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GAMMA-RAY AND CONVERSION ELECTRON SPECTRA FROM PRIMARY ^{252}Cf FISSION FRAGMENTS

Berkeley, California

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R. L. Watson, H. R. Bowman, S. G. Thompson and J. O. Rasmussen

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Over the past several years we have been investigating the prompt gamma rays and conversion electrons accompanying the spontaneous fission of ^{252}Cf. It appears, based upon the success met so far, that the type of experimental approach used in our studies may be particularly applicable to the detailed nuclear spectroscopic study of a large number of neutron-excess isotopes not accessible by other more standard means. There are at present, however, a number of complications associated with the unique assignments of fission fragment isotopes from which the gamma rays and electrons are emitted. The energy spectra measured in these studies are rather complex and not completely resolvable, and there are overwhelming quantities of data which must be correlated. Thus, the goals of assigning transitions to particular nuclei and of deriving level schemes may be attained in large measure only after considerably more work. Promising beginnings on detailed interpretation have been made (cf. Ref. 1, p. 138 and Ref. 2, p. 96), but we shall not present such material here. Rather, we feel it may be of value here to make available our data in a form useful for further analysis and for comparison and correlation with the results of such studies by other investigators.

The experimental details associated with these studies have been discussed elsewhere,[1,2] and hence only a brief summary will be given here. Basically, the experiments were of the three-dimensional type, where the energies of the two coincident fission fragments were measured along with either the gamma-ray or conversion-electron energy. The three energies were stored on magnetic tape and later processed on a 7094 IBM computer. In this processing, the fragment masses were calculated from their recorded energies and the gamma rays and conversion electrons were sorted with respect to their coincident fragment masses into intervals of every two mass units.

The gamma rays were detected by a lithium-drifted germanium detector, and spectra were taken at 90° and at 0°-180° with respect to the fragment flight path for gamma rays emitted up to 50 nsec after fission. Since the fragment flight path was 1.3 cm in the gamma-ray experiments, those gamma rays emitted within approximately 1.3 nsec after fission (fragment velocity ~ 1 cm/nsec) showed a Doppler shift in the 0°-180° runs.

In the conversion-electron experiments, a lithium-drifted silicon electron detector was employed along with a fringing field magnetic-steering mechanism. The magnetic-steering mechanism was used to guide the electrons away from the source region so that the electron detector could be shielded against interference from alpha particles, fission fragments, gamma rays and X-rays. The fission source was positioned in such a way as to limit detection to only those electrons which were emitted in the approximate time interval of 0.2 to 1.8 nsec after fission ($\bar{t}$ ~ 1 nsec) from fragments in flight. Detection was further limited to electrons emitted near 90° with respect to the fragment flight path.

The experimental energy spectra from these experiments are presented in Figs. 3 through 52 in sets of four distributions for each fragment mass interval. The internal conversion electron spectra are shown on the lefthand pages along with the 90° gamma-ray spectra—one above the other for ease of comparison. As a further aid in correlating the conversion-electron and 90° gamma-ray spectra, the electron spectra have been displaced upward in energy by the amount labeled "delta" to the lower right on each electron spectrum. The magnitude of this energy shift was chosen such as to align in energy K-conversion electron lines arising from isotopes of the most probable charge for the given mass intervals with their corresponding gamma rays in the figure below. Hence, in order to read the correct energy of an electron peak, the quantity "delta" must be subtracted from the energy value obtained from the energy scale. In correlating an arbitrary electron peak with its corresponding gamma-ray peak from these spectra, both peak energies are first read from the energy scales and the quantity "delta" subtracted from the electron-peak energy. The resulting electron-peak energy must further be corrected for the slight upward shift in energy resulting from a relativistic effect of the fragment motion by subtracting the appropriate shift correction given in Table I

as a function of measured peak energy and fragment mass.[2] In estimating the conversion-electron-gamma-ray energy differences, account must be taken of the increase in electron binding energies experienced by fission fragments as a result of their high ionic charges. We have carried out Hartree-Fock calculations on this problem and found that the K and L binding energies are both increased by an approximately constant 0.9 keV over the whole region of fission product isotopes.[3]

On the righthand pages are given the 0°-180° and the 90° gamma-ray spectra—again one above the other for ease of comparison. In the gamma-ray experiments, it was not possible to separate gamma rays emitted by each member of coincident fragment pairs and so each gamma-ray spectrum contains both gamma rays emitted by fragments belonging to the specified mass interval and gamma rays emitted by fragments belonging to the complementary mass interval. (Complete separation was attainable in the case of the electron spectra). The 0°-180° gamma-ray spectra were taken with the gamma detector positioned such that fragments belonging to the mass intervals specified in each spectrum were traveling toward the gamma detector, while fragments belonging to the complementary mass interval were traveling away from the gamma detector. Many double peaks can be seen in the 0°-180° spectra with a Doppler shifted component for decay in flight and a non-shifted component resulting from gamma-ray emission after the fragment has come to rest in the fragment detector. Hence, many of the gamma-ray peaks associated with the specified mass interval in each 0° spectrum may be identified by their Doppler shift up in energy relative to their position in the 90° spectrum

$$E_{0^\circ} = \frac{E_{90^\circ}(1 + \beta)}{\sqrt{1 - \beta^2}}$$

while others may be identified with fragments traveling in the 180° direction (i.e. belonging to the complementary mass interval) by their downward Doppler shift,

$$E_{180^\circ} = \frac{E_{90^\circ}(1 - \beta)}{\sqrt{1 - \beta^2}}$$

where β is the ratio of the fragment velocity to the speed of light. Also the relative intensities of a gamma ray will be greater when the fragment from which it is emitted is traveling toward the gamma detector than when the fragment is traveling away due to the increasing detection geometry for the former case partly due to simple solid angle considerations for gammas emitted with lifetimes $\gtrsim$ 1 nsec and partly due to Lorentz contraction considerations for decay in flight.

The average values of a number of quantities relating to the calculations of the fragment masses are given in Table II, from which the average fragment mass (labeled "after nu emit. mass 2") and the average complementary fragment mass (labeled "after nu emit. mass 1") associated with any mass interval may be found. Other quantities given in Table II include the average numbers of neutrons emitted (NU1 and NU2), the average total and individual fragment kinetic energies (ET, E1 and E2) and the average velocities (V1 and V2) of mass 1 and mass 2 fragments respectively. The velocities listed in Table II may be used to calculate gamma-ray Doppler shifts.

It may be noted in the spectra of Figs. 3 through 52 that each peak or group of peaks is spread over 5 to 6 mass intervals. This spread is caused by the dispersion involved in the fragment energy measurements and the neutron evaporation processes and necessitates the plotting of peak relative intensities as a function of mass for the true mass identification of a given gamma or electron line. Since many of the peaks are not single lines, but the sum of a number of lines, the energies of these peak centroids are not necessarily the correct individual transition energies and the mass intervals at which these peaks appear in their highest intensities are not necessarily indicative of the true masses associated with the individual lines. Single gamma-ray lines should have a full width at half maximum (FWHM) of approximately 5 keV. The conversion electron lines, on the other hand, are much more sensitive to the fragment motion and hence show a fairly rapid broadening as a function of electron energy and fragment velocity. The conversion electron peaks were found to be Gaussian in shape and the calculated standard deviation (σ = FWHM/2.36) is given in Fig. 1 as a function of electron energy for several fragment mass intervals.[2]

The efficiency times geometry curve ($\Omega\epsilon$) for the gamma-ray detector as a function of energy is given in Fig. 2. This curve was calibrated with sources located 3 cm away from the detector (i.e. in the fission source position for both the 90° and the 0°-180° runs). The dimensions of the germanium detector were 2 cm × 3 cm with a 3 mm depletion depth. The total detection efficiency times geometry for the conversion electrons was very nearly independent of electron energy and was determined to be 0.05 ±0.01. The total number of fission events and the total number of fragments falling in each mass interval are listed in Table III for the conversion electron, 90° gamma-ray and 0°-180° gamma-ray runs. Intensities may be determined relative to the total number of fissions or relative to the total number of fragments of a given mass from the following relations

$$\text{Events/fragment} = \frac{\text{Total counts}}{\Omega\epsilon \times \text{total fragments}}$$

$$\text{Events/fission} = \frac{\text{Total counts}}{\Omega\epsilon \times \text{total fissions}}$$

In each case, it must be borne in mind that the intensities only apply to electrons emitted in the time interval 0.2-1.8 nsec and to gamma rays in the interval 0-50 nsec. Thus, to estimate absolute intensities it is necessary to know the transition half-lives and to apply appropriate correction factors.

ACKNOWLEDGMENTS

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2. R. L. Watson, A Study of the Internal Conversion Electrons Emitted Within Three Nanoseconds after the Spontaneous Fission of ^{252}Cf (Ph.D. Thesis), University of California Lawrence Radiation Laboratory Report UCRL-16798, July 1966.
3. R. L. Watson and J. O. Rasmussen, University of California Lawrence Radiation Laboratory Report UCRL-17290, December 1966 (to be published).

FIGURE CAPTIONS

Fig. 1. Calculated standard deviation of the conversion electron peaks as a function of electron (laboratory) energy for several fragment mass intervals.

Fig. 2. The efficiency times geometry ($\Omega\epsilon$) curve for the lithium-drifted germanium ($2 \times 3 \times 0.3$ cm) gamma-ray detector.

Figs. 3-52. The conversion electron spectrum and 90° gamma-ray spectrum (lefthand pages), and the 0°-180° gamma-ray spectrum and 90° gamma-ray spectrum (righthand pages)—associated with each interval of fragment mass. All spectra contain two plots; the larger of the two is a times 4 magnification of the smaller.

Table I. Electron energy shift corrections.

Average Mass	100	104	108	112	116	120	132	136	140	144	148	152	156	160
E_{lab} (keV)							Correction (keV)							
20.00	0.59	0.56	0.54	0.51	0.49	0.46	0.39	0.35	0.32	0.30	0.28	0.25	0.23	0.21
40.00	0.61	0.59	0.56	0.53	0.50	0.48	0.39	0.36	0.34	0.31	0.29	0.26	0.24	0.21
60.00	0.64	0.61	0.58	0.55	0.52	0.50	0.41	0.37	0.35	0.32	0.30	0.27	0.25	0.22
80.00	0.66	0.63	0.60	0.57	0.54	0.51	0.42	0.39	0.36	0.33	0.31	0.28	0.25	0.23
100.00	0.68	0.65	0.62	0.58	0.56	0.53	0.43	0.40	0.37	0.35	0.32	0.29	0.26	0.24
120.00	0.70	0.67	0.64	0.60	0.58	0.55	0.45	0.41	0.39	0.36	0.33	0.30	0.27	0.24
140.00	0.73	0.69	0.66	0.62	0.60	0.57	0.46	0.43	0.40	0.37	0.34	0.31	0.28	0.25
160.00	0.75	0.71	0.68	0.64	0.61	0.58	0.48	0.44	0.41	0.38	0.35	0.32	0.29	0.26
180.00	0.77	0.73	0.70	0.66	0.63	0.60	0.49	0.45	0.42	0.39	0.36	0.33	0.30	0.27
200.00	0.79	0.76	0.72	0.68	0.65	0.62	0.51	0.47	0.43	0.40	0.37	0.34	0.31	0.27

Table II. Average values with respect to fragment mass after neutron emission.

MASS INTERVAL		TOTAL COUNTS	NU TOTAL	NU 1	NU 2	AFTER NU EMIT. MASS 1	MASS 2	BEFORE--AFTER NU EMIT. FT	E1	E2	V1	V2
91	93	2406.	5.38	3.77	1.61	154.56	92.06	172.46	62.62	106.49	0.880	1.482
93	95	3496.	4.86	3.21	1.66	153.13	94.01	174.83	65.04	106.60	0.901	1.467
95	97	4587.	4.61	3.00	1.60	151.33	96.06	176.03	66.91	106.07	0.919	1.447
97	99	6621.	4.29	2.78	1.51	149.65	98.06	177.73	68.95	105.92	0.939	1.432
99	101	9770.	4.03	2.53	1.51	147.93	100.04	179.37	71.06	105.56	0.958	1.415
101	103	14047.	3.84	2.24	1.60	146.13	102.03	181.20	73.38	105.11	0.980	1.398
103	105	18141.	3.71	1.96	1.75	144.28	104.01	183.15	75.83	104.59	1.003	1.381
105	107	20891.	3.65	1.73	1.92	142.36	105.98	185.34	78.40	104.18	1.026	1.366
107	109	20622.	3.77	1.60	2.17	140.25	107.98	186.91	80.76	103.22	1.049	1.347
109	111	17685.	3.95	1.46	2.48	138.07	109.99	188.16	83.07	101.98	1.073	1.326
111	113	14731.	4.00	1.27	2.73	136.04	111.96	190.10	85.68	101.22	1.098	1.310
113	115	11461.	3.99	1.00	2.99	134.10	113.90	192.23	88.49	100.50	1.124	1.294
115	117	7420.	3.92	0.68	3.24	132.18	115.90	195.45	91.91	100.31	1.153	1.282
117	119	2916.	4.36	0.58	3.78	129.77	117.87	196.72	94.52	98.64	1.180	1.260
119	121	699.	4.52	0.67	3.85	127.76	119.72	199.22	97.12	98.43	1.206	1.249
121	123	128.	5.10	1.87	3.23	124.73	122.17	195.08	95.53	95.60	1.210	1.219
123	125	84.	4.32	1.98	2.34	124.22	123.46	201.05	98.76	98.84	1.233	1.233
125	127	340.	5.08	4.20	0.88	120.24	126.68	193.44	94.64	94.86	1.227	1.192
127	129	1675.	5.26	4.53	0.73	118.69	128.05	190.73	93.97	92.70	1.230	1.172
129	131	3585.	4.83	4.20	0.63	117.07	130.10	191.19	95.84	91.53	1.251	1.155
131	133	7114.	4.94	4.05	0.89	114.95	132.11	189.40	96.59	88.89	1.267	1.130
133	135	13687.	4.34	3.17	1.17	113.62	134.03	189.38	98.87	87.05	1.290	1.110
135	137	15137.	4.26	2.80	1.46	111.71	136.03	187.55	99.87	84.33	1.307	1.085
137	139	17407.	3.95	2.42	1.53	110.07	137.97	187.74	101.71	82.93	1.329	1.068
139	141	20005.	3.80	2.15	1.65	108.27	139.93	186.62	102.81	80.87	1.347	1.047
141	143	20861.	3.53	1.83	1.70	106.52	141.95	185.84	104.13	79.03	1.367	1.028
143	145	20473.	3.37	1.57	1.80	104.67	143.97	185.03	105.40	77.14	1.388	1.008
145	147	16257.	3.36	1.40	1.97	102.72	145.91	183.96	106.48	75.07	1.408	0.988
147	149	11196.	3.55	1.32	2.23	100.56	147.90	182.15	107.09	72.61	1.427	0.965
149	151	7104.	3.75	1.32	2.43	98.36	149.89	180.64	107.73	70.37	1.447	0.944
151	153	4396.	4.14	1.43	2.71	95.95	151.91	178.26	107.75	67.75	1.465	0.920
153	155	3354.	4.39	1.41	2.98	93.69	153.92	176.84	108.41	65.57	1.488	0.899
155	157	1800.	4.74	1.30	3.44	91.38	155.88	175.82	109.55	63.36	1.514	0.878
157	159	931.	5.32	1.23	4.09	88.85	157.82	174.18	110.33	60.78	1.541	0.855
159	161	387.	5.89	1.21	4.68	86.24	159.87	173.32	111.56	58.50	1.573	0.833
161	163	178.	6.43	1.20	5.22	83.74	161.83	172.50	112.70	56.39	1.604	0.813
163	165	44.	7.21	1.13	6.08	80.87	163.92	169.73	112.90	53.29	1.634	0.785
TOTAL		321636.					AVE.	185.56				
							SIGMA	9.74				

Table III. Total fragments per mass interval.

Mass Interval	Conversion Electrons	Experiment 90° Gamma Rays	0-180° Gamma Rays
97-99	4.869×10^6	1.048×10^6	2.028×10^6
99-101	7.590×10^6	1.703×10^6	3.017×10^6
101-103	11.350×10^6	2.470×10^6	4.659×10^6
103-105	14.953×10^6	3.459×10^6	6.077×10^6
105-107	17.307×10^6	4.009×10^6	7.377×10^6
107-109	17.713×10^6	4.095×10^6	7.530×10^6
109-111	14.942×10^6	3.458×10^6	6.315×10^6
111-113	12.617×10^6	2.957×10^6	5.225×10^6
113-115	9.521×10^6	2.316×10^6	4.025×10^6
115-117	6.020×10^6	1.387×10^6	2.327×10^6
133-135	11.457×10^6	2.246×10^6	3.848×10^6
135-137	14.118×10^6	2.550×10^6	4.815×10^6
137-139	16.476×10^6	3.256×10^6	5.641×10^6
139-141	17.650×10^6	3.444×10^6	6.511×10^6
141-143	18.019×10^6	3.653×10^6	6.620×10^6
143-145	18.664×10^6	3.681×10^6	6.454×10^6
145-147	15.433×10^6	2.880×10^6	5.312×10^6
147-149	11.016×10^6	2.066×10^6	3.617×10^6
149-151	7.103×10^6	1.291×10^6	2.392×10^6
151-153	4.565×10^6	0.867×10^6	1.505×10^6
153-155	3.490×10^6	0.614×10^6	1.094×10^6
155-157	2.050×10^6	0.375×10^6	0.681×10^6
157-159	1.097×10^6	0.191×10^6	0.328×10^6
159-161	0.476×10^6	0.084×10^6	0.164×10^6
161-163	0.228×10^6	0.035×10^6	0.090×10^6
Total Fissions	279.529×10^6	59.069×10^6	106.555×10^6

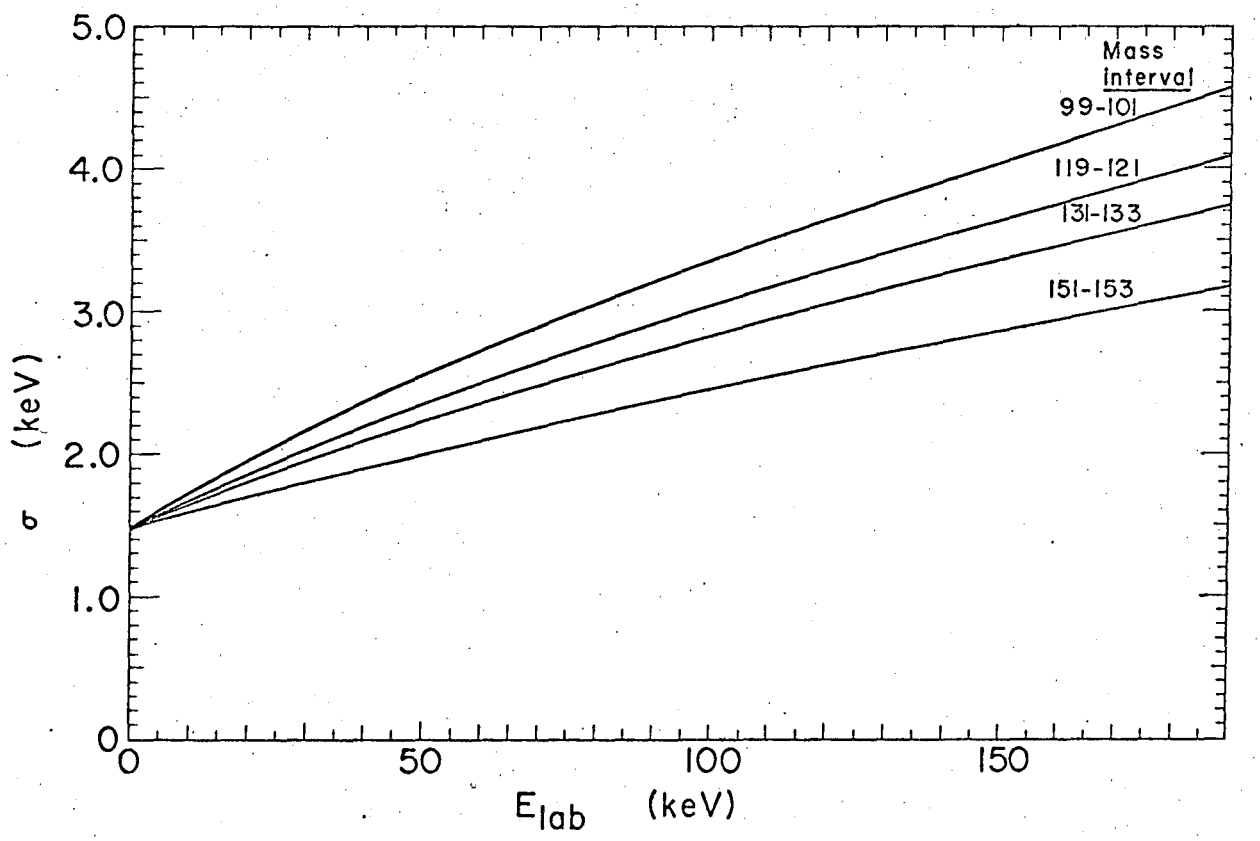


Fig. 1

MUB-11227

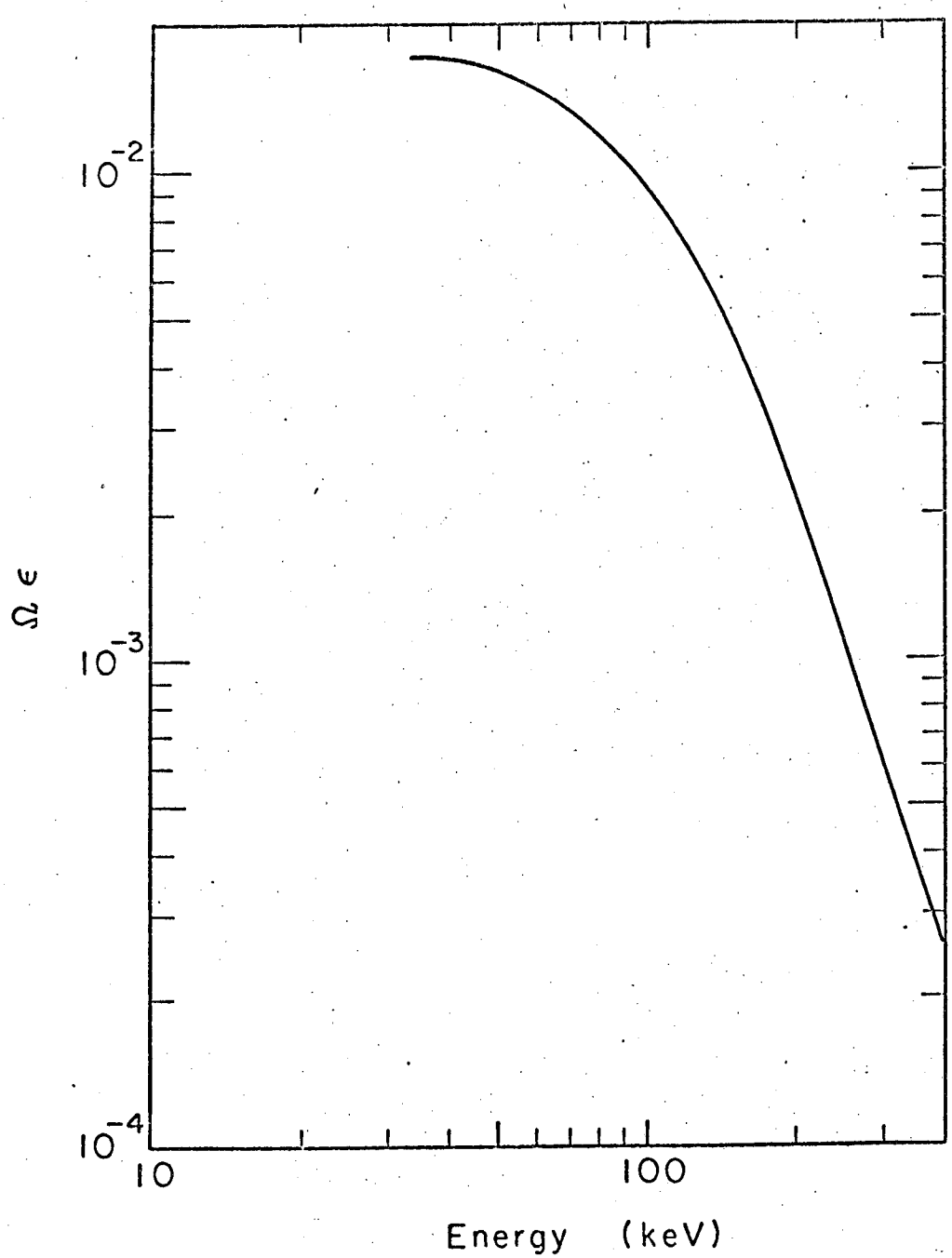


Fig. 2

MUB-13639

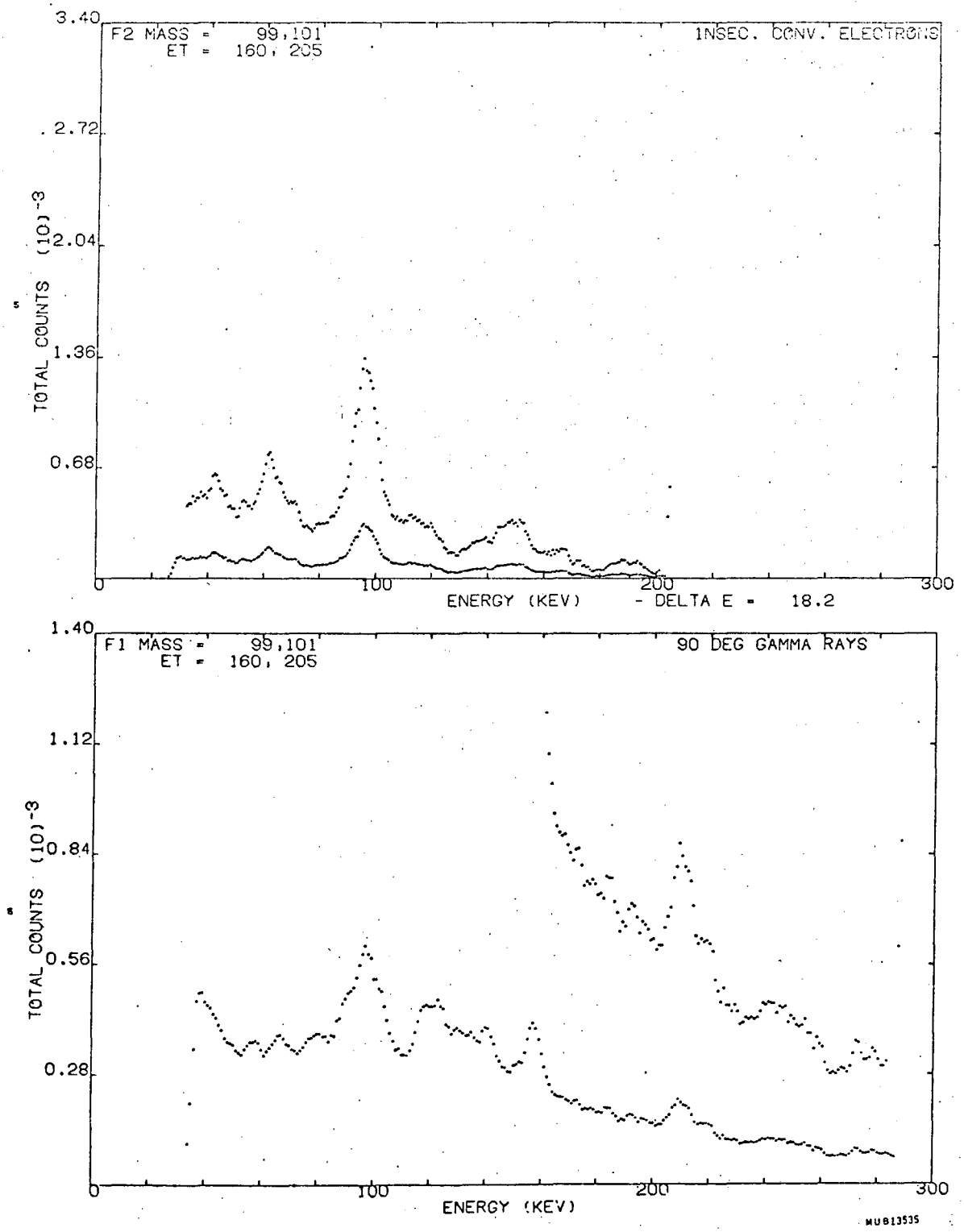

F2 MASS = 99,101
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 18.2
F1 MASS = 99,101
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB13535

