Design of a computerbased resonator-simulator for tests of RF control systems

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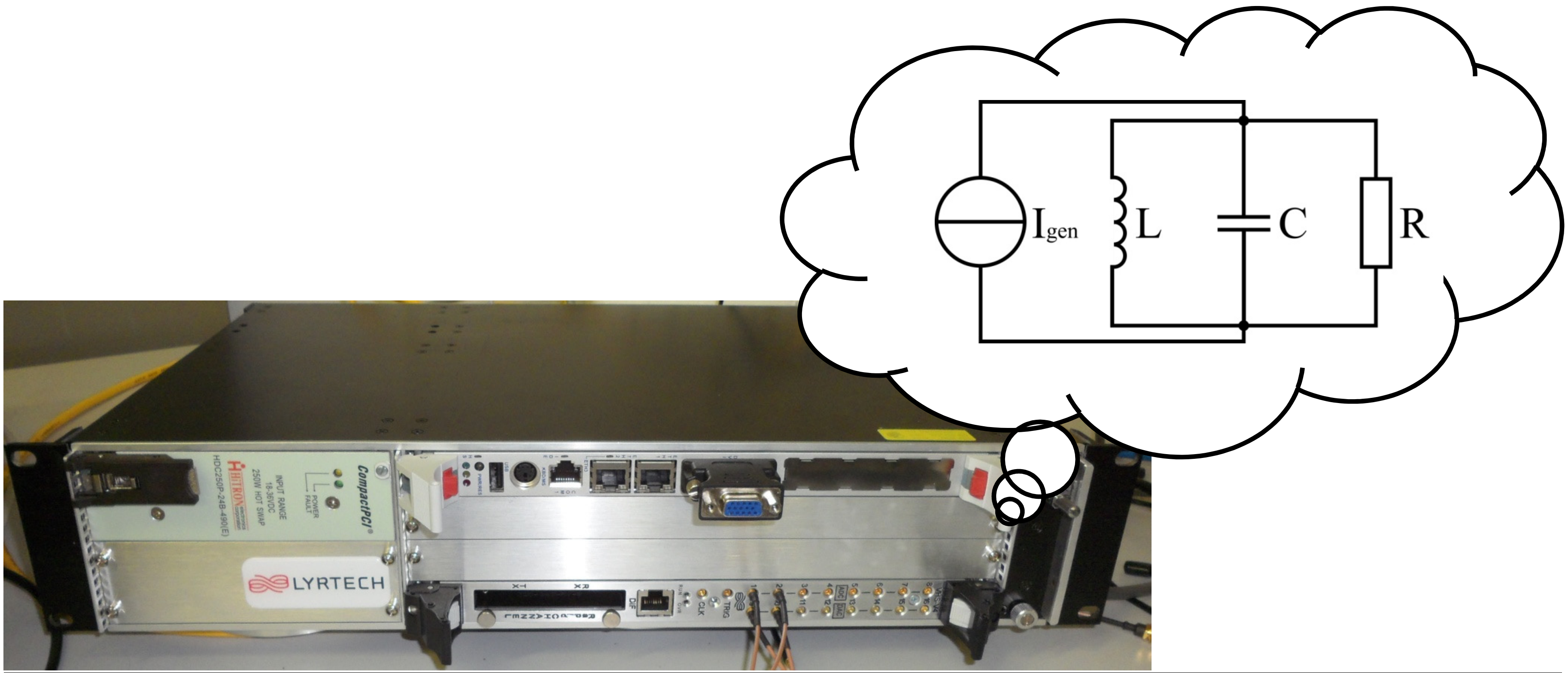

Outline

Introduction/Motivation

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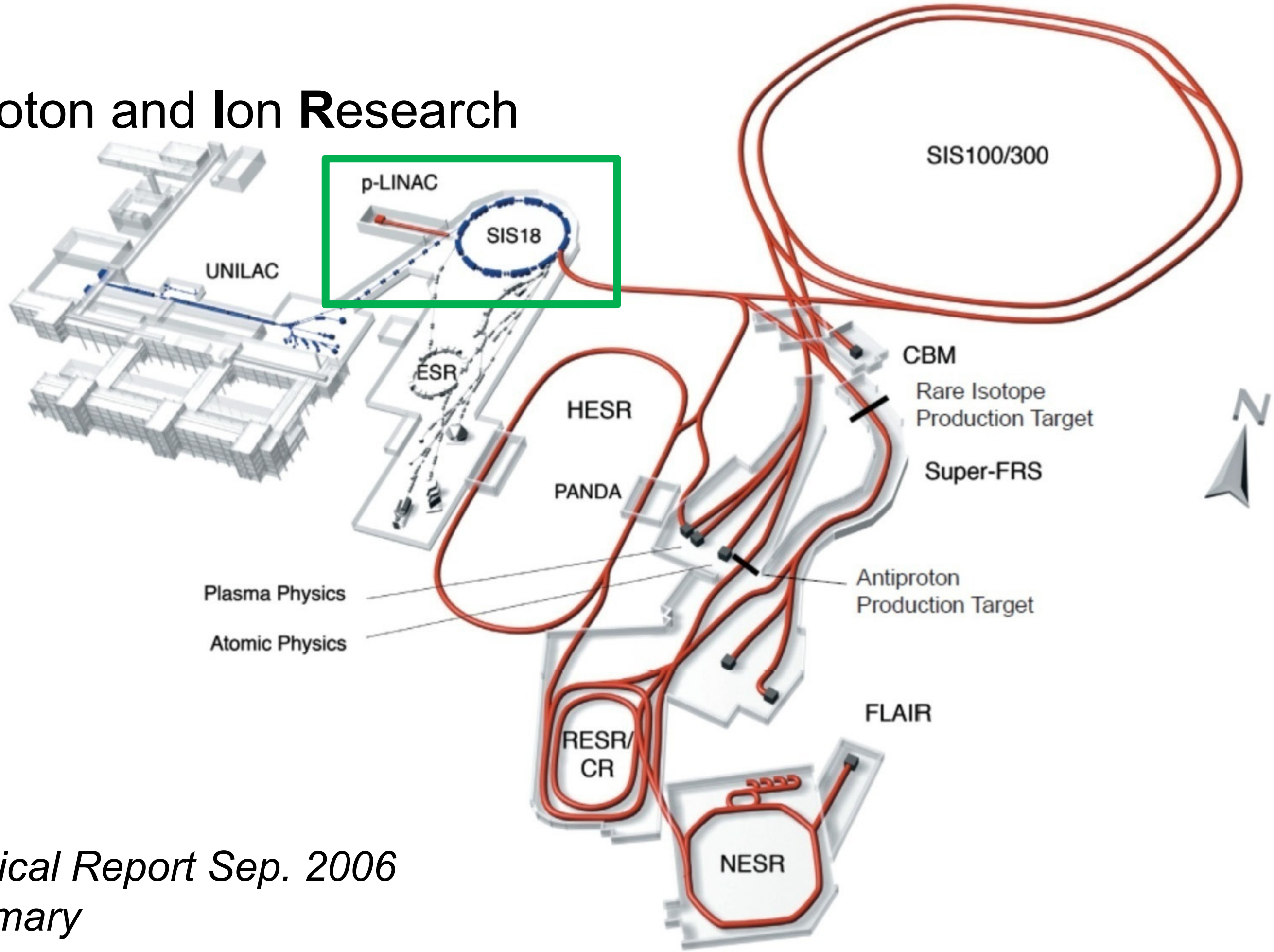
FAIR –

