# DAMC-DS5014DR

## The DAMC-DS5014DR, a high-speed Digitizer, leveraging the cutting-edge AMD ZYNQ Ultrascale+ RFSoC Technology in a MicroTCA.4 form factor.

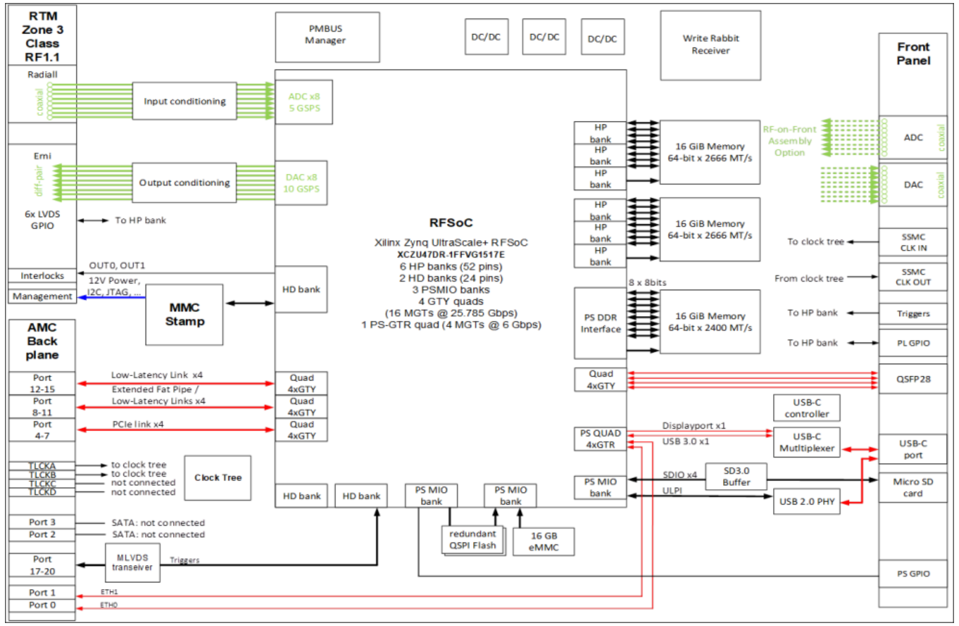
(13th MT ARD ST3 Meeting 2025 at DESY in Zeuthen, 25 to 27 June, Germany)

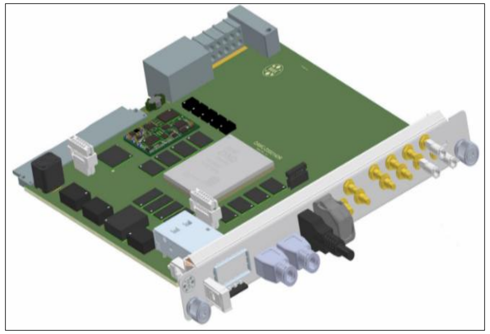
Behzad Boghrati, Michael Fenner, Cagil Gümüs, Szymon Jablonski,
Burak Dursun, Stanislav Chystiakov, Johannes Zink

# The DAMC-DS5014DR, a high-speed Digitizer, leveraging the cutting-edge AMD ZYNQ Ultrascale+ RFSoC Technology in a MicroTCA.4 form factor.

## Main Features

- **Form Factor:** Mid-size, double-width Advanced Mezzanine Card (AMC) board.
- **Processing Core:** 3rd-generation Zynq Ultrascale+ RFSoC ZU47DR with 930k logic cells and 4272 DSP slices.
- **Data Conversion:** 8-channel, 14-bit ADCs at 5 GSPS with 6 GHz analog bandwidth; 8-channel, 14-bit DACs at 10 GSPS.
- **Analog Input Features:**
  - Hybrid AC/DC coupling for input channels.
  - Signal pre-conditioning on the AMC board.
  - 8 single-ended inputs via Zone 3 Radiall COAXIPACK2 from RTM, supporting AC (0.03–6 GHz) or DC (DC–6 GHz) coupling.
  - User-customizable signal conditioning on the Rear Transition Module (RTM).
- **Analog Output Features:**
  - 4 differential outputs via ERNI to RTM, DC-coupled (DC–2.5 GHz).
  - 4 single-ended outputs via Radiall to RTM, AC-coupled (0.03–6 GHz).
- **RF Connectivity:** Zone 3 RF connector compliant with Class RF1.1.
- **High-Speed Interfaces:**
  - QSFP28+ supporting 100Gb Ethernet or optical PCIe Gen.4 x4 (16 Gbps/lane).
  - PCIe Gen.4.0 x8 for data transfer to the MicroTCA.4 backplane.
- **Timing and Triggers:** Eight independent timing/trigger inputs for event-coincident data capture.
- **CPU Functionality:**
  - Operates as a CPU module with a front-panel USB Type-C supporting DisplayPort and USB 3.
  - Up to 16 GB PS DDR4 and 32 GB PL DDR4 memory.
  - Runs Yocto Linux from eMMC, QSPI or SD card.
- **Clock Synchronization:** High-frequency clock synthesizer with inputs from RTM, front panel, or backplane.
- **White Rabbit Support:** CERN White Rabbit endpoint capability for precise timing.



3D Layout

| | | Digital Clock IO | Digital Fixed IO | Digital Clock Input | Digital User IO | | Differential DACs | | | MTCA.4 Management | |
|---|---|---|---|---|---|---|---|---|---|---|---|
| J30 | | 10 | 9 | 8 | 7 | 6 | 5 | 4 | 3 | 2 | 1 |
| - | F | AMC-CLK- | OUT1-/D8- | RF-CLK3- | DAC7- | D5- | DAC4- | D2- | DAC1- | TMS | TDO |
| + | e | AMC-CLK+ | OUT1+/D8+ | RF-CLK3+ | DAC7+ | D5+ | DAC4+ | D2+ | DAC1+ | TD1 | TCK |
| - | d | RF-CLK2- | OUT0-/D7- | RF-CLK1- | D6- | DAC5- | D3- | DAC2- | D0-CC- | SCL | SDA |
| + | c | RF-CLK2+ | OUT0+/D7+ | RF-CLK1+ | D6+ | DAC5+ | D3+ | DAC2+ | D0-CC+ | MP | PS# |
| - | b | RF-CLK0- | AMC-TCLK- | RTM-CLK- | DAC6- | D4- | DAC3- | D1- | DAC0- | PWRB2 | PWRB1 |
| + | a | RF-CLK0+ | AMC-TCLK+ | RTM-CLK+ | DAC6+ | D4+ | DAC3+ | D1+ | DAC0+ | PWRA2 | PWRA1 |

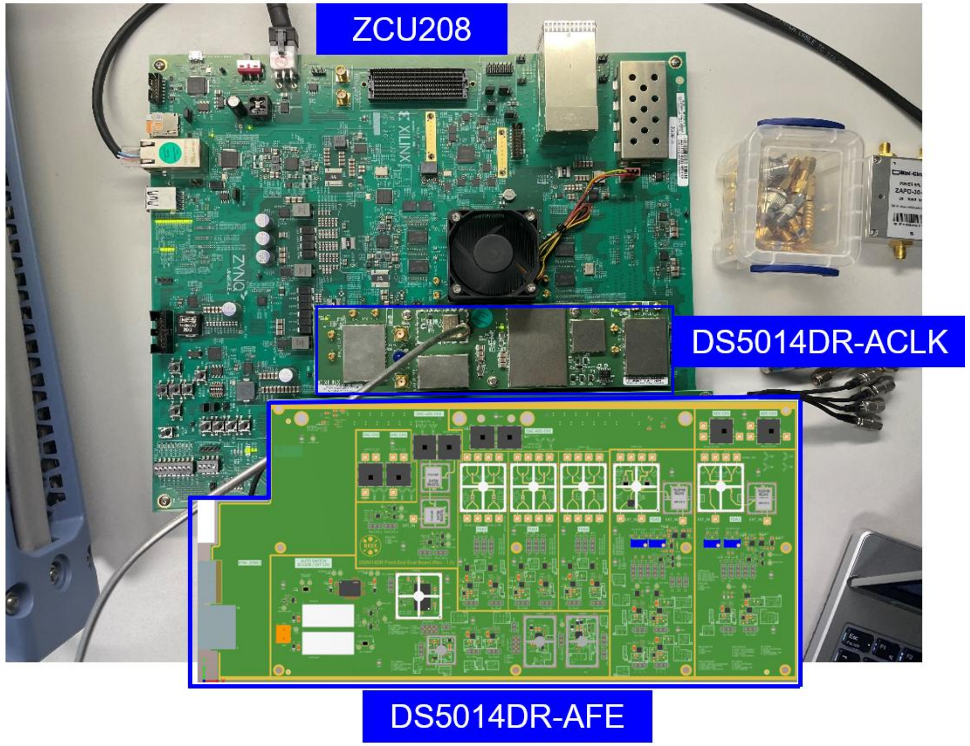
| | Single Ended Analog Signals | | |
|---|---|---|---|
| J31 | 3 | 2 | 1 |
| B | ADC-IN7 | DAC-OUT1 | DAC-OUT3 |
| A | ADC-IN6 | DAC-OUT0 | DAC-OUT2 |
| J32 | 3 | 2 | 1 |
| B | ADC-IN1 | ADC-IN3 | ADC-IN5 |
| A | ADC-IN0 | ADC-IN2 | ADC-IN4 |

Zone 3 – Class RF1.1 pin assignment J30, J31, and J32 connector, AMC side view.

# The DAMC-DS5014DR, a high-speed Digitizer, leveraging the cutting-edge AMD ZYNQ Ultrascale+ RFSoC Technology in a MicroTCA.4 form factor.

## DS5014DR Analog Frontend Evaluation Board and High-Frequency Synthesizer Evaluation board

- **Primary Objective:** Assess the performance of the DS5014DR's hybrid coupling system, supporting both AC and DC coupling channels.
- **Hybrid Coupling Mechanism:** Utilizes an assembly option to toggle between AC and DC coupling modes.
- **AC Coupling Characteristics:** Employs a passive Balun design, supporting input frequencies from 30 MHz to 6 GHz.
- **DC Coupling Characteristics:** Features an RF fully differential amplifier (TRF1305B2) with a bandwidth from DC to 7 GHz, offering three power gain variants:
  - 5 dB (TRF1305A2)
  - 10 dB (TRF1305B2)
  - 15 dB (TRF1305C2)
- **DC Coupling Input Specifications:** In single-ended mode, supports a dynamic range of 1 Vpp (±0.5 V) with a 0 V DC common mode input voltage.
- **Evaluation Using DS5014DR-AFE Board:** Measures analog converter dynamic performance, including:
  - Noise floor
  - Time latency
  - Static and Dynamic performance metrics
- **RF Switch and ADC Design:** Incorporates an RF switch and an RF-ADC with an interleaving architecture, potentially requiring calibration.



# SYSTEM-ON-CHIP-BASED MAGNET CONTROL IN A MICRO TCA SYSTEM.

Speed Talk -

13th MT ARD ST3 Meeting 2025 Zeuthen

Jana Miericke
DESY Hamburg, MSK

26.06.2025

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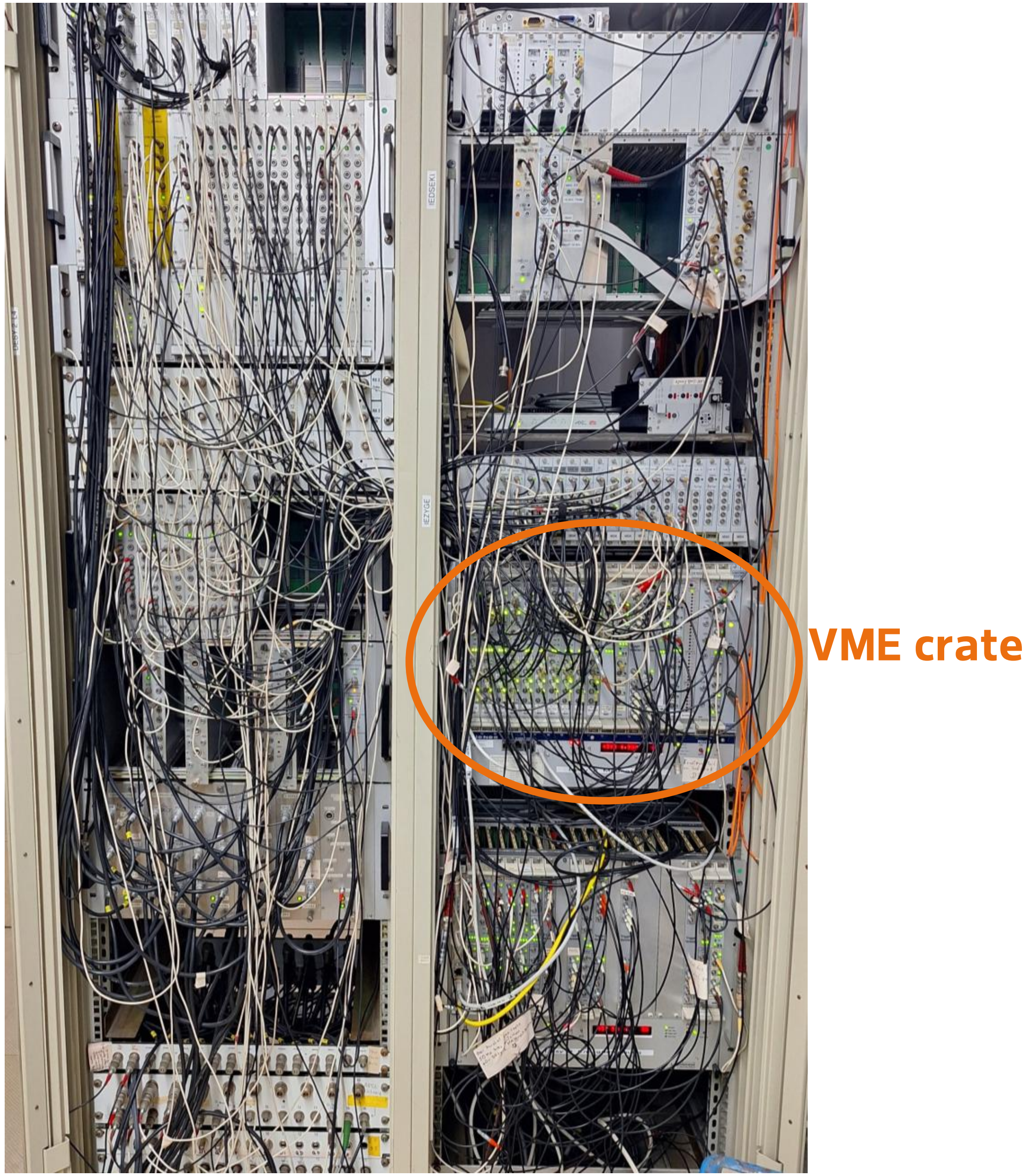
# Current DESY II magnet control

