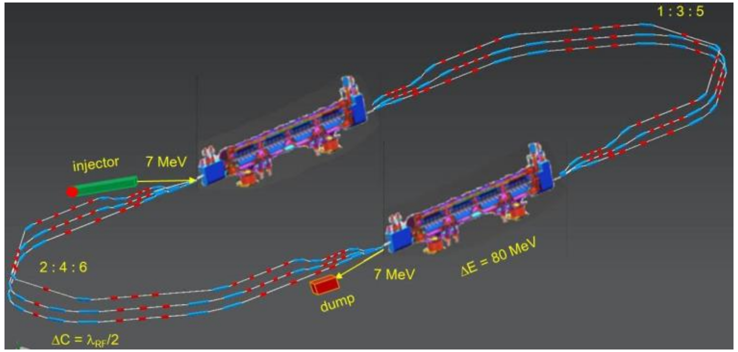
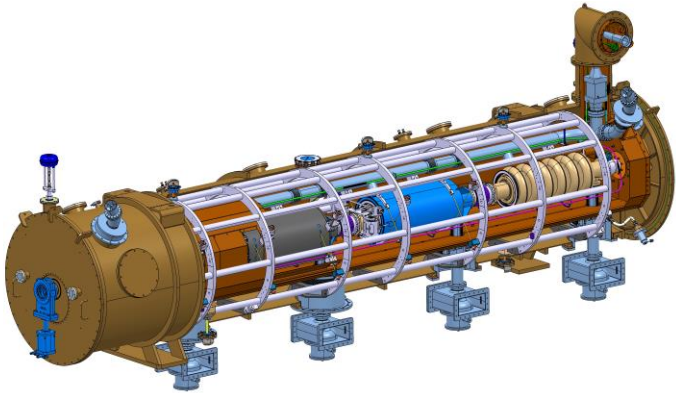
CRYOMODULE FOR PERLE @ ORSAY



PERLE COLLABORATION MEETING
CERN

June 22, 2023



SUMMARY

- Program general considerations
- Genesis of a choice
- ESS elliptical cryomodule presentation
- Components to be reused, modified, not reused
- Cavity, Cold Tuning System & HOM couplers
- Cryogenic and thermal aspects

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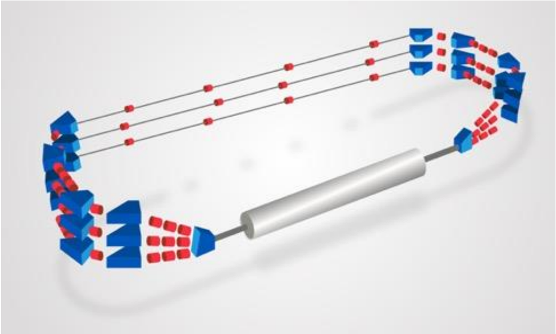
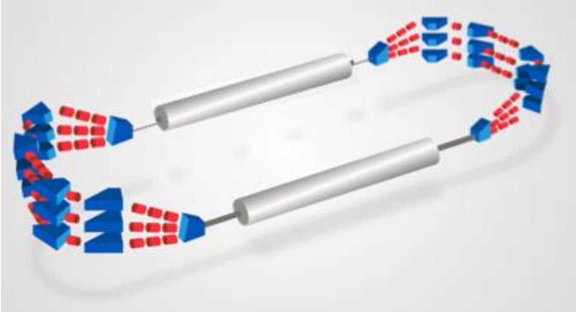
PERLE @ ORSAY
- 5 cells elliptical cavities at 801,58MHz
- 2 cryomodules composed of 4 superconducting cavities

FIRST MILESTONE
- 1 cryomodule prototype
- Complete cryomodule ready for test
- Limited cryogenic plant
- Full RF power on one cavity

SECOND MILESTONE
- Integration of the cryomodule in the PERLE phase 1 layout
- Operation at 250MeV

THIRD MILESTONE
- Integration of the second cryomodule
- Final PERLE layout (phase 2)
- Operation at 500MeV





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DESIGN OF THE CRYOMODULE

WICH DESIGN?

Recently, several projects worldwide have designed cryomodules for elliptical cavities with a cavity configuration (number, length and diameter) which is very close to the one required for PERLE

Design performed at IJCLab.

PROJECT	Number of cavities	Number of cells	Frequency (MHz)	β
PERLE à Orsay	4	5	802	1
ESS	4	6 5	704	0,67 0,85
SPL	4	5	704	1

Design performed at IJCLab & CERN
Some components available

→ Opportunity to reuse the design and the components

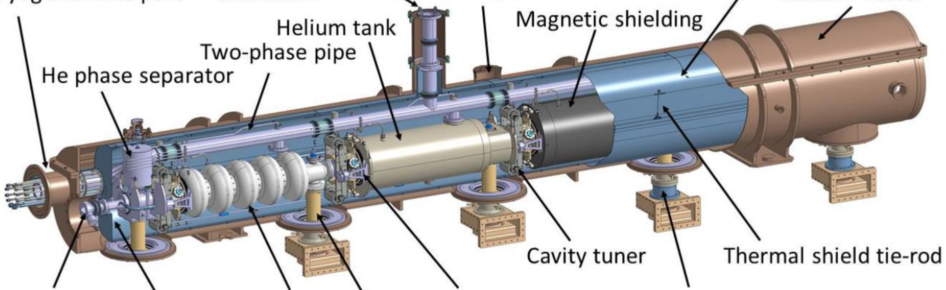
MAIN DIMENSIONAL CHARACTERISTICS OF THE CAVITIES

CHARACTERISTICS	ESS (704MHz)	SPL (704MHz)	PERLE / JLAB (802MHz)
Coupler to coupler length (mm)	1500	1490,5	-
Length flange to flange (mm)	1258,8 (Mβ) / 1316,3 (Hβ)	1397,3	1292,5
Coupler to flange dimension (mm)	115 (Mβ) / 130 (Hβ)	116,4	96,7
Cells external diameter (mm)	378,9 (Mβ) / 385,7 (Hβ)	386,5	335
Beam port internal diameter (mm)	135,8 (Mβ) / 139,8 (Hβ)	129,8 / 139,8 (coupler side)	130
Flanges internal diameter (mm)	135,8 (Mβ) / 139,8 (Hβ)	79,7 (CF100)	130 (CF160)
Vacuum valve diameter	CF100	CF63	tbd
Coupler internal diameter (mm)	100	100	100
Coupler flange	D100	CF100	CF100
Beam axis to ext. coupler flange	374,25	403	tbd

→ **SIMILAR FEATURES**

POTENTIAL REUSE OF THE SPL/HG CRYOMODULE DESIGN AND COMPONENTS

CERN proposed to re-use the existing SPL short cryomodule prototype either as it is or replacing the 704 MHz cavities by the perle referenced 802 MHz cavities



- Design of the cryomodule performed by IPNO and updated by CERN.
- Vacuum vessel and parts of cryogenic lines (not welded) delivered.

