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POSSIBLE ISR TESTS WITH CIRCULATING BEAMS, DURING OCTOBER/NOVEMBER 1970

by

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1. General remarks

It is planned, at present, to devote at least 30 hours of PS beam-time to ISR injection studies in October/November. We should keep 15 GeV/c nominal PS momentum for all tests. As much of the work as possible should be done with 2 to 4 bunches and with injection at the PS repetition rate, but 20 bunches and single-shot injection is required for some tests (i.e., beam-life, intensity dependence of beam-life, instabilities). Only Ring 1 is available.

At first, a circulating beam has to be obtained. This will not be discussed here. Trying to get the beam to circulate may take (or exceed) all available time and we will certainly call it a success if a circulating beam is obtained just after 30 hours. It is more probable, however, that some time will be available for circulating beam studies, and we must be prepared for this. Adjustments of injection parameters should be provisionally terminated as soon as possible. Refined adjustments of injection conditions may then become necessary or desirable at various points later on. In addition a short period of injection studies may be scheduled at the beginning of each run. This could also include an exploration of available vertical aperture at injection (by varying the angle at which the beam is steered through the inflector).

It has been stated by B. de Raad (and agreed by everyone concerned) that he will try, at first, to make the beam circulate on an average radius, that is 26 mm inside the central orbit in mid F sectors. If this is approximately achieved, we should not change it during October/November. Only if the first successful injection orbit is so near (or even beyond) the centre that there is no room for r.f. acceleration should we readjust the average injection radius during this period.

It seems that most circulating beam experiments that one may possibly propose for 1970 fall into one of the following groups:

Group 1 Beam is circulating on injection orbit, no radio frequency.

Group 2 The bunches are trapped by r.f., beam remains on injection orbit.

Group 3 R.F. acceleration out of injection orbit.

Group 4 Adiabatic decrease of r.f. voltage.

Group 5 Variation of main magnetic field to move beam. No. r.f.

Group 6 Attempts to stack a few pulses.

Group 7 Closed orbit corrections, experiments with orbit bumps.

Detailed experiments belonging to all groups except 7 are discussed in part 2 of this note. It is improbable that we will come into contact with all groups, let alone do all the work per group discussed in part 2. However, one is rather free to choose out of the given list, according to circumstances.

The work listed in Group 1 can be done as soon as one has a circulating beam of sufficiently low loss rate to make the pick-up stations work properly. No further equipment or complication is required. Most of the experiments of Group 1, except the beam-life measurement, can and should, go partially in parallel. Some of them (e.g., the Q-measurement) could also go on in parallel with r.f. experiments, except that for the very first tests, the presence of the same experts is required in different locations (SRC and A1).

I propose that, after we have obtained a circulating beam for the first time, we should spend a certain time with experiments 1.1 to 1.10 (c.f., part 2). After about 2 hours, or when we are satisfied with the Q-measurements and their result and with pick-up checking, whichever occurs later, we should spend about ½ hour with a first beam-life observation at the injection orbit. Then we should try to turn on the r.f. and proceed roughly along the sequence in which experiments are listed, and according to the remarks made, in part 2, but arranging the detailed schedule according to circumstances.

Experiment 1.8 (orbit observations in spite of debunching) becomes superfluous as soon as one has r.f. trapping. Experiments 1.9 and 1.10 (related to instabilities) are automatically taken up again when we start studying r.f. debunching (Group 4). If the other experiments of Group 1 have not been completed before the first r.f. turn-on (a very likely situation) their continuation has to be fitted into the rest of the program.

If, at first, we do not succeed with r.f. trapping and acceleration, experiment 5.1, (moving the beam by magnetic field variation), including the beam-life experiment, should be tried rather soon.

If the r.f. still does not work after this, we have to go back to Group 1, spending the rest of available time with these tests.

The importance of orbit corrections in 1970 depends entirely on the circumstances. Generally, we should work as much as possible with the bare, uncorrected magnet system. Orbit analysis and corrections will become much easier next year, when computer-processing of orbit measurements (and remote-controlled vertical magnet positioning) will be available. However, if it should turn out that correction windings and/or horizontal field magnets have to be energized in order to obtain a circulating beam, a revision of the situation must be done as soon as possible, i.e., after r.f. trapping at the latest. Also, if we cannot move the beam out of the inflector for lack of radial aperture (which does not seem likely) corrections have to be made. However, in this case it seems best to complete all the work that can be done on the injection orbit first.

