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TITLE COMPUTATION OF ANGLE AVERAGED CROSS SECTIONS IN A DEGENERATE COMPTON SCATTERING MEDIUM

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COMPUTATION OF ANGLE AVERAGED CROSS SECTIONS IN A DEGENERATE COMPTON SCATTERING MEDIUM

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ABSTRACT

An accurate yet simple analytic method is developed for calculating Compton scattering cross sections for monoenergetic photons interacting with an isotropic and degenerate distribution of relativistic electrons.

INTRODUCTION

Computer models of plasmas in which Compton scattering is important require accurate as well as rapid methods for computing Compton cross sections. This research is pertinent to both P_n and S_n formalisms which require knowledge of cross sections averaged over all angles. An extension of previous work[1] addresses the case when the electron distribution is both relativistic and degenerate. In such a distribution, the electrons are at a low enough temperature and/or sufficiently high density so that the number of final energy states available to the scattered electrons is limited. There are a number of physical systems which are degenerate. They include electron gasses present in interial confinement fusion reactors, fusion weapons and white dwarfs. Previous approaches to the treatment of Compton scattering include the Fokker-Planck formalism[2] and lengthy numerical integration methods[3]. As an alternative approach, an analytic technique is presented which provides accurate cross sections averaged over three collision angles. The regime for use of this method includes photons and electrons with kilovolt energies, and proves to be very accurate.

In order to facilitate continuity and comprehension, the results will be presented first, then the derivation of the method.

RESULTS

Differential Compton cross sections were computed for electron temperatures of 1 and 20 kilovolts, number densities of 10^{27}, 10^{31}, 10^{33}, and 10^{35} electrons per cubic meter; and for incident photons with energies of 5, 10, 20, 40 and 60 keV. Figures 1 and 2 show the differential cross section in millibarns per keV. The solid lines are the cross sections in the non-degenerate limit. These "tents" show characteristics identical to results listed in Reference 3. A factor of 1-n(e) is incorporated into the computations to account for the degeneracy of the electron gas. n(e) is the probability of final state occupation for the electron, and through the use of term statistics is determined to be

$$n(\epsilon) = \frac{1}{\epsilon(\epsilon-\mu)/kt + 1} \tag{1}$$

The chemical potential, μ, is given as

$$\mu = \epsilon f\left[1 - \frac{\pi^2}{12}\left(\frac{T}{T_f}\right)^2 + \frac{\pi^4}{720}\left(\frac{T}{T_f}\right)^4\right] \tag{2}$$

when $\mu > 0$. T_f and ϵf are the Fermi temperature and energy respectively. In the other limit, $\mu \leq 0$, the chemical potential is

$$\mu = -kt \log\left\{\frac{GV}{N}\left(\frac{m_0 kt}{2\pi\hbar^2}\right)^{3/2}\right\} \tag{3}$$

The dashed lines in Figures 1 and 2 show the cross sections when the electron gas is degenerate. With the number of final states limited, the instances where the electron delivers most of all of its energy are decreased. If a Compton scattering event does occur, the photon will most likely downscatter. Thus, a slight shift to lower energies is seen in the tents. Also, the peaks of the cross section tents decrease due to the overall decrease in the scattering probability.

A deeper appreciation of this development can be given by noting reduction in computational times required to determine the Compton cross sections. Exact evaluation of Equation 21 took approximately one hour of CRAY time for each given photon energy, electron temperature and number density. The results cited in this report (Equation 27) required a little over two and a half seconds on a CDC 7600 using the same parameters.