Facility for **A**ntiproton and **I**on **R**esearch



source:

GSI - Baseline Technical Report Sep. 2006
Executive Summary

Introduction/Motivation

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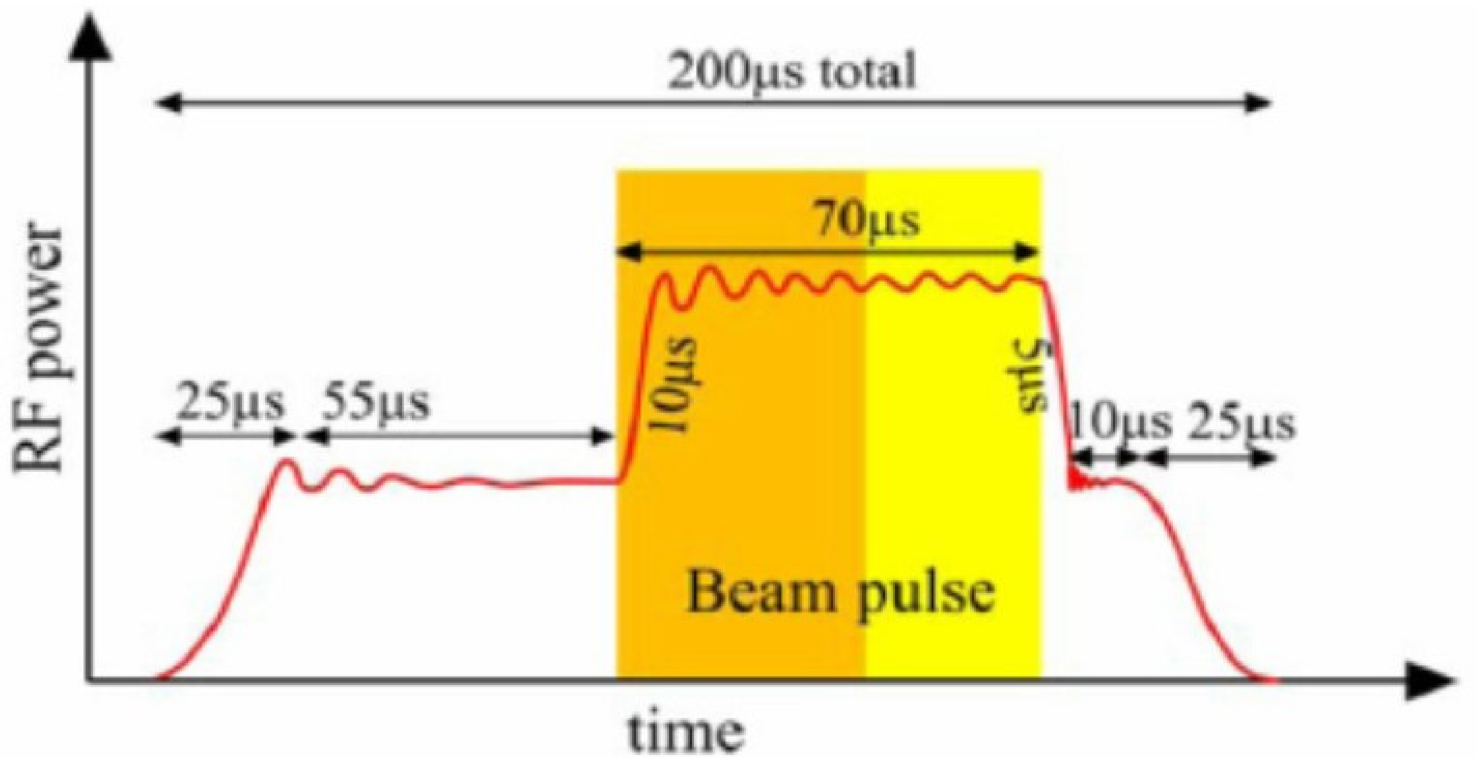
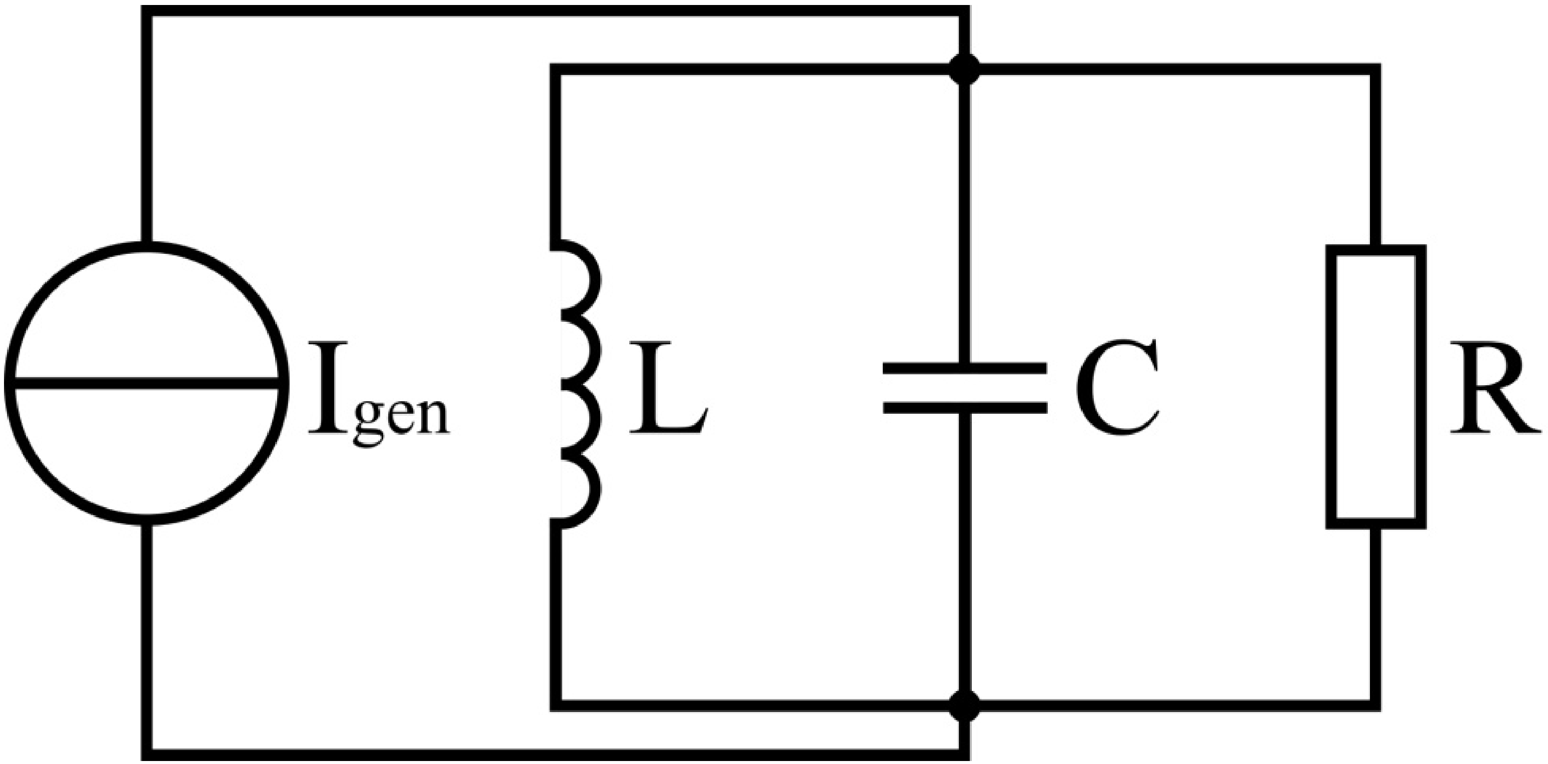
The input power of the p-LINAC resonator



source:
Technical Design Report, FAIR Proton-Linac. 2008.

