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DESIGN OF A DIAGNOSTIC AREA-TYPE BEAM POSITION MONITOR FOR X-RAY BEAMLINES AT THE NATIONAL SYNCHROTRON LIGHT SOURCE

NATIONAL SYNCHROTRON LIGHT SOURCE

bnl

MASTER

BROOKHAVEN NATIONAL LABORATORY
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DESIGN OF A DIAGNOSTIC AREA-TYPE BEAM POSITION MONITOR FOR X-RAY BEAMLINES AT THE NATIONAL SYNCHROTRON LIGHT SOURCE

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ABSTRACT

We have built a prototype area-type beam position monitor for use as a diagnostic tool at the National Synchrotron Light Source. The device is compact and fits into a vacuum cross. We completed range and resolution tests of the device at beamline X-19A at the NSLS and concluded that such a monitor can be placed in the confines of the vacuum cross.

DISCLAIMER

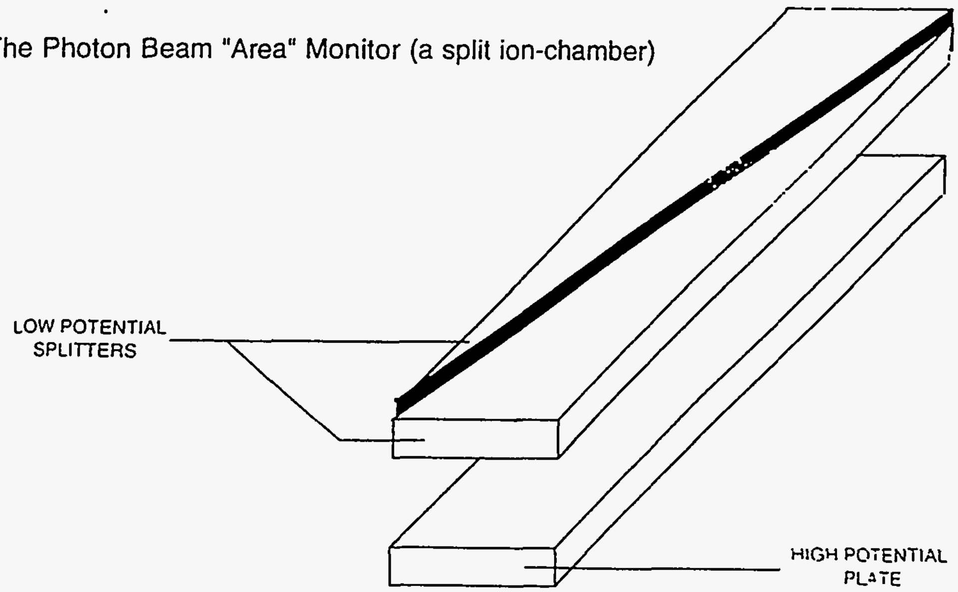
I. INTRODUCTION:

In many cases, the stability of a photon beam provided by a synchrotron is of utmost importance in order that experimenters may take advantage of the transverse dimensions of a photon beam. For this reason, efforts must be made to keep such beam deviation to within a fraction of the beam's transverse dimensions. [1]

To counter this problem, the NSLS is currently developing a family of photon beam position monitors for use on the beamlines as feedback and diagnostic elements in hopes that a device which is sufficiently general in design and relatively inexpensive will gain acceptance from both users and accelerator physicists. Such devices exploit the photo-electric effect and all should also have sensitivity on the order of microns. [1]

The following paper presents our design for an "area-type" beam position monitor (BPM) which is actually a split ionization-chamber as described by Tischler et al. [2]. We have designed it such that it has a generic design in that it can fit into a vacuum cross and with minor modifications can double as a normal ion-chamber, and it was inexpensive.

Figure 1. The Photon Beam "Area" Monitor (a split ion-chamber)

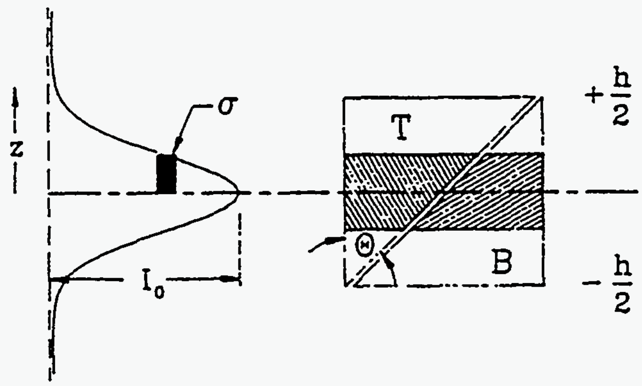


II. THEORY

The split ion-chamber differs from a conventional ion chamber in that the low potential side of the chamber consists of two triangular plates (splitters) instead of one (fig. 1), and associated with each of these splitters is a current dependent upon the potential between it and the full plate yet independent of the other splitter.

In essence, the incident beam passes over the first splitter and ionizes the gas residing in the chamber via the photo-electric effect. Electrons resulting from the collisions of photons and gas particles seek the low potential split plates while their counterpart ions go to the the high potential. This results in a current later defined as I_T registered at the top splitter.

Figure 2. Beam Coverage on 1/2 BPM



Continuing on its flight, the photon beam passes over the bottom plate and photons within the beam collide with gas particles resulting in current I_B at the bottom plate.

Assuming the photon beam to be a Gaussian, one may show that the top and bottom currents are respectively,

$$I_T = \frac{I_o(t)}{\sigma\sqrt{2\pi}} \tan\theta \int_{-\frac{h}{2}}^{\frac{h}{2}} (\delta + \tfrac{h}{2}) \exp\left[\frac{-z^2}{2\sigma^2}\right] dz$$

and

$$I_B = \frac{I_o(t)}{\sigma\sqrt{2\pi}} \tan\theta \int_{-\frac{h}{2}}^{\frac{h}{2}} (\tfrac{h}{2} - \delta) \exp\left[\frac{-z^2}{2\sigma^2}\right] dz$$

where height h of the nested plates, the pitch angle θ and the beam height σ are defined in fig. 2.

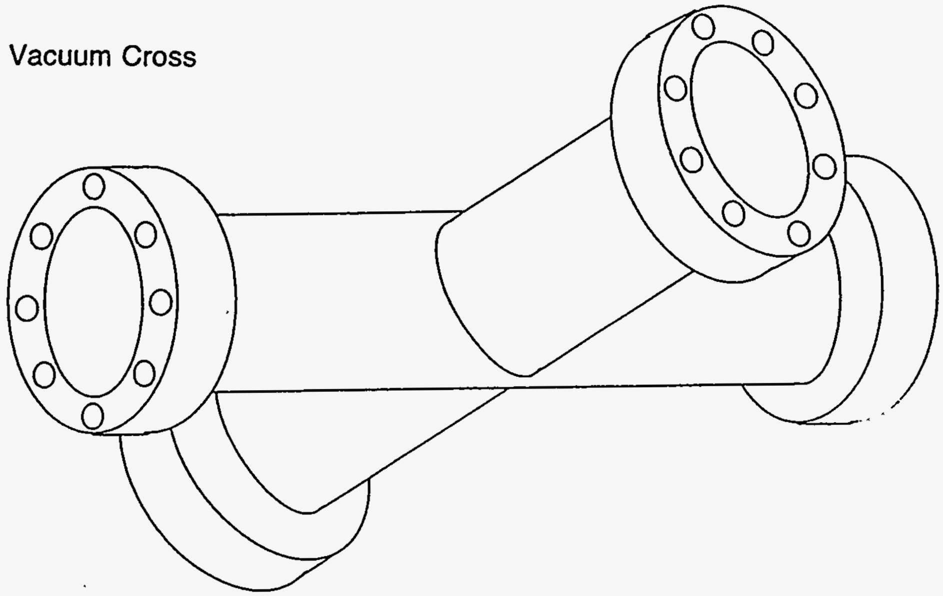
In and of themselves the currents I_T and I_B tell us nothing about beam position.

