# LHC start-up
Season II

Cogging

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Numerology

- For each ring:
  - The 400 MHz RF defines 35640 buckets, spaced by one RF period, and numbered from 1 to 35640
  - Bucket 1 is the first bucket after the 3 μs long abort gap (defined from bucket 34442 to 35640)
  - Bunches in bucket 1 of the two rings collide in IP1 (and IP5)

Bunch Numbering

- **Convention:** bunches in bucket 1 of the two rings collide in IP1

- **FAQ**
  - Q: Bunches in bucket 1 of both rings meet in IP1 (and IP5). Can this be changed ?
  - A: No…but if we want to have single bunch collisions in another IP we should **inject in a different bucket of ring 2**. For example for collision in IP2: Inject pilot in bucket 1 ring 1, and pilot in bucket 1 + 35640/4 = 8911 ring 2 .
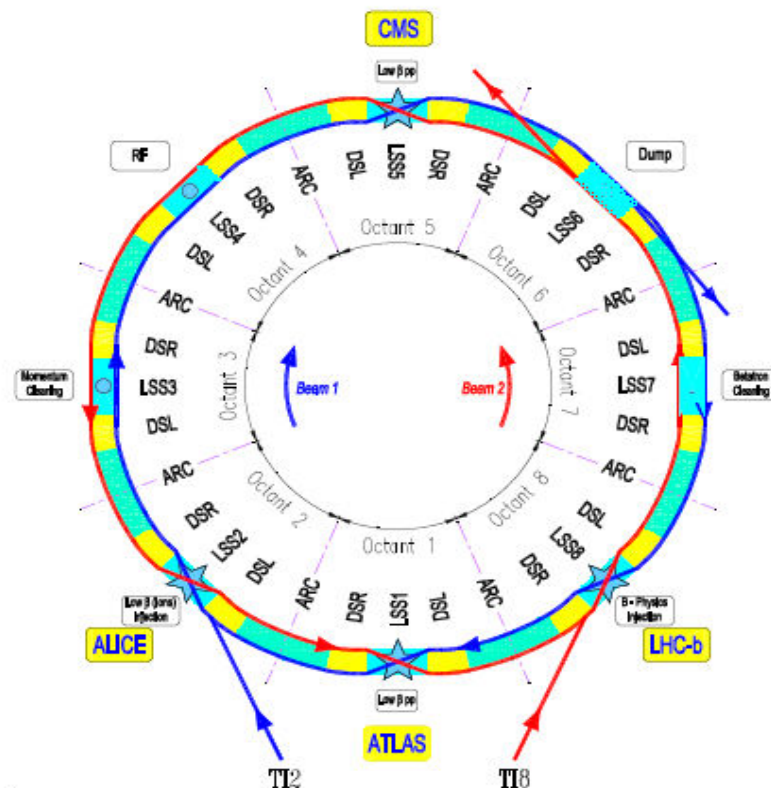
By delaying the ring 2 injection bucket by ¼ turn we displace the collision point by 1 octant

Revolution Frequency or Orbit

- For each ring:
  - At a **given place** in the machine, and at a **given beam energy** (that is fixed RF frequency) the **delay between the pulse and the passage of a bunch in bucket 1 will be fixed from run to run**
  - Drift during the ramp: during the acceleration ramp due to the difference between signal transmission delay and the beam time of flight. For protons we have 6.5 ps/km, for ions 41.25 ps/km. Hopefully not a problem.

Bunch Clock

- For each ring:
  - At a given place in the machine, and at a **given beam energy** (RF frequency) the **delay between the edge of the Bunch Clock and the passage of a bunch will be fixed** from run to run
  - Drift during the ramp: At a given place, but varying energy (frequency) the edge will drift with respect to the bunch. (Same figures as for the Revolution Frequency pulses.)

Start-up 2009

Ramping frequency references.
R RF Prog1= F RF Prog2 if ramping to physics.

