

b Physics at RHIC

F. Paige

Brookhaven National Laboratory

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Frank E. Paige

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In high energy hadronic collisions, b mesons are produced primarily by gluon-gluon fusion,

$$g + g \rightarrow b + \bar{b}. \quad (1)$$

At SSC energies this cross section is several hundred microbarns, making it potentially possible to study samples of 10^{12} b mesons to search for rare decays, CP violation, and other new phenomena with sensitivities not achievable in e^+e^- collisions. This was extensively discussed for the SSC in Snowmass 86, especially in the group headed by B. Cox and F. Gilman. There was much more optimism than previously, in part because people now believe it may be possible to use microvertex detectors at high luminosity and in part because it was realized that some rare, KM-suppressed decay modes have large CP-violating partial rate asymmetries.

The pp option of RHIC might offer an opportunity to do similar physics. However, at the lower energy the cross section calculated for the process in Eq. (1) is significantly lower, as is seen in the following table:

Collider	\sqrt{s} (GeV)	σ (μb)	L (cm^{-2})	$N_{b\bar{b}}$ (yr^{-1})
RHIC	500	5.8	2×10^{31}	1.2×10^9
RHIC*	600	7.6	10^{32}	7.6×10^9
SSC	40000	460.	10^{33}	4.6×10^{12}

* Includes UPGRADES DESCRIBED IN THE CONCEPTUAL DESIGN REPORT.

Because of QCD scaling violations, the EHLQ parameterization of the gluon structure function at the typical value $x = 2m_b/\sqrt{s}$ increases by a factor of 5 to 10 over this energy range; the rapidity distribution also becomes wider. It should be realized, however, that the gluon structure function is not known for the important values of x , especially for the SSC.

The following histograms show a number of distributions of the b mesons and of their decay products for RHIC at the two energies and for the SSC. Histogram 101 shows the p_T distribution; the mean value is of order m_b , as expected. Histogram 102 shows the rapidity distribution for the b mesons. The distribution is quite wide at the SSC; the feeling at Snowmass was that it was better to work at moderately large rapidity to facilitate lepton identification. The distribution at RHIC is more central, and any experiment probably should be done at 90° . Histogram 103 shows the difference in the rapidities of the two b mesons in each event; for some measurements of CP-violation it is necessary to detect both. Histogram 104 shows a scatter plot of the two rapidities. Histogram 112 shows the maximum rapidity of any decay product from a b meson. Histogram 113 shows the difference between the minimum and the maximum rapidity, i.e., the range of rapidity covered by the decay products. The mean value is about 2 units, meaning that any useful detector must cover a range of this order. Histogram 114 shows the same information as a scatter plot.

In summary, the SSC has a substantial advantage over RHIC both in cross section and in luminosity for rare b decays and similar physics. Detection of standard-model CP-violation is difficult at the SSC and probably impossible at RHIC. But RHIC would offer a potential advantage over existing e^+e^- machines. To realize that advantage, it is probably necessary to build a detector covering at least $\Delta y = \pm 1$ and $\Delta\phi = 2\pi$ with high-resolution microvertex detectors, very good tracking and electromagnetic calorimetry, and sufficient hadronic calorimetry to allow a first-level trigger on a jet with $p_T \sim 10$ GeV. It would clearly be advantageous to increase the luminosity.

