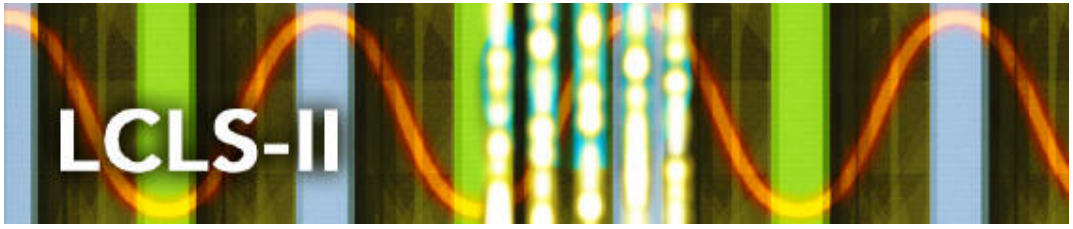
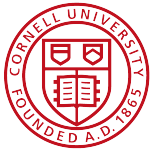


Cryomodule-on-Chip Simulation Engine (CMOC)

C. Serrano, L. Doolittle & V. Vytla



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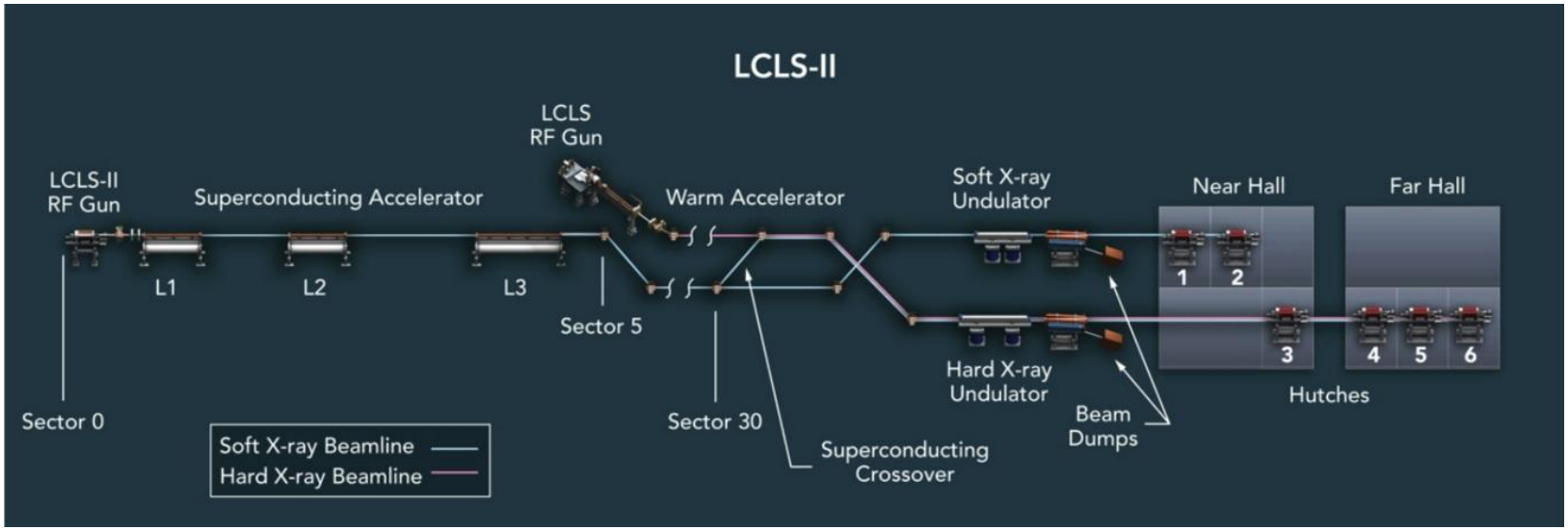
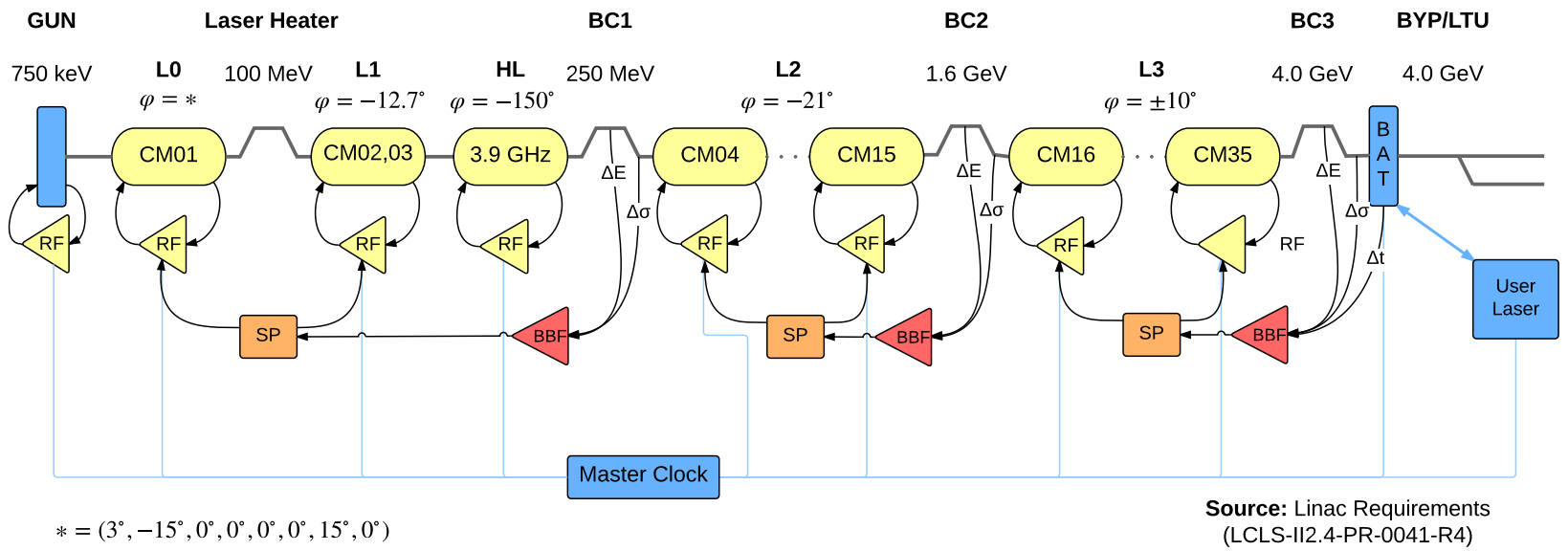
Motivation

