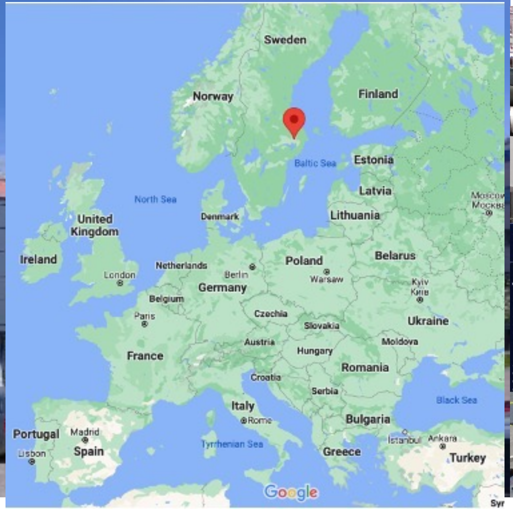
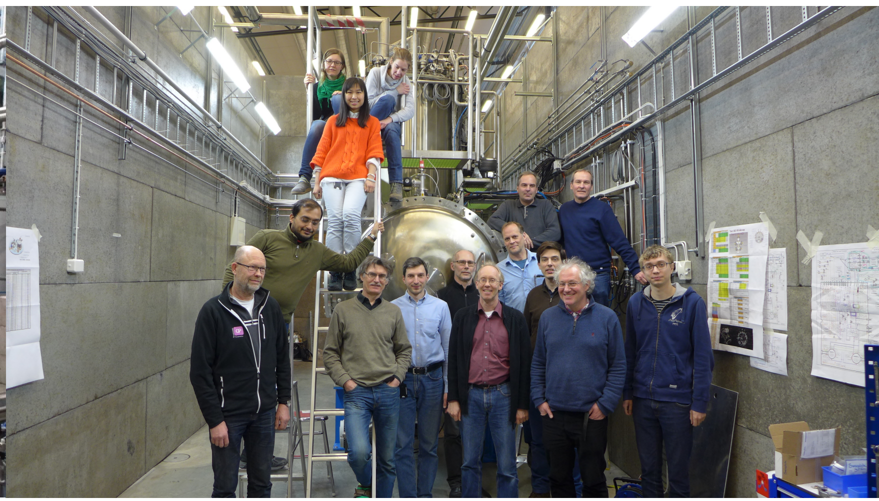


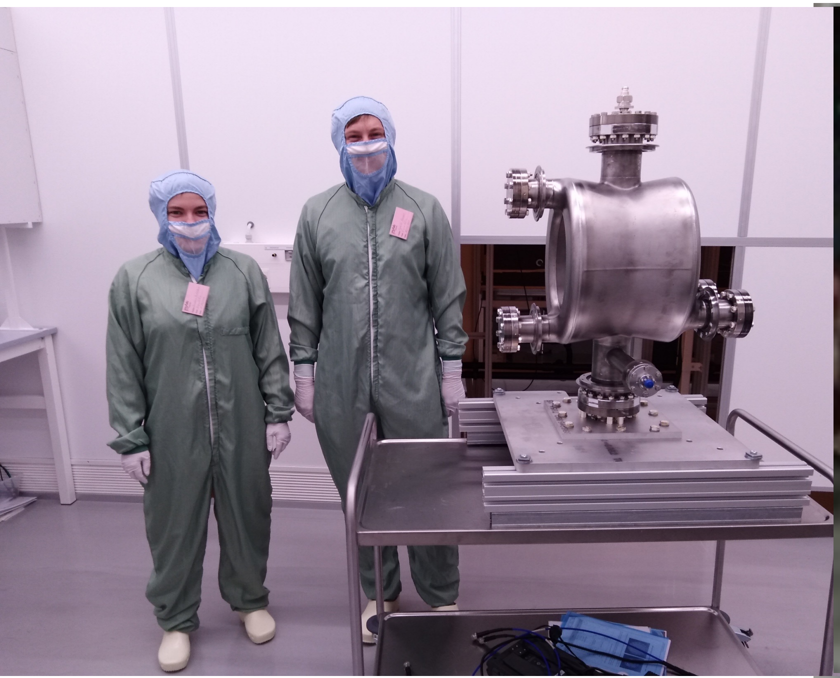


FREIA Laboratory

—Accelerator R&D Facility at Uppsala —

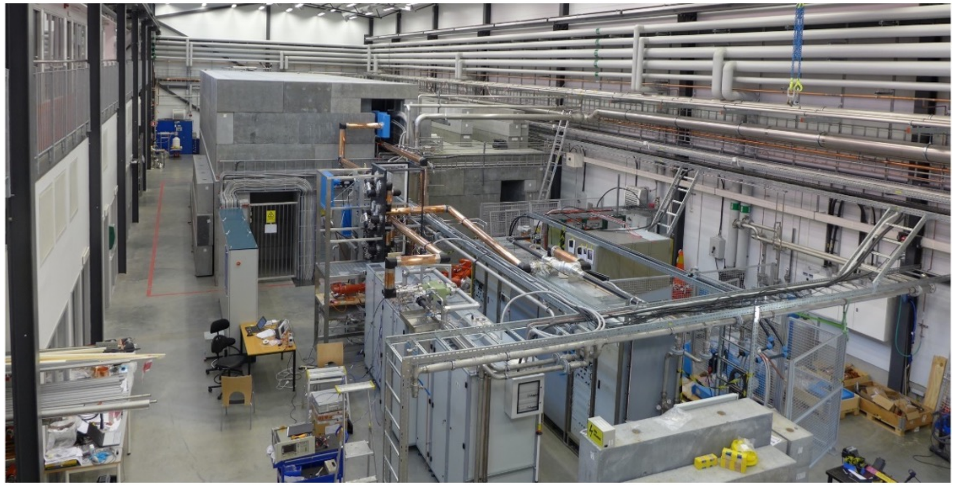
A. Miyazaki

On behalf of FREIA team



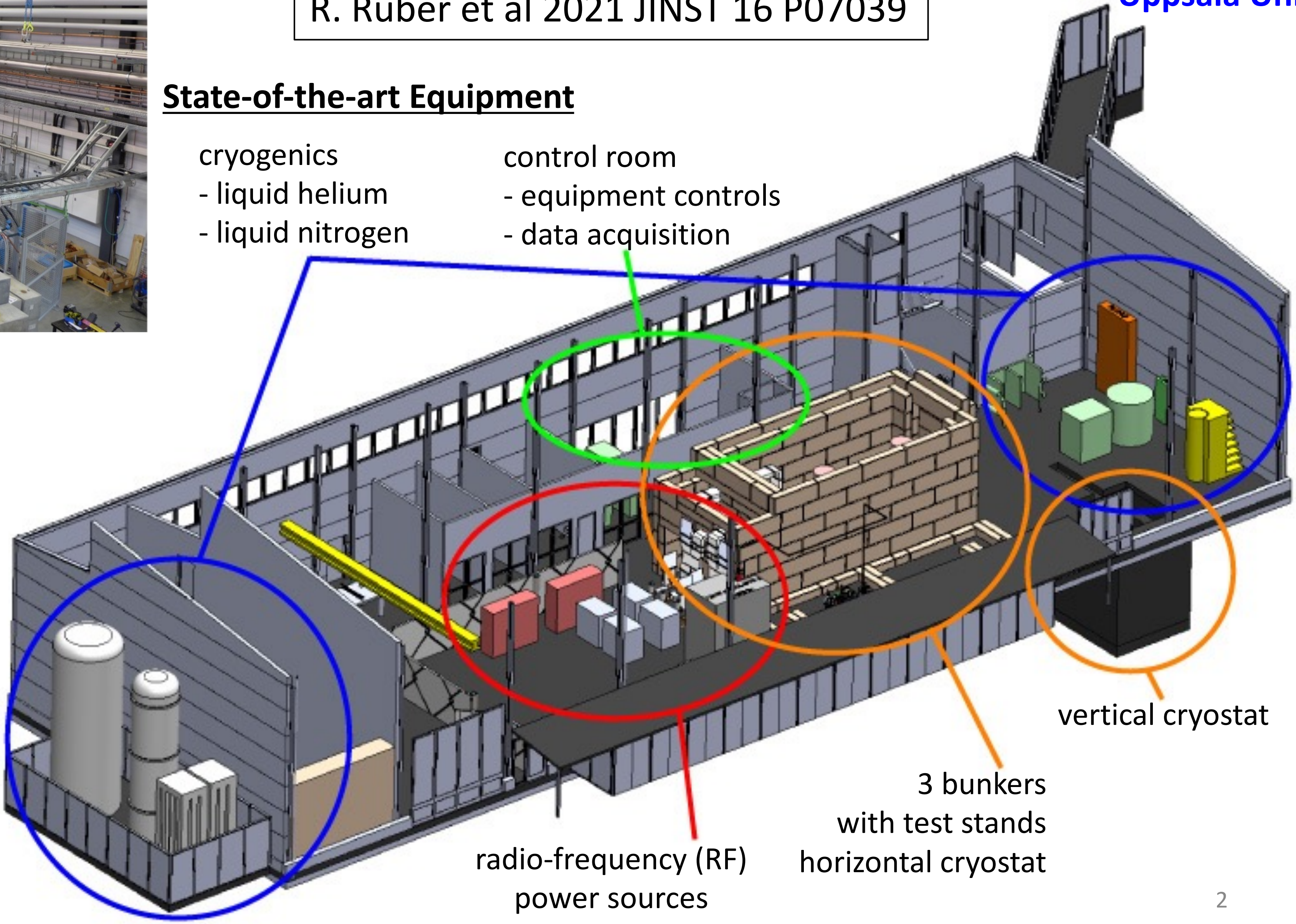
FREIA Laboratory (Facility for REsearch Instrumentation and Accelerator development)

Funded by KAWS, Government, Uppsala Univ.



R. Ruber et al 2021 JINST 16 P07039

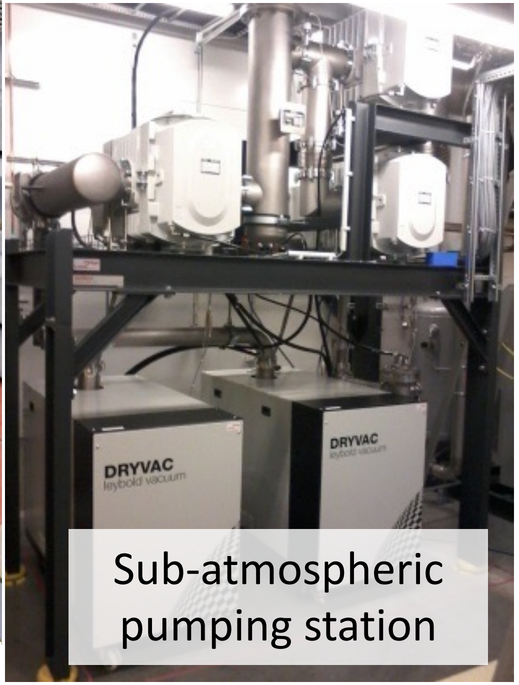
State-of-the-art Equipment



Competent and motivated staff

collaboration of physics (IFA)
and engineering (Teknikum).

