p. Bar Note
#571

Recent AP2 studies and a proposal to increase the transverse aperture to 40 pi-mm-mrad

M Church 10/06/97

AP2 Transverse Aperture -- an informal description of work done to date and a proposal to increase the transverse aperture of AP2 to 32π x 32π M Church 8/06/97

Overview With reverse protons, the downstream aperture of AP2 (downstream of IQ33) has been measured to be $\approx 20\pi$ at the central momentum. Based on trim scans, the upstream end appears to be much larger than this. If the aperture can be increased to 32π x 32π then the yield into the Debuncher will go up by approximately 30%, based on MCLENS simulations. Of course, in order for this to be fully realized, the Debuncher aperture must also be increased. In the considerations that follow, I design for a 40π aperture on paper, so that 32π can be realized in practice, in order to account for uncertainty in beta functions, alignment errors, beam steering errors, etc. There are 4 elements to upgrading the AP2 beamline transverse aperture:

1) Install motors on D4Q8 so that a 4-bump can be used in both dimensions to carefully adjust the Debuncher closed orbit in the injection region;
2) Modify the beampipe in several locations between D4Q3 and IQ33 to make a larger physical aperture;
3) Modify D4Q5 (LQE) so that it has a larger horizontal injection channel aperture;
4) Build a new septum magnet with a 13% larger horizontal aperture.

Geometry and Beampipe Figure 1 is a schematic of the downstream end of AP2. Beam is incident coming down from the left, bent up by ~30 mr by Q405, bent up by ~30 mr by ISEP, and then kicked onto the central orbit by IKIK. SEM733 measures injected beam, and SEM403 measures injected and circulating beam. A vertical 3-bump is possible with V401,V403,V406, and a horizontal 3-bump is possible with H501,H403,H405. Vertical beamline steering is provided with VT723, V730, ISEP, IKIK, and to some extent Q405. Horizontal beamline steering is provided with HT727, HT730, and HT731.

Figures 2- 10 show the apertures at critical locations between IKIK and Q405. In all cases, the "x" is the injected beam, and the "+" is the circulating beam. These drawings assume circulating beam centered in the quadrupoles, and that beamline elements are aligned perfectly horizontally. (Closed orbit measurements in the Debuncher indicate that in fact we run with a upward vertical bump at the injection area.) Dimensions are taken from mechanical drawings of beampipes and beampipe assemblies, and from actual measurements in the tunnel. Beta functions are from the "TEV I model" modulo a 4.7" move of Q406 upstream. (Q406 was moved 4.7" upstream about 1 year ago in order to place a larger injection line beampipe in the area above Q406.) The beta functions for this lattice differ from the TEV I model by <4%.

Injection kicker The injection kicker was calibrated using reverse protons and SEM733 to be 6.06 mr at 63 kV. Because of the electric field, this becomes 6.34 mr for pbars. (Design is 6.1 mr @ 60kV -- Pbar Note 364.) Dump resistors were subsequently changed to better match to the kicker, and the kicker recalibrated to be 6.81 mr at 64.5 kV for pbars. Using reverse protons, kicker flattop was measured to be flat to better than ±1%, (averaged over 180 nsec beam pulse [9 bunches]), the length was measured to be ~1480 nsec, and falltime was measured to be ~250 nsec. Figure 2 shows that aperture is not a problem in the kicker.

Q404 downstream Figure 3 shows the aperture at the downstream end of Q404. The vertical aperture for the injected beam is limited by the top of the beampipe to 26.0π.

Q404 center Figure 4 shows the aperture at the center of Q404. The star shape beampipe has been modified by extending the upper lobe by about 9.2mm. The vertical aperture for the injected beam is limited by the top of the beampipe to 38.7π.

BPM u.s. of Q404 Figure 5 shows the aperture at the BPM upstream of Q404. The BPM has been welded onto the star-shaped beampipe with a 3.2mm centerline offset to provide more aperture at the top. The outside of the BPM is flush against the magnet coils. Depicted in the drawing are the BPM electrodes. The vertical aperture for the injected beam is limited by the top of the BPM electrode to 33.9π.

Septum downstream Figure 6 shows the aperture at the downstream end of the septum. The d.s. beampipe has been welded onto the end of the Q404 BPM with an addition 3.2mm centerline offset. Together with the vertical slope of the beampipe to Q405, and the previous 3.2mm offset, this accounts for the 5.8mm offset of the circulating beam wrt the beampipe center. The vertical aperture for the injected beam is limited by the septum to 18.3π. The septum magnet was calibrated with reverse protons and SEM733 to give 32.8 mr at 14.4kA. The septum is designed to run at 20kA with a bend of 41.1 mr (Pbar Note 396). This implies a bend of 29.6 mr at 14.4kA, which is 10% different than the beam calibration.

Septum upstream Figure 7 shows the aperture at the upstream end of the septum. The vertical aperture for the injected beam is limited to 14.0π and the horizontal aperture for the circulating beam is limited to 31.4π. The septum itself is curved and the radius of curvature is optimized for a 41 mr bend. If one makes a closed orbit vertical bump upward, than the vertical injection aperture can be improved to about 20π throughout the injection region, while not compromising the circulating beam vertical aperture. I believe this is how we currently operate.

Q405 (LQE) downstream Figure 8 shows the aperture at the downstream end of Q405. The horizontal aperture for the injected beam is limited to 27.2π.

<u>Q405 (LQE) center</u> Figure 9 shows the aperture at the center of Q405. The horizontal aperture for the injected beam is limited to 25.7π. The dipole kick given by Q405 is based on a quadrupole gradient of 9.53 T/m (from the TEV I Design Report).

<u>Q405 (LQE) upstream</u> Figure 10 shows the aperture at the upstream end of Q405. The horizontal aperture for the injected beam is limited to 26.9π. The beampipe here is snug between the magnet pole faces and is hard up against the magnet coils at the u.s. end.

<u>Between Q405 and IBV1</u> The tightest spot is the u.s. end of IBV1 which has a physical horizontal half aperture of 39.0mm and a horizontal beta function of 36.1m, which gives an aperture of 42.1π. The nominal vertical bend of IBV1 (a modified B1 with ~3.2" aperture) is 61.9 mr at the present operating current. The above calculated exit angle (for reverse protons) from Q405 is 59 mr. Quad steering measurements with reverse protons show that the vertical beam offsets in IQ31, IQ32, and IQ33 are -.3mm, -4.5mm, and +2.9mm respectively (i.e., beam is well centered). Using the recent survey data, this extrapolates backward to within 5-10mm of the center of tht IBV1 d.s. face and forward to a position of 144-145 mm on the u.s. face of Q405, which is consistent with the previous calculations and a 6mm vertical bump in the Debuncher. However, the angle is 64-65 mr wrt Debuncher quad centerline, which is not consistent with the 59.1 mr angle calculated from the ISEP and Q405 kicks. Displacing the beam up by 6mm in Q405 increases its kick by 1.7 mr, but that is not enough to account for the discrepancy. I have not resolved these discrepancies in angles.

<u>Upstream of IBV1</u> Using a model for reverse protons matched to the Debuncher, the maximum beta functions are 110m horizontally and 76m vertically, which requires a 5.2" aperture horizontally and a 4.3" aperture vertically to fit 40π beam (at dp/p=0). The star chambers inside the small quads in AP2 have a horizontal aperture of 5.6" (at 0 vertical emittance), and the BPM's have an aperture of 5.7". Steering studies using trim magnets in AP2 with beam blown up transversally in the Debuncher indicate no aperture restrictions. Recent survey data indicate that all quads are aligned to within ±3mm.

<u>Modeling</u> A TRANSPORT-like application program (W138) was used to develop a model for reverse protons in AP2. The beam position in SEM grids was measured as a function of trim magnet current, and this data was used to adjust quadrupole strengths in the model via $\Delta x = \Delta\theta\sqrt{\beta_{SEM}\beta_{TRIM}}\sin(\phi_{SEM} - \phi_{TRIM})$. 32 independent measurements were made, and the difference between measured and predicted beta functions averages 13%, with a maximum discrepency of 25%. The model shows a reasonable beta function match into the Debuncher, but that the horizontal dispersion is not correctly cancelled after the left bend in AP2. For matching into the Debuncher, the beta function at the downstream focus of the lithium lens was taken to be

4.5 meters. According to MCLENS this phase space ellipse gives maximum yield into the Debuncher for an acceptance of 32π.

Beampipe modifications Figures 11-19 show the beampipe modifications that will increase the AP2 aperture to approximately 40π x 40π.

1) Run the kicker at 64.5 kV (6.81 mr kick).

2) Offset the beampipe and flanges between SEM403 and Q404 upward by 9mm.

3) Modify the star chamber in Q404 to increase the upper lobe by 6mm. (There is room beneath the coils.)

4) Offset the inner BPM electrode on Q404 upward by 6.1mm. (Probably want to recalibrate BPM gain and offset because of capacitance change.)

5) Offset the septum downstream end down by 2.8mm and enlarge septum horizontal aperture by 13%.

6) Increase beampipe size in Q405 by flattening 2.50" O.D. pipe to oval pipe and mill out Q405 pole faces to fit.

Future plans and suggestions

1) If study time is available, remeasure kicker flattop, length, and falltime more accurately with fewer bunches (maybe).

2) If study time is available, repeat AP2 dispersion measurements. This requires that horizontal SEM719 be operational. (maybe).

3) Do Poisson calculation for LQE magnet with pole faces milled out.

4) Verify that ISEP power supply can be run at 15% more current. (Obie has promised.)

5) Get cost estimate for LQE modification at TS. (D Harding has volunteered to look into this.)

6) Review septum design to see if simple modifications to present design will suffice. Make cost estimate.

7) Make up-to-date TURTLE model of AP2 and couple to MCLENS (maybe).

7) During upcoming shutdown, install motorized stand on Q408 (5k$ - 10k$).

8) During upcoming shutdown, make beampipe modifications between Q405 and IKIK (??$).

9) Remove, modify, measure, reinstall Q405 during upcoming shutdown if TS can fit it in their schedule.

10) Start construction of new septum magnet and spare.

AP2 Transverse Aperture -- Addendum on Dispersion M Church 10/03/97

A proper understanding of dispersive effects requires a good tracking study (TURTLE) to accurately model the beam losses for off-momentum particles. This is also true for understanding losses of particles with both vertically and horizontally large amplitudes. In addition, the phase space volume occupied by the particles coming out of the lens does not fit easily into an ellipse, but rather has a "butterfly" shape in phase space. This fact further obviates the need for an accurate tracking study. However, the following considerations shed some light on dispersive effects in AP2.

The nominal vertical dispersion at the downstream end of AP2 is very small (see Figure 20 and Table 1). The largest dispersion is at IQ33 and is .49 m. A particle with a 2% momentum deviation has a displacement of 9.8 mm. The vertical beta function here is 21.2 m, and the vertical aperture (for centered beam and no horizontal betatron amplitude) is ±71.0 mm. Therefore the vertical aperture here for a 2% off-momentum particle is 176.7 pi-mm-mrad. From the upstream end of Q405 and beyond, the vertical dispersion is everywhere less than .13 m. The worst case in this region is at the BPM at the upstream end of Q404 where the vertical aperture of a 2% off-momentum particle is reduced to 36.8 pi-mm-mrad from 40.3 pi-mm-mrad.

My model for the horizontal dispersion function in the AP2 beamline does not match the original design. Unfortunately, study time was not available to verify the accuracy of the model in predicting the dispersion function. Figure 21 shows the current modelled dispersion in AP2 -- it is not correctly cancelled coming out of the left bend. However, a +17A change in Q719 plus a +3A change in Q716 gives a much better dispersion cancellation and keeps the beta function match into the Debuncher fairly good. This is shown in Figure 22 and Table 2. For the "fixed" line, the horizontal dispersion is less than .015m everywhere downstream of the vertical bend IBV1, so that the transverse aperture for off-momentum particles is not significantly reduced by downstream aperture restrictions.

The aperture limitations for off-momentum particles comes primarily from the left bend, where the aperture for a 2% off-momentum particle is reduced to 0 pi-mm-mrad. The beampipe here is a combination of rectangular cross section straight sections connected together with bellows, BPM's, flanges, and round cross section straight sections. Many "kinks" are visible to the casual observer.

Appendix 1

Fermilab

To: John Marriner
From: Mike Church
Subject: AP2 beampipe modifications
Date: Sept. 18, 1997

This is a list of beampipe modifications required to increase the AP2 aperture to nominally 40 pi.

1) Install vertical and horizontal motion control on D4Q8 so that this quad can be moved remotely by ±5mm in either dimension. This requires new bellows also.
2) Offset the beampipe and flanges between SEM403 and Q404 upward by 9mm.
3) Modify the star chamber in Q404 to increase the upper lobe by 6mm beyond its current extension. (There is room for this beneath the coils.) Q404 should remain in its current location.
4) Offset the inner BPM electrode on Q404 upward by 6.1mm.
5) Offset the septum downstream end downward by 2.8mm from its current location. This includes the Debuncher beampipe also and requires that the flanges be offset here.
6) Offset the upstream end of the septum downward by 2.4 mm from its current location. {**MDC Note 10/03/97 -- currently space between septum and beampipe at upstream end is about 19 mm, with adequate clearance everywhere; however, flange upstream of septum is hard against the beampipe and will need to be either ground down, or moved farther upstream}**

The above modifications should obtain a vertical aperture of nominally 40 pi if the beam is well-steered and the kicker is run at maximum (64.5 kV). To obtain a horizontal aperture of 40 pi the following is required.

