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Review Report on the doctoral thesis

Lambda transverse polarization in proton-proton interactions in NA61/SHINE at the CERN SPS

Thesis author: Yehor Bondar

Background & research goals

The topic of the PhD thesis *Lambda Transverse Polarization in Proton–Proton Interactions in NA61/SHINE at the CERN SPS* by Mr. Yehor Bondar is related to studies of the internal structure of hadronic matter and how its fundamental properties emerge. Specifically, the origin of transverse polarization of hyperons has been investigated for decades, including in recent results from LHC experiments. Several models have been proposed to describe hyperon polarization; however, no fully convincing mechanism explaining the observed effect has yet been identified. The thesis aims to provide new experimental results to help discriminate between the proposed models. Therefore, the selected research problem is both interesting and important for improving our understanding of the emerging properties of hyperons.

Thesis structure and content

The thesis has a classical structure. It begins an introduction to the research goals and a brief overview of the state of the art, both for experimental results and theoretical considerations.

Chapter 3 and 4 describe the experimental apparatus and experimental techniques used in the NA61/SHINE experiment for particle track reconstruction, particle identification, reconstruction of Λ baryons. Chapters 5 - 6 present the central part of the thesis, namely details of data analysis and corresponding Monte Carlo simulations (Chapter 5), while Chapter 6 contains the obtained results and their discussion. Chapter 7 presents the summary of the research and concludes the dissertation, providing also an outlook for future studies of transverse polarization of Λ baryons using new high-quality data samples collected recently by NA61/SHINE. Appendices A – D provides additional and supplemental information.

The overall structure is appropriate for the given topic, with the most prominent part devoted to the experimental techniques, data analysis and related simulations, and the final results.

The thesis is very carefully prepared. The text is well written, the figures and illustrations are of high quality. The detailed discussion of the systematic effects and their impact on the results is especially valuable.

Introduction and state of the art

The thesis briefly introduces the experimental results on hyperon polarization in high-energy nuclear reactions and relevant theory and models. This section is relatively short but supported by

sufficient references, making it fully appropriate and adequate given the experimental nature of the work. The general goals and specific objectives of the conducted research are clearly identified.

Presentation of experimental apparatus and techniques

The presentation of the NA61/SHINE detector setup and the experimental techniques used for Λ baryon reconstruction (including particle track reconstruction and identification, and Monte Carlo simulations) is very well developed and fully adequate. The thesis provides all the relevant information, including quality assurance criteria applied in the analysis. The text very convincingly demonstrates the author has an in-depth understanding of the experimental techniques and all the complex steps necessary to obtain the final physics results on Λ transverse polarization.

Data analysis and results

The work presents a study of Λ transverse polarization in proton-proton collisions recorded by the NA61/SHINE experiment at a proton beam momentum of 158 GeV/c.

The research methodology is well justified and credible, as it uses standard techniques employed in high-energy particle and nuclear experiments. The identification of hadrons used for Λ baryon reconstruction is performed via measurements of energy loss dE/dx as a function of momentum, while Λ candidates are identified using the invariant mass method. The results are binned as functions of relevant kinematic quantities. Monte Carlo simulations are employed to obtain corrections for detection efficiencies and experimental biases, as well as to estimate the systematic uncertainties related to the determination of corrections for detector effects. Finally, the polarization parameters, together with their statistical and systematic uncertainties, are obtained as functions of the Feynman variable x_F and transverse momentum p_T.

The analysis and results are presented with a high level of detail. The decisions made at various stages of the study are well-reasoned and credible, and the obtained results are sound and robust. Nevertheless, I have a few questions and remarks, which I list below.

The final results consist of transverse polarization of Λ baryons as a function of x_F and p_T, which are then compared with other available data and selected theoretical models. The NA61/SHINE data agree well with other experiments in the overlapping kinematic region.

Overall, I find the presentation of the analysis techniques pedagogical, which will make this thesis an excellent reference for future studies of this kind at NA61/SHINE. Although the precision of the experimental data does not allow for discrimination between the models, the results obtained in this thesis are interesting and represent a significant contribution to the field.

Questions and remarks

Below I summarize the points which are not fully clear to me.

1. Fig. 5.2 (page 38): What are the sources of difference between Monte Carlo simulations and experimental data?
2. Can you please elaborate on possible sources of issues resulting in not showing results at $x_F > 0.2$?
3. What are the potential sources of systematic uncertainties presented in Figs. 5.24 and 5.25?

Summary and final evaluation

The thesis presents a comprehensive analysis of Λ transverse polarization in proton-proton collisions at a beam momentum of 158 GeV/c, based on data recorded by the NA61/SHINE experiment at CERN. The work includes the reconstruction of Λ baryons, corrections for experimental biases and detector effects, calculation of the transverse polarization parameter, and a careful assessment of systematic uncertainties and related effects. The final results are presented as function of x_F and p_T and are compared with selected models and measurements from other experiments.

The author has demonstrated solid knowledge of the relevant theory and familiarity with other experimental results. He has mastered all the technical and data analysis skills required for work in modern high-energy particle or nuclear experiments. The thesis shows that the author possesses a strong understanding of the strengths and limitations of the NA61/SHINE experiment, as well as the methods and techniques he employed. I particularly appreciate the extensive discussion of systematic uncertainties and detector effects, which is presented with a high level of detail and will serve as a highly useful reference for future studies.

The presented results are both original and robust, making them a significant contribution to the field. The thesis demonstrates the scientific maturity of Mr. Yehor Bondar and his ability to undertake research projects independently.

In my opinion, the thesis demonstrates that Mr. Yehor Bondar meets the requirements laid down by the Polish law (*Prawo o szkolnictwie wyższym i nauce*, Dz. U. z 2020 r. poz. 85 z późniejszymi zmianami) for candidates for the degree of Doctor of Philosophy in Physics.

Uważam, że przedstawiona mi do recenzji rozprawa w pełni spełnia wymagania stawiane pracom doktorskim i z przekonaniem wnoszę o dopuszczenie Pana mgr. Yehora Bondara do dalszych etapów przewodu doktorskiego.

Podpisane elektronicznie przez Daniel Piotr Kikoła (Certyfikat kwalifikowany) w dniu 2025-12-29.