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Some Tests of Avalanche Photodiodes Produced by Advanced Photonix, Inc.

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FERMILAB TM-1943, July 1995

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PRODUCED BY ADVANCED PHOTONIX, INC.

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INTRODUCTION

The goal of the measurements presented here is to check some parameters of the high gain avalanche photodiodes (APD's) produced by Advanced Photonix, Inc. [1]. Samples with 16 mm and 5 mm diameter sensitive areas were tested.

SETUPS

The tests were performed at FNAL. The new photomultiplier testing facility were used for gain measurements, linearity, and nonuniformity studies. The setup consists of laser with shifted wavelength of 440 nm, 10 Hz repetition rate and a pulse duration of 15 nsec. The laser light was transported to the APD by 1 mm diameter clear fiber. An amount of laser light was adjusted by rotating wheels of fixed light attenuation. The dynamic range of the APD, an amplifier (AMP) and an ADC was about 1000. To get the nonuniformity data the APD was mounted on a movable stage under management and control of computer. The positioning of the fiber along sensitive surface of the APD was better than 100 microns. The setup is shown in fig.1.

A second setup was used to measure the APD signal for muons passing through the APD, and also for muons passing through a scintillator viewed by the APD. The scintillator size are 33x17x7 mm, and the side 7x17 mm was viewed by the APD (fig. 2). The APD (with and without scintillator) was triggered by 2 scintillator counters.

The FNAL proton pool area magnet facility (fig. 3) was used to check APD's properties in magnetic field. It was possible to get there the magnetic field up to 2.43 Tesla. The nonuniformity of magnetic field along the APD's sensitive area was less than 3%. A blue light pulse generator outside the magnetic field was used to illuminate the APD. The generator's blue light was transported to the APD by a clear optical fiber.

MEASUREMENTS

The supply voltage scheme for the APD recommended by producer was chosen (fig. 4). The gain of the of the APD as a function of bias voltage is shown in fig.5a. The uniformity of response is shown in fig.5b.

Fig. 6 presents the linearity. The APD was tested for dynamic range 1000. The noticed nonlinearity was less than + 0.35% and can be explained as an apparatus effect but not the APD itself. 90% of the charge is collected in 60 nsec.

Measurements of the APD output signal for muons passing through the APD as well as through the scintillator (through 7 mm of thickness) were performed for different gains (fig.7). The amount of photoelectrons produced by muons passing through the scintillator and the number of electrons produced by the muons ionization inside the APD also as their ratio in dependence on the gain are presented at the same picture. These values were estimated from knowledge of collected charge for all circuits used (APD gain, amplifier, ADC count etc.) in number of electrons. The signal produced by the scintillator, and also as by 30 layers of tile/fiber calorimeter (each layer giving 15 photoelectrons with the APD) is also shown in fig.8.

The data for the 5 mm diameter sensitive area APD are presented in fig.9, 10.

The APD were placed in magnetic field of 2.37 Tesla (fig.11). The gain of the APD's with and without magnetic field was tested first. No changes in the dependencies gain versus the bias was

observed with better than 1% of accuracy (fig.12). The same was obtained for dependencies of the gain versus the magnitude of the magnetic field also as for the angle between the direction of the magnetic field and the electric field of the APD.

ACKNOWLEDGMENTS

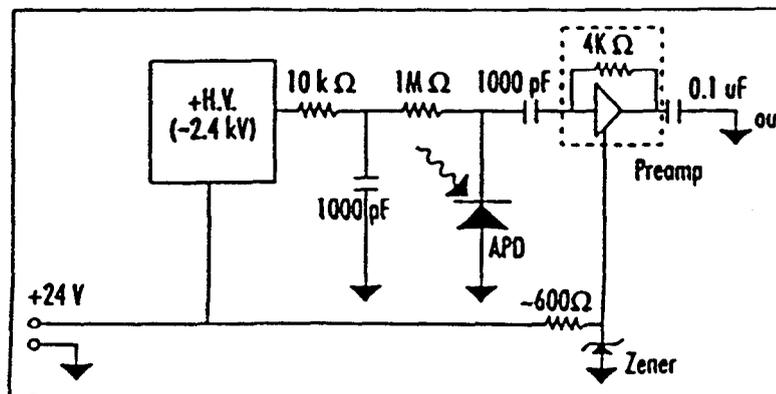
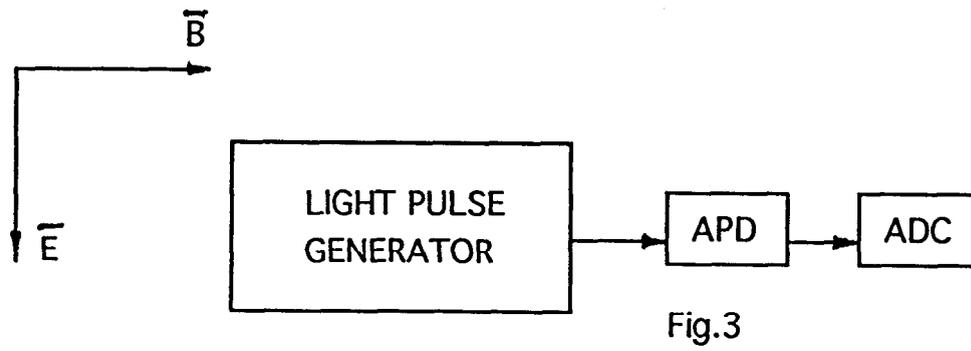
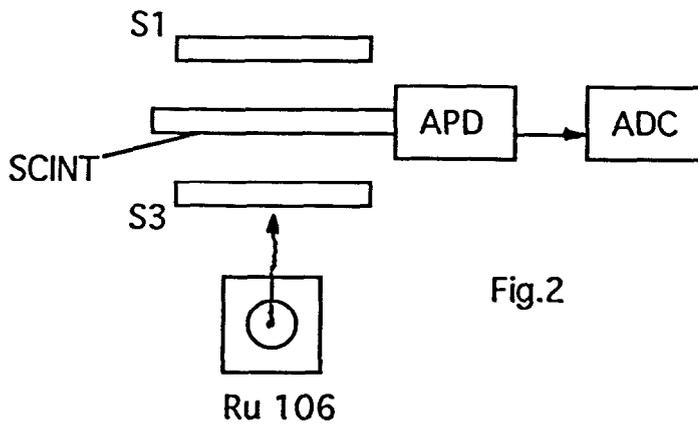
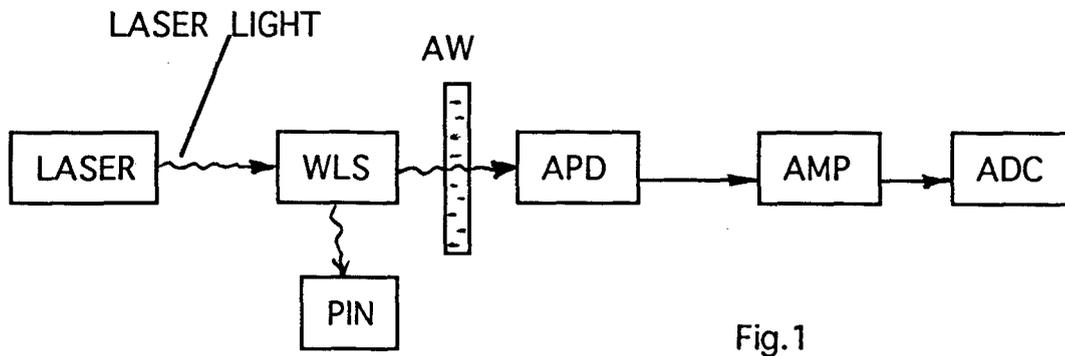
We would like to thank Aesook Byon-Wagner, Julius Lentz and Hogan Nguyen for technical support. We appreciate Dan Green, Jim Freeman and John Elias for useful discussions. Our thanks to Marek Szawlowsky for the APD,s.

