Lodz University of Technology contribution to ESS-ERIC

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on behalf of the ***TUL-DMCS team***

Workshop on Research & Innovation in Poland, 1–2 Dec 2025
Institute of Nuclear Physics Polish Academy of Sciences

Contributions summary

#	Type	Title	Realization
1	**AiK 8.2**	**Development and delivery of LLRF Control system to THE IN-KIND CONTRIBUTION AGREEMENT SIGNED BETWEEN European spallation source ERIC and the Polish Electronic Group (PEG)**	05.2016 – 08.2025
2	**IIK 14.4.3**	**IPMI-EPICS-BLM-RTM SOFTWARE AND FIRMWARE DEVELOPMENT**	04.2018 – 09.2021
3	PO 24022731	Piezo Driver requirements and specification change	04.2021– 03.2024
4	PO 24028668	The Neutron beam loss monitoring system software/firmware support	03.2022 – 10.2025
5	**AIK 19.2**	**Software for superconducting cavities characterisation and the Ess Test stand 2 cryomodule programme**	12.2023 – 12.2025

AiK 8.2 - Main facts

- Project title:

Development and delivery of LLRF Control system to THE IN-KIND CONTRIBUTION AGREEMENT SIGNED BETWEEN European spallation source ERIC and the Polish Electronic Group (PEG)

- Based on:

THE IN-KIND CONTRIBUTION AGREEMENT SIGNED BETWEEN EUROPEAN SPALLATION SOURCE ERIC (ESS ERIC) AND PEG (NCNR, WUT, TUL)

- Project beginning:
  - 11.08.2016 (effectivelly beg. 2017),

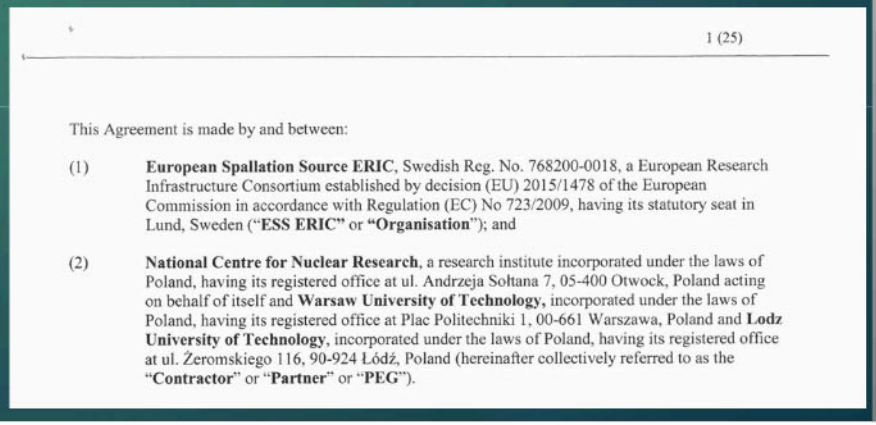
- Project end date:
  - 30.07.2025,

PEG for LLRF

- **Polish Electronic Group:**
  - **National Center for Nuclear Research**
  - **Warsaw University of Technology**
  - **Lodz University of Technology**

  passionate about complex systems
- Working together on different LLRF system for over a decade (FLASH/XFEL)…
- In 2017, we were invited to join the ESS LINAC project endeavor
- Our mission?