the resonator model



the resonator model

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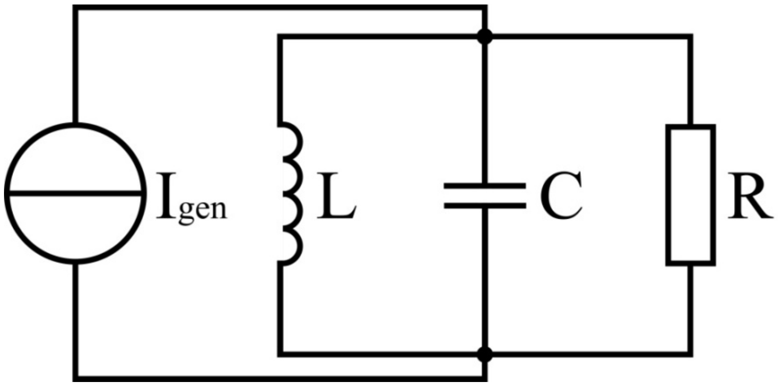
$$\ddot{U} + \frac{1}{RC}\dot{U} + \frac{1}{LC}U = \frac{1}{C}\dot{I}_{\text{gen}}$$



resonance frequency $\omega_r = \frac{1}{\sqrt{LC}}$

loaded quality factor $Q_L = \omega_r RC$

$$\Rightarrow \ddot{U} + \frac{\omega_r}{Q_L}\dot{U} + \omega_r^2 U = \frac{\omega_r}{Q_L}\dot{U}_{\text{gen}}$$

Das Resonatormodell

Ansatz:
$$U(t) = U_0 \cdot e^{i\omega_r t}$$
$$= U_0 \cdot e^{i(\omega+\Delta\omega)t} = \underline{U_0 \cdot e^{i\Delta\omega t}} \cdot e^{i\omega t}$$
$$=: \underline{(V + iW)} \cdot e^{i\omega t}$$

$$\ddot{U} + \frac{\omega_r}{Q_L}\dot{U} + \omega_r^2 U = \frac{\omega_r}{Q_L}\dot{U}_{\text{gen}}$$

+ approximations:

$$\ddot{V} \approx 0; \quad \ddot{W} \approx 0$$
$$\omega_{1/2} \ll \omega$$
$$\Delta\omega \ll \omega$$

+ time discretisation

$$\dot{V} \approx \frac{\Delta V}{\Delta t} = \frac{V(t+\Delta t) - V(t)}{\Delta t}$$

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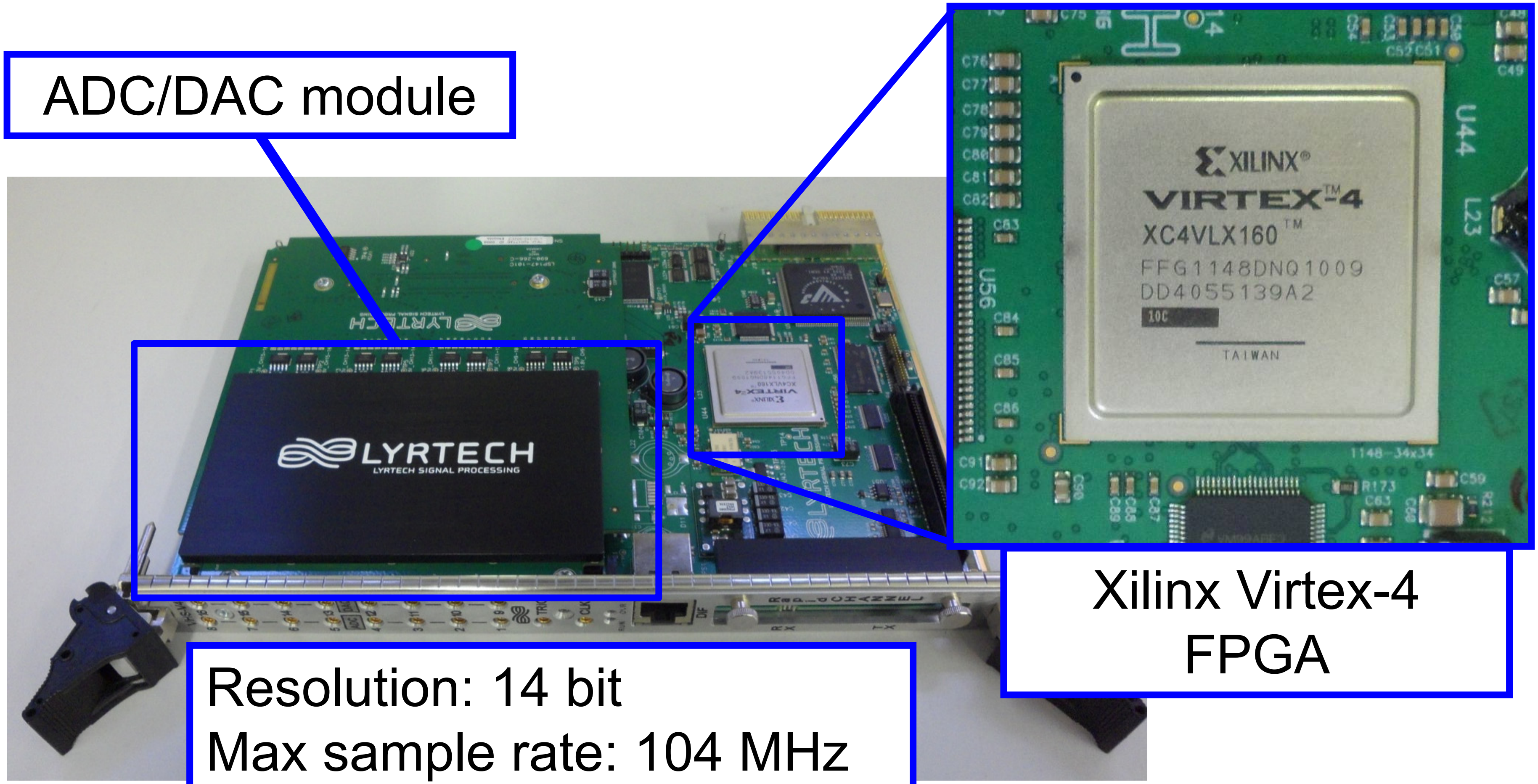
$$
\begin{aligned}
V(t+\Delta t) &= V(t) + \left[\omega_{1/2}\left(V_{\text{gen}} - V(t)\right) - \Delta\omega W\right] \cdot \Delta t \\
W(t+\Delta t) &= W(t) + \left[\omega_{1/2}\left(W_{\text{gen}} - W(t)\right) + \Delta\omega V\right] \cdot \Delta t
\end{aligned}
$$