BIBLIOGRAPHY

**1.The Avalanche Photodiode Catalog, Advanced Photonix, Inc.,
1240 Avenida Acaso, Camarillo, CA 93012**

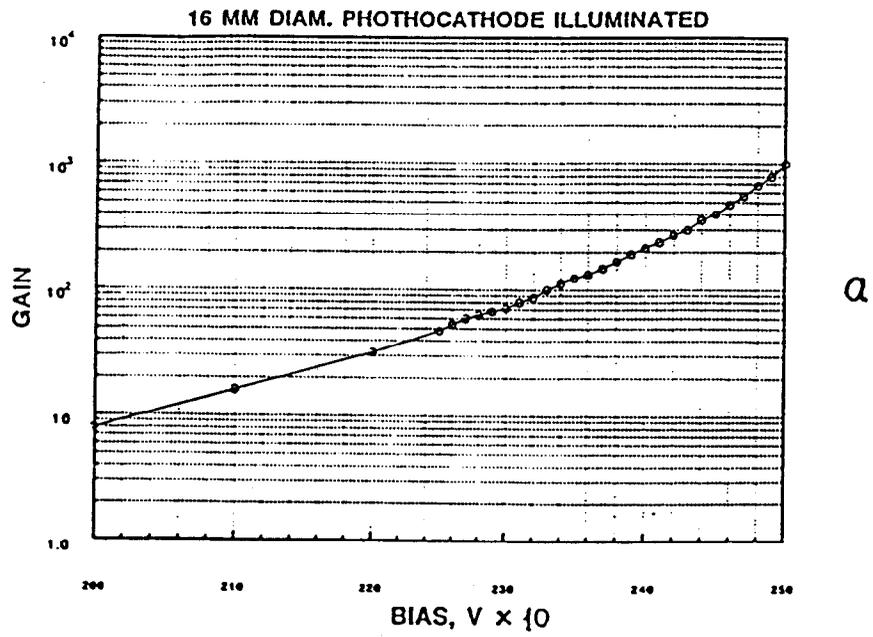
FIGURES.

1. Setup to measure gain, linearity and nonuniformity of the APD.
APD - avalanche photodiode, AMP - amplifier, PIN - photodiode,
WLS - wave length shifter, AW - attenuation wheel.
2. Setups to measure response of the APD to muons passing through the scintillator fastened to the APD as well as to muons passing through the APD. S1, S2 are triggering counters, Ru106 is a radioactive source.
3. Setup to study performance of the APD in the magnetic field.
4. APD's circuit diagram.
5. a) Dependence of the APD gain on bias voltage.
b) APD's nonuniformity (relative units) for two perpendicular directions.
- 6a. 1) APD linearity (APD signal versus PIN diode signal),
2) Deviation of APD signal from linear fit (ADC counts).
3) Deviation of APD signal from linear fit (percentage).
4) APD's resolution (sigma/mean for APD's signal's distribution) as a function of an illumination for different biases.
5,6) Oscilloscope traces of the APD signals.
- 6b. The same as fig. 6a for lower values of the APD's gain and by using an amplifier on the output of the APD.
7. Distribution of: 1) signals of muons passing through scintillator, and
2) signals of muons passing through the APD for different bias voltage.
Two pictures in the lower right corner present the number of electrons dependent on the APD's gain of muons passing through scintillator, through the APD, and the ratio of these two values as function of gain.
8. Distribution of signals of the APD: a) for muons passing through scintillator, b) of muons passing through 30 tile/fiber layers, c) for pedestals.
9. The same as fig. 5 for 5 mm diameter sensitive area APD.
- 10 a,b. The same as figs. 6a,b for 5 mm diameter sensitive area APD.
11. Schematic view of the magnet poles. The magnitude of the magnetic field as a function of coil current for different pole sizes.
12. The dependence of the APD (5 mm) gain: 1) on the bias with and without 2.37 Tesla magnetic field. Magnetic field is perpendicular to the APD's electric field. 2) on the angle between electric and 1 Tesla magnetic field. 3) on the magnitude of perpendicular magnetic field for different bias voltage. 4) The gain of the APD (16 mm) versus the magnitude of the magnetic field perpendicular to the electric field of the APD.



