RESPONSE CALCULATIONS FOR LEAD-GLASS CERENKOV DETECTORS

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To further our understanding of the response characteristics of the lead glass detectors used in our preliminary (p,π^0) studies[1], and to facilitate analysis of that and future data, we have found it necessary to construct a program incorporating as much of the physics involved in the detection mechanism as possible. Because of the large number and the complexity of physical effects involved, such a program of necessity must utilize Monte Carlo techniques[2]. A number of such studies have been performed in the past [3],[4],[5],[6],[7], however, these studies have generally been on materials other than lead glass[5] and have generally confined themselves to showers generated by photons and electrons with energies greater than or equal to 100 MeV.

Our research necessitates having a program capable of simulating showers in a variety of types of lead glass in any geometry, and of considering incident photons and electrons with energies as low as 20 MeV. Another problem with these previous calculations has to do with the way they treat the particle transport processes in the energy region below 50 MeV. If one considers the Cerenkov light output of an electron in a typical lead glass, (Schott LF5), (Fig. 1), one sees that it is probably necessary to track the particles in a cascade down to an energy of at least 2 MeV. Hence one would suspect that a

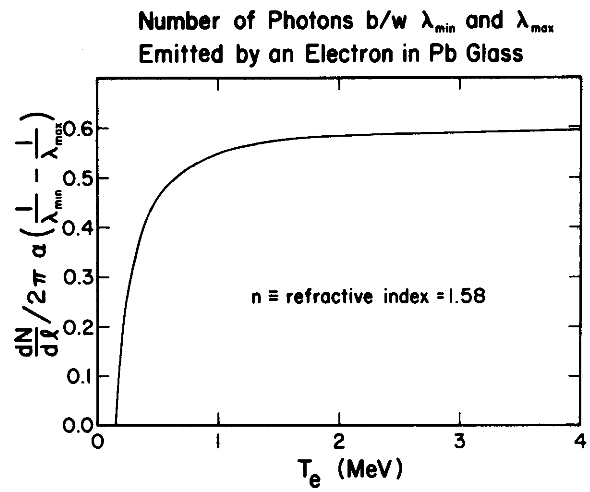

Figure 1.

good description of the physical processes affecting the transport of particles in that low energy region might be important. Research in the last few years has enabled one to have a much better quantitative description of such processes. The results of such research are being incorporated into our code. Further, the influence of various approximations used in the low energy region are also being investigated.

The physical processes influencing cascades incorporated into our code are:

1) pair production
2) Compton scattering
3) photoeffect
4) bremsstrahlung
5) Møller and Bhabha scattering
6) positron-electron annihilation in flight

7) ionization loss and multiple scattering

The manner in which these processes are incorporated into the code is similar to that of other authors[3), 4),5),6),7)]. To obtain the response spectrum of a detector we included the generation of Cerenkov light and the detector optics in the main code.

We compute the distance travelled between electron, or positron, scattering points and the average momentum and direction between those points. This information gives us the number of photons emitted between the wavelengths chosen as cutoffs and the direction of travel of the photons. Since the number of such photons emitted varies as $^1/\lambda^2$, the wavelength of each such photon must be chosen according to that distribution. These photons are then tracked through the detector until they are absorbed, escape, or meet the phototube face. The tracking routine takes into account the variation of transmission with wavelength and the variation of the probability of reflection with angle of incidence on the detector walls. Finally, if one such photon does make it to the phototube face, the probability of detection of such a photon must vary as the quantum efficiency of the phototube.

Preliminary calculations have been performed using this code. In the calculations the model detector was a 6" X 6" X 10" block of Schott LF5 lead glass with a RCA 4525 (bialkali) phototube mounted on the back 6" X 6" face. Electrons with momenta 50, 75, 100, 125, 150 and 200 MeV/c normally incident on the center of the front 6" X 6" face generated the showers. In each case 1000 showers were generated, and the particles in each shower were tracked until they had a momentum of 2 MeV/c. At the end of each shower the number of photoelectrons generated was stored. At the end of the 1000 showers, the number distribution of photoelectrons was evaluated. To reduce fluctuation, events were grouped in bins of 10 photoelectrons. The result is expected to correspond to the response spectrum of the detector. Calculations for 50, 100, and 150 MeV/c electrons are shown in (Fig.2). Experimental measurements corresponding to this simulation show that the variation of peak position with electron bombarding energy is very linear[8)]. This behavior is easily reproduced by the code (Fig. 3).

