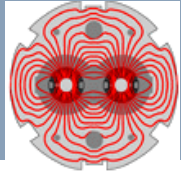
Operational Issues

L. Ponce

Outline

- Operational use of the feedbacks
  - OP needs
  - Feedbacks statuses during a cycle
  - Central role of the OFSU
- A bit of statistics
- Main issues with Tune feedbacks:
  - problems
  - solutions
- Main issues with Orbit feedback
  - Description of the problem

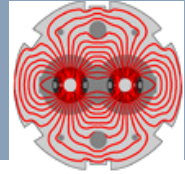
Interface with Operation

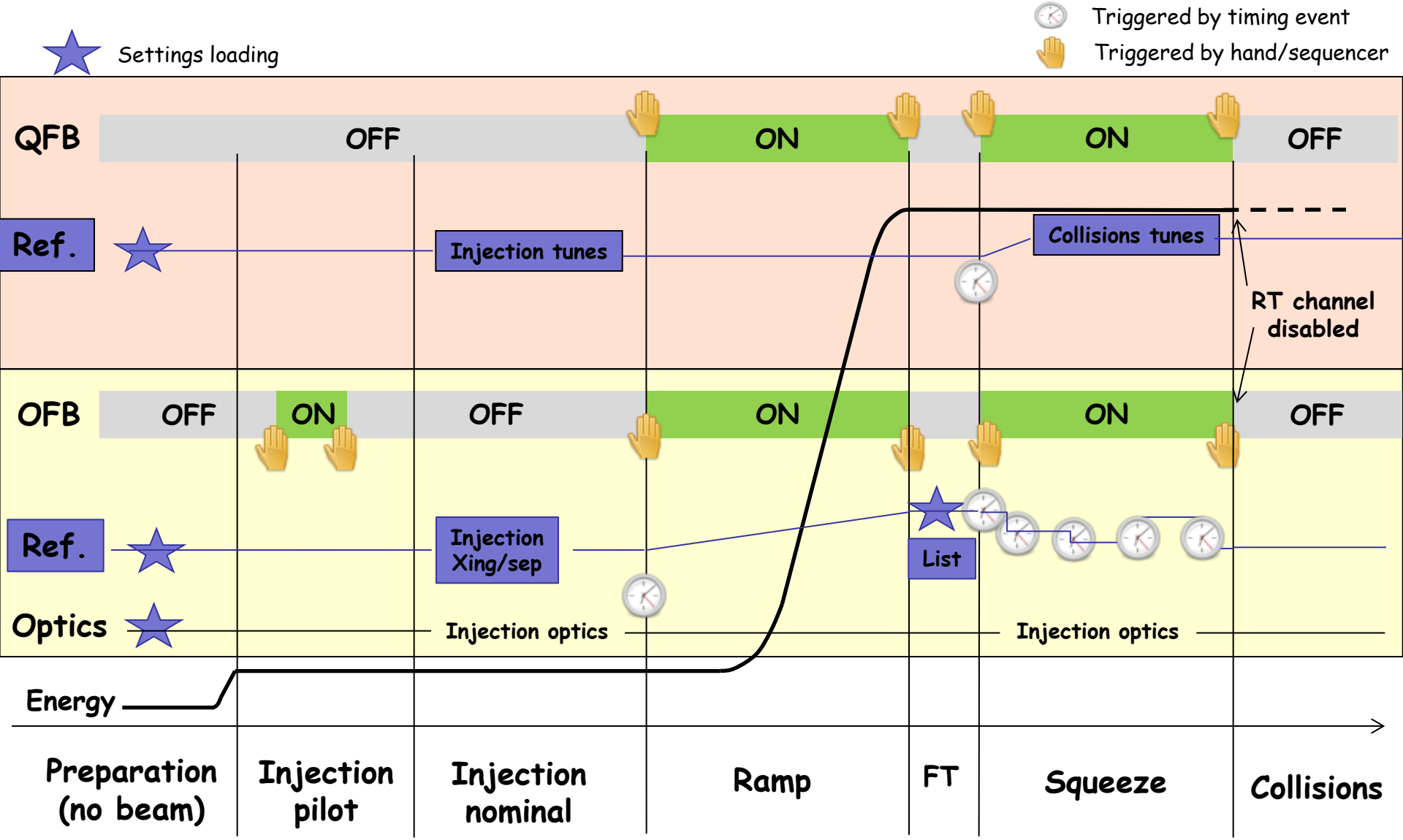


- Functionalities used/needed by operation:
  - On/Off of the FBs via sequencer or application
  - Loading of references and optics (= set to OFSU)
  - Dynamic change of the references (ramp/squeeze)
  - (Wreboot)
- “Expert” settings (via YASP):
  - Eigen values
  - BPM status
- Other parameters (bandwith, gain) in “specialized” properties, not accessible for OP.

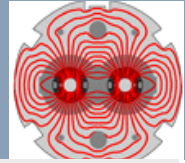
- Both tune and orbit references set in 2 different properties of the OFSU class
  - Critical dependence on OFSU when timing is needed

