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TEST OF MAGNETIC SHIELDING CASES FOR A 3" PHOTOTUBE ATTACHED TO A LEAD GLASS COUNTER

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Test of Magnetic Shielding Cases for a 3" Phototube attached to a Lead Glass Counter

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Abstract

Effect of a magnetic shielding for a phototube of 3" diameter attached to a lead glass counter has been studied using permalloy shielding cases with two kinds of shapes. Both cases show sufficient shielding effect with magnetic field up to around 30 gauss.

KEYWORDS: Magnetic shielding, Phototube, Lead glass, Permalloy

1. Introduction

In high energy physics experiments, calorimeters which use phototubes are often used in a combination with a magnetic tracking spectrometer. Sufficient magnetic shielding for a phototube is important in order to obtain a good performance of a calorimeter. Usually, the magnetic shielding of phototubes is made by covering a phototube with a cylindrical permalloy case. It is necessary to have a light guide between a phototube and a radiator when the radiator is a lead glass. It is proved, however, that the use of a light guide deteriorates energy resolution and electron pion separation factor/1/. It is very important to adopt a way of magnetic shielding that does not use a light guide or a way to reduce the light guide effects as much as possible.

In this report, two kinds of magnetic shielding cases have been designed and tested to be used in the VENUS electromagnetic calorimeter/2/, where leakage magnetic field of about 30 gauss is expected/3/. The one is the way that uses a thin permalloy sheet covering around lead glass block for magnetic shielding and does not use a light guide. The other is the way that uses an ordinary cylindrical permalloy case for magnetic shielding and uses a special light guide/4/ to keep good performance of a lead glass counter. Test results are reported in detail.

2. Magnetic Shielding Case I

Magnetic shielding is rather difficult in a direction parallel to the axis of a phototube. To get an idea on allowed magnetic field strength in a shielding case, the gain variation of a 3" phototube in an axial field is shown in Fig. 1. As can be seen in the figure, magnetic field strength should be less than, say, 2 gauss, if you want to suppress the gain variation less than 1 %. The design should go under the above constraint.

A design drawing of a magnetic shielding case I is shown in Fig. 2. A sheet of PC permalloy/5/, 0.2 mm thick and 15 cm long, which covers side face of a lead glass counter is tightly connected to a PC permalloy flange. A PC permalloy cylindrical case of 1 mm in thickness and 80 mm in diameter covers a phototube and is connected to a permalloy flange.

The magnetic field was calculated for above configuration by Poisson equation under the external magnetic field of 33 gauss. The result is shown in Fig. 3. In practical use, small gap between permalloy sheets and permalloy flange may be unavoidable. In the same figure are shown the results for such cases. For the case where there is a gap of less than 0.2 mm between a permalloy sheet and permalloy flange, field strength satisfies the present constraint. It should be stressed, however, that if there is a non-negligible gap, field strength sharply becomes large. In

Fig. 4 is plotted magnetic field measured by Hall probe for the magnetic shielding case I described above. The abscissa, X, is defined in Fig. 2. A permalloy sheet was carefully glued to permalloy flange by epoxy. The gap may be around 0.1 mm. The cylindrical case is welded to the flange. The data seems to be consistent with the calculation where there is 0.2 mm gap. In Fig. 5 is plotted pulse height peak for 1.33 MeV γ from Co^{60} measured by using NaI scintillator. The shielding case is the same as used in Fig. 4. The shielding effect of less than 1 % in gain variation of a phototube is obtained with the external magnetic field strength up to 60 gauss for the both directions, parallel and perpendicular to the axis of a phototube. At around 60 gauss, a 0.2 mm thick permalloy sheet saturates. Needless to say, it was observed that a slight gap deteriorates shielding effect largely.

3. Magnetic Shielding Case II

Though the magnetic shielding case I described in section 2 is attractive, there may be a drawback in practical use. The shielding effect is very sensitive to the connection between a thin permalloy sheet and permalloy flange as discussed in preceding section. The method of gluing doesn't assure firm connection. Welding seems to be unique solution for this purpose. But it is not applicable when a lead glass block is tapered toward its front face.

The introduction of a special light guide studied in ref. 4 makes a convenional cylindrical shielding case applicable for magnetic shielding without degradation of the performance of a lead glass counter. In this section, a cylindrical magnetic shielding case is studied for some detail on configuration and material.

In Fi.g. 6, magnetic field is calculated for a 1 mm thick cylindrical case by Poisson equation. In Fig. 7 is shown the measuerd magnetic field. As can be seen from these figures, the length of light guide should be larger than 6 cm for 3" phototube.

Experimental test were done by observing the peak of 1.33 MeV γ from Co^{60} for various materials. In Fig. 8 is shown the result in a magnetic field for 1.5 mm thick PB and PC permalloy/5/ cases with various anealing condition. Among them, a PC permalloy case show best shielding effect in the region of low magnetic field. In Fig. 9 is shown the shielding effect for a 1.5 mm thick PC permalloy case, a 1.5 mm thick PB permalloy case, a 1.5 mm thick PC permalloy case with a 0.2 mm thick PC permalloy sheet in it, a 1.5 mm thick PB permalloy case with a 0.2 mm thick PC permalloy sheet in it, and a 1.5 mm thick PB permalloy case with a 0.35 mm thick PC permalloy sheet in it. A

PC permalloy case with a 0.2 mm thick PC permalloy sheet shows the best shielding effect among the materials tested, while its saturation field is low. The shielding effect in axial direction is rather worse than magnetic shielding case I. The gain of a phototube drops by 1 % at external magnetic field of around 30 gauss. As can be seen in Fig. 9, a PB permalloy case also show good shielding effect when a thin PC permalloy sheet is inserted in it. The shielding effect was insensitive to the length of this thin sheet.

