ISR-BT/BdeR/EEK 23rd March, 1971

ISR RUNNING-IN

Run 36, 15 GeV, 20 bunches, last 2.5 hours

Background and scraping studies

The purpose of the run was to study how the background in I2, I4 and I5, resulting from stacks in Ring 1 would depend on vertical and horizontal scraping. The circulating current was in the range 2A to 3A.

1) Working point

In order to push the brick wall instability above 3A it is necessary to produce with sextupoles a variation of Q_H and Q_V across the aperture which is much larger than that existing in the "bare" machine. At the same time one must choose the Q_H and Q_V of the machine such that the working line in the Q_H, Q_V diagram crosses as few resonances as possible. Several different working lines have been studied by Resegotti during run 31 (see his Mr. X report and the attached Fig. 1 which has been copied from that report). The most attractive is probably the working line GINA, -1.5, 1 *) since it crosses only one resonance line in the Q_H, Q_V diagram. Moreover, an aperture scan, in which a coasting beam is slowly moved across the aperture by decreasing or increasing the main magnetic field had shown very small losses under these conditions (see Fig. 12 of the above mentioned Mr. X report by Resegotti). However, this working line has a negative $\Delta Q'_H$ and this is not liked by the RF people since there is a suspicion that this may cause a radial instability which develops when the beam circulating on the injection orbit is captured by the RF. Until this matter has been studied further, it seemed better to use a working line with $\Delta Q'_H > 0$ and therefore we have chosen the working line FATA, 1.5, 1, near the main diagonal. When making

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*) A working point corresponding to certain values of Q_H and Q_V on the central orbit is given a name, such as GINA, if it could be a useful point for making high intensity stacks. The two numbers behind the name define the working line by indicating that the sextupoles are excited to produce a Q-variation across the aperture (in addition to the Q-variation already present in the bare machine) of $\Delta Q'_H = \Delta(dQ_H/\frac{dp}{p}) = -1.5$ and $\Delta Q'_V = \Delta(dQ_V/\frac{dp}{p}) = 1$.

an aperture scan, Resegotti had found a 50% beam loss (see his Fig. 10) at <r> = -11 mm due to the 5th order resonance $3Q_H + 2Q_V = 43$. One can apparently live with this, since it is below the bottom of the stack and since during the stacking process the protons cross this resonance line sufficiently fast to avoid beam loss. During run 35 Autin had corrected the horizontal closed orbit by exciting 7 different correction windings and this reduced the beam loss found in an aperture scan by about an order of magnitude.

Before the background studies were started an aperture scan was made, with Ring 1 adjusted to FATA, 1.5, 1 and with Autin's closed orbit corrections. The result is shown in the two upper curves of Fig. 2. A loss occurs at <r> ≈ -15 mm but it is only about 5%. The Q-values on the injection orbit were measured and found to be Q_H = 8.596 and Q_V = 8.550 in exact agreement with the lower end of working line shown in Fig. 1. In an attempt to displace the beam loss to a more negative value of <r> the value of Q_V was increased by 0.01, at constant Q_H. The corresponding aperture scan, labelled 2 in Fig. 2 showed a much larger beam loss. Therefore we went back to the original line FATA, 1.5, 1 and remained there for the rest of the run. The corresponding third aperture scan, which is also shown in Fig. 2 gives the same result as the first scan.

The magnetic field on the central orbit was kept to 15.344 GeV/c during the whole experiment

2) Background studies

The monitors in I2, I4 and I5 consisted of either double or triple coincidence scintillation telescopes with, unfortunately, a different geometry in the different crossing points. Their dimensions and layouts are shown in Fig. 3. The counting rates were communicated by the three experimental groups to the SRC, where, furthermore, the counting rates of the telescopes in I4 and I5 were displayed on ratemeters.

Only Ring I was used during the experiment. Five stacks were made with 20 bunches and with the shutter of the inflector moving during injection. The shutter was protected by the scraping target against intercepting non-stacked protons. The stacking procedure was repetitive, i.e. with stacking at the top of the stack.

