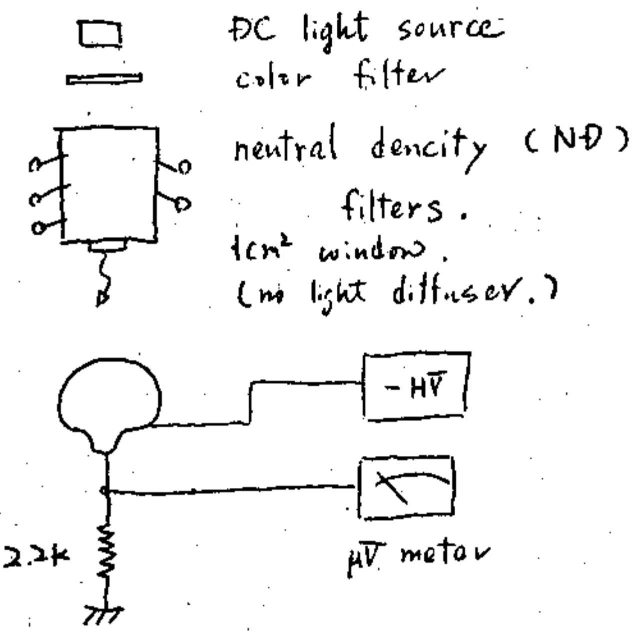
* Experimental note on 16" PMT tests.

6. Sep '83 S. Matsuno

We recieved a good 16" Hamamatsu photomultiplier tube (PMT) in July. Laboratory tests of the PMT have been performed since then and some encouraging data were obtained. I summarize here the method used to make these tests and the results obtained.

i) Gain and dark current of the PMT.



The figure to the right shows the configuration used to measure gain and dark current of the 16" PMT. The PMT was used in the cathode high voltage (- HV) mode and the output current of the anode was directly measured by a voltmeter. Although it wasn't necessary to use the light source to measure the dark current, I did severel measurments at the same time.

The intensity of the light source was measured by using a calibrated PIN diode. Taking into account the spectral response of the PIN diode and that of the color filter which we usually used (Melles-Griot, 03F1B003 ; see Fig.1), we could calculate the relation between the light intensity and the output current of the PIN diode. We find a value of $\tilde{\approx}$ 10^{10} photons/s/nA. Using this value, the light intensity was estimated within the accuracy of $\tilde{\approx}$ 20 %.

The PMT anode output current was measured against a certain light intensity and a certain HV value. The data are shown in Fig.2 for HV = 2.0, 2.2, 2.5, and 2.7 kV. The anode current is a function of not only the gain of the PMT and the light intensity but also a quantum efficiency (QE) and a collection efficiency (CE) of the PMT. The gain of the PMT was estimated assuming as QE $\times$ CE = 0.1.

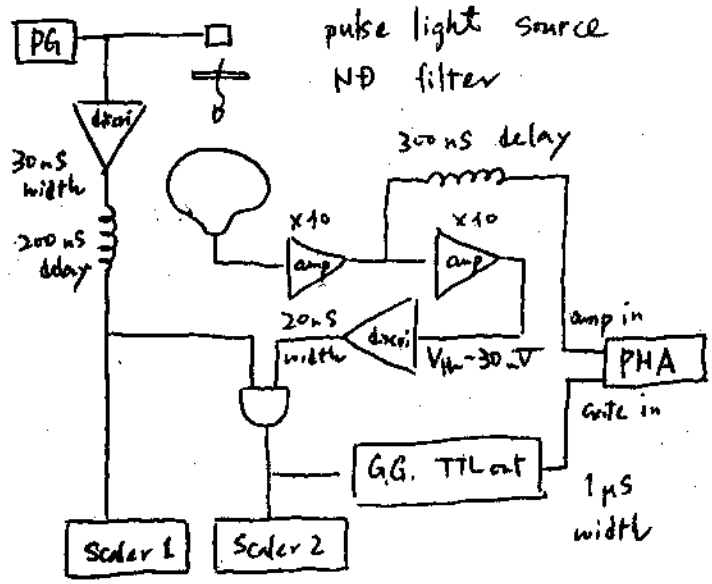
The calculated gain of the PMT was plotted against the HV value in Fig.3 along with the data on the dark current. The solid lines represent the data sent by the Hamamatsu Co..

The present dark current data is consistent with the data from Hamamatsu except in the higher voltage region. The difference is within 30 % and not too significiant. I should mention that it had been hard to measure the dark current especially in the higher voltage region because the PMT was already in the unstable region. The dark current occasionally jumped up about one order of magnitude.

