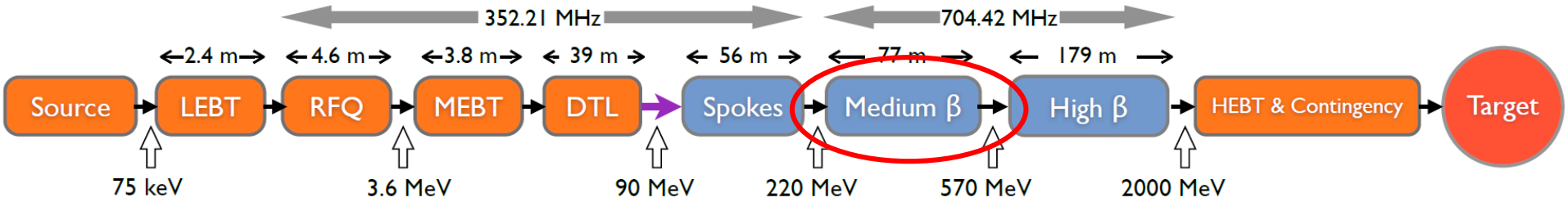
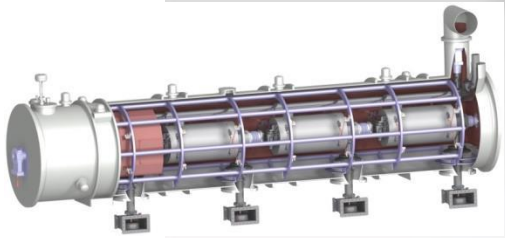
Main Requirements of the Medium Beta Elliptical Cavities Cryomodules

Pierre BOSLAND, CEA Saclay
External WP5 leader

CDRM-1
April , 2017

WP5: Elliptical Cryomodules





	MEDIUM-β	HIGH-β
β	0.67	0.86
# CM	9	21
Cav. /CM	4	4
# Cav.	36	84
CM L [m]	6.584	6.584
Sector L [m]	77	179

