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THE EFFECTS OF MAGNETIC FIELD ON 20cm HAMAMATSU R1408 PMT

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The electric fields in a photomultiplier is normally designed for optimum transmission of electrons from the photocathode to the first dynode and from one dynode to the next. Earth's magnetic field changes the electron optics and may deflect these electrons away from the acceptance aperture of the dynodes, resulting in lower electron collection efficiency. This is normally not a serious problem for a scintillator detector which uses small PMT and produces hundred to thousands of photoelectrons per pulse. However, the effects can be drastic in large PMTs, particularly for PMTs to be used in single photon counting experiments.

External magnetic field can affect the photon detection efficiency, gain, single photoelectron (spe) charge resolution, photoelectron transit time and spe timing resolution. Because of the long flight paths from the photocathode to the first dynode, it is expected that photon detection efficiency, photoelectron and spe timing resolution to be more sensitive to magnetic field than the other two quantities. In the R1408 PMT, Hamamatsu Photonics decided to use large dynode area to increase the photoelectron collection efficiency and make the photon detection efficiency less sensitive to external magnetic field. The first dynode acceptance aperture of this PMT is about 2.6cm by 2.6cm (the corners of the square are rounded off). Figure 1 shows the Monte Carlo simulation of the photoelectron landing pattern at the first dynode aperture. The results were provided by Hamamatsu Photonics. The photoelectrons are emitted randomly over the whole photocathode and the potential difference between the photocathode to dynode 1 is 570V. With no magnetic field, the photoelectron collection efficiency is about 96% (figure 1a) and magnetic field along the PMT axis does not affect this quantity much (figures 1d and 1e). In a direction perpendicular to the PMT axis, a 10μT field lowers the collection efficiency to 92% (figure 1b) and a 40μT field lowers the collection efficiency to 88% (figure 1c). Only 500 photoelectrons were generated in each of these simulations. Similar calculations were performed at Queen's University and the results are shown in table 1. The potential difference between the photocathode and the first dynode is 800V, close to the value expected to be used in the Heavy Water Cerenkov Detector. About 11000 photoelectron were generated in each simulation.

Table 1

B	Direction	pe col. eff.	pe flight time
0μT		91%	22ns
20μT	Along Axis	90%	22ns
20μT	Perp. Axis	89%	22ns

Results from calculations done at Queen's University and Hamamatsu Photonics shows that magnetic field along the PMT axis has almost no effect on the photoelectron collection efficiency, and a 20µT magnetic field perpendicular to the PMT axis reduces this quantity by approximately 2%.

The magnetic field sensitivity of four R1408 PMTs were measured at Queen's University. The serial numbers are ZW531 (Schott 8246 bulb), ZW535 (Schott 8246 bulb and has off axis dynode), ZW274 (Pyrex bulb) and ZW262 (Pyrex bulb). Magnetic field was generated by a set of square Helmholtz coils. The apparatus is shown in figure 2. ^{90}Sr inside a piece of acrylic was used to generate Cerenkov photons for these measurement. A 190mm diameter collimator was placed in front of the PMT to define photocathode area of the PMT as specified in the contract. By changing the current in the Helmholtz coil, the magnetic field in the direction perpendicular to the PMT axis can be varied from 45µT (Earth's field at test location) to -45µT. Only the effects of perpendicular magnetic field are measured as Monte carlo studies show that axial magnetic field has much weaker effects on the PMT.

The results are shown in figures 3, 4, 5 and 6
In each figure, (a) shows the changes in photon detection efficiency (the threshold is fixed at 0.25 pe level at zero magnetic field throughout measurement; that is, the threshold is not adjusted for each magnetic field to allow for the small changes in the PMT gain), (b) shows the change in gain and (c) shows the changes in electron transit time (cross, circle or triangles) and the spe timing resolutions (σ, typically 1.5ns)) are shown in (c) as the length of the error bar.

