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Fermi National Accelerator Laboratory

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Magnetic Fields and SDC Endcap Scintillator Performance

Dan Green

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January 1993

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MAGNETIC FIELDS AND SDC ENDCAP SCINTILLATOR PERFORMANCE

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1. Introduction

Many detectors designed to operate in colliders contain both magnetic fields, usually solenoids, and scintillators. The former is known to influence the operation of the latter. A first look is taken in this note at the implications of that influence for the SDC detector.

2. Light Yield vs B Field

The light yield from scintillators has been measured to depend on the magnetic field in which the plastic is immersed [1]. A plot of the field dependence of the scintillator light output for the ZEUS detector is shown in Fig. 1. There is little dependence for magnetic fields between 0.01 and 1 kG, where the fractional light output shift is ~ 0.8%. Below 0.01 kG the shift is immeasurably small. Above 1 kG the shift is roughly linear in the applied field, with a slope of 0.6%/kG. High field data points are not available [1].

3. Field Gradients and HAD Calorimeter Performance

Obviously, the flux return in the endcap of SDC creates a field which has a gradient over a calorimeter tower. Given that the field changes the light output, the field gradient makes the calorimeter tower a nonuniform medium. A nonuniform medium has an additional "induced constant term" error due to shower development fluctuations within the medium. Therefore, the flux return will degrade the performance of the calorimeter immersed in the return. The problem is to quantify that degradation and evaluate whether or not it is important.

The full field map for the SDC magnetic "circuit" is not yet available. If it were, one could take each individual tile and apply a light shift to that tile knowing its location in the field. Then the nonuniform response could be applied to an existing data set, such as the Hanging File (HF) data, [2], to see the effect of the nonuniformity on the performance of the calorimeter.

To get started, as a first rough approximation, the induced error due to random rms variations in the tile light output is shown in Fig. 2. The dependence is roughly linear with a slope which is an ~ 4% error in energy measurement for an ensemble of tiles with a 10% rms random error [3]. Clearly, this random error is not the same as applying the shifts due to B field variations, as these have a well defined pattern. However, Fig. 2 will be used as a first crude indicator of the order of magnitude of the problem.

4. Field Gradients and Calibration Issues

The fields in the electromagnetic (EM) and hadronic (HAD) compartments of the SDC endcap calorimeter are large [4]. Plots of Br and Bz for a simple model of the endcap assuming azimuthal symmetry are shown in Fig. 3 as a function of z for a few representative r values (towers). The field is quite constant over the size of an EM tower. Therefore, the EM towers will probably only need to be recalibrated. First, one can use the field map measured during final assembly and the measured light yield shift as a function of field. Second corrections to that map can be made in situ using electrons of known momentum, e.g. $Z \to ee$ decays.

However, it would seem that the precise EM tower measure of energy will not be compromised by the existence of the solenoidal field flux return assuming that the corrections of the mean shift can be made to < 0.5%. This value corresponds to a field of ~ 0.8 kG, which then sets the scale for the needed knowledge of the field within a given EM tower.

The HAD compartment is another story. The fields are again large, necessitating recalibration in situ. In addition, the field gradients are large. This raises the possibility of degraded HAD calorimeter performance. The shaded region in Fig. 3 corresponds to the region over which Bz varies by 10 kG. If we accept that the slope measured by ZEUS at low fields applies to the higher endcap fields, then the Bz variation by 10 kG means a 6% variation in scintillator light output in depth in the HAD1 compartment. A comparable, or even larger, variation exists in the Br field component over the HAD1 depth. The 6% variation in light output will induce a constant term error of roughly (Fig. 2) 2.4%. This constant term remains within the SDC specification for hadronic calorimetry [3].

A first attempt at a more realistic scenario was made assuming a linear magnetic field variation over the HAD1 compartment (the first 25 Fe plates of 1" thickness). A 10% maximum light output variation (roughly 16 kG field variation) was assumed to occur either at the front or back of HAD1. The induced constant term was 2.7% and 2.1% respectively. Since the variation is ~ ± 5%, the coherent variation does not appear to make a much larger error than the random variation (which is ~ 2.2% for a rms light fluctuation of 5%, see Fig. 2.)

A large part of this induced constant term for the EM compartment is simply due to a shift in the mean. For example, in the EM calorimeter, the sensitivity of the energy mean to longitudinal errors is reduced by a factor 8 if the tower mean is recalibrated [4]. Recalibration of the mean can again first be made from an a priori knowledge of the magnetic field map. Refinements in recalibration will then follow from in situ measurements. The requirements on HAD calorimetry are looser than those on EM calorimetry. Therefore, if in situ calibration of the mean suceeds for EM, it must also for HAD. The HAD differs in being immersed in large field gradients. However, they do not appear to induce unacceptably large energy measurement errors.

5. Summary

The tentative conclusion is that the sensitivity of scintillator light output to magnetic field is fairly low. Thus, quite large field gradients can be tolerated with no knowledge of the field values. Given a field map, the mean can be recalibrated; first a priori, and then followed by in situ measurements. If the light yield/B field slope is as assumed, if the field gradients within a tower are < 10 kG, and if the constant term energy error/light yield is as assumed, then the recalibrated mean will reduce the energy error due to field gradients to adequately small values.

Clearly, the numerical values of the quantities given in Fig. 1 and Fig. 2 need to be verified, extended to larger B field values, and applied to shifts (given a real field map) before these tentative conclusions can be accepted with any sense of assurance.

