

Particle spectrograph

Wave operator and propagator

| | $\sigma_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\sigma_{1+}^{\#2} \dagger^{\alpha\beta}$ | $\tau_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\sigma_{1-}^{\#1} \dagger^{\alpha}$ | $\sigma_{1-}^{\#2} \dagger^{\alpha}$ | $\tau_{1-}^{\#1} \dagger^{\alpha}$ | $\tau_{1-}^{\#2} \dagger^{\alpha}$ |
|---|---|---|---|---|--|------------------------------------|---|
| $\sigma_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\frac{1}{k^2(2r_1+r_5)}$ | 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 | $\frac{1}{k^2(r_1+r_5)}$ | $\frac{\sqrt{2}}{k^2(1+2k^2)(r_1+r_5)}$ | 0 | $\frac{2i}{k(1+2k^2)(r_1+r_5)}$ |
| $\sigma_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | 0 | $\frac{\sqrt{2}}{k^2(1+2k^2)(r_1+r_5)}$ | $\frac{3k^2(r_1+r_5)+2t_3}{(k+2k^3)^2(r_1+r_5)t_3}$ | 0 | $\frac{i\sqrt{2}(3k^2(r_1+r_5)+2t_3)}{k(1+2k^2)^2(r_1+r_5)t_3}$ |
| $\tau_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $\tau_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | 0 | $-\frac{2i}{k(1+2k^2)(r_1+r_5)}$ | $-\frac{i\sqrt{2}(3k^2(r_1+r_5)+2t_3)}{k(1+2k^2)^2(r_1+r_5)t_3}$ | 0 | $\frac{6k^2(r_1+r_5)+4t_3}{(1+2k^2)^2(r_1+r_5)t_3}$ |

| | $\omega_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\omega_{1+}^{\#2} \dagger^{\alpha\beta}$ | $f_{1+}^{\#1} \dagger^{\alpha\beta}$ | $\omega_{1-}^{\#1} \dagger^{\alpha}$ | $\omega_{1-}^{\#2} \dagger^{\alpha}$ | $f_{1-}^{\#1} \dagger^{\alpha}$ | $f_{1-}^{\#2} \dagger^{\alpha}$ |
|---|---|---|--------------------------------------|--------------------------------------|--------------------------------------|---------------------------------|---------------------------------|
| $\omega_{1+}^{\#1} \dagger^{\alpha\beta}$ | $k^2(2r_1+r_5)$ | 0 | 0 | 0 | 0 | 0 | 0 |
| $\omega_{1+}^{\#2} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $f_{1+}^{\#1} \dagger^{\alpha\beta}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $\omega_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | 0 | $k^2(r_1+r_5)+\frac{2t_3}{3}$ | $-\frac{\sqrt{2}t_3}{3}$ | 0 | $-\frac{2}{3}i\sqrt{2}kt_3$ |
| $\omega_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | 0 | $-\frac{\sqrt{2}t_3}{3}$ | $\frac{t_3}{3}$ | 0 | $\frac{1}{3}i\sqrt{2}kt_3$ |
| $f_{1-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | 0 | 0 | 0 | 0 | 0 |
| $f_{1-}^{\#2} \dagger^{\alpha}$ | 0 | 0 | 0 | $\frac{2ikt_3}{3}$ | $-\frac{1}{3}i\sqrt{2}kt_3$ | 0 | $\frac{2k^2t_3}{3}$ |

Quadratic (free) Lagrangian density

$$\begin{aligned}
 & \frac{2}{3}t_3\omega_{\lambda}^{\alpha\lambda}\omega_{\kappa\alpha}^{\alpha\lambda}\omega_{\kappa\alpha}^{\alpha\lambda}+f^{\alpha\beta}\tau_{\alpha\beta}+\omega^{\alpha\beta\chi}\sigma_{\alpha\beta\chi}-r_5\partial_{\lambda}\omega_{\kappa}^{\kappa\lambda}\partial^{\lambda}\omega_{\lambda}^{\alpha}+\frac{2}{3}r_1\partial^{\beta}\omega^{\theta\alpha}\partial_{\kappa}\omega_{\alpha\beta}^{\kappa}- \\
 & \frac{2}{3}r_1\partial_{\theta}\omega_{\alpha\beta}^{\kappa}\partial_{\kappa}\omega_{\alpha\beta}^{\theta\kappa\lambda}+\frac{2}{3}r_1\partial_{\theta}\omega_{\alpha\beta}^{\kappa}\partial_{\kappa}\omega_{\alpha\beta}^{\theta\kappa\lambda}-r_5\partial_{\alpha}\omega_{\lambda}^{\alpha}\partial_{\theta}\omega_{\lambda}^{\theta\kappa\lambda}+ \\
 & r_5\partial_{\theta}\omega_{\lambda}^{\alpha}\partial_{\kappa}\omega_{\alpha}^{\theta\kappa\lambda}-r_5\partial_{\alpha}\omega_{\lambda}^{\alpha}\partial_{\theta}\omega_{\lambda}^{\theta\kappa\lambda}+2r_5\partial_{\theta}\omega_{\lambda}^{\alpha}\partial_{\kappa}\omega_{\lambda}^{\theta\kappa\lambda}-\frac{2}{3}t_3\omega_{\kappa\alpha}^{\alpha}\partial^{\kappa}f_{\lambda}^{\lambda}- \\
 & \frac{2}{3}t_3\omega_{\kappa\lambda}^{\lambda}\partial^{\kappa}f_{\lambda}^{\lambda}-\frac{4}{3}t_3\partial^{\alpha}f_{\kappa\alpha}\partial^{\kappa}f_{\lambda}^{\lambda}+\frac{2}{3}t_3\partial_{\kappa}f_{\lambda}^{\lambda}\partial^{\kappa}f_{\lambda}^{\lambda}+\frac{2}{3}t_3\omega_{\lambda\alpha}^{\alpha}\partial^{\kappa}f_{\kappa}^{\lambda}+ \\
 & \frac{2}{3}t_3\omega_{\lambda\alpha}^{\lambda}\partial^{\kappa}f_{\kappa}^{\lambda}+\frac{2}{3}t_3\partial^{\alpha}f_{\alpha}^{\lambda}\partial^{\kappa}f_{\lambda\kappa}+\frac{2}{3}r_1\partial_{\kappa}\omega^{\alpha\beta\theta}\partial^{\kappa}\omega_{\alpha\beta\theta}-\frac{2}{3}r_1\partial_{\kappa}\omega^{\theta\alpha\beta}\partial^{\kappa}\omega_{\alpha\beta\theta}+ \\
 & \frac{2}{3}r_1\partial^{\beta}\omega_{\lambda}^{\alpha\lambda}\partial_{\lambda}\omega_{\alpha\beta}^{\lambda}-\frac{8}{3}r_1\partial^{\beta}\omega_{\lambda}^{\lambda}\partial_{\lambda}\omega_{\alpha\beta}^{\lambda}+r_5\partial_{\alpha}\omega_{\lambda}^{\alpha}\partial_{\theta}\omega_{\lambda}^{\theta\kappa}-r_5\partial_{\theta}\omega_{\lambda}^{\alpha}\partial_{\alpha}\omega_{\lambda}^{\theta\kappa}
 \end{aligned}$$