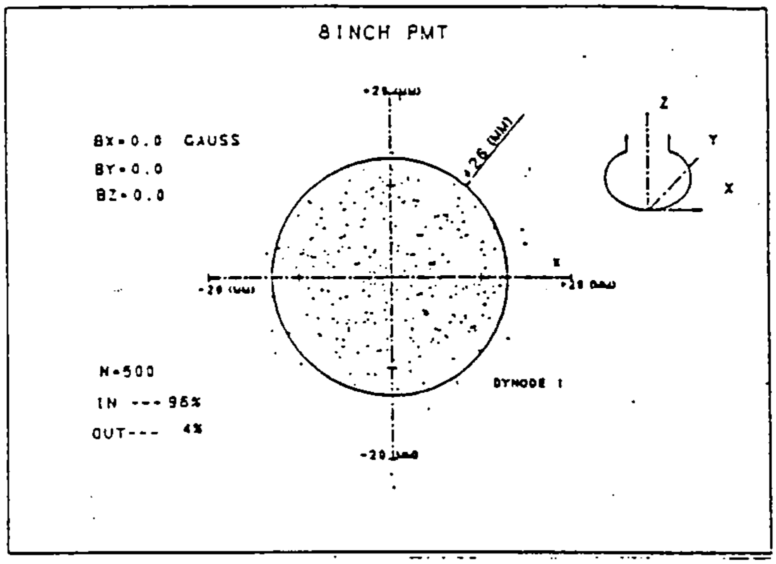
The magnetic has very little effect on the gain and timing properties of R1408 PMT. As indicated by Monte carlo simulations, the photon detection efficiency decreases as the strength of magnetic field increases. At 45µT, the detection efficiency decreases by approximately 10% which is in reasonable agreement with calculated results. At 20µT, the detection efficiency decrease by approximately 3%.

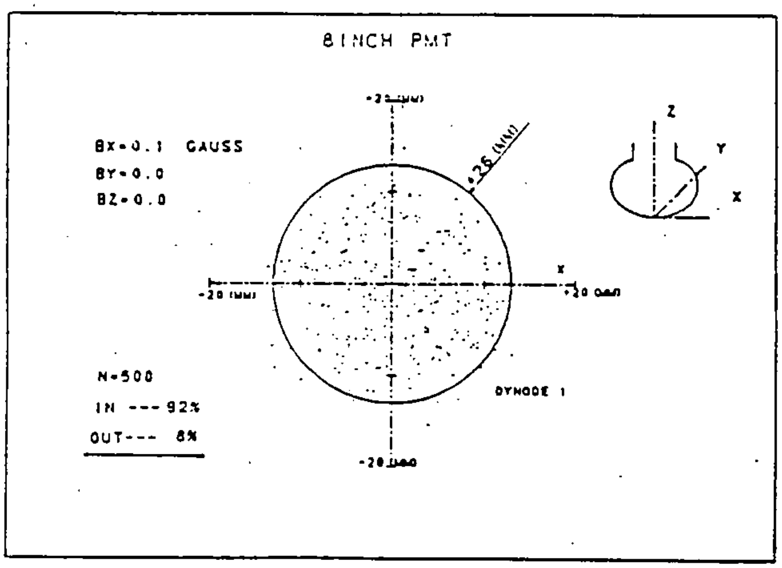
Conclusion.

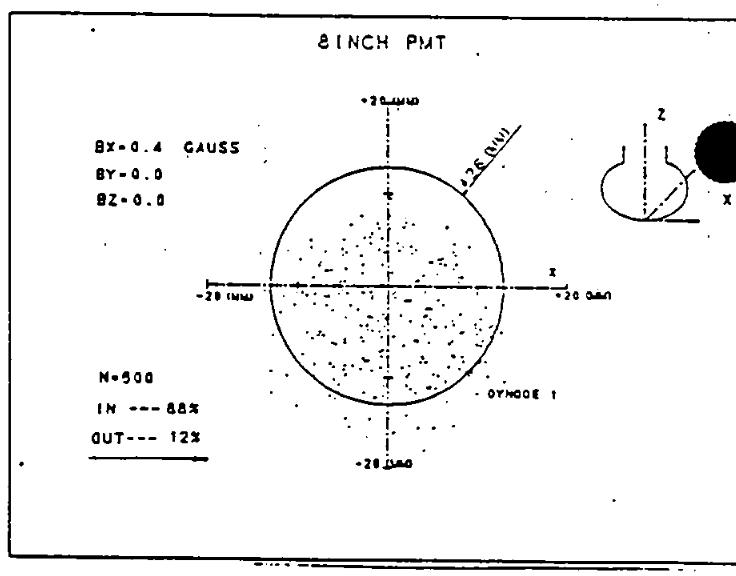
The single photoelectron response of the R1408 PMT is not strongly affected by external magnetic field. Up to an absolute strength of 20µT, the decrease in detection efficiency is about 3% for magnetic field perpendicular to PMT axis and less for filed along the PMT axis. Thus if the magnetic field in the SNO detector can be compensated to 20µT, the effect of this residual field on the detector performance is likely to be less than 2%.

