Friday Seminar: European Spallation Source

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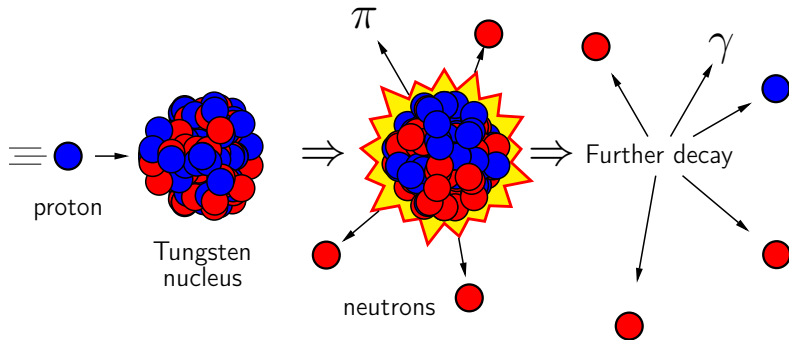
Introduction Viedo
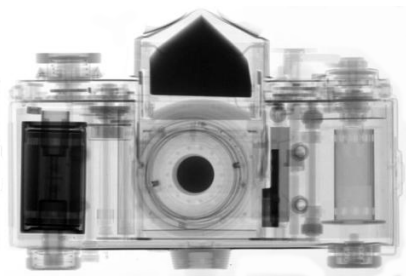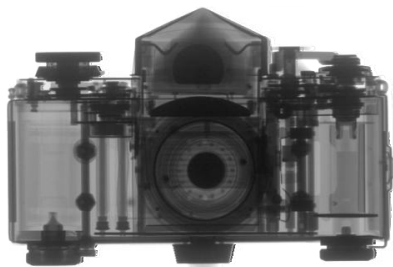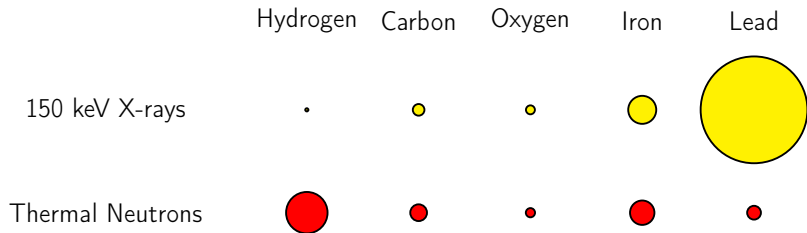
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https://www.youtube.com/watch?v=xJU1FxZ8oxA
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Overview

- Spallation - what is it, why and how
- What are the control problems?
- Some pictures

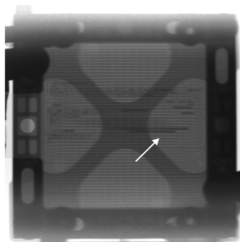# What is spallation?

What are neutrons good for? (1/3)

(a) X-Rays
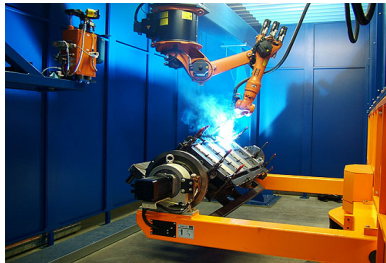
(b) Neutrons

What are neutrons good for? (2/3)
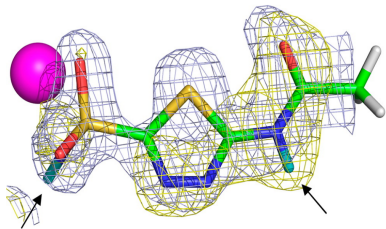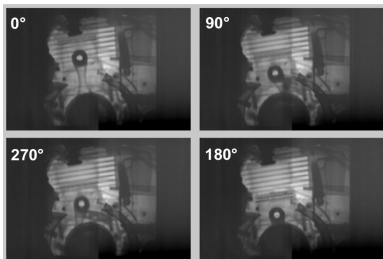

