XMM Optical Monitor

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Mid term Report-B on the life time estimation of FM-intensifiers

<< Intense illumination of DEP_#8 intensifier >>

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10. Light source

A new light source was made for brighter and more accurate illumination. The problems associated with the former light source are;
(a) The light source was a surface fluorescence panel driven by an AC 100V. It showed lickering synchronized with the 50Hz electric power.
(b) The fluorescence from the light source was a problem to measure dark current of an image intensifier.
(c) It was necessary to reduce brightness of the light source to calibrate absolute brightness of pinholes. The uniformity of the illumination was, however, not guarantied when a very low voltage was applied. This inhibited accurate calibration.
(d) The previous mask pattern employed 4 plastic ND1.2 filters to create brightness ratio of 1E+4.8 among the pinholes. It, however, could created only 1E+3, which was due to red leak of the cheap plastic ND filters.

The new light source employs 64 green LEDs to avoid fluorescence and flickering. The 64 LEDs were divided into 2 groups of 32 LEDs, and each of the 32 LEDs were connected together in series to be driven by one of the two identical current sources (see Fig 17). This approach allowed to handle only 100V DC in stead of 200V DC to light the 64 LEDs. The brightness can be changed to 10 fixed levels (+ dark). The 32 LEDs were covered with 4 sheets of diffuser to improve uniformity of the illumination (see Fig 18). A mask pattern with 11x11 pinhole array was located 46 mm above the diffuser. A green interference filter, whose pass band is 5300-5700A, was placed beneath the mask pattern to cut red leak through ND filters. Four ND filters were sticked beneath each of the columns in the pinhole mask pattern to create 11 different brightness levels. The two of the four were glass ND1.0 filters, whose extreme low red leak was measured and confirmed by the manufacture. Other two were the previously used plastic ND1.2 filters. The latter two definitely have red leak, but should not be a problem in the attenuation level of 1E+2.4 with the help of the green narrow band filter. The scattered light from the brightest pinholes overpowers the light from the faintest pinholes, because of the large difference of brightness (ratio=1.8E4). The brightest pinholes can be covered with an optional blackout material to obtain more accurate data for the faintest pinholes.

The 11x11 pinhole array was projected on right edge of the intensifier using a F/2 IPCS lens with the image reduction of 1.7. Diameter of the pinholes is 100um on the mask.

This relatively large diameter was for providing sufficiently high intensity from the individual pinholes. Since the image was suffered from optical aberration due to strong curvature of the detector window, the pinhole diameter of the projected image varied from 60 to 70um depending on the positions at the detector (best focused for the brightest pinholes). As the width of electron cloud inside the intensifier is 70-80um, the change of diameter hopefully does not affect results much.

The pinhole array images were acquired with the MIC photon counting detector to determine the absolute brightness of individual pinholes at the 10 LED brightness levels. CCD camera format of 256(H)x100(V) was employed to enhance dynamic rage of the MIC photon counting detector. It achieved the frame rate of 217.3251619Hz, in other word, the frame period of 4.6014ms. Since photons from a pinhole was missed during the frame transfer period, 0.2304ms, the duty ratio of was 94.993% (= 1 - 0.2304ms / 4.6014ms). Even with this fast frame rate, coincidence loss exceeds 10% if a pinhole emits in the rate of 50 events/sec. The dead time and the coincidence were corrected by the following equation,

$$x\_real = FR * \{ -\ln(1 - x\_det/FR) \} /(1 - FT/P)$$

where, x_det denotes detected events in a pinhole, x_real true number of events, FR the frame rate of the CCD camera, FT the duration of frame transfer, and P frame period of the CCD camera (ref. XMM-OM/ MSSL/TC/0050 Nov '98).

The maximum brightness ratio among the pinhole columns and that among the different LED currents are more than 1E+4. These are far beyond the coverage of the MIC detector. Therefore, brightness ratios between non-saturated pinholes only were determined at a LED brightness level. The ratios between other pinholes were measured by changing the LED brightness. The optional blackout material was used in these measurements when the LED brightness level was higher than 3. An extra blackout material was also placed above pinhole columns of medium brightness when the LED brightness level was higher than 7 to obtain best data for the faintest pinholes. The ratio of the faintest pinholes to the brightest ones was derived by connecting above ratios, as a final product. The procedure of brightness determination is described in table 13. The brightness ratios of individual columns to the 1st column are tabulated in table 14.

The brightness ratios at different LED currents were determined in the same manner. The results are tabulated in table 15.

Intense photon dose in this life time test was carried out with the new light source at the LED brightness level of 10. Count rate of individual pinholes and corresponding magnitude in terms of B0 star are listed in table 16. The highest illumination was 2E+6 c/s (5.6mag B0 star with the clear filter), which was 10 times as bright as that in the previous experiment.

Table 13. Column to column brightness ratios measured at different LED current level

Level	L=10	L=9	L=8	L=7	L=5	L=4	L=3	L=2	L=1
11									110.52
10									110.85
9								17.32	16.65
8								11.87	11.67
7					177.486	10.279	10.094	1.327	1.261
6					155.265	8.866	8.764	1.00*	1.00*
5				18.189	17.820	1.00*	1.00*		
4				9.065	8.885	0.4867			
3		1.807	1.801	1.920	1.807				
2	1.046	1.056	1.047	1.073	1.016				
1	1.00*	1.00*	1.00*	1.00*	1.00*				

Table 14. Brightness ratio among the pinhole columns

column	1	2	3	4	5	6	7	8	9	10	11
Brightness	1.00	1.05	1.80	9.00	18.0	160	183	1900	2700	17700	17700

Table 15. Brightness of LEDs at different current levels

Level	L=1	L=2	L=3	L=4	L=5	L=6	L=7	L=8	L=9	L=10
current	.02	.05	.10	.20	.49	.99	1.98	4.95	9.91	19.8 mA
Intensity	1.00	3.82	11.7	37.1	179	529	1600	6500	15600	31500

Table 16. Pinhole brightness at LED current level = 10

column	1	2	3	4	5	6	7	8	9	10	11
Brightness (c/s)	117	123	210	1050	2100	19k	21k	220k	320k	2070k	2070k
B0 star (mag)	16.2	16.2	15.6	13.8	13.1	10.7	10.6	8.0	7.6	5.6	5.6

Kawakami H. and Fordham J., "Flat Field coincidence loss in the MIC detector for XMM-OM", XMM-OM/MSSL/TC/0050 (1998).

Files used for this section
/depfm8/zpin507.dat
zpin527.dat - zpin537.dat
/depfm8/pincal.dat

11. Measurement

Three F-F images for reference were acquired in photon counting mode before starting the intense photon dose. They were illuminated by the blue LED (460nm) at the light level of 8,000-12,000 c/s /(18x18 mm2). CCD readout window was placed at the right edge of the detector to cover the whole 11x11 pinhole array image. The CCD camera format of 256(H) x100(V) was employed to achieve a fast frame rate, 217Hz. The individual CCD pixels were divided into 8x8 subpixels, which created the plate scale of 1 subpixel = 9.69um.

Pulse height distributions for reference were measured before starting the photon dose. The light source was the pinhole image. This lighting enabled to involve the exactly same pores of MCPs as those of the photon dose. The pulse height distributions were derived separately for the individual pinhole columns, 4-11. The brightest pinholes (column 10 and 11) were covered with the optional blackout material when measuring the pinhole columns 4-7.

The intense photon dose was carried out at the LED brightness level = 10, which provided pinhole illumination of 117 - 2,070,000 counts/sec/pinhole. The exposure time of the photon dose increased day by day, namely 18min for the 1st day, 42min the 2nd, 2 hours 3rd, 4 hours 4th, 8 hours 5th, 15 hours 6th, 20 hours 7th and 8th, and finally 30 hours in the 9th day. The total exposure time reached 100 hours.

Pulse height distributions for the individual columns were measured twice after each photon dose, i.e. within 1.5 hours after the illumination and on the following day.

Fluorescences were monitored with the time resolution of 5min until 30min since the end of illumination. Another series of fluorescence monitoring started later than 1.5 hours since the end of illumination. It continued until the next intense illumination with the time resolution of 2 hours . A 15 hours F-F image was acquired in photon counting mode, starting later than 24 hours since the end of illumination. The light source was the blue LED (460nm) tuned at the light level of 8,000-12,000 c/s /(18x18 mm2). Its integration was carried out in the middle of the fluorescence monitoring, since the fluorescence in the F-F had to be corrected for an accurate analysis. Both of F-F and fluorescence were acquired in photon counting mode with the CCD camera format of 256 (H) x100(V). 800(H)x800(V) pixels, which contains the whole 11x11 pinhole array image, were extracted out of full image, format 2048(H)x800(V) pixels, and were stored into a hard disk.

The detector was illuminated intensively for one minute between two long intense illuminations to gauge the remaining fuel for fluorescence (i.e. impure ions within the MCP pores). The subsequent fluorescences were monitored with time resolution of 5min until 30min since the end of illumination.

F-F images in analog mode, which include effects due to both of photocathode sensitivity loss and MCPs gain depletion, were sometimes measured.

All of experiments carried out are summarized in Appendix.

12. Fluorescence

A strong and long lasted fluorescences appeared after an intense illumination as shown in Fig. 19. This affects F-F images of this experiment, and may do a science data of XMM-OM if the telescope is pointed to a bright start even for a short time.

In order to identify the origin and mechanism of fluorescence, the intensifier was illuminated intensively several times with different photocathode voltages, and the subsequent fluorescences were monitored. The experiment procedures and evidences were;
i) The intensifier was intensively illuminated for 1 min with photocathode voltage = 0V and with MCPs ON. A dark image was integrated for 5min, starting at 30sec after the end of illumination, with photocathode voltage = 400V and with MCPs ON. No fluorescence was seen in the dark image (Zbin541.dat).
ii) The intensifier was intensively illuminated for 1 min with photocathode voltage = 400V and with MCPs ON. A dark image was integrated for 5min, starting at 30sec after the end of illumination, with photocathode voltage = 400V and with MCPs ON. A significant fluorescence was seen in the dark image (ZDrk542.dat).
iii) The intensifier was intensively illuminated for 10 min with photocathode voltage = 400V and with MCPs ON. A dark image was integrated for 5min, starting at 23min after the end of illumination, with photocathode voltage = 400V and with MCPs ON. Fluorescences were seen in the dark image (ZDrk574.dat). Next dark image was integrated for 10min, starting at 32min after the end of illumination, with photocathode voltage = 0V and with MCPs ON. Fluorescence was not seen in the dark image (ZDrk575.dat).

	illumination			image acquisition			fluorescence
	Vc	Vmcp	exposure	Vc	Vmcp	integration	
i)	0V	2250V	1min	400V	2250V	5min	None
ii)	400V	2250V	1min	400V	2250V	5min	seen
iii)	400V	2250V	10min	400V	2250V	5min	seen
				0V	2250V	10min	None

From the above 3 evidences, it is concluded that the fluorescence is originated in photocathode, which stores electrons generated by ion feedback from MCP pores and emitted slowly. The evidence (iii) ruled out the possibility of glow within MCP pores. The evidence (i) ruled out the possibility of glow at detector window or at photocathode generated by the input photons.

The 11x11 array of fluorescence spots were averaged along the columns to improve S/N. Then, the acquired events within central D=21 twixels (= 407um) circular region were summed up to determine whole fluorescence from a spot. Background dark current was determined from 37x37 square twixels (=717um) region excluding the D=21 twixels circle, and was subtracted. Figs. 20a-20c show time profiles of fluorescence until 10 hours since the end of illuminations. The count rate was pretty high, 8000 counts/hour/spot, in the first 5min when illuminated for 42 min by the 2E+6 c/s pinholes in the 4th day (Fig. 20a). The fluorescence of this short duration component decreased to 1/10 in 1 hour. The short duration component did not depend much on the illumination period. For instance, a 10 min illumination in the 1st day created fluorescence of 3700 counts/hour/spot in the 2nd 5 min, while 4 hours illumination in the 4th day 4100 counts/hour/spot in the 2nd 5 min (Fig. 20b). The fluorescence in the 9th day even faded due to exhaustion of fuel after the 100 hours scrubbing (Fig. 20c).

The fluorescence of short duration component is followed by long duration component (Figs. 21a-21c), which did not emit intensively but remained to emit 100 counts/hour/spot even 1 day after an illumination. This component increased significantly with illumination period as shown in Figs 21a and 21b (42 min and 4 hours illuminations). Further long illumination period of 30 hours, however, did not (Fig. 21c). The fluorescence rather faded due to the lack of fuel.

One minute intense illuminations were carried out between two long illuminations to gauge the remaining fuel. Subsequent fluorescences were monitored for 25min (5 x 5min). The monitoring was always started at 30 seconds after the 1 min illumination. The 11x11 array of fluorescence spots were averaged along the columns to improve S/N. The day by day change of the averaged spots is shown in Fig. 22. Right hand side of the fluorescence profile disappeared gradually. By this effect, the centre of gravity of the fluorescence, which coincided with pinhole position in the 1st day, shifted toward left by 4 twixels (= 77.5um) in the last day. Fig. 23 shows fluorescence profile at the column 11 (2E+6 c/s illumination) along different days. The fluorescence decreased with the days. Fig. 24 shows fluorescence count rate normalized by that in the 1st day. The figure suggests ion feedback decreased after 1E+9 dose events.

Fig. 25 shows the day by day change of the fluorescence profile of the long duration component. The fluorescences were started to be integrated later than 1.5 hours since the end of the long illuminations. The 11x11 array of fluorescence spots were added together along the columns. Since the integration period, start of the integration, and illumination period were different day by day, the absolute intensity of the spots do not have meaning. Therefore, the intensities of fluorescence profile were normalized by the spots at columns 10 and 11 for each day. The poor S/N of the 5th day was due to break down of the MIC electronics for a whole day. The image acquisition re-started at 21 hours since the end of illumination and total integration period was only 6 hours.

The width of fluorescence increased with time. The profile at the columns 8-11 eventually got black hole in the centre. The position of the black hole coincides with the pinhole position. The long duration component showed non-linearity against estimated ion feedback. For instance, the intensities of fluorescence at columns 8 - 9 (220k-320k c/s) are nearly same as those at columns 10 - 11 (2070 kc/s). Within a profile, wing part is enhanced. The short decay component did not show the doughnut shape, mentioned above, since it had not extended wing in profile. Fig. 26 shows profiles of the long and the short duration components after completing the 100 hours photon dose. The difference between the 2 components is clear.

The correction of fluorescence was essential to assess sensitivity loss in a photon counting F-F image in this experiment, even if the F-F was acquired 1 day after illumination. Two adjacent dark images, before and after a F-F, were used for estimating fluorescence in the F-F. Then, the impact on sensitivity loss at peak and average were calculated consulting with the standard profiles shown Fig. 25. The corrections for peak and average were, for instance, 1% at the brightest pinhole positions in the F-F on the 4th day, whose acquisition was started at 26 hours since the end of illumination. The F-F image on the fist day was unusual, because its acquisition was carelessly started only 3 hours later the end of illumination. The corrections were 3.7% and 2.6% for peak and average. The correction became smaller in the latter days both for peak and average, because of the exhaustion of fuel.

A dark image was integrated for 5 min, starting at 1 min after an 1min illumination on the 1st day, while the other dark integration was started 30 sec after the other 1min illumination. Impulsive component of the fluorescence was derived by differentiating these 2 dark images. Fluorescence from the 2E+6 c/s pinholes were 375 counts/spot during the elapsed time of 0.5-5.5 min since the end of illumination, 300 counts/spot during 1.0-6.0 min , and 12 counts/spot during 5.5-6.0 min. These led that fluorescence of 87 counts/spot (10000 c/hour/spot) was emitted during the impulsive period, 0.5-1.0 min.

The 1min intense illuminations were followed by a 2min and a 10min illuminations in the 1st day to investigate the dependence of fluorescence on illumination period. The fluorescence in the 1st 5min after the 1 min illumination was 56% of that after the 10min illumination for the 2E+6 c/s pinholes, and the 2 min illumination was 75%. It is extrapolated that a 10sec illumination by 2E+6 c/s pinholes causes fluorescence of 95 counts in the 1st 5min. Therefore, it is safer not starting observation for more than 5min if 5.6mag star is accidentally captured by the OM-telescope.

No fluorescence was detected after 30 hours illumination with the intensity of 2.1 kc/sec/pinhole (13.1mag B0 star). A little fluorescence was, however, seen in the long duration component after 4 hours illumination with the intensity of 19 kc/sec/pinhole (10.7mag B0 star).

Ref-12 Files used for this section
/depfm8/Zbin541.dat
ZDrk542.dat - Zdrk575.dat
ZDrk579.dat, ZDrk581.dat, ZDrk584.dat
ZDrk588.dat - ZDrk592.dat
ZDrk594.dat - ZDrk596.dat
ZDrk599.dat, ZDrk601.dat
ZDrk602.dat - ZDrk606.dat
ZDrk611.dat - ZDrk619.dat
ZDrk622.dat, ZDrk624.dat
ZDrk625.dat - ZDrk629.dat
ZDrk631.dat - ZDrk641.dat, ZDrk644.dat
ZDrk645.dat - ZDrk663.dat
ZDrk665.dat, ZDrk667.dat, ZDrk669.dat, ZDrk670.dat,
ZDrk671.dat - ZDrk675.dat
ZDrk678.dat - ZDrk684.dat
ZDrk686.dat - ZDrk695.dat
ZDrk697.dat - ZDrk699.dat, ZDrk701.dat
ZDrk702.dat - ZDrk706.dat
ZDrk709.dat - ZDrk713.dat
ZDrk715.dat - ZDrk727.dat
ZDrk729.dat, ZDrk730.dat, ZDrk732.dat, ZDrk734.dat,
ZDrk735.dat - ZDrk740.dat
ZDrk744.dat - ZDrk749.dat
ZDrk751.dat - ZDrk753.dat, ZDrk755.dat, ZDrk757.dat
ZDrk759.dat - ZDrk763.dat
ZDrk767.dat - ZDrk772.dat
ZDrk773.dat - ZDrk777.dat
ZDrk779.dat - ZDrk789.dat
ZDrk792.dat, ZDrk794.dat, ZDrk795.dat
ZDrk797.dat - ZDrk799.dat
ZDrk801.dat, ZDrk803.dat, ZDrk808.dat
ZDrk811.dat - ZDrk815.dat
ZDrk817.dat - ZDrk819.dat, ZDrk821.dat, ZDrk822.dat
ZDrk824.dat - ZDrk839.dat
ZDrk841.dat - ZDrk843.dat
ZDrk846.dat - ZDrk848.dat
ZDrk851.dat, ZDrk852.dat
ZDrk855.dat - ZDrk863.dat
ZDrk867.dat - ZDrk871.dat
ZDrk874.dat - ZDrk878.dat, ZDrk880.dat

13. Gain depletion of MCPs

Pulse height distributions (hereafter, PHD) for individual columns, 4-11 (2E+3-2E+6 c/s), in the pinhole array were measured twice after each photon dose, i.e. within 1.5 hours after the illumination and on the following day. The recovery on the following days was significant in the earlier days for the weaker illumination. Pulse height distribution was also monitored for half month after completing this photon dose test. Recoveries of 3-5% were seen.

Fig. 27a shows the original PHD before the dose and the one after 100 hours photon dose by the 2E+6 c/s pinholes. The gain reduced to 1/3 of the original. Fig. 27b shows the same PHDs, but the one after the 100 hours dose was expanded along abscissa for comparison. Wing profile in high energy side of the expanded PHD looks similar to the non-dosed PHD, but valley in the lower energy side disappeared. The gain depletions throughout this experiment were quantified from peak positions of the PHDs. The peak shape of the PHD, however, became fuzzy if the gain depletion was too strong as shown in the figure. Therefore, the gain depletion was determined manually by looking at wing in high energy side, when the gain was lower than 0.4 of the original.

Day by day change of MCP gain is tabulated in Table 17. The results are plotted against integrated dose events as shown in Fig. 28. The gain decreased more slowly for the higher intensity pinholes. This is due to pore paralysis of MCPs. It will be helpful for modelling if the gain depletion could be plotted against accumulated anode current, in stead of accumulated dose events (ref. James(1998)).

The threshold level for event detection in the photon counting imaging was modified from 30ADU to 15ADU during XMM-OM project. This experiment employed threshold level of 15ADU for most of image acquisition. This change rescued many photons, which were supposed to be lost after the severe gain depletion in the former threshold level. The last 7 F-F images were acquired in even lower threshold level, 8ADU, to separate photocathode sensitivity loss more clearly from the effect of gain depletion. The event losses due to the gain depletion were calculated with the both threshold levels, 15ADU and 8ADU, and were tabulated in Table 18.

The gain depletion for DEP's QM-intensifier was plotted in the same scale in Fig. 29. It did not contain very high intensity illumination (2E+6 c/s), but medium to low intensity illuminations showed that the QM-intensifier decreased gain more slowly by 50%.

Table 17. Gain depletion (fitted by hand, if gain < 0.4)

Total dose (hour)		Pinhole intensity (counts/sec) 1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
0.3	I,*	.918,	.947,	.957,	.949,	.922,	.908,	.855,	.836,
0.3	D,*	.999,	.971,	.977,	.968,	.927,	.922,	.847,	.854,
1.0	I,	.978,	.968,	.943,	.928,	.872,	.850,	.751,	.765 ,
1.0	D,	.997,	.993,	.973,	.964,	.875,	.874,	.774,	.785,
3.0	I,	.954,	.946,	.885,	.894,	.779,	.756,	.662,	.663,
3.0	D,	.999,	.965,	.925,	.925,	.815,	.783,	.685,	.687,
7.0	I,	.952,	.902,	.842,	.844,	.726,	.694,	.572,	.567,
7.0	D,	.930,	.917,	.835,	.854,	.721,	.677,	.572,	.581,
15.0	D,	.875,	.847,	.741,	.741,	.638,	.609,	.452,	.493,
30.0	I,	.908,	.878,	.713,	.705,	.522,	.501,	.392,	.408,
30.0	D,	.884,	.869,	.718,	.718,	.540,	.510,	.408,	.408,
50.0	I,	.870,	.837,	.636,	.649,	.465,	.439,	.317,	.345,
50.0	D,	.889,	.853,	.674,	.671,	.500,	.465,	.339,	.351,
70.0	I,	.826,	.793,	.588,	.586,	.400,	.385,	.260,	.278,
70.0	D,	.840,	.826,	.606,	.609,	.435,	.400,	.286,	.299,
100.0	I,	.825,	.768,	.540,	.541,	.351,	.347,	.238,	.238,
100.0	D,	.836,	.800,	.590,	.585,	.385,	.357,	.238,	.250,
100.0	3D,	.832,	.797,	.591,	.584,	.385,	.370,	.250,	.270,
100.0	4D,	.858,	.823,	.611,	.610,	.408,	.392,	.263,	.286,
100.0	5D,	.867,	.833,	.618,	.613,	.417,	.392,	.278,	.290,
100.0	8D,	.848,	.802,	.585,	.595,	.417,	.385,	.278,	.286,
100.0	10D,	.861,	.827,	.622,	.621,	.435,	.426,	.294,	.294,
100.0	11D,	.871,	.827,	.629,	.646,	.435,	.412,	.294,	.303,
100.0	15D,	.862,	.828,	.642,	.639,	.435,	.417,	.303,	.308,
100.0	17D,	.874,	.847,	.630,	.629,	.444,	.426,	.290,	.303,
100.0	19D,	.866,	.820,	.643,	.641,	.455,	.417,	.294,	.313,

Note) I: PHD was measured Immediately after intense illumination
xD: PHD was measured x Days after intense illumination

Table 18. Sensitivity loss due to gain depletion

Total dose (hour)		Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
				(Threshold = 15 ADU)							
0.3		.000	.000	.000	.002	.001	.002	.004	.005	.007	.009
1.0		.000	.000	.000	.000	.002	.002	.007	.009	.012	.013
3.0		.000	.000	.000	.002	.005	.005	.011	.017	.018	.020
7.0		.000	.000	.006	.006	.010	.010	.018	.027	.030	.031
15.0		.000	.000	.010	.012	.016	.019	.026	.036	.054	.048
30.0		.000	.000	.009	.010	.018	.021	.039	.053	.068	.073
50.0		.000	.000	.008	.011	.022	.025	.047	.063	.099	.098
70.0		.000	.000	.012	.014	.030	.033	.065	.086	.140	.134
100.0	1D	.000	.000	.013	.016	.032	.036	.083	.105	.195	.186
100.0	3D	.000	.000	.013	.016	.032	.036	.083	.099	.180	.162
100.0	4D	.000	.000	.011	.014	.029	.032	.073	.088	.163	.145
100.0	5D	.000	.000	.010	.013	.028	.032	.070	.088	.148	.142
100.0	8D	.000	.000	.012	.016	.032	.035	.070	.092	.148	.145
				(Threshold = 8 ADU)							
100.0	8D	.000	.000	.000	.000	.000	.000	.015	.023	.037	.039
100.0	10D	.000	.000	.000	.000	.000	.000	.012	.016	.033	.036
100.0	11D	.000	.000	.000	.000	.000	.000	.012	.019	.033	.033
100.0	15D	.000	.000	.000	.000	.000	.000	.012	.018	.030	.032
100.0	17D	.000	.000	.000	.000	.000	.000	.011	.016	.034	.033
100.0	19D	.000	.000	.000	.000	.000	.000	.010	.018	.033	.031

Ref-13
James A. "A fast plasma analyser for the study of solar wind interaction with Mars", PHD thesis for UCL (1998).

Files used for this section
/depfm8/ZPHD539.dat
ZPHD578.dat, ZPHD582.dat, ZPHD593.dat, ZPHD597.dat
ZPHD607.dat, ZPHD620.dat, ZPHD630.dat, ZPHD642.dat
ZPHD664.dat, ZPHD685.dat, ZPHD696.dat
ZPHD714.dat, ZPHD728.dat, ZPHD750.dat, ZPHD754.dat
ZPHD778.dat, ZPHD790.dat, ZPHD800.dat, ZPHD804.dat
ZPHD809.dat, ZPHD823.dat, ZPHD844.dat, ZPHD849.dat
ZPHD864.dat, ZPHD872.dat, ZPHD882.dat

14. Sensitivity loss in photon counting image

A F-F image with the blue LED (460nm) was integrated for 15 hours in photon counting mode after each intense illumination to see the impact on science image. The integration started at the elapsed time of >24 hours after the illuminations (except in the 1st day) to avoid fluorescence. Fig. 30 shows 2 raw F-F images, one taken prior to the photon dose for reference and the other after the 100 hours dose. The F-F after the dose clearly shows an array of black spots corresponding to the pinhole positions.

