



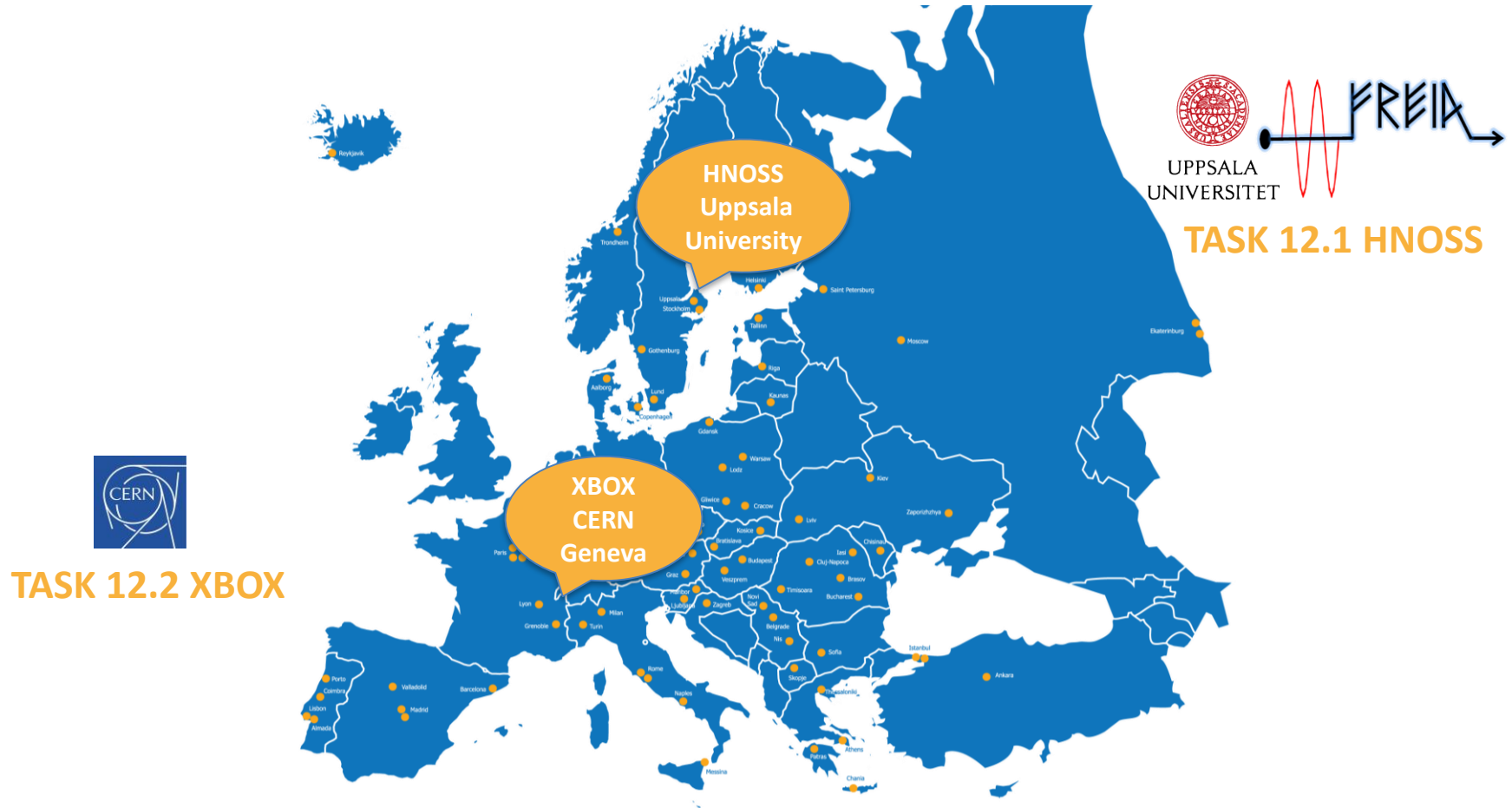
Testing of Advanced RF Structures Report from TNA WP12

Final Review Meeting, 15 July 2022

Roger Ruber (Uppsala University)

Walter Wuensch (CERN)

WP12 RF Testing Facilities



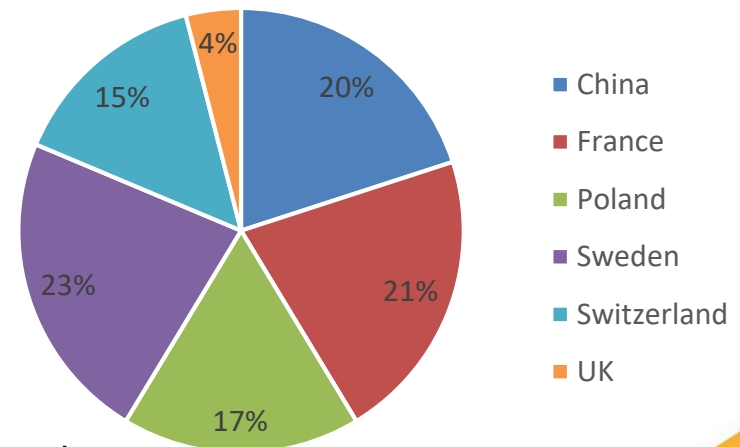
The TNA within WP12 groups **TWO** facilities devoted to testing of superconducting RF cavities and normal conducting RF cavities.

