger^{\alpha \beta \chi}$  $-\frac{a_0}{2}$

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

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

$\Gamma_{2^+}^{#1} \dagger^{\alpha \beta}$  $\Gamma_{2^+}^{#2} \dagger^{\alpha \beta}$  $\Gamma_{2^+}^{#3} \dagger^{\alpha \beta}$  $h_{2^+}^{#1} \dagger^{\alpha \beta}$  $\Gamma_{2^+}^{#1} \dagger^{\alpha \beta \chi}$  $\Gamma_{2^+}^{#2} \dagger^{\alpha \beta \chi}$  $\frac{a_0}{4}$  $-\frac{a_0}{2}$  $\frac{a_0}{4}$  $-\frac{a_0}{2}$  $-\frac{a_0 k^2}{8}$  $\frac{a_0}{4}$  $0$  $\frac{a_0}{4}$  $0$

## Massive and massless spectra



Quadratic pole

Pole residue:  $-\frac{1}{a_0} > 0$

Polarisations: 2

(No massive particles)

## Unitarity conditions

$a_0 < 0$