DE LA RECHERCHE À L'INDUSTRIE

Cryomodule Tooling

C. MADEC

September 4th, 2018

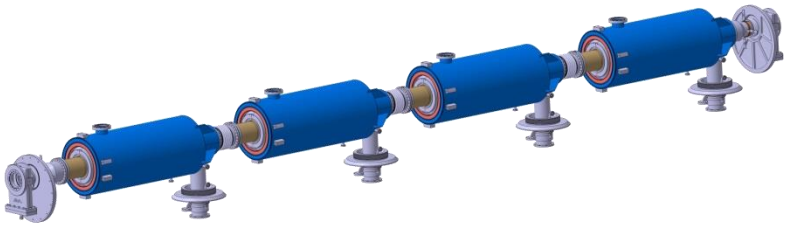
International Workshop on Cryomodule Design and Standardization

OVERVIEW

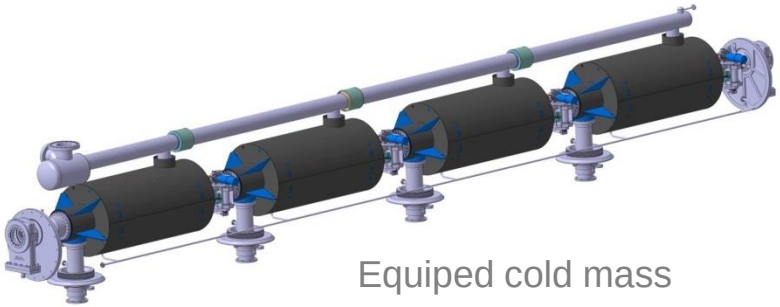
- Steps for the tooling development
- Specific environment : Clean room, alignment, welding …
- Mock-ups and evolution
- Off-the-shelf tooling
  - Vacuum groups, welding equipment, RF test stands
- QA/QC

Steps for tooling development : Define steps and conditions

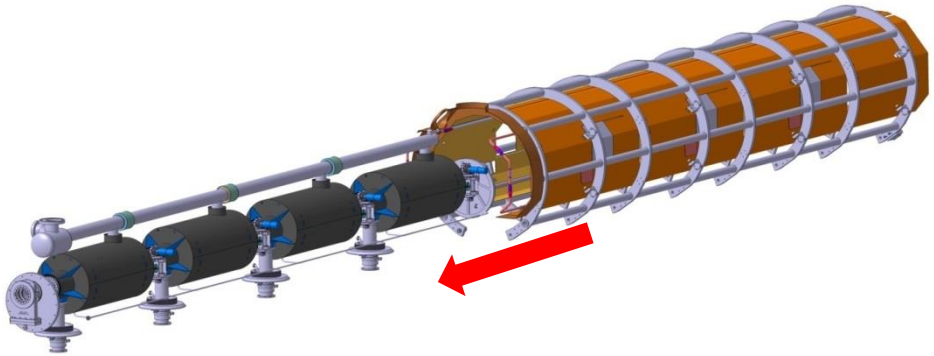
From the 3D model of the cryomodules, the assembly is broken down in steps separating the assembly conditions (clean room / halls, mechanical/RF/vacuum)



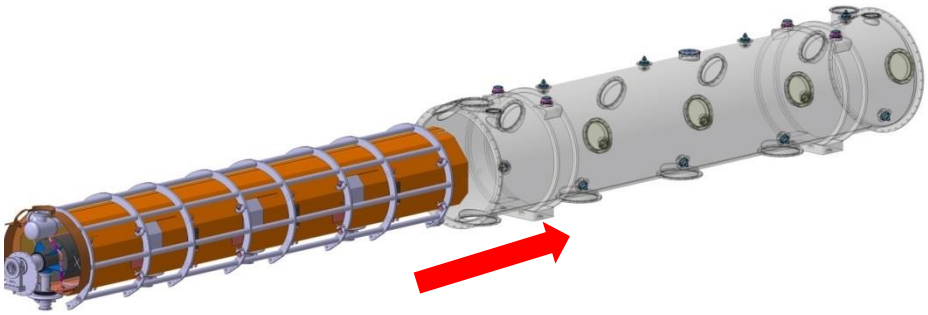
Cavity string to be assembled in clean room



Equiped cold mass



Spaceframe and themal shield

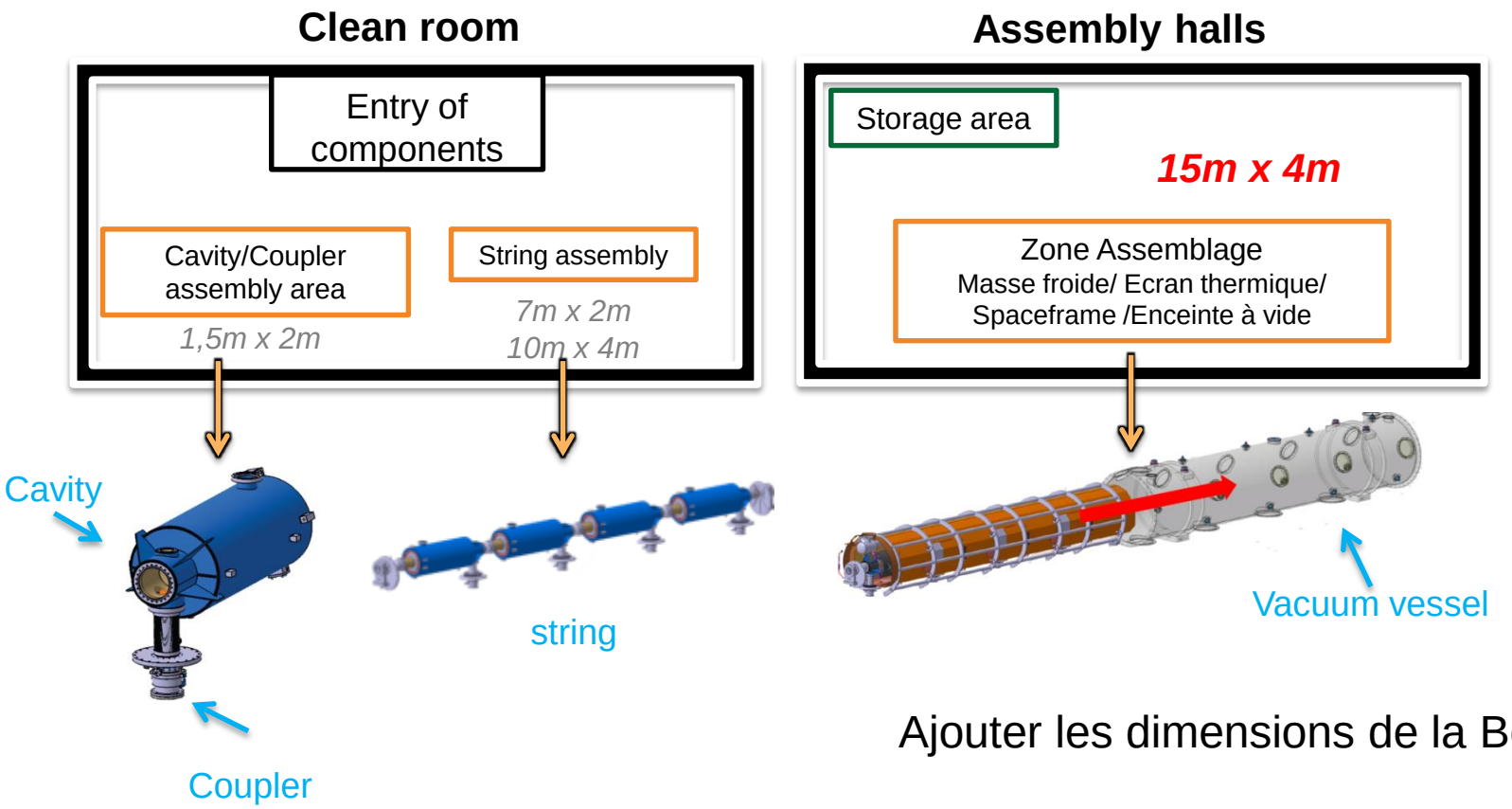


Space frame and vacuum vessel

Detailed study of assembly steps

Infrastructures needed : Clean room and Halls

- Not only the rooom for the components but for the lifter, the tools table with wrench, N2 gun, particle counters …the people to work around

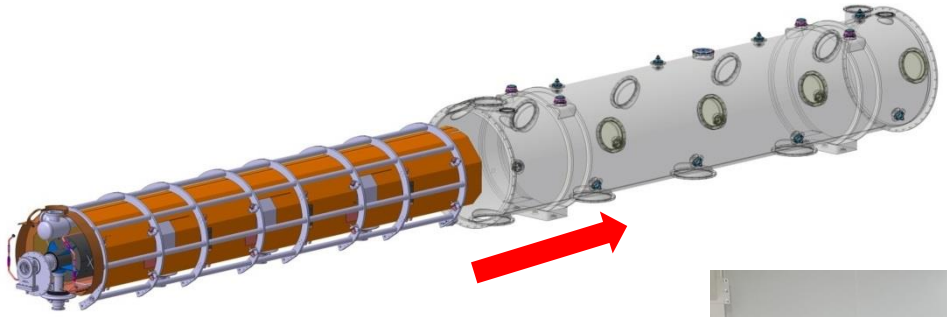


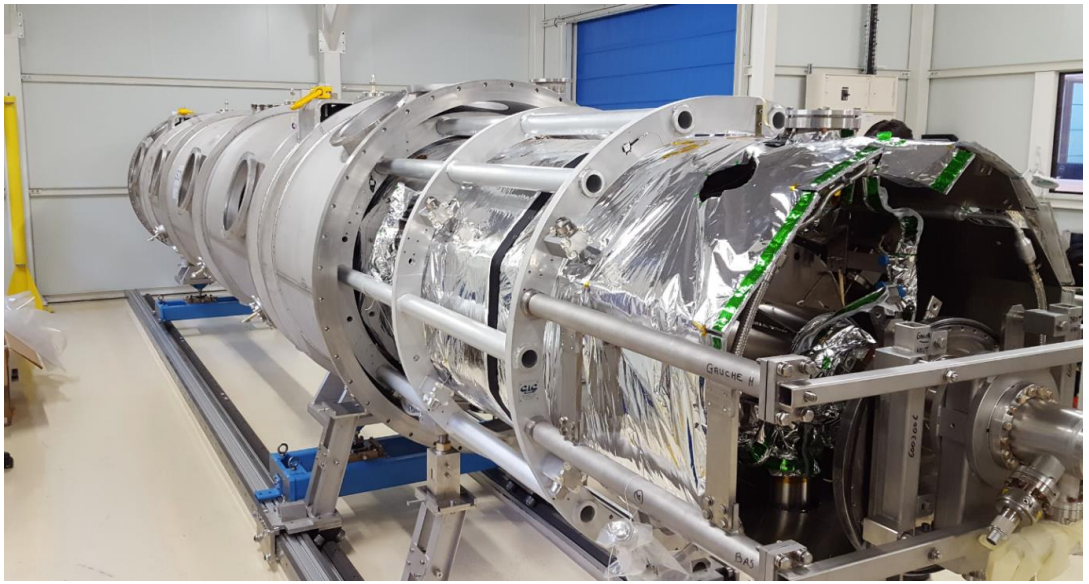
Ajouter les dimensions de la Both

Description of the tool

From the 3D model of the cryomodules, one describes :

