Operational availability Optimizing LHC

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With the (un)intentiona lcontribution of all OP crew

What do I call “Operational availability”?

“*everything which is not an equipment fault*“

- It includes:
  - dumps due to exceeded thresholds
  - Hidden effects (no PM, no fault):
    - set-up time
    - “Cooling” time
  - mistakes (expert/OP)

- Not discussed today:
  - Cycle or sequence optimization (ramp/squeeze…)

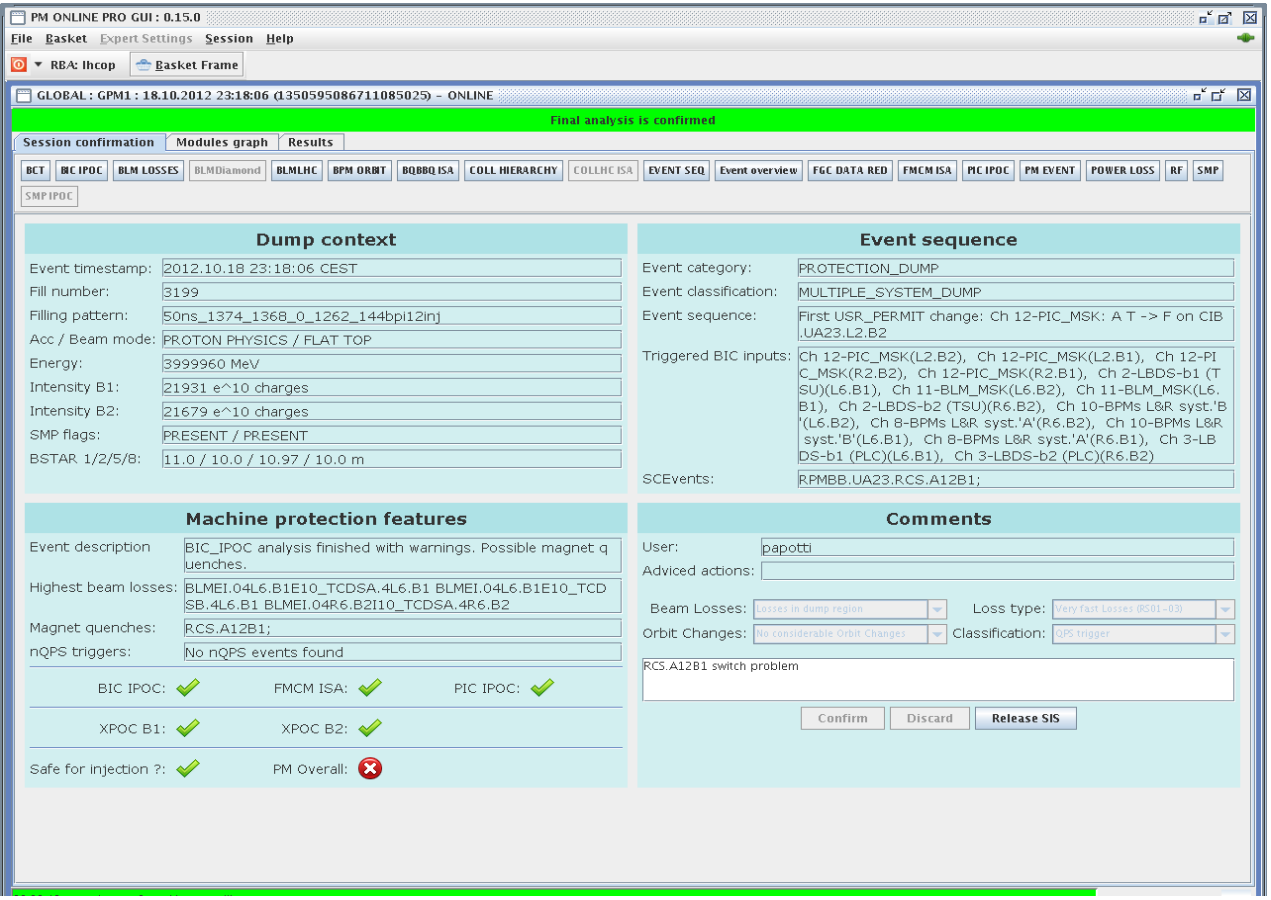
Contents

- What dumped the beams (other than a trip)?
  - From the Post Mortem files
  - Disentangle the dump causes which just need a restart
- What cost extra time in the cycle?
  - From the OP e-logbook
  - Try to find what is not the nominal preparation time

