DRIVING THE LHC – SESSION 2

G. Arduini (chairman) and M. Pojer (Scientific secretary), CERN, Geneva, Switzerland

Abstract

The main aim of the session is the identification of improvements in procedures and software tools to enhance the efficiency in running the LHC with beam and favour the analysis and understanding of its performance and performance limitations.

HOW TO IMPROVE THE TURN-AROUND, S. REDAELLI

A minimum theoretical turn-around time was estimated in the order of 2h. The reality showed a much higher average of 4h27 min, which is nevertheless well below what other machines obtained after years of operation. The minimum turn-around time was 2h45m last year.

Only the physics fill with injection of trains were considered in the analysis (29 good fills ending in Stable Beams).

In terms of average time spent in the different beam modes, these are the estimated values: injection 3h (with some outliers above 6h and most between 1 and 4h, with no significant improvement with experience), ramp preparation 0.14h, energy ramp 0.43h, flat-top 0.13h, squeeze 0.56h and adjust 0.22h. A series of suggestions were presented to try and reduce downtime in each of the phases.

Proposals for improvements

<u>Injection.</u>

1- LHC beam setup in the injectors: improve the communication, also with early requests; finish the beam setup in the pre-cycle; check beam availability/quality before dumping.
2- Over-injection and: leave the pilot in slot 1, without over-injection; or move the pilot in the slot of the second train to avoid having the machine empty in case of over-injection with no beam coming from the SPS. An SPS super-cycle featuring two cycles for the pilot beam and the physics beam would also reduce the time required to switch from pilot to physics beam. During the discussion it was noted that this will impact the availability of the SPS for fixed target physics.
3- Injection Quality Checks (IQC): need faster response. During the discussion it was noted that the issues with the BPM and BLM data were fixed. Separate injection request of one beam from the IQC result of the other one; realistic thresholds for IQC parameters.
4- RF loops: set well-defined limits on the allowed loop errors and define a clear procedure for corrections.
5- Setup of pilot beams: the decay of the b3 in the dipoles at the injection plateau should be compensated to minimize the setting-up time (chromaticity correction).
6- Tools: automatic logbook entries for images.

<u>Ramp Preparation.</u>

1- Perform the setting incorporation after switching FBs on.
2- b3 compensation would avoid the verification of the chromaticity before the start of the ramp which is difficult with high intensity beams.

<u>Energy ramp.</u>

There is not much space for improvement, unless reducing the 400s decay time. It was noted that the combination of part of the squeeze with the end of the ramp would avoid stopping for allowing the decay at the end of the flat-top as this would be included in the last part of the squeeze.

<u>Flat-top.</u>

1- Start incorporation and FB preparation during the ramp.
2- Establish a policy for the chromaticity measurements at the end of the flat-op and at the end of the squeeze. This issue would be solved if we combine the end of the ramp with the beginning of the squeeze.

<u>Squeeze.</u>

1- Remove stopping points.
2- Use the same orbit reference through the squeeze or a dynamic reference is made possible for the orbit FB.
3- New studies are ongoing to optimize squeeze time.

<u>Adjust.</u>

1- Reduce the parallel beam separation during the ramp would increase aperture and reduce the time to bring the beams in collision.
2- Declare Stable Beams before luminosity scans.

Also the time needed for handshakes was estimated: 13 min for dump and 11 min for adjust. Do we need the dump handshake at all?

SOFTWARE AND CONTROL ISSUES, D. JACQUET

Reactivity and flexibility have been the secret for the impressive amount of well working applications, but still much has to be improved.

Many improvements were requested, aimed at reducing turn-around and down time, improving efficiency, minimizing risk of error and helping in diagnosing problems.

<u>Equipment control.</u>

- TCDQ: it happened a few times that they stayed armed, reporting idle and then moved unexpectedly. A new software version of the PLC is being implemented.

- RF: interlock details are needed, plus signals for diagnostics.
- Power converters: not efficient to restart a few power converters that tripped. It was requested to implement some tool into the sequencer to allow restarting only the tripped power converters so to avoid using the equipment stat application.

Injection.

- Problems have been reported with the publication of the circulating bunch configuration problem in case of BCT measurement problem, this was frequently observed during the ion run:
    - check Beam Quality Monitor (BQM) measurement versus DB before injection to prevent over-injection;
    - cross-check with ring BCT;
    - it was noted that it will be possibile to set the circulating bunch configuration with the measured bunches in the LHC BQM.

LHC sequencer.

A new GUI was developed mainly to solve issues of flexibility and ergonomics. Still some improvements to do for the check list panel or to interactively set a parameter.

Machine state application.

It is in the debugging phase, with check of transition already operational. In the future, the behaviour of certain control software (LSA, Sequencer) should be constrained by operational state (e.g. state should influence the LSA settings or sequencer tasks that can be used).

