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Lattice Status & Commissioning Plan

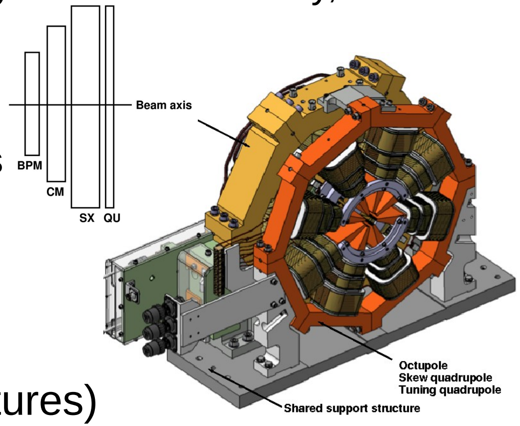
SLS 2.0 Machine Advisory Committee Meeting 19.-20.09.22

Commissioning Requirements

- Pre-commissioning after (before?) tunnel closure
- Commissioning 1^{st} day
- Commissioning n^{th} day stored beam (n = ?)
- Commissioning accelerator & beamlines >~3 months

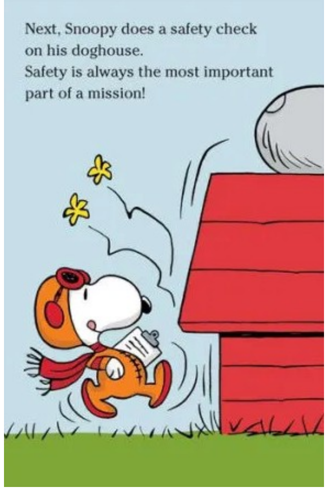
Pre-commissioning after tunnel closure I

- Linac / Booster Re-Commissioning / BTR transfer line (magnets / diagnostics)
  - Some systems utilized by the ring like timing system working
  - Establish operation of booster at 2.7 GeV including emittance exchange
- Fine alignment of girders in the tunnel using girder mover system
  - Reduction of vertical adjustment range to +-100 um for adjustment with beam (either integrated with EPICS control system → good test whether system works reliably, or by hand using the mechanical adjustments screws)
- BPM/OC/SX alignment measurements
  - Mechanical part of BBA constant → Creation of lookup tables
- Powering of all magnets
  - Power supply and magnet polarity checks
  - Injection elements
- RF commissioning and cavity conditioning (3HC cold)
- Screen monitor checks (move screens in/out, take test pictures)



Pre-commissioning after tunnel closure II

- Loss monitors
  - Fast (scintillators Libera based) & Slow (CMOS PSI based)
- BPM tests
  - Cable measurements, pilot signal calibration → Electrical part of BBA constant → Creation of lookup tables
- Temperature control
  - Tunnel ventilation and stabilization
  - Water cooling
- Temperature sensors for vacuum system protection
  - Turned out to be vital during SLS 1.0 commissioning
- Machine Interlock System (MIS) tests
- Collimator tests
  - Check adjustability (positioning in/out)
- Radiation measurement setup
  - Define possible hot spots (injection area, collimator location)



Commissioning 1st day I

- EPICS channels of installed hardware components available in the control room
  - Hardware can be accessed
  - Diagnostics output can be visualized and analyzed
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  - Status and modification of system parameters possible
- Save and Restore of machine setups
- Alarmhandler → diagnose problems with systems
- BPM System *(vital for commissioning !)*
  - Single and multi-turn capability
  - Closed-orbit mode (a few Hz)
- Screen monitors
- Slow (Fast) loss monitors
- Radiation measurement setup
- Current measurement (IPCT, BPM sum signal)
- Tune pickup → FFT to get tune peaks
- Streak camera → bunch length measurements
- Beam size measurement