WP12 Overview

- Access given per facility

Facility	No. of projects					No. of users					No. of access units					
	P1	P2	P3	Total	Total Annex 1 (amended numbers)	P1	P2	P3	Total	Total Annex 1 (amended numbers)	P1	P2	P3	Total	Total Annex 1 (amended numbers)	
HNOSS	2	2	0	4	4	18	24	7	49	44	1,330	2,084	1,080	4,494	3,790	119%
XBox	2	2	0	4	4	13	11	6	30	24	1,680	2,500	6,521	10,701	7,500	143%
WP TOTAL	4	4	0	8	8	31	35	13	79	68	3,010	4,584	7,601	15,195	11,290	135%

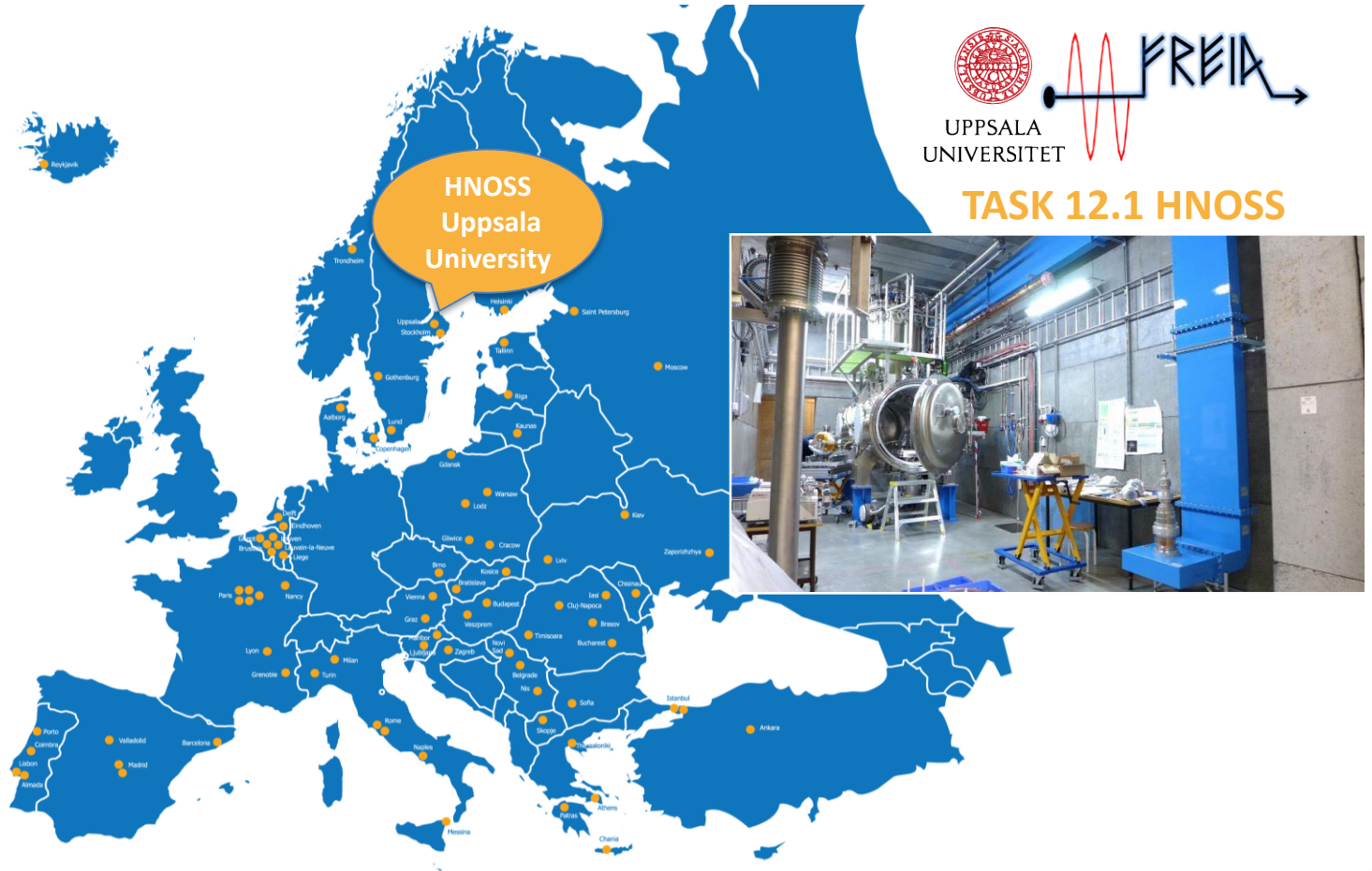
- Users by country of institute:
- Users total **79**,
of which 8 female (10%)
- Publications up to now: **18**
(articles, conf. poster, open access reports)



