HGCAL: la production des cassettes

Journée des groupes techniques

3 Juillet 2025

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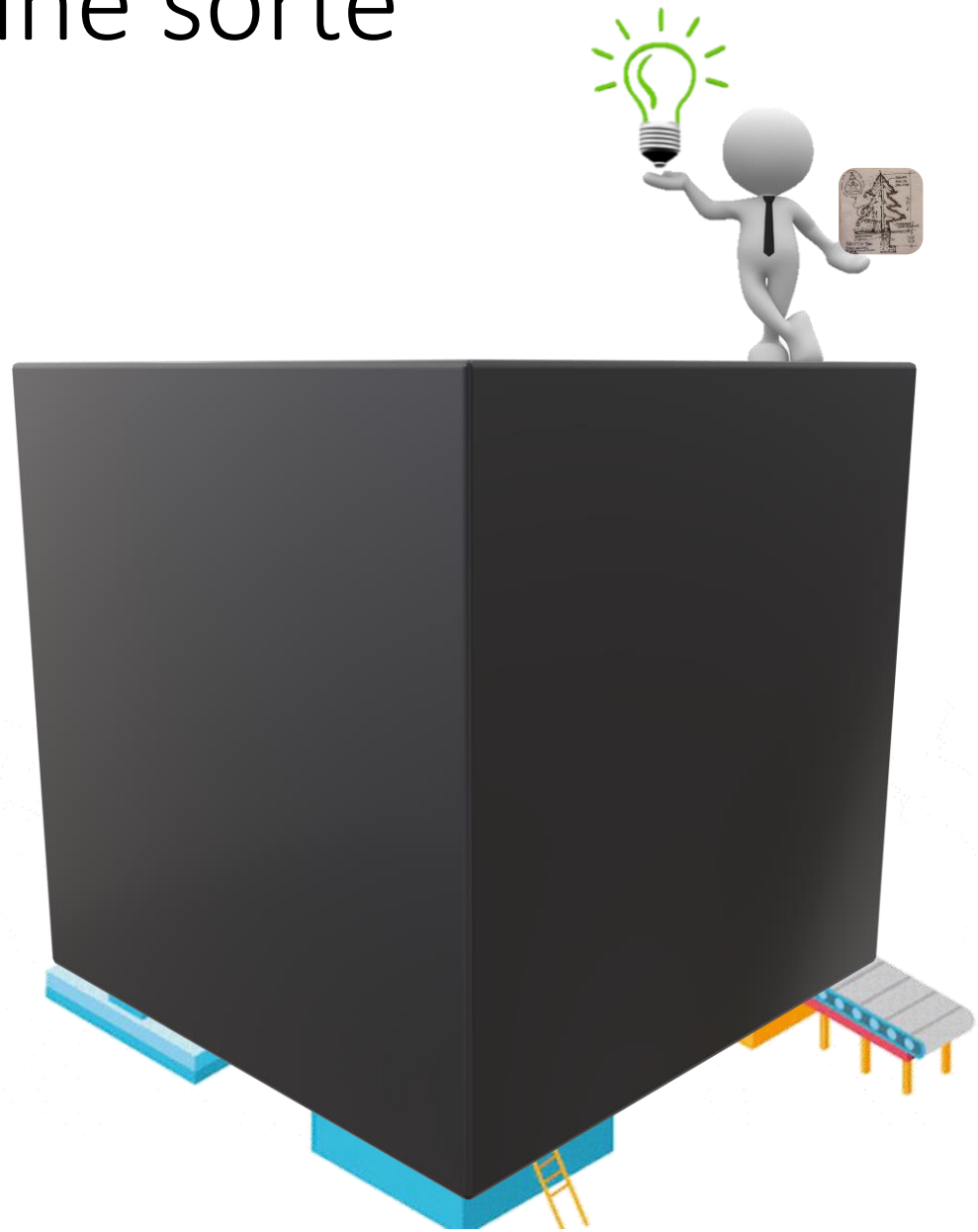
La mécanique une sorte de boite noire

