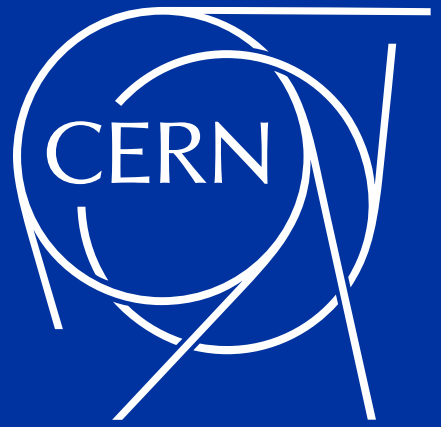

Validation of method to measure aperture margin between IR6 and TCTs with non-nominal phase advance

MD #7008

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rMPP meeting on MD1 2022 approval

Method and objectives

➢ Method to validate the retraction of the TCT in IR5 with respect to the TCDQ / TCSP

- Validate correct protection of the TCT from direct impact in case of asynchronous dump
- Uses a long closed-orbit bump extending from IR6 to IR5 for Beam 2 with circulating beams
- Provides aperture margin measurement
- Validates that the phase advance requirement from MKD to TCTH in IR5 is satisfied (must be < 30 degrees)

➢ Objectives of the MD

- Extend results from MD #2186 (2018) where the method was tested for a nominal optics configuration
- Validate the method with intentionally detuned phase advance between IR6 and IR5. Two configurations:
  1. Using the MQTs in Arc 56 to detune the phase advance
  2. Using the MQs in Arc 56 (and Arc 45) to change the phase advance while limiting the beta-beating wave

MD description

1. **Simulate MKD kicked trajectory with a closed bump between IR6 and IR5 (based on the model)**
   - Correct the orbit outside the IR6 to IR5 region to remove leakage
   - Assuming the absence of significant perturbation between the 2 correctors opening the bump and the TCDQ we obtain the “true” trajectories with circulating beams
2. **Increase the bump strength so that the TCDQ/TCDSP defines the aperture**
3. **Measure the bump shape and beam position at TCTPH.4R5.B2**
4. **Perform BBA with TCTPH.4R5.B2 to measure**

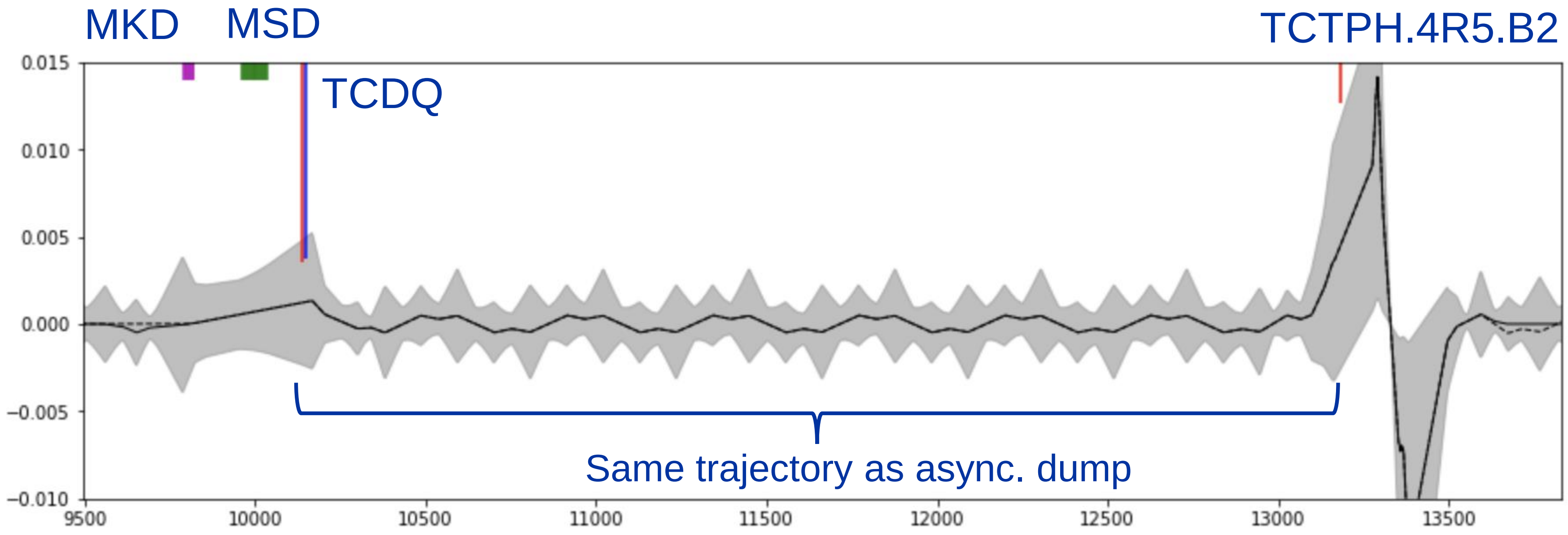
Validate the method in non-nominal optics conditions and quantify the retraction between TCDQ/TCSP and IR5 TCT

