RF Summary

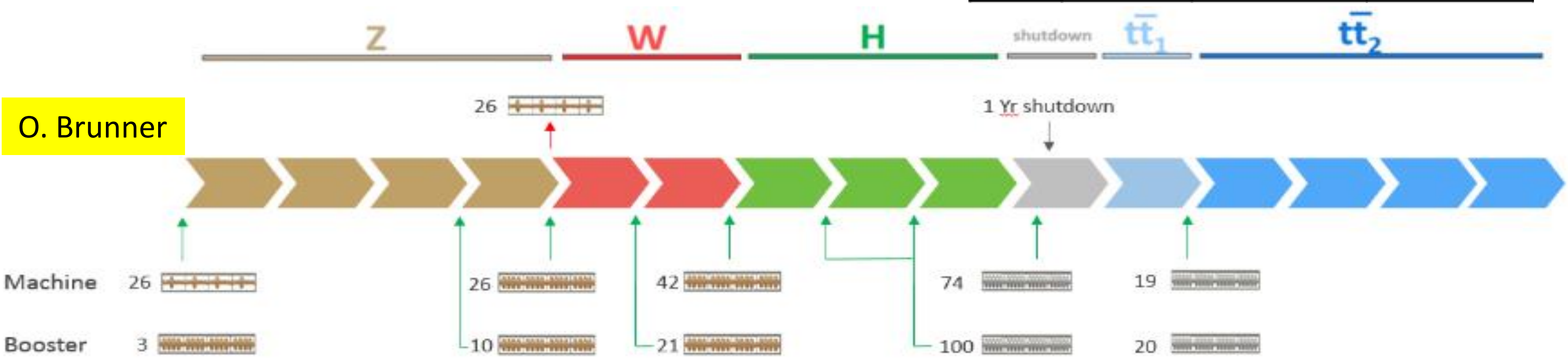
F. Peauger

FCC-ee RF system

- Designed for fixed synchrotron radiation power of 50 MW per beam
- Elliptical shape cavities in CW mode

WP	V_{rf} [GV]	#bunches	I_{beam} [mA]
Z	0.1	16640	1390
W	0.44	2000	147
H	2.0	393	29
ttbar	10.9	48	5.4

O. Brunner



- **400 MHz 1-cell cavities**
- **Nb/Cu, 4.5 K**
- **104 cavities**
- **Eacc=10 MV/m**
- **1 MW /cav**
- **4 cav./cryom.**
- **Re-used for FCC-hh (48 MV, 24 cavities)**

- **400 MHz 4-cell cavities**
- **Nb/Cu, 4.5 K**
- **408 cavities**
- **Eacc=10 MV/m**
- **1 MW to 200 kW per cav.**
- **4 cav. /cryom.**

- **800 MHz 5-cell cavities**
- **bulk Nb, 2 K**
- **852 cavities**
- **Eacc=20 MV/m**
- **200 kW/cav.**
- **4 cav./cryom.**

SRF session

SRF and powersources R&D overview *Crowne Plaza Brussels Le Palace*	*Anne-Marie Valente-Feliciano*	14:30 - 15:00
HOM damping design studies for FCC-ee cavities *1st floor*	*Shahnam Gorgi Zadeh*	08:30 - 08:48
Requirements for longitudinal HOM damping in FCC-hh *1st floor*	*Ivan Karpov*	08:48 - 09:06
Possible Designs of HOM Couplers for Superconducting 400 MHz RF Cavities *1st floor*	*Nils Petry*	09:06 - 09:24
R&D of seamless elliptical cavities *1st floor*	*Cristian Pira*	09:24 - 09:42
Electrodeposition of copper for seamless cavity *1st floor*	*Guillaume Jonathan Rosaz*	09:42 - 10:00
NB film engineering with energetic condensation for tailored RF behavior *1st floor*	*Anne-Marie Valente-Feliciano*	10:30 - 10:48
RF performances of superconducting coatings on copper for the FCC study *1st floor*	*Dr Marco Arzeo*	10:48 - 11:06
Development of a T_c test stand to analyze superconducting thin-film coatings *1st floor*	*Dorothea Fonnesu*	11:06 - 11:24
Characterization of a nobium thin film deposited on 6 Ghz SRF cavities *1st floor*	*Reza Valizadeh*	11:24 - 11:42
FCC-ee ERL option for low power and/or high energy *1st floor*	*Maria Chamizo Llatas et al.*	11:42 - 12:00
Active shielding for Cryomodules *1st floor*	*Anton Evgeniev Ivanov*	13:30 - 13:52
Test results and Operational experience of the High Power IOT development for ESS *1st floor*	*Morten Jensen*	13:52 - 14:14
High efficiency klystrons development at CERN *1st floor*	*Jinchi Cai*	14:14 - 14:36
Towards a high efficiency klystron for LHC *1st floor*	*Armel Beunas*	14:36 - 14:58

Total of 15 talks (+ 5 posters)

3 talks on HOM couplers

6 talks on cavity fabrication and coatings

covered by FCC-ee machine design summary

1 talk on cryomodule magnetic shielding

3 talks on high power RF sources

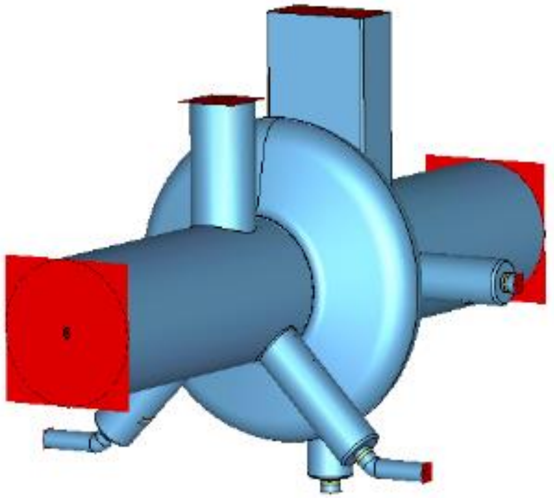
HOM damping design studies for FCC-ee cavities