Commissioning 1st day II

- Bunch pattern measurement → Filling control
- Girder remote control for Beam-based Girder Alignment (BBGA)
  - Girder-Girder touch sensors (linear encoders)
- High & intermediate level BD applications (→next slide)
  - Tested with already existing virtual accelerator / soft channels during dark time
- Radiation safety (Safety zones, dosimeters whole SLS building)
- *Organisation of shift crews (length of shifts ?, length of overlap ?)*
  - *Only day shifts if possible with critical experts available, nights for machine conditioning*

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High & Intermediate level BD applications for commissioning

- Beam Threading and BPM offset discrimination
- Measurement of injected beam trajectory
- Lifetime Measurement (IPCT / Loss Monitors)
- Tune Measurement
- Dispersion and Chromaticity Measurement
- Nonlinear Optimizer → DA and lifetime
- Emittance Measurement
- Emittance Controller (?)
- BBA Beam-Based Alignment (Slow (Fast))
- BBGA Beam-Based Girder Alignment
- Optics correction (LOCO / Quad Variation / Turn-by-Turn)
- Orbit Correction (SOFB / FOFB)

Commissioning nth day (n=?)

- Commissioning of important subsystems with beam
  - When **NEEDED** → should **NOT slow down commissioning process**
- BPM gain settings for different currents
- BPM operation modes needed at the time (FOFB not so urgent)
- BPMs for vibration characterization (FFTs, PSDs)
- MBFB for higher current operation and diagnostics
  - multi-bunch instabilies
- 3HC at higher currents for better lifetime
- FPFB for top-up operation with well defined filling pattern
- Safe beam dump / autodump for various machine conditions
- Collimation → reduction of losses at higher currents

Commissioning accelerator & beamlines >~3 mths

- Commissioning of important subsystems with beam
- BPMs
  - Fast Orbit Feedback (FOFB) commissioning
  - Tune feedback
- Loss monitors to center e-beam in Insertion Devices (IDs)
- Photon monitors (X-BPMs) before the photon shutter
  - SOFB on X-BPMs within FOFB loop
- Insertion device (ID) commissioning
  - Alignment of IDs with respect to e-beam
  - Minimization of ID induced distortions (orbit, optics)
- Beamline commissioning
  - Beamline photon diagnostics
  - Beamline and photon beam adjustment
  - First expert user experiments

Commissioning Phases

The commissioning can divided into seven phases:

- *Phase 1 – Linac, booster and transfer line commissioning*
- Phase 2 – First-turn in storage ring
- Phase 3 – Second-turn and multi-turn
- Phase 4 – Accumulation, basic feedbacks and linear optics
- Phase 5 – Nominal beam current with advanced settings and feedbacks
- Phase 6 – Insertion device and collimator setup, making first photon beams
- Phase 7 – Finalization

Phase 2 – First-turn in storage ring

Masamitsu + Andreas

- Goal: full control of the first-turn beam trajectory

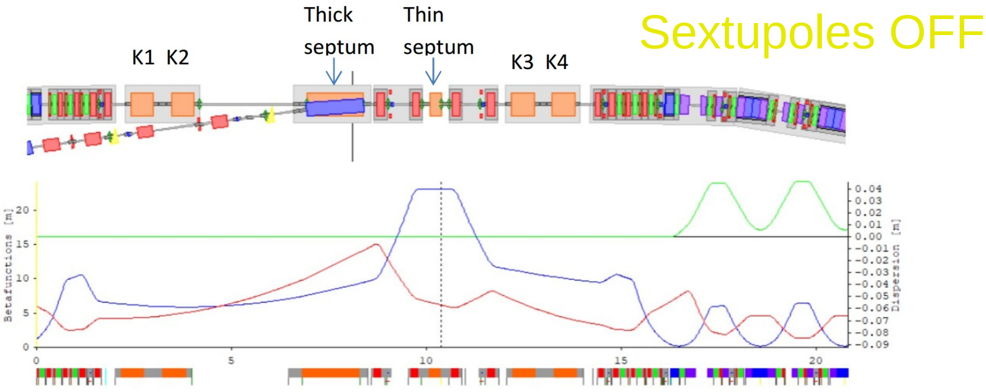
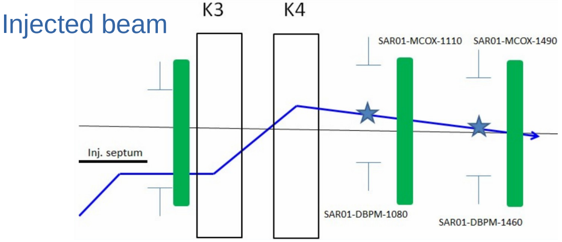
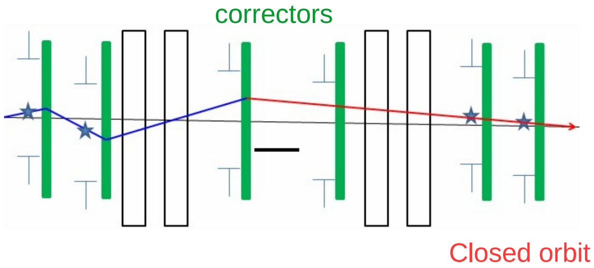