Used hardware



Simulation of normal conducting resonators

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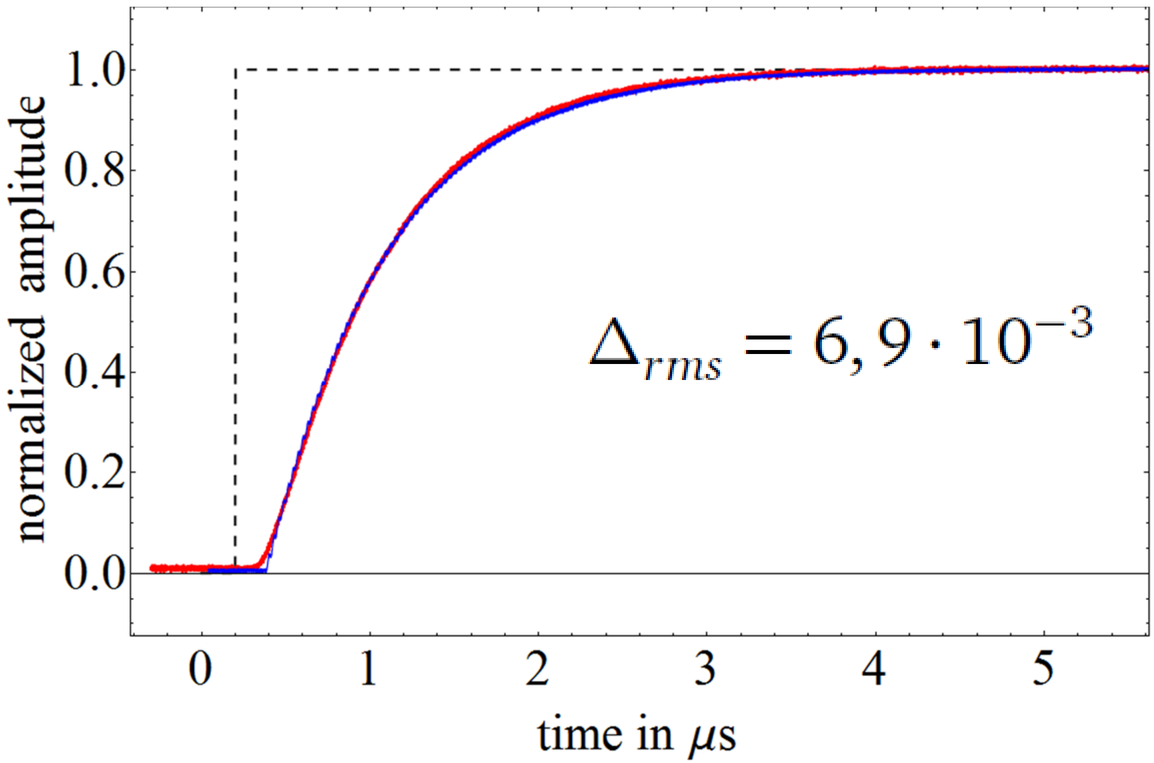
Reference cavity

$$f_{\text{res}} = (2994,1 \pm 0,475)\ \text{MHz}$$