Shahnam Gorgi Zadeh (Univ. Rostock)

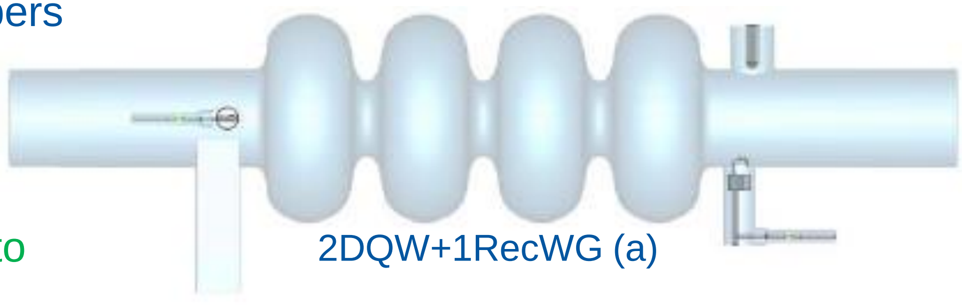
Universität Rostock Traditio et Innovatio

- Different configuration of HOM couplers have been studied (hook, probe, DQW, rectangular waveguide, ridged waveguide)
- For each FCCee machine, detailed evaluation of HOM power has been calculated (up to 30 kW for Z)
- For the Z and W machine: combination of waveguides and coaxial (hook or DQW) couplers have been proposed (+ absorbers at the cryomodule extremities)

→ Integration into cryomodule configuration to be studied ?



4 Hook-type couplers +
1 Rectangular WG (4H1RecWG)



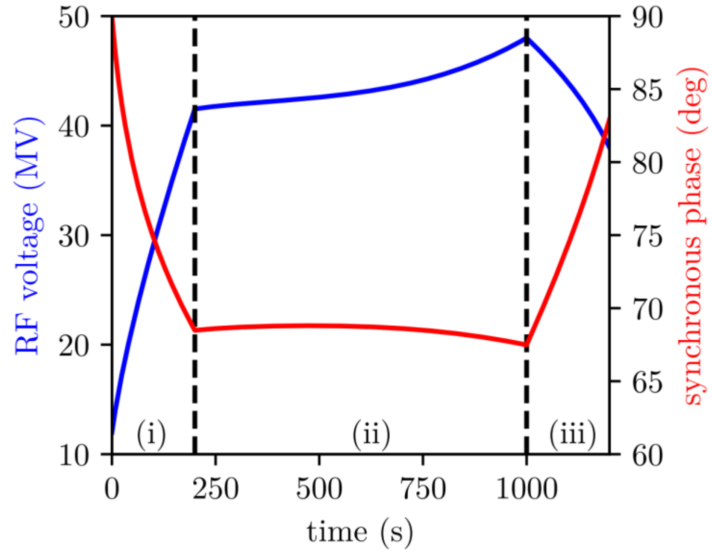
2DQW+1RecWG (a)

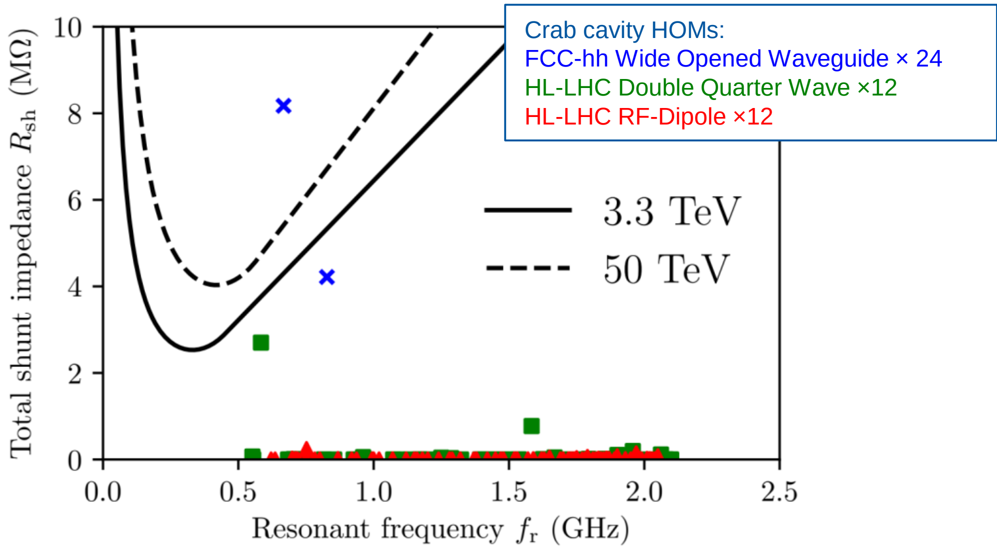
Requirements for longitudinal HOM damping in FCC-hh

Ivan Karpov (CERN)

- Thresholds of beam stability have been evaluated with semi analytical model
- Realistic accelerator cycle have been used

→ Wide Opened Waveguide FCC-hh crab cavities shows too high impedance and needs to be revisited