However, the difference over the sum of the two currents yields the beam displacement δ from the center of the monitor, or

$$P(\delta) = \frac{I_T - I_B}{I_T + I_B}$$

thus allowing for a 1:1 mapping from electronic to spacial quantities [1].

Figure 3. A Vacuum Cross



III. DESIGN

We have designed half of an area-type beam position monitor which fits into a stainless steel vacuum cross (fig. 3). The completed device would consist of two such vacuum crosses placed in a line and each containing monitors oriented perpendicular to one another.

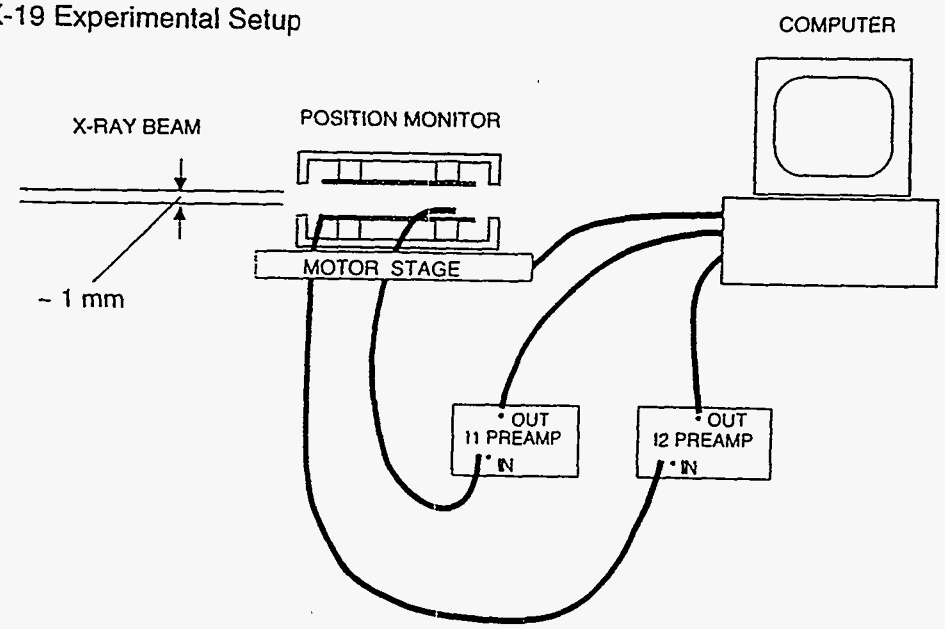
In designing our prototype BPM, we have constrained ourselves to the parameters of low-cost, simplicity of design, and the dimensions of a vacuum cross. To such an end, we built this BPM with a limit on specialized machining and focused on drawing ready-made components from available stock thus optimizing the cost and simplicity of the device.

In essence, an Aluminum channel connected on one end by a conflat flange with a round hole in the center slides into the vacuum cross. The high-voltage plate connects to one side of the Al channel while the two splitters connect to the other side to form a rectangle. All such plates have been tapped and connect to the channel via nylon screws. Appendix A contains a photograph of our BPM while Appendix B contains the a scale assembly diagram and Appendix C the blueprints used in designing the device.

IV. EXPERIMENTAL

We carried out preliminary testing of our half-BPM on NSLS beamline X-19A with a 1mm high monochromatic, 7 keV x-ray beam in an open air environment. We placed a 300V potential between the plates and oriented the device such that the plates were perpendicular to the experimental floor.

Figure 4. X-19 Experimental Setup



We simulated beam motion by mounting the BPM on a stepping motor stage which would scan the BPM in the the horizontal and vertical dimensions. Using a laser position finder and burns on x-ray sensitive paper, we roughly positioned the beam near the center of the BPM. Keithley preamplifiers boosted the incoming signal, and count-rate vs. postion data was recorded by the in-house ACE program [3]. Figure 4. represents a schematic of our experimental setup.

V. RESULTS

Appendix D contains the raw data collected during our experiment. We completed data analysis with the XMGR program.

Figure 5a represents a vertical scan within the limits of the BPM while the beam is centered on the horizontal We have defined the signal starting in the upper left hand corner as I_1 and the bottom left to be I_2. Notice as I_1 registers a high count rate, I_2 registers a much lower count rate. As the beam (or in our case the motor) approaches the horizontal origin, the signal I_1 decreases as I_2 increases. The intersection of the I_1 and I_2 represent the geometric vertical center where both splitters will register similar currents (that is $I_1 = I_2$).

Note also in figure 5a. that if the beam had been properly centered, the intersection of I_1 and I_2 would occur at zero-point on the Vertical Position (mm) axis. We will touch upon this more fully in the discussion.

Figure 5b. represents the difference over the sum of the signals I_1 and I_2. Here it is important to note that the difference over the sum be a straight line, and in this case it nearly is straight.

Figure 6a. represents another vertical scan but the beam has been displaced 4mm from the horizontal. We feel that the "electron deficiency" in the top left of the I_1 signal occurs because the I_1 splitter resides in close proximity to the Al channel wall which "robs" photo-electrons originally in-bound for the I_1 splitter. Perhaps the cause of this problem is due to the electrical edge effects on the side of the plate.

Dips also occur in both I_1 and I_2at this position. We can provide no satisfactory explanation to this problem

Figure 6b. shows us the difference over the sum of the signals I_1 and I_2 from figure 6a. It is apparent that the electron deficiency is of no consequence. However the central dip in the difference over the sum shows that the device cannot provide adequate resolution at 4mm from the horizontal.

VI. DISCUSSION OF RESULTS

It is apparent from figure 5a that we did not center the beam properly. To exploit the difference over the sum as a mapping tool it is helpful that the beam be centered inside the high and low voltage plates during calibration. Although this is not necessary, it is far easier to center the beam and get an absolute result as opposed to not centering the beam and having to make further necessary calculations.

We have proposed a modification to the initial beam positioning procedure which should be implemented in the future. Using a laser position finder and x-ray burns one

Figure 5a.

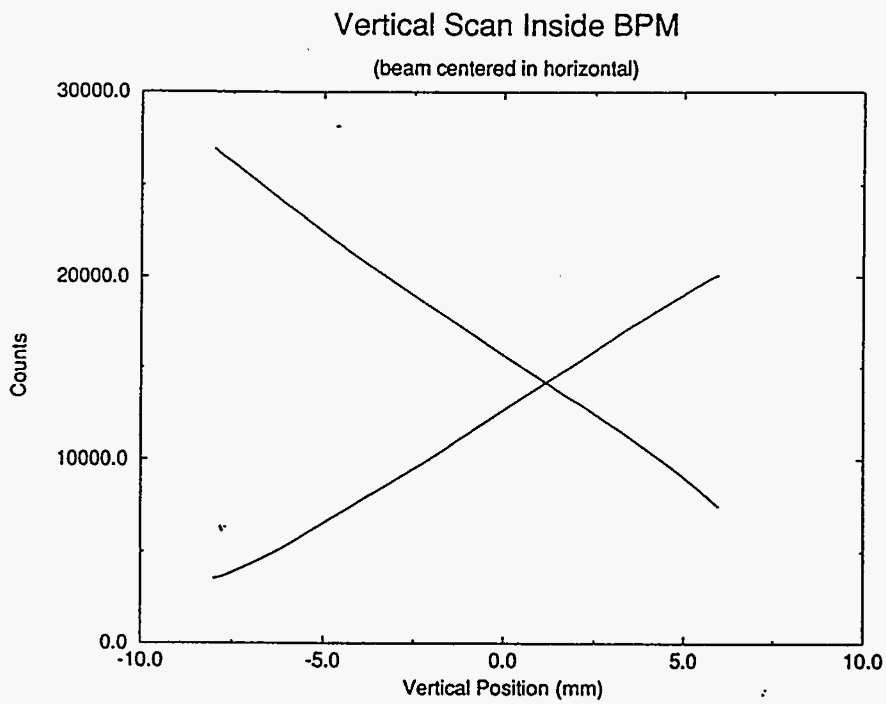


Figure 5b.

