1. Introduction

A previous note[1)] discussed the effect on the beam spot at the west target of beam line 2A of a window placed at various distances upstream of the target. Since that report was issued a decision to insert two windows upstream of the target has been made.

The first, located 44 inches (1.1176 m) upstream of the target, is an aluminum window 0.005 in. thick that serves to isolate the beam line 2A vacuum (and thus the cyclotron) from the (relatively) poor vacuum of the target module. The second, located 16 inches (0.4064 m) upstream of the target, is a copper window 0.010 in. thick at the entrance of the target module containment vessel. (A third window, similar the the second, is located at the exit of the containment vessel but does not concern the study presented here.)

This note presents a REVMOC study of the effect of the effect of these windows on the beam size at the target location.

2. Method of approach

A TRANSPORT[2)] run was made in which the measured effective lengths of the quadrupoles were used in the determination of the optics of the beam line. In addition the effective length of the 15° dipole that has been field-mapped to date was used for each of the 15° dipoles that direct beam to the target. Because neither of the 27.5° vault dipoles have yet been field-mapped, their effective lengths were taken as the nominal design value.

The effect of these (relatively minor) changes in the effective lengths of the quadrupoles and the 15° dipoles in the TRANSPORT calculations was virtually transparent. Consequently, it is expected that insertion of the measured effective lengths of the remaining 15° dipole and the two 27.5° vault dipoles will not affect the calculations that follow.

Transport element settings obtained from TRANSPORT were inserted into the program REVMOC[3)] and used to predict the effect of the stripper and the windows on the beam spot at the west target. This was done in three consecutive runs; first, the stripper foil only, second, the stripper foil and the aluminum window and third, the stripper foil and both of the windows. In this manner it was possible to determine which scattering elements most affected the beam size at the target.

In each case 150,000 particles were traced through the system. Each window was divided into the appropriate number of 0.001 in.-thick slices.

2.1 The effect of the stripper foil only

The first run was made with only the stripper foil inserted. This we use as the reference for the beam size at the target. Figure 1 shows the predicted beam size at the west target *without* the stripper foil—that is, what the beam spot is to be predicted to be without foil scattering. In figure 2 is shown the effect on the beam profile when scattering in the foil is included. In these and all subsequent plots, units along the horizontal and vertical axes are cm, the x-axis is horizontal and the y-axis is vertical.

With no foil scattering REVMOC predicts that the beam size at the target would be ±0.23 cm horizontally by ±0.30 cm vertically. When foil scattering is included it is predicted that the beam size will increase to ±0.32 cm both horizontally and vertically. However, the fraction of beam predicted to lie outside the unscattered dimensions of ±0.23 cm horizontally by ±0.30 cm vertically is only 0.049% in the horizontal plane and 0.001% in the vertical.

Thus we conclude that foil scattering alone does not contribute substantially to an increase in beam size at the target.

2.2 The effect of the stripper foil and the aluminum window

As a second step, an aluminum window 0.005 in. thick was inserted 44 inches upstream of the target. This window was in addition to the stripper foil. A REVMOC run was then made with this configuration. Figure 3 shows the prediction of the beam size at the west target with scattering in both the stripper foil and the aluminum window included. From figure 3 it is seen that virtually all of the beam is predicted to lie within ±0.93 cm in each of the horizontal and vertical planes.

The same data, plotted on an expanded scale to match that of figure 2, is shown in figure 4. From figure 4 it is seen that the central core of the beam—that is, that portion lying between ±0.32 cm in each of the horizontal and vertical planes—contains 99.55% of the beam in the horizontal plane and 99.30% in the vertical plane. Thus the percentage of beam lying outside of the region predicted for the stripper foil only is increased by approximately 0.5% when the 0.005 in.-thick aluminum window is added.

Thus we conclude that the addition of the 0.005 in.-thick aluminum window causes a small additional amount of beam halo but does not significantly disrupt the core of the beam. The vertical size of the beam at the target is predicted to be more affected by scattering in the aluminum window than is the horizontal beam size.

2.3 The effect of the stripper foil and aluminum and copper windows

A final REVMOC run was made with the insertion of a copper window 0.010 in. thick, located 16 inches upstream of the target. The stripper foil and the 0.005 in.-thick aluminum window were also included in this run. Figure 5 is the REVMOC prediction of the beam spot at the west target under these conditions. It is seen that the beam is predicted to fill the entire 4-inch diameter of the beam line at the target location.

The data shown in figure 5 is replotted on an expanded scale in figure 6 where it is seen that REVMOC predicts that only 0.10% of the beam is outside the region bounded by $x = \pm 1$ cm and 0.11% lies outside the region bounded by $y = \pm 1$ cm. Thus approximately 99.8% of the beam is contained in an area of 1 cm^2.

Figure 7, drawn to the same scale as figure 2, is a plot of the same data on and even more expanded scale. From this figure it is seen that 2.57% of the beam is predicted to lie outside of the region bounded by $x = \pm 0.32$ cm and 3.39% lies outside the region bounded by $y = \pm 0.32$ cm. Thus approximately 94% of the beam lies within the area predicted were the only scatterer the stripper foil.

From figures 5, 6 and 7 we see that the beam is predicted to be significantly larger at the target with the addition of the copper window. Thus we conclude that the addition of the copper window significantly increases beam halo at the target but that approximately 94% of the beam still lies within an area defined by the reference beam ($x = \pm 0.32$ cm and $y = \pm 0.32$ cm).

3. Beam loss and spill calculations

Inherent in the program REVMOC is the calculation of beam loss caused by multiple scattering, absorbtion and nuclear scattering in materials placed in the beam path. Absorbed particles are removed by nuclear interactions and do not contribute to beam spill downstream. Particles lost by nuclear scattering have been scattered such that they hit the wall of the beam tube causing beam spill and activation of the beam line and its components.

Absorbtion and nuclear scattering data from the above runs are listed in table 1. Losses are tabulated as a function of the distances downstream of the scatterers. Downstream of a scatterer any losses listed at a given point are to be construed as occurring between that point and the previous listed location.

It should be noted that the data presented in table 1 are not inconsistent even though they appear to be. Thus, for example, 0.005% of 150,000 particles represent only 7.5 particles and, given that this is a statistical process, the error on that number is $\pm\sqrt{7.5} = \pm 2.74$ or $\pm 0.0018\%$. All data presented in the table should be viewed with that in mind.

From table 1 we note that between the vault exit and the aluminum window that separates the beam-line vacuum from the target containment vacuum REVMOC predicts no beam loss—at least to the level of 1 particle in 150,000 or $7\times10^{-4}\%$. Beam spill between the exit of the aluminum window and the entrance face of the copper window is predicted to be 0.0159% where we have averaged the predictions for the stripper and aluminum window alone and those for the stripper and aluminum and copper windows. At 100 μA this represents at spill of 15.9 nA per 0.7112 m or 22.4 nA/m. The prediction of beam spill between the exit face of the copper window and the target is 0.0240% over a distance of 0.4064 m (16 in.). Again, at 100 μA this represents at spill of 59 nA/m.

Any designs for target protection and/or beam collimation should bear these figures in mind. To this end we present in figures 8–12 the REVMOC predictions of the beam sizes at and downstream of the aluminum window. Figure 8 shows the beam spot at the exit of the aluminum window where the overall beam size is predicted to be approximately 1.24 cm in the x-plane by 2.5 cm in the y-plane. Figures 9 and 10 show the predicted beam size 0.2794 m (11 in.) and 0.5588 m (22 in.), respectively, downstream of the aluminum window. Figure 11 shows the predicted beam size at the upstream face of the copper window, 0.7112 m (28 in.) downstream of the aluminum window and 0.4064 m (16 in.) upstream of the target. There the beam size is predicted to measure approximately 1.2 cm in each of the horizontal and vertical planes. Finally, figure 12 shows the predicted beam profile 0.1270 m (5 in.) downstream of the copper window.

4. Estimate of power loss in the aluminum and copper windows

Figure 13 shows the same data as figure 8 but on an expanded vertical scale because it is clear from figure 8 that most of the beam at the exit of the aluminum window is contained in an area smaller than 1.24 cm square. From figure 13 we find that 85.8% of the beam lies between $x = \pm 0.18$ cm in the horizontal plane and that 87.6% of the beam lies between the same vertical limits (that is, $y = \pm 0.18$ cm). On the assumption that horizontal and vertical losses are independent we then have the probability of the beam lying *outside* of an area 0.36 cm square is

$$\begin{aligned}
\mathrm{P}(\text{outside } x = \pm 0.18 \text{ cm and } y = \pm 0.18 \text{ cm}) &= \mathrm{P}(\text{outside } x = \pm 0.18 \text{ cm}) + \mathrm{P}(\text{outside } y = \pm 0.18 \text{ cm}) \\
&\quad - \mathrm{P}(\text{outside } x = \pm 0.18 \text{ cm}) \times \mathrm{P}(\text{outside } y = \pm 0.18 \text{ cm}) \\
&= 0.146 + 0.124 - (0.146)(0.124) \\
&= 0.252.
\end{aligned}$$

From this we conclude that 25.2% of the beam lies outside an area 0.36 cm square of that 74.8% of the beam is contained within that area. REVMOC predicts an average energy loss of 1.5×10^{-2} MeV per 0.001 in. of thickness of the aluminum window. Thus a total energy of 0.075 MeV is predicted to be deposited in and area 0.36 cm by 0.36 cm. At a beam current of 100 μA this represents a power density of

$$\begin{aligned}
\text{Power density in aluminum window} &= \frac{(0.075 \text{ MeV})(100\ \mu\text{A})}{(0.36 \text{ cm})(0.36 \text{ cm})} \\
&= 57.9 \text{ W/cm}^2.
\end{aligned}$$

