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b Physics At RHIC

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June 1986

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U.S. Department of Energy
USDOE Office of Science (SC)

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RHIC-PH-17

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

$$g + g \rightarrow b + \bar{b}. \tag{1}$$

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.

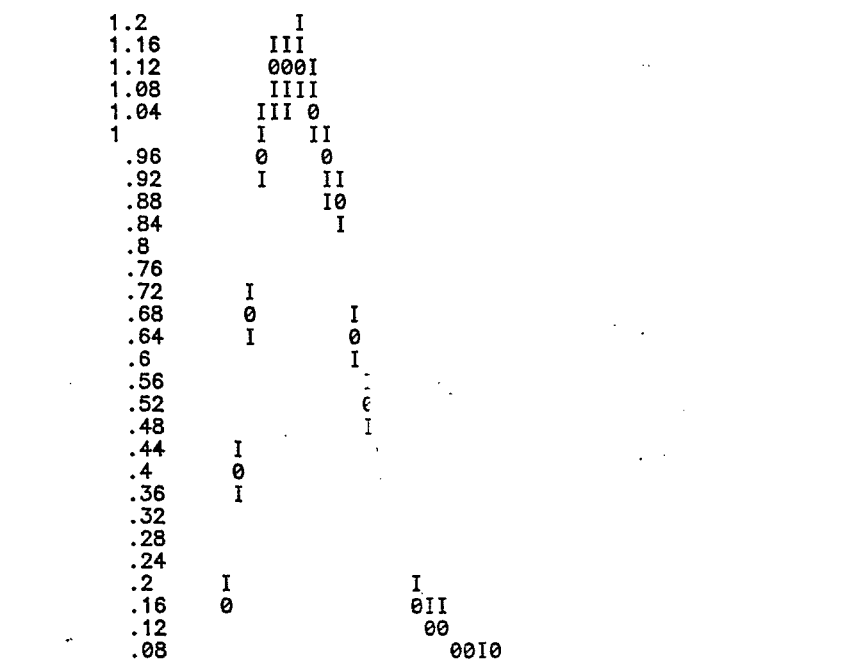
Because of QCD scaling violations, the EHLQ parameterization of the gluon structure function at the typical value $x = 2m_b/\sqrt{s}$ increases by a factor of 5 to 10 over this energy range; the rapidity distribution also becomes wider. It should be realized, however, that the gluon structure function 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 $p_T \sim 10\,\mathrm{GeV}$. It would clearly be advantageous to increase the luminosity.

PT B MESON (RHIC 500)

HBOOK ID = 101 DATE 07/17/86 NO = 1

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CHANNELS  10   0        1        2         3         4         5
           1   12345678901234567890123456789012345678901234567890

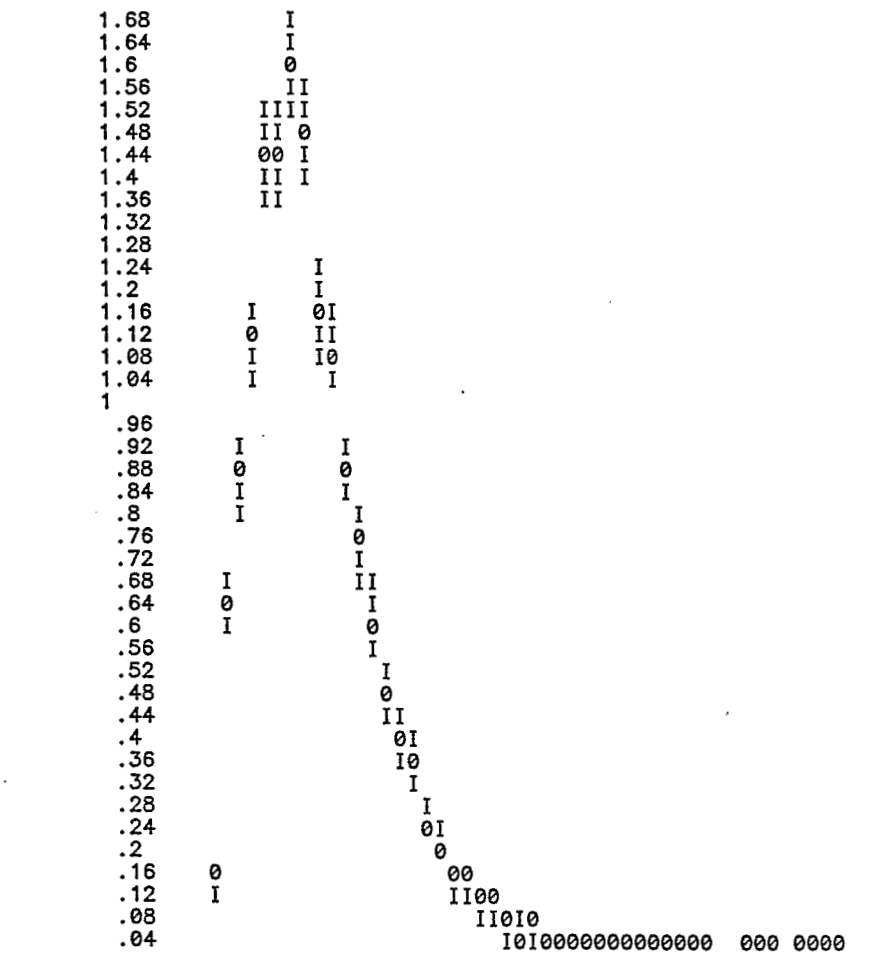
CONTENTS   1.      1111
*10**  3   0   13690010986500111100000000000000000000000000000000
           0   47648912253600411653421111111000000000000000000000
           0   45463213567600360786808294544378511101101001000 0
           0   26709863256900309942641330800508388808808008000 0

LOW-EDGE  10                      11111111111111111112222222222
           1.    1122334455600389900112233445566778899001122334 4
           0   05050505050500350505050505050505050505050505050505

 * ENTRIES =       4000       L CHANNELS =  .1155E-01      * UNDERFLOW =  .0000E+00      * OVERFLOW =  .0000E+00
 * BIN WID =  .5000E+00       AN VALUE   =  .4161E+01      * R . M . S =  .2568E+01      * ABNOR CHA=  .0000E+00
```

PT B MESON (RHIC 600)

HBOOK ID = 101 DATE 07/24/86 NO = 1




```
CHANNELS  10   0        1         2         3         4         5
           1   12345678901234567890123456789012345678901234567890