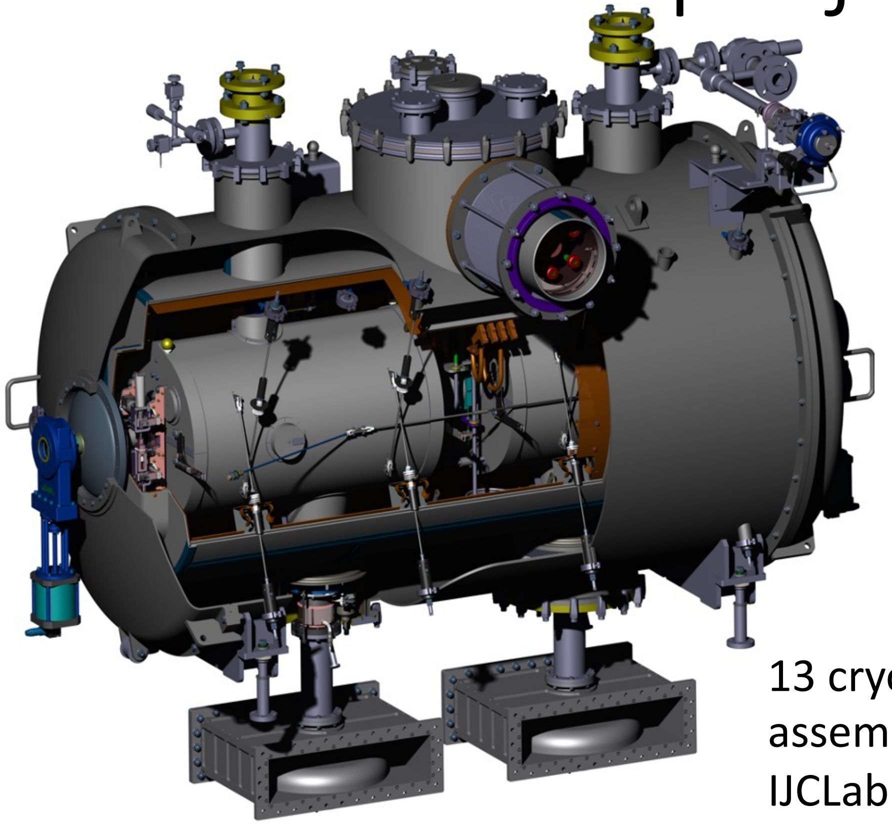
FREIA: cryogenic centre of Uppsala university



- **Helium liquefaction**
  - 150 L/h at 4.5K (LN2 pre-cooling)
  - 2k+1k L LHe Dewar/buffer, 3+1 outlets
  - cryostats connected in closed loop
- **Gas recovery**
  - 100 m^3 gasbag
  - 3x 25=75 m^3/h compressor
    → being upgraded with 200m^3/h
  - 10 m^3 200 bar storage
    → being upgraded
- **2K Pumping**
  - ~3.2 g/s at 10 mbar
  - ~4.3 g/s at 15 mbar
  - **110(90)W at 2.0(1.8)K**
- **Liquid nitrogen**
  - 20 m^3 LN2 tank
  - Periodically filled by an external company

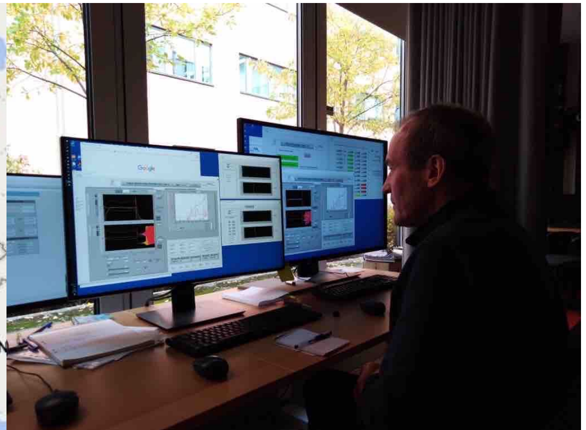
R. Ruber et al, diva2:814268
E. Waagaard et al, arXiv:2104.10435

Present main project: ESS double spoke modules



13 cryomodules assembled by IJCLab Orsay

<u>Test & assess series cryomodules → ESS in Lund</u>



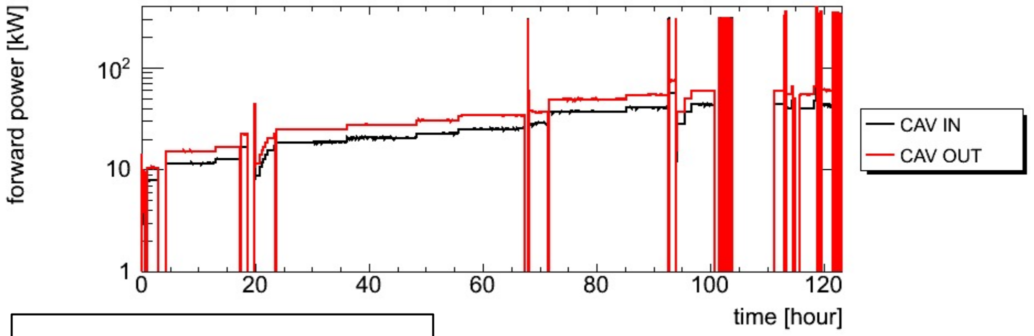
Typical results of ESS double spoke cryomodule testing

H. Li et al diva2:1427442

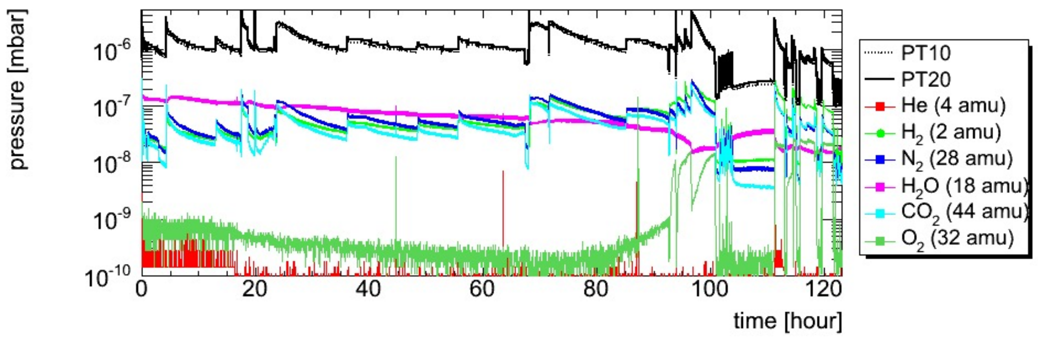
Equipment	Responsible		September				October				November			
			6	13	20	27	4	11	18	25	1	8	15	22
		week #	36	37	38	39	40	41	42	43	44	45	46	47
Liquefier & 2K pumps	Esat													
RF power stations	Mykhailo													
Cryomodule test stand	Akira					CM04					CM03			

- 5-6 weeks turn-over time
- Coupler conditioning 1 week
- Cold test 2 weeks
- Mechanical work 1-2 weeks

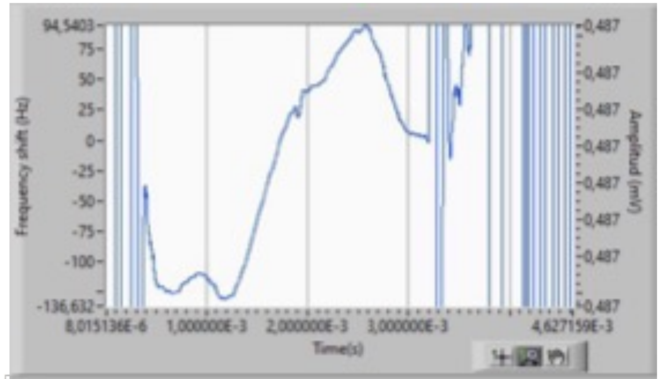
Coupler conditioning and outgas analysis



