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Resonant extraction tests at Q_H = 26 2/3 and at Q_H = 27 (approached from below) on 10th March 1977

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1. Summary

1.1 Extraction at Q_H = 26 2/3 seems to work as well as the third-integer extractions at Q_H = 27 1/3 and Q_H = 27 2/3 previously tested and used in operation. First tests of a slow spill learning program gave encouraging results.

1.2 Tests of fast integer extraction at Q_H = 27 (approached from below) and at 400 GeV/c were less successful than previous tests at Q_H = 27 (approached from above) and at Q_H = 28, both done at 200 GeV/c. Without using the special fast bumpers it was not possible to obtain spills shorter than about 7 ms. In addition, the density distribution at the electrostatic septum did not agree with the theoretical predictions. When the fast bumpers MPZH were powered spills of about 1 ms length were achieved. However, the losses at the electrostatic septum became unacceptably high, not permitting systematic measurements.

2. Slow extraction at Q_H = 26 2/3

The experiment was done on the 200 GeV flat top of cycle 8, set up with the horizontal and vertical tunes close to 26.6. The extraction procedure was the same as described previously for extraction at Q_H = 27 2/3 (SPS Comm. Rep. No. 23) except that a different set of sextupoles was used.

These sextupoles were LSE 1260, LSE 2260, LSE 4260 and LSE 5260. LSE 1260 and LSE 4260 had positive polarity, the other two sextupoles had negative polarity. The normalized strength was 6 m^{-1} per sextupole.

During the tests the RF was kept on at 985 kV, whilst the RF servo was off.

The upper photograph of Fig. 1 shows a typical spill obtained under these conditions. No attempt was made to compensate the 50 Hz ripple.

The lower photograph of Fig. 1 shows how the spill shape was improved shortly after the learning program had been started. (Note that for the BSI signal the sensitivity of the scope was changed from 50 mV/div to 20 mV/div before the second photograph was taken.) The learning program modified the current waveform of QE 5360 after having analyzed the BSI signal. The basic features of this program are discussed in a memorandum by C.G. Harrison (ref. SPS/AOP/CGH/jf, dated 4 February, 1977).

Fig. 2 shows the density distribution of the resonant protons at the electrostatic septum ZS. This distribution is in perfect agreement with theoretical predictions. Fig. 3 shows the horizontal profile of the extracted beam at the extractor magnet. The width of the profile is as expected for an RF voltage around 1 MV. No widening due to the action of the learning program on QE 5360 can be observed.

3. Fast resonant extraction at $Q_H = 27$

3.1 Experimental procedure

The extraction test was done at 400 GeV/c on cycle 8, set up with the horizontal and vertical tunes close to 26.6 as mentioned above. The machine intensity was reduced to about $1 * 10^{12}$ protons at 400 GeV/c. The experimental procedure was as follows :

- During the round-off before the 400 GeV flat top the machine tune was changed within 60 ms (between 6240 ms and 6300 ms after injection) from Q_H = 26.63, Q_V = 26.54 to Q_H = 27.86, Q_V = 27.59.

- The strength of the electrostatic septum was adjusted to 105 kV/cm. The magnetic septa and the vertical bumpers were excited within 300 ms, reaching their nominal strength at 6180 ms after injection. The extraction quadrupole QE 6143 was excited to a normalized strength of -.6498 simultaneously with the horizontal bumpers within 100 ms (between 6240 ms and 6340 ms after injection). Finally, the sextupoles LSE 5260 and LSE 6060 were powered at 6300 ms after injection, reaching the required strength of + 5 m^{-1} per sextupole at 6350 ms.

- The protons were extracted on the 400 GeV flat top by one of the following methods :

  a) The RF was switched off and the main magnet field was increased at the maximum possible rate of 6 * 10^{-3} per 60 ms. The corresponding rapid displacement of the beam in the extraction quadrupole resulted in an extraction of all protons with approximately 7 ms.

  b) After having done a number of measurements on the 7 ms spill the modification of the main magnet field on the 400 GeV flat top was cancelled and the fast bumpers MPZH 6140 and MPZH 6143 were powered in series by a capacitor discharge. The polarity of the bumpers and the current waveform were the same as for extraction at Q_H = 28 (compare SPS Comm. Rep. No. 39). The capacitor charging voltage was 1 kV. All protons were extracted within about 1 ms. However, the losses on the electrostatic septum were unacceptably high.

