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COMMENTS ON RECONSTRUCTION PROGRAMS

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1 Introduction

This report discusses the current fitting programs and their characteristics, suggested fitting programs and the requirements and structure of these fitting programs

2 Current Fitting Programs

Current vertex fitting programs usually begin by minimization of the timing residuals. (Referred to as TFIT in this report) This is well known to have the characteristic that on average the reconstructed vertex will have a systematic displacement from the 'true' vertex along the direction of the track. This is the so called driving effect and has been demonstrated by P. Skensved that for low energy events this effect is due to the Rayleigh scattered light and the reflected light. The direction of the track is determined from the charged weighted sum of the unit vectors from the reconstructed vertex to the PMT's and does not involve any fitting procedure.

A simple geometric picture is presented to give the reader a feel for the cause of the drive and why on the average it is in the direction of the track. Refer to Fig 1. Consider two PMT's, one at the Cerenkov angle a distance ρ_{41} from the vertex with a measured time of T_{41}, and a second tube at some wider angle say 70 degrees with a distance and time of ρ_{70} and T_{70}. For simplicity both PMT's are placed on a wall perpendicular to the track direction a distance, d, from the vertex.

$$T_{70} - T_{41} = \rho_{70} - \rho_{41}$$

$$\sqrt{(\rho_{41}^2 + d^2)} = \frac{\rho_{70}^2 - \rho_{41}^2 - \Delta T^2}{2\Delta T}$$

where $\Delta T = T_{70} - T_{41}$

When both PMT's receive direct light, the distance d calculated will be the correct one. Now consider the case where the wider angle one arrives at a later time due to a path taken by multiple scattering. Then the *relative* time of of the two PMT's (ΔT) is increased. This forces ρ_{70} to increase *relative* to ρ_{41} which it does by moving the vertex closer to prompt PMT. Moving the vertex further from the wall only serves to make the difference between the two distances approach zero. This is reflected in the above equations which show d gets smaller as the relative time increases. This argument can be made more symmetric by using more tubes in a phi symmetric pattern around the track direction. Clearly single events can be constructed that will violate the above argument, but it does represent what happens on the average.

Kamioka uses a fitting procedure (called NFIT) that breaks the minimization function into the sum of a timing residual function and θ_{pt} distribution function, where θ_{pt} is the angle between the track direction and the vector from the vertex to the PMT. The θ_{pt} distribution was determined from Monte Carlo simulations. This eliminated the driving effect for events within a fiducial volume greater than 2 meters from the PMT's, with the θ_{pt} part of the minimization function supplying the small correction needed to remove the drive. As with TFIT there is a PMT selection criteria to remove PMT's that are way our of time due to noise or reflections.

3 Suggested Fitting Procedures

SNO will have PMT's with much greater timing resolution then Kamioka (2.5ns compared to Kamioka's 14 ns) and it remains to be shown that NFIT can totally eliminate the drive. Blindly using the Kamioka θ_{pt} distributions and applying it to SNO events does mitigate the driving effect, but does not completely remove it. It is possible that using a modified θ_{pt} will eliminate the drive, but this has to be demonstrated.

There is a fundamental problem with both TFIT and NFIT in that a χ^2 fitting procedure is used, where it is assumed that the timing residuals and errors are Gaussian distributed. This is clearly not the case since the scattered light will produce an asymmetric residual timing distribution. This would suggest a Maximum Likelihood analysis which uses a timing distribution that has the proper tails from the scattered and reflected light. This was attempted, and no improvement over the χ^2 method was obtained. Another possibility is to maximize the Kolmogoroff-Smirnov probability, which would use all the PMT's.

If NFIT fails it will probably be due to the fact that the correlation between the timing and θ_{pt} is neglected. For example the residual timing distribution of the PMT's about the Cerenkov angle is much more sharply peaked about zero than the residual timing distribution of the PMT's that are in the backwards direction. This is due to the fact that a lot of the backwards light comes from reflections and scattering and hence occur at later times. Thus an estimator is required that is a two parameter function of timing and θ_{pt} and does not factorize the timing and θ_{pt} components as NFIT does. A two parameter estimator may preclude using a Kolmogoroff-Smirnov analysis and in all probability a Maximum Likelihood analysis will have to be employed. True?