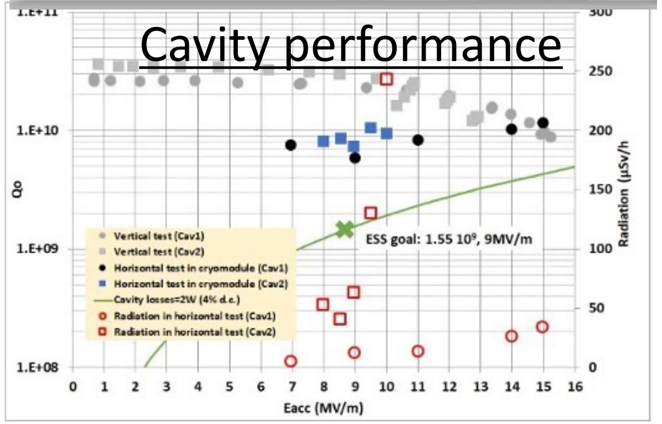
arXiv:2005.00761



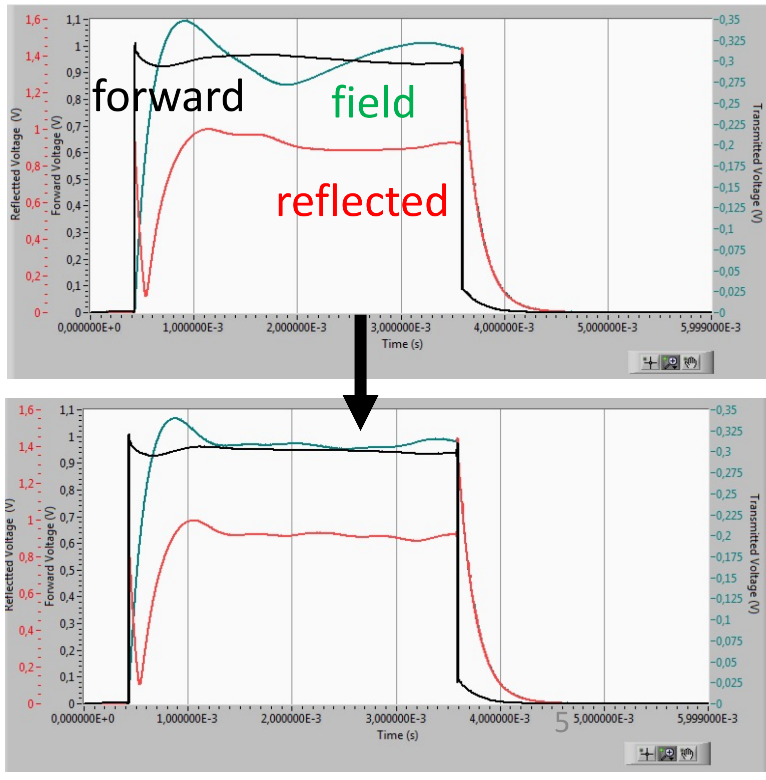
Dynamic LFD



Cavity performance

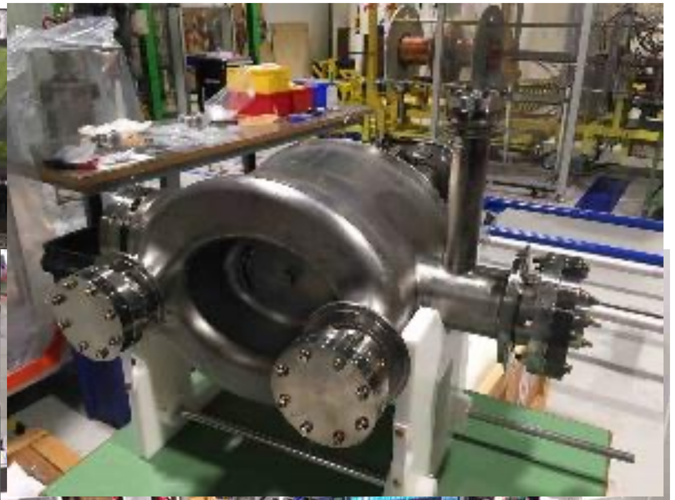


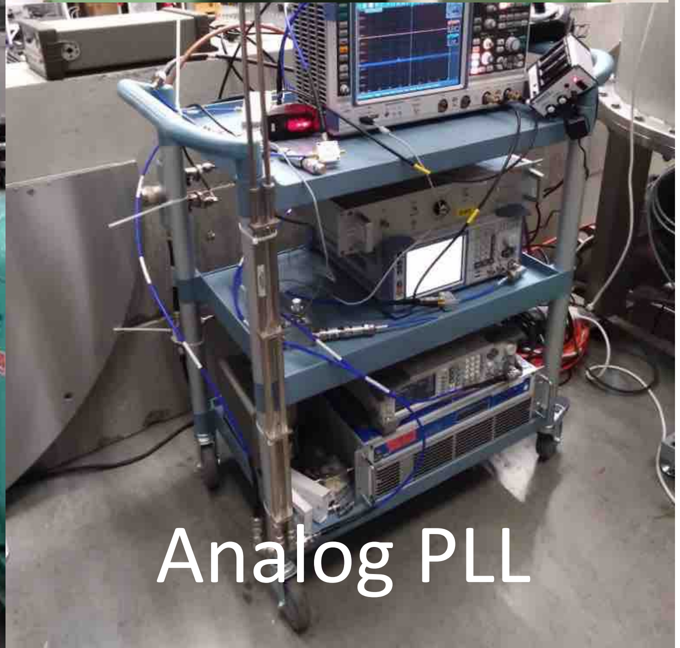
Piezo compensation



Superconducting test programs for HL-LHC

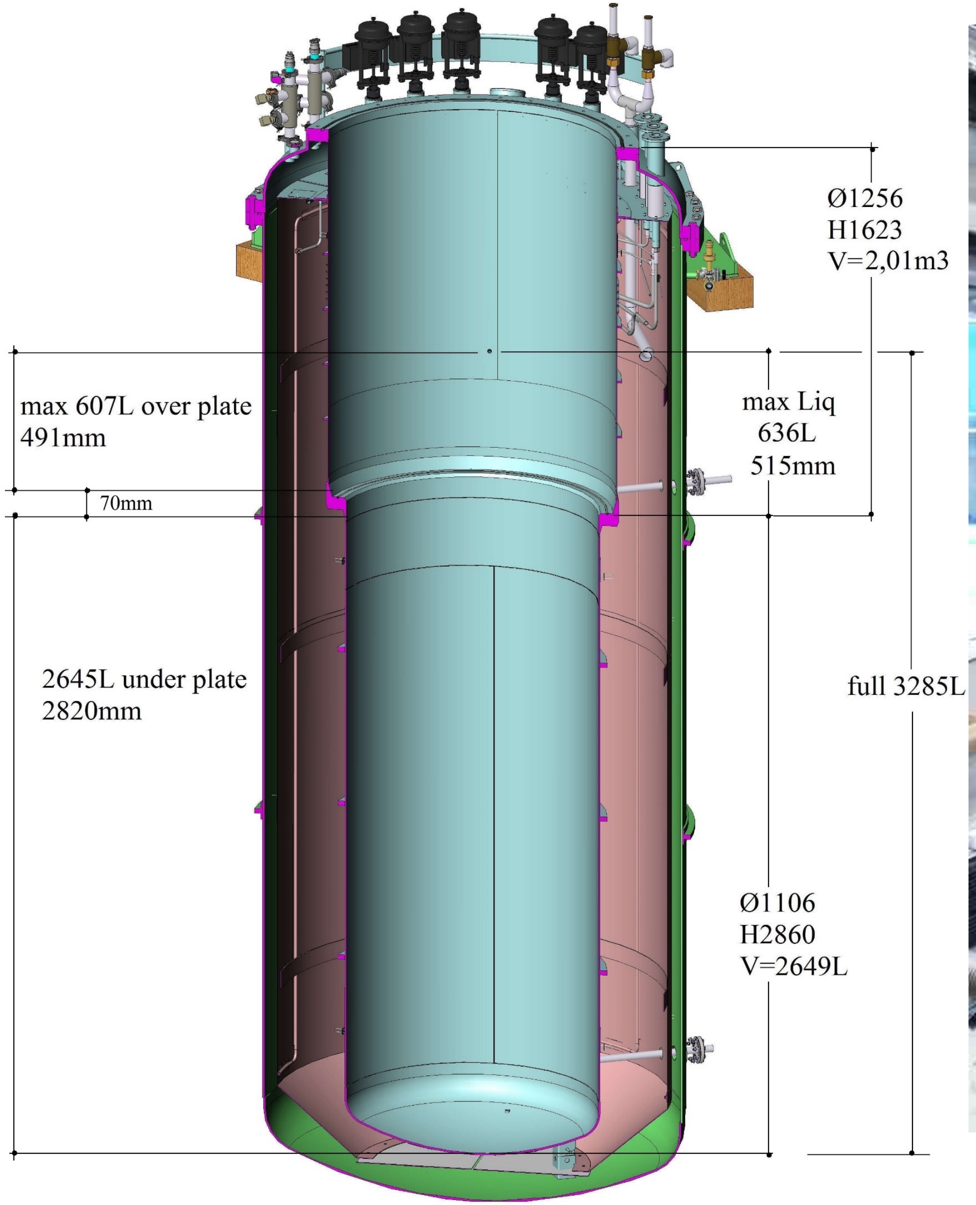
Double Quarter-wave (DQW) crab cavity





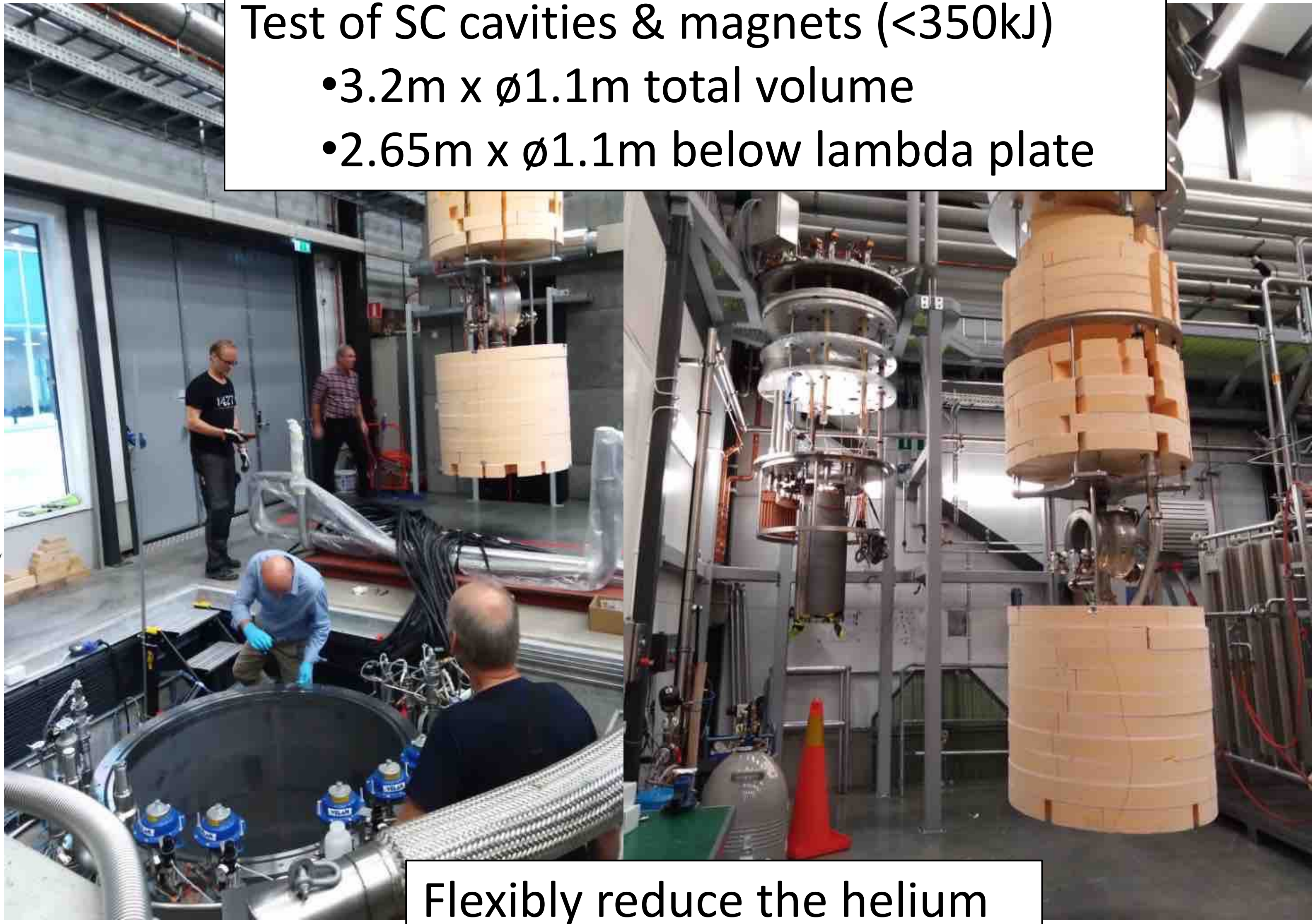
LHC MCBC corrector magnet

Vertical cryostat GERSEMI



Test of SC cavities & magnets (<350kJ)

- 3.2m x ø1.1m total volume
- 2.65m x ø1.1m below lambda plate

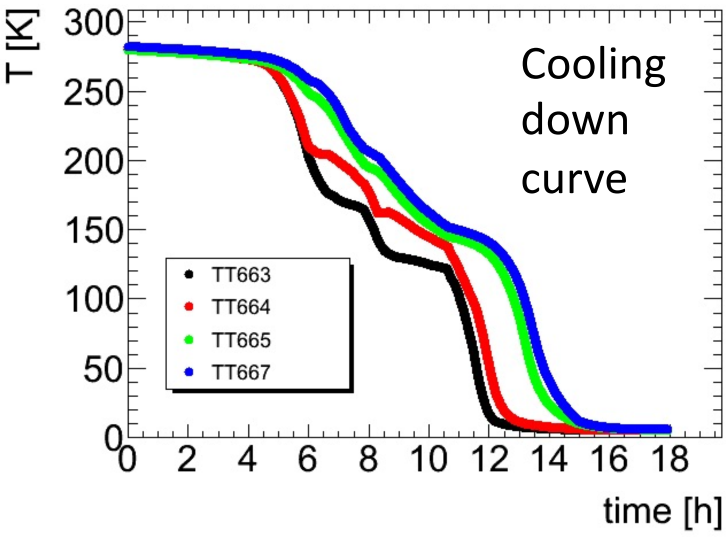


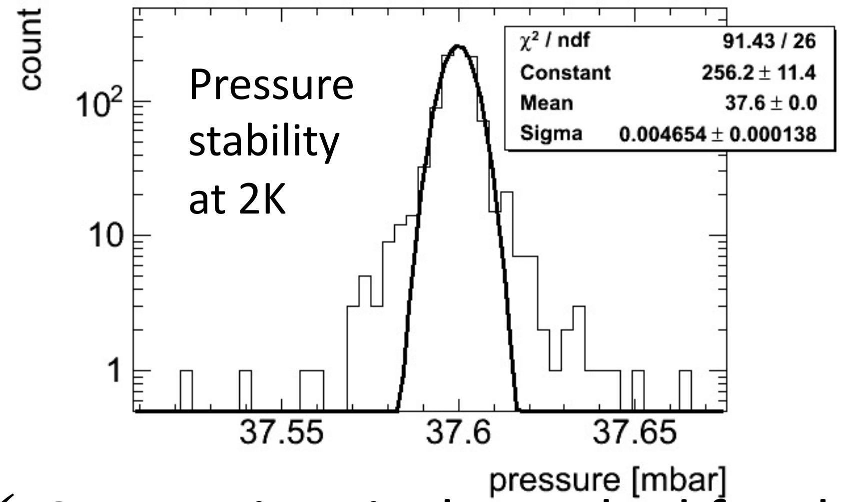
Flexibly reduce the helium volume by cryogenic foams