CDRM-1 is a milestone for the M-ECCTD

Objective: agreement on the procurement plan of components of the series

CONTEXT OF THE ACTIVITIES ON THE ELLIPTICAL CRYOMODULES

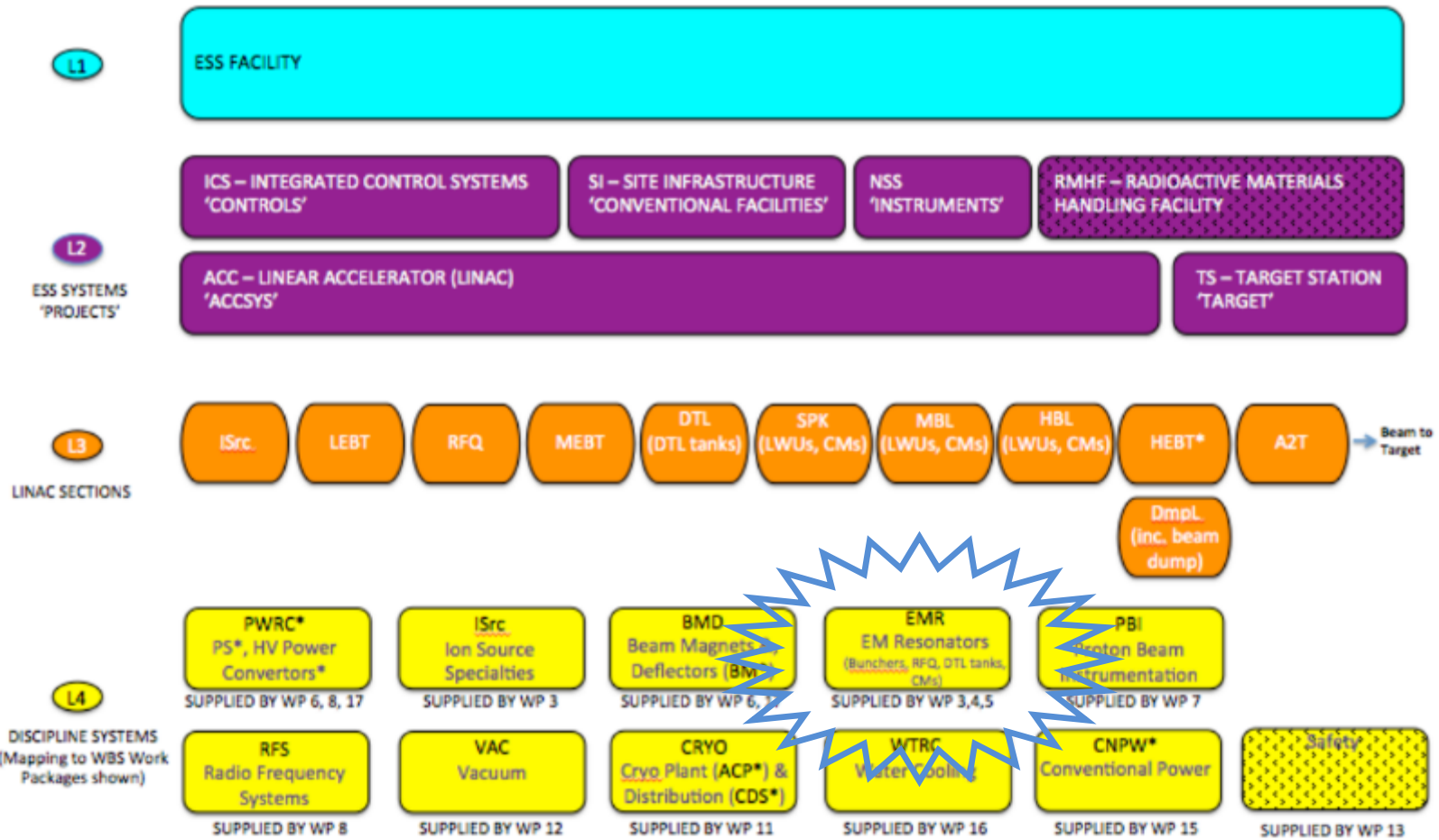
General context presented by Franck

Scope of the project at CEA Saclay

Context of the In Kind Contribution of CEA for the ESS Accelerator

The Fr-Sw Agreement and IKC Schedules

ESS requirements distribution in 4 levels



Level 4 requirements for the cryomodules

DOORS (Dynamic Object-Oriented Requirements System)
Tool for the management of requirements.

Allow a dynamic update of the requirements
⇒ Need of fixed tables of requirements before the contract signature
⇒ 2 documents have been referenced on the CHESS data base:

1. **ESS-0041762 Elliptical Cavity Cryomodule Requirements, 13 Oct 2015, Rev 1, State Released** (Requirements for each of the medium and high beta cryomodules)
2. **ESS-0041759 Elliptical Cavity Cryomodule Interfaces Requirements, 13 Oct 2015, Rev 1, State Released** (Interfaces requirements with the adjacent WP)

Status of the Elliptical Cryomodule Requirements

ESS-0041762 Elliptical Cavity Cryomodule Requirements, 13 Oct 2015, Rev 1, State Released

Description	
Document Number	ESS-0041762
Date	13 October 2015

TABLE 1: MEDIUM-BETA ELLIPTICAL CAVITY CRYOMODULE REQUIREMENTS

DWA ID	Name	Primary Text	Clarification	Units	Min.	Nominal	Max.	Status
MBL_EMR-49	Resonant Frequency	The nominal resonant frequency of each medium beta elliptical cavity shall be 704.42 MHz.	The resonant frequency is defined as that for the cavity installed in the cryomodule, at the nominal operation temperature, with no RF or beam fields present, and within the operating range of the tuner.	MHz		704,42		ACPTD
MBL_EMR-79	Accelerating mode tuning: Lower extreme	The lower limit of the tuning range of the frequency of the accelerating mode shall be less than or equal to 704.37 MHz	That is, the tuning system shall be capable of setting the resonant frequency of the cavity to a value >=50 kHz below the nominal accelerating frequency	MHz			704,37	ACPTD
MBL_EMR-80	Accelerating mode tuning: Upper extreme	The upper limit of the tuning range of the frequency of the accelerating mode shall be greater than or equal to 704.47 MHz	That is, the tuning system shall be capable of setting the resonant frequency of the cavity to a value >=50 kHz above the nominal accelerating frequency	MHz	704,47			ACPTD
MBL_EMR-50	Number of Cavities per Cryomodule	The number of cavities per cryomodule shall be 4.	This value shall be referred to in other documentation by the symbol, n_cav.	Quantity		4		ACPTD
MBL_EMR-51	Cavity type - geometrical	Each cavity shall be a series of elliptical cells coupled via their beam pipes	I.e., so-called multi-cell elliptical cavities					ACPTD
MBL_EMR-52	Cell count	The number of cells in each cavity shall be 6.		Quantity		6		ACPTD
MBL_EMR-53	Accelerating mode type	The accelerating mode shall be the pi-mode of the first monopole passband						ACPTD

