Software Interlock System
-
Real Time Feedbacks

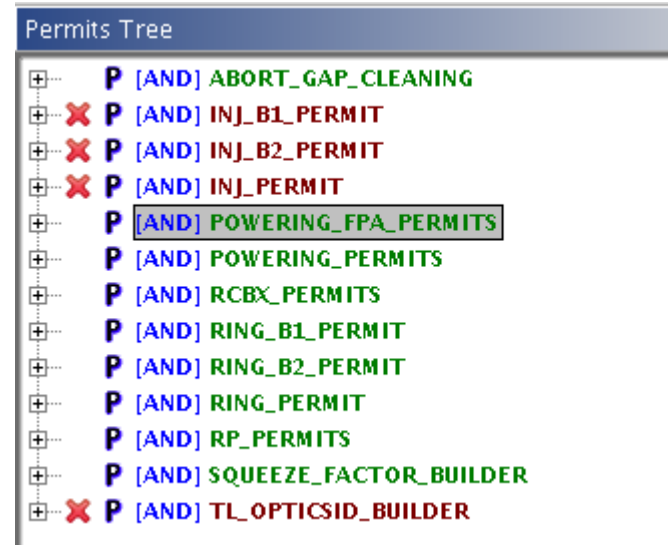L. Ponce

- ## SIS:
  - ➤ 2015 tree structure
  - ➤ Status of interlocks and masks
  - ➤ Dumps in 2015

- ## Tune and Orbit Feedbacks:
  - ➤ Usage in the cycle
 - ➤ Status of OFB
  - ➤ Status of QFB

Mixed forest: new species introduced for 2015

➤ **3 INJECTION PERMITS:** exported to injection BICs for TI2 and/or TI8.

➤ **3 RING PERMITS:** exported to ring BICs (SR3 B1/2 and CCR) to abort the beam

➤ **RCBX PERMIT**: exported to BIC and PIC

➤ *2 POWERING_PERMIT: exported to the PIC PVSS system to lock PCs.*

➤ **RP PERMIT** taken out from RING PERMIT, only announcer

➤ **ABORT GAP CLEANING**: exported to abort gap cleaning

➤ **2 BUILDERs** exported to Telegram

Permits Tree

- P [AND] ABORT_GAP_CLEANING
- ✖ P [AND] INJ_B1_PERMIT
- ✖ P [AND] INJ_B2_PERMIT
- ✖ P [AND] INJ_PERMIT
- P [AND] POWERING_FPA_PERMITS
- P [AND] POWERING_PERMITS
- P [AND] RCBX_PERMITS
- P [AND] RING_B1_PERMIT
- P [AND] RING_B2_PERMIT
- P [AND] RING_PERMIT
- P [AND] RP_PERMITS
- P [AND] SQUEEZE_FACTOR_BUILDER
- ✖ P [AND] TL_OPTICSID_BUILDER

> Interlocks combined by an OR logic with the safe beam flag = true conditions

> No new interlocks since end of 2012

> All branches logic tested.