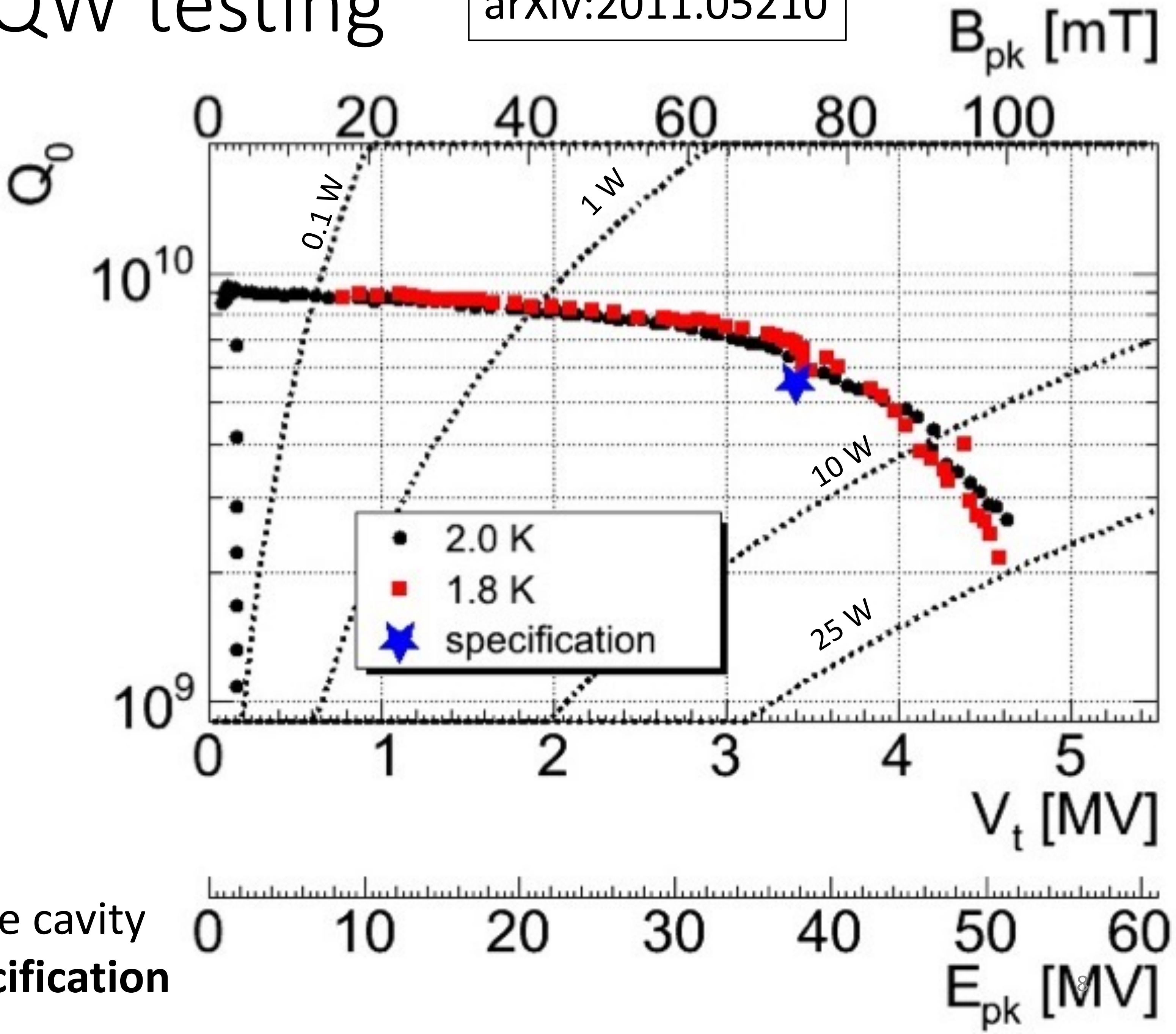
Operation on liquid bath or pressurized (with a 2K heat exchanger)

First result of DQW testing

arXiv:2011.05210





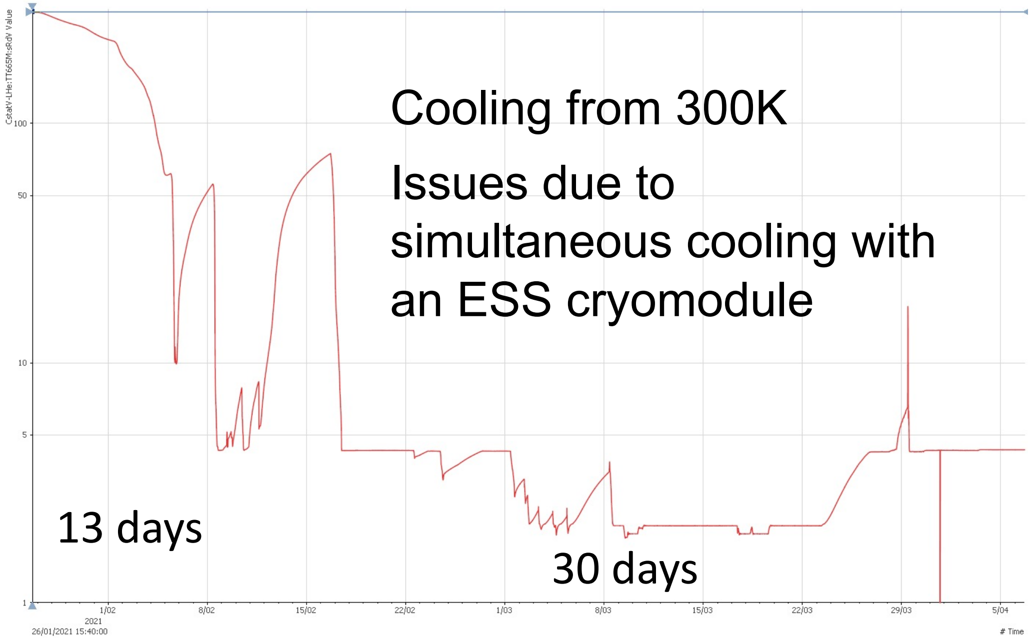


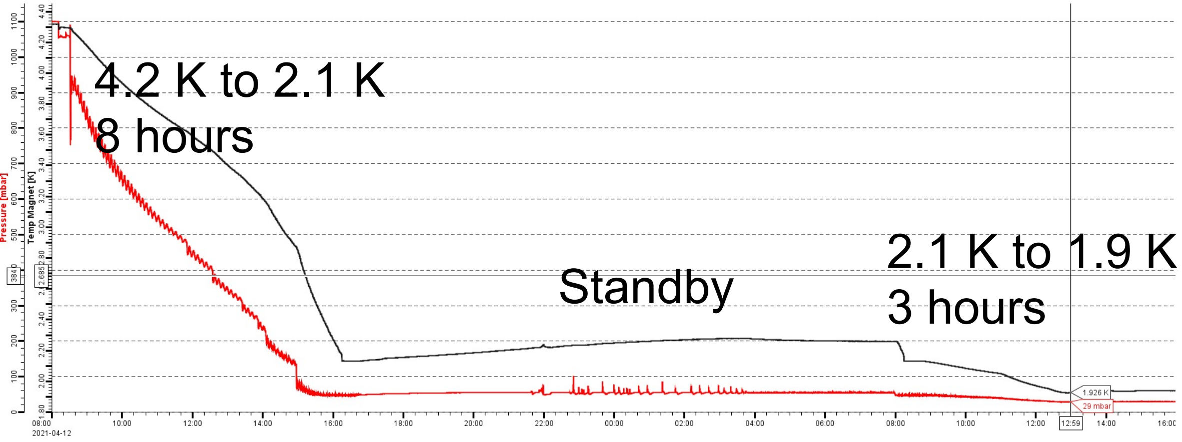
- ✓ Cryogenics nicely worked for the cavity
- ✓ **The result met the project specification**