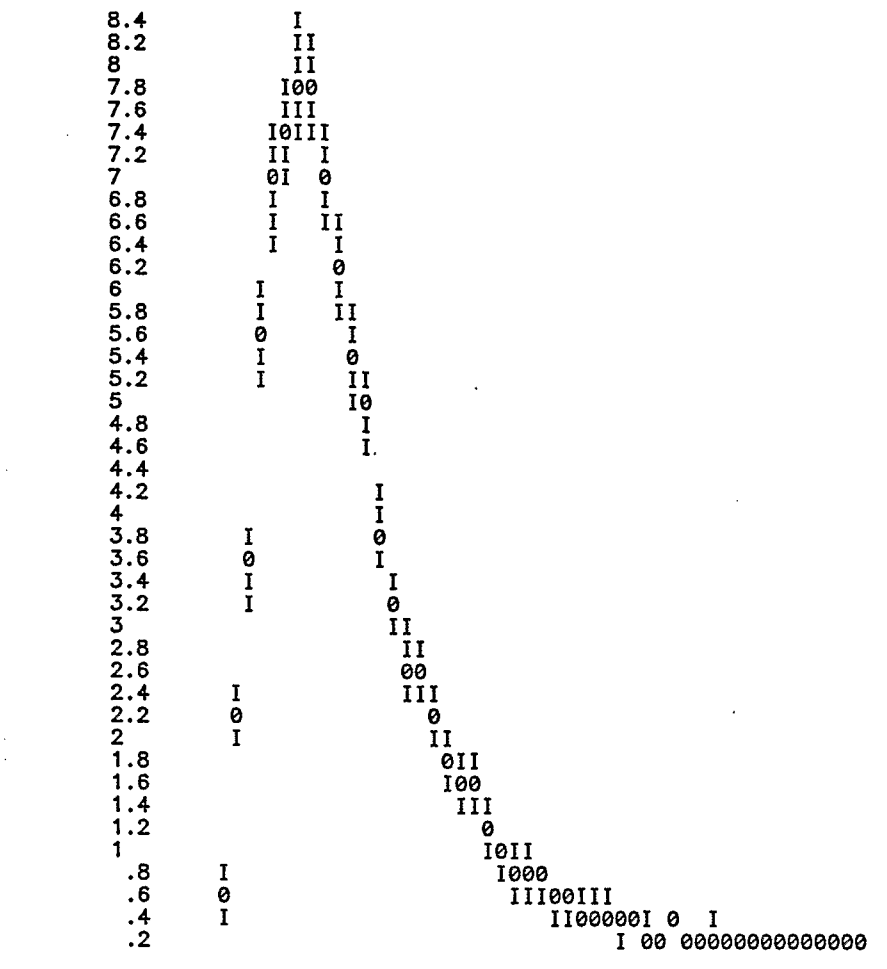
CONTENTS   1.     1111111
*10**  3   0   16804454108754332111000000000000000000000000000000
           0   21481086476297932832884342222110100000000000000000
           0   57004742671670507255085126136114144444004440222200
           0   90133614964464234199841481481998988888008880444400

LOW-EDGE  10                          11111111111111111111222222222
           1.    11223344556677889900112233445566778899001122334 4
           0   05050505050505050505050505050505050505050505050505
```

* ENTRIES =	4000	* ALL CHANNELS =	3E-01	* UNDERFLOW =	.0000E+00	* OVERFLOW =	.2376E-05
* BIN WID =	.5000E+00	* MEAN VALUE =	-3E+01	* R . M . S =	.2599E+01	* ABNOR CHA=	.0000E+00

PT B MESON (SSC)

HBOOK ID = 101 DATE 07/17/86 NO = 1

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CHANNELS  10   0        1         2         3         4         5
           1   12345678901234567890123456789012345678901234567890

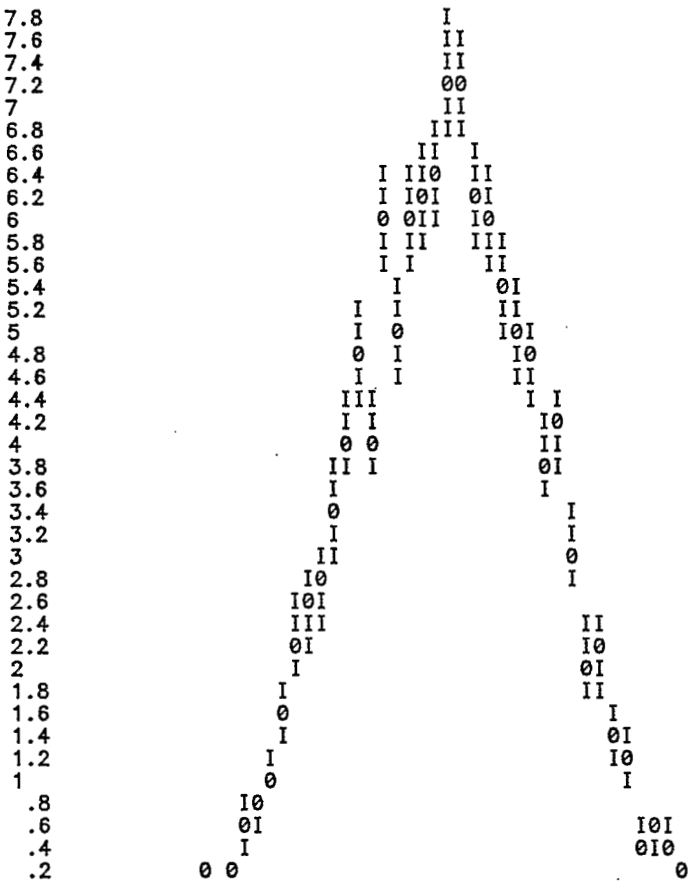
CONTENTS   1.   23567776654332221111
*10**  2   0   40448377913870551744187664433322102101111000000000
           0   94680495213329932787530953433348478396313993335310
           0   62434712250337580479021150977731941138121337776780
           0   40657515860528803885565079622260990176141775552570

LOW-EDGE  10                         11111111111111111112222222222
           1.    11223344556677889900112233445566778899011223344
           0   05050505050505050505050505050505050505050505050505
```

* ENTRIES =	4002	* ALL CHA_S =	.9134E+00	* UNDERFLOW =	.0000E+00	* OVERFLOW =	.1686E-02
* BIN WID =	.5000E+00	* MEAN VA_ =	.5197E+01	* R . M . S =	.3526E+01	* ABNOR CHA=	.0000E+00

Y B MESON (RHIC 500)

HBOOK ID = 102 DATE 07/17/86 NO = 2




```
CHANNELS  10   0        1         2         3         4         5
           1   12345678901234567890123456789012345678901234567890

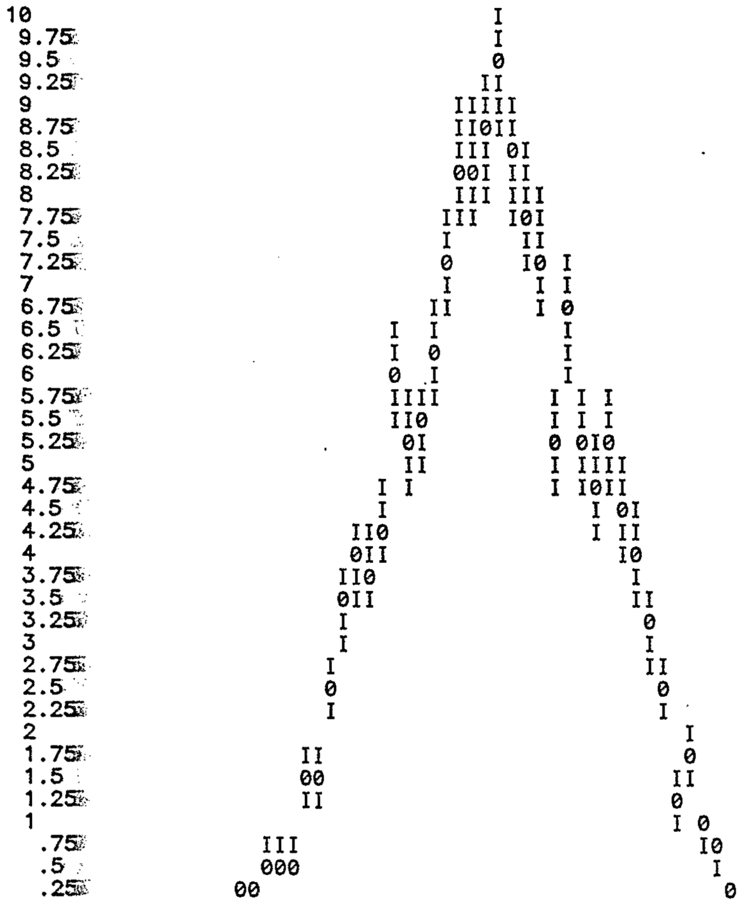
CONTENTS   1.              12223343545667765544342121 1
*10**  4   0   00000000046941463969989121119396709902134300000000
           0   00000040490976311939575265002230602948433650000000
           0   00000000095117064941772335252769322192797170000000
           0   00000020292831411182372268662204653038510770000000

LOW-EDGE       ____________________________
           1.  54444433333222221111         11111222223333344444
           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

Y B MESON (F HIC 600)

HBOOK   ID = 102   ATE 07/24/86   NO = 2