4. Conclusion

We have tested two kinds of magnetic shielding cases which are applicable for a 3" phototube attached to a lead glass counter. Both shielding cases show sufficient shielding effect with magnetic field up to around 30 gauss. For VENUS lead glass counters, a magnetic shielding case II was chosen for practical reasons.

References

1) K.Ogawa R. Sugahara, K. Takahashi, F. Takasaki, T. Tauchi, N. Awaji, H. Hayashii, S. Iwata, H. Ozaki, S. Suzuki, and R.A. Gearhart, Japan. Jour. Appl. Phys. 23(1984) 897

2) K.Ogawa et al. to be published in Nucl. Instr. and Meth.

3) Y. Arai et al., TRISTAN Proposal EXP001.

4) K.Ogawa T. Sumiyoshi, F. Takasaki, S. Sugimoto, K. Doi, T. Khozuki, and R.A. Gearhart, Nucl. Instr. and Meth. 228(1985) 309.

5) Japanese Industrial Standards: PB is nickel iron soft alloy containing 40-50 % nickel and PC, nickel iron soft alloy containing 70-80 % nickel. The magnetization curves for both materials are shown in Fig.10.

Figure Captions

Fig. 1 Gain of a 3" phototube ,R1911, of Hamamatsu Photonics under the axial magnetic field.

Fig. 2 Drawing of a magnetic shielding case I

Fig. 3 Axial magnetic field in the magnetic shielding case I calculated by poisson equation. The extermal magnetic field is 33 gauss.

Fig. 4 Measured axial magnetic field in a magnetic shielding case I under the various axial external magnetic field.

Fig. 5 Gain change of a 3" phototube shielded by a magnetic shielding case I under the magnetic field of following directions: (a) parallel to an axis of a phototube, (b) perpendicular to an axis of a phototube. X-direction is parallel to the box of the first dynode and Y-direction, perpendicular to it.

Fig. 6 Axial magnetic field in the cylindrical magnetic shielding case(magnetic shielding case II) calculated by Poisson equation.

Fig. 7 Measured magnetic field for magnetic shielding case II. X is the distance from the end of the cylinder.

Fig. 8 Gain of a 3" phototube shielded by magnetic shielding case II (a cylinder of 80 mm in diameter, 186 mm in length, and 1.5 mm in thickness) with various materials and anealing conditions under the magnetic field of following directions: (a) parallel to an axis of a phototube, (b) perpendicular to an axis of a phototube and parallel to a box of the first dynode.

Fig. 9 Gain of a 3" phototube shielded by magnetic shielding case II (a cylinder of 80 mm in diameter, 186 mm in length, and 1.5 mm in thickness) for various material and configuration under the external magnetic field of the following directions: (a) parallel to an axis of a phototube , (b) perpendicular to an axis of a phototube and parallel to the box of the first dynode.

The open circles are data for a 1.5 mm thick PC permalloy case, Closed circles, for a 1.5 mm thick PC permalloy case with a 0.2 mm thick PC permalloy sheet in it, closed triangles, for a 1.5 mm thick PB permalloy case, open rectangulars, for a 1.5 mm thick PB permalloy case with a 0.2 mm thick PC permalloy sheet in it, closed rectangulars, for a 1.5 mm thick PB permalloy case with a 0.35 mm thick PC permalloy sheet in it.

Fig.10 Magnetization curves for a PB and a PC permalloy. (The figure is taken from a catalogue of Tokin Corpolation.)

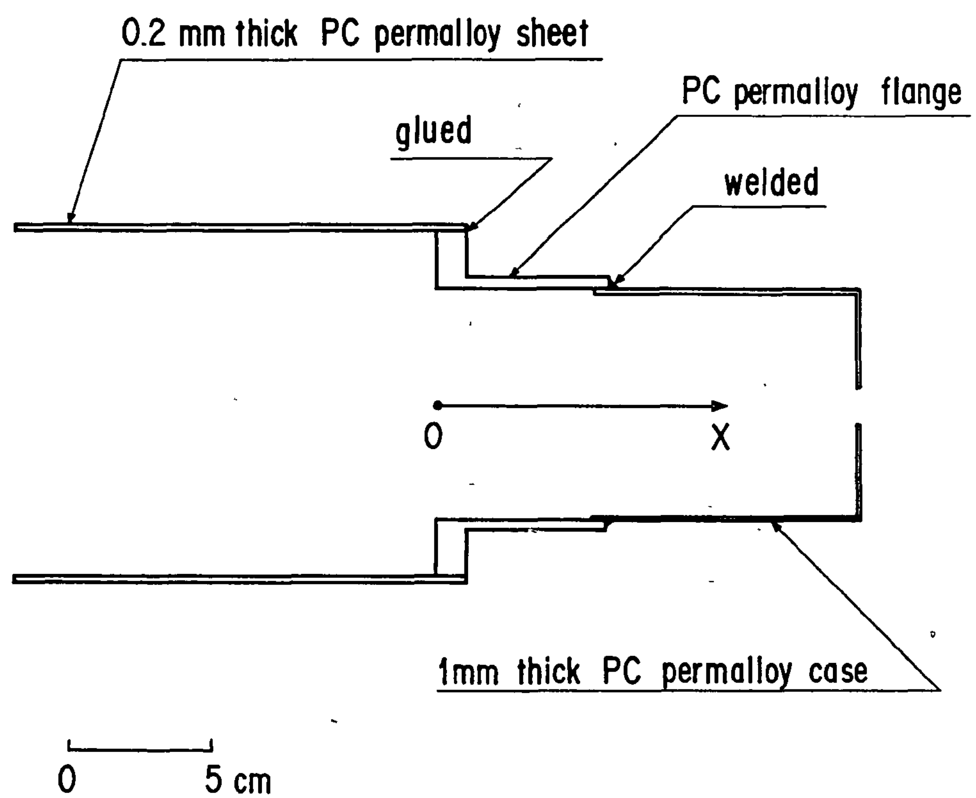

0.2 mm thick PC permalloy sheet
glued
PC permalloy flange
welded
O
X
1mm thick PC permalloy case
0
5 cm

