Beam dump matrix modifications of the WIC in the PSB and PSB extraction lines

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on behalf of the PSB operation and commissioning team

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Introduction

- **In LS2** - within the framework of the **LIU project** - the **W**arm magnet **I**nterlock **C**ontroller system (WIC) of the **PSB has been upgraded** alongside with the deployment of an **additional WIC system** to cover the modified **extraction transfer lines from the PSB to the PS**, see EDMS 883871 and 1701480
- Each WIC system has one or several connections to the Linac4 and PSB **B**eam **I**nterlock **S**ystems (BIS) to **interrupt the beam** in case of a magnet or power converter failure.

Why proposing changes to the PSB WIC dump matrix?

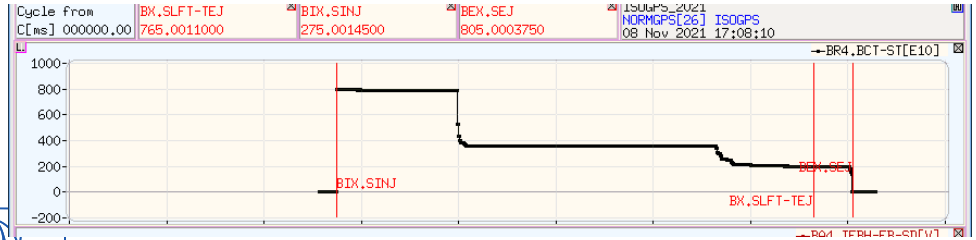
- **Additional QSTRIPs and Multipole converters** will be installed during the **YETS** – EDMS 2607246 – so we had to prepare an **ECR to include this new equipment**.
- Discussing with **R. Mompo**, we took the occasion to also **review the current logic and update it, following the operational experience** of this year - first beam commissioning and (fixed-target) physics run post-LS2.
- **Goal: Optimise operational flexibility, while still maintaining equipment safety.**

Introduction

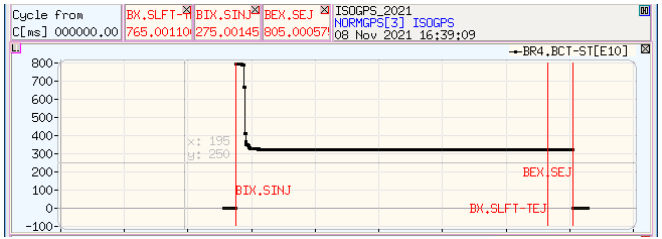
- The proposed changes have been summarized in a **document** **https://edms.cern.ch/document/2649462/0.1** **which has been circulating for approval.**
- This talk is the result of a few fruitful discussions with members of the MPP team and equipment experts.
- In this talk I will **cover the operational aspects** of the proposed changes.
- In this talk I will **not discuss the technical aspects** related to the WIC implementation.
- **Nota bene:** The **magnet protection** ensured by the WIC is **not affected** by the proposed changes → in case a **magnet overheats, the power converter(s) concerned will be switched off and the beam permit removed.**

Multipoles for Resonance Compensation (I)

- **Proposal to disable** the WIC ‘User_Permit’ signal sent to the BIS of the normal quadrupole converters **QNO 311L1, 412L3, 816L1, 816L3** in the PSB.
- Original **inclusion was based on the pre-LS2 resonance compensation scheme for half integer resonance.** → Currently we **do not inject above the half integer**. Not clear if we will ever do it.
- If we are ever going to inject above the half integer, and lose one of the multipoles, most - if not - all the beam will be lost. These **losses are equivalent to ones that we currently experience** in the PSB, because of other equipment, e.g. the TFB (example below from a problem in R4 in Nov. 2021).
- No additional danger for the equipment, beyond what is already happening on a yearly basis.



Intensity along the cycle with TFB issue in R4



Intensity along the cycle with TFB issue in R4

Multipoles for Resonance Compensation (II)

- Based on ABP studies, it should be **possible to compensate for a non-working multipole power converter from this list with others** to restore an acceptable compensation of the resonances.
- In the worst-case scenario, it should be still possible to **provide beam with lower intensity** than the specifications (degraded mode) in the affected ring.
- Maintain the PSB availability → A failure in 1 ring won't block the entire proton chain and there is no additional danger for the equipment wrt what is currently happening.
- During a **transitional period of adjustment there might be increased beam losses which will be at the same level of the ones currently experienced because of other equipment. We judge that no additional danger is introduced by removing the aforementioned multipoles from the WIC.**
- The **beam loss monitors and the watchdog (both connected to the BIS)** will provide an additional layer of protection.

