LS-16
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Parameters and Spectral Brilliance of the Aladdin Undulators

This note shows tunable ranges of photon energies and the brilliances for different undulator periods and electron beam parameters.

1. Undulator Parameter

Undulator parameters of Table 1 are generated with a minimum gap of 3.5 cm and with a peak field B on the axis of the undulator

$$B = 1.30 \times 0.95 \exp(- \pi g/\lambda_u), \tag{1}$$

where g = undulator gap,
λ_u = undulator period.

Here a filling factor for the assembly of the undulator is assumed to be 95%.

2. Electron Beam Parameter

The horizontal and vertical beam emittances are determined by a coupling constant K^2 and natural emittance ε_{xo}:

$$\varepsilon_x = \varepsilon_{xo}/(1 + K^2),$$

$$\varepsilon_y = \varepsilon_{xo}K^2/(1 + K^2). \tag{2}$$

Parameters of beam size and beam divergence are related as

$$\sigma_{x,y} = (\beta\ \varepsilon_{x,y})^{1/2},$$

$$\sigma'_{x,y} = (\varepsilon_{x,y}/\beta)^{1/2}. \tag{3}$$

In the following table, β = 4.0 m and K^2 = 0.5 are used.

$\varepsilon_{xo}(10^{-6}$ m-rad)	Near Diffraction Limit	0.02	0.10	0.15	0.20
σ_x (mm)	0.01	0.231	0.516	0.632	0.730
σ_y (mm)	0.01	0.163	0.365	0.447	0.516
σ'_x (mrad)	0.005	0.0577	0.129	0.158	0.182
σ'_y (mrad)	0.005	0.0408	0.092	0.112	0.129

- Figure 1 shows the variation of the deflection parameter K as a function of the undulator gap for several values of the undulator period. Tunable ranges, by increasing the gap from the minimum value of 3.5 cm, depend on the choice of the undulator period. An important restriction is $K \gtrsim 0.4 \sim 0.5$ to have reasonable photon flux.

- Figure 2 shows the photon energy at the first harmonics (E/E_{p1} = 1) vs gap for several values of the period. From the value of K in Fig. 1 and from the upper curve in Fig. 2, it is seen that the upper limit of E_{p1} for a tunable undulator is around 180 eV.

- Figures 3 - 5 compare the spectral brilliance in the forward direction for the minimum and possible maximum gaps of the undulator with λ_u = 5.0 cm, 6.0 cm, and 7.0 cm. In all cases, $\varepsilon_{xo} = 0.1 \times 10^{-6}$ m-rad was used. In Fig. 3, only the first and second harmonics are shown. Figures 4 and 5 show up to the fourth harmonics.

- The brilliances in Figs. 6-8 obtained with $\varepsilon_{xo} = 0.15 \times 10^{-6}$ m-rad for λ_u = 5.0 cm, 6.0 cm, and 7.0 cm. Note the change of the scale in the x-axis.

Peak Brilliance at the First Harmonics

Period (cm)	Gap (cm)	Brilliance $\varepsilon_{xo} = 0.1 \times 10^{-6}$	Brilliance $\varepsilon_{xo} = 0.15 \times 10^{-6}$
5.0	3.5	2.05×10^{15}	4.62×10^{14}
5.0	4.25	8.22×10^{14}	2.13×10^{14}
6.0	3.5	1.77×10^{15}	8.41×10^{14}
6.0	4.25		5.47×10^{14}
6.0	5.0	7.71×10^{14}	3.05×10^{14}
7.0	3.5	1.13×10^{15}	1.00×10^{15}
7.0	4.5		7.76×10^{14}
7.0	5.5		4.62×10^{14}
7.0	6.0	5.53×10^{14}	

- Figures 9 - 13 compare the brilliance for a wide range of the horizontal natural emittance, including the diffraction limit for the cases of λ_u = 5.0 cm and 6.0 cm. Note the different vertical scales used for the high and low emittances. In Fig. 9, only the first and second harmonics are shown, and in Fig. 11, the third harmonic is beyond the scale of the x-axis. Figures 10, 12, and 13 show the brilliance up to the fourth harmonics, and in Figs. 12 and 13, the two highest peaks are the first and third harmonics in the diffraction limit. Note that near the diffraction limit of low emittance the peak of the second harmonic is suppressed.

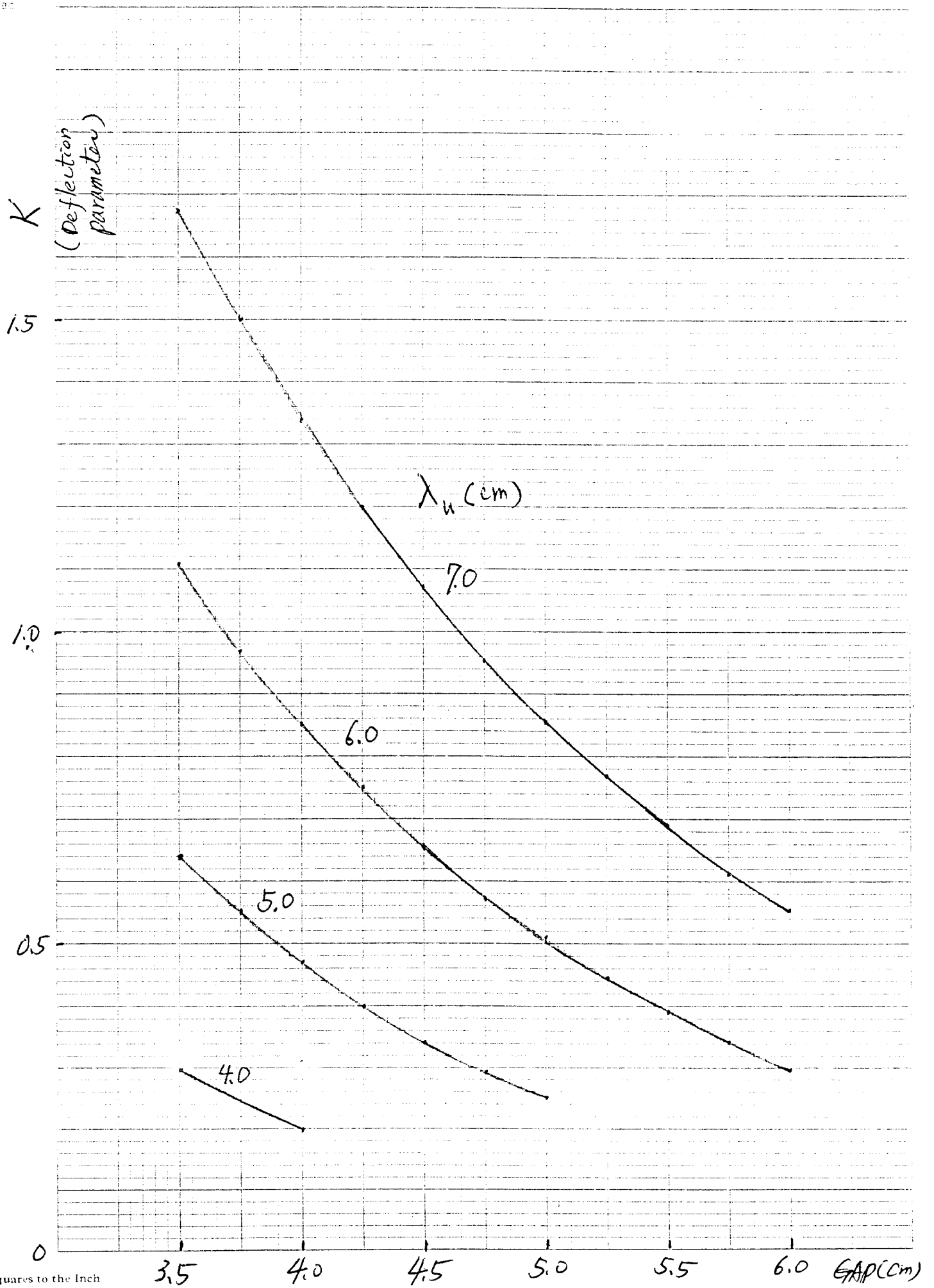
- Figure 14 shows the peak brilliance <u>near</u> the first and third harmonics as a function of the natural emittance. Note that the brilliances of the first harmonics at $\varepsilon_{xo} = 0.02 \times 10^{-6}$ and 1.0×10^{-6} are approximately 10^{-1} and 10^{-2} of those in the diffraction limit, respectively.