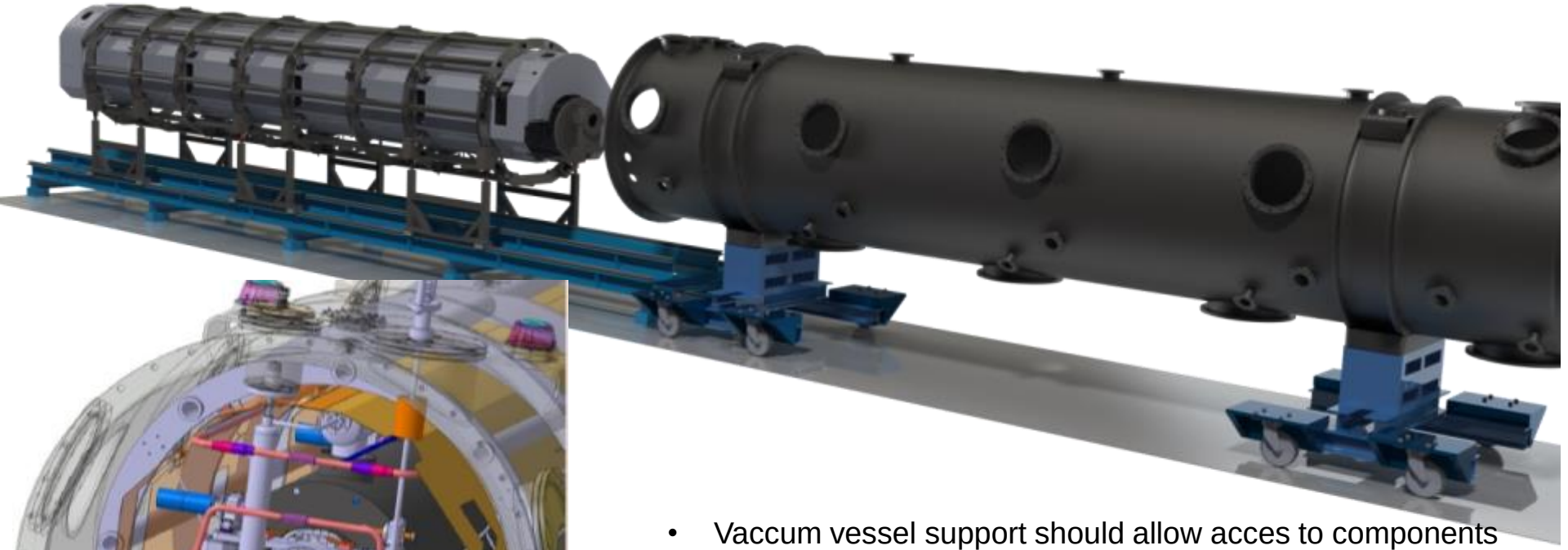
- Parts to be assembled — **Space frame and vacuum vessel**
- Funcionality of the tool — **Roll the space frame in VV, maintain the alignment**
- Legal/regulatory framework — **none**
- Environment (Clean room, halls) — **halls**

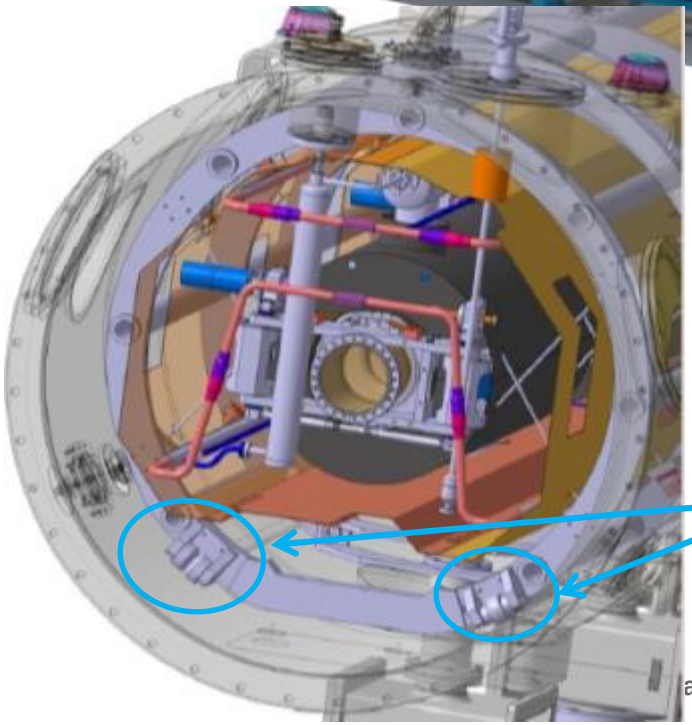




START THE TOOLING DESIGN WHEN DESIGNING THE COMPONENTS

Start the tooling design when designing the components so that interfaces can be added on components



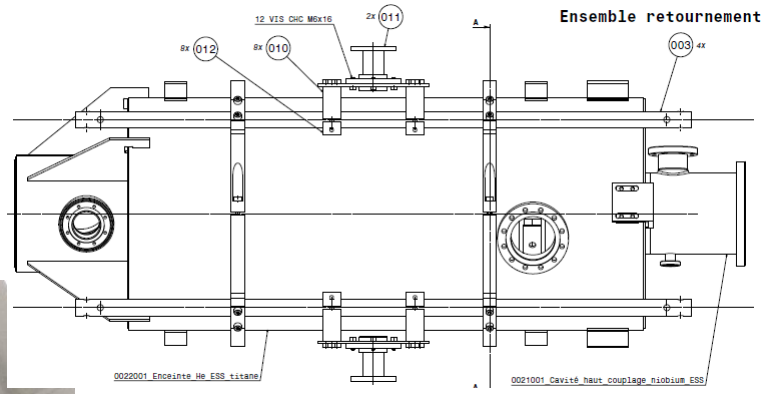


- Vaccum vessel support should allow acces to components

  => Door added
- Insertion of space frame slowly
- Spaceframe with wheels under each circles.
- Vacuum vessel with rails

ANTICIPATE MANUFACTURING DEFECTS

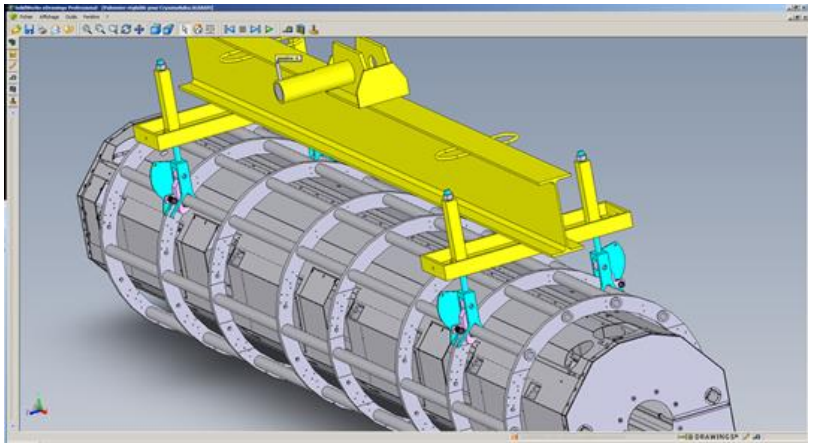
Example : welds thickness and position specified to be able to assemble the tooling



REGULATORY FRAMEWORK

Lifting tools have to match the lifting regulatory framework

Welding to match the welding regulatory framework



For PIP2, framework has to be checked for the use in each country (SARAF project)

REGULATORY FRAMEWORK

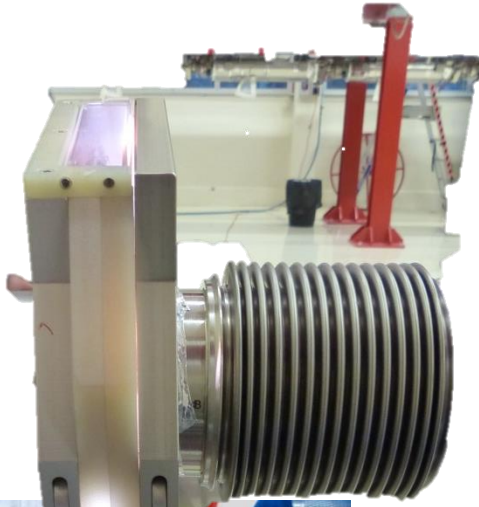
XFEL EXAMPLE : CHAQUE CRYOMODULE DOIT RÉPONDRE AUX RÈGLES DU PRESSURE EQUIMENT DEVICE. LA PRESSION MAXIMALE EST DE 6 BARS. LES COMPOSANTS DE RÉSEAU HÉLIUM 2K DOIVENT POUVOIR CONTENIR CETTE PRESSION SANS RUPTURE.

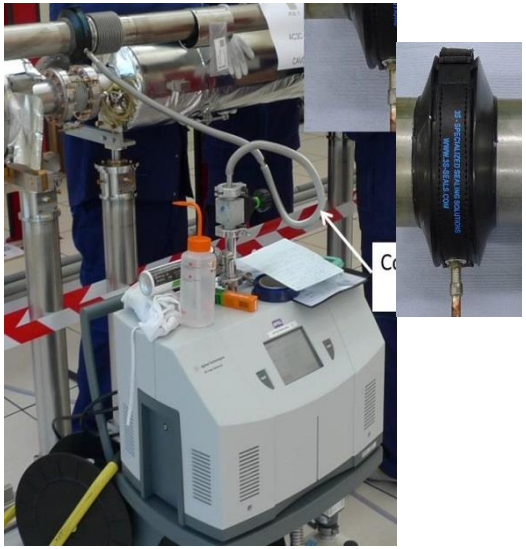
CERTIFICATION NF EN ISO 10675-1 : 2013 - NIVEAU 1

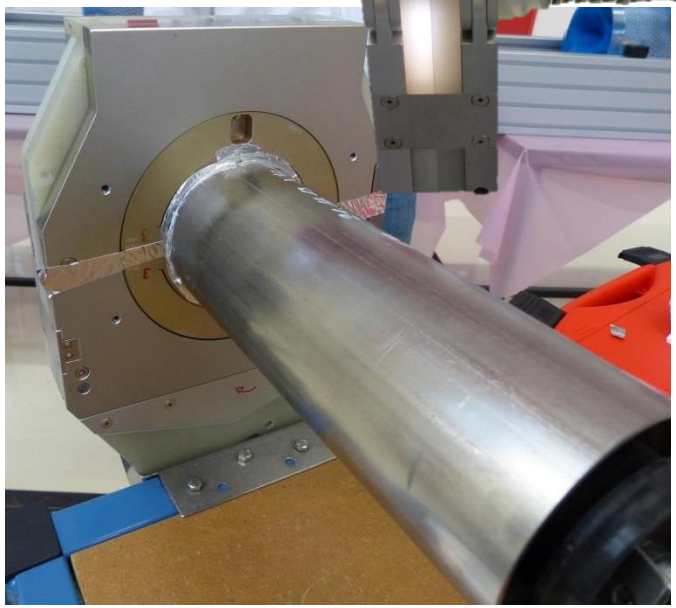
=> Soudure avec soufflures inférieures 0.4mm (tube 2mm)

Matériau : Inox et Titane

Soudure orbitale sur tube ou TIG manuelle







- TEST VISUEL
- RADIOGRAPHIE X
- TEST D'ÉTANCHÉITÉ
- RESSUAGE

WHEN DESIGNINING TOOLING, ENVIRONMENT

When designing the tooling, take into account the environment, for example clean room:

- No grease on the tooling
- Protection of already prepared

sub assembly (no glued sensors or protected ones not to pollute the clean room)

