BNL-104222-2014-TECH
AGS.SN350;BNL-104222-2014-IR

# Proton Beam Emittance in the BTA Line

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April 1996

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

## DISCLAIMER

| AGS Complex Machine Studies<br>(AGS Studies Report No. 350)<br>Proton Beam Emittance in the BTA Line |
|---|
| **Study Period**: April 16 to June 27, 1996 |
| **Participants**: MCR Staff, S.Y. Zhang |
| **Reported by**: S.Y. Zhang |
| **Machine**: BTA |
| **Beam**: Proton |
| **Tools**: BTA Multiwires |
| **Aim**: To understand the proton beam emittance and the line acceptance at BTA. |

## Proton Beam Emittance in the BTA Line

# 1 SUMMARY


1. In 1996 HEP run, both horizontal and vertical normalized emittances of the high intensity proton beam are about 60 $\pi$ *mmmr* in the BTA line, including 95% particles.
2. Both horizontal and vertical acceptances of the BTA line are about the same as that beam emittance.
3. The vertical beam size is kept constant during the period of middle of April to the end of run, but the horizontal size is slightly decreased in the later run, which is explained by the dispersion induced scraping with larger momentum spread of the beam.


# 2 BEAM EMITTANCE

The beam size in the BTA line at MW006, MW060, MW125 and MW166 in the Daily Log, from middle of April to the end of run, is studied. During this period, the BTA line optics had been roughly in four settings, as shown in Table 1. Note that these settings are slightly different from one to another, with the setting I a little distinguished from the others, and III and V are the same. To estimate the beam emittance, therefore, we use the optics III (V), and disregard the slight error introduced hereby.

Using the beta functions given by the BTA model, the beam emittance calculated from one multiwire can be different from another by a factor of two. If the beam size obtained from the multiwires can be trusted, then it seems that the consistent beam emittance might be a better criterion than the model in judging the local beta functions. In this sense, the beta functions given by the model are modified, according to consistent beam emittances, to see if a reasonable agreement can be reached. In both horizontal and vertical, the upstream beta functions at MW006 and MW060 can be kept unchanged, and the downstream ones, at MW125 and MW166, are modified as shown in Fig.1A for horizontal and Fig.1B for vertical. The locations of the multiwires are marked by 'x', and the modified beta functions are marked by 'o'. The beta functions given by model are shown in parentheses, if they are different from the modified ones. Considering the sensitivity of the downstream optics, the modifications are not large, which can be generated by a few amperes driving current change in upstream quadrupoles. The horizontal and vertical beam emittances calculated using the beta functions given by the model and the modified ones are shown in Figs. 2 and 3, respectively. It is shown that for the high intensity proton run, both horizontal and vertical beam normalized emittances in the BTA line are roughly 60 $\pi$ *mmmr*, including 95% particles.

| | I | II | III | IV | V | Unit |
|---|---|---|---|---|---|---|
| Begin | 4/16 | 4/21 | 5/11 | 6/18 | 6/25 | |
| End | 4/18(?) | 5/10 | 6/17 | 6/24 | 6/27 | |
| Q1 | 359 | 349 | 349 | 352 | 349 | *A* |
| Q2 | 453 | 453 | 453 | 453 | 453 | *A* |
| Q3 | 460 | 460 | 460 | 460 | 460 | *A* |
| Q4 | 579 | 579 | 579 | 579 | 579 | *A* |
| Q5 | 500 | 508 | 508 | 508 | 508 | *A* |
| Q6 | 524 | 529 | 529 | 534 | 529 | *A* |
| Q7 | 261 | 264 | 264 | 273 | 264 | *A* |
| Q8 | 272 | 272 | 272 | 272 | 272 | *A* |
| Q9 | 439 | 439 | 439 | 439 | 439 | *A* |
| Q10 | 140 | 140 | 140 | 140 | 140 | *A* |
| Q11 | 214 | 218 | 208 | 208 | 208 | *A* |
| Q12 | 308 | 298 | 298 | 298 | 298 | *A* |
| Q13 | 475 | 475 | 475 | 475 | 475 | *A* |
| Q14 | 296 | 296 | 296 | 296 | 296 | *A* |
| Q15 | 0 | 0 | 0 | 0 | 0 | *A* |

Table 1

# 3 BTA LINE ACCEPTANCE

The BTA line horizontal and vertical physical apertures are shown in Fig.4 and Fig.5, respectively. The local pipe diameter is denoted by 'D', and the beam half sizes with normalized emittance of 60 $\pi$ *mmmr*, including 95% particles, are also shown for comparison.