2 innovative points:

- the cavity string directly supported by the power coupler and with dedicated inter-cavity support features.
- integrates a full length demountable top lid, enabling the cavity string assembly from the cryomodule top

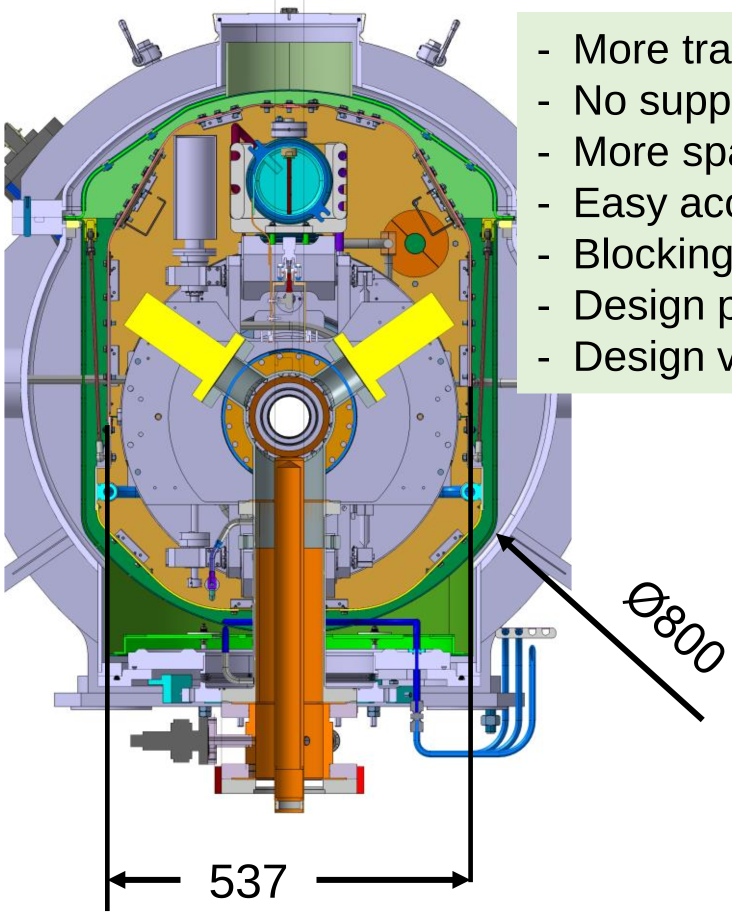
POTENTIAL REUSE OF THE SPL/HG CRYOMODULE DESIGN AND COMPONENTS

MAIN ISSUES

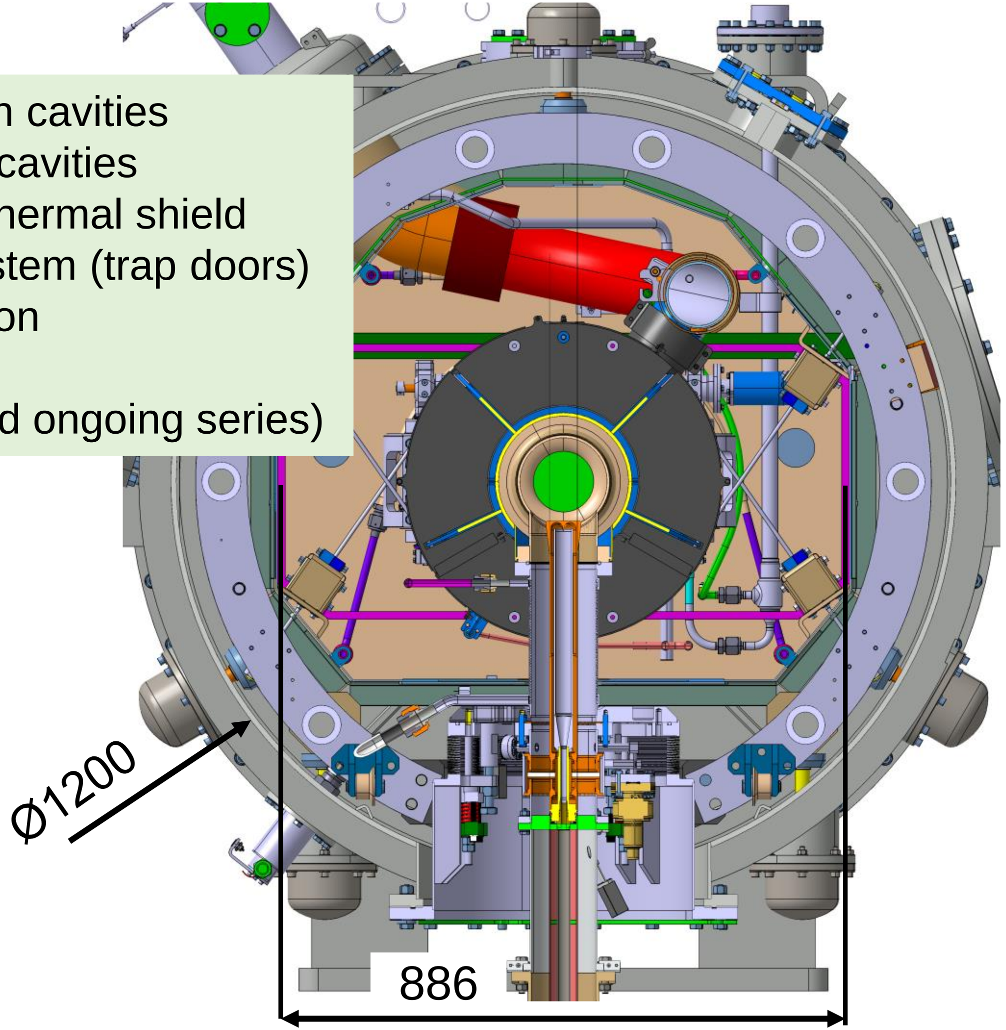
- Beam vacuum valve not compatible with beam vacuum (vatterfly valve instead of all metal gate valve)
- Second bursting disk needed
- Internal space very crowded. Difficulties to find additional space for HOM couplers and their cooling
- Cryogenic lines to be adapted. Potentially important refurbishing for HOM active cooling
- Uneasy access to cold tuning system (top cover to be removed)
- New cover needed (second bursting disk, new feedthroughs and instrumentation for HOM, connection to valve box?)
- Is the valve box location compatible with beam spreaders?