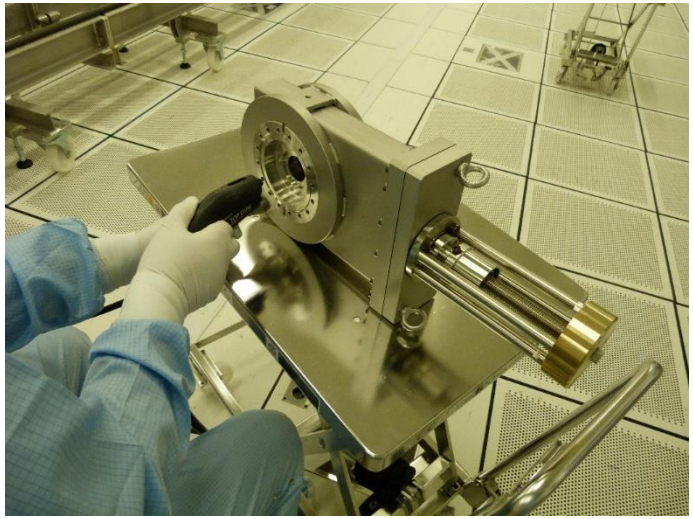
- Local bags

TTC topical Workshop on SRF cryomodule clean room assembly :

https://indico.in2p3.fr/event/10347/timetable/#all

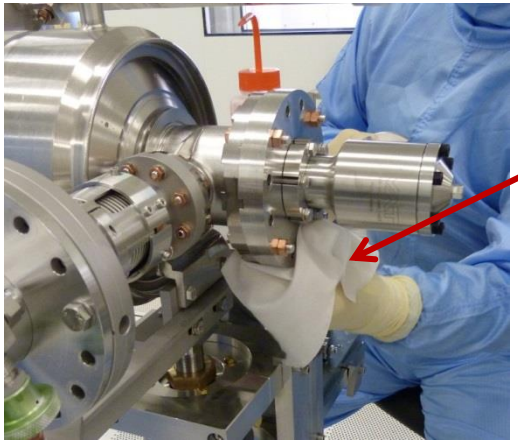
SPECIFIC ENVIRONMENT

CLEANING AND BLOWING ON INDIVIDUAL COMPONENTS



Courtesy of ESS

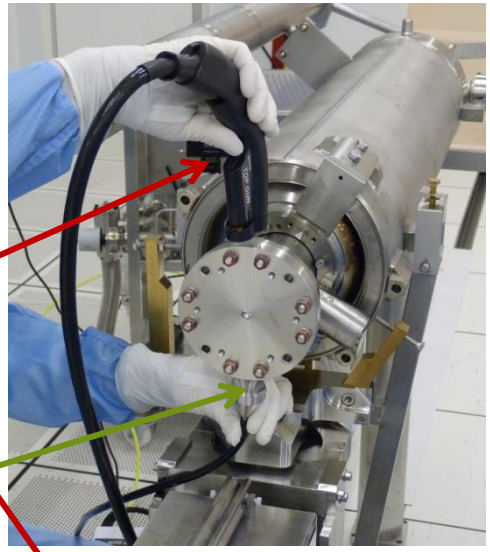
CLEANING AND BLOWING ON SUB-ASSEMBLIES

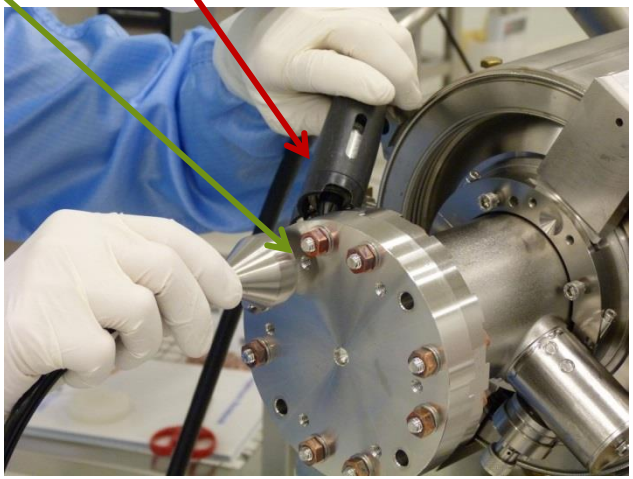


Cleaning

Blowing with Deionsed N2

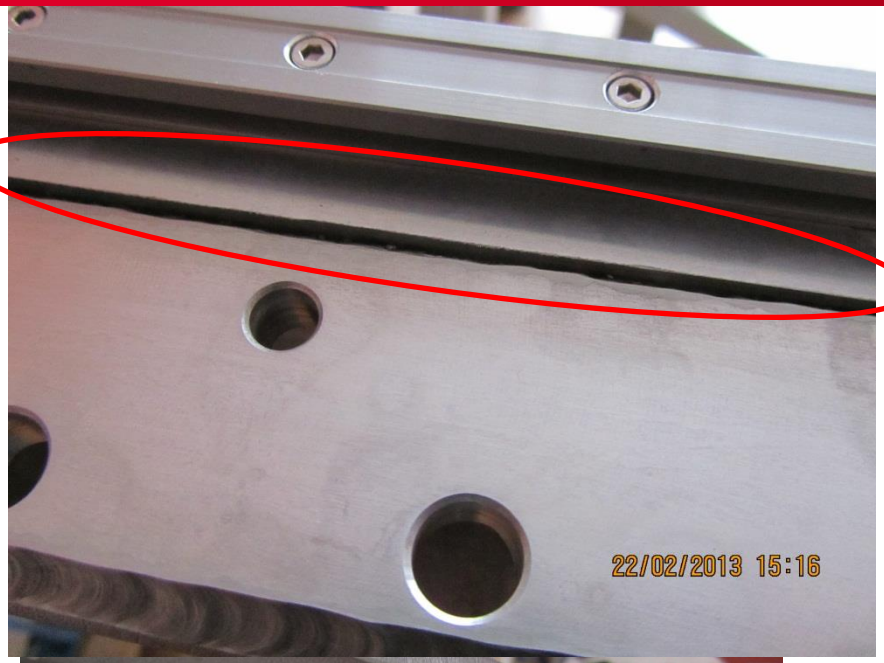
Particules counting

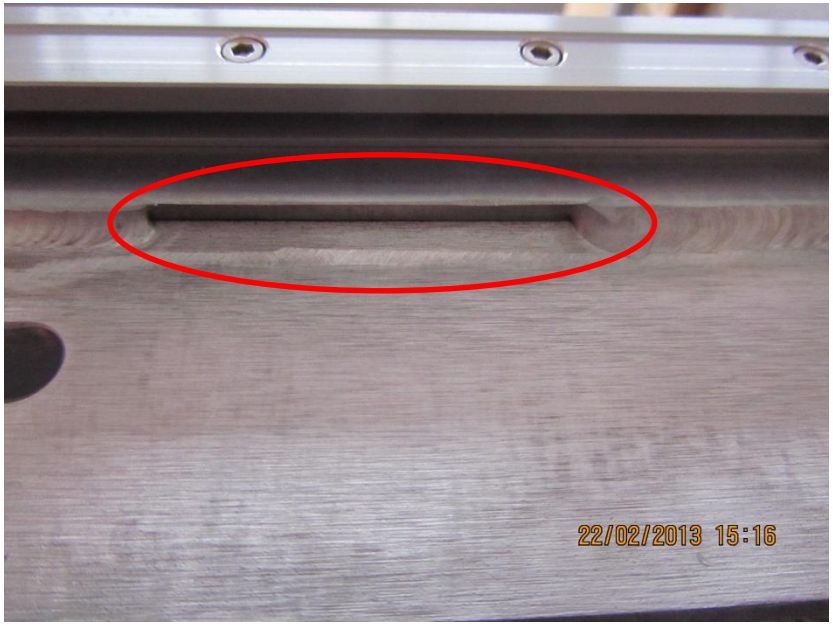


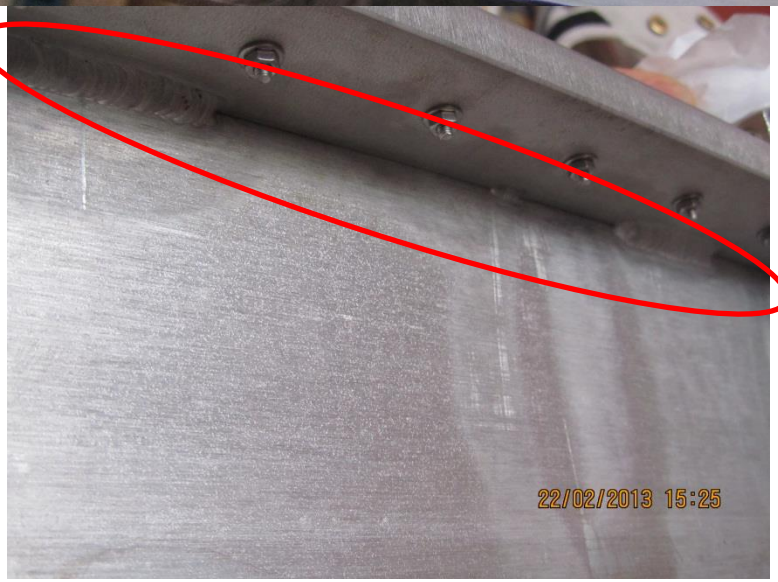


counted are below 10 parts (>0,3 µm) during 1 min

MAKE COMPONENTS OR TOOLS CLEANABLE





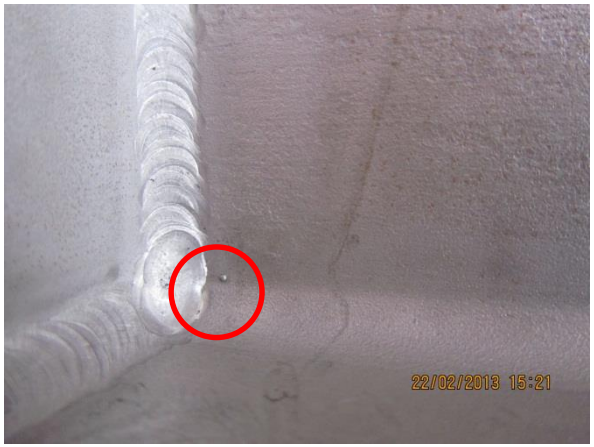


Circled areas are difficult to clean and could be dust traps

⇨ Weld all along

Courtesy of N. Bazin

MAKE COMPONENTS OR TOOLS CLEANABLE



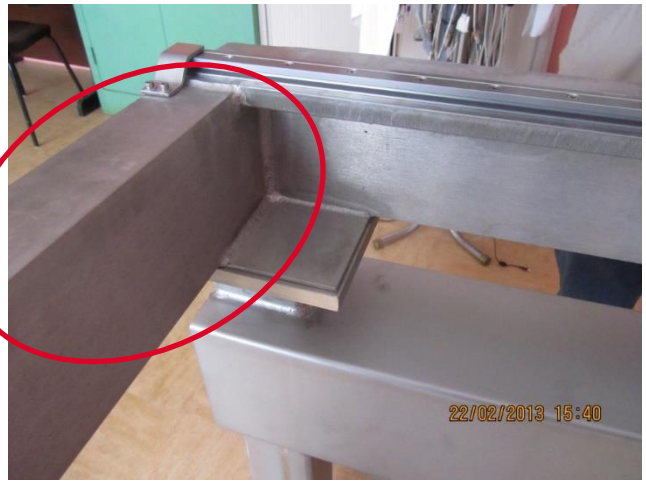
Avoid welding beads and burrs to prevent from tearing clean room tissues

Courtesy of N. Bazin

MAKE COMPONENTS OR TOOLS CLEANABLE

Surface finish is important.

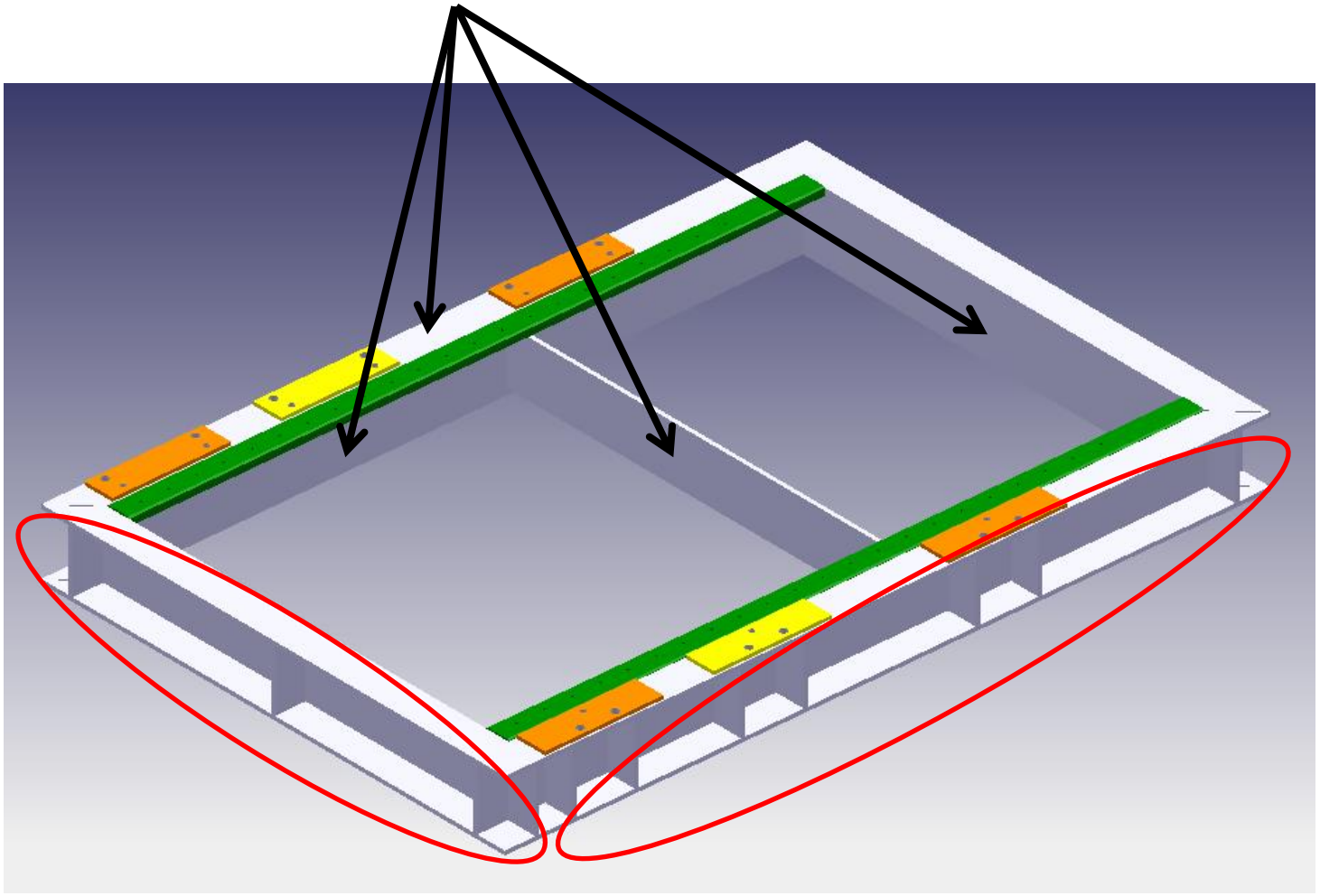
The cleaning is more difficult (and sometimes impossible) when the tooling was grinded as on the picture. It is better to leave with stainless steel aspects or paint the surface.