For horizontal, the beam size with dispersion effect of $dp/p = 0.3\%$ is also shown. It can be observed that at F6 the aperture is tight, and in the rest part of the line, the condition is not as bad. The real situation at F6, in fact, is worse than that shown in Fig.4, because for some reason the beam has to be set up to scrape the septum, according to Bleser, in AGS Studies Report No.324. For convenience we use the acceptance defined as the normalized emittance including 95% particles. Then we may conclude that the horizontal acceptance in the BTA is determined by F6 septum, at about 60 $\pi$ *mmmr*. It is important to indicate that this acceptance at F6 is very sensitive to the beam momentum spread, because of the dispersion effect.

The vertical acceptance, as shown in Fig.5, is determined by the F6 septum, also at 60 $\pi$ *mmmr*. In some other places, such as D2, D3, D4, D5 and L20, the apertures are also tight, but not as this tight.

# 4 DISCUSSION

1. By comparing the beam size with the BTA line acceptance, it seems that the BTA line is filled up. This fact is important, especially if one considers that both Booster and AGS acceptances are substantially larger than that of BTA line. For example, at the Booster, the vertical acceptance is larger than 200 $\pi$*mmmr* at extraction, and at AGS

injection porch, this acceptance is larger than 120 $\pi mmmr$, whereas at BTA, this is 60 $\pi mmmr$.

2. The beam vertical emittance in this period of run is remarkably constant, if we disregard the short period in the middle of April, where as shown in Table1, the optics is somehow different from the one we used. This fact is in agreement with the speculation of the filling of the BTA line.

3. It can be noticed that the beam horizontal emittance is somehow flat before the middle of May, and is decreased after that. Presumably, the smaller beam emittance should correlate with higher BTA efficiency. It is not. As shown in Fig.6, the BTA transfer efficiency is also decreased. Starting from the middle of May, the Linac beam was deteriorated in the sense of enlarged momentum spread. Therefore, we may explain that the decrease of the beam horizontal size is because of the worsen beam scraping at F6, due to enlarged beam momentum spread, which is accompanied by the decreased BTA transfer efficiency. Meanwhile, the vertical beam size was unaffected.

