ISR-BOM/JP/TR/AV/ml

23.9.1982

ISR PERFORMANCE REPORT

Run 1290 - Rings 1 and 2 - 26 GeV - 8 September 1982

Set-up, stacking and beam observation with the new DL scheme

1. Purpose and conclusion

During the last $p\bar{p}$ run with th DL machine (run 1278) it was observed that the proton beam was blowing up rapidly and that losses could be seen even on the $\bar{p}$ beam. As these phenomena could be attributed to the excitation of the non linear resonances of order 7 to 9, a new scheme with reduced β's (and hence a reduced excitation of the resonances) was made.

This run was devoted to the set-up of this new scheme followed by stacking in both rings and observation of the beams for some hours.

The set-up was made without any serious problem following the standard procedure for injecting with the SL insertion on an unknown orbit[1)].

15 A were stacked in each ring. Luminosity curves were made as well as several beam adjustments according to the standard procedures.

The comparison between the loss rate obtained here and the loss rate during the $p\bar{p}$ run and the subsequent pp calibration run with the DL machine is difficult. However I8 and I1 reported better conditions for this present run.

2. Set-up of the BASE machine (ring 1 and 2)

All experimental magnets including SFM were off.

The set-up of the BASE machine had to be made before turning on the insertions because the QT's excitations for the new DL scheme were very different from those of the old scheme. Therefore the theoretical off-momentum closed orbits were different as well as the PFW's currents.

A first trial was to inject the machine with the new QT's and the old DL PFW's, this machine having tunes suitable for injection. As the attempts were unsuccessful, injection was tried with only the old DL PFW's currents and the FP26 orbit correctors. Q-shifts Q_h = Q_v = + 0.02 were applied in order to avoid the resonance $Q_h + Q_v = 17$. It was then possible to inject. The injection orbit was at - 47, which explains why injection was not possible with the above conditions, because of the modulation of the dispersion introduced by the new QT's (D_{max} = 2.70 m versus 2.3 for the machine without QT's). The B-pulse was increased from 12470 to 12530 and the injection orbit went to - 40, the main fields corresponding to 26.596 GeV in ring 1 and 26.604 GeV in ring 2.

The QT's were powered with the new values, Q-shifts $\Delta Q_h = \Delta Q_v = -.02$ were applied. The measurements of the associated working line is shown on Fig. 1, where the theoretical line computed by AGS is also given.

Q-shifts were applied in order to obtain the base working line which is defined by:

$$\left.\begin{array}{lll} Q_h = 8.735 & Q_h' = 1.89 & Q_h'' = -20.0 \\ Q_v = 8.372 & Q_v' = 4.05 & Q_v'' = -2.0 \end{array}\right\} \text{ for ring 1}$$

$$\left.\begin{array}{lll} Q_h = 8.765 & Q_h' = 1.80 & Q_h'' = -15.0 \\ Q_v = 8.334 & Q_v' = 3.79 & Q_v'' = -7.0 \end{array}\right\} \text{ for ring 2}$$

After the Q-shifts had been applied, the measurements of the working line were perturbed by the resonance $Q_h + Q_v = 17$ and it was necessary to make additional Q-shifts in order to obtain an injection point above this resonance in the $Q_h - Q_v$ plane. The SFM was turned on, however it was only possible to measure about half of the working line because of the numerous non-linear resonances in this part of the $Q_h - Q_v$ plane. Thus only one half of the BASE working line was checked.

The measurement of the BASE working line is shown on Fig. 2 for ring 2: the Q-values are a little too high because the 4th order resonances had to be avoided at injection. The same was done in ring 1.

The measurements of the closed orbit and the single turn trajectory at injection were copied in the files REF1,2 and SRF1,2 respectively. They are used as references for the INCO calculations below.

3. Injection on the new DL machine

3.1 Ring 2

This ring was treated first because of a power failure in the injection septum of ring 1.

The insertions were powered.

The injection was checked with stopper 548 set.

Stopper 548 was removed and a single turn measurement was made with the BST set.

INCO was applied only downstream I1 as no losses at injection occured in I8. After 1 correction in each plane:

Vertically	2H848	+ 6.5 %	2H116	- 23.7 %
Horizontally	2CR860	+ 5.3 %	2CR108	- 5.5 %

a single turn trajectory was remeasured. As INCO computed increments of the order of 2 %, the BST was removed and the beam did circulate.

The closed orbit at injection was corrected in order to redistribute the above (local) correction. The working line was measured (see Fig. 3) and was found to be shifted w.r.t. the theoretical line by the same amount as the BASE line (see Fig. 2). This shows that no gross quadrupole error existed in this machine.

After the correction of the working line and the closed orbits in the whole aperture, the currents in the machine were copied in the files MD26 and 26DM (see Table 2) and the injection orbit was copied in the file MDR2 (see Fig. 4) for the next run with this machine. The orbit measurement at + 25 is shown in Fig. 5; it was not possible to accelerate the pulses further than + 30 although the orbits remained good. Since only 15 Amp stacks were required, this problem was left aside for the time being.

The outer collimators were set by "find beam" with a pulse at + 30 for stacking.

3.2 Ring 1

The procedure is more complicated than in ring 2 because the SL insertion is just upstream from the injection point.

The injection was checked with stopper 449 set, after the insertions had been turned on. Then the stopper was removed, the BST being in place and a single turn measurement was made. INCO was aplied for I1. A single turn trajectory was remeasured and INCO was applied for I8, the corrections required were of the order of some percent in both planes and circulating beam was easily obtained. The closed orbit was corrected in several stages and finally at + 44 mm, peak to peak values of 8.1 mm (HOR) and 8.6 mm (VERT) were obtained (see Fig. 6). Care was taken at each correction to adjust the injection according to the new orbit calculated by COCO before injecting the next pulse, thus minimising the risk of quenching. Several iterations were required to correct the working line, as the QPQQ coefficients were taken from the SL machine, which introduces some errors.

The injection orbit was copied in the file MDR1 (see Fig. 7); the currents in the machine were copied in the file MD26 (see Table 1).

4. Stacking of 15 A x 15 A

4.1 Experimental magnets

The experimental magnets (solenoid, R608/1 and OAFM) were switched on and compensated according to the file generated by program SUSA. This means that the local compensation of the experimental magnets valid for the old DL machine were used. The orbits were still good after this: the peak to peak distortion became at the most 10 mm instead of 8 mm in both planes in the whole aperture. The power supply values of the "new DL machine" without experimental magnets were kept in file DL26, after the content of this file (i.e. the old DL machine) had been copied into file DLDL. This manipulation was necessary for using SUSA.

4.2 Stacking

The collimators were set at the inside with POCO, at the outside manually with a pulse circulating at + 43 mm in ring 1, and at + 30 mm in ring 2. The space charge compensation was done with TUCO, using SL parameters, the measurement of the working line by means of the Schottky scans after the compensation at 5 A is shown in Fig. 8. The top of the stacks were set at + 15 mm, the densities obtained were 0.6 A/mm (see Fig. 9). Under these conditions 15 A could easily be stacked in each ring.

4.3 Luminosity

After stacking a luminosity calibration was performed together with the experiments, in all intersections except I2, I3 and I7.

The computer output of the computation of the effective heights is shown in Table 3. The graph of the measurements is shown in Fig. 10. The analysis of these results is given in Table 4. The average emittance is $(0.47 \pm 0.07)\ 10^{-6}$ rad m; it is about the same value as for run 1260. It corresponds to the case of injection with light shaving (removal of 20 mA) and no coupling compensation ($|c| \sim .005$).

5. Observations during the physics run

At the end of the luminosity steering (20h.30) stable beams were given for a short period during which the first observations were made. The first thing was that the background as seen on the SEFRAM recorder (from the standard monitors) looked very clean. The loss rate in ring 1 was initially 50 - 60 ppm/m. It was observed that the coupling was much higher in ring 1 and also the working line was too low (about half-way between DLDL, the theoretical line at a distance of .02 from the diagonal, and the diagonal at the bottom).

