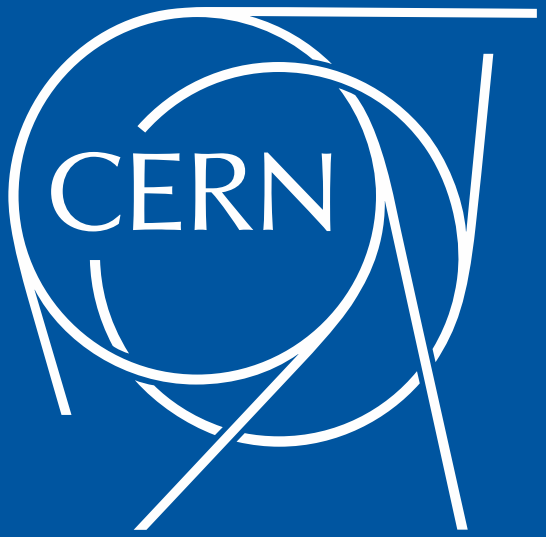

CERN

# LHC intensity cruise checklist

Yuancun NIE
TE-MPE-PE

Acknowledgments:
D. Wollmann, M. Zerlauth, J. Uythoven, R. Schmidt, etc

# Outline

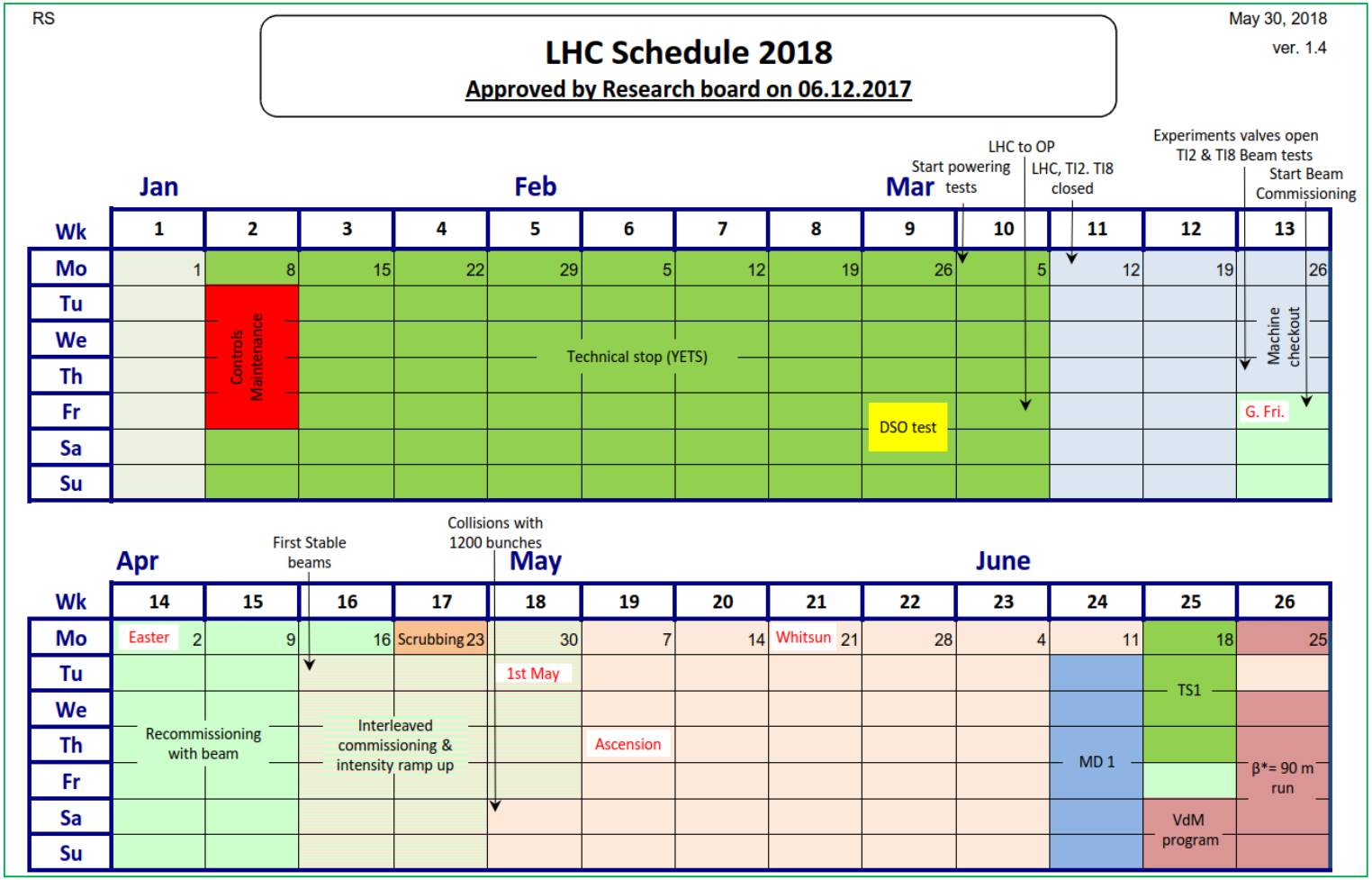
I. What is LHC intensity cruise checklist