Fig. 2

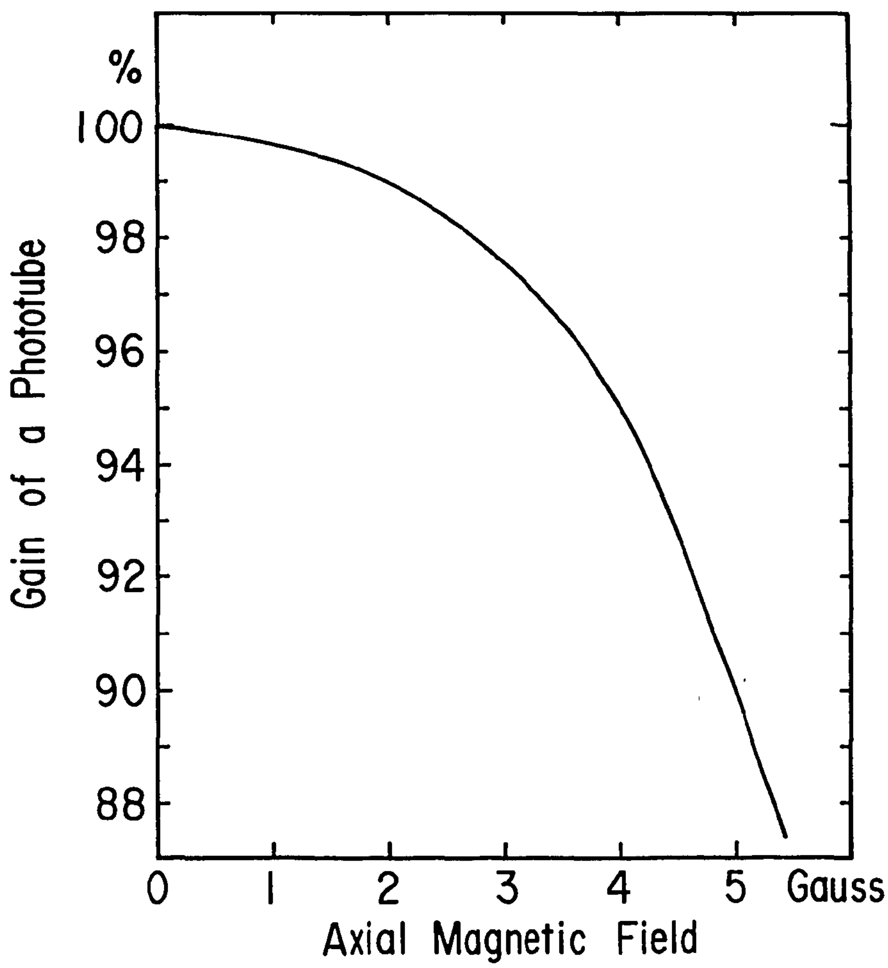

%
100
98
96
94
92
90
88
Gain of a Phototube
0
1
2
3
4
5
Gauss
Axial Magnetic Field