The ring 1 coupling was minimised; ΔC_R = - .004 and ΔC_I = + .002. This reduced the coupling signal by a factor $\sim$4 and significant improvements were observed on the standard background monitors for changes as small as .00025 in the coupling coefficient.

A tune shift of $\Delta Q'_h$ outer = + .2 and ΔQ_v = + .007 was made in ring 1. The horizontal shift was very small (top of stack was at 22 mm) and in retrospect it should have been larger to fully correct the line. The vertical shift moved the distribution to the theoretical line(± .001) and the overall effect was a significant improvement in backgrounds.

At this stage (12h.15) we asked the experimenters to evaluate the beam quality. I2 required an improvement which was found with the collimation. The beams were then not touched for almost 2 hours during which time I4's conditions deteriorated.

Beam growth was observed in both planes and a series of Schottky scans was made which showed rapid growth of the 8th order horizontal resonance in both rings (Figs. 11 and 12). The 7th order horizontal resonance was also observable after about 1 hour of stable beams but only in ring 2. By 01h.45 it was beginning to appear in ring 1 also.

There are two comments relevant to the difference between the two rings. Firstly, the tune shift and coupling compensation at 21h.00 will have re-distributed the ring 1 stack whilst R2 had no tune shift after 18h.30. Secondly, the horizontal tune spread in ring 2 was greater than in R1.

	Ring 1		Ring 2	
	Bottom - 10 mm	Top 22 mm	Bottom - 12 mm	Top 20 mm
Q Hor.	8.849	8.889	8.841	8.897
Q Vert.	8.865	8.923	8.862	8.923

The region of the stack in ring 1 crossing the 7th order horizontal resonance was much less dense than that in ring 2.

In ring 1 we also observed the 9th order vertical resonance (by about 00h.00), the vertical beam transfer function showing what looked like "normal" beam-beam resonance excitation. This might be expected since the beams were not optimised in all intersections.

At the end of the run ring 1 developed a rather spiky background. This was more noticeable after a cleanup. Investigation of this phenomenon at the end of the run was inconclusive but it was possible that the top of the working line was just touching the 9th order horizontal. The maximum amplitude (at the top of the spike) was however, still lower than the minimum background level before the cleanup.

The cleanup done after about 4 hours of stable beams (00h.45) reduced the loss rate in ring 2 from about 35 ppm/m to 15 ppm/m, whereas in ring 1 there was little change, the rate remaining at about 25 ppm/m. The difference may perhaps be attributed to the spiky effect described above.

The loss rates were difficult to measure because of intermittant equipment malfunctions and the frequency of interventions for beam adjustments. The loss rate in ring 1 changed in approximately the following way:

Initial	60 ppm/m	
Reduced to	30 ppm/m	With Q-shift and coupling adjustment
to	25 ppm/m	with cleanup and collimation adjustment
"Constant"	25-30 ppm/m	during 2 hour stable period and after another cleanup.

In ring 2:

Initial	25 ppm/m	
Increased to	35 ppm/m	
Reduced to	17 ppm/m	During 3 hour stable period with cleanup and collimation and remained fairly con stant for the final hour.

5.1 Conclusions

The beam conditions looked good; in I1 they were not good enough for $\bar{p}$ work, but were the best seen so far on the DL machine. I2 were satisfied and I6 looked OK on the standard background monitors but they did not have their detectors on and were unable to comment themselves. I4 however, were not as good although they could work. It is probable that a steering exercise would have benefitted I4 since the beams were not steered in I3 during the luminosity. I8 were delighted and reported very clean conditions.

Natural Schottky measurements indicated a strong excitation of the 8th order horizontal resonance ($8Q_h = 71$) and a less strong excitation of the 7th ($7Q_h = 62$). Background conditions in the intersections could be improved by cleanups and collimator adjustments but the rate of beam loss seemed high for "young" beams.

In general the conditions seemed to be better on this new machine and for a first attempt it was very successful.

J. Poole   T. Risselada   A. Verdier

Reference

1. Memorandum from T. Risselada and A. Verdier, Instructions pour le remplissage, centrage et accélération sur la machine DL, 18.5.82.

Table 1

Currents for operating the new DL scheme. Ring 1. 26 GeV.

```
/XDUD (IF=MD26,R1,ALL)     TIME:09H33M31S      DATE:82-09-14
/LAST-RUN:1290    LAST-TIME:[illegible]       LAST-DATE:82-09-0[illegible]
/MA RUN R1/R2:1290/1290
     1DEV      +26.5955      1DVM      +76.523      1WE       X3
     1CP       +47.19
/QF RUN R1/R2:1290/1290
     1QI2      -44.40        1QI1      -30.25       1QI8      +1.83
     1QI3      -2.15         1QI5      -9.94        1QI7      +1.10
     1SLQ9     +84.11
/FF RUN R1/R2:1290/1290
     1PEF1     -46.46        1PEF2     -57.91       1PEF3     -34.09
     1PEF4     -25.93        1PEF5     -15.60       1PEF6     -10.64
     1PEF7     -7.50         1PEF8     +1.34        1PEF9     +13.89
     1PEF10    +16.33        1PEF11    +22.75       1PEF12    +15.45
     1PED1     -83.37        1PED2     -81.89       1PED3     -39.18
     1PED4     -39.01        1PED5     -40.72       1PED6     -42.21
     1PED7     -40.04        1PED8     -33.84       1PED9     -22.35
     1PED10    -20.00        1PED11    -22.53       1PED12    -15.41
/H RUN R1/R2:1290/1290
     1H749A    +0.02         1H817     -3.93        1H333     +27.89
     1H417     -1.00         1H617     +0.05
/CR RUN R1/R2:1290/1290
     1CR761    +8.50         1CR841    +0.39        1CR813    -3.81
     1CR105    +11.97        1CR213    -5.18        1CR361    -2.98
     1CR541    -8.98         1CR425    -6.91
/BD RUN R1/R2:1290/1290
     1LBC1     -9.55
/QS RUN R1/R2:1290/1290
     1QS2      -0.54         1QS3      +0.27        1QS4      +1.03
     1QS5      -17.04        1QS6      +9.08        1QS7      -10.64
/SL RUN R1/R2:1290/1290
     1SEQ1     +75.574       1SLS1     +47.90       1SLD1     +67.68
     1SLQ3     +82.231       1SLS3     +47.87       1SLD3     +36.01
     1SEQ5     +72.922       1SLS5     +47.88       1SLD5     -22.80
     1SLQ7     +71.663       1SLS7     +23.27       1SLD7     +6.59
/EB RUN R1/R2:1290/1290
     1LBQ1     +71.83        1LBQ3     -65.60       1LBQ5     +68.26
     1EBQ7     +53.30        1EBQ9     -68.56
/AFM RUN R1/R2:1290/1290
     1AFC3     +10.01
/T2 RUN R1/R2:1290/1290
     QF337M    +76.991       QD338M    +76.192      VB303M    +75.459
     HB332     +41.482       QD346     +54.755      QF347     +21.309
     QD348     +45.058       QF349     +56.220      VB309     +57.077
     QD350     +55.124       QF351     +82.410      UH301B    +25.167
/TS RUN R1/R2:1290/1290
/TIH RUN R1/R2:1290/1290
/TIF RUN R1/R2:1290/1290
/EM RUN R1/R2:1290/1290
/SFM RUN R1/R2:1290/1290
     LIEIM     +22.560       SFM       -84.776      SCM1      +62.137
     ECM1      +64.447
/IH RUN R1/R2:1290/1290
     HB333     +15.997       HB334     +52.555      IR717     +67.73
/IV RUN R1/R2:1290/1290
     VB307     +38.425       VB306     +56.875
/ END OF DATA
```

