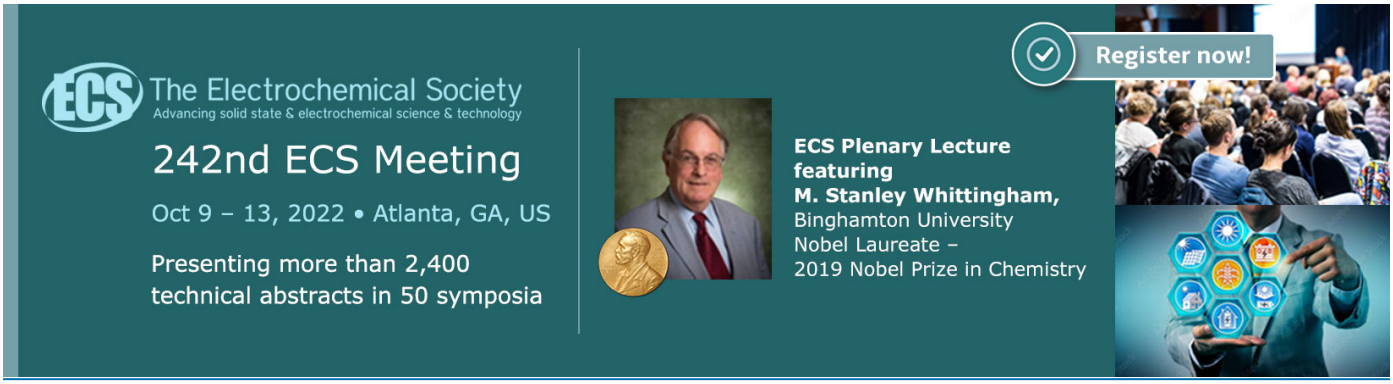
HADES Forward Wall calibration procedure



HADES Forward Wall calibration procedure

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Abstract. The Forward Wall (FWall) detector is a segmented scintillation forward hodoscope with PMT readout. The FWall is one of the detector subsystems in the HADES experimental setup at SIS18 (GSI, Darmstadt, Germany) used for determination of the collision centrality and event plane orientation in nucleus-nucleus collisions. The quality of the FWall calibration is a crucial point for these tasks. The HADES experiment on particles production in Ag+Ag reaction at 1.23 and 1.58AGeV has been performed in 2019. FWall calibration was performed for both data sets. In this work the results of the FWall calibration at 1.58AGeV are presented.

1. Introduction

In 2019 data of Ag+Ag interactions at 1.23 and 1.58AGeV were collected by HADES experiment. The FWall detector was used in this experiment for the collisions centrality and the event plane orientation measurements and quality of its calibration in one of the important tasks of data analyses. The detector construction is briefly described in the next section. A detailed description of the calibration procedures for both measured time and amplitude is presented in section 3, the results of calibrations for Ag+Ag at 1.58AGeV data are given in section 4.

2. HADES experimental setup

The HADES experiment (The High-Acceptance Dielectron Spectrometer) is intended mainly to study the properties of nuclear matter at energies of the order of 1-4 GeV per nucleon [1]. At such energies, confinement and chiral symmetry breaking of a strongly interacting nuclear matter are most prominent. The study of azimuthal flow at such energies is mainly aimed at studying the equation of state of nuclear matter. The experimental setup consists of six identical sectors located around the beam axis, figure 1. Its main components are trigger beam detectors system (START and VETO), tracking system (MDC - multiwire drift chambers), time-of-flight system (TOF+RPC), electromagnetic calorimeter (ECAL) and forward hodoscope (FWall) [2]. The FWall total transverse sizes are 176 x 176 cm^2. It is placed at the beam axis at 7m from the target and consists of 288 individual scintillation detectors (cells) (figure 2). The PMTs are used for converting the light to signal readout.

