Crab Cavity Failure Scenarios with 200 MHz

Andrea Santamaría García
H. Burkhardt, K. Sjobak

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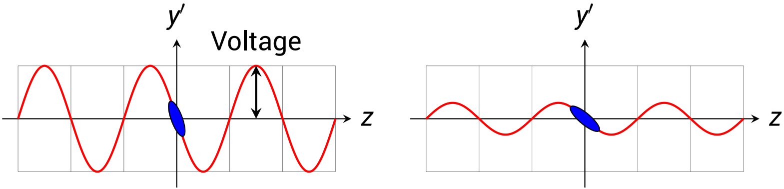
Crabbing

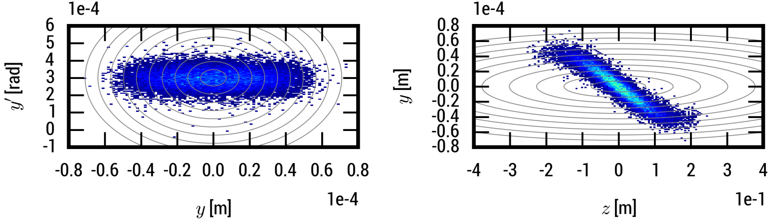
A crab cavity is a hollow superconductor that stores energy through the standing waves that resonate inside its structure.

- The standing waves are synchronized with the arrival of the bunch so that their phase is zero.
- The particles of the center of the bunch will then see no voltage, while the ones at larger z will see an increasing voltage.

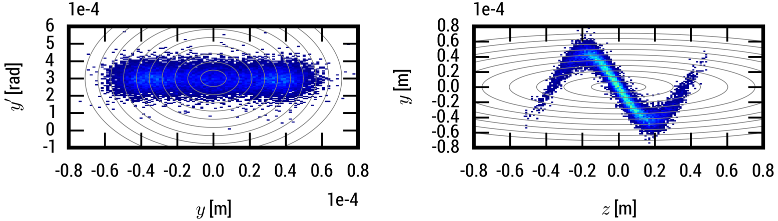


Crabbing in IP1

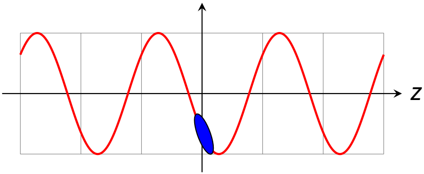
Turn 2, 400MHz



Turn 2, 200MHz

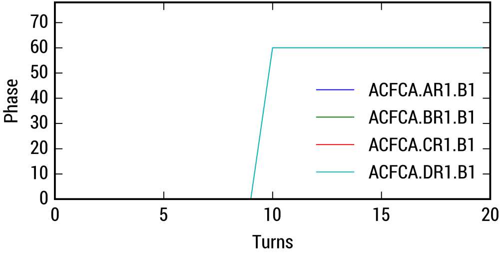


Toy Model



A **phase slip** can kick the core of the beam, making it the most dangerous failure scenario.

- For the purpose of this study, a **phase slip of 60 °** was selected as failure scenario (for the 4 crab cavities downstream).
- The crab cavity voltage is kept constant at **3.4 MV**.



Toy Model

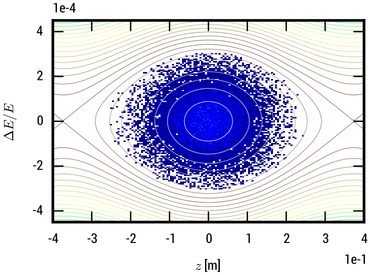
Some remarks:

- This failure case corresponds to a direct change of the crab cavity settings from the control room. The limitation is the power that can be supplied to the cavity.
- Four crab cavities were chosen in order to have a more powerful kick, so that the failure is visible. Reducing the number of cavities would reduce the amplitude of the kick.

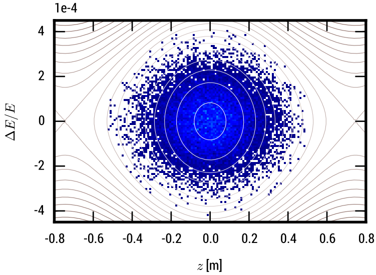
Additional details:

- Particles tracked with SixTrack 4.5.38.
- Machine model from optics 1.2 for HL-LHC.
- Nominal collimator openings.