Courtesy of N. Bazin

MAKE COMPONENTS OR TOOLS CLEANABLE

Surfacing of the areas done after manufacturing



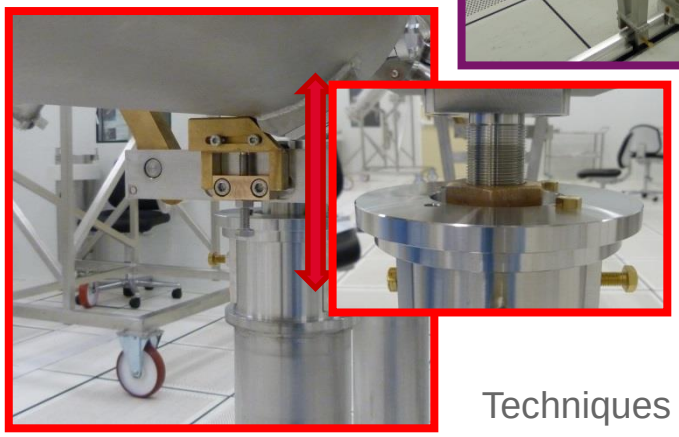
Other surfaces have been cleaned in ISO7 and then sealed with NITO film

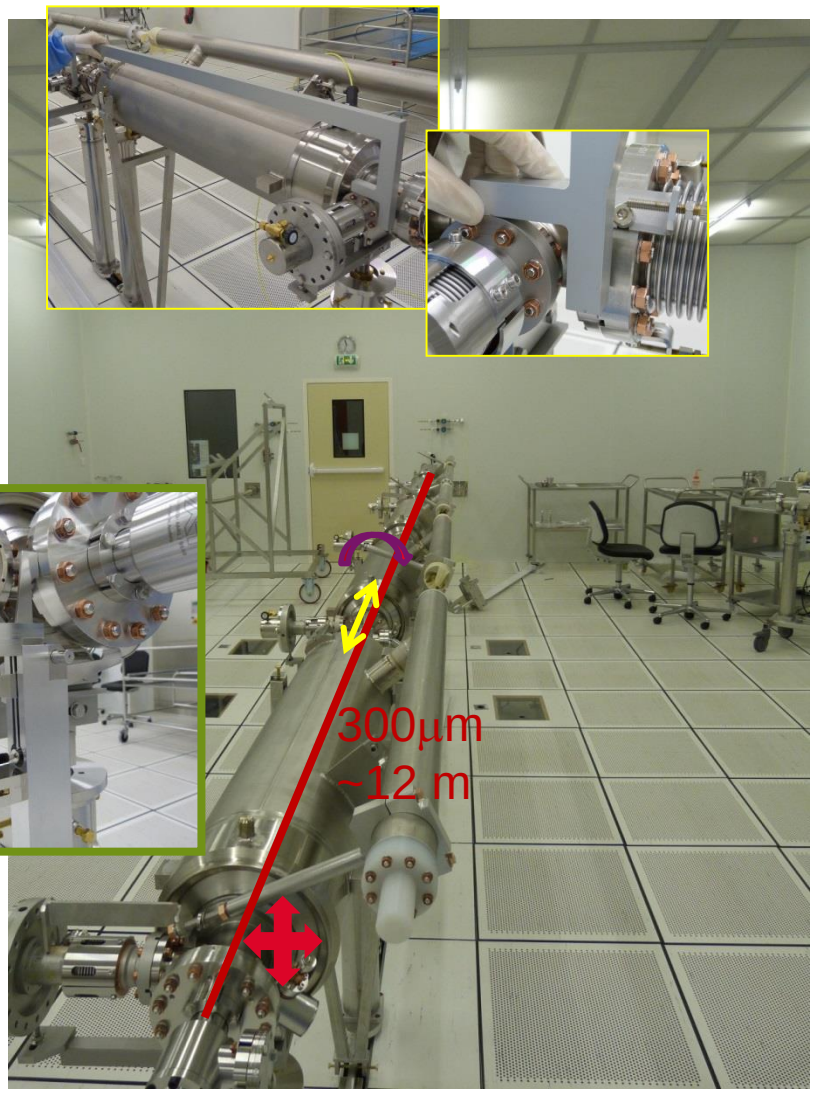
Courtesy of N. Bazin

PRE-ALIGNEMENT

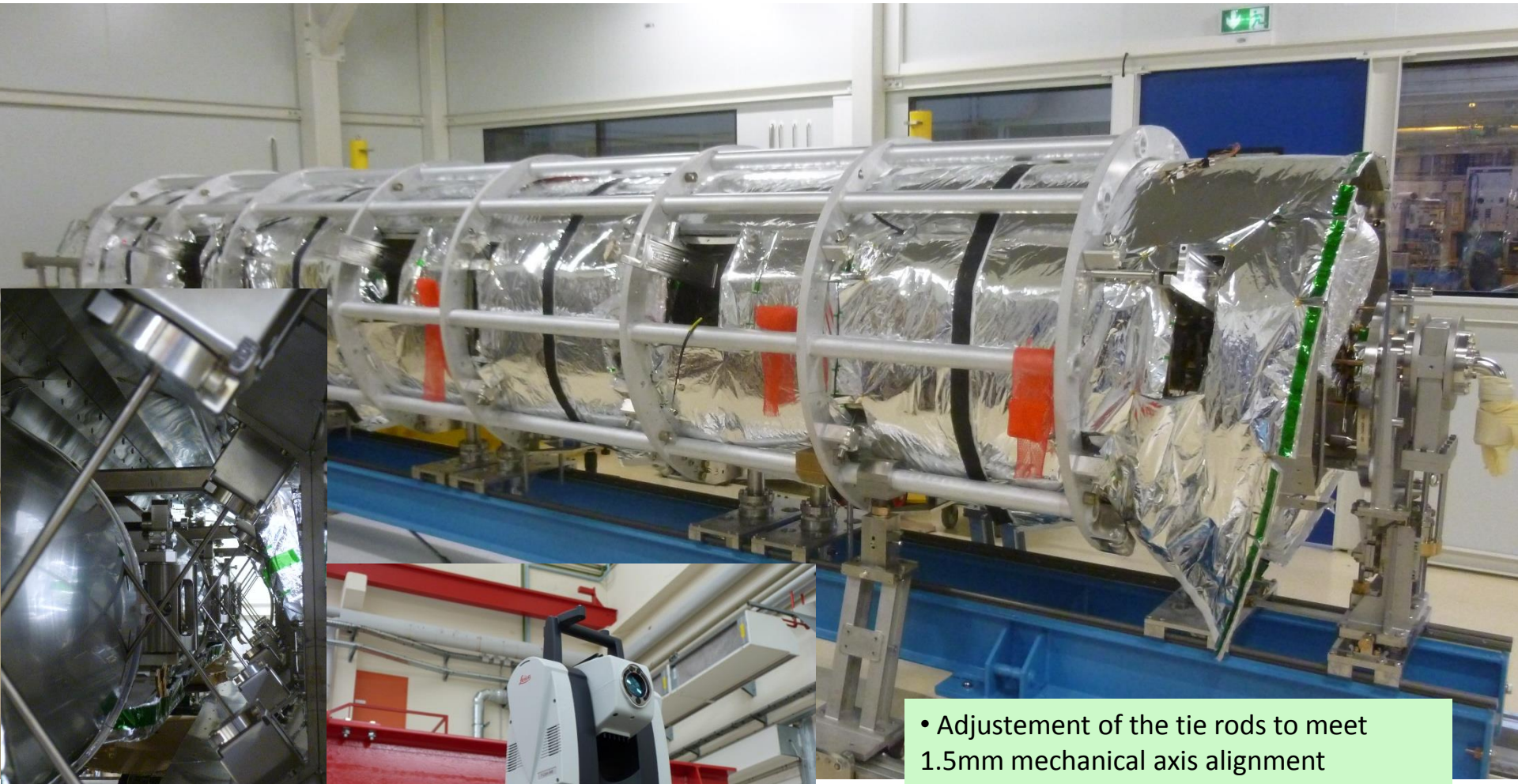
Prealignment in clean room is mandatory : prevent bellow rotation outside the cleanroom, reduce operations outside the cleanroom.

When specifying components take into account how they will be mounted.





ESS ALIGNMENT



• Adjustement of the tie rods to meet 1.5mm mechanical axis alignment specifications

PUMP AND BACKFILL

- PARTICULATES SHOULD NOT MOVE OR BE INTRODUCED IN THE STRING DURING PUMPING DOWN OR BACKFILLING.

- DESY STUDIES ON A 10M-LONG TUBE, 63MM SAME LENGTH AS XFEL CRYOMODULE (*REF SRF2009-THPP0104)*

as far as possible from components being sensitive to particles

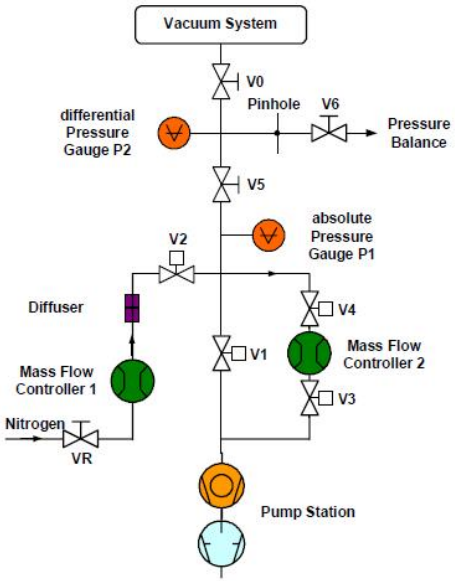
- Movement of particles is mainly observed at the position next to the pumping and venting ports. The long tube homogenizes the gas flow and reduces turbulences.