* ENTRIES = 4000
* BIN WID = .5000E+00

* ALL CHANNELS = 3E-01
* MEAN VALUE = -3E+01

* UNDERFLOW = .0000E+00
* R . M . S = .2599E+01

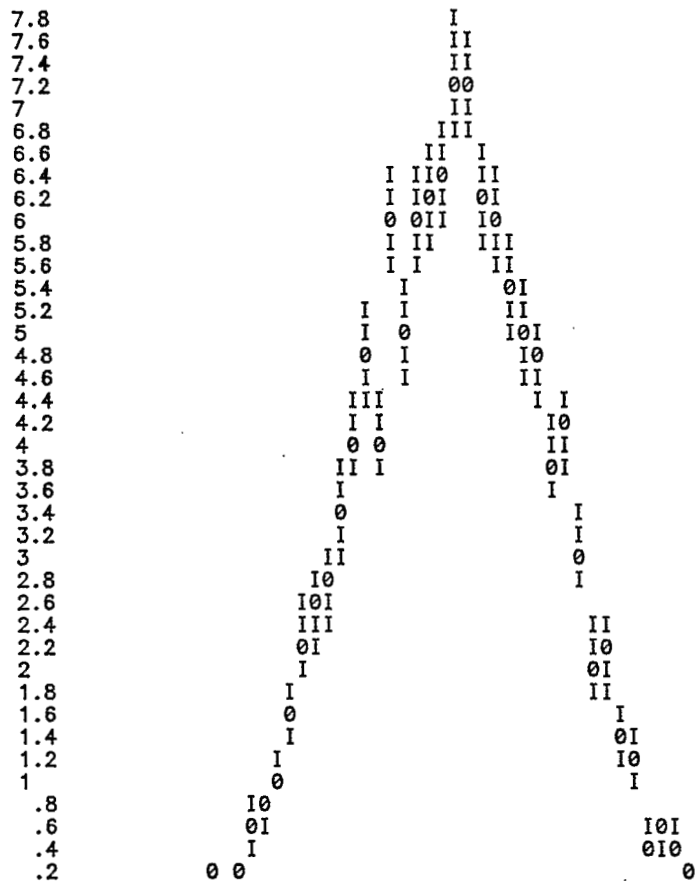
* OVERFLOW = .2376E-05
* ABNOR CHA= .0000E+00

* ENTRIES = 4002
* BIN WID = .5000E+00

* ALL CHA_S = .9134E+00
* MEAN VAL = .5197E+01

* UNDERFLOW = .0000E+00
* R . M . S = .3526E+01

* OVERFLOW = .1686E-02
* ABNOR CHA= .0000E+00



CHANNELS 10 0 1 2 3 4 5
 1 12345678901234567890123456789012345678901234567890

CONTENTS 1. 122233435456677655443421211
 *10** 4 0 00000000046941463969989121119396709902134300000000
 0 00000040490976311939575265002230602948433650000000
 0 000000000951170649417723352527693221927971700000000
 0 00000020292831411182372268662204653038510770000000

LOW-EDGE 1. 5444443333222211111 1111122222333344444
 0 08642086420864208642086420246802468024680246802468

* ENTRIES = 4000 * ALL CHANNELS = .1155E-01 * UNDERFLOW = .0000E+00 * OVERFLOW = .0000E+00
 * BIN WID = .2000E+00 * MEAN VALUE = .1673E-01 * R . M . S = .1319E+01 * ABNOR CHA= .0000E+00


```

2.9      I
2.85     I
2.8      I
2.75     I I
2.7      I I
2.65     I 0
2.6      II I
2.55     III I
2.5      I0I I I
2.45     I III I I
2.4      I I II0 I I
2.35     I I I III I
2.3      I I I 0II I
2.25     I I IIIIII 0
2.2      I 0 0II II I
2.15     I II III II I
2.1      0IIIIIII I II I
2.05     IIIIII0 I III II
2        I IIIIII 0 II II
1.95     II II0III I II IIII
1.9      II I0I 0 I I I0 I0II
1.85     III II I I I I0I 0III
1.8      II0 II I I III IIII
1.75     I I0I II I III III00
1.7      I IIII I I III IIIII
1.65     III0III 0I 0IIII I
1.6      IIIIII I I II I I
1.55     I I 0IIIII0 I I III I
1.5      I I I00I I I I III I
1.45     I I III I I I0II II I
1.4      I 0 III I 0III 0II I
1.35     0 I III I I I0I III I
1.3      I I II III0II0III
1.25     IIIIIIII I IIIII010
1.2      IIIIIIII I III IIII
1.15     I I III I II0 II0II
1.1      II0 000 0 I IIIIII
1.05     III III I I I 0II
1        0II III I I I III
.95     I0I III I I I0I
.9      II I I I0
.85     II I II
.8      I II
.75     I I

```

CHANNELS 10 0 1 2 3 4 5
1 12345678901234567890123456789012345678901234567890

CONTENTS 1. 1111111111111121121222221211121111111111111111111
*10** 2 0 99030003054467750891810243966882688773432132212098
0 72635886826642508827671995832373025405417287204316
0 65664471111147059390086207306390512271228420486046
0 91271915198884644314817702100855115306503651319977