3.2 Results of measurements and observations

Fig. 4 shows the spill obtained when the main magnet field was

increased by $6 * 10^{-3}$ per 60 ms. An attempt to achieve a faster rate of change led to a drop out of the main magnet power supplies.

Fig. 5 shows the density distribution of the resonant protons at the electrostatic septum. This distribution is in disagreement with theoretical calculations which yield a maximum jump of 13 mm and no "jump spread". The measured beam width at the extractor magnet MSE (Fig. 6) is about 1.3 times as large as predicted. A few more observations are worth mentioning :

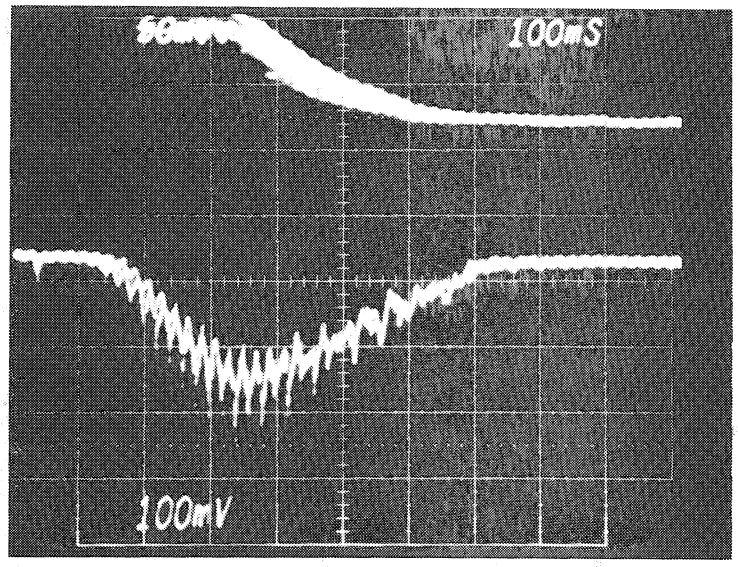
- During the experiment some instability caused the loss distribution at the electrostatic septum to flip between two distinct patterns which alternately were adopted for a number of cycles. The above beam profiles were measured when the loss distribution looked "normal".

- The horizontal machine tune is very critical when doing integer extraction. For the nominal tune $Q_H = 26.86$ the desired orbit deformation in the extraction region was obtained without any noticeable distortion in the rest of the ring. Changing the tune by as little as 0.01, however, caused considerable orbit distortions along the circumference and led to a complete loss of the circulating beam.

- Due to the high losses at ZS no systematic measurements could be done on the 1 ms spill obtained by powering the fast bumpers MPZH. Incomplete measurements indicate, however, that the density distribution at ZS was very similar to the distribution previously observed (compare Fig. 14 of SPS Comm. Rep. No. 42) when the resonance at $Q_H = 27$ was approached from above: the maximum jumps at the electrostatic septum were of the order of 5 mm only, with the beam intensity decreasing almost linearly between the wire plane and this maximum.

Such a distribution of the resonant protons is in complete contradiction to computer simulations which predict jumps of more than 12 mm and no "jump spread". No explanation for this discrepancy has been found to date.

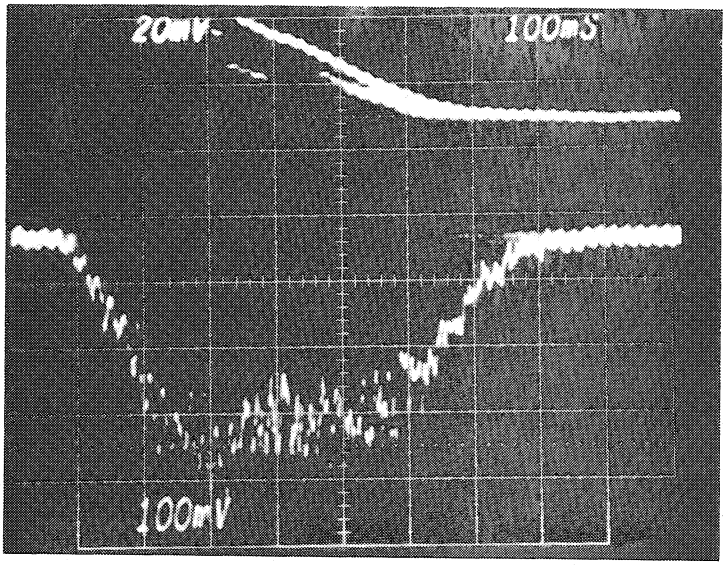
Reported by : K.H. Kissler



BCT ring

BSI 6103

Spill at Q_H = 26 2/3 without learning program.