Source of data

Post Mortem server:

- 1 PM file for every dump
- All PM files signed (= commented) by operator
- All PM above injection energy analyzed by MPP



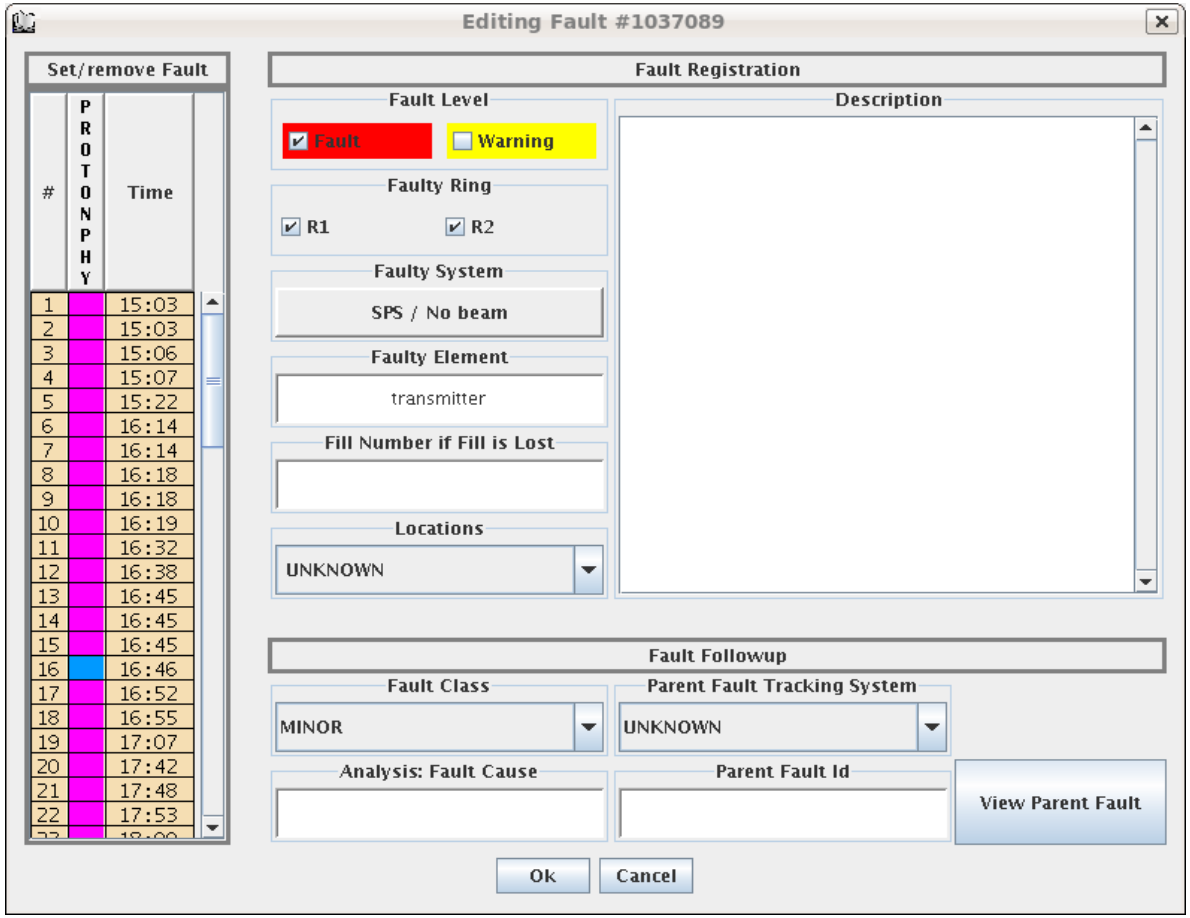
List of predefined cause:

- Access
- Coll
- Losses
- Transverse instabilities
- QPS
- Programmed dump
- Other
- ...

