
CERN

8th LHC Operations Evian Workshop

Session1 - Availability and system performance

LHC Operation

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Outline

- Preliminary remarks
- Splitting the cycle

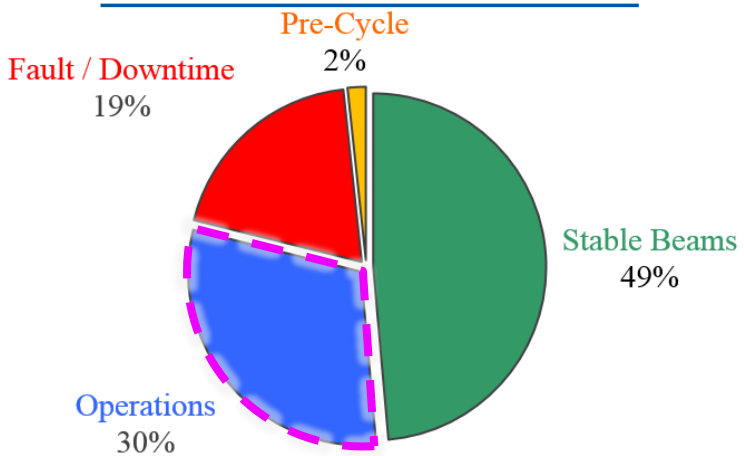
(for each phase, analyze the median/average time and extreme cases, plus comments)

  - Ramp-down
  - Injection
  - Filling
  - Prepare Ramp and Ramp
  - Tune Change and Squeeze
  - Adjust and Collide

