CONCEPTUAL DESIGN OF A COLLIMATION SYSTEM FOR THE CERN SUPER PROTON SYNCHROTRON

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The Super Proton Synchrotron (SPS) is the last accelerator in the LHC Injectors Chain. Its performance is constantly being improved in the framework of the LHC Injectors Upgrade (LIU) project in order to prepare it for the future operation as foreseen by the HL-LHC (High Luminosity LHC) project. One of the LIU goals is to nearly double the intensity extracted from the SPS, up to 2.32 $\times 10^{11}$ p/bunch. In recent years, nearly 10% of losses are observed for nominal intensity and LHC-type beams; they grow to about 20% for the intensity approaching the HL-LHC target. Beam losses imply activation and aging of the SPS hardware; the possibility to add a collimation system is being considered to mitigate this problem. The concept is based on a primary horizontal collimator located in an available position with high enough dispersion, and a secondary collimator to intercept the particles leaking out from the primary collimator. Performance of the proposed collimation system is evaluated by means of numerical simulations.

Introduction

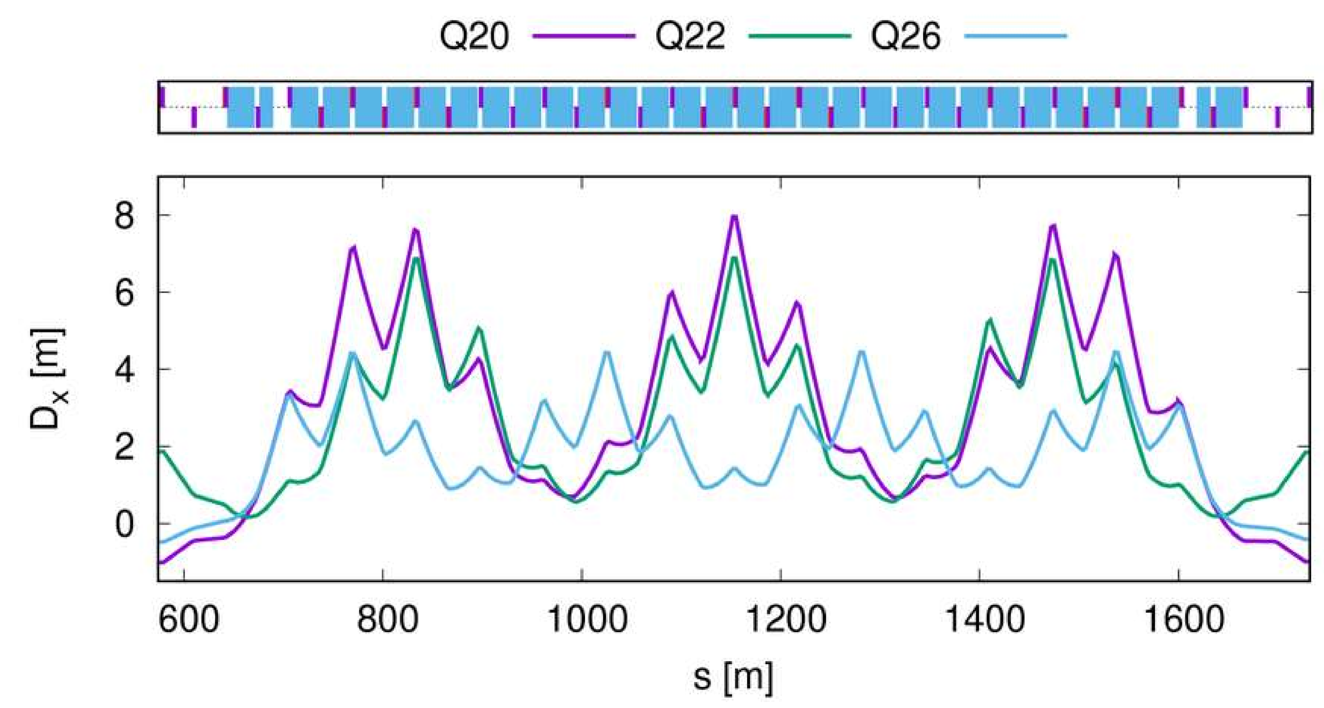
The SPS currently delivers to the LHC up to four batches of 72 bunches, accelerated from 26 GeV/c up to 450 GeV/c, with an intensity of about 1.33$\times 10^{11}$ protons per bunch. The SPS bunch intensity at injection will be nearly doubled (up to 2.57$\times 10^{11}$p/b) as foreseen by the HL-LHC project, with a budget for particle losses of 10% to guarantee 2.32$\times 10^{11}$ p/b at extraction.

Longitudinal effects are mostly responsible for the observed losses:

- uncaptured beam from the Proton Synchrotron (PS, the last acceleration stage before the SPS) due to its longitudinal emittance and tails (S-shape)
- particles being close to the separatrix that fall out of the SPS rf bucket.