References

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4. D. Green, "Source Calibrations and SDC Calorimeter Requirements", SDC-92-322, Fermilab-TM-1799 (1992).
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Figure Captions

1. Percent fractional light yield shift as a function of magnetic field. The slope is roughly 0.6% per kG.

2. Induced constant term in a homogenous HAD calorimeter as a function of a random light output error. The slope is roughly 0.4% per rms %.

3. Magnetic field components Br and Bz as a function of z at ~ constant r (towers). The HAD1 compartment extends roughly from -4.4m to -5.3m. Perfect azimuthal symmetry has been assumed in the field configurations. The shaded region corresponds to a 10 kG Bz variation over the tower region in depth, z.
    a. r ~ 0.55m.
    b. r ~ 1.07m.
    c. r ~ 1.52m.

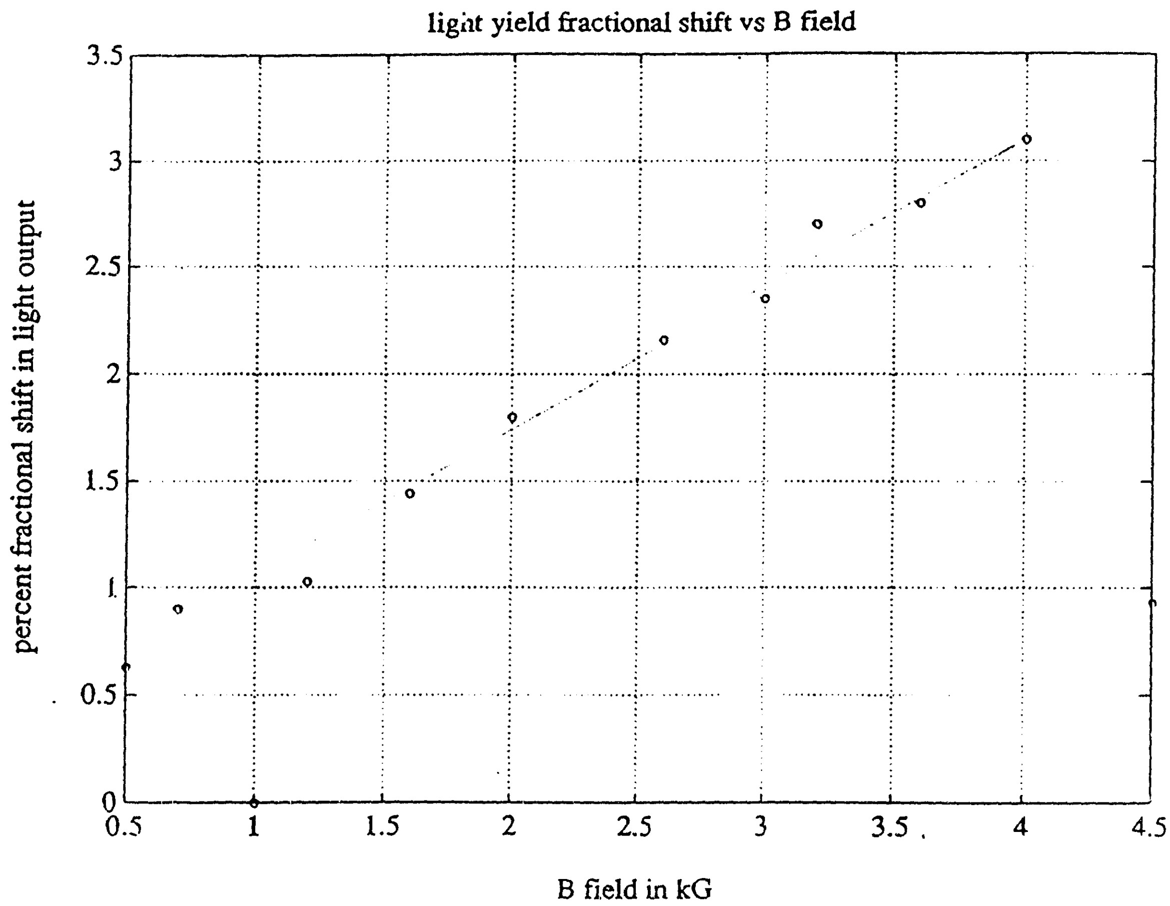

light yield fractional shift vs B field
percent fractional shift in light output
B field in kG
0
0.5
1
1.5
2
2.5
3
3.5
4
4.5