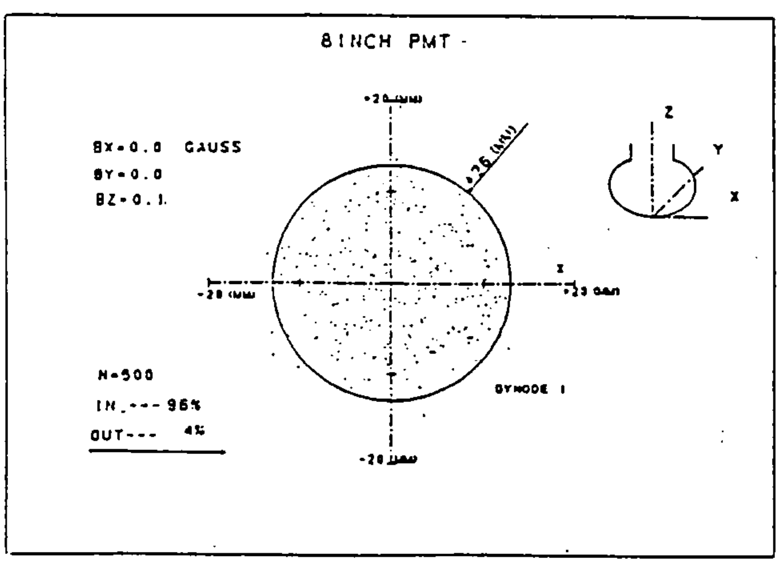
magnetic field sensitivity ①

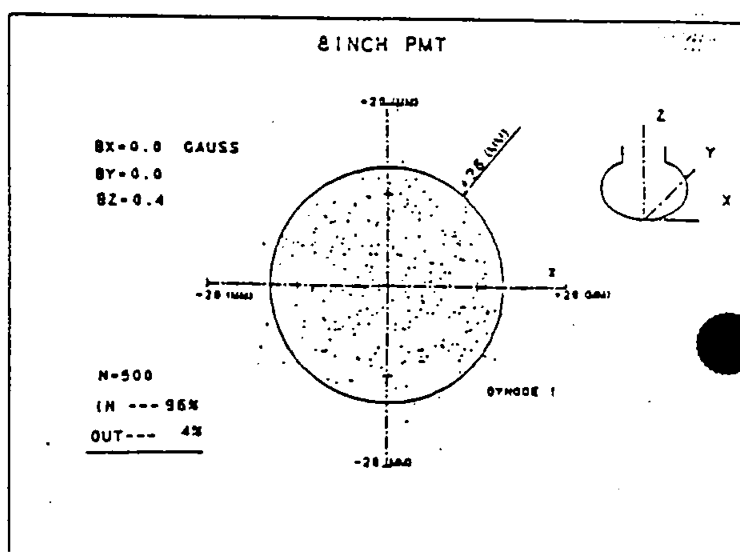
R1408 (K-DY1 = 570V)