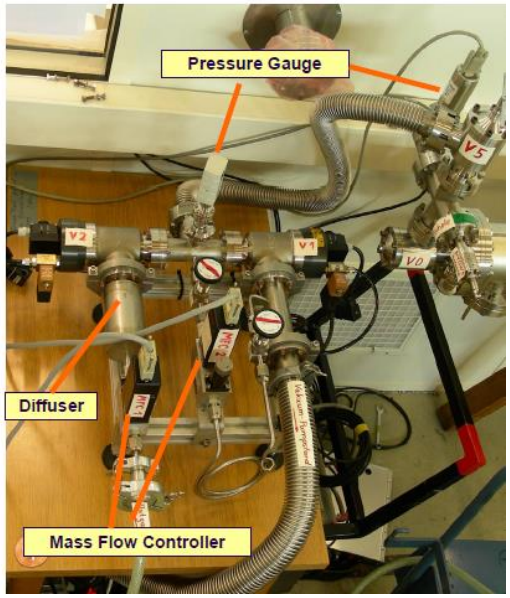
Manual valves, even needle valves, not well suited to adjust the gas flow

After venting a system Dp between the vacuum vessel and atmosphere should be Δp < 1 mbar before opening

- During pump down the number of particles decreases with decreasing pressure, indicating a reduction of turbulences. In the dirty system particles could be measured down to a pressure of about 100 mbar. If turbulences are again introduced by sudden changes of the throughput of e.g. changing the position of a needle valve, particles had been detected down to pressures of about 1 mbar. Only for pressures < 1 mbar no more particle movement has been observed even when moving valves.

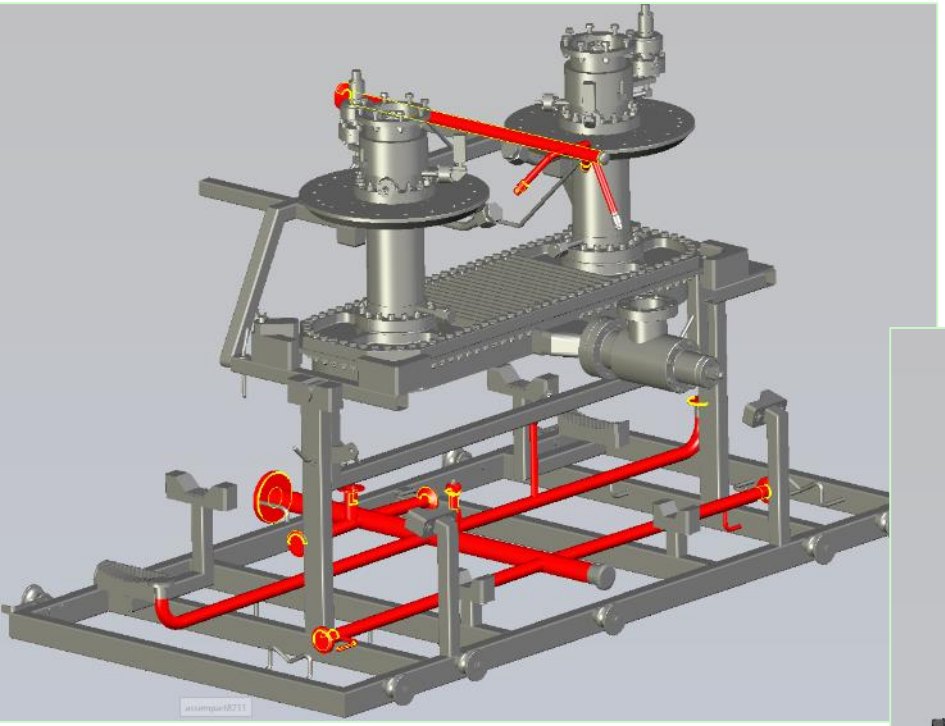
SCHEMATIC OF THE VACUUM GROUP SYSTEM



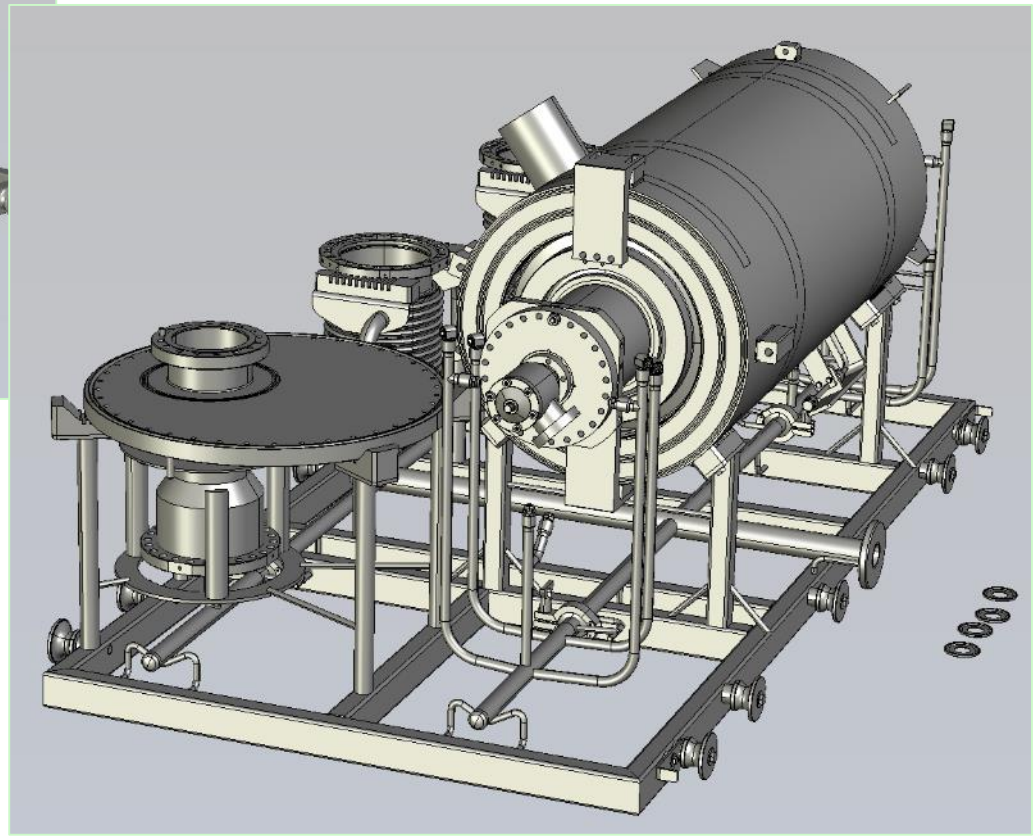


- Mass flow controler which maintains a constant flux by adjusting the diaphragm opening
- Diffuser to diffuse the flux by almost 360° (from semiconductor industry) to reduce the turbulences with a removal rating 0.003 μm
- Gauges : 1 abs at 1 mbar et 1 differential
- Back to atmospheric pressure : N2 flow (1-1000mbar – Dp(cav-pump) <1mbar) : 50 mbar l/s.
- For venting particle filtered gas (N2 or Ar) (particle size ≤ 0.04 μm) and a gas quality of 99.9999% has to be used or evaporation gas

OUTSOURCED TOOLING



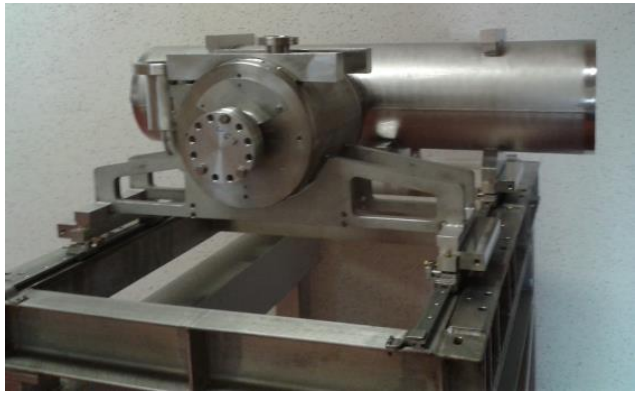
Washing machine cavity and coupler carriage

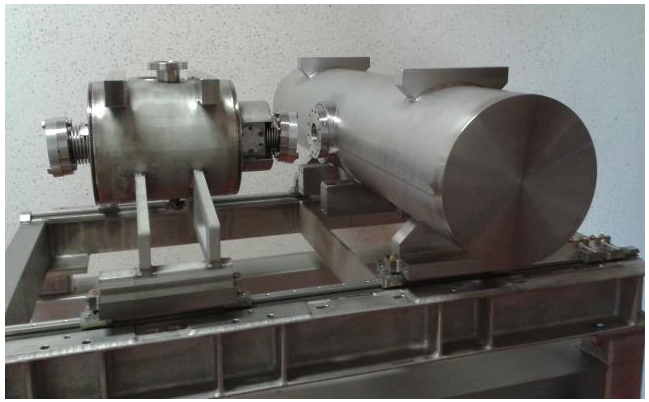


MOCK-UPS AND EVOLUTION

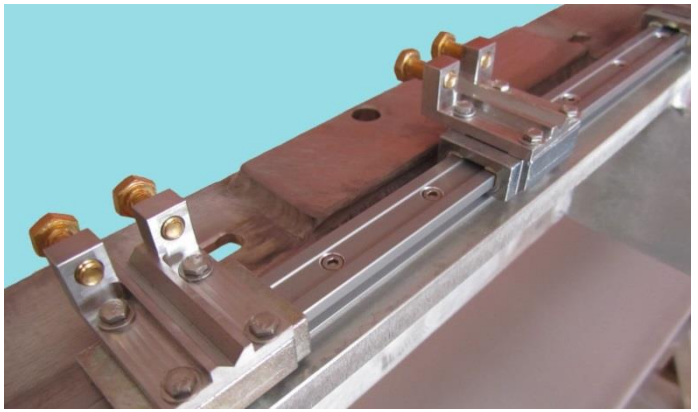
MOCK-UP TESTS : VALIDATION OF THE CLEAN ROOM ASSEMBLY PROCEDURE

- To validate and / or improve the clean room assembly procedure and the associated tools, a test bench as realistic as possible is needed.
- A frame, a little bit bigger than one eight of the final support and equipped with the linear guides and the positioning system, was manufactured. It is possible to assemble one solenoid and two cavities.
- Because of the late delivery of the final elements, a dummy cavity, a dummy solenoid and a dummy coupler were manufactured.





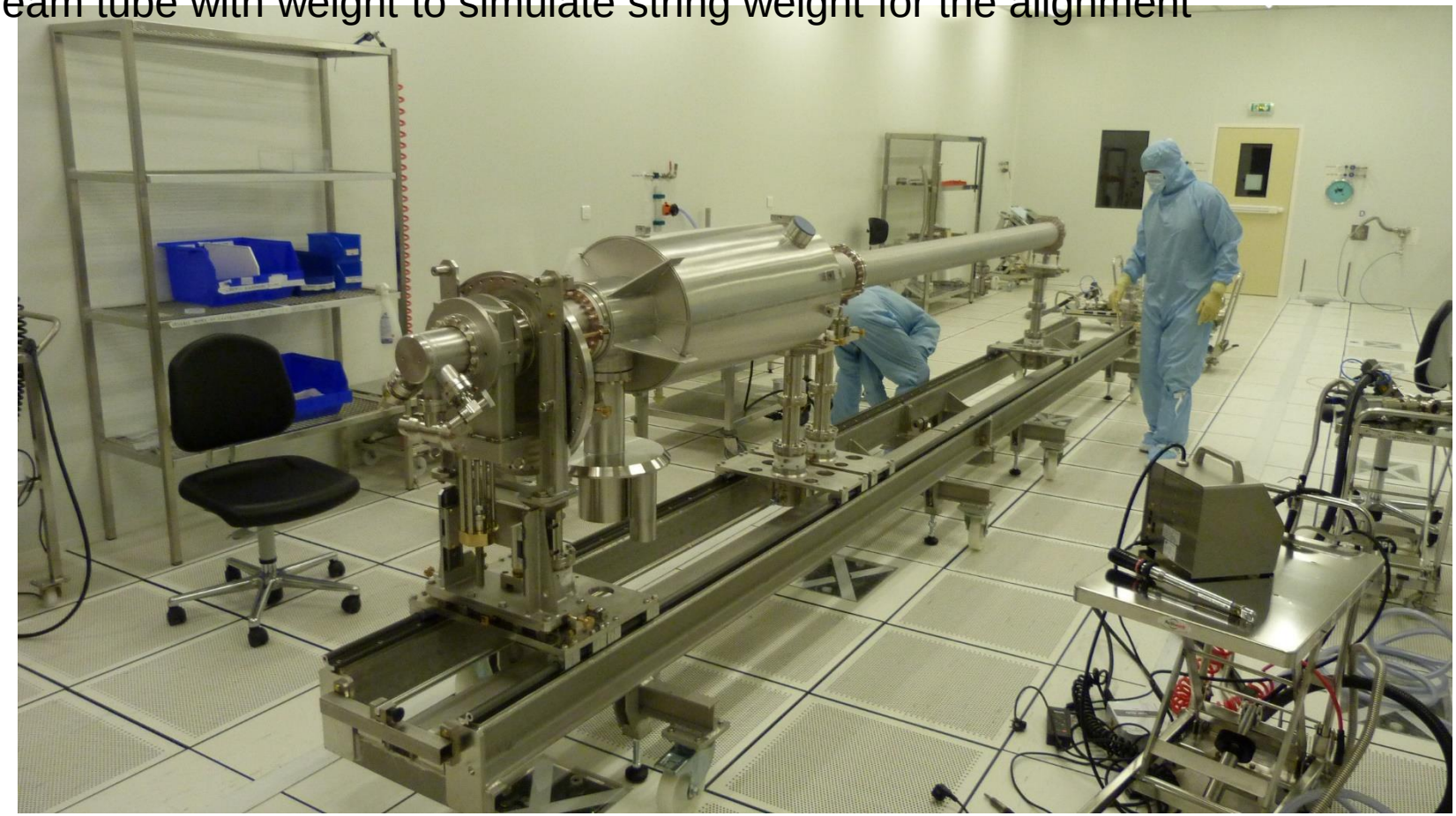
- All the tools were manufactured and tests have shown no show stopper after CR.