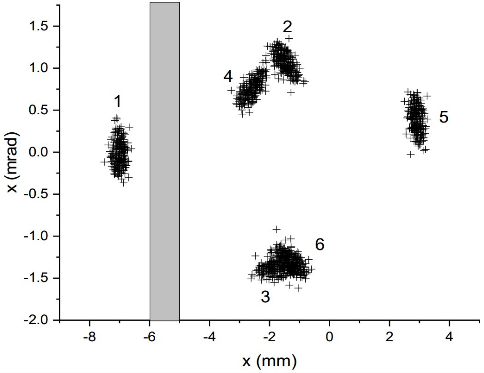
Figure 3. Layout of injection straight and optical functions.

Misalignment	
Girder absolute	60 mm rms
Girder-to-girder	20 mm rms
Individual component	30 mm rms
Component roll error	300 mrad rms
BPM	
Electronic offset	300 mm rms
Electronic roll error	10 mrad
Resolution in turn-by-turn mode	50 mm rms
Resolution in orbit mode	50 nm rms
Magnetic field error	0.2% rms
Corrector strength	
Horizontal plane	600 mrad*
Vertical plane	400 mrad

MM = Micro Meter



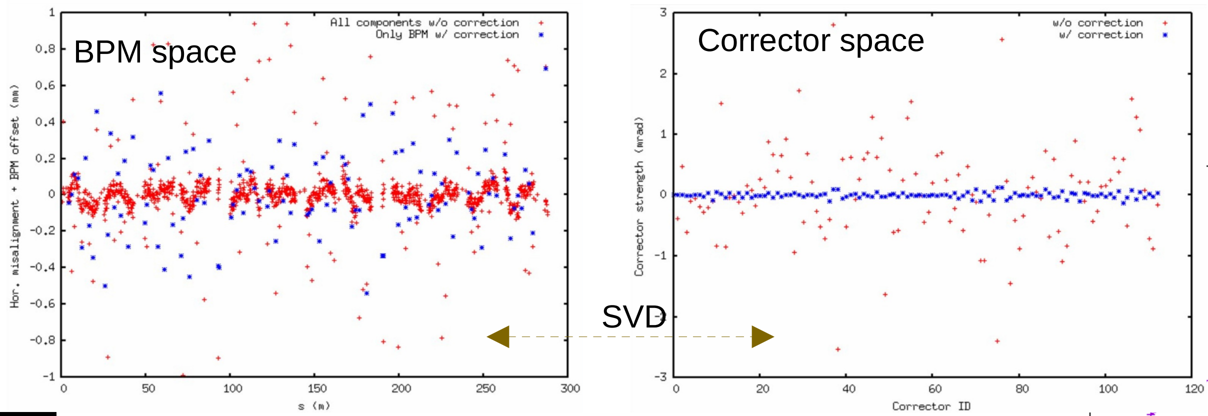


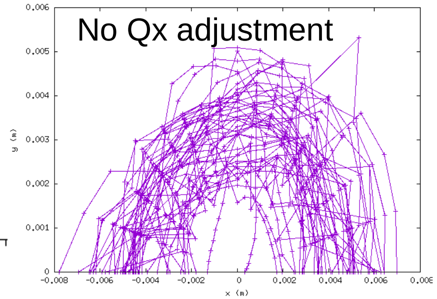