A F-F image in each day of photon dose was divided by the reference F-F to remove detector artefacts and illumination non-uniformity. Then, the 11x11 array of black spots were averaged along the columns to improve S/N. Central positions of the black spots coincided with pinhole positions in the accuracy of 10um. The day by day growth of the black spots is shown in Fig. 31. These images contain all factors, i.e. fluorescence, gain depletion and photocathode sensitivity loss. White spots appeared at 2E+6 c/s pinhole positions in the 1st day, as the fluorescence dominated photocathode sensitivity loss and MCPs gain depletion. The black spots are seen for the illumination intensities of > 19kc/s after the 100 hours dose but not obvious for the illumination intensities of < 2.1kc/s. This is big improvement from the DEP-QM intensifier, in which black spots were clearly seen for the illumination intensities of 0.8kc/s after 21 hours dose (ref. XMM-OM/MSSL/TC/0044). Fig. 32 shows profiles of the averaged black spots from the 5th to the 9th days. Y-width of the slice is 3 twixel (= 58um). Since the integrations were started after the decay of fluorescence for these 5 F-Fs, the peak depths were not affected by fluorescence more than 0.8%. The depth of black spots reached 30% for the brightest illumination after 100 hours dose.

The sensitivity loss at the peak position was quantified from the average of 3x3 twixels square centred on the black spots. The normalization level was determined from 37x37 twixels (=717um) square excluding central D=21 twixels circular area. Then, the effect of fluorescence (3.8% in maximum) was subtracted. The results were tabulated in Table 19 and were plotted against accumulated dose events in Fig. 33. The sensitivity did not decrease up to 1E+8 dose events. It started to decrease steeply from 1E+10 dose events. The sensitivity decreased more slowly for the brighter pinholes. This is again the effect of pore paralysis.

The sensitivity loss for DEP's QM-intensifier was plotted in the same frame as shown in Fig. 34. The QM-intensifier lost sensitivity by 3% at 3E+7 dose events, while the DEP_# 8 intensifier did not up to 3E+9 dose events. The ruggedness of DEP_#8 intensifier is clear at the lower dose events.

The sensitivity loss in F-F image was averaged over central D=210um (=11 twixels) circular area to characterize spatial extent of damage as well as the depth. The results are tabulated in Table 20 and plotted in Fig. 35 after the correction of fluorescence.

A Gaussian profile was fitted to deep black spots to investigate the spatial extent directly. The results are tabulated in Table 21 and shown in Fig. 36. The width of the black spots increased with accumulated dose events. It started from 80um(FWHM) and reached 120um after acquiring 1E+12 dose events.

The sensitivity loss seen in F-F image is the combination of gain depletion and photocathode sensitivity loss. The photocathode sensitivity losses were calculated by removing the effect of gain depletion. The results were tabulated in Table 22 and were shown in Fig. 37. The sensitivity loss of photocathode is not obvious up to 1E+9 dose events. The plot has large scatter at larger dose events, since the calculation becomes less accurate when the gain depletion is large. For instance, 20% of photo-events were lost due to the gain depletion at 2E+6 c/s pinhole position after 100 hours dose.

Table 19. Sensitivity decrease in blue F-F at peak

Total dose (hour)	Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
0.3	.996	1.004	.989	1.000	.996	.991	.994	.984	.979	.981
1.0	.994	.980	.990	.983	.986	.992	.999	.988	.980	.983
3.0	.997	1.003	.996	1.000	.983	.986	.981	.967	.968	.971
7.0	.997	1.002	.998	1.012	.971	.981	.963	.961	.911	.928
15.0	.998	.995	.984	1.000	.970	.975	.934	.937	.870	.894
30.0	.999	1.002	.988	1.001	.954	.960	.905	.896	.785	.821
50.0	.994	.992	.984	.990	.942	.950	.883	.878	.747	.779
70.0	1.009	.996	.979	.990	.929	.917	.844	.836	.667	.694
100.0 1D	.996	1.000	.974	.979	.932	.925	.824	.819	.623	.665
100.0 2D	1.003	.980	.976	.981	.942	.938	.881	.848	.652	.698
100.0 5D	1.001	.990	.979	.981	.948	.944	.879	.852	.663	.713

Table 20. Sensitivity decrease in blue F-F averaged over D=213um circular area

Total dose (hour)	Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
0.3	.996	.999	1.001	.997	.998	1.000	.996	.994	.992	.989
1.0	.998	1.001	1.000	.998	.995	.994	.995	.989	.991	.991
3.0	.998	.998	1.000	1.000	.997	.998	.994	.989	.993	.988
7.0	.997	.997	1.004	1.000	.997	.994	.989	.983	.972	.973
15.0	.996	.994	1.002	.999	.996	.992	.980	.974	.956	.952
30.0	.995	.994	1.004	.998	.987	.988	.968	.958	.925	.924
50.0	.994	.995	1.000	.995	.983	.986	.959	.952	.906	.906
70.0	1.000	.990	.999	.992	.980	.976	.946	.939	.872	.875
100.0 1D	.996	.995	.999	.992	.974	.975	.934	.925	.846	.846
100.0 2D	.997	.993	1.000	.993	.980	.978	.942	.930	.855	.858
100.0 5D	.997	.994	.999	.996	.983	.984	.948	.938	.868	.874

Table 21. Gaussian width of depletion profile in blue F-F (FWHM, um)

Total dose (hour)	Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
0.3	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
1.0	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A	N/A
3.0	N/A	N/A	N/A	N/A	N/A	N/A	87.6	85.2	75.8	59.3
7.0	N/A	N/A	N/A	N/A	N/A	N/A	83.6	91.0	91.8	84.1
15.0	N/A	N/A	N/A	N/A	N/A	N/A	92.0	106.0	101.0	97.7
30.0	N/A	N/A	N/A	N/A	N/A	N/A	95.3	104.1	111.8	104.9
50.0	N/A	N/A	N/A	N/A	N/A	N/A	102.2	106.5	117.0	113.2
70.0	N/A	N/A	N/A	54.4	88.9	85.8	109.9	110.8	123.8	114.5
100.0 1D	N/A	N/A	45.7	83.1	90.1	112.7	103.2	111.5	122.1	122.8
100.0 2D	N/A	N/A	58.7	88.0	79.5	105.3	105.1	111.0	124.2	121.0
100.0 5D	N/A	N/A	55.8	129.2	77.2	101.0	103.6	112.3	124.3	118.1

Table 22. Photocathode sensitivity decrease at peak

Total dose (hour)	Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
0.3	.996	1.004	.989	1.002	.997	.993	.998	.989	.986	.989
1.0	.994	.980	.990	.983	.988	.994	1.006	.997	.992	.996
1.0	.994	.980	.990	.983	.988	.994	1.006	.997	.992	.996
3.0	.997	1.003	.996	1.002	.988	.991	.992	.984	.986	.991
7.0	.997	1.002	1.004	1.018	.981	.991	.981	.988	.939	.958
15.0	.998	.995	.994	1.012	.986	.994	.959	.972	.920	.939
30.0	.999	1.002	.997	1.011	.972	.980	.942	.946	.842	.885
50.0	.994	.992	.992	1.001	.963	.975	.926	.937	.829	.864
70.0	1.009	.996	.991	1.004	.958	.948	.903	.915	.776	.801
100.0 1D	.996	1.000	.986	.995	.963	.959	.899	.915	.774	.817
100.0 2D	1.003	.980	.989	.997	.973	.973	.961	.942	.795	.833
100.0 5D	1.001	.990	.989	.994	.975	.975	.945	.934	.778	.831

Ref-14
Kawakami H. "The DEP chevron image intensifier tube", XMM-OM/MSSL/TC/0044 (1997).

Files used for this section
/depfm8/ZDEP580.dat, ZDEP600.dat, ZDEP623.dat, ZDEP643, ZDEP668
ZDEP700.dat, ZDEP733.dat, ZDEP756.dat
ZDEP793.dat, ZDEP796.dat, ZDEP810.dat

15. Photocathode sensitivity loss at different colours

After completing the 100 hours photon dose, F-F images with red and green LEDs were acquired in photon counting mode to assess colour dependence of photocathode damage. The gain depletion of MCPs for the >320 kc/s illumination was very severe at 1 day after the illumination, and was dominant cause of sensitivity loss (10-20%) in the F-F images. Fortunately, the gain recovered slowly in a week, and lightened the effect on the F-Fs. All F-Fs analyzed in this section were acquired later than 5 days after completing the 100 hours dose. These F-Fs were free from fluorescence, as the elapsed times were sufficiently long.

The 11x11 array of black spots in the F-F images were averaged along the columns (Fig. 38). Fig. 39 shows the slices of the black spots in the three colours. Both of depth and width are largest in red. Although the gain depletion was still recovering very slowly, these profiles should be very close to permanent sensitivity loss.

Fig. 40 shows sensitivity loss at depletion peak in the blue, green and red F-F images. Fig. 41 shows sensitivity loss averaged over D=210um circular area. Figs. 42 shows widths of the black spots in the F-F images. These results are tabulated in Tables 23, 24 and 25. It should be noted that the sensitivities must have decreased more slowly for the brighter pinholes due to pore paralysis, but they are not visible in these figures. The sensitivity loss is more severe in the longer wavelength. The loss at peak reached 46% in red for the brightest pinholes, while 36% in green and 32% in blue. The colour dependence of spot width is also clear. The growth of width is largest in red covering 50-195um (FWHM), while 50-125um in blue (see Fig.36).

It is necessary to remove the effect of gain depletion to estimate the photocathode sensitivity loss from a F-F image. To improve the estimation accuracy, F-F images were acquired with threshold level of 8 ADU in stead of the standard 15 ADU. This reduces the effect of the gain depletion on photon counting images (Table 18), although it might have sacrificed centroiding accuracy and picked up low energy noise events. Since F-F images in the 3 colours were acquired later than 10 days after end of the 100 hours dose, the effects of fluorescence were negligible. The detector was illuminated for one minutes for the fuel test at 8 days after the dose, but it did not affect the F-F images by fluorescence as the illumination period was short.

The 11x11 array of black spots in the F-F images were averaged along the columns (Fig. 38). Fig. 43 shows the slices of the black spots in the three colours. Since effects of gain depletion on the photon counting images were less than 4% even for the highest illumination position, the depth and profile of the black spots approximately show photocathode damage. Then, the sensitivity losses at peak in the 3 colours were estimated by removing the tiny effect of gain depletion, and were plotted in Fig. 44 and tabulated in Table 26. The widths of the black spots are plotted in Fig. 45 and tabulated in Table 27. The photocathode sensitivity loss at peak reached 36% in red for the brightest pinholes, while 27% in green and 20% in blue. The colour dependence of spot width is again clear. Width of photocathode damage is slightly broader than that in F-F image, but almost same. The width at the highest illumination position is 210um (FWHM) for red light, while 130um for blue. The photocathode damage is more sever in the longer wavelength.

Table 23. Sensitivity decrease in F-Fs at peak

Total dose (hour)	Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
Blue										
100.0 hr	1.002	.993	.979	.983	.951	.945	.876	.850	.657	.698
Green										
100.0 hr	.995	1.002	.981	.991	.930	.933	.836	.825	.629	.655
Red										
100.0 hr	.999	.988	.975	.975	.943	.936	.832	.807	.530	.550

Table 24. Sensitivity decrease in F-Fs averaged over D=210um circular area

Total dose (hour)	Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
Blue										
100.0 hr	.998	.997	.999	.998	.985	.983	.946	.937	.865	.864
Green										
100.0 hr	.999	.997	.999	.996	.976	.980	.937	.928	.832	.830
Red										
100.0 hr	.996	.997	1.000	.994	.979	.975	.915	.908	.738	.729

Table 25. Gaussian width of depletion profile in F-Fs (FWHM, um)

Total dose (hour)	Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
Blue										
100.0 hr	N/A	N/A	52.7	137.7	72.8	98.8	104.5	114.7	126.3	122.3
Green										
100.0 hr	N/A	N/A	52.0	114.1	96.0	104.8	111.6	117.2	146.7	147.8
Red										
100.0 hr	N/A	N/A	53.0	95.9	88.2	106.8	135.3	145.6	195.7	194.6

Table 26. Photocathode sensitivity decrease at peak after 100 hours dose

Total dose (hour)	Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
Blue										
100.0 hr	.992	1.002	.984	.998	.954	.947	.897	.897	.756	.807
100.0 hr	.990	.998	.971	.984	.950	.952	.899	.913	.781	.842
100.0 hr	1.003	.990	.982	.996	.968	.964	.931	.929	.754	.831
Green										
100.0 hr	.988	.998	.980	1.000	.951	.947	.879	.891	.696	.763
Red										
100.0 hr	.991	.996	.982	.993	.939	.951	.852	.865	.598	.657
100.0 hr	.996	.990	.981	.961	.957	.947	.896	.891	.591	.667
100.0 hr	.992	.998	.986	.998	.952	.949	.870	.874	.623	.680

Table 27. Gaussian width at phtocathode damage (FWHM, um) after 100 hours dose

Total dose (hour)	Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
Blue										
100.0 hr	N/A	N/A	N/A	N/A	81.6	104.7	104.7	107.1	128.0	128.4
100.0 hr	N/A	N/A	N/A	N/A	93.5	109.7	116.4	113.7	126.6	135.2
100.0 hr	N/A	N/A	N/A	N/A	58.5	101.7	99.3	118.7	133.4	133.6
Green										
100.0 hr	N/A	N/A	N/A	N/A	78.8	106.3	109.1	112.0	148.2	156.1
Red										
100.0 hr	N/A	N/A	N/A	N/A	79.1	114.1	143.3	144.5	205.1	205.5
100.0 hr	N/A	N/A	N/A	N/A	83.6	112.1	157.5	149.6	215.8	216.8
100.0 hr	N/A	N/A	N/A	N/A	79.6	127.4	150.8	145.7	205.8	208.0

Ref-15 Files used for this section
/depfm8/ZDEP810.dat, ZDEP816.dat, ZDEP820.dat (TH=15 ADU)
ZDEP845.dat, ZDEP850.dat, ZDEP854.dat (TH= 8 ADU)
ZDEP866.dat, ZDEP873.dat, ZDEP879.dat (TH= 8 ADU)

16. Spatial extent of MCPs gain depletion

A F-F image in analog mode includes effects due to both of photocathode sensitivity loss and MCP gain depletion, while a F-F image in photon counting mode mainly effect due to phtocathode and a little due to gain depletion. The effect of gain depletion was extracted from the analog F-F by comparing with the photon counting F-F.

Fig. 46 shows a F-F image acquired in analog mode with the comparison of that in photon counting mode. Both F-Fs were illuminated by the blue LED, since the photocathode damage was smallest in blue among the 3 colours. The threshold level was set to 8ADU for the photon counting imaging to highlight the photocathode damage, in which the estimated photon loss due to the gain depletion is only 3% for the highest dose positions. The photon counting F-F image was binned by 8x8 to match the plate scale to that of the analog F-F. The sliced profile along the highest dose spots shows sharp depletion at the pinhole position in the photon counting F-F. The profile in the analog F-F shows a large extent of depleted region as well as the sharp depletion. The width of the sharp depletion is a little broader in analog image, but it is due to image blurring by under sampling of a CCD pixel and spatial extent of event splash on the phosphor screen.

Fig. 47 shows the analog F-F divided by the photon counting F-F. Since sensitivity loss in the photon counting F-F is mainly due to phtocathode damage, the figure approximately describes spatial distribution of MCP gain depletion. It shows plateau at the depth of 35%, bridging black spots. The black spots are still seen in the 2 dimensional image but their depths are not significant. Fig. 48 is the magnified image. A sliced profile shows that the extent of the gain depletion for the highest dose spots is 800um (half width at half depth). The spatial extent of gain depletion was discovered by Edgar et. al. in 1992 (Ref-16). This experiment showed similar extent of gain depletion.

Depth of the depletion in the analog F-F is not consistent with the gain depletion derived from pulse height distribution. The gain depletions were 30% from the analog F-F, while 65% from the pulse height distribution. Illumination for PHD was the pinhole images in a modest count rate (30-50 c/s/pinhole). The possibility of pore paralysis is ruled out, because the pulse height distributions by pinhole illumination and by F-F illumination were same before starting the photon dose.

One of the explanation is large gain drop (~ 45%) at MCP1. When illuminated by the pinholes, all photo-electrons fall into specific pores of MCP1 (diameter~70um). While, when illuminated by a F-F, event splash, which came through other MCP1 pores outside the 70um diameter, can hit the CCD pixel located beneath a black spot, because of the wide spread of event splash and under sampling of a CCD pixel. The full width of this image blurring is about 100um, which can dilute the deep and sharp gain depletion at the pinhole positions. A shallow gain depletion is ideal for the 10 years XMM-OM observations even if damage area is large. When the gain depletion region covers whole detector field evenly, it can be compensated by raising HVs to MCPs. This hypothesis on the gain depletion at MCP1 suggests deep and sharp damage, which is not ideal for the XMM-OM.

Ref-16
Edgar M., Lapington J. and Smith A. "The spatial extent of gain depression for MCP-based photon detectors", Rev. Sci Instrum vol 63 p816 (1992).

Files used for this section
/depfm8/ZAna865.dat, ZDEP866.dat

17. Summary

a) There are short duration (<30min) and long duration components in fluorescence. One minute illumination by a 5.6mag B0 star (2070 kc/sec/pinhole) caused fluorescence of 330 counts in the 1st 5min. It is extrapolated that a 10sec illumination can cause fluorescence of 95 counts in the 1st 5min. No fluorescence was detected after 30 hours illumination by a 13.1mag star (2.1 kc/sec/pinhole). A little fluorescence was, however, seen in the long duration component after 4 hours illumination by a 10.7mag star (19 kc/sec/pinhole).
The long duration component was not intense but lasted more than 1 day. For instance, fluorescence was still 80counts/hour/spot one days after 42min illumination by the 5.6mag star.
Longer illumination was not effective to increase the short duration component. For instance, 2 hours illumination caused only 700 counts in the 1st 5min. While, it was effective for the long duration component.
Profile of the long duration component is broader than that of short duration component.
Exhaustion of fuel for fluorescence was seen after acquiring 1E+10 dose events. The profile of fluorescence changed with photon dose. It got doughnut shape after acquiring 2E+11 dose events.

b) MCPs gain reduced to half after acquiring 5E+10 dose events from a 220 kc/s pinhole (8.0mag B0 star). This life time is shorter than DEP-QM tube by 50%. The gain depletion curve showed 3 branches, depending on the intensity of illumination. This is due to the effect of pore paralysis. It is useful to measure anode current during the intense illumination for modelling the gain depletion.

c) Sensitivity loss was not detected below 1E+8 dose events in photon counting image for blue light. The loss became 10% at 3E+10 dose events, and reached 35% at 7.5E+11 dose events. The improvement in DEP_#8 intensifier is noticeable below 1E+9 dose events, compared with DEP-QM intensifier.

d) Photocathode sensitivity loss was not detected below 1E+9 dose events for blue light.

e) Width of black spot in a photon counting image increased with photon dose, from 70 to 120um for blue light.

f) The photocathode sensitivity losses were assessed at 3 colours (i.e. 4600, 5500, 6200A) after completing the 100 hours photon dose. The loss was deeper in the longer wavelength. The width of the black spot was larger in the longer wavelength (200um for red).
It is essential to measure the sensitivity losses in other wavelengths, since the spectral coverage of XMM-OM is 1700-6000A.

g) Spatial extent of MCP gain depletion, 800um, was seen. It can be assessed more accurately with UV light, where photocathode sensitivity loss is expected to be minimum.
The depth of gain depletion seen in an analog F-F did not agree with the results from pulse height distribution. The inconsistency should be investigated further. Measuring

pulse height distribution with re-positioning pinhole by 60um may give further information.

Appendix. Experiment procedure for DEP_#8 intensifier

17 Sept - 10 Nov 1999

File Name	Pinhole	PHD	Dark	F-F	Time(start)
Before damage for reference					
					1999/09/17
PHD369		1000FR			17H 33M 31S
PHD370		8x8 80000FR			17H 59M 11S
					1999/09/18
Bin371			th=24 54000S		17H 22M 03S
					1999/09/19
Bin372			SW-on Th=24 54000S		12H 24M 43S
					1999/09/20
DRK373			3600S		12H 56M 40S
ANA374				1000FR	16H 15M 18S
ANA375				200FRs	16H 37M 07S
ANA376			off_cover	200FRs	16H 50M 31S
ANA377			off_cover	200FRs	16H 56M 44S
ANA378			open box	200FRs	17H 07M 03S
ANA379			open box	200FRs	17H 15M 11S
ANA380			op box-sm	200FRs	17H 23M 59S
ANA381			op box-sm	200FRs	17H 29M 16S
ANA382			op v sml	200FRs	17H 38M 55S
ANA383			op v sml	200FRs	17H 46M 11S
ANA384			op v sml	200FRs	17H 51M 37S
Bin385			Th=24 1800S		18H 41M 39S
Bin386			SW-on Th=24 54000S		19H 17M 49S
					1999/09/21
Bin387			Th=24 3600S		10H 34M 35S
Ana388				4000FRs	12H 58M 46S
DEP389	Res 0600S 630nm				15H 41M 42S
DEP390	Res 0600S				15H 54M 21S
DEP391	Res 0600S				16H 05M 46S
DEP392	Res 0600S				16H 16M 59S
DEP393	Res 0600S				16H 35M 48S
DEP394	Res 0600S 460nm				17H 18M 09S
DEP395	Res 0600S				17H 29M 36S
DEP396	Res 0600S				17H 41M 58S
DEP397	Res 0600S				17H 55M 30S
DEP398	Res 0600S				18H 07M 20S
Bin399			-90R Th=24 54000S		19H 17M 15S
					1999/09/22
SNP400			Hot spot 4FRs		14H 20M 00S
Bin401			Hot spot 60S		14H 24M 44S
Bin402			Hot spot 60S		14H 30M 22S
SIB403		100FRs x3 mag			16H 15M 00S
|		|			|
SIB502		100FRs x3 mag			16H 40M 00S
Bin504			th=24 54000S		19H 00M 25S
					1999/09/23
FSh505			Flash 50000FRs		11H 35M 18S
PHD506		8x8 80000FR			19H 10M 36S
					1999/09/24
Pin507	L=1 3541S				16H 18M 50S

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--------------------------------------------------------------------
File Name      Pinhole        PHD                Dark     F-F          Time(start)
--------------------------------------------------------------------

Pin508    L=3   3600S                                         18H 44M 24S
DEP509                                              54000S    21H 15M 00S
                                                                1999/09/25
DEP510                                              18000S    12H 52M 32S
DEP511                                              54000S    19H 57M 02S
                                                                1999/09/26
DEP512                                         arc? 54000S    15H 16M 45S
                                                                1999/09/27
Pin513    L=2   2400S -----                                   13H 20M 41S
Pin514    L=3   1000S   |                                     14H 04M 21S
Pin515    L=4   1000S   |                                     14H 24M 57S
Pin516    L=5   1000S   |                                     14H 53M 03S
Pin517    L=6   1000S   |                                     15H 14M 17S
Ana518    L=6  1000FRs  |                                     15H 32M 36S
Pin519    L=7   1000S  Bit Broken                             16H 19M 57S
Pin520    L=7    100S   |                                     17H 30M 07S
Pin521    L=8    100S   |                                     17H 34M 08S
Pin522    L=9    100S   |                                     17H 39M 56S
Pin523    L=10   100S   |                                     17H 43M 38S
Pin524    L=1   1000S   |                                     18H 03M 43S
PHD525                     4000FRs                            19H 43M 01S
DEP526                -----                         54000S    20H 20M 47S
                                                                1999/09/28
Pin527    L=3   3600S                                         15H 30M 00S
Pin528    L=4   2400S                                         18H 39M 54S
Pin529    L=5   1000S                                         19H 24M 32S
Pin530    L=6    100S                                         19H 46M 39S
Pin531    L=7   0100S                                         19H 51M 53S
Pin532    L=7   0100S                                         20H 00M 01S
Pin533    L=8   0100S                                         20H 03M 35S
Pin534    L=9   0100S                                         20H 08M 35S
Pin535    L=10  0100S                                         20H 12M 42S
Pin536    L=2   1000S                                         20H 19M 30S
Pin537    L=1   1000S                                         20H 40M 11S
DEP538                                              54000S    21H 10M 14S
                                                                1999/09/29
PHD539                   60000FRs                             12H 45M 46S
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Start damage

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                                                                1999/09/30
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            50min      Vc=0, Blackout   14:00 - 14:50     1999/09/30
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Bin540                           LED Flu 0900S                14H 53M 33S
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             1min  0th  Vc=0   Day-1    15:20 - 15:21     1999/09/30
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Bin541                          Vc=0 Flu 0300S                15H 21M 54S
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File Name	Pinhole	PHD	Dark	F-F	Time(start)
	1min 1st	Day-1	15:32 - 15:33		1999/09/30
Drk542			0300S		15H 33M 41S
Drk543			0300S		15H 40M 26S
Drk544			0300S		15H 46M 44S
Drk545			0300S		15H 53M 05S
Drk546			0300S		15H 59M 36S
	1min 2nd	Day-1	16:06 - 16:07		1999/09/30
Drk547			0300S		16H 07M 39S
Drk548			0300S		16H 13M 34S
Drk549			0300S		16H 19M 23S
Drk550			0300S		16H 25M 17S
Drk551			0300S		16H 31M 02S
	1min 3rd	Day-1	16:43 - 16:44		1999/09/30
Drk552			0300S		16H 45M 08S
Drk553			0300S		16H 50M 59S
Drk554			0300S		16H 57M 05S
Drk555			0300S		17H 03M 11S
Drk556			0300S		17H 09M 02S
	1min 4th	Day-1	17:15 - 17:16		1999/09/30
Drk557			0300S		17H 17M 09S
Drk558			0300S		17H 23M 02S
Drk559			0300S		17H 28M 50S
Drk560			0300S		17H 34M 28S
Drk561			0300S		17H 40M 08S
	2min 1st	Day-1	17:46 - 17:48		1999/09/30
Drk562			0300S		17H 49M 11S
Drk563			0300S		17H 54M 51S
Drk564			0300S		18H 00M 29S
Drk565			0300S		18H 06M 18S
Drk566			0300S		18H 12M 00S
	2min 2nd	Day-1	18:18 - 18:20		1999/09/30
Drk567			0300S		18H 21M 09S
Drk568			0300S		18H 26M 47S
Drk569			0300S		18H 32M 27S
	10min	Day-1	18:40 - 18:50		1999/09/30

File Name	Pinhole	PHD	Dark	F-F	Time(start)
Drk570			0300S		18H 50M 39S
Drk571			0300S		18H 56M 21S
Drk572			0300S		19H 02M 09S
Drk573			0300S		19H 07M 49S
Drk574			0300S		19H 13M 29S
Drk575			Vc=0 0600S		19H 22M 06S
Pin576	L=1 0300S				19H 45M 07S
Bin577			Vc=0 0300S		19H 51M 48S
PHD578		60000FRs			20H 03M 58S
Drk579			1107S		20H 59M 55S
DEP580				54000S	21H 21M 39S
*					1999/10/01
Drk581			3600S		13H 23M 31S
PHD582		60000FRs			15H 33M 19S
Drk583			3600S		22H 15M 17S
Drk584			54000S		23H 25M 55S
					1999/10/02
DEP585				54000S	18H 36M 42S
					1999/10/03
Bin586			11596S		09H 36M 56S
Pin587	L=1 0300S				13H 24M 38S