On the other hand, the data on the gain of the PMT looks inconsistent with Hamamatsu's data. However our measurments of the PMT gain had inaccuracies not only in the light intensity but also in the assumption of QE $\times$ CE = 0.1. In this light, these data seems consistent with each other within the accuracy of our measurment ($\tilde{\approx}$ 50%). Or if we assume Hamamatsu's gain figure accurate, the QE $\times$ CE value must be about 7 %.

2) 1 photo electron characteristic.

a) HV response.



The PMT response at 1 photo electron (pe) level against the supply HV was measured by using logic curcuits and scalors (see the fig. at right). The scaler 1 was used for counting the number of the light pulses and scaler 2 was used for counting the number of the coincidence pulses.

The data are shown in Fig.4. In this fig. the vertical axis represents the coincidence rate per 104 light pulses. From this fig., the 1 pe plateau is found to be aruond 2.8 kV.

b) pulse height distribution

The pulse height distribution at the 1 pe level was measured by using the coincidence pulses mentioned above as a gate pulse for the PHA. The data was shown in Fig.5. The coincidennce rate, the number of the light pulses, the peak channel no., and the resolution, which is given by FWHM / peak channel no. , are tablated below.

HV	coin/light pulses,	peak ch. ,	resolution
2.7 kV	10.2 k / 219 k	≃ 140	≃ 80 %
2.5 kV	9.9 k / 396 k	≃ 100	≃ 100 %
2.2 kV	4.2 k / 1.5 M	≃ 30	≃ 140 %

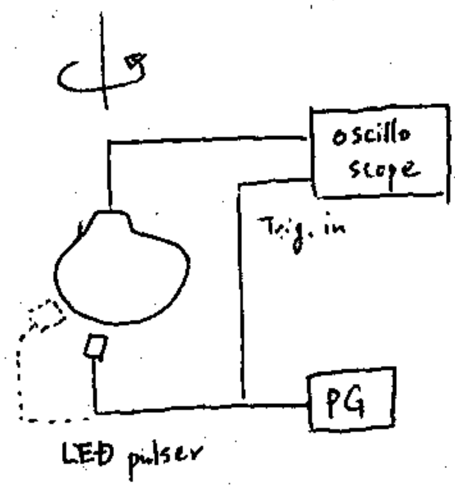
3) Pulse height distribution of dark pulses.

The pulse height distribution of the dark pulse of the PMT is shown in Fig.6. This data was taken for HV = 2.5 kV and the small arrow within the fig. indicates the peak channel for 1 pe.

The frequency of the dark pulses greater than 1 pe was $\sim$ 5.8 kHz and that greater than 1/4 pe was $\sim$ 30 kHz. The present data on the dark pulses greater than 1/4 pe is consistent with that from Hamamatsu, 32.4 kHz. It should be also noted that the noise counts drops fast with amplitude being 1.4 kHz above 2 pe and 600 Hz above 3 pe.

4) Geomagnetic effect.

The geomagnetic field strength in the 322 lab. and in the test water tank was measured to be $\sim$ 0.24 gauss which is two thirds of what it should be in Honolulu, 0.359 gauss. Although these values are small, the significant effect on the output pulse height might be expected because of the long electron path between the photocathode and the first dynode of the 16" PMT. The LED light pulser and the oscilloscope were used to check the geomagnetic effect on the PMT output pulse (see fig. above).



Data was taken for four LED pulser positions and for two HV values. The results were shown in Fig.7. In contrast to the previous measurments done by Mitsui using anther sample PMT at HV = 1.5 kV, we found a very small effect on the output pulse height of PMT. The maximum effect is about 15 %,therefore we need not be too nervous about geomagnetic effects.

5) Summery.

a) The DC gain of this PMT is a little less than what we want. In the voltage region greater than 2.0 kV the noise current is not proportional to the PMT gain at all. If we get a PMT with gain sevarel times that of this PMT, we can use it in a relatively low voltage region. This means that we can use it in a low noise region.

b) The 1 pe characteristics look nice. The tube needs to be operated at a higher voltage (> 2.7 kV) to reach plateau, but this is not easy because of the PMT stability.

c) Our noise measurements roughly agree with these supplied by Hamamatsu.

d) The geomagnetic effect is not important for this PMT.

e) We will make tests on the PMT sensitivity versus the direction of light and on the timing distribution using the test tank lab. soon.