Feedbacks during LHC cycle





Sequencer tasks



PREPARE FEEDBACKS FOR INJECTION

- PREPARE FEEDBACKS FOR INJECTION
  - SET FEEDBACK OFSU PRO
  - CHECK FEEDBACK STATE ORBIT OFF
  - DISARM FEEDBACKS
  - RESET TIME CONSTANT FOR FBS
  - FETCH ALL OPTICS TO OFSU
  - SET OPTICS OPERATION MODE MANUAL
  - DRIVE INJECTION SETTINGS FOR OFB
    - MAKE LHC.USER.INJECTION RESIDENT
    - LOAD INJECTION REF ORBIT FOR OFB
    - SET ACTIVE ORBIT INDEX
    - CALC ACTIVE BEAM PROCESS OPTIC IGNORE
    - SET ACTIVE BEAM PROCESS OPTICS TO OFC
  - DRIVE TUNE FB SETTINGS FOR INJECTION
    - SWITCH FEEDBACK STATE TUNE_B1 OFF
    - SWITCH FEEDBACK STATE TUNE_B2 OFF
    - MAKE LHC.USER.INJECTION RESIDENT
    - LOAD FEEDBACK INJECTION SETTINGS
    - LOAD TUNE FITTER SETTINGS B1
    - LOAD TUNE FITTER SETTINGS B2
    - LOAD TUNE FITTER SETTINGS B2 (FFT3)
    - LOAD TUNE FITTER SETTINGS B1 (FFT3)
    - LOAD TUNE FITTER SETTINGS B2 (FFT1)
    - LOAD TUNE FITTER SETTINGS B1 (FFT1)
  - SELECT QFB DEVICE FOR PILOT

PREPARE RAMP

- PREPARE RAMP
  - PREPARE OFB SETTINGS WHILE FILLING
  - ENABLE POST MORTEM EVENTS
  - FORCE SBF TO FALSE
  - SWITCH OFF ABORT GAP CLEANING
  - RF CHECKS: WATCHDOG&FREQ B1/B2 LINKED
  - DISABLING INJECTION AND INJ COLL OUT
  - DISABLE INJECTION CLEANING
  - HANDSHAKE END OF INJ - SM&BM = PREPARE RAMP
  - STOP FIDEL TRIMMING
  - CALCULATE FIDEL RAMP CORRECTIONS
  - SWITCH ON AND ARM OFB
    - SWITCH ON ORBIT AND ENERGY FEEDBACKS
    - ARM ORBIT FEEDBACKS
      - LOAD RAMP OPTICS ORBIT CHANGE TABLE
      - ARM OFB REF ORBIT CHANGE
  - INCORPORATE INJECTION TRIMS INTO THE RAMP
  - TRIM ADT NORMALIZED GAINS TO RAMP VALUES
  - LOAD ADTDSPU BUNCH MASK FOR RAMP
  - SWITCH ON BBQ BUNCH GATING
  - CHECK TUNE FEEDBACK CONFIGURATION
  - SWITCH TUNE FB ON
  - MAKE LHC USER FIDEL RESIDENT
  - MAKE LHC.USER.RAMP RESIDENT
  - LOAD RAMP SETTINGS IN PC&RF FGC
  - ARM LONGITUDINAL BLOW-UP
  - LOAD CLEANING & DUMP PROTEC COLL RAMP SETTINGS
  - CHECK INJ-PROT OUT COLL INTERLOCKED OUT
  - END SUBSEQUENCE BREAK

SQUEEZE TO 0.6M 2012

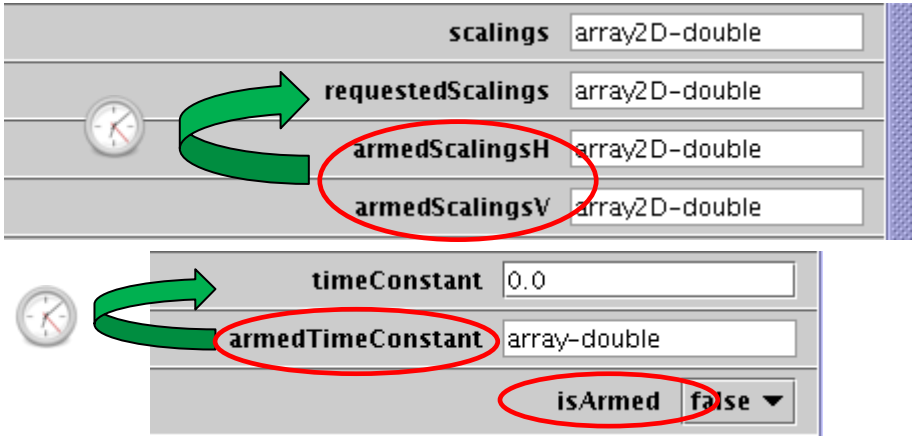
- SQUEEZE TO 0.6M 2012
  - SWITCH OFF TUNE FB
  - SWITCH OFF BBQ BUNCH GATING
  - ADT LOAD WIDEBAND SETTINGS
  - INCORPORATION INTO SQUEEZE BP AND LOAD TABLE
  - LOAD SQUEEZE FUNCTIONS FOR TCT COLL IN IP1/5/8
  - LOAD SQUEEZE FUNC FOR ADT GAINS AND PHASE_SHIFT
  - LOAD ADTDSPU BUNCH MASK FOR SQUEEZE
  - DRIVE SQUEEZE IN 1 STEP WITH QFB ON
    - SET SQUEEZE SEGMENT 0-> 925S
    - SET USER FOR BP REGENERATION AT 925 S
    - PREPARE OFB FOR SQUEEZE
      - SWITCH ORBIT AND ENERGY FB OFF
        - ARM REF ORBITS FOR THE SQUEEZE
        - SET ACTIVE ORBIT INDEX 0
        - CHECK ref orbit for squeeze
        - INFO: CHECK REFERENCE ORBIT CORRECTLY LOADED
        - LOAD ORBIT AND OPTICS TABLE CHANGE FOR SQUEEZE
        - ARM OFB REF ORBIT CHANGE
        - SLEEP 5S
      - SWITCH ON ORBIT AND ENERGY FEEDBACKS
    - PREPARE TUNE FB FOR SQUEEZE
    - LOAD SQUEEZE 2011 PC TABLES SEGMENT
    - CHECK FEEDBACKS ARMED
    - CHECK CHIRP AND OFB OFF
    - MOVE STATE/BEAM_MODE = SQUEEZE
    - SEND START TBL (33) EVT