Phase shifter used to rotate beam 2 with respect to beam 1 on flat top
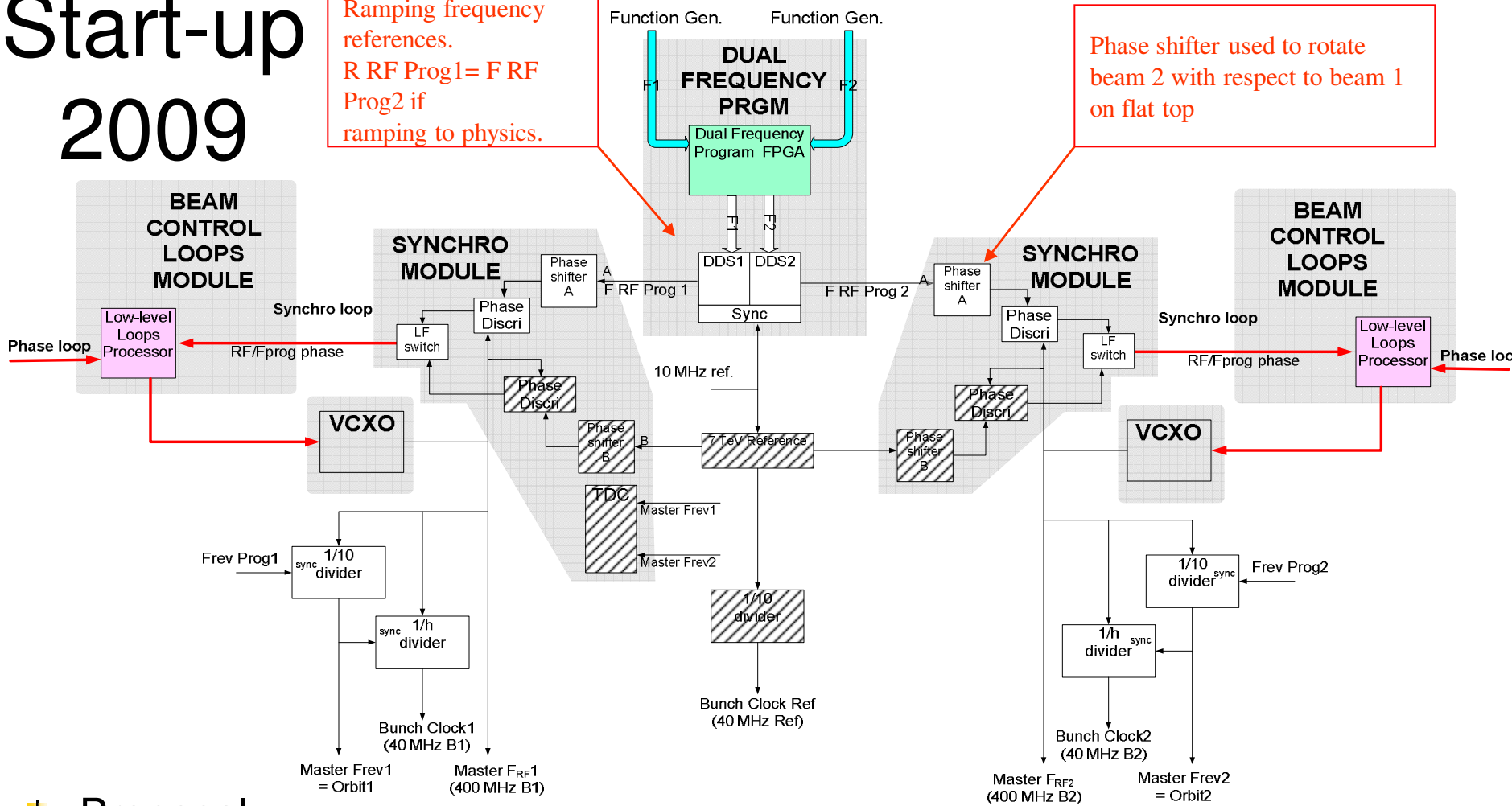
- Proposal:
 - Use only BC1 and BC2
  - **NO rephasing to BCref**
- Before physics, fine phasing of BC2 to get collision in detectors

Cogging strategy (1)

- Step1: Coarse adjust position of bucket 1, beam 2 so that buckets 1 collide in IP1/IP5
    - Done by adjusting FrevProg2 delay BEFORE injection
    - Transparent to the experiments (effect during the Sequencer RF Resync)
    - Need coarse measurement from experiments. Observe time difference in beam 1-2 passing by IP1 or IP5 (or other IPs). Calls for ~ 2.5 ns resolution

Cogging strategy (2)

- Step2: **Fine adjust**. On flat top, before physics, rotate beam 2 so that buckets 1 collide in the middle of the detectors IP1/IP5 (or other)

  - Done by Phase Shifting beam 2 (and BC2) w.r.to beam 1 (see page 6).

