Recent experience with spoke cavity technology at Orsay: a potential area of contribution to PIP-II

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Past experience on spoke cavities @ Orsay

- Started in 2000 at IPNO with Guillaume's Ph-D and the design, fabrication and test of the first european spoke (SSR β0.35)

- Continued within the framework of both the EURISOL Design Study project and several R&D programs on MYRRHA:

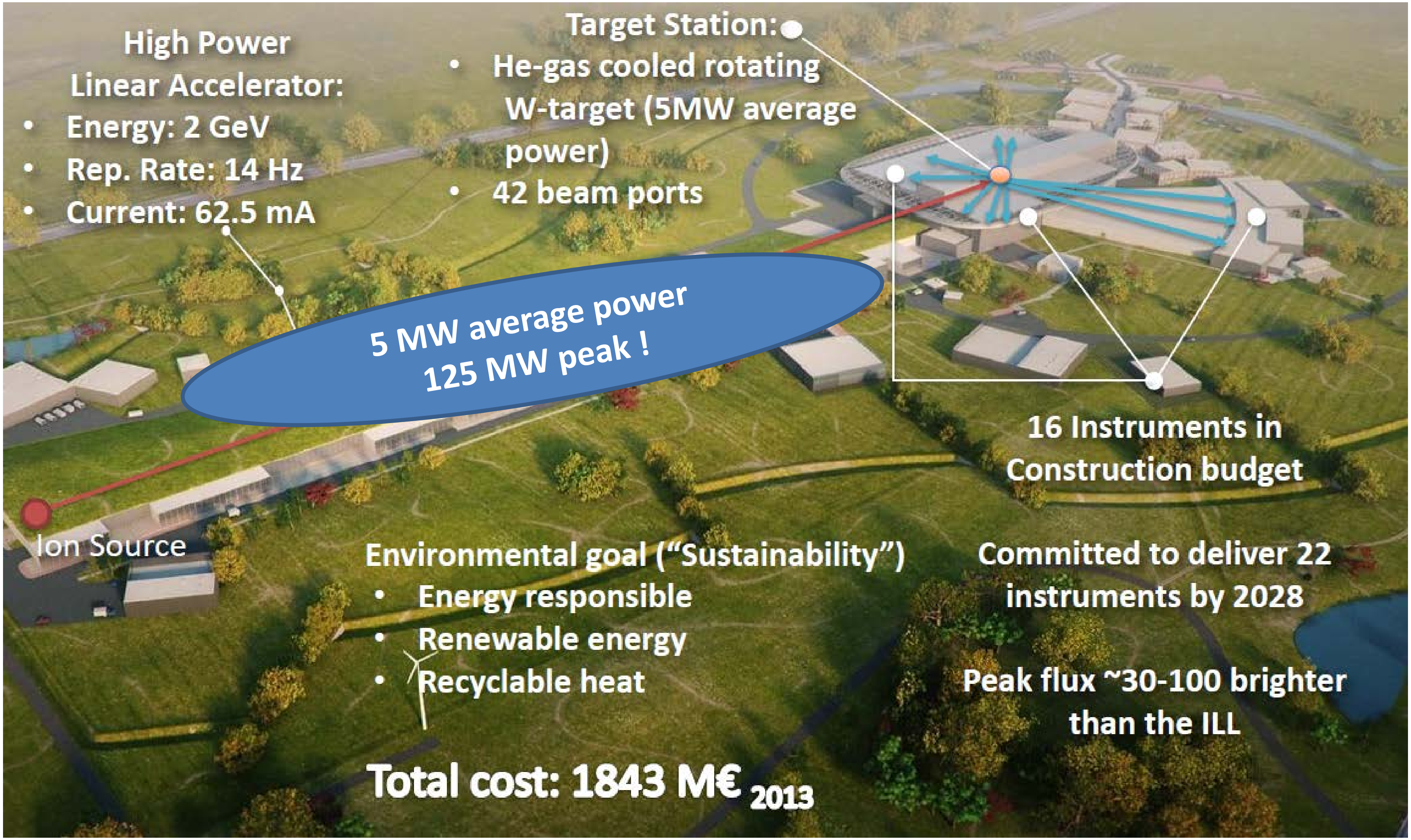
  Development of

  - SSR β0.15
  - triple spoke β 0.30

- And now ongoing:
  - ESS: double spoke β 0.5:

  - MYRRHA: SSR β0.37

European Spallation Source (ESS)



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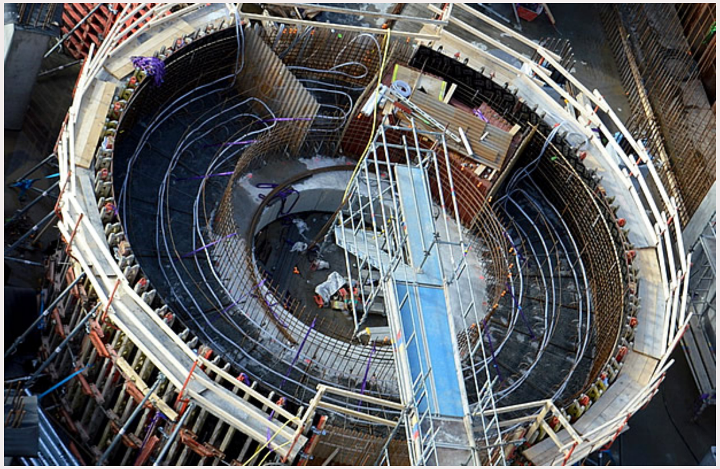
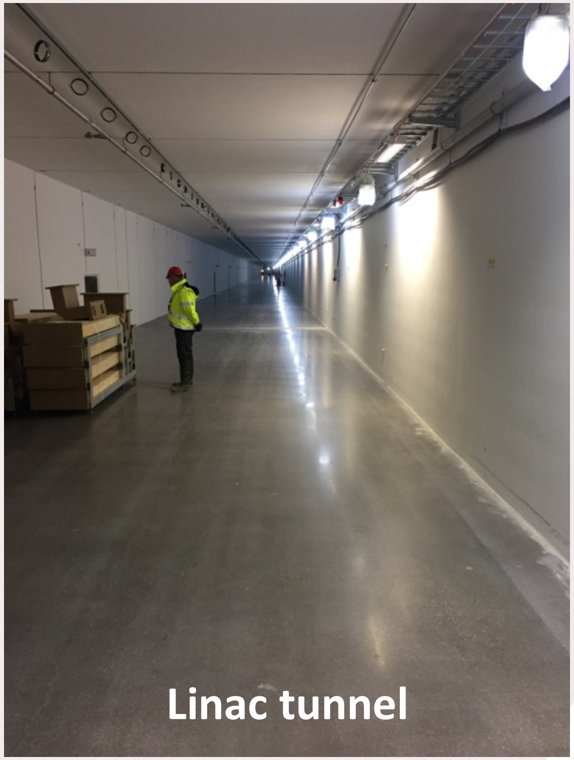
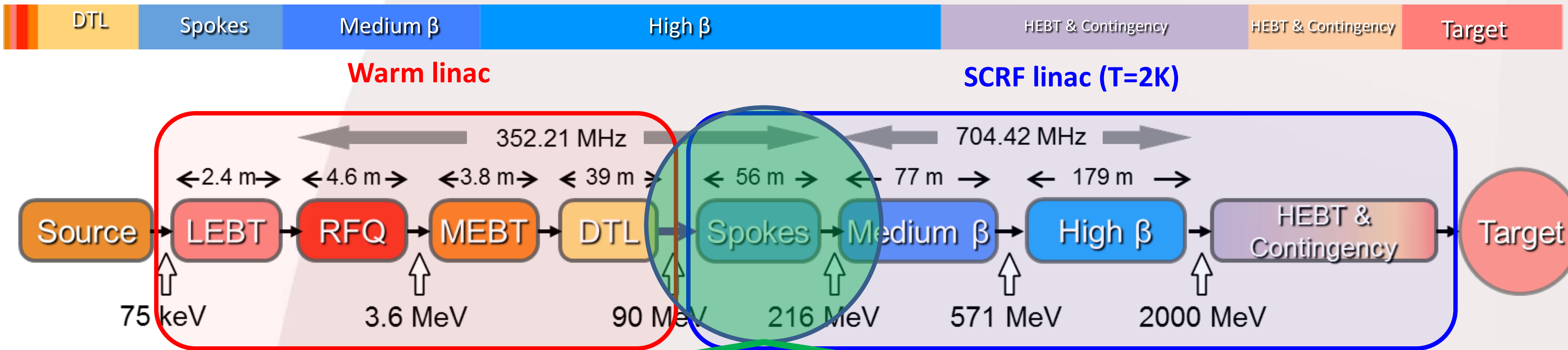