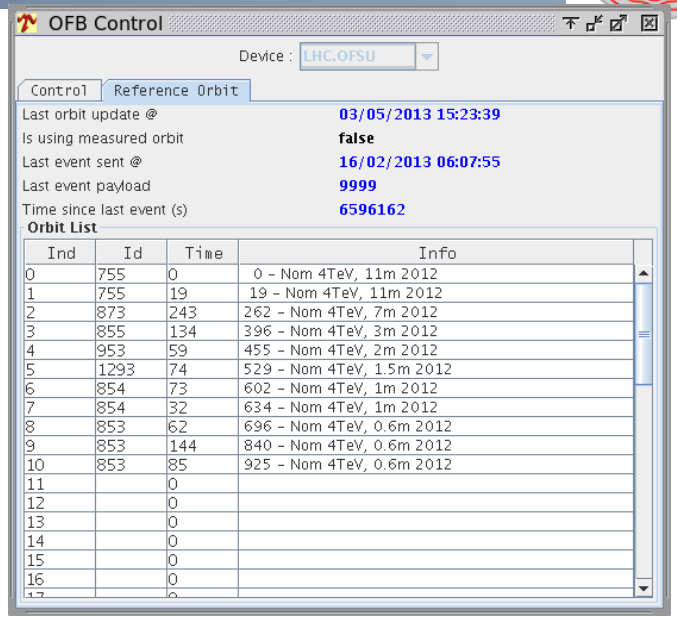
PREPARE OFB SETTINGS WHILE FILLING

- PREPARE OFB SETTINGS WHILE FILLING
  - CHECK BEAMS PRESENCE=TRUE
  - CALC ACTIVE OPTIC FOR ACTUAL BP
  - SET ACTIVE BEAM PROCESS OPTICS TO OFC
  - SET AND LOAD REF ORBITS FOR THE RAMP
  - CHECK ref orbit for ramp
  - INFO: CHECK REFERENCE ORBIT CORRECTLY LOADED

OFB: Reference change

(see Kajetan's presentation)