Fig. 1

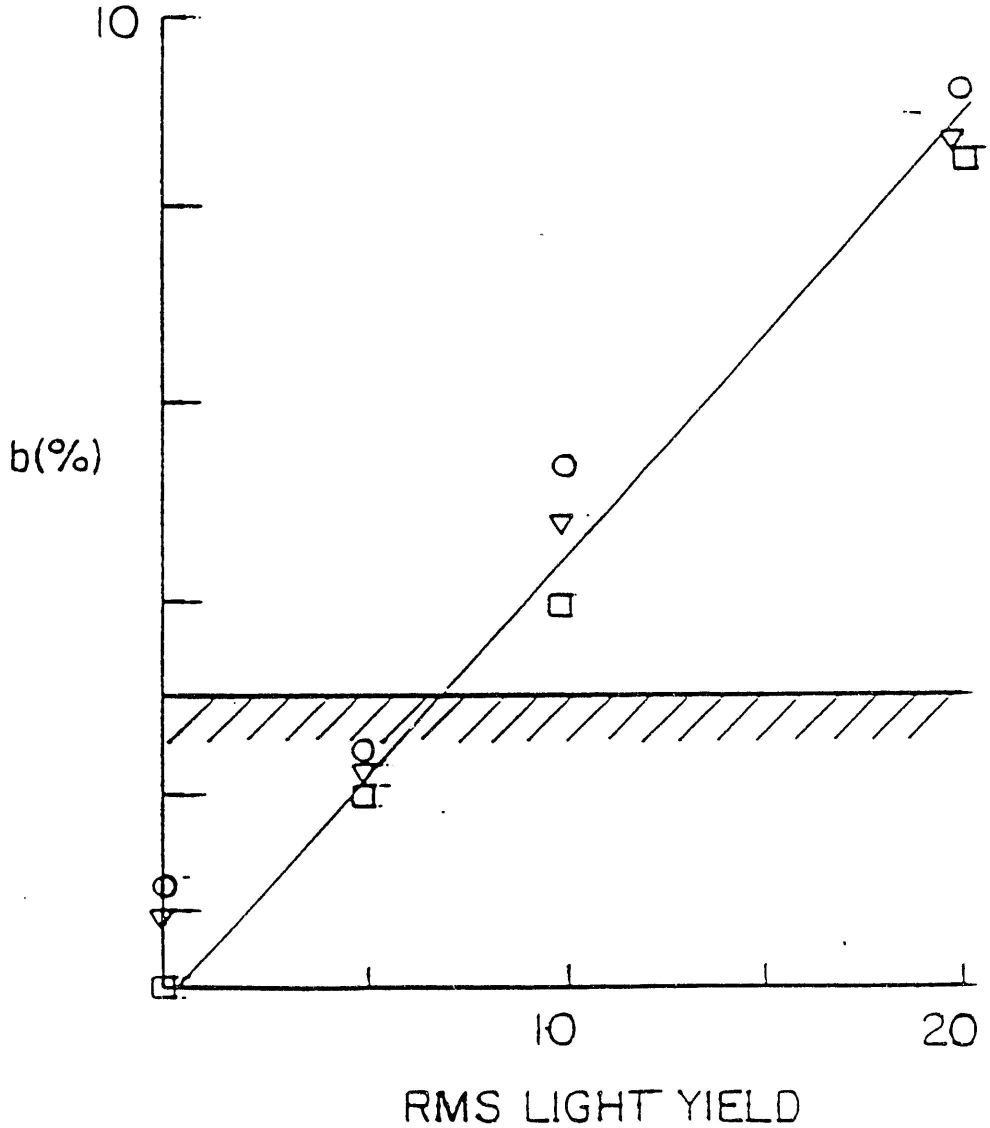