Requested machine and beam parameters

Time required per MD [h]	**8h**
Beams required	**Beam 2** only
Beam energy [GeV]	**6.8 TeV**
Optics (injection, squeezed, special)	**Collisions** (**β* = 60 cm**, **tele-index = 1**, nominal crossing angle)
Bunch intensity and number of bunches	**3 pilots** distributed in the B2 ring (buckets 1, 8911, 17851)
Optics change [yes/no]	**Yes**. Phase advance detuning in S56
Orbit change [yes/no]	**Yes**. Closed 4 corrector-bump from IP6 to IP5
Collimation change [yes/no]	**Yes**.
RF system change [yes/no]	No.
Feedback changes [yes/no]	**Yes**. Orbit feedback to be switched off at flat top.
What else will be changed?	ADT excitation of pilots (as for loss maps).

Long-orbit bump

- **Open the bump upstream of MKD and close downstream of TCTPH in IR5**
  - MCBH.11R6.B2, MCBCH.9R6.B2, MCBCH.9L5.B2, MCBCH.7L5.B2
  - Correct the leakage in the rest of the ring manually using YASP and a few correctors L5 (feedback off)
  - Increase amplitude in steps of 0.5 sigma up to 2 sigma then in steps of 0.1 sigma until reaching 3 sigma (ensuring that the TCDQ / TCSP defines the aperture - TCDQ@7.3 and TCP@5.0)