In figure 14 we show the predicted beam profile at the exit of the copper window. Here 93.6% of the beam is predicted to lie between $x = \pm 0.18$ cm and 88.4% of the beam is predicted to lie between the same vertical limits. (Remember that the beam is still converging to the target despite scattering upstream.) Proceeding again on the assumption that horizontal and vertical beam losses are independent we find the probability of the beam lying *outside* of an area 0.36 cm square is

$$\begin{aligned} \text{P(outside } x = \pm 0.18 \text{ cm and } y = \pm 0.18 \text{ cm)} &= \text{P(outside } x = \pm 0.18 \text{ cm)} + \text{P(outside } y = \pm 0.18 \text{ cm)} \\ &\quad - \text{P(outside } x = \pm 0.18 \text{ cm)} \times \text{P(outside } y = \pm 0.18 \text{ cm)} \\ &= 0.064 + 0.116 - (0.064)(0.116) \\ &= 0.173. \end{aligned}$$

Thus 17.3% of the beam is predicted to lie outside of an area 0.36 cm square and therefore 82.7% of the beam lies within that area. For the copper window REVMOC predicts an average energy loss of 4.32×10^{-2} MeV per 0.001 in. of thickness of copper or a total energy deposition of 0.432 MeV. At a beam current of 100 μA the power density that is predicted to be deposited in the window is then

$$\begin{aligned} \text{Power density in copper window} &= \frac{(0.432 \text{ MeV})(100\ \mu\text{A})}{(0.36 \text{ cm})(0.36 \text{ cm})} \\ &= 333.3 \text{ W/cm}^2. \end{aligned}$$

To be on the safe side, we suggest that the aluminum window be cooled such that a power density of at least 100 W/cm^2 could easily be accommodated. For the copper window a cooling capability of at least 600 W/cm^2 should be designed in.

5. Discussion

This note has presented a study of the effect of the proposed windows that are to be inserted upstream of the west target of ISAC. It is shown that at a beam current of 100 μA the insertion of the aluminum window can be expected to cause beam spills of the order of 20 nA/m downstream of it and upstream of the copper window. The addition of the copper window could produce spills of the order of 60 nA/m between it and the target.

In addition, we suggest that the aluminum window be provided with a cooling capacity of at least 100 W/cm^2 and that the copper window be provided a cooling capacity of at least 600 W/cm^2.

References

1. G. M. Stinson, TRIUMF report TRI-DNA-96-8, September, 1996.
2. K. L. Brown and S. K. Howry, *TRANSPORT/360*, SLAC–91, Stanford Linear Accelerator Laboratory, July, 1970.
3. C. J. Kost and P. A. Reeve, TRIUMF report TRI-DN-82-28, TRIUMF, 1982.

Table 1

Calculated beam loss for the cases of a) stripper foil only,
b) stripper foil and aluminum window and
c) stripper foil and aluminum and copper windows.

All losses are expressed as a percentage of initial beam.

Location	Case a)		Case b)		Case c)	
	Absorbed	Nuclear Scattered	Absorbed	Nuclear Scattered	Absorbed	Nuclear Scattered
Stripper	0.0044		0.0057		0.0078	
Extraction		0.0023		0.0030		0.0042
Al window			0.0339		0.0382	
Al Window + 0.2794 m				0.0014		0.0008
Al Window + 0.5588 m				0.0097		0.0130
Al Window + 0.7112 m				0.0036		0.0033
Cu window					0.1893	
Cu Window + 0.1270 m				0.0014		0.0025
West target (Cu Window + 0.4064 m)				0.0031		0.0215

```
               97/11/18 - 2A AT 500 MEV - FINAL Leff - Stripper ONLY, NO Windows

    Space # 8:  Distribution of particles as a function of  X  AT TGT2   (Element #170)     (along HORIZONTAL axis)
                                                          & Y  at TGT2   (Element #170)     (along VERTICAL axis)

          Distribution of particles INITIALLY ACCEPTED
                                                        COUNTS  = 150000.
                                                         X PROJECTION

                                                    1  1  1  1  1  1  1
                                       1  3  5  7  9  1  3  4  4  3  3  1  9  7  5  3  1
                                 1  7  8  5  4  5  8  5  2  2  4  9  1  7  8  6  4  3  6  5
                                 0  3  1  4  9  5  2  9  5  1  0  6  4  7  0  9  2  7  5  5  5
                 0  0  0  0  0  6  5  5  8  8  0  1  0  4  9  3  6  9  7  2  9  7  2  8  2  9  0  0  0  0  0
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
  0.3190     -                                                                                             -        0
  0.2970     |                                                                                             |        0
  0.2750     |                                                    1     1                                  |        2
  0.2530     |                                     1  4  6  4  7 10  4  6  3 14  8  7  7 12  2  2  2     1                |      100
  0.2310     |                               1  2  4 12 19 27 36 41 41 50 46 32 33 49 33 29 18  7  2                     |      482
  0.2090     |                               1  4  9 23 45 67 66 99106111112118124 99 73 77 39 31 11  4  1               |     1220
  0.1870     |                               1 11 24 47 92133147156222220224214192164154114 78 56 25 12                  |     2286
  0.1650     |                               2 13 38 92119160235288291331329315308295214178121 78 41 13  1               |     3462
  0.1430     |                               3 21 62104174276321380438488480472428392313262181126 44 16  3               |     4984
Y 0.1210     |                               2 24 72148221331387498577643670570531522440330271138 85 30  6               |     6496 Y
  0.9900E-01 -                               8 38 92188299375484591703753758763700613543400272188 85 34  4               -     7891
  0.7700E-01 |                              10 42114231361480587687752880908835829734651496315208101 27  4               |     9252 P
A 0.5500E-01 |                               6 59113221377530679811906941***942928778677511379240115 32  4               |    10256 R
T 0.3300E-01 |                               4 68135243402531747833957979******980874695607407282122 44  3               |    10981 O
  0.1100E-01 |                               7 61156243416564759859***************879737607408264144 35  3               |    11527 J
T -.1100E-01 |                               7 55162292428614791942***************923817617425255137 41  7               |    11908 E
G -.3300E-01 |                              10 58150285423572774873990************946744536410268123 44  2               |    11693 C
T -.5500E-01 |                               7 60135281410556781875954*********939882759558367231114 40  4               |    11202 T
2 -.7700E-01 |                               3 47117270354518676777911982***972904819649543385226103 46  5               |    10337 I
  -.9900E-01 |                              11 47105225371458633760816849858832830722555475362186102 25  4               |     9226 O
  -.1210     -                               7 41 89191281392491623734753691785636590526378270192 94 32  1               -     7797 N
  -.1430     |                               4 31 86154263334416511604583623515525526437325235128 70 29  1               |     6400
  -.1650     |                               1 24 67119157253326385448476482466474400311259191110 59 20  3               |     5031
  -.1870     |                               4  9 40 89138181247292320312331323292270212168127 71 32  7                  |     3465
  -.2090     |                               5 13 22 57 73108148178224235189210199168124116 97 45 27 11  1               |     2250
  -.2310     |                               2  3 19 19 52 52 63 84113119105121103 84 93 68 47 27  8  8  1               |     1191
  -.2530     |                                  4  3  9 15 27 14 28 53 44 37 50 45 35 32 32 18 11 10  2                  |      469
  -.2750     |                                        1  2  7  6  8 10 12  8  6 13  5  6  1  2  2  2                     |       91
  -.2970     |                                                                   1                                       |        1
  -.3190     |                                                                                             |        0
  -.3410     -                                                                                             -        0
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                 -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                 .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                 3  3  2  2  2  2  2  1  1  1  1  0  0  0  0  0  0  0  0  0  0  1  1  1  1  2  2  2  2  2  3
                 4  1  9  7  5  3  0  8  6  4  2  9  7  5  3  1  1  3  5  7  9  2  4  6  8  0  3  5  7  9  1
                 1  9  7  5  3  1  9  7  5  3  1  9  7  5  3  1  1  3  5  7  9  1  3  5  7  9  1  3  5  7  9
                                                         X  AT TGT2
```

