IReS 98-03

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EFFECT OF RADIATION INDUCED SUBSTRATE DEFECTS ON MICROSTRIP GAS CHAMBER GAIN BEHAVIOUR. PART II : experimental consequences

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Abstract

The aim of our work was to quantify the influence of radiation induced substrate defects on microstrip gas chamber gain behaviour (MSGC). In this second paper, the radiation sensitivity of Desag D263 glass has been linked to the behaviour of the detector under irradiation. Comparative gain measurements were taken before and after substrate irradiation at 10 and 80 kGy (respectively minimal dose received during LHC operation and dose for which defect density is maximum).

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1.INTRODUCTION

In a previous paper, we have showed the influence of irradiation on the classically used Desag D263 glass substrate [1]. Irradiation induces defects inside the material. According to their position inside the CMS spectrometer, substrates will receive irradiation doses ranging between 10 and 50 kGy (equivalent doses in SiO_2 material) during 10 years LHC operation. We studied the evolution of defect concentration versus the accumulated dose, up to 480 kGy. At 10 kGy, the measured defect concentration could be equivalent to an accumulated charge of about 60 mC/cm^3. The maximum defect concentration was observed to be around 80 kGy which could correspond to a macroscopic charge of 100 mC/cm^3. For comparison, we also studied the well-known pure silica in the same conditions. We have seen that the defect concentration in Desag D263 glass could be up to 10^4 times greater than in pure silica. This substrate behaviour may lead to a degradation of detectors characteristics under irradiation. In these conditions, the next step was clearly study of influence of these defects on the chamber behaviour.

To make sure that our study only concerns substrate effects, we have performed a specific procedure: it takes into account the results of substrates irradiation and is also based on an appropriate detector operating mode. Two irradiation series were carried out with 3 detectors. We have used 2 different doses. The first one (10 kGy) corresponds to the dose received by a detector located in the central part of the CMS spectrometer. The second irradiation (80 kGy) gives the maximum defect concentration inside the substrate (twice as high as for 10 kGy). During irradiation, the operating mode of detectors was as follows, identical for each detector : strips were normally polarized, because it seemed to us that this parameter would influence at the same time both the defect creation (specially the carrier generation) and the charge migration of alcalin species inside the substrate which is a very well known effect of irradiation [2]. On the other hand, the drift plane was not polarized, so as to avoid gas multiplication and discharges in the chamber. Lastly, chambers were in ambient air to avoid polymerization on the strips, another common ageing effect [3]. In these conditions, we think that if any modification of the detector behaviour is observed, it can only come from a substrate effect.

2. EXPERIMENTAL CONDITIONS

2.1. IRRADIATION

Six detectors were used for these two irradiations. Precise detector design is described elsewhere [4]. Strips cover a 26*26 mm^2 area with 128 anode/cathode pairs. Anodes are 9 µm wide, cathodes are 70 µm wide and the pitch is 200 µm. These detectors have been assembled at the Centre de Recherches Nucléaires (CRN) in Strasbourg. Strips were processed by the PHASE laboratory (Strasbourg) with Ti/Al and chemical etching (5 detectors : P39, P40, P43; P47 and P48) or by Optimask with Al and plasma etching (1 detector : P34).

For practical reasons, it was not possible to use the same facility as for the substrate irradiation (Co source). Here, irradiations were performed with an electron beam of 2.2 MeV provided by the AERIAL* society. For each dose, the 3 detectors were irradiated all together. A waggon was used to carry the detectors inside the beam and a scanning system ensured a homogeneous irradiation. The same rate of irradiation, at around 80 krad/s, was selected for the 2 experiments at 10 and 80 kGy. Around the detectors, ceramics and electronics were protected by a 1 cm thick polyethylene plate. We have tested components before and after irradiation to ensure they were not affected by the beam. As mentionned above, during irradiation only the strips were polarized while the drift plane was floating. Cathods were grounded and anodes were polarized at -420 V. This set of voltages was also used during the gain measurements (with a negative drift voltage). Also note that there was ambient air in the chambers during irradiation.

2.2. GAIN MEASUREMENTS

All measurements have been taken with the same electronic system. Functioning cathodes were connected all together. The readout system was composed by an Ortec 142A preamplifier, a Schlumberger 7129 amplifier and an Inel Cato multichannel analyser. A ^{55}Fe source was used for gain measurements. The set of voltages used for gain monitoring was: 0 V (anodes), -420 V (cathodes) and -1200 V (drift plane). The gas was a classical Ar - DME (90% - 10%) mixture. All these conditions result in a small gain value (around 800), but a very stable operation mode. Gain is very sensitive to the mixture homogeneity and to impurities. Gas mixture was flushing for a minimum of 12 hours before measurements.

Two kinds of gain measurements have been taken. Firstly, different scans parallel and perpendicular to the strips were done to verify that irradiation was homogeneous (the behaviour difference before and after irradiation must be the same at any location in the detector). Two scans were performed in each direction : perpendicular and along anode strips (see figure 1). Measurements were set to begin 4 hours after polarization of detectors to take into account possible gain evolution after polarization. Moreover, all the measurements were always done in the same order. Secondly we looked at the gain behaviour with time after brutal polarization, by focusing measurement on one point of the detector (figure 1). To be sure that the detectors were initially in an equilibrium state, this kind of measurement was taken at least 12 hours after the last run of the detector. This approach mainly allows to characterize possible charge migration inside the bulk material.