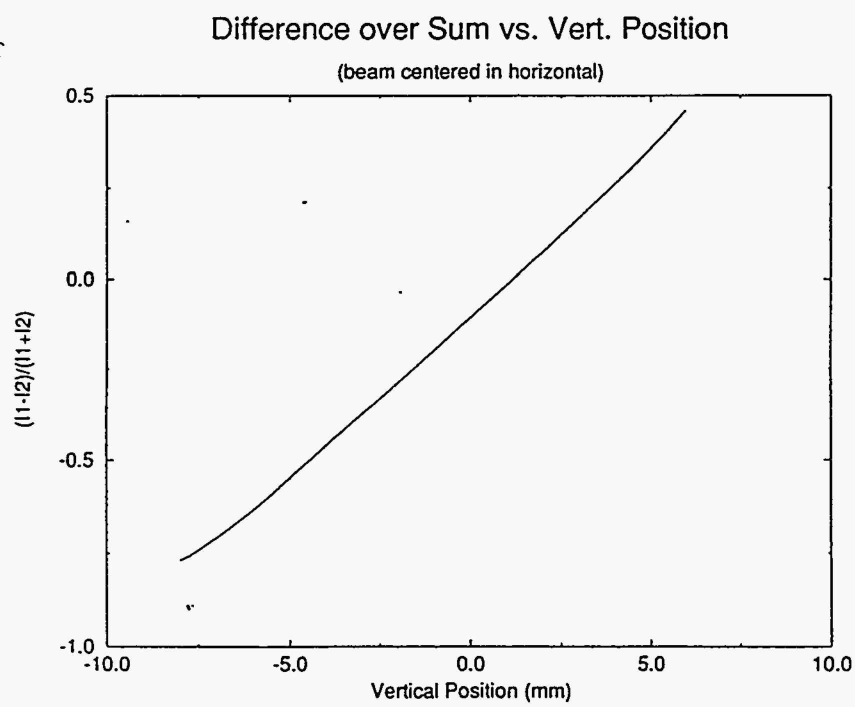


Figure 6a.

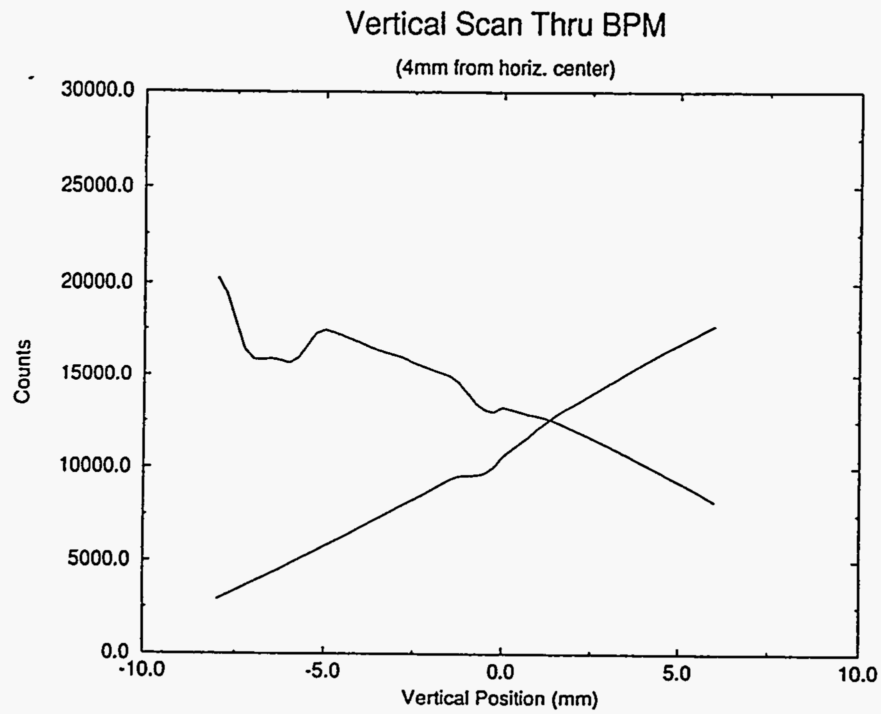
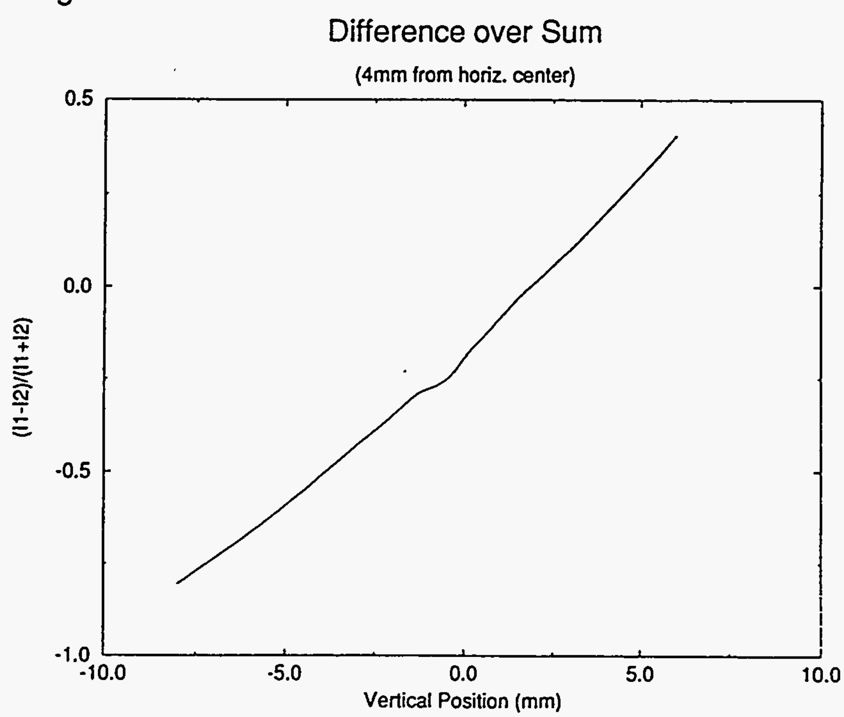


Figure 6b.



can roughly postion the beam in the center of the device as we have. The next step, the one we neglected to implement, is to set up a cross-hair across the face of the device, the intersection of which is centered across the high and low voltage plates. At this point one must produce more burns while moving the motor stage such that the device centers itself on the beam.

It appears that the electron deficiency seen in I_1 of figure 6a. is of no consequence because there is no trace of it in the difference over sum (fig. 6b.). However, it would be ecclectically pleasing to get rid of this behavior and thus we propose a solution of milling a 3/4" slot down the channel wall such that electrons which normally would go there, are incapable because of the greater distance between the channel wall and the splitter. A second and more common solution would be to place buffer plates close to but not touching the ends of the two splitters. Each of these plates would maintain a potential equal to that of one of the plates.

Regarding the central dips in figure 6a., we suggest milling a slot down the center of the splitter mounting wall. Like the slot above, it would allow the individuals splitters to attract their photo-electrons without the interference of the lower potential channel wall.

VII. CONCLUSIONS

This paper has discussed the design and performance of a low-cost and inexpensive area-type beam postition monitor built almost exclusively of NSLS stock materials. The next stage in development of this BPM is to build a second prototype with modifications as discussed in section VI. Assuming success, a duplicate will be placed in line with the existing half-BPM such that the two will allow an x-ray beam to pass unmolested. Following such, we will seal our BPM and run free-flowing helium through the monitor and test the completed monitor with potentials higher than 300V.

