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R. G. Alsmiller, Jr.
J. Barish

JANUARY 1974

* Computer Sciences Division.

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Energy Deposition by 45-GeV Photons in
H, Be, Al, Cu, and Ta

R. G. Alsmiller, Jr. and J. Barish

Abstract

Electron-photon cascade calculations have been carried out for zero-width beams of 45-GeV photons normally incident on semi-infinite slabs of hydrogen, beryllium, aluminum, copper, and tantalum. The energy deposition is given as a function of both depth and radius in the slabs.

I. INTRODUCTION

A computer code that uses Monte Carlo techniques to study the lateral and longitudinal development of electron-photon cascades induced in matter by high-energy electrons and photons has previously been written by Zerby and Moran.¹⁻³ In this report, results obtained with this code on the energy deposited by the cascades induced in H, Be, Al, Cu, and Ta by 45-GeV photons are presented.*

II. CALCULATIONAL DETAILS AND RESULTS

The electron-photon cascade code has been described in detail elsewhere¹⁻³ and will not be discussed here. The only difference in the code used here and that described previously is that the density-effect correction to the electron stopping power has been included in the calculations since this correction has been shown to have some effect.^{4,5} The geometry considered is that of a zero-width beam of photons normally incident on a semi-infinite slab. Calculations have been carried out for 45-GeV photons incident on H, Be, Al, Cu, and Ta. In carrying out the calculations, electrons and photons with energies < 10 MeV were not transported but were assumed to deposit their energy at their point of origin.

The densities and radiation lengths of the materials used in the calculations are given in Table 1. In Tables 2-6 the energy deposition in H, Be, Al, Cu, and Ta, respectively, is given as a function of depth and radius.

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*When a narrow beam of high-energy hadrons enters matter, the spatial distribution of energy deposition is determined to a considerable extent by the spatial distribution of the energy deposited by the high-energy photons that are produced from the decay of π^0 mesons. The results presented here were obtained to aid M. Awschalom of the National Accelerator Laboratory in designing instrumentation to measure high-energy hadrons.

It is important to note that the data given in Tables 2-5 represent energy deposition per incident photon and not energy deposition per unit volume per incident photon; i.e., the data given in the tables have not been divided by the specified volumes. It should also be noted that the spatial intervals considered in Table 2 are quite different, because of the small hydrogen density used, from the spatial intervals considered in Tables 3-6. In general, the cascades spread laterally only very slowly with depth for all of the materials considered.

Table 1
Densities and Radiation Lengths of Materials
Used in the Calculations

Target Material	Density (g cm ⁻³)	Radiation Length (cm)
H	0.060	1155
Be	1.80	37.8
Al	2.70	9.03
Cu	8.96	1.43
Ta	16.6	0.382

Table 2
Energy Deposited in the Indicated Spatial Intervals for a
Zero-Width Beam of 45-GeV Photons Incident
on a Semi-Infinite Slab of Hydrogen

Depth Interval (cm)	Energy Deposited Per Incident Photon [MeV(Incident Photon) ⁻¹]								
	Radial Interval								
	(cm)								
	0.0-5.0	5.0-15	15-25	25-50	50-100	100-150	150-250	250-500	500-∞
0.0- 578	38	2	1	1	0	0	0	0	0
578- 1155	138	27	7	2	0	0	0	0	0
1155- 1732	203	71	24	21	6	0	0	0	0
1732- 2310	352	105	54	46	17	2	1	0	0
2310- 2887	563	255	95	79	25	1	0	0	0
2887- 3465	627	470	161	145	38	7	4	0	0
3465- 4042	649	607	306	262	98	12	6	2	0
4042- 4620	688	760	411	403	215	43	12	3	0
4620- 5197	652	813	512	523	256	64	22	4	0
5197- 5775	580	864	491	601	318	67	33	9	1
5775- 6352	570	850	550	690	355	86	45	10	1
6352- 6930	448	819	557	681	433	83	51	22	2
6930- 7507	346	756	505	672	453	115	62	29	2
7507- 8085	254	692	448	658	425	133	49	32	6
8085- 8662	146	706	420	541	390	150	79	40	7
8662- 9240	127	600	439	605	344	142	79	33	5
9240- 9817	113	432	341	512	409	111	82	45	8
9817-10390	80	346	285	477	380	97	81	45	5
10390-10970	53	231	212	373	352	99	59	43	2
10970-11550	53	218	172	317	297	86	57	31	11
11550-∞	380	1190	1050	1757	1932	637	492	319	104