| | $\sigma_{2+}^{\#1} \dagger^{\alpha\beta}$ | $\tau_{2+}^{\#1} \dagger^{\alpha\beta}$ | $\sigma_{2-}^{\#1} \dagger^{\alpha\beta\chi}$ |
|---|---|---|---|
| $\sigma_{2+}^{\#1} \dagger^{\alpha\beta}$ | 0 | 0 | 0 |
| $\tau_{2+}^{\#1} \dagger^{\alpha\beta}$ | 0 | 0 | 0 |
| $\sigma_{2-}^{\#1} \dagger^{\alpha\beta\chi}$ | 0 | 0 | $\frac{1}{k^2r_1}$ |

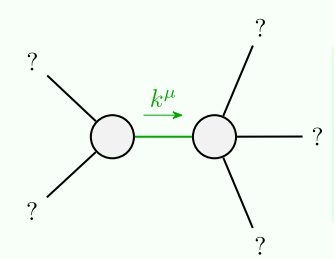
| | $\omega_{2+}^{\#1} \dagger^{\alpha\beta}$ | $f_{2+}^{\#1} \dagger^{\alpha\beta}$ | $\omega_{2-}^{\#1} \dagger^{\alpha\beta\chi}$ |
|---|---|--------------------------------------|---|
| $\omega_{2+}^{\#1} \dagger^{\alpha\beta}$ | 0 | 0 | 0 |
| $f_{2+}^{\#1} \dagger^{\alpha\beta}$ | 0 | 0 | 0 |
| $\omega_{2-}^{\#1} \dagger^{\alpha\beta\chi}$ | 0 | 0 | k^2r_1 |

| Source constraints/gauge generators | Multiplicities |
|---|----------------|
| $\sigma_{0-}^{\#1} == 0$ | 1 |
| $\tau_{0+}^{\#2} == 0$ | 1 |
| $\tau_{0+}^{\#1} - 2ik\sigma_{0+}^{\#1} == 0$ | 1 |
| $\tau_{1-}^{\#2\alpha} + 2ik\sigma_{1-}^{\#2\alpha} == 0$ | 3 |
| $\tau_{1-}^{\#1\alpha} == 0$ | 3 |
| $\tau_{1+}^{\#1\alpha\beta} == 0$ | 3 |
| $\sigma_{1+}^{\#2\alpha\beta} == 0$ | 3 |
| $\tau_{2+}^{\#1\alpha\beta} == 0$ | 5 |
| $\sigma_{2+}^{\#1\alpha\beta} == 0$ | 5 |
| Total constraints: | 25 |

| | $\omega_{0+}^{\#1} \dagger^{\alpha}$ | $f_{0+}^{\#1} \dagger^{\alpha}$ | $f_{0+}^{\#2} \dagger^{\alpha}$ | $\omega_{0-}^{\#1} \dagger^{\alpha}$ |
|--------------------------------------|--------------------------------------|---------------------------------|---------------------------------|--------------------------------------|
| $\omega_{0+}^{\#1} \dagger^{\alpha}$ | t_3 | $-i\sqrt{2}kt_3$ | 0 | 0 |
| $f_{0+}^{\#1} \dagger^{\alpha}$ | $i\sqrt{2}kt_3$ | $2k^2t_3$ | 0 | 0 |
| $f_{0+}^{\#2} \dagger^{\alpha}$ | 0 | 0 | 0 | 0 |
| $\omega_{0-}^{\#1} \dagger^{\alpha}$ | 0 | 0 | 0 | 0 |

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

Massive and massless spectra



| | |
|----------------|--|
| Quadratic pole | |
| Pole residue: | $-\frac{1}{r_1(r_1+r_5)(2r_1+r_5)p^2} > 0$ |
| Polarisations: | 2 |

(No massive particles)

Unitarity conditions

$$r_1 < 0 \&\& (r_5 < -r_1 \parallel r_5 > -2r_1) \parallel r_1 > 0 \&\& -2r_1 < r_5 < -r_1$$