LCLS-II

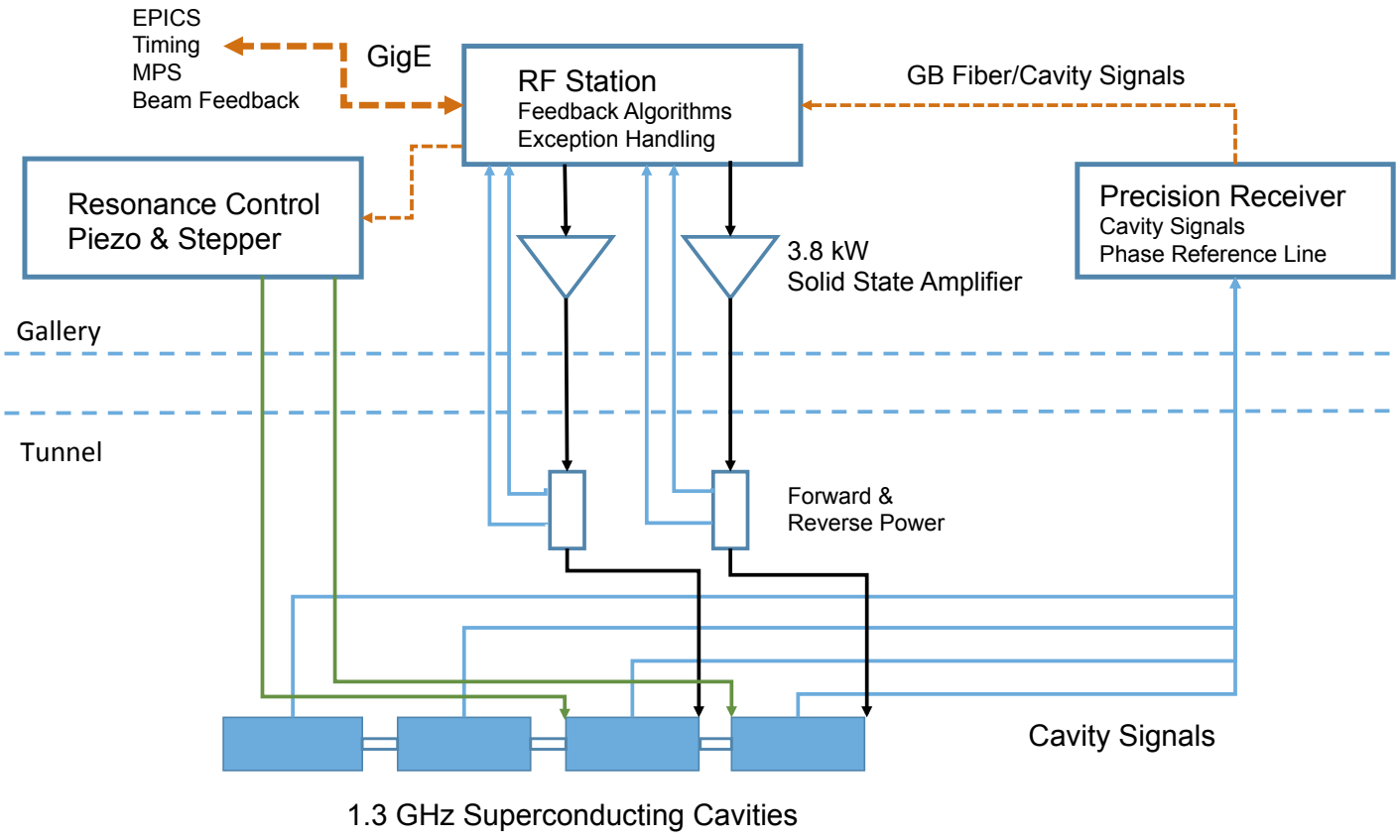

LCLS-II
LCLS
RF Gun
LCLS-II
RF Gun
Superconducting Accelerator
Warm Accelerator
Soft X-ray
Undulator
Near Hall
Far Hall
L1
L2
L3
Sector 5
1
2
3
4
5
6
Hard X-ray
Undulator
Hutches
Sector 0
Sector 30
Beam
Dumps
Superconducting
Crossover
Soft X-ray Beamline
Hard X-ray Beamline

LCLS-II Feedback



Source: Linac Requirements (LCLS-II2.4-PR-0041-R4)

LCLS-II LLRF System Architecture



LLRF Modeling Flow

Analytical Studies

Determine feedback equations and apply control theory to analyze stability.

