NUMERICAL INVESTIGATION OF THE FEASIBILITY OF BEAMSCOPE MEASUREMENTS WITHOUT PARASITIC SHAVING IN THE PSB

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1. **INTRODUCTION**

During measurements of the beam emittances by Beamscope, it is important to know that all shaving occurs at the aperture for all the Q-values of interest. At certain contractions in the vacuum chamber, e.g. the bending magnet scrapers, parasitic shaving could possibly occur in the vertical plane. It is also of interest to find out whether the closed orbit changing during the cycle would affect the measurements.

The simulation of the beam envelope was performed using the program ORBIT described in the Appendix.

2. **METHOD OF CALCULATIONS**

Essentially, the beam envelope at all important points in the machine was simulated, using the program ORBIT. The machine configuration is shown in Fig. 1 where the points at which the beam envelope was calculated are indicated. The points 4 and 16 correspond to the bending magnet scrapers. The aperture at which wanted shaving takes place is located at the point 13 of period 8. The dipoles for deflecting the beam against the aperture are located in position 12 of the periods 7, 8 and 9. Thus, the deflection was superimposed onto the existing closed orbit, if one had been measured, in such a manner that the beam envelope just came into contact with the aperture. By simulating the beam for the whole machine, any parasitic shaving at some other part of the periods 7, 8 and 9 could be checked. The deflection direction can be chosen to be positive or negative. The aperture existing in the machine is a rectangle of 70 x 80 mm.

3. **CALCULATIONS, RESULTS AND CONCLUSIONS**

The Q-values chosen were $Q_H = 4.16, Q_V = 5.23$, the normal operational values, and the following pairs:
Thus, all practical and theoretical cases of interest were considered. For the size of the beam, zero diameter and emittance, intermediate emittance, and maximum emittances were used. The calculations were performed for deflections in both the horizontal and vertical planes. The measured existing closed orbit was superimposed onto the deflecting bump for the case of the normal running Q-values. All the computational results are summarized in Fig. 2-64. The plots show the periods 7, 8 and 9 where the beam is deflected, the deflecting bump, an existing closed orbit, and the beam envelope. The positions of scrapers and aperture are indicated, so is the shape of the vacuum chamber with all the contractions. Also are shown the sections of bending magnet scrapers, the aperture and Fl centre. Figures 2 and 3 show the maximum permissible emittances for the existing aperture in the machine as a function of Q-values.

It turns out that maximum permissible emittances are determined by the aperture. No parasitic shaving occurs in either plane. The suspected spot of trouble constituted by the bending magnet scrapers during measurements of vertical emittances does not materialize. All the beam is shaved at the aperture.
The program can be used to test other aperture sizes and to investigate the range of allowable maximum emittances that can safely be measured using the beamscope.

ACKNOWLEDGEMENTS

The problem was defined by H. Schönauer.
APPENDIX

INPUT DATA FOR THE BEAMSCOPE PROGRAM

(See Fig. 4 for reference)

