LHC Injector Complex Status

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LHC Performance Workshop Chamonix 2014
Outline

- LS1 modifications impacting LHC beam performance
- re-start after LS1: main issues, lessons learned (for LS2)
- first months of operation / commissioning
- 2015 re-start and first months
PROTON INJECTORS
Linac2

LS1 work:
- no shutdown work impacting the LHC beam parameters

start-up:
- main start-up issues were due to RF controls (delayed FESA class)
  - work started when beam should normally have already been produced
- otherwise “normal” start-up issues
- as Linac2 is the first machine to start up, they suffer particularly from delays and problems with the general services (e.g. access system, cooling water, ...)
- once these issues were solved, the actual start-up went rapidly and without major problems

present status:
- almost at full intensity, stable running
PSB LS1 Work (Main Items)

- Implementation of digital RF control
- Upgrade of diagnostics (BLMs, orbit, BPMs + BCTs in transfer lines)
- Multipole power supply renovation
- Machine alignment

- New main dump (cooling delayed)
- Additional 5 prototype Finemet cavity cells
- Limited cabling campaign and cable identification
- Some last-minute civil engineering related to cabling
- Controls upgrade (change of many FECs)
- Consolidation of lifting equipment
- New extraction BIC
- Cabling of beam stoppers (delayed)
PSB Start-up

- first beam in the machine very rapidly...
  - Monday 2 June first beam injected into the BI line around lunch time
  - first beam (4E10) injected in R3, lost after 5 ms
  - afternoon small intensity accelerated in all 4 rings

- ... followed by very slow progress
PSB Start-up Summary

- first beam in the machine rapidly
- controls reasonably OK, issues attacked as they arose; the CO dry runs and good preparation paid off
- new LL RF successfully commissioned, RF specialists were working round the clock and did a great job; final adjustments of the new LL-RF control system plus integration of the control for OP still ongoing

- FGC3s had many issues
- ISOLDE line bending magnets pulsing at wrong values, in particular BTY.BVT301 which switches between the two targets (only BIC prevented...)
- access system: many issues concerning all machines, patrols lost, etc.
- beam stoppers: cabling was not ready, which led to beam being dumped on the beam stoppers (not authorized)
- cotton in the cooling circuits of the magnets, led to overheating of two magnets short circuit on BT.BHZ10, longer intervention
- BTY line quadrupole and steerers with inverted polarity
- wrong alignment of the injection pick-ups
- long list of BI issues (BPMs, BLMs, SEM grids, ...); blind flight during the first days/weeks
- late deployment of certain equipment FESA classes, debugging during beam operation

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PSB Present Status

LHC beams:
- LHCINDIV and PROBE OK
- 25 ns and 50 ns have been set up, fine tuning in progress
- BCMS not yet prepared

non-LHC user beams:
- EAST, TOF, AD, ISOLDE (normal and staggered); SFTPRO, MTE beam

About 3 months after first beam in the machine were still debugging hw and sw, we were able to provide the first user beams in time (but only because the users were also delayed) and we had only just started to set up LHC type beams. Only now we are slowly entering into a stable phase.
PS LS1 Work

- alignment of the main magnets
- diagnostics: new BCT, TRIC card deployed everywhere, BWS calibrated
- 10 MHz system recabled, more voltage per harmonics
- new 1-turn delay feedback, now completely digital
- Finemet cavity installed but not yet in operation

- refurbishment of 7 magnets (to improve reliability); PFWs renovated but not main coils
- renovation of the ventilation system (still the original one of ‘58) and asbestos removal; legal requirement; ALARA improvement; uncontrolled temperature fluctuations can change machine alignment
- septa changed by spares (preventive maintenance)
- kicker controls for CT extraction renovated (still original CAMAC)
- some new power converters for auxiliary magnets
- POPS: some improvements with capacitor banks and control systems; “degraded modes” were improved; no fundamental improvements on the capacitor banks
- improved interlock for high-harmonics system, after incident of last year for 40 MHz
- installation of dummy septum (impact on non-LHC beams)
- pick up for ion tune measurement
shielding increase on top of PS at level of SMH16

