Overview of the SPS Target Autopilot application

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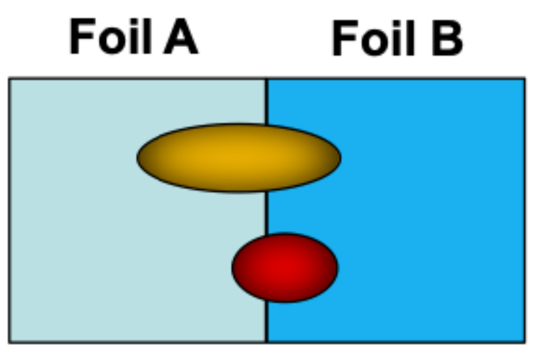
Introduction

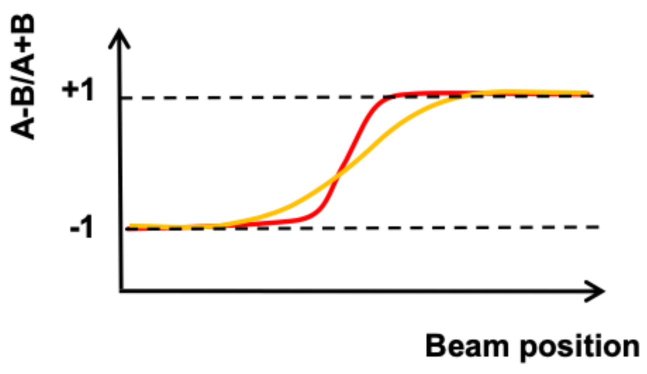
- The SPS delivers high-intensity beams to the three primary targets in the North Area (NA) [1] by employing resonant extraction at nominal momentum of 400 GeV/c
- The delivered intensities, as well as the position of the beam with respect to each target, is critical for the success of the NA experiments; the working point of the beam can be affected e.g. from hysteresis effects or wrong hardware settings and can therefore degrade the quality of the spill
- To ensure continuous optimization of the spill structure and of the beam delivery, the **SPS Target Autopilot** application has been developed for regulating automatically beam position and intensity at the primary targets, as well as to optimize the shape of the spill structure

Target symmetry & Intensity sharing

- The extracted beam is sent through the TT20 transfer line to pass from two vertical splitters that distribute the intensity among the three primary targets **T2**, **T4** and **T6**
- Beam intensity is measured with single foil secondary emission monitors (BSI). while beam position is measured by using the signal from two split foils (BSM) and calculating the target symmetry **S**