7) Remove Q405 (LQE) and ship to magnet factory for field measurement and pole face modification.
8) Reinstall Q405 with new beampipe installed. Increase beampipe size in Q405 by flattening 2.50" O.D. pipe to oval pipe. This will require new transition pieces upstream and downstream of the magnet.
9) IBV1, IQ31, IQ32, and IQ33 will require minor realignment.
10) To realize the full aperture increase in the horizontal dimension, a new septum with 13% wider horizontal aperture will need to be made. This septum can have the same length and the same vertical aperture, and the current power supply and cables will be adequate.

Appendix 2

Fermilab

Sept. 29, 1997

To: Victor Yarba

From: Mike Church

Subject: Initial specification for new Antiproton Source septum magnet

As part of a project to increase the transverse aperture of the Debuncher injection beamline (AP2) we are asking the Technical Division to fabricate and measure two new septum magnets (1 being a spare). This magnet will be required for the Collider Run II startup, currently scheduled at about 9/99. It is a modification of the septum magnets currently in use in the Antiproton Source. Essentially, we need the aperture in the field direction (referred to as horizontal) to be increased by 13% -- from a nominal 39 mm to 44 mm. Below is an initial list of specifications, with some discussion.

1) Horizontal aperture increases from 39 mm to 44 mm. This implies that the laminations need to be redesigned, and that possibly the copper bus and endplates require redesign.

2) Vertical aperture remains the same. Initially this was 53 mm but was later reduced to 49.8 mm with the insertion of aluminum(?) tabs to better constrain one of the copper bus bars.

3) Overall length remains the same to within +-2 mm.

4) Radius of curvature is increased from approximately 50 m to 60 m. This implies some redesign on the vacuum enclosure.

5) Lamination thickness, material, and insulation remains the same.

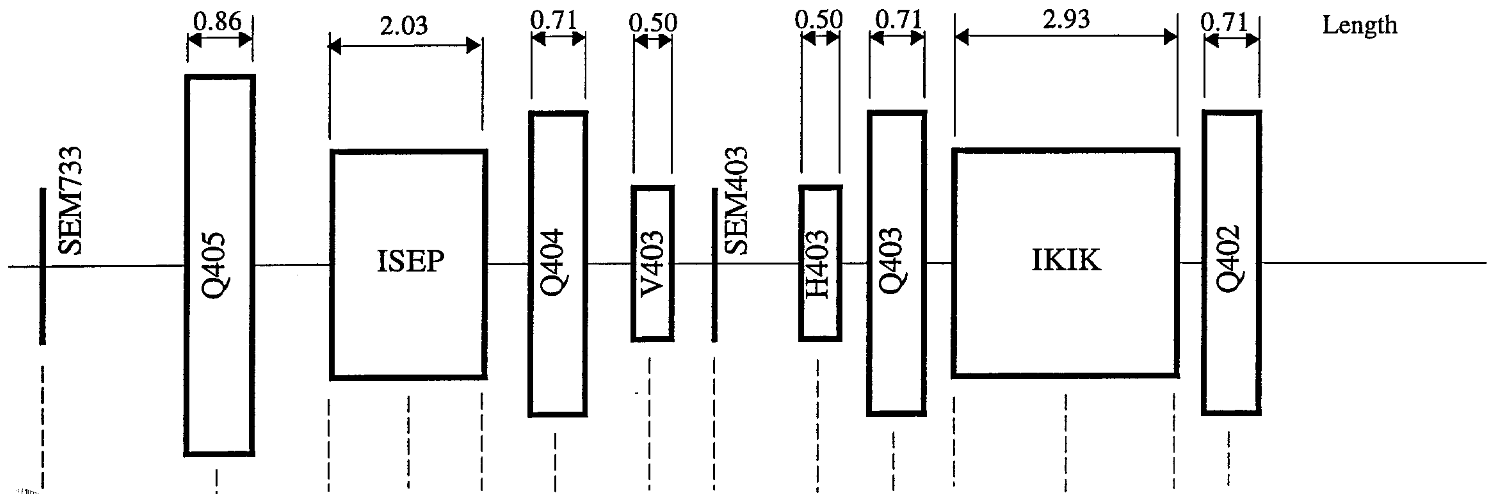
6) Septum thickness does not increase beyond the current nominal 13mm. It is preferrable that this is smaller.

7) External dimensions, other than radius of curvature, remain the same.

8) Field quality specification remains the same as the original: dB/B < +-.2% within 35 mm from septum; B < 2 Gauss on field free side of septum.

9) Nominal field is 6 kG at 20,000 A. Currently this magnet is run at about 14,400 A. I assume that with a 13% increase in horizontal aperture, approximately 13% more current is required for the same field. This magnet is pulsed with a half-sine wave of length about 500 usec. Other septa magnets of the same design run routinely at 20,000+A in the Antiproton Source. These magnets are pulsed every 2.4 seconds (to be increased to once every 1.5 seconds in future).

Debuncher injection area
(asymmetric lattice)



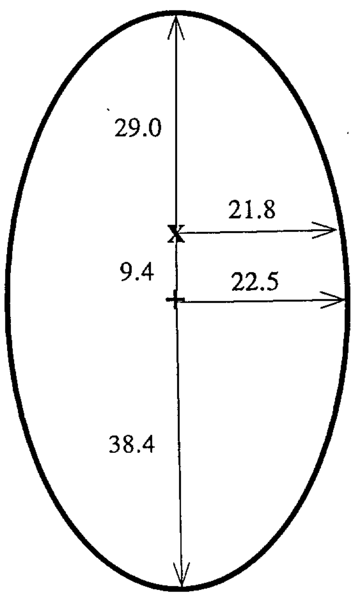
[illegible].56	17.73	16.29	15.27	14.26	13.30	12.06	11.26	9.83	8.86	8.12	6.65	5.17	4.43	s (from D50)
8.64	17.83	12.12	8.44	5.64	3.97	4.93	6.16	9.22	11.48	10.09	7.10	5.15	4.77	H beta
150.5	137.9	132.1	126.4	118.1	106.2	89.6	81.0	70.2	64.8	61.2	51.1	36.7	28.1	H phase (from D50)
8.42	3.24	5.15	7.60	10.85	14.02	10.94	8.91	6.17	5.13	6.18	9.75	14.69	16.98	V beta
162.0	128.2	106.9	97.6	91.4	86.8	81.4	76.7	65.5	55.4	47.9	36.7	29.9	27.0	V phase (from D50)

Figure: 1

AP2 downstream layout.

D:IKIK

betaX d.s. = 5.15
betaX cen = 7.10
betaX u.s. = 10.09
betaY d.s. = 14.69
betaY cen = 9.75
betaY u.s. = 6.18
phaseY = 36.7



x = injected beam (u.s)
\+ = circulating beam
= quad centerline

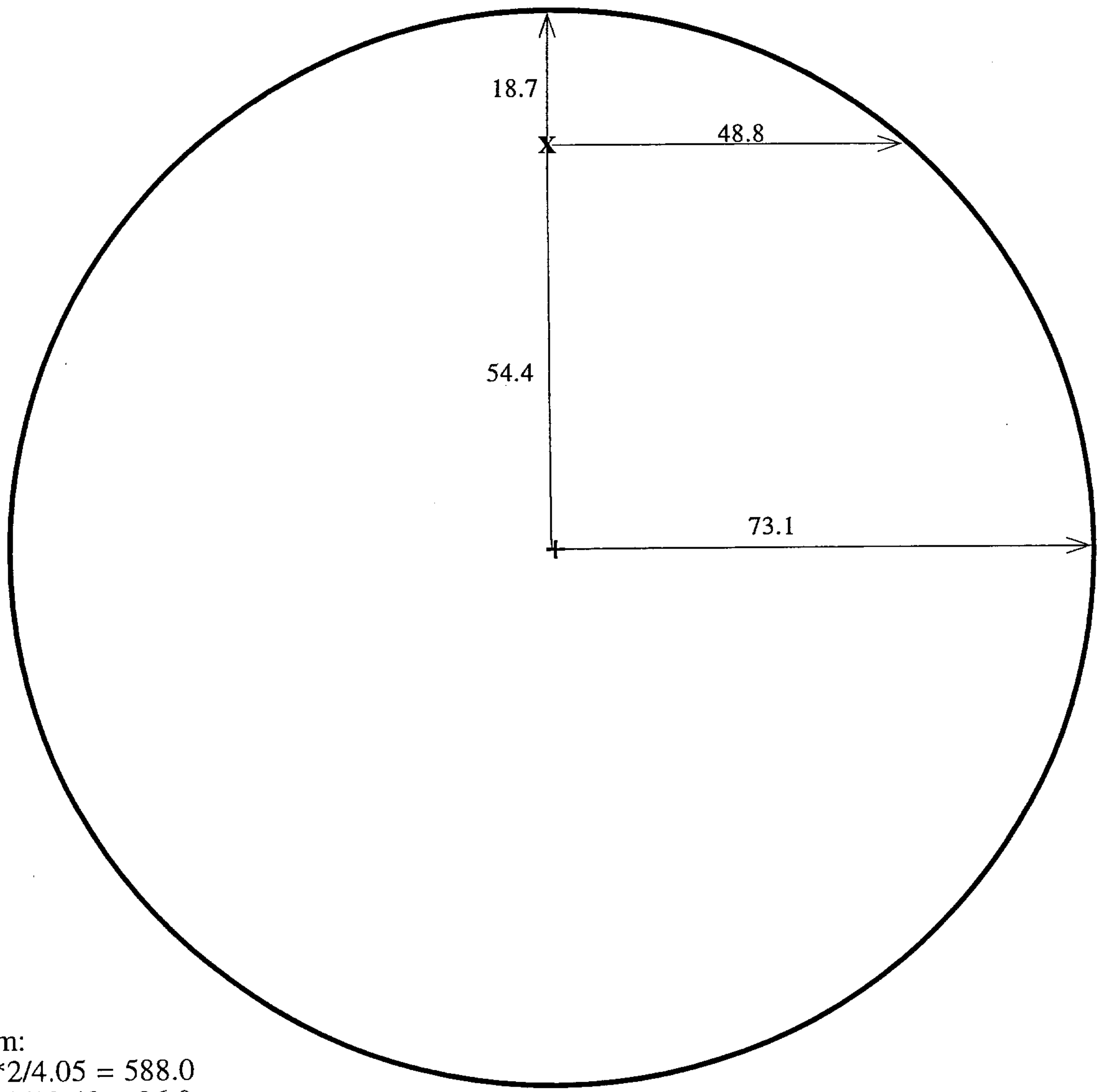
Apertures:
circulating beam:
H u.s. = 22.5**2/10.09 = 50.2
V d.s. = 38.4**2/14.69 = 100.4
injected beam:
H u.s. = 21.8**2/10.09 = 47.1
V u.s. = 29.0**2/6.18 = 136.1

kick angle = 6.34 mr

Figure 2: D:IKIK aperture

Q404 d.s.

