Optimization of cavity-amplifier interaction in low-MHz cavity systems

TECHNISCHE UNIVERSITÄT DARMSTADT

Challenges:

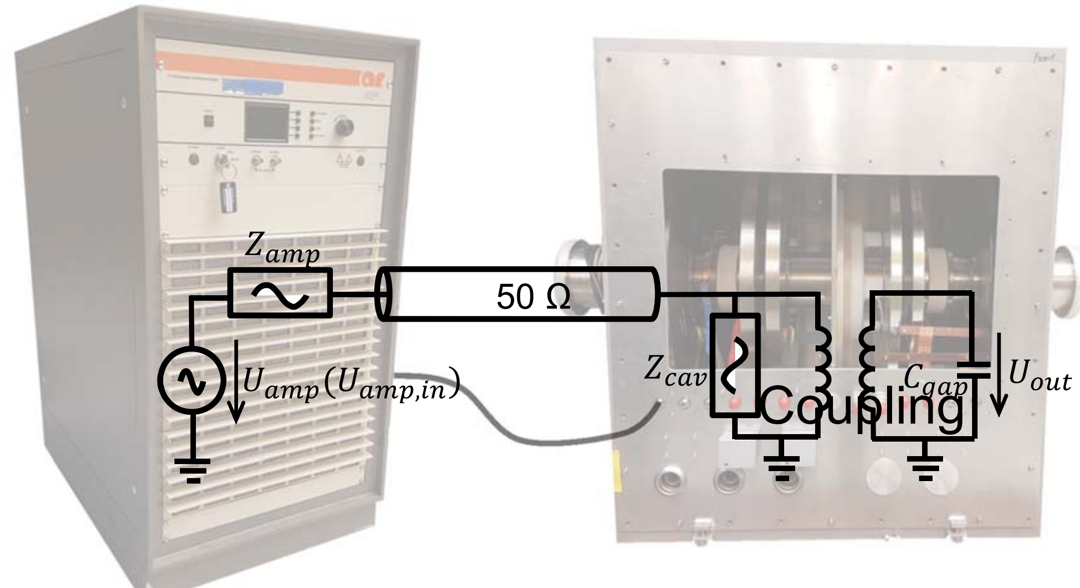
- Multi-parameter optimization problem
- strong constraints (e.g. only few amplifiers available for specific application)
- usually broad frequency range

Technical objectives:

Increase of voltage transfer from the amplifier to the cavity gap
→ higher gap voltage
→ lower costs
→ higher efficiency

Research objectives:

- General design guidelines
- Prototype verification



- Solid state amplifier
  - inner impedance
  - nonlinearity
  - reflected power
- Tube amplifier
  - operation point
  - circuitry

→ frequency dependent
→ nonlinear

- Cavity
  - ring core material
  - ring core geometry
  - coupling
  - gap design

→ frequency dependent
→ sometimes nonlinear

Optimization of cavity-amplifier interaction in low-MHz cavity systems

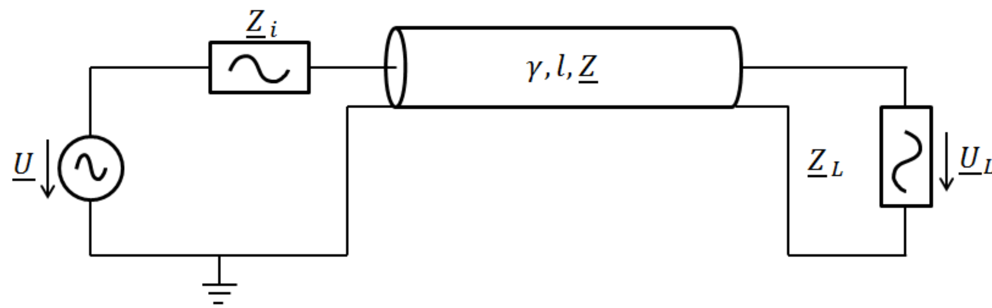
TECHNISCHE UNIVERSITÄT DARMSTADT

Example:

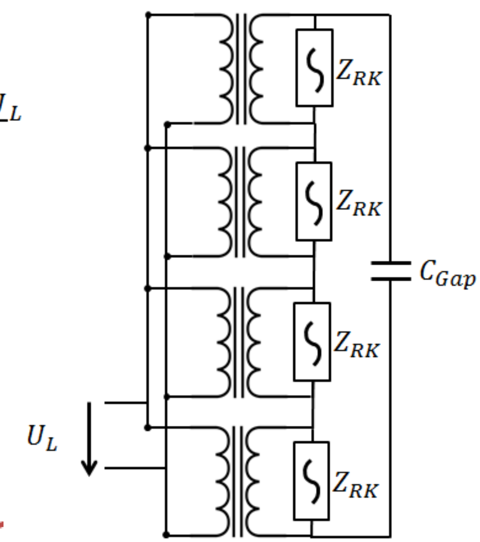
Most simple case:

$\underline{Z}_i = 50\ \Omega$

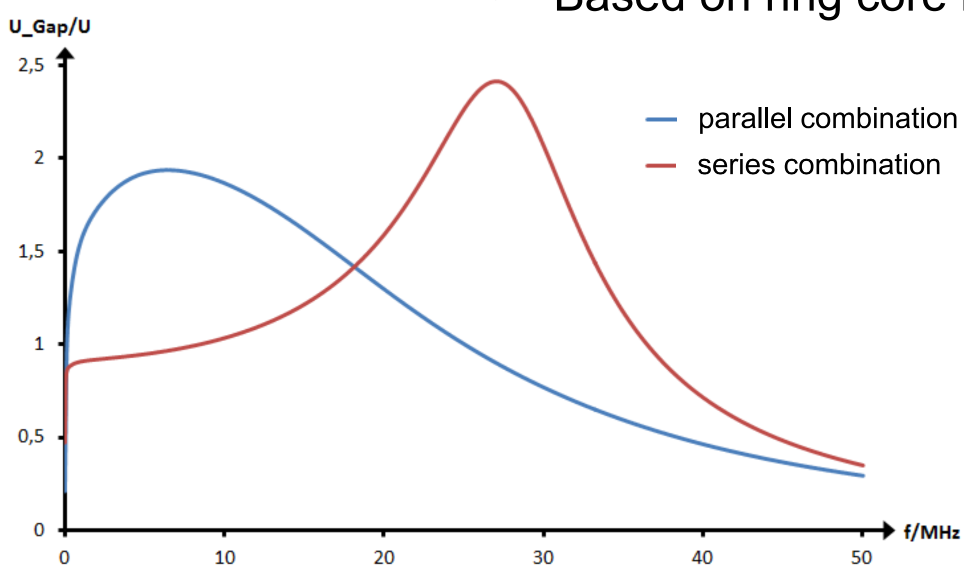
l= 0 m

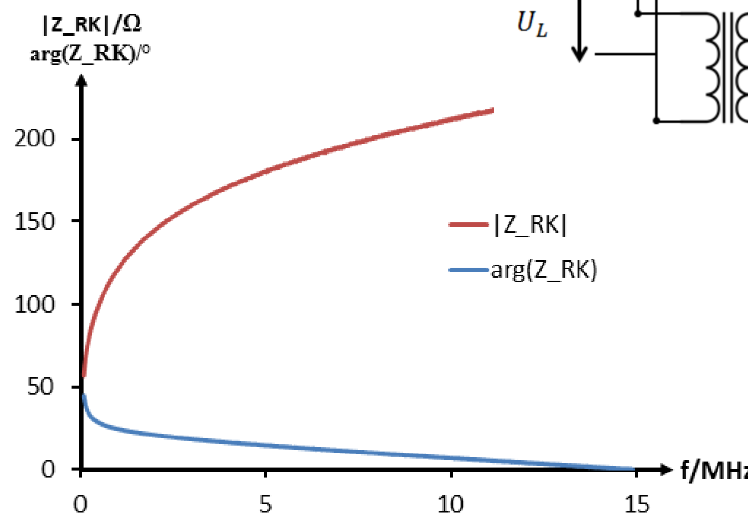


Parallel combination:



- PSpice simulation with coupling model
- Based on ring core measurement data





- Series combination: less voltage drop at inner impedance
- Parallel: factor 4 for voltage on secondary side (beam), but high voltage drop on primary side

Beam-Loading in Pulsed, Broadband and Deactivated RF Systems

TECHNISCHE UNIVERSITÄT DARMSTADT

Background/Relevance

- Beam-loading during **barrier-bucket** operation in SIS100:
  - planned cavities: two MA cavities with 500...1000 Ω / 15 kV each
  - typical beam current: 1 A