Though our BPM cannot provide adequate resolution for current needs, our project has been a success in that we have designed a low-cost BPM of sufficiently general design to build the majority of components from existing materials. We feel that further generations of this device will provide the necessary resolution as well as the existing features previously discussed.

VIII. ACKNOWLEDGEMENTS

We thank R. Thomas and the the DOE Science and Engineering Research Semester Program for funding this project. One of us (D.C.) thanks the NSLS R&D machinists R. Green and G. Nintzel for suggestions and help during the developmental stages. Likewise, D.C. thanks G. Vanderlaske for his timeless patience in teaching machine skills and shop safety at the NSLS User Machine Shop. D.C. also thanks E. Fontes for taking time to proof this paper. Special thanks go to D.C.'s advisor L. Berman for his guidance, generosity, and friendship.

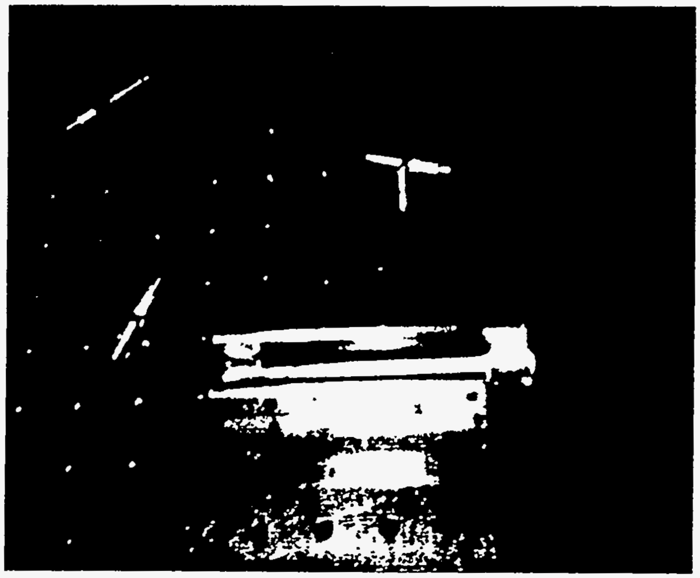
IX. REFERENCES

[1] S. Krinsky, J. Bittner, A.M. Fauchet, E.D, Johnson, J. Keane, J. Murphy, R.J. Nawrocky, J. Rogers, O.V, Singh, and L.H. Yu, *Storage Ring Development at the National Synchrotron Light Source*, **BNL Tech. Note #46615**

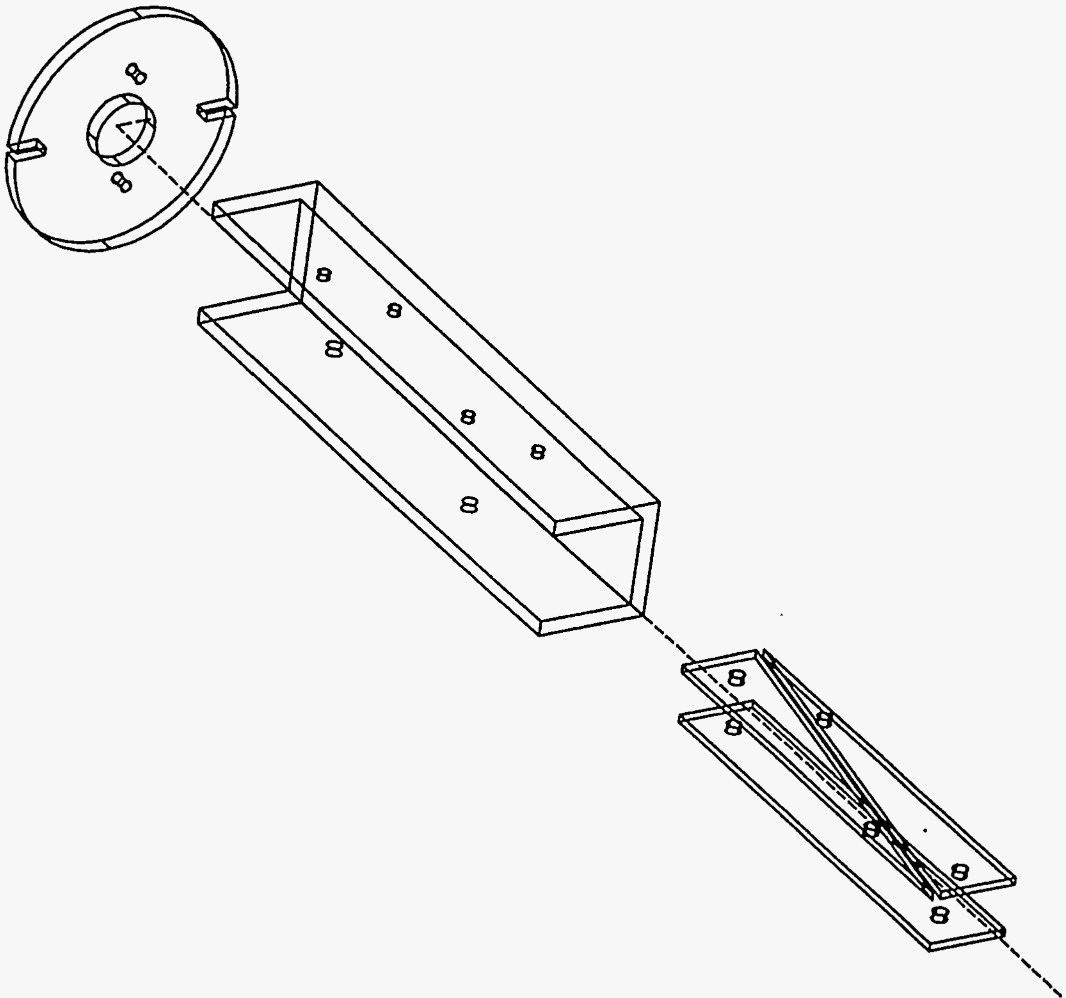
[2] J.Z. Tischler and P.L Hartman, **Nucl. Instrum. Methods,** 172, 67-71 (1980)

[3] S.K. Feng-Berman, D.P. Siddons, and L.E. Berman, **Nucl. Instrum Methods Phys. Research Sect. A,** 347, 603-606 (1994)

