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Review of PhD thesis entitled
„Development and applications of tracking of pellet streams"
by Andrzej Pyszniak

An important step for the understanding of the properties of hadrons and the strong interaction will be given by the new PANDA experiment which will be located at the GSI research center in Darmstadt, Germany. PANDA will be operated at the HESR accelerator (High Energy Storage Ring) providing anti-proton beams with momenta of 1.5 – 15 GeV/c. The target material will be mainly hydrogen consisting of protons. One of the advantages of colliding antiprotons with protons is that it makes possible formation of states of all quantum numbers. $\bar{p}p$ collisions will allow for hadron spectroscopy of charmonium, D mesons and strange and charmed baryons. Also, it will be possible to search for glueballs (particles consisting solely of gluons) and hybrids (consisting of quark, antiquark and excited glue). These states are allowed by QCD, but not yet confirmed experimentally. It will be possible to search for gluonic hadrons with masses above 2.5 GeV/c^2, where the density of conventional quark-antiquark states becomes smaller. Also a study of non-perturbative QCD dynamics will be possible in baryon-antibaryon interactions. Main target material in this experiment will be hydrogen. Usage of this element implies the requirement of having a cryogenic target since frozen hydrogen is the only solution providing high density of the target. Cryogenic hydrogen target exists in two variants: cluster jet target and pellet target. Studies described in the thesis are devoted to the pellet kind of target.

The reviewed dissertation consist in its essence of 7 chapters, chapters 8, 9, 10, contain summaries in English, Swedish and Polish. Acronyms used in the thesis are listed in Appendix A. Terms defined for the purpose of the described studies, as well as definition of the coordinate system of WASA and PANDA, are placed in Appendix B. Detailed case classification in a search for pellets are included in Appendix C, very detailed results of simulations are placed in Appendix D. Reviewed work includes 124 figures and 29 tables, 12 of them in Appendix D, 36 references are cited.

The studies described in this thesis are based on experiments carried out at Uppsala Pellet Test Station (UPTS) and at the WASA-at-COSY experimental site. In the chapter 1. Introduction the physics of strong interaction is explained and the justification for the PANDA experiment. The concurrence of particle tracking in combination with a precise definition of the interaction vertex is explained. The basic principle of pellet concept in terms of technical implementation is featured.

The second chapter contains description of various illumination conditions checked, with different models of lasers, different optics, different illumination angles and number of lasers. Different models of cameras were checked, with different optics and operated with different cycle structure. Means of processing the image from the cameras to obtain information about detected pellets were investigated. The chapter contains a description of the Uppsala Pellet Test Station and the means of pellet detection. The results of the studies and the best found settings obtained are presented. Also, a description of the simulation procedures developed to simulate pellet detection process is presented.

The next chapter describes the studies of the pellet stream. The parameters of the stream were measured at fixed levels and also in correlation between different measurement levels are shown. Distributions of pellet stream density, pellet stream shape and divergence were measured. Also, measurements of pellet velocity, velocity spread and a source of the velocity spread were carried out. A description of simulation procedures developed to simulate pellet stream behavior is extensively presented.

Chapter 4. contains very detailed description of design simulations of the tracking system for PANDA. Based on realistic pellet stream and detection parameters from UPTS measurements and constraints from the PANDA setup, simulations of pellet tracking performance were described. Various parameters of pellet stream and pellet detection were checked. There is presented a procedure of pellet track reconstruction developed for the purpose of the study. In this chapter the possibility of data analysis when full scale pellet tracking is operated at a particle detector system is discussed.

Next chapter contains a discussion of usage of the information from pellet tracking in hadron data analysis. An advanced algorithm of pellet track reconstruction is described. This algorithm is claimed to be very robust, flexible and provides very high reconstruction efficiency even in case of substantial detection inefficiencies.

The most important part of the work on the pellet tracking system is contained in Chapter 6. which reports on the tests of the system when operated at a real hadron physics experiment. One of the information given by the pellet tracking is the number of pellets present in the interaction region. The possibility of obtaining and making use of such information was checked in a different way - by using a Long Range TDC, recording times of elastic scattering events. Based on the instantaneous event rate and the knowledge that presence of pellet in the beam region increases this rate, an event classification method was developed and the hadronic data were analyzed separately for "pellet" and "non-pellet" case. The study has clearly shown that one can distinguish between the two event classes. Moreover, the method gave experience on using two different systems synchronized with each other - normal experiment DAQ and another

system, which works with a much longer time scale - similar to the pellet tracking system.

The Author clearly presented his own involvement in the project what facilitates evaluation of his real considerable contribution. The following activities described in the thesis were done by the Author:
a) participation in hadron physics experiments using pellet target at the WASA-at-COSY detector setup;
b) participation in experimental tests of pellet detection conditions and pellet stream parameters at UPTS;
c) analysis of the UPTS experimental data obtained in velocity measurement configuration;
d) preparation of detailed procedures simulating the behavior of pellets in the stream and of pellet detection;
e) preparation of pellet track reconstruction procedures and performing detailed design simulations of resolution and performance of the tracking system for PANDA;
f) analysis of the data from Long Range TDC and preparing procedures simulating the spectra;
g) analysis of data from the WASA-at-COSY detector setup with usage of Long Range TDC information.

Conclusions from the presented in the dissertation investigations are following:

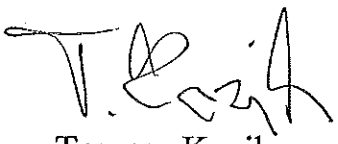
The detection efficiency together with the obtained time and position resolutions are sufficient for the purpose of pellet tracking. The pellet stream parameters are suitable for pellet tracking and the obtained values may be used in the simulations for development of the tracking system. For this purpose, two versions of track reconstruction algorithm were developed: a fast algorithm, quickly reconstructing pellet tracks, enabling first approach to the data analysis and possible to be used in online analysis, and an advanced algorithm, providing very high efficiency of pellet track reconstruction required in the final analysis. The information from pellet tracking can be used in background events rejection and to provide the vertex position in particle track fitting.

Turning to the assessment of the PhD dissertation of Andrzej Pyszniak I certify that the work is written in concise scientific language and has a clear layout. Small and very few faults I found in the work, do not pose any particular problems for the reader. However, the duty of the referee is to indicate these minor shortcomings:

1) The very detailed information contained in some tables (e.g. Tables from Appendix D) are the technical information and should not be in an academic paper, they have the ability to be a user reference manual.

2) The data presented in tables are difficult for clear rapid interpretation, far better to present them in the form of graphic illustrations.
3) Polish summary is paradoxically somewhat linguistically clumsy in several sentences, probably as a result of an automatic translation from the English language

The reviewed dissertation contains report of the accurate and thorough studies of pellet technique demonstrating Author's general physics knowledge, confirming the ability to independently carry out scientific work and is a testament to the skill development of research methods and deepen expertise. It was made by methods deemed appropriate in the discipline of particle physics. I am convinced that the work of Andrzej Pyszniak meets with a requirements of doctoral work in Poland by applicable laws and therefore I request admission of the Author to the further stages of a doctorate.



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