CERN

SRF thin film activities status at CERN

EUCARD2 WP12 2nd Annual Meeting, DESY 8th-9th Apr 2015

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CERN / TE-VSC-SCC

Content

- Why thin films?
- SRF thin films activities
  - Nb3Sn
  - HiPIMS
  - HIE-ISOLDE
  - LHC
  - Simulation

Why thin films?

- Future accelerators needs:
  - Low power consumption
- Savings on cryogenics systems
  - More efficient heat transfer

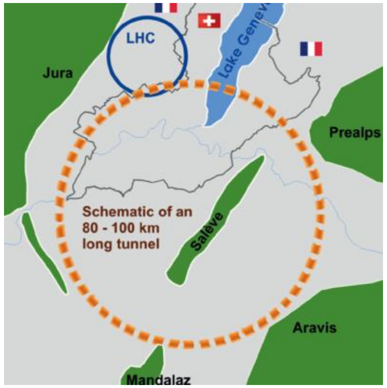
→ Alternative to Nb bulk cavities

→ Cu cavities

→ Need of superconductivity: thin film

Nb_3Sn Status

Why and How?



A15 : Among the most promising solutions to

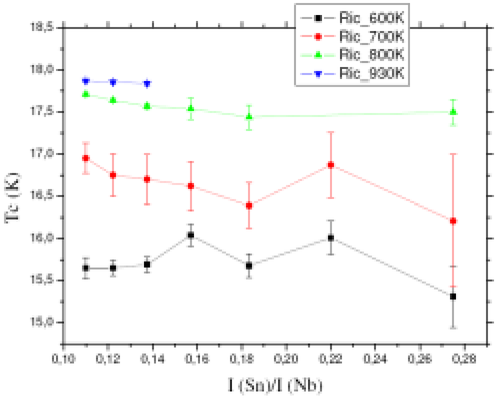
- Low Power losses (necessary for future colliders)
- High T_C
- High Q_0 at low field (Not High Q dedicated)
- Q slope disease

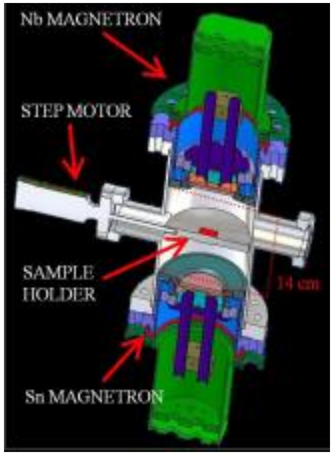
Multiple studies carried out:

- Tin diffusion in bulk Nb
- Co-sputtering (Palmieri)
- Sputtering (R.T. Kampwirth, J.W. Hafstrom, C.T.Wu)

Past work

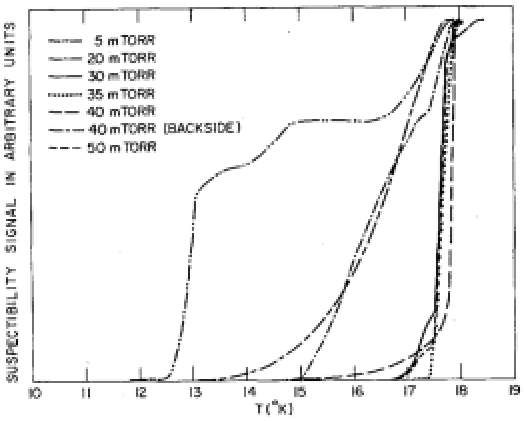
- Palmieri

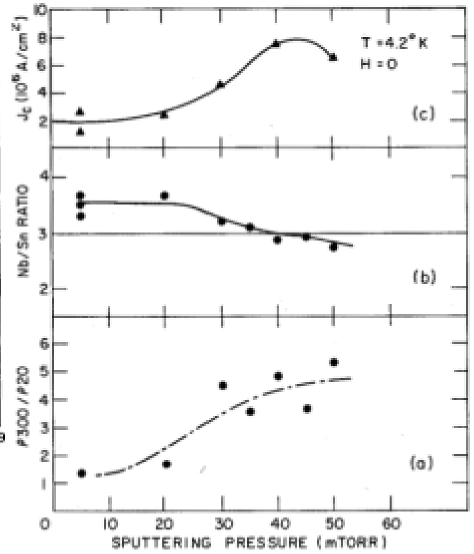




Dual cathodes sputtering

- Hafstrom



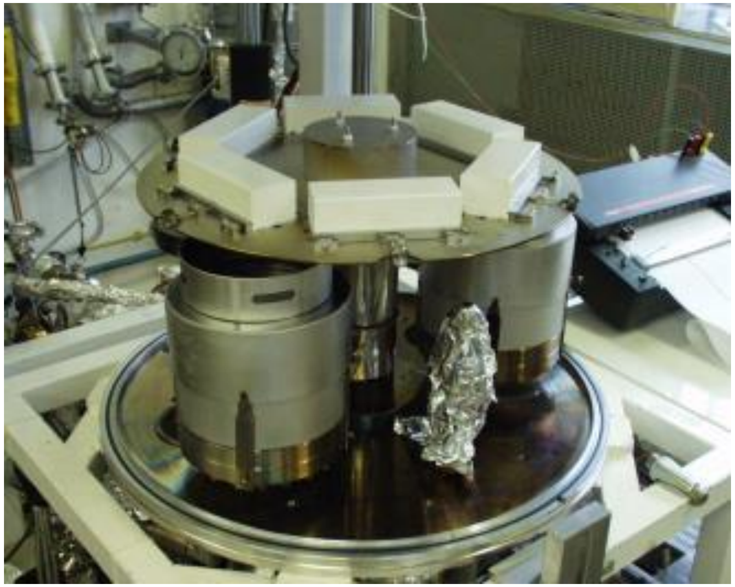


- Importance of neutral species thermalization
  - High pressure
  - T_{eff} close to T_{sample}
  - Avoid defects in the layer
  - # and sharpness of SC transition

