Working Group Title Summary

Olivier Napoly

2nd PIP-II Technical Meetings Closeout

July 25, 2022

PIP-II is a partnership of:
- US/DOE
- India/DAE
- Italy/INFN
- UK/STFC-UKRI
- France/CEA, CNRS/IN2P3
- Poland/WUST

Session Agenda Overview: HB650 CM production (J. Ozelis chair)

Tuesday, 12-July 2022

Talk #	Title	Presenter	Affiliation	Duration	Discuss	Start	End
1	Introduction, Goals of WG#1	J. Ozelis	FNAL	0:10	0:02	9:30	9:42
2	Status of HB650 Prototype CM Assembly	C. Grimm	FNAL	0:30	0:12	9:42	10:24
	Break - 10min			0:10	0:00	10:24	10:34
3	Summary of HB650 String Assembly Lessons Learned Meeting	J. Ozelis	FNAL	0:20	0:10	10:34	11:04
4	Current Non-Conformances and Lessons Learned from CM Assembly	V. Roger (rmt)	FNAL	0:30	0:15	11:04	11:49

Wednesday, 13-July 2022

Talk #	Title	Presenter	Affiliation	Duration	Discuss	Start	End
5	Description of the FNAL Non-Conformance/Discrepancy Reporting Process	M. Luedke	FNAL	0:15	0:05	8:00	8:20
6	Open Issues with HB650 CM Design - Changes for Production	V. Roger (rmt)	FNAL	0:30	0:20	8:20	9:10
7	Status of and Open Issues with LB650 CM Design	R. Cubizolles	CEA	0:45	0:20	9:10	10:15
	Break - 15min			0:15	0:00	10:15	10:30
8	Status of CM Assembly Infrastructure at CEA	J. Drant	CEA	0:30	0:15	10:30	11:15
9	Status of CM Assembly Infrastructure at UKRI	M. Pendleton	UKRI	0:20	0:10	11:15	11:45

Thursday, 14 July 2022

Talk #	Title	Presenter	Affiliation	Duration	Discuss	Start	End
10	Status of CM Development at RRCAT	P. Khare	RRCAT	0:30	0:15	8:00	8:45
11	Results from transport testing, lessons learned	J. Holzbauer	FNAL	0:30	0:15	8:45	9:30
12	Open for discussions as requested			2:30	0:00	9:30	12:00
13	WG1 Summary - via Email	O. Napoly	FNAL	0:00	0:00	12:00	12:00

Charles Grimm, *Status of HB650 Prototype CM Assembly*

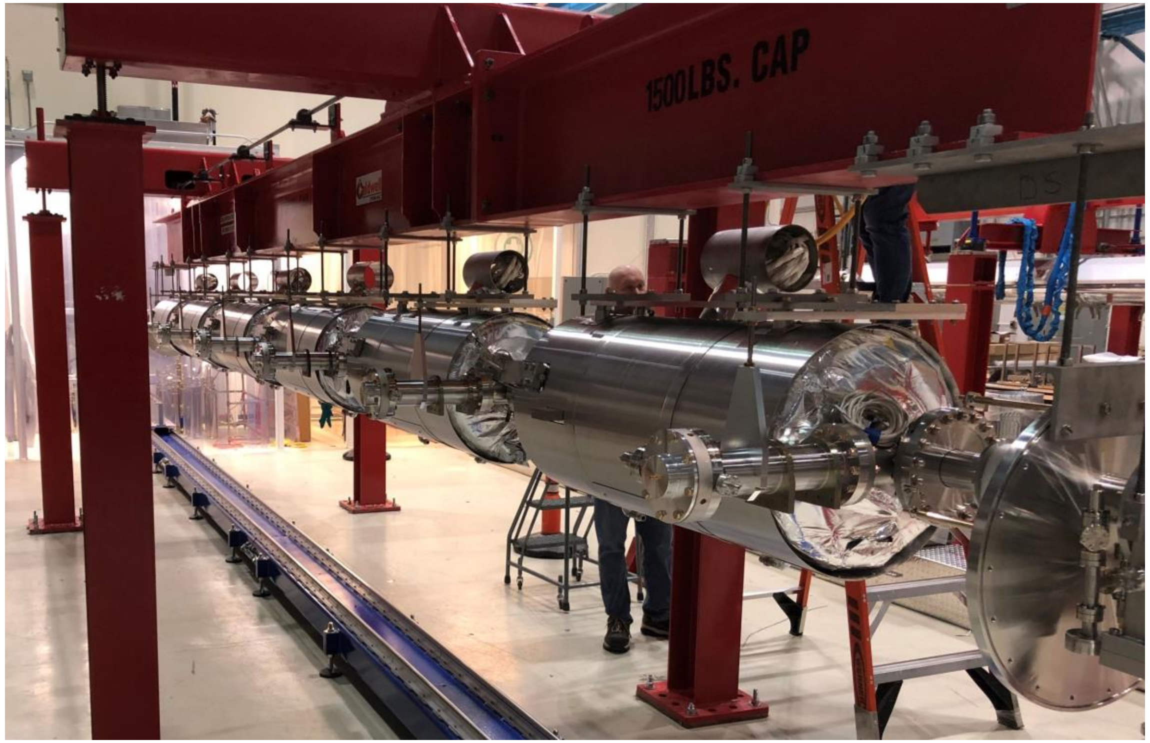
String Details

- Mixture of B92 and B90 cavities
- Four cavities with internal instrumentation
- All Cavities dressed at FNAL

4 July 12, 2022 C. Grimm | PIP-II 2nd Technical Workshop July 12-14, 2022 PIP-II

Phase 1A: Beam Line Assembly

- Lift String From the Cleanroom Stands
  - Disconnect connections of cleanroom stands and back off alignment screws
  - Slowly lift until loose from cleanroom stands
  - Move stands back into the cleanroom



Phase 1B: Strongback Fitment and Assembly

- Straddle Vacuum Vessel over Rails
  - Align and level vacuum vessel over rails to except strongback for fitment test
  - Vessel resting on eight 6 ton leveling jacks
    - Four used for leveling
    - Four used for additional stability

Key Takeaways / Lessons Learnt / Open Issues

- Rails alignment is key for smooth roll-in and roll-out
- PIP-II rails at Fermilab/MP9 are larger the LCLS-II/XFEL and improved greatly the cold mass stability to roll angle.
- Alignment of rails, lifting tool, SB, VV : ideally provide enough length for

  ‘string under lifting tool’ -- ‘strongback’ -- ‘VV’ on rails, or along the rail axis
- Alternatively provide 2 separate workstations:
  - ‘string under lifting tool’ -- ‘strongback’ on rails
  - ‘strongback’ -- ‘VV’ on rails, or along the rail axis
- Lifting tool works fine.
- Use pre-manufactured MLI blankets for cavities and 40 K thermal shields.
- Tuner preloading, procedure, customization and assembly tooling is complex, not discussed enough.
- Many collisions between tuners and cavity magnetic shields, to be fixed.
- Strongback and VV alignment (pre-fitment and roll-in) will be facilitated by ‘H-moving supports’.

Joe Ozelis, *HB650 pCM String Assembly Lessons Learned*

Lessons Learned - Room pressure difference > 5 mbar.

- **Issue #16**
  - The room pressure difference was larger than the 5 mbar. When the cavity pressure at the center of the room was 5-mbar higher than the corner pressure, it tricked the control software to stop purging. The purging will not activate if the cavity pressure is >5mbar above the ambient.
- **Root Cause**
  - No prewarning about the pressure difference. The design did not consider that. A mock-up test may not capture the failure.

Ambient pressure was measured near the corner of the cleanroom

Cavity pressure was measured near the center of the cleanroom

24 12-July, 2022 PIP-II 2nd Technical Workshop | WG1 | J. Ozelis, HB650 pCM String Assy Lessons Learned Summary PIP-II

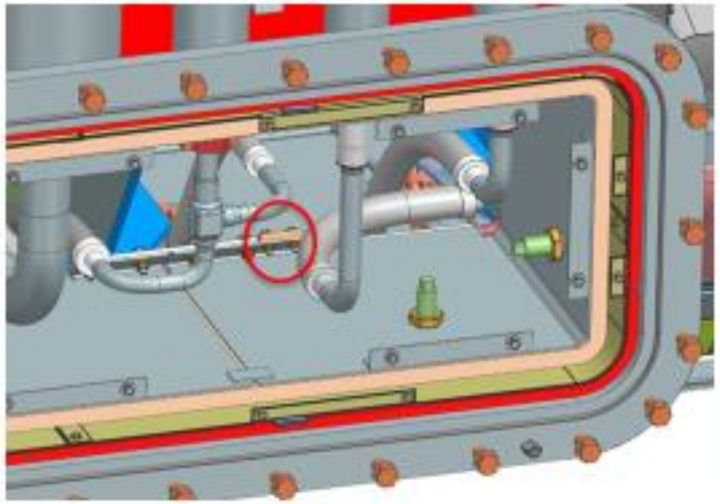
Key Takeaways / Lessons Learnt / Open Issues: high view

- Prior to start of production string assembly, clean room **infrastructure and equipment** should be properly **commissioned** as to:
  - Cleanliness
  - Operability
  - Error handling
- Prior to start of production string assembly, **assembly tooling** should be proven operational and global coherence with the **working ergonomics** should be checked in real life (mock-up assembly, operator training, etc.)
- Detailed summary provided in Joe's presentation, with emphasis on early Quality Control

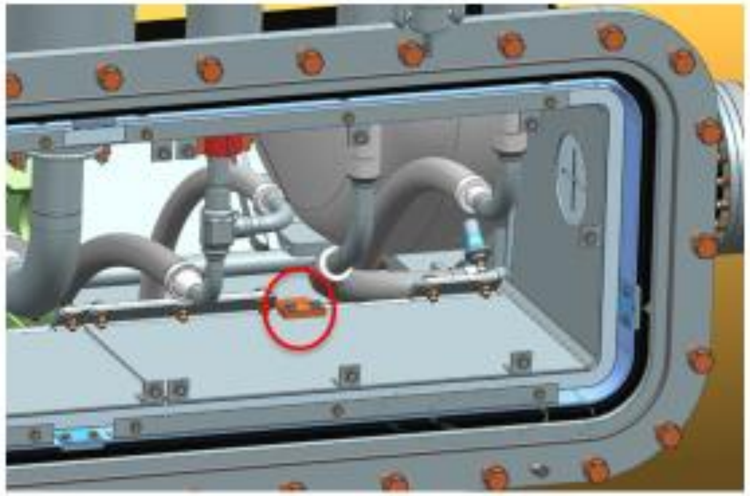
Vincent Roger, *HB650 CM - Design optimization*

HTTS

The location of the thermal strap connecting the main part of the HTTS to the side part will change to improve the thermal contact (this optimization is already designed for SSR2 ppCM). Better performance – Heat loads.



