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SUMMARY OF THE MAGNETIC MEASUREMENTS FOR THE SHORT BOOSTER QUADRUPOLES

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U.S. Department of Energy

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SUMMARY OF THE MAGNETIC MEASUREMENTS FOR THE SHORT BOOSTER QUADRUPOLES

BOOSTER TECHNICAL NOTE
NO. 226

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August 15, 1995

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INTRODUCTION

This note summarizes the results of the measurements on the 25 AGS Booster short quadrupole magnets. The measurements were carried out by the Magnet Division Measurements Group in 1990, and a preliminary report which included details of the magnets was given in Booster Technical Note No. 174.

RESULTS

The nomenclature for this note is:

$$B_y\,(X) = B_0 + B_1 * X + B_2 * X^2 + B_3 * X_3 + \ \ldots$$

$$B_x(X) = A_0 + A_1 * X + A_2 * X^2 + A_3 * X_3 + \ \ldots.$$

In a quadrupole the only allowed terms are B_1, B_5, etc. All the other terms should be zero. The data was taken with a long coil so the data is reported as $B_n * L_{eff}$.

Figure 1 shows the measured quadrupole field divided by I at I = 2500 Amps for each of the magnets. This plot emphasizes that magnet numbers 1 and 2 differ from the other magnets. These results were noted when they were initially measured and no explanation was found even though magnet 2 was rechecked dimensionally both before and after a recompression. We might assume the magnet iron was different for these two magnets, but we have no hard evidence for the source of this problem. For the rest of this note we shall do a statistical analysis on the 23 latter magnets. Figure 2 shows a histogram of these results with a curve fitted to the 23 magnets.

Figures 3 through 8 show similar plots for higher order terms. Table 1 summarizes these results. Several observations from Table 1 are:

1. The quality control of the construction is very good. The measured random error for the harmonic terms in these magnets is typically one to two orders of magnitude smaller than the specified tolerance for machine operation.

2. The average value for all the forbidden terms, except for A_3, is within one standard deviation of zero. The measured average value for A_3 is significantly

different from zero but that can be attributed to the effect of the earth's magnetic field on the long measuring coil.

3. The allowed term, B_5, is slightly different from zero, but is still 2 orders of magnitude smaller than the allowed systematic error for B_5.

Figure 9 shows the B_5 and A_5 terms versus magnet number. This plot suggests that about the middle of the production run something changed, but it was a very small effect and we have no explanation.

Table 2 lists the magnets by serial number, their positions in the Booster ring, the field strength for each magnet, and the percentage deviation from the average for each magnet. The standard deviation of the random errors for the quadrupole field for the 23 magnets is 4.4 parts in ten thousand, one half the allowed random error. If magnets 1 and 2 are included in the analysis the standard deviation of the measured random error is 30% larger than the allowed error. At the time of construction it was decided to go ahead despite this problem since it would not produce a problem for machine operations. The higher order terms for Magnets 1 and 2 are in good agreement with those of the other magnets.

TABLE 1

Summary of Harmonics

Bn/B1	Units	Avg	Std	Allowed Tolerance
B2/B1	cm ^ −1	−1.4E−06	1.52E−05	1.20E−04
B3/B1	cm ^ −2	−7.0E−07	2.20E−06	8.70E−04
B4/B1	cm ^ −3	3.9E−08	1.86E−07	2.50E−05
B5/B1	cm ^ −4	2.0E−07	1.41E−07	1.20E−05

An/A1	Units	Avg	Std	Allowed Tolerance
A2/A1	cm ^ −1	−6.9E−06	1.47E−05	1.20E−04
A3/A1	cm ^ −2	−9.4E−06	1.21E−06	8.70E−04
A4/A1	cm ^ −3	−8.9E−08	2.27E−07	2.50E−05
A5/A1	cm ^ −4	−1.0E−07	1.18E−07	1.20E−05

TABLE 2

Booster Short Quadrapole
Positions and Strengths

Magnet number BMQ	Position in ring	B/I @ 2500 Amps G*m/(cm*A)	% dev from avg
1	D4	0.090725	−0.3639
2	C8	0.090597	−0.5041
3	E2	0.091017	−0.0432
4	D2	0.091057	0.0012
5	D8	0.09105	−0.0068
6	E4	0.091043	−0.0142
7	A8	0.091066	0.0107
8	E8	0.091087	0.0336
9	C2	0.09105	−0.0065
10	F2	0.091086	0.0328
11	E6	0.091092	0.0397
12	B4	0.091091	0.0380
13	B8	0.091026	−0.0332
14	B2	0.091087	0.0342
15	B6	0.091053	−0.0030
16	F8	0.091126	0.0772
17	D6	0.091103	0.0512
18	A4	0.091107	0.0559
19	A2	0.090973	−0.0916
20	C6	0.090961	−0.1043
21	A6	0.091007	−0.0537
22	C4	0.091057	0.0010
23	F4	0.091044	−0.0130
24	F6	0.091027	−0.0316
25	*G.C.	0.091079	0.0254

