XMM Optical Monitor

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

<< Characteristics of DEP_#8 intensifier >>

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Mid term Report-A on the life time test of DEP intensifier

<< Characteristics of DEP_#8 intensifiers >>

1. Introduction

Ruggedness of the FM intensifiers against bright stars has to be characterized before the launch of XMM for a safe observation in an early period.

The life time performances of DEP's QM intensifier (XMM demonstration model) were fully assessed in 1997 (XMM-OM/MSSL/TC0044). The intensifier was suffer from same MCP's gain depletion as other models, but showed significantly longer photocathode life time (x10 times). The FM intensifiers were designed based on the QM-intensifier. The differences are 8um MCP1 and S20 photocathode employed for the FMs, while 10um MCP1 and Extended S20 for the QM. The change of the MCPs should not affect the life time performance. While, the change of the photocathode from E-S20 to S20 is expected to enhance the life time performance.

One of the problem with the QM intensifier was the low gain of the MCPs, which required V_mcp=2450V and V_anode=5500V. This anode voltage was higher than other QM-models by 1000V. The pulse height distribution was broad, which indicated lack of saturation within MCPs. It was not known, why the MCPs were not saturated with the highest MCP voltage. The 7 FM intensifiers (5 deliverable, 1 ruggedness test, 1 set-up) produced by DEP in 1998 showed significant improvement in the gain and pulse height distribution. This may be due to more experience of DEP in scrubbing process. Since MCPs lose gain with time when exposed to an intense electron cloud, too much scrubbing can shorten the life time of MCPs. The higher gain of FM intensifiers is good sign in this aspect. The less scrubbing, however, could leave more ions within the MCPs pores, therefore can damage photocathode more by the stronger ion feedback.

The low gain and the lack of saturation with the QM-intensifier might have given better results in the life time performance. The number of electron at the bottom of the MCP was fewer than other intensifiers because of the lower gain. The length of MCP pores interacting with a dense electron cloud was shorter because of the less saturation. Therefore, ion feedback was less produced. If the long life time of the QM-intensifier was achieved by its lower gain, its results are not applied to the 7 FM intensifiers.

This mid term report-A describes the characteristics of DEP_#8 intensifier, which is going to be damaged by pinhole light source in the intensity of 100 - 1,760,000 c/s for 100 hours. The following two must be proven before starting the damage test;

1) The intensifier does not show too excellent performances

2) The intensifier has reasonably good performance to be a representative of other FM intensifiers.

2. Resolution

The resolutions of DEP_#8 intensifier were measured at 460nm and 630nm. Blue (centred on 460nm) and red (630nm) LEDs were used for the light sources. Pinhole images were projected on an intensifier using Nikon 50mm/F8 printing lens (Fig. 1). The image size on the detector is smaller than 6um. The pinhole images were acquired with 5 different photocathode voltages, Vc=400, 300, 200, 100 and 50 volts, to separate the photocathode gap effect from other effects (i.e. optical aberration, centroiding inaccuracy and off-focussing). The 122-125 spots, depending on how many pinholes were located within a selection area (central 4.7mm x4.7mm), were used for assessing the resolution. The sizes of the spots were measured individually, and the average was calculated (see table 1).

Fig. 2 shows standard spot profiles for the blue LED at different photocathode voltages. These were created from the 122-125 pinholes. The difference in resolution among the intensifiers is apparent, specially at the lowest photocathode voltage. The DEP_#8 intensifier shows as poor resolution as DEP_#7. Fig. 3 shows standard profile for the red LED. The spot size is smaller. The difference between the intensifiers and width changes in the photocathode voltage are less obvious, but the poor resolution of the DEP_#8 intensifier is still noticeable.

Figures 4 and 5 show the relationship between resolution and photocathode voltage for the blue LED and for the red LED with the comparison of other intensifiers. The mean of X- and Y- spot widths was used as the representative of resolution. The image blurring due to the photocathode gap was quantified from the gradient of the curves and was tabulated in table 2. If image blurring due to the photocathode gap is large, the gradient becomes steep. Other effects (i.e. optical aberration, off-focussing, centroiding inaccuracies) shift the curve upward.

This intensifier did not show attractive performance in resolution. Its poor resolution will be amplified to 45mm at the wavelength of 3000A.

Table 1. Spot size in raw image DEP_#8

	400V	300V	200V	100V	50V
630nm	19.9um	21.1um	23.3um	28.0um	34.9um
460nm	27.2um	30.0um	33.9um	42.4um	53.1um

Table 2. Image blurring due to photocathode gap

	DEP_#8	DEP#1	DEP#2	DEP#4	DEP#5	DEP#6	DEP#7
630nm	11.09um	9.24	8.44			7.08	
460nm	18.9 um	17.7	16.3	18.2	18.1	13.5	20.2

estimation for Vc=400V

Ref-2 Files used for this section
/depfm8/zdep389.dat - zdep393.dat (Red LED)
zdep394.dat - zdep398.dat (Blue LED)
/depfm8/res/res_#8r.dat (Red resolution results)
res_#8b.dat (Blue resolution results)

3. Quantum Efficiencies

XMM-OM intensifiers employ S-20 photocathode to cover a wide spectral range, i.e. 1700-6000A. Thanking to the excellent effort by DEP, all of the 7 FM intensifiers showed high Q.E.s and almost same spectral profiles. The results of R.Q.E. measurement for the DEP_#8 intensifier are shown in Fig. 3 with those for DEP_#7 as a reference.

The DEP_#8 intensifier showed similar Q.E. in VUV region and from green to red region, but noticeably lower at 2900-3800A. This might be due to a lack of an alkali material, which is responsible for 2900-3800A photons. The life time performance of DEP_#8's photocathode may be different with those of the 2 FM-intensifiers, as the composition of photocathode material seems to be slightly different. It will be useful to measure the sensitivity loss at as many wavelengths as possible. The losses shorter than 2900A and longer than 3800A hopefully represents those of the 2 FM-intensifiers.

Ref-3 Files used for this section
/depfm8/qe/rqetab7.deu (RQE DEP_#8)

4. Photocathode and MCPs dark currents

A long integration was carried out in photon counting mode with the photocathode-ON under dark conditions (Fig. 7). The dark currents were measured after one week dark run of the intensifier to eliminate effects of fluorescence of the window material and trapped charge within the photocathode. DEP_#8 intensifier has relatively large dark current with global change from top to bottom. The dark current is 80 c/s cm2 at the centre of the detector field but 140 c/s cm2 at 7mm off centre toward top left. This global change seems to be due to irradiation by strong edge emissions.

A long integration with photocathode-OFF was also carried out to assess dark current originated in the MCPs (Fig. 8). There are 3 noticeable white spots within the central 18x18mm window, but all are far below the specification (0.05 c/s). The average MCP-dark is pretty high, 10.7 c/s cm2, which is more than 10 times of other DEP intensifiers. This noisy MCP characteristics indicate that this intensifier was manufactured in less clean chamber than the others (DEP_#1, #2, #4, #5, #6, #7).

A short integration with photocathode-OFF was carried out to assess strong SW-on channels. One is detected near the centre of detector field, which was not seen in the long integration image because of overflow of computer memory. There is a very high count rate SW-channel at the edge of the detector. Since the SW-channel was not saturated in a CCD snap frame with the exposure time of 100ms, the count rate of the channel should not far exceed 100 c/s. Fig. 9 was acquired with Vc=400V to show the relative position of the SW-channel to the detector imaging area.

Table 3. Dark current

	#8	#1	#2	#4	#5	#6	#7
Average Vc-ON	80	80	---	13.3	10	11	7.4
Average Vc-OFF	10.7	0.24	---	0.46	0.63	0.4	0.58
SW-on channel (>0.05 c/s)	1	None	Big 4	None	1	None	None
Edge emission with Vc-ON	8000	70	---	3400	1240	340	7
Edge emission with Vc-OFF	(100c/s)	19	---	None	224	None	3

unit: counts/(sec cm2)

Ref-4 Files used for this section
/depfm8/zbin387.dat (photocathode dark)
zbin386.dat (MCP dark)
zbin401.dat (SW-on channel)

5. Flat Field

Flat field images were acquired in photon counting mode to assess black blemishes in the intensifiers (Fig. 10). The blue LED was used as the light source. Sensitivity non-uniformity at the central 4.7mmx4.7mm is 5.2%(rms). There is a big blob at 7.5mm off centre toward top. Its size is 0.85mm, and the depth is 30%.

Some of the black blemishes seen in a raw F-F image are due to the CCD camera. The F-Fs were therefore divided by another F-F image acquired with a different CCD position (i.e. rotating by 90 degrees). This is shown in Fig. 11 with descriptions on depth of individual blemish. This intensifier got many deep black blemishes. Most of them has the width of >75um. The blemish aspect of this intensifier is in lower standard than other DEP tubes.

Table 4. Flat field image uniformity

	#8	#1	#2	#4	#5	#6	#7
Rms (%)	5.2	3.6	4.3	3.7	5.0	6.4	5.7
No. of black blemishes	35	10	11	1	2	7	5

Ref-5 Files used for this section
/depfm8/zbin504.dat (F-F in photon counting mode)
zbin399.dat (F-F rotated by 90 degrees)

6. Pulse Height Distribution

The pulse height distributions of the DEP_#8 intensifier is shown in Fig. 12. Events are selected from a central 18x18mm region. Its width, valley depth and valley positions are tabulated in table 5. The parameters are farely standard.

The central 18x18mm region of the detector was divided into 8x8 sectors, and the gain at each sector was measured. The results are tabulated in table 6. Fig. 13 shows the pulse height distributions from two different sectors along y-direction. The gain variation of this tube is small compared with other 6 DEP intensifiers.

Table 5. Pulse height distribution from central 18x18mm area

	DEP_#8	DEP_#1	DEP_#2	DEP_#4	DEP_#5	DEP_#6	DEP_#7
Vmcp	2250V	2200V	2200V	2310V	2360V	2400V	2450V
dG/G	138%	129%	134%	110%	121%	97%	111%
Peak/Valley pos	5.7	5.3	6.0	4.3	4.3	5.8	5.7
Valley depth (of peak)	17%	18%	14%	19%	18%	10%	12%
Gain Variation (p-p)	40%	60%	50%	30%?	60%	40%	60%

Table 6. Relative gain at individual 8x8 sectors
DEP_#8 tube 23 Sept 1999 <=== PHD506.DAT

.78	.84	.85	.86	.86	.88	.86	.79
.90	.93	.94	.95	.95	.95	.94	.90
.96	1.00	1.01	1.04	1.03	.99	.99	.94
1.02	1.04	1.11	1.14	1.12	1.05	1.02	.98
1.04	1.12	1.16	1.20	1.19	1.10	1.05	1.03
1.03	1.12	1.18	1.24	1.18	1.13	1.08	1.05
1.02	1.10	1.14	1.20	1.15	1.12	1.10	1.05
1.01	1.07	1.11	1.12	1.13	1.11	1.11	1.07

Ref-6 Files used for this section
/depfm8/phd506.dat

7. Event profile and SIBs

The XMM-OM intensifier output interfaces to a tapered fibre with image reduction of 3.37. Faint events on the phosphor screen were captured through x1.7 magnification optics with a low noise slow scan CCD camera (manufacture: Santa Barbara Instrument Group, hereafter SBIG CCD camera) With the magnifying optics and a small CCD pixel size (9um), a plate scale of 18.5um/pixel on the phosphor screen was achieved.

