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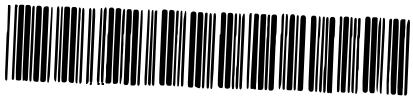

CM-P00072690

ISR-RF/JB/ps

15th December 1972

ISR PERFORMANCE REPORT

Beam Observation

Test of BPMS in "single turn" mode

Run 265, 11.12.72, 22 GeV/c, 20 bunches, 1 pulse out of 3

During run 251 (see report dated 16.11.72) we have already seen that the system was able to measure "first turn" orbits, although its performance in R1 was just acceptable and in R2 the system did not work. The main aim of these tests, however, was to check the very critical timing distribution. We found out that there were errors around the machine and that the timing pulses were not in correct phase with the beam induced signal. We then checked the electrical length of the suspected distribution cables and we found that there were large errors. These errors were corrected by Mr Steinberg during the shut-down week.

During run 265 we checked the system again and we found that it is now performing very well and in both rings. The single turn system is operational and one can measure the injection orbits. With 20 bunches and $1.5 \cdot 10^{12}$P/pulse, data averaged over 5 readings (to eliminate PS jitter and improve signal to noise ratio of the system), we found that the peak error (resolution) is about ± 1.5 mm radially and ± 1 mm vertically. This result is not yet optimum, since we have to recheck the signal processors in which some components have become noisy. We have to replace them.

Fig. 1 and 2 show average and single turn orbits of R1. Fig. 3 and 4 show the orbits of R2. Both rings were meant to be in optimized condition and one can still observe large betatronic oscillations. Single turn orbits can be selected from the first to the tenth ones. Fig. 5 shows the second turn and fig. 6 the tenth one.

This part of the experiment having been successful, we continued with Mr Kemp. We introduced known errors in angle and position at injection and measured the orbits. We collected a maximum of data which were processed later. The aim was to check the feasibility of correcting the injection errors by calculating them out of the orbits data. It was also a test of the software. We have obtained very interesting results which are described in

Kemp's report.

Fig. 7 shows an orbit with four mm betatronic oscillation and Fig. 8 the difference orbit between average and single turn, as it will be displayed by Kemp's program. It presents only the betatronic oscillation to the operator.

Conclusion

The calculations of injection errors with Kemp's program have shown that even with an unoptimized system, the resolution of betatronic oscillations is quite good (below 0.5 mm rms) thanks to the statistic over most of the P.U.'s. There are, however still more fundamental difficulties in using it for injection tuning, as described in Kemp's report. From an operational point of view, the "single turn" system is an interesting tool to follow injection optimization without the help of Polaroïd pictures. Also the data of the real betatronic orbit can give interesting information on machine working lines, such as local effect on phase advance and finding the real phase advance of machine components.

J. Borer.

FILE:PUSO,PE
RING 1 HORIZONTAL PLANE
DATE:721211 TIME:185208
MOMENTUM(GEV/C)= 22.5049
DP/P= -0.0222

PU	MMS	ORBIT DISTORTION
365	-39.8	
357	-38.3	
349	-40.7	
341	-41.7	
333	-41.3	
321	-41.7	
313	-42.8	
305	-42.7	
761	-39.4	
745	-41.8	
733	-51.6	
721	-42.5	
717	-49.7	
705	-40.8	
665	-39.3	
657	-41.2	
649	-40.9	
641	-39.6	
633	-41.2	
[illegible]21	-41.5	
613	-41.2	
605	-42.0	
561	-40.1	
545	-41.2	
533	-52.0	
521	-42.9	
505	-41.5	
465	-39.4	
457	-41.3	
449	-41.3	
441	-40.9	
433	-40.6	
421	-42.3	
413	FAULT	
405	FAULT	
361	-39.7	
345	-42.7	
[illegible]33	FAULT	
[illegible]21	-43.4	
305	-41.9	
265	-39.8	
257	-40.1	
249	-42.4	
241	-42.7	
233	-41.6	
221	-39.9	
213	-39.4	
205	-42.5	
161	-40.4	
145	-41.9	
133	-51.0	
121	-41.7	
105	-43.6	

