RESEARCH NOTE

Calculated Angular and Energy Distributions of Bremsstrahlung Radiated by MINI-C and EROS Electrons

The electron transport code ETRAN has been used to calculate angular and energy distributions of bremsstrahlung photons radiated in carbon and tungsten by electrons with energies and angles of incidence typical of the simulators MINI-C and EROS. Energies of 0.8 to 2 MeV are relevant in the former case and 4.0 to 7.0 MeV in the latter. For MINI-C electrons the appropriate angles of incidence - obtained by fitting the shapes of the measured energy deposition profiles to the code ZEBRA* - are 45° and 60° (0.8 and 2 MeV incidence on carbon) and 60° and 75° (0.8 and 2.0 MeV incidence on tungsten). For EROS electrons at 4 MeV the fit is rather insensitive to angle of incidence but the data suggest a value between 0 and 45° for both carbon and tungsten - somewhat nearer to 0° for carbon and nearer to 45° in the case of tungsten. No experimental results are available at 7 MeV, but the angles are not likely to differ appreciably from those at 4 MeV.

Table 1 and Figure 7 show the radiation yield in carbon and tungsten as a function of thickness.

Figures 1, 2, 4 and 5 show the trend of the experimental results recently reported by Rester and Dance (J. Applied Physics 14, 2682, 1970). These data were obtained using a d.c. Van de Graaff accelerated electron beam (0.2-2.8 MeV) directed at normal incidence onto thick targets of Be, Al, Fe, Sn, and Au. Bremsstrahlung photons were detected using a NaI anticoincidence spectrometer. Agreement between these data, where comparisons can be conveniently made - i.e. at 0° incidence and 2 MeV - and the present ETRAN calculations is seen to be generally good. The discrepancy at large photon angles in the case of C/Be is probably due to the different target thicknesses.

P. Fieldhouse
D. W. Large
E. Morris
G. W. Sentance

6 November 1970

*A simplified version of ETRAN.