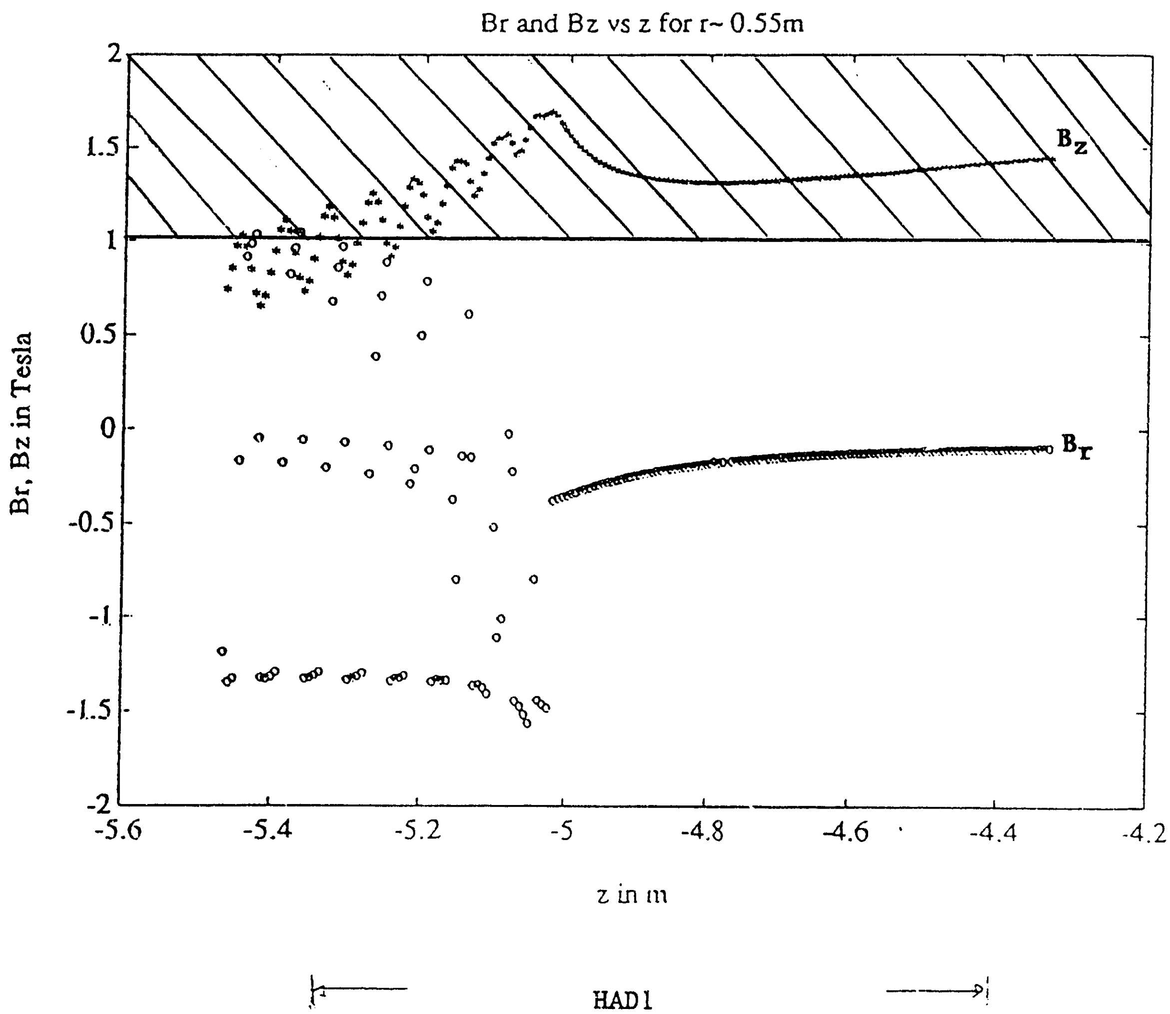
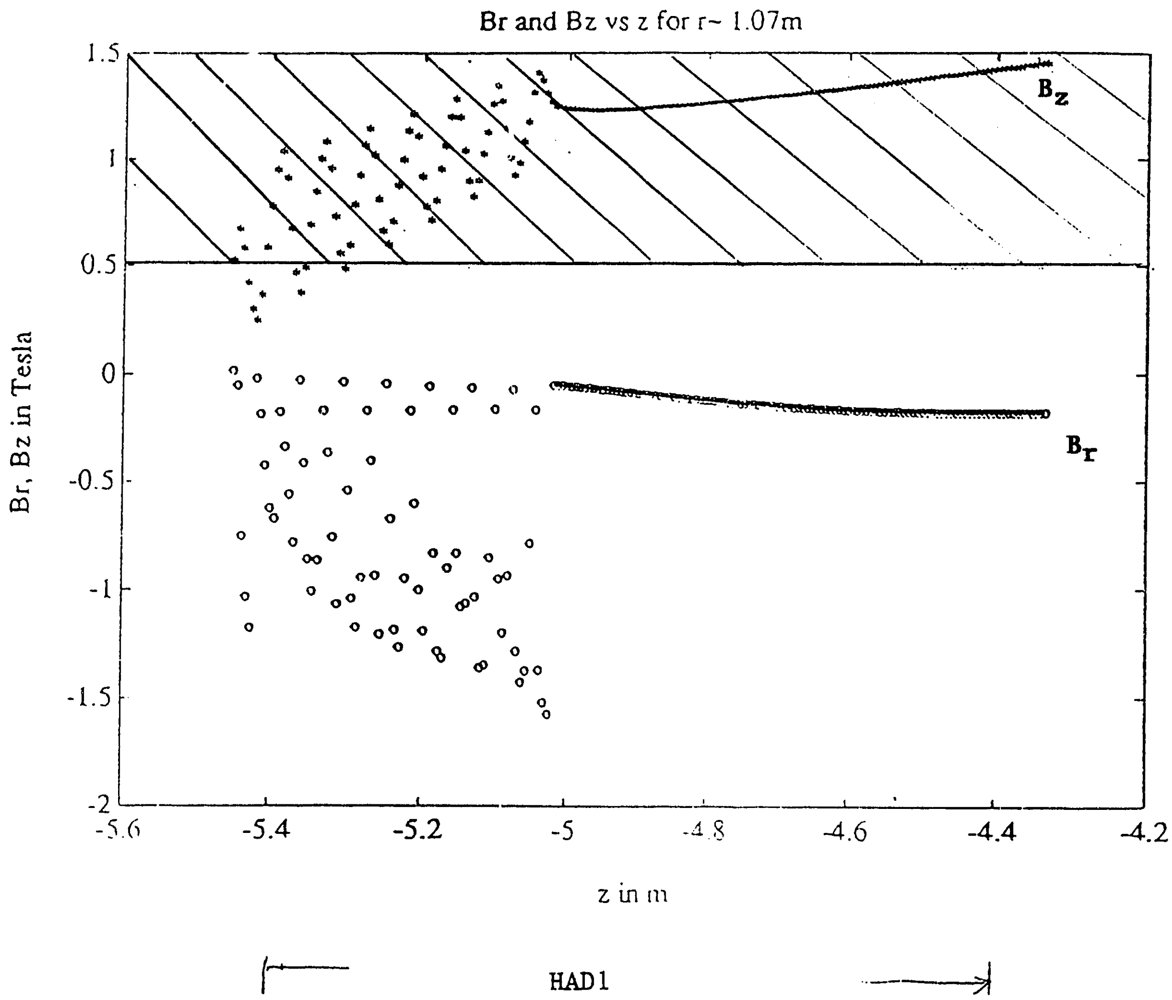