> Tolerances for critical parameters back to initial values:
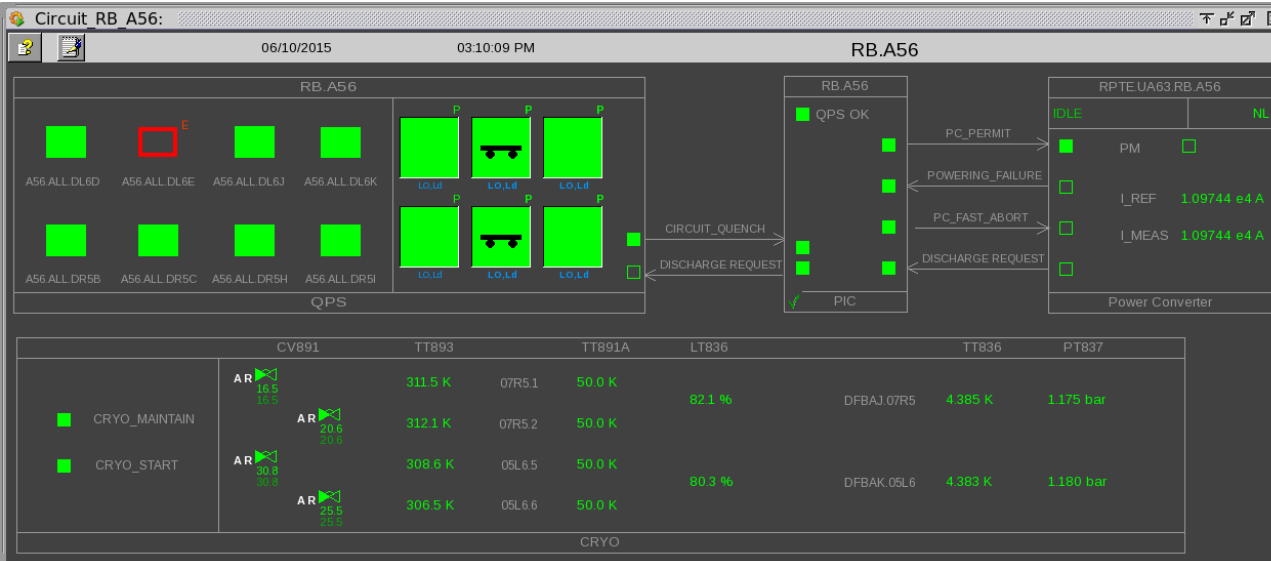
>> MKI temp and vac interlocks…
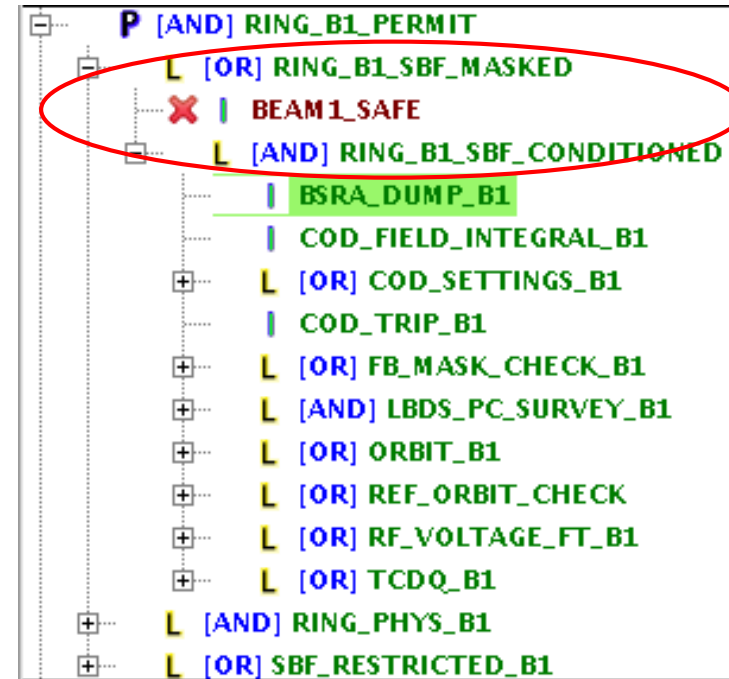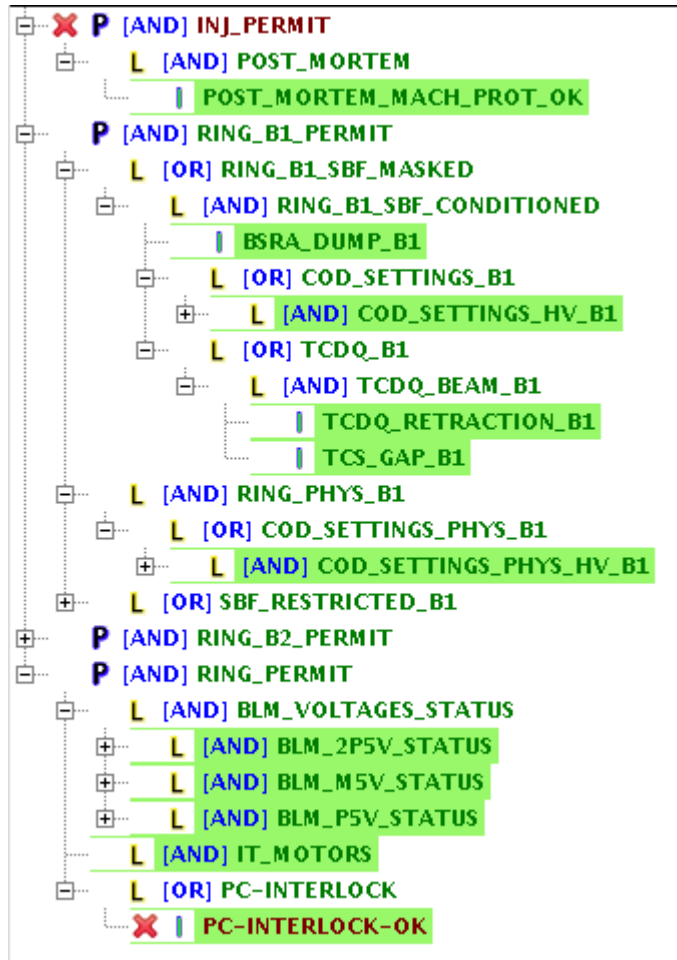
> ➢ Several interlocks are still masked, but OK:

> ➢ PM_MACH_PROT_OK (injection permit)

> ➢ COD settings in physics

> ➢ TCDQ_BEAM masked for first collisions

> ➢ BSRA dump level

> ➢ PC interlock not yet fully commissioned -> masked and COD settings still used (also masked)

➢ Complex interlocking logic to limit global orbit excursion and catch un-detected bumps (COD settings)

➢ Tolerances depend on beam modes and ring positions

  ➢ For non-IR region:

    ➢ $\pm$ 2 mm for injection (2 BPMs trigger)

    ➢ 1 mm for dump in all modes (15 BPMs trigger)

    ➢ 0.6 mm for dump in stable beams (15 BPMs trigger)

  ➢ In the IR (1+2+5+8): more complex because of specific conditions (VdM, low beta…)

➢ CODs settings checks is redundant with the PC interlock, will be replaced as soon as PC interlock is validated

  ➢ For injection, tolerance is 15 urad

  ➢ For dump logic, between 12 ad 20 urad, but have to exclude Xing, sep and lumi CODs due to large change during cycle

  ➢ Still masked to get more experience
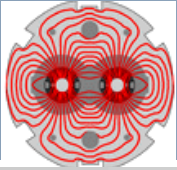
> QPS_OK signal is not reliable for the main circuits (signal flickering)

> As it is blocking injection, masked to be efficient for injection

> Risk to let it masked after injection and then interlock became useless

> New interlock introduced to cope with possible failure of the quench loop.

> Logic implemented and tested
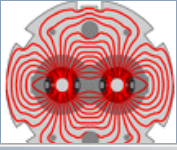
> No exporter yet (= no action): to be deployed and tested during TS1