-51 -41 -31

AVERAGE ORBIT(MM)= -41.5
R.M.S.(MM)= 1.0
PKTOPK(MM)= 4.3

FILE:PUSO,PE
RING 1 VERTICAL PLANE
DATE:721211 TIME:185208
MOMENTUM(GEV/C)= 22.5049

PU	MMS	ORBIT DISTORTION
865	-0.9	
857	-0.5	
849	-0.8	
841	-0.2	
833	FAULT	
821	-0.6	
813	0.5	
805	0.6	
761	-0.1	
745	-0.7	
733	0.3	
721	1.1	
717	-0.6	
705	0.0	
665	0.2	
657	0.2	
649	-0.6	
641	-0.4	
633	0.1	
621	0.3	
613	0.5	
605	-0.4	
561	-2.5	
545	1.3	
533	1.3	
521	1.5	
505	-2.2	
465	0.5	
457	1.0	
449	-0.5	
441	0.6	
433	-0.4	
421	0.2	
413	FAULT	
405	FAULT	
361	-0.2	
345	2.6	
333	FAULT	
321	-0.4	
305	-1.3	
265	-1.0	
257	0.2	
249	1.4	
241	0.6	
233	-0.6	
221	-0.8	
213	-1.3	
205	-1.5	
161	0.4	
145	-2.3	
133	-2.1	
121	-0.6	
105	1.5	

-10 -0 10

AVERAGE ORBIT(MM)= -0.1
R.M.S.(MM)= 1.0
PKTOPK(MM)= 5.0

R1
Average Orbit

Fig. 1

FILE:PUSO,PE
RING 1 HORIZONTAL PLANE
DATE:721211 TIME:190659
MOMENTUM(GEV/C)= 22.5049
DP/P= -0.0227

PU	MMS	ORBIT DISTORTION
865	-39.9	
857	-37.6	
849	-40.3	
841	-42.9	
833	FAULT	
821	-42.5	
813	-42.9	
805	-42.3	
761	-39.7	
745	-42.3	
733	-53.5	
721	-63.1	inj.
717	-49.2	
705	-41.9	
665	-41.5	
657	-42.3	
649	-41.4	
641	-39.5	
633	-41.7	
621	-43.3	
613	-43.0	
605	-43.8	
561	-39.8	
545	-39.8	
533	FAULT	
521	-42.6	
505	-42.5	
465	-41.1	
457	-41.7	
449	-40.9	
441	-40.1	
433	-40.8	
421	-43.9	
413	FAULT	
405	FAULT	
361	-38.8	
345	-42.2	
333	FAULT	
321	-45.7	
305	-43.9	
265	-40.8	
257	-40.1	
249	-42.2	
241	FAULT	
233	-43.6	
221	-42.0	
213	-39.9	
205	FAULT	
161	-39.4	
145	-41.7	
133	FAULT	
121	-44.3	
105	FAULT	

-52 -42 -32

AVERAGE ORBIT(MM)= -42.4
R.M.S.(MM)= 3.2
PKTOPK(MM)= 23.1

FILE:PUSO,PE
RING 1 VERTICAL PLANE
DATE:721211 TIME:190659
MOMENTUM(GEV/C)= 22.5049

PU	MMS	ORBIT DISTORTION
865	-1.7	
857	-0.9	
849	-0.3	
841	0.8	
833	-1.9	
821	-0.9	
813	-0.5	
805	-0.2	
761	0.6	
745	0.4	
733	FAULT	
721	0.9	
717	-0.1	
705	1.0	
665	0.7	
657	0.1	
649	-1.1	
641	-0.8	
633	0.0	
621	0.7	
613	1.4	
605	-0.3	
561	-3.2	
545	1.0	
533	FAULT	
521	2.2	
505	-2.2	
465	-0.1	
457	FAULT	
449	-1.0	
441	1.0	
433	0.2	
421	0.6	
413	FAULT	
405	FAULT	
361	-1.5	
345	2.8	
333	FAULT	
321	0.7	
305	-1.3	
265	-2.4	
257	-0.8	
249	FAULT	
241	1.5	
233	0.7	
221	-0.6	
213	-2.0	
205	-2.8	
161	-0.1	
145	-1.6	
133	FAULT	
121	-0.3	
105	0.8	