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42min Day-2 13:38 - 14:20 1999/10/03

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File Name	Pinhole	PHD	Dark	F-F	Time(start)
Drk588			0300S		14H 20M 44S
Drk589			0300S		14H 26M 06S
Drk590			0300S		14H 31M 27S
Drk591			0300S		14H 36M 48S
Drk592			0300S		14H 42M 09S
PHD593		60000FRs			14H 48M 42S
Drk594			3600S		15H 50M 31S
Drk595			54000S		16H 50M 52S
					1999/10/04
Drk596			10800S		07H 51M 12S
PHD597		60000FRs			11H 23M 14S
Pin598	L=1 7200S				12H 19M 30S
Drk599			7200S		16H 20M 03S
DEP600				54000S	19H 14M 03S
					1999/10/05
Drk601			7200S		10H 27M 34S

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2 hour Day-3 12:47 - 14:47 1999/10/05

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File Name	Pinhole	PHD	Dark	F-F	Time(start)
Drk602			0300S		14H 47M 41S
Drk603			0300S		14H 53M 11S
Drk604			0300S		14H 58M 32S
Drk605			0300S		15H 03M 53S
Drk606			0300S		15H 09M 16S
PHD607		60000FRs			15H 20M 26S
Pin608	L=5 3600S				16H 13M 38S
Pin609	L=5 0600S				17H 49M 22S
Drk611			7200S		21H 03M 30S
Drk612			7200S		23H 03M 50S

File Name	Pinhole	PHD	Dark	F-F	Time(start)
					1999/10/06
Drk614			7200S		03H 04M 24S
Drk616			7200S		07H 04M 56S
Drk617			7200S		09H 05M 16S
Drk618			7200S		11H 07M 51S
Drk619			7200S		13H 08M 53S
PHD620		60000FRs			15H 20M 41S
Pin621	L=1 1800S				17H 00M 48S
Drk622			7200S		18H 23M 35S
DEP623				54000S	20H 23M 57S
					1999/10/07
Drk624			1800S		11H 28M 19S
	4 hour	Day-4	12:06 - 16:06		1999/10/07
Drk625			0300S		16H 07M 23S
Drk626			0300S		16H 12M 58S
Drk627			0300S		16H 18M 36S
Drk628			0300S		16H 24M 02S
Drk629			0300S		16H 29M 23S
PHD630		60000FRs			16H 35M 29S
Drk631			7200S		17H 30M 01S
Drk632			7200S		19H 30M 22S
Drk633			7200S		21H 30M 42S
Drk634			7200S		23H 31M 02S
					1999/10/08
Drk635			7200S		01H 31M 22S
Drk636			7200S		03H 31M 43S
Drk637			7200S		05H 32M 04S
Drk638			7200S		07H 32M 25S
Drk639			7200S		10H 49M 47S
Drk640			7200S		12H 50M 08S
Drk641			7200S		14H 50M 34S
PHD642		60000FRs			17H 02M 19S
DEP643				54000S	18H 20M 35S
					1999/10/09
Drk644			7200S		09H 20M 58S
Fuel Test	1min	Day-4	12:08 - 12:09		1999/10/09
Drk645			0300S		12H 09M 46S
Drk646			0300S		12H 15M 07S
Drk647			0300S		12H 20M 28S
Drk648			0300S		12H 25M 50S
Drk649			0300S		12H 31M 11S
	8 hour	Day-5	13:20 - 21:20		1999/10/09

File Name	Pinhole	PHD	Dark	F-F	Time(start)
Drk650	-----		0300S		21H 24M 45S
Drk651			0300S		21H 30M 07S
Drk652			0300S		21H 35M 29S
Drk653			0300S		21H 40M 50S
Drk654			0300S		21H 46M 11S
Drk655			7200S		21H 51M 33S
Drk656			7200S		23H 51M 55S
	X-LUT broken				1999/10/10
Drk657			7200S		01H 52M 17S
Drk658			7200S		03H 52M 39S
Drk659			7200S		05H 53M 01S
Drk660			7200S		07H 53M 23S
Drk661			7200S		09H 53M 45S
Drk662			7200S		11H 54M 07S
Drk663	-----		7200S		13H 54M 29S
PHD664		70000FRs			16H 44M 13S
Drk665			7200S		18H 01M 03S
					1999/10/11
DEP666				29100S	10H 22M 33S
Drk667			7200S		15H 57M 58S
DEP668				54000S	17H 58M 22S
					1999/10/12
Bin669			7200S		08H 58M 46S
Drk670			7200S		10H 59M 03S

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Fuel Test 1min Day-5 13:09 - 13:10 1999/10/12

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File Name	Pinhole	PHD	Dark	F-F	Time(start)
Drk671			0300S		13H 10M 36S
Drk672			0300S		13H 16M 00S
Drk673			0300S		13H 21M 23S
Drk674			0300S		13H 26M 46S
Drk675			0300S		13H 32M 09S
Pin676	L=1 1800S				14H 22M 34S
Pin677	L=5 1800S				14H 57M 10S

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15 hour Day-6 16:00 - 07:00 1999/10/12

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File Name	Pinhole	PHD	Dark	F-F	Time(start)
					1999/10/13
Drk678			0300S		07H 02M 18S
Drk679			0300S		07H 07M 41S
Drk680			0300S		07H 13M 04S
Drk681			0300S		07H 18M 27S
Drk682			0300S		07H 23M 50S
Drk683			7200S		07H 29M 14S
Drk684			7200S		09H 29M 37S
PHD685		70000FRs			11H 31M 49S
Drk686			7200S		13H 05M 54S
Drk687			7200S		15H 06M 17S
Drk688			7200S		17H 06M 40S
Drk689			7200S		19H 07M 03S
Drk690			7200S		21H 07M 26S
Drk691			7200S		23H 07M 49S

File Name	Pinhole	PHD	Dark	F-F	Time(start)
					1999/10/14
Drk692			7200S		01H 08M 12S
Drk693			7200S		03H 08M 36S
Drk694			7200S		05H 08M 59S
Drk695			7200S		07H 09M 22S
PHD696		70000FRs			09H 15M 19S
Drk697			7200S		10H 22M 27S
Drk698			7200S		12H 22M 50S
Drk699			7200S		14H 23M 13S
DEP700				54000S	17H 18M 04S
					1999/10/15
Drk701			7200S		08H 18M 30S

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Fuel Test 1min Day-6 11:00 - 11:01 1999/10/15

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File Name	Pinhole	PHD	Dark	F-F	Time(start)
Drk702			0300S		11H 02M 21S
Drk703			0300S		11H 07M 44S
Drk704			0300S		11H 13M 07S
Drk705			0300S		11H 18M 30S
Drk706			0300S		11H 23M 53S
Pin707	L=1 1800S				11H 49M 56S
Pin708	L=5 1800S				12H 27M 43S

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20 hour Day-7 15:00 - 11:00 1999/10/15

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File Name	Pinhole	PHD	Dark	F-F	Time(start)
					1999/10/16
Drk709			0300S		11H 00M 57S
Drk710			0300S		11H 06M 20S
Drk711			0300S		11H 11M 45S
Drk712			0300S		11H 26M 05S
Drk713			0300S		11H 31M 28S
PHD714		70000FRs			11H 42M 41S
Drk715			7200S		12H 36M 43S
Drk716			7200S		14H 37M 06S
Drk717			7200S		16H 37M 29S
Drk718			7200S		18H 37M 52S
Drk719			7200S		20H 38M 15S
Drk720			7200S		22H 38M 38S
					1999/10/17
Drk721			7200S		00H 39M 01S
Drk722			7200S		02H 39M 24S
Drk723			7200S		04H 39M 47S
Drk724			7200S		06H 40M 10S
Drk725			7200S		08H 40M 33S
Drk726			7200S		10H 40M 56S
Drk727			7200S		12H 41M 19S
PHD728		70000FRs			14H 53M 00S
Drk729			7200S		16H 00M 37S
					1999/10/18
Drk730			7200S		10H 32M 16S
Ana731				30000FRs	12H 41M 43S
Drk732			7200S		15H 25M 31S
DEP733				54000S	17H 25M 55S

File Name	Pinhole	PHD	Dark	F-F	Time(start)
					1999/10/19
Drk734			7200S		08H 26M 19S
Fuel Test 1min		Day-7	10:46 - 10:47		1999/10/19
Drk735			0300S		10H 48M 05S
Drk736			0300S		10H 53M 31S
Drk737			0300S		10H 58M 55S
Drk738			0300S		11H 04M 23S
Drk739			0300S		11H 09M 47S
Drk740			0300S		11H 15M 10S
Ana741	L=2 5000FRs				11H 22M 24S
Pin742	L=1 1800S				12H 03M 44S
Pin743	L=5 1800S				12H 39M 13S
20 hour 2nd		Day-8	15:00 - 11:00		1999/10/19
					1999/10/20
Drk744			0300S		11H 10M 35S
Drk745			0300S		11H 15M 59S
Drk746			0300S		11H 21M 22S
Drk747			0300S		11H 26M 45S
Drk748			0300S		11H 32M 08S
Drk749			0300S		11H 37M 31S
PHD750		70000FRs			11H 49M 21S
Drk751			7200S		12H 46M 02S
					1999/10/21
Drk752			7200S		10H 15M 48S
Drk753			7200S		12H 16M 12S
PHD754		70000FRs			14H 23M 03S
Drk755			7200S		15H 53M 16S
DEP756				54000S	17H 53M 41S
					1999/10/22
Drk757			7200S		08H 54M 06S
Ana758				30000FRs	11H 16M 34S
Fuel Test 1min		Day-8	14:48 - 14:49		1999/10/22
Drk759			0300S		14H 49M 37S
Drk760			0300S		14H 55M 01S
Drk761			0300S		15H 00M 25S
Drk762			0300S		15H 05M 49S
Drk763			0300S		15H 11M 13S
Ana764	L=2 5000FRs				15H 19M 45S
Pin765	L=1 1800S				15H 50M 50S
Pin766	L=5 1800S				16H 29M 26S
Drk767			7200S		17H 28M 53S
Drk768			7200S		19H 29M 14S
Drk769			7200S		21H 29M 35S
Drk770			7200S		23H 29M 55S
					1999/10/23
Drk771			7200S		01H 30M 15S
Drk772			7200S		03H 30M 35S

30 hour Day-9 06:00 - 12:00 1999/10/23

File Name	Pinhole	PHD	Dark	F-F	Time(start)
					1999/10/24
Drk773			0300S		12H 01M 53S
Drk774			0300S		12H 07M 18S
Drk775			0300S		12H 12M 41S
Drk776			0300S		12H 18M 05S
Drk777			0300S		12H 23M 28S
PHD778		70000FRs			12H 38M 50S
Drk779	-----		7200S		13H 33M 45S
Drk780			7200S		15H 34M 09S
Drk781			7200S		17H 34M 32S
Drk782			7200S		19H 34M 56S
Drk783			7200S		21H 35M 19S
Drk784			7200S		23H 35M 43S
	Bit Broken				1999/10/25
Drk785			7200S		01H 36M 07S
Drk786			7200S		03H 36M 30S
Drk787			7200S		05H 36M 54S
Drk788			7200S		07H 37M 18S
Drk789	-----		7200S		09H 37M 42S
PHD790		70000FRs			12H 09M 49S
Ana791			(256V)	20000FRs	13H 27M 38S
Drk792			7200S		17H 35M 01S
DEP793				54000S	19H 35M 26S
					1999/10/26
Drk794			7200S		10H 35M 51S
Drk795			7200S		12H 36M 14S
DEP796				54000S	15H 36M 21S
					1999/10/27
Drk797			7200S		06H 36M 42S
Drk798			7200S		08H 37M 00S
Drk799			7200S		10H 37M 18S
PHD800		70000FRs			13H 57M 59S
Drk801			7200S		16H 32M 46S
DEP802			Red	54000S	18H 35M 03S
					1999/10/28
Drk803			7200S		09H 35M 28S
PHD804		70000FRs			11H 59M 52S
Ana805			(256V)	1000FRs	13H 33M 39S
DEP806			Green	54000S	18H 25M 09S
					1999/10/29
Bin807			4x4B	7200S	09H 25M 30S
Drk808			7200S		11H 35M 12S
PHD809		70000FRs			14H 18M 11S
DEP810			Blue	54000S	16H 14M 10S
					1999/10/30
Drk811			7200S		07H 14M 42S
Drk812			7200S		09H 15M 09S
Drk813			7200S		11H 15M 35S
Drk814			7200S		13H 16M 01S
Drk815			7200S		15H 16M 27S
DEP816			Red	54000S	18H 35M 51S

File Name	Pinhole	PHD		Dark	F-F	Time(start)
						1999/10/31
Drk817				7200S		09H 36M 21S
Drk818				7200S		11H 36M 47S
Drk819				7200S		13H 37M 13S
DEP820				Green	54000S	16H 30M 16S
						1999/11/01
Drk821				7200S		07H 30M 52S
Drk822				7200S		09H 31M 25S
PHD823		70000FRs				11H 56M 29S

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Fuel Test 1min Day-9 13:28 - 13:29 1999/11/01

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File Name	Pinhole	PHD		Dark	F-F	Time(start)
Drk824				0300S		13H 30M 07S
Drk825				0300S		13H 35M 42S
Drk826				0300S		13H 41M 17S
Drk827				0300S		13H 46M 52S
Drk828				0300S		13H 52M 27S
Drk829				7200S		14H 26M 40S
Drk830				7200S		16H 27M 09S
Drk831				7200S		18H 27M 37S
Drk832				7200S		20H 28M 05S
Drk833				7200S		22H 28M 33S
						1999/11/02
Drk834				7200S		00H 29M 01S
Drk835				7200S		02H 29M 29S
Drk836				7200S		04H 29M 58S
Drk837				7200S		06H 30M 26S
Drk838				7200S		08H 30M 54S
Drk839				7200S		10H 31M 22S
DEP840			TH=8	Blue	54000S	18H 14M 26S
						1999/11/03
Drk841				7200S		09H 15M 02S
Drk842				7200S		11H 15M 37S
Drk843				7200S		13H 16M 12S
PHD844		70000FRs				15H 19M 39S
DEP845			TH=8	Green	54000S	16H 48M 22S
						1999/11/04
Drk846				7200S		10H 06M 33S
Drk847				7200S		12H 07M 26S
Drk848				7200S		15H 01M 50S
PHD849		70000FRs				18H 02M 12S
DEP850			TH=8	Red	54000S	19H 04M 05S
						1999/11/05
Drk851				7200S		10H 04M 41S
Drk852				7200S		12H 55M 49S
Ana853			(256V)	Red	20000FRs	16H 12M 21S
DEP854			TH=8	Red	54000S	19H 35M 22S
						1999/11/06
Drk855				7200S		10H 35M 52S
Drk856				7200S		12H 36M 18S
Drk857				7200S		14H 36M 44S
Drk858				7200S		16H 37M 10S
Drk859				7200S		18H 37M 36S

File Name	Pinhole	PHD		Dark	F-F	Time(start)
Drk860				7200S		20H 38M 02S
Drk861				7200S		22H 38M 28S
						1999/11/07
Drk862				7200S		00H 38M 54S
Drk863				7200S		02H 39M 20S
						1999/11/08
PHD864		70000FRs				11H 17M 17S
Ana865			(256V)	Blue	30000FRs	12H 17M 42S
						1999/11/09
DEP866			TH=8	Blue	54000S	10H 12M 37S
						1999/11/10
Drk867				7200S		01H 13M 13S
Drk868				7200S		03H 13M 46S
Drk869				7200S		05H 14M 19S
Drk870				7200S		07H 14M 52S
Drk871				7200S		09H 15M 25S
PHD872		70000FRs				15H 00M 10S
DEP873			TH=8	Blue	54000S	17H 51M 10S
						1999/11/11
Drk874				7200S		08H 51M 40S
Drk875				7200S		10H 54M 00S
Drk876				7200S		12H 54M 35S
Drk877				7200S		14H 55M 10S
Drk878				7200S		16H 55M 45S
DEP879			TH=8	Red	54000S	20H 00M 25S
						1999/11/12
Drk880				7200S		11H 01M 01S
Ana881			(256V)	Red	30000FRs	13H 11M 26S
PHD882		70000FRs				17H 42M 34S

Effect of Fluorescence on F-F at Peak

Total dose (hour)	120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
	Pinhole intensity (counts/sec)									
Blue										
0.3 hr	.000	.000	.000	.000	.000	.000	.011	.011	.038	.036
1.0 hr	.000	.000	.000	.000	.000	.000	.001	.002	.005	.006
3.0 hr	.000	.000	.000	.000	.000	.000	.002	.003	.005	.006
7.0 hr	.000	.000	.000	.000	.002	.002	.006	.006	.010	.011
15.0 hr	.000	.000	.000	.000	.000	.002	.005	.006	.006	.007
30.0 hr	.000	.000	.000	.000	.003	.002	.007	.008	.007	.005
50.0 hr	.000	.000	.000	.000	.001	.002	.003	.003	.001	.002
70.0 hr	.000	.000	.001	.000	.003	.003	.005	.004	.001	.001
100.0 hr	.000	.000	.000	.001	.003	.003	.006	.005	-.001	-.000
100.0 hr	.000	.000	.001	.000	.002	.002	.004	.003	-.001	-.000
100.0 hr	.000	.000	.000	.000	.001	.001	.001	.001	.000	.000
Green										
100.0 hr	.000	.000	-.000	.000	.001	.000	.001	.001	.000	.000
Red										
100.0 hr	.000	.000	.000	.000	.001	.001	.000	.000	.000	.000
Threshold level = 8ADU										
Blue										
100.0 hr	.000	.000	.000	.000	.001	.000	-.001	.000	.000	.000
100.0 hr	.000	.000	.000	.000	.000	-.000	-.000	-.000	.000	.000
100.0 hr	.000	.000	-.000	.000	.000	.001	-.001	.000	.000	.000
Green										
100.0 hr	.000	.000	-.000	.000	.000	.001	.000	-.000	.000	.000
Red										
100.0 hr	.000	.000	.000	.000	-.000	.001	.001	.000	.000	.000
100.0 hr	.000	.000	.000	.000	.001	.001	-.000	-.000	.000	.000
100.0 hr	.000	.000	-.000	-.000	-.000	.001	-.001	-.001	.000	.000

Effect of Fluorescence on F-F (Average over circle D=213um)

Total dose (hour)	Pinhole intensity (counts/sec) 120c/s	210	1.1k	2.1k	19k	21k	220k	320k	2070k	2070k
Blue										
0.3 hr	.000	.000	.000	.000	.000	.000	.007	.008	.027	.025
1.0 hr	.000	.000	.000	.000	.001	.000	.001	.001	.004	.004
3.0 hr	.000	.000	.000	.000	.000	.000	.002	.002	.004	.004
7.0 hr	.000	.000	.000	.000	.001	.001	.005	.004	.009	.009
15.0 hr	.000	.000	.000	.000	.001	.002	.004	.004	.007	.008
30.0 hr	.000	.000	.000	.000	.002	.002	.006	.007	.008	.007
50.0 hr	.000	.000	.000	.000	.001	.001	.003	.002	.002	.002
70.0 hr	.000	.000	.001	.001	.003	.002	.004	.004	.003	.003
100.0 hr	.000	.000	.001	.001	.003	.003	.005	.005	.003	.003
100.0 hr	.000	.000	.001	.001	.002	.002	.004	.003	.001	.002
100.0 hr	.000	.000	.000	.000	.001	.001	.001	.001	.000	.000
Green										
100.0 hr	.000	.000	-.000	.000	.001	.000	.001	.001	.000	.000
Red										
100.0 hr	.000	.000	.000	.001	.001	.001	.000	.000	-.000	-.000
Threshold level = 8ADU										
Blue										
100.0 hr	.000	.000	.000	.001	.001	.000	-.001	.000	-.001	-.000
100.0 hr	.000	.000	.000	.001	.000	-.000	-.000	-.000	-.001	-.001
100.0 hr	.000	.000	-.000	.000	.000	.001	-.001	.000	-.001	-.000
Green										
100.0 hr	.000	.000	-.000	.000	.000	.001	.000	-.000	-.001	-.001
Red										
100.0 hr	.000	.000	.000	.001	-.000	.000	.001	.000	-.001	-.000
100.0 hr	.000	.000	-.000	.001	.001	.000	-.000	-.000	-.001	-.001
100.0 hr	.000	.000	-.000	-.000	-.000	.001	-.001	-.001	-.001	-.001