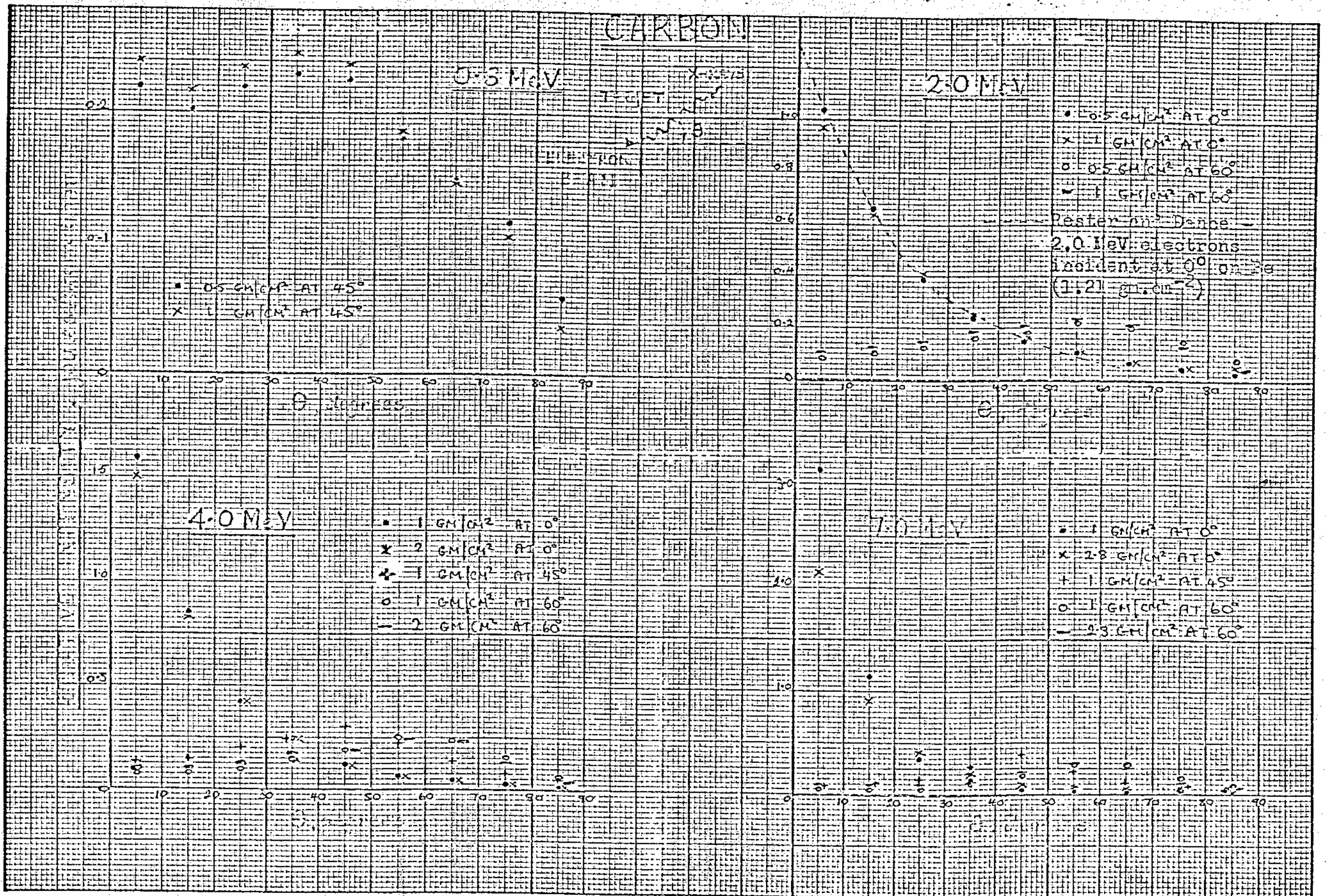

FIGURE 1 - CALCULATED (ETRAN) BREMSSTRAHLUNG ANGULAR DISTRIBUTIONS FROM CARBON TARGETS OF VARIOUS THICKNESSES FOR ELECTRONS INCIDENT AT 0°, 45° AND 60° WITH COMPLEX ENERGY SPECTRA OF 0.8, 2.0, 4.0 AND 7.0 MeV (MAX).
(Curves are normalised to 1 joule in the forward 2π hemisphere).

