Time calibration of WASA-at-COSY Forward Detector

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For precise studies of rare decays of the η and η' mesons with the WASA-at-COSY [1] detector, using the $pp \to ppX$ reaction one has to reconstruct the missing mass distribution with very good accuracy. The resolution of the missing mass depends on the accuracy of the kinetic energy reconstruction and measured angles of two forward outgoing protons. In order to improve the accuracy of the energy reconstruction, in addition to the energy loss method one can also use information about Time-of-Flight (TOF) measured using several scintillating layers of the WASA Forward Detector [2, 3]. This method is under development and in this report we present the current status of the time calibration and energy reconstruction algorithm.

As a first step using the elastic scattering events $pp \to pp$, the five thin plastic scintillating layers of FWC and FTH were calibrated [4]. The calibration constants includes: (i) correction for the realitive time offsets between modules, (ii) compensation for the "walk effect", and (iii) time propagation of the light in the scintillator material. Each of the constants was determined separately for each scintillating module. After calibration based on the measured time diffrences between layers we have determined the absolute time resolution for each thin layer: $\sigma_{FTH_1} = 0.27\ ns$, $\sigma_{FTH_2} = 0.34\ ns$, $\sigma_{FTH_3} = 0.37\ ns$, $\sigma_{FWC_1} = 0.37\ ns$, and $\sigma_{FWC_2} = 0.40\ ns$. Furthermore based on the known scattering angle θ of the elastic event we have calculated the TOF between each FWC and FTH layers and compared it with the corresponding TOF measured with scintillators. The difference between the TOF_θ and reconstructed TOF_β (see Fig 1) gives the overall time resolution of all scintillating layers: $\sigma = 0.37\ ns$. This resolution includes also the uncertainty originating from the determination of the TOF_θ.

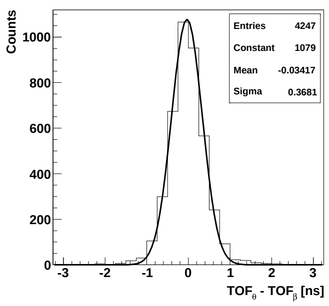

Fig. 1: Overall TOF resolution determined based on the pp elastic scattering events yelds $\sigma = 0.37\ ns$.

In order to reconstruct the energy of protons the time obtained from each FWC and FTH layer has been parametrized as $t = const + \frac{1}{\beta} \cdot d$, where β is the velocity of protons and d denote the hit position along the beam direction. Using the measured time for each single proton track and the known distance we have determined the velocity by fitting linear function to the experimental points. The example of fit is shown in Fig. 2. The achieved accuracy of the velocity determination based on the first five layers amounts to around 15%. In order to improve further the resolution of the determination of the proton velocities we plan to use all scintillator detectors for the time measurement: FWC, FTH, FRI, FRH and the FVH. This will enable us to measure time signals in 14 points on a distance of around 2 m and will improve the accuracy significantly.

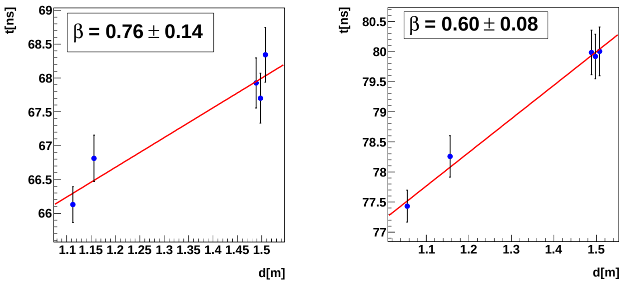

Fig. 2: Proton velocity determined based on the times measured in each layer of the FWC and FTH detectors.

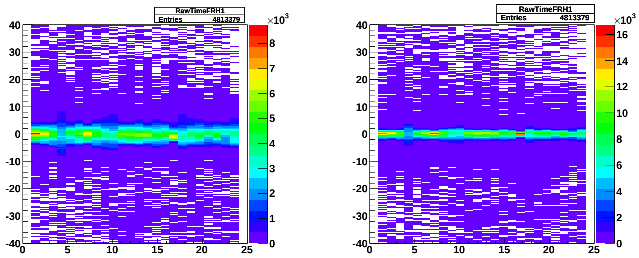

Fig. 3: Time difference between the FTH_1 and FRH_1 as a function of the element number in the FRH_1 before (left) and after (right) the offsets adjustments.

For the time calibration of the FRH detector, experimental data from the reaction $pp \to pp\eta$ measured in 2008 have been used. This detector is built out of scintillators with thickness from 11 cm up to 15 cm, therefore particles passing through it will loose their energy and velocity significantly. In a first step, relative offsets between individual elements have been determined. Then, the correction of the walk effect was introduced using the linear dependence between the time and the inverse of the square root of the ADC. Next, we took into account the time of the light propagation in the scintillator. Fig. 3 shows the time difference between the reference detector (FTH_1) and FRH_1 as a function of the element number in the FRH_1 before (left) and after (right) the offsets adjustments. The time resolution has been improved from 2.4 ns to 1.1 ns. As a next step we will determine the absolute offset for all 5 layers of the FRH detector and implement the method of calculating the proton deceleration in scintillating material based on measured energy loss.

References:

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