- And of course: High Temperature step to get A15 phase

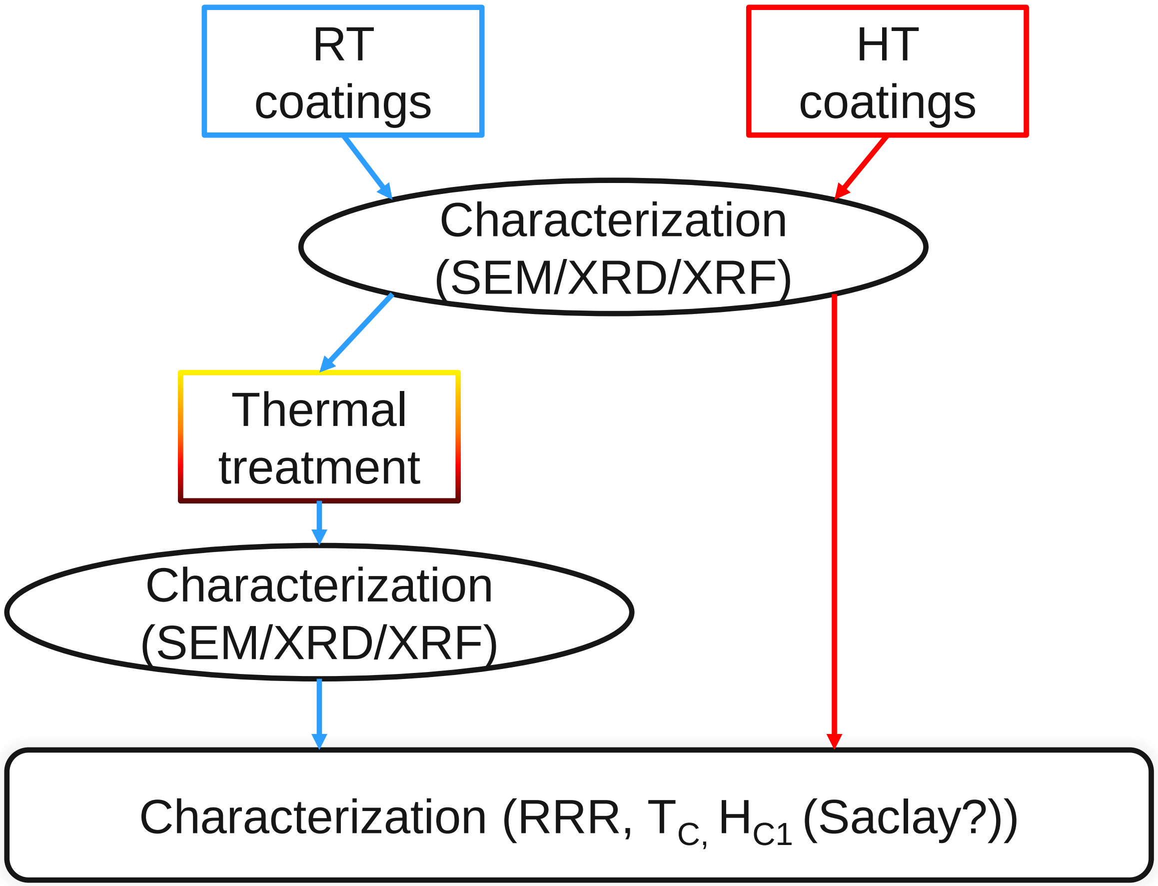
Coating Method

- Magnetron sputtering
- Initial idea (EUCARD): co-sputtering
  - Sn low melting point
  - Possibility to get alloyed targets
- Alloyed target
  - Stoichiometry conservation
  - Scale up
- Low voltage (400V)
- Wide range of pressures
  - 1.10^{-4} up to 1.10^{-1} mbar



- Sample holder and heating element in fabrication for high temperature coatings

Approach



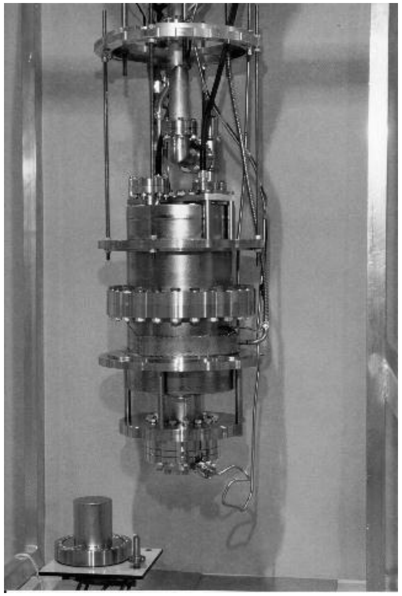
GOAL:

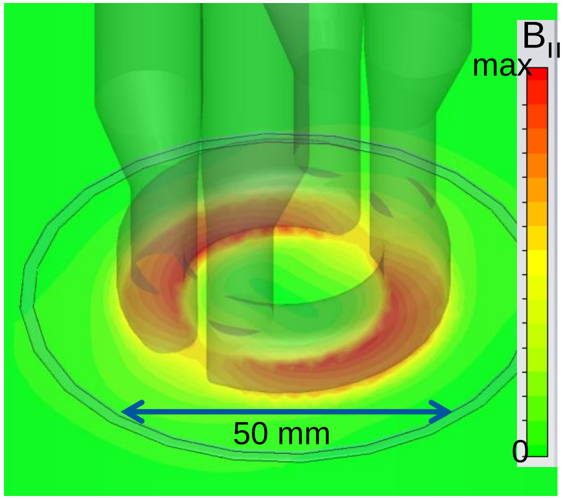
EXPLORE AND VALIDATE PROCESS PARAMETERS BEFORE STEPPING INTO RF CHARACTERIZATION

RF QPR SAMPLES

RF Characterization

- Quadrupole resonators
- Resonant Frequencies: 400MHz, 800MHz, 1200MHz
- Broad temperature range above the bath temperature is available
- Measurement of , penetration depth, quench field (high T), thermal conductivity, RRR
- Separate losses due to magnetic and electric field
- Study the influence of trapped magnetic flux
- **GOAL: At least one QPR coated before end 2015 (EUCARD2 deliverable: April 2016)**
- **Contact: Sarah Aull (sarah.aull@cern.ch)**





Status

- 2 Nb3Sn 150mm cathodes available
- Composition validated by EDS measurements

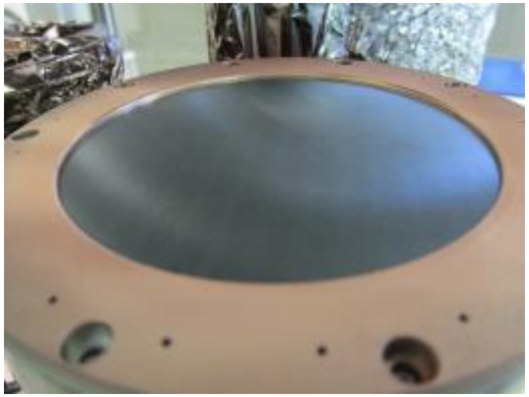


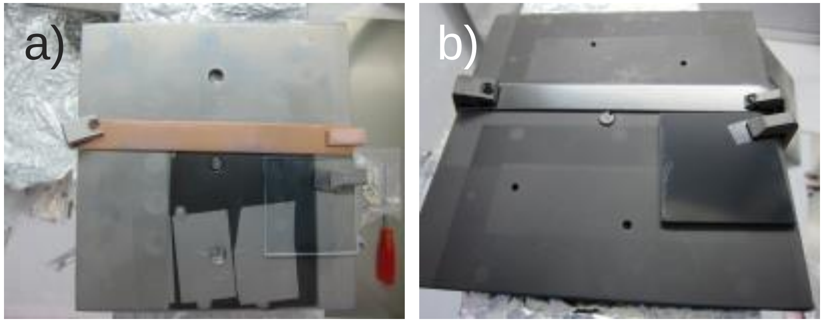
Table 1 – Summary of EDS values in atomic % for various spectrum.