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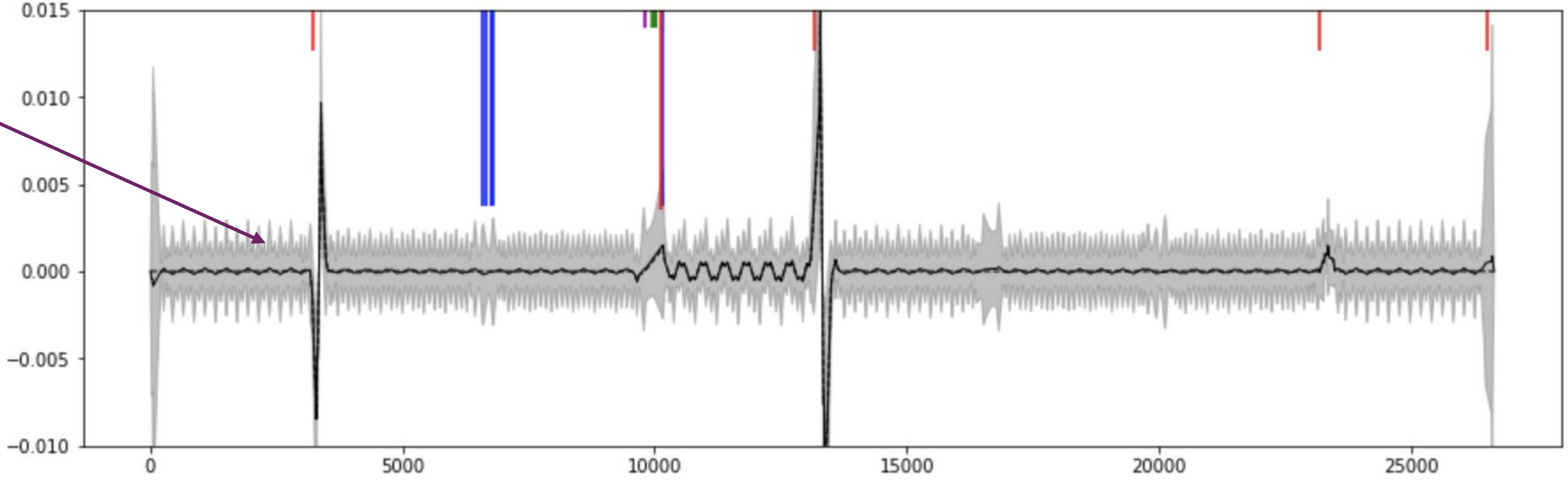
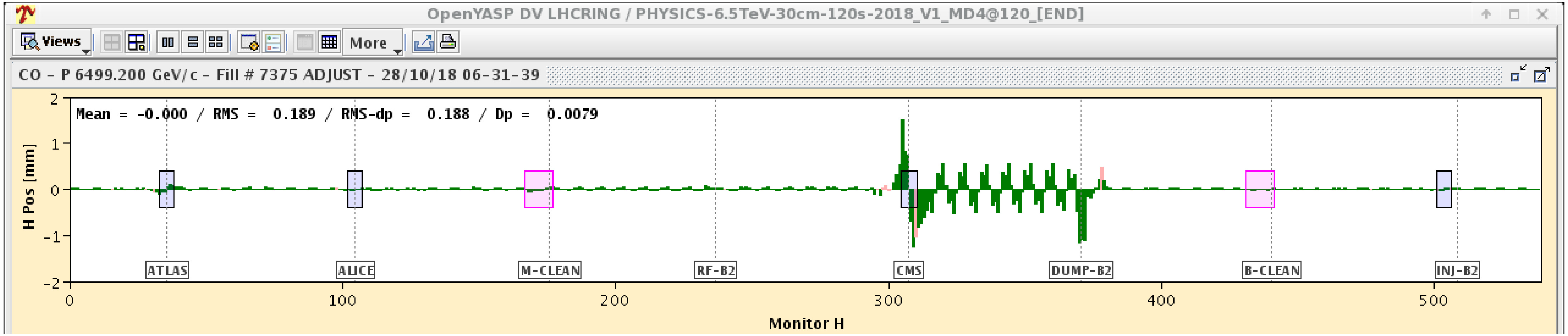
Expected leakage for non-nominal optics (see next)