```
CHANNELS     0    0             1             2             3             4    5
             1    123456789012345678901234567890123456789012345   3

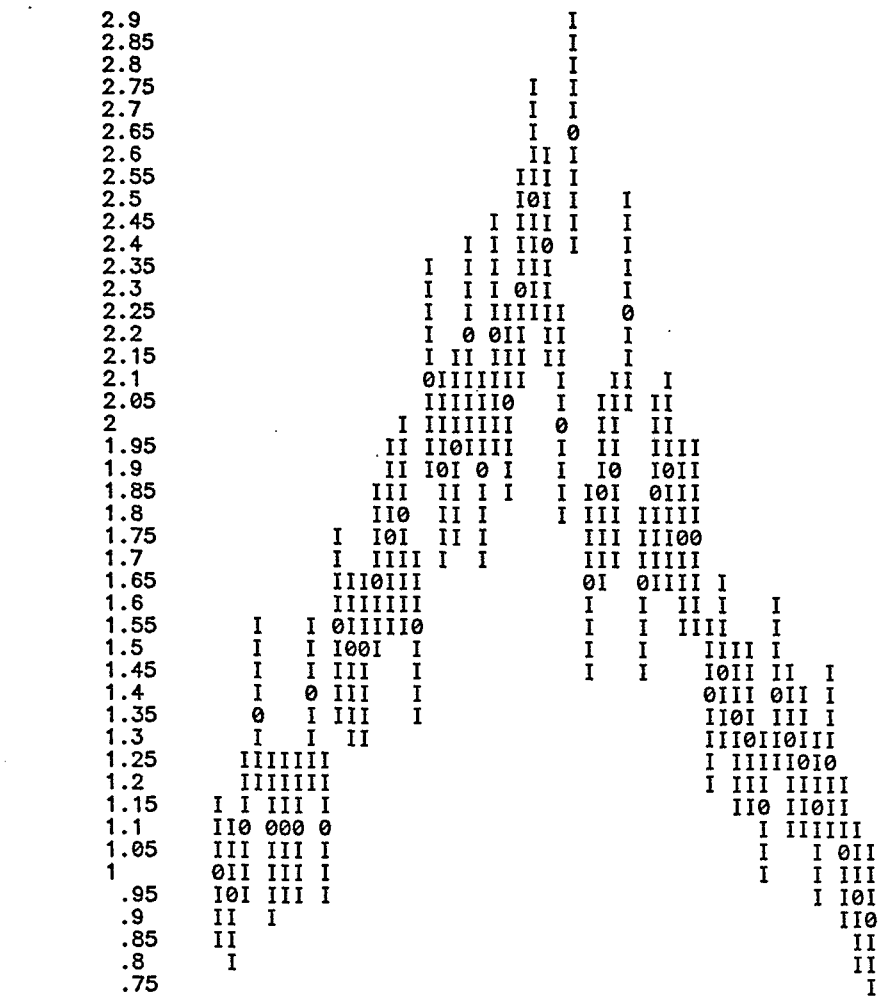
CONTENTS    1.              1123334555678889877565454332 11
*10**  4     0    0000000344433386180210115336205051480426751 0   3
             0    0000055998168518826626880328260676382130512 0   3
             0    0000022277479189435633571258659004448336019 0   3
             0    0000077485948310888241888120386608721519821 0   3

LOW-EDGE          ____________________________
            1.    54444433333222221111 1          11111222223333 —4
             0    086420864208642086420864202468024680246802 46   3
```

* ENTRIES = 4000   * ALL CHANNELS = .1528E-01   UNDERFLOW = .0000E+00   * OVERFLOW = .0000E+00
* BIN WID = .2000E+00   * MEAN VALUE = .5164E-02   R . M . S = .1414E+01   * ABNOR CHA= .0000E+00

Y B MESON (SSC)

HBOOK ID = 102 DATE 07/17/86 NO = 2



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CHANNELS  10   0        1         2         3         4         5
           1   12345678901234567890123456789012345678901234567890

CONTENTS   1.    1111111111111121121222221211121111111111111111
*10**  2   0   99030003054467750891810243966882688773432132212098
           0   72635886826642508827671995832373025405417287204316
           0   65664471111147059390086207306390512271228420486046
           0   91271915198884644314817702100855115306503651319977

LOW-EDGE       ____________________
           1.  544444333332222211111          111112222233333444444
```

```
          0   0864208642086420864208642024680246802468024680246802468

 * 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
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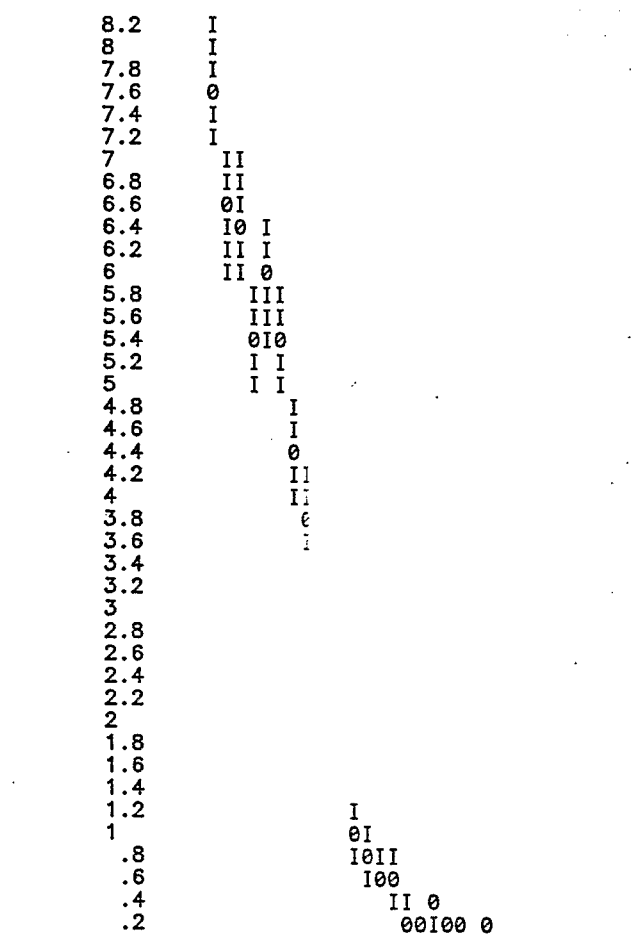
Y1-Y2 B MESONS (RHIC 5

HBOOK ID = 1 DATE 07/17/86 NO = 3



CHANNELS 10 0 2 3 4 5
1 12345678. 456789012345678901234567890123456789

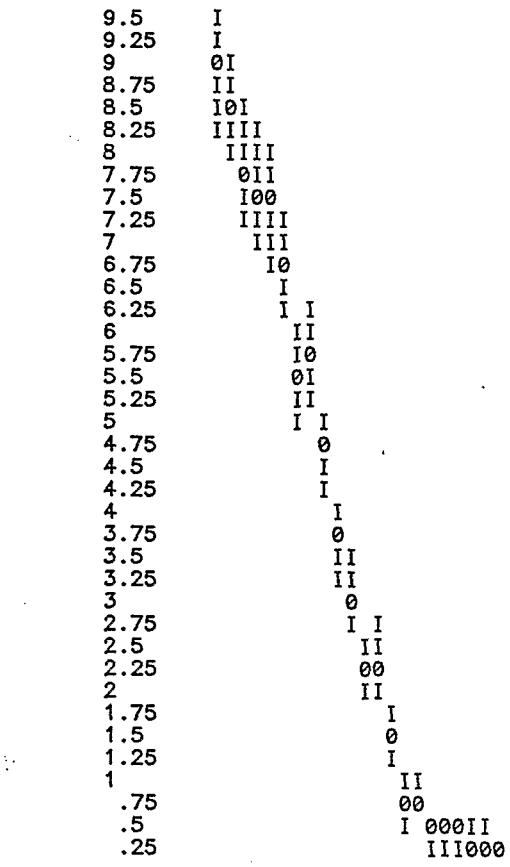
CONTENTS 1. 76655543
*10** 4 0 54338337 -9654102000000000000000000000000000000
0 30863008 :685757051040000000000000000000000000000
0 94404255 :957705177000000000000000000000000000000
0 60205397 26626307602000000000000000000000000000

LOW-EDGE 1. 11 =2233333444445555566666777778888899999
0 02468024 -6802468024680246802468024680246802468

* ENTRIES = 2000 * ALL CHANNELS = .5774E-02 * UNDERFLOW = .0000E+00 * OVERFLOW = .0000E+00
* BIN WID = .2000E+00 * MEAN VALUE = .1065E+01 * R . M . S = .8137E+00 * ABNOR CHA= .0000E+00

Y1-Y2 B MESONS (RHIC 600)

HBOOK ID = 103 DATE 07/24/86 NO = 3