B1	for 23 magnets	
Average	=	0.091056
Std	=	0.00004

*G.C. = gauss clock

FIGURE 1

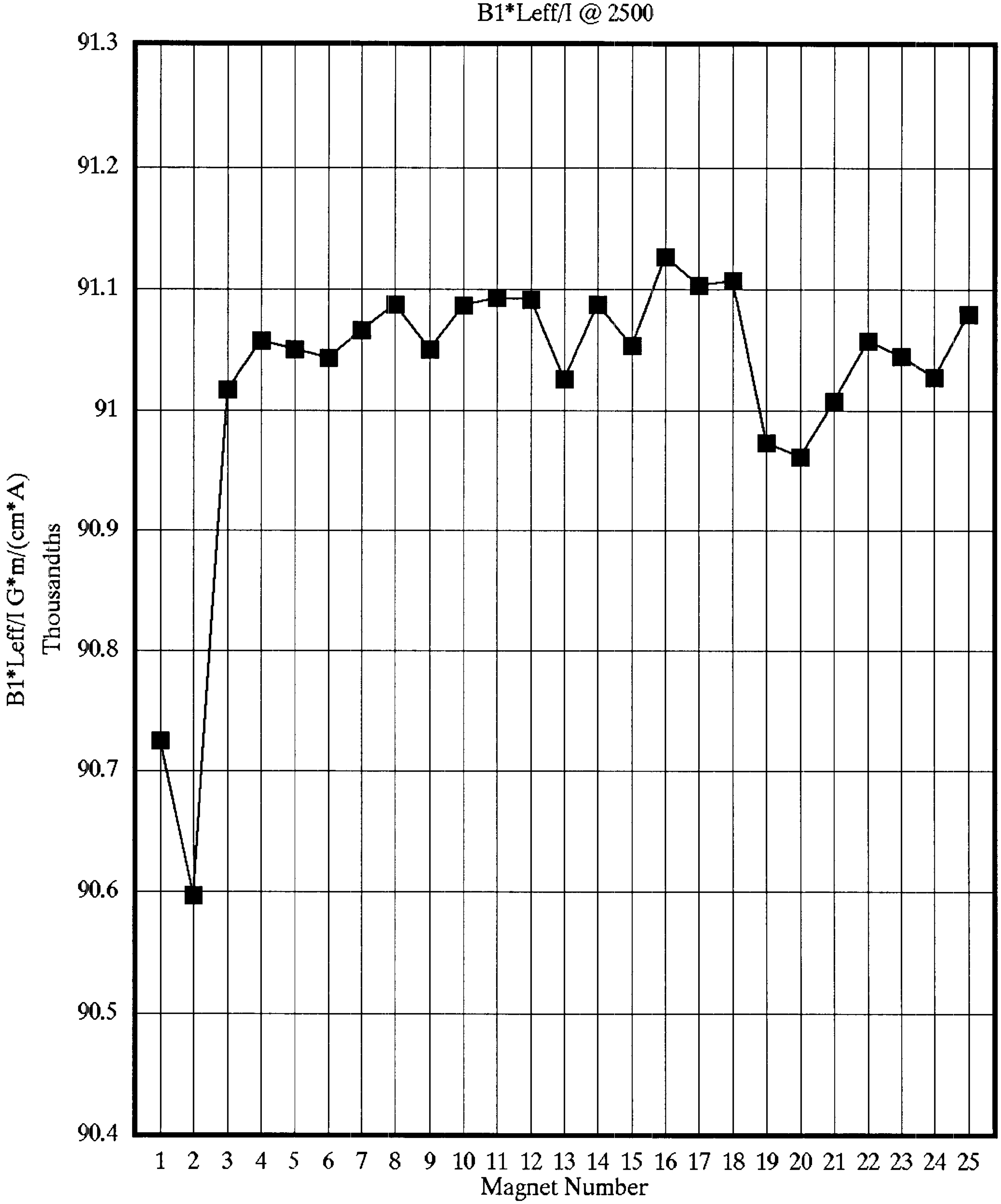
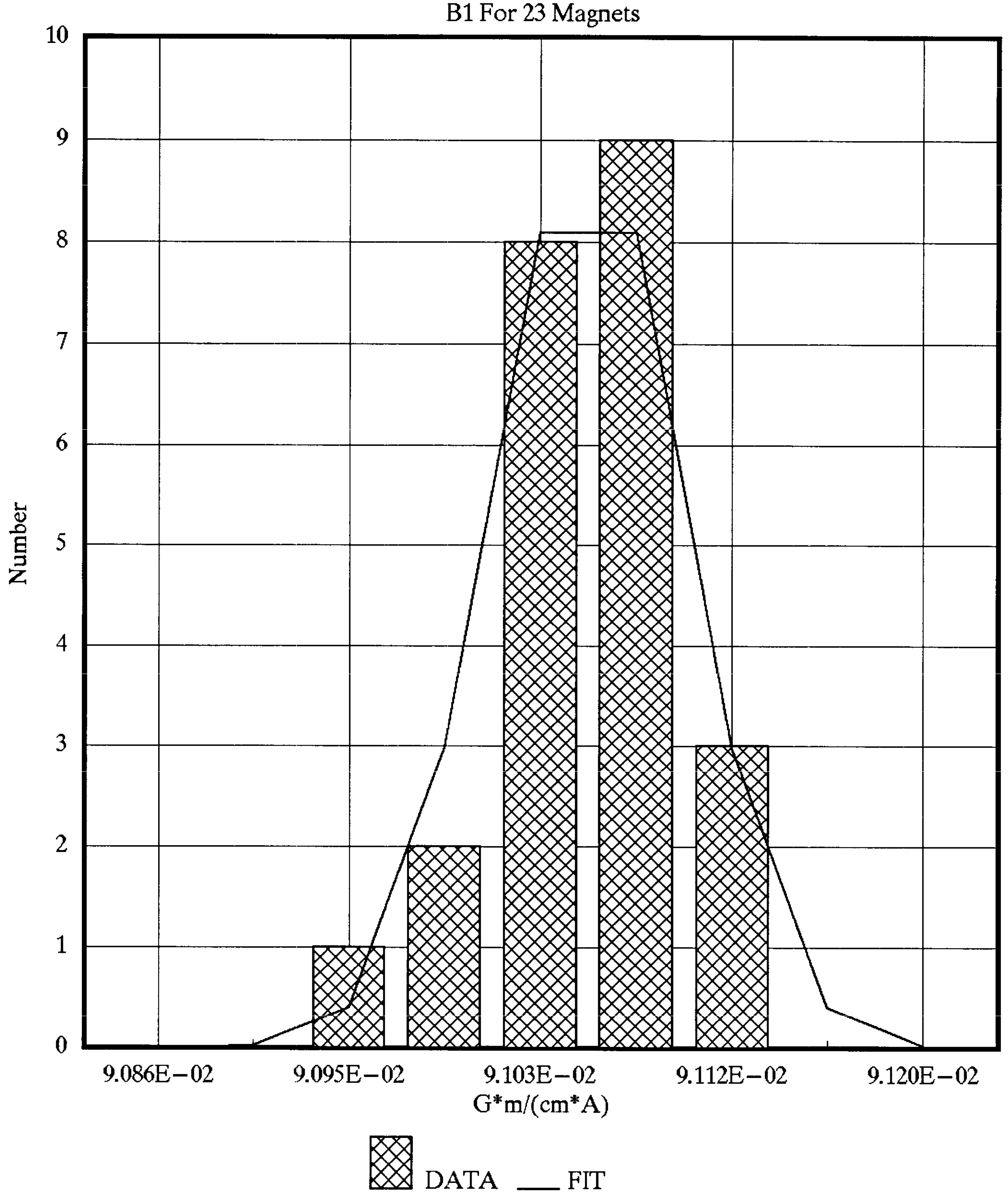