Fig. 14 is a snap frame of photo-events at the phosphor screen. There is no noticeable satellite events (SIB). The SIBs broaden the effective event width, hence causing an increase in coincidence. The SIBs also cause a centroiding error, hence degrading the resolution. 100 CCD snap frames were acquired and 1287 events were analysed for event width, whose distribution was 77.2+/-3.9um along x-direction and 67.7 +/-3.5um. The event width is small and ideal. The small variation of width is outstanding.

Standard event profiles were made from the 1287 events in Fig. 15. Since event profile depends on event intensity, the events were classified into 10 intensity levels. Events were added on top each other according to their intensity levels. The event shape is nearly round, but major axes of the profiles (clearer in the lower energy events) are misaligned to x-axis by +48 degrees.

1159 main events, which have no neighbouring events within 32 CCD pixels, were used for SIB analysis and only 172 SIBs were detected after careful subtraction of main event profile. Some of the SIBs were isolated from a main event, but most were semi-detached or hidden inside a main event. Fig. 16 shows that majority of SIBs energies are below 20% of main event energy. This intensifier definitely has little SIBs. It has been believed throughout XMM-OM project that SIBs are associated with contamination of MCP pores. The high MCP dark noise of this intensifier is, however, direct evidence of uncleanliness of the MCPs. We have to re-consider the hypothesis on SIB v.s. contamination relation.

Table 7. Event profile

	DEP_#8	DEP_#1	DEP_#4	DEP_#5
event X-width	77 +/-4um	79um	81um	77um
event Y-width	68 +/-3um	74um	70um	75um
orientation of major axis	48 deg	0 deg	-12 deg	-20 deg
SIBs (> 7.5% energy of main events)	15%	49%	11%	21%

Ref-7 Files used for this section
/depfm8/sbig/zsib403.dat - zsib502.dat
zdrk503.dat
zstd403.dat
zphd403.dat

8. Ruggedness

8-1. Current consumption

Current leakages at the photocathode gap and at the anode gap are indications of tightness and reliability of the mechanics. The current between MCP_in and MCP_out is dominated by the flying current through the MCPs, but is useful for checking for any damage to the MCPs.

The anode gap and photocathode gap showed similar impedance to the other DEP intensifiers. The results are tabulated in table 8. These very high impedances were measured using the amplifier made for the R.Q.E measurement, which can provide 44V by batteries to two arbitrary terminals (XMM-OM/MSSL/TC/0053).

A Keithley 485 Autoranging Picoammeter was inserted between the MCP_in terminal and ground to measure the MCP current. The photocathode gap voltage was closed to zero during the measurement. The impedance at the nominal operation voltage, 2400V, was estimated from that at 1800V (see table 9). The impedance varies from tube to tube, i.e. 4.5-6.4uA. The DEP_#8 intensifier shows highest impedance, which may suffer from highest pore paralysis, hence gain depletion by a bright light source may progress more slowly.

8-2. Edge emission

Strong bright circles were seen in the dark images with all DEP intensifiers. This may be caused by a small number of UV photons (a few 10s/sec of UV photons), which are related to the current leakage at photocathode gap, hitting the edge of MCP1 and generating low energy event. The edge emission may be the sign of fragility of the tube. DEP_#8 has highest edge emission (see table 8).

8-3. Flash

The intensifiers with low dark current (i.e. DEP_#4,#5,#6,#7) showed flashes every 5-10 sec. This might be an indication of weakness of mechanics or short life time of the intensifiers. Only DEP_#1 intensifier did not show noticeable flashes, though the flash might be hidden by its relatively high dark current.

The flashing was investigated quantitatively with the #8 tube. 50,000 CCD snap frames were acquired in the dark conditions with Vc=ON, and statistics on number of events per frame were investigated. The events were sampled from central D=5.9mm circle area to exclude edge emission from this analysis. As the dark current of this intensifier is relatively high, peak position was located at 2.5 events/frame, in stead of 0 events/frame. It is difficult to define clear threshold to separate high count tail of the dark event distribution and the flash. But, it is obviously outside the dark distribution if >20 evetns/frame, because one sigma of the distribution is 4 events/frame. The event distribution is tabulated in table 10. If the flash is defined as >20 events/frame, then flashes occurred in a mean interval of 16 seconds (see table 11). DEP_#8 intensifier has smaller number of flashes compared with DEP_#7.

Table 8. Impedance of tube body (unit: Ohm)

	DEP_#2	DEP_#5	DEP_#6	DEP_#7	DEP_#8
Ph-cath gap (at 44V)	40.8E+12	6.9E+12	15.9E+12	9.9E+12	9.1E+12
across MCPs (at 1800V)	377E+ 6	420E+ 6	405E +6	380E+ 6	531E+ 6
Anode gap (at 44V)	.063E+13	2.5E+13	34.E+13	6.9E+13	5.1E+13
Edge emission	----	1240	340	7	8000

Table 9. Current v.s. voltage applied to MCPs [unit: uA]

Voltage	DEP_#2	DEP_#5	DEP_#6	DEP_#7	DEP_#8
0V	0.024	0.012	0.013	0.020	0.010
200V	0.502	0.464	0.488	0.505	0.359
400V	1.001	0.918	0.951	1.016	0.732
600V	1.519	1.378	1.441	1.540	1.100
800V	2.044	1.862	1.920	2.052	1.462
1000V	2.551	2.330	2.405	2.588	1.837
1200V	3.096	2.812	2.909	3.113	2.211
1400V	3.640	3.294	3.416	3.653	2.600
1600V	4.200	3.796	3.920	4.192	2.996
1800V	4.779	4.288	4.444	4.743	3.388

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Table 10. Statistics of 50,000 CCD frames

Events	0	1	2	3	4	5	6	7	8	9	10	>10	>20	>40
Frame	2191	6588	10319	10947	8603	5669	3102	1472	625	252	103	129	31	4

Table 11. Flash intervals

	DEP_#8	DEP_#7
>10 events/FR	3.9sec	6.0sec
>20 events/FR	16.1	13.3
>40 events/FR	125.0	47.6

Ref-8 Files used for this section
/depfm8/zbin387.dat (photocathode dark)
zbin386.dat (MCP dark)
zbin401.dat (SW-on channel)
zfsh505.dat (flash)

9. Summary and acknowledgement

a) The DEP_#8 intensifier employed out-of date potting material. The potting was proceeded by MSSL (only for this intensifier), though it plays important role to prevent arcing. The intensifier arced 3 times during characterization test which may be due to the old potting material. Because of arcing, the intensifier will not be used for a field trial.

b) There is a turn-on channel at the top edge of the intensifier. This may decrease cleanliness within the intensifier in a long time scale.

c) R.Q.E. is lower than other 6 intensifiers at 2900A-3800A. This does not deny the usefulness of this intensifier, as these wavelengths are not important for observation from the ground. This, however, may give different results in photocathode sensitivity loss for the life time test.

d) Resolution is only 27um at 460nm, which is as poor as the worst tube (DEP_#7 in this item).

e) Flat field images showed a large sensitivity loss region. The diameter is 0.85mm, depth 30% and the location 7.5mm from the centre of the detector field. There are 35 black blemish spots, whose depths are deeper than 25% and the sizes are >75um. The blemishes aspect is worst, excluding DEP_#2.

f) Optimum MCP voltage is 2250V. The gain of MCPs is reasonably high.

g) Characteristics of pulse height distribution are reasonable. Variation of gain across detector field is small.

h) Strongest edge emission, 8000c/s cm2, was seen. It is 3 times as bad as the 2nd worst tube (DEP_#5 in this item).

i) High photocathode dark current, 80 c/s/cm2, which is similar to the worst tube (DEP_# 1 [FM-secondary] in this item).

j) High MCP noise 10.7 c/(s cm^2), which is exceptionally higher than the other intensifiers.. The 2nd worst (DEP_#5 in this item) got only 0.63 c/(sec cm^2).

k) Event splash at phosphor screen is very good. The typical widths are 70-80um. Its distribution is outstandingly narrow.

l) FLASH does not exist obviously. This is the best among the 7 intensifiers

m) SIBs are as small as the best tube (DEP_#4 [FM-primary]). The population of SIBs (>7.5% energy of main event) is 15% of main events.

As listed above, DEP_#8 showed unattractive performances in many items, though the items k), l) and m) are attractive. Because of the resolution, the number of black blemishes, the dark current, the turn-on channel and the edge emission, this intensifier is not better than the 2 remaining DEP intensifiers (DEP_#5 and DEP_#7). Therefore, it should not be problem even if the intensifier is sacrificed for the life time test.

The next questions are the effect of some items on the life time test. The followings should be bear in minds to estimate characteristics of the FM intensifiers from the life time test;
1) The high MCP dark current and existence of the turn-on channels are the indication of uncleanliness of the intensifier, therefore this intensifier may give worse results than the two FM-intensifiers.
2) The sensitivity loss against bright light source of this intensifier may not represent other FM intensifiers in the wavelength range of 2900A-3800A.
3) Impedance of DEP_#8 intensifier higher than others, which may cause more pore paralysis, hence may be damaged more slowly.

The author wishes to express thanks to DEP for the special offer of this ruggedness intensifier.
Thanks also go to Prof. Keith Mason, PI of XMM-OM, for his encouragements and suggestions.