Table 2

Currents for operating the new DL scheme. Ring 2. 26 GeV.

```
/XOUT(IF=MD24,R2,ALL)      TIME:09H34M20S      DATE:82-09-14
/LAST-RUN=1290     LAST-TIME=16H45M09S      LAST-DATE=82-09-08
/MA RUN R1/R2:1290/1290
     2DEV      +26.6042      2IVM      +75.477       2WE        82
     2CP       +42.45
/QT RUN R1/R2:1290/1290
     2QT2      -44.40        2QT1      -30.25        2QT8       +1.83
     2QT3      -2.17         2QT5      -9.94         2QT7       +1.10
     2SLQ10    +82.35
/PF RUN R1/R2:1290/1290
     2PFF1     -72.80        2PFF2     -50.15        2PFF3      -23.32
     2PFF4     -23.24        2PFF5     -15.97        2PFF6      -7.40
     2PFF7     -5.54         2PFF8     +5.03         2PFF9      +13.90
     2PFF10    +20.53        2PFF11    +21.17        2PFF12     +31.76
     2PFD1     +87.87        2PFD2     +7.47         2PFD3      -27.59
     2PFD4     -52.73        2PFD5     -51.86        2PFD6      -50.15
     2PFD7     -39.42        2PFD8     -34.55        2PFD9      -32.89
     2PFD10    -20.31        2PFD11    -17.41        2PFD12     -16.97
/H RUN R1/R2:1290/1290
     2H616     -2.49         2H752     -9.45         2H716      +0.02
     2H116     +0.02
/CR RUN R1/R2:1290/1290
     2CR556    -10.30        2CR840    +5.30         2CR108     -9.97
/SO RUN R1/R2:1290/1290
     2LBC4     -10.01
/SS RUN R1/R2:1290/1290
/SL RUN R1/R2:1290/1290
     2SLQ2     +77.173       2SLS2     +48.58        2SLD2      +24.61
     2SLQ4     +83.743       2SLS4     +48.17        2SLD4      -15.58
     2SLQ6     +71.392       2SLS6     +47.24        2SLD6      -37.89
     2SLQ8     +68.655       2SLS8     +38.56        2SLD8      +38.31
/LB RUN R1/R2:1290/1290
     2LBB2     +77.71        2LBB4     -62.79        2LBB6      +67.36
     2EBR5     +54.32        2EBQ15    -72.85
/AFM RUN R1/R2:1290/1290
     2AFB2     +9.42
/IP RUN R1/R2:1290/1290
/FS RUN R1/R2:1290/1290
/EIH RUN R1/R2:1290/1290
     QD408     +55.970       [illegible] +75.515     QF409      +60.545
     HB404M    +75.423       QD410     +40.713       QF411      +64.594
     QD412     +66.772       QF413     +54.083       HB428M     +68.430
/EIO RUN R1/R2:1290/1290
     HB435C    -60.01        QD414M    +61.060       QF415M     +64.626
     VB403M    +75.402       HB432     +3.235        QD444      +61.941
     QF447     +49.872       QD448     +64.255       QF449      +55.859
     VB469     +57.672       QD450     +51.709       QF451      +61.321
     VH401M    +85.097
/OI RUN R1/R2:1290/1290
/SFM RUN R1/R2:1290/1290
     2TFIM     +27.115       SCM2      +62.169       LCM2       +64.447
/TH RUN R1/R2:1290/1290
     HB433     +14.031       HB434     +29.597       IK248      +64.45
/TV RUN R1/R2:1290/1290
     VB407     +30.553       VB408     +58.747
/END-OF-DATA
```

Table 3

Output of the computation of the effective heights

```
I RUN: 1290                         LUMINOSITY MEASUREMENT                                      I
I E1= 26.0000 GEV/C   E2= 26.0000 GEV/C                                              [illegible] I
I I1= 15.0416 AMPS    I2= 15.4183 AMPS    INITIAL                                              I
I I1= [illegible] AMPS    I2= 15.4072 AMPS    FINAL                                            I
I**********************************************************************************************I
I [illegible]                                                                                   I
I      I        I R1      R2  I CONS     I EB         I          I          I PT I    I         I
I [illegible]                                                                                   I
I      I  MM    I MM      MM  I MUB      I C/S        I   (*)    I          I    I    I         I
I [illegible]                                                                                   I
I                              STANDARD MONITORS                                               I
I [illegible]                                                                                   I
I  I   I 2.125 I 0.30 -0.30 I    458.7 I    5032.7 I 10.97 I  0.00 I 13 I  36 I
I [illegible]                                                                                   I
I  5   I 4.494 I 0.46 -0.46 I    649.4 I    3370.0 I  5.19 I       I  9 I   3 I
I [illegible]                                                                                   I
I  8   I 0.733 I -0.12 0.12 I     29.7 I     945.6 I 31.81 I  0.60 I 10 I  35 I
I [illegible]                                                                                   I
I                              PHYSICS MONITORS                                                I
I [illegible]                                                                                   I
I  4   I 4.602 I -0.22 0.22 I    281.9 I    1171.1 I  4.15 I  0.00 I  7 I   3 I
I  5   I [illegible]                                                                            I
I**********************************************************************************************I
[illegible]
```

Table 4

Effective heights analysed in terms of vertical emittance and β_v^*.

Intersection	Average β_v^* on the central orbit	Effective height (mm)	Emittance $\times 10^6$ m/π (m)	Luminosity $10^{30} cm^{-2} s^{-1}$
1	3.77	2.1	0.37	11.0
4	13.66	4.6	0.49	4.2
5	15.08	4.5	0.3	5.2
6	13.94	4.8	0.53	4.8
8	0.316	0.73	0.54	32.0