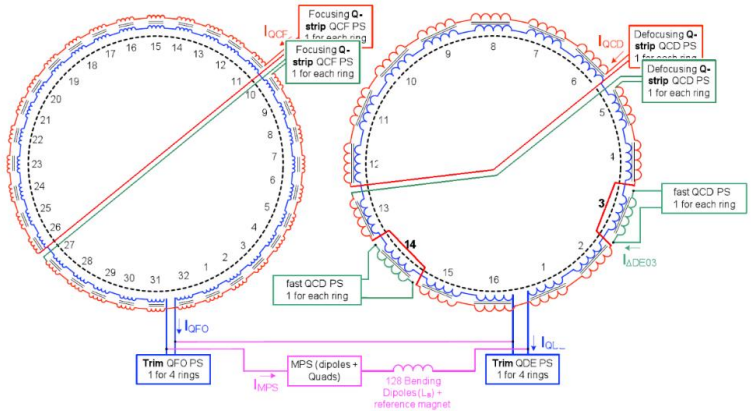
POPS-B and old MPS

- **Proposal to disable** the WIC ‘User_Permit’ signal sent to the BIS of the new main power supply system, **POPS-B**.
  - Equipment already protected with a **direct connection already existing in BIS**.

- **Proposal to disable** the WIC ‘User_Permit’ signal sent to the BIS of the old power supply system, **PSB MPS**.
  - Backup for catastrophic scenarios, e.g., long-term issues with POPS-B (fire, explosion, etc, etc).
  - The **MPS will be connected to the BIS** as part of switching procedure, EDMS 2379626.
  - Another layer of protection **provided by the External Condition (timing).**

QSTRIPs (I)

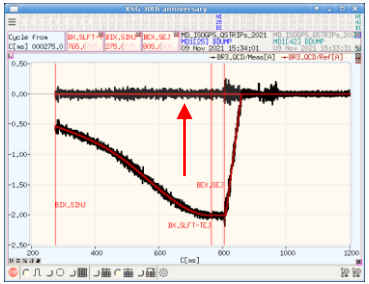
- The **PSB QSTRIP** system is constituted of **two chains of electrically isolated windings** on the main focusing and defocusing quadrupole magnets per each ring:
  - Additional trim on top of the main quadrupole magnets.
  - Purpose is to **allow for ring-by-ring different tunes.**
- The **magnets in sectors 3 and 14** are removed from the chain and **powered separately because an additional fast correction for beta-beating compensation is necessary**. The beta-beating is induced by the decay (t_{decay} = 5ms) of the BI.BSW which are part of the new PSB injection chicane.



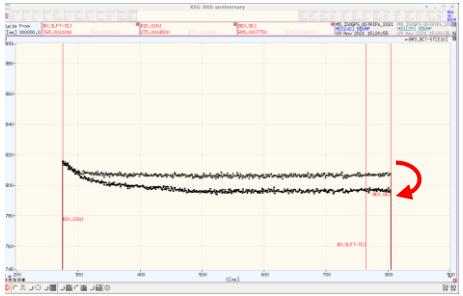
QSTRIPs (II)

- **Proposal to disable** the WIC ‘User_Permit’ signal sent to the BIS.
- Original **inclusion based on the pre-LS2 operational experience:** Pre-LS2, the PSB would rely on the **QSTRIPs to tweak the injection tune in order to optimize injection transmission.**
- Currently with the **new tune controller and injection schema**, they are powered at very **low current** as we generally use the same tune for all rings given the beam type.

- To validate the proposal, **an MD was carried over in ring3** with a high intensity beam, by disabling each of the chains one by one (BR3.QCD, BR3.QCF, BR3.QCD3, BR3.QCD14) and checking the losses and tune:
  - No significant impact in terms of losses in the ring.
  - No significant impact in terms of losses at extraction.
  - Link to MD test, here.



BR3.QCD



Intensity along the cycle

QSTRIPs (III)

- **Proposal to disable** the WIC 'User_Permit' signal sent to the BIS.
- Original **inclusion based on the pre-LS2 operational experience:** Pre-LS2, the PSB would rely on the **QSTRIPs to tweak the injection tune in order to optimize injection transmission.**
- Currently with the **new tune controller and injection schema**, they are powered at very **low current** as we generally use the same tune for all rings given the beam type.

- Operationally, it was also proven to be **possible to run without one of the circuits in 3 or 14** for the fast beta-beating correction, e.g., for ~10 days the PSB run without the BR3.QCD03 (connector issue on the magnet side) without remarkable loss of performance.