Table 12. Summary of DEP tubes 4th batch

	DEP_#8 (F??????) F813193
Resolution @630nm	11.09um (Vc=400V)
@460nm	18.9
RQE @300nm	20.62
@520nm	10.85
Dark (c/s cm2)	80
MCP voltage	2250 V for nominal gain
dG/G	138%
Peak/Valley position	5.7
Valley depth	17% of peak
Gain Variation	40%p-p
SIBs (> 7.5% energy of main events)	15%
Event size (average)	77um _X 68um _Y
Sw-on channel (Vc=0) (>0.05c/s)	1
Blemishes (>50um)	35 black
Edge emission	8000 c/s cm2
Flash period	5.4sec (>10 events/FR) 12.8sec (>20 events/FR) 50.0sec (>40 events/FR)

Appendix. Experiment procedure for DEP_#8 intensifier

17 - 28 September 1999

Before Damage for reference

File Name	Pinhole	PHD	Dark	F-F	Time(start)
					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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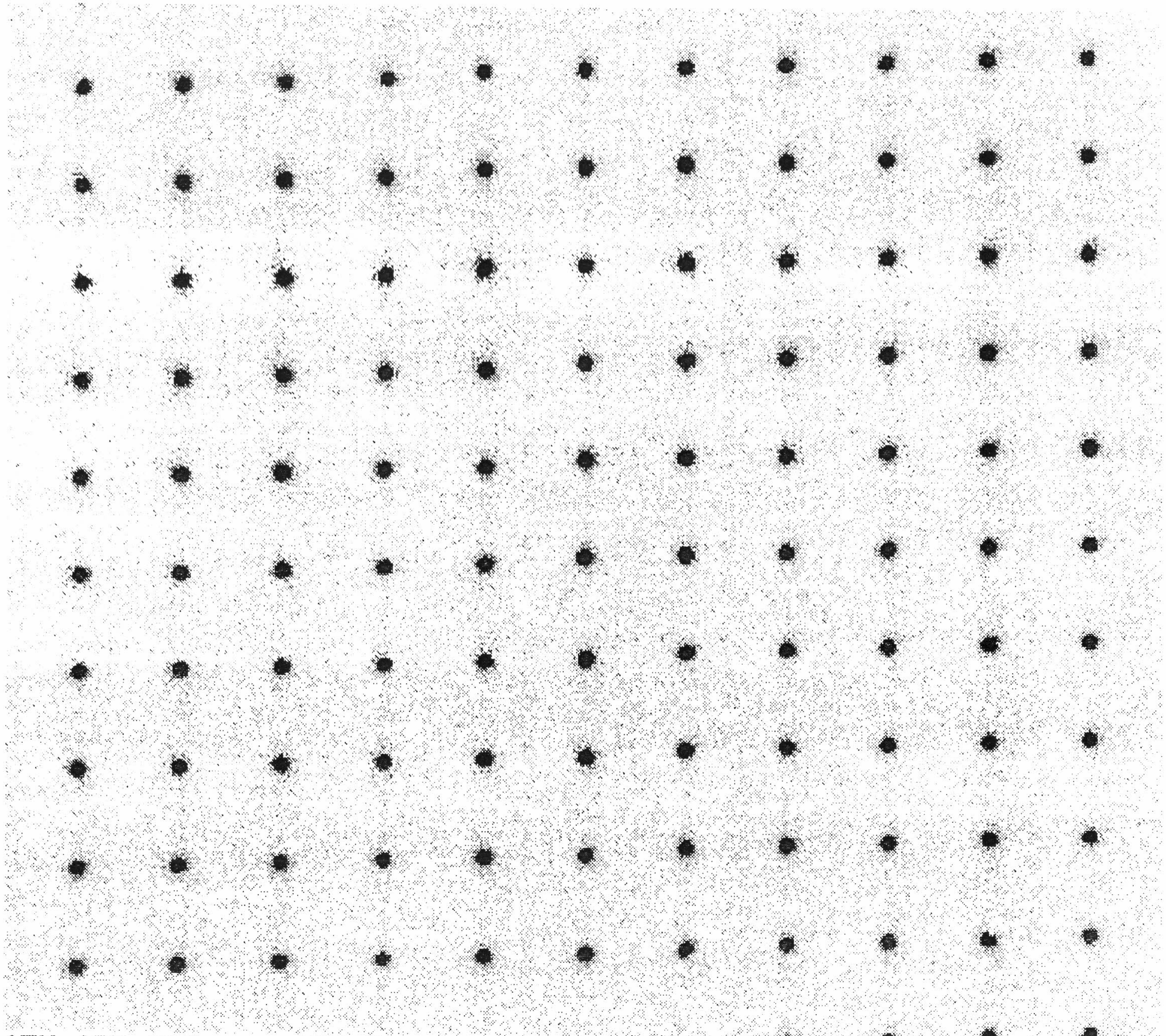
Pin508   L=3  3600S                                              18H 44M 24S
DEP509                                           54000S          21H 15M 00S
                                                                   1999/09/25