„ Support the design and deliver rock-solid LLRF systems — the nervous system of a world-class accelerator"



1 (25)

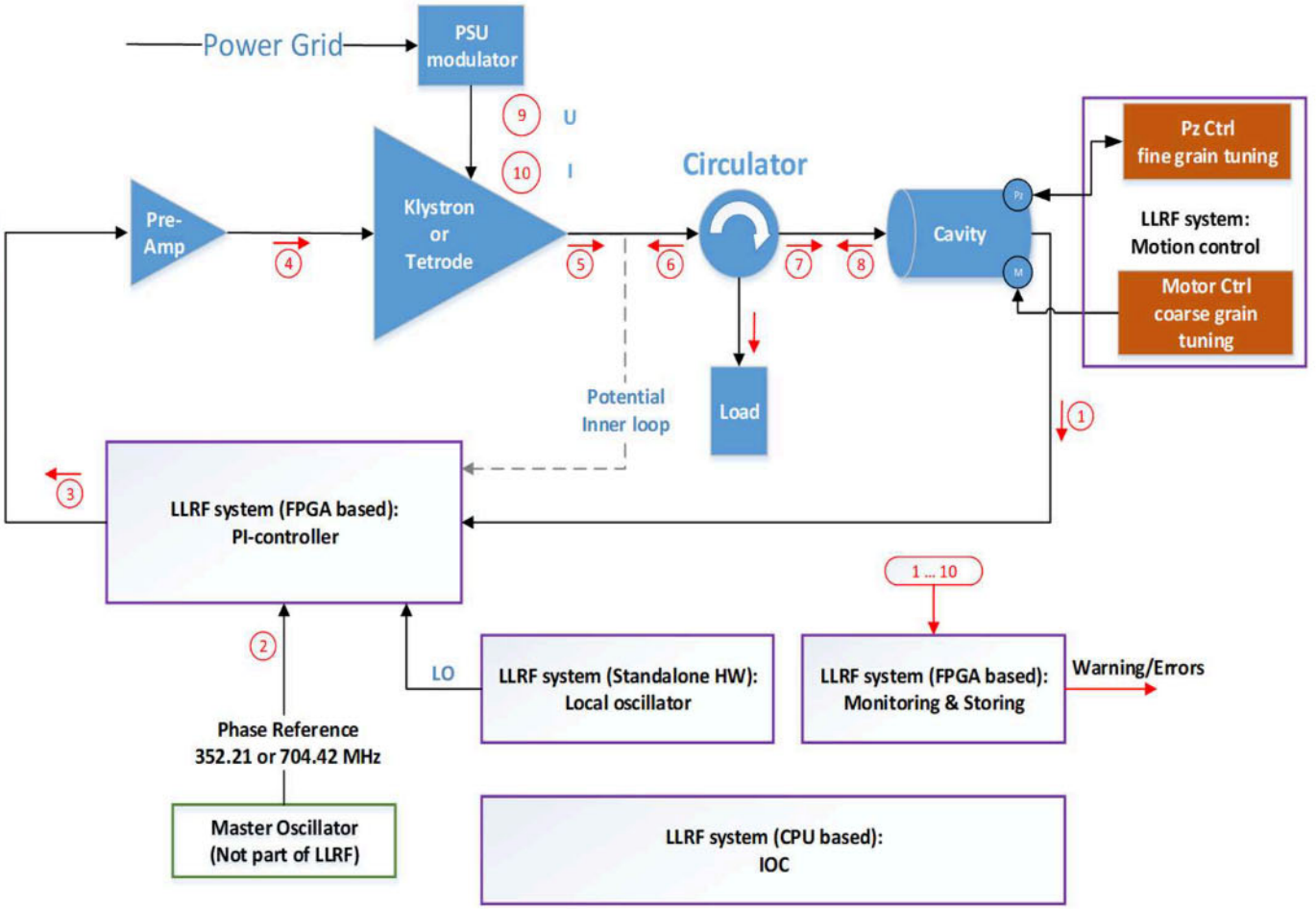
This Agreement is made by and between:

(1) **European Spallation Source ERIC**, Swedish Reg. No. 768200-0018, a European Research Infrastructure Consortium established by decision (EU) 2015/1478 of the European Commission in accordance with Regulation (EC) No 723/2009, having its statutory seat in Lund, Sweden ("**ESS ERIC**" or "**Organisation**"); and

(2) **National Centre for Nuclear Research**, a research institute incorporated under the laws of Poland, having its registered office at ul. Andrzeja Sołtana 7, 05-400 Otwock, Poland acting on behalf of itself and **Warsaw University of Technology,** incorporated under the laws of Poland, having its registered office at Plac Politechniki 1, 00-661 Warszawa, Poland and **Lodz University of Technology**, incorporated under the laws of Poland, having its registered office at ul. Żeromskiego 116, 90-924 Łódź, Poland (hereinafter collectively referred to as the "**Contractor**" or "**Partner**" or "**PEG**").

