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General Features of the E-144 CCD Spectrometer

The major components of the CCD spectrometer are listed below. Items 2 and 8 (collimators and sweeping magnet) have not been discussed much previously. The radiation damage experienced in the silicon calorimeters during the August 1993 test run has convinced me that there is a critical need for these. An Appendix contains some discussion of the acceptance of the spectrometer.

1. **Vacuum pipe extension** from the end of present γ line inside the FFTB tunnel to a new γ-beam stop about 100 m downstream of IP1. There must be no material in the path of the CCD's, since there may be as many as 10^7 γ's per pulse down this pipe in the pair-creation experiment.

2. A set of **collimators** to mask synchrotron radiation. For the Compton experiment, the convertor CCD (item 4) should only see synchrotron radiation from the very soft bends, whose deflection angle is 50 μrad. Hence the collimation angle here should be, say, 40 μrad, for which Compton photons of energy greater than 5 GeV would still be accepted. For the pair-creation experiment the convertor CCD is not used, but the pair-spectrometer CCD's (item 6) must be protected. In principle no collimation is needed in the vertical direction, and the horizontal collimation angle should be less than that of the active area of the CCD's – about 70 μrad.

   The collimators should be made of about 30 X_0 of tungsten (?), and be located well upstream of the CCD's, perhaps even inside the FFTB tunnel (above the electron dump (?)). At, say, 30 m from IP1, ± 40 μrad implies a gap of ± 1.2 mm for the collimators. Alignment of the collimators will be very important, and may need remote adjustment of both position and angle. If the collimators are made as planar jaws, we would need 4 jaws, each with two remote motions for a total of 8 motions.

3. The CCD detector should be located in a **detector building** about 100 m downstream of IP1. Building 111 would be an excellent location for the spectrometer. However, presuming it is not available, the portable building 401 (?) is a good candidate. I recall this building as having floor area $12' \times 18'$. It will be preferable to orient the building so the short dimension is along the beam, to provide room for the detector electronics and people inside the building. See the sketch at the end of this note.

4. A **convertor CCD** that can be inserted into the γ beam to convert the photon we desire to analyze in the precision Compton experiment. A CCD made from 300 μm-thick silicon has 0.003 X_0 which may be sufficient by itself (assuming we mount the active side of the CCD downstream). The CCD is, of course, inside the vacuum pipe. The needed active area of the CCD is only about 2×2 mm^2. However, we plan to use the same 17×27 mm^2 CCD as in the pair spectrometer. The convertor CCD must be retractable to a position well shielded by a lead wall. The required motion will

be about 5 cm. The CCD and its surrounding vacuum box will occupy about 0.5 m along the beam. This CCD is the most upstream of the components inside the detector building.

5. An **analysis magnet** with kick at least 200 MeV/c will be located just downstream of the converter CCD. We desire to analyze electrons and positrons of momenta down to about 5 GeV/c, so the maximum kick angle is about 1/25. The vacuum pipe inside the magnet must therefore have aperture of at least $2 \cdot (L/2) \cdot (1/25) = L/25$ where L is the length of the magnet. For example, if $L = 1$ m, the aperture must be at least 4 cm.

6. The **CCD pair spectrometer** consists of two arms of four 17×27 mm^2 CCD's each, all inside the vacuum pipe. Each arm must be retractable to a position shielded by a lead wall, requiring a motion of about 5 cm for each arm. The CCD's will be about 10 cm apart, so the array of four occupies about 30 cm along the beam. The spectrometer should accept electrons and positrons of momenta between about 5 and 25 GeV/c. The Appendix gives a brief discussion of the acceptance of the pair spectrometer, where it is found that a good configuration is that the inner edge of the CCD's be about 7 mm from the beamline, and that the magnet kick be 200 MeV/c. The CCD array and its vacuum box will be about 0.6 m long, with a gap of about 0.45 m between the magnet and the vacuum box. The lead shield for the CCD's will sit in this gap.