(a) Life Science

(b) Fuel Cells
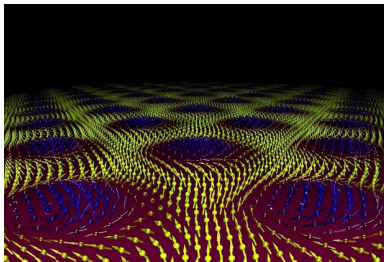

(c) Solar Cells

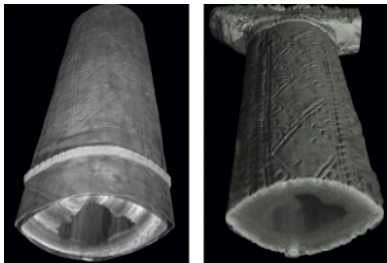(d) Engineering Materials
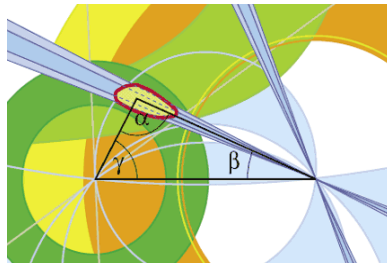
What are neutrons good for? (3/3)

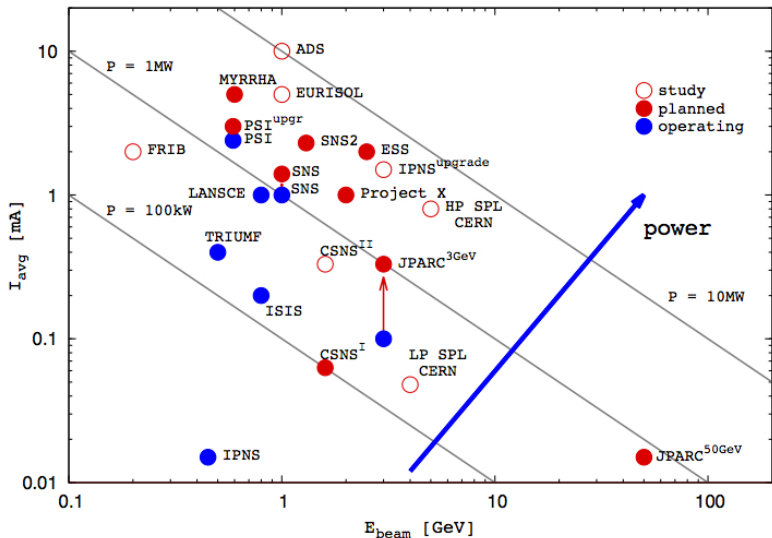(a) Non-destructive inspection

(b) Magnetic Phenomena

(c) Archeology

(d) Quark Mixing Matrix Studies

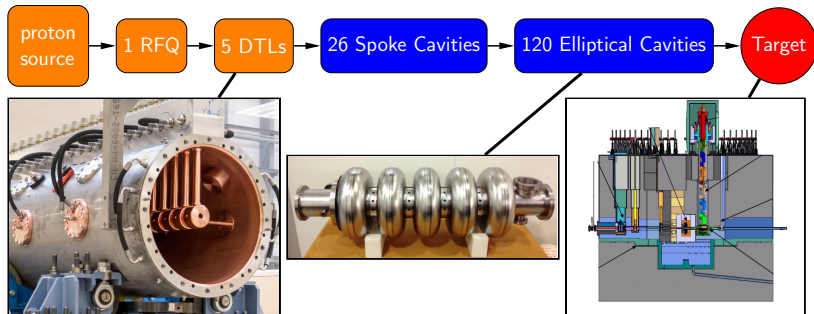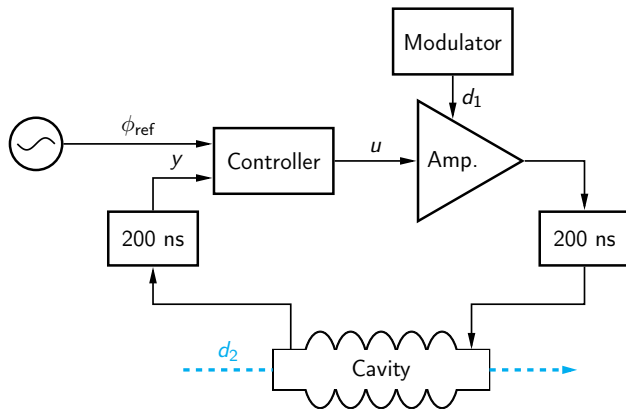# The highest power accelerator in the world

The accelerator

Important that electric fields have correct phase and amplitude for proper acceleration and focusing of particle bunches.
A control problem!

