Beam coupling impedance reduction techniques

Mario Beck - HSC section meeting - 2 October 2017

Thanks to: The Impedance Working Group, Bruno Balhan, Mike Barnes, Giovanni Rumolo, Carlo Zannini

Introduction I

- Beam coupling impedance describes the interaction of the beam with its surrounding in frequency domain (wake in time domain)
- It is mainly associated to:
  - Changes in the beam's surrounding aperture (step transitions, cavity like structures)
  - Non-PEC EM properties of the surrounding materials

Introduction II

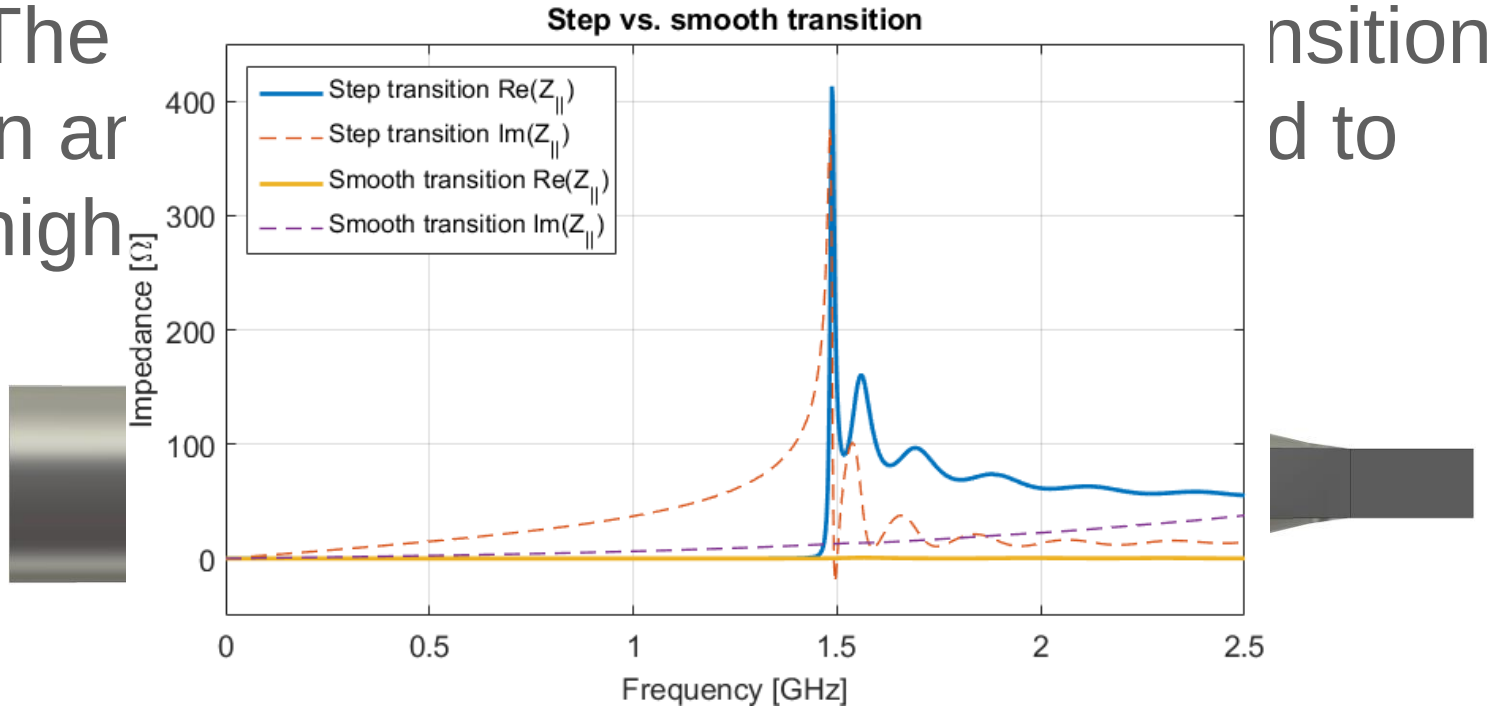
- Strong beam coupling impedance can lead to multiple problems in modern particle accelerators (beam instabilities and heating)
- To minimize the beam coupling impedance, the beam should see as little change in surrounding diameter as possible (no undesired cavities, step transitions)
- Materials with low losses also lead to a lower beam coupling impedance

