HOM mitigation for future SPS 33-cell 200 MHz accelerating structures

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- Beam coupling impedance calculations
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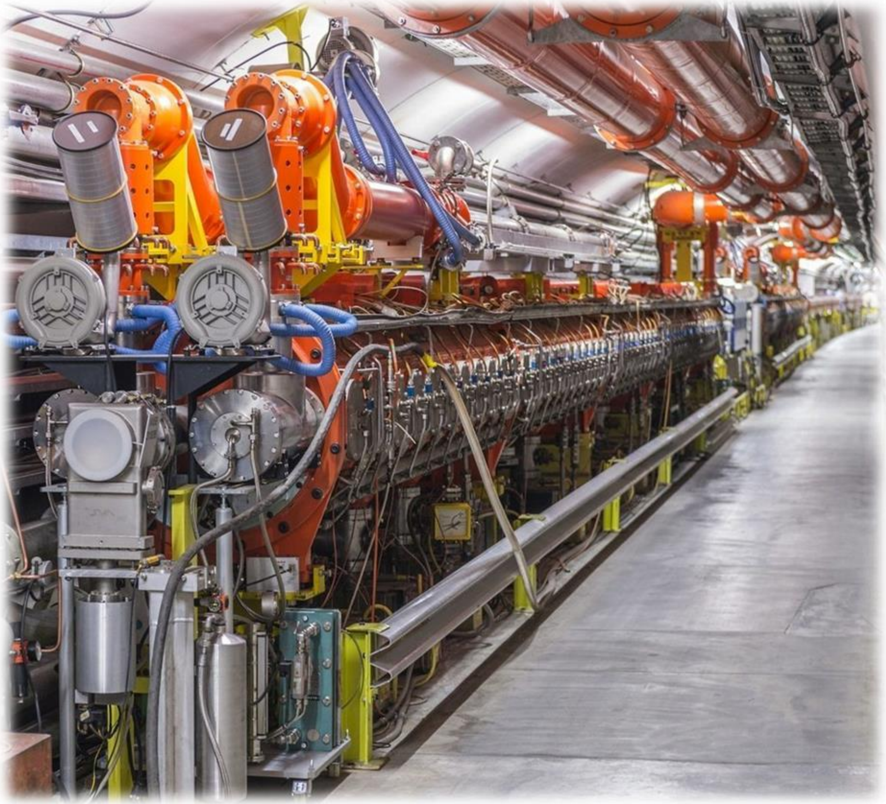
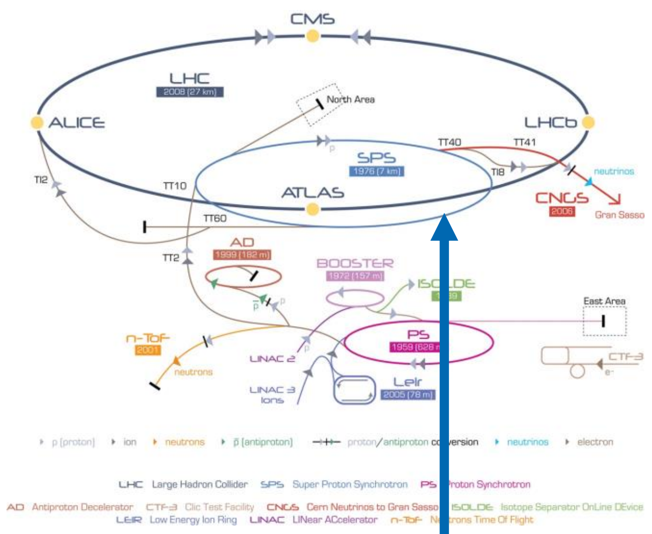
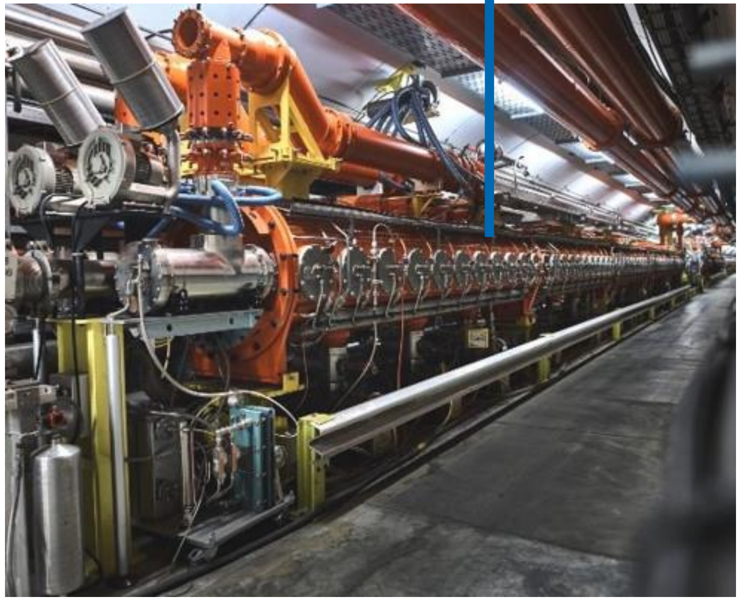