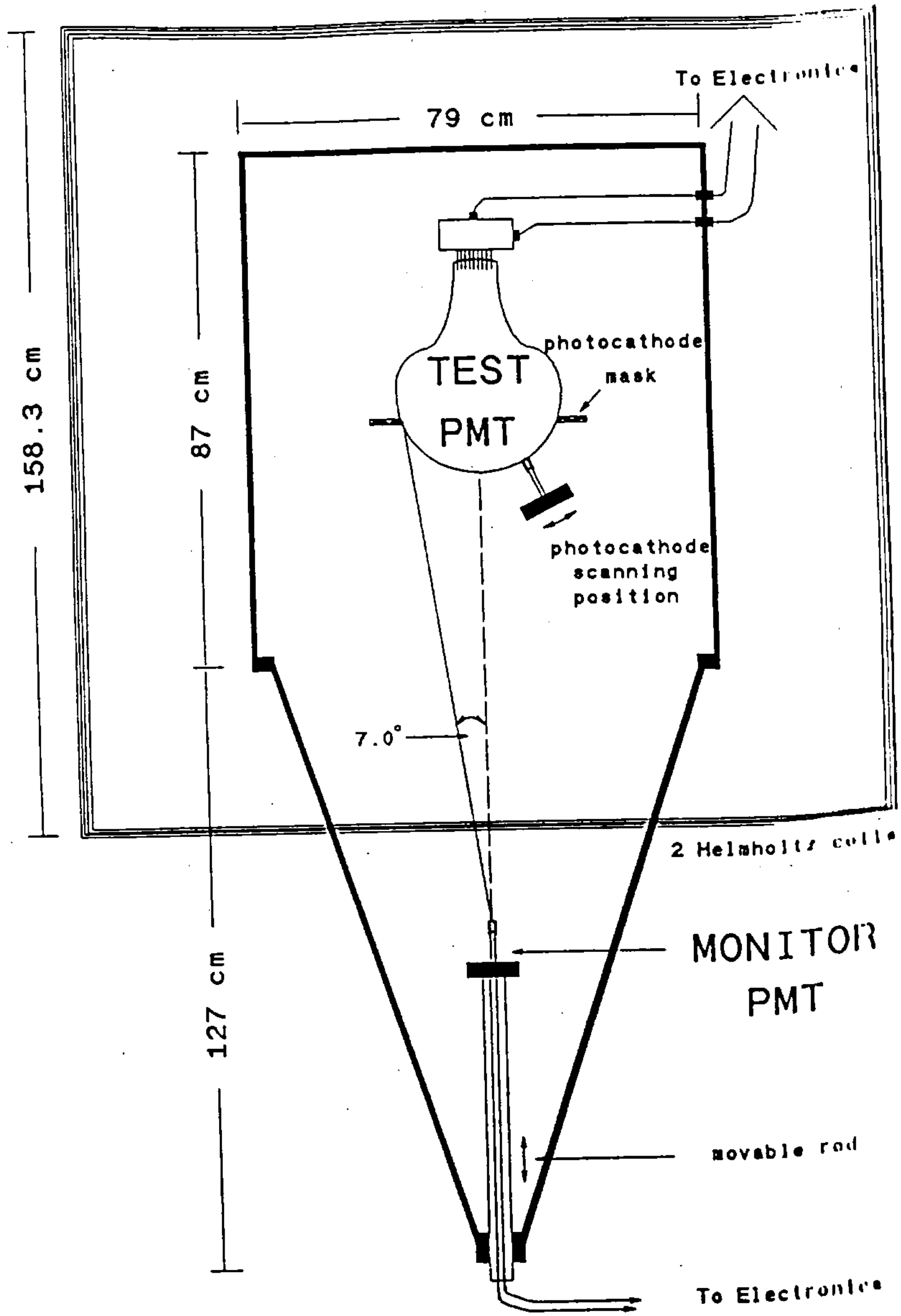
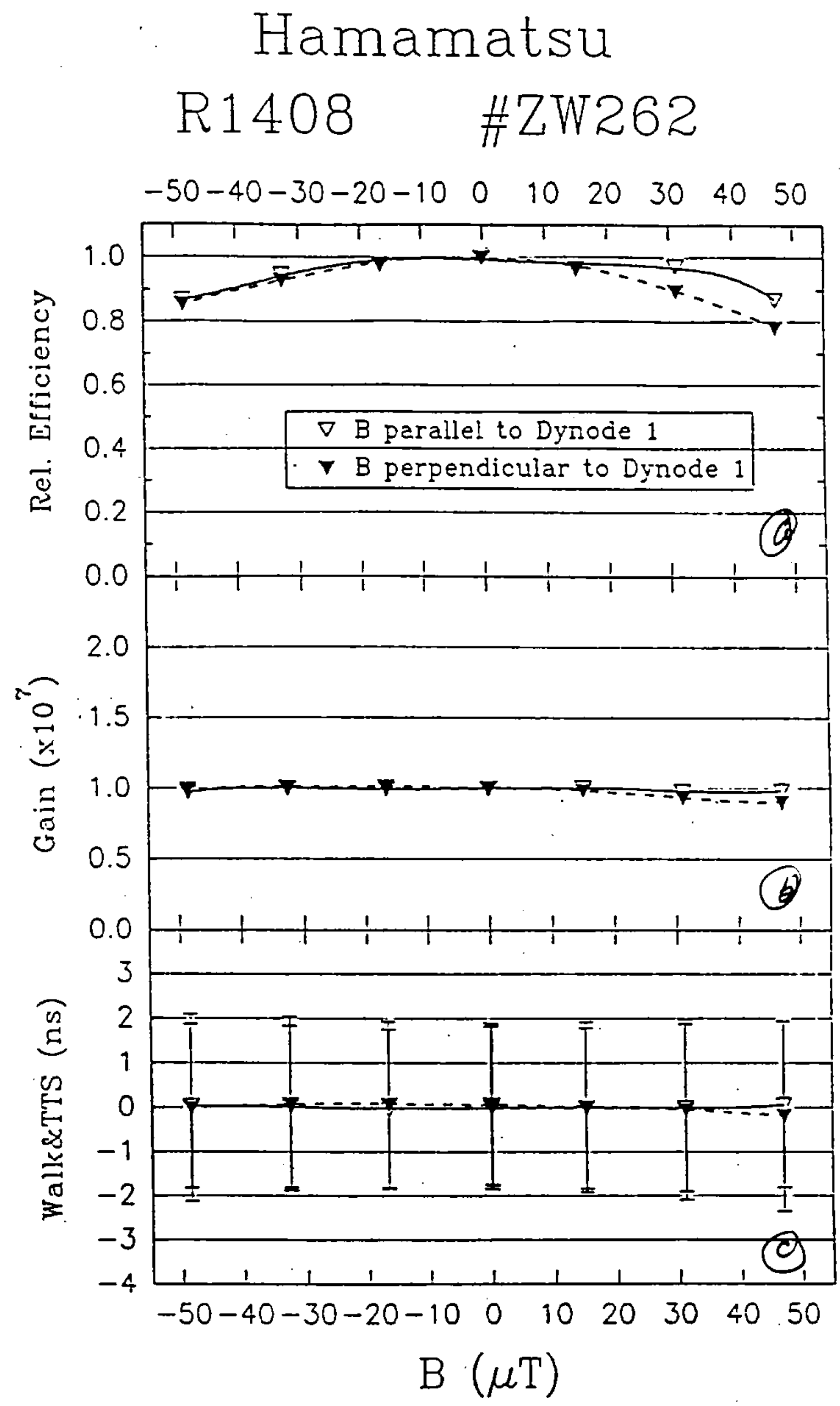