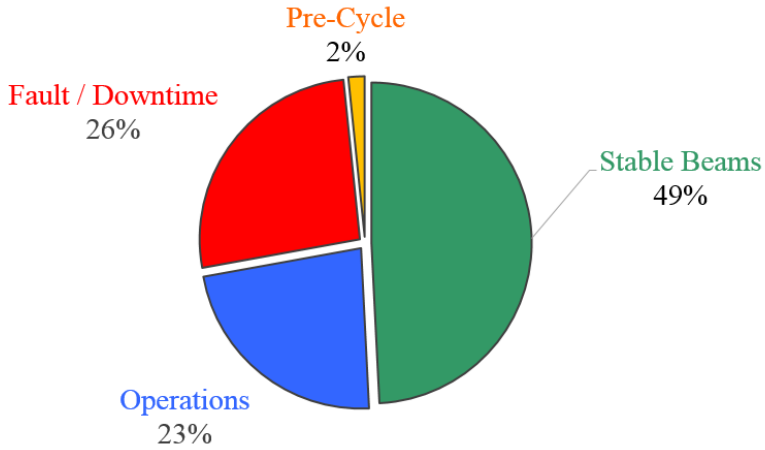
- Combining all data
- Dealing with it

Operations phase

Mode breakdown in 2017



Mode breakdown in 2016



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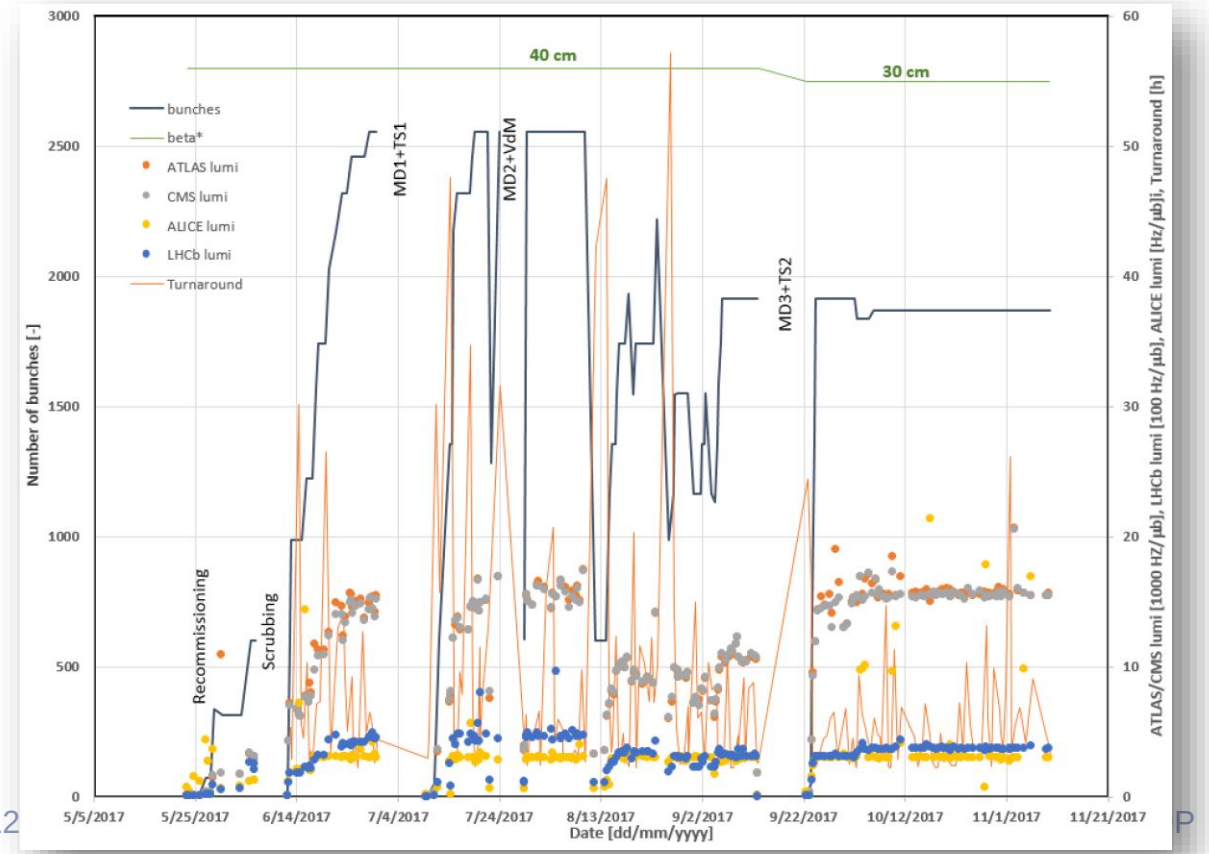
Data mining

- The analysis which follows is mainly based on the machine modes, but not only (Beam Dump is just before Ramp Down, but you might have dumped and not changed the status…)
- All MDs and other non-operational times removed; the periods considered in the analysis are:
  - From end of scrubbing to MD1 (commissioning excluded)
  - From end of TS1 to MD2 (excluding the 50 ns tests)
  - From end of VdM to MD3
  - From end of TS2 to end of run, excluding the Xe run and few days of setup of the special runs
- For the filling time I considered only fills above 1500 bunches



Splitting the cycle

Beam Dump to Ramp-down

	Beam lost to BD	BD to RD
Median	0:02:01	0:00:36
Average	0:04:25	0:01:57
StDev	0:05:46	0:05:09
Min	0:00:03	0:00:04
Max	0:24:01	0:56:12

- **Physiological time**: cannot gain much
- In case of premature dump, you don't want to lose important infos and some time is typically needed to analyze the dump, above all when some circuits tripped or a system is faulty
  - **Are we lacking diagnostic tools?** The equipment owners could maybe help here…
- Some time lost due to breakpoints in the sequence (i.e. XPOC check or MKISS)
  - Could gain with **parallelism**
- A couple of cases where we did not realize that the beam was dumped
  - Background noise was too high
  - Announcer volume too low
- Can we have a dedicated "Dump announcer" which is separate from the warning announcer and cannot be switched off, and has an 'adequate' volume, *à la SPS obrigado*?
  - Maybe we could have an electrifier connected to EIC and operator in case of dump (For Rossano: the new chairs could already incorporate that…)

