Effective Velocity and Minimal Fitter Radial Pull

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It is known that a systematic pull (vertex mis-reconstruction error) will result when incorrect velocity of light (in media) is used in time-of-flight based vertex fitters (Fig.1). The Sudbury Neutrino Observatory is a complex detector comprises of different kinds of optical media. Consequently the velocity of the photons is not known *a priori* from the data except for bounds due to (1) Cerenkov radiation has an intrinsically wide-band spectrum, (2) detector media are in general optically dispersive (n(ω)), (3) photons (with frequency ω) travel with group velocity $v_g(\omega) = c/[n(\omega)+\omega(dn(\omega)/d\omega)]$, (4) SNO PMT readout does not provide frequency information, and (5) photons will trespass different kind of detector material (e.g. D_2O, acrylic, H_2O, ...) before they are detected by the PMTs. To minimize the radial pull, a ray-tracing fitter for non-reflected light was developed. The fitter assumes a straight ray and the velocity of light v_g is calculated locally and dynamically from the media environment during the fitting process. Numerical derivatives are used to obtain the gradients of the chi-square in the (x, y, z, t) space during least chi-square minimization. The result of improvement is shown in Fig.2 for e^- Monte Carlo data, where the frequency of the optical photons and the group velocity is known from the code. For real data, effective velocities for each media need to be used. These values are subsequently determined by best-fitting to calibration source positions which are known geometrically. In our actual SNO analysis, the geometrical point where the N16 calibration source touches the inner wall of the acrylic vessel is used. Even though N16 is a gamma source, the centroids of the reconstructed vertices x-, y-, and z-distributions are good representations of the source position.

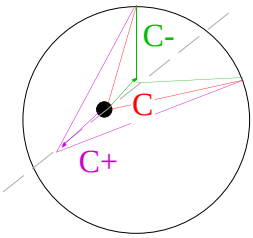

Fig.1 Velocity related systematic pull. Let C be the real velocity, then C+ will have the effect of systematically pushing the fitted vertex away from the PMTs and vice versa for C-.

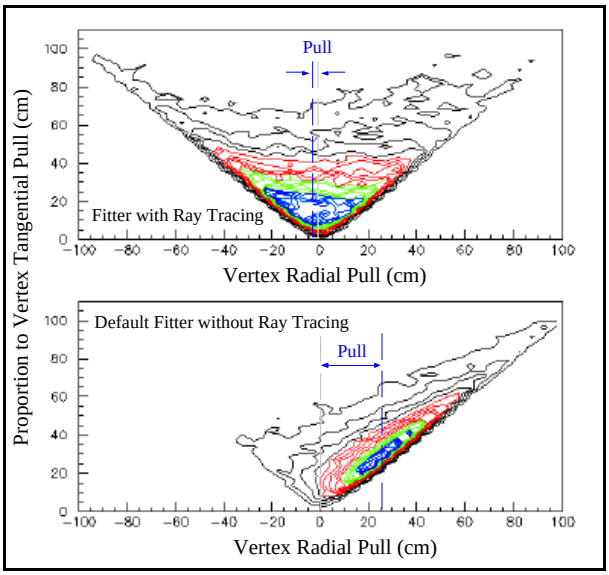

Fig. 2. Monte Carlo comparison between fitters with and without the ray tracing correction. There is a significant improvement in minimizing the radial pull.