Scraping of the stacks was performed either by a vertical displacement of the beam dump absorber block or with the scraping target. The dump block has a vertical aperture of 32 mm. This is slightly larger than the scaled ISR aperture which is 30 mm at that position. The dump block was always placed at -6 mm during stacking or during subsequent scraping operations, thereby reducing the scaled ISR aperture to 20 mm. The reason is, that the scraping target, which is only 0.1 mm thick and is made of tantalum, mainly acts as a scattering target. If the dump block is the vertical aperture limitation, it will intercept most of the protons which are scattered by the scraping target. Furthermore, the dump at z = -6 mm scrapes off the vertical halo from the stacked beam. By this procedure, the induced radioactivity is concentrated as much as possible in crossing point 3, where the dump is located.

The dump block was always returned to its centered position (z = 0 mm) when the stacking or the scraping was finished. Similarly, the inflector magnet was withdrawn radially out of the ISR aperture, after stacking. This withdrawal was made with the shutter centered, i.e. gap closed, in order to eleminate protons possibly left behind near the injection orbit.

Only the outer edge of the stack was scraped during the horizontal scraping operation, since the withdrawal of the inflector provides sufficient horizontal aperture for the inner edge of the stack.

The results of the scraping experiments depend strongly on the loss rate of protons from the unscraped stacked beam. This in turn depends on the operating conditions of the ISR in a way that is only partially understood. This limits the validity of the background measurements which were made. We shall therefore concentrate on the trends shown by the measurements rather than give detailed results.

The following background experiments were made :

1) A first stack of 2.02 A was studied with the inflector and the dump block at the stacking positions and subsequently with the inflector withdrawn and with the dump block centered at z = 0 mm.

2) The second stack of 2.5 A was studied with the dump block withdrawn to z = 0 mm, after vertical scraping down to a beam height of 14.2 mm*) with a beam loss of 0.27A and after horizontal scraping to r = + 25 mm at the scraping target with a further beam loss of 0.23 A.

3) The third stack of 2.5 A was studied under similar conditions as the second stack but with first a horizontal and then two vertical scrapings to beam heights of 14.9 mm (2.01A) and 10.6 mm (1.51A).

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*) All beam height figures refer to the total beam height at the scraping target.

4) The fourth stack of 2.5A was studied for each of the following positions of the dump block :
-6, 0, -7, 0, -8, 0, -10 and 0 mm.

5) The fifth stack of 2.98A was studied with the dump block at 0 mm after scraping the beam down to respectively a height of 18.6 mm (2.78A), 14.2 mm (2.47A), 9.8 mm (1.79A) and 7.3 mm (0.99A) at the position of the scraping target.

Although these stacks had typical decay rates of about 10^{-4}/min and were among the best stacks which have been made so far for stacked currents of 2 to 3 A, they still have a higher loss rate than the stacks of 0.5 to 1A made with four bunches under otherwise similar conditions. This appears in the background rates which under the best conditions were now in I4 a factor 2 and in I5 a factor 3 to 10 above the rate for beam-gas interactions.

The background rates measured in I4 were much more constant than expected. Even during scraping or with the dump block at $z = -10$ mm, when the background rates in I2 and I5 increased by more than a factor 100, the rates in I4 went up less than a factor two. At the same time the background rate in I4 after the scraping always improved less than a factor two compared to the rate before the scraping.

It was found that only intermittent scraping with the heam dump block or the scraping target reduced the background rates. In fact, the background rates increase in each of the three crossing regions when the beam is continuously scraped by keeping the dump at $z = -6$ mm or lower. This is especially the case in I2 and I5 where the rates increase by more than an order of magnitude in this situation. The dump block must therefore be kept in the centered position during physics experiments.