   The detector elements: conversion CCD, analysis magnet and two-arm CCD array thus occupy about $0.5 + 1 + 0.45 + 0.6 = 2.55$ m $\approx 9'$ along the beam. As noted earlier, this fits well inside the $12'$ shorter dimension of building 401.

   I estimate these detector elements as occupying about $2'$ transverse to the beam. If we desire at least $2.5'$ clearance on each side of the elements for personnel access, we need $7'$ transverse space. A radiation fence of about $1'$ thickness will bound this region on one side, and the wall of the building bound the other. If building 401 is oriented with its $12'$ dimension transverse to the beam, only $4'$ remain for electronics and people, which seems too little. If the $18'$ dimension is transverse, we have $10'$ remaining, which seems adequate for people + rack + walkway behind rack.

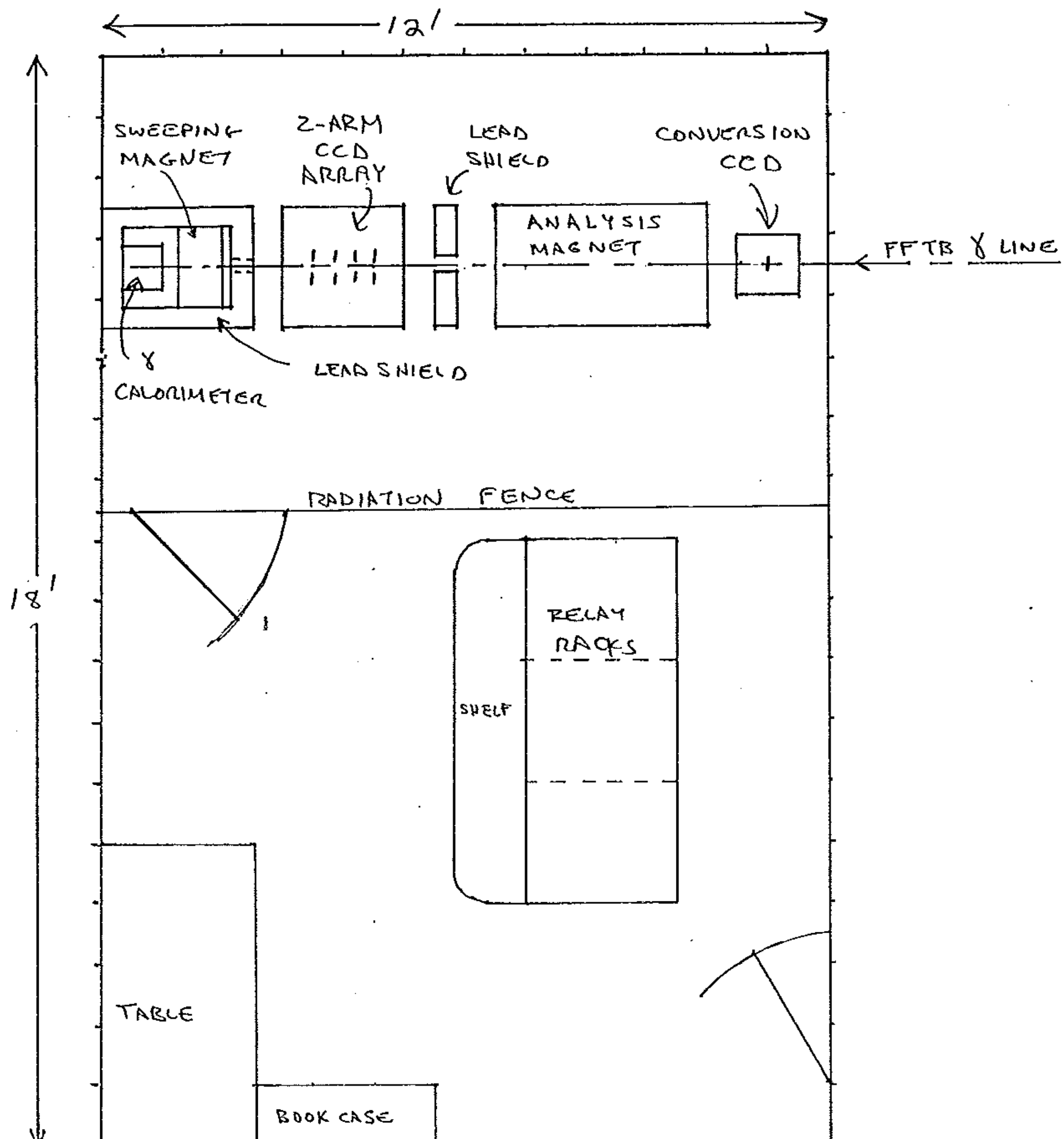
7. A **lead wall** should be placed just downstream of the CCD arms to shield them from backsplash from the γ-beam dump. The lead wall should be $4''$ thick, *i.e.*, made from standard bricks. I suggest the well enclose the sweeping magnet and γ calorimeter discussed below. It may not be necessary for the lead wall to have an accompanying roof and floor.

