Review

of Master's thesis of Viktoriia Lysenko, a student of the study programme Nuclear and particle physics, elaborated on the topic:

Efficiency and accuracy of time-of-flight detector measurements in the ATLAS experiment and di-photon vertex reconstruction for the search for an axion-like particle in data from LHC Run-3

Submitted work deal with data taken by the AFP detector installed in the forward region of the detector ATLAS at CERN laboratories. A special attention was devoted to the time-of-flight subdetector (ToF) which could help with background rejection in the physics studies of di-photon interactions related to existence of so-called Axion-like particles (ALPs). These particles are considered as candidates for particles that make up missing dark matter. The performance of the ToF detector was the main topic. The performance analysis was done upon two dedicated runs of the newest Run-3 data from 2022 hereby following up on the study by Karel Cerny made on Run-2 data. As the ToF detector was significantly redesigned in between, the study made by student were of increased interest and presented results are undoubtedly valuable.

She continuously presented ongoing status of her analysis during plenty of video-conference meetings where she got relevant feed-back from members of AFP collaboration. In the frame of this task, the student encountered processes and procedures existing in the ATLAS collaboration, she learned how the AFP detector works, and she gained experience with the ROOT analysis tool.

Structure of thesis

The thesis is divided into seven chapters starting with Introduction and ending with Conclusions. The Introduction is devoted to the physics motivation based on central exclusive di-photon production assuming an axion-like particle and how the AFP detector could contribute to such physics studies on ATLAS detector. It also includes an introduction to the detector ATLAS. The second chapter describes at glance the ATLAS and AFP detectors including AFP's ToF detectors in more details. Third chapter deals with the timing resolution and efficiency of the ToF detector using Run-3 data. Chapter 4 describes di-photon vertex reconstruction process using both corresponding simulations and data from the Run-2 and briefly from the Run-3. The Chapter five comes back to the ToF with the topic about vertex reconstruction with the ToF. This includes calculations of time delay coefficients and that of the whole timing resolution of the

AFP ToF detectors using information from the ATLAS beam spot monitor. The sixth chapter discusses eventual future applications on the search of the Axion-like particles using the ToF detector.

The chapter structure is properly straightforward and includes a necessary physics motivation. Maybe swapping the Chapter 4 with the Chapter 5 would improve the structure. There is a custom to write scientific texts in past tense form about all activities associated with the work. This is not the case here unfortunately.

There are 27 references, of which 12 were properly cited articles, 4 of them were insufficiently cited through a link to iopscience or optica websites, 3 references probably with a restricted access (internal notes), and one link to a source file in C++ language.

Topic elaboration

As mentioned above, the topic itself is important for the AFP community and thus this work is appropriately valuable in general.

The performance analysis was done using two dedicated runs of the Run-3 campaign, one with an average pile-up of 37.5 (a high-μ run) and the latter one with a low pile-up of 0.02 (a low-μ run). The student decided to plot raw time distributions from both A and C sides in one histogram to save space. However, the right distribution for the side A is very close the upper limit of the histograms. There are plenty of histograms of time differences among bars across all trains not all of them. Corresponding widths of time differences of all combinations are summarized in tables. This approach would be quite cumbersome for readers. Instead, one could prefer present few histograms' examples with summarizing tables adding full set of histograms to an appendix.

The student defined two procedures for the efficiency analysing: a so-called dividing histograms method and a direct method. Both methods led to different results despite rather small differences. In the case of the first method, there is a misleading definition of a reference due to presence of optional condition for the ToF trigger (OFF). But I suppose it is just about the description in the text. Plots of parasitic efficiencies in Figures 3.29 – 3.36 are useful as well. The empty boxes in plots are not visually suited, however. One must guess there is zero response of a corresponding bar.

In Chapter 4, there is a histogram in Figures 4.1 and 4.3 of a $z_0 - z_1$ the distribution without any explanation what does these quantities mean. This is done in caption of Figure 4.5 few pages hereafter. There is no information about which data set is plotted in Figure 4.7 (or if all datasets were used) and why

a simulated sample for ALPs of 400 GeV were chosen. Subsection *Background rejection* is important, and it deserves more attention. It would be interesting to mention which processes contribute to the background relevant for ALP studies, the pile-up level assumed in simulations, and what position the *z* value from the ToF is compared to. Is it position of primary vertices of photon pairs? If so, there is rather high uncertainty of this quantity as seen in Figure 4.7.

In Chapter 5, extraction of time delay coefficients is based on time (or position) differences between ToF detectors and the ATLAS beam spot. There is a mention that raw positions of z_{ToF} are distributed around the z_{BS} in a Gaussian-like manner. It would be convenient to show such distribution. I don't understand zero values in upper plots of Figure 5.6. Are these z_{BS} positions? As both datasets are predominantly in blue colour, the legend is useless here (the same stands for lower plots).

Questions

1. Chapter 3.1. One of additional requirements on ToF was a cut on measured ToF arriving time period. Can you specify?
2. Chapter 3.3. How do you explain differences in efficiencies between the two used methods – method of dividing histograms and direct method?
3. Section 4.1.1, Figure 4.2. Is there any explanation of correlation between ALP mass and the width of the primary vertex distribution of unconverted photons?
4. Chapter 4.1.2, section Background rejection. Which physics processes were counted to the background to a possible di-photon signal. Which vertex positions the ToF positions were compared to? (PV of di-photons interaction or ATLAS PV?)
5. Chapter 5.2. There is a statement that high-μ runs include too much combinatorics, so they are not used for vertex matching procedure. Can you support this statement with an example?

Final assessment

I rate the submitted work positively. The author got expertise in analysis of data in the leading ATLAS experiment. She obtained results demanding for the AFP collaboration and this thesis would be a valuable reference in further applications.

Suggested grade: B (very good).

In Olomouc, May 17, 2023

Libor Nozka, Ph.D.
Palacky University in Olomouc, Faculty of Sciences