

# Particle spectrograph

# Wave operator and propagator

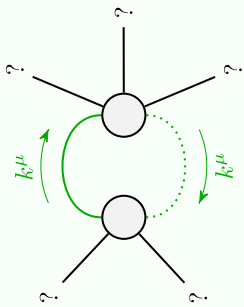
## Quadratic (free) action

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

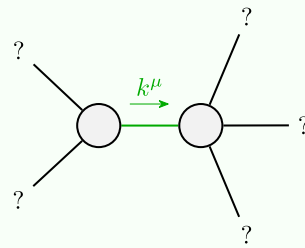
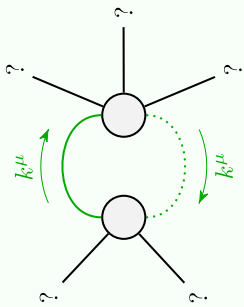
Diagram illustrating the construction of the source-free constraint matrix for the case where the source is not constrained. The diagram shows a sequence of operations on a matrix. It starts with a 2x2 matrix with elements 0,  $\frac{1}{\alpha k^2}$ ,  $\frac{1}{(-\alpha+\beta)k^2}$ , and 0. This is followed by a series of additions and multiplications involving terms like  $h_0^{\#1}$ ,  $h_0^{\#2}$ ,  $h_1^{\#1}$ ,  $h_1^{\#2}$ , and  $h_2^{\#1}$ , leading to a final matrix with elements  $\frac{1}{\alpha k^2}$ , 0,  $-\frac{2}{\alpha k^2}$ , and  $-\frac{1}{\alpha\beta}k^2$ . A green box labeled "(No source constraints)" is placed below the initial matrix.

# Massive and massless spectra

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

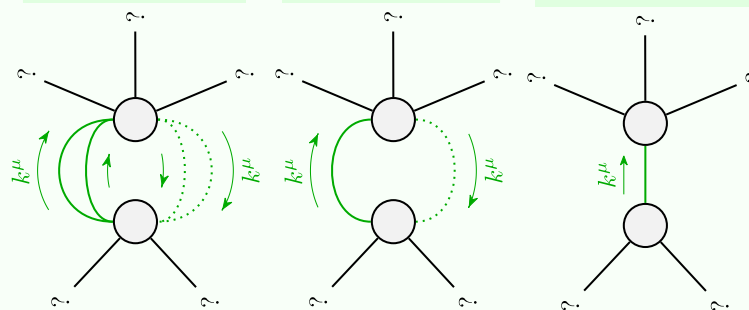
Quadratic pole	
Pole residue:	$\frac{1}{\alpha} + \frac{1}{\alpha - \beta} > 0$
Polarisations:	2

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:	$-\frac{1}{\alpha} + \frac{1}{-\alpha+\beta}$
Polarisations:	2



# Unitarity conditions

(Unitarity is demonstrably impossible)