Time calibration of the COSY-11 neutron detector

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A neutron detector at the COSY–11 internal facility was extended by 12 new scintillation modules [1], and at present it consists of 24 segments positioned at a distance of about 7 m from the target, as depicted schematically in figure 1. This detector in conjuction with the existing COSY-11 detection setup [2] will allow to extend hithertho performed investigations [3] of the production of neutral Λ and Σ^0 hyperons to other isospin channels. In particular, we intend to study the $pp \to nK^+\Sigma^+$ reaction [4], by the simultaneous registration of neutrons and K^+ mesons produced by the COSY proton beam on the hydrogen cluster target. The identificaton of the unregistered short living Σ^+ hyperons will be fulfilled via the missing mass method.

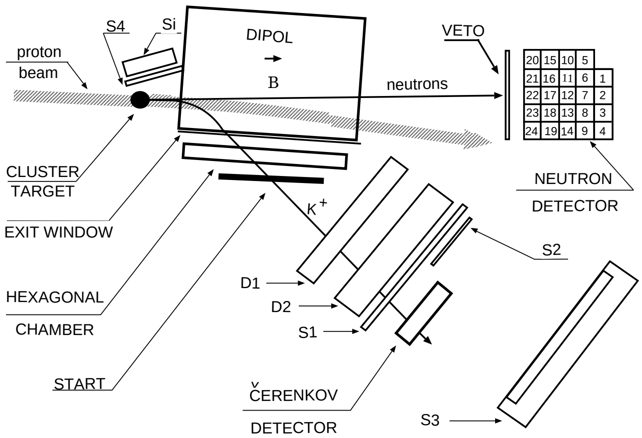

Fig. 1: COSY–11 detection setup [2] with the emphasised neutron detector and superimposed tracks of kaon and neutron from the $pp \to nK^+\Sigma^+$ reaction. The neutron detector on the figure is blown–up in comparison to others detection system components.

An experimental resolution of the missing mass determination depends on the reconstruction accuracy of the four-momentum vectors for the registered neutrons and kaons. The momentum vector of the K^+ meson can be established by tracking the K^+ trajectory – reconstructed from signals registered in the drift chambers– through the magnetic field back to the target point. The absolute momentum of the neutron can be calculated from the time-of-flight between the target and neutron detector, and the momentum components can be deduced from the position of the first hit module. Thus the precision of the time measurement by each separate module as well as the relative timing between segments are crucial factors for the resolution of the Σ^+ mass determination.

Here we report on the calibrations performed this year in order to determine both: time offset and a time resolution of each single detection unit. For this purpose we have derived – from the experimental data– distributions of time differences between neighbouring segments and in parallel we have generated corresponding spectra using a GEANT-3 simulation code. An example presented in figure 2 shows that the shape of the simulated distribution agrees very well with the experimental data. This corroborates the correctness of the performed simulations and enables to establish the values of the investigated parameters by the comparison of the simulated and measured spectra. The mean of the distribution corresponds to the difference between the time offsets between appropriate modules. Its width reflects i) the time resolution of the involved modules, ii) the smearing of velocities from the secondary particles and, iii) the distribution of the positions at which they were created. A difference measured between the i'th and the j'th module can be expressed as:

$$\Delta_{ij} = t^i_{TDC} - t^j_{TDC} = t^i_{real} - t^j_{real} + off^i - off^j \qquad (1)$$

where t^i_{TDC} and t^j_{TDC} denote the time registered by the TDC (time-to-digital converter) in $i's$ and $j's$ modules of the neutron detector, respectively. t_{real} stands for the real time at which the secondary charged particle produced a light signal inside a scintillator and off summarises all delays between the module and the TDC converter. In the simulations the difference $off^i - off^j$ was set to zero.

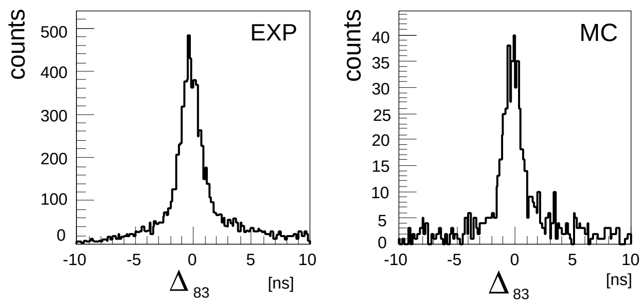

Fig. 2: Distribution of the time difference between the 8^{th} and the 3^{rd} module of the neutron detector. (left side) experimental data, (right side) Monte-Carlo simulation. The long tails of the distribution may be caused by events where the secondary neutral particles with significantly different velocities induce nuclear reactions in the neighbouring segments. More detailed studies of that issue are in progress.

By the comparison of the experimental and simulated distributions of all of the possible combinations of Δ_{ij} we have established the relative time offsets between the segments and found out that the time resolution of a single module amounts to 0.4 ns (rms). This value is smaller than the one obtained for the former installation [5] since, at present, light signals of each module are read out on both sides by separate photomultipliers, whereas in the former version of the neutron detector the scintillation light was collected only on one side of the segment.

References:

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