Specimen	50 mm diameter		150 mm diameter	
	Atomic (%)			
SOI	Nb	Sn	Nb	Sn
1	74.4	25.7	73.9	26.1
2	73.5	26.5	71.5	28.5
3	78.3	21.7	71.9	28.1
4	76.1	23.9	78.8	21.2
5	78.2	22.9	73.8	26.2
Average	76.1	24.1	74.0	26.0
STDEV	2.2	2.0	2.9	2.9

- XRD on going
- Evolution of cathode aging to be studied
  - Comparison (ESD/XRD) as received and after several coatings

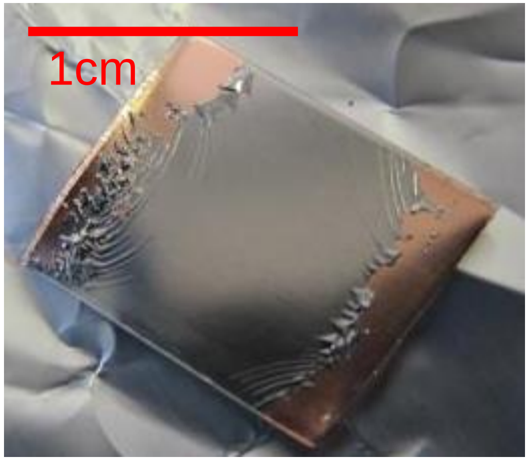
Status

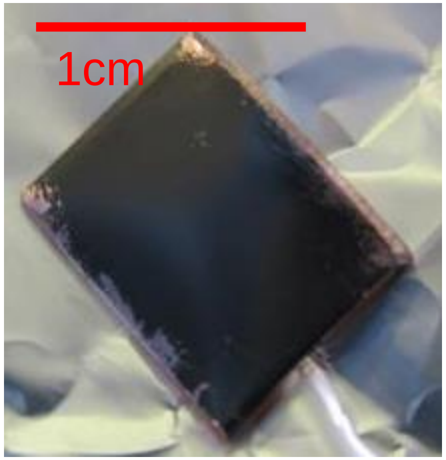
- First samples
  - Low P (1.10-3 mbar) – Cu and glass
  - High P (5.10-2 mbar) – Cu and glass
  - Constant power (200W)
  - Low Voltage drop (250-350V)



Cu and glass samples before (a) and post coating (b)

- Coating rate from 0.5 nm/s (1.10^{-3}mbar) to 0.6 nm/s (5.10^{-2} mbar)
- XRD/SEM characterization on-going (TE-EN-MME)
- Post coating annealings to be scheduled





Peel-off is more important in case of low pressure coatings.

To be quantified by adhesion tests. (technician internship)

Forecast

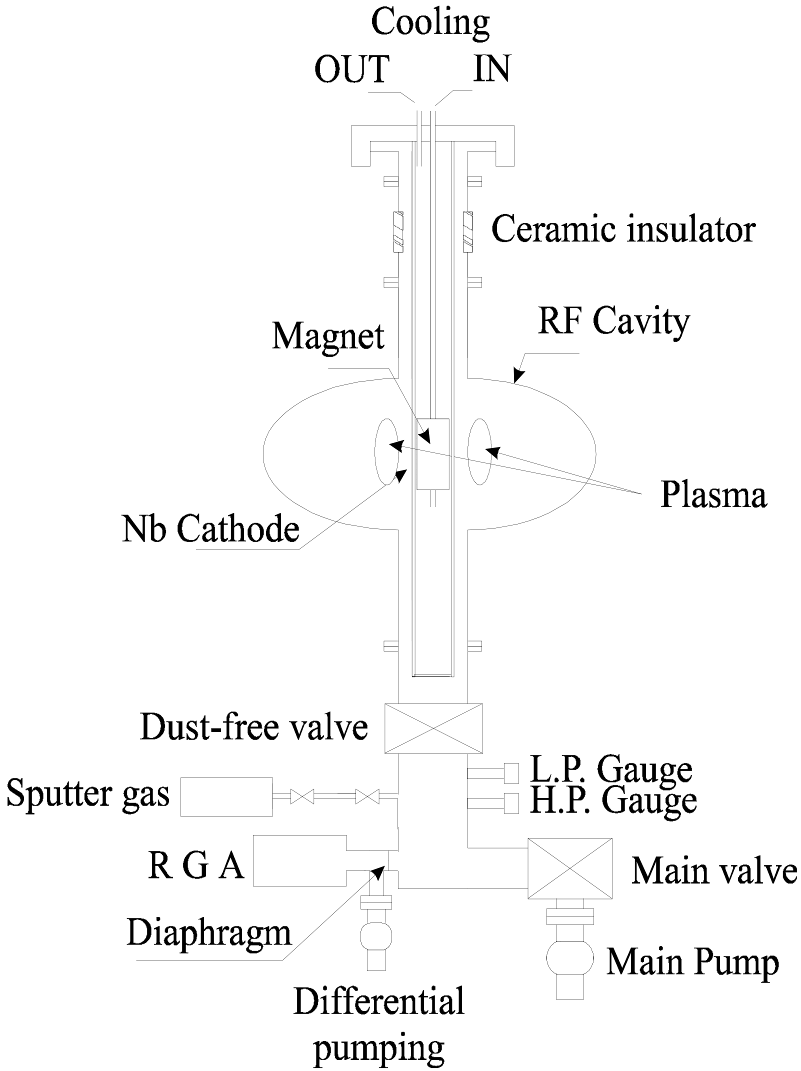
- 1 fellow to start in fall 2015
- Open to other A15 (V_3Si, Nb_3Ge, Nb_3Al)
- Think: scale-up

- Summer 2015
  - A15 phase
  - First parameters screening
  - First High temperature coatings

- Long term goal:
  - Get a correlation between nano/microstructure (not only @ surface) and RF performances