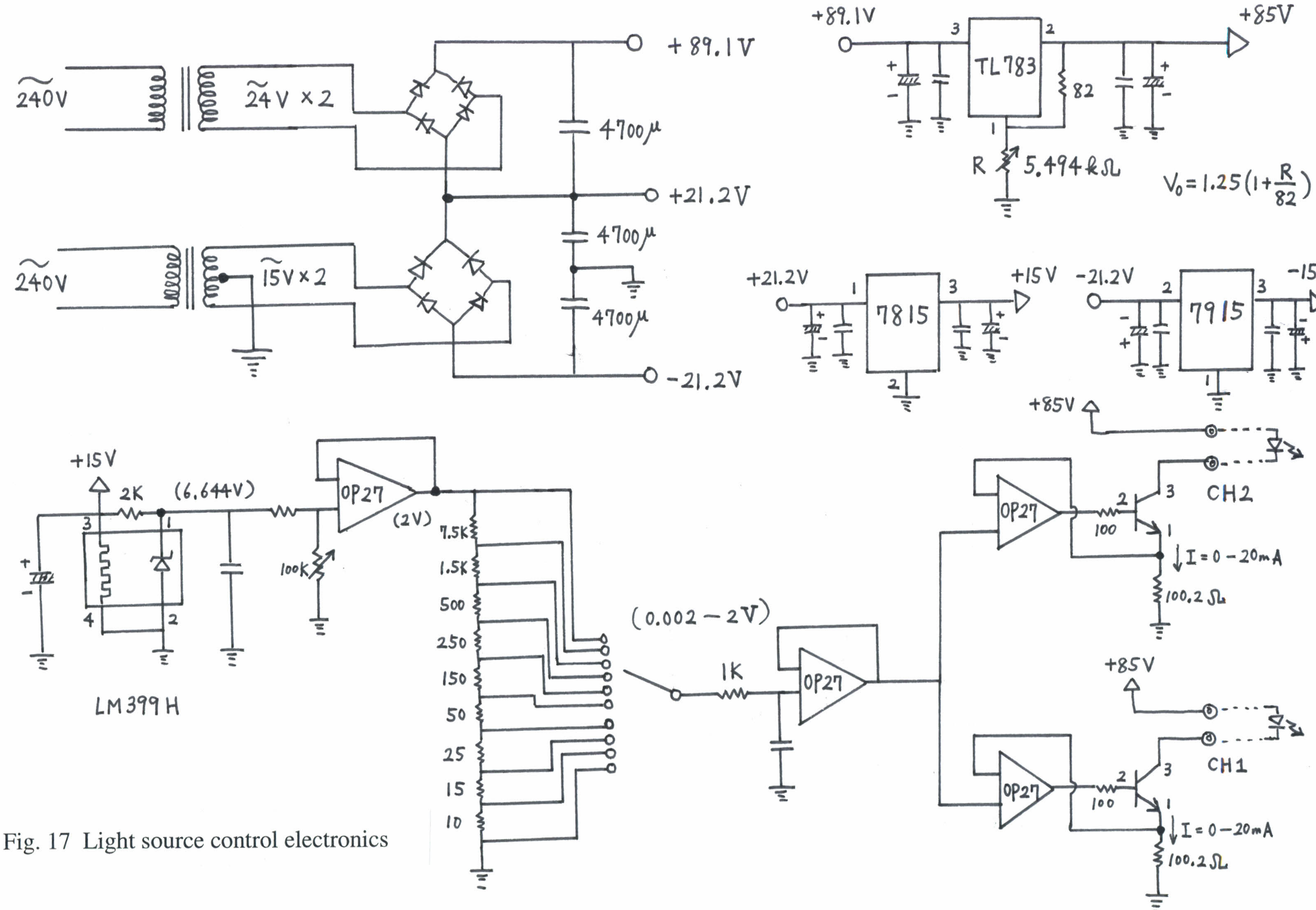


Fig. 17 Light source control electronics

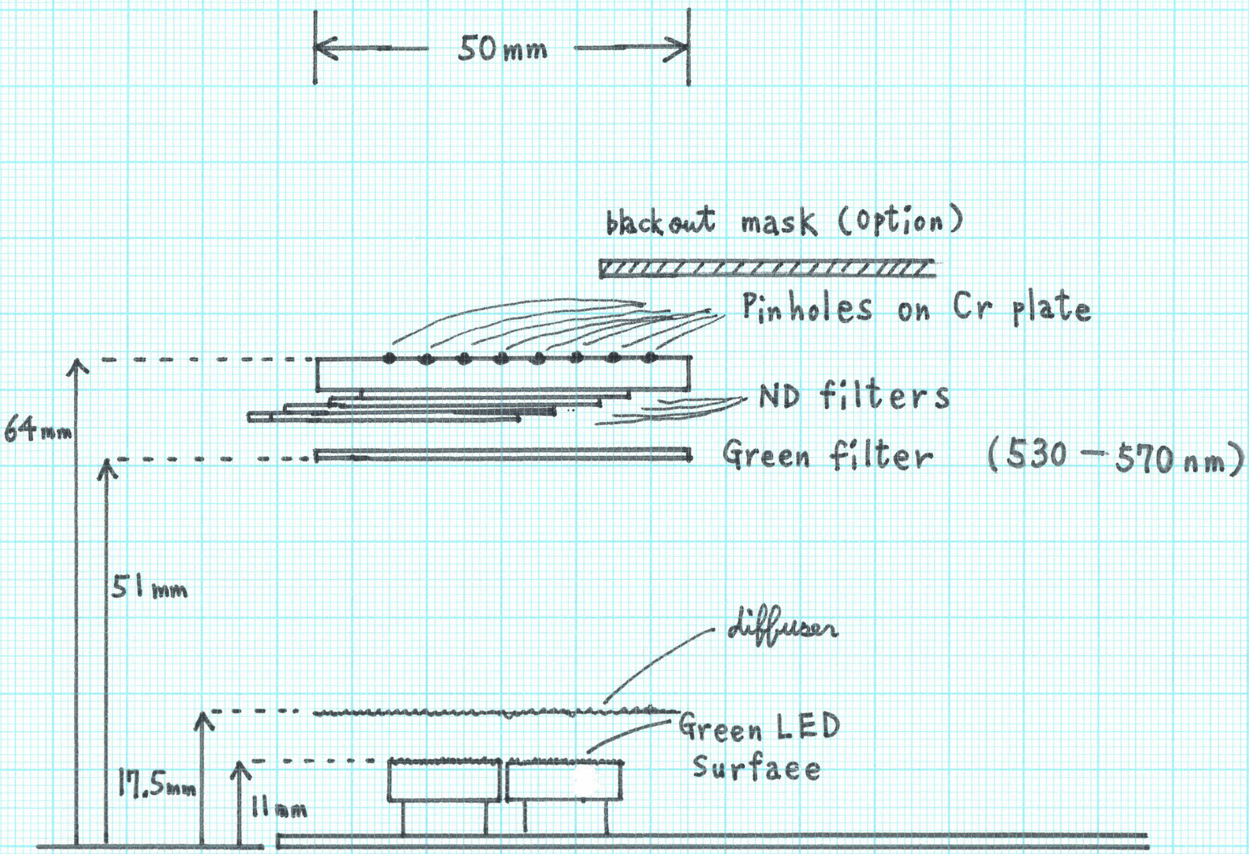


Fig. 18 Pinhole light source

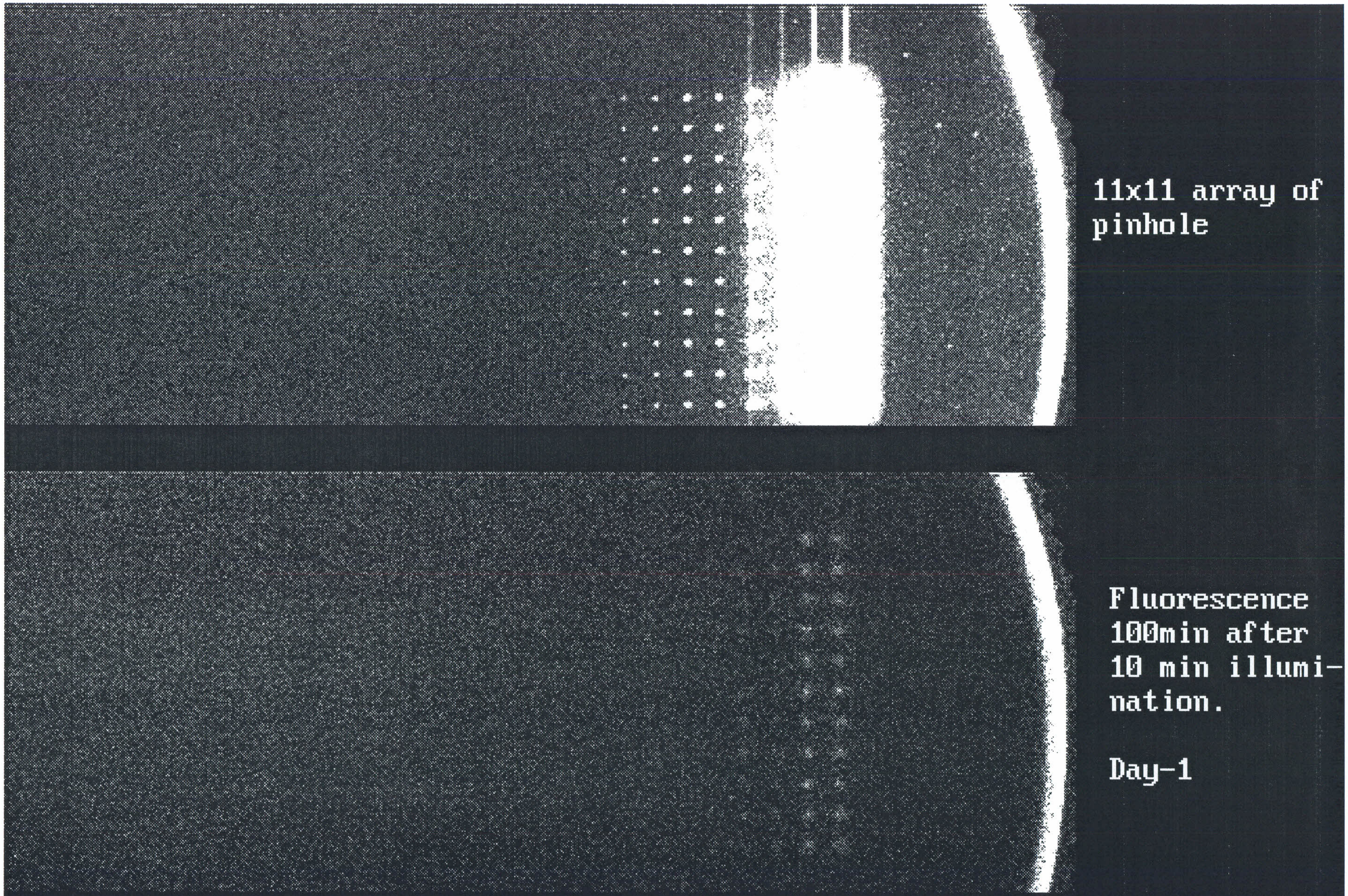


Fig. 19 Intense illumination by pinhole array and fluorescence DEP_#8 tube

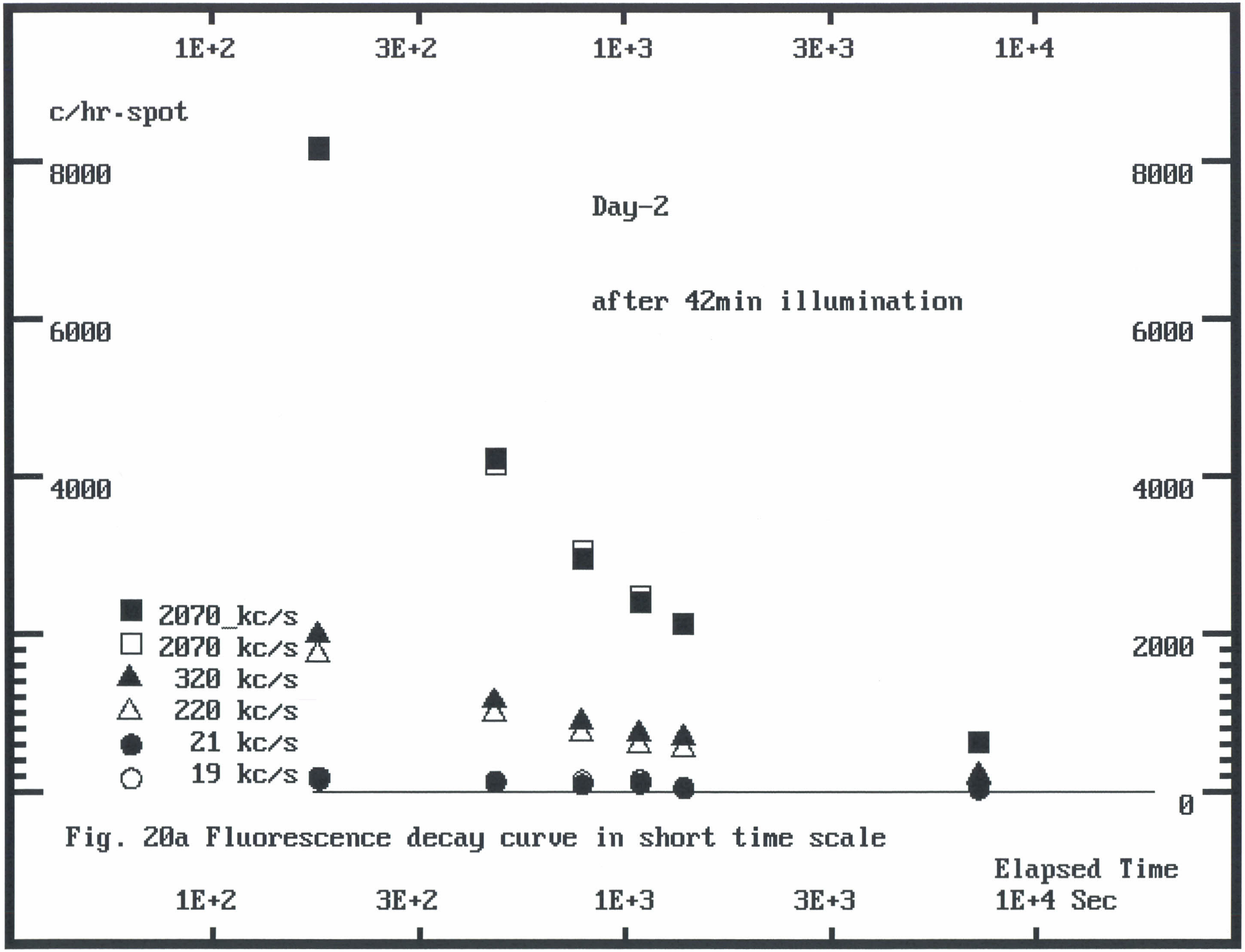


Fig. 20a Fluorescence decay curve in short time scale

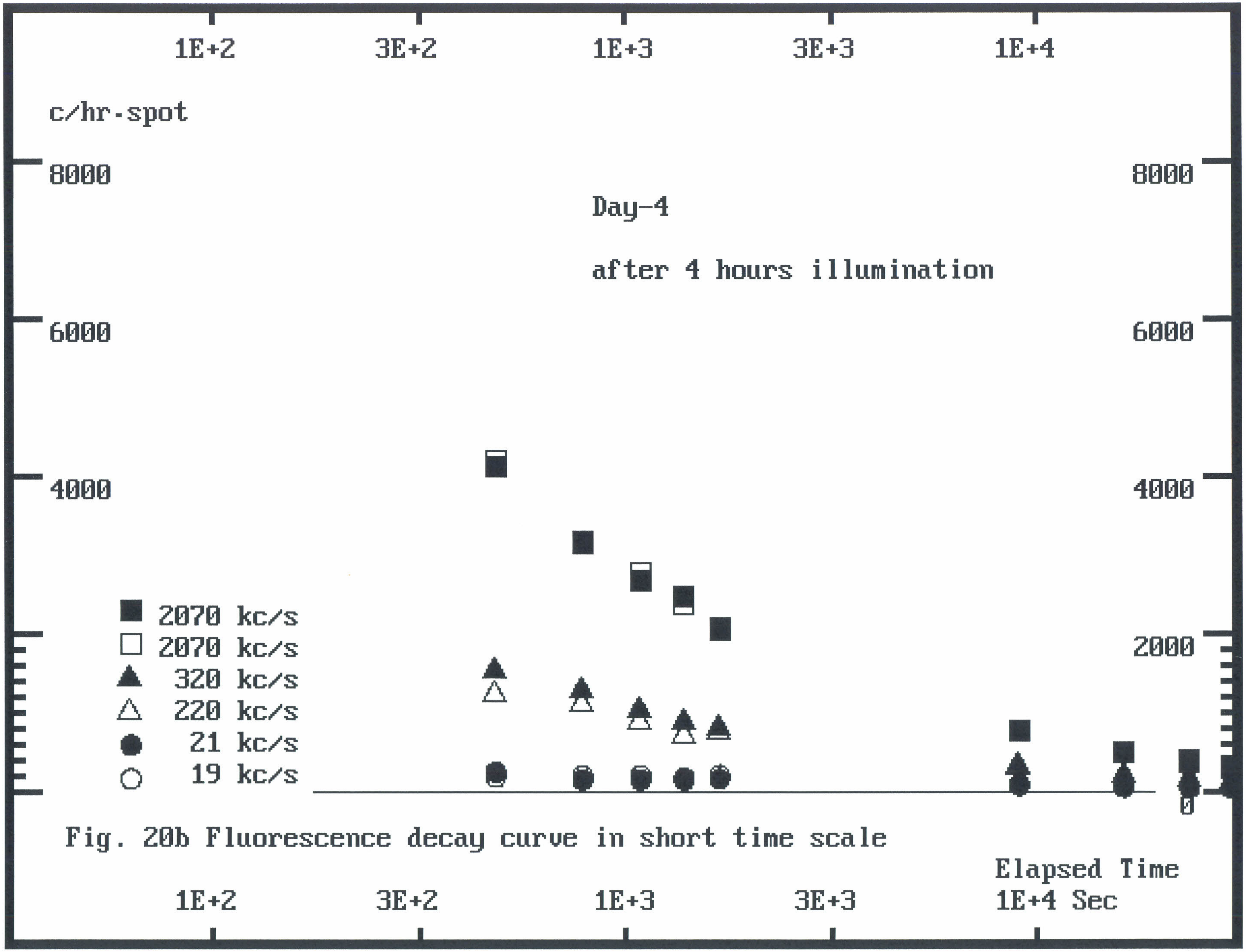


Fig. 20b Fluorescence decay curve in short time scale

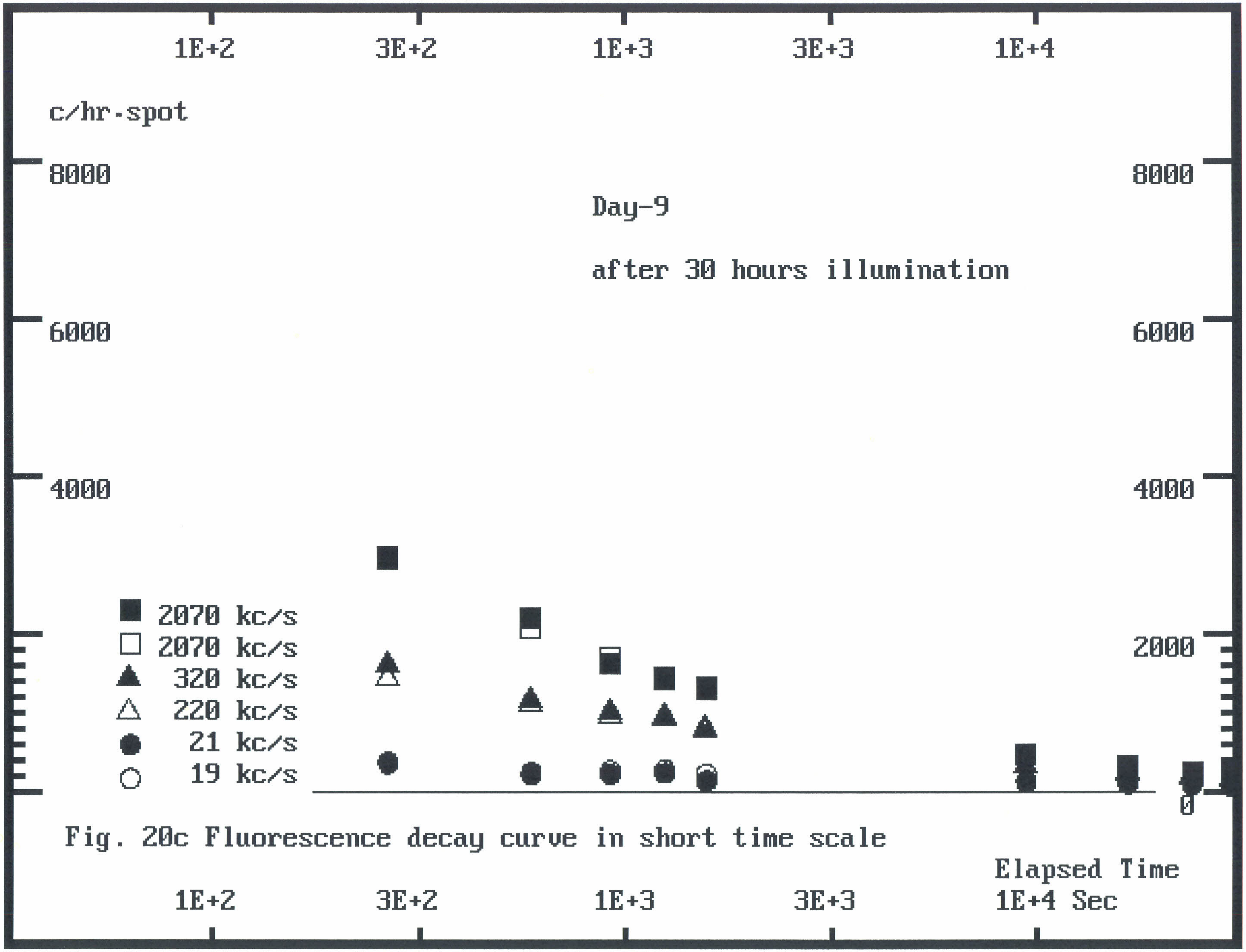


Fig. 20c Fluorescence decay curve in short time scale

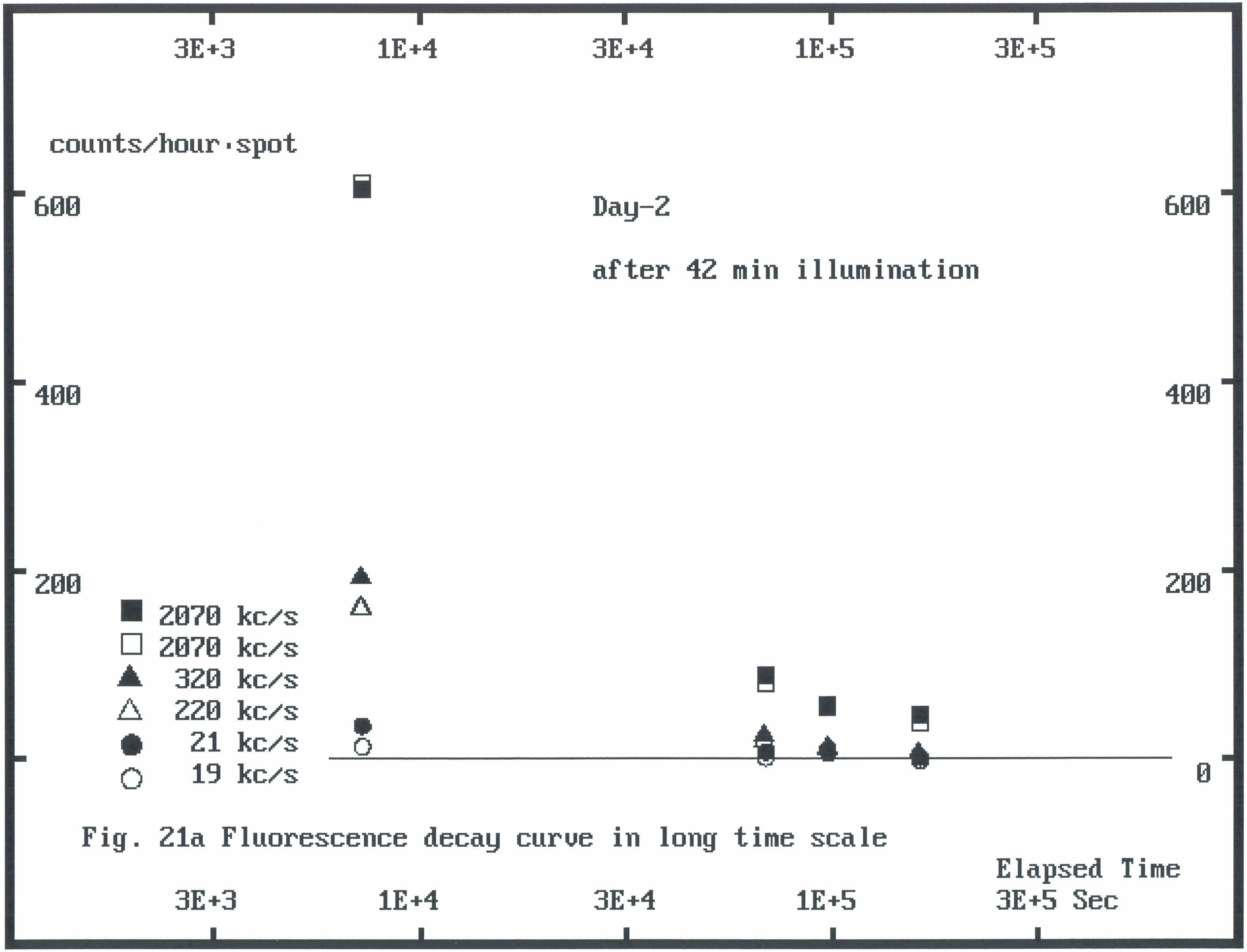


Fig. 21a Fluorescence decay curve in long time scale

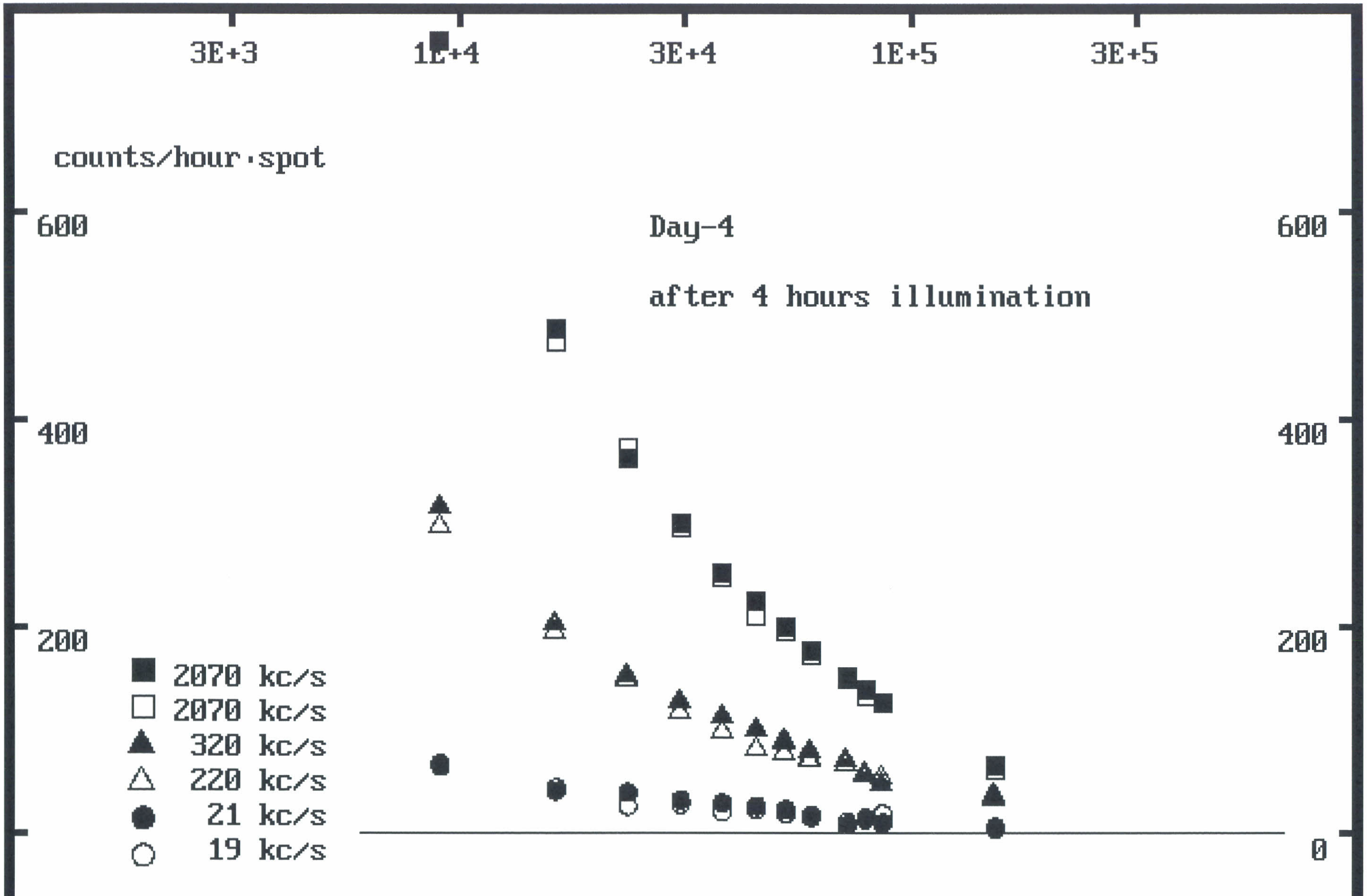


Fig. 21b Fluorescence decay curve in long time scale