Project Goal

- Deliver 120+ LLRF racks, ready for 24/7 mission-critical operation (finally 80 + components for 40)
- Provide flexibility for different RF systems types operation,
- Operate in an international environment with evolving requirements



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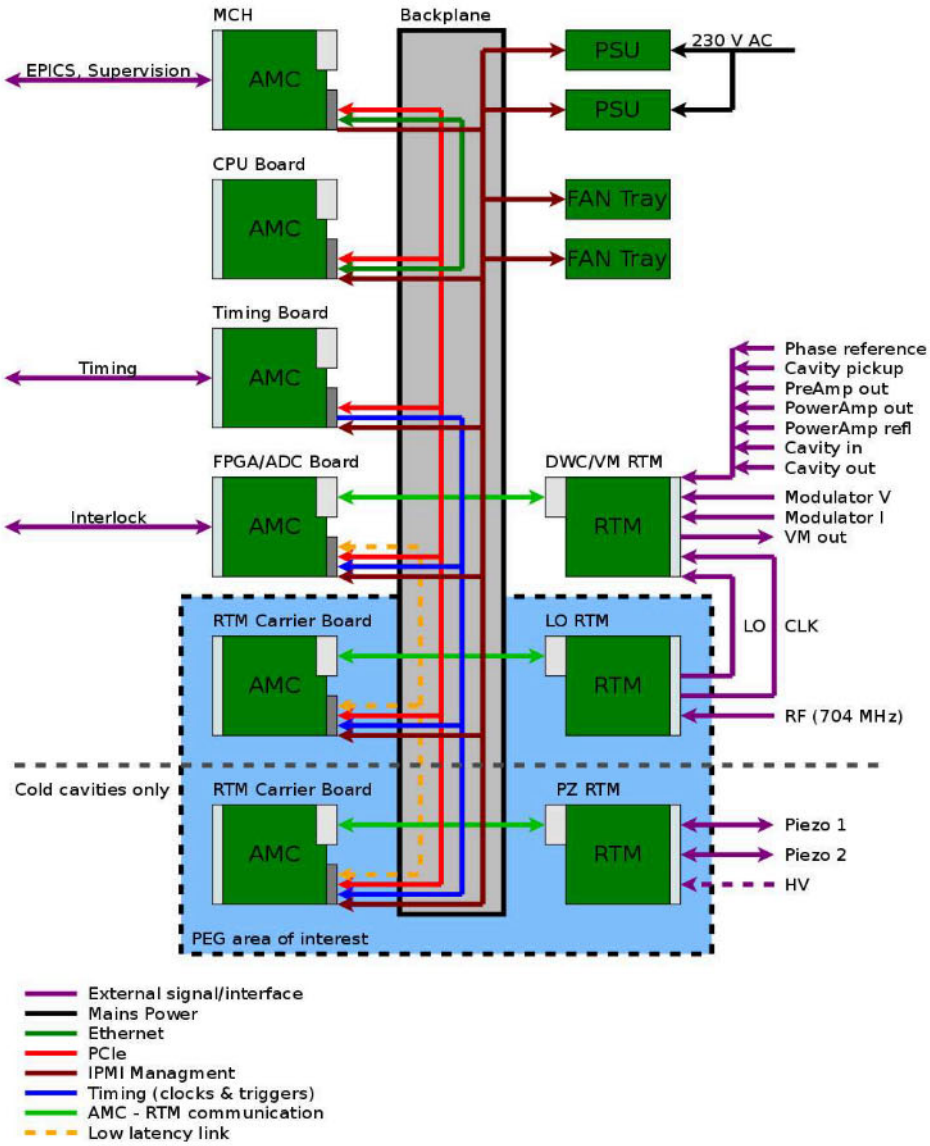
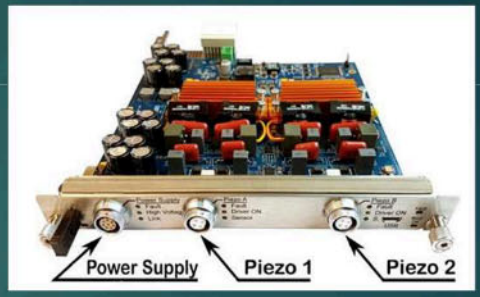