## Using VMEbus

- DESY II → pre-accelerator of PETRA III
- Ramps up energy from 450 MeV to 6 GeV for extraction into PETRA III
- DESY II is old → VMEbus standard → fading expertise
- Upgrade → Migration to MicroTCA



# Migration to MicroTCA

## Master's Thesis

**How dow we use MTCA for DESY II magnet control?**

**Is it possible without VxWorks?**

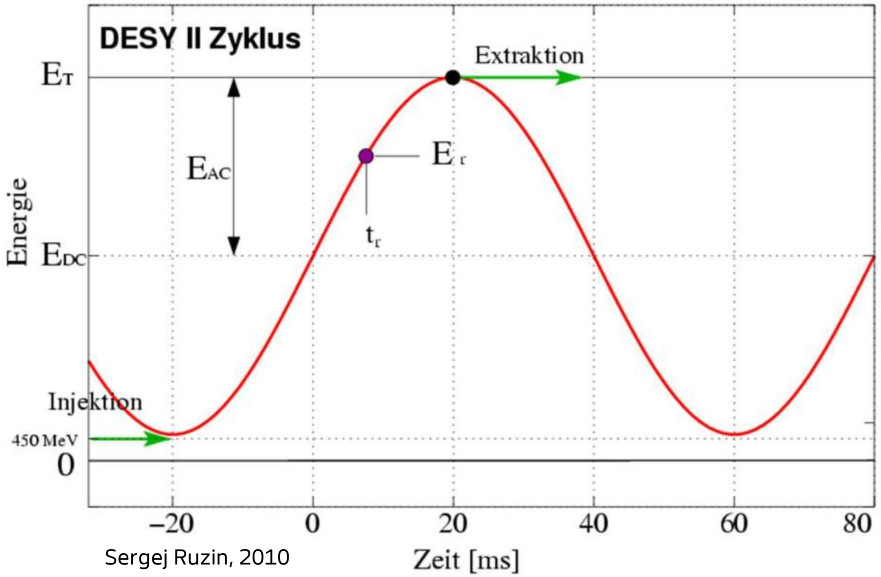
**Current system:**

Real-time requirement **80 ms**

→ Real-time operating system **VxWorks**

**Thesis**:

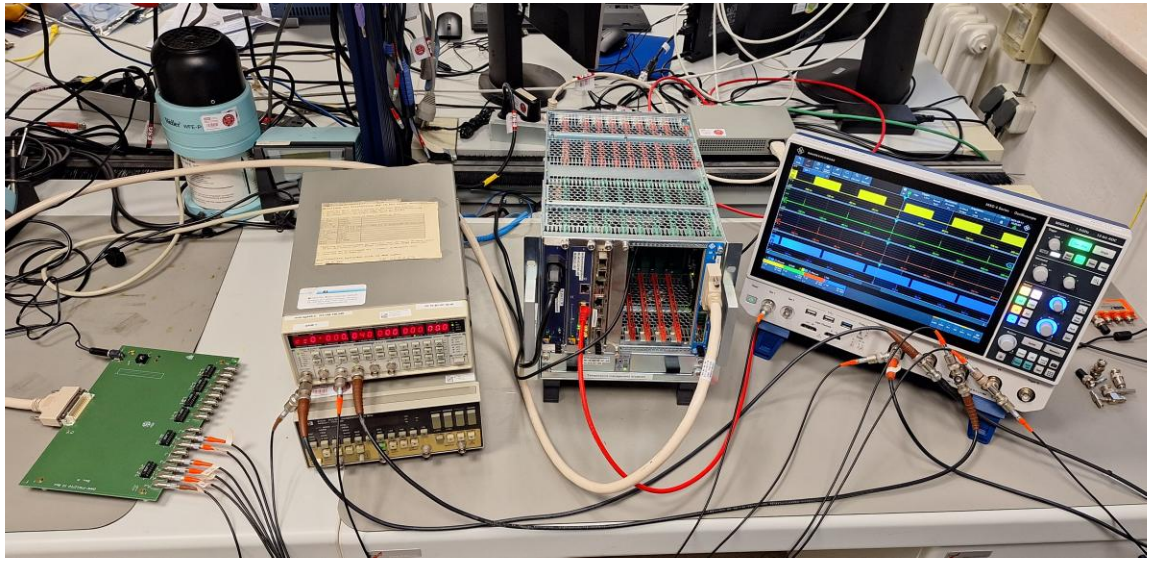
- Implemented full functionality on MicroTCA
- Real-time requirement is met without the use of VxWorks




Sergej Ruzin, 2010

6 GeV

450 MeV



→ **Details on my poster!**

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# KOOPMAN MEETS KALMAN

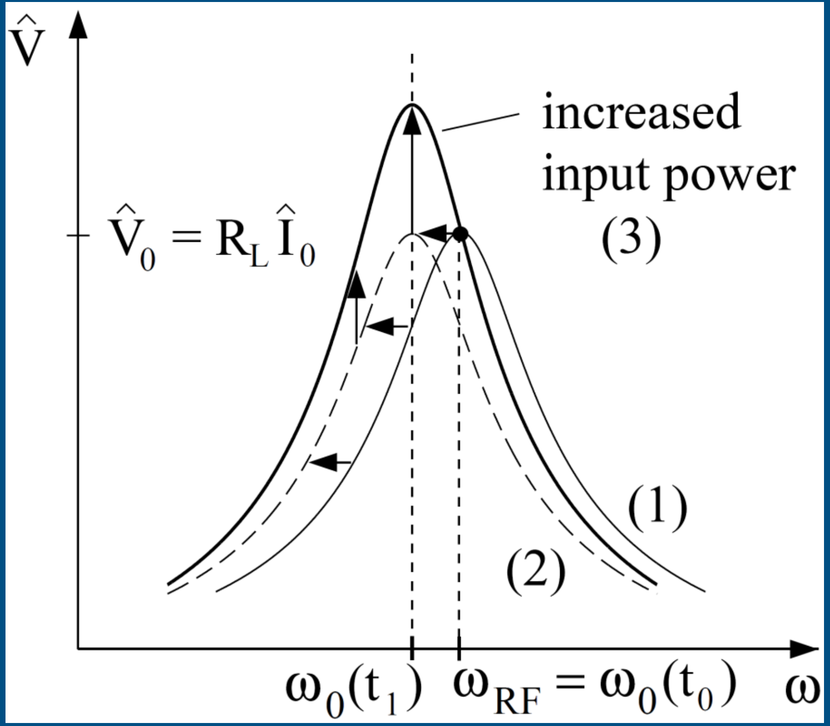
## A deep learning approach to model RF cavity detuning

Andrei Maalberg et al. | ST3 Meeting in Zeuthen, 26.06.2025

# RF cavity detuning

- Represents a decades-old topic in control for accelerator physics
- Affects energy consumption in particle accelerators
- Still remains an open issue

- We need a better detuning modeling approach!




Principle of cavity detuning. Adapted from [1].

[1] T. Schilcher. Vector Sum Control of Pulsed Accelerating Fields in Lorentz Force Detuned Superconducting Cavities. Ph. D. dissertation, Hamburg University, 1998.

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# Kalman-inspired neural decomposition, or KIND

- Decompose detuning into stationary and transient dynamics
- Use deep learning to make the decomposition data-driven
- Become inspired by Kalman and blend the dynamics as
- We get a promising modeling approach for nonlinear and time-varying cavity dynamics!

# Thank you

Koopman went to meet Kalman

# Feedback Optimization at EuXFEL.

MT ARD ST3 Meeting

Beam Control Speedtalk

Christian Hespe, Jan Kaiser, Jannis Lübsen, Frank Mayet, Matthias Scholz, and Annika Eichler
DESY MSK

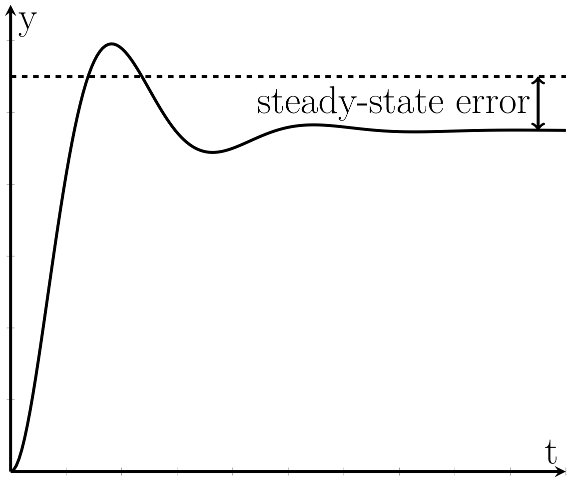
26.06.2025

HELMHOLTZ

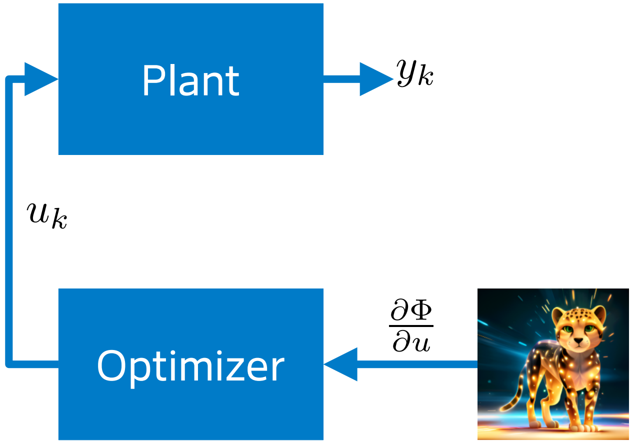
# Learning-Based Feedback Optimization

## Steady-State Control for Dynamic Systems

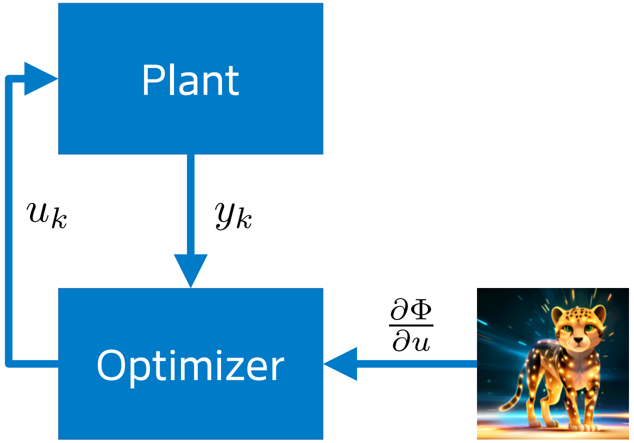
- Problem: Find optimal steady-state pair $(u, y)$
- Solution: Gradient-based optimization
  a) Rely on model knowledge
  b) Approximate gradient by sampling & heuristics
  c) Recursive estimation



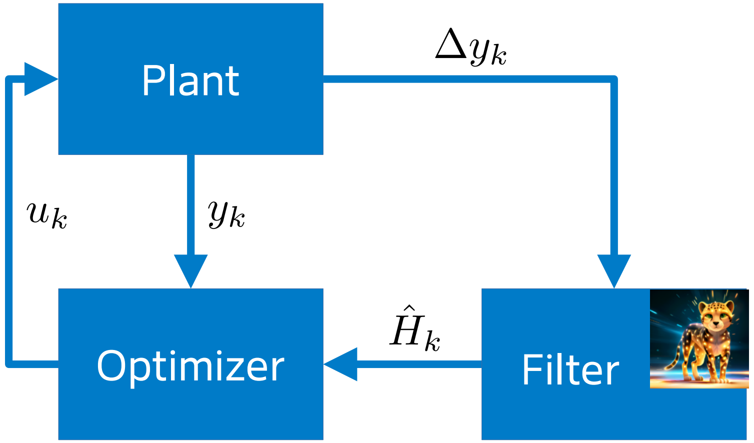

### „Feedforward“ Optimization




### Feedback Optimization




### Learning-Based Feedback Optimization



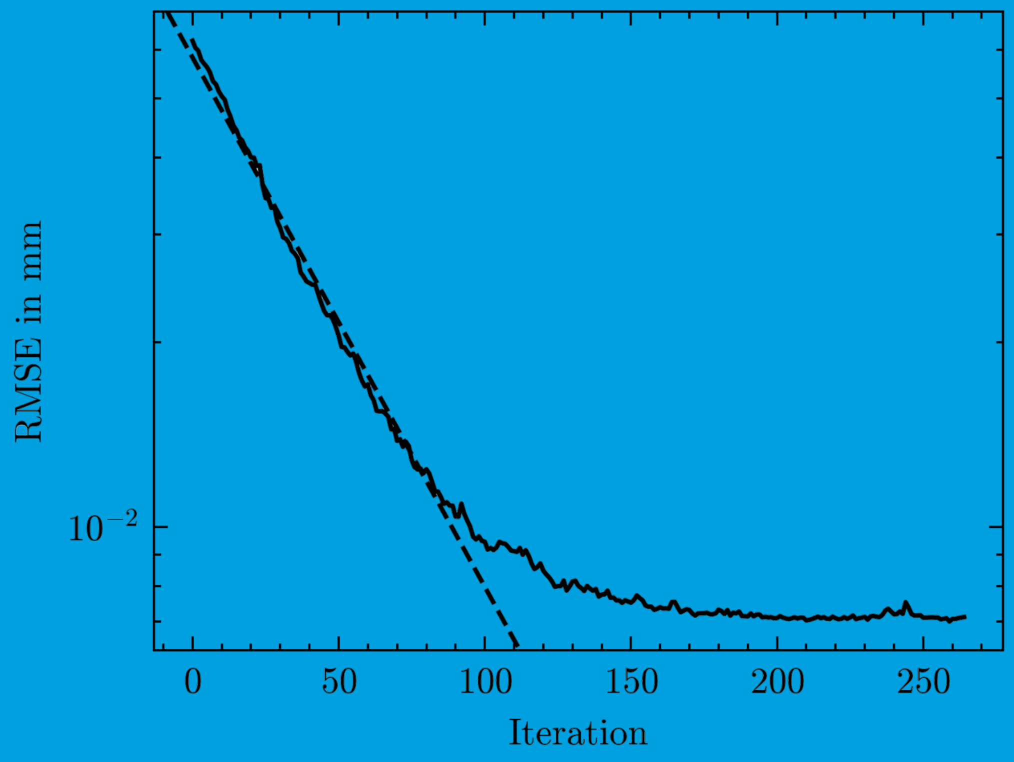
# Feedback Optimization for Beam Orbit Control