  ⇒ **induced: 0.5 – 1 kV (3 – 7%)**

  → feed-forward compensation necessary to keep emittance low?
- Short, high current pulses during **bunch rotation** in SIS100: evaluation of **deactivation / impedance reduction** w.r.t. beam loading including **all** cavities
- **Longitudinal feedback** based on CW signal generation → currently not designed for pulsed operation

Challenge

Merging

- ...beam dynamics simulations during RF gymnastics, especially
  - barrier bucket pre-compression
  - bunch rotation (compression)
- ...with models of all FAIR RF systems
  - acceleration
  - barrier bucket
  - longitudinal feedback
  - bunch compression
- ...and solutions for deactivation
  - detuning
  - gap switches
  - ring core saturation

Research objectives:

Definition of technical measures to improve beam quality

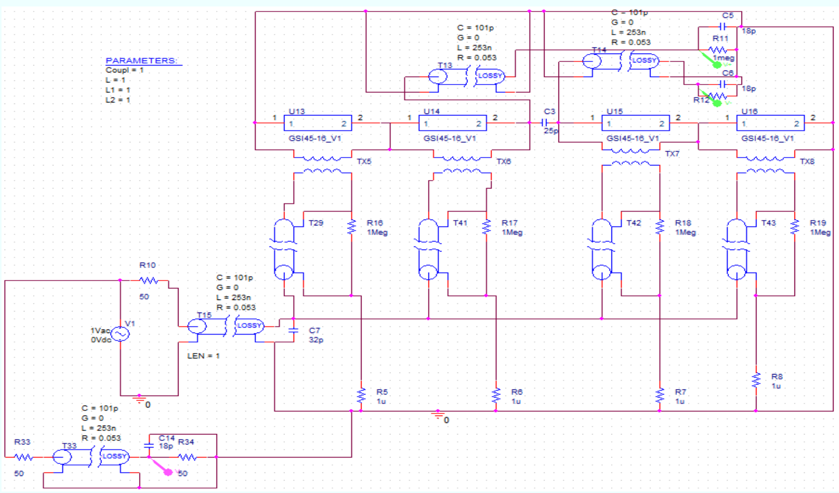
Beam-Loading in Pulsed, Broadband and Deactivated RF Systems

TECHNISCHE UNIVERSITÄT DARMSTADT

State of Research

RF System Models

- **PSpice**



- LTspice with rudimentary beam dynamic simulations
- realistic frequency responses based on measurements
- GSI infrastructure & know-how for further measurements

cavity as impedance

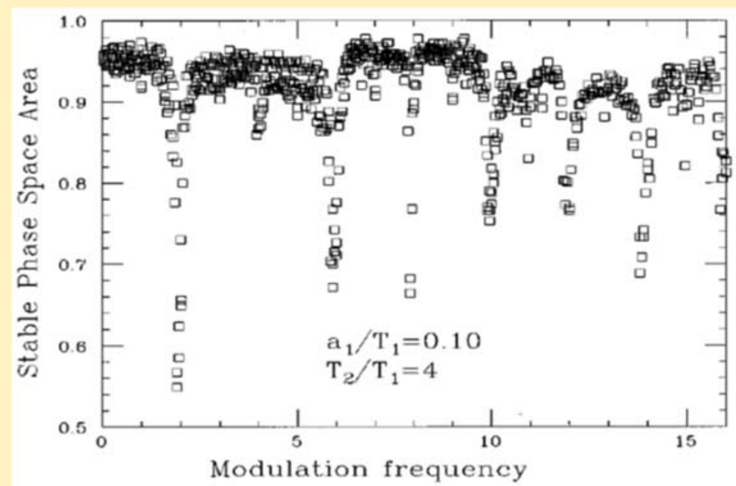
in barrier buckets

Beam Loading/Dynamics

- during standard operation
  (BMBF 2009, Prof. Adamy)
- influence of empty buckets
  (running cooperation project, Adamy)

- Group of Prof. Boine-Frankenheim
  e.g. Phys. Rev. STAB 13, 034202 (2010)

- open-loop excitation
  Lee, Ng: Phys. Rev. E 55, 5992 (1997)



Fault-tolerant distributed digital electronics for particle accelerators

TECHNISCHE UNIVERSITÄT DARMSTADT

particle accelerator driven nuclear reactors (e.g. MYRRHA)

