BROOKHAVEN NATIONAL LABORATORY

MAGNET DIVISION NOTES

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Title: DRS006 with Saturation Suppressor Holes

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DRS006 with Saturation Suppressor Holes

Ramesh Gupta

Abstract

In this note we examine the measured and expected magnetic performance of the RHIC short dipole DRS006 with saturation suppressor holes[1]. It was rebuilt with an additional hole in each quadrant to reduce b_2 and b_4 saturation.

Performance

The measured field harmonics b_2, b_4, *and* b_6 as a function of current in the magnet DRS006 (Rebuild) are shown in figure 1. In figure 2, we have compared these harmonics with those in DRS008 (Rebuild) which did not have the saturation suppressor holes. One can clearly see the improvement in b_2 and b_4 saturation. As expected the b_6 has become worse but that seems to be acceptable since b_4 harmonic is more important then b_6 harmonic (particularly at high current) from beam dynamics considerations. The maximum value of saturation induced harmonics is 0.1 unit or less for b_8 and higher harmonics.

In reference 1, we have discussed what to expect in the long dipoles built with the saturation suppressor holes. The so called saturation induced harmonics in the measurements also include the harmonics induced by coil motion, etc. The goal in optimizing the location and size of the saturation suppressor hole was to empirically subtract them out to minimize the variation in the measured harmonics which matters in the actual magnet rather then just minimizing the iron saturation effects. In figures 4-6 we have compared the measured, expected and computed current dependence of the b_2, b_4, *and* b_6 harmonics. Computed are the results of POISSON calculations and expected are adding onto that the differences between the calculations and measurements in the absence of saturation suppressor holes. POISSON model is shown in figure 3. A 10 mil gap at the mating plane of the top and bottom half at $Y = 1''$ is assumed at the place shown in the figure. In the model, it runs from $X = 4''$ to the outer radius of the yoke.

Following the standard procedure, we have removed the geometric part of the multipoles in the above figures by averaging up and down ramps and by subtracting the offset of the values of these harmonics at 2 kAmp so that all harmonics are arbitrarily made zero at 2 kAmp. It may be mentioned that in the above analysis we have used the results of the magnetic measurements with $9''$ coil in both magnets DRS006 and DRS008. Both magnets

were rebuilt to remove an strain gauge which was located in the middle of these magnets. Before the rebuild the magnetic measurements in magnets DRS005, DRS006, DRS007 and DRS008 were done with a 30″ coil. The length of the coil straight section in short dipole is 36.9″. The total length of coil (including ends) is 51.5″ and of iron yoke is 51″. The iron yoke i.d. is 4.7″. When the harmonics are measured with a 30″ coil, the ends of the dipole would influence the harmonics in the 30″ body of the magnet and therefore they are not a true representation of the harmonics in the cross section of the magnet. This becomes more important for saturation induced harmonics at high field since the iron in the body of the magnet is highly saturated but not so in and near the ends of the magnets. In figures 7-9 we have plotted the current dependence of the b_2, b_4, *and* b_6 harmonics measured with the 30″ coil in magnets DRS005, DRS006, DRS007 and DRS008. Since there is a little magnet to magnet variation in the measured current dependence in these four magnets, one is justified in using the 9″ coil measurements in the magnet DRS006 (with saturation suppressor holes) and the 9″ coil measurements in the magnet DRS008 (without saturation suppressor holes) in analyzing the influence of saturation suppressor holes as if the experiment was done in the same magnet.

Conclusion

The saturation suppressor holes have been able to reduce b_2 and b_4 saturation significantly in the RHIC arc dipoles. Therefore, it has been decided that they would be an integral part of the yoke to be used in the magnets DRE011 and DRE012 and also in the magnets to be built by the industry. Expected current-dependent variation in b_2 harmonics in those magnets would be $\sim$ 2 unit and b_4 would be $\sim \frac{1}{2}$ unit.

References

1. R. Gupta, "Reducing iron saturation in arc dipoles with a saturation suppressor hole", Magnet Division Note No. 447-16 (RHIC-MD-158), June 10, 1992.

