



WP2: LLRF

Steering Committee meeting, 20 Oct. 2026

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WP2: Low Level RF controls **20.10.2026**

DESY, HZB, CNRS

Convener & deputy: Julien Branlard (DESY) & Joshua Einstein-Curtis (DESY)

Main contacts with other partners: Axel Neumann (HZB), Christophe Joly (CNRS)

Task 2.1: Coordination of R&D on LLRF – M1-M48

- *Work package organization, meeting coordination, status reporting, milestones and deliverables*

Task 2.2: Efficient field control for high loaded-quality factor cavities – M1-M48

- *Develop techniques to efficiently drive cavities very narrow bandwidth*

Task 2.3: Vibration analysis and detuning control of cavities – M1-M36

- *Microphonics measurements and development of counter measures for accurate detuning control*

Task 2.4: Integrated LLRF control using Ferro-Electric Fast Reactive Tuners – M13-M48

- *Investigate and develop use of FE-FRT for detuning control*

Task 2.5: Energy efficient supervision and fault diagnosis – M1-M48

- *Develop new techniques, including machine learning, to improve fault diagnosis and RF system supervision*



WP2 – LLRF: status/evolution of Task 2.1

Coordination of R&D on LLRF

- **Past developments**

- Submitted milestone M40 (Impact risk analysis WP2) but no status update since ?
- A couple of WP2 coordination meetings

- **Current developments**

- Researcher hires and changes in WP composition → see slide 12
- Missed the August 26 deadline for **Milestone M6** (Demonstration of efficient solid state amplifier operation). Several reasons → see status / evolution of Task 2.5 on slide 8
- Upcoming deadline **Milestone M7** (Vibration analysis and detun. ctrl of cav.) → **on track**



WP2 – LLRF: status/evolution of Task 2.2

Efficient field control for high loaded-quality factor cavities

- **Past developments**

- Tests with Q-corrector show **factor 5 reduction** in forward power for only 8% coupler temperature
 - No new test (test stand is now occupied for cryogenic tests...)
 - Tests will resume next year, then publication to validate the work

- **Current developments**

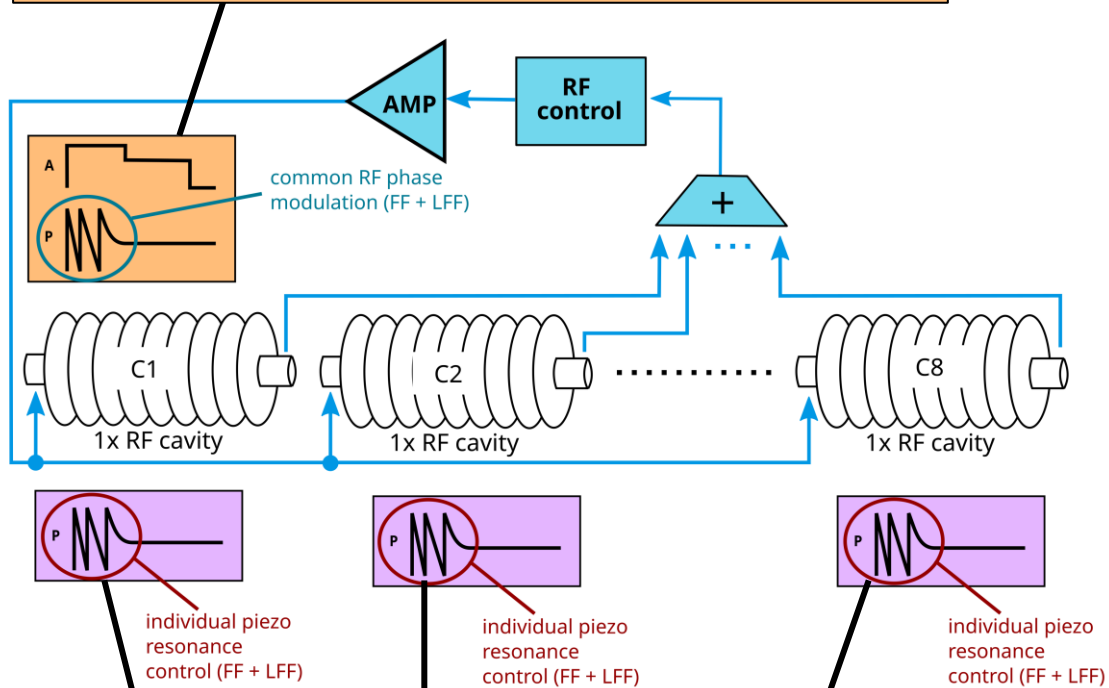
- Developed **techniques** (“resonant filling”) to **drive high loaded-quality factor** (narrow bandwidth) cavities (not using self-excited loop or PLL), adapted to pulsed and vector sum operation (i.e. interesting for XFEL upgrade) → see next slide