APD # 630-70-72-500

7 Feb. 1994



440 nm DYE

APD # 630-70-72-500

UNIFORM

STEP 1 MM

BIAS 2420, GAIN 300

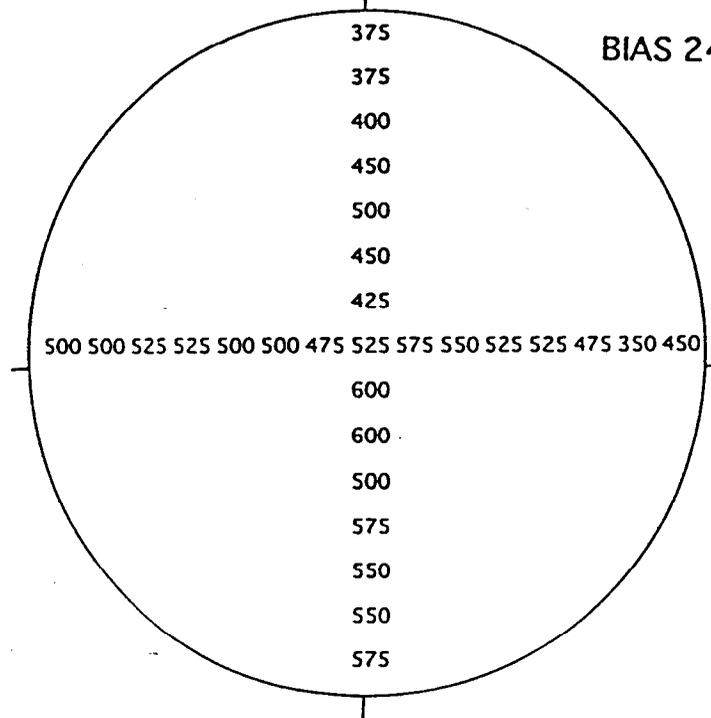
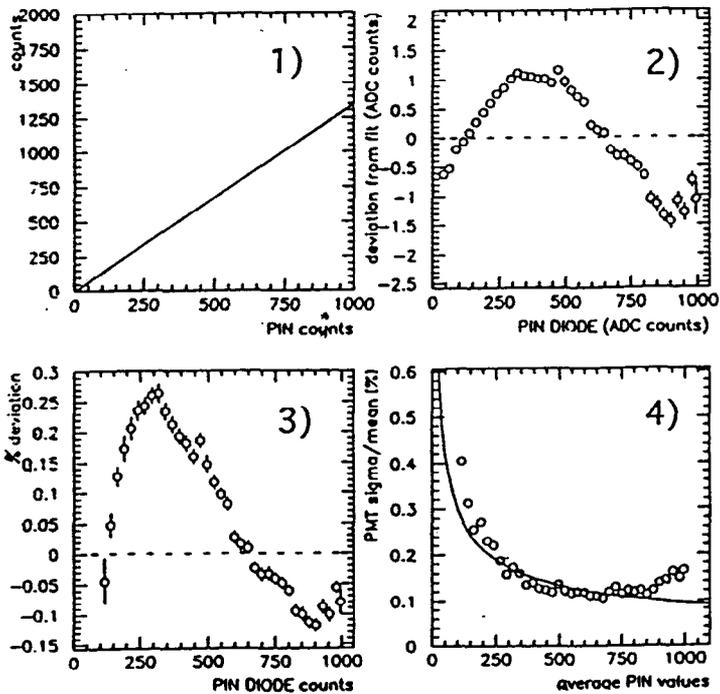
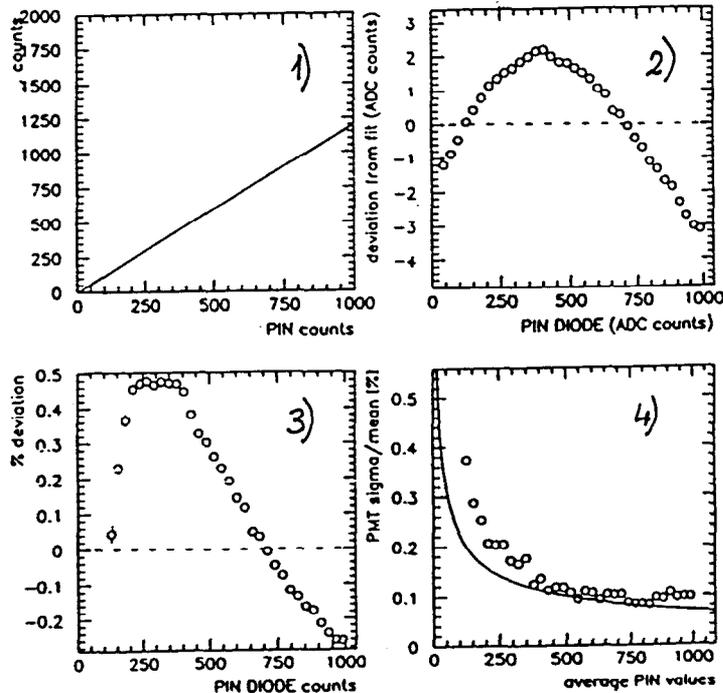


Fig. 5

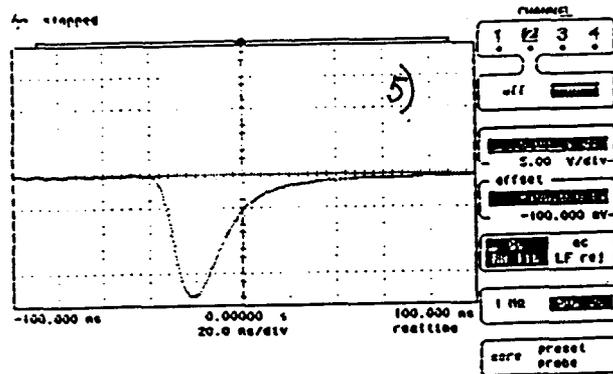
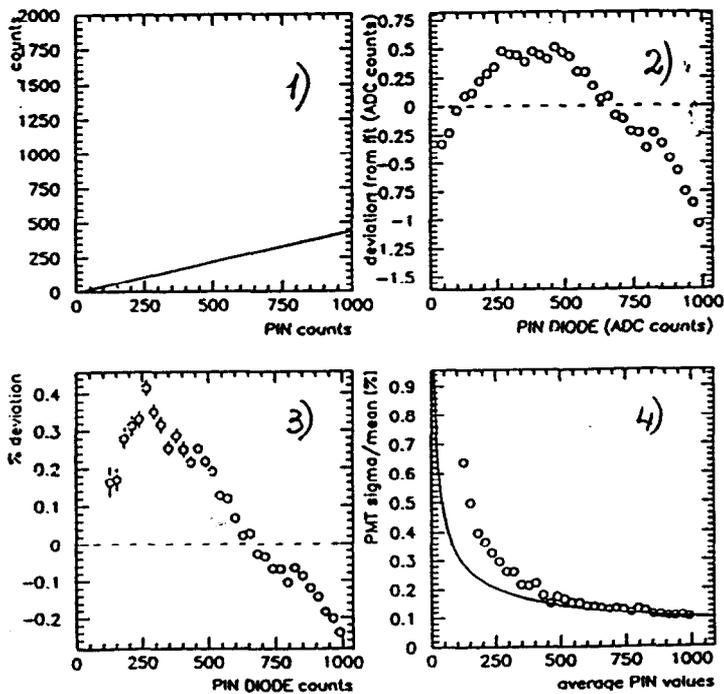
BIAS 2454, GAIN 450