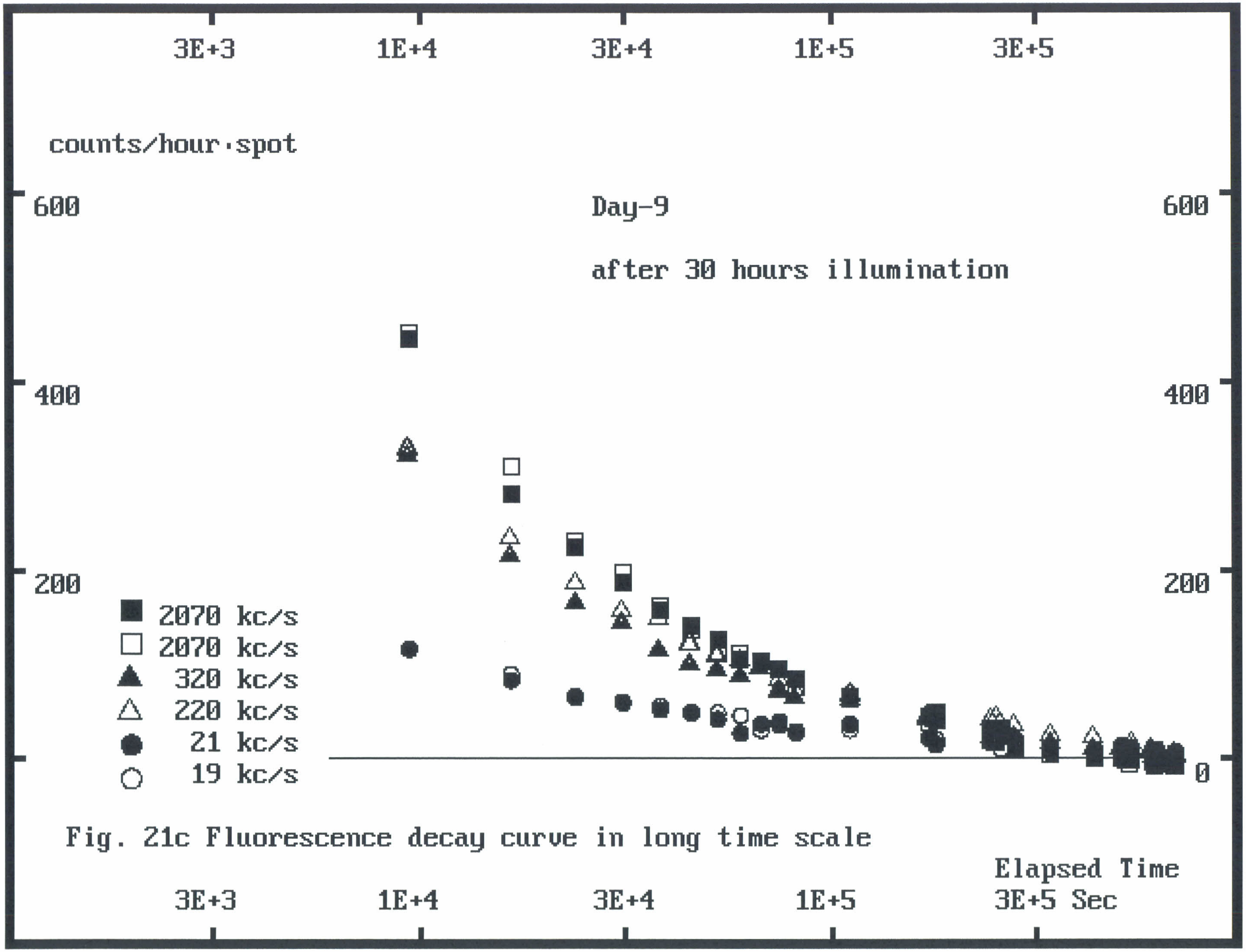


Fig. 21c Fluorescence decay curve in long time scale

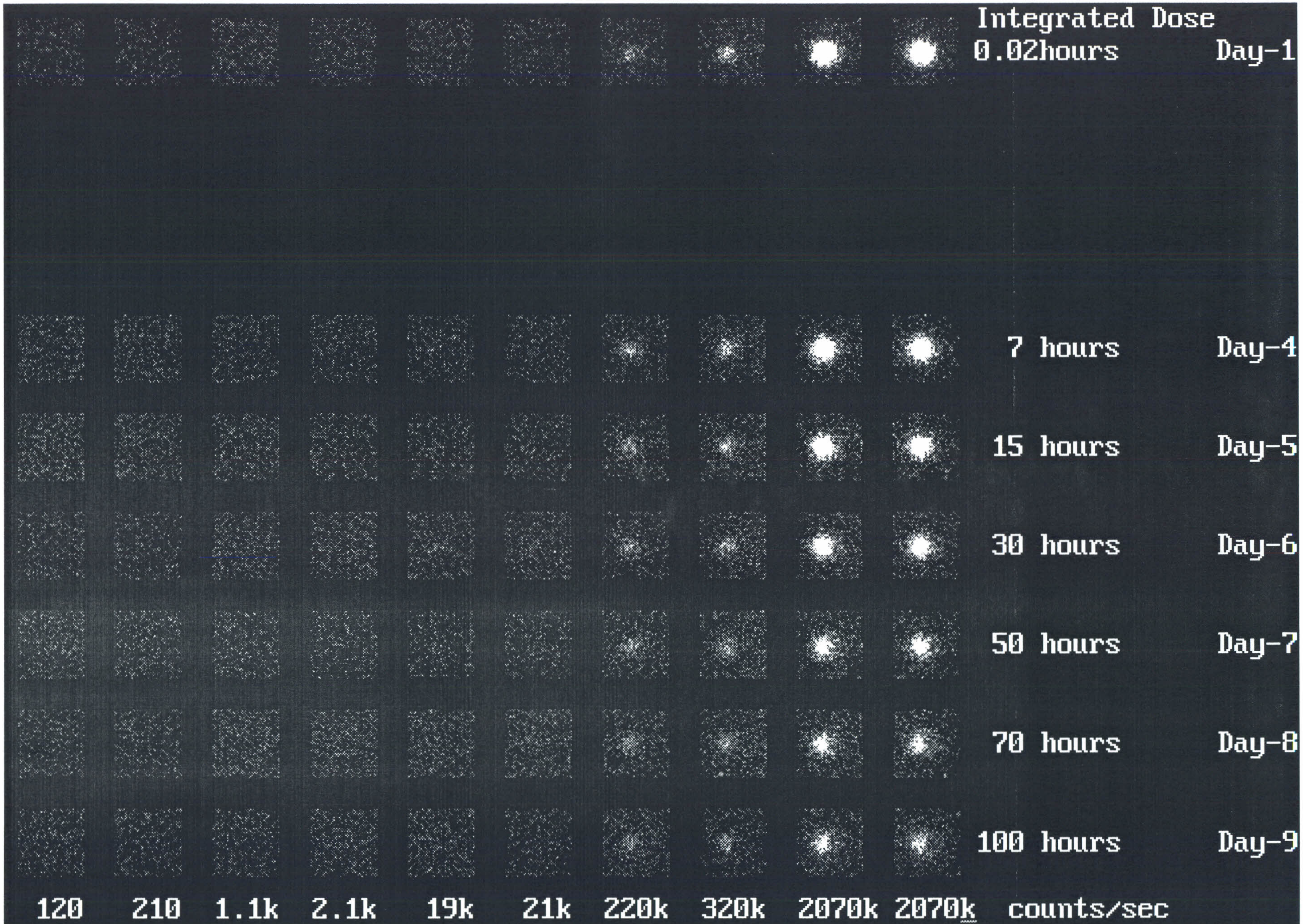


Fig. 22 Fluorescence by 1min illumination Short decay component DEP_#8 Tube

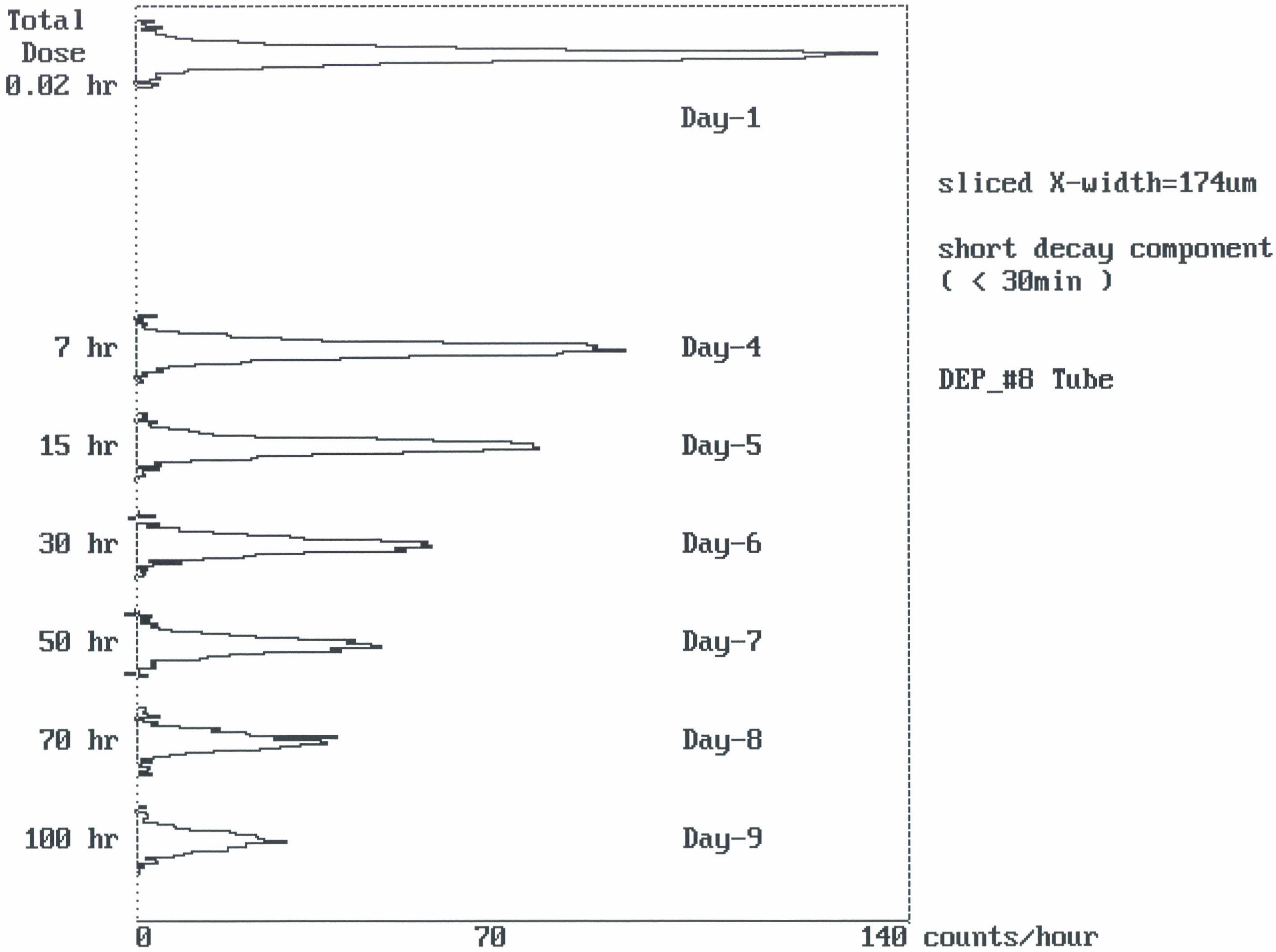


Fig. 23 Fluorescence after 1 min illumination by 2E+6 c/s pinholes

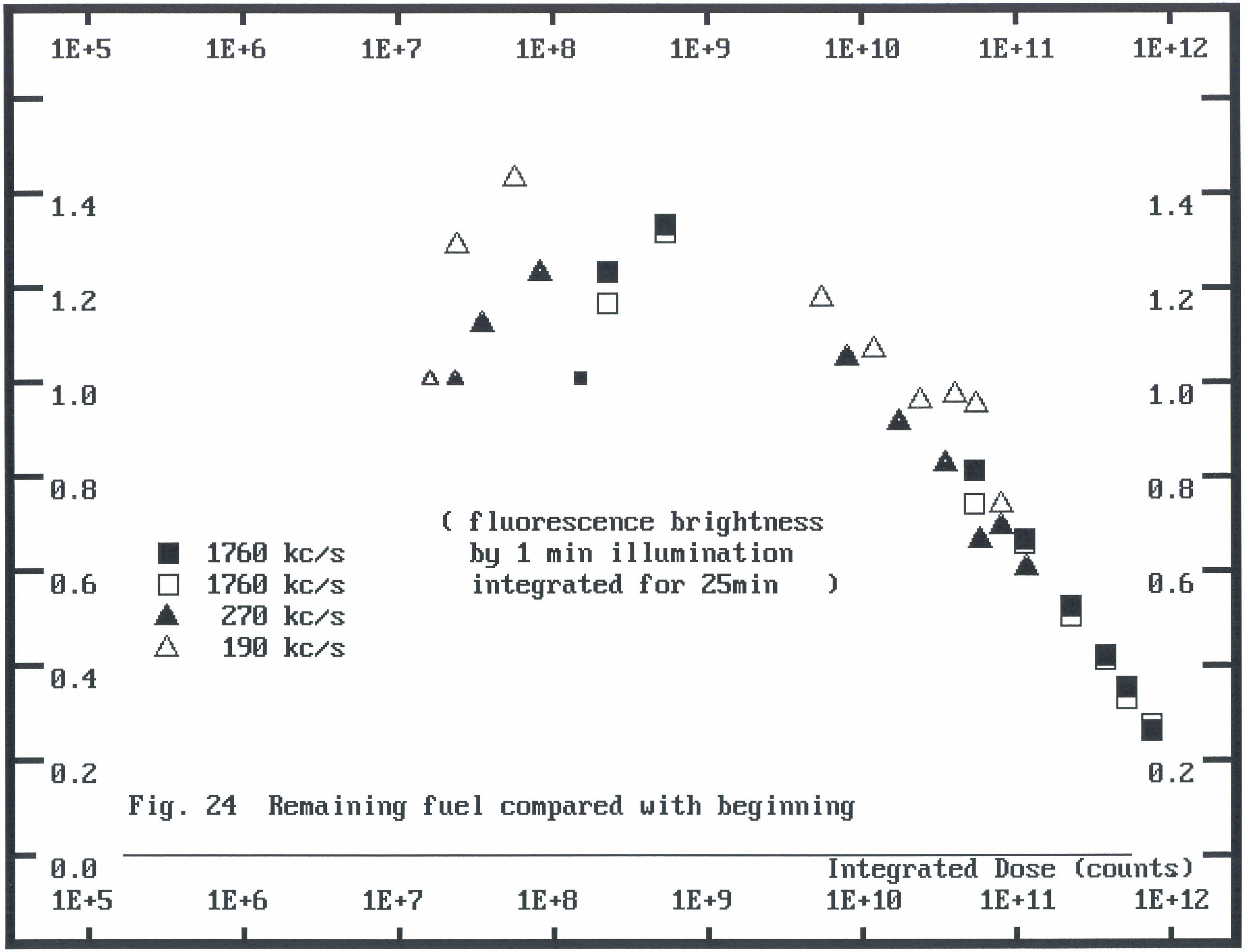


Fig. 24 Remaining fuel compared with beginning

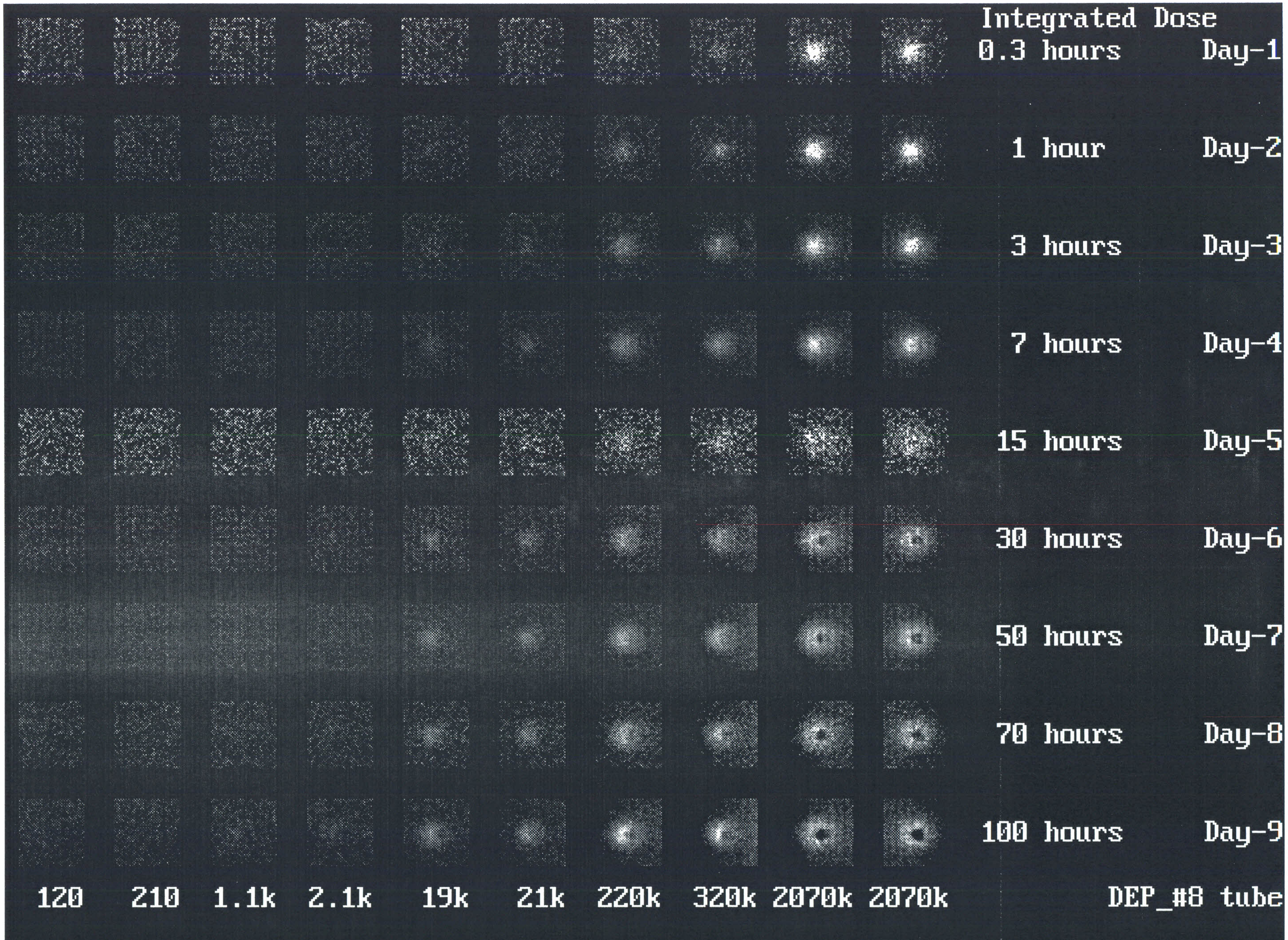


Fig. 25 Day by day change of fluorescence Long decay component

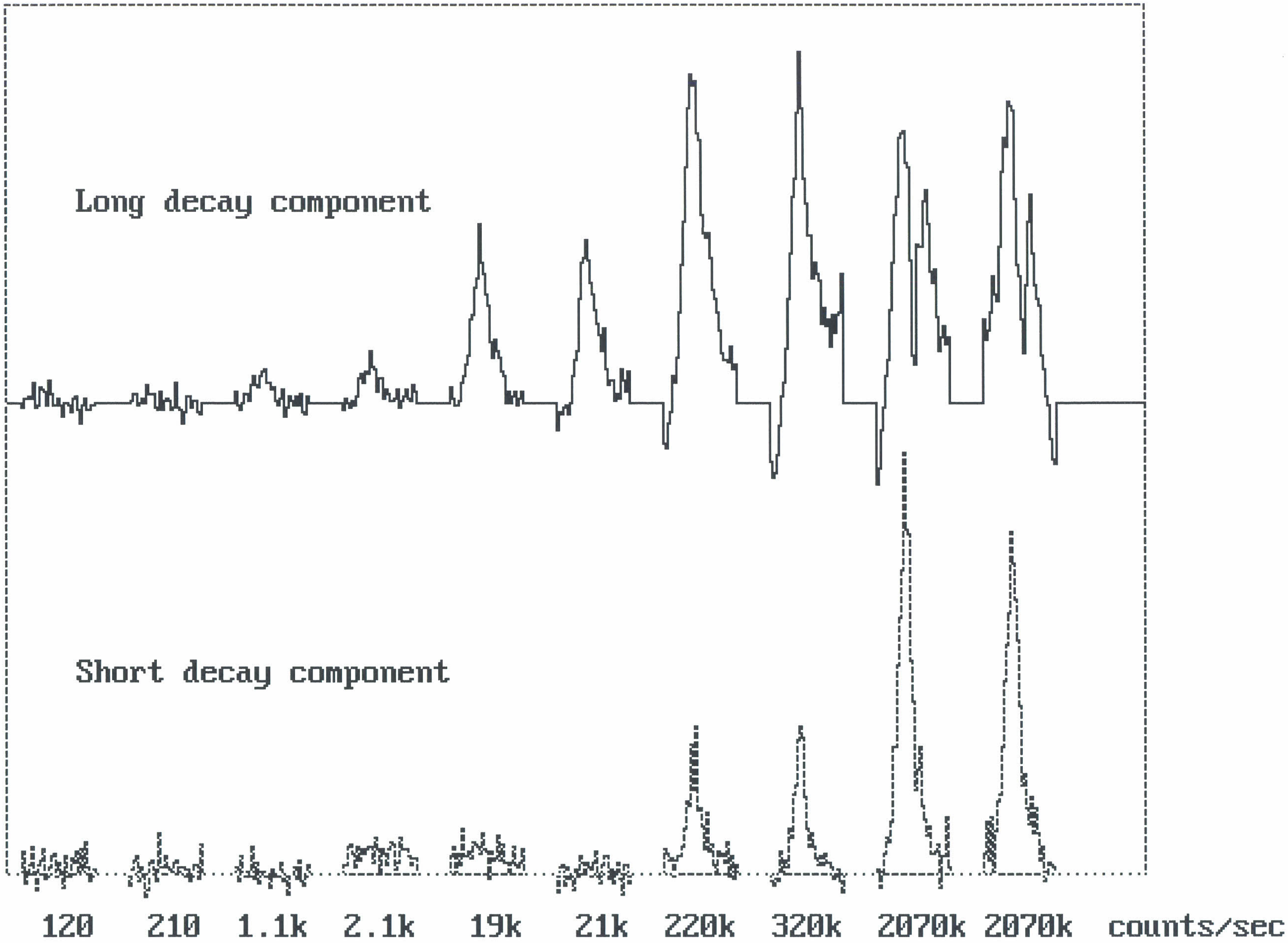


Fig. 26 Profiles of fluorescence after 100 hours dose DEP_#8 Tube

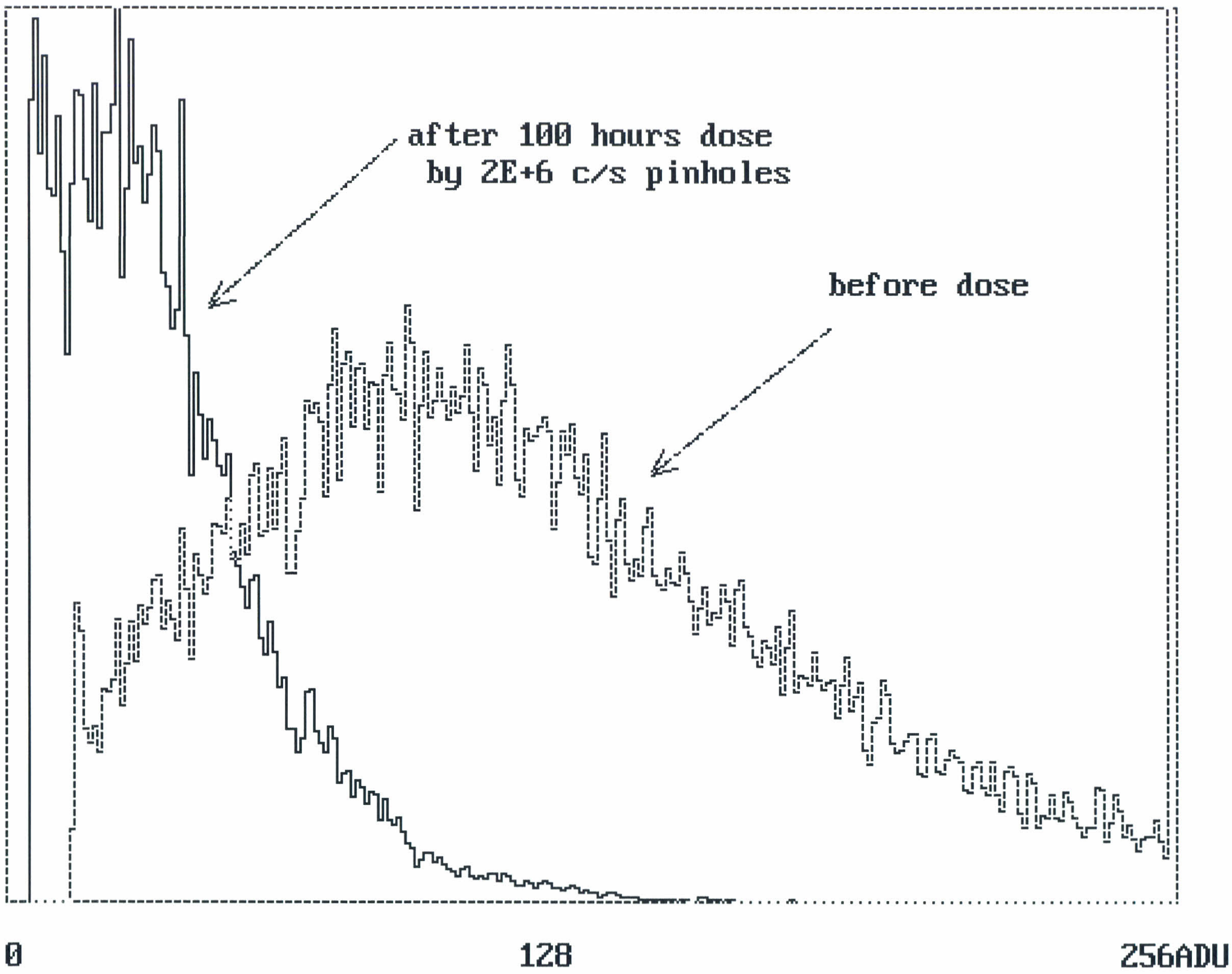


Fig. 27a Pulse height distributions before and after 100 hours dose DEP_#8

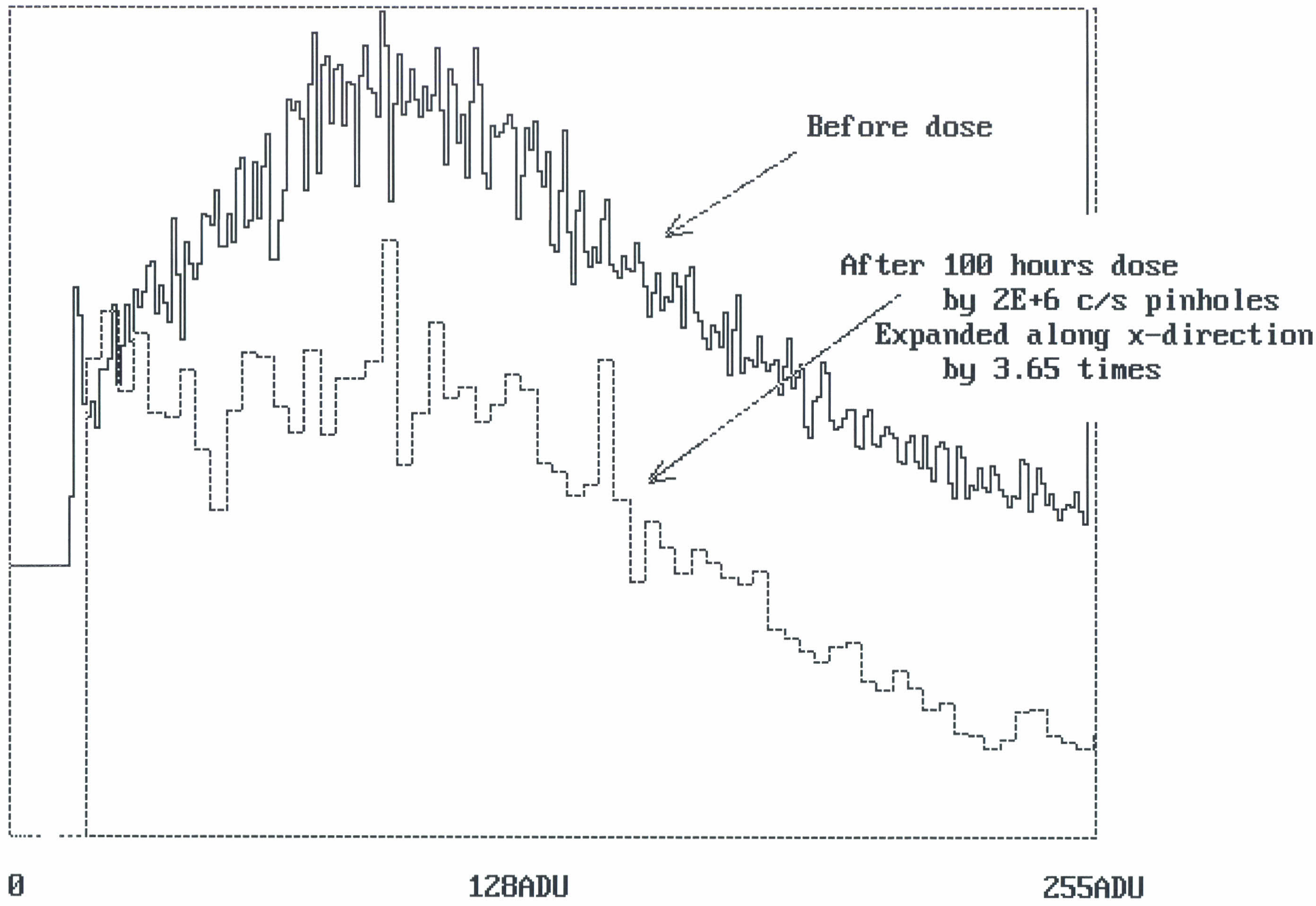