The sizes of FWall cells are increasing from the center to the periphery, there are 144 small cells with sizes 4x4cm^2, 64 medium cells with sizes 8x8 cm^2 and 96 large cells with sizes 16x16 cm^2. To avoid radiation damage of the FWall scintilators there is a hole in the center with sizes 8x8 cm^2, where the largest and most energetic bunches of spectators from the most peripheral

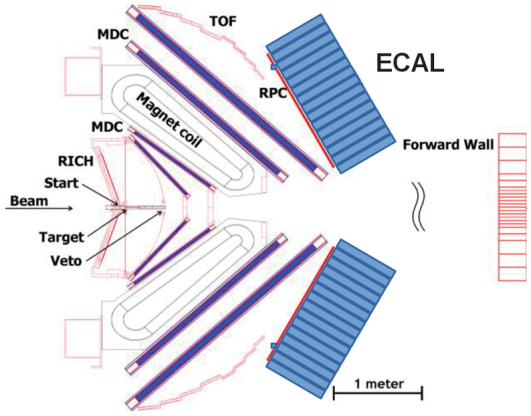

Figure 1. HADES experimental setup.

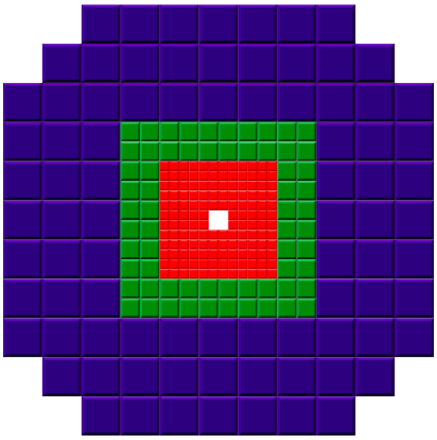

Figure 2. Scheme of the Forward Wall.

events and the beam particles without interaction fly through. The data of the Ag+Ag collisions at two energies, 1.58AGeV and 1.23AGeV were collected during the HADES data taking in March 2019.

3. Scheme of calibration

The FWall calibration includes both time and amplitude calibrations. The aim of amplitude calibration is to equalize responses of all FWall cells for a certain charge of the particles (Z=1, 2, etc.). With time calibration parameters it becomes possible to reconstruct expected particles time of flight from the target to FWall. The time and amplitude calibrations were done for each FWall cell. Due to time-dependence of the calibration parameters corresponding sets of parameters were provided for each day of the data taking period.

3.1. Time calibration steps

The calibration is done for each cell individually. The first step is Walk Time Correction. The purpose is to define corrected time (T_{cor}) by correcting measured time (T_{raw}) on its dependence on measured amplitude (signal time over threshold, ToT_{raw}). The corresponding dependence is shown in figure 3 and T_{cor} can be determined according to formula:

$$T_{cor} = T_{raw} \cdot slope_{tdc} - WC1 - \frac{WC2}{\sqrt{ToT_{raw}}}, \quad (1)$$

where WC1 and WC2 are fitting parameters of this dependence caused by electronic channel properties, $slope_{tdc}$=0.1 is a value to convert raw time scale to nanoseconds. Applying the WC1, WC2 parameters eliminates measured time dependence on measured amplitude (figure 4). Secondly, the expected particles time of flight from the target to the FWall for analyzed reactions is about 25 nsec. Tops of corrected time distributions in cells were fitted with Gauss function and the differences between expected time and mean values of these distributions determine the offsets, which were used to calculate calibrated time (T_{cal}):

$$T_{cal} = T_{cor} + tdc_{offset} \quad (2)$$

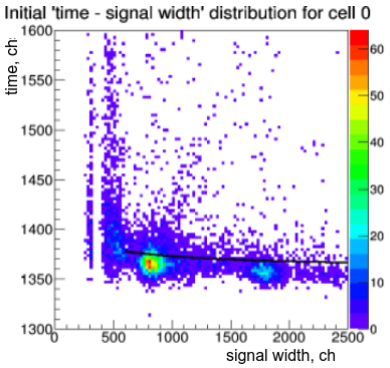

Figure 3. Raw time dependence on amplitude before calibration for one of the FWall cells.

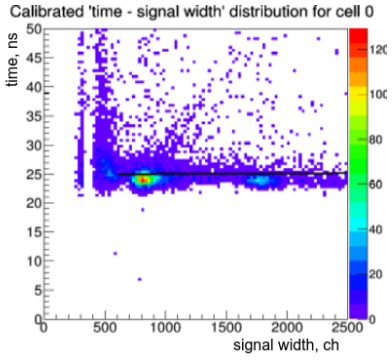

Figure 4. Raw time dependence on amplitude after calibration for one of the FWall cells.