List of 37 requirements for the Mbeta cryomodules

- **35 in status Accepted**
- **2 in status TBC**

(But can be quickly updated in status Accepted: max volume of the LHe tank of cavities = 48l, and value of the minimum field flatness 93%)

Status of the Elliptical Cryomodule Requirements

Selected main requirements for M beta cryomodules:

Frequency:	704,42 MHz
Nb superconducting cavities at 2K :	6 cell at β_{geo} =0,67
Maximum accelerating gradients Eacc:	45MV/m peak field (corresponding to Eacc max 19MV/m) Eacc nominal = 16,7MV/m
Max RF power dissipation at nominal gradient corresponding to Q_0=5 10^9 (Cryo. duty cycle: 4,7%):	4,9W
Maximum RF peak power:	1,1MW
No HOM coupler:	*All higher order modes (HOMs) shall be at least 5 MHz away from integer multiples of the beam-bunching frequency (352.21 MHz) for any HOMs whose resonant frequencies are below the cut-off frequency of the beam-pipe."*

Status of the Elliptical Cryomodule Interfaces Requirements

More than 160 interfaces requirements with adjacent Work Packages:

WP02 :	Beam physics	
WP07 :	Beam Diagnostics	?
WP08 :	RF Systems	
WP99 :	Accel Infrastructure & Installation	just started
WP10 :	Test Stand	not started
WP11 :	Cryogenics	
WP12 :	Vacuum	
WP13 :	Safety	in progress (see Duy's presentation)
WP15 :	Cabling & Conventional Power	
WP16 :	Cooling supports	
WP17 :	Power Converters	
ICS :	Control/Command	not started

Status of the Elliptical Cryomodule Interfaces Requirements

ESS-0041759 Elliptical Cavity Cryomodule Interfaces Requirements, 13 Oct 2015, Rev 1, State Released

Description	
Document Number	ESS-0041759
Date	29 Sep 2016

ACC.ACC-SyR766	RFDS to MBL EMR interface - number of interfaces	There shall be one interface per MBL EMR cavity with RFDS.				1		ACPTD
ACC.ACC-SyR426	Helium supply safety valve, inner diameter d0	The cryomodule helium supply line shall be protected by a safety valve with a minimum relieving diameter equal to 10 mm	This CRYO safety valve is listed in Fig.2 of ESS-0011309R1.1 as SV02, for safety calculation see document ESS-0051459	mm	10			ACPTD
ACC.ACC-SyR291	WTRC - HBL MBL Cooling Water Pressure Drop: Maximal	The pressure drop caused by the MBL and HBL couplers between the WTRC-MBL.HBL coupler supply and return interfaces shall not exceed 3 bars.		bar			3	TBD
ACC.ACC-SyR292	WTRC - HBL MBL Cooling Water Flow rate	The WTRC systems shall be able to deliver a cooling water flow rate up to 2.5 L/min at the supply connection.	reference: CEA-ESS-CMD-NT-0003 A, Definition of the water characteristics for the cooling system of the elliptical cavity coupler (need a copy in CHESS)	l/min			2,5	TBD
ACC.ACC-SyR286	WTRC MBL HBL RF Coupler Interface location	The WTRC-MBL.HBL supply and return interface locations shall be on the RF coupler as per CHESS document (set of drawings) TBD.						TBD
ACC.ACC-SyR297	WTRC MBL HBL Nominal Cooling Water Supply Pressure	The pressure of the water supplied to the MBL and HBL RF couplers shall not exceed 2 bar(g) at the WTRC-MBL.HBL couplers interface		bar(g)		2	3	TBD
	WTRC - MBL	The MBL and HBL coupler parts in touch						

