WP12 Innovative RF Technologies

Peter McIntosh (STFC Daresbury Laboratory)

Nicoleta Baboi (DESY)
Juliette Plouin (CEA Saclay)

4th EuCARD-2 Annual Meeting,
Strathclyde University, UK
28 – 30 March 2017

EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453

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WP12 Collaborative Team

Task 12.2
SRF Thin Films
C Antoine (CEA)

CEA Saclay · CERN · HZB Helmholtz Zentrum Berlin · Grenoble INP

Task 12.3
High Gradient NC
W Wuensch (CERN)

CEA Saclay · Lancaster University · Paul Scherrer Institut PSI · Uppsala Universitet · ScandiNova 2016
CERN · The University of Manchester · Science & Technology Facilities Council · THALES 2015

Task 12.4
SRF HOM Beam Diagnostics
R Jones (Manchester Univ)

DESY · Universität Rostock · The University of Manchester

Task 12.5
RF Photocathodes
R Nietubyc (NCBJ)

DESY · HZDR Helmholtz Zentrum Dresden Rossendorf · HZB Helmholtz Zentrum Berlin · NCBJ · Science & Technology Facilities Council

Fundamental Objectives

12.2 Thin Films

Exploitation of new superconducting materials, such as Nb_3Sn and the development of new nano and multi-layer thin films, each anticipated to **break new ground in the performance of SC accelerator cavities**, with the potential of **achieving gradients well beyond present Nb technology**.

12.3 High Gradient NC Cavities

Development of an efficient NC structure **capable of high gradient operation (Eacc > 100 MV/m)** but **free from dangerous wakefield contributions**.

12.4 SRF HOM Beam Diagnostics

Development of electronics for utilising Higher Order Mode (HOM) signals from accelerating cavities for **precision beam position diagnostics in high-energy electron linear accelerators**, with the goal of **substantially improving beam quality**, critical for XFEL applications.

12.5 RF Photocathodes

Development of next generation advanced RF photocathodes, exploring revolutionary production techniques as lead deposition, diamond amplifier cathode and metallic photocathodes, enhancing the **ability to reach fs response time,** for more effective electron beam generation, capture and transport with **high brightness** and **low intrinsic emittance**.

Task 12.2 SRF Thin Films

Niobium on copper (µm)

- After ~ 20 years stagnation : revolutionary deposition techniques (ALD, HIPIMS)
- Great expectations in cost reduction
- Improved performances c.f. bulk Nb

Higher Tc material (µm)

- Based on superheating model (NbN, Nb_3Sn).
- Higher field and Qo expected

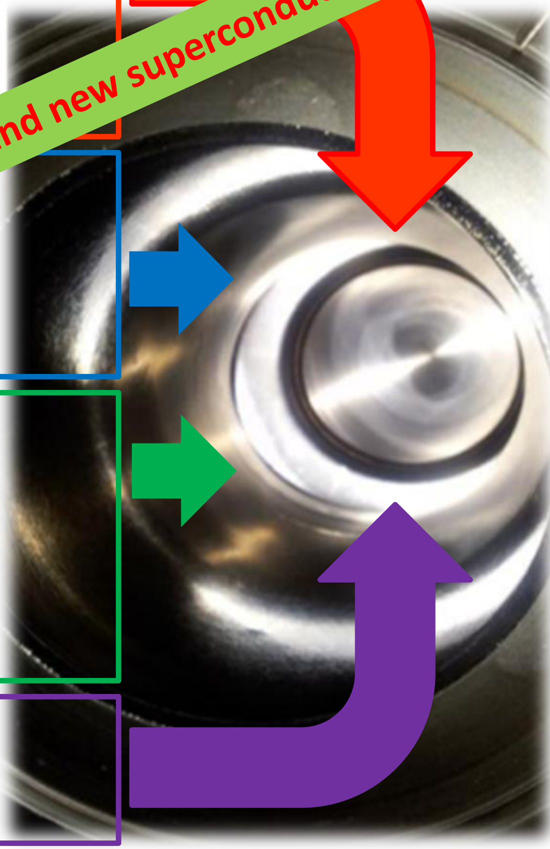
Higher Tc material (nm), multilay

- Based on trapped model (Gurevich)
- Higher Qo expected
- experimental evidences

See Claire Antoine (CEA) talk today: Beyond Niobium SRF materials: thin films and new superconductors

Specific characterization tools needed

Better understanding of SRF physics needed

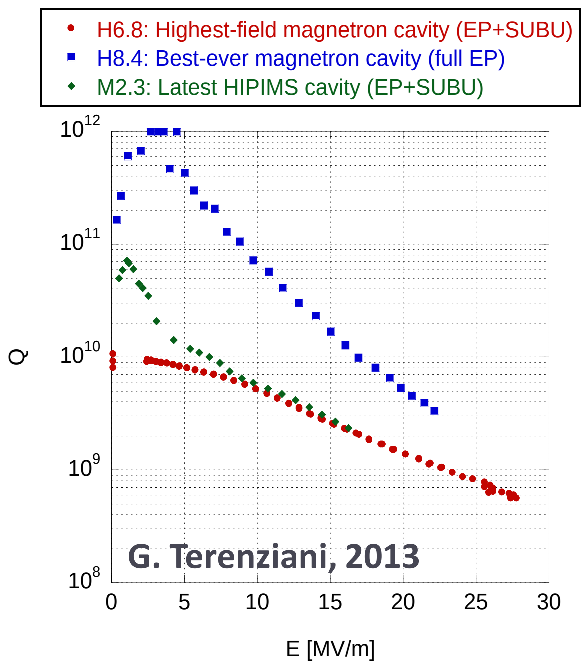


Task 12.2 Coordinator: Claire Antoine (CEA Saclay)

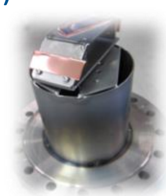
HIPIMS @ CERN

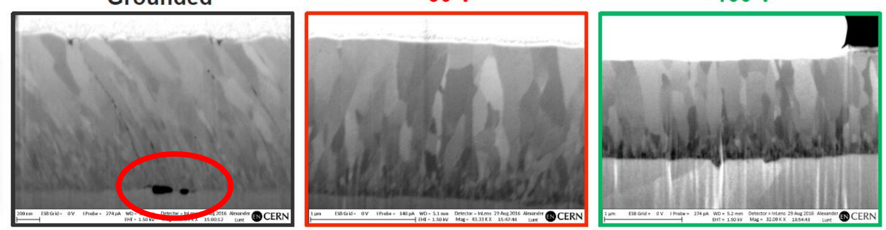
HIgh Power Impulse Magnetron Sputtering:

- Pulsed PSU (~100 µs pulses, 1% duty, up to 1 kHz)
- Power density:
  - DC: 12 W/cm² c.f. HiPIMS: ~1 kW/cm²
- Ionization of sputtered species up to 90%
- Better coating conformity
- Lower substrate heating
- Lower coating rate: ions captured at the cathode
- Sensitive to cathode surface (roughness) → arcing

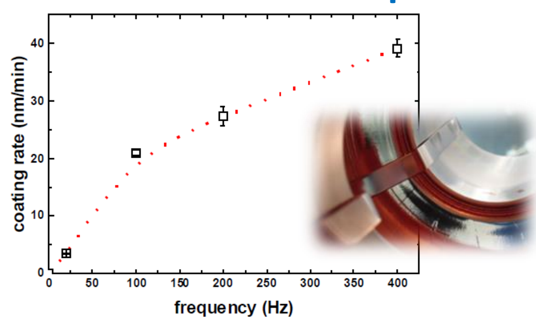


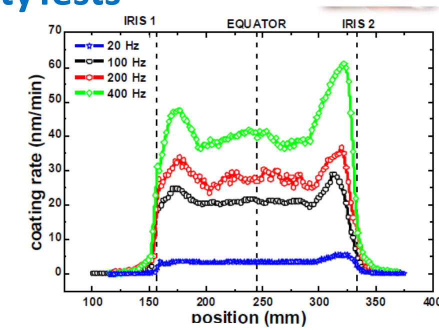
Small Sample Tests



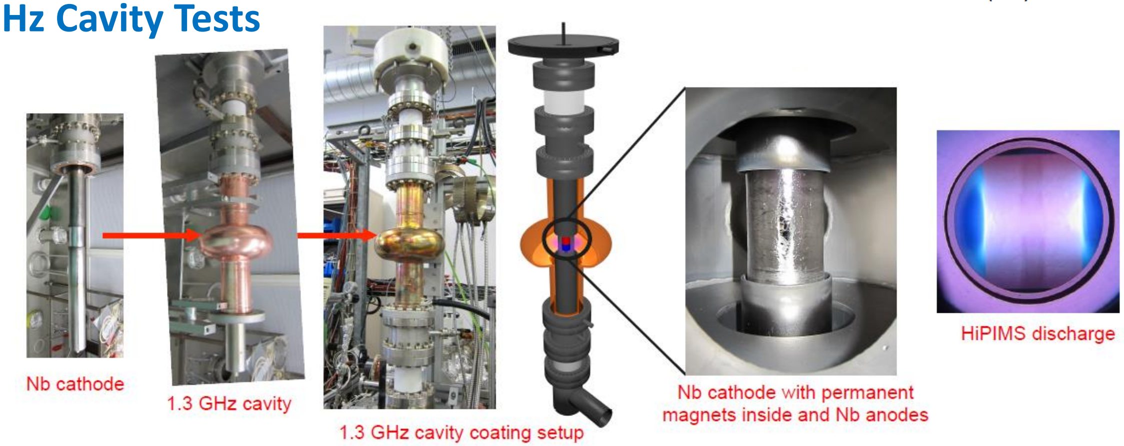


Replica CavityTests



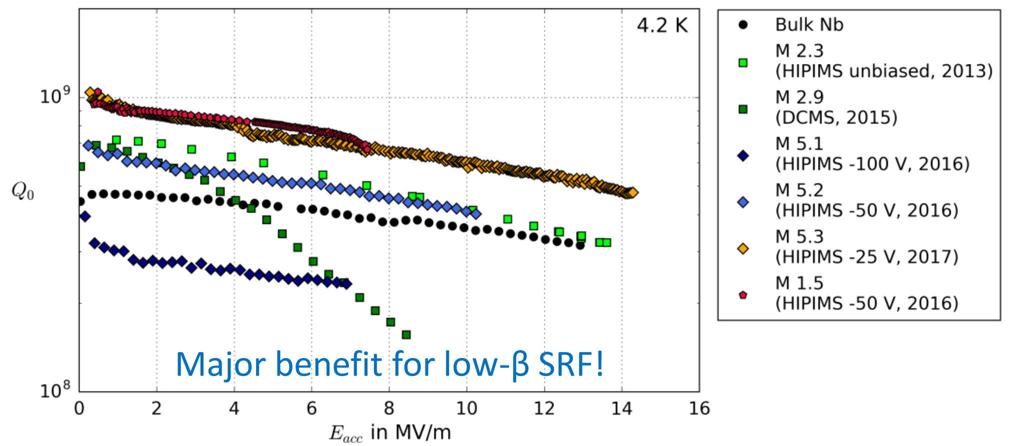


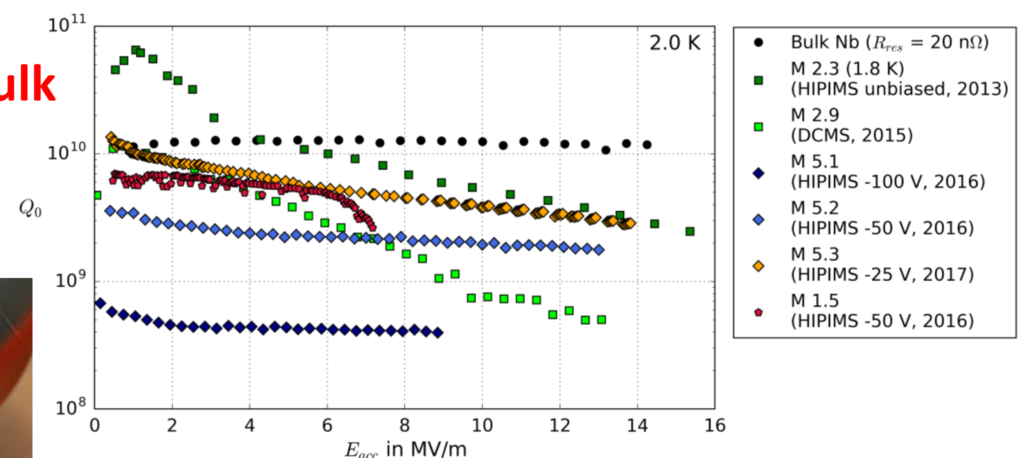
1.3GHz Cavity Tests

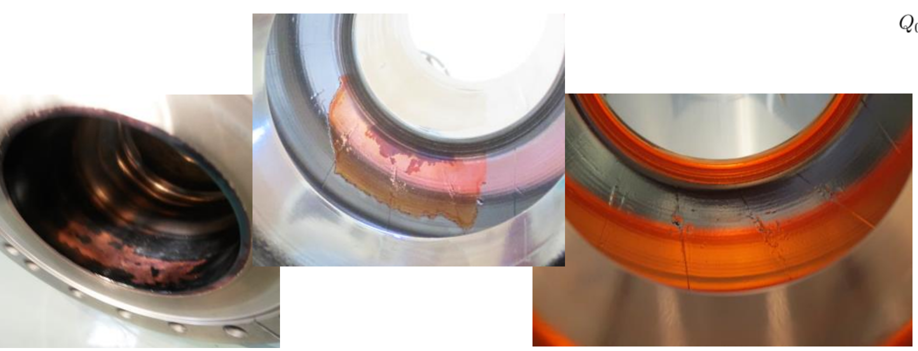


Biased HIPIMS Cavity Tests

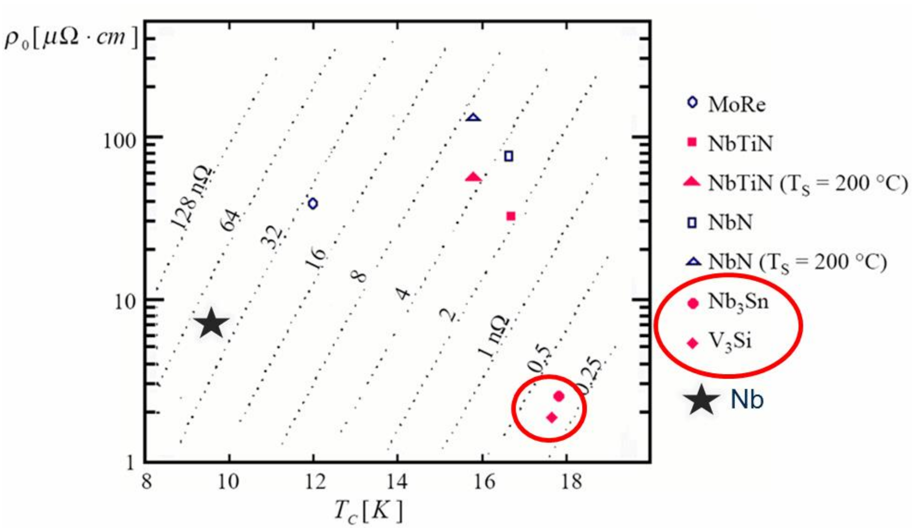
- 12 cavities coated in 2016:
  - 4 measured (adhesion issues).
  - Coating pressure and bias showed a strong Q impact.
- Able to flatten Q_{slope} compared to DCMS:
  - Best R_{res} = 25 nΩ
- Poor substrates quality:
  - Peel-off and substrate defects
  - 10 new substrates delivered @ CERN
- More parameters to optimise,
- **Biased HIPIMS now very close to bulk Nb performance!**







Nb_3Sn (A15) @ CERN

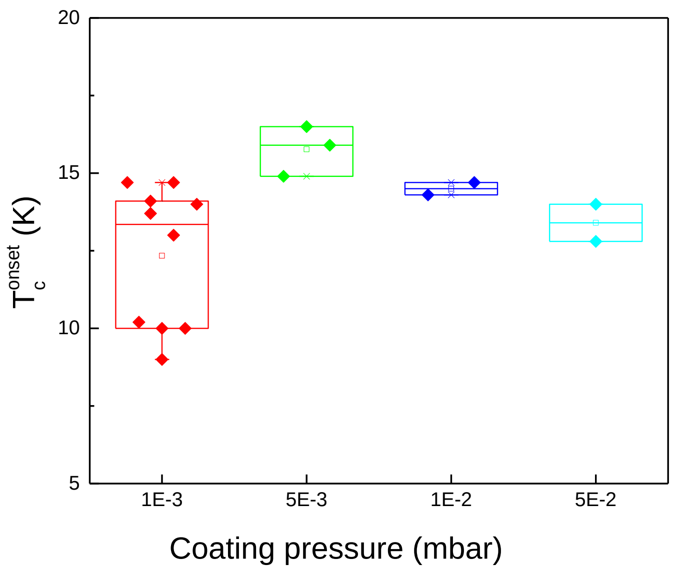


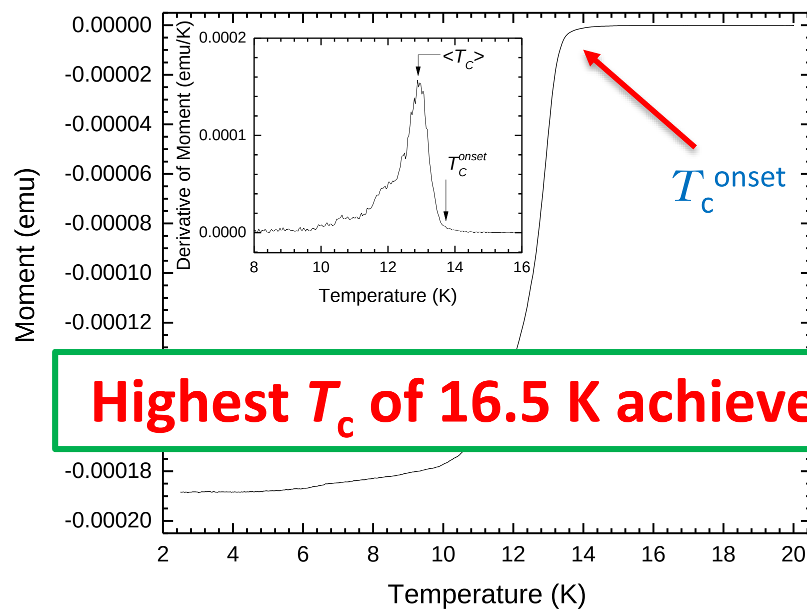
Alternative SC materials:

- "High" T_C
- Low resistivity
- Low surface resistance
- Single SC gap
- Remain SC in high B-fields

Achieved:

- Recipes defined for LT and HT deposition to achieve A15 SC phase.

