

# Particle spectrograph

# Wave operator and propagator

## Quadratic (free) action

§

$$\begin{aligned}
& -2r_3(\partial_\beta \mathcal{A}^\theta_\theta \partial' \mathcal{A}^{\alpha\beta}_\alpha + \partial'_\beta \mathcal{A}^\theta_\theta \partial' \mathcal{A}^{\alpha\beta}_\alpha + \partial'_\alpha \mathcal{A}^{\alpha\beta}_\alpha \partial_\beta \mathcal{A}^\theta_\theta - \\
& \quad \partial' \mathcal{A}^{\alpha\beta}_\alpha \partial_\beta \mathcal{A}^\theta_\theta + \partial'_\alpha \mathcal{A}^{\alpha\beta}_\alpha \partial_\beta \mathcal{A}^\theta_\theta - \\
& \quad 2\partial' \mathcal{A}^{\alpha\beta}_\alpha \partial_\beta \mathcal{A}^\theta_\theta + 2\partial_\beta \mathcal{A}^\theta_\theta \partial'^\theta \mathcal{A}^{\alpha\beta}_\alpha) + \\
& \quad \frac{2}{3}r_1(3\partial_\beta \mathcal{A}^\theta_\theta \partial' \mathcal{A}^{\alpha\beta}_\alpha + 3\partial'_\beta \mathcal{A}^\theta_\theta \partial' \mathcal{A}^{\alpha\beta}_\alpha + \\
& \quad 3\partial_\alpha \mathcal{A}^{\alpha\beta}_\alpha \partial_\beta \mathcal{A}^\theta_\theta - 6\partial' \mathcal{A}^{\alpha\beta}_\alpha \partial_\beta \mathcal{A}^\theta_\theta + \\
& \quad 3\partial_\alpha \mathcal{A}^{\alpha\beta}_\alpha \partial_\beta \mathcal{A}^\theta_\theta - 6\partial' \mathcal{A}^{\alpha\beta}_\alpha \partial_\beta \mathcal{A}^\theta_\theta - 2\partial_\beta \mathcal{A}^\theta_\theta \\
& \quad \partial'^\theta \mathcal{A}^{\alpha\beta}_\alpha + \partial_\beta \mathcal{A}^\theta_\theta \partial'^\theta \mathcal{A}^{\alpha\beta}_\alpha + 2\partial_\beta \mathcal{A}^\theta_\theta \partial'_\alpha \mathcal{A}^{\alpha\beta}_\alpha - \\
& \quad \partial'_\beta \mathcal{A}^\theta_\theta \partial'^\theta \mathcal{A}^{\alpha\beta}_\alpha + \partial_\beta \mathcal{A}^\theta_\theta \partial'^\theta \mathcal{A}^{\alpha\beta}_\alpha + \partial_\beta \mathcal{A}^\theta_\theta \partial'^\theta \mathcal{A}^{\alpha\beta}_\alpha) + \\
& \quad r_5(\partial'_\beta \mathcal{A}^\kappa_\theta \partial'^\theta \mathcal{A}^{\alpha\beta}_\alpha - \partial_\beta \mathcal{A}^\kappa_\theta \partial'^\theta \mathcal{A}^{\alpha\beta}_\alpha - (\partial_\alpha \mathcal{A}^{\alpha\theta}_\theta - 2\partial'^\theta \mathcal{A}^{\alpha\beta}_\alpha) \\
& \quad (\partial_\kappa \mathcal{A}^\kappa_\theta - \partial_\kappa \mathcal{A}^\kappa_\theta))) [t, x, y, z] dz dy dx dt
\end{aligned}$$

## Source constraints

SO(3) irreps	Fundamental fields	Multiplicities
$\sigma_0^{#1} == 0$	$\epsilon \eta_{\alpha\beta\chi\delta} \partial^\delta \sigma^{\alpha\beta\chi} == 0$	1
$\sigma_1^{#2\alpha} == 0$	$\partial_\chi \partial_\beta \sigma^{\alpha\beta\chi} == 0$	3
$\sigma_1^{#2\alpha\beta} == 0$	$\partial_\delta \partial_\chi \partial^\alpha \sigma^{\beta\chi\delta} + \partial_\delta \partial^\delta \partial_\chi \sigma^{\alpha\beta\chi} == \partial_\delta \partial_\chi \partial^\beta \sigma^{\alpha\chi\delta}$	3
$\sigma_2^{#1\alpha\beta} == 0$	$3 \partial_\delta \partial_\chi \partial^\alpha \sigma^{\beta\chi\delta} + 3 \partial_\delta \partial_\chi \partial^\beta \sigma^{\alpha\chi\delta} + 2 \eta^{\alpha\beta} \partial_\epsilon \partial^\epsilon \partial_\delta \sigma^{\chi\delta} ==$ $2 \partial_\delta \partial^\beta \partial^\alpha \sigma^{\chi\delta} + 3 (\partial_\delta \partial^\delta \partial_\chi \sigma^{\alpha\chi\beta} + \partial_\delta \partial^\delta \partial_\chi \sigma^{\beta\chi\alpha})$	5
Total constraints/gauge generators:		12

