Beam performance characterisation across the complex

A. Huschauer with input from and special thanks to H. Bartosik, M. Fraser, M. Hostettler, V. Kain, A. Lasheen, K. Li, B. Mikulec, M. Schenk, G. Trad, J. Wenninger

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Overview

• Introduction

• Proposal to improve LHC filling

• Examples where systematic performance quantification is missing

• Improving the diagnostics

• Ideas to improve communication and to exploit NXCALS data

• Conclusions
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Charge questions

- What are our **metrics** to qualify beam performance and beam quality?
- **How do we know beam is bad** and requires adjustments, optimization?
- What **observables** are we missing?
- **How do we qualify** that a beam is good for delivery (spill quality, emittance preservation, longitudinal parameters, logging of the parameters...)?
- Where is the beam qualified only based on **qualitative aspects** (overall shape) and not on **quantitative aspects** (i.e. is not ready for numerical optimization)?
- What could be done to improve qualification between two machines (e.g. 200MHz modulation and splitting efficiency of SFTPRO beams, information of intensity transmission from one machine to another)?
- How to **better use downstream machines for better qualification** (e.g. bunch by bunch intensity variations in LHC as input for PS/SPS, “closed loop” beam qualification)
Performance metrics and data exchange between machines

- **Goal:** improve performance by quantifying beam characteristics and automating communication/data exchange between machines or facilities

  - **Prerequisites:**
    i. data acquisition, transformation and logging in appropriate format
    ii. nominal values and acceptable tolerances well defined
    iii. establishment of clear and unambiguous communication lines

- **Whenever possible:** profit from downstream machines to quantify or cross-check

- **Not addressing additional needs for instrumentation → see next talk by Athanasios**
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Imagine: increasing LHC efficiency by automating LHC fillings

• Why change?
  ▪ Efficient beam preparation in the injectors is a key ingredient for integrated luminosity production
  ▪ NA, AWAKE, HRMT physics always strongly perturbed by inefficient LHC filling
  ▪ Beam preparation and requested intensity currently triggered by oral communication between the islands
  ▪ Large potential to decrease spread in injection time (see Michi’s talk yesterday)

• Most of the required tools already available today!
Imagine: increasing complex efficiency by automating LHC fillings

Automatic execution of 3 distinct phases in the injectors

- Filling initiation
- Beam preparation
- LHC injection
Phase 1: Filling initiation

- **RAMP DOWN** timing event triggers phase 1

- **Automatic execution of**
  - **CPS + SPS announcement**: “LHC ramping down, filling in 45 minutes”
    - exceptions, e.g. LHC going into access to be taken into account
  - PS high-frequency **cavity warm up** initiated if not ready
Phase 2: Beam preparation

- Beam preparation starts once the PS cavities are ready
  ① CPS only:
  - automatic switch to pre-defined BCDs with 12b or operational LHC physics beam (36b/48b/56b/72b, etc.)
  - measure and adjust longitudinal beam characteristics (bunch-by-bunch intensity and length variations)
  - measure transverse emittances
  ② CPS + SPS:
  - automatic switch to (dedicated) LHC filling sequence and check longitudinal and transverse beam quality in SPS
    - back to ① if quality insufficient
    - back to standard NA physics BCD if quality ok

available today or after the YETS

today done manually, can be automated

today only manual, effort required to automatise
Phase 3: LHC injection

- Phase 3 could be triggered X minutes after injection forewarning, etc.
  - Automatic switch to dedicated LHC filling BCDs
    - PILOT + 12b
    - INDIV and multi-bunch
Imagine: increasing complex efficiency by automating LHC fillings

- Could also include automatic intensity adjustment (PSB turns and L4 chopping factor, SPS scrapping, taking transmission into account, ...)
  - Based on a setting on the LHC side

- Consider special cases
  - LHC access, pre-cycle needed, etc.
  - Implement VETOs in each phase of the LHC filling

- Orchestration in the injectors → LHC filling sequencer?
  - Yet another request for the sequencer...
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Examples where systematic quantification is still missing – LHC-type beams

- Longitudinal characteristics
  - Amplitude spread, bunch length, emittance **not continuously monitored** at PS extraction
    - **no target value defined** for bunch-by-bunch variations – **what should we aim for?**

  - Measurement used to be purely on-demand in the PS, implemented **PS last-turn logging in UCAP** this year as proof of principle
  - SPS-PS feedback loop closed by oral communication between islands

- **no big issue for experiments**
- **where does it come from?**
  - intensity
  - emittance

M. Hostettler
Examples where systematic quantification is still missing

• **Longitudinal characteristics of the TOF beam**
  - bunch length, front tail, pre-pulses, etc.
  - Measured on-demand with BSM → data not logged, performance not tracked

• **Bunch rotation on EAST beams**
  - Bunch rotation impacts spill quality (see Marc’s talk on Monday)
Examples where systematic quantification is still missing

• **SFTPRO parameters partially quantified → room for improvement**
  - **MTE splitting efficiency** quantified and logged using TT2 wide-band BPM signal
    - calculation **to be validated for barrier bucket** extraction
    - **spill flatness** not yet quantified or used as target for correction (first successful tests in MDs performed in 2022)
    - for 2023: use **SPS fast BCTs** for comparison
  - **Horizontal emittance** not regularly measured (PS or SPS BGIs eventually)
Examples where systematic quantification is still missing - generic

- **“Golden” trajectories**
  - exist only in the machine-specific YASP configurations
  - don’t exist (so far) for stitched configurations
  - traceable definition of golden trajectories required → NXCALS tagging
    - “Is the beam on the golden? – Which golden?”