Introduction III

- But components besides the beam pipe needed (e.g. for acceleration, extraction, injection)
- Different methods exist to reduce the beam coupling impedance
- The principle is to give the image current, induced into the machine by the beam, a high(er) conductivity path to follow the beam

Smooth transition

- The creation of wakes can be strongly reduced by smoothening transitions between beam pipe geometries
- The in ar high



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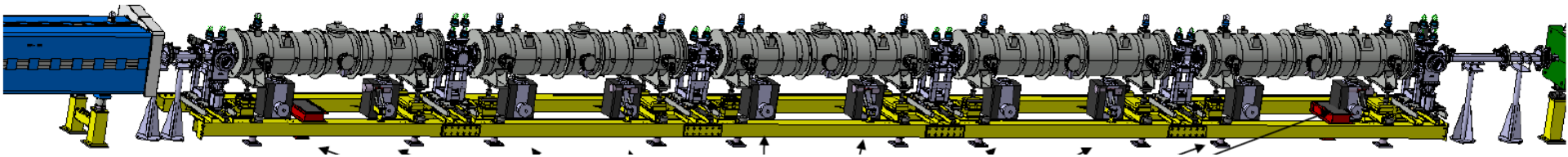
Shielding of unwanted cavities

- Unwanted cavities can be introduced for example by beam instrumentation tools, tanks housing beam steering devices or vacuum pumping ports
- Shielding these undesirable cavities can reduce the impedance quite significantly

Example: SPS extraction septum

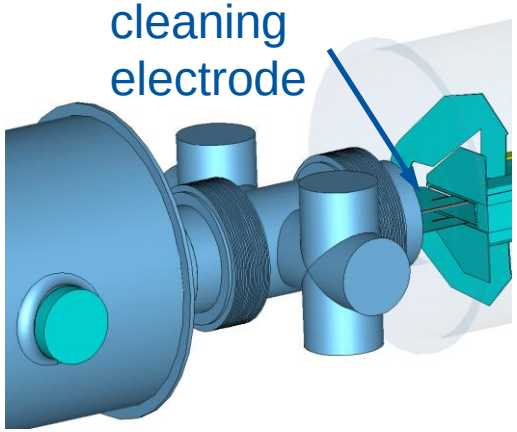
- The extraction septum (ZS) consists out of 5 tanks connected by beam pipes housing beam instrumentation tools
- The ZS is up for a general reconditioning and the equipment owner asked the IWG for proposals to reduce the beam coupling impedance