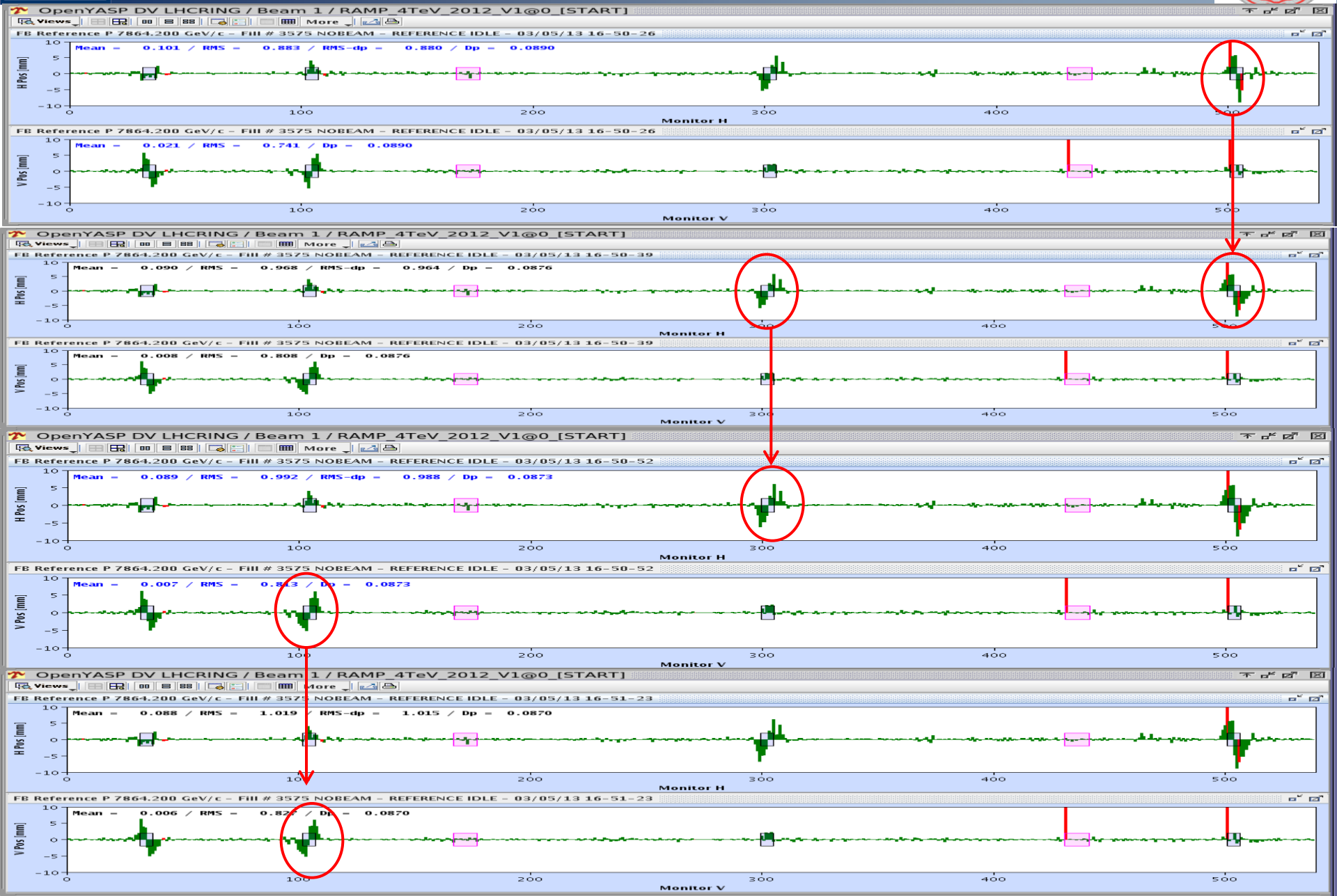




Ind	Id	Time	Info
0	755	0	0 - Nom 4TeV, 11m 2012
1	755	19	19 - Nom 4TeV, 11m 2012
2	873	243	262 - Nom 4TeV, 7m 2012
3	855	134	396 - Nom 4TeV, 3m 2012
4	953	59	455 - Nom 4TeV, 2m 2012
5	1293	74	529 - Nom 4TeV, 1.5m 2012
6	854	73	602 - Nom 4TeV, 1m 2012
7	854	32	634 - Nom 4TeV, 1m 2012
8	853	62	696 - Nom 4TeV, 0.6m 2012
9	853	144	840 - Nom 4TeV, 0.6m 2012
10	853	85	925 - Nom 4TeV, 0.6m 2012
11		0	
12		0	
13		0	
14		0	
15		0	
16		0	

- Orbit reference is a sum of a base orbit and bumps
- Timing event sent to OFSU: OFC woke up by OFSU
- Bumps amplitude change during the ramp:
  - Settings loaded in *armed* field
  - Copy triggered by timing event in *requested* field
  - Change played over the *timeConstant* time
- Bumps shape change in several points during the squeeze
  - List of reference orbits loaded at the beginning of BP
  - Each change triggered by timing event with index as payload
  - Payload 9999 used to "disarm"

Example of OFB references change

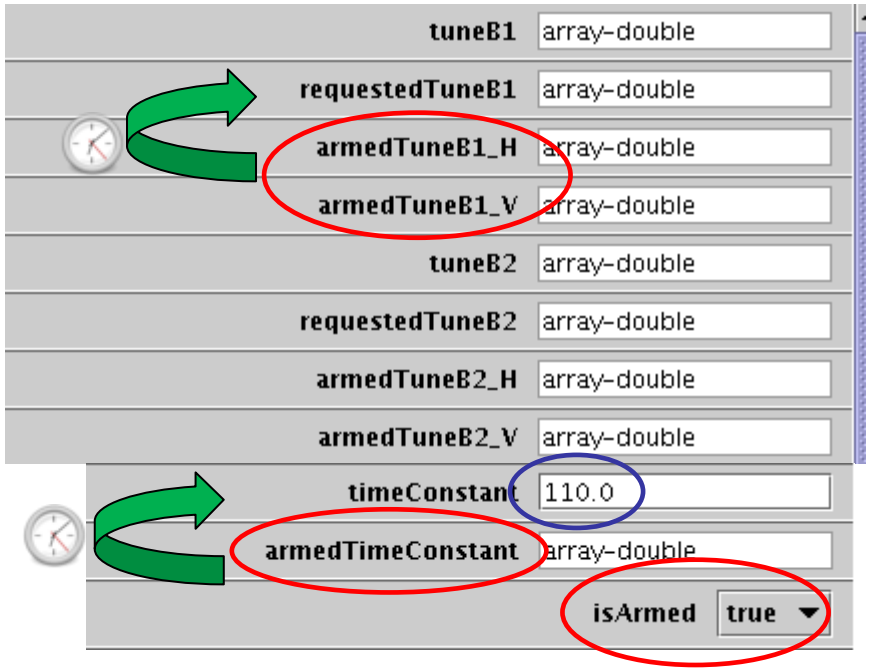


Change of reference

- 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)*
  - *Not playing a function*
- Triggered by timing event send to OFSU.

- Mechanics for tune feedback:

- Set to the *armedXXX* fields before playing the Beam Process
- Arming = set the field *isArmed* to true
- Dedicated Timing event to trigger feedback included in the start table
- When timing event received, *armedXX*" field is copied into the corresponding *requestedXXX field*



Some statistics

- 43 beam dumps flagged “feedbacks issue”

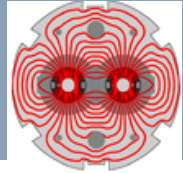
RF mod	Orbit FB		Tune FB	
2010	2010-2011	2012-2013	2011	2012
1	7	15	18 (++)	1

++ more fills lost, not flagged FB issues

- Distribution by beam mode:

Beam mode	OFB	QFB	total
INJECTION PROBE/ PHYSICS	2/1	2/0	1123
PREPARE RAMP/RAMP	1/7	0/5	676
FLAT TOP	3	0	153
SQUEEZE	10	13	205
ADJUST	2	0	327

Main issues with Tune FB

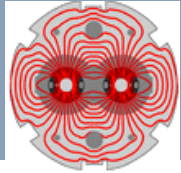


- 3 main causes:
  - Triggering of trim quadrupoles (RQTF/D) QPS
  - Issues with references received by FB controller
    - Dynamic change not triggered
  - Instabilities of the tune measurement:
    - Tune FB driving tunes to third order resonance (beam dumped by BLM) during the squeeze
- Large majority of the dumps due to QPS trips:

	Number	% of the total
QPS triggering (+)	23	69
Wrong references	5	14
Instabilities	6	15