One of the purposes of the experiment was to see if a stack which is made by scraping vertically the intensity of a 2.5 A or 3 A stack down to a lower current of e.g. 2A with the scraping target is cleaner than a 2A stack that is obtained by stopping the stacking at a current of 2A and leaving the beam untouched. The result is that the background rate is about the same in the two cases and this is valid down to circulating currents as low as 1A.

Vertical scraping proved to be more effective than horizontal scraping which showed only insignificant reductions in the background rate, except in I5 where for example during the third stack the rate went down for a short moment to twice the number for beam-gas interactions.

Intermittent vertical scraping with either the scraping target or the dump block reduced the background rate in I5 typically by a factor of about 3 while the reduction in I2 was somewhat smaller. The measurements showed that the reduction in background rate in I5 usually lasted only for a few minutes whereafter the background rate increased again to the level which existed before the scraping operation. On the other hand, in I2, the improvement remained during the subsequent time interval that no further scraping operations were made on the stack. However, for reasons of available machine time, the intervals between successive scraping operations were always shorter than 5 minutes. It was further noticed, particularly in I5, that the increase in background rate was often not monotonous as a function of time, but fluctuated with time intervals of up to several seconds and with peaks in the background rates that were about a factor 3 above the normal rates. This indicates that the instability mechanism causes intermittent loss of protons from the stack.

We mentioned already that the vertical scraping in I3 either with the target or the dump block had not much influence on the background rates in I4, gave some improvement in I2 and gave the largest improvement in I5 where, however, the improvement only lasted for a few minutes. When speculating what the reason for the different behaviour in the different crossing regions could be, it is interesting to note that the ISR beams move inwards in I2 and I4, and outwards in I5.

The largest difference in beam size upstream of the intersection regions between these two situations occurs in the horizontal rather than in the vertical plane, since β_H has its largest values in the inner arcs while the maximum values of β_V occur immediately upstream as well as donwstream of the intersection straight sections. This difference could be significant and to the disadvantage of intersection regions with outward going beams in case of radial beam loss from the coasting stack. It would be interesting, therefore, to see if the background rate in I5 can be reduced by moving the stack to the centre of the vacuum chamber if this can be done without causing a sudden loss of protons from the stack. On the other hand it must be admitted that the upper edge of the stacks as usually made at present and especially after horizontal scraping to r = + 25 mm at the (mid D) scraper is already quite far from the vacuum chamber wall.

Another difference between the measurements in I4 and I5 may be due to the fact that the telescopes in I4 are much more directional in the selection of detected background than the telescope in I5, as can be judged from Fig. 3.

The available ISR time did not permit longer observation periods than up to 5 minutes between the various scraping operations. It is therefore not possible to state what the maximum scraping frequency must be for stacked beams as are made at present and we propose to extend this experiment to a run in which the number of scraping operations is much smaller but the stack is observed over a longer time interval after each scraping operation. It is further strongly suggested that all experimental groups should set up in their respective crossing points identical counter telescopes with two scintillators of 10 cm x 10 cm in similar positions with respect to the ISR vacuum chamber in order to facilitate the comparison of the background rates in the different intersection regions.

