dr hab. inż. Tomasz Szumlak
Wydział Fizyki i Informatyki Stosowanej
Akademia Górniczo-Hutnicza
im. Stanisława Staszica w Krakowie

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Referee report on Ph.D. thesis entitled:

Self-Supporting Straw Tube Detectors for the COSY-TOF and PANDA Experiments

Sedigheh Jowzaee took part in studying behaviour of the self-supporting straw tube tracking detectors and performed data analysis regarding the reaction $\vec{p}p \rightarrow pK^{+}\Lambda$ with a polarised proton beam. Both topics are covered in the presented thesis. It should be noted, already at the beginning, that both aspects of the work done by Sedigheh Jowzaee are of the outmost importance for each experimental physicist. Intimate knowledge of the detection system is absolutely necessary for successful data analysis.

The submitted thesis consists of seven chapters that are preceded by a short introduction, describing the content of the paper and is finished by an overview that summarises the results and describe the future possible enhancements of performed studies presented by the Author. The main text can be divided logically into three parts. First (Chapters 1 - 3 and 5) presents both PANDA and COSY-TOF experiments as well as gives an exhaustive overview of physics and simulation models of the straw tube detectors. Second, related to detector physics studies, (Chapters 4 and 6) gives a detailed description of the application of the straw tube tracking devices for particle identification based on measuring Time-over-Threshold (TOT) information and calibration procedure for the COSY-TOF tracker. Finally third and last part (Chapter 7) presents the data analysis of the elastic proton-proton scattering and the $\vec{p}p \rightarrow pK^{+}\Lambda$ reaction using data sample collected by the COSY-TOF experiment. The content of these chapters will be shortly described and discussed below and followed by some general comments regarding the thesis composition and the overall text quality. The chapters are ordered according to the logical division laid out above.

The first Chapter covers a short description of the FAIR accelerator facility as well as the future PANDA (antiProton Annihilation at Darmstadt) experiment. The Author describes here in a very generic way the physics programme of the experiment and presents the anatomy of the PANDA detection system. Special attention is given to the PANDA's Straw Tube Tracker (STT) detector, which confirms Author's wide knowledge and proficiency with this part of the experimental setup. Also, quite detailed description of the front-end electronic read-out chip (developed by the AGH microelectronic team) is given. One serious deficiency of this Chapter, in my opinion, is total lack of discussion regarding alignment of the PANDA's tracker system (alignment issues are briefly discussed in Chapter 6 for the COSY-TOF tracker). Another problem is related to the description of the physics program – no specific analyses have been listed. In addition no background for the physics programme of the PANDA experiment, with respect to the present results of other collaboration, has been offered. Also, the idea of self-supporting straw tubes, that do not require any frames or external

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support structure, seems rather novel and should, in my opinion, be stressed a little bit more in the text.

The next Chapter presents some general information on physics of straw tubes detectors and is of compilation nature. The Author discusses here such phenomena as ionisation in gases induced by passing charged particles, drift of electrons and ions in gases as well as gas amplification and signal creation. At the end of this Chapter Author discusses also a critical practical issue related to straw tube detectors, i.e., choosing the right gas mixture for the proper straw operation. The text in this part of the thesis is very clear and reads well. In parts it is almost didactical in nature and shows great understanding of the physics of gaseous detectors acquired by the Author.

Simulation studies are of vital importance in experimental particle physics. The Author presents various simulation models used in her work in Chapter 3. The main software suite used for simulating the straw tube detectors is Garfield that was developed at CERN. This program needs a specific geometry description as well as electric and magnetic field maps that are provided especially for the COSY-TOF straws. Garfield can also interface with Magboltz and Heed programs that can be used for estimating transport properties of electrons and ions in gas and ionisation process in gas mixture by traversing charged particles respectively. The Author used this software to simulate the charge multiplication and signal formation on the straw's electrodes. The most interesting result obtained was significant discrepancy in simulated and measured value of the gas gain. This was investigated and it turned out that the original model did not included indirect ionisation effects called the Penning effect during the gas multiplication process. After an appropriate correction has been introduced to the Townsend coefficient the simulation results became describe the measured data very well. This is showed for instance for the gas gain curves presented in Figure 3.13.

In Chapter 5 the COSY-TOF experiment is described. A short description for the COSY (COoler SYnchrotron) complex, COSY-TOF physics programme and the detector itself is given. Since the PANDA experiment is not yet operational the COSY-TOF is the perfect place to test the performance of charge particle tracking by the self-supporting gas straw detectors. This is very important for the presented thesis since the data collected by the COSY-TOF are essential for physics analysis discussed in Chapter 7.