Figure 3.2: Schematic drawing of the light tight box showing the location of the light source for relative efficiency measurements and for photocathode scans.

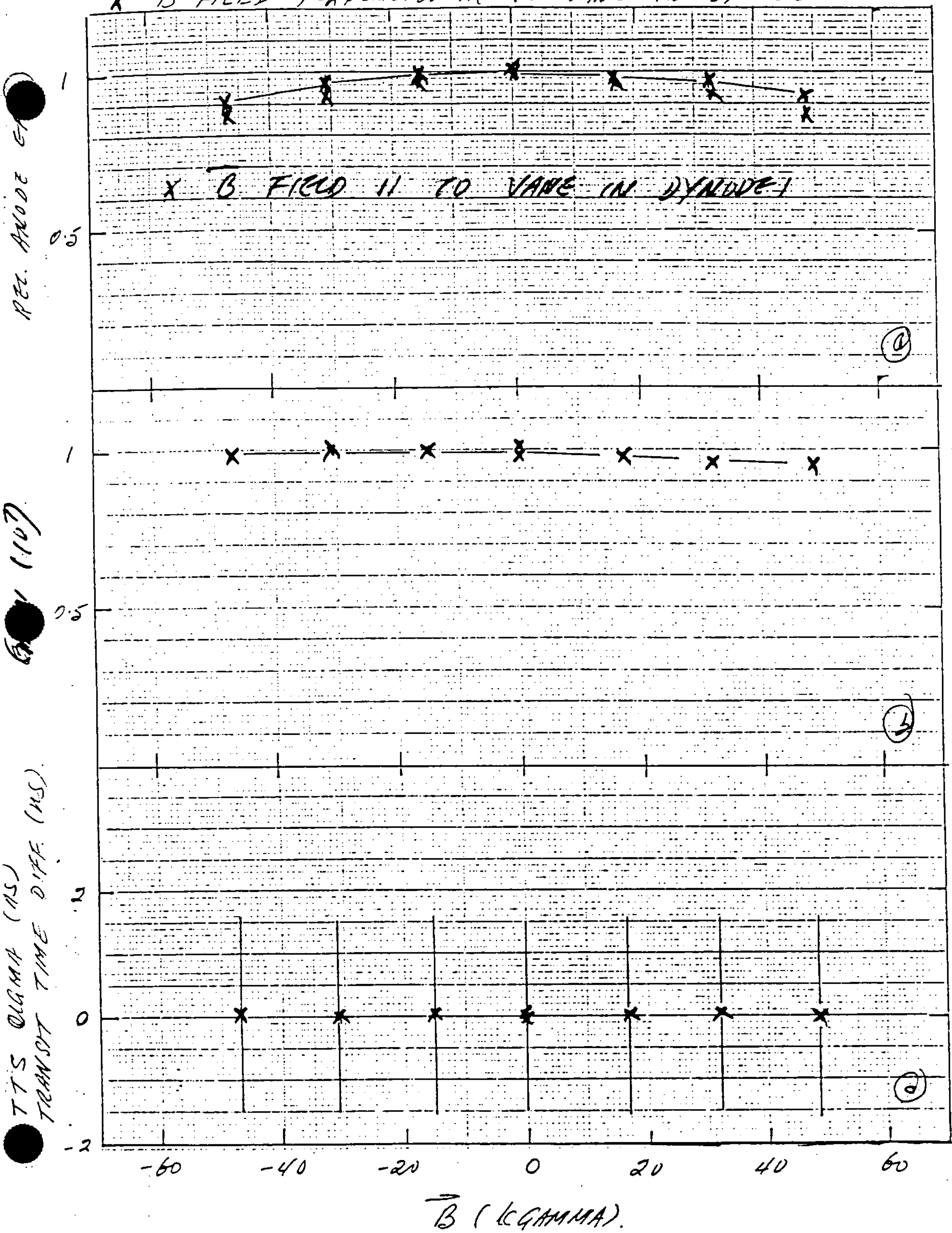