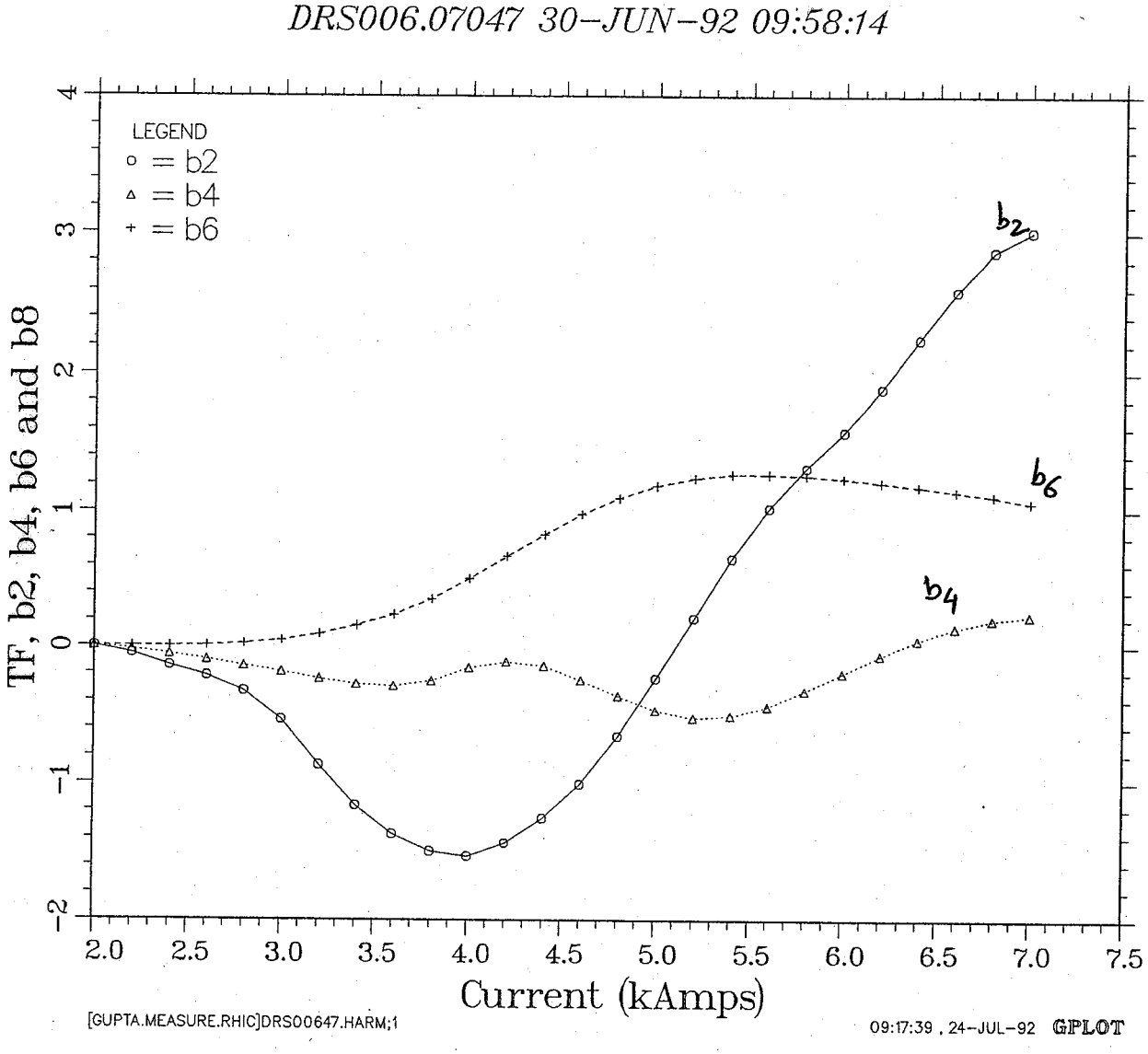

Figure 1: The measured current dependence of the field harmonics in the magnet DRS006 with saturation suppressor holes.

