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Review report

on the PhD dissertation of Zoltán Varga

The central topic of the PhD dissertation of Zoltán Varga is the investigation of penetrating probes in high-energy heavy-ion collisions, in particular jets, their shapes and substructures; but also heavy flavor production. These topics are of highest relevance in today's research as these probes carry information about the early stages of the evolving matter created in ultra-relativistic heavy-ion collisions.

The dissertation is organized as follows. After a general introduction in Chapter 1, a more detailed description of the investigated topics is presented in Chapter 2, where all the necessary phenomena, observables and tools are thoroughly discussed. The subsequent chapters detail the work of the applicant. Chapter 3 is about the multiplicity dependence of jet shapes, Chapter 4 about jet structure scaling—both of these present phenomenological findings of the author. Chapter 5 discusses measured jet multiplicity distributions, obtained in the ALICE Collaboration. Chapter 6 discusses correlations of heavy-flavor electrons, also measured with ALICE, while the topic of Chapter 7 is simulated charmed baryon production. While each chapter contains its own summary, the entire document is also concluded by an overall summary. The thesis is furthermore well written and structured, with carefully prepared plots (although for some the labels or legends are a bit small).

I consider the following parts of the thesis as new scientific results.

1. The applicant analyzed the multiplicity dependence of the differential and integral structure of jets in pp collisions, with the Pythia event generator, comparing findings to experimental data. These represent a significant step in understanding jet production and evolution. He furthermore found scaling relations of (heavy-flavor) jets, also with the Pythia event generator.

2. In his work with the ALICE Collaboration, he measured unfolded jet multiplicity distributions in $\sqrt{s} = 13$ TeV pp collisions. His main role was to correct these for detector effects, and investigate scaling relations.

3. The applicant furthermore measured azimuthal correlations of heavy-flavor electrons in $\sqrt{s_{NN}} = 5.02$ TeV pp and p-Pb collisions; he mainly contributed to this ALICE analysis by performing simulations that made the comparison between the two collision systems possible.

4. Finally, he investigated event classifiers and their sensitivity to charm baryon production, utilizing Pythia simulations of pp collisons.

All these results are based on several high-quality papers. The applicant has five few-author publications about the phenomenology topics: one in Adv. High En. Phys., one in Universe, one in Symmetry, and two in J. Phys. G. He furthermore made significant contributions to a regular ALICE publication, appeared in Eur. Phys. J. C. This in my opinion means that the applicant is a successful scientist, with a considerable variety of results at an early career stage. Coincidentally, the thesis surely fulfills the criteria for moving forward with the doctoral defense.

I have the following questions:

1. There are many types of observables shown from both data and simulations. What would be one of the final, global goal of these investigations? In other words, ultimately what physical property of the strong interaction can be determined from these, and how? Is it the coupling constant of QCD, the quark-hadron transition temperature, or some kind of a transport property of the Quark-Gluon Plasma?

2. For many results, Pythia 8 was used, with a given set of settings (a "tune"). How much would the obtained results depend on the particularities of these settings, and is this dependence (or does it have to be) incorporated in the final systematic uncertainties?

3. While Chapter 3 utilizes the jet "radius" (R parameter) of 0.7 (as in the corresponding CMS analysis), for Chapter 5, $R = 0.4$ was used. Both analyses are in pp collisons. What is the reason behind this difference? How much do the results depend on this parameter?

4. In Section 5.3, the usage of RooUnfold is mentioned. How were uncertainties, in particular bin-by-bin correlations treated in this case, when estimating the uncertainties of the unfolded result? Furthermore, the author mentions that a 4D response matrix was created. Is this really still a 2D matrix, for which each "supercolumn" is a matrix, flattened?

5. Subtracting the baseline from angular correlations, as indicated in Section 6.4, needs a good control of angular event shapes, in particular higher-order flow coefficients. Based on that, would such a measurement, as the one shown in Figure 6.3 or 6.4, be also possible in PbPb collisions? This was once a highlight of jet-suppression measurements, as shown in Figure 2.9. What are the challenges in such a measurement, going from pp to pPb and PbPb?

Budapest, October 8, 2024

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