APPENDIX A: PHOTOGRAPH OF BPM



APPENDIX B: ASSEMBLY DIAGRAM

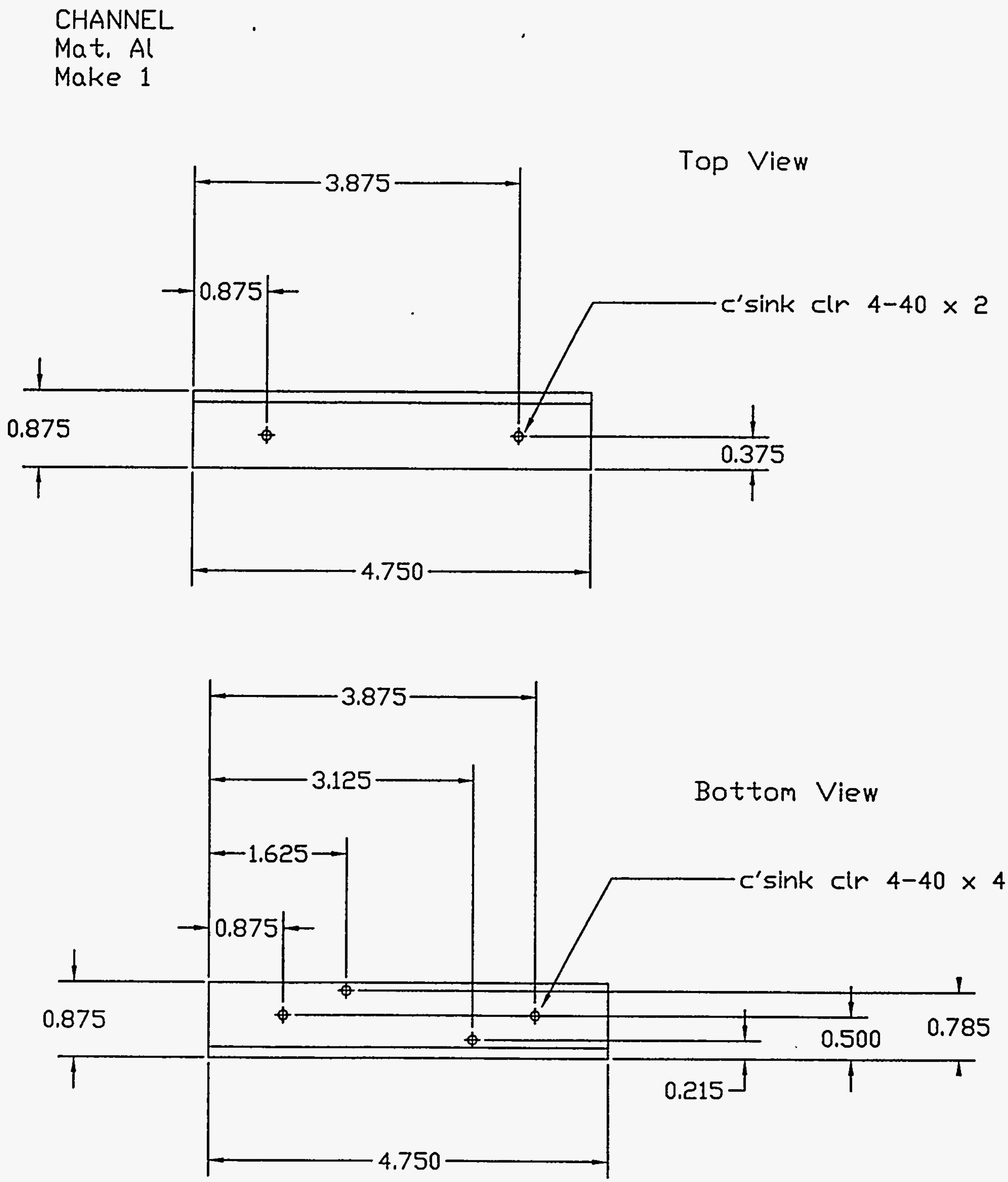


NSLS	NATIONAL SYNCHROTRON LIGHT SOURCE BROOKHAVEN NATIONAL LABORATORY UPTON, NY 11973-5000

AREA-TYPE BEAM POSITION MONITOR ASSEMBLY VIEW

DRAWN BY	DRAWN FOR	DATE	
[illegible]	[illegible]	[illegible]	All Dimensions are in Inches

APPENDIX C: BLUEPRINTS



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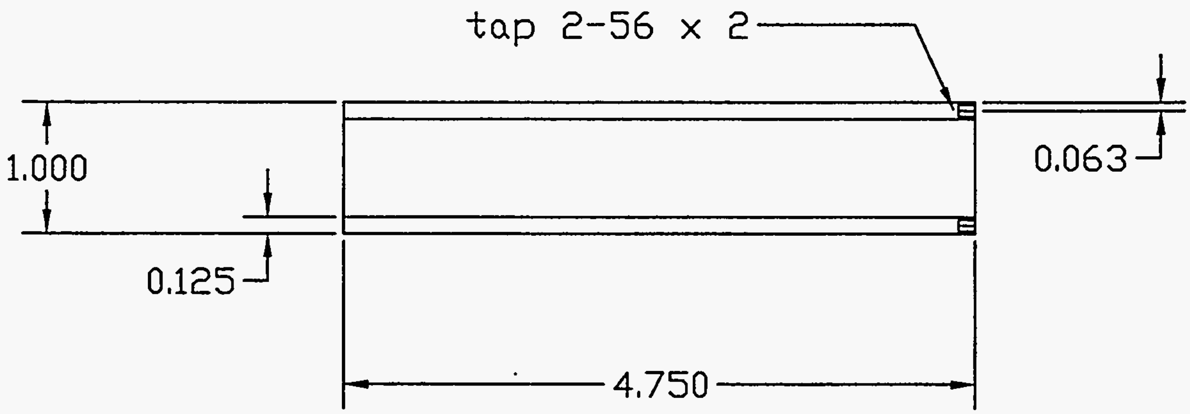
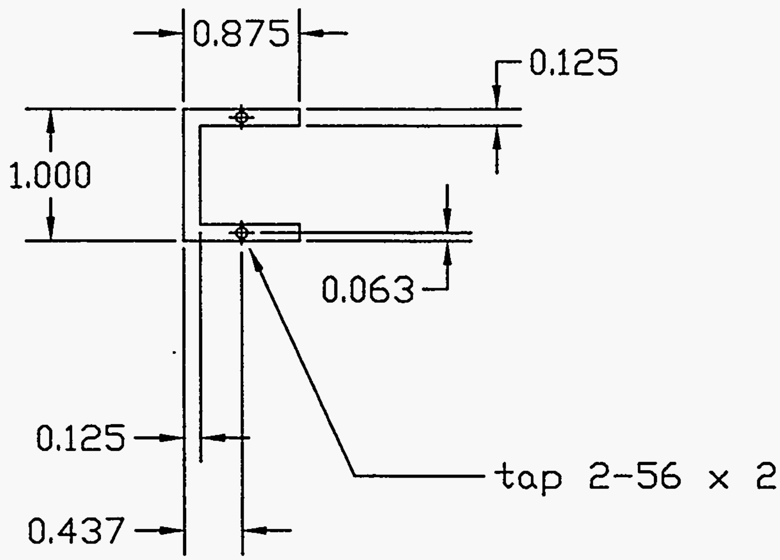
AL CHANNEL (Top and Bottom Views)

CHANNEL

Side View



Front View



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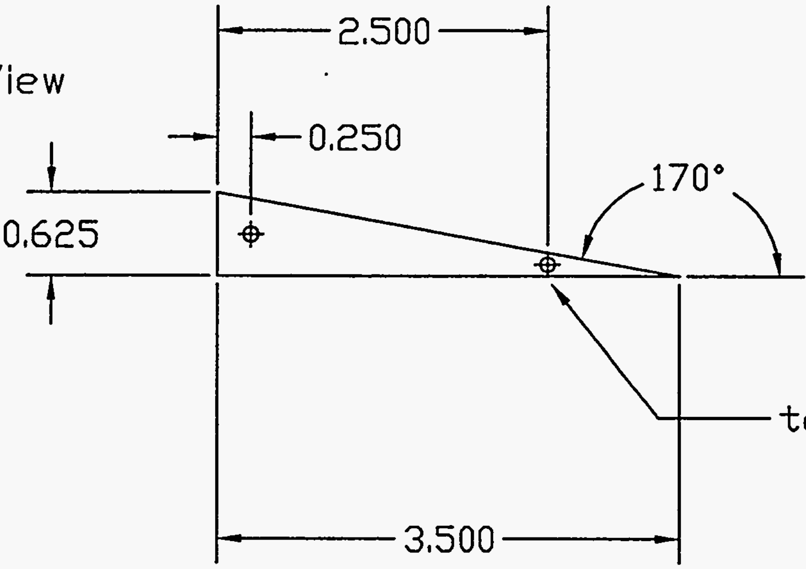
AL CHANNEL (Side and Front Views)