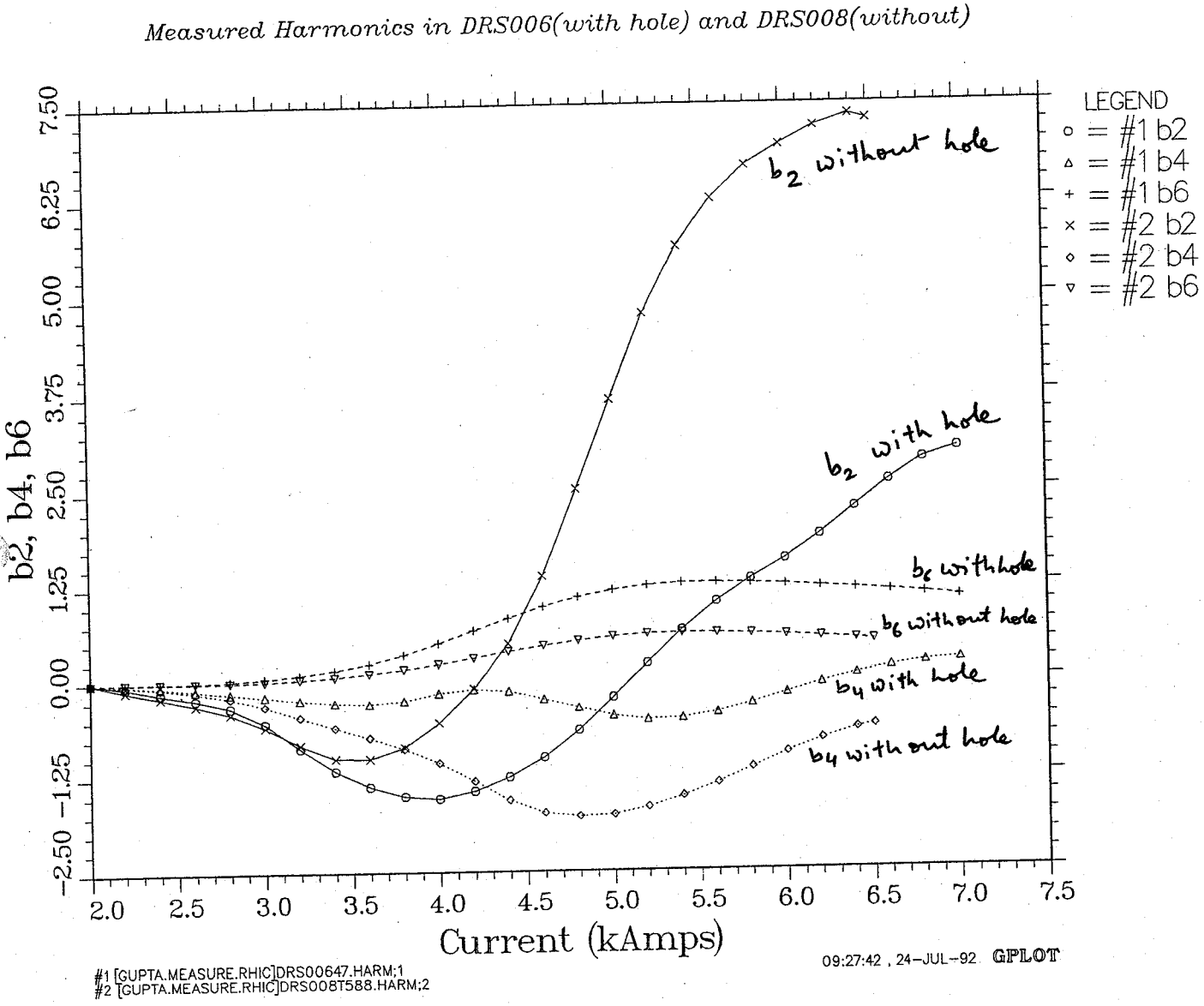

Figure 2: The measured current dependence of the field harmonics with (DRS006) and without (DRS008) saturation suppressor holes.