3. RESULTS

Typical results of scans for detector referenced as P39 are presented in figures 2a and 2b. This detector is built on strips made by the PHASE laboratory and was irradiated at a dose of 10 kGy. In each case, we can see that gain is essentially the same before and after irradiation : small differences can be attributed to the reading error and to the variations of gain due to pressure and temperature variations more probably than to irradiation. We have thus seen that a 2 degrees temperature variation results in a gain variation of about 10% [5] These curves show a good homogeneity of irradiation since gap gain before and after irradiation is the same at any place of the detector. Other results of this kind of studies after 10 kGy irradiation have been assembled together in table 1. Note that detector P34 whose strips have been made by the industry with Al and plasma etching have the same behaviour as the other one which is built on Ti/Al strips and chemical etching. With these 3 detectors, we can see that the general tendancy is a non significant influence of irradiation on gain behaviour since the more significant part of the difference can easily be attributed to reading errors and temperature variations.

At a dose of 80 kGy, corresponding to the maximum defect concentration observed with ESR analysis, the behaviour is once again the same as illustrated on figure 3a and 3b for detector P47. The parallel scan induced us to suppose that in this case, irradiation is less homogeneous. But the small gain falls and rises are within the reading error margin which was initially estimated at 3%. Table 2 sums up the results obtained on

the 3 detectors after 80 kGy irradiation. Once again, we can conclude that at this dose, which corresponds to the maximum defect concentration in the substrate, there seems to be no influence of the irradiation.

Studies of gain variation with respect to time of polarization complete the ones presented before. A fall in the gain, after the first few minutes of polarization, is usually observed in MSGC. This is due to charge migration in the bulk because of the electric field [6,7,8]. Here we want to ascertain wheter if this phenomenon was influenced by the irradiation. Results concerning the 6 detectors have been synthetized in figures 4a and 4b where detectors have been associated according to the received dose (10 and 80 kGy). These curves show that the behaviour of the gain with respect to time of polarization is the same before and after irradiation for all these detectors. Gain differences correspond to a simple translation of values. However, after 10 kGy irradiation, for 2 detectors (P34 and P39), there is a drop in gain (6 and 10% respectively), while the gain has increased by 5% for detector P40. This point was already observed during scanning measurements and these differences can be interpreted in terms of pressure and temperature variations. The same kind of observations can be made after 80 kGy irradiation. In all cases, only a translation of the curve is observed; its shape is not modified after irradiation. We concluded that irradiation probably does not modifies the charge migration induced by an electric field.

4. CONCLUSIONS

MSGC gain measurements before and after 2.2 MeV electrons irradiation at 10 and 80 kGy doses show no significant differences. Paramagnetic defects created inside the substrate bulk have no relevant effect on the gain measurements nor on the gain behaviour with respect to time. The small gain falls and rises observed are less than or equal to 10% and can be better taken into account in terms of pressure and temperature variations .

This is the first experimental evidence that bulk phenomena seem to have no significant effect on microstip gas chambers. Irradiation with a ^{60}Co source or with 2.2 MeV electron beam will affect the bulk of a material : particles will mostly cross through. This is not the case for RX or ^{90}Sr irradiation which are often used to simulate MSGC ageing process. Low energy particles will be stopped in surface of the sample as

illustrated by figure 5. Defect creation will be inhomogeneous and concentrated on the surface of the substrate. One can suppose that inhomogenous defect concentration leads to gain perturbation (local gain drop). This is a definitive argument which supports the hypothesis that MSGC gain behaviour under irradiation is only related to surface effects.

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Detector reference	Gain versus position (scans)	Gain versus time
P34	0%	- 6%
P39	- 2%	- 8%
P40	+ 10%	+ 10%

Table 1 : Average gain variations oberved before and after 10 kGy irradiation.

Detector reference	Gain versus position (scans)	Gain versus time
P43	+ 10%	- 5%
P47	0%	- 3%
P48	+ 4%	+ 8%

Table 2 : Average gain values oberved before and after 80 kGy irradiation.

FIGURE CAPTIONS

Figure 1 : Description of gain measurements.

Figure 2 : Gain measurements of P39 before and after 10 kGy irradiation.
a) perpendicular to strips.
b) parallel to strips.

Figure 3 : Gain measurements of P47 before and after 80 kGy irradiation.
a) perpendicular to strips.
b) parallel to strips.

Figure 4 : Gain evolution with time.
a) before and after 10 kGy irradiation.
b) before and after 80 kGy irradiation.

Figure 5 : Photon attenuation as a function of energy and thickness of irradiated Desag D263 glass substrate.