BIAS 2415, GAIN 250

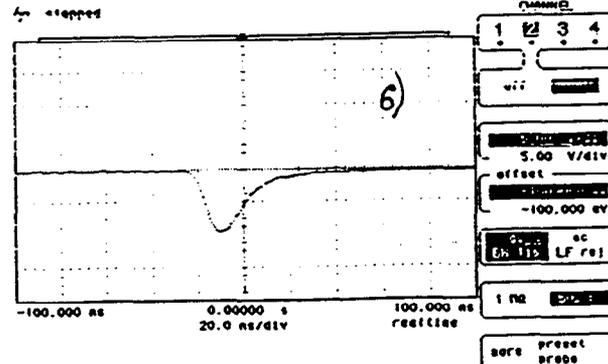


BIAS 2380, GAIN 170



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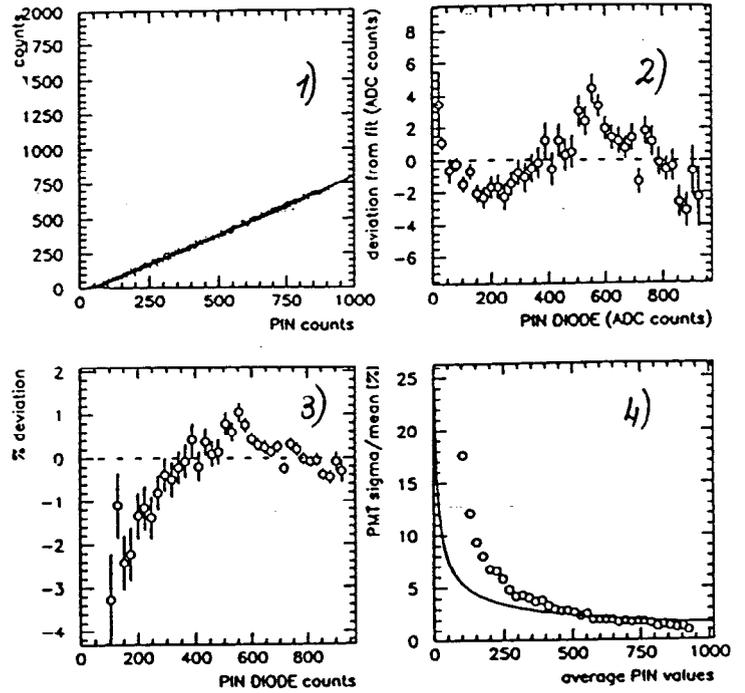
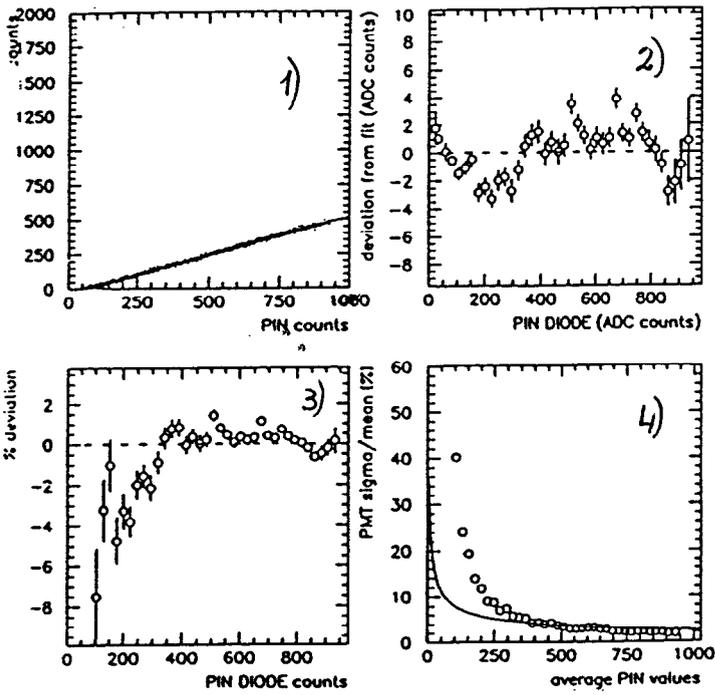
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Trigger Level(s)
Channel 2 = -5.37500 V (noise reject OFF)
HoldOff = 40.000 ns



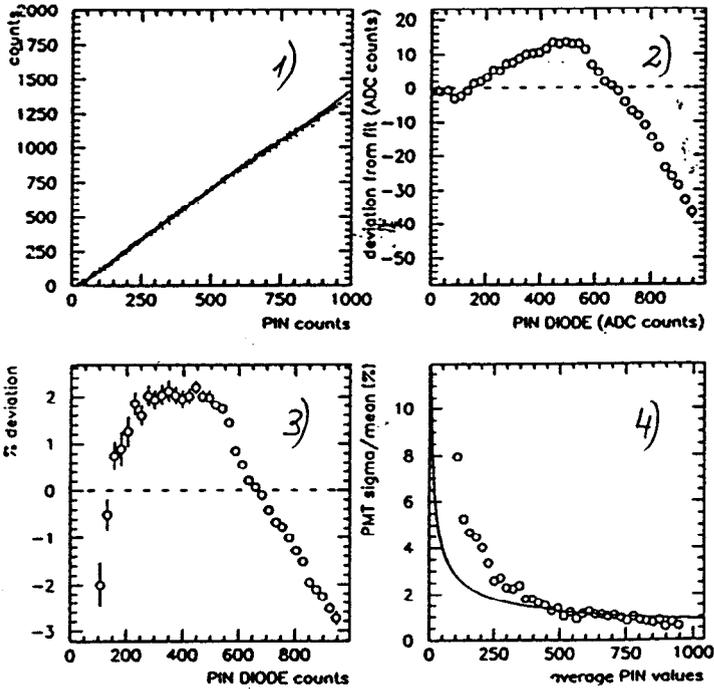
Channel 2 Sensitivity 5.00 V/div Offset -100.000 mV Probe 10:1 Coupling dc BU lin Impedance 50 ohm

Trigger Mode: Edge
On the Positive Edge of Channel 2
Trigger Level(s)
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HoldOff = 40.000 ns

Fig.6a

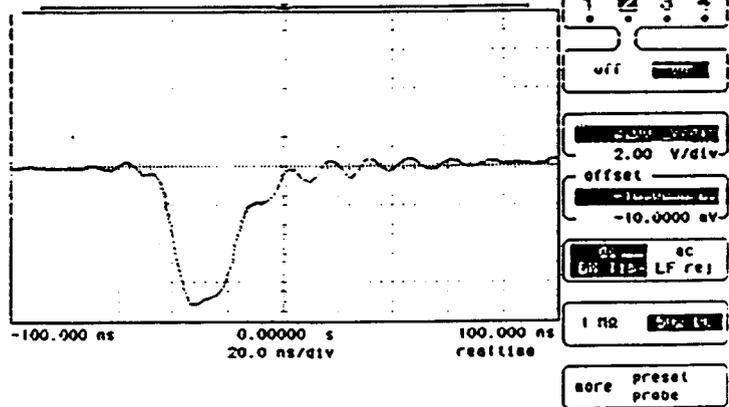


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Channel 2	Sensitivity	Offset	Probe	Coupling	Impedance
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Trigger Mode: Edge
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 Trigger Level(s)
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 HoldOff = 40.000 ns