B1*Leff/I @ 2500
91.3
91.2
91.1
91
90.9
90.8
90.7
90.6
90.5
90.4
B1*Leff/I G*m/(cm*A)
Thousandths
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Magnet Number

FIGURE 2



B1 For 23 Magnets
Number
10
9
8
7
6
5
4
3
2
1
0
9.086E−02
9.095E−02
9.103E−02
9.112E−02
9.120E−02
G*m/(cm*A)
DATA
FIT

FIGURE 3

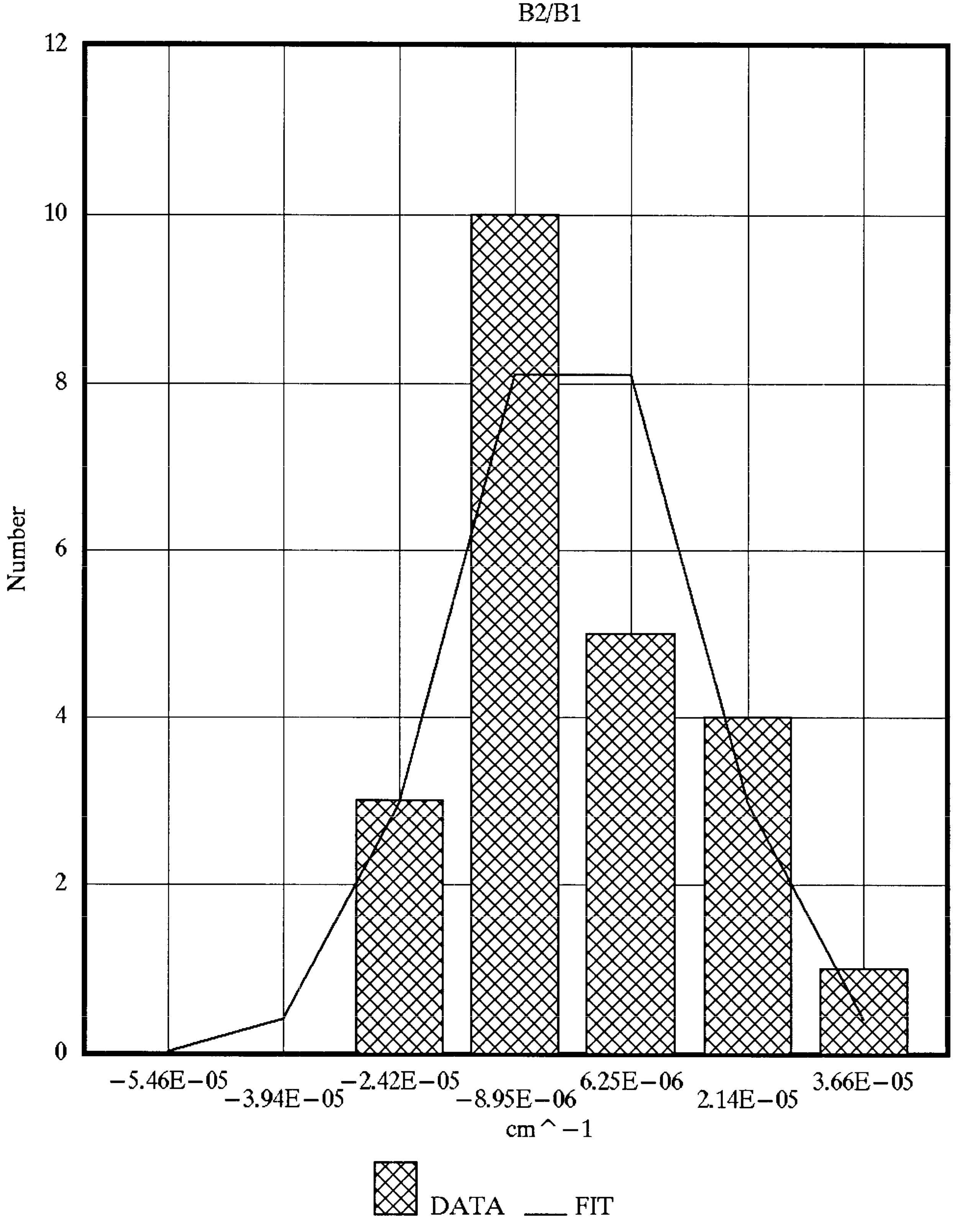

B2/B1
Number
12
10
8
6
4
2
0
−5.46E−05
−3.94E−05
−2.42E−05
−8.95E−06
6.25E−06
2.14E−05
3.66E−05
cm ^ −1
DATA
FIT

FIGURE 4

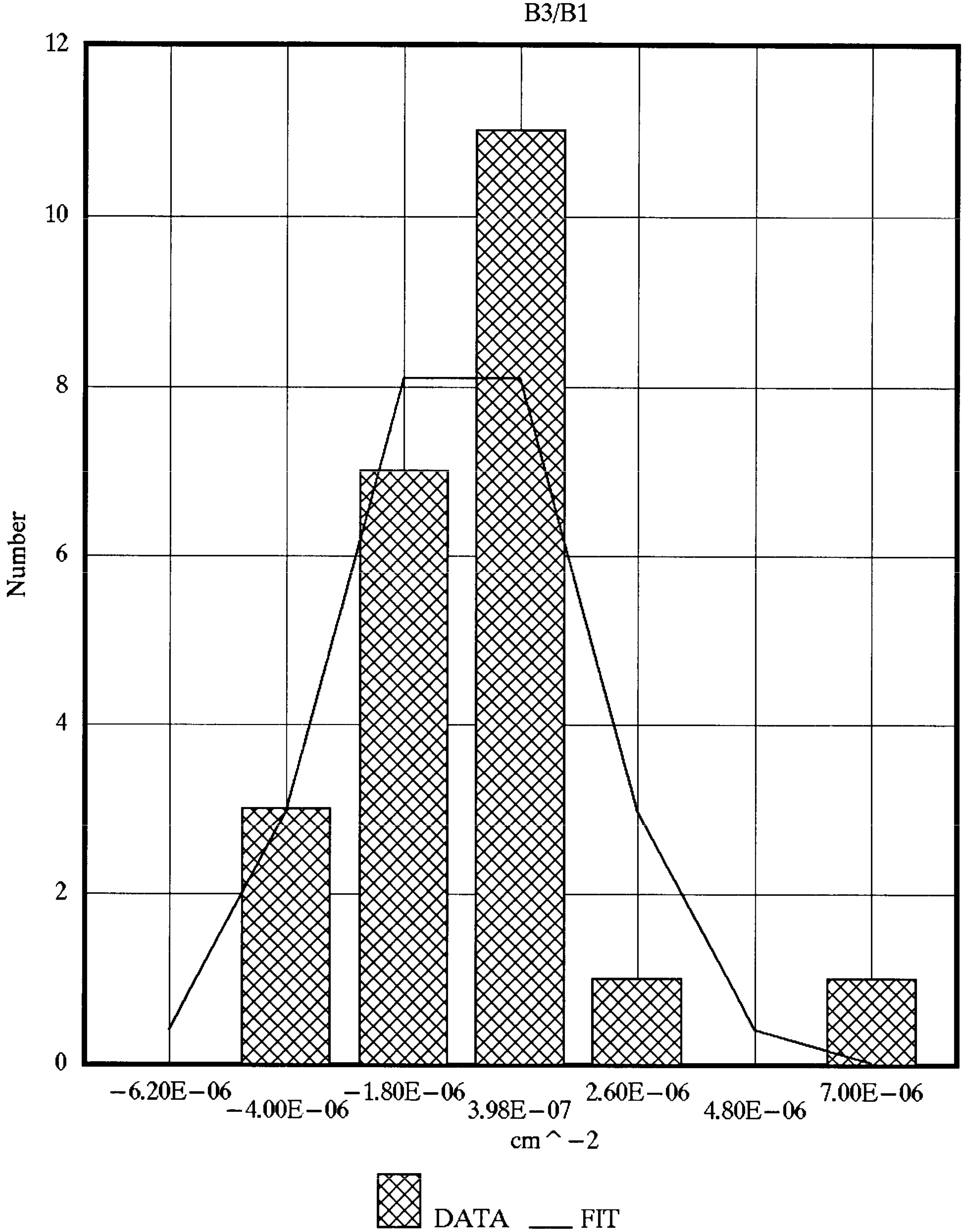

B3/B1
12
10
8
6
4
2
0
Number
−6.20E−06
−4.00E−06
−1.80E−06
3.98E−07
2.60E−06
4.80E−06
7.00E−06
cm ^ −2
DATA
FIT