WP2 – LLRF: status/evolution of Task 2.2

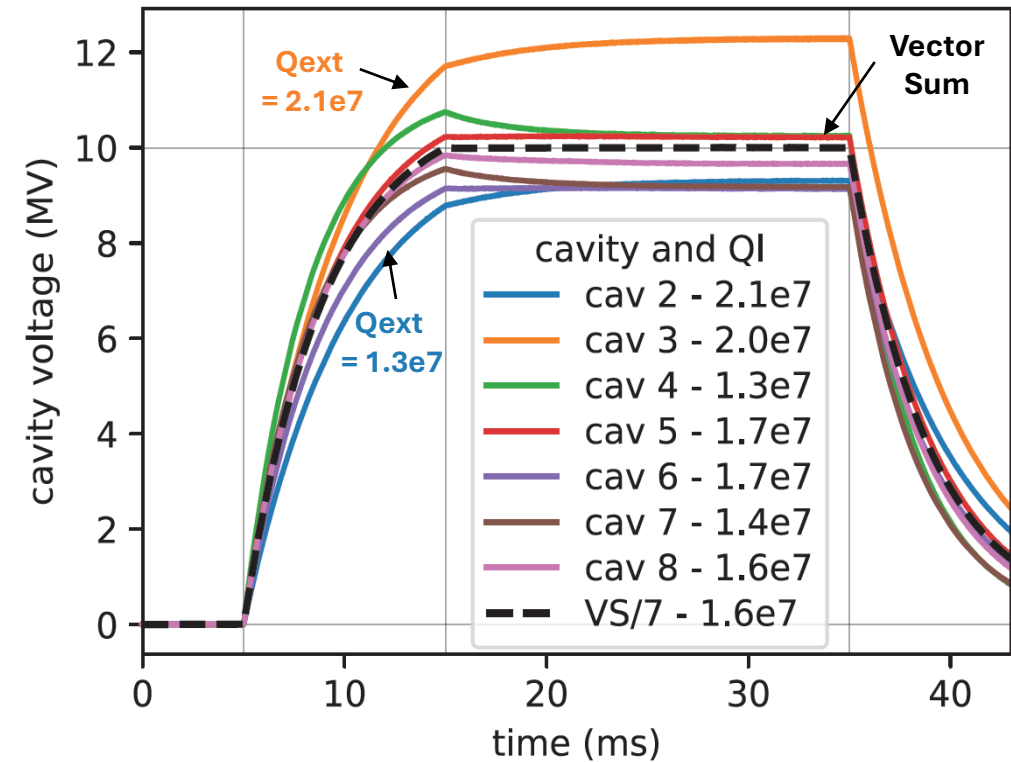
Efficient **field control** for high loaded-quality factor cavities

R&D to operate MCAV with high Q_{ext}

Drive all cavities in the VS with a **common RF phase modulation** to match the cavity resonance during fill



Compensate for remaining frequency mismatches with **individual piezo detuning compensation**



Demonstration at CMTB, MCAV (7 cavities), in long pulse operation with $Q_{ext} > 1 \times 10^7$

Presented **last week** at the LLRF topical workshop on advanced Feedback control

Proceeding in preparation



WP2 – LLRF: status/evolution of Task 2.3

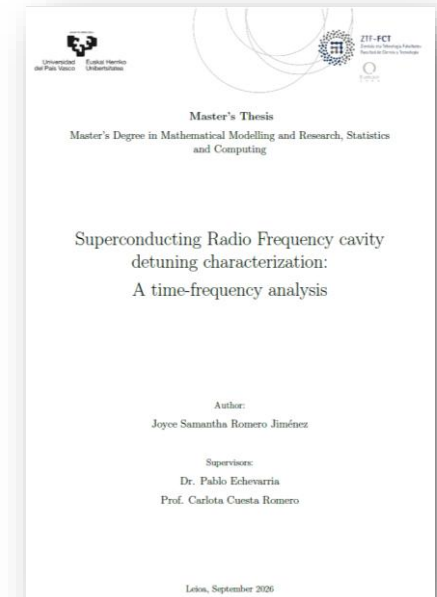
Vibration analysis and detuning control of cavities

- **Past developments**

- Energy efficient Lorentz force detuning compensation at EuXFEL → presented at Padova 2025 + published at IPAC 2025
- Developed an observer-based measurement of cavity detuning → published at Phys Rev Accel & Beam May 2026

- **Current developments**

- Implemented a **narrow bandwidth active noise cancellation** algorithm, test in CW at LCLS-II (SLAC) → presented and published at IPAC in **May 2026**
- Developed an **observer-based detuning** estimator at the EuXFEL gun → presented and published at IPAC in **May 2026** → update with new results presented at LLRF topical workshop **last week**)
- Exploring **AI-based method** to achieve detuning compensation → presented and published at IFAC in **Aug. 2026**
- **Master Thesis** on detuning characterization using wavelets → thesis accepted **Sept. 2026**
- Thorough analysis of **microphonics** at DESY (XFEL + test stand) → report in preparation on impact for CW operation (→ **Deliverable D5**)





WP2 – LLRF: status/evolution of Task 2.4

Integrated LLRF control using Ferro-Electric Fast Reactive Tuners

- **Past developments**

- ...

