

# Particle spectrograph

# Wave operator and propagator

## Quadratic (free) action

$$S \equiv$$

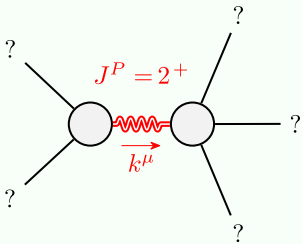
$$\iiint (\beta (h_{\alpha\beta} h^{\alpha\beta} - h^\alpha_\alpha h^\beta_\beta) + h^{\alpha\beta} \mathcal{T}_{\alpha\beta} + \frac{1}{2} \alpha (\partial_\beta h^\chi_\chi \partial^\beta h^\alpha_\alpha + 2 \partial_\alpha h^{\alpha\beta} \partial_\chi h^\chi_\beta - 2 \partial^\beta h^\alpha_\alpha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

Figure 1 illustrates the construction of the augmented Hessian matrix  $H^{\#}$  for the augmented Lagrangian method. The matrix is partitioned into blocks corresponding to the primal variables  $x$  and the dual variables  $\lambda$ . The blocks are:

- $H^{\#}_{xx} = H_{xx} + \sum_{i=1}^m \lambda_i^{\#} \nabla^2 L_i(x, \lambda_i^{\#})$
- $H^{\#}_{x\lambda} = -\sum_{i=1}^m \nabla L_i(x, \lambda_i^{\#})$
- $H^{\#}_{\lambda x} = \sum_{i=1}^m \nabla L_i(x, \lambda_i^{\#})$
- $H^{\#}_{\lambda\lambda} = \sum_{i=1}^m \nabla^2 L_i(x, \lambda_i^{\#})$

The diagram shows the iterative update of the dual variables  $\lambda_i^{\#}$  using the augmented Lagrangian method, which involves solving a subproblem for  $x$  and then updating  $\lambda_i^{\#}$  based on the constraint violation. The final matrix  $H^{\#}$  is used to solve the augmented Lagrangian problem, which is equivalent to the original problem.

# Massive and massless spectra



Massive particle	
Pole residue:	$-\frac{2}{\alpha} > 0$
Polarisations:	5
Square mass:	$\frac{2\beta}{\alpha} > 0$
Spin:	2
Parity:	Even

(No massless particles)

## Unitarity conditions

$$\alpha < 0 \ \&\& \ \beta < 0$$