Auxiliary linear guide assembled on the support frame with two carriages equipped with positioning adjustment elements

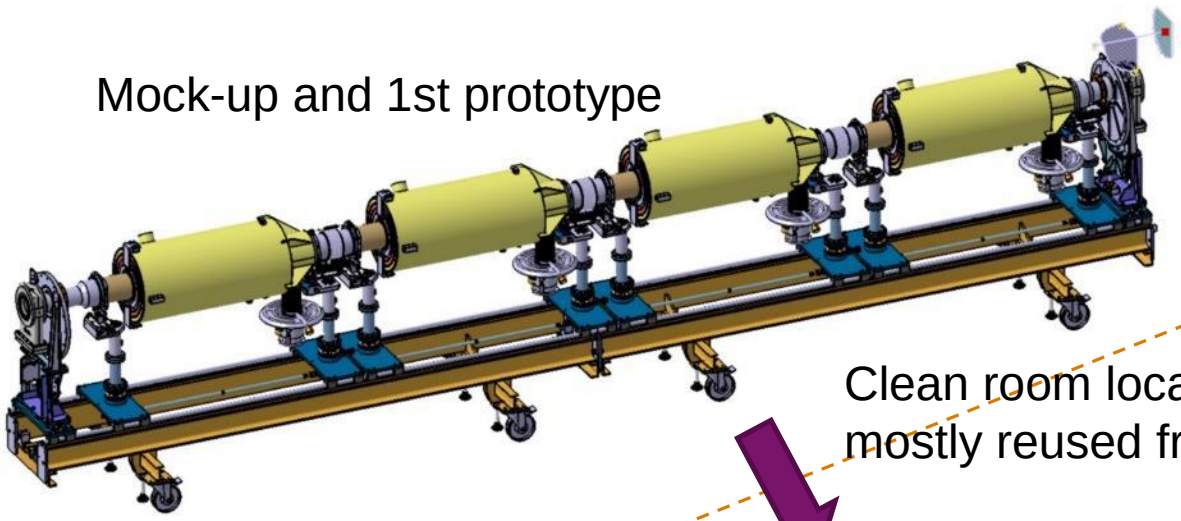
ESS MOCK-UP TEST IN CLEAN ROOM

Mock-up test of the cavity string in the clean room with operators wih mock-up cavity, Beam tube with weight to simulate string weight for the alignment

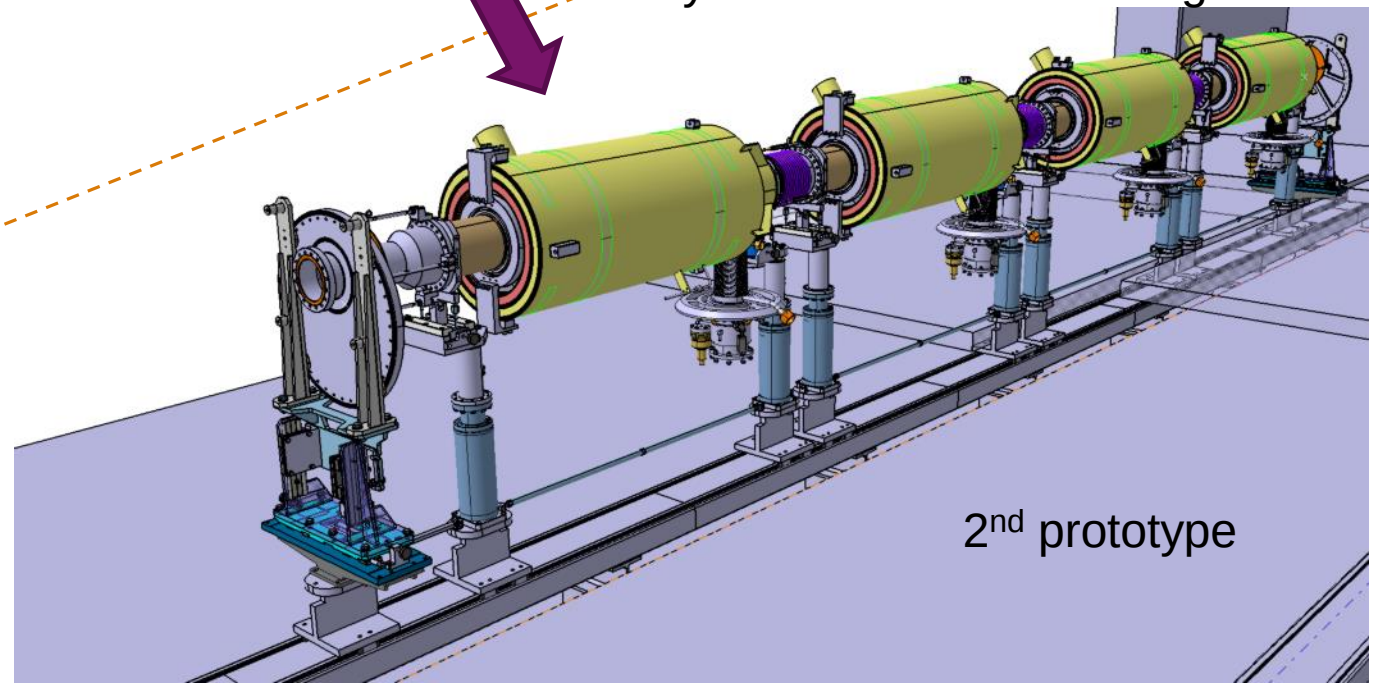


TOOLING EVOLUTION AFTER MOCK-UP OR PROTOTYPE

Mock-up and 1st prototype

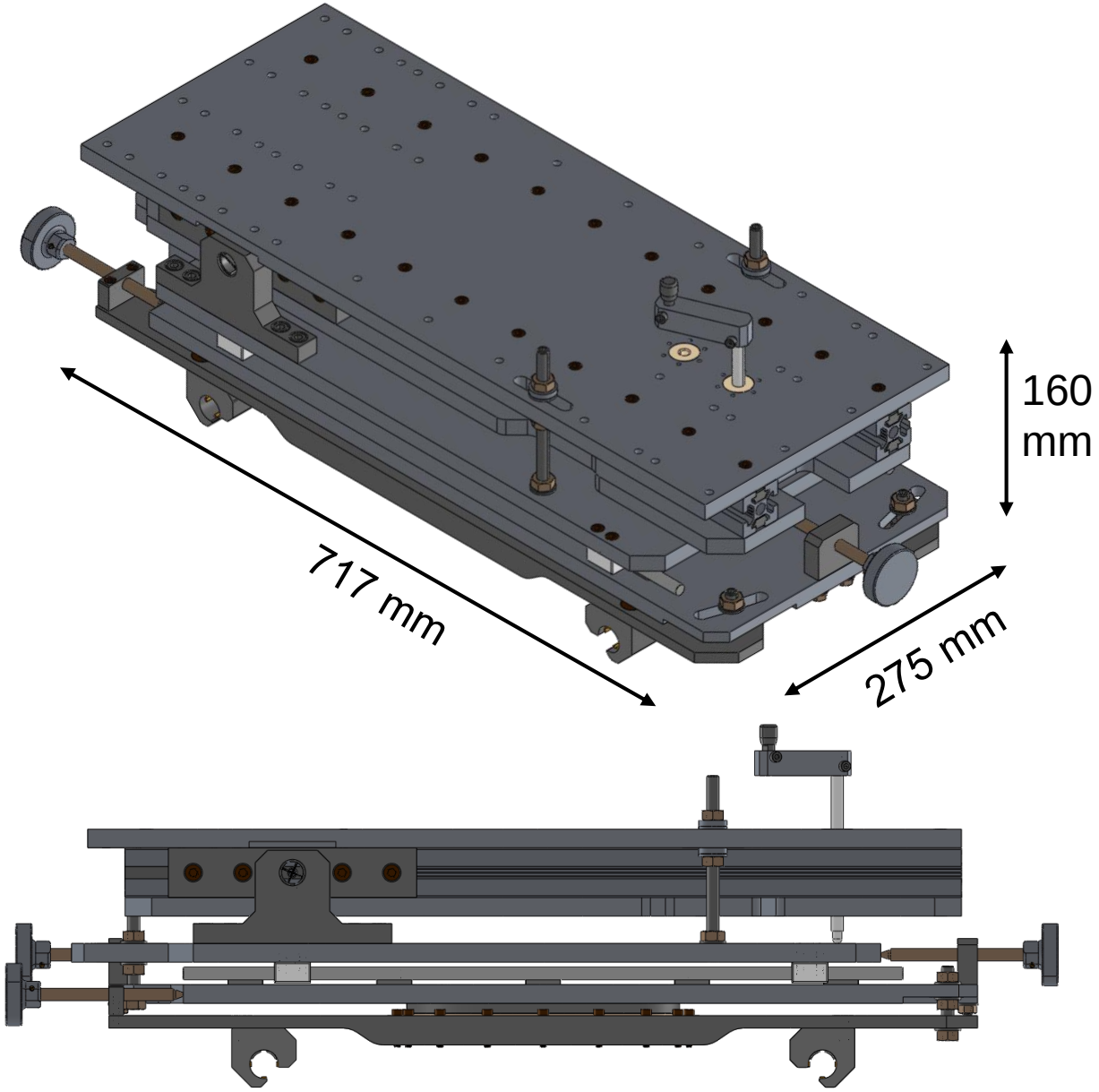


Clean room location has changed, mostly reused from 1st tooling



EVOLUTION : MECHANICALLY WELDED FRAME AND SPECIFIC TOOLING

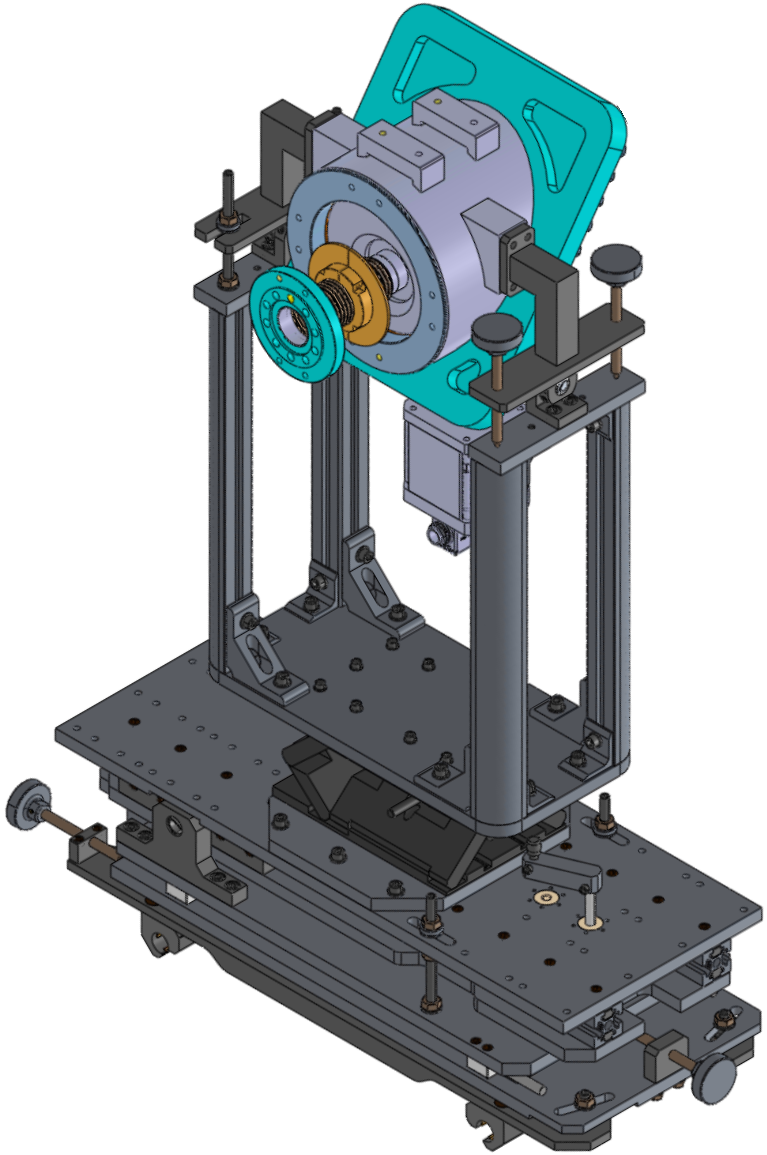
To reduce tailored tooling, use off-the-shelves and standard part to be assembled

