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Using I-10 Vertical Bump Magnet to Investigate the Clearance of H-5 Kicker Magnet

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Reported by I-H Chiang

Subject Using I-10 Vertical Bump Magnet to Investigate the Clearance of H-5 Kicker Magnet

Observations and Conclusion

In order to investigate the clearance of the H-5 kicker clearance, we activate the H7 3/2 λ bump such that the circulating beam goes through the H5 kicker. The vertical aperture of the kicker is 14.2 mm with top and bottom lips of 0.76 mm. Hence, the effective aperture is 12.7 mm. Fig. 1 shows measures of beam loss near the kicker vs the readback value of I10 power supply. The calibration is 10 counts/amp, which implies we have a range of 250 Amp in the plateau region. Fig. 2 shows the H4 pickup electrode difference signal vs the I10 readback values. From the graph we concluded that the vertical beam motion at H4 without loss is ~ 3.5 mm.

To cross check this number, we have to use the close orbit deformation formula for the I10 dipole.

$$\Delta y = 1/2 \frac{\sqrt{\beta_{I10}\,\beta_i}\;\theta}{\sin \pi \nu} \cos\left[\psi_i - \psi_{I10} - \pi \nu\right]$$

where ν is the vertical tune of the machine; θ is the angle of kick due to I10; β_{I10}, β_i are the vertical β's at I10 and the observation point; and $\psi_i - \psi_{I10}$ is the phase difference between I10 and the observation point.

The field produced by I10 is

$$B = \frac{\text{Amp x Turn}}{\text{Gap (meter)}} 4\pi \times 10^{-3} \text{ Gauss} = \frac{250 \times 48 \times 4\pi \times 10^{-3}}{0.1625 \text{ meter}} =$$

928 Gauss

$$\theta = \frac{0.30\ HL}{P} = \frac{0.3 \times 0.928 \times (24 \times 2.54)}{28 \times 10^3} = 0.61 \text{ mr}$$

using $\nu = 8.7$

$$\frac{\Delta\psi}{\text{magnet}} = \frac{\nu \times 360}{240 \text{ mag}} = 13.05°/\text{magnet}$$

$$\Delta\text{mag}_{H4 \rightarrow I10} = 26 \text{ mag} \qquad \Delta\psi_{H4 \rightarrow I10} = 339.3°$$

$$\pi\nu = 8.7\ \pi = 0.7\ \pi + 4 \times (2\pi) = 126° + 4\ (360°)$$

$$\Delta y_{H4} = 1/2 \frac{\sqrt{\beta_{I10}\ \beta_{H4}}\ 0.61}{\text{Sin } 126°} \quad \text{Cos } (339.3° - 126°)$$

$$\beta_V \text{ I10} \cong 12 \text{ meter while } \beta_V \text{ H4} \cong 15 \text{ meters}$$

$$\therefore \Delta y = -4.22 \text{ mm}$$

This is very close to the PUE measurement of 3.5 mm. To infer the H5 clearance we use

$$\Delta \psi_{H5-I10} = 326° \quad \beta_{H5} \cong 10.5 \text{ meter}$$

$$\Delta y_{H5} = 1/2 \frac{\sqrt{12 \times 10.5} \times 0.61}{\text{Sin } 126°} \quad \text{Cos } (326° - 126°) = 3.97 \text{ mm}$$

The PUE measurement referred to H5 would be 3.5 mm x $\left(\frac{10.5}{15}\right)^{1/2}$ x $\frac{\cos (326-126)}{\cos (330-126)} = 3.3$ mm

We concluded that the H5 has ~ 4.0 mm ± 1 mm clearance. Assuming our loss limit is set at less than 1% of the beam, and that the beam has a Gaussian profile, then the IPM measurement, Fig. 3, implies we have a beam size of 2.14 mm (σ) x 2 x 2.6 ≅ 11 mm.

The IPM is located at E10 straight section with $\beta \cong 15$ meters while the β_{H5} is 10.5 meters. We have to scale the 11 mm by $\sqrt{10.5/15}$. The inferred IPM measurement at H5 is $\cong$ 9.2 mm. The H5 available aperture is 12.7 mm subtracting the 4.0 mm clearance the inferred beam size is 8.7 mm $\pm$ 1 mm. The agreement is reasonable.

Conclusions

1. The agreement among the three different measurements gives us more confidence in our results, and an estimate of their errors.

2. The present fast kicker has 12.7 mm available aperture. The measured clearance is 4.0 $\pm$ 1 mm which implies our beam size ($\leq$ 1% loss) is 8.7 $\pm$ 1 mm at 6×10^{12}. The IPM confirms this beam size.