-10 -0 10

AVERAGE ORBIT(MM)= -0.2
R.M.S.(MM)= 1.3
PKTOPK(MM)= 6.1

R1

"Single turn"
5 readings aver.
First turn

Fig. 2

FILE:PUSO,PE
RING 2 HORIZONTAL PLANE
DATE:721211 TIME:183743
MOMENTUM(GEV/C)= 22.5049
DP/P= -0.0223

PU	MMS	ORBIT DISTORTION
04	-42.7	
12	-43.7	
20	-42.3	
28	-42.0	
36	-40.1	
48	-40.5	
56	-41.9	
64	-42.5	
204	-43.0	
220	-40.8	
232	-49.7	
244	FAULT	
248	-49.8	
260	-41.4	
304	-41.2	
312	FAULT	
320	-42.9	
328	-41.6	
6	-43.3	
348	-41.5	
356	-41.8	
364	-39.5	
404	-40.2	
420	-41.7	
432	-50.6	
444	-40.8	
460	FAULT	
504	-42.5	
512	-41.4	
520	-42.2	
528	-43.8	
536	-43.0	
548	-39.5	
556	-40.6	
564	-40.8	
604	-43.3	
620	-44.1	
2	-50.6	
644	-39.5	
660	-40.0	
704	-42.9	
712	-42.9	
720	-45.1	
728	-43.2	
736	-40.8	
748	-40.0	
756	FAULT	
764	-41.6	
804	-43.8	
820	-41.1	
832	-49.4	
844	-40.3	
860	-41.3	

-52 -42 -32

AVERAGE ORBIT(MM)= -41.7
R.M.S.(MM)= 1.2
PKTOPK(MM)= 5.3

FILE:PUSO,PE
RING 2 VERTICAL PLANE
DATE:721211 TIME:183743
MOMENTUM(GEV/C)= 22.5049

PU	MMS	ORBIT DISTORTION
104	-2.3	
112	-1.9	
120	-0.5	
128	0.6	
136	1.7	
148	FAULT	
156	-1.1	
164	-1.5	
204	-1.2	
220	-1.0	
232	-1.5	
244	-0.8	
248	-0.9	
260	-0.5	
304	0.1	
312	FAULT	
320	0.5	
328	0.2	
336	0.8	
348	-0.2	
356	-1.8	
364	-2.5	
404	-1.5	
420	1.5	
432	0.9	
444	-0.6	
460	FAULT	
504	-1.2	
512	-0.2	
520	0.4	
528	1.0	
536	1.8	
548	FAULT	
556	-0.5	
564	-1.6	
604	-2.7	
620	1.2	
632	1.1	
644	1.0	
660	-0.6	
704	-2.5	
712	-1.0	
720	0.8	
728	1.6	
736	0.7	
748	-1.0	
756	-1.2	
764	-1.4	
804	-1.2	
820	0.3	
832	0.5	
844	1.5	
860	0.8	

-10 -0 10

AVERAGE ORBIT(MM)= -0.3
R.M.S.(MM)= 1.2
PKTOPK(MM)= 4.4

R2
Average Orbit

Fig. 3

LE:PUSO,PE
ING 2 HORIZONTAL PLANE
ATE:721211 TIME:183543
OMENTUM(GEV/C)= 22.5049
P/P= -0.0221

	MMS	ORBIT DISTORTION
	-42.5	
	-44.2	
	-44.5	
	FAULT	
	-39.4	
	-38.9	
	-41.2	
	-43.7	
	-45.5	
	-40.2	
	-47.0	
	FAULT	- - - - - - inject.
8	-51.3	
0	-41.4	
4	-38.8	
2	FAULT	
0	-41.4	
8	-42.2	
6	-45.0	
8	-41.0	
6	-39.7	
4	-37.2	
04	-38.2	
20	FAULT	
32	-52.7	
44	FAULT	
60	FAULT	
04	-39.6	
12	-40.0	
20	-42.3	
28	-45.8	
36	FAULT	
48	-38.3	
56	-38.5	
64	-39.9	
04	-44.8	
20	-47.1	
32	FAULT	
44	-39.3	
60	-37.5	
04	-40.8	
12	-42.8	
20	FAULT	
28	-44.6	
36	-40.3	
48	-37.5	
56	-39.7	
64	-41.8	
04	-45.3	
20	-43.6	
32	FAULT	
44	-38.1	
60	-38.4	