400 MHz



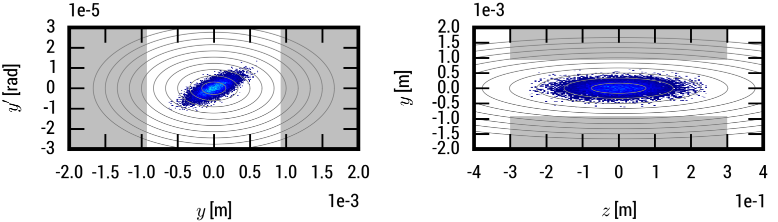
200 MHz



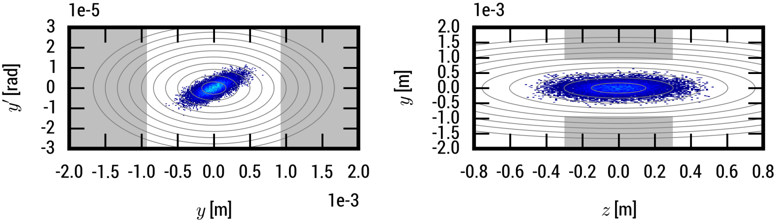
- The bucket length is doubled.
- Energy spread and momentum compaction factor remain the same.

Initial Distribution at TCP.D6L7.B1 (5.7 σ)

Turn 2, 400MHz

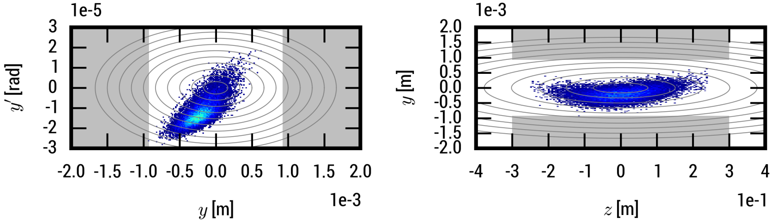


Turn 2, 200MHz

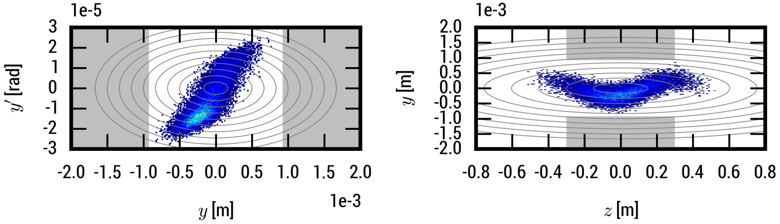


Failure Turn at TCP.D6L7.B1

Turn 10, 400MHz

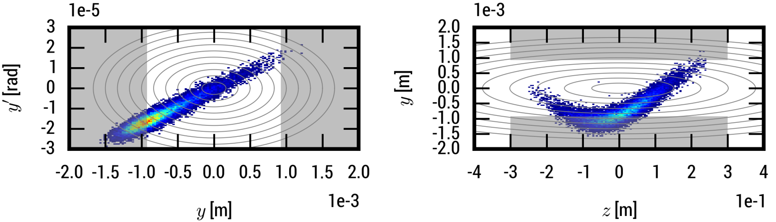


Turn 10, 200MHz

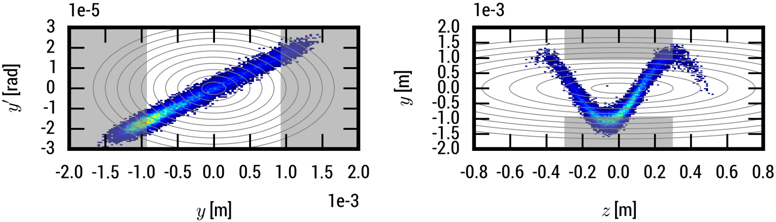


1 Turn After the Failure at TCP.D6L7.B1

Turn 11, 400MHz

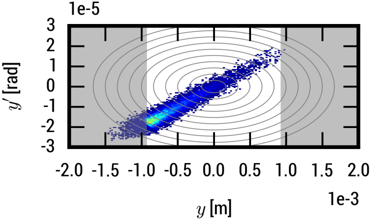


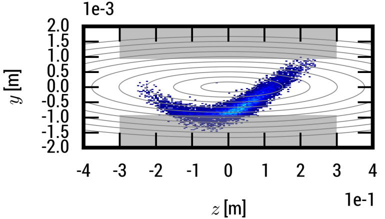
Turn 11, 200MHz



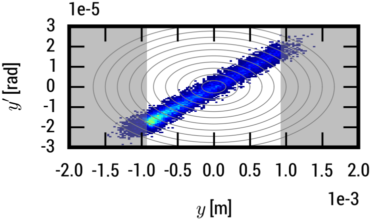
4 Turns After the Failure at TCP.D6L7.B1