Table 1

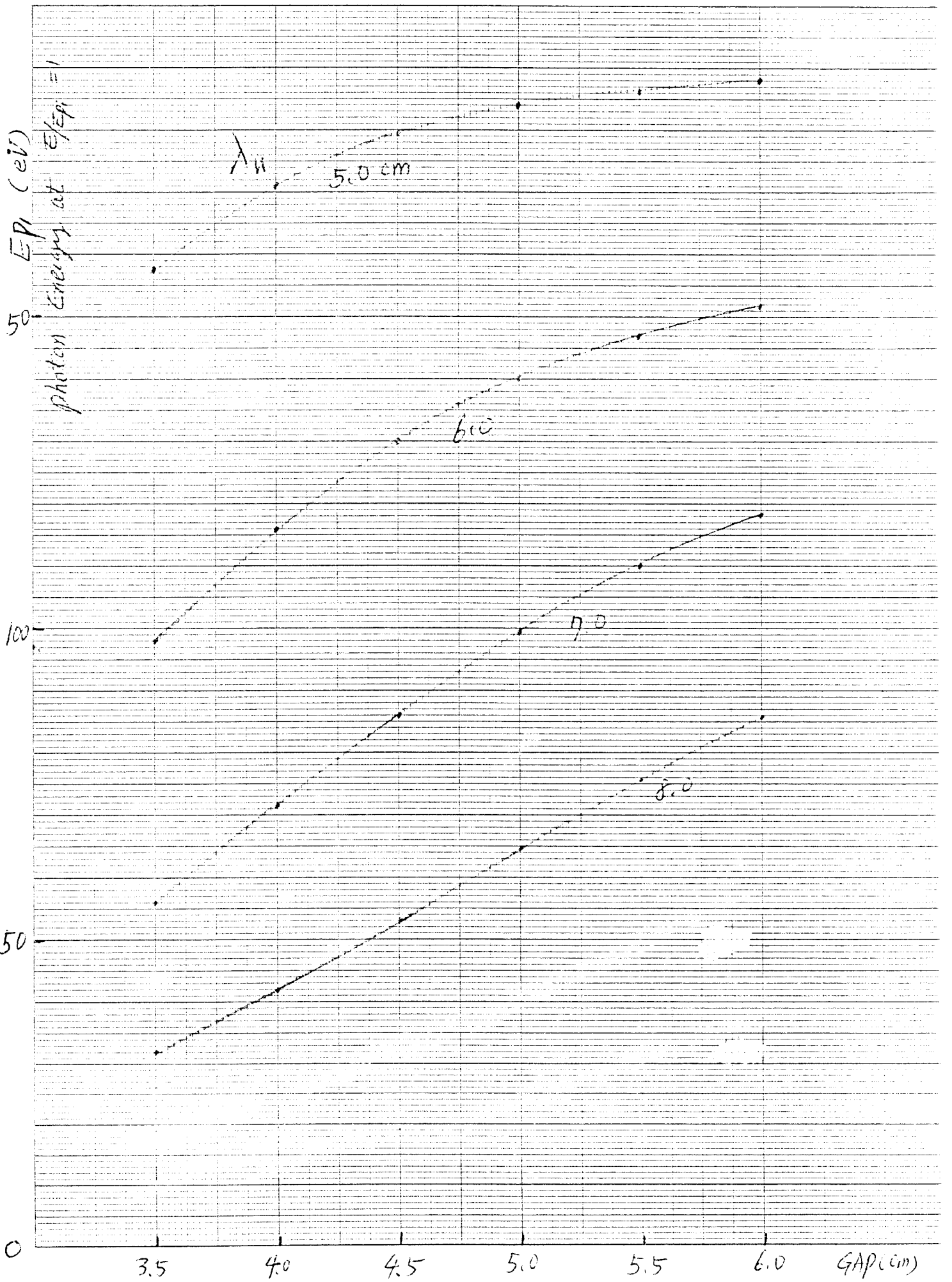
λ_u UNP (CM)	GAP (CM)	B (TESLA)	K	WL1 (A)	EP1 (EV)
5.000	3.500	0.137	0.640	78.633	157.694
5.000	3.750	0.117	0.547	75.033	165.260
5.000	4.000	0.100	0.467	72.404	171.262
5.000	4.250	0.085	0.399	70.483	175.928
5.000	4.500	0.073	0.341	69.080	179.501
5.000	4.750	0.062	0.292	68.056	182.203
5.000	5.000	0.053	0.249	67.307	184.229
5.000	5.250	0.046	0.213	66.761	185.738
5.000	5.500	0.039	0.182	66.362	186.855
5.000	5.750	0.033	0.156	66.070	187.680
5.000	6.000	0.028	0.133	65.857	188.287
5.500	3.500	0.167	0.859	98.318	126.121
5.500	3.750	0.145	0.745	91.732	135.176
5.500	4.000	0.126	0.646	86.792	142.887
5.500	4.250	0.109	0.560	83.062	149.286
5.500	4.500	0.094	0.485	80.266	154.486
5.500	4.750	0.082	0.421	78.165	158.639
5.500	5.000	0.071	0.365	76.586	161.910
5.500	5.250	0.062	0.316	75.399	164.459
5.500	5.500	0.053	0.274	74.507	166.428
5.500	5.750	0.046	0.238	73.836	167.939
5.500	6.000	0.040	0.206	73.332	169.093
6.000	3.500	0.198	1.107	126.363	98.130
6.000	3.750	0.173	0.971	115.301	107.545
6.000	4.000	0.152	0.852	106.786	116.120
6.000	4.250	0.133	0.748	100.233	123.711
6.000	4.500	0.117	0.656	95.190	130.266
6.000	4.750	0.103	0.575	91.308	135.805
6.000	5.000	0.090	0.505	88.320	140.399
6.000	5.250	0.079	0.443	86.020	144.152
6.000	5.500	0.069	0.389	84.250	147.181
6.000	5.750	0.061	0.341	82.888	149.600
6.000	6.000	0.053	0.299	81.839	151.516
6.500	3.500	0.228	1.381	165.814	74.783
6.500	3.750	0.202	1.224	148.436	83.538
6.500	4.000	0.179	1.085	134.788	91.996
6.500	4.250	0.158	0.961	124.071	99.943
6.500	4.500	0.140	0.852	115.654	107.217
6.500	4.750	0.124	0.755	109.044	113.716
6.500	5.000	0.110	0.669	103.853	119.400
6.500	5.250	0.098	0.593	99.776	124.278
6.500	5.500	0.087	0.525	96.575	128.397
6.500	5.750	0.077	0.466	94.061	131.829
6.500	6.000	0.068	0.413	92.087	134.656
7.000	3.500	0.257	1.679	220.134	56.329
7.000	3.750	0.229	1.500	194.257	63.833
7.000	4.000	0.205	1.341	173.580	71.437
7.000	4.250	0.183	1.199	157.060	78.951
7.000	4.500	0.164	1.072	143.861	86.195
7.000	4.750	0.147	0.958	133.314	93.013
7.000	5.000	0.131	0.856	124.888	99.289
7.000	5.250	0.117	0.765	118.155	104.947
7.000	5.500	0.105	0.684	112.775	109.953
7.000	5.750	0.094	0.611	108.477	114.310
7.000	6.000	0.084	0.547	105.043	118.047

Table 1 (Cont'd.)