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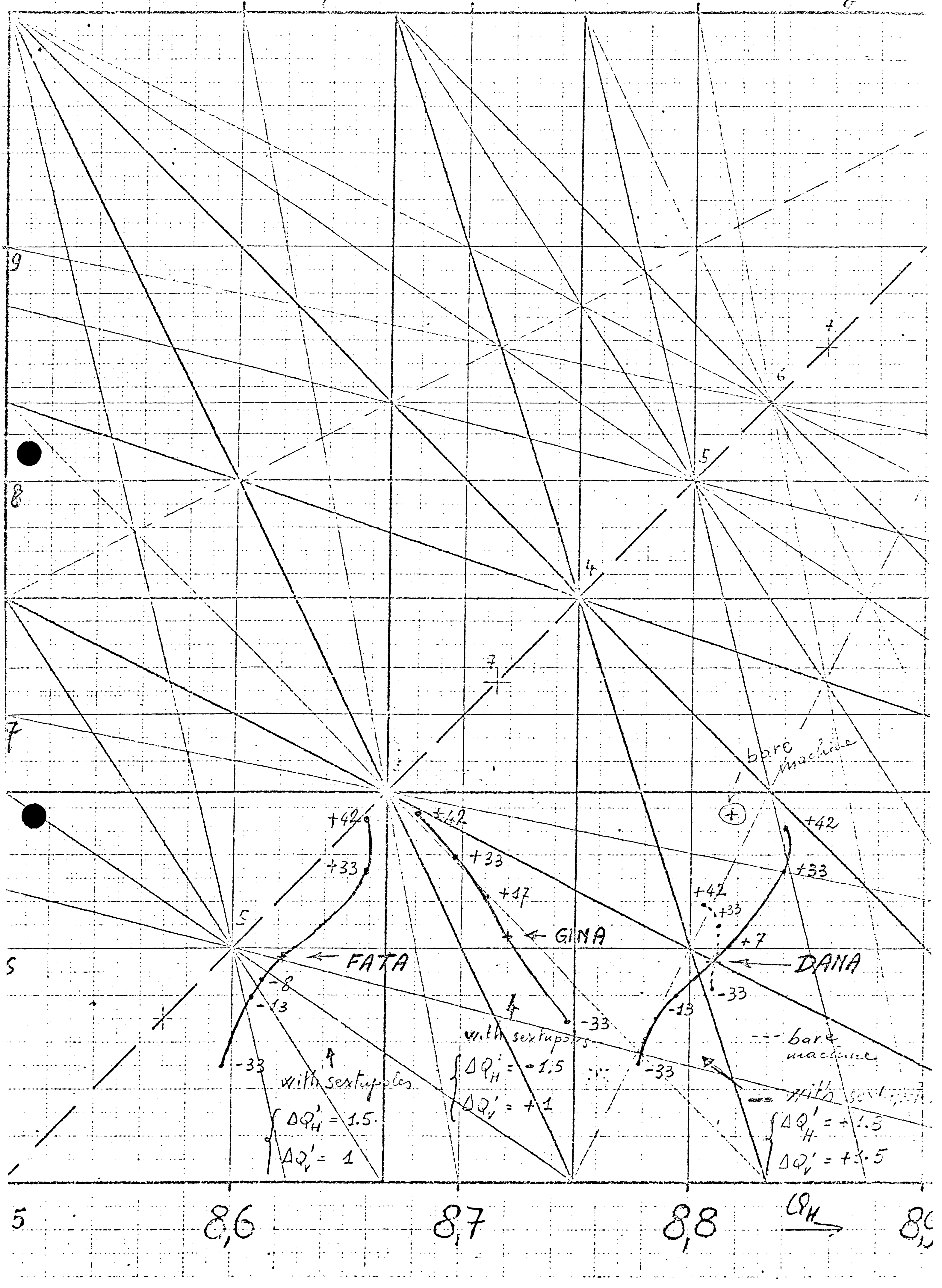
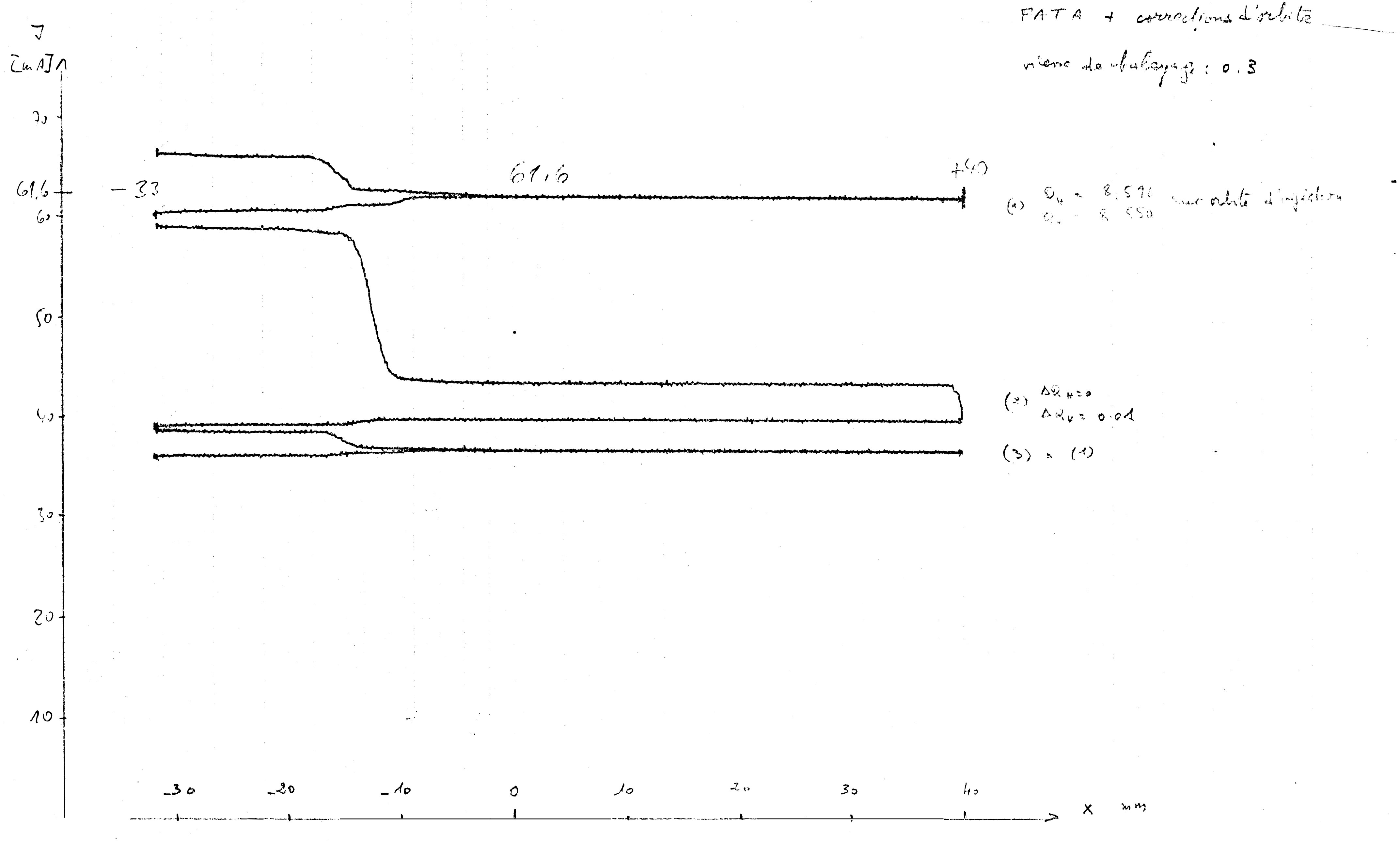
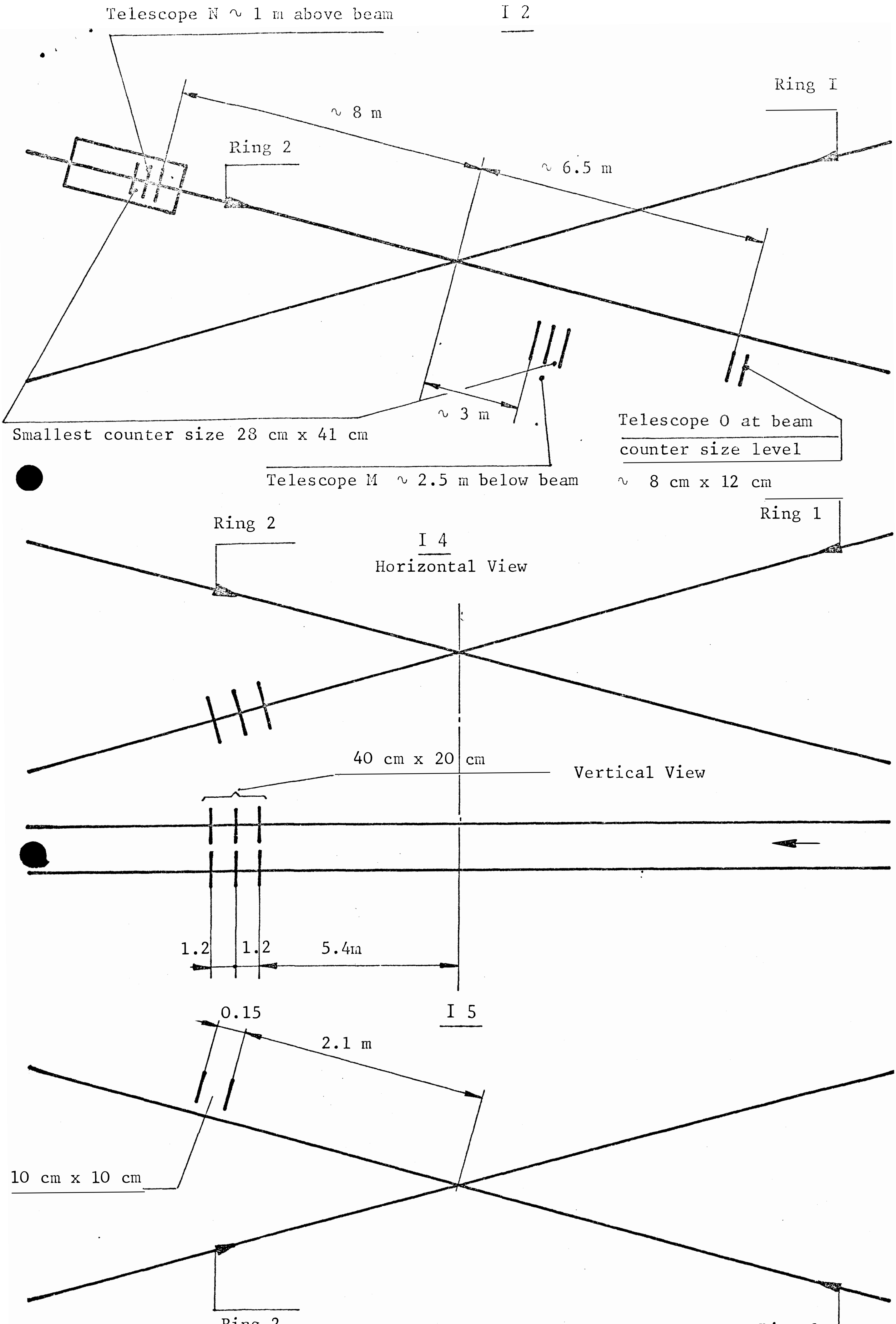
Run 31 - Working lines with sextupoles at 15 GeV - fig 1



- FIGURE 2 -


RUN 36 22-h
FATA + corrections d'orbite
vitesse de balayage : 0.3
I [mA]
70
61.6
60
50
40
30
20
10
-33
61.6
+40
(1) Q_H = 8.592 sur orbite d'injection
Q_V = 8.550
(2) ΔQ_H = 0
ΔQ_V = 0.01
(3) = (1)
-30
-20
-10
0
10
20
30
40
x mm



I 2
Telescope N ∿ 1 m above beam
Ring I
∿ 8 m
Ring 2
∿ 6.5 m
∿ 3 m
Smallest counter size 28 cm x 41 cm
Telescope 0 at beam
counter size level
Telescope M ∿ 2.5 m below beam
∿ 8 cm x 12 cm
Ring 2
Ring 1
I 4
Horizontal View
40 cm x 20 cm
Vertical View
1.2
1.2
5.4m
0.15
I 5
2.1 m
10 cm x 10 cm
Ring 2
Ring 1

Fig. 3