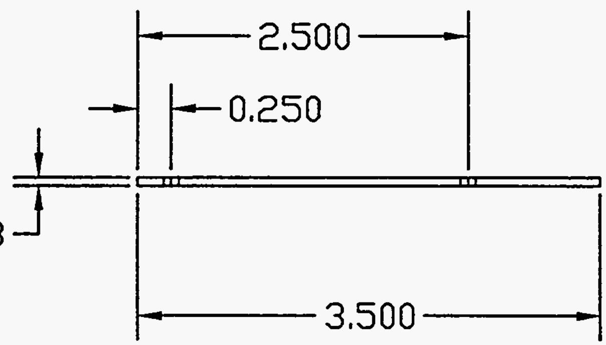
DRAWN BY:	DRAWN FOR:	DATE:	
[illegible]	[illegible]	[illegible] June [illegible]	All Dimensions are in Inches

SPLITTER
Mat. Al
Make 2

Top View



Side View



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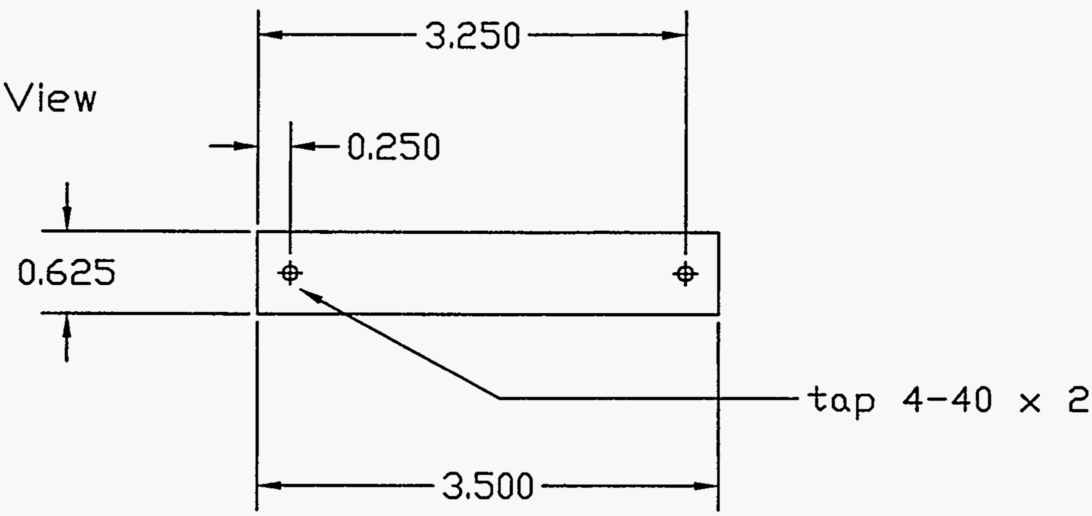
SPLITTER (Top and Side Views)

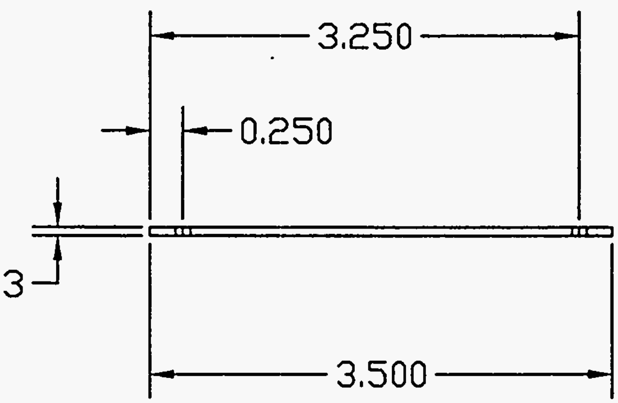
DRAWN BY:	DRAWN FOR:	DATE:	
[illegible]	[illegible]	[illegible]	All Dimensions are in Inches

RECTANGLE PLATE
Mat. Al
Make 1

Top View



Side View



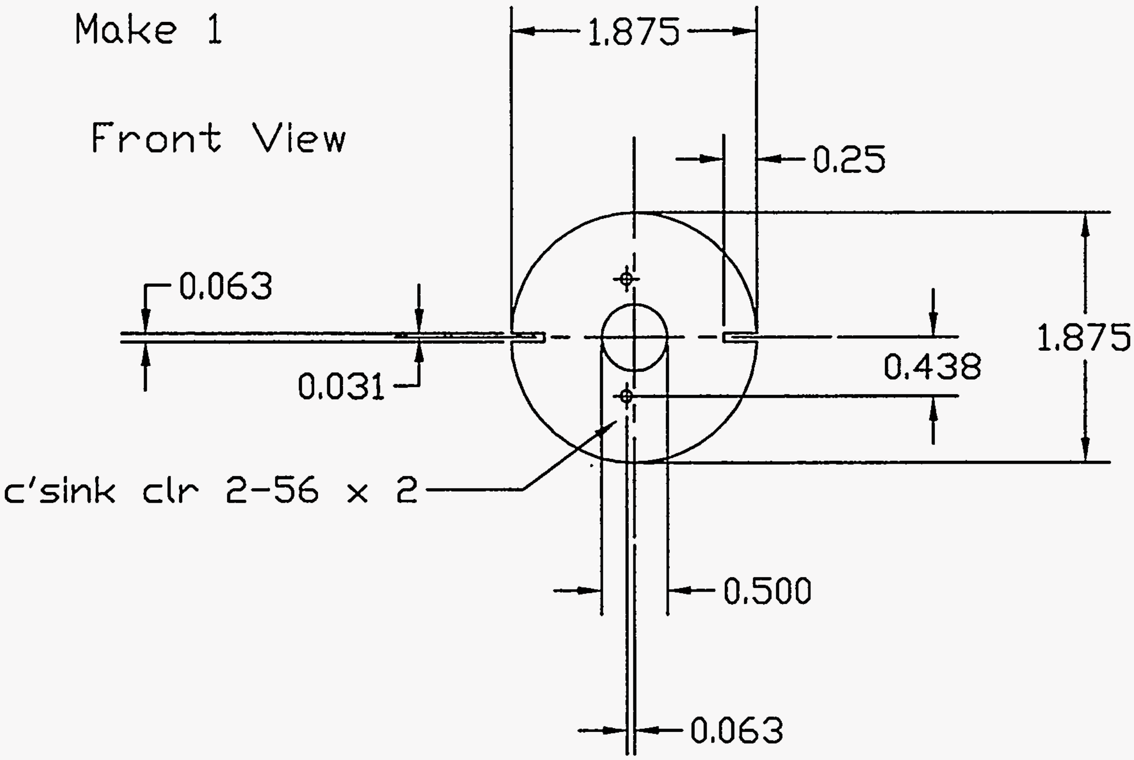
NOTE: plates separated from channel by mylar spacers and nylon screws

NSLS	NATIONAL SYNCHROTRON LIGHT SOURCE BROOKHAVEN NATIONAL LABORATORY UPTON, NY 11973-5000
RECTANGLE PLATE (Top and Side Views)	

DRAWN BY:	DRAWN FOR:	DATE:	
[illegible]	[illegible]	[illegible]	All Dimensions are in Inches

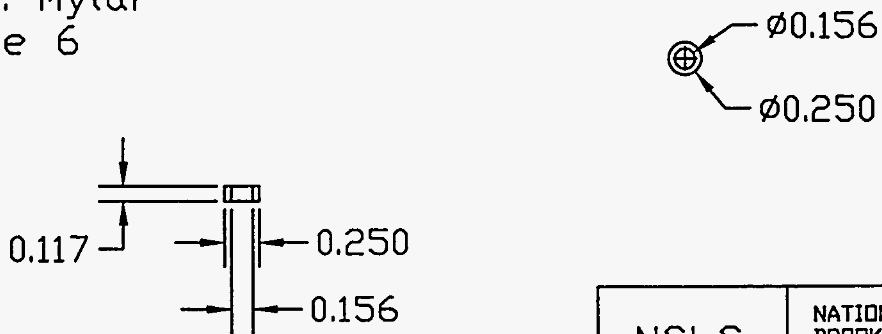
MOUNTING FLANGE
Mat. Cu
Make 1

Front View



NOTE: Fashioned from 1-7/8" conflat

SPACER
Mat. mylar
Make 6



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MMOUNTING FLANGE AND SPACER

DRAWN BY:	DRAWN FOR:	DATE:	
[illegible]	[illegible]	[illegible]	All Dimensions are in Inches