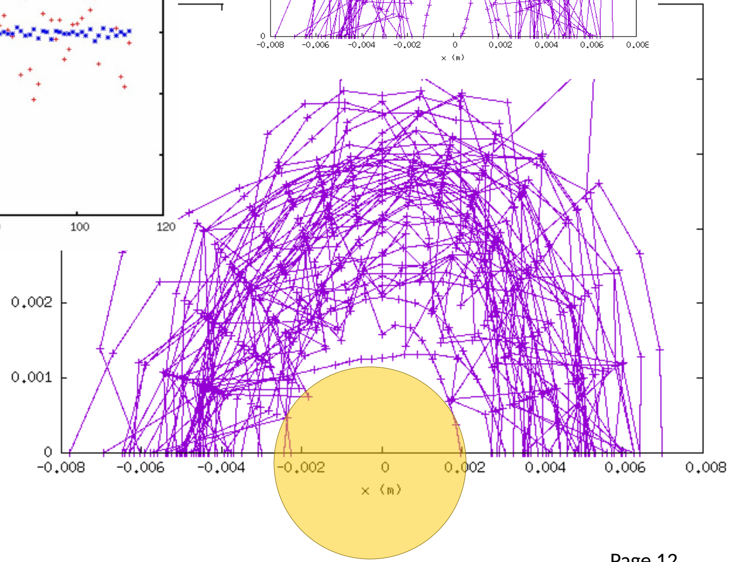
Phase 3-4 – First-, second-, + multi-turn + CO

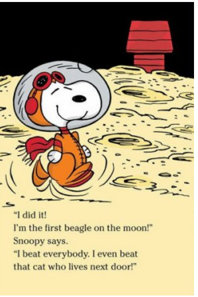
Masamitsu

- Despiking of BPM readings with large offsets before BBA using SVD eigenvalue cut-off in corrector space (red before → blue after):









→ after applying offset corrections hard orbit correction with all eigenvalues possible !

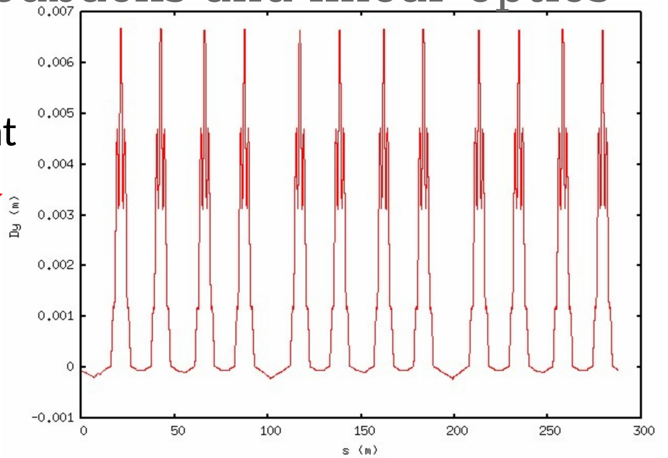
DA plot visualizes the expected horizontal DA at the thin septum before optics, coupling correction, after despiking and horizontal tune adjustment for 50 seeds including errors