Figure 1

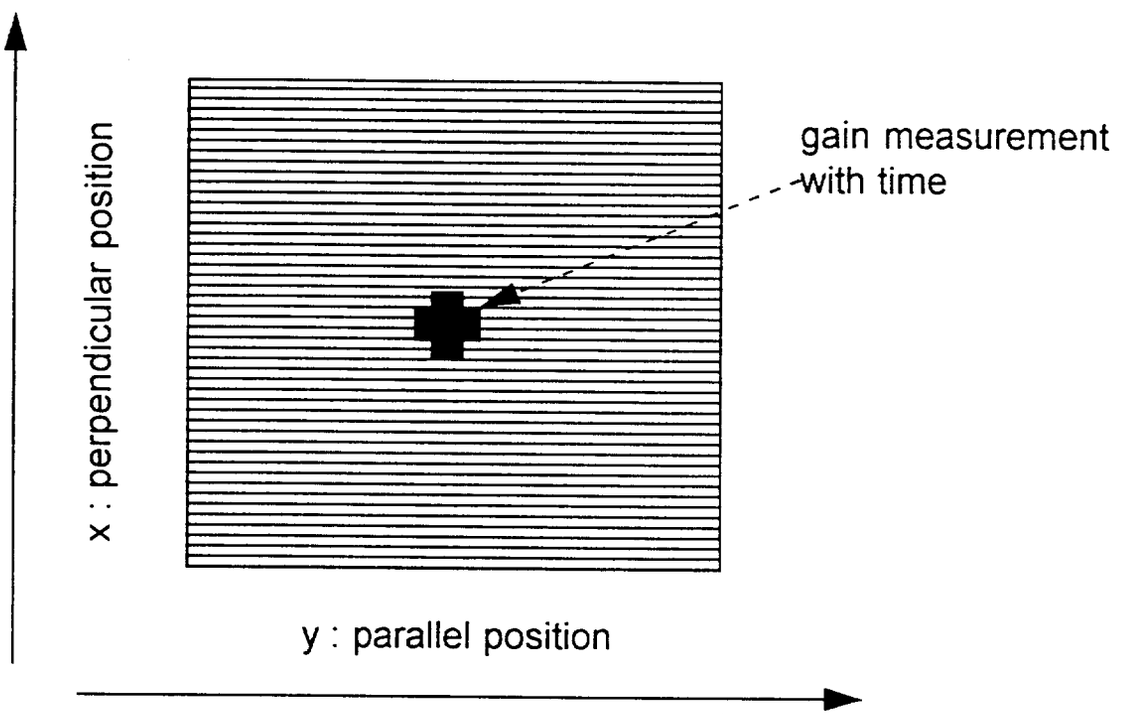
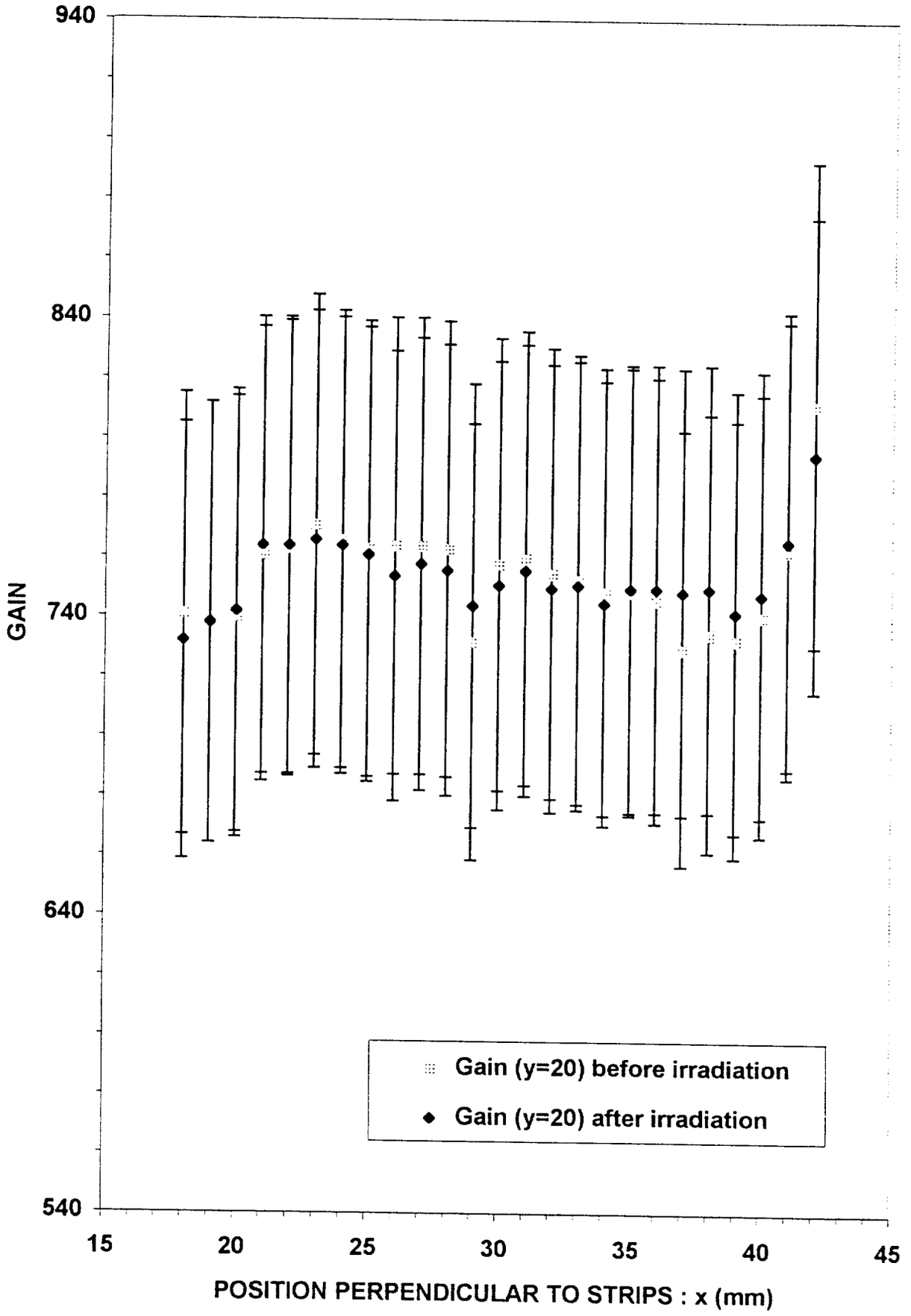