Fig. 3

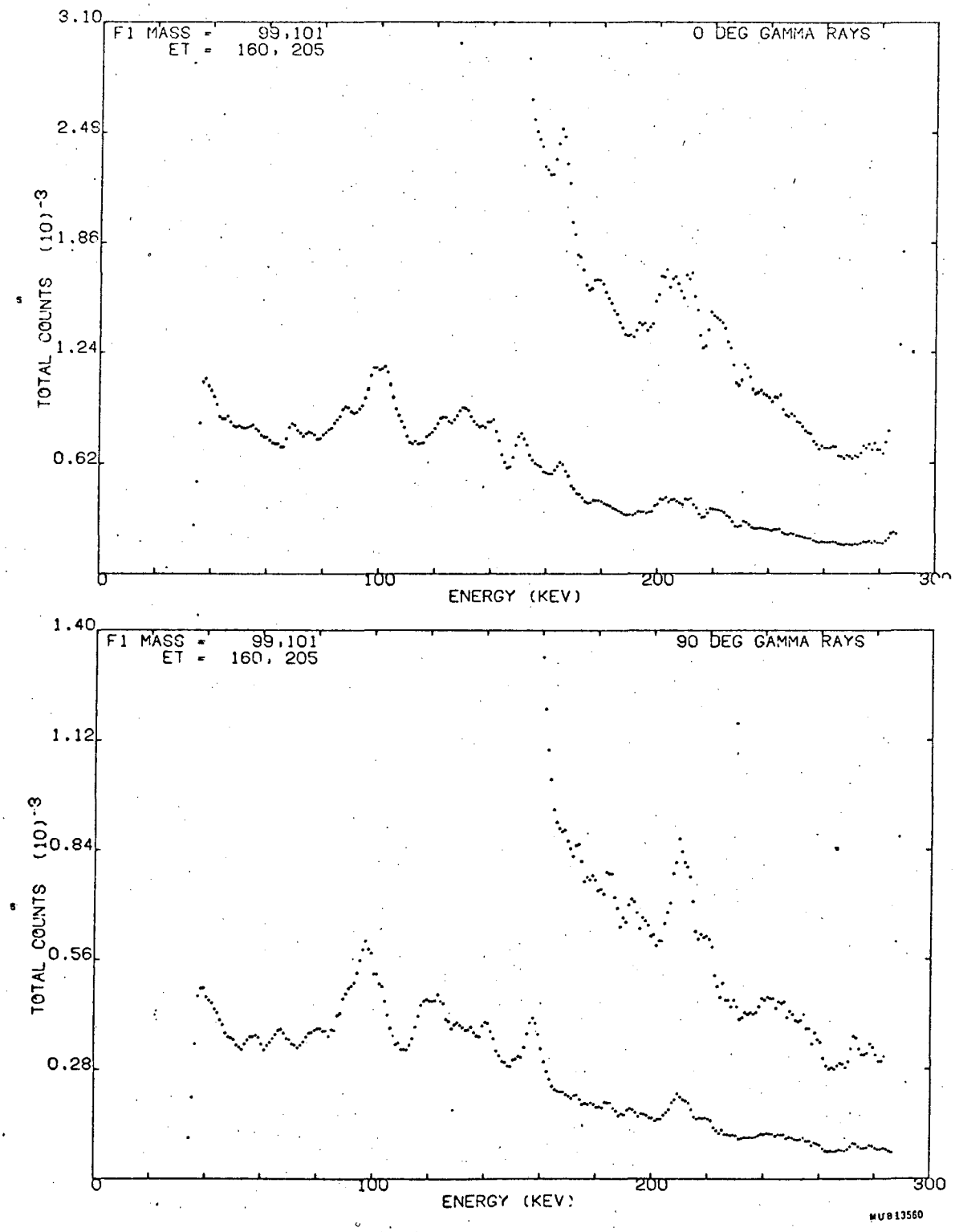

F1 MASS = 99,101
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 99,101
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB13560

Fig. 4

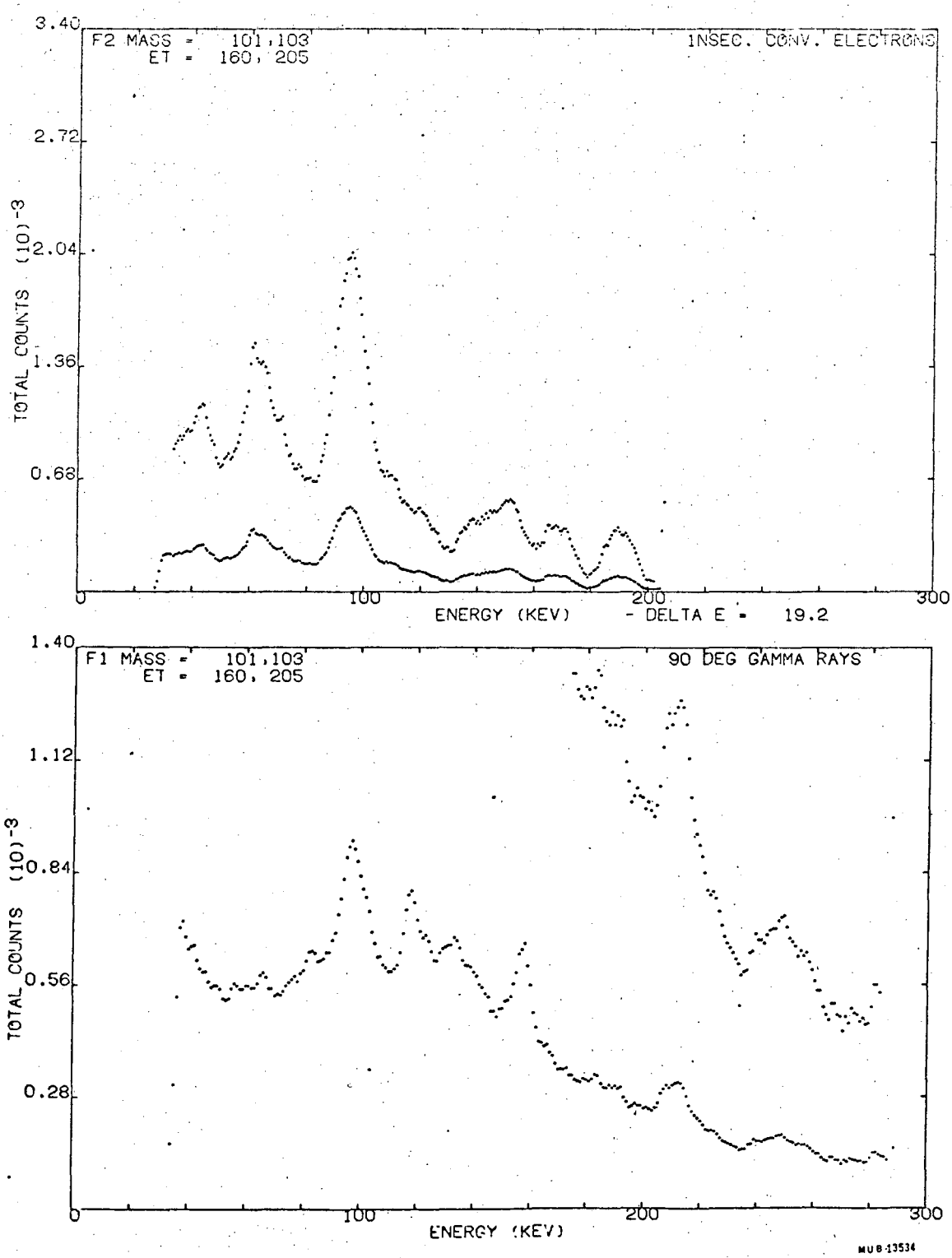

F2 MASS = 101,103
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
- DELTA E = 19.2
F1 MASS = 101,103
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13534

Fig. 5

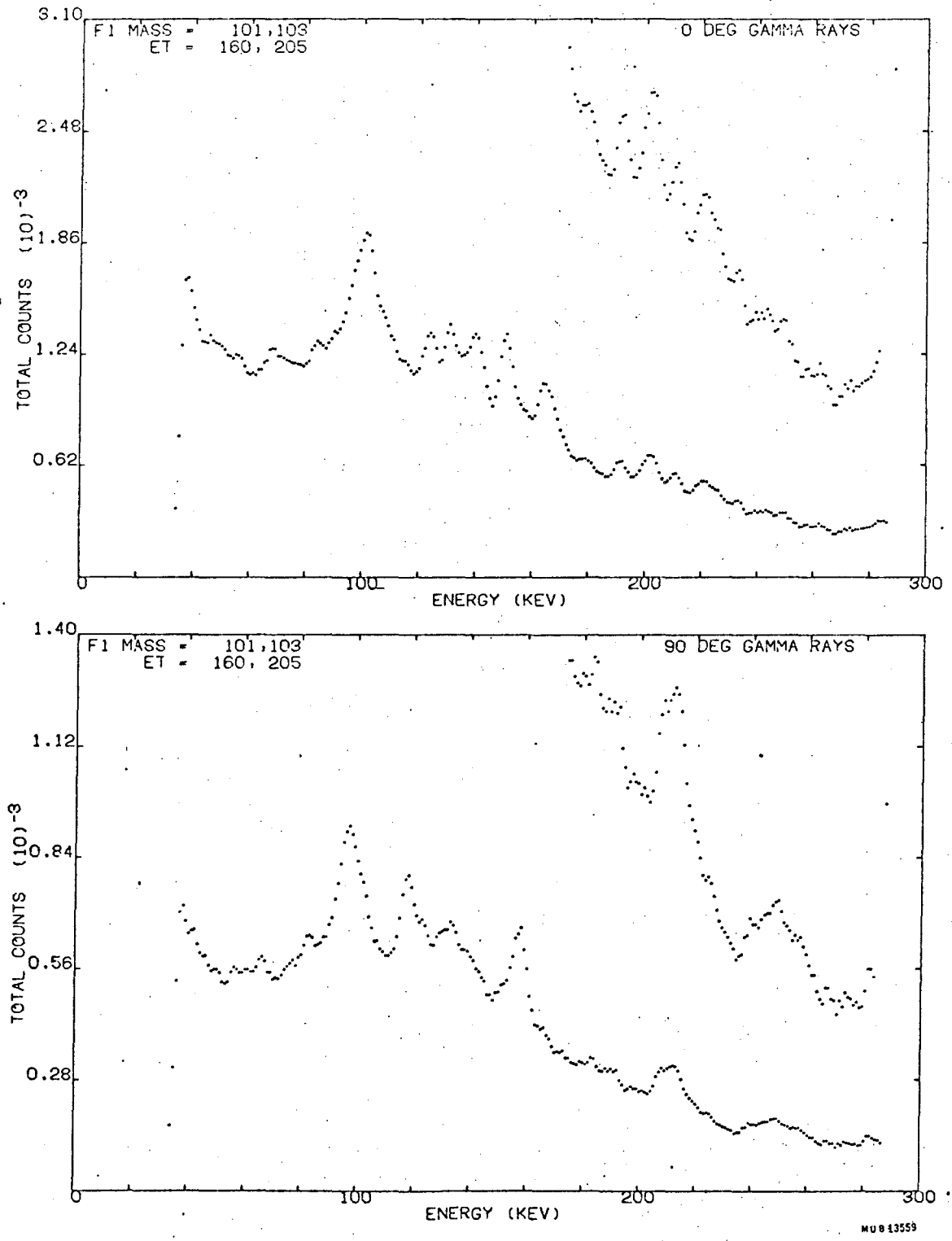

F1 MASS = 101,103
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 101,103
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB 13559

Fig. 6

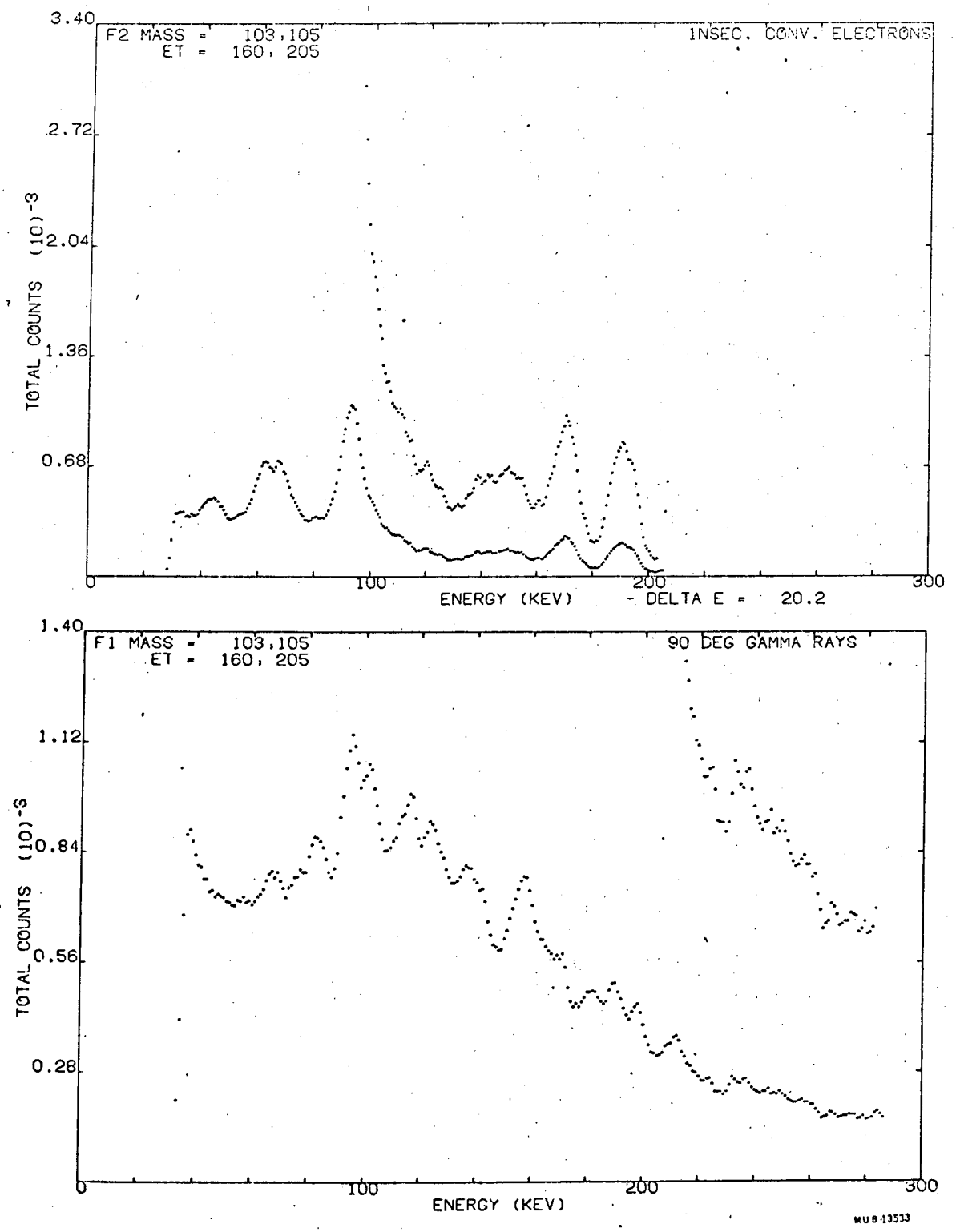

F2 MASS = 103,105
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 20.2
F1 MASS = 103,105
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MU 8-13533

Fig. 7

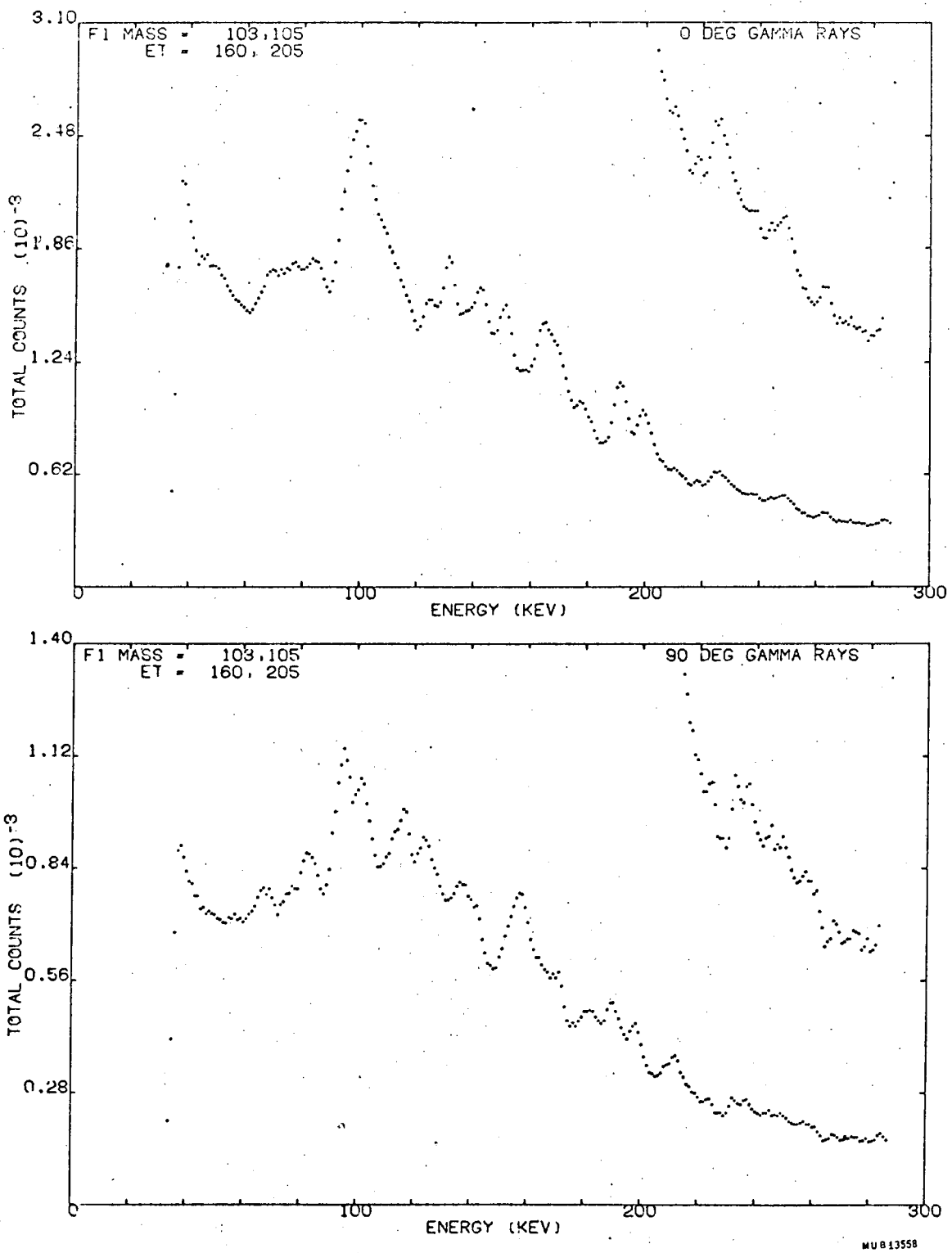

F1 MASS = 103,105
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 103,105
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB13558

Fig. 8

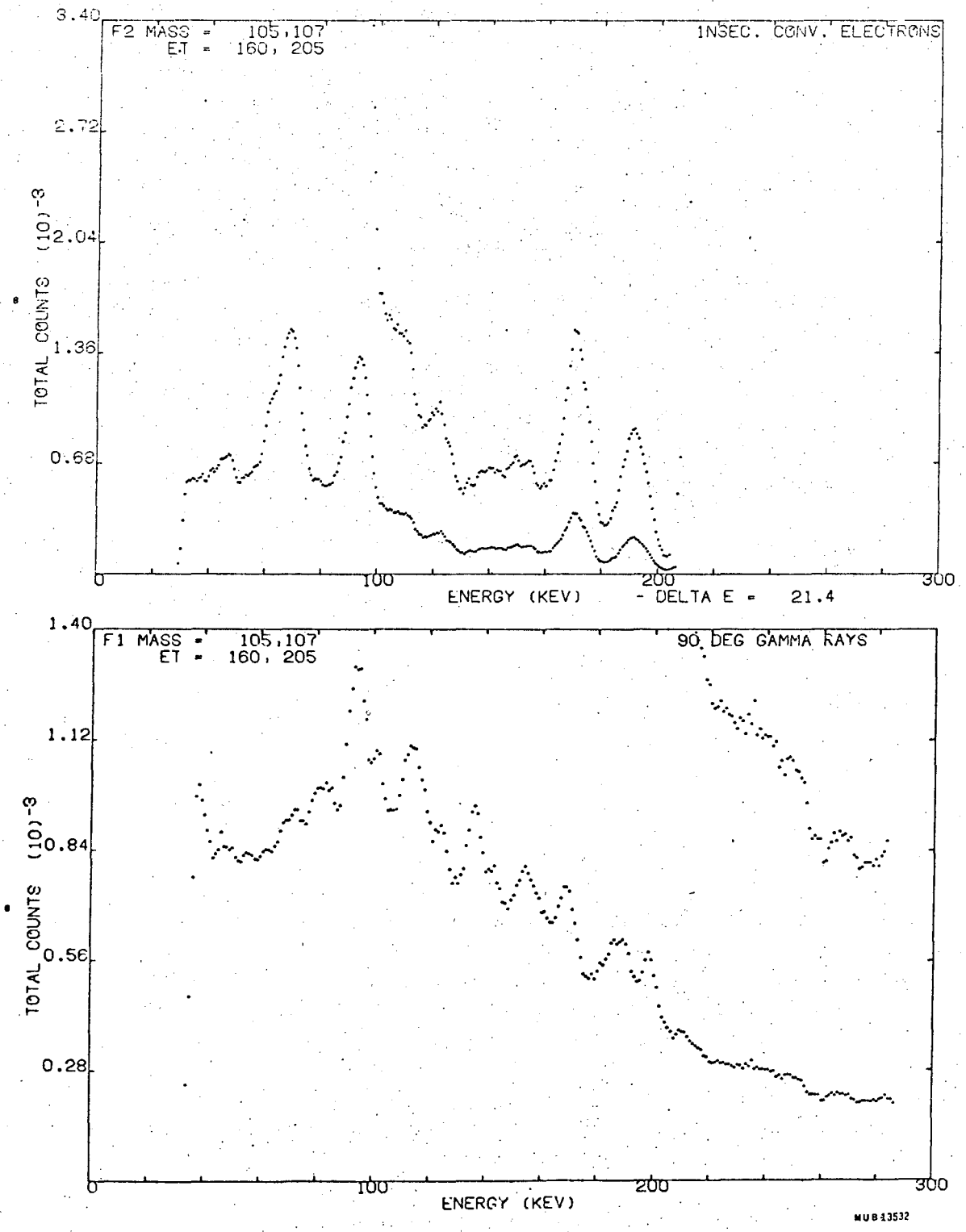

F2 MASS = 105,107
ET = 160, 205
INSEC. CONV. ELECTRONS
TOTAL COUNTS (10)-3
3.40
2.72
2.04
1.36
0.68
0
100
200
300
ENERGY (KEV)
- DELTA E = 21.4
F1 MASS = 105,107
ET = 160, 205
90 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
1.40
1.12
0.84
0.56
0.28
0
100
200
300
ENERGY (KEV)
MUB-13532

Fig. 9

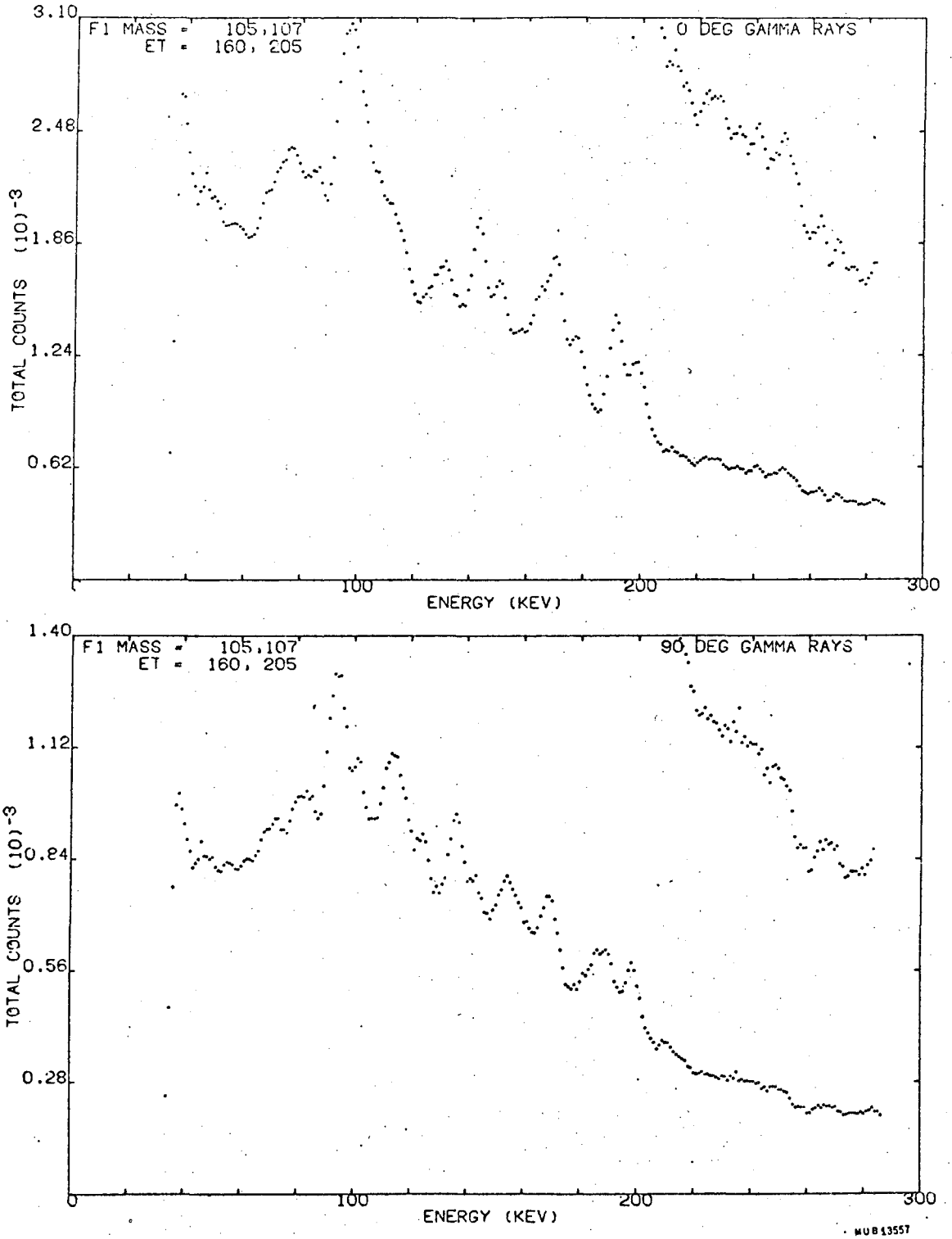

F1 MASS = 105,107
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 105,107
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB 13557