Fig. 27b Pulse height distributions before and after 100 hours dose DEP_#8

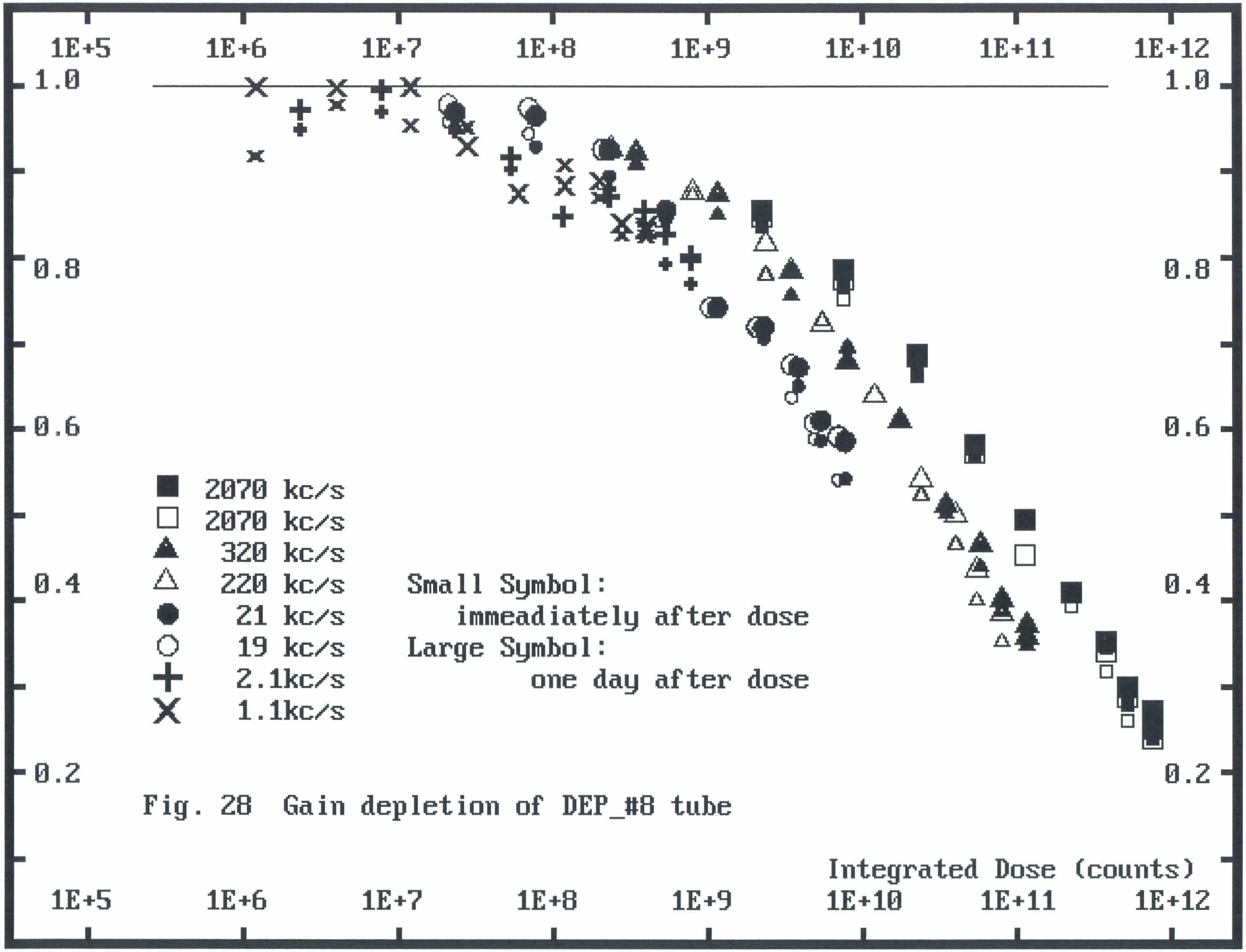


Fig. 28 Gain depletion of DEP_#8 tube

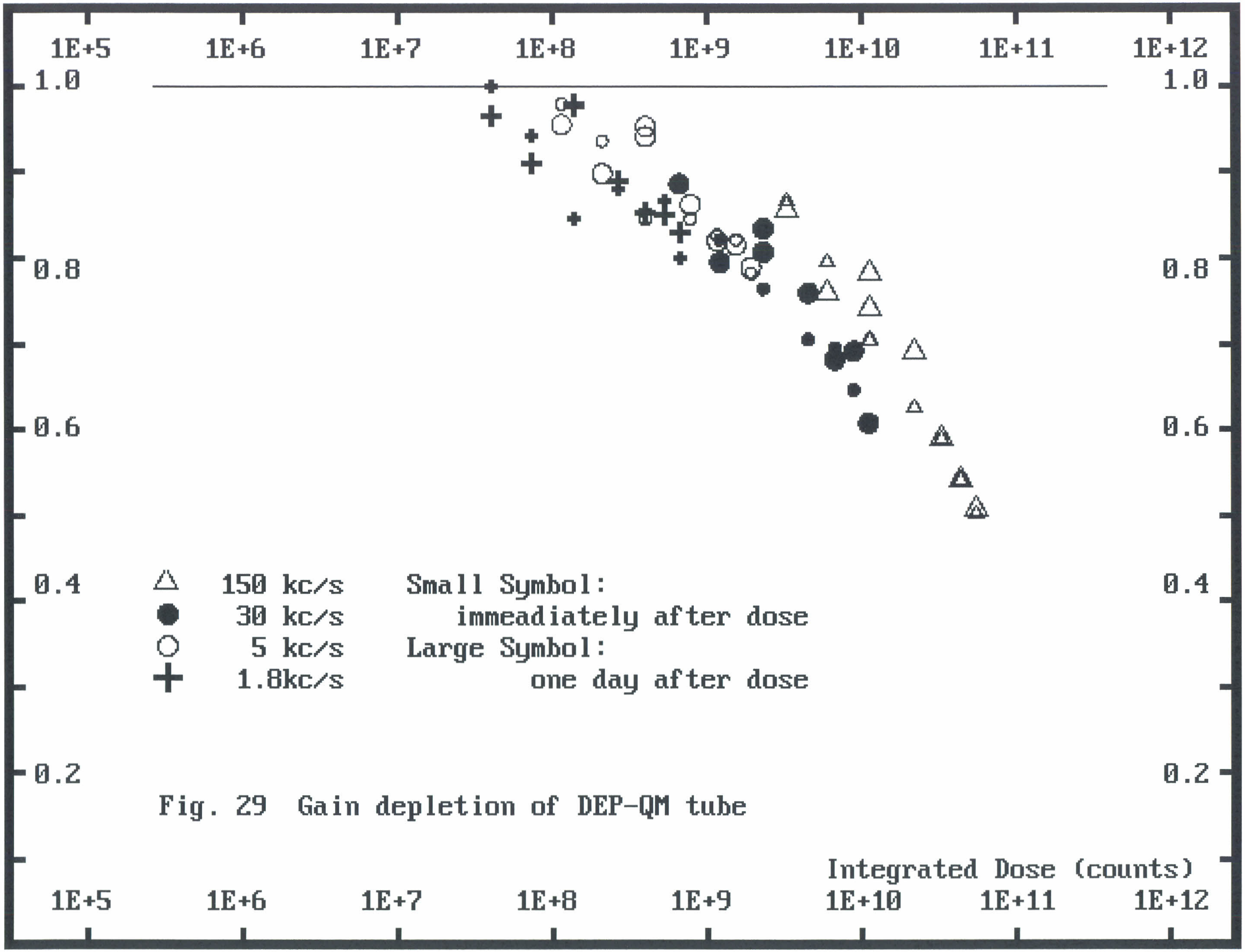


Fig. 29 Gain depletion of DEP-QM tube

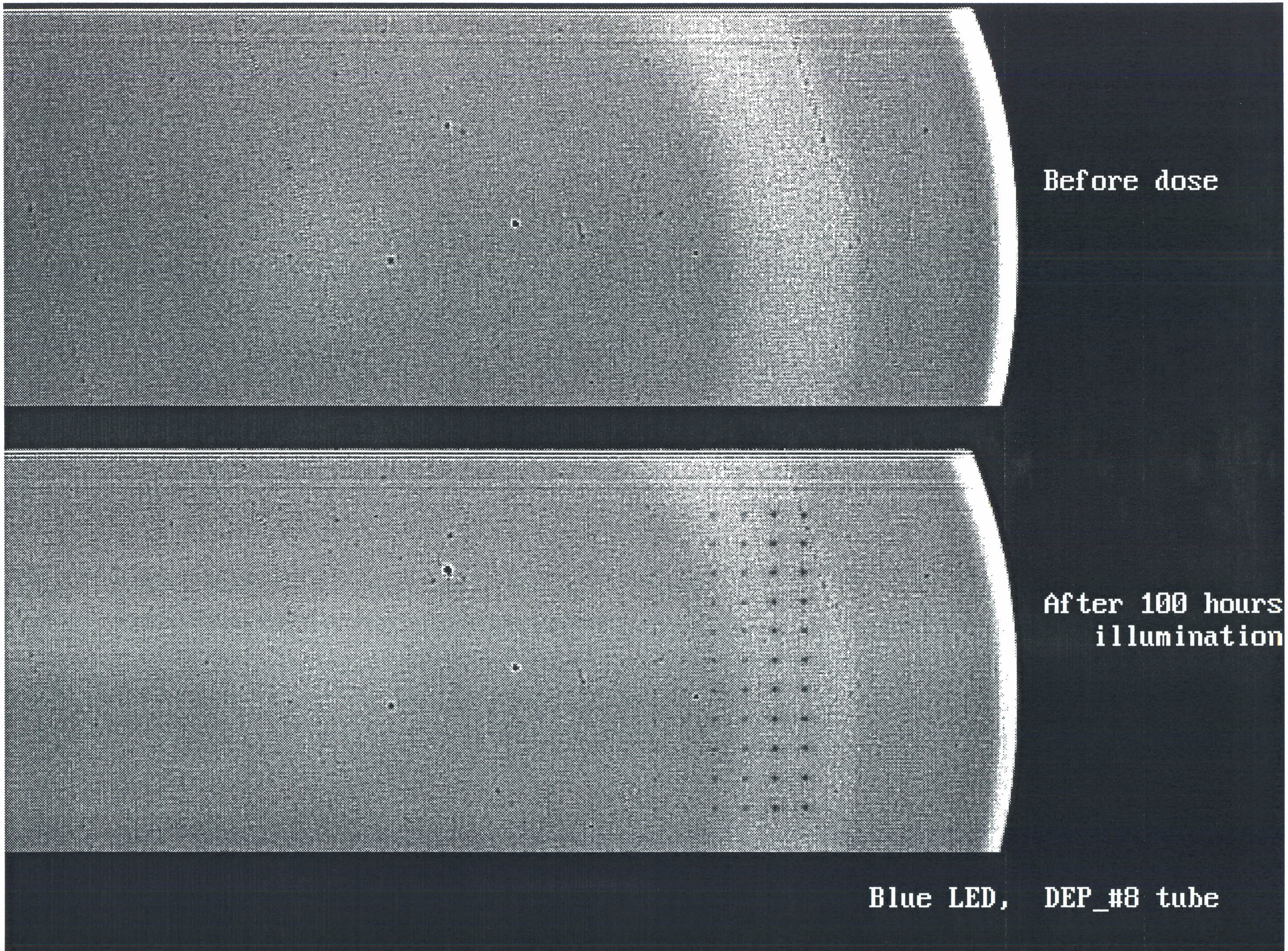


Fig. 30 F-F images acquired in photon counting mode, before and after Dose

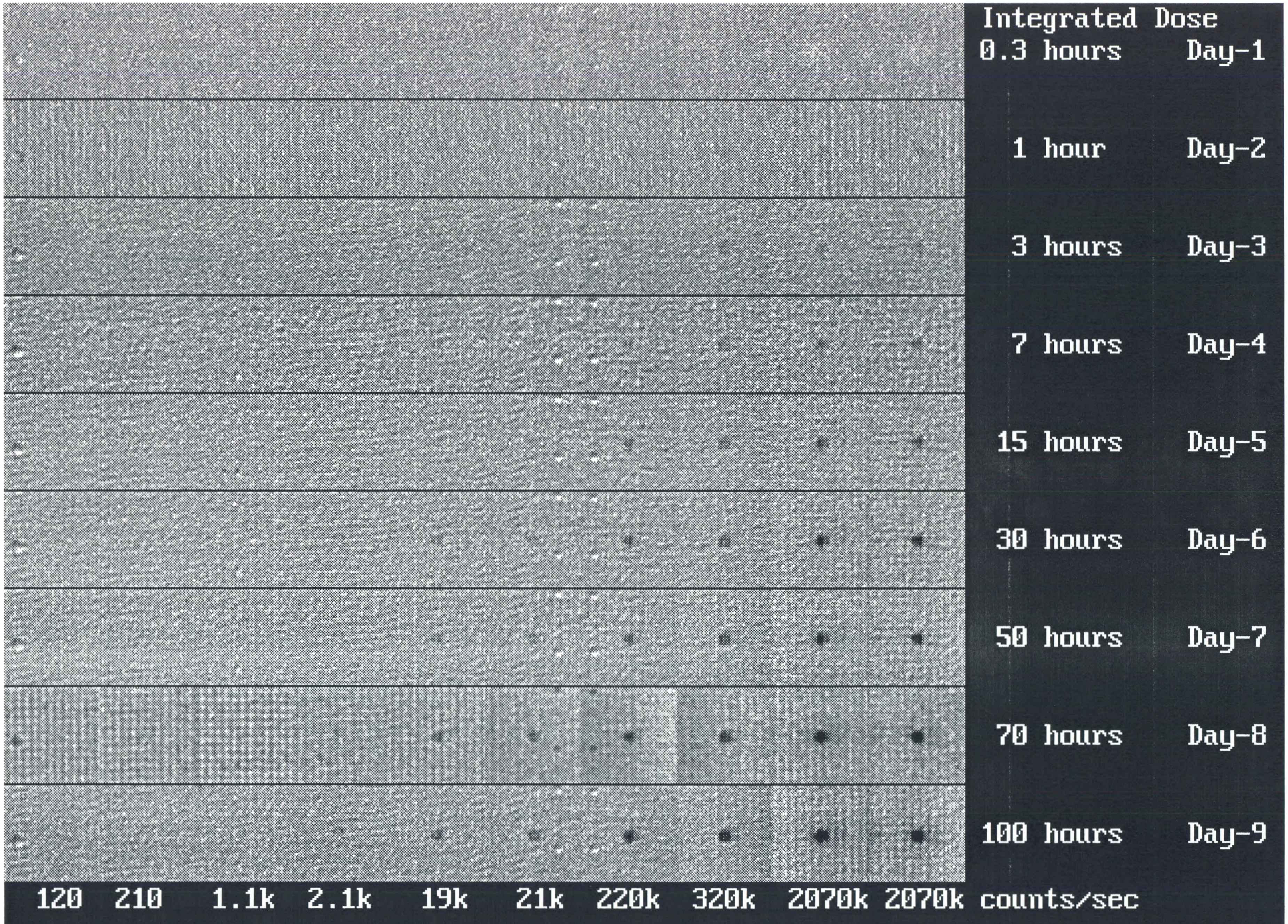


Fig. 31 Day by day change of black spots in F-F 11 spots are averaged DEP_#8

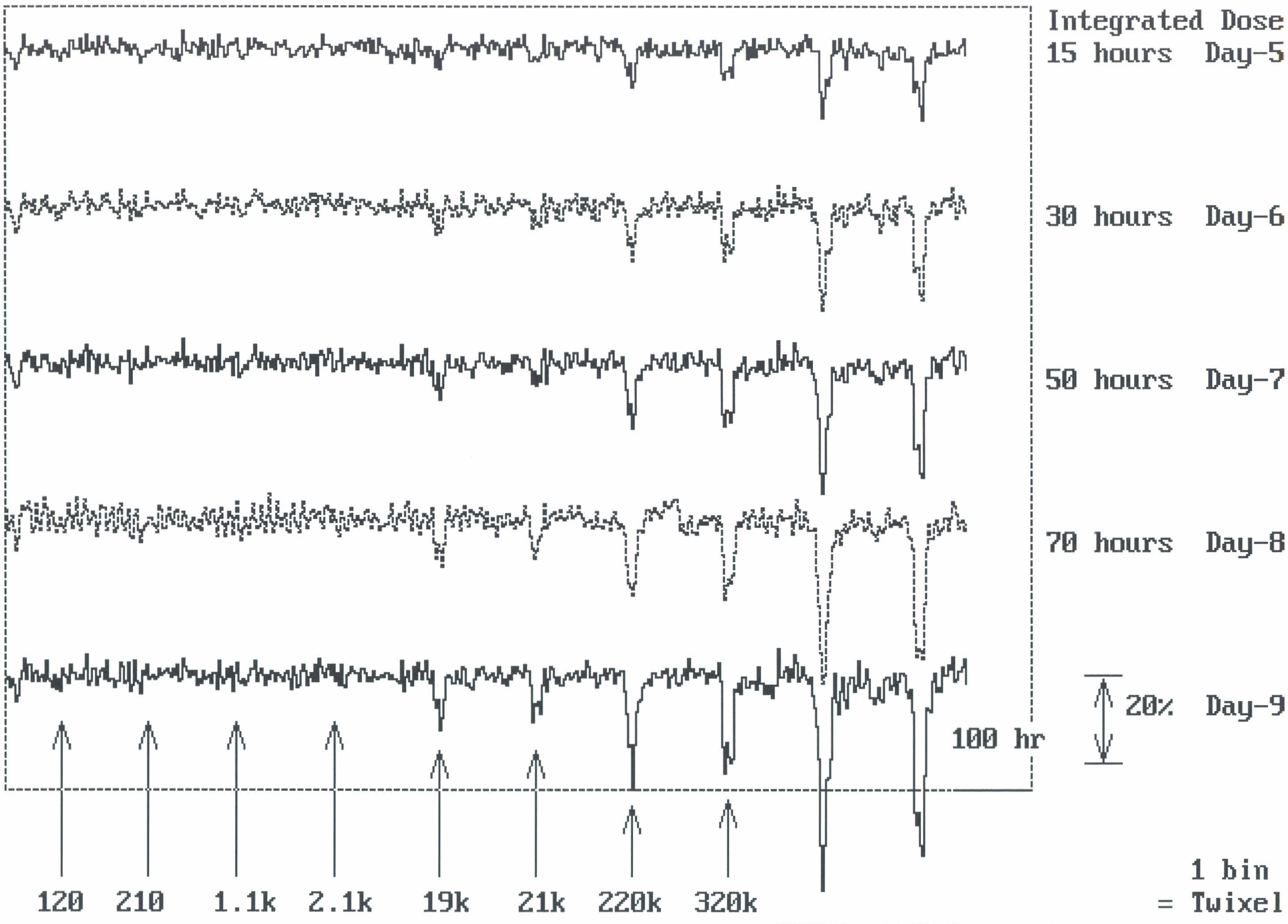


Fig. 32 Growth of sensitivity loss in F-F image with blue LED DEP_#8 tube

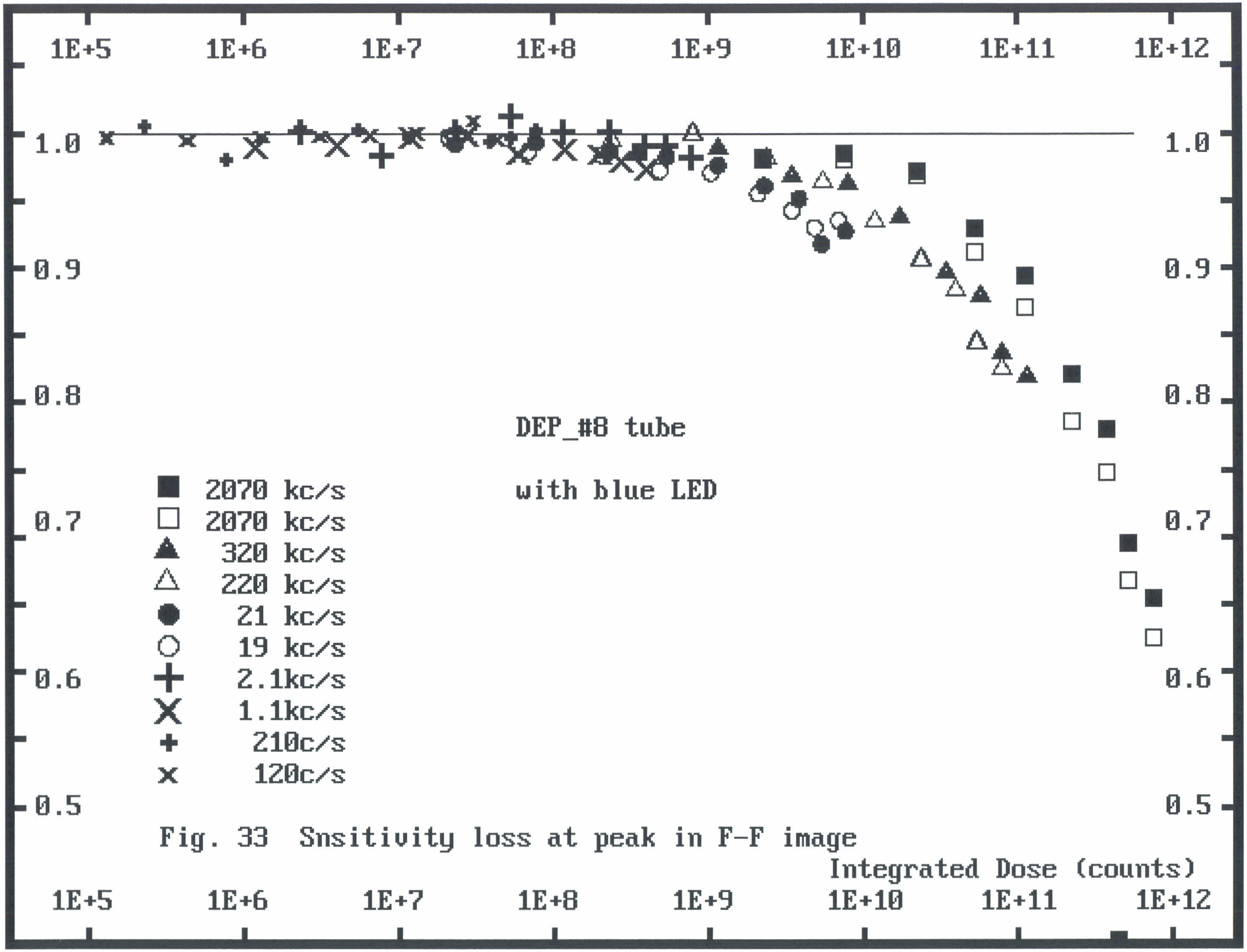


Fig. 33 Snsitivity loss at peak in F-F image

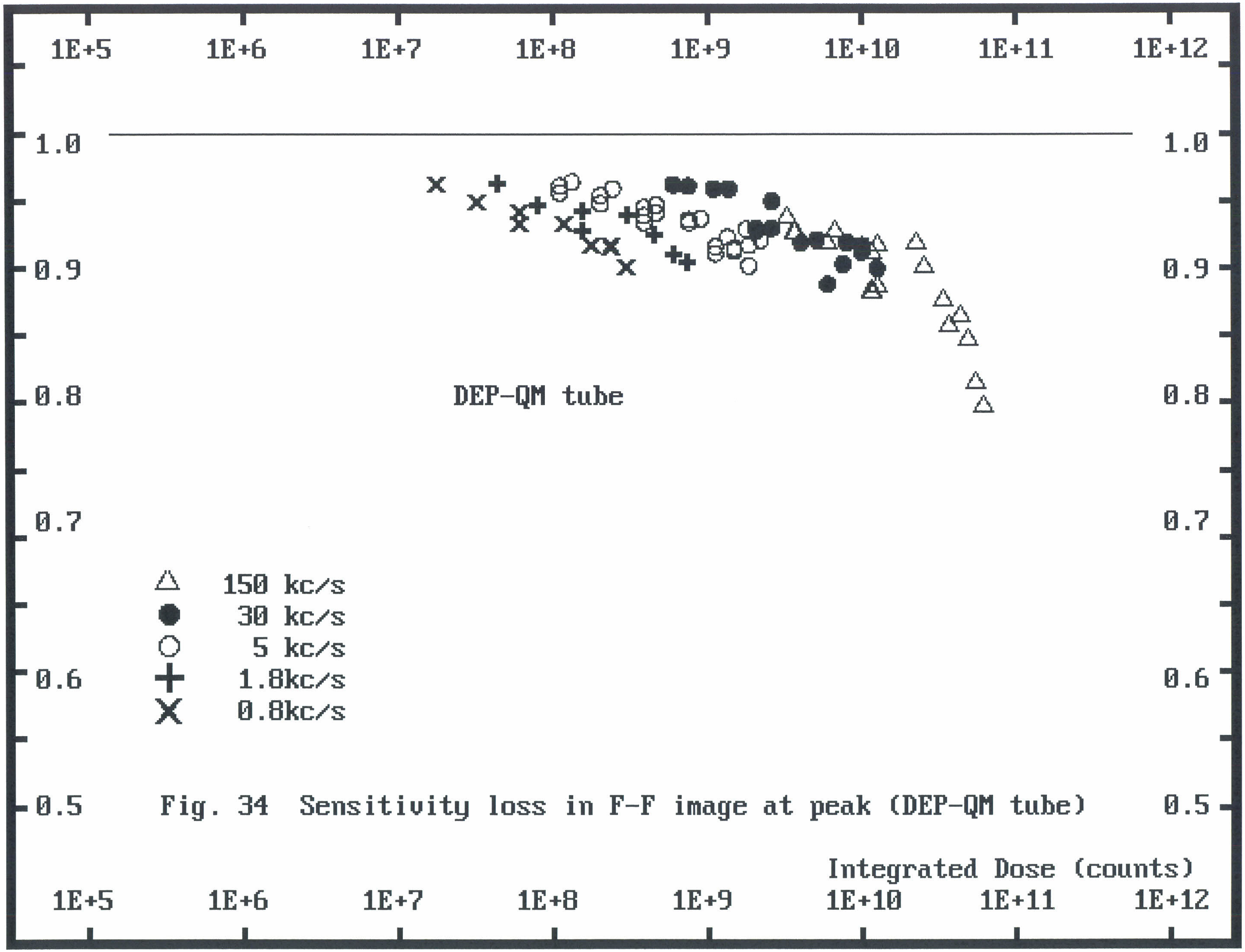


Fig. 34 Sensitivity loss in F-F image at peak (DEP-QM tube)