DEP510                                           18000S          12H 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
----------------------------------------------------------------------------------------------
```



17H 18M 09S 17H 28M 09S 1999/09/21/

Fig. 1 Pinhole array image with blue LED 400-2250-5400 DEP_#8

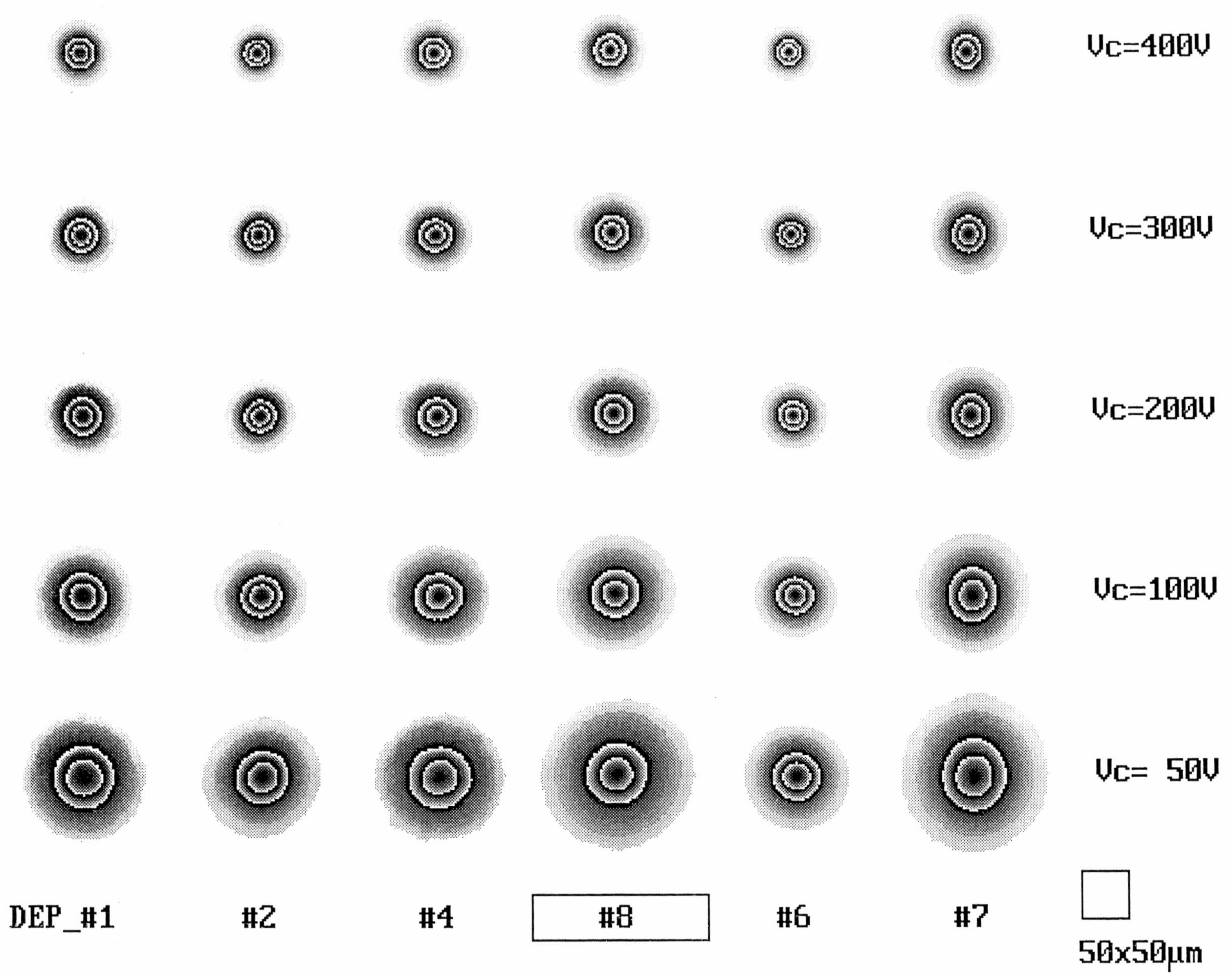


Fig. 2 Pinhole profile in blue Vc=400, 300, 200, 100 and 50 volts

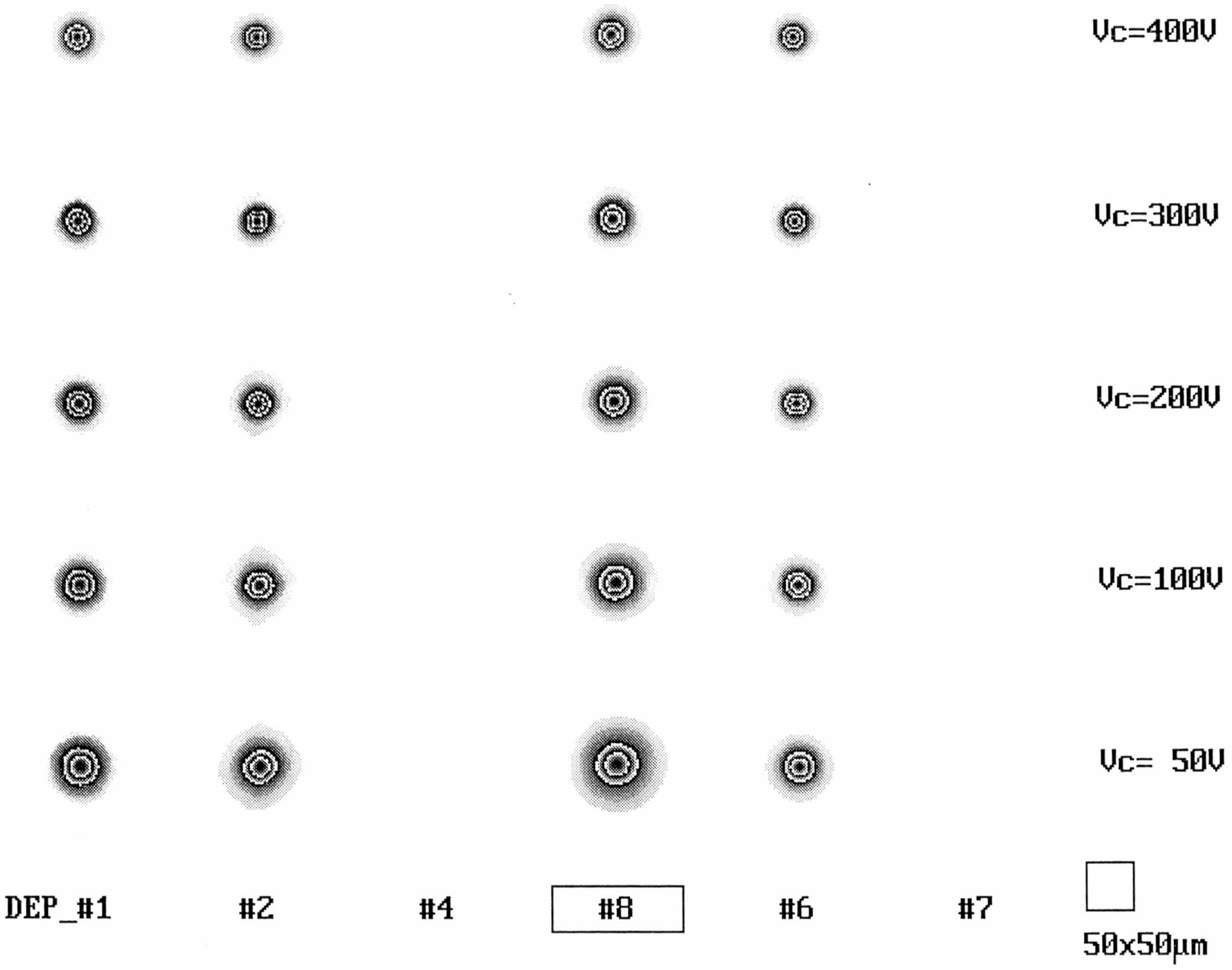


Fig. 3 Pinhole profile in red Vc=400, 300, 200, 100 and 50 volts