II. How to prepare a checklist

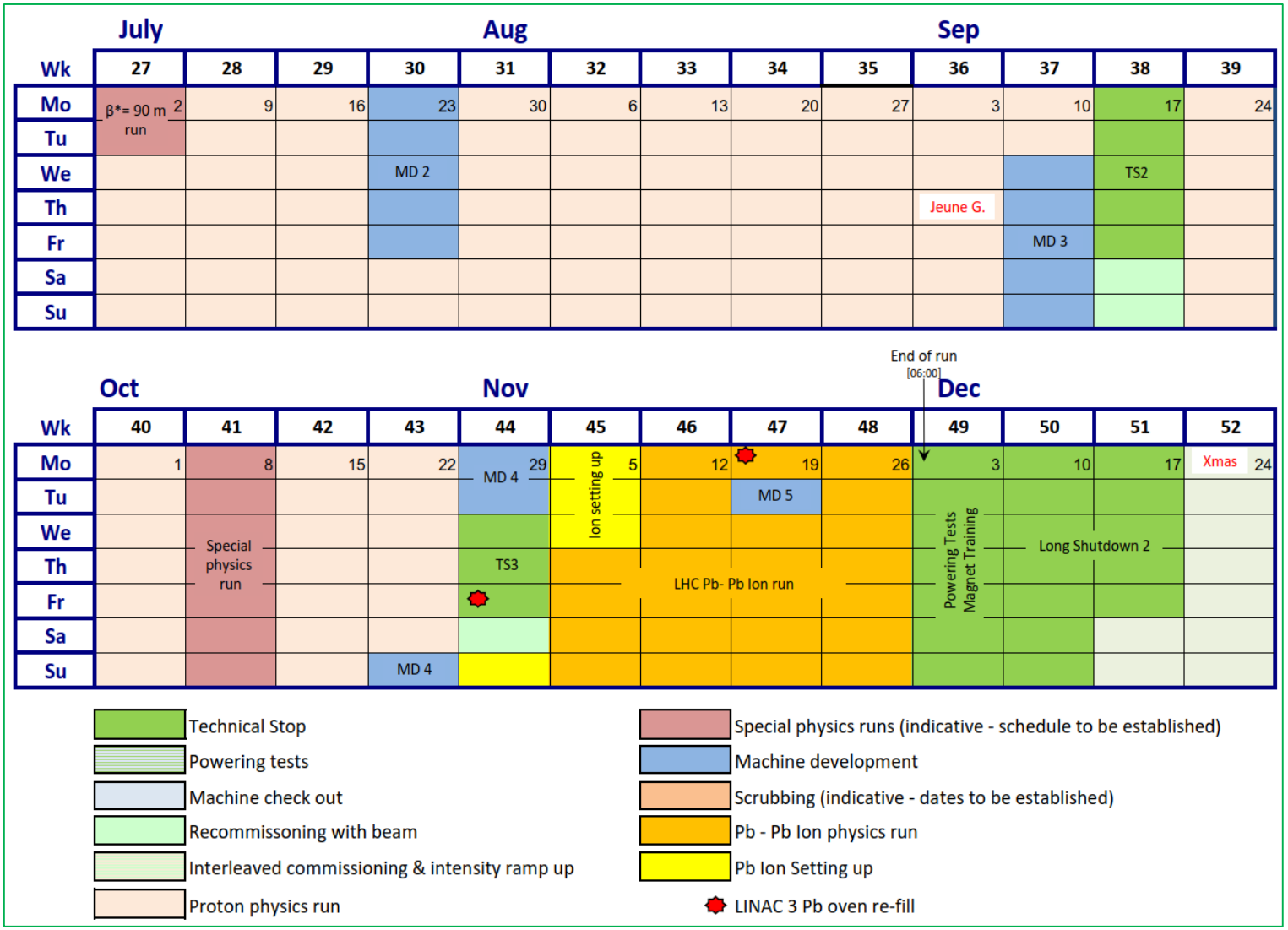
III. Examples of beam dump

IV. Conclusion

# I. What is LHC intensity cruise checklist



# I. What is LHC intensity cruise checklist



# I. What is LHC intensity cruise checklist

- Regular checklists during the LHC intensity cruise, in order to
  - Analyse and document the correct functionality and performance of the machine protection systems and other critical systems (magnet powering MP3, beam and powering interlocks, RF, BI, Collimation, Operation/orbit and feedbacks, Beam dump, Injection, Heating of equipment).
- Note that for the same purpose, intensity ramp-up checklists are needed during the restart after long technical stop (YETS)
- An example of checklist can be seen here: LHCintensityCruiseJune2018

# I. What is LHC intensity cruise checklist

- 8 intensity increase checklists during ramp up, from 17th April to 4th May 2018
- 2 intensity cruise checklists before TS1 (18th-21st June 2018)
- One checklist is under preparation for June-August 2018

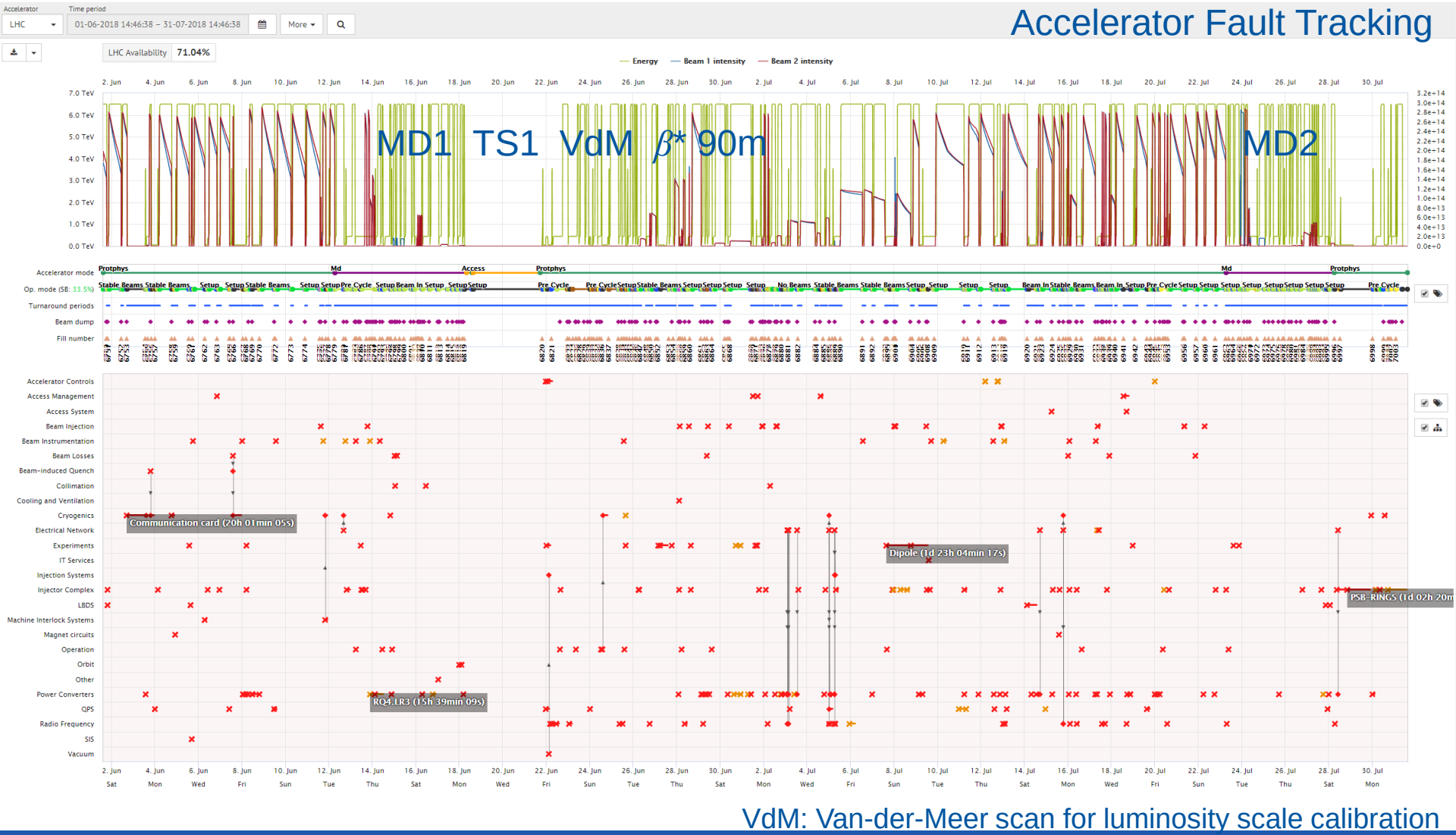
| | | | | |
|---|---|---|---|---|
| LHC intensity increase check list for going from 3/12b to 75b - 25 ns o... | 1 | Released | 2018-04-19 | Daniel WOLLMANN |
| LHC intensity increase check list for going from 75b to 300b - 25 ns o... | 1 | Released | 2018-04-21 | Daniel WOLLMANN |
| LHC intensity increase check list for going from 300 to 600 bunches | 1 | Released | 2018-04-25 | Markus ZERLAUTH |
| LHC intensity increase check list for going from 600b to 950b - 25 ns ... | 1 | Released | 2018-04-26 | Daniel WOLLMANN |
| LHC intensity increase check list for going from 950b to 1200b - 25 ns | 1 | Released | 2018-04-28 | Markus ZERLAUTH |
| LHC intensity increase check list for going from 1200b to 1800b - 25 ns | 1 | Released | 2018-04-30 | Markus ZERLAUTH |
| LHC intensity increase check list for going from 1800b to 2100b - 25 ns | 1 | Released | 2018-05-02 | Markus ZERLAUTH |
| LHC intensity increase check list for going from 2100b to 2556b - 25 ns | 1 | Released | 2018-05-04 | Markus ZERLAUTH |
| LHC intensity cruise checklist May 2018 | 1 | Draft For Discussion | 2018-06-05 | YUANCUN NIE |
| LHC intensity cruise checklist June 2018 | 1 | Draft For Discussion | 2018-07-16 | YUANCUN NIE |

# II. How to prepare a checklist: workflow

1. Period, Fills, Dump statistics → **MPP (global check)**
2. MP3, Interlocks, RF, BI, Collimation, Operation/orbit and feedbacks, Beam dump, Injection, Heating of equipment → **respective experts (comments, new failures/behaviours)**
3. Follow up and finally document/share with CERN colleagues via **EDMS**:

LHC Operation/Restricted Machine Protection Panel (rMPP)/Intensity Checklists

# II. How to prepare a checklist: tools




VdM: Van-der-Meer scan for luminosity scale calibration

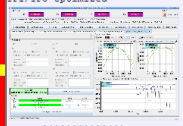
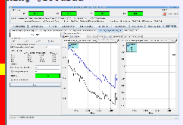
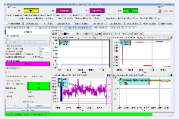
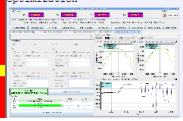
# II. How to prepare a checklist: tools

http://elogbook.cern.ch

LHC OP ▾ Consignes Phones Vistars Others search

LHC OP [Wednesday 01-Aug-2018 Morning]

FILTERS: EVT SOURCES ▾ LOCATIONS ▾ CIRCUITS ▾ ACCESS ▾ INFO ▾ OPERATION ▾ PIQUETS ▾ EXPERTS ▾ BEAM MODE ▾ Clear

| # | Time | PROTONPHY | Comment |
|---|---|---|---|
| 1 | 07:01 | 1 | Ron & Matte |
| 2 | 07:10 | 1 | Cryo asked to postpone the dump. They have presently some issues to regulate the B8 cooling with 600 b, due to the "missing" compressor in P8 |
| 3 | 08:45 | 1 | We postpone the dump to around midday |
| 4 | 09:55 | 1 | FX24 put in maintenance mode. |
| 5 | 12:33 | 1 | IP1/IP5 optimized  20180801123401.png |
| 6 | 13:11 | 1 | Continuous Xing angle levelling stopped. We'll do the last 2 urad manually to anticipate the beta* levelling |
| 7 | 13:12 | 1 | LHC SEQ: IP1/IP5 TCTs THRESHOLDS TIGHTENED FOR BETA STAR LEVELLING |
| 8 | 13:12 | 1 | Xing @130urad  20180801131248.png |
| 9 | 13:22 | 1 | beta* = 25 cm  20180801132304.png  20180801132310.png |
| 10 | 13:23 | 1 | optimization  |

| | | | |
|---|---|---|---|
| | | | Global Post Mortem Event |
| | | | Event Timestamp: 01/08/18 14:15:02.586 |
| | | | Fill Number: 7005 |
| 19 | 14:15 | 1 | Accelerator / beam mode: PROTON PHYSICS / STABLE BEAMS |
| | | | Energy: 6499200 [MeV] |
| | | | Intensity B1/B2: 4635 / 4627 [e^10 charges] |
| | | | Event Category / Classification: PROGRAMMED_DUMP / MULTIPLE_SYSTEM_DUMP |
| | | | First BIC input Triggered: First USR_PERMIT change: Ch 1-Programable Dump b1: B T -> F on CIB.CCR.LHC.B1 |
| | | | Global Post Mortem Event Confirmation |
| 20 | 14:15 | 1 | Dump Classification: Programmed Dump |
| | | | Operator / Comment: gtrad / Programmed End of the ~600b fill (trains of 12 b) |

# II. How to prepare a checklist: tools

http://lhc-postmortem.web.cern.ch/lhc-postmortem/

Post Mortem Database - Data Browser

User: YNIE Help

Logout

Global PM events | Powering PM events | Global statistics | Fill Statistics | MPS Statistics | SEU Failure Count | Events Data | Analysis Data | Raw Data