WP12 User Selection Panel (USP)

- Common USP
 - selection based on scientific quality and feasibility,
 - 3 independent experts:
 - Kenneth Österberg (Helsinki Univ., Finland)
 - Jiaru Shi (Tsinghua Univ., China)
 - Slava Yakovlev (Fermilab, US)
 - facility coordinators:
 - Roger Ruber (HNOSS, UU)
 - Walter Wuensch (XBox, CERN)

WP12.1 UU/FREIA HNOSS Facility



The **HNOSS** facility at the FREIA Laboratory, Uppsala University, Sweden, is available for testing of superconducting RF cavities with integrated helium tank.

WP12.1 HNOSS at Uppsala University

HNOSS = Horizontal Nugget for Operation of Superconducting Systems

- Horizontal cryostat for superconducting cavities.
 - Up to two cavities simultaneously,
 - each equipped with helium tank,
 - option: fundamental power coupler and (cold) tuning system
- Low or High power RF testing
- Operation in the range 1.8 to 4.5K.



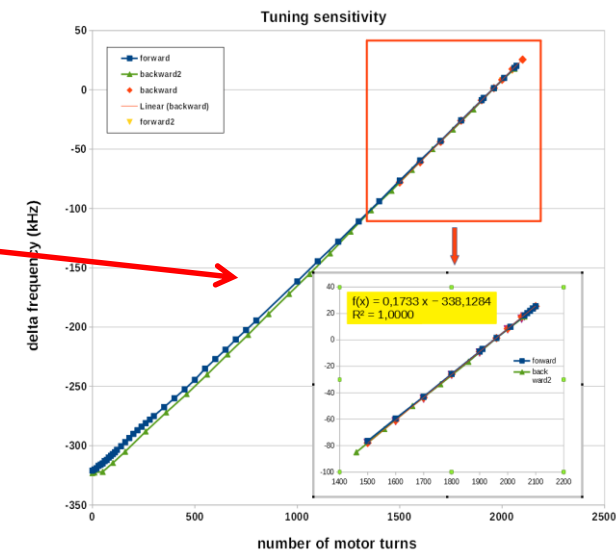
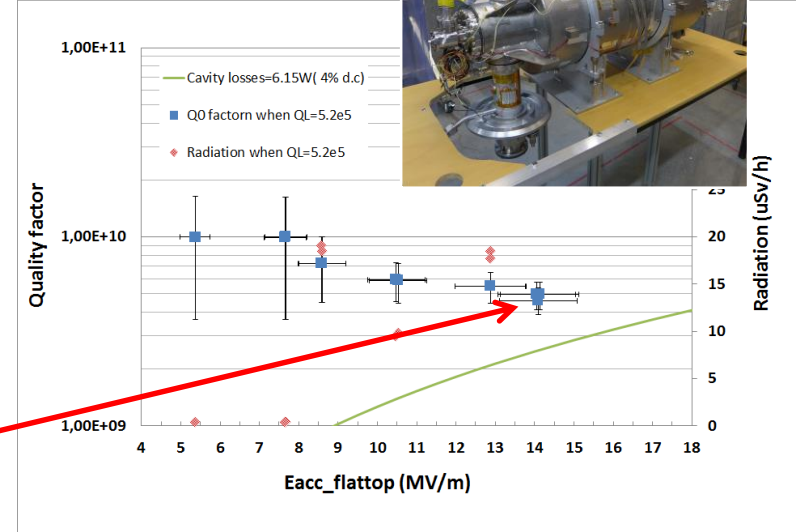
WP12.1 UU/FREIA HNOSS - Overview

In proposal - 4 projects with a total of ~~2880~~ 3790 access units.