HB650 CM



SSR2 CM

Fermilab

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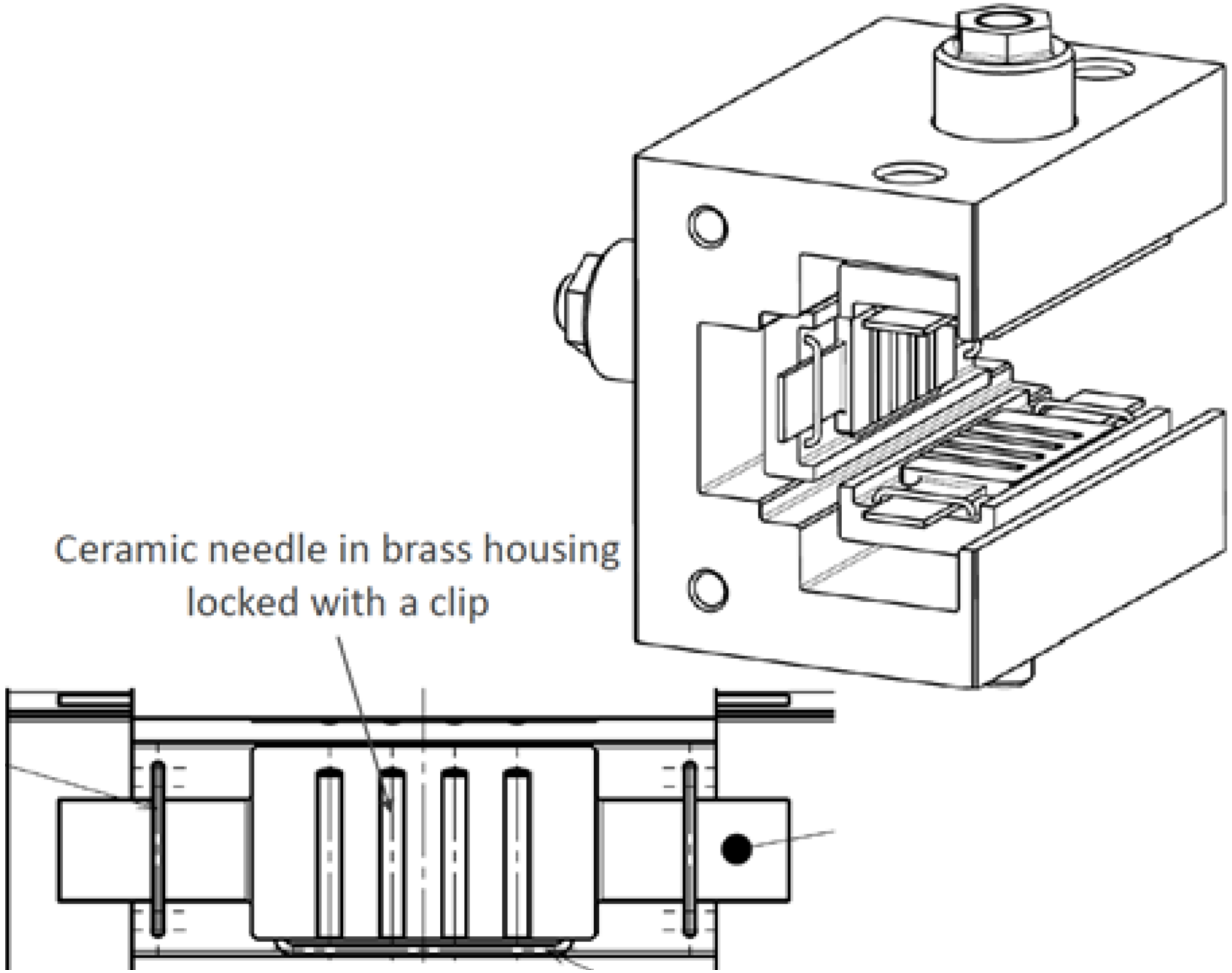
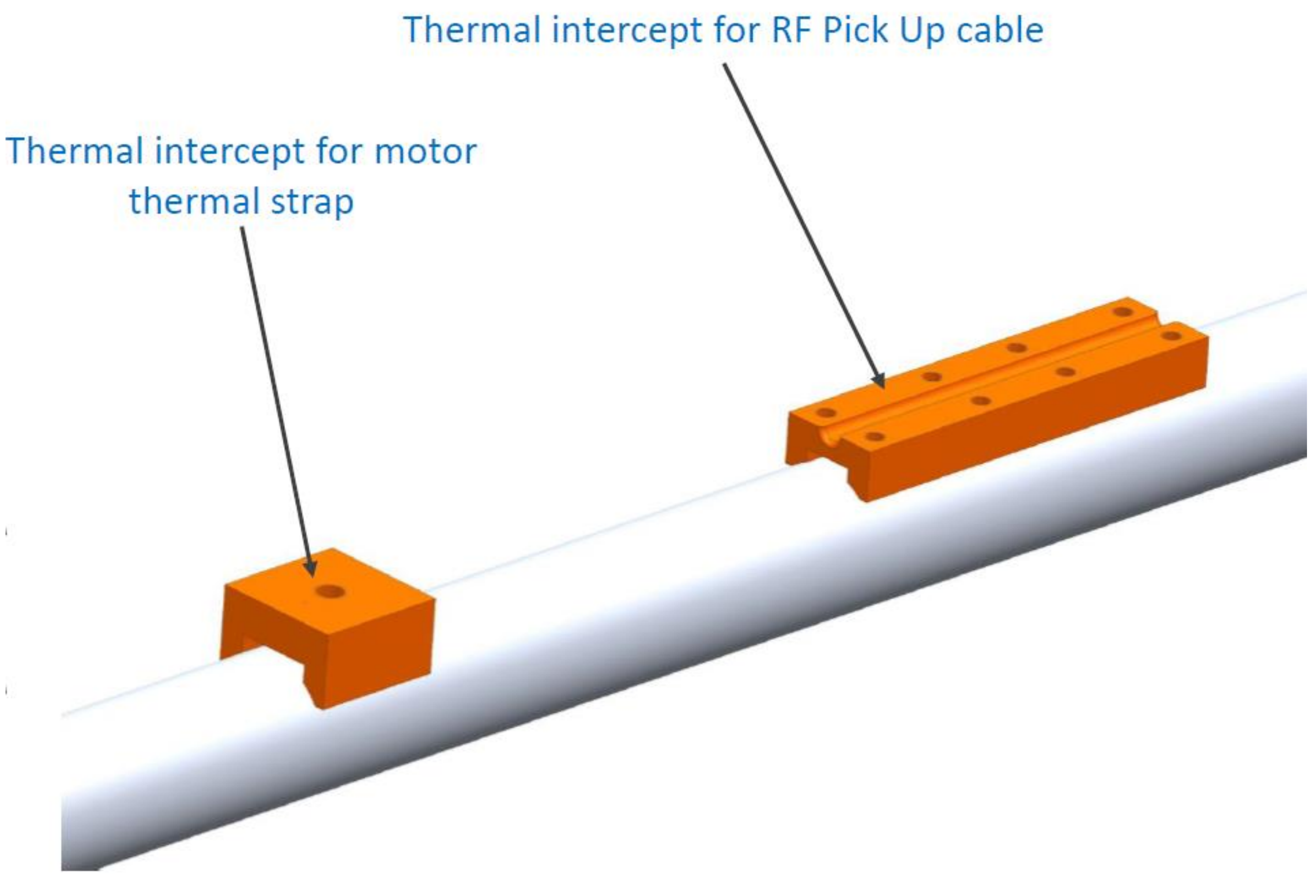
C-Brackets & cavity support

- **The C-Brackets design should be optimized based on CEA design on the LB650 CM.** **Better magnetic hygiene & easier assembly process.**



LTTS

- **Thermal intercept may be improved based on CEA design.** **Better performance – Heat loads.**