Go Actions

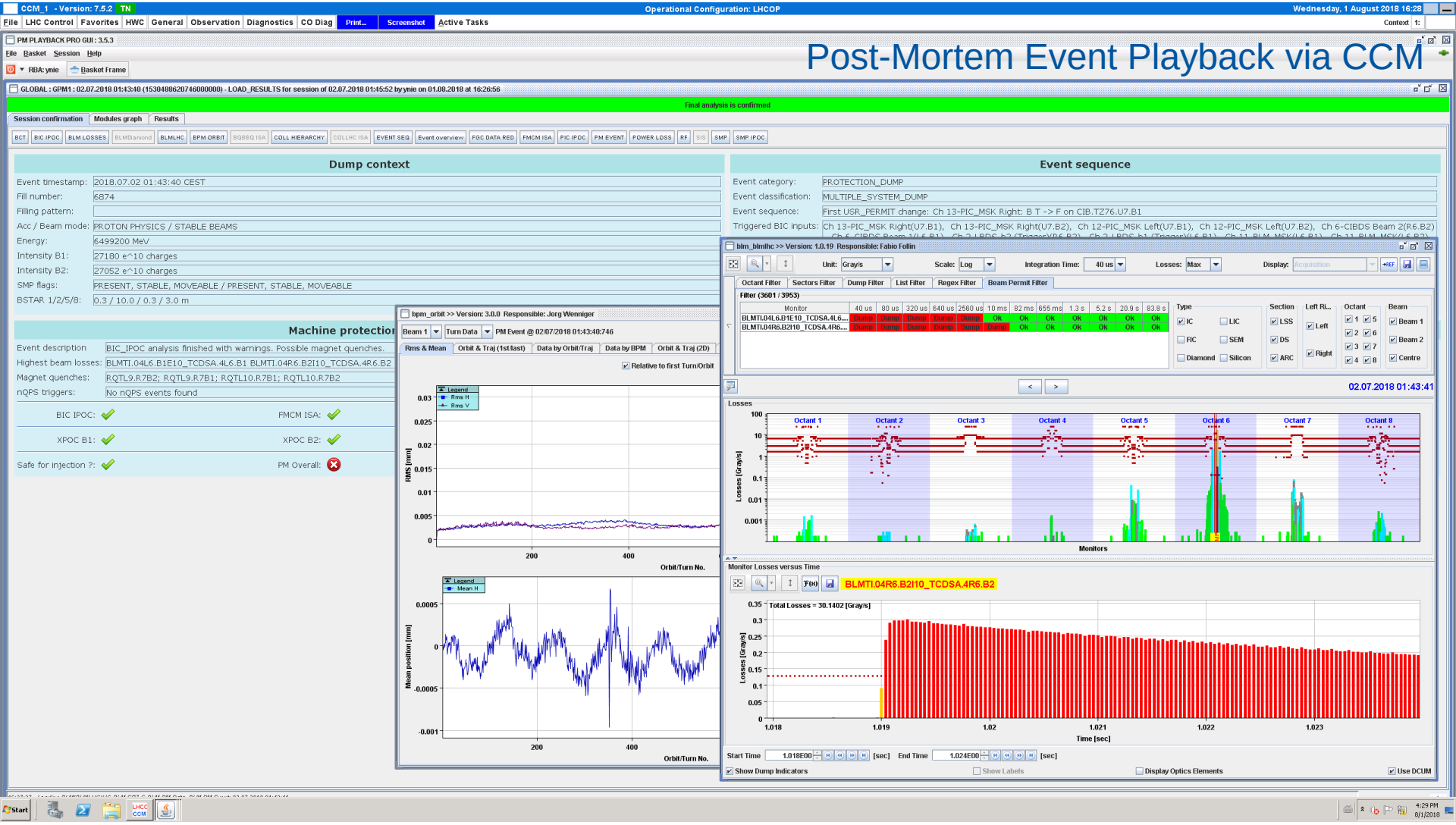
Event Timestamp is in the last 1 months

## Post-Mortem Event Database

| Event Timestamp | Fill Number | Beam Energy [MeV] | Intensity B1 [1e10] | Intensity B2 [1e10] | Stable Beams [hours] | Fill Luminosity [nb^-1] | Mps Dump Cause | Mps First Detection | Mps Expert Comment | Injection Scheme |
|---|---|---|---|---|---|---|---|---|---|---|
| 01-JUL-2018 20.51.31.698927 | 6871 | 6499200 | 8 | 9 | 0 | 0 | Beam Loss | BLM | Off-momentum loss map at Flat Top, nominal cycle, RF trim -500Hz. MPS dump cause: Beam Loss? | 2nominals_10pilots_lossmaps_coll_allIPs |
| 01-JUL-2018 22.16.01.889000 | 6872 | 449880 | 135 | 1834 | 0 | 0 | - | - | - | 25ns_2460b_2448_2052_2154_144bpi_19injv2 |
| 01-JUL-2018 23.08.06.689000 | 6873 | 450000 | 136 | 136 | 0 | 0 | - | - | - | 25ns_2460b_2448_2052_2154_144bpi_19injv2 |
| 01-JUL-2018 23.47.23.883000 | 6873 | 449880 | 2097 | 2104 | 0 | 0 | - | - | - | 25ns_2460b_2448_2052_2154_144bpi_19injv2 |
| 02-JUL-2018 01.43.40.746000 | 6874 | 6499200 | 27180 | 27052 | .285 | 24.027538 | PC | PIC | Dump of fill with 2460b in stable beam by PC trip of RQTL9.R7B1. Clean dump. | 25ns_2460b_2448_2052_2154_144bpi_19injv2 |
| 02-JUL-2018 05.23.01.961000 | 6875 | 450000 | 26732 | 27435 | 0 | 0 | - | - | - | 25ns_2460b_2448_2052_2154_144bpi_19injv2 |
| 02-JUL-2018 07.33.04.463000 | 6877 | 450000 | 0 | 0 | 0 | 0 | - | - | - | 100ns_86b_84_0_0_18bpi_7inj |
| 02-JUL-2018 12.36.22.746000 | 6877 | 6499200 | 734 | 727 | 2.5 | 19.069658 | EOF | OK | Operator dump of first ramp-up fill with 90m and 100ns bunch spacing. Clean dump. | 100ns_86b_84_0_0_18bpi_7inj |
| 02-JUL-2018 14.27.49.889000 | 6878 | 449880 | 17 | 9 | 0 | 0 | - | - | - | 100ns_302b_300_0_0_72bpi_7inj |
| 02-JUL-2018 14.40.45.089000 | 6879 | 450000 | 9 | 9 | 0 | 0 | - | - | - | 100ns_302b_300_0_0_72bpi_7inj |
| 02-JUL-2018 14.52.18.689000 | 6879 | 450000 | 9 | 9 | 0 | 0 | - | - | - | 100ns_302b_300_0_0_72bpi_7inj |
| 02-JUL-2018 19.30.54.595989 | 6879 | 6499200 | 2161 | 2124 | 2.72 | 44.261982 | EOF | OK | Second ramp-up fill for 90m with 100ns bunch spacing. Clean dump | 100ns_302b_300_0_0_72bpi_7inj |
| 03-JUL-2018 02.40.13.533000 | 6880 | 450000 | 5496 | 5491 | 0 | 0 | - | - | - | 100ns_734b_732_0_0_72bpi_13inj |
| 03-JUL-2018 03.59.38.999000 | 6881 | 450000 | 0 | 0 | 0 | 0 | - | - | - | 100ns_734b_732_0_0_72bpi_13inj |
| 03-JUL-2018 13.28.50.504690 | 6881 | 6499200 | 5191 | 4882 | 6.34 | 218.93726 | EL Net | FMCM | Fill dumped by electrical glitch affecting FMCM on exchanged RD1.LR5. Clean dump. | 100ns_734b_732_0_0_72bpi_13inj |
| 04-JUL-2018 08.54.14.999000 | 6882 | 6499200 | 4873 | 4904 | 15 | 511.0395 | EOF | OK | Programmed dump at the end of fill with 734b in 90m run. Clean dump. | 100ns_734b_732_0_0_72bpi_13inj |
| 04-JUL-2018 14.34.58.376989 | 6884 | 6499200 | 2724 | 2705 | 2.24 | 72.547325 | EOF | OK | Programmed dump of 90m 50ns fill with 302b in stable beam. Clean dump. | 50ns_302b_300_70_63_72bpi_7inj |
| 05-JUL-2018 00.20.22.199000 | 6885 | 6499200 | 5943 | 5762 | 2.12 | 136.27235 | EL Net | FMCM | Dump of 90m 50ns fill with 734b just before the programmed dump due to electrical glitch. Clean dump. | 50ns_734b_732_284_398_144bpi_11inj |
| 05-JUL-2018 06.31.14.919000 | 6887 | 450000 | 1188 | 97 | 0 | 0 | - | - | - | 50ns_1452b_1450_21_1128_144bpi_11inj |
| 06-JUL-2018 13.01.18.415364 | 6890 | 6499200 | 10893 | 11165 | 22.9 | 1705.5411 | EOF | OK | Programmed dump of fill with 1452b. Clean dump. | 50ns_1452b_1450_21_1128_144bpi_11inj |
| 06-JUL-2018 23.50.19.087980 | 6891 | 6499080 | 11264 | 11169 | 7.45 | 924.52167 | PC | WIC | Dump due to spurious trip of RMSD.LR6B2. Clean dump. | 50ns_1452b_1450_21_1128_144bpi_11inj |
| 07-JUL-2018 14.02.20.346000 | 6892 | 6499200 | 9668 | 9553 | 11.3 | 1036.8818 | EOF | OK | Programmed dump of 50ns fill with 1452b. Clean dump. | 50ns_1452b_1450_21_1128_144bpi_11inj |
| 07-JUL-2018 15.52.13.787000 | 6893 | 450000 | 0 | 0 | 0 | 0 | - | - | - | 2nominals_10pilots_RomanPot_Alignment |
| 07-JUL-2018 16.28.07.889000 | 6894 | 450000 | 0 | 0 | 0 | 0 | - | - | - | 2nominals_10pilots_RomanPot_Alignment |
| 08-JUL-2018 00.15.52.289000 | 6896 | 450000 | 130 | 1828 | 0 | 0 | - | - | - | 25ns_2460b_2448_2052_2154_144bpi_19injv2 |
| 08-JUL-2018 01.00.14.674000 | 6898 | 450000 | 18996 | 9423 | 0 | 0 | - | - | - | 25ns_2460b_2448_2052_2154_144bpi_19injv2 |
| 08-JUL-2018 01.59.24.689000 | 6900 | 450000 | 11272 | 1798 | 0 | 0 | - | - | - | 25ns_2460b_2448_2052_2154_144bpi_19injv2 |
| 08-JUL-2018 18.20.13.404364 | 6901 | 6499080 | 6663 | 6822 | 14.3 | 233221.16 | EOF | OK | Programmed dump of 25ns fill with 2460b to refill for physics. Clean dump. | 25ns_2460b_2448_2052_2154_144bpi_19injv2 |