→ Reuse of the SPL cryomodule very difficult
Heavy constraints from the beginning, inducing bad compromises

2nd OPTION: ESS CRYOMODULE (ELLIPTICAL CAVITIES)



- More transversal space between cavities
- No supporting system between cavities
- More space between tank and thermal shield
- Easy access to Cold Tuning System (trap doors)
- Blocking system for transportation
- Design performed at IJCLab
- Design validated (prototypes and ongoing series)



ESS CRYOMODULE FOR ELLIPTICAL CAVITIES

- CEA in charge of the In-kind contribution for medium and high beta section (elliptical cavities)
- Design of the cryomodule (common for Mβ and Hβ) by IJCLab (excepted cavities string)
- Components of the Mβ prototype purchased and delivered by IJCLab
- Assembled and tested at CEA Saclay
- Tested at ESS Lund

ESS has agreed to provide the cryomodule components to IJCLab for its first Perle cryomodule

ESS prototype cryomodule in LUND test stand

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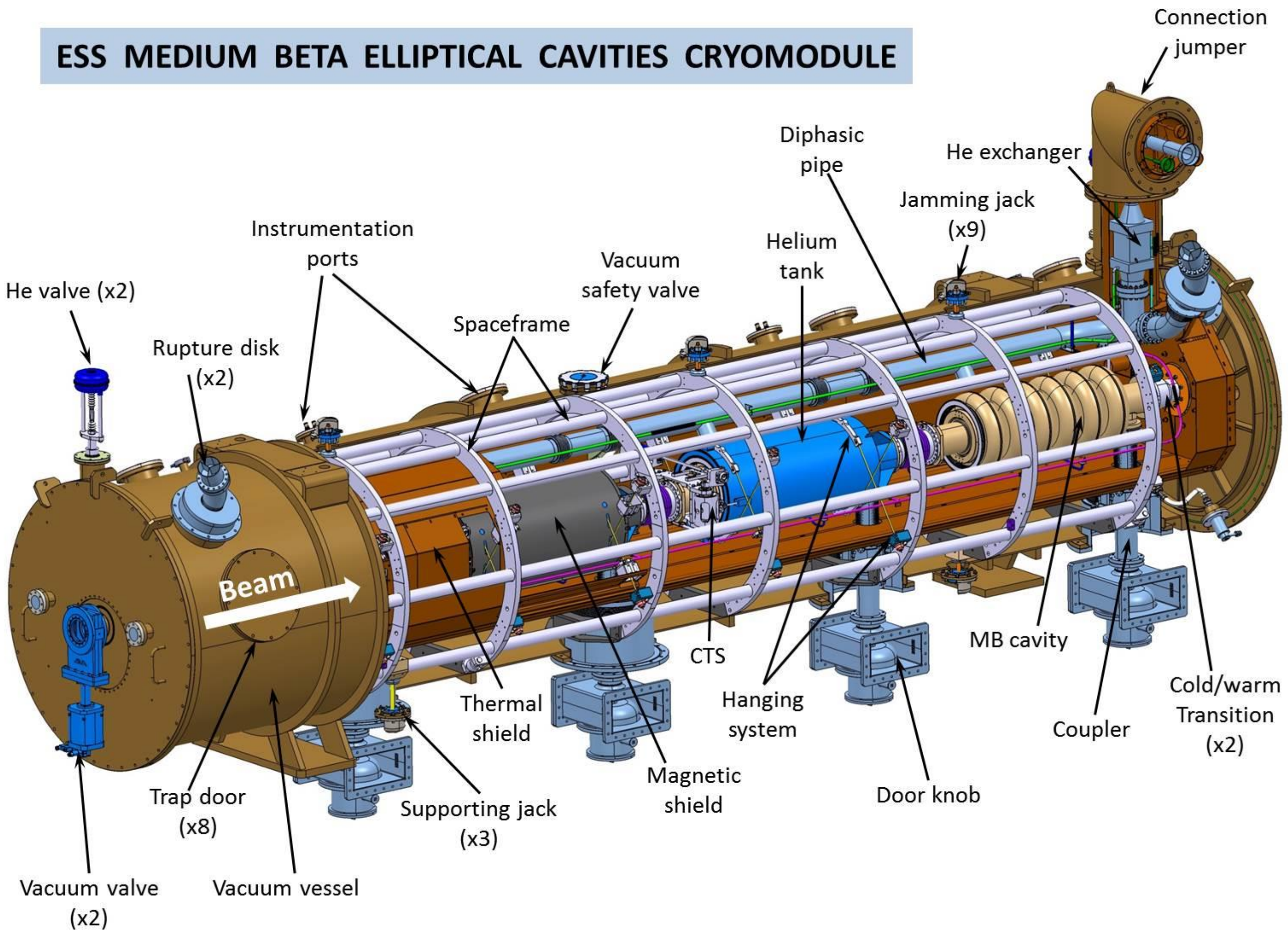
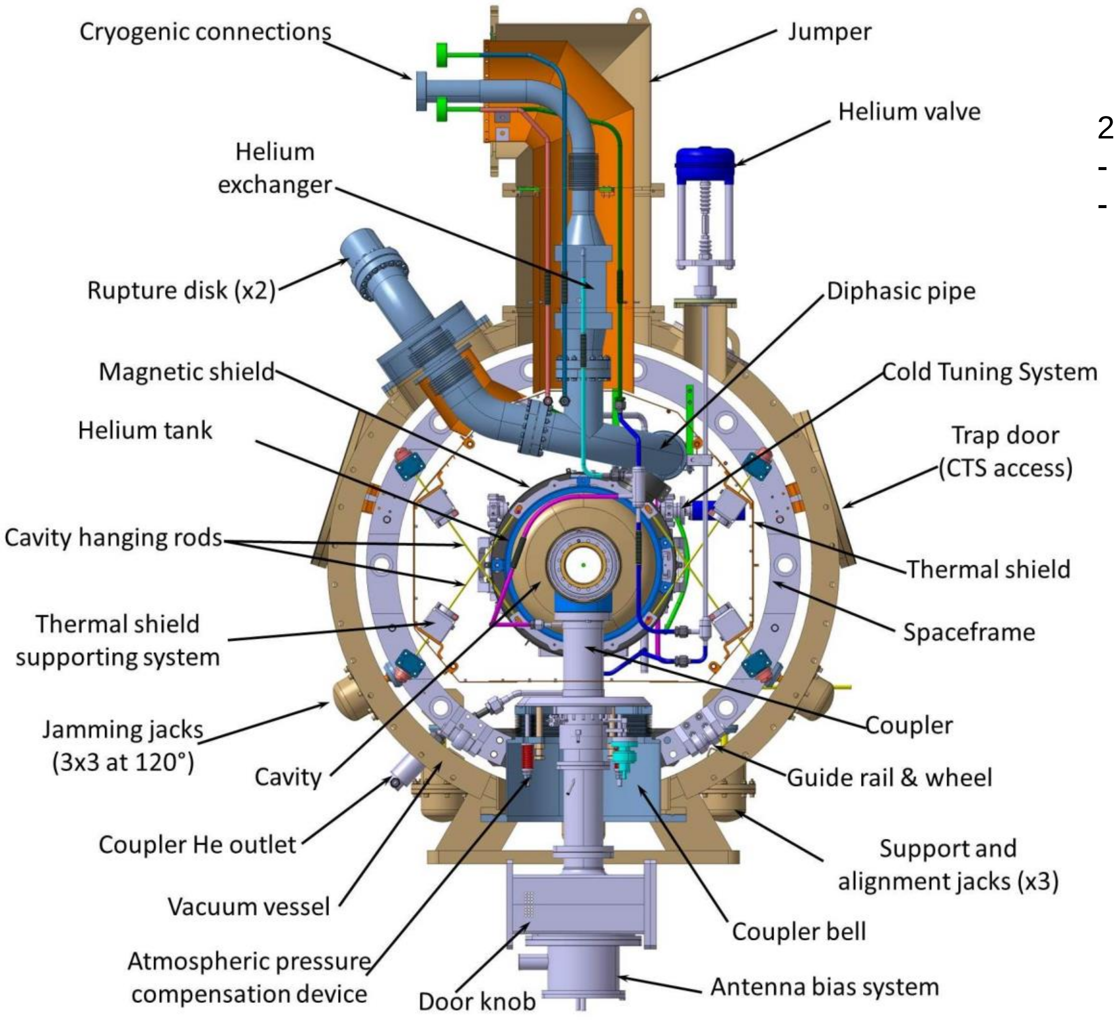
ESS CRYOMODULE FOR ELLIPTICAL CAVITIES