```
CHANNELS  10   0        1         2         3         4         5
           1   12345678901234567890123456789012345678901234567890

CONTENTS   1.  88777655432221
*10**  4   0   737425355591136723212000000000000000000000000000000
           0   573594360900825280881505000000000000000000000000000
           0   492526955240488110110202000000000000000000000000000
           0   884648469017319995987707000000000000000000000000000

LOW-EDGE   1.        1111122222333334444455555666667777788888999999
           0   024680246802468024680246802468024680246802468024680246802468
```

* ENTRIES = 2000 * ALL CHANNELS = .7642E-02 * UNDERFLOW = .0000E+00 * OVERFLOW = .0000E+00
* BIN WID = .2000E+00 * MEAN VALUE = .1115E+01 * R . M . S = .8215E+00 * ABNOR CHA= .0000E+00

```
 Y1-Y  Y2 B MESONS (SSC)

 HBOOK      ID =        103                                        DATE  07/17/86              NO =  3

           4.6     I I
           4.4     0II
           4.2     II0I
           4       I0II
           3.8      I 0    I
           3.6        IIII0
           3.4         000II
           3.2         III 0I
           3           I I II
           2.8             I0
           2.6              I
           2.4               I
           2.2                0
           2                  I I
           1.8                 I0
           1.6                 0I
           1.4                 I 0I
           1.2                   I0
           1                       I
            .8                     0I
            .6                     I00
            .4                      III000
            .2                        0III00000   00

 CHANNELS  10    0         1         2         3                   5
            1    12345678901234567890123456789012345 7  234567890

 CONTENTS   1.   434333333221111
 *10 **   2 0    291723240704621754122200000000000000  000000000
            0    442871484746727101762248175000250000  000000000
            0    856961085957726559260051824000740000  000000000
            0    885335544399814239514470770000000000  000000000

 LOW-EDGE   1.        1111122222333334444455555666667    888899999
            0    0246802468024680246802468024680246802  246802468