#	Name	Institutes	Status	Access Units	Users
1	ESS High-beta Elliptical Cavity	CEA Saclay	Completed. Reported and published.	1330	18
2	Validation of a prototype double spoke cavity cryomodule	IPN Orsay	Completed. Reported and published.	2048	14
3	RF and piezo actuators study on spoke cavities	Lodz University of Technology	Completed. Reported and published.	36	8
4	HL-LHC crab cavity cold testing	CERN	Completed. Reported and published. Remote participation due to Covid pandemic.	1080	7
TOTAL Achieved				4494 (119%)	47

WP12.1 FREIA-HNOSS-2017-01 (#1)

- Prototype superconducting high-beta elliptical cavity for ESS
 - experiment run in June and August 2018,
 - start-up delay due to technical issues with high power klystron and RF-load
 - cold tuner problem
 - → warm-up and fix
- Results
 - $Q_0 > 10^9$
 - not much multipacting,
 - Lorenz force detuning, cavity tuning sensitivity ok
 - lost some motor steps during 1st movement, others ok
 - test of new electronics for cold tuner system
- Successful validation of cavity package and new tuning control systems



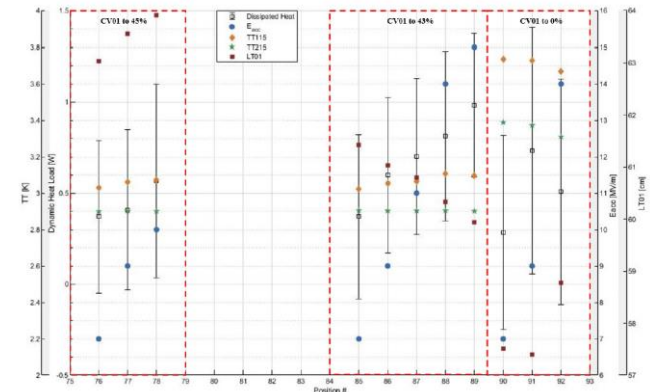
WP12.1 FREIA-HNOSS-2018-01 (#2)

- Validation of prototype double spoke cavity cryomodule

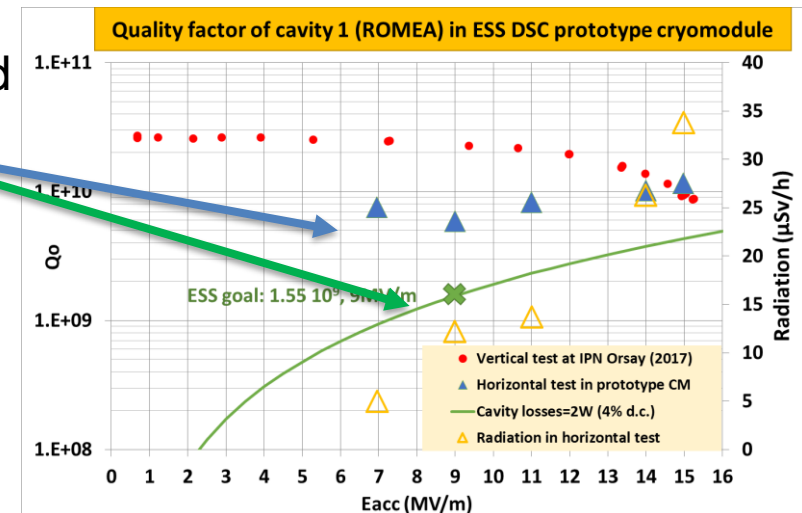
- thermo-acoustic (Taconis) oscillations in valve-box → installed RLC circuit
- cryomodule quench → rupture disk replaced

- Results

- RF conditioning → several multipacting bands
 - revealed problems in RF stations and LLRF synchronization → fixed!
- stable operation at 2K
- measured accelerating gradient, heat load → better than target requirements
- studied Lorenz force detuning, frequency sensitivity vs. temp., pressure



Cavity 1 dynamic heat load at different filling valve opening



WP12.1 FREIA-HNOSS-2019-01 (#3)

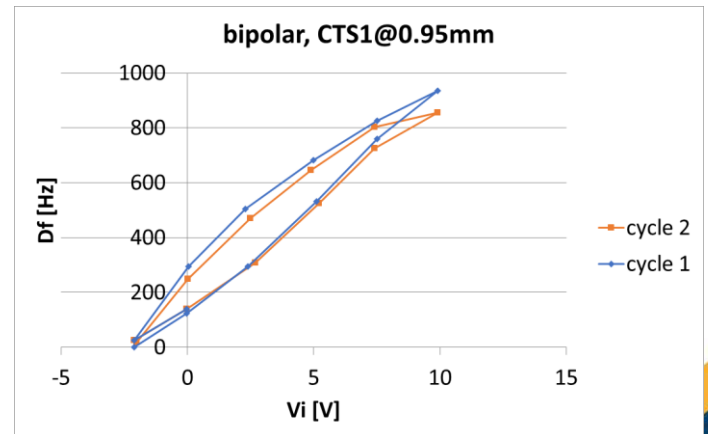
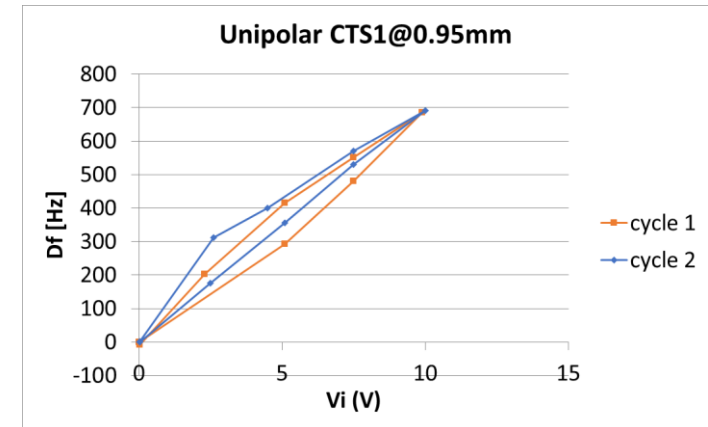
- RF and piezo actuators study on spoke cavities
 - use cavities from cryomodule project HNOSS-2018-01