3. The new H5 kicker will have the 0.76 mm lips removed and hence have an aperture of 14.2 mm. The clearance will become 5.5 $\pm$ 1 mm. The 6×10^{12} beam will fill about 60% of the aperture of the new kicker.

4. Fig. 4 shows the IPM measurement of $\sigma = 1.71$ mm at 2×10^{12}. From this and the 6×10^{2} data ($\sigma = 2.14$ mm) we can linearly extrapolate to 1.6×10^{13}

$$\sigma_{(1.6 \times 10^{13})} = \sigma_{(6 \times 10^{12})} + \frac{\left[\sigma_{(6 \times 10^{12})} - \sigma_{(2 \times 10^{12})}\right]}{4}$$

$$\times 10 = 3.2 \text{ mm}$$

IPM measurement at 1.5×10^{13} suggests this procedure slightly over estimates the beam size.

$$\therefore \frac{\text{beam size } (1.6 \times 10^{13})}{\text{beam size } (0.6 \times 10^{13})} = \frac{3.21}{2.14} = 1.5$$

Using conclusion #2

Beam size at $6 \times 10^{12} = 8.7 \pm 1$ mm

Beam size at $1.6 \times 10^{13} = 1.5 \times (8.7 \pm 1) = 13.1 \pm 1.5$ mm

The present kicker (with lips, effective aperture 12.7 mm) will be very marginal at 1.6×10^{13} circulating beam intensity. We should install the new kickers, which have 14.2 mm vertical aperture, to provide some safety margin.

The study leaves unanswered the question as to the cause of the kicker failure during the 1983 FEB run.

mvh-6/25/84

Distribution: Dept. S&P Staff

H_5 BB = 3150 3048 readback.

SBER

H_5 BB = 2955 (2871)