 * ENTRIES =        1999      * ALL CHANNELS =  .4571       * UNDERFLOW =  .0000E+00      * OVERFLOW =  .0000E+00
 * BIN WID =  .2000E+00      * MEAN VALUE   =  .1359       * R . M . S =  .9944E+00      * ABNOR CHA=   .0000E+00
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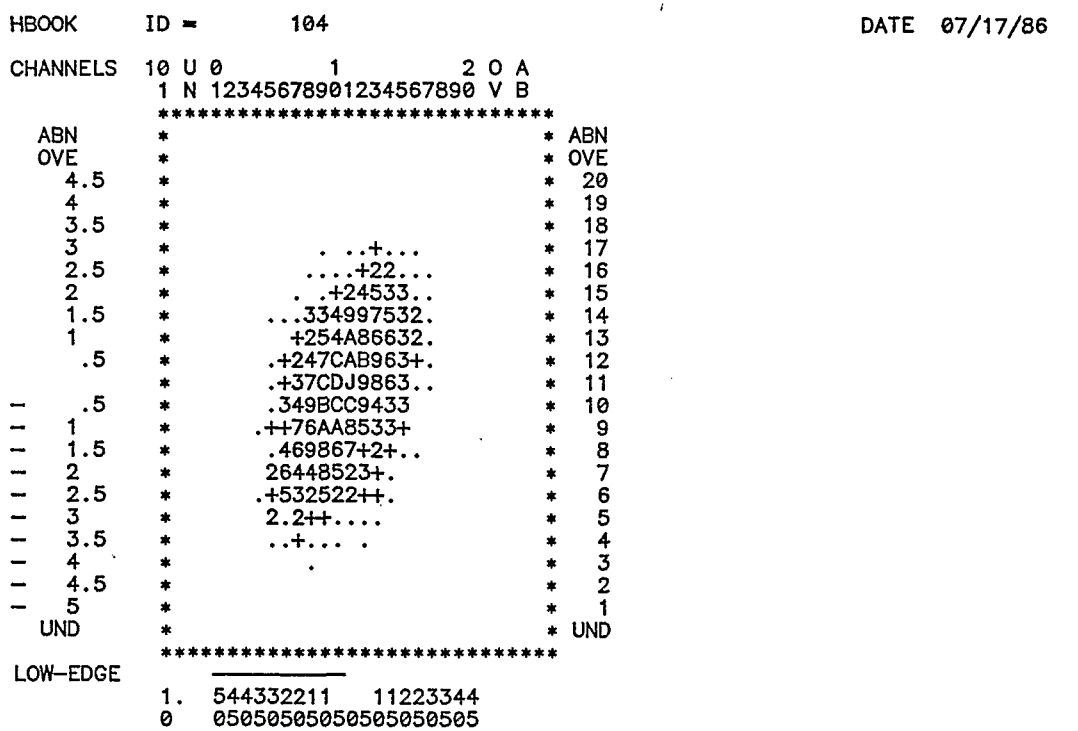
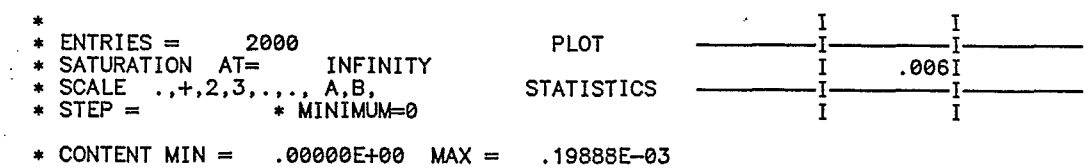
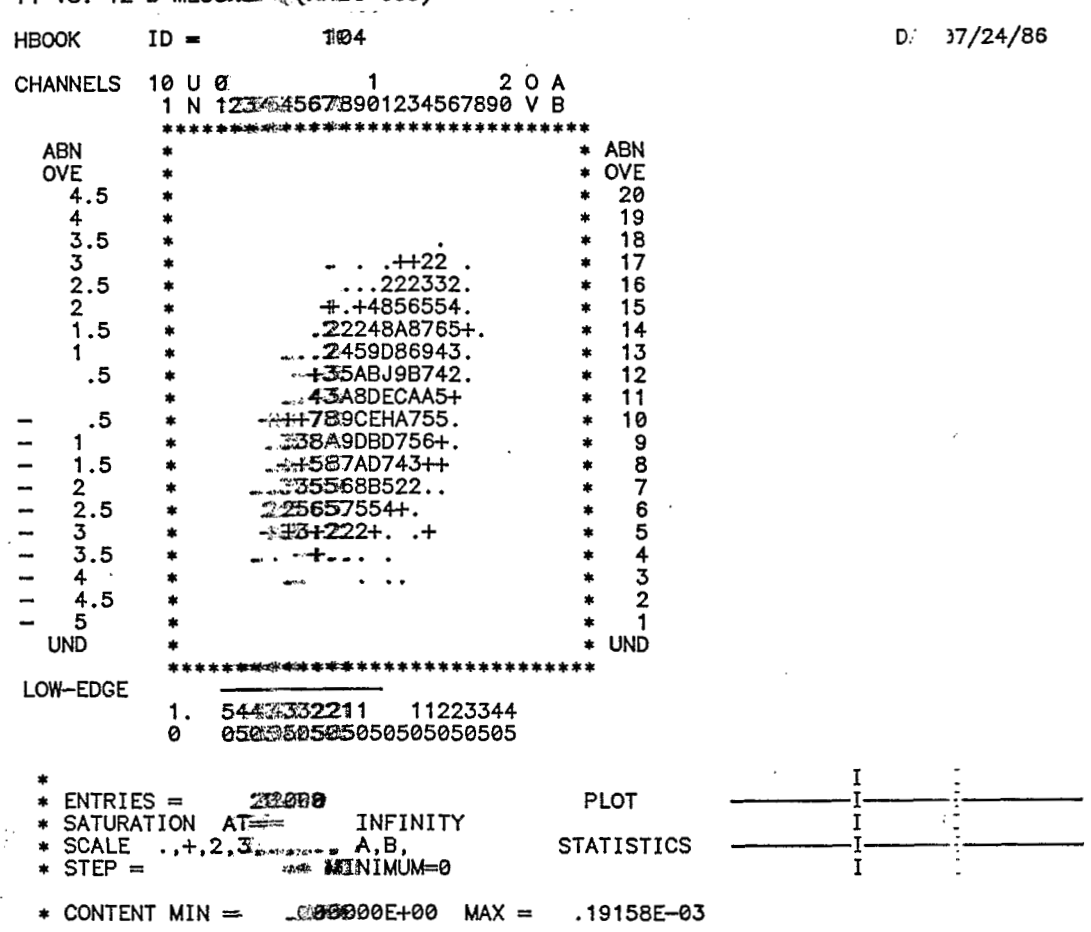
Y1 VS. Y2 B MESONS (RHIC 500)

HBOOK ID = 104 DATE 07/17/86 NO = 4

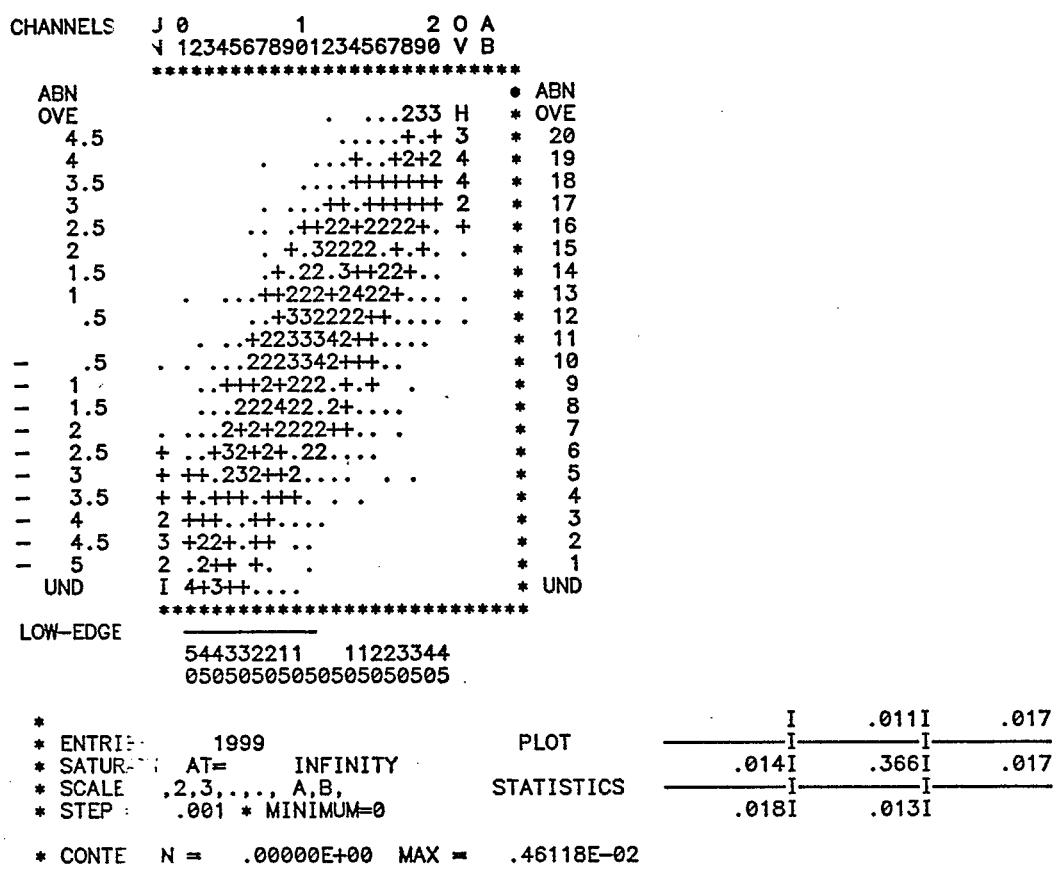





Y1 VS. Y2 B MESONS (RHIC 600)
HBOOK ID = 104
D: 07/24/86
NO = 4
CHANNELS 10 U 0 1 2 O A
1 N 1234567890123456789 0 V B
ABN OVE
4.5
4
3.5
3
2.5
2
1.5
1
.5
.5
1
1.5
2
2.5
3
3.5
4
4.5
5
UND
LOW-EDGE
1. 54433221 11223344
0 0505050505050505050505
ENTRIES =
SATURATION AT= INFINITY
SCALE .,+,2,3,.....A,B,
STEP = MINIMUM=0
PLOT
STATISTICS
CONTENT MIN = .00000E+00 MAX = .19158E-03