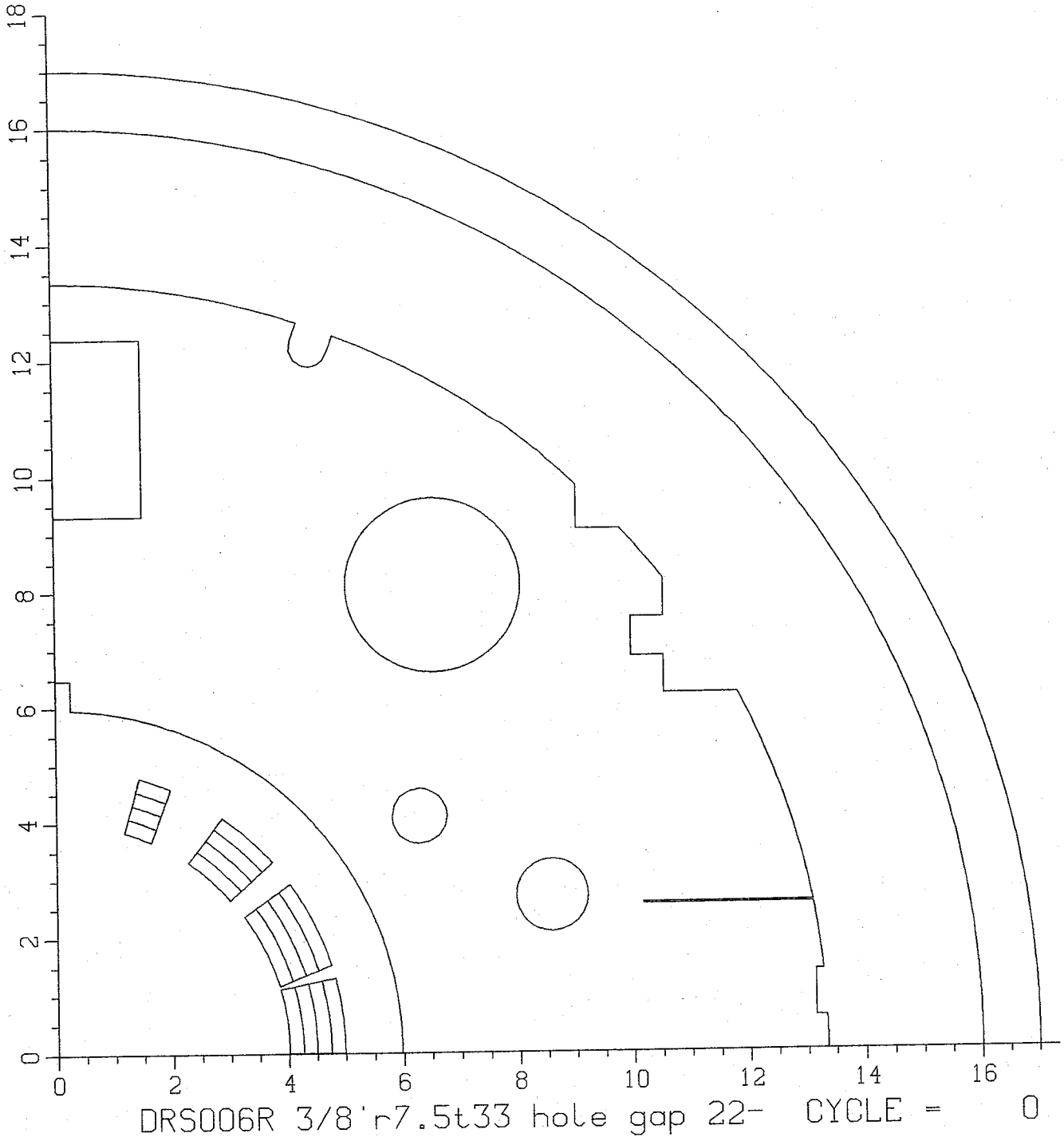

Figure 3: The POISSON model used in the calculations of the magnet DRS006-Rebuild is shown here. A 10 mil gap at Y = 1″ is assumed from X = 4″ to the outer radius of the yoke.

Computed, Measured and Expected bn' in DRS006R with hole

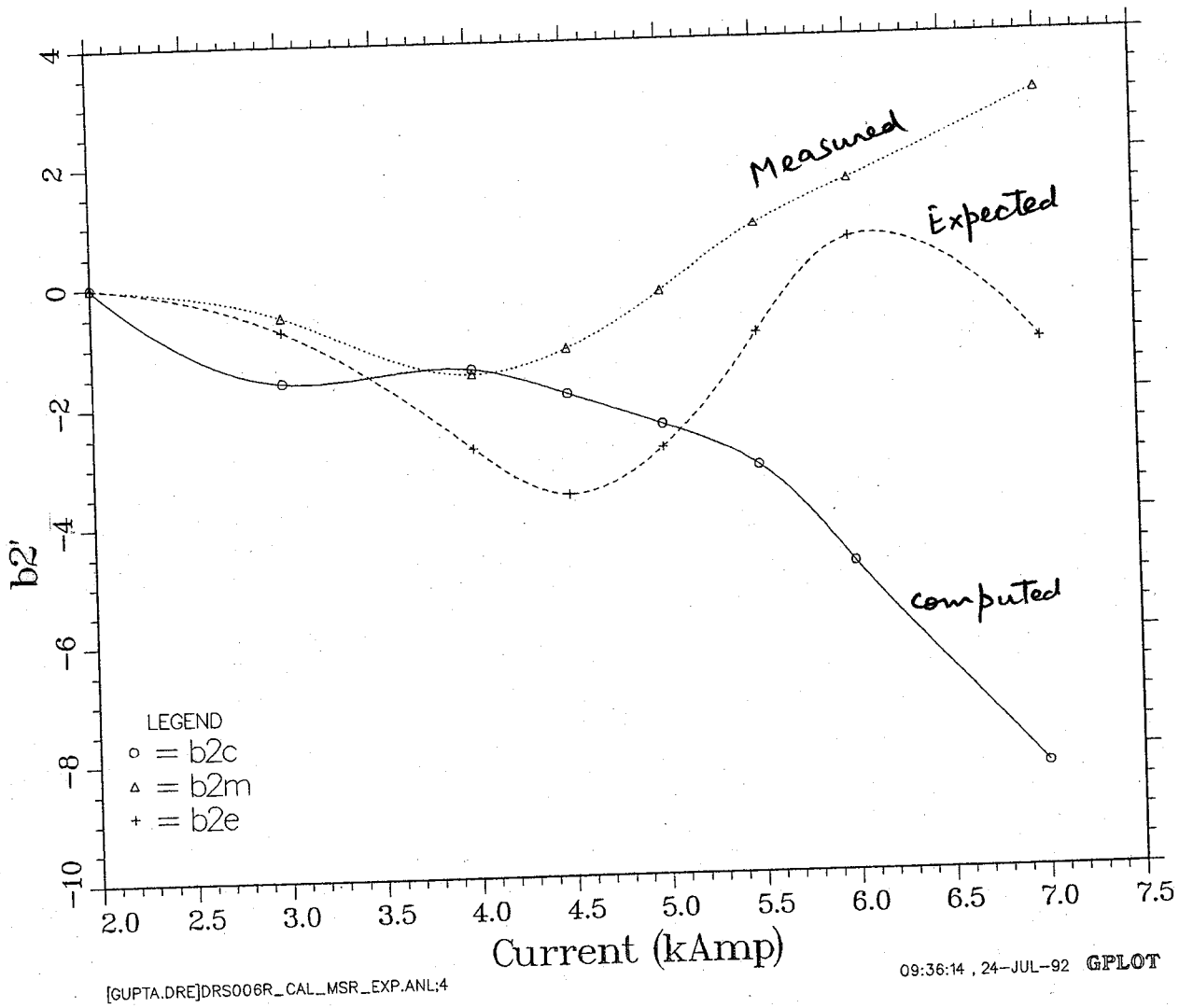

Figure 4: The measured, expected and computed (only iron saturation) current dependence of the field harmonic b_2 in the magnet DRS006 with saturation suppressor holes.