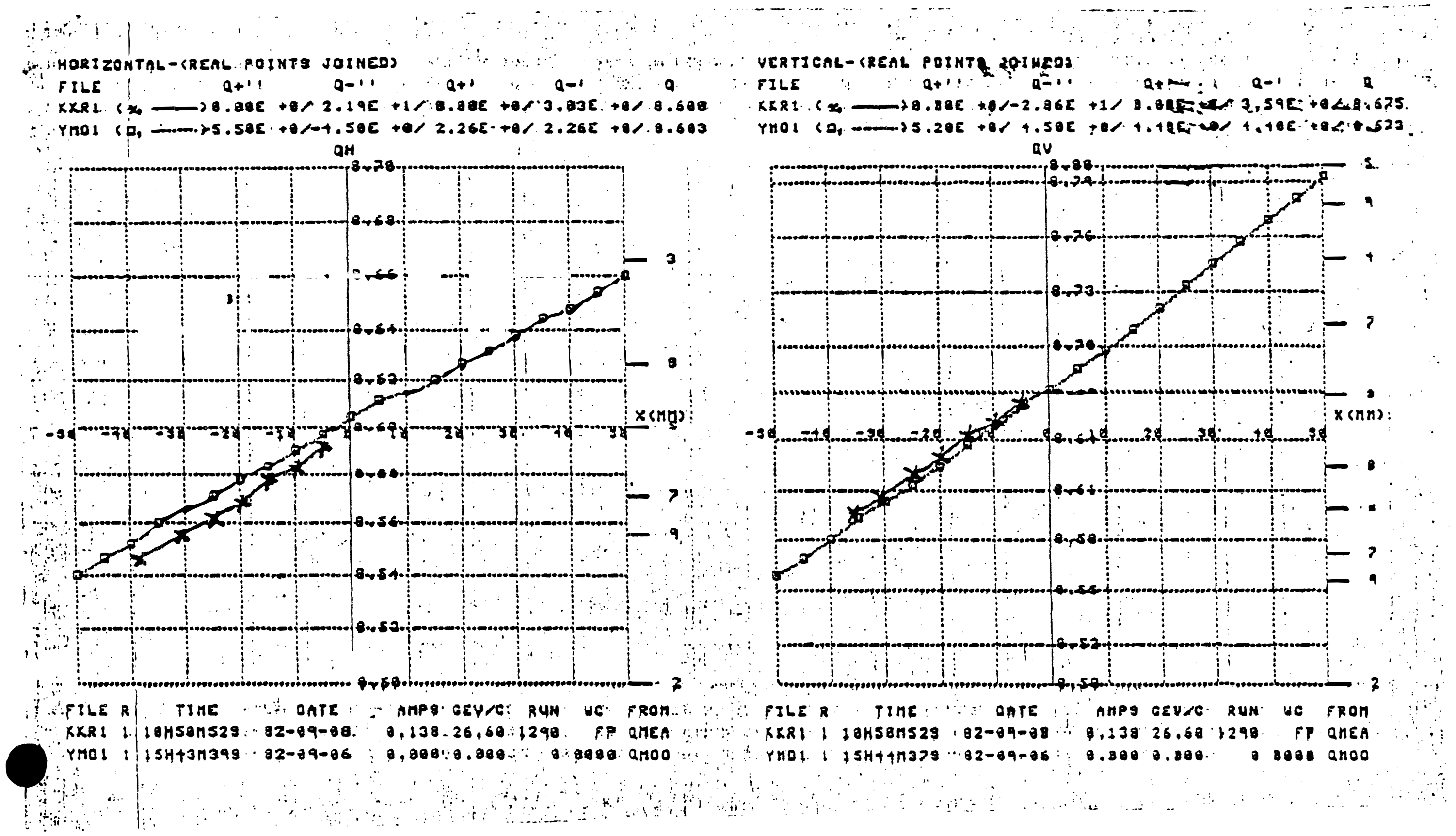

Fig. 1: Working line obtained with the PFW's currents of the old DL and the QT's of the new DL. The crosses are the measured points. The squares are the theoretical points computed by AGS.

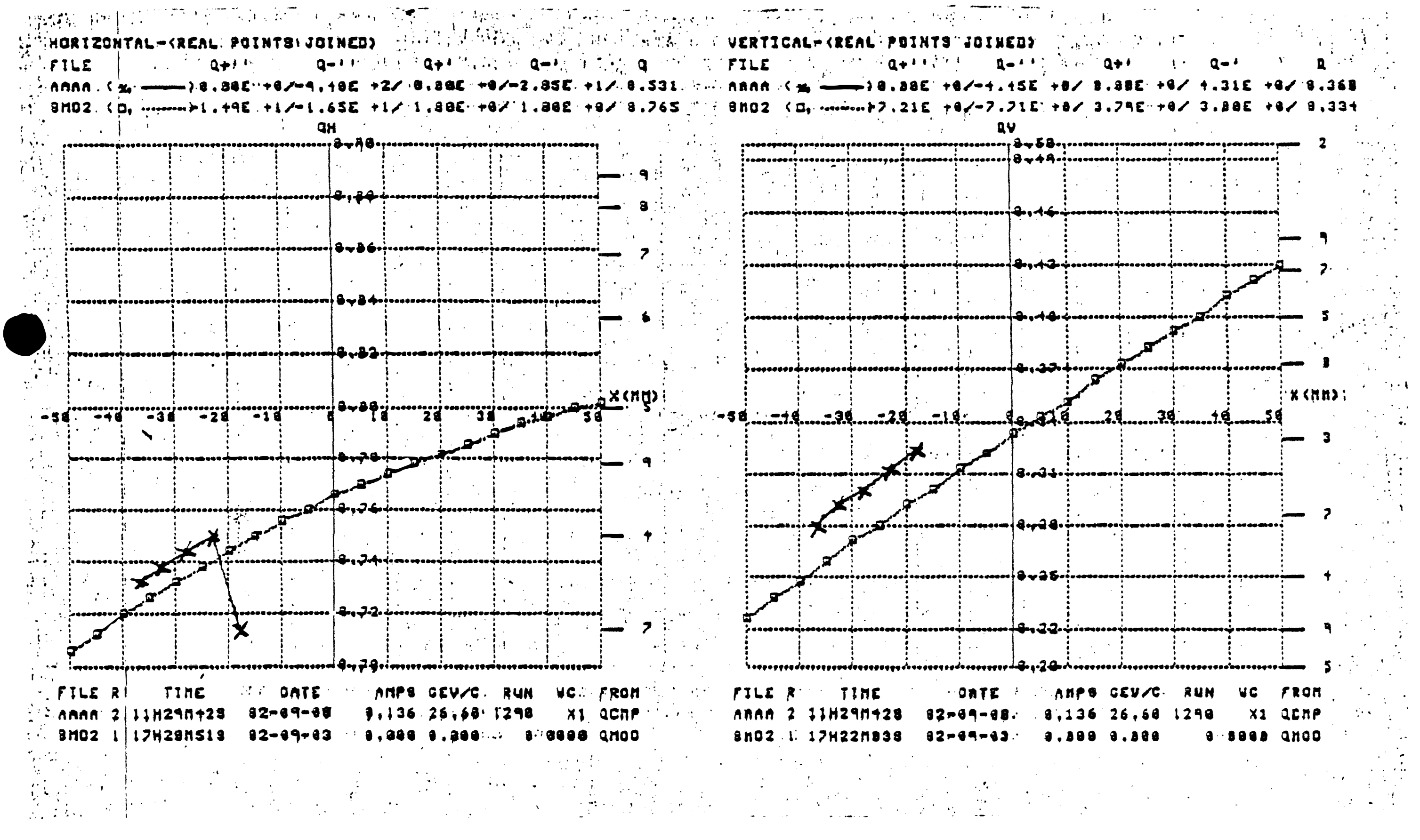

Fig. 2: Base working line of the new DL machine. The crosses are the measured points: the wrong point in the H plane is due to the resonance $Q_h + Q_v = 17$. The squares are the theoretical points computed by AGS. This line is obtained just before turning on the insertions (ring 2).