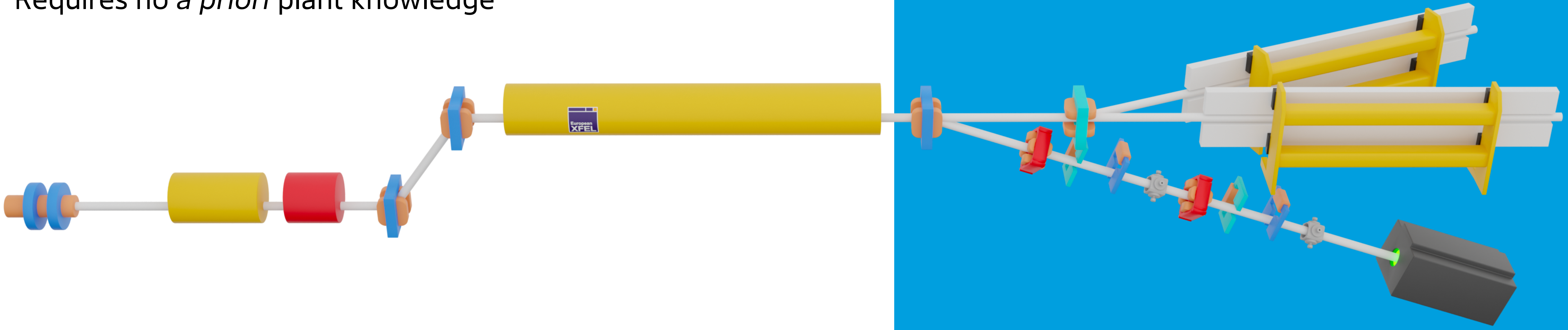
### Scenario: EuXFEL Electron Dump Beamline

- Control drifting beam orbit
- Testbed for learning controllers
- Evaluated on the machine

### Model-Free Optimization in Simulation

- Simultaneous learning and control
- Requires no *a priori* plant knowledge



13th MT ARD ST3 Meeting 2025 bei DESY in Zeuthen

HZB Helmholtz Zentrum Berlin

# ADAPTIVE FEEDFORWARD CONTROL OF SUPERCONDUCTING RESONATORS ON RFSOC

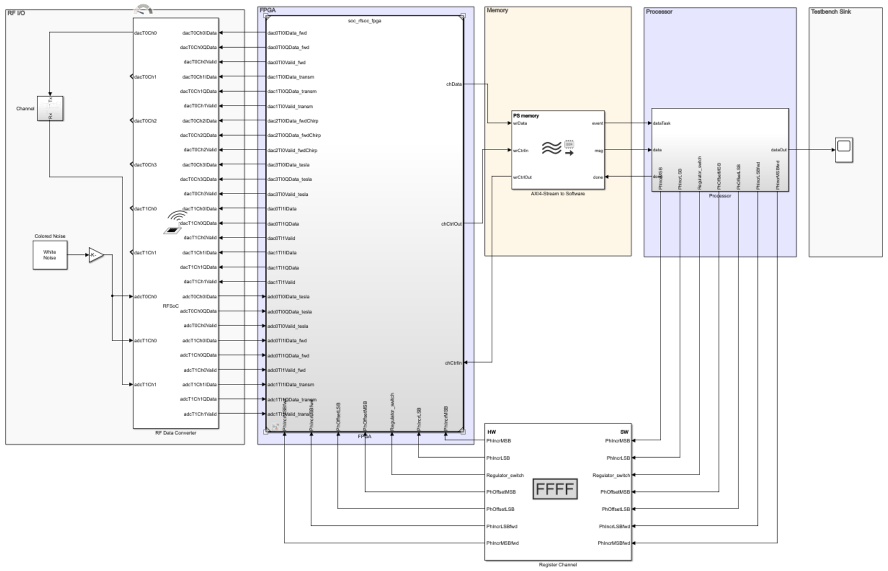
A. Ushakov, A. Neumann, N. Shipman

26.06.2025

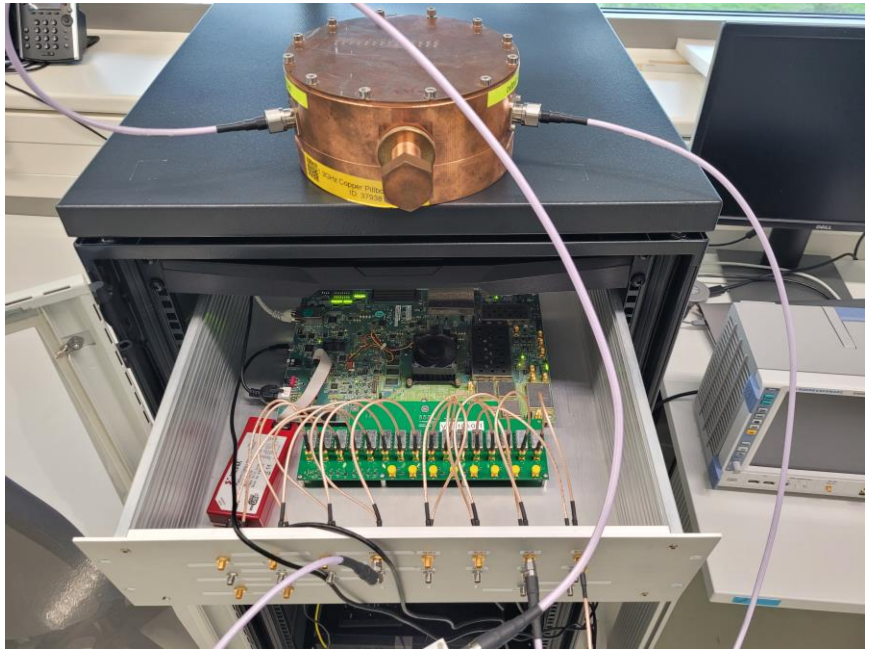
# RFSoC laboratory bench for debugging control algorithms

- mTCA is widely used as control hardware for accelerators in HZB
- RFSoC advantages:
  - adjustable PLL
  - ADC/DAC (mixing, Nyquist zone and bandwidth tuning)
  - Support for DSP algorithms by design tools
- The developed setup is based on Xilinx ZCU111 RFSoC
- This allows to develop :
  - Fully digital PLL on RFSoC
  - Self-excited loop for FRT control
  - TESLA RF simulator

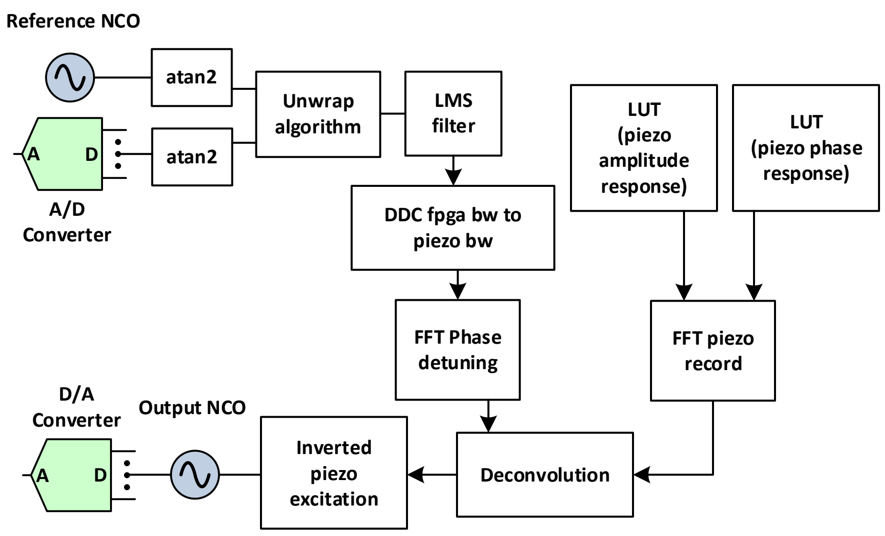
## SW/FW development environment



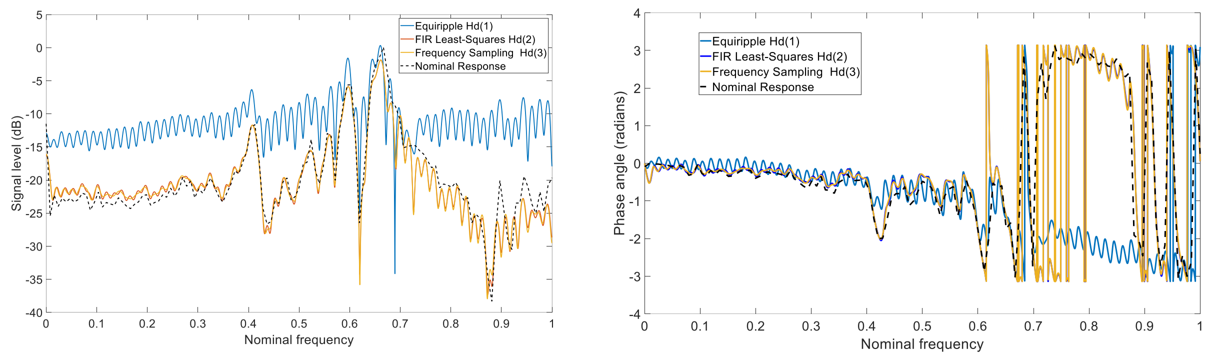
## Hardware implementation



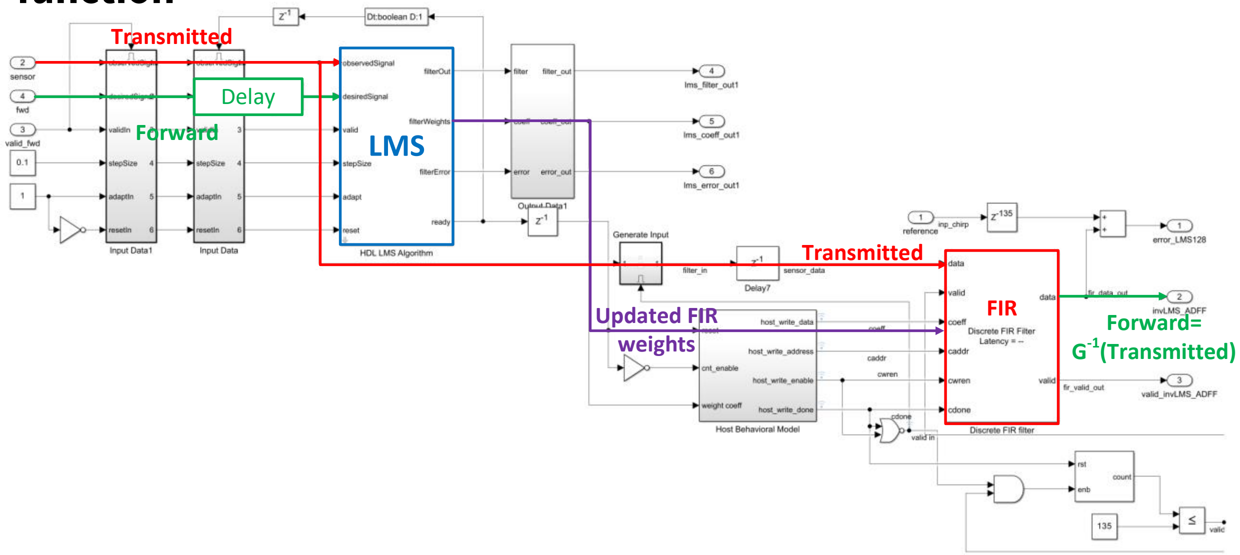
## Initial idea for adaptive feed-forward control