Fig. 1

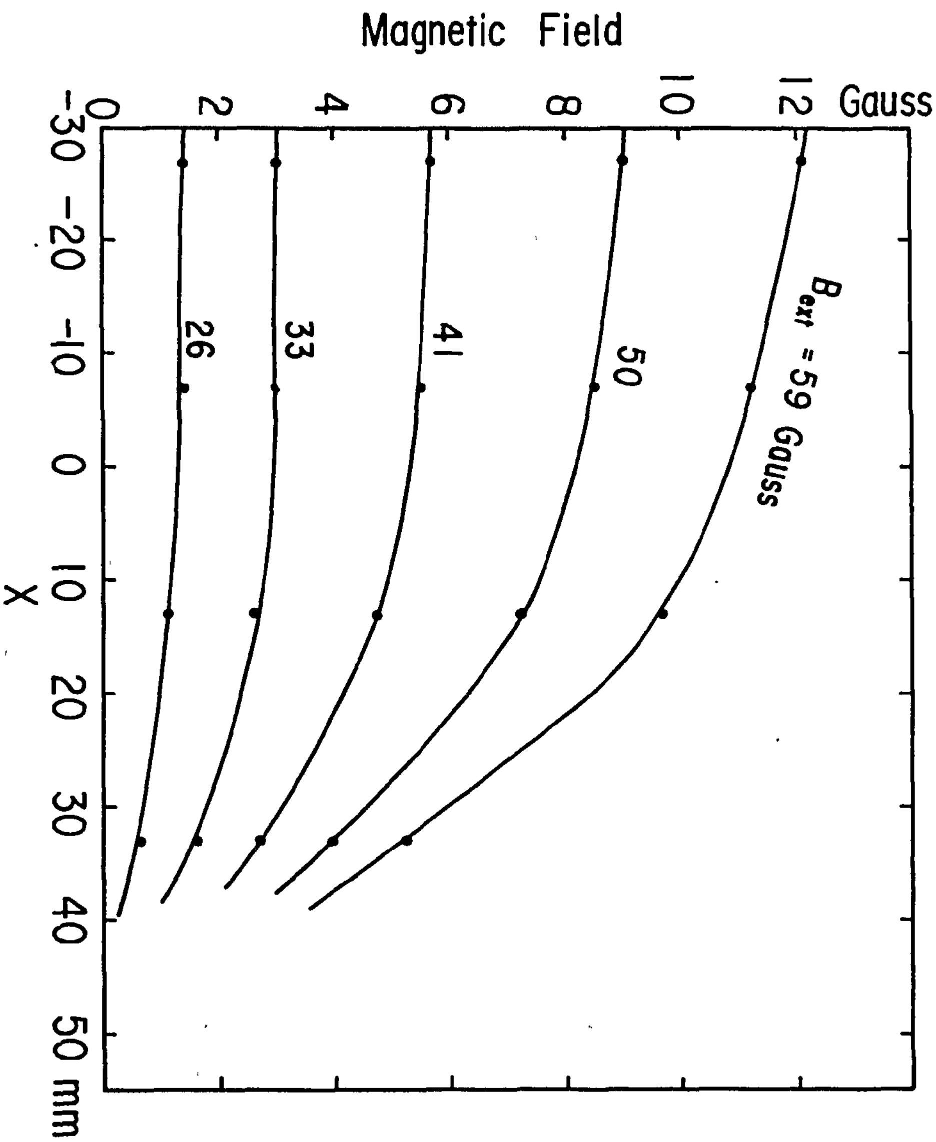

Magnetic Field
Gauss
0
2
4
6
8
10
12
-30
-20
-10
0
10
20
30
40
50 mm
X
B ext = 59 Gauss
50
41
33
26

Fig. 4

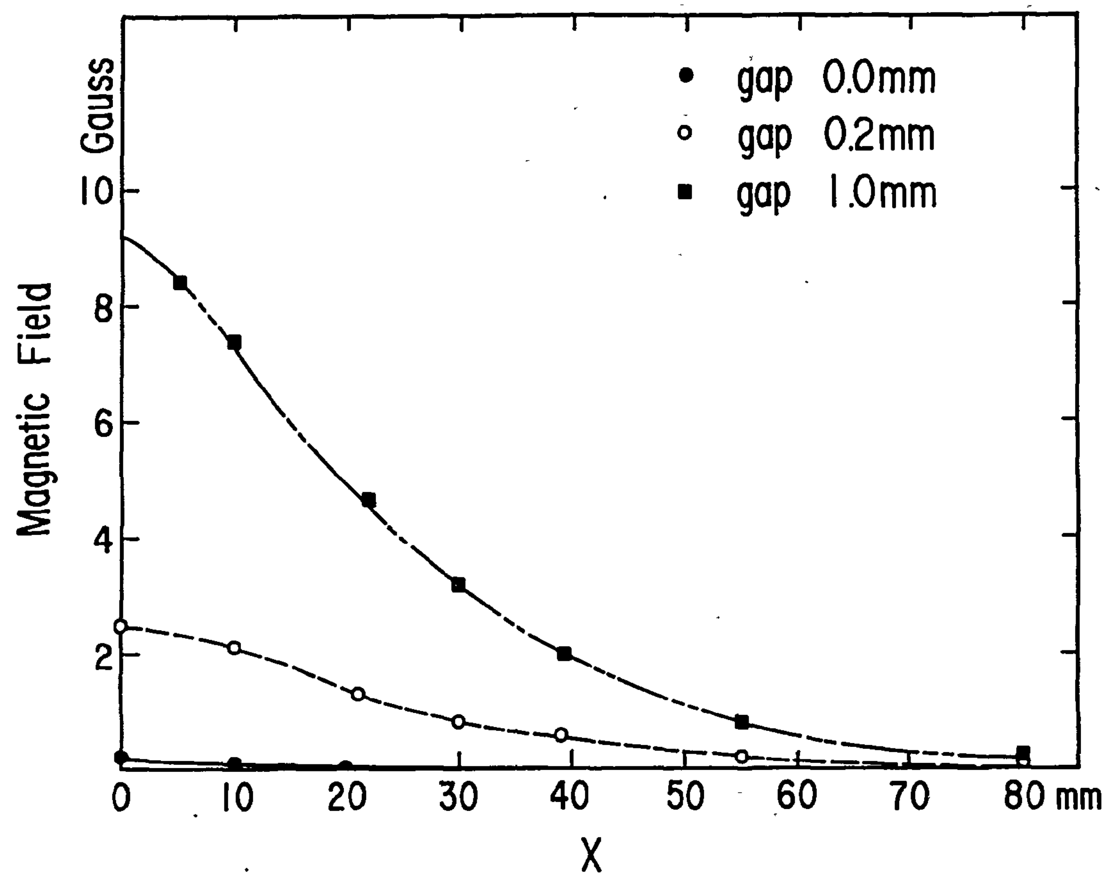

Magnetic Field
Gauss
10
8
6
4
2
0
10
20
30
40
50
60
70
80 mm
X
gap 0.0mm
gap 0.2mm
gap 1.0mm