Table 3
Energy Deposited in the Indicated Spatial Intervals for a
Zero-Width Beam of 45-GeV Photons Incident
on a Semi-Infinite Slab of Beryllium

Depth Interval (cm)	Energy Deposited Per Incident Photon [MeV(Incident Photon) ⁻¹]								
	Radial Interval								
	(cm)								
	0.0-0.25	0.25-0.50	0.50-1.0	1.0-2.0	2.0-3.0	3.0-5.0	5.0-7.5	7.5-10	10-∞
0.0- 18.9	17	0	0	0	0	0	0	0	0
18.9- 37.8	65	4	4	3	1	0	0	0	0
37.8- 56.7	122	22	15	14	5	3	0	0	0
56.7- 75.6	204	48	52	32	8	5	4	0	0
75.6- 94.4	270	104	90	73	33	23	6	0	0
94.4-113.3	338	152	176	134	63	44	16	4	4
113.3-132.2	370	194	198	197	104	87	28	4	4
132.2-151.1	419	248	290	267	129	109	49	14	5
151.1-170.0	442	300	366	372	176	134	59	20	14
170.0-188.9	431	337	398	435	243	204	87	29	16
188.9-207.8	359	346	440	516	262	258	93	36	29
207.8-226.7	341	333	501	540	317	280	120	46	44
226.7-245.5	296	351	516	615	333	334	138	56	62
245.5-264.4	234	306	503	607	349	391	164	59	60
264.4-283.3	209	280	462	596	311	355	172	68	89
283.3-302.2	212	259	428	592	328	356	186	80	106
302.2-321.1	211	261	395	528	312	362	196	75	87
321.1-340.0	142	216	368	519	326	301	204	76	126
340.0-358.9	108	165	338	516	310	332	157	74	138
358.9-377.8	84	114	274	458	308	326	164	77	137
377.8-∞	247	653	1179	2043	1776	2232	1500	753	1552

Table 4
Energy Deposited in the Indicated Spatial Intervals for a
Zero-Width Beam of 45-GeV Photons Incident
on a Semi-Infinite Slab of Aluminum

Depth Interval (cm)	Energy Deposited Per Incident Photon [MeV(Incident Photon) ⁻¹]								
	Radial Interval (cm)								
	0.0-0.25	0.25-0.50	0.50-1.0	1.0-2.0	2.0-3.0	3.0-5.0	5.0-7.5	7.5-10	10-∞
0.0- 4.52	9	0	0	0	0	0	0	0	0
4.52- 9.03	40	2	2	0	0	0	0	0	0
9.03-13.6	93	8	5	3	0	0	0	0	0
13.6-18.1	210	35	18	14	4	0	0	0	0
18.1-22.6	311	59	45	22	2	1	0	0	0
22.6-27.1	426	112	100	61	16	5	0	0	0
27.1-31.6	531	178	182	130	28	16	3	0	0
31.6-36.1	660	242	250	194	56	27	3	0	0
36.1-40.6	727	299	328	254	85	52	6	2	1
40.6-45.2	794	424	414	344	119	62	13	1	1
45.2-49.7	707	461	526	424	154	90	25	2	4
49.7-54.2	675	478	589	522	179	104	23	9	5
54.2-58.7	626	516	650	594	226	143	33	9	8
58.7-63.2	511	456	626	634	254	180	52	7	7
63.2-67.7	450	424	600	625	294	192	52	18	15
67.7-72.2	394	374	532	609	257	210	62	21	20
72.2-76.8	309	337	526	552	249	206	75	30	20
76.8-81.3	311	291	500	557	251	221	84	26	25
81.3-85.8	274	282	461	507	247	235	79	25	32
85.8-90.3	201	258	403	497	255	218	104	35	31
90.3-∞	758	1033	2032	2910	1759	1889	994	503	720

