



## MTHS24 – Exercise sheet 5

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Friday, 19 July 2024

## Lecture material

### Discussed topics:

- Three body decay kinematics
- Cascade parametrization of decays
- Helicity and covariant formalism

### References:

- A.D. Martin, T.D. Spearman, Elementary Particle Theory, [inSpire](#)
- Eero Byckling, K. Kajantie, Particle Kinematics, [inSpire](#)

## Exercises

### 5.1 Plastisin and Wires

In a laboratory setup, particle vectors for a three-body decay are represented using metal wire sticking out from a plasticine ball. The particles involved in the decay have masses of 1 GeV, 2 GeV, and 3 GeV respectively.

- (a) Compute the center of mass energy.
- (b) Compute the boost to the rest frame.
- (c) Locate the kinematic point on the Dalitz plot.
- (d) Use the plasticine and wire to show how the decay kinematics looks like in the system rest frame.

### 5.2 Spin of a New $\Lambda_b^{**0}$ State

A new  $\Lambda_b^{**0}$  state has been discovered decaying into  $\Lambda_b^0\pi^+\pi^-$  with a prominent  $\Sigma_b^*$  resonance line on the Dalitz plot. The decay intensity distribution along the  $\Sigma_b^*$  band is provided in the supplementary material, which includes the helicity angle distribution. Your task is to determine the spin  $J$  of the  $\Lambda_b^{**0}$  state.

- (a) Write down the decay matrix element for  $\Lambda_b^{**0} \rightarrow \Lambda_b^0\pi^+\pi^-$  using helicity formalism.
- (b) Identify the partial waves in the decay  $\Sigma_b^* \rightarrow \Lambda_b^0\pi$ .
- (c) Determine the partial waves in the decay  $\Lambda_b^{**0} \rightarrow \Sigma_b^*\pi$  for  $J^P = \frac{1}{2}^\pm, \frac{3}{2}^\pm, \frac{5}{2}^\pm$ .
- (d) Compute the unpolarized differential distribution given by:

$$\frac{dI}{d\cos\theta} = \sum_{\lambda_0, \lambda_1}^{\{-1/2, 1/2\}} \left| \langle L, 0; 3/2, \lambda_0 | J, \lambda_0 \rangle d_{\lambda_0, \lambda_1}^{3/2}(\theta) \langle 1, 0; 1/2, \lambda_1 | 3/2, \lambda_1 \rangle \right|^2$$