PS dummy septum with shielding partly in place

Finemet cavity partly in place
PS Start-up

- as in the PSB first beam very quickly
- rather quickly 26 GeV beam for orbit measurement available
- instrumentation: basic things were running but with some subtle issue to identify

first beam going around in the PS
PS Start-up

- beam based alignment repeated twice due to error in the FESA class that sends data to YASP (which itself was working correctly); time consuming
- the Finemet cavity was found to be ringing at 40 MHz; some gaps short-circuited, presently no performance limitation, under investigation
- magnetic field non-reproducibility at injection being investigated.
- vacuum leak on extraction kicker 79 was the only major intervention
- MTE kickers need repair (PFN)
- two wire scanners broke after a short while
- teething prbs with controls, tackled as they arose
- otherwise minor hw issues (e.g. KFA71 tube fault)
**LHC beams:**
- LHCINDIV
- 25 ns and 50 ns have been set up, RF gymnastics established
- Setting up of the 72 bunches with double injection started
- 12 bunches of 25 ns beam sent to SPS
- BCMS not yet prepared
- Initially it was intended to use MTE extraction towards the SPS; due to prbs with the MTE kickers now the NA physics beam is delivered using CT

**non-LHC user beams:**
- EAST beams in good shape, AD beam in good shape, TOF still not at ultimate intensity, SFTPRO delivered to SPS, MTE beam started but now on hold

Although now all user beams are delivered in time and specs, still not back to efficient and smooth operation; still issues being followed up
SPS LS1 Work

- alignment TT10 following tunnel maintenance, beam went through at first shot
- big realignment campaign everywhere, especially in LSS1, 5 and 6
- removal of earth loops
- installation of graphite (aC) coated magnets in 4 complete half-cells
- installation of final serigraphed kicker to reduce heating with 25 ns
- new power system for 2nd 800 MHz cavity, new cavity probes, new LLRF system (but late, deployment only in 2015)
- new wire scanner (only the tank installed so far)
- installation of SR light monitor to spare the FWS at high energy (IGM will be a back-up)
- survey of ring elements for impedance sources

- repair of instrumentation for FT (SEM grids etc.)
- started construction of new building for 200 MHz upgrade
SPS Commissioning Status

- first beam injected Saturday 13 September 4 a.m.
- beam accelerated on the FT cycle
- 12 bunches 25 ns beam accelerated
- some work done to find right settings and gains for the BPMs
- machine seemed pretty misaligned RMS 10 mm (normally 2 mm)
- simultaneous beam-based alignment done for Q26 and Q20 optics, good results
- so far going reasonably well
- main issues now related to power supplies
ION INJECTORS
Linac3

LS1 work:
- no shutdown work impacting the LHC beam parameters

start-up:
- many things delayed (e.g. stripper mechanism, pepper pot)
- floating planning

present status:
- Linac3 is now running with Ar for FT physics
- in order to change to Pb, the source needs to be dismantled and parts to be exchanged
- only then re-start for LHC beams
- LHC type beam not yet produced, but at least general issues solved

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LS1 work:
- no shutdown work impacting the LHC beam parameters

start-up:
- cold check-out inexistent because HW test period lingered on
- consequently debugging happened with beam
- controls issues mitigated by presence of excellent controls coordinator
- issues with power supplies
- lesson learned: never do a re-start after an LS with a new ion species

present status:
- LEIR is now running with Ar for FT physics
- LHC type beam not yet produced, but at least general issues solved

some know-how missing (e.g. LSA modelling of the machine); team of full-time dedicated machine supervisors would be beneficial
A Word on Controls (all machines)

- FECs renovated after LS1
- FECs renovated during LS1
- FECs already renovated
CO dry runs were essential and extremely successful. Good support and collaboration controls issues during start-up were addressed as they arose.