First result of MCBC testing

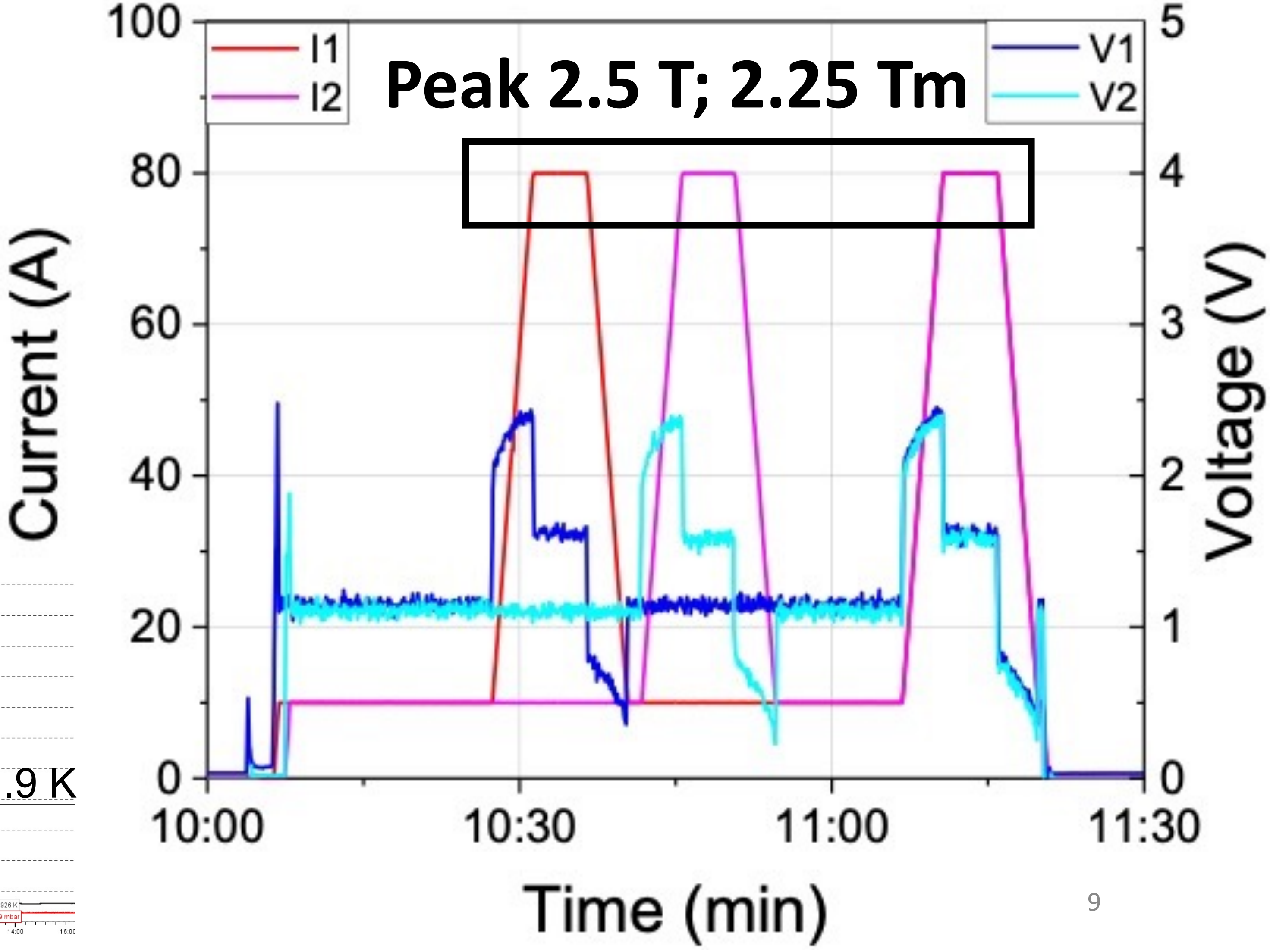
arXiv:2108.10648

Cooling down curves





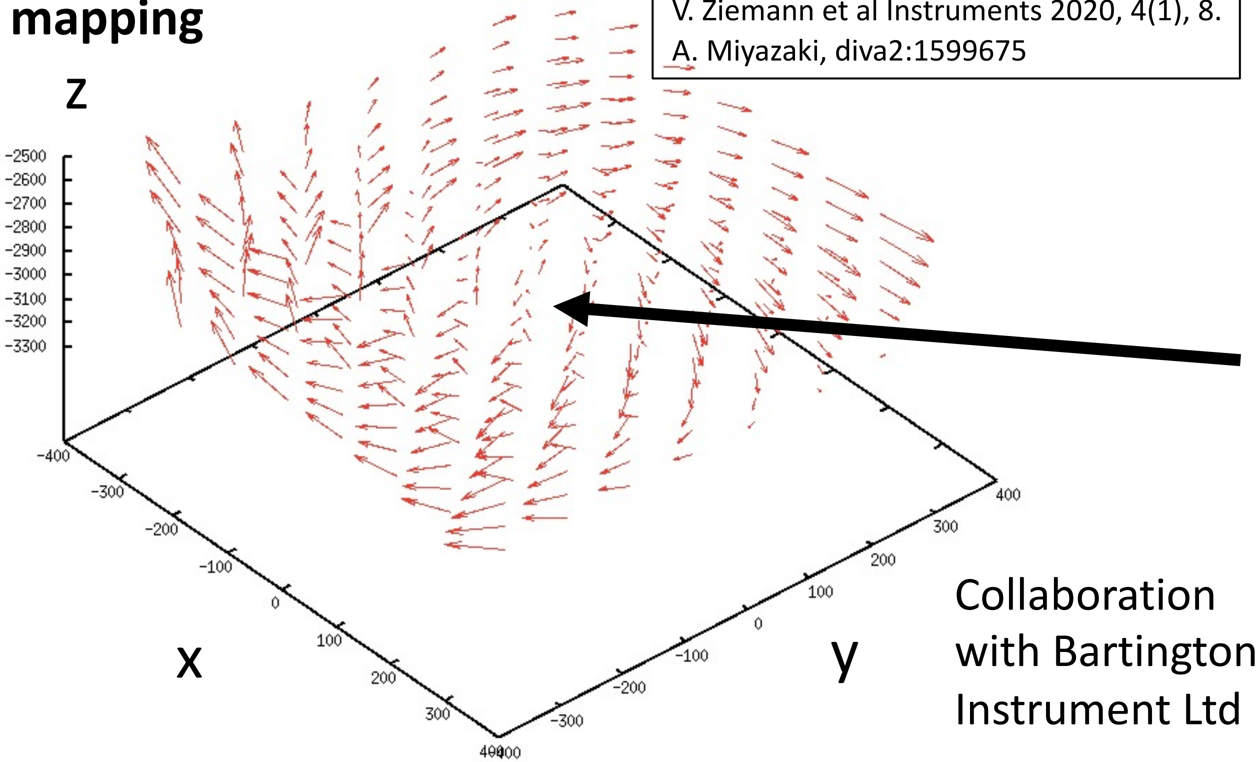
Powering at 1.9 K



SC magnet & SRF cavity → magnetization in the cryostat?

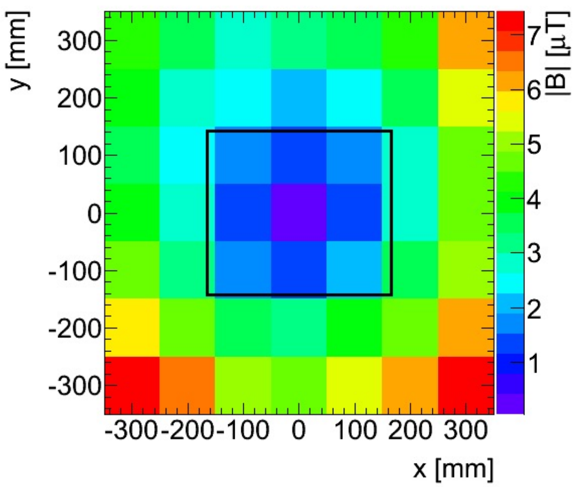
3D mapping

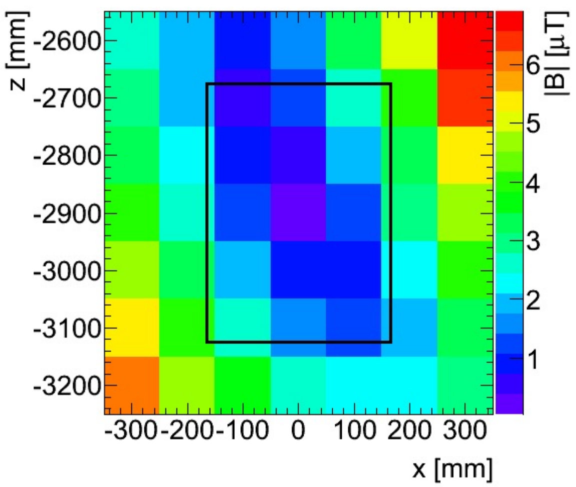
V. Ziemann et al Instruments 2020, 4(1), 8.
A. Miyazaki, diva2:1599675