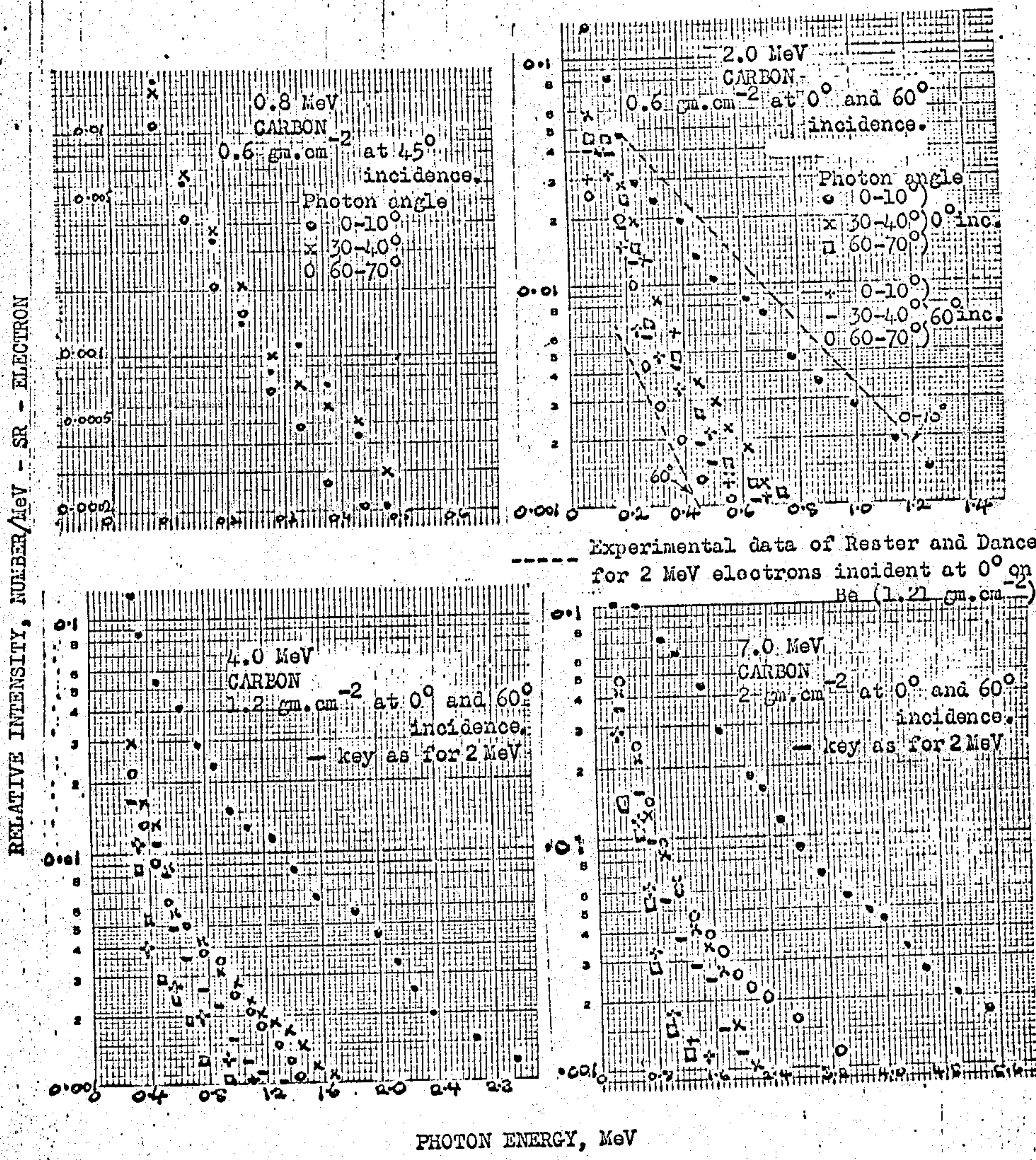

FIGURE 2 - CALCULATED (ETRAN) BREMSSTRAHLUNG DIFFERENTIAL INTENSITY SPECTRA FROM CARBON TARGETS OF VARIOUS THICKNESSES FOR ELECTRONS INCIDENT AT 0°, 45° AND 60° WITH COMPLEX ENERGY SPECTRA OF 0.8, 2.0, 4.0, 7.0 MeV (MAX)

(Curves are normalised to 1 incident electron)