FIGURE 5

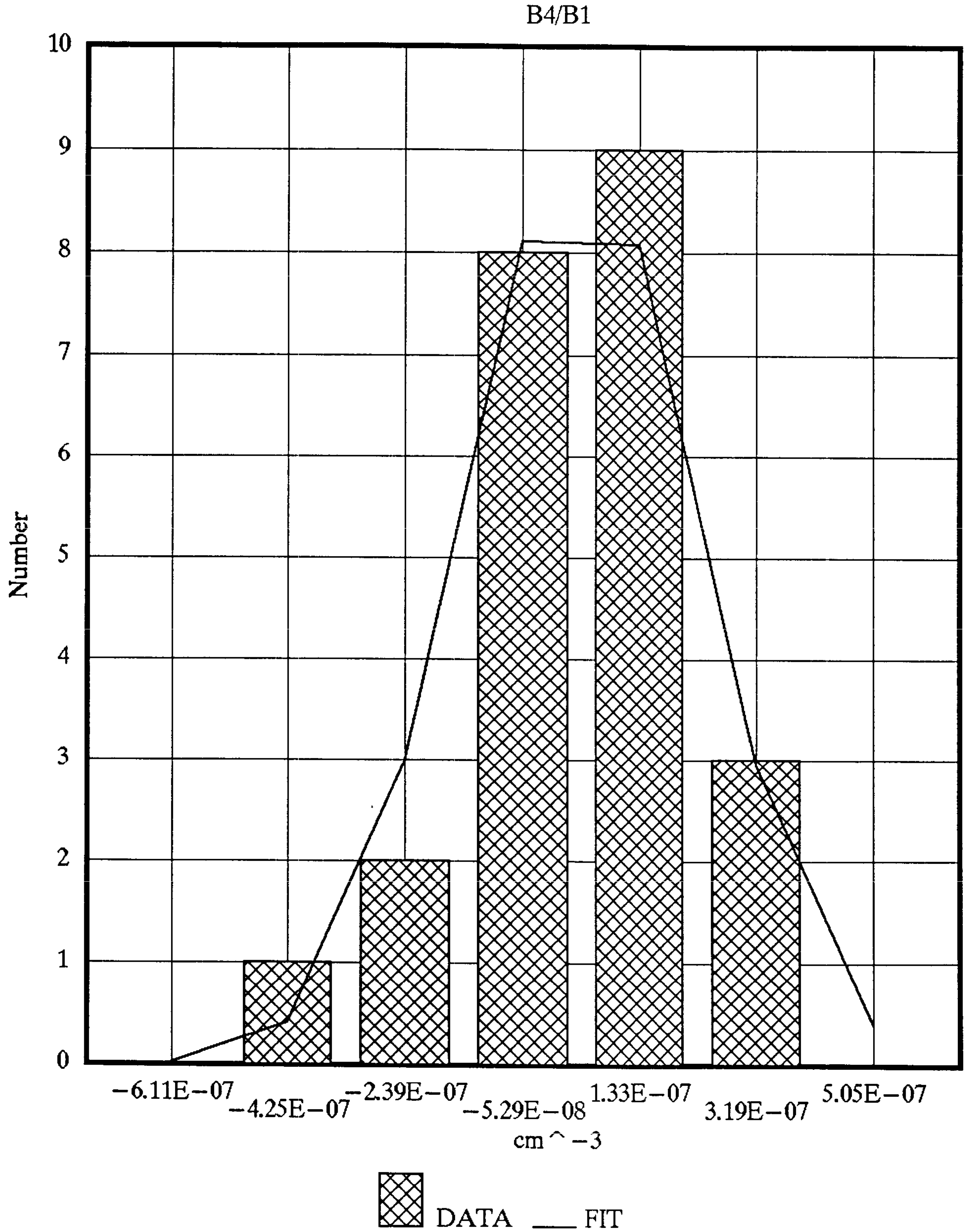

B4/B1
10
9
8
7
6
5
4
3
2
1
0
Number
-6.11E-07
-4.25E-07
-2.39E-07
-5.29E-08
1.33E-07
3.19E-07
5.05E-07
cm ^ -3
DATA
FIT