$$\Delta f_{FWHM} = (475 \pm 20)\ \text{kHz}$$



Simulation of normal conducting resonators

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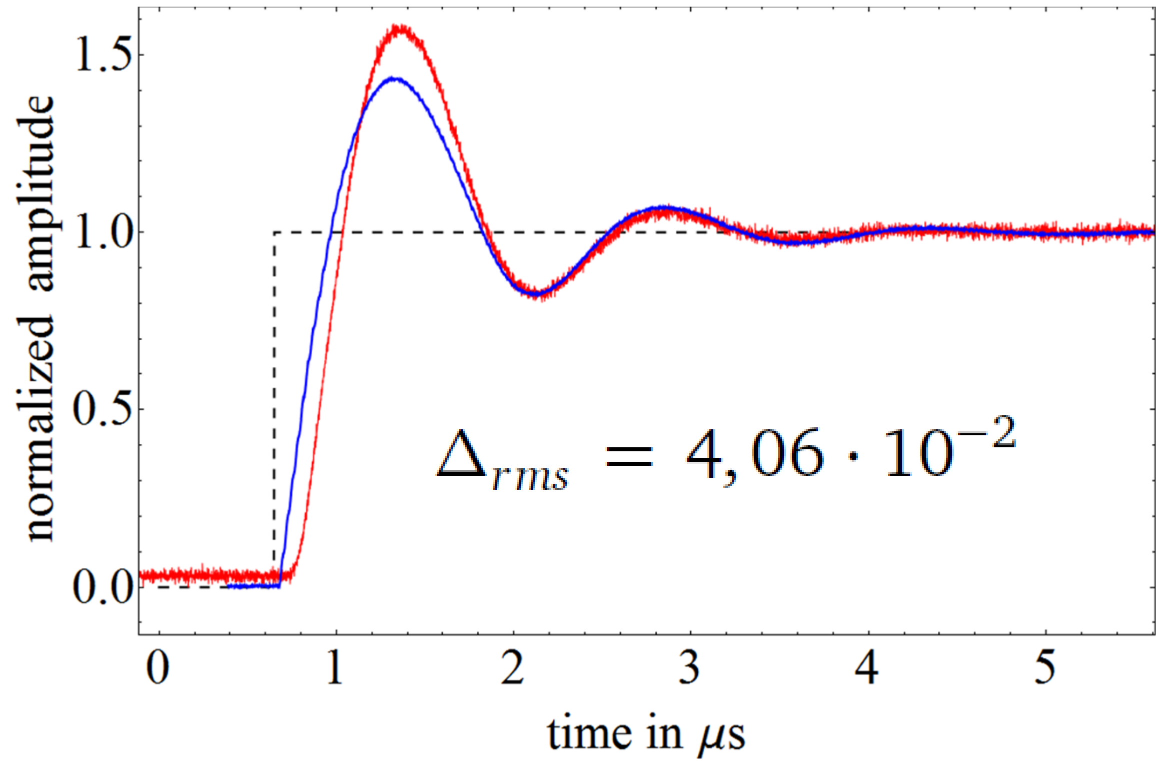
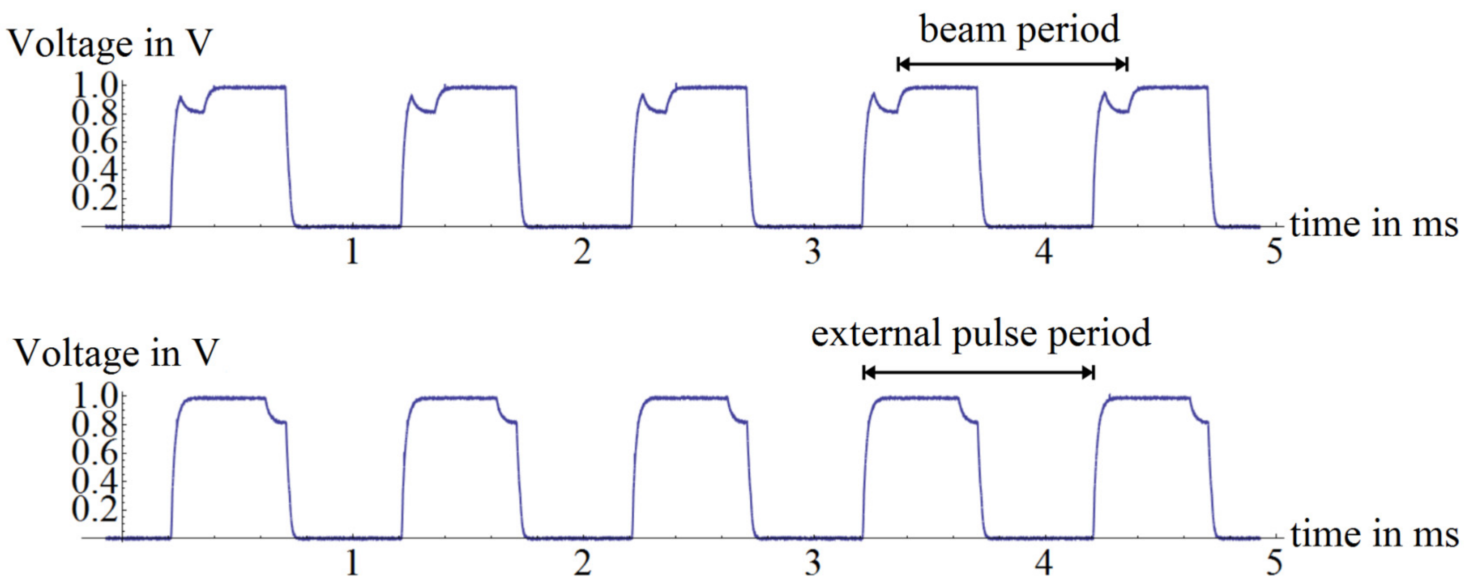
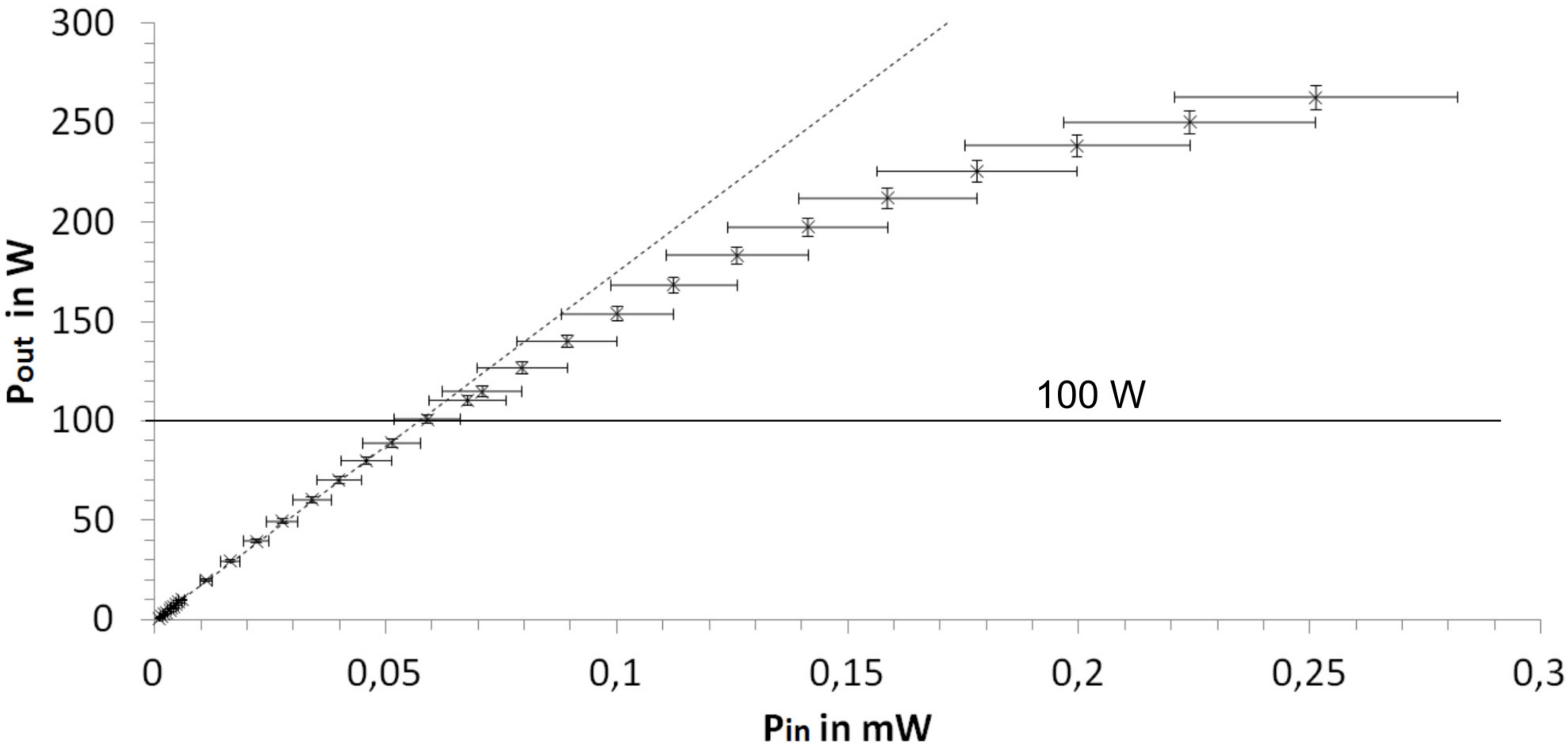


