CERN

Injection system

Evian 2021

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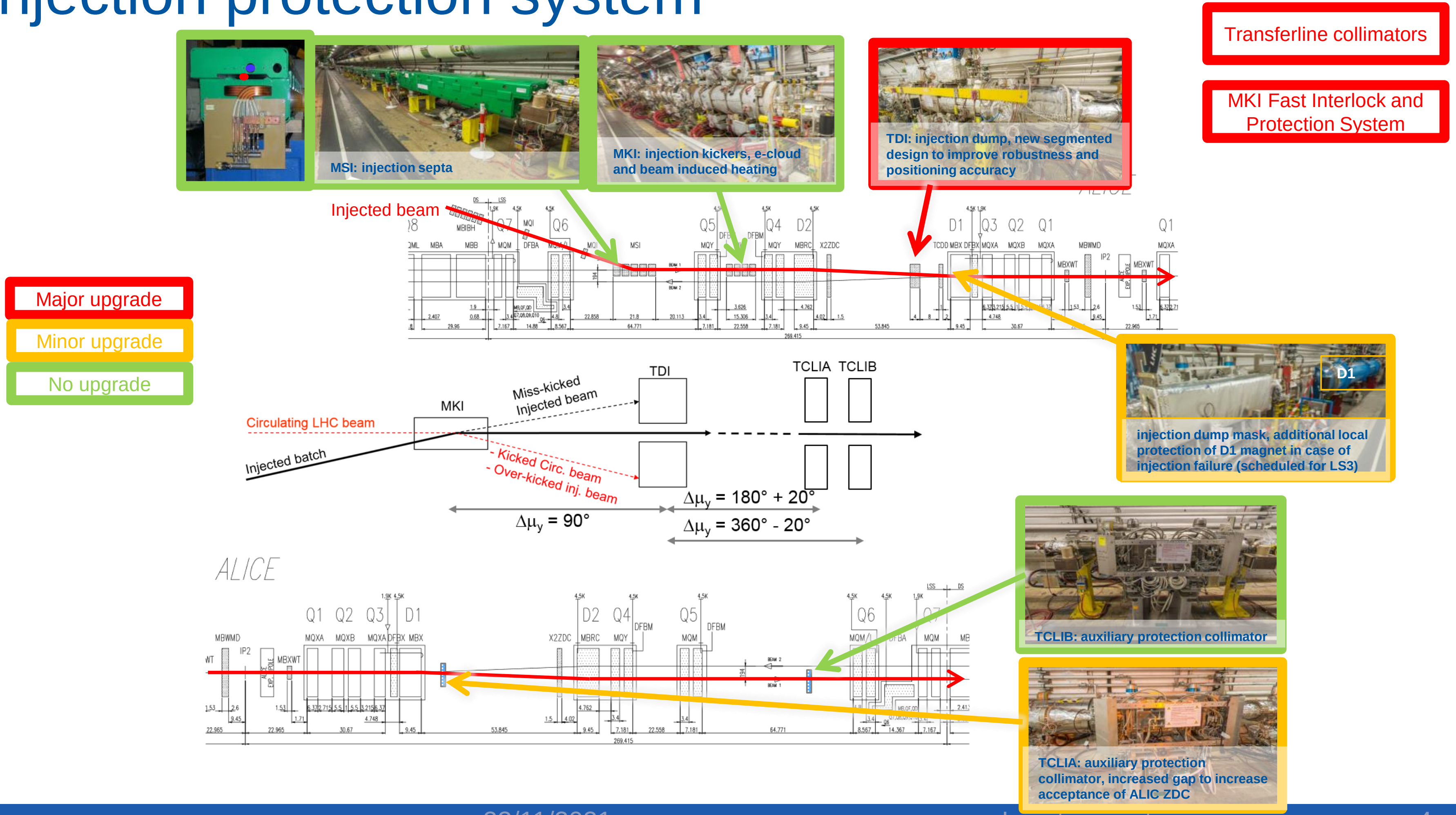
SY-ABT