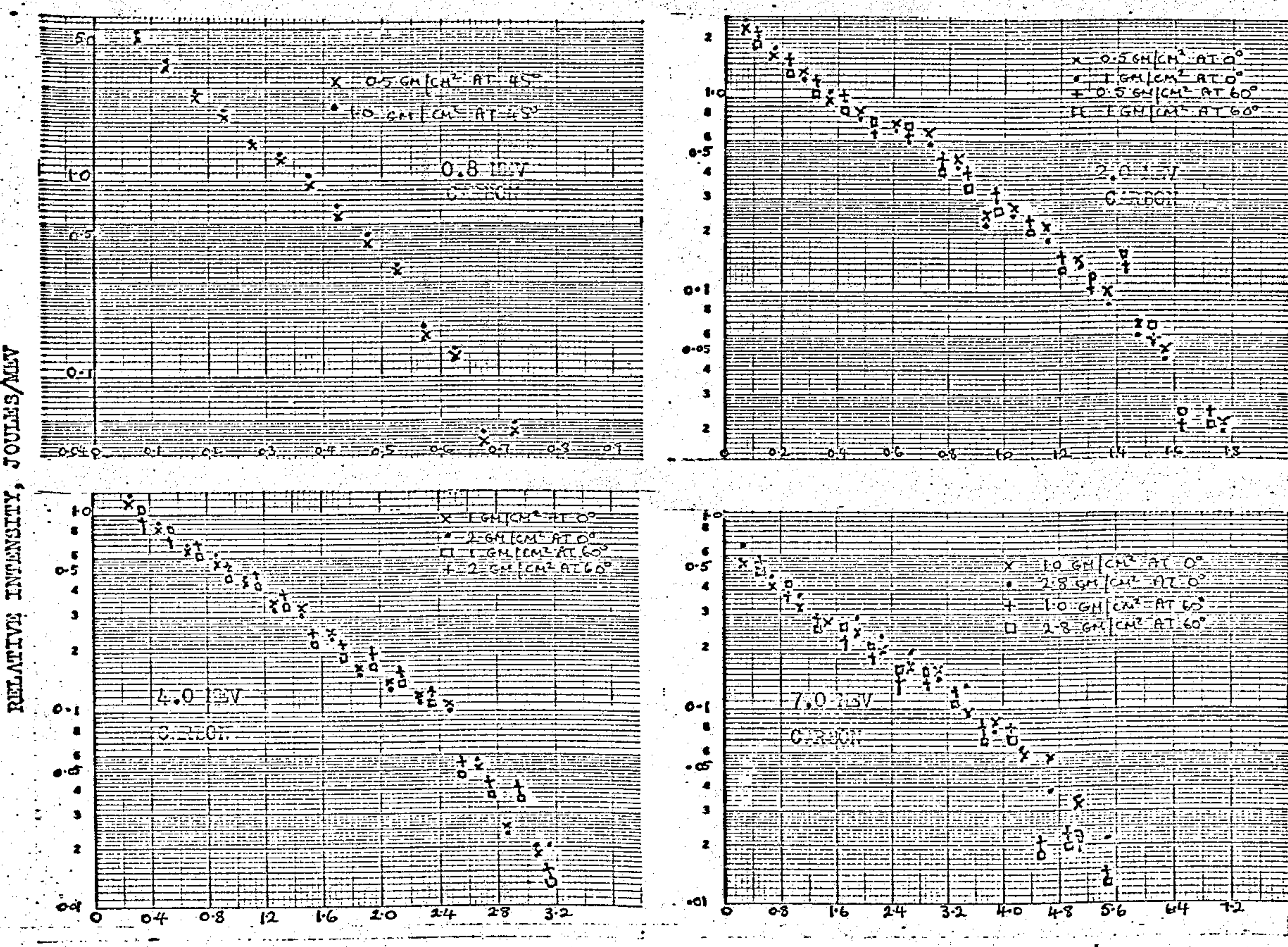

FIGURE 3 - CALCULATED (ETRAN) BREMSSTRAHLUNG ENERGY SPECTRA FROM CARBON TARGETS OF VARIOUS THICKNESSES FOR ELECTRONS INCIDENT AT 0°, 45° AND 60° WITH COMPLEX ENERGY SPECTRA OF 0.8, 2.0, 4.0 AND 7.0 MEV (MAX). (Curves are normalised to 1 joule into the forward 2π hemisphere).