- During a **transitional period of adjustment there might be increased beam losses which will be at the same level of the ones currently experienced because of other equipment. We judge that no additional danger is introduced by removing the QSTRIP chains from the WIC.**
- Additionally. the **beam loss monitors connected to the BIS** will provide an additional layer of protection.

New Power Converters

- The new converters (EDMS 2607246) will be used for:
  - **Doubling the number of QSTRIPs converters** to deal with the **elevated induced voltage from POPS-B** and ensure a **long-term reliability**.
  - Increase the number of **power converters available for multipole magnets** (also renew the available stock because of the age of some of the existing elements).

- **Proposal to disable the WIC 'User_Permit' signal sent to the BIS,** following the same logic discussed so far.

Correctors in the PSB extraction lines

- **Proposal to disable** the WIC ‘User_Permit’ signal sent to the BIS for the correctors in the BT, BTM, BTP lines.
- Operationally, it should be possible to **compensate for a non-working corrector power converter from this list with others** to restore an acceptable beam trajectory along the extraction transfer line
- A **few tests have been carried over by the PS team** to verify that the PS injection could be recovered, even losing the most critical converters close to the PS injection, **BTP.DVT40 & BTP.DVT50**.
- As a side note, the removal of correctors from the interlock in an accelerator or TL is a standard practise, if there is enough flexibility to recover the steering, which is the case in the PSB-PS TL.
- During a **transitional period of adjustment there might be increased beam losses which will be at the same level of the ones currently experienced because of other equipment. We judge that no additional danger is introduced by removing the PSB-PS TL correctors from the WIC.**
- Additionally. the **beam loss monitors connected to the BIS** will provide an additional layer of protection.

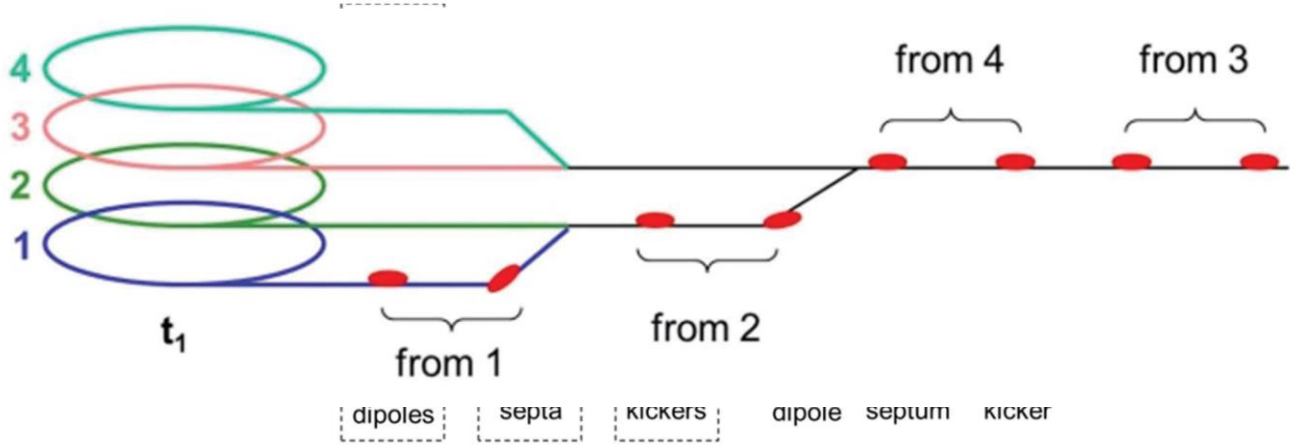
BTP.QNO10

- **Proposal to disable** the WIC ‘User_Permit’ signal sent to the BIS.

- **Old equipment installed in the wall** between the PSB and the PS:
  - **Difficult access** for repair.
  - **Not used in operation,** but only for special **MDs for optics studies**.
    - In this case, we will limit the test to **single LHC bunch intensity**, as done in **pre-LS2**.

Recombination Line

- At the end of the acceleration cycle, the bunches at the PSB are first synchronized and then extracted by a system of slow bumpers, fast extraction kicker and a horizontal septum.
- The beams from the four rings are then **recombined by a system of vertical bending magnets, kickers and septa**.
- **The order of extraction is 3-4-2-1**



BT.SMV10/20 (I)

- **Proposal to disable** the WIC ‘User_Permit’ signal sent to the BIS.

- **Initial idea came to homogenize the behaviour with respect to the recombination kickers failures,** governed by the renovated External Conditions (EC) timings.

- When one of the **recombination kickers fails**, the PSB retains the flexibility to produce beam with the non-affected rings, i.e. **degraded mode**.