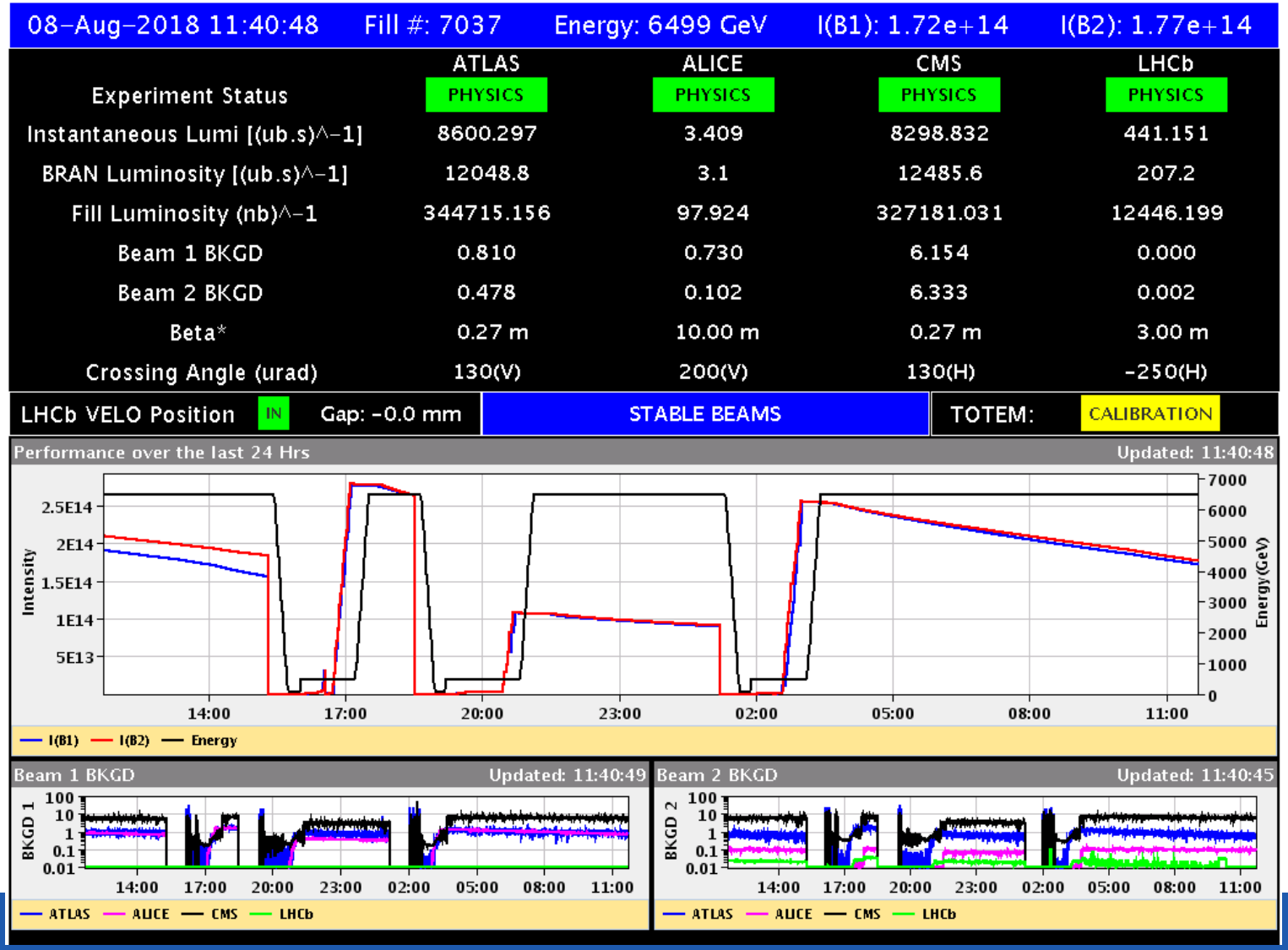
# II. How to prepare a checklist: tools

## Post-Mortem Event Playback via CCM

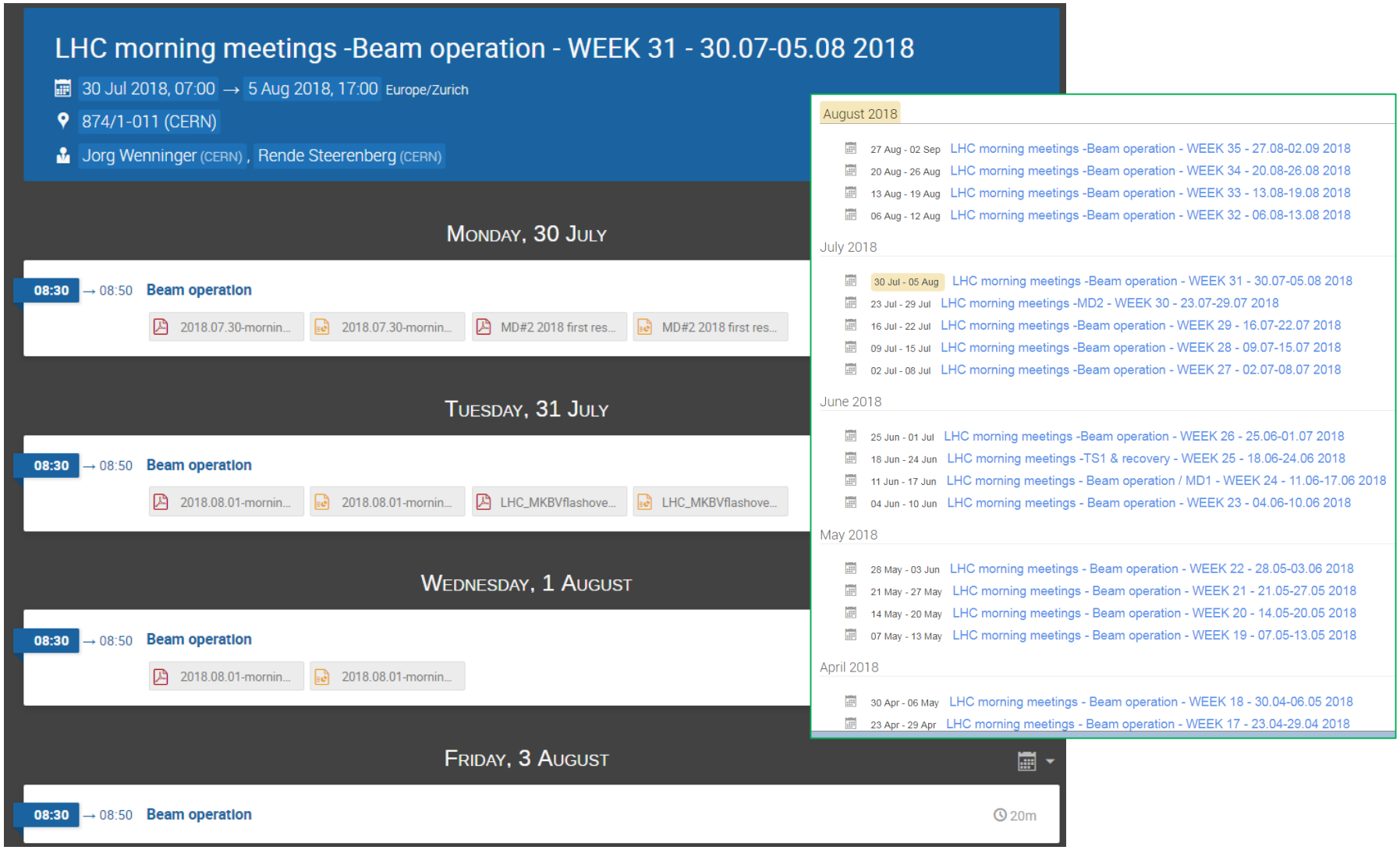


# II. How to prepare a checklist: tools

https://op-webtools.web.cern.ch/vistar/vistars.php?usr=LHC3



# II. How to prepare a checklist: tools



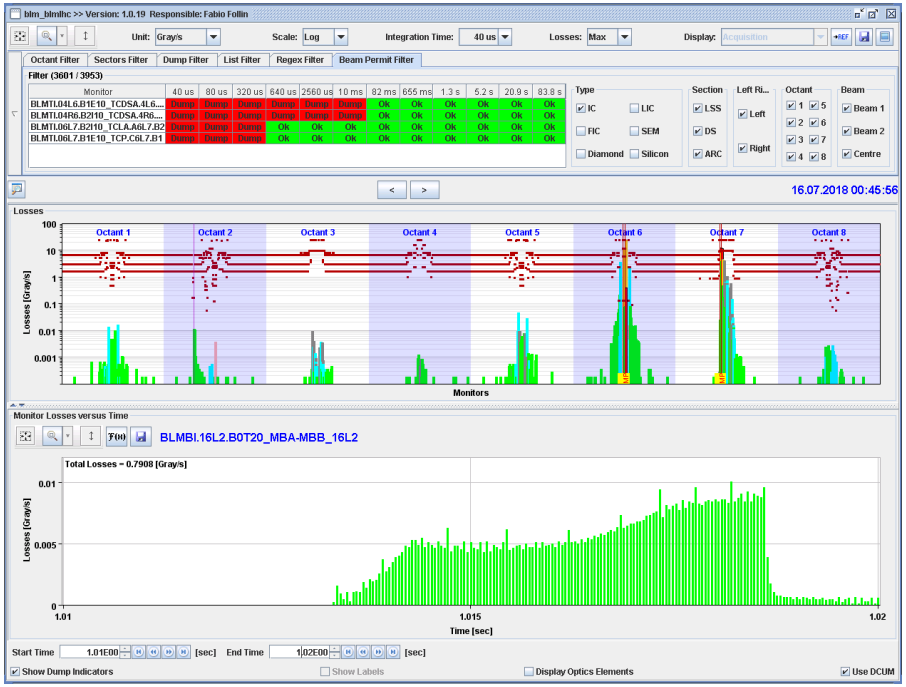
# III. Examples of beam dump: UFOs at top energy