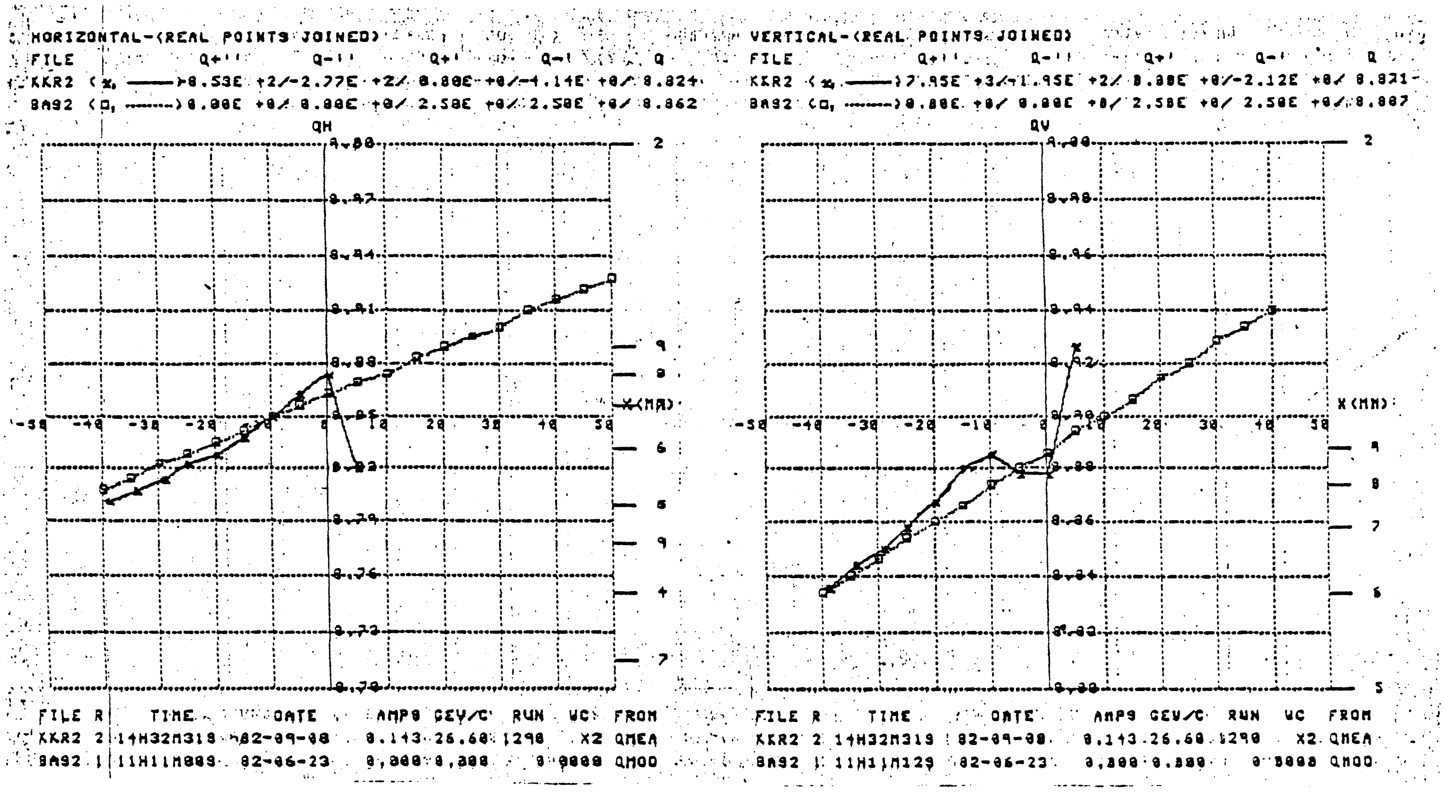

Fig. 3: Working line obtained just after having turned on the insertions (ring 2).

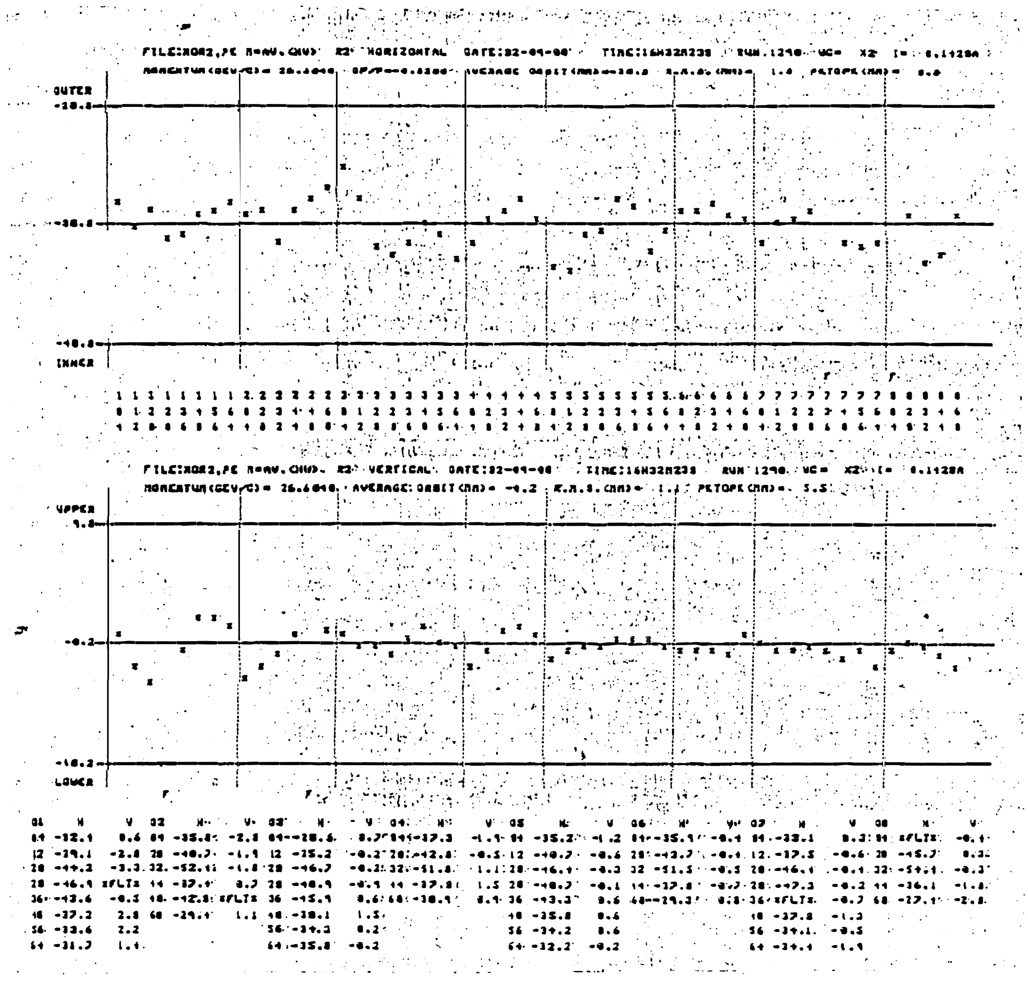

Fig. 4: Injection orbit for the new DL scheme in ring 2. Copied in the file MDR2, PE. The value of the main field corresponds to 26.604 GeV, the B-pulse is 12530.

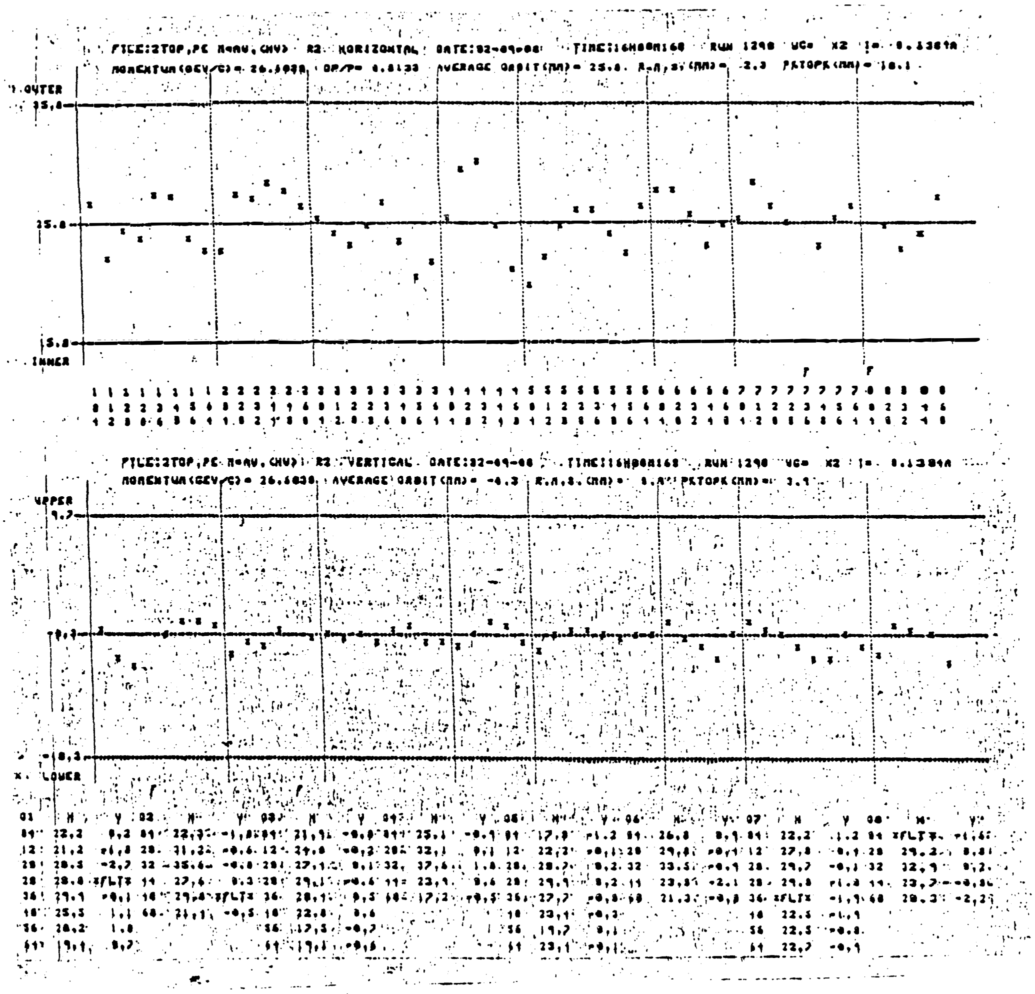

Fig. 5: Closed orbit measurement at + 25 in ring 2.