Fig. 3

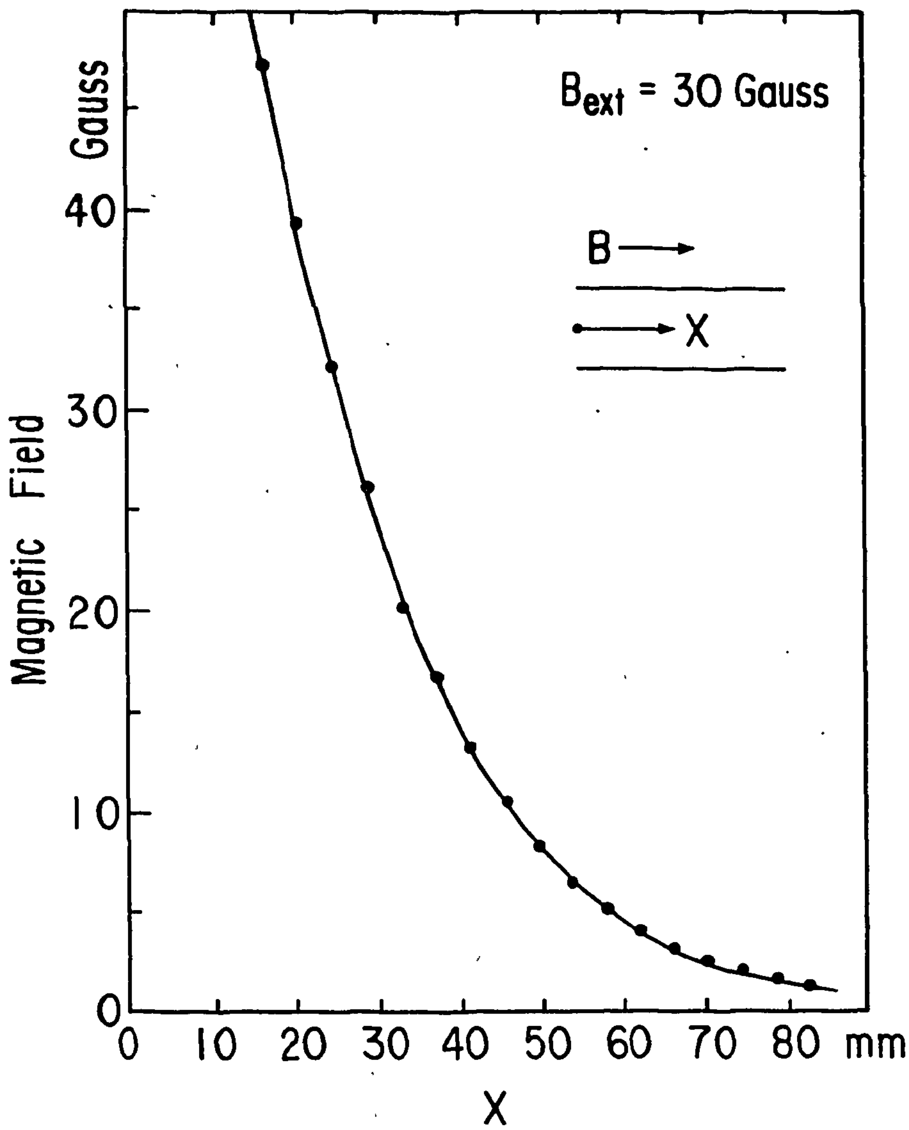
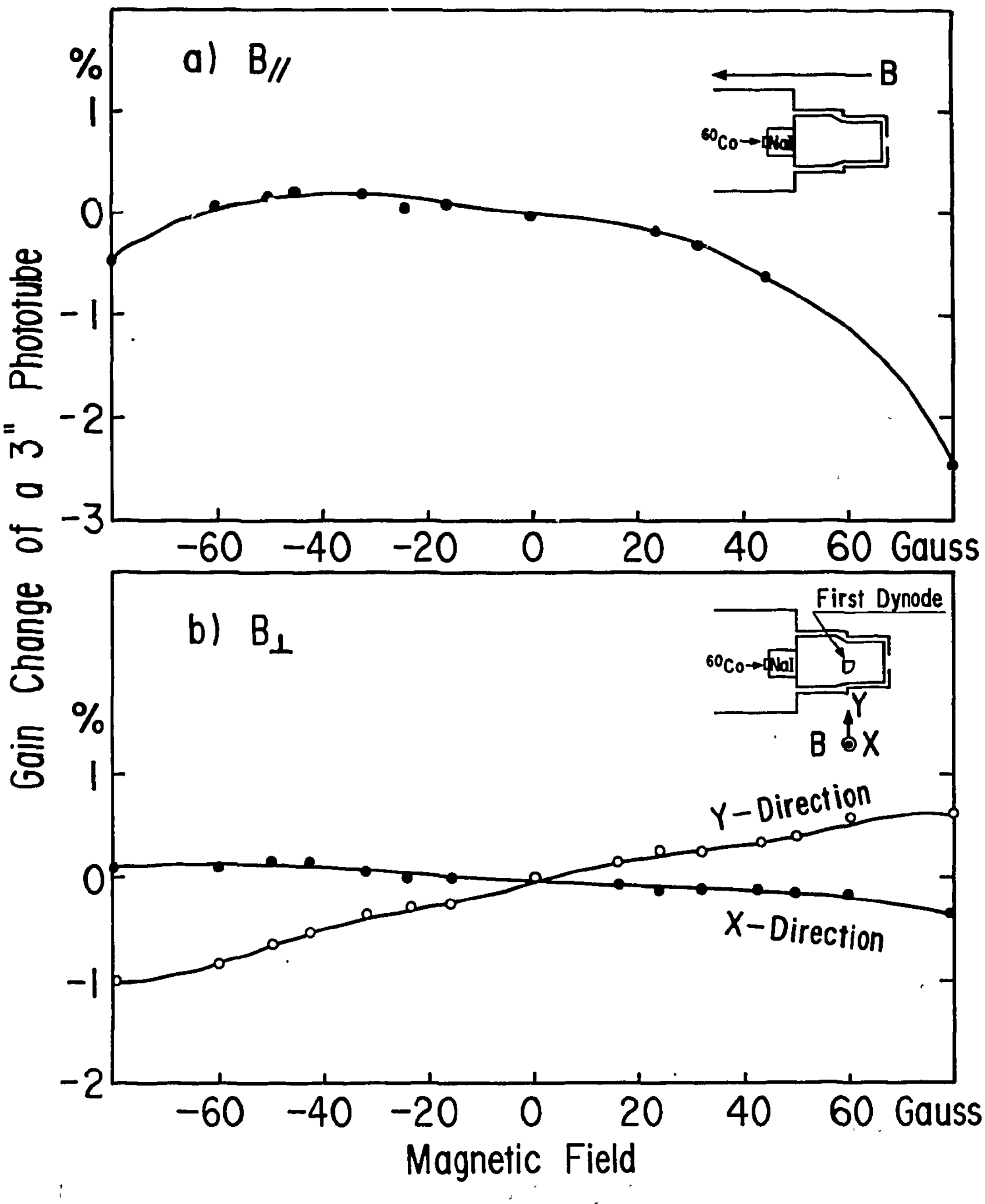