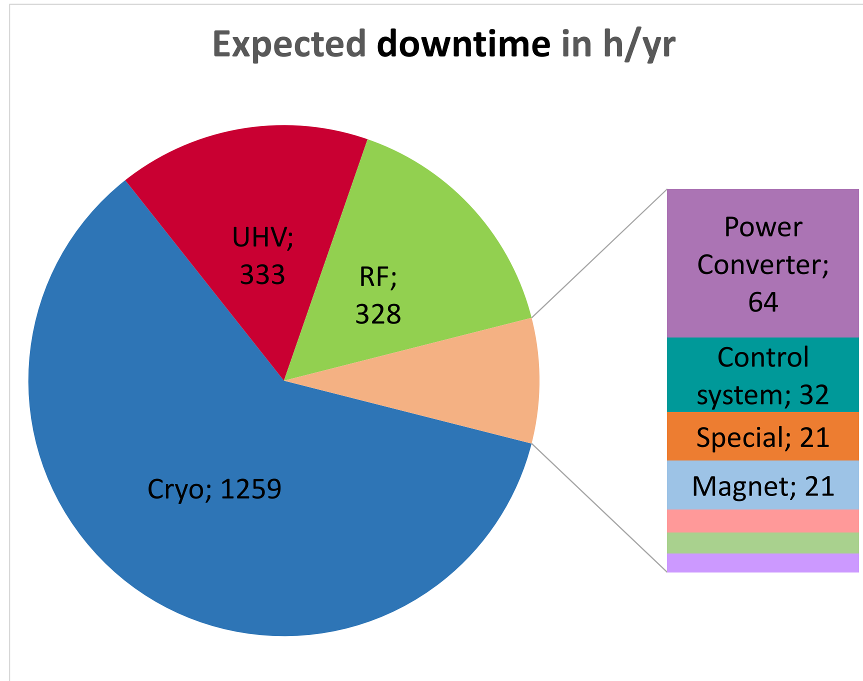
medical applications

x-ray sources

Raising of reliability & availability indispensable

machine protection systems (e.g. LHC)
- high power beams
- large stored energy

Estimated availability for SIS100 (FAIR): 65%



C. Omet et al.: SIS100 Availability And Machine Protection, Proceedings of IPAC 2016, Busan, Korea

Examples for complex distributed systems @ FAIR: LLRF, longitudinal feedback, closed orbit control, bunch to bucket transfer etc.

Fault-tolerant distributed digital electronics for particle accelerators

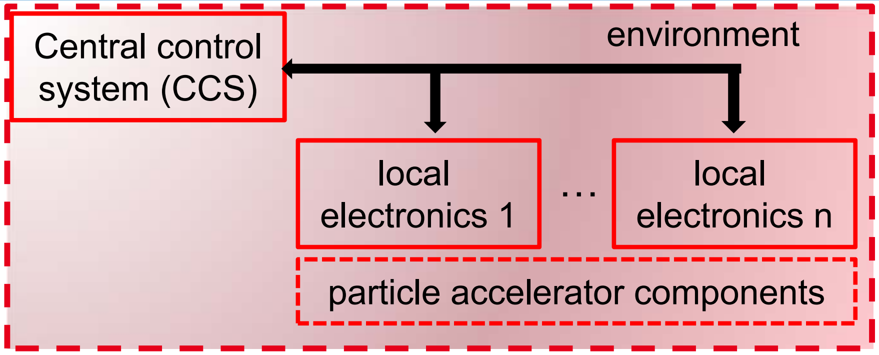
TECHNISCHE UNIVERSITÄT DARMSTADT

Specific to particle accelerators

- High requirements on real-time ability (e.g. protocols with error correction may be too slow for closed-loop control)
- EMC (high power vs. sensitive systems)
- Radiation (only relevant for some parts)

Objectives:

- Guidelines for the design of fault-tolerant distributed digital electronics for particle accelerators
- Prototype implementations for some components and systems



Possible failures:

- HW defects
- SW crashes (e.g. unexpected modes of operation)
- communication errors (e.g. EMC)
- operator errors

Possible measures:

- Component quality
- Fault-tolerance
  - Communication protocols
  - Redundancy → requires fault diagnosis (e.g. watchdogs)
  - Further system design aspects
    - e.g. deterministic behavior - not guaranteed by some modern SW techniques)
    - e.g. memory refresh, discarding defective memory cells