RF Synchro

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Adiabatic Recapture

- Let beam debunch in injector
- Transfer beam to receiver machine (RF OFF)
- Slowly (adiabatically) raise voltage in receiving machine to capture beam
- Problems:
  - Continuous beam in receiving machine with all buckets filled in at least part of ring
  - Capture loss show up at beginning of ramp
- Used for Pb ions FT in SPS

Bunch into bucket transfer

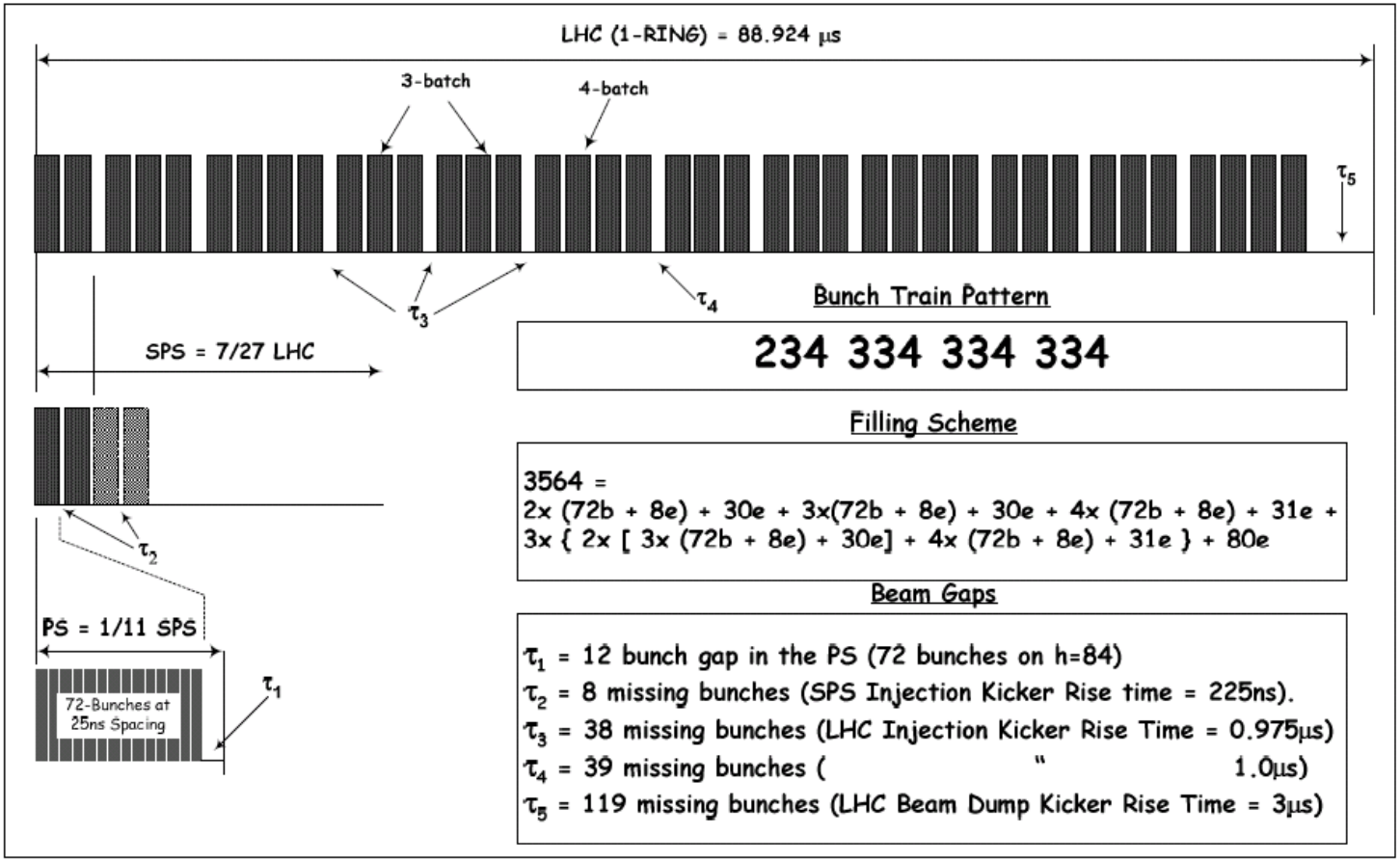
- Bunches in RF buckets of injecting machine must be placed in chosen RF buckets of receiving machine
- Simple scheme: receiving machine filled in one shot
  - RF and frev of receiving machine defined by injector
  - Receiving machine synchronizes its RF and frev on these before beam transfer. No beam manipulation