The control loop

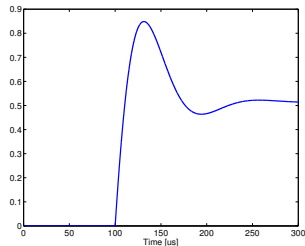Neglecting amplifier nonlinearity and dynamics gives:

$$P(s) = \frac{K_p e^{-i\gamma} e^{-Ls}}{s + \omega_{1/2} - i\Delta\omega}$$

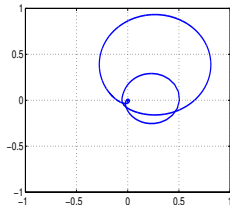FOTD system with complex coefficients!

FOTD system with complex coefficients

$$\frac{K_p e^{-i\gamma} e^{-Ls}}{s + \omega_{1/2} - i\Delta\omega}$$

Step Response

Nyquist curve

Frequency response will not be symmetric around zero, Nyquist's theorem still applies.

$e^{-i\gamma}$ needs to be compensated, but otherwise quite similar to standard FOTD.

Warning: `lsim`, `nyquist` and `hinfnorm` does not work properly for systems with complex coefficients.

Have *you* seen this in a feedback context before?

ESS in numbers

- 500 m long
- 20 experiments
- 125 MW power to beam (pulsed)
- 2B€ cost of design and construction
- 95% up-time
- 96% of speed of light (proton speed)
- 0.5 ps required accuracy of field control
- 100 MHz sample frequency (LLRF system)
- 2025 in full operation

What is my contribution to ESS?