The SPS accelerating structure

- The Super-Proton-Synchrotron is the final pre-injector to the LHC
- Travelling wave acceleration @200MHz
- Periodically stem-loaded waveguide
  - 4 structures used today (up to 21m in length)
  - 44- and 55-cells





Injector preparation for HL-LHC

- High-Luminosity LHC
  - Increase collision rate by x10
  - Requires 2x today's intensity ($2.4 \bullet 10^{11}$p/b) [1]
- Upgrade of 200MHz TWS necessary
  - Shorter 33-cells due to beam loading
  - Increase HOM-damping around 630MHz by x3 due to long. instability [1]

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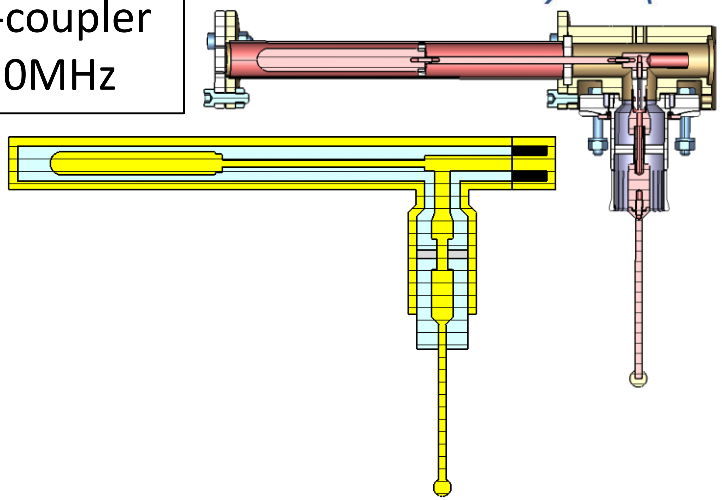
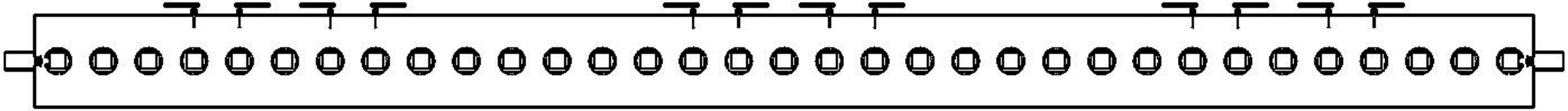
- HOM-damping since 1976
  - Already great damping performance
  - $Q_0 \approx 35000$, $Q_{ext} \approx 400$