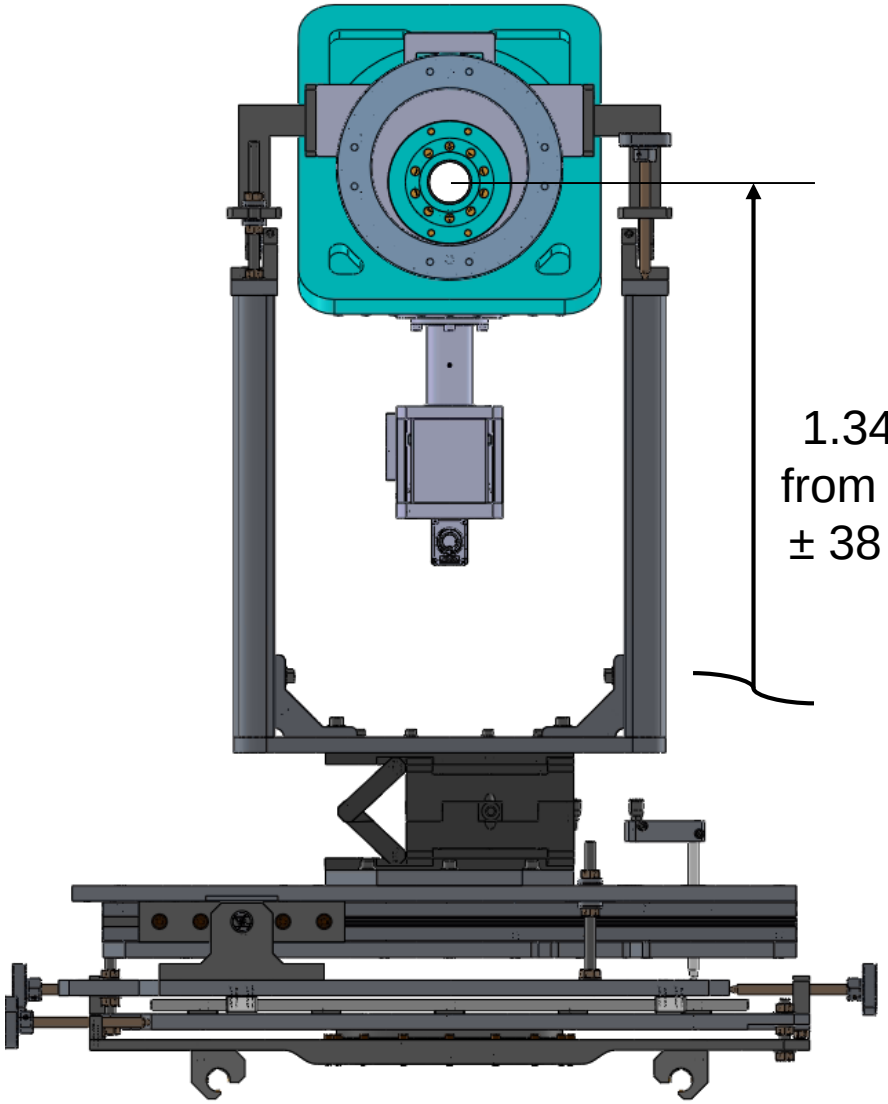


- A 4 DOF platform can be used for the HB cavity, LB cavity and Cold-warm/Warm-cold transitions
- Each DOF can be easily regulated and locking devices enable to fix the position
- The structure is mainly built in Aluminum

Courtesy of M. Parise

To reduce tailored tooling, use off-the-shelves and standard part to be assembled