- ▶ Simulation, control design, analysis
  - ▶ Control of "complex" FOTD system
  - ▶ Iterative Learning Control
  - ▶ Linearization of amplifier (possibly inner loop)
  - ▶ Controlling mechanical deformation of cavity
  - ▶ Control architecture
- ▶ Discussing component specifications
- ▶ Control performance should not be measured in amplitude and phase errors
- ▶ Feedforward from beam current measurement
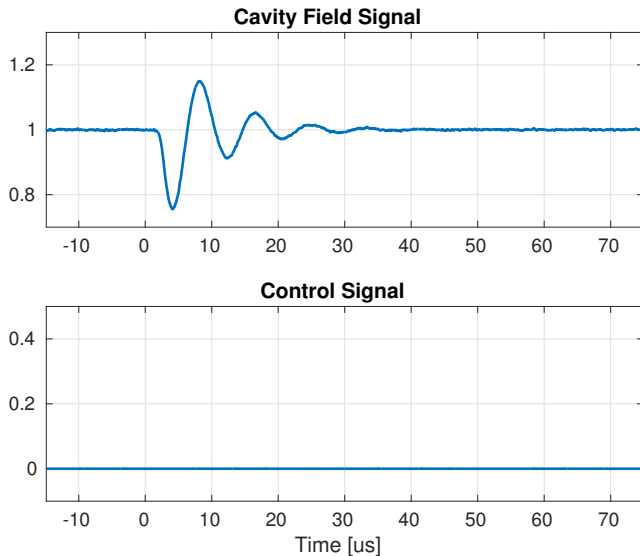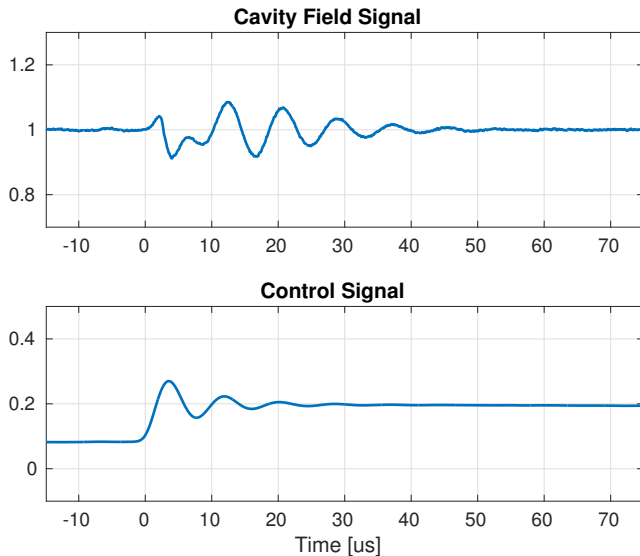- ▶ Enlight people about the teachings of control theory
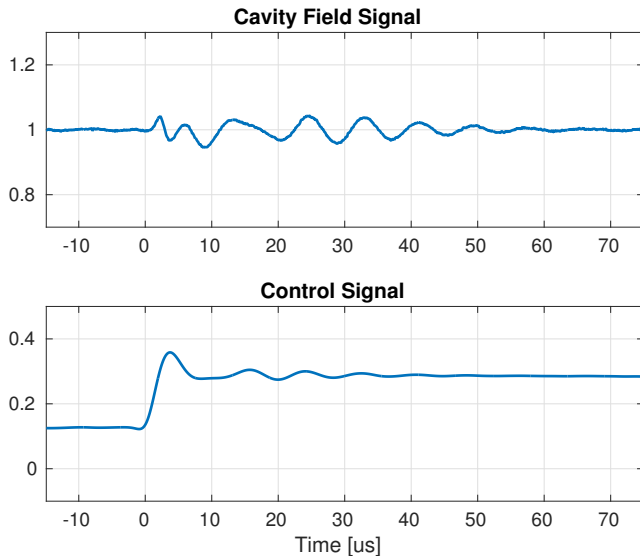
Test stand in M-building
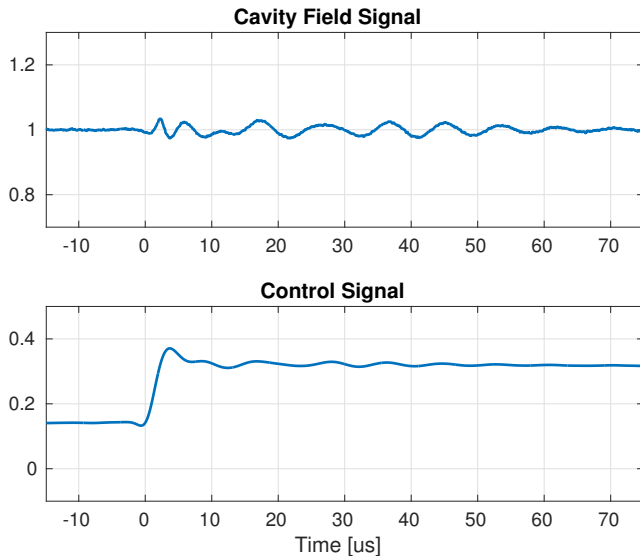
Test setup in E-building
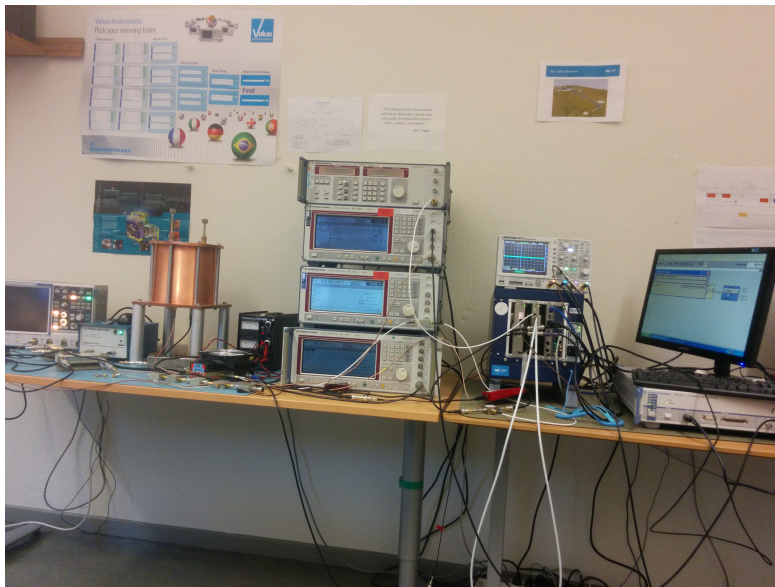
Iterative Learning of beam loading

