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dr hab. Jerzy Łukasik
IFJ PAN

Review of the PhD thesis of
Akshay Malige, M.Sc
entitled
Read-out and online processing for the Forward Tracker in HADES and PANDA

The PhD thesis of Akshay Malige, M.Sc, contains the results of the research related to the readout electronics and to the online processing of the signals and correlations among them from the straw tube detectors of the HADES and PANDA systems. It describes the results of the tests performed with the use of the tools and methods developed by the author.

The thesis is well structured and well written. It starts from the presentation of the physical and technical background leading to the current main stream research in particle and nuclear physics. In many cases it starts from a general description of the subject and goes through more specific to very detailed description. The thesis refers to the design, construction, commissioning and testing of the Forward Tracker, a subsystem of the existing HADES and of the constructed PANDA detectors. These are new generation detectors capable of dealing with high position and time resolutions at very high event rates. Specifically, there were two aspects in which the author substantially contributed to the development of this subsystem. The first one was the development of necessary tools (hardware and software) and performing the tests that allowed to select an optimal combination of parameters assuring the required position, time and energy resolutions as well as the uniformity of the output throughout all the channels and a long life time of the detector. The second one was the design and testing of the firmware for real time data reduction and filtering as well as sorting and tracking implemented in the near front end FPGA arrays.

Three main chapters of the thesis (3, 4 and 5, 60% of the volume) describe the results obtained by the author. Chapters 1 and 2 introduce the physical and technical background and context, the necessary notions and definitions, and provide general descriptions of the main subjects of the thesis. Chapter 6 discusses the results and outlines the possible improvements. It is followed by a set of appendices and the bibliography.

Concerning the main results. An important contribution of the author to the development of the data acquisition based on the Trigger Readout Boards for the PANDA Forward Tracker is mentioned already in Ch. 2.

At the end of sect. 3.1.1 the author draws a physical picture of the signal formation in a cylindrical proportional counter (a straw tube). Unlike the rest of the thesis, this picture seems to be not quite precise. Reading the last paragraph of this section, the reader might have an impression that the signal is formed after the charge carriers reach the electrodes, what causes recharging of the detector. Obviously, this is not the case. Signal formation takes place while the carriers move and its rate depends on the charge induced on the electrodes. The author uses the concept of the induced current

later on and measures the drift times, so he is aware of this, but the formulation of this paragraph might be misleading. Treating the detector as a capacitor (or in fact a current source) simplifies its description and is useful for electronic engineers, but **what is the actual physics picture behind the measured pulse shape, what are its time characteristics?** This question refers also to eqs. (3.5) and (3.6). There seem to be some simplifications here, no dependence on pressure or mobility, no dependence on the preamplifier timing properties (RC). The equations should have at least a reference to their origin, or much better, they should be derived in the thesis. This thesis is of great value for the future PANDA and HADES users due to its details in electronics and data analysis, but it should also be a place for derivation of important formulas.

Chapter 3 shows the results of the tests of the ASIC used for the pulse processing: noise characteristics, baseline alignment, time over threshold spectra. **The question is whether the methods developed can be used to test and align all the many thousands of channels? Is there a way to do it automatically?** The author provides also sets of optimal settings for the parameters of the ASIC.

Chapter 4 presents the results of the beam test of the tracker prototype at COSY and at SIS. The author shows the results obtained for the track reconstruction using his on-line analysis routines. By looking at Fig. 4.11 **one can wonder whether it could be possible to have perfectly horizontal tracks, which could cause ambiguity in their vertical offset extraction?**

Figure 4.12 presents the drift time spectra obtained from the uniform irradiation. It is interesting **why the response is not uniform despite the 98% efficiency of the straw?** The figure implies that the peripheral hits (tracks at the edge of the straw) are much less abundant (if not missing) than the hits in the vicinity of the wire.

Using the plastic detector as a start detector it was possible to perform the drift time calibration and obtain the time-radius dependence and measure the position resolution of the straws.

In sect. 4.3.8 the author performs the time over threshold calibration. Figure 4.18 left, shows the TOT dependence on the drift time, which is intuitive. Longer drift times correspond to peripheral tracks depositing little energy and thus lead to smaller TOT. **What is the purpose of making this dependence flat?** Calculating the separation power using these flat distributions may be too optimistic. It would be more useful to provide the energy loss vs TOT calibration, if possible. This would allow to sum up the ΔE along the track to get a more realistic measure of the resolution.