Fig. 2



Br and Bz vs z for r~ 0.55m
Br, Bz in Tesla
z in m
B_z
B_r
2
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-5.6
-5.4
-5.2
-5
-4.8
-4.6
-4.4
-4.2
HAD1

Fig. 3a


Br and Bz vs z for r~ 1.07m
Br, Bz in Tesla
z in m
Bz
Br
1.5
1
0.5
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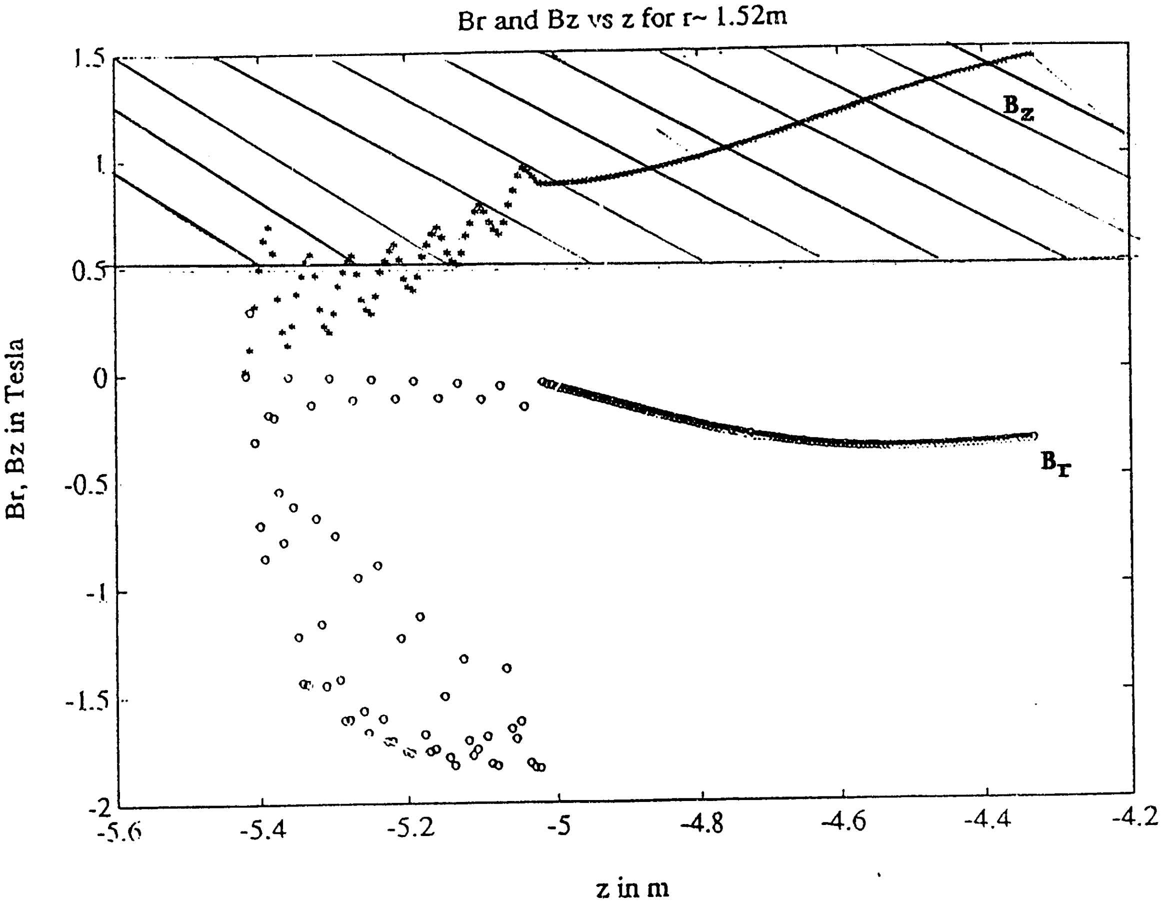
-1
-1.5
-2
-5.6
-5.4
-5.2
-5
-4.8
-4.6
-4.4
-4.2
HAD1

Fig. 3b


Br and Bz vs z for r~ 1.52m
Br, Bz in Tesla
z in m
Bz
Br
1.5
1
0.5
0
-0.5
-1
-1.5
-2
-5.6
-5.4
-5.2
-5
-4.8
-4.6
-4.4
-4.2

HAD1

Fig. 3c

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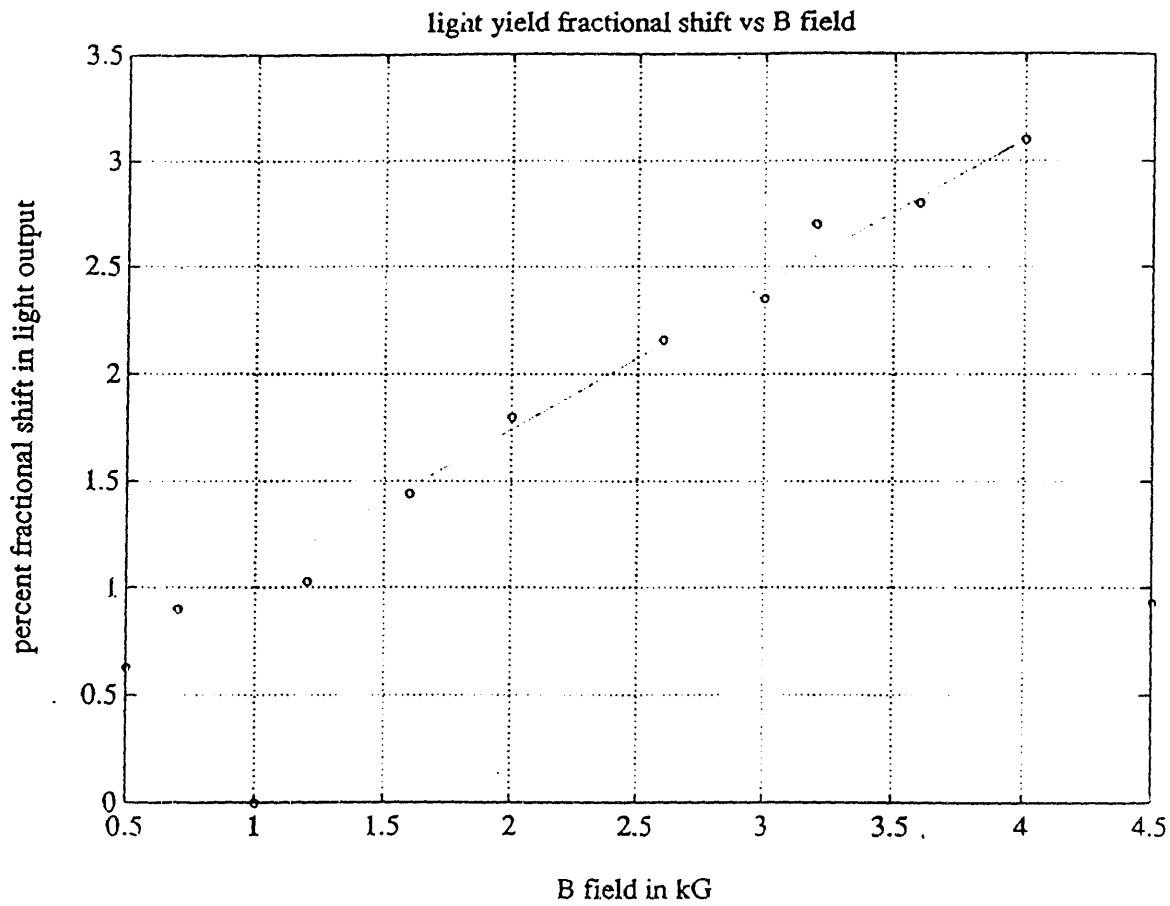
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Fig. 1