betaX = 4.05
betaY = 13.43
phaseY = 85.3

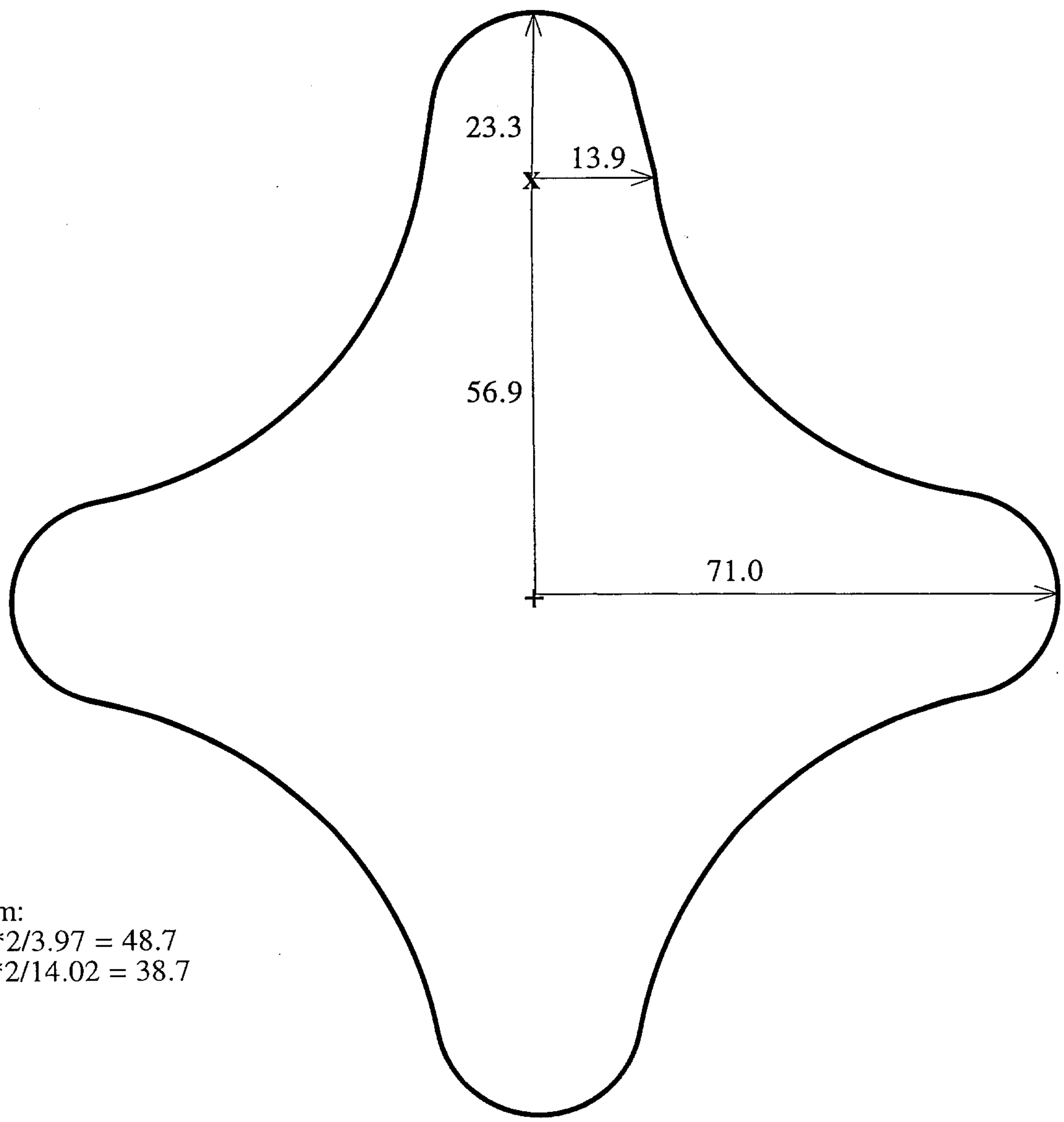


Apertures:
injected beam:
H = 48.8**2/4.05 = 588.0
V = 18.7**2/13.43 = 26.0

Figure 3. Aperture on D.S. end of Q405

Q404 center

betaX = 3.97
betaY = 14.02
phaseY = 86.8

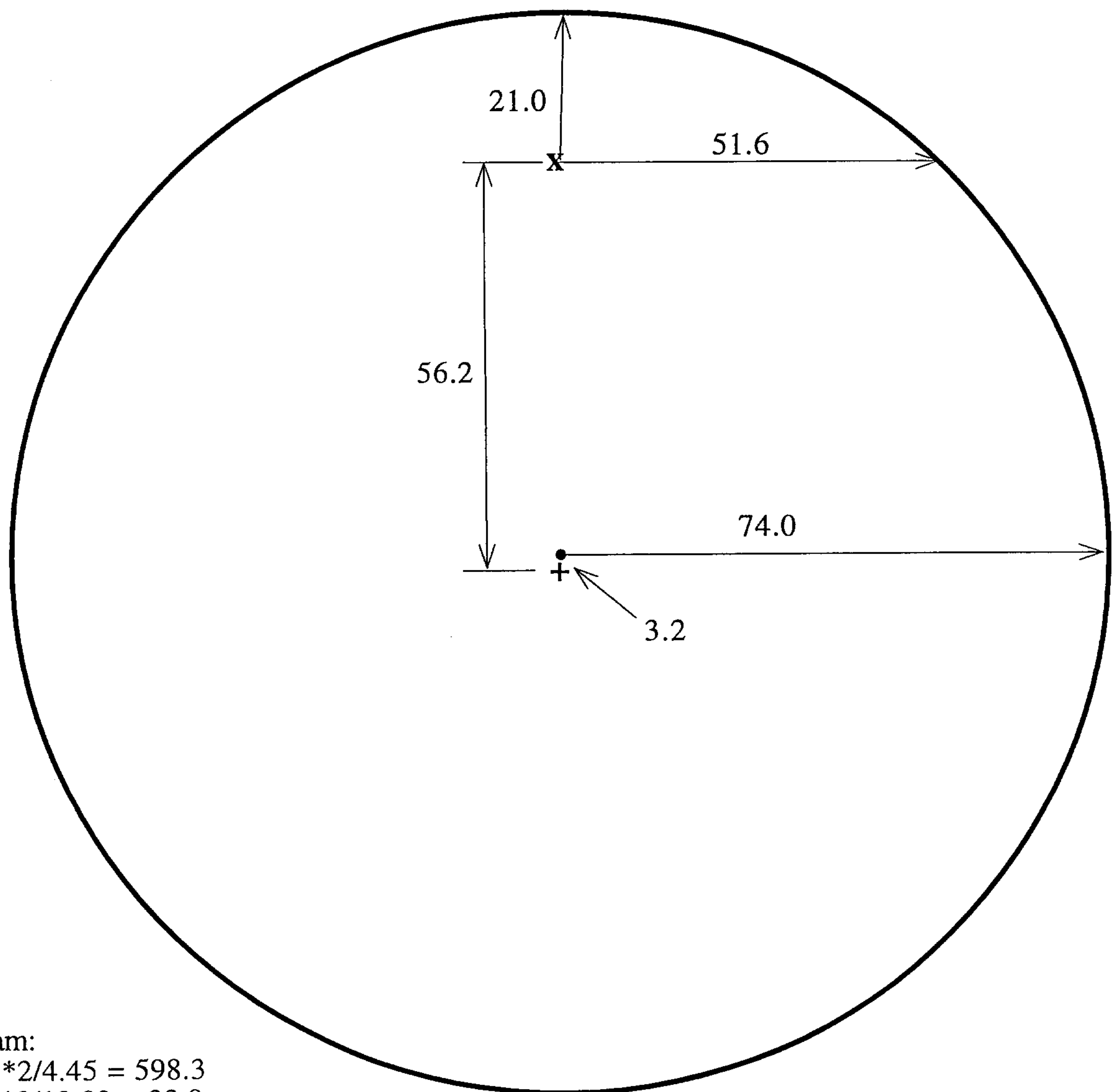


Apertures:
injected beam:
H = 13.9**2/3.97 = 48.7
V = 23.3**2/14.02 = 38.7

Figure 4: Q404 aperture @ center.

BPM @ Q404

betaX = 4.45
betaY = 13.02
phaseY = 88.6



Apertures:
injected beam:
H = 51.6**2/4.45 = 598.3
V = 21.0**2/13.02 = 33.9

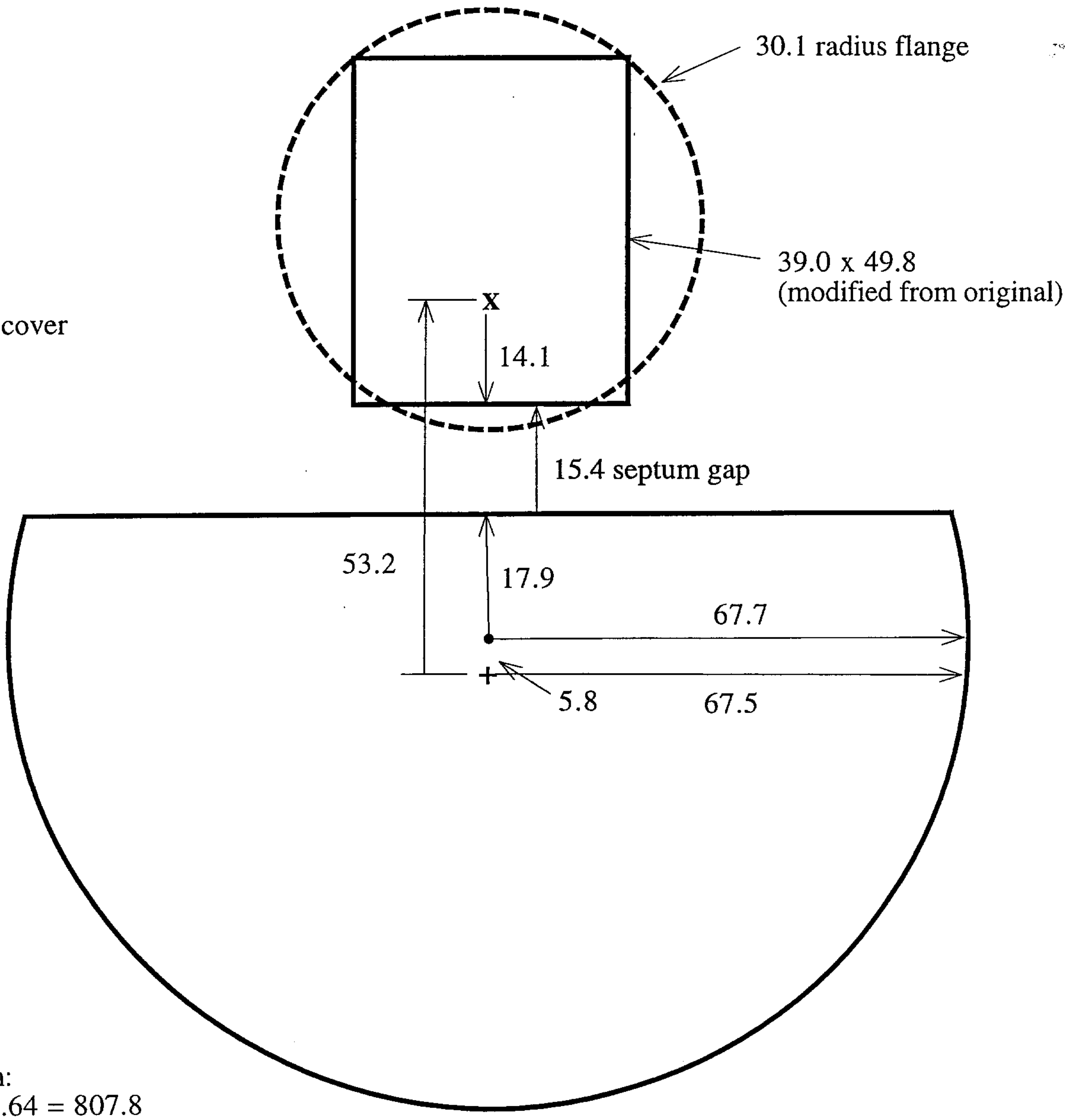
Figure 5: BPM @ upstream end of Q404

Septum d.s.

betaX = 5.64
betaY = 10.85
phaseY = 91.4

Angle of injected beam with respect
to quad centerline = -5.4 mr

Septum gap:
3.2 Cu
4.7 SS
0.3 Kapton
4.8 Steel
2.4 Beampipe cover



Apertures:
circulating beam:
H = 67.5**2/5.64 = 807.8
V = 23.7**2/10.85 = 51.8
injected beam:
H = 19.5**2/5.64 = 67.4
V = 14.1**2/10.85 = 18.3

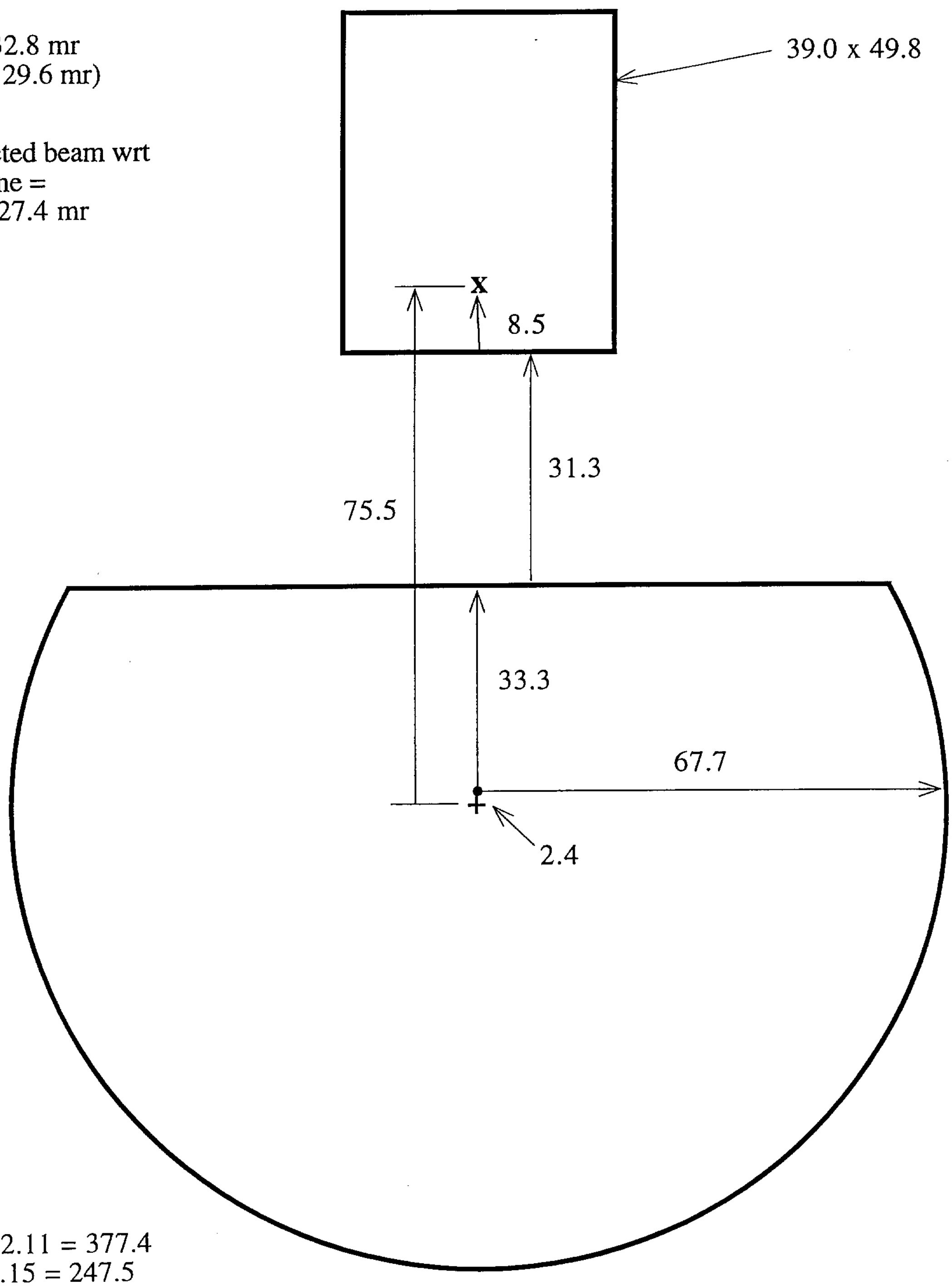
Figure 6

Septum u.s.