Losses occur mainly in the horizontal plane, at locations of large horizontal dispersion. The dispersion function changes between the 3 optics being used in the SPS: Q26, Q22 and Q20, denoting the integer value of tune. Beam Loss Monitor (BLM) data indicate that losses are localized in a few locations along the ring rather than equally distributed.

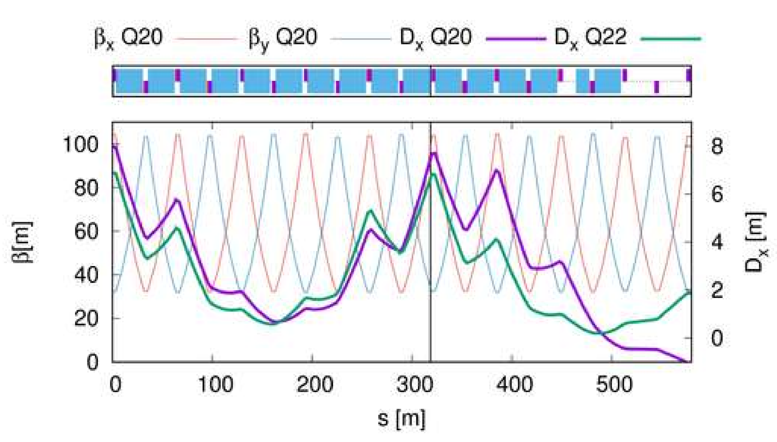
Two designs of the off-momentum collimation system have been proposed and compared.



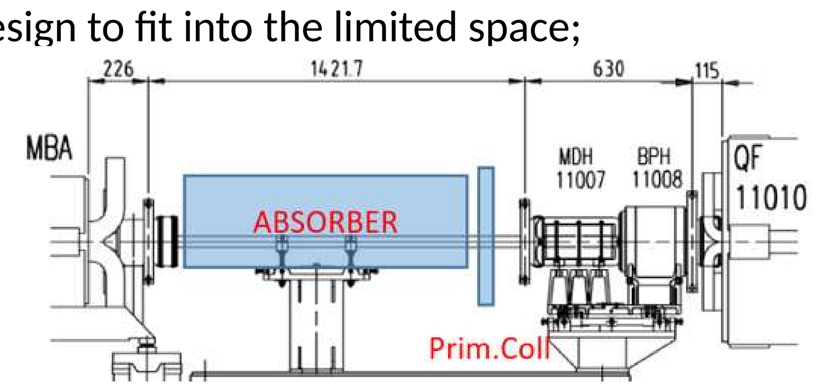
Horizontal dispersion (Dx) for Q20, Q22 and Q26 optics. Only 1/6 of the SPS ring is given due to the optics symmetry. Losses occur mainly at high dispersion locations.

Both stages in the arc

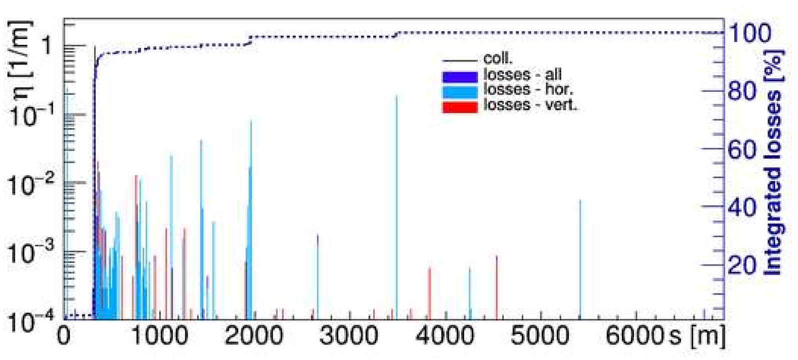
- Both collimators in the arc in the same insertion;
- Collimators in the maximum of the dispersion for best off-momentum cleaning:



- Rather unusual design with a long absorber followed by a short (5mm) primary collimator:
  - based on dispersion;
  - a narrow primary collimator increases |dp/p| to send protons towards the absorber's front face
  - compact design to fit into the limited space;



- Global cleaning efficiency improves with a denser material:
  - 73% for 1m of Molybdenum-Graphite
  - 85% for 1m of Copper
  - 88% for 0.6m of Tungsten