Beam Loading



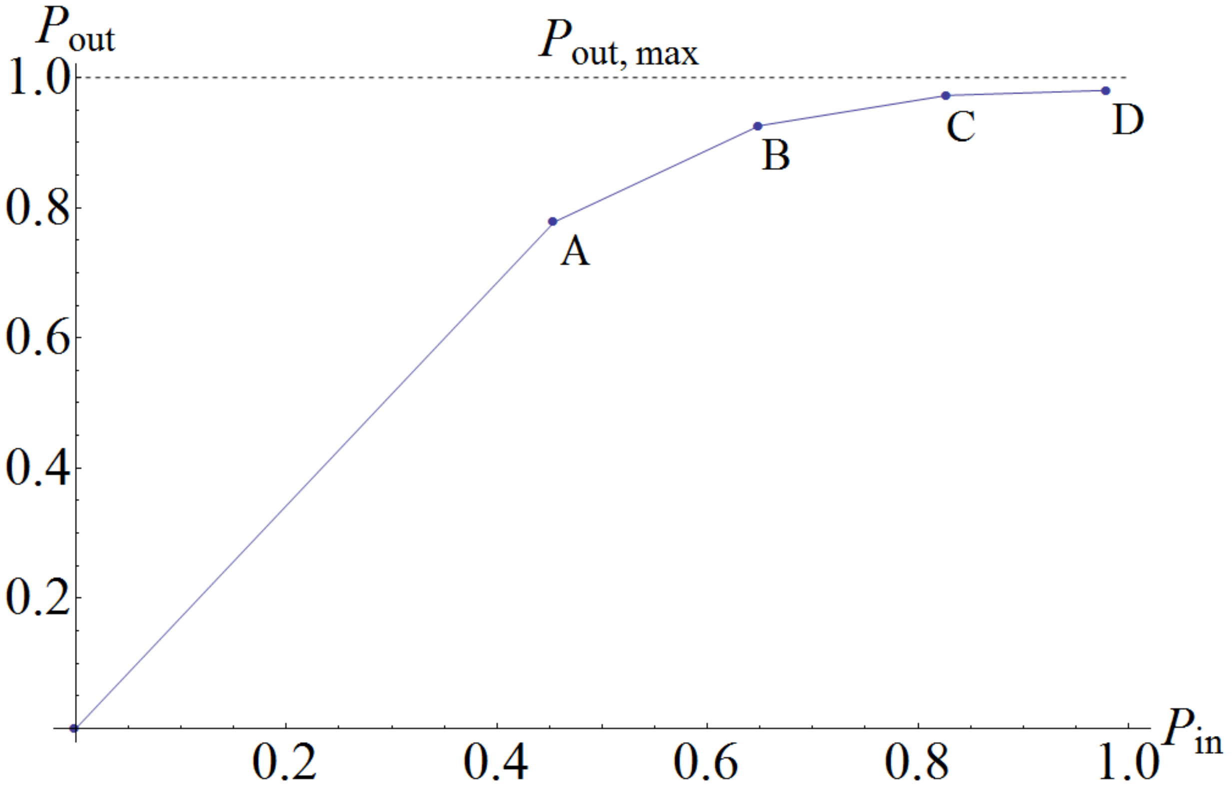
Amplifier saturation

Output characteristics of a traveling-wave tube



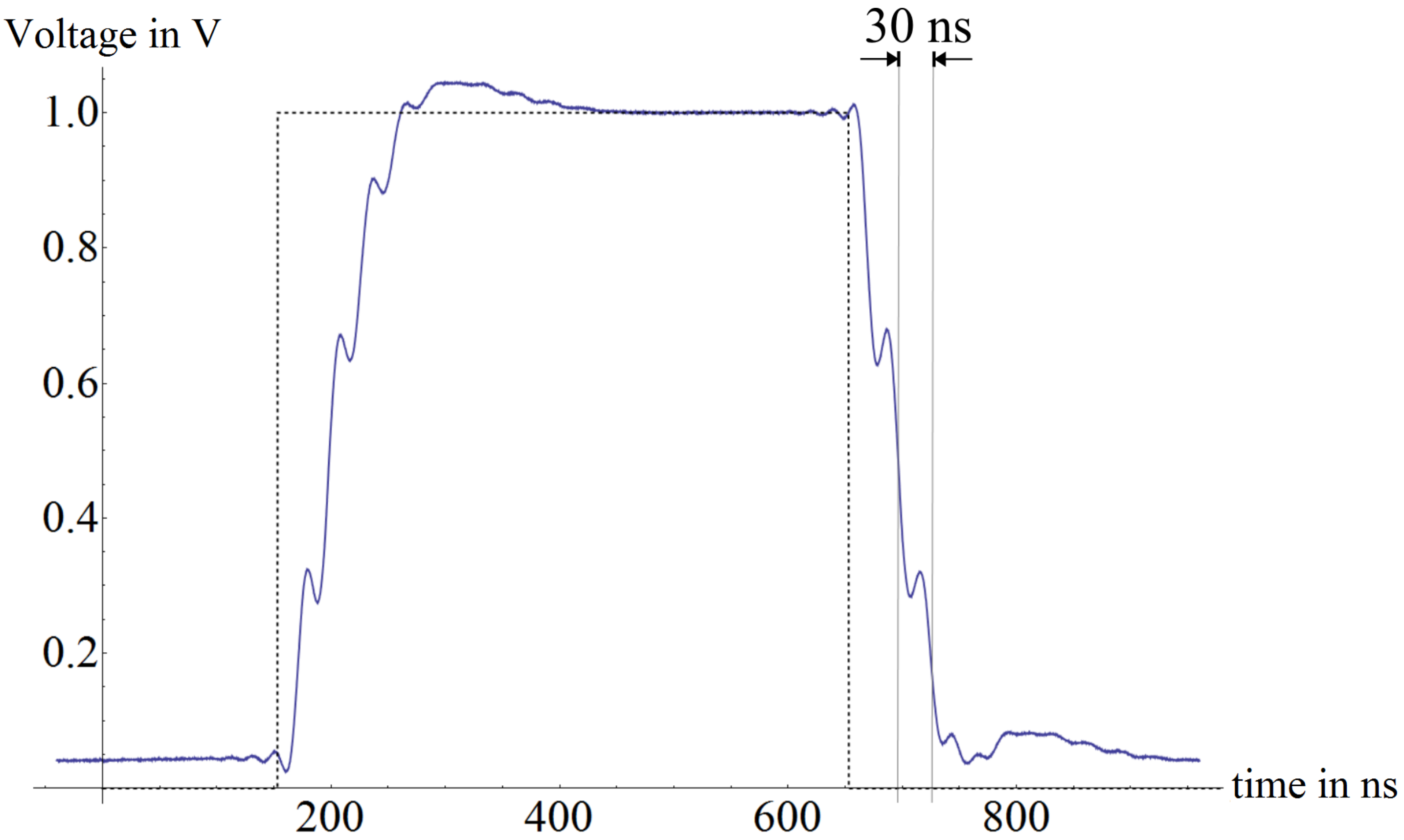
Amplifier saturation

Output characteristics of the simulator
4-point approximation (example)

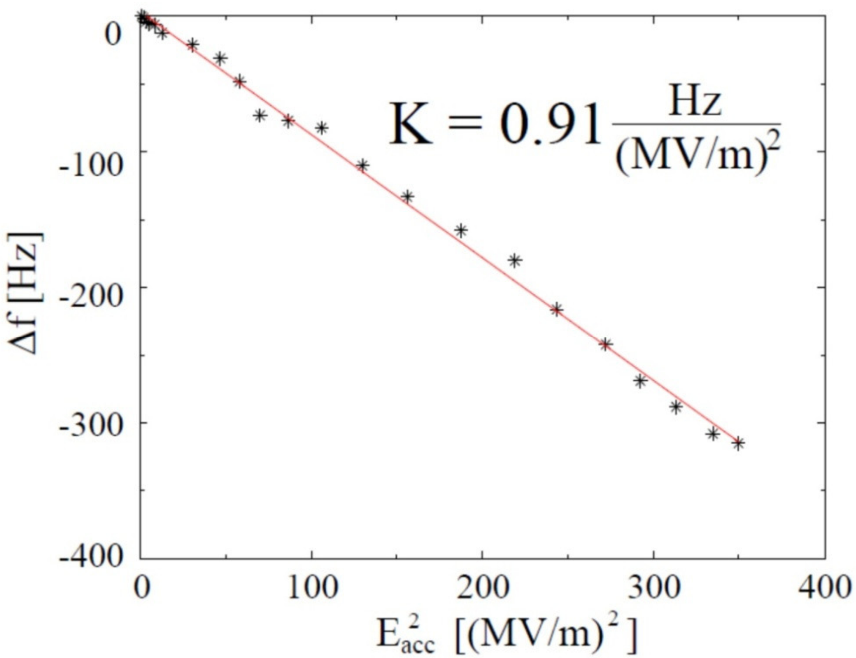


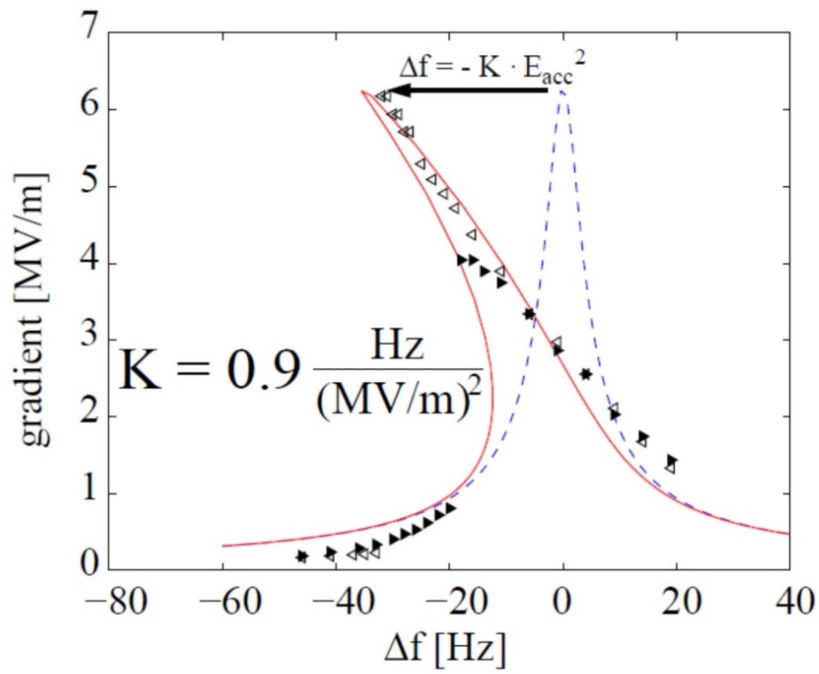
Timing constraints

Simulated bandwidth of 1 MHz



Simulation of superconducting resonators





$$\Delta\omega_{LFD} = -2\pi \cdot K \cdot E_{acc}^2$$

source:

SCHILCHER, T.: *Vector Sum Control of Pulsed Accelerating Fields in Lorentz Force Detuned Superconductiong Cavities*. Doktorarbeit, Universität Hamburg, 1998.

