Position Sensitivity of LYCCA Time-of-Flight Detectors*

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Introduction

The Lund York Cologne CAlorimeter (LYCCA) [1, 2] is an essential system of the PreSPEC-AGATA setup [3] located at GSI. Its main purpose is the identification (Z,A) and tracking $(\vec{v})$ of reaction products from the secondary target. The Z identification is done with a large $\Delta E - E$ telescope, consisting of Double-sided Silicon Strip Detectors (DSSSD) for the energy loss as well as position measurements, and CsI scintillation detectors to measure the residual particle energy. An additional time of flight (ToF) measurement is used to determine the particle mass. Thin, circular-shaped plastic scintillation detectors, read out with 12 or 32 photomultiplier tubes (PMTs), are used to achieve the required timing precision [1, 4]. The large diameter of 27 cm of the ToF-Start and ToF-Stop membranes necessitates a correction for the path length of the photons inside the membrane. Therefore, the ion position inside the membrane has to be known and is usually determined with additional tracking detectors. This report describes a method of determining the particle position, based only on the 32 time signals from the large membrane's PMTs.

Method and Results

The position information is implicitly given as the minimum of the log-likelihood function $\log L(\vec{r}_p)$ of the particle hit position $\vec{r}_p$ on the membrane. Given the $N = 32$ PMT time signals, t_i, it can be written as

$$\log L(\vec{r}_p) = \frac{1}{N}\sum_{i=1}^{N} t_{c,i}^2(\vec{r}_p) - \left(\frac{1}{N}\sum_{i=1}^{N} t_{c,i}(\vec{r}_p)\right)^2 \quad (1)$$

where the measured time signals, corrected for the photon path length, are defined by $t_{c,i}(\vec{r}_p) = t_i - t_{i,\mathrm{prop}}(d_i)$. The propagation time, $t_{i,\mathrm{prop}}(d_i)$, is the time a photon needs to travel from the particle hit position in the membrane $\vec{r}_p$ to position $\vec{r}_i$ of the i-th PMT. It is assumed to be a linear function of the photon travel distance $d_i(\vec{r}_p) = |\vec{r}_i - \vec{r}_p|$. The two linear coefficients can be determined beforehand by a calibration procedure, using known particle positions measured with the DSSSD tracking and plotting the known distance d_i versus $t_i - \langle t_c \rangle$, as shown in fig. 1. The average $\langle t_c \rangle = \sum_i t_{c,i}$ is the best estimate of the time when the particle passes the membrane. The minimum of (1) is determined numerically by an iterative procedure, starting at the center of the membrane. As a final step, additional empirical corrections for small offsets and shearing effects are applied.

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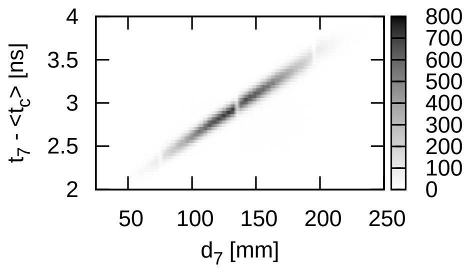

Figure 1: Linear correlation between $t_{c,7}(\vec{r}_p)$ and $d_7(\vec{r}_p)$ for the 7-th PMT.

The spatial resolution can be deduced from the differences between the positions given by DSSSD detectors and the result from the membrane detector. The resulting distribution is shown in fig. 2 and has 7.6 mm FWHM along the x and 6.8 mm along the y-direction, respectively. Taking into account the 3.6 mm wide DSSSD strips, the resulting position resolution for the membrane detector is 6.7 mm and 5.1 mm FWHM in x and y-direction, respectively. The reason for the difference in x and y is not yet understood. The analysis procedure was done using a new analysis framework for PreSPEC-AGATA data analysis [5] and data from a ^{132}Sn fragmentation setting. Upgrades of the LYCCA ToF system foresee the digitization of PMT signal heights, which should further improve the membranes' intrinsic position resolution.

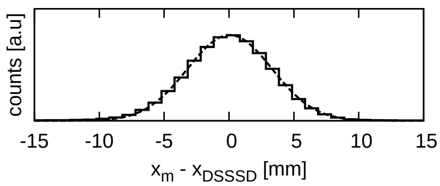

Figure 2: Histogram (solid line) of x-position difference from membrane (x_m) and DSSSD tracking (x_DSSSD). The dashed line is a Gaussian fit ($\mathrm{FWHM} = 7.6\,\mathrm{mm}$).

References

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