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



Transferline collimators

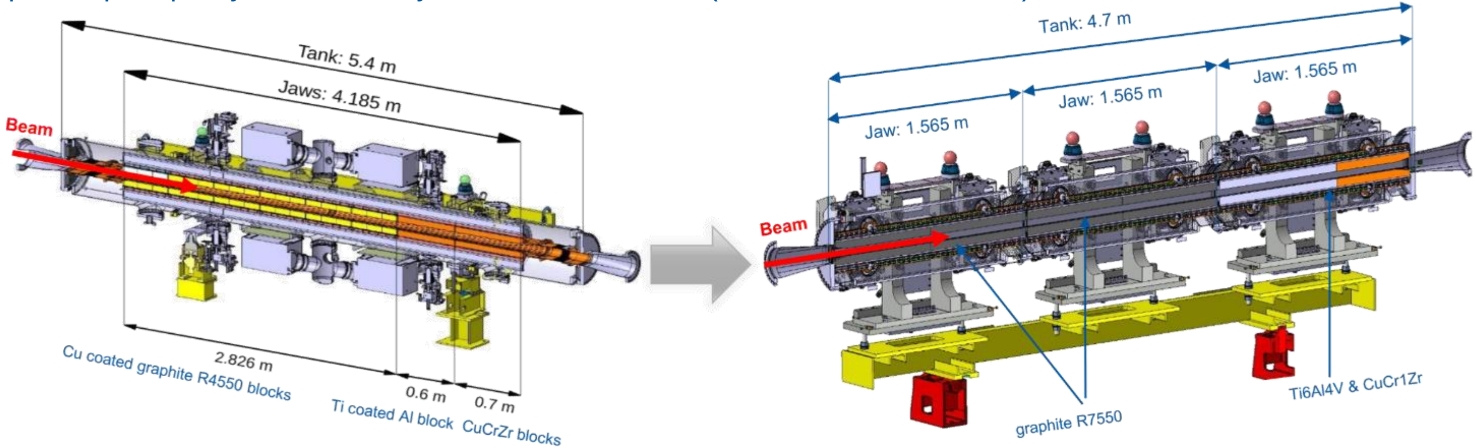
- Pre-LS2 collimators not compatible with operation with high brightness beams:
  - Not robust enough
  - Not enough dilution
- Graphite R4550 1.2 m long collimators replaced with 3D C/C 2.1 m long absorbers.
- TI2:
  - TCDIV.20607 momentum collimator removed (always set at ±10 mm during Run2)
  - Collimators 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

Existing Collimator Name	Existing Position s_{end} [m]	New Collimator Name	New Position s_{end} [m]	Difference in Position (centre-to-centre) [m]
TCDIV.29012	2952.670	TCDIV.29011	2953.250	+0.00
TCDIH.29050	2971.670	TCDIH.29049	2972.250	+0.00
TCDIH.29205	3014.670	TCDIH.29206	3016.500	+1.25
TCDIV.29234	3029.170	TCDIV.29233	3028.170	-1.58
TCDIH.29465	3099.170	TCDIH.29464	3099.170	-0.58
TCDIV.29509	3107.670	TCDIV.29508	3108.250	+0.00

Existing Collimator Name	Existing Position s_{end} [m]	New Collimator Name	New Position s_{end} [m]	Difference in Position (centre-to-centre)[m]
TCDIH.87441	2387.665	TCDIH.87606	2432.032	+44.787
TCDIV.87645	2450.165	TCDIV.87644	2450.745	+0.000
TCDIV.87804	2499.965	TCDIV.87804	2501.125	+0.580
TCDIH.87904	2546.152	TCDIH.87822	2510.430	-35.502
TCDIH.88121	2619.837	TCDIH.87939	2566.345	-54.072
TCDIV.88123	2621.237	TCDIV.88121	2620.897	-0.920

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

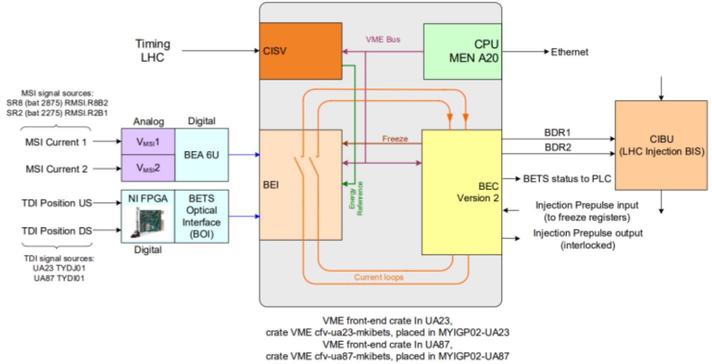


Figure 1 — BETS MSI-TDI overview (pre-LS2)