In Chapter 4 Monte-Carlo studies regarding particles identification by the straw tube detector is presented. First detailed simulation of the straw detector electric (induced currents) response is described. Since the amplitude of the obtained signal is very small a specially designed ASIC chip is necessary. The appropriate software emulation of the front-end read-out electronics is also taken into account in order to make the simulation more realistic and reliable. The method that was used to estimate the PID (Particle Identification) performance of the straws based on the specific energy loss is using the TOT measurement. This technique is relatively new and based on the similar approach used by the ATLAS experiment. The TOT method is very sensitive to track distance to the anode. The Author describes this effect in detail as well as the appropriate correction that needs to be applied. Presented results of the simulated studies shows very good separation of the protons, charged kaons and pions based on the distance corrected TOT measurements. These results are further compared with the measurements using the prototype straw tube detector developed for the PANDA's Forward Tracker. The comparison of the simulated and real TOT spectrum curves, with applied detection thresholds, shows good agreement. Also, the efficiency for the TOT measurement and separation power for protons, kaons and pions were estimated. The efficiency as a function of the distance to the anode wire is close to 100% apart from a region very close to the tube wall. This effect is known for straw gas detectors and expected. Obtained results confirm high quality and reliability of the used simulation software. In turn, the results regarding the separation power show that the used TOT technique gives very similar results to more conventional one based on total integrated charge.

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In Chapter 6 the Author describes calibration procedures for the STT system of the COSY-TOF detector. Presented discussion spans from TDC time correction, calibration of the time-to-distance (TDC), studies of the mean residual distribution measured by the STT, alignment studies (position and rotation degrees of freedom of the tracker) and finally spatial resolution of the straws is presented. The Author shows exceptional knowledge of the calibration procedures for the main tracking device of the COSY-TOF setup and understands its paramount importance for the high quality of physics data. Both structure and content of this chapter shows that the Author took active role in defining and applying the calibration procedure during the data taking. This conclusion is supported by the bibliography attached to this thesis. Specifically, positions [69] and [71] are the internal technical documents prepared by the Author and describe the calibration procedure and improvements in spatial resolution respectively. Also, one can find a publication regarding the calibration procedure [72].

The final part of this thesis given in Chapter 7, presents the data analysis that consists of two distinctive parts: the pp elastic scattering and $\vec{p}p \rightarrow pK^{+}\Lambda$ channel studies. Both parts are intimately related since elastic events are used to determine a number of parameters, such as target position and its dimensions or beam polarisation, necessary for subsequent analysis of the $pK^{+}\Lambda$ events. The beam polarisation, determined using left-right asymmetry observable, was measured to be approximately 87.5 %. The further analysis of the $\vec{p}p \rightarrow pK^{+}\Lambda$ associated strangeness production is also described in this chapter. Studying the production of Λ hiperons in p-p collisions is one of the golden processes studied by the COSY-TOF experiment and belong to its core physics programme. The Author shows excellent knowledge of the preliminary and final signal selection algorithms. She also discusses in details reconstruction efficiency and its uncertainty as well as vertex, momentum and invariant mass resolutions and their vital meaning for the performed data analysis. The main observables presented for the discussed analysis were angular distributions of the final state particles (obtained in the CMS) and the Dalitz plots for the selected $pK^{+}\Lambda$ events. The respective angular distributions were used for the partial wave analysis by the means of fitting the Legendre polynomials. The Dalitz plots were, in turn, used to study the reaction mechanism. The analysis revealed significant discrepancy between the simulated and real data. A number of clear enhancements in the Dalitz plot for $\{p\Lambda\}$ subsystem were observed, which were identified as, so called, cusp effects. Also, the novel part of this analysis was studying the cusp shapes for different regions of the Dalitz plot using the helicity angle information. Obtained results shows a necessity of additional theoretical input in order to explain the observed $N\Sigma$ cusp effects.

In summary, I believe that presented thesis makes a fine and valuable contribution to the COSY-TOF experiment and to the entire low energy particle physics field. The author constantly proves throughout the text her very good knowledge of the experimental particle physicist craft, both for the detector setup operation and data analysis. Some textual inefficiencies, related mainly to usage of articles (a, an, the) does not change my high opinion of the presented thesis. One thing that would make a good addition would be a short summary of the work done exclusively by the Author. The referee must constantly guess what was the actual contribution made by the Author by looking at the bibliography. Also, there is no discussion regarding plans for publishing the results of the physics analysis presented in the last chapter of this thesis.

In conclusion, the dissertation presented by Sedigheh Jowzaee contains valuable and original results and satisfies all the formal requirements for doctoral thesis and I hereby agree for the public defense.

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