HOM-coupler for 630MHz





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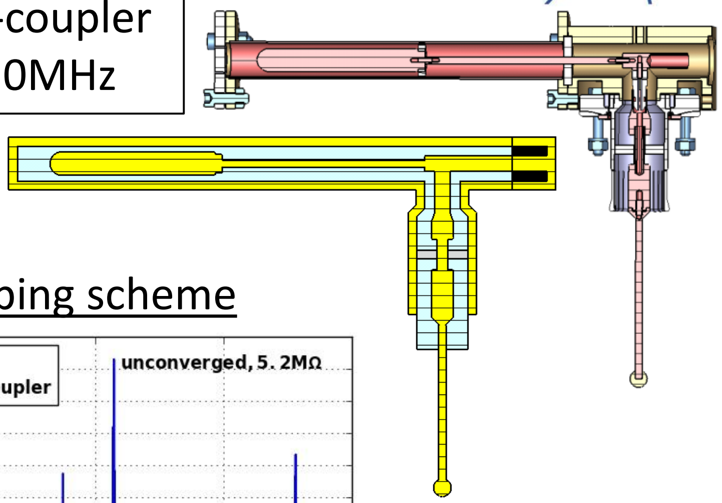
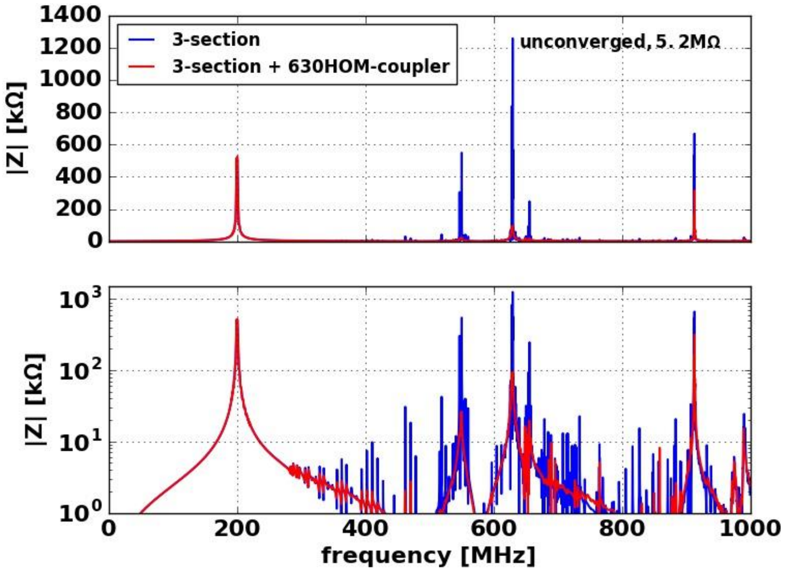
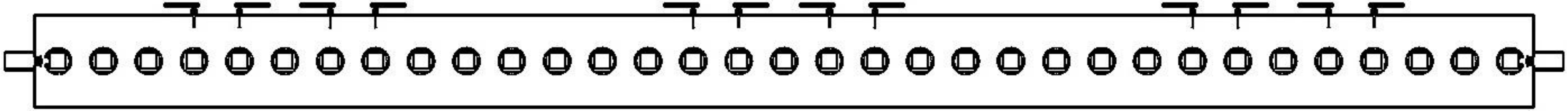