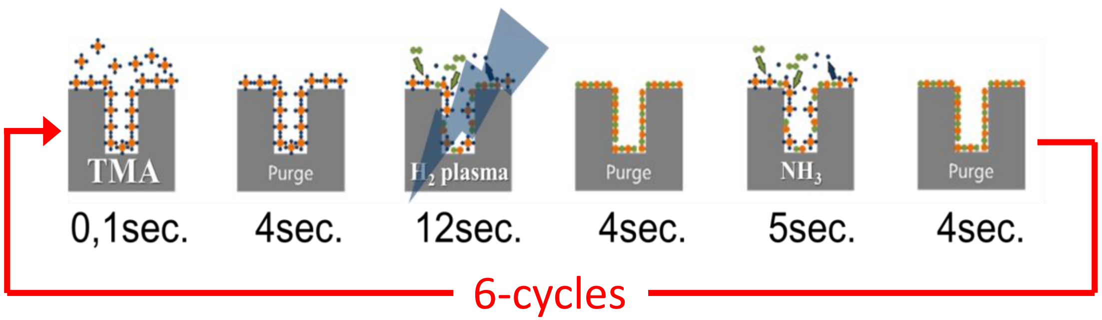




Highest T_c of 16.5 K achieved

ALD @ INP-Grenoble

Optimised PEALD 'SuperCycle'



Insulating AlN, t ≈ 10 nm

SC NbN (Tc > 9K) t ≈ 80 nm

Insulating AlN, t ≈ 10 nm

Bulk Nb, Tc = 9 K
RF cavity

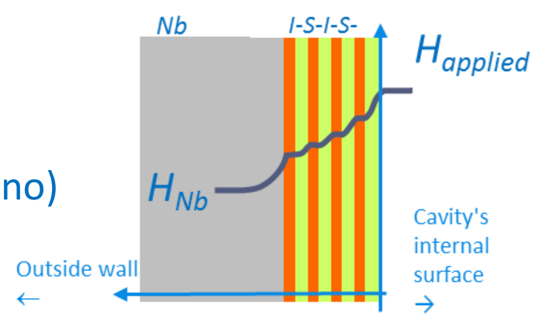
A Gurevich:
Enhancement of the quality factor and reduction of the electomagnetic loss

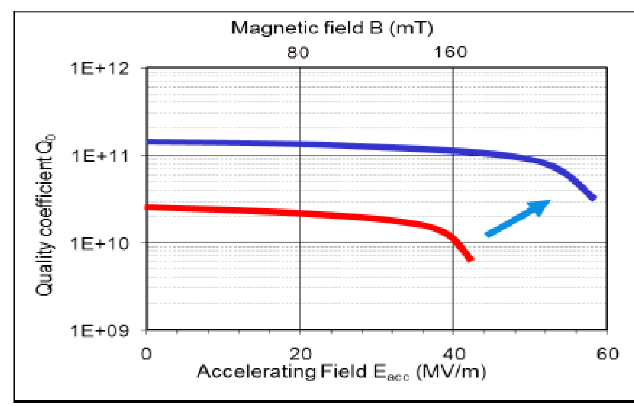
AlN deposition:

- Refined PEALD settings:
  - Al source : TMA (Tri-Methyl Aluminium)
  - N source : NH3 **plasma**
  - Temperature : 350°C

NbN:

- Refined PEALD settings:
  - Nb source : TBTDEN (tert-butylimido)bis(dimethylamino)
  - N source : NH3 **plasma**
  - Temperature : 240°C





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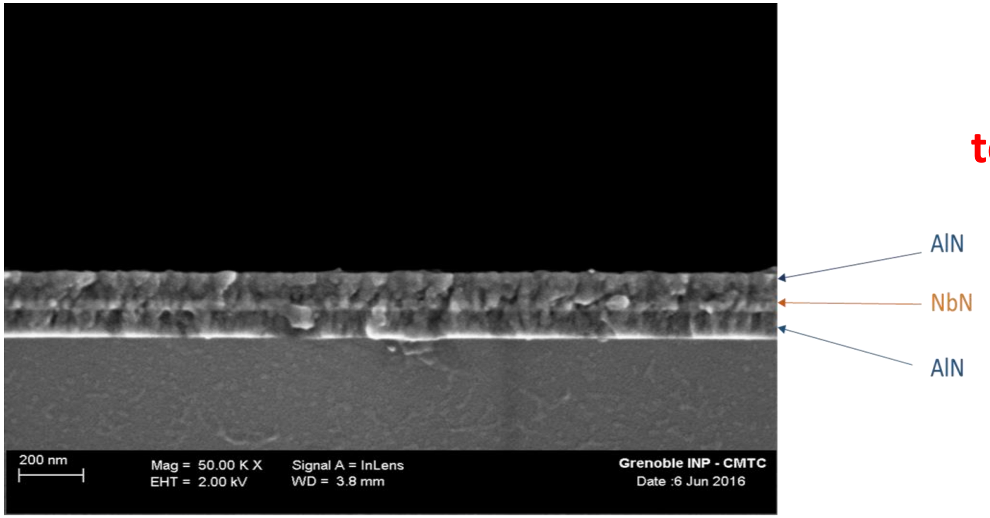
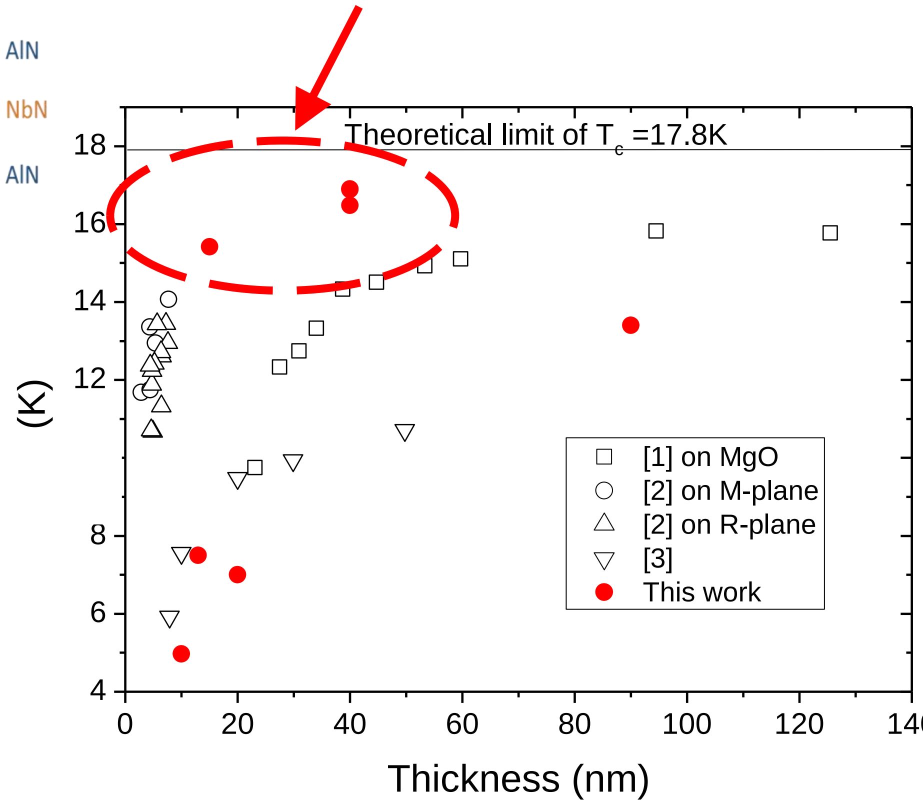
PEALD Multilayer Achievement



Highest T_c reported (17.06K) for NbN together with low resistivity value (50 µΩcm)



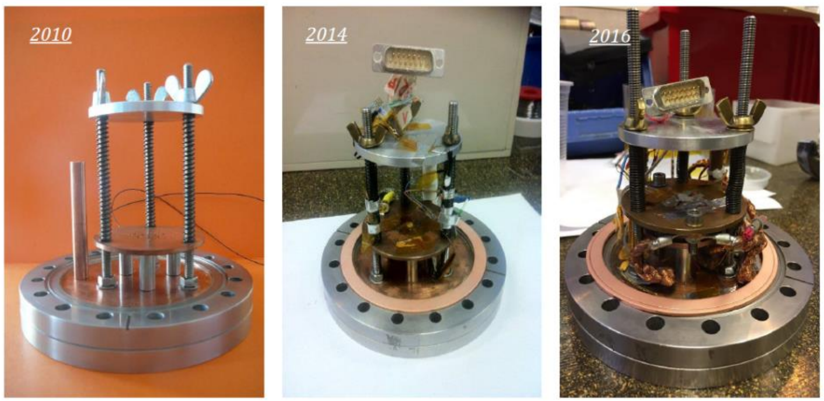
QPR samples prepared:

- BCP and HT at CEA
- AlN/NbN multilayer deposition @ INP
- Magnetometry tests at CEA
- RF tests to be performed using HZB QPR

[1] Miki et al. Applied Physics Express 2 (2009) 075002
[2] Villegier et al. APL 2009
[3] Shiino et al. Supercond. Sci. Technol. 23 (2010) 045004

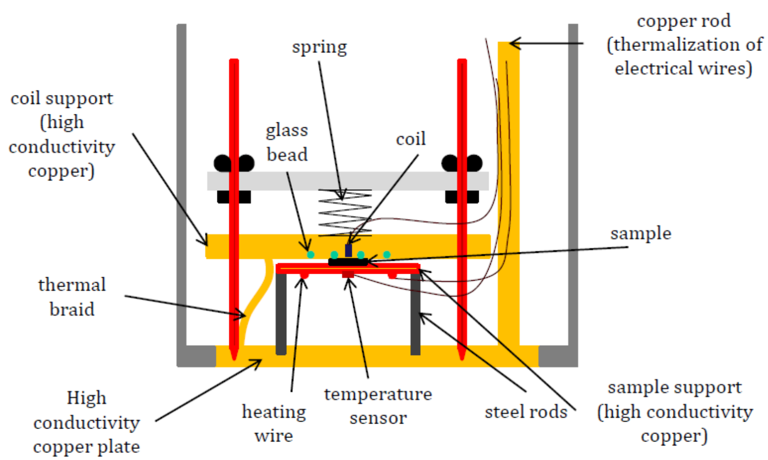
H_{c1} Magnetometry Characterisation of SIS layers @ CEA

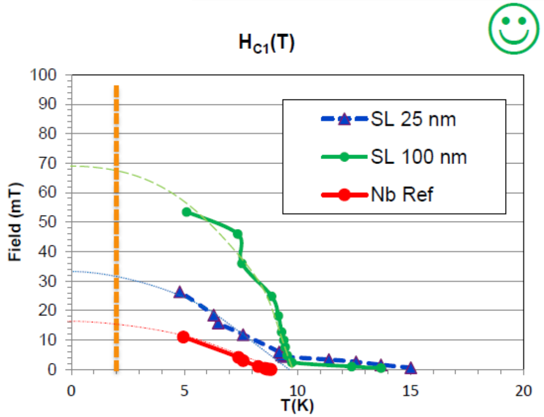
- Local magnetometer gives more precise H_{c1} characterisation without edge/demagnetisation effects seen from SQUID.



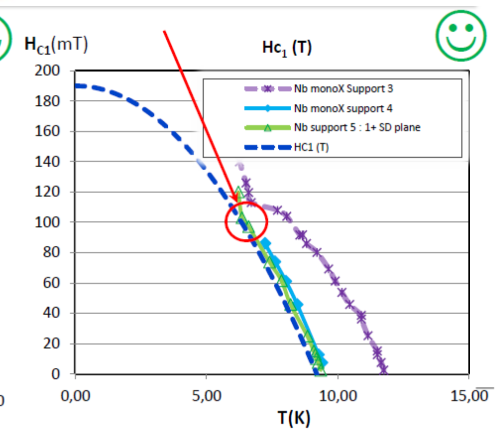
Magnetometer

Insert | Cryostat | Measurement devices





First acceptable results



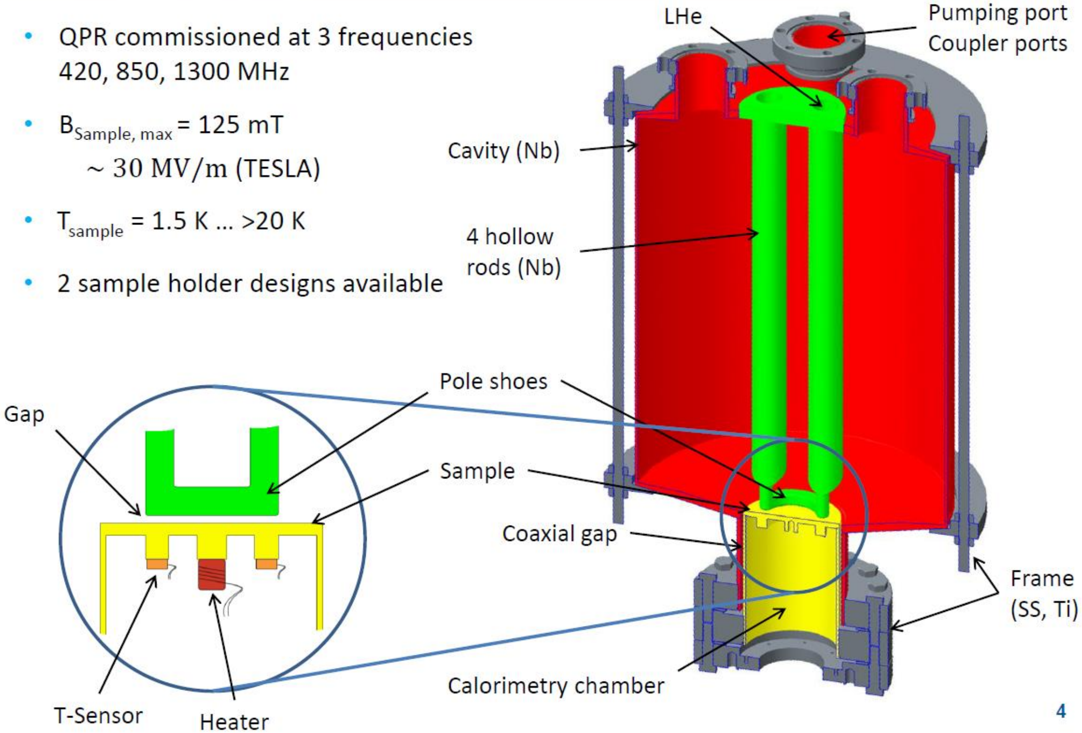
Calibration with a monocrystalline Nb

QPR RF Test Cavity @ HZB

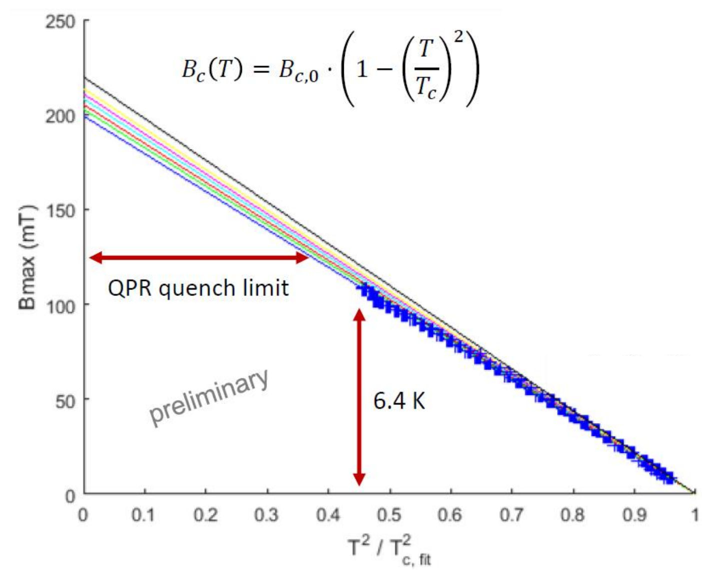
The Quadrupole Resonator (QPR)

HZB Helmholtz Zentrum Berlin

- QPR commissioned at 3 frequencies 420, 850, 1300 MHz
- $B_{Sample,\,max}$ = 125 mT
  ~ 30 MV/m (TESLA)
- T_{sample} = 1.5 K ... >20 K
- 2 sample holder designs available



RF Critical Field



Resolution & Measurement Limits

Sample temperature	Reference power	R_S resolution limit
1.9 K	2.4 mW	0.006 nΩ
2 K	4.6 mW	0.011 nΩ
4 K	83 mW	0.2 nΩ
7 K	375 mW	0.9 nΩ

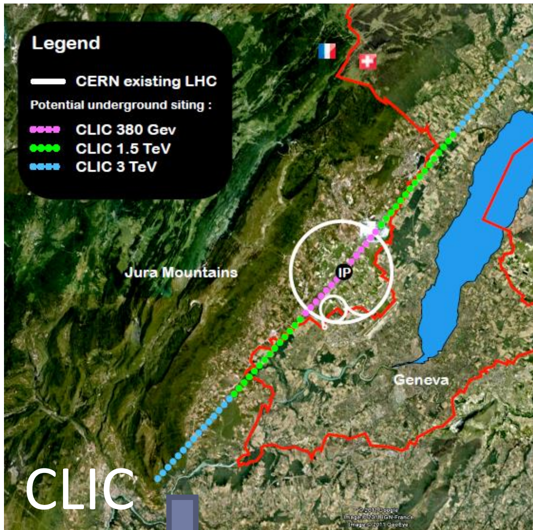
Task 12.3 High Gradient Normal Conducting

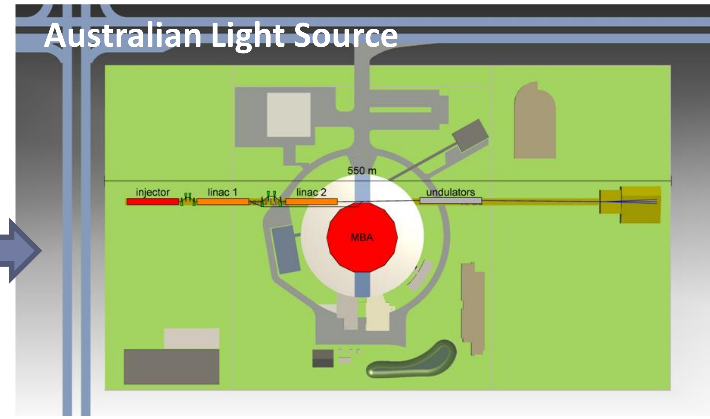
- Where are we going with X-band and high-gradients?