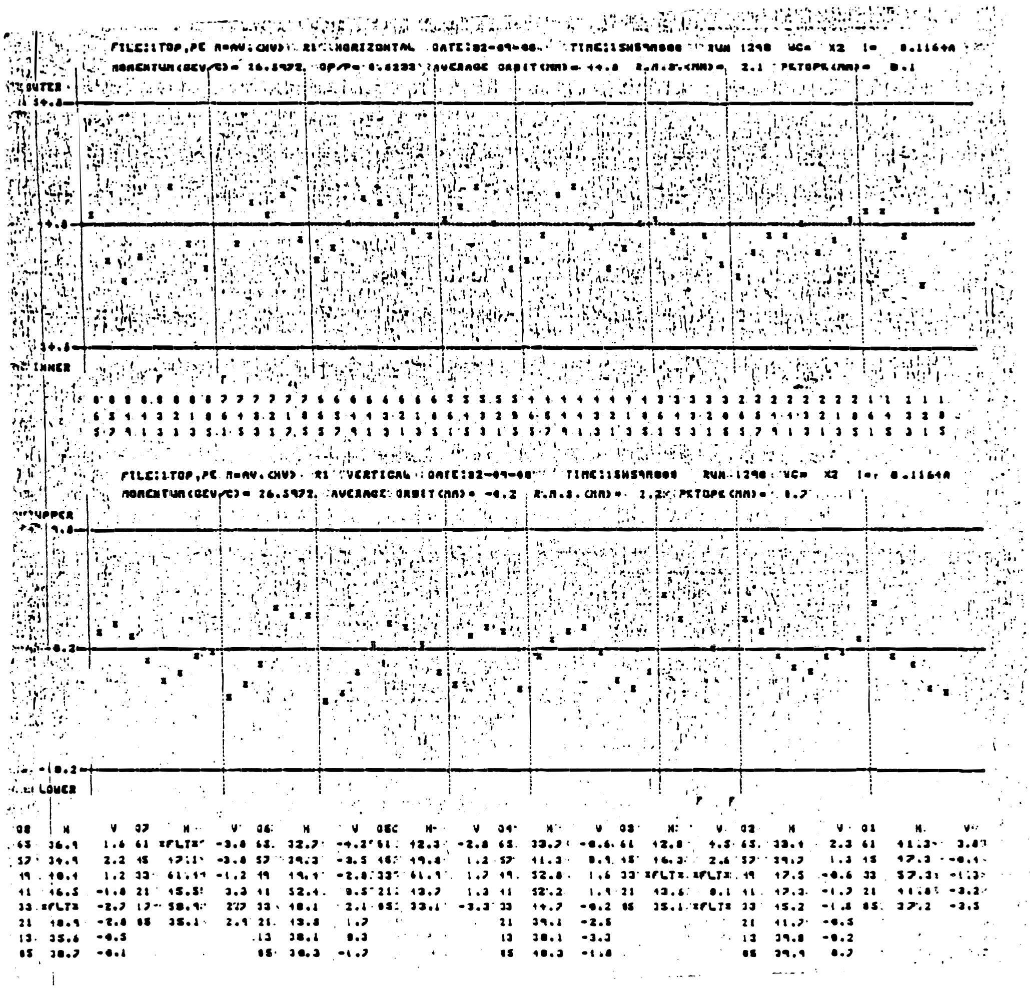

Fig. 6: Closed orbit measurement at + 44 in ring 1 (at this position about 20 mA had been lost).

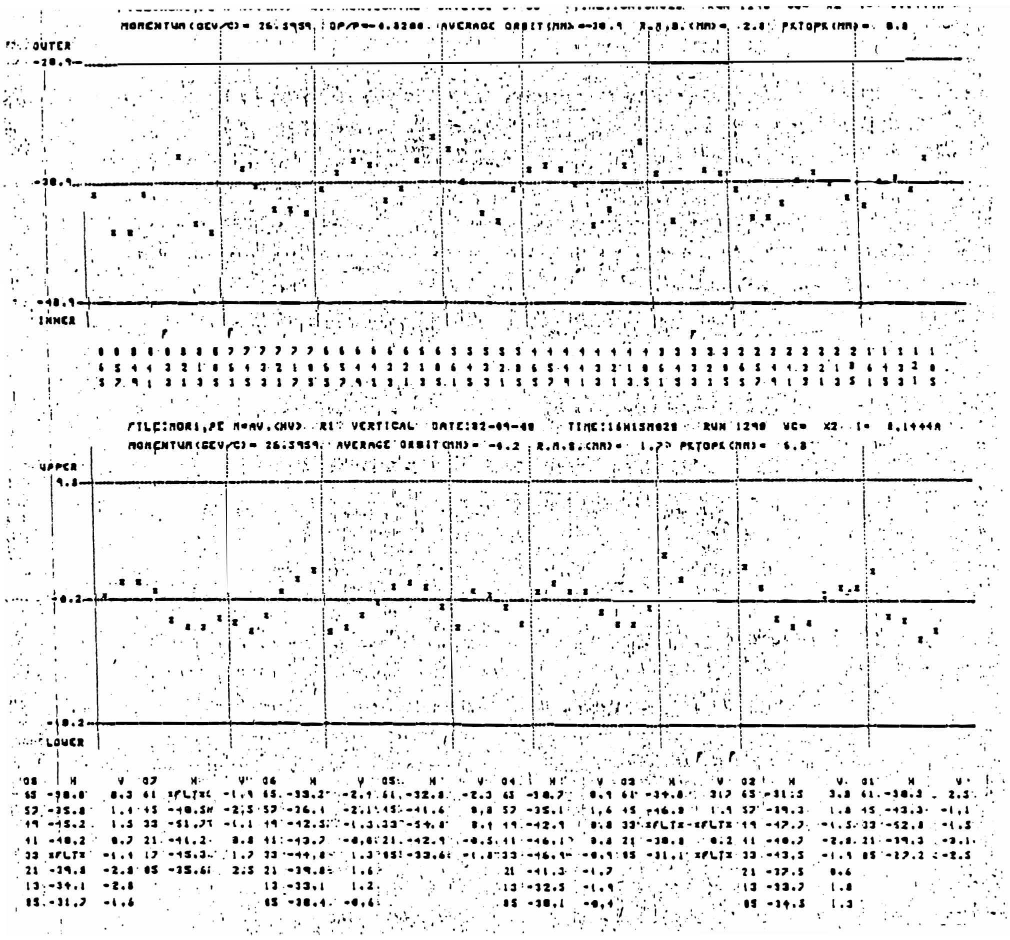

Fig. 7: Orbit at injection for the new DL scheme in ring 1. Copied in the file MDR1. The main field corresponds to 26.596 GeV, the B-pulse is 12530.

