Injection system

Evian 2021

Y. Dutheil, M.J. Barnes, C. Bracco, F. M. Velotti
SY-ABT
Outline

• Injection protection system and upgrades
• MKI-Cool and HL-LHC readiness
• Injection steering with high intensity
• IQC and changes to the GUI
• Experience from the beam test
• Commissioning plan
• Conclusion
Injection protection system

- MSI: injection septa
- MKI: injection kickers, e-cloud and beam induced heating
- TDI: injection dump, new segmented design to improve robustness and positioning accuracy
- TCLIB, TCLIA: auxiliary protection collimators, increased gap to increase acceptance of ALIC ZDC
- D1: injection dump mask, additional local protection of D1 magnet in case of injection failure (scheduled for LS3)

**Major upgrade**

**Minor upgrade**

**No upgrade**

Injection system
Transferline collimators

- Pre-LS2 collimators not compatible with operation with high brightness beams:
  - Not robust enough
  - Not enough dilution

- Graphite R4550 1.2 m long collimators replaced with 3D C/C 2.1 m long absorbers.

- TI2:
  - TCDIV.20607 momentum collimator removed (always set at ±10 mm during Run2)
  - Collimators installed at the same location (within 1 m) as before LS2, no change in optics

- TI8:
  - New TL optics (two new PC to allow powering independently MQIF.87000 and MQID.87100)
  - Horizontal collimators moved to more favorable locations (larger spot-size)

- Status
  - Transferline optics & aperture tested and validated during October’s beam test
  - No implication for operation
  - No intensity limits

<table>
<thead>
<tr>
<th>Existing Collimator Name</th>
<th>Existing Position $x_{out}$ [m]</th>
<th>New Collimator Name</th>
<th>New Position $x_{out}$ [m]</th>
<th>Difference in Position (centre-to-centre) [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCDIV.29012</td>
<td>2952.670</td>
<td>TCDIV.29011</td>
<td>2953.250</td>
<td>+0.00</td>
</tr>
<tr>
<td>TCDIH.29050</td>
<td>2971.670</td>
<td>TCDIH.29049</td>
<td>2972.250</td>
<td>+0.00</td>
</tr>
<tr>
<td>TCDIH.29205</td>
<td>3014.670</td>
<td>TCDIH.29206</td>
<td>3016.500</td>
<td>+1.25</td>
</tr>
<tr>
<td>TCDIV.29234</td>
<td>3028.170</td>
<td>TCDIV.29233</td>
<td>3028.170</td>
<td>-1.58</td>
</tr>
<tr>
<td>TCDIH.29465</td>
<td>3099.170</td>
<td>TCDIH.29464</td>
<td>3099.170</td>
<td>-0.58</td>
</tr>
<tr>
<td>TCDIV.29509</td>
<td>3107.670</td>
<td>TCDIV.29508</td>
<td>3108.250</td>
<td>+0.00</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Existing Collimator Name</th>
<th>Existing Position $x_{out}$ [m]</th>
<th>New Collimator Name</th>
<th>New Position $x_{out}$ [m]</th>
<th>Difference in Position (centre-to-centre) [m]</th>
</tr>
</thead>
<tbody>
<tr>
<td>TCDIH.87441</td>
<td>2387.665</td>
<td>TCDIH.87606</td>
<td>2432.032</td>
<td>+44.378</td>
</tr>
<tr>
<td>TCDIV.87645</td>
<td>2450.165</td>
<td>TCDIV.87644</td>
<td>2450.745</td>
<td>+0.000</td>
</tr>
<tr>
<td>TCDIV.87804</td>
<td>2499.965</td>
<td>TCDIV.87804</td>
<td>2501.125</td>
<td>+0.180</td>
</tr>
<tr>
<td>TCDIV.87904</td>
<td>2546.152</td>
<td>TCDIV.87822</td>
<td>2510.430</td>
<td>-35.502</td>
</tr>
<tr>
<td>TCDIV.88121</td>
<td>2619.837</td>
<td>TCDIV.87939</td>
<td>2566.345</td>
<td>-54.472</td>
</tr>
<tr>
<td>TCDIV.88123</td>
<td>2621.237</td>
<td>TCDIV.88121</td>
<td>2620.897</td>
<td>-0.920</td>
</tr>
</tbody>
</table>
**TDIs**