- **Monitoring of transmission between machines to be improved**
  - across-complex BPT still to be established

- **PS-SPS synchronisation, i.e. simulated vs. measured frequency**
  - data available, but not continuously monitored
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Improved characterisation requires improved diagnostics

• Improved diagnostics != additional instrumentation
  ▪ Plenty of excellent equipment already available
  ▪ Challenge is to
    - make the most out of the available data
    - rethink the way we operationally use the equipment
Longitudinal observations in the PS

- Longitudinal characterisation based on Tomoscope and bunch shape measurement (BSM)
  - Single acquisition on a single user, only two channels available
  - Two additional channels available after this YETS (new WCM in SS98)
Longitudinal observations in the PS

- **Moving from single to continuous acquisitions**
  - Proof-of-principle: up to 16 multi-burst triggers with new trigger card
    - can interleave single turn acquisitions with tomograms
  - Prerequisite for **quasi-continuous emittance characterisation** along the cycles
  - Move analysis to UCAP and use applications purely for visualisation
    - Demonstrator project in the PSB by S. Albright, A. Lu

- **Work towards a coherent implementation in the injectors**
Transverse emittance characterisation

- Very good experience using the LIU wire scanners post-LS2
- Next steps: prepare the ground for automatic transverse emittance measurements
  - Most of the building blocks available today (see George’s implementation for LHC)
  - **longitudinal observation crucial** input especially in PSB and PS (non-zero dispersion at monitors)

- Actors to trigger measurement if not continuous
- Transverse beam size
- Longitudinal beam characteristics
- Beam intensity
- Optics
- UCAP transformation
- Emittance logging, BPT, vistars, …

most work required here
Transverse emittance characterisation

- Make the most of the PS BGIs
  - Requirements:
    - **high-voltage increase** for vertical BGI
    - proton beams can currently only be measured at flat top
    - Signal low even for ion beams
Transverse emittance characterisation

• Make the most of the PS BGIs
  • **Requirements:**
    • **high-voltage increase** for vertical BGI
      • proton beams can currently only be measured at flat top
      • Signal even low for ion beams
    • **online background/beam loss suppression** for both devices (currently only possible in post-processing)
      • SFTPRO example:
        • **saturation flag**
          • implemented, to be published via FESA
Transverse emittance characterisation

- **Common effort needed: BI/OP benchmarking campaign between BGIs and WS**
  - To find optimum settings for different cycles, different energies, different intensities/beam sizes
    - initial focus on measurements at LHC flat top

- **OP investigations on beam loss in this region**
  - passive dosimeters installed for the last weeks of the run to check asymmetry of beam loss
  - increased loss level also indicated by short lifetime of gas injection valves

- **All above points important in view of SPS BGI installation**
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A concrete example to improve communication

- **PS-SPS transfer dashboard**
  - extension of SPS LARGERs to be used by PS and SPS
  - main LHC and SFTPRO quantities on a single screen
    - splitting quality
    - transmission
    - cavity status
    - bunch number
    - RMS trajectory deviation in TT2/TT10
    - frequency (simulated vs. real)
    - fast BCT comparison TT2/TT10
    - ...
  - including **history plots** for e.g. intensity, cavity status, PSR-SPSR transmission, etc.
  - color coding to indicate status, values exceeding limits (tolerance definition!), etc.

- Agree together on most useful quantities
PS performance monitoring system

- **Work on a pilot project is just starting**
  - Bringing equipment and beam performance monitoring together in a single system (UCAP-based, interaction with SIS, AFT, etc.)
  - Profiting from developments in L4, PSB and LEIR

- **Close collaboration with equipment groups essential**
  - Avoid redundant and aim at synergetic system development

- **Will significantly improve the (automatic) communication between machines**
Keeping track of beam (+equipment) characteristics - automated weekly logs?

• **Weekly logs recorded in the PSB**
  - **Snapshot** of the beam performance at a given moment
  - Very useful to compare from one log to another
  - **Manually** done today, quite an effort, requires quiet time for the operators to do that

• **Extend from PSB to other machines and automate!**
  - Profit from the vast amount of data logged in NXCALS
  - Could imagine **BPT-like approach, including** as well **equipment performance and settings**
  - Proper **definition of references** required
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• Improving communication between machines relies on metrics and automatic ways of data exchange

• Great software infrastructure available, let’s exploit it!
  ▪ Heavily relying on UCAP
  ▪ Need to discuss strategy for future of sequencer and vistar developments

• Many different approaches across the complex
  ▪ Impacting many groups (OP, equipment groups, CSS, …)
  ▪ Strategic decisions and ATS-wide guidance required

• Make automatic LHC filling preparation (and dedicated filling) a priority in the injectors
  ▪ Beneficial impact for LHC and NA physics, almost transparent for other users
  ▪ Most of the tools available, missing pieces to come during 2023
    - Longitudinal and transverse characterisation, GeOFF-server implementation, definition of references, …