Key Takeaways / Lessons Learnt / Open Issues

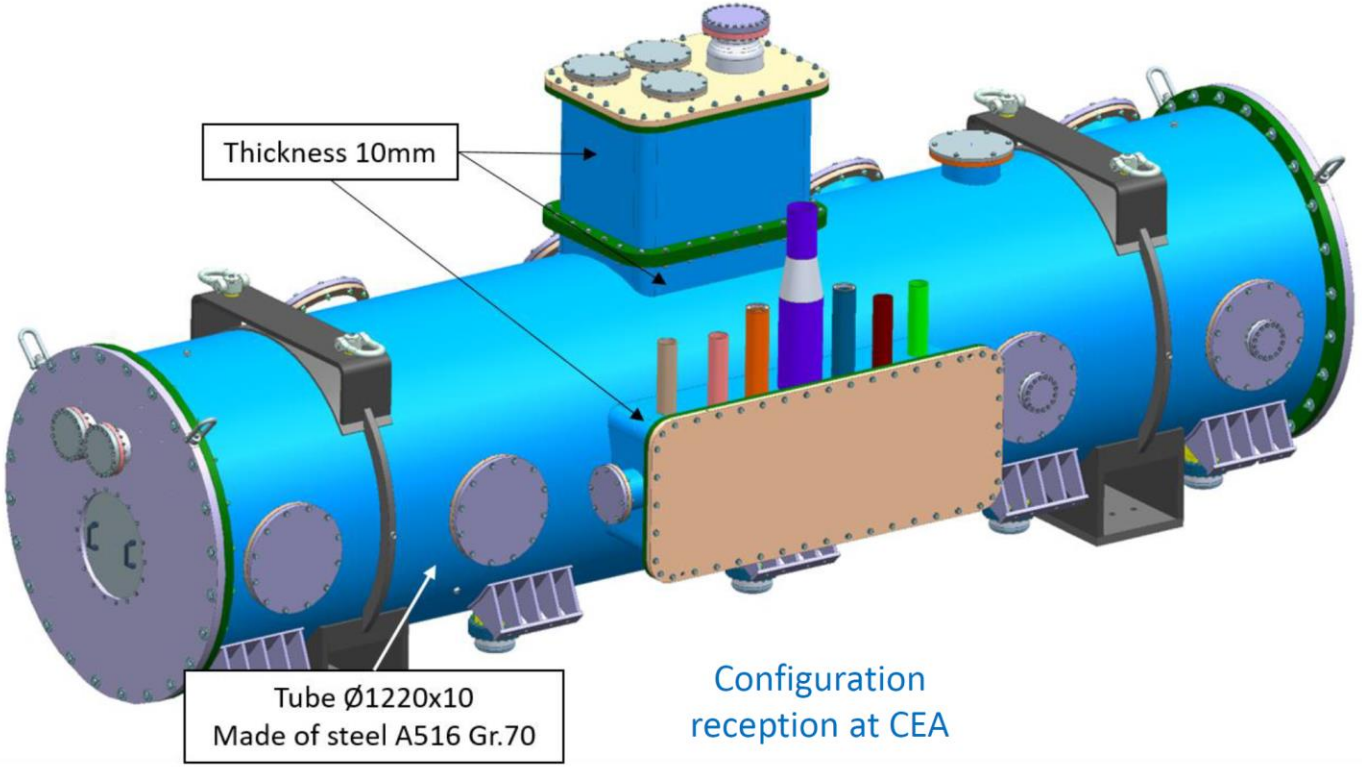
- About 30 different items underwent 'design optimization', which is pursued very actively, while pCM is being assembled.
- The 'joint Fermilab-CEA design team' proves quite efficient and beneficial, with many crossed **inputs with the ongoing SSR2 design activity**. ☺☺
- Particular attention in identifying, intercepting and reducing **static heat loads**.
- Design improvements to the local and global magnetic shields are already underway.

Robin Cubizolles, Status of and Open Issues with LB650 CM Design

Vacuum vessel

Vacuum vessel main dimensions

- ❑ Calculation in compliance with ASME BPVC Section VIII on going.
- ❑ All part in 304L except the main tube in steel A516 Grade 70. The top port and side port are in 304L.

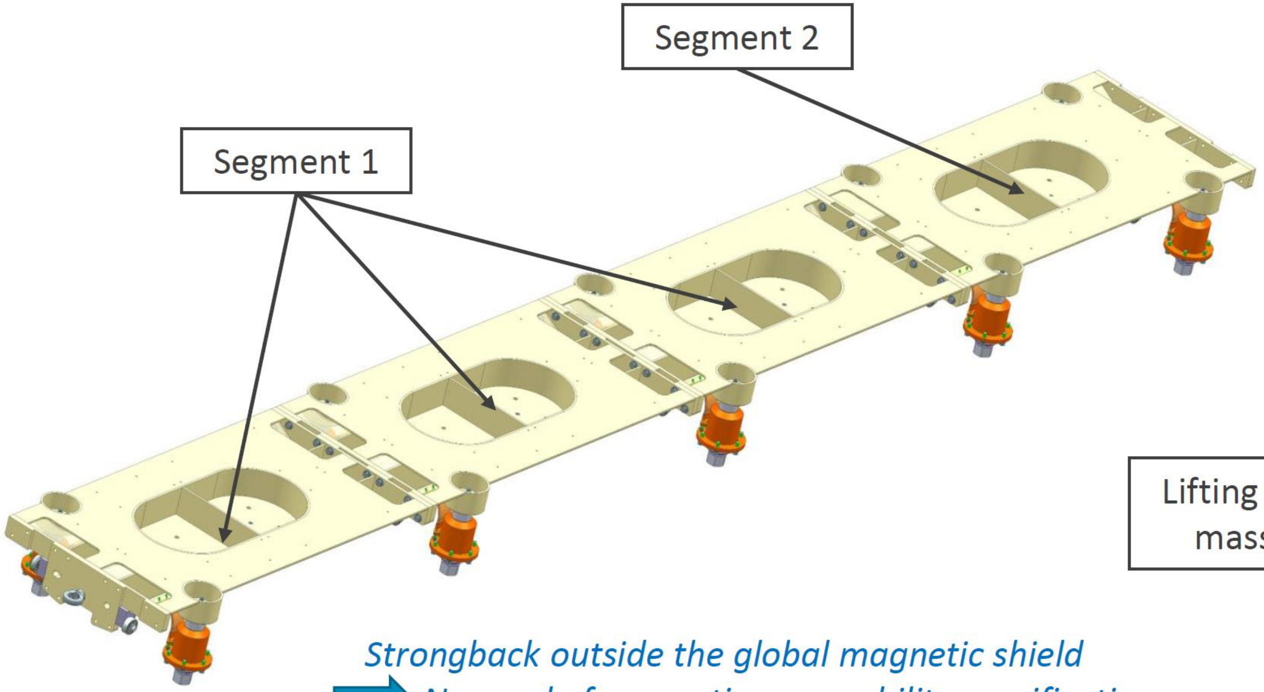


Configuration reception at CEA

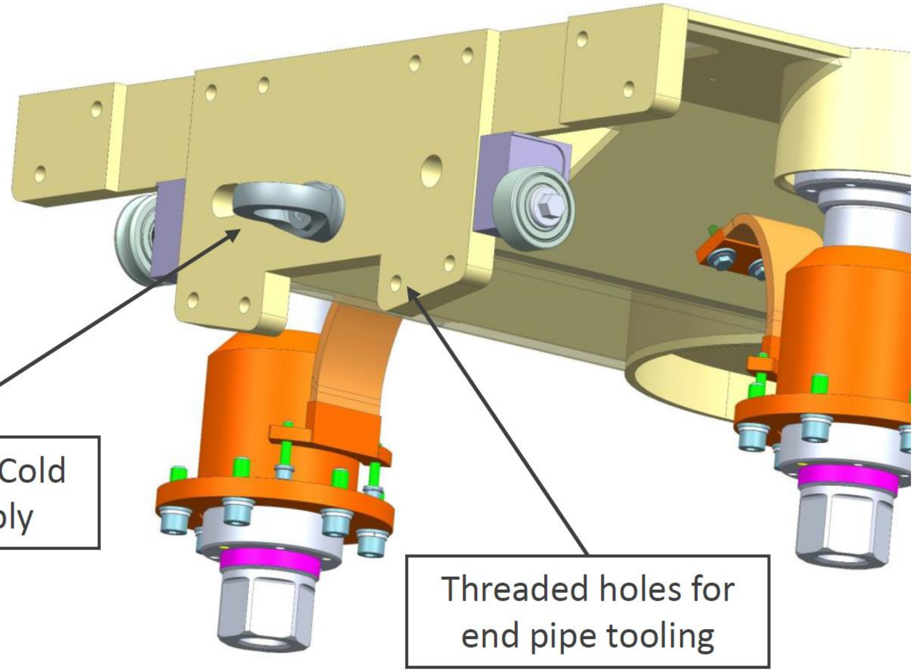
Strongback

Design similar to the HB650, made of two types of segments

- Made of stainless steel 316L.
- Interface for the cold mass assembly.
- Tooling interfaces for the strongback assembly.
- Simulations for displacement, stress and screws dimensioning are on-going (taking into account the HB650 REX assembly).