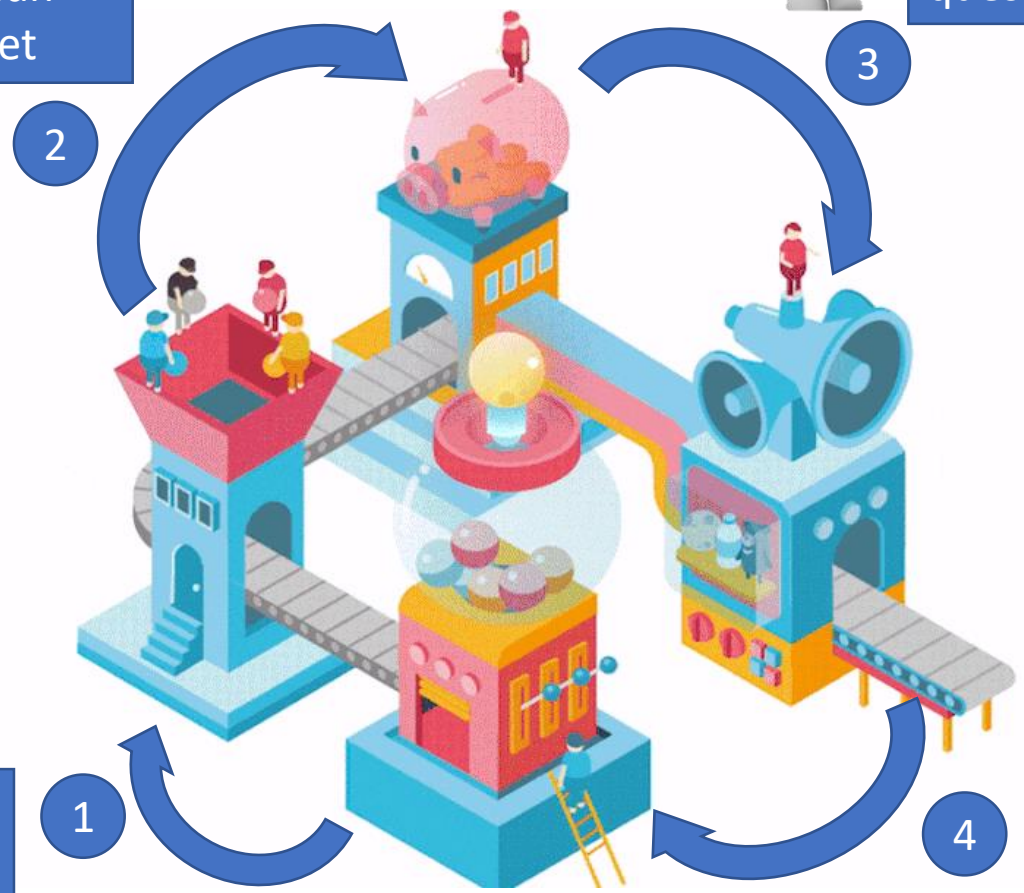
- Dans laquelle on rentre des idées
- Et qui produit des pièces en retour pour construire des éléments utiles à la physique
- Avec un échelle de temps variable en fonction de la complexité
- Mais que contient cette boite noire?



…Voici l'intérieure

Un précieux travail d'équipe est permettant de bénéfice des compétences de chacun pour convertir l'idée de départ en objet

- Les choses se complexifient à l'intérieur de cette boite



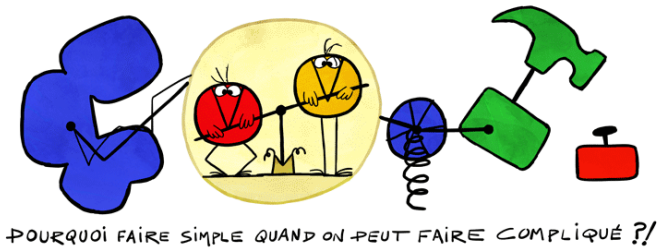
Trouver les meilleures techniques et solutions pour produire l'objet en question (interne et/ou externe)

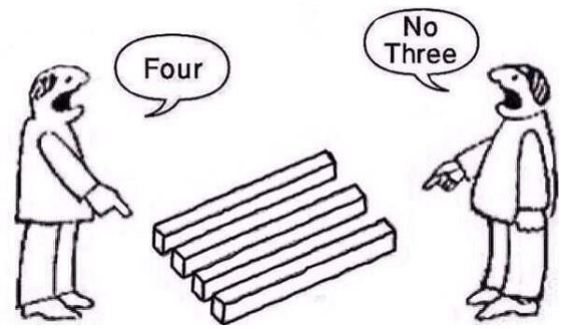
Besoin de digérer et assimiler les attentes à partir d'une idée

Itérations possibles si nécessaire