Simulation of superconducting resonators

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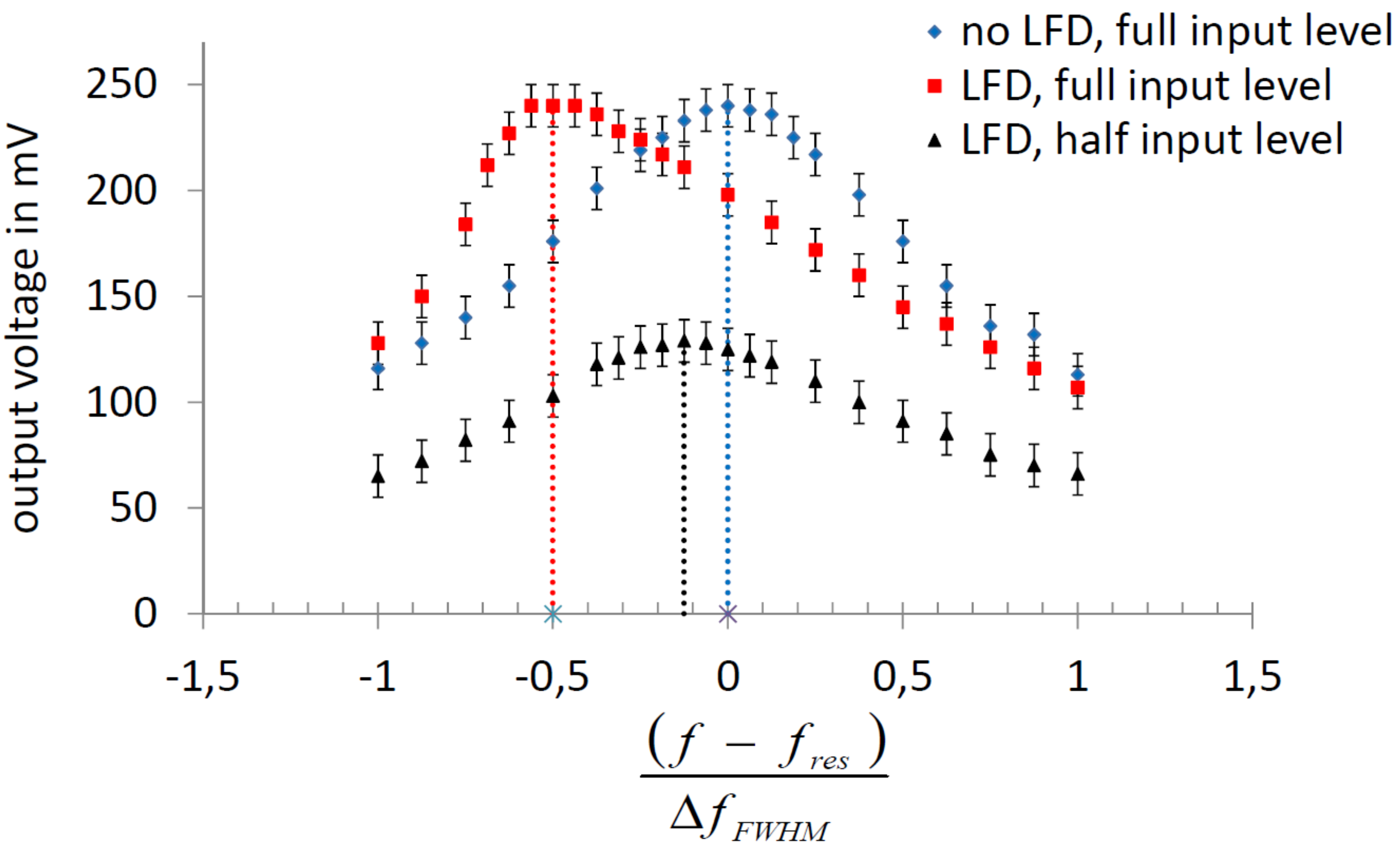
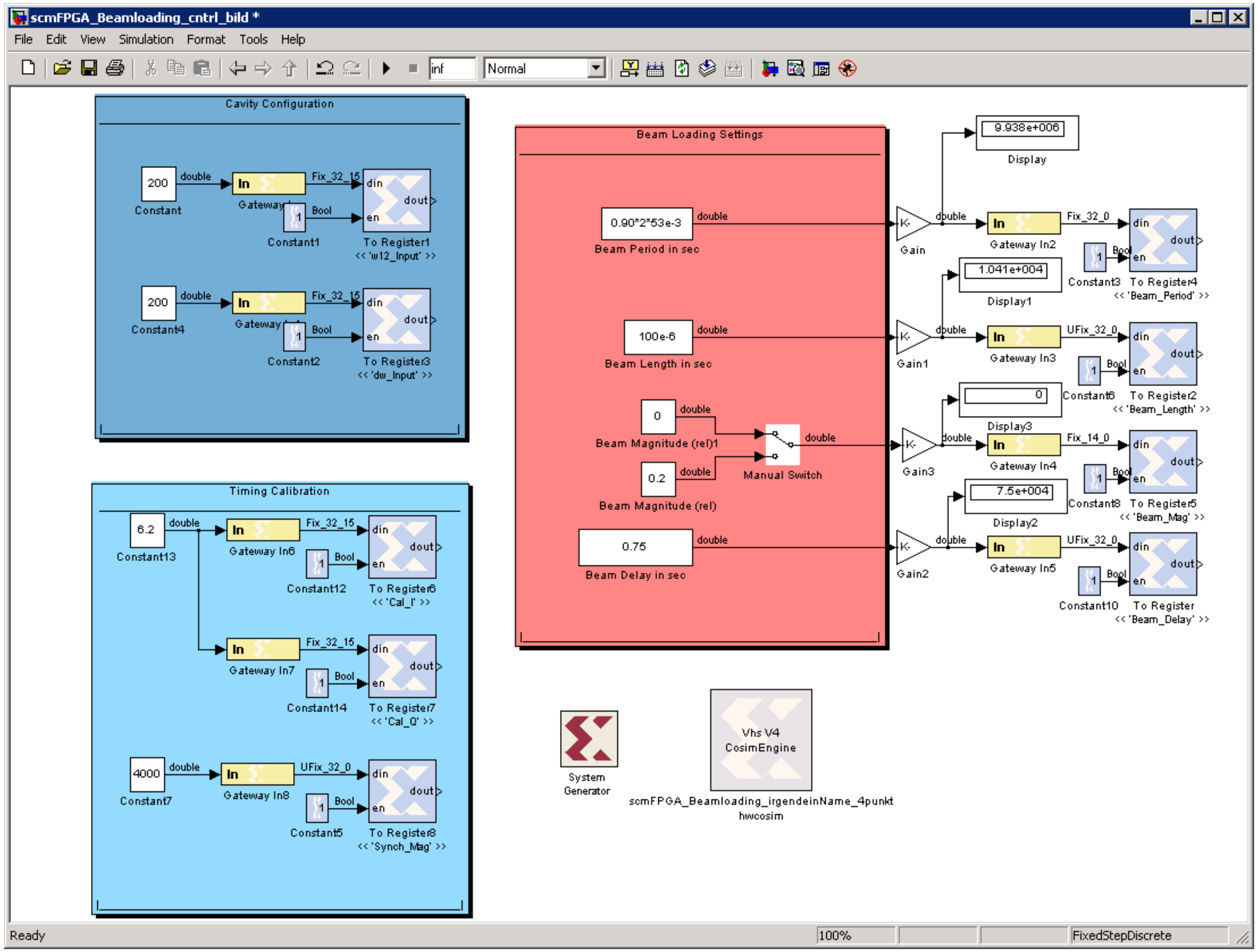
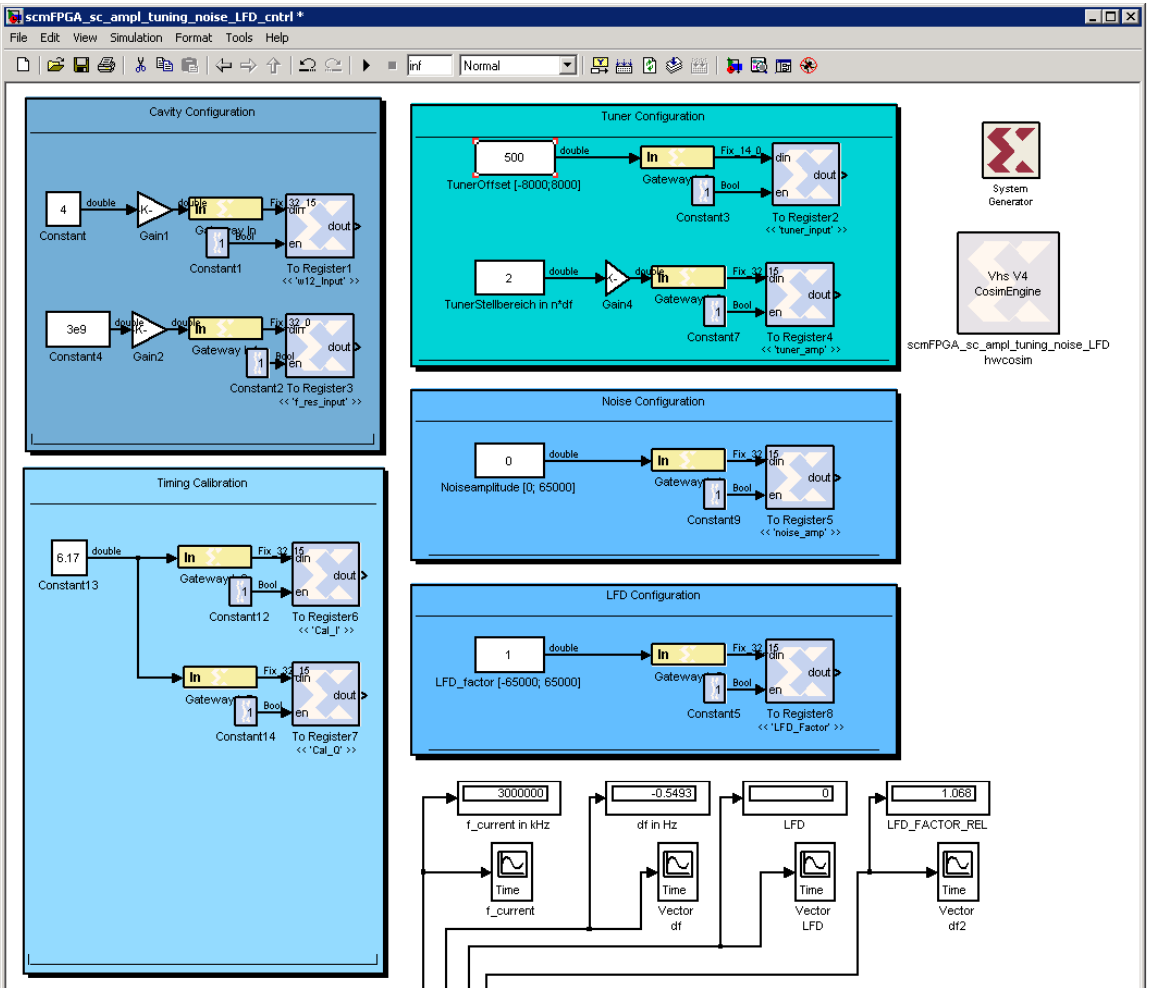