The MTCA modules: Piezo Driver RTM

- Piezo Driver RTM and external Power Supply Module- designed, developed, produced and delivered by DMCS-TUL
  - Provides two independent piezo supply channels:
    - Output voltage (0- 200V, -40 to 160V),
    - Can work in actuator and sensor mode,
    - Output signal BW up to 3 kHz,
    - External power supply module for high voltage delivery,
    - Integrated acquisition capability of voltage and currents of ouput and input signals,
    - Integrated diagnostics and over-voltage and over current protection,
    - Flexibility of configuration for operation with spoke and elliptical cavities.
- **Four prototype versions** prepared and **successfully tested** with dedicated modules in the local test-stands and in the ESS test stand 2 and Freia (spoke and H-Beta) ,
- The Piezo Driver modules delivery:
  - **Specification change** as well as **Covid-19 pandemic** situation driven design adjustments required due to components obsolescence and/or long delivery time,
  - **All required boards produced**, tested and delivered to ESS,
  - **Modules integrated in LLRF systems** (or delivered for temporary storage before next LLRF systems integration).



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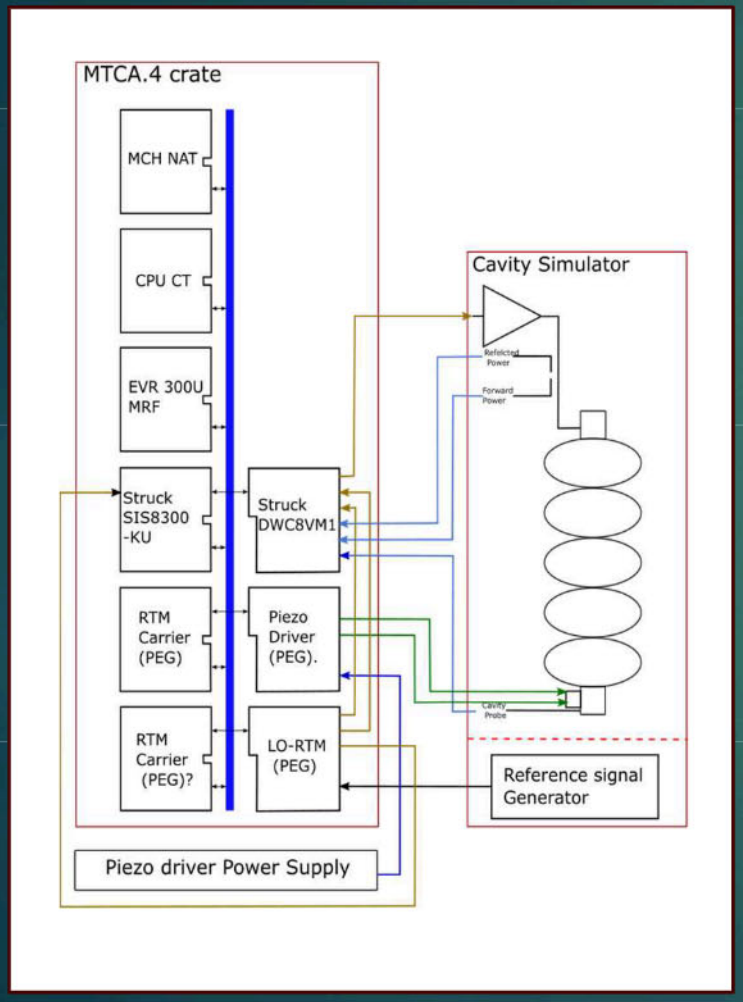
The LLRF reference system integration and evaluation