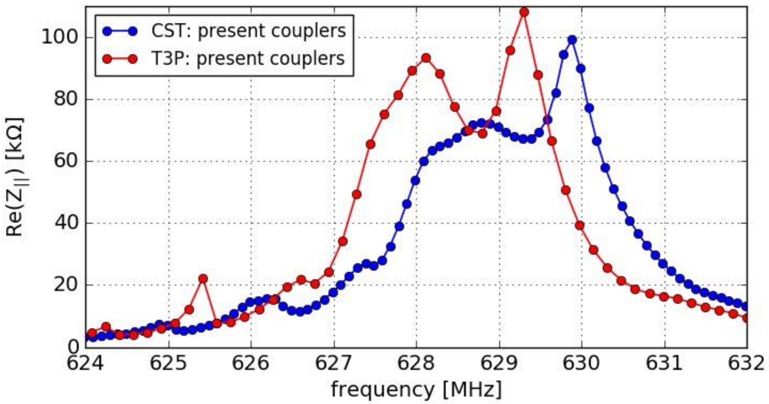
present damping scheme

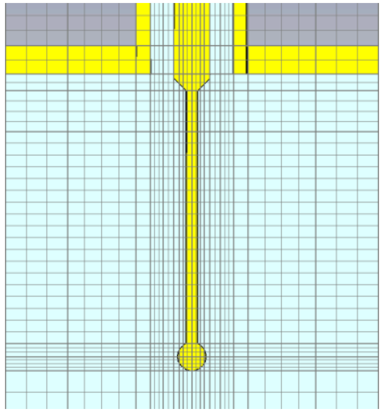




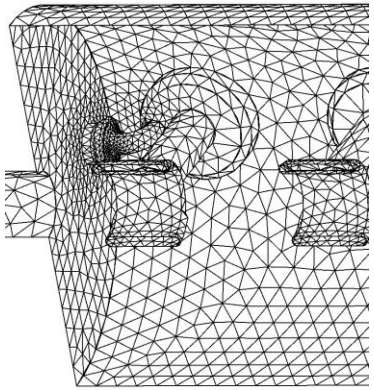
Beam impedance calculations

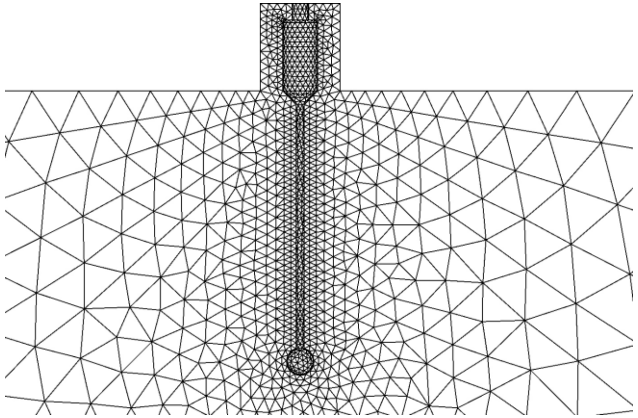
- Two different solver types used
  - Confirmation due to importance of the project
  - ACE3P & CST (FEM & FDTD)
    - Time-domain wakefield simulations
- Large volume but also fine structures need to be meshed

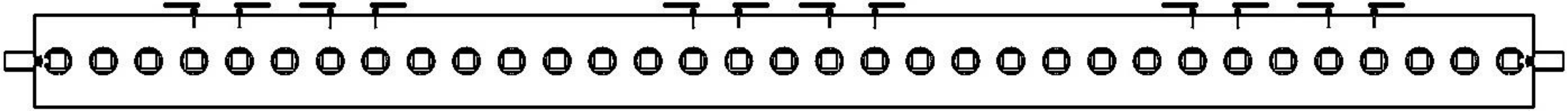




	T3P	CST
f_{max} [GHz]	1	1
# mesh [Mio.]	1.2 - 1.4 tets	16 - 21 hex
wake [km]	2/1.5	3