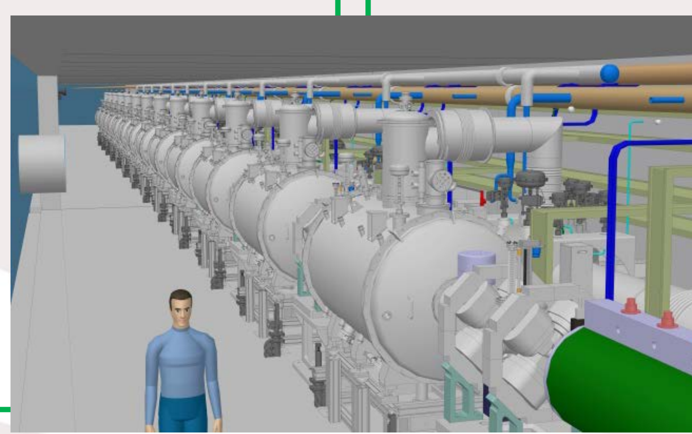


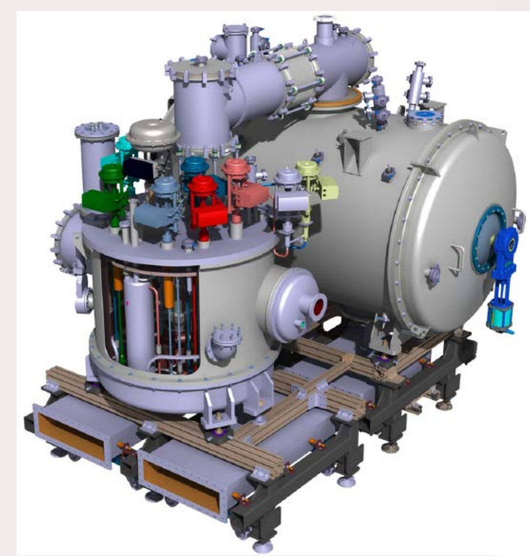
Contribution of CNRS/IN2P3/IPNO to ESS



The 13 spoke cryomodules composing the first superconducting acceleration stage of ESS.

All the 13 cryogenic distribution system for the spoke section (valve boxes, cryolines, cryo end box)





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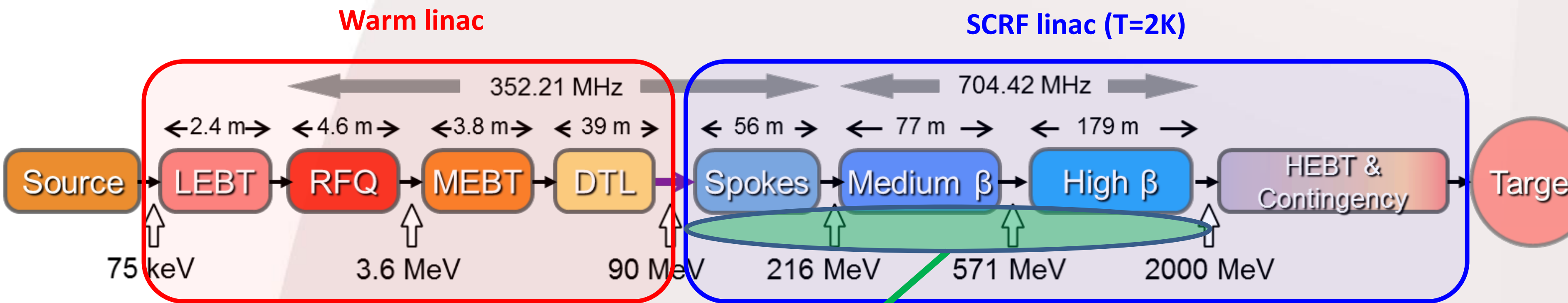
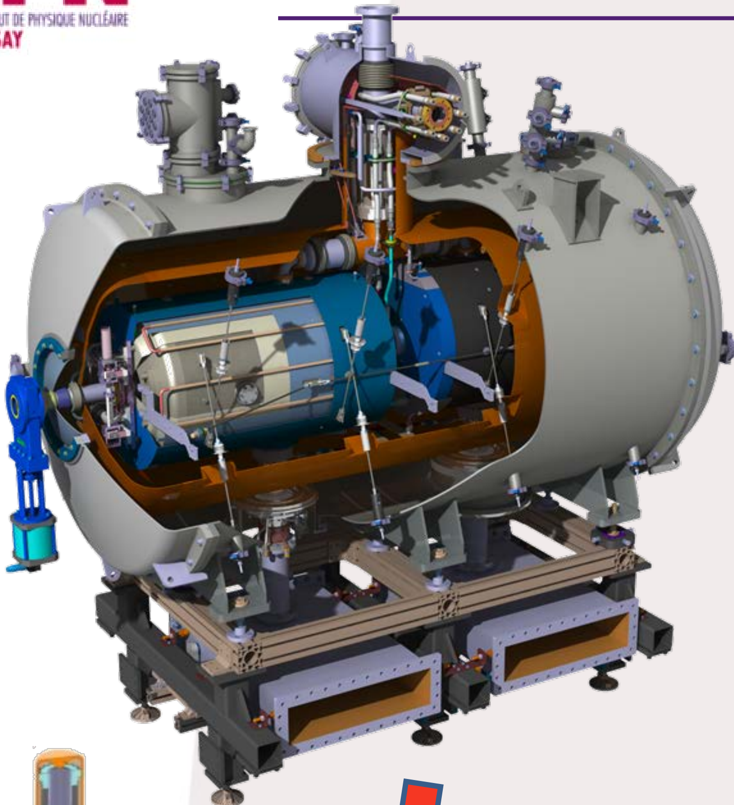
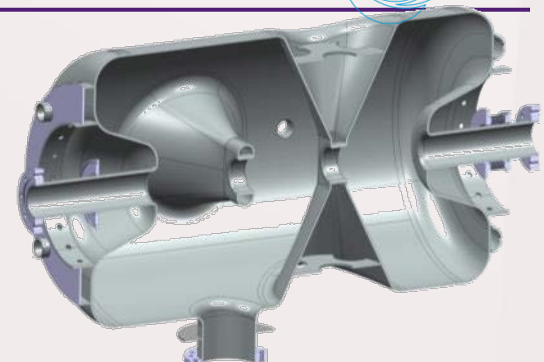