LOW-EDGE 1. 54444433333222211111 111112222333344444

0 08642086420864208642086420246802468024680246802468

* ENTRIES = 4002 * ALL CHANNELS = .7878E+00 * UNDERFLOW = .6403E-01 * OVERFLOW = .6322E-01
* BIN WID = .2000E+00 * MEAN VALUE = -.2369E-01 * R . M . S = .2544E+01 * ABNOR CHA= .0000E+00

HBOOK ID = 104

DATE 07/17/86

NO = 4

CHANNELS 10 U 0 1 2 O A
1 N 12345678901234567890 V B

```

*****
ABN * * ABN
OVE * * OVE
4.5 * * 20
4 * * 19
3.5 * * 18
3 * * 17
2.5 * * 16
2 * * 15
1.5 * * 14
1 * * 13
.5 * * 12
- .5 * * 11
- 1 * * 10
- 1.5 * * 9
- 2 * * 8
- 2.5 * * 7
- 3 * * 6
- 3.5 * * 5
- 4 * * 4
- 4.5 * * 3
- 5 * * 2
UND * * 1
*****

```

LOW-EDGE

```

1. 544332211 11223344
0 05050505050505050505

```

```

* ENTRIES = 2000
* SATURATION AT= INFINITY
* SCALE .,+,2,3,..., A,B,
* STEP = * MINIMUM=0

```

PLOT

STATISTICS

```

      I      I
-----I-----I-----
      I      I
      .006I
-----I-----I-----
      I      I

```

* CONTENT MIN = .00000E+00 MAX = .19888E-03

HBOOK ID = 104

D: 37/24/86

NO = 4

CHANNELS 10 U 0 1 2 O A
1 N 12345678901234567890 V B

```

*****
ABN * ABN
OVE * OVE
4.5 * 20
4 * 19
3.5 * 18
3 * 17
2.5 * 16
2 * 15
1.5 * 14
1 * 13
.5 * 12
- .5 * 11
- 1 * 10
- 1.5 * 9
- 2 * 8
- 2.5 * 7
- 3 * 6
- 3.5 * 5
- 4 * 4
- 4.5 * 3
- 5 * 2
UND * 1
UND * UND
*****

```

LOW-EDGE

```

1. 544332211 11223344
0 05050505050505050505

```

```

* ENTRIES = 22000
* SATURATION AT= INFINITY
* SCALE .,+,2,3 A,B,
* STEP = MINIMUM=0
* CONTENT MIN = .00000E+00 MAX = .19158E-03

```



Y1 VS. Y2 RESONS (SSC)

HBOOK = 104

DATE 07/17/86

NO = 4

CHANNELS J 0 1 2 O A
V 12345678901234567890 V B

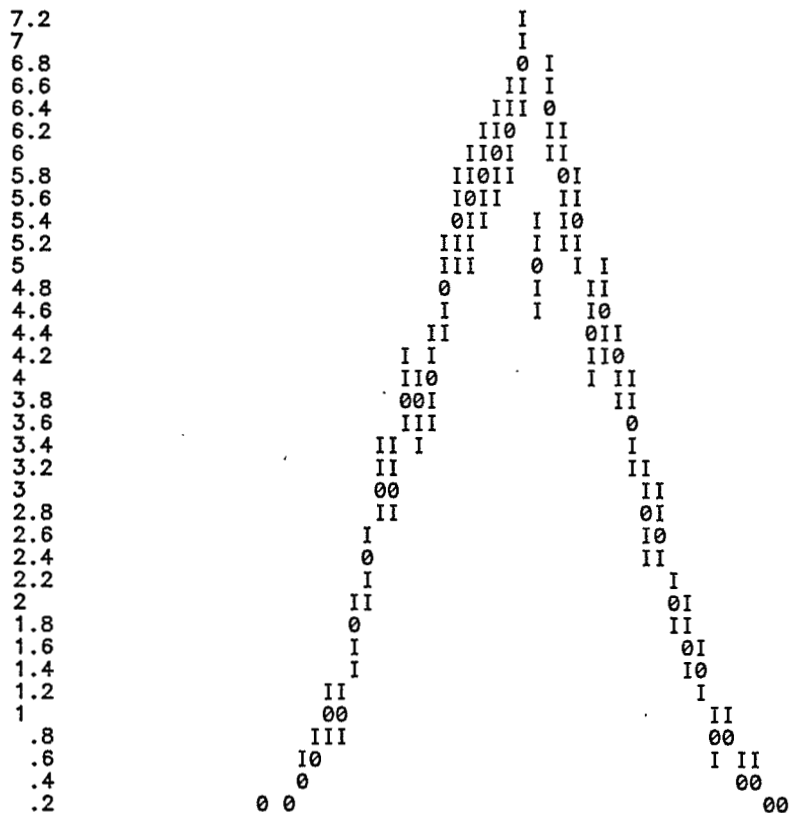
ABN			• ABN
OVE		...233 H	* OVE
4.5	+.+ 3	* 20
4		...+.+2+2 4	* 19
3.5		...+++++ 4	* 18
3		...+.+++++ 2	* 17
2.5		..+22+2222+. +	* 16
2		.+.32222.+.+. .	* 15
1.5		+.22.3++22+. .	* 14
1		...+222+2422+. .	* 13
.5		..+332222+. . . .	* 12
- .5		...+2233342+. . . .	* 11
- 1		...2223342+++ . .	* 10
- 1.5		..++2+222.+.+ .	* 9
- 2		..222422.2+. . . .	* 8
- 2.5	2+2+2222+. . .	* 7
- 3		+ . . .+32+2+.22. . . .	* 6
- 3.5		+ ++.232++2.	* 5
- 4		+ +.+++ .+++	* 4
- 4.5		2 +++ .+.	* 3
- 5		3 +22+.+.	* 2
UND		2 .2++ +.	* 1
		I 4+3+.	* UND