FIGURE 6

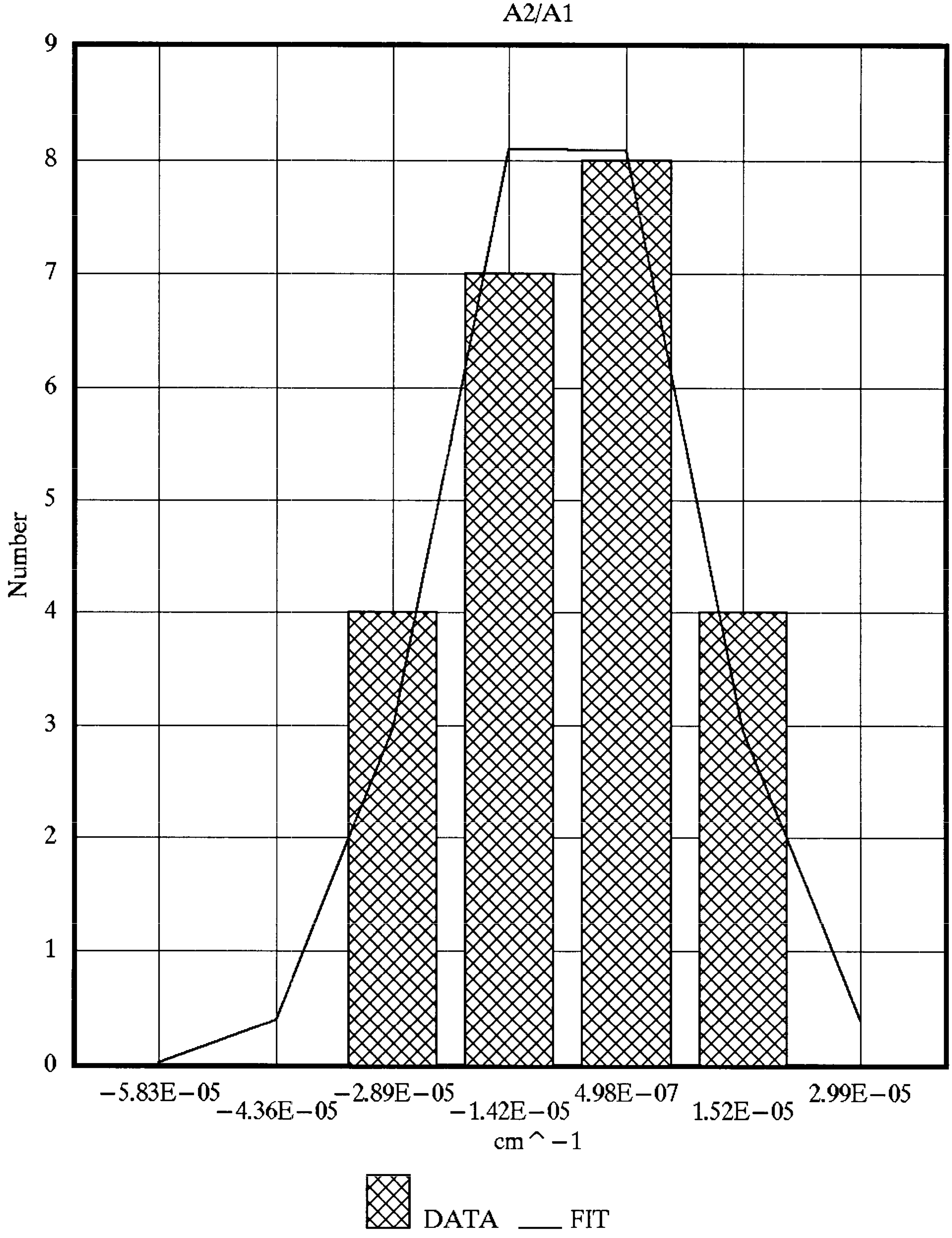