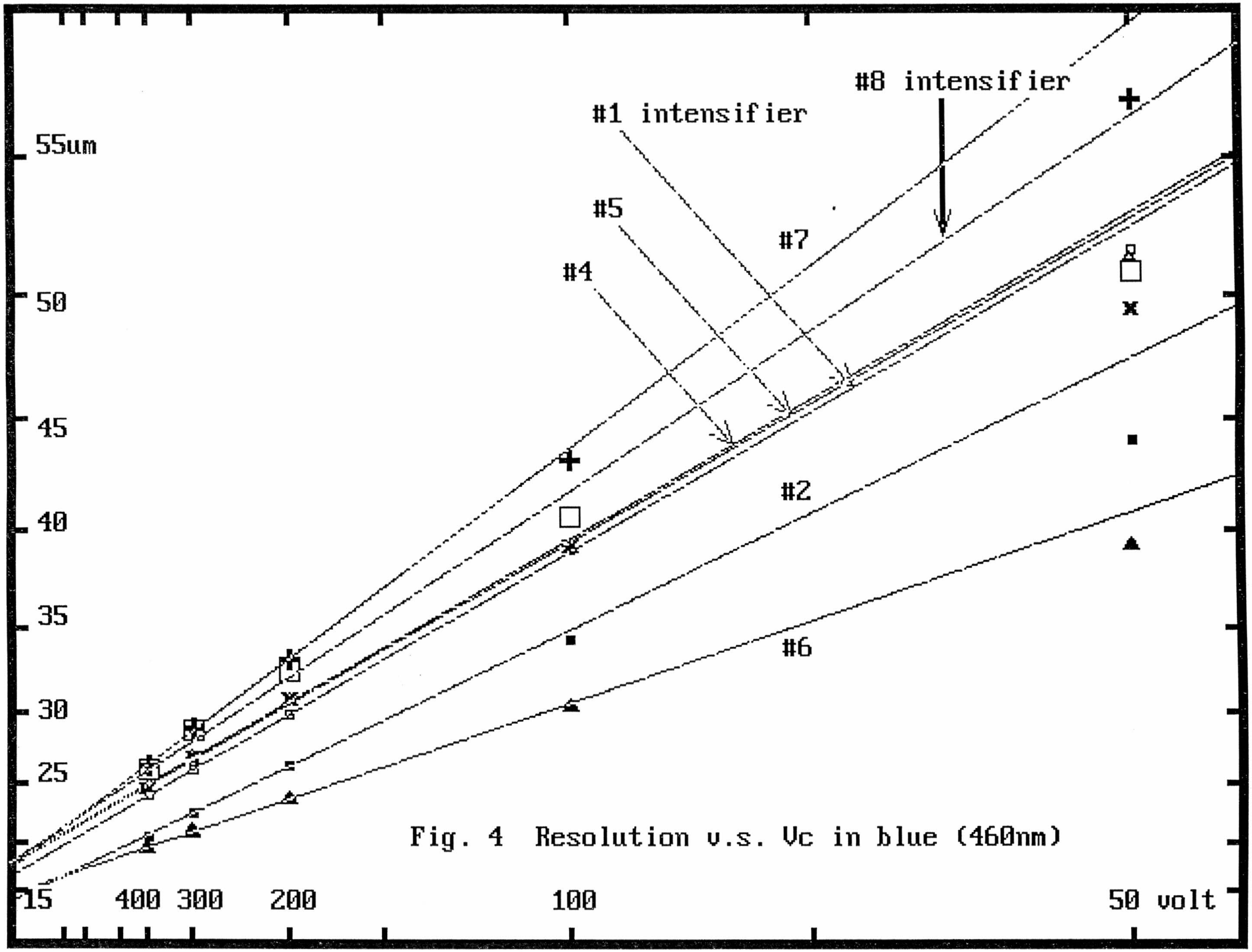


Fig. 4 Resolution v.s. Vc in blue (460nm)

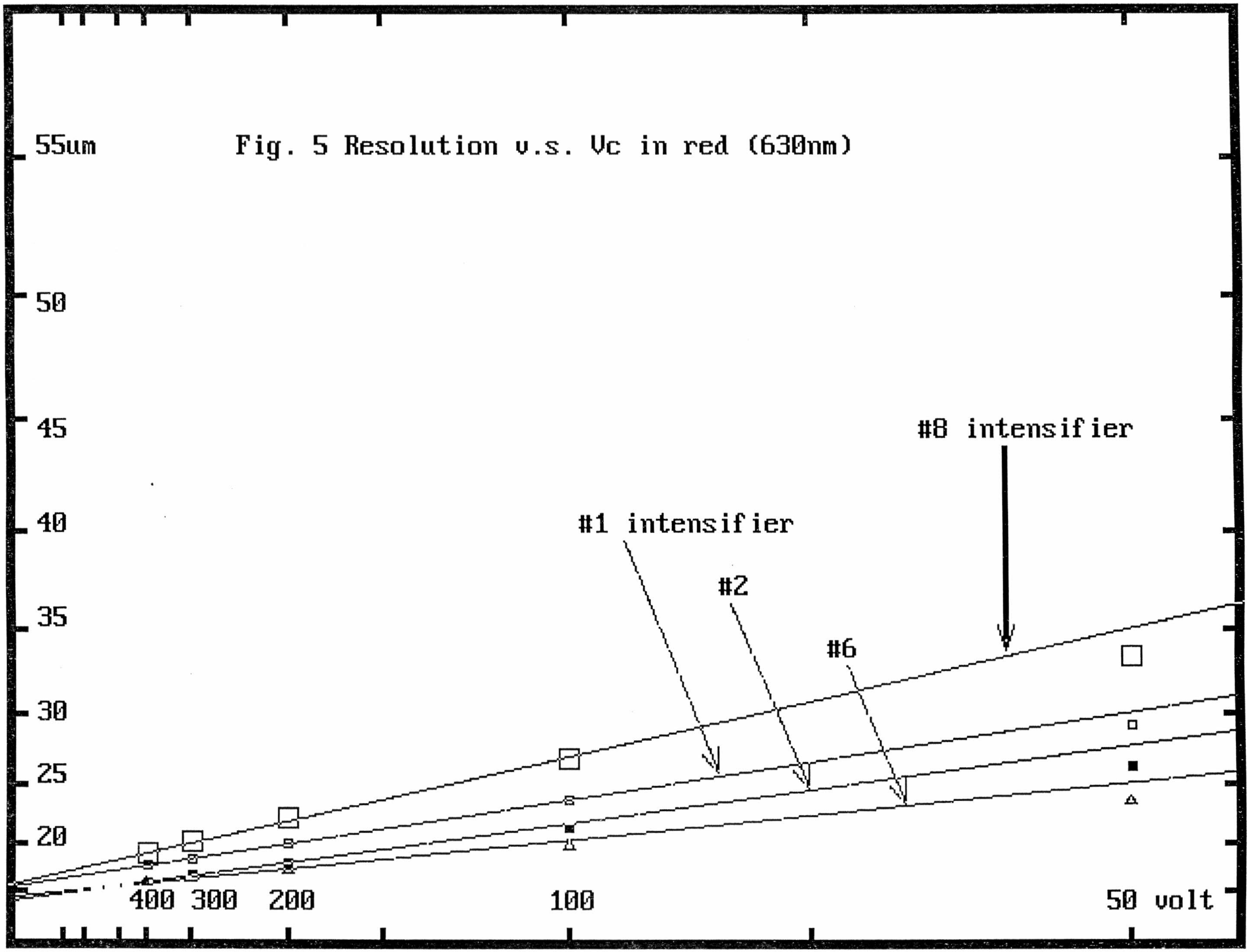


Fig. 5 Resolution v.s. Vc in red (630nm)
55um
50
45
40
35
30
25
20
400
300
200
100
50 volt
#8 intensifier
#1 intensifier
#2
#6

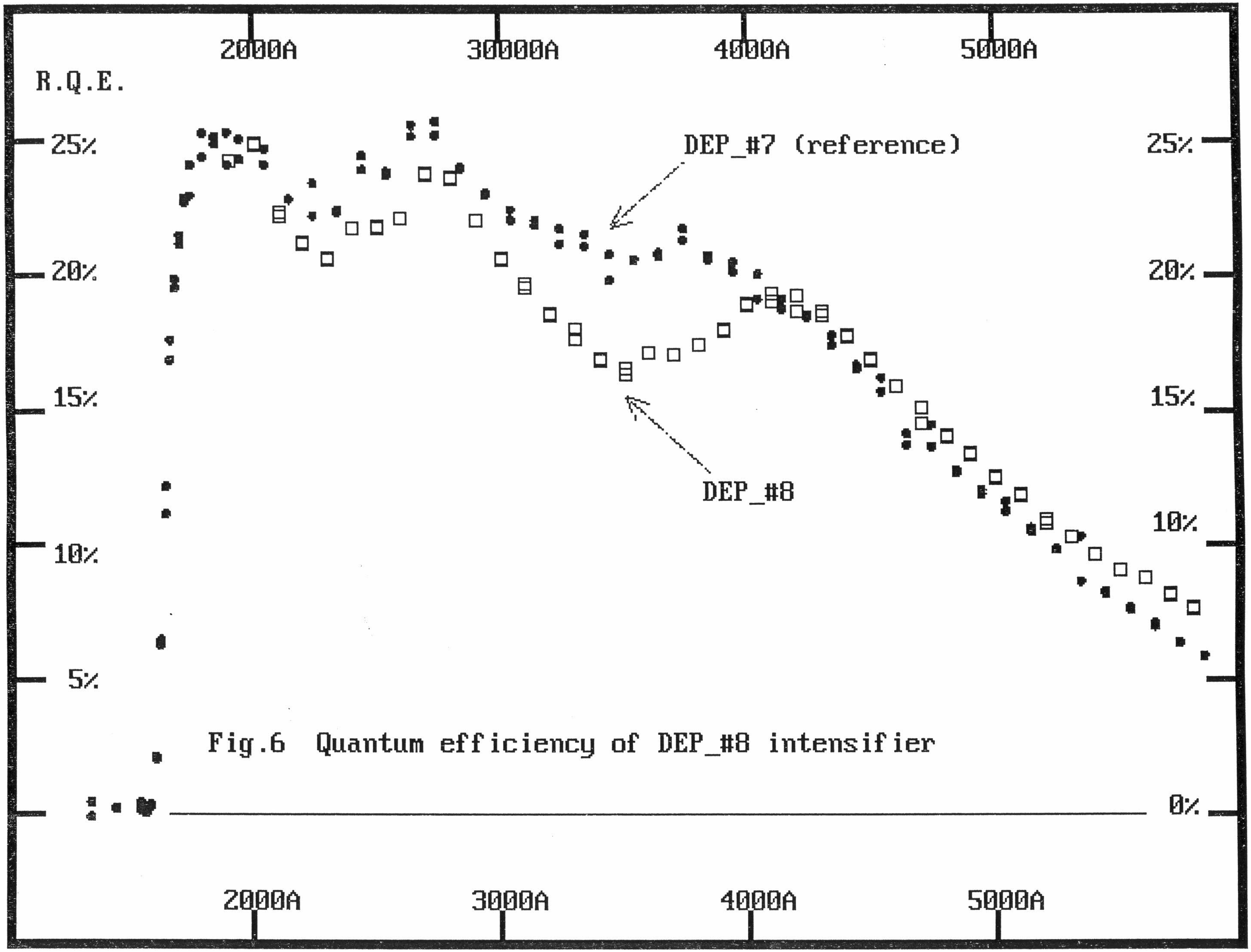


Fig.6 Quantum efficiency of DEP_#8 intensifier

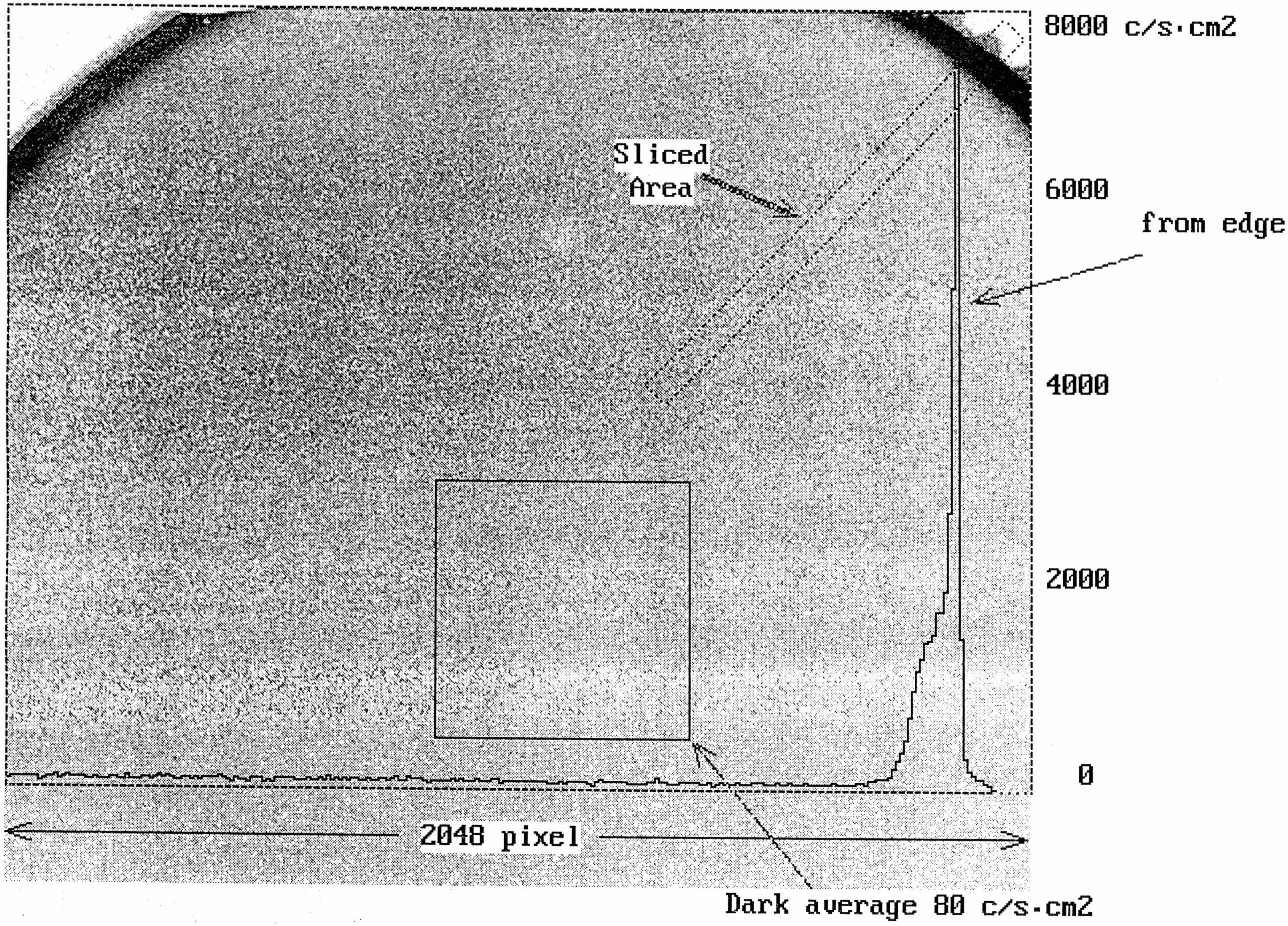


Fig. 7 Dark image 3600sec 400-2250-5410 Th=24ADU DEP_#8 tube

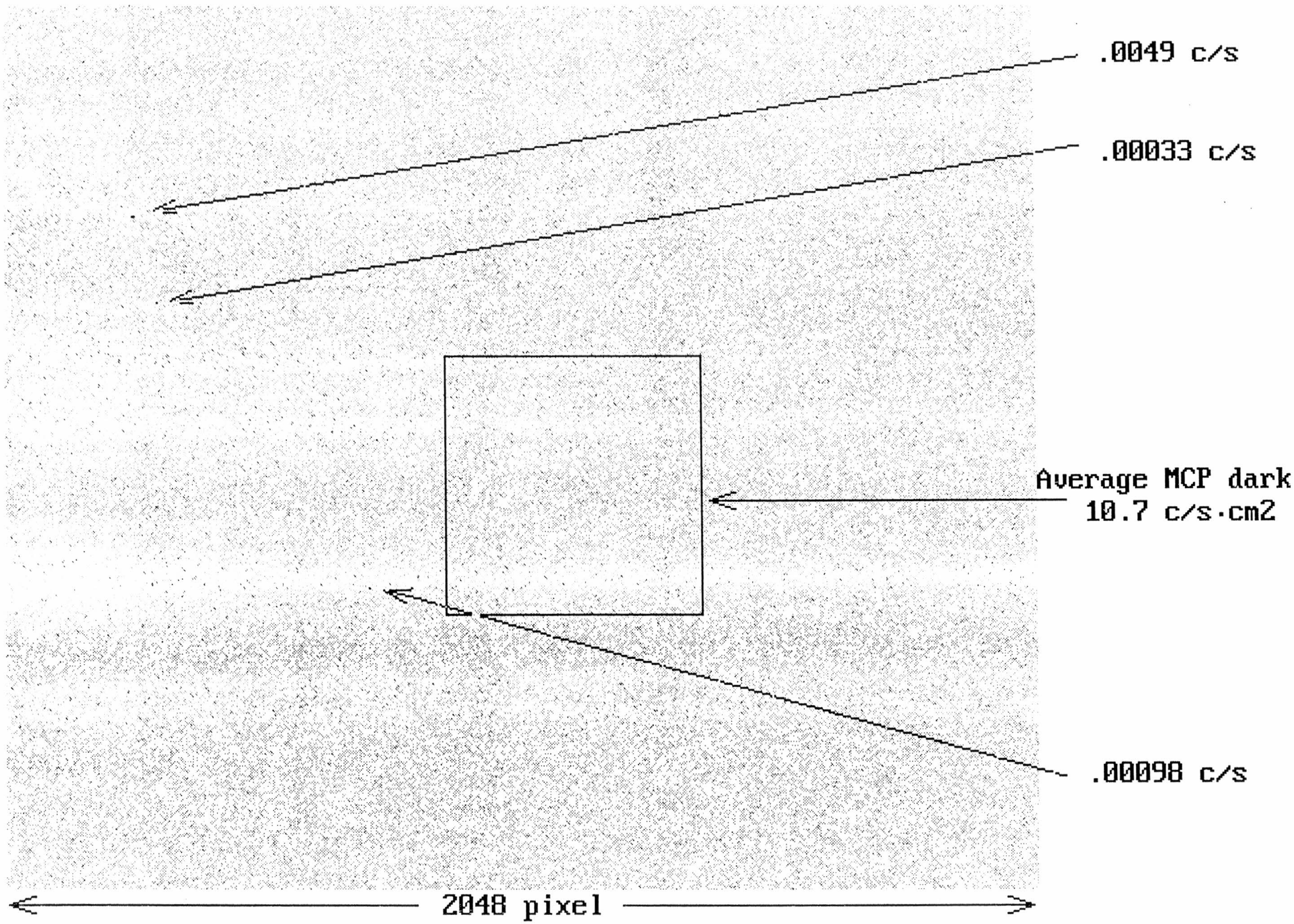


Fig. 8 MCP Dark image 54000sec 0-2250-5420 Th=24ADU DEP_#8 tube