2. List of experiments with circulating beam

Injection and dumping at PS repetition rate of 2 or 4 bunches, is assumed, unless stated otherwise.

Group 1 Beam is circulating at injection orbit without r.f. Neighbouring bunches start overlapping after roughly 10 ms, azimuthal structure at revolution frequency starts to disappear after about 0.3 s.

1.1. Beam-dump operation. Trigger beam-dump kicker (FKID) from injection pre-pulse, say 20 ms, before new injection. Bring dump into operation. If the pre-pulse can be gated, so that it does not appear unless it is followed by an actual firing of the injector, this trigger may remain connected to FKID for everything but stacking. It may nevertheless be safer to interrupt the FKID trigger manually for beam-life measurements. If the beam dump facility does not work at once, one may nevertheless try to do the experiments listed below, although the fraction of old beam surviving new injection may lead to some confusion.

1.2. Bunch frequency measurement. Trigger bunch-frequency meter (BF) with injection pulse (directly, and via variable delay). The BF should yield average radius information at once, with a fraction of a millimetre precision. Vary trigger delay up to a few ms. Accumulate statistics.

If possible, (and as soon as convenient), change the main field (but nothing else) by $1.6 \cdot 10^{-3}$ say, corresponding to 3 mm average radial shift. Observe change in BF reading.

1.3. Automatic Q-measurement. Trigger the automatic Q-meter (QM) with injection pulse (if possible IF pulse from pick up in beam transfer channel). Read Q (fractional part only), vertical and horizontal. Vary parameters of device (cycles before count, cycles counted, choice of filter). Inspect internal wave-forms. The QM should work with whatever residual coherent oscillations are left, even after careful adjustment of injection parameters. Otherwise (e.g., if there is too much vertical-horizontal mixture in the pick-up signal) increase oscillations in one plane.

1.4. Direct Q-measurement. Measure fractional part of Q by directly observing beat pattern in wide-band pick-up signal. Take photographs. Compare with results of the QM (1.3. above).

This is more likely to require an artificial increase of the coherent oscillations.

1.5. Q-shift. If possible, energize pole-face windings (PFW) to produce a known Q-shift (calculated, and observed on reference magnet display). Repeat 1.2. and 1.3. above.

This experiment should only be included in the first few hours of circulating beam studies, if it can be done very quickly (rapid setting of PFW currents to precalculated values from SRC), or if the Q-value without PFW is unacceptable or very strange. However, an attempt should be made in any case to do a Q-shift experiment during on of the 1970 runs.

1.6. Coupling. Try to make initial oscillations in one plane (probably horizontal) a few times larger than in the other. Observe build-up rate or peak amplitude of signal in the other plane, either directly or behind filter of QM.

1.7. Pick Up check. (combined with crude orbit observation). Inspect each pair of pick-up signals, one by one, on a dual-beam oscilloscope. Use fast sweep to see bunches. Trigger by delayed (0.5 ms say ?) injection pulse. Check down qualitative observations (like "up", "down", "centre", "strange", "no signal") on a prepared list, for each station, vertical and horizontal. Do not take a large number of individual photographs during the first run.

1.8. Pick-up video scan in spite of debunching.*

a. Trigger video scanner with injection pulse, one scan per PS cycle. Try to put orbit on a a memoscope (scanner staircase signal on X-axis), take photograph. Later analysis may yield closed orbit in spite of the rapid debunching.

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* I assume, that only the video branch of the beam observation system is ready. If a fraction of the computer processing equipment should be ready, it can be tested in parallel wtih most other experiments.

b. Use video scanner and memoscope as above but one step of the scanner per PS pulse, until all stations have been scanned. Take photograph. This takes a few minutes and a steady PS beam, but it should yield the best closed orbit information available without r.f. (and without signal processor and sample-and-hold).