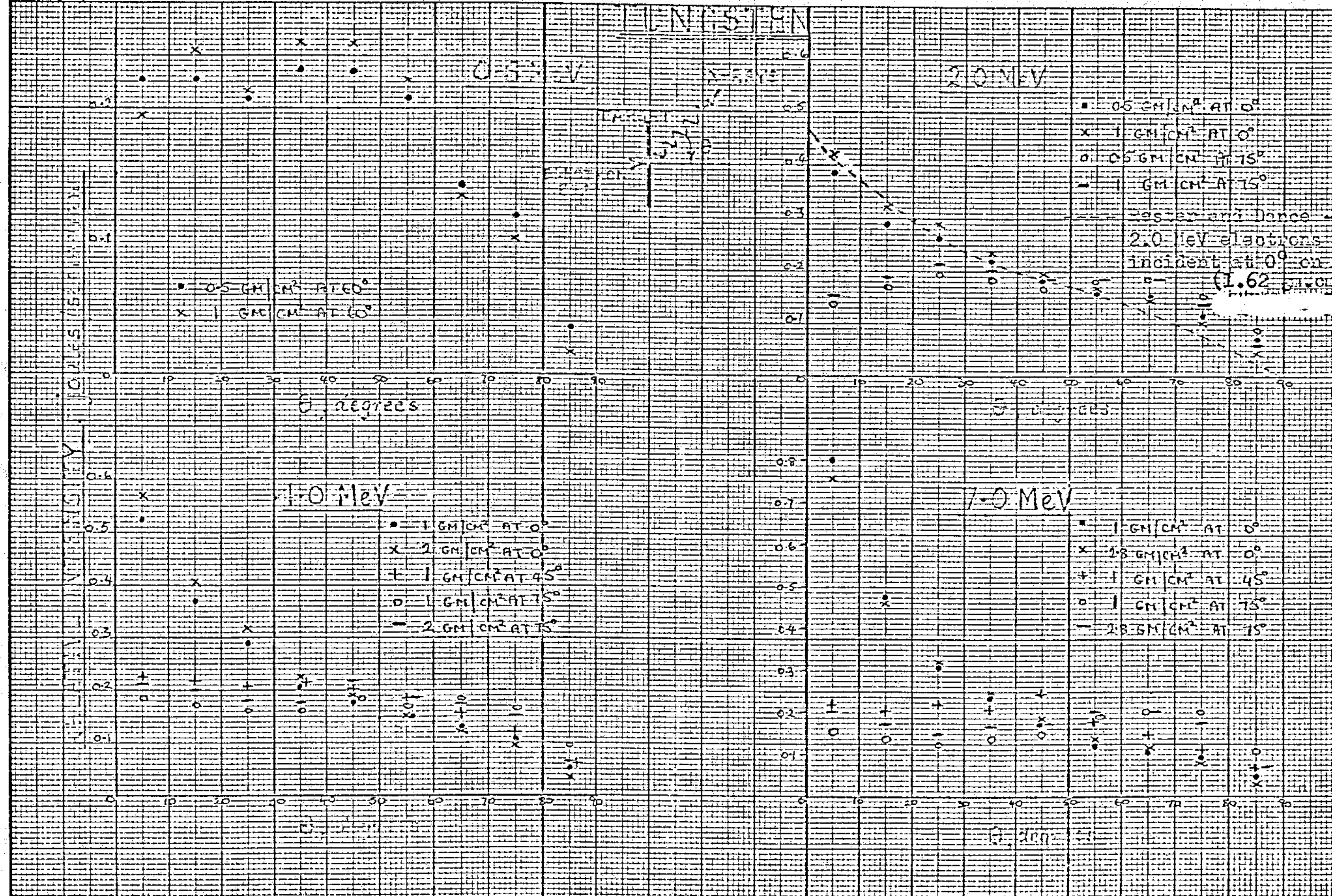

FIGURE 4 - CALCULATED (ETRAN) BREMSSTRAHLUNG ANGULAR DISTRIBUTIONS FROM TUNGSTEN TARGETS OF VARIOUS THICKNESSES FOR ELECTRONS INCIDENT AT 0°, 45°, 60° AND 75° WITH COMPLEX ENERGY SPECTRA OF 0.8, 2.0, 4.0 AND 7.0 MEV (MAX).
(Curves are normalised to 1 joule in the forward 2π hemisphere).