The cryogenic control & command system for all superconducting cryomodules: spoke (x13), medium β (x9) and high β (x21) and their associated cryogenic valve boxes.

Contribution of CNRS/IN2P3/IPNO to ESS

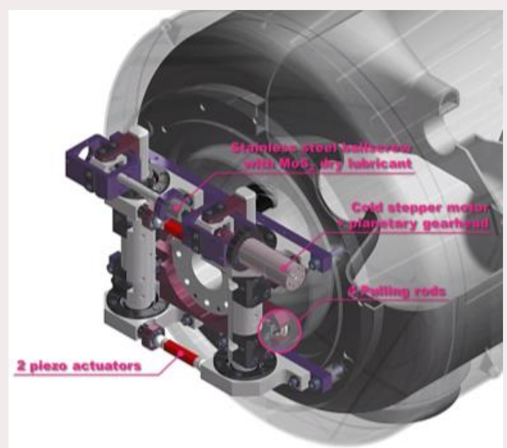


Double Spoke SRF Cavities



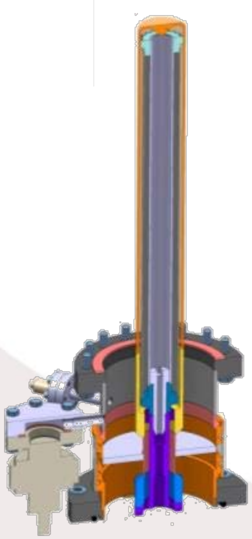
- Double spoke cavity (3-gaps), 352.2 MHz, β=0.50
- **Goal: Eacc = 9 MV/m** *[Bp= 62 mT ; Ep = 39 MV/m]*
- 4.2 mm (nominal) Niobium thickness
- Titanium Helium tank and stiffeners
- Lorentz detuning coeff. : ~-5.5 Hz/(MV/m)^2
- Tuning sentivity $\Delta f/\Delta z$ = 130 kHz/mm

Cold Tuning System



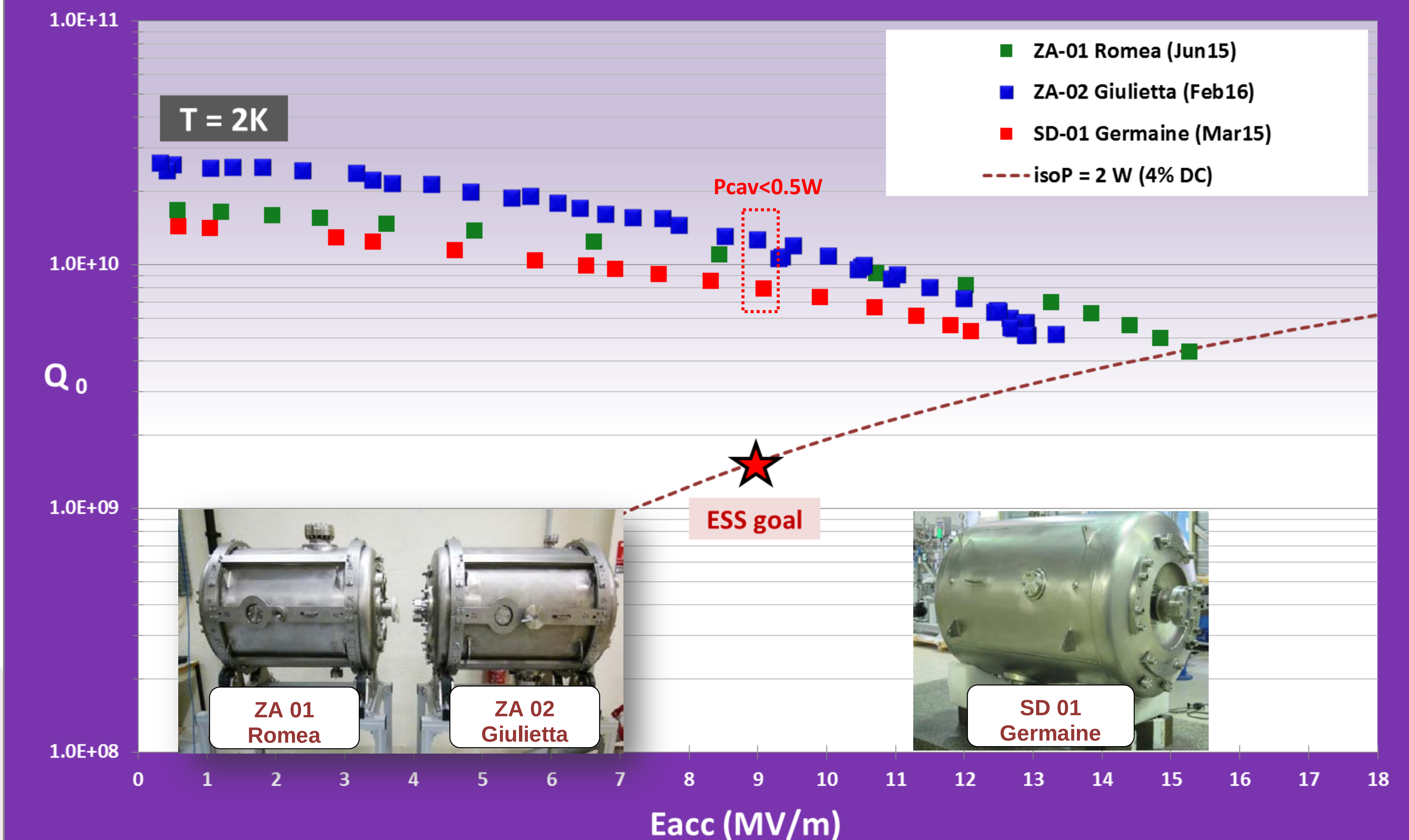
- Slow tuning (stepper motor):
  Max stroke: ~ 1.3 mm
  Tuning range: ~ 170 kHz
  Tuning resolution: 1.1 Hz
- Fast tuning (piezo-actuator):
  Applied voltage up to +/- 120V
  Tuning range at 2K: 675 Hz (min)