LOW-EDGE

544332211 11223344
050505050505050505

*
 * ENTRIES: 1999 PLOT
 * SATUR: AT= INFINITY
 * SCALE: 2,3, . . . , A,B, STATISTICS
 * STEP: .001 * MINIMUM=0
 * CONTE N = .00000E+00 MAX = .46118E-02

I	.011I	.017
I	I	I
.014I	.366I	.017
I	I	I
.018I	.013I	

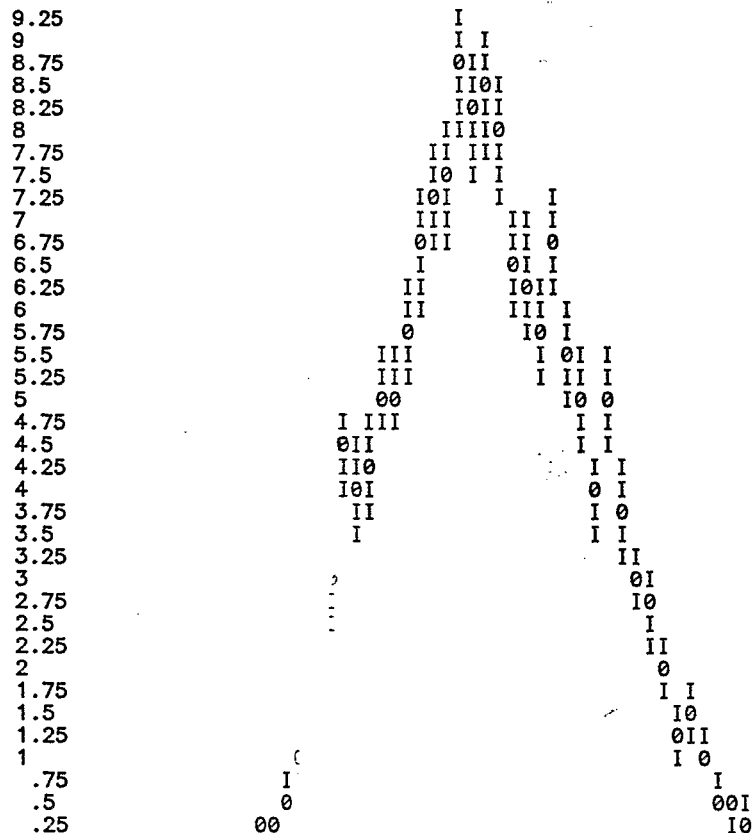


CHANNELS 10 0 1 2 3 4 5
 1 12345678901234567890123456789012345678901234567890

CONTENTS 1. 122233345555664655444322111
 *10** 4 0 00000000000013599629976973479069263350475953773300
 0 00000000004018830157454356160775814631501370696478
 0 00000000000056798677281879289555413342215828689650
 0 00000000002057626818259517788673540166758413081534