Strongback outside the global magnetic shield
→ *No need of magnetic permeability specification*

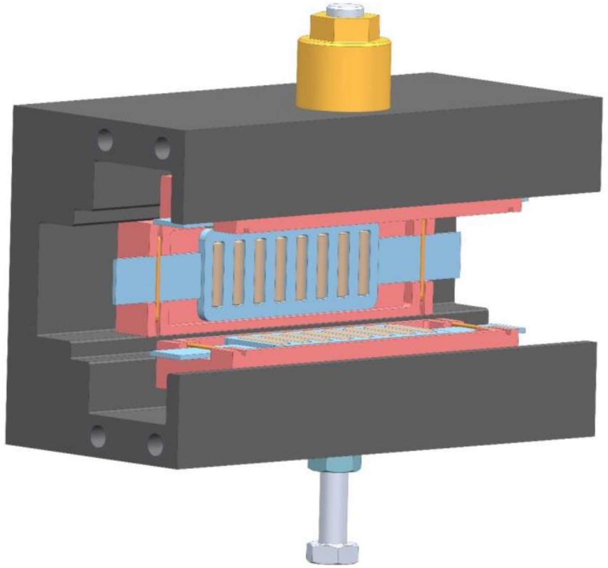


C-Shaped element

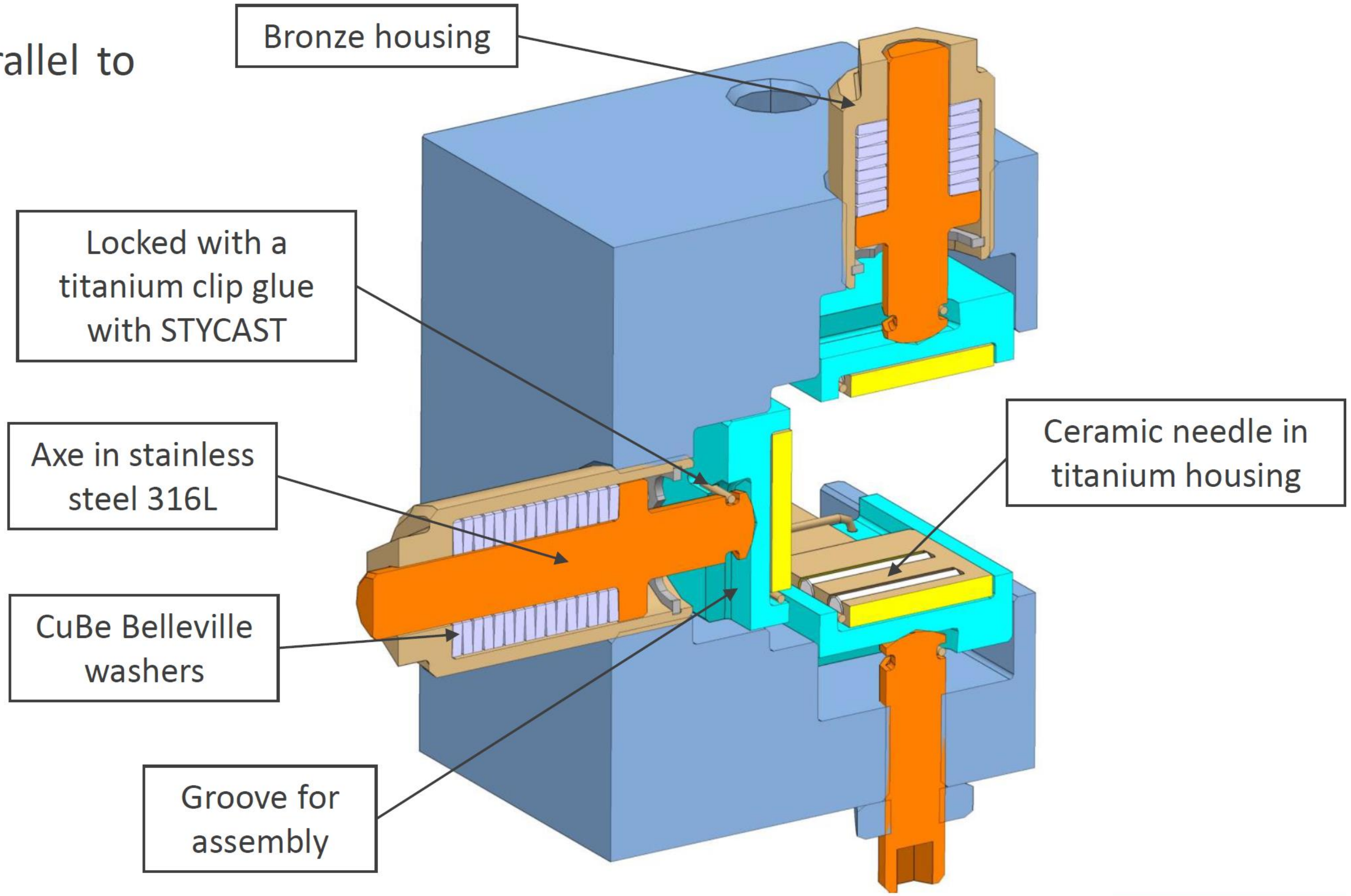
Small modifications of the HB650 design

- Limitation of the use of Stainless steel for magnetic hygiene.
- Completely assembled on a table in parallel to the cryomodule assembly.

FNAL C shaped element



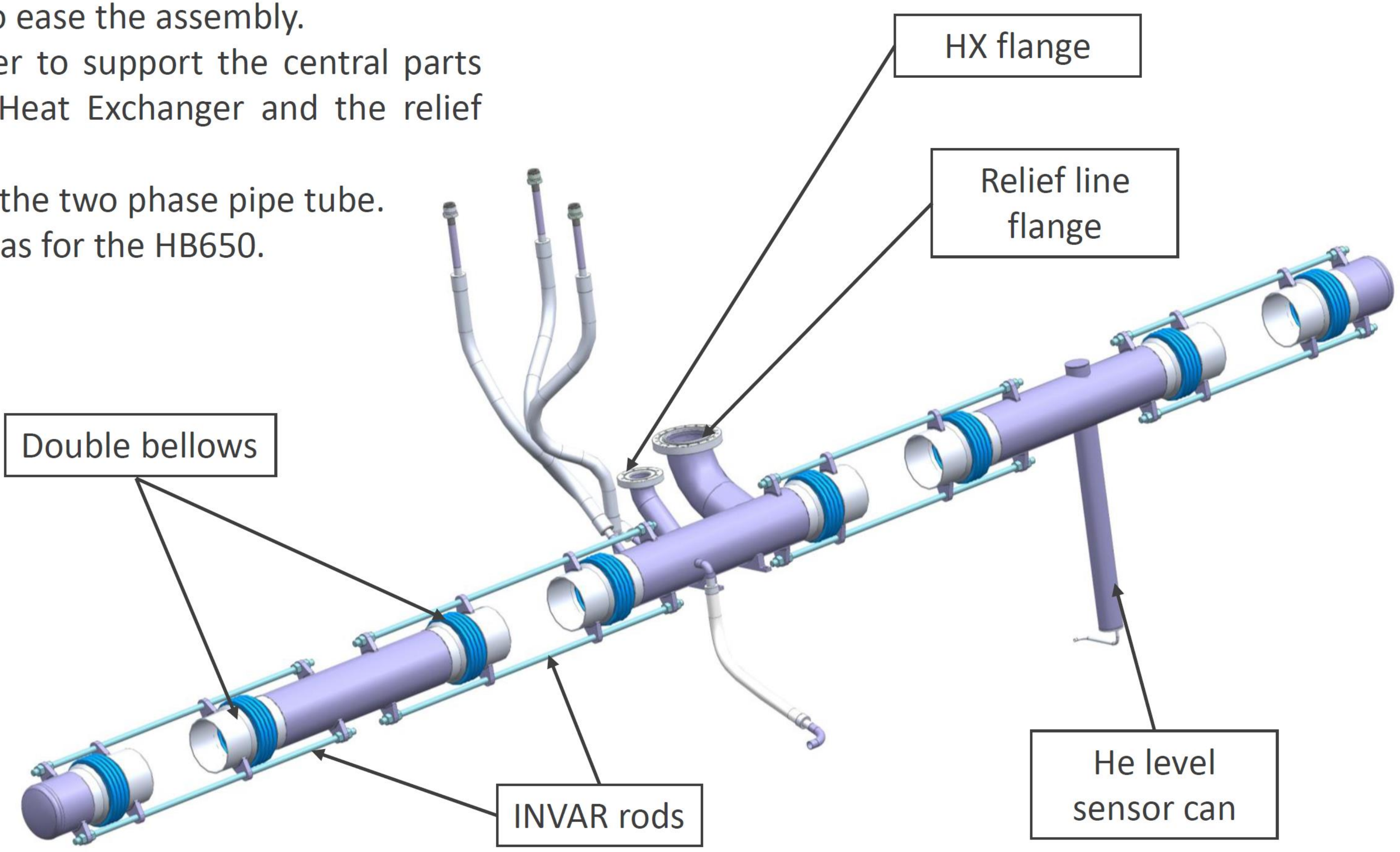
Proposed design



Two phase pipe

Two phase pipe design

- Double bellows in order to ease the assembly.
- G11 support used in order to support the central parts (with the weight of the Heat Exchanger and the relief line).
- Inlet on the upper part of the two phase pipe tube.
- A baffle have been added as for the HB650.