Figure 1. The predicted beam spot at a target *without* foil scattering.

```
                 97/11/18 - 2A AT 500 MEV - FINAL Leff - Stripper ONLY, NO Windows

   Space # 8:  Distribution of particles as a function of  X  AT TGT2   (Element #169)     (along HORIZONTAL axis)
                                                         & Y  at TGT2   (Element #169)     (along VERTICAL axis)

    REAL! Distribution of FINAL RUN FOUND HERE
                                                      COUNTS  = 149990.
                                                        X PROJECTION

                                                    1  1  1  1  1  1  1
                                     1  3  5  7  9  1  3  4  4  3  3  1  9  7  5  3  1
                               2  8  9  5  4  5  6  7  0  1  2  8  1  5  7  7  4  4  7  6  1
                         1  2  0  0  0  6  6  8  3  7  7  4  3  6  5  8  9  6  2  5  1  5  1  1
                2  1  4  0  7  3  4  2  5  7  7  4  8  1  6  7  7  2  6  3  5  7  1  8  4  0  7  5  5  1  1
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
  0.3190     -                                                                          1                  -        1
  0.2970     |                                                                                             |        0
  0.2750     |                                      1     1        1     1        1                        |        5
  0.2530     |                    1  2  2  5  5 12 13  6  5  9 11  3 10  8  5  5  3  1  2                  |      108
  0.2310     |             1  2  2  5 10 22 28 28 48 42 48 42 28 53 45 35 36 19  6  2                     |      502
  0.2090     |                1  3 13 21 49 56 67 87114126113122119104 81 67 34 34 17  5        1         |     1234
  0.1870     |             1  2 11 19 52 89147146169211229225196177180144129 88 50 30 13  2               |     2310
  0.1650     |          2     5 15 34 99114178224272311296335311321264222177125 92 32 19  2               |     3450
  0.1430     |          2  1  8 25 71 97195242312379443497448463435363326257171103 60 12  3  1            |     4914
Y 0.1210     |          1     7 30 85137225323411533529660664590532520466354259154 77 40 11               |     6608 Y
  0.9900E-01 -          1  4 13 40106195287384465604676765765734700618521429281181 81 34  7  5            -     7896
  0.7700E-01 |             2 14 52100236344477551716745898858823794724634507333203126 43  4  3            |     9187 P
A 0.5500E-01 |  1       1  2 15 50133248408506669809875950955993885792650504367250125 39  9  1            |    10237 R
T 0.3300E-01 |        1    2 14 68137228377571716880958984*********857704581392278132 44  9  1            |    11020 O
  0.1100E-01 |          1  2 10 72154248430572731864************988879750636446271129 52  5  2  2  1      |    11458 J
T -.1100E-01 |        1  1  2 17 57162287453594780903***************889790619406267144 49 10               |    11912 E
G -.3300E-01 |             1 16 55165282406595782892966************910737576390268131 44  7     1         |    11638 C
T -.5500E-01 |          1  1 16 67145295389581743884970*********978887744568374228111 55  9               |    11242 T
2 -.7700E-01 |        1     1 16 48125260378495642798846994***947922800640518397239117 47 11     1         |    10254 I
  -.9900E-01 |             3  8 59115233337440646800797874835848861694591425349211 95 24  6  4     1      |     9256 O
  -.1210     -             1 15 46 97183263408484652738742752699642594509397298200 87 49  2              1-     7859 N
  -.1430     |             1  6 40 80158235353381500574594556529525527432313236128 83 28  4        2      |     6285
  -.1650     |        1          27 63113180245359376430492502483448388310254197108 52 25  6        1      |     5060
  -.1870     |  1                8 13 45 89127203253294316317328310299251230195110 78 38 12                  |     3517
  -.2090     |     1        2  6 12 28 53 78111140172227224201211180162145112 79 55 23  9  2               |     2233
  -.2310     |                1  7 13 25 56 49 62 85116120104119122 83 86 67 54 20 13  6  1           1   |     1210
  -.2530     |                1  4  4 11 15 20 21 34 42 40 38 46 43 36 32 35 14 20 11  2                  |      469
  -.2750     |                      1  2  4  4  7 12 10 10 17 10 13  8  5  2  3  3  1                     |      112
  -.2970     |                2        1  1     2  1  1     1  1     1     1                              |       12
  -.3190     |                                                               1                              |        1
  -.3410     -                                                                                             -        0
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                3  3  2  2  2  2  2  1  1  1  1  0  0  0  0  0  0  0  0  0  0  1  1  1  1  2  2  2  2  2  3
                4  1  9  7  5  3  0  8  6  4  2  9  7  5  3  1  1  3  5  7  9  2  4  6  8  0  3  5  7  9  1
                1  9  7  5  3  1  9  7  5  3  1  9  7  5  3  1  1  3  5  7  9  1  3  5  7  9  1  3  5  7  9
                                                      X  AT TGT2
```

Figure 2. The predicted beam spot at a target *with* foil scattering.

```
                  97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44" UPSTREAM of target

   Space # 7:  Distribution of particles as a function of  X  AT TGT2   (Element #169)     (along HORIZONTAL axis)
                                                         & Y  at TGT2   (Element #169)     (along VERTICAL axis)

    REAL! Distribution of FINAL RUN FOUND HERE
                                                    COUNTS  = 149907.
                                                      X PROJECTION

                                                       1  2  3  2  1
                                                 2  7  8  9  3  8  8  7  2
                                           1  5  3  8  5  0  3  8  4  9  0  4  1
                                  1  4  6  4  0  2  9  0  0  0  6  1  4  9  7  4  8  3  2  1
                4  0  0  1  3  5  6  1  3  2  5  4  8  3  0  1  2  4  0  7  9  3  0  5  7  1  7  2  1  0  3
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
  0.8700     -  1                                                                                         2-       2
  0.8100     |                                                                                             |       0
  0.7500     |  0                                                                                          |       0
  0.6900     |                                                  3                                          |       3
  0.6300     |                                   2                 1                                       |       3
  0.5700     |                                   1  1     3     2  2     1  1  1  1                        |      13
  0.5100     |                          1     2     2  2  3  3  2  2  3  3  6  1                           |      30
  0.4500     |                       1        2  1  1  6  7  6  3  5  3  3  3  1  1     1                  |      44
  0.3900     |                             1  3 10  5 14 17 11  9  9  4  5  1  3        1                  |      93
Y 0.3300     |                          1  4  6 14 16 24 40 46 34 28 16 15  6  3  1  2                     |     256 Y
  0.2700     -              1     2  1  2  5 12 15 56123188216188 92 71 18 11  3  3  1  1                 0-    1009
  0.2100     |                    1  7  4  9 27 64212526740858744499237 57 19 11  9  3  1  3               |    4031 P
A 0.1500     |                 1  1  4  7 14 34156555***************547146 40  8  9  3  4     1            |   10318 R
T 0.9000E-01 |                    2  4 11 10 62281*********************264 61 19 10     1  1  1  2         |   18916 O
  0.3000E-01 |           1        1  7  5 23 69372*********************323 76 12  7  3  1     1            |   26096 J
T -.3000E-01 |  0           2     3  4  5 17 76419*********************385 82 21  7  4  4  2        1     1|   28656 E
G -.9000E-01 |                 2  1  3  6 16 62411*********************365 52 17 10  2  3  1  1            |   25859 C
T -.1500     |                 1  2  1  3 12 57285988******************240 45 17  5  4  2     2            |   18832 T
2 -.2100     |                    1  3  3 14 40158535***************533160 27 10  4  2  1  0  1            |   10334 I
  -.2700     |                 1     2  6  8 24 71201468741832778476235 67 25  9  5  3  4  1               |    3957 O
  -.3300     -  0                 2  2  3  3 12 42 59118174216166132 61 29  9  3  6  3  2  2               -    1044 N
  -.3900     |                          2  4  4 10 12 26 29 35 42 22 19  9  4  3     4                     |     225
  -.4500     |                       1  3  1  5  8  9  8 11 12 12 11  3  3  7     2     1                  |      97
  -.5100     |                          1     5  1  3  4  4  7  3  2  2  2  3                              |      37
  -.5700     |                                2  3     1  3  6  2  4  2  2                                 |      25
  -.6300     |                       1     1  1     3  1  2  2  1     1     1  1     1                     |      16
  -.6900     |                                      1  1        1  1                                       |       4
  -.7500     |                                                  1                                          |       1
  -.8100     |                                                  1                                          |       1
  -.8700     |                                                                                             |       0
  -.9300     -  2     0  0                                                               0                 -       3
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                9  8  8  7  6  6  5  5  4  3  3  2  2  1  0  0  0  0  1  2  2  3  3  4  5  5  6  6  7  8  8
                3  7  1  5  9  3  7  1  5  9  3  7  1  5  9  3  3  9  5  1  7  3  9  5  1  7  3  9  5  1  7
                                                      X  AT TGT2
```