BCT ring

BSI 6103

Spill at Q_H = 26 2/3 shortly after the learning program had been started.

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Fig. 1

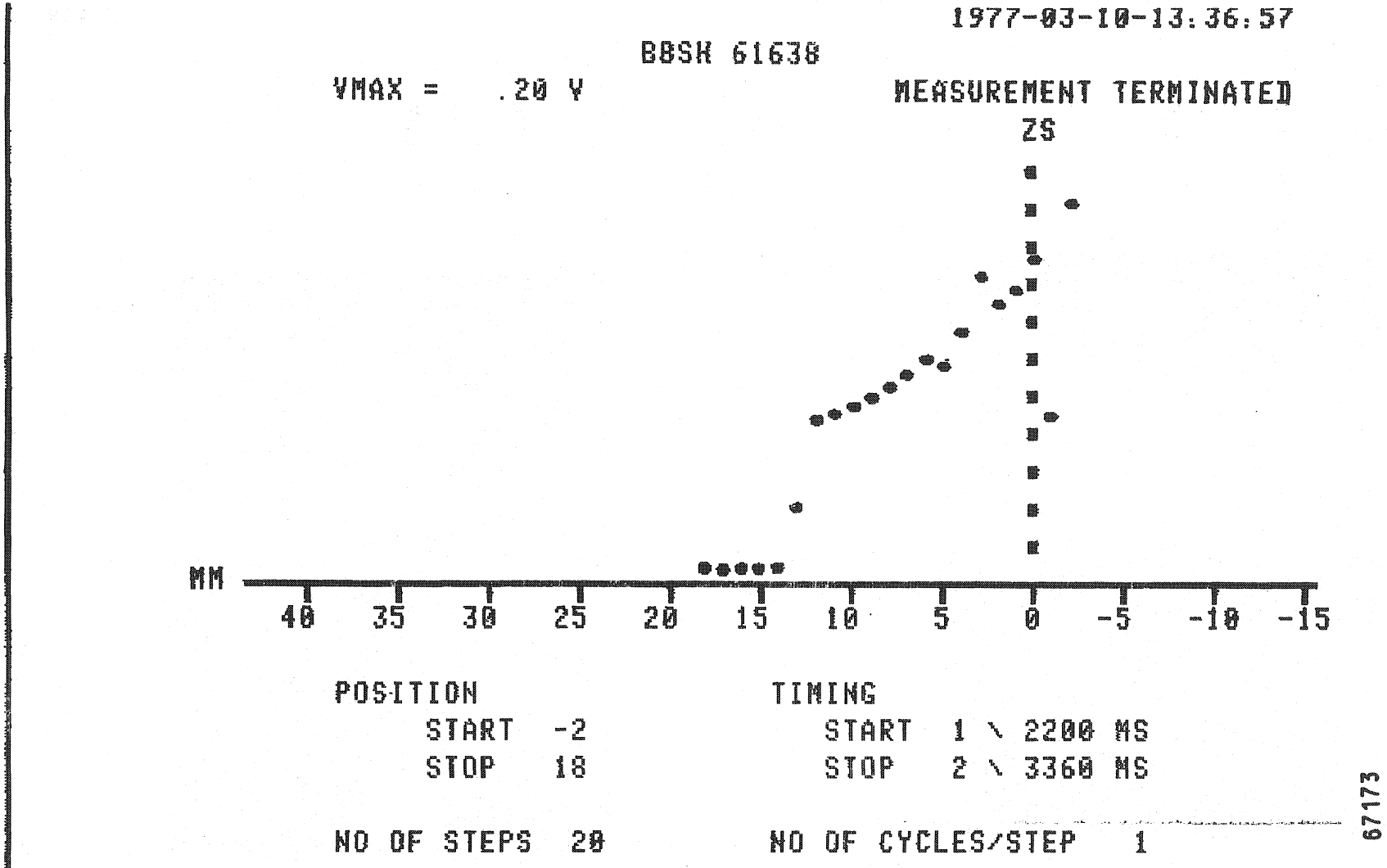


Fig. 2 Density distribution at the electrostatic septum ZS for a slow spill at Q_H = 26 2/3.