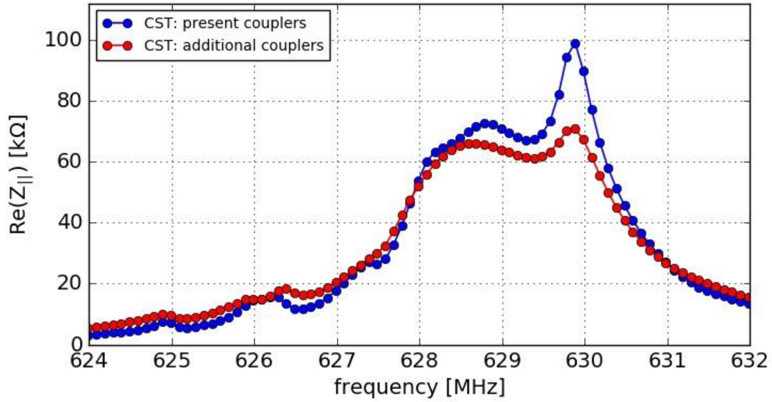


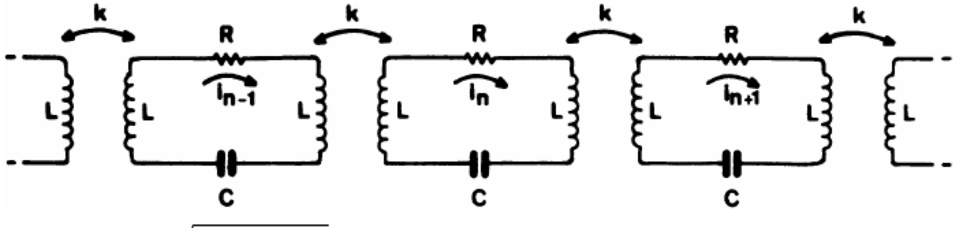




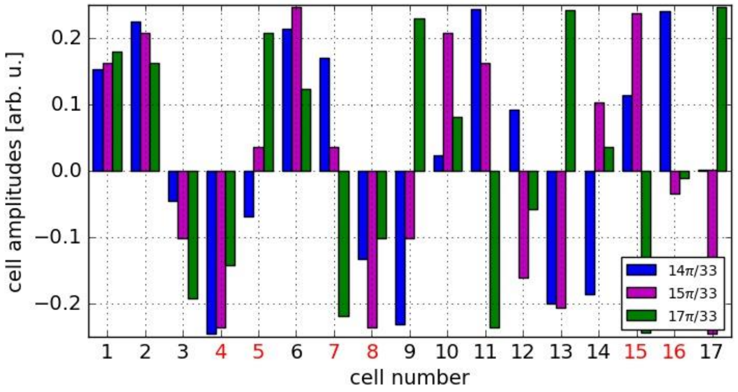
Additional HOM-couplers

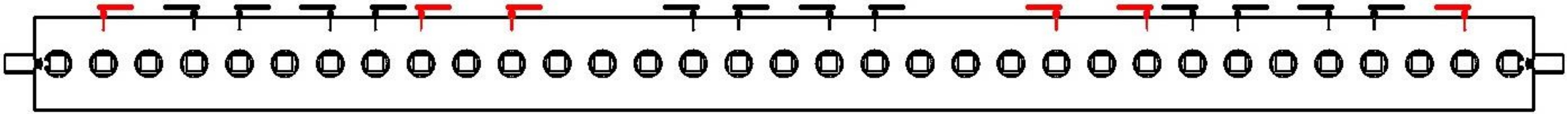
- Two high-R/Q modes (14π/33 & 15π/33)
- One high-Q mode (17π/33)
- Place additional couplers in cells with strong electric field





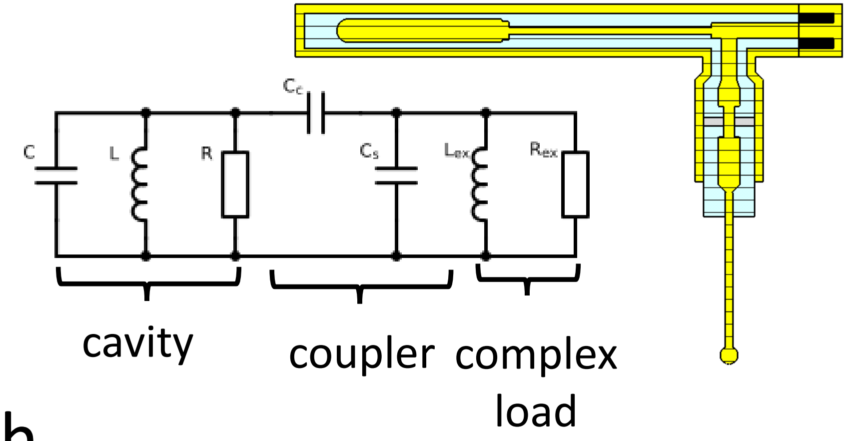
$$I(m,j) = \sqrt{\frac{2-\delta_{mN}}{N}} \sin\left[m\pi\left(\frac{2j-1}{2N}\right)\right]$$ [2]



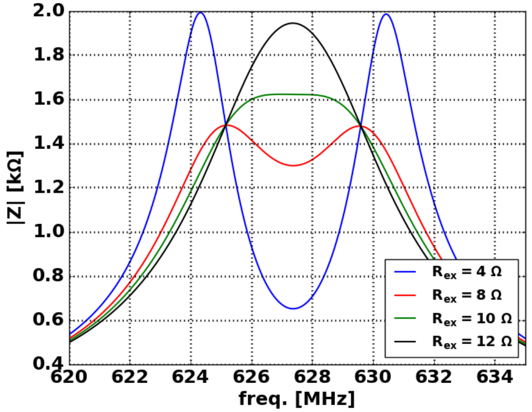


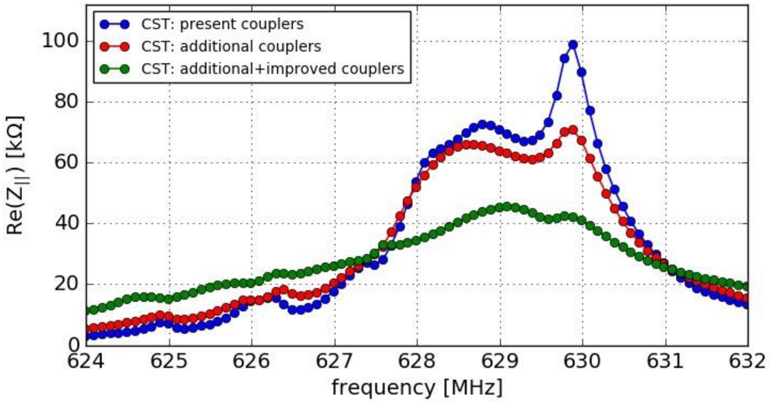
Improvement of HOM-couplers

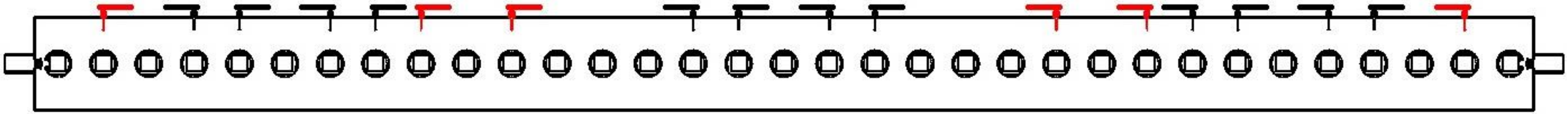
- Under-critical coupling of existing 50Ω-coupler
  - Electric probe already compensated at 630MHz
- Near critical coupling to high-R/Q modes obtained with 23Ω-coupler