Power Coupler



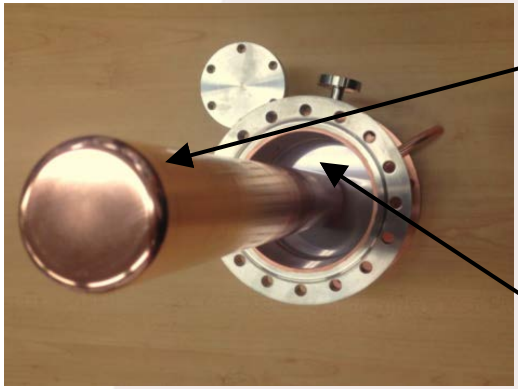
- Ceramic disk, 100 mm diameter
- 400 kW peak power (335 kW nominal)
- Antenna & window water cooling
- Outer conductor cooled with SHe
- Doorknob transition from coaxial
  to ½ height WR2300 waveguide

High performing prototypes



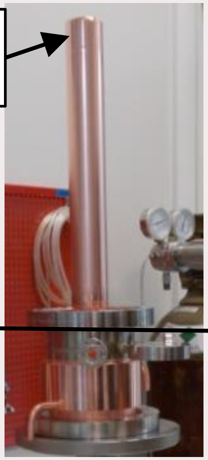
ESS Spoke power couplers

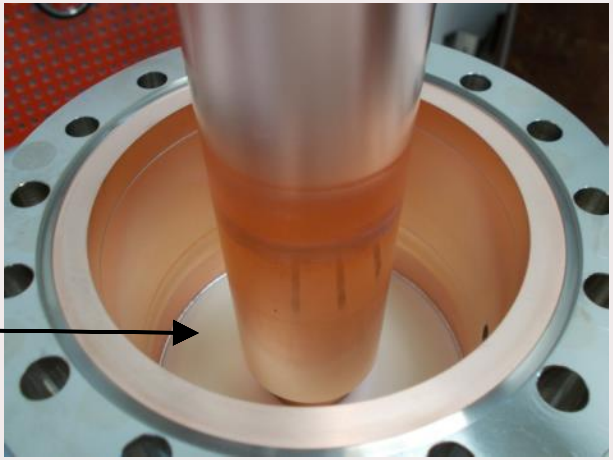
Spoke couplers: 4 prototypes + 2 pre-series fabricated and tested



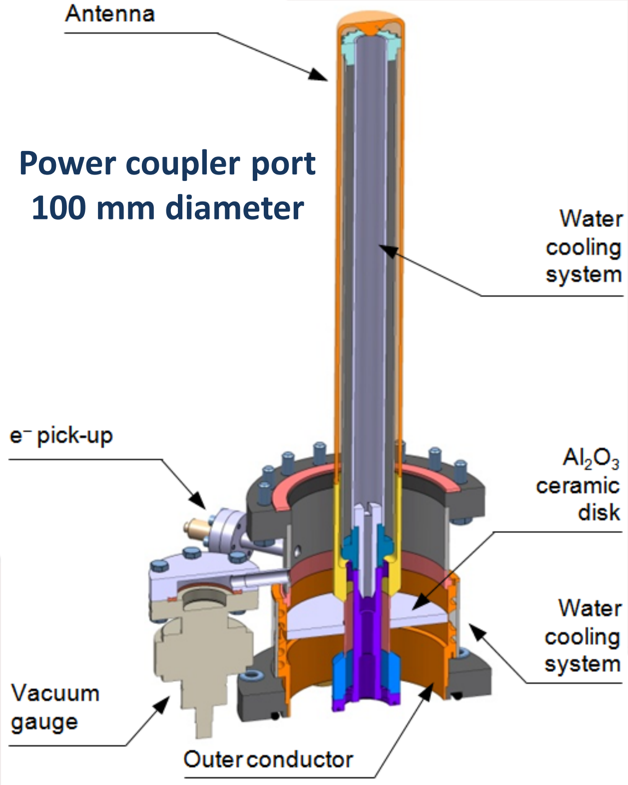
Electropolished antenna

TiN coating

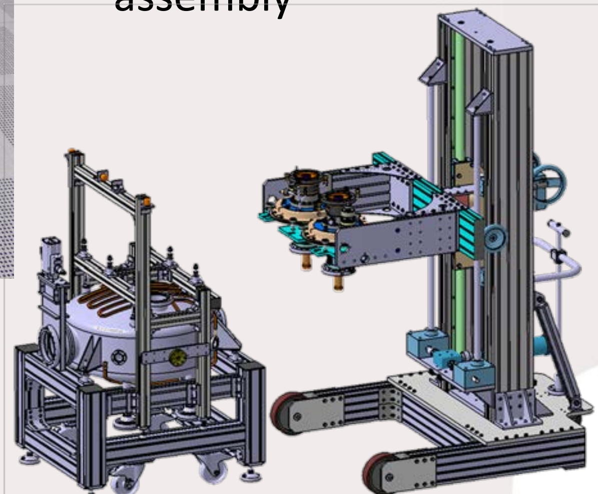




Power coupler port 100 mm diameter



Clean room assembly



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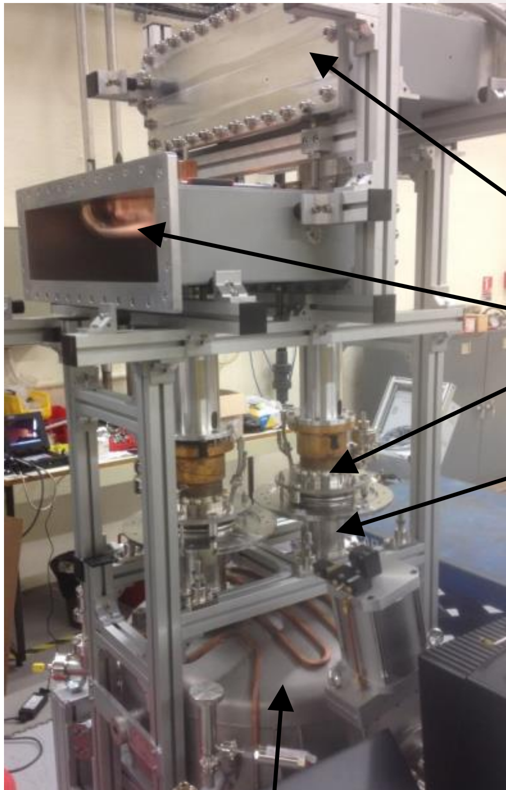