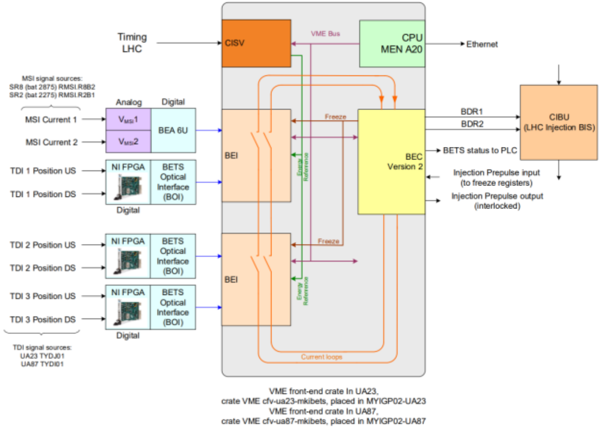
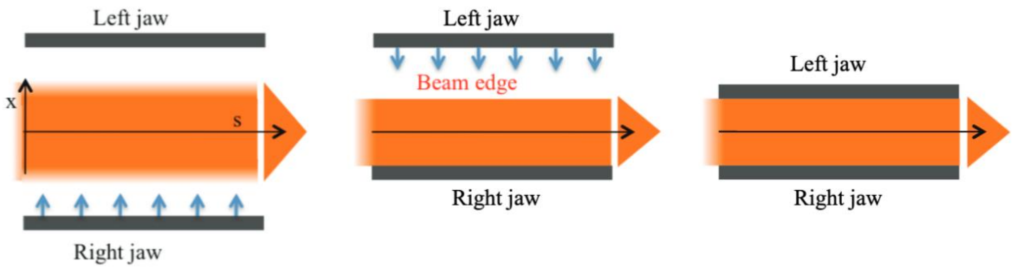


Figure 2 — BETS MSI-TDI overview (post-LS2)

- Status
  - Each jaw was moved and the BETS signal checked
  - No change from the point of view of the BIS

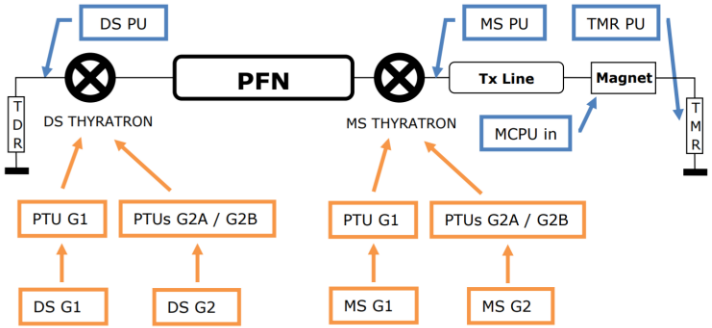
TDIs alignment (1 nominal bunch)