List of a total of 161 interfaces requirements identical for medium and high beta cryomodules:

- **93 in status Accepted (58%)**
- **68 in status TBC or TBD (42%)**

Status of the Elliptical Cryomodule Interfaces Requirements

Status:

- A lot of work has been done and the **main requirements have been put.** There is still some work for completion.
- The **tests of the M-ECCTD** are needed to confirm many requirements still in status TBC
- We need to **finalize** the analysis of the interface requirements with WP7, 99, 10, and ICS **before the CDRM-2** held after the tests of the M-ECCTD
- As the main requirements are established, the **CEA launched the procurements** of less risky components in order to limit the shift of the time schedule (see Florence presentation).
- However some **modifications or evolutions** of the interfaces are **expected** due to incomplete requirements list and change requests that may be needed from the different WPs (safety, cryo, ...)
- **Some procurements are in standby waiting for clarification.**

Example of evolution of the table of requirements

ESS-0041759 Elliptical Cavity Cryomodule Interfaces Requirements, 13 Oct 2015, Rev 1, State Released

Description	
Document Number	ESS-0041759
Date	29 Sep 2016

Evolution of the requirements since the date of signature

ACC.ACC-SyR766	RFDS to MBL EMR interface - number of interfaces	There shall be one interface per MBL EMR cavity with RFDS.				1		ACPTD
ACC.ACC-SyR426	Helium supply safety valve, inner diameter d0	The cryomodule helium supply line shall be protected by a safety valve with a minimum relieving diameter equal to 10 mm	This CRYO safety valve is listed in Fig.2 of ESS-0011309R1.1 as SV02, for safety calculation see document ESS-0051459	mm	10			ACPTD
ACC.ACC-SyR291	WTRC - HBL MBL Cooling Water Pressure Drop: Maximal	The pressure drop caused by the MBL and HBL couplers between the WTRC-MBL.HBL coupler supply and return interfaces shall not exceed 3 bars.		bar			3	TBD
ACC.ACC-SyR292	WTRC - HBL MBL Cooling Water Flow rate	The WTRC systems shall be able to deliver a cooling water flow rate up to 2.5 L/min at the supply connection.	reference: CEA-ESS-CMD-NT-0003 A, Definition of the water characteristics for the cooling system of the elliptical cavity coupler (need a copy in CHESS)	l/min			2,5	TBD
ACC.ACC-SyR286	WTRC MBL HBL RF Coupler Interface location	The WTRC-MBL.HBL supply and return interface locations shall be on the RF coupler as per CHESS document (set of drawings) TBD.						TBD
ACC.ACC-SyR297	WTRC MBL HBL Nominal Cooling Water Supply Pressure	The pressure of the water supplied to the MBL and HBL RF couplers shall not exceed 2 bar(g) at the WTRC-MBL.HBL couplers interface		bar(g)		2	3	TBD
	WTRC - MBL	The MBL and HBL coupler parts in touch						

Recent example of interface modification needed by WP11 (Cryo)

Drafting of the Elliptical Cryomodule interfaces sheets started but not yet frozen

See Franck presentation

Other WP have finalized their interfaces sheets => possible mismatches

(ex. With WP11: some orphans have been identified and evolution have been requested)

Change of the flanges of the cryogenic interface connexion between the cryoline and the cryomodule. A change request is being registered allowing a follow up of these evolution required.