- **Results**

- measurement of piezo & cavity operational parameters,
 - verified and modified specifications
- design verification of control system and algorithms.
 - main parameters of designed driver modified
 - triggered discussion to harmonize piezo driver system for ESS spoke and elliptical cavities

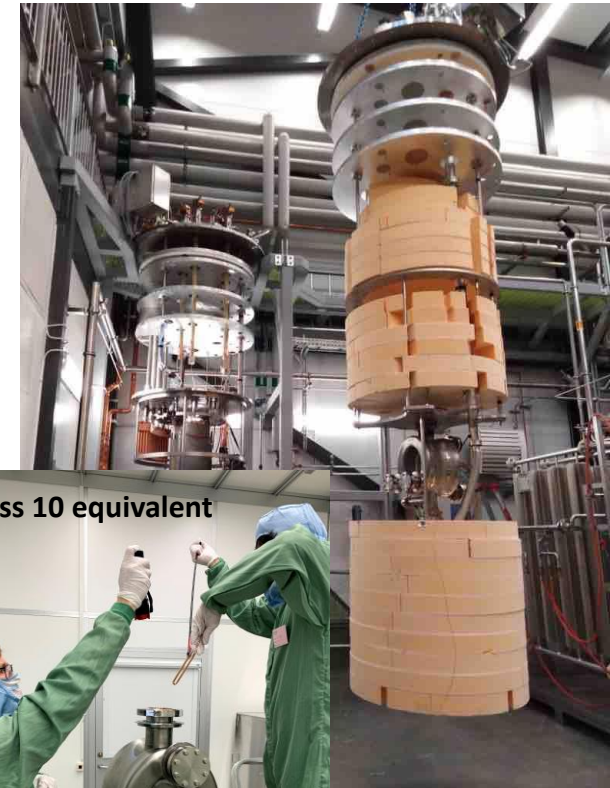
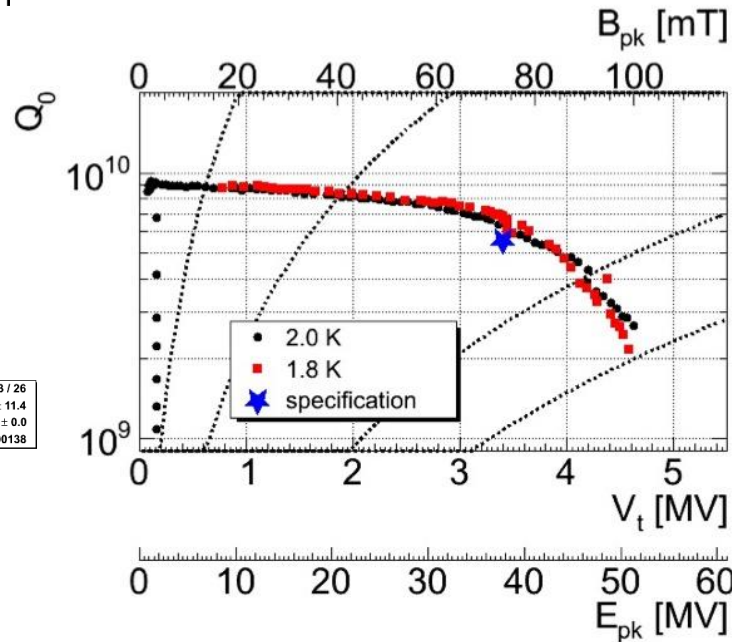
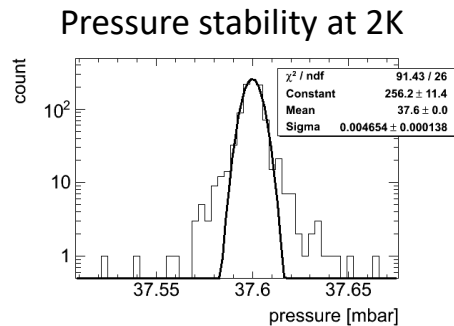