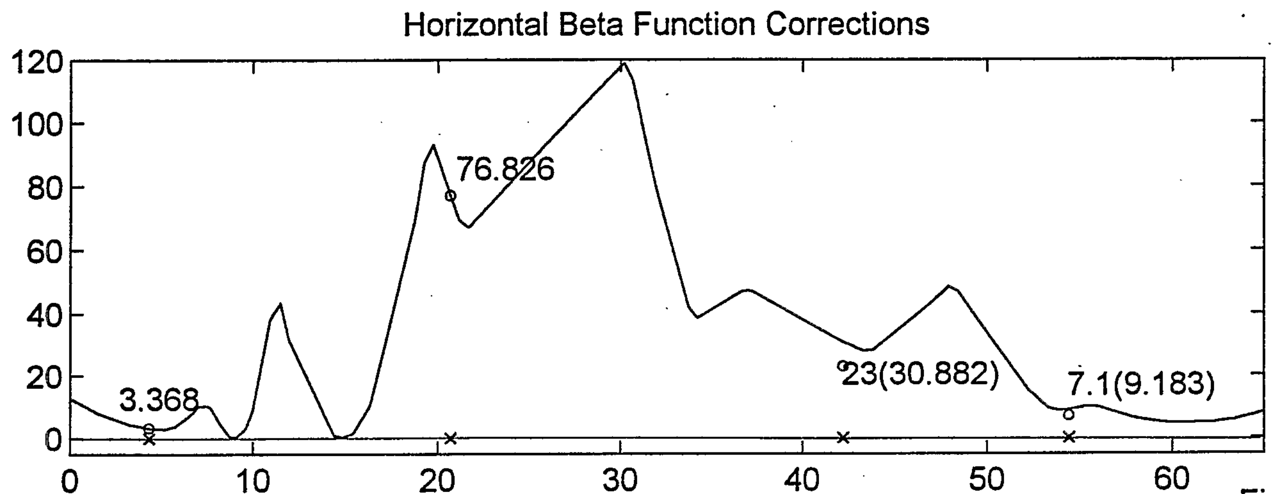

Horizontal Beta Function Corrections
120
100
80
60
40
20
0
3.368
76.826
23(30.882)
7.1(9.183)
0
10
20
30
40
50
60

Fig.1A

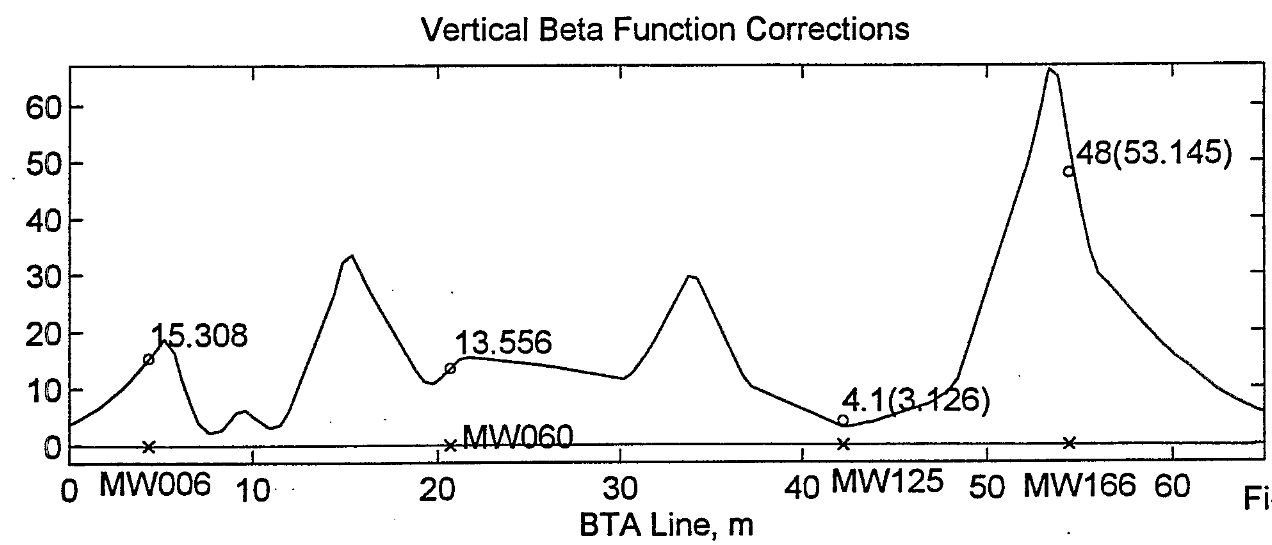

Vertical Beta Function Corrections
60
50
40
30
20
10
0
15.308
13.556
MW060
4.1(3.126)
48(53.145)
0
MW006
10
20
30
40
MW125
50
MW166
60
BTA Line, m