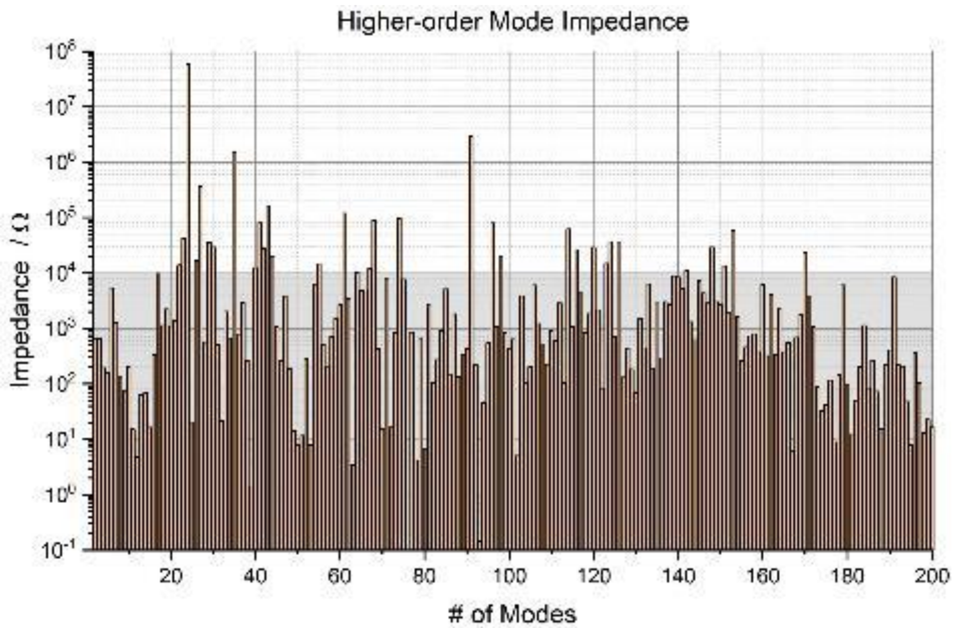


Possible Designs of HOM Couplers for Superconducting 400 MHz RF Cavities

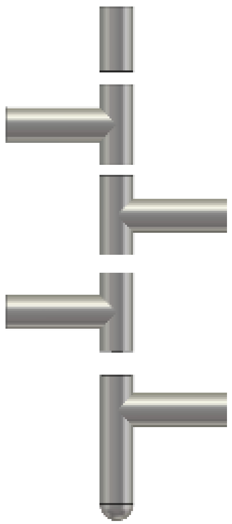
Nils Petry (IAP)

- New HOM coupler design proposed
- Impedance calculated for the first 200 modes

→ not as efficient as the LHC type design, investigations are ongoing



High-pass filter coupler



Band-stop filter coupler

R&D of seamless elliptical cavities

Cristian Pira (INFN)

INFN LNL
Istituto Nazionale di Fisica Nucleare
Laboratori Nazionali di Legnaro

- Cheap fabrication and potentially better performances
- Successive steps of spinning and annealing operations

→ good shape accuracy achieved on one cavity

→ some cracks and orange peel observed: need further studies (simulations + experiment on smaller cavities)

→ why not limiting the spinning process to the equator region only ?

1st Thermal Annealing

2nd Thermal Annealing

Spinning of Cavity #2 completed

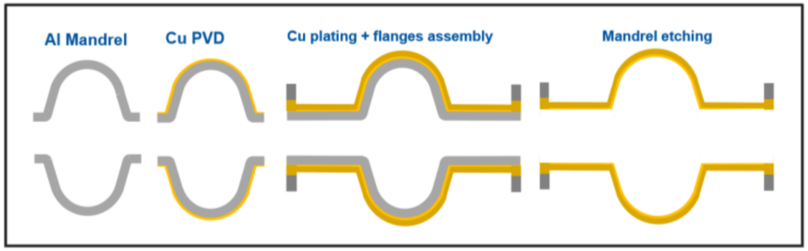
1st Thermal Annealing

2nd Thermal Annealing

3rd Thermal Annealing

Electrodeposition of copper for seamless cavity
Guillaume Jonathan Rosaz (CERN)

- No risk of mechanical cracks
- Possibility to include the stainless steel flanges in the process (no welding required at all)



→ Mechanical and RF properties at cold temperature checked (RRR > 200)

→ one demonstrator fabricated

→ one prototype cavities (1.3 GHz) under fabrication, to be RF tested

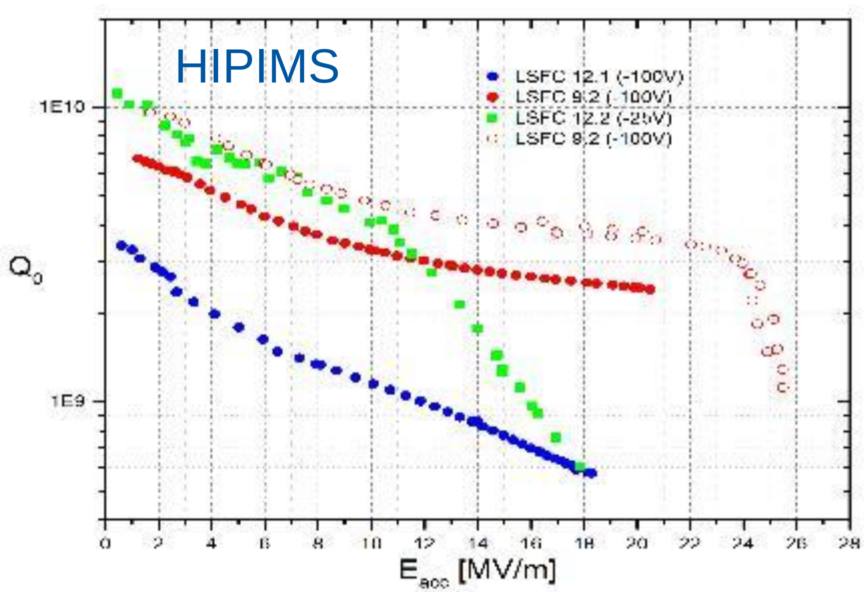
NB film engineering with energetic condensation for tailored RF behavior