Software Models

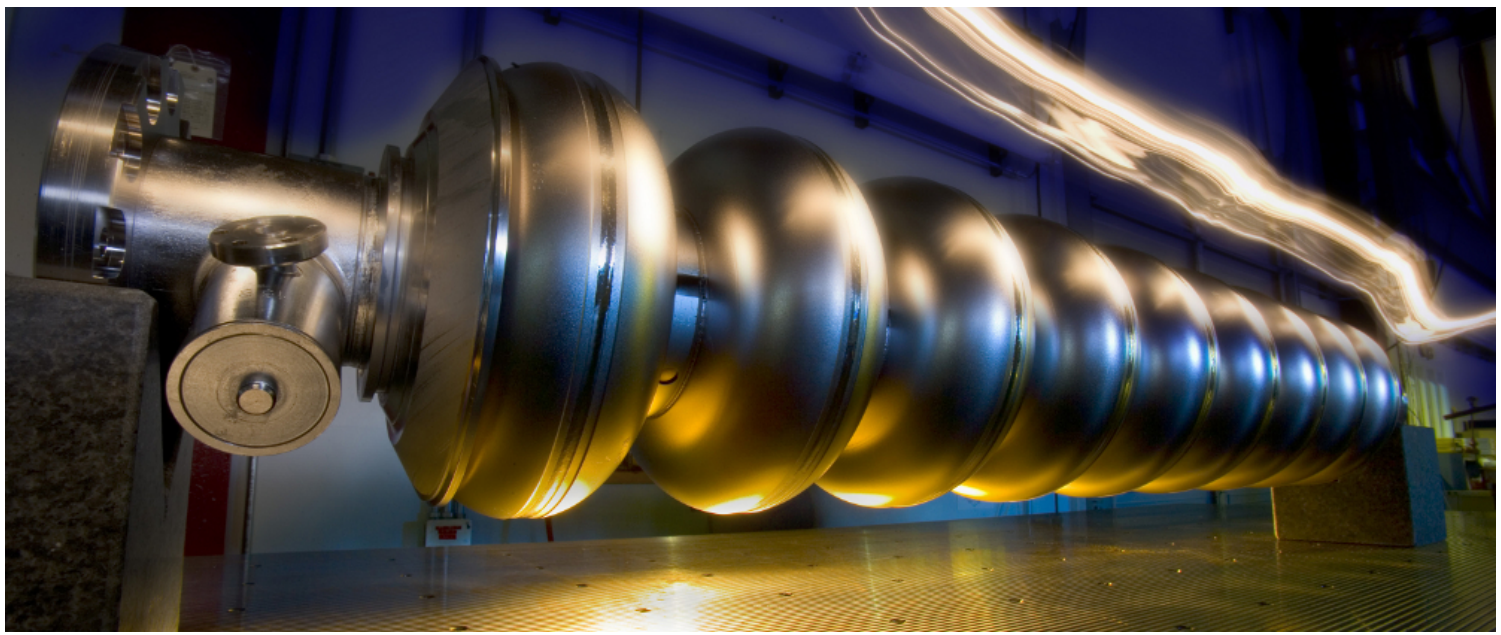
Discretize feedback equations and run feedback numerical simulations to analyze dynamics and behavior.

FPGA Models

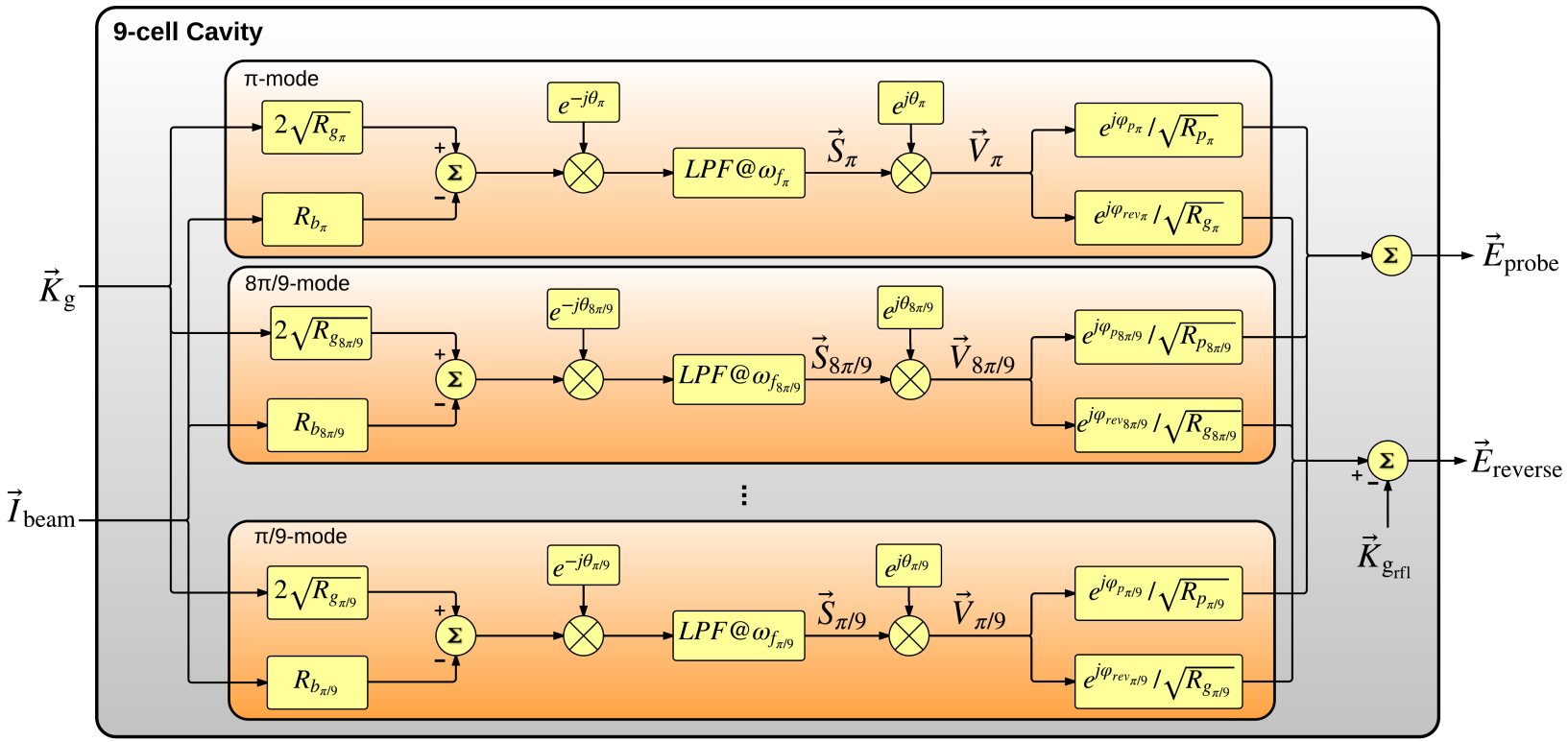
Implement state-space model inside FPGA to exercise controller HDL implementation.