HiPIMS

Standard DCMS Setup



Sputtering parameters (ex: 1.5 GHz):

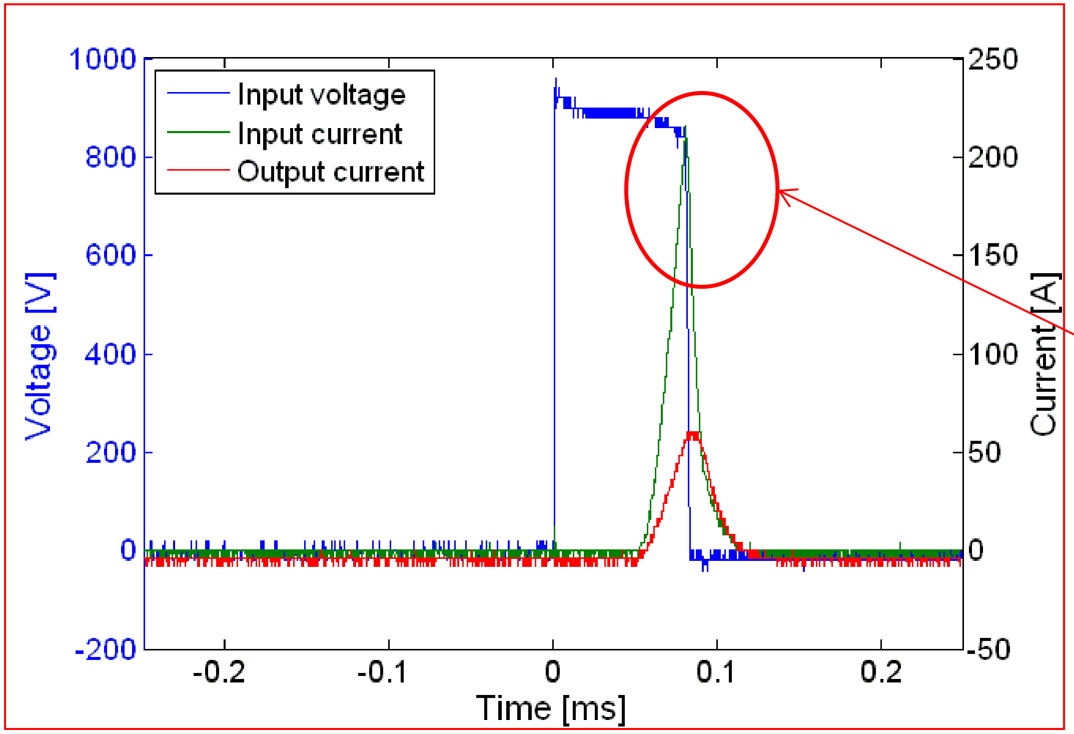
- Sputter gas pressure of 1.5×10^{-3} mbar (Ar or Kr)
- Plasma current stabilized at 3A - DC
- Sputter potential ~ -360 V
- Coating temperature is 150 °C.
- Thickness: 1.5 µm

"Standard films":

- RRR: 11.5 ± 0.1
- Argon content: 435 ± 70 ppm
- Grain size: 110 ± 20 nm
- Tc: 9.51 ± 0.01 K
- Strain: $\Delta a_{\perp}/a_{\perp}$ = 0.636 ± 0.096 %

HIPIMS basics (invented in 1999)

In standard DC magnetron sputtering the power is (typically) ~ kW
The sputtering rate is proportional to the power
The plasma current $I \propto V^{5 \div 15}$



HIPIMS uses pulses of 100s of µs of very high peak power keeping the same average power.
Peak to DC ratio can be in the order of 1000

(Ex: peak power 160 kW)

The amount of sputtered Nb can be so large that its "pressure" is larger than the noble gas pressure.
As a consequence also the Nb becomes ionised, and guided with a bias.