Fig.1B

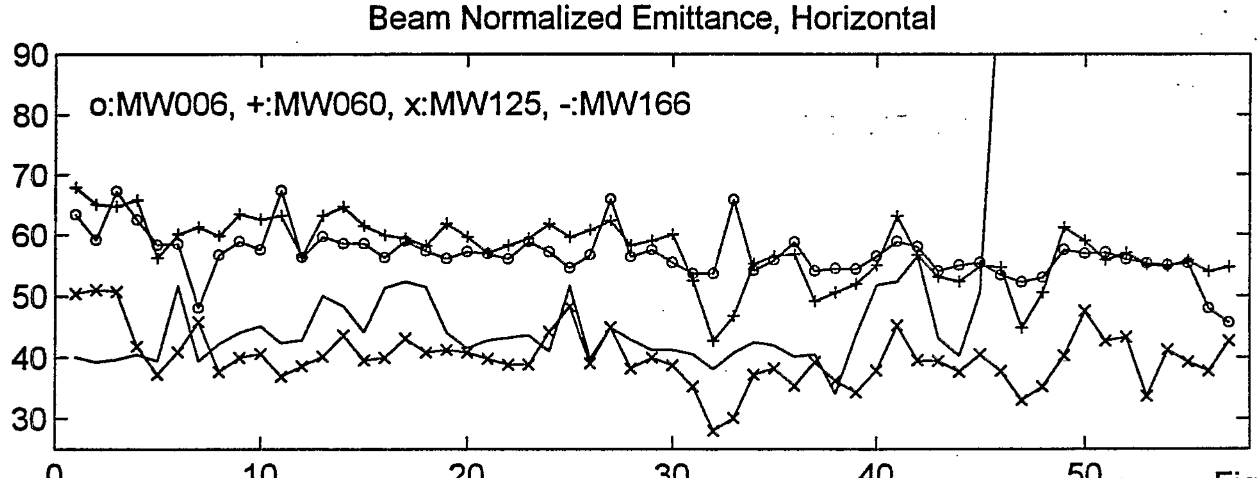

Beam Normalized Emittance, Horizontal
o:MW006, +:MW060, x:MW125, -:MW166
90
80
70
60
50
40
30
0
10
20
30
40
50

Fig.2A

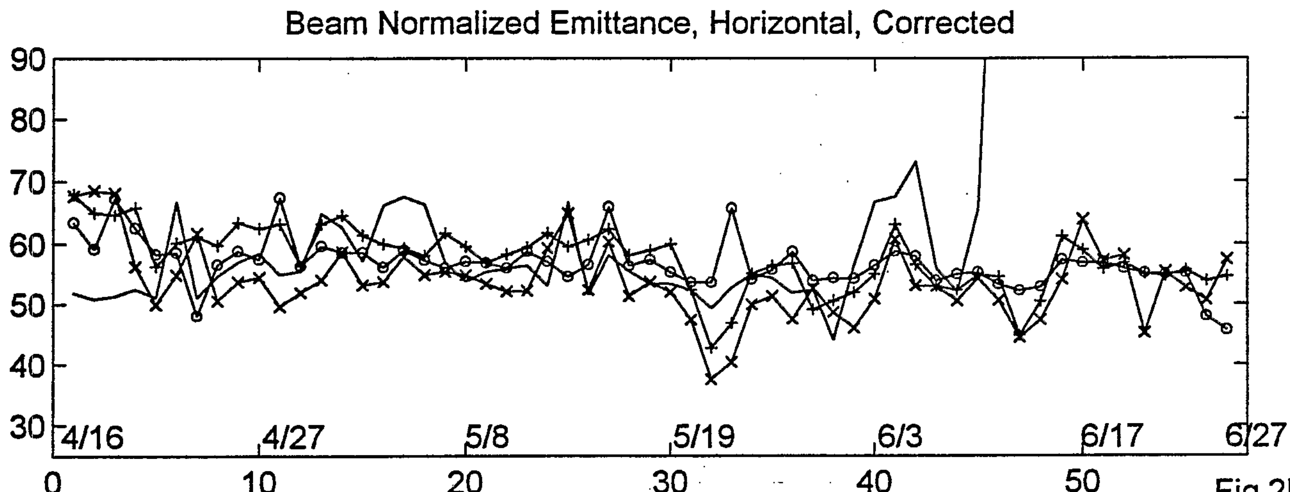

Beam Normalized Emittance, Horizontal, Corrected
90
80
70
60
50
40
30
4/16
4/27
5/8
5/19
6/3
6/17
6/27
0
10
20
30
40
50