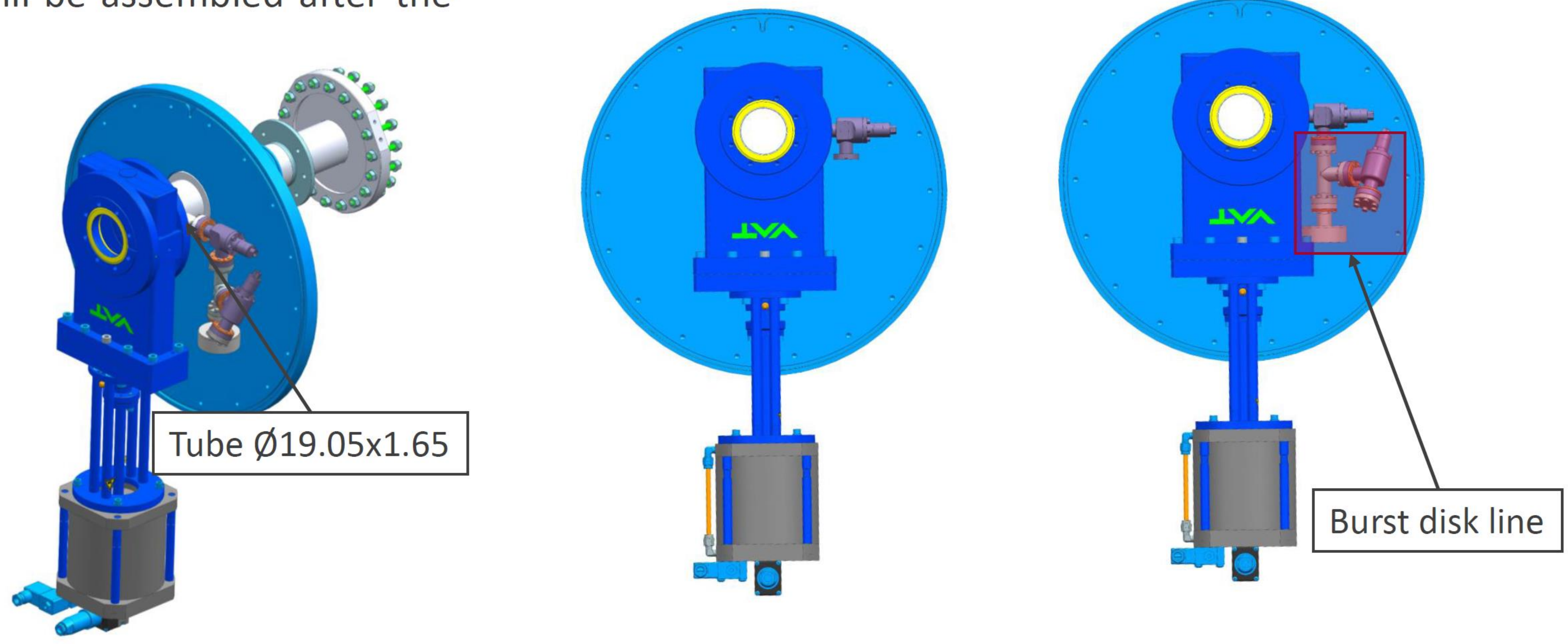


Proposition of end pipe tube modification in order to ease the clean room and the end cap assembly.

- ❑ Orientation of the burst disk line on the horizontal plane.
- ❑ The Burst disk line will be assembled after the end cap assembly.

Configuration for clean room assembly

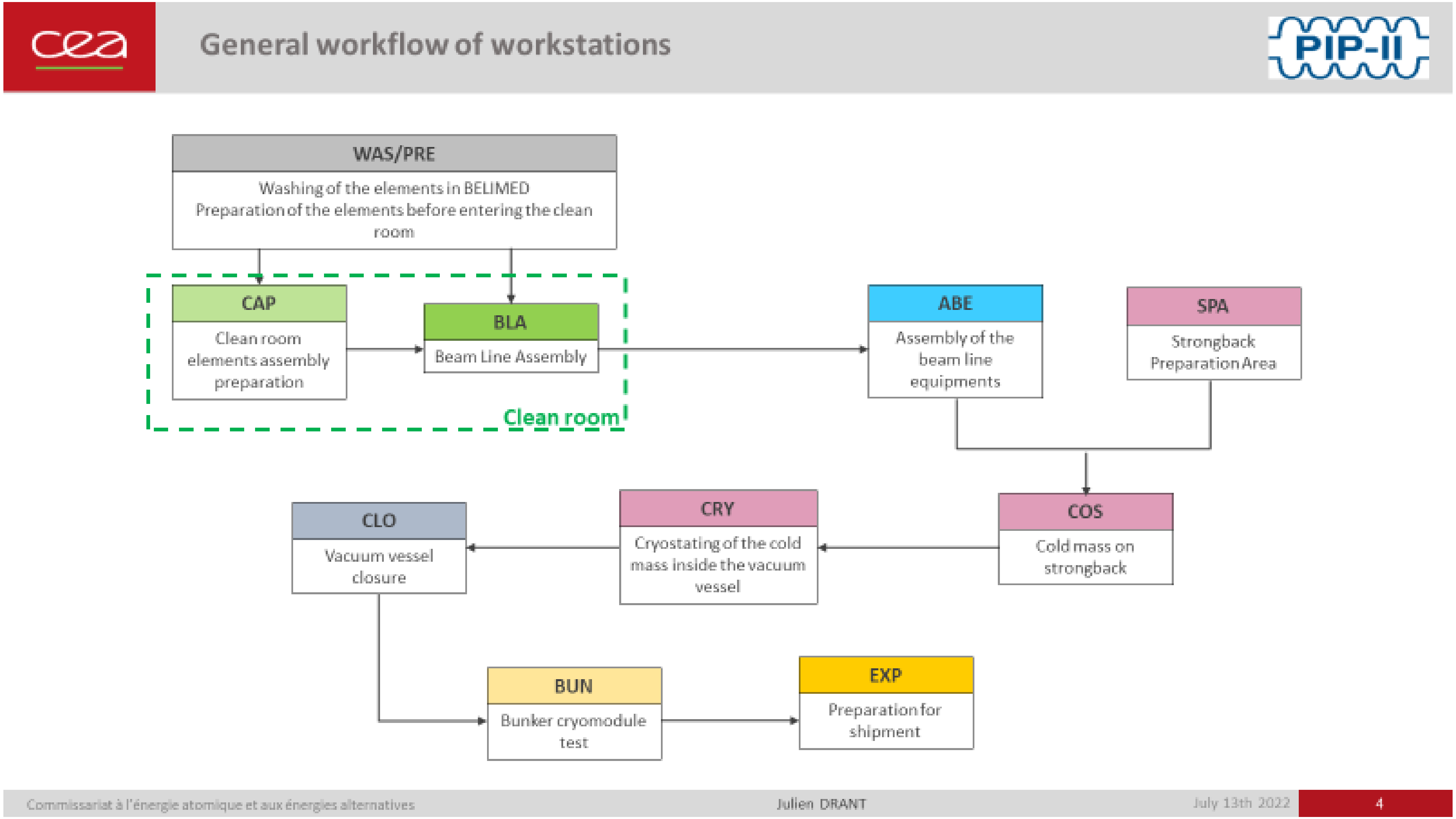
Final configuration



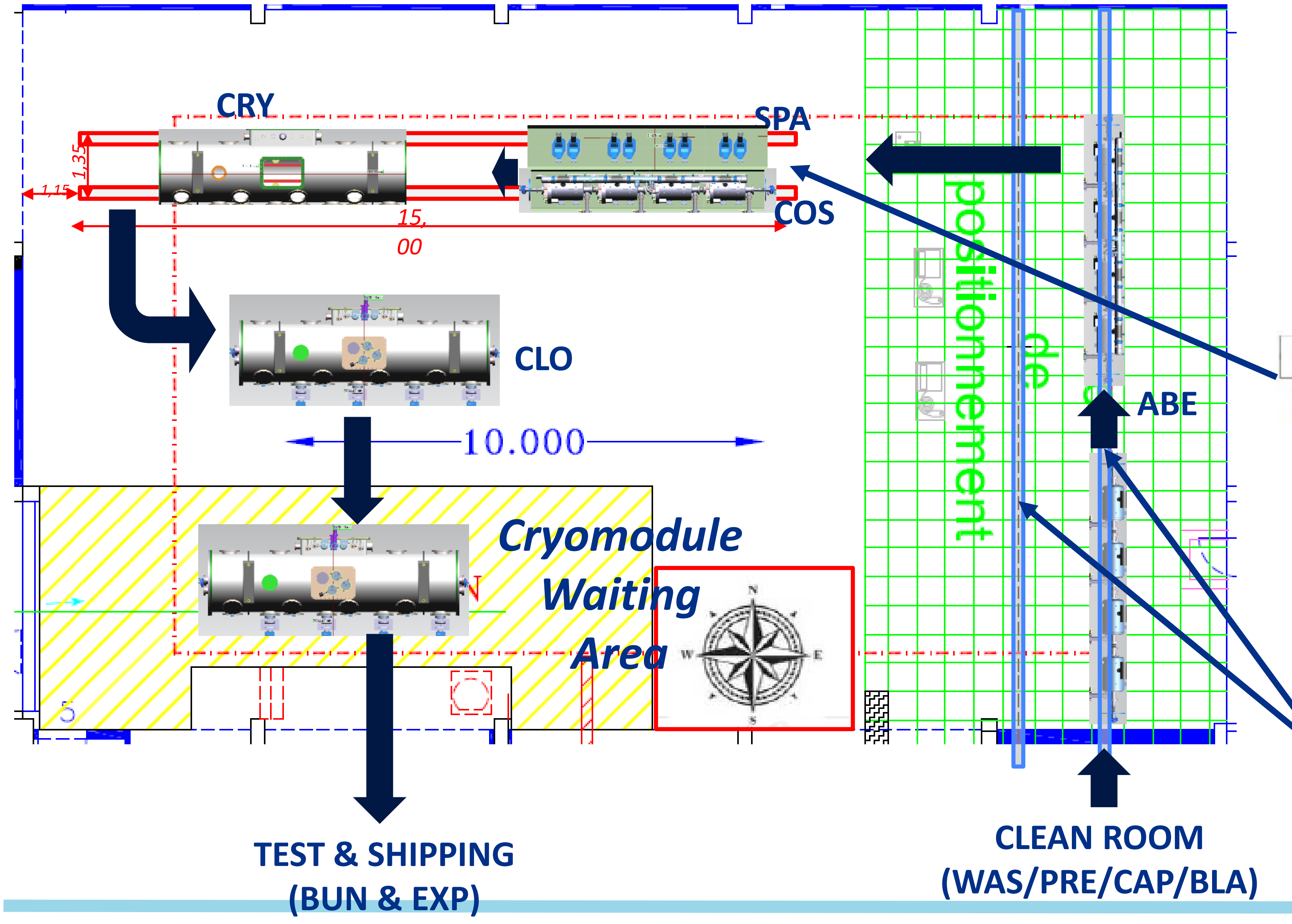
Key Takeaways / Lessons Learnt / Open Issues

- LB650 pre-production cryomodule design is very advanced, including mechanical and thermal calculations.
- Some design aspects are specific to LB650 cavities and ppCM cryomodule.
- Some design features can be transposed on the production HB650 design.
- Constant and high-quality communication between LB650 and HB650 designers must be maintained for the best advantage of the 650 sector.