Fig. 10

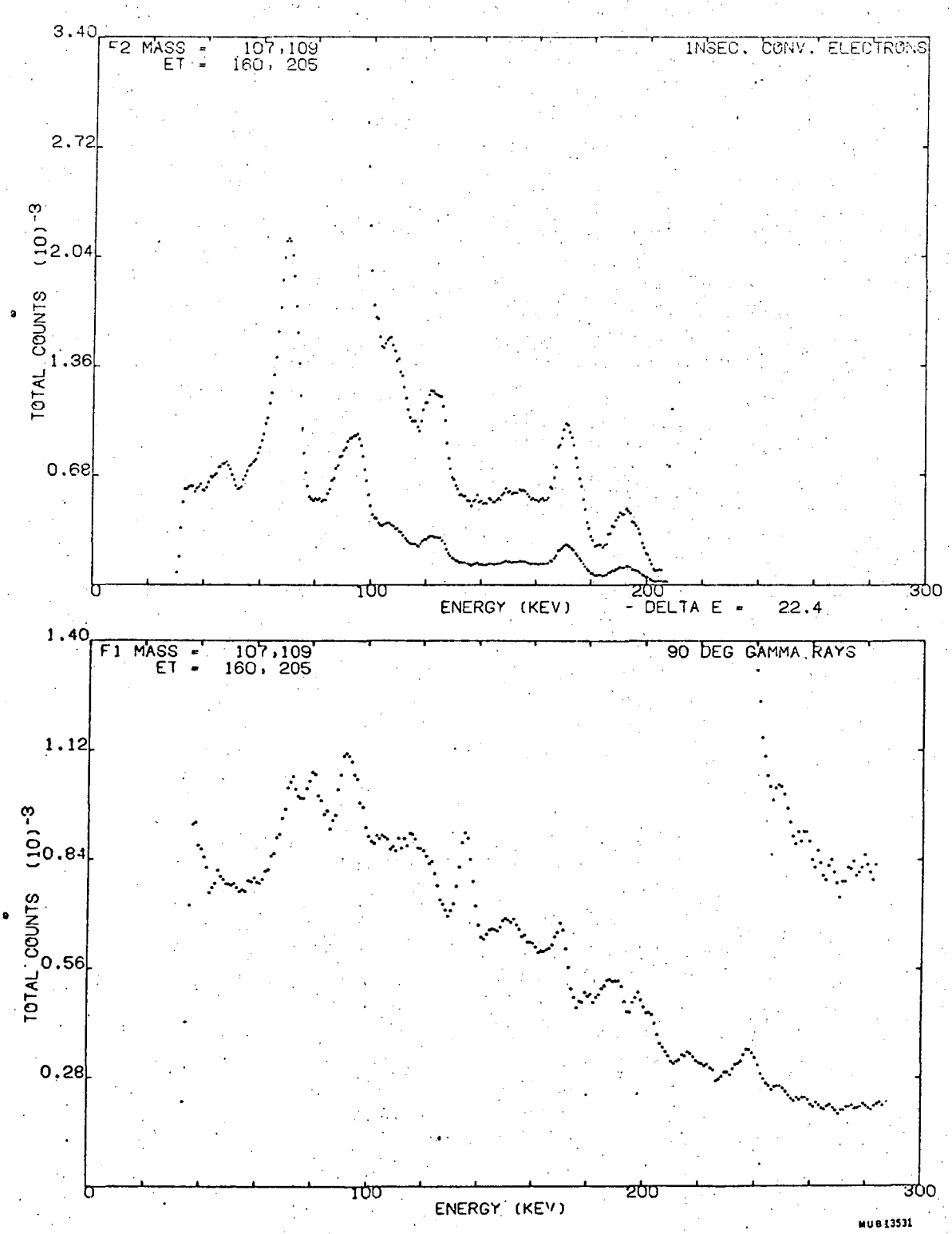
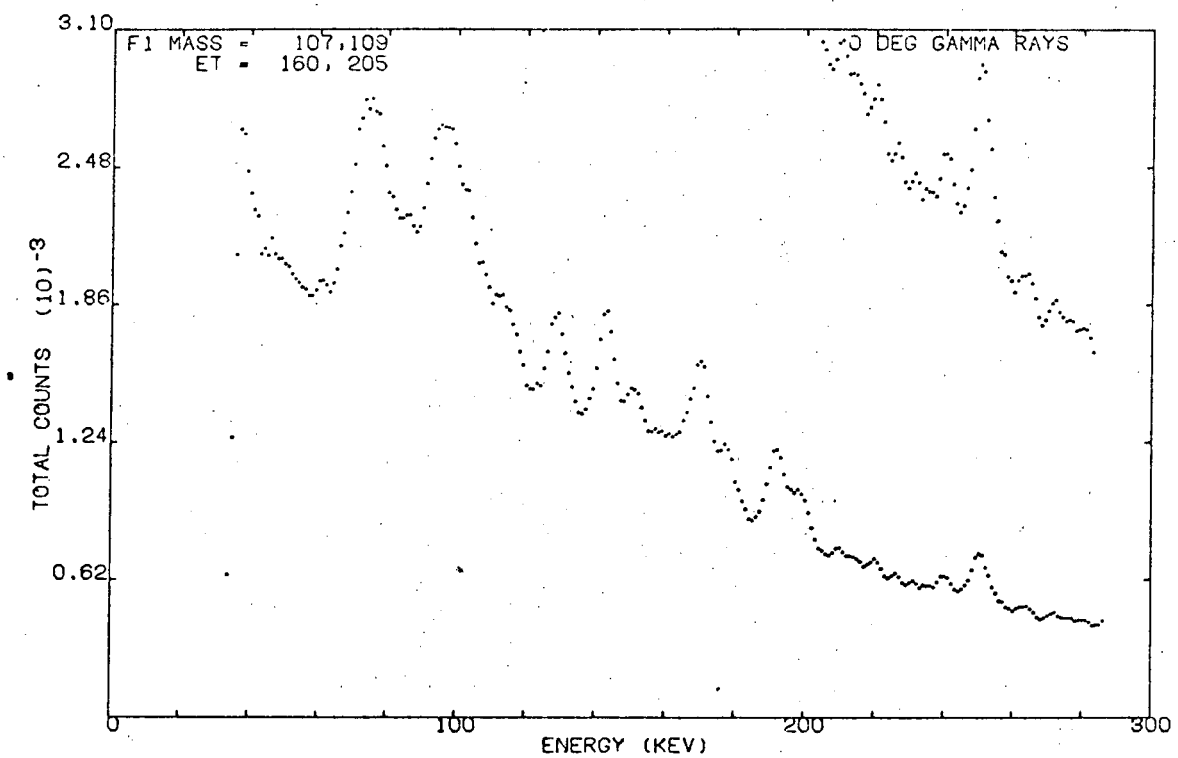

F2 MASS = 107,109
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 22.4
F1 MASS = 107,109
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB 13531

Fig. 11


F1 MASS = 107,109
ET = 160, 205
90 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
3.10
2.48
1.86
1.24
0.62
0
100
200
300
ENERGY (KEV)

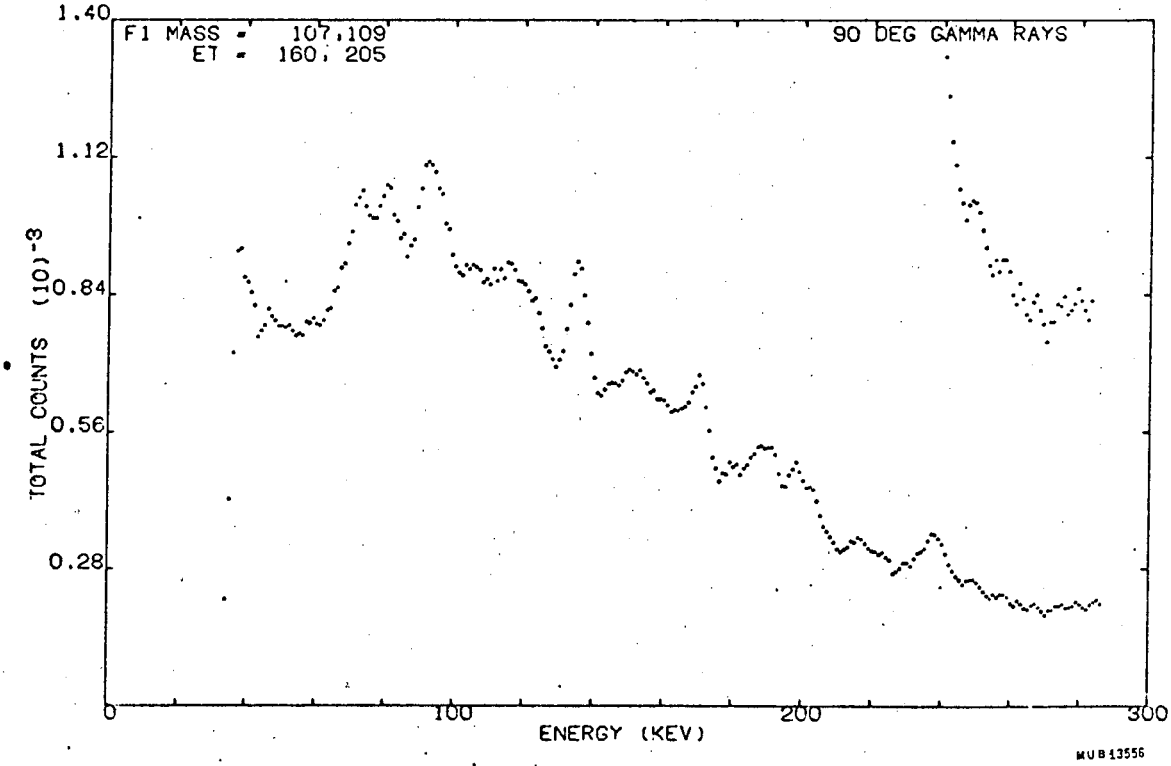

F1 MASS = 107,109
ET = 160, 205
90 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
1.40
1.12
0.84
0.56
0.28
0
100
200
300
ENERGY (KEV)
MUB 13556

Fig. 12

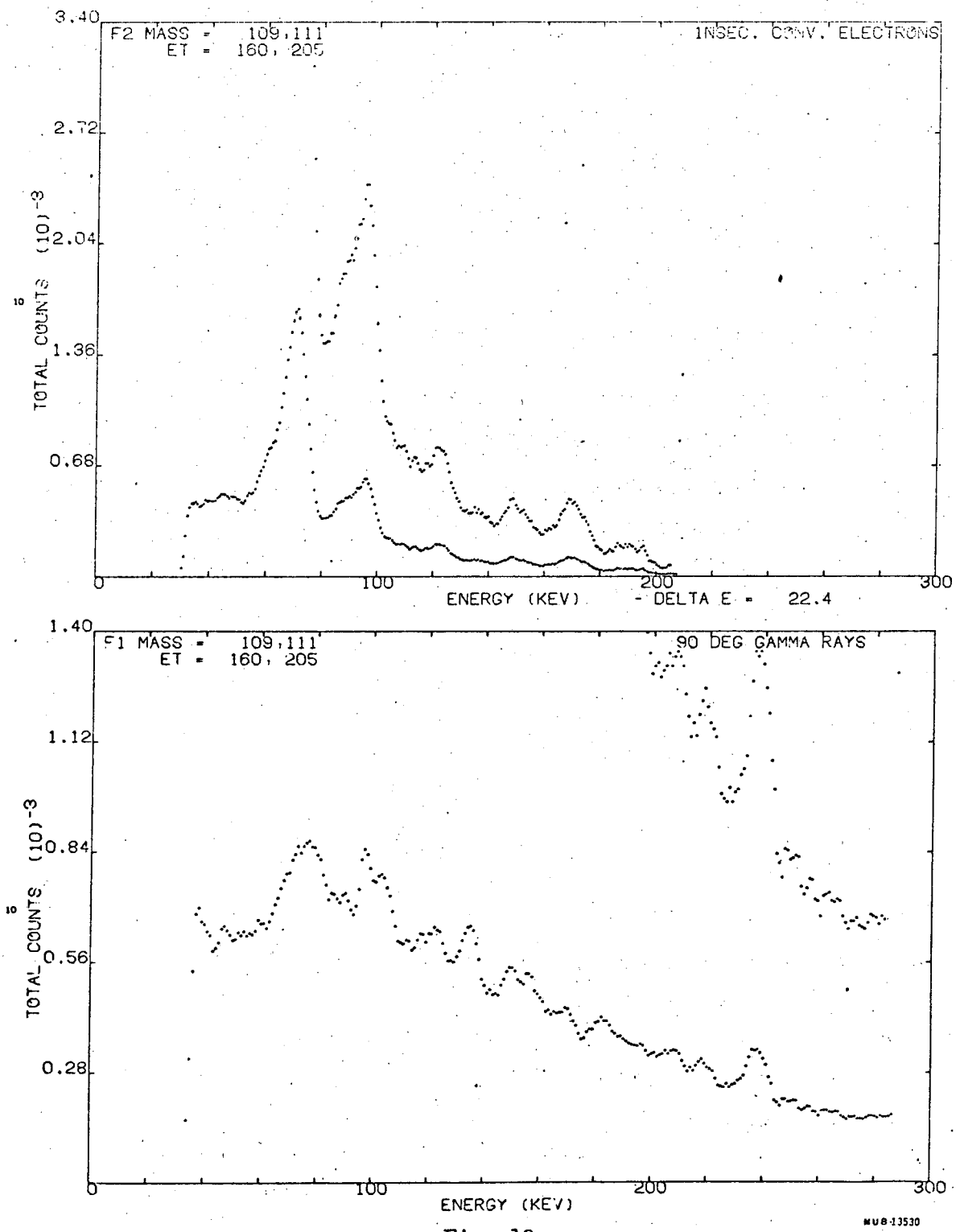

F2 MASS = 109,111
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 22.4
F1 MASS = 109,111
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MU8-13530

Fig. 13

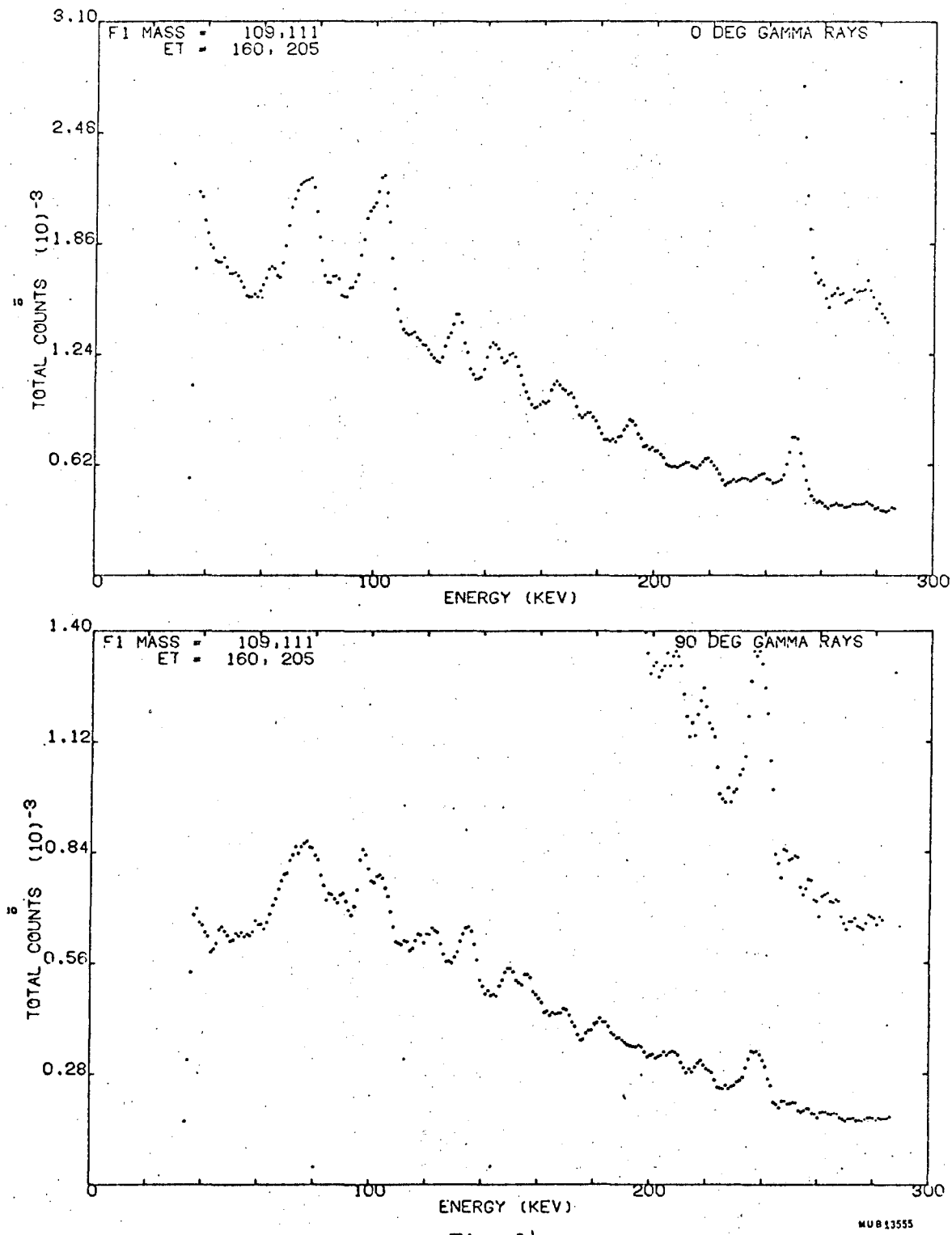

F1 MASS = 109,111
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.46
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 109,111
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB 13555

Fig. 14

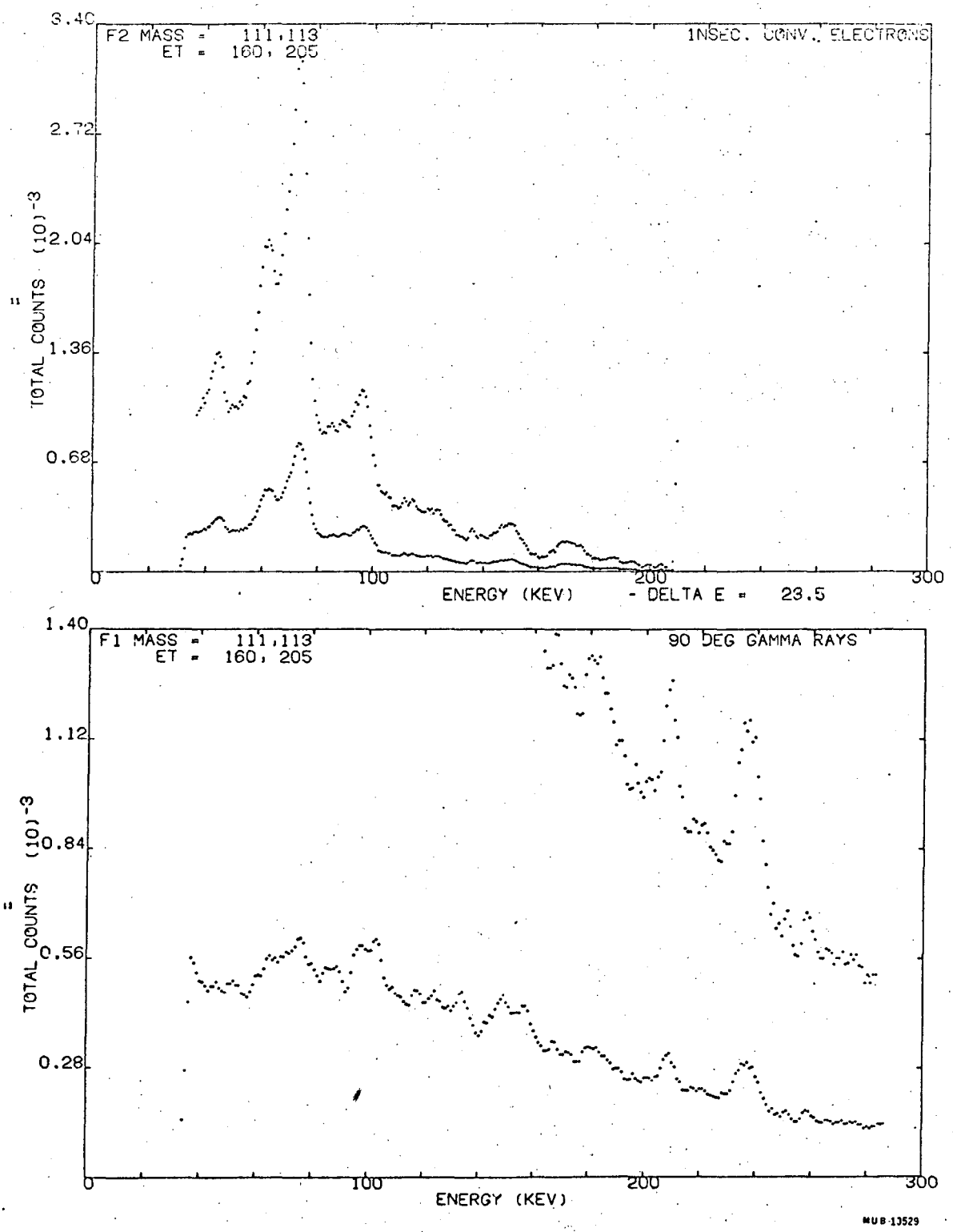

F2 MASS = 111,113
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 23.5
F1 MASS = 111,113
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13529

Fig. 15

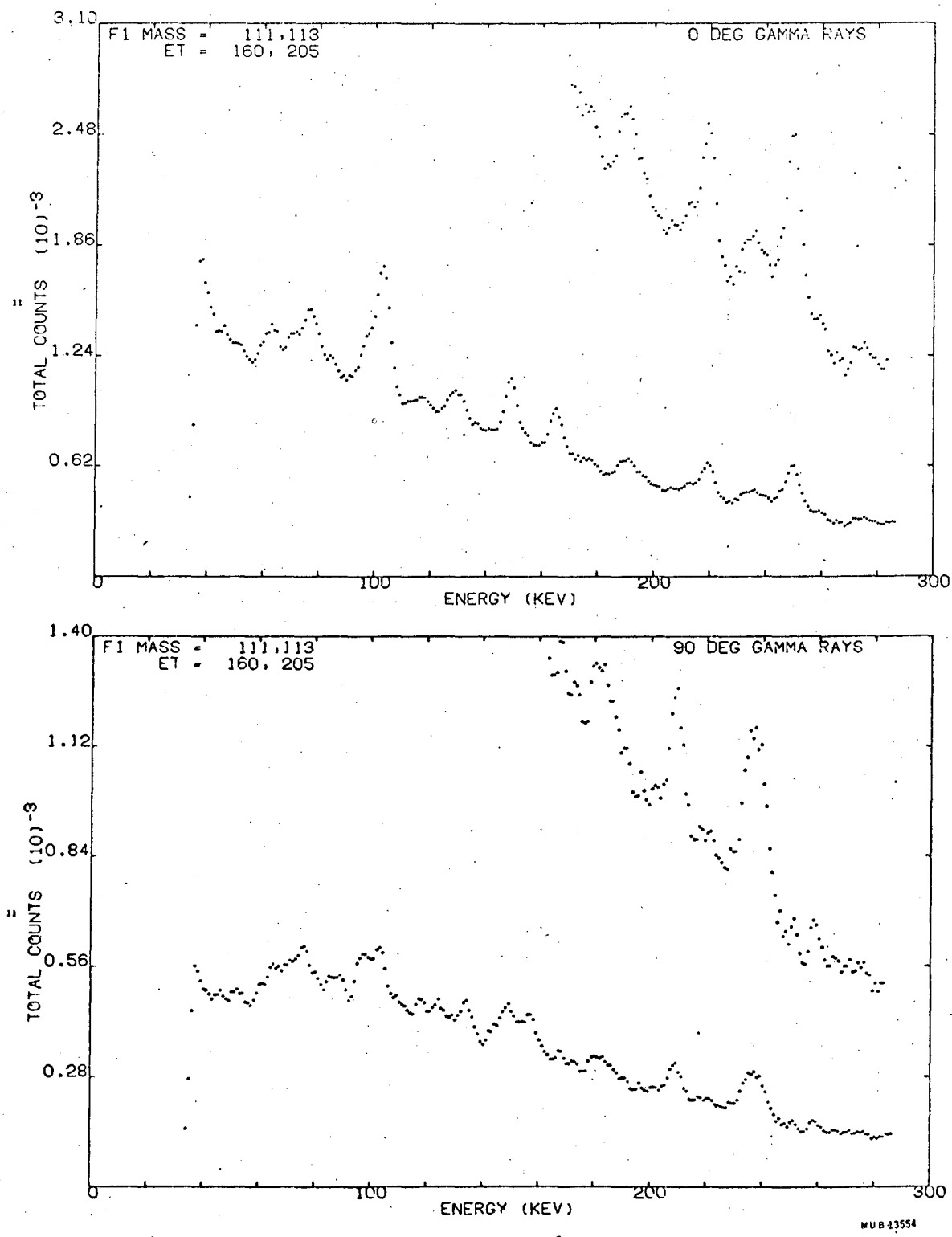
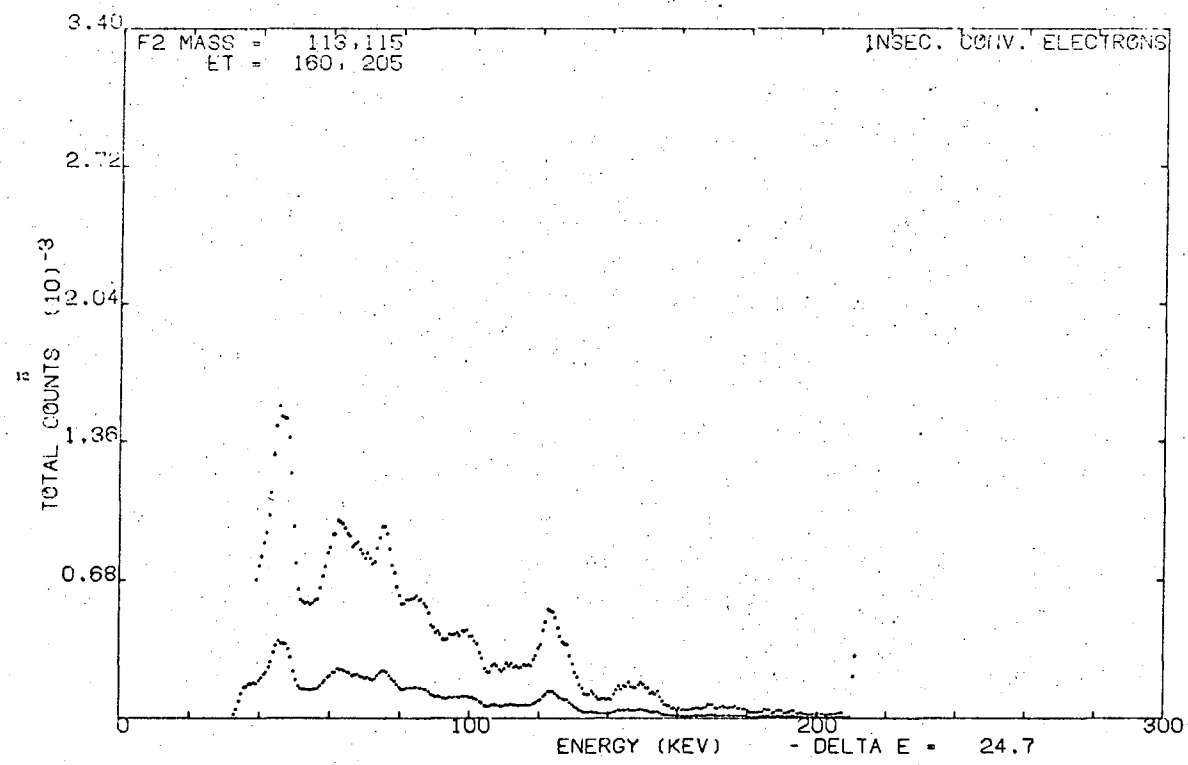

F1 MASS = 111,113
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 111,113
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13554

Fig. 16


F2 MASS = 113,115
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 24.7

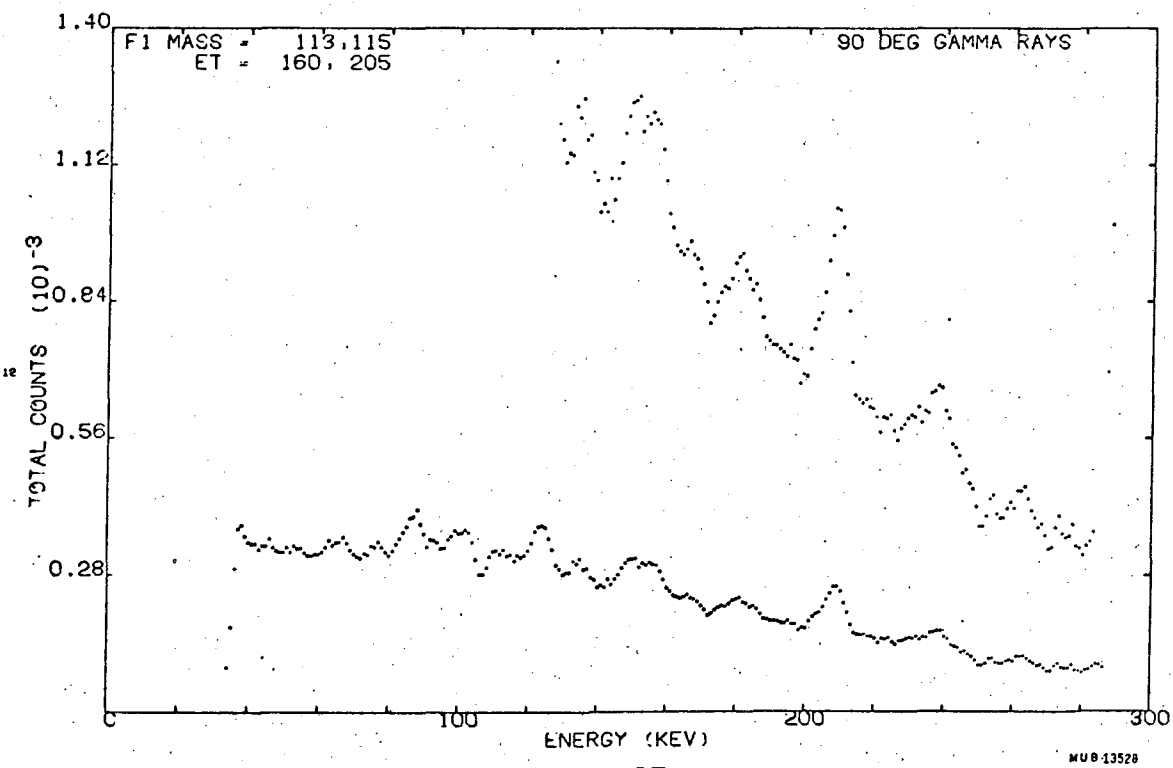

F1 MASS = 113,115
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13528

Fig. 17

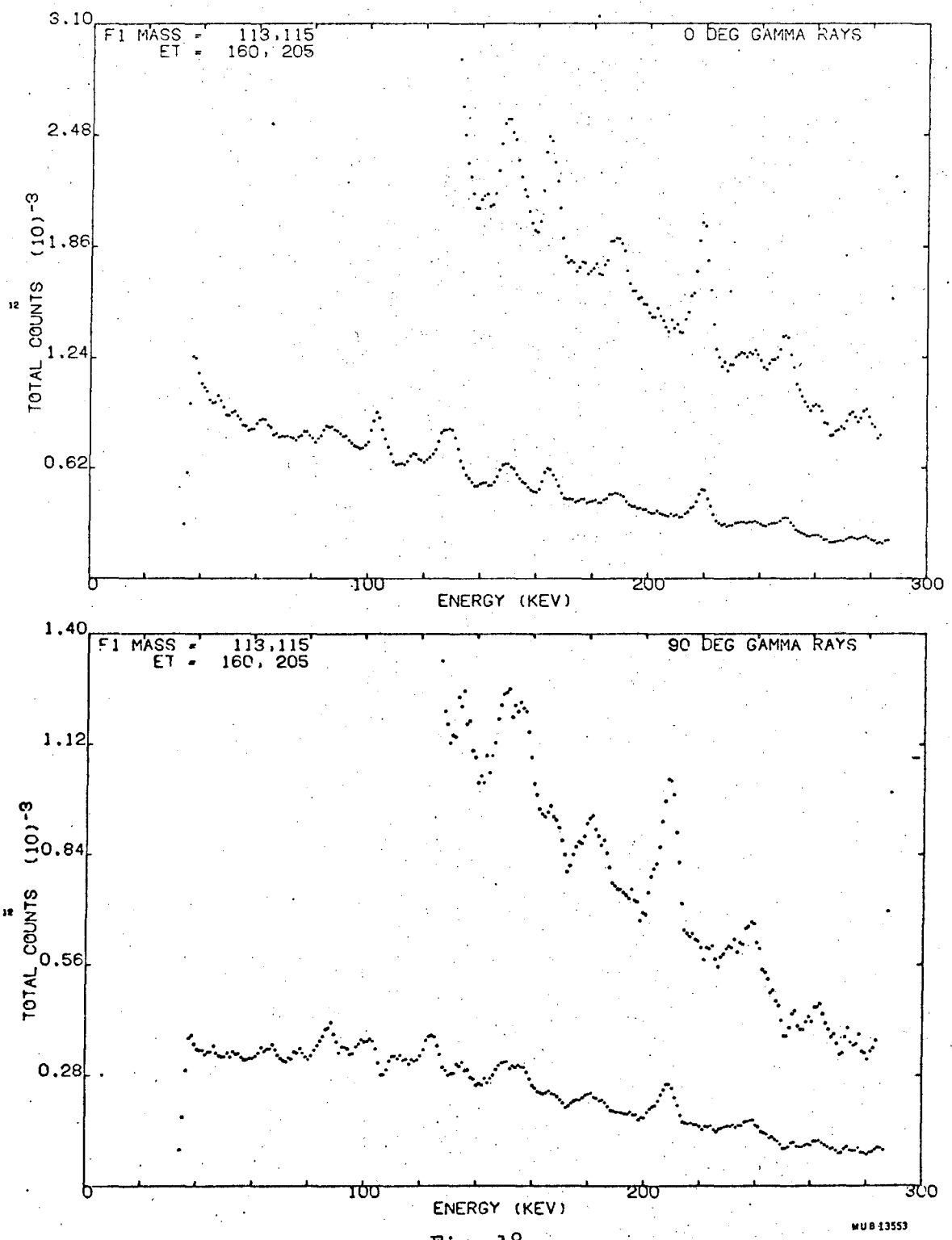

F1 MASS = 113,115
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 113,115
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB 13553