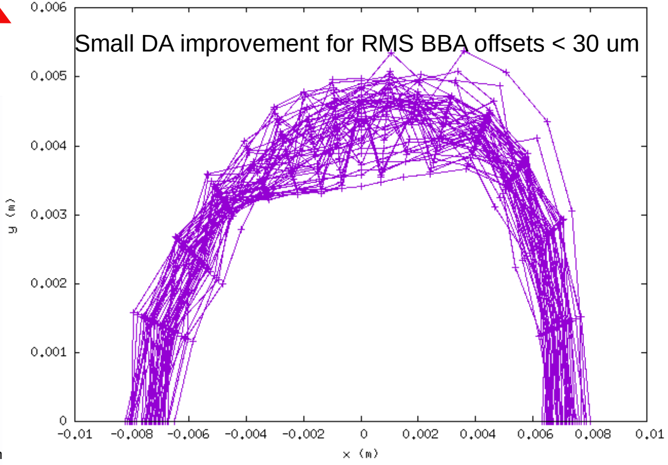
→ DA sufficient to accumulate !

Phase 4 – Accumulation, basic feedbacks and linear optics

- After LOCO/Quad Variation (264 observables !) <1/0.5% beat
- After application of dispersion bump (ey = 10pm)
- After dispersion and betatron coupling correction

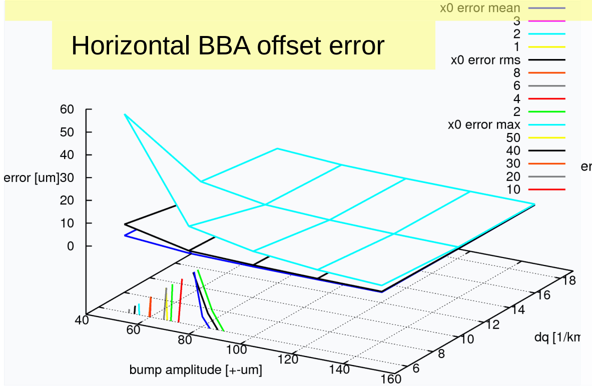
→ +-6.5 mm DA @ the thin septum



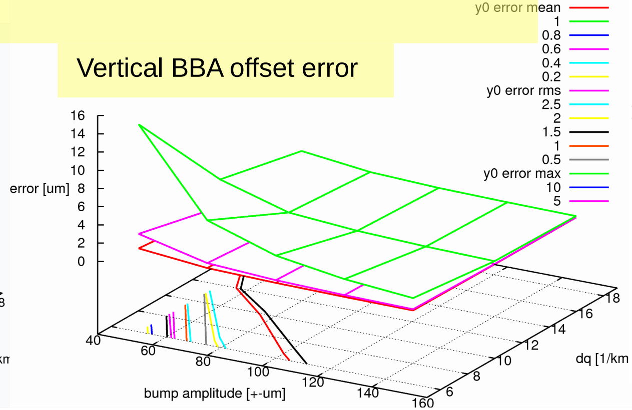


Simulation of BBA procedure including all errors +100 nm RMS BPM noise + 18-bit corrector noise → dQ = ~10 1/km (1/3rd of dQmax) sufficient to get sub-micron BBA offset error in x + y plane !