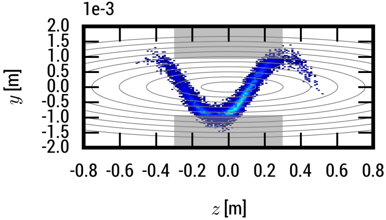
Turn 14, 400MHz





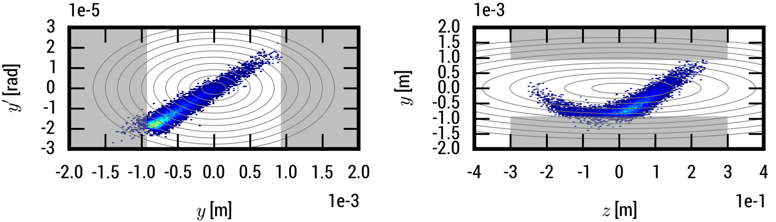
Turn 14, 200MHz



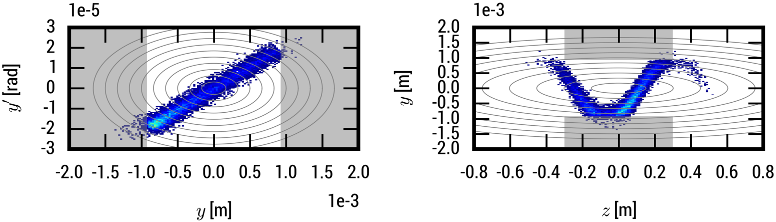


7 Turns After the Failure at TCP.D6L7.B1

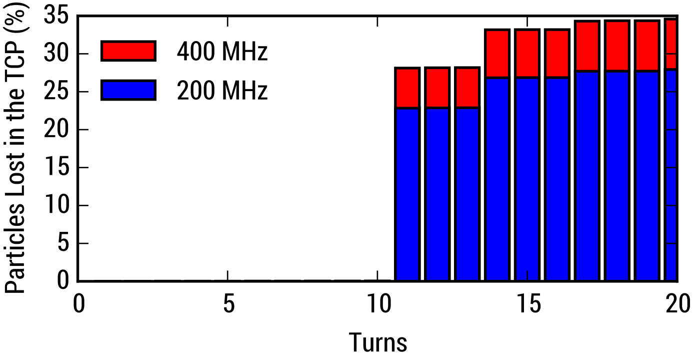
Turn 17, 400MHz



Turn 17, 200MHz



Losses



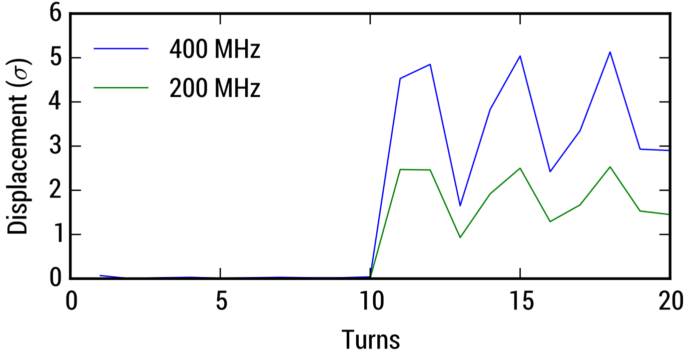
400 MHz

- Losses in the collimation system: 44 %
- Losses in the TCP : 35 %

200 MHz

- Losses in the collimation system: 35 %
- Losses in the TCP : 28 %

Centroid Displacement



Portrays the average movement of the particles that make up the bunch.

Outlook

- By doubling the bunch length, we are spreading the particles in z. If we keep the same number of particles this means that the longitudinal density decreases.
- Crabbing couples transverse and longitudinal planes, so in a case of failure that would affect the core, this dilution plays a role in the losses around the ring.
- This translates into 10% less losses in the collimation system for 200 MHz system, for this specific failure case.
- More realistic failure cases are always milder, so we can assume that the effects of the 200 MHz RF system will be less visible.

ECFA, Joint Annual Meeting and Hollow e- lens Review 2016 In preparation

Crab Cavity Failure Studies

- *Introduction to Crab Cavities & their Failure Modes.*, A. Santamaría García

IPAC'16

- *Machine Protection from Fast Crab Cavity Failures in the High Luminosity LHC*, A. Santamaría García et al.
- *Time Scale of Crab Cavity Failures Relevant for High Luminosity LHC*, K. Sjobak et al.

Joint HiLumi LHC-LARP Meeting 2015

- *Crab Cavity Failure Modes and IR Protection.*, A. Santamaría García
- *Crab Cavity Failure Scenarios and their Tracking.*, K. Sjobak

IPAC'15

- *General functionality for turn-dependent element properties in SixTrack*, K. Sjobak et al.
- *Limits on failure scenarios for crab cavities in the HL-LHC*, A. Santamaría García et al.