- **The first fully integrated LLRF system for elliptical cavities**
- Set-up included COTS and PEG modules
- Established and maintained by TUL-DMCS,
- Used for:
  - Hardware evaluation,
  - Firmware and software development and evaluation,
  - Integration and verification test preparation and evaluation.
- Allowed for infrastructure weakness and faults determination and diagnosis,
- Still maintained in operation for the FW improvements testing and potential main systems servicing purposes.

Scope summary

- **Hardware components design, evaluation and production for M-Beta and H-Beta cavities control systems:**
  - **RTM Carrier board,**
  - ***RTM Piezo Driver,***
  - **Local Oscillator board,**
  - **PSS switch,**
  - **Pin diode,**
  - **Electron pick-up,**
  - **RF splitbox**
- **Hardware cavity simulator design and evaluation,**
- ***Reference LLRF system integration and evaluation,***
- ***LLRF systems integration, installation in the ESS and evaluation,***
- ***Chosen firmware components preparation.***

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IIK 14.4.3 - Main facts

- Project title:

IPMI-EPICS-BLM-RTM SOFTWARE AND FIRMWARE DEVELOPMENT

- Based on:

THE IN-KIND CONTRIBUTION AGREEMENT SIGNED BETWEEN EUROPEAN SPALLATION SOURCE ERIC (ESS ERIC) AND PEG (NCNR, WUT, TUL)

- Project beginning:
  - 04.2018,
- Project end date:
  - 15.09.2021,

In-Kind project scope

Task no.	Deliverables	Delivery Deadline / Delivery MS
WU 1	MTCA.4 RTM Carrier board integration	2021-09-15
WU 2	icBLM and nBLM controls and realization	2021-09-15
WU 3	IPMI EPICS integration	2021-09-15

- Due to the pandemic, project deadline extended till 15.09.2021. Additional months for ESS support,

WU 1 RTM Carrier integration

- **WU1 – MTCA.4 RTM Carrier board integration**

In the LLRF system of ESS there will be an AMC board for supporting the RTMs dedicated to the Local Oscillator and the piezo-driver. Partner's contribution will consist of the following contributions

- Development of kernel drivers and user space drivers to allow the AMC integration,

- Development of EPICS device support and basic OPI for the management of the AMC board.

WU 1 – Deliverables – Summar

- SAT procedure completed and acceptance protocols for deliverables signed (needed for Ministry reporting process and final delivery),
- Main achievements:
  - RTM Carrier hardware:
    - Piezo Driver board integration done,
    - Locall oscillator module integration done,
    - HW specification change – prototyping and evaluation completed,
  - BSP firmware (by NCBJ) for the RTM carrier, synchronized with FW,
- Adaptation to the operator/users took place @ TS2 – piezo mainly,
- Extension of the piezo driver functionality done in the scope of different project.

WU 2 - nBLM controls and realization

- **WU2 – icBLM and nBLM controls and realization**

The Beam Loss Monitor system for ESS comprises two types of devices to detect beam loss. A system based on ionization chambers (icBLM) is the primary method to detect beam losses in the superconducting linac. This system is crucial for machine protection. In the low-energy part of the linac, a different system will be used that is based on detection of neutrons, called the neutron Beam Loss Monitor (nBLM) system. Developing (FPGA) firmware for the nBLM system is also a part of this task.