Complex filling scheme

Successive injections in different parts of receiving machine

All this leads to a typical filling scheme …

2808 bunches for the standard 25ns Physics operation



Bunch Train Pattern

234 334 334 334

Filling Scheme

3564 =
2x (72b + 8e) + 30e + 3x(72b + 8e) + 30e + 4x (72b + 8e) + 31e +
3x { 2x [3x (72b + 8e) + 30e] + 4x (72b + 8e) + 31e } + 80e

Beam Gaps

τ_1 = 12 bunch gap in the PS (72 bunches on h=84)
τ_2 = 8 missing bunches (SPS Injection Kicker Rise time = 225ns).
τ_3 = 38 missing bunches (LHC Injection Kicker Rise Time = 0.975μs)
τ_4 = 39 missing bunches (" 1.0μs)
τ_5 = 119 missing bunches (LHC Beam Dump Kicker Rise Time = 3μs)

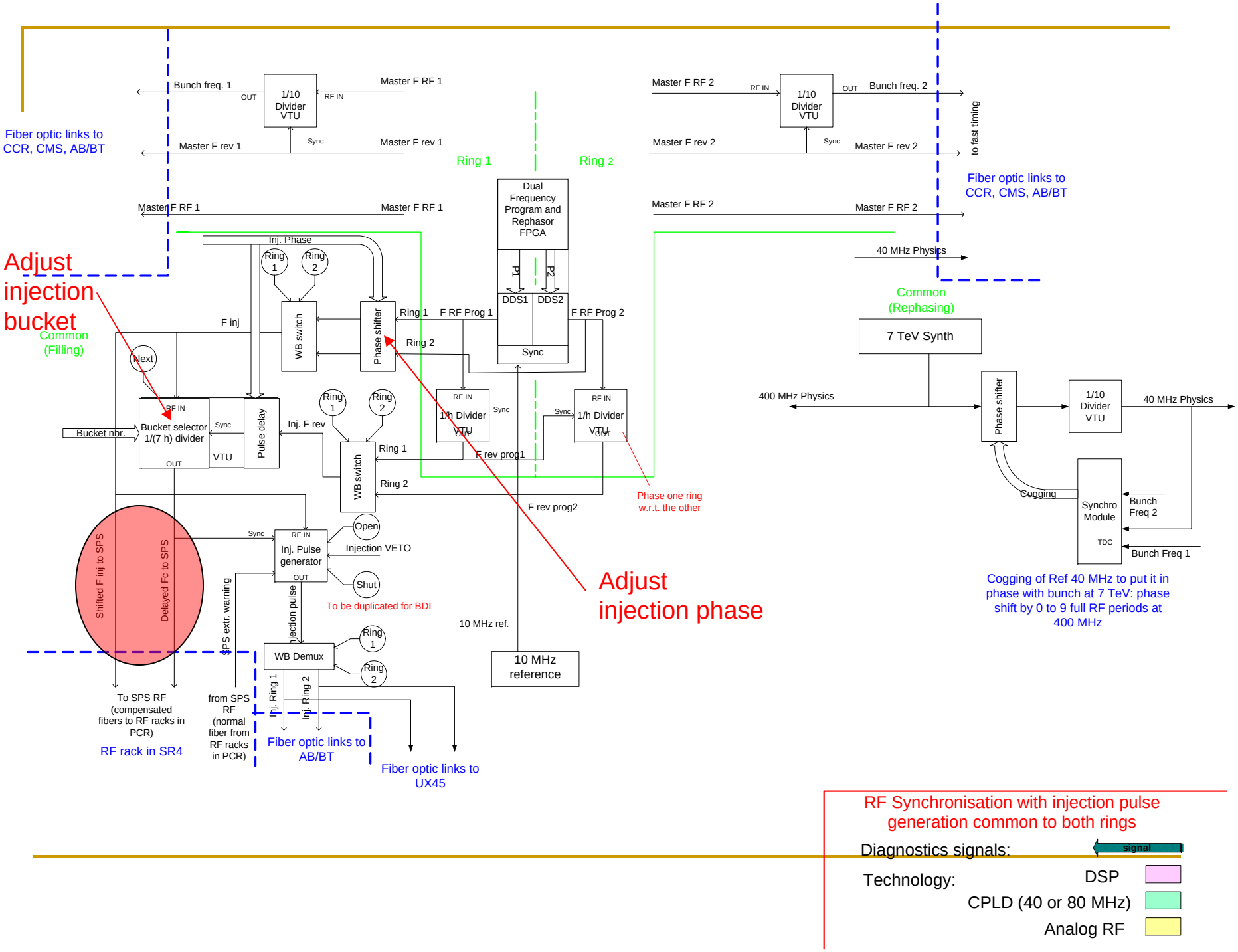
Receiving machine is Master

- Two reference signals sent to slave:
  - Fiducial frequency pulse train

$$fc = FrevSPS / 27 = FrevLHC / 7$$

$$fc' = FrevSPS = FrevCPS / 11$$

  - Master RF for fine phase synchro


Fiber optic links to CCR, CMS, AB/BT
Bunch freq. 1
OUT
1/10 Divider VTU
RF IN
Master F RF 1
Sync
Master F rev 1
Ring 1
Ring 2
Master F RF 1
Master F RF 1
Inj. Phase
Ring 1
Ring 2
Dual Frequency Program and Rephasor FPGA
P1
P2
DDS1
DDS2
Sync
Adjust injection bucket
Common (Filling)
F inj
Next
WB switch
Phase shifter
Ring 1
F RF Prog 1
Ring 2
F RF Prog 2
RF IN
Bucket selector 1/(7 h) divider
Sync
VTU
OUT
Bucket nbr.
Pulse delay
Inj. F rev
Ring 1
Ring 2
WB switch
Ring 1
Ring 2
RF IN
1/h Divider VTU
Sync
OUT
F rev prog1
F rev prog2
Sync
RF IN
1/h Divider VTU
OUT
Phase one ring w.r.t. the other
Shifted F inj to SPS
Delayed Fc to SPS
Sync
RF IN