Permits Tree

- P [AND] ABORT_GAP_CLEANING
- ❌ P [AND] INJ_B1_PERMIT
- ❌ P [AND] INJ_B2_PERMIT
- ❌ P [AND] INJ_PERMIT
- P [AND] POWERING_FPA_PERMITS
  - L [AND] RB_FPA_STATE
    - L [OR] RB12_FPA_STATE
      - ❌ | RB12_IN_SIMULATION
      - ❌ | RB12_LOW_CURRENT
      - L [AND] RB12_PIC_STATE
        - | RB12_PIC_ABORT_OK
        - | RB12_PIC_DISCHARGE_OK
    - L [OR] RB23_FPA_STATE
    - L [OR] RB34_FPA_STATE
    - L [OR] RB45_FPA_STATE
    - L [OR] RB56_FPA_STATE
    - L [OR] RB67_FPA_STATE
    - L [OR] RB78_FPA_STATE
    - L [OR] RB81_FPA_STATE
  - L [AND] RQD_FPA_STATE
    - L [OR] RQD12_FPA_STATE
    - L [OR] RQD23_FPA_STATE
    - L [OR] RQD34_FPA_STATE
    - L [OR] RQD45_FPA_STATE
    - L [OR] RQD56_FPA_STATE
    - L [OR] RQD67_FPA_STATE
    - L [OR] RQD78_FPA_STATE
    - L [OR] RQD81_FPA_STATE
  - L [AND] RQF_FPA_STATE
    - L [OR] RQF12_FPA_STATE
    - L [OR] RQF23_FPA_STATE
    - L [OR] RQF34_FPA_STATE
    - L [OR] RQF45_FPA_STATE
    - L [OR] RQF56_FPA_STATE
    - L [OR] RQF67_FPA_STATE
    - L [OR] RQF78_FPA_STATE
    - L [OR] RQF81_FPA_STATE
- P [AND] POWERING_PERMITS

➢ Based on Abort Gap monitor, request to activate the cleaning sent by SIS.

➢ not commissioned yet:

  ➢ no signal received,

  ➢ no device to act on.
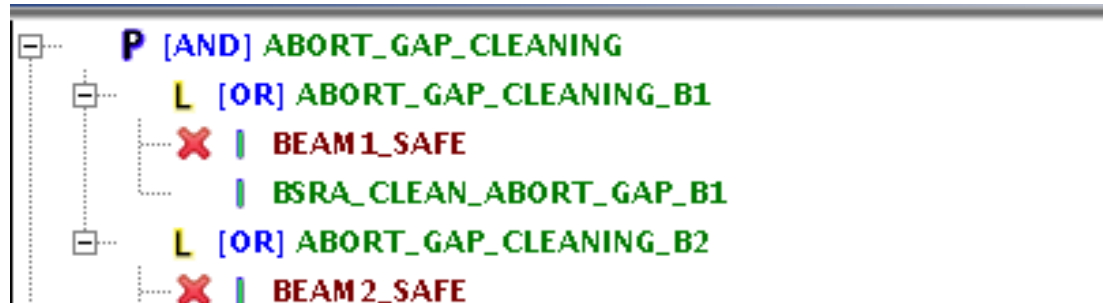
- 15 dumps caused by SIS in 2015:

  - 7 caused by TGM timeout problem

  - 4 caused by communication problem with BLM crate

  - 3 due to subscription problems: Safe Beam Flag "blocked" to false without beam in the machine, IT motors surveillance

  - 1 due to real interlock

    - IR6 BPM faulty channel triggered the TCS-beam offset interlock

    => Nothing related to intensity

> ## TGM timeout problem:

>> > Telegram signal is lost for long period (up to 25s) on SIS machine,

>> > Logic programmed such that after a programmed timeout, default energy value is 450GeV -> beam dump at 6.5 TeV by COD settings…

> > CO experts working on finding a solution, In the meantime, timeout has been increased and default energy value is set to 6.5 TeV .

> ## BLM-SIS communication problem:

>> > Some BLM crates (in pt 6 and 7) are becoming unstable, when additional readout are coming (UFO buster, XPOC, IQC..) 1 Hz readout data is blocked and SIS triggered

> > BI experts investigating, in the meantime, UFO buster disabled.
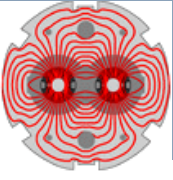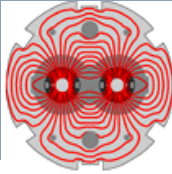
Real Time Feedbacks
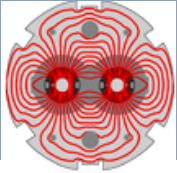
- ➢ Major refactoring of BFSU/OFC during LS1:
  - ➢ new machines, migration to FESA3, new developers
  - ➢ But functionalities not changed for the restart
  - ➢ Diagnostics improved