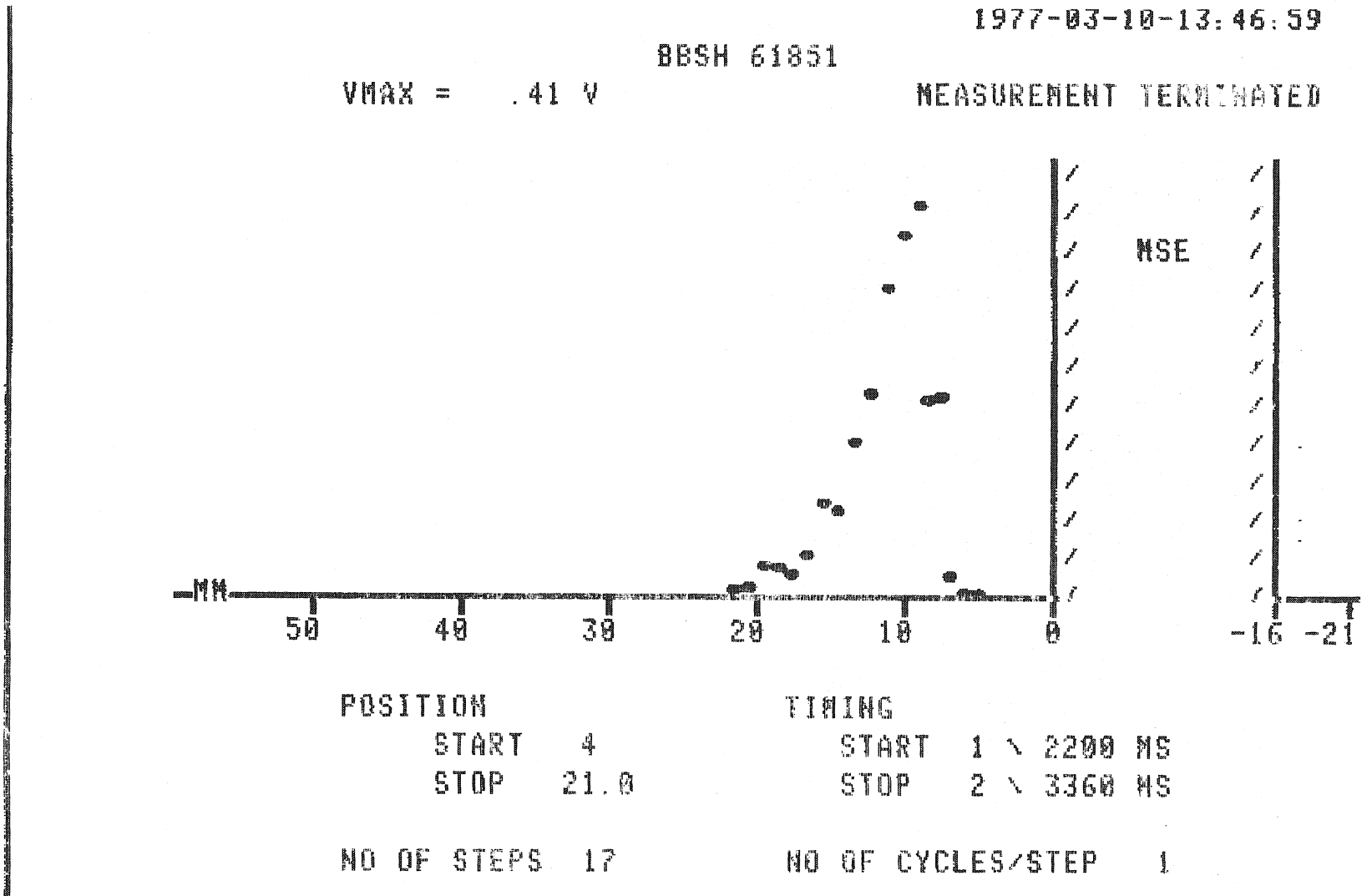
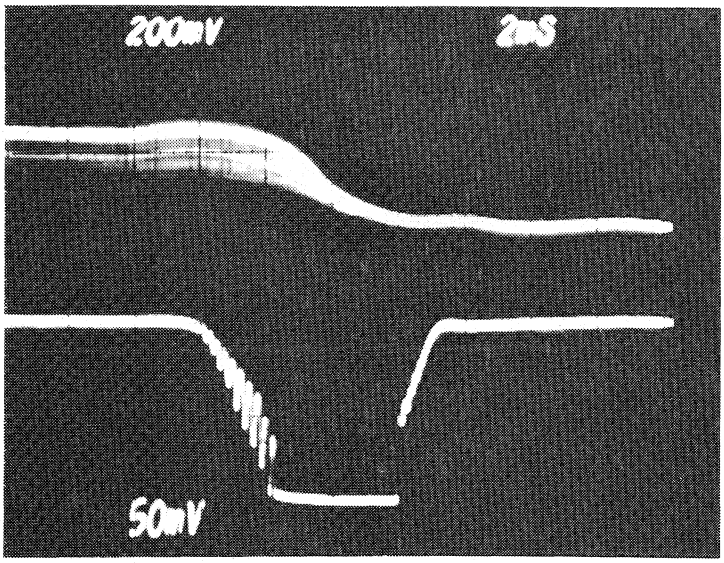


Fig. 3 Horizontal profile of the extracted beam at the extractor magnet for a slow spill at Q_H = 26 2/3.