Ramp-down to injection

Median	0:58:05
Average	2:31:16
StDev	4:14:19
Min	0:35:53
Max	32:55:32

- Obviously **the period most affected by faults**, mainly appearing in physics
  - Big faults (18 kV transformer, cryogenics, LBDS,..) dominate the average
  - **The excess average 2h account for about 17% of the total time**
  - No extremely long faults this year
- Also the median is very large (25 min more than the minimum needed time)
  - **Many small faults, sometimes requiring investigation by experts and possibly access**
  - Pre-cycle of few tripping elements (not declared as precycle) and EIS (”**no cost access**”…)
  - Access for experiments, *partially* in the shadow (EIS precycle, ”no cost access”…)
  - No beam from injectors or beam being set up

- Ramp-down is fixed and limited by the slowest elements
  - RQs are now in the shadow of the ITs
    - IT.L2 is the slowest and is **~6 min longer** than the RQ4.R2 (accounts for 0.8% of “lost” time); could think about a major modification when you reach in median the min time…
  - Some time lost due to trips of circuits, mainly 600 A due to 0-V crossing
    - Are most a concern of MPE for EE maintenance, not precycled after a trip
    - Should be improved by **tuning the ramp rate** (requires time and the commissioning is already tight…)

Ramp-down to injection

Median	0:58:05
Average	2:31:16
StDev	4:14:19
Min	0:35:53
Max	32:55:32

- The preparation of the machine during ramp-down is often parallelized by-hand to avoid discovering issues at the last moment
  - BI preparation done together with RF and collimators and…
    - Sometimes not appropriate… things cannot all be run in parallel
    - Could be improved with **parallelism**
  - **MKI soft-start** selection could be **automatized**, i.e. waiting time and length of the soft-start automatically selected and started (with approval of operator)
    - Avoid mistakes and improve efficacy (too many times it was not done when ready to inject!)
  - Can we move the injection **handshake earlier**?
    - Avoid losses of time, above all realizing later that the experiments are not ready

Injection of pilots and set up

Median	0:15:46
Average	0:18:57
StDev	0:12:30
Min	0:03:15
Max	1:25:43

- Statistics based only on cases where the previous dump energy was above 450 GeV (-> exclude cases where you are already set up at injection)

- Repetition of previous issues (HS, MKI SS, missing beam from injectors, tripping circuits)
- Sometimes injection missed due to missed interlocks (missing PM signature, QPS not OK): **should include a check in the machine state**
  - "Erratic" message is all and nothing…
- Often huge injection oscillations with the pilots:
  - **Shouldn't feed-forward more often?**
  - **IQC shouldn't latch on pilot injection oscillations**
- Need time to measure tune, chroma and coupling via the *cockpit*
  - Definitely good to have all in one place, but the **coupling analysis is far too long**; sometimes preferred to correct by hand
- Pilots are often injected twice
  - To correct the RF phase (do we really need to dump the pilot if we correct the phase?)
  - If lost due to mistakes or wrong settings

For more details on injections, see GHH's

Filling to Prepare Ramp

Median	0:39:00
Average	0:58:09
StDev	0:59:08
Min	0:24:44
Max	7:05:53

- Statistics based only on cases where injecting more than 1500 bunches

- Mainly dominated by
  - Missing injections (**beam quality on injectors**)
  - **Mixed scheme, requiring the change of SPS cycle**, often with reverification
  - Steering of transfer lines
  - Wrong chroma/octupoles settings, leading to **blow-up:**
    - Could we have a table with suggested values?
    - A pop-up to set the physics value is maybe not enough: discussions are ongoing to automatically set the value from LSA (based on the first point of the ramp) and send via sequencer
  - Wirescans
    - "We never stop the injection to do wirescans!"
      - Could be improved by automatizing the wirescans (luckily we have a BI guy in the team now!)
  - "anti-16L2 schemes" was not longer since we had less bunches injected, but had the impression that the **stability of 8b4e is worse** (or more difficult to tune… or less experience in the injectors with this beam)