Fig.6b

APD # 630-70-72-500

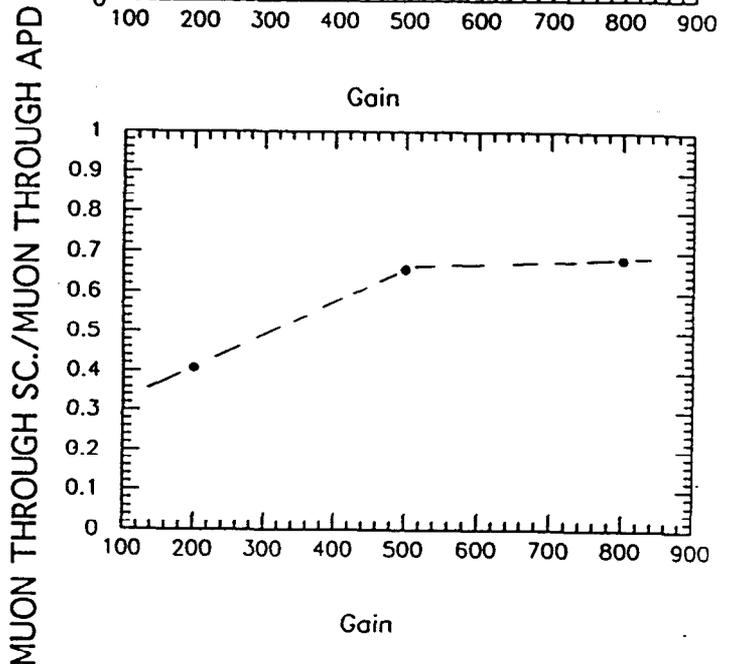
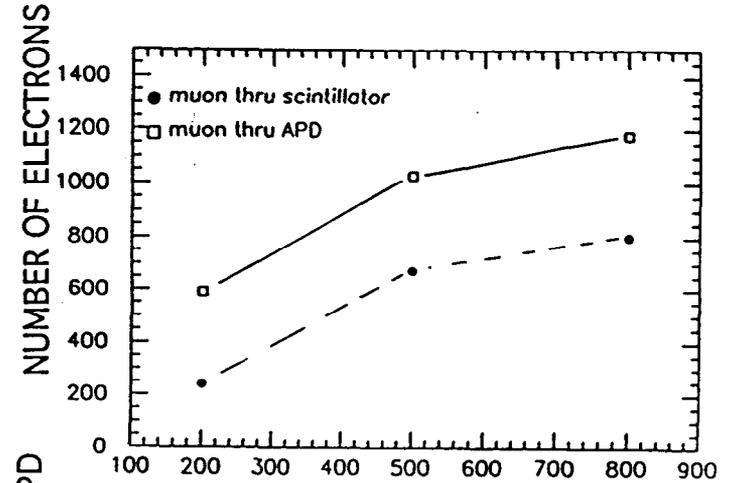
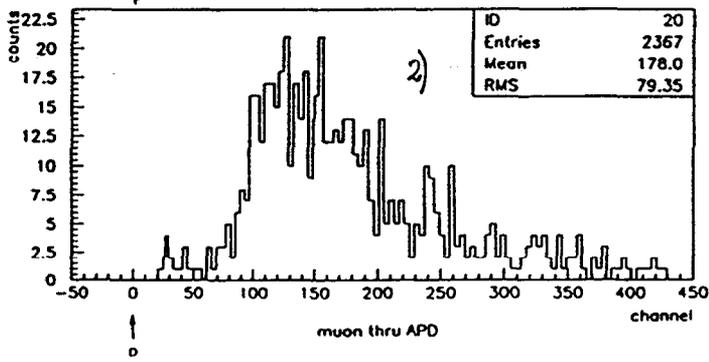
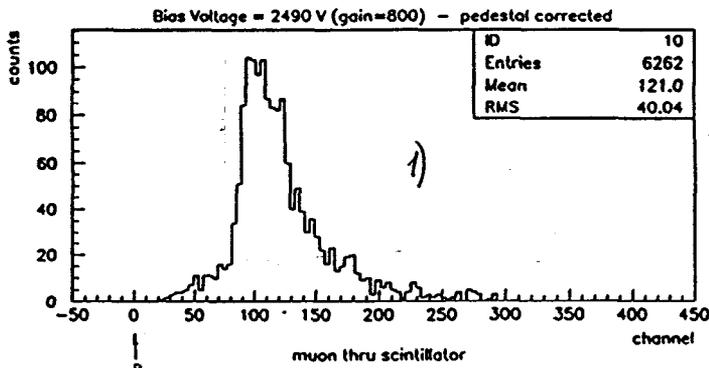
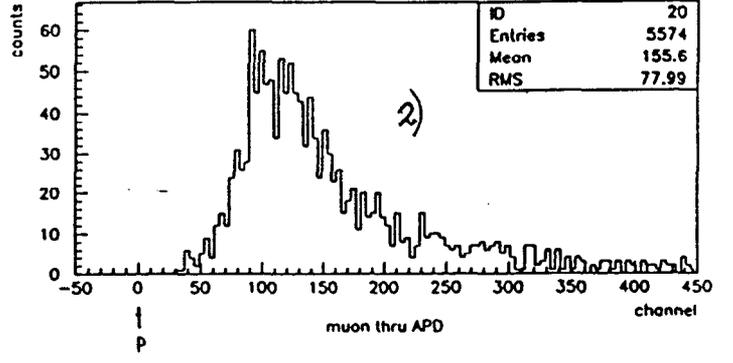
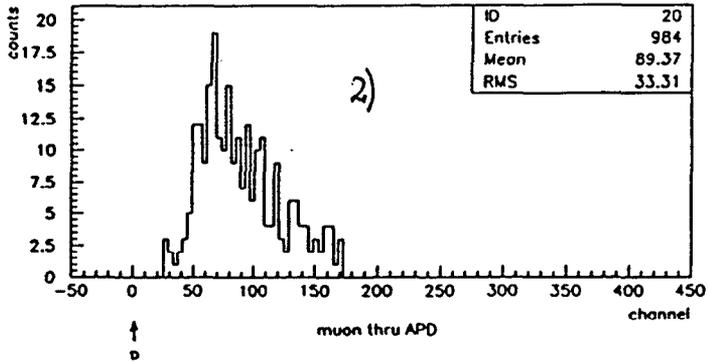
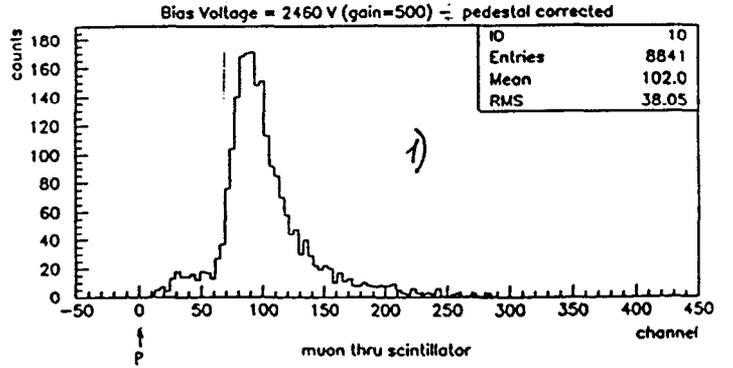
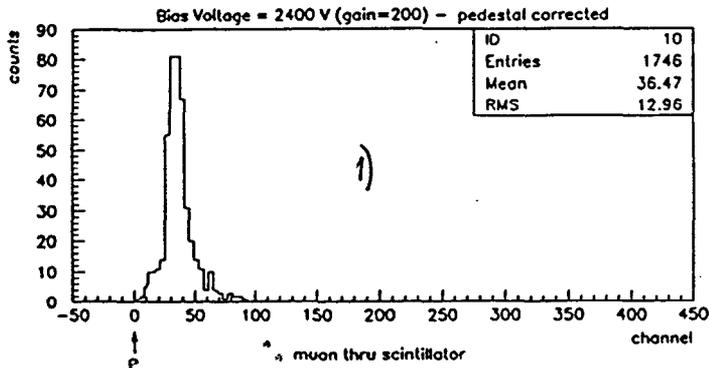
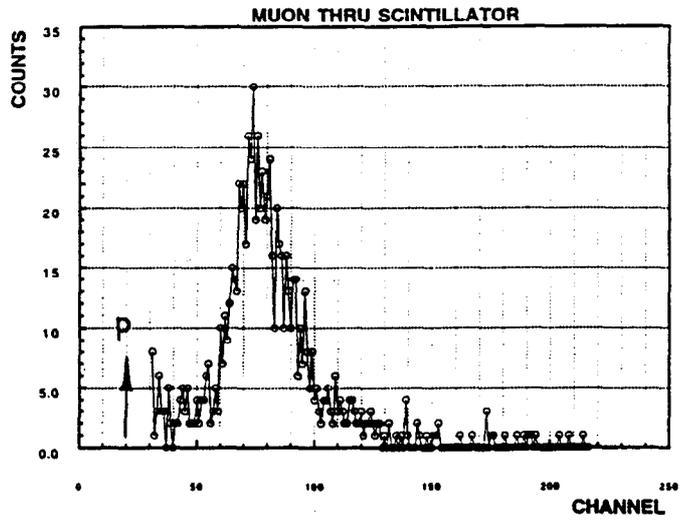