BCT ring

BSI 6103

(saturated)

Fig. 4 Fast integer spill at $Q_H = 27$ approached from below.

$\frac{\Delta B}{B}$ on 400 GeV flat top: $6 * 10^{-3}$ per 60 ms

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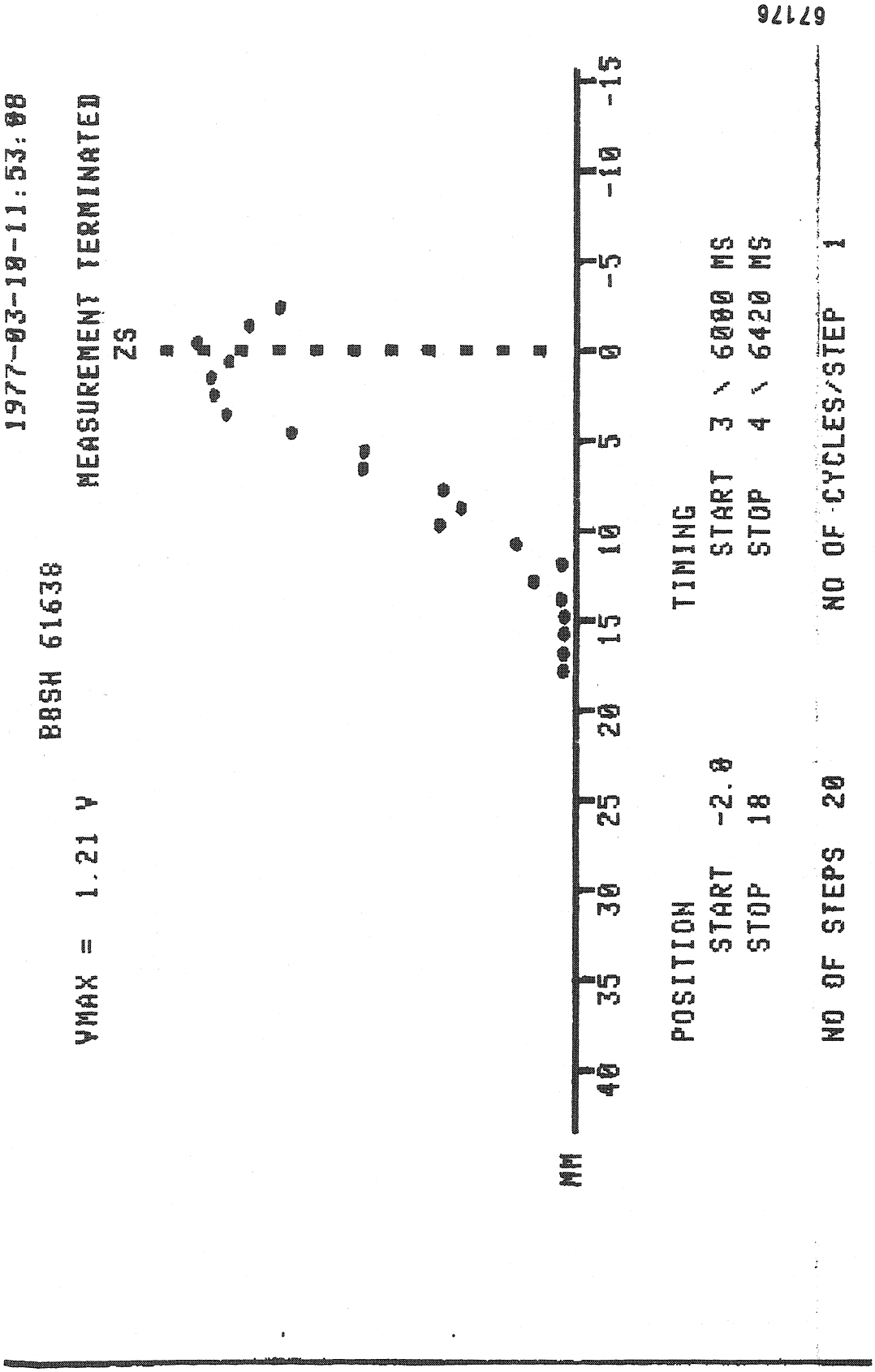

Fig. 5 Density distribtuion at the electrostatic septum ZS for a 7 ms spill at Q_H = 27.