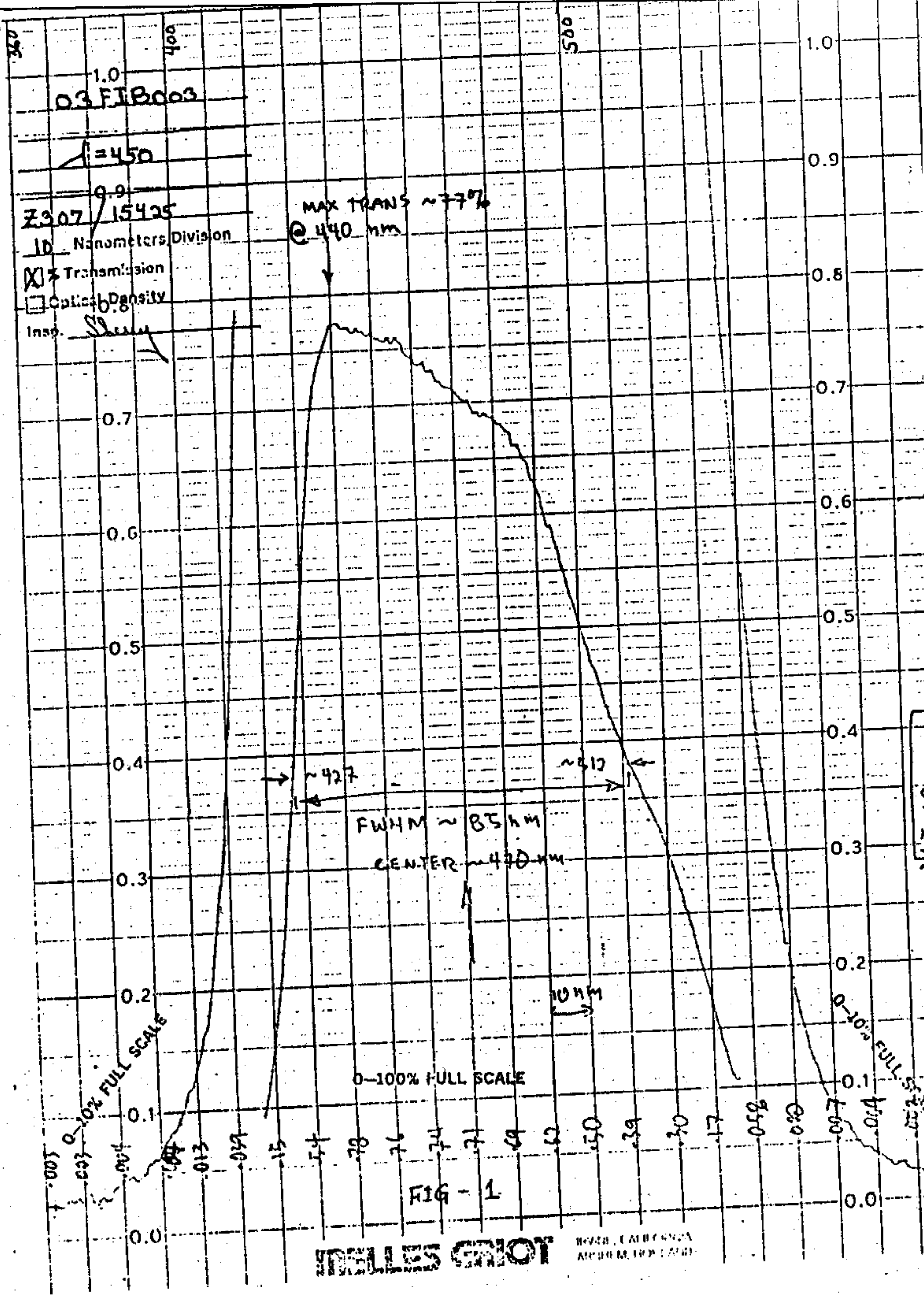
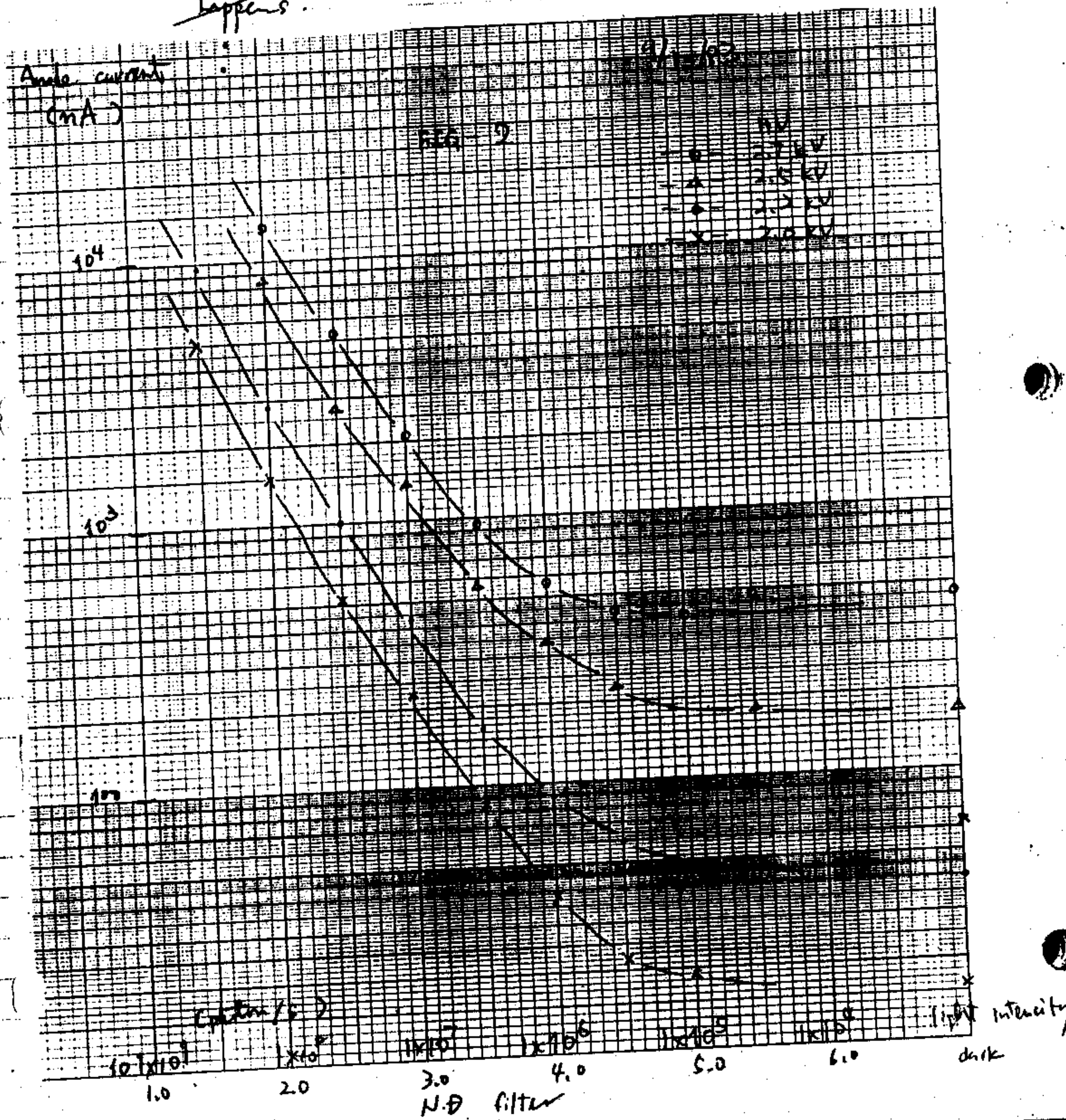