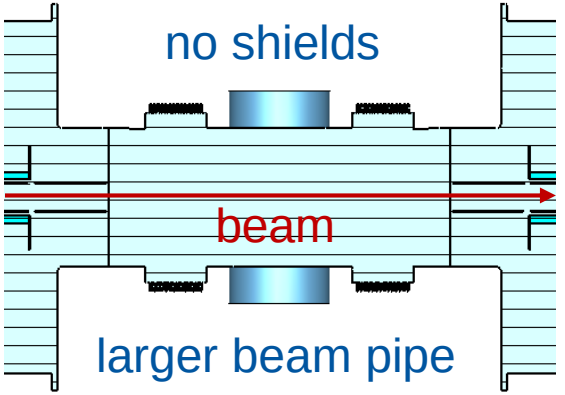


Example: Modifications to the ZS

old connector

cleaning electrode

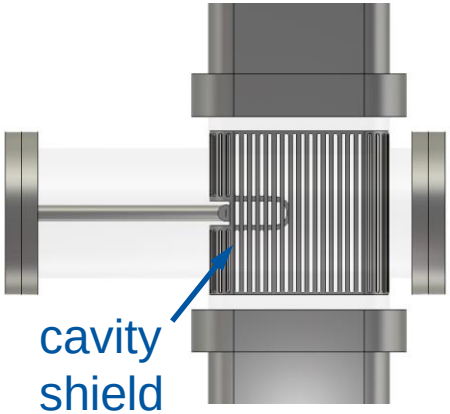


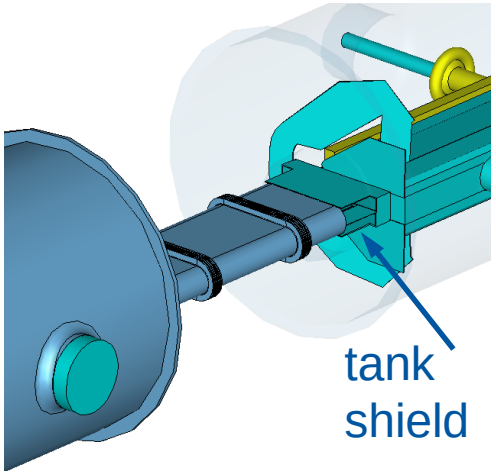


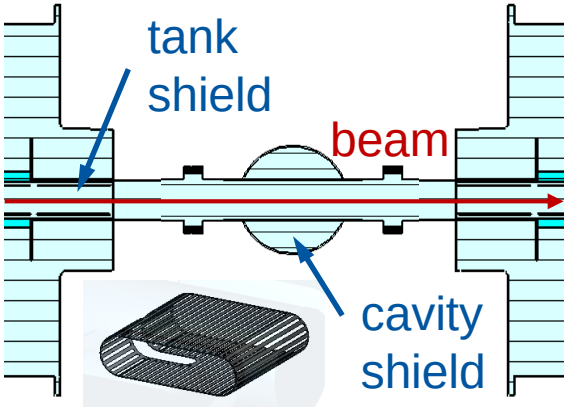
before modifications ↑

↓ after modifications

new connector

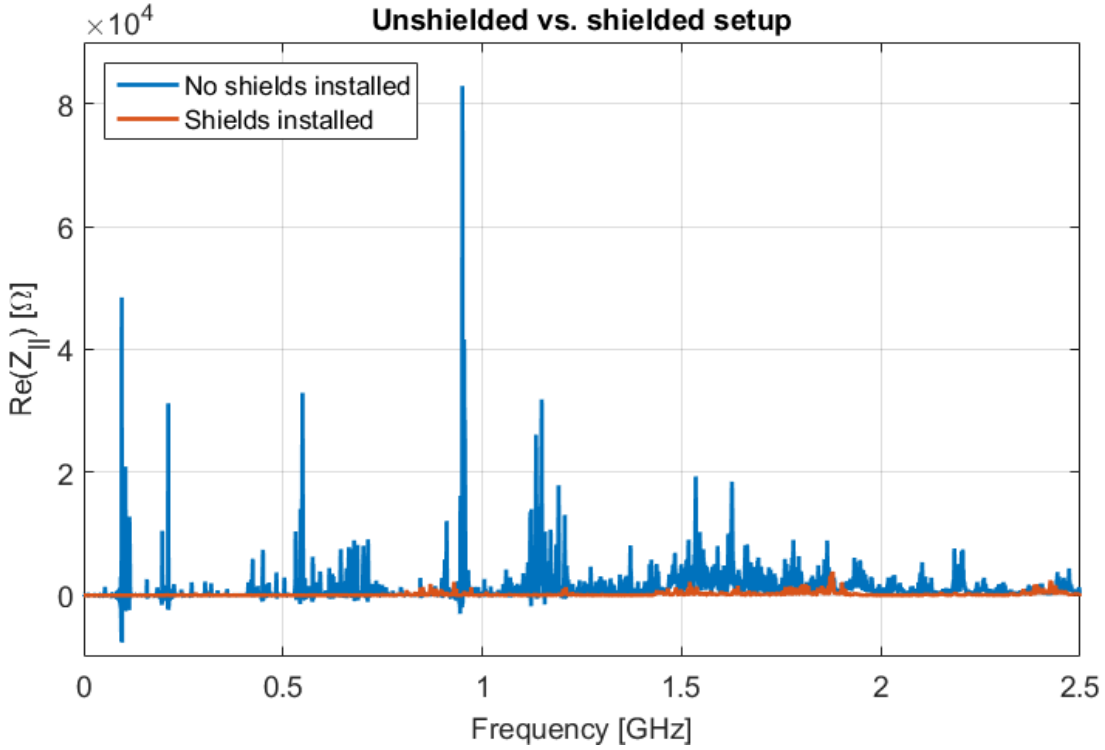






Example: Effects of modifications

- The shielding of all the cavities and tanks from the beam reduces the impedance in the order of several magnitudes