8. The γ beam should be end in a **γ-calorimeter beam dump**. This is a lead-silicon calorimeter, perhaps the present γ-calorimeter made from surplus SLD luminosity-monitor silicon. It serves to monitor the total flux in the γ beam, as well as providing information on beam steering via the transverse segmentation. This information must be in a form for quick access by the operators at Main Control.

   The γ-calorimeter will occupy about $1'$ along the beam.

9. Backsplash from the beam dump can be a problem for the CCD's. We will have up to 10^7 γ's in a beam pulse during the pair-creation experiment. Roughly 1 low-energy electron emerges from the beam dump per γ, so we have a flux of some 10^7 electrons/pulse back towards the CCD's. Those at larger angles will cross the beam pipe and can be intercepted by the lead wall downstream of the CCD's. But some electrons are at small enough angles to stay inside the beampipe through the lead wall. To suppress these electrons it would be desirable to have a **sweeping magnet** with kick at least 50 MeV/c downstream of the lead wall and upstream of the γ calorimeter. A small trim magnet will likely do, and might occupy about 1′ along the beam.

Thus, downstream of the CCD array we have a lead wall, sweeping magnet, and γ-calorimeter, which occupy an additional 3′, bringing the total required space along the beamline to 12′. This just barely fits into building 401. A sketch of the layout is attached.



Appendix: Acceptance Estimate for the Pair-Creation Experiment

I used a short Monte Carlo calculation to estimate the acceptance of the CCD spectrometer for electron-positron pairs created at IP2. The pair energy was taken as 29 GeV, the endpoint of the Compton-photon spectrum for collisions between 46.6 GeV electrons and 0.532 nm laser photons. The invariant mass of the pairs was generated between threshold and 3 MeV/c^2, and the angular distribution of the pairs was assumed to be isotropic in the pair rest frame.

The kick of the spectrometer magnet could be varied, as could the distance between the inner edge of the CCD's and the beamline. The CCD's were all 17×27 mm^2 in area. A plot of the acceptance *vs.* kick and position of the inner edge is given below. It appears that the acceptance is maximal for a kick of 200 MeV/c and a distance of 7 mm between the CCD's and the beamline.