gain measurement
with time
x : perpendicular position
y : parallel position

Figure 2.a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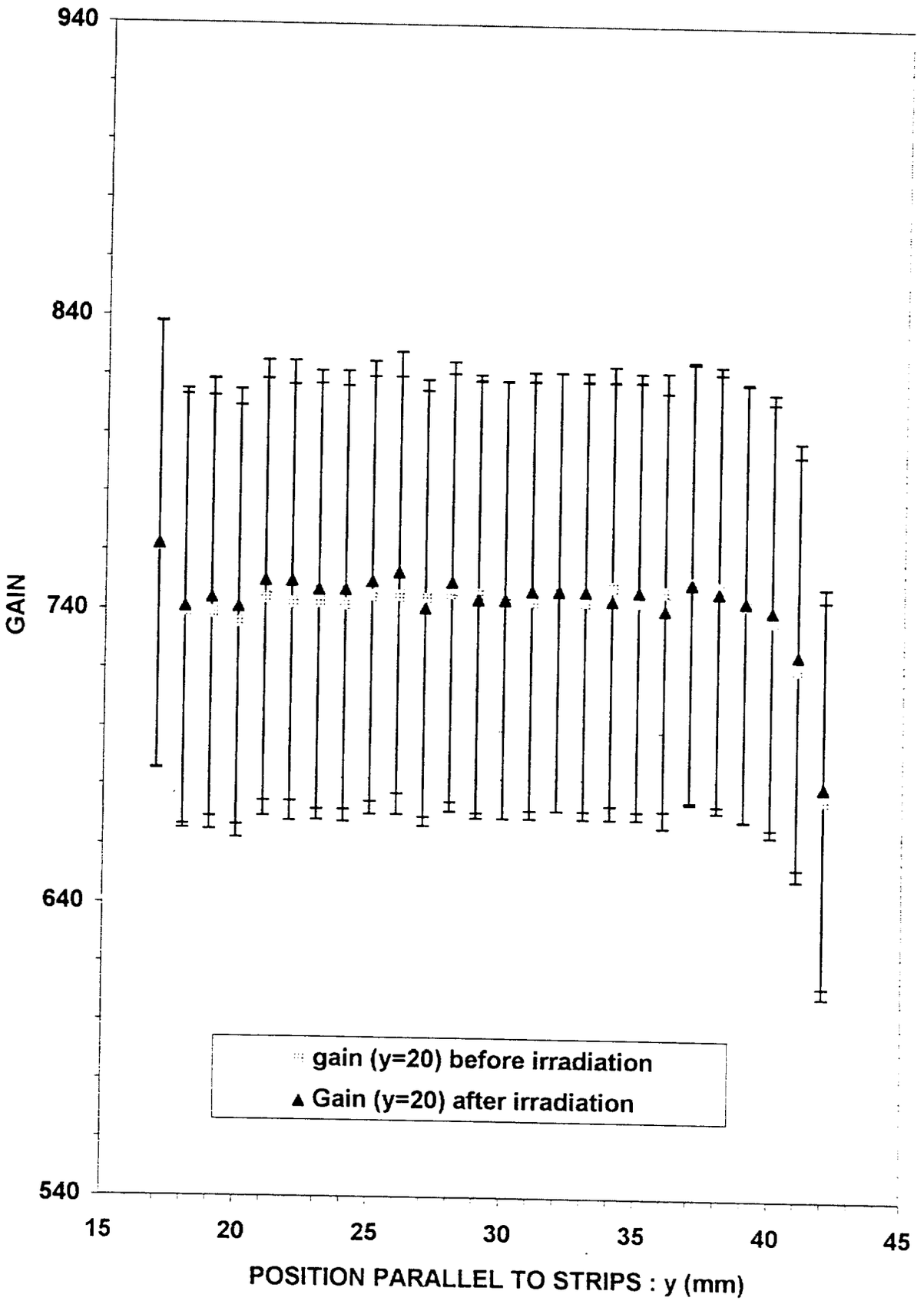
840
740
640
540
GAIN
15
20
25
30
35
40
45
POSITION PERPENDICULAR TO STRIPS : x (mm)
Gain (y=20) before irradiation
Gain (y=20) after irradiation