Bext = 30 Gauss
B
X
Magnetic Field Gauss
0
10
20
30
40
0 10 20 30 40 50 60 70 80 mm
X

Fig. 6



a) B//
B
60Co→NaI
b) B⊥
First Dynode
60Co→NaI
Y
B X
Y-Direction
X-Direction
%
Gain Change of a 3" Phototube
-60 -40 -20 0 20 40 60 Gauss
Magnetic Field

Fig. 5

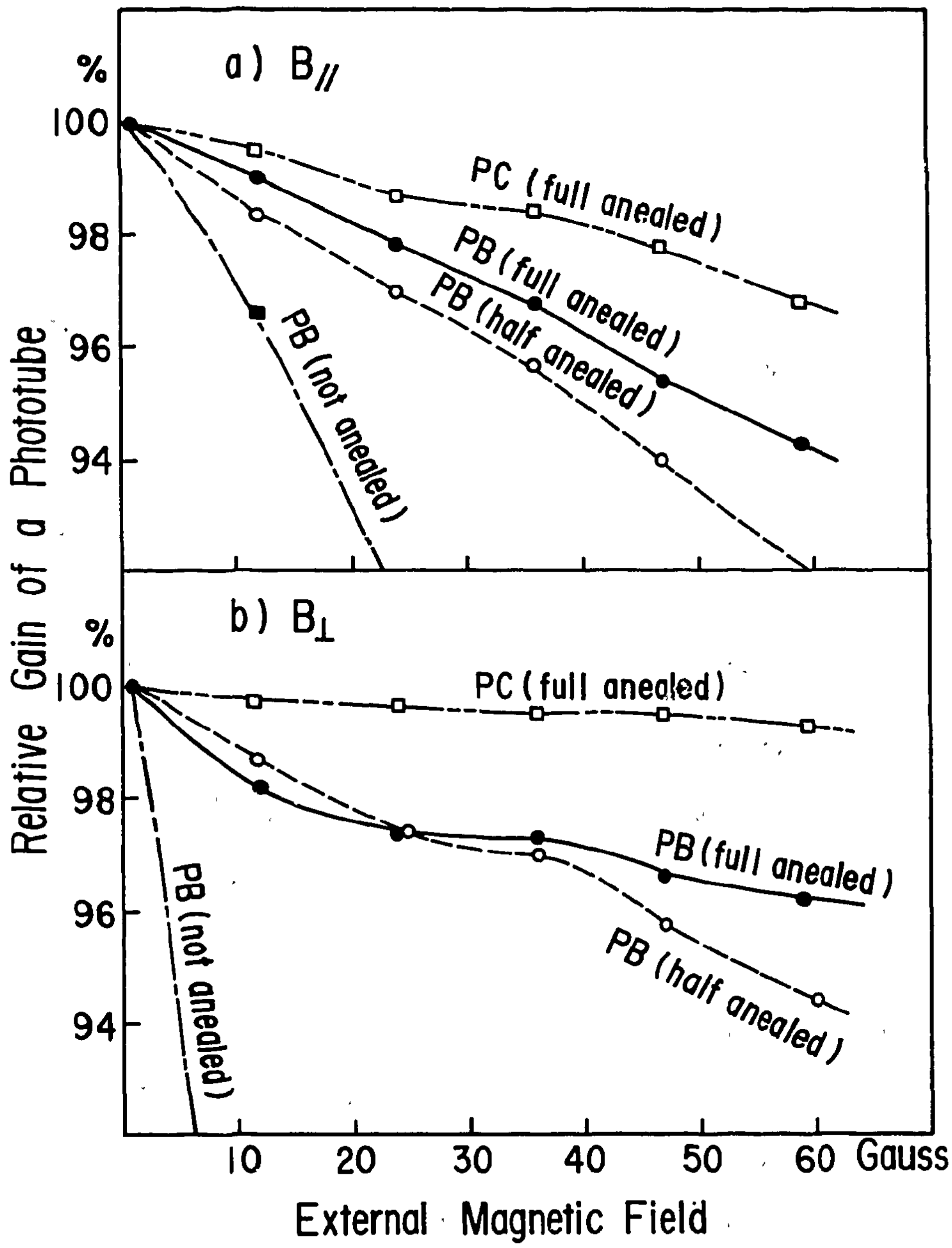

a) B//
%
100
98
96
94
PC (full anealed)
PB (full anealed)
PB (half anealed)
PB (not anealed)
b) B⊥
%
100
98
96
94
PC (full anealed)
PB (full anealed)
PB (half anealed)
PB (not anealed)
Relative Gain of a Phototube
10
20
30
40
50
60
Gauss
External Magnetic Field