Julien Drant, *Status of LB650 CM Assembly*

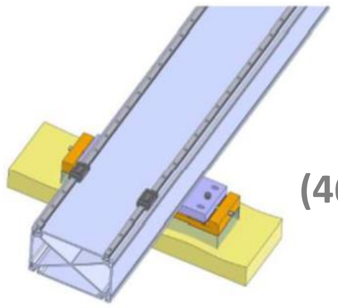


Geographical location of the assembly workstations



Detailed view of the layout of the various assembly stations within the assembly hall, based on the layout of the ESS project

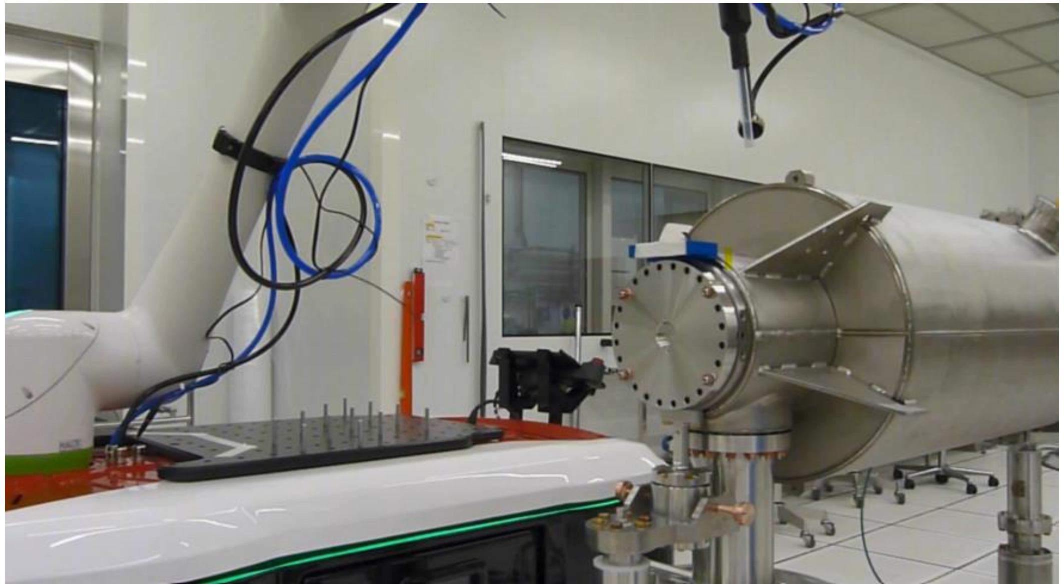
East to west rails (15m)
Strongback and vacuum vessel



South to North rail
(46m) for the beam line

Flange Cleaning Procedure : Robot Assistance

- A current R&D project aims at developing the use of robot assistance during flange cleaning phases
- All flange/holes cleaning steps could be realized with a robot assistance
- A pre-cleaning step is realized with lint free cloth
- The robot is equipped with Ionized nitrogen blower and a particle counter
- The cleaning process is carried out until the targeted cleanliness criterion is validated
- Slow implantation in ESS clean room production workflow

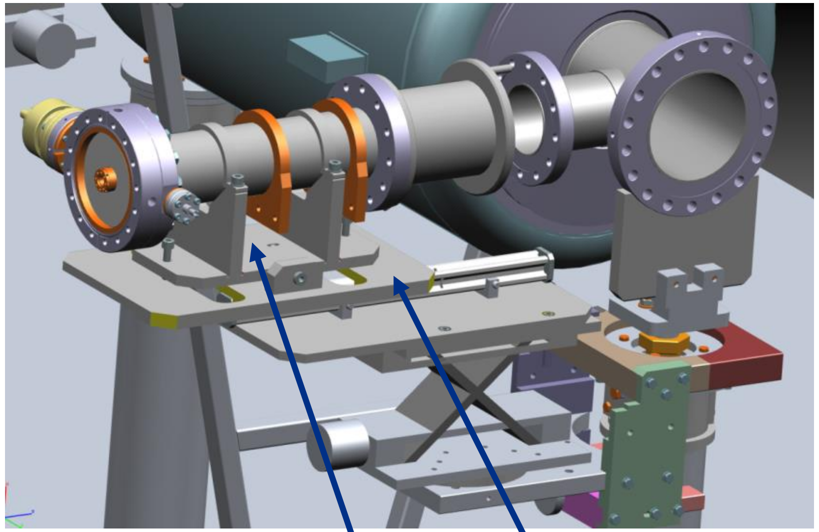


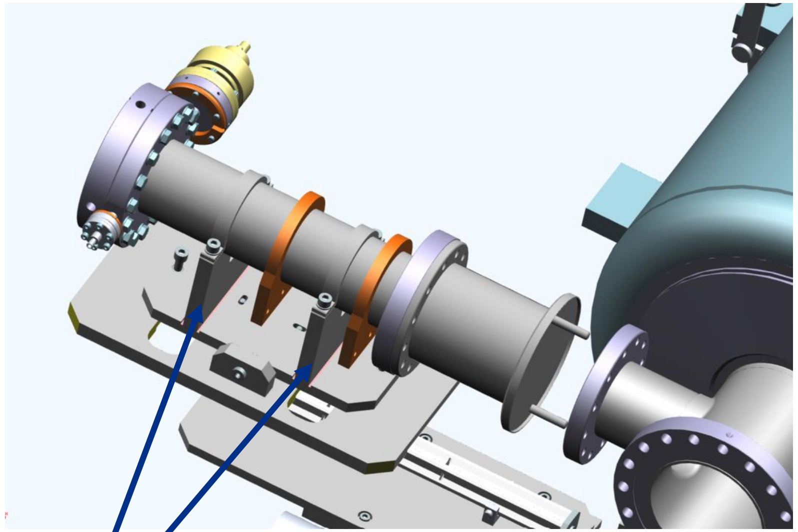
Flange cleaning procedure can be used in LB650 clean room assembly workflow with the ESS experience

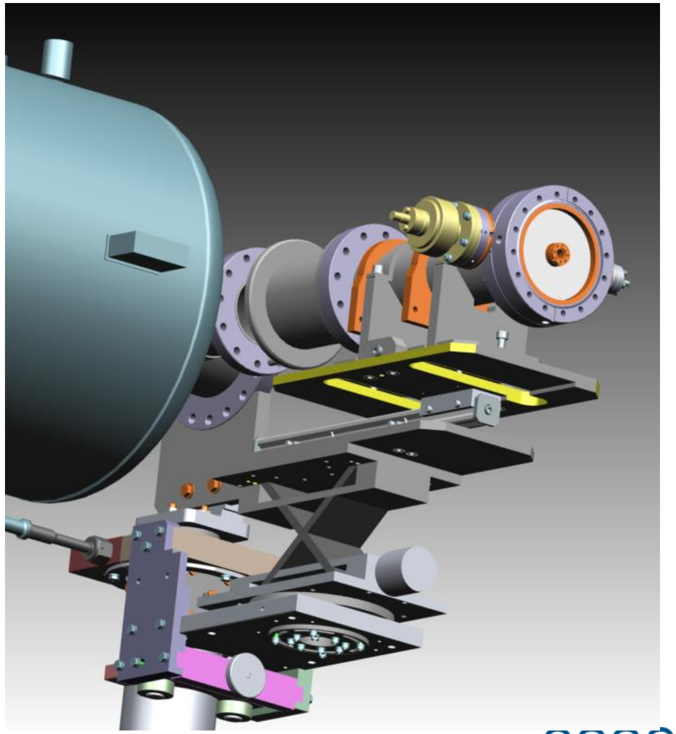
Assembly tooling

- Some tooling for the assembly steps are designed or in design finalization.
- They are inspired by previous CEA projects (XFEL, ESS,…) and the experience from PIP-II pCM HB650
- Aluminum/Polymers is favored over stainless steel for parts that will be handled regularly or on which the stresses remain low