Example

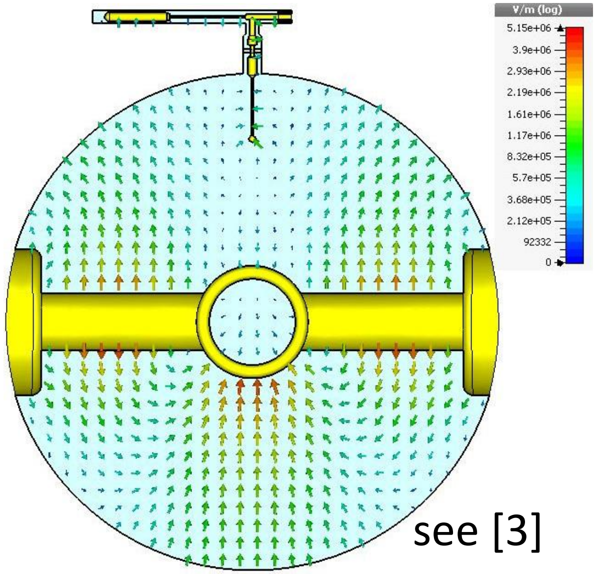




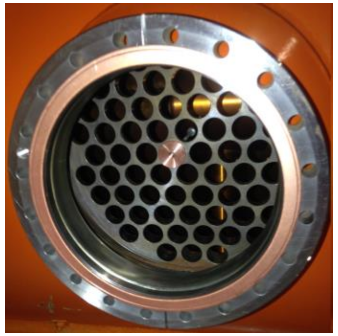


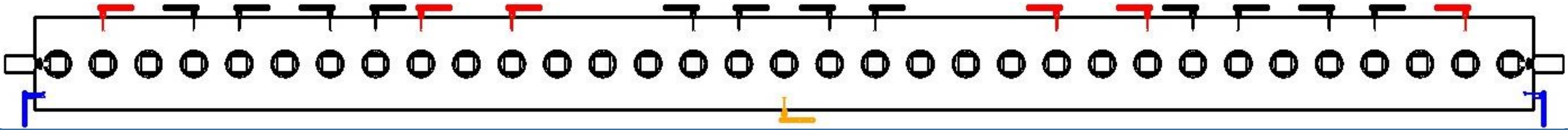
The limit of HOM-damping

- $Q_L \approx 200$ with improved scheme
- Violation of top/ bottom symmetry
  - Numerous couplers on-top
  - HOM-energy stored in lower part of the structure
- Only 2 dedicated access ports in the lower half on end-plates
- Conventional HOM-couplers unfeasible
  - Impact of fundamental mode (FM)
  - Require machining with potential integrity risk



see [3]

