PS/AA/ME/Note 66 29 June 1983
SVDM/afm

EXPERIMENT : Trying a new RF function for unstacking

DATE : 23 June 1983

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1. Purpose of the new function

It has been shown recently that after transfer of intense batches to the SPS the horizontal stack emittance is larger than before transfer (see log XXVII, p. 75). This does not occur after low-intensity pilot shots. If a transverse instability would cause this effect (possibly because of the change in longitudinal distribution), we would expect it in the vertical plane rather than in the horizontal one.

A more plausible explanation seems to be the "overlap knock-out" phenomenon, sometimes observed at the ISR. This might occur if higher harmonics of the bunch frequency of the unstacked beam would coincide with transverse sidebands of the stack; the excitation of horizontal oscillations then occurs by the space-charge coupling between the beams where they are horizontally separated. For a beam at the ejection orbit, this would happen around the 50th harmonic of the bunch frequency.

Such high harmonics are most pronounced when the bunches are short, i.e. near the end of the unstacking cycle, where the voltage is raised to its maximum value to match the bunches to the PS buckets. With the old function, this voltage increase started at 1847.9 kHz, so that part of the frequency change was done at high voltage. In addition, the short bunches existed for a few hundred ms before being ejected.

The new function first moves the beam to the ejection frequency before increasing the voltage. In addition, the function length is adjusted so that the beam is ejected 50 ms after the peak voltage is reached.

2. Description of the new function

The old function is shown in Fig. 1, the new one in Fig. 2. The following explanation refers to the new function.

Initial values. The frequency and voltage are made equal to the values for sequence 10 to prevent jumps at the start of the cycle.

Sequence 1. The voltage is reduced to 5 V.

Sequence 2. The frequency is moved to the trapping frequency (determined by the pilot pulse programme to catch the required number of particles). Note that $\Gamma \gg 1$ for this sequence.

Sequence 3. Trapping with the specified bucket area.

Sequence 4. Matching to $\Gamma = 0.34$. This is somewhat higher than the value of 0.31 used before in order to recuperate some time lost in the final sequences. Note that this Γ value depends on the bucket area; it is automatically reduced for larger buckets in order to prevent the frequency at the end of sequence 4 becoming lower than the frequency of sequence 5.

Sequence 5. Moving to f = 1853.5, i.e. outside the stack.

Sequence 6. Now that we are outside the stack, the bucket area may be increased to 120 Hz without causing stack dilution. This bucket increase is necessary in order to save time in the following acceleration sequences.

If the trapping bucket is larger than 120 Hz, this sequence will keep it constant.

Sequence 7. Moving to 1846.5 Hz (near the ejection orbit).

Sequence 8. Γ is reduced to 0.005 while the frequency is changed to the specified ejection value. Note that we cannot reduce Γ to zero because the last vector of this sequence would then become too long.

Sequence 9. The voltage and frequency are kept constant; the duration of this sequence is adjusted so that the total function length becomes 1.95 s, independent of bucket area, trapping frequency, etc. The ejection kicker is triggered 2 s after the function start.

Sequence 10. Finally, the bucket area is increased to near the maximum value.

The timing for the phase-lock is automatically adjusted so that it is switched on when the frequency is about 800 Hz below the capture frequency. This is done to prevent phase-loop instabilities that might occur if the phase-lock is switched on too near to the stack core.

3. The experiment

A pilot pulse was first transferred with the new function. The result seemed entirely normal.

A large triple shot was then sent to the SPS, again with the new function. The stack emittances were (in mm.mrad):

	H	V
before unstacking	1.6π	1.6π
after restacking	1.8π	1.8π

With the old RF function, the horizontal emittance used to be blown up to ~2.2π mm.mrad after a triple shot. A later transfer (27 June) again showed a small, but acceptable blow-up.

Finally, a single intense batch was unstacked and restacked. The emittances were:

	H	V
before unstacking	1.3π	1.4π
after restacking	1.5π	1.4π

It should be noted that it is not entirely sure that the restacking functioned correctly; when this is used next, the emittances should again be checked.

It was noticed that the longitudinal stack distribution was more disturbed by the new function than it used to be by the old one without, however, causing any $\bar{p}$ losses. This may be caused by the higher Γ value in sequences 4-7. In order to (possibly) improve this, the duration of the matching sequence 4 was increased to 0.15 s and the frequency of sequence 5 increased by 0.1 kHz to regain the time lost. These changes (Fig. 3) were made after the experiment.