Figure 3. The predicted beam spot at the target with scattering from the foil and 0.005 in.-thick aluminum window.

```
              97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44" UPSTREAM of target

Space # 8:  Distribution of particles as a function of  X  AT TGT2   (Element #169)     (along HORIZONTAL axis)
                                                      & Y  at TGT2   (Element #169)     (along VERTICAL axis)

 REAL! Distribution of FINAL RUN FOUND HERE
                                                 COUNTS  = 149907.
                                                   X PROJECTION

                                                  1  1  1  1  1  1  1
                                 1  1  2  4  5  7  9  0  1  1  2  2  1  0  8  7  5  4  3  1  1
                3  1  2  4  8  2  9  9  4  9  4  0  3  5  9  3  1  3  3  9  4  9  3  0  9  1  6  3  2  1  3
                2  5  2  2  0  4  6  6  1  8  1  8  6  4  9  5  7  7  3  9  3  7  2  9  7  6  9  7  0  6  4
                1  3  7  7  0  8  6  2  8  7  8  6  7  9  3  9  2  9  0  1  4  7  3  7  1  6  4  6  6  3  8
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
  0.3190     - 14  6  2 10 12 10 10 12 13 17 26 29 27 31 36 32 22 33 15 18 23 24 10 17  8 10 13  7  9  8 20-      524
  0.2970     |  2  1  2     1  2  5  3 12  8 15 15 24 21 19 22 22 15 14 22  9 13  3 11  9  3  3  2  2     2|      282
  0.2750     |  8  3  1     4  5  9  9 15 25 19 28 31 33 52 27 41 53 30 26 18 11 16  9  9  3  2  1  2  2  4|      496
  0.2530     |  6  4  4  2  3  8 12 18 21 32 41 52 46 60 70 79 59 70 57 46 39 37 24 23 14  6 10  1  3  3 10|      860
  0.2310     | 10  1  1  5 13 11 22 28 33 68 83 93 80116109 98118 97 96 88 56 63 34 33 14  7  6  6     2 10|     1401
  0.2090     | 11  5  6  7  8 18 24 50 56 90103113146141165146160142129121 99 81 67 51 38  7 15  7  4  3 12|     2025
  0.1870     |  8  2  4 13 12 31 54 63 93129138149174215238230238216205167147129 79 49 33 21 15  5  8  7 13|     2885
  0.1650     | 10  5  8 11 23 30 47 65120140182255271317338341284301286229206175128 91 61 37 20 12  8  3  6|     4010
  0.1430     | 14  7  9 17 21 32 47 94159193232313347427415452398389362309267178131109 70 40 11  8 10  9 11|     5081
Y 0.1210     |  8  6  8 20 25 59 90137201243301364449500508540502452463393335269159152 85 52 36 24 11  6 15|     6413 Y
  0.9900E-01 - 14  8 10 17 41 57 95141238263367457526598577594592551502455370286222148102 59 34  6  7  6 17-     7360
  0.7700E-01 | 13  9 14 16 51 62118160257371397533572640697701690655633501396324251180 93 59 28 21 12 13 11|     8478 P
A 0.5500E-01 | 17  8 14 25 52 82112188268385448575616715769823800708638561470387273168141 60 36 32 14  6  9|     9400 R
T 0.3300E-01 | 15  7 14 19 54 81133225302406499587717826809877819796705616493422297188128 68 47 23 13  7 13|    10206 O
  0.1100E-01 | 12 11 15 25 56 78122223291403543647739795870877818809707636534419299230130 83 65 22 18  9 17|    10503 J
T -.1100E-01 | 11  5 13 21 53 82125192325441551653746815867859927837729663544417300225136 85 37 26 13 14 14|    10726 E
G -.3300E-01 | 15  6 12 29 47 83144204309416532608731769796886844734733603494415300212128 71 43 18  8  6 13|    10209 C
T -.5500E-01 | 14  5 14 36 45101116211296411496646715831770862797792645588498396306189125 85 40 31  6 10 15|    10092 T
2 -.7700E-01 | 12  2  7 27 47 74130173268366463602683744749752801759642590474365250158130 81 52 17  5  7 19|     9449 I
  -.9900E-01 | 14  6 14 22 41 80115158215322406480572643645705659643529483424340241163110 58 34 16  6  6 12|     8162 O
  -.1210     - 11  9  9 18 41 57102147241292338466488575612563591584562460378290230158107 50 31 20  6  2 12-     7450 N
  -.1430     |  5  3 10 17 35 45 96104202266317374456488520505550424434378310249163154 78 51 26 13 10  4 13|     6300
  -.1650     |  7  4  4 17 27 27 69102133228287291393359428455434429367291263191143108 62 49 24 15  7  7 10|     5231
  -.1870     |  7  4  5 13 24 31 54 83111144228263285303293309338273274253210157131 78 48 34 12  8  5  1  6|     3985
  -.2090     | 11  5  9 15 17 23 43 50 78114166196174202236215234217200166123121 87 65 36 26 13  7  1  3 10|     2863
  -.2310     | 11  5  5  7 16 24 26 46 52 89 92113122154147155165170126126 97 83 71 36 32 17 13  7  6  5  9|     2027
  -.2530     |  6  3  3  1  8 15 13 34 45 48 62 78107102100100114100 92 84 61 49 35 40 23 10 11  3  3  1  8|     1359
  -.2750     |  4  1  3  4  5  6  7 15 20 37 34 46 59 53 72 64 63 52 73 62 39 32 21 20  7 11  3  6  4  1  8|      832
  -.2970     |  8     2  5  6 12  8 13 20 15 27 23 32 30 38 41 36 30 21 20 21 22 22 10  6 10  5  3     4  6|      496
  -.3190     |  2  1  2  3  2  8  5  2 10 10  7 17 21 18 21 16 24 17 24 13 15  8 10  7  1  1  3  2        8|      278
  -.3410     - 19 11  3  5 10 14 13 12 14 15 18 20 18 28 27 33 32 31 37 23 21 24 20 15  7 12  6  7  5  8 14-      523
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                3  3  2  2  2  2  2  1  1  1  1  0  0  0  0  0  0  0  0  0  0  1  1  1  1  2  2  2  2  2  3
                4  1  9  7  5  3  0  8  6  4  2  9  7  5  3  1  1  3  5  7  9  2  4  6  8  0  3  5  7  9  1
                1  9  7  5  3  1  9  7  5  3  1  9  7  5  3  1  1  3  5  7  9  1  3  5  7  9  1  3  5  7  9
                                                   X  AT TGT2
```

Figure 4. The predicted beam spot at the target with scattering from the foil and 0.005 in.-thick aluminum window on an expanded scale.

```
                  97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44", 0.010 Cu 16" UPSTREAM of target

   Space # 9:  Distribution of particles as a function of  X  AT TGT2   (Element #169)     (along HORIZONTAL axis)
                                                         & Y  at TGT2   (Element #169)     (along VERTICAL axis)

    REAL! Distribution of FINAL RUN FOUND HERE
                                                    COUNTS  = 149579.
                                                      X PROJECTION

                                                             1
                                                          1  2  1
                                                          4  0  4
                                                       1  4  5  0  1
                                              1  1  1  6  7  6  5  4  1  1  1  1  1  1
                โ€‹0  0  2  0  3  6  8  8  7  8  4  1  4  7  8  3  5  7  2  3  1  2  2  0  5  3  1  3  2  1  0
             +--|--------------|--------------|--------------|--------------|--------------|--------------|--------------|+
   5.075     -                                                                                             -        0
   4.725     |                                                                                             |        0
   4.375     |                                   1     0                 0  0                              |        2
   4.025     |                             0        0           0  0                                       |        2
   3.675     |                       0        0  0  0        1     0  1                                    |        5
   3.325     |                 0              0        2           0     0                                 |        4
   2.975     |                    0              0  0  0  1  0  0  0  0     1  1  1           0            |        8
   2.625     |                    0  0  0  1  0        1        1           0  0     0                     |        7
   2.275     |                       1  0  0  0     1        1  0              0  0              0         |        6
Y  1.925     |           0        1     0        0  1     1     1        0        0     1  1     0  0      |        9 Y
   1.575     -                    0  0     1  0  0        0  1  0  0     0  1  1  0  2           0  0      -       12
   1.225     |              0  0  0           0  0  1  1     0     0     0     0     1     0               |        8 P
A 0.8750     |                       1  1     1  1  1  0  1  1  2  0  1     0  0  0                        |       14 R
T 0.5250     |        0        2     0     1  1  1  0  2 51 79 30  1  0  0  1        1                 0   |      175 O
  0.1750     |        1        0  0  1        0     0 35********* 32  1  1  1  0  1     1        1  0      |    17230 J
T -.1750     |        0     1     0  0     0     0  0 78********* 75  1  1     0  3     0  0        0      |   114774 E
G -.5250     |              1     0           1     0 36********* 32  0  2  1  1  0                        |    17042 C
T -.8750     |                 0        1  0  1  0  0  2 41 96 35              1        0  0               |      181 T
2 -1.225     |     0        0  0  0     0  0  3     1  1  1  0  3     0  2  0  0  1  0  0              0   |       19 I
  -1.575     |                       0           2  1     1  0        1  0  1  2  1  2  1        0         |       14 O
  -1.925     -                 1  1        0        1  1  1  2     0  2  1     0  0           1            -       14 N
  -2.275     |                    0  1  0     1  1  0  1     0  0  0  0     0  0  1  0     0               |       11
  -2.625     |              0  0        1  0  1     2  1     0  0     0  1  1  1                           |       11
  -2.975     |                    1  1           0     0  0  1     0  0  1  1        1                     |        9
  -3.325     |                    0        0  0        0  0           0     0        1                     |        5
  -3.675     |                 0              1  0     0  1     1  0  1     0     0        0               |        7
  -4.025     |                    0        1           1  0     0                       0                  |        4
  -4.375     |                          1     0           0        0        0     0                        |        3
  -4.725     |                                      0  0  0     0        0     0                           |        3
  -5.075     |                                         0                                                   |        0
  -5.425     -                                                                                             -        0
             +--|--------------|--------------|--------------|--------------|--------------|--------------|--------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
                5  5  4  4  4  3  3  2  2  2  1  1  1  0  0  0  0  0  0  1  1  1  2  2  2  3  3  4  4  4  5
                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                4  0  7  3  0  6  3  9  6  2  9  5  2  8  5  1  1  5  8  2  5  9  2  6  9  3  6  0  3  7  0
                3  8  3  8  3  8  3  7  3  7  2  7  2  8  2  7  8  3  8  3  8  3  8  3  8  3  8  3  8  3  8
                                                      X  AT TGT2
```