Fig.7

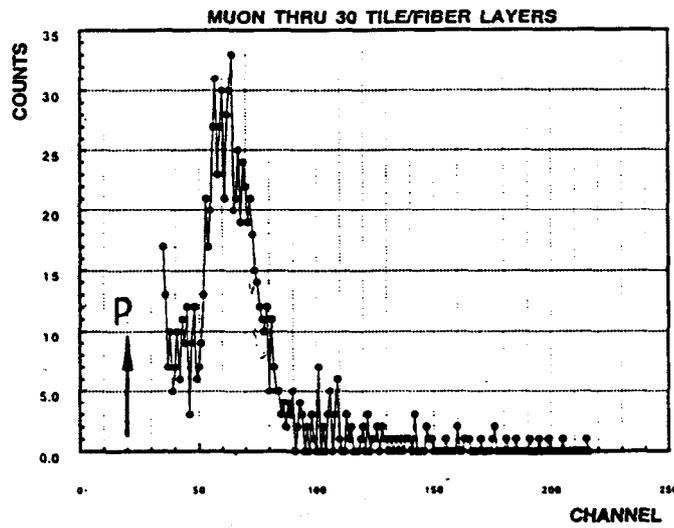
—○— C

APD #630-70-72-500



—●— D

APD #630-70-72-500



—●— B

APD #630-70-72-500

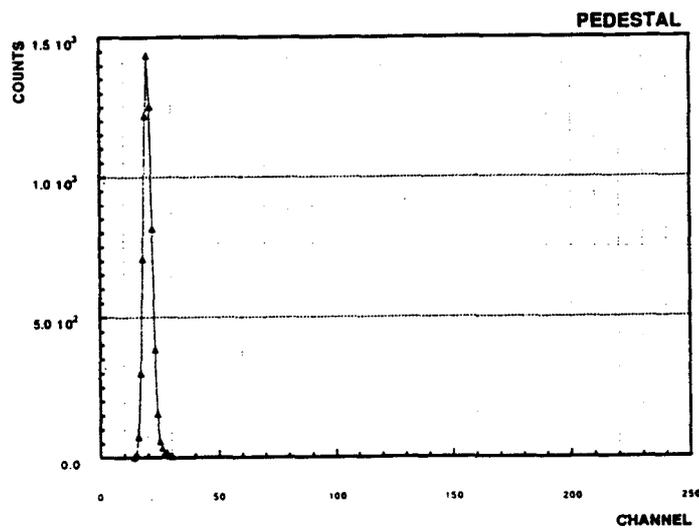
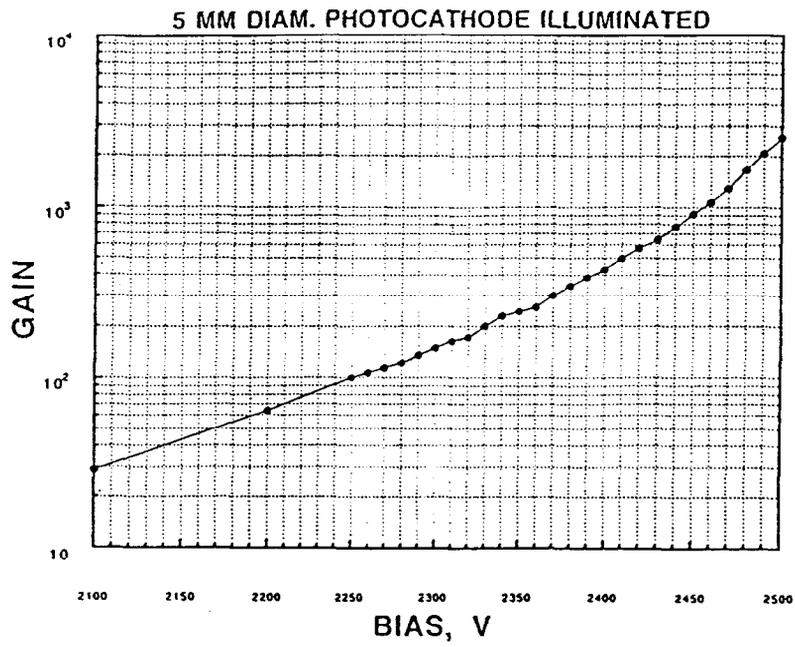


Fig.8



440 nm DYE

APD # 197-70-72-520

UNIFORM. STEP 1 MM

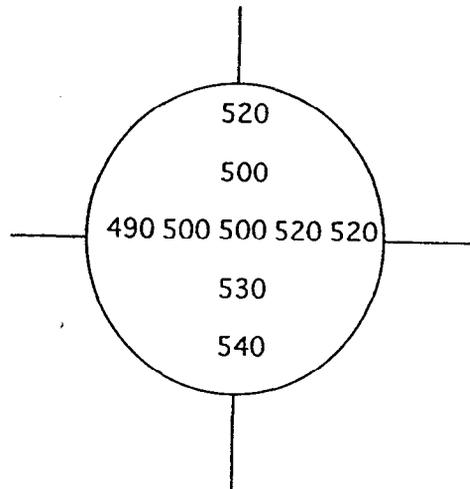
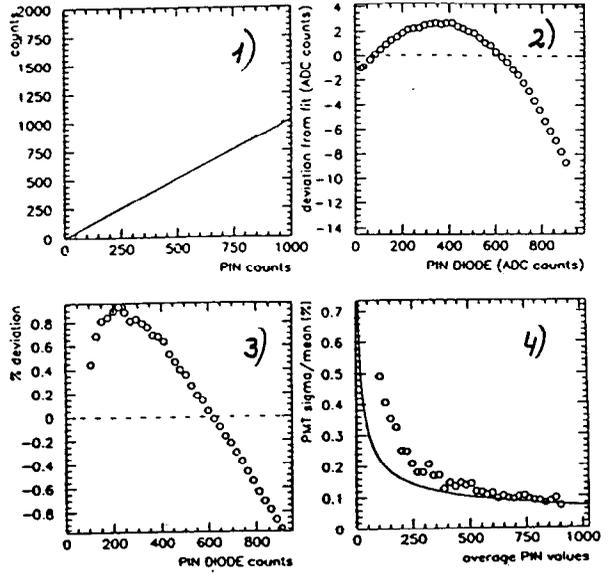
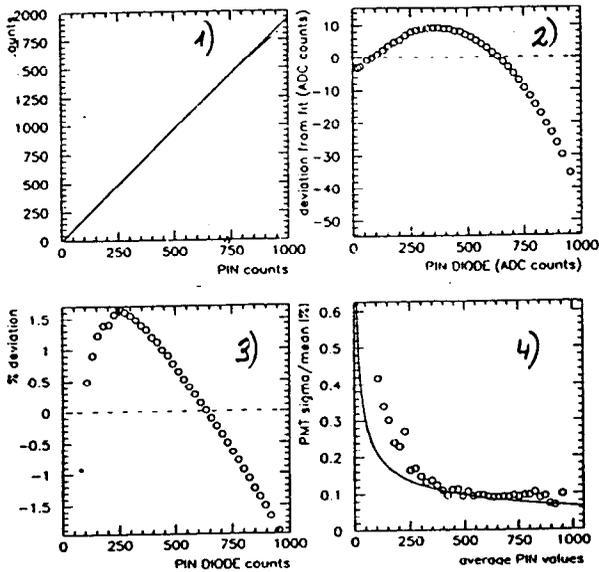