Fig. 8

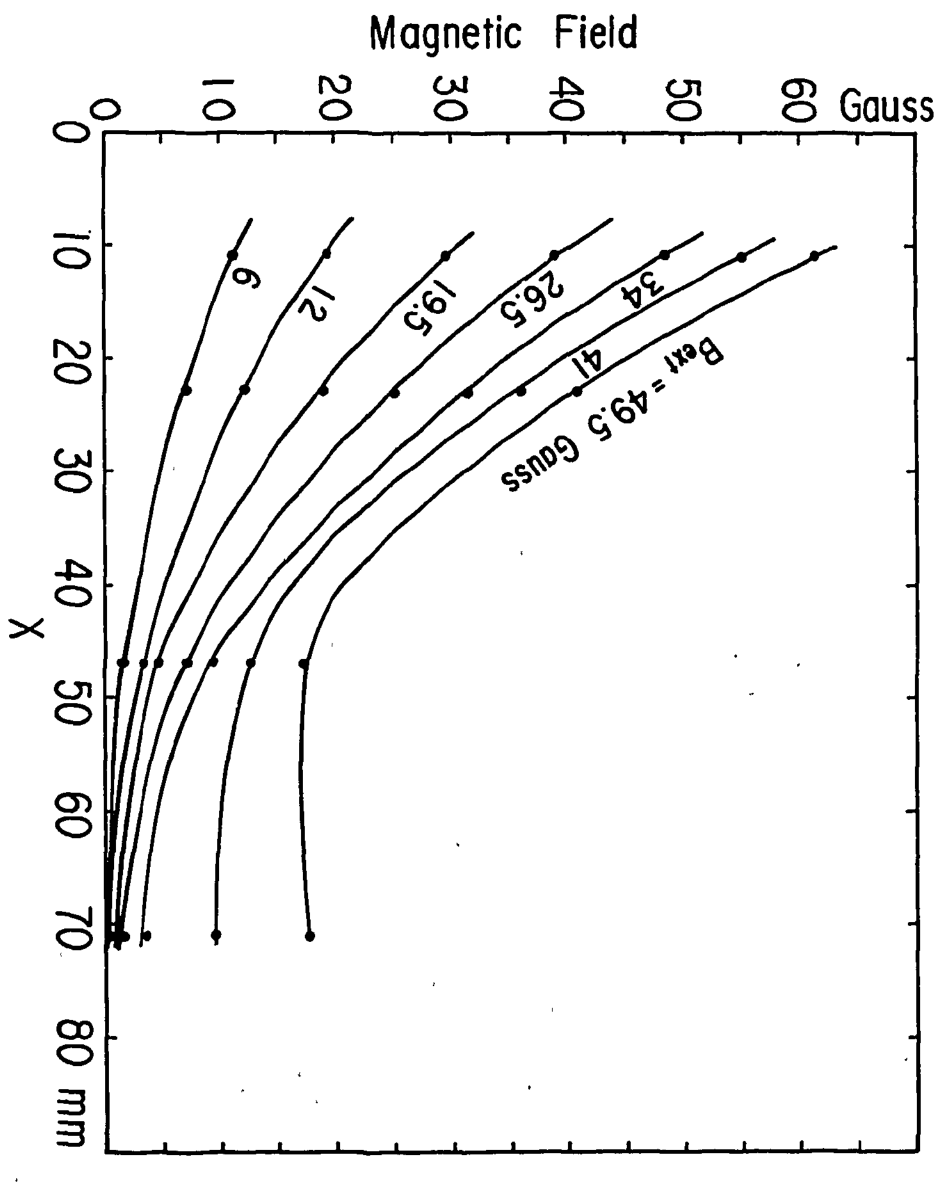

Magnetic Field
0
10
20
30
40
50
60 Gauss
0
10
20
30
40
50
60
70
80 mm
X
6
12
19.5
26.5
34
41
B_ext = 49.5 Gauss