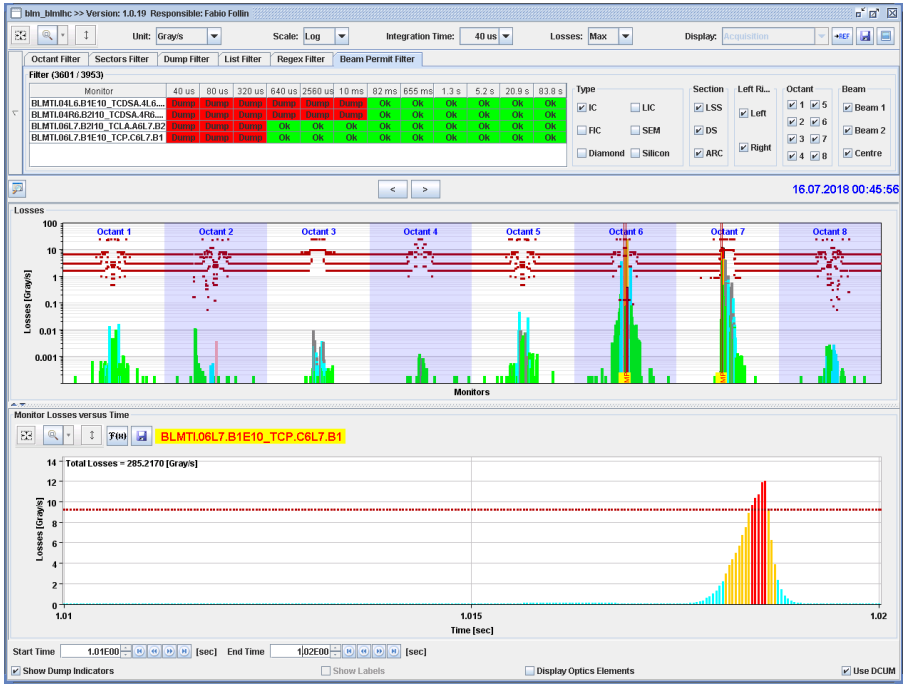
| Event Timestamp | Fill Number | Mps Expert Comment | Mps First Detection | Mps Dump Cause |
|---|---|---|---|---|
| 06-MAY-2018 09.46.28.715000 | 6647 | UFO in triplet R1, triggered dump by ATLAS_DET. Clean dump. | EXP | UFO |
| 15-MAY-2018 02.57.41.764903 | 6683 | 16L2 event with 2556b at 6.5 TeV, B1, very fast (~3ms), dumped in IP7. Clean dump. | BLM | UFO |
| 31-MAY-2018 16.51.55.236000 | 6746 | 16L2 B1 (2556b) @ 6.5TeV during squeeze, ~10ms, dumped in IP7. Clean dump. | BLM | UFO |
| 07-JUN-2018 14.35.51.879000 | 6765 | Large-UFO induced quench of A22R3, subsequent quench of B22R3 and C22R3 due to magnetic coupling, and subsequent quench of 5 other magnets (3 dipoles, 2 quads) at lower current due to heat propagation. Total of 8 magnet quenches (1 beam induced). About 12h cryo recovery. (during RAMP @ 6.4 TeV) | BLM | UFO |
| 16-JUL-2018 00.45.56.199827 | 6927 | 16L2 B1 (2556b) @ 6.5 TeV, ~5 ms, dumped in IP7. Clean dump. | BLM | UFO |
| 17-JUL-2018 22.07.21.108775 | 6938 | Dumped by 16L2 losses when squeezing down, due to a small UFO in 16L2, ~20 ms, B1. Clean dump. | BLM | UFO |
| 21-JUL-2018 21.17.09.546000 | 6956 | Dumped by small UFO in IR8 and LHCb. Fast losses at the experiment (LHCb_DET) triggered the interlock, not the ring BLMs. Clean dump. | EXP | UFO |
| 07-AUG-2018 18.31.17.111935 | 7035 | 16L2 B1 (2556b) @ 6.5TeV, ~5ms, dumped in IP7. Clean dump. | BLM | UFO |

- Mostly UFO type II (16L2), also UFO type I
- In the 16L2 events, beam usually dumped by losses at IP7, and occasionally by losses at 16L2 (Fill #6938)
- UFOs can result in beam dump, and occasionally magnet quenches

# III. Examples of beam dump: UFOs at top energy

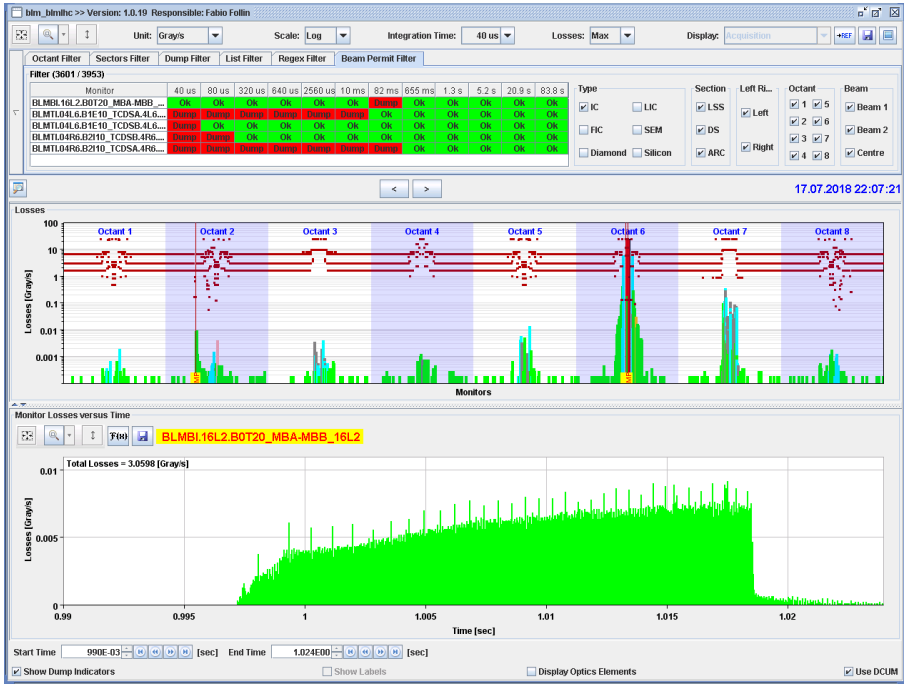
| Event Timestamp | Fill Number | Mps Expert Comment | Mps First Detection | Mps Dump Cause |
|---|---|---|---|---|
| 16-JUL-2018 00.45.56.199827 | 6927 | 16L2 B1 (2556b) @ 6.5 TeV, ~5 ms, dumped in IP7. Clean dump. | BLM | UFO |