Computed, Measured and Expected bn' in DRS006R with hole

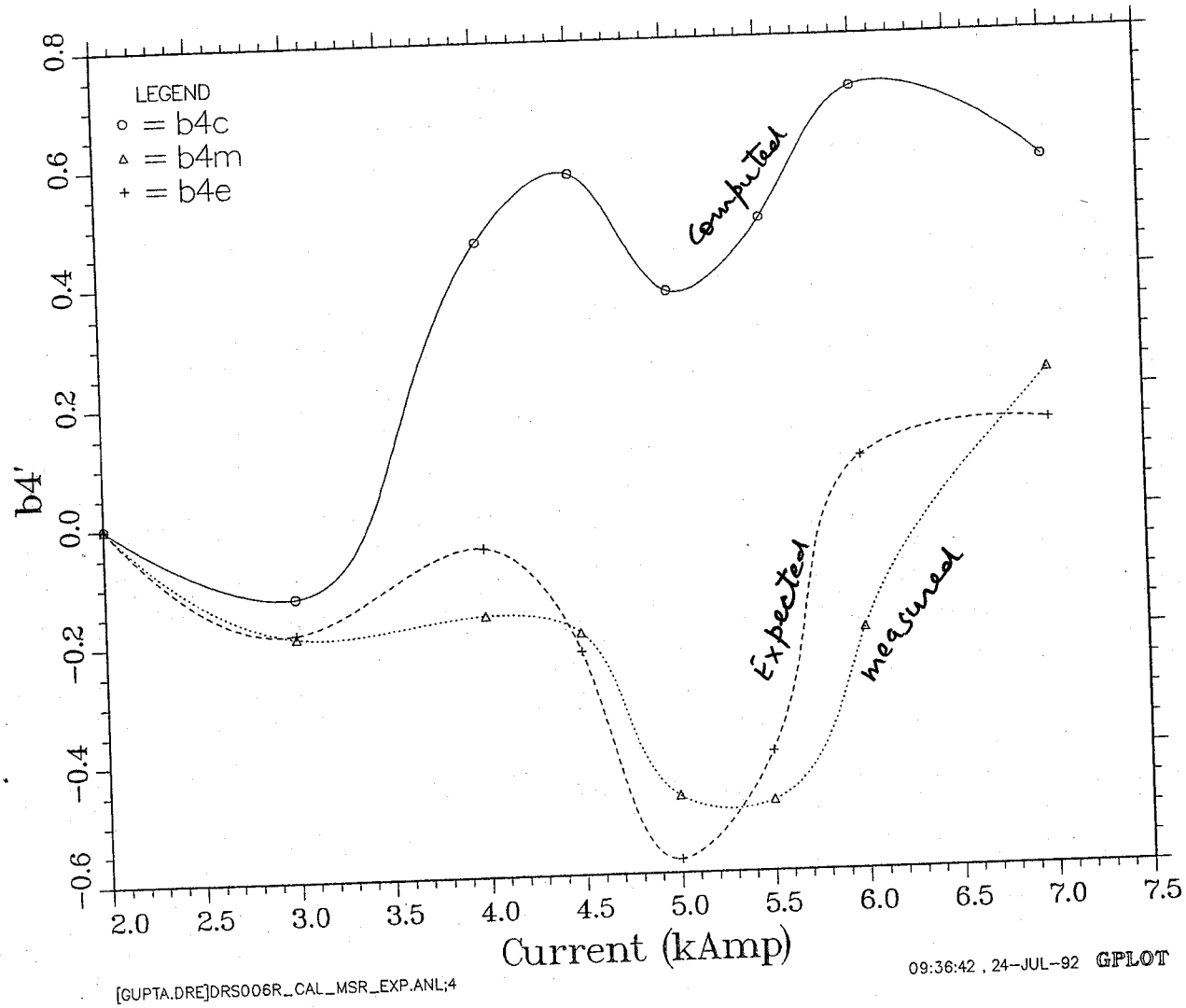

Figure 5: The measured, expected and computed (only iron saturation) current dependence of the field harmonic b_4 in the magnet DRS006 with saturation suppressor holes.