<u>Assets:</u>

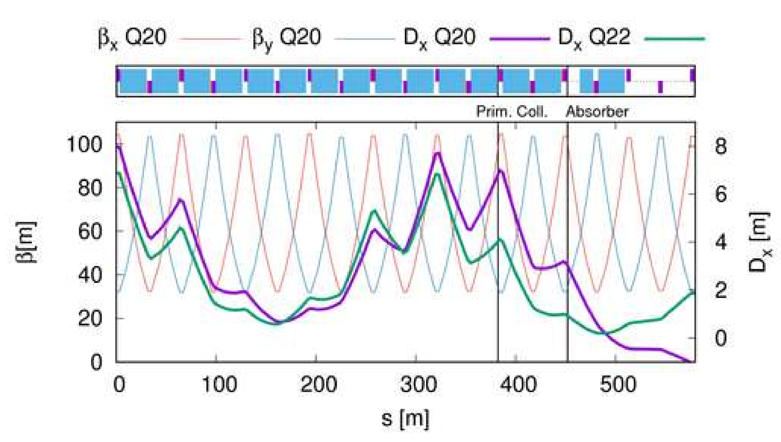
- Compatible with all SPS optics without any further adjustment.
- Not sensitive to common machine errors.

<u>Liabilities:</u>

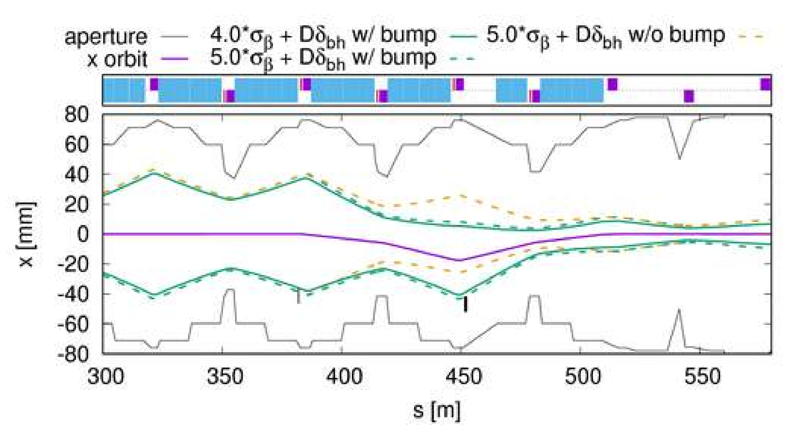
- Elements directly downstream exposed to secondary showers.
- Challenging integration into the machine.

Primary collimator in the arc, secondary coll. in the straight section

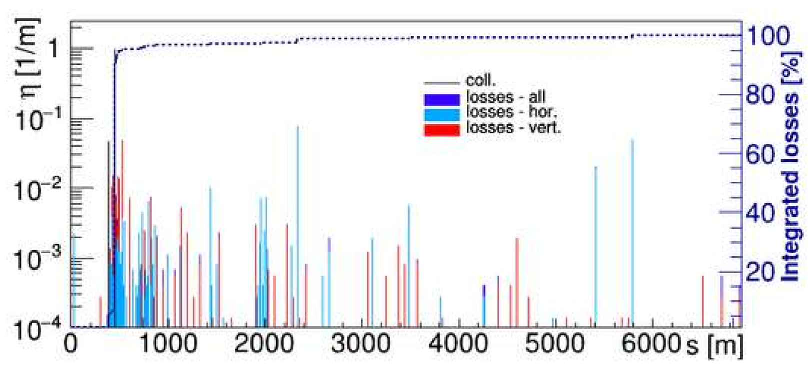
- Primary collimator in the arc, absorber in the dispersion suppressor;
- Much lower dispersion at the absorber, but more space available:



- This design relies more on the betatron motion:
  - Phase advance close to 90 deg;
  - Absorber can be reached already at the same turn.
- Large absorber opening (~40mm) is needed for compatibility with all SPS optics.
- An orbit bump is needed to reach the absorber:



- Increased cleaning efficiency:
  - 87 % for 1m of Molybdenum-Graphite + the downstream TIDP (existing momentum scraper);
  - 82 % if TIDP is the only absorber.



<u>Assets:</u>

- Provides better cleaning.
- Secondary showers are not a concern for downstream elements.

<u>Liabilities:</u>

- Requires a good control over the orbit.
- Orbit correctors strength limitted to flat bottom and beginnig of ramp.

Conclusions

An off-momentum collimation system can be a viable solution to the beam losses in the SPS foreseen by the HL-LHC project. Two designs have been proposed, both considering a two-stages collimation system. The first design conceives both stages in the arc, at the peak of dispersion. It makes the system very compact and insensitive to common machine errors, providing a good cleaning efficiency. The second design conceives to move the second stage to the dispersion suppressor region and therefore reduce the radiation effects on the elements immediately downstream. This design is characterized by an improved cleaning efficiency, but it requires a well controlled orbit bump. It also allows to re-use the existing TIDP as a secondary stage, with no substantial degradation of the cleaning performance, but saving on new hardware. It is planned to compare in detail the two options based on energy deposition studies, feasibility of the orbit bump control and robustness to errors. Decision on the collimation system implementation is expected by the end of 2018.