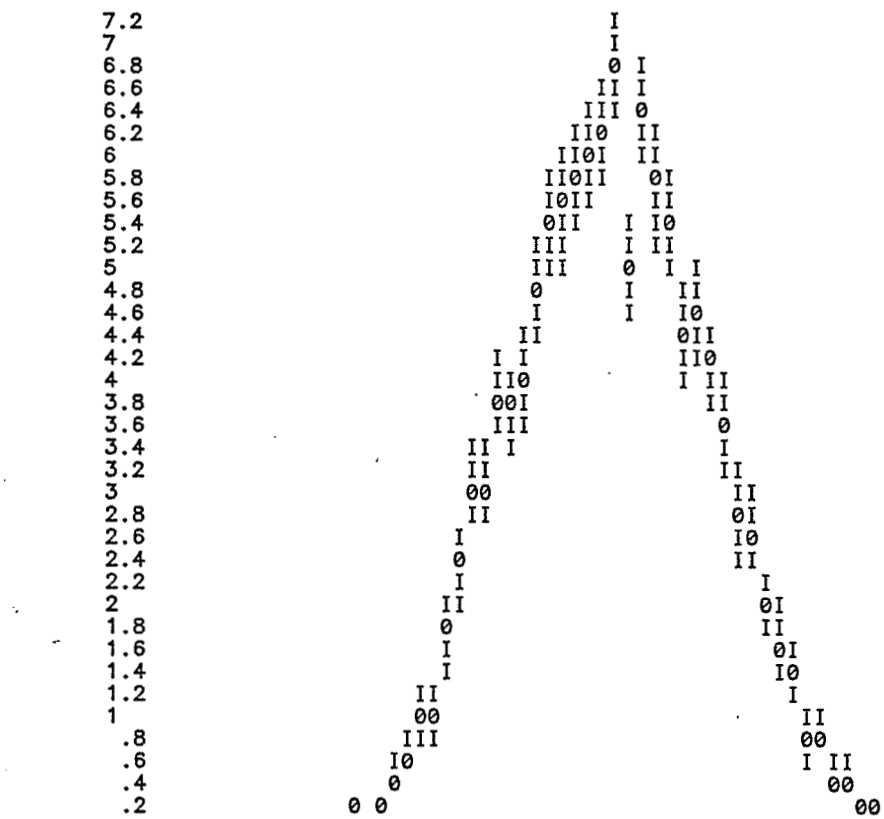
Y1 VS. Y: -ESONS (SSC)

HBOOK = 104 DATE 07/17/86 NO = 4



YMAX DECAY PRODUCTS (RHIC 500)

HBOOK ID = 112 DATE 07/17/86 NO = 7




```
CHANNELS  10   0        1         2         3         4         5
           1   12345678901234567890123456789012345678901234567890

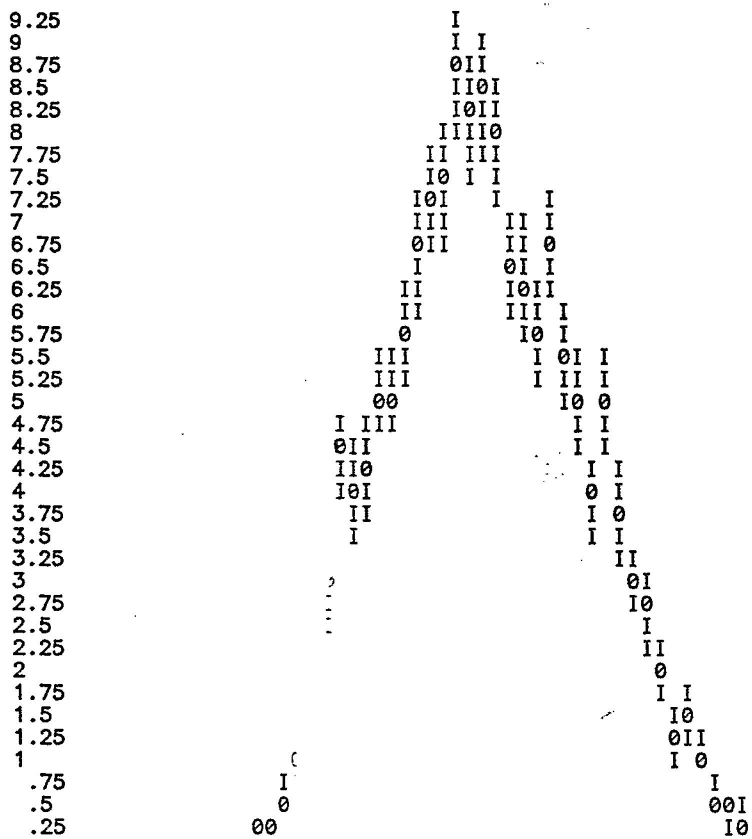
CONTENTS   1.                  12223334555566465544432211
*10**  4   0   00000000000013599629976973479069263350475953773300
           0   00000000004018830157454356160775814631501370696478
           0   00000000000056798677281879289555413342215828689650
           0   00000000020576268182595177886735401667584130815 34

LOW-EDGE       ____________________
           1.  544444333332222211111          11111222223333344444
           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

YMAX DECAY (RHIC 600)

HBOOK ID = 112 DATE 07/24/86 NO = 7



```
CHANNELS  10   0         1         2         3         4         5
           1   12345678901234567890123456789012345678901234567890

CONTENTS   1.                       2434445677888766565434322111
*10** 4    0   00000000001047 3281996512502842672878685804943 2
           0   0000000000259  6518672297572043094762746539653
           0   0000000000927  2656904327660671291006827518088 4
           0   0000000001782  5366450016275341899563018136494 4

LOW-EDGE       ------------------------
           1.  544444333332 2   11         1111122222333334444 4
           0   086420864208 6  -2086420246802468024680246802468

* ENTRIES =       4000    * CHANNELS =  .1524E-01   * UNDERFLOW =  .0000E+00   * OVERFLOW =  .4110E-04
* BIN WID =  .2000E+00    * N 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

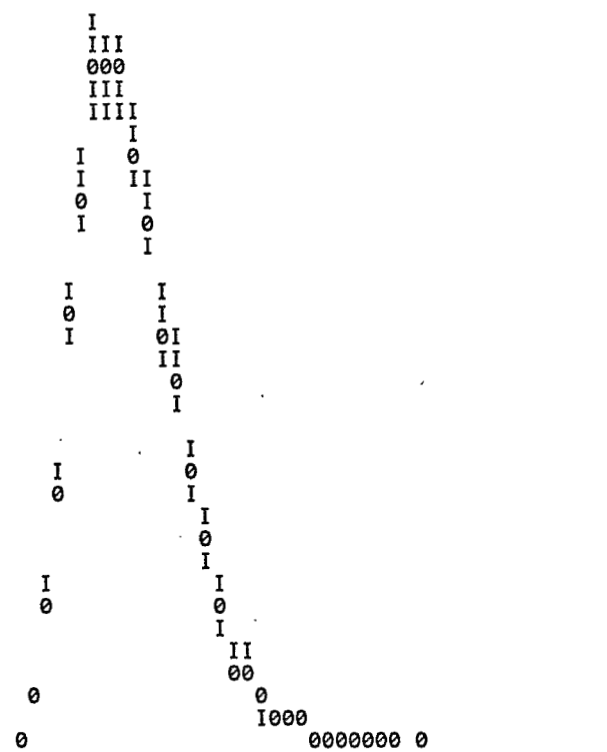
CONTENTS   1.       11 11111111111111111222222222111111111111111111
*10**  2   0   56976029112336152576783890561005216888955333630222
           0   09254005834457724054194931290389159972872217173838
           0   32202878653534263162567950516278496399737286549622
           0   11955382911030531566302976270625546859579404022667