Computed, Measured and Expected bn' in DRS006R with hole

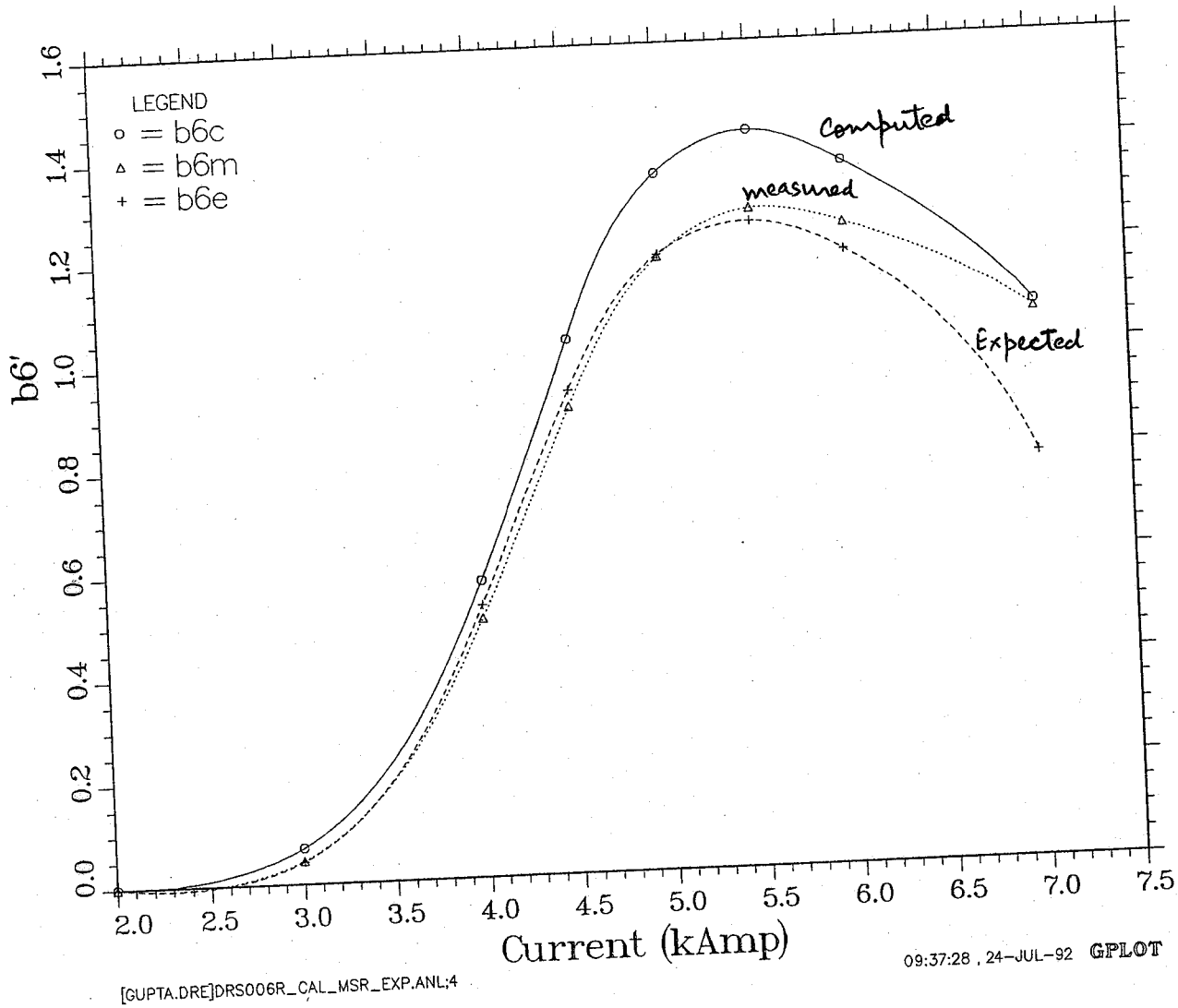

Figure 6: The measured, expected and computed (only iron saturation) current dependence of the field harmonic b_6 in the magnet DRS006 with saturation suppressor holes.