Source of data

OP e-logbook:

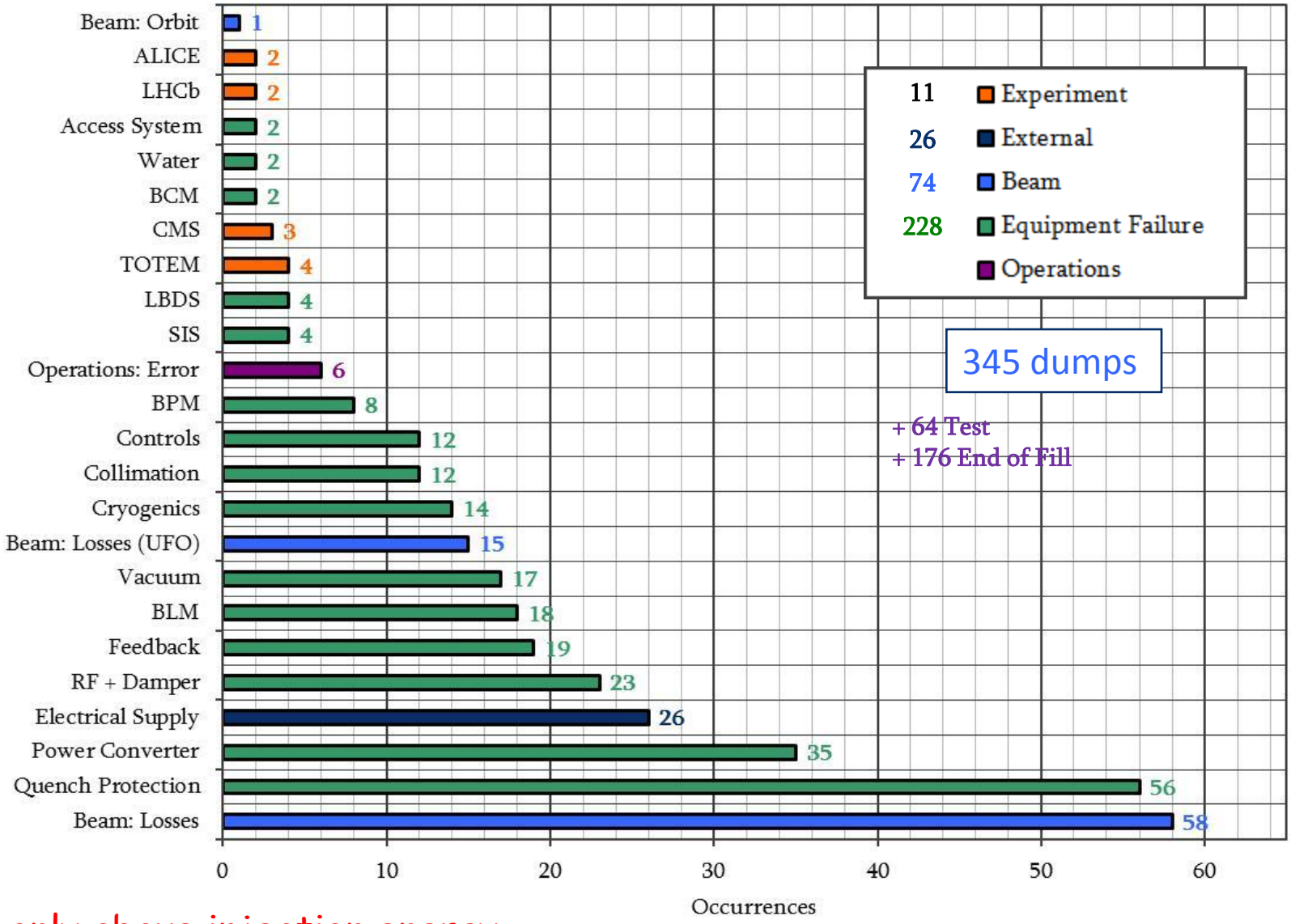
- Manual entry for each fault (= 1 line)
- Manual entry for start and end time



Also list of predefined faulty system, but different:

- Beam Instr.
- Coll
- Controls
- Cryo
- Injection
- QPS
- RF
- SPS
- PS
- Technical services
- Vacuum
- ...