Fig. 18

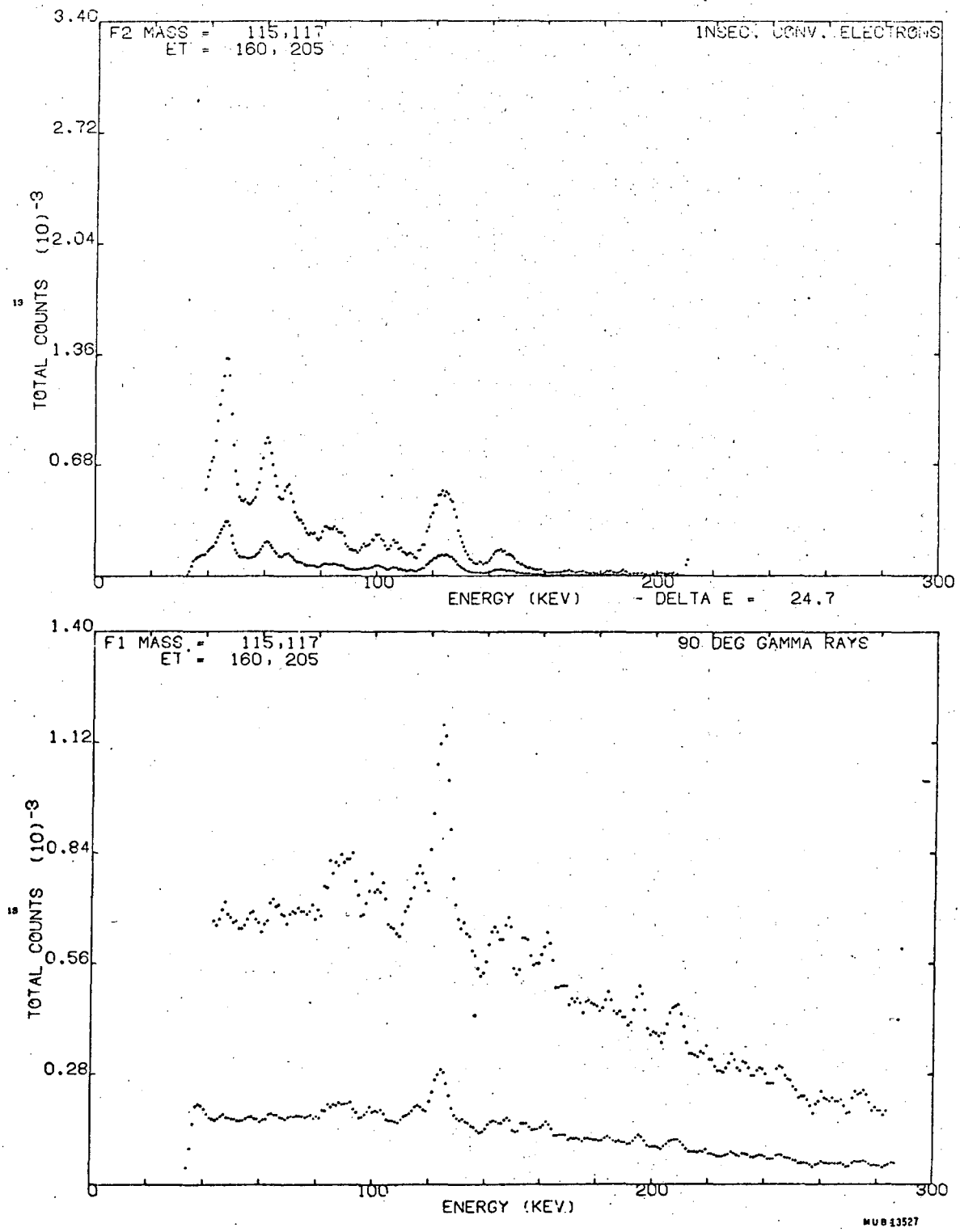

F2 MASS = 115,117
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 24.7
F1 MASS = 115,117
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB 13527

Fig. 19

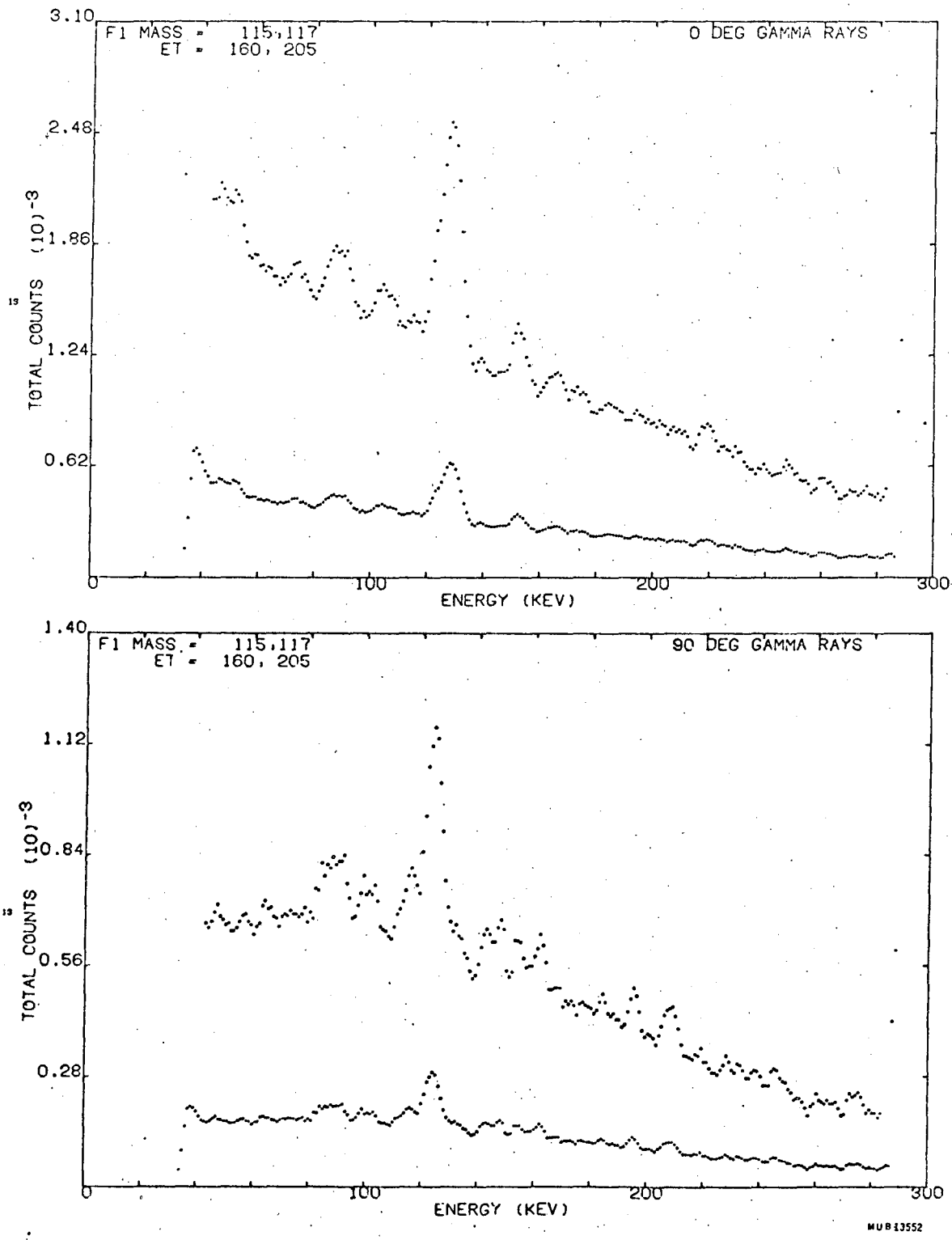

F1 MASS = 115,117
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 115,117
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB 13552

Fig. 20

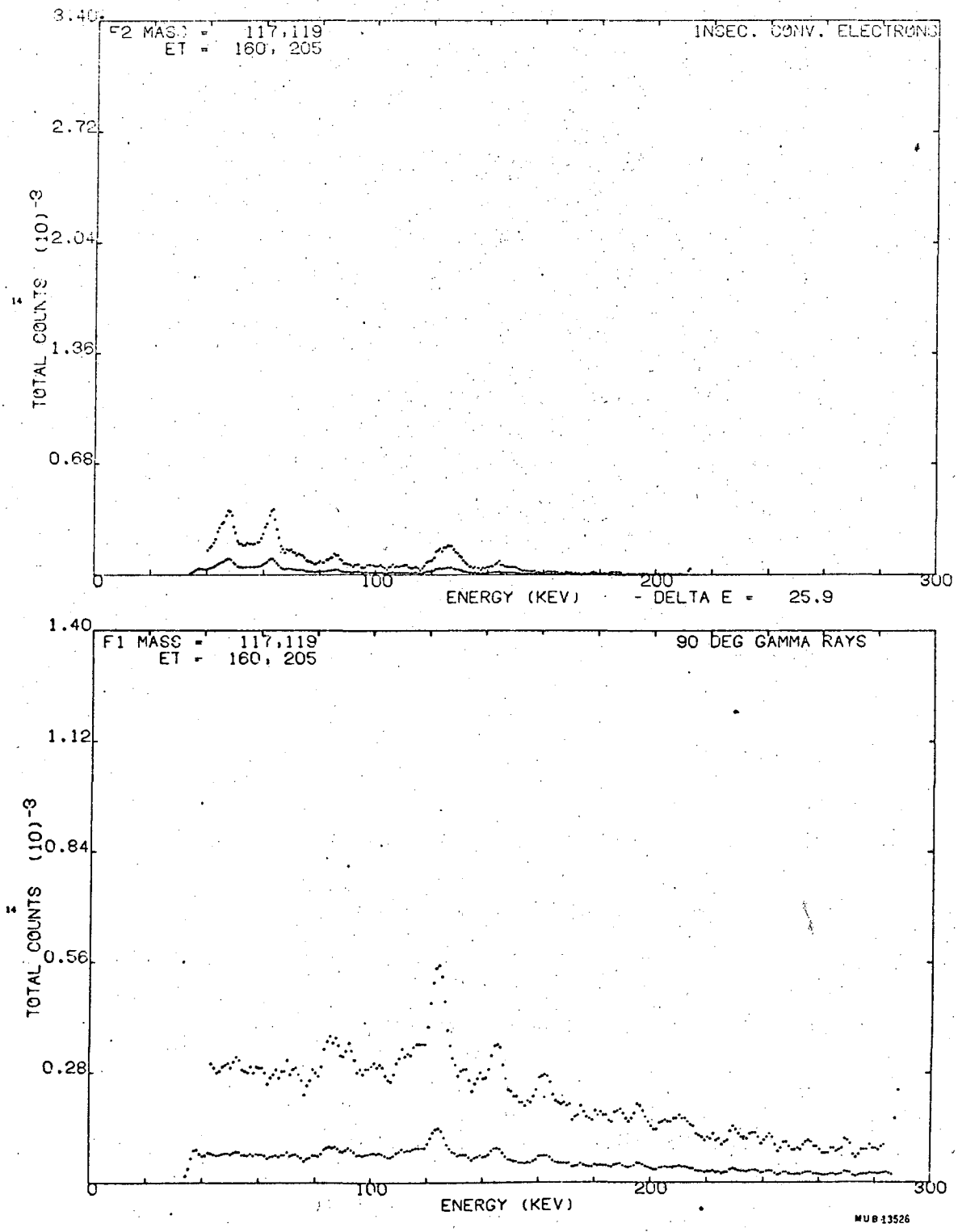

F2 MASS = 117,119
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 25.9
F1 MASS = 117,119
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB 13526

Fig. 21

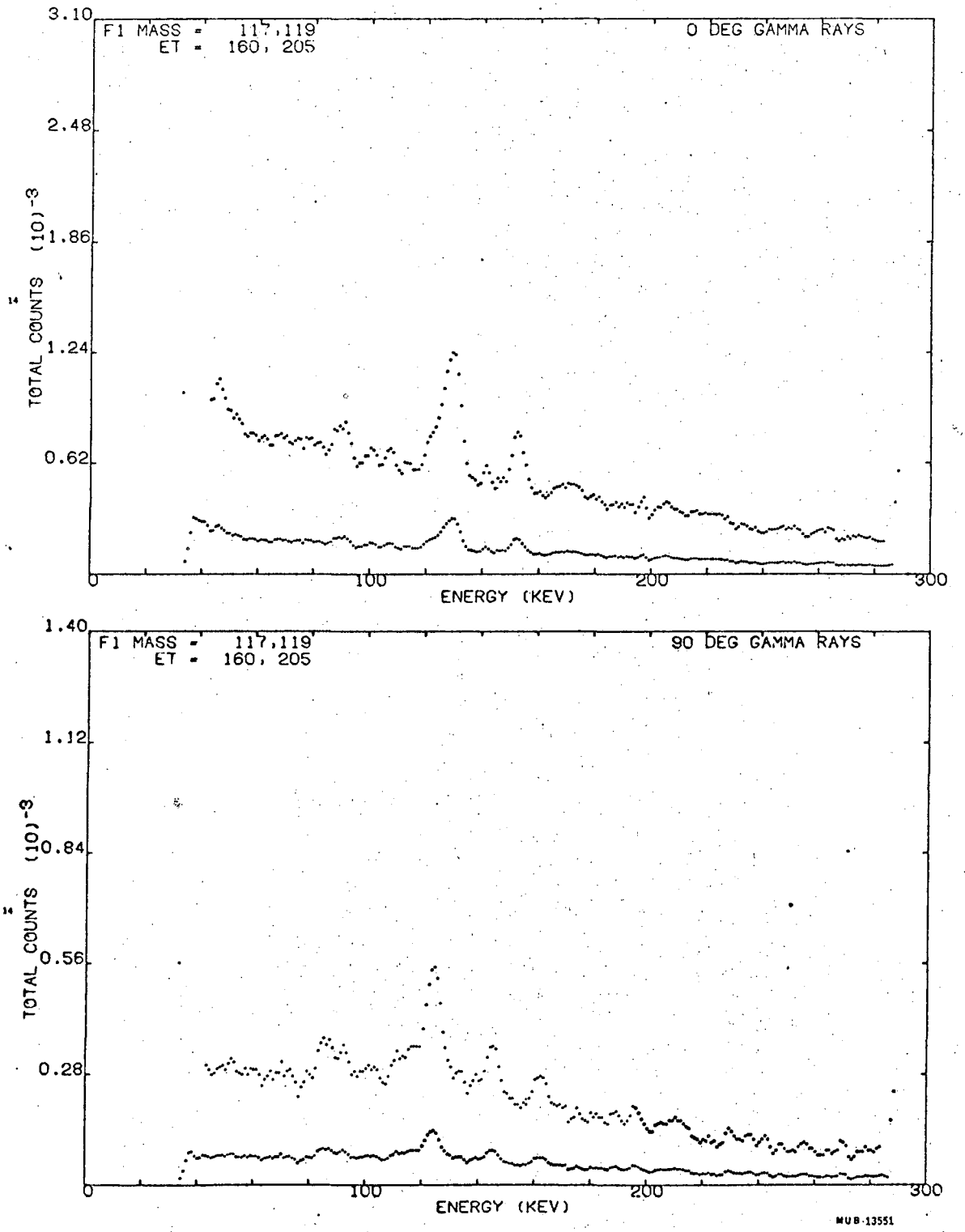

F1 MASS = 117,119
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 117,119
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13551

Fig. 22

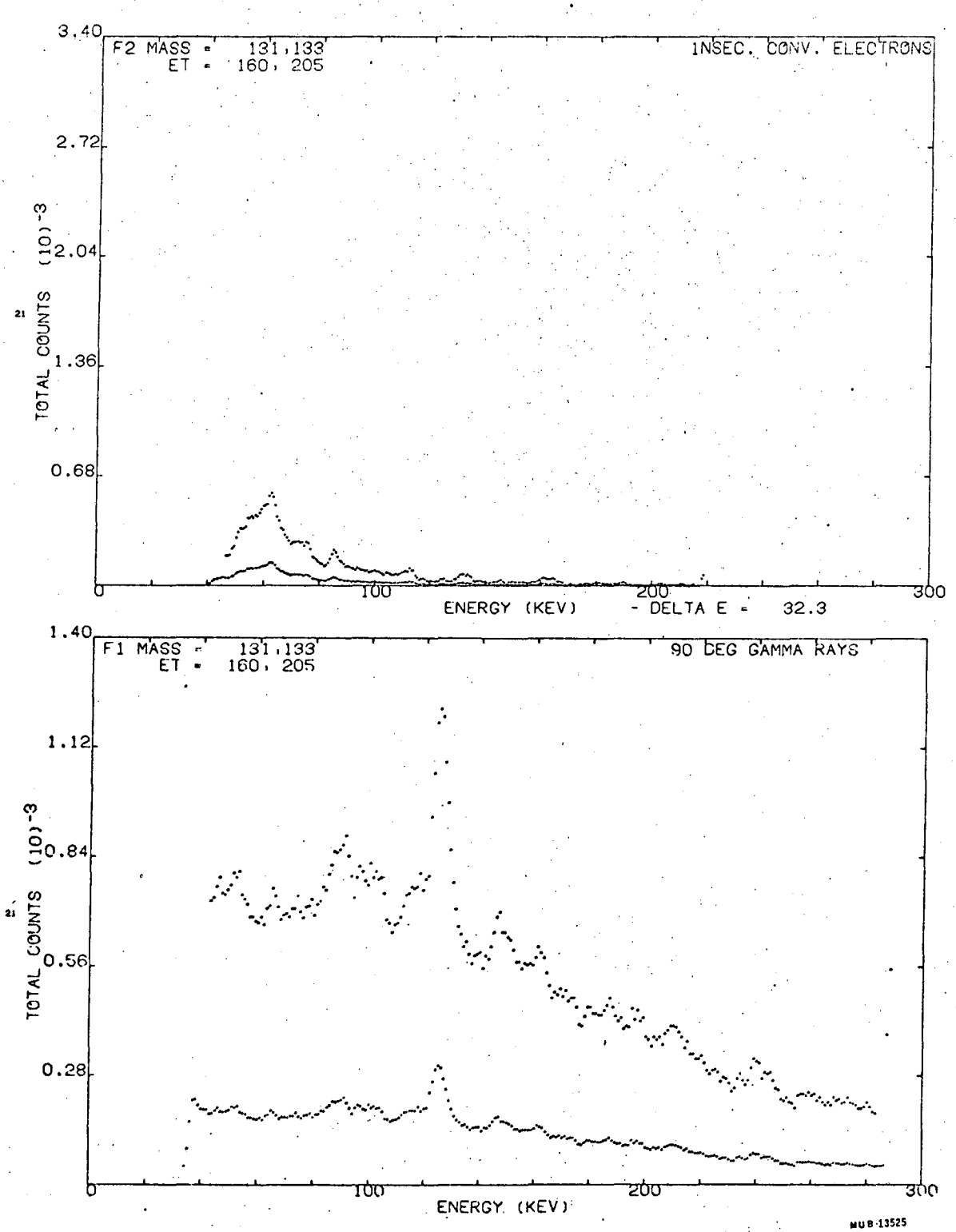

F2 MASS = 131,133
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 32.3
F1 MASS = 131,133
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13525

Fig. 23

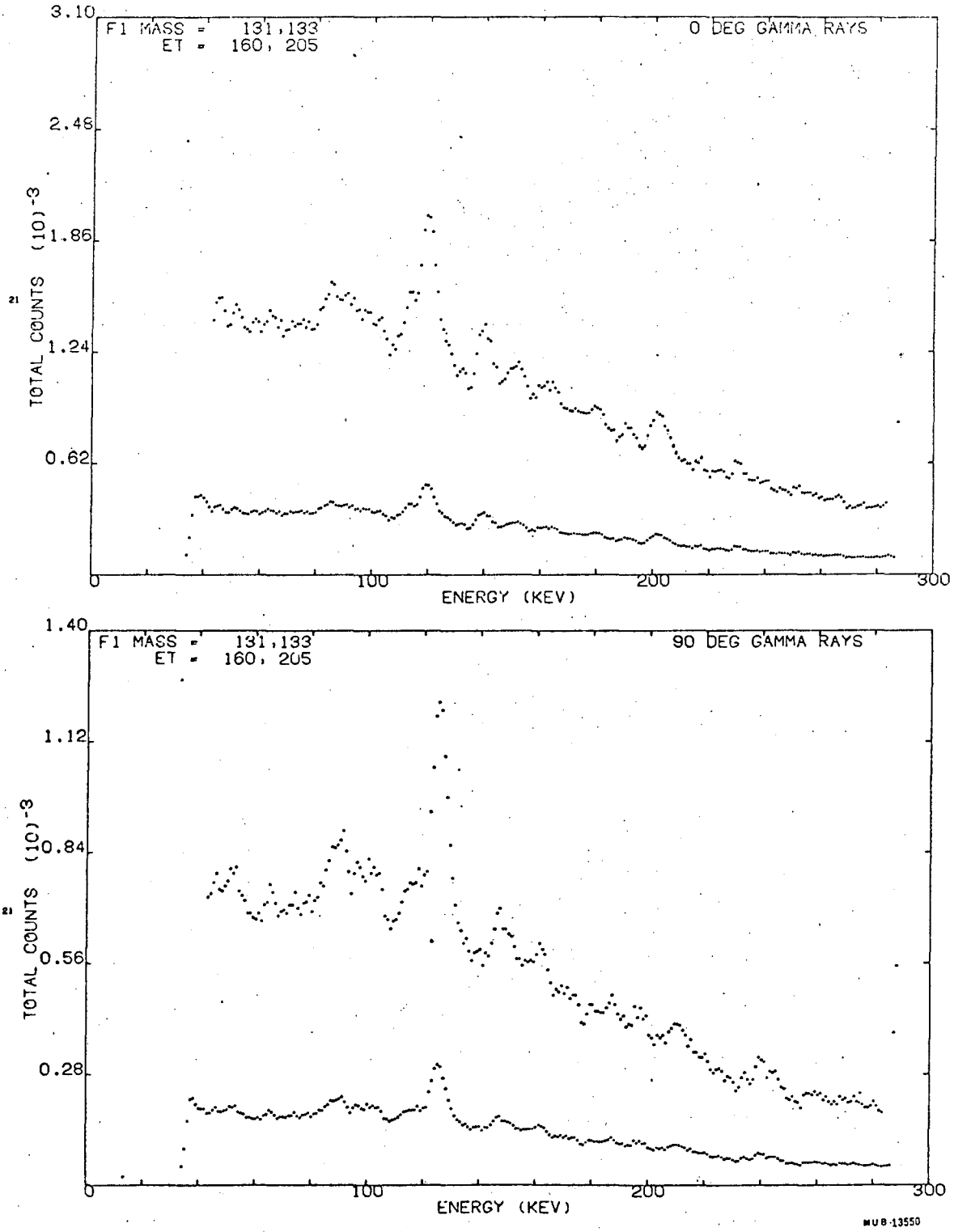

F1 MASS = 131,133
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 131,133
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13550

Fig. 24

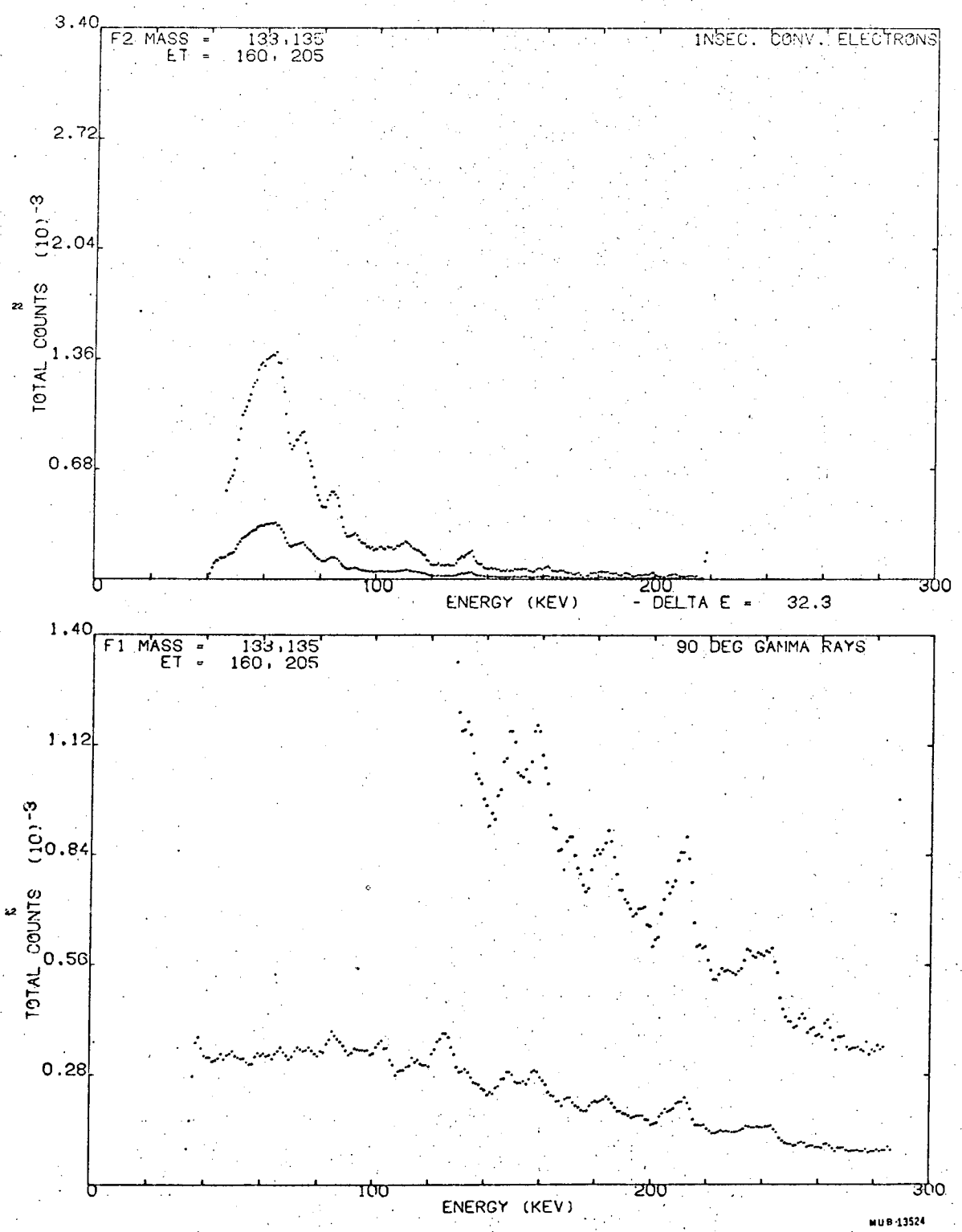
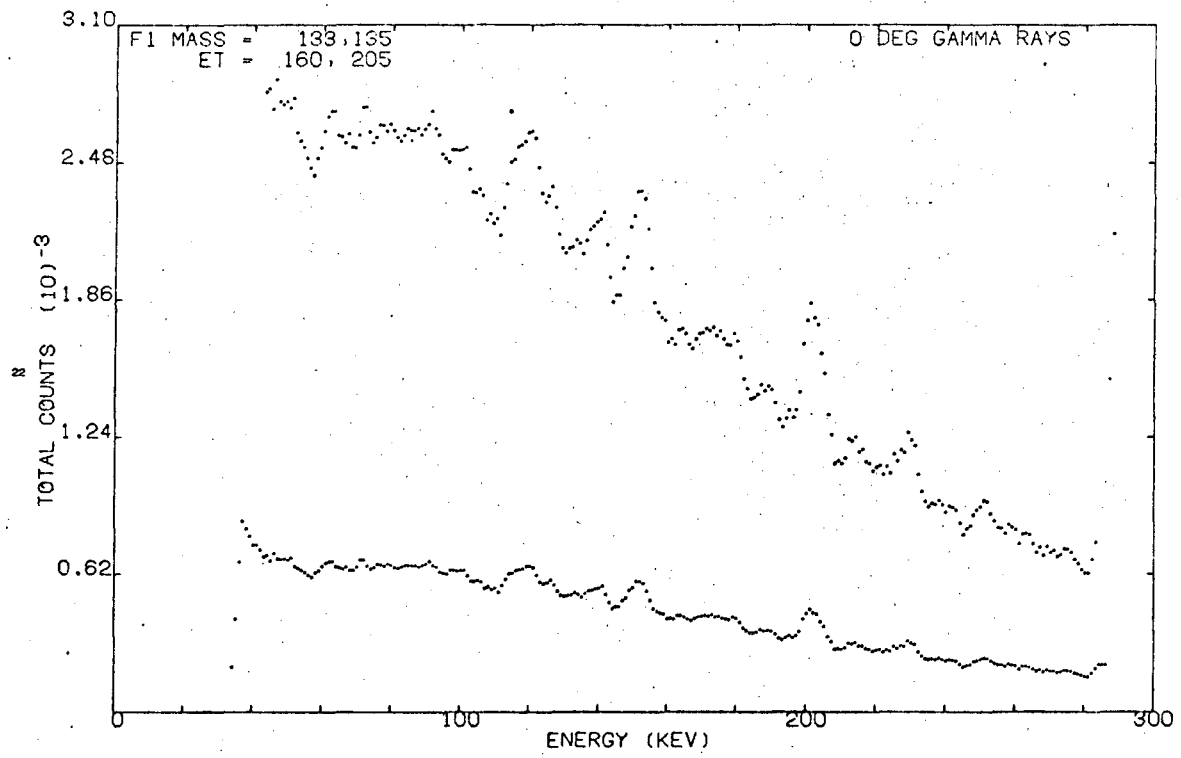