LOW-EDGE       ____________________
           1.  544444333332222211111          11111222223333344444
           0   08642086420864208642086420246802468024680246802468

* 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
```

YMAX-YMIN DECAY PRODUCTS (RHIC 500)

HBOOK ID = 113 DATE 07/17/86 NO = 8




```
CHANNELS  10   0        1         2         3         4         5
           1   12345678901234567890123456789012345678901234567890

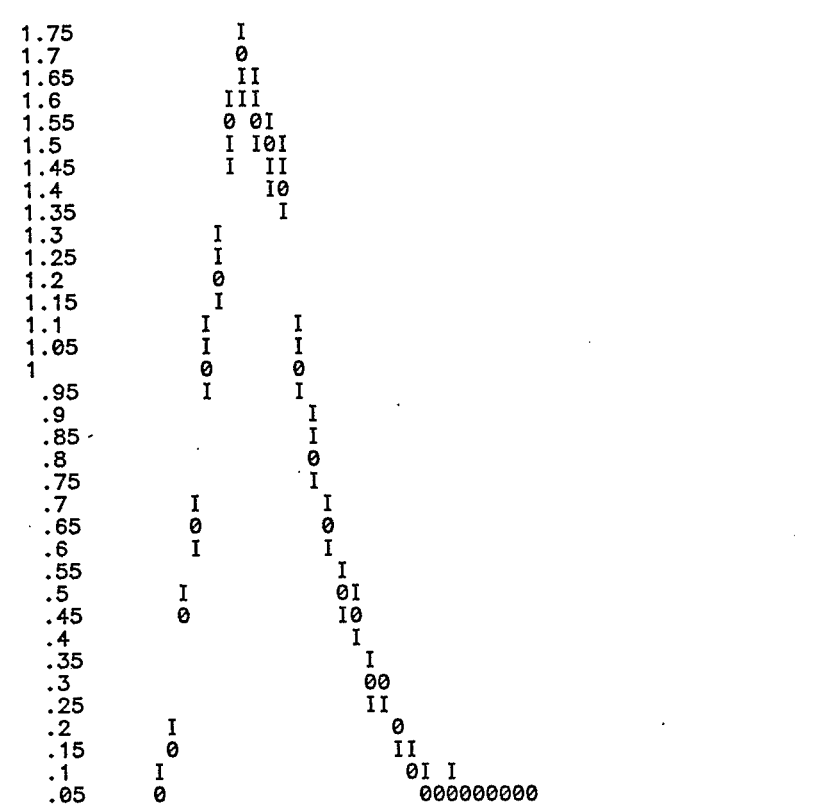
CONTENTS   1.          1111
*10**  3   0   00024792220976532110000000000000000000000000000000
           0   02977792006557185549665121100000000000000000000000
           0   01876643884323442139427556951401000000000000000000
           0   06158351814918024790580691688008000000000000000000

LOW-EDGE   1.        11111222233333444445555566666777778888899999
           0   02468024680246802468024680246802468024680246802468
```

* ENTRIES = 4000 * ALL CHANNELS = .1155E-01 * UNDERFLOW = .0000E+00 * OVERFLOW = .0000E+00
* BIN WID = .2000E+00 * MEAN VALUE = .2022E+01 * R . M . S = .8199E+00 * ABNOR CHA= .0000E+00

YMAX-YMIN DECAY (RHIC 600)

HBOOK ID = 113 DATE 07/24/86 NO = 8




```
CHANNELS  10   0        1         2         3         4         5
           1   12345678901234567890123456789012345678901234567890

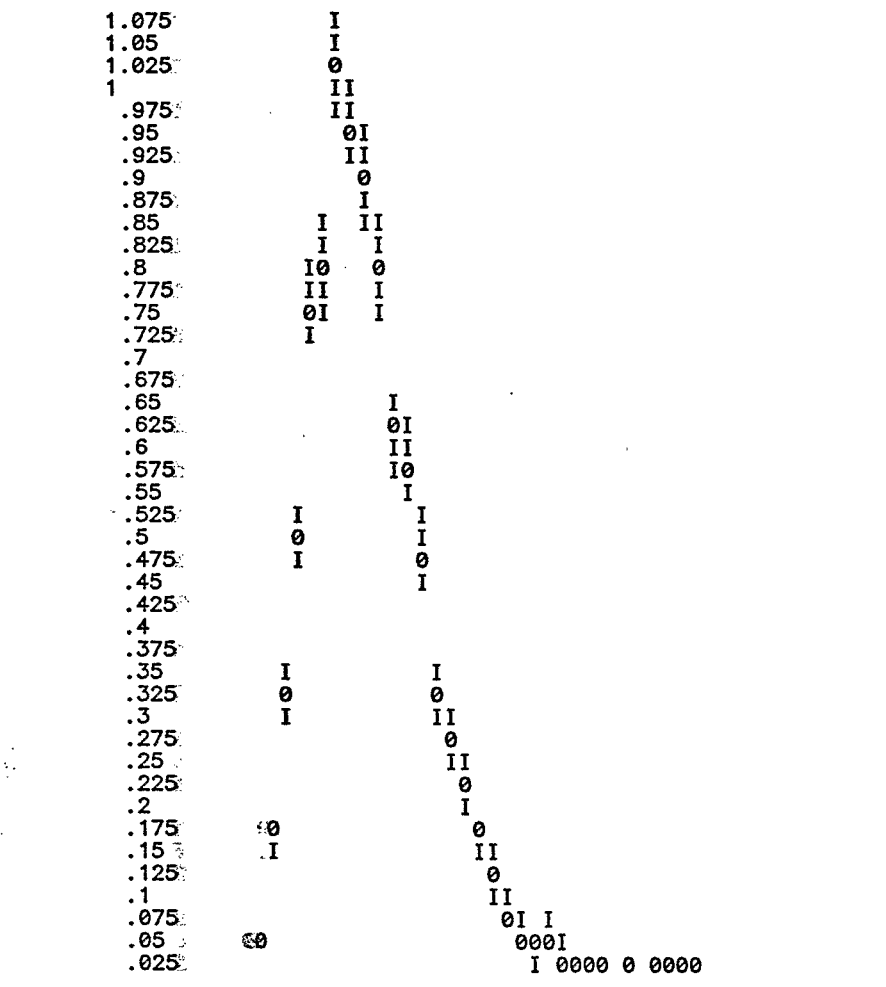
CONTENTS   1.         111111
*10**  3   0   00146915654397644221000000000000000000000000000000
           0   03344890535889261666943431110000000000000000000000
           0   09987911954873369930550862502700000000000000000000
           0   06286472307800999712196749854600000000000000000000

LOW-EDGE   1.        11111222223333344444555556666677777888899999
           0   02468024680246802468024680246802468024680246802468