- Deepen the technological base:
  - WFM instrumentation and electronics from PSI
  - New high efficiency X-band klystron design from CEA
  - New high gradient DDS and 380GeV DDS cavity designs from UMAN.
  - Flexible modulator development and discharge studies from UU.
- Broaden the use in accelerators:
  - Crab cavity/deflector development from Lancaster Univ & STFC

Task 12.3 Coordinator: Walter Wuensch (CERN)

Applications of X-band Technology

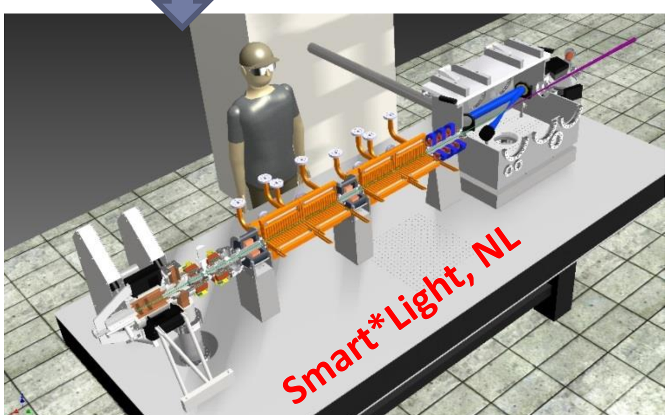




XFEL – 1 to 10 GeV

Thompson/Compton source – few 100s MeV

Tsinghua, China

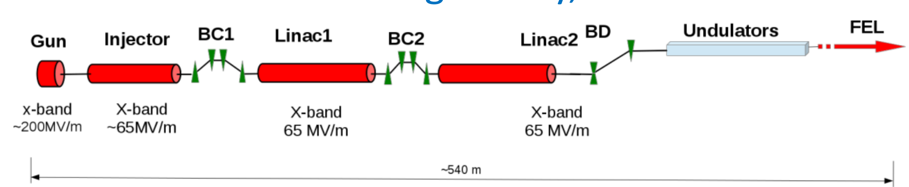


Compact Compton source
few 10s MeV

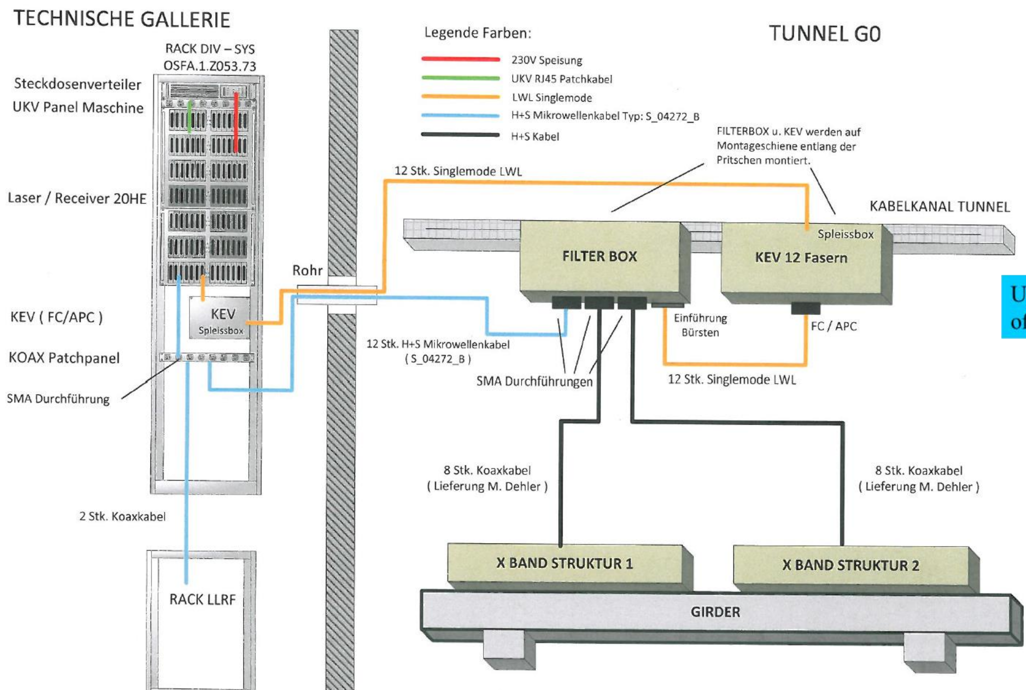
CompactLight, EU

26 collaborating EU organisations

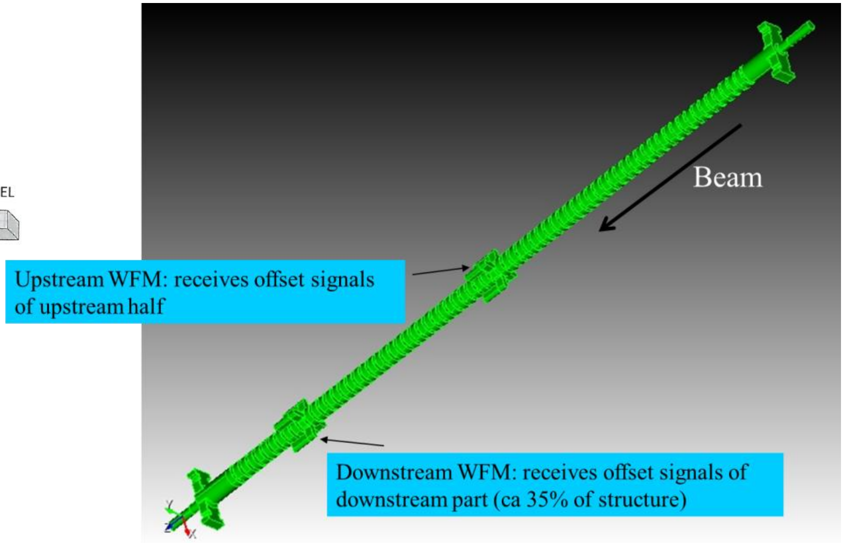
H2020 X-band FEL Design study, submission Mar17



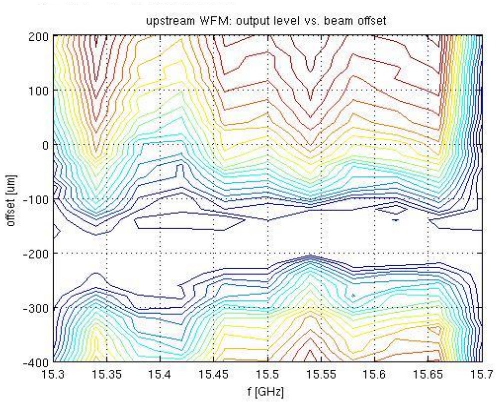
Wakefield Monitors @ PSI

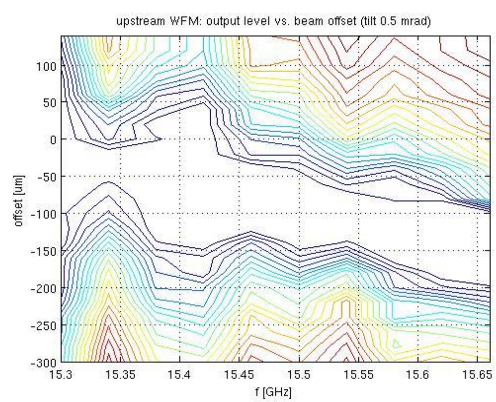


Prinziplayout Wake Field Monitore SwissFEL



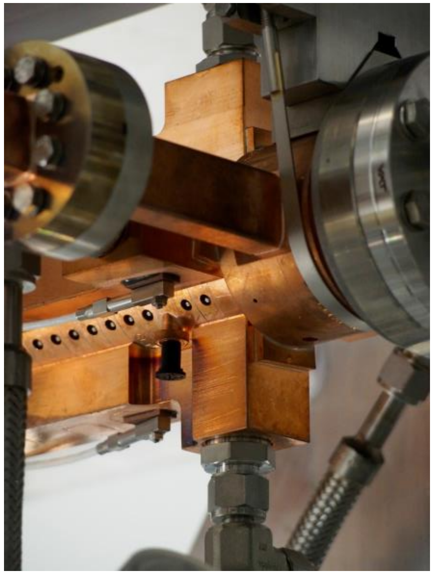
- Constant gradient X-band Structure:
  - dipole band spread out in frequency.
- Frequency of interaction correlated with position inside structure:
  - Low-f upstream, high-f downstream
- Dipole modes don‘t extend over full length of structure
- Big Advantage:
  - Spectrum contains information about tilt and internal misalignments (72 cavity BPMs!)

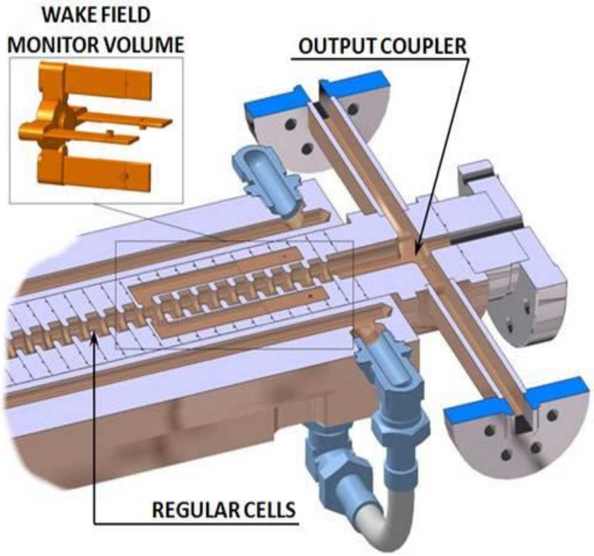




Minimum WFM signal ⇒ minimum emittance dilution!

SwissFEL WFM Testing



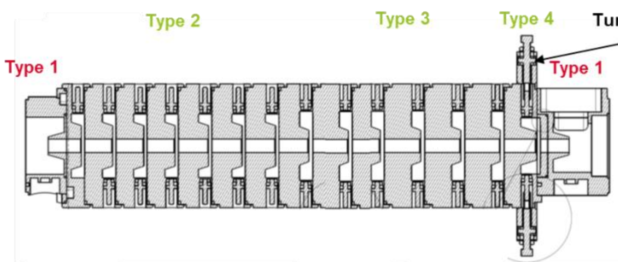


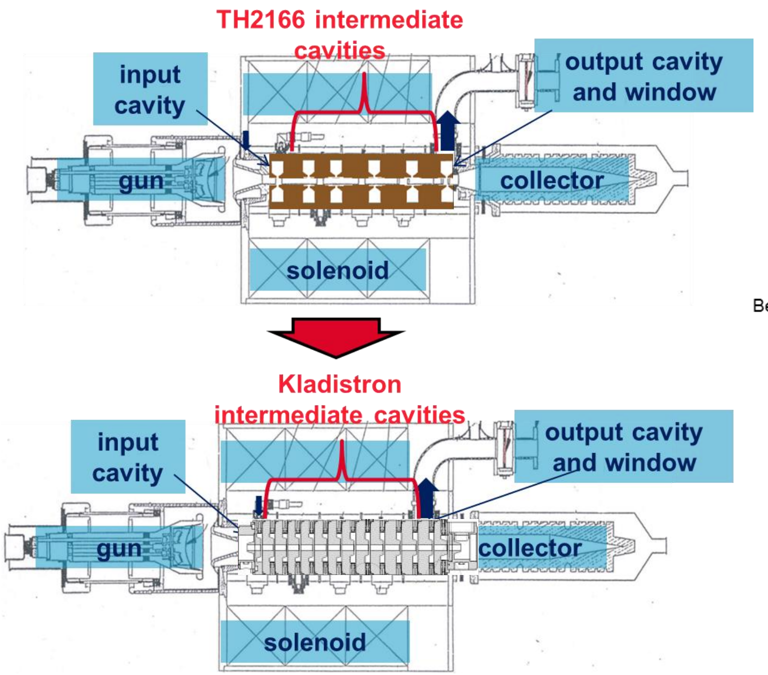
- 14 µm measurement resolution achieved on SwissFEL test facility.
- Noise contributions being mimimised to improve measurement resolution:
    - Carrier, thermal, shot and Johnson.
- **Tests expected to start on SwissFEL injector from May17.**

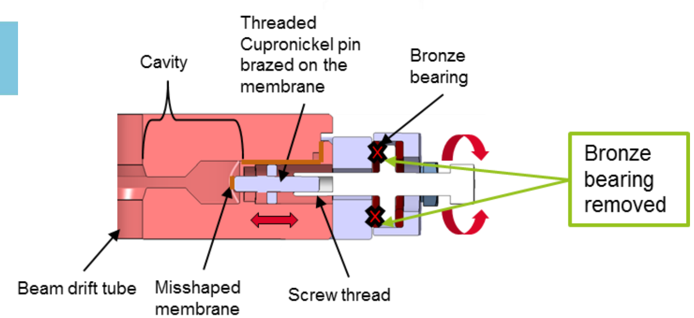
High Efficiency ‘Kladistron’ @ CEA

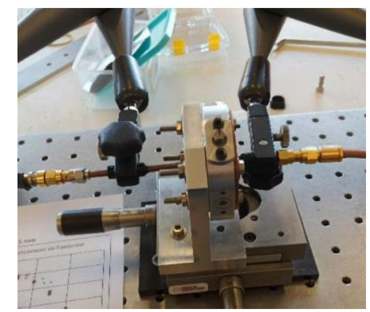
- The approach is to adiabatically bunch the beam with a large number of small kicks instead of a small number of larger kicks:
  - Benchmark simulation tools
  - Build technology demonstrator
  - Demonstrate efficiency increase from 50% to >70%
- **2015: New collaboration with Thales!**
  - **Part funding Phd student with CEA.**

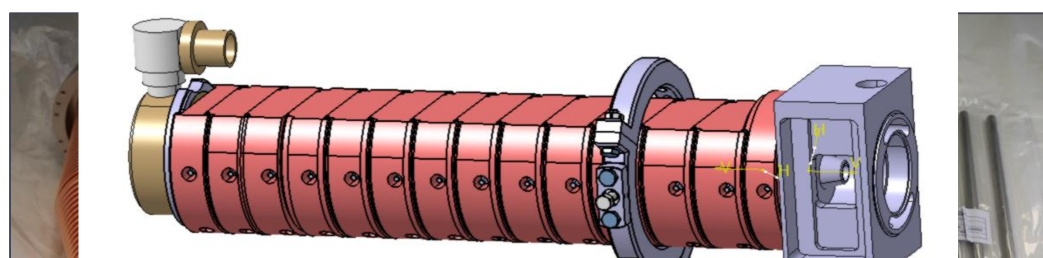
Improved 16-cell interaction design











VDL to provide interaction line and tuning system.
Brazing, integration & testing to be done at Thales (Jun17)

Flexible Modulator @ Uppsala Univ

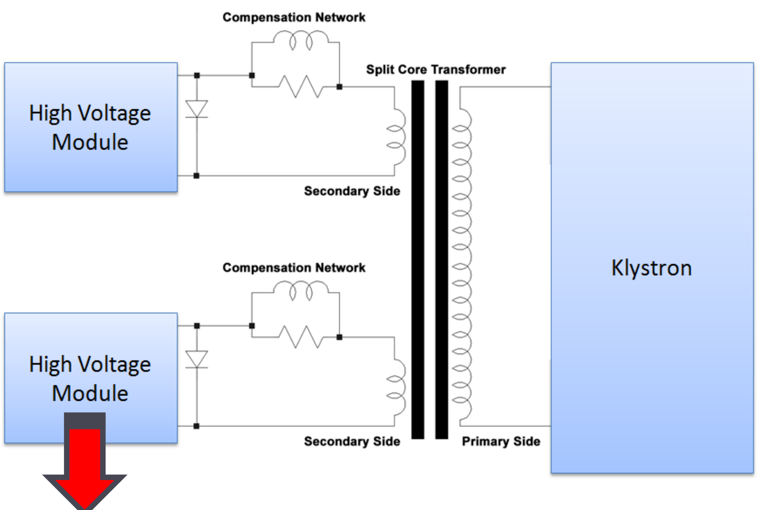
CPI VKX-8311A

Thales TH2100C

ScandiNova

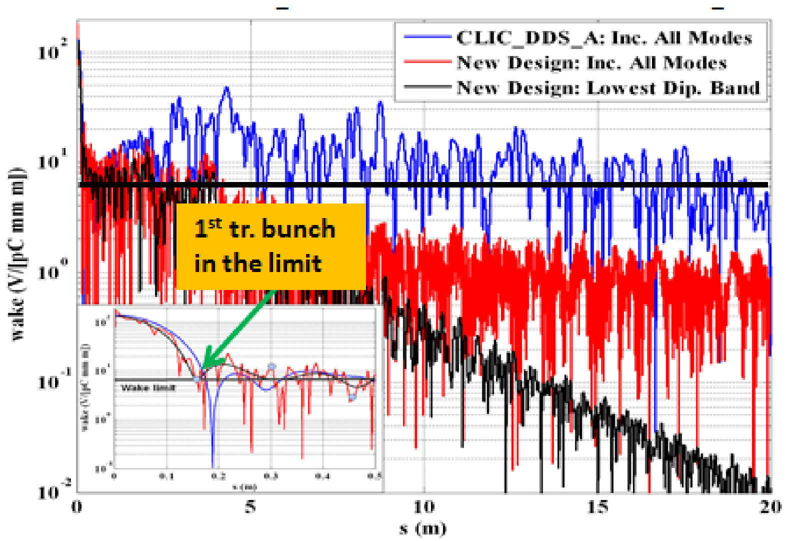
- Uppsala Univ. formed **new collaboration with Scandinova in 2016**.
- To develop a flexible modulator platform design:
  - Able to support **~25% adjustment** in klystron voltage and perveance.
  - Define modulator component specifications to provide necessary variability.
- Focusing on S and X-band klystron compatibility.