7.500	3.500	0.285	1.997	293.161	42.298
7.500	3.750	0.257	1.798	256.268	48.387
7.500	4.000	0.231	1.620	226.346	54.783
7.500	4.250	0.208	1.459	202.078	61.362
7.500	4.500	0.188	1.314	182.396	67.984
7.500	4.750	0.169	1.183	166.434	74.504
7.500	5.000	0.152	1.065	153.487	80.788
7.500	5.250	0.137	0.959	142.987	86.721
7.500	5.500	0.123	0.864	134.471	92.213
7.500	5.750	0.111	0.778	127.564	97.206
7.500	6.000	0.100	0.701	121.963	101.670
8.000	3.500	0.312	2.334	389.055	31.872
8.000	3.750	0.283	2.116	338.316	36.652
8.000	4.000	0.257	1.918	296.623	41.804
8.000	4.250	0.233	1.739	262.363	47.263
8.000	4.500	0.211	1.576	234.211	52.944
8.000	4.750	0.191	1.429	211.077	58.746
8.000	5.000	0.173	1.295	192.068	64.560
8.000	5.250	0.157	1.174	176.447	70.276
8.000	5.500	0.142	1.064	163.612	75.789
8.000	5.750	0.129	0.965	153.064	81.012
8.000	6.000	0.117	0.875	144.397	85.874
8.500	3.500	0.339	2.689	512.266	24.206
8.500	3.750	0.309	2.452	444.556	27.893
8.500	4.000	0.282	2.235	388.271	31.936
8.500	4.250	0.257	2.038	341.483	36.312
8.500	4.500	0.234	1.858	302.590	40.980
8.500	4.750	0.213	1.694	270.259	45.882
8.500	5.000	0.195	1.545	243.363	50.948
8.500	5.250	0.177	1.408	221.042	56.098
8.500	5.500	0.162	1.284	202.471	61.243
8.500	5.750	0.147	1.171	187.033	66.299
8.500	6.000	0.134	1.067	174.200	71.183
9.000	3.500	0.364	3.060	667.490	18.577
9.000	3.750	0.334	2.804	579.409	21.401
9.000	4.000	0.306	2.570	505.434	24.533
9.000	4.250	0.280	2.355	443.306	27.972
9.000	4.500	0.257	2.158	391.128	31.703
9.000	4.750	0.235	1.978	347.308	35.703
9.000	5.000	0.216	1.812	310.504	39.935
9.000	5.250	0.198	1.661	279.595	44.350
9.000	5.500	0.181	1.522	253.636	48.889
9.000	5.750	0.166	1.395	231.834	53.486
9.000	6.000	0.152	1.278	213.524	58.073
9.500	3.500	0.388	3.444	859.640	14.425
9.500	3.750	0.357	3.171	747.532	16.588
9.500	4.000	0.329	2.919	652.511	19.003
9.500	4.250	0.303	2.688	571.970	21.679
9.500	4.500	0.279	2.474	503.704	24.618
9.500	4.750	0.257	2.278	445.841	27.813
9.500	5.000	0.236	2.097	396.797	31.250
9.500	5.250	0.218	1.931	355.228	34.907
9.500	5.500	0.200	1.778	319.993	38.751
9.500	5.750	0.184	1.637	290.128	42.740
9.500	6.000	0.170	1.507	264.815	46.825



10 Squares to the Inch



46 1473
10 X 10 TO ½ INCH • 7½ X 10 INCHES
KEUFFEL & ESSER CO. MADE IN U.S.A.