Hamamatsu
R1408 #ZW262
Rel. Efficiency
B parallel to Dynode 1
B perpendicular to Dynode 1
Gain (x10^7)
Walk&TTS (ns)
B (μT)

(3)

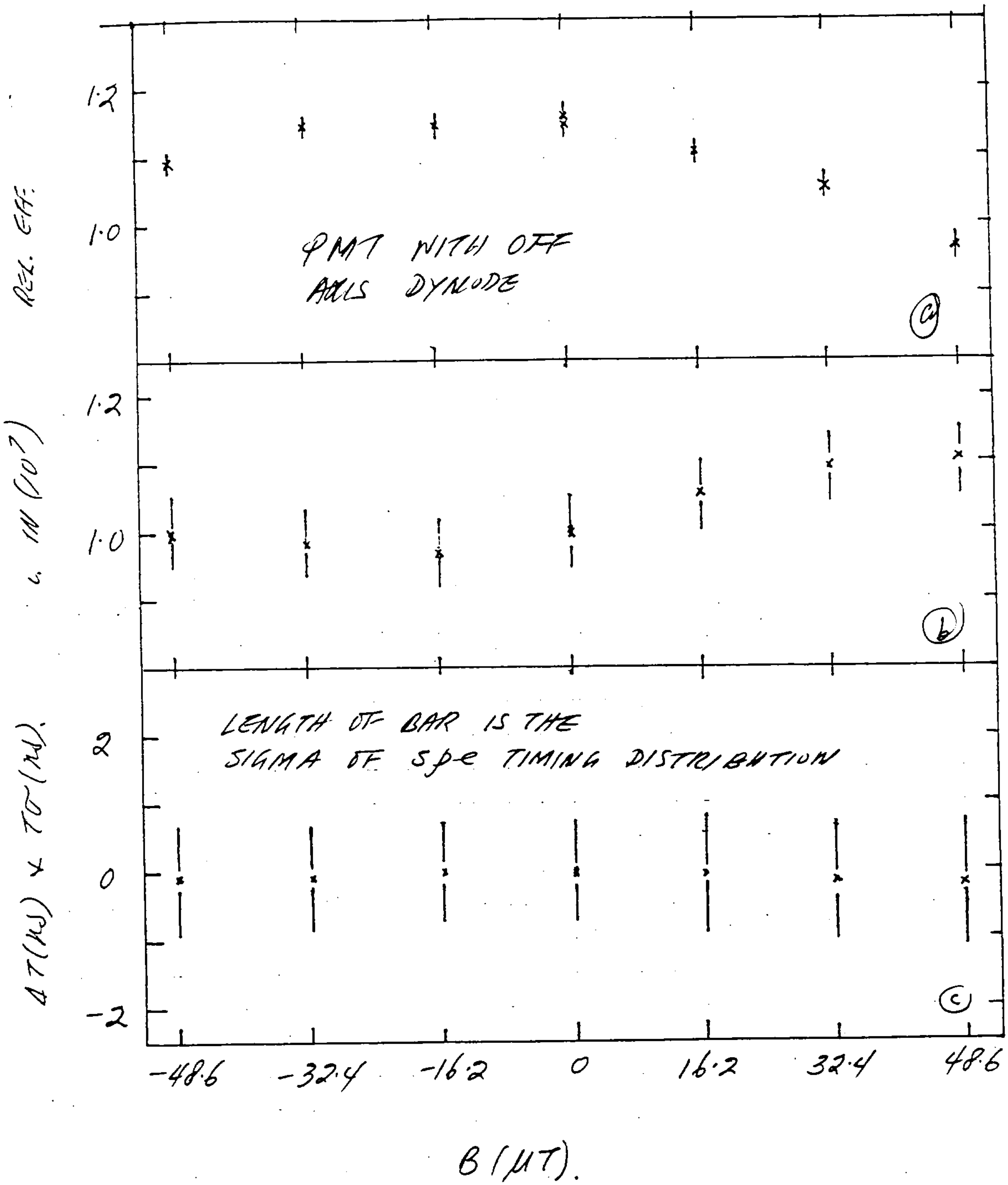
MAGNETIC FIELD SCAN PMT [illegible]14.