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Lessons learned...
Lessons from the Re-start after LS1

Things to be improved
(not for discussion)

1. end of shutdown was not respected
(also safety concern)

2. hw commissioning and test were to
large parts not done properly
e.g. missing cables, faulty instruments,
inverted polarities, ...

3. delays
e.g. FESA classes not ready for the
start-up with beam

4. application programs not ready

Possible mitigation measures
(for discussion)

1. – 3.
○ coherent follow up of the whole
  process (shutdown – hw test –
  cco – startup); one person per
  machine?
○ more rigorous check-out with
  check-lists, signatures, ?

4. make it part of the check-out

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Lessons from the Re-start after LS1

5. alignment on several occasions not conform to request needed to be re-done, requiring access and causing delays

6. equipment working only partially and debugging lengthy

7. support of equipment groups in some cases not ideal e.g.: absences, single-expert systems, ...

5. alignment needs to be checked more rigorously by the alignment expert; delay to enter results in GEODE should be of the order of few days; magnets that cannot be aligned should be clearly marked

6. presence of equipment specialist in the CCC during the start-up, pro-active participation in the debugging and not only on request

7. the end of an LS is not the end for the eqp specialists (mental problem, also large number of accumulated leave days); see 6. also: the start-up fell in the middle of the holiday period
Lessons from the Re-start after LS1

8. in some cases initial situation got lost (interlock connectivity; SEM grid channel alignment for LBS line)

8. situation before replacement of equipment/controls has to be perfectly documented
Lessons for LS2

- The focus of LS1 was on the LHC and only some work was done on the injectors.
- The focus of LS2 will be on the injectors and there will be drastic changes to the injector complex.
- We will re-start the injector complex after LS2 with (almost) new machines, and there will be quantitatively more and qualitatively new issues.
- The “standard” interventions must be absolutely transparent, we will be busy enough with the new and unexpected problems.
- The scheduled time for commissioning must be sufficient. If we try to squeeze it too much, we will end up not meeting the deadlines; a very thorough planning has been made for the RLIUP review.
- SW development has to be ready and tested as far as possible before starting the HW tests.
- HW tests should be more rigorous and comprehensive; each equipment group should have well-organised and documented dry runs.

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First Look at 2015
2015 Injectors Q1

2015 Injector Accelerator Schedule
Draft for approval

Weeks 1 to 13 for January, February, and March

- Controls maintenance
- Start linacs
- Beam to Booster
- Beam to SPS
- Beam available to LHC
- Start LHC commissioning

Days of the week:
- Mo: Monday
- Tu: Tuesday
- We: Wednesday
- Th: Thursday
- Fr: Friday
- Sa: Saturday
- Su: Sunday

- Technical stop
- Recommission injectors (protons & ions)
- Argon set-up (2 weeks - distributed)
- Sector test S23
- Sector test S78
- NA argon physics (6 weeks)
- Operation as LHC Injector

Legend:
- Green: Injector Complex MD Block
- Yellow: Ions to LHC
- Yellow: Ions to North Area
- Orange: HiRadMat: possible beam request
- Red: AD Setting-up & Studies
- Blue: Injector Stop
- Floating injector MD - LHC beam has priority

ML
September 16, 2014
V0.4

M. Lamont
2015 Injectors Q2

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2015 Injectors Q3/Q4

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Technical stops and MD to add

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Conclusion / Summary

2014:
- start up was (is) tedious and lengthy
- the points to be improved have been listed; the underlying problem across all machines is non-respect of the planning, delayed delivery, work overload
- the items where we were most worried about (CO) worked well (which shows that it is possible), whereas some of the “standard” items where we paid less attention worked less well (cabling errors or missing cabling, lack of testing, ...)

2015:
- hot start up
- the X-mas stop includes w51, 52, 1, 2 & 3
- only necessary interventions which do not impact on start-up schedule (FOM approval)
2014 Start-up