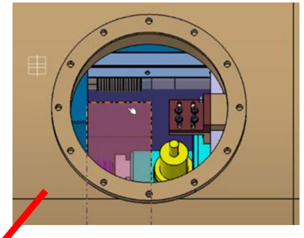


ESS CRYOMODULE FOR ELLIPTICAL CAVITIES

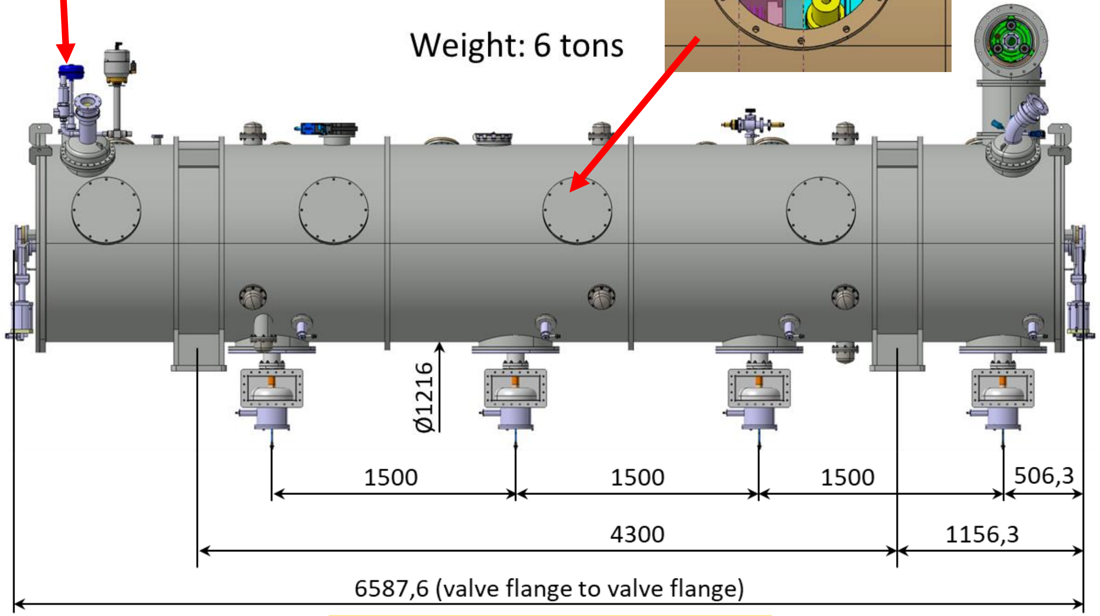


2 helium valve inside the cryomodule:
- JT valve
- Cooling down

- Access to CTS
- Blocking of cavities, spaceframe & thermal shield for transportation