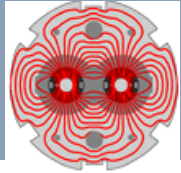
Post Mortem : Dump Cause – 2012



only above injection energy

B. Todd @ LHC Beam Operation Workshop Evian 2012

Different numbers from PM



All PM from 2012 classified by hand:

- 870 = Total number of PM from 1st of March till 6th of December
- Category based on OP comment

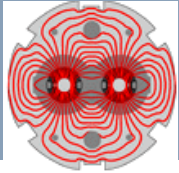
PM category		
End Of Fill	97	11%
HW fault	326	37.5%
threshold	252	30%
Expert/OP errors	70	8%
MPS test	125	14%
Total	**870**	

Threshold = BPM, BLM, AG thresholds or SIS limits exceeded (whatever are the running conditions)

=> *Can restart without repair*

- Potential high gain if we manage to decrease the occurrences

Details by system

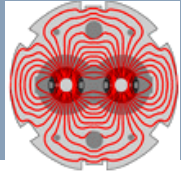


Looking at the occurrences only (EOF and test excluded = 135 dumps)

Dumps cause	Total 2012	HW*	Thresholds*	Errors*
Beam losses + UFO	58+15	0	58+15	0
QPS	56	56	0	0
PC	35	35	0	0
Electrical Supply + Water	26+2	26+2	0	0
RF + damper	23	21	2	0
Feedback	20	15	4	0
Vacuum	17	8	9	0
BLM	18	17	1	0
Cryogenics	14	14	0	0
Collimation	12	5	2	5
Controls	12	12	0	0
BPM	8	3	5	0
SIS + orbit	4	2	2	0
Exp	10	3	5	2
BCM	13	2	11	0
Access System	2	2	0	0
Not specified in PM server	381	98	139	56

Purely “dynamic”
Purely HW
Mixed

Details “thresholds exceeded”



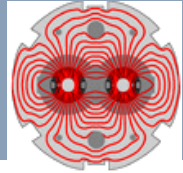
- Including the dumps at injection:

Dumps cause	Only above injection	All dumps
Beam losses + UFO	58+15	74+16
RF + damper (inc. setting-up)	2	7
Feedback	4	4
Vacuum	9	14
BLM	1	1
Collimation (inc. TDI)	2	8
BPM	5	60
Orbit	1	6
Exp	5	5
BCM	11	13
OP	1	2
Test and development	8	8
Injection quality (BLM/BPM)	0	24
Set-up	0	9

Significant contribution:

- from UFO and losses above BLM thresholds
- from BPM “false trigger” at injection)
- from injection “quality” (first input =BPM or BLM or Orbit)

Possible gain?



- Even if dumps at injection energy are faster to recover, still could easily gain 30min (PM signature + recovery sequence, back to pilot…)

- How can we reduce the number of dumps?
  - BPM setting-up for each new type of beam
  - Better preparation for beam set-up/MD
  - revisiting BLM thresholds: UFO and BLM working groups)?

- But we already relaxed/adjusted thresholds in 2012

Closer look at fault duration

- The goal was to try to understand the components of the average turn-around time to be able to extrapolate for higher energy run
  - What is the precycle contribution, what are the “hidden” downtime?
- Source of data is the OP e-logbook fault entries (manual)
  - E-logbook is first a track of OP facts and actions
- With the statistics tool:

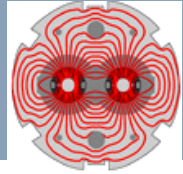
Statistics for the eLogbook: LHC OP From: 20120301 calendar Period: Morning To: 20121206 calendar Period: Morning

Start Statistics ...