-51 -41 -31

AVERAGE ORBIT(MM)= -41.3
R.M.S.(MM)= 2.3

FILE:PUSO,PE
RING 2 VERTICAL PLANE
DATE:721211 TIME:183543
MOMENTUM(GEV/C)= 22.5049

PU	MMS	ORBIT DISTORTION
104	-4.1	
112	-3.7	
120	-1.3	
128	2.5	
136	3.2	
148	0.8	
156	-2.5	
164	-3.6	
204	-1.4	
220	0.9	
232	-0.1	
244	-1.9	
248	-0.3	
260	0.5	
304	1.7	
312	FAULT	
320	-0.5	
328	-1.1	
336	-0.4	
348	0.4	
356	-0.1	
364	-1.0	
404	-2.7	
420	0.1	
432	-0.2	
444	0.1	
460	FAULT	
504	-1.2	
512	-0.7	
520	-0.9	
528	0.2	
536	2.2	
548	FAULT	
556	0.2	
564	-1.5	
604	-4.6	
620	~~-36.4~~	
632	0.6	
644	2.5	
660	-0.3	
704	-3.8	
712	-2.6	
720	0.5	
728	FAULT	
736	2.2	
748	-0.4	
756	-2.1	
764	-3.2	
804	-3.9	
820	1.3	
832	2.7	
844	3.1	
860	-0.1	

-11 -1 9

AVERAGE ORBIT(MM)= -1.2
R.M.S.(MM)= 5.4
PKTOPK(MM)= 39.6

R2

"Single turn"
5 readings aver.
First Turn

Fig. 4

FILE:PUSO,PE
RING 2 HORIZONTAL PLANE
DATE:721211 TIME:195625
MOMENTUM(GEV/C)= 22.5049
DP/P= -0.0221

PU	MMS	ORBIT DISTORTION
04	-42.3	
12	-40.4	
20	-39.7	
28	FAULT	
36	-41.9	
48	-41.6	
56	-40.5	
64	-39.4	
04	-41.0	
20	-40.0	
32	-50.8	
44	FAULT	
48	-46.1	
60	-40.3	
04	-42.4	
12	FAULT	
20	-43.0	
28	-39.4	
36	-40.0	
[illegible]8	-40.9	
56	-43.2	
64	-41.4	
04	-40.3	
20	FAULT	
32	-47.1	
44	FAULT	
60	FAULT	
04	-44.5	
12	-42.1	
20	-40.8	
28	-41.0	
36	FAULT	
48	-40.9	
56	-42.8	
64	-40.9	
04	-40.8	
20	-39.9	
32	FAULT	
[illegible]	-40.1	
60	-42.7	
04	-43.9	
12	-41.7	
20	FAULT	
28	-40.3	
36	-40.2	
48	-41.8	
56	-42.4	
64	-39.9	
04	-40.0	
20	-37.6	
32	FAULT	
44	-42.8	
60	-43.4	

-51 -41 -31

AVERAGE ORBIT(MM)= -41.1
R.M.S.(MM)= 1.9
PKTOPK(MM)= 8.0

FILE:PUSO,PE
RING 2 VERTICAL PLANE
DATE:721211 TIME:195625
MOMENTUM(GEV/C)= 22.5049

PU	MMS	ORBIT DISTORTION
104	-0.5	
112	-1.0	
120	-1.1	
128	-0.7	
136	0.0	
148	0.8	
156	0.4	
164	0.2	
204	-1.7	
220	-2.1	
232	-2.3	
244	-1.0	
248	-1.1	
260	-2.9	
304	-1.1	
312	FAULT	
320	1.1	
328	1.7	
336	1.8	
348	-0.6	
356	-2.9	
364	-3.6	
404	-0.4	
420	2.9	
432	1.3	
444	-1.2	
460	FAULT	
504	-1.0	
512	0.9	
520	1.0	
528	0.9	
536	1.6	
548	FAULT	
556	-0.6	
564	-0.9	
604	-1.1	
620	-5.5	
632	0.5	
644	-0.7	
660	-1.1	
704	-0.7	
712	0.3	
720	1.1	
728	FAULT	
736	-1.0	
748	-1.5	
756	-0.4	
764	0.1	
804	-0.4	
820	-0.8	
832	-0.8	
844	-0.1	
860	1.7	