$$S = \sqrt{1 - \frac{|A-B|}{A+B}}$$



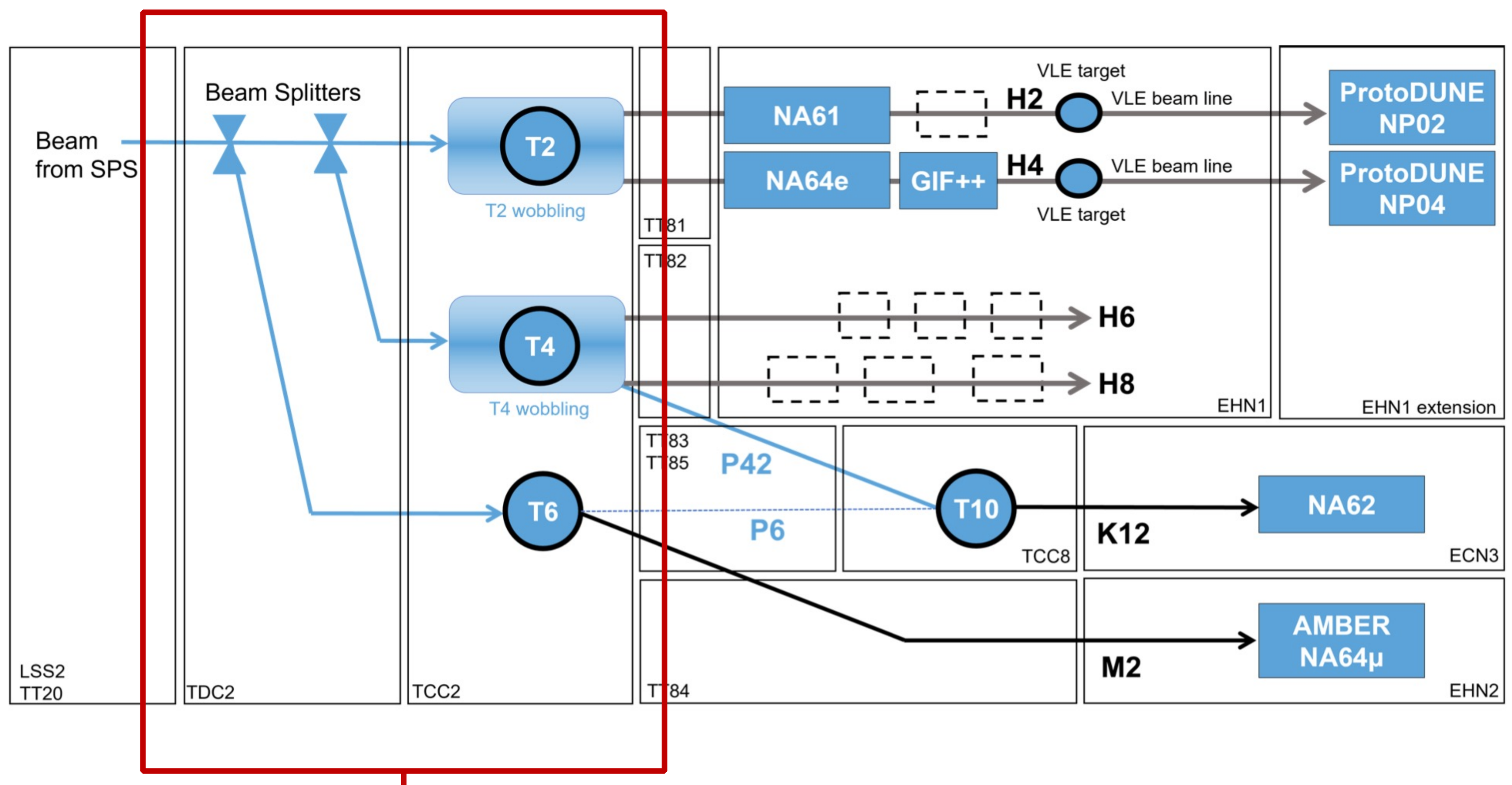
The SPS Target Autopilot application

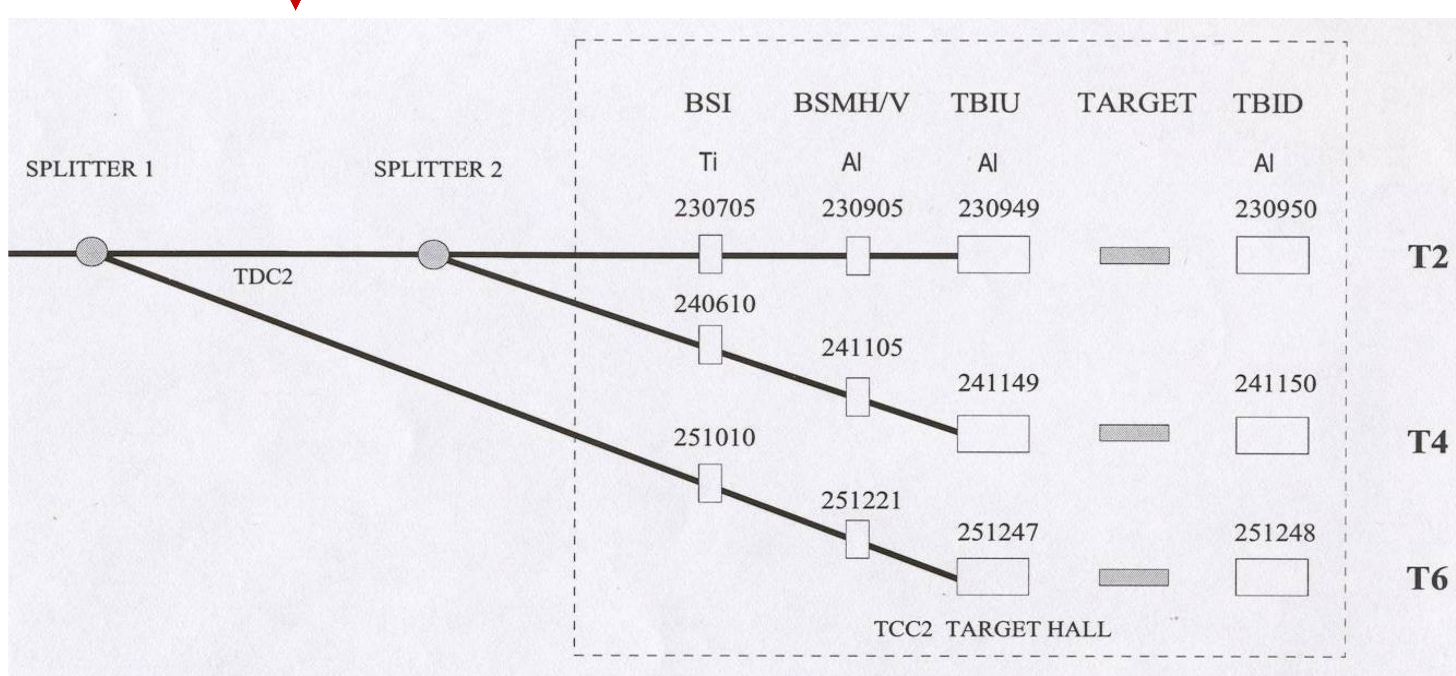
Correction of symmetries & intensity

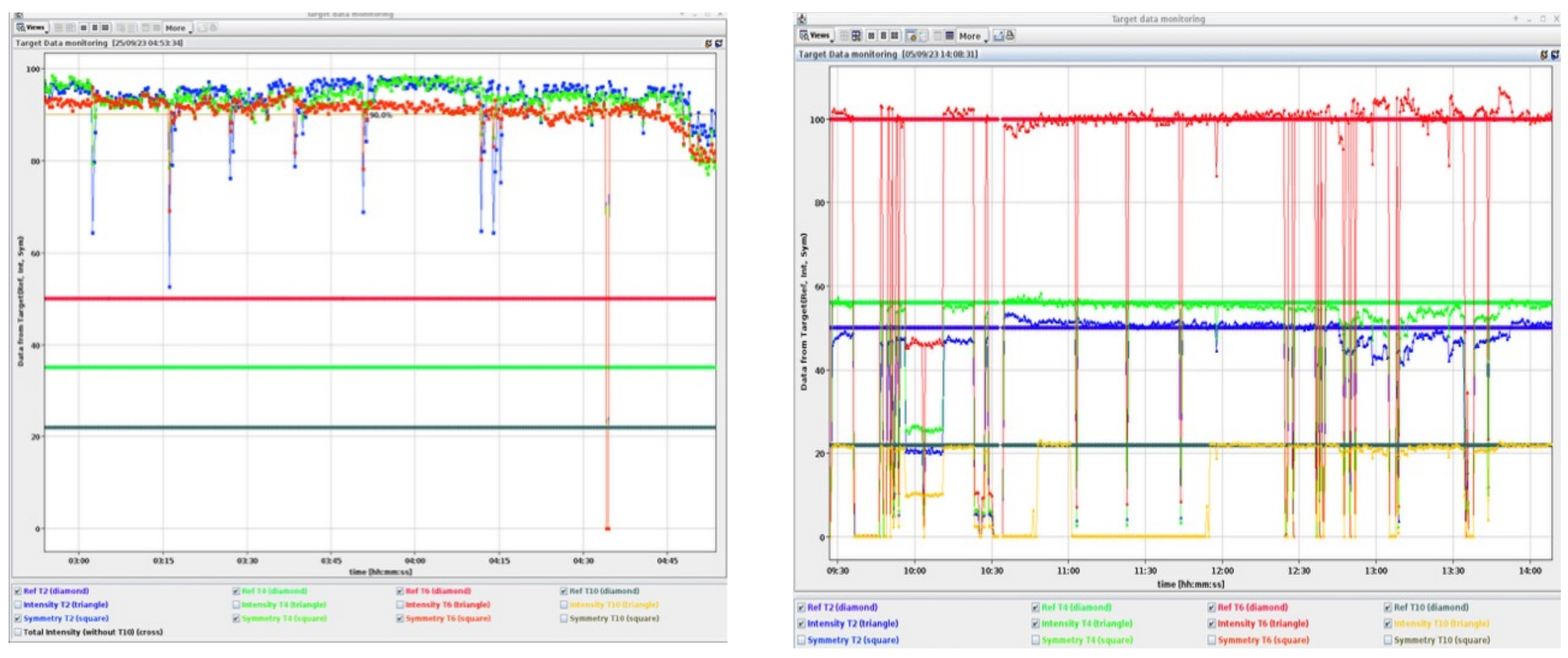
- The symmetry at the BSMs is monitored continuously and compared to reference values in **LSA** [2]; if the value falls below **90%** but above **10%**, a corrective action is triggered externally at **YASP** [3] steering application
- Communication between YASP and SPS Target Autopilot is achieved by subscribing to a virtual parameter in LSA
- If the intensity sharing deviates from the reference values, the application triggers direct corrections on LSA knobs for moving the beam vertically across the splitters