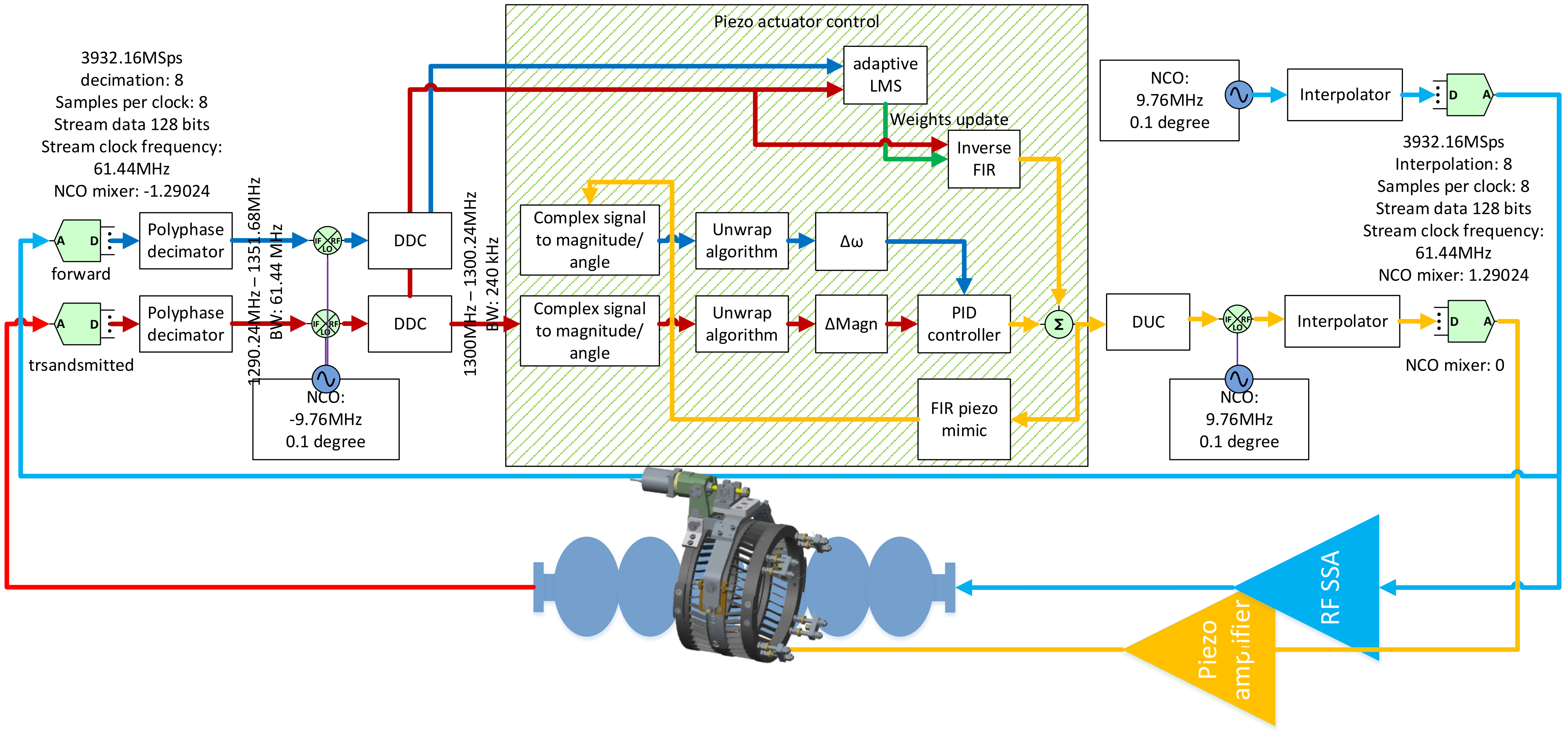

## Description of object behavior by a finite filter based on the transfer function




## Feed-forward control based on the inverse transfer function



# Adaptive feed-forward piezo element control scheme



# APPLICATION OF THE CARRIER SUPPRESSION INTERFEROMETRY IN THE MAGO PROJECT.

Can Dokuyucu, Frank Ludwig, Giovanni Marconato, Julien Branlard, Krisztian Peters, Louise Springer, Marc Wenskat, Matthias Hoffmann, Tom Krokotsch

DESY, Zeuthen, 26.06.2025

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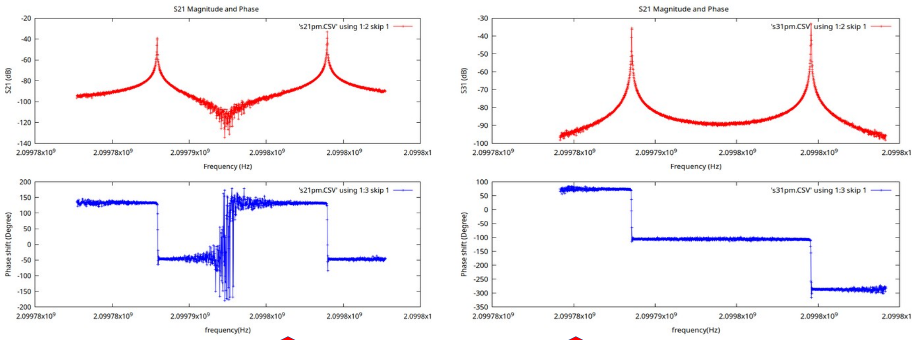
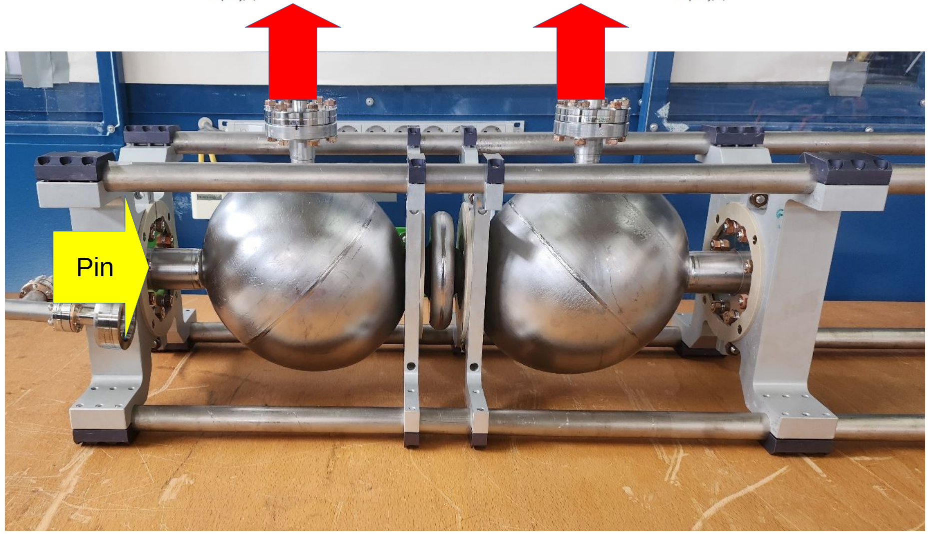
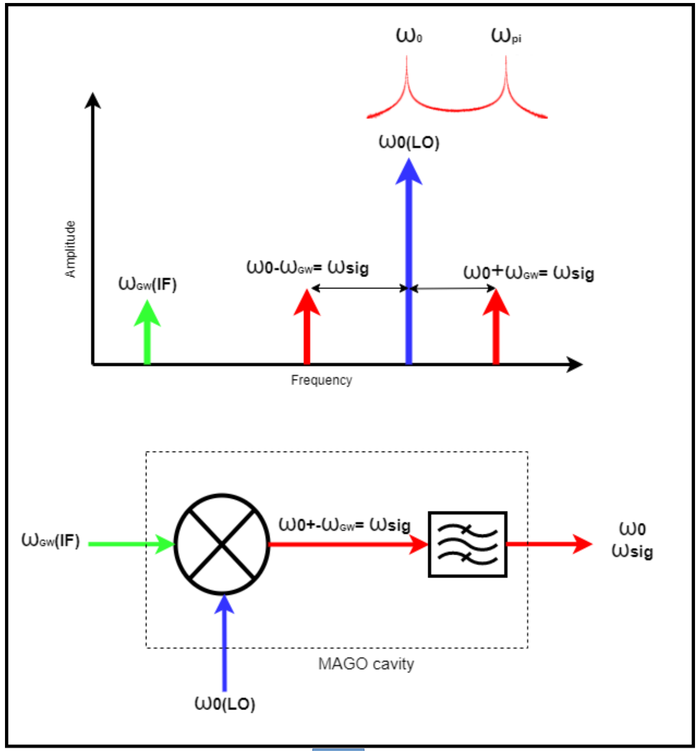
DESY.

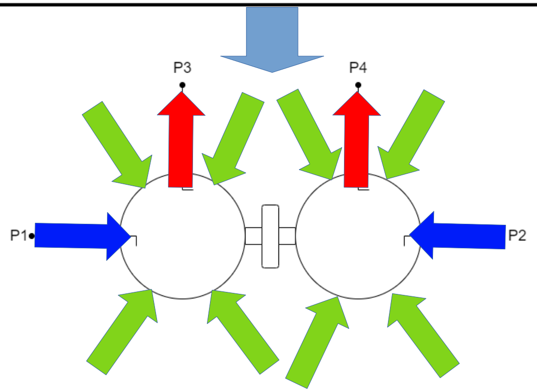
# MAGO Project (Microwave Apparatus for Gravitational Waves Observation)



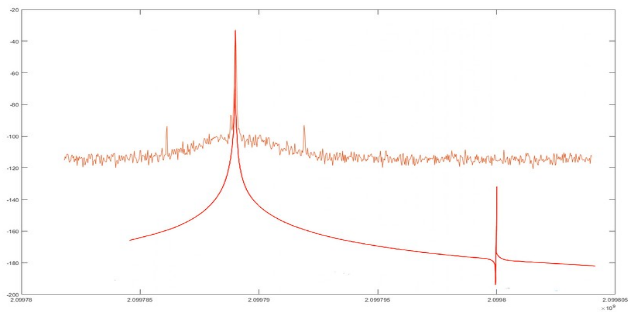

MAGO cavity



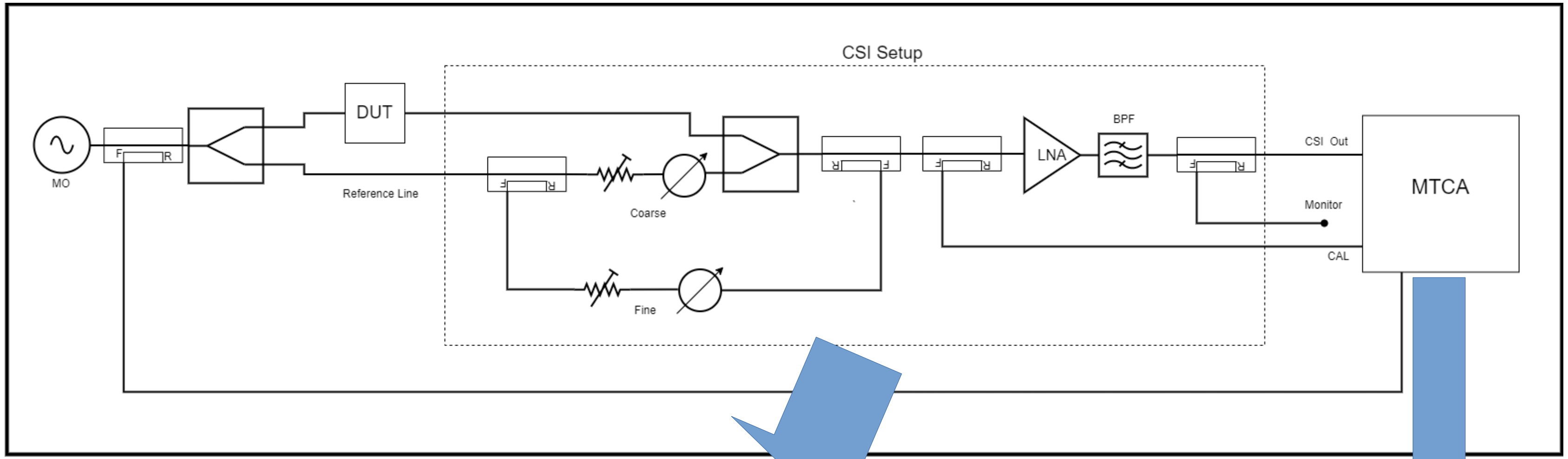

## Principle of the detection

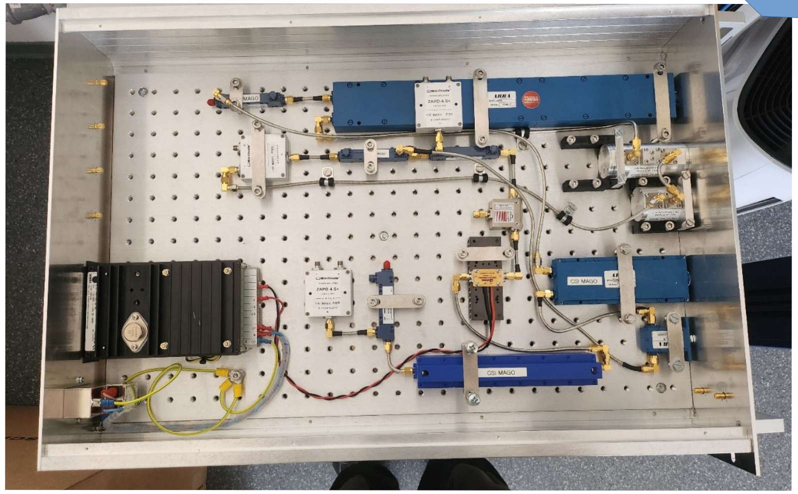
- MAGO cavity consists weak coupling of the two identical spherical cells. Coupling of the two cells causes a split in the resonance frequency. (Zero and pi mode)
- Resonant behavior of the cavity is similar to coupled pendulums.
- Since working principle relies on heterodyne detection, MAGO cavity acts like an RF mixer and band pass filter.
- When the GW interacts with the cavity, frequency of the GW causes harmonic generation around the zero mode frequency.
- Pi mode of the cavity filters out the lower harmonic and only allows the passage of the higher harmonic. GW signal appears on pi mode frequency of the cavity.
- Reception frequency can be tuned by changing the coupling between the cells (Coupling changes the band gap between modes) .