-10 -0 10

AVERAGE ORBIT(MM)= -0.5
R.M.S.(MM)= 1.5
PKTOPK(MM)= 8.4

R2

"Single turn"
5 readings
Secand Turn

Fig. 5

FILE:PUSO.PE
RING 2 HORIZONTAL PLANE
DATE:721211 TIME:195903
MOMENTUM(GEV/C)= 22.5049
DP/P= -0.0220

PU	MMS	ORBIT DISTORTION
104	-42.3	
112	-40.2	
120	-39.6	
128	FAULT	
136	-41.5	
148	-41.5	
156	-40.4	
164	-39.4	
204	-39.9	
220	-39.5	
232	-50.4	
244	FAULT	
248	-46.0	
260	-40.1	
304	-42.2	
312	FAULT	
320	-42.9	
328	-39.7	
336	-40.1	
348	-40.7	
356	-43.1	
364	-41.4	
404	-40.2	
420	FAULT	
432	-46.9	
444	FAULT	
460	FAULT	
504	-44.5	
512	-42.2	
520	-40.7	
528	-40.8	
536	FAULT	
548	-40.2	
556	-42.7	
564	-41.4	
604	-40.8	
620	-39.9	
632	FAULT	
644	-40.1	
660	-42.5	
704	-43.8	
712	-41.7	
720	FAULT	
728	-40.0	
736	-39.9	
748	-41.8	
756	-42.3	
764	-39.9	
804	-40.0	
820	-36.0	
832	FAULT	
844	-43.3	
860	-45.8	

-51 -41 -31

AVERAGE ORBIT(MM)= -41.1
R.M.S.(MM)= 2.2
PKTOPK(MM)= 11.9

FILE:PUSO.PE
RING 2 VERTICAL PLANE
DATE:721211 TIME:195903
MOMENTUM(GEV/C)= 22.5049

PU	MMS	ORBIT DISTORTION
104	-0.6	
112	-0.9	
120	-1.1	
128	-0.7	
136	-0.1	
148	0.9	
156	0.4	
164	0.3	
204	-1.6	
220	-2.5	
232	-2.3	
244	-0.6	
248	-1.3	
260	-2.8	
304	-1.1	
312	FAULT	
320	1.1	
328	1.8	
336	1.9	
348	-0.3	
356	-3.0	
364	-3.5	
404	-0.6	
420	3.0	
432	1.4	
444	-1.2	
460	FAULT	
504	-0.9	
512	0.8	
520	1.0	
528	0.9	
536	1.5	
548	FAULT	
556	-0.6	
564	-0.9	
604	-1.0	
620	~~-53.6~~	
632	0.6	
644	-0.7	
660	-1.1	
704	-0.7	
712	0.2	
720	1.2	
728	FAULT	
736	-0.9	
748	-1.6	
756	-0.5	
764	0.1	
804	-0.4	
820	-1.6	
832	-2.1	
844	-0.2	
860	-1.9	

-12 -2 8

AVERAGE ORBIT(MM)= -1.5
R.M.S.(MM)= 7.6
PKTOPK(MM)= 56.6

R2
"Single turn"
5 readings
10th. turn

Fig. 6

FILE:XTUR,PE
RING 1 HORIZONTAL PLANE
DATE:721211 TIME:195156
MOMENTUM(GEV/C)= 22.5049
DP/P= -0.0222

PU	MMS	ORBIT DISTORTION
865	-38.8	
857	-36.4	
849	-39.7	
841	-41.6	
833	FAULT	
821	-41.6	
813	-42.2	
805	-42.1	
761	-39.2	
745	-41.0	
733	-52.1	
721	-61.6	- - - - - inject.
717	-48.1	
705	-40.9	
665	-40.4	
657	-41.4	
649	-40.9	
641	-38.5	
633	-41.0	
621	-42.1	
613	-42.0	
605	-42.4	
561	-39.0	
545	-39.5	
533	FAULT	
521	-41.9	
505	-42.1	
465	-39.6	
457	-40.9	
449	-39.8	
441	-39.4	
433	-39.8	
421	-42.5	
413	FAULT	
405	FAULT	
361	-38.0	
345	-41.2	
333	FAULT	
321	-44.4	
305	-42.5	
265	-39.5	
257	-39.0	
249	-41.0	
241	FAULT	
233	-41.6	
221	-40.7	
213	-39.0	
205	FAULT	
161	-38.2	
145	-40.7	
133	FAULT	
121	-42.8	
105	FAULT	