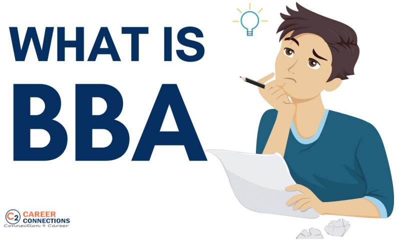
Horizontal BBA offset error



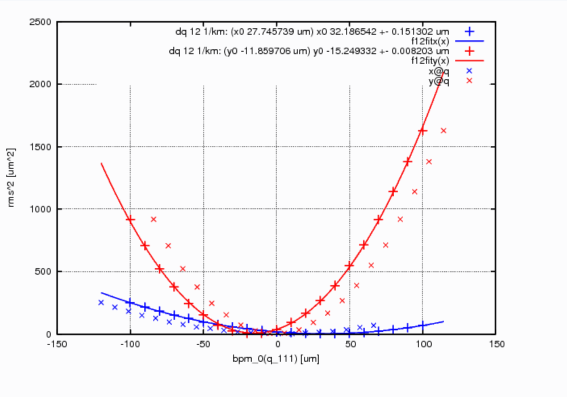
Vertical BBA offset error

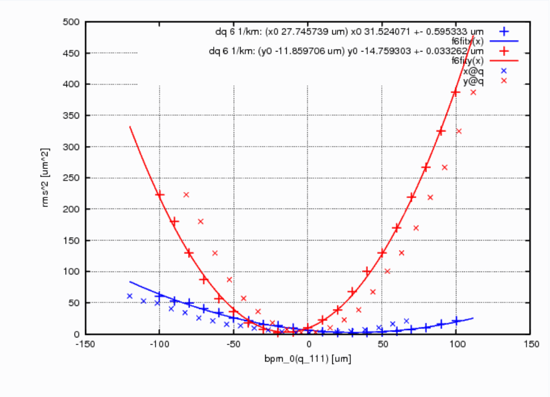


Phase 4 – Beam-Based Alignment



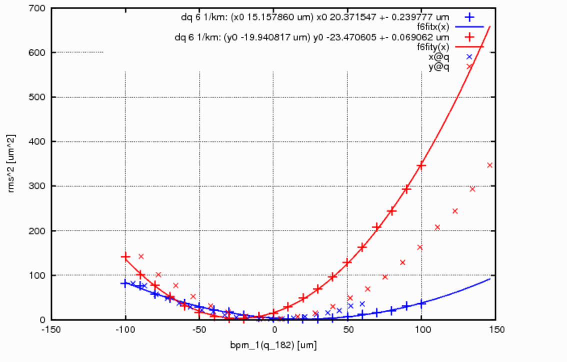
Plots depict simulated BBA data for 4 BPMs. The randomly (30 um RMS 2s cut) chosen BPM offsets (minima of parabolas) are reconstructed by the BBA simulation.

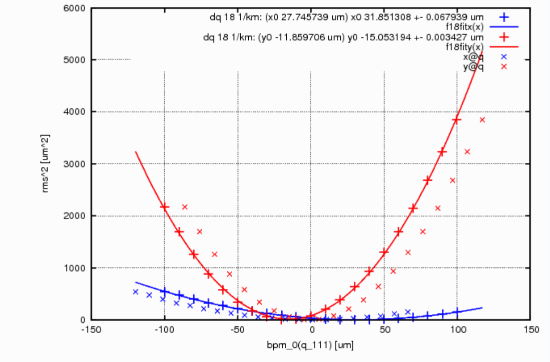




Y Blue = horizontal rms difforbit^2 [um]

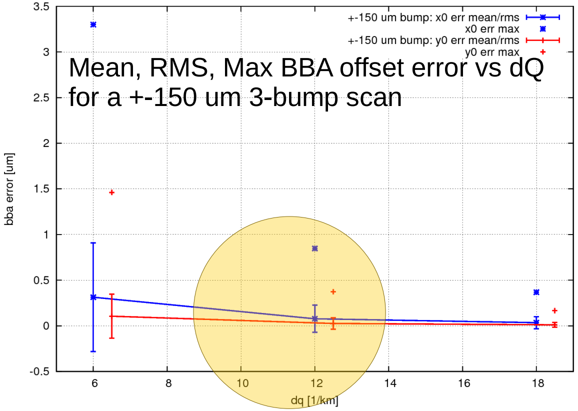
Y Red = vertical rms difforbit^2 [um]