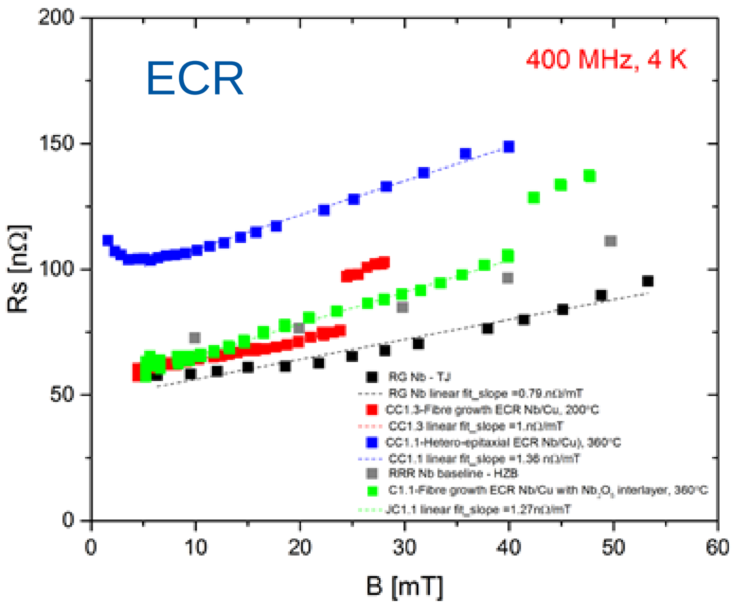
Anne-Marie Valente-Feliciano (JLAB)

Jefferson Lab

- Several "knobs to turn" to tune Nb film structure have been presented
- Mitigation of Q-slope is the main objective

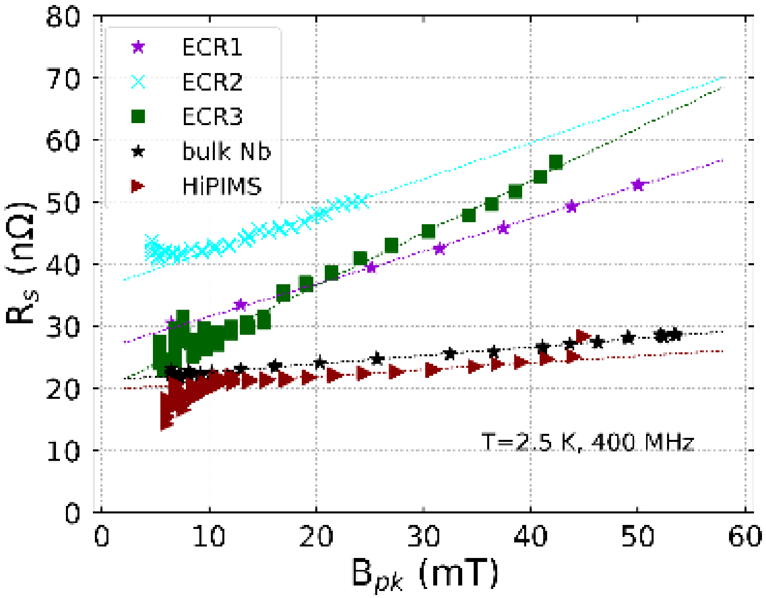
→ Energetic condensation techniques show promising SRF results with unprecedented thin film material properties, considerably improved compared to the state-of-the-art





RF performances of superconducting coatings on copper for the FCC study

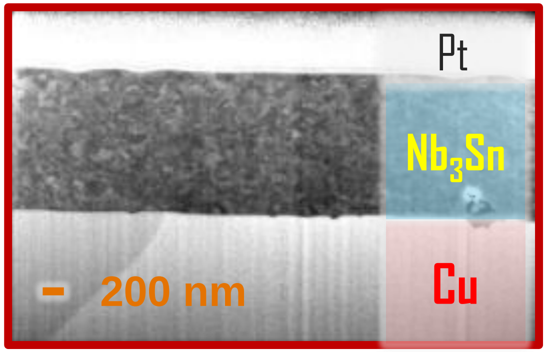
Marco Arzeo (CERN)

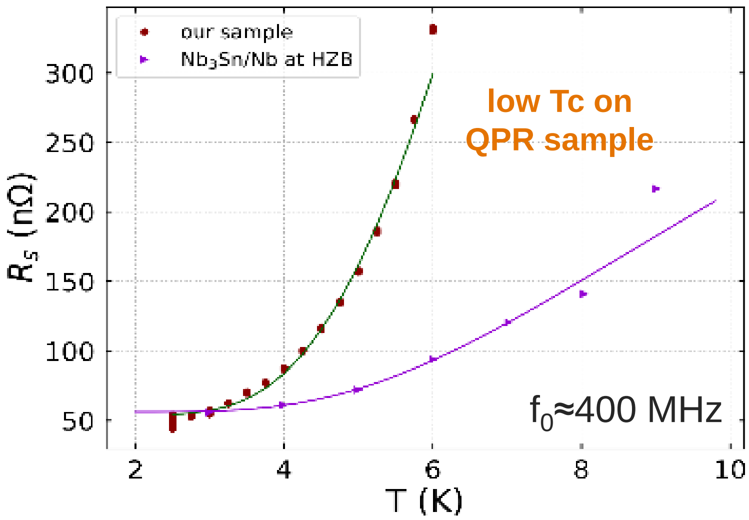


→ Best Nb/Cu HiPIMS samples in the last two years !