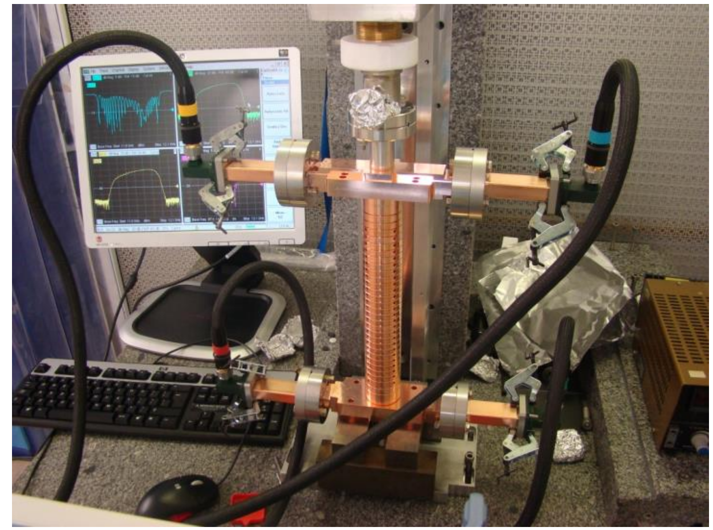
Klystron	Frequency (MHz)	Voltage (kV)	Current (A)	Pmax (MW)	Pavg (kW)
CPI VKX-8311A	11994	410	310	50	5
Thales TH2100C	2998	304	335	45	20

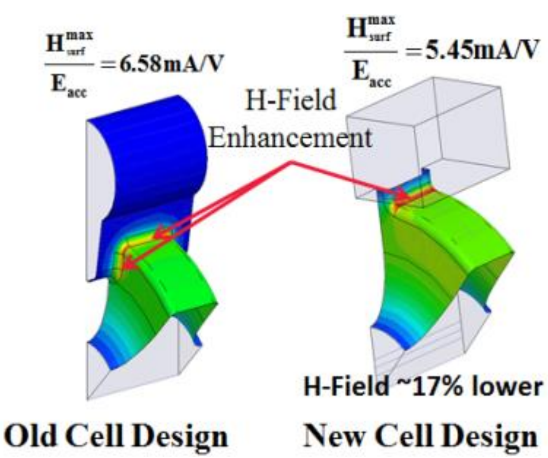


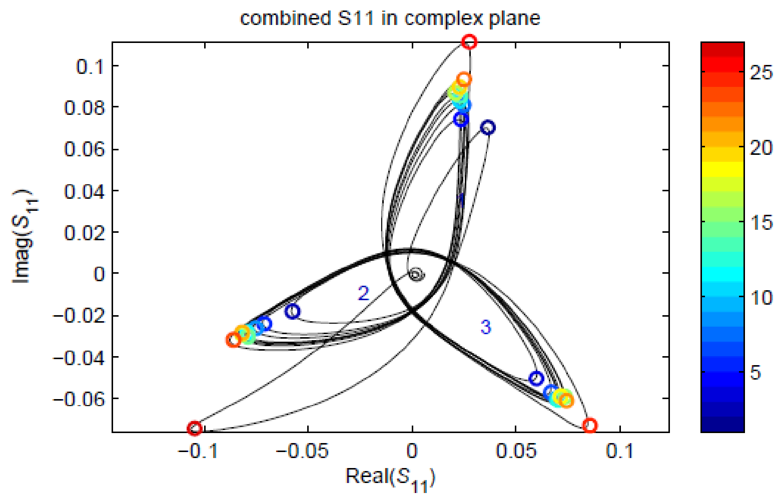
More compensation networks, depending on flexibility needed.

DDS Cavity Tuning @ UMAN







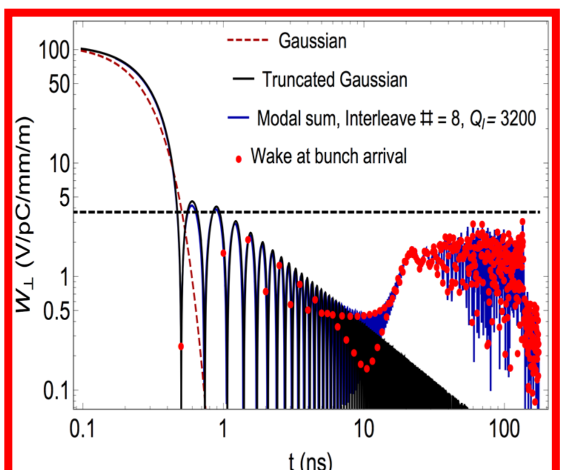


Cavity awaiting high power tests at CERN, targeting >100MV/m.

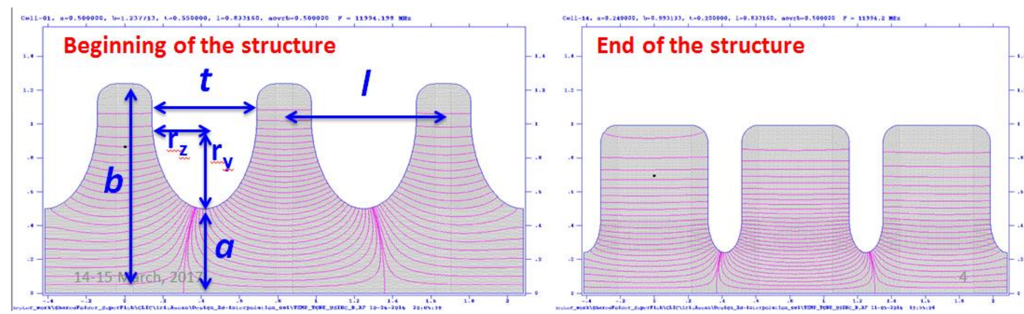
N Shipman (UMAN)

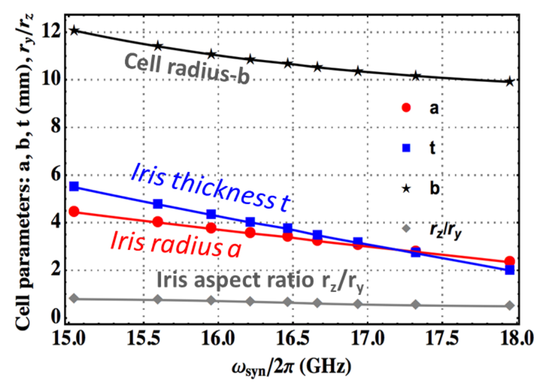
CLIC 380 GeV DDS Cavity Design @ UMAN

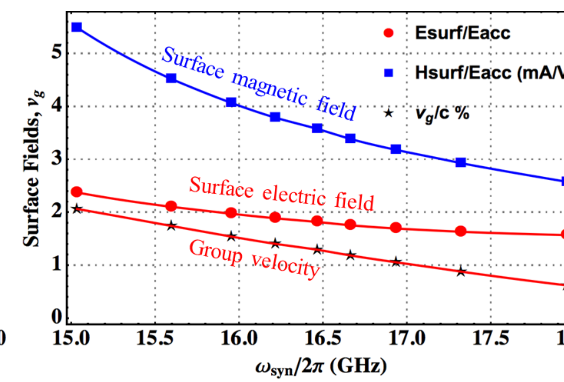
Parameters	3 TeV	380 GeV
Length of main linac (km)	48	11
Frequency (GHz)	11.994	11.994
Synchronous phase (deg)	120	120
# of cells	26	33
E_{acc} [MV/m]	100	72
# particles/bunch [10^9]	3.72	5.2
Bunch separation [ns]	0.5	0.5
# bunches/train	312	352
Wakefield [V/pC/mm/m]	6.3	3.7

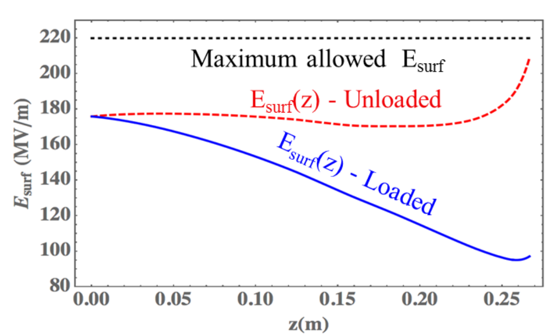


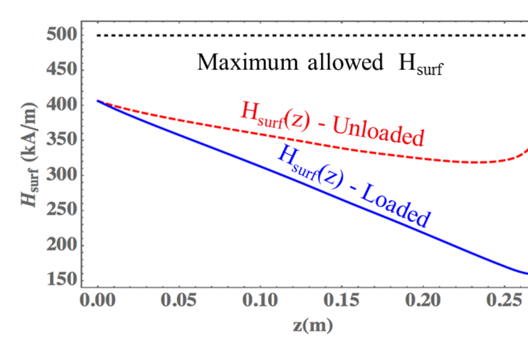
DDS Cell Parameterisation







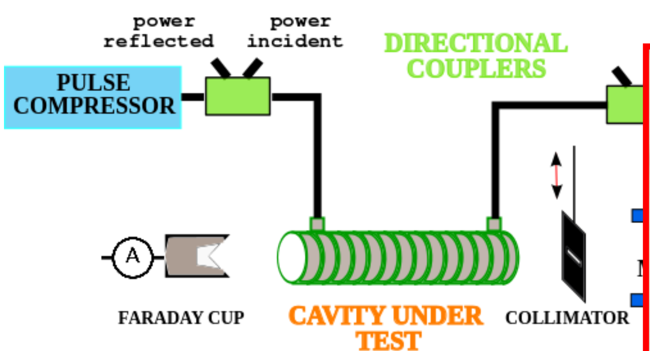


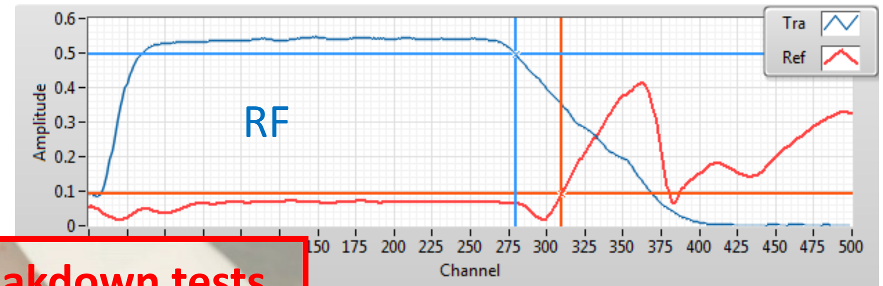


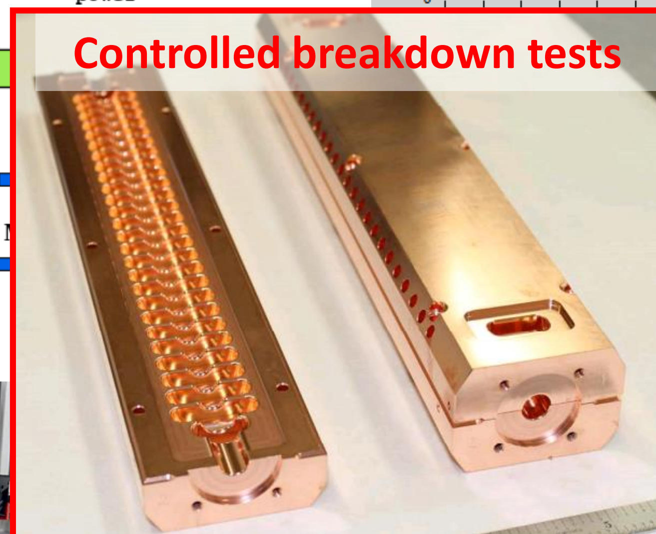
Breakdown Discharge by Uppsala Univ

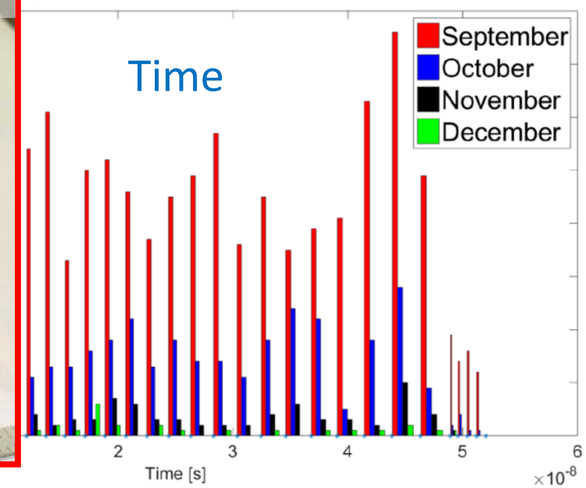
Uppsala CLIC X-Band Spectrometer (UCXS)

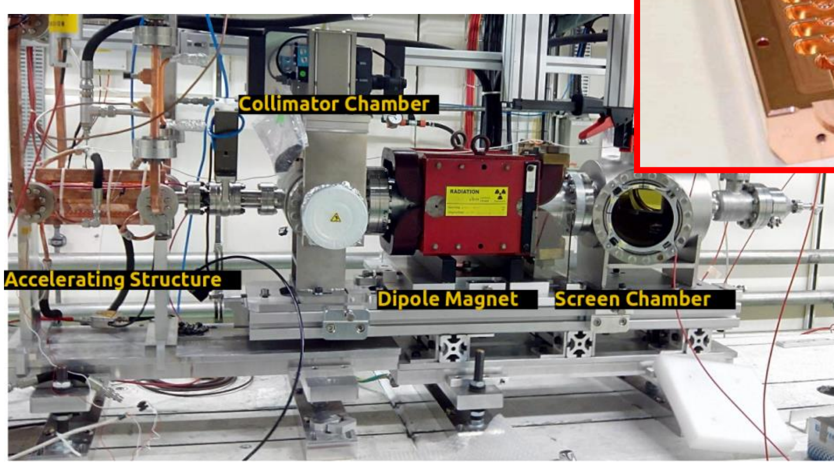
Detection and measurements of dark and breakdown currents during structure conditioning.



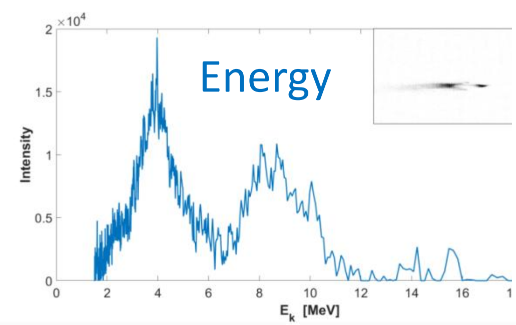


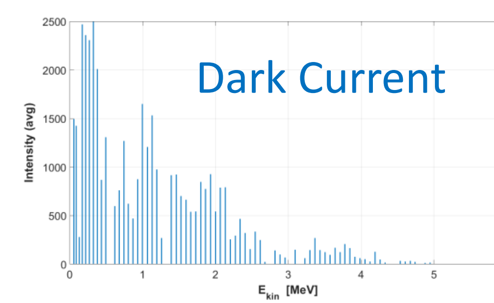




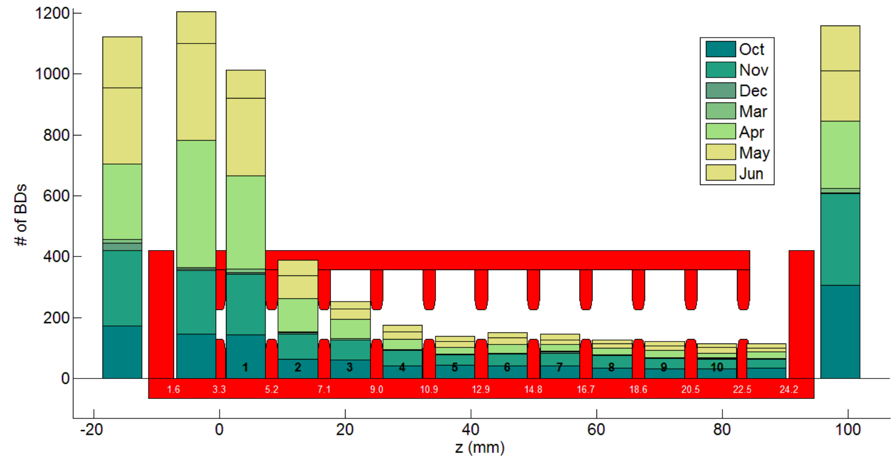


UCXS installed on Xbox-2 @ CERN

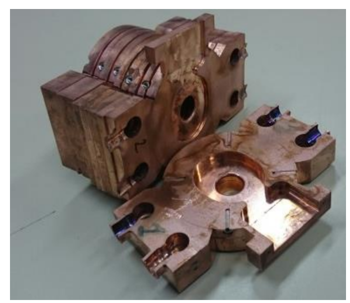


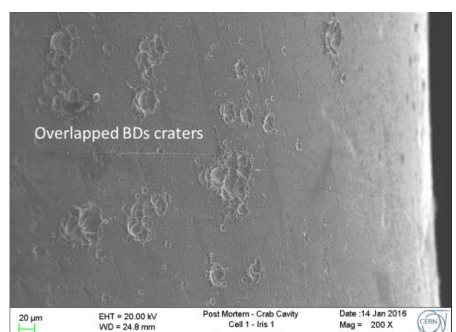


ULAN Crab Cavity Testing @ CERN

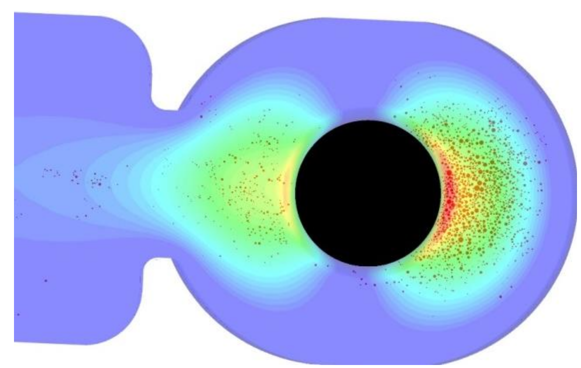


- First UK ‘un-damped’ crab cavity successfully tuned:
  - XBOX2 test stand @ CERN used for high power breakdown tests.
- **Conditioned to 43 MW input power, 200ns pulses, BDR 3e-6 – twice the design gradient achieved!**
- Breakdown analysis shows breakdown at high E-field regions of coupling and C1 cells.