RF couplers conditioning bench

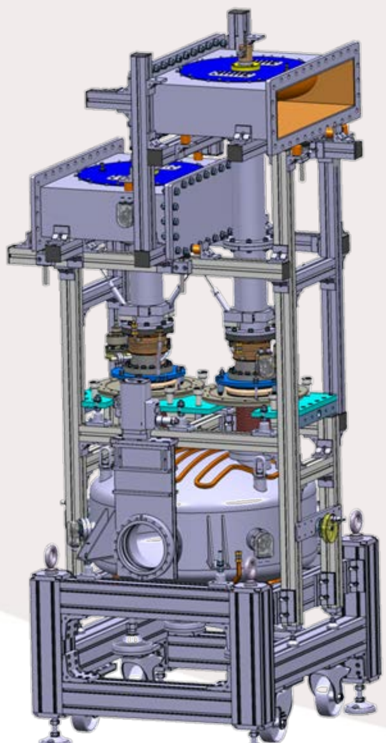
1/2 height WR 2300

Doorknob

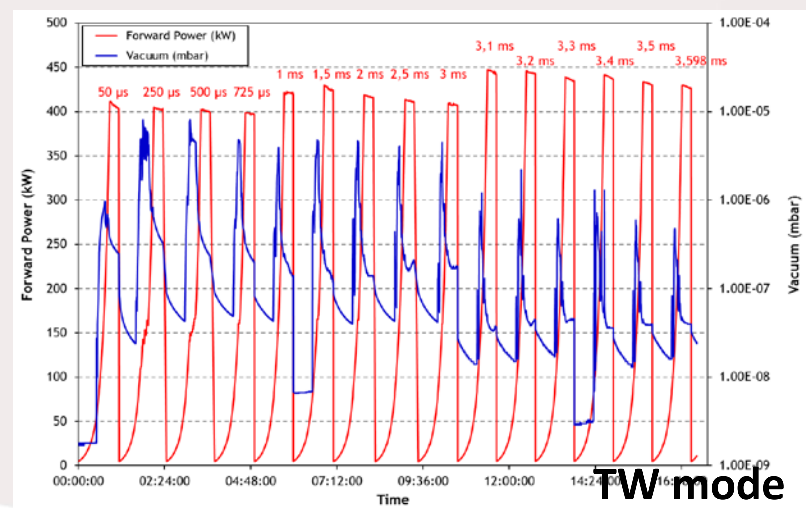
Power coupler window

Double-walled tube

RF conditioning cavity with water cooling loop



Spoke pre-series power coupler successfully conditioned both in standing wave @ 120kW and travelling wave @ 400 kW in fall 2017

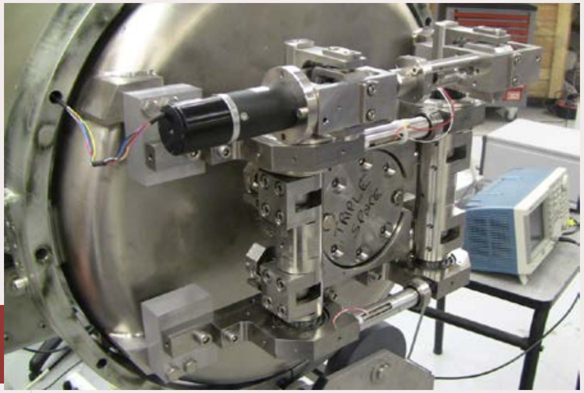


TW mode

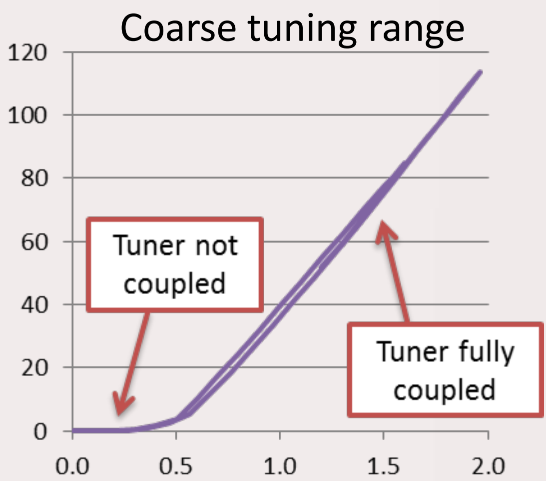
ESS Spoke cold tuning system

Several prototypes tuners fabricated and tested (Cryo, VT)

- With 50 mm piezos length → All specifications reached
- With 90 mm piezos length (purpose: extra margin → Bad performances. Analysis in progress



Cavity ID		ZA01 Romea	ZA02 Giulietta	SD01 Germaine	ZA01 Romea
VT date		janv-15	feb-15	apr-15	juin-15
Piezo #1		Noliac 50 mm	Noliac 50 mm	PI 36 mm	PiezoMec. 90 mm
Piezo #2		Noliac 50 mm	Noliac 50 mm	Noliac 50 mm	PI 90 mm
Tuner sensitivity @2K	kHz/mm	78	88	68	-
Tuner sensitivity @4K	kHz/mm	79	92	73	82
Tuner sensitivity @300K	kHz/mm	-	-	67	-
Cavity sensitivity @300K	kHz/mm	-	-	144	-
Detuning range Piezo #1 @2K	Hz	930	953	542	306 (+/- 120V)
Detuning range Piezo #2 @2K	Hz	680	717	791	0 (issue)
Frequency @4K (w/o tuner)	MHz	352.453	352.123	352.038	352.409
Frequency @2K (w/ tuner)	MHz	352.429	352.100	352.032	352.419
Pressure sensitivity (w/o tuner)	Hz/mbar	25.5	23.3	5.5	-
Pressure sensitivity (w/ tuner)	Hz/mbar	28.8	28.8	14.5	-
Static Lorentz coefficient	Hz/(MV/m²)	-8.5	-6.8	-8.1	-



Cavity detuning (kHz) Vs Motor position (mm) (SD01 cold test)

Series production started for some parts

- Investigation still on-going on some sub-components (ball bearings material, backup disconnection system,…)

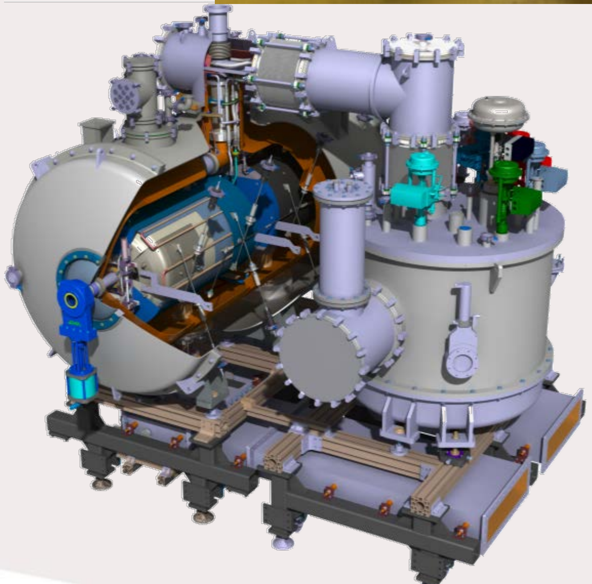
From prototype to series…

Cryo test of the Prototype spoke cryomodule

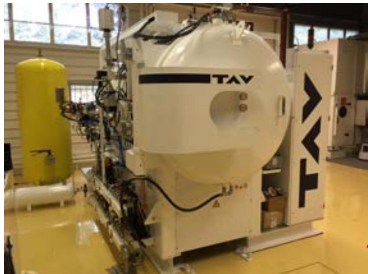
- 2K regulation successful
- Magnetic shielding validated
- Full cryo test @ nominal RF to be performed at Uppsala