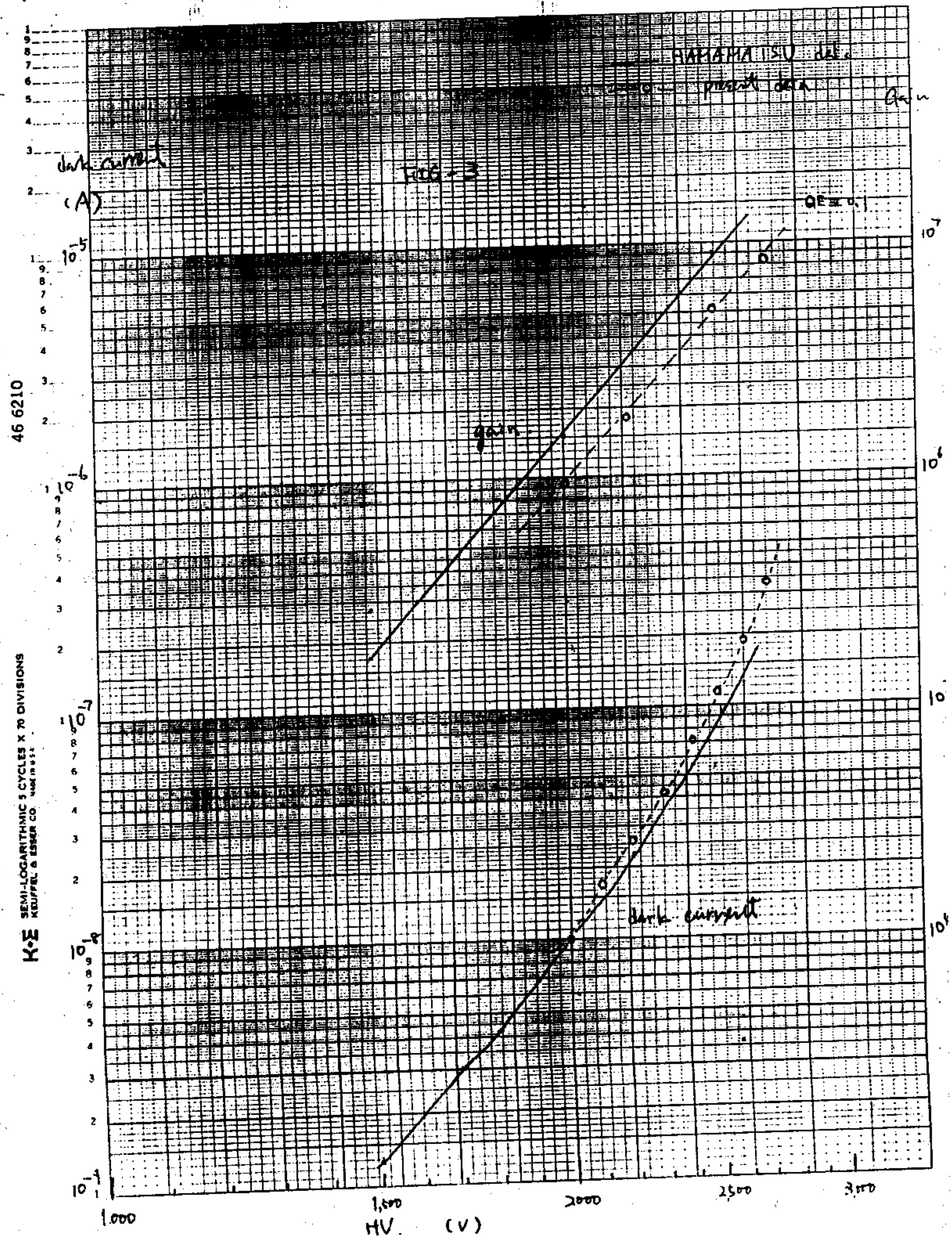

