

# Particle spectrograph

# Wave operator and propagator

## Quadratic (free) action

$$S = \iiint (h^{\alpha\beta} \tau_{\alpha\beta} + \beta \partial_\alpha h^{\alpha\beta} \partial_\chi h_\beta^\chi + \frac{1}{2} \alpha (\partial_\beta h_\chi^\beta \partial^\beta h_\alpha^\alpha - 2 \partial^\beta h_\alpha^\alpha \partial_\chi h_\beta^\chi - \partial_\chi h_{\alpha\beta} \partial^\chi h^{\alpha\beta})) [t, x, y, z] dz dy dx dt$$

Diagram illustrating the construction of the source-free constraint matrix for the case where the source is not constrained. The diagram shows a sequence of operations on a matrix.

The initial matrix is:

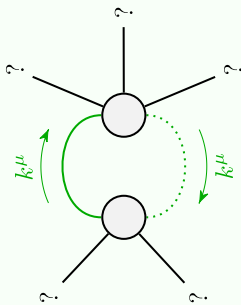
$$\begin{bmatrix} 0 & \frac{1}{\alpha k^2} \\ \frac{1}{(-\alpha + \beta) k^2} & 0 \end{bmatrix}$$

Operations shown include additions and multiplications involving terms like  $h_0^{#1}$ ,  $h_0^{#2}$ ,  $h_{-1}^{#1}$ , and  $h_{-1}^{#1-\alpha}$ .

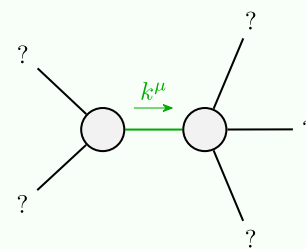
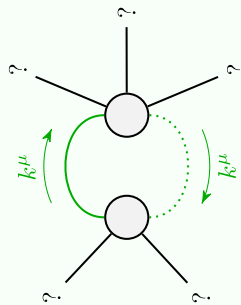
The final result is a matrix with the same structure as the initial one, but with a note "(No source constraints)" indicating the final state.

# Massive and massless spectra

Quartic pole	
Pole residue:	$0 < \frac{6 \alpha + 3 \beta \sqrt{3} \sqrt{12 \alpha^2 + 12 \alpha \beta + 19 \beta^2 + 64 (\alpha - \beta)^2} p^2}{\alpha (\alpha - \beta)} \&$ $\frac{6 \alpha + 3 \beta \sqrt{3} \sqrt{12 \alpha^2 + 12 \alpha \beta + 19 \beta^2 + 64 (\alpha - \beta)^2} p^2}{\alpha (\alpha - \beta)} > 0$
Polarisations:	1



Quartic pole	
Pole residue:	$0 < \frac{6 \alpha + 3 \beta + \sqrt{3} \sqrt{12 \alpha^2 + 12 \alpha \beta + 19 \beta^2 + 64 (\alpha - \beta)^2} p^2}{\alpha (\alpha - \beta)} \& \&$ $\frac{6 \alpha + 3 \beta + \sqrt{3} \sqrt{12 \alpha^2 + 12 \alpha \beta + 19 \beta^2 + 64 (\alpha - \beta)^2} p^2}{\alpha (\alpha - \beta)} > 0$
Polarisations:	1



Quadratic pole	
Pole residue:	$-\frac{2\alpha\beta + \sqrt{20\alpha^2 - 36\alpha\beta + 17\beta^2}}{\alpha^2 - \alpha\beta} > 0$
Polarisations:	1

Quadratic pole	
Pole residue:	$\frac{-2\alpha+\beta+\sqrt{20\alpha^2-36\alpha\beta+17\beta^2}}{\alpha(\alpha-\beta)} > 0$
Polarisations:	1

Quadratic pole	
Pole residue:	$-\frac{1}{\alpha} + \frac{5}{-\alpha+\beta} > 0$
Polarisations:	1

Quadratic pole	
Pole residue:	$\frac{1}{\alpha} + \frac{1}{\alpha - \beta} > 0$
Polarisations:	2

Quadratic pole	
Pole residue:	$\frac{1}{\alpha} + \frac{5}{\alpha - \beta} > 0$
Polarisations:	1

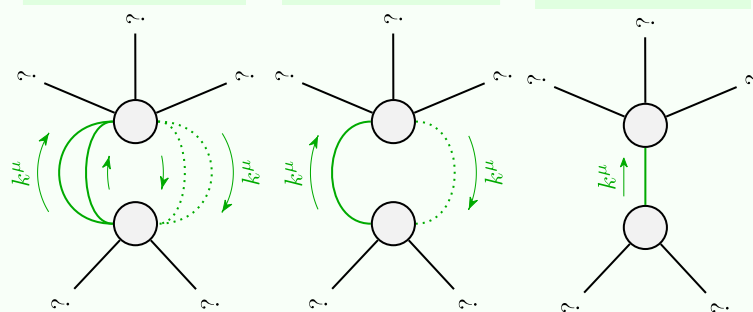
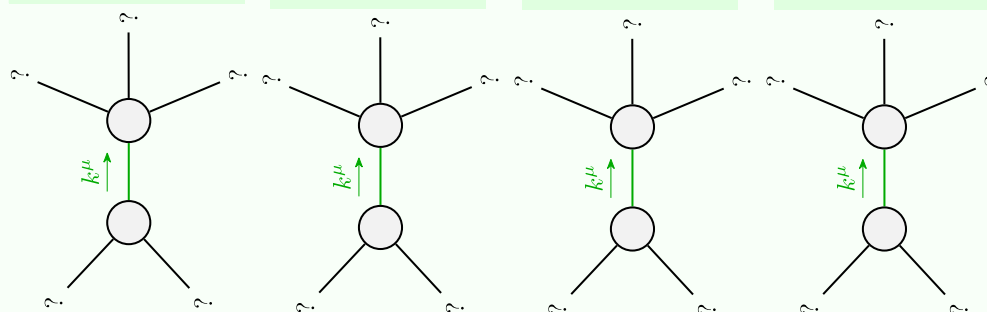
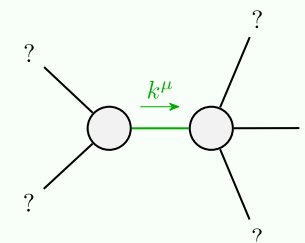
Hexic pole	
Pole residue:	$0 < \frac{2\alpha+\beta}{\alpha^2-\alpha\beta} \ \& \ \frac{2\alpha+\beta}{\alpha^2-\alpha\beta} > 0$
Polarisations:	1

Quartic pole	
Pole residue:	$0 < \frac{\beta}{\alpha^2 - \alpha\beta} \ \&\& \ \frac{\beta}{\alpha^2 - \alpha\beta} > 0$
Polarisations:	2

Quadratic pole	
Pole residue:	$-\frac{1}{\alpha} + \frac{1}{-\alpha+\beta} > 0$
Polarisations:	2

(No massive particles)

Quadratic pole	
Pole residue:	$-\frac{1}{\alpha} > 0$
Polarisations:	2



# Unitarity conditions

(Unitarity is demonstrably impossible)