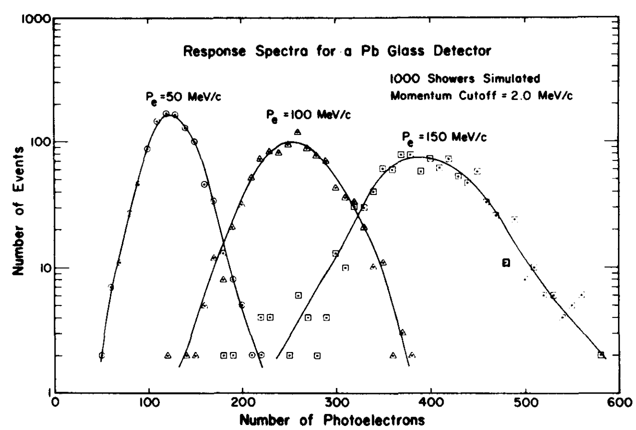

Figure 2.

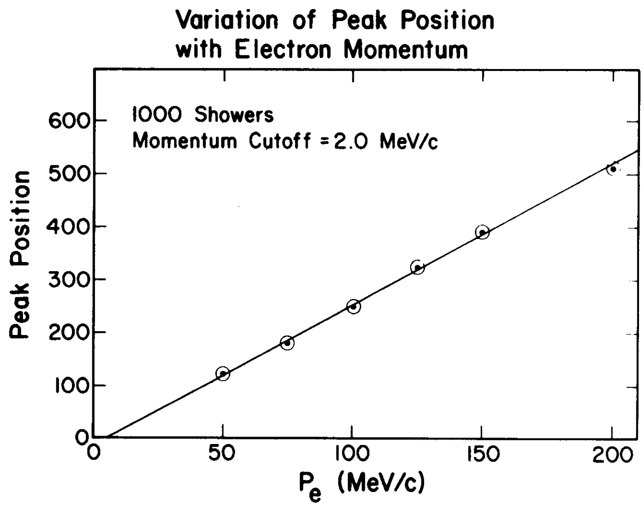

Figure 3

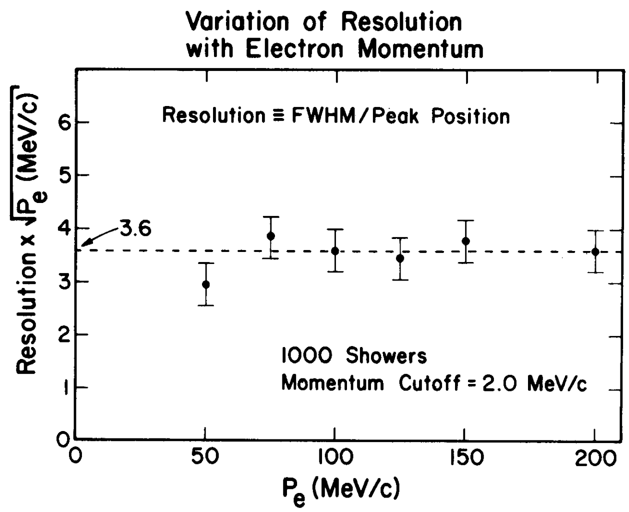

Figure 4

A more stringent test of the validity of the model, however, is the ability to reproduce the energy resolution that is measured. Experimentally one finds that a very good expression giving the variation of resolution as a function of energy to be

$$\frac{\text{FWHM}}{\text{Peak Position}} = \frac{\Delta E(\text{FWHM})}{E} = C/\sqrt{E}$$

(E in MeV).

where C is a constant depending on the type of glass and phototube used. Typically it varies between about 3.0 and 6.0[8]. Our program is again successful in meeting this test (Fig. 4).

In the future this program will be used to enable us to extract absolute cross sections for the (p,π°) reaction near threshold from our observed γ-γ coincidence yields.

1) IUCF Technical and Scientific Report, Nov. 1, 1975 - Jan. 31, 1977, p. 31.

2) We thank J.D. Bowman and M.D. Cooper (Los Alamos Scientific Laboratory) for their help and suggestions in initiating these studies.

3) M. Ya. Borkorskii, S.P. Kruglov, Soviet Journal of Nuclear Physics, 16, 194 (1973).

4) M. Tamura, Progress of Theoretical Physics, 34, 912 (1965).

5) E. Longo, I. Sestilli, Nuclear Instruments and Methods, 128, 283 (1975).

6) H.-H. Nagel, Z. Physik, 186, 319 (1965).

7) H. Messel, F. Crawford, Electron-Photon Shower Distrib. Function Tables for Lead, Copper, and Air Absorbers, Pergamon Press (1970).

8) M.D. Cooper, private communication.