3.2. Amplitude calibration steps

Firstly, all peaks in cell charge distribution (as shown in figure 5) are marked and fitted with multiple Gauss function. The Z1 and Z2 positions are extracted from the fit. Then the ADC parameters are determined with formulae:

$$slope_{adc} = \frac{100}{ToT_{Z2} - ToT_{Z1}} \tag{3}$$

$$offset_{adc} = 100 - slope_{adc} \cdot ToT_{Z1} \tag{4}$$

where $slope_{adc}$ reflects the behavior of the electronics channel (PMT divider), ToT_{Z2} and ToT_{Z1} - raw peak positions for the particles with Z=2 and Z=1, correspondingly, $offset_{adc}$ reflects the positions of the peaks for these particles and depends on the PMT voltage.

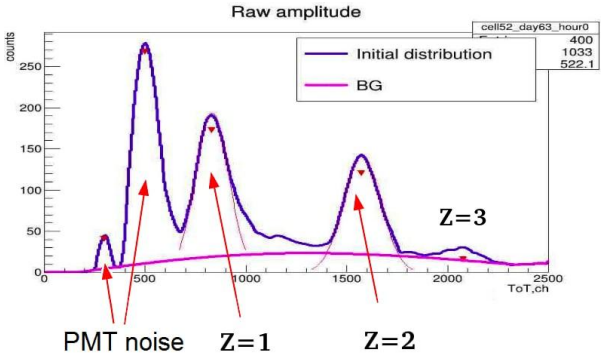

Figure 5. Raw amplitude distribution of one of the FWall cell.

4. Results of the FWall calibration

The FWall amplitude and time calibration parameters were determined according to the described procedures for each cell and separately for each day of data taking. Applying the time calibration parameters allows to reconstruct expected particles time of flight from the target

to the FWall (figure 6). Using of the amplitude calibration parameters provides positions for particles with Z=1 and Z=2 in the 100 and 200 channel (a.u.), correspondingly, as presented in figure 7. In figure 8 amplitude spectra for various cells after applying the calibration parameters are shown. Small deviations from cell to cell for particles with $Z \geq 3$ are due to non-linearity of the PMTs response.

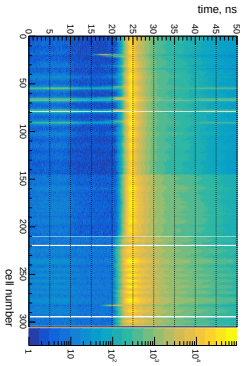

Figure 6. Time vs. cell number dependence for one day after calibration.

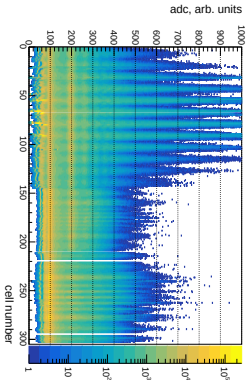

Figure 7. Amplitude vs. cell number dependence for one day after calibration.

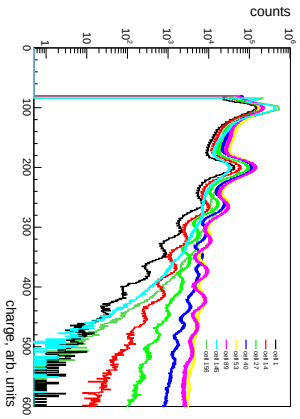

Figure 8. Amplitude spectra for various cells for one of the days after calibration.

In addition, after the precise time and amplitude calibrations the correction factors for beam shifts along both X and Y axises have been calculated for each set of calibration parameters.

5. Conclusion

Amplitude and time calibration procedure of the FWall scintillation detectors based on matching of the recorded signals with a certain charge of the charged spectators was done for Ag+Ag collisions at the energy of 1.58AGeV and 1.23AGeV for each of data taking days. Corrections for beam shifts along the x and y axes for all days were determined and together with calibration parameters will be used in further analyses.

References

[1] Agakishiev G *et al.* 2009 *Eur. Phys. J.* A **41** 243–77
[2] Andreeva O V *et al.* 2014 *Inst. and Exp. Techniques* **57** 103–19