- Conversely, **a failure in one of the recombination septa stops currently beam production** from all rings, while having the same functional requirement as the respective kicker, i.e. recombine a beamlet from one ring to another.

BT.SMV10/20 (II)

- Consulting with **J. Borburgh**, SY-ABT performed some studies on the impact of a complete loss of the beam on the septa blades for the different scenarios:
  - LIU beam:
    - Kinetic Energy = 2.0 GeV
    - 4 bunches @ 325E10 protons per ring, $\varepsilon_H/\varepsilon_V$ = 1.8/1.8 μm
    - bunch spacing (distance between bunches) = 310 ns
  - MTE beam:
    - Kinetic Energy = 2.0 GeV
    - 8 bunches, 2 per ring @ 250E10 protons per bunch, $\varepsilon_H/\varepsilon_V$ = 10/3 μm
    - bunch spacing = 290 ns
  - ISOLDE beam:
    - Kinetic Energy = 1.4 GeV
    - 4 bunches @ 900E10 protons per bunch, $\varepsilon_H/\varepsilon_V$ = 10/7 μm
    - bunch spacing = 565 ns

BT.SMV10/20 (III)

- Consulting with **J. Borburgh**, SY-ABT performed some studies on the impact of a complete loss of the beam on the septa blades for the different scenarios:

"[…] I managed to get a zero-order assessment of the local heating in case the septum would stop pulsing, while the beam would still be sent and hit the blade. In short: this shouldn't be destructive for the septum.

Despite its lower energy, the Isolde beam is most energetic. The BTSMV20 combines 2 rings onto the PS level, so this is the most exposed septum in case of failure. Also, Matthew determined that the beam size is smallest at this septum. Taking this all into account, I found an average heating increase of a few degrees in case the septum stops pulsing, which is acceptable. The instantaneous temperature rise of the copper blade however is about 140K. This won't be very healthy for sustained periods, but the Beam loss alarms, and the vacuum will degrade sufficiently quick to trigger an interlock.

In conclusion, I feel we can indeed remove the BT septa from the interlock chain as proposed in EDMS 2649462, provided the WIC continues to monitor the normal interlock signals for each device (mainly water flow and vacuum) as described."

- We also plan to **protect the septa with SIS**, i.e., after the PC stops the SIS will zero the ring(s) affected. An identical SIS is currently in place for the recombination kicker. **Work on SIS already ongoing, SIS-1228**

Summary

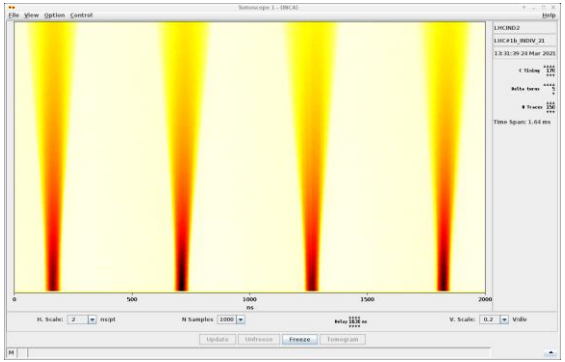
- Presented a list of **proposed modifications** to the WIC beam dump matrix of the PSB rings and extraction lines.
- Aim is **to increase operational flexibility and remove un-necessary redundancy, while keeping the equipment safe.**
- Consulting with different experts, the studies and observations performed so far show that the **WIC modifications are still compatible with the current level of equipment safety.**
- **Additional mitigation measures** will be also put in place for the most sensitive cases.
- **Next:**
  - **Update the ECR** (https://edms.cern.ch/document/2649462/0.1) with the feedback received in the last month of discussions.
  - **Submit the document for another round of approval.**
  - **If/When approved, R. Mompo will implement the modifications.**

Additional Slides

BDL

- The BDLs are **extra circuits per ring** to control **2 additional windings installed on 30/32 main magnets.**

- It provides a **ring-by-ring handle to adjust the extraction energy of each ring:**
  - Value set-up together with PS to **match the energy arrival at the PS.**
  - Fine tuning needed because of the different saturation of the internal/external main magnets.
  - **Powered in one ring only (R4) at about 30A** (over the 5400A of POPS-B)



- **Proposal to disable** the WIC 'User_Permit' signal sent to the BIS.

- Operationally, it should be **possible to inject in the PS without the BDL in R4 working**.
  - Possible **RF adjustment needed on the PS** side and run in "degraded" mode in case.
- In the worst-case scenario, it should be still possible to **provide beam with lower intensity** than the specified one (degrade mode) in the affected ring. → Idea is once again **avoid stopping the proton operation if one ring fails.**