Previous work

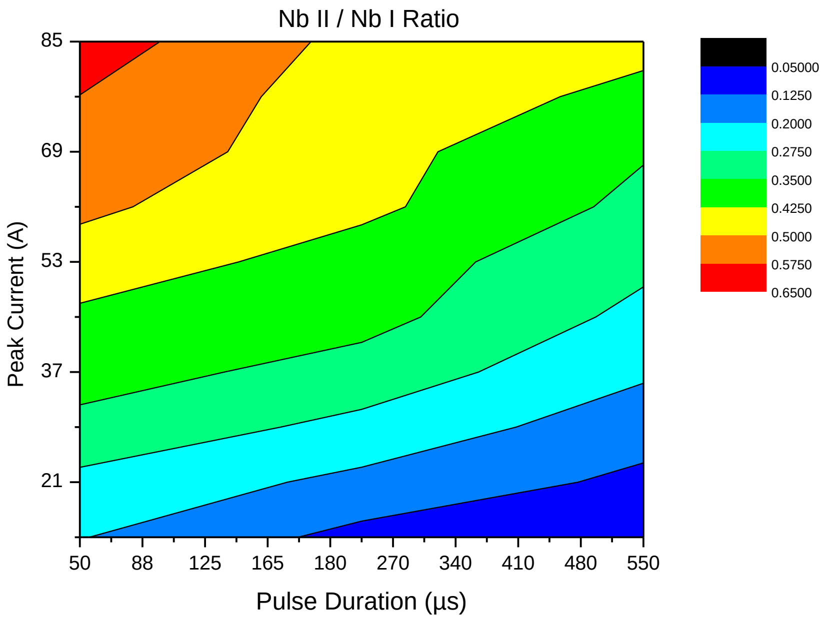
G. Terenziani PhD Thesis

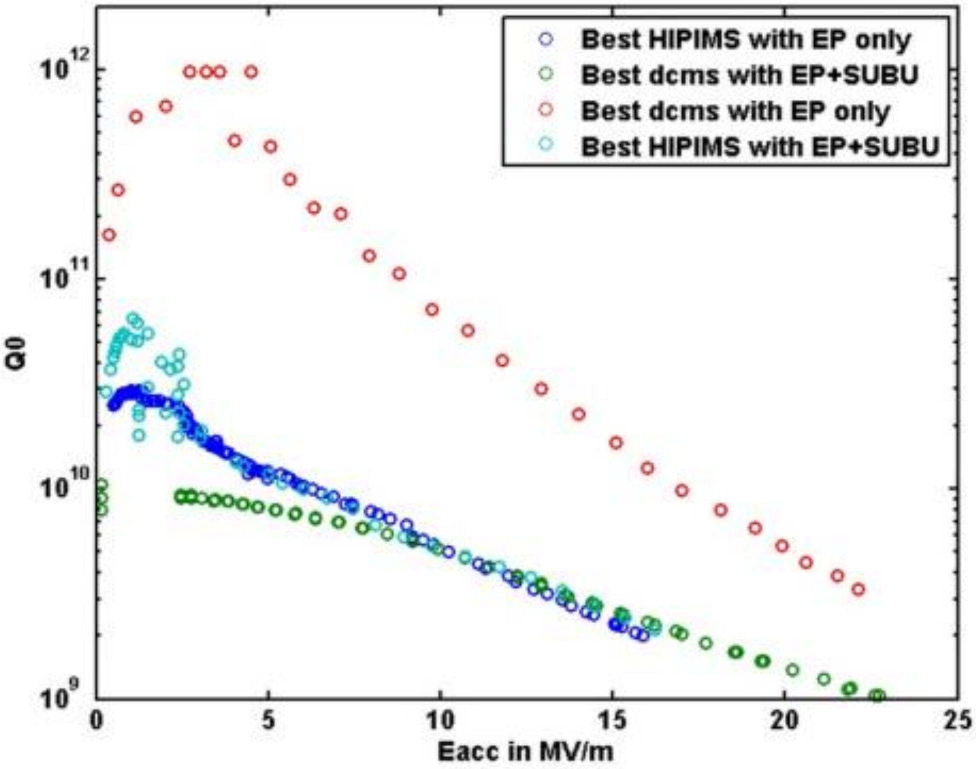
- Standard HiPIMS coating
  - Cavity grounded

- None of the coatings have ever been better than the best DCMS coating combined with EP.

- How to improve?

- Next steps?



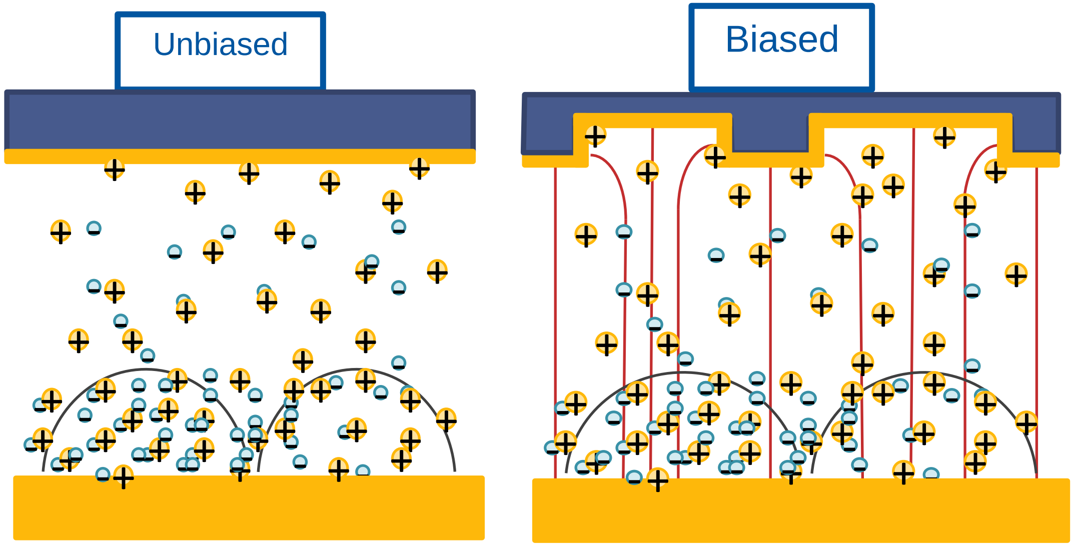


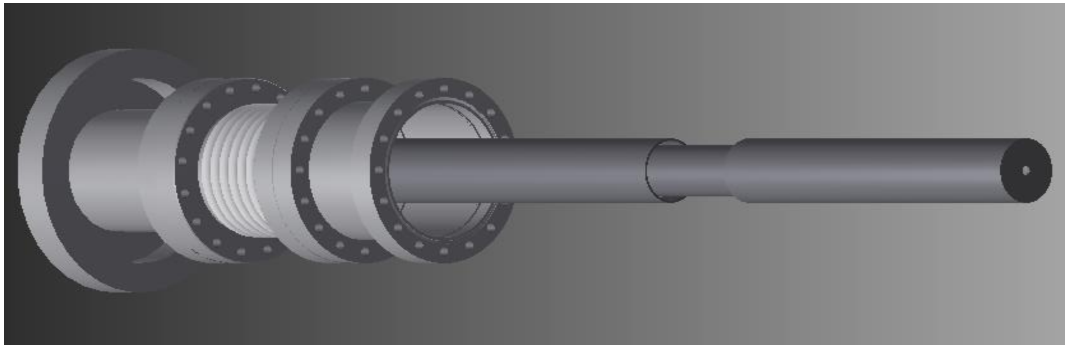
Toward bias configuration

Standard HiPIMS gave promising results but could be improved further

HiPIMS+Bias to be investigated
- Controlled ion flux
- Denser film
- Smoother surface

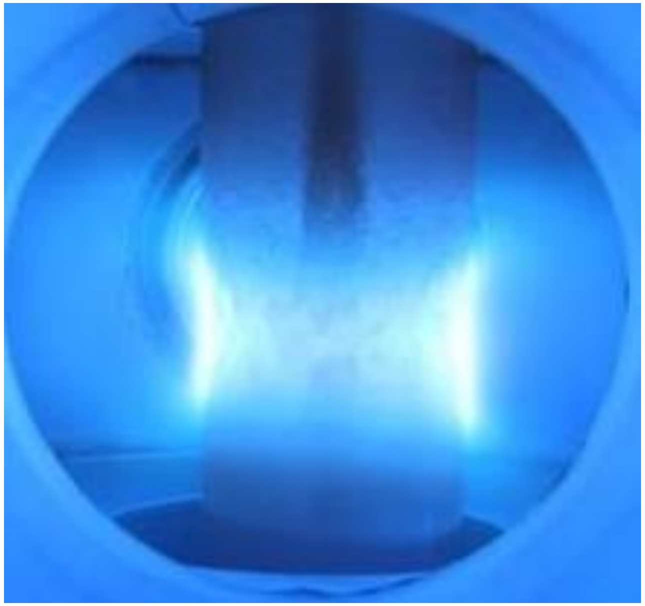
Requirements
- Ground potential surface
  - Modified cathode

