Systematic Checks of PMT Timing Calibration in SNO

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Timing information of detected photons are very important for SNO data analyses, especially for event reconstructions. Each PMT needs to be calibrated to correct for the time shift from cable delays and the time walk. This calibration process is called PMT Timing Calibration or PCA. SNO uses a pulsed laser source to carry out such a calibration. Our analyses on the SNO LED data indicated there might be a systematic error on the nominal laser position, which is an important input to the PCA process.

One way to provide an independent cross check to the nominal laser position reported by the deployment mechanism is to directly use the data to reconstruct the source position. However, as described above, in order to do the reconstruction, the PCA process has to be carried out first where the laser position is an essential input. This seems to be a loop with no way out. We developed a technique which can reconstruct laser position without knowledge of delay time due to difference in cable length, thus avoiding inputs of the nominal laser position. The analysis uses two data sets with the laser deployed to different positions are used in the analysis. For data set 1, the time of photons detected by the ith PMT is:

$$t_{i1} - t_1 = \frac{d_{i1}\langle n\rangle}{c} + \triangle t_i \qquad (1)$$

where t_{i1} is the hit time, t_1 is the source time, d_{i1} is the distance between the source and the ith PMT and $\triangle t_i$ is the delay time of the PMT. The same equation also holds for data set 2:

$$t_{i2} - t_2 = \frac{d_{i2}\langle n\rangle}{c} + \triangle t_i \qquad (2)$$

If we subtract Eqn. 1 by Eqn. 2, we have:

$$t_{i1} - t_{i2} - \triangle t = \frac{d_{i1}\langle n\rangle}{c} - \frac{d_{i2}\langle n\rangle}{c} \qquad (3)$$

Table 1: Reconstructed laser positions compared with their simulated positions

		x (cm)	y (cm)	z (cm)
1	$\vec{r}_{simulated}$	0	0	400
	$\vec{r}_{fit}$	-1.30	-0.27	398.25
2	$\vec{r}_{simulated}$	0	0	-400
	$\vec{r}_{fit}$	-1.06	-0.15	-400.61

where $\triangle t$ is the difference in source time between two data sets. In this way, the time delays due to different cable length are cancelled.

We have roughly 9000 such equations, each of which corresponds to a single PMT. Because the number of data is much larger than the number of parameters to fit (six spatial coordinates of two laserball positions and the difference between 2 source time) , we should be able to fit the laser positions very accurately.

Monte Carlo simulations have been carried out to verify this method. In the simulation, random delay times were assigned to each PMT, thus reconstructing the laser position is impossible. However, with the method discussed above, we were able to reconstruct both of 2 laserball positions very accurately as shown in Table 1. We are currently applying this technique to actual data. Preliminary results show that there might be a systematic offset in the nominal laser position.