F2 MASS = 133,135
ET = 160, 205
INSEC. CONV. ELECTRONS
TOTAL COUNTS (10)-3
3.40
2.72
2.04
1.36
0.68
0
100
200
300
ENERGY (KEV) - DELTA E = 32.3
F1 MASS = 133,135
ET = 160, 205
90 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
1.40
1.12
0.84
0.56
0.28
0
100
200
300
ENERGY (KEV)
MUB-13524

Fig. 25


F1 MASS = 133,135
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)

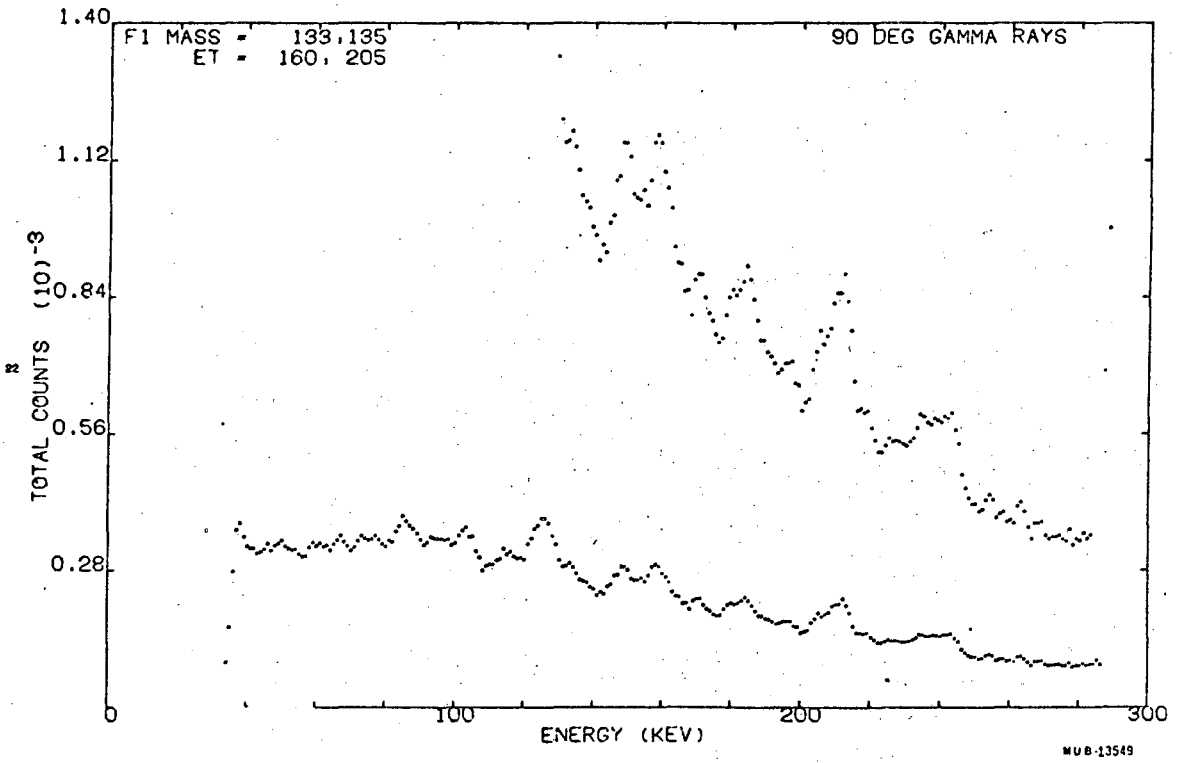

F1 MASS = 133,135
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13549

Fig. 26

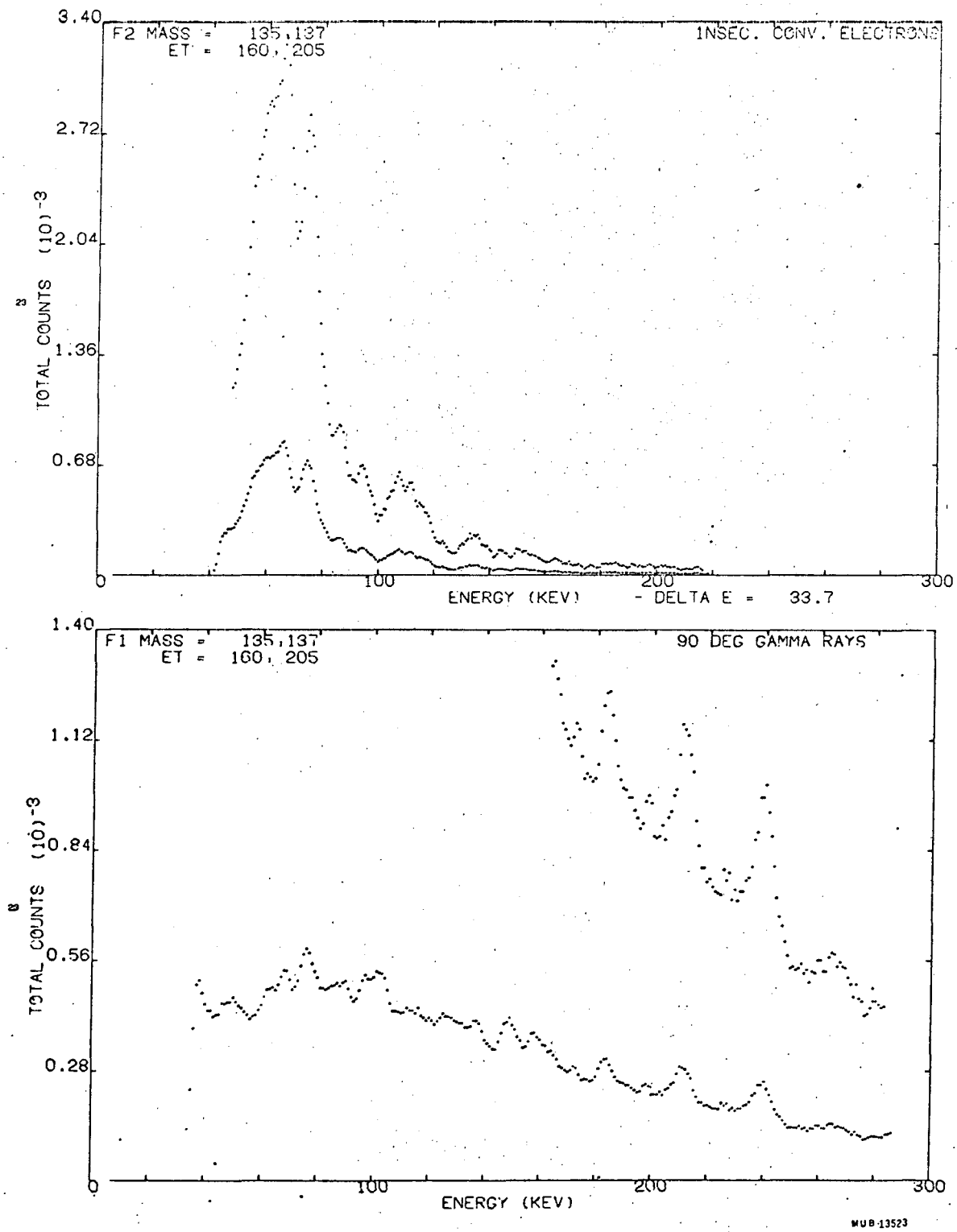
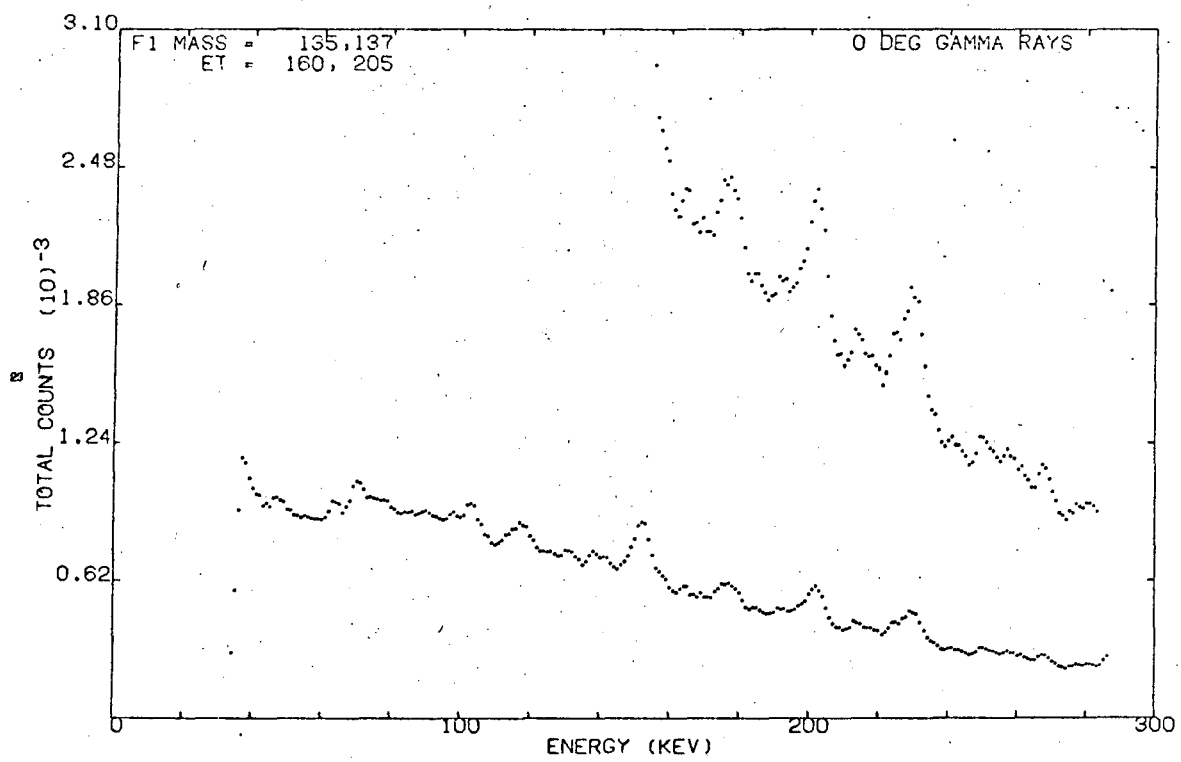

F2 MASS = 135,137
ET = 160, 205
INSEC. CONV. ELECTRONS
TOTAL COUNTS (10)-3
3.40
2.72
2.04
1.36
0.68
0
100
200
300
ENERGY (KEV)
- DELTA E = 33.7
F1 MASS = 135,137
ET = 160, 205
90 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
1.40
1.12
0.84
0.56
0.28
0
100
200
300
ENERGY (KEV)
MUB-13523

Fig. 27


F1 MASS = 135,137
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)

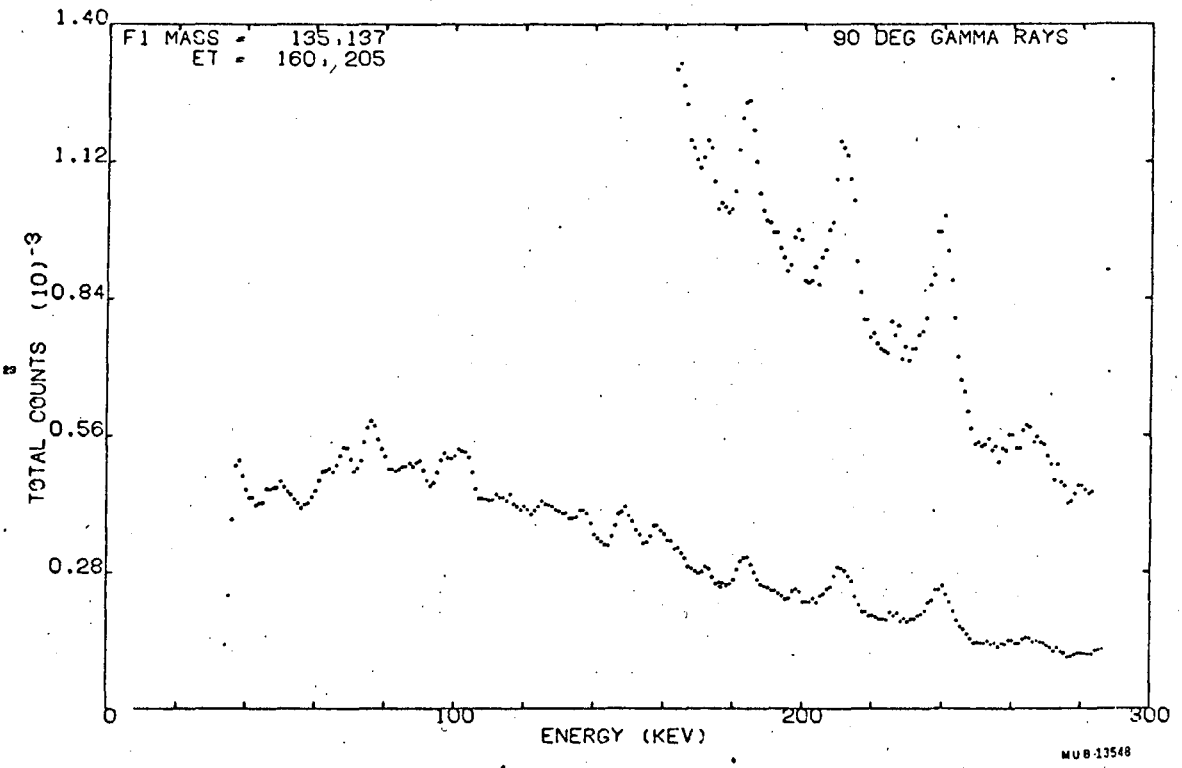

F1 MASS = 135,137
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13548

Fig. 28

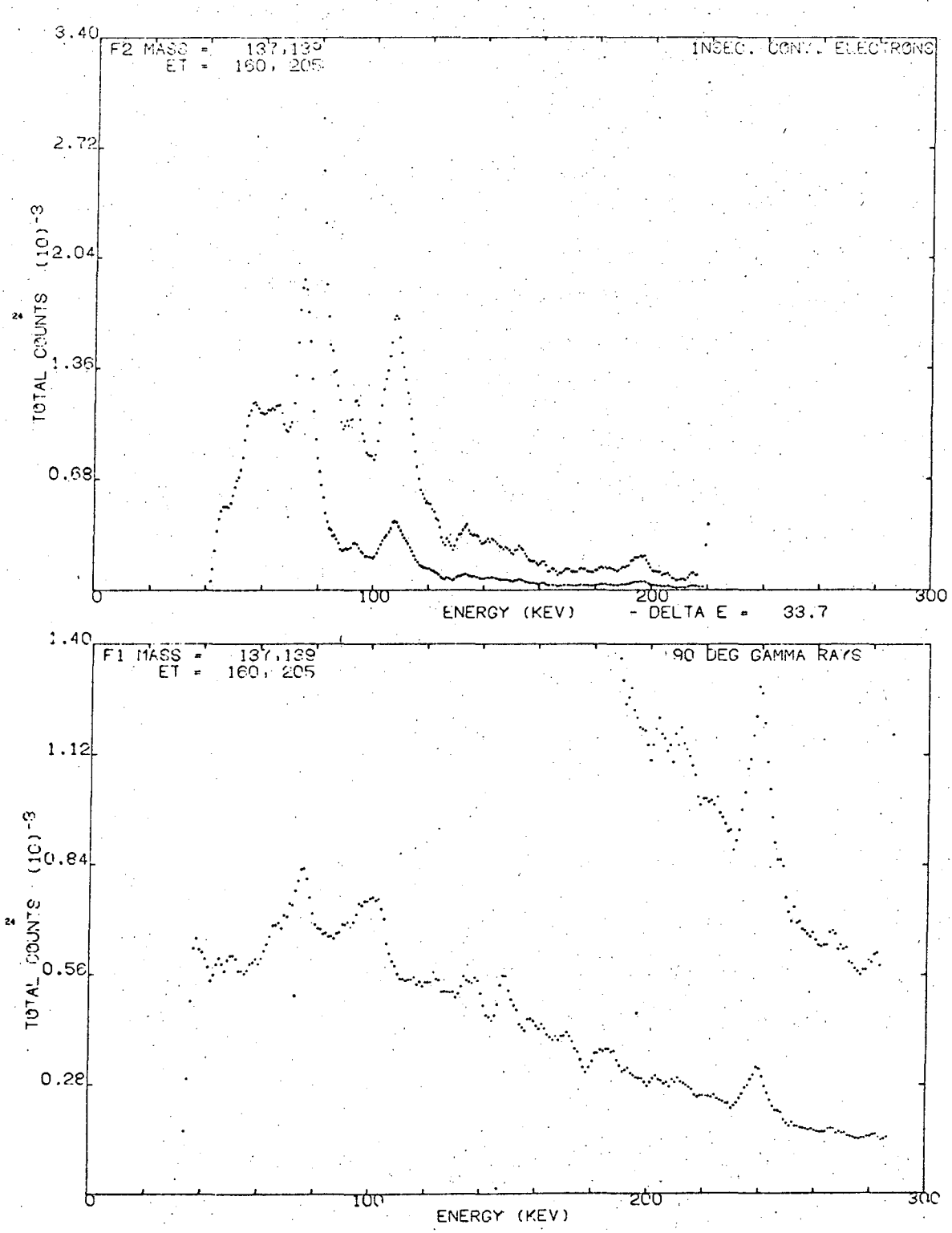

F2 MASS = 137,139
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 33.7
F1 MASS = 137,139
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13522

Fig. 29

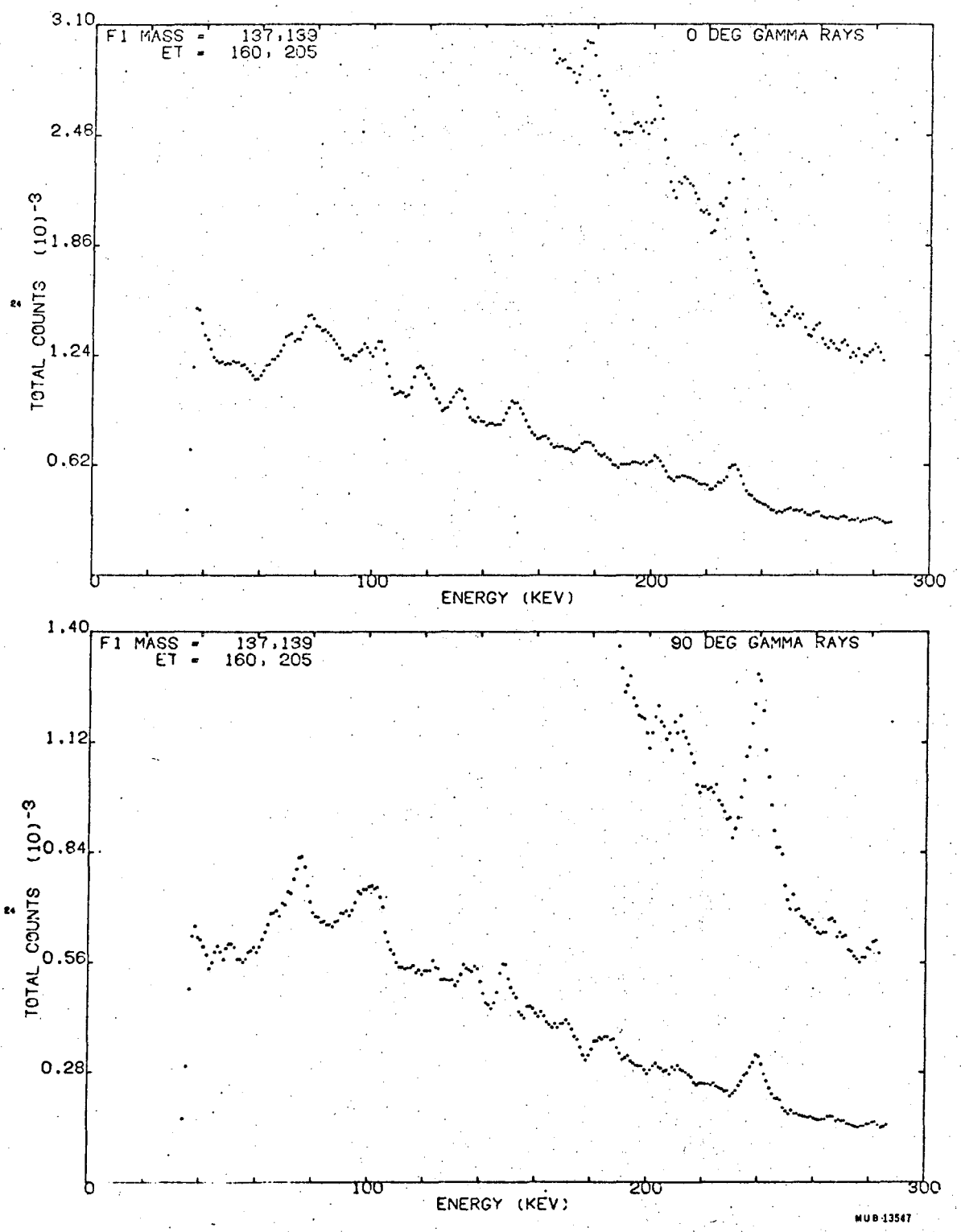

F1 MASS = 137,139
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 137,139
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13547

Fig. 30

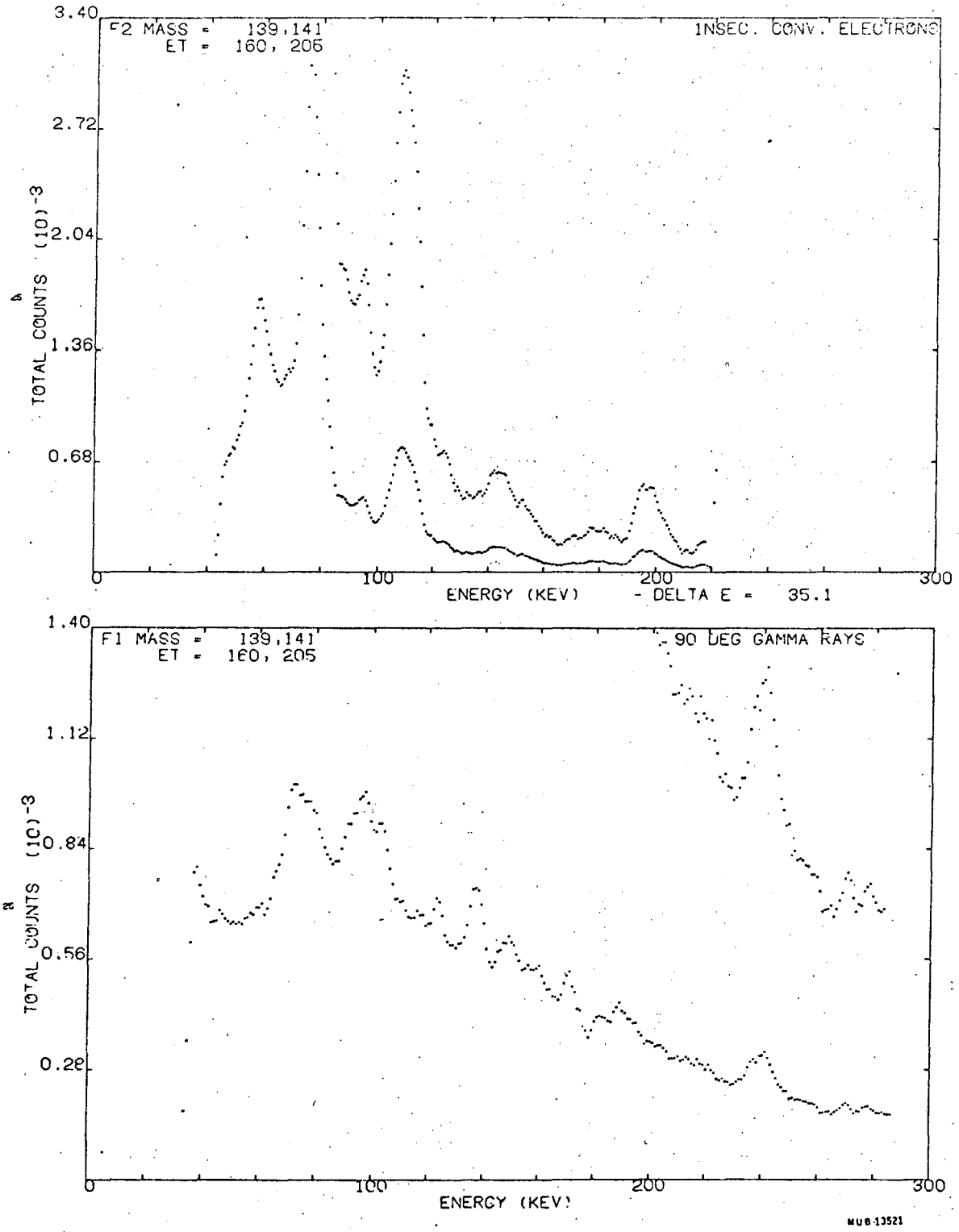

F2 MASS = 139,141
ET = 160, 205
INSEC. CONV. ELECTRONS
TOTAL COUNTS (10)-3
3.40
2.72
2.04
1.36
0.68
0
100
200
300
ENERGY (KEV) - DELTA E = 35.1
F1 MASS = 139,141
ET = 160, 205
90 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
1.40
1.12
0.84
0.56
0.28
0
100
200
300
ENERGY (KEV)
MUB-13521