The Partner shall:

- Develop FPGA firmware that runs on the icBLM and nBLM back-end electronics (BEE) and has the following tasks:
    - Process the incoming data (from ADC or other front-end electronics)
    - Provide the data to the (EPICS) control system for monitoring purposes
    - Run algorithms for machine protection purposes that assess the beam conditions and in case of unacceptable beam losses inform the Beam Interlock System by dropping the BEAM_PERMIT signal and also providing data that is needed to analyse the conditions that led to dropping the beam permit
    - Perform checks to verify that the system components and functions are working properly.

The firmware development and implementation, which includes integration of the nBLM and icBLM systems in the ESS firmware framework, shall be compliant with the standards set by ESS ERIC and performed in collaboration with the Beam Diagnostic section of the Accelerator Division at the ESS ERIC.

WU 2 - icBLM controls and realization

- Develop and implement the following software:
  - icBLM specific algorithms for data processing that run on the icBLM BEE CPU,
  - the low-level drivers to interface to the (EPICS) control system,
  - implement EPICS databases to store and process the data,
  - Develop graphical user interfaces to visualize the icBLM specific data.

The software development and implementation, which includes software integration of the icBLM system in the ESS ERIC standard control system, shall be compliant with the standards set by ESS ERIC and performed in collaboration with the Beam Diagnostic section of the Accelerator Division at the ESS ERIC.

(Software development for the nBLM system is covered by a separate contract and is not in the scope of this contract.)

WU 2 – nBLM controls and realization – Deliverables

Del. ID	Main deliverables	Delivery MS	Acceptance Criteria type	Comment
D2.1	Specification revision	MS1	Review	Delivered
D2.2	Firmware with functionallity realization	MS10	Review	Delivered
D2.3	Device driver and User space driver	MS10	Review	Delivered
D2.4	~~Epics device suport~~	~~MS10~~	~~Review~~	
D2.5	~~OPI GUI~~	~~MS10~~	~~Review~~	
D2.6	Test Plan	MS10	Test report	Delivered

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D2.4	Epics device suport	MS10	Review	
D2.5	OPI GUI	MS10	Review	
D2.6	Test Plan	MS10	Test report	

WU 3 – IPMI EPICS integration – Deliverables

Del. ID	Main deliverables	Delivery MS	Acceptance Criteria type	Comment
D3.1	Specification revision	MS1	Review	
D3.2	Low Level library (communication with MCH)	MS10	Review	
D3.3	Daemon service for constant monitoring	MS10	Review	Obsolete
D3.4	Epics device support	MS10	Review	
D3.5	IOC integration	MS10	Review	
D3.6	OPI GUI	MS10	Review	
D3.7	Test Plan	MS10	Test report	

WU 3 E4I – Deliverables - Summary

- Epics 4 IPMI functionality provided according to the TA scope,
- All software components done,
- Verification done in-house and on the dedicated test stand platfrom – SAT accepted,
- DMCS ready to support deployment/commissioning process.

AIK 19.2 - Main facts

- Project title:

SOFTWARE FOR SUPERCONDUCTING CAVITIES CHARACTERISATION AND THE ESS TEST STAND 2 CRYOMODULE PROGRAMME,

- Based on:

THE IN-KIND CONTRIBUTION AGREEMENT SIGNED BETWEEN EUROPEAN SPALLATION SOURCE ERIC (ESS ERIC) AND LODZ UNIVERSITY OF TECHNOLOGY (TUL)

- Project beginning:
  - 01.06.2023 (According to the TA),
  - 01.10.2023 (According to the application to the MoSaHE),
  - 29.12.2023 (Agreement singed with funding agency)

- Project end date:
  - 31.12.2025 (According to the TA),
  - 30.03.2026 (According to the application to the MoSaHE),

Organization

Contact person from the Partner:

General and Technical Coordinator:
Wojciech Cichalewski (wcichal@dmcs.pl)

Contact persons from ESS ERIC:

SRF Section Leader and SCL G01 Machine Section Coordinator:
Paolo Pierini (Paolo.Pierini@ess.eu)

TS2 Machine Section Coordinator:
Cecilia Maiano (Cecilia.Maiano@ess.eu)

In-kind Project Polish side contribution

- Project supported by Polish funding agency:
Ministry of Science and Higher Education.