4. Piezo Driver module #1
3. Piezo Driver module #2
2. DC/DC Boost converter
1. AMC carrier module with MMC



WP12.1 FREIA-HNOSS-2020-01 (#4)

- Validation of prototype crab-cavity
 - Cavity was without helium vessel, so test in helium bath of vertical cryostat
 - A pick-up antenna fallen off during transport
 - successfully fixed in the cleanroom
- Results
 - met project specifications



WP12.2 CERN XBox Facility



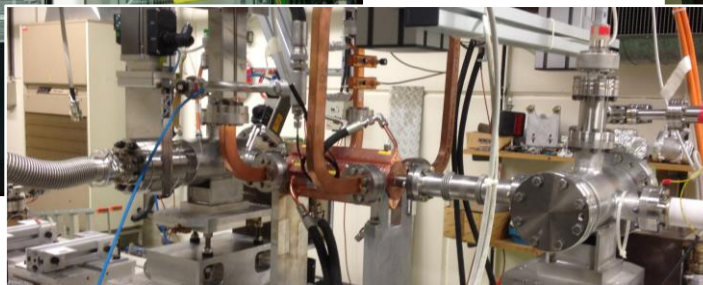
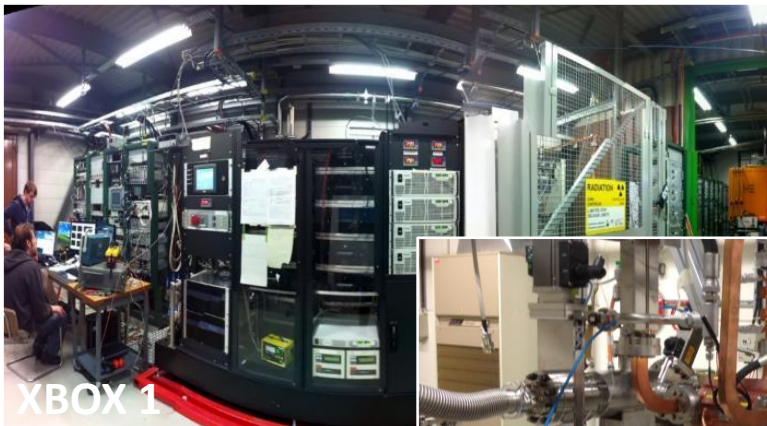
TASK 12.2 XBOX



The **XBox** facility at CERN, Switzerland, is available for testing of normal conducting RF cavities/structures at X-band frequency.

WP12.2 XBox at CERN

- State-of-the-art klystron-based X-band (11.994 GHz).
- High-gradient structure development
 - in the range of 100 MV/m,
 - very high peak power >100 MW,
- 6 Test slots (with pulse compressor)
 - XBox 1-2: 50 MW/1.5 μ s/50 Hz klystron,
 - XBox 3: 4 x 6 MW/5 μ s/400 Hz klystron,



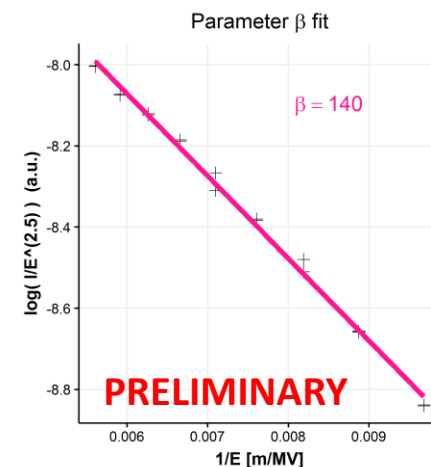
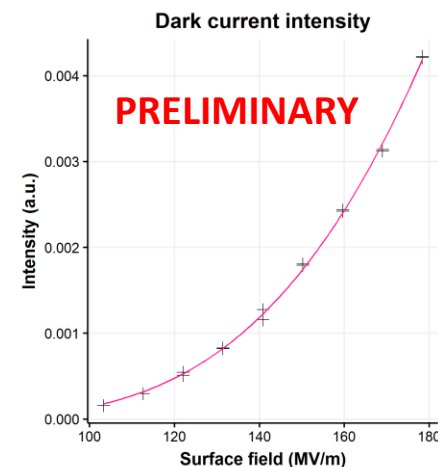
WP12.2 CERN XBox - Overview

In proposal - 4 projects with a total of ~~6000~~ 7500 access units.