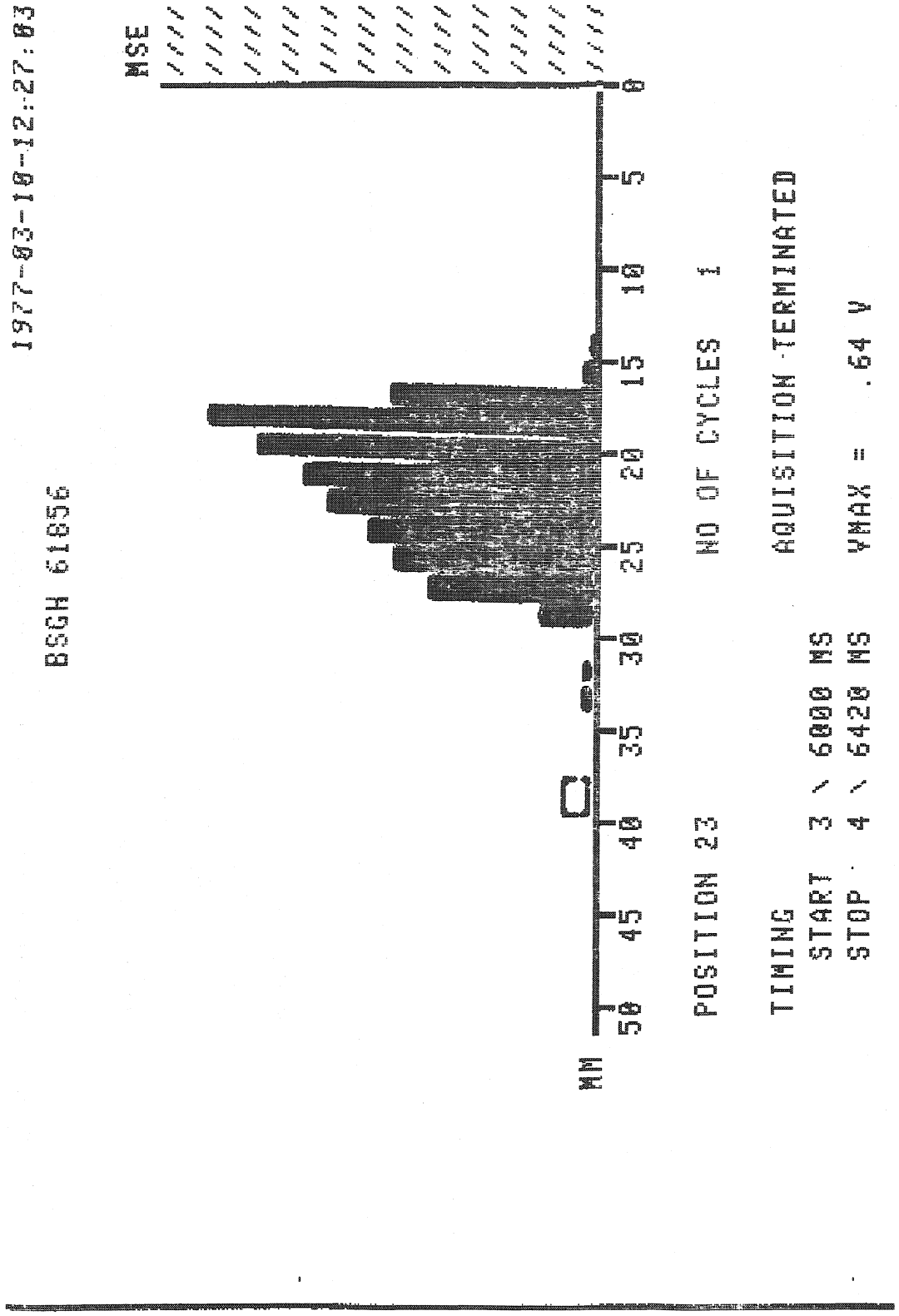

Fig. 6 Horizontal profile of the extracted beam at the extractor magnet for a 7 ms spill at $Q_H = 27$.