Figure 2.b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840
740
640
540
GAIN
15
20
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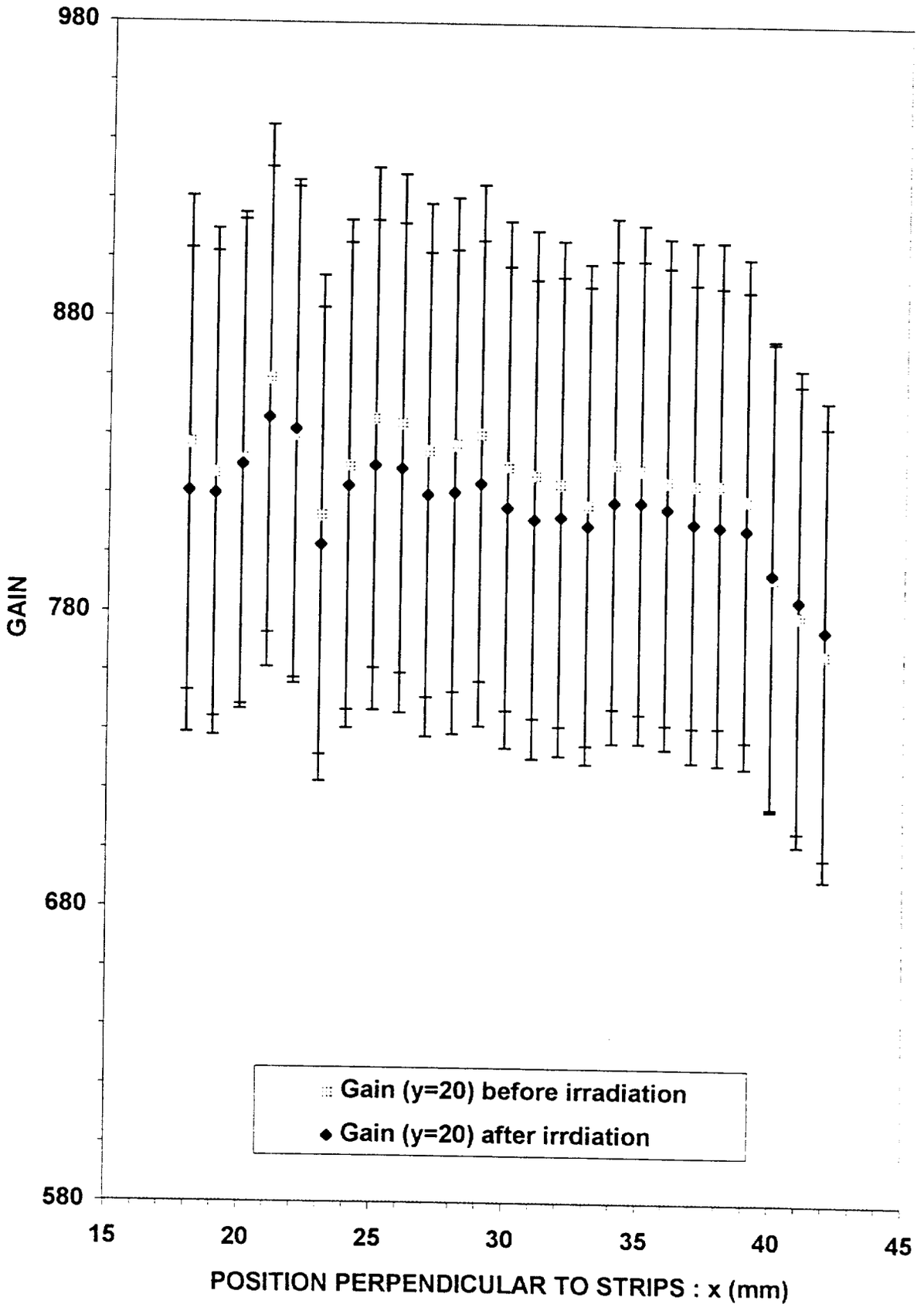
40
45
POSITION PARALLEL TO STRIPS : y (mm)
gain (y=20) before irradiation
Gain (y=20) after irradiation