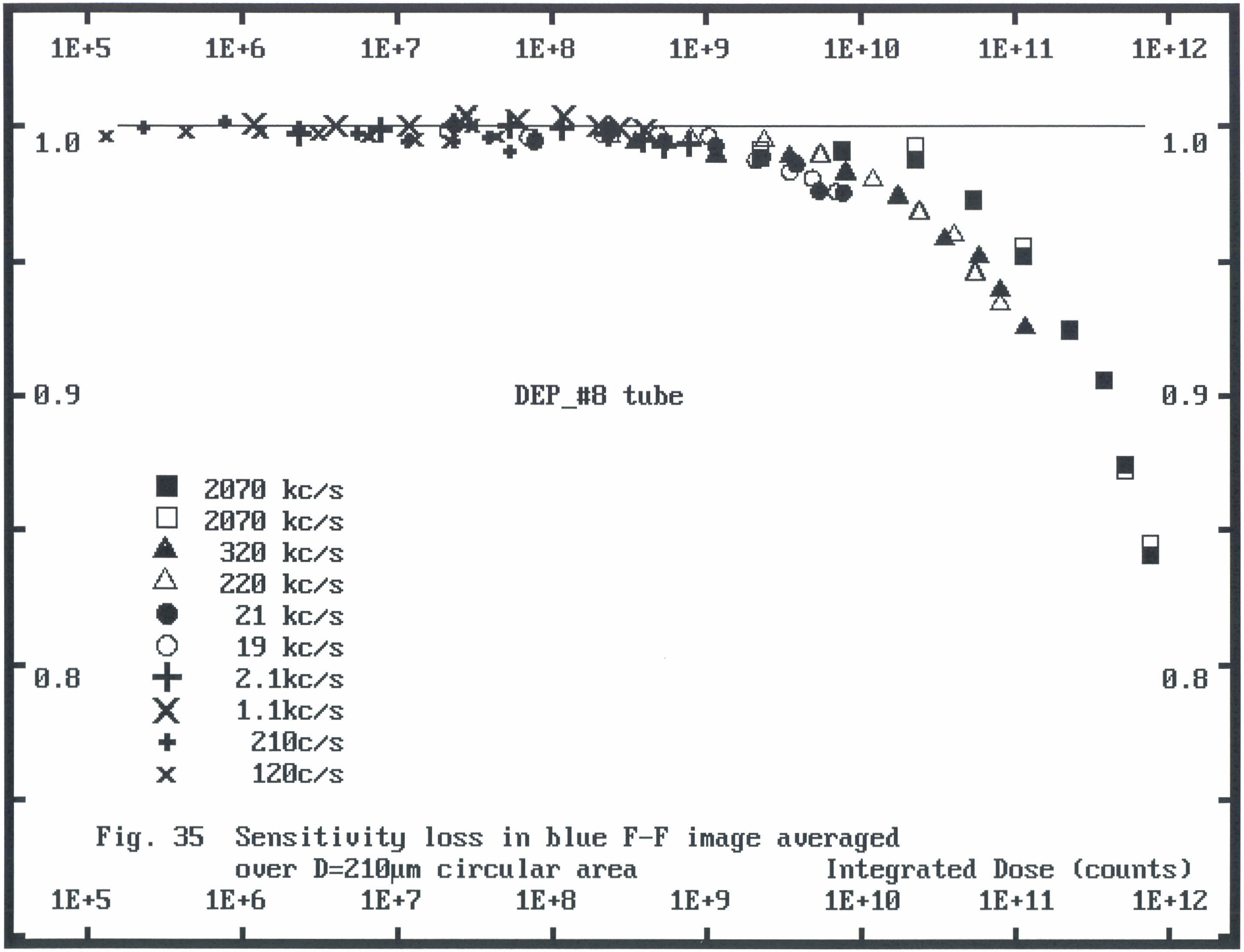


Fig. 35 Sensitivity loss in blue F-F image averaged over D=210µm circular area

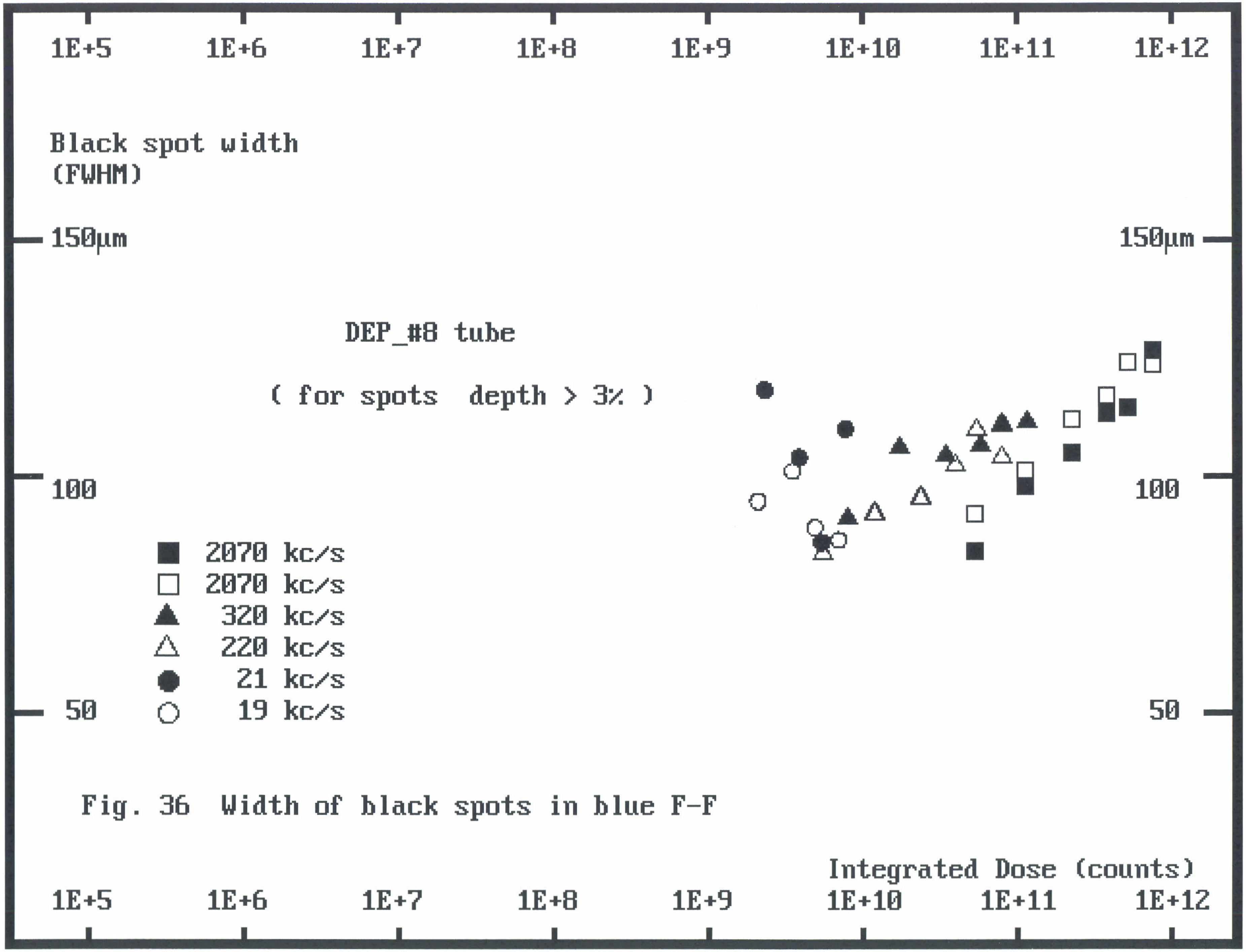


Fig. 36 Width of black spots in blue F-F

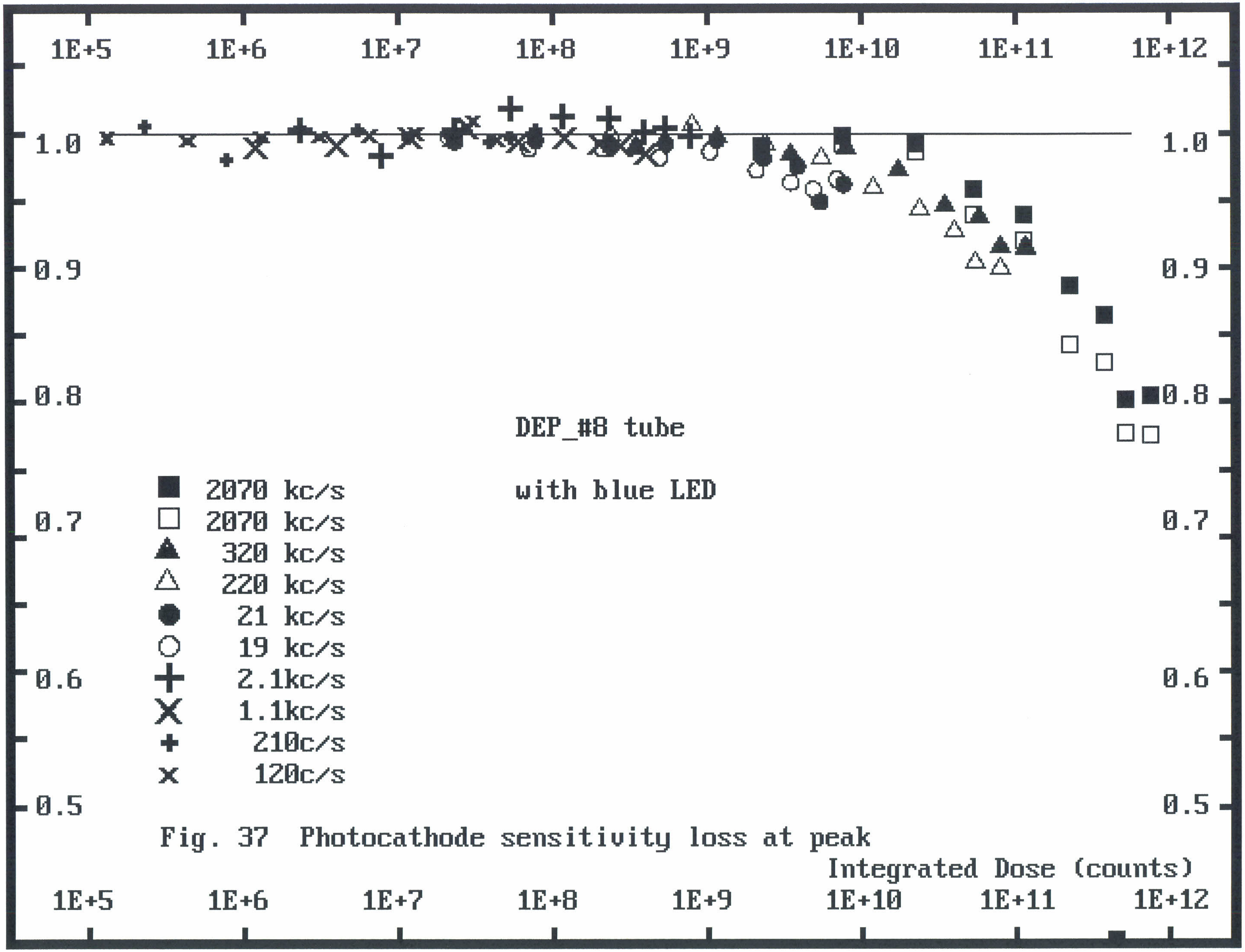


Fig. 37 Photocathode sensitivity loss at peak

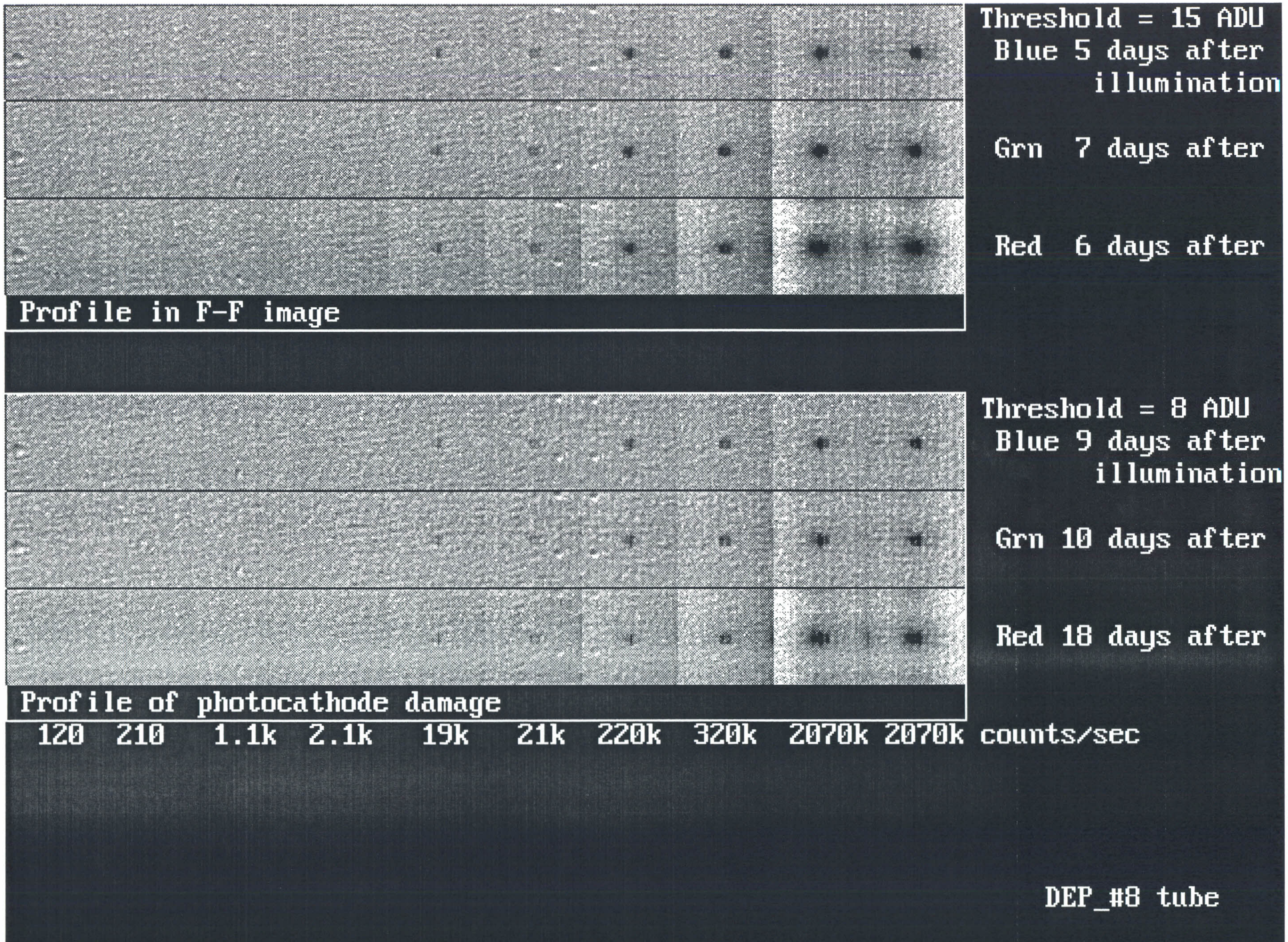


Fig. 38 Sensitivity loss in different colours Total dose = 100 hours

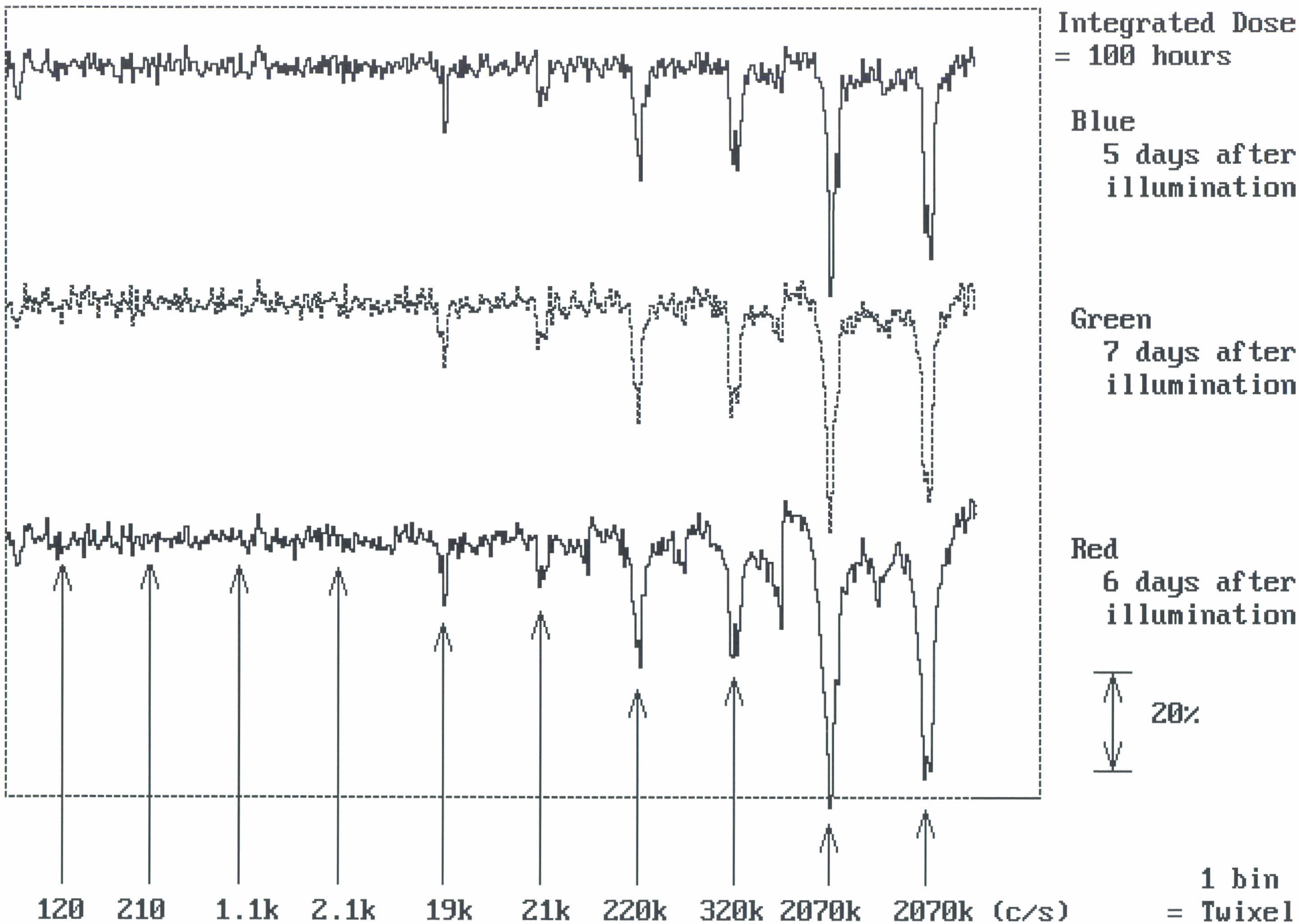


Fig. 39 Sensitivity loss in F-F image with different colours DEP_#8 tube

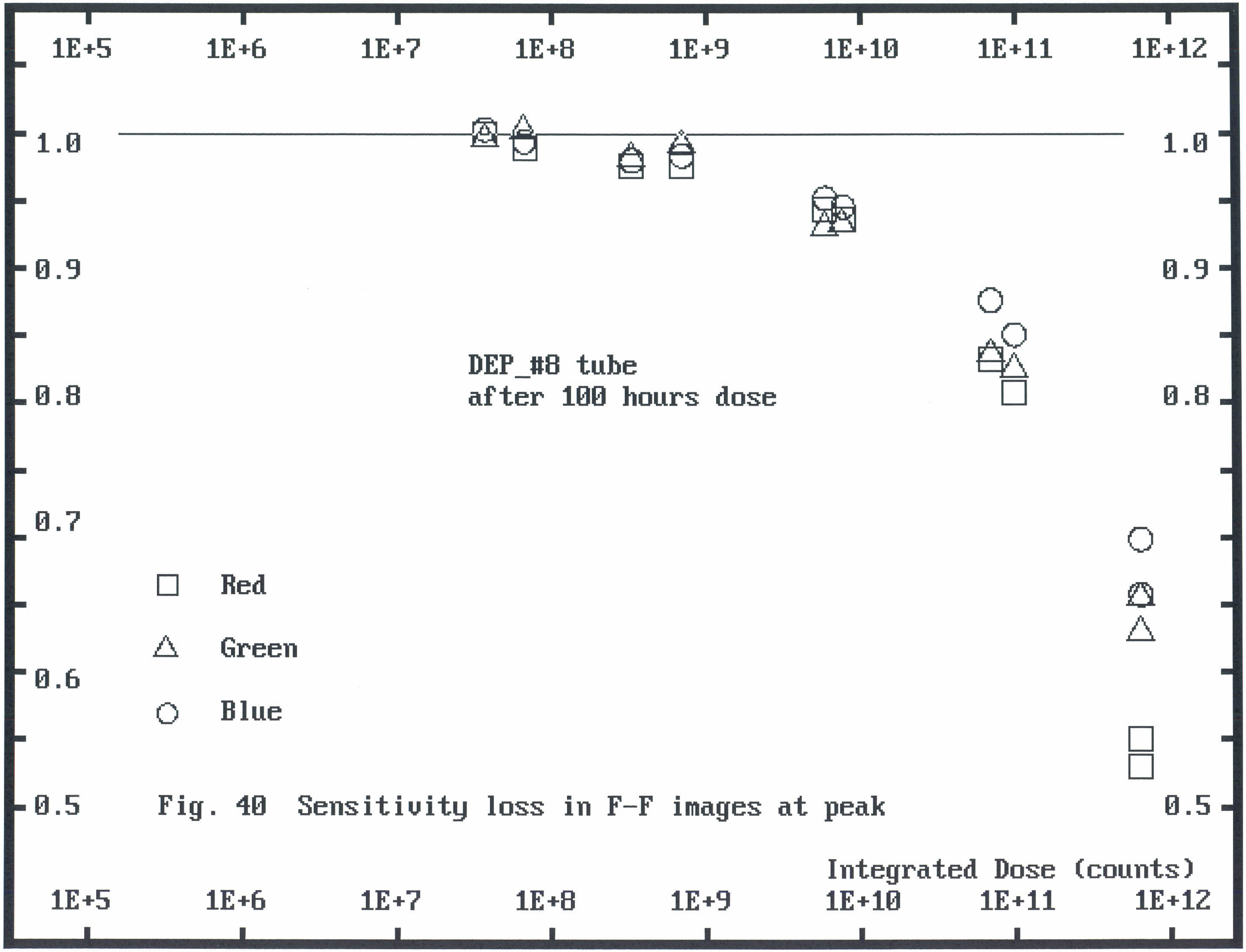


Fig. 40 Sensitivity loss in F-F images at peak

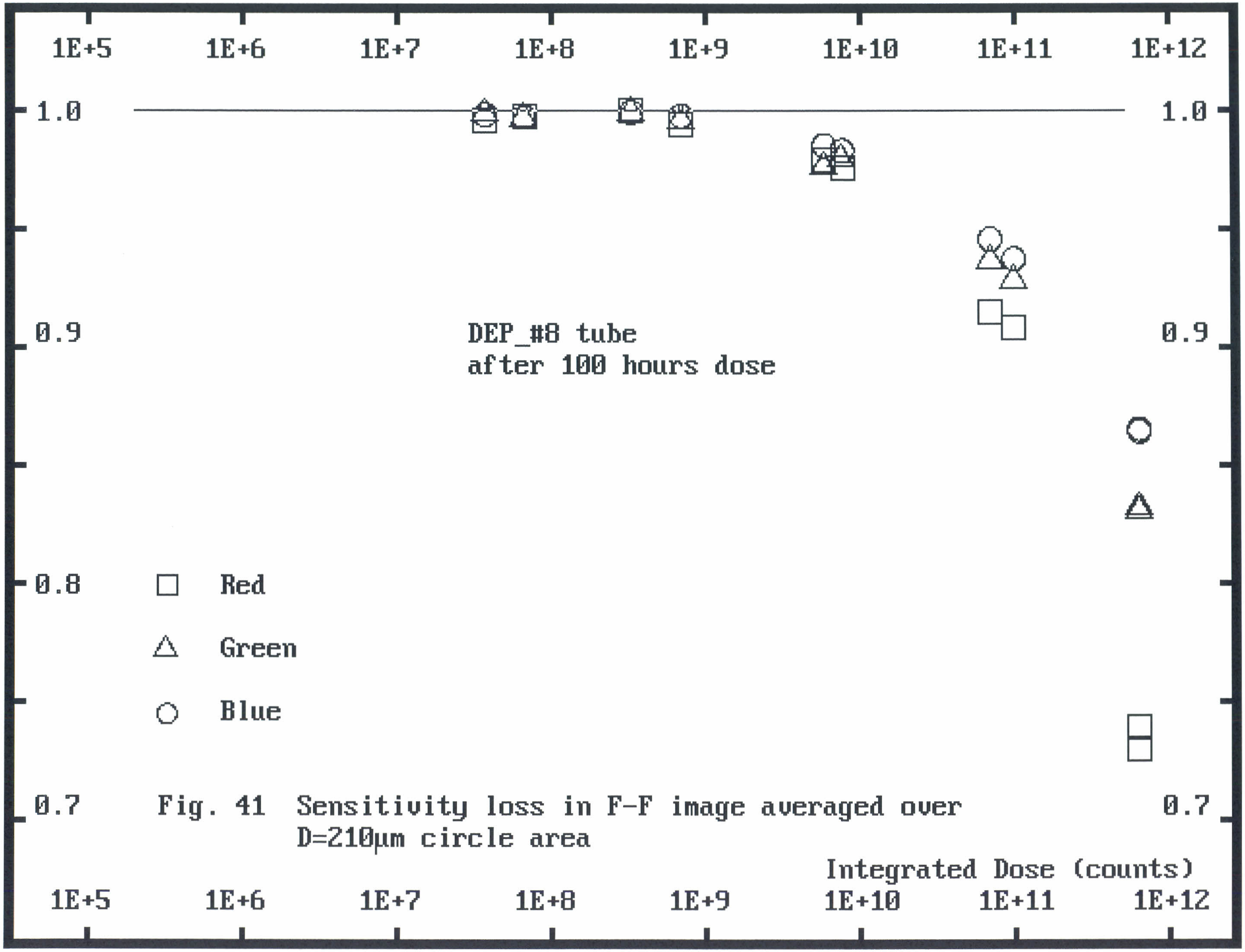


Fig. 41 Sensitivity loss in F-F image averaged over D=210μm circle area

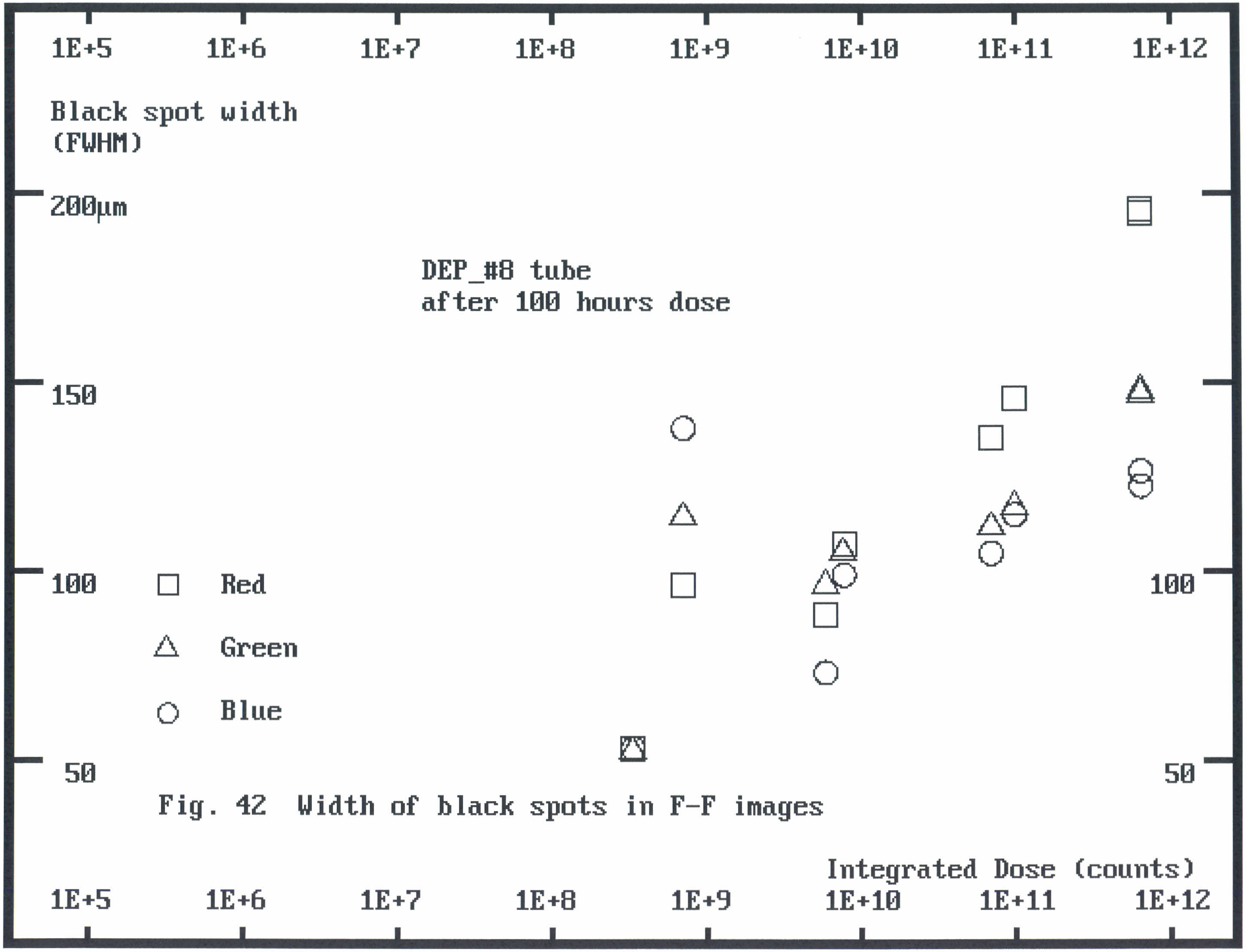