- Nb3Sn A15 compounds which have the potential to outperform niobium

→ very encouraging results obtained on A15-on-Cu samples

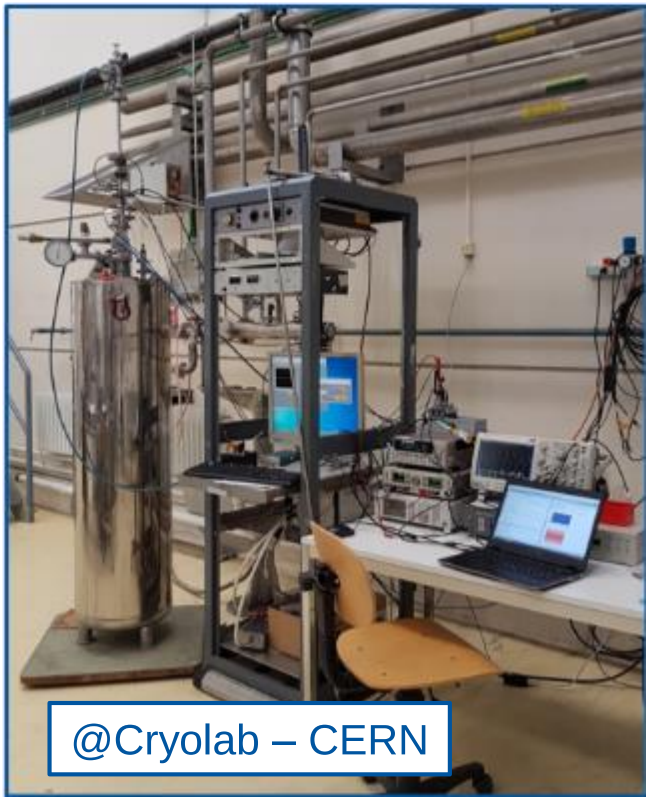


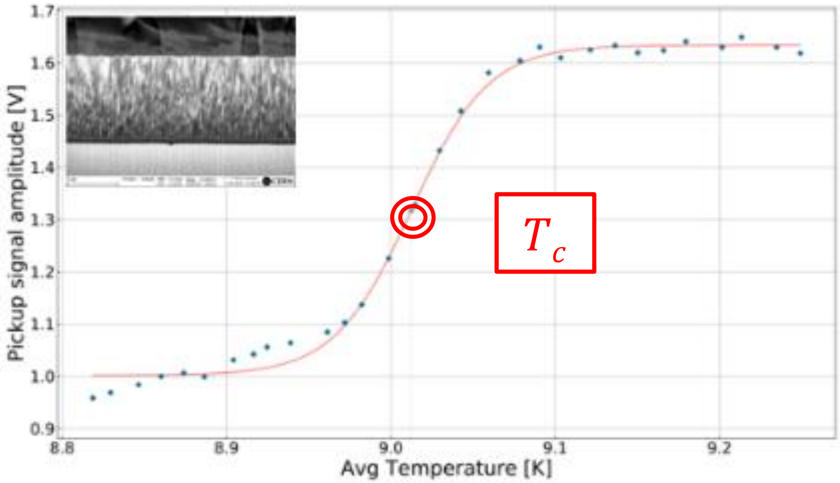


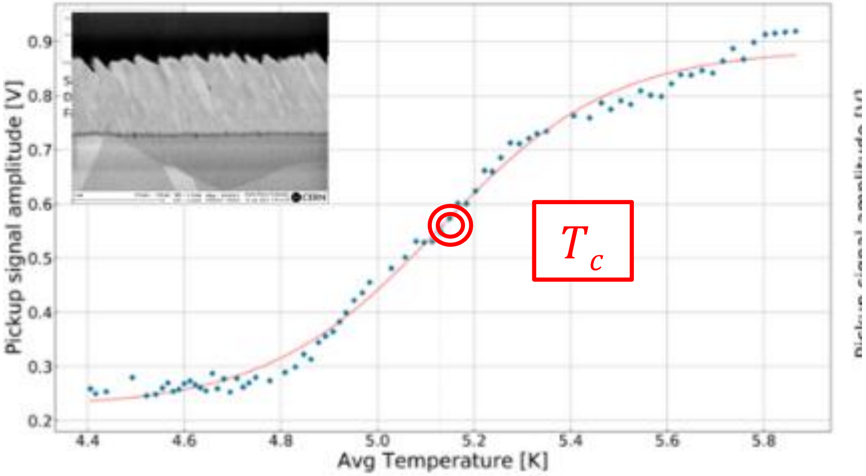
Development of a Tc test stand to analyze superconducting thin-film coatings

Dorothea Fonnesu (CERN)

- New set-up developed at CERN to measure critical temperature of superconductors
- Validated on Niobium sample
- Many measurements performed on thin films