Inj. Pulse generator
OUT
Open
Injection VETO
Shut
To be duplicated for BDI
SPS extr. warning
Injection pulse
10 MHz ref.
WB Demux
Ring 1
Ring 2
10 MHz reference
Inj. Ring 1
Inj. Ring 2
To SPS RF (compensated fibers to RF racks in PCR)
RF rack in SR4
from SPS RF (normal fiber from RF racks in PCR)
Fiber optic links to AB/BT
Fiber optic links to UX45
Adjust injection phase
Master F RF 2
RF IN
1/10 Divider VTU
OUT
Bunch freq. 2
to fast timing
Master F rev 2
Sync
Master F rev 2
Fiber optic links to CCR, CMS, AB/BT
Master F RF 2
Master F RF 2
40 MHz Physics
Common (Rephasing)
7 TeV Synth
400 MHz Physics
Phase shifter
1/10 Divider VTU
40 MHz Physics
Cogging
Synchro Module
TDC
Bunch Freq 2
Bunch Freq 1
Cogging of Ref 40 MHz to put it in phase with bunch at 7 TeV: phase shift by 0 to 9 full RF periods at 400 MHz
RF Synchronisation with injection pulse generation common to both rings
Diagnostics signals:
signal
Technology:
DSP
CPLD (40 or 80 MHz)
Analog RF

Rephasing in the injector.Principle

- At constant B field offset the RF -> beam displaced radially -> slips a bit at each turn
- When beam at correct position get back to centered orbit
- Limitation: ΔR (aperture), df/dt (bucket size), d^2f/dt^2 (adiabaticity)

Rephasing procedure

- Runs in the VME CPU
- Triggered by timing
- Step 1: Send LHC freq (numerically) to Freq Prgm DSP and tell it to generate small freq “step” to go to LHC frequency
- Step 2: Measure TDC, pass measurement to Freq Prgm DSP and tell it to do a small freq bump. Repeat once if needed.
- Step 3: Tell Freq Prgm DSP to close PLL on Phase Meas