betaX = 12.11
betaY =5.15
phaseY = 106.9

Septum kick:
measured = 32.8 mr
(calculated = 29.6 mr)

angle of injected beam wrt
quad centerline =
32.8 - 5.4 = 27.4 mr

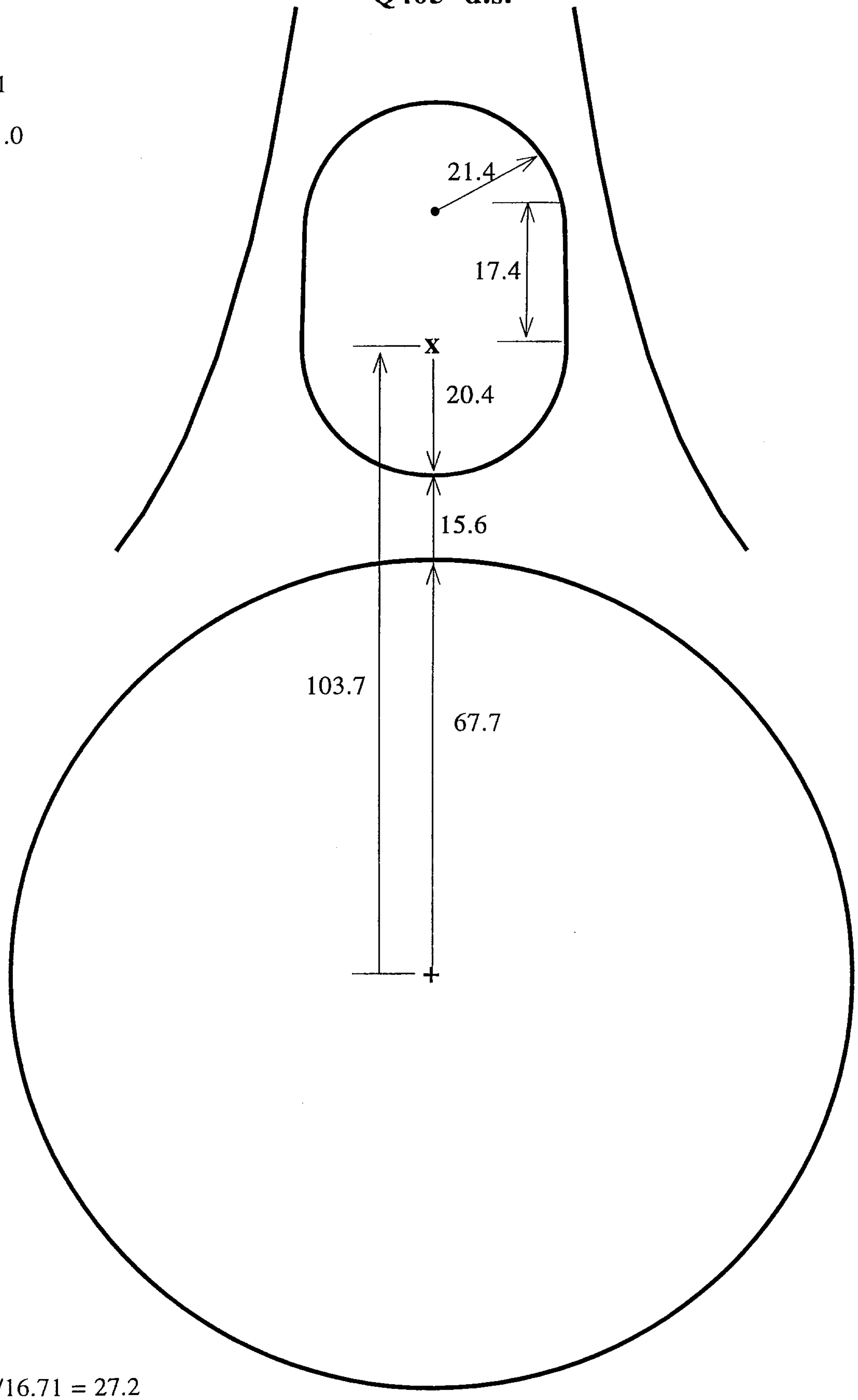


Apertures:
circulating:
H = 67.6**2/12.11 = 377.4
V = 35.7**2/5.15 = 247.5
injected beam:
H = 19.5**2/12.11 = 31.4
V = 8.5**2/5.15 = 14.0

Fig 7

Q405 d.s.

betaX = 16.71
betaY = 3.49
phaseY = 121.0

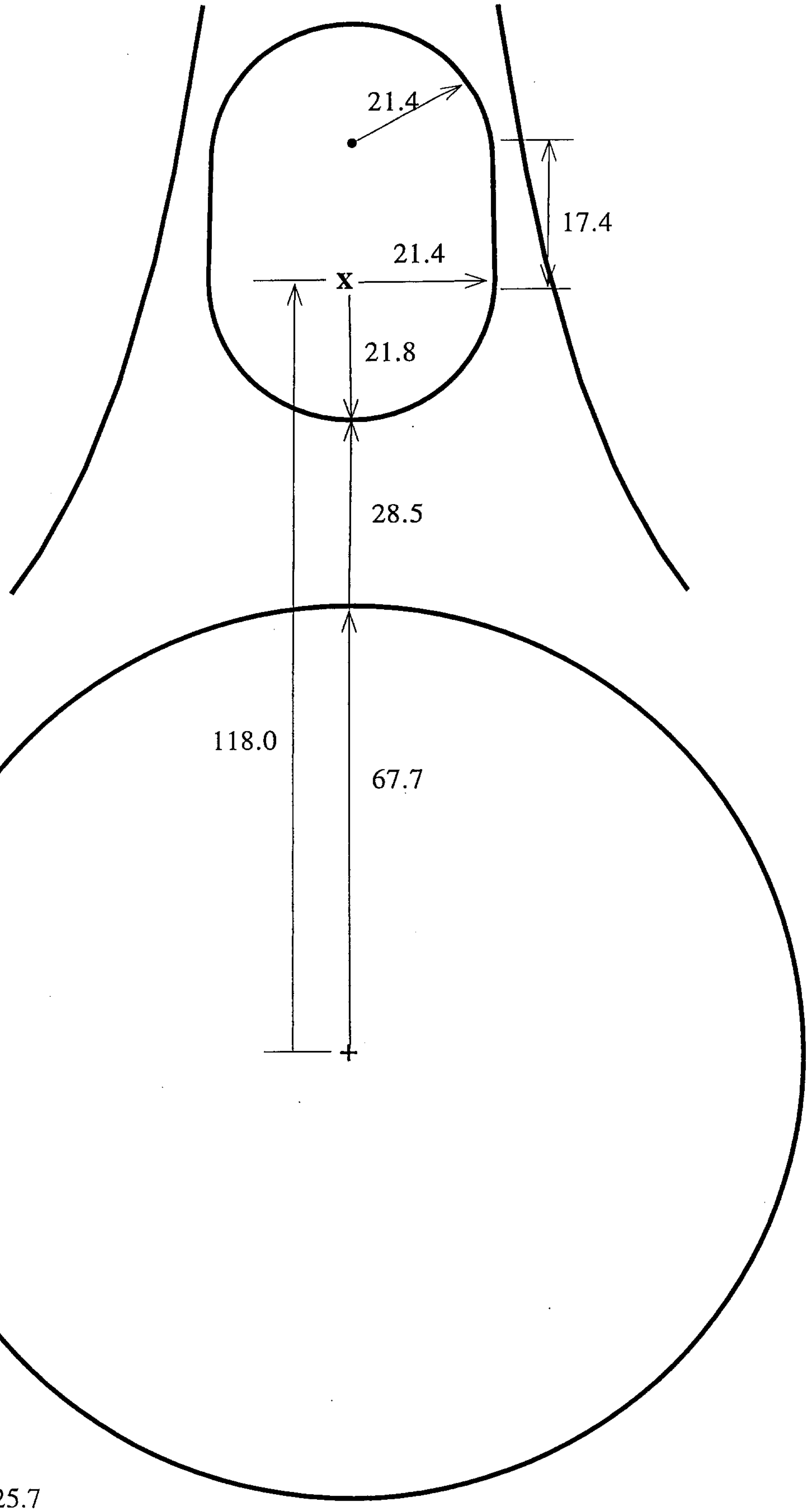


Apertures:
injected beam:
H = 21.3**2/16.71 = 27.2
V = 20.4**2/3.49 = 119.2

Fig. 8

Q405 center

betaX = 17.83
betaY = 3.24
phaseY = 128.2



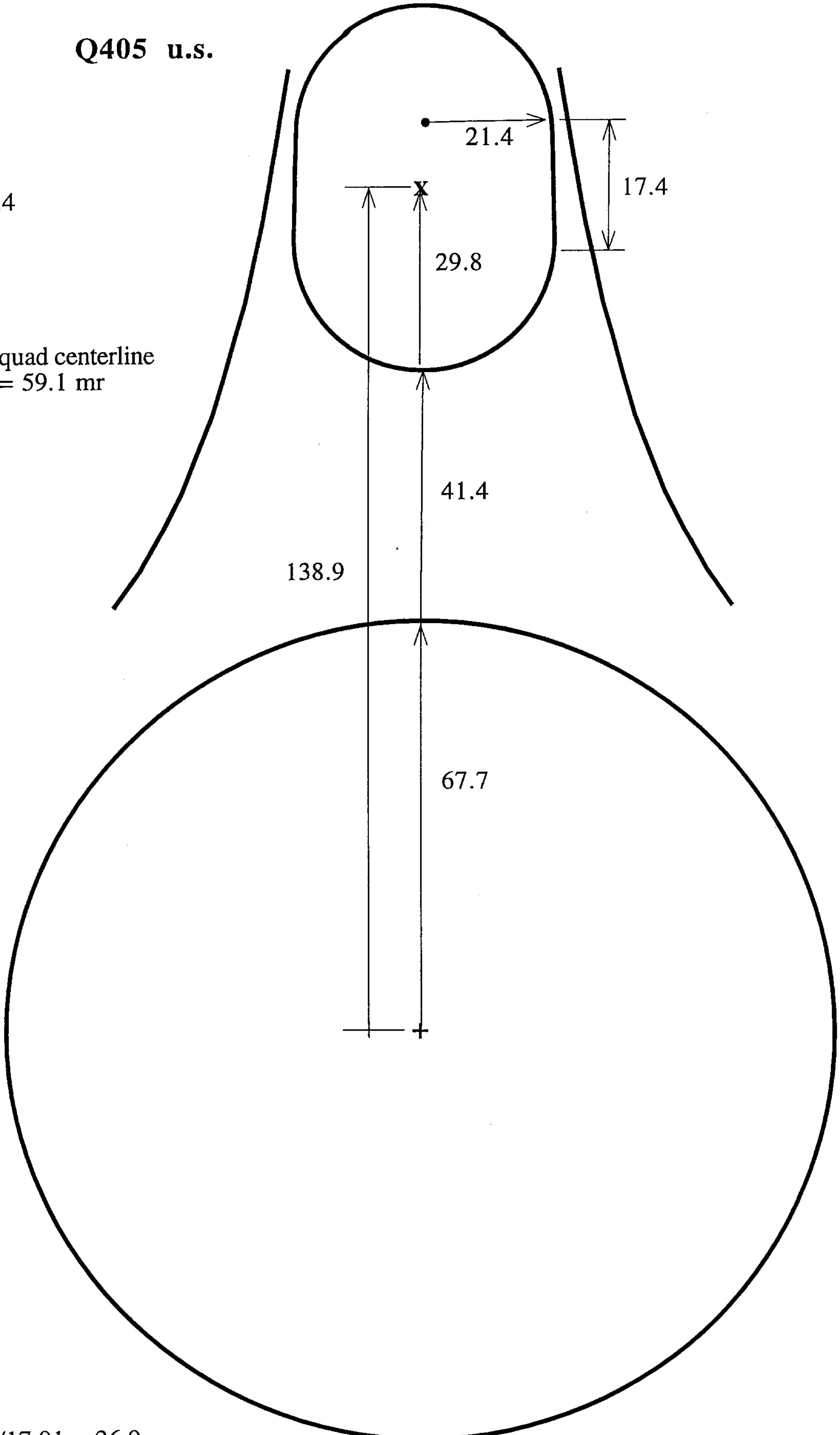
Apertures:
injected beam:
H = 21.4**2/17.83 = 25.7
V = 21.8**2/3.24 = 146.7

Fig. 9

Q405 u.s.