Figure 3.a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880
780
680
580
GAIN
15
20
25
30
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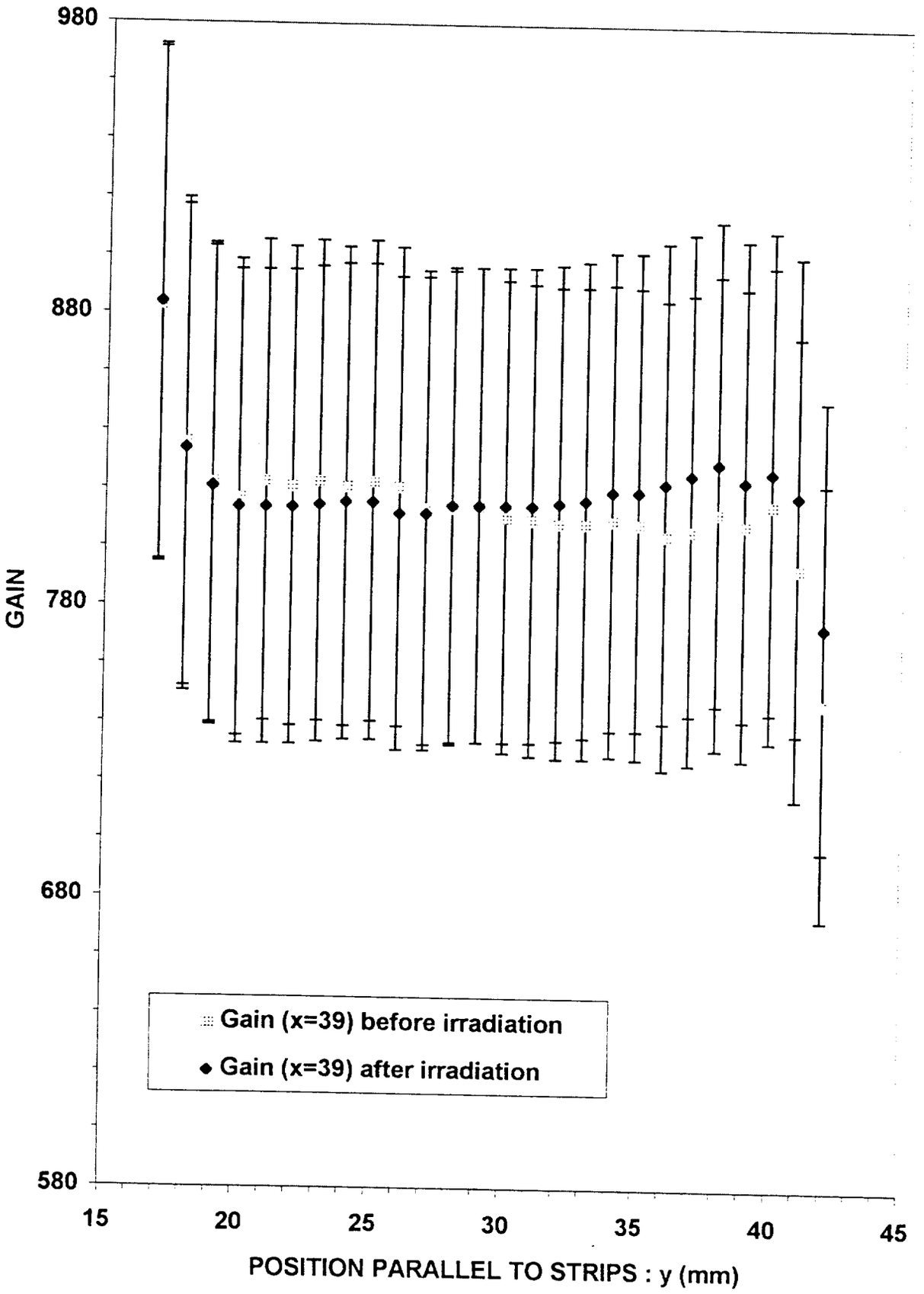
40
45
POSITION PERPENDICULAR TO STRIPS : x (mm)
Gain (y=20) before irradiation
Gain (y=20) after irrdiation

Figure 3.b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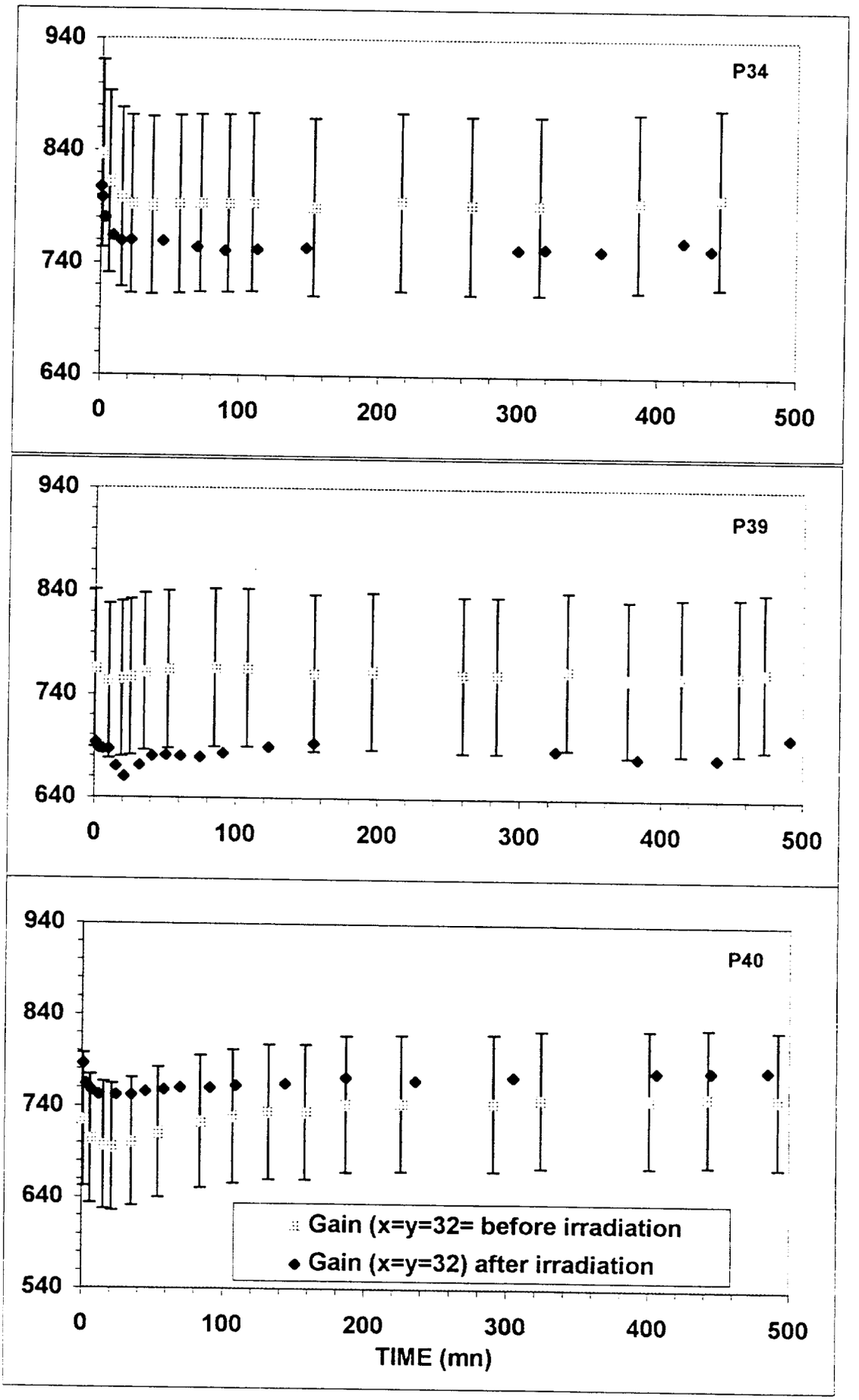
880
780
680
580
GAIN
15
20
25
30
35
40
45
POSITION PARALLEL TO STRIPS : y (mm)
Gain (x=39) before irradiation
Gain (x=39) after irradiation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840
740
640
P34
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100
200
300
400
500
940
840
740
640
P39
0
100
200
300
400
500
940
840
740
640
540
P40
Gain (x=y=32= before irradiation
Gain (x=y=32) after irradiation
0
100
200
300
400
500
TIME (mn)