-51 -41 -31

AVERAGE ORBIT(MM)= -41.3
R.M.S.(MM)= 3.1
PKTOPK(MM)= 22.8

FILE:XTUR,PE
RING 1 VERTICAL PLANE
DATE:721211 TIME:195156
MOMENTUM(GEV/C)= 22.5049

PU	MMS	ORBIT DISTORTION
865	-3.4	
857	-4.1	
849	-2.6	
841	1.4	
833	-0.0	
821	1.6	
813	0.0	
805	-2.1	
761	-4.8	
745	0.8	
733	FAULT	
721	-3.3	- - - - - inj.
717	-3.0	
705	-0.9	
665	5.4	
657	4.6	
649	-0.2	
641	-4.0	
633	-5.1	
621	-1.2	
613	3.8	
605	4.6	
561	1.0	
545	-2.1	
533	FAULT	
521	-1.9	
505	0.9	
465	5.7	
457	FAULT	
449	-2.1	
441	-4.0	
433	-5.0	
421	0.7	
413	FAULT	
405	FAULT	
361	-1.7	
345	-2.1	
333	FAULT	
321	-0.3	
305	3.6	
265	0.6	
257	-0.3	
249	FAULT	
241	-2.1	
233	-1.3	
221	1.4	
213	1.3	
205	-0.3	
161	-3.9	
145	-4.7	
133	FAULT	
121	2.7	
105	5.3	

-10 -0 10

AVERAGE ORBIT(MM)= -0.5
R.M.S.(MM)= 3.0
PKTOPK(MM)= 10.8

"Single turn"
5 readings
-4 mm
injection error
First turn

Fig. 7

FILE:AMST,PE
RING 1 HORIZONTAL PLANE
DATE:721211 TIME:191151
MOMENTUM(GEV/C)= 22.5049
DP/P= 0.0000

FILE:AMST,PE
RING 1 VERTICAL PLANE
DATE:721211 TIME:191151
MOMENTUM(GEV/C)= 22.5049

DIFFERENCE ORBIT

PU	MMS	ORBIT DISTORTION	PU	MMS	ORBIT DISTORTION
865	2.7		865	-0.6	
857	FAULT		857	-0.5	
849	-0.4		849	0.4	
841	-0.7		841	1.2	
833	FAULT		833	FAULT	
821	FAULT		821	-0.2	
813	2.6		813	-0.7	
805	0.1		805	-0.9	
761	-2.1		761	0.6	
745	-0.6		745	1.2	
733	0.0		733	FAULT	
721	FAULT	---- inj.	721	FAULT	---- inj.
717	-2.0		717	0.6	
705	-2.4		705	1.2	
665	-0.7		665	0.7	
6[illegible]	2.0		657	-0.1	
649	FAULT		649	-0.8	
641	2.0		641	-0.7	
633	-1.2		633	-0.2	
621	-1.7		621	0.2	
613	0.4		613	0.9	
605	2.6		605	0.4	
561	4.5		561	-0.9	
545	2.8		545	-0.4	
533	FAULT		533	FAULT	
521	-1.5		521	0.3	
505	-0.9		505	0.1	
465	2.4		465	-0.6	
457	3.3		457	FAULT	
449	2.0		449	-0.6	
441	0.2		441	0.6	
433	-0.8		433	0.6	
421	0.5		421	0.4	
4[illegible]	FAULT		413	FAULT	
4[illegible]	FAULT		405	FAULT	
361	3.5		361	-1.4	
345	-0.0		345	0.2	
333	FAULT		333	FAULT	
321	-0.7		321	1.1	
305	2.3		305	-0.0	
265	3.1		265	-1.4	
257	2.6		257	-1.2	
249	0.4		249	FAULT	
241	FAULT		241	0.7	
233	-1.7		233	1.2	
221	1.4		221	0.2	
213	3.6		213	-0.8	
205	FAULT		205	-1.2	
161	0.8		161	-0.5	
145	-0.5		145	0.8	
133	FAULT		133	FAULT	
121	0.6		121	0.3	
105	FAULT		105	-2.0	

-10 0 10 -10 -0 10

AVERAGE ORBIT(MM)= 0.0
R.M.S.(MM)= 2.0
PKTOPK(MM)= 6.9

AVERAGE ORBIT(MM)= -0.0
R.M.S.(MM)= 0.8
PKTOPK(MM)= 3.2

"Average" — "Single turn" orbits — 4mm horizontal error

Fig. 8