4. Provision for 3.5 GeV/c ISR operation

For transfers to the ISR at 3.5 GeV/c, the momentum spread must be kept down to the present value, but the batches should be as intense as possible. This means that the ejected bunches should be as long as possible. To provide sufficient space for the rise of the ejection kicker, a length of 350 ns seems suitable. This length will be obtained if the bucket area of sequence 10 is made equal to 1.56 × the trapping bucket.

The pilot pulse programme will do this automatically whenever the trapping bucket is equal to 150 Hz or larger. A value of 200 Hz would give about the same $\Delta p/p$ as used at present; a slightly higher value might be possible.

Note that this feature has not yet been tested.

Reported by S. van der Meer

[illegible] [illegible]

	t−FPA	f
PHASE LOCK ON	.320	1854.11
PHASE LOCK OFF	0	1845.93

→ 1Hz=.00917eVs

			VALUES AT END OF SEQUENCE				
SEQUENCE	TYPE	Δt	t−FPA	f	A Hz	Γ	V
INITIAL			[illegible]	[illegible]	1159	0	[illegible]
1	DHS	[illegible]	.1	[illegible]	23	0	[illegible]
2	DHS	[illegible]	.2	[illegible]	26	0	[illegible]
3	TRP	[illegible]	.35	1854.98	[illegible]	0	18
4	MAT	[illegible]	.5	1854.87	[illegible]	[illegible]	74
5	MOV	.522	1.022	[illegible]	50	[illegible]	80
6	MAT	[illegible]	1.122	1853.02	[illegible]	[illegible]	474
7	MOV	.354	1.477	[illegible]	120	[illegible]	521
8	MOV	.272	1.749	[illegible]	120	[illegible]	129
9	DHS	[illegible]	1.800	[illegible]	121	0	[illegible]
10	MAT	[illegible]	1.950	1845.93	[illegible]	[illegible]	11862

Fig. 1 - New function (with some small changes in seq 3 and 5)

[illegible] [illegible]

	t-FPA	•
PHASE LOCK ON	.008	1854.07
PHASE LOCK OFF	0	1845.93

→ 1Hz=.00917eVs

SEQUENCE	TYPE	Δt	t-FPA	f	A Hz	Γ	V
			VALUES AT END OF SEQUENCE				
INITIAL			[illegible]	[illegible]	1159	0	[illegible]
1	DHS	[illegible]	.1	[illegible]	23	0	[illegible]
2	DHS	[illegible]	.2	[illegible]	26	0	[illegible]
3	TRP	[illegible]	.35	1854.99	[illegible]	0	18
4	MAT	[illegible]	.45	1854.92	[illegible]	[illegible]	73
5	MOV	.582	1.032	[illegible]	50	[illegible]	80
6	MAT	[illegible]	1.132	1852.92	[illegible]	[illegible]	476
7	MOV	.347	1.479	[illegible]	120	[illegible]	521
8	MOV	.272	1.752	[illegible]	120	[illegible]	129
9	DHS	[illegible]	1.8	[illegible]	121	0	[illegible]
10	MAT	[illegible]	1.95	1845.93	[illegible]	[illegible]	11862

Fig. 2 - New function (as tested)

3 STANDARD UNSTACKING FUNCTION —— DEFAULT   83-06-22   83-06-22

	t-FPA	f
PHASE LOCK ON	.939	1853.97
PHASE LOCK OFF	0	1845.93

→ 1Hz=.00917eVs

			VALUES AT END OF SEQUENCE				
SEQUENCE	TYPE	Δt	t-FPA	f	A Hz	Γ	V
INITIAL			[illegible]	[illegible]	1159	0	[illegible]
1	DHS	[illegible]	.1	[illegible]	23	0	[illegible]
2	DHS	[illegible]	.2	[illegible]	26	0	[illegible]
3	TRP	[illegible]	.35	1854.97	[illegible]	0	18
4	MAT	[illegible]	.45	1854.92	[illegible]	[illegible]	65
5	MOV	.719	1.169	[illegible]	50	[illegible]	70
6	MAT	[illegible]	1.269	1853.04	[illegible]	[illegible]	417
7	MOV	.358	1.627	[illegible]	120	[illegible]	463
8	MAT	[illegible]	1.727	1846.34	[illegible]	[illegible]	12928
9	MOV	.059	1.787	[illegible]	1160	[illegible]	11862

Fig. 3 - Old function