Long-orbit bump

- **Already tested in 2018**
  - Need to (re)-create the knob prior to the MD

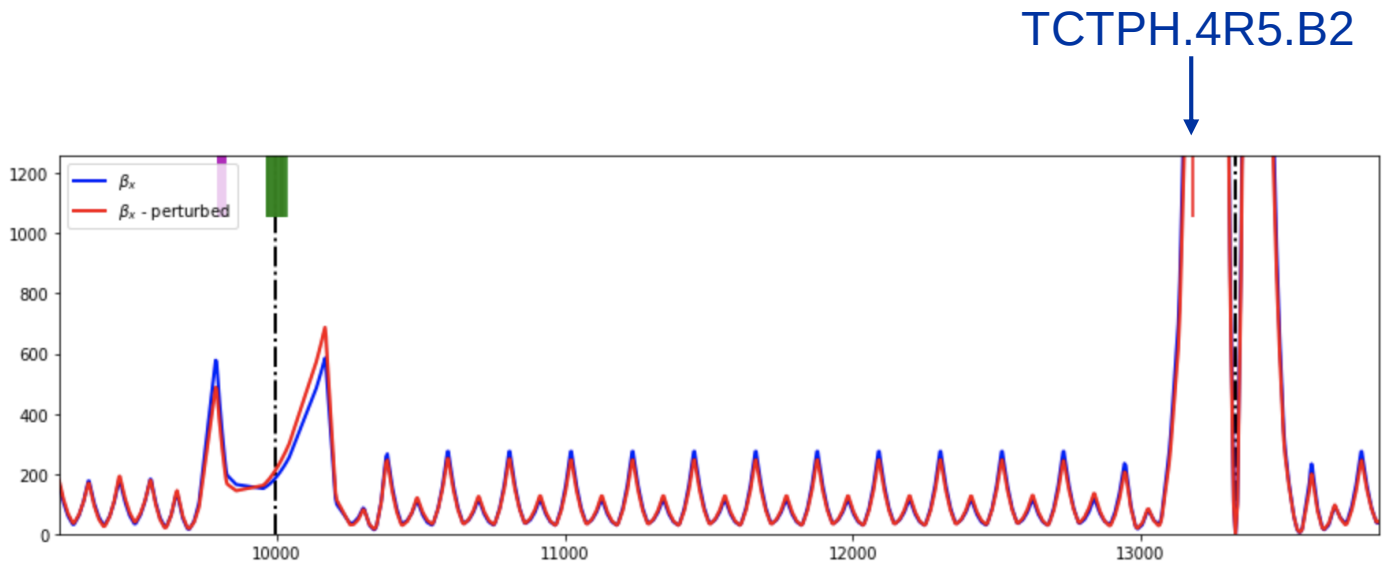


Optics detuning

- **Is the method able to reveal insufficient retraction in case of non-nominal optics?**
  - Nominal horizontal phase advance from MKD to horizontal TCT : 28 degrees
  - Voluntarily increase the phase advance to increase the trajectory excursion at the TCT, in turn reducing the effective aperture margin
  - Squeezed optics (beta* = 60cm) with tele-index = 1 to be used

Optics detuning

- **Using the trim quadrupoles in S56 (MQTs) at constant tune**
  - Use kqtf.a56b2, kqtd.a56b2 to change the horizontal phase advance to **58 degrees** (constant vertical phase advance) using about half maximum strengths (236A) for the MQT-F
  - Keep the tunes constant using the tune “tele-knobs” (i.e., trim quads in ATS arcs not used)
  - Will proceed in small trim steps, with the tune feedback acting on the tele-knobs
  - Beta-beating expected (around 15% at the TCT)



Optics detuning

- **Using the main quadrupoles in Arc 45 and 56 (MQs) at constant tune**
  - Non-nominal configuration to provide a similar phase advance detuning but a reduced beta-beating
  - Use the the MQs in Arc 56 to detune the horizontal phase advance (at constant vertical phase advance)
  - Use the MQs in Arc 45 to compensate for the tune
  - Proceed in small steps with the tune feedback active to correct residual tune drift
  - On the 4 circuits, maximum change of 1% to obtain a 30 degrees phase advance detuning

Variable	Final Value	Initial Value
kqd.a56	-8.68995e-03	-8.70476e-03
kqf.a56	8.62071e-03	8.70330e-03
kqd.a45	-8.72009e-03	-8.70476e-03
kqf.a45	8.78219e-03	8.70330e-03

Needs from / impact on collimation

- **Collimation settings remain nominal…**
  - In the spirit of a “true” validation method
- **… except**
  - TCTPH.4R5.B2
    - Need to measure aperture and perform BBA
    - Will remain at nominal position (assuming aperture margin is present) when starting the measurement
    - Will be (gently) opened if aperture margin is found to be absent
  - Limits will be opened for TCP.C6L7.B2 (horizontal), TCDQ, TCSP and TCTPH.4R5.B2
- **TCDQ / TCSP will become primaries**
  - Low intensity, must ensure slow and controlled transverse blow-up from the ADT to avoid excessive losses on Q4 from TCDQ and TCSP