- ➢ Functionalities used/needed by operation:
  - ➢ On/Off of the FBs via sequencer or application
  - ➢ Loading of references and optics (= set to BFSU)
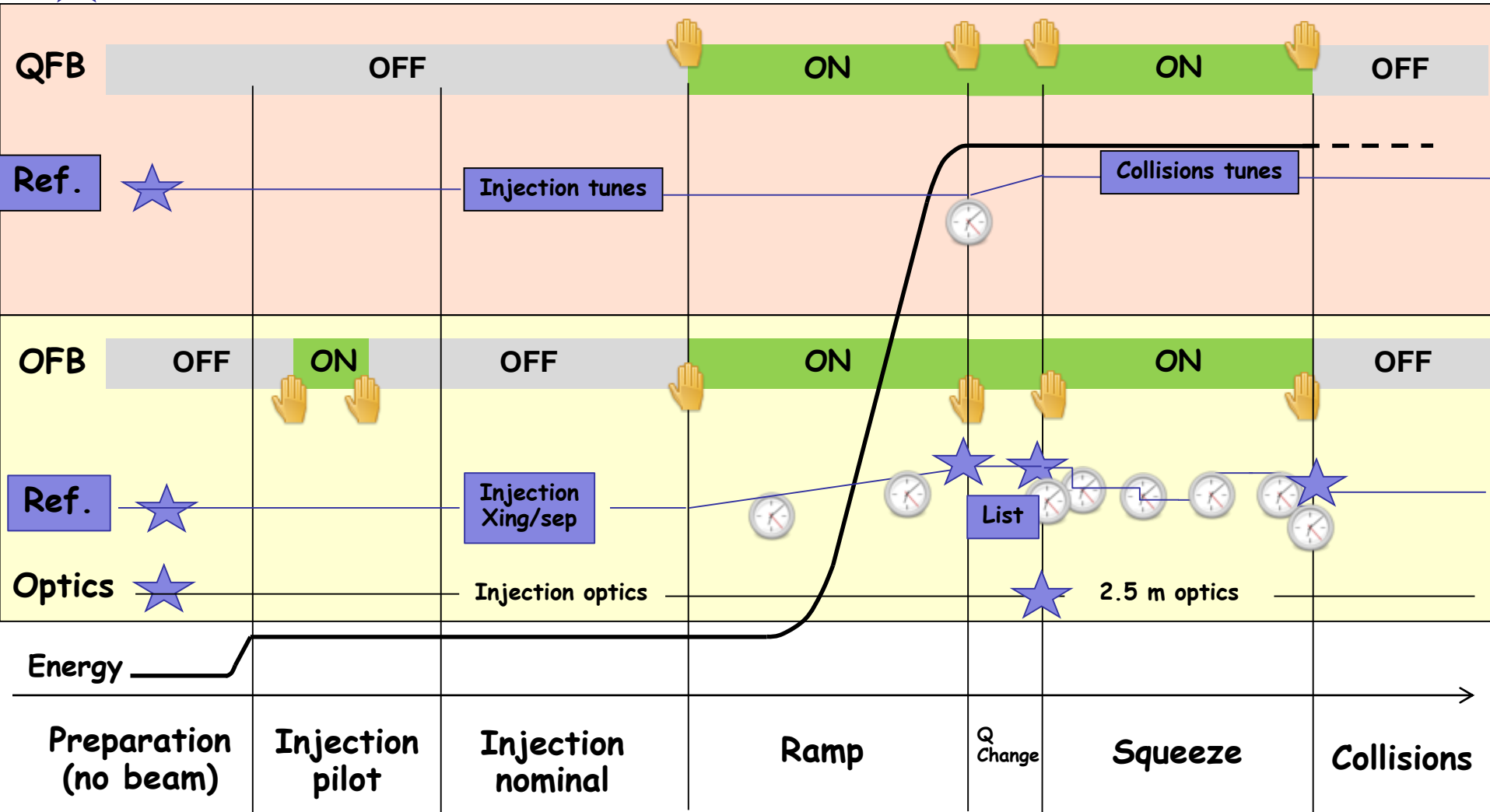 - ➢ Dynamic change of the references (ramp/Qchange/squeeze)

