ISR RUNNING-IN
Run 86, 9.7.71, 19.30 - 22.00, 20 bunches, 22 FA
Run 90, 22.7.71, 9.30 - 12.30, 4 bunches, 22 FA
Run 93, 28.7.71, 13.00 - 15.45, 20 bunches, 22 FA

Investigation of horizontal beam profiles
with scraping targets

We shall restrict ourselves to showing pictures obtained during these runs and to making semi-quantitative comments. The quantitative analysis of our data is quite hard and involves, in addition, rather restrictive assumptions.

1. Scraper calibrations

The relative position of the scraper with respect to the average radius was determined by accelerating a single pulse to a specified and measured average radius and then killing it with the scraper. Fig. 1 shows both the current recordings and the calibration line for Run 86, Fig. 2 shows the calibration curve for Run 90. One concludes that the radial displacement at the scraper is 0.8 cm for one cm displacement in average radius, as expected. We have also confirmed the calibration of the horizontal scale of the RF scans: at 22 GeV/c it is very nearly 1 HP cm/1 cm in average radius.

2. Vertical beam size measurements with PB

We have measured the vertical beam radius at the PB position as a function of the number of injected pulses, using 5 V bias in Run 86, and 1 V bias in Run 90. The result is shown in Fig. 3. It seems to confirm that at the moment saturation and rapid beam losses are accompanied by large beam radii, as is required when one wants to explain them by multiple scattering. Note the different horizontal scales on the two graphs. The horizontal measurements were spoiled by the long tail of the stacks and are not worth reporting.
The current loss during 4 PB operations is only 1 or 2 %, thus the beam size is measured at the far tail of the distribution function. It would be more useful for measuring beam sizes if one were permitted to kill more beam by the PB.

3. **Scraper scans**

We have killed stacks by running scrapers into them, both from the inside and from the outside. In the first (second) case we can get some idea about the horizontal betatron amplitude at the inner (outer) edge of the beam. The results are shown in Figs. 4 - 22. (Only a limited selection is reproduced in this note; the full set is available with K. Hübner for those interested.) Note "REV" (≡ reverse) indicates that the scraper scan goes from outside to inside with the OUTER ST.

The following observations can be made on the 20 bunch scans:

i. For small currents (20 and 40 pulses) the scans are fairly narrow; indeed their full width at half height is roughly the same as that of the r.f. scans, all scaling factors taken into account. This is one indication that the horizontal betatron amplitudes are small - a few millimetres, say.

ii. Also for small current, the displacement between inwards and outwards scans is also rather small - again a few millimetres. This is another indication that the horizontal betatron amplitudes are rather small.

iii. For 60 or more stacked pulses we observe a large displacement between the inwards and outwards scans, sometimes accompanied by a change of shape, and sometimes not. A difference in shape can be explained by assuming that the beam size is a function of the place in the stack, and for our scans, is bigger at the inside edge of the stack.
Our experimental accuracy is insufficient to distinguish between large betatron amplitudes and a "hollow" beam which do not result in a large difference of the shape of the scraper scans. Assuming that the beam is not hollow we find that the rms betatron amplitude for 65 pulses is about 8 mm at the scraper, corresponding to a beam radius of 25 mm at maximum horizontal $\beta$. For 75 stacked pulses the beam radius is even bigger. These results were obtained both in Run 86 and in Run 93.

The 4-bunch scans made in Run 91 are shown in Figs. 23 - 35, (limited selection reproduced here). The following comments can be made:

i. Their widths gradually become larger as one puts in more pulses, as one would expect.

ii. The inwards and outwards scan coincide well for all numbers of pulses injected. This suggests that the betatron amplitudes are small for all stackwidths quite in contrast to the scans made in the 20 bunch run.

iii. It therefore seems that there is a high-current phenomenon which causes strange things to happen when the current in the ISR exceeds about 4 A.

4. Single pulses (Run 93)

We have killed single pulses with the ST, both from the inside and from the outside ("rev"). The results which are shown in Figs. 36 - 41 are very reproducible. They indicate that the rms betatron amplitude is about 2 mm at the scraper, and that the half width of the momentum distribution is about 1 mm. This corresponds to a horizontal beam radius of 6 mm at maximum horizontal $\beta$, and a momentum half width of 1.25 mm at average $\alpha_p$, or to $\Delta p/p = 0.7 \times 10^{-3}$. 
5. Small stacks at different radial positions, (Run 93)

We find, that the results are very reproducible, and that the betatron amplitudes found are quite small in all cases, as shown in Figs. 42 - 51. Explicitly, we find:

<table>
<thead>
<tr>
<th>no. of pulses</th>
<th>radial stacking position</th>
<th>beam radius at $\beta_{\text{max}}$</th>
</tr>
</thead>
<tbody>
<tr>
<td>20</td>
<td>+ 40 mm</td>
<td>12 mm</td>
</tr>
<tr>
<td>40</td>
<td>+ 40 mm</td>
<td>12 mm</td>
</tr>
<tr>
<td>20</td>
<td>+ 20 mm</td>
<td>?</td>
</tr>
<tr>
<td>40</td>
<td>+ 20 mm</td>
<td>12 mm</td>
</tr>
<tr>
<td>20</td>
<td>+ 5 mm</td>
<td>10 mm</td>
</tr>
</tbody>
</table>

This shows that the effect which increases the horizontal betatron amplitude is not due to the radial position at which stacking occurs; it does depend on the stacked current.

6. Vertical scraper scans (Run 93)

They were made for a single pulse and for 65 pulses and are shown in Figs. 52 - 53. There is not much difference between them.

7. Conclusions

We have observed that large betatron oscillations occur when one stacks to saturation, i.e., to more than about 4 A. They are not due to the radial position of the stack because lower current stacks at different radial position and stacks made with 4 bunches do not show an increase in radial betatron amplitude.

We also observed that the vertical beam size increased from about the same current level until the beam essentially fills the vertical aperture.

E. Keil        B.W. Montague

Distribution
ISR Group Leaders
Running In Committee
Engineers in Charge
E. Brouzet MPS
M. Höfert HP
Single pulse at +20 mm

Vertical scraper scan and phase space density

Ref. 52
Fig. 26
40 pulses

INPUT VALUES TAKEN ON 7/18/72 AT 11:55:36
Fig. 35
160 pulses

INPUT VALUES: TAKEN ON 7/10/72, AT 12:18:47
Fig. 45

40 μm

90 μm
INPUT VALUES TAKEN ON 7/10/726 AT 144323

Graph with data points and lines.
INPUT VALUES TAKEN ON 7/10/726 AT 151605

[Graph with labeled axes and data points]