  - On the longest one, we had a series of problems (missing XPOC data, BPMs@6 triggering, kicker fault, steering, wrong settings)
  - The shortest one was during a fill for physics with 1868b!...and overnight…

From end of inj. to FT

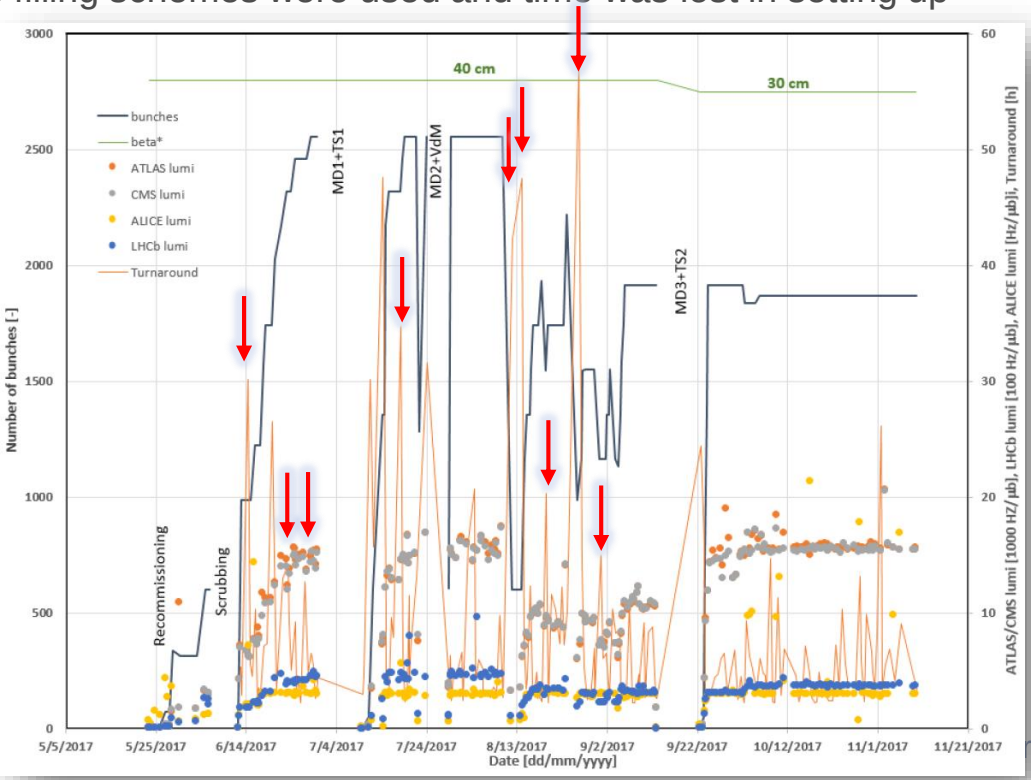
	Inj-end to Ramp	Ramp to FT
Median	0:03:51	0:20:22
Average	0:04:58	0:20:27
StDev	0:12:01	0:00:42
Min	0:02:18	0:20:14
Max	3:13:28	0:30:55

- Takes about 5 min to move collimators, close HS, incorporate, load functions…
  - Could profit from **parallelism** of tasks (people are already parallelizing, with the risk of mistakes)
  - Could do most of the steps while filling
    - All but collimators, incorporation of spools, HS
    - If we lose the fill meanwhile, the cost is less to go back to injection
- New **shorter ramp**(&squeeze)
  - Tested in MD, could save 2 min
  - A bit of time to be invested during commissioning, but transparent wrt the rest
- The longest Prepare Ramp to Ramp was dominated by a collimator triggering at the prepare ramp, but also by **wrong masking/SBF status**
  - Could include an automatic set of masks in the sequencer, according to the state (pilot, nom, MD)
    - Alternatively, we could populate the sequences of warning messages
- All ramps are completed, but not all beams make it at the FT…
  - **52oo277 fills did not reach end of the ramp**
    - Many were lost because of 16L2