Figure 5. The predicted beam spot at the target with scattering from the foil and 0.005 in.-thick aluminum and 0.010 in.-thick copper windows.

```
                 97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44", 0.010 Cu 16" UPSTREAM of target

  Space # 7:  Distribution of particles as a function of  X  AT TGT2  (Element #169)     (along HORIZONTAL axis)
                                                         & Y  at TGT2  (Element #169)     (along VERTICAL axis)

   REAL! Distribution of FINAL RUN FOUND HERE
                                                     COUNTS  = 149579.
                                                       X PROJECTION

                                                       1  2  3  2  1
                                              1  3  9  8  6  0  6  7  8  3  1
                                        1  4  2  5  1  1  9  7  8  8  8  4  1  4  1
                7              2  4  8  9  4  0  0  3  8  3  4  8  0  7  6  2  1  7  8  3  1              8
                3  5  4  7  9  1  6  4  3  3  1  5  6  9  8  4  7  6  6  8  0  5  4  4  4  9  6  3  1  4  0
             +--|--------------|--------------|--------------|--------------|--------------|---------------|+
   1.015     - 23  2  1  1  2  0  1  0        2     0  1  0  1  1  1  0  1  1  1  1     0  1  0  0     1 21-      68
  0.9450     |  1                                1                       1                       0        1|       5
  0.8750     |  0                                      0                    0  0                          1|       3
  0.8050     |  2                             2     1                                                     1|       6
  0.7350     |  2                                1  1              0  3                                    |       8
  0.6650     |  1                       0     3     2  2  1  2  1              1           0  1           0|      16
  0.5950     |  0                       3  1  4  3  1  5  3  2  3  4  2  3  5  2  0                 0      |      43
  0.5250     |  1              0  0  1  2  3  3  9 10 16 10 11 10  9  4  5  3  2                          1|     102
  0.4550     |  0                    1  2  6  5  9 22 23 19 26 30 28 27  2  4  5  4     1           0     1|     216
Y 0.3850     |  0        1     1  3  1  3  7 12 24 44 60 83100 83 52 39 25 10  9  2  2  1  0              1|     564 Y
  0.3150     -  1              1     5  6 15 26 51 99183283293270200112 73 22 11  6  1  2                 2-    1664
  0.2450     |  1              3  1  6 15 21 46124304506797892807551272131 43 17 17  8  1  3              1|    4568 P
A 0.1750     |  0        0     1  4  6 18 34 91237608***************615237 92 36 12  7  4  1              1|   10218 R
T 0.1050     |           0  1  2  7  4 15 55119423*********************403121 40 14 11  3  2              0|   17926 O
  0.3500E-01 |  1           2  1  3  5 20 42155583*********************557175 57 15  5  3  2              1|   24959 J
T -.3500E-01 |  1  0           2  5 14 24 65203634*********************617176 61 23  9  2  3           1  1|   28390 E
G -.1050     |  0              4  4  6 26 57179581*********************532159 55 27 17  3     1           0|   25533 C
T -.1750     |  0           2  1  3 12 20 58127399*********************414120 40 18 10  2  2     0        2|   17965 T
2 -.2450     |  0              1  2  8 13 22 98220581***************637254 79 29 10  7  4  2  1           2|   10169 I
  -.3150     |  1              1  4  3  9 22 53113269565799878743542294101 52 17  4  3        1  1        0|    4476 O
  -.3850     -  1  0     1     1  4  5  4 12 30 54101173244288283186127 55 26  9 10  2  3  1  1           2-    1624 N
  -.4550     |              0  1     1  6 11 20 21 31 62 73 95 73 62 39 29 16 10  4  1  2  1              0|     559
  -.5250     |                       3  3  6  9  8 21 24 22 25 18 18 21 13  7  7  4     2     0           0|     213
  -.5950     |  0        0           1  1  2  6  3 13  7 20 12 13  9  7  6  5  3                          1|     110
  -.6650     |  0                       0     2  3  3  3  3  5  3  6  4  5  1                             0|      39
  -.7350     |  0              0           2  1  1  1  2  1  1  2  2  1  1                                 |      16
  -.8050     |  1                 0           2  0     1  1  1     2     0                                0|      10
  -.8750     |  1     0                                1           1  1     0  0                           |       5
  -.9450     |  2                                                        1        1                       1|       5
  -1.015     |  2                                                           0                             2|       4
  -1.085     - 25  2  3  2  1     3  1  2  1  2  1  0  0  1  0  1  1     1  0  1  1  0  0     0  1  0  2 32-      90
             +--|--------------|--------------|--------------|--------------|--------------|---------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
                1  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1
                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                0  0  9  8  8  7  6  5  5  4  3  3  2  1  1  0  0  1  1  2  3  3  4  5  5  6  7  8  8  9  0
                8  1  4  7  0  3  6  9  2  5  8  1  4  7  0  3  3  0  7  4  1  8  5  2  9  6  3  0  7  4  1
                5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
                                                       X  AT TGT2
```

Figure 6. The predicted beam spot at the target with scattering from the foil and 0.005 in.-thick aluminum and 0.010 in.-thick copper windows on an expanded scale.

```
              97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44", 0.010 Cu 16" UPSTREAM of target

 Space # 8:  Distribution of particles as a function of  X  AT TGT2   (Element #169)     (along HORIZONTAL axis)
                                                       & Y  at TGT2   (Element #169)     (along VERTICAL axis)
   REAL! Distribution of FINAL RUN FOUND HERE
                                                   COUNTS  = 149579.
                                                     X PROJECTION

                 1        1  1  2  3  4  5  6  7  7  8  9  9  9  9  9  8  7  6  6  4  4  3  2  1  1        1
                 9  6  9  2  8  5  1  1  0  0  2  9  6  1  6  8  5  2  7  8  8  0  8  0  2  3  7  3  9  6  8
                 8  8  9  9  6  0  9  8  2  0  7  6  1  1  3  3  6  4  3  5  7  6  7  3  0  6  5  5  7  5  5
                 4  7  4  0  3  1  2  5  5  6  2  8  8  1  2  9  5  0  0  5  9  8  8  3  2  7  4  2  3  6  3
              +--|--------------|--------------|--------------|--------------|--------------|--------------|+
  0.3190      -155 24 29 32 38 53 51 79 69 97 98103131121134129123126130 97105101 72 69 60 52 47 31 27 31128-    2548
  0.2970      | 21 11  4 12 17 10 23 25 32 25 30 55 47 54 58 63 55 65 47 61 37 45 33 24 18 19 11 13  7  5 18|     946
  0.2750      | 27  7 10  9 22 30 31 42 40 40 62 66 68 80 80 85 79 71 93 70 62 49 44 38 31 26 18  9 12  7 23|    1331
  0.2530      | 36  6 14 15 25 25 36 50 57 64 78 88110104107120101 98 87 80 70 73 52 38 40 32 17 17 18 11 39|    1708
  0.2310      | 28  6 13 22 42 43 44 57 75 96105109125137155130148153119115103 81 77 71 44 32 27 22 21 14 29|    2244
  0.2090      | 41 11 22 29 35 50 58 83 97116152161143169184192198175174145139110 95 71 60 55 30 28 15 16 42|    2897
  0.1870      | 55 18 21 33 38 55 86106109130170184201231218253226225232172159131122 92 78 47 40 32 20  6 51|    3542
  0.1650      | 55 26 29 33 47 57102139118181229219247263277278281260243214213173120117 98 69 49 36 31 22 53|    4279
  0.1430      | 74 26 30 50 72101117128168203240294297296303338357318350255234200187135102 97 62 50 40 21 53|    5198
Y 0.1210      | 54 31 43 55 64 96118164227233270318349367369398363371352329275280192166135 78 63 55 36 16 58|    5925 Y
  0.9900E-01 - 69 30 37 49 89108150185217294340362405410396444404391407373297318204162148102 83 68 36 31 69-    6678
  0.7700E-01 | 74 31 44 79 98109139214269323382372452459509471498461399409331305237195135121 70 66 40 34 72|    7398 P
A 0.5500E-01 | 62 35 50 68102128155217279337396477430507544516509504471466360325274187168123 84 62 49 37 86|    8009 R
T 0.3300E-01 | 65 33 61 61105150167230307376411471527516563577532532545437375333272236167118102 86 46 38 79|    8518 O
  0.1100E-01 | 94 42 61 74113129192250284365424476520573605588599585541439398354278254200137111 70 53 37 79|    8926 J
T -.1100E-01 | 84 47 63 66102155194234294366444517489578600604566557511508412345302261205144 96 71 61 29 78|    8983 E
G -.3300E-01 | 93 40 54 56113146188280321327411452515512581597564575507469450356294246168132105 75 49 37 89|    8802 C
T -.5500E-01 | 93 36 56 72 98166191232289328434459515528570587557544504447412328241237189119100 81 52 42 79|    8586 T
2 -.7700E-01 | 74 34 45 74 98155205238259302446480467500549522546465486434383338258220162138 91 65 40 27 78|    8179 I
  -.9900E-01 | 83 27 49 68 93101166215246296385399459436471544511496453413347331271206146126 94 62 45 19 84|    7643 O
  -.1210      - 75 24 44 47 94120134198226284313378407412456471410424394338310291213168140110 78 55 49 27 69-    6759 N
  -.1430      | 70 32 36 57 78 84151167211220279296369381379338410357361307310219184164142 81 70 49 33 18 62|    5916
  -.1650      | 66 18 35 45 62 91106125178215247263289341328378308339273281249209193137125 64 53 46 42 21 51|    5178
  -.1870      | 54 22 34 25 40 70 80134150177215256245275278285306275223225206173143116 90 68 63 44 33 20 39|    4364
  -.2090      | 37 14 28 31 23 57 70 98137139180184195212240243228222210188152147121 95 73 63 47 38 18 23 43|    3556
  -.2310      | 43  9 18 32 31 46 57 88 84120145127163162185176189164151156120118 95 80 70 54 29 26 22 15 36|    2812
  -.2530      | 34 11 10 19 31 34 46 45 81 77 99112142120133146148154155111101 96 80 52 54 35 30 22 13 11 30|    2233
  -.2750      | 30  6 12 15 18 28 27 56 59 69 79 83 97109 90103 97 99 92 88 86 68 64 47 40 27 28 13 13  8 29|    1681
  -.2970      | 20  6  9 12 14 31 29 27 48 63 70 47 70 81 82 65 63 66 61 68 42 43 52 30 30 27 10  7 12  6 24|    1216
  -.3190      | 31  4 11 10 18 29 24 24 28 43 44 51 48 59 59 75 59 56 50 41 45 41 36 37 21 12 12 10  4  3 19|    1004
  -.3410      -179 19 22 40 43 44 55 54 66 99 93109 96118129123130112109119 95 87 71 82 63 59 33 42 36 24159-    2516
              +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                 -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                 .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                 3  3  2  2  2  2  2  1  1  1  1  0  0  0  0  0  0  0  0  0  0  1  1  1  1  2  2  2  2  2  3
                 4  1  9  7  5  3  0  8  6  4  2  9  7  5  3  1  1  3  5  7  9  2  4  6  8  0  3  5  7  9  1
                 1  9  7  5  3  1  9  7  5  3  1  9  7  5  3  1  1  3  5  7  9  1  3  5  7  9  1  3  5  7  9
                                                     X  AT TGT2
```