Physics

LCLS-II Cavities



Cavity model: 9-cell Cavity ($\sum \vec{V}_\mu$)

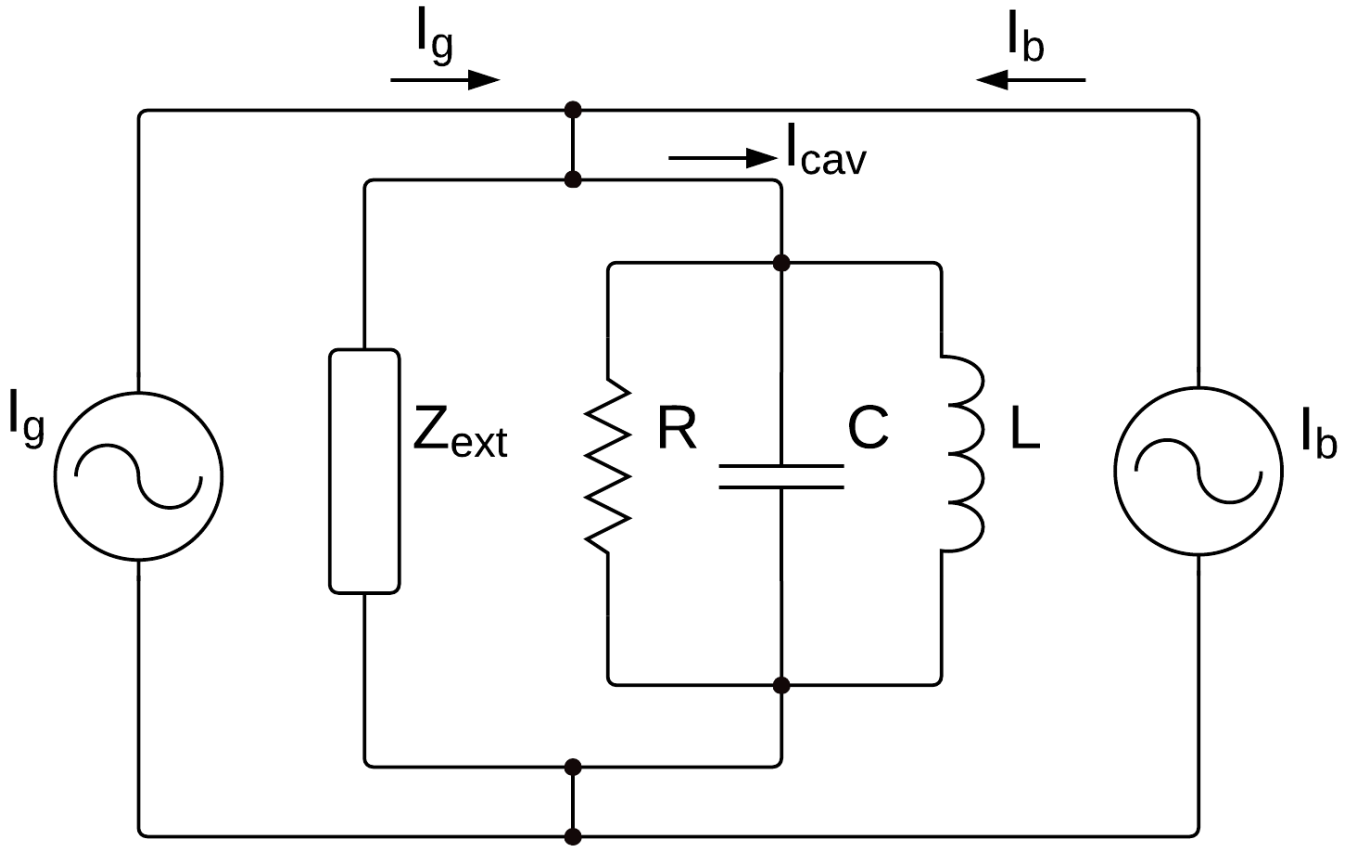


$$\omega_{f_\mu} = \text{mode } \mu \text{ bandwidth}$$

$$R_{g_\mu} = Q_{g_\mu}(R/Q)_\mu$$
$$R_{b_\mu} = Q_{L_\mu}(R/Q)_\mu$$
$$R_{p_\mu} = Q_{p_\mu}(R/Q)_\mu$$