Weight: 6 tons

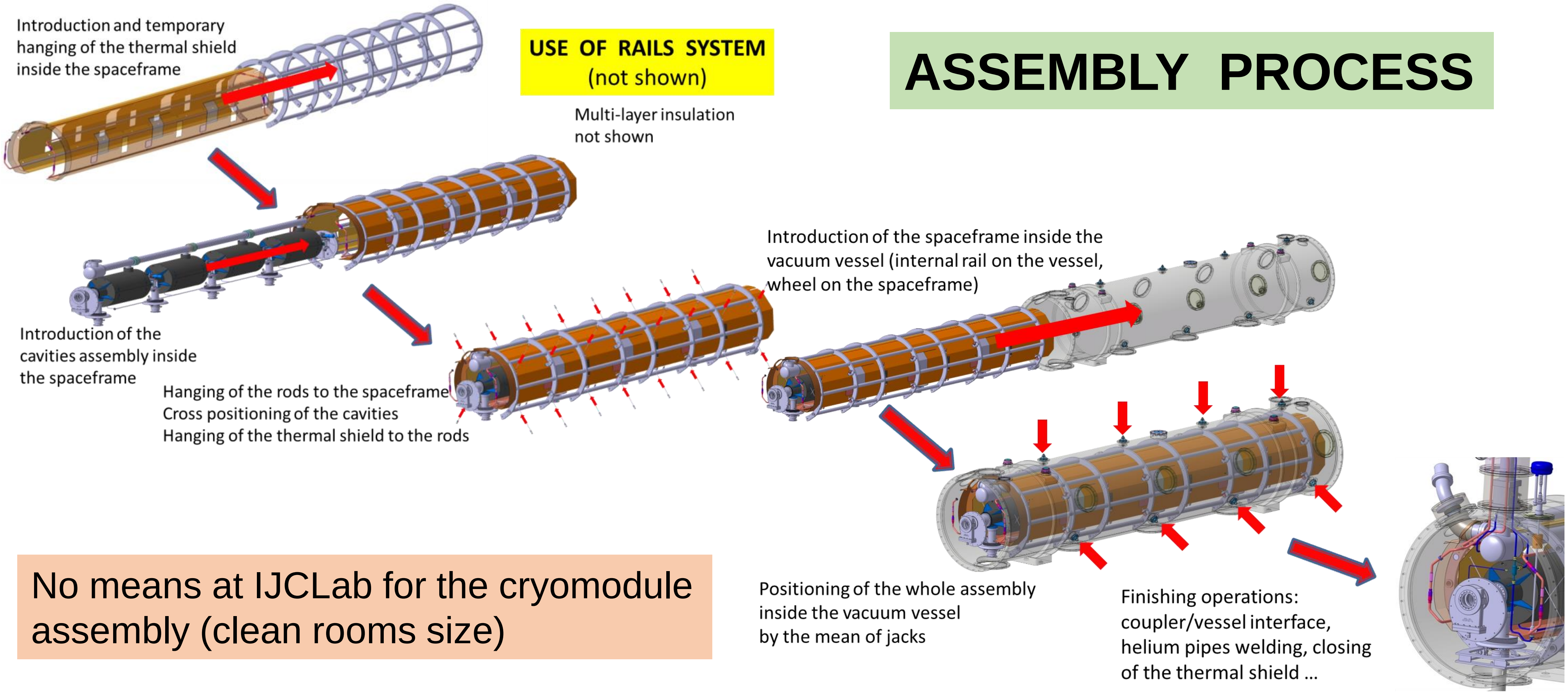


Main dimensions

ESS CRYOMODULE FOR ELLIPTICAL CAVITIES

ASSEMBLY PROCESS

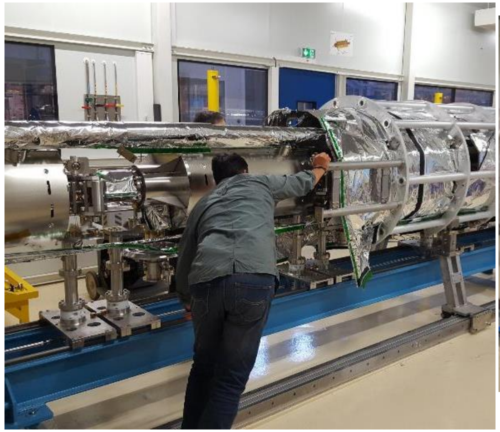
USE OF RAILS SYSTEM
(not shown)

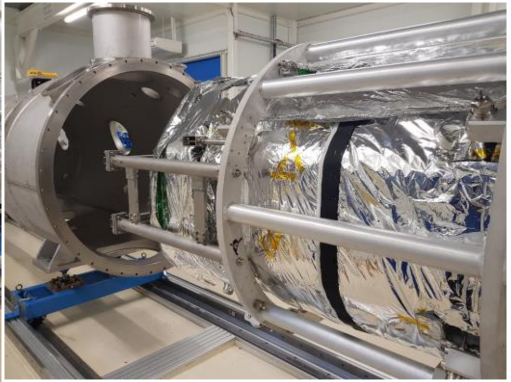


No means at IJCLab for the cryomodule assembly (clean rooms size)

ESS CRYOMODULE FOR ELLIPTICAL CAVITIES

2017-2018



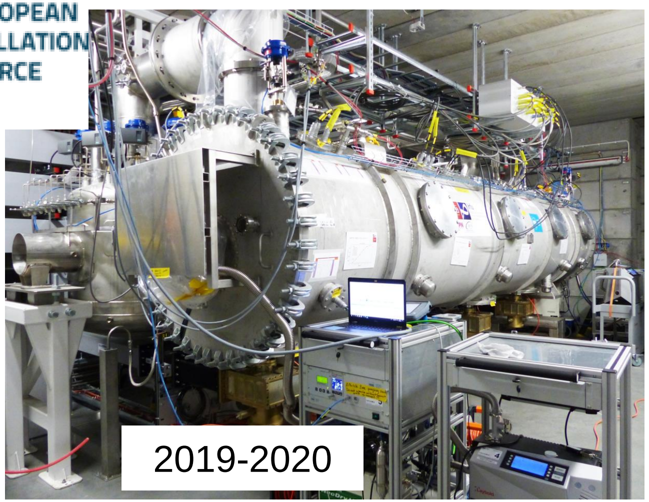


Irfu

cea

2018

ess EUROPEAN SPALLATION SOURCE



2019-2020

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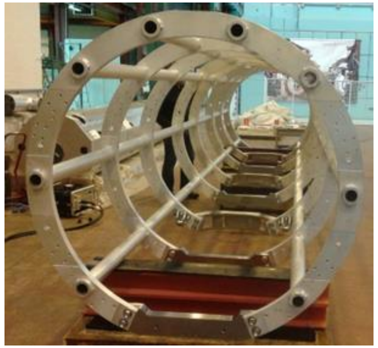
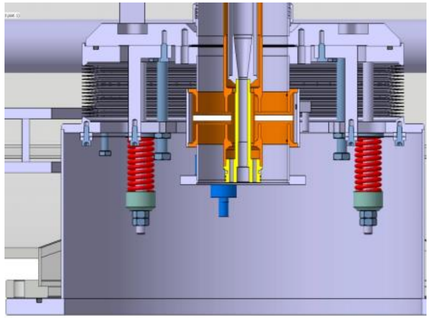
COMPONENTS TO BE REUSED