betaX = 17.01
betaY = 3.46
phaseY = 135.4

exit angle wrt quad centerline
= 27.4 + 31.7 = 59.1 mr

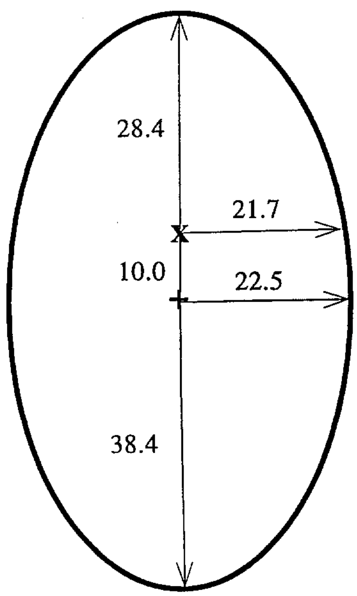


Apertures:
injected beam:
H = 21.4**2/17.01 = 26.9
V = 29.8**2/3.46 = 256.7

Fig. 10

D:IKIK
(40pi)

betaX d.s. = 5.15
betaX cen = 7.10
betaX u.s. = 10.09
betaY d.s. = 14.69
betaY cen = 9.75
betaY u.s. = 6.18
phaseY = 36.7



x = injected beam (u.s)
+ = circulating beam
= quad centerline

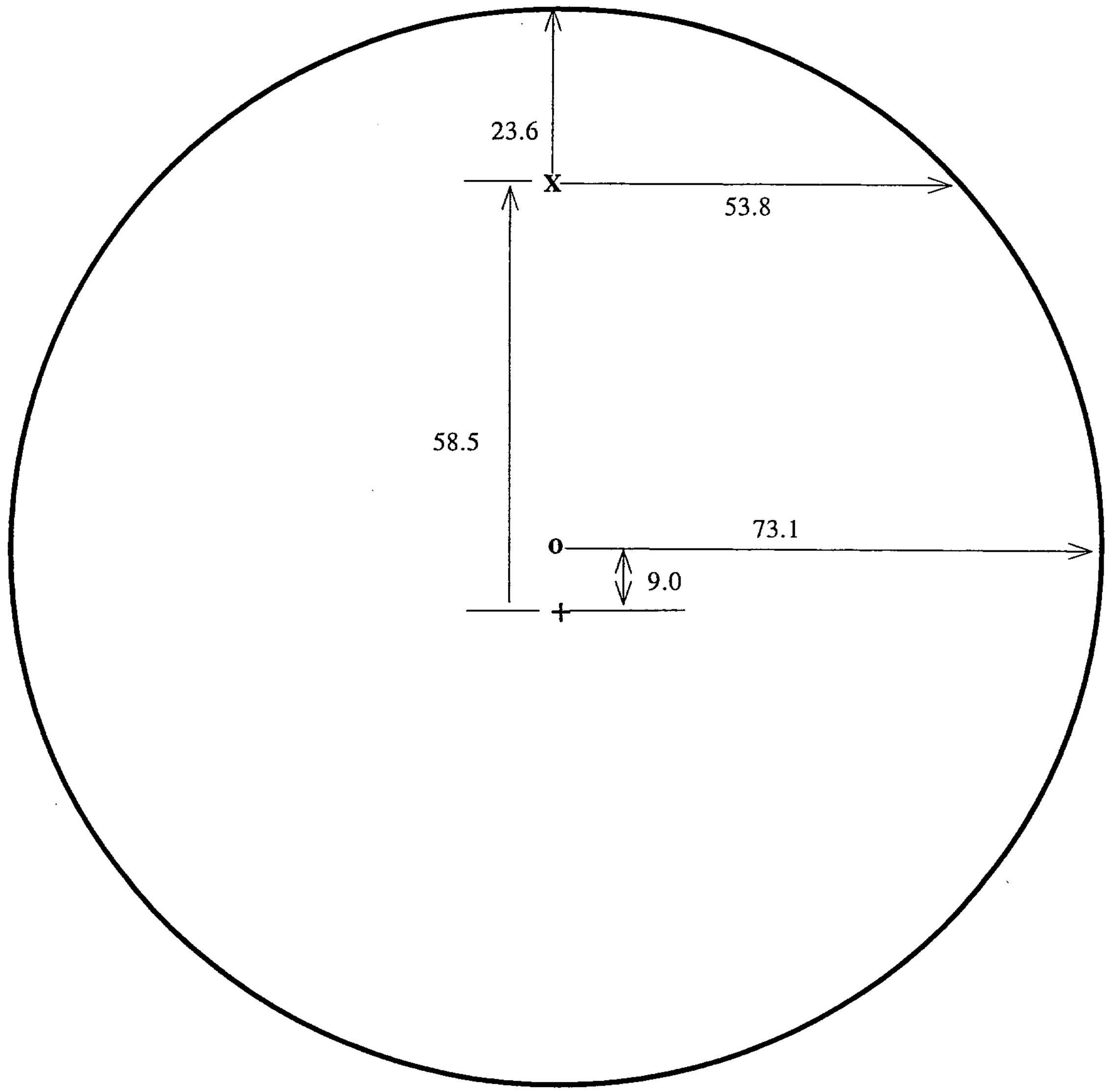
Apertures:
circulating beam:
H u.s. = 22.5**2/10.09 = 50.2
V d.s. = 38.4**2/14.69 = 100.4
injected beam:
H u.s. = 21.7**2/10.09 = 46.7
V u.s. = 28.4**2/6.18 = 130.5

kick angle = 6.81 mr

Fig. 11

Q404 d.s.
(40pi)

betaX = 4.05
betaY = 13.43
phaseY = 85.3

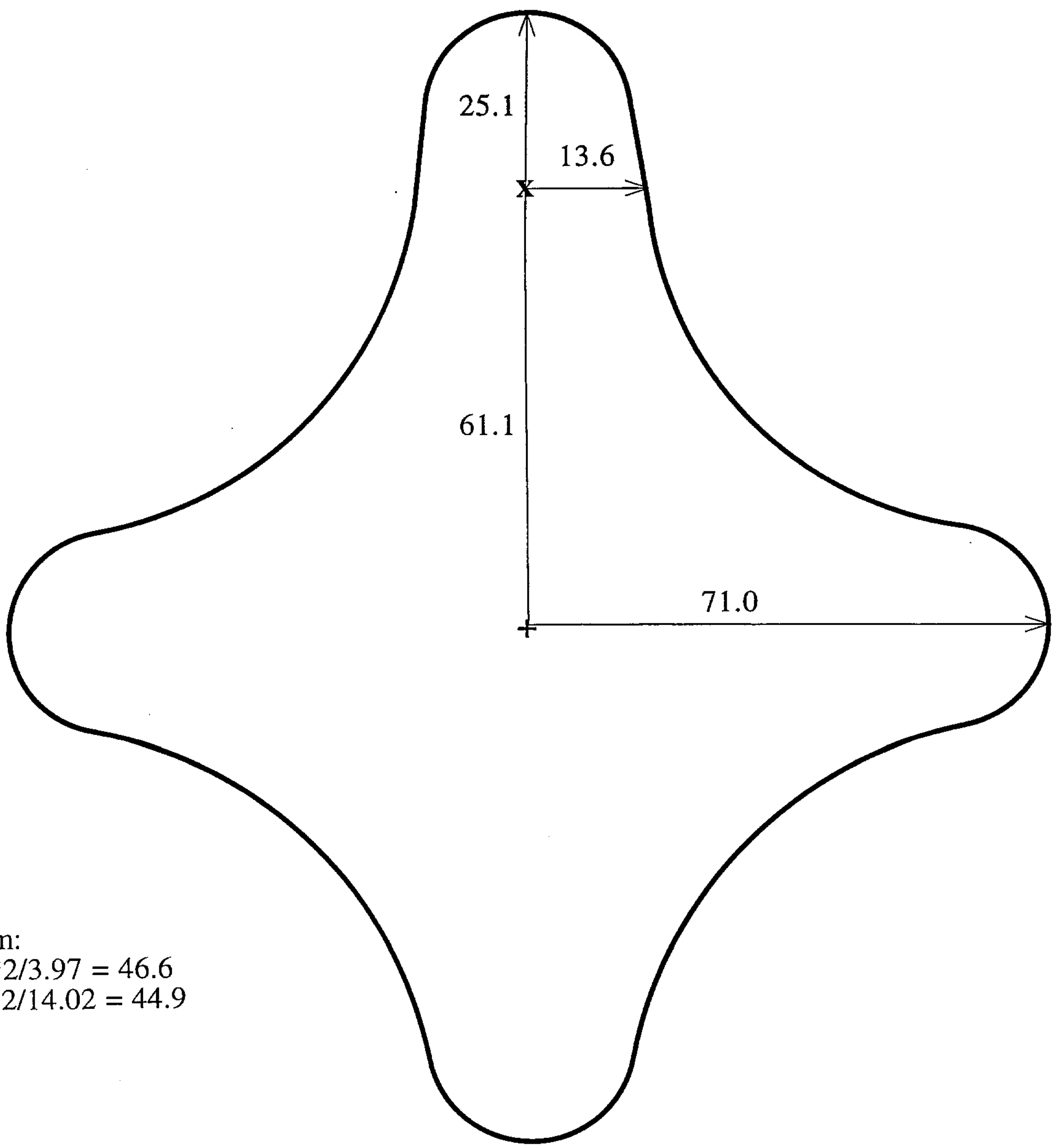


Apertures:
injected beam:
H = 53.8**2/4.05 = 714.7
V = 23.6**2/13.43 = 41.5

Fig. 12

Q404 center
(40pi)

betaX = 3.97
betaY = 14.02
phaseY = 86.8

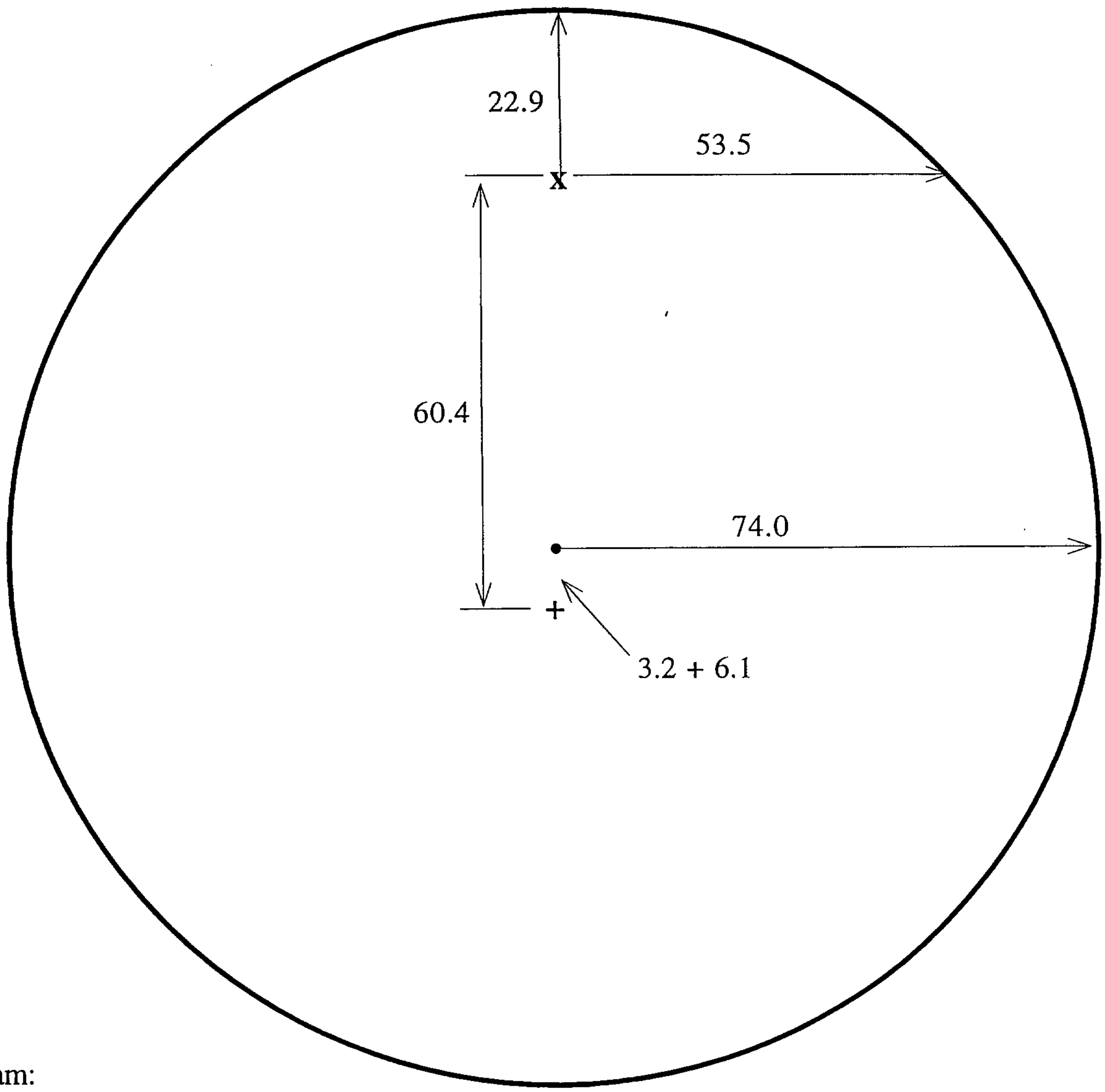


Apertures:
injected beam:
H = 13.6**2/3.97 = 46.6
V = 25.1**2/14.02 = 44.9

Fig. 13

BPM @ Q404
(40 pi)