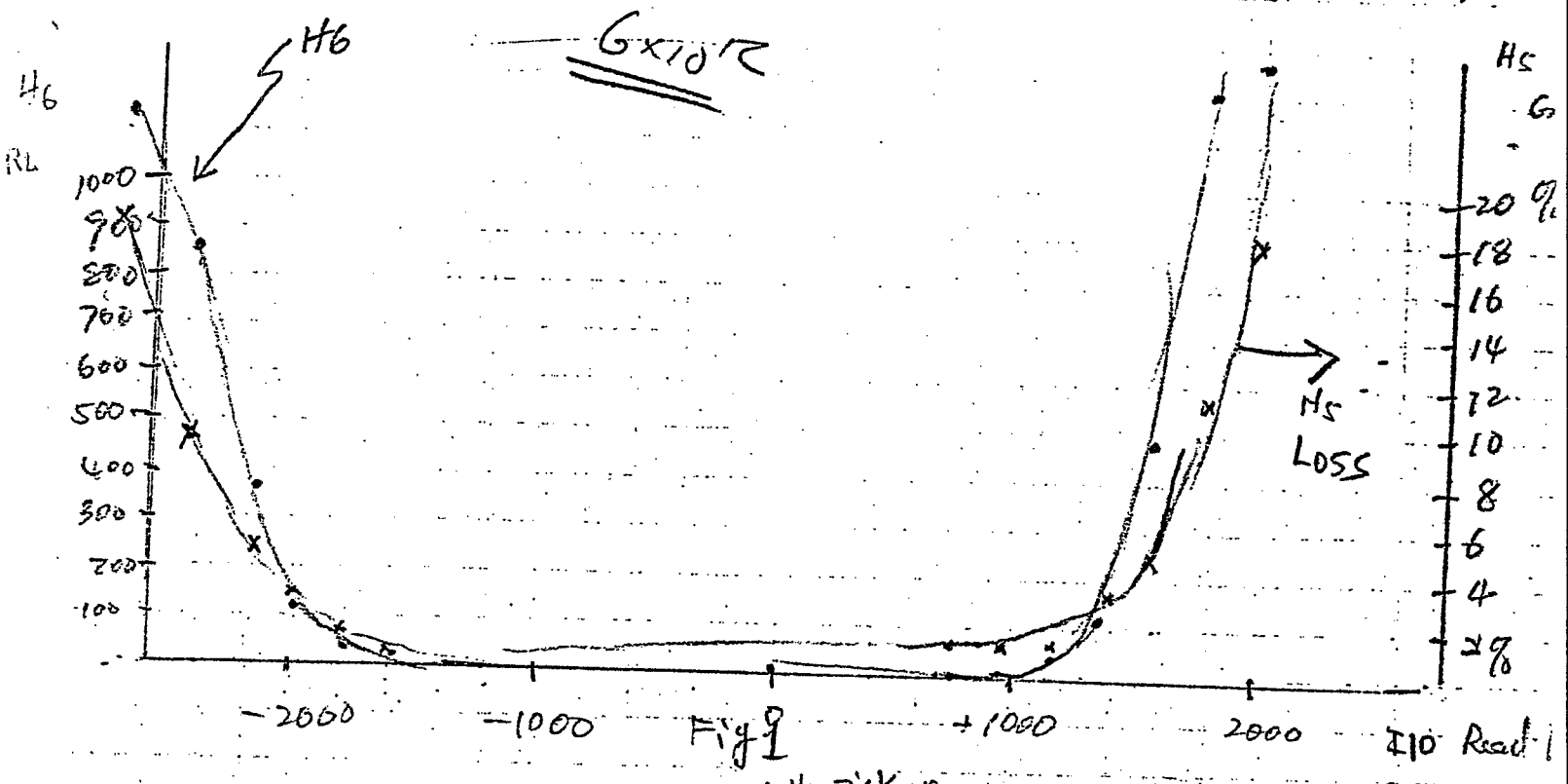


Fig 1