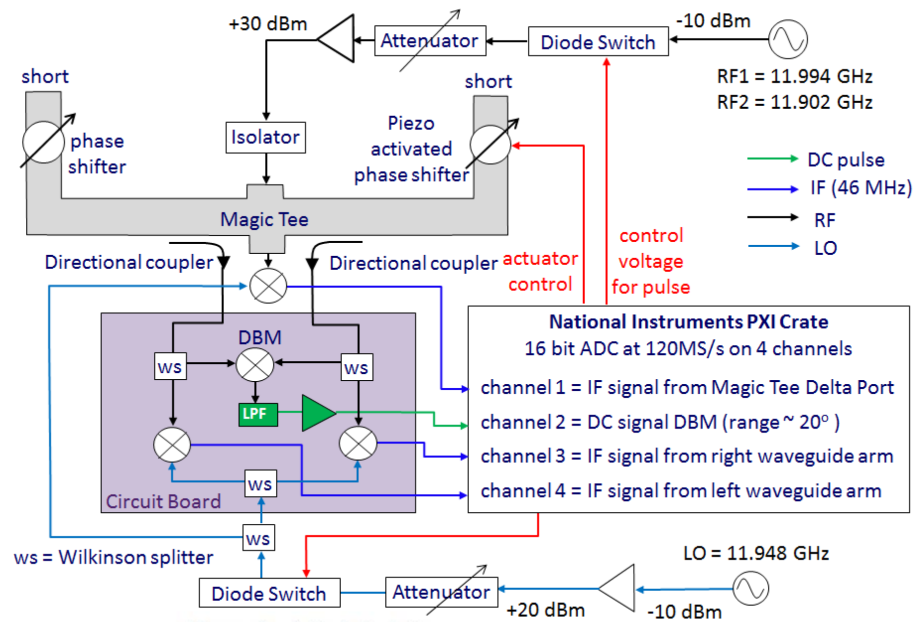


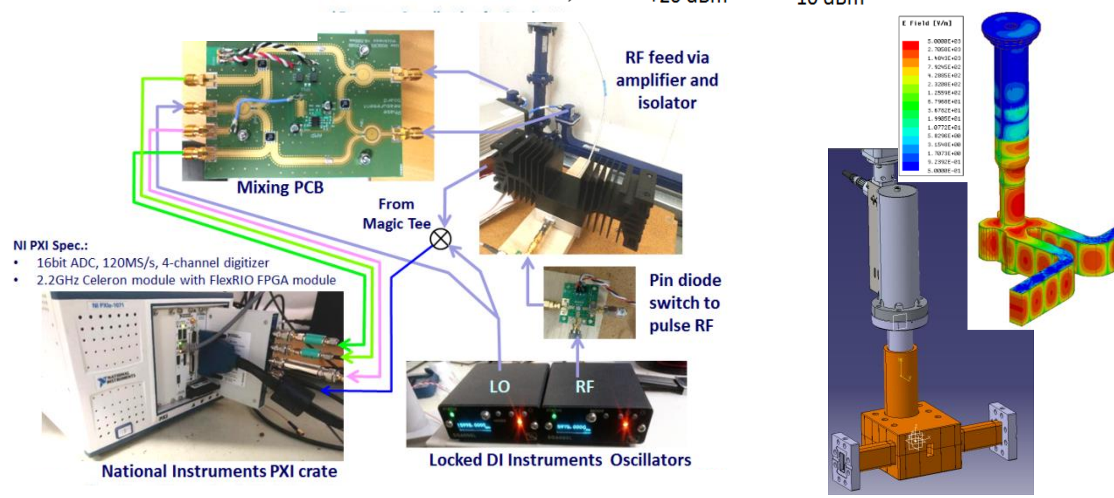
Cell 1 – Iris 1



ULAN Crab Cavity Synchronisation

- CLIC crab synchronisation target needs 0.019° for 156 μs pulse length.
- An X-band waveguide interferometer configured with Piezo-activated phase shifters to control arm lengths.
- NI-PXI DAQ and control system set-up to measure the phase difference and amplitude of signals returning on the interferometer arms.
- **10 milli-degrees for 30 micro second pulses at X-band demonstrated.**
- New HP phase-shifter design completed, awaiting fabrication and further tests.



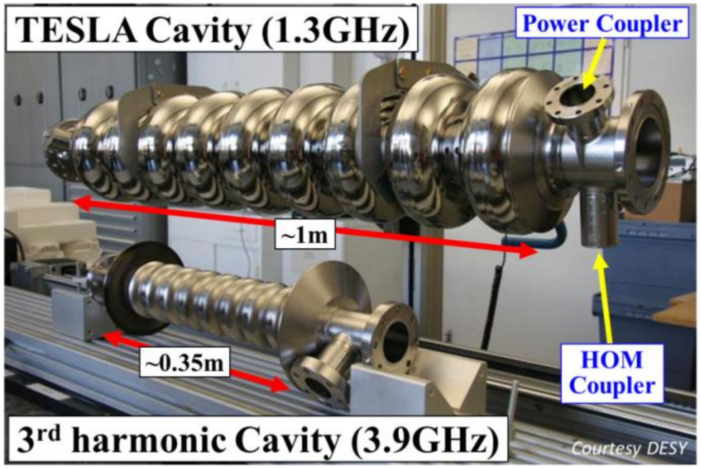


Task 12.4 SRF HOM Diagnostics

Overall Objective:

- Develop system which can be used to monitor HOM spectra to:
  - Characterise beam phase (wrt RF) and position within both 1.3 GHz and 3.9 GHz XFEL cavities.
  - Provides information for remote structure alignment.

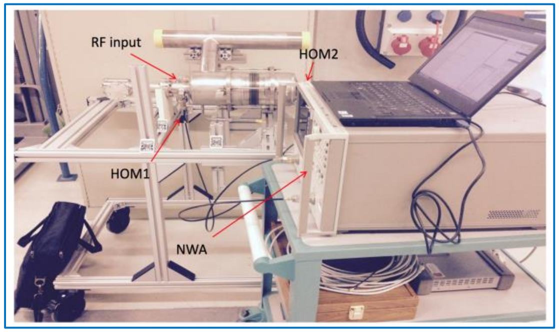
- HOM-BPM (DESY)
  - Electronics development and experimental characterisation.
- HOM-CD (UNIMAN)
  - Cavity Diagnostics – EM simulations of FLASH and XFEL modes.
- HOM-GD (Rostock)
  - Geometric Dependencies – Long cavity string determination using concatenation processes.

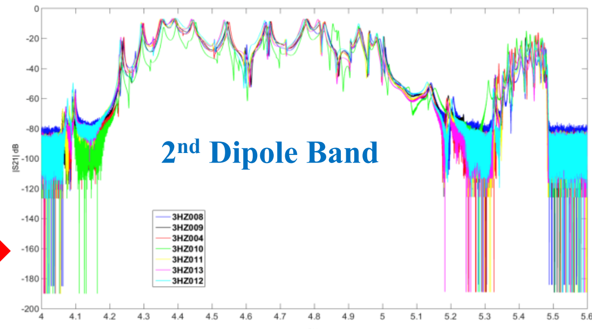


Task 12.4 Coordinator: Roger Jones (Manchester Univ)

HOM Measurements @ DESY

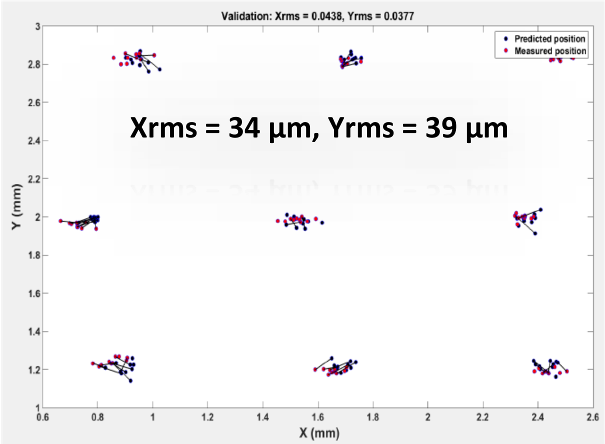
- S21 measurements for 7 out of the 8 x 3.9 GHz cavities needed for XFEL modules.
- Measurements will aid evaluation of the coupled-cavity spectrum for a complete XFEL cryomodule.



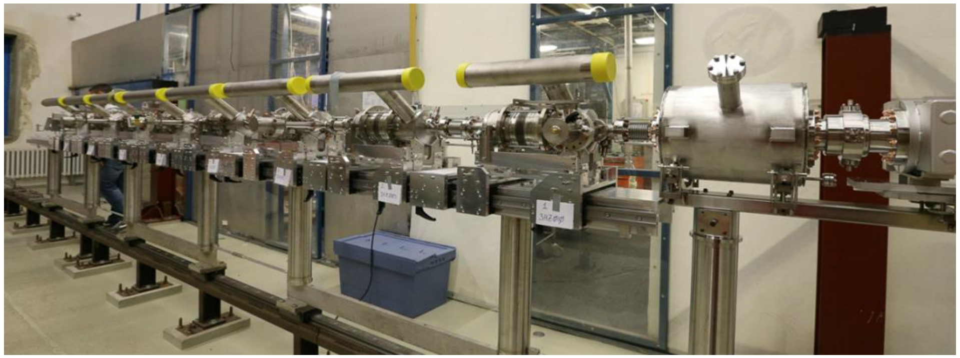


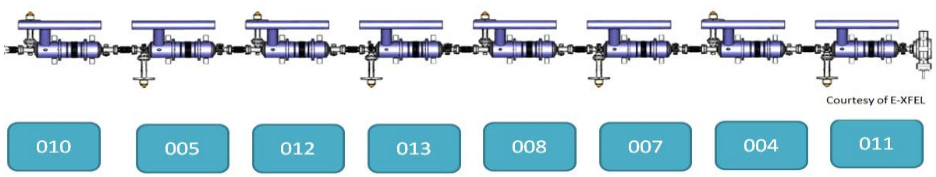
Each colour represents a different cavity

- FLASH stable beam position recorded over a period of 5 days using HOMBPMs in 1.3 GHz cavities – first measurement (Jan15).



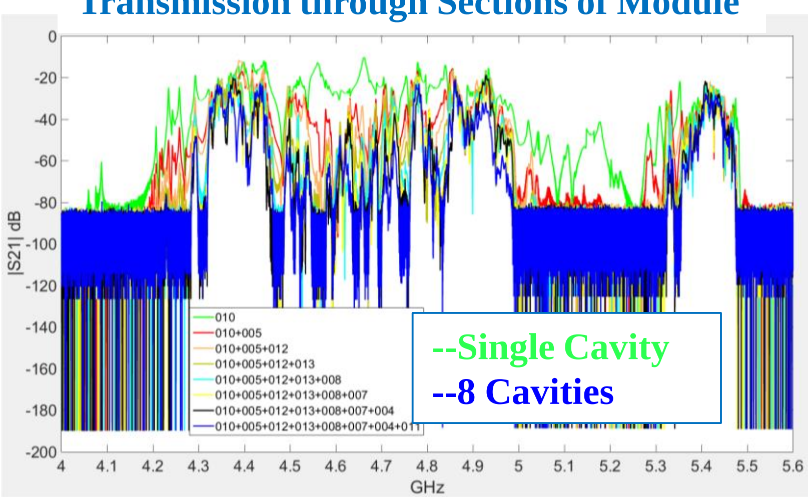
XFEL 3.9 GHz HOM Measurements @ DESY



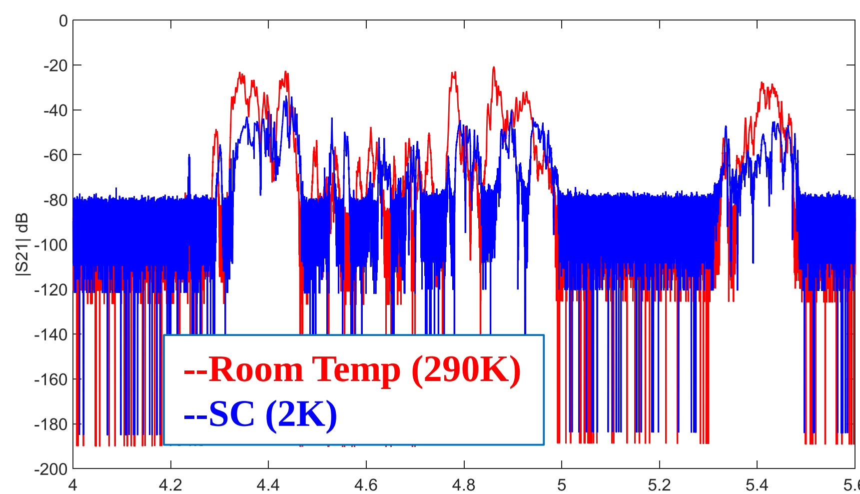


- First transmission measurements performed at 2 K for complete 3.9 GHz (8-cavity) XFEL cryomodule.
  - Dense spectrum of coupled modes.
- XFEL beam tests anticipated in near future.

Transmission through Sections of Module

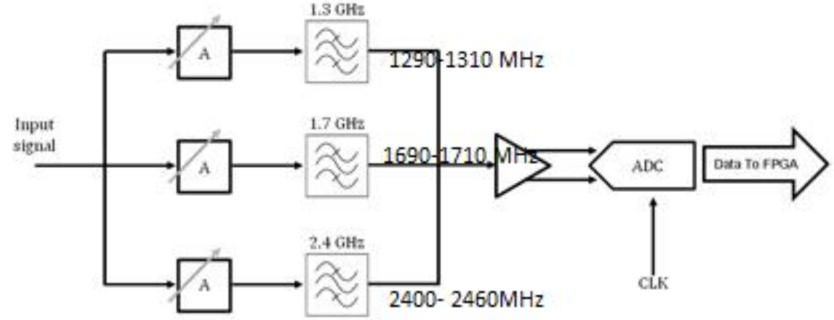


Transmission through Complete Module



HOM-Based Electronics @ DESY

Electronics for 1.3 GHz Cavities



- The electronics are compact and can be used for beam phase and beam position measurements.
- They fully comply with MicroTCA.4 standard.

Fast digitizer

Courtesy of Uros

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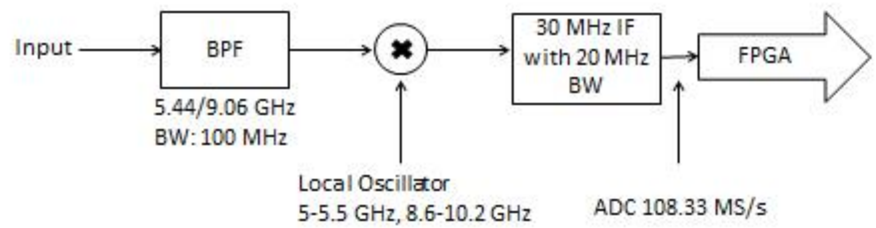
Electronics for 3.9 GHz Cavities



Filters

PLL card

Downconverter card

First Tests of a MICRO-TCA-Based Downconverter Electronics for 5GHz Higher Order Modes in Third Harmonic Accelerating Cavities at the XFEL, T. Wamsat, IBIC14, pp.557

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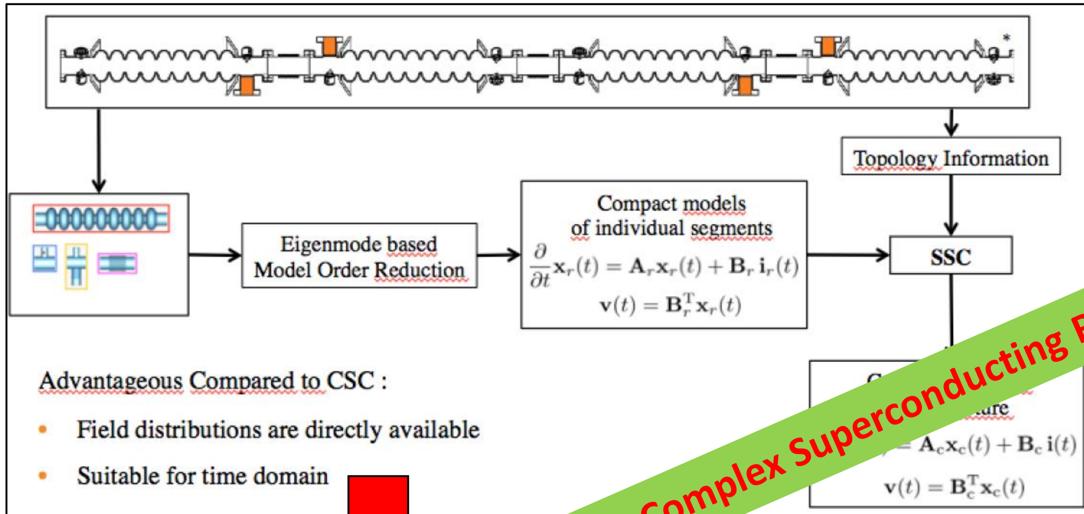
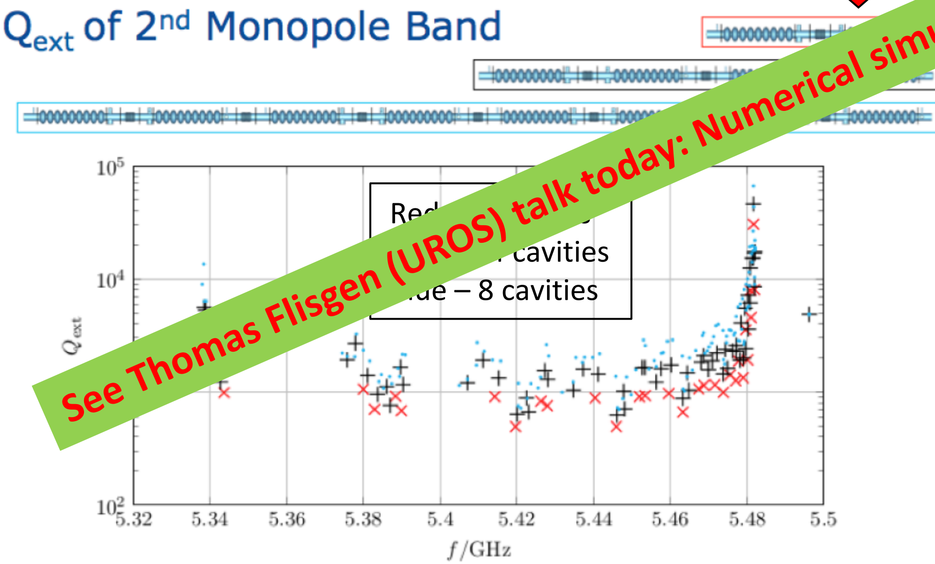
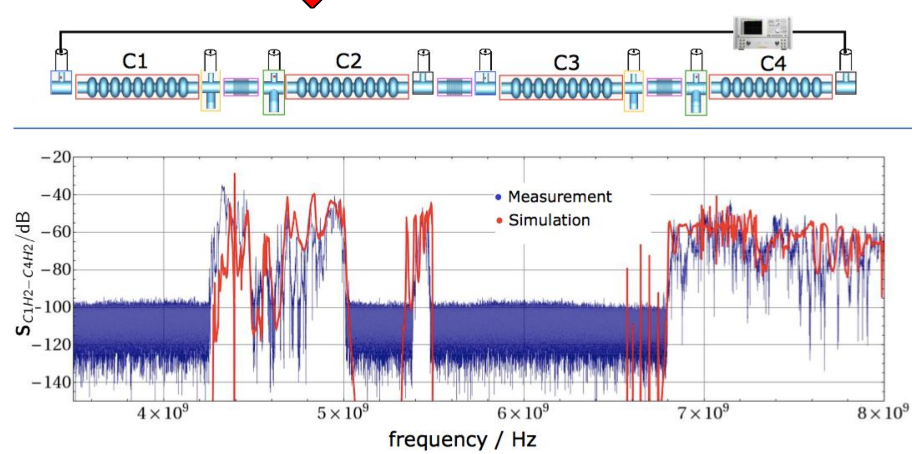
HOM Simulations @ UROS