Coating

- Some components in the accelerator use materials with a high inherent impedance (e.g. collimators, protection devices).
- To reduce the impedance of those elements coating with a high conductivity material can be applied provided:
  - The correct functionality of the device is preserved
  - The vacuum requirements are fulfilled
  - The coating does not facilitate the creation of unwanted electron clouds

Serigraphy – Problem

- Some kickers use ferrites to deflect the beam. Some ferrites begin to heat up when exposed to high intensity beam EM fields
- The heated ferrite may lead to:
  - Intolerable outgassing (unacceptable vacuum degradation)
  - The loss of its magnetic properties (if the ferrite is heated above its Curie temperature)

Serigraphy - Concept

- A coating would impact the magnetic field the kicker produces and thus impair its performance
- A coupling structure (serigraphy) is printed on the ferrite
- This allows the kicker to function still within the specifications, but provides the image current an easier path to follow the beam

Example of serigraphy on the MKE

Serigraphy - MKP

- Compared to the MKE (extraction kicker) the MKP (injection kicker) has shorter ferrite cells due to different requirements
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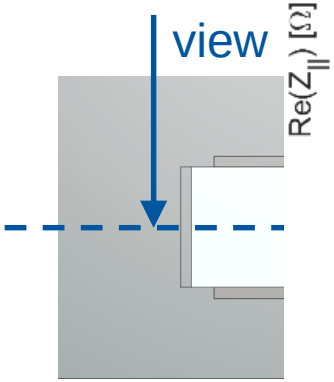