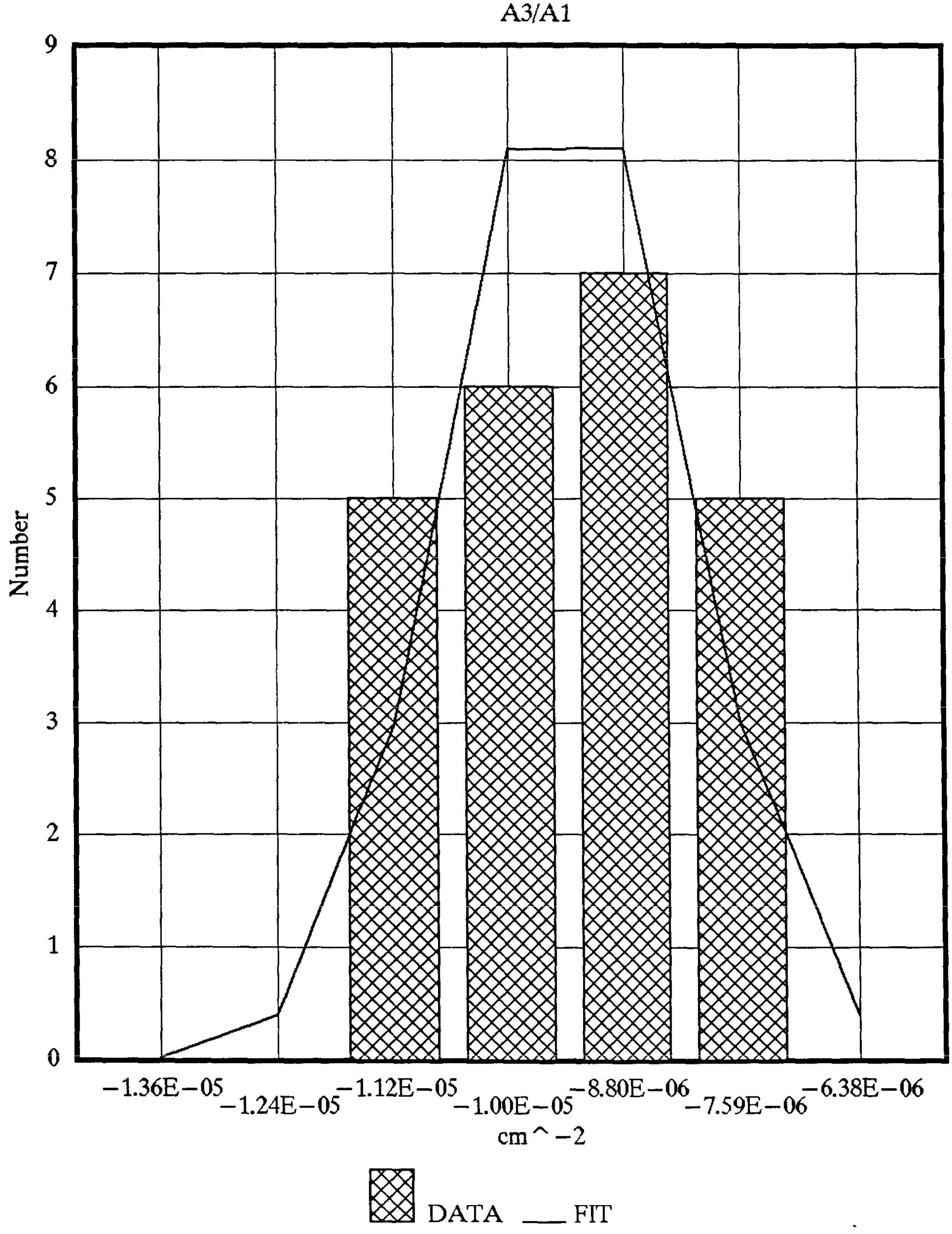
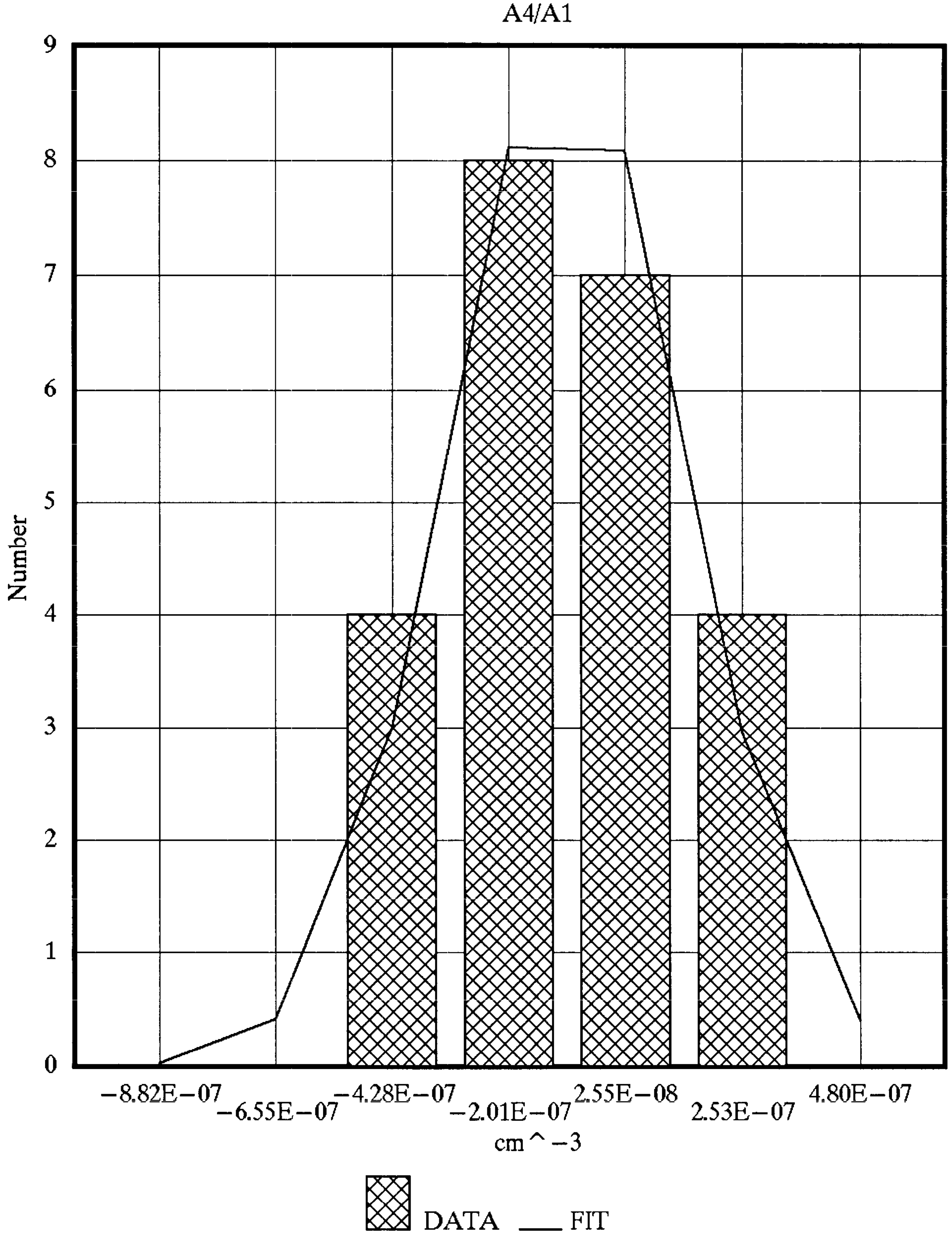