- ➢ "Expert" settings becoming operational (set via YASP and stored in LSA):
  - ➢ Eigen values, bandwith, gains
  - ➢ BPM status

- ➢ Both tune and orbit references set in 2 different properties of the BFSU class
  - ➢ Critical dependence on BFSU when timing is needed

- ➢ QFB:
  - ➢ Loosing the peak, coupling too large (automatic off), fake noise peaks…
  - ➢ Interference with transverse damper: time is needed top optimize the settings

- ➢ OFB:
  - ➢ Missed timing events to change references: critical in the ramp

- ➢ Dependence on FBs can be reduced with feed-forward of the real-time trims into the PC functions (for next fills).
  - ➢ High(er) survival probability when FBs switch off.

- ➢ The SVD matrix should in principle be recomputed for each optics:
  - ➢ Quite long process: Take between 1 and 2 minutes

- ➢ Dynamic change of the optics during the squeeze is implemented, never used in nominal operation:
  - ➢ Reduced list of optics to avoid crash of BFSU
  - ➢ Never tried the re-computation with feedback ON
  - ➢ Re-computation time versus squeeze segment length?

- ➢ Only used for squeeze in a discrete mode:
  - ➢ FB stopped, optics recomputed and sleep time before switching ON again


```
▽ 📁 LOAD REF ORBIT AND OPTICS FOR OFB
   ▷ 📁 SWITCH ORBIT AND ENERGY FB OFF
   ● calc ALL optics for the squeeze
   ● set active optic 2734 (2.5m)
   ● ARM REF ORBITS FOR THE SQUEEZE
   ● SET ACTIVE ORBIT INDEX 0
   ● SLEEP  5S
   ▷ 📁 SWITCH ON ORBIT AND ENERGY FEEDBACKS
```

- ➢ Needed during ramp and squeeze, following PC functions
- ➢ Settings stored in LSA and tasks executed by sequencer
- ➢ Linear interpolation between actual settings and requested settings over a time set by the task (*timeConstant)*
  - ➢ *BFSU is not playing a function*
- ➢ Changes triggered by timing events send to BFSU.

- ➢ Mechanics for tune feedback:

- ➢ All timing events for given BP are generated in the dynamic timing table which is played at the same time as the:
  - ➢ 11 events sent for the squeeze to 80 cm

OFB Control   示 ⊓ᵏ ⊠

Device : LHC.BFSU

| Control | Reference Orbit | BandWidth |

| Arm /Dis-arm OFB | Trigger / abort ref. change |

Time since last update	**1 seconds**
Last orbit upload @	**11/06/2015 17:24:15**
Is using measured orbit	**false**
Last event sent @	**11/06/2015 04:36:26**
Last event payload	**9999**
Time since last event (s)	**46074**
Current time constant (s)	1

Orbit List

| Ind		Time	Scaling	Info
0	164	0	1.000	0 – R2015–flat-top
1	1633	85	0.000	85 – R2015–lowbeta-900cm
2	1634	91	0.000	176 – R2015–lowbeta-700cm
3	163	122	0.000	298 – R2015–lowbeta-400cm
4	163	54	0.000	352 – R2015–lowbeta-300cm
5	1637	67	0.000	419 – R2015–lowbeta-250cm
6	1638	78	0.000	497 – R2015–lowbeta-200cm
7	1639	74	0.000	571 – R2015–lowbeta-150cm
8	1643	38	0.000	609 – R2015–lowbeta-120cm
9	1640	49	0.000	658 – R2015–lowbeta-100cm
10	1641	37	0.000	695 – R2015–lowbeta-90cm
11	1614	54	0.000	749 – R2015–lowbeta-80cm
12		0	0.000	