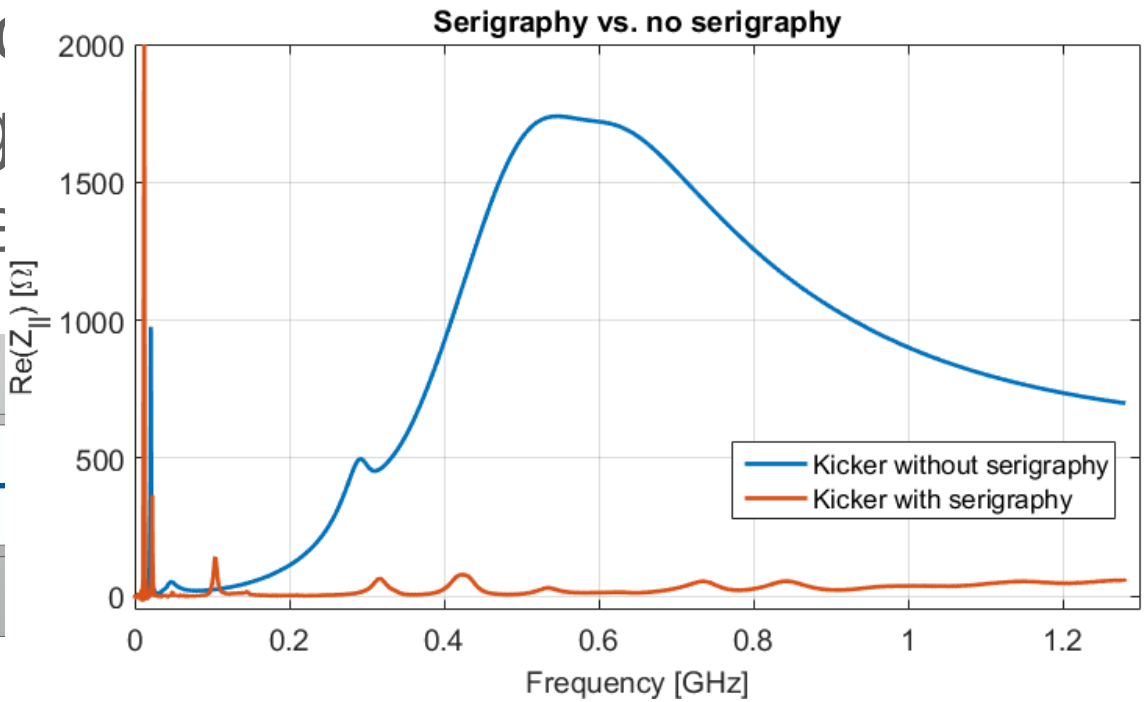

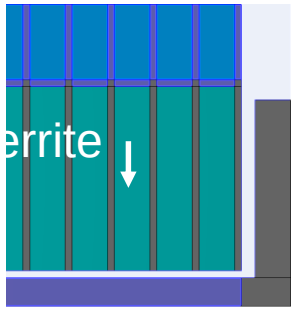

Serigraphy - Heating

- The heating of the ferrite is proportional to the power deposited in it. The power loss is highly dependent on the impedance of an obje
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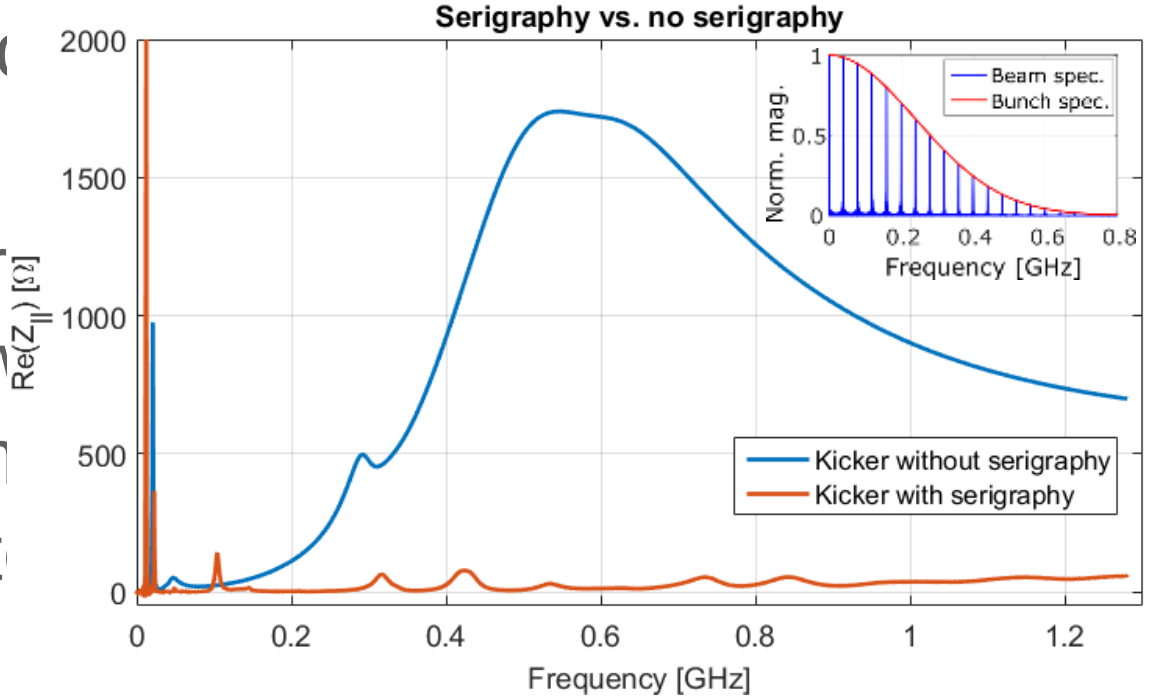

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Impedance model

- To see the effect of the updated beam coupling impedance on the beam dynamic, PyHEADTAIL simulations are needed
- Reviewing / improving the SPS impedance model; taking into account recent changes in the machine (changed MKE serigraphy length) and studying the case of the new Q22 optics
- Create a LIU-SPS impedance model

Conclusion

- It is of high importance to include impedance considerations at the design or upgrade phase of an accelerator
- Methods relatively simple to implement can minimize the impedance compatible with other requirements
- The results of the simulations can be used for the impedance model and thus lead to a better under standing of the machine