Fig. 7

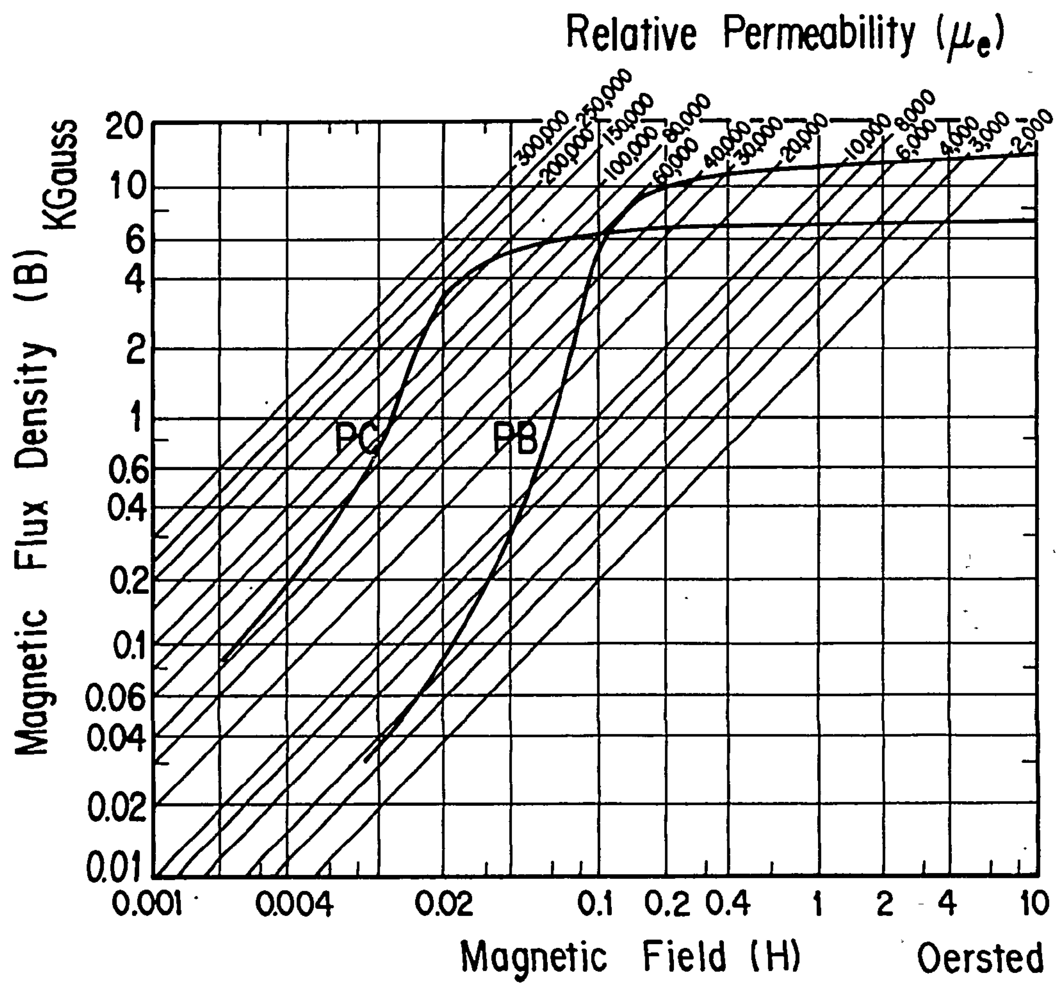

Relative Permeability (μ_e)
Magnetic Flux Density (B) KGauss
Magnetic Field (H) Oersted
PC
PB
300,000
250,000
200,000
150,000
100,000
80,000
60,000
40,000
30,000
20,000
10,000
8,000
6,000
4,000
3,000
2,000

Fig. 10

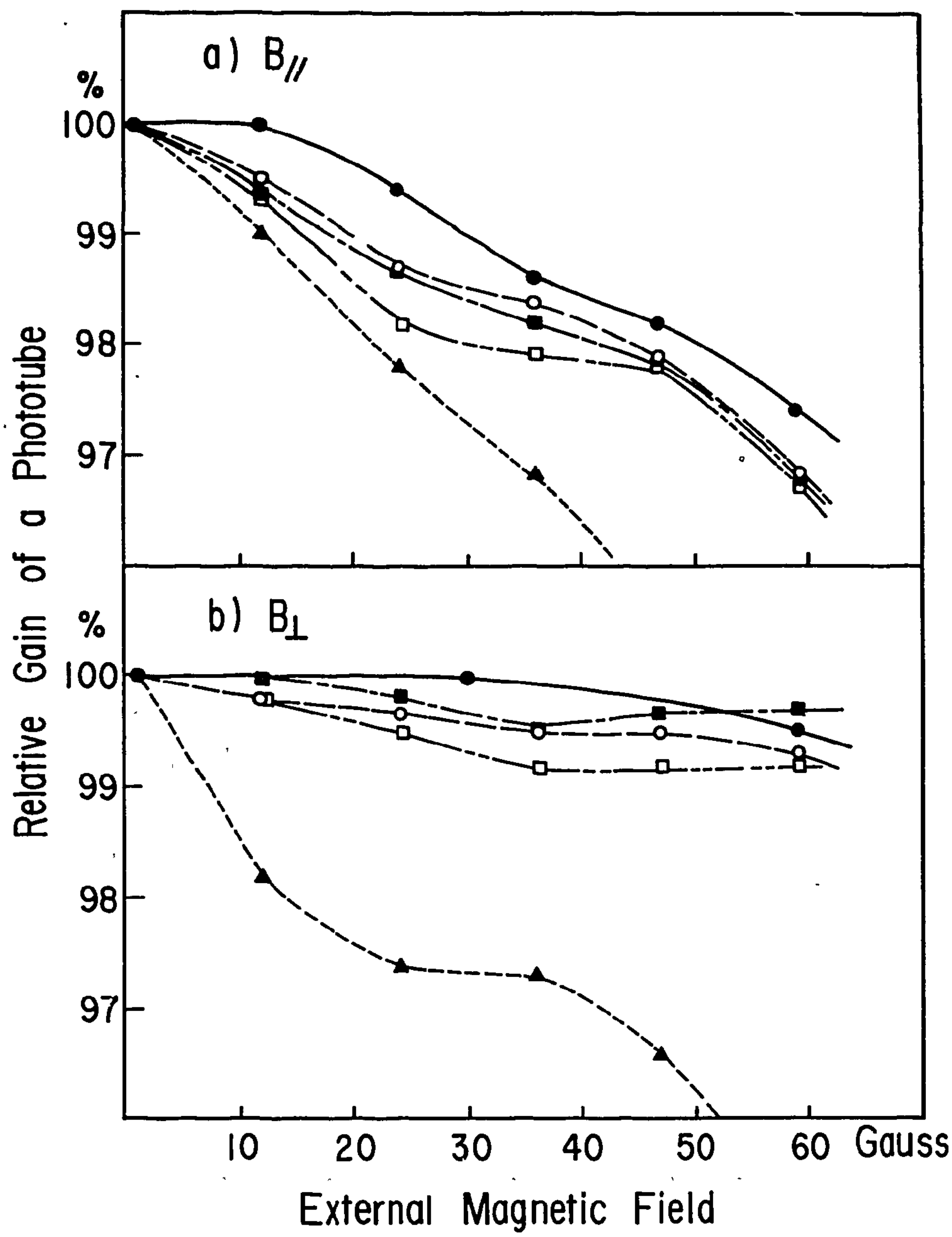

a) B//
%
100
99
98
97
b) B⊥
%
100
99
98
97
Relative Gain of a Phototube
10
20
30
40
50
60
Gauss
External Magnetic Field

Fig. 9

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