- **Current developments**

- Adaptation of an **existing cavity simulator** (including LLRF action)
 - The cavity used for simulation is 704 MHz elliptical 5 cells (Eurotrans) with a known mechanical response
 - **Now adding FE-FRT with 4 blocks**
 1. HV amplifier
 2. Conversion HV → E-field (needs clarification)
 3. E-field to Ferro-Electric behavior (using report from WP1 as reference)
 4. Ferro-Electric to detuning
 - For the milestone validation
 - WP1 expects a full test and demonstrator with a 2-cell cavity and FE-FRT in Dec. 2026
 - Once this data is available, we will use these results to adjust the model

WP2 – LLRF: status/evolution of Task 2.5

Energy efficient supervision and fault diagnosis

- **Past developments**

- AI-based diagnostic for LLRF (presented and published at IPAC 2025)

- **Current developments**

- **Delays with the SSPA test stand → missed deadline for Milestone M6**
- The situation was identified and presented as a risk in the risk analysis (Milestone 40)
- Root cause comes from the fact that it was expected to perform study together with Cryoelectra (when setting up milestones)
- CRE did not join the iSAS so DESY is trying to do this test alone → acquiring an SSA + setting up of a test stand
- Still milestone on track until summer 2026 when the SSPA was damaged (too high reflection / overheating)
- Now, SSA is **repaired**, **more personnel** assigned to the task and **tests can continue**
- Goal is to submit **milestone M6 by end of 2026** (instead of Aug. 2026)



Damaged power amplifier chip on the Qorvo 1 kW SSPA



WP2 – LLRF: progress to take into account Advisory Board recommendations

- **Progress** to take into account Advisory Board recommendations

- Recommendation from Advisory Board to WP2

“The Board encourages the teams to maintain this momentum and to continue delivering high-quality results in support of the overall project objectives. ”

- Beyond this, there were general comments to work on visibility
 - Action: systematic check before publication of proper iSAS acknowledgment
 - Action: visibility through presence at workshop and conferences
 - Not just WP2, also External Relations (Maud Baylac) ESSRI workshop for ex.



WP2 – LLRF: plans to achieve milestones & deliverables

- Milestones & deliverables **on track?**
- Plans to **achieve** milestones & deliverables
 - Almost all milestones and deliverable are on track
 - Only M6 delayed → assigned more resources + pushed other tasks to lower priority

- **Conference talks, proceedings, publications**
 - Were presented in the previous slides (where relevant).
 - Below current list of iSAS publications for WP2

2025

- IPAC'25 (Max Herrmann et al.) Optimization of piezo operation for superconducting Tesla cavities at EuXFEL
- IPAC'25 (Burak Dursun et al) Enhancing quench detection in SRF cavities at the EuXFEL: towards machine learning approaches and practical challenges → cannot be accounted for due to missing iSAS acknowledgement
- IPAC'25 (Yue Sun. et al.) Machine learning for calibration drift forecasting in superconducting RF cavities
- arXiv (Bozo Richter et al.) Estimation of superconducting cavity bandwidth and detuning using a Luenberger observer

2026

- PRAB May 2026 (Bozo Richter) Estimation of superconducting cavity bandwidth and detuning using a Luenberger observer
- IPAC'26 (Max Herrmann et al.) Detuning Estimation for a doubly-fed Normal Conducting Gun
- IPAC'26 (Bozo Richter et al.) Narrowband Active Noise Control for Continuous for Continuous Wave Operation of Tesla Cavities
- IPAC'26 (J. S. Romero Jiménez) SRF cavity detuning characterization by continuous wavelet transform: a time-frequency analysis
- IFAC'26 (Andrei Maalberg) KIND : a Kalman-inspired adaptive estimator for SRF cavity detuning
- Uni. Basque Country Master Thesis Sept. 26 (J. S. Romero Jiménez) Superconducting Radio Frequency cavity detuning characterization: a time-frequency analysis
- LLRF topical workshop Oct. 2026 (Bozo Richter et al.) Resonant filling for long pulse operation of EuXFEL using iterative learning based feed forward

WP2 – LLRF: young researcher hires, changes in WP composition

- Young researcher hires, changes in WP composition
 - DESY: hired **student helper** Mona Eberenz (May 2026)
→ helping with microphonics tests and cavity bandwidth characterization
 - New WP2 **deputy**: Christian Schmidt → Josh Einstein-Curtis (DESY)
 - DESY : setting up 1 year **consulting contract** for a senior colleague Heinz Prysichelski
→ support with SSPA test stand (milestone M6)



Mona Eberenz



Josh Einstein-Curtis



Heinrich Prysichelski



WP2 – LLRF: ideas for connections to industry

- Ideas for connections to industry
 - At DESY, long standing collaboration with industry for MTCA board production
 - At DESY, company ELSPEC (RF cables) has an on-campus office (tests with industry)
 - Contact exchange with vendors at workshop and conferences
 - Setup the E2Scale research proposal together with Cryoelectra (news?)