Figure 7. The predicted beam spot at the target with scattering from the foil and 0.005 in.-thick aluminum and 0.010 in.-thick copper windows on a further expanded scale.

```
                  97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44", 0.010 Cu 16" UPSTREAM

   Space # 1:  Distribution of particles as a function of  X  AT ALW5   (Element #154)     (along HORIZONTAL axis)
                                                         & Y  at ALW5   (Element #154)     (along VERTICAL axis)

    REAL! Distribution of FINAL RUN FOUND HERE
                                                   COUNTS  = 149925.
                                                     X PROJECTION

                                                          1  1  1  1  1  1  1
                                               1  3  5  9  2  5  7  8  7  5  2  9  5  3  1
                                            3  2  1  8  1  5  5  6  1  7  8  7  1  7  1  2  3
                                         5  6  6  6  7  2  4  4  3  9  4  8  6  7  9  4  4  0  5  1
                1  3  5  7  9  9  0  7  0  9  9  6  6  2  7  3  1  8  5  0  2  4  2  8  0  1  5  4  0  0  1
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
   1.450     -                                                     1                                       -       1
   1.350     |                                            1                                                |       1
   1.250     |                                                                                             |       0
   1.150     |                                2                          1  2           1                  |       5
   1.050     |                                2        1                 2     1                           |       6
  0.9500     |                                                     1     1           2                     |       4
  0.8500     |                       1  1                 1              2  1        1     1               |       8
  0.7500     |     1  1     1     2  1  1        1  2     2                 1                              |      13
  0.6500     |              1           2     2  1  1  2     2  2  2  1     2  1                           |      19
Y 0.5500     |                          2  2  2  1  3  4  4  4  4  2  1  1                                 |      30 Y
  0.4500     -           1              3  4  6  4  3  5  5  9  8  4  2  3  1  1  2        1              1-      63
  0.3500     |  1  1        1           6  5 17 17 19 24 18 25 23 23 13 10 13  6  5  2  2  1               |     232 P
A 0.2500     |        1     1     3 10 18 49 83101152181209241211170133 98 62 36 24  4  2                  |    1790 R
T 0.1500     |                    4 32108288514826*********************826510274118 29  5  2  1  2         |   13348 O
  0.5000E-01 |              1  2  6 83296792*********************************744285 71  9  2               |   35435 J
A -.5000E-01 |           4  2  3 12110398993*********************************982372 85 11     1  1         |   47550 E
L -.1500     |              2    12 82288712*********************************752307 70 11  1  1            |   36005 C
W -.2500     |                    4 31114279533855*********************819516282102 35  5  1  1            |   13193 T
5 -.3500     |     1  1           1  8 20 31 68 87165188222203242189173102 70 55 16  6     1               |    1849 I
  -.4500     |           1        2  3  4  8  7 12 16 17 17 14 17 26 21 12  9  6  5  2  2  1               |     202 O
  -.5500     -        1        1     1     2  3  3  9  3 10  7  7  8  3  5  2  1  1     1        1        -      69 N
  -.6500     |              1  1  2  2        5  3  3  5  5  3  6  1  3           1                        |      41
  -.7500     |        1  1     1     1  1  1           2  2  2     2     1  2                 2            |      19
  -.8500     |                       1  1  1  2  1     1  1     2  1  1           1                        |      13
  -.9500     |              1     1              2  2     1        1           1                           |       9
  -1.050     |                    1  1           1  1     2              1     1                           |       8
  -1.150     |                    1                                         1     1     1                  |       4
  -1.250     |                                   1  1     1              1  2  1                           |       7
  -1.350     |                                                                                             |       0
  -1.450     |                                                                                             |       0
  -1.550     -                                                                                             -       0
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                6  5  5  5  4  4  3  3  3  2  2  1  1  1  0  0  0  0  1  1  1  2  2  3  3  3  4  4  5  5  5
                2  8  4  0  6  2  8  4  0  6  2  8  4  0  6  2  2  6  0  4  8  2  6  0  4  8  2  6  0  4  8
                                                     X  AT ALW5
```

Figure 8. The predicted beam spot at the exit of the aluminum window.

```
                 97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44", 0.010 Cu 16" UPSTREAM

   Space # 2:  Distribution of particles as a function of  X  AT M8382  (Element #155)     (along HORIZONTAL axis)
                                                         & Y  at M8382  (Element #155)     (along VERTICAL axis)

    REAL! Distribution of FINAL RUN FOUND HERE
                                                     COUNTS  = 149924.
                                                       X PROJECTION

                                                    1  1  2  2  2  1  1
                                              1  6  1  8  3  5  3  8  2  5  1
                                           3  8  0  7  4  5  4  6  8  0  8  7  2
                1                    1  2  3  1  6  6  7  5  2  9  5  0  5  1  5  3                       1
                4  0  0  0  1  3  8  3  2  7  0  0  8  8  3  3  0  1  1  9  3  6  0  8  2  0  1  0  0  0  9
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
   1.450     -  3                       0                          0                 0              0     4-       9
   1.350     |                                                                                             |       0
   1.250     |  1                                                                                          |       1
   1.150     |                                                     1                                      0|       1
   1.050     |  0                                            1                                      0      |       2
  0.9500     |  0                                   1                        1                             |       2
  0.8500     |                                   1  1        0  1  1  1                                    |       5
  0.7500     |                                            1     1  3  3     1                              |       9
  0.6500     |                 1  1        2     2     1           1        2  1                          1|      12
Y 0.5500     |                       1  1  2  1  2  1  1  2  4  2  2  1  2  1                             0|      23 Y
  0.4500     -                                1  2  3  8  8  6  4  2  2                                   0-      36
  0.3500     |  0              1  1           2  9 15 10 13 17 21 13  8  1  1  2        1     1           1|     117 P
A 0.2500     |              1        1  2  5 19 68101162200197208135 94 45 15  6  1                       0|    1260 R
T 0.1500     |                       1  1 40147495******************961491149 25  2     1                 1|   12613 O
  0.5000E-01 |  1                    1  4 66458***************************426 63  7  3                    0|   36032 J
M -.5000E-01 |                    3  4  2101583***************************538 67  8  1                    0|   49285 E
8 -.1500     |           0        1     3 77424***************************417 61  3  1                     |   36624 C
3 -.2500     |  0                 1     1 31150525*********************517144 23  3  1                    0|   12383 T
8 -.3500     |  0              1     1  1  8 16 32 81169210198200198 88 55 13  5  3                       0|    1280 I
2 -.4500     |                    1  1  2     3  6  8 14 16 14 19 10  7  3  3     1  1                    1|     110 O
  -.5500     -  1                       3  2  4  1  5  1 10  7  2  4  4                                   0-      44 N
  -.6500     |  0                    1        1  3  2     4  4  3  1  3        1  2                       0|      26
  -.7500     |  1                    1     1  1     2  3        2     1     1                              |      13
  -.8500     |  0                       1  1     1     1  2  1        1  1  1           0                 0|      12
  -.9500     |  0                       1              1  1        1     1  1  1                           |       7
  -1.050     |                                               1        1                        0          0|       3
  -1.150     |                                                                                             |       0
  -1.250     |  1                    0                                             0                      0|       2
  -1.350     |                                                                                             |       0
  -1.450     |  1                                                 0                                       0|       2
  -1.550     -  2                          0                                       0        0             5-       9
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                7  7  6  6  5  5  4  4  3  3  2  2  1  1  0  0  0  0  1  1  2  2  3  3  4  4  5  5  6  6  7
                7  2  7  2  7  2  7  2  7  2  7  2  7  2  7  2  2  7  2  7  2  7  2  7  2  7  2  7  2  7  2
                5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5  5
                                                     X  AT M8382
```

Figure 9. The predicted beam spot 0.2794 m (11 in.) downstream of the aluminum window.

```
                 97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44", 0.010 Cu 16" UPSTREAM

   Space # 3:  Distribution of particles as a function of  X  AT M5588  (Element #156)     (along HORIZONTAL axis)
                                                         & Y  at M5588  (Element #156)     (along VERTICAL axis)

    REAL! Distribution of FINAL RUN FOUND HERE
                                                    COUNTS  = 149904.
                                                      X PROJECTION

                                                    1  1  2  2  2  1  1
                                           1  3  7  2  7  0  2  0  7  2  7  3  1
                                        2  2  7  7  4  2  8  1  8  5  8  7  4  0  2
                               2  2  7  9  6  1  6  7  9  7  5  7  9  6  2  3  7  4  5  2  1              1
                9  0  0  2  1  1  8  7  4  4  8  5  8  9  3  6  1  0  2  1  6  8  9  9  5  3  5  0  0  0  0
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
  0.8700     -  2                                                     1     0                             3-       7
  0.8100     |                                               1                                             |       1
  0.7500     |                                                                 1                           |       1
  0.6900     |                                      1                                                      |       1
  0.6300     |                                1           1  1     1                                       |       4
  0.5700     |                                                  1  4  1  1                                0|       7
  0.5100     |                 1        1        1     1  2              1  1     1                        |       9
  0.4500     |              1        1  1        1  1        3  1  3  1        1                          0|      14
  0.3900     |                       1  1  2  3  1  1  4  6  6  4  3        4                             0|      36
Y 0.3300     |                          2  3  4  9  8  9 17 14 10 11  9  2  2  2                           |     102 Y
  0.2700     -  0        1     3        4  4 19 35 48 58 61 67 63 60 43 27 16  6  3  1     1               -     520
  0.2100     |  0              1  1  3  3 26 87173244347425476442334260147 78 23  6  2  1     1           0|    3081 P
A 0.1500     |  0              1     5 24 76231518868***************813498205 78 25  4  1  1  1            |    9755 R
T 0.9000E-01 |                 1  3  8 40169500************************965471137 29  7  5     2            |   19121 O
  0.3000E-01 |                 2  5 11 41256679***************************595195 34 10  5  5               |   26808 J
M -.3000E-01 |                 1  6 12 57238730***************************715180 46 10  5  1               |   30435 E
5 -.9000E-01 |                 4  4  9 55213635***************************630206 38  9  1     1            |   27326 C
5 -.1500     |                 2  3  9 33161460***************************412123 35  9  2  2             0|   19212 T
8 -.2100     |                 1  3  6 15 78273506817***************873510229 89 21  3     1               |    9690 I
8 -.2700     |           1     4     4 14 19 74174255331416431391367291182 55 31  7  2  3  2               |    3054 O
  -.3300     -                    1  2  2  7 16 24 46 63 78 64 66 58 53 27 15  4  4     1                  -     531 N
  -.3900     |  0                 1  2     7  3  4  7  9 10  6 18  9  5  3  3                              |      87
  -.4500     |                       2     1  2  3  7  3  5  4  3  4  1  4  1           1                  |      41
  -.5100     |                             2        1  2  2  3  2  2  2  1  2        2                     |      21
  -.5700     |                    1  1  1  2  1     2  1  1  2                 1                           |      13
  -.6300     |  0                                   1     2  1     1  1     1  1                          0|       9
  -.6900     |                       1                             1                                       |       2
  -.7500     |                                         1     1        1  1                                 |       4
  -.8100     |                                                                                            0|       0
  -.8700     |                                                                                             |       0
  -.9300     -  5     0                                                     0                             3-       9
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                6  5  5  5  4  4  3  3  3  2  2  1  1  1  0  0  0  0  1  1  1  2  2  3  3  3  4  4  5  5  5
                2  8  4  0  6  2  8  4  0  6  2  8  4  0  6  2  2  6  0  4  8  2  6  0  4  8  2  6  0  4  8
                                                      X  AT M5588
```