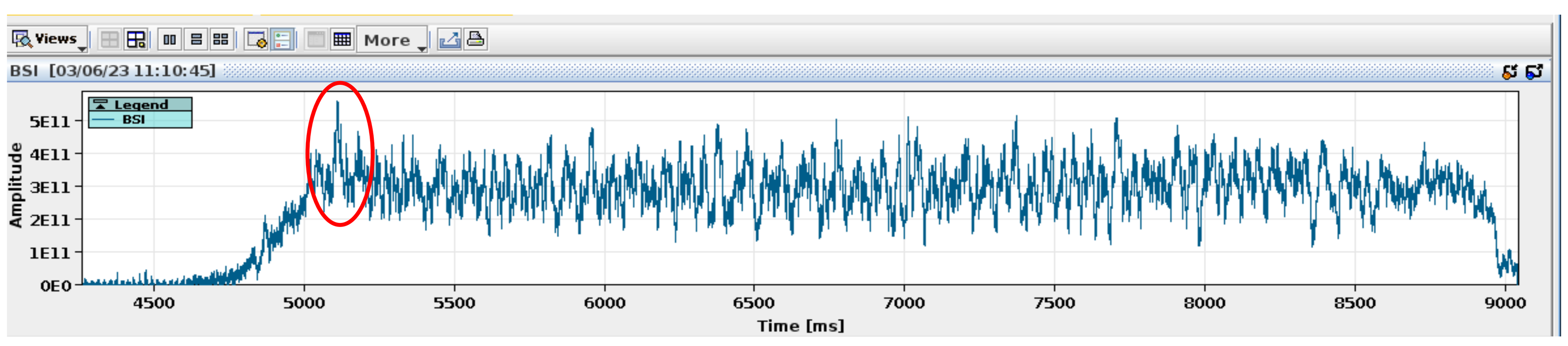
Working point adjustment

- The rotation of the separatrix as the beam approaches the third order resonance, induces beam losses on the extraction equipment; by means of the **COSE** [4] method, this rotation could be minimised and, in combination with **local crystal shadowing** [5], these losses are well suppressed today.
- Abrupt changes of the horizontal tune (Q_H) can create **spikes** in the spill structure; the SPS Target Autopilot facilitates efficient on-line tune adjustments by suggesting Q_H corrections according to observations of the spill evolution









Future plans

- Other optimization agents are running in parallel to the SPS Target Autopilot, such as an **Adaptive Bayesian Optimiser** to minimise 50 Hz and 100 Hz spill harmonics, or an on-demand splitter losses optimizer
- Some of these optimizations risk to interfere and compete with each other, potentially compromising their capabilities
- We plan to explore a centralising framework in order to efficiently orchestrate the multitude of controller and optimizers that may find their way to the SPS in the future

References

[1] Post-LS3 experimental options in ECN3, CERN-PBC Report-2023-003

[2] D. Jacquet et al., "LSA: The high-level application software of the LHC and its performance during the first three years of operations.", Proceedings of ICALEPS2013, San Francisco, CA, USA

[3] J. Wenninger, "YASP: Yet Another Steering Program"

[4] V. Kain et al., "Resonant slow extraction with constant optics for improved separatrix control at the extraction septum", Physical Reviews Accelerator & Beams, 22, 101001 (2019)

[5] F. Velotti et al., "Septum Shadowing by means of a bent crystal to reduce slow extraction beam loss", ", Physical Reviews Accelerator & Beams, 22, 093502