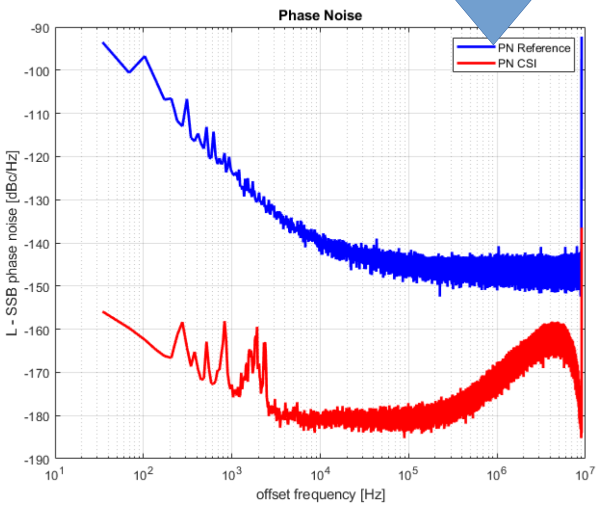
Noise floor covarage of the zero mode

# Carrier Suppressing Interferometry (CSI)



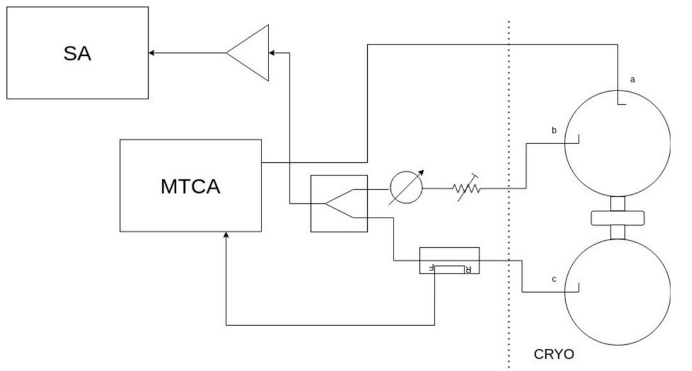



CSI setup for the MAGO (Under development)

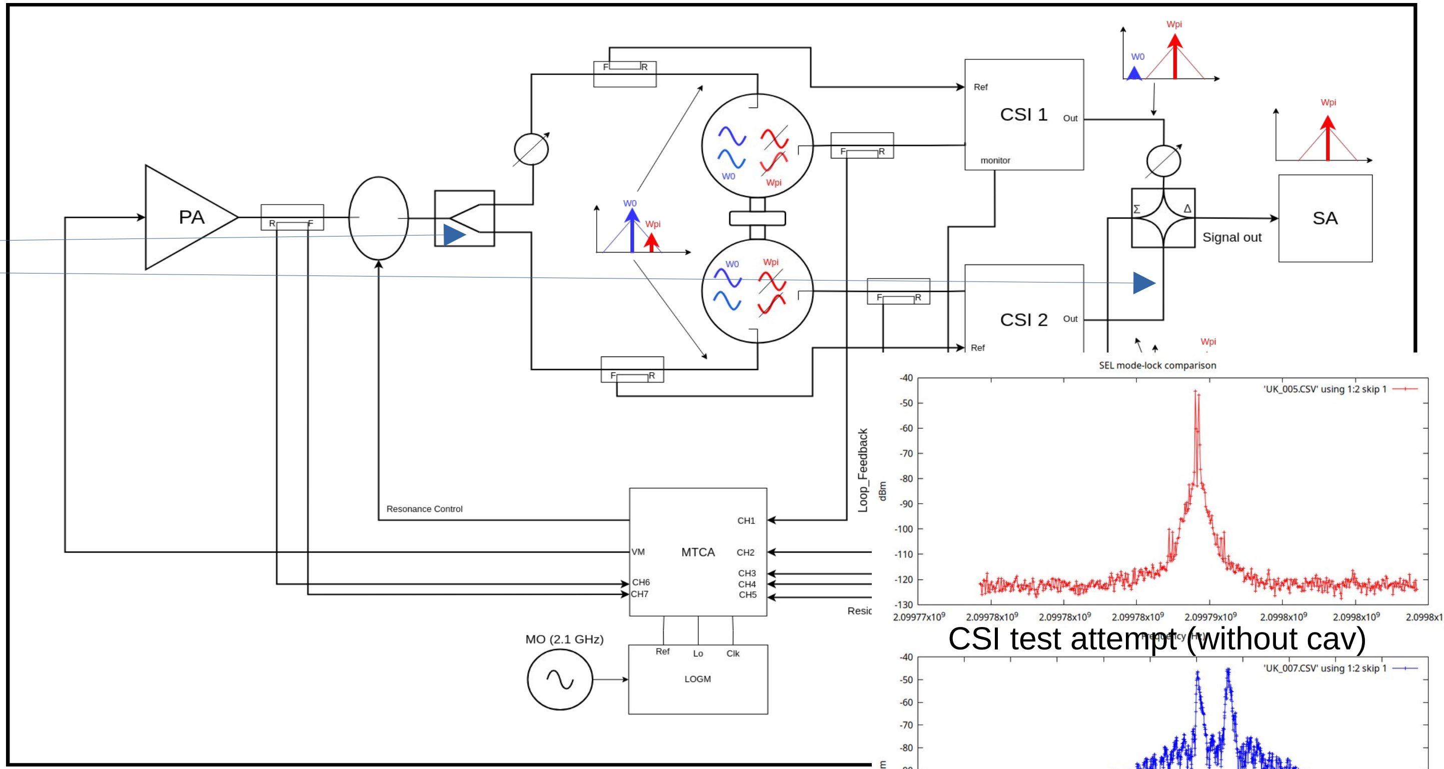


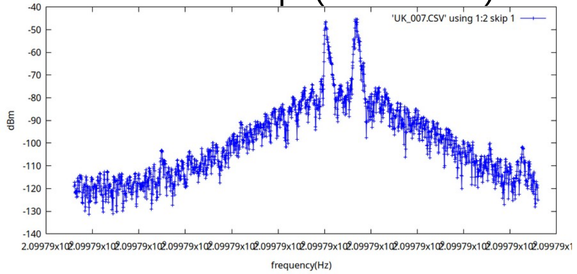

- **Carrier Suppressing Interferometry (CSI) is a setup for measuring extremely low (-205 dBc/Hz) phase noise by suppression of the carrier noise floor.**
- **Working principle of the CSI relies on destructive interference between reference (carrier) signal and the reference signal pass through device under test. Because of the difference between the two signals, resulting signal gives information about devices phase noise characteristics.**
- **CSI is a promising method for the extraction of the GW signal in the MAGO project. Due to extremely low amplitudes of the GW signal.**
- **CSI setup will be used for rejection of the excited mode (zero mode) signal to increase the detection sensitivity of the pi mode signal.**

# CSI for the Signal Extraction



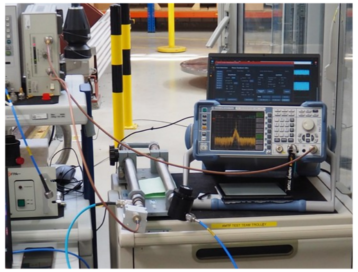

Mode rejection test setup (First 4K test of the cavity)



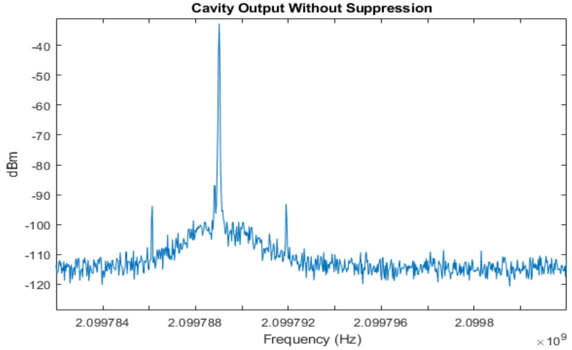



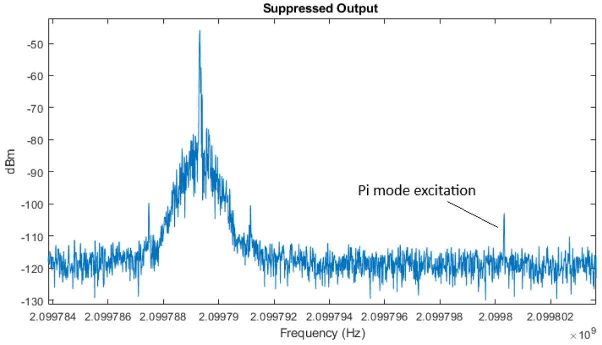

CSI test attempt (without cav)


Digital self excited loop for the resonance tracking



Prototype mode rejection setup




- Signal extraction setup consists of three main d… the pi mode, second stage is for suppression of … residual noise and amplification of the GW signa…
- In the first cold test of the cavity, MTCA based digital self excited loop used as resonance tracker.
- Bandwidth of the drive signal should be narrower than the bandwidth of the cavity for the noise free suppression of the output signal of the MAGO cavity. And resonance tracker should not add phase noise to the input signal.

# Thank You.

E-Mail: can.dokuyucu@desy.de

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Notkestraße 85 22607 Hamburg

HELMHOLTZ

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Universidad del País Vasco Euskal Herriko Unibertsitatea

HZB Helmholtz Zentrum Berlin

# MODIFIED ACTIVE DISTURBANCE REJECTION CONTROL FOR MICROPHONICS REDUCTION IN SRF CAVITIES

24.06.2025

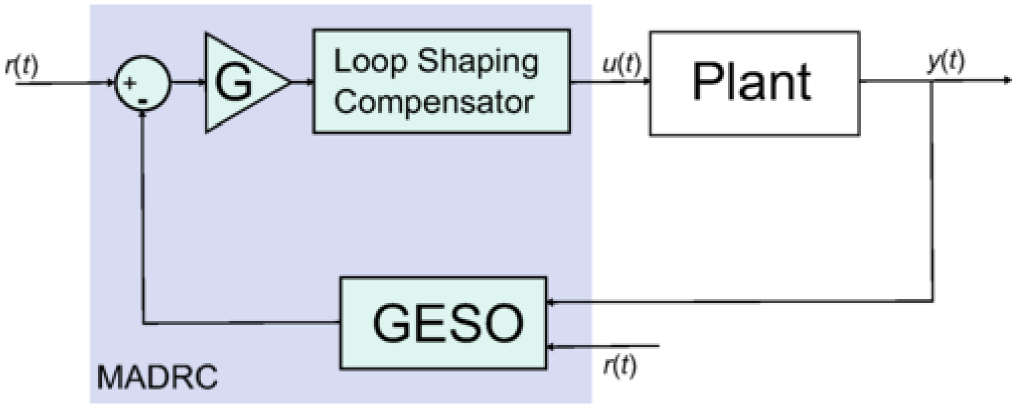
13th MT ARD ST3 meeting

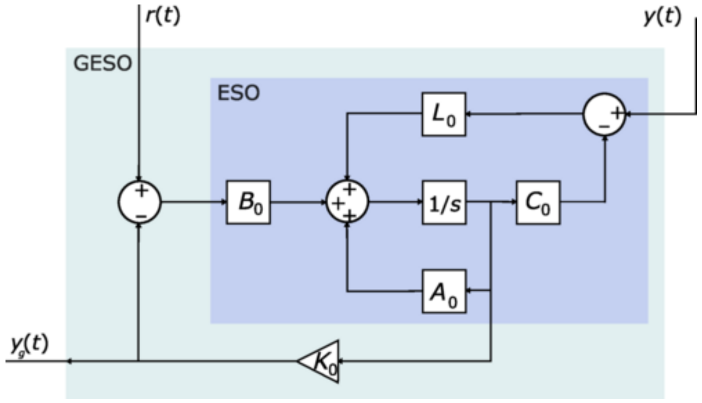
Pablo Echevarria et al.

# Modified Active Disturbance Rejection Control

## Detuning feedback in SRF cavities with high QL

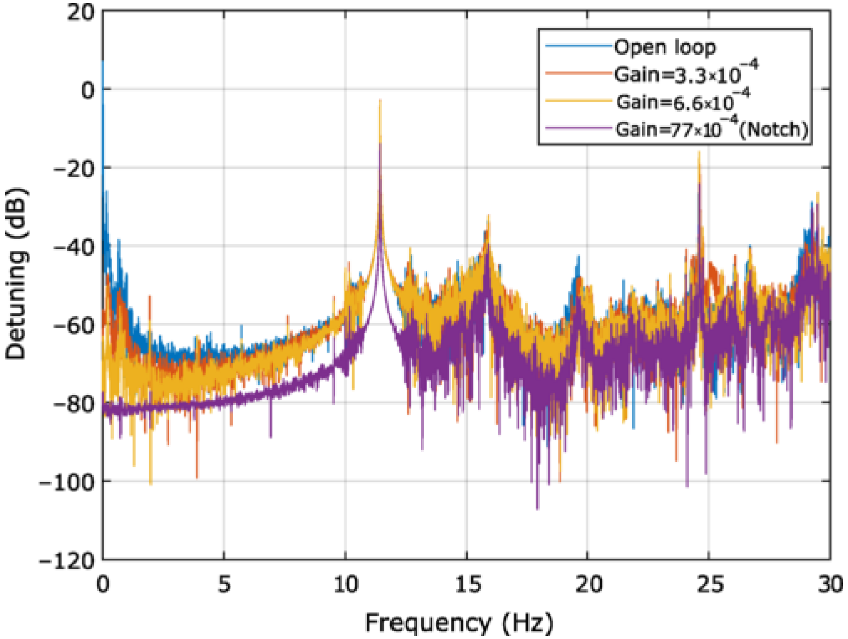
- **Feed-forward →** vibrations whose **frequency is fixed and localized.**
- **Low-frequency stochastic disturbances → feedback** is necessary**.**
- **Mechanical eigenmodes** make PIDs instable even with low gains
- **Active Disturbance Rejection Control (ADRC)** as an alternative to PIDs