Figure 4.a

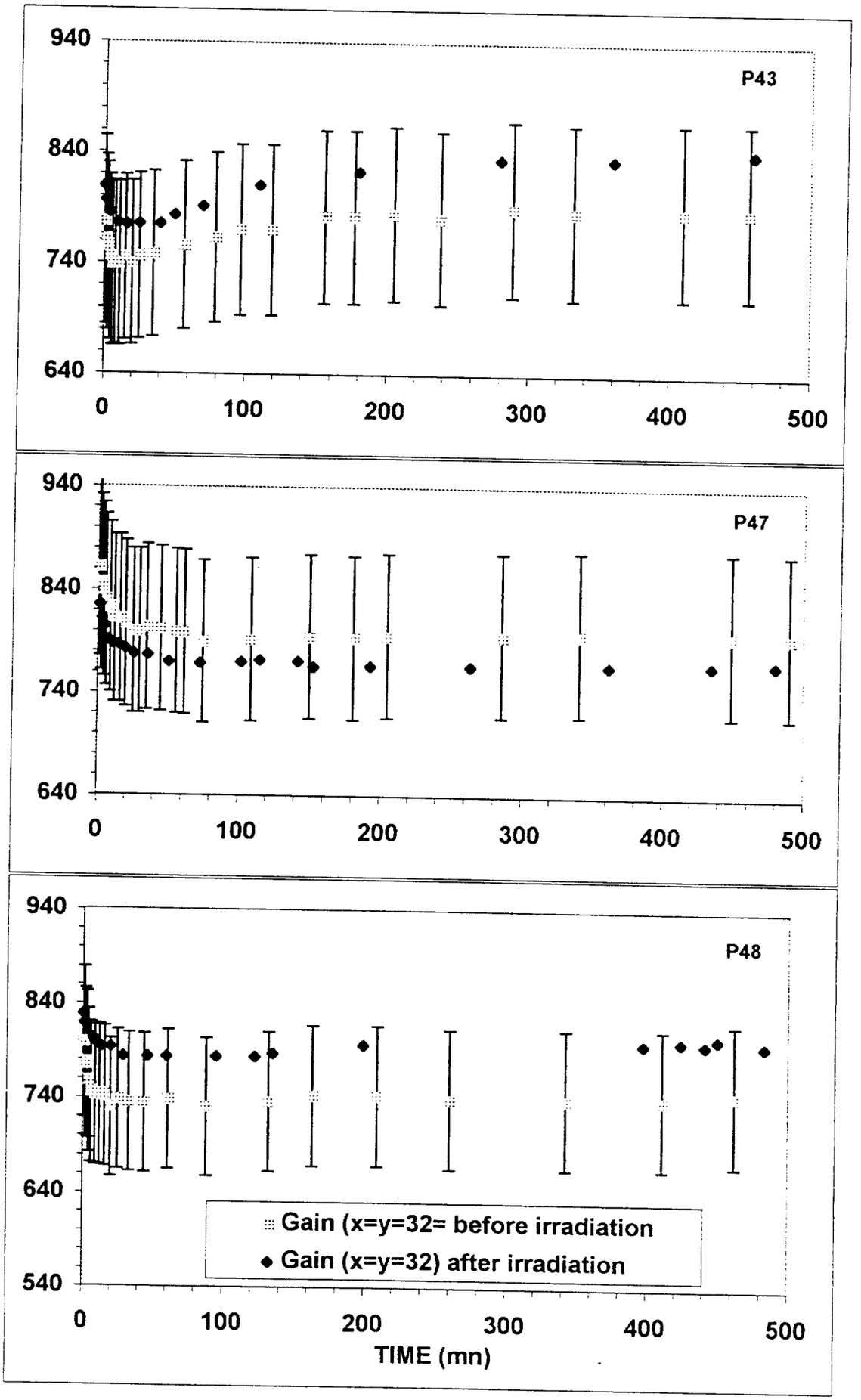
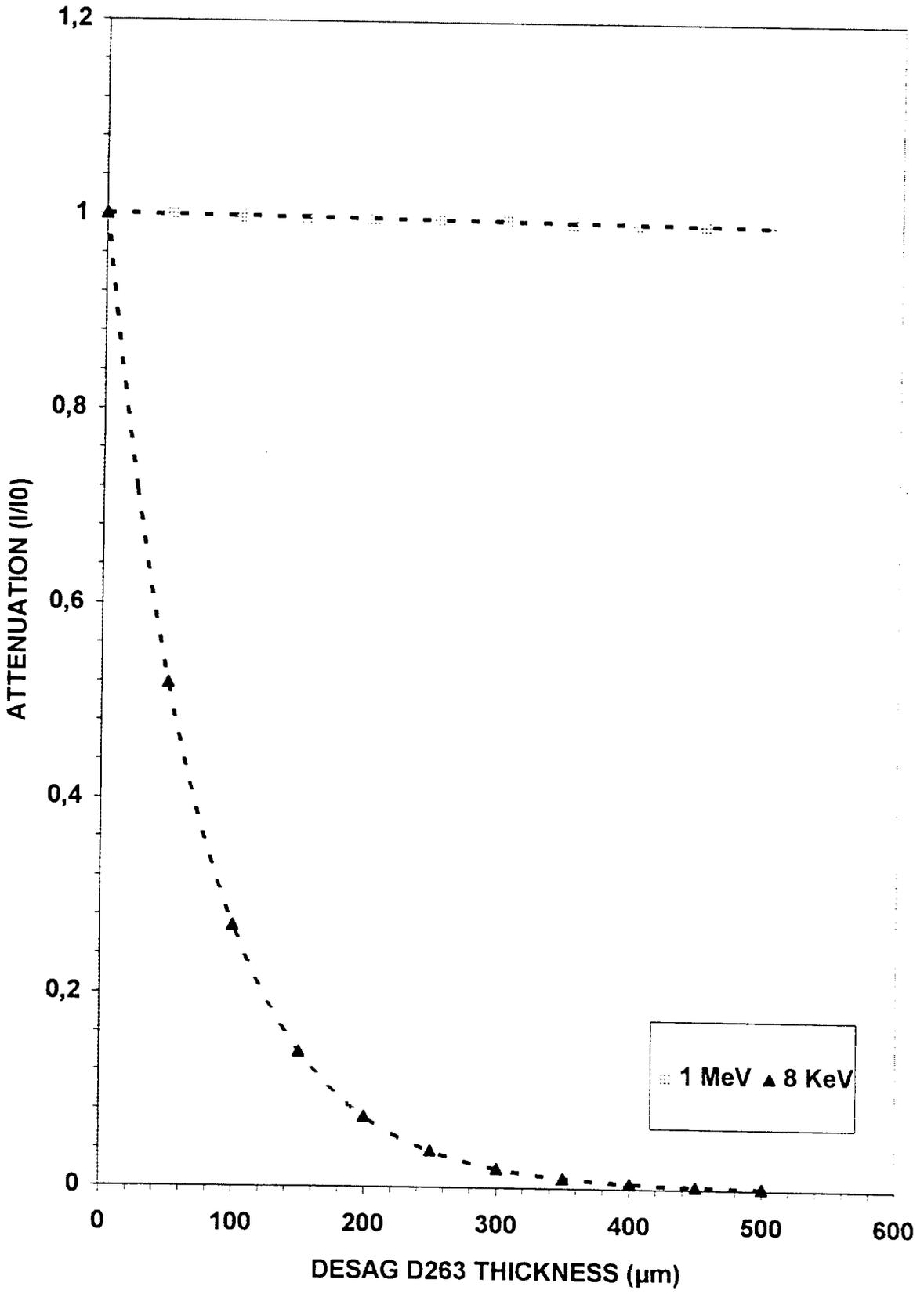

940
840
740
640
0
100
200
300
400
500
P43
P47
P48
Gain (x=y=32= before irradiation
Gain (x=y=32) after irradiation
540
TIME (mn)

Figure 4.b

Figure 5


1,2
1
0,8
0,6
0,4
0,2
0
ATTENUATION (I/I0)
0
100
200
300
400
500
600
DESAG D263 THICKNESS (µm)
1 MeV
8 KeV