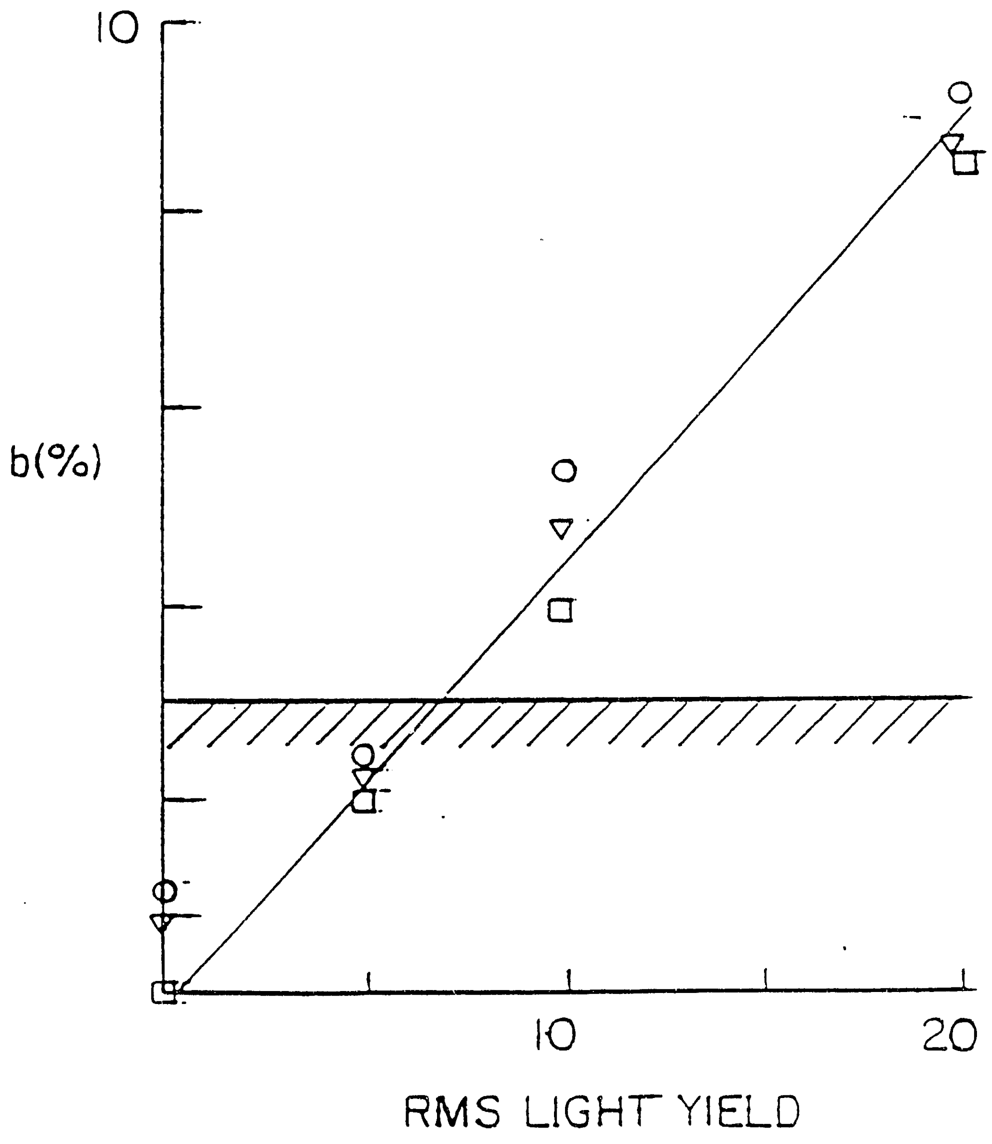
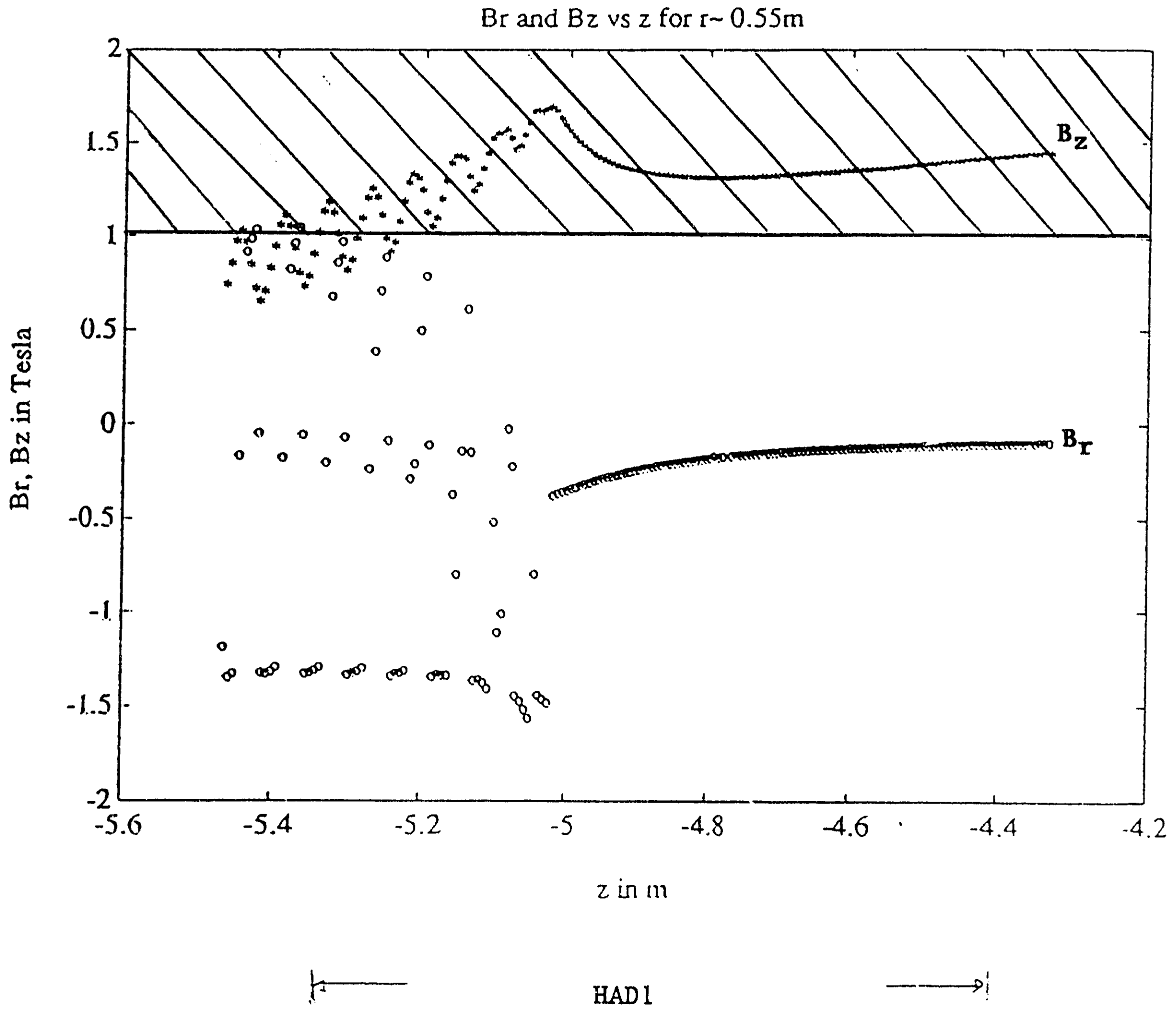