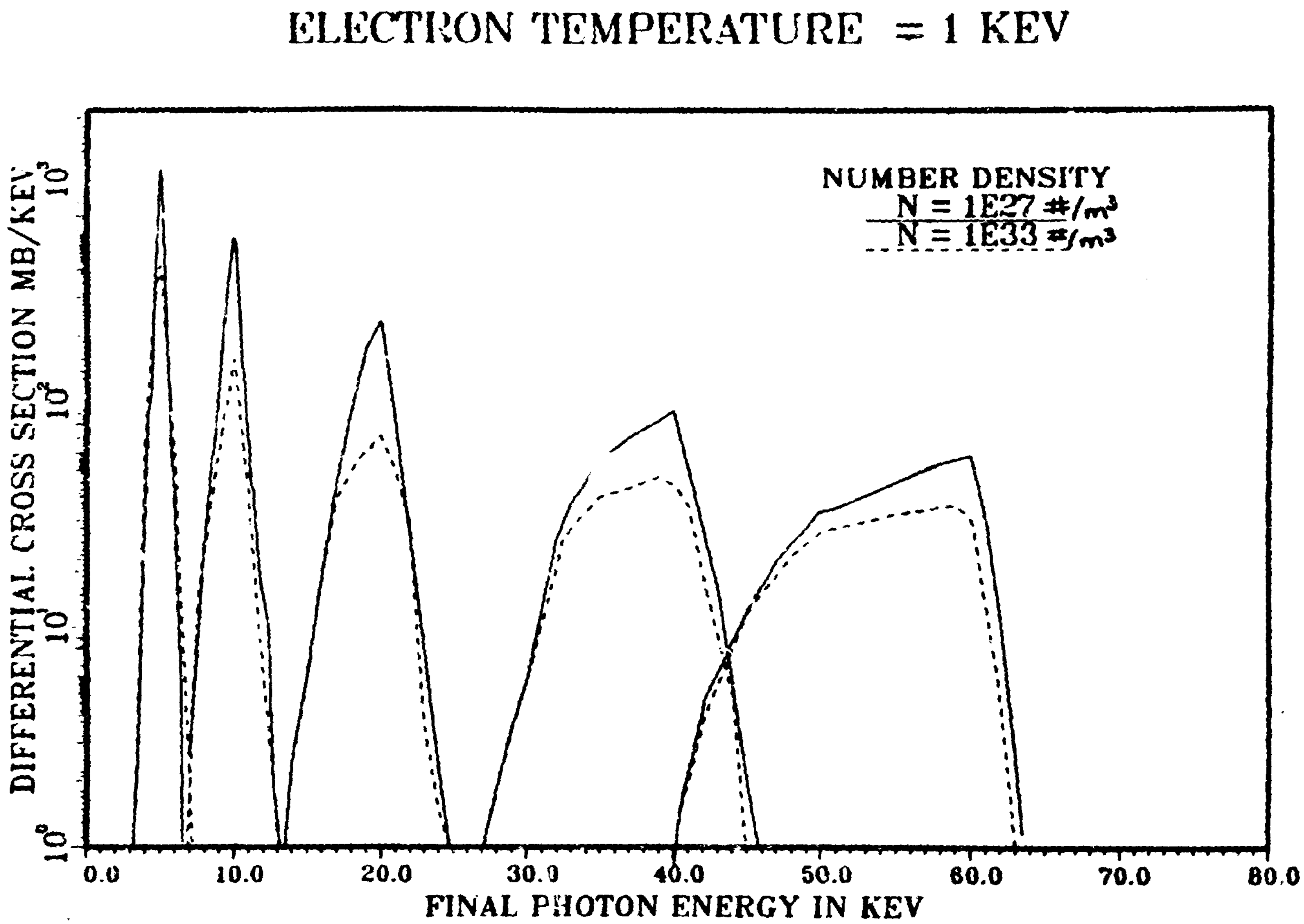

Fig.1 Differential Cross Section vs. Final Photon Energy (kT = 1 KeV)

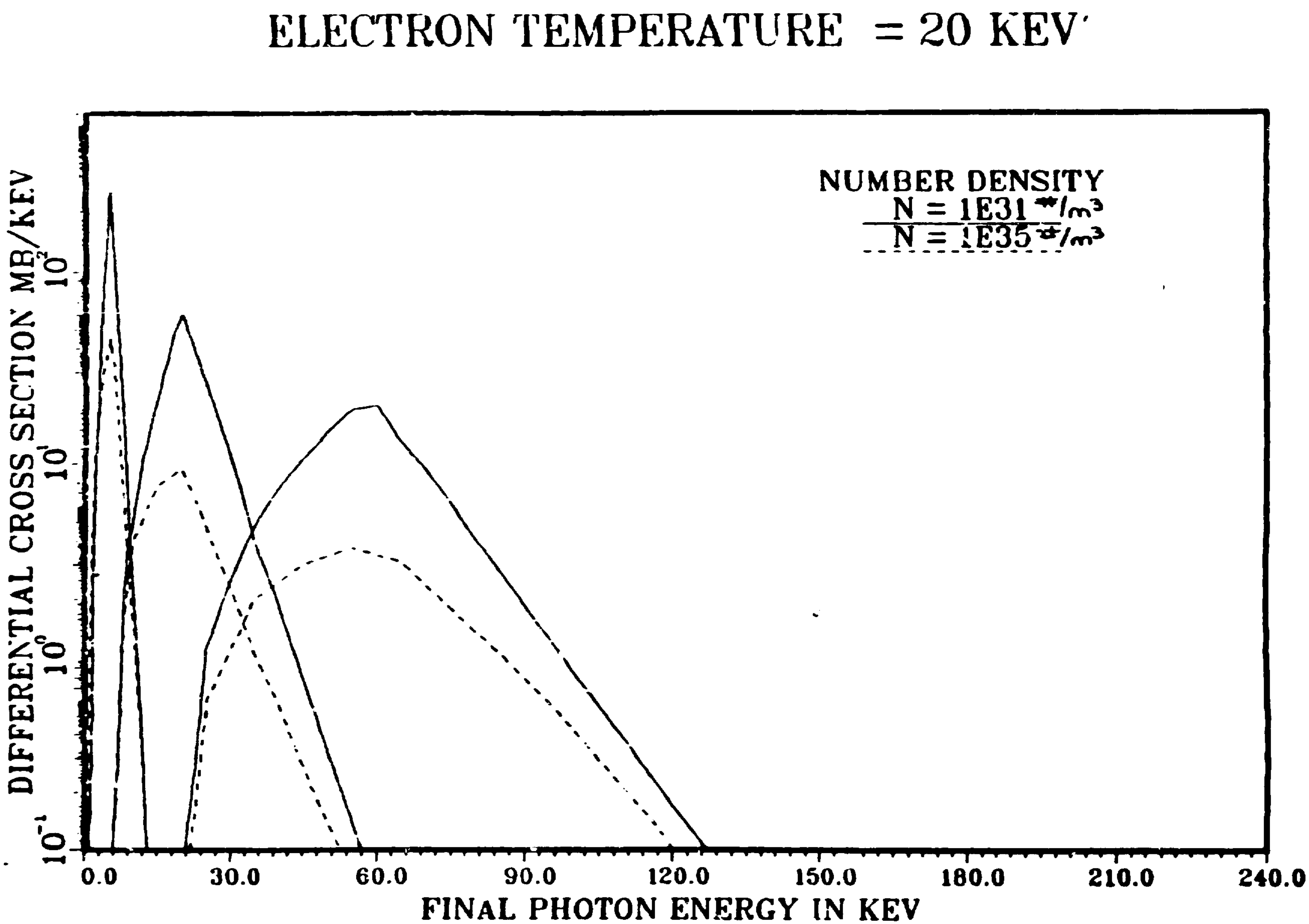

Fig. 2 Differential Cross Section vs. Final Photon Energy (kT = 20 KeV)

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