Coupling impedance to drive, beam and probe ports

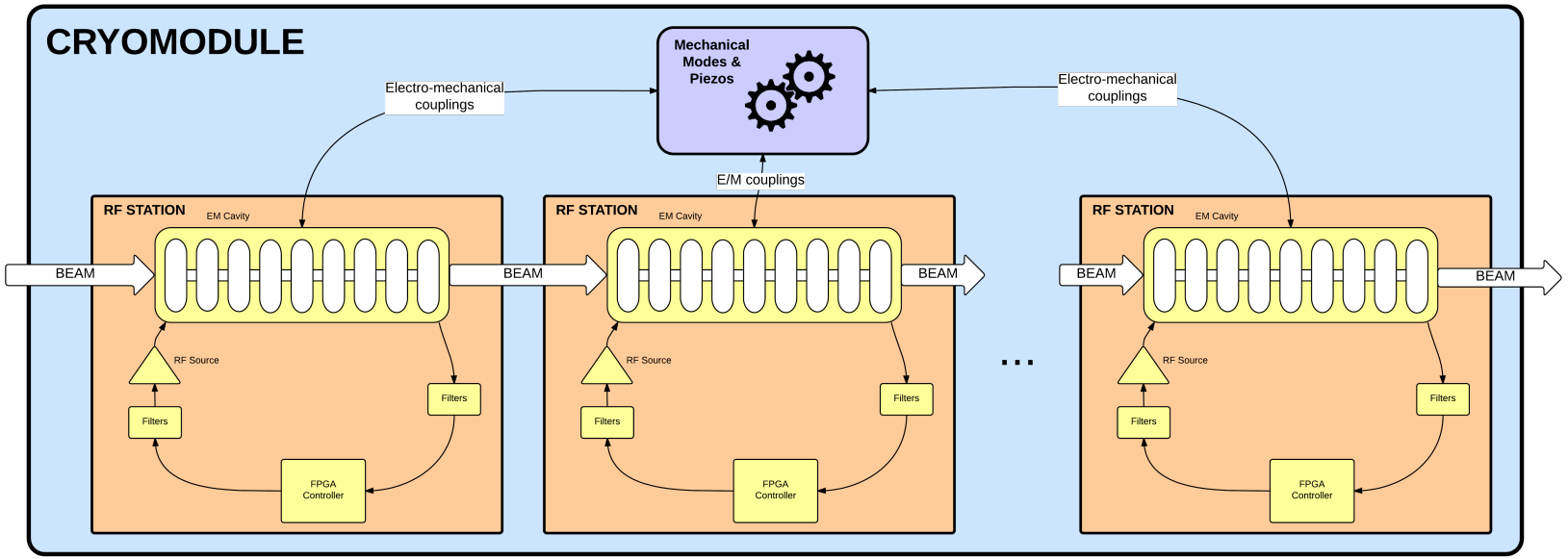
Cavity model: Single Eigenmode (μ)



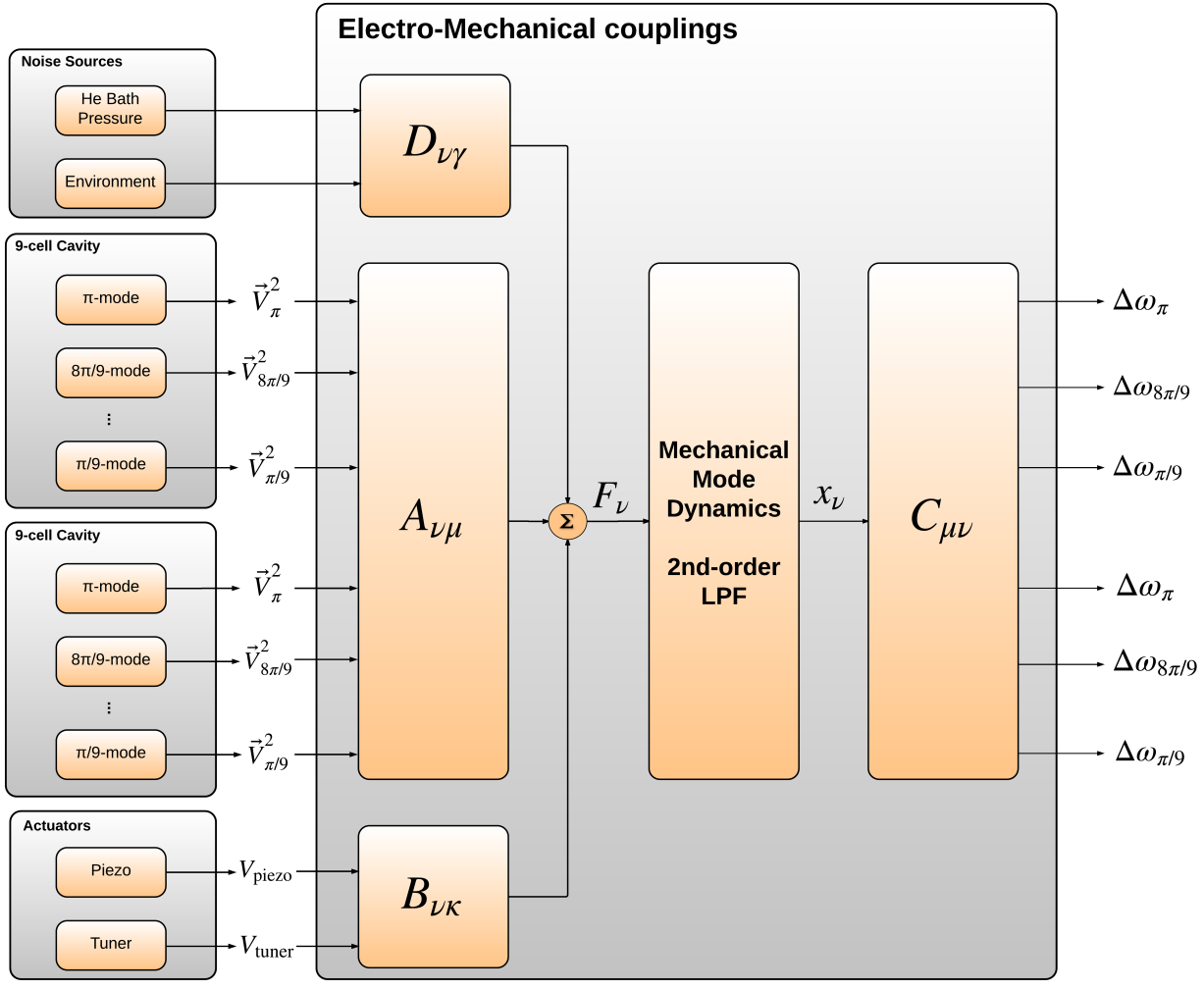
$$\left(1 - j\,\frac{\omega_{d_\mu}}{\omega_{f_\mu}}\right)\vec{V}_\mu + \frac{1}{\omega_{f_\mu}}\,\frac{d\vec{V}_\mu}{dt} = 2\vec{K}_{\mathrm{g}}\sqrt{R_{\mathrm{g}_\mu}} - R_{\mathrm{b}_\mu}\vec{I}_{\mathrm{beam}}$$