- Project title (in Polish):
„Projekt KMiTI PŁ w ramach ESS - ERIC”

- Agreement No:
Nr 2023/WK/11

- Project beginning
01.10.2023

- Project end
30.03.2026 (31.12.2025)

Main contributions

- **Provide complete set with four piezo system** (2 channels) for the four cavities module operation at the ESS Test Stand 2. **The piezo systems** do not require new hardware developments and are of **the same design** of the component provided with **the PEG IK contribution to the construction phase** (AIK 8.2). **The units** object of the delivery **will provide** at the TS2 **the same functionality** foreseen in the linac **and will enable testing** of the piezo-assisted cavity field control **prior to the linac commissioning.**

- **Prepare, develop, evaluate, deliver, test and deploy software** (and/or possibly firmware) solutions **providing functionality** needed **for superconducting cavities testing** and **characterization** at the ESS Test Stand 2.

- **Prepare, develop, evaluate, deliver, test and deploy software** (and/or possibly firmware) solutions **supporting resonators operation** (configuration, monitoring and management), **especially related to the Piezo Drivers** (PD) provided by TUL-DMCS.

Project structure

- Identified Work Units:

1. Software tools for superconducting cavities testing and characterization at the ESS Test Stand 2,

2. Software solutions supporting resonators operation especially related to the Piezo Drivers (PD),

3. Four piezo systems delivery for the TS2 operation

WU 1. Software tools for superconducting cavities testing and characterization at the ESS Test Stand 2

- WU Scope:
  - **1.1. Tool for determining LFD static/dynamic coefficients**
  - **1.2. Tool for automated measurement of piezo range and polarity control**
  - **1.3. Identification of the longitudinal mechanical modes using PD**
  - **1.4. Pi-modes and passband modes identification,**
  - **1.5. Cavity performance evaluation without beam,**
  - **1.6. Piezo capacitance characterization,**

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WU 2. Software solutions supporting resonators operation especially related to the Piezo Drivers (PD)

- WU Scope:

2.1. Cavity parameters identification (bandwidth and detuning)

2.2. Overall status monitoring (grad. phase, regulation performance, etc.)

2.3. Piezo capacitance measurement

2.4. DAC offset compensation

2.5. Piezo range optimization (pr. C)

2.6. Forward and reflected power signal calibration (cross-talk reduction/directivity) verification

2.7. Virtual probe signal monitoring

2.8. Slow and Fast cavity quench detection

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WU 3. Four piezo systems delivery for the TS2 operation

- WU Scope:

3.1. Piezo driver, PD power supply and AMC board production and purchase

3.2. Delivery and installation

3.3. Integration and commissioning

Summary

- Successfully completed two in-kind project with ESS,
- Last in-kind project realized as a part of the ESS initial operation scope – to be concluded beg. 2026,
- Contribution scope mainly dedicated to the accelerator systems:
  - LLRF systems and superconducting cavities fast tuners (piezo),
  - Beam instrumentation (Beam Loss Monitors via ICS)
  - Superconducting structures parameters characterization and operation support,

Summary

- Funds provided by Ministry of Science and Higher Education via dedicated ESS in-kind initiative,
- Work engagement still continues towards new fields of the accelerator systems improvement and development (operation automation, control algorithms implementation, AI deployment, others….)
- Happy to continue our successful cooperation with ESS in this new and challenging endeavor

Thank you for your attention

That work has been supported by
the Polish Ministry of Science and Higher Education ,
agreement no. 2023/WK/11.