Series production has started

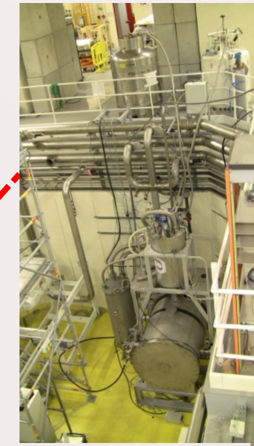
- Niobium production for spoke section completed
- First 4 spoke cavities out of the 30 to be delivered in april and may
- Heat exchangers, cryovalves, stepper motors, T° sensors… ordered and partially received



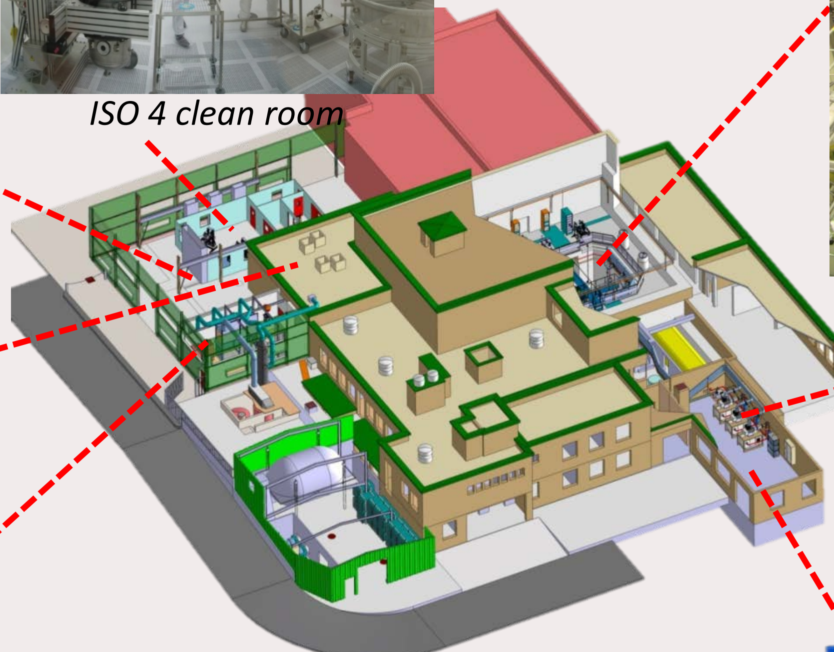
Technological platform SupraTech for SRF


Vacuum furnace


ISO 4 clean room


Cryogenic test hall


Assembly hall




Helium pumping system

352 MHz RF Source


Chemical etching lab


Helium liquefier


Cryogenic temperature sensor calibration station

Experience on power coupler

Clean room: 70 m^2 ISO5 (Class 100)

1.3 GHz RF station 5 MW

LAL Orsay: Recent experience on the production, follow-up, preparation and conditioning of the 800 XFEL power couplers

Potential contribution to PIP II : SSR2

1/ Potential contribution to the engineering design of:

- the cavity
- the power coupler
- the cold tuning system
- the cryomodule (?)

Several questions to understand the extent of the scope of the contribution:

For any of these systems: ***SSR2 functional requirements specification are existing.***

- ***How frozen are they ? (for instance material of the helium tank)***
- ***What is the present status of the SSR2 cavity and ancillaries design ?***
- ***What constraints/required compatibility/standardization with SSR1 ?***
- ***Is there interest for design innovation ? (for instance a tuning system based on a niobium plunger like the one we developed for Spiral-2 QWR)***

Potential contribution to PIP II : SSR2

2/ Potential contribution to the cavity surface preparation procedure set-up

How much this procedure (chemical etching, heat treatments) is already defined and set ?

Need to develop N-doping, infusion ?

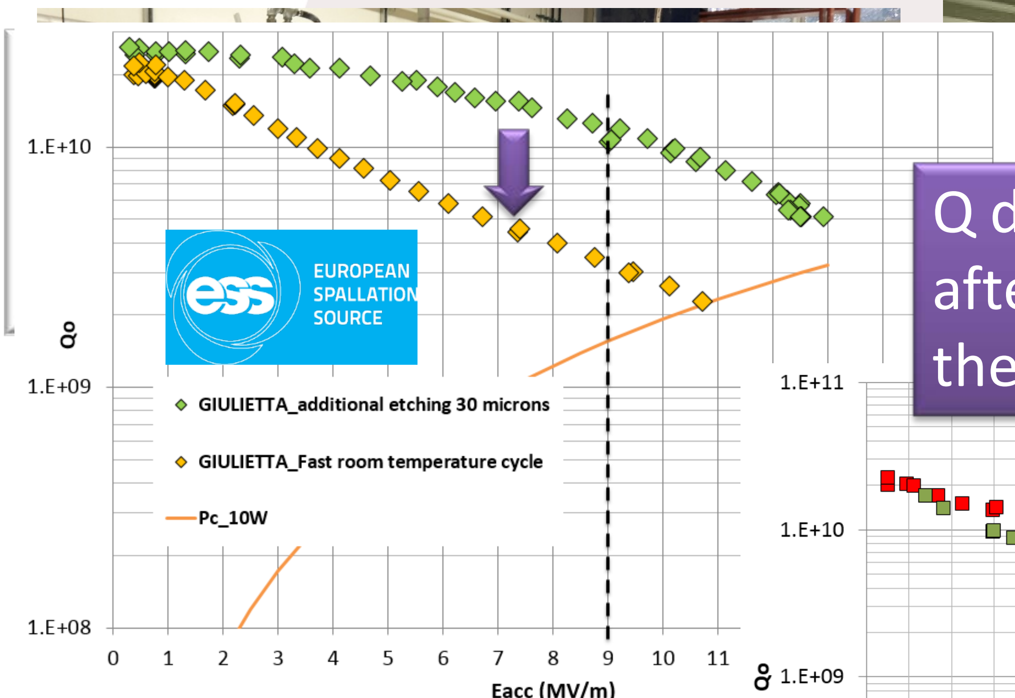
i.e. is there need/room for R&D program on spoke surface preparation ?