ALADDIN UNDULATOR

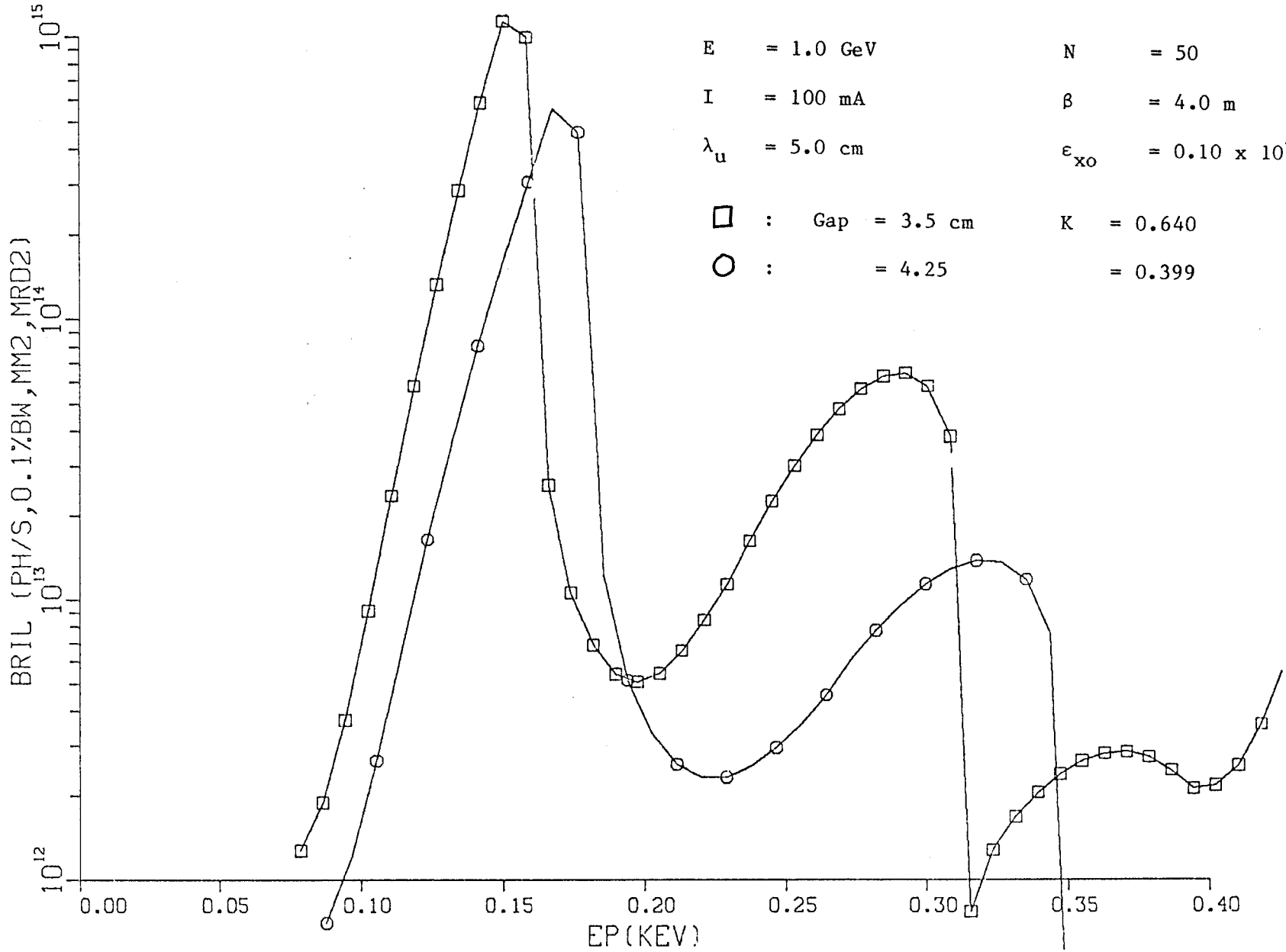


Figure 3

PLOT 1 09.32.17 TUES 12 MAR, 1985 JOB-UNDPL7 , ARGONNE DISSPLA 9.0

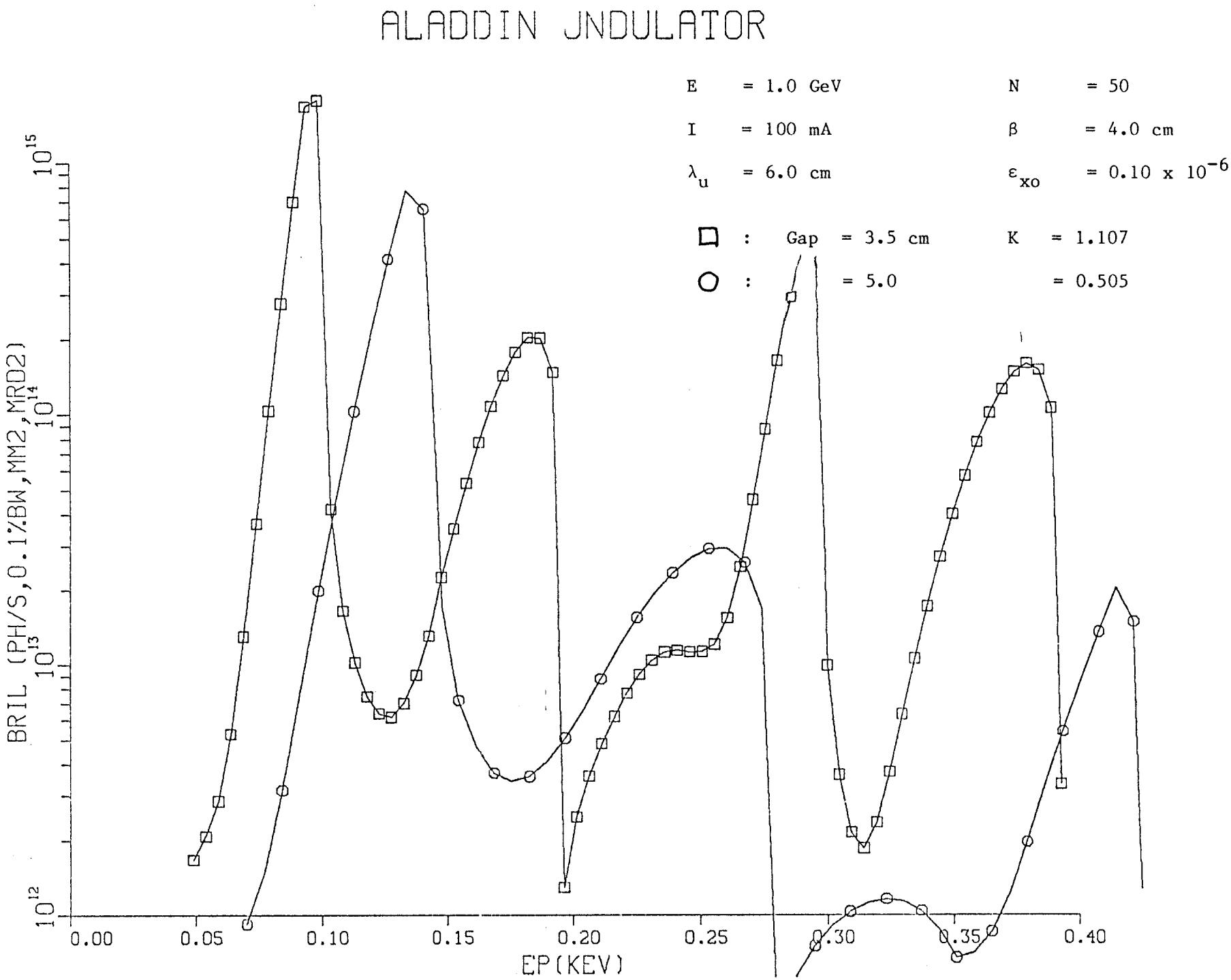


Figure 4

PLOT 1 09.28.44 TUES 12 MAR, 1985 JOB-UNOPLG , ARGONNE DISSPLA 9.0

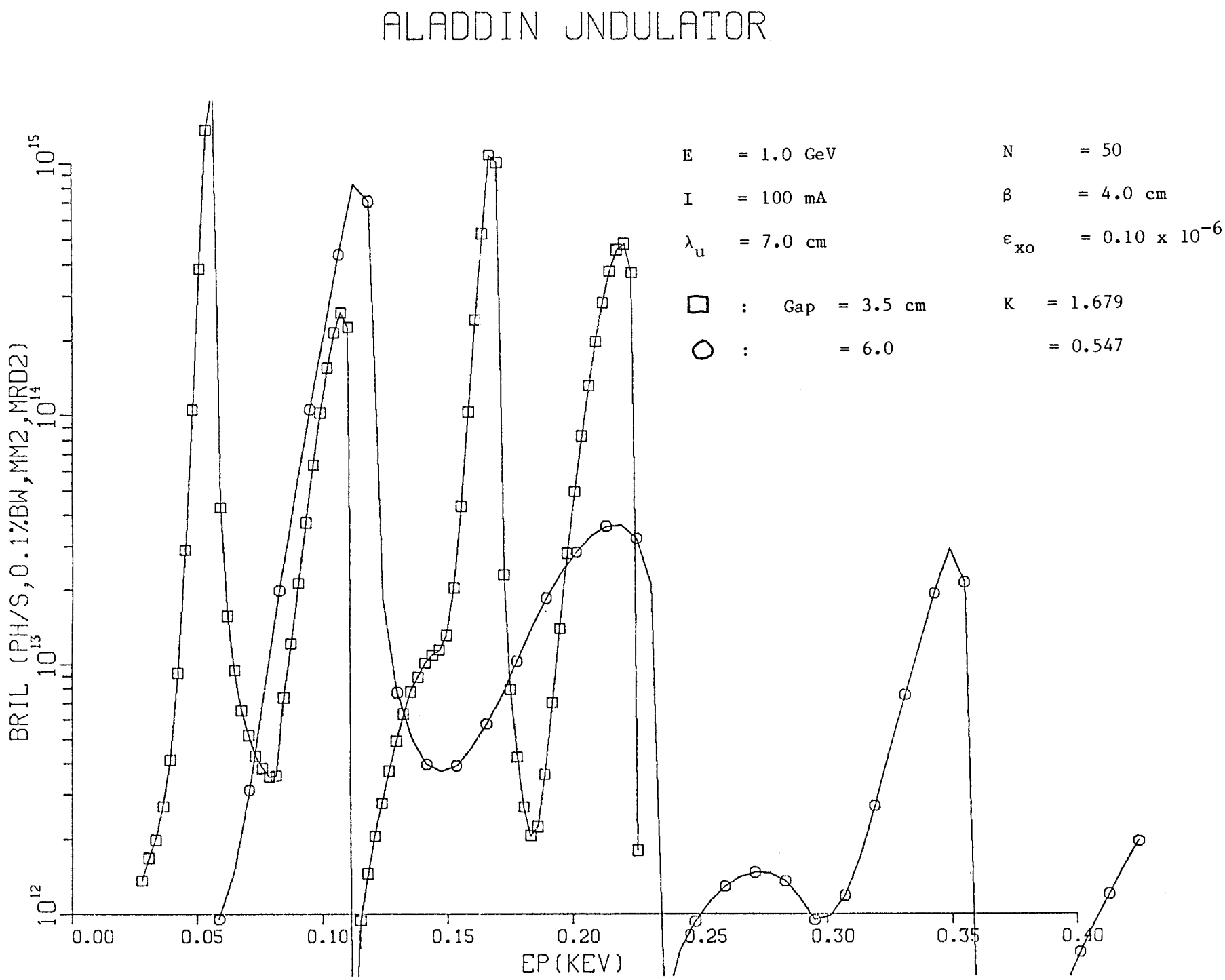


Figure 5

PLOT 1 08.27.06 TUES 12 MAR, 1985 JOB-UNDPLS , ARGONNE DISSPLA 9.0