  - Seen by experiments, but very smooth. NO DRIFT of bunch with respect to corresponding BC during rotation

  - Need fine measurement from the experiments IP1 /IP5 (or other). ~ 100 ps resolution
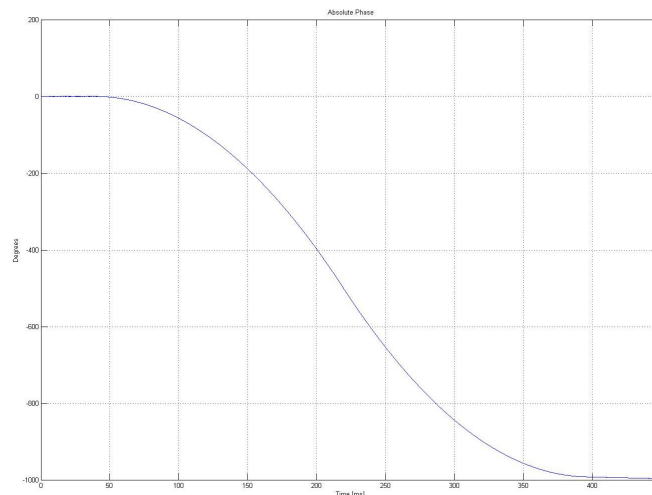
Parabolic-Linear-Parabolic phase step. Max 25 ns/second. Corresponds to 10 Hz @ 400 MHz (-0.1 mm or $\Delta p/p$= -8 x 10-5). No limit on the amplitude: Rephasing ¼ turn (= 8910 buckets) would take 891 seconds (~ 15 min)! Expect less than 2.5 ns.
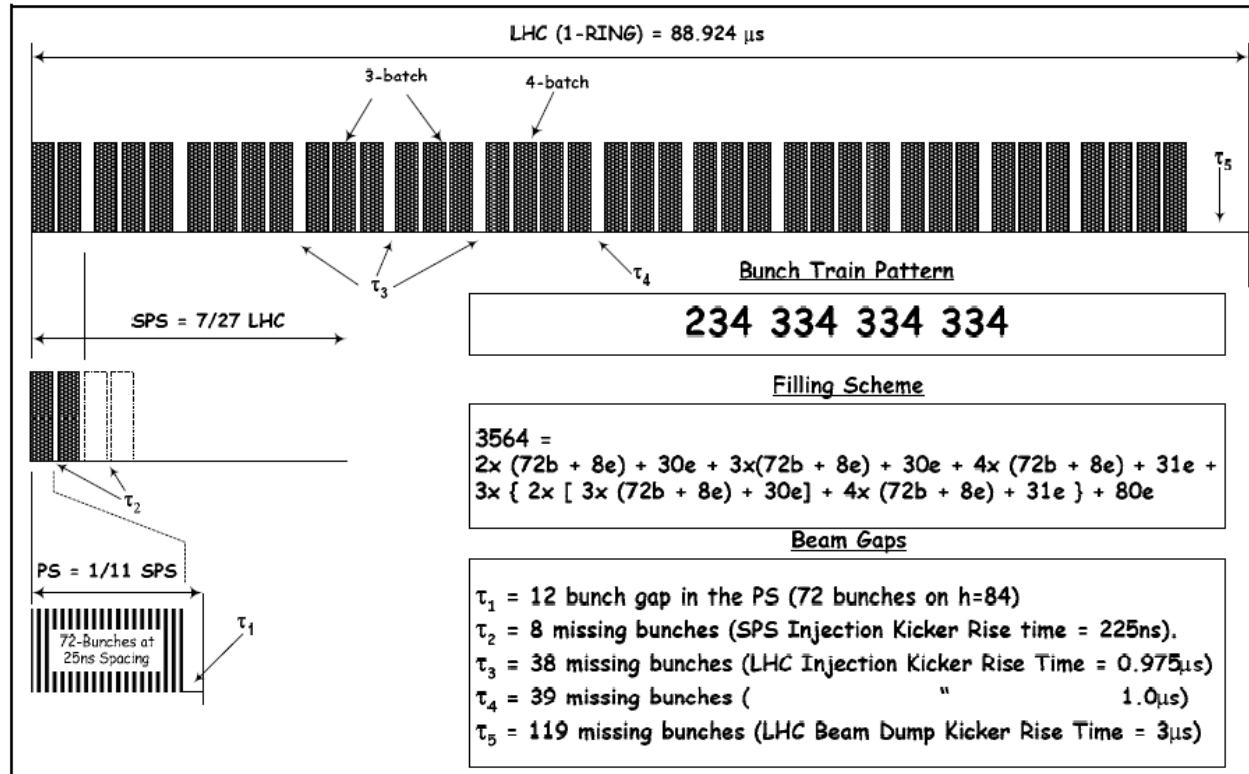
Additional material if needed

Numerology (2)

Figure 1: Schematic of the Bunch Disposition around an LHC Ring for the 25ns Filling Scheme (2808 Bunches/Ring).

