Time calibration of the neutron detector for $pp \to nK^+\Sigma^+$ reaction.

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In the threshold production of the Σ^+ hyperon via the $pp \to nK^+\Sigma^+$ reaction [1] at COSY-11 [2] the four momenta of the K^+ and the neutron have to be determined in order to calculate the missing mass for the identification of Σ^+ events. The accuracy of the neutron momentum calculation is crucial and strongly depends on the precision of the neutron time of flight determination. The neutron particle detector consists of 24 segments (9x9 cm^2 each) of scintillator/lead sheets positioned as depicted schematically in figure 1 in ref. [3].

The first row of modules is at a distance of 7.36 m from the target. The timing for the neutron detector is nearly independent of the hit position within a module since the timing (t^i_{TDC}) from the $i\,'s$ module is taken from the average of the upper and lower photomultiplier signals. In order to relate the time measurement it is necessary to know the relative time offsets between any two neighbouring modules which is performed by comparing the signals of different modules [4].
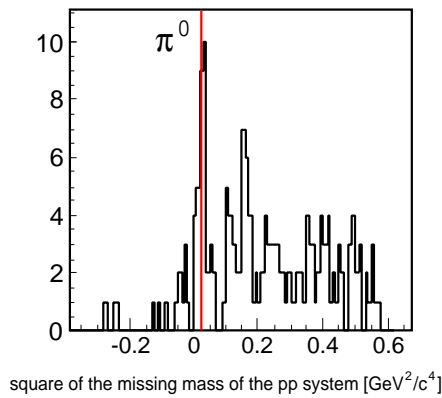

Fig. 1: The square of the missing mass distribution for two track events with a signal in the neutron detector. The π^0 peak is clearly seen.

In addition, the general time offset between the neutron production and the hit time in the neutron detector has to be determined. The global offset was found using the $pp \to pp\pi^0$ reaction. Two track events were selected and the four-momenta of both protons were determined by backtracking through the known magnetic field to the target and the π^0 was identified via the missing mass technique. The square of the missing mass distribution for two track events with a signal in the neutron detector including 30 % of the data is shown in fig.1. The statistics is very low due to the small detection acceptance but some $pp\pi^0$ events can be definitely identified. The π^0 meson decays with a $c\tau$ value of 25 nm immediately in the target and the γ's from the decay will reach the neutron detector with the speed of light and no further delay. Knowing the distance between the target and the first row of the modules of the neutron detector and the speed of light in air, one can adjust the general time offset for the neutron detector with high precision. In fig 2. the time distribution for the selected π^0 events is shown. The total event number as well as the width of the discussed peak corresponds to the expectation from Monte Carlo studies

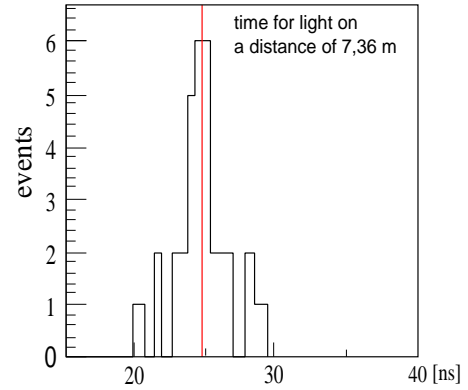including the measured time resolution of a single module of $\sigma = 0.5$ ns.

Fig. 2: Time signal in the neutron detector for γ's from the π^0 decay selected from experimental events: $pp \to pp\pi^0$.

The global timing for the neutron detector is taken as the difference between the time of the reaction (taken from the backtracking of positively charge particles through the known magnetic field) and the shortest time in the neutron detector. The distribution of the modules with the first signal, i.e. where the γ conversion happened, is shown in figure 3. It occurs mostly in the first row as expected from the radiation length of 0.56 cm in lead. Contrary with neutrons, the distribution is more homogeneous with a maximum in the middle part of the neutron detector.
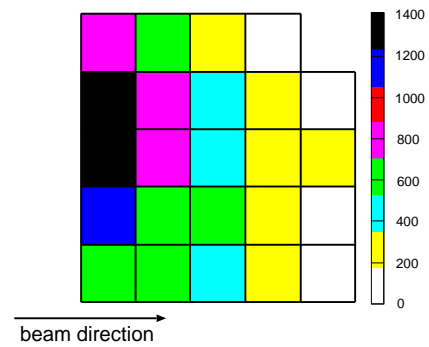

Fig. 3: Distribution of the γ conversion probability in the neutron detector. The module where the conversion happens was defined by the first signal.

References:

[1] T. Rożek et al., COSY Proposal no. 117 (2002).

[2] S.Brauksiepe et al.,Nucl.Inst.& Meth.A 376 (1996) 397-410.

[3] T. Rożek et al., Threshold Production of Σ^+ an COSY-11, Annual Report 2003, FZ Juelich, 2004.

[4] T. Rożek et al., Time calibration of the COSY-11 neutron detector, Annual Report 2002, FZ Juelich, 2003, Jul-4052.