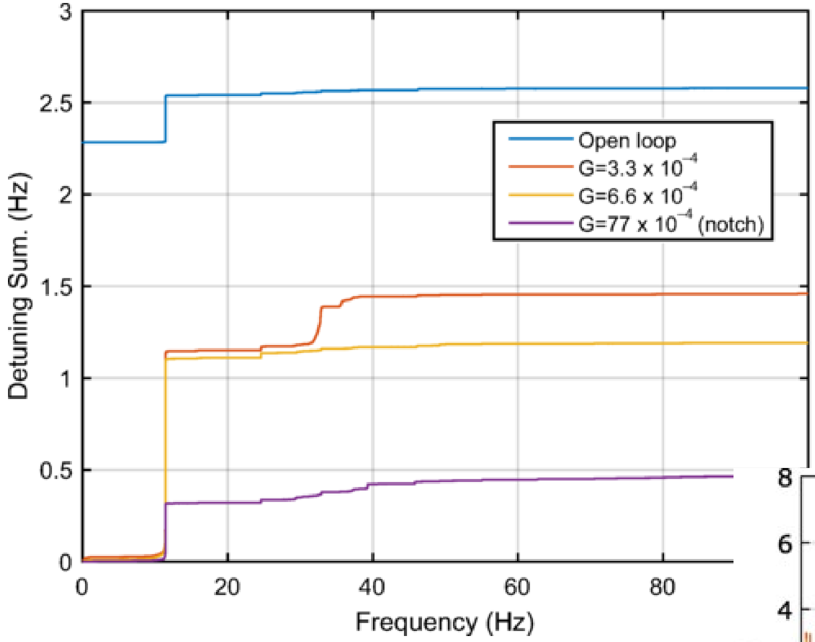



In the „classical“ ADRC time delay is a show stopper

# Results with a TESLA cavity @ HoBiCaT (HZB)



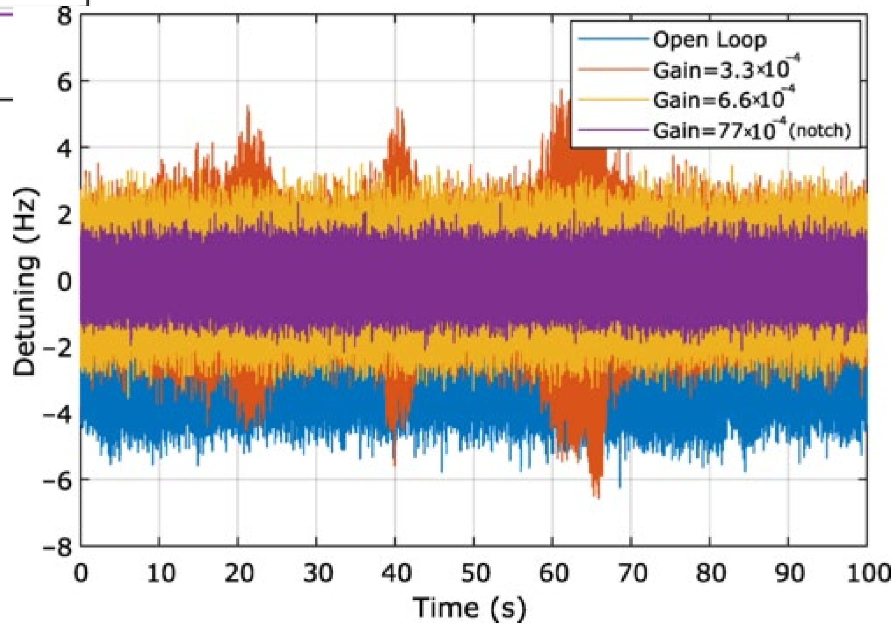




Frequency and integrated frequency response

(with an external excitation @ 11Hz)

Time domain response

(without external excitation)



# Recent activities using Distributed Acoustic Sensing (DAS) at DESY

Erik Genthe, Markus Hoffmann, Holger Schlarb
on behalf of the Wave Collaboration
https://wave-hamburg.eu/

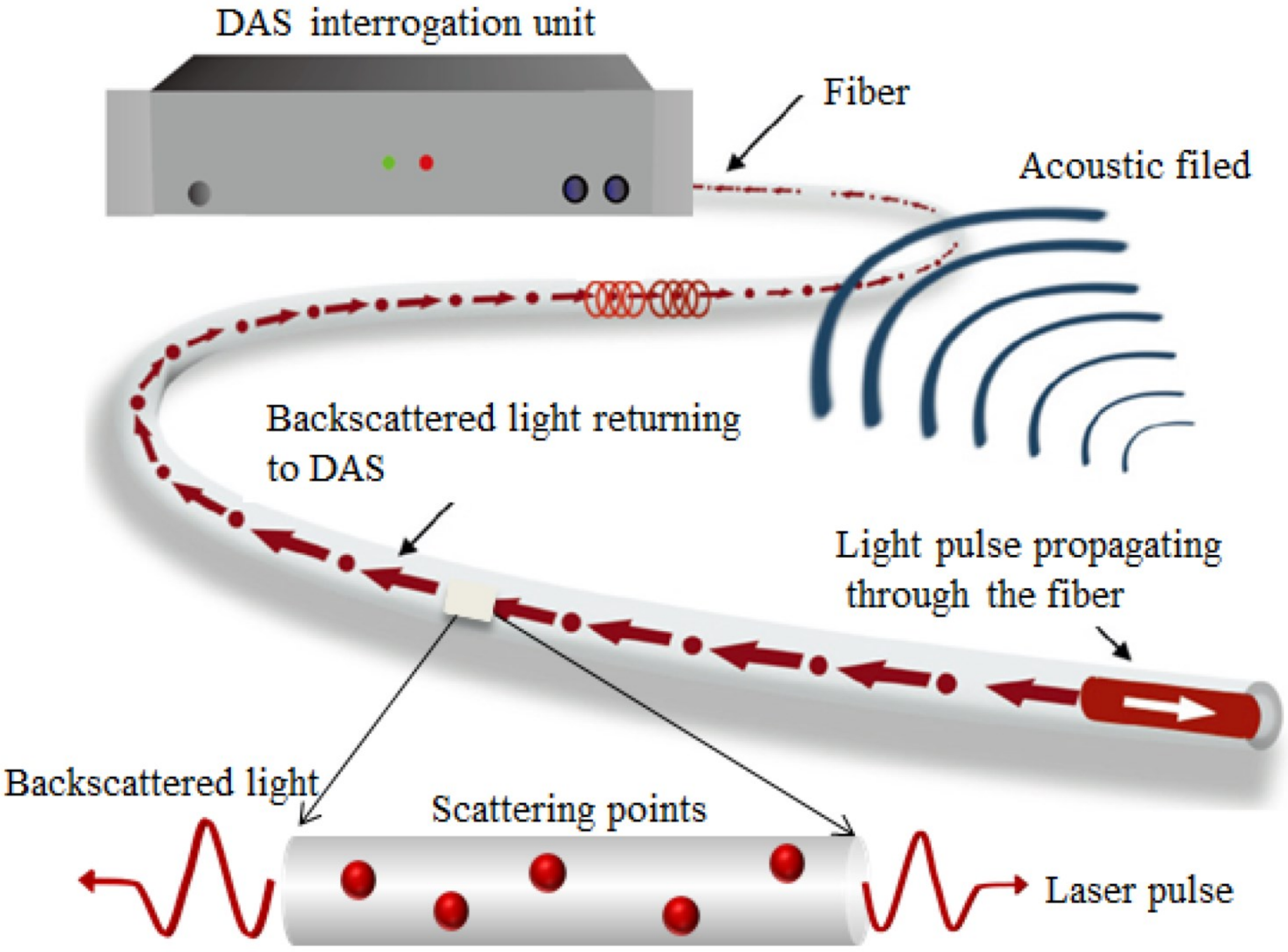
DESY, Zeuthen, 26.06.2025

HELMHOLTZ

DESY.

# What is Distributed Acoustic Sensing (DAS)

## Interrogate optical fibres with a single unit…




**Allows for monitoring seismic & acoustic waves:**

- Detects strain or strain rate
- Super sensitive ~ $10^{th}$ of pm/m
- Frequency rate of ~ 1 kHz
- Spatial resolution ~ 1 m
- Uses ordinary single-mode fibres
- 10.000's of detectors simultaneously