Table 5
Energy Deposited in the Indicated Spatial Intervals for a
Zero-Width Beam of 45-GeV Photons Incident
on a Semi-Infinite Slab of Copper

Depth Interval (cm)	Energy Deposited Per Incident Photon [MeV(Incident Photon) ⁻¹]								
	Radial Interval (cm)								
	0.0-0.25	0.25-0.50	0.50-1.0	1.0-2.0	2.0-3.0	3.0-5.0	5.0-7.5	7.5-10	10-∞
0.0 - 0.71	5	0	0	0	0	0	0	0	0
0.71- 1.43	21	0	0	0	0	0	0	0	0
1.43- 2.14	68	1	0	0	0	0	0	0	0
2.14- 2.86	130	5	0	0	0	0	0	0	0
2.86- 3.57	231	18	6	0	0	0	0	0	0
3.57- 4.29	396	36	13	2	0	0	0	0	0
4.29- 5.00	554	64	24	4	0	0	0	0	0
5.00- 5.71	727	100	56	3	1	1	1	0	0
5.71- 6.43	924	175	73	17	1	0	1	0	0
6.43- 7.14	1065	227	111	22	0	0	1	0	0
7.14- 7.86	1151	288	156	30	1	2	0	0	0
7.86- 8.57	1261	340	196	49	4	2	1	0	0
8.57- 9.29	1305	400	233	49	5	3	1	0	0
9.29-10.0	1308	444	262	80	9	2	2	0	0
10.0 -10.7	1280	439	292	90	9	4	0	0	0
10.7 -11.4	1275	483	286	100	18	8	2	1	0
11.4 -12.1	1212	507	322	132	15	9	1	0	0
12.1 -12.9	1126	496	362	132	26	8	1	1	0
12.9 -13.6	1036	481	343	121	22	11	2	2	0
13.6 -14.3	955	453	347	142	25	19	3	0	0
14.3 - ∞	7253	4544	4054	2488	739	466	131	38	19

Table 6
Energy Deposited in the Indicated Spatial Intervals for a
Zero-Width Beam of 45-GeV Photons Incident
on a Semi-Infinite Slab of Tantalum

Depth Interval (cm)	Energy Deposited Per Incident Photon [MeV(Incident Photon) ⁻¹]								
	Radial Interval (cm)								
	0.0-0.25	0.25-0.50	0.50-1.0	1.0-2.0	2.0-3.0	3.0-5.0	5.0-7.5	7.5-10	10-∞
0.0 -0.19	3	0	0	0	0	0	0	0	0
0.19-0.38	22	0	0	0	0	0	0	0	0
0.38-0.57	53	0	0	0	0	0	0	0	0
0.57-0.76	98	1	0	0	0	0	0	0	0
0.76-0.96	207	3	0	0	0	0	0	0	0
0.96-1.15	362	5	2	0	0	0	0	0	0
1.15-1.34	522	8	0	1	0	0	0	0	0
1.34-1.53	750	6	0	1	1	0	0	0	0
1.53-1.72	985	32	2	1	0	0	0	0	0
1.72-1.91	1198	56	7	1	0	0	0	0	0
1.91-2.10	1421	67	8	1	0	0	0	0	0
2.10-2.29	1633	124	25	4	0	0	0	0	0
2.29-2.48	1769	131	24	2	1	0	0	0	0
2.48-2.68	1905	174	29	6	0	0	0	0	0
2.68-2.87	1953	205	55	10	0	0	0	0	0
2.87-3.06	1975	221	51	7	0	0	0	0	0
3.06-3.25	1855	233	56	21	2	1	0	0	0
3.25-3.44	1848	277	57	15	4	3	0	0	0
3.44-3.63	1745	273	81	14	2	2	0	0	0
3.63-3.82	1671	267	108	18	1	0	0	0	0
3.82- ∞	13020	4083	2104	873	165	52	10	2	0

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