CERN SPS dilution kicker vacuum pressure behaviour under unprecedented beam brightness

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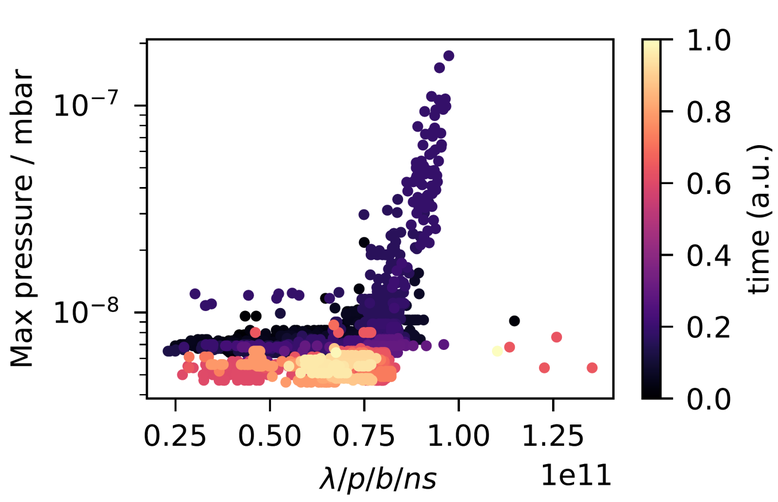
Context

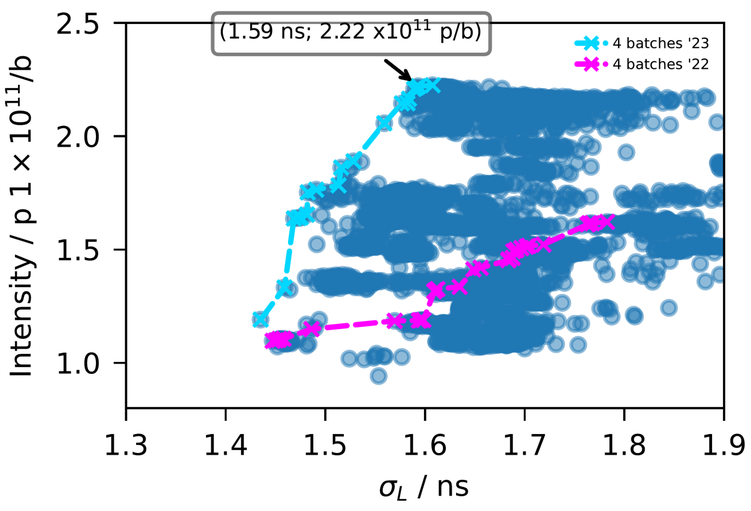
- The CERN Super Proton Synchrotron (SPS) experienced modifications including a new internal dump system and a relocation/redesign of the Beam Dumping System (SBDS) as part of the LHC Injectors Upgrade (LIU) program to handle beams with specific characteristics.
- After the upgrade, increasing LHC-type beam intensities revealed unexplained and unreplicated phenomena of rapid vacuum pressure increases at the MKDH, particularly when intensity per bunch increased and bunch length decreased, sometimes exceeding safe operational limits.

Pre-LS2 observations

- The LHC utilizes beams of up to 288 bunches, encountering a challenge where the MKDV's vacuum pressure exponentially increases with both the intensity per bunch and bunch length in the SPS, which can be mitigated by conditioning through consistent high-intensity beam circulation, demonstrating a conditioning effect that reduces subsequent pressure increases for equivalent line densities.

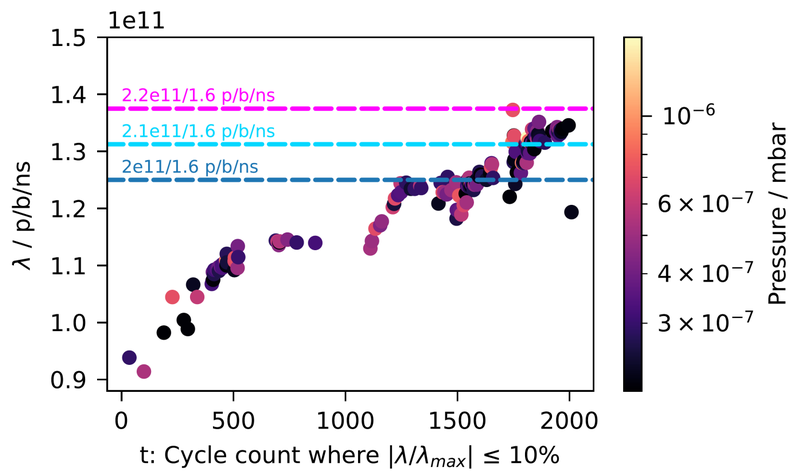


Best performance obtained



Observations after LS2

- The High-Luminosity Large Hadron Collider (HL-LHC) aims to achieve a peak of 2.3×10^{11} protons per bunch with 288 bunches at 450 GeV, requiring machine-wide conditioning, especially of critical components like kickers and RF cavities; the replacement of a high-impedance injection kicker (MKP-L) improved the system's capacity, but the MKDH exhibited rapid pressure increases when line density reached new peaks, revealing a threshold effect influenced by bunch intensity and length, with slight beam parameter adjustments significantly affecting pressure surges.



Conditioning evolution with 288 bunches

- Following the replacement of the MKP-L, the MKDH's conditioning in 2023 was notably efficient also due to the introduction of cycles with an extended flat top
- Using a Monte Carlo Markov Chain (MCMC) technique, the conditioning rate was determined and projected, revealing an initial rapid phase and subsequent stabilization, and providing estimates for future conditioning durations under various scenarios and operational efficiencies.