03FIB003
λ=450
Z307 / 15425
10 Nanometers/Division
[X] % Transmission
[ ] Optical Density
Insp.
MAX TRANS ~77%
@ 440 nm
~427
~512
FWHM ~ 85 nm
CENTER ~470 nm
10 nm
0–10% FULL SCALE
0–100% FULL SCALE
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
400
500
MELLES GRIOT

FIG - 1

- coincidence rate vs HV doesn't looks constant.
- dark current on High HV (> 2.5 kV) is not consistent with Hamamatsu data
- PMT gain is not checked because something strange happens.




HAMAMATSU data
present data
Gain
dark current
(A)
FIG-3
QE = 0.1
gain
dark current
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{7}
10^{6}
10^{4}
1,000
1,500
2000
2,500
3,000
HV. (V)
46 6210
K·E SEMI-LOGARITHMIC 5 CYCLES X 70 DIVISIONS
KEUFFEL & ESSER CO.

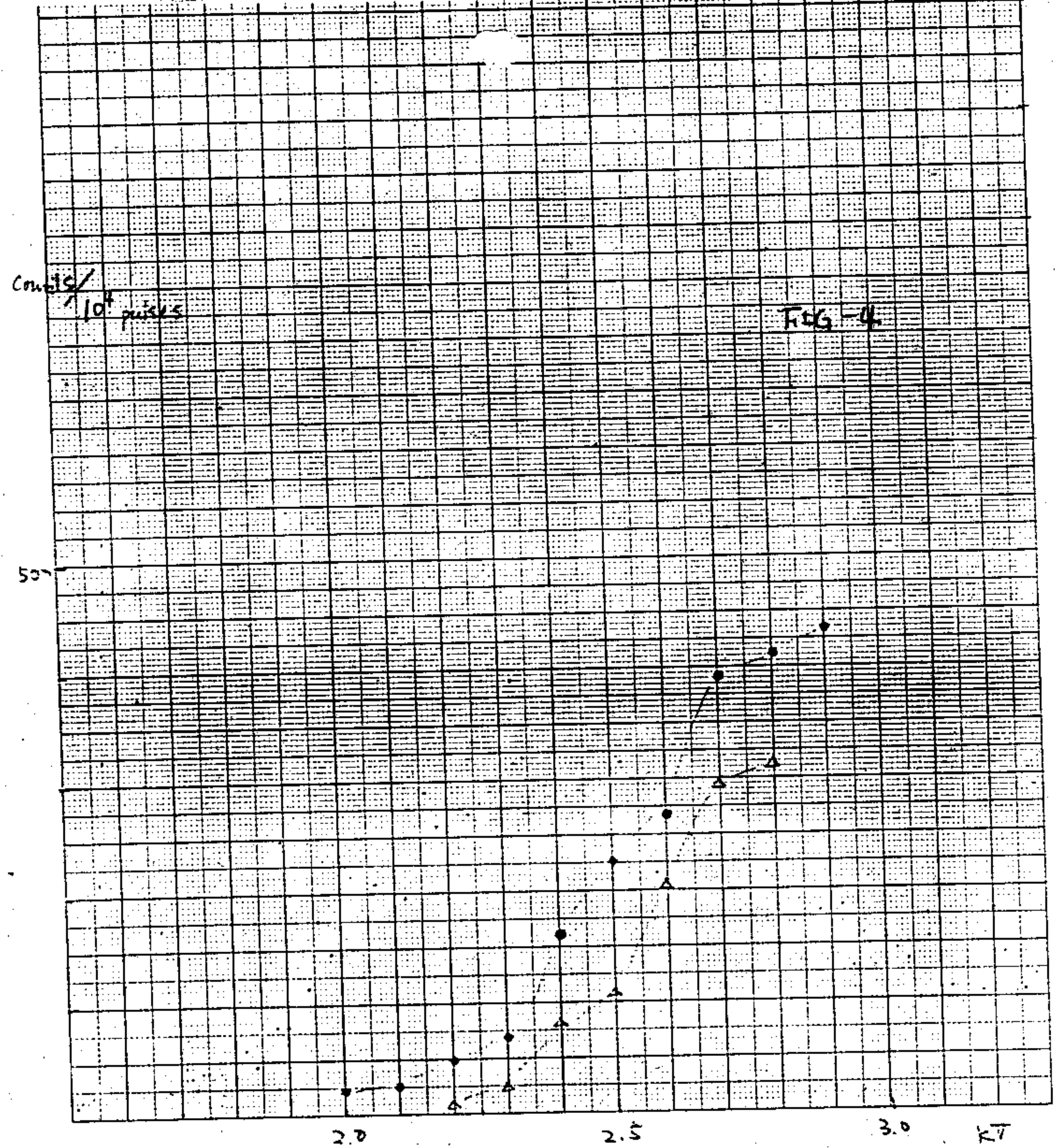


FIG - 4
Counts/10⁴ pulses
50
2.0
2.5
3.0
kT

FIG- 5

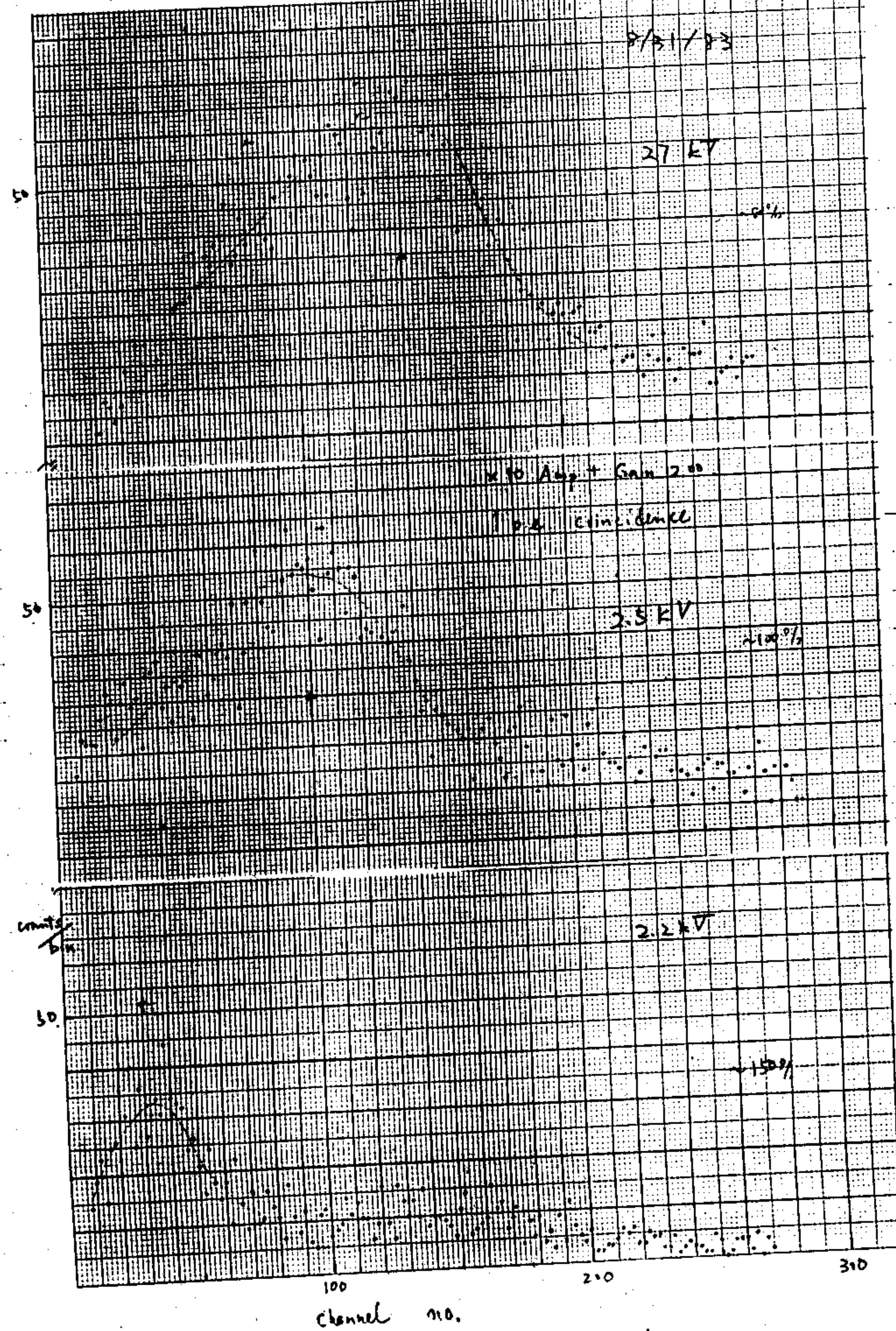

8/31/83
27 KV
50
~6%
x 10 Amp + Gain 200
1 p.s. coincidence
50
3.5 KV
~100%
2.2 KV
counts/bin
30
~150%
100
200
300
Channel no.