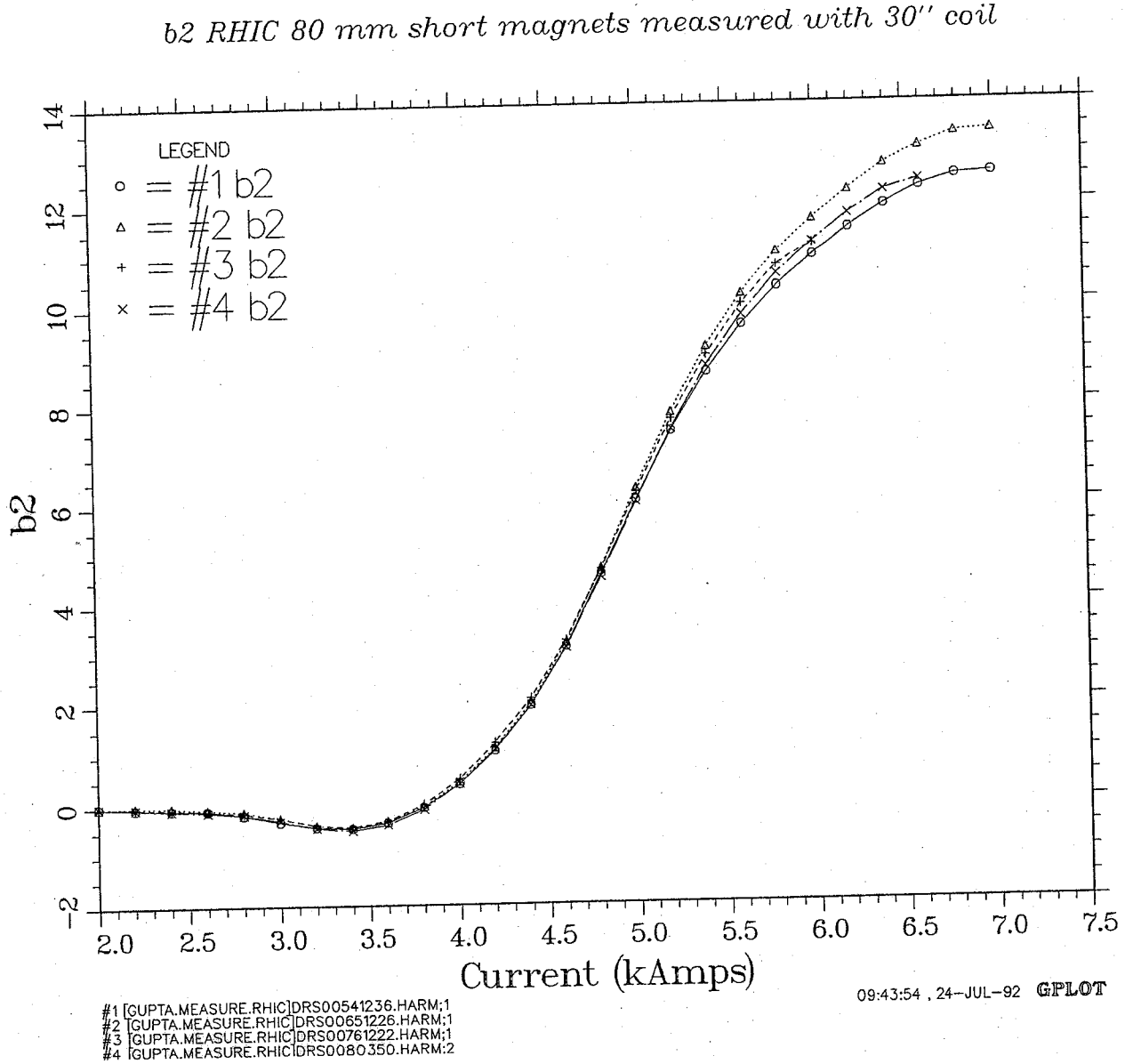

Figure 7: The measured current dependence of the field harmonic b_2 in the RHIC short dipoles DRS005, DRS006, DRS007 and DRS008 without saturation suppressor holes.