**Context**
- Intended for downstream equipment protection in case of injection kicker magnets failure
- In Run1&2, issues with vacuum and structural behavior were discovered
- Extrapolation to HL-LHC intensities highlighted the need for an upgraded device

**New design, TDIs**
- Three independent shorter modules (1.6 m each) improve alignment accuracy and reduce beam induced deformation
- The modules are installed on a common girder, aligned on surface and transported as a single device in the tunnel (spares under vacuum and ready for installation with reduced bake out in the tunnel)
- Minimise impedance (beam induced heating): materials, coating, longitudinal and lateral RF fingers, tapering, tank and transition geometry, cooling, etc.
- Improve vacuum performance: materials, coating, operational gaps.
- Improve mechanics and diagnostics
- Improve spare policy: full assembly vacuum conditioned (additional sector valves) for installation in tunnel without bake-out
TDIs BETS

- Now 3 modules instead of one, system modified according to ECR EDMS # 2337989
  - Additional 2 BETS input for the additional 2 modules, for each ring

- Status
  - Each jaw was moved and the BETS signal checked
  - No change from the point of view of the BIS
TDIs alignment (1 nominal bunch)

- Three independent modules, each of two jaws which have to be aligned independently.
- First two modules at 6.8σ, last module 2 mm further retracted.
- The shorter length of the jaws, the improved mechanics and alignment references do not require anymore to perform the angular alignment.
- Standard beam based alignment as for other LHC collimators:
  - Beam envelope defined by vertical primary in point 7.
  - Approach one TDIS jaw at the time to the beam envelope until it touches it.
  - Approach other jaw until it touches the beam.
  - Calculate centre and retract to nominal settings.
  - ~30 minutes to align all of modules at one IP (parallel alignment at two Ips possible).
  - Possible envisaging to use automatic procedure of collimation team → further reduced alignment time.
- This year, the alignment procedure will start by performing a complete beam scraping to find the LVDT readout at the center of the beam for each jaw.
MKI Fast Interlock and Protection System

- System to detect abnormal triggering or HV breakdown
- New system installed during LS2 and completely validated before the beam test
- Several advantages over the previous system: more flexibility, easier calibration, industrial interface and advanced diagnostics and such as power trigger surveillance and thyatron protection
TCLIA

• Context
  – Pre-LS2 configuration: TCLIA in point 2 main aperture bottleneck limiting ALICE ZDC acceptance (not compatible with 50 ns spaced ion bunches)
TCLIA

• Context
  – Pre-LS2 configuration: TCLIA in point 2 main aperture bottleneck limiting ALICE ZDC acceptance (not compatible with 50 ns spaced ion bunches)

• Upgrade
  – HW modified and maximum achievable gap increased from 56 mm up to 60 mm
  – Modified HW installed at new position ~2m closer to IP

• Status
  – No impact on commissioning or operation
MKI readiness for HL-LHC

• Context
  • MKIs have screen conductors to reduce beam induced heating;
  • Screen conductors are supported in slots of an alumina tube;

• Alumina tube SEY
  • A newly installed MKI vacuum conditioning should be in the shadow of the 2022 intensity ramp-up
  • MKI8D was exchanged during the 2017-2018 YETS
    • its alumina tube has 50nm Cr2O3 coating
    • low SEY, doesn’t increase the probability of UFOs
    • beneficial for the high voltage environment

• MKI-Cool
  • In MKI Cool, an RF damper relocates heating from the ferrite yoke to a, water cooled, ferrite cylinder which is away from the pulsed high voltage
  • Needed for HL-LHC beam
  • Original goal was to replace an MKI with an “MKI-Cool” during LS2.
  • However, a high-voltage issue was encountered due to con-conforming, 3m long, alumina tubes.
MKI readiness for HL-LHC