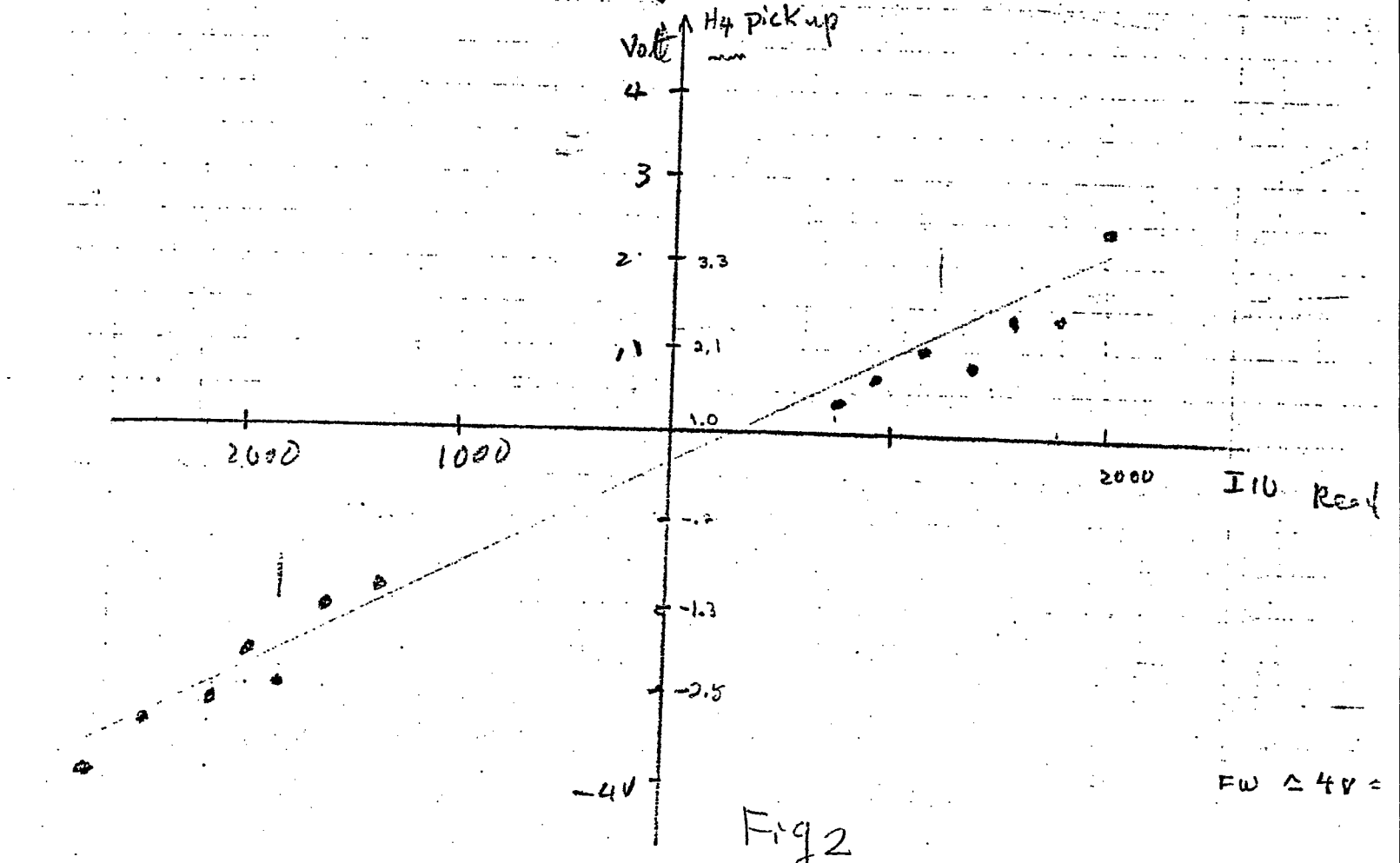
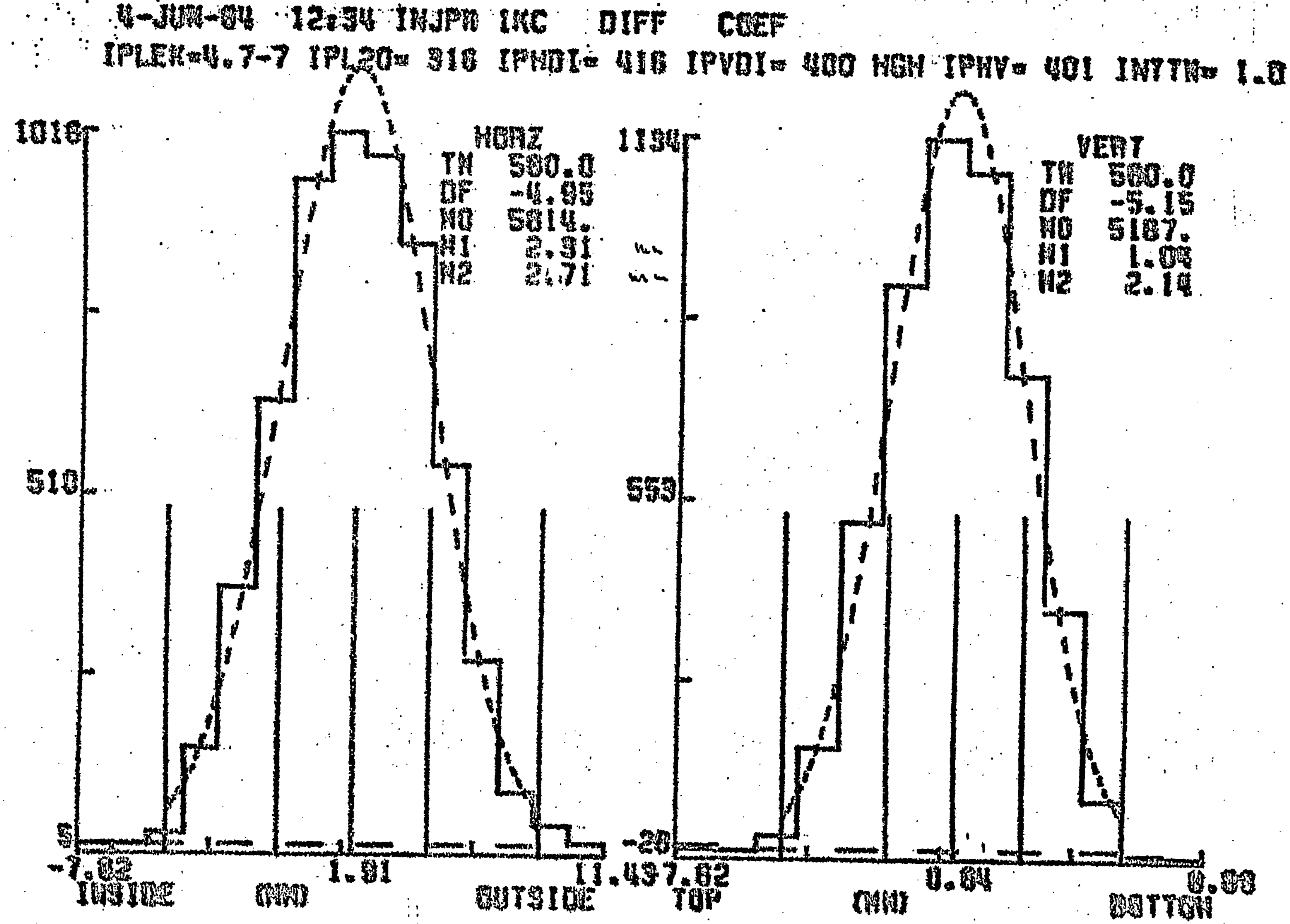