Fig. 2



Br and Bz vs z for r~ 0.55m
Br, Bz in Tesla
z in m
2
1.5
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-1
-1.5
-2
-5.6
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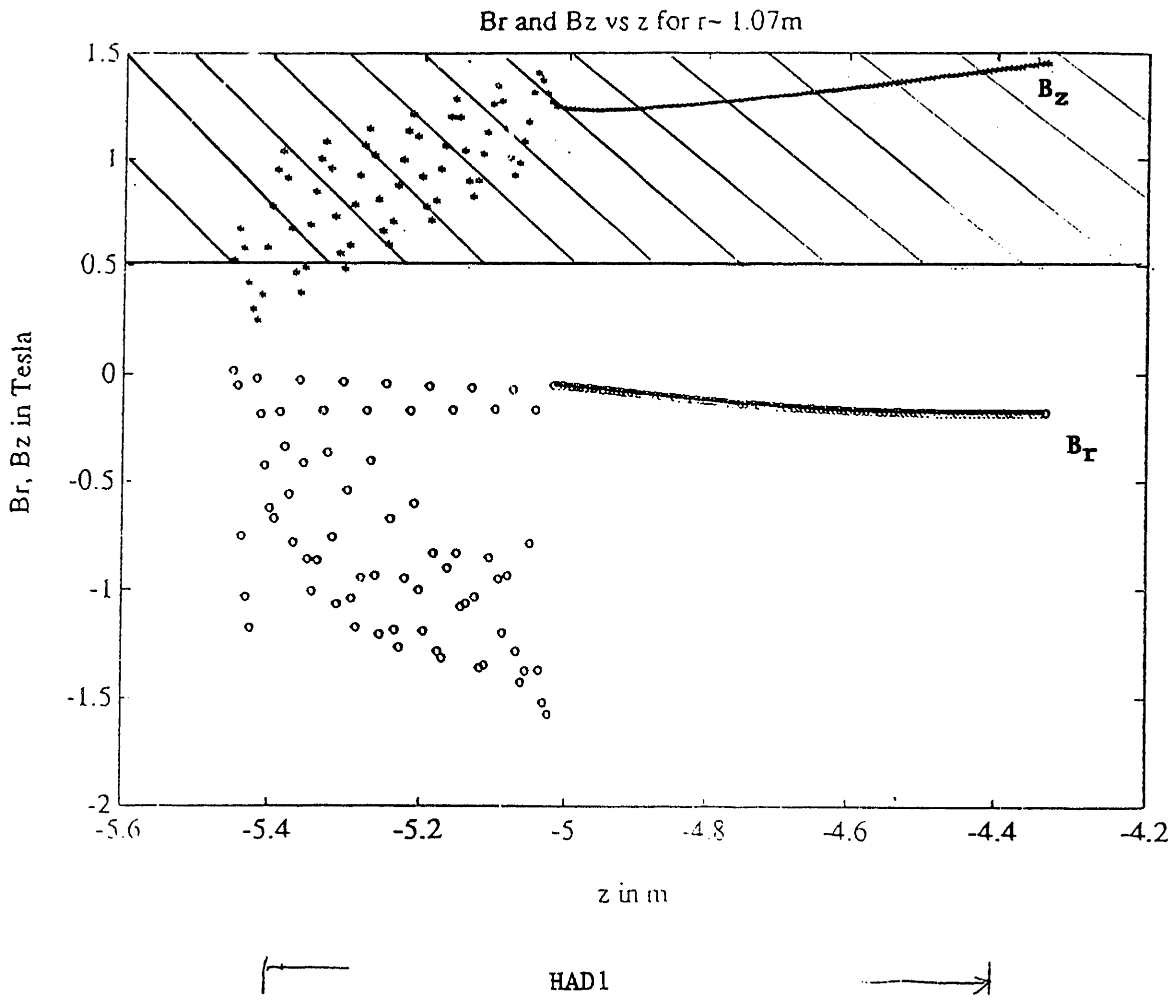
Bz
Br
HAD1