Fig. 31

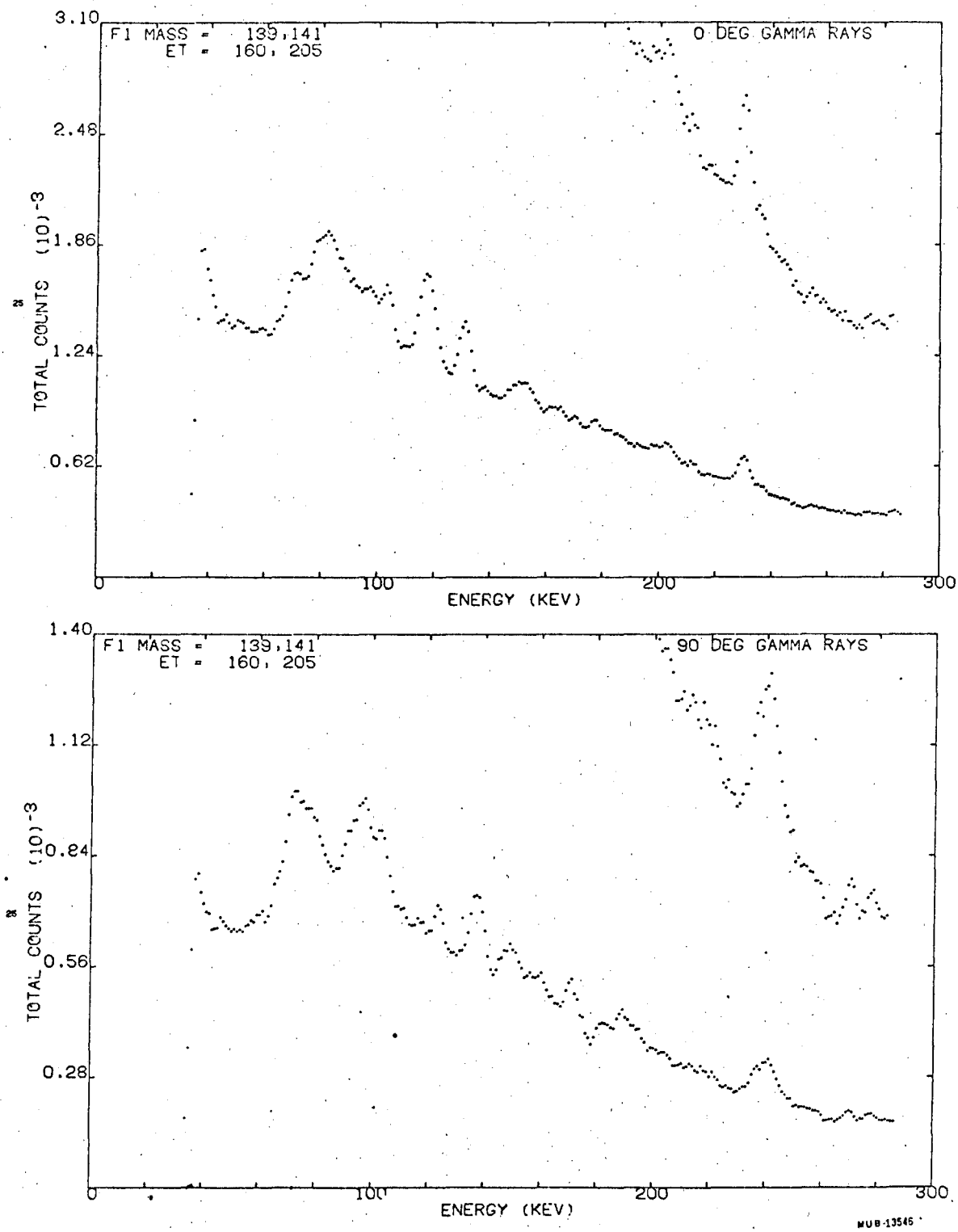

F1 MASS = 139,141
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 139,141
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13546

Fig. 32

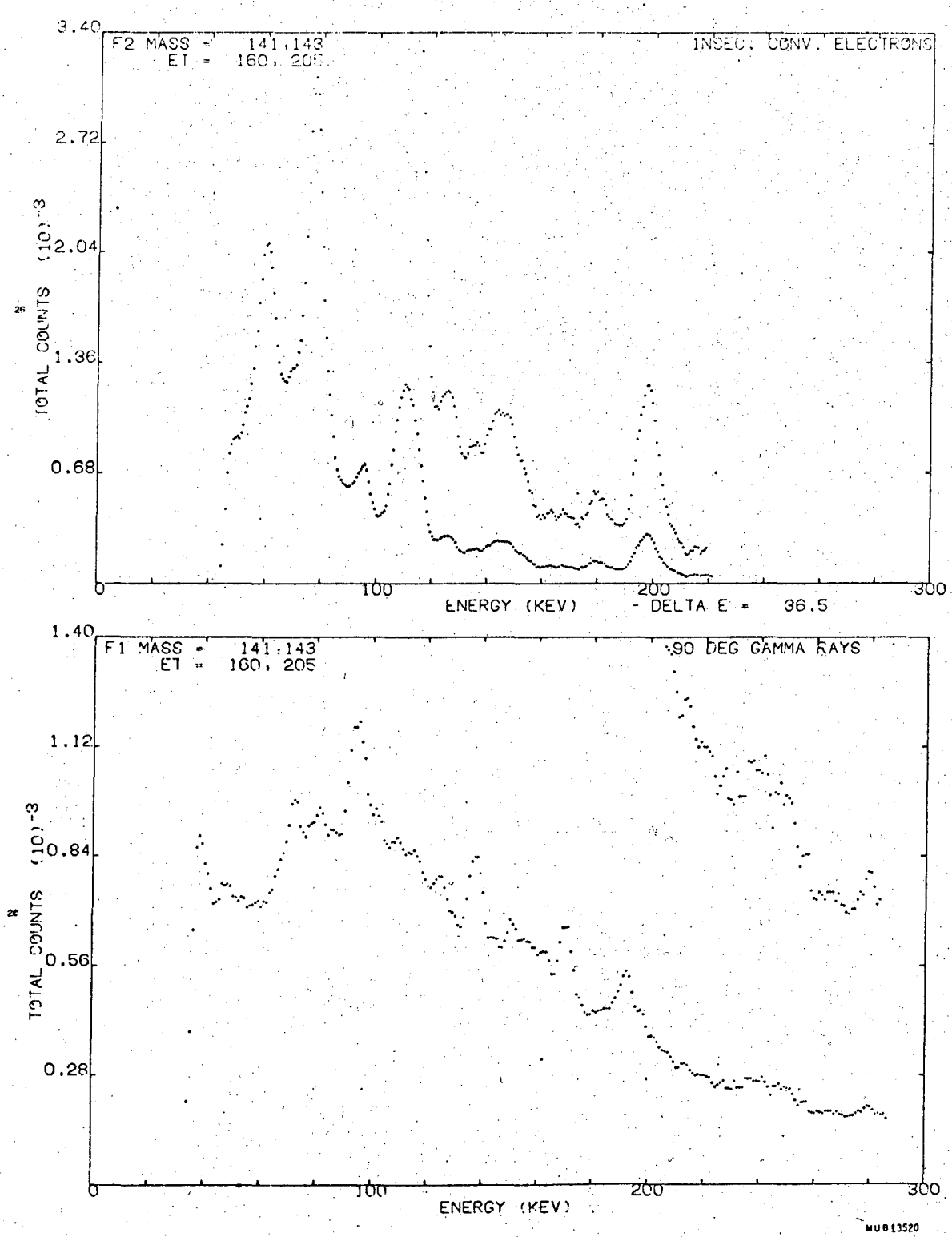

F2 MASS = 141,143
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
- DELTA E = 36.5
F1 MASS = 141,143
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB 13520

Fig. 33

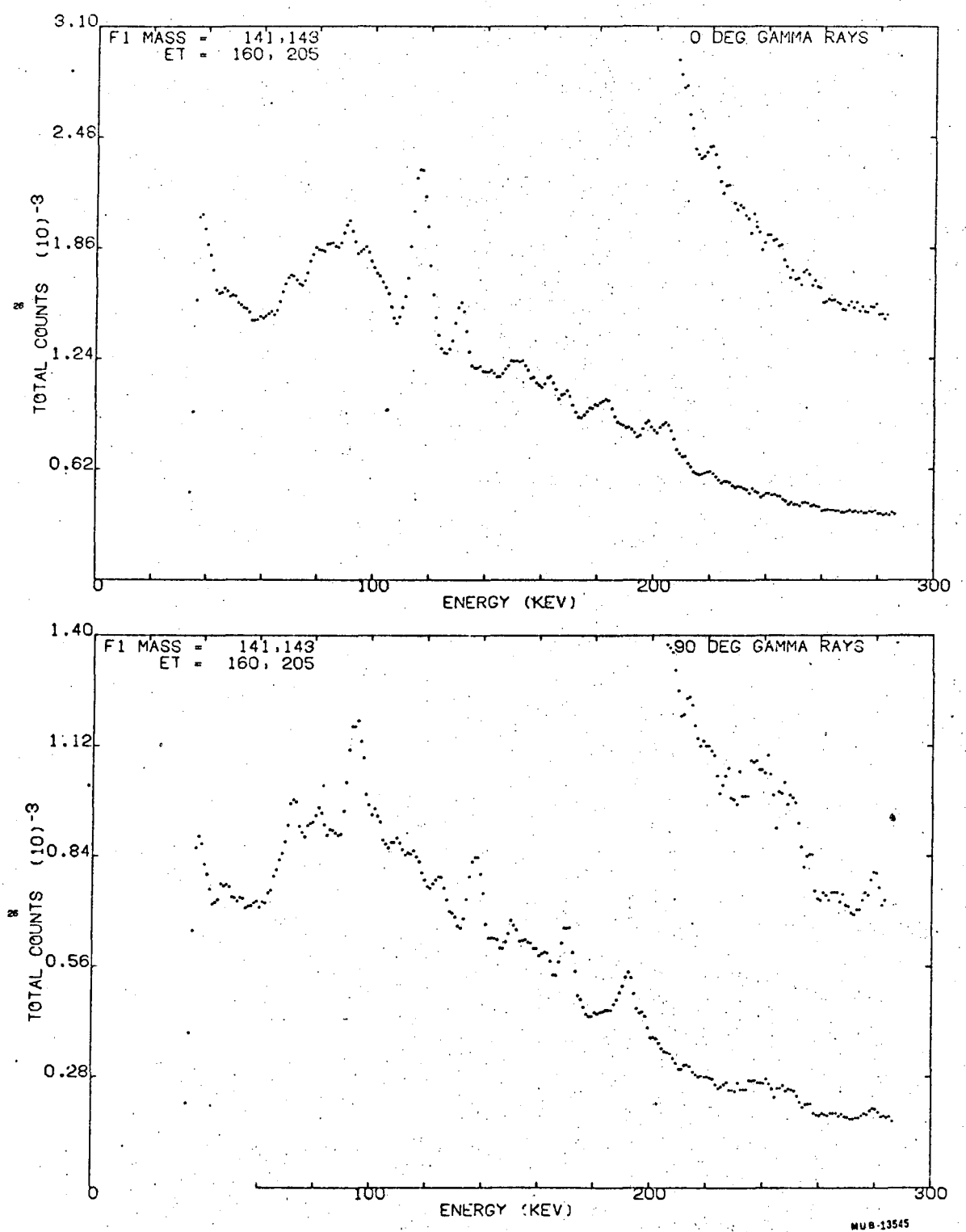

F1 MASS = 141,143
ET = 160, 205
0 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
3.10
2.48
1.86
1.24
0.62
0
100
200
300
ENERGY (KEV)
F1 MASS = 141,143
ET = 160, 205
90 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
1.40
1.12
0.84
0.56
0.28
0
100
200
300
ENERGY (KEV)
MUB-13545

Fig. 34

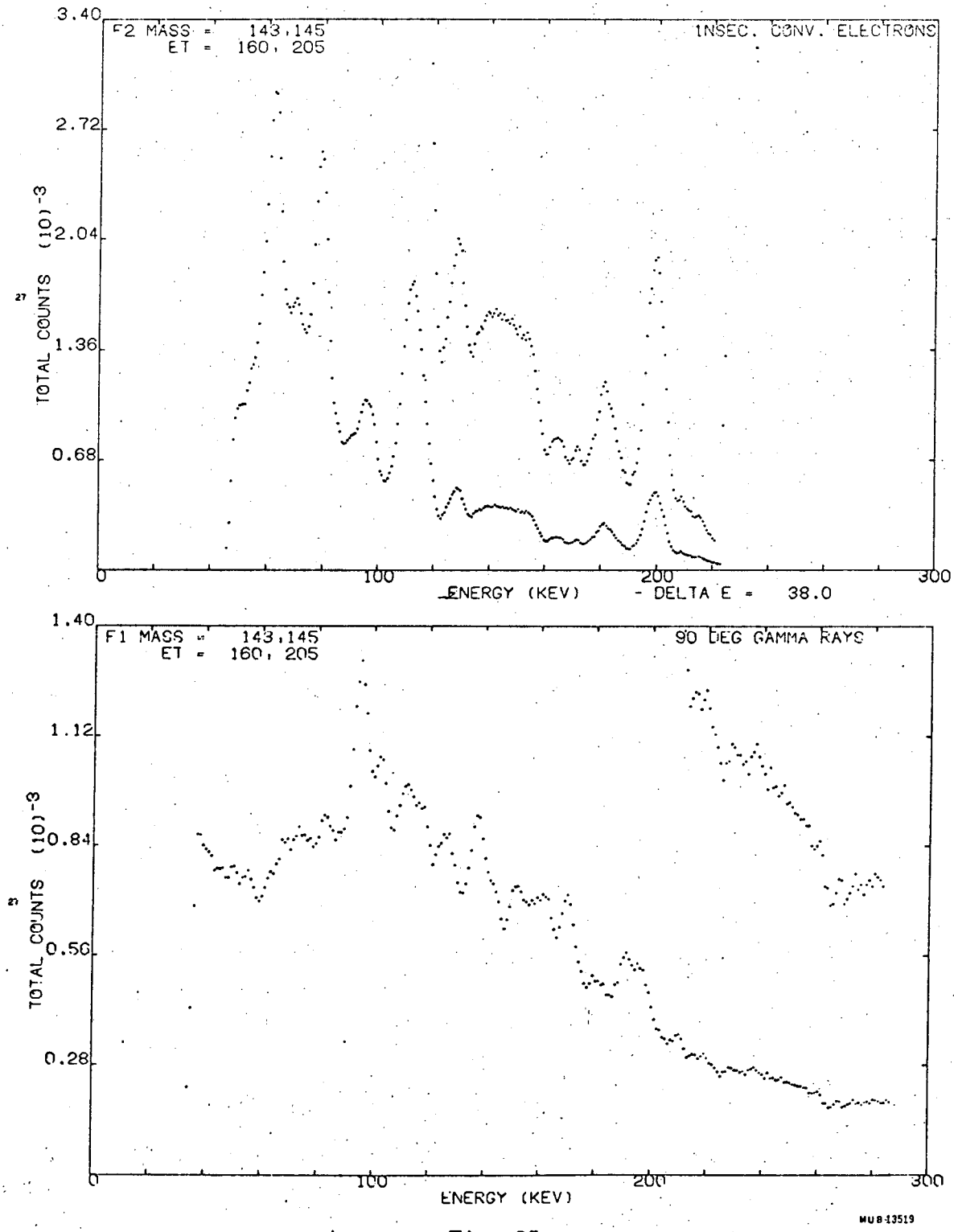

F2 MASS = 143,145
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
- DELTA E = 38.0
F1 MASS = 143,145
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13519

Fig. 35

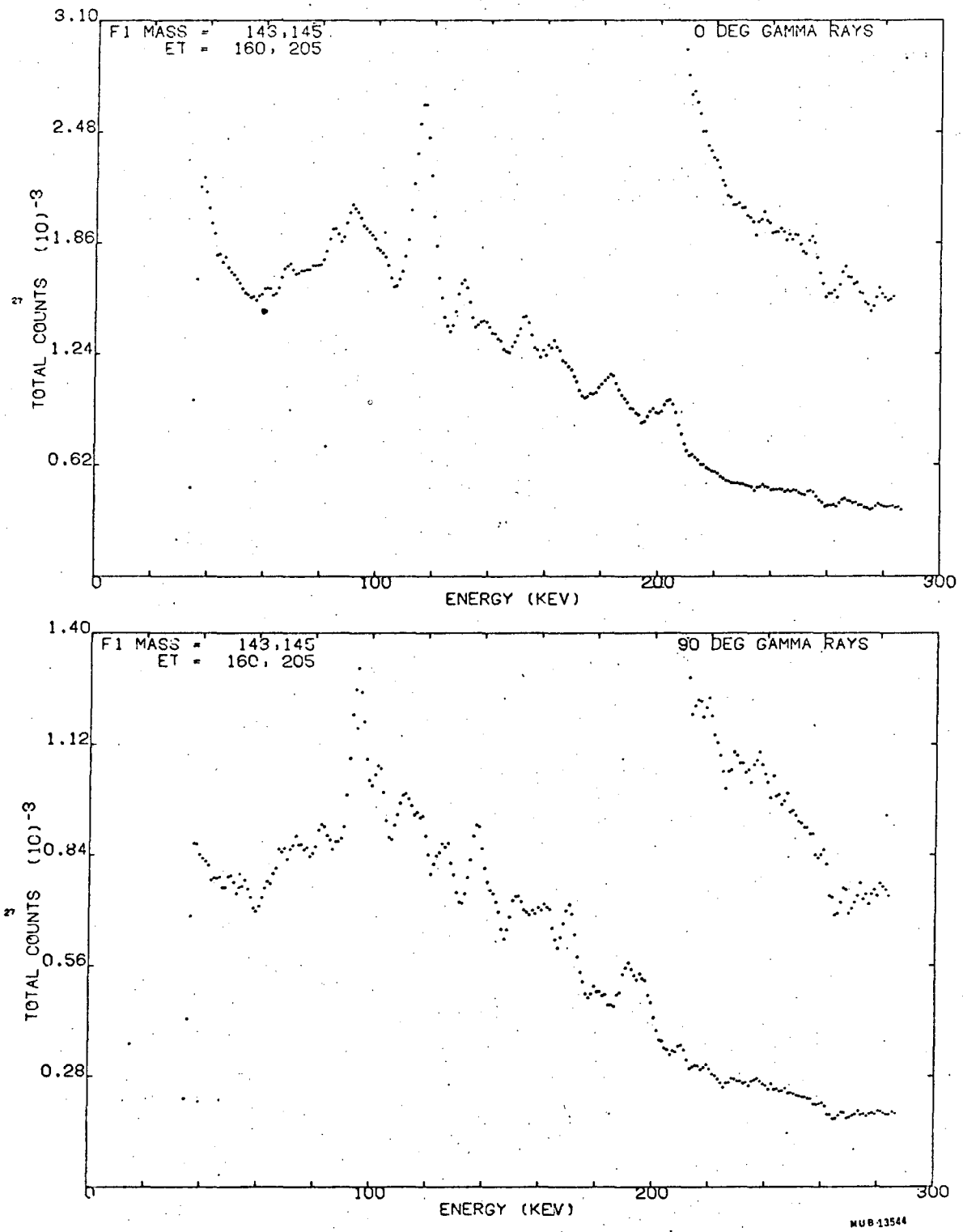

F1 MASS = 143,145
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 143,145
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13544

Fig. 36

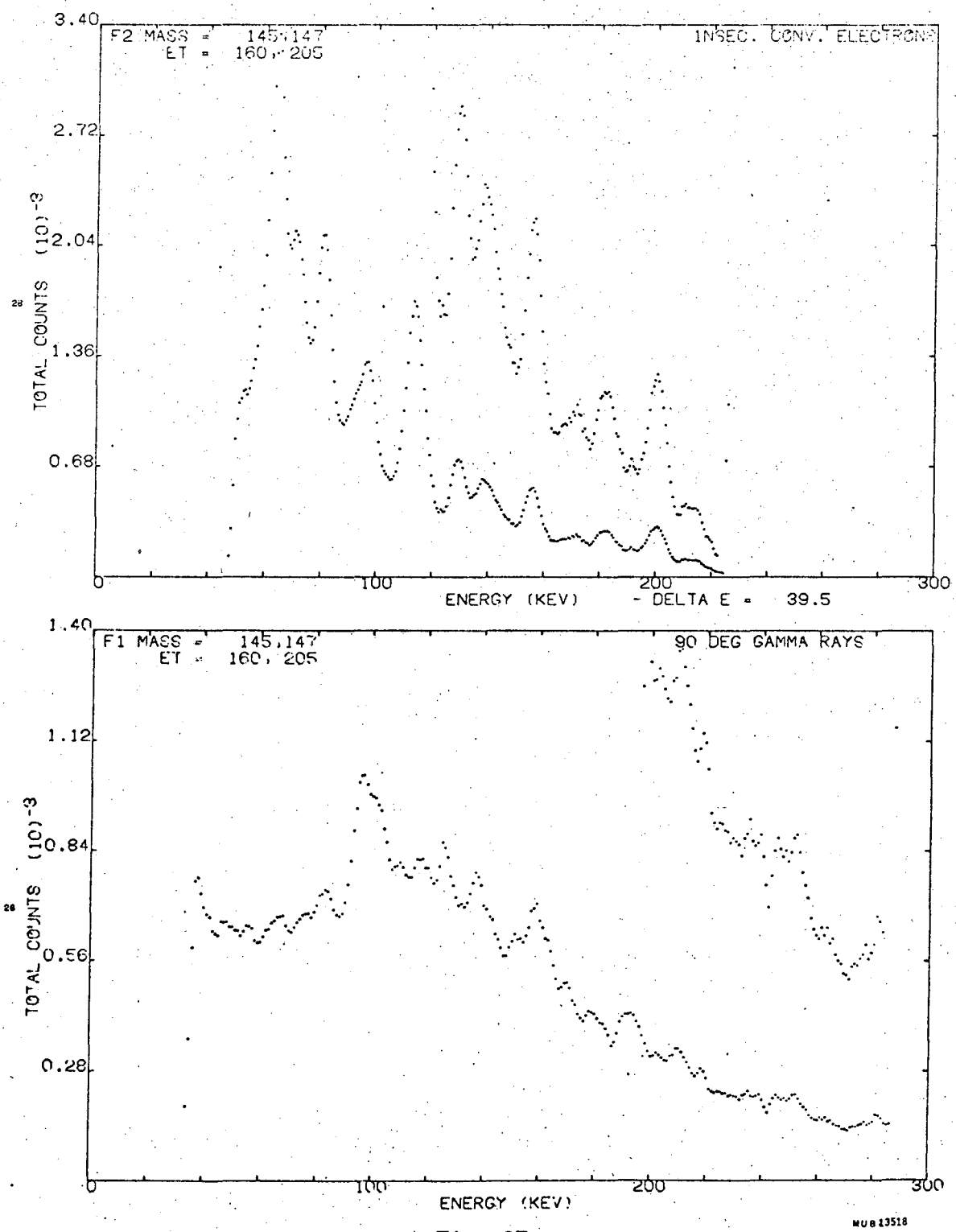

F2 MASS = 145,147
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 39.5
F1 MASS = 145,147
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB 13518

Fig. 37

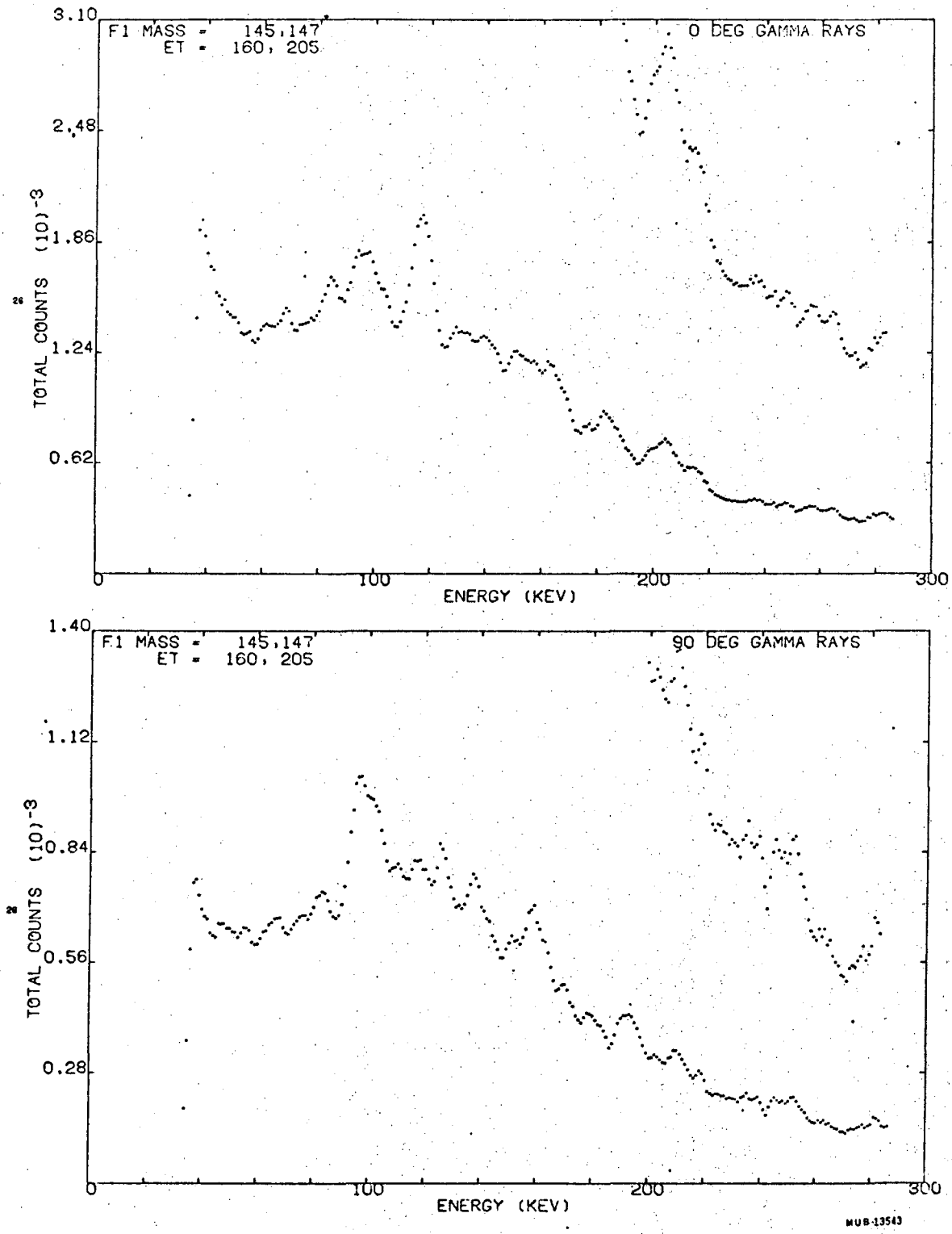

F1 MASS = 145,147
ET = 160, 205
0 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
3.10
2.48
1.86
1.24
0.62
0
100
200
300
ENERGY (KEV)
F1 MASS = 145,147
ET = 160, 205
90 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
1.40
1.12
0.84
0.56
0.28
0
100
200
300
ENERGY (KEV)
MUB-13543

Fig. 38

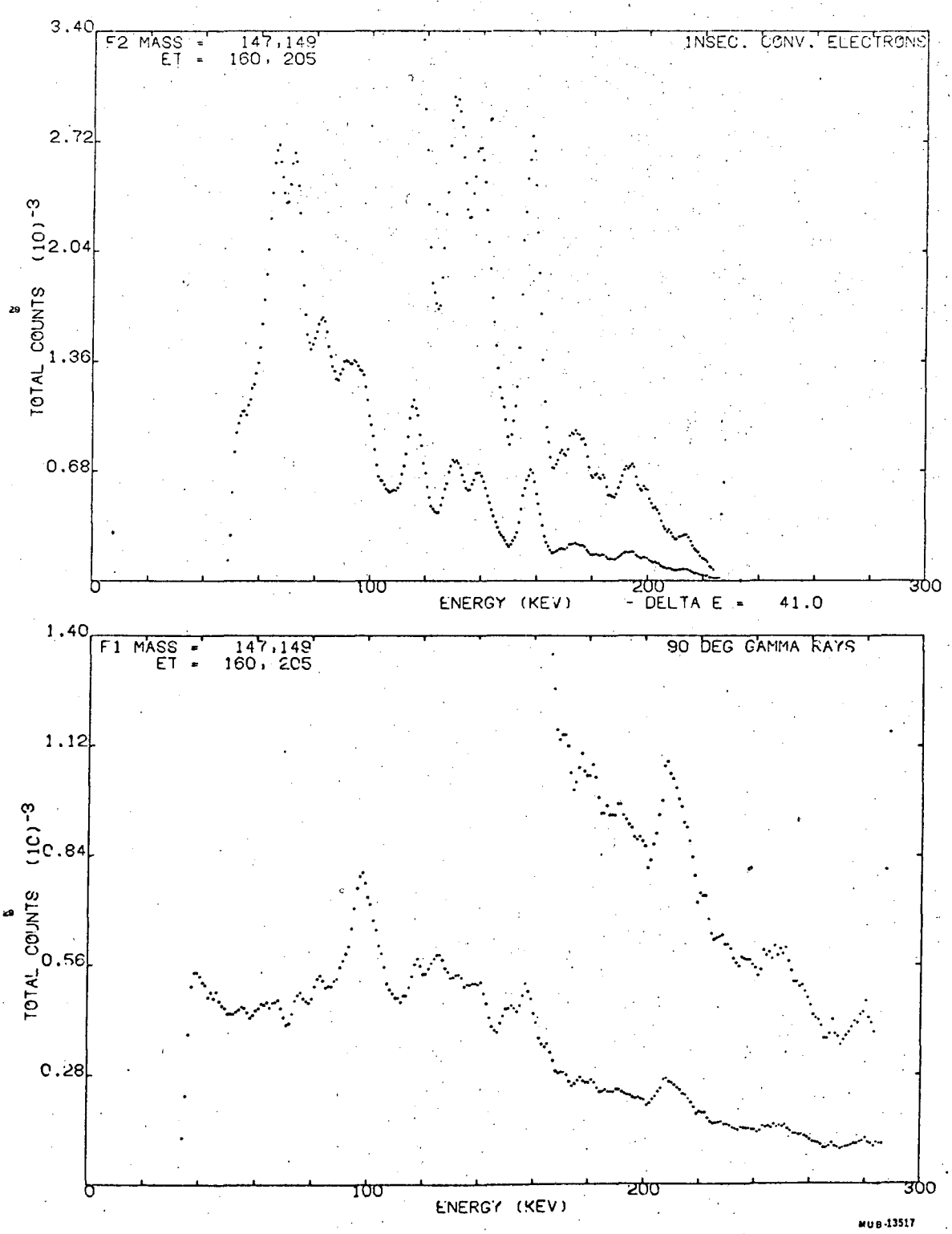

F2 MASS = 147,149
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 41.0
F1 MASS = 147,149
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (1C)-3
0
100
200
300
ENERGY (KEV)
MUB-13517

