Simple Vertex Considerations

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Abstract: A primitive event Monte Carlo generator and reconstruction program are used to investigate vertex errors as a function of position, number of hits and attenuation lengths. Models with both a single attenuation length and with two attenuation length regions are considered.

1. Description of Program

Events are considered pointlike. For each event, some number of photons are sent in random directions. The PMT positions are taken to be in those directions, except that if two hits fall within 10 cm at the PMT position, they are taken to be within the same (8") PMT and the hits are combined. The effect of attenuation lengths is taken into account. The size of the hits are smeared by a normal distribution with a standard deviation of 30%, unless indicated otherwise.

The reconstruction program uses as a first approximation, the charge-weighted average position of the hit PMT's. MINUIT is then used to minimize the chi-squared using the size versus predicted size of the hits. Timing is not used.

The events are generated at ($x = 0,\ y = 0,\ z$). That is, z is the radial position of the event and errors in x and y are errors in the transverse directions. Five hundred vertices were generated at each position.

2. Results for a Single Attenuation Length Model

Here the PMT's were taken to be at 5 m and the attenuation length taken as 15 m. This simulation is useful to examine effects as the events get very near the PMT's. One thousand photons were thrown for each event. First we assume no smearing for the charges in the PMT's. (At the meeting, I mis-identified this table as the table with smearing.) We obtain the following:

Table 1: Single Attenuation Length Model–No Charge Smearing.

z	x-recon	y-recon	z-recon
0.	0 ± 0.021	0 ± 0.020	0 ± 0.023
1.	0 ± 0.021	0 ± 0.021	1 ± 0.025
2.	0 ± 0.024	0 ± 0.023	2 ± 0.036
3.	0 ± 0.028	0 ± 0.027	3 ± 0.041
4.	0 ± 0.044	0 ± 0.042	4.1 ± 0.068
4.5	0 ± 0.069	0 ± 0.067	4.9 ± 0.074
4.8	0 ± 0.022	0 ± 0.022	5.04 ± 0.012

As the outer radius of the detector is approached, distortions of the order of 10 cm and more appear. The widths of the distributions (rms) also increase. Extremely near the wall (at $z = 4.8$ m), the distributions sharpen up again as the wall tends to form a soft limit, at least for this reconstruction.

The x and y distributions should be the same of course. Both are listed as a sanity check on the program. Since they are independent, they also indicate something of the scatter of the results.

Next we introduce 30% charge smearing at the PMT's. We obtain:

Table 2: Single Attenuation Length Model–With 30% Charge Smearing.

z	x-recon	y-recon	z-recon
0.	0.01 ± 0.25	0 ± 0.23	0 ± 0.25
1.	0.01 ± 0.25	0 ± 0.23	1.01 ± 0.25
2.	0.01 ± 0.25	0 ± 0.23	2.02 ± 0.26
3.	0.01 ± 0.22	0 ± 0.21	3.04 ± 0.27
4.	0.02 ± 0.21	0 ± 0.20	4.14 ± 0.28
4.5	0.01 ± 0.18	0 ± 0.17	4.88 ± 0.19
4.8	0 ± 0.034	0 ± 0.036	5.04 ± 0.025

The distortions are seen to be about the same as without smearing, but the errors are much larger.

3. Results for a Two Attenuation Length Model

Here the PMT's were taken to be at 2.8 m. An inner sphere of radius 2.0 m was taken to be the event sphere with an attenuation length of 4.0 m. The outer region, the guard region was given an attenuation length of 15 m. Again, one thousand photons were thrown for each event. 30% charge smearing was taken at the PMT's.

We obtain the following:

Table 3: Two Attenuation Lengths Model.

z	x-recon	y-recon	z-recon
0.	$0. \pm 0.25$	0 ± 0.23	0 ± 0.068
0.5	0.01 ± 0.24	0 ± 0.23	0.51 ± 0.069
1.	0.01 ± 0.24	0 ± 0.23	1.019 ± 0.071
1.5	0.02 ± 0.23	0 ± 0.22	1.53 ± 0.065
1.8	0.02 ± 0.24	0 ± 0.23	1.83 ± 0.046
2.0	0.02 ± 0.27	0.01 ± 0.26	2.03 ± 0.058

There is essentially no distortion in the mean values as the edge of the inner volume is approached, since the events are not extremely close to the PMT positions.

The effect of changing the number of photons per event was examined. The widths of the distributions go approximately as the inverse of the square root of the number of photons, as expected.

The effect of changing the inner attenuation length was also examined. $z = 1$ was chosen. The following results were obtained:

Table 4: Effect of Changing Inner Attenuation Length ($z = 1$).

Atten. Len	x-recon	y-recon	z-recon
4.	0.01 ± 0.24	0 ± 0.23	1.019 ± 0.071
8.	0.01 ± 0.25	0 ± 0.24	1.028 ± 0.14
15.	0.01 ± 0.25	0 ± 0.23	1.028 ± 0.22

The radial distortion and distribution width increases as the inner attenuation length is increased. The attenuation of the signal is a significant aid in determining the position of the event.

Finally the smearing was varied with the following results for $z = 1$.

Table 5: Effect of Changing Smearing ($z = 1$).

Charge Smear	x-recon	y-recon	z-recon
10%	0.01 ± 0.086	0 ± 0.083	1.013 ± 0.27
30%	0.01 ± 0.24	0 ± 0.23	1.019 ± 0.071
60%	0.04 ± 0.42	0 ± 0.40	1.04 ± 0.14

4. Conclusions

Although this is a primitive model, the essential features are expected to model the situation reasonably.

It is likely that event reconstruction with an error of the order of 5-10 centimeters in the radial direction can be obtained for a two attenuation length situation. No appreciable distortion is expected radially out to the limit of the inner radius.

The smearing in the transverse directions is larger, of the order of 25 centimeters.

These results were obtained for 1000 photons and 30% charge smearing. Errors go approximately as the inverse of the square root of the number of photons. The charge smearing is also seen to dominate the errors. The errors are approximately proportional to the amount of smearing.