Fig.2B

Beam Normalized Emittance, Vertical

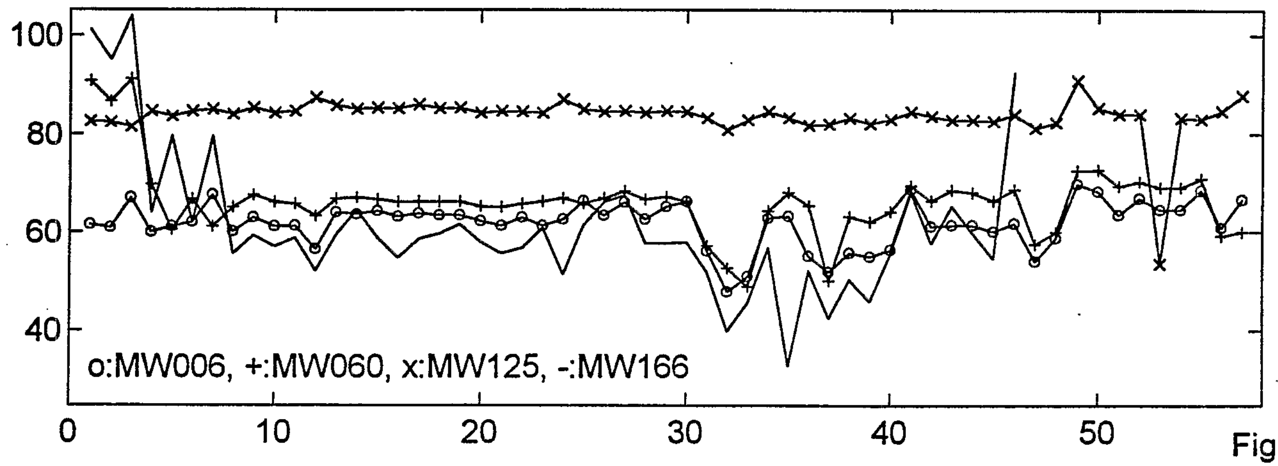



Fig.3A

Beam Normalized Emittance, Vertical, Corrected

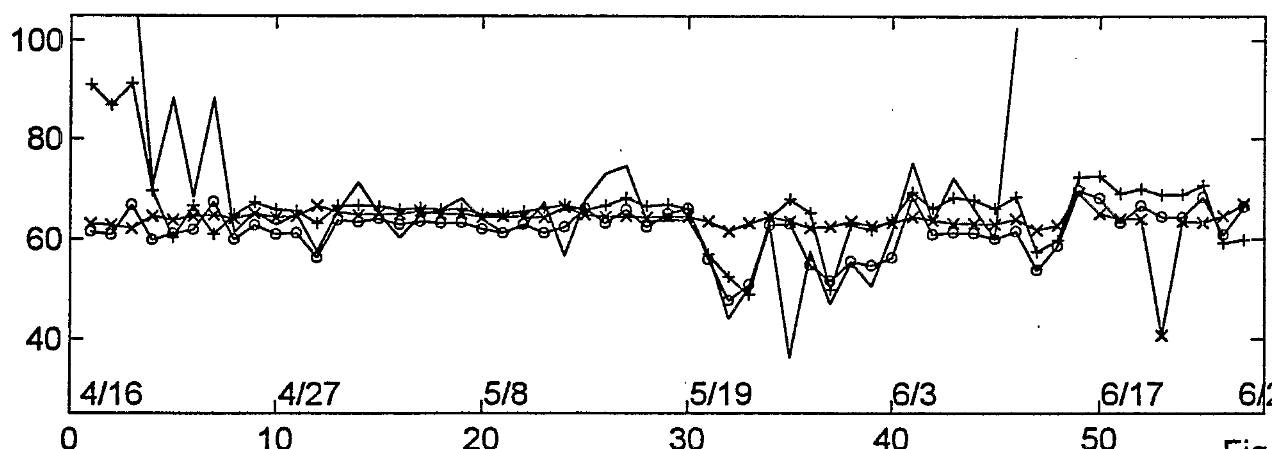
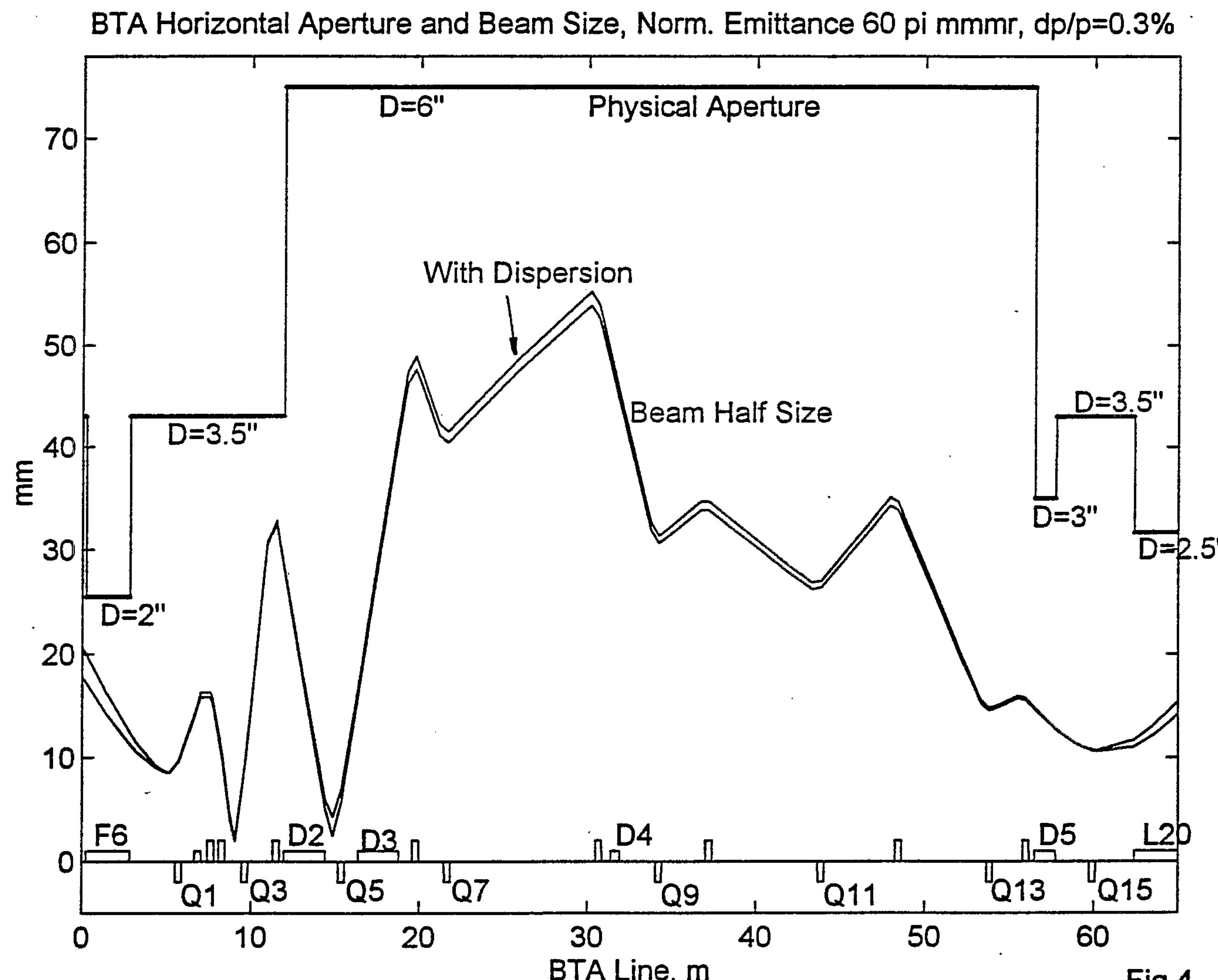



Fig.3B


BTA Horizontal Aperture and Beam Size, Norm. Emittance 60 pi mmmr, dp/p=0.3%
D=6"
Physical Aperture
With Dispersion
Beam Half Size
D=3.5"
D=2"
D=3.5"
D=3"
D=2.5"
mm
F6
D2
D3
D4
D5
L20
Q1
Q3
Q5
Q7
Q9
Q11
Q13
Q15
BTA Line, m
Fig.4