GUI (normal conducting mode)

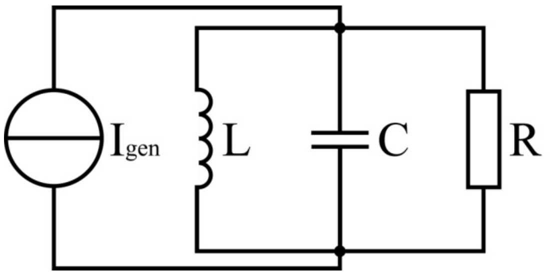


GUI (superconducting mode)



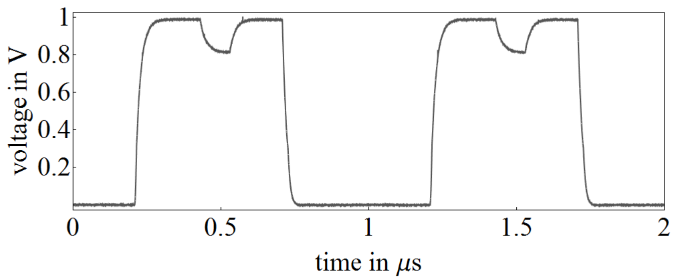
Summary

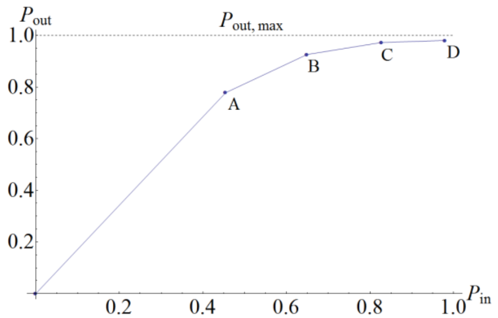
The simulator is based on a simple parallel shunt circuit

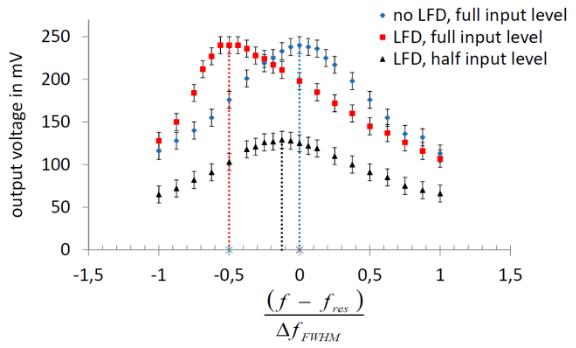


Normal conducting cavities:

- Beam loading
- Amplifier saturation







superconducting cavities:

- shifting the res. frequency
- Lorentz-force detuning

Thanks!

Thank you
for your attention!