* ENTRIES =       4000      * ALL CHANNELS =  .1528E-01      * UNDERFLOW =  .0000E+00      * OVERFLOW =  .0000E+00
* BIN WID =  .2000E+00      * MEAN VALUE   =  .2031E+01      * R . M . S =  .8276E+00      * ABNOR CHA=  .0000E+00
```

YMAX-YMIN DECAY PRODUCTS (SSC)

HBOOK ID = 113 DATE 07/17/86 NO = 8



CHANNELS 10 0 1 2 3 4

1 12345678901234567890123456789012345678901234567

CONTENTS 1 1

*10** 1 0 0013477098765432211000000000000000000000000000

0 0035084804880771625174242101000000000000000000000

0 0034563828286142535500812688040224200000000000000

0 0072470511300361520899956211060776700000000000000

LOW-EDGE 1 1111122222333334444455555666667777788888995

0 0024680246802468024680246802468024680246802468024680246802

• E··ES =	3998	• ALL CHANNELS =	.9120E+00	* UNDERFLOW =	.0000E+00	* OVERFLOW =	.2287E-02
• E ··ID =	.2000E+00	* MEAN VALUE =	.1946E+01	* R . M . S =	.8548E+00	* ABNOR CHA=	:0000E+00

YMIN VS. YMAX DECAY PRODUCTS (RHIC 500)

```
HBOOK      ID =        114                                               DATE  07/17/86                 NO =  9

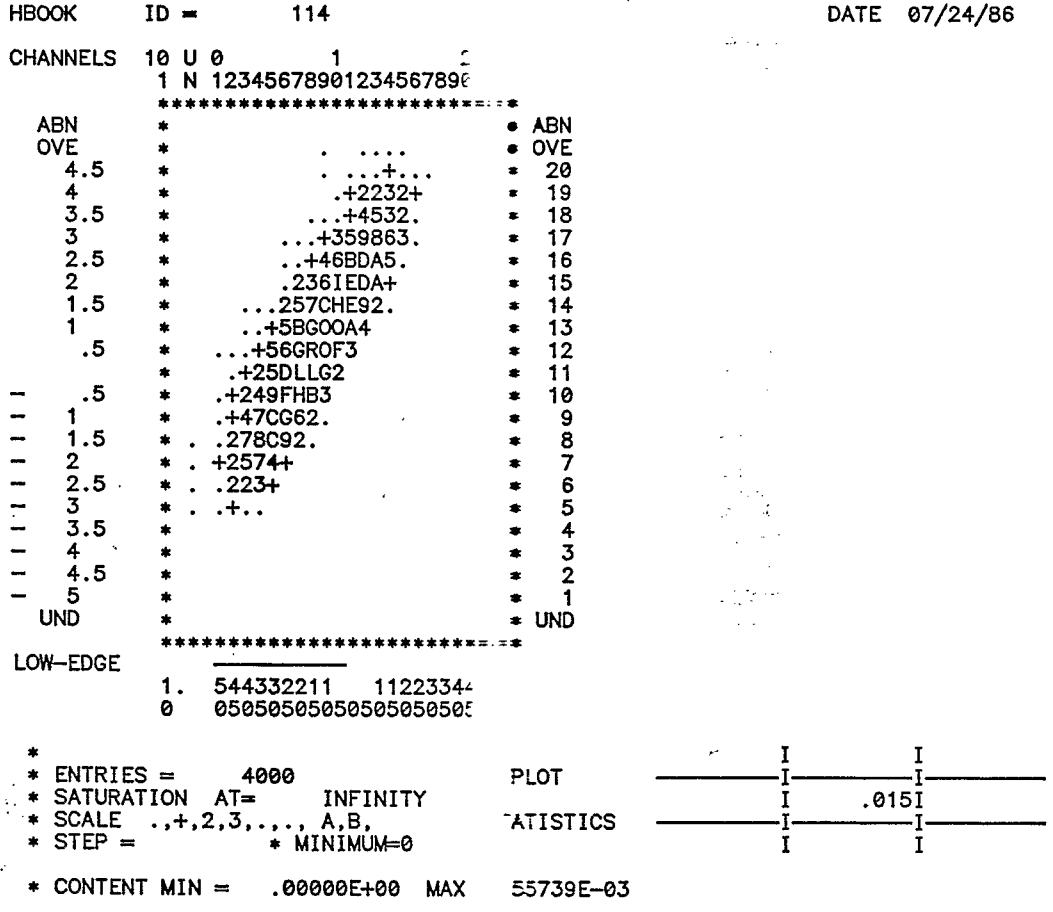
CHANNELS  10 U 0         1          2 O A
           1 N 12345678901234567890 V B
           ******************************
   ABN     *                             * ABN
   OVE     *             .  .....        * OVE
     4.5   *             . .....         *  20
     4     *           .  ..++++.        *  19
     3.5   *           . ..+233+         *  18
     3     *           ...+3674.         *  17
     2.5   *         ...+256992.         *  16
     2     *         ..227BBC6.          *  15
     1.5   *       ...+48EHF8+           *  14
     1     *       ...36AKI8+.           *  13
      .5   *       .+26BGJD2.            *  12
           *      ...59IGC2.             *  11
-     .5   *     ...37BG92.              *  10
-    1     * . .+259D7+.                 *   9
-    1.5   * . .+38852                   *   8
-    2     * .  .343..                   *   7
-    2.5   * . .+++.                     *   6
-    3     *      ..                     *   5
-    3.5   *                             *   4
-    4     *                             *   3
-    4.5   *                             *   2
-    5     *                             *   1
   UND     *                             * UND
           ******************************
LOW-EDGE
           1.   544332211   11223344
           0    0505050505050505050505

 *
 * ENTRIES =      4000                      PLOT         ---------I----------I---------
 * SATURATION  AT=      INFINITY                                  I      .011I
 * SCALE  .,+,2,3,.,., A,B,              STATISTICS      ---------I----------I---------
 * STEP =             * MINIMUM=0                                 I          I

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

YMIN VS. YMAX DECAY (RHIC 600)

HBOOK ID = 114 DATE 07/24/86 NO = 9



```
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       * .        .  ...258DJHK P   * OVE
    4.5     *            ...+24695.      *  20
    4       *           ...+26763.       *  19
    3.5     *          . .2337A43        *  18
    3       *         . ++26795+         *  17
    2.5     *      . ...++7D95+          *  16
    2       *      . ++2378B72           *  15
    1.5     *      ..+2579B92            *  14
    1       *   .  ..24ACBB2.            *  13
     .5     * .   ..348BD92              *  12
            * . ..++47CHA2               *  11
-    .5     * . ..+45BD52                *  10
-   1       * . .+35CA53.                *   9
-   1.5     * . .35A7A+                  *   8
-   2       * 2 227A7+.                  *   7
-   2.5     * 4 46B52                    *   6
-   3       * 9 6842.                    *   5
-   3.5     * G 53..                     *   4
-   4       * K 6..                      *   3
-   4.5     * H .                        *   2
-   5       * G                          *   1
   UND      * R                          * UND
            ******************************
 LOW-EDGE       ----------
            1.  544332211   11223344
            0   05050505050505050505

  *                                                       .001I     .091I     .026
  * ENTRIES =     3998                   PLOT       ----------I---------I---------
  * SATURATION  AT=     INFINITY                          .09 I     .679I
  * SCALE  .,+,2,3,.,.,., A,B,         STATISTICS   ----------I---------I---------
  * STEP =     .001 * MINIMUM=0                           .028I         I

  * CONTENT MIN =   .00000E+00  MAX =   .17610E-01
```