LOW-EDGE
 1. 54444433333222211111 111112222333344444
 0 08642086420864208642086420246802468024680246802468

* ENTRIES = 4000 * ALL CHANNELS = .1151E-01 * UNDERFLOW = .0000E+00 * OVERFLOW = .3793E-04
 * BIN WID = .2000E+00 * MEAN VALUE = .1006E+01 * R . M . S = .1410E+01 * ABNOR CHA= .0000E+00



CHANNELS 10 0 1 2 3 4 5
 1 1234567890123456789012345678901234567890

CONTENTS 1. 1234445677888766565434322111
 *10** 4 0 00000000010471 32819965125028426728786858049432
 0 000000000025991 6618672297572043094762746539653
 0 000000000092757 6569043276606712910068275180884
 0 00000000001782 53664500162753418995630181364944

LOW-EDGE
 1. 5444443333222 11 1111122222333344444
 0 08642086420864 -2086420246802468024680246802468

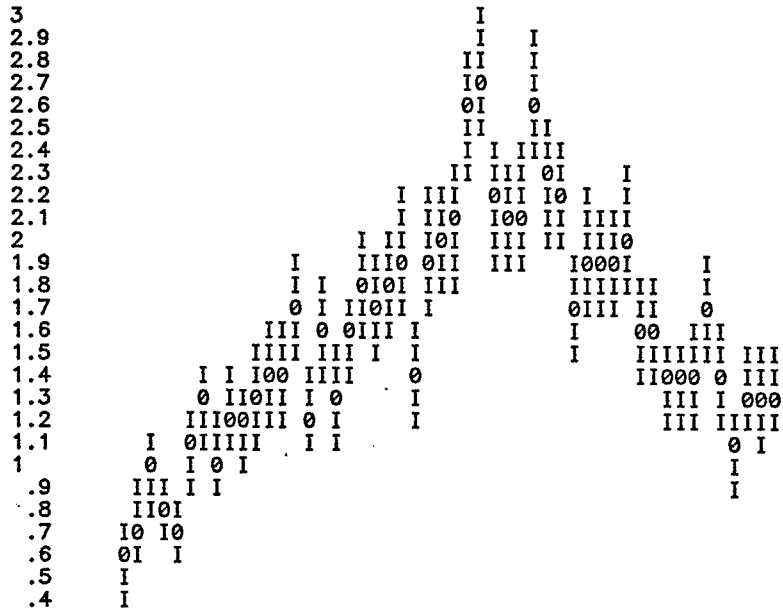
* ENTRIES = 4000 * CHANNELS = .1524E-01 * UNDERFLOW = .0000E+00 * OVERFLOW = .4110E-04
 * BIN WID = .2000E+00 * VALUE = .1002E+01 * R . M . S = .1504E+01 * ABNOR CHA= .0000E+00

YMAX DECAY PRODUCTS (SSC)

HBOOK ID = 112

DATE 07/17/86

NO = 7



CHANNELS 10 0 1 2 3 4 5
 1 12345678901234567890123456789012345678901234567890

CONTENTS 1. 11 1111111111111111111122222222111111111111111
 *10** 2 0 56976029112336152576783890561005216888955333630222
 0 09254005834457724054194931290389159972872217173838
 0 32202878653534263162567950516278496399737286549622
 0 11955382911030531566302976270625546859579404022667

LOW-EDGE
 1. 5444443333322221111 1111122222333344444
 0 086420864208642086420864202468024680246802468

* ENTRIES = 3998 * ALL CHANNELS = .7692E+00 * UNDERFLOW = .2787E-01 * OVERFLOW = .1172E+00
 * BIN WID = .2000E+00 * MEAN VALUE = .3882E+00 * R . M . S = .2524E+01 * ABNOR CHA= .0000E+00

• FILES = 3998
• E-ID = .2000E+00

• ALL CHANNELS = .9120E+00
• MEAN VALUE = .1946E+01

* UNDERFLOW = .0000E+00
* R . M . S = .8548E+00

* OVERFLOW = .2287E-02
* ABNOR CHA= .0000E+00

YMIN VS. YMAX DECAY PRODUCTS (RHIC 500)

