Referee report on Nora Salone, "Properties of Hyperon Decays"

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I have read Nora's thesis with a lot of interest. The thesis unveils a deep understanding of the candidate on the relation between theoretical foundations of effective models describing hadrons, and the possibilities to measure these experimentally. While the second and third chapter gives insights into the framework on which the thesis is based, namely the two main publications with Nora as the main author, the first chapter is an independent work, explaining the common objects of these two following parts, as these are the time-like and space-like form factors for the pair production and the decay of hyperons, respectively. In addition, the author gives an overview over the theoretical instruments used to describe the processes, as these are the spin-density matrix and the helicity formalism. Nonleptonic and semileptonic decays are the processes that, after the production of hyperons, are used to analyse the polarisations of the hyperons involved into the process.

While the general picture is very good and certainly sufficient to grant the title of a Doctor in Natural Sciences, in detail there are a couple of weak points I would like to stress in this report, combined with questions to the candidate. To start with the first chapter, I was slightly irritated on page 7 to see the vacuum polarisation of the gluon contributed only by the (one-loop) quark loops and (two-loop) pure gluonic loops containing four-gluon vertices, but not to see the one-loop contribution containing the three-gluon vertices. Is this a misunderstanding, or is there a deeper reason behind this?

As in the following chapters, there are also minor issues in this first chapter which are obviously typos, like the electron–proton scattering mentioned in the Summary of the first chapter, the lacking definition of the acronym SCTF for the Super Tau-Charm Factories that is exemplified first in the second chapter, and the relation between the constants A and B in Eq. (1.26) and the quantities S and P found in Eq. (1.28).

In the second chapter, I was surprised to see a linear factor C_{00} in the denominator of Equation (2.41), contrasted with the statement in the text after this equation that the tensor defined here results in the value 1 for $\mu = \nu = 1$. Considering this independenly from what is said about the Fisher information matrix, is looks more obvious to have a C_{00}^2 instead. On the other hand, using Equation (2.57) inserted into (2.52) makes it obvious that Equation (2.41) is valid. Do the candidate has some explanation for this discrepancy?

Again, there are a couple of minor issues, like for instance the normalisation of the first line in Equation (2.88) as compared to the second, the discrepancy between the footnotes labels in Table 2.2 (again occuring in Table 3.1 and probably caused by copying these tables from the publications without keeping the style options), the use of the particular

couple (Ξ, Λ) of baryons in (2.70-75) instead of the general notation (B, b) employed later, and the definition of $a^D_{\mu\nu}$ in Equation (2.49) after this quantity is used in Equation (2.46). Finally, I had problems to understand why the last indices in (2.50) are zero, while a rest frame is assumed only for the decaying baryon, not the baryon resulting from the decay.

The index notation for the bases employed in the third chapter is confusing. Regardless of the fact that the three chapters are taken from different sources, causing a different definition of the antibaryon bases in Figures 1.10 and 2.2 as compared to the one in Figure 3.1, the use of the indices 1 and 3 for the bases of the baryon and antibaryon frames look quite arbitrary and is caused only by the fact that a basis with index 2 is defined as the basis of the baryon, originally with index 1, in the rest frame of the baryon. I am used to the convention that boosted frames are indicated by primes attached to the basis vectors and coordinates instead of changing the index. The basis with index 1, by the way, is not defined in Figure 3.2, as stated in the caption, but rather in Figure 3.1, as Figure 3.2 does not indicate any angles or relations of this basis to the rest frame of the baryon.

To mention again a couple of minor issues for the third chapter (a list of suggestions in case the candidate wants to create a revision is added), Section 3.3 is not mentioned in the introduction of the chapter, the momentum four-vector before (3.7) should be written in contravariant instead of covariant components, the Pauli matrices in (3.37) are not transformed but the components they are acting on, and ε in (3.47) is not defined but could probably be defined in Equation (3.16). The wording at Equation (3.71) is misleading, as the author sets the matrix b to the unit matrix in order to get this matrix back in a general shape. Rather, it should be stressed that in order to extract the matrix R, the matrix b is first set to unity. After the determination of R, the general result for b can be obtained.

The fourth chapter summarises the preceding chapters in a conclusive way and gives a well-suited outlook into possible future investigations. The common features as well as the differences between the chapters are explained, concluding in this the introduction started in the first chapter. The steps done so far are summarised by this thesis in a reasonable way, and the author of this work has demonstrated that she has gained expertise and worked successfully on this interesting subject. Therefore, I support to grant the applicant the degree of a Doctor of Natural Sciences.

Tartu, September 9th, 2024 (Assoc. Prof. Dr. Stefan Groote)

Suggestions and further questions

- What is the reason for the factor $\sqrt{2}$ after Eq. (2.35)?
- The abbreviation s.d. is only rarely used and non-standard, and should be avoided.
- As a_b occurs in the denominators of (2.71-74), it is better to use $a_b \to 0$ than $a_b = 0$ in the second point on page 51. Where is the normalisation N from (2.70) gone?
- Wouldn't it be better to define $\mathcal{E}^{\mathrm{f}}_{11}$ with the opposite sign in order to align the flip part (3.54) with the non-flip part (3.51)?
- (3.74) is called the Euler rotation matrix.
- The sentence starting with "We do not consider ..." in Section 3.7 on page 91 would fit better to the next paragraph.
- The Summary of the third chapter contains a lot of acronyms that are not explained (JAD) or should be mentioned again at this point (SL, FF) in order to read this Summary independently from the main text.
- In the references, care should be taken about the umlauts, compare Refs. [156–158] (two occurrences in Ref. [157]) for instance with Ref. [175]. Note that in older papers, umlauts are often skipped, as the arXiv at that time did not show these umlauts in a proper way.