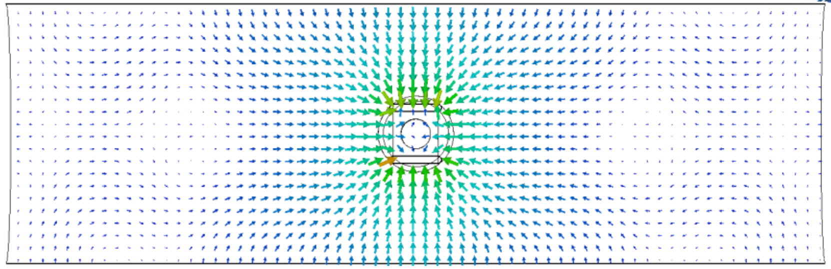




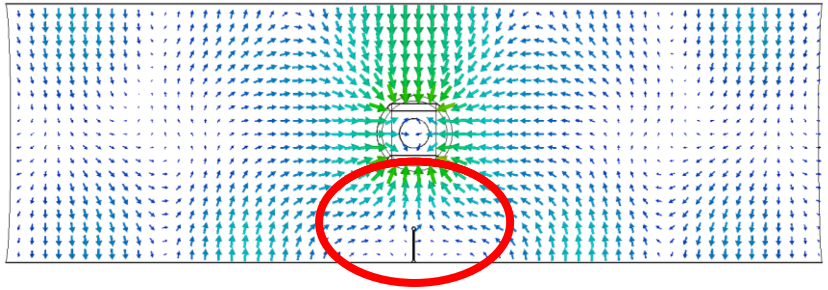
Mitigation of geometry factor R/Q

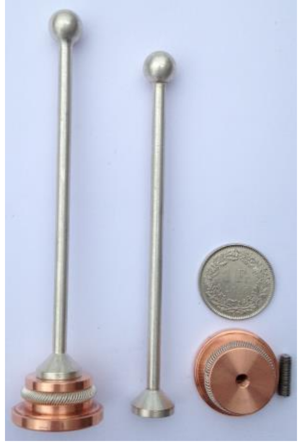
- Mitigation of modes with high R/Q by change of structure
- Strategic placement of resonant posts in some Vacuum-Pumping-Ports
  - Short-circuiting of displacement current to ground
  - EM-fields pushed towards couplers on-top

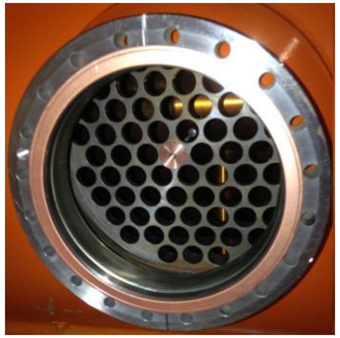
No post:

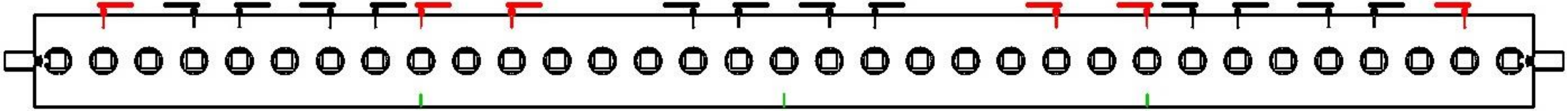


With post:



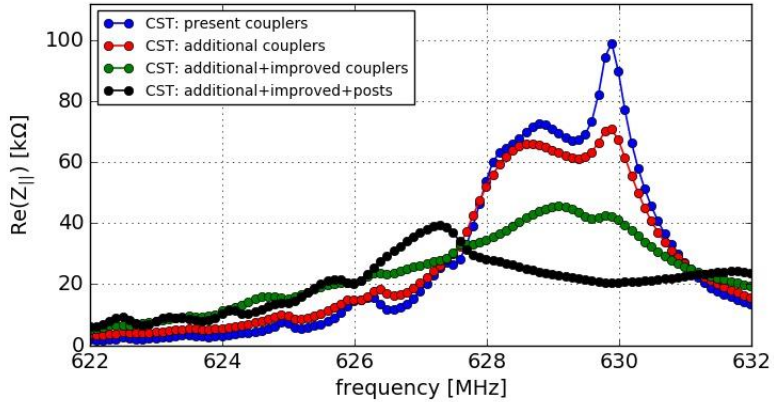


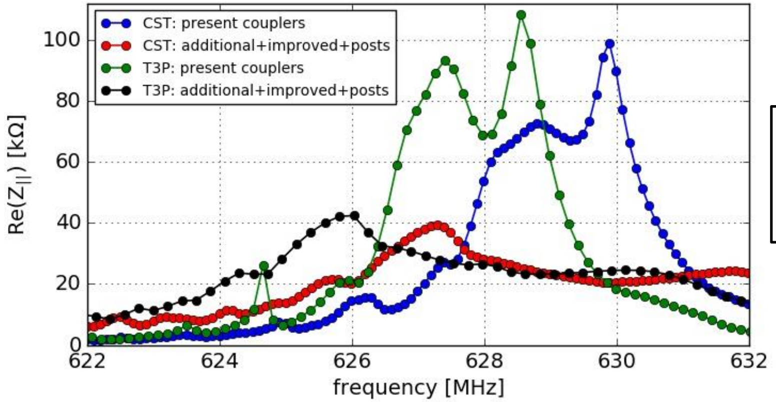




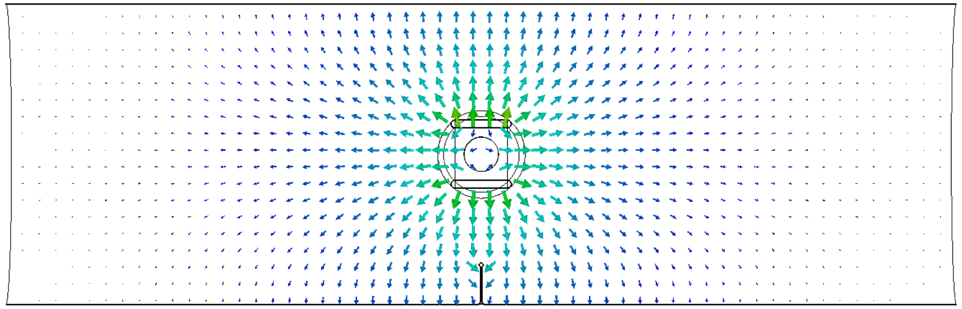
Mitigation of geometry factor R/Q

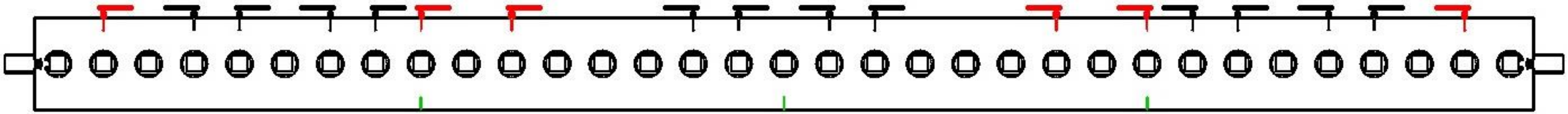
- Additional damping by x3 can be achieved
  - Improved couplers narrowband in first tests
- Impact on FM must be studied in more detail





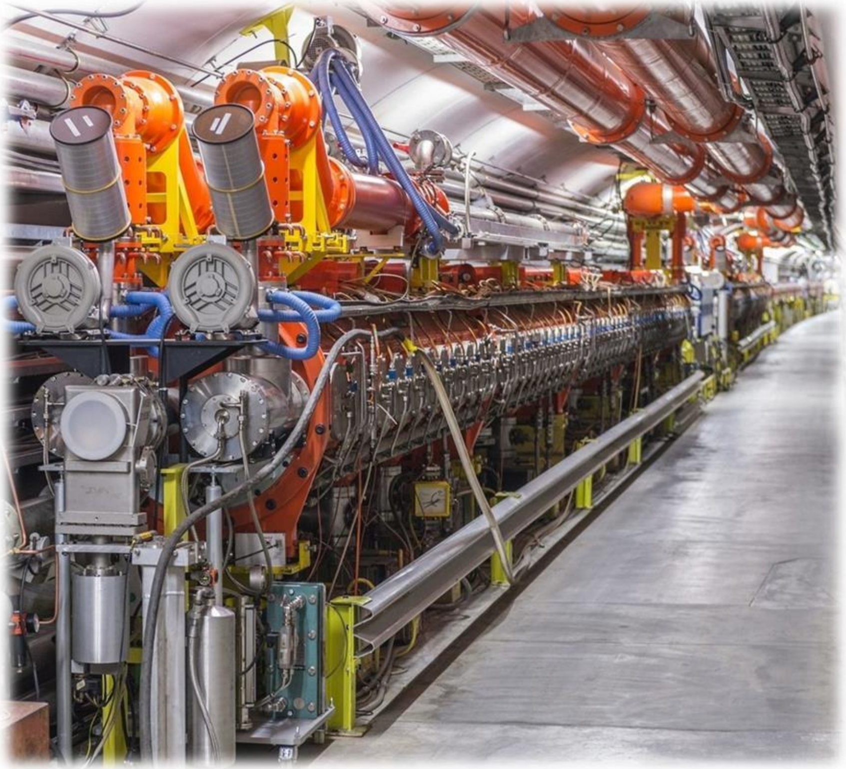
Comparison CST – T3P





Conclusions

- Beam impedance calculations of long structures with small features
- Discrepancies in beam impedance calculated by T3P and CST observed
- Additional damping by x3 can be achieved with the methods presented
  - Mitigation of Q and R/Q of HOMs



References

- [1] E. Shaposhnikova et al., *"Removing Known SPS Intensity Limitations for High Luminosity LHC Goals"*, CERN-ACC-2016-289, 2016.
- [2] H. Padamsee et al., *"RF Superconductivity for Accelerators"*, 2nd ed. Wiley, 2008.
- [3] [P. Kramer and C. Vollinger], in Proceedings of the ICFA Mini-Workshop on Impedances and Beam Instabilities, Benevento, Italy, 18-22 September 2017, CERN-2018-003-CP, pp. 57-62, https://doi.org/10.23732/CYRCP-2018-001.

Thank you for your attention!