Figure 10. The predicted beam spot 0.5588 m (22 in.) downstream of the aluminum window.

```
                  97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44", 0.010 Cu 16" UPSTREAM

   Space # 4:  Distribution of particles as a function of  X  AT M4064  (Element #157)     (along HORIZONTAL axis)
                                                         & Y  at M4064  (Element #157)     (along VERTICAL axis)

    REAL! Distribution of FINAL RUN FOUND HERE
                                                    COUNTS  = 149899.
                                                      X PROJECTION

                                                    1  1  2  2  2  1  1
                                           1  3  7  2  7  1  2  1  7  2  7  3  1
                                        3  1  4  3  5  4  2  7  3  6  7  2  1  0  2
                            1  1  3  8  0  3  2  4  1  6  7  0  1  6  7  8  3  0  4  7  3  2
                7  0  1  4  8  8  8  5  9  6  0  0  5  0  7  6  1  3  1  3  7  4  6  1  5  1  7  4  4  0  7
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
  0.8700     -  1                                                                 0                       2-       4
  0.8100     |                                                                                             |       0
  0.7500     |                                                                                             |       0
  0.6900     |                                                        1                                    |       1
  0.6300     |                                               1                 1                          0|       2
  0.5700     |                                                                                             |       0
  0.5100     |                                   1  1     1  1  1  1                                      0|       6
  0.4500     |                 1        2     1  2     1  2  1  1  5  2  1  1  2                           |      22
  0.3900     |  0                    1     3     5  3  2  2  4  5  5  3        1  2                        |      36
Y 0.3300     |                 1     2  3  2  1  9 11 10 18 15  9  5  8  5  4  1     1                    0|     105 Y
  0.2700     -           2  1     1     2  1 22 34 48 69 84 83 71 61 46 31 14 11  2  3  1  1               -     588
  0.2100     |  1              1  2  4 10 30 84169267336451497440353285175 68 25  7  2     2        1      |    3210 P
A 0.1500     |              2     2  1 27 77212488862***************790430215 66 22  6  6  2     1         |    9789 R
T 0.9000E-01 |              2  1  6 12 35149462980*********************921409126 34  5  3  3        1      |   19095 O
  0.3000E-01 |              2  4  6 15 50206619***************************551173 43  7  6  3  1  3         |   26653 J
M -.3000E-01 |              2  3  4 14 54223694***************************626176 40  8  5  2  4            |   30289 E
4 -.9000E-01 |              3  2  7 15 44197571***************************566185 29 12  6  2               |   27244 C
0 -.1500     |           1  2  2  3  7 30130446939*********************979384120 35 10  3  1        1     0|   19178 T
6 -.2100     |              1  1  5  8 26 73228517807***************866478205 81 19  5  5     1     1      |    9800 I
4 -.2700     |        1  1  2  1     4 13 25 57171258346430458369389288159 72 28  7  5     4  1            |    3089 O
  -.3300     -              1     1  1  5 14 19 34 47 67 77 76 82 64 52 34 14  5  2  5     1               -     601 N
  -.3900     |                 1  1     3  4  2  6  9  9 11 11 15  6 12  8  2  3  4  1                     |     108
  -.4500     |                       1  3  2  1     3  1  7  4  7  3  3  4  4        1                     |      44
  -.5100     |  0                       2     1  1  3  2  1  1     1  1     2                              |      15
  -.5700     |                                      1  1     2  2  1  1  1                                 |       9
  -.6300     |                                               1                                             |       1
  -.6900     |                                                                                             |       0
  -.7500     |  0                                                                                          |       0
  -.8100     |                                                                                            0|       0
  -.8700     |                                                                                             |       0
  -.9300     -  3                                                           0                             3-       7
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                6  5  5  5  4  4  3  3  3  2  2  1  1  1  0  0  0  0  1  1  1  2  2  3  3  3  4  4  5  5  5
                2  8  4  0  6  2  8  4  0  6  2  8  4  0  6  2  2  6  0  4  8  2  6  0  4  8  2  6  0  4  8
                                                      X  AT M4064
```

Figure 11. The predicted beam spot 0.7112 m (28 in.) downstream of the aluminum window.

```
                 97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44", 0.010 Cu 16" UPSTREAM

   Space # 7:  Distribution of particles as a function of  X  AT M2794  (Element #168)     (along HORIZONTAL axis)
                                                        & Y  at M2794  (Element #168)     (along VERTICAL axis)

    REAL! Distribution of FINAL RUN FOUND HERE
                                                    COUNTS  = 149611.
                                                      X PROJECTION

                                                          3  7  3
                                                       1  4  7  3  1
                                                       9  1  6  7  7
                                        1  1  1  1  9  3  4  8  6  3  9  2  1  1
                5  1  0  0  2  3  4  5  0  1  2  8  7  8  7  4  1  6  6  2  7  4  7  3  4  2  1  1  0  0  5
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
   2.175     -  1                                            0        0                                   0-       2
   2.025     |                                                                                            0|       0
   1.875     |                                                           0                                 |       0
   1.725     |                                                                                             |       0
   1.575     |                       0        0           0                 0                              |       2
   1.425     |                    0     0     1        0                 1        0                       0|       4
   1.275     |                             0     0  0     0     1     0                                    |       3
   1.125     |                             0     0  0  2  0  0  1  1                 0           0         |       7
  0.9750     |     0           0  0  0        0     0  1  1     1     1  1  1  0     0     0     0         |      11
Y 0.8250     |  0  0  0                 1  1  0  0  0  1  1  1  0     0  0  0     0     0                  |      12 Y
  0.6750     -                    0        0  1              1  1     0  0  1  0     0                    0-       8
  0.5250     |  0           0        0  0  1  1  0  2  1  2  5  3  2  1     0  1  0  0  0                 0|      24 P
A 0.3750     |              1  0     0  0     0  0  2 13 31 29 20  8  1  1  2  1  1     0                 0|     114 R
T 0.2250     |  0  0           0  0     1  1  1  2  8 71806***821 59  5  1  1                              |    3484 O
  0.7500E-01 |  0                 1     1     0    19495*********422 17  3  1  1  1     1           0      |   36140 J
M -.7500E-01 |                 0  1  0  1  1     2 26817*********731 31  1  1  1        0                  |   69729 E
2 -.2250     |                 0        1  0     2 23448*********427 21  4  1  1  1           0           0|   36437 C
7 -.3750     |              0           1        5  9 74757***835 69 12  0  1  1              0            |    3431 T
9 -.5250     |                 0     1           0  2  7 28 34 28  9  0  1  2  2     0     0               |     119 I
4 -.6750     |           0           0  1  1  1  1  1  2  4  2  2  2  1  1  0  0  0  0  0                  |      25 O
  -.8250     -                             0  1        2  0  1  1  0  1  3  1  0                           -      13 N
  -.9750     |  0           0        0  1  0  1  0  1  0  1  1     1  1     0  1  0        0              0|      13
  -1.125     |                          0     0  1  1        2  0  0  0        0  0        0               |       8
  -1.275     |  0                    1     0  1  0        1  0  0  0        1  0  1                       0|       9
  -1.425     |  0                          0        0     1        1     1                                 |       5
  -1.575     |  0                             0     0     1        0           0  0  0     0              0|       5
  -1.725     |                                                                                             |       0
  -1.875     |  0                                                                                          |       0
  -2.025     |  0                                0              0        0                                 |       2
  -2.175     |                 0              0                                                            |       1
  -2.325     -                    0                             0  0           0        0                 1-       3
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -
                2  2  2  1  1  1  1  1  1  0  0  0  0  0  0  0  0  0  0  0  0  0  0  1  1  1  1  1  1  2  2
                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                3  1  0  8  7  5  4  2  1  9  8  6  5  3  2  0  0  2  3  5  6  8  9  1  2  4  5  7  8  0  1
                3  7  3  8  3  8  3  7  3  8  2  7  2  8  2  8  8  3  8  3  8  3  8  3  8  3  8  3  8  3  7
                                                     X  AT M2794
```