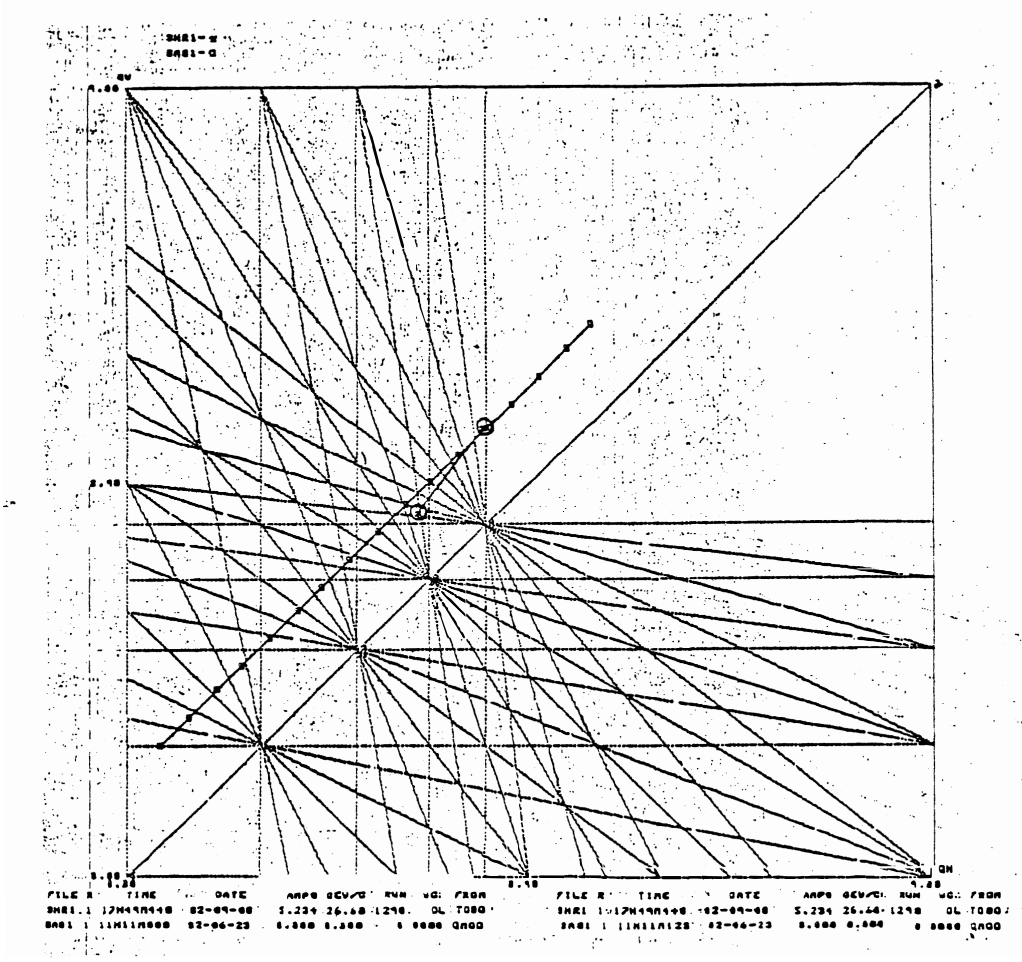

Fig. 8: Measurement of the working line after the space charge compensation for 5 A. The two circles indicate the measurements (ring 1).

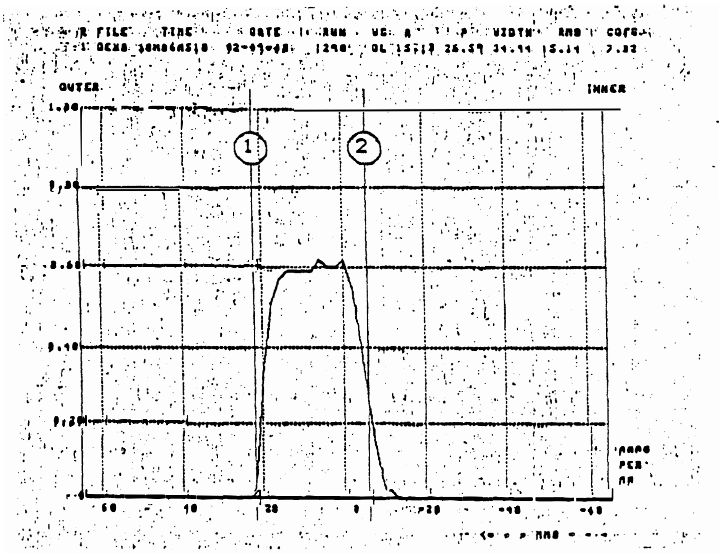

Fig. 9: Density profile of the 15 A stack in ring 1.

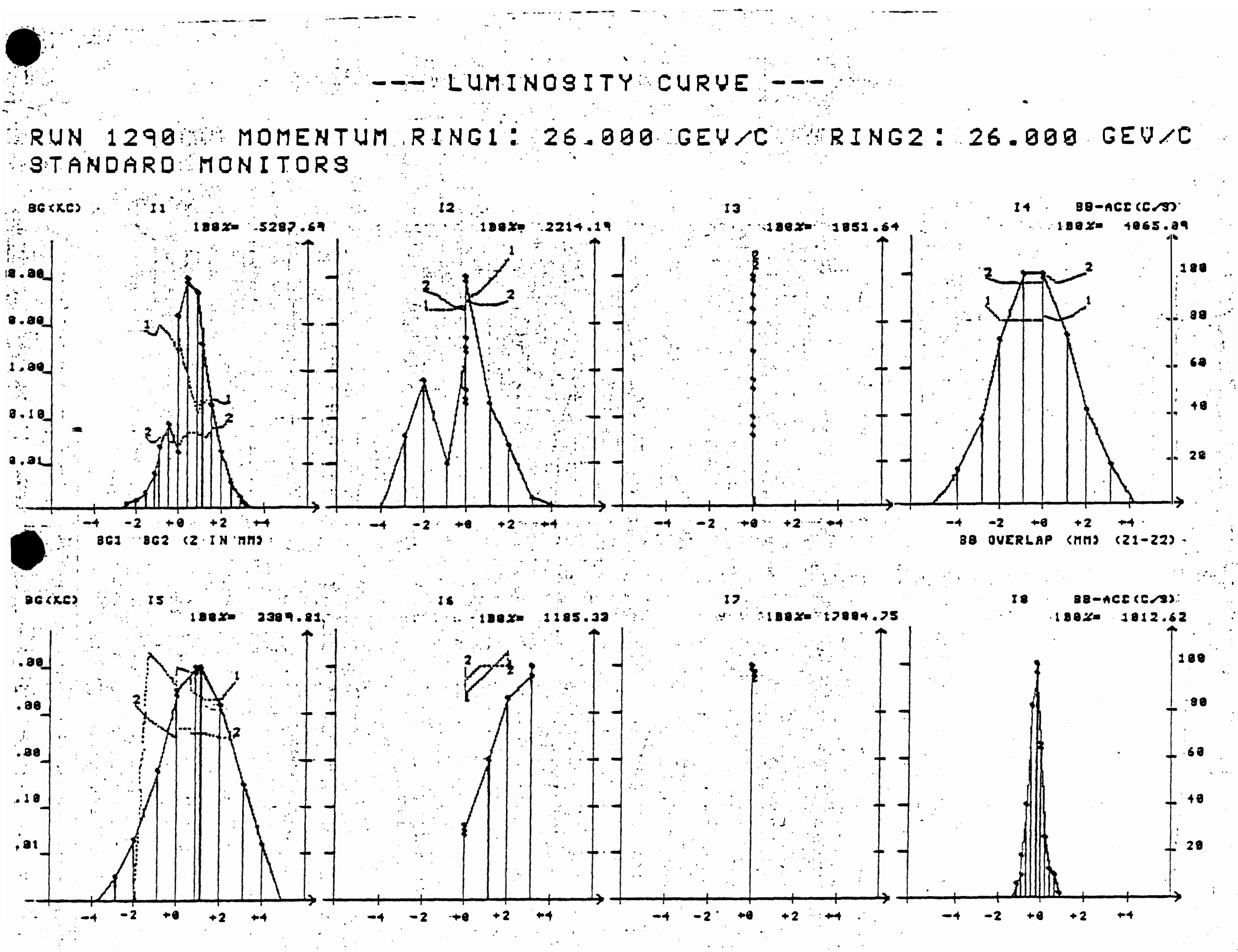

Fig. 10: Luminosity curves with the new DL scheme. 15 A x 15 A.