#	Name	Institutes	Status	Access Units	Users
1	Dark current and breakdown Spectrometer	Uppsala University	Completed. Reported and published	1,680	6
2	X-band pulse compression chain	PSI and Tsinghua University	Completed. Reported and published, PRAB.	4,000	7
3	X-band RF deflecting structure testing	Lancaster University and SARI (Shanghai)	Running. Full remote participation due to Covid pandemic.	5,021	13
4	Measurement of the Average Power limitation for High Gradient X-band Accelerating Structures for Future Light Sources	Technical University of Eindhoven	Approved. Not carried out due to Covid pandemic.	-	5
TOTAL Achieved Today				10,701 (143%)	19

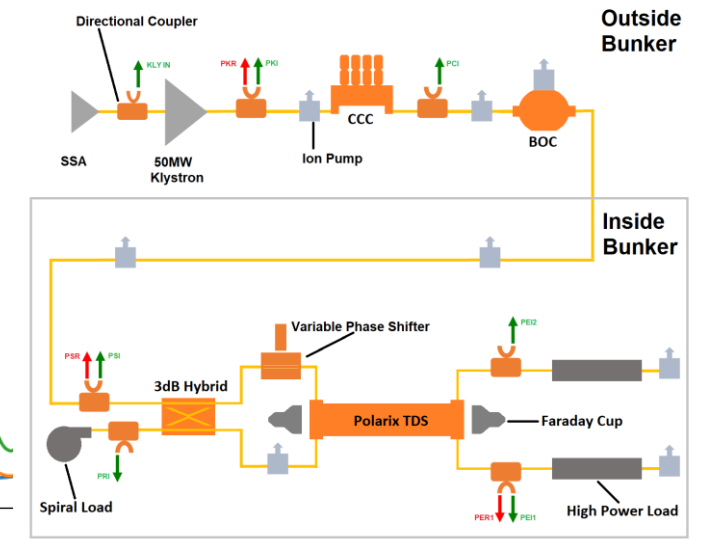
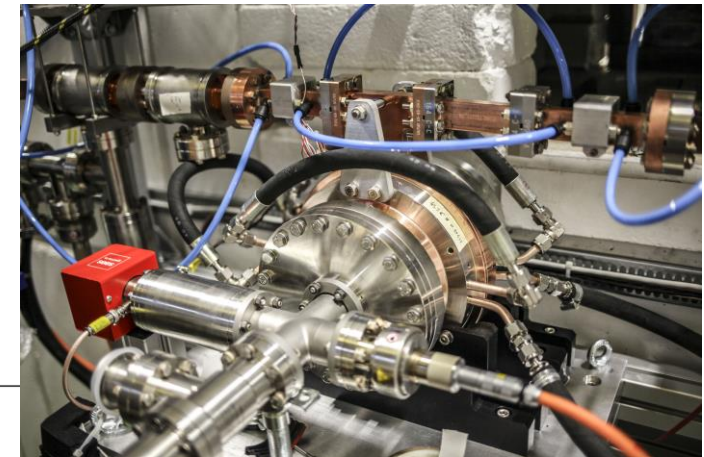
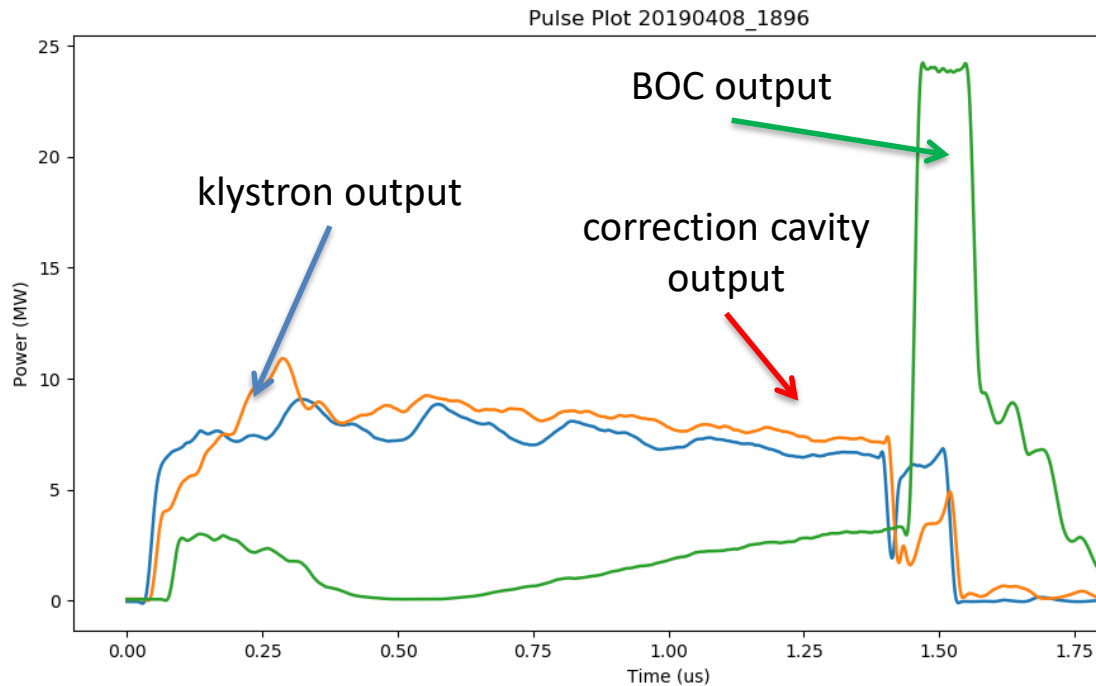
WP12.2 CERN-XBOX-2017-01 (#1)