A2/A1
9
8
7
6
5
4
3
2
1
0
Number
−5.83E−05
−4.36E−05
−2.89E−05
−1.42E−05
4.98E−07
1.52E−05
2.99E−05
cm ^ −1
DATA
FIT

FIGURE 7



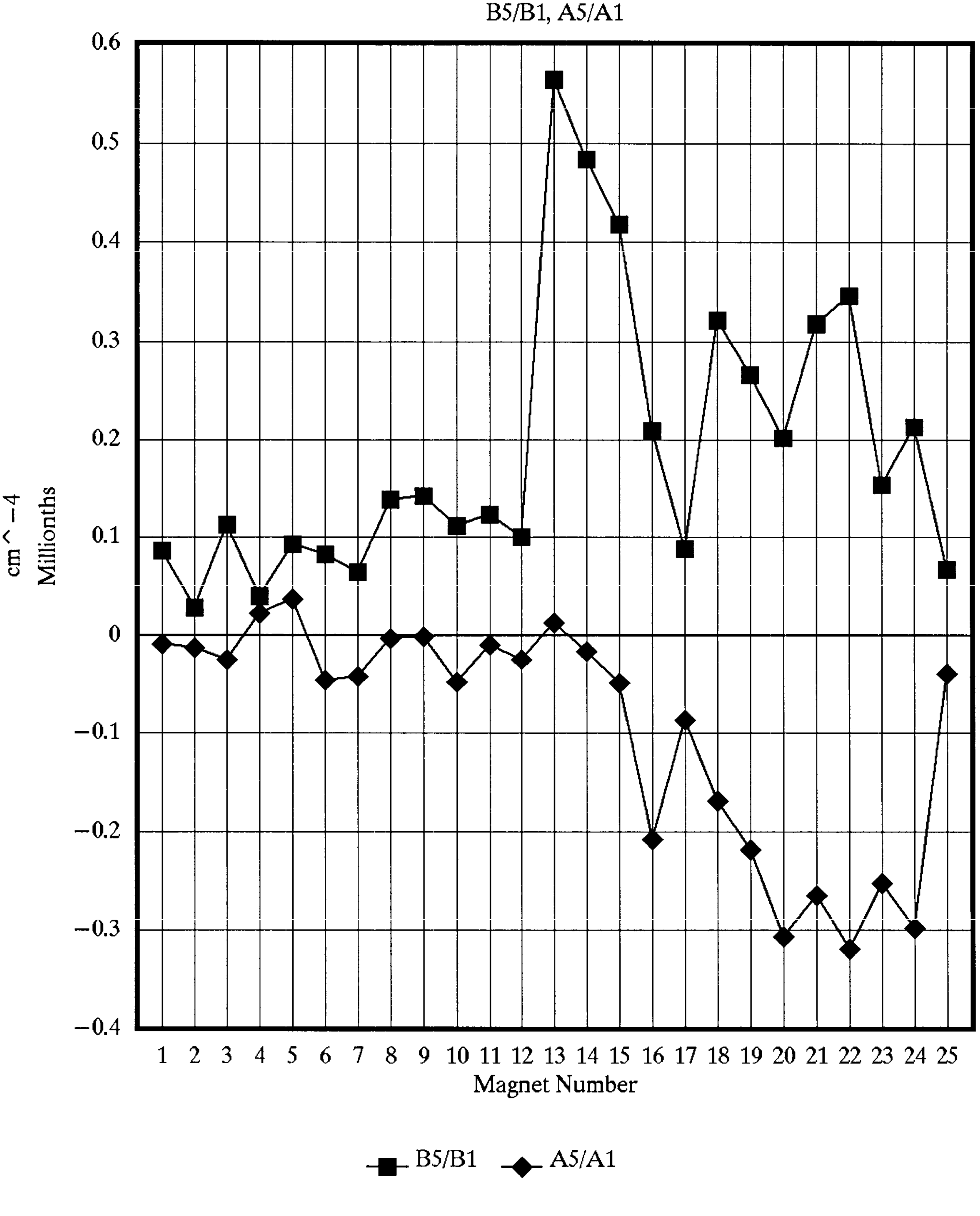
A3/A1
Number
9
8
7
6
5
4
3
2
1
0
−1.36E−05
−1.24E−05
−1.12E−05
−1.00E−05
−8.80E−06
−7.59E−06
−6.38E−06
cm ^ −2
DATA
FIT

FIGURE 8



A4/A1
9
8
7
6
5
4
3
2
1
0
Number
−8.82E−07
−6.55E−07
−4.28E−07
−2.01E−07
2.55E−08
2.53E−07
4.80E−07
cm ^ −3
DATA
FIT

FIGURE 9


B5/B1, A5/A1
0.6
0.5
0.4
0.3
0.2
0.1
0
−0.1
−0.2
−0.3
−0.4
cm ^ −4
Millionths
1 2 3 4 5 6 7 8 9 10 11 12 13 14 15 16 17 18 19 20 21 22 23 24 25
Magnet Number
B5/B1
A5/A1