Vacuum vessel



Spaceframe

Thermal shield



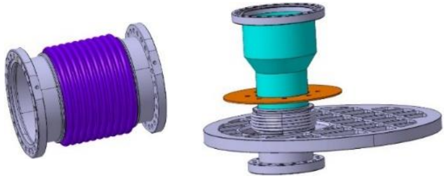
Coupler « bell » & Patm compensation (x4)

And also:
- 2 UHV all metal gate valves (???)
- 2 helium valves
- Angle vacuum valves
- Thermal shield multi layer insulation + parts of cold mass
- Instrumentation (temperature gauges, level gauges, pressure gauges)
- Wiring and connectors

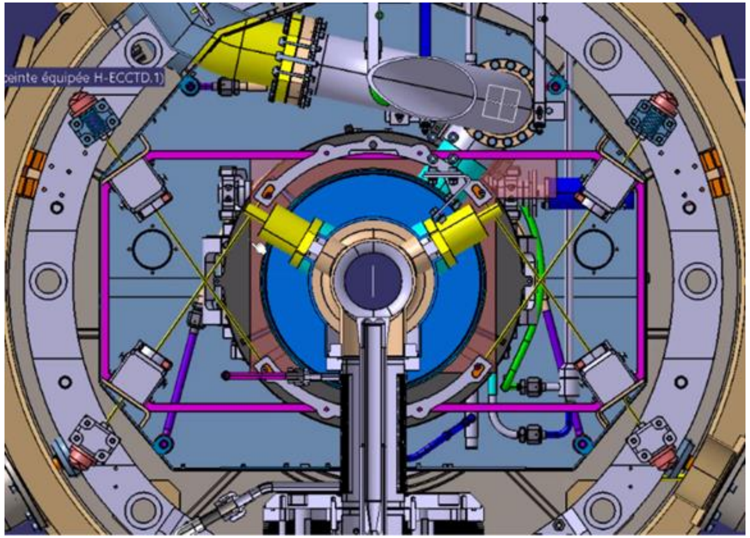
Pressure safety devices:
- Bursting disks (x2)
- Controlled valve
- Safety valve

COMPONENTS NOT REUSED OR MODIFIED

Magnetic shield
(not reused)



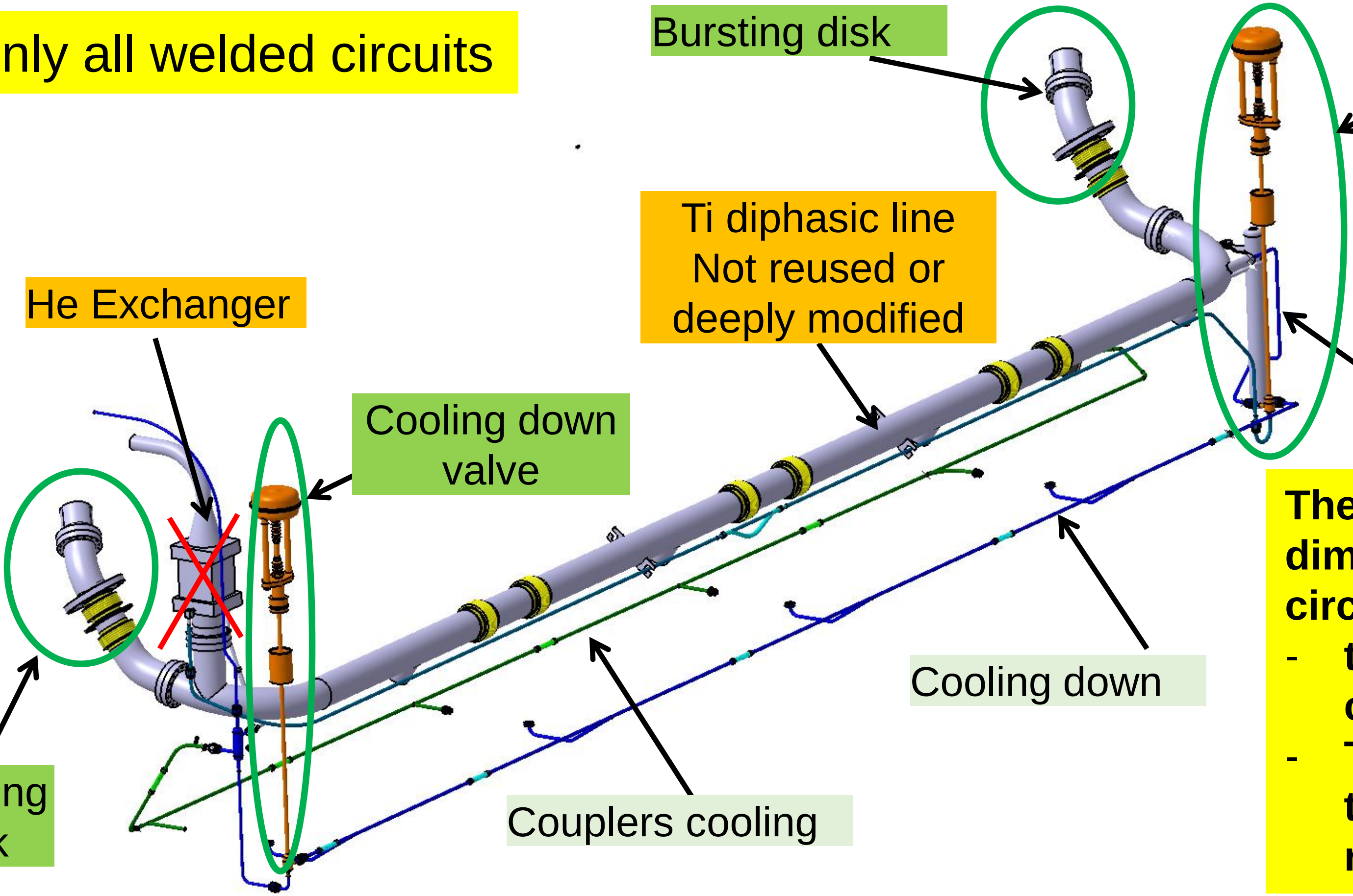
Inter cavities bellows
& Cold/warm transitions
(not reused)