LSA-settings management.

Problems have been encountered in the generation of functions with too tight points or too large acceleration rates leading to trips induced by the Quench Protection System. Add verifications of the acceleration rates and distance between consecutive points at the generation level would help. The incorporation mechanism will have to be as well revised, to allow for more sophisticated rules, capable, for example, of including snapback and dynamic b3 corrections.

Alarms.

Too many alarms are always displayed. The list and level of alarm should be reviewed by a joint group of equipment, operation and controls experts. Mode-dependent alarms should be introduced.

Diamon.

Not clear to detect and identify problems: need to work on the configuration and on the hierarchy between application, middletears, proxy and front-ends.

Others.

- Front-ends have still too many crashes.
- Orbit and tune feedbacks should follow a dynamic reference (function).
- Sequence editor should be more user-friendly and allow for track changes and rollback.

CAN WE IMPROVE THE MAGNETIC CYCLE/MODEL AND THEIR EFFECT, E. TODESCO

In 2010 four combinations of pre-cycles were used. Only in September operation was performed with the nominal ramp rate of 10 A/s, with same parameters for physics cycle and pre-cycle. The present difference from the nominal 7 TeV cycle is the energy. The lower energy implies a smaller decay and snapback (about half). During operation, only in 3% of the cases, the machine was not properly pre-cycled; in 54% of the ramps, the previous physics cycle was used as a pre-cycle. This means that, since the pre-cycle takes 90 min, on average the time used for pre-cycle was 45 min, mainly dominated by the MQM-MQY.

Measurements performed in SM18 showed that, after 30 minutes, most of the b_3 decay has taken place, on the other hand beam measurements have shown that the magnitude of the decay matches the magnetic measurements (leading to a change of 10 to 15 units in chromaticity) but lasts 20 times longer.

Chromaticity correction is normally performed using lattice sextupoles (MSF/D) whereas the sextupole spool pieces (MCS) should be used. An automatic correction of the b3 decay is going to be implemented for the start-up.

During the ramp, the chromaticity changes as follows:

- $\pm$ 7 units, during snapback;
- $\pm$ 3 units, during the ramp;
- 7 units decay at flat-top.

Tracking precision is sufficient for operation, but it could be improved in the snapback part.

The tune decays at injection by 0.005 units over 1 h soon after the pre-cycle and should be included in the automatic correction.

For the hysteresis, there are two main issues: the IR quadrupoles during squeeze, when the current is ramping down, and the manual and FB trims on the correctors. At present the hysteresis branch is changed when the current direction is changing. This has some drawbacks, as the change of branch also happens with very small changes of current, which has resulted in a discrepancy between measured and expected beta beating corrections after incorporation of the trims in the squeeze. Since the impact of hysteresis is small and can originate, if neglected, a beta beating smaller than 10%, the proposed strategy is to remove the actual branch correction.

WHAT DO WE NEED TO UNDERSTAND AND OPTIMIZE THE LHC, O. BRÜNING

The expected main performance limitations for the operation are: electron cloud effects, UFOs, beam-beam effects, faults and overall efficiency.

E-cloud effects.

Electron cloud effects have been observed: vacuum pressure rise, instabilities and emittance growth along bunch trains, additional heat loads in the beam screens. Vacuum fixed-displays are available but it would be helpful to have windows with locations and vacuum values for the top 10 pressure maxima. Displays showing the heat load on the beam screens along each sector during scrubbing are required to be able to evaluate the effectiveness of the scrubbing and adapt the beam parameters accordingly. Bunch-by-bunch emittance displays should be available online, showing the evolution of the emittance along the bunch train as a function of time.

Unidentified Falling Objects.

The rate of this kind of events observed during the year resulted to be proportional to the total beam current (number of bunches), with no preferred location. No UFO was observed at injection, while most of them occurred below the BLM threshold.

For the monitoring of the UFOs, a display of the number of UFO events over a fill should be implemented, even for losses below BLM threshold, plus a histogram of their occurrence along the machine.

Beam-beam.

An online display of the tune diagram with bunch-by-bunch tune shift and lifetime could help to adjust the working point in collision.

For the tune and closed orbit variations along a bunch train, bunch-by-bunch orbit and tune measurements are essential for understanding the long-range beam-beam effects.

Performance monitoring.

Online statistics spread-sheets should be filled as a standard procedure, to monitor performance evolution. The statistics should include all beam parameters, the initial and final luminosity, the fill length, the reason for dump. For the whole week, the number of fills, the efficiency and the turnaround should be added as well.

Other suggestions.

A series of other suggested improvements are:

- routines for QPS reset made available for LHC operators
- emittance monitoring tool for beam quality at the injectors and time evolution
- flags/statistics for “hump” activity
- in Timber, possibility of cross-check of different variables, functionality to display vectors and general statistics pages (fault statistics and key statistics).