Alignment tooling for cavity/coupler connection







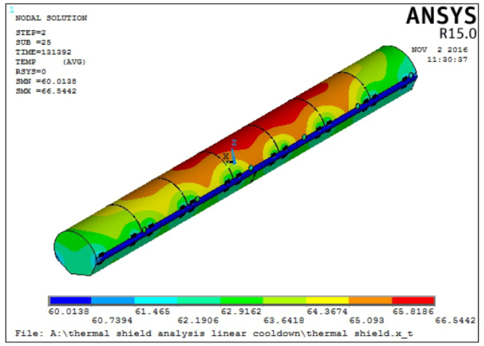
Key Takeaways / Lessons Learnt / Open Issues

- Assembly work flow is defined in the clean room and assembly hall currently operated by CEA for ESS
- Strong CEA effort in tooling definition and optimization, including cobot
- **Ideally, the best tooling between CEA and Fermilab designs, should be decided and shared with the other partners, with an obvious impact on procedures.**
  - *Can we implement that goal, and how ?*

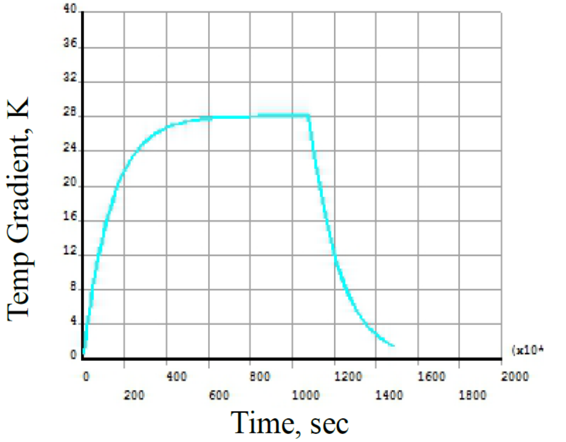
HB 650 Cryomodule: 70K Thermal Shield Design

30 Hrs Linear Cooldown of Thermal Shield

- Finger welds optimized for 40K gradient
- Variation of h with temperature considered
- Variation of properties with temperature
- Steady state temperature within 10K
- Max. Gradient = 28 K (complies with 40 K limit)
- Structural analysis at maximum gradient done



Steady state Temperature Distribution



Temp gradient V/s time

Fast Cooldown Analysis of 650MHz Cavity

Assumptions:

- Chimney positioned to the center plane of the cavity
- One Fourth Model using two symmetric planes

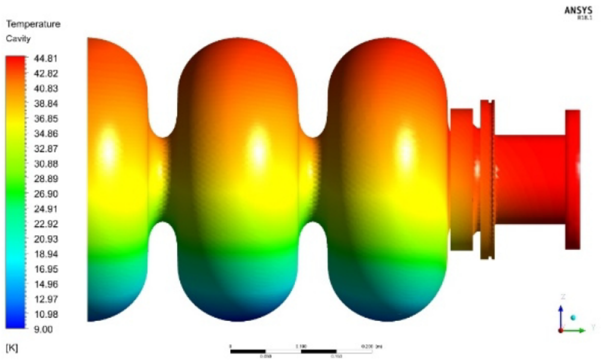
Results:

1) For mass flow rate of 12 g/s

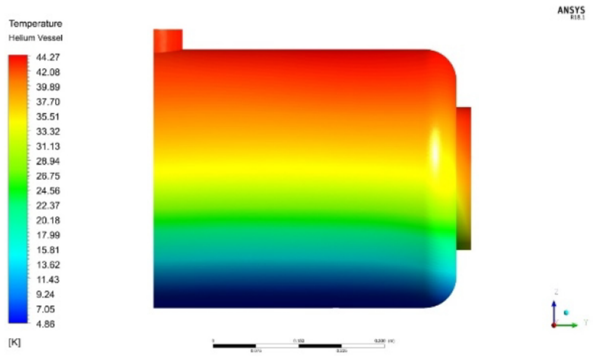
Simulation has been completed for ~180 s

- Cavity bottom reaches 9.17 K in 62 secs
- Cavity top temperature is 44 K
- ΔT = 35 K
- Helium Vessel has temperature ~4.8 to ~44.5 K

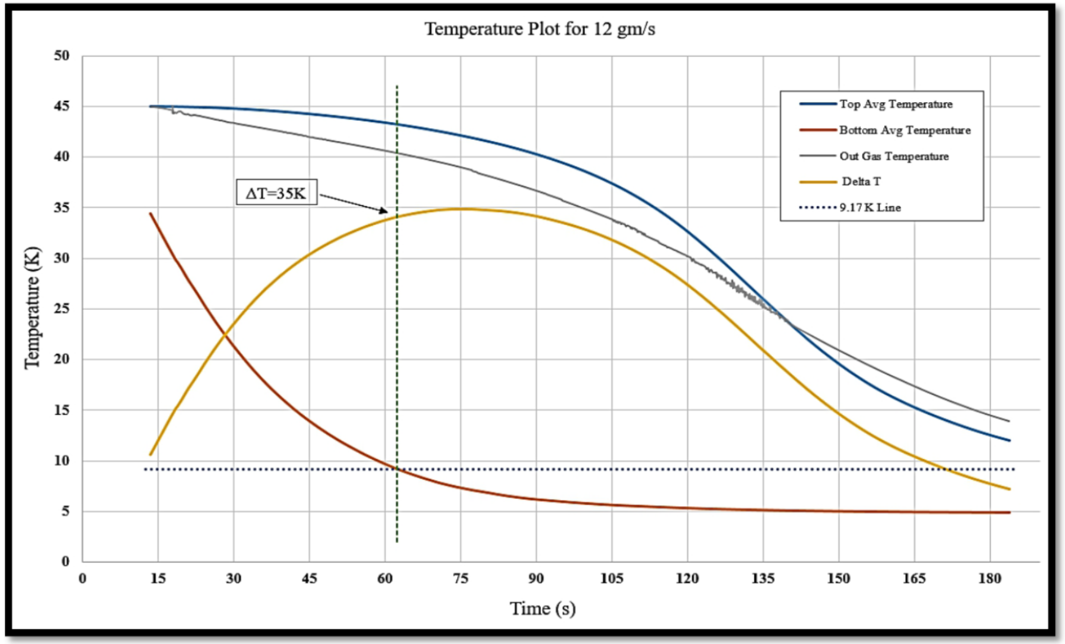
Flow Rate	Bottom Temperature	Top Temperature	Temperature Difference (ΔT)	Time
4 g/s	9.17 K	37 K	27 K	193 sec
6 g/s	9.17 K	43 K	34 K	126 sec
8 g/s	9.17 K	44 K	35 K	95 sec
12 g/s	9.17 K	43 K	34 K	62 sec
16 g/s	9.17 K	44 K	35 K	50 sec
Requirement	9.17 K	>17 K	>8 K	<150 sec



Temperature Contour of Cavity



Temperature Contour of Helium Vessel



Temperature vs Time plot of Cavity

HTS-2 Cryostat (April, 2019)

HTS Cryostat at INOXCVA

HTS Cryostat Installed at RRCAT

Integral helium leak rate of the order of 10^{-9} mbar.l/sec has been achieved at room temperature and at Liquid Nitrogen temperature as well.

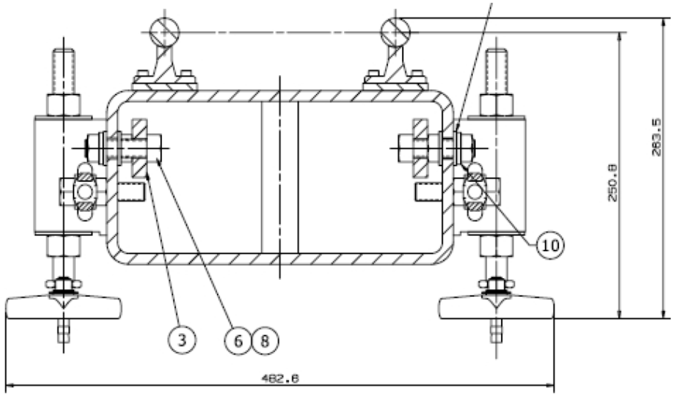
CM Assembly Infrastructure Development at RRCAT

Jacking system (Spreader Bar) for lifting cavity string Installed

High Bay Area of CM Building **84m x20m**

Jacking system installed at high bay

- Building is ready with EOT crane
- Capacity 6 Ton in Compression with 1m Stroke
- Translating, inverted type self locking worm gear screw jack (Make Powerjack)
- Speed range 30 to 300 mm/min at any desired intermediate speed with VFD control
- Overall Length 10 m with 1.6 m wide clear space between columns
- Minimum Height under the Beam 1.5 m (at lowest position)



8" Wide Rail System Drawings

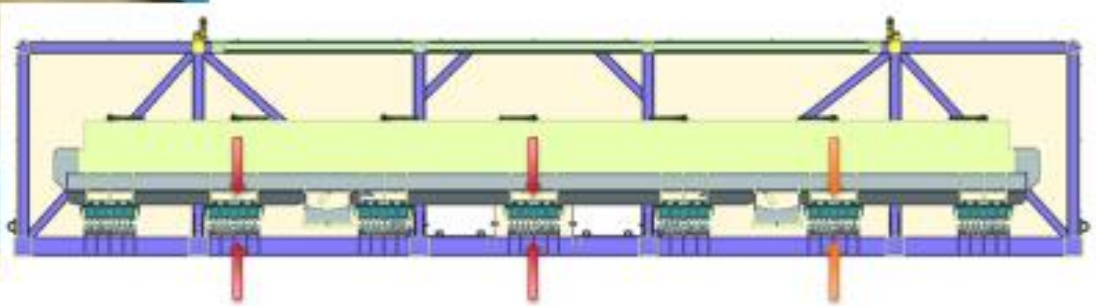
Key Takeaways / Lessons Learnt / Open Issues