- 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

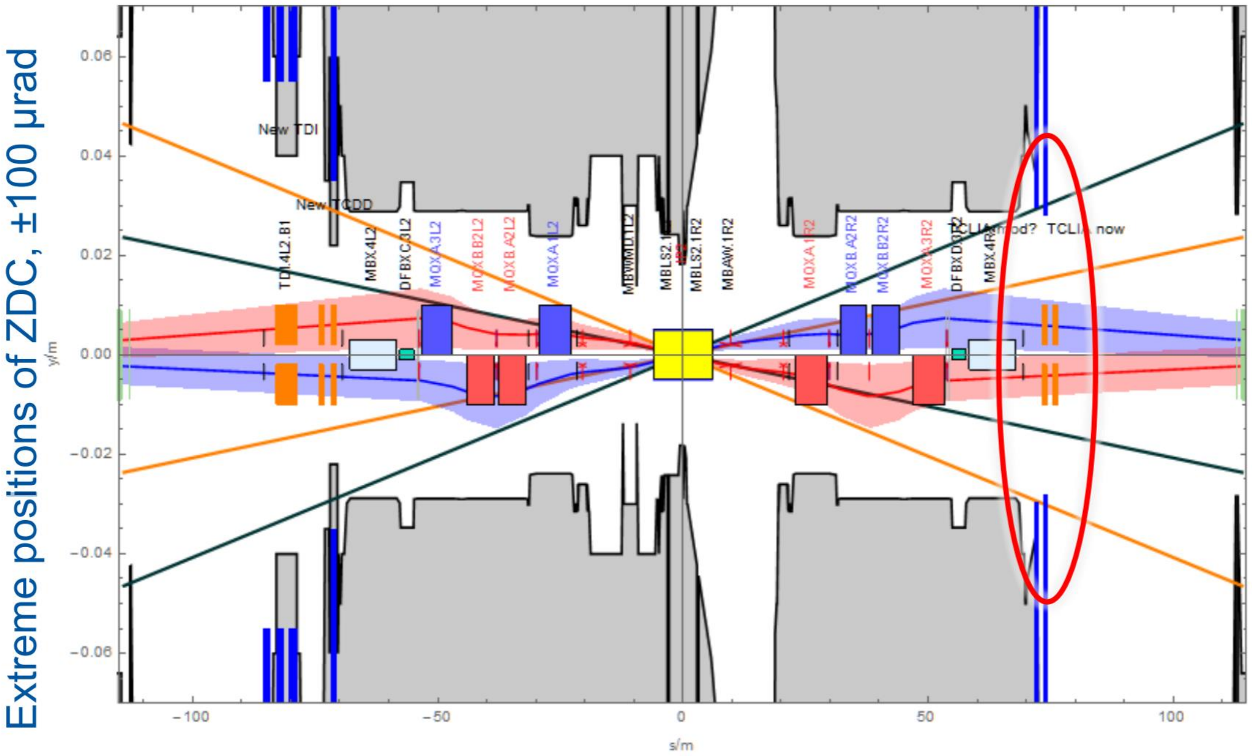
- System to detect abnormal triggering or HV breakdown
- New system installed during LS2 and completely validated before the beam test
- Several advantages over the previous system : more flexibility, easier calibration, industrial interface and advanced diagnostics and such as power trigger surveillance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



MKI8 - MYIGP07
New fast interlock rack

TCLIA

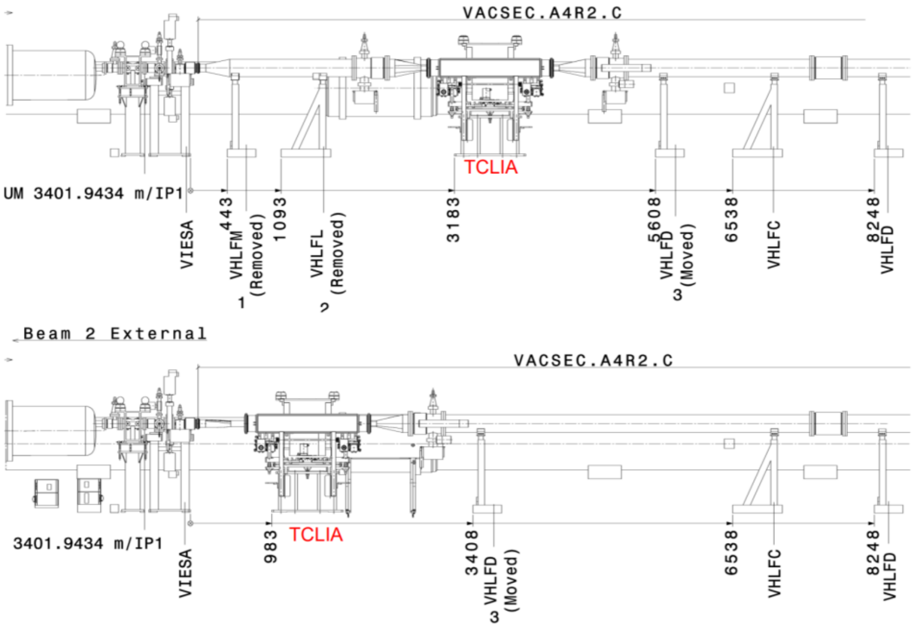
- Context
  - Pre-LS2 configuration: TCLIA in point 2 main aperture bottleneck limiting ALICE ZDC acceptance (not compatible with 50 ns spaced ion bunches)