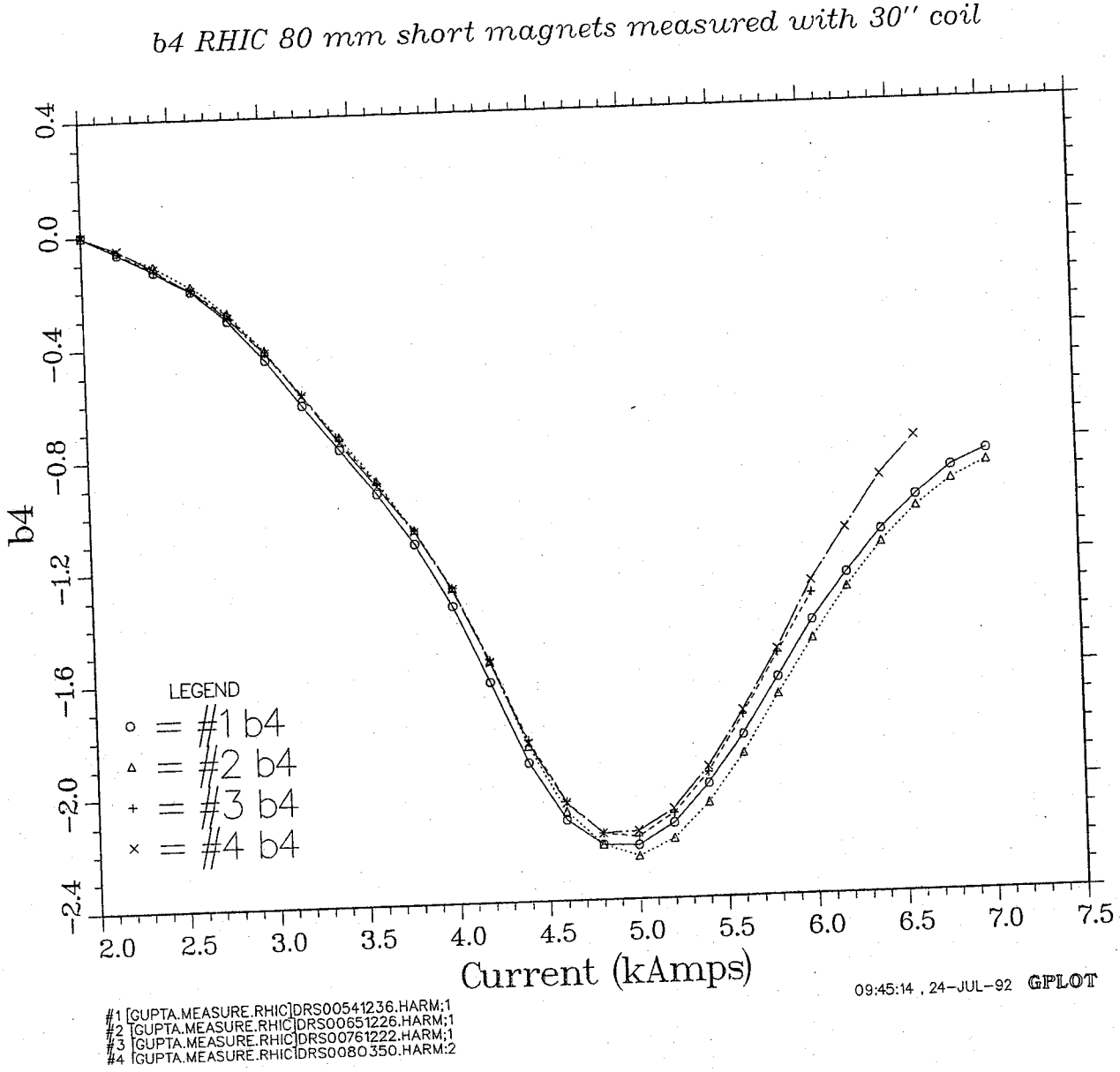

Figure 8: The measured current dependence of the field harmonic b_4 in the RHIC short dipoles DRS005, DRS006, DRS007 and DRS008 without saturation suppressor holes.

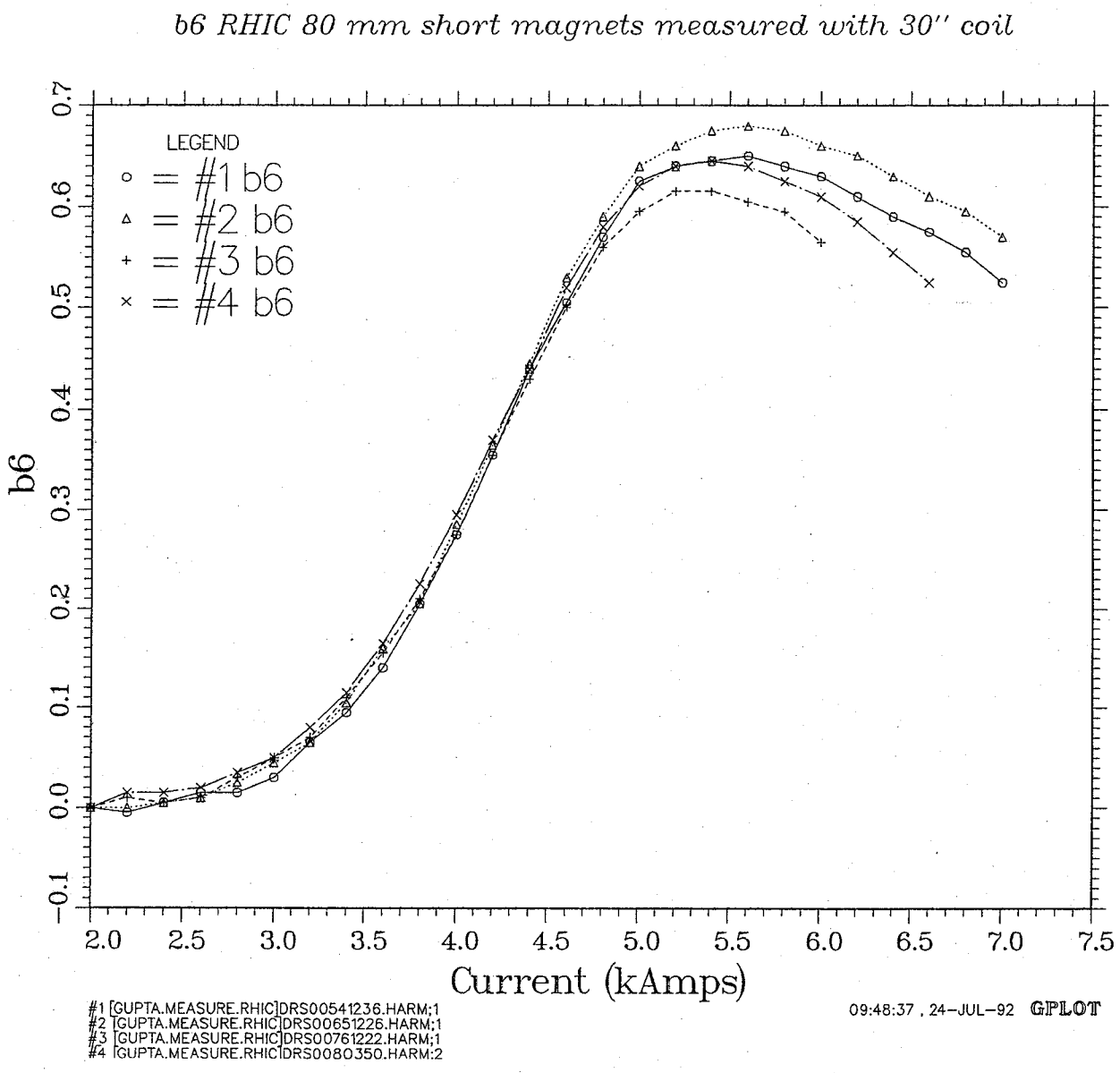

Figure 9: The measured current dependence of the field harmonic b_6 in the RHIC short dipoles DRS005, DRS006, DRS007 and DRS008 without saturation suppressor holes.