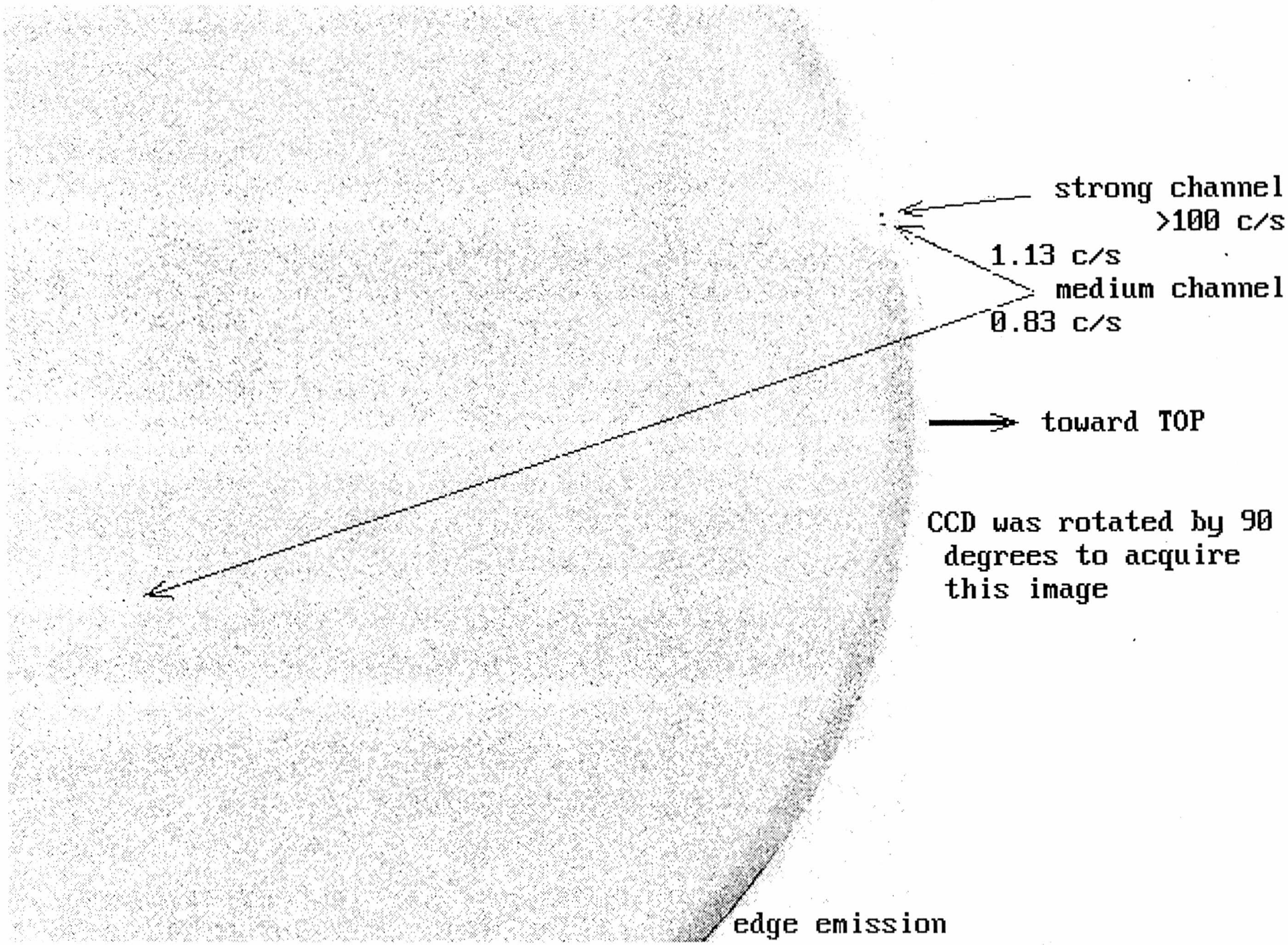


Fig. 9 SW-on channels exp=60sec 400-2250-54000 DEP_#8 tube

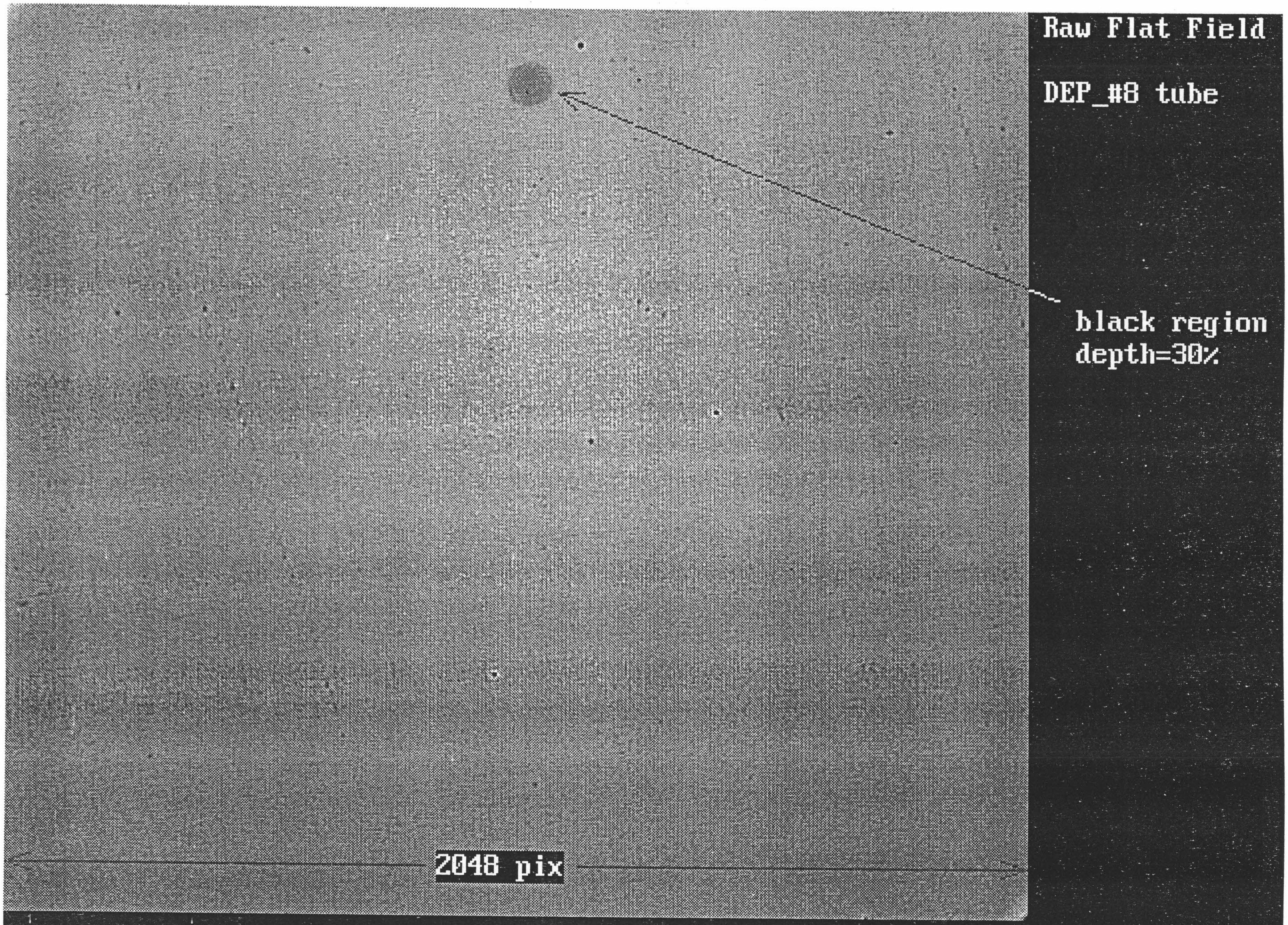


Fig. 10 Flat Field image in photon counting mode   DEP_#8 tube

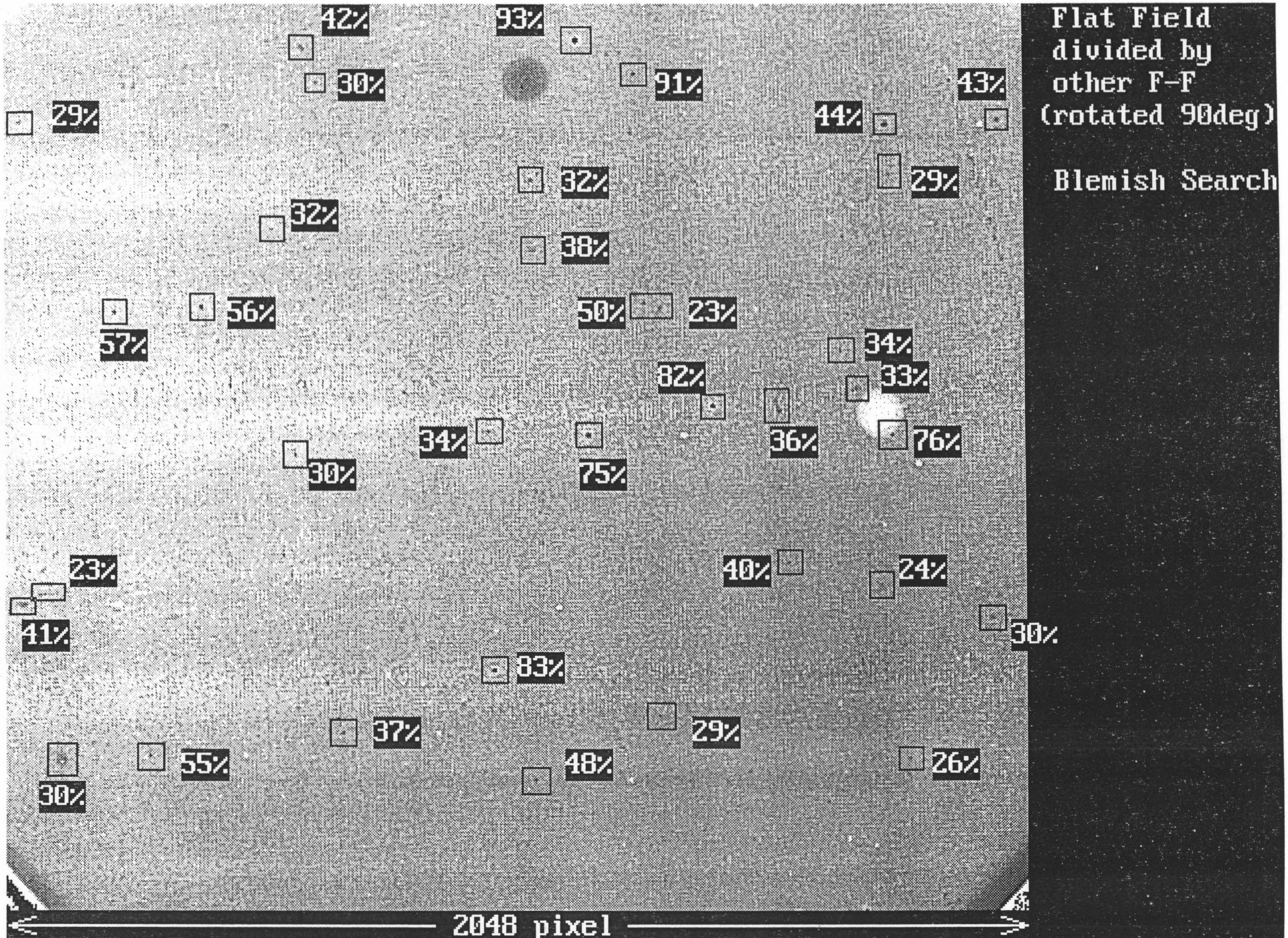
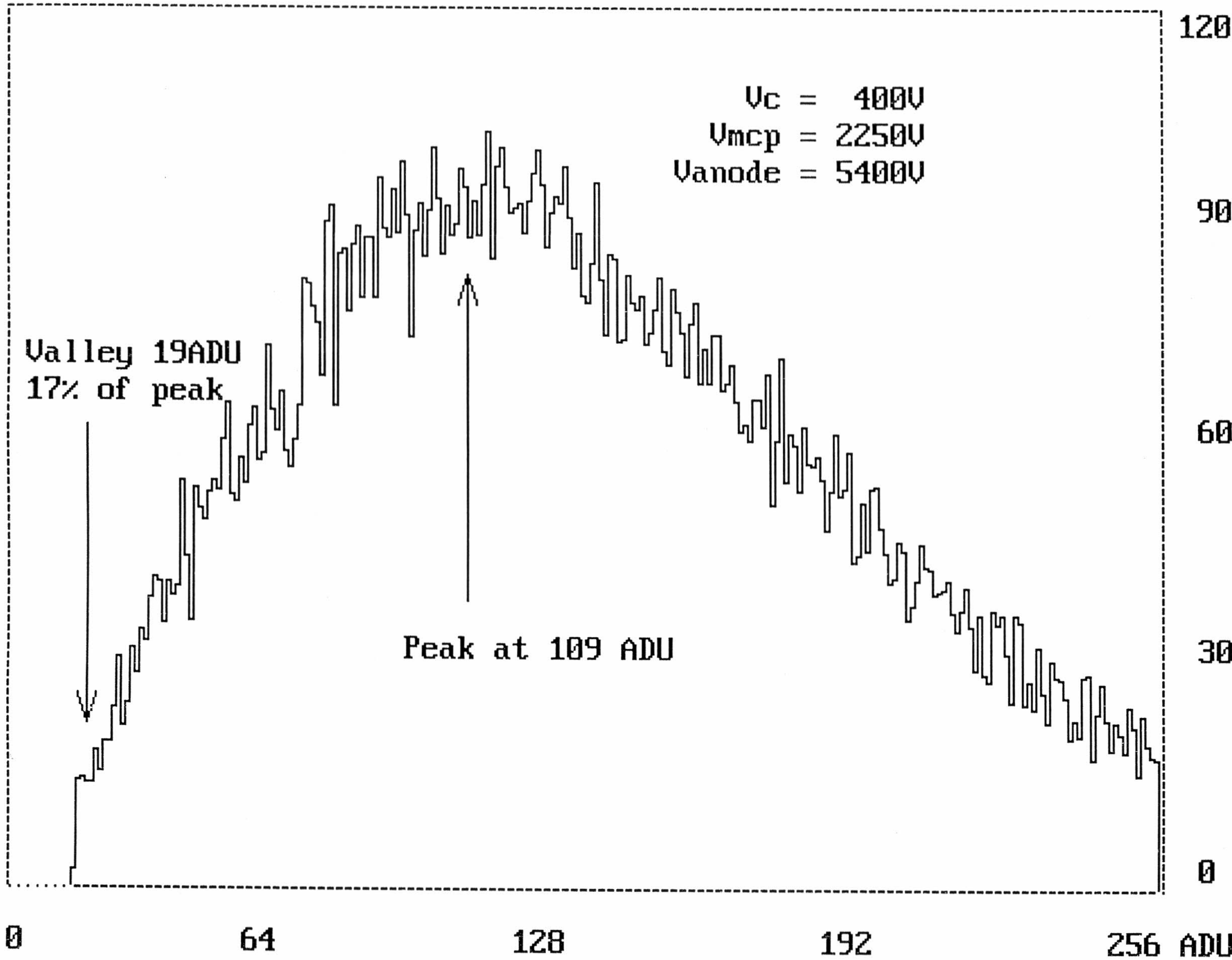


Fig. 11 Black blemishes of DEP_#8 tube



17 Sept '99

Fig. 12 Pulse height distribution of DEP_#8 tube from central 18x18mm region

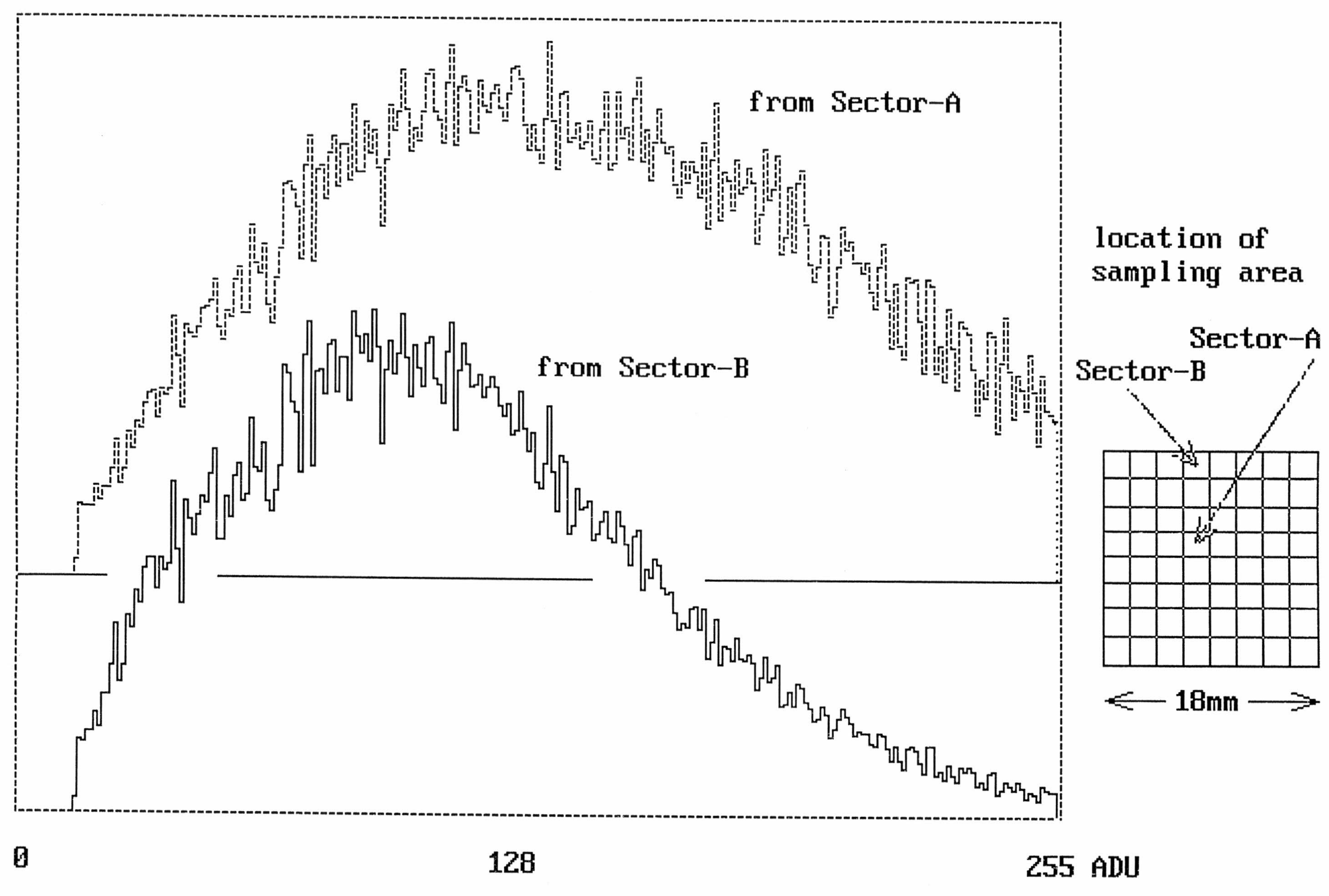
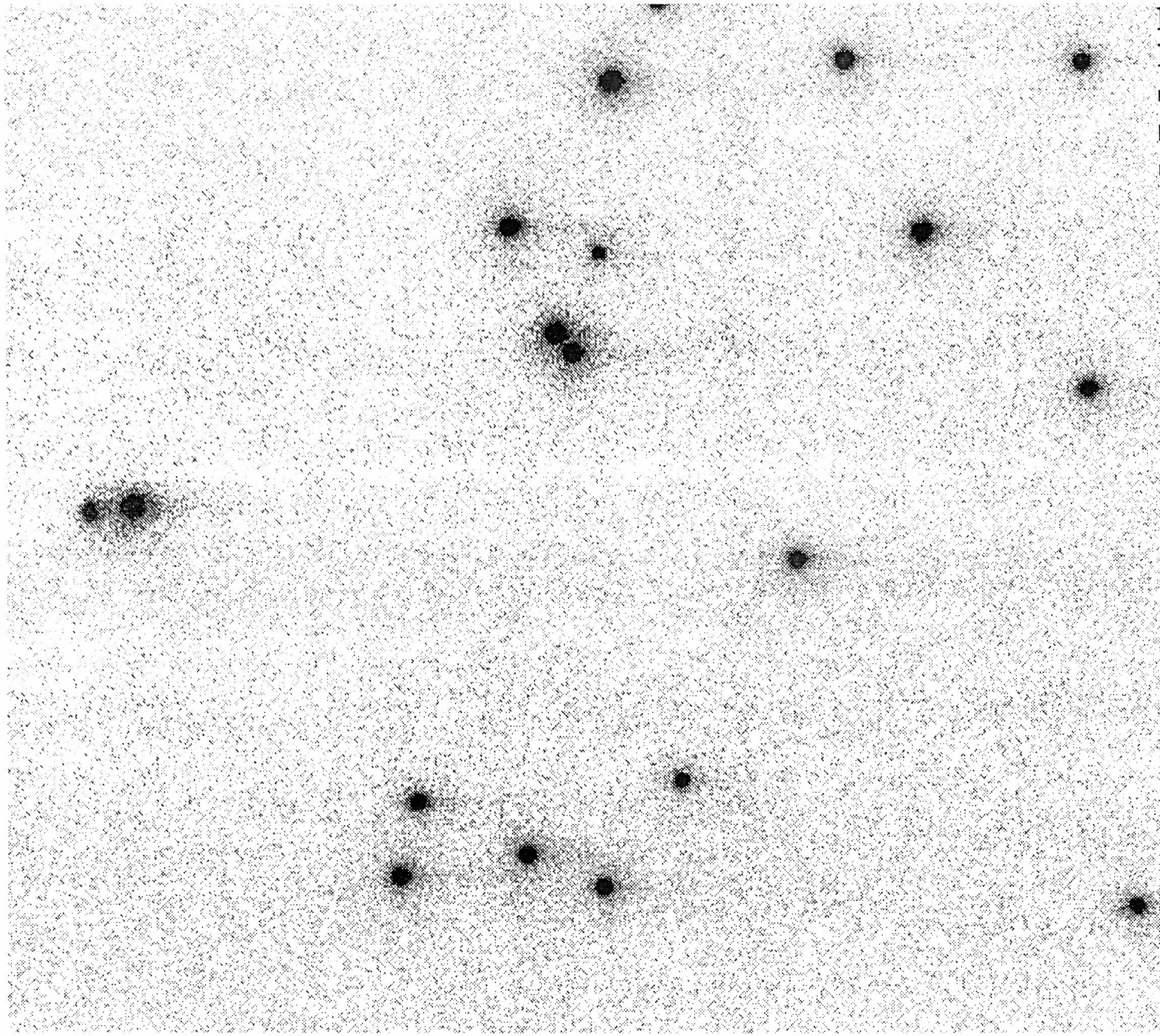