- ➢ Traced back to a configuration problem of the O/S in the processing of interrupts: 2 timing events were sen too close
- ➢ Several mitigation methods put in place after the events:
  - ▪ Configuration of the BFSU machine corrected
  - ▪ Introduced a delay between the timing event to changed the optics and the one to trigger the change of reference

- ➢ No more missing event observed since few weeks.

MTG tables	SELECTED MTG TABLE DETAILS			
rampdown injection BLM_capture_test **optics_orbit_changes** precycle Injection_BI	TABLE NAME (no space)	optics_orbit_changes		
	START EVENT	HX.START–TBL–CT (33) – Start table(s)		Set start Event
	RUN COUNT	–1		

EVENT NAME	PAYLOAD	OFFSET (ms)	EVENT DESCRIPTION
HX.FBOREF–CT	1	0	Start Orbit Feedback reference change
HX.SIS–SSQU–CT	283	0	Start SQUEEZE for PC intlck
HX.OPTID–CT	2727	500	Optics Identifier
HX.FBOREF–CT	2	65000	Start Orbit Feedback reference change
HX.OPTID–CT	2770	65500	Optics Identifier
HX.FBOREF–CT	3	108000	Start Orbit Feedback reference change
HX.OPTID–CT	2768	108500	Optics Identifier

- ➢ Not a feedback issue, but efficient tune feedback need good tune measurement quality
- ➢ 2 different problems: Saturation and S/N ratio
  - ➢ Saturation = peak disappearing
    - – Fixed in 2012: Device sensitivity adapted for high bunch intensity (2 different devices for pilot and nominal bunches
    - – Saturation observed during LHCf physics, to be checked during TS
  - ➢ Bad S/N ratio: multiple peaks
    - – BBQ vs ADT settings
    - + co-existence with abort gap cleaning?

=> In 2012, after feed-forward during commissioning phase, Tune Feedback left OFF during squeeze and if stopping in the ramp.

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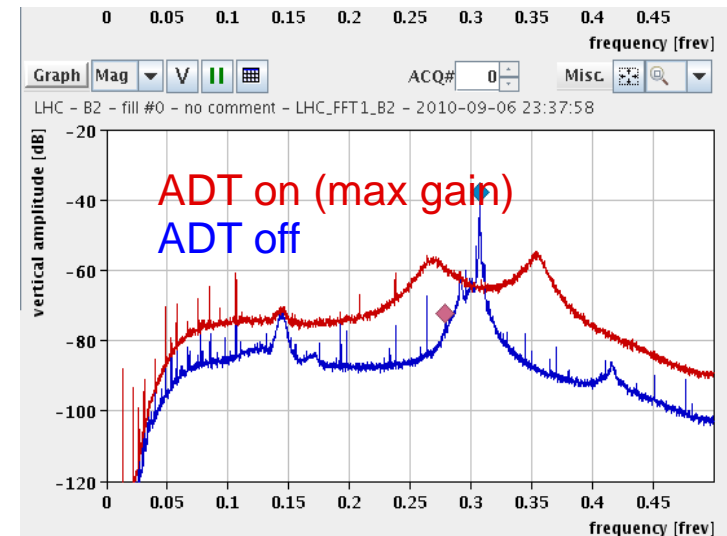
➢ SIS logic ready for intensity ramp-up, but still controls problem to be consolidated.

➢ Feedbacks are crucial for operation

➢ Worked very well most of the time with some exceptions when dynamic change of references is needed:

    ➢ Gymnastics with the sequencer tasks

    ➢ Consolidated during commissioning, working well now

➢ Need a bit of beam time to optimize settings