- For 25ns operation the bunches will occupy buckets 1, 11, 21 etc. with gaps occurring every PS or SPS kicker gap. (see Figure 1 above reproduced from *LHC-OP-ES-0003 rev 1.0*).
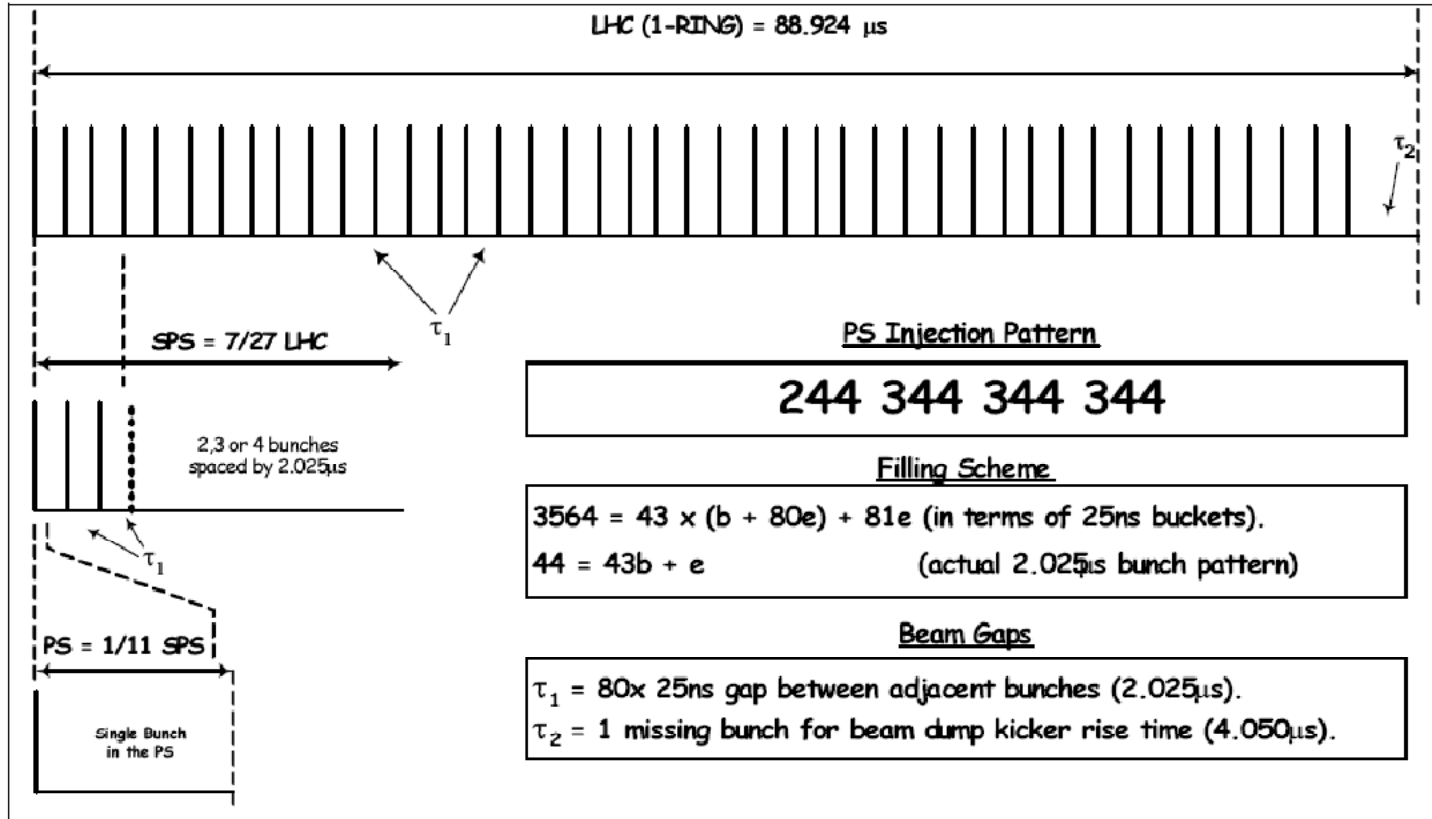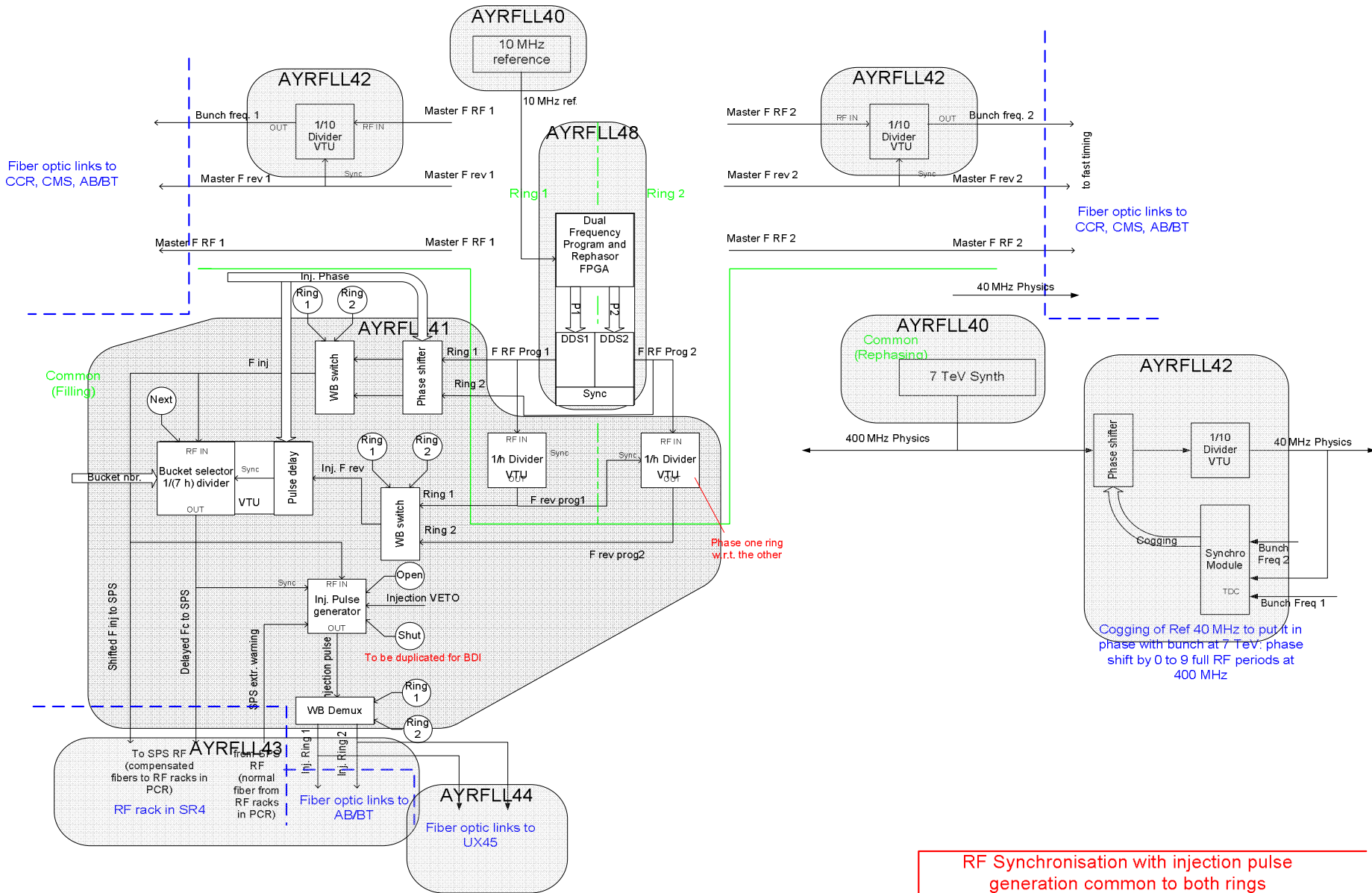
Numerology (3)

Figure 3: Schematic of the Bunch Disposition for the 43-Bunch Filling Scheme (43 Bunches/Ring).

- For 43 bunch operation the bunches will occupy buckets 1, 811, 1621, etc. (see Figure 3 above reproduced from *LHC-OP-ES-0003 rev 1.0*).

RF Synchronisation with injection pulse generation common to both rings

Diagnostics signals: signal

Technology: DSP

CPLD (40 or 80 MHz)

Analog RF