Fig.9

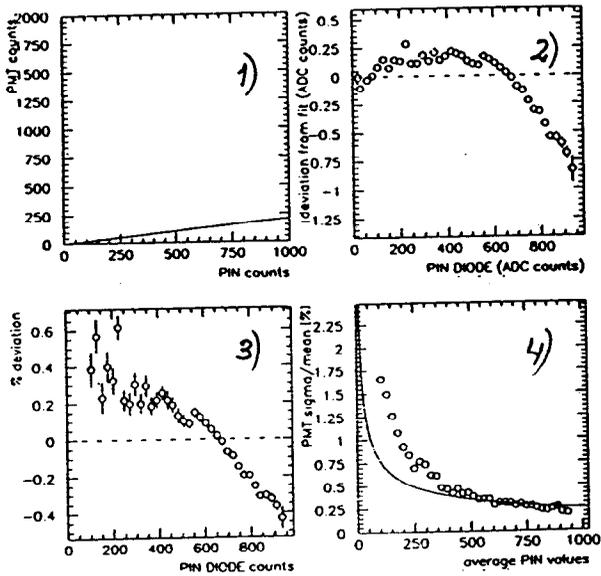
BIAS 2430, GAIN 630

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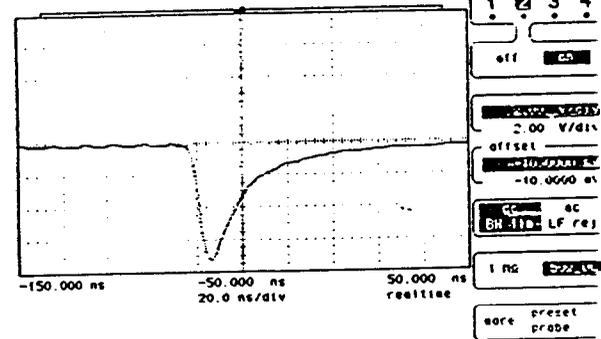


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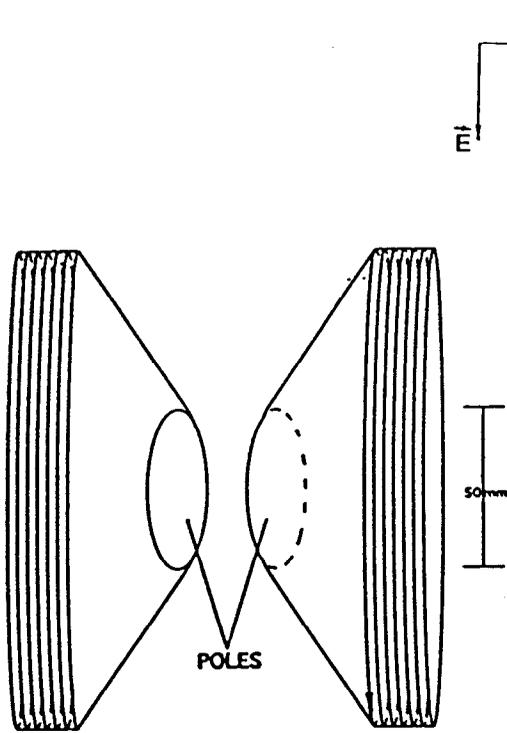
Ap stopped



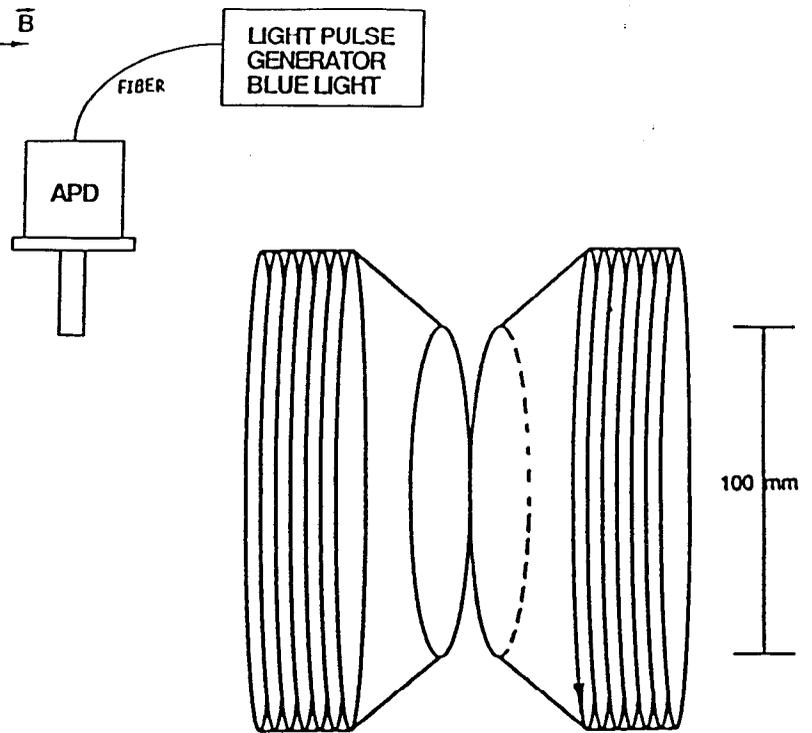
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Trigger Mode: Edge
On the Positive Edge of Channel 2
Trigger Level(s)
Channel 2 = -783.000 mV (noise reject OFF)
HoldOff = 40.000 ns

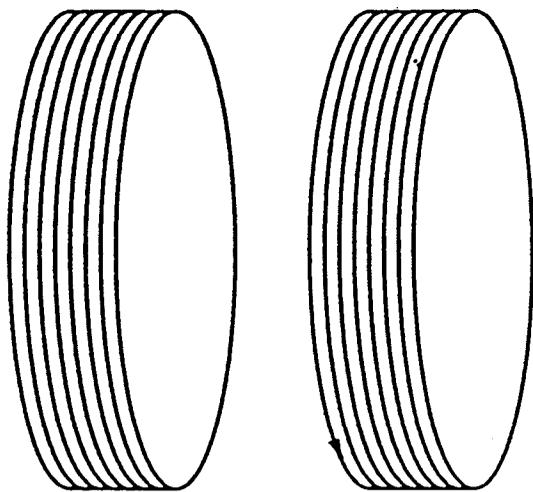
Fig.10a



WHEN DISTANCE BETWEEN POLES IS 15 MM MAGNETIC FIELD IS 2.5 TESLA (CURRENT 50 A)