betaX = 4.45
betaY = 13.02
phaseY = 88.6



Apertures:
injected beam:
H = 53.5**2/4.45 = 643.2
V = 22.9**2/13.02 = 40.3

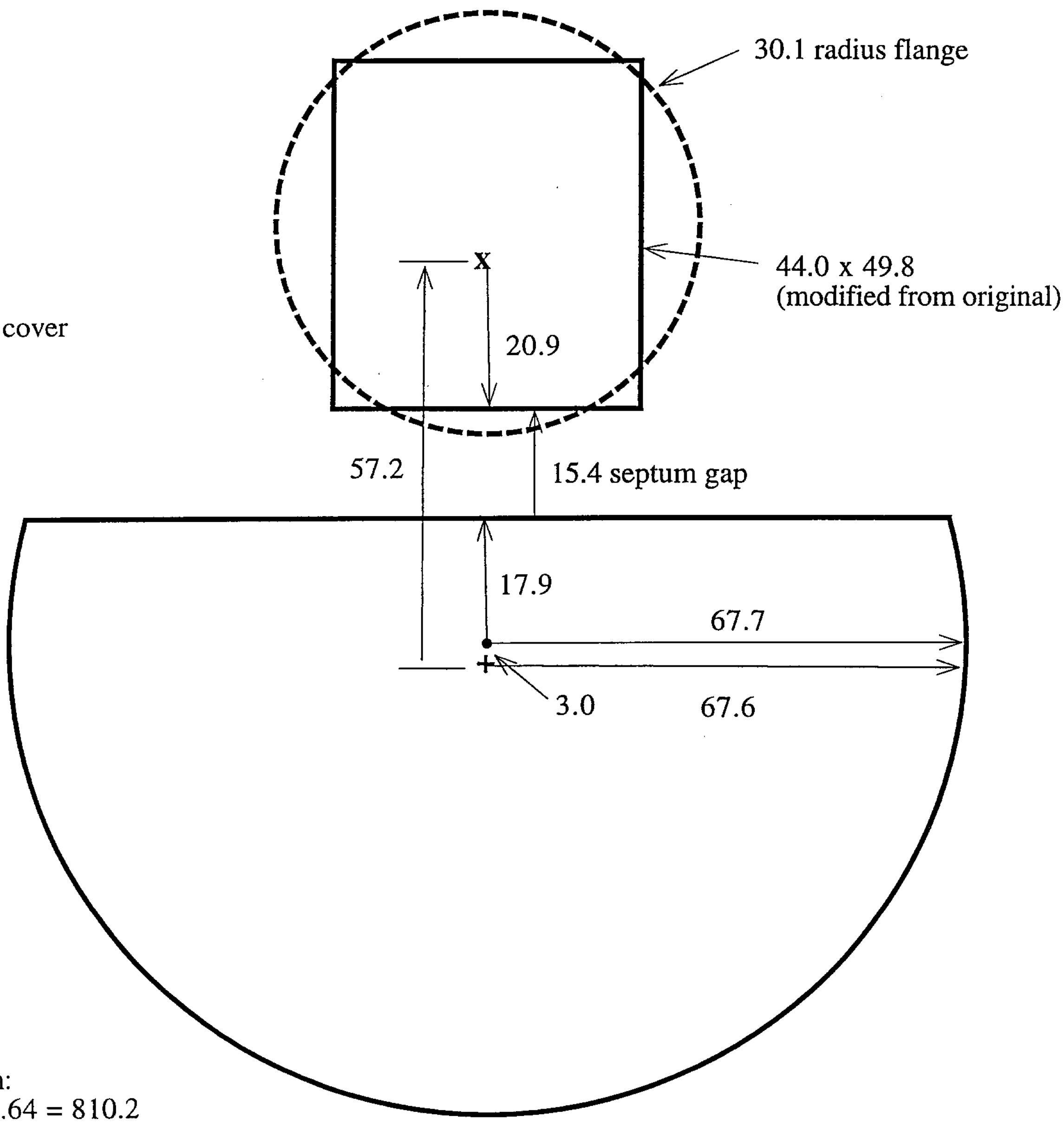
Fig. 14

Septum d.s
(40pi).

betaX = 5.64
betaY = 10.85
phaseY = 91.4

Angle of injected beam with respect to quad centerline = -5.76 mr

Septum gap:
3.2 Cu
4.7 SS
0.3 Kapton
4.8 Steel
2.4 Beampipe cover



Apertures:
circulating beam:
H = 67.6**2/5.64 = 810.2
V = 20.9**2/10.85 = 40.3
injected beam:
H = 22.0**2/5.64 = 85.8
V = 20.9**2/10.85 = 40.3

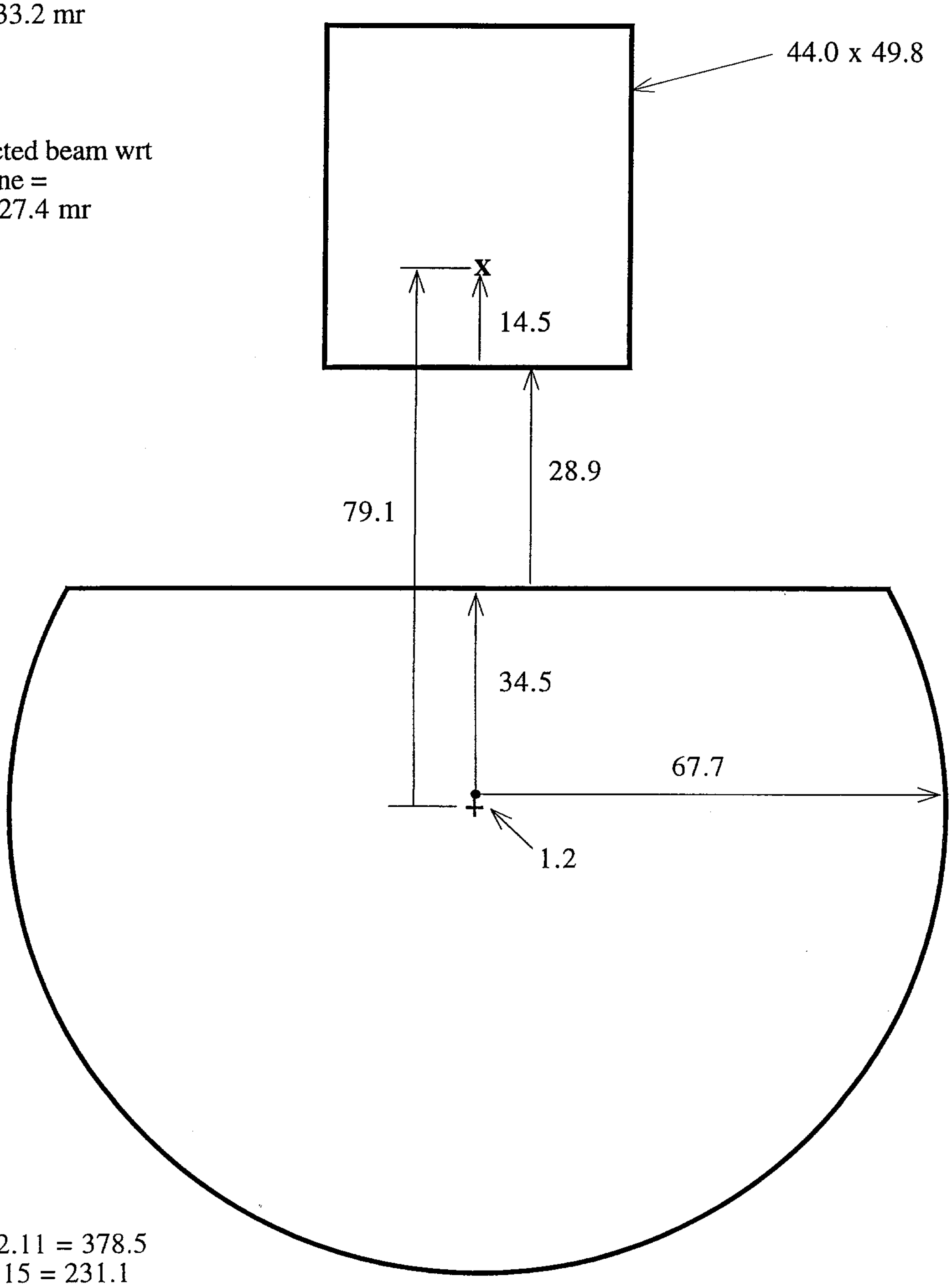
Fig 15

Septum u.s.
(40 pi)

betaX = 12.11
betaY =5.15
phaseY = 106.9

Septum kick: 33.2 mr
(@16.4 kA)

angle of injected beam wrt
quad centerline =
33.2 - 5.8 = 27.4 mr

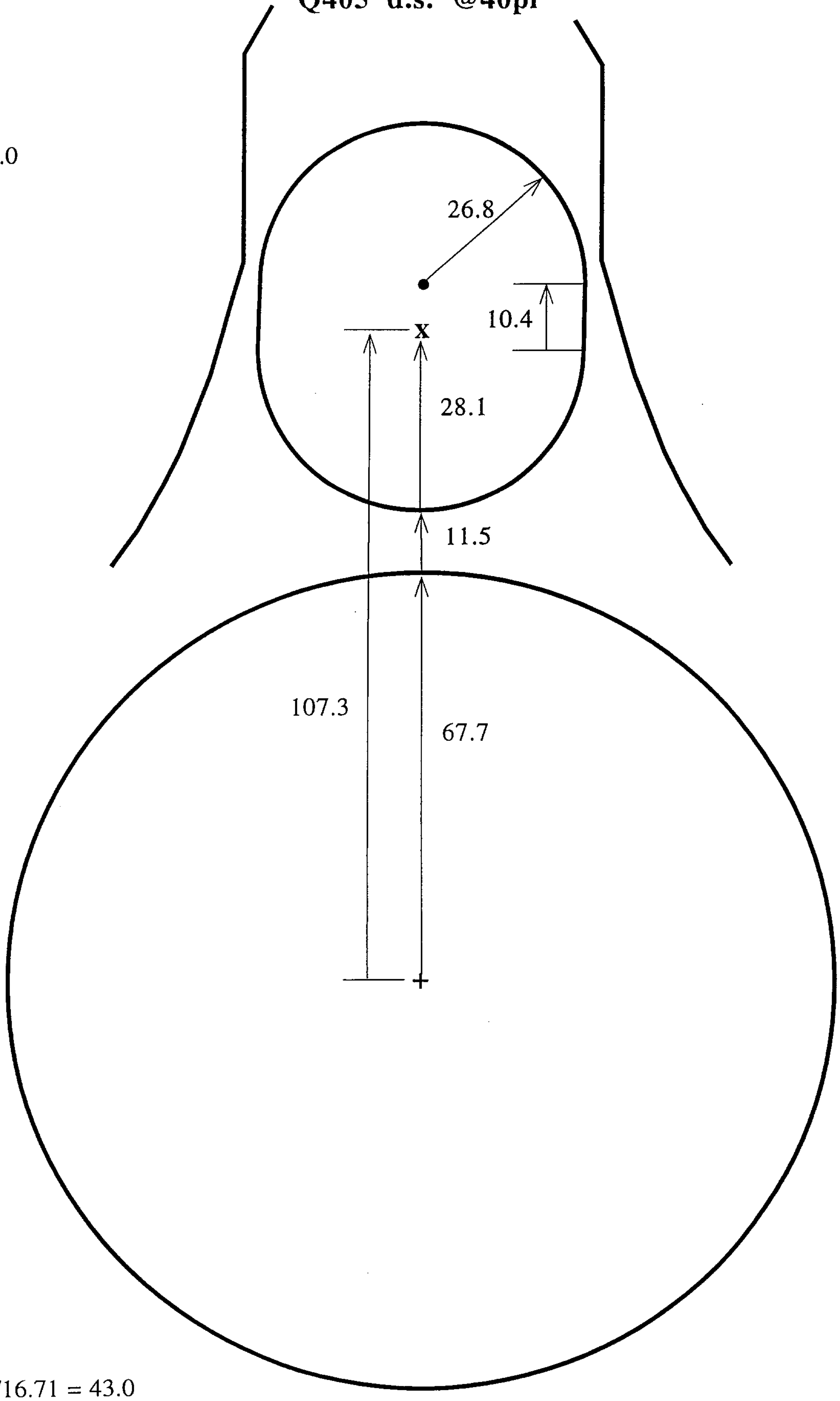


Apertures:
circulating:
H = 67.7**2/12.11 = 378.5
V = 35.7**2/5.15 = 231.1
injected beam:
H = 22.0**2/12.11 = 40.0
V = 14.5**2/5.15 = 40.8