- Dark and breakdown current measurements with spectrometer
- Dark current can give information about changes inside the structure during conditioning:
 - use the spectrometer to look at the changes, both spatially on the screen and by measuring the energy spectrum
- Enhancement factor β accounts for increase in local (microscopic) field E_{local} from the ideal surface field E
 - $E_{\text{local}} = \beta * E$
- **Results**
 - Good agreement with underlying theory of field emission



WP12.2 CERN-XBOX-2018-01 (#2)

- Validation of the high power performance of a new pulse compressor cavity (BOC) and correction cavity chain (CCC) for X-band operation



WP12.2 CERN-XBOX-2019-01 (#3)

High-power test of **two** transverse deflecting cavities

1) prototype crab cavity for the CLIC final focus system

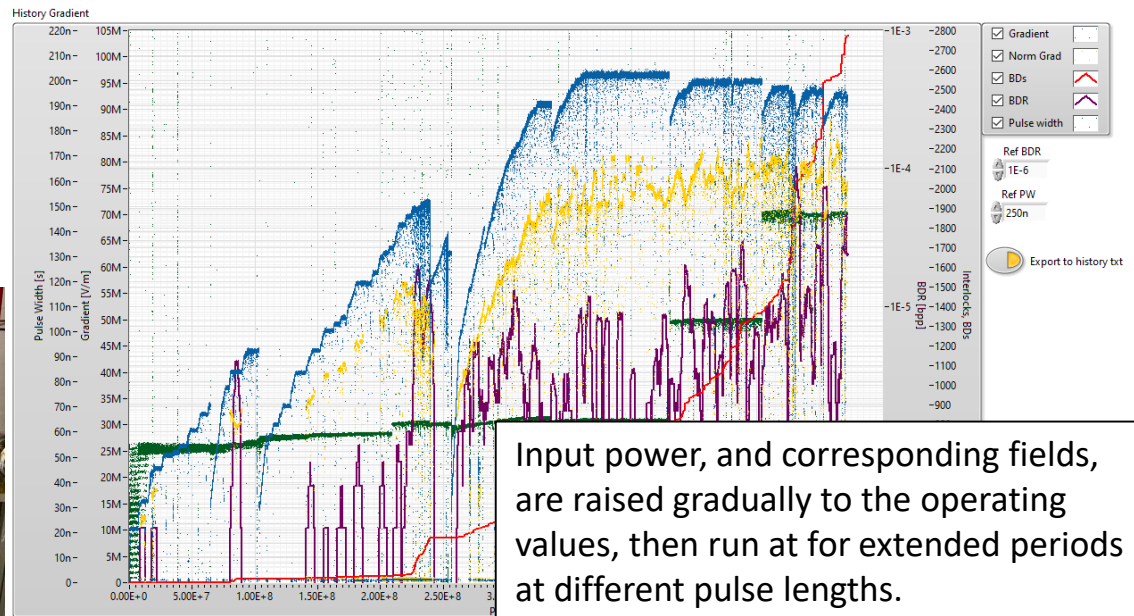
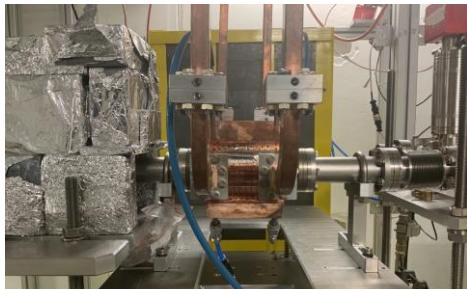
- 13 cell structure built by University of Lancaster

2) deflector to measure longitudinal profile of very short bunches in XFEL

- 20 cell structure built by SSRF.

• Results

- high field conditioned and then operated with input power up to 40 MW



WP12.2 CERN-XBOX-2020-01 (#4)

- Measurement of the Average Power limitation for High Gradient X-band Accelerating Structures for Future Light Sources
 - aim for better understanding of the average power capabilities of high gradient accelerating structures and their limitations by peak surface electric field and cooling capacity.
- Not carried out due to coronavirus restrictions followed by the departure from the proposing university of key staff

WP12 TNA - Summary

- A **typical User Project is quite complex**, often requires some form of approval at the level of the proposing institutes, so lead times are long.
- ARIES TNA has become **very successful** for the facilities and its users!
- We could open to new users with **exciting projects**.
- User **response has been very positive** and overall the users were very pleased to receive these access possibilities.
- It was a **great experience** which we will to **continue** in...