Fig. 42 Width of black spots in F-F images

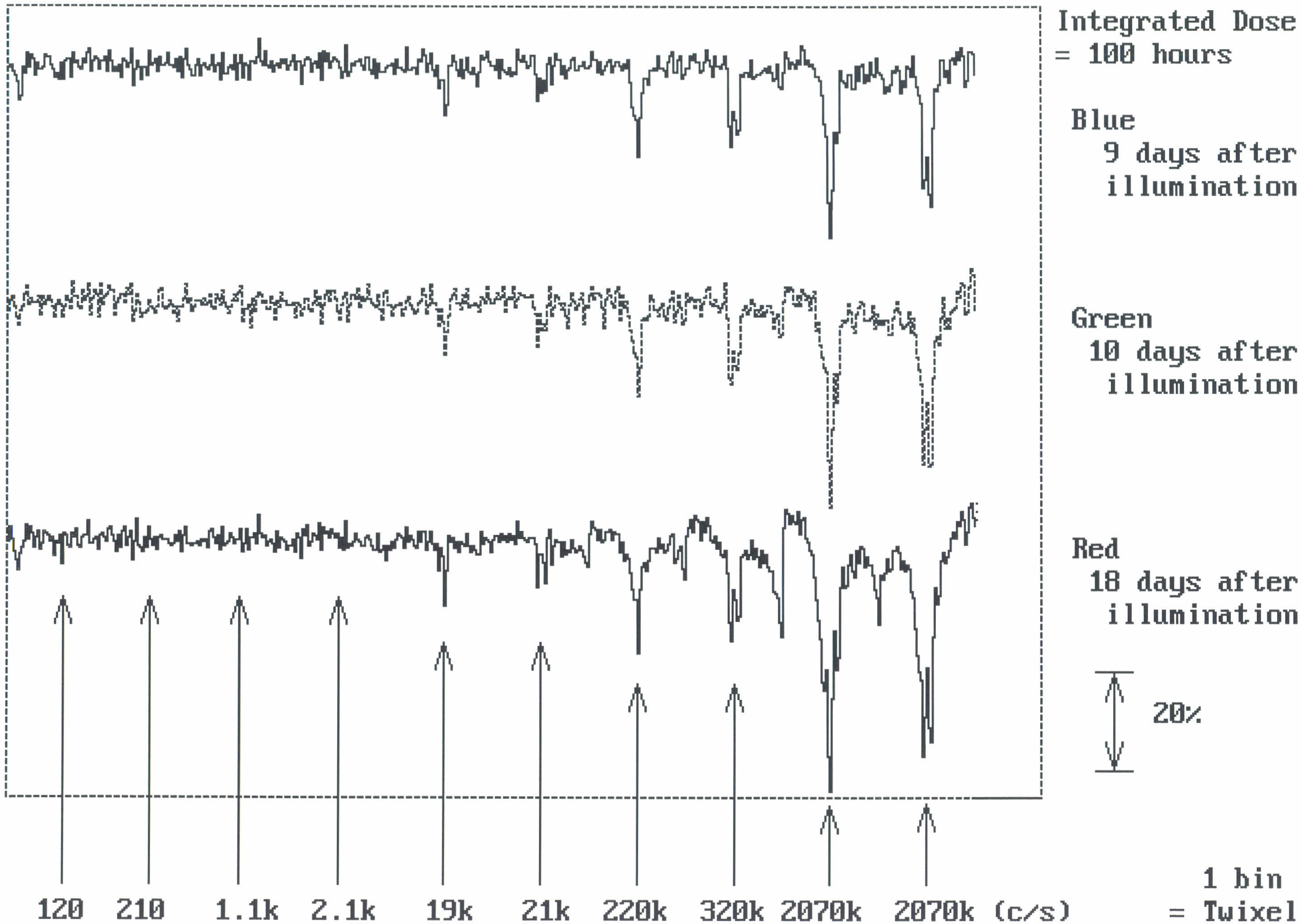
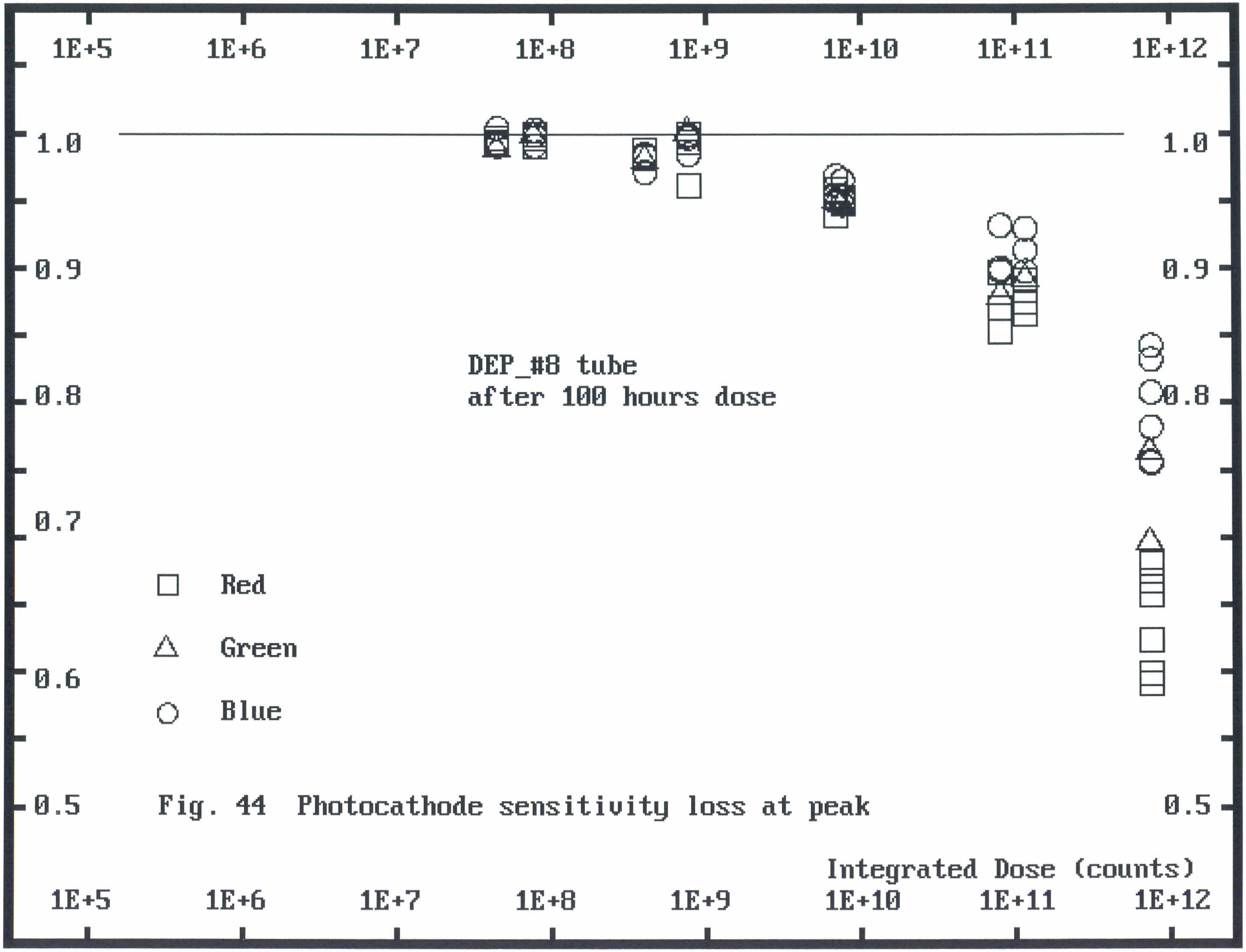


Fig. 43 Photocathode sensitivity loss in 3 colours DEP_#8 tube


1E+5
1E+6
1E+7
1E+8
1E+9
1E+10
1E+11
1E+12
1.0
0.9
0.8
0.7
0.6
0.5
DEP_#8 tube
after 100 hours dose
Red
Green
Blue
Fig. 44 Photocathode sensitivity loss at peak
Integrated Dose (counts)

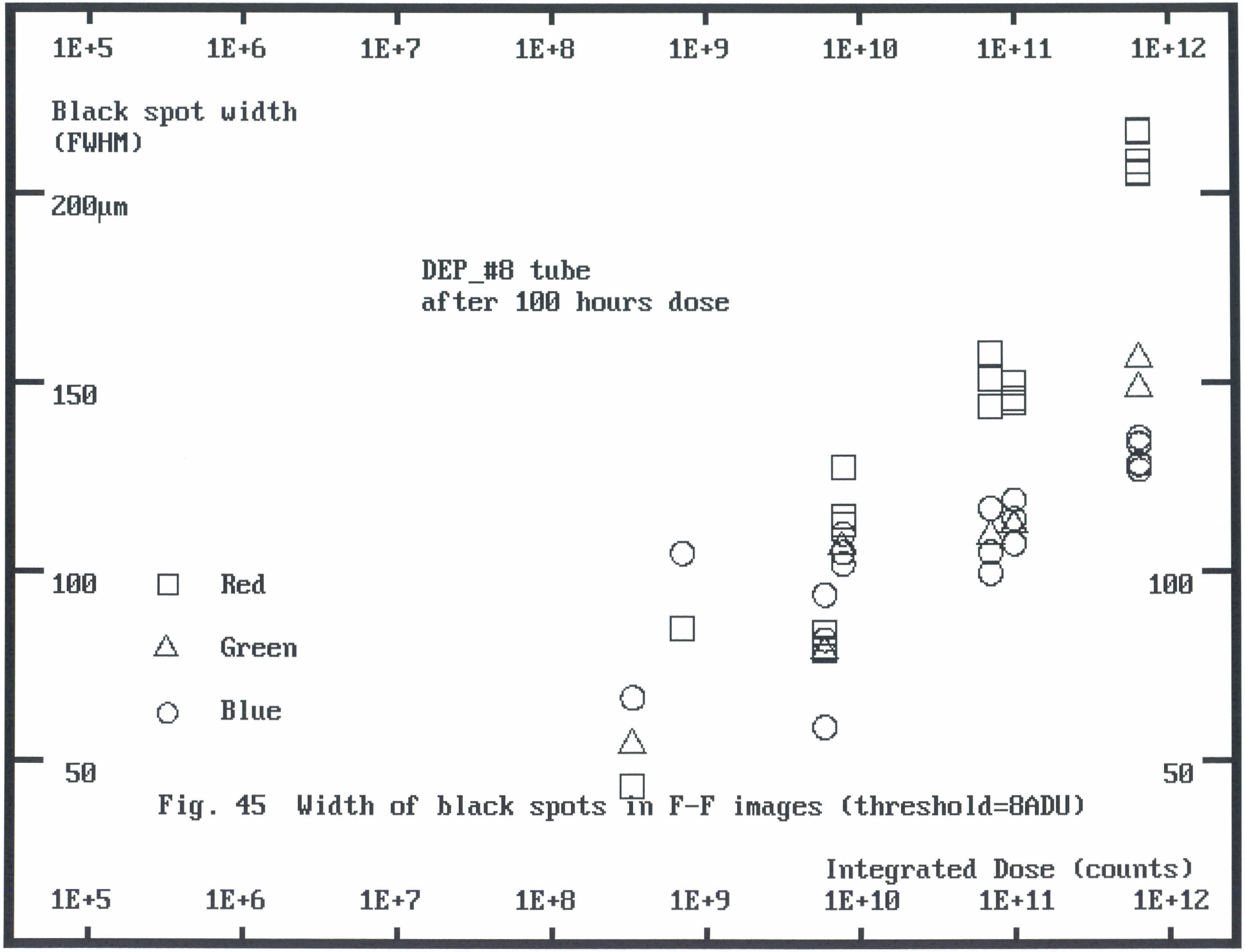


Fig. 45 Width of black spots in F-F images (threshold=8ADU)

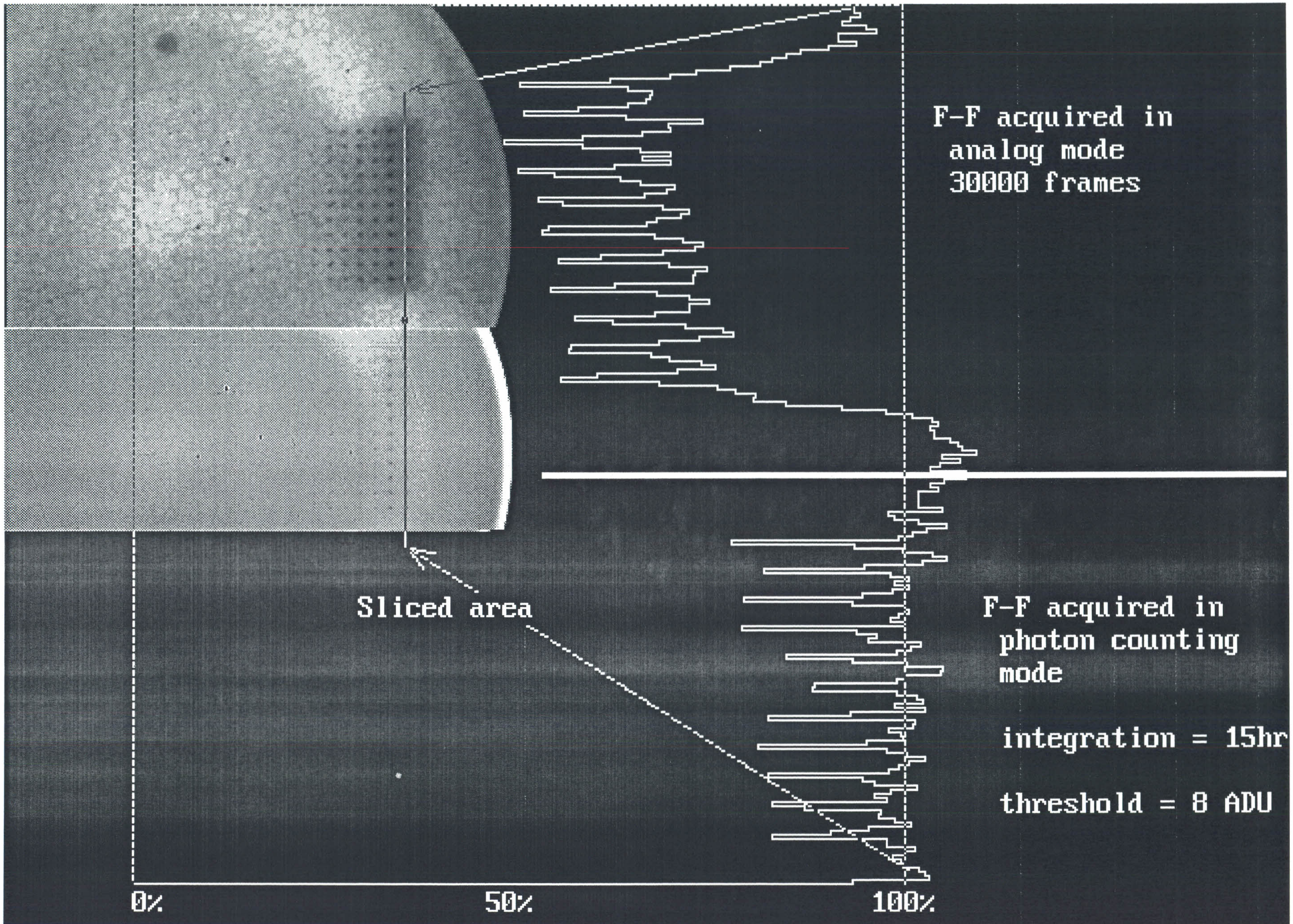


Fig. 46 Photon counting and analog F-F images, with blue Led, dose=100 hours

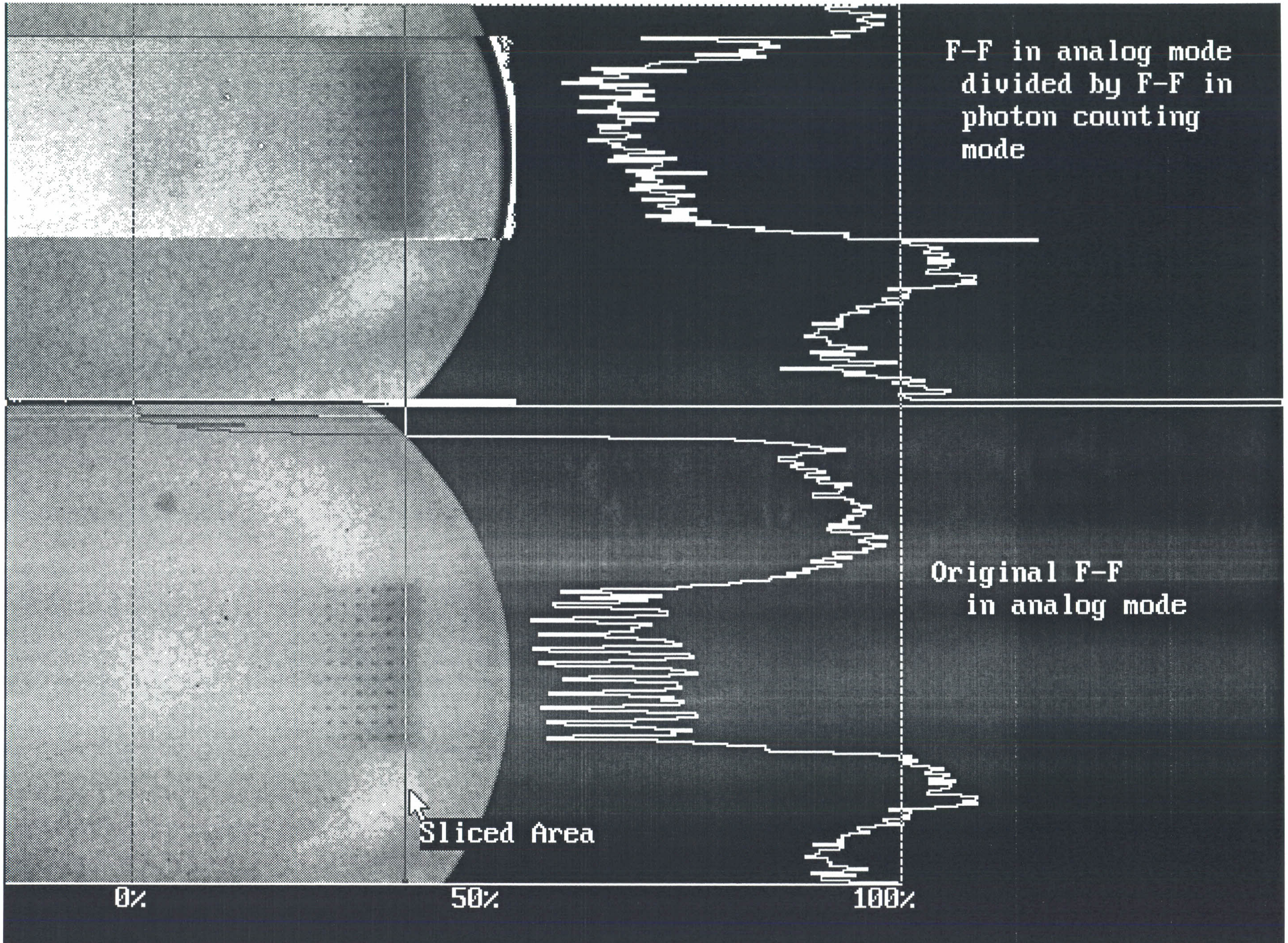


Fig. 47 Spatial extent of MCP gain depletion

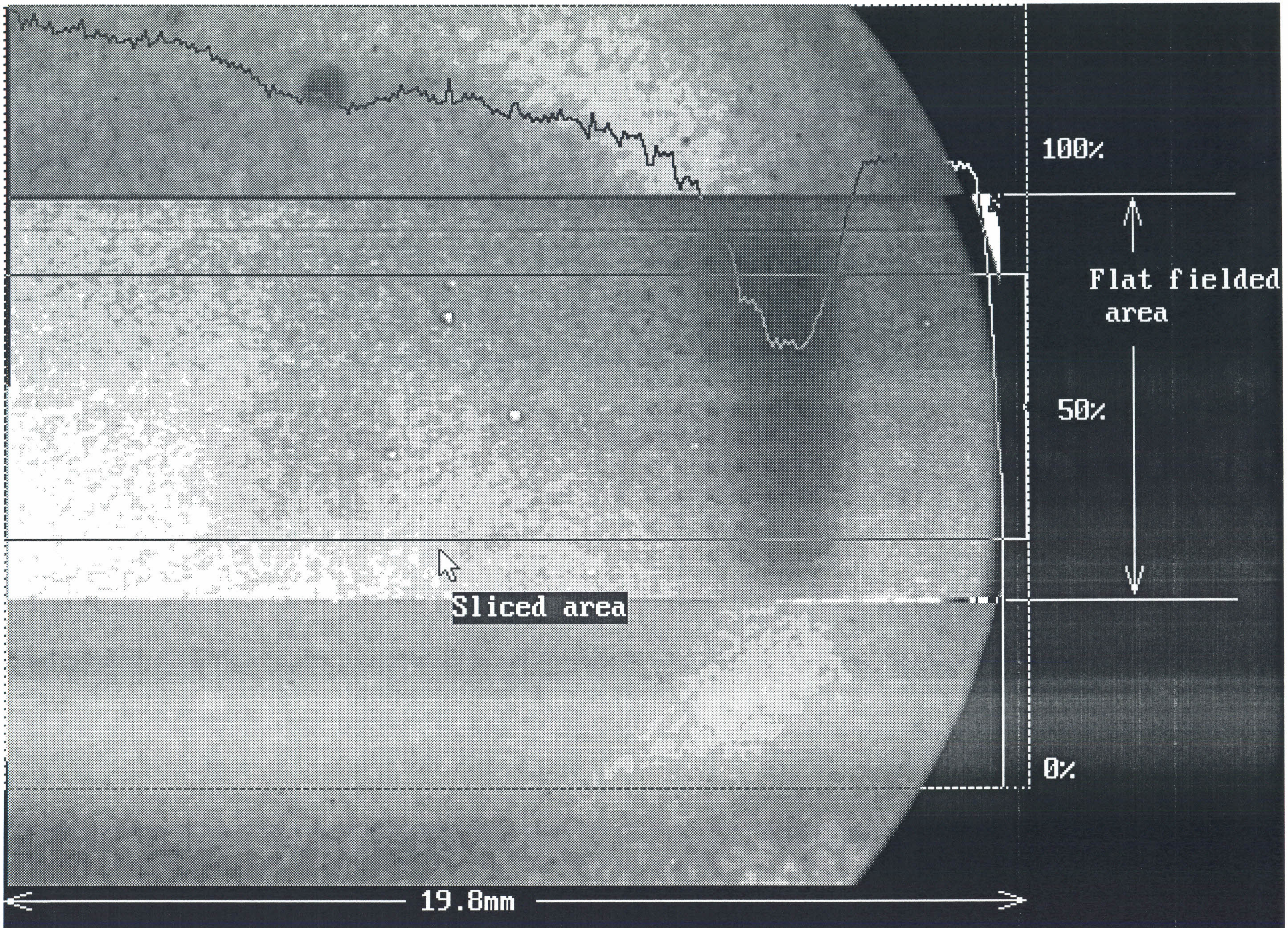


Fig. 48 Spatial distribution of MCP gain depeletion   Dose=100 hours