1.9. Normal debunching. Observe debunching with a fast oscilloscope and the $\sum$ pick-up (100 MHz). Use slow sweep (observing peak envelope) and variable delayed fast sweep (to see bunches in different states of debunching). Take photographs. This should give first indications about possible longitudinal instabilities.

Repeat observations with 20 bunches as soon as is convenient.

1.10. Microwave pick up. Look for signals from microwave pick-up (PM) with spectrum analyser and/or with travelling wave amplifier, detector and oscilloscope.

This is a purely passive observation, that should not have an influence on the time schedule during a run.

1.11. Second debunching without r.f. If one fails altogether to get the r.f. system working, and comes back to Group 1 experiments, one should include the experiment described under 4.2., but without r.f.

1.12. Beam-life at injection orbit. Go to single shot injection. Observe DC beam current, I_{dc}, from PIDC on memoscope and on digital printer (or strip chart recorder). Try to exceed 10 min. beam life. Record vacuum pressures as completely as possible.

If there is doubt about being able to measure beam life at the central orbit (3.4. below), repeat 1.12. with 20 bunches as soon as it is convenient.

Group 2 R.F. trapping. Beam stays at injection orbit (apart from a possible small drift). Control of R.F. from A1, but some observations in SRC.

2.1. Trapping. Follow normal sequence of r.f. trapping with full 20 kV per turn, no "missing buckets" scheme, and not matching at first.

2.2. Phase oscillation observation. Take photograph of Σ pick-up signal envelope. Analyse later for frequency and modulation amplitude (amount of mismatch with PS bunches). Later, observe and photograph bunches with fast single sweep and variable trigger delay.

2.3. R.F. drift observation. Observe frequency analogue voltage (taken from variable oscillator input) on slow sweep oscilloscope. Take photograph.

At a convenient (later) moment : Repeat with phase-lock switched off $\sim$100 ms after injection.

2.4. R.F. noise observation. Observe debunching times with and without phase-lock,(Σ pick-up, wide-band oscilloscope very slow sweep). This is likely to need single-shot injection and should only be done during a later run, or whenever it fits in conveniently, e.g., together with the beam life experiment 3.4.

2.5. R.F. matching. Whenever there is a convenient moment, try to adjust main r.f. matching by amplitude and/or by phase.

2.6. Closed orbit observation. Make one complete scan of video scanner per PS pulse, use memoscope. Take photographs. QM and BF readings must be taken at the same time, and recorded on the photographs. This is the most elaborate stage of closed-orbit observation for 1970.

2.7. Bunch-synchronized timing. Bring Bunch-synchronized Timing into operation. This work can be done in parallel with everything else of this Group and even with experiments of other groups.

Group 3 R.F. acceleration. Start acceleration wtih AS pulse, rather soon ($\sim$50 ms) after injection. Accelerate with full voltage, phase-lock, and Γ = 0.5 or a little less.

3.1. Radial aperture measurement. Display (in SRC and in A.1) Σ-pick-up signal and I_{dc} versus frequency analogue voltage (available from r.f. system) on oscilloscope. Take photographs.

Trigger BF (in SRC) from delayed pulse, made to coincide with a given degree of beam loss (by displaying the pulse on the oscilloscope display of I_{dc}). Read BF, mark on photograph.

This gives two measurements of available radial aperture, both in terms of frequency.

The frequency shift to the onset of loss gives the available room for stacking. If one measures the frequency shift for complete loss (this may, however, create difficulties with the phase-lock) and for about 15% loss (H.G. Hereward recommends 14.6%) one obtains the available space for closed orbits, and the beam half-width.

3.2. Orbit versus momentum measurement. As in 3.1 above but stop acceleration with AO pulse from r.f. timer.

a. Trigger video scanner and BF with AO (or AO delayed a little). Vary timing of AO systematically, observe orbits on memoscope (vertical first !) and take photographs, recording the BF reading on the photographs. This yields closed orbits as a function of momentum. If the BF does not work, use zero beat device or F pulse (derived from frequency analogue voltage) to generate AO.

b. If there is any difficulty or delay with the video scanner, do the following first : display signals of a single vertical pick-up station versus the frequency analogue voltage on an oscilloscope and take a photograph ("tilt of the median plane"). Repeat with a few more pick-up stations, if possible.