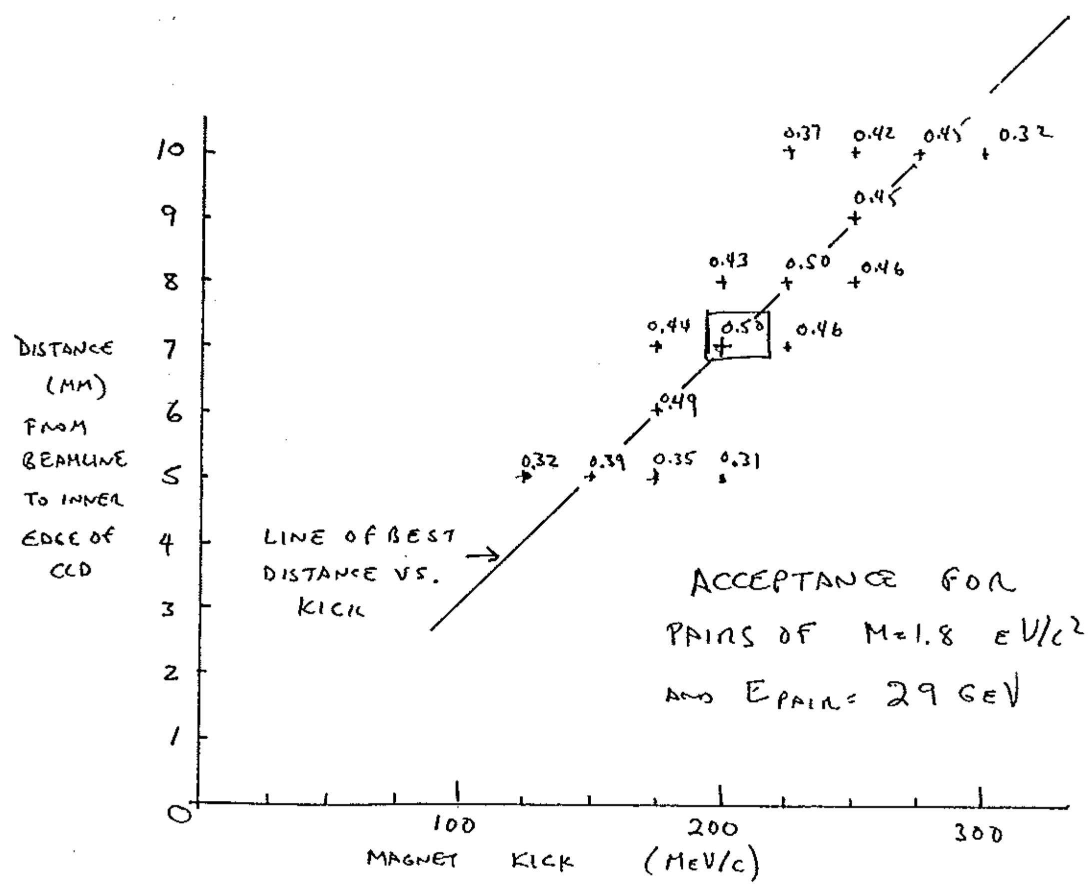
We show four additional plots:

1. Acceptance *vs.* pair mass. The Darmstadt peaks correspond to a mass of about 1.8 MeV/c.

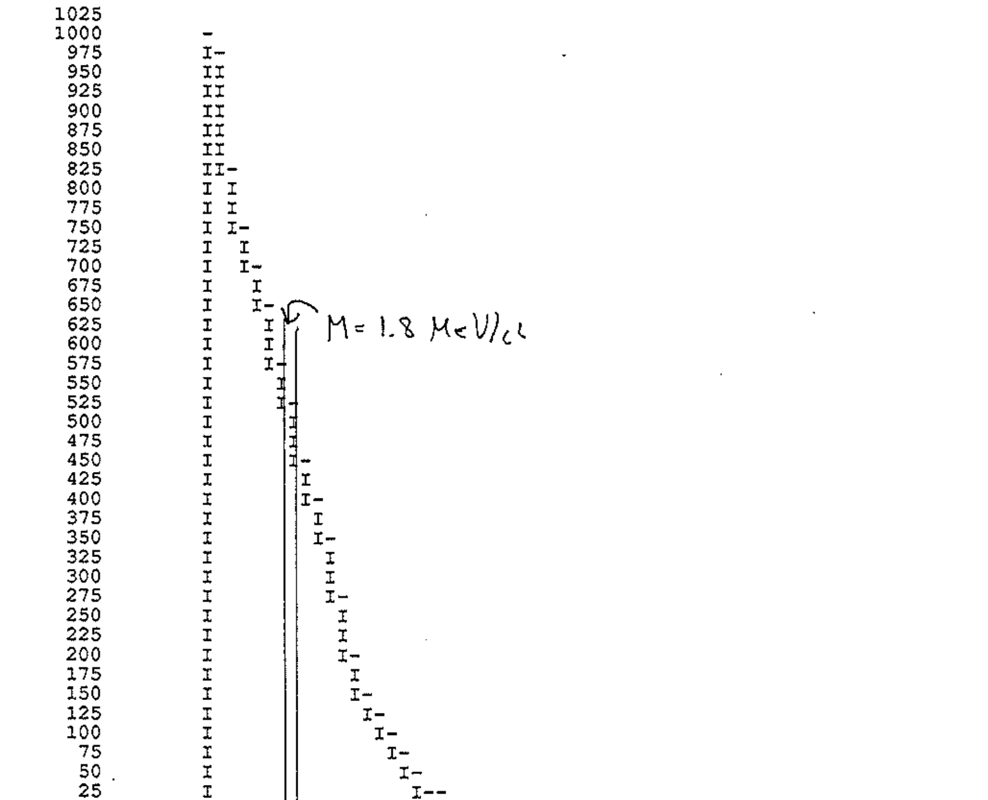
2. Number of accepted particle *vs.* momentum. This shows that we will have acceptance for particles only in the range 7-22 GeV/c.

3. Position distribution the electrons and positrons at the entrance to the spectrometer magnet. Simply multiply distance in mm by 10 to get the angle in μrad. The synchrotron-radiation collimator truncates this distribution to the central region shown as a box.

4. Position distribution of electrons and positrons at the plane of the first CCD in the pair spectrometer. The active area of the CCD is shown on the plot.

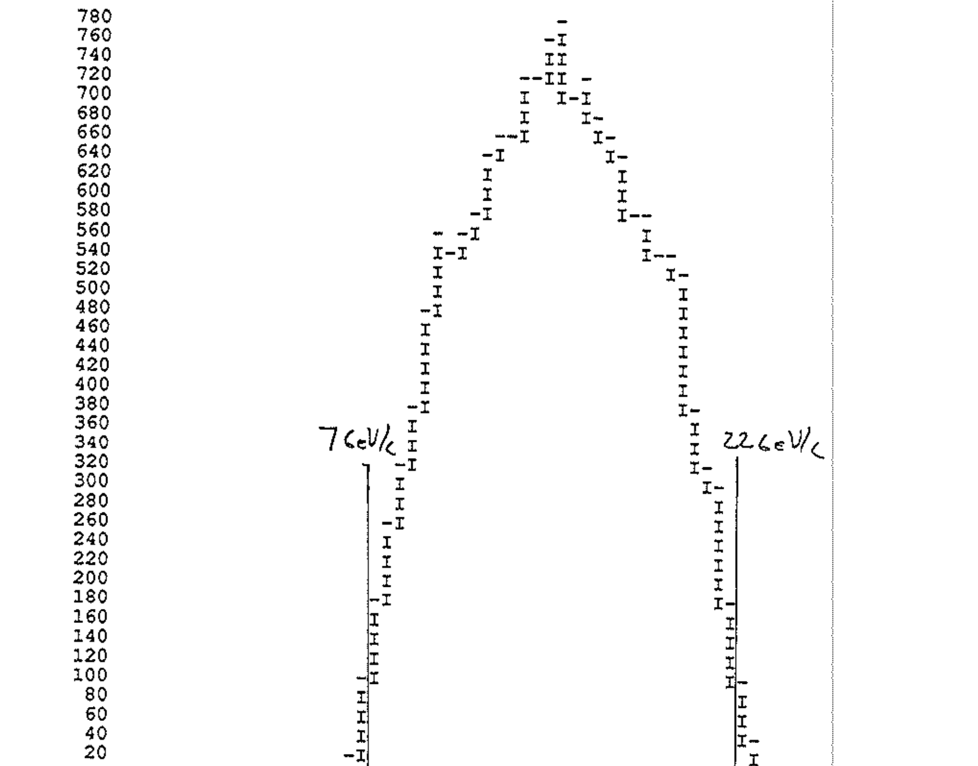


```
wpair acc

HBOOK       ID =        12                                       DATE  27/11/93
              NO =     2
```