WHEN DISTANCE BETWEEN POLES IS 15 MM MAGNETIC FIELD IS 22 TESLA (CURRENT 50 A)



MAGNETIC FIELD IS 17 TESLA 15 MM DISTANCE BETWEEN POLES

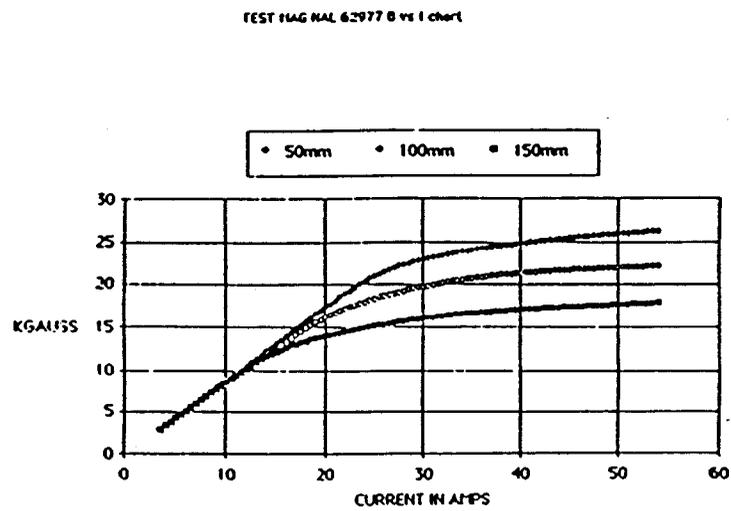
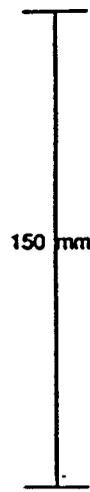


Fig.11

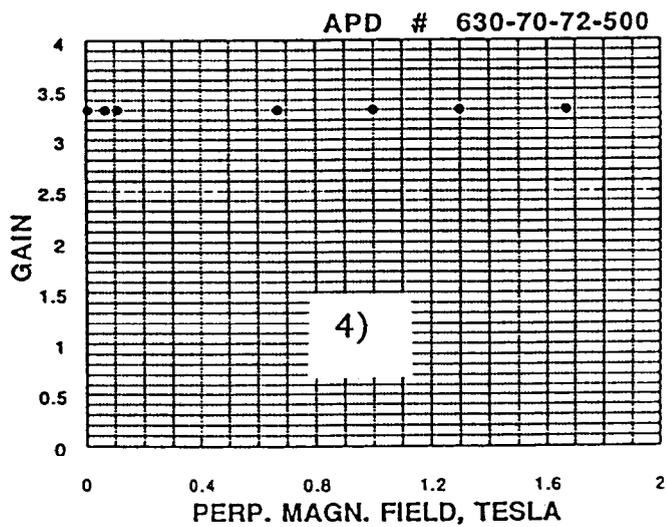
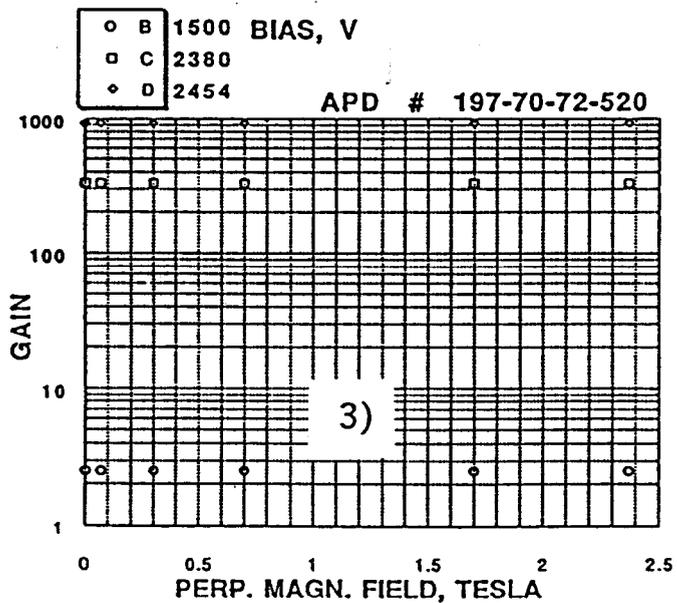
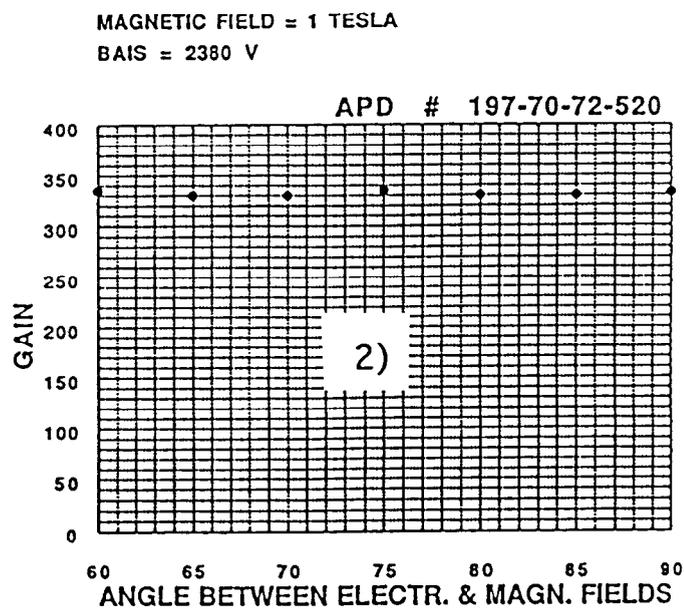
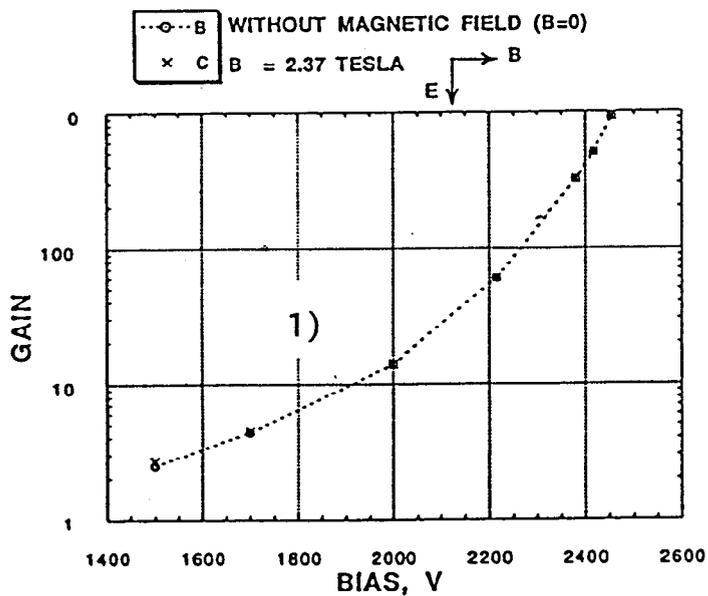


Fig.12