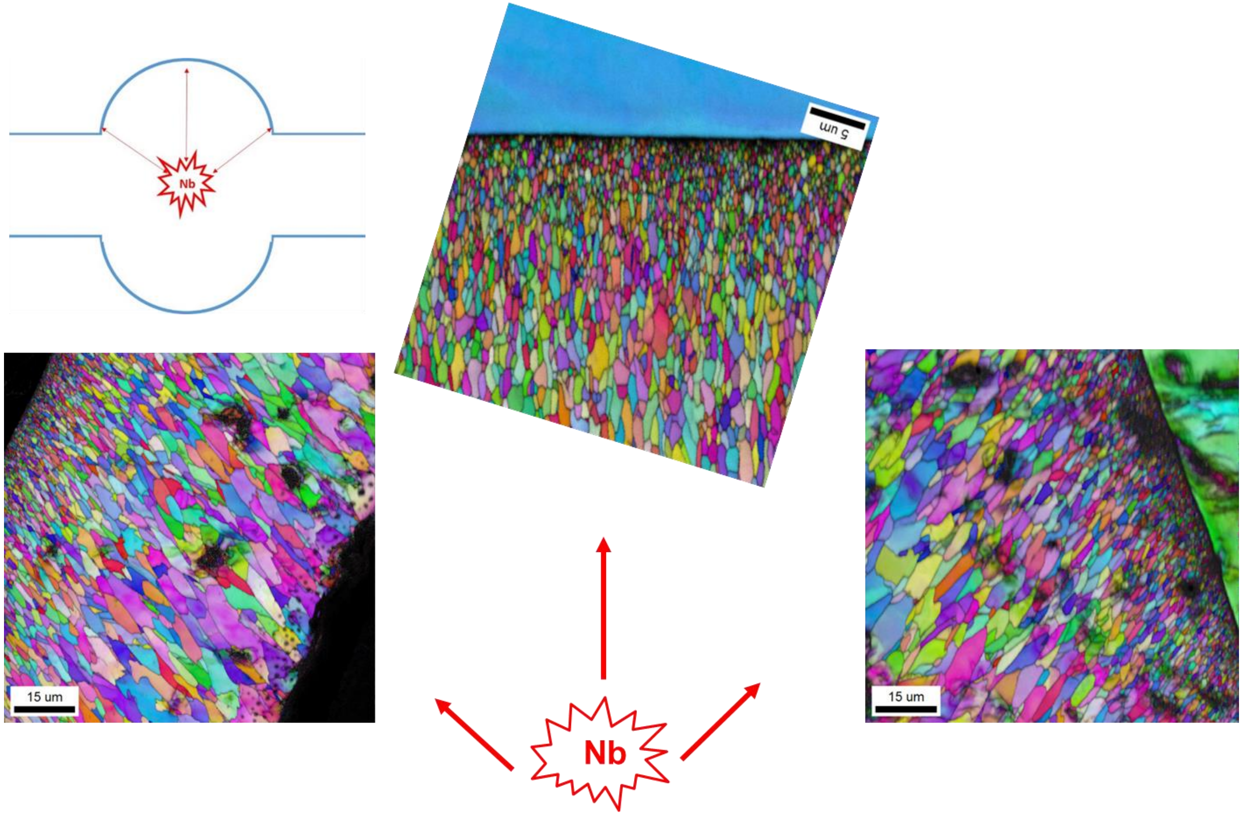




Characterization of a nobium thin film deposited on 6 GHz SRF cavities

Reza Valizadeh (STFC)

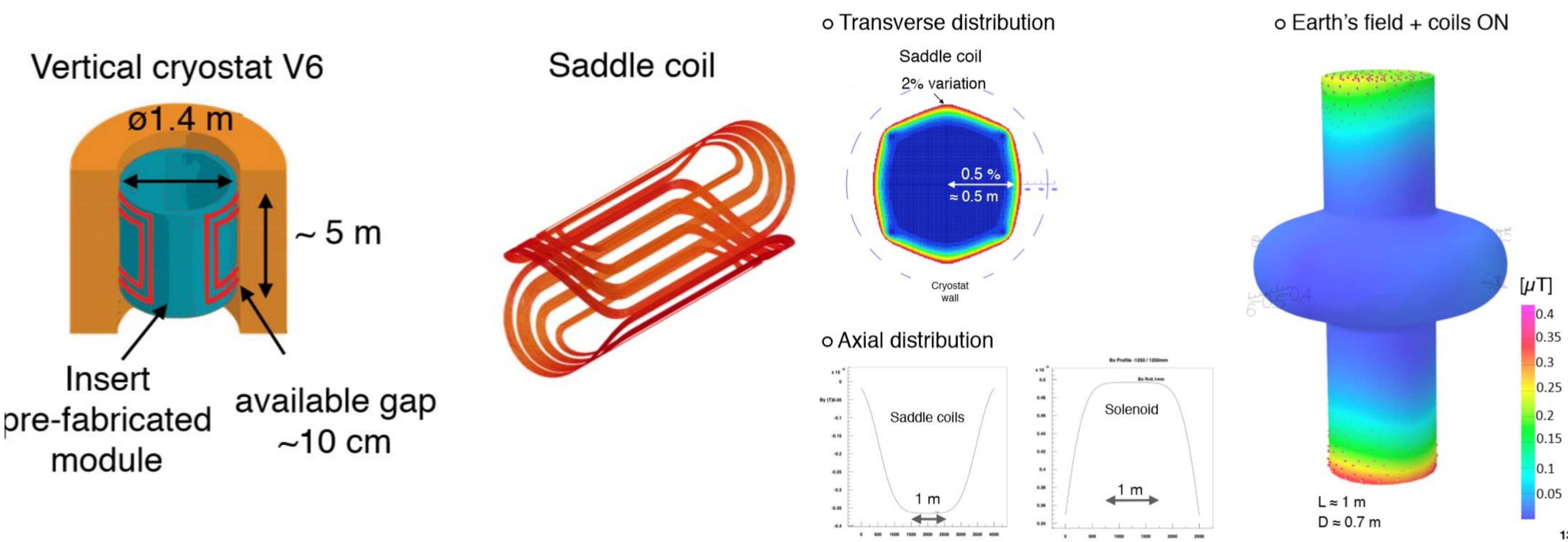
- Different polishing technics of samples studied
- Microstructure of the thin film characterized
- Hfp value measured between 140 to 155 mT



Active shielding for Cryomodules

Anton Ivanov (CERN)

- Objective: reduce the residual resistance due to magnetic flux trapping
- [Solenoid + 2 x cos theta saddle coils] proposed around the V6 cryostat at CERN (M. Karppinen)
- ~ 0.25 µT in a volume of 400 MHz LHC-type cavity



Test results and Operational experience of the High Power IOT development for ESS

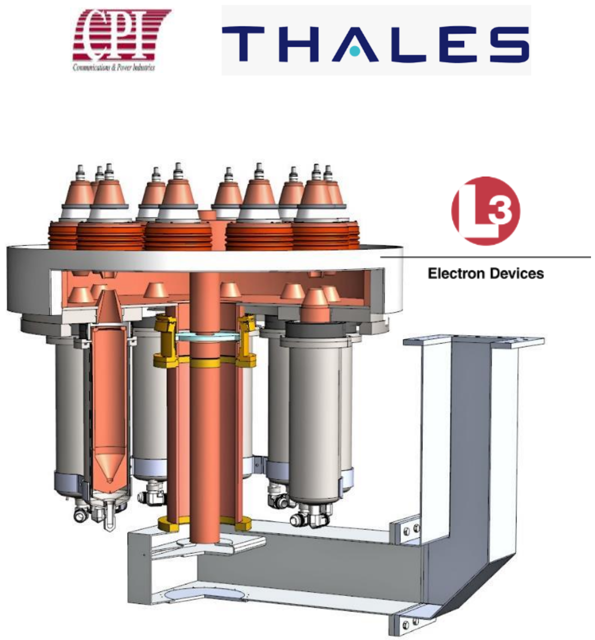
Morten Jensen (ESS)

