# $K_l \rightarrow \pi^0\nu\overline{\nu}$ Simulation Analysis 2

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ABSTRACT

Monte Carlo produced data for $K_l \rightarrow \pi^0\nu\overline{\nu}$ decays were studied in simulation 1 in order to deduce acceptable showers in the endcap preradiator. Using these showers, results for the resolution of the K decay vertex and time and the photon angular resolution have been obtained.

## 1. Introduction

In this note the showers passing all cuts described in simulation 1 were used to obtain the K decay time and position, the photon polar angle, and the opening angle. Two such determinations were made using the mwpc averaged coordinates in the first 2 layers of each good shower: 1) a dead reckoning determination (nofit) and 2) a constrained fit using the program KINFIT described by M Ito.

## 2. Method

Recall that in simulation 1 642 good events were obtained from 5000 generated events. These events had two or more showers each with at least two layers of mwpc information. For the fits described below I used the 2 showers which had the most layers of mwpc information. In case of a tie the first such shower found was used. The detected mwpc averaged coordinates, as described above, are called $x_{ij}, y_{ij}$. Here i labels the shower (1 or 2) and j labels the layer on the shower (1 or 2). The z coordinates $z_{ij}$ are obtained from the layer struck and enter the fits as parameters. The other 2 detected quantities are the minimum time of the layer 1 hit of each shower $t_i$, which is determined from the scintillator of that layer.

The unmeasured quantities are the K decay vertex and time $x_k, y_k, z_k, t_k$ and the photon slopes in the xz,yz plane called $dxdz_i, dydz_i$. The way P Gumplinger wrote the Monte Carlo code the actual value of $t_k = 0$ and $x_k, y_k, z_k$ are in the output ntuple. Also in the output ntuple are the polar angle of each photon, $\theta_i$, and the opening angle, $\theta_o$ between the photons. These angles are simply obtained from $dxdz_i, dydz_i$ as follows:

$$cos\theta_i = (1 + dxdz_i^2 + dydz_i^2)^{-0.5} \tag{1}$$

$$cos\theta_0 = Fcos\theta_1 cos\theta_2 \tag{2}$$

$$F = (1 + dxdz_1 dxdz_2 + dydz_1 dydz_2) \tag{3}$$

Using simple algebra the 10 measured quantities determine the unmeasured quantities (the nofit values in the figures). For example,

$$dxdz_i = (x_{i2} - x_{i1})/(z_{i2} - z_{i1}) \tag{4}$$

Before calculation of the unmeasured quantities the measured quantities were smeared (gaussian) as follows: $\sigma_t$=0.3ns,$\sigma_x$=$\sigma_y$=0.02cm (200 $\mu$). After the nofit values of the unmeasured quantities are obtained the measured, unmeasured quantities, the measured variance matrix, $v_{ij,ij} = \sigma^2$, and the constraints are fed into the fitting program KINFIT. There are 10 constraints which the fit will try to zero by varying the measured and unmeasured quantities to produce a minimum chisq. The constraints are:

$$con(1) = (x_{11} - x_k) - dxdz_1(z_{11} - z_k) \tag{5}$$

$$con(2) = (x_{12} - x_k) - dxdz_1(z_{12} - z_k) \tag{6}$$

$$con(3) = (x_{21} - x_k) - dxdz_2(z_{21} - z_k) \tag{7}$$

$$con(4) = (x_{22} - x_k) - dxdz_2(z_{22} - z_k) \tag{8}$$

$$con(5) = (y_{11} - y_k) - dydz_1(z_{11} - z_k) \tag{9}$$

$$con(6) = (y_{12} - y_k) - dydz_1(z_{12} - z_k) \tag{10}$$

$$con(7) = (y_{21} - y_k) - dydz_2(z_{21} - z_k) \tag{11}$$

$$con(8) = (y_{22} - y_k) - dydz_2(z_{22} - z_k) \tag{12}$$

$$con(9) = d_1 - ct_1 \tag{13}$$

$$con(10) = d_2 - ct_2 \tag{14}$$

In the above c is the speed of light and

$$d_i = ((x_{i1} - x_k)^2 + (y_{i1} - y_k)^2 + (z_{i1} - z_k)^2)^{0.5} \tag{15}$$

**3. Results**

Figure ID 29-30-59 shows the chisq distribution (ID 29) and the number of iterations required (ID 30) for events which KINFIT successfully fit. Note 604/642 produced good fits. ID 59 shows the chisq distribution for fitted events after the xyz cut: $x_k$ is between -150cm and 150cm, $y_k$ is between -5cm and 5cm, and $z_k$ is between 0 and 330cm. In this case the number of events is 269.

In the next 3 figures ID 31,37, and 38 the stretch functions for the measured quantities $t_1, x_{21}, y_{21}$ are shown. The definition of the stretch function is taken from M Ito's note:

$$s_i = (x_{ij} - xfit_{ij}))/(v_{ij,ij} - vfit_{ij,ij})^{0.5} \tag{16}$$

The stretch functions for $t_2$ and the other coordinates are similar. These stretch functions should have mean=0 and $\sigma$=1. Those here are not gaussian due to long tails from poorly fit showers, but the means and $\sigma$s are in the right ball park.

The next 6 figures, each with 4 panels, show the resolution results for the quantities tk(ID 25-51-61-71), xk(ID 22-52-62-72), yk(ID 23-53-63-73), zk(ID 24-54-64-74), opening angle(ID 26-55-65-75), and photon polar angle(ID 27-56-66-76). The latter has two entries/event. Going from left to right the panels show the nofit (642 events), all successful fit (604 events), successful fit with xyz cut ( 269 events), successful fit with xyz cut and chisq($<2$) cut (181 events) distributions. Again going from left to right each step improves the resolution and the $\sigma$s found from a gaussian fit to these distributions are:

$t_k$ - 0.94, 0.57, 0.33, 0.33 ns
$x_k$ - 5.69, 4.42, 3.12, 2.75 cm
$y_k$ - 6.05, 4.50, 2.31, 2.22 cm
$z_k$ - 12.59, 10.22, 8.58, 8.65 cm
$\theta_o$ - 3.31, 3.29, 2.10, 1.81 deg
$\theta_i$ - 1.68, 2.18, 1.16, 0.96 deg

In the case of the polar angle we wanted to reach a resolution of 0.025rad or about 1.4 deg. This is more than accomplished by successful fitting with xyz cut (without this cut the K vertex is not guaranteed to be in the fiducial region). The acceptance of the endcap at this stage is 269/5000=5.4%. Also the values of $t_k$ and $z_k$ which are important in determining the K momentum are determined within the resolutions desired. The determination of $z_k$ is out of a flight path of between 7 to 10.3m, that of $t_k$ just depends on the scintillator and beam bunching time resolutions achieved.

Thus, this type of endcap preradiator seems to suffice for our purposes, although with somewhat smaller, but not catastrophic, acceptance, than expected.

I tried the same analysis with showers requiring at least 3 layers with mwpc information and using the information from the first 3 layers. This just resulted in lower acceptance (604/5000 to 551/5000 successful fits) and no improvement in resolution.

The endcap calorimeter will be studied when the new geometry is ready.