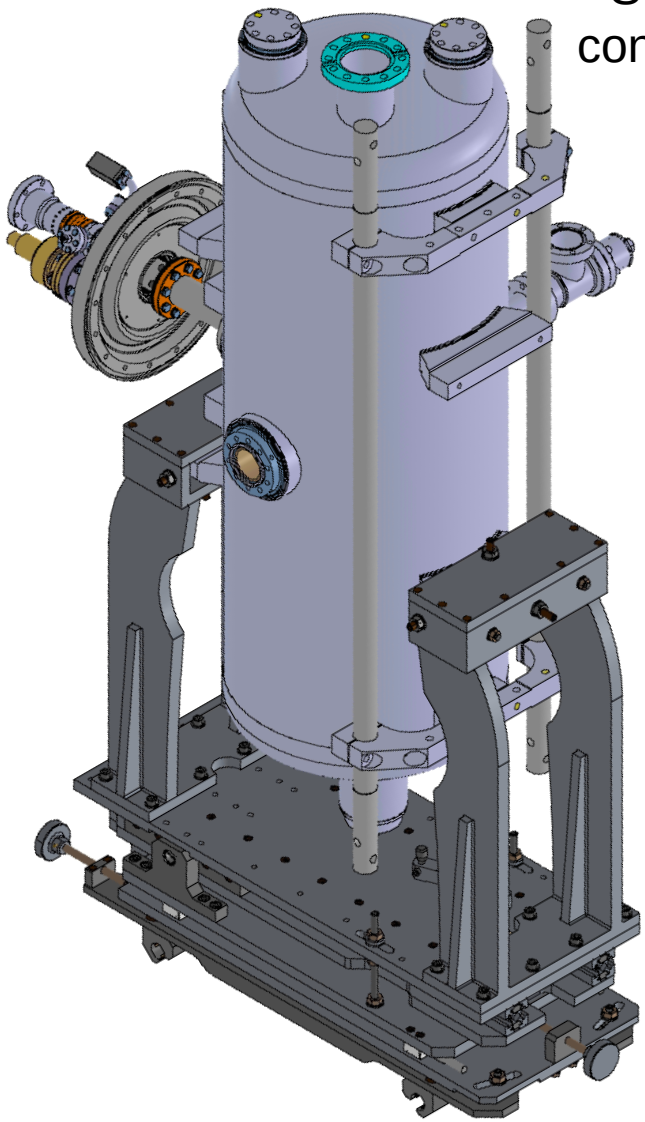




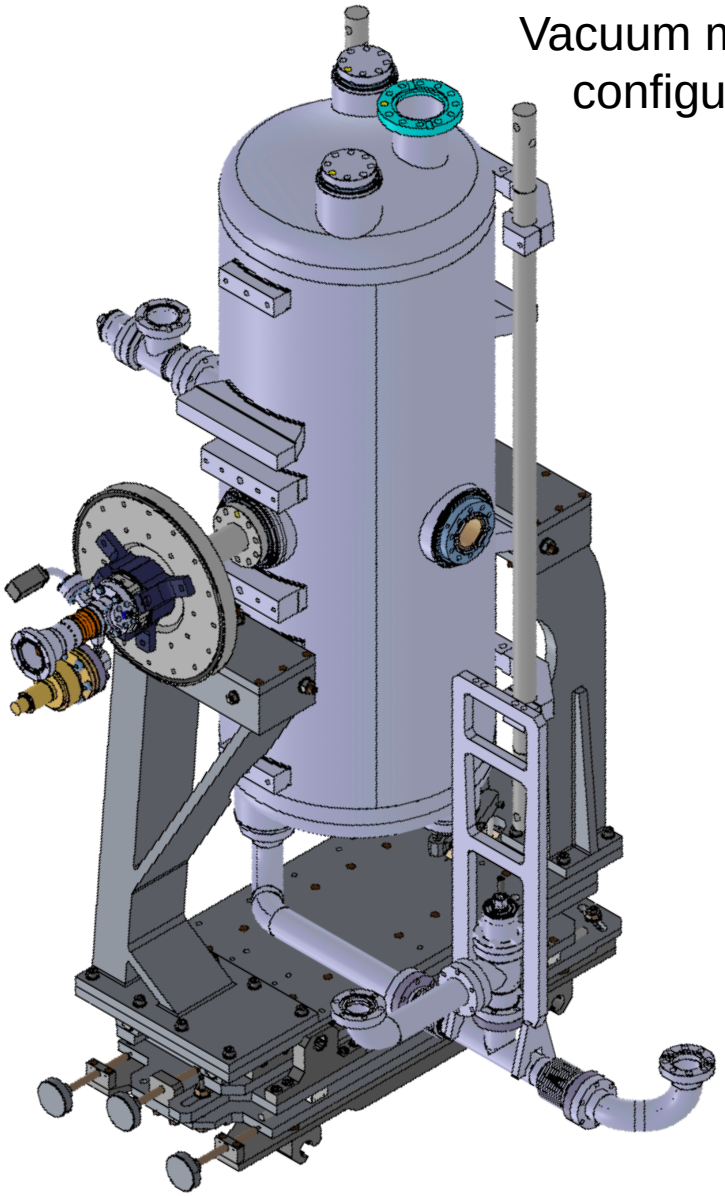
Courtesy of M. Parise

TOOLING: ALWAYS CHECK THE INTERFACES AND INTERFERENCES

Standard configuration

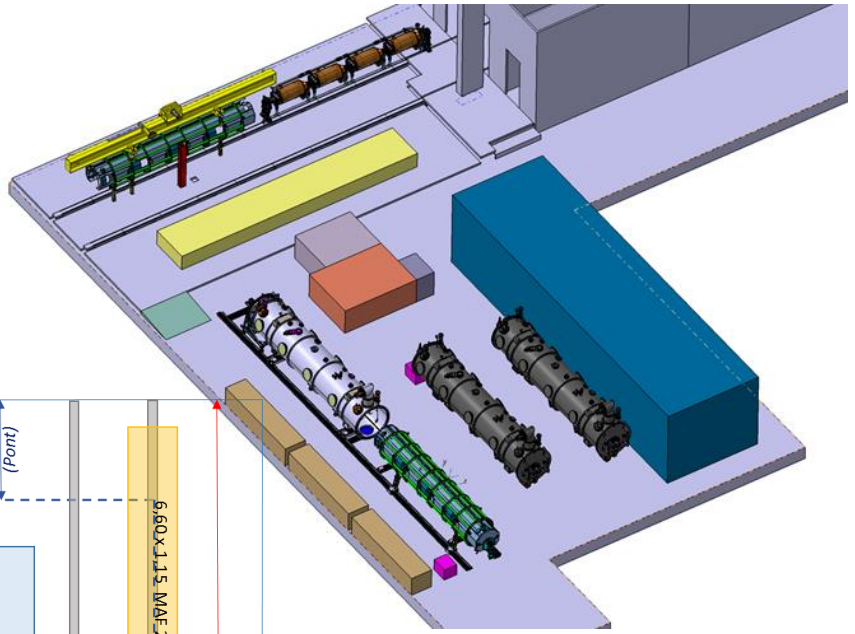


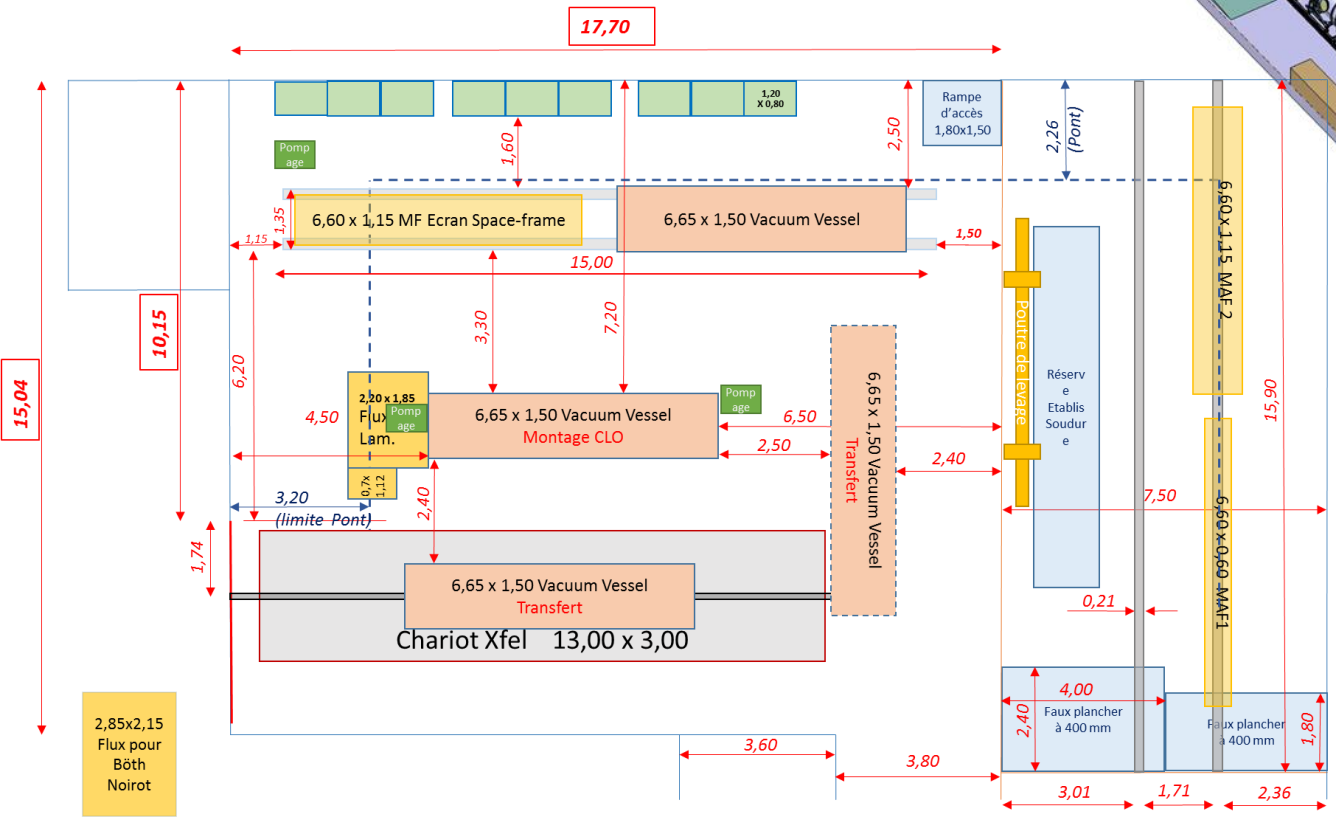
Vacuum manifold configuration



VALIDATION AND FINAL PREPARATION OF ASSEMBLY HALLS

During the tooling development, mock-up tests and prototype, track modifications and check that they will match the assembly halls (lifting equipement, fluids, alignment fiducials) or update.





OFF THE SHELVES

OFF THE SHELVES

- Vacuum group : components off-the-shelves, assembly in house or by a company. Some are the lab ones, other for our partners (ESS, SARAF)
- Laser tracker : components off-the-shelves, one at CEA
- RF bench : existing, need refurbishment for each project including maintenance (because developped and used on XFEL), amplifiers and acquisition prg to be done
- N2 gun, particle counters : maintenance or new
- And more …

QA/QC

ASSEMBLY PROCEDURE

Procédure d'assemblage d'un ensemble cavité coupleur

Cette Fiche d'Instructi

FICHE D'INSTRUCTIONS OI	
	Ré
Fonction	
Nom	
Date	
Signature	

AJOUTER TEST

1. Contenu

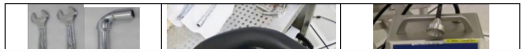
2. Table des matières

3. Moyens

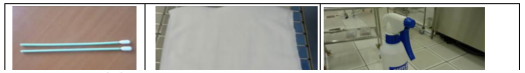
3.1 Prérequis destinés à l'instructeur et aux utilisateurs de la gamme

L'instructeur doit s'assurer que les gammes ASS-COU 01, 02, 06, 03 et 04 sont effectives.

3.2 Outillages de montage et petits outillages



3.3 Pièces, éléments et consommables de montage



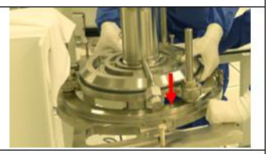
4 Descriptif des opérations

4.1 Préparation du poste et du matériel

- Préparer votre poste de travail en vous assurant que tout le matériel dont vous aurez besoin y est disponible : outillage, visserie et joints nettoyés et contrôlés.

4.2 Réglage et contrôle de la course du plateau cavité coupleur

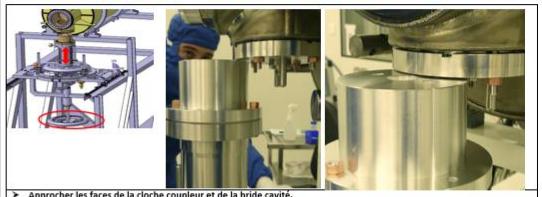
- Déplacer le plateau coupleur sous la cavité pour commencer les premières étapes d'alignements.



- Positionner le plateau en position basse.
- Utiliser le volant tournant sous le banc pour faire descendre le plateau et donc le coupleur.

- Régler la distance à 1mm entre les pions de la bride cavité.
- Effectuer ce réglage en jouant sur les trois vis rotules argentées de réglages du plateau.

4.3 Réglage de la planéité entre bride coupleur et bride cavité



- Approcher les faces de la cloche coupleur et de la bride cavité.
- Utiliser le volant tournant sous le banc pour faire monter le plateau et donc le coupleur.

- Corriger la planéité entre ces deux faces en jouant sur les 3 vis rotules argentées de réglages du plateau.
- Redescendre le plateau et vérifier que la distance pion/cloche est toujours de l'ordre de 1 mm. Si ce n'est pas le cas ajuster cette distance puis re-régler la planéité.

RECORDING

Assembly Report:
Coupler part assembly on cavity - Medium beta -

Template_AR_à definir

1	General Information		
	Team Folder	1_STR	Document Type:
	Manufacturer Name	Commissar. À l'énergie atomique	Assembly Report
	Location	COU : Coupler-Cavity assemby in ISO 4	

2	Part Information					
	Part	PBS ID	Part Name (Part Type)			Quantity
	Assembly	ce code n'existe pas dans le PB	CCC: Cavity + Cold Coupler			---
	Component 1	3.1.0.0.0.0.0	Cavity M-Beta			(x1)
	Component 2	3.2.0.0.0.0.0	Coupler M-Beta			(x1)

3	Validation by Technician & Integration Manager		
		Technician	Integration Manager
	Name		
	Date (Ctrl + . ;)		

Operation Sequence				
Designated		Serial No.	MBL-CM	M-ECCTD
		Serial No.	CCC	
1	Cavity M-Beta	Serial No.		
	Coupler M-Beta	Serial No.		
	Nom d'enregistrement du fichier:	#REF!		

	Action			Fix Text	Validation
2	Cleaning Alu gasket *Nettoyage joint aluminium*	Particle Count No . *Compteur de particules N°.*		Recording No . *Enregistrement N° .*	
	Cleaning threaded rods *Nettoyage tiges filetées*	Particle Count No . *Compteur de particules N° .*		Recording No . *Enregistrement N° .*	
	Cleaning nuts *Nettoyage écrous*	Particle Count No . *Compteur de particules N° .*		Recording No . *Enregistrement N° .*	
3	Check for proper antenna orientation on coupler: *Vérification de l'orientation de l'antenne coupleur :*				
4	Cleaning antenna *Nettoyage de l'antenne*	Particle Count No . *Compteur de particules N° .*		Recording No . *Enregistrement N° .*	
5	Blowing cavity flange *Soufflage trou de bride cavité*	Particle Count No . *Compteur de particules N° .*		Recording No . *Enregistrement N° .*	

6	Additional Comments *(Remarques suplémentaires)* :

Assembly Report:
Coupler part assembly on cavity - Medium beta -

Template_AR_à definir

1	General Information		
	Team Folder	1_STR	Document Type:
	Manufacturer Name	Commissar. À l'énergie atomique	Assembly Report
	Location	COU : Coupler-Cavity assemby in ISO 4	

2	Part Information					
	Part	PBS ID	Part Name (Part Type)			Quantity
	Assembly	ce code n'existe pas dans le PB	CCC: Cavity + Cold Coupler			---
	Component 1	3.1.0.0.0.0.0	Cavity M-Beta			(x1)
	Component 2	3.2.0.0.0.0.0	Coupler M-Beta			(x1)

3	Validation by OPERATOR & Integration Manager		
		OPERATOR	Integration Manager
	Name	CYRIL BOULCH & ADRIEN BOUYGUES	S. BERRY
	Date (Ctrl + . ;)	25/01/17	

Operation Sequence				
Designated		Serial No.	MBL-CM	M-ECCTD
		Serial No.	CCC	001
	Cavity M-Beta	Serial No.	ESS 067	P02
1	Coupler M-Beta	Lot No.	PMB	PMB 1002-001
	Nom d'enregistrement du fichier:	#REF!		

	Action			Fix Text	Validation
2	Cleaning Alu gasket *Nettoyage joint aluminium*	Particle Count No . *Compteur de particules N°.*	1	Recording No *Enregistrement N°*	2714
	Cleaning threaded rods *Nettoyage tiges filetées*	Particle Count No . *Compteur de particules N° .*	1	Recording No *Enregistrement N°*	2711
	Cleaning nuts *Nettoyage écrous*	Particle Count No . *Compteur de particules N° .*	1	Recording No *Enregistrement N°*	2691
3	Check for proper antenna orientation on coupler: *Vérification de l'orientation de l'antenne coupleur :*				OK
4	Cleaning antenna *Nettoyage de l'antenne*	Particle Count No . *Compteur de particules N° .*	6	Recording No *Enregistrement N°*	1367
5	Blowing cavity flange *Soufflage trou de bride cavité*	Particle Count No . *Compteur de particules N° .*	6	Recording No *Enregistrement N°*	1337

6	Additional Comments *(Remarques suplémentaires)* :

début : 9h30
4 vis enlevées de la bride coupleur de la cavité pour nettoyage des taraudages (photos). Vis remplacées par des propres TEMPORAIRES ==> Les écrous/vis sont soufflés comptés pour les temporaires et les premières (pas toutes) pour nettoyage de cette bride, 2 postes de nettoyage/comptage ont été mis en place.
Desassemblage du coupleur sur la boite avec outillage temporaire (fourches) prise sur la grande bride du tube double paroi
nettoyage et comptage de particule sur antenne et bride cavité du coupleur : en position verticale (antenne vers le bas)
Réf de l'antenne coupleur : PMB 1002-001 associé à tube double paroi PMB 1002-003
goujons M8x50 : ne permet pas de faire un serrage au couple. suggestion d'utiliser des VIS CHC M8x35 argentés
Seuls les goujons ne pouvant pas être serrés à la clé de 13 (côté cavité) sont changés par des vis CHC M8x35 argentés pour finir le serrage. (serrage effectué à 20N.m-1 pour l'ensemble des goujons et vis)
a la descente du plateau, risque de de contact de la jauge avec le plateau. solution : déplacement du plateau latéralement pour donner plus d'espace autour de la jauge et permettre l'abaissement du plateau de l'outillage d'assemblage. point critique
fin assemblage 17H

THANKS FOR YOUR ATTENTION

Commissariat à l'énergie atomique et aux énergies alternatives
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Etablissement public à caractère industriel et commercial | R.C.S Paris B 775 685 019

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