Step-by-step

Focus on machine protection aspects

A. Preparation

1. **Open collimator limits**
   - Horizontal TCT in IR5 (TCTPH.4R5.B2), TCP.C6L7.B2, TCDQ B2 and TCSP B2
2. **Mask interlocks**
   - Force Beam Setup Flag to true using the “Setup beam” equation
   - TCDQ IR6
   - TCDQ BETS IR6
   - Beam excursion in IR6
   - Loss maps (all IR, BPM/BLM/BCCM)
   - BPM (below minimum intensity)
3. **Switch off orbit feedback**

B. Nominal optics

1. **Create the long orbit bump and increase the amplitude to 3 sigma**
   - Monitor and correct, if required, the leakage in the ring
   - Measure the closed-orbit (globally) and with the DOROS BPM at the horizontal TCT
2. **Blow up the horizontal emittance of the first pilot until losses are observed on the TCDQ/TCSP**
3. **Perform the beam-based alignment of TCTPH.4R5.B2 in steps of 15 µm**

C. Non-nominal optics I (using the MQTs in S56)

1. **Restore configuration**
   - Move the TCT back to nominal position
   - Remove the orbit bump, verify and correct the orbit if needed
2. **Detune the optics using the kqtf.a56b2 and kqtd.a56b2 knobs**
   - Uncorrected horizontal tune change would be 8e-2
   - Proceed in steps equivalent to tune change of a few 1e-3, wait for the tune feedback to react
3. **Create the long orbit bump and increase the amplitude to 3 sigma**
   - Monitor and correct, if required, the leakage in the ring
   - Measure the closed-orbit (globally) and with the DOROS BPM at the horizontal TCT
4. **Blow up the horizontal emittance of the first pilot until losses are observed on the TCDQ/TCSP**
5. **Perform the beam-based alignment of TCTPH.4R5.B2 in steps of 15 µm**

D. Non-nominal optics II (using the MQs in S45-56)

1. **Restore configuration**
   - Move the TCT back to nominal position
   - Remove the orbit bump, verify and correct the orbit if needed
   - Revert the trims on the MQTs in steps (see C.)
2. **Detune the optics using the kqf/d.a56 and kqf/d.a45 knobs**
   - Proceed in 10 steps, wait for the tune feedback to react
3. **Create the long orbit bump and increase the amplitude to 3 sigma**
   - Monitor and correct, if required, the leakage in the ring
   - Measure the closed-orbit (globally) and with the DOROS BPM at the horizontal TCT
4. **Blow up the horizontal emittance of the first pilot until losses are observed on the TCDQ/TCSP**
5. **Perform the beam-based alignment of TCTPH.4R5.B2 in steps of 15 µm**

E. Recovery

1. **Restore orbit and optics configuration**
   - Move the TCT back to nominal position
   - Remove the orbit bump, verify and correct the orbit if needed
   - Revert the trims on the MQs in steps (see D.)

2. **Verify that the orbit and tunes are back to nominal settings**

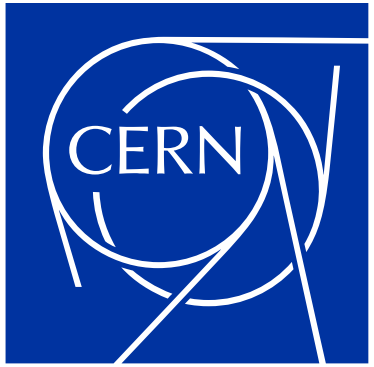
3. **Unmask all masked interlocks and forced flags**

4. **Restore the collimator limits**

Conclusion

- **MD implies configuration changes for the collimation, optics and orbits. Mitigations**
  - Low intensity (3 pilots)
  - Long orbit bump already tested in 2018
  - Collimation changes limited to strict minimum (nominally only the horizontal TCT will move)

- **Measurement of the retraction of the TCT in IR5 with respect to the TCDQ / TCSP with circulating beams**
  - Validate the method with intentionally detuned phase advance between IR6 and IR5



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