APPENDIX D: RAW DATA

Beam centered on horizontal

```
#Filename : pm.004
#code position    unit  pulse_pos pulse/unit drv slot addr MinSpd MaxSpd Acc Back
#  pv      9.0000     mm          3600    400.000  e500 22   6     0   500   100
#  ph      0.0000     mm             0   -400.000  e500 22   7     0   500   100
 ode    cnt type          counts slot addr time base Preset/Monitor    name
#  cl   kcnt.cnf               0   17    1     0    0 P              clock
#  i0   kcnt.cnf               0   18    1 -25000    0 C     mon ion chamber
#  i1   kcnt.cnf               0   17    3     0    0 C            plate 1
#  i2   kcnt.cnf               0   18    3     0    0 C            plate 2
#  i-   kcnt.cnf               0   18    3     0    0 C   electron current
#  r3        mca               0    1    3   175  208 C                tds
#  r1        mca               0    1    1    51   80 C                 cu
#  r2        mca               0    1    2   104  130 C              ta/rb
#Mon Dec  4 00:40:28 1995
#Motor pv scan from      -8.0000 to       6.0000.
#Instead of align offset [      15.0000,       10.0000].
# ** scan no.: 0 **
```

#step	pv Pos.	cl	i0	i1	i2
0	-8.0000	100001	32147	3532	26947
1	-7.7500	100002	32129	3666	26533
2	-7.5000	100001	32160	3881	26168
3	-7.2500	100001	32172	4107	25771
4	-7.0000	100002	32171	4343	25396
5	-6.7500	100001	32192	4589	24999
6	-6.5000	100001	32182	4842	24623
7	-6.2500	100001	32162	5100	24233
8	-6.0000	100001	32142	5368	23859
9	-5.7500	100001	32162	5670	23506
10	-5.5000	100001	32150	5963	23130
11	-5.2500	100001	32168	6267	22786
12	-5.0000	100002	32144	6557	22408
13	-4.7500	100001	32142	6840	22048
14	-4.5000	100002	32193	7126	21711
15	-4.2500	100002	32197	7414	21350
16	-4.0000	100001	32169	7719	20998
17	-3.7500	100001	32164	8019	20642
18	-3.5000	100001	32161	8302	20295
19	-3.2500	100002	32178	8600	19960
20	-3.0000	100001	32177	8896	19625
21	-2.7500	100001	32185	9198	19301
22	-2.5000	100001	32163	9486	18960
23	-2.2500	100001	32190	9781	18633
24	-2.0000	100002	32206	10091	18307
25	-1.7500	100001	32186	10395	17964
26	-1.5000	100001	32203	10713	17655
27	-1.2500	100001	32224	11035	17330
28	-1.0000	100002	32212	11347	16999
29	-0.7500	100001	32209	11667	16679
30	-0.5000	100002	32212	11982	16334
31	-0.2500	100002	32225	12310	16011
32	0.0000	100001	32250	12637	15682
33	0.2500	100002	32244	12956	15357
34	0.5000	100002	32239	13282	15039
35	0.7500	100001	32220	13602	14711
36	1.0000	100001	32249	13935	14396
37	1.2500	100001	32237	14257	14051
38	1.5000	100001	32277	14587	13727
39	1.7500	100001	32265	14889	13395
40	2.0000	100002	32260	15226	13094
41	2.2500	100001	32290	15577	12783

42	2.5000	100001	32272	15906	12445
43	2.7500	100002	32295	16235	12128
44	3.0000	100001	32326	16557	11805
45	3.2500	100001	32364	16900	11485
46	3.5000	100002	32333	17199	11149
47	3.7500	100001	32334	17511	10805
48	4.0000	100001	32373	17831	10459
49	4.2500	100002	32367	18132	10112
50	4.5000	100001	32397	18446	9772
51	4.7500	100001	32384	18730	9405
52	5.0000	100001	32381	19018	9040
53	5.2500	100001	32408	19321	8675
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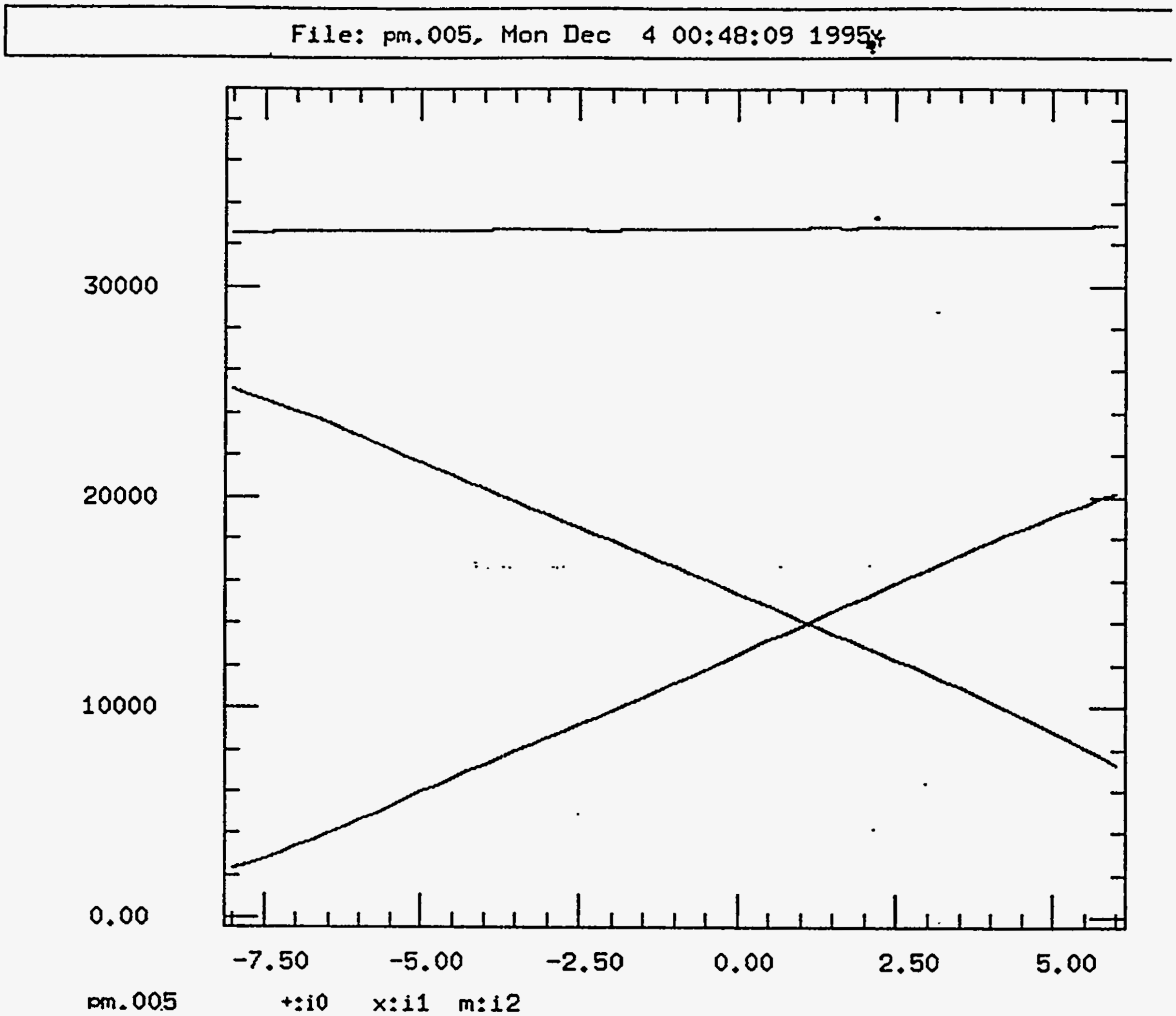
File: pm.005, Mon Dec 4 00:48:09 1995
30000
20000
10000
0.00
-7.50
-5.00
-2.50
0.00
2.50
5.00
pm.005
+:i0 x:i1 m:i2