Iterative Learning of beam loading

Iterative Learning of beam loading

Iterative Learning of beam loading

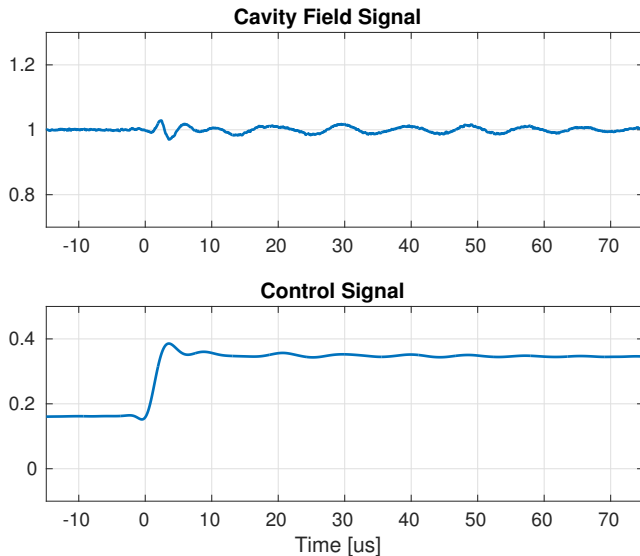# Iterative Learning of beam loading
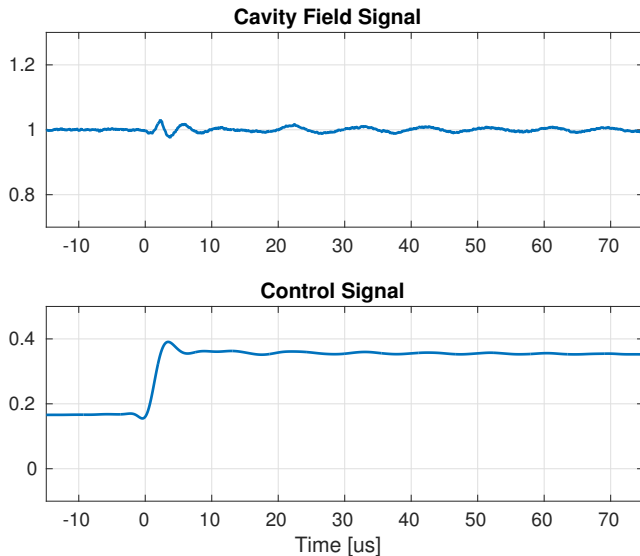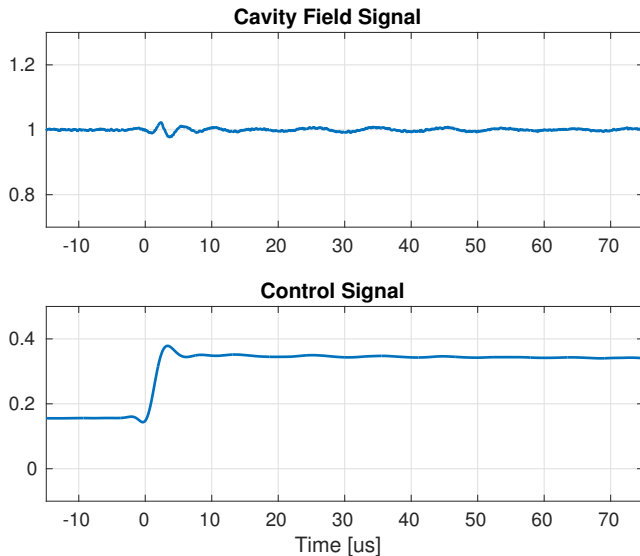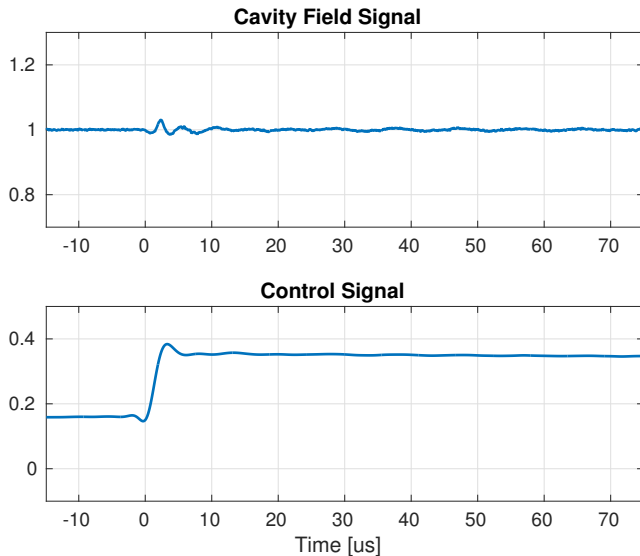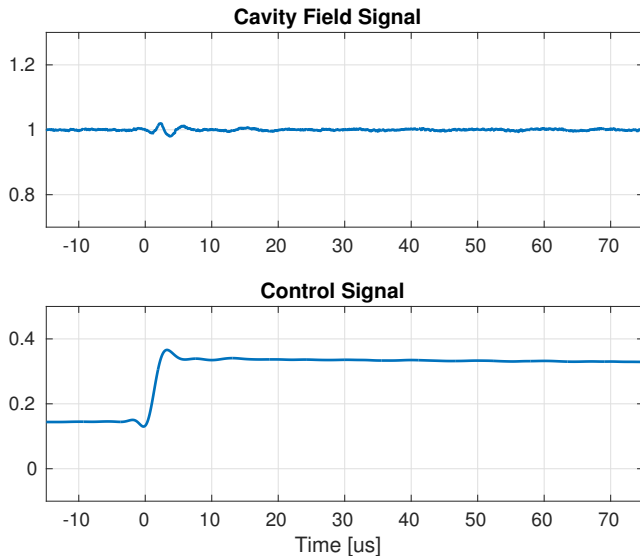
Iterative Learning of beam loading
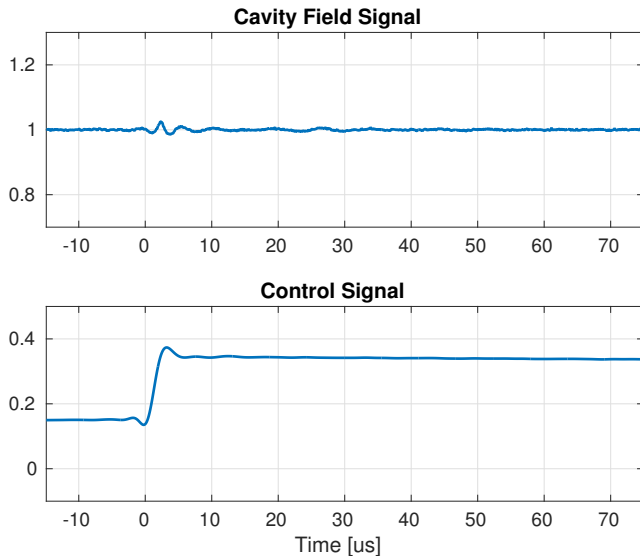
Iterative Learning of beam loading

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Iterative Learning of beam loading

Thank you for listening!

More information

Progress at construction site:
www.europeanspallationsource.se/site-weekly-updates

Technical Design Report :
www.europeanspallationsource.se/accelerator-documents

Info on neutron science:
www.psi.ch/niag/what-is-neutron-imaging

Systems Engineering - System Breakdown

- Conventional Facilities (Buildings)
- Accelerator
  - RF
  - Cryo
  - Vacuum
  - Magnets
- Target
- Experiments
- (Integrated Control System)