Barrier bucket multi-turn extraction from PS to SPS for fixed-target experiments

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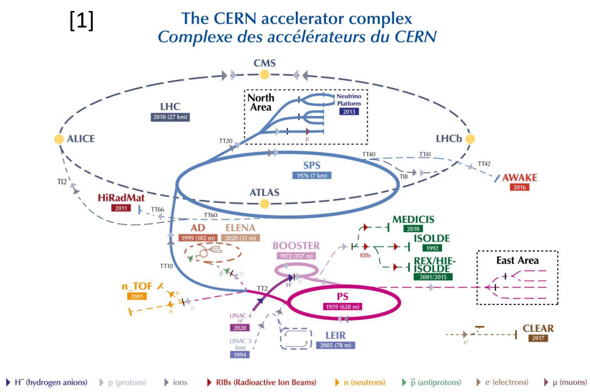
Introduction and motivation

[1]



Fixed target experiments require large numbers of protons, but intensity is limited by **beam loss**, in particular during the **transfer from PS to SPS**.
Two processes were developped to minimize these losses :

● Multi-turn extraction (MTE) : Beam splitting in **5 islands in the transverse plane** using nonlinear magnets before **extracting one island per turn** [2].
As PS circumference is $^{1}/_{11}$ of SPS, MTE can almost **fill SPS in 2 PS cycles**.

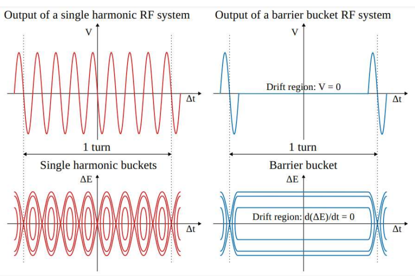
● Barrier buckets (BB) : The field in the kicker magnets aiming to deflect the beam towards the transfer line needs time to rise. If the beam passes through the kickers during this **rise time**, it will result in **beam loss**. **Longitudinal manipulations** (barrier buckets) were designed to generate a kicker gap and avoid this effect [3].

→ The combination of these two techniques is operational up to moderate intensities [4], but has yet to be optimized for **high intensity** both on the longitudinal and transverse plane.

Barrier bucket principle

In usual RF systems designed for acceleration, the electric potential is applied in the form of a **sine wave, at an integer multiple of the revolution frequency**, confining particles in **bunches** inside the so-called **RF buckets**.

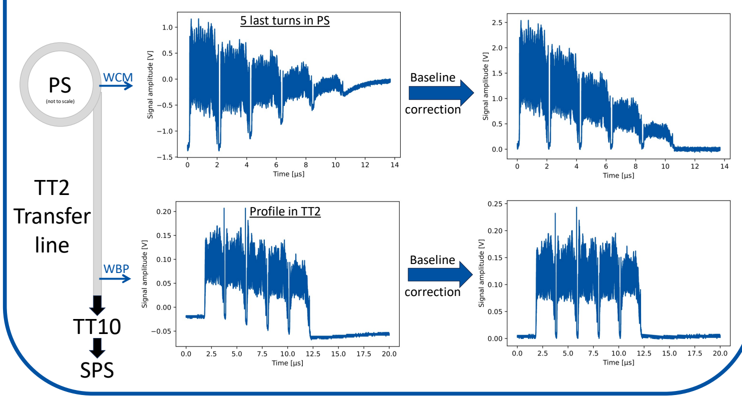
[4]



→ By inverting the RF voltage of a single pulse in the time domain, one can create a **flat bucket** (the **drift region**) delimited by **potential barriers**. If the **size** and **phase** of the potential barriers **match the ramping time**, no particles will traverse the kickers while they rise, **avoiding beam loss**.

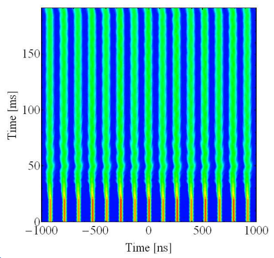
First Measurements

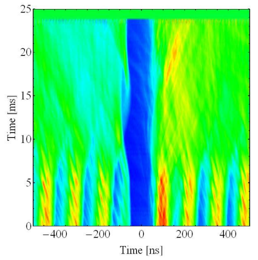
Measurements were done (05/07/2023) to study the **longitudinal bunch profile** in both PS and TT2 transfer line. **Baseline corrections** were applied during post-processing for data analysis purposes.



Intensity effects

At **high intensity**, **instabilities** tend to appear. In the case of usual RF systems, **control loops** act on the RF fields to prevent these instabilities from growing. However, the **barrier bucket synchronization** requires to **disable these loops** at the start of the flat-top. Hence **beam instabilities cannot be damped** with conventional techniques.
During last MD (19/07/2023), the beam intensity was **pushed up to $3{\cdot}10^{13}$ protons per pulse**, without relevant sign of longitudinal instability.





What to do next ?

→ The data acquired on 05/07/2023 and 19/07/2023 has **yet to be analysed in detail**. In particular, the **bunch profile in PS** can be compared **with the sum of each island in TT2**. In absence of losses during extraction, both profiles are supposed to be **strictly identical**. Different profiles (by taking losses into account) hence reveal the **particular dynamics of the five-turn extraction process**.

→ **Pushing beam intensity** as much as possible is the main objective for future fixed-target experiments. An intensity of **$3{\cdot}10^{13}$ is the highest studied so far**, but the absence of instabilities indicates that reaching even **higher intensities will be possible**. The next MDs will focus on carefully **increasing intensity** up to the **instability treshold**, while maintaining clean beams with minimal losses.

→ Future results will be reported on my CERN Summer Student Project Notes. Feel free to look at it if you're interested !

References :

[1] E. Lopienska, *The CERN Accelerator Complex* (original picture modified). Copyright CERN (2022)
[2] A. Huschauer et al, *Transverse beam splitting made operational: Key features of the multiturn extraction at the CERN Proton Synchrotron*, Phys. Rev. Accel. Beams **20** 061001 (2017)
[3] M. Vadai, *Beam Loss Reduction by Barrier Buckets in the CERN Accelerator Complex*, Thesis (2021)
[4] M. Vadai et al, *Barrier bucket and transversely split beams for loss-free multi-turn extraction in synchrotrons*, EPL **128** 14002 (2019)

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