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OBSERVATION OF THE 16.7 MeV D-T FUSION GAMMA
USING A GAS CERENKOV DETECTOR

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Abstract

A measurement of the 16.7 MeV gamma production in a D-T fusion plasma was performed, using a four channel carbon dioxide gas Cerenkov detector system to measure the Cerenkov light generated by the gamma conversion electrons produced in a thin aluminum foil.

We report here on the use of a four channel GCD system to measure the 16.7 MeV gamma output from a D-T fusion plasma.

A single GCD channel is shown schematically in Fig. 1. Incoming gamma rays strike a thin foil producing a spectrum of "conversion electrons". These conversion electrons are magnetically deflected out of the gamma line of sight into a gas chamber filled with CO_2; those electrons with an energy above the Cerenkov light production threshold produce visible and UV light which is collected and focused onto a light sensitive detector for recording.

A photograph of the four GCD channels used in the experiment is given in Fig. 2. Note that in addition to the three channels containing a deflecting magnet (labeled A, B, and C in Fig. 2), a fourth "straight through" channel (labeled D in Fig. 2) was also included in the system. This was done to see if the deflecting magnets (which were used primarily to reduce possible low energy electron background) were absolutely necessary.

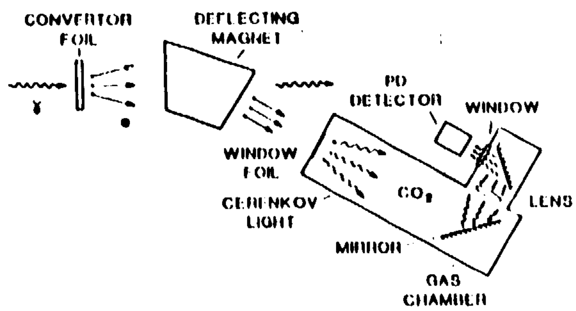

Figure 1. Schematic diagram of a typical GCD channel.

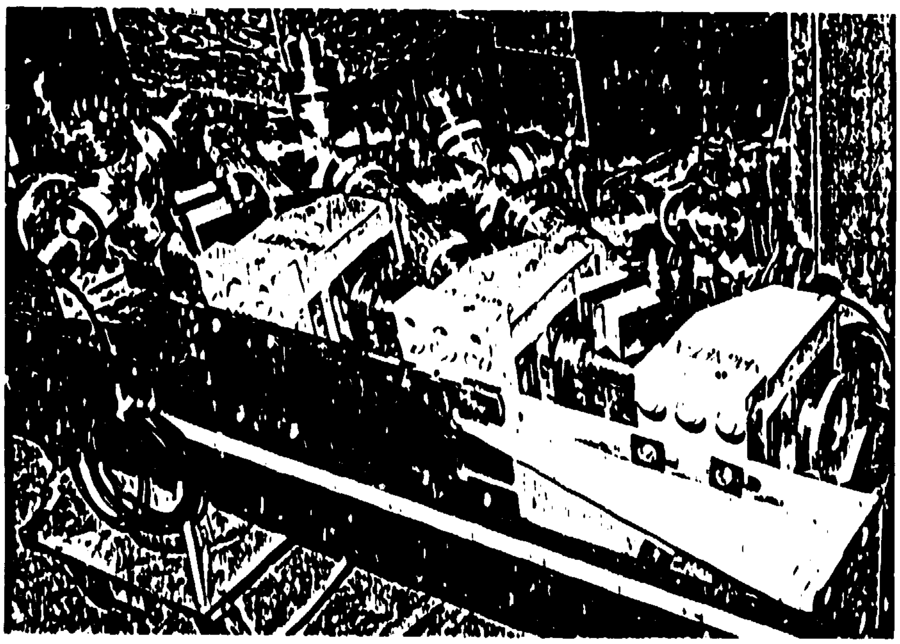

Figure 2. Photograph of four channel gas Cerenkov detector system.