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

CONTENTS1000     1
         100     0987765543321111
          10     0504047049469308542 1
           1.    0618085342398798744 3

                                                    PAIR MASS
                                                    ------->

LOW-EDGE   1.    11111111112222222222233333333334444444444555555555
           0     01234567890123456789012345678901234567890123456789

* ENTRIES =       8049      * ALL CHANNELS = 0.8049E+04      * UNDERFLOW = 0.000
0E+00      * OVERFLOW = 0.0000E+00
* BIN WID = 0.1000E+00      * MEAN VALUE   = 0.1655E+01      * R . M . S = 0.414
4E+00
```

```
p acc

HBOOK       ID =        11                                       DATE  27/11/93
              NO =     1
```




```
CHANNELS  10     0         1         2         3         4         5         6
           1     123456789012345678901234567890123456789012345678901234567890

CONTENTS 100                   1233455555666777767666555553321
          10                  18651684357245005691752783307187 93
           1.                 84851101712937636602363204347819 44

                                                                  MOMENTUM
                                                                  ------->

LOW-EDGE  10                             111111111111111111112222222222222222222
           1.          1122334455667788990011223344556677889900112233445566778899
           0         050505050505050505050505050505050505050505050505050505050505

* ENTRIES =       16098     * ALL CHANNELS = 0.1610E+05      * UNDERFLOW = 0.000
0E+00      * OVERFLOW = 0.0000E+00
* BIN WID = 0.5000E+00      * MEAN VALUE   = 0.1455E+02      * R . M . S = 0.376
1E+01
```

```
x-y of pair at magnet center

HBOOK      ID =          1                                      DATE  27/11/93
             NO =     3

CHANNELS   10 U 0        1         2         3         4         5 O
            1 N 12345678901234567890123456789012345678901234567890 V
            **********************************************************
  OVE       *   45443453325++                                        * OVE
   24       *   3964+2224+                                           *  25
   23       *   244223 652+3                                         *  24
   22       *   265257+35++2232 3+                                   *  23
   21       *   43B2484542623+62+ 2+                                 *  22
   20       *   5AA496455343233 4  2                                 *  21
   19       *   78546995538+322++33 2                                *  20
   18       *   9B68B7AB9468+4532+3+++                               *  19
   17       *   IGDDJIC87C7533454443 +2                              *  18
   16       *   FGMGIEI89C7A23 3243+4 +3                             *  17
   15       *   PNHPLIECA7877A663223 ++2                             *  16
   14       *   SVMHQURMFK6AF5767822 3                               *  15
   13       *   **NNZJTLLFFK7D877353625++                            *  14
   12       *   *****RRPLMKBJ875C635+  +3                            *  13
   11       *   *****ZYV*TNIBD8D87472322 +2                          *  12
   10       *   **********QOHH8H9864523++ 3                          *  11
    9       *   *********V*VOGJ7C9855+244+                           *  10
    8       *   ***********YMOGEB774B95 53 2                         *   9
    7       *   ***********VPMJM9F595532 22+                         *   8
    6       *   ***********XZEGLDAA73533+2+3                         *   7
    5       *   ************UQTFJCBA3237 3+                          *   6
    4       *   *************VIKE79522+23+3++                        *   5
    3       *   *************VLMF96764+3+2                           *   4
    2       *   **************RZNJFB97474543+                        *   3
    1       *   **************RMFEC853557+ +                         *   2
            *   ***************PGCA8C964232+                         *   1
  UND       *                                                        * UND
            **********************************************************
LOW-EDGE   10            1111111111222222222233333333334444444444
            1.  1234567890123456789012345678901234567890123456789