We have some recent interesting experience with spoke heat treatment

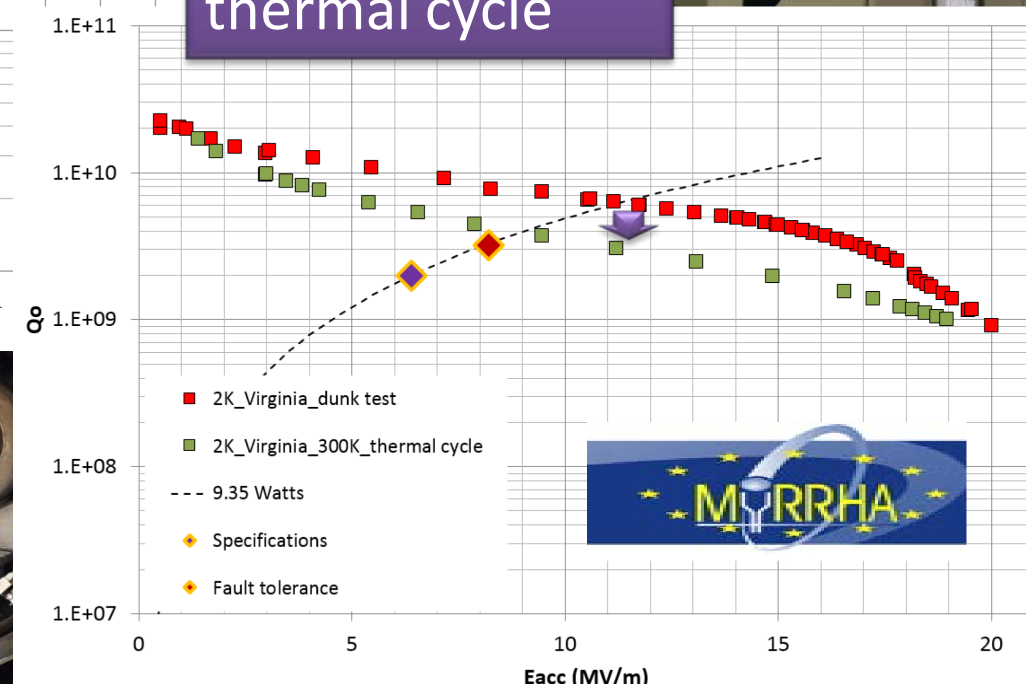
HYDROGEN DEGASSING OF LOW BETA

HEAT TREATMENTS

- **Hydrogen degassing at IPNO :**

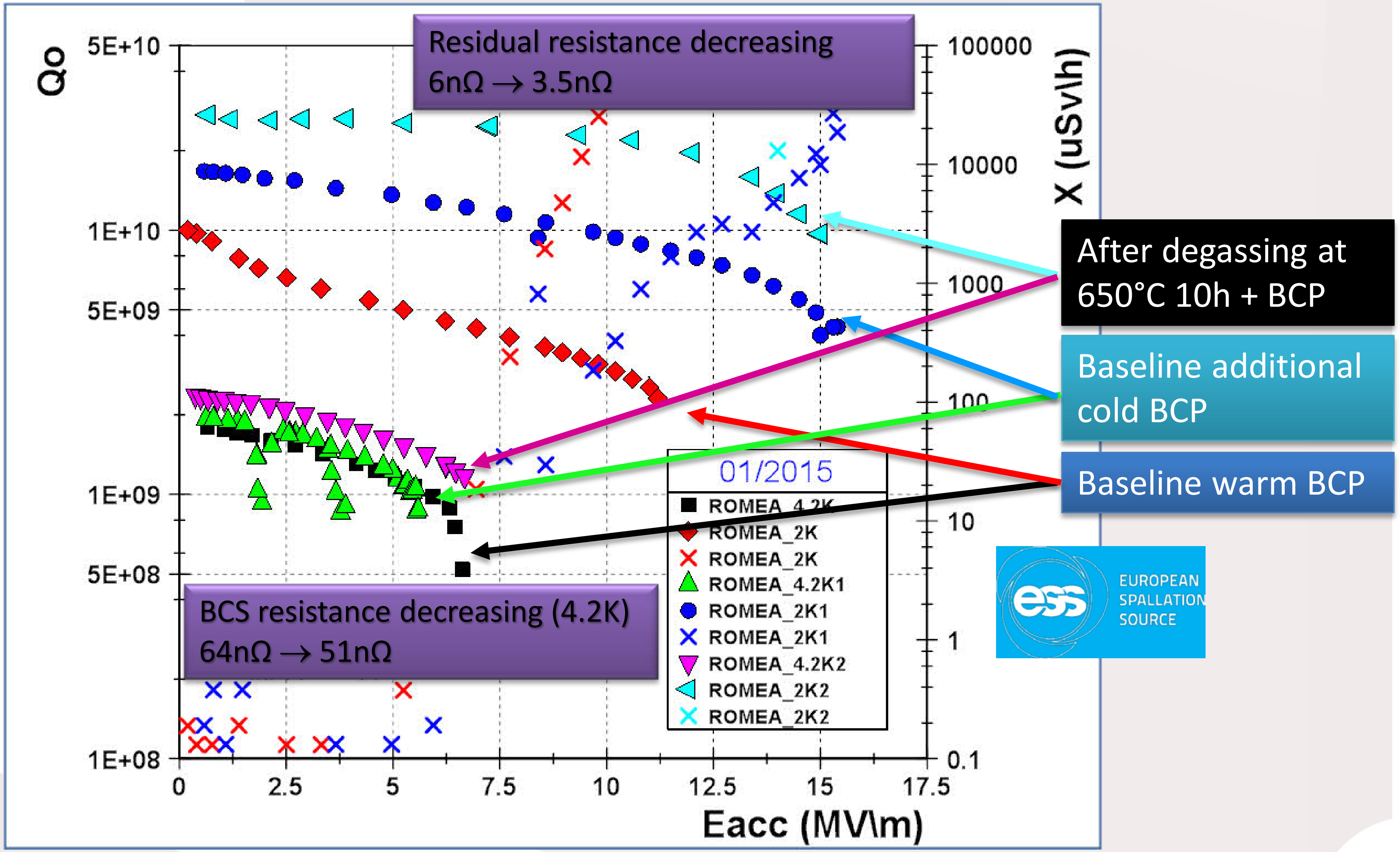


Q degradation after 300K thermal cycle



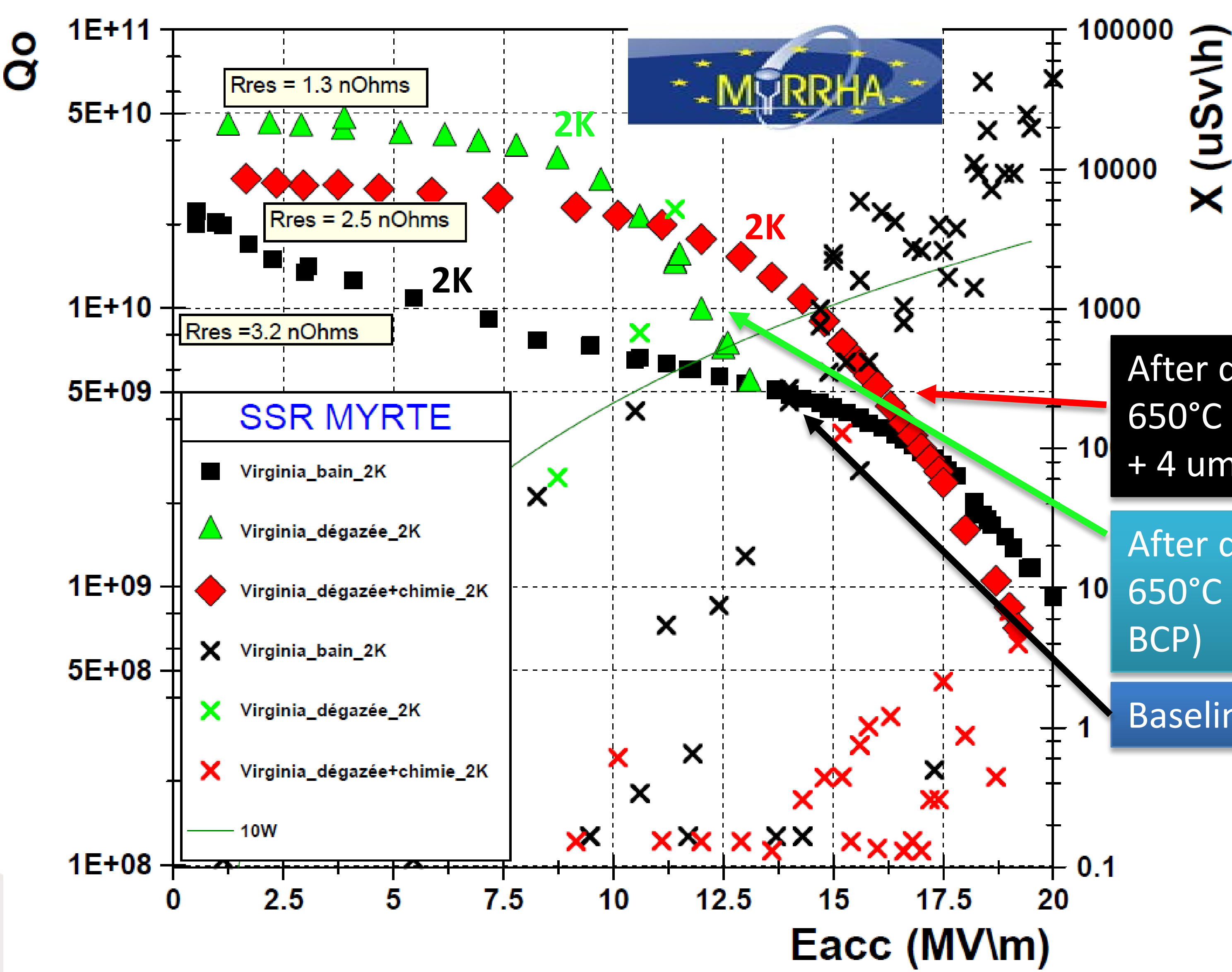
HYDROGEN DEGASSING OF LOW BETA

- **Hydrogen degassing at IPNO :**



HYDROGEN DEGASSING OF LOW BETA

