# Particle spectrograph

## Wave operator and propagator

Quadratic (free) Lagrangian density

$$\frac{2}{3} t_2\, \omega_i{}^{\kappa\lambda}\, \omega_{\kappa\lambda}{}^i + \frac{1}{3} t_2\, \omega_{\kappa\lambda}{}^i\, \omega^{\kappa\lambda}{}_i + f^{\alpha\beta}\, \tau_{\alpha\beta} + \omega^{\alpha\beta\chi}\, \sigma_{\alpha\beta\chi} - r_3\, \partial_i\omega^{\kappa\lambda}{}_\kappa\, \partial^i\omega_\lambda{}^\alpha{}_\alpha + \cdots$$

### Matrix tables

| $\sigma_{0^+}^{\#1}$ | $\tau_{0^+}^{\#1}$ | $\tau_{0^+}^{\#2}$ | $\sigma_{0^-}^{\#1}$ |
|---|---|---|---|

| | $\sigma_{0^+}^{\#1}$ | $\tau_{0^+}^{\#1}$ | $\tau_{0^+}^{\#2}$ | $\sigma_{0^-}^{\#1}$ |
|---|---|---|---|---|
| $\sigma_{0^+}^{\#1}\dagger$ | $\frac{1}{6\,k^2\,r_3}$ | 0 | 0 | 0 |
| $\tau_{0^+}^{\#1}\dagger$ | 0 | 0 | 0 | 0 |
| $\tau_{0^+}^{\#2}\dagger$ | 0 | 0 | 0 | 0 |
| $\sigma_{0^-}^{\#1}\dagger$ | 0 | 0 | 0 | $\frac{1}{k^2\,r_2+t_2}$ |

| | $\omega_{0^+}^{\#1}$ | $f_{0^+}^{\#1}$ | $f_{0^+}^{\#2}$ | $\omega_{0^-}^{\#1}$ |
|---|---|---|---|---|
| $\omega_{0^+}^{\#1}\dagger$ | $6\,k^2\,r_3$ | 0 | 0 | 0 |
| $f_{0^+}^{\#1}\dagger$ | 0 | 0 | 0 | 0 |
| $f_{0^+}^{\#2}\dagger$ | 0 | 0 | 0 | 0 |
| $\omega_{0^-}^{\#1}\dagger$ | 0 | 0 | 0 | $k^2\,r_2+t_2$ |
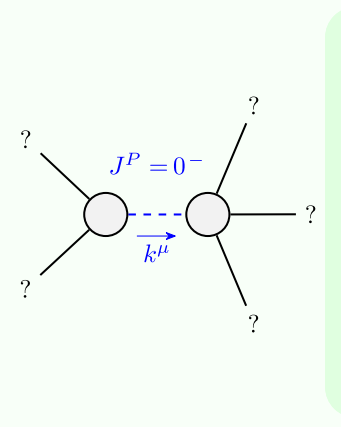
### Source constraints/gauge generators

| SO(3) irreps | Multiplicities |
|---|---|
| $\tau_{0^+}^{\#2} == 0$ | 1 |
| $\tau_{0^+}^{\#1} == 0$ | 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 |
| $\sigma_{2^+}^{\#1\,\alpha\beta} == 0$ | 5 |
| Total constraints: | 29 |

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

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

## 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 |

$J^P = 0^-$

(No massless particles)

## Unitarity conditions

$r_2 < 0\ \&\&\ t_2 > 0$