Availabilities			
Lines	**In Super Cycle**	**In Fault**	**Availabilities (%)**
CHECKOUT	25 [min] 33[s]	30 [s]	98%
ACCESS	628 [h] 59 [min] 51[s]	159 [h] 06 [min] 16[s]	74%
BeamSetup	1412 [h] 17 [min] 27[s]	216 [h] 24 [min] 37[s]	84%
PROTONPHY	4060 [h] 31 [min] 56[s]	945 [h] 33 [min] 12[s]	76%
MD	366 [h] 35 [min] 41[s]	46 [h] 10 [min] 06[s]	87%
ProtNucPhy	92 [h] 58 [min] 48[s]	50 [h] 31 [min] 02[s]	45%
TOTAL	**6561 [h] 49 [min] 16[s]**	**1417 [h] 45 [min] 43[s]**	**78%**

- Inconsistent data, not really satisfactory

Faults in the e-logbook



- Some numbers :
  - 515 entries (all manual for LHC) in Beam Setup, MD or Proton Physics machine mode subtracting injectors problems.
  - Only 182 are related to an automatic PM entry
    - To be compared with the 648 PM unprogrammed entries
  - 169 are followed by a precycle (fixed time)
  - 191 needed an access to fix the problem

- Precycle give a fix extra duration in the turn-around
- Frequency of access also linked with the precycle number

  - Far from complete picture of what happened

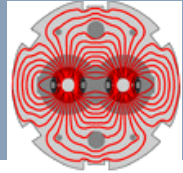
Problem in the data

- Definition of a “fault” for the machines = period without beam (automatic entries based on BCT data for SPS)
  - Does not work for LHC as long preparation time (ramp down or precycle)
- Duration of a fault is not fair:
  - Precycle included or not
  - Parallel faults are added
  - Not possible to suspend a fault
  - Exemple: network glitch fault of 1 s at 10:06, beam back only at 14:30 because a patrol was needed

Controls	Infrastructure	BBQ server & OFSU	20:14 25/05/12	27 [min] 13[s]
Controls	Network	network in uj56	10:06 28/07/12	01 [s]
Controls	Software	RBAC token in sequence for collimator reset	08:36 01/06/12	03 [min] 15[s]
Controls	Software	NOT SPECIFIED	15:20 20/08/12	1 [h] 31 [min] 18[s]
Controls	Software	RBAC on OASIS?	11:03 05/09/12	21 [min]
Controls	Software	OFSU	11:09 13/10/12	59 [min] 31[s]
Controls	Software	PM	12:26 16/10/12	45 [min] 13[s]
Controls	Software	PM_MACH_PROT_OK	05:27 22/11/12	1 [h] 01 [min] 08[s]
Controls	Timing	All collimators in point 2	02:18 04/06/12	3 [h] 22 [min] 50[s]
Controls	Timing	can't change sequence	08:05 20/08/12	48 [min] 47[s]
Controls	Timing	Telegram	00:03 07/11/12	2 [h] 15 [min] 28[s]
Controls	WorldFIP	WorldFip for mains QPS controller in S78	16:29 11/05/12	3 [h] 54 [min] 23[s]
Controls	WorldFIP	repeater for cryo in 78	05:28 19/10/12	2 [h] 02 [min] 53[s]

- More discipline, clear definition needed
- slightly modified tools also needed to have realistic statistics
  - Most of what is needed is already in the logbook but need adaptation based on 2012 run experience

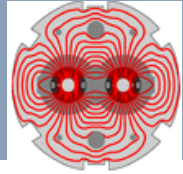
details by equipment



- More discipline needed to have realistic statistics

Fault category	total	related to a PM	Precycle needed	Access needed
Access	26	6	8	17
Beam dump	28	9	2	9
Beam instrumentation	47	17	0	3
Collimator	29	2	0	2
Controls	21	5	2	4
Cryogenics	31	20	26	22
Injection	31	4	4	5
Miscellaneous	47	9	11	16
Operation	2	2	0	0
Power converters	58	28	42	27
QPS	54	18	42	30
RF	61	20	0	22
Technical Services	35	24	27	12
Vacuum	17	10	5	7

MKI Heating

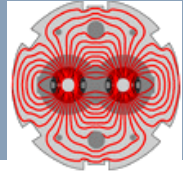


- Appeared with higher intensity
- Was registered in the logbook from the ready to inject:
  - More than 23 extra hours waiting

- After LS1:
  - Ceramic chamber changed (24 stripes instead of 24)

