Review of the Ph. D. Thesis entitled:

Determination of the analysing power for the vec(p)p → ppη reaction using WASA-at-COSY detector system

Written and presented by Iryna Schätti-Ozeriansk

under the supervision of
Prof. Dr. hab. Pawel Moskal (Advisor)
and Dr. ing. Marcin Zielinske (Co-Advisor)

The presented thesis describes the determination of the analysing power of the eta-meson (η) produced in the proton proton interaction close to threshold.

States observed in nature consist of three-quark combinations (the baryons) and a quark-antiquark system (the mesons). At lower energy scales of three flavors the families of mesons are containing of $3^2 = 9$ states, called nonets. Both particles the eta (η) and the eta prime (η') mesons belong to the "pseudo-scalar" nonet made of a mixture of up, down and strange quarks and their antiquarks. They have spin J = 0 and negative parity, zero total isospin I and zero strangeness and hypercharge. Each quark which appears in an η particle is accompanied by its antiquark (the particle overall is flavorless) and all the main quantum numbers are zero. The η was discovered in pion-nucleon collisions at the Bevatron in 1961 by A. Pevsner et al. . The difference between the mass of the η and that of the η' is larger than the quark model can naturally explain. This "η - η' puzzle" can be resolved by the 't Hooft instanton mechanism, whose 1/N realization is also known as Witten-Veneziano mechanism

The basic SU(3) symmetry theory of quarks for the three lightest quarks, which only takes into account the strong force, predicts corresponding particles called η_8 (octet) and η_1 (singlet). However in this case the weak and electromagnetic forces, which can transform one flavor of quark into another, cause a significant, though small, amount of "mixing" of the eigenstates with a mixing angle of θ_P of about -15.5^0 such that the actual quark composition is a linear combination of the octet and singlet. Thus the unsubscribed name η refers to the real particle which is actually observed and which is close to the η_8. The η' is the observed particle close to η_1.

The in-medium η-N interaction near and below threshold is a further actual research topic which might lead to dynamical processes as described by the thesis in the chapter 2 for possible scenarios of the η meson production in the nucleon-nucleon collision.

At threshold the p-p interaction of the production of the η meson starts with a pure s-wave production. With increasing energy higher partial waves start to contribute and thus interference terms between various partial wave amplitudes become more and more important. Interestingly enough since the final state nucleons in the vec(p)p → ppη reaction are not to be distinguished no s- p- interference terms of the mesons are observed in the differential cross sections. Still, s- p- interference terms are not going to disappear necessarily in the analyzing power of the proton. Consequently a precise measurement of the analyzing power allows the determination of relatively small higher order partial wave contributions as e.g. the certainly first contributing p-wave.

These facts are all fairly well documented in the presented work and the reader is lead to the experimental setup which was performed at the 3.3 GeV/c proton cooler synchrotron COSY running at the National Research Center Jülich/Germany. Previous very close to threshold experiments were performed at the zero-degree spectrometer COSY-11, an experimental facility for precise close to threshold meson production nucleon-nucleon interactions, a pioneering experiment which is given lots of credit in the present work. The research was to be continued at the compact WASA detector installed again as an internal experiment at the COSY ring originally operating at the CERLSIUS ring in Uppsala/Sweden. But since the Swedish laboratory was shut down the detector was moved to Jülich for a new installation and specialized for meson production in the nucleon-nucleon interaction. With all rights it is pointed out in the thesis that the former experiments for threshold production of the η meson (the DISTO and the COSY-11 facilities) were not sufficient due to the low statistics achieved and thus WASA was the right thing to do.

Thus, after the general introduction consequently the detector is introduced. Here the description lacks on clarity in many details and sometimes it would have been better to skip descriptions instead of having them incomplete. Here an example could be the Chapter 3.2.9 Central Detector (CD) where no clear overview is given but rather only mentioned that the Superconducting Solenoid was switched off for increasing the precision. This is hard to be understood here not outlining clearly the effect of the fringe field of the internal magnet on the polarization of the antiproton beam. Along this line it is not very precise when it says in Chapter 6 and in the conclusion, that due to the missing magnetic field only the neutral channels of the η decay could be studied and prevented the registration and further reconstruction of trajectories of charged particles. Certainly the trajectories could have been extracted though the charge as such would be unknown.

Another sloppy presented item is e.g. the description of the Forward Trigger Hodoscope (FTH). It says that overlapping the three layers of 24 left and 24 right twisted combined with 48 radial sectors would result in a 48x24x24 pixel map, which would mean 27648 pixels. This is wrong and should be reconsidered. As a rough estimate the two 24 element layers would result in 576 pixels if the bending angle would be 180^0 but it is less and the straight scintillator element would at most double this number.

After the description of the production of the polarized proton beam the experimental section continues with the data acquisition and the trigger system which is logically presented but still could be improved by a kinematic consideration plot.

I appreciate very much the thoroughly analysis of the vertex position determination which is very essential for the estimate of the uncertainty achievable. Were most details are clearly described I am missing sometimes helpful explanations as e.g. in Fig. 4.6 where I cannot see the difference off hand between the left and the right part of the figure, a hint would be very helpful. Or if it says at the end of page 42 "The result established by the two methods differ by less than +_ 0.5 mm" what does this mean in terms of precision?

Three essential chapters follow which concentrate on the determination of the beam polarization, the selection of the vec(p)p → ppη reaction itself and the analyzing power A_y for the vec(p)p → ppη reaction at the excess energy of Q = 15 MeV (p_{beam} = 2026 MeV/c) and Q = 72 MeV (p_{beam} = 2188 MeV/c) data including a very careful analysis of the statistical und systematical uncertainties. This all seems to be fine, thoroughly and well done, however I feel that the reader is left alone when coming to the interpretation of the results. Fig. 8.1 shows the analyzing power for both experiments and demonstrates that the presented theory of both the vector as well as the pseudoscalar meson exchange models at Q = 15 MeV are opposing each other and have nothing in common with the data. For the Q = 72 MeV data the theoretical curves given were calculated only for Q = 36 MeV, which seems to be uncritical in the case of the pseudoscalar meson exchange model but extreme sensitive for the vector meson one, which varies from an amplitude of Ay = 0.2 to Ay = 0 going from Q = 10 MeV to Q = 36 MeV. Thus the comparison is rather meaningless as long as the parameters are so sensitive. Still, it seems obvious that none of the theoretical considerations is going to work for the reaction under study. I would have wished that some more hints from discussions with respective theoreticians would have been presented on how to get out of this dilemma. On the other hand I appreciate the heroic effort of the present thesis to provide a large amount of collected date for the η production with statistical uncertainties of the analyzing power which are much smaller than any previous data available. Finally, the determination of the associated Legendre polynomials clearly shows the increase of higher partial wave contribution to the reaction process with increasing excess energy.

In conclusion, Iryna Schätti-Ozeriansk demonstrated by this thesis her clear work of analyzing the complicated data. Clear results have been obtained and one could not blame the experimental physics author that the precise data and the present theoretical understanding have nothing in common.

In general the thesis is fair and well written - though improvements could be suggested – and therefore I would recommend continuing the Ph.D. procedure at the Jagiellonian University since I am convinced that it will be successfully completed.

Walter Oelert

Walter Oelert, Genf 27.01.2016

Retired Prof. University Bochum
Retired as leading scientist from the Research Center Jülich
Visiting Scientist at the Research Center CERN
Supervisory Professor, Johannes Gutenberg Universität, Mainz

Private Address:
Walter Oelert
Neue Aue 5
D – 52355 DUEREN
Germany