Supporting system to be adapted to Perle cavity.
Perle tank diameter < ESS diameter

CRYOGENIC LINES

Mainly all welded circuits



The configuration and the dimensioning of the Cryogenic circuits strongly depends on:

- **the characteristics of the HOM couplers cooling**
- **The power to be dissipated by the low pressure circuit (see related slide)**

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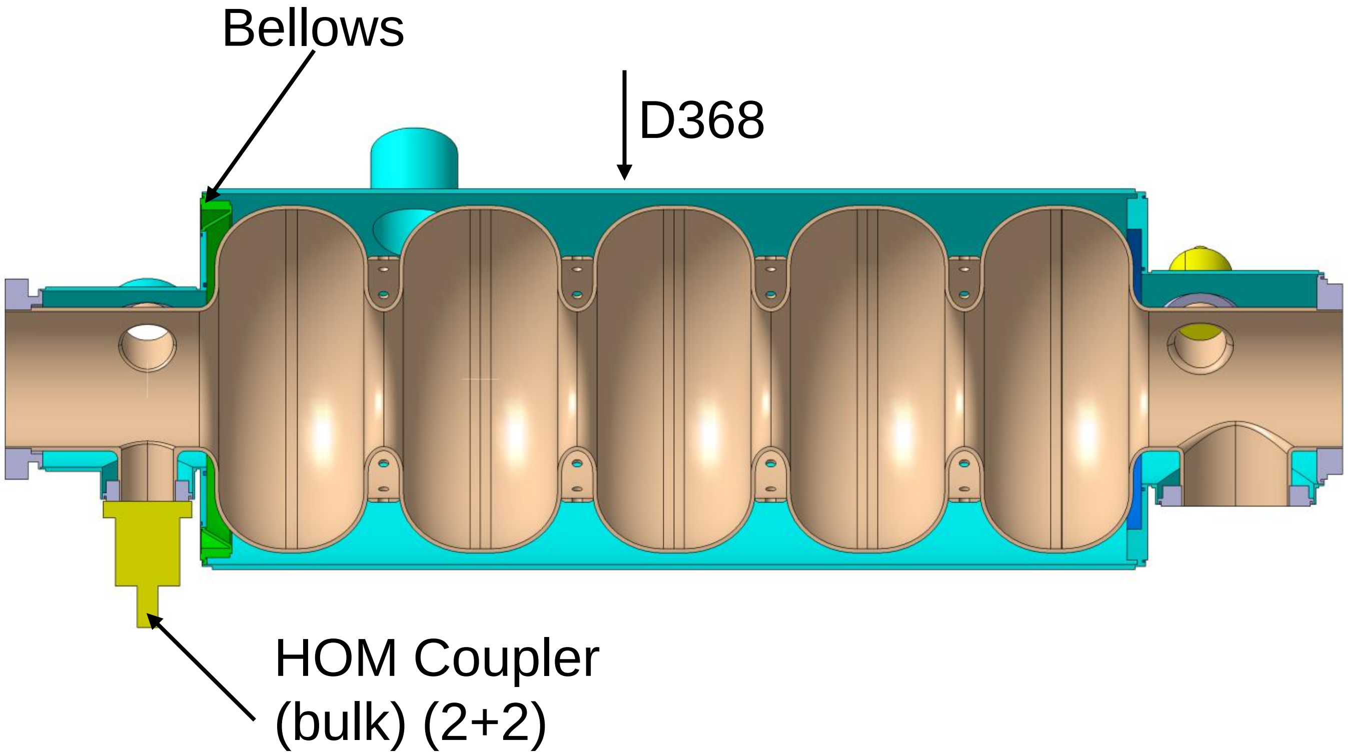
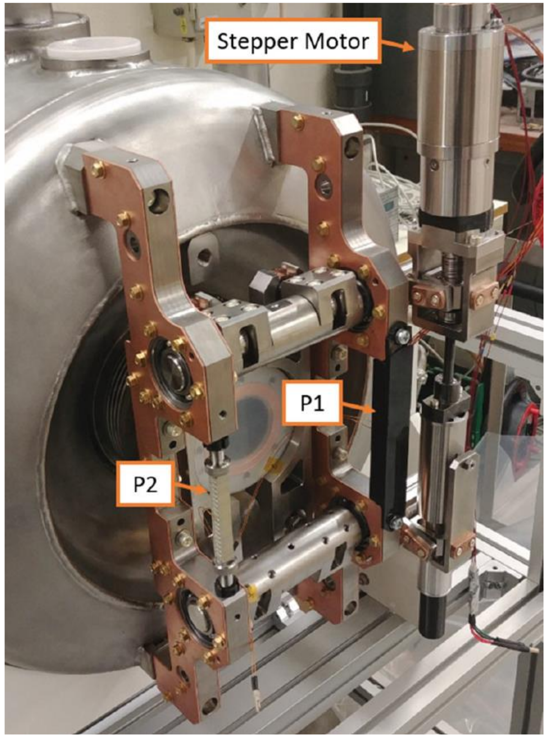
CAVITY

- First draft
- Design Jlab
- 2+2 HOM couplers
- HOM coupler basis cooled by Lhe
- Compatibility with ESS Cryomodule: positions of main coupler & helium ports, link to the supporting system…