3.3. Q versus momentum measurement. The special full aperture kickers (or "ticklers") are not ready yet. It may, however, be possible to use the inflector stray field, triggering the inflector a second time per PS cycle, for measuring the radial Q. For this : use r.f. acceleration (no AO is needed), trigger inflector (in addition to its normal trigger) and QM and BF, all from the same pulse, which may be a delayed IF, an F or an r.f. timer pulse.

3.4. Beam life at central orbit. Proceed as in 3.1. above, adjust AO such as to deposit beam approximately on central orbit (or, at least, out of the inflector). Then go to single shot injection, observe I_{dc} and Σ-pick up signal as a function of time.

Repeat with r.f. switched off by VO pulse derived from AO, (yields debunched beam of PS momentum spread, rather than blown-up by noise in ISR r.f.

Repeat with 20 bunches, as soon as it is convenient. This gives increased accuracy of PIDC and may(hopefully not!) show intensity dependent beam-life.

Record vacuum pressures as well as possible. Try to reach 15 to 20 min. beam life. If necessary take precise enough recordings of I_{dc} to permit calculation of half-lives in excess of that time.

In principle, this beam-life measurement has a much higher priority than experiments 3.2. and 3.3., but it takes time, interruption of cycling at PS up-rate, and even a change to

20 bunches. It should, therefore, be done as soon as it is convenient, considering the circumstances of the moment. In any case, each run should be terminated by a beam-life experiment, using the last beam injected from the PS.

Group 4 R.F. adiabatic turn-down. This can (and 4.1. must,) be done at the injection orbit. (No AS pulse).

4.1. R.F. adiabatic debunching. Trigger start of adiabatic turn down (DS pulse) about 50 ms after IF. Derive r.f. off pulse (VO) from end-of-decay pulse (DO + tl with tl = 0). Decrease final voltage setting in systematic steps. Observe debunching on Σ pick-up and microwave signals as under 1.9. and 1.10. Repeat with 20 bunches as soon as possible. Instabilities are expected to show up.

4.2. Second debunching after r.f. turn-down. Go to 20 bunches. Let beam debunch completely after r.f. off (VO), then trigger inflector a second time from a (VO + delay) pulse. This will kick out the beam around most of the circumference. Observe the debunching of the remaining beam (Σ -pick-up). Observation of the times for the first (after VO) and the second (after the inflector firing) debunchings should reveal a blow-up of energy spread by (possibly invisible) instabilities.

It may be difficult to squeeze the entire process - an adiabatic r.f. turn down and two debunching processes - into the PS cycle time. One may, therefore, have to go to single-shot injection.

Group 5 Radial motion by change of field, no r.f. Single-shot injection required.

5.1. Outwards motion by field variations. Change main field in small steps ($\sim 10^{-3}$) to move beam out of injection orbit, and note field variation required to produce loss of beam observed on PIDC. Or, if possible (?) : observe I_{dc} as a function of an analogue voltage proportional to change of field on a memoscope.

Move beam near central orbit. Observe beam life with PIDC.

These experiments should only be done to replace 3.1. and 3.4. in case the r.f. system does not work.

5.2. Inwards motion by field variation. After single-shot injection, withdraw injection kicker from aperture, then move beam inwards by change of main field until loss occurs.

Since the r.f. system does not easily decelerate inwards, this is a convenient way of measuring the available free aperture inside the injection orbit.

Group 6 Attempts to stack a few pulses. Set up a simple stacking program with final voltage, initial r.f. off frequency and frequency increment (if any) set according to the results of the debunching experiments (Group 4). Inhibit FKID trigger. Observe increase (if any !?) of I_{dc} during stacking. Repeat with 20 bunches at once. Measure beam-life.

Since the movable screen in front of the inflector may not work, stacking more than a few pulses may be difficult. In no case should a stacked current of 1A be exceeded, as there is no emergency beam-dump yet.

The contents of this note have been discussed with the Parameter Committee and the Running-In Committee, and in particular with H.G. Hereward who has suggested part of the experiments and contributed many useful remarks.