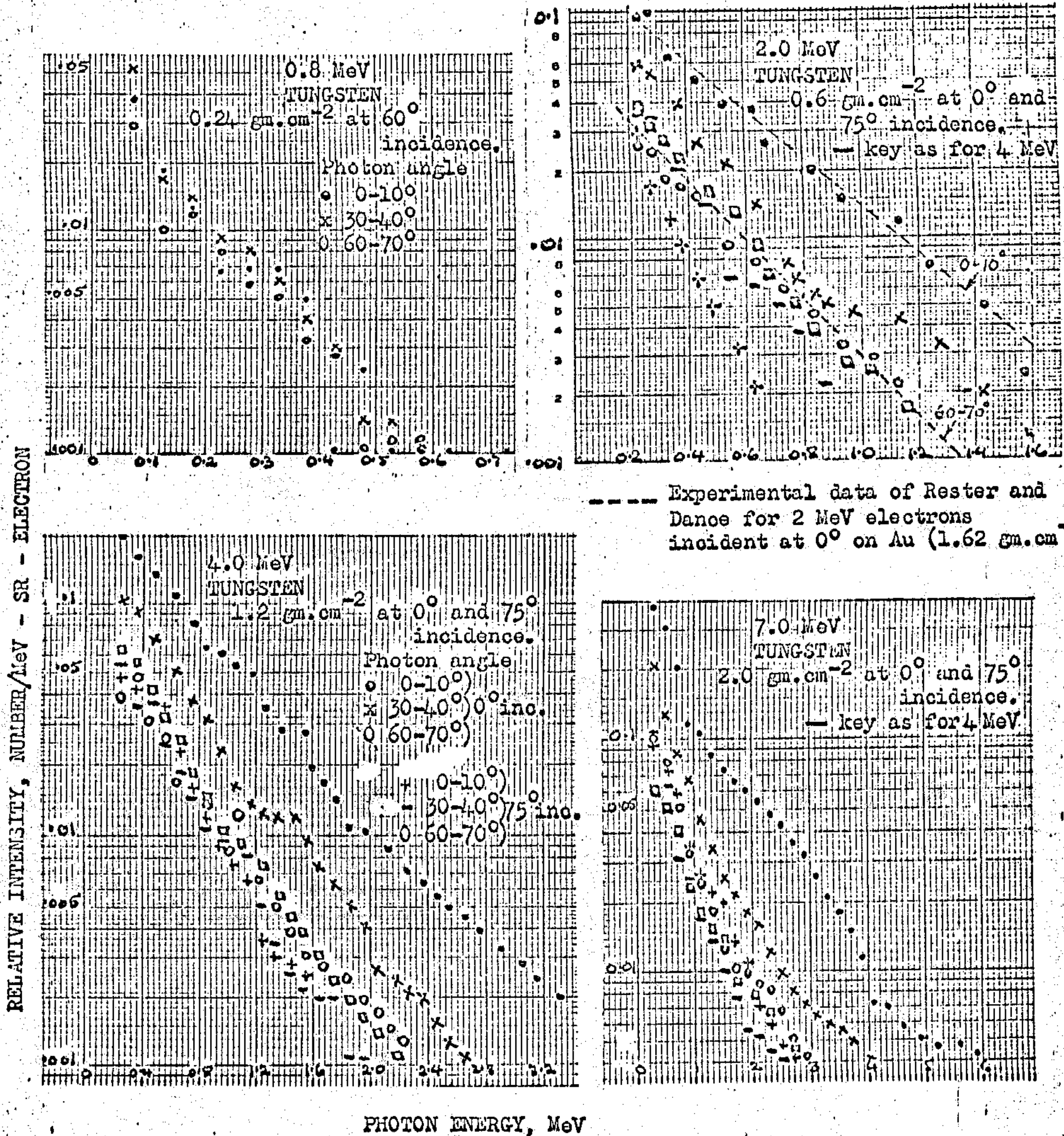

FIGURE 5 - CALCULATED (ETRAN) BREMSSTRAHLUNG DIFFERENTIAL INTENSITY SPECTRA FROM TUNGSTEN TARGETS OF VARIOUS THICKNESSES FOR ELECTRONS INCIDENT AT 0°, 60° AND 75° WITH COMPLEX ENERGY SPECTRA OF 0.8, 2.0, 4.0, 7.0 MeV (MAX)

(Curves are normalised to 1 incident electron)