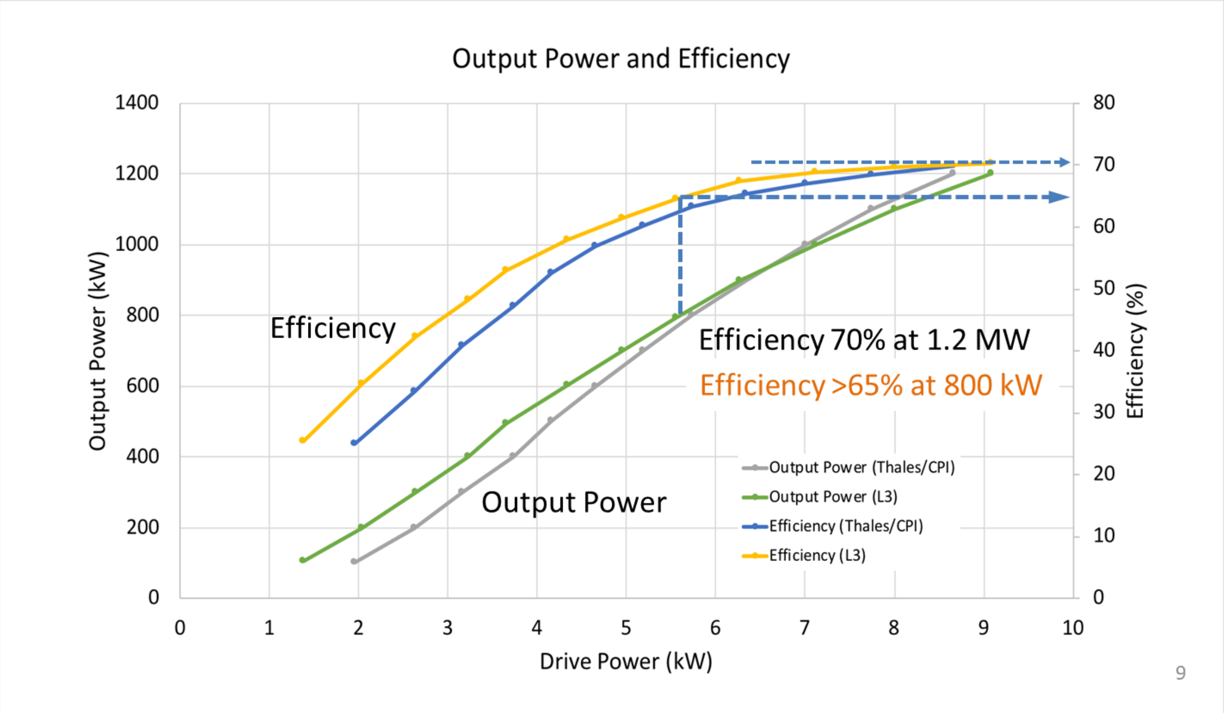
- Two multibeams IOTs developed for ESS
- High power test performed at CERN

→ Peak RF power of 1.2 MW achieved in pulsed mode (3.5 ms, 14 Hz)

= **World record !**

→ Is 1.2 MW in CW mode feasible ?

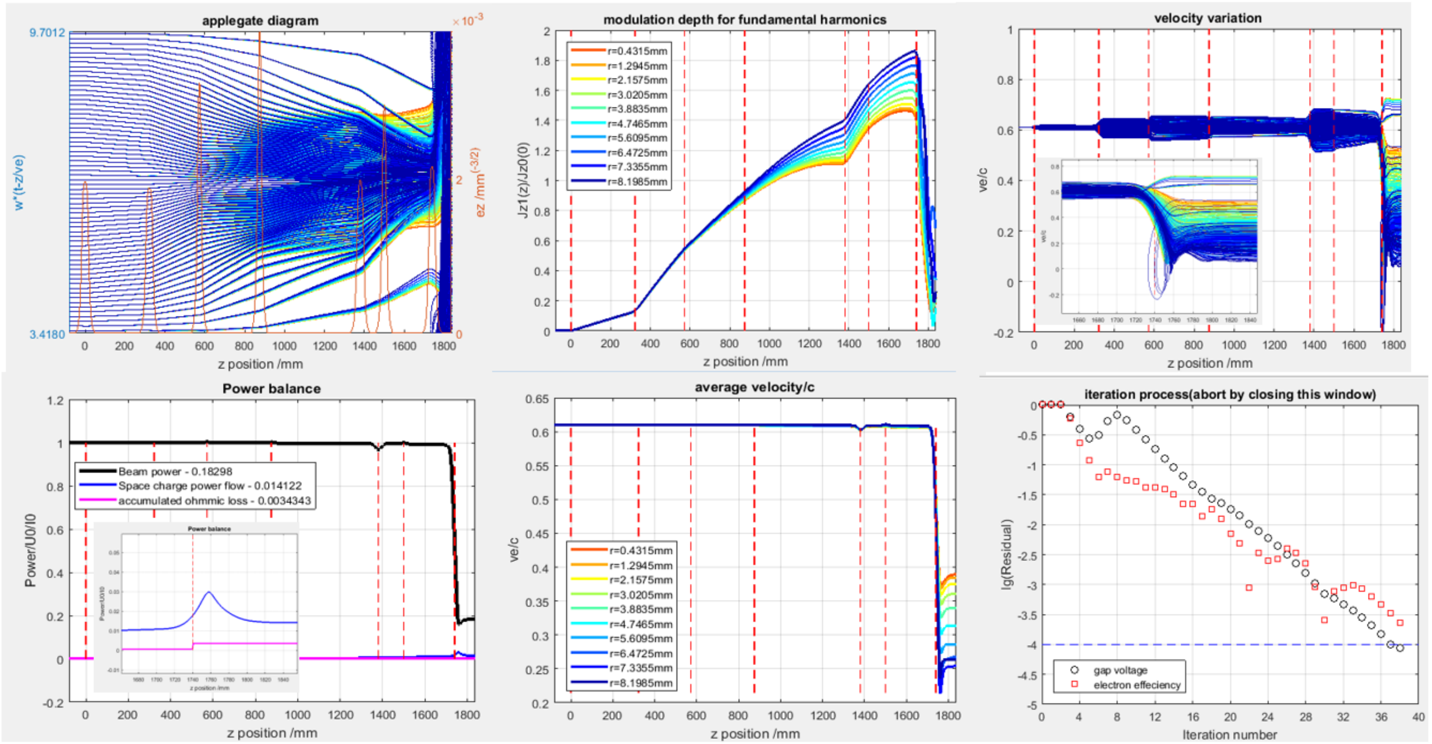




High efficiency klystrons development at CERN
Jinchi Cai (CERN)