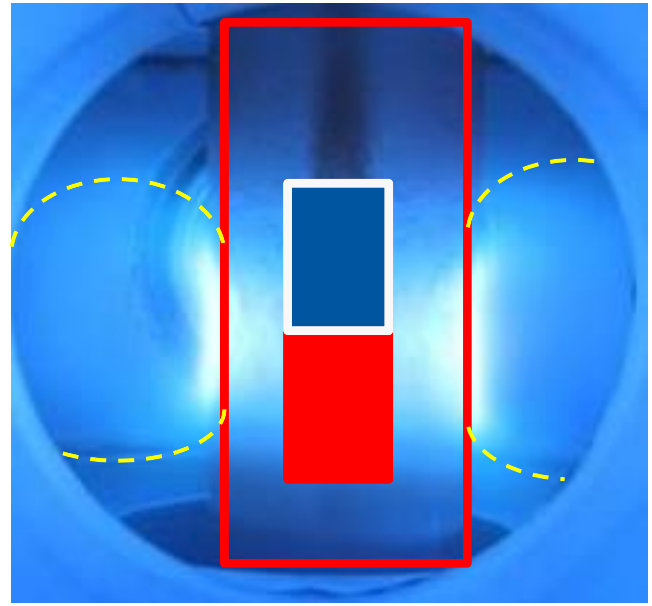




Issues:
Impossible to strike plasma using cathode/anode setup
Possible causes: magentic configuration / anode design

Magnetic configuration





- Good for unbiased configuration
  - Strong ion flux directed toward cavity - unbalanced
- Problematic in case of an internal anode presence
  - Not enough charges collected by anode → another electrode needed to strike the plasma : cavity – NO -

Forecast

- June 2015: HiPIMS conference, Braunschweig
- Summer 2015: Setup upgrade
  - Parts modifications
  - New designs – magnetics and mechanics
- Fall 2015: 1 technical student (Master thesis)

Conclusion

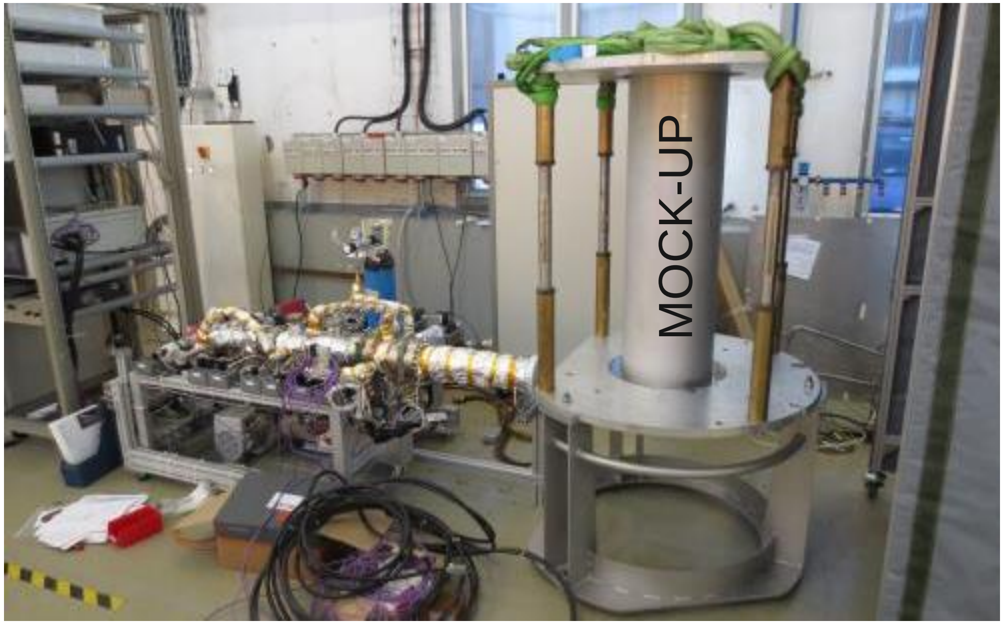
- First Nb_3Sn coatings and characterization on-going.
- First High T coatings summer 2015
- HiPIMS results encouraging but not yet better than standard DCMS coatings

Thank you for your attention

LHC – spare cavities

LHC – spare cavities

- Consolidation project
- Setup to be commissioned by mid April
- 1 CM to be completed
  - 4 cavities
- Nb coating by magnetron sputtering
- 2 Cavities in fabrication