1. A heading of up to 80 characters.
2. \(Q_H, Q_V\) in FORMAT(2F10.4).
3. Integer 1 in FORMAT(I10).
4. BEAM in FORMAT(A4).
5. FINEPLOT in FORMAT(A8).
6. DEFLECTION in FORMAT(A10).
7. A blank card.
8. To calculate the bump orbit:
   HORIZONTAL in FORMAT(A10) for horizontal plane, or VERTICAL in FORMAT(A5)
   for vertical plane.
   CONTINUE in FORMAT(A8) to continue with beamscope computations after
   the bump orbit has already been computed, or
   STOP in FORMAT(A4) to end computations.
9. Period number, position number (see Fig. 1), deflection angle in [mrad]
   in FORMAT(2I10, F10.4).
   For beamscope 7 12 1.0 is read and the kicks for the dipoles in
   periods 8 and 9 become:
   \(Q_9 = Q_7\); \(Q_8 = 20_7 \cos \left(\frac{2\pi Q_7}{16}\right)\)
   A zero for period number terminates this data.
10. Measured values of the existing closed orbit in [mm] in FORMAT(8F10.4).
11. POSITIVE in FORMAT(A8) for a bump in positive direction, NEGATIVE in
    FORMAT(A8) for a bump in negative direction.
12. \(\varepsilon_H, \varepsilon_V\) in FORMAT(2F10.4).
    A negative value of \(\varepsilon_H\) terminates reading of emittances. Otherwise,
    any number of emittance values can be considered.
13. MAXEMIT in FORMAT(A7) to calculate the beam for a maximum permissible
    emittance. A blank card otherwise.
JOB CONTROL STATEMENTS TO RUN ORBIT PROGRAM
<table>
<thead>
<tr>
<th>Code</th>
<th>Description</th>
<th>Data</th>
</tr>
</thead>
<tbody>
<tr>
<td>100</td>
<td>BEAMSCOPE, Horizontal Deflection</td>
<td></td>
</tr>
<tr>
<td>110</td>
<td>42</td>
<td>4.2</td>
</tr>
<tr>
<td>120</td>
<td>1</td>
<td></td>
</tr>
<tr>
<td>130</td>
<td>BEAM</td>
<td></td>
</tr>
<tr>
<td>140</td>
<td>FINEPLOT</td>
<td></td>
</tr>
<tr>
<td>150</td>
<td>DEFLECTION</td>
<td></td>
</tr>
<tr>
<td>160</td>
<td>INJECTION</td>
<td></td>
</tr>
<tr>
<td>170</td>
<td>HORIZONTAL</td>
<td></td>
</tr>
<tr>
<td>180</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>190</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>200</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>210</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>220</td>
<td>VERTICAL</td>
<td></td>
</tr>
<tr>
<td>230</td>
<td>7</td>
<td>12</td>
</tr>
<tr>
<td>240</td>
<td>0</td>
<td></td>
</tr>
<tr>
<td>250</td>
<td>0.0</td>
<td>0.0</td>
</tr>
<tr>
<td>260</td>
<td>0.0</td>
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<tr>
<td>270</td>
<td>CONTINUE</td>
<td></td>
</tr>
<tr>
<td>280</td>
<td>NEGATIVE</td>
<td></td>
</tr>
<tr>
<td>290</td>
<td>350.0</td>
<td>200.0</td>
</tr>
<tr>
<td>300</td>
<td>-1</td>
<td>0</td>
</tr>
<tr>
<td>310</td>
<td>STOP</td>
<td></td>
</tr>
</tbody>
</table>

Typical data for orbit program (BEAMSCOPE)
ONE BOOSTER PERIOD AND NUMBERING OF THE POINTS.

1. BENDING MAGNET
2. BENDING MAGNET
3. FOCUSING QUADRUPOLE
4. FOCUSING QUADRUPOLE
5. FOCUSING QUADRUPOLE
6. DEFOCUSING QUADRUPOLE
7. DEFOCUSING QUADRUPOLE
8. DEFOCUSING QUADRUPOLE
9. DEFOCUSING QUADRUPOLE
10. DEFOCUSING QUADRUPOLE
11. DEFOCUSING QUADRUPOLE
12. DEFOCUSING QUADRUPOLE
13. DEFOCUSING QUADRUPOLE
14. DEFOCUSING QUADRUPOLE
15. DEFOCUSING QUADRUPOLE
16. DEFOCUSING QUADRUPOLE
17. DEFOCUSING QUADRUPOLE
18. DEFOCUSING QUADRUPOLE
19. DEFOCUSING QUADRUPOLE

FIG. 1
MAX. VERTICAL EMITTANCES AT THE APERTURE AS A FUNCTION OF QV.

FIG. 2

MAX. HORIZ. EMITTANCES AT THE APERTURE AS A FUNCTION OF QH.

FIG. 3
DATA FLOW DIAGRAM FOR THE BEAMSCOPE PROGRAM (SEE DATA DESCRIPTION).