As the principle details of the GCD as a gamma detector have been published elsewhere,[1] we discuss here primarily the experimental results obtained with the four channel GCD system. As depicted in Fig. 2, the four channel system had three magnetically deflected channels with Cerenkov thresholds of 12 MeV (A), 14 MeV (B), and 16 MeV (C) and one in line channel with a Cerenkov threshold of 14 MeV (D). The original throught in this design was to set one magnetic channel (B) for "nominal" gamma energy, one magnetic channel (C) for "high energy background" and one magnetic channel (A) for "low energy background." The in line channel (D) was also set for "nominal" gamma energy. Although the D-T gamma-ray energy of interest is 16.7 MeV, the approximately 3 MeV lower threshold for the B and D channels was chosen to insure adequate light output. This is necessary since the light output at threshold is very small, but rises rapidly with energy above threshold (e.g., see Fig. 3). As will be discussed shortly, even this 3 MeV threshold "offset" in the nominal energy channels was not enough to adequately take into account the downgraded energy spectrum produced in the gamma to electron conversion Process.

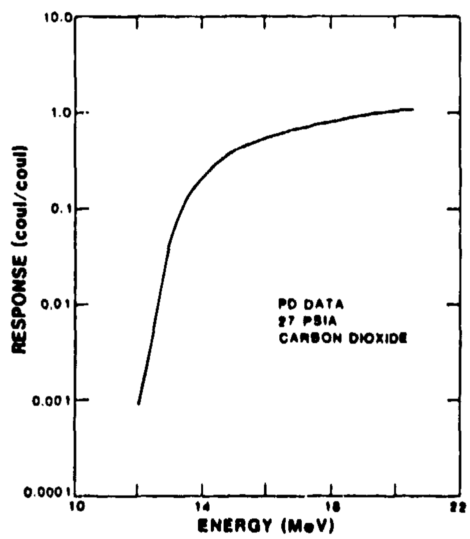

Figure 3. Gas Cerenkov detector response curve for threshold energy of 12 MeV.

In order to determine the gamma sensitivity of any of the four GCD channels, one must know the details of the gamma to electron conversion process and the details of the electron to Cerenkov light production process. The transmission of the conversion electron spectrum through the magnetic deflection region must also be considered for those channels containing a magnet. The electron to Cerenkov light process has been carefully measured at the EG&G Electron Linac Facility in Santa Barbara, California. Figure 3 shows a typical measured response curve of the gas chamber portion of the GCD system. The gamma to electron conversion process was examined by Monte Carlo simulation using a modified version of Cyltran,[2] a well proven photon electron interaction code. The predicted conversion electron energy spectrum produced by a monoenergetic 16.7 MeV gamma incident on 16 mils of Al is given in Fig. 4.

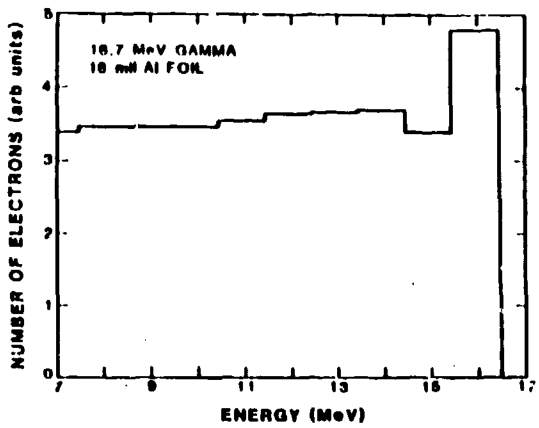

Figure 4. Predicted conversion electron energy spectrum from Cyltran Monte Carlo simulation for 16.7 MeV incident gamma on 16 mil Al foil.

In order to determine the transmission properties of the deflecting magnets, careful field maps of each of the magnets used in the GCD system were performed prior to final assembly. These field maps were then used in a 2-D electron trajectory ray trace code to determine the phase space transmission of the conversion electrons as a function of electron energy. The calculated transmission of the channel A deflecting magnet is shown in Fig. 5. Note the error in assuming a uniformly filled transverse momentum distribution as compared to that calculated by Cyltran.