➔ to monitor vibrations

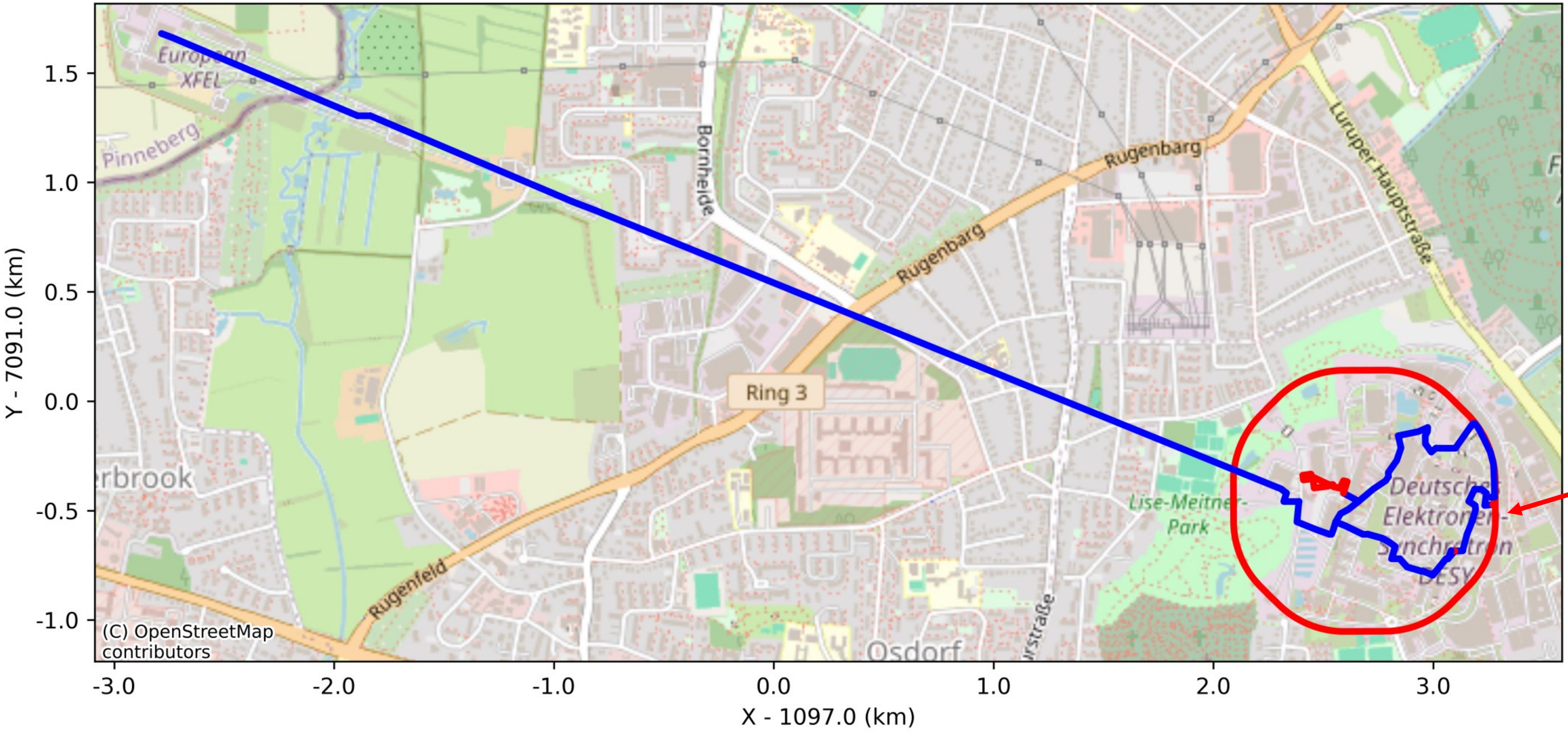
➔ to determine sources

➔ to mitigate perturbations

# Where was it used

## DESY campus… since 2021

DESY DAS fiber path

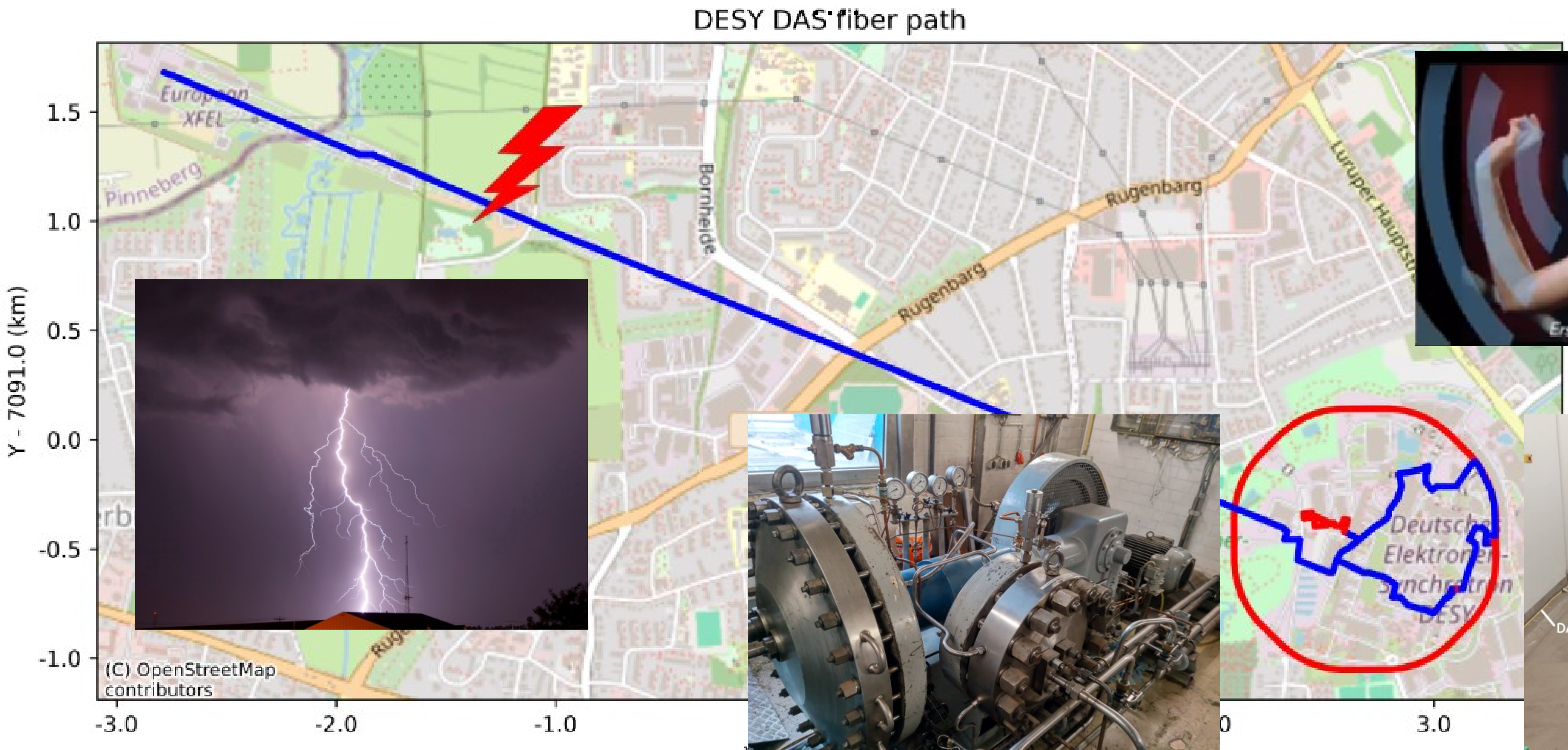


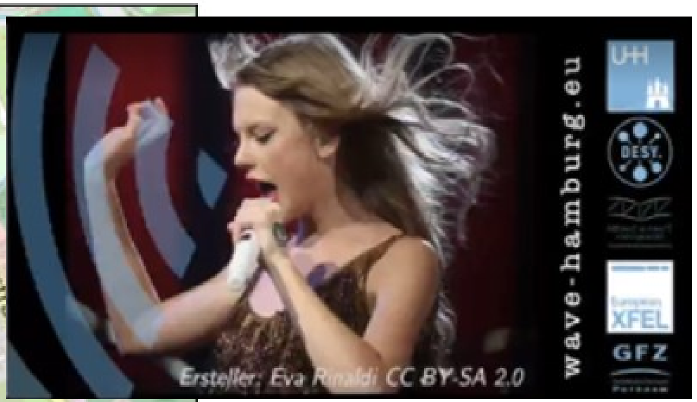

- Across DESY Campus
- Along EuXFEL
- Always forth and back
- Recently, the PETRA III ring was added

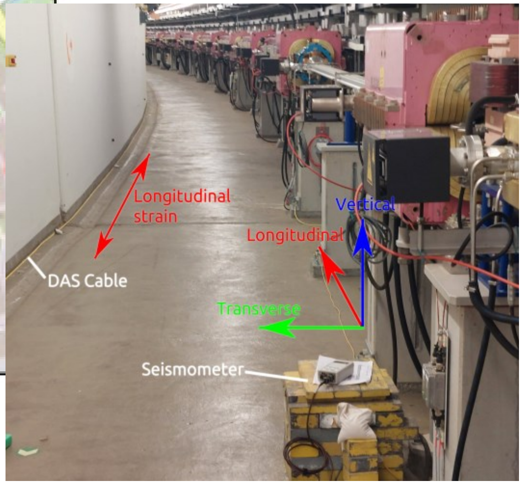
# If you like to know what happens when …

## Curiosity cabinet of seismic events …

➔ Come to my poster



# USE OF DESY'S FPGA FRAMEWORK IN THE LISA MISSION.

**Gianmarco Ricci**, Burak Dursun, Holger Schlarb

DESY - Machine Strahlkontrollen (MSK)

25/06/2025

HELMHOLTZ

DESY.

# Laser Interferometer Space Antenna (LISA) Mission.

- The objective of the LISA mission is to detect low-frequency **gravitational waves**.
- LISA will consist of three spacecraft exchanging laser beams arranged in a triangle formation.
- The **phase-meter** precisely measures gravitational waves by tracking tiny phase shifts in the laser light.

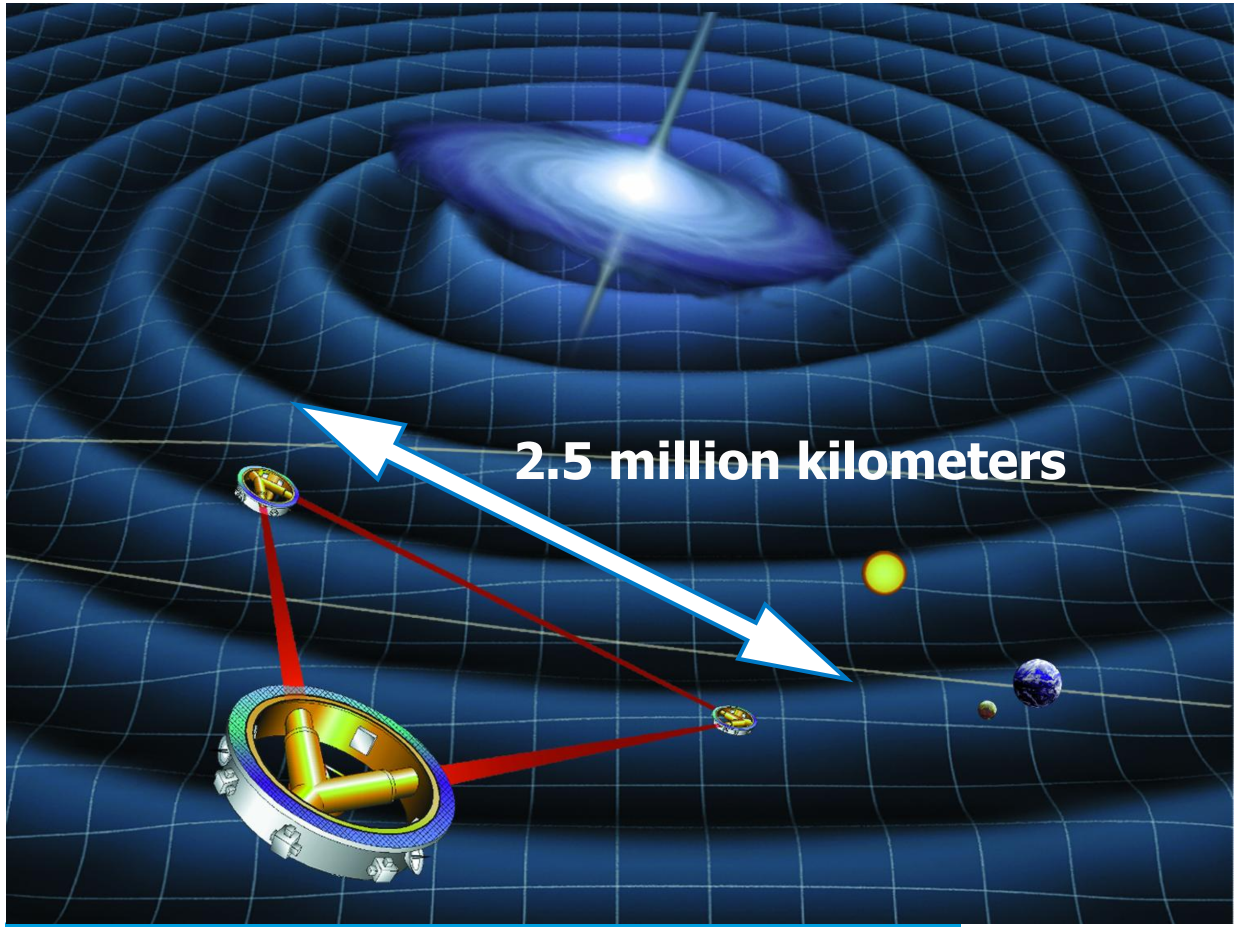



Figure: Three LISA spacecrafts in orbit, from [1].

[1] NASA Illustration of LISA, https://www.lisamission.org/.

# DESY's role in the mission.

- DESY’s Machine Beam Control (MSK) Group has multi-year experience in MicroTCA board design and development.
- Open-source FPGA firmware framework (FWK).


Figure: DAMC-FMC1Z7IO, fitted with a SoC from the Xilinx Zynq7000 family, from [2].

- MicroTCA & FWK combination enables **seamless transfer of technologies** from accelerator-based setups to other research applications.

[2] Cost-Optimized IO-Controller and Processing-Board: DAMC-FMC1Z7IO.

# What is the FPGA Firmware Framework?

- **Main goals**: standardize FPGA firmware project structure and project build process.

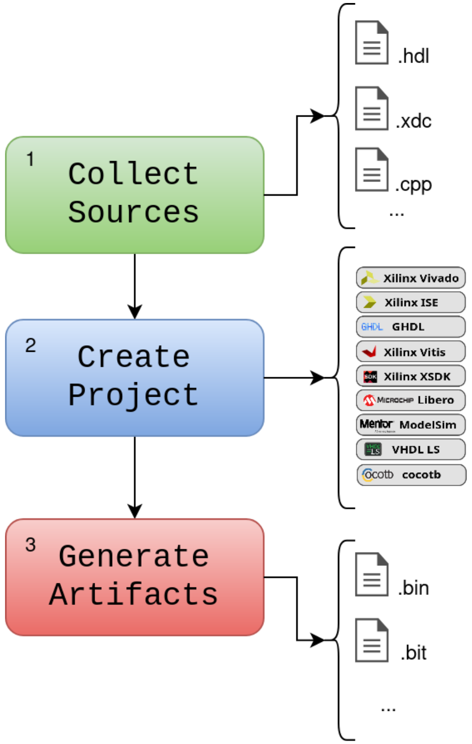
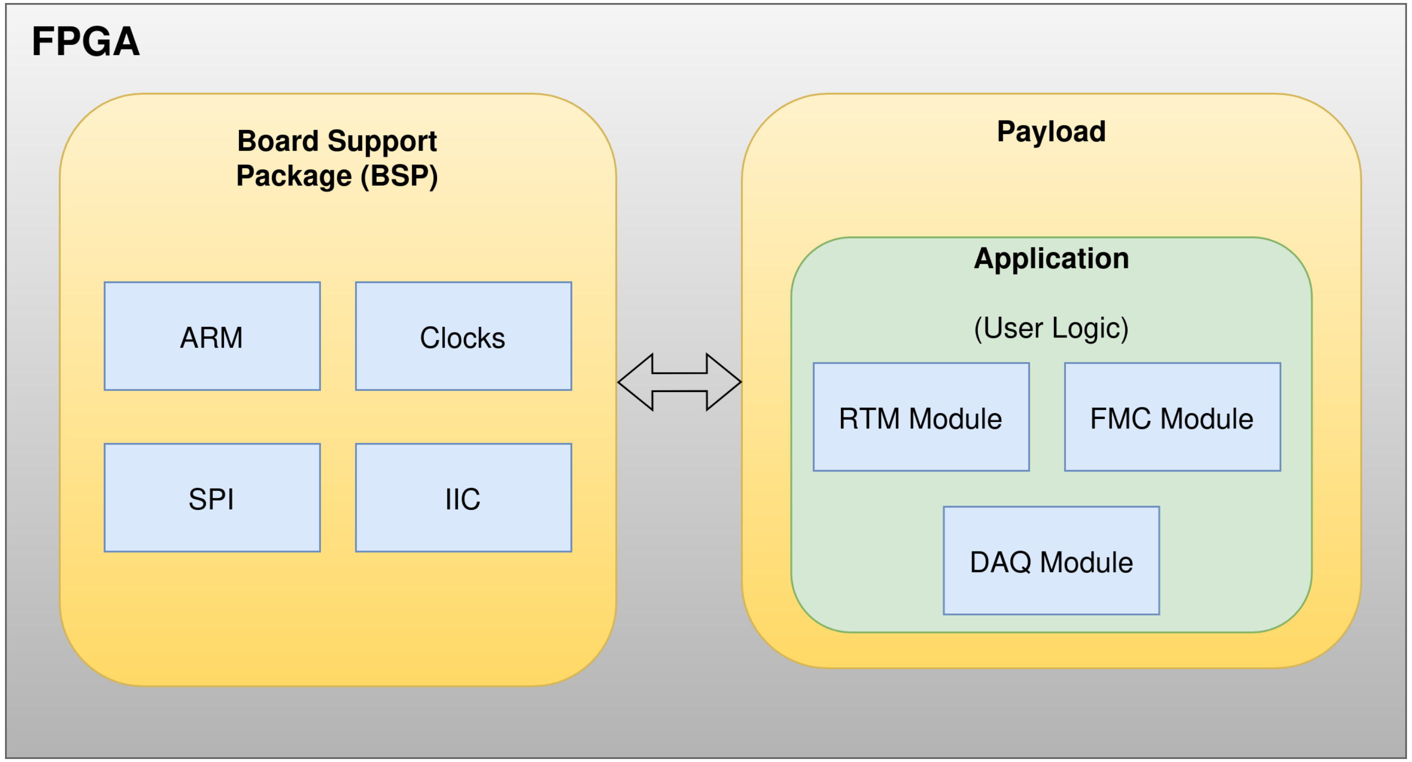



Figure: FPGA firmware framework workflow.




1. One Board Support Package (BSP) - Multiple applications.
2. Easy porting of existing applications to a new board.
3. **Open Source** BSPs available from DESY Gitlab.