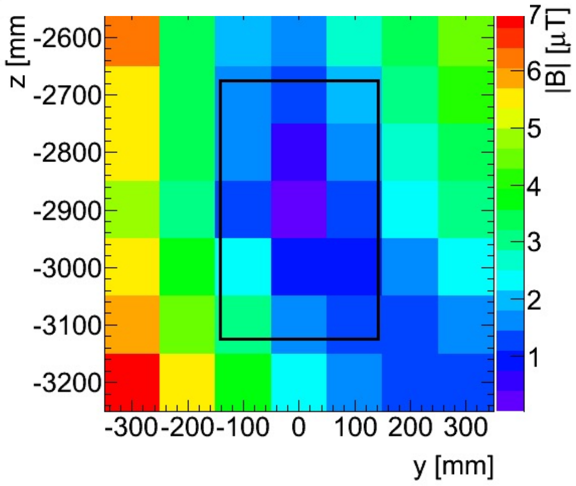


Center of the cavity can be perfectly 0 field

Collaboration with Bartington Instrument Ltd



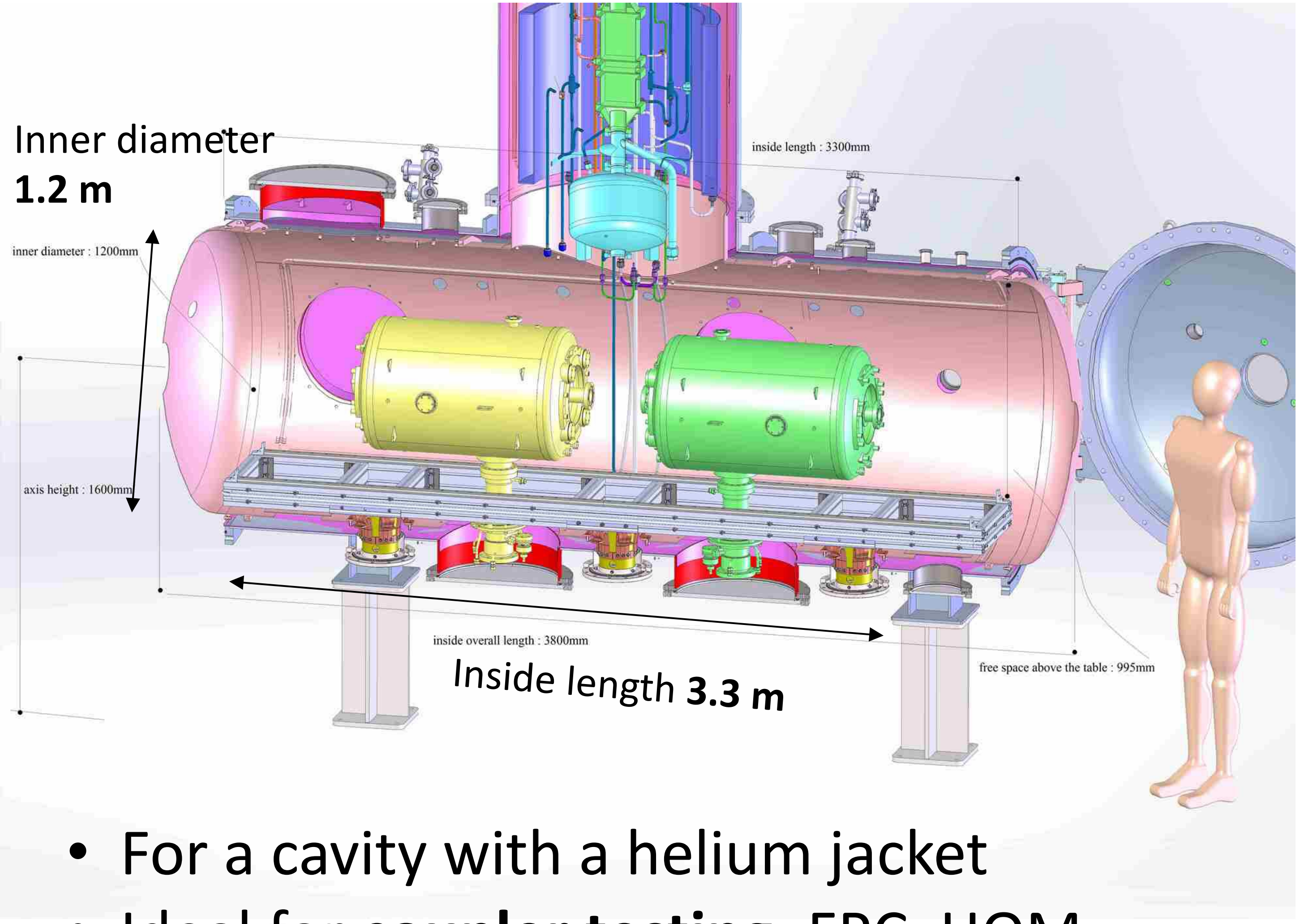


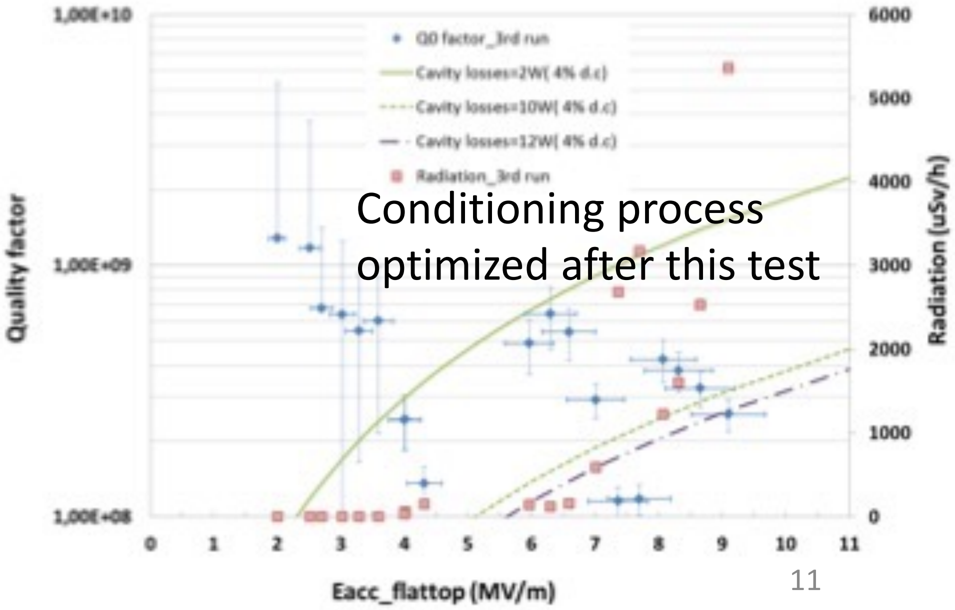


- No huge magnetization so far
- Field compensation by coils are not perfectly uniform
- Residual ambient field of 3-4 uT
- Possible influence to 400 MHz bulk Nb cavity R_{mag}~6.5 nΩ
- To be optimized in the future

Horizontal cryostat HNOSS

H. Li et al, NIMA 927, 63 (2019)
H. Li et al, LINAC 2018, THOP066





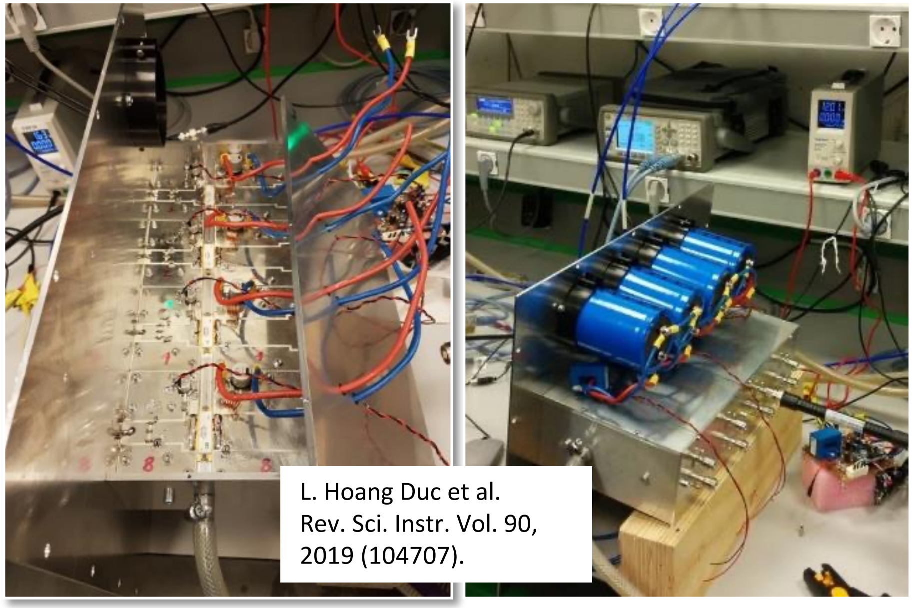
- For a cavity with a helium jacket
- Ideal for **coupler testing**: FPC, HOM
- **Two cavities**/magnets at the same time

NEW Cleanroom became available for SRF activities

✓ A pick-up antenna falling off during transport was successfully fixed in the cleanroom

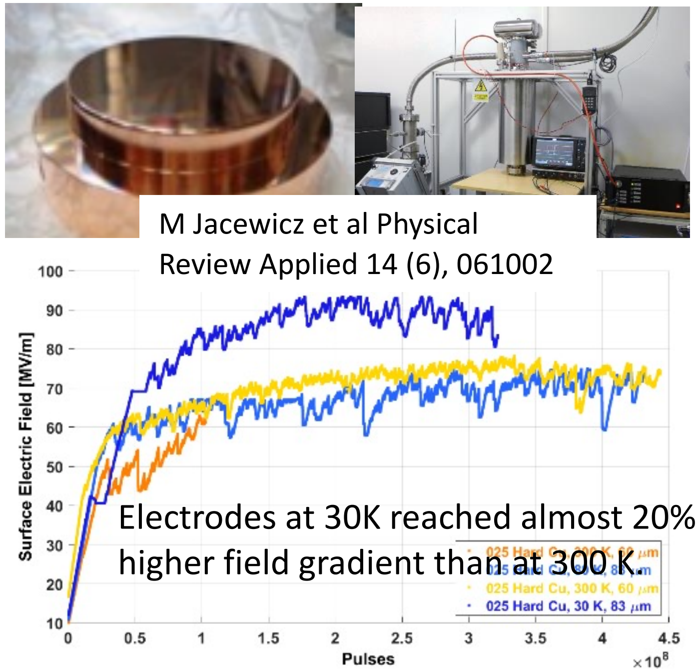
R&D and user facility projects on-going in FREIA

SSA: highly efficient combiner



L. Hoang Duc et al.
Rev. Sci. Instr. Vol. 90,
2019 (104707).

Cryogenic breakdown for CLIC

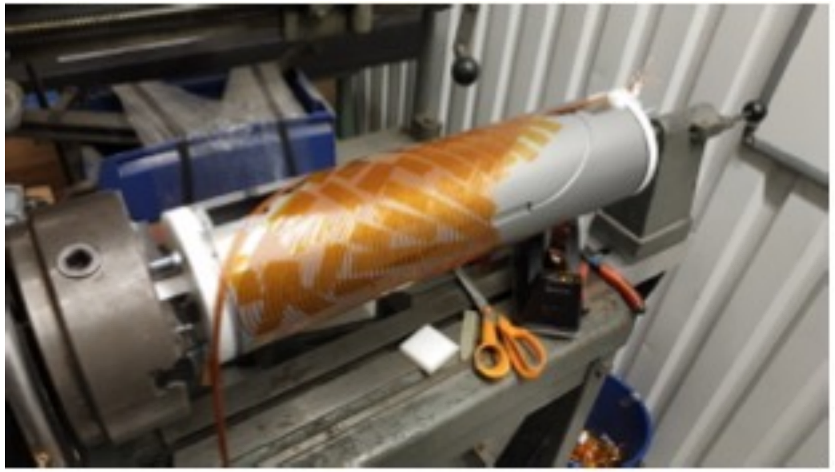


M Jacewicz et al Physical Review Applied 14 (6), 061002

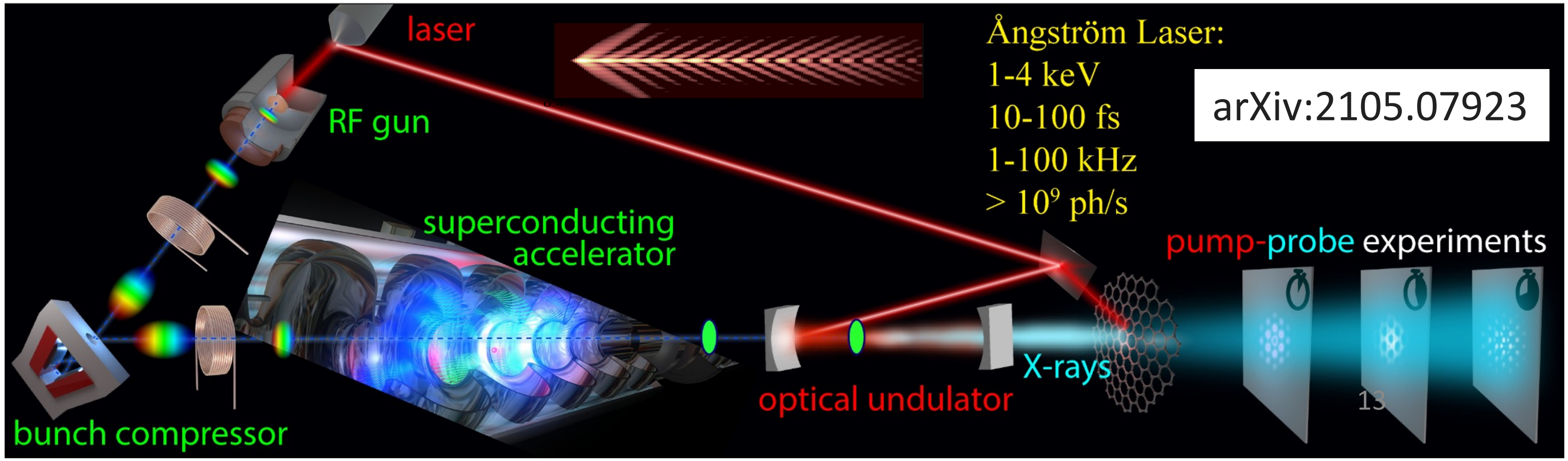
Electrodes at 30K reached almost 20% higher field gradient than at 300 K.