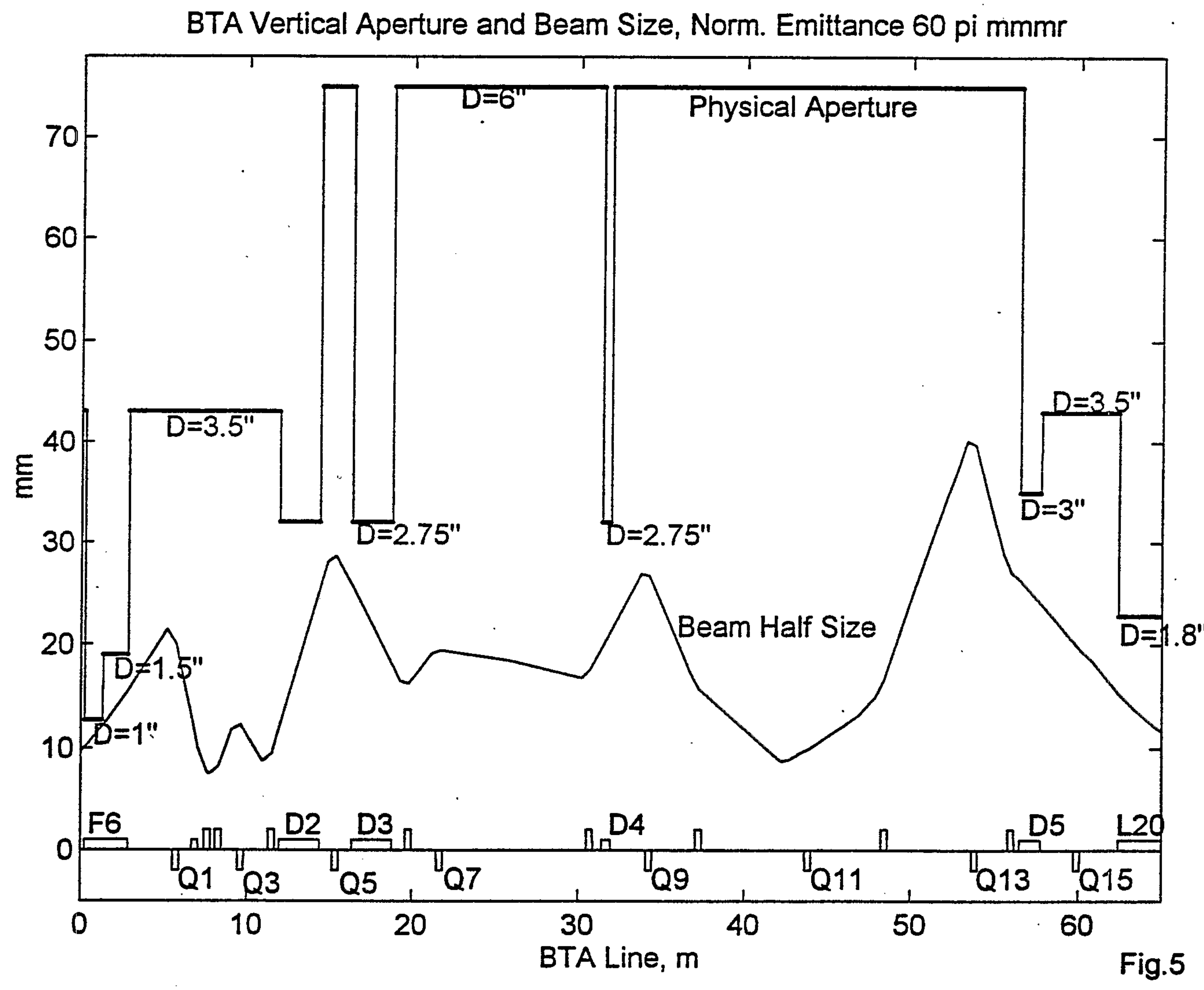
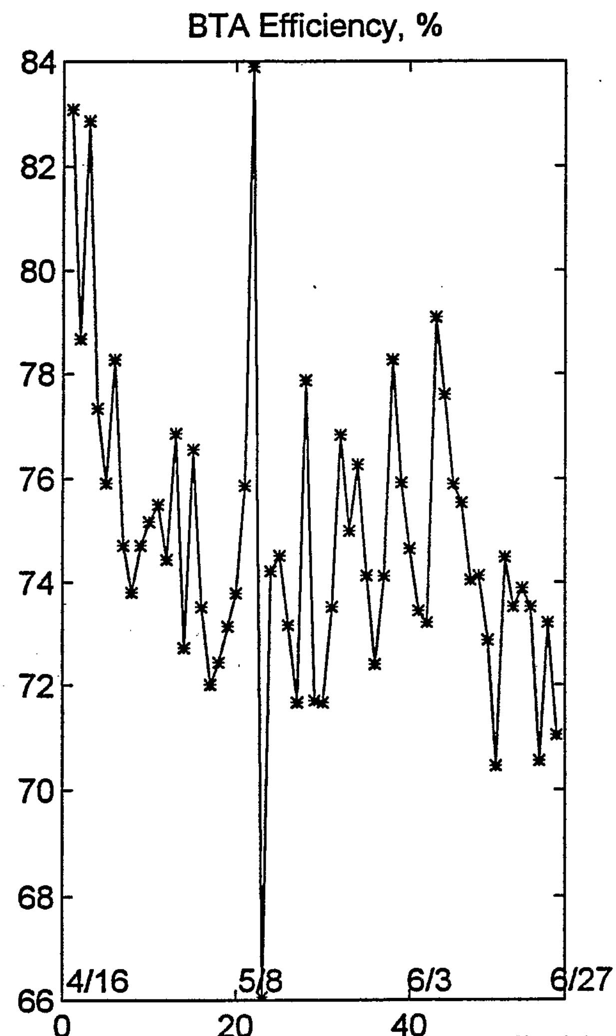
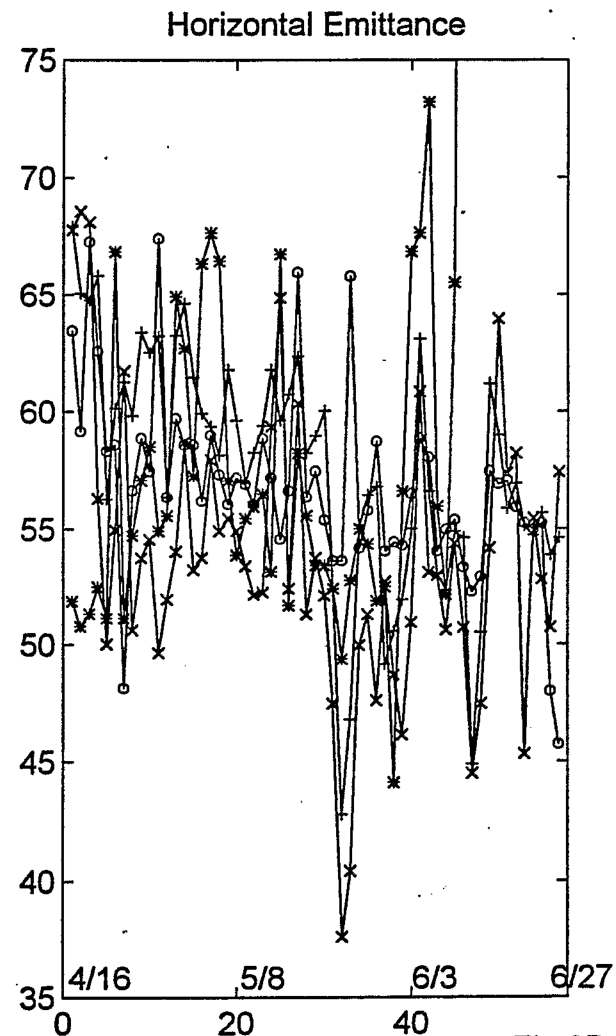

BTA Vertical Aperture and Beam Size, Norm. Emittance 60 pi mmmr
D=6"
Physical Aperture
D=3.5"
D=3.5"
D=2.75"
D=2.75"
D=3"
Beam Half Size
D=1.8"
D=1.5"
D=1"
F6
D2
D3
D4
D5
L20
Q1
Q3
Q5
Q7
Q9
Q11
Q13
Q15
mm
BTA Line, m

Fig.5


BTA Efficiency, %
84
82
80
78
76
74
72
70
68
66
0
20
40
4/16
5/8
6/3
6/27
Fig.6A


Horizontal Emittance
75
70
65
60
55
50
45
40
35
0
20
40
4/16
5/8
6/3
6/27
Fig.6B