EUROPEAN SPALLATION SOURCE

Document Type	Change Request
Document Number	ESS-0100756
Date	Mar 15, 2017
Revision	1 (1)
State	Preliminary
Confidentiality Level	Internal
Page	1 (2)

Change Request

CHANGE DATA			
CR ID	Accelerator CR 11.00122.1	**Date created**	Mar 15, 2017
Title of the CR	Changes in the process line interconnections in the interface between Elliptical Cryomodule and Cryogenic Distribution System for Lund Test Stand 2		
Name of Change Leader	Wolfgang Hees (WP10 Leader, Test Stand 2)	**Change originator**	Jaroslaw Fydrych (WU 11.6 Cryodistribution coordinator)
Change class	☐ Class A, European Spallation Source ERIC Council	☐ Class C Project Manager	☒ Class D Work Package Leader
Approving entity			

Question of CEA : the maximum He flow rate delivered by the cryogenics

Requirements on minimum helium supply mass flow : 3,3 g/s

SyR527	Vacuum barrier	system.	jumper connections on the CDS side.					ACPTD
ACC.ACC-SyR539	Supercritical inlet line minimum operating mass-flow	The supercritical inlet line (BC) shall supply helium at a minimum operating mass-flow of 3.3 g/s	Requirements valid during the nominal operation phase	g/s	3,3			ACPTD
	REDS to HBI							

No max value

Estimation of the total heat load at 2K:

37 W for the Mbeta cryomodules
41W for the Hbeta cryomodules
(**~13W** static load fro both cryomodules)

The sizing of the cryogenics must take into account possible additional heat loads:

- + 50% static load => **20W**
- + 100% for cavities and couplers => **56W**

} **= 3,3g/s** He mass-flow

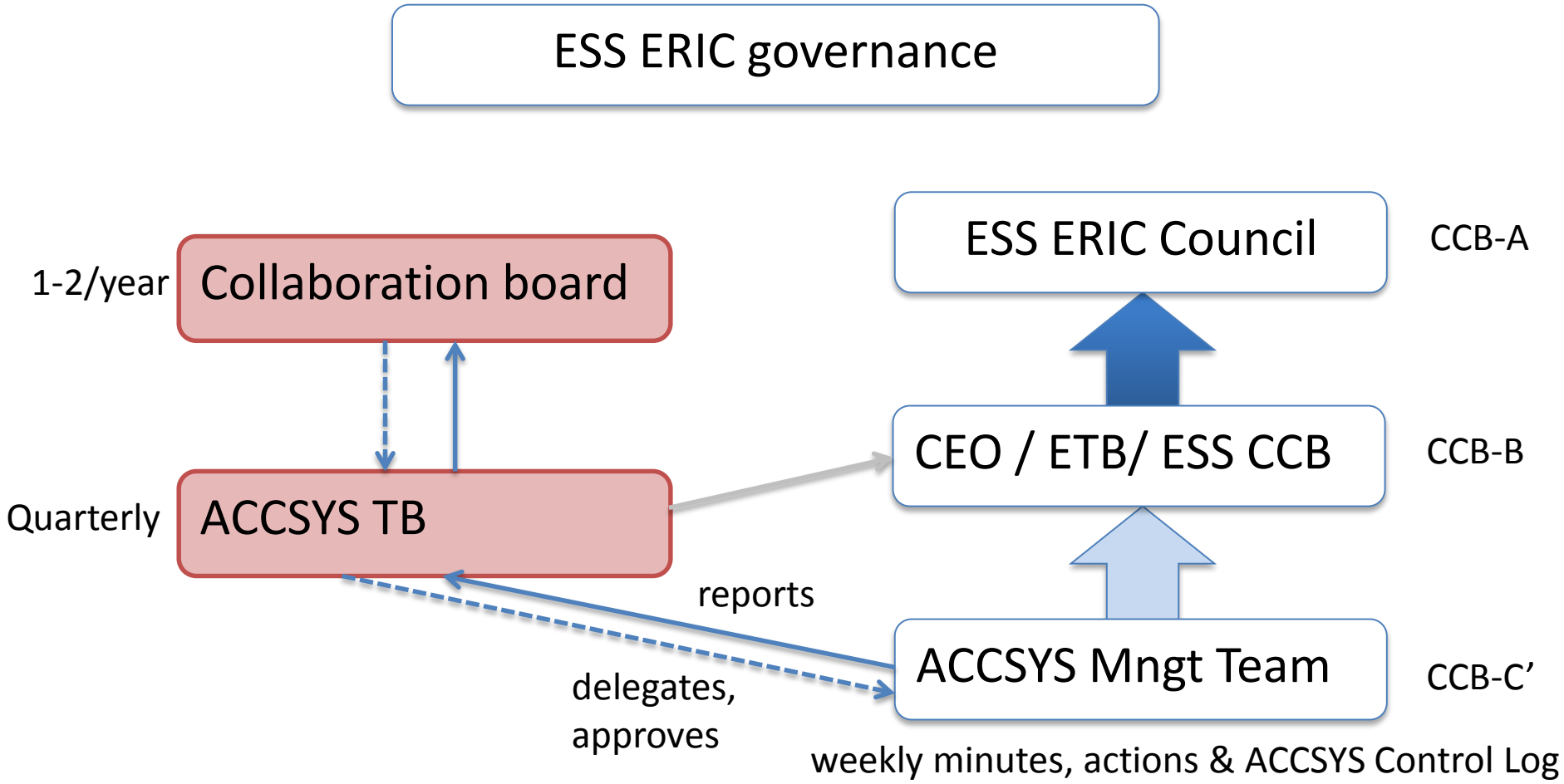
=>

Sizing of the internal heat exchanger: **4,5g/s max for the M-ECCTD**.

- **Is there any requirement on the max value of the He flow rate from ESS?**
- **We would prefer keeping the maximum value of the He flow rate at 4,5g/s for the series?**

See presentation of Bertrand

Control Change Boards (CCB) & control flow for ACCSYS



Compliance matrix for acceptance of the Cryomodules

Acceptance of the cryomodules in two steps:

1. Before shipment to Lund: quality of the cryomodule assembly
   - Follow-up of the assembly and controls done by CEA
   - Acceptance pronounced by ESS (based on non conformity registers)

2. After tests of the CM at Lund in TS2

Test plan of the M-ECCTD in progress (see Olivier's presentation)
Test plan for the series will be based on the M-ECCTD's one

First draft in preparation of a compliance matrix for the acceptance cryomodules of the series.

- **First version in progress by CEA (~ready for the tests of the M-ECCTD)**
- **Final version for the CM of the series will be under the responsibility of ESS (who pronounces the acceptance of the cryomodule)**

Drafting of compliance matrix for acceptance of the Cryomodules

CEA - Saclay

EUROPEAN SPALLATION SOURCE

CONFORMANCE MATRIX – MEDIUM BETA CRYOMODULES – RF POWER TESTS

Name	Units	Min.	Nominal	Max.	Design value	Measured value	accepted
Cryomodule beam vacuum pressure	mbar			1E-7			
Cryomodule beam vacuum connections leak rate	mbar l/s			1E-10			
Insulation vacuum pressure requirement	mbar			1E-05			
Insulation vacuum leak rate	mbar l/s			3E-8			
Process pipe connection tightness	mbar l/s			1E-8			
Vacuum jacket connection tightness	mbar l/s			1.0E-7			
Operating He mass-flow (cavities @ 2K)	g/s			3.3	1.8		
Thermal shield							

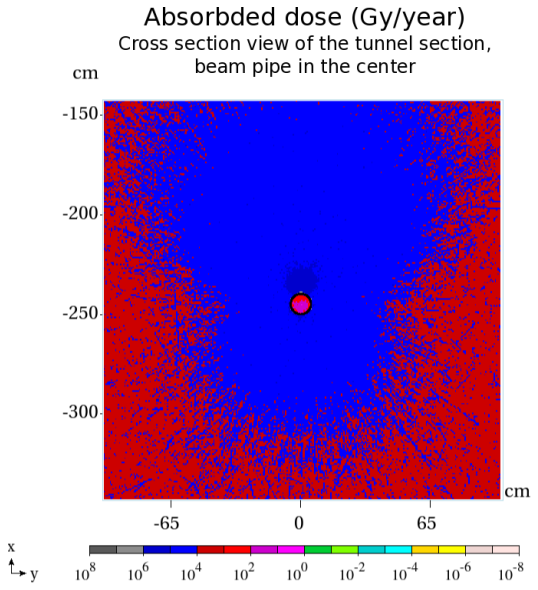
Document to be completed

Other aspects of the requirements: PED, RX, …

See Christine and Vincent presentations

TÜV NORD

Pre-study of legal QC requirements for pressure equipment (cryo)



Thank you for your attention