- AWAKE
- HL-LHC ColdBox production
- Beam dynamics in ESSνSB project
- MAXIV end-station
- Neutron instrumentation
- MYRRHA/MINERVA
- Anti-cryostat for rotational coils
- …

Canted Cosine-Theta SC magnet



Laser lab for future compact XFEL



arXiv:2105.07923

Conclusion: core competence of FREIA

- Superconducting RF cavities: theory and experiment
- Superconducting magnets: design and experiment
- Cryogenics: theory, design, practical work and operation
- Vacuum: practical work, cleanroom available
- High power RF: vacuum tube, solid state amplifier R&D, HV modulators
- Electronics: repairing most of the things in-house
- LLRF: development of beyond the state-of-the-art FPGA algorithms
- Mechanical engineering: excellent designers and in-house workshop
- Beam dynamics: theory and simulation, FEL application
- Laser: design and operation
- Normal conducting RF: break-down field R&D for CLIC, klystrons for AWAKE

Last but not least : enthusiastic and organized personals

backup

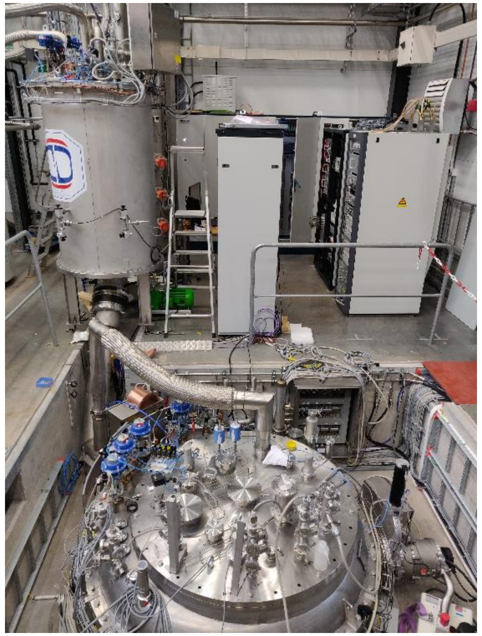
Research Infrastructure for accelerator projects

Cryogenics

High-power RF amplifiers

Specific and general LLRF system; EPICS-based control system

Vertical cryostat

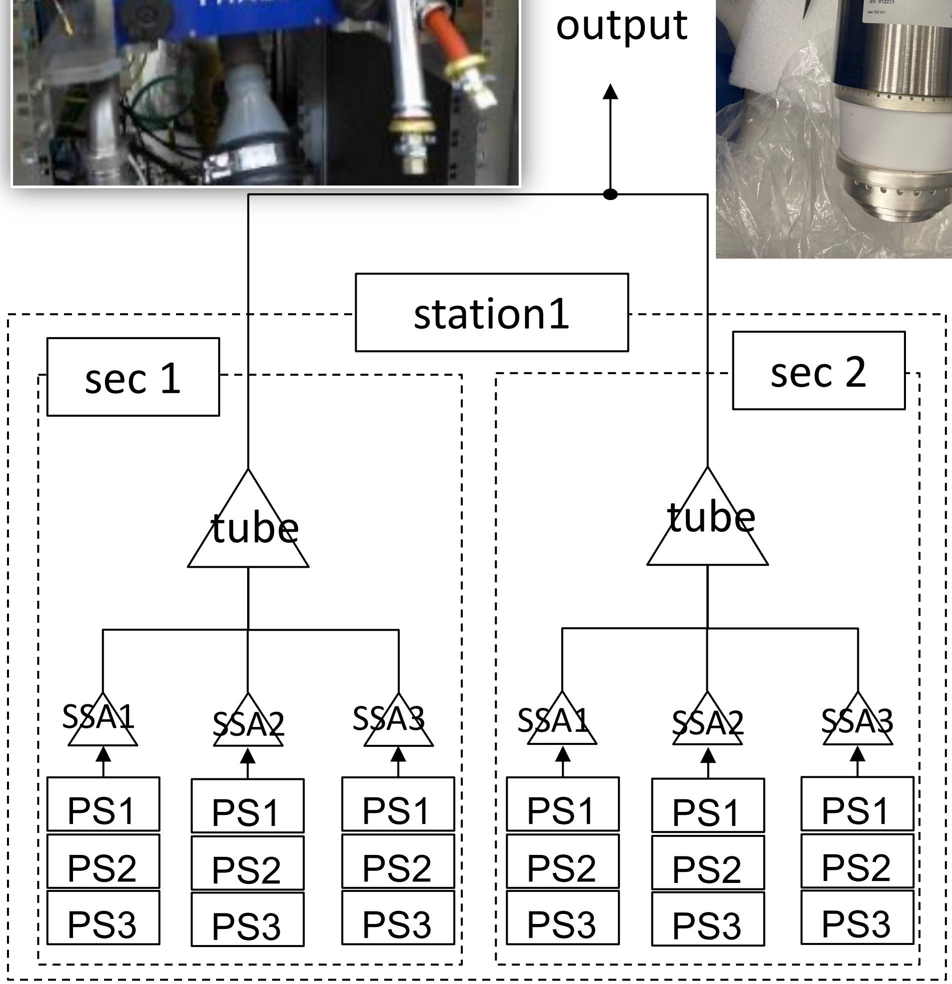


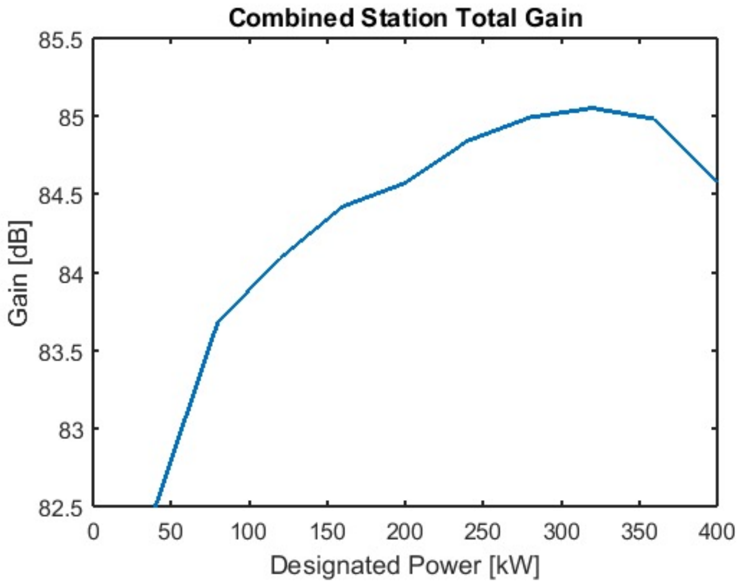
Horizontal cryostat

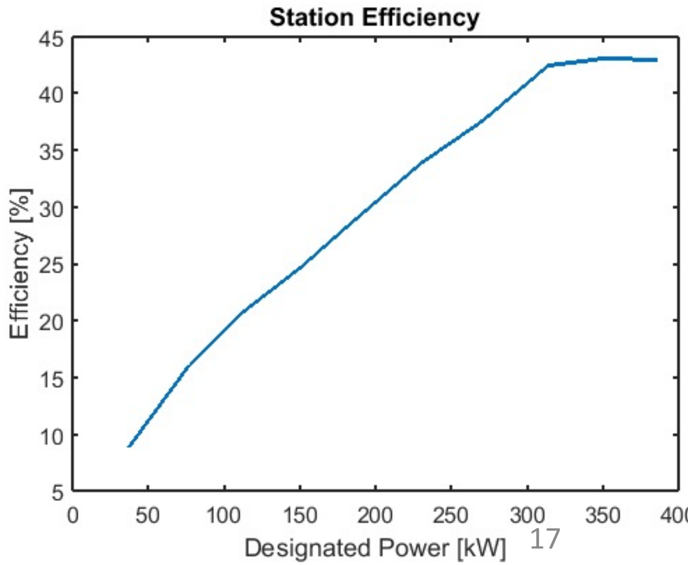
FREIA: high power RF stations

R. Ruber et al, diva2:1371207

400 kW pulsed (325-352 MHz)
- 2 stations
- 3.2 ms, 14 or 28 Hz

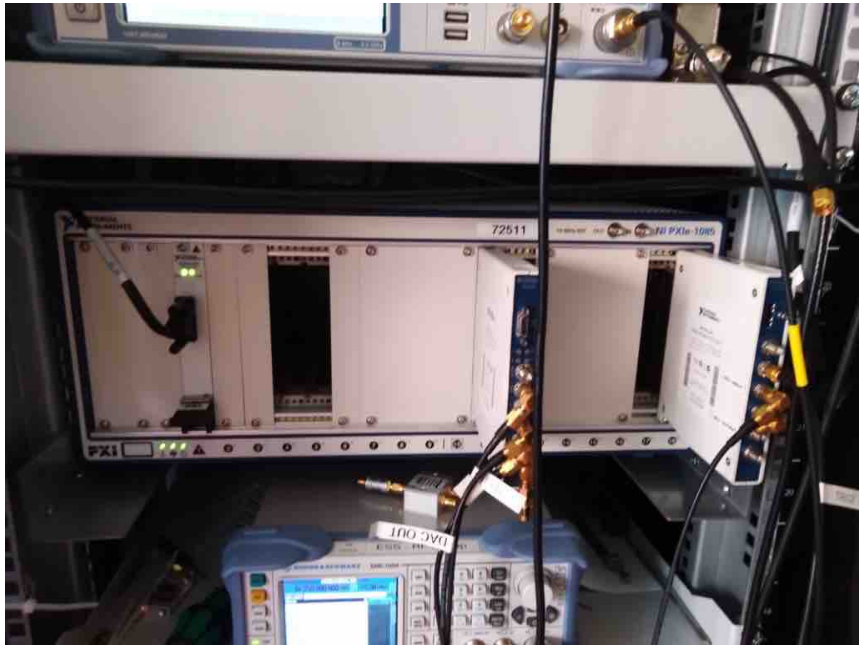






LLRF development and testing

General purpose LLRF (beyond SoA)



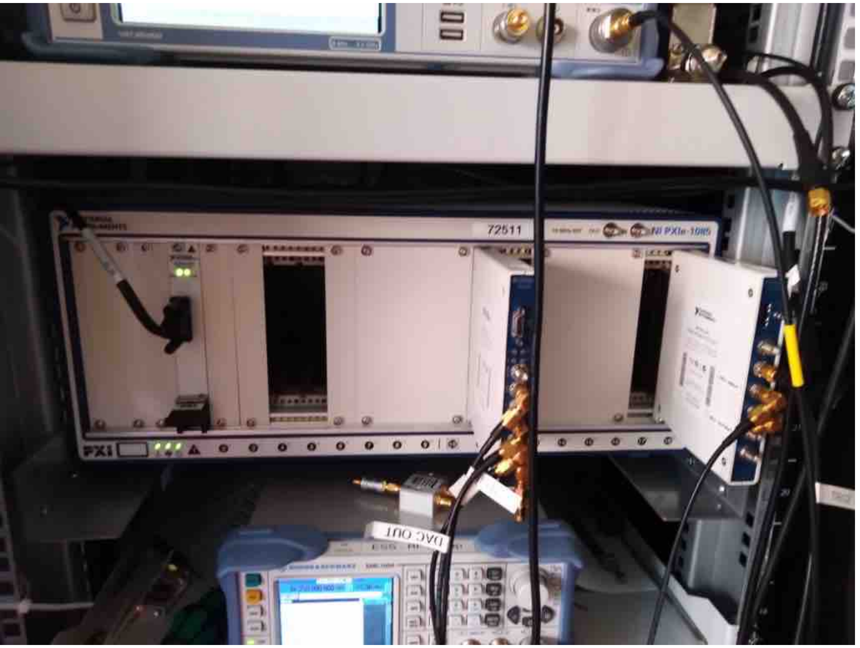
- **Our own development** based on NI-PXI FPGA and ADC cards (two sets of system)
- Up to 6 GHz can be handled
- CW & pulsed Self-Excited Loop (SEL)
- pulsed signal driven feedback
- pulsed feedforward
- Pulsed “inverse-cavity” locking
- Quench detection from decay constant