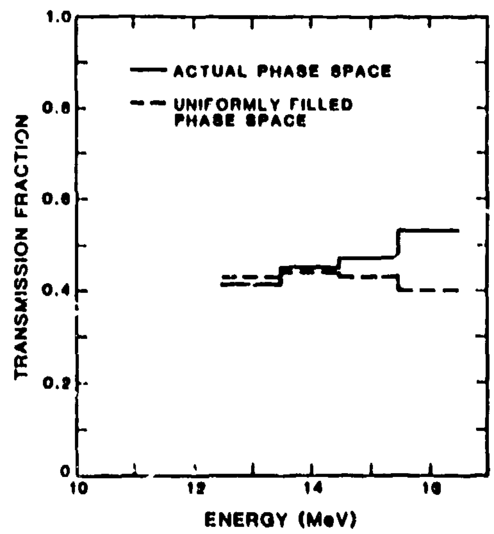

Figure 5. Calculated phase space transmission of deflecting magnet used on channel A of GCD system. Actual phase space calculation refers to conversion electron angular spectrum predicted in Monte Carlo simulation.

Folding the results discussed above together with the actual detector sensitivities yields the overall channel sensitivities given in Fig. 6. The uncertainties of the sensitivities depicted in Fig. 6 are the result of the combined uncertainty in the gamma to electron conversion calculation, magnet transmission calculation, and electron to Cerenkov light gas calibration. The relatively low sensitivity of the B and D channels compared to the A channel is due to the downgraded conversion electron spectrum (see Fig. 4) folded with the rapidly changing response curve in the neighborhood of threshold (see Fig. 3). Simply put, the 3 MeV threshold offset discussed earlier was not sufficient to produce maximum sensitivity in the B and D channels, since there are a sufficiently large number of conversion electrons produced several MeV below the incident gamma energy, and it is in this region the response curve is falling most rapidly.

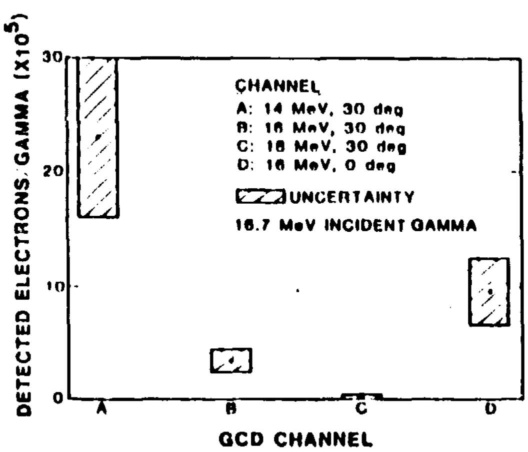

Figure 6. Calculated sensitivities of the four GCD channels. Sensitivities given in number of electrons produced at detector output per incident 16.7 MeV gamma at converter foil.

Figure 7 shows a comparison of the observed peak detector signals and the predicted signal values based on the sensitivities given in Fig. 6 and the calculated[3] D-T peak gamma yield. Note the calculated peak currents given in Fig. 7 assume a D-T gamma branching ratio of 8.8×10^{-5} which is in good agreement with recent measurements of Cecil and Wilkinson.[4]

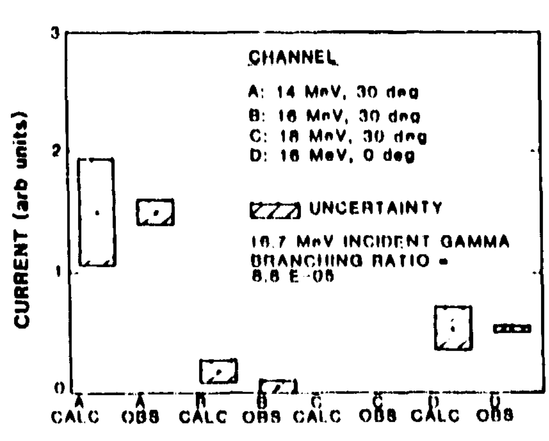

Figure 7. Comparison of peak currents observed with four channel GCD system and predicted peak currents.

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[3] R. Streetman, Los Alamos National Laboratory (private communication).

[4] F. E. Cecil and F. J. Wilkinson, III, Phys. Rev. Lett. 53, 767 (1984).