(+) PM flagged to QPS faults included

Trip of QPS

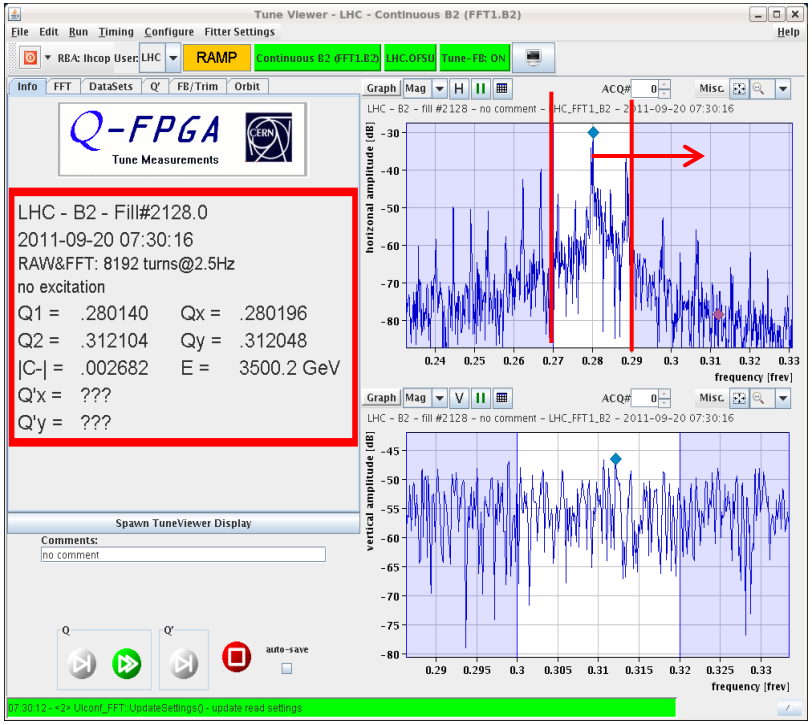


- Due to high rate and oscillating corrections, inductive voltage increasing above threshold, triggering the QPS on trim quadrupoles.
- For 4 TeV operation, QPS thresholds have been relaxed with a HW limitation at 200A
  - No more dumps in 2012
- Solution on QPS side under investigation for 7 TeV operation
- Second solution: reduce the “noise” introduced by RT trims
  - Tune FB response bandwidth could be reduced especially after Feed Forward
  - High gain was motivated by initial specification of keeping dQ<0.001 => could it be relaxed?

Dynamic ref change not triggered

- Problem at the beginning of the squeeze when working point is changed
- What happened, 3 different cases:
  1. Time constant not correct (OFSU+BQBBQ)
  2. Tune Fitter Windows not following the reference tune value (BQBBQ)
  3. Wrong reference

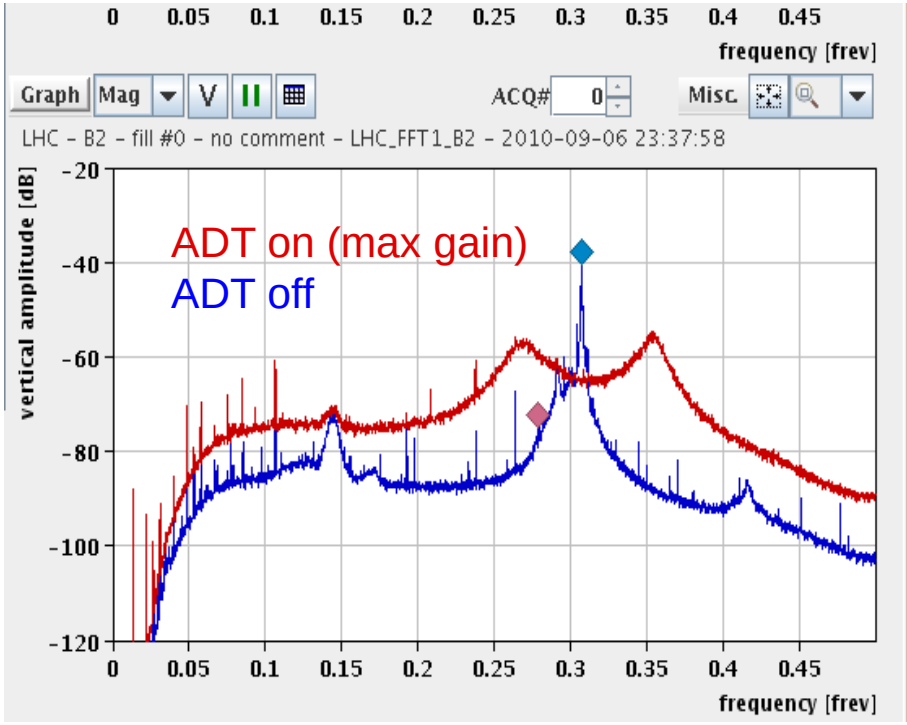
- Consequences:
  - Tune peak signal outside the detection windows
  - Wrong corrections applied and tune pushed towards resonances => beams dumped by Beam Loss System
- Reason:
  - In few occasions, wrong settings after copying hypercycle
  - Thread concurrency issues
  - Communication problem?



Tune measurement quality

- Not a feedback issue, but efficient tune feedback need good tune measurement quality
- 2 different problems: Saturation and S/N ratio

- Saturation = peak disappearing
  - In 2012: Device sensitivity adapted for high bunch intensity
  - Pb: 2 different devices for pilot and high intensity bunch
- Bad S/N ratio: multiple peaks
  - BBQ vs ADT settings
  - Still a problem even with CHIRP/gating