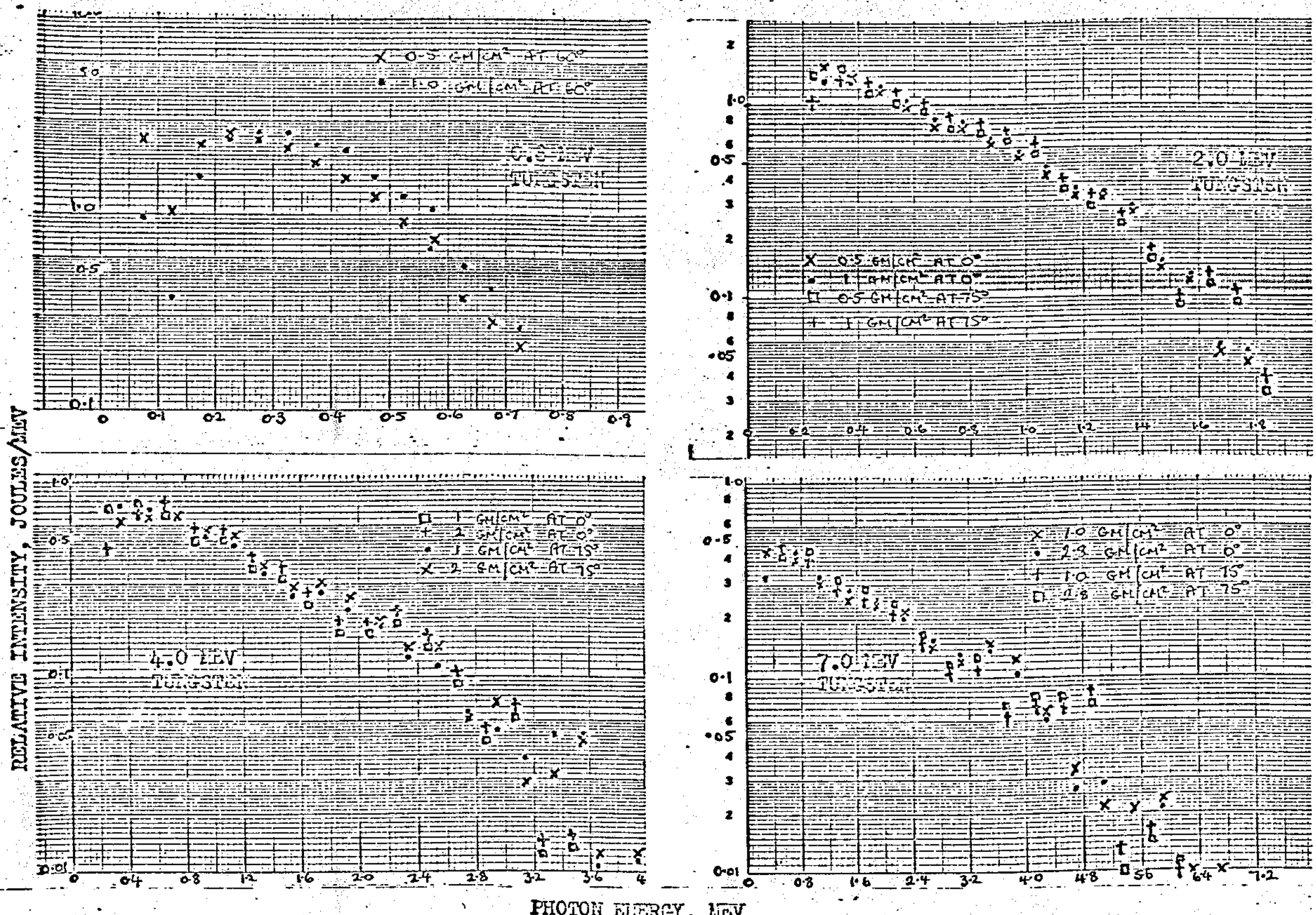

FIGURE 6 - CALCULATED (ETRAN) BREMSSTRAHLUNG ENERGY SPECTRA FROM TUNGSTEN TARGETS OF VARIOUS THICKNESSES FOR ELECTRONS INCIDENT AT 0°, 60° AND 75° WITH COMPLEX ENERGY SPECTRA OF 0.8, 2.0, 4.0 AND 7.0 MEV (MAX). (Curves are normalised to 1 joule into the forward 2π hemisphere).

TABLE 1

PERCENTAGE BREMSSTRAHLUNG RADIATION YIELDS

(Integrated over all photon energies and angles into the forward 2π hemisphere)

Complex Spectra:					
E_{MAX},	MeV	0.8	2.0	4.0	7.0
$E_{AVERAGE}$,	MeV	0.66	1.66	3.07	5.38

E_{MAX} MeV	Target	Thickness gm.cm^{-2}	% Radiation Yield*			
			Electron Angle of Incidence 0°	45°	60°	75°
0.8	Tungsten	0.5			0.5 (0.1)	
		1.0			0.3	
2.0	"	0.5	2.6 (0.5)			1.6 (0.5)
		1.0	2.3			1.3
4.0	"	1.0	5.7 (1.0)	5.3 (1.0)	4.3 (0.8)	3.3 (0.8)
		2.0	4.8	4.4	3.5	2.7
7.0	"	1.0	9.9 (1.6)	10.0 (1.6)	8.7 (1.2)	6.3 (1.2)
		2.8	10.3	9.4	7.7	5.2
0.8	Carbon	0.5		0.14 (0.2)		
		1.0		0.12		
2.0	"	0.5	0.43 (0.8)		0.40 (0.5)	
		1.0	0.46		0.36	
4.0	"	1.0	0.77 (1.4)	0.78 (1.0)	0.71 (0.8)	
		2.0	0.80	0.71	0.60	
7.0	"	1.0	1.1 (2.4)	1.4 (2.0)	1.6 (1.6)	
		2.8	1.7	1.6	1.4	

*Defined as the fraction of its energy which an electron will radiate as bremsstrahlung photons in the course of slowing down. Figures in brackets are the target thicknesses (gm. cm^{-2}) giving the maximum radiation yield.

