Circulating beam and RF capture

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Nominal or degauss?

- Nominal cycle and wait vs. degauss

	Q_H' De-gauss	Q_V' De-gauss	Q_H' Waiting	Q_V' Waiting
No correction	+83	-263	-179	-1
80% dipole correction – spool pieces only	-75	-105	-110	-70
Natural Q' corrected with lattice sextupoles	+176	-176	-86	+86
Both	+18	-18	-17	+17

Starting point

- Which machine will we inherit?
- What can be measured and corrected from first-turn data?
- Tune (integer) + coupling?

Closed orbit

- Close the trajectory on itself to obtain closed orbit: comparison between two consecutive turns (or at least some pick-up for the second turn) ➔ close with two closed orbit correctors
- By averaging over at least 10(?) turns (Q_H=64.28, Q_V=59.31)

How many turns can we see?

- How many turns can we see with the BPMs and with RF OFF?
- Main problem for the BPMs as a result of bunch length increase is the loss of linearity
- The BPM system can cope with an increase from in r.m.s. bunch length σ_t from 0.4 to 1.3 ns. ➔

$$\sigma_t(N) = \sqrt{\sigma_t(0)^2 + \left(N\,T\,\alpha_c \sigma_{\delta E/E_0}(0)\right)^2} \quad \sigma_t(0) = 0.37ns$$

$$\alpha_c = 3.225 \times 10^{-4} \quad \sigma_{\delta E/E_0}(0) = 3.06 \times 10^{-4} \quad T = 88.9\mu s$$

- 142 turns
- It is possible to increase it by reducing the momentum spread at extraction from the SPS by using pilot with smaller longitudinal emittance and or reducing the RF voltage SPS extraction

Tunes

- Tune measurement:
  - Integer part from trajectory difference for two different injection settings
  - Fractional part from phase advance per turn: e.g. it can be measured by putting together the turn-by-turn data from two pick-ups at ~90^0 phase advance
- Need error study?

Decoherence

- Issue is the decoherence time due to chromaticity: if no correction ➔ measurement possible in the V-plane only (for nominal cycle). In the H-plane not feasible:

$$< X > (N) \propto e^{-\frac{1}{2}\alpha^2 N^2} \sin(2\pi Q N)$$

$$\alpha = 2\pi Q' \sigma_{\delta E/E_0}$$

- 3 turns for Q_H'=-179 ➔ need correction
- 30 turns for Q'_H=-17, Q'_V=17. Can be further increased by reducing the momentum spread at extraction from SPS.
- Can we gate on the centre of the bunch (no decoherence of the signal but reduction of the signal)

Energy matching: measuring f_{rev}

- With pilot bunch, RF off:
  - f_{rev} measured by observing bunch slip wrt. RF:
  - Either looking at bunch on longitudinal pickup vs. revolution frequency (scope)
  - or using phase detector in beam control system
  - Bunch lengthening not critical for longitudinal pickup. Should be able to measure f_{rev} over several hundred turns
  - For 10^{-4} dB/B (~ 0.15 mm LHC or ~ 15 Hz @ 400 MHz) the beam slips 10 RF periods in 0.5 seconds

Energy matching: correction

- 3 variables: B_{LHC}, B_{SPS}, f_{RF}
- 2 constraints: radial position before and after capture should be equal and, as far as possible, centred
  - in the matched condition the radial offsets for the first turn and the orbit after capture are equal
- LHC and SPS RF frequencies are linked:

$$f_{revLHC}/f_{revSPS} = (7/27)$$

$$f_{rfLHC}/f_{rfSPS} = 2$$

  - any frequency change produces a radial position and momentum change in SPS

Energy matching: correction

- Adjust (at least) 2 out of the 3 variables: B_{LHC}, B_{SPS}, f_{RF} :

- B_{LHC} (CODs and/or MBs):
  - need to assess the implication of changing the B-field in LHC
  - also quadrupoles, etc.
- f_{RF}:
  - Any frequency change will require re-tuning of the SPS RF:
    - timing of the fine rephasing
    - retraining of the frequency program (for future reference: this is also true when changing cycle e.g from pilot to LHC filling)
  - radial position and momentum change in SPS
  - Philippe's view:
    - should not treat f_{RF} as a "free parameter"
    - we should aim to minimize the number of times we change the frequency
    - establish a "standard" frequency early on, which will then remain fixed
- B_{SPS}:
  - also quadrupoles, etc, plus transfer lines
  - retraining of the frequency program

Example: adjust f_{RF} and B_{LHC}

- In theory we should be able to correct both B and f_{RF} in one iteration:

$$- \delta R/R = -1/\gamma_{tr}^2 \, \Delta B/B + \gamma_{SPS}^2/\, \gamma_{tr}^2 \, . \, \Delta f_{inj}/f$$

$$- \delta f/f \quad = -1/\gamma_{tr}^2 \, \Delta B/B - [(\gamma^2 - \gamma_{tr}^2)/\gamma^2 \, \gamma_{tr}^2 \, .\gamma_{SPS}^2 + 1] \, \Delta f_{inj}/f$$

radial position error of captured beam

frequency error of uncaptured beam

adjustment on LHC B-field

change in injection frequency

Energy matching: 2 rings

- For 2 LHC rings, a third constraint: f_{RF} is the same but circumference may be slightly different
  - unless we are very lucky, the beams cannot be centered in both rings: must find a compromise in which the average radial position in the 2 rings is zero
  - 1cm length difference ~ 1.5 mm radial offset ~ 150Hz
- Will have to inject fairly soon in 2^{nd} ring to check this
  - need to define what is the minimum set of measurements and corrections on the first ring before going to the second