HBOOK ID = 114

DATE 07/17/86

NO = 9

CHANNELS 10 U 0 1 2 O A
 1 N 12345678901234567890 V B

```

*****
ABN * ABN
OVE * OVE
4.5 * 20
4 * 19
3.5 * 18
3 * 17
2.5 * 16
2 * 15
1.5 * 14
1 * 13
.5 * 12
- .5 * 11
- 1 * 10
- 1.5 * 9
- 2 * 8
- 2.5 * 7
- 3 * 6
- 3.5 * 5
- 4 * 4
- 4.5 * 3
- 5 * 2
UND * 1
*****

```

LOW-EDGE

1. 544332211 11223344
 0 050505050505050505

* ENTRIES = 4000
 * SATURATION AT= INFINITY
 * SCALE .,+,2,3,..., A,B,
 * STEP = * MINIMUM=0

PLOT
 STATISTICS

```

      I      I
-----I-----I-----
      I      I
      .011I
-----I-----I-----
      I      I

```

* CONTENT MIN = .00000E+00 MAX = .41021E-03

YMIN VS. YMAX DECAY (RHIC 600)

HBOOK ID = 114

DATE 07/24/86

NO = 9

CHANNELS 10 U 0 1 2
 1 N 12345678901234567890

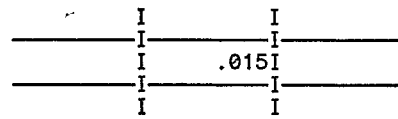
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*****
ABN *
OVE *
4.5 * . . . . . * ABN
4 * . . . + . . . * OVE
3.5 * . . . +2232+ * 20
3 * . . . +4532. * 19
2.5 * . . . +359863. * 18
2 * . . . +46BDA5. * 17
1.5 * . . . +236IEDA+ * 16
1 * . . . +257CHE92. * 15
.5 * . . . +5BG00A4 * 14
- .5 * . . . +56GROF3 * 13
- 1 * . . . +25DLLG2 * 12
- 1.5 * . . . +249FHB3 * 11
- 2 * . . . +47CG62. * 10
- 2.5 * . . . +278C92. * 9
- 3 * . . . +2574+ * 8
- 3.5 * . . . +223+ * 7
- 4 * . . . +. . . * 6
- 4.5 * . . . * 5
- 5 * . . . * 4
UND * . . . * 3
* . . . * 2
* . . . * 1
*****
    
```

LOW-EDGE
 1. 544332211 11223344
 0 05050505050505050505

```

* ENTRIES = 4000
* SATURATION AT= INFINITY
* SCALE .,+,2,3,.... A,B,
* STEP = * MINIMUM=0
* CONTENT MIN = .00000E+00 MAX 55739E-03
    
```



YMIN VS. YMAX DECAY PRODUCTS (SSC)

HBOOK ID = 114

DATE 07/17/86

NO = 9

CHANNELS 10 U 0 1 2 O A
 1 N 12345678901234567890 V B

```
*****
* ABN * ABN
* OVE * OVE
4.5 * . . . . .258DJHK P * 20
4 * . . . . .+24695. * 19
3.5 * . . . . .+26763. * 18
3 * . . . . .2337A43 * 17
2.5 * . . . . .+26795+ * 16
2 * . . . . .+7D95+ * 15
1.5 * . . . . .+2378B72 * 14
1 * . . . . .+2579B92 * 13
.5 * . . . . .24ACBB2. * 12
* . . . . .348BD92 * 11
* . . . . .+47CHA2 * 10
- .5 * . . . . .+45BD52 * 9
- 1 * . . . . .+35CA53. * 8
- 1.5 * . . . . .35A7A+ * 7
- 2 * 2 227A7+. * 6
- 2.5 * 4 46B52 * 5
- 3 * 9 6842. * 4
- 3.5 * G 53.. * 3
- 4 * K 6.. * 2
- 4.5 * H . * 1
- 5 * G * 1
UND * R * UND
*****
```

LOW-EDGE
 1. 544332211 11223344
 0 050505050505050505

```
*
* ENTRIES = 3998 PLOT .001I .091I .026
* SATURATION AT= INFINITY .09 I .679I
* SCALE .,+,2,3,.,.,., A,B, STATISTICS .028I I
* STEP = .001 * MINIMUM=0
* CONTENT MIN = .00000E+00 MAX = .17610E-01
```