

# Particle spectrograph

## Wave operator and propagator

$$S = \int d^4x \left( f^{\alpha\beta} \tau_{\alpha\beta} + c_3 \partial_\mu f^\nu \partial^\mu f^\alpha_\alpha + c_3 \partial_\mu f^{\alpha\mu} \partial_\nu f^\nu_\alpha - 2 c_3 \partial^\mu f^\alpha_\alpha \partial_\nu f^\nu_\mu - 2 c_2 \partial_{\alpha f} \partial_\beta \partial^\nu f^{\alpha\beta} + c_2 \partial_\beta f_{\alpha\nu} \partial^\nu f^{\alpha\beta} + c_2 \partial_\nu f_{\beta\alpha} \partial^\nu f^{\alpha\beta} - 2 c_1 \partial_{\alpha f} \partial_\nu \partial^\rho f^{\alpha\nu} + 2 c_1 \partial_\rho f_{\alpha\nu} \partial^\rho f^{\alpha\nu} \right) [t, x, y, z] d^4x$$

Spin-parity form	Covariant form	Multiplicities
$\#2$ $0^+ \tau = 0$	$\partial_\beta \partial_\alpha \tau^{\alpha\beta} = 0$	1
$\#1$ $1^- \tau^{\alpha} = 0$	$\partial_\chi \partial_\beta \partial^\alpha \tau^{\beta\chi} = \partial_\chi \partial_\beta \partial_\beta \tau^{\beta\alpha}$	3
Total expected gauge generators:		4

$\#1$ $1^+ \tau^{\alpha\beta}$	$\#1$ $1^- \tau_\alpha$	$\#2$ $1^- \tau_\alpha$
$\frac{1}{(2c_1+c_2)k^2}$	0	0
0	0	0
0	0	$\frac{1}{(2c_1+c_2+c_3)k^2}$

$\#1$ $1^+ \tau^{\dagger}$	$\#2$ $0^+ \tau^{\dagger}$	$\#1$ $0^+ \tau$	$\#2$ $0^+ \tau$
$\frac{1}{(2c_1+c_2+3c_3)k^2}$	0	0	0
0	0	0	0
0	0	0	0

$\#1$ $1^+ f^{\dagger}$	$\#1$ $1^+ f^{\dagger}$	$\#1$ $1^+ f^{\dagger}$	$\#1$ $1^+ f^{\dagger}$
$\frac{1}{(2c_1+c_2)k^2}$	0	0	0
0	0	0	0
0	0	0	0

$\#1$ $0^+ f$	$\#2$ $0^+ f$
$(2c_1+c_2+3c_3)k^2$	0
0	0

$\#1$ $2^+ f_{\alpha\beta}$
$(2c_1+c_2)k^2$

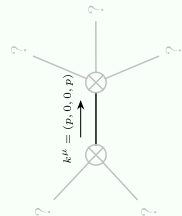
$\#1$ $2^+ \tau^{\dagger}$	$\#1$ $2^+ \tau^{\dagger}$	$\#1$ $2^+ \tau^{\dagger}$
$\frac{1}{(2c_1+c_2)k^2}$	0	0
0	0	0
0	0	0

$\#1$ $2^+ \tau_{\alpha\beta}$
$\frac{1}{(2c_1+c_2)k^2}$

## Massive and massless spectra

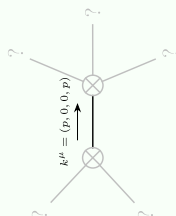
(No particles)



Massless particle

$$\text{Pole residue: } -\frac{\sqrt{64c_1^4+32c_1^3(c_2+c_3)+28c_1^2(c_2+c_3)+4c_1^2(5c_2^2+2c_2c_3+c_3^2)+c_2^2(9c_2^2+16c_2c_3+8c_3^2)}}{(4c_1^2-c_2^2)(2c_1+c_2+c_3)} > 0$$

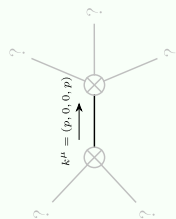
Polarisations:	2
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Massless particle

Poles residue:  $\frac{\sqrt{64c_1^4 + 32c_1^3(c_2 + c_3) + 28c_1c_2^2(c_2 + c_3) + 4c_1^2(5c_2^2 + 2c_2c_3 + c_3^2) + c_2^2(9c_2^2 + 16c_2c_3 + 8c_3^2)}}{(4c_1^2 - c_2^2)(2c_1 + c_2 + c_3)} > 0$

Polarisations:	2
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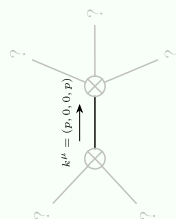
Massless particle

Polarisations:	1
Polarresidue:	$\frac{4+(2c_1+c_2+c_3)^2}{(2c_1+c_2)(2c_1+c_2+c_3)(2c_1+c_2+3c_3)} > 0$

## Polarisations

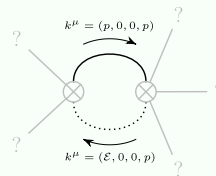
Massless particle

Poleresidue:	$\frac{1}{2c_1 - c_2} > 0$
Polarisations:	1



## Massless particle

Poleresidue:	$\frac{1}{2c_1+c_2} > 0$
Polarisations:	2



Quartic pole

Pole residue:	$0 < \frac{c_2^2 + 2c_1(c_2 + c_3)}{(4c_1^2 - c_2^2)(2c_1 + c_2 + c_3)} \&\& \frac{c_2^2 + 2c_1(c_2 + c_3)}{(4c_1^2 - c_2^2)(2c_1 + c_2 + c_3)} > 0$
Polarisations:	2

## Unitarity conditions