Figure 12. The predicted beam spot 0.1270 m (5 in.) downstream of the copper window and 0.2794 m (11 in.) upstream of the target.

```
              97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44", 0.010 Cu 16" UPSTREAM

 Space # 2:  Distribution of particles as a function of  X  AT ALW5   (Element #154)     (along HORIZONTAL axis)
                                                       & Y  at ALW5   (Element #154)     (along VERTICAL axis)

  REAL! Distribution of FINAL RUN FOUND HERE
                                                       COUNTS  = 149925.
                                                         X PROJECTION

                                                    1  1  1  1  1  1  1
                                        1  3  5  9  2  5  7  8  7  5  2  9  5  3  1
                                     3  2  1  8  1  5  5  6  1  7  8  7  1  7  1  2  3
                                  5  6  6  6  7  2  4  4  3  9  4  8  6  7  9  4  4  0  5  1
                1  3  5  7  9  9  0  7  0  9  9  6  6  2  7  3  1  8  5  0  2  4  2  8  0  1  5  4  0  0  1
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
  0.5800     -     1  1     1  1  2  2  2  4  5  4  6  5 10  2  4  5  9  5  1  2  4  1  1                  -       78
  0.5400     |           1              2  1  1  1  1  2     2  3        1  1                              |       16
  0.5000     |                             1  2  1  1     2  2  2  3  2        1     1        1            |       19
  0.4600     |                                1  3     1  3  3  5  4  2  2  1        1                    1|       27
  0.4200     |     1                    2  2  3  5  6  9  5  7  5  6  2  2  4  2  2                        |       63
  0.3800     |  1                       1  2  5  6  8  9  6 11  8  7  6  2  2  3  2  2  1  1               |       83
  0.3400     |              1           4  3  9  8  9 14 13 12 20 15  9  9 10  1  2     1                  |      140
  0.3000     |                    3  3  7 12 17 24 29 40 38 56 39 24 29 20 12  6  5  1                     |      365
  0.2600     |              1        5  6 24 47 48 97 92113118114 96 65 48 32 23 15  3  2                  |      949
Y 0.2200     |        1           1  5 22 53 94122196263269319296271196177 97 38 27  5  1                  |     2453 Y
  0.1800     -                    1 11 35114200348440532596628604494423286184109 48 11  1     1  1         -     5068
  0.1400     |                    2 26 72180349528727927*********919722547345186 58 18  3  2     1         |     8769 P
A 0.1000     |                 1  3 23 98281458796*********************775481269108 28  3                  |    12593 R
T 0.6000E-01 |              1  1  1 41138353652976*********************973589328124 32  6  2               |    15904 O
  0.2000E-01 |           2  2  1  5 51161418692***************************720370163 34  3                  |    18520 J
A -.2000E-01 |           1     2  2 44165410763***************************744406138 30  6        1         |    19384 E
L -.6000E-01 |           1        9 30154369729***************************724384148 36  3     1            |    18525 C
W -.1000     |              1     2 50135305636989************************681351139 33  7                  |    16354 T
5 -.1400     |              1     5 24 94265513774*********************765475262111 23  3                  |    12689 I
  -.1800     |                    3 18 67182317559724893995******955708543329174 64 17  4  2  1            |     8624 O
  -.2200     -                    1 13 49105219311450499576612572536435323199112 45 14  1     1            -     5074 N
  -.2600     |                    3  4 22 50107156206254266272284249214151 90 62 19 10                     |     2420
  -.3000     |        1              6 12 15 39 50 84 95126117137113 90 56 43 30  8  3                     |     1025
  -.3400     |     1                 1  4  5  6 19 36 46 50 41 39 30 32 19  9 13  3  1     1               |      356
  -.3800     |                    3  2  3  4  5  3 11 12 16  9 17 18 15  9  8  4  1  2     1               |      143
  -.4200     |           1           2     4  3  8  4  5  4  6  4 11 12  4  3  1  3  1  1                  |       77
  -.4600     |                          1  2  1  3  5  4  1  5  4  3  2  1  1  3  3     1                  |       40
  -.5000     |        1                    2  2  2  6  2  6  2  3  6  1  2  1  1        1                  |       38
  -.5400     |                 1     1        1     2     4  2  1  2  1  3                       1         |       19
  -.5800     |                    1                    3  1  6  3  3                 1                     |       18
  -.6200     -        1  1  1  2  3  5  4  2  2  9  7  5 10  5  4  7  2  6  5  3  2     1  2               -       89
             +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0

                .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                6  5  5  5  4  4  3  3  3  2  2  1  1  1  0  0  0  0  1  1  1  2  2  3  3  3  4  4  5  5  5
                2  8  4  0  6  2  8  4  0  6  2  8  4  0  6  2  2  6  0  4  8  2  6  0  4  8  2  6  0  4  8
                                                      X  AT ALW5
```

Figure 13. The predicted beam spot at the exit of the aluminum window on an enlarged scale.

```
                   97/11/18 - 2A AT 500 MEV - FINAL Leff - 0.005" Al 44", 0.010 Cu 16" UPSTREAM

    Space # 7:  Distribution of particles as a function of  X  AT CUW10  (Element #167)     (along HORIZONTAL axis)
                                                          & Y  at CUW10  (Element #167)     (along VERTICAL axis)

     REAL! Distribution of FINAL RUN FOUND HERE
                                                    COUNTS  = 149615.
                                                       X PROJECTION

                                                     1  1  2  2  2  1  1
                                          1  3  7  2  7  1  2  1  7  2  7  3  1
                                       3  1  4  3  4  4  2  6  2  6  7  2  1  0  2
                           1  1  3  8  0  3  0  3  9  2  3  7  6  3  4  6  3  0  4  7  3  2
                 7  0  1  4  8  8  8  6  7  3  9  0  4  9  3  1  3  7  7  1  3  0  5  0  5  1  7  4  4  0  7
              +--|--------------|--------------|--------------|--------------|--------------|--------------|+
   0.5800     -  1                                            1        1        1  0                       3-       8
   0.5400     |                                      1                                                      |       1
   0.5000     |                                   1        1  1  1  1                                      0|       5
   0.4600     |                 1        1     1  2     1  2  1  1  4  1  1     1                           |      17
   0.4200     |  0                    1  1        2     1  2  1  4  5  1     1                              |      19
   0.3800     |                 1        1  4     4  3  1  1  4  2  2  4  1     1  2                        |      31
   0.3400     |                       2  2        5  5  7 12 12  6  1  2  4  3        1                    0|      62
   0.3000     |           1              1  1 14 13 20 20 28 26 28 20 20  6  5  5  1  2                     |     211
   0.2600     |           1  1     1     2  5 13 39 54 87 95 99 76 81 58 44 13 10  2  1  1  1               |     684
 Y 0.2200     |  1              1  2  2  8 17 59110158215280312282225168100 45 15  4  1     1        1      |    2010 Y
   0.1800     -              1     1  3 11 42 98237390499726705668525398231104 31 10  4  4  3               -    4692
   0.1400     |              1     1  3 25 63193420741981************691378193 60 20  5  2  1     1  1      |    8482 P
 A 0.1000     |              2  1  3  8 20 97310650*********************601270 84 24  1  1  1               |   12713 R
 T 0.6000E-01 |                 2  5  9 27139389785*********************824328112 28  8  3  2     2         |   16438 O
   0.2000E-01 |              4  2  4  8 35138437896*********************873404108 25  2  6  2  1  1         |   18913 J
 C -.2000E-01 |                 1  4 10 34150437923*********************998415120 29  6  3  2  4            |   20351 E
 U -.6000E-01 |                 2  4 11 38134442963*********************919386128 24  7  4  1               |   19245 C
 W -.1000     |              3  2  3  9 28116345803*********************826363112 15  8  3  1               |   16765 T
 1 -.1400     |           1  2  2  2  4 17 92304633*********************654253 81 25  5  3  1        1     0|   12784 I
 0 -.1800     |                 1  3  6 18 61201418684996*********985746415170 55 19  5  3           1      |    8506 O
   -.2200     -           1  1  1  3  4 15 35101265365519656700636573416219103 41  5  2  2  1  1            -    4667 N
   -.2600     |        1     2        3  9 19 36109179222272295224229188106 51 21  6  5     2               |    1980
   -.3000     |              1     1  1  4  4 18 34 56 73 95 96 91 83 60 34 10  9  2  2     2  1            |     677
   -.3400     |                       1  3 11  5 10 14 27 18 21 25 18 15 14  7  1  2  3                     |     196
   -.3800     |                 1        2  2  1  5  7  5  8  7  8  6  8  5  1  2  1  1                     |      70
   -.4200     |                    1     1  1        1  1  5  5  3  2  4  4  2  1  1                        |      32
   -.4600     |                       1  2  2  1     2  1  3  3  4  1  2  1  2        1                     |      26
   -.5000     |  0                       1     1  1  3  1           1        2                              |      10
   -.5400     |                          1           1     1  2  2  1                                       |       8
   -.5800     |                                         1              1  1                                 |       3
   -.6200     -  4                                            1              0                             3-       8
              +--|--------------|--------------|--------------|--------------|--------------|--------------|+
                 -  -  -  -  -  -  -  -  -  -  -  -  -  -  -  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0  0
                 .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .  .
                 6  5  5  5  4  4  3  3  3  2  2  1  1  1  0  0  0  0  1  1  1  2  2  3  3  3  4  4  5  5  5
                 2  8  4  0  6  2  8  4  0  6  2  8  4  0  6  2  2  6  0  4  8  2  6  0  4  8  2  6  0  4  8
                                                       X  AT CUW10
```

Figure 14. The predicted beam spot at the exit of the copper window on an enlarged scale.