T Flisgen (UROS)



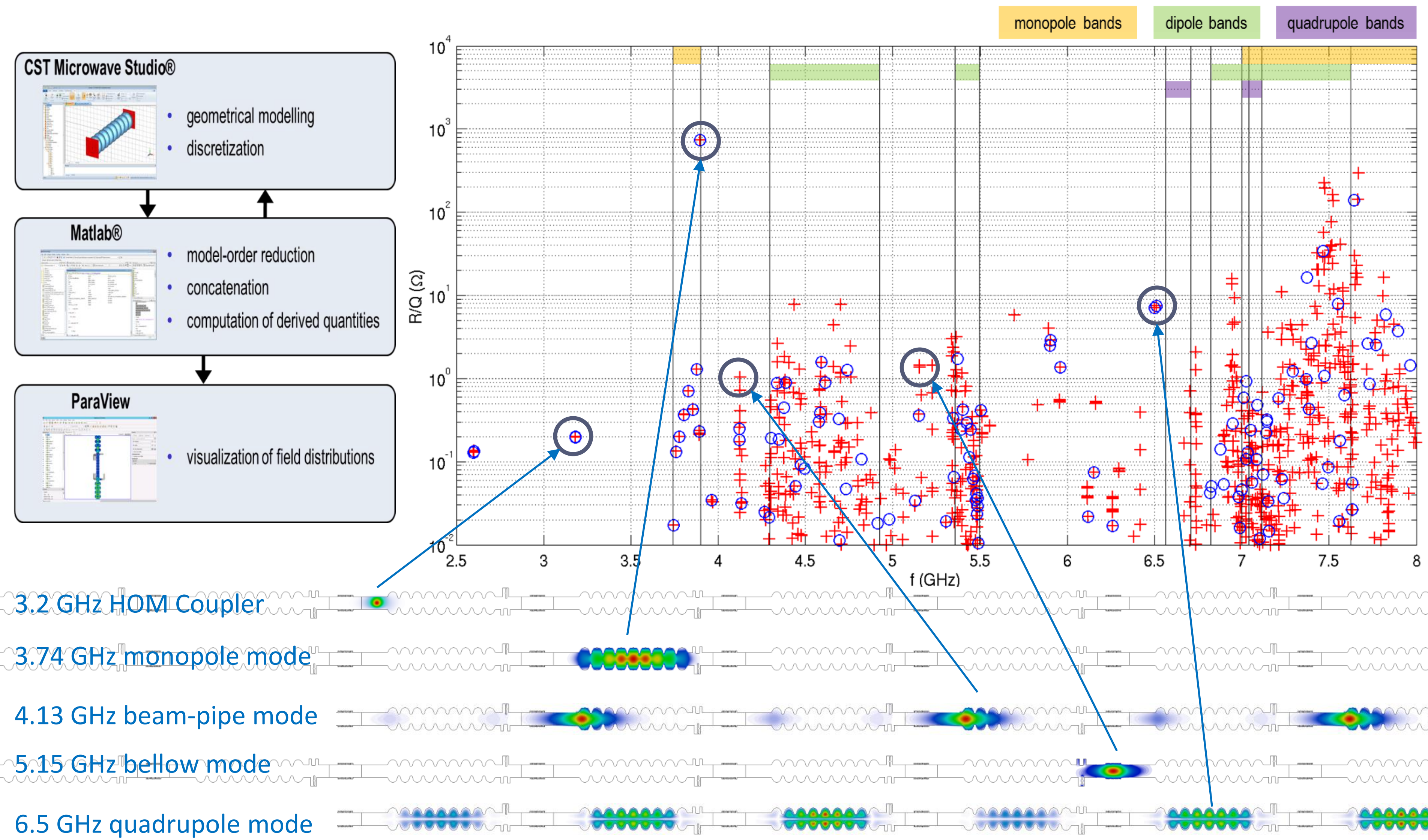
Q_{ext} of 2^{nd} Monopole Band



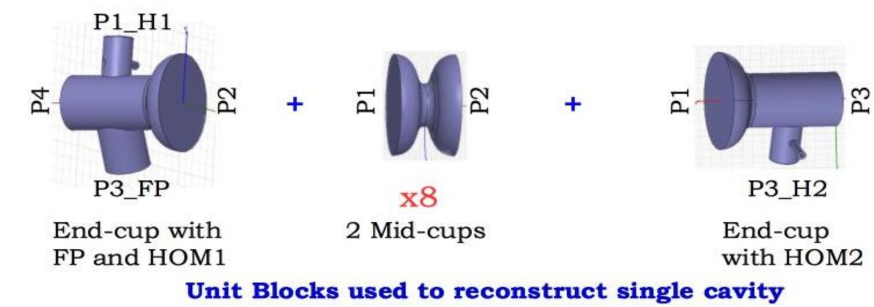


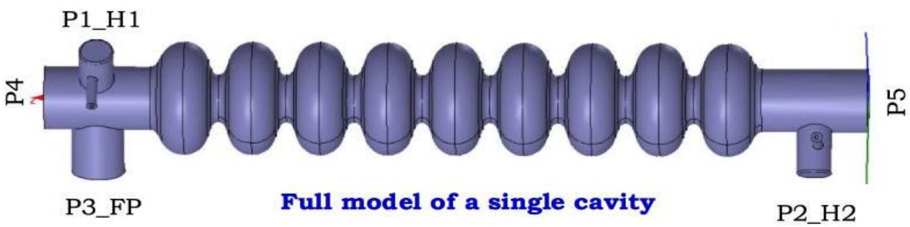
See Thomas Flisgen (UROS) talk today: Numerical simulations for Complex Superconducting RF Structures

3.9 GHz 8-cavity Chain Analysis

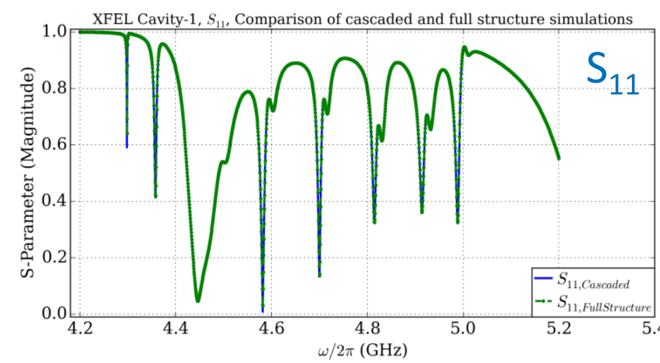


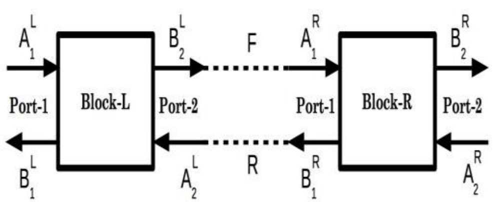
Generalised Scattering Matrix (GSM) Analysis @ UMAN





- S-parameters of each block simulated separately, and cascaded to reconstruct the large structure.
- Smaller structure can be simulated with higher accuracy, in shorter time duration.
- Significant computation time reduction for long cavity chain simulations.



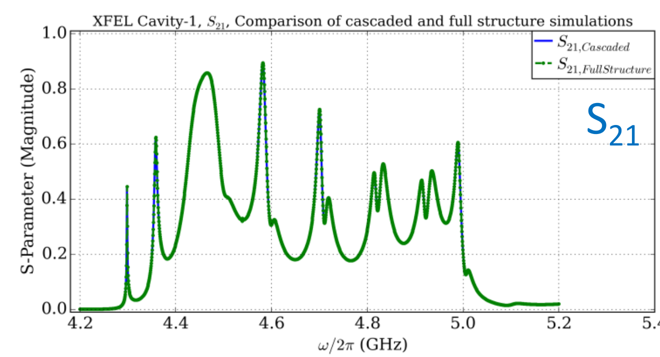


$$S_{11}^{LR} = S_{11}^{L} + S_{12}^{L}\left[I - S_{11}^{R}S_{22}^{L}\right]^{-1} S_{11}^{R}S_{21}^{L}$$

$$S_{12}^{LR} = S_{12}^{L}\left[I - S_{11}^{R}S_{22}^{L}\right]^{-1} S_{12}^{R}$$

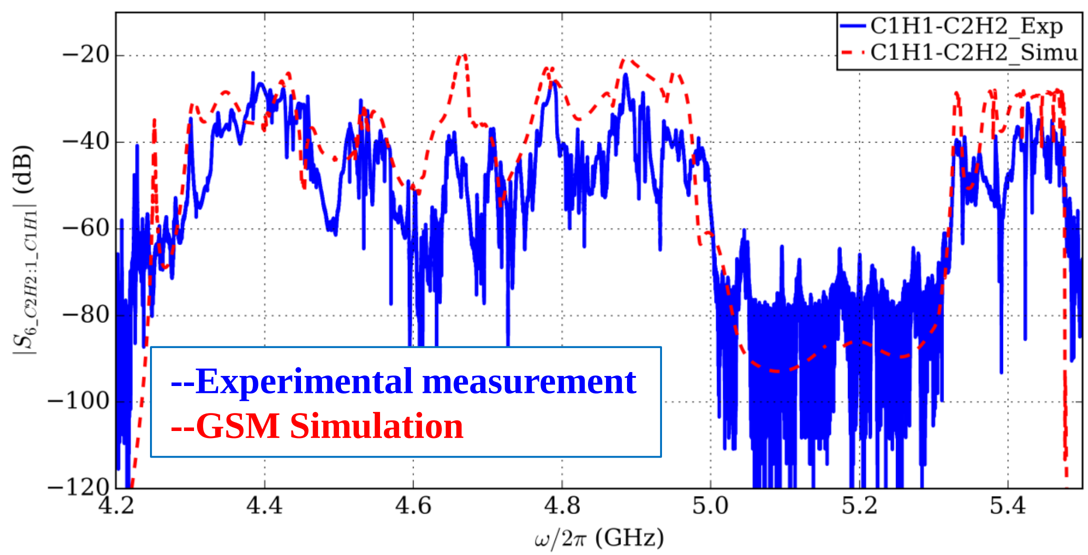
$$S_{21}^{LR} = S_{21}^{R}\left[I - S_{22}^{L}S_{11}^{R}\right]^{-1} S_{21}^{L}$$

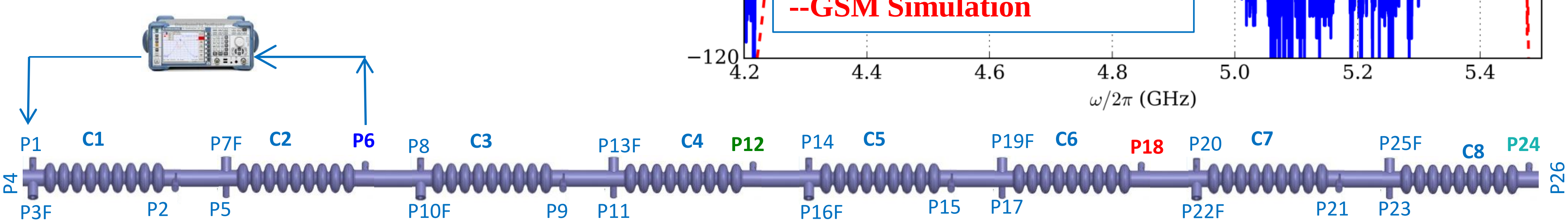
$$S_{22}^{LR} = S_{22}^{R} + S_{21}^{R}\left[I - S_{22}^{L}S_{11}^{R}\right]^{-1} S_{22}^{L}S_{12}^{R}$$



GSM Measurement Comparison

- S-parameters measured on FLASH 8-cavity module installed in the injector section, in superconducting state:
  - Input port: HOM-1 port on first cavity
  - Output measured at HOM-2 ports of Cavity-1 to Cavity-8.
  - Frequency step size 5kHz (Experiment), 500 kHz (simulation, 50kHz in narrow peak regions.)
- Additional amplitude loss of 10 dB observed in experiment:
  - additional cable loss in experimental setup.
- The simulated first dipole band was shifted left by 45 MHz, and second band was shifted by 25 MHz.





Task 12.5 RF Photocathodes (PCs)

- Material R&D for advanced PCs for NC RF guns.
- Evaluate Pb PC deposition for improved performance of SRF guns.
- Characterise and optimise performance of Diamond Amplifier Cathode solutions for SRF guns.

Actions and institutions:

Action	Institutions
SAPI commissioning and PCs characterisation	**STFC**
Pb PCs: deposition improvement, post-deposition treatment, Q and QE measurements	**NCBJ, DESY, HZDR**
DAC PCs	**HZDR, HZB**

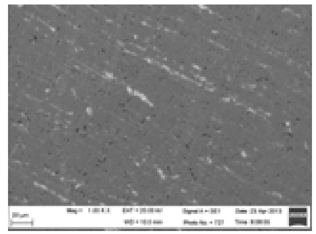
Task 12.5 Coordinator: Robert Nietubyc (NCBJ)

EuCARD²

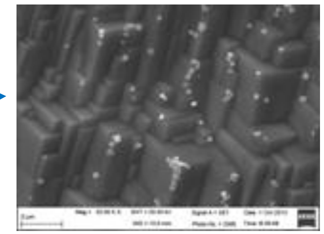
Pb Deposition Evolution @ NCBJ

Pre-deposition Nb substrate preparation

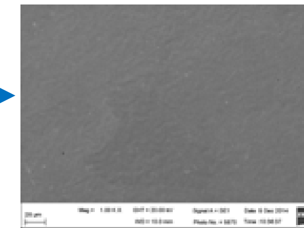
polishing



BCP



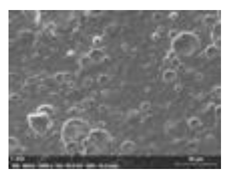
EP



Deposition system reconstruction to find better compromise between thickness and low micro-droplets population:

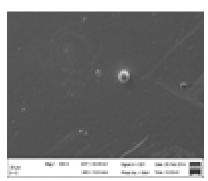
UHV non-filtered arc:

- >>40 um extrusions
- 3000 nm/min



UHV filtered arc:

- Upto 40 um diameter extrusions
- 200 nm/min



Evaporation:

- <5 um extrusions
- 60 nm/min

Post–deposition flattening:

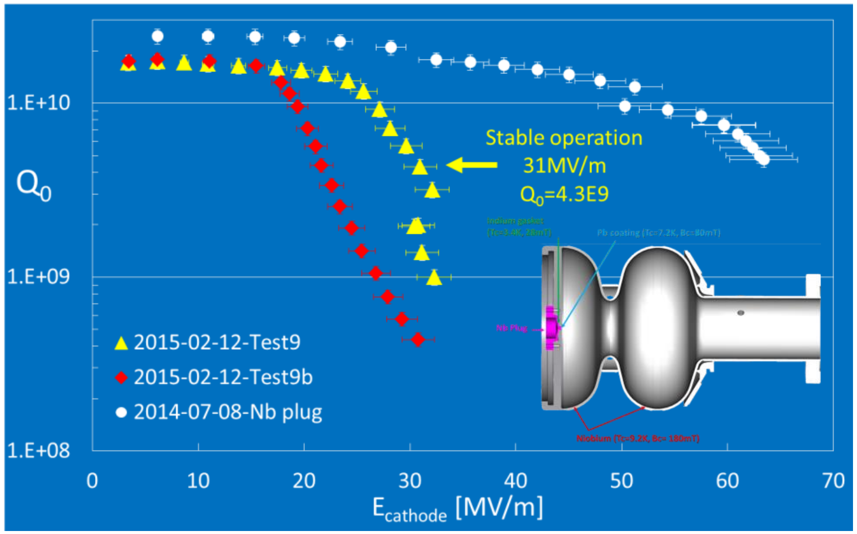
Plasma ion pulse irradiation

Laser irradiation

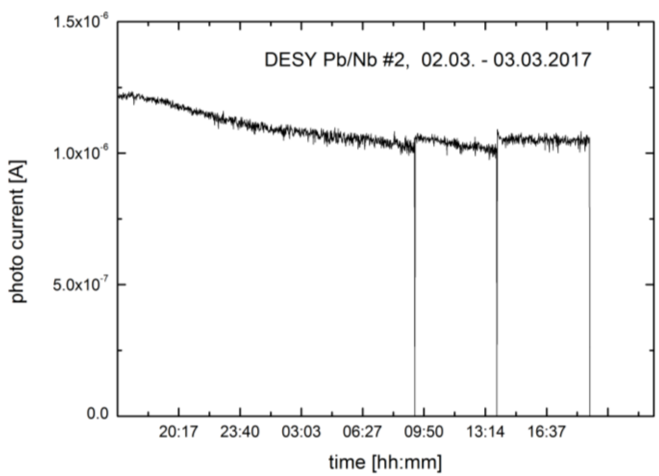
Annealing

Improved cooling cathode plug
Evaporation coated to test at DESY/BNL and HZDR

EuCARD² Pb PC Developments @ NCBJ

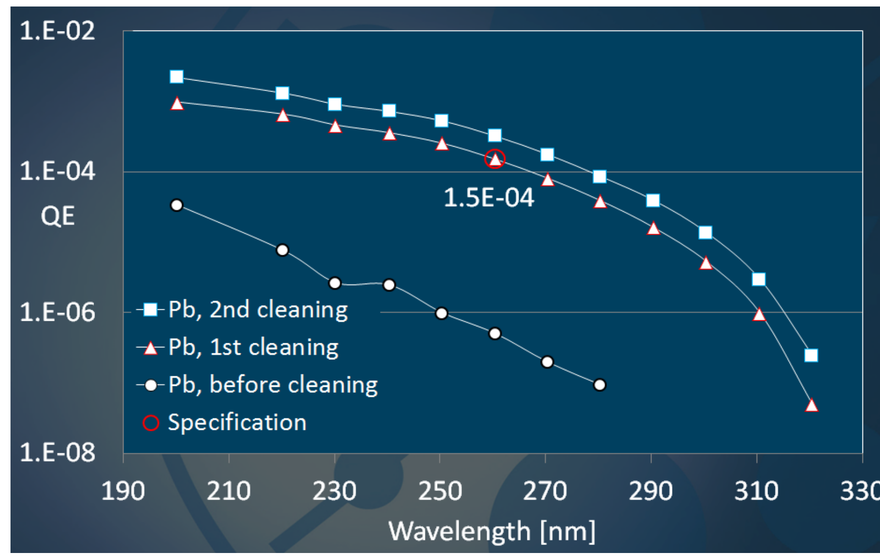


<10 µm Pb surface roughness PC - DESY/NCBJ



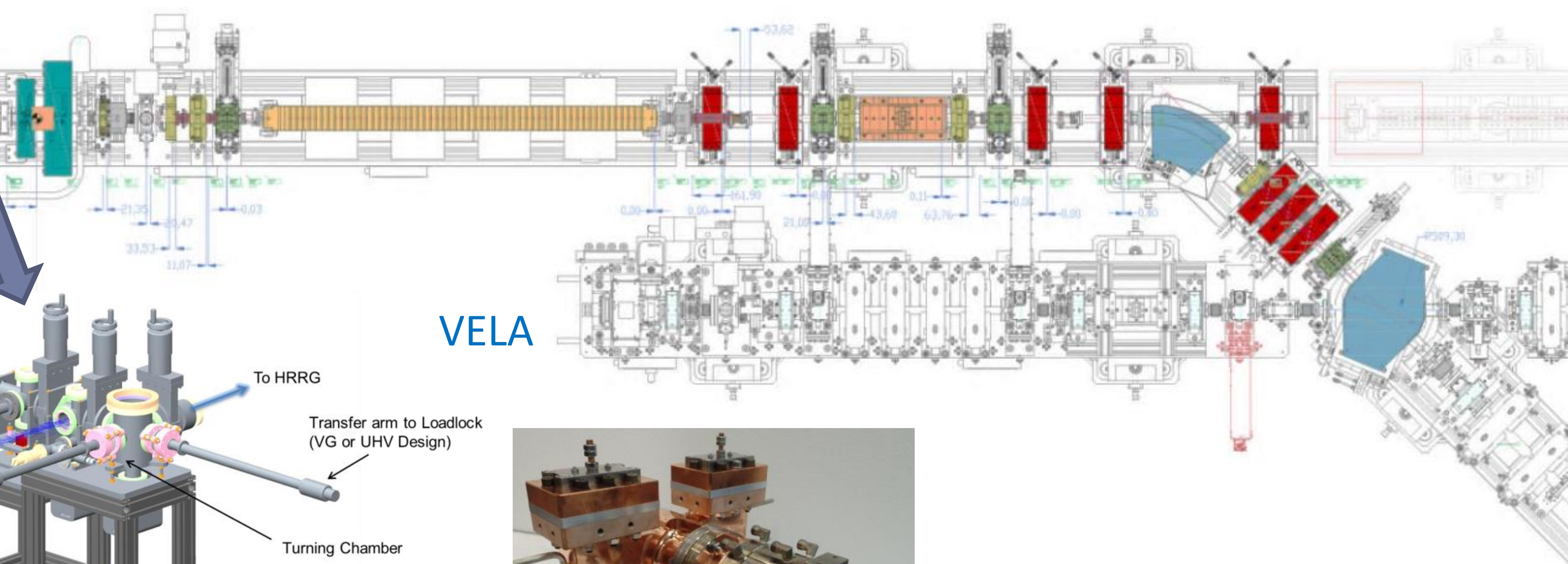
Operational tests of Pb/Nb PC @ HZDR

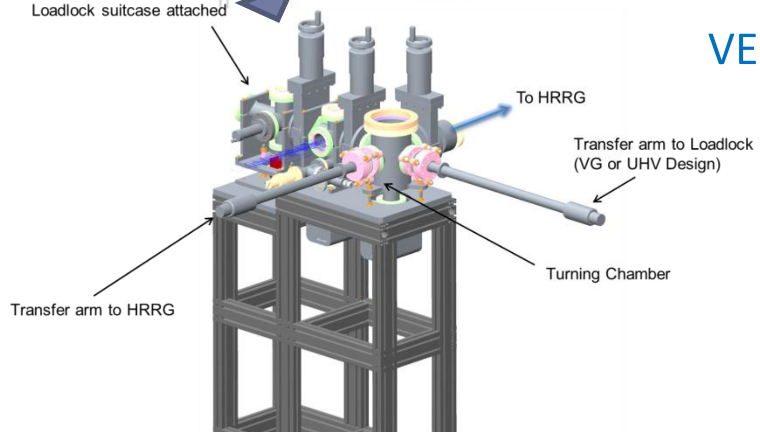
- Laser cleaning tests at BNL for Pb PC.

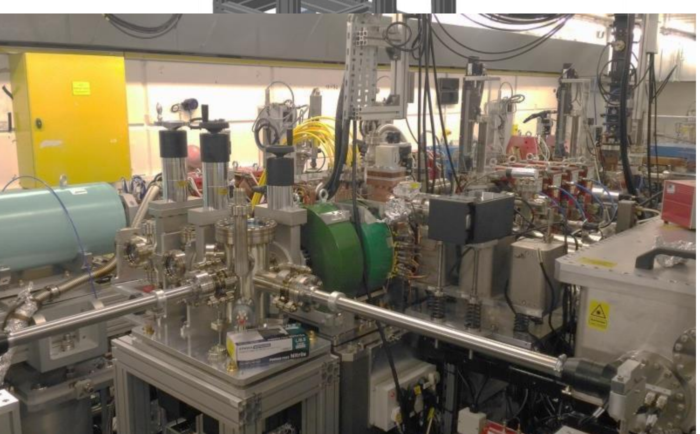


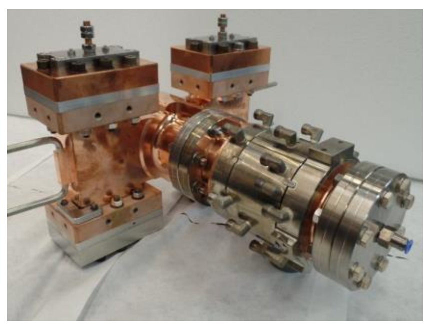
- Plasma irradiation leaves Pb surface smooth (<10 µm achieved).
- Laser treatment increases the QE a lot.
- This is accompanied with roughening the surface.

VELA/CLARA PC Transport System @ STFC

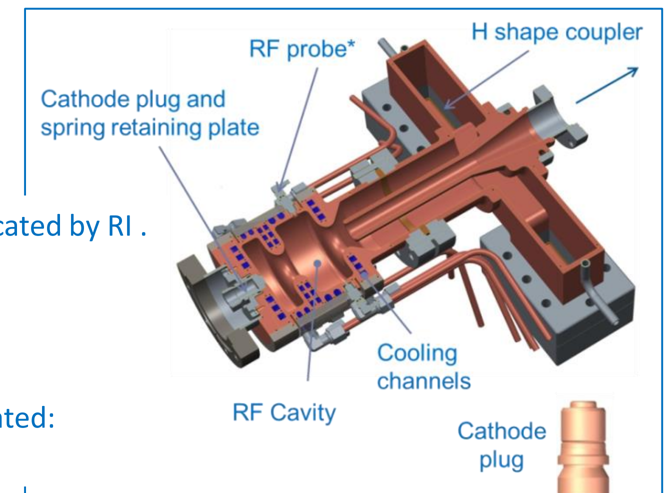








New 400 Hz RF-Gun



- 1.5 cell S-band with RF probe fabricated by RI .
- Max. gradient:
  - 120 MV/m @ 100 Hz or
  - 100 MV/m @ 400 Hz
  - 10 kW cooling capacity
- Vacuum load lock system incorporated:
  - easy PC exchange.

VELA/CLARA PC @ STFC

Metal Photocathodes:

- PC-plug based on FNAL/INFN/DESY design with reduced 10 mm tip.

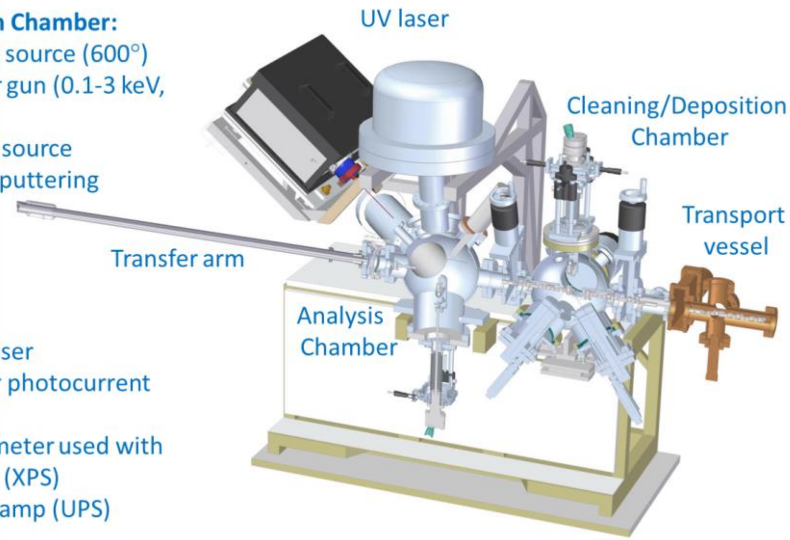
- R&D program on metal PCs to develop high QE, with bulk and thin films.
- Research facility with extensive analytical instrumentation set up:
  - PC transport systems compatible with other laboratories.
  - PC Preparation and Characterisation Facility dedicated for VELA/CLARA operational PCs.

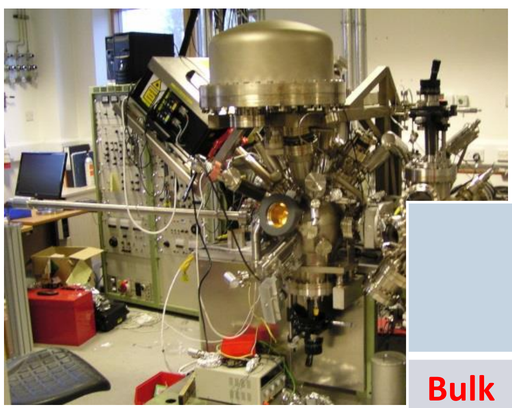
Cleaning/Deposition Chamber:

- Radiative heating source (600°)
- Argon ion sputter gun (0.1-3 keV, 15 μA)
- Atomic hydrogen source
- Two magnetron sputtering
- sources

Analysis Chamber:

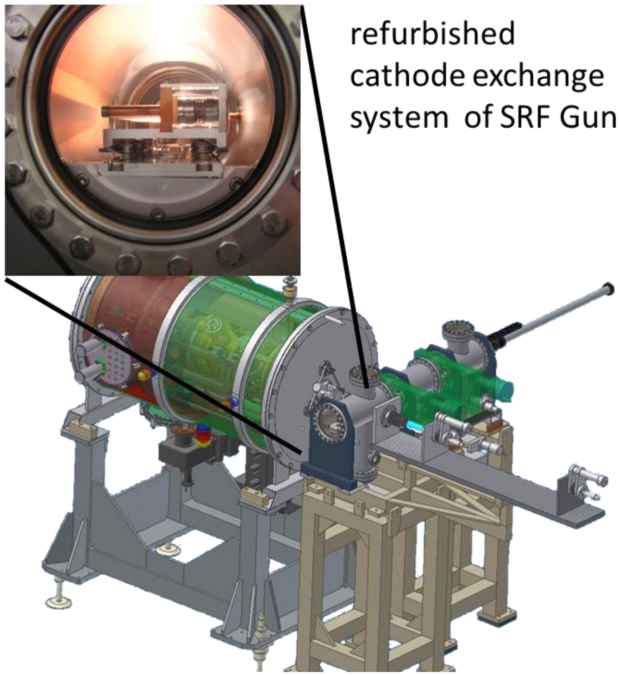
- UV 266 nm CW laser
- Pico-ammeter for photocurrent measurement
- Electron spectrometer used with
  - X-ray source (XPS)
  - Ultra-violet lamp (UPS)





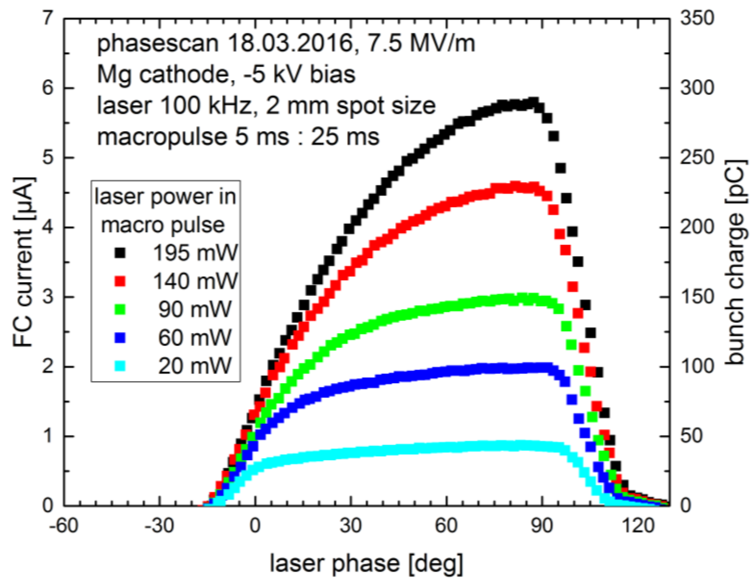
	QE as received	QE after ion-bombardment & annealing
Bulk	5×10^{-6}	1.7×10^{-5}
Thin Film	1.5×10^{-6}	1.2×10^{-4}

Mg photocathode in SRF Gun-II on ELBE @ HZDR



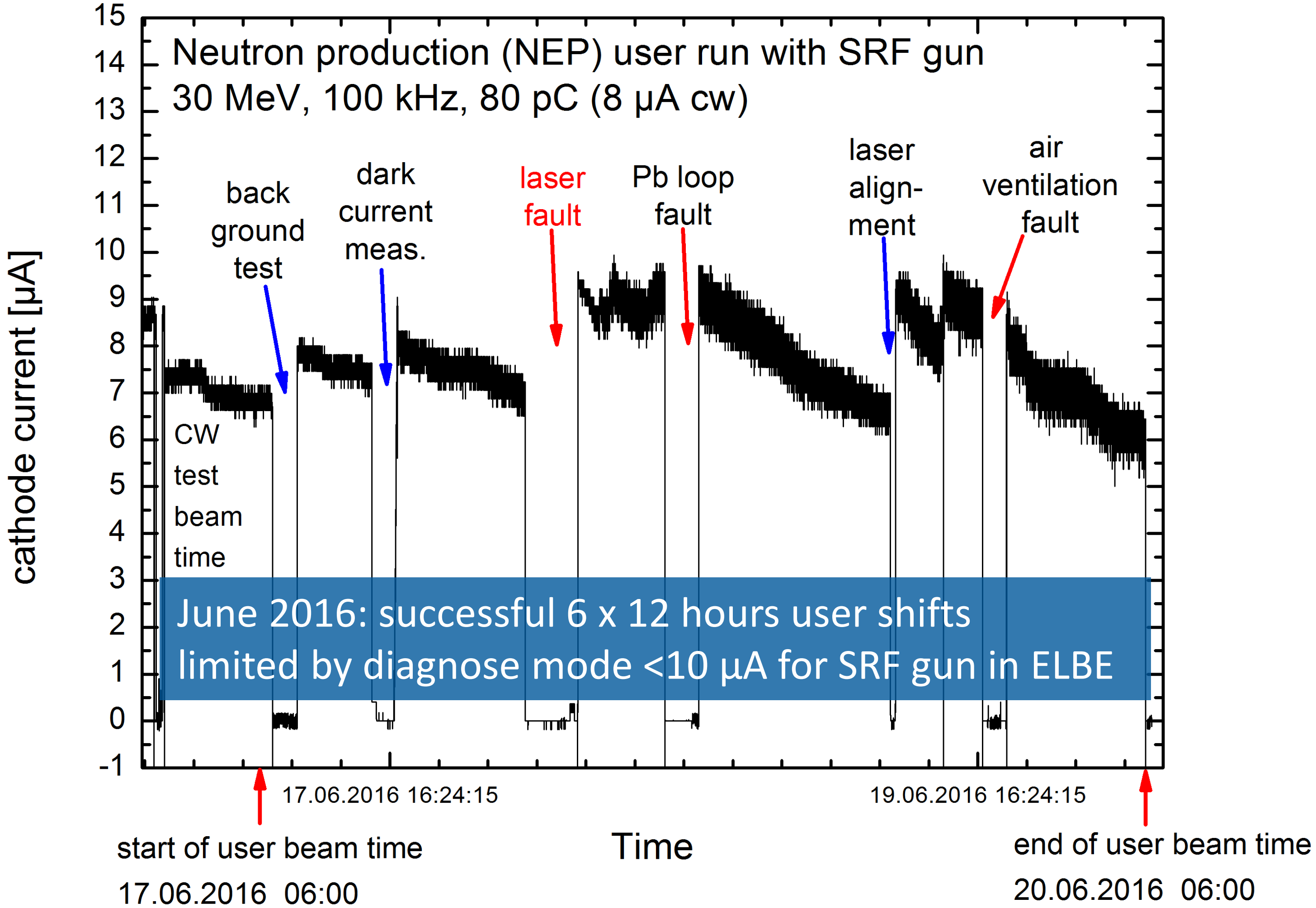
refurbished cathode exchange system of SRF Gun I