Fig 2

6X pole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HORZ
TH 580.0
DF -4.95
NO 5814.
H1 2.91
H2 2.71
1016
510
5
-7.62
1.91
11.49
INSIDE
(MM)
OUTSIDE
VERT
TH 580.0
DF -5.15
NO 5187.
H1 1.09
H2 2.14
1194
553
-20
7.62
0.64
8.89
TOP
(MM)
BOTTOM

Fig 3

2X10

4-JUN-84 12:06 INJPK 1KC DIFF COEF FILE:WSR [025,025]
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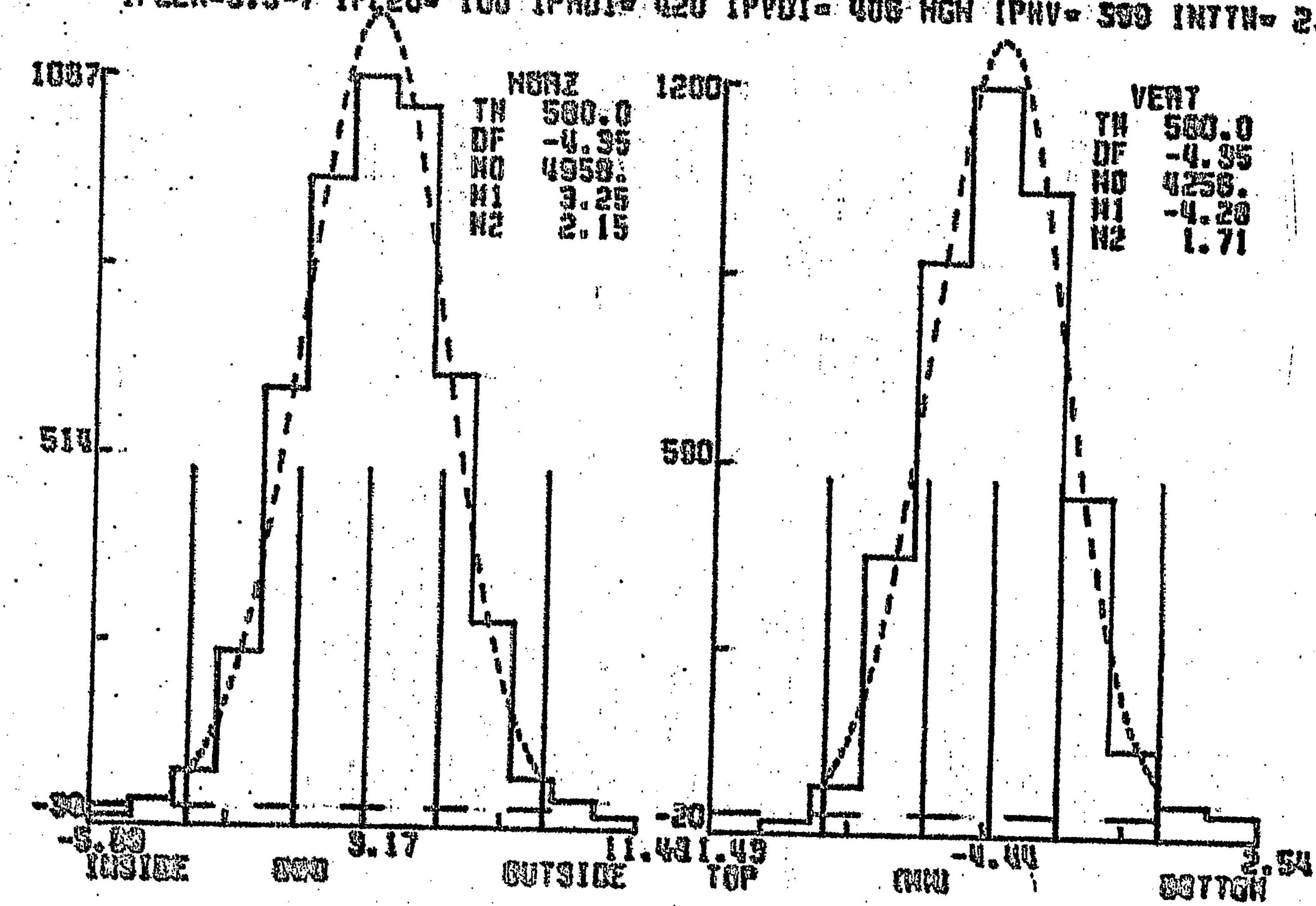

Fig 4