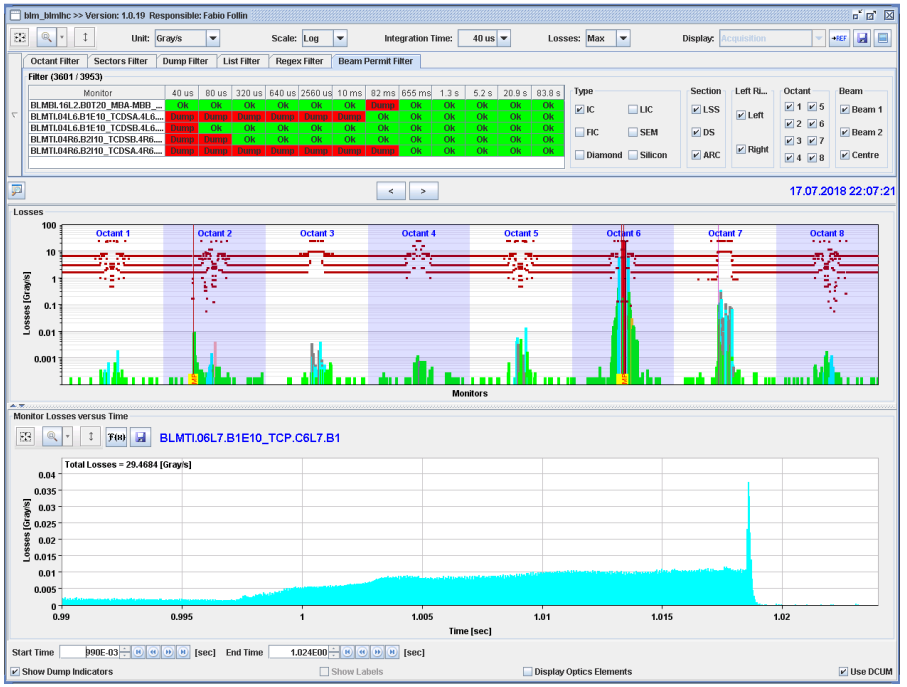


# III. Examples of beam dump: UFOs at top energy

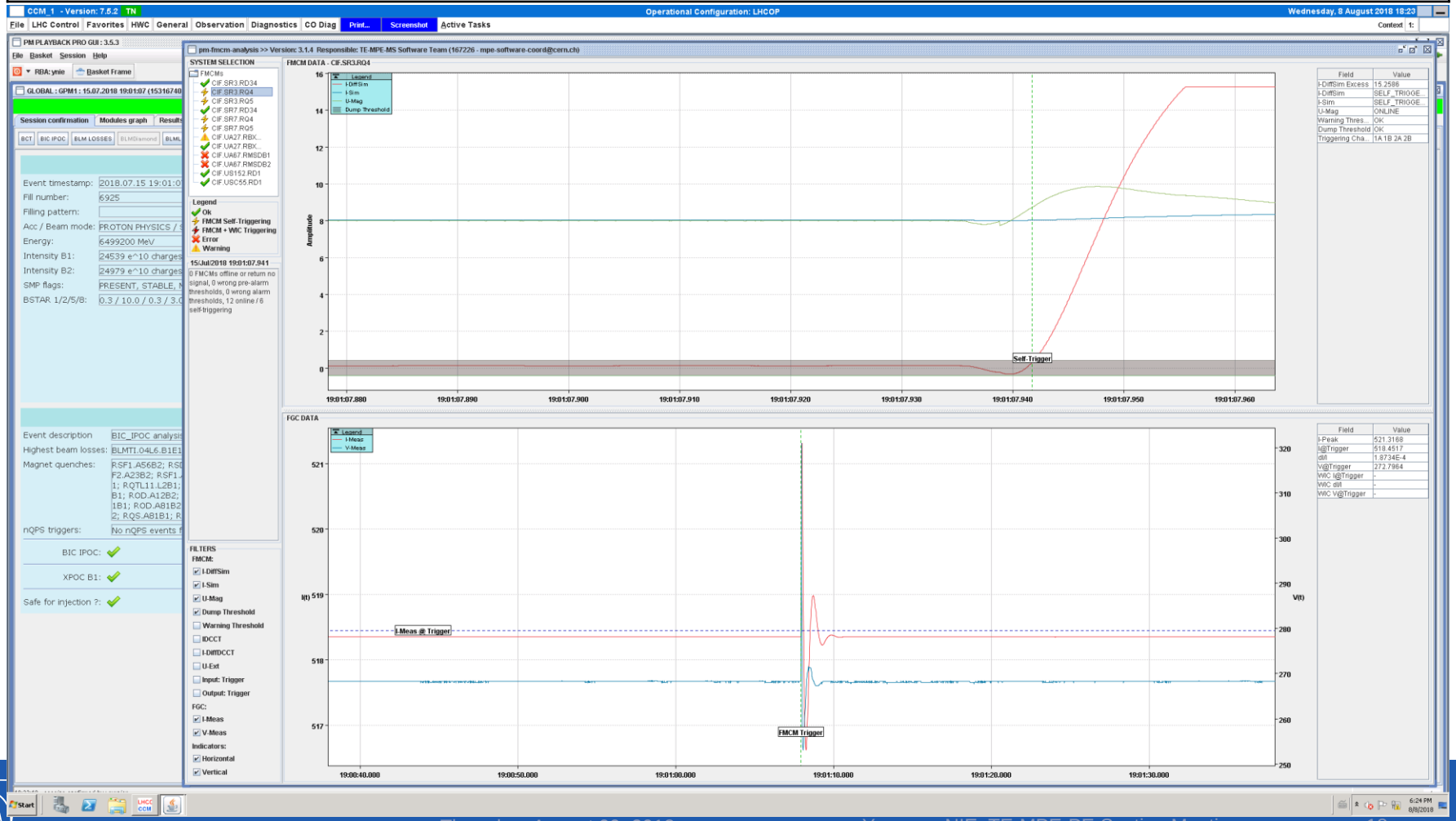
| Event Timestamp | Fill Number | Mps Expert Comment | Mps First Detection | Mps Dump Cause |
|---|---|---|---|---|
| 17-JUL-2018 22.07.21.108775 | 6938 | Dumped by 16L2 losses when squeezing down, due to a small UFO in 16L2, ~20 ms, B1. Clean dump. | BLM | UFO |



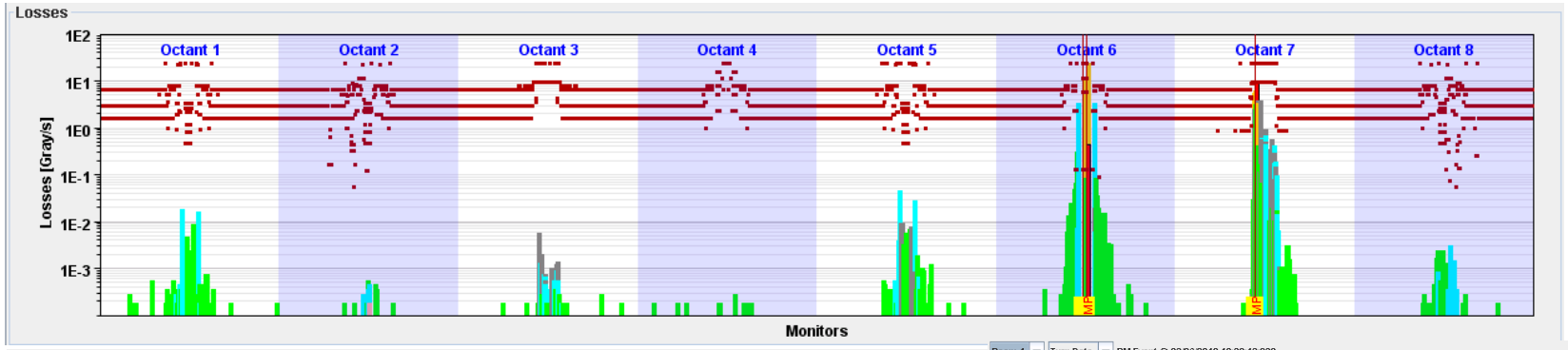
# III. Examples of beam dump: EL Net at top energy