FIG - 6

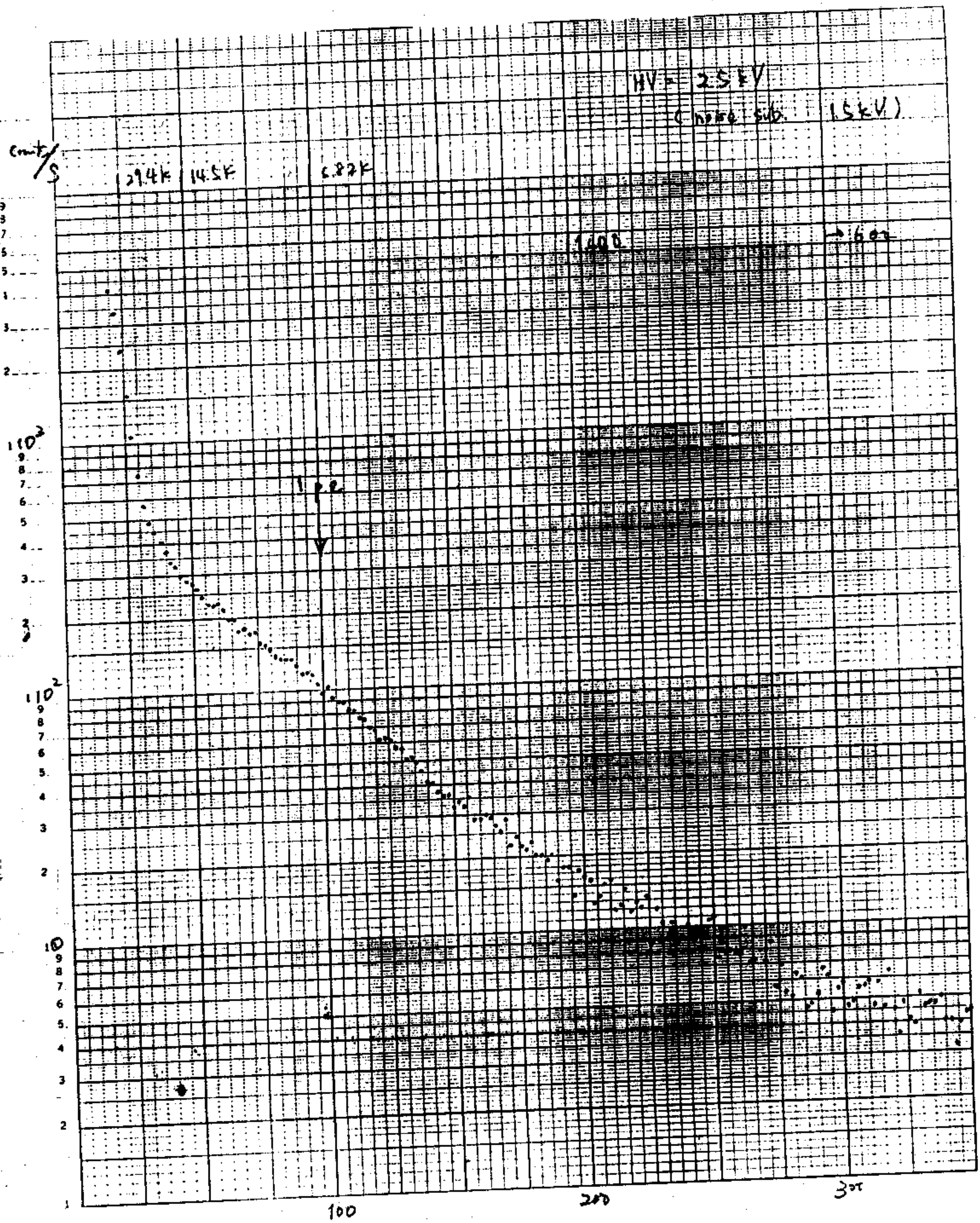
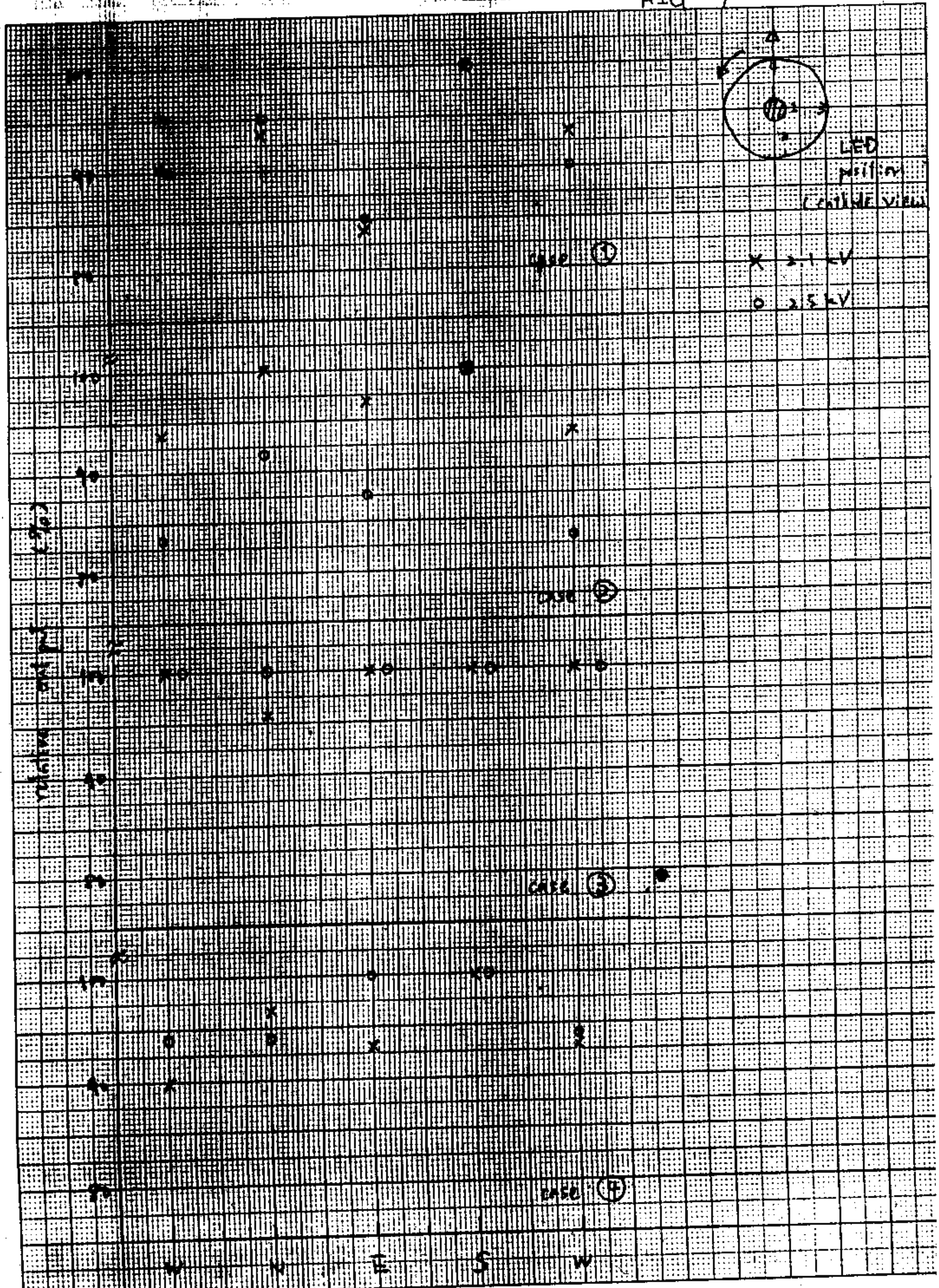

HV = 25 kV
(noise sub. 15 kV)
count/S
29.4k
14.5k
6.82k
1.00
1.60
1.82
10³
10²
10
100
200
300

FIG-7


LED
position
(cathode view)
case 1
x 2.1 kV
o 2.5 kV
case 2
case 3
case 4
W
N
E
S
W