The impact of 16L2

	Ramp to Squeeze
Median	0:24:47
Average	2:01:00
StDev	4:53:13
Min	0:23:07
Max	29:32:24

- 31 dumps before squeeze (59 in total) are recorded in AFT as caused by 16L2
  - The longest period with beams dumped on the ramp was almost 30h
  - In four cases, this period was above 16h
- Big implications on machine availability and performance
  - Several studies were performed to use a different working point
  - At least 2 long fills of scrubbing were performed to mitigate its effects
  - Multiple filling schemes were used and time was lost in setting up



Squeeze to Adjust

	40 cm	30 cm
Median	0:08:15	0:14:23
Average	0:12:17	0:18:04
StDev	0:36:56	0:19:35
Min	0:08:11	0:13:23
Max	7:06:13	2:22:18

- The tune change takes typically between 2 and 4 minutes
  - Can we include the tune change in the R&S or squeeze?
    Could save 2-3 min due to incorporation, OFB, etc
  - Might be moved to the end of the squeeze

- The squeeze itself has a **physiological length**
  - Time is typically spent in this phase to optimize the settings
  - If the new telescopic squeeze scheme will not be applied next year, we should merge the 40 and 30 cm in a single step

Collide

Median	0:07:55
Average	1:56:48
StDev	5:00:44
Min	0:03:18
Max	39:18:37

- The approach to this phase should be maybe more systematic
  - Conditions changed several times during the year…
- Should declare Stable Beams ASAP
- This year, for IP1 and 5 we used the strategy to optimize on the 2 planes and then separate
  - We'll certainly do as for the others this year, i.e. preventive separation
    - 2σ were the typical value
  - Could save few minutes in declaring SB (1 plane less to optimize and no waiting time to steer down…)

For more details on collisions, see Theo's

Combining all data

Wrapping up

- And comparing with the performance of the past years:

Beam modes	2015	2016	2017
Beam dump	n.a.	n.a.	2.6
Ramp-down	n.a.	n.a.	58.1
Injection probe	14.7	15.7	15.8
Injection Physics	34.9	36.7	39.0
Prepare Ramp	5.4	4.9	3.9
Ramp	20.4	20.5	20.4
Flat Top (Q change)	5.9	5.6	4.3
Squeeze	14.1	18.1	14.4
Adjust	13.7	16.1	7.9

All values expressed in min

Turnaround time and ideal cycle

- Only fills with more than 1500 bunches have been considered of the calculation of the turnaround.
- The median value is very good, but the average is strongly biased by the big faults (16L2 fist of all)

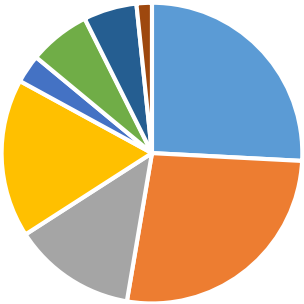
Median	4:41:28
Average	7:33:19
StDev	8:25:55
Min	2:12:42
Max	57:06:19

- If we combine the min from all phases, we get an ideal (real) cycle length:

D->BD	BD->RD	RD->Inj	Setup	Filling	Fill->R	Ramp	Qch	Squ->Adj	Adj->SB	Tot
0:00:03	0:00:04	0:35:53	0:03:15	0:24:44	0:02:18	0:20:14	0:04:16	0:13:23	0:03:18	**1:47:28**