LCLS-II Cryomodule

Cryomodule Model

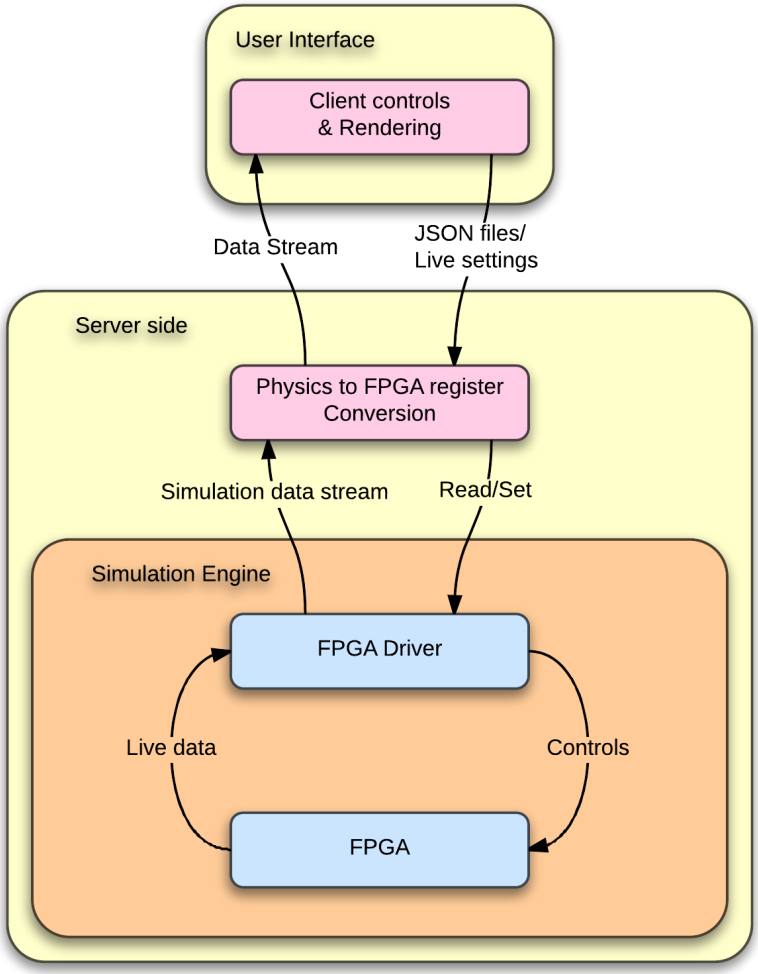


Electro-mechanical interactions

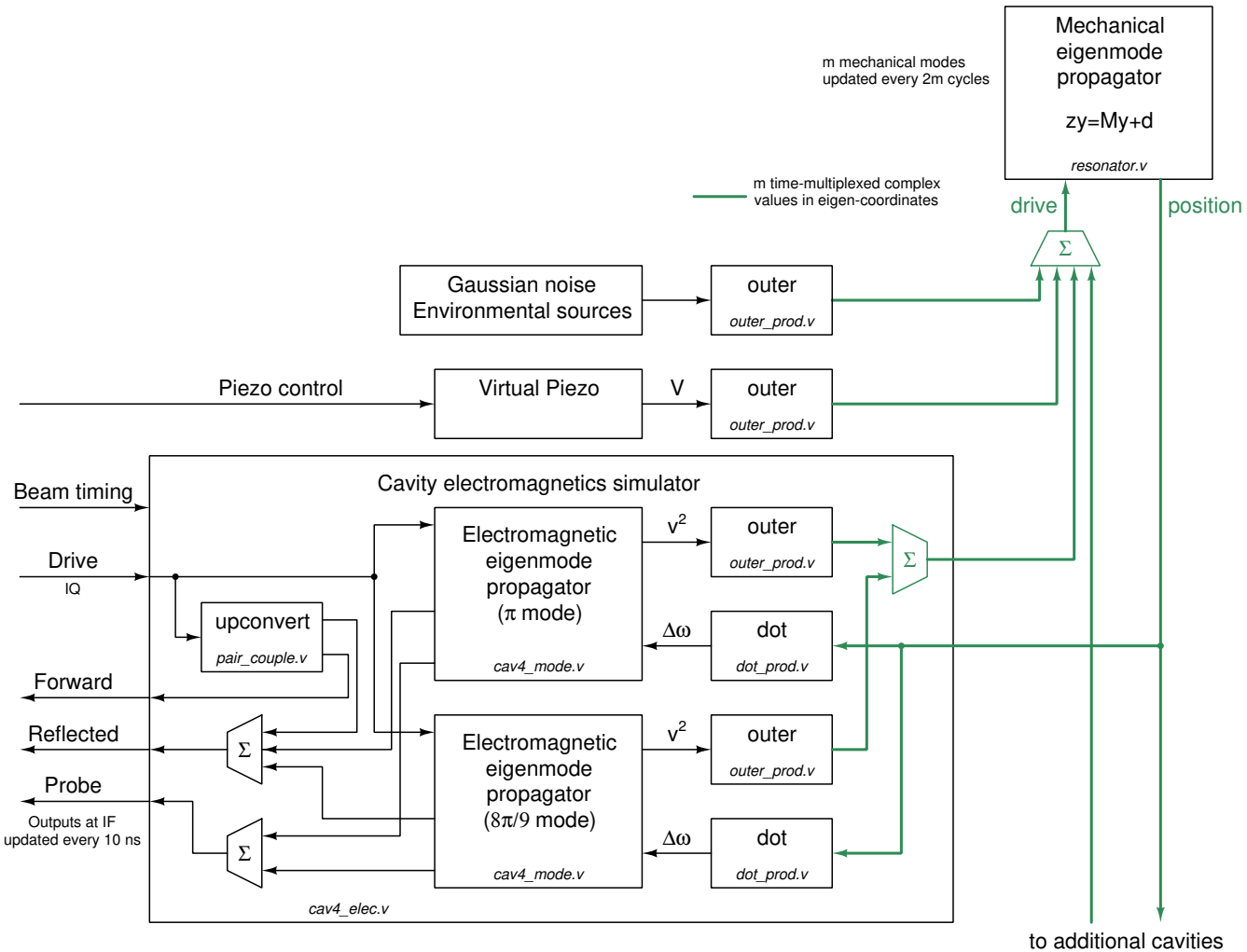


Requirements

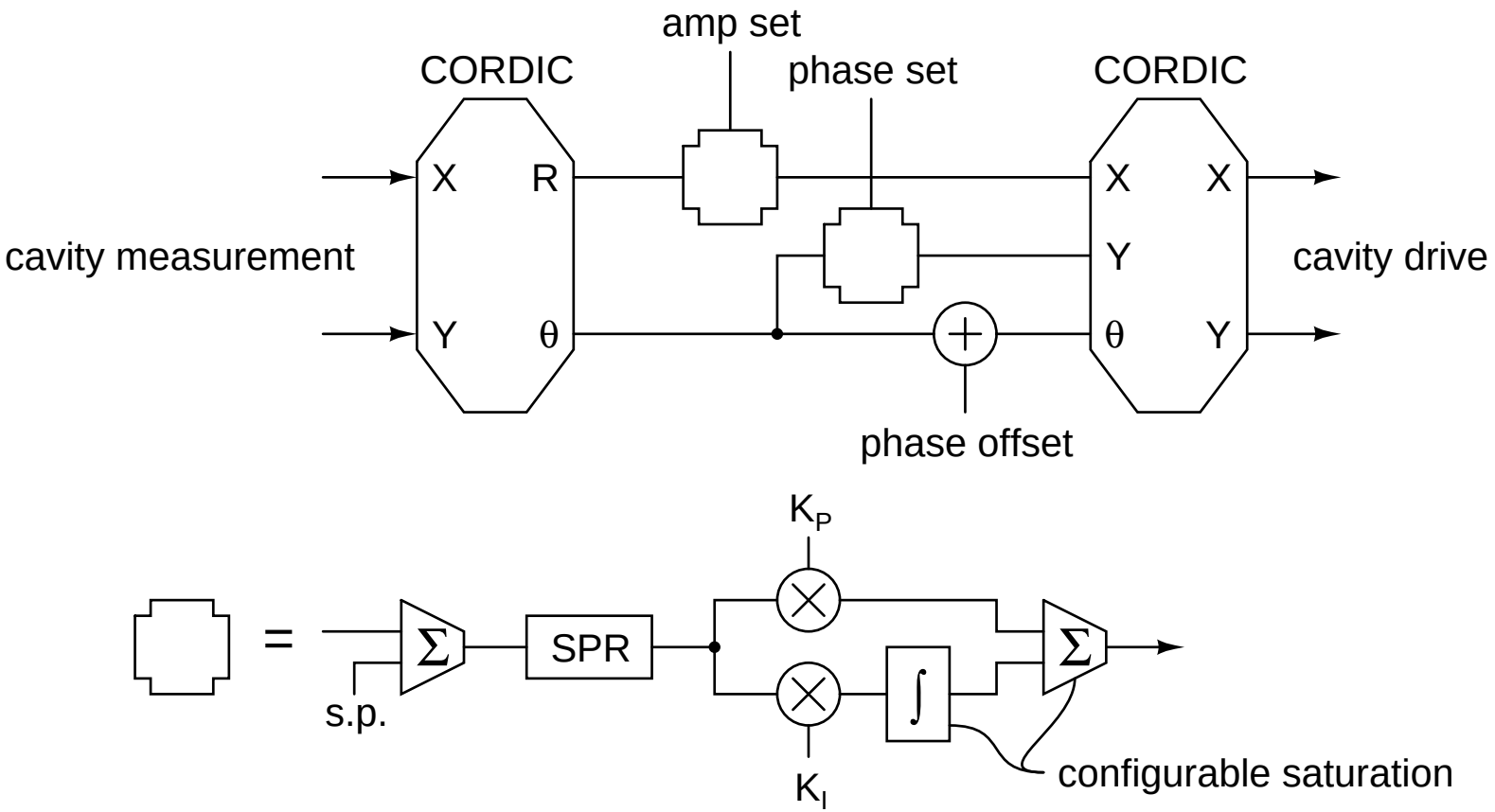
FPGA Model Architecture



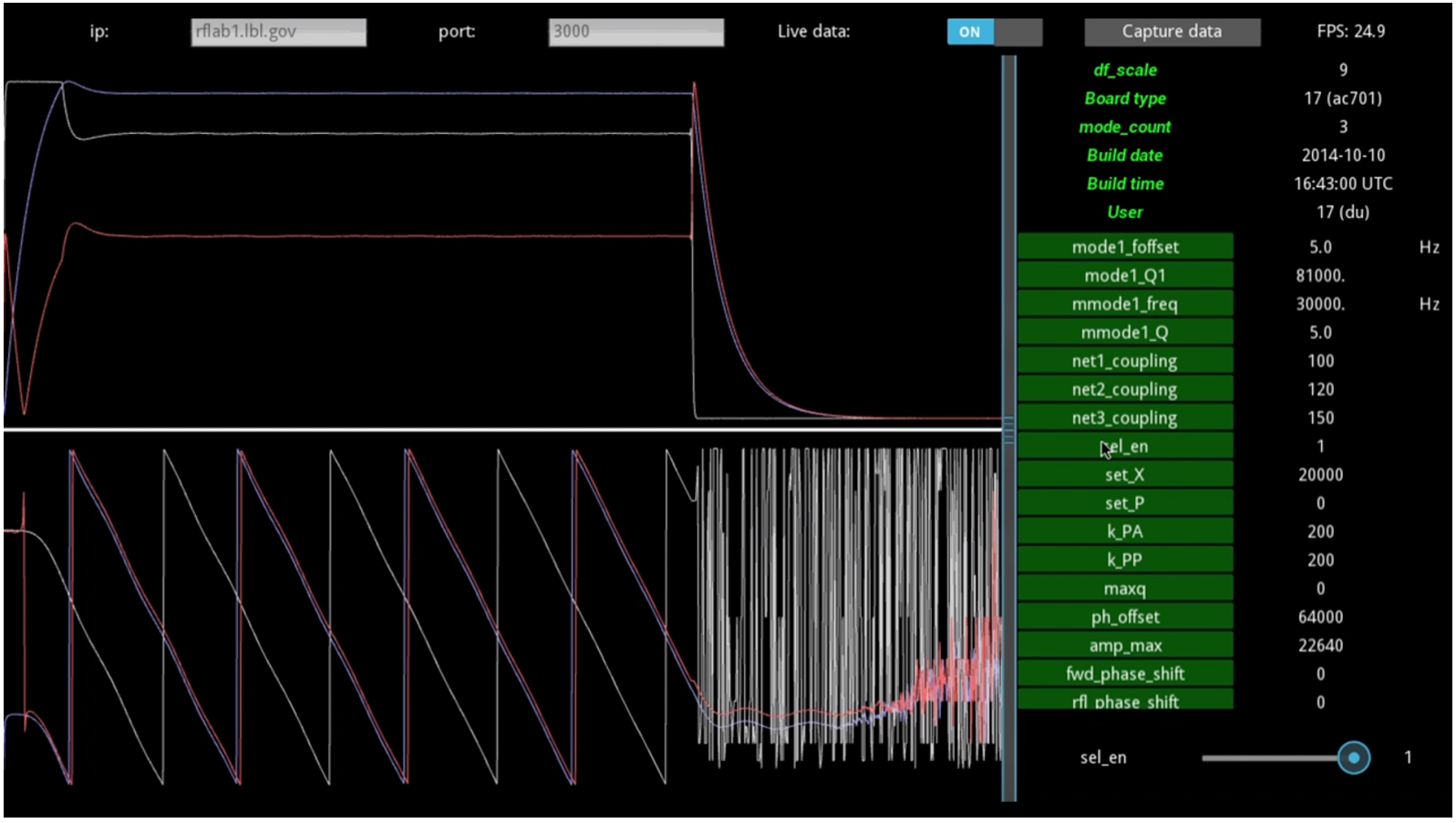
FPGA Model Implementation



FPGA Controller Implementation



User Interface



*Live Demo with Hardware at Thursday's speakers corner (THSH202).

Conclusions

One step closer to final result

FPGA simulation adds FPGA implementation testing before tests with RF.

Live simulations

CMOC provides the same level of user interaction as a real cavity and a tool to explore longer time-scale effects.

Communications, controls and training

Full framework for communications testing and a test bed for controls integration and training.