$$\begin{array}{c}
\mathcal{A}_{0+}^{\#1} \quad \mathcal{A}_{0-}^{\#1} \\
\mathcal{A}_{0+}^{\#1} \dagger \quad \begin{array}{|c|c|} \hline 6k^2(-r_1+r_3) & 0 \\ \hline \end{array} \\
\mathcal{A}_{0-}^{\#1} \dagger \quad \begin{array}{|c|c|} \hline 0 & 0 \\ \hline \end{array}
\end{array}$$
  

$$\begin{array}{c}
\sigma_{1-}^{\#2} \alpha \quad \sigma_{1-}^{\#1} \alpha \\
\sigma_{1-}^{\#2} \alpha \quad \begin{array}{|c|c|c|c|} \hline 0 & 0 & 0 & 0 \\ \hline \end{array} \\
\sigma_{1-}^{\#1} \alpha \quad \begin{array}{|c|c|c|c|} \hline 0 & 0 & \frac{1}{k^2(-r_1+2r_3+r_5)} & 0 \\ \hline \end{array} \\
\sigma_{1+}^{\#2} \alpha \beta \quad \begin{array}{|c|c|c|c|} \hline 0 & 0 & 0 & 0 \\ \hline \end{array} \\
\sigma_{1+}^{\#1} \alpha \beta \quad \begin{array}{|c|c|c|c|} \hline \frac{1}{k^2(2r_3+r_5)} & 0 & 0 & 0 \\ \hline \end{array}
\end{array}$$
  

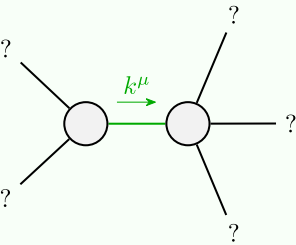
$$\begin{array}{c}
\sigma_{0+}^{\#1} \quad \sigma_{0-}^{\#1} \\
\sigma_{0+}^{\#1} \dagger \quad \begin{array}{|c|c|} \hline \frac{1}{6k^2(-r_1+r_3)} & 0 \\ \hline \end{array} \\
\sigma_{0-}^{\#1} \dagger \quad \begin{array}{|c|c|} \hline 0 & 0 \\ \hline \end{array}
\end{array}$$
  

$$\begin{array}{c}
\mathcal{A}_{2+}^{\#1} \alpha \beta \quad \mathcal{A}_{2-}^{\#1} \alpha \beta \chi \\
\mathcal{A}_{2+}^{\#1} \dagger \alpha \beta \quad \begin{array}{|c|c|} \hline 0 & 0 \\ \hline \end{array} \\
\mathcal{A}_{2-}^{\#1} \dagger \alpha \beta \chi \quad \begin{array}{|c|c|} \hline 0 & k^2 r_1 \\ \hline \end{array}
\end{array}$$
  

$$\begin{array}{c}
\sigma_{2+}^{\#1} \alpha \beta \quad \sigma_{2-}^{\#1} \alpha \beta \chi \\
\sigma_{2+}^{\#1} \dagger \alpha \beta \quad \begin{array}{|c|c|} \hline 0 & \frac{1}{k^2 r_1} \\ \hline \end{array} \\
\sigma_{2-}^{\#1} \dagger \alpha \beta \chi \quad \begin{array}{|c|c|} \hline 0 & 0 \\ \hline \end{array}
\end{array}$$
  

$$\begin{array}{c}
\mathcal{A}_{1+}^{\#1} \alpha \beta \quad \mathcal{A}_{1+}^{\#2} \alpha \beta \quad \mathcal{A}_{1-}^{\#1} \alpha \quad \mathcal{A}_{1-}^{\#2} \alpha \\
\mathcal{A}_{1+}^{\#1} \dagger \alpha \beta \quad \begin{array}{|c|c|c|c|} \hline k^2(2r_3+r_5) & 0 & 0 & 0 \\ \hline \end{array} \\
\mathcal{A}_{1+}^{\#2} \dagger \alpha \beta \quad \begin{array}{|c|c|c|c|} \hline 0 & 0 & 0 & 0 \\ \hline \end{array} \\
\mathcal{A}_{1-}^{\#1} \dagger \alpha \quad \begin{array}{|c|c|c|c|} \hline 0 & 0 & k^2(-r_1+2r_3+r_5) & 0 \\ \hline \end{array} \\
\mathcal{A}_{1-}^{\#2} \dagger \alpha \quad \begin{array}{|c|c|c|c|} \hline 0 & 0 & 0 & 0 \\ \hline \end{array}
\end{array}$$

# Massive and massless spectra



## Quadratic pole

Pole residue:	$\frac{1}{r_1 (r_1 - 2 r_3 - r_5) (2 r_3 + r_5)} > 0$
Polarisations:	2

(No massive particles)

# Unitarity conditions

$$r_1 < 0 \&\& (r_5 < r_1 - 2r_3 \parallel r_5 > -2r_3) \parallel r_1 > 0 \&\& -2r_3 < r_5 < r_1 - 2r_3$$