X $\overline{B}$ FIELD PERPENDICULAR TO VANE IN DYNODE 1.



ZW535 MAGNETIC FIELD SCAN.

$\overline{B}$ ⊥AR TO DYNODE AXIS



ZW531 MAGNETIC FIELD SCAN (FIELD ⊥ TO VANE OF FIRST DYNODE)

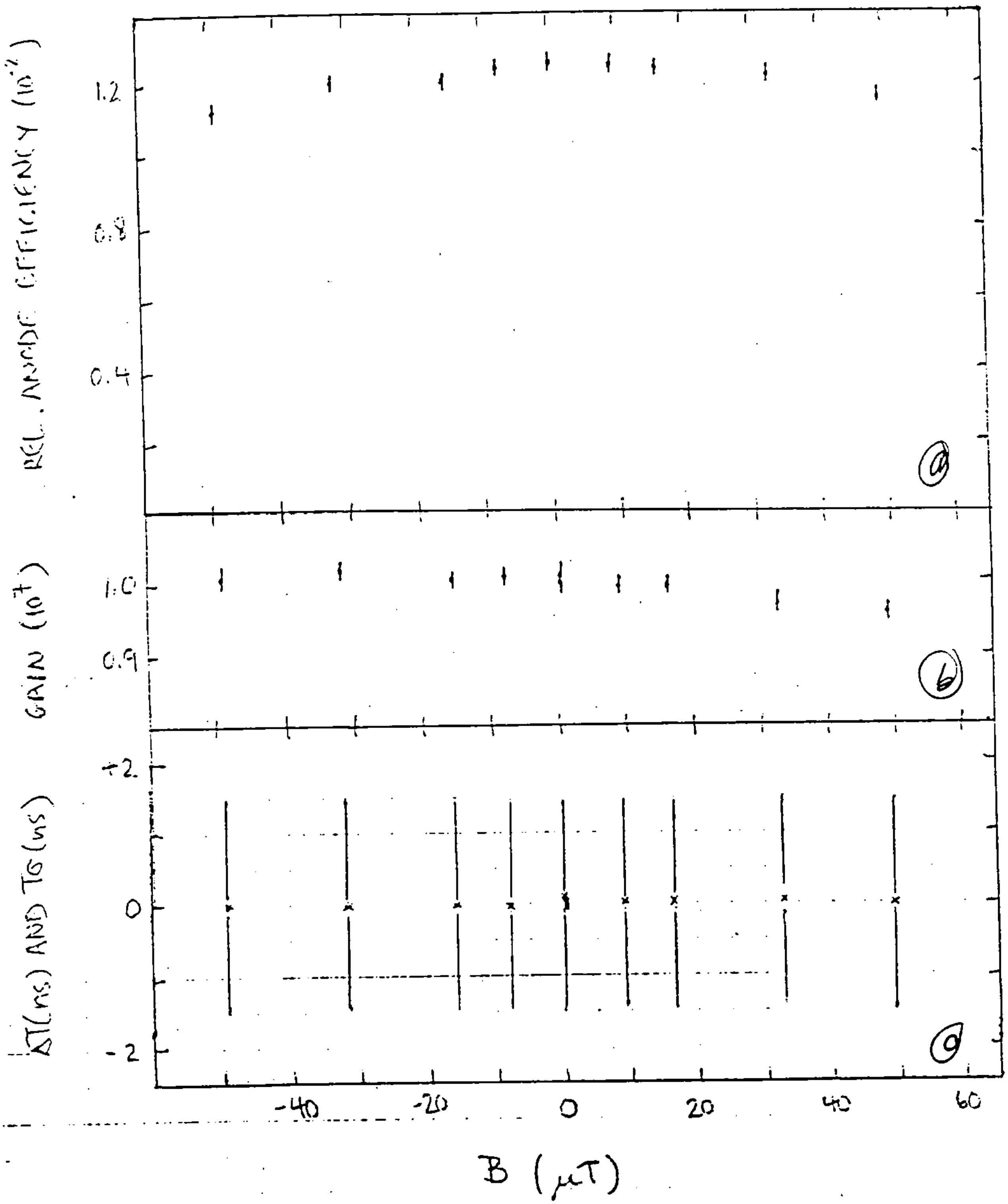


FIGURE 6

ZW531 MAGNETIC FIELD SCAN (FIELD ∥ TO VANE OF FIRST DYNODE)

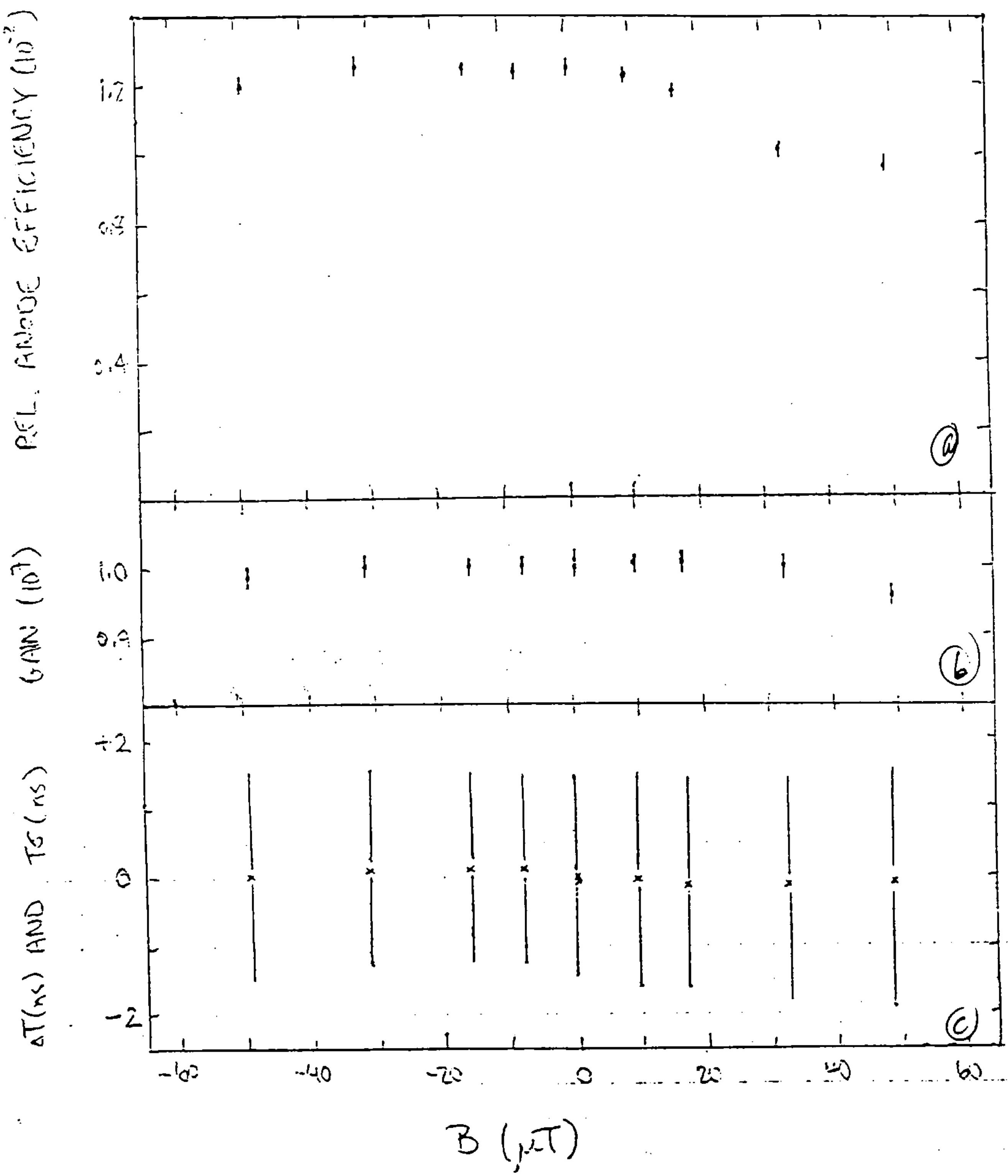


FIGURE 6