Fig. 39

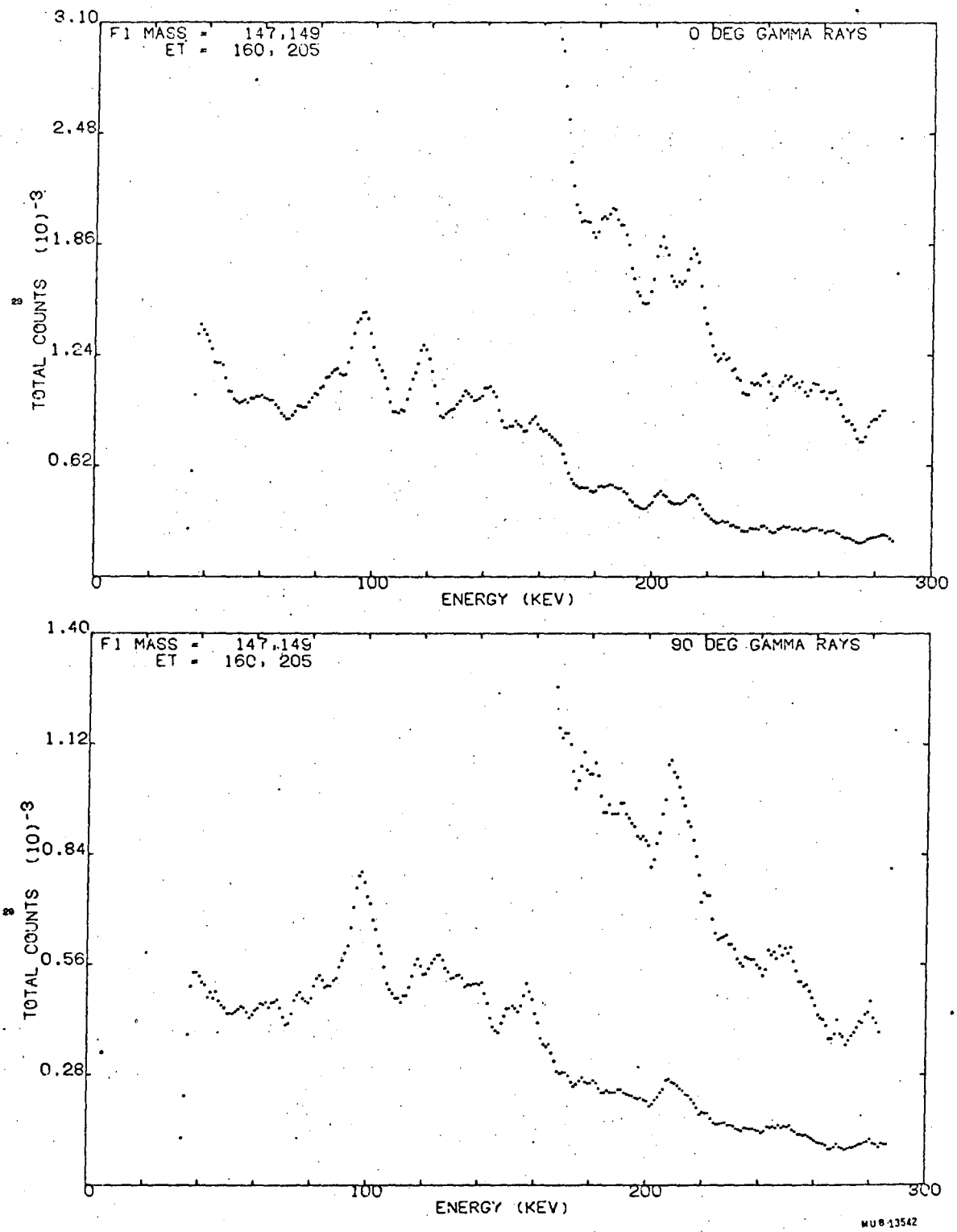

F1 MASS = 147,149
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 147,149
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MU8-13542

Fig. 40

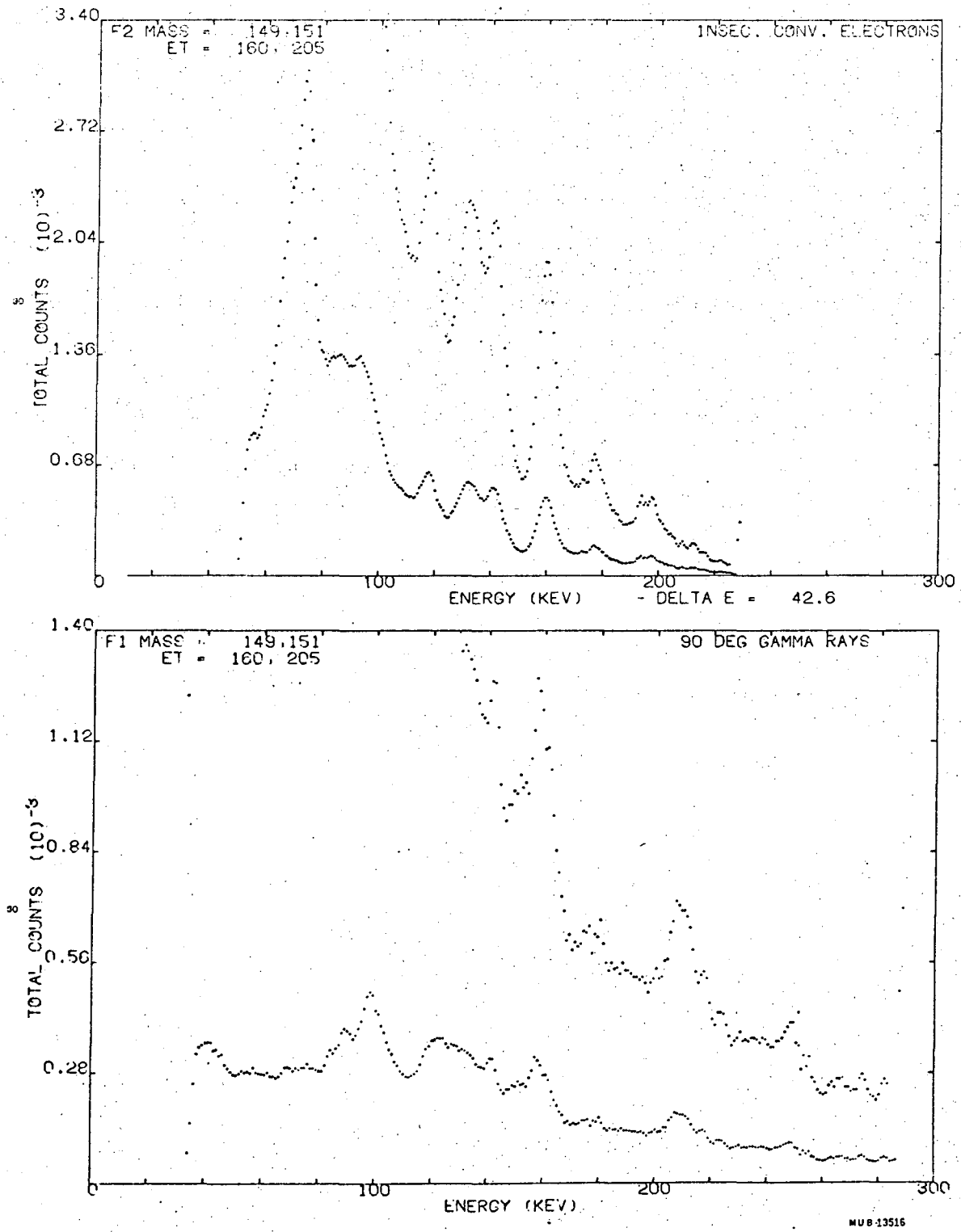

F2 MASS = 149,151
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
0
TOTAL COUNTS (10)^-3
100
200
300
ENERGY (KEV) - DELTA E = 42.6
F1 MASS = 149,151
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
0
TOTAL COUNTS (10)^-3
100
200
300
ENERGY (KEV)
MUB-13516

Fig. 41

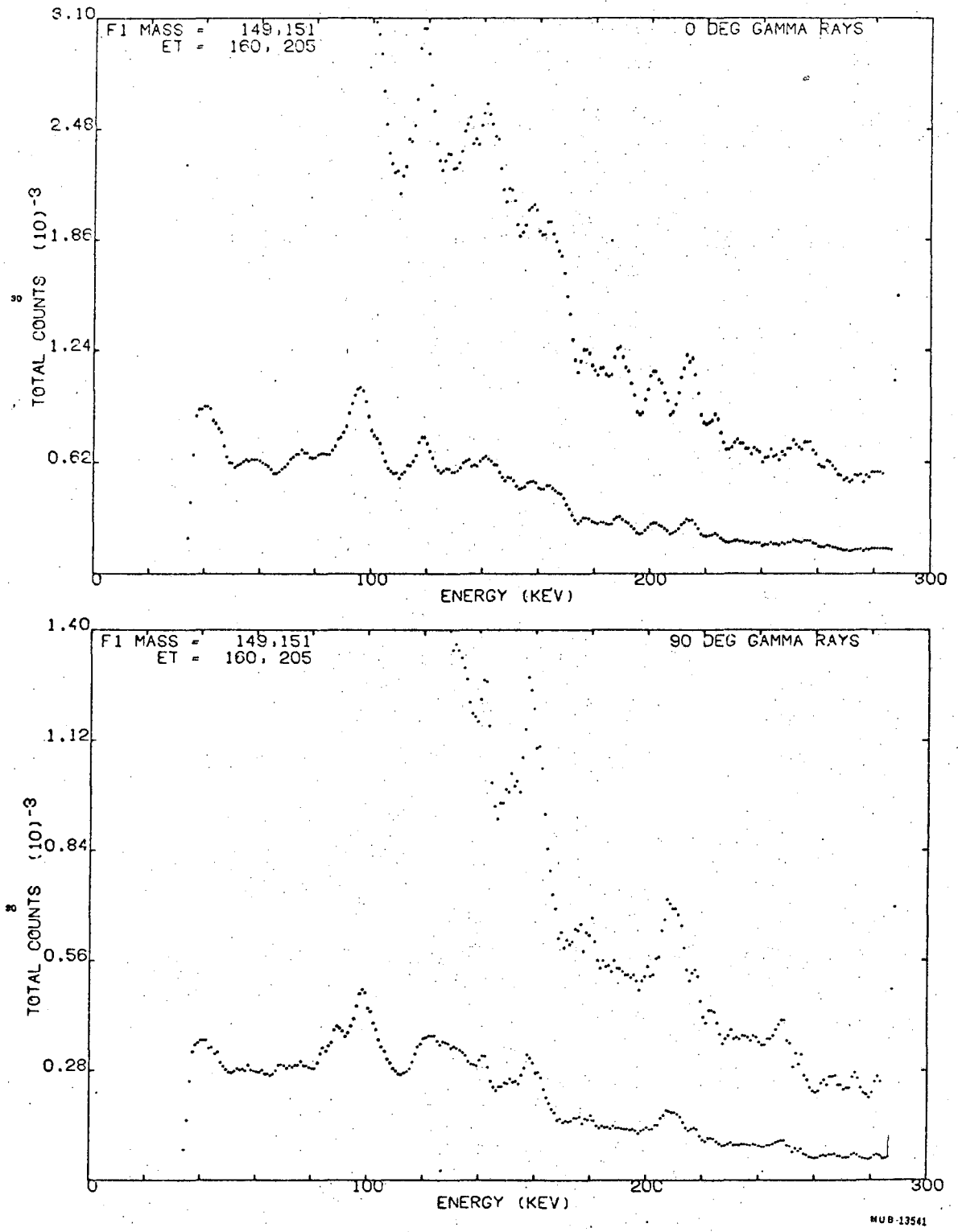

F1 MASS = 149,151
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 149,151
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13541

Fig. 42

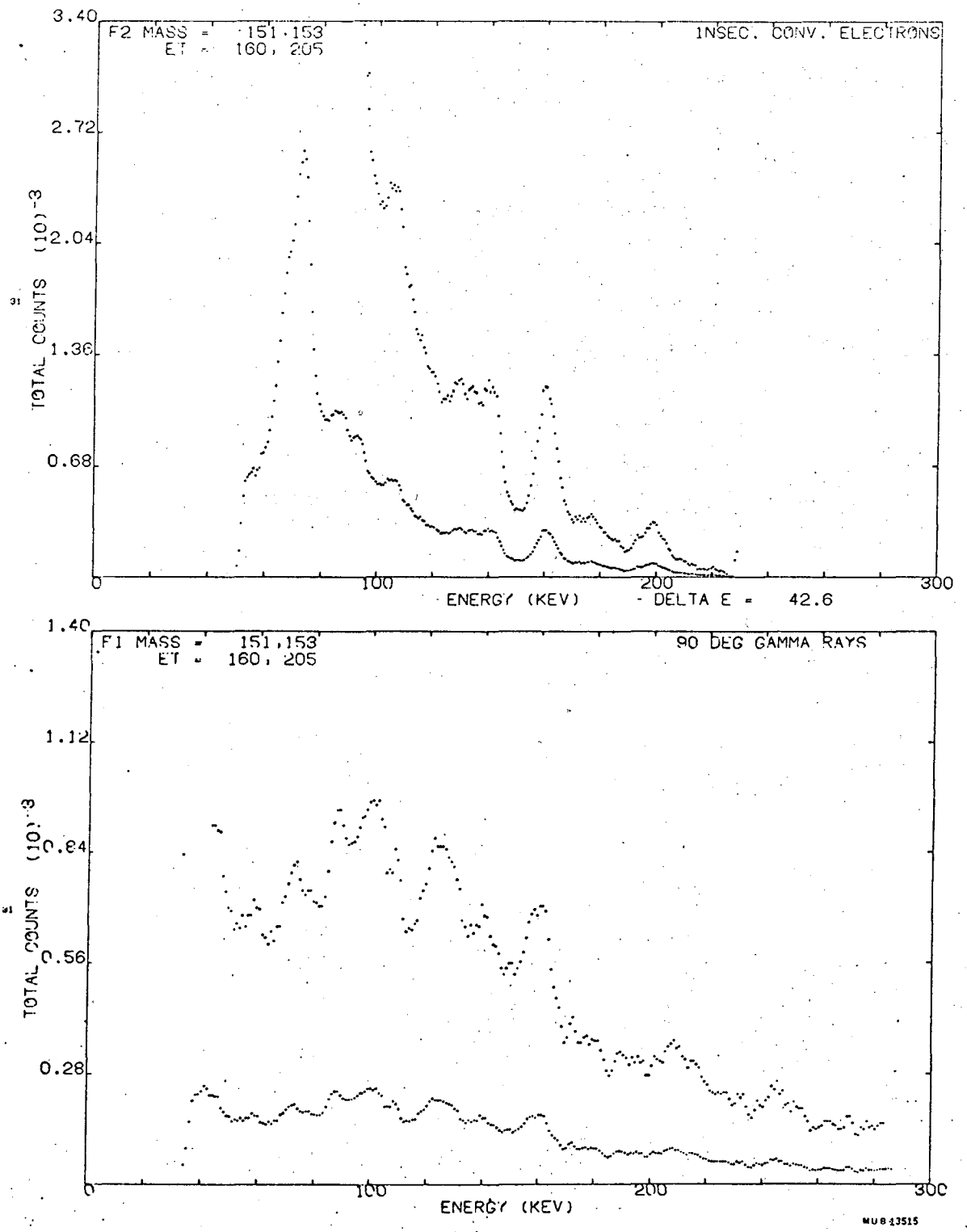

F2 MASS = 151,153
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
DELTA E = 42.6
F1 MASS = 151,153
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13515

Fig. 43

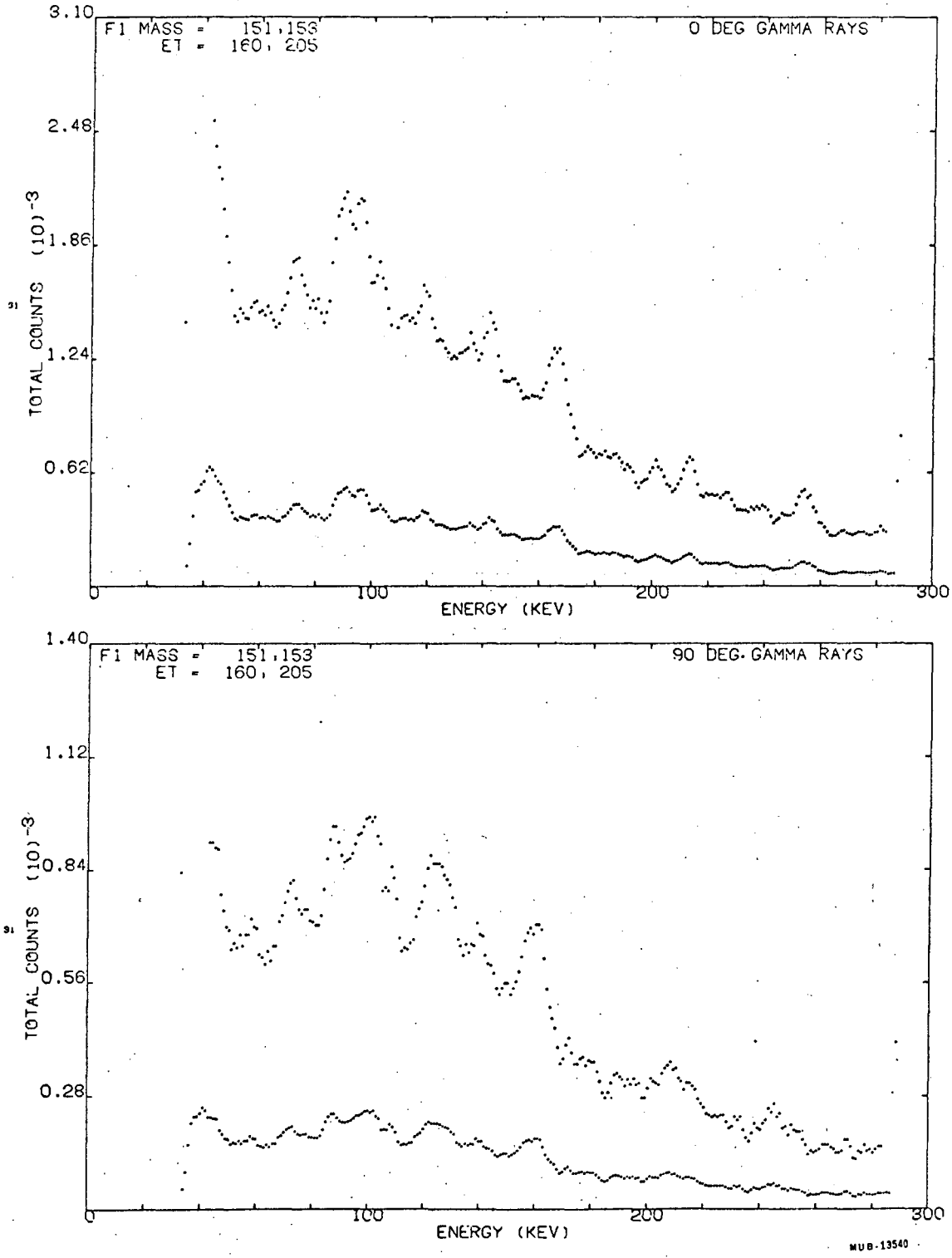

F1 MASS = 151,153
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
F1 MASS = 151,153
ET = 160, 205
90 DEG. GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13540

Fig. 44

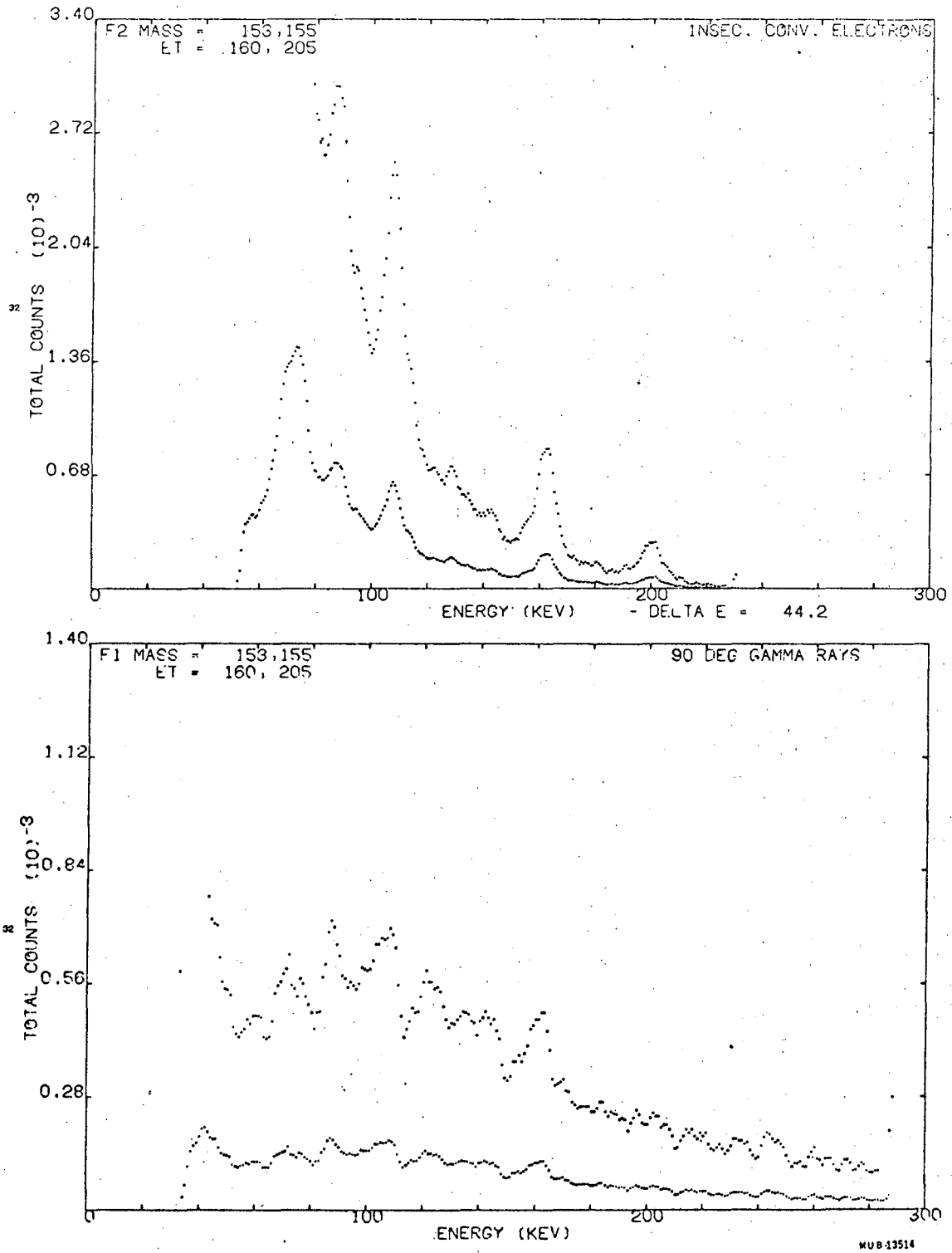
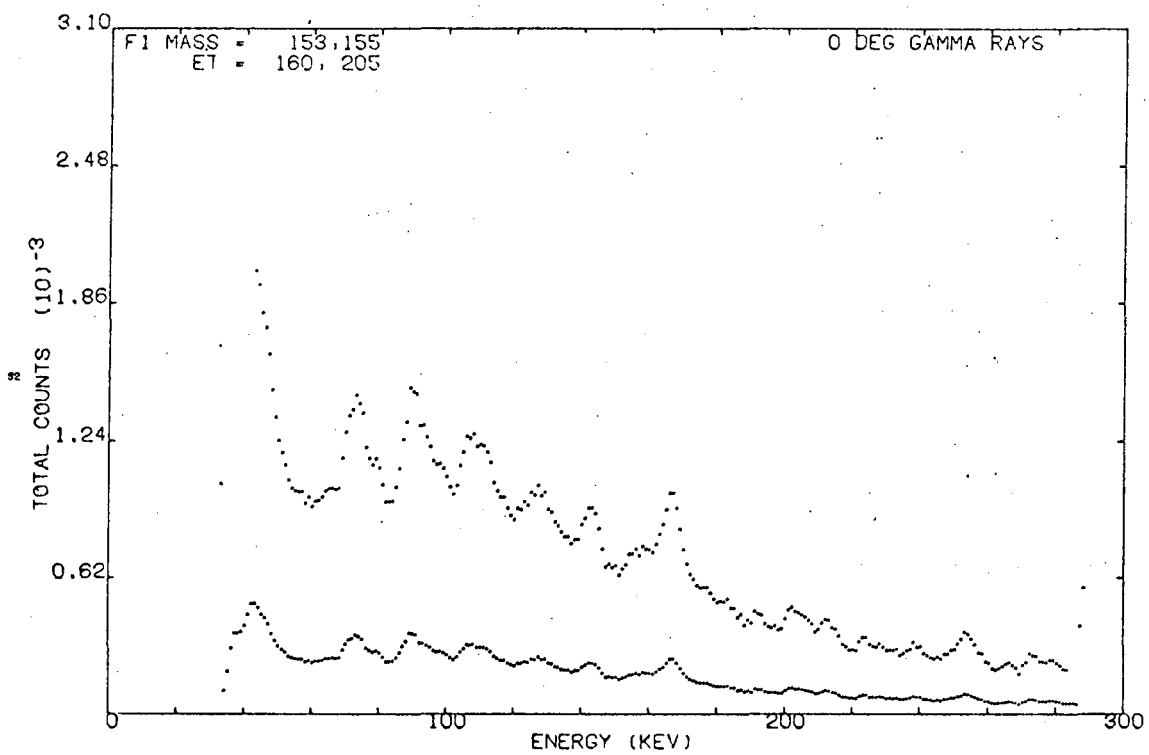

F2 MASS = 153,155
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 44.2
F1 MASS = 153,155
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13514

Fig. 45


F1 MASS = 153,155
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)