• Status
  - Completed HV conditioning and reached target 56.1 kV and 8.8 µs flattop
    - with more pulses and more strong sparks than normal so decided to remove and inspect
    - Puncture through wall of alumina tube due to thin wall (~1.2mm c.f. 2.4mm specified)
  - Characterisation of all every alumina tubes with different methods
  - Two conforming alumina tubes identified and optimum angle of orientation for installation determined;
    - Both alumina tubes sent for Cr2O3 coating (for reducing SEY and hence E-cloud)

• Plan
  - One MKI-Cool ready by October 2022
  - Five MKI-Cools installed by early 2025
  - Assuming start of LS3 is delayed until end of 2025, the additional three MKI Cools will be installed in 2026
  - Four spare MKIs converted to Cools during 2027 (during LS3)
Turn-around & possible improvements

- Procedure for TL steering discussed after Run 2
  - Discussed at EVIAN19 and MPP workshop 2019
  - Establish *golden trajectories* for both the ring and the transferlines as soon as multi-bunch trains are extracted from the SPS
  - Perform SVD steering cleaning campaigns periodically – ideally this could be done every technical stop
  - Steering with low intensity (1-12 bunches)
    - Regularly done, encouraged for every fill
    - Following is a reset of the correctors FEI limits around the new settings
  - Steering with high intensity (>12 bunches)
    - If necessary, during the filling without needing to restart it
    - Allow steering with up to ~3 correctors and ~5 µrad

- Efforts to improve turn-around using automatized procedures in the injectors, see F. Velotti IEF21 contribution
Changes to IQC GUI

- New BLM layout includes IR6 & 7 to see collimator and dump regions
- DBLM new tab to report on diamond BLM data
  - Not available during the beam test
  - Issues with the data and its readout, will take some time next year to solve

- Status
  - Used during beam test
  - Transferline BLMs not available in IQC during the beam test. A fix was applied after the beam test and will be tested next year
Experience from the beam test

- Very useful for the injection system
- All tests needed for low intensity done successfully
  - MKI delays
  - TL optics, aperture and BLM response
  - Dispersion measurement coherent with the model. As pre-LS2 dispersion mismatch in T18 and should be investigated further
  - TL aperture measurement inline with previous years
  - TL BLMs
  - TL automatic collimator setup application developed by Y. Le Borgne
  - All associated software and controls

- Issues & lessons learned
  - Wrong MKI strength on first pulse after a soft-start
    - Tracked down to an issue with PLC software version
    - Special attention needs to be given to PLC code upgrade and software version
  - MKI-RF fine delay
    - Very different from Run2 despite special attention by ABT to preserve the system’s internal response times
    - Will be rechecked at the start of Run3
  - BTV orientation
    - Confusing injection BTV’s reported beam position
    - Orientation can be controlled before injection using the video to observe the screen’s motion
Commissioning plan

• MP checklist, EDMS #889343

• With low intensity
  – Injection with probe and nominal
  – Full setup and validation of of TDIS, TCLIA and TCLIB
    . Including full beam scraping for each jaw of the TDIS, just for this year
    . Check the collimation hierarchy remains
  – AGK tests, and verification with beam of the first and last buckets allowed
  – MKI waveform edge scan for both rings
  – Setup of transferline collimators and check of complete phase space coverage

• Injection with trains and intensity ramp-up
  – With the injection system ready and fully validated
  – Starting with trains of 12 bunches
  – Increase to 72, 144, 216 and 288 bunches, while carefully checking IQC data
Conclusion

• Very useful for the beam test, for the systems & the people!
• No MKI-cool installed but first one ready by October 2022
• Major changes to the injection collimation system but without fundamental impact to operation
• Some potential improvement of turn around time are being investigated
• Commissioning procedure
  – MP tests listed in EDMS #889343
  – Clear sequence and procedure for injection setup and intensity ramp-up to 288 bunches
• Systems are ready and an extension of Run3 will have no impact on the injection system operation
Thank you