Fig 16

Q405 d.s. @40pi

betaX = 16.71
betaY = 3.49
phaseY = 121.0

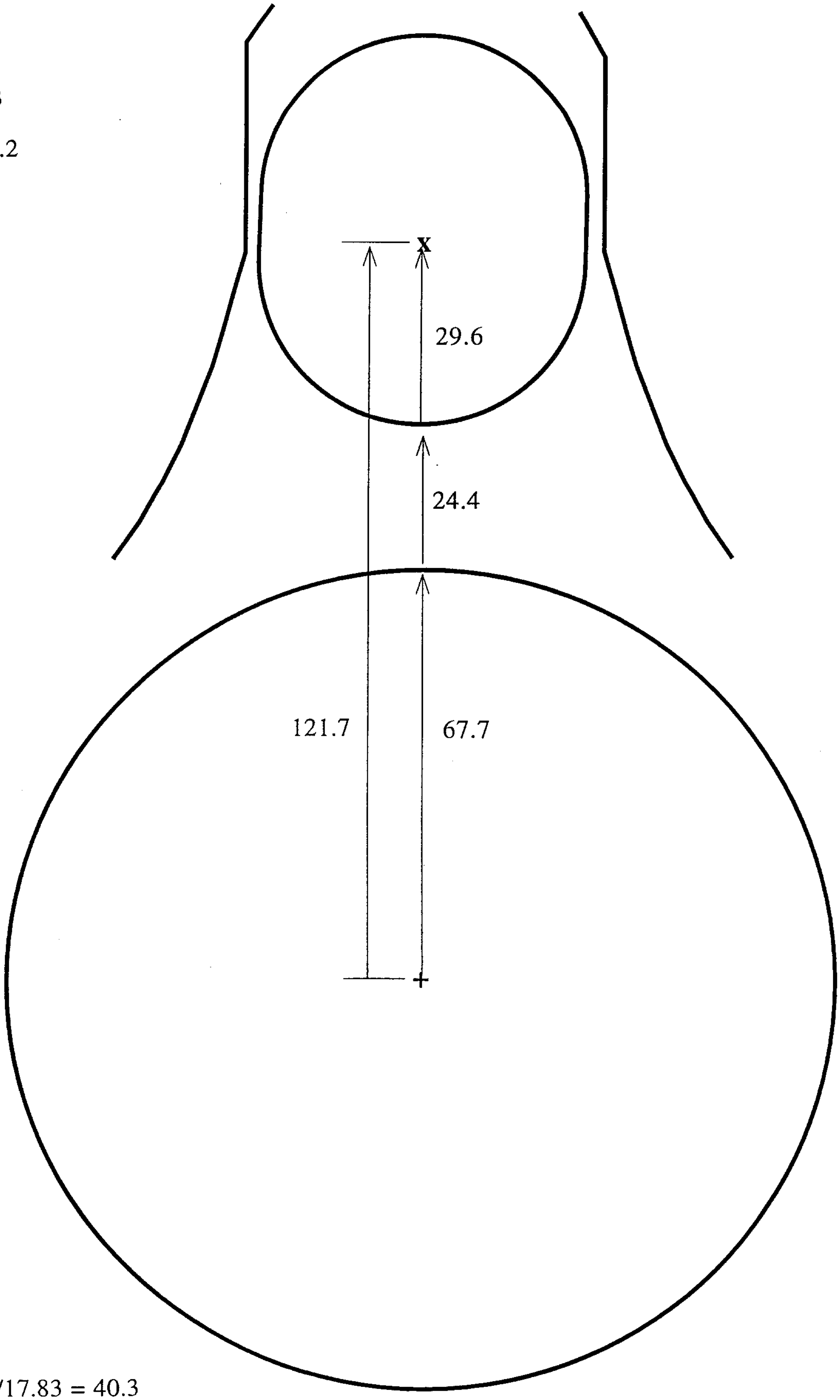


Apertures:
injected beam:
H = 26.8**2/16.71 = 43.0
V = 28.1**2/3.49 = 226.2

Fig 17

Q405 center @40pi

betaX = 17.83
betaY = 3.24
phaseY = 128.2



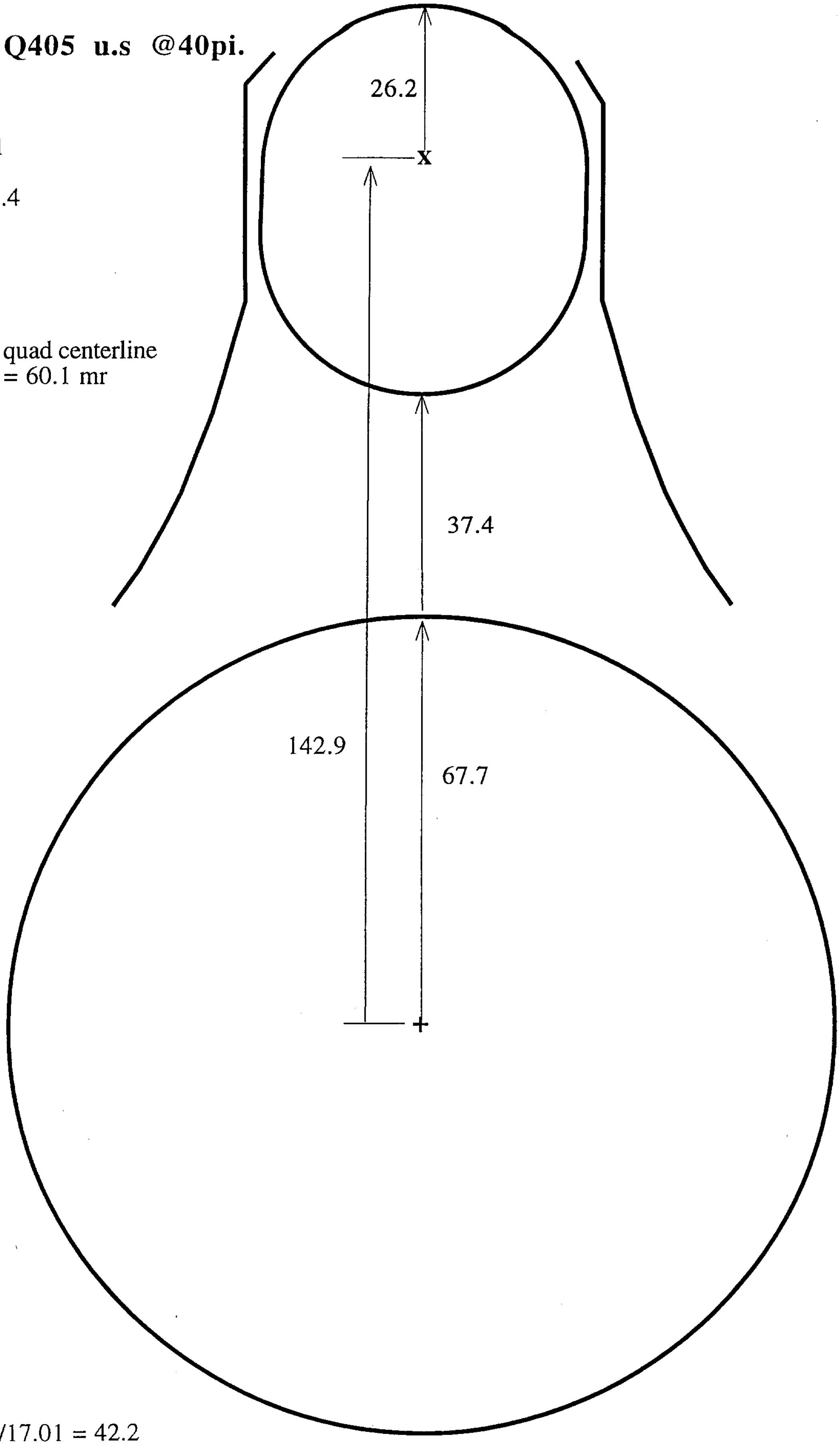
Apertures:
injected beam:
H = 26.8**2/17.83 = 40.3
V = 29.8**2/3.24 = 270.4

Fig. 18

Q405 u.s @40pi.

betaX = 17.01
betaY = 3.46
phaseY = 135.4

exit angle wrt quad centerline
= 27.4 + 32.7 = 60.1 mr



Apertures:
injected beam:
H = 26.8**2/17.01 = 42.2
V = 26.2**2/3.46 = 198.4

Fig 19

Console Location 135, 6-OCT-1997 09:50
Untitled

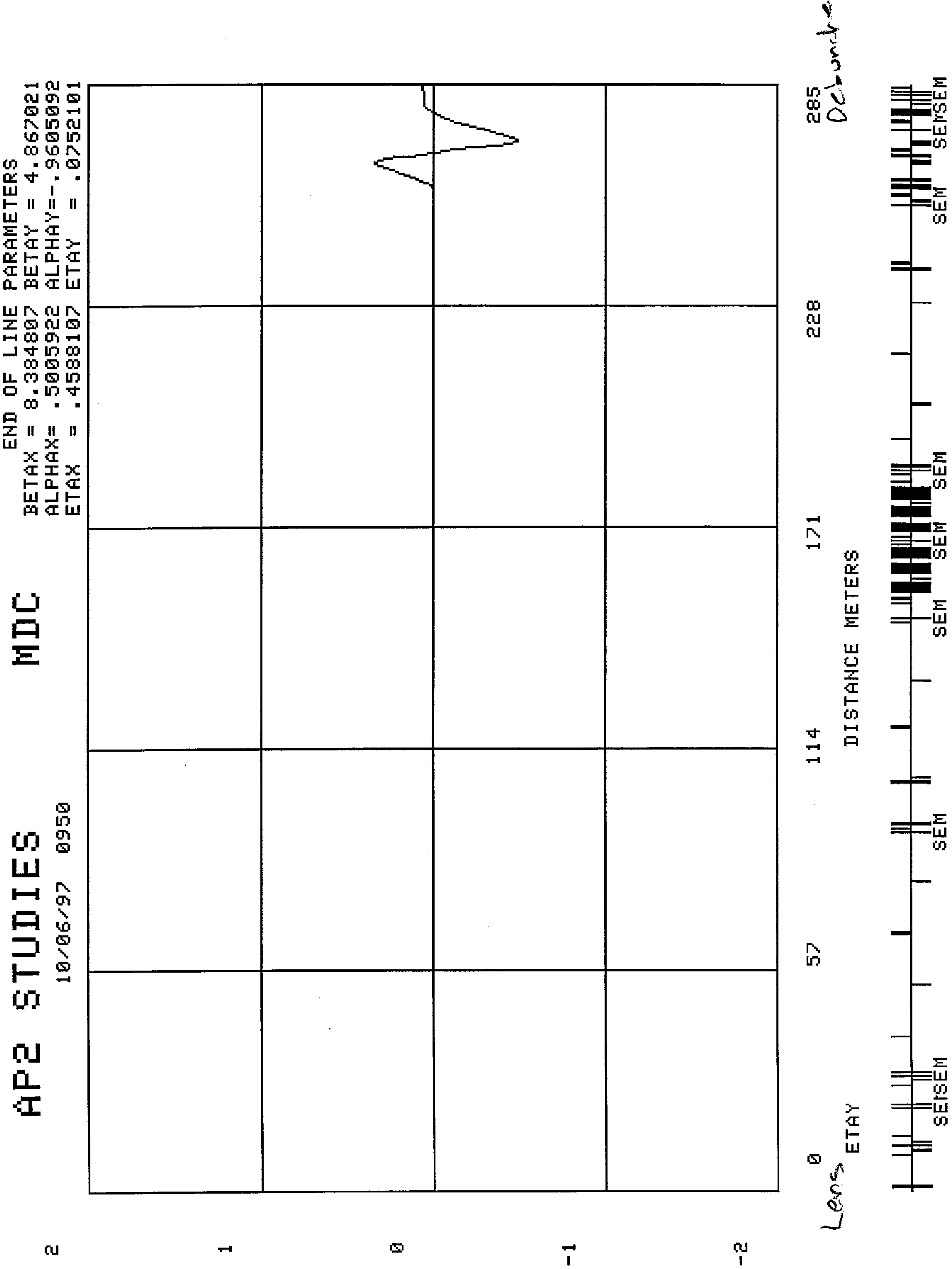


Figure 20: AP2 vertical dispersion

Console Location 135, Untitled

6-OCT-1997 10:52

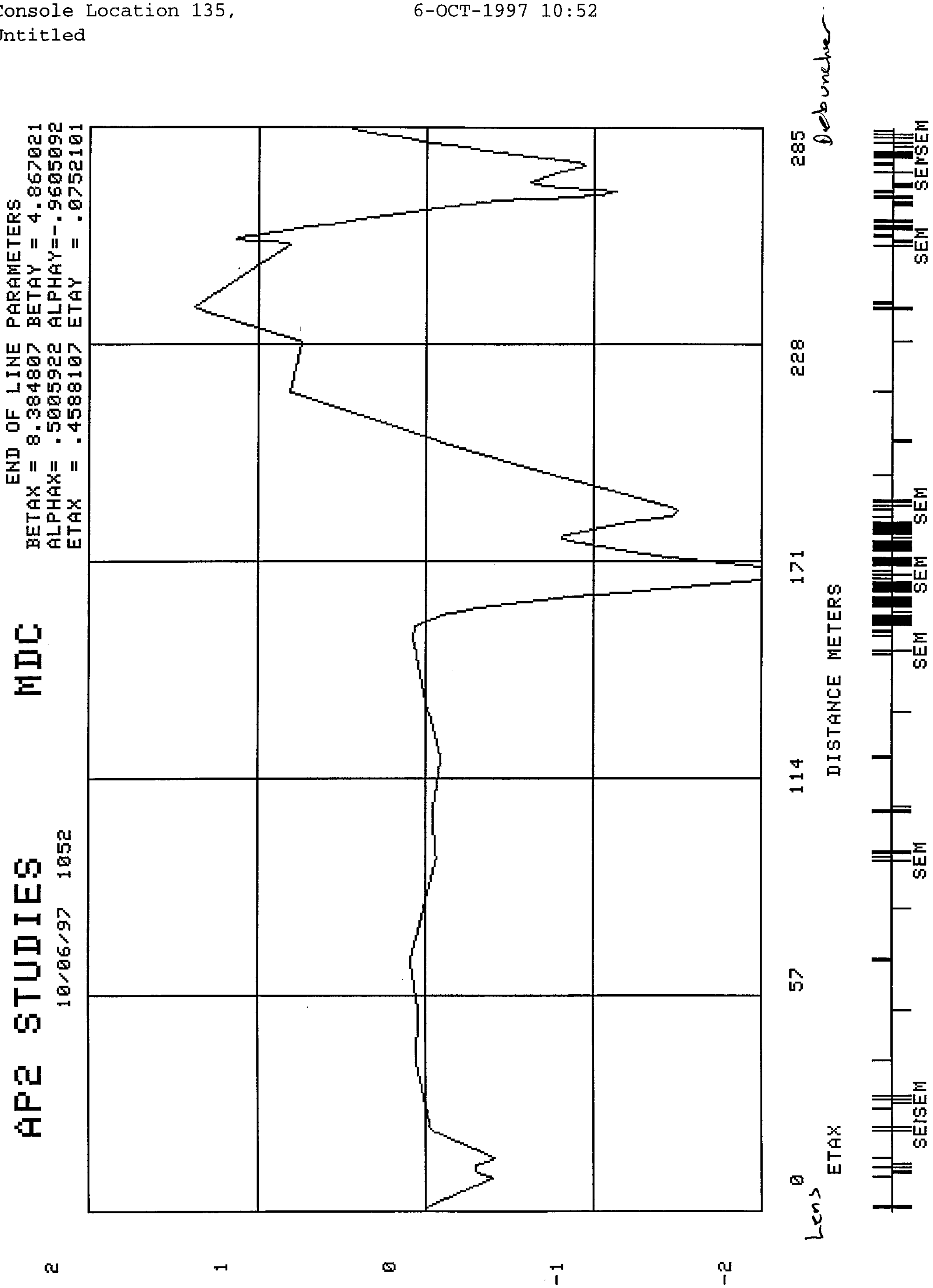


Figure 21. AP2 horizontal dispersion, as is

AP2 STUDIES MDC

10/06/97 0951

END OF LINE PARAMETERS
BETAX = 8.384807 BETAY = 4.867021
ALPHAX= .5005922 ALPHAY=-.9605092
ETAX = .4588107 ETAY = .0752101