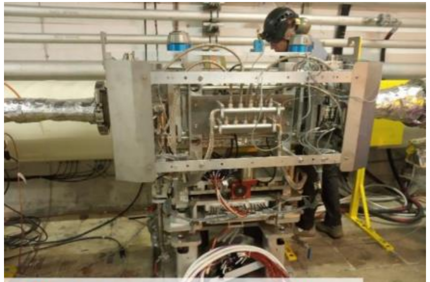


Showing 100 μrad neutron cones

TCLIA

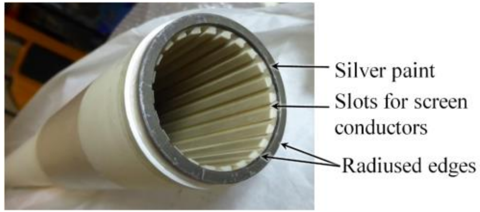
- Context
  - Pre-LS2 configuration: TCLIA in point 2 main aperture bottleneck limiting ALICE ZDC acceptance (not compatible with 50 ns spaced ion bunches)
- Upgrade
  - HW modified and maximum achievable gap increased from 56 mm up to 60 mm
  - Modified HW installed at new position ~2m closer to IP
- Status
  - No impact on commissioning or operation

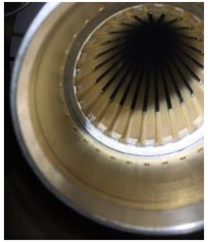



TCLIA at new position in LHC

MKI readiness for HL-LHC

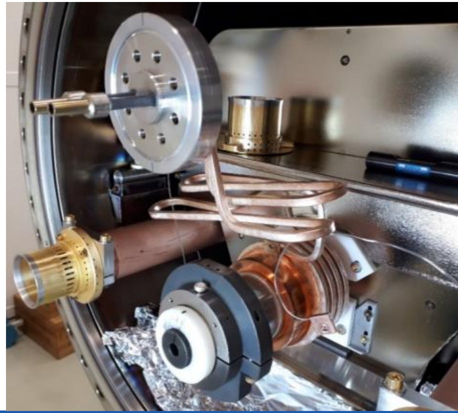
- Context
  - MKIs have screen conductors to reduce beam induced heating;
  - Screen conductors are supported in slots of an alumina tube;





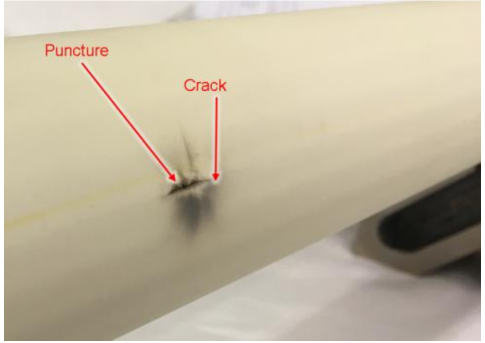
- Alumina tube SEY
  - A newly installed MKI vacuum conditioning should be in the shadow of the 2022 intensity ramp-up
  - MKI8D was exchanged during the 2017-2018 YETS
    - its alumina tube has 50nm Cr_2O_3 coating
    - low SEY, doesn't increase the probability of UFOs
    - beneficial for the high voltage environment

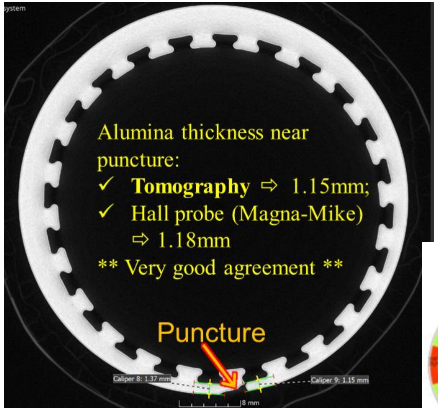
- MKI-Cool
  - In MKI Cool, an RF damper relocates heating from the ferrite yoke to a, water cooled, ferrite cylinder which is away from the pulsed high voltage
  - Needed for HL-LHC beam
  - Original goal was to replace an MKI with an "MKI-Cool" during LS2.
  - However, a high-voltage issue was encountered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