# Vielen Dank

**Kontakt**

Gianmarco Ricci, PhD

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**Machine Strahlkontrollen (MSK)**

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# The progress report on Gun5.2 Operation

Avni Aksoy
On behalf of PITZ Team
Zeuthen, 26.06.2025

HELMHOLTZ

# Introduction

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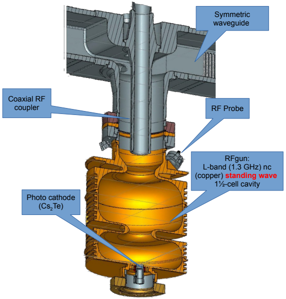
## PITZ RF gun

- L-band (1.3 GHz)
- normal conducting (copper)
- standing wave
- $1\frac{1}{2}$ - cell cavity
- max. power $\sim$7 MW
- max. gradient 60 MV/m
- max. RF pulse length: 1ms



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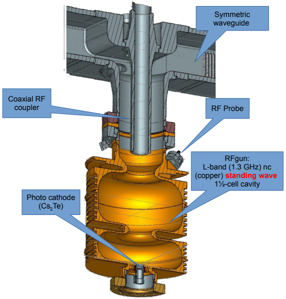
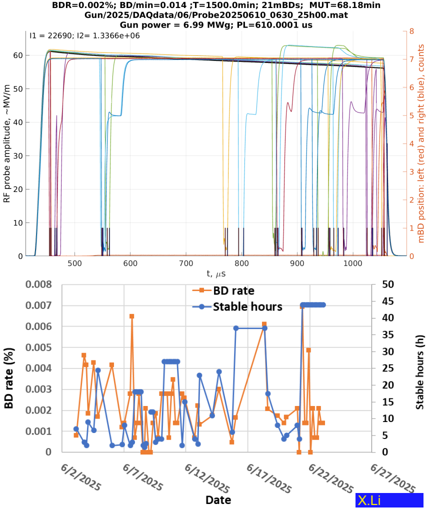



## What is new?

- Two in-cavity symmetric RF probes allow for improved LLRF regulation
- New motorized solenoid mover to minimize misalignment
- Improved cathode contact spring to improve point-to-point contact
- Symmetric wave-guide power coupling to minimize transverse kick induced by RF

# Some achievements




The BD rate is 100 times lower compared to the Gun 5.1.

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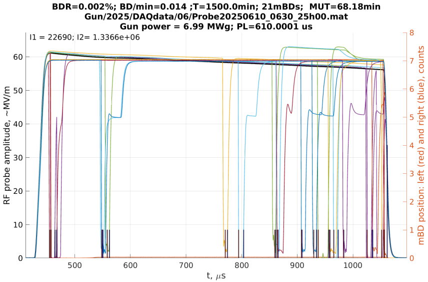
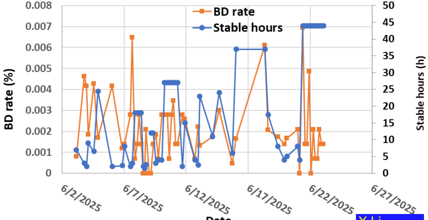
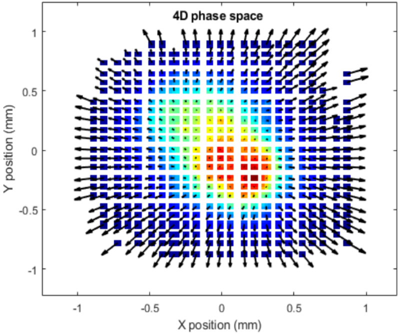
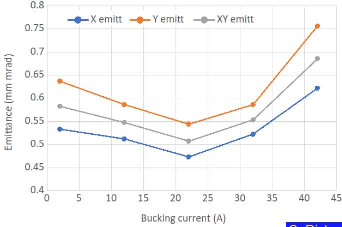



X.Li

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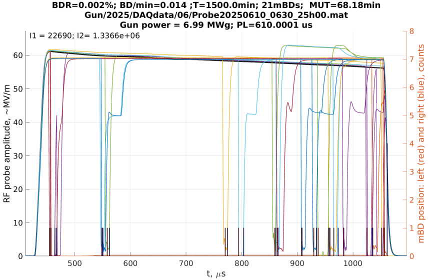


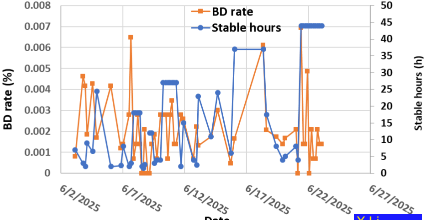


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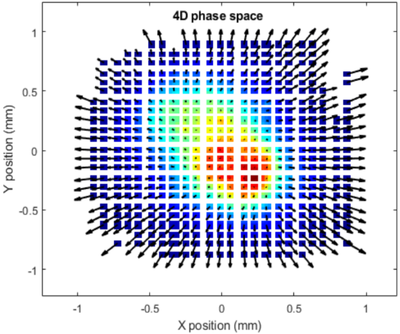


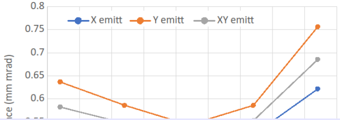


- Transverse emittance (gun quads off/off): 0.667/0.553 mm.mrad.
- Much better emittance, but still see X-Y discrepancy.
- The bucking coil needs to be tuned to get even better emittance.

Bucking current (A)

C. Richard

# Conclusion

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  - A higher accelerating gradient and improved solenoid alignment result in smaller beam emittance
  - bucking coil still needs to be optimized
- New laser beamline get into operation at PITZ ==> installation ongoing
  - We will work on different laser profiles on cathode

# Response Matrix Identification and Control

## Slow Feedback Controller Design for XFEL Using SINDy, LQR, and Kalman Filtering

Bindu Sharan, Marie Kristin Czwalinna and Annika Eichler

DESY MSK, 26.06.2025

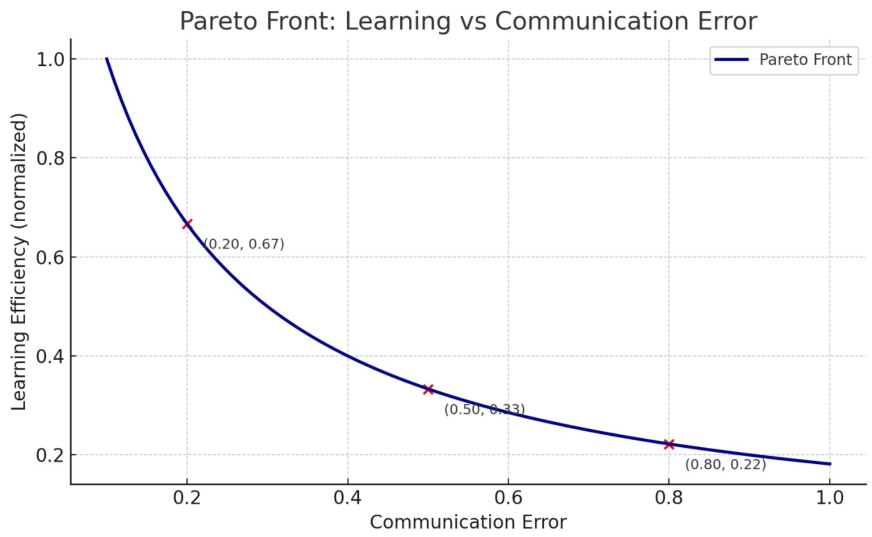
HELMHOLTZ

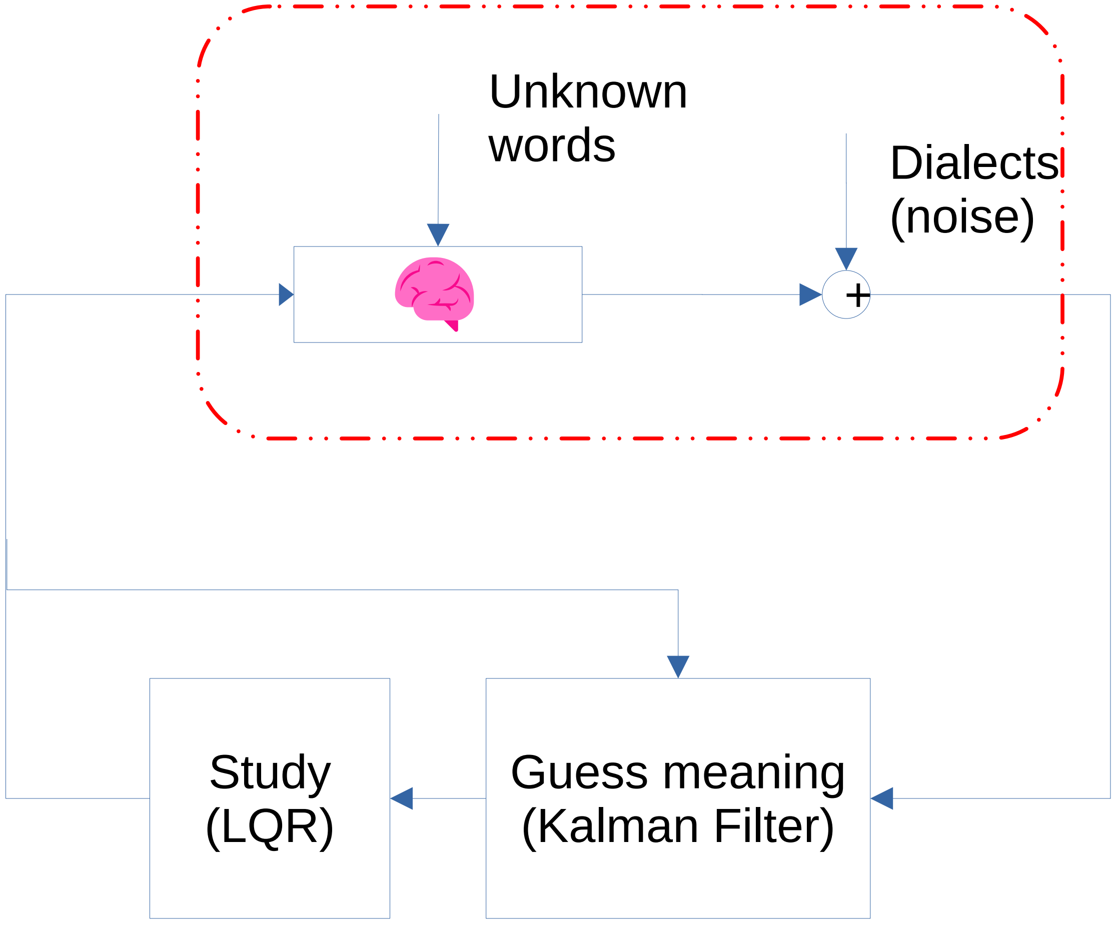
# Language Learning = Control System

## An Intuitive Analogy

**Imagine learning a new language:**

- Build knowledge (system)
- Hear dialects (noise)
- Guess meaning (Kalman Filter)
- Choose when, how and how much to study (LQR)



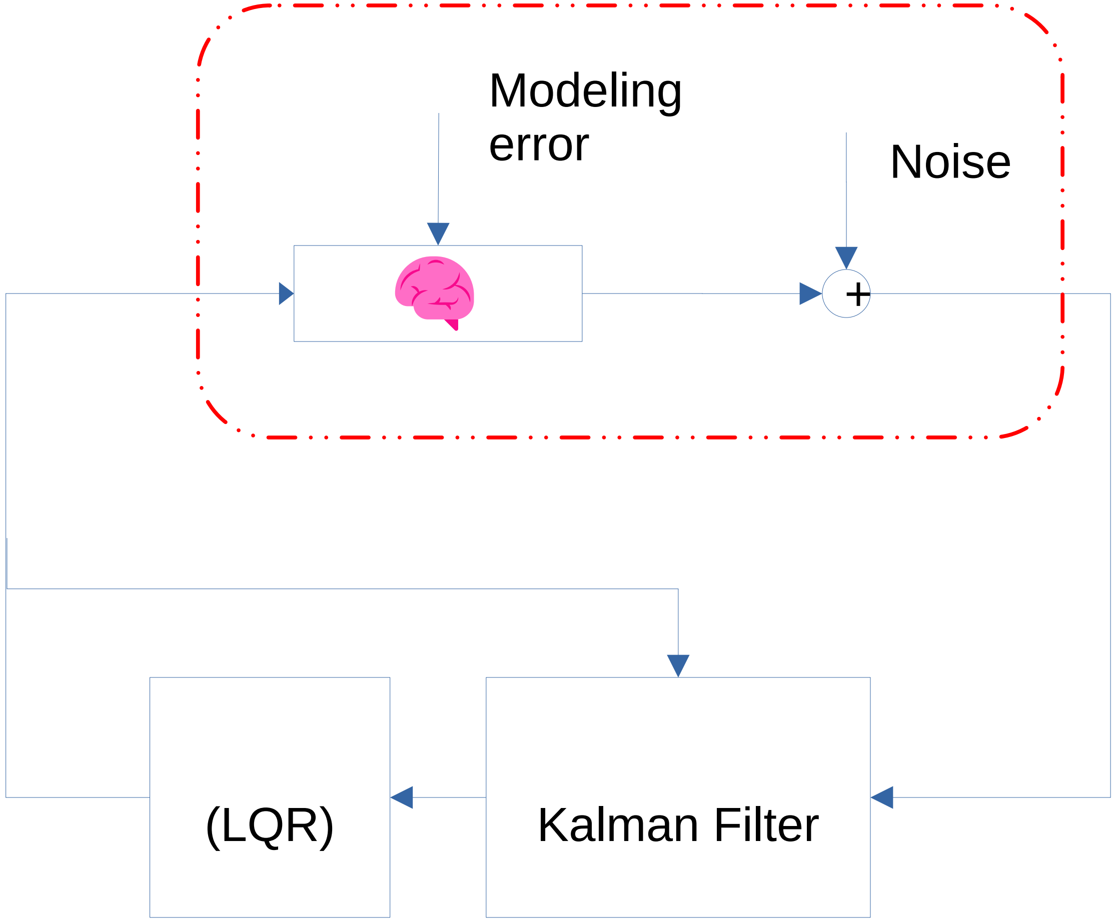



# What’s in Poster

## Slow feedback control for XFEL

**XFEL**

- Input: SumVoltage and Chirp
- Output : Beam arrival time and beam compression
- Model 🧠 : Response Matrix
- LQR objective: Have a specified arrival time and compression of beam with minimum change in Sumvoltage and Chirp




For more details come to my Poster