Fig. 3a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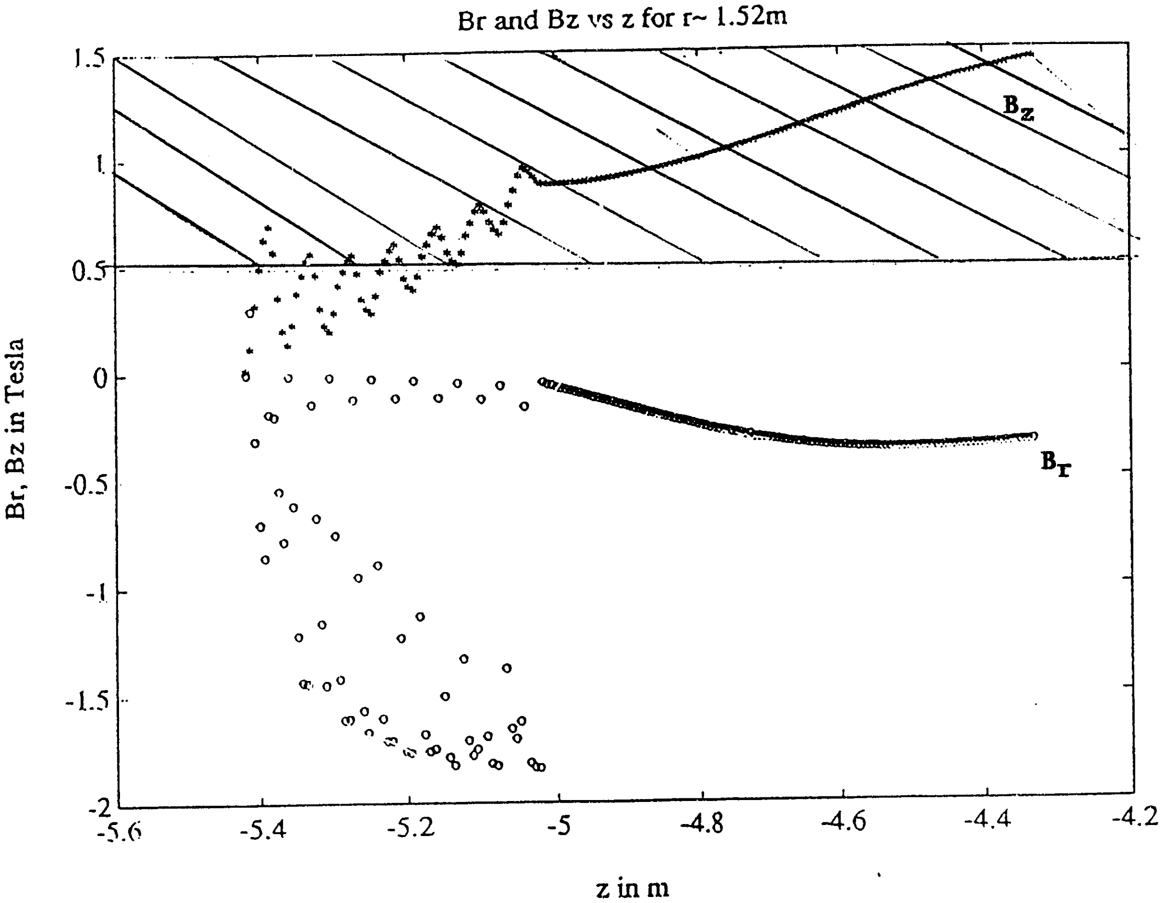
Bz
Br
HAD1

Fig. 3b


Br and Bz vs z for r~ 1.52m
Bz
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-4.6
-4.4
-4.2

HAD1

Fig. 3c

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