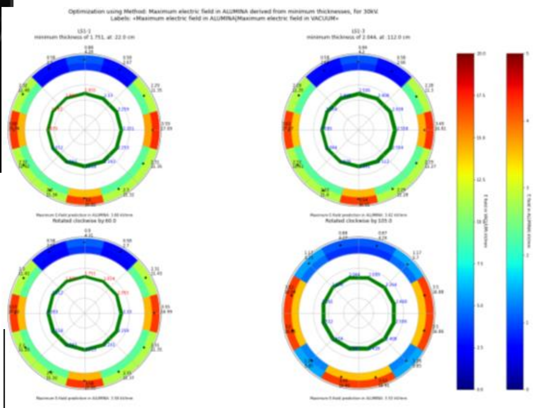


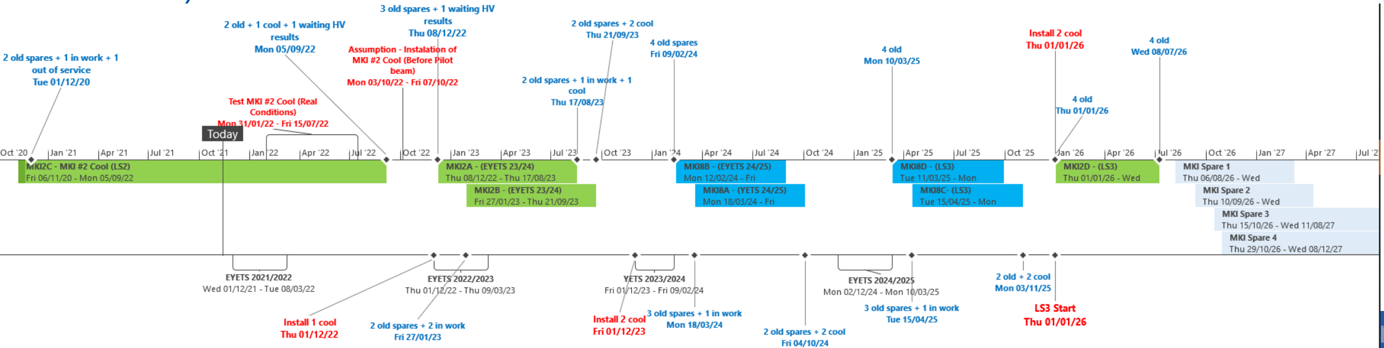
MKI readiness for HL-LHC

- 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 Cr_2O_3 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)