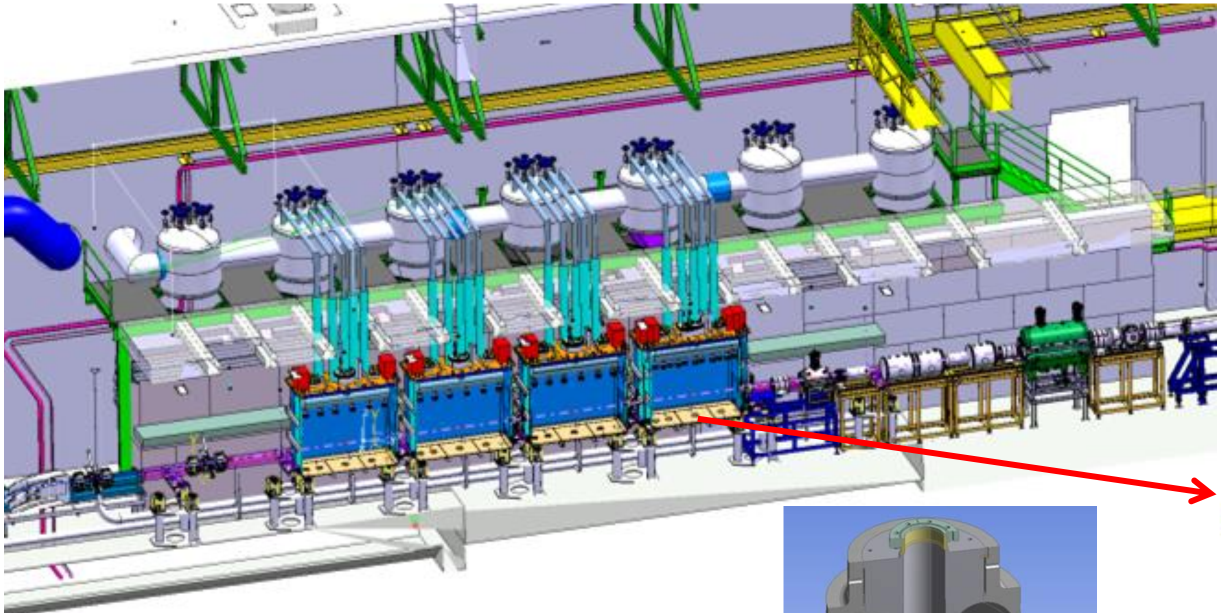


HIE-ISOLDE

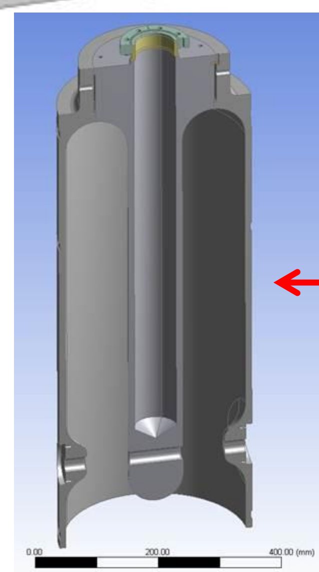
HIE-ISOLDE upgrade project

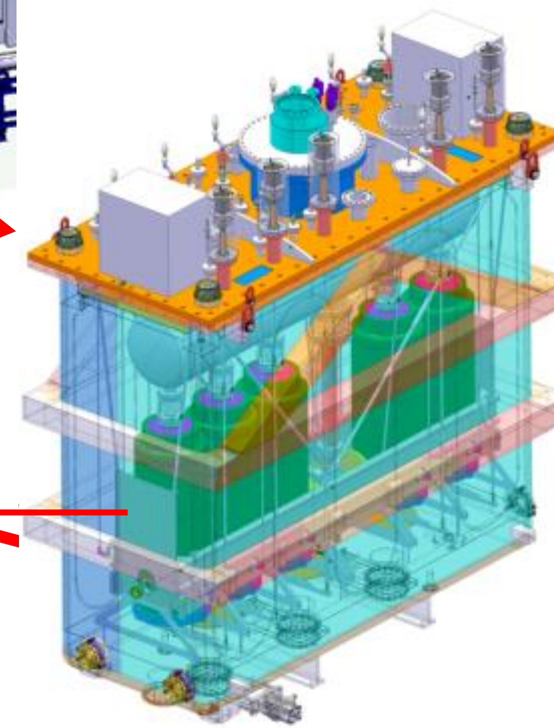
→ Boost the radioactive beam energy from 3MeV/u to 10MeV/u by using SC linac.

High Energy and Intensity – Isotope Separator On Line DEtector

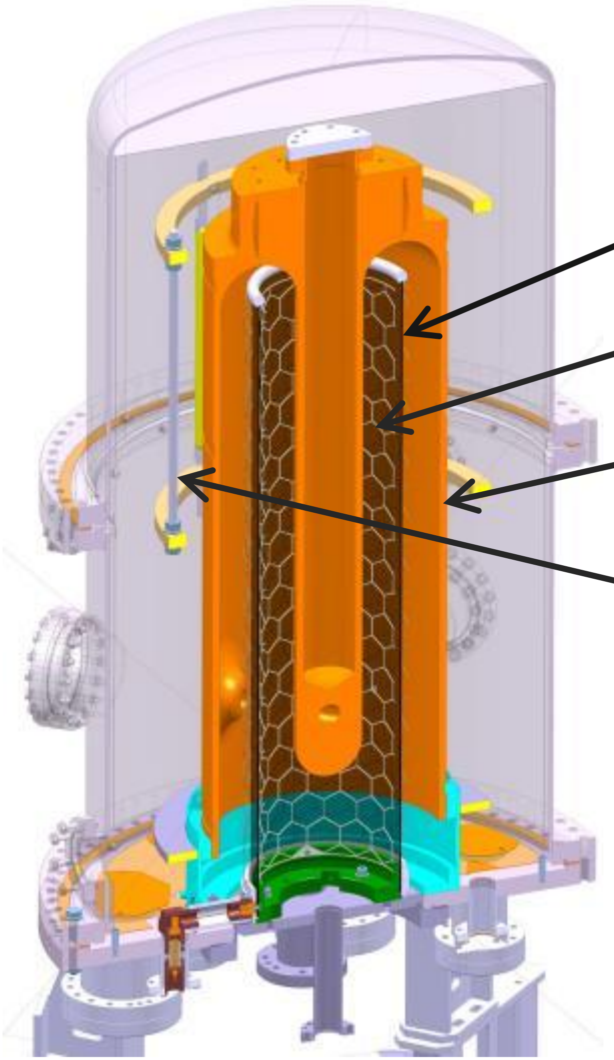


Quarter-wave resonator (QWR):
Nb thin film sputtered
on 3D forged OFE Cu substrate