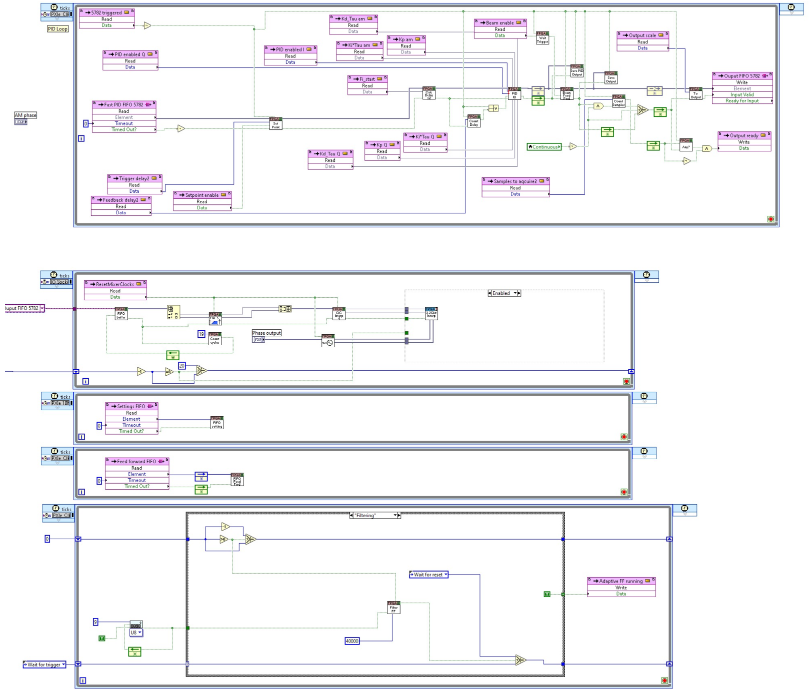
Special LLRF dedicated to ESS

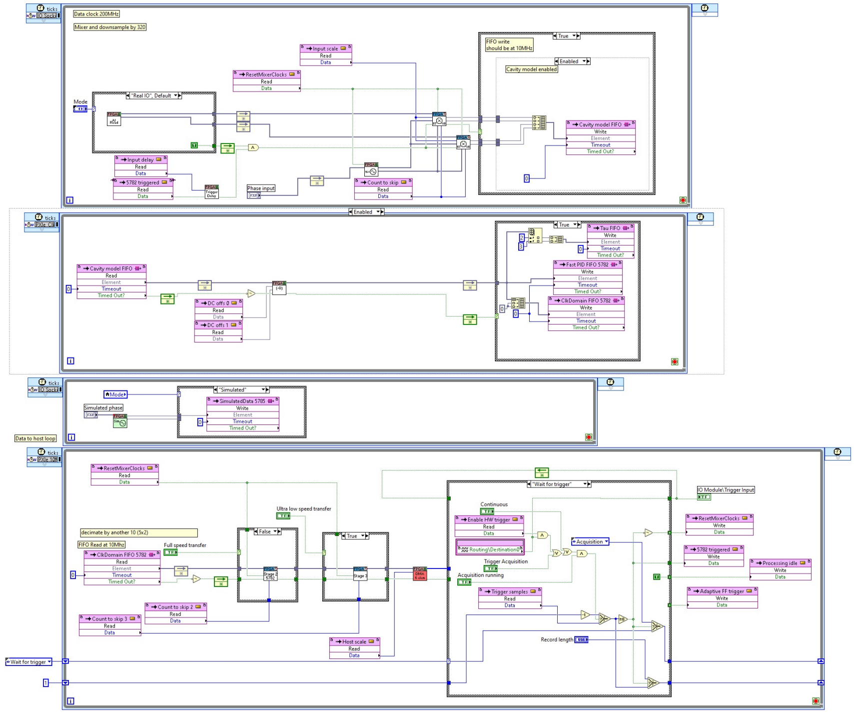
- ESS product based on μTCA provided by Lund for testing purpose (two sets of system)
- 352 MHz (external reference), 3.2 ms, 14 Hz
- Pulse generator included
- Waveform monitoring, signal driven feedback
- Fast interlock from over/under THR in ADC

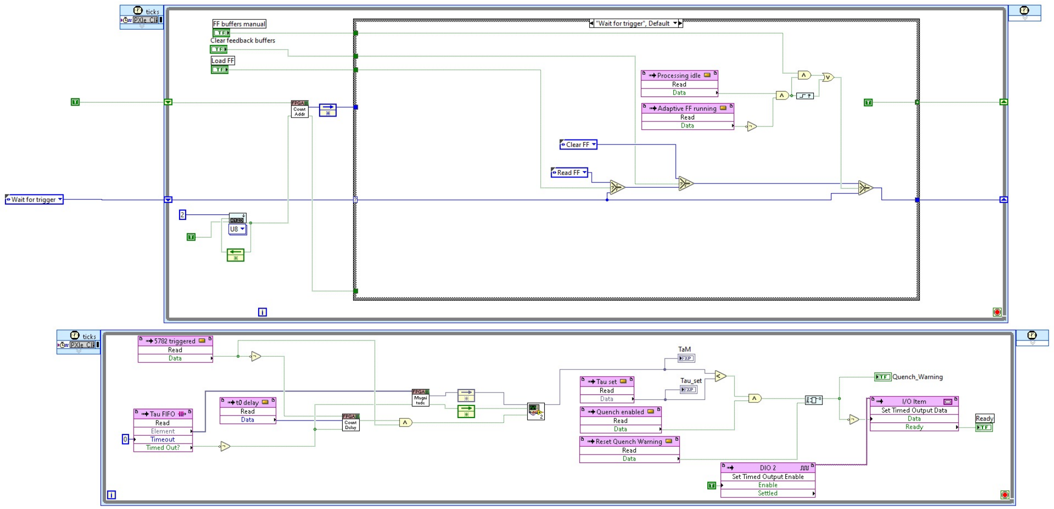
→ **ESS cryomodules are tested by combining above two different LLRF systems**

LLRF system developed in house





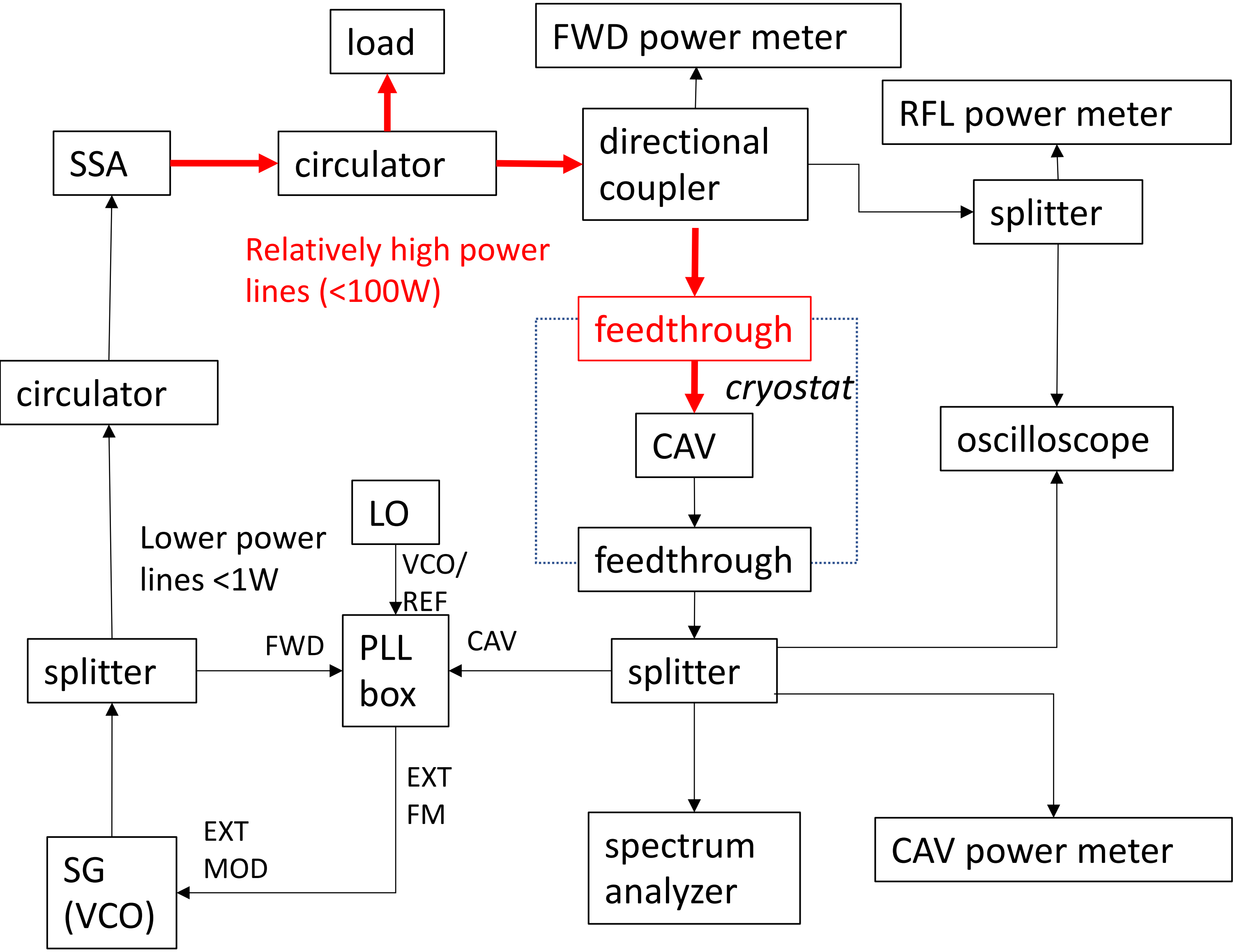




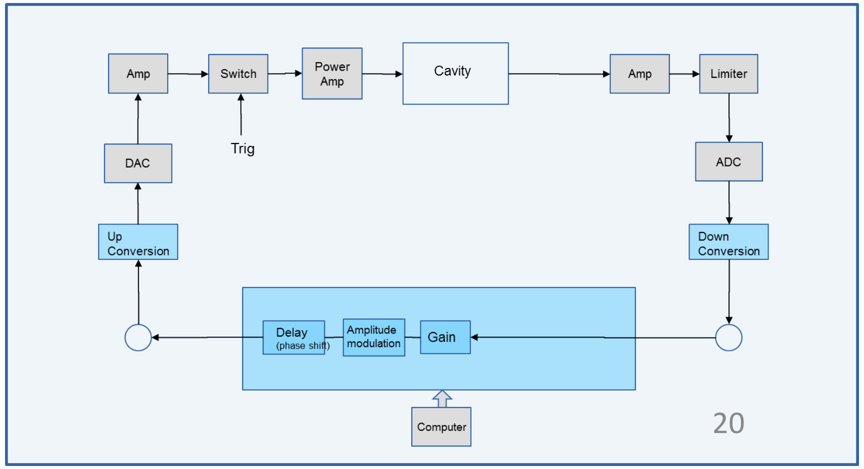
- Based on NI-PXI FPGA and ADC cards Up to 6 GHz can be handled
- CW & pulsed Self-Excited Loop (SEL)
- pulsed signal driven feedback
- pulsed feedforward
- Pulsed “inverse-cavity” locking
- Quench detection from decay constant

SRF Cavity testing: PLL was used but SEL was developed

Broadband PLL circuit (partially from CERN)



Digital SEL (NI-PXI based FPGA)



SC magnet testing