This chapter provides also an estimate of the efficiency of straws reaching 98%. The author has also investigated the effect of deformations of straws on the TOT resolution. Visually the effect is noticeable. The measurement of the gain drop as a function of the accumulated charge indicated the need for optimizing the bias to reduce the aging effects. The performed tests and analyses allowed for further refinement of the optimal parameters of the ASIC which was a kind of a balance and a compromise among many, sometimes contradictory requirements.

The Forward Tracker has also successfully been used in the HADES experiment and fulfilled its expectations as a luminosity detector, by selecting and measuring the elastic p+p collisions.

Chapter 5 provides very interesting results on the ability of real time filtering and sorting the hits and fitting the tracks in the Forward Tracker. The processing has been done for the tracks without the

magnetic field. Implementation of the filters and of the tracking engine on a hardware allowing for a real time feature extraction and allowing for taking online decisions on the data reduction is a great achievement. Results presented in section 5.2.2 confirming the efficacy of the real time tracking are outstanding.

The drift time, i.e. the time between the primary ionization due to the charged particle passing through the straw and the beginning of the avalanche is in fact a non-measurable time delay, unless an external reference start signal is provided. It is so because the contribution of the primary ionization to the output pulse is negligible compared to the contribution of the avalanche. In experiments with trigger-less data taking the lack of an external start signal would preclude the high resolution tracking. That is why the result presented in Fig. 5.11 is also very important and encouraging. By the way, the shapes of the distributions from Fig. 4.12 and 5.11 are different. The latter seem to be more sensitive for the peripheral tracks. **What could be the reason for that?**

In sect. 5.3 the author discusses the goal of rejecting the secondary tracks. The question is whether this data reduction would not diminish the detection ability of the detector. For instance it would be interesting to check **what is the efficiency of the straw tracker to detect neutrons or other neutral particles?** Rejecting the "feature-less" events might result in rejecting some exotic but nevertheless interesting events or hits.

The thesis is written in very good English, in a clear manner. A couple of minor corrections are specified below:

p. 1 One aspect → There is one aspect
p. 9 physic program → physics program
p. 12 has 1024 arranged → has 1024 straws arranged
p. 18 KeV → keV
p. 29 expect count rates → expected count rates
p. 30 multiplying the separation of electrons → multiplying the number of electrons
p. 33 long amplitude tail → long time tail
p. 37 measurements have shown → measurements have shown that
p. 44 generated pulsed → generated pulses
p. 46 (caption) here is due to partially → here is partially
p. 49 Power consummation → Power consumption
p. 62 (0.505 mm) → (0.505 cm)
p. 63 ionised electrons → electrons created in an ionizing event (or liberated electrons)
p. 64 eqs. (4.1) and (4.2) → t instead of t_{max} in the upper limits
p. 67 Bethe-Bloch low → Bethe-Bloch law
p. 68 high-voltage → high-voltages
p. 69 as considered → were considered
p. 72 has will have → will have
p. 75 (caption) increases with the increase → with the increase
p. 84 beam momenta → beam momentum
p. 84 momenta is → momenta are

Summarizing, the thesis of Akshay Malige, MSc, presents:

- results of the tests of the state of the art ASIC designed with the contribution of the author for the front end processing of signals from the new generation detectors,
- results of the beam tests of the prototype straw detector and its electronics performed with the use of the author's tracking software, data acquisition and analysis tools,
- encouraging results of the real time filtering and tracking performed with the use of the firmware and software developed by the author.

The results confirm that the electronics, the firmware and software designed for the HADES and PANDA detectors fulfill their expectations. The thesis, thanks to its details, can serve as a manual and reference for other researchers involved in further development of the detectors, in tests and experiments. The work done by the author is a significant contribution to the future successful experiments.

Referring to the questions emphasized in the text should not be a problem. They do not question the results obtained but are raised rather to trigger more discussions and allow better understanding.

Akshay Malige is a co-author of already 16 publications (according to the Web of Science), which confirm his engagement, activity and skills.

Taking into account the author's workload, his attention to the correctness and precision of the results as well as the quality and originality of the presented achievements, I believe that the material and form of presentation contained in the thesis meet the requirements for doctoral dissertations and I apply for admission of Akshay Malige, MSc, to the further stages of doctoral dissertation.

Biorąc pod uwagę nakład pracy autora, jego dbałość o poprawność i precyzję wyników oraz jakość i oryginalność prezentowanych osiągnięć uważam, że zawarty w rozprawie materiał i forma prezentacji spełniają wymagania stawiane rozprawom doktorskim i wnoszę o dopuszczenie mgra Akshaya Malige do dalszych etapów przewodu doktorskiego.

J. Łukasik

Digitally signed by
Jerzy Łukasik
Date: 2023.03.06
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