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

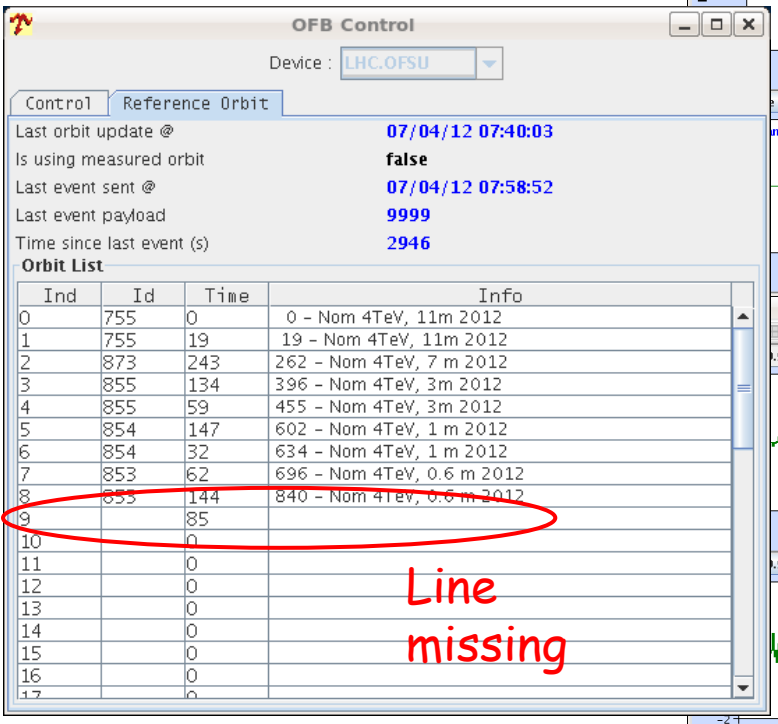
Main issues with Orbit FB

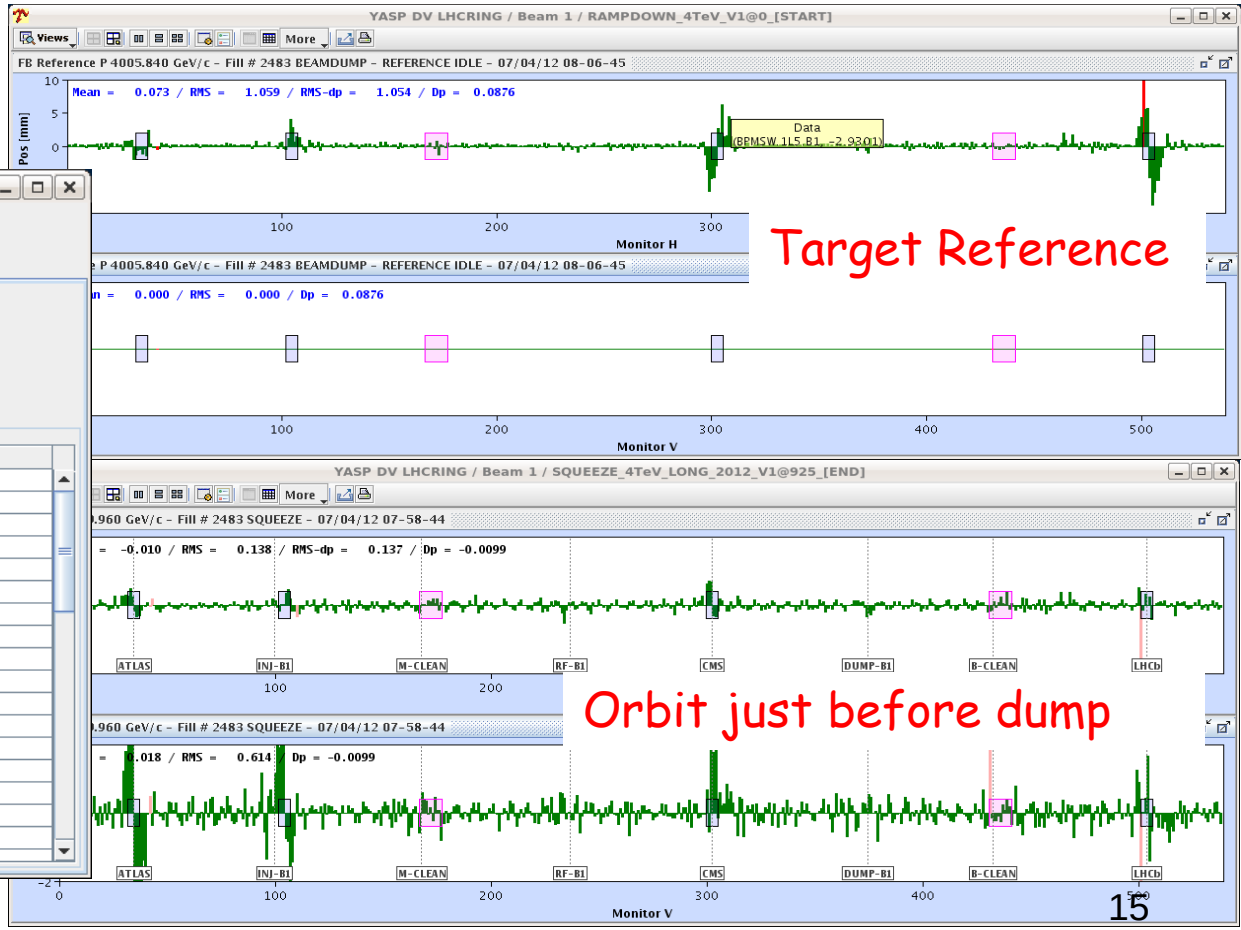
DUMP REASON	NUMBER	BEAM MODE
Communication problems	12	RAMP/SQUEEZE/SB
Special settings test (high gain, single beams, ATS, MD)	5	RAMP/SQUEEZE
Disabled BPM used	3	INJECTION/ADJUST
Diverging orbit	3	INJ/RAMP/SQUEEZE
Total	23	

- Beams dumped mainly due to communication with OFSU or crash OFSU/OFC
- Several problems (rare) appeared at non critical period (injection or collisions) when feedback is OFF or in “constant” mode

