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Recenzja rozprawy doktorskiej magistra Akshay Malige zatytułowanej:

# Read-out and online processing for the Forward Tracker in HADES and PANDA

The doctoral thesis of Mr. Akshay Malige concerns the readout and data of the Forward Tracking (FT) for HADES and PANDA experiments at GSI-Darmstadt FAIR accelerator complex. It was conducted under supervision of prof. dr hab. Piotr Salabura and dr Grzegorz Korcyl. The thesis topic is closely aligned with a scientific activity of Hadrons Physics group that is responsible for construction of Gas Straw Tube detectors and their readout for the two aforementioned experiments.

The thesis consists of 6 chapters and one appendix, above 100 figures and tables and 35 references. It is very well written. Especially appreciated are introductory sections in each chapter, and chapters 1 and 2 that form a very complete and pedagogical introduction to the topic. The impressive list of goals and tasks of the thesis spanning from initial Front End Boards (FEB), qualification all the way to commissioning in the detector are clearly itemised. The online data compression goal (topic of chapter 5), needed for PANDA is also clearly stated here.
Particularly detailed chapter 2 offers a detailed tour over the detectors designs in the top to bottom approach starting from a global FAIR facility description, HADES and PANDA detectors, down to the details such as construction of an individual straw of the FT. What turns out to be very important for the remainder of the text, the readout infrastructure description is also provided here. The reader also finds an excellent idea that the requirements for the detectors and readout are very clearly enumerated.
It is not common in PhD theses to contain introductions which are well thought over and equally well written. Therefore, the thesis will likely serve as an excellent reference for whoever who will work on FT readout in the future.

Chapter 3 describes the readout of the FT and qualification of FEBs PASTTREC readout chip. Again, the author described the basic principles of the signal collection and shaping together with possible challenges associated with it in a very pedagogical manner. Results of the chip qualification, noise analysis, and optimisation of chip configurable settings like baseline are shown here. The results that are obtained by the author are exemplified in figures 3.16 and 3.17. These

initial studies with a $^{55}Fe$ source resulted in qualification of FEBs and an indication of the ranges of desired readout chip parameters.

In chapter 4 the next phase of readout commissioning using 3 GeV/c proton beams at COSY synchrotron in Julich is described. The test setup, with auxiliary detectors providing timing and calorimetry, consisted of the FT stations in configurations like designed for PANDA stations 5 and 6 (outermost), that is with eight double-layers of the FT straws. Such a scale of the setup allowed to conduct extensive tests of the readout and eventually test the algorithmic tracking chain. This chapter describes a drift time calibration procedure and the results obtained. The final tuning of the PASTTREC readout chip settings in relation to the detector voltage optimisation was studied. Maximisation of the efficiency, reduction of the noise with as low voltage as possible were achieved. The described procedure is convincing and optimal parameters are shown in table 4.5. Further in this chapter results of the FT detector operation within the HADES setup are described and first results of the physical analysis are shown.

In chapter 5 the online data processing, that is specific to the the application of FT in PANDA is described. In this case the continuous readout and high hits rate result in a significant amount of data that needs to be stored. Fortunately, quite advanced data reduction can be implemented early in the data collection chain that allows to reduce the data without loosing important information related to the tracks. The solution was provided by the author of the thesis. It is an approximate tracking reconstruction algorithm implemented on hardware (FPGAs). As shown in final figures of this chapter (Figures 5.8, 9 and 10) its performance is nearly identical as the same tracking procedure performed offline. Both, excellent efficiency of 99% and fake rate of only 3% were obtained. The data throughput requirement was significantly reduced by about 75%.

The thesis is summarised in chapter 6 neatly recapitulating the scientific achievements of the PhD candidate. The thesis ends with outlining further developments needed for application of the same readout in the central PANDA tracker during the high luminosity phase.

Referee was only able to find a handful of editorial mistakes in the entire manuscript, for instance confused subscripts in symbols on page 68 or a missing definition of track residual. Remaining ones are too minor to comment on. The figures are typically of adequate quality however in many of them the y axis is not labeled, e.g. Figures 3.17, 4.7, 4.10 and several others, sometimes leaving the reader puzzled. Some figures would benefit from a logarithmic or more adequate scale choice like Figures 4.16 or 5.10 but overall, the quality of the manuscript is very good.

The thesis concentrates on the experimental aspect of FT readout commissioning and is missing the description of MC modeling of this system. The only comparison that one can find is at the end of chapter 4 (Figure 4.39). The differences in the resolutions related to polar and azimuthal angles shown there indicate 30-40% worse resolutions in data compared to simulations which is left without comment. It is not clear if MC simulation of individual straws and the whole detector exists. Hopefully this is the case and therefore it is surprising why comparisons of lower level quantities (drift times, TOT, occupancies) have not been shown in the thesis.
The calibration procedure described in section 4.2 indicates a slightly different relation of drift time and drift radius for four double layers (the color-coding is not explained in Figure 4.16). It seems to be an open question if this is an effect really pertaining to the layers of the detector or perhaps an averaged effect of differences in particular straws. Presumably a similar crosscheck could be preformed for individual straws?

In the description of the track reconstruction process in section 4.3 there seems to be a missing feedback loop for very precise calibration of the TOT and drift time which can only be performed given approximate track parameters like incidence angle or position in the straw. This may be however a consideration that belongs more to the precise offline track reconstruction.
It would be interesting to see ratio plots in comparisons presented in Figures 5.8, 9 and 10. In the description of these figures the reference frame is undefined and therefore brings a question, for instance about the appearance of the entries in the offset histogram below 8cm.

Summarising, the doctoral thesis presented by Mr. Akshay Malige is of very high quality and describes a significant body of work. Described contributions to two unique experiments, HADES and PANDA, are of high importance to the current and future physics programmes at GSI. As rightly noted by the author in the introduction the HEP experiments have unique needs for the data processing that can only be addressed by dedicated solutions. These solutions need to be then deployed in the experimental reality for optimal results. The thesis presents such process that started from FEB qualification and concluded with application in real experimental conditions of the large scale detector. It is a major achievement for PhD student to complete such a project within the time allotted for PhD programs. In addition, the implementation of online data filtering system with such excellent parameters is an achievement by itself. These results were published in IEEE Transactions of Nuclear Science with PhD candidate as main author and also were presented at two conferences.

Given these significant achievements referee advises that a congratulatory letter should accompany the PhD degree certificate.

Stwierdzam że przedstawiona praca spełnia wymagania stawiane pracom doktorskim i wnioskuję do Rady Dyscypliny Nauki Fizyczne Uniwersytetu Jagiellońskiego w Krakowie o dopuszczenie pana magistra Akshay'a Malige do dalszych etapów przewodu doktorskiego.

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