4 Requirements and Structure of the Fitting Program

The vertex determination will be preceded by a PMT selection process, so it is proposed that the fitting process be broken into calls to two subroutines namely the PMT selection and the vertex determination itself. The input to the fitting program will require input from three sources.

- The event itself which will have the charge and timing information of the tubes participating in the event. This will come from our standard dynamical memory which in all probability will be ZEBRA.
- The coordinates of the PMT's, which will reside in a data base
- It is possible that the charge will be used as a weighting factor in the fitting programs, and as such the attenuation length of the water would be required to correct the PMT charge for the flight path of the Cerenkov photons. This will also come from a data base.

The fitting programs will require access to a minimization package such a CERN's MINUIT and should we decide to use other statistics besides χ^2 or Maximum Likelihood, such as Kolmogoroff-Smirnoff, access to statistical packages would be required. The output should be placed in its own memory bank and contain the following information:

- Header containing the date analyzed and by whom.

- A group assigned number designating the PMT selection and vertex determination programs that are used.
- The PMTs selected for the vertex determination along with their position, measured timing, residual timing, and charge.
- Reconstructed vertex and direction
- The statistic of the event ie χ^2 or Kolmogoroff-Smirnoff probabalibity or whatever. In fact no matter what statistical analysis is used, it will be useful to also include the χ^2 of the timing residuals.

This data bank can then be easily read to generate histograms at any later time or to compare with results from a previous or subsequent analysis whose results will reside in similar banks.

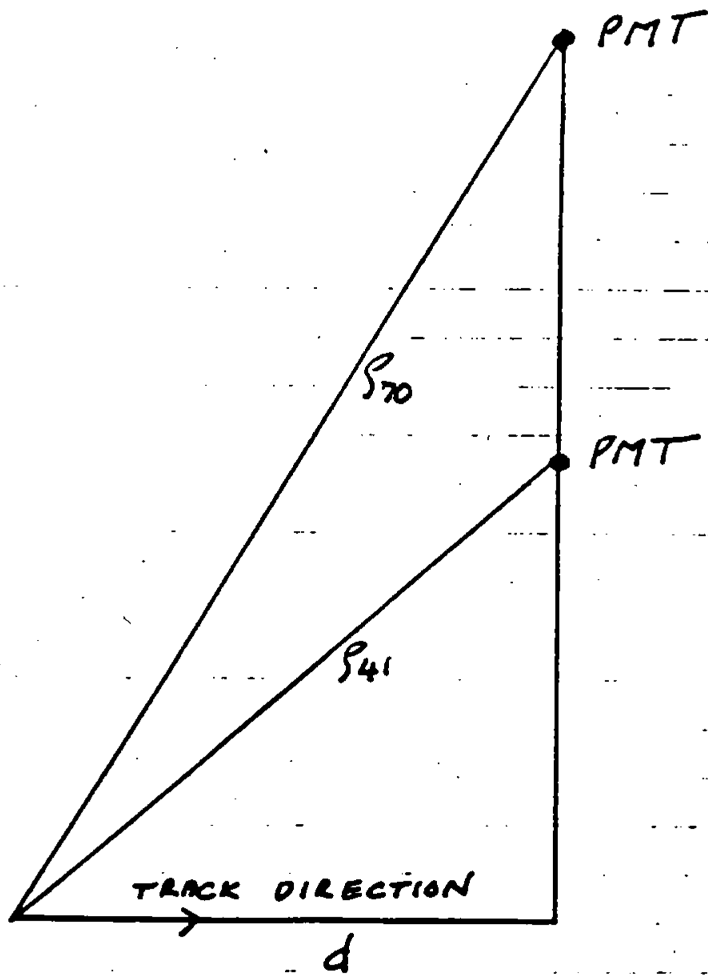

Fig 1