HEAT TREATMENTS



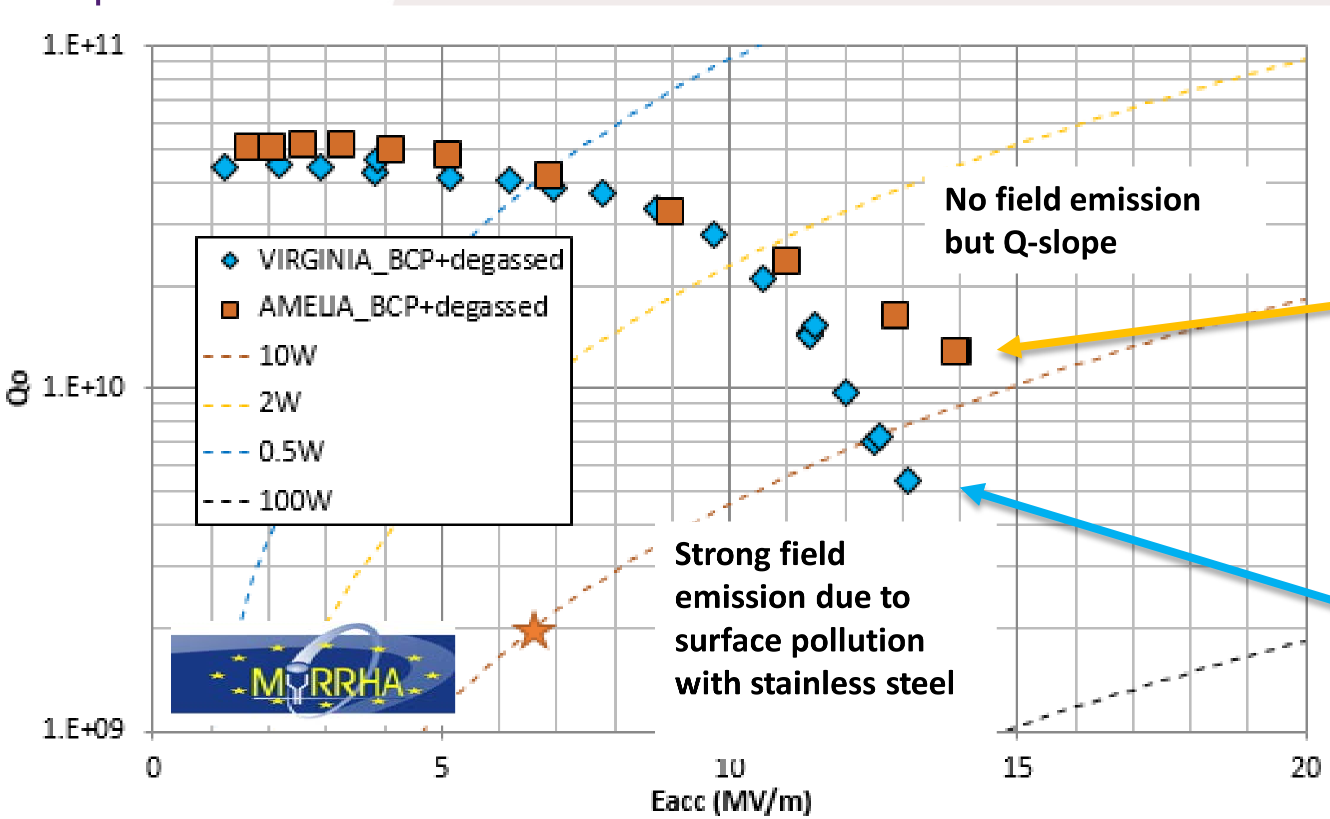
After degassing at 650°C 10h + 4 um BCP

After degassing at 650°C 10h (no post-BCP)

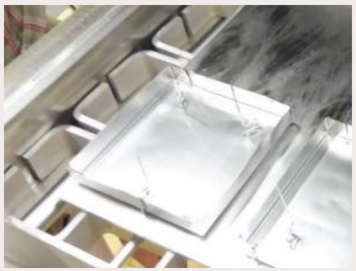
Baseline warm BCP

Comparison good and bad caps

NO BCP treatment after degassing : it works with titanium tank



Niobium caps + Niobium wire



Niobium caps + stainless steel wire

Infusion investigation required

- Baking not efficient to remove HFQS