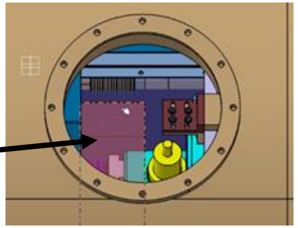


Tuner for:
- ESS double spoke
- Myrrha single spoke

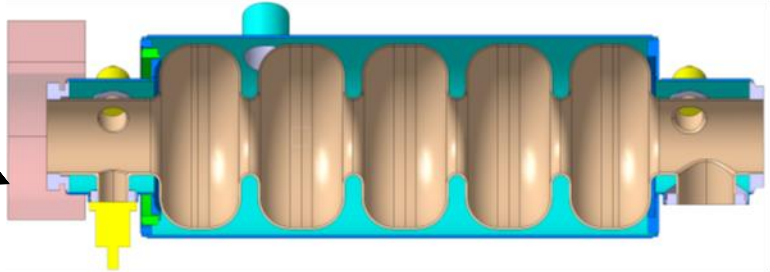
- Compact design
- Allows enough space for HOM couplers
- Moved back from the helium tank
- Need of adaptation for flange and tank interfaces
- Need of adaptation for bigger beam pipe
- Pay attention to the overall stiffness
- Designed, tested and validated at IJCLab

Cavity	Type	Fréquency (MHz)	Stiffness (KN/mm)	Sensitivity (KHz/mm)
Myrrha	Simple spoke	352,21	16	181
ESS	Double spoke	352,21	20	135
ESS medium beta	Elliptical (6 cells)	704,42	1,3 (theor.) to 1,6	215
ESS high beta	Elliptical (5 cells)	704,42	2,82 (théor.) to 3,54	197

Easy access via the trap doors

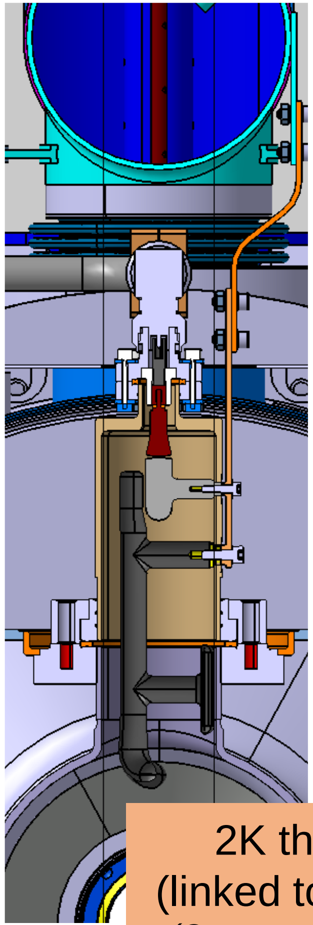


Maximum bulk of the tuner



HOM POWER EXTRACTION / DISSIPATION

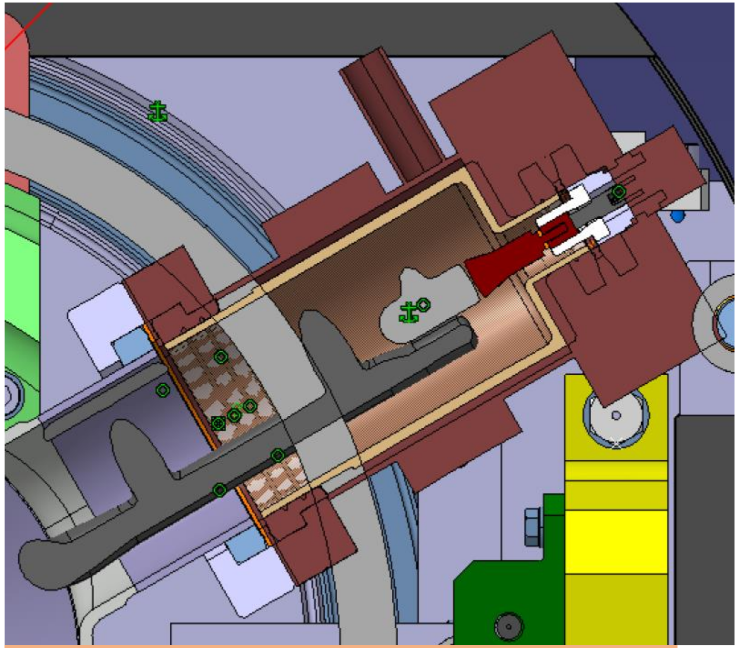
- Tens of Watt to be extracted.
- RF losses (<10mW @ 2K) on the coupler port (antenna & cylinder)
- What about HOM power not extracted (beam pipe absorbers)?



2K thermalization
(linked to diphasic pipe)
(Courtesy of CERN/HG team)

Thermal loads due to RF cable:
- Static conduction through the RF cable
- Dynamic loads in the RF cable
- Intermediate thermalizations needed à 2 & 50K
- RF coax cable thermal behaviour to be analysed.

Cooling possibilities:
- Thermalization 2/4K of the antenna
- Thermalization 2/4K of the coupler sleeve
- Active cooling 2/4K of the antenna
- Active cooling 2/4K of the coupler sleeve



Loop coupling with active cooling
(Courtesy of CERN/HG team)

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HEAT LOSSES FOR CRYOGENIC LINES

ESS medium beta Heat balance

	Calculated: Medium beta, 50K Stat.	50K Dyn.	2-5K Stat.	2-5K Dyn.	Measured MB cryom.
Cavity string					
Beam losses (0.5W/m)				3.25	
RF losses				20	24 to 40
Radiations (14m²)			0.7 (HB: 24,4)		
Cold to warm transition (x2)	3		2		
Supporting system	6		0.25		
Helium piping					
Supporting system	0.2		0.4		
Bursting disks (x2)	3		0.15		
Helium valves (x2)	1		0.2		
Safety relief valves (x2)	0.03		0.03		
Thermal shield radiations (21m²)	31.5				70 to 80
Couplers (x4)					
Sleeve cooling (4*23 mg SHe at 5K)			4	(4)	
Radiation from antenna to cavity			2.8		
Instrumentation, heaters and actuators	1.5		2.7		
TOTAL Static load	46.23		13.23		16 to 20
TOTAL Dynamic load				23.25	
TOTAL	46.5		(HB: 27,65) 37 (HB: 41)		

Static & Dynamic 2/4K heat loads for 4 cavities

CIRCUIT	Heat load ESS Ell. (W)	Heat load PERLE (W)
RF losses	40	260 (Q0 1.E+10)
Beam losses	3,25	??
HOM ports		10 mW à 2K
HOM beam pipes		20/40 W
Static losses	20	20

Preliminary estimate

Heavy figures for helium consumption at 2K.
Dimensioning of the low pressure circuit to be assessed

THANK YOU FOR YOUR ATTENTION