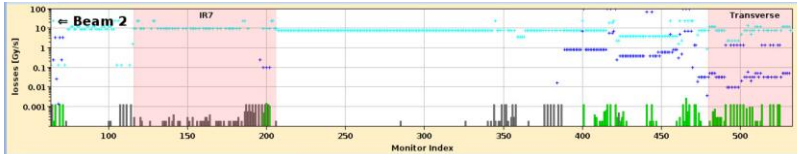


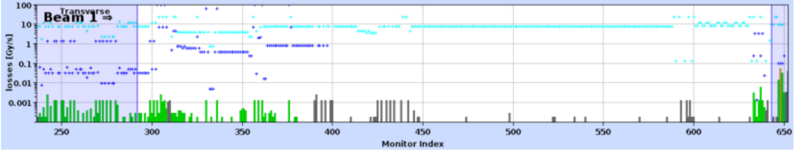
Turn-around & possible improvements

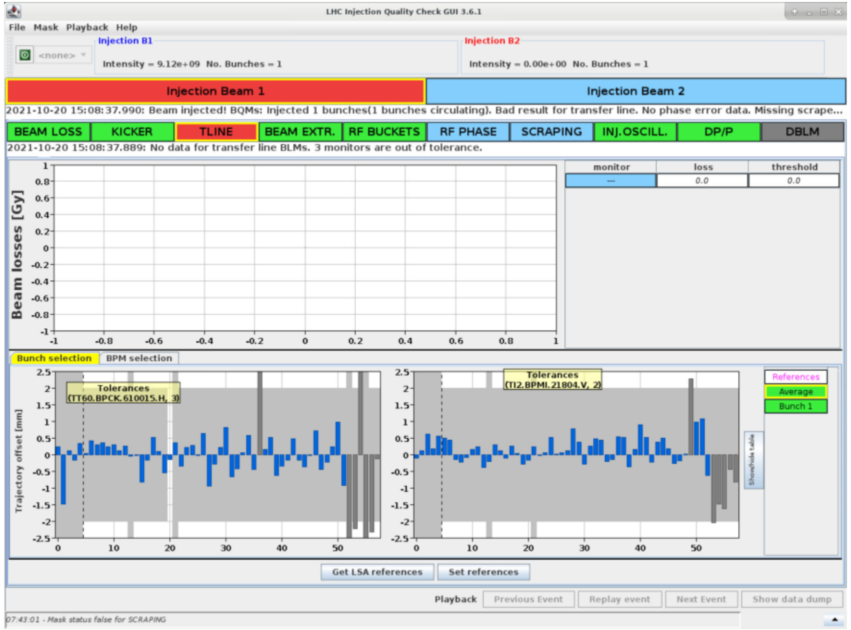
- Procedure for TL steering discussed after Run 2
  - Discussed at EVIAN19 and MPP workshop 2019
  - Establish *golden trajectories* for both the ring and the transferlines as soon as multi-bunch trains are extracted from the SPS
  - Perform SVD steering cleaning campaigns periodically – ideally this 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





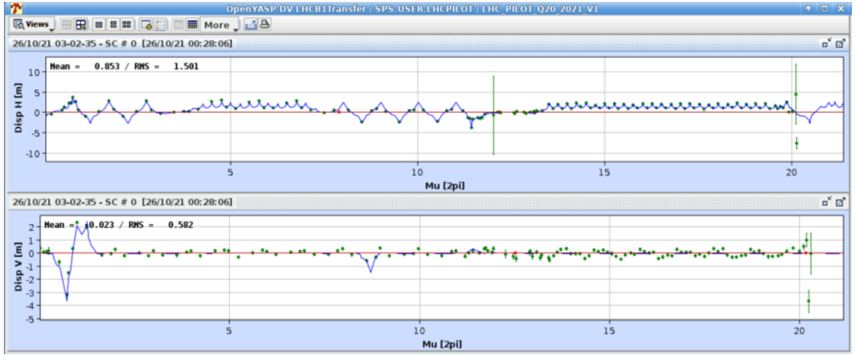


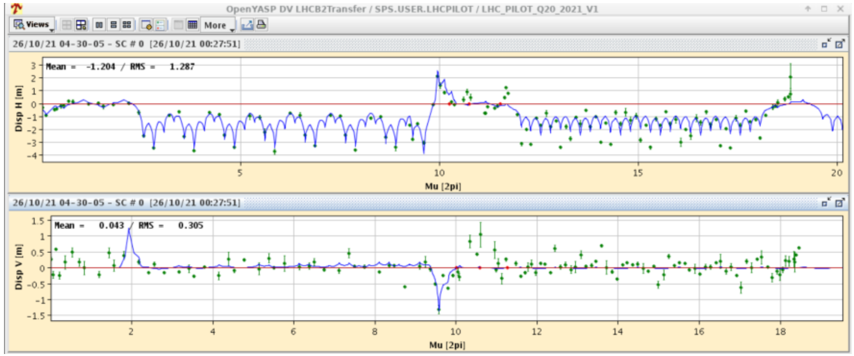
- Status
  - Used during beam test
  - Transferline BLMs not available in IQC during the beam test. A fix was applied after the beam test and will be tested next year

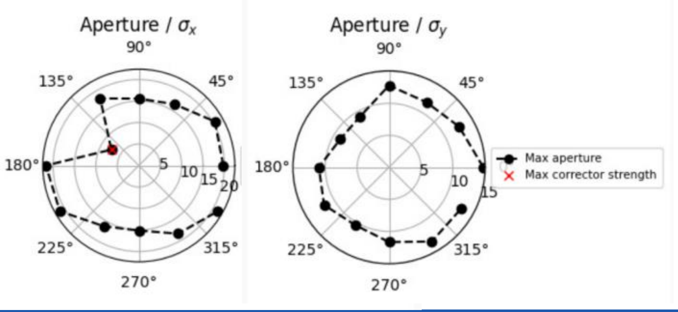
Experience from the beam test

- 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 TI8 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' 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 288bunches
- Systems are ready and an extension of Run3 will have no impact on the injection system operation

Thank you