Loss of orbit references

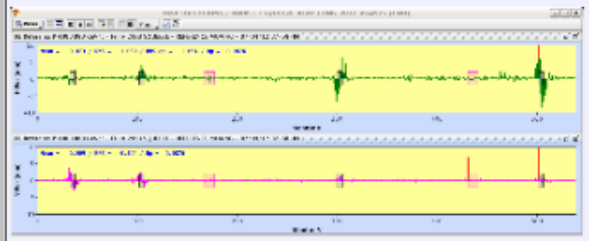
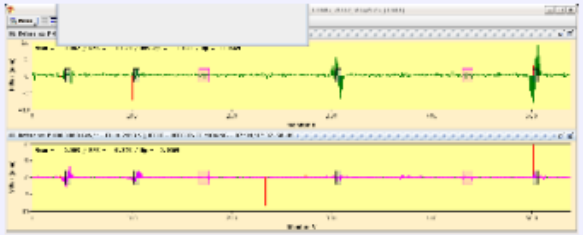
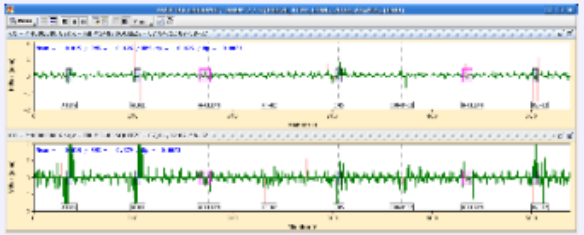
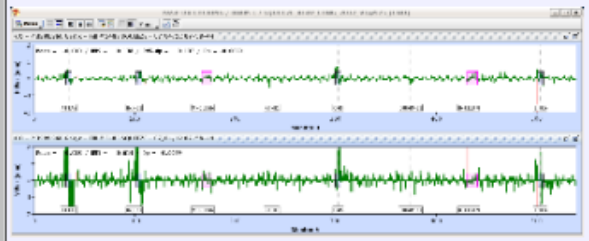
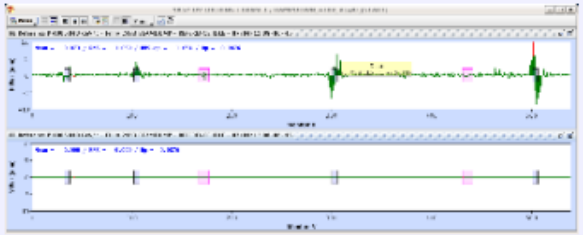
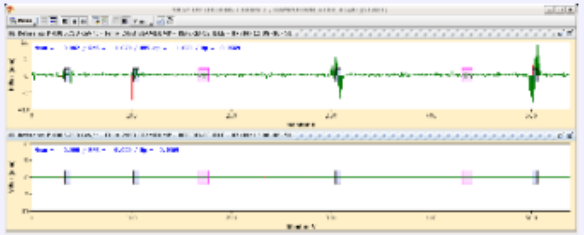
- Different symptoms mainly in 2012:
  - Zeroing of the reference during the squeeze
  - Time constant lost
  - One reference missing in the list





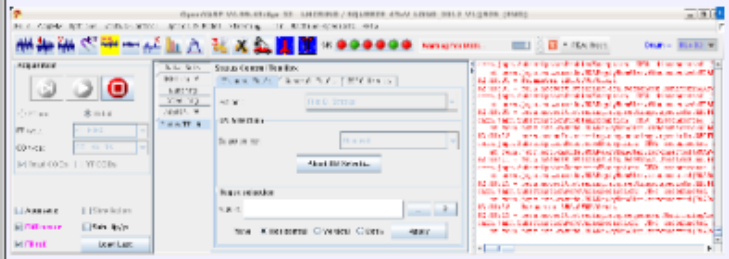
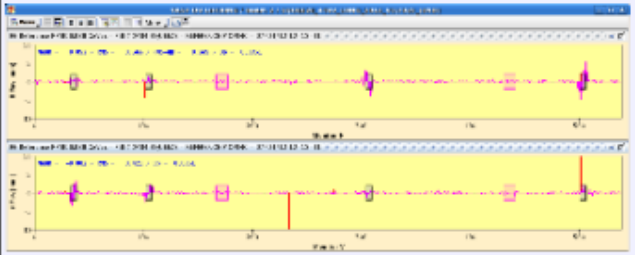
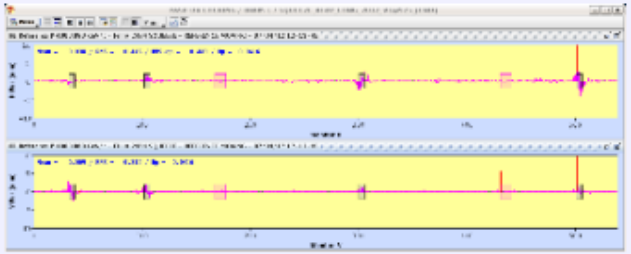
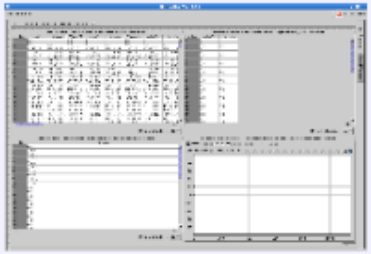
“Bloody Saturday”

- Several events occurred in the same shift…
  - One plane of the reference is sent to zero

12	07:57	NB	we again lost the reference orbit which went to zero in V!!!! just had the time to switch off FB before the SIS interlock dumped the beams.  20120407075805.png  20120407075810.png  20120407075838.png  20120407075845.png  20120407080646.png  20120407080652.png created by lh
13	07:58	NB	Global Post Mortem Event Event Timestamp: 07/04/12 07:58:53.021 Fill Number: 2483 Accelerator / beam mode: PROTON PHYSICS / SQUEEZE Energy: 3999960 [MeV] Intensity B1/B2: 3609 / 3587 [e^10 charges] Event Category / Classification: PROTECTION_DUMP / MULTIPLE_SYSTEM_DUMP First BIC input Triggered: First USR_PERMIT change: SW Permit: A T -> F on CIB.CCR.LHC.B1 created by c
14	07:58	NB	Global Post Mortem Event Confirmation Dump Classification: Feedback issue Operator / Comment: lponce / reference orbit set to zero in V plane in the last step of the squeeze, new SIS interlock triggered created by c