Comparison of Beam Dump Modes 2016/2017

Number of Beam Dumps per Mode 2016



STABLE BEAMS INJECTION PHYSICS BEAM ADJUST
INJECTION PROBE BEAM RAMP FLAT TOP
SQUEEZE PREPARE RAMP

Beam Mode	2016
STABLE BEAMS	203
INJECTION PHYSICS BEAM	211
ADJUST	104
INJECTION PROBE BEAM	134
RAMP	24
FLAT TOP	52
SQUEEZE	45
PREPARE RAMP	13

Number of Beam Dumps per Mode 2017

STABLE BEAMS INJECTION PHYSICS BEAM ADJUST
INJECTION PROBE BEAM RAMP FLAT TOP
SQUEEZE PREPARE RAMP

Beam Mode	2017
STABLE BEAMS	204
INJECTION PHYSICS BEAM	195
ADJUST	123
INJECTION PROBE BEAM	99
RAMP	69
FLAT TOP	51
SQUEEZE	20
PREPARE RAMP	5

- Significant differences:
  - 2017: More dumps in ADJUST and RAMP than 2016
  - 2016: More dumps in INJECTION PROBE BEAM

Dealing with it

Managing the faults: diagnostics and access

- Often a problem is hiding another one
  - Typically, after a quench/trip, we discover secondary problems only after recovery
    - Should prepare all other circuits ASAP
    - Could be improved by removing the Global Protection Mechanism
      - MPE is discussing about de-activating it at injection from after LS2
    - Prepare the machine ASAP to avoid bad surprises from other systems
      - Don't wait to recover the circuits to prepare/check the other systems
- Missing procedure to be provided
  - Map of circuits to precycle!
  - Procedure to recover a main circuit after trip from high current (information already distributed, but should be better formalized in a procedure)
- Should improve diagnostics on some equipment?
- May we have automatic entries in the equipment logbook suggesting who to call/ what to do? Kind of MPE logbook….
- Do we always prepare a tunnel access when needed or switch off all circuits uselessly when not needed?
  - Inefficient preparation of an access might cost much more than the access itself…
  - Should we improve our knowledge of the tunnel?
    - Layout DB: a tutorial on how to use it could be a valuable option for the winter training.

Interlocks and masks

- Operational mistakes:
  - 8/11 due to SETUP beam flag forced to UNSAFE with active interlocks during commissioning
  - Only 2 above injection energy
- Settings issues:
  - 4/12 due to Pilot intensity too high (left over from previous fill)
  - 2 during physics production (ALICE trims)

- Most of the OP mistakes appear when switching from OP sequence to special one
  - Trying to inject a pilot with forced beam flag.

- Should maybe improve our culture of procedure writing
  - Reading for newcomers…
- Could include automatic (un)masking by the sequencer

Managing the communication

- We have learned how to check&dump (= check status of injectors and dump)
- Injectors are often not aware of the requested beam (not sure about the LHC…)
  - Sometimes not ready when at injection
- Would encourage a closer collaboration between the different machines
  - No special tests on Wed….

- A (careful) use of the mailing lists would be certainly appreciated by the teams on shift, which cannot always take part in the 8:30 meeting (and, often, post meeting)
  - Not everybody is in the LPC distribution list
  - Maybe all OP shifters could be in the machine coordinators list

- Should encourage the redaction of the shift summary
  - Include it in the MM presentation?
  - I let Rossano decide on a new tool for the chairs….

Concluding remarks

- After a lot of work done in the past years, it seems that “operation” performance are levelled in the last triennium
- Still something can be gained
  - Not much from settings and hardware
  - A lot with some rigorousness and improved diagnostics plus procedures
- Should maybe try to be more conservative and less inventive along the year with parameters, beam type, etc (look at the last production period)
  - But maybe then the fun would be over…

- I hope nobody will ever do another talk on this subject!

Did the LHC team a good job in 2017?

Maybe not the best ever… but it could be worse…

Thank you for the attention!

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