scan pv -8 6.25

#Filename : pm.007

#code	position	unit	pulse_pos	pulse/unit	drv	slot	addr	MinSpd	MaxSpd	Acc	Back
# pv	6.0000	mm	2400	400.000	e500	22	6	0	500	100	
# ph	4.0000	mm	-1600	-400.000	e500	22	7	0	500	100	

ode	cnt type	counts	slot	addr	time	base	Preset/Monitor	name
" cl	kcnt.cnf	100001	17	1	0	0	P	clock
# i0	kcnt.cnf	33797	18	1	-25000	0	C	mon ion chamber
# i1	kcnt.cnf	20601	17	3	0	0	C	plate 1
# i2	kcnt.cnf	7284	18	3	0	0	C	plate 2
# i-	kcnt.cnf	7284	18	3	0	0	C	electron current
# r3	mca	0	1	3	175	208	C	tds
# r1	mca	0	1	1	51	80	C	cu
# r2	mca	0	1	2	104	130	C	ta/rb

#Mon Dec 4 01:04:19 1995
#Motor pv scan from -8.0000 to 6.0000.
#Instead of align offset [15.0000, 10.0000].
** scan no.: 3 **

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1	-7.7500	100002	34462	3152	19463
2	-7.5000	100002	34455	3404	17885
3	-7.2500	100001	34477	3643	16417
4	-7.0000	100001	34483	3884	15882
5	-6.7500	100001	34479	4112	15882
6	-6.5000	100001	34459	4340	15929
7	-6.2500	100002	34463	4563	15831
8	-6.0000	100002	34461	4809	15679
9	-5.7500	100001	34495	5051	15987
10	-5.5000	100001	34481	5287	16617
11	-5.2500	100002	34489	5531	17287
12	-5.0000	100001	34505	5777	17461
13	-4.7500	100002	34479	6019	17330
14	-4.5000	100001	34495	6263	17149
15	-4.2500	100001	34507	6516	16963
16	-4.0000	100002	34501	6787	16777
17	-3.7500	100002	34500	7033	16575
18	-3.5000	100002	34519	7294	16392
19	-3.2500	100001	34503	7544	16236
20	-3.0000	100001	34541	7806	16116
21	-2.7500	100001	34547	8051	15941
22	-2.5000	100001	34517	8276	15675
23	-2.2500	100001	34546	8539	15490
24	-2.0000	100001	34544	8813	15313
25	-1.7500	100001	34533	9082	15128
26	-1.5000	100001	34539	9349	14949
27	-1.2500	100001	34573	9537	14596
28	-1.0000	100002	34569	9574	14020
29	-0.7500	100001	34587	9579	13464
30	-0.5000	100001	34565	9708	13107
31	-0.2500	100001	34577	10016	12998
32	0.0000	100001	34557	10587	13249
33	0.2500	100002	34589	10940	13132
34	0.5000	100001	34597	11278	12990
35	0.7500	100001	34601	11640	12858
36	1.0000	100001	34613	12057	12768
37	1.2500	100001	34591	12421	12639
38	1.5000	100001	34638	12787	12479
39	1.7500	100001	34641	13104	12267
40	2.0000	100001	34620	13376	12044
41	2.2500	100002	34610	13656	11822

Beam displaced 4mm from horizontal

42	2.5000	100001	34613	13941	11597
43	2.7500	100001	34613	14233	11377
44	3.0000	100001	34610	14517	11146
45	3.2500	100001	34610	14794	10923
46	3.5000	100001	34621	15108	10706
47	3.7500	100001	34639	15403	10468
48	4.0000	100001	34622	15678	10216
49	4.2500	100001	34636	15967	9969
50	4.5000	100001	34665	16234	9729
51	4.7500	100001	34658	16493	9479
52	5.0000	100001	34630	16726	9236
53	5.2500	100002	34658	16989	9001
54	5.5000	100002	34642	17228	8742
55	5.7500	100001	34651	17487	8482
56	6.0000	100001	34636	17736	8216

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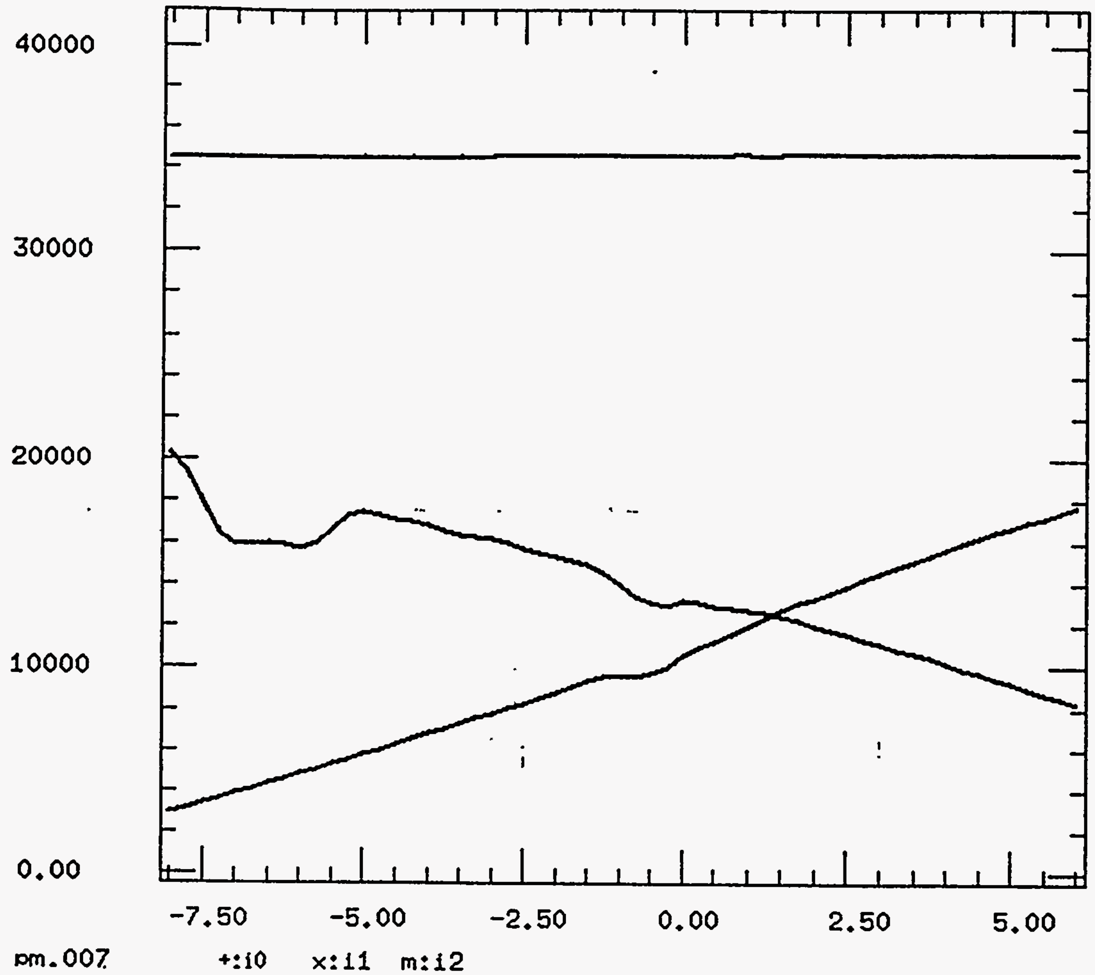

scan pV -8 6 .25

at 4mm (horiz position)