Laser cleaning PC surface

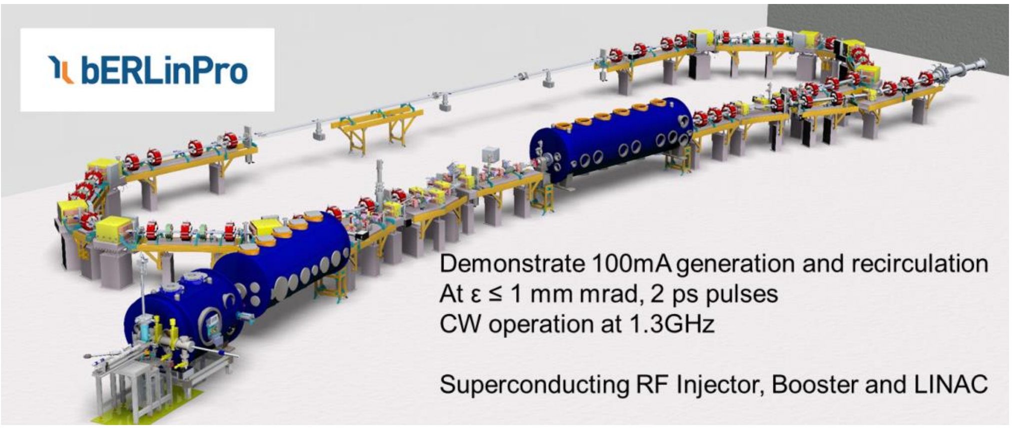


Metal (polycrystalline)	QE (%)	ϕ (eV)
Cu	10^{-6} - 10^{-5}	4.6
Mg	10^{-6} - 10^{-4}	3.6
Mo	10^{-6}	4.5
Nb	10^{-6}	4.3
Pb	10^{-6}	4.25

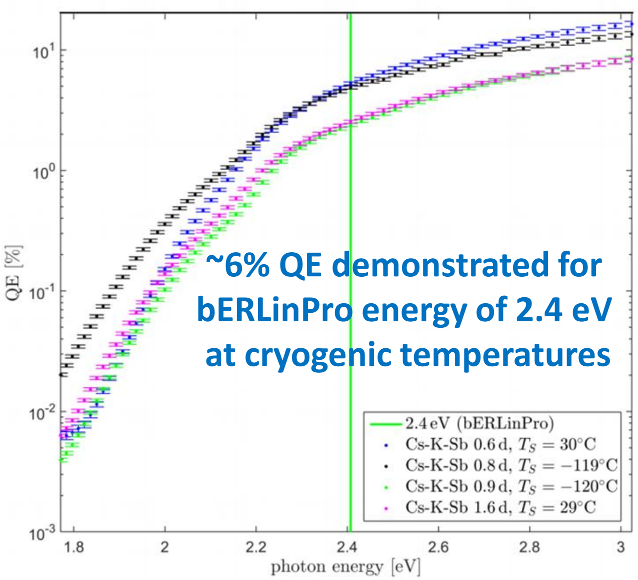
First Mg PC Operation in SRF Gun @ ELBE



Alkali PC Activities @ HZB



- $Cs_{2.7}K_{1.7}Sb$ composition after Cs deposition

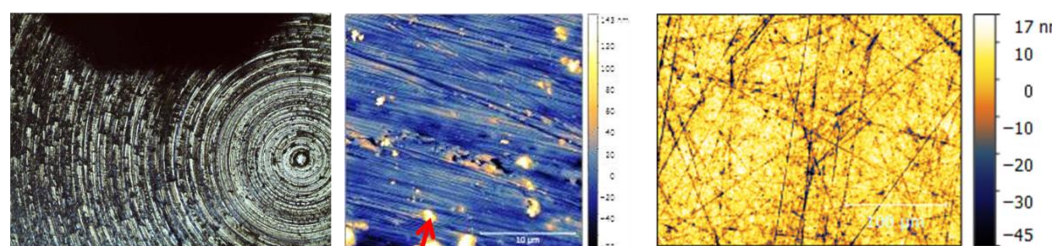


PC Plugs

Ø 10 mm x 6 mm from Mo or Cu rods machined to roughness Ra = 10 µm:

- **Mo** from sintered material polished samples have roughness ~ 8nm rms
- **Cu** from OFHC copper 20nm rms roughness after polishing

Mo after turning   AFM : Cu after polishing   WLI : Mo after polishing

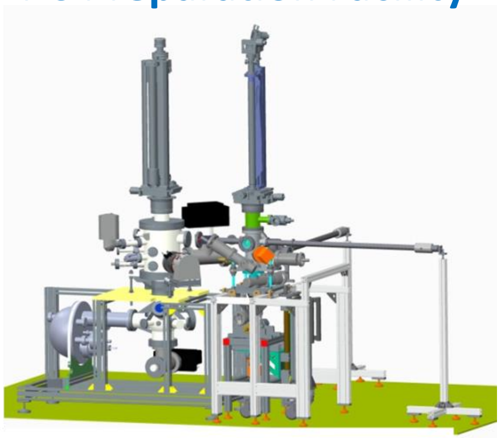


Protrusions in the AFM images for Mo and Cu

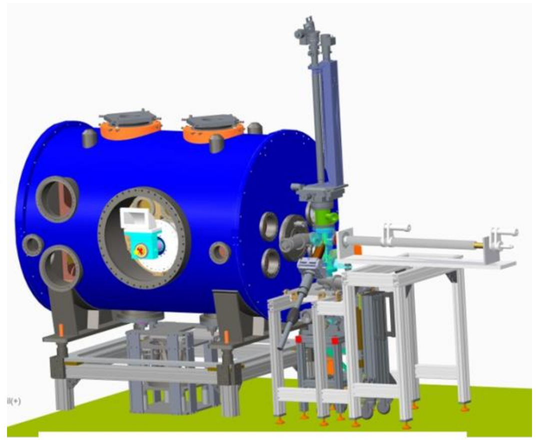
White light interferometry of Mo samples shows scratches, boundaries

PC Preparation/Implementation and DAC @ HZB

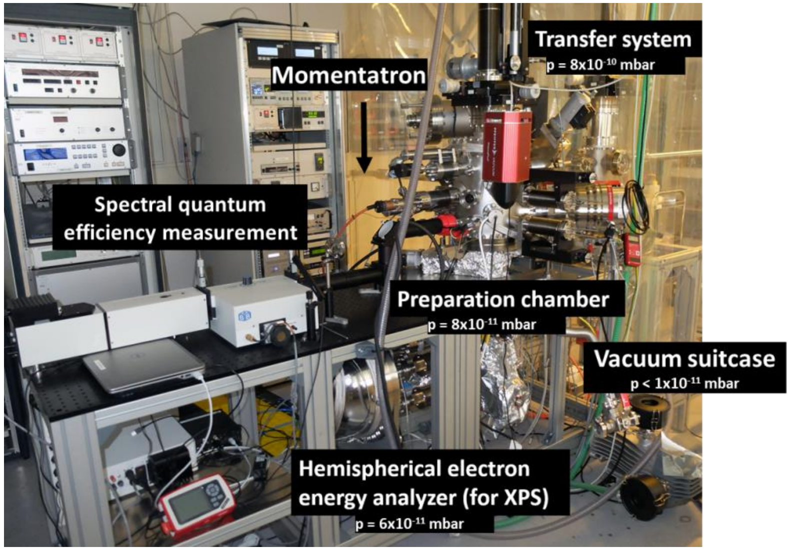
PC Preparation Facility



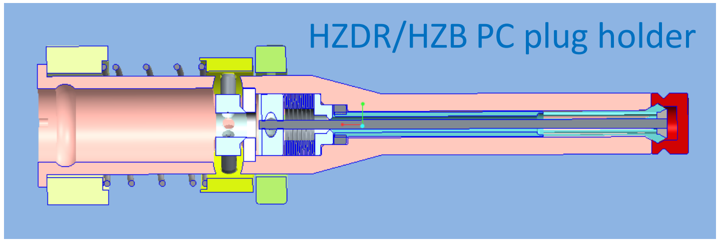
Transfer System #1 at Prep Chamber

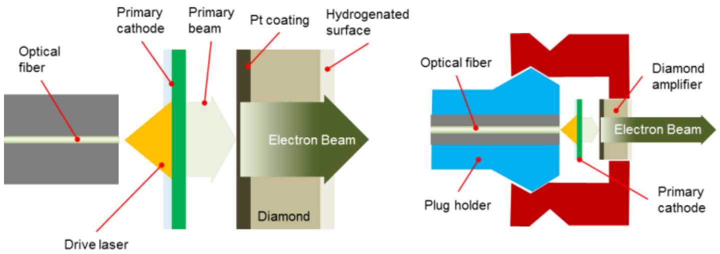


Transfer System #2 at Gun Module



Diamond Amplifier Cathodes





Challenges:

- Operation inside a SRF gun.
- Beam properties (thermal emittance, response time).
- Unwanted beam production, field emission.

Steps towards a DAC in an SRF gun

- Collaboration with BNL.
- Back-illuminated engineering design for operation of DAC in SRF gun at ELBE/HZDR and BERLinPro/HZB.

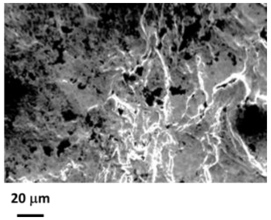
WP12 Milestone Achievements

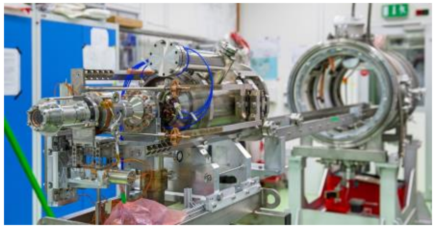
Milestone	Title	Beneficiary	Date	Comments	
MS87	Fundamental SRF Thin Film physics report	CEA	M48	Final Activity Report	Task 12.2
MS84	Deposition test facility designed at CEA.	CEA	M40	Facility designed and validated (Merge with D12.10)	
MS78	Characterisation test facility implemented at HZB	HZB	M30	Facility implemented and validated	
MS88	Report summarising the results obtained in characterising the various new thin film technologies developed, which include both multilayer and monolayer techniques	CEA	M48	Final Activity Report	
MS81	RF design CLIC_DDS_B (Scope change agreed)	UNIMAN	M36 – Delayed to M48	Activity Report	Task 12.3
MS86	RF design of fully interleaved structure and CLIC SW study.	UNIMAN	M45	Activity Report	
MS76	1D-2D Code Benchmarking for a High Efficiency Klystron	CEA	M24	Activity Report	
MS74	Design concept RF front end	PSI	M12	Activity Report	
MS77	Phase stabilisation experiment design	ULANC	M24	Activity Report	
MS79	Crab cavity electromagnetic design	ULANC	M30	Activity Report	
MS82	Completed coupled cavity simulations of 8-cavity module	UNIMAN	M36	Activity Report (Merged with D12.7)	Task 12.4
MS80	Demonstrated operation of improved deposition system, Pb layers of 1 μm in thickness.	NCBJ	M30	Report on sample characterisation	Task 12.5
MS73	Commissioning of the SAPI for operation with metal photocathodes	STFC	M8	Publication report	
MS75	Investigation of quantum yield and energy spectrum of the electrons, emitted from the metal photocathode surface in SAPI	STFC	M18	Intermediate scientific report	
MS83	Manufacturing and commissioning of the photocathode transport system	STFC	M36	Technical design report	
MS85	Investigation of the brightness of different metal photocathodes in a S-band NCRF gun	STFC	M42 – Delayed to M48	Scientific report	

WP12 Deliverables Achievement

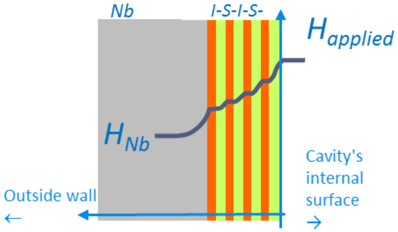
Deliverable	Title	Beneficiary	Date	Comments
D12.1	Deposition test facilities implemented and verified at CERN and INPG.	CERN	M18	Report
D12.5	First resonator deposited and qualified at CERN.	CERN	M40	Report
D12.10	Cavity deposited and qualified at CEA.	CEA	M48	Report
D12.2	Initial progress report of task 12.3.	CERN	M18	Report
D12.6	Intermediate progress report of task 12.3.	CERN	M36	Report
D12.11	Final report of task 12.3.	CERN	M48	Report (Under review)
D12.3	Design of electronics for XFEL HOM diagnostics.	DESY	M18	Report
D12.7	Completed characterisation of HOMs in the 8-cavity XFEL 3HC module.	UNIMAN	M36	Report
D12.12	Report on characterisation of HOMs in XFEL coupled 3HC cryomodule.	UNIMAN	M48	Report
D12.4	Scientific report on photocathode R&D.	STFC	M18	Report
D12.8	Optimised procedure for preparation of flat, clean and adherent Pb/Nb films. (Scope change agreed)	NCBJ	M36	Report
D12.9	Pb/Nb plug photocathodes measurements and characterization.	HZDR	M42	Report
D12.13	Results of DAC implementation in SRF guns.	HZB	M48	Report (Under review)

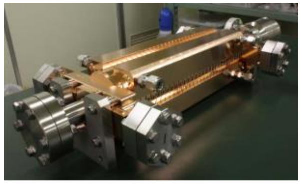
WP12
Pushing the Envelope

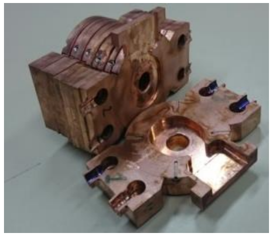




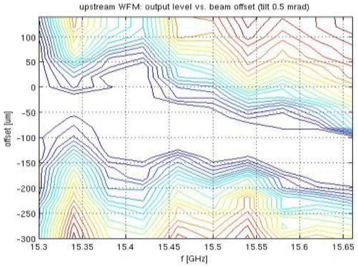
Beam Generation:
- New photocathodes providing demonstration of highest beam intensities and smallest beam emittances.
- Now operating in SRF and NC guns!

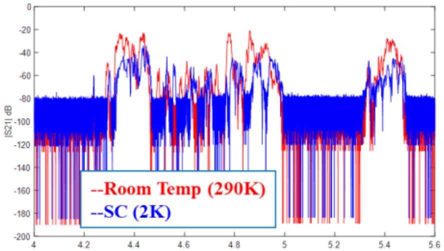




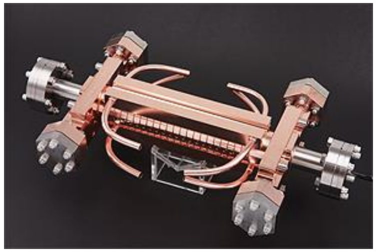


Acceleration:
- Demonstration of the highest level of acceleration performance.





Beam Diagnostics/Control:
- Demonstration of high performance and low cost beam position diagnostic.
- Now operating in SRF and NC FEL facilities.



Integrated and balanced programme encompassing high performance capabilities across both SC and NC technologies.

WP12 Monographs

Task 12.2 SRF Thin Films

- **Raphael Kleindienst (HZB) – Thin film characterisation**
- **Sebastian Kechert (HZB) – QPR characterisation system development**

Task 12.3 High Gradient Normal Conducting

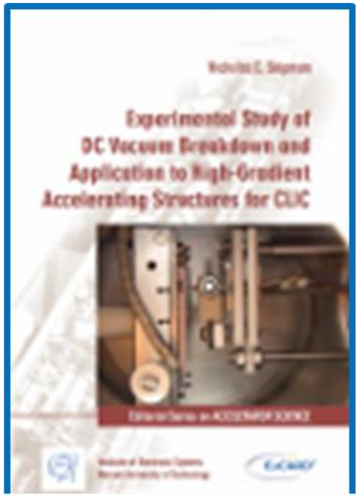
- **Ben Woolley (ULAN) – Crab cavity design and testing**
- **Antoine Mollard (CEA) – High efficiency klystron development**

Task 12.4 SRF HOM Diagnostics

- **Liangliang Shi (DESY) – SRF HOM diagnostics system development**

Task 12.5 RF Photocathodes

- **Sunil Patel (STFC) – Metallic photocathodes**



N Shipman (UMAN)

T Flisgen (UROS)

Summary of WP12 Achievements

Task 12.2 SRF Thin Films

- High Tc Biased HIPIMS demonstrated, comparable with bulk Nb!
- High Tc Nb3Sn demonstrated with LT and HT deposition.
- PEALD 'Supercycle' developed and highest recorded Tc achieved for ALD NbN.
- State-of-the-art DC and RF characterisation systems now available.
- Real cavity tests verifying high performance SRF thin films.

WP15: Thin Films for SRF Cavities
O. Malyshev (STFC)

Many achievements have exceeded previous capabilities and now become state-of-the-art!

Many new RF technologies are now installed and operating in working accelerators – FLASH, SwissFEL, CLARA, ELBE, XFEL

- Cavity phase and alignment processes demonstrated and electronics fabricated for XFEL.

Task 12.5 RF Photocathodes

- Ultra-flat, high QE Pb/Nb photocathode performance confirmed in SRF cavity tests.
- First Mg photocathode laser cleaning & high performance operation in ELBE SRF Gun.
- Copper photocathode development and high QE achieved, now installed in CLARA high-rep Gun.
- DAC photocathode design developed for SRF Gun at HZB.

Many Thanks to all WP Collaborators

The WP12 Innovative RF Team

EuCARD-2 is co-funded by the partners and the European Commission under Capacities 7th Framework Programme, Grant Agreement 312453