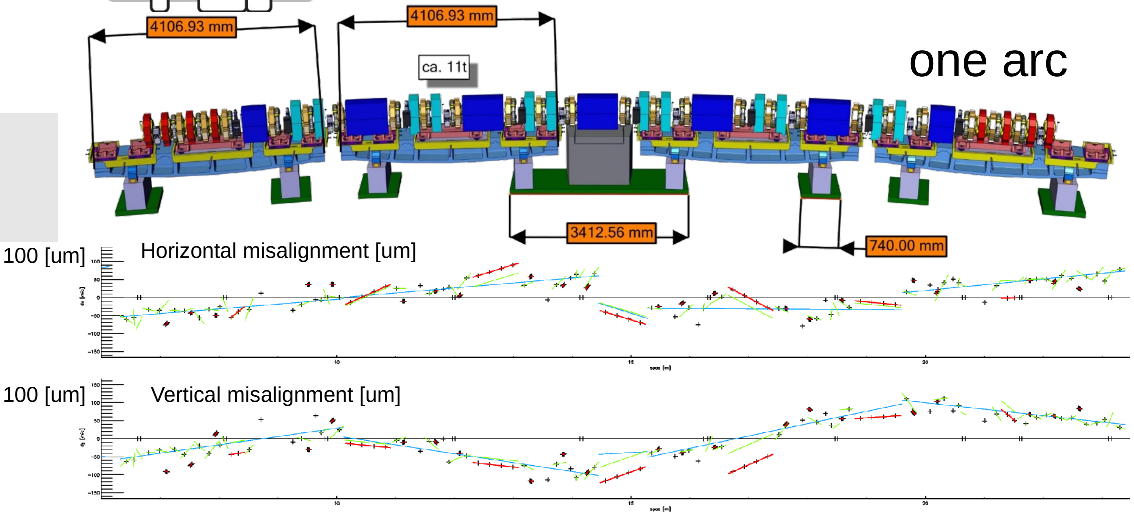


X Blue = horizontal BPM reading [um]

X Red = vertical BPM reading [um]



Phase 4 – Beam-Based Girder Alignment (BBGA)



SLS 1.0 Experience: 48 girders have been used to reduce the total vertical corrector kick ky from 150→50 urad RMS (see example for 4 girders in sector 1). Remotely controlled girders can speed up this realignment since it can be done with stored beam and directly verified by observing the reduction of corrector strength

- High precision BBA and successive orbit correction (SOFB) to BPM centers using ALL orbit correctors (no eigenvalue cut) in order to LOCALIZE alignment errors
- Girder realignment (pitch & heave) with beam and SOFB within +-100 um to optimize the alignment error distribution in favour of machine performance and minimize the needed orbit corrector strength

Example: 20 um→10um RMS joint precision after girder realignment → adapt errors to 60/10/30 2sig cut for joints: ky = 77→41 urad RMS, 375→182 urad MAX → 94%→46% of ky_max = 400 urad

- If the +-100 um range is not sufficient manual vertical realignment of girders in the tunnel (→ final SLS 2.0 alignment planned after Phase 4). Manual horizontal realignment of girders based on BBGA prediction !

Phase 4–5: (Nominal) beam current with advanced settings

- Reduction of horizontal corrector range from +-600 → +- 400 urad (→ after BBGA and shimming of permanent magnets) in order to increase corrector resolution by 30% for improved FOFB operation
- 3HC tuning to maximize lifetime, MBFB commissioning, instability studies, FPFB control, Beam dump control, collimator tuning to reduce losses using loss monitors
- Tune Feedback, FOFB commissioning, Dynamic beam size control by adding white noise into MBFB loop (horizontal and vertical)
- Chromaticity correction, dynamic aperture studies and nonlinear optics optimization using geometric sextupoles and octupoles.

Phase 6-7: Insertion devices and first photon beams + Finalization

- Closure of insertion devices (IDs) one by one, minimize losses on individual IDs by advanced collimator setup and proper centering of the beam within the IDs using loss monitors
- ID Feed-Forward tables (integrated dipole kicks, beta beat, coupling) for ring transparent ID operation (including photon beam position stabilization by means of frontend X-BPM readings used as an input for the FF table generation)
- Refinement of all previous optimization steps at nominal current, consolidation for beam line commissioning
- Orbit manipulations for beam lines to adjust the photon beam (→ large orbit changes should be avoided, a realignment of the beam line with respect to the machine should be the preferred solution)