1. H  
   HEADING OF UP TO 80 CHARACTERS
2. QH, QV  
   HORIZONTAL AND VERTICAL Q-VALUES
3. IOBIT  
   INTEGER I FOR BEAMSCOPE
4. TYPE  
   BEAM FOR BEAMSCOPE
5. PLOT  
   FINEPLOT FOR BEAMSCOPE
6. PERTUR  
   DEFLECTION FOR BEAMSCOPE
7. TIME  
   BLANK CARD
8. PLANE  
   HORIZONTAL, VERTICAL, STOP OR CONTINUE

9. PLANE=CONTINUE
   HORIZONTAL VERTICAL
10. I, J, T  
    POSITIVE OR NEGATIVE
11. NO  
    HORIZONTAL AND VERTICAL EMITTANCES
12. COMPUTN.  
    PERIOD, SECTION, DEFLECTION ANGLE
13. Y1  
    MAXEMIT FOR MAX.EMIT
14. COMPUTN.  
    BLANK OTHERWISE
15. DIR  
    MEASURED CLOSED ORBIT VALUES
16. EMIT  
17. EMIT  
   BLANK MAXEMIT
18. COMPUTN.  
   END OF PROGRAM
19. AMODE  
20. AMODE=  
   END
21. COMPUTN.  
22. END
FIG. 17A

100.0 - BEAMSCOPE, HORIZONTAL DEFLECTION. NO CLOSED ORBIT. MOR. PLANE

50.0

25.0

0.0

-25.0

-50.0

-75.0

-100.0

6 7 8 9 PERIOD

FIG. 17B

100.0 - BEAMSCOPE, HORIZONTAL DEFLECTION. NO CLOSED ORBIT. VER. PLANE

50.0

25.0

0.0

-25.0

-50.0

-75.0

-100.0

6 7 8 9 PERIOD
Fig. 19a

B EAMS CPE. HORIZONTAL DEFL EICTION. NO CLOSED ORBIT.
HOR. PLANE

B EAMS CPE. HORIZONTAL DEFL EICTION. NO CLOSED ORBIT.
VER. PLAN
NO CLOSED ORBIT.

FIG. 29a

FIG. 29c
FIG. 34a

FIG. 34c

FIG. 34b

FIG. 34d
Fig. 36a

Fig. 36b

Fig. 36c

Fig. 36d
Figure 37a

BEAMSCOPE, VERTICAL DEFLECTION

NO CLOSED ORBIT

NORMAL PLANE

ORBIT-BEAM (MM)

75.0

50.0

25.0

0.0

-25.0

-50.0

-75.0

-100.0

6

7

8

9

PERIOD

B H D F B

B H D F B

B H D F B

QH GV E(H) E(V) T(H) T(V)

4.200 4.800 20.000 4.000 0.000 -2.602

- BEAM ENVELOP

- BUMP

- CLOSED ORBIT

Figure 37b

BEAMSCOPE, VERTICAL DEFLECTION

NO CLOSED ORBIT

VERTICAL PLANE

ORBIT-BEAM (MM)

75.0

50.0

25.0

0.0

-25.0

-50.0

-75.0

-100.0

6

7

8

9

PERIOD

B H D F B

B H D F B

B H D F B

QH GV E(H) E(V) T(H) T(V)

4.200 4.800 20.000 4.000 0.000 -2.602

- BEAM ENVELOP

- BUMP

- CLOSED ORBIT
Fig. 38a

Fig. 38b

Fig. 38c

Fig. 38d
Fig. 57a

**BEAMSCOPE, VERTICAL DEFORMATION**

- **NO CLOSED ORBIT**
  - **NORMAL PLANE**

- **APERTURE**
- **VACUUM CHAMBER**

<table>
<thead>
<tr>
<th>QM</th>
<th>QQ</th>
<th>E(H)</th>
<th>E(V)</th>
<th>T(M)</th>
<th>T(V)</th>
</tr>
</thead>
<tbody>
<tr>
<td>4.800</td>
<td>4.200</td>
<td>286.638</td>
<td>111.864</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

**BEAM ENVELOPE**

- **BUMP**
- **CLOSED ORBIT**

Fig. 57b

**BEAMSCOPE, VERTICAL DEFORMATION**

- **NO CLOSED ORBIT**
  - **VERT. PLANE**

- **APERTURE**
- **VACUUM CHAMBER**

<table>
<thead>
<tr>
<th>QM</th>
<th>QQ</th>
<th>E(H)</th>
<th>E(V)</th>
<th>T(M)</th>
<th>T(V)</th>
</tr>
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<td>4.800</td>
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<td>286.638</td>
<td>111.864</td>
<td>0.000</td>
<td>0.000</td>
</tr>
</tbody>
</table>

**BEAM ENVELOPE**

- **BUMP**
- **CLOSED ORBIT**
Fig. 65a

Fig. 65b