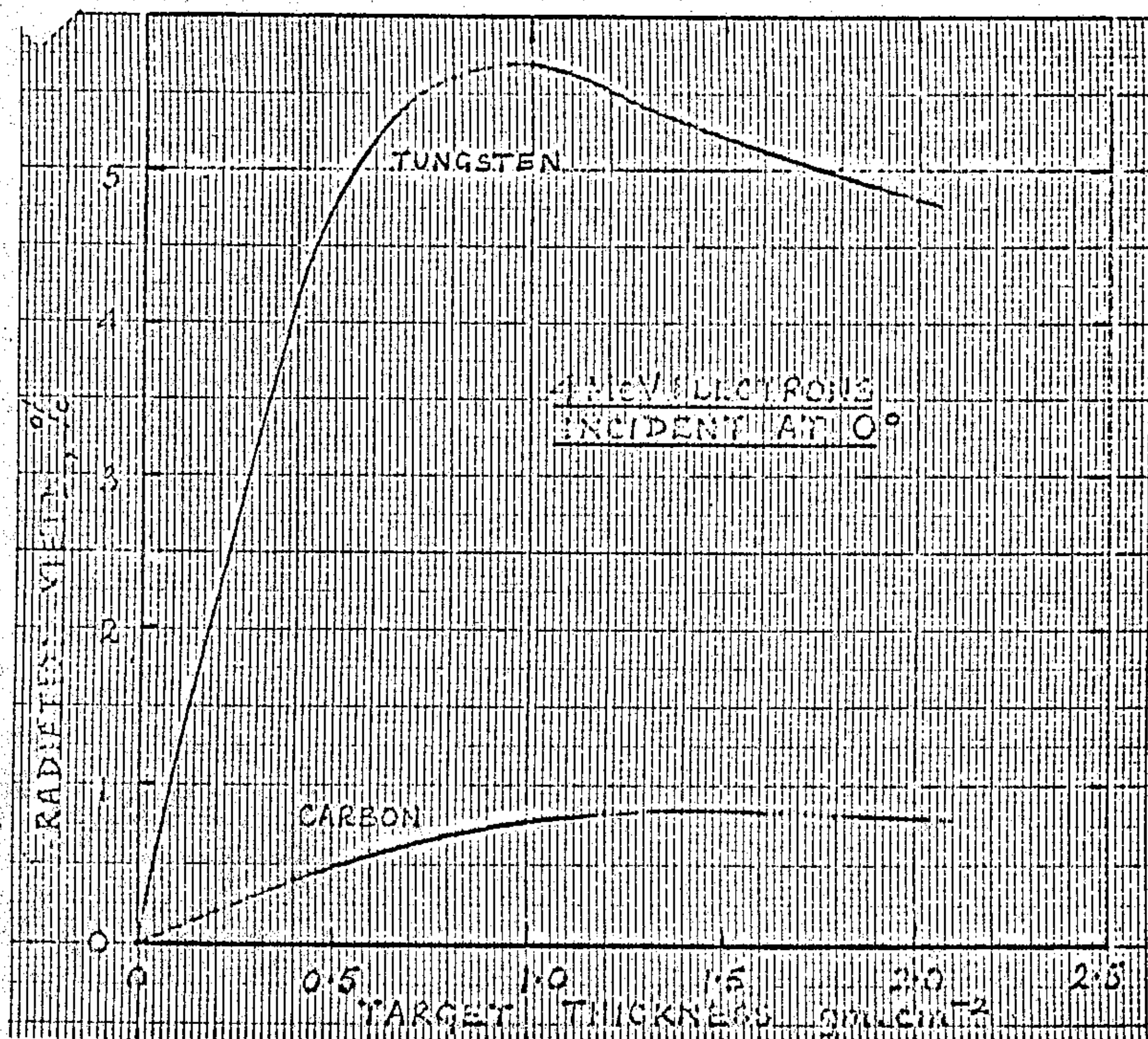

FIGURE 7 - BREMSSTRAHLUNG RADIATION YIELDS FOR TUNGSTEN AND CARBON AS A FUNCTION OF THICKNESS. (Forward 2π hemisphere).

FUNCTION OF THICKNESS. (Forward 2π hemisphere).