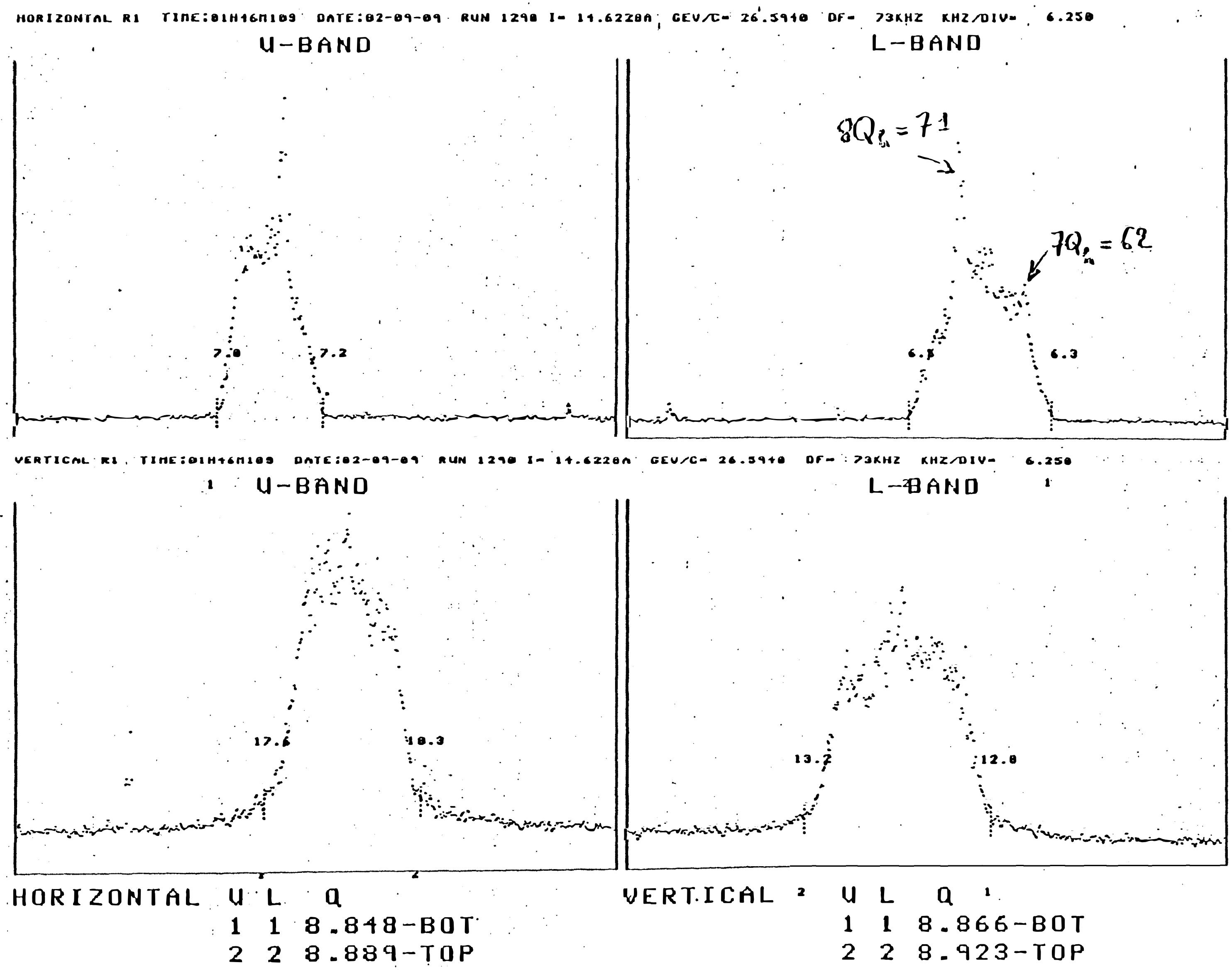

Fig. 11: Transverse Schottky scan for the 14.6 A stack in ring 1. The peaks in the horizontal spectra (upper) correspond to 8 Q_h = 71 (large peak) and 7 Q_h = 62 (small peak).

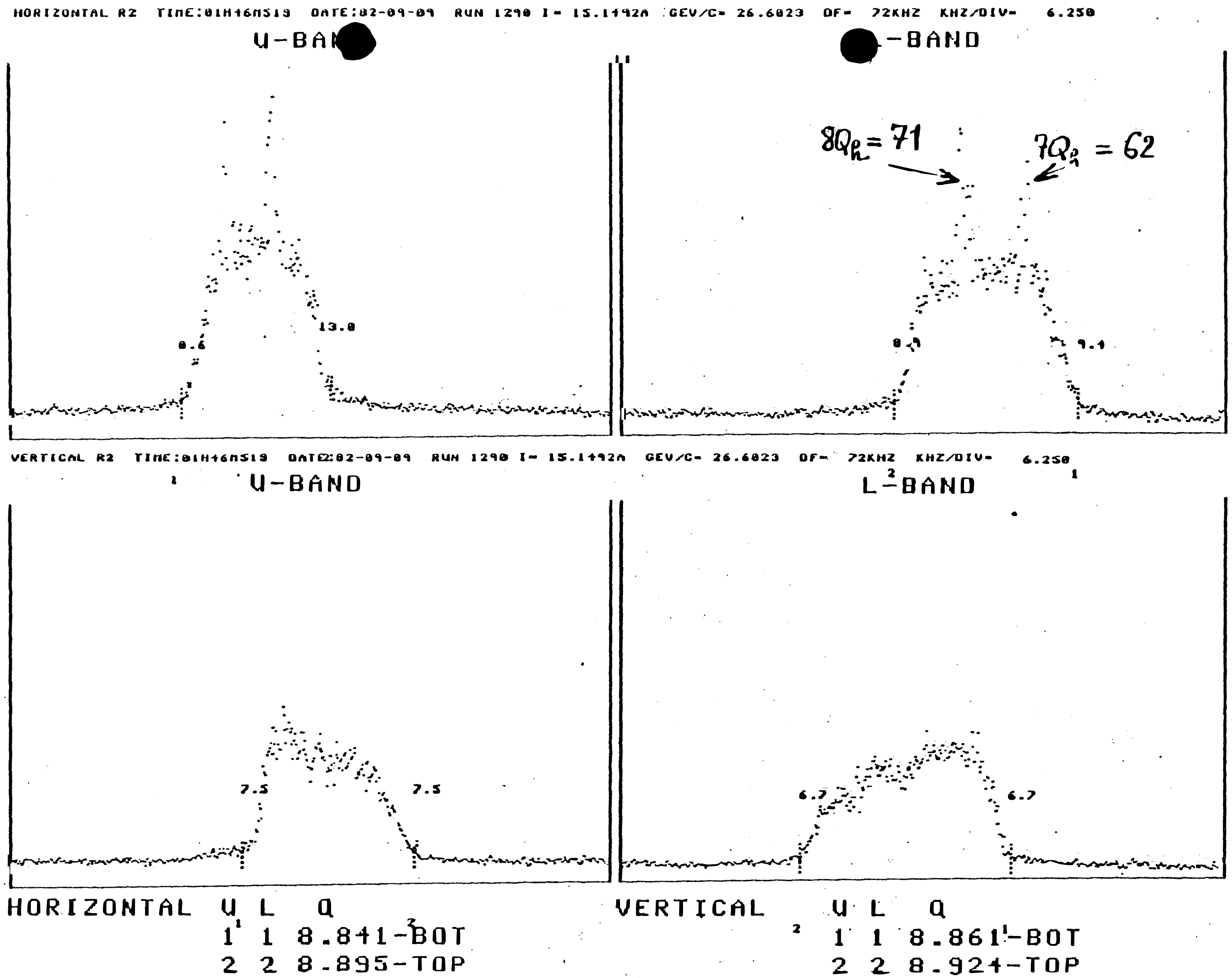

Fig. 12: Transverse Schottky scan for the 15.1 A stack in ring 2. The two peaks in the horizontal spectra (upper) correspond to the resonances 7 Q_h = 62 and 8 Q_h = 71.