Fig. 13 Pulse height distributions from different places DEP_#8 tube



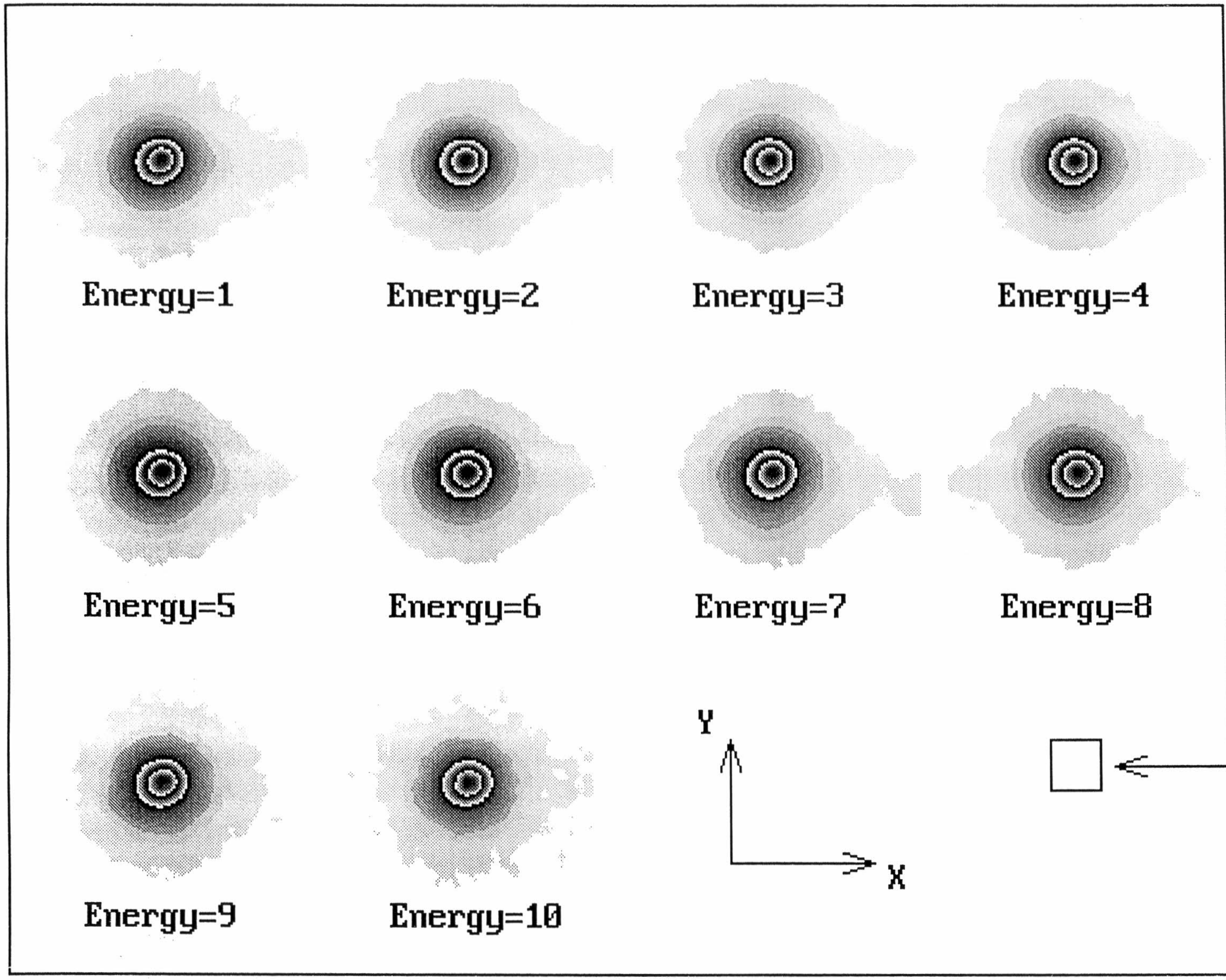
Events captured by SBIG CCD camera through magnification optics.

DEP_#8 tube for ruggerdness test

This tube is SIB-free.

<— 9.5 mm —>

Fig. 14 DEP_#8 tube Snap frame   1 pix = 18.5um on phosphor screen



Standard event profiles from 1287 events

100x100 µm on phosphor screen

Fig. 15 DEP_#8 tube from 100 frames x4 400-2250-5500

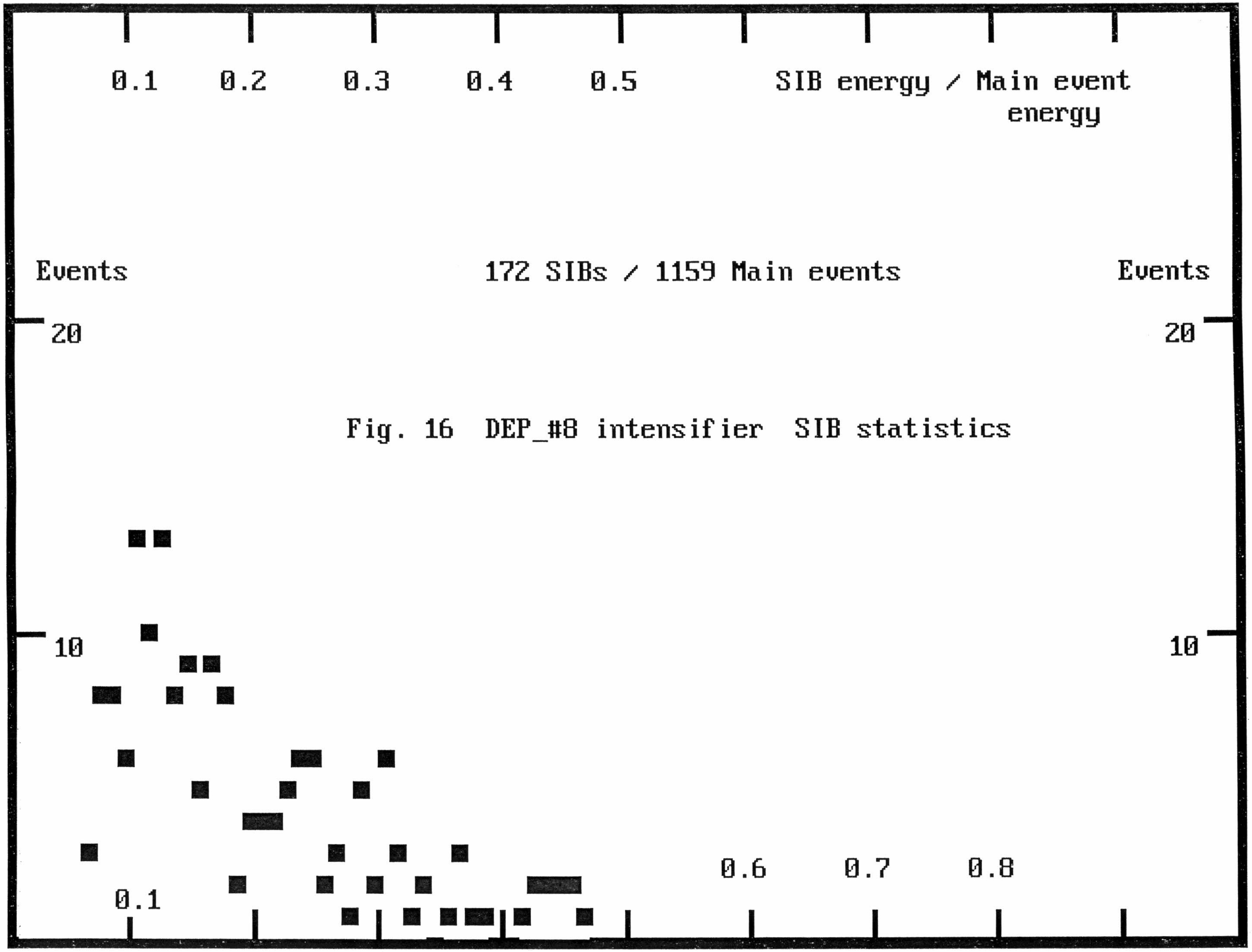


Fig. 16 DEP_#8 intensifier SIB statistics