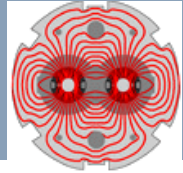
Injection	Controls	transfer line steering needed	18:01 16/06/12	21 [min] 17[s]
Injection	Hardware	TDI.4R8	03:22 03/05/12	09 [min] 23[s]
Injection	Hardware	BLM Crate	15:03 03/06/12	28 [min] 05[s]
Injection	Hardware	MKI8.CB2.up temperature	04:52 11/06/12	2 [h] 26 [min] 03[s]
Injection	Hardware	MKI8 too warm	08:16 14/06/12	1 [h] 35 [min] 31[s]
Injection	Hardware	MKIs too warm	17:04 15/06/12	26 [min] 02[s]
Injection	Hardware	MKI8 too warm	15:01 16/06/12	2 [h] 16 [min] 58[s]
Injection	Hardware	MKI temperature too high	14:27 17/06/12	4 [h] 09 [min] 12[s]
Injection	Hardware	Injection kickers B2 temperature interlock	02:02 18/06/12	3 [h] 14 [min] 44[s]
Injection	Hardware	Injection kickers B1	06:21 19/08/12	2 [h] 07 [min] 34[s]
Injection	Hardware	MKI beam 1 hot	19:59 22/08/12	1 [h] 11 [min] 55[s]
Injection	Hardware	MKI2 generator heater fault	08:52 23/08/12	1 [h] 44 [min] 59[s]
Injection	Hardware	MKI2.UA23.CB1	05:44 24/08/12	43 [min] 56[s]
Injection	Hardware	MKI2	17:01 24/08/12	1 [h] 06 [min] 53[s]
Injection	Hardware	MKI2	20:21 24/08/12	28 [min] 35[s]
Injection	Hardware	MKI2	03:15 26/08/12	1 [h] 03 [min] 19[s]
Injection	Hardware	MKI_B temperature	19:24 26/08/12	32 [min] 15[s]
Injection	Hardware	MKI-B1	19:19 08/09/12	1 [h] 19 [min] 08[s]
Injection	Hardware	MKI-NB2	10:41 15/09/12	2 [h] 24 [min] 20[s]
Injection	Hardware	MKI8	20:56 13/10/12	2 [h] 03 [min] 21[s]
Injection	Hardware	TDI.L2	12:03 14/10/12	4 [h] 07 [min] 57[s]
Injection	Hardware	TI2	01:31 16/10/12	01 [s]
Injection	Hardware	MKI.Ua87 temperature	21:06 21/10/12	48 [min] 11[s]
Injection	Hardware	MKI8	02:03 31/10/12	48 [min] 14[s]
Injection	Hardware	MKI8_C	16:51 01/12/12	1 [h] 07 [min] 08[s]

TDI heating



- Appeared also with high intensity circulating beams
  - Steps lost
  - Blocking injection: cannot restore the injection settings, experts intervention needed
  - Some 25 hours lost at injection in Spring 2012
- Cured by opening to parking position when circulating beams
- After LS1:
  - Complete service of the step motors during LS1+ parking position as soon as injection completed

Transfer line steering



- Mandatory set-up time:
  - Limit injection losses and injection oscillations
  - Experts needed
- Really difficult to evaluate the time spent in steering from the logbook data:
  - Some 10 hours recorded, but under-estimated
- Improvement along the run:
  - Shift crew to do “standard” steering
- After LS1:
  - Properly tag the time spent in steering
  - Need of better diagnostics (TL steering or beam quality in the injectors)

Future

- Difficult to conclude on the operational availability because of not precise enough tracking
- To improve the situation after LS1, we need:
  - To really have a fault or an event register for each PM
  - To register if precycle/access is needed
  - to quantify where time is spent abnormally in the cycle (mainly at injection)
- Based on the previous analysis attempt, a list of requirements to adapt the e-logbook and the PM server is ready:
  - To allow a proper flag of the different beam set-up phases: test cycle, TL steering, commissioning ...
  - To ease the tracking on a weekly basis : 1 OP responsible

- Now that we know a bit more what to look at, we know better what we need to register