- Very advanced dynamical cooldown simulations
- HTS installed and repaired
- HB650 Infrastructure development is underway in High Bay Area
- **Emphasis is on development of Indian industry**

Jeremiah Holzbauer, *HB650 Dummy Load Transportation Test Results*

Instrumentation

- Endaq tri-axial sensor packages (1 kHz sampling)
- Six sensor packages, three pairs:
  - Driver's Side Front
  - Driver's Side Center
  - Passenger Side Rear
- GPS Tracking



Shock Performance – Both Road Tests

- Resonant behavior is likely understood and not a concern for CM
- **Shock behavior is within specifications for both tests**
- Tightest spec is transverse, which has comfortable margin *even after 4.5 hours of the worst freeways we could find with no driver restrictions*

	X (transverse)	Y (vertical)	Z (longitudinal)
Trip 1 Front	0.93	0.79	0.30
Trip 1 Center	1.13	0.85	0.31
Trip 1 Rear	1.33	0.93	0.38
Trip 2 Front	1.04	0.81	0.32
Trip 2 Center	0.94	0.81	0.35
Trip 3 Rear	1.21	0.74	0.32
Specification	<1.50	<2.5	<3.5

Peak shock in X, Rear, Trip 1 is a single event <10 ms

To be clear, the level of scrutiny of these tests is extremely high, PIP-II must be able to rely on this design and validation effort

Key Takeaways / Lessons Learnt / Open Issues

- The transportation plan is going forward (recently passed TRR for dummy load)
- Path forward is as follows:

Local Validation with Dummy Load (Second Road Test Completed 2022-04-29)

↓

International Validation with Dummy Load (Aug/Sept-2022)

↓

Local Validation with pCM (After Cold Testing)

↓

International Validation with pCM (Ship to STFC-UKRI & Back then Repeat Cold Testing)

Matt Luedke, *Nonconformance / Discrepancy Reporting Process*

Vector

- Location for all travelers to reside
  - Can run reports to see how many travelers are open vs closed.
  - Capable of sorting by series or even down to a specific component.
  - Also same for DRs.
  - Allows for revision history.
  - Repository of other supporting procedures to be located and linked into related travelers.

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DR Tracker

- Provides method to easily view snapshot of related traveler DRs.
- Reviewed during weekly meetings with 650MHz prototype cryomodule team.
- Can link in Travelers and DRs for quick edits or updates.

Traveler	Series	Serial No.	DR	Description	Disposition	Disposition verification	Assigned verification	Cause	Corrective Action	Corrective Action Verification	Assigned verification	Target Date	Status
464613 HB650 pCM Assembly Phase 1a -Beamline Assembly			12760	RRCAT-506 threaded studs for beamline bellow connection facing the wrong direction.	Rework	Verified	Damon B.	Direction of excess stud length was not called out in the traveler 464612. A new revision, 464612 Rev. A is currently pending, and incorporates a special note in step 7.2 designating which direction the extra length, if any, should face.	Added instructions on which direction excess stud should face to traveler 464612. Design change for shorter studs. Look for drawings being released.	Verified	Damon B.	6/22/2022	Open
			12761	AES-007 sitting lower than rest of string	Rework	Verified	Chuck G.	Table did not have adequate travel because it physically attached to the support post higher than it was mocked up in the model. This created a need for the cavity to be higher in order to line up with the bellows.	Heights can be re-checked prior to each cavity to cavity connection. Bellows supports that sit on table to be lower. Table to be redesigned.	Verified	Chuck G.	4/15/2022	Open
			12806	String assembly is too long by 16mm	Rework	Not Verified	Chuck G.	The BPE sub-assembly length was overlooked in the procedure. The tooling of cavity to cavity spacing adjustment failed in several places.	A revision of the BPE sub-assembly in cleanroom was identified. The new procedure is pending tooling design approval. The cavity spacing adjustment tool is to be reworked to allow a better fitting.	Not Verified	Chuck G.	8/1/2022	Open
				Plates on cavity not installed due to hole patterns not lining up. Additionally RRCAT-502 and AES-007	Rework			The 4 lifting lugs original intent was purely for cavity lifting. The intent changed causing a need for more	LB650 Helium Tank – F10127683, looks like someone has started those changes. Sheet 2 should have the true position tolerance changed to 0.5 and pointing to the threaded hole. LB Lifting Lug – F10128778, should have threaded hole removed, no need for				

Key Takeaways / Lessons Learnt / Open Issues

- The methodology and electronic software to upload the Travelers and the Discrepancy Report from Partners is still to be defined and implemented.
- It should be based of Sharepoint platforms.

Yi Xie, *HB650 vacuum vessel magnetic field*

Vacuum vessel demag

- HB650 vacuum vessel was received on May 2022, demag was performed immediately after. Coils were freshly made, shown below.
- Magnetic field measurements were performed before and after demag on lower equator, upper equator.

Bare VV

Making and installing demag coils

Fermilab

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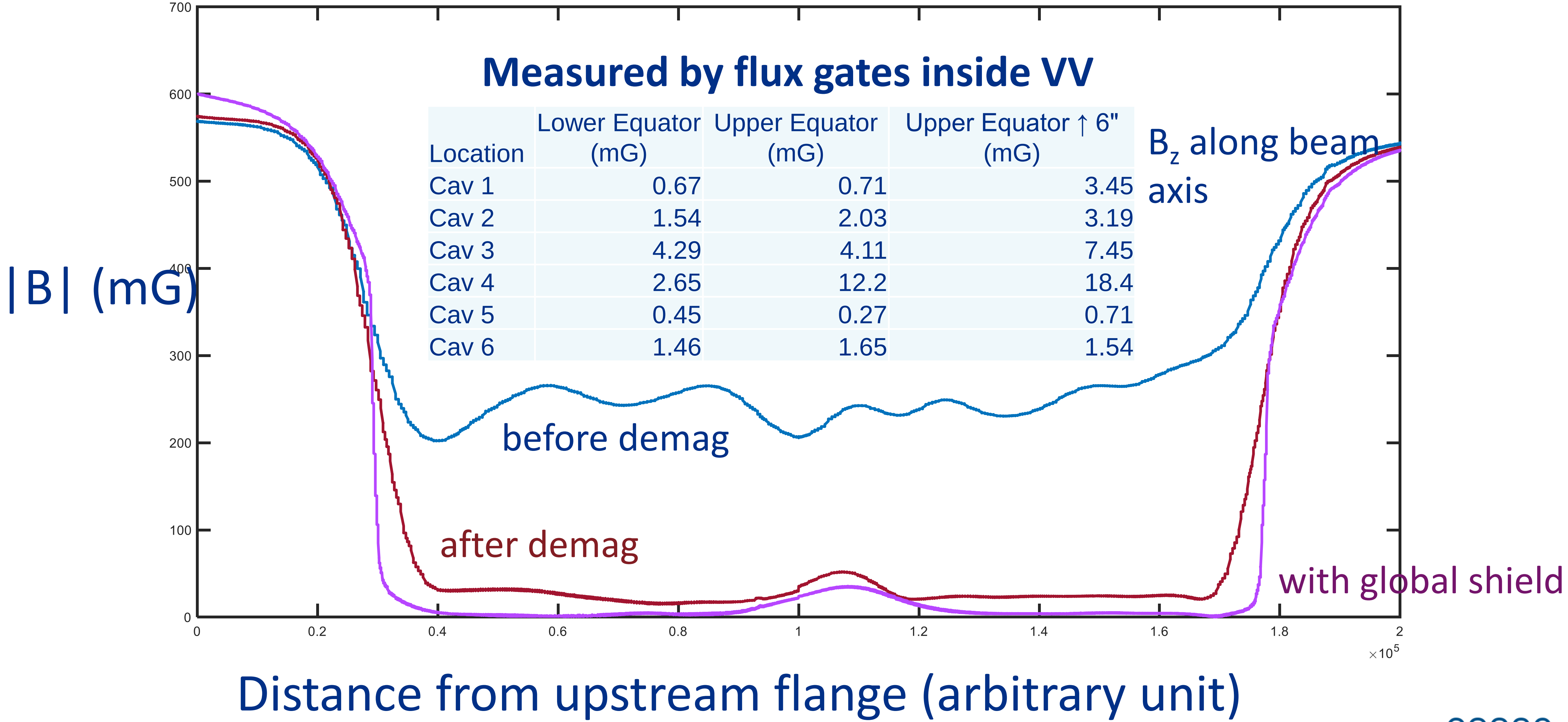
Upper equator data inside VV



Measured by flux gates inside VV

Location	Lower Equator (mG)	Upper Equator (mG)	Upper Equator ↑ 6" (mG)
Cav 1	0.67	0.71	3.45
Cav 2	1.54	2.03	3.19
Cav 3	4.29	4.11	7.45
Cav 4	2.65	12.2	18.4
Cav 5	0.45	0.27	0.71
Cav 6	1.46	1.65	1.54

Key Takeaways / Lessons Learnt / Open Issues

- Vacuum Vessel demagnetization was successful
  - Demag coil: 100 + 96 + 100 turns
  - Demag process : measure VV → demag VV → measure VV → install MS → measure VV
  - Bz ≈ 1 µT (10 mG)
- Strongback magnetization low enough w/o demag

Summary

- Isn’t it a summary already ?

- Apologies to Mark Pendleton (UKRI) for missing his talk and communicating to late.

Thank you