NAME	ETAY	NAME	ETAY	NAME	ETAY	NAME	ETAY	NAME	ETAY
DRIFT	0	D:VT711	0	DRIFT	0	D:HT731	.0792	DRIFT	
D:PMAGV	0	D:VT711	0	D:Q716	0	DRIFT	-.01	DRIFT	
DRIFT	0	DRIFT	0	DRIFT	0	D:Q731	-.1173	DRIFT	
D:Q701	0	D:Q707	0	D:SM723	0	D:Q731	-.2495	DRIFT	
DRIFT	0	DRIFT	0	DRIFT	0	DRIFT	-.3762	DRIFT	
D:Q702	0	D:Q707	0	D:VT723	0	D:Q731	-.4837	DRIFT	
DRIFT	0	DRIFT	0	D:VT723	0	D:Q731	-.4876	DRIFT	
D:VT702	0	D:Q707	0	DRIFT	0	DRIFT	-.3132	DRIFT	
DRIFT	0	DRIFT	0	D:Q716	0	D:SM733	-.3132	DRIFT	
D:Q702	0	D:Q715	0	DRIFT	0	DRIFT	-.1283	DRIFT	
DRIFT	0	DRIFT	0	D:Q716	0	D:IB	-.0772	DRIFT	
D:Q701	0	D:SM715	0	DRIFT	0	DRIFT	-.0265	DRIFT	
DRIFT	0	DRIFT	0	D:Q719	0	D:ISEPV	.0153	DRIFT	
D:SM704	0	D:Q716	0	DRIFT	0	D:ISEPV	.0404	DRIFT	
DRIFT	0	DRIFT	0	D:Q719	0	DRIFT	.0505	DRIFT	
D:H704	0	D:Q716	0	DRIFT	0	D:QSSRF	.0568	DRIFT	
DRIFT	0	DRIFT	0	D:HT727	0	DRIFT	.0576	DRIFT	
D:Q701	0	D:H717	0	D:HT727	0	D:V403	.0583	DRIFT	
DRIFT	0	DRIFT	0	DRIFT	0	DRIFT	.059	DRIFT	
D:Q701	0	D:Q718	0	D:Q719	0	D:SM403	.059	DRIFT	
DRIFT	0	DRIFT	0	D:Q719	0	DRIFT	.0605	DRIFT	
D:SM706	0	D:H717	0	DRIFT	0	D:H403	.0611	DRIFT	
DRIFT	0	DRIFT	0	D:SM728	0	DRIFT	.0616	DRIFT	
D:VT706	0	D:H717	0	DRIFT	0	D:QSSRF	.0682	DRIFT	
DRIFT	0	DRIFT	0	D:Q729	0	DRIFT	.0752	DRIFT	
D:Q707	0	D:Q719	0	D:Q729	0	END	.0752	DRIFT	
DRIFT	0	DRIFT	0	DRIFT	0	DRIFT		DRIFT	
D:Q707	0	D:SM719	0	D:Q729	0	DRIFT		DRIFT	
DRIFT	0	DRIFT	0	D:Q729	0	DRIFT		DRIFT	
D:Q707	0	D:Q719	0	DRIFT	0	DRIFT		DRIFT	
DRIFT	0	DRIFT	0	D:V730	.0118	DRIFT		DRIFT	
D:Q707	0	D:H717	0	D:V730	.0472	DRIFT		DRIFT	
DRIFT	0	DRIFT	0	DRIFT	.079	DRIFT		DRIFT	
D:SM710	0	D:H717	0	D:HT730	.1026	DRIFT		DRIFT	
DRIFT	0	DRIFT	0	D:HT730	.1261	DRIFT		DRIFT	
D:Q707	0	D:Q718	0	DRIFT	.3447	DRIFT		DRIFT	
DRIFT	0	DRIFT	0	D:Q731	.3477	DRIFT		DRIFT	
D:HT711	0	D:H717	0	D:Q731	.2779	DRIFT		DRIFT	
D:HT711	0	DRIFT	0	DRIFT	.1985	DRIFT		DRIFT	
DRIFT	0	D:Q716	0	D:HT731	.1389	DRIFT		DRIFT	

Table 1: AP2 vertical dispersion

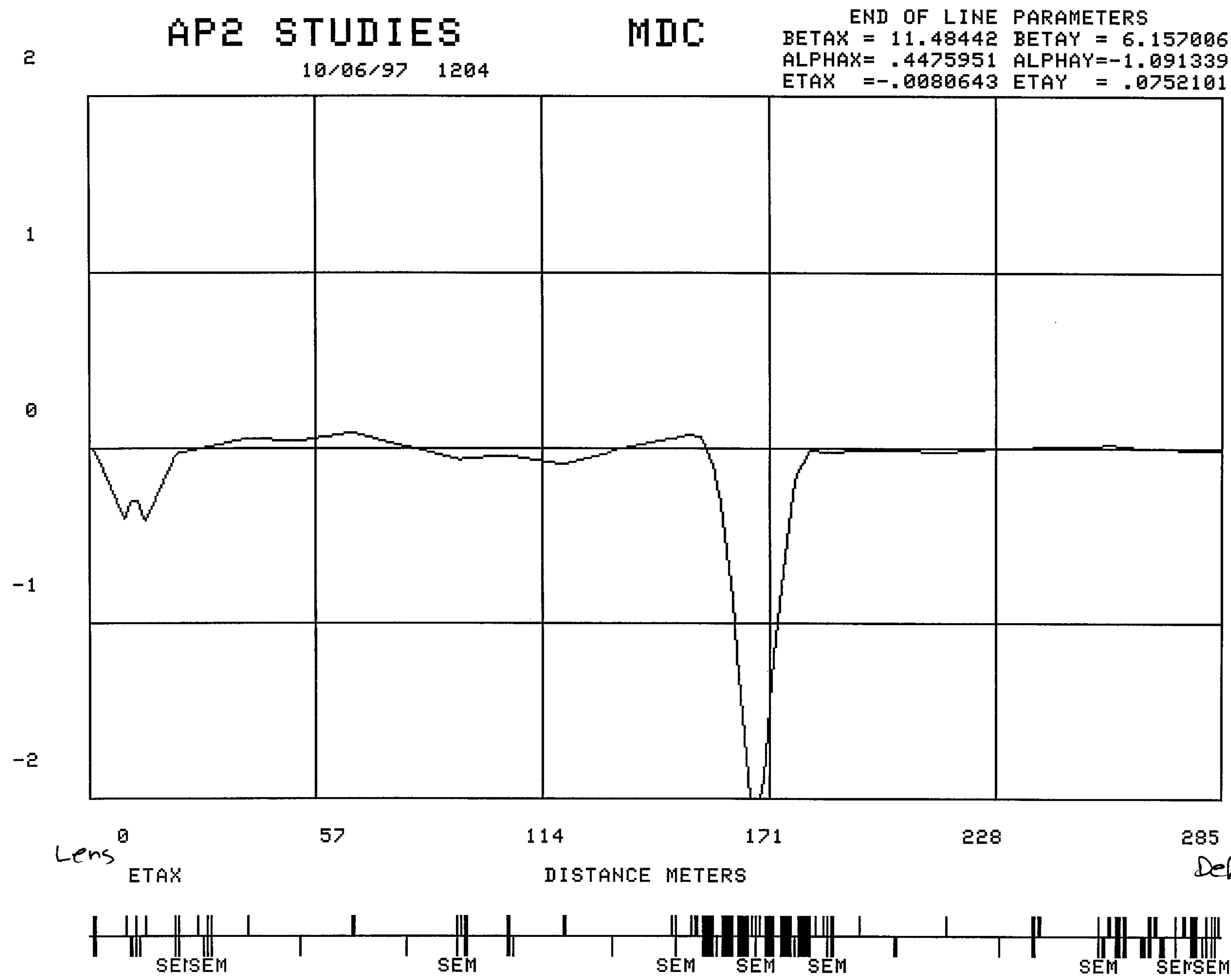


Figure 22: AP2 horizontal dispersion, fixed

AP2 STUDIES MDC

10/06/97 1207

END OF LINE PARAMETERS
BETAX = 11.48442 BETAY = 6.157006
ALPHAX= .4475951 ALPHAY=-1.091339
ETAX =-.0080643 ETAY = .0752101

NAME	ETAX	NAME	ETAX	NAME	ETAX	NAME	ETAX	NAME	ETAX
DRIFT	0	D:VT711	-.0465	DRIFT	-.0172	D:HT731	.0025	DRIFT	
D:PMAGV	-.0233	D:VT711	-.0462	D:Q716	-.0174	DRIFT	.0025	DRIFT	
DRIFT	-.4011	DRIFT	-.0456	DRIFT	-.0173	D:Q731	.0022	DRIFT	
D:Q701	-.3868	D:Q707	-.0464	D:SM723	-.0173	D:Q731	.0014	DRIFT	
DRIFT	-.331	DRIFT	-.0925	DRIFT	-.0171	DRIFT	.0006	DRIFT	
D:Q702	-.2999	D:Q707	-.0915	D:VT723	-.017	D:Q731	-.0003	DRIFT	
DRIFT	-.3008	DRIFT	-.0186	D:VT723	-.0169	D:Q731	-.0012	DRIFT	
D:VT702	-.3017	D:Q707	-.0147	DRIFT	-.0142	DRIFT	-.0049	DRIFT	
DRIFT	-.3027	DRIFT	.0517	D:Q716	-.014	D:SM733	-.0049	DRIFT	
D:Q702	-.3368	D:Q715	.0537	DRIFT	-.011	DRIFT	-.0087	DRIFT	
DRIFT	-.3956	DRIFT	.0557	D:Q716	-.0112	D:IB	-.009	DRIFT	
D:Q701	-.4121	D:SM715	.0557	DRIFT	-.0216	DRIFT	-.0082	DRIFT	
DRIFT	-.0636	DRIFT	.0729	D:Q719	-.0214	D:ISEPV	-.0073	DRIFT	
D:SM704	-.0636	D:Q716	.074	DRIFT	-.0037	D:ISEPV	-.0065	DRIFT	
DRIFT	-.0579	DRIFT	.0737	D:Q719	-.0032	DRIFT	-.006	DRIFT	
D:H704	-.017	D:Q716	.07	DRIFT	.0051	D:QSSRF	-.0059	DRIFT	
DRIFT	-.0068	DRIFT	.0619	D:HT727	.0053	DRIFT	-.0064	DRIFT	
D:Q701	-.0042	D:H717	-.1049	D:HT727	.0056	D:V403	-.0068	DRIFT	
DRIFT	.0003	DRIFT	-.1467	DRIFT	.0056	DRIFT	-.0073	DRIFT	
D:Q701	.0037	D:Q718	-.2221	D:Q719	.0058	D:SM403	-.0073	DRIFT	
DRIFT	.0063	DRIFT	-.3137	D:Q719	.0059	DRIFT	-.0082	DRIFT	
D:SM706	.0063	D:H717	-.8704	DRIFT	.0137	D:H403	-.0086	DRIFT	
DRIFT	.0088	DRIFT	-1.175	D:SM728	.0137	DRIFT	-.0089	DRIFT	
D:VT706	.0115	D:H717	-1.883	DRIFT	.0139	D:QSSRF	-.0087	DRIFT	
DRIFT	.0587	DRIFT	-2.095	D:Q729	.0148	DRIFT	-.0081	DRIFT	
D:Q707	.0602	D:Q719	-2.204	D:Q729	.017	END	-.0081	DRIFT	
DRIFT	.0452	DRIFT	-2.205	DRIFT	.0193	DRIFT		DRIFT	
D:Q707	.046	D:SM719	-2.205	D:Q729	.0213	DRIFT		DRIFT	
DRIFT	.0931	DRIFT	-2.207	D:Q729	.0215	DRIFT		DRIFT	
D:Q707	.0922	D:Q719	-2.1	DRIFT	.0173	DRIFT		DRIFT	
DRIFT	.0115	DRIFT	-1.89	D:V730	.0157	DRIFT		DRIFT	
D:Q707	.0074	D:H717	-1.191	D:V730	.0141	DRIFT		DRIFT	
DRIFT	-.058	DRIFT	-.8913	DRIFT	.0131	DRIFT		DRIFT	
D:SM710	-.058	D:H717	-.3455	D:HT730	.0123	DRIFT		DRIFT	
DRIFT	-.0604	DRIFT	-.2562	D:HT730	.0114	DRIFT		DRIFT	
D:Q707	-.0618	D:Q718	-.1853	DRIFT	.004	DRIFT		DRIFT	
DRIFT	-.0614	DRIFT	-.1477	D:Q731	.003	DRIFT		DRIFT	
D:HT711	-.061	D:H717	-.0121	D:Q731	.0026	DRIFT		DRIFT	
D:HT711	-.0607	DRIFT	-.0147	DRIFT	.0026	DRIFT		DRIFT	
DRIFT	-.0469	D:Q716	-.0161	D:HT731	.0026	DRIFT		DRIFT	

Table 2: AP2 horizontal dispersion fixed