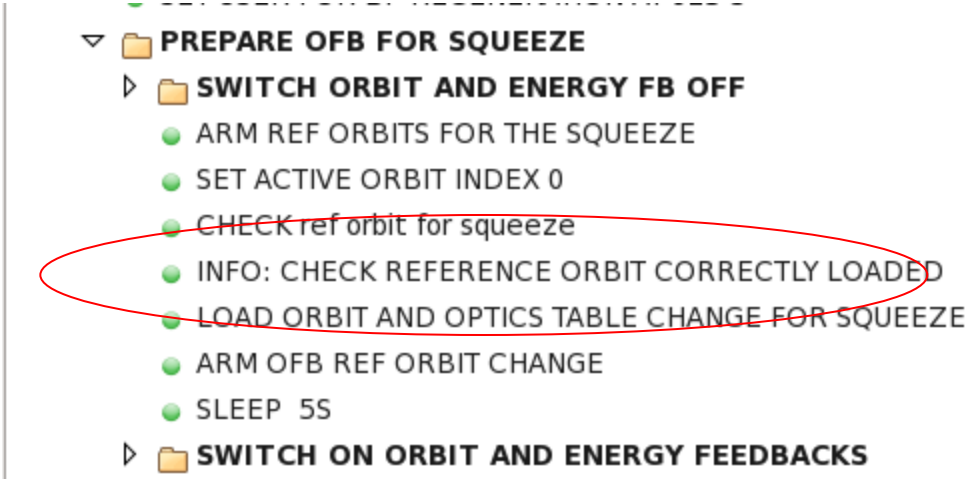
“Bloody Saturday”

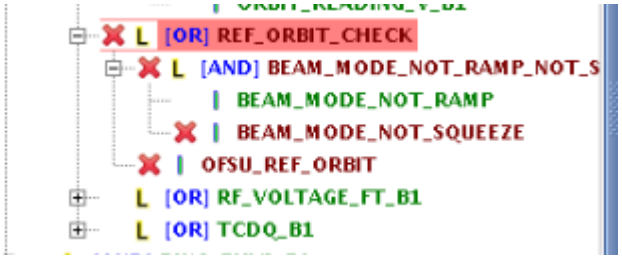
- 2 hours later: Non persistency of some settings after a crash

66	12:10	NB	OFSU crashed during the squeeze. It reconnected with the correct reference orbit, but was disarmed. We rearmed it and cross finger taht it will take the next reference change  20120407121050.png
67	12:13	NB	it did take a reference but with zero scalings, beams dumped by SIS  20120407121342.png  20120407121350.png  20120407121515.png  20120407122441.png  20120407123322.png
			Global Post Mortem Event Event Timestamp: 07/04/12 12:13:39.047 Fill Number: 2484

Loss of orbit references

- Several mitigation methods put in place after the events:
  - SIS interlock to dump in case of OFSU crash
  - Check tasks added all along the cycle
  - Systematic wreboot of the OFSU before every fill (temporary during time to find some memory leaks)
- Generating another black week-end when un-necessary dumps occurred because of OFSU crash after the dynamic change but still in bad machine mode

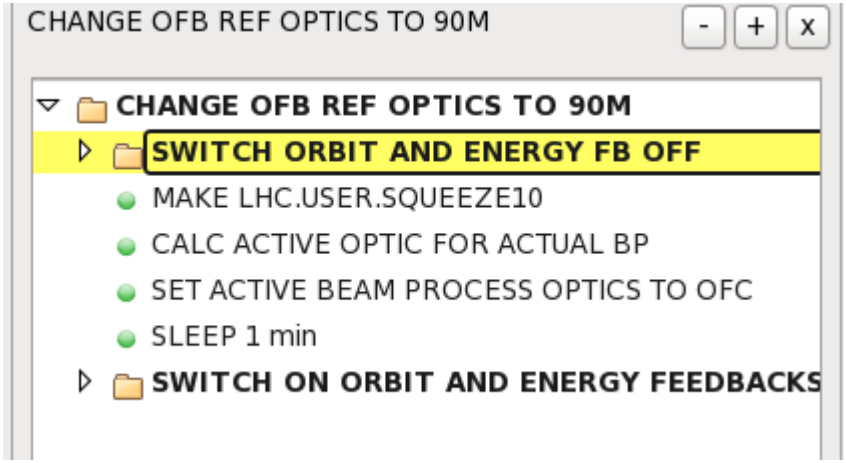




Change of Optics

- The SVD matrix should be recomputed for each optics
- Dynamic change of the optics during the squeeze is implemented, never used in nominal operation:
  - Reduced list of optics to avoid crash of OFSU
  - Never tried the re-computation with feedback ON
  - Re-computation time versus squeeze segment length?

- Only used for ATS and High beta in a discrete mode:
  - FB stopped, optics recomputed and sleep time

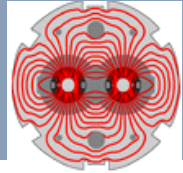


Miscellaneous

- List of non critical problems (no dumps), but still not fully understood
  - Problem of matrix computation:
    - Triggering of the re-computation when changing BPM status sometimes not working
  - Slow convergence of the feedback at injection
    - Up to 2 min
  - OFB using disabled BPM -> orbit divergence

- Lack of diagnostics to analyze the problems (logging of the actual reference, access to the computed matrix…)

Conclusions



- Feedbacks are crucial for operation
- Worked very well most of the time
- With some exceptions when dynamic change of references is needed:
  - Communication problems
  - OFSU crashes
- Gymnastics with the sequencer tasks and SIS to try to catch communication problems before the critical time in the beam cycle.
- If we subtract QPS trips and communication issues from statistics, we are left with 11 dumps over 3 years