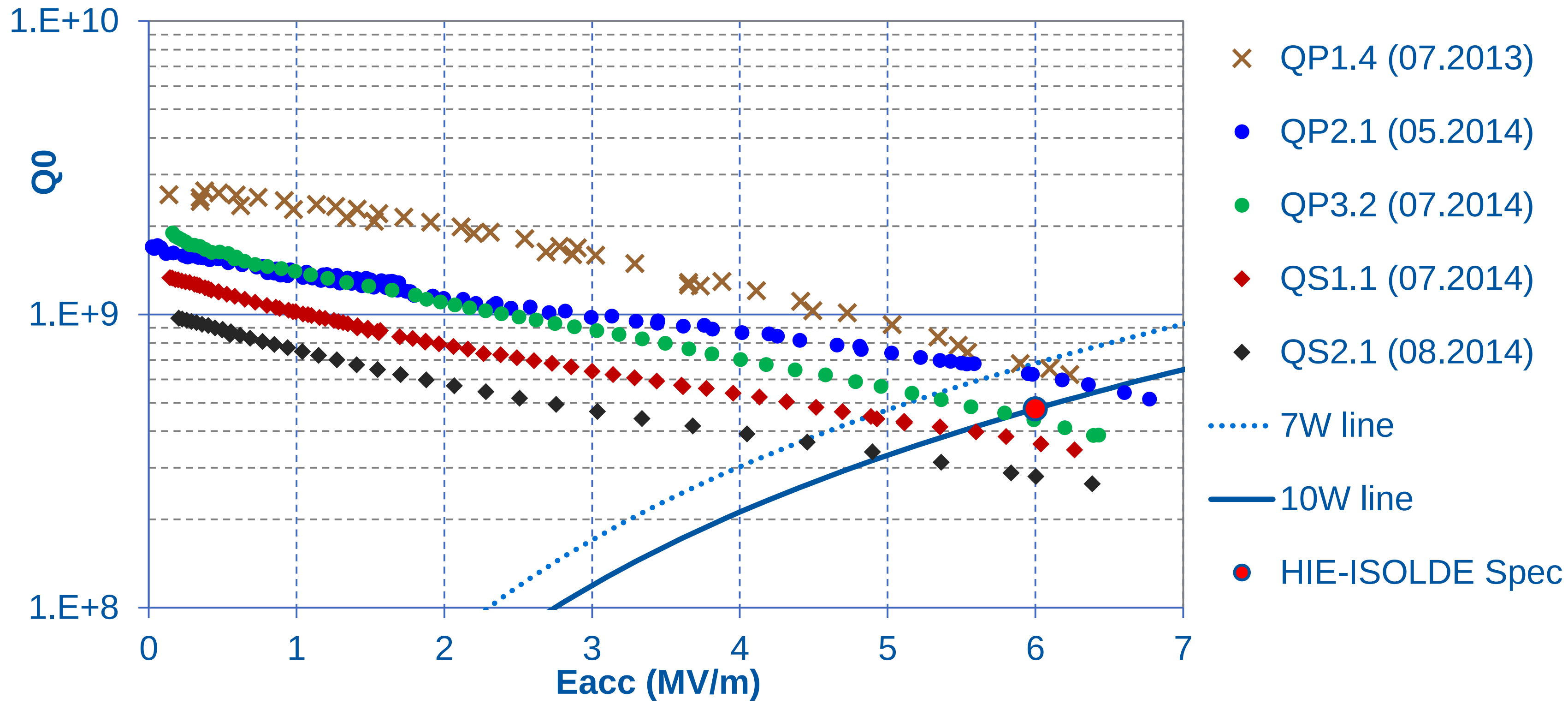
Coating hardware



2 coating benches functional at CERN:

- Nb cylindrical cathode at -1000V
- Grids grounded for plasma polarization
- Adjustable cavity bias: ions flux
- Cavity bakeout to 650°C with IR lamp prior to coating
- Coating with hot substrate (300-620°C)
- Thermocouples along cavity to monitor temperature during bakeout and coating
- Pressure control and RGA monitoring

Cavities performances



Eacc=6MV/m	HIE-ISOLDE specifications	QP1.4 test Prototype	QP2.1 Prototype 2	QP3.2 Prototype 3	QS1.1 pre-Serie	QS2.1 pre-Serie
Q0	4.7E+08	6.51E+08	6.23E+08	4.37E+08	3.61E+08	2.80E+08
Pcav(W)	10	7.5	7.6	10.8	12.5	17.0

for cryomodule, avg = 12 W

HIE-ISOLDE : today

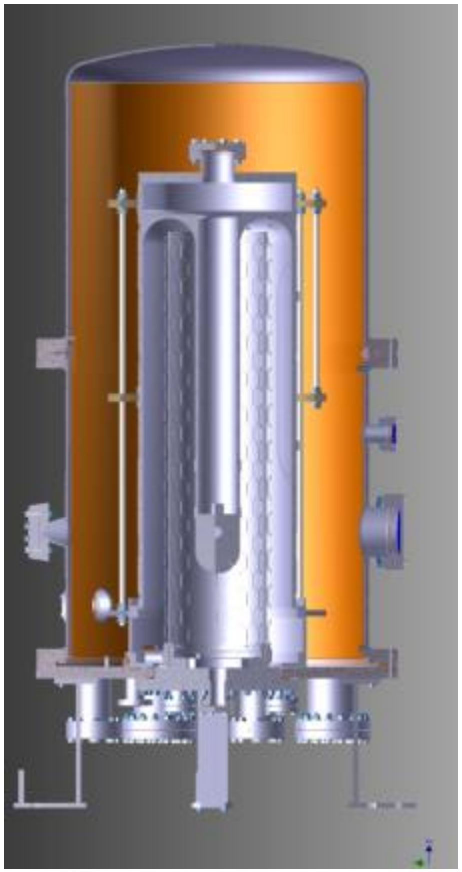
- 5 cavities + 1 spare for CM1 coated
- CM1 assembly on-going
- 5 cavities for CM2 to be coated by June 2015
- Study on-going toward film quality improvement
  - Dummy cavity / samples mounting

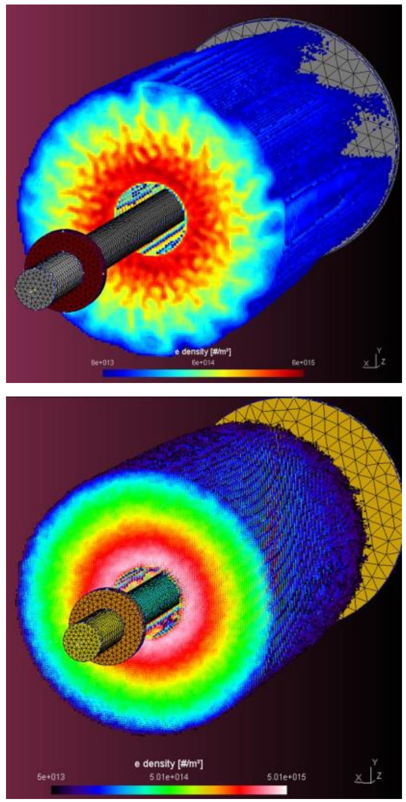
Simulation

Plasma behaviour in complex shapes

- PhD thesis : T.Richard (supervisors: A.Sublet and I. Furno (EPFL))

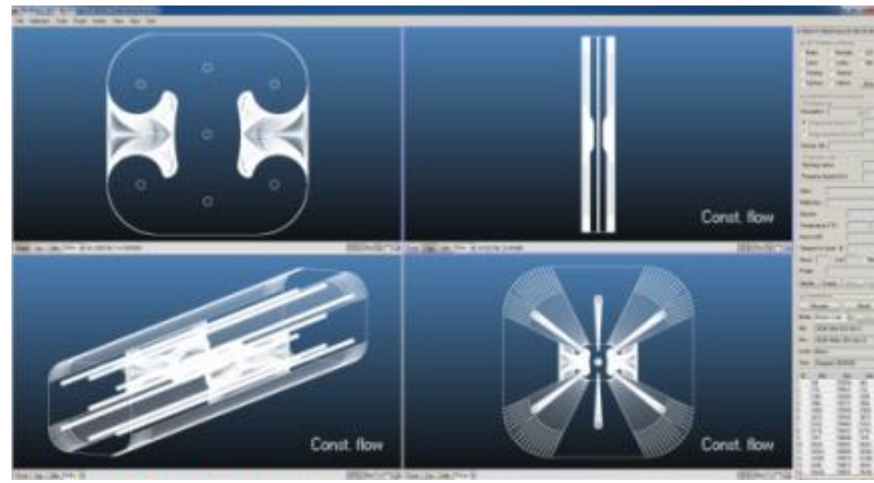
HIE-ISOLDE





Courtesey: A.Pflug / Fraunhofer-Institut

CRAB cavities



Understand plasma behaviour
Optimize cathodes shapes

Test bench for validation