 *                                                         I    44    I
 * ENTRIES =     40000                  PLOT      ----------I----------I----------
 * SATURATION  AT=          255                             I    23361I
 * SCALE  .,+,2,3,.,.,  A,B,          STATISTICS  ----------I----------I----------
 * STEP = 1.00      * MINIMUM=0.000E+00                     I          I
```

|y|(MM) ↑

← Effect of collimator

|x|(MM) →

```
x-y of pair at detector

HBOOK      ID =          2                                      DATE  27/11/93
             NO =     4

CHANNELS   10 U 0        1         2         3         4         5 O
            1 N 12345678901234567890123456789012345678901234567890 V
            **********************************************************
  OVE       *                                            +++2++34+ Z * OVE
   24       *                                       +2 222+2   ++  M *  25
   23       *                                  +2 323352+++     +3 K *  24
   22       *                              +5++++++22++   22+ +3   J *  23
   21       *                            +4235++3+4 +3+242+2   +3  R *  22
   20       *                         4524 2 +3++242+323++2 3+343+ T *  21
   19       *                       5+++++6+43333424+3242 ++ 2++22 O *  20
   18       *                     52593272266+262245 3565 ++3+ +23 N *  19
   17       *                   379A57945864424625444745333 +22+4+ * *  18
   16       *                 2776A79AB939365467263623227 4++++4 + R *  17
   15       *               +987C97977DB997752A94+456+45422242+3+2 U *  16
   14       *              2KFHAICCEMADA8C5A73467656553+ +72 3+3+  * *  15
   13       *             6GJRILFHFHA8CE8CD988AA643264+3++++3++233 * *  14
   12       *           +CJTO*VQUHL6IH88M77728687635252+563572++ 4 * *  13
   11       *          +JTPZ**IQOJHMD7LBD7IB7B595746866532+5++4262 * *  12
   10       *          Q******W*WVKOIIHHDBECB898565545B76437+3+223 * *  11
    9       *         A**********SVOKFGDIBGB664B7A855443483+23255  * *  10
    8       *        E************ZXPMLJDCDLCG69A8762836496++4272  * *   9
    7       *       5*************V*KHJKGPKAE697568C9+32244264+52+ * *   8
    6       *       *************T*RUEVNMIEA9796AD955F256532342254 * *   7
    5       *      6****************ZMQSDGEB5BB477D975546424332253 * *   6
    4       *      ****************UTQLLFIHFEFBCA33443665356322325 * *   5
    3       *      ******************WPPEDCCCC7799653456332823  64 * *   4
    2       *     C*****************YSLRQIKCGHA495CC58A56335 32+4+ * *   3
    1       *     *******************XLMNQLI6FD26CBD56436542 32622 * *   2
            *     ********************OPITH9B8E9C66BD4446+3326724+ * *   1
  UND       *                                                        * UND
            **********************************************************
LOW-EDGE   10       111112222233333444445555566666777778888899999
            1.  2468024680246802468024680246802468024680246802468

 *                                                         I    15    I   35
 * ENTRIES =     40000                  PLOT      ----------I----------I----------
 * SATURATION  AT=          255                             I    26881I  917
 * SCALE  .,+,2,3,.,.,  A,B,          STATISTICS  ----------I----------I----------
 * STEP = 1.00      * MINIMUM=0.000E+00                     I          I
```

MAGNET KICK = 200 MeV/c

|y|(MM) ↑

ACTIVE AREA OF CCD

→ |x|(MM)