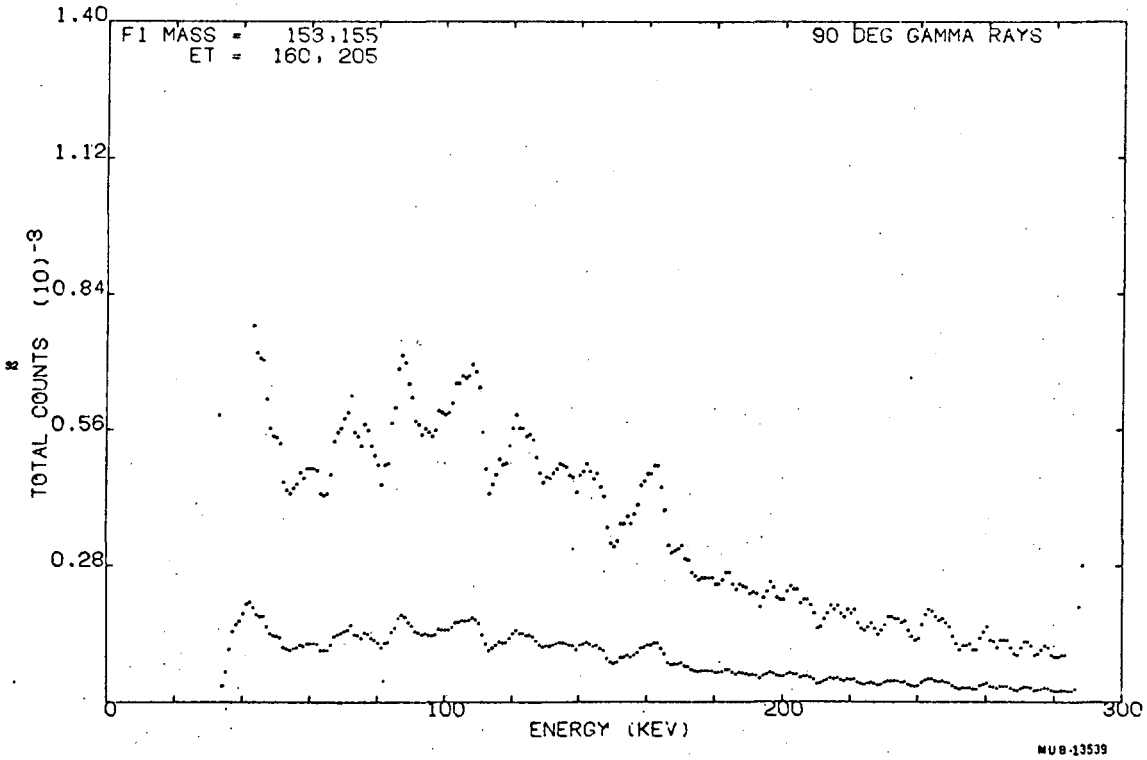

F1 MASS = 153,155
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13539

Fig. 46

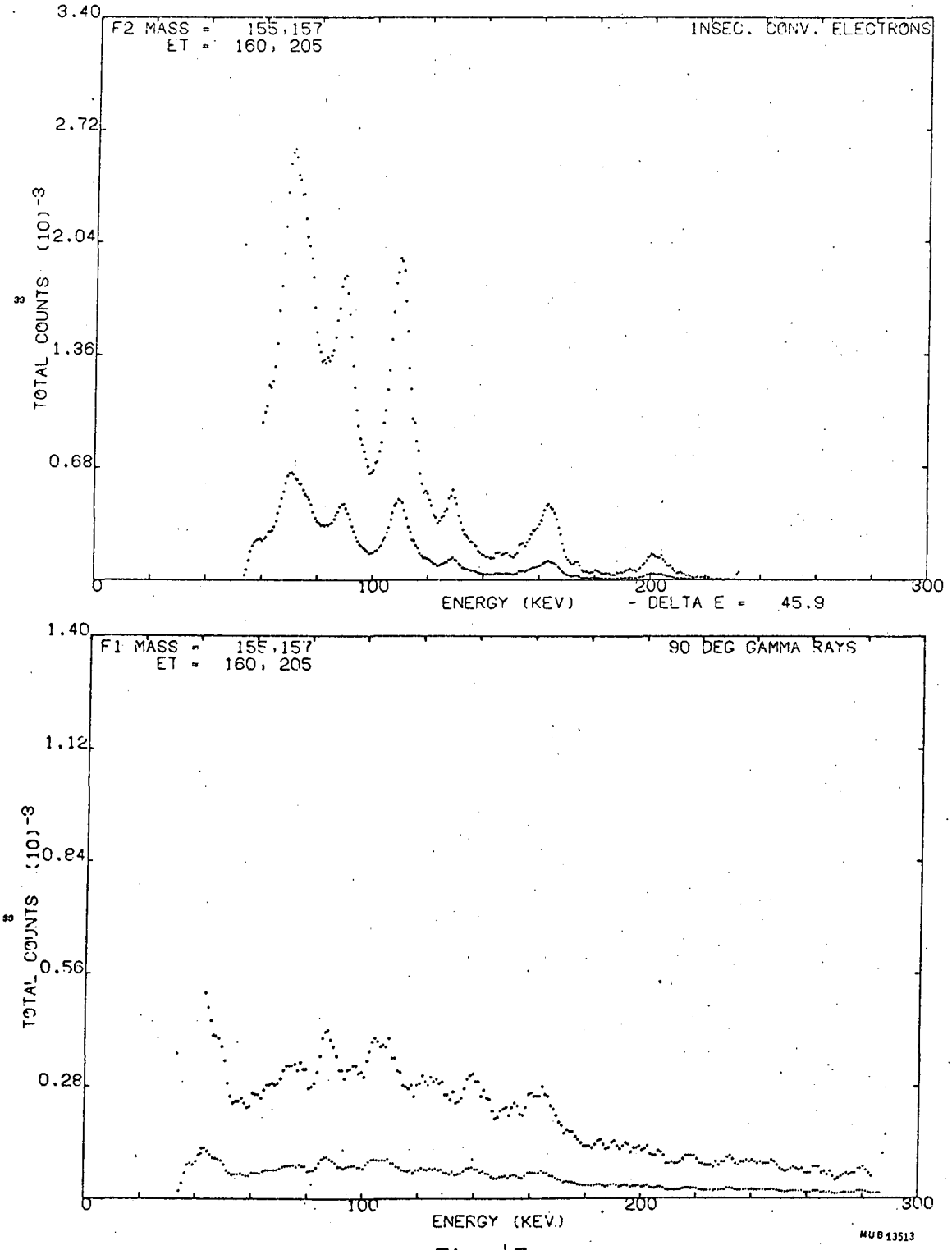
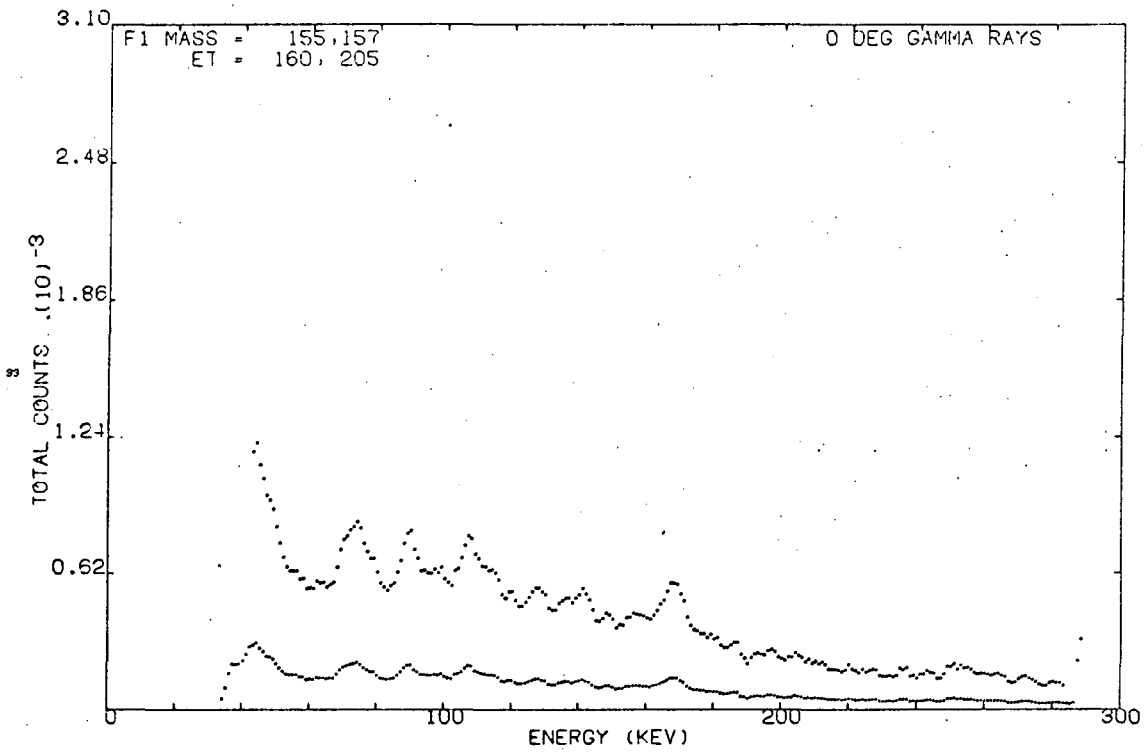

F2 MASS = 155,157
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV) - DELTA E = 45.9
F1 MASS = 155,157
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV.)
MUB 13513

Fig. 47


F1 MASS = 155,157
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)

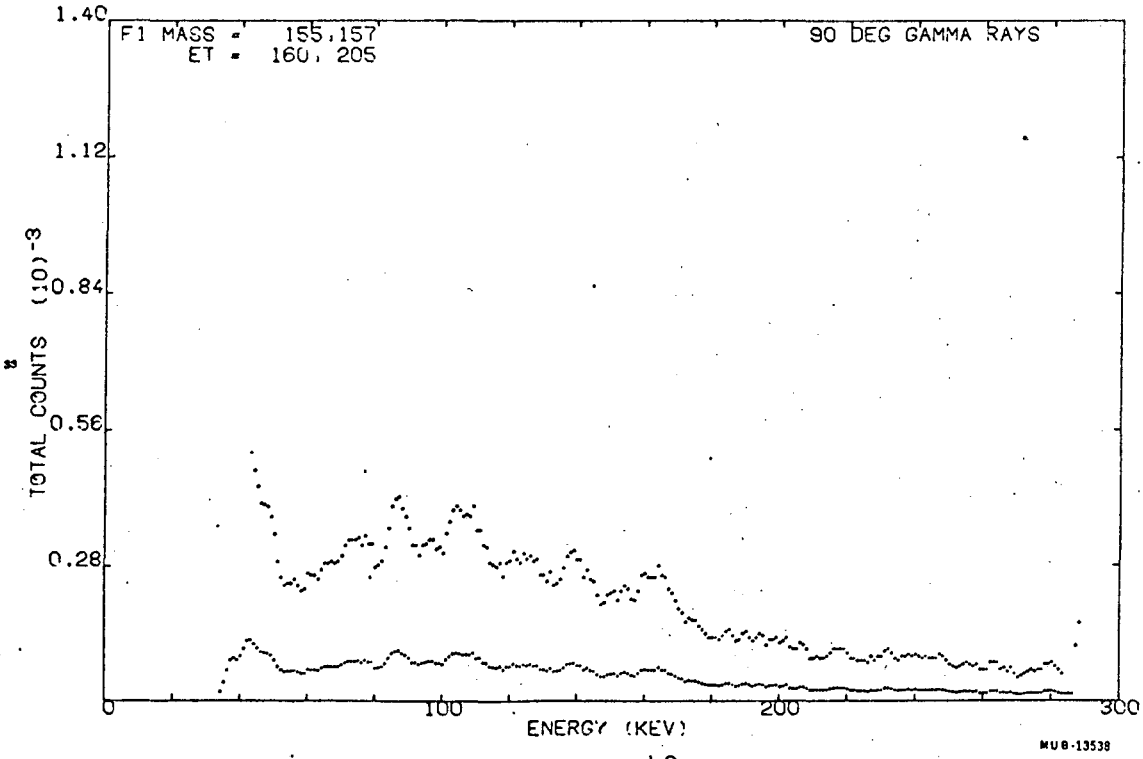

F1 MASS = 155,157
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13538

Fig. 48

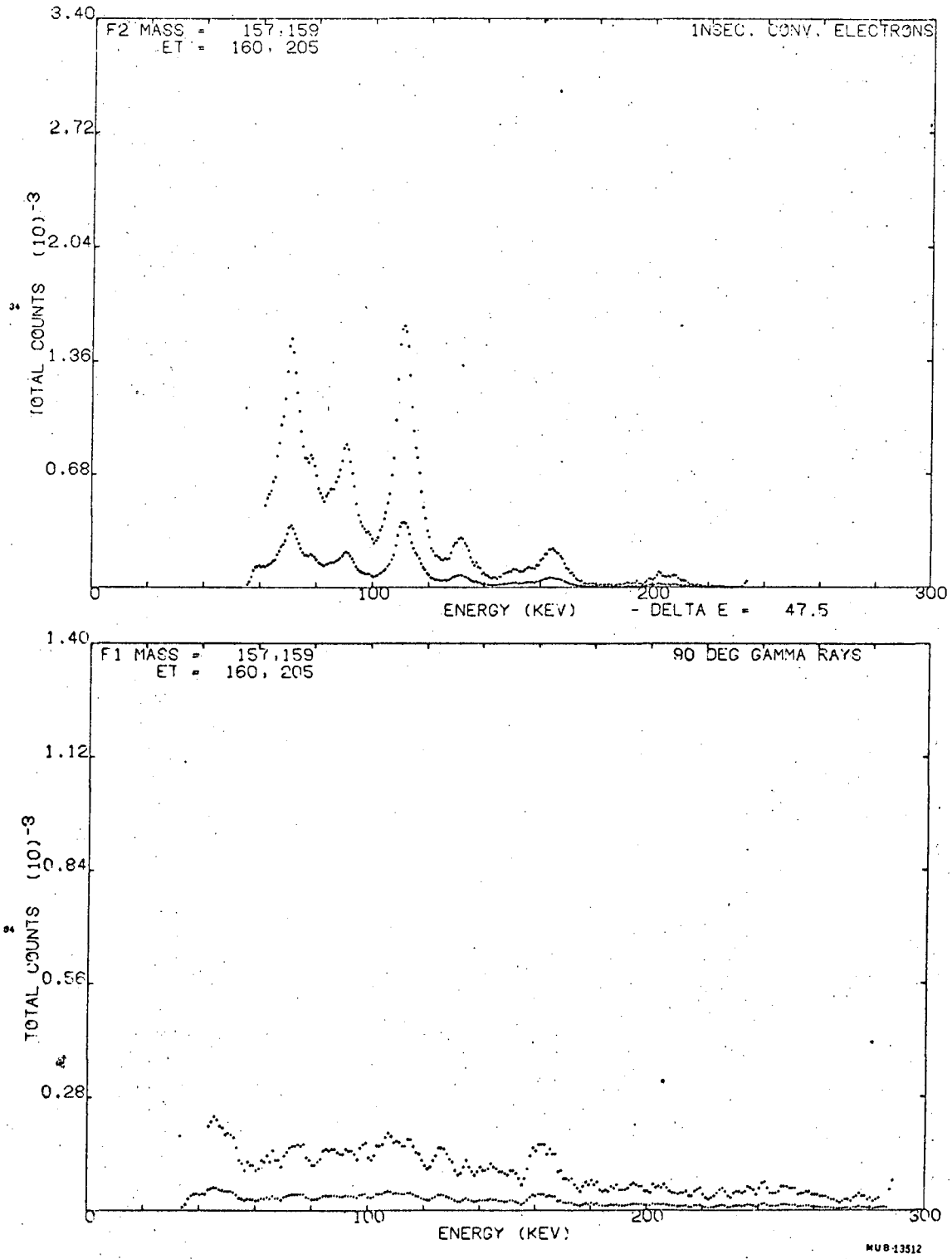
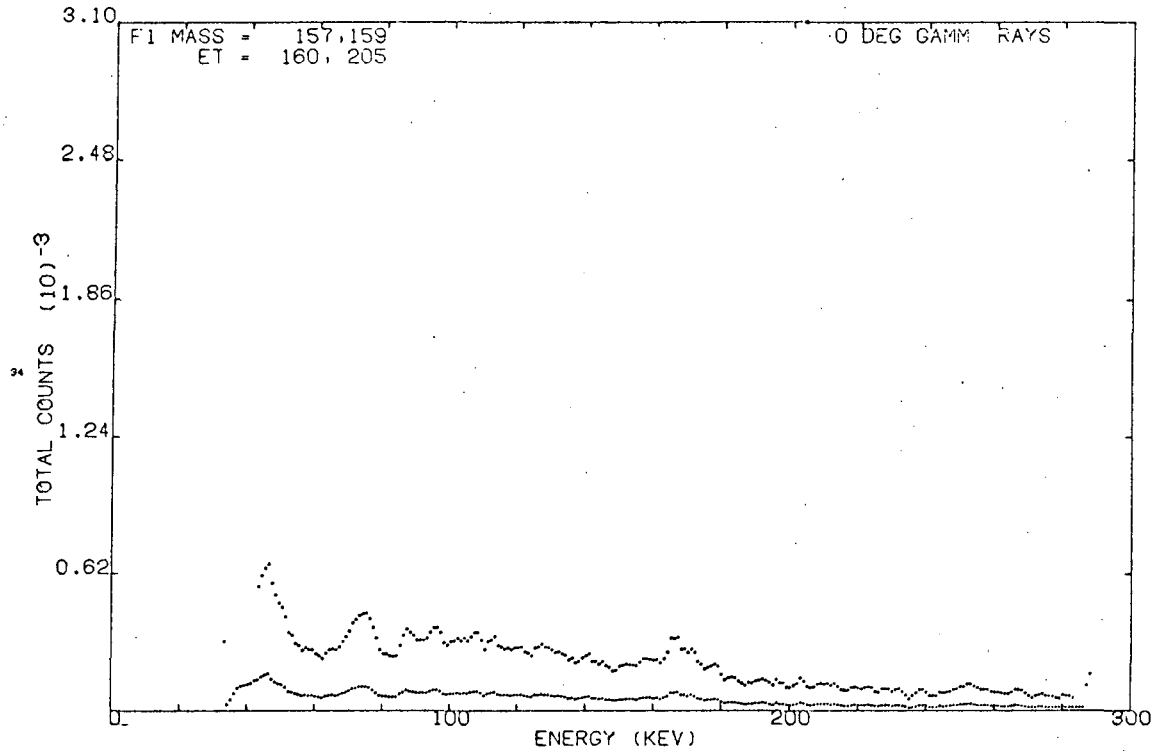

F2 MASS = 157,159
ET = 160, 205
INSEC. CONV. ELECTRONS
3.40
2.72
2.04
1.36
0.68
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
- DELTA E = 47.5
F1 MASS = 157,159
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13512

Fig. 49


F1 MASS = 157,159
ET = 160, 205
0 DEG GAMM RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)

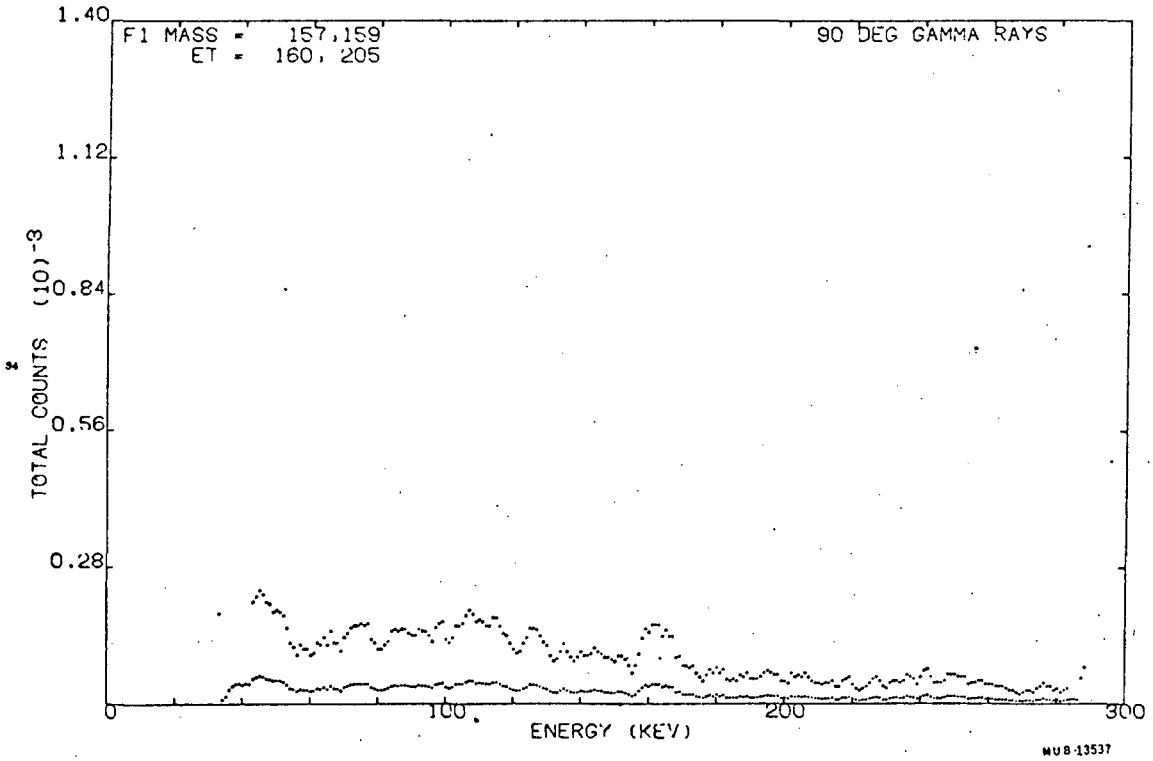

F1 MASS = 157,159
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13537

Fig. 50

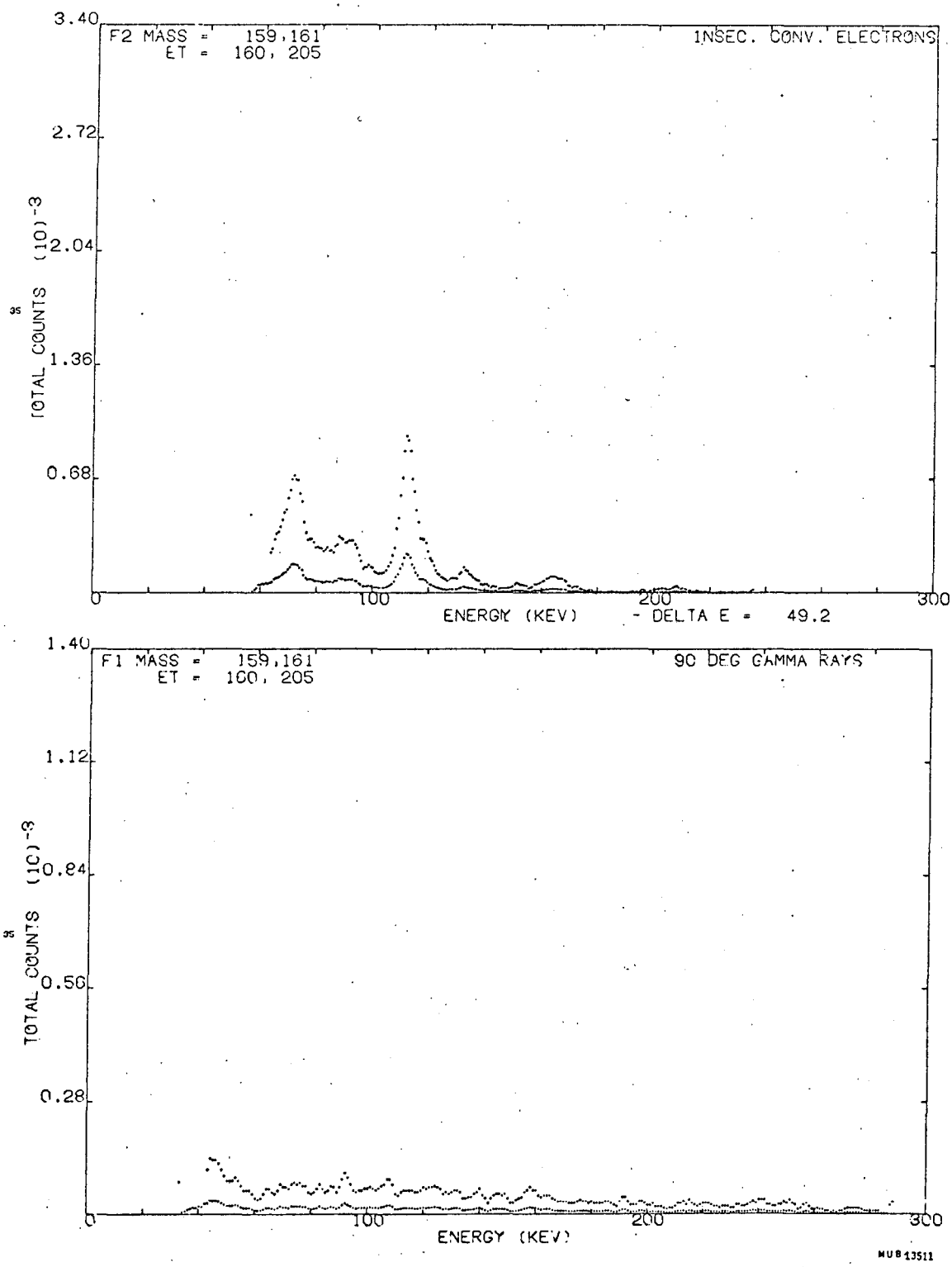
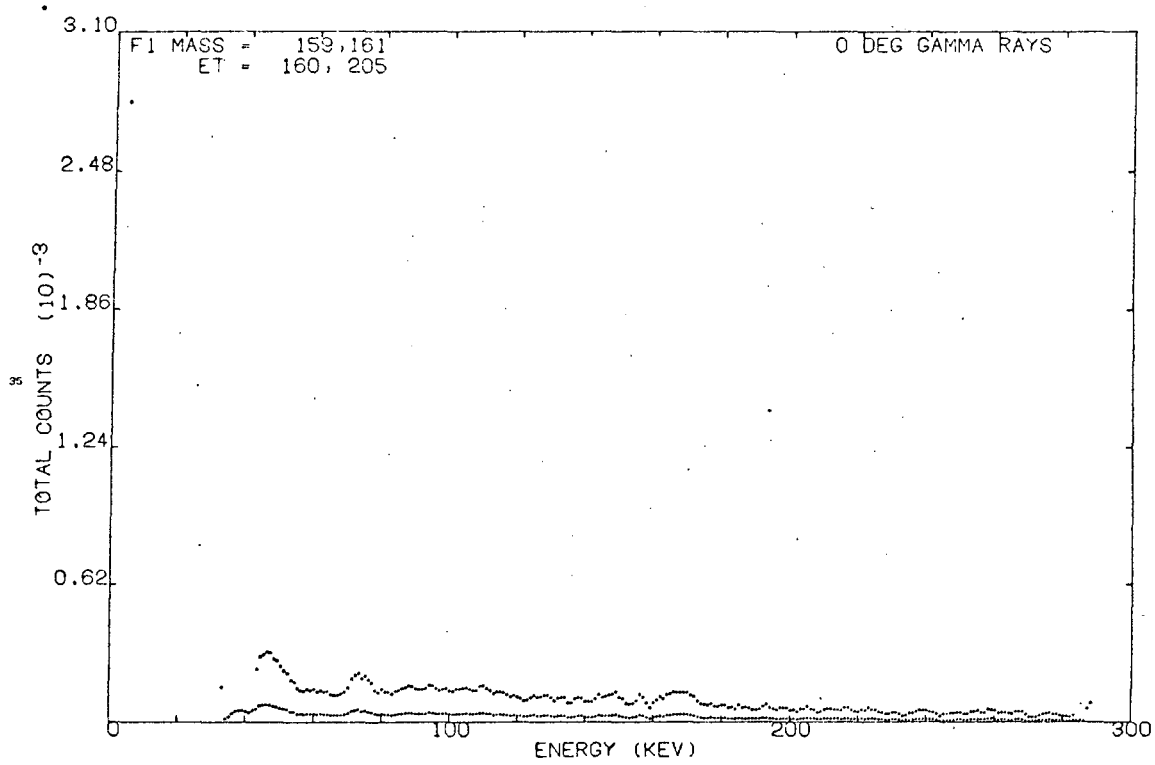

F2 MASS = 159,161
ET = 160, 205
INSEC. CONV. ELECTRONS
TOTAL COUNTS (10)-3
3.40
2.72
2.04
1.36
0.68
0
100
200
300
ENERGY (KEV) - DELTA E = 49.2
F1 MASS = 159,161
ET = 160, 205
90 DEG GAMMA RAYS
TOTAL COUNTS (10)-3
1.40
1.12
0.84
0.56
0.28
0
100
200
300
ENERGY (KEV)
MUB 13511

Fig. 51


F1 MASS = 159,161
ET = 160, 205
0 DEG GAMMA RAYS
3.10
2.48
1.86
1.24
0.62
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)

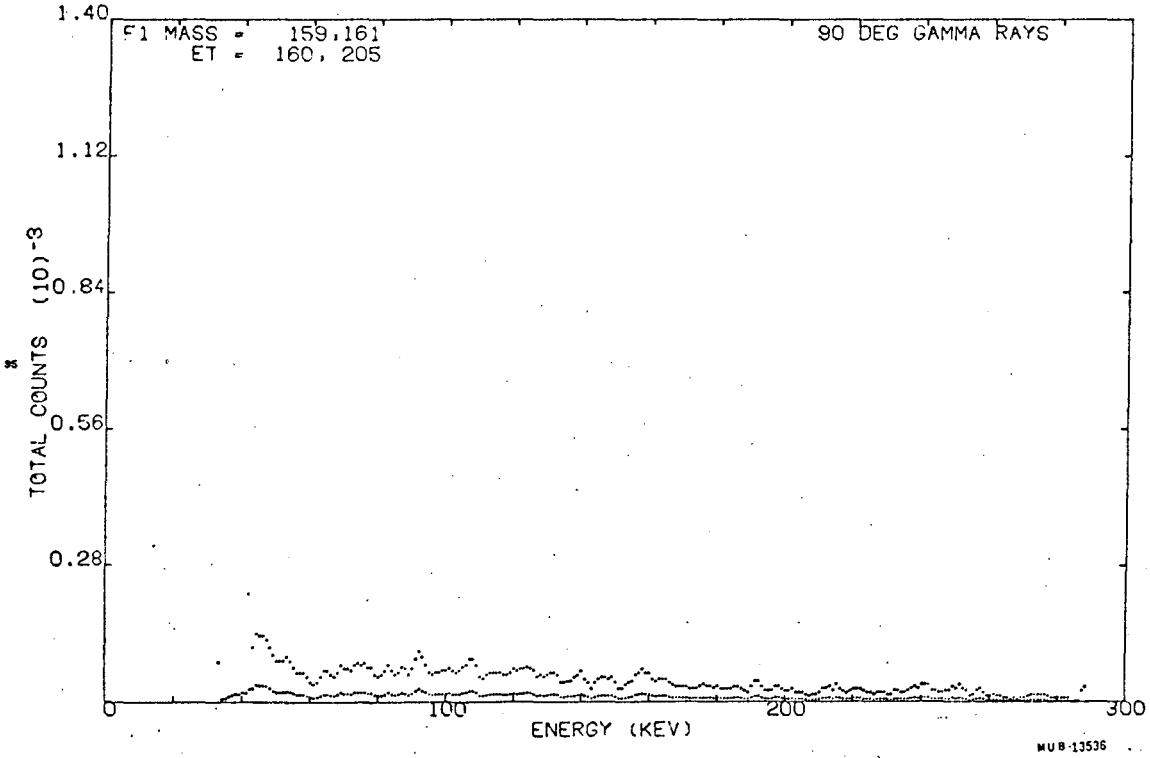

F1 MASS = 159,161
ET = 160, 205
90 DEG GAMMA RAYS
1.40
1.12
0.84
0.56
0.28
TOTAL COUNTS (10)-3
0
100
200
300
ENERGY (KEV)
MUB-13536

Fig. 52

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