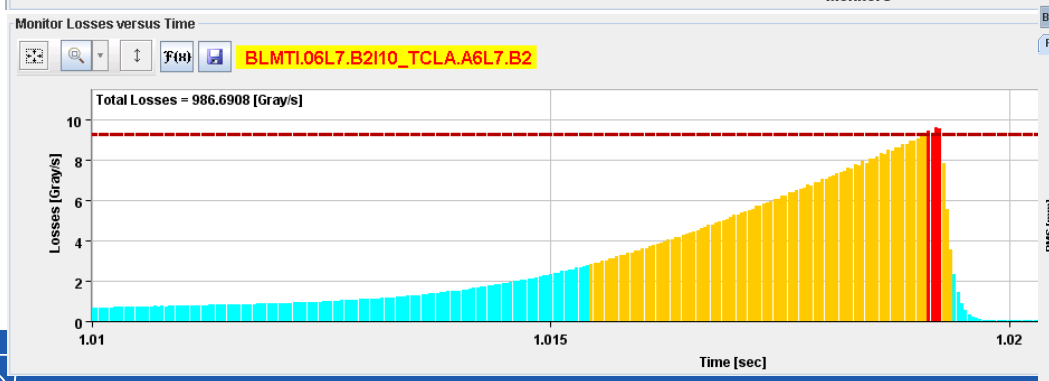
| Event Timestamp | Fill Number | Mps Expert Comment | Mps First Detection | Mps Dump Cause |
|---|---|---|---|---|
| 15-JUL-2018 19.01.07.941718 | 6925 | Dumped by FMCM of RQ4.LR3 due to glitch on the 400 kV network, which tripped many circuits in all sectors: IT.R1 quenched and also Q10.L2 and Q8.R8; RF line M2B2 tripped as well. Clean dump. | FMCM | EL Net |

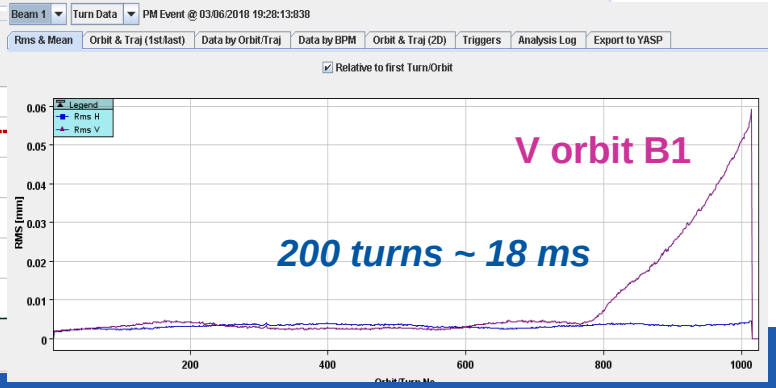


# III. Examples of beam dump: magnet quenches

| Event Timestamp | Fill Number | Mps Expert Comment | Mps First Detection | Mps Dump Cause |
|---|---|---|---|---|
| 01-JUN-2018 01.11.40.289000 | 6748 | Injection losses triggered quench heater firing on dipole B8L2 (2 QH first, followed 200ms later by the second two after detection of quench by QPS). | BLM | Transv. beam instability |
| 03-JUN-2018 19.28.13.838000 | 6755 | The vertical orbit of B1 drifted by 60 um rms leading to a dump by BLMs @6.5 TeV. Quench of ITR1, but first trigger sent by BLM in point 7. No local losses at ITR1. The quench heaters were fired on triplet R1 with a PIC interlock arriving ~17 ms after the dump. 20 ms before the dump a current decay could be observed on RTQX1.R1, which is likely responsible for the trigger of the QPS. | BLM | Cryo |



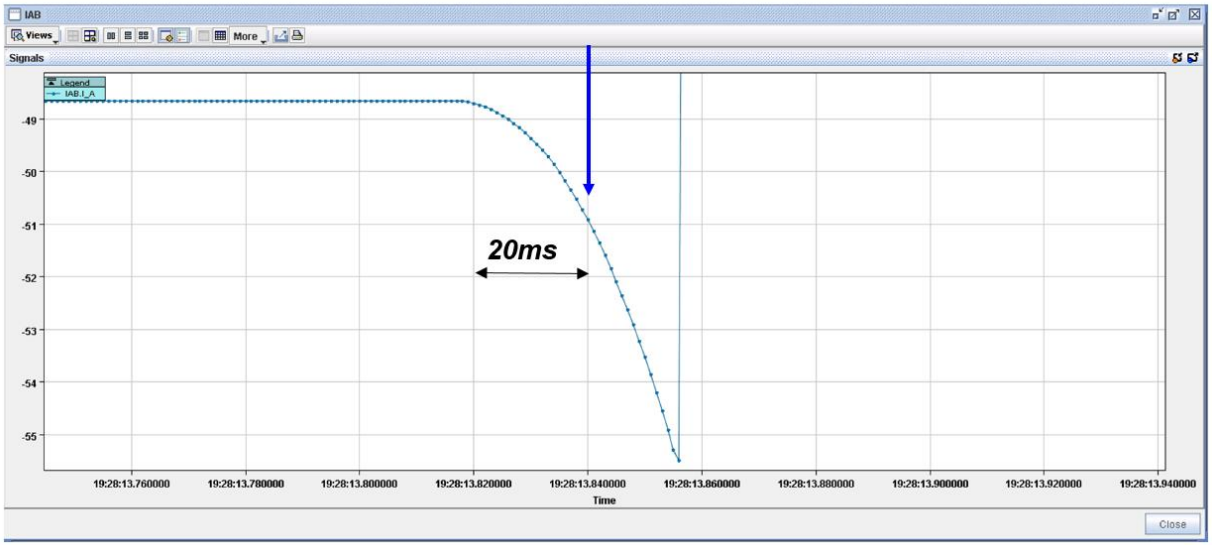



# III. Examples of beam dump: magnet quenches

| Event Timestamp | Fill Number | Mps Expert Comment | Mps First Detection | Mps Dump Cause |
|---|---|---|---|---|
| 01-JUN-2018 01.11.40.289000 | 6748 | Injection losses triggered quench heater firing on dipole B8L2 (2 QH first, followed 200ms later by the second two after detection of quench by QPS). | BLM | Transv. beam instability |
| 03-JUN-2018 19.28.13.838000 | 6755 | The vertical orbit of B1 drifted by 60 um rms leading to a dump by BLMs @6.5 TeV. Quench of ITR1, but first trigger sent by BLM in point 7. No local losses at ITR1. The quench heaters were fired on triplet R1 with a PIC interlock arriving ~17 ms after the dump. 20 ms before the dump a current decay could be observed on RTQX1.R1, which is likely responsible for the trigger of the QPS. | BLM | Cryo |

*Dump by BLMs*




[LHC morning meeting, 4th June 2018]

**MP3:** symmetric quench in Q1 due to the collision debris in ATLAS leading to loss of cryo condition.

# IV. Conclusion

- LHC intensity ramp-up and cruise checklists are important to make sure the correct functionality and performance of the critical systems relating to machine protection.
- It is a daily work to prepare/organize regular checklists during the LHC intensity cruise. Main efforts are put at top energy (6.5 TeV), but also at injection/ramp when important thing happens (magnet quenches, UFOs, etc).
- This is an efficient way to cooperate with many system experts, to run the complex machine safely, to detect new failure scenarios/behaviours, and to explore new mitigation methods of failures for the existing and future machines.


www.cern.ch