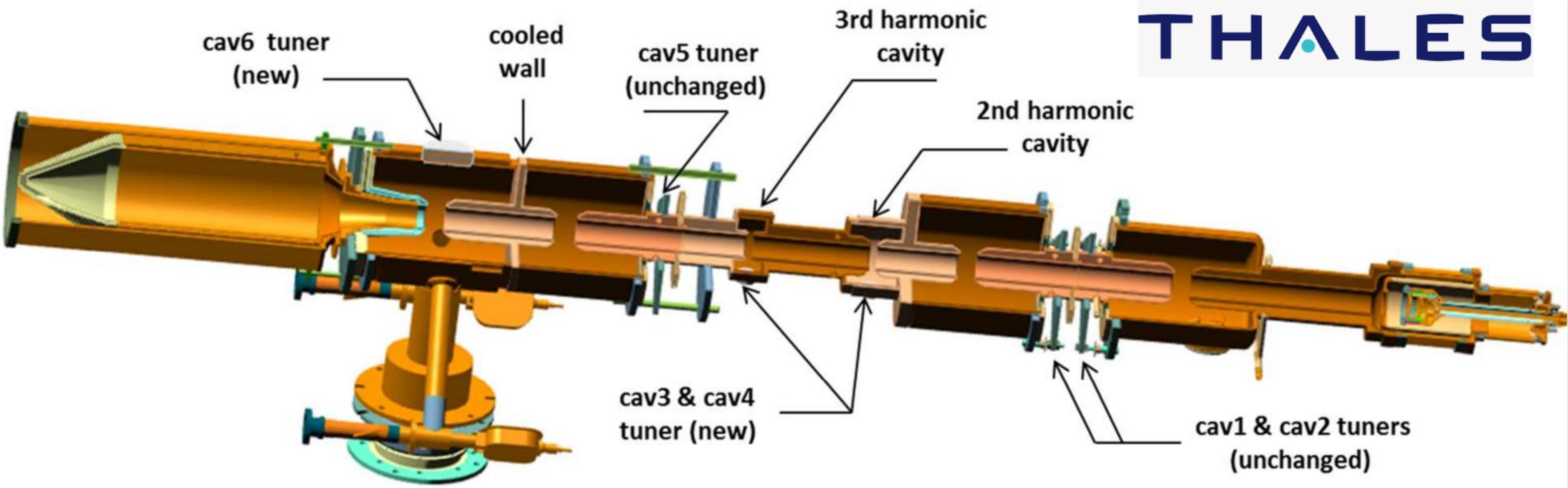
- New computer code KlyC developed at CERN and fully benchmarked
- FCC-ee 800 MHz klystron design finished with efficiency ~80%.
- Scaling procedure and efficieny limits are well established

FCC-ee klystron
800 MHz
133.9 kV
12.5 A
80% efficiency
Prf = 1.3 MW



Towards a high efficiency klystron for LHC
Armel Beunas (THALES)

- Upgrade of the existing LHC 400 MHz 300 kW klystrons for HL-LHC
- New beam-RF interaction structure designed by CERN
- Predicted power is 345 kW at 54kV 9A with and a gain of 36.5 dB and 71% efficiency



Conclusion

- The FCC(-ee) RF system is based on a solid and well established technology
- A significant R&D effort is made to improve the performances and reduce the cost of each component
- Next:
  - Pursue R&D, specially on cavity fabrication and thin films
  - ➢ Prototyping phase ?
    - ➢ «equipped FCC cavity» with power coupler, HOM couplers, tuner, magnetic shielding
    - ➢ Full FCC cryomodule

Thank you for your attention

Table 3.12: Detailed RF configuration of each machine and booster ring.

	Z		WW		ZH		$t\bar{t}_1$		$t\bar{t}_2$	
	per beam	booster booster	per beam	boo-ster	per beam	booster booster	2 beams	booster	2 beams	booster
Total RF voltage [MV]	100	140	750	750	2000	2000	9500	9500	10930	10930
Frequency [MHz]	**400**									
RF voltage [MV]	100	140	750	750	2000	2000	4000	2000	4000	2000
E_{acc} [MV/m]	5.1	8	9.6	9.6	9.8	9.8	10		10	
# cell / cav	1	4	4		4		4		4	
V_{cavity} [MV]	1.92	12	14.4	14.4	14.7	14.7	15		15	
# cavities	52	12	52	52	136	136	272	136	272	136
# CM	13	3	13	13	34	34	68	34	68	34
T operation [K]	4.5		4.5		4.5		4.5		4.5	
Dyn losses/cav [W]	14	11	210	26	202	29	210	30	210	30
Stat losses/cav [W]	8		8		8		8		8	
Q_{ext}	$4.4\ 10^4$		$6.6\ 10^5$		$1.9\ 10^6$		$4\ 10^6$		$4.7\ 10^6$	
P_{cav} [kW]	962		962		368		175		149	
Frequency [MHz]	**800**									
RF voltage [MV]							5500	7500	6930	8930
E_{acc} [MV/m]							19.8	20	19.8	19.8
# cell / cav							5		5	
V_{cavity} [MV]							18.6	18.75	18.6	18.6
# cavities							296	400	372	480
# CM							74	100	93	120
T operation [K]							2		2	
Dyn losses/cav [W]							66	10	66	10
Stat losses/cav [W]							8		8	
Q_{ext}							$3.9\ 10^6$		$5.6\ 10^6$	
P_{cav} [kW]							176		155	