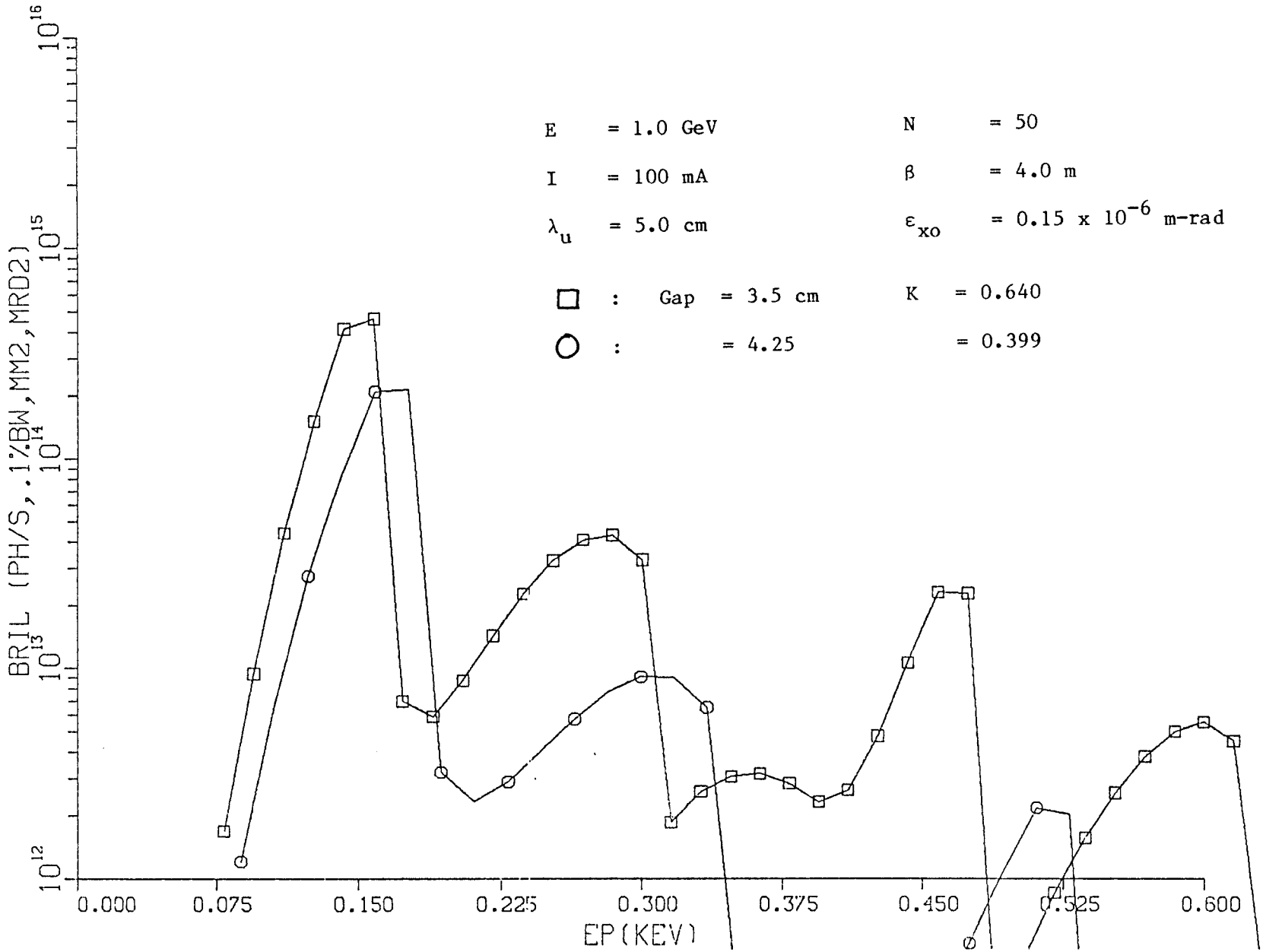


Figure 6

PLOT 1 18.10.01 FRI 8 MAR, 1985 JOB-UNDPL9 , ARGONNE DISSPLA 9.0

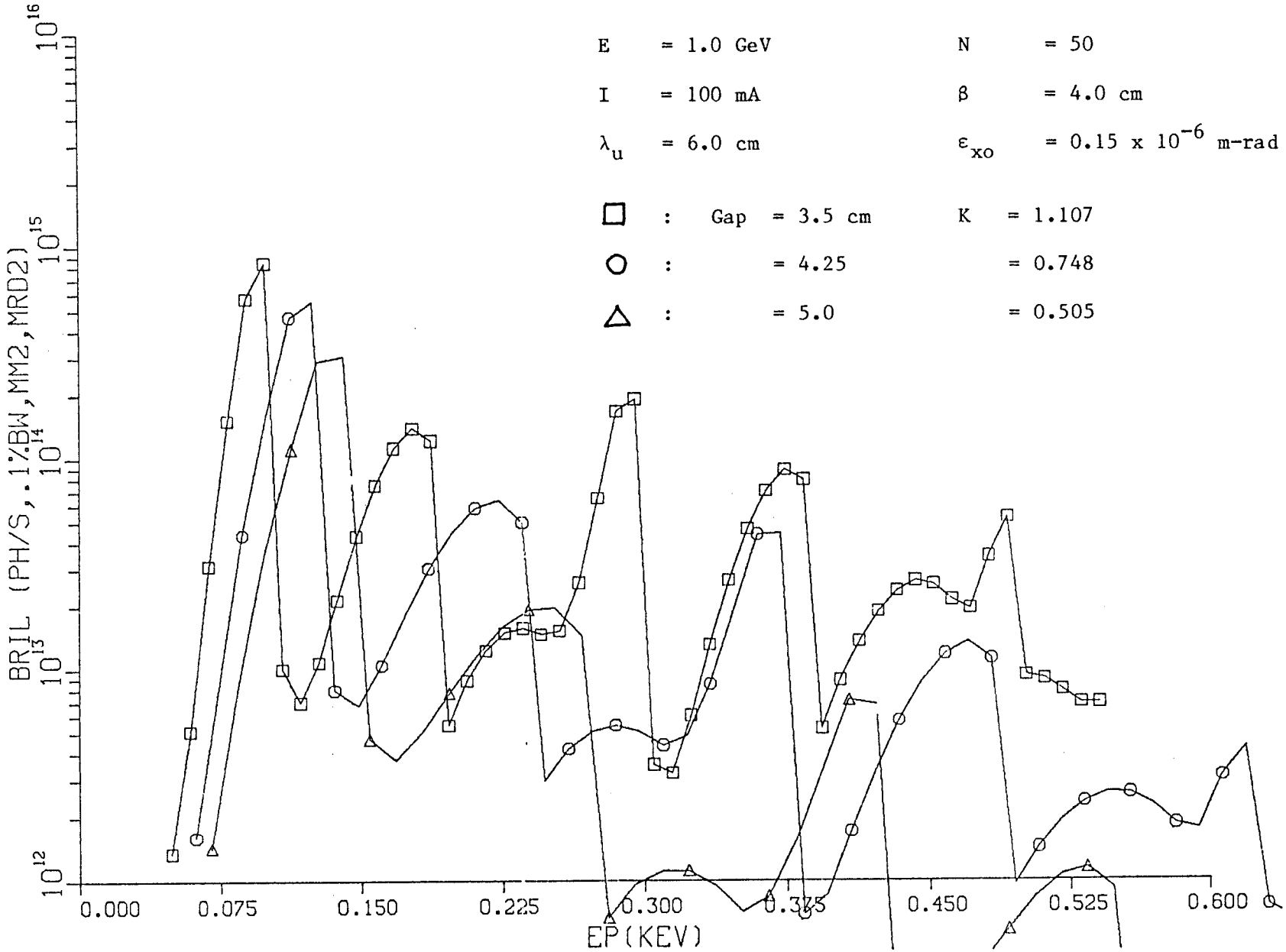


Figure 7

PLOT 1 17.51.05 FRI 8 MAR, 1985 JOB-UNDPL6 , ARGONNE DISSPLA 9.0

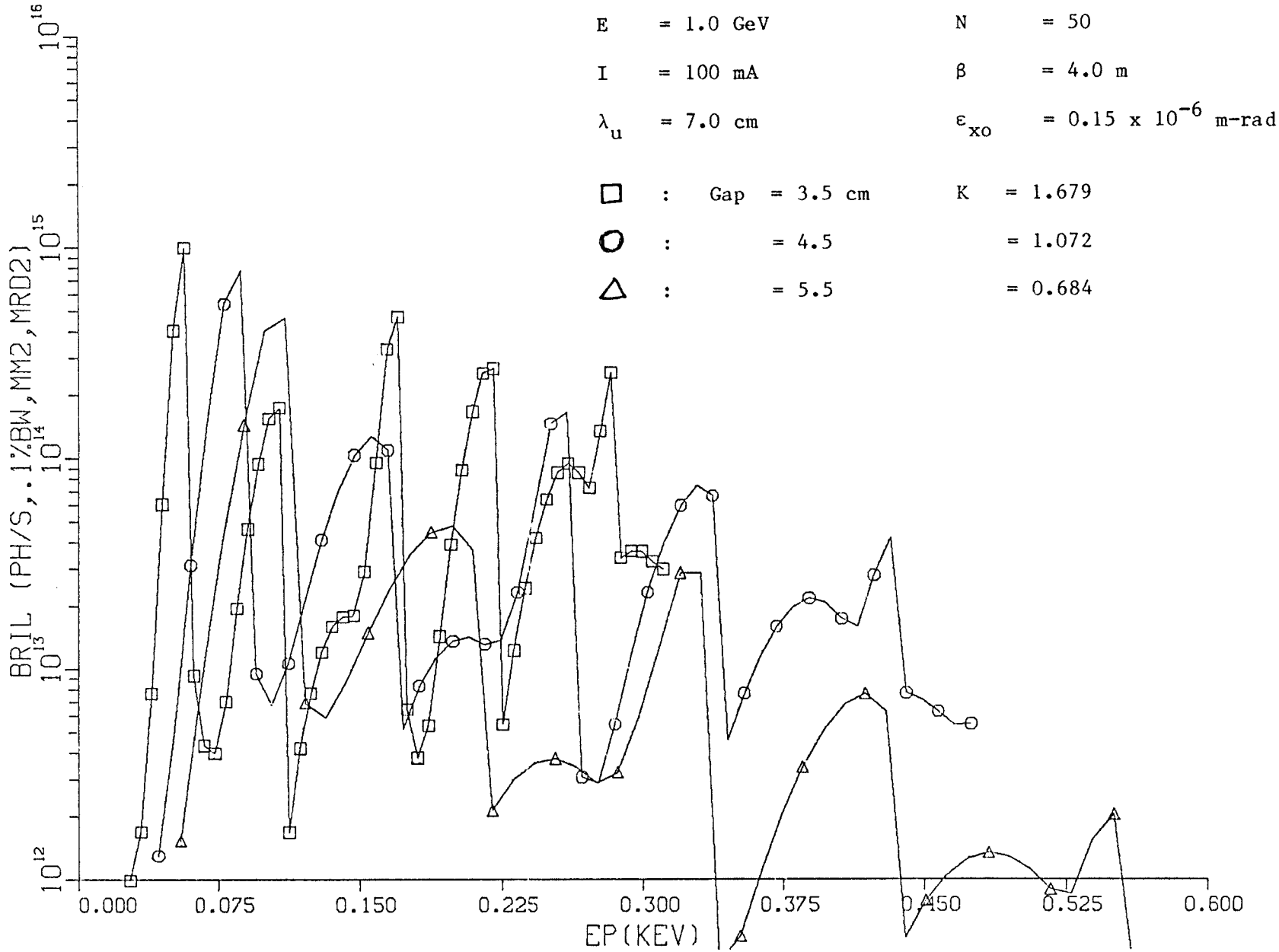


Figure 8

PLOT 1 17.55.24 FRI 8 MAR, 1985 JOB-UNOPL7 , ARGONNE DISSPLA 9.0

ALADDIN UNDULATOR

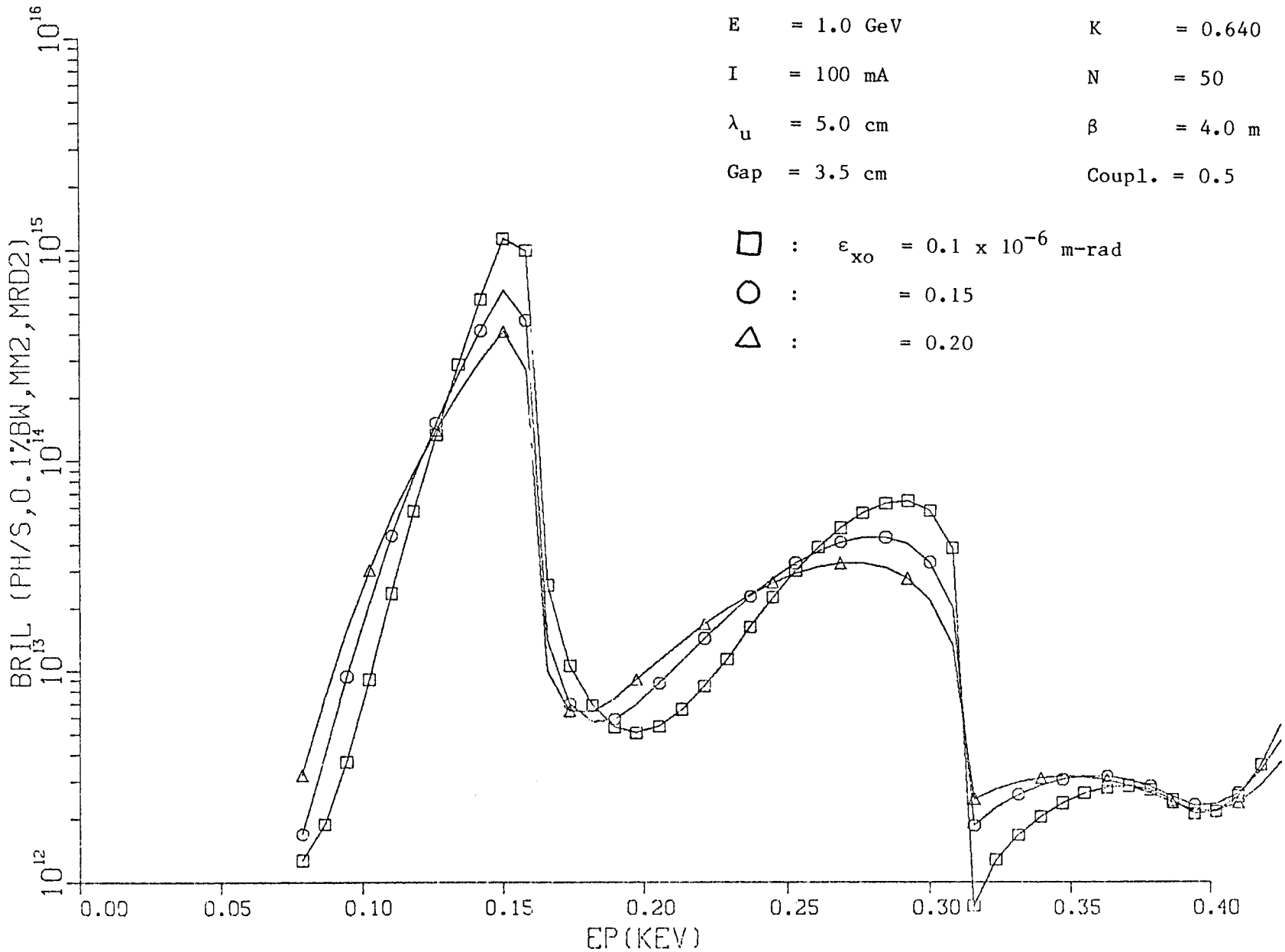


Figure 9

PLOT 1 09.19.03 TUES 12 MAR, 1985 JOB-UNOPL3 , ARGONNE DISSPLA 9.0

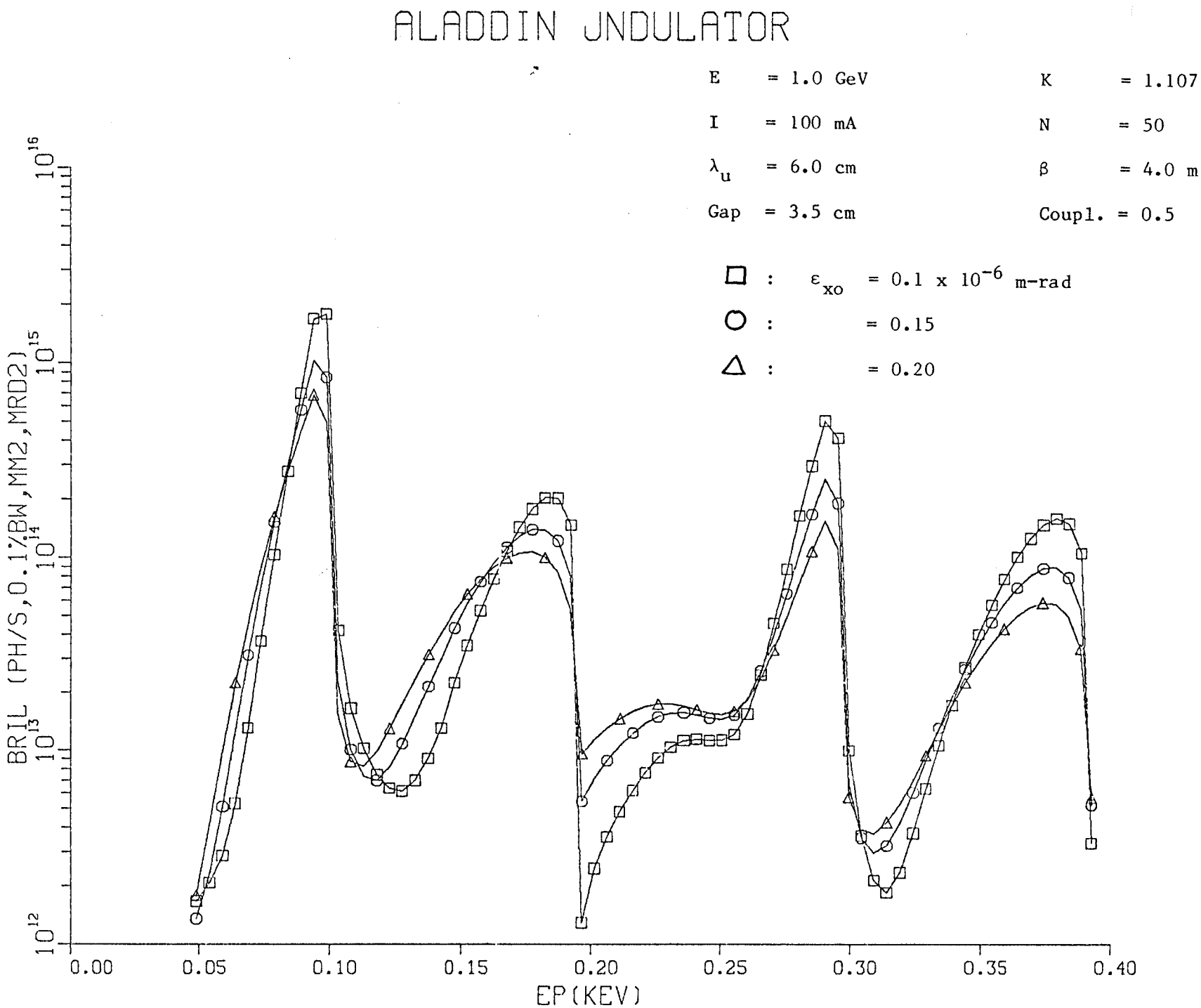


Figure 10

PLOT 1 09.23.33 TUES 12 MAR, 1985 JOB-UNDPL4 , ARGONNE DISSPLA 9.0

ALADDIN JNDULATOR

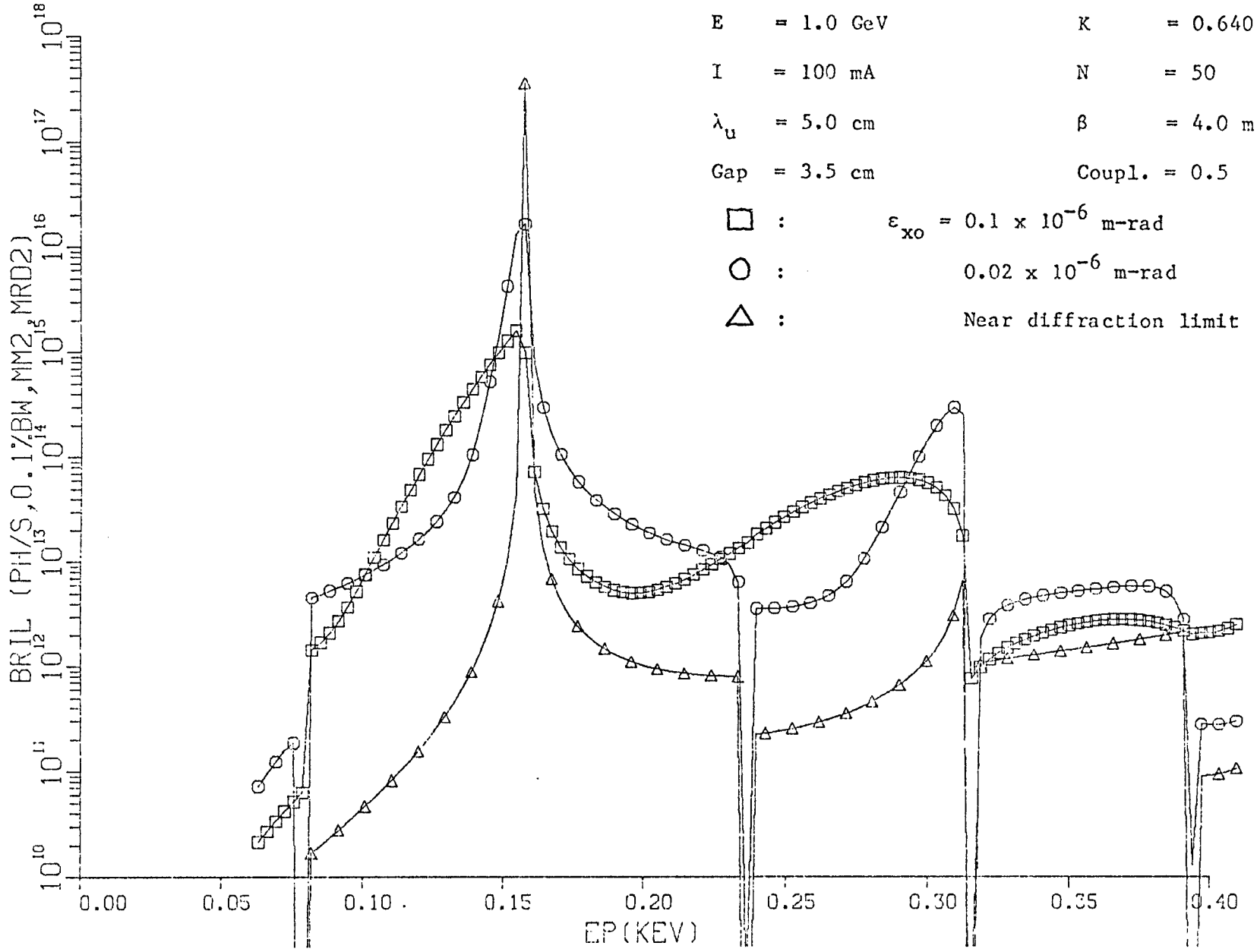


Figure 11

PLOT 1 17.04.37 WED 13 MAR, 1985 JOB-UNDPL3 , ARGONNE DISSPLA 9.0

ALADDIN UNDULATOR

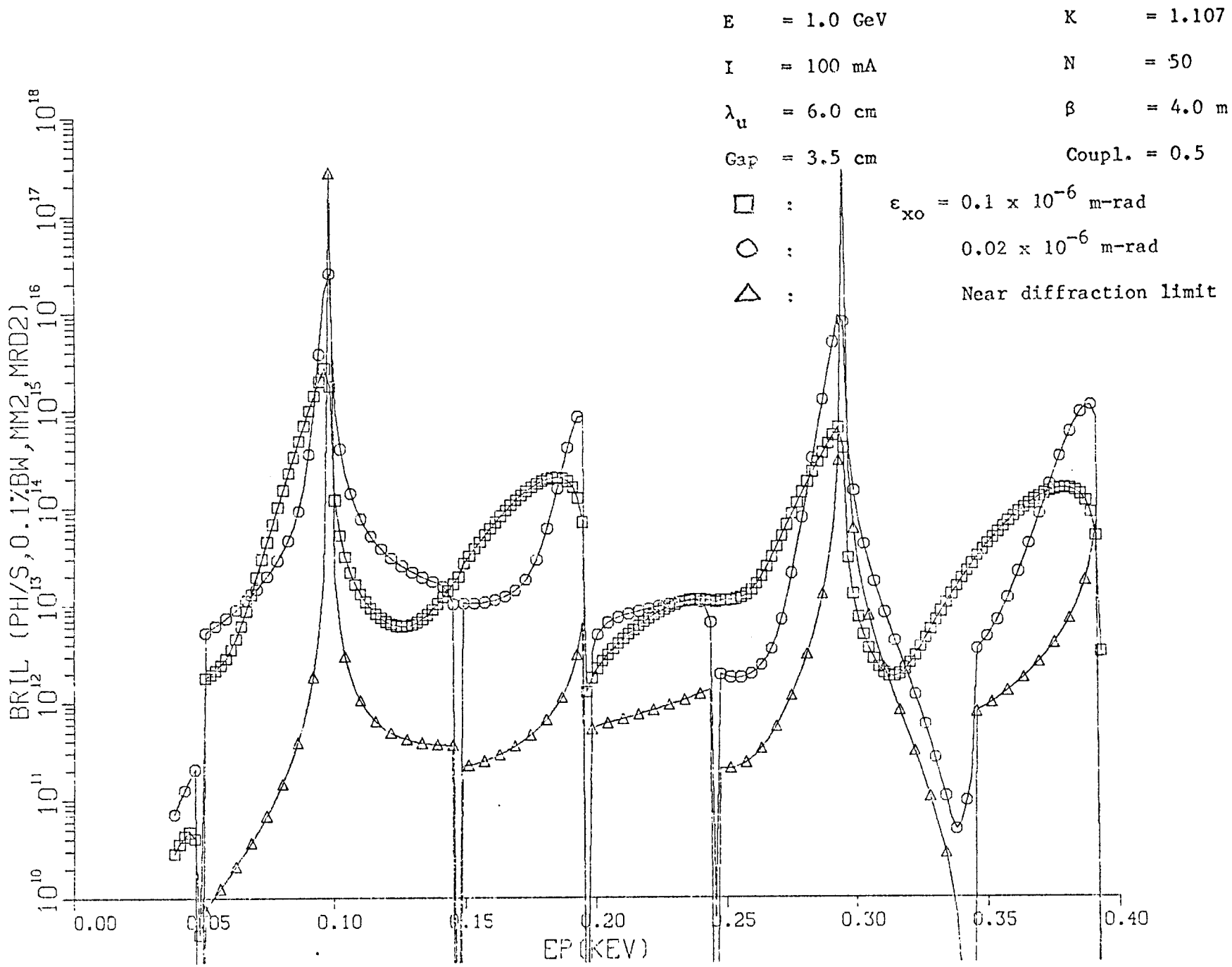


Figure 12

PLOT 1 16.53.29 WED 13 MAR, 1985 JOB-UNDPL2 , ARGONNE DISSPLA 9.0

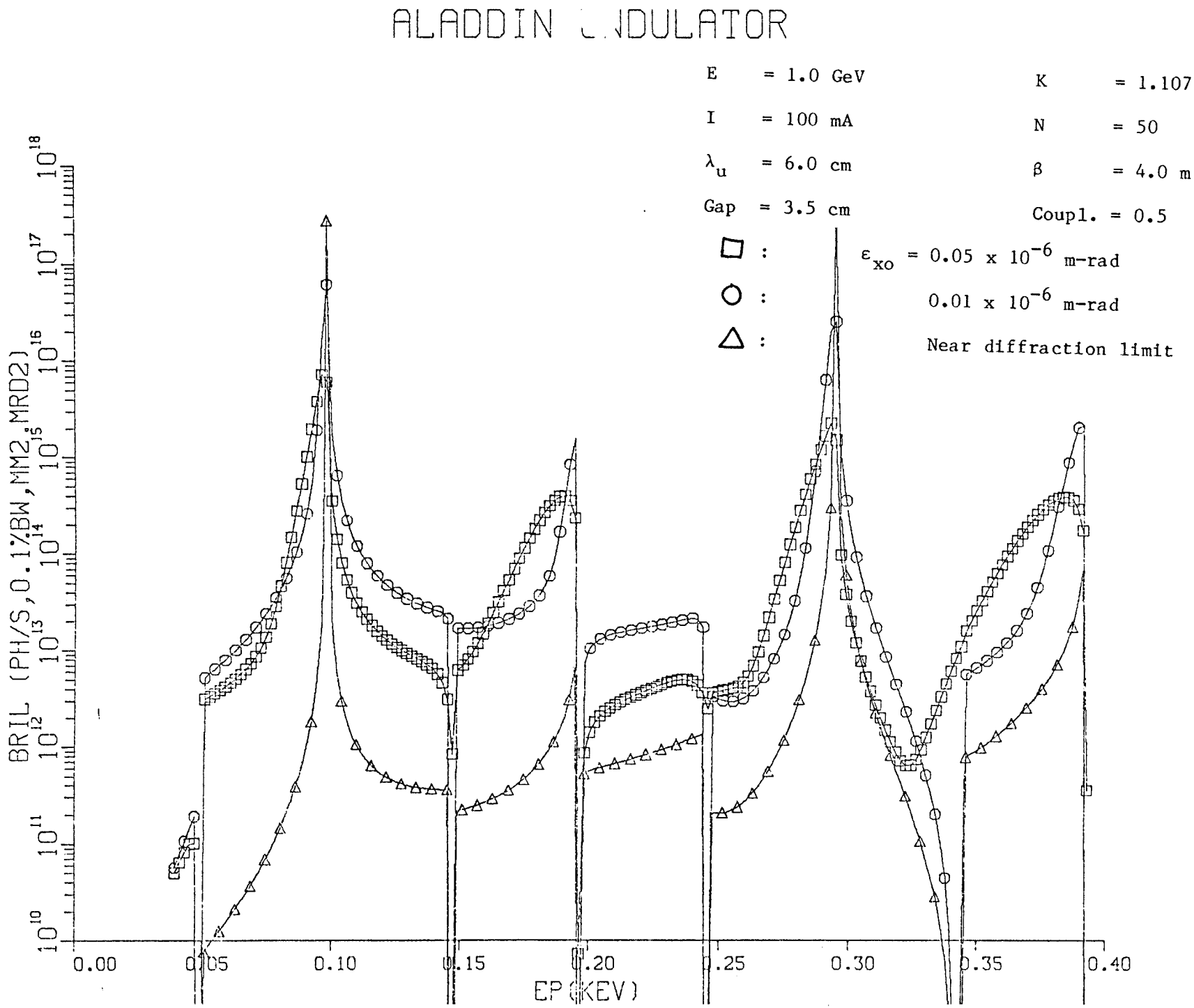
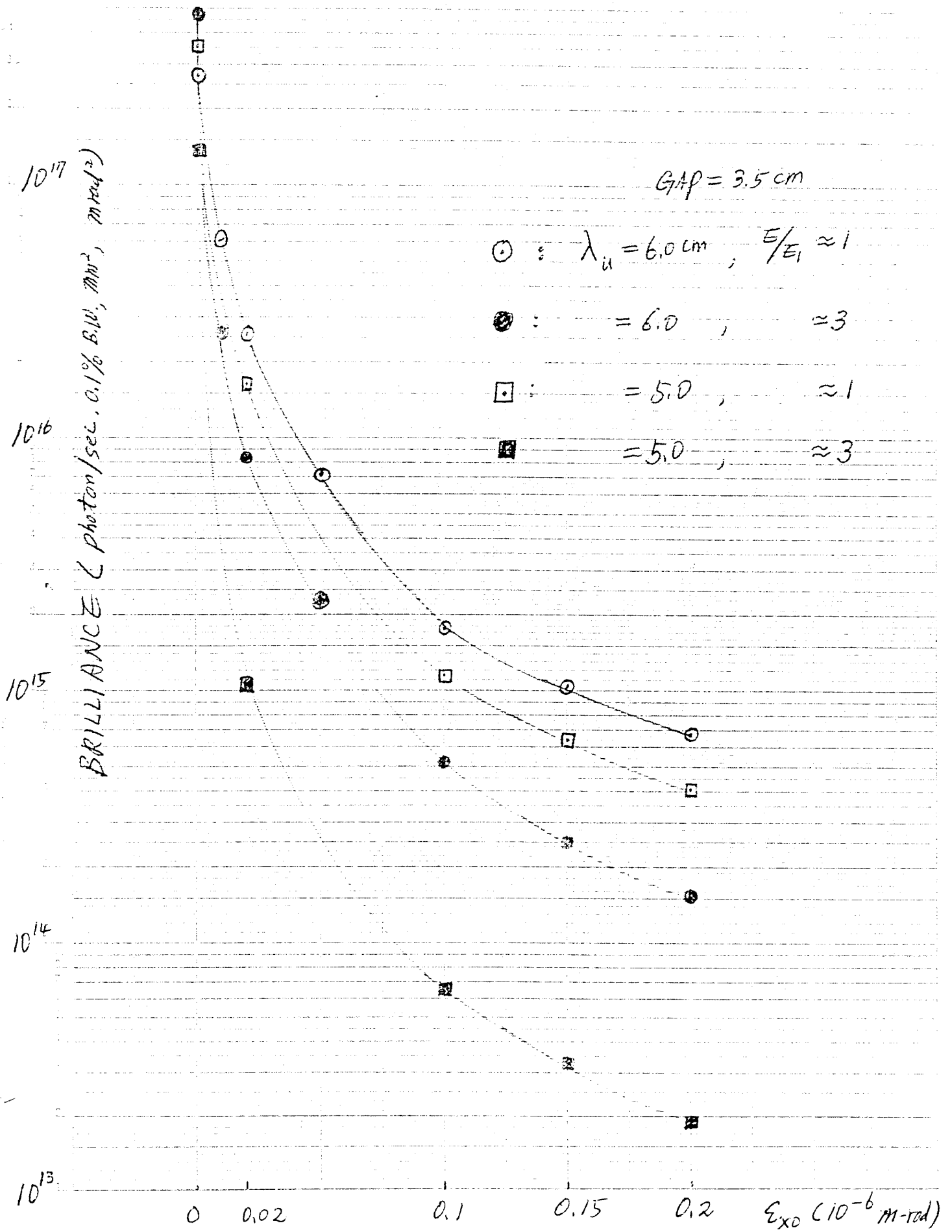

ALADDIN UNDULATOR
E = 1.0 GeV
I = 100 mA
λu = 6.0 cm
Gap = 3.5 cm
K = 1.107
N = 50
β = 4.0 m
Coupl. = 0.5
□ : εxo = 0.05 x 10-6 m-rad
○ : 0.01 x 10-6 m-rad
△ : Near diffraction limit
BRIL (PH/S,0.1%BW,MM2,MRD2)
10^10
10^11
10^12
10^13
10^14
10^15
10^16
10^17
10^18
0.00
0.05
0.10
0.15
0.20
0.25
0.30
0.35
0.40
EP (KEV)

Figure 13


GAP = 3.5 cm
⊙ : λ_u = 6.0 cm , $E/E_1 \approx 1$
● : = 6.0 , ≈ 3
⊡ : = 5.0 , ≈ 1
■ = 5.0 , ≈ 3
BRILLIANCE (photon/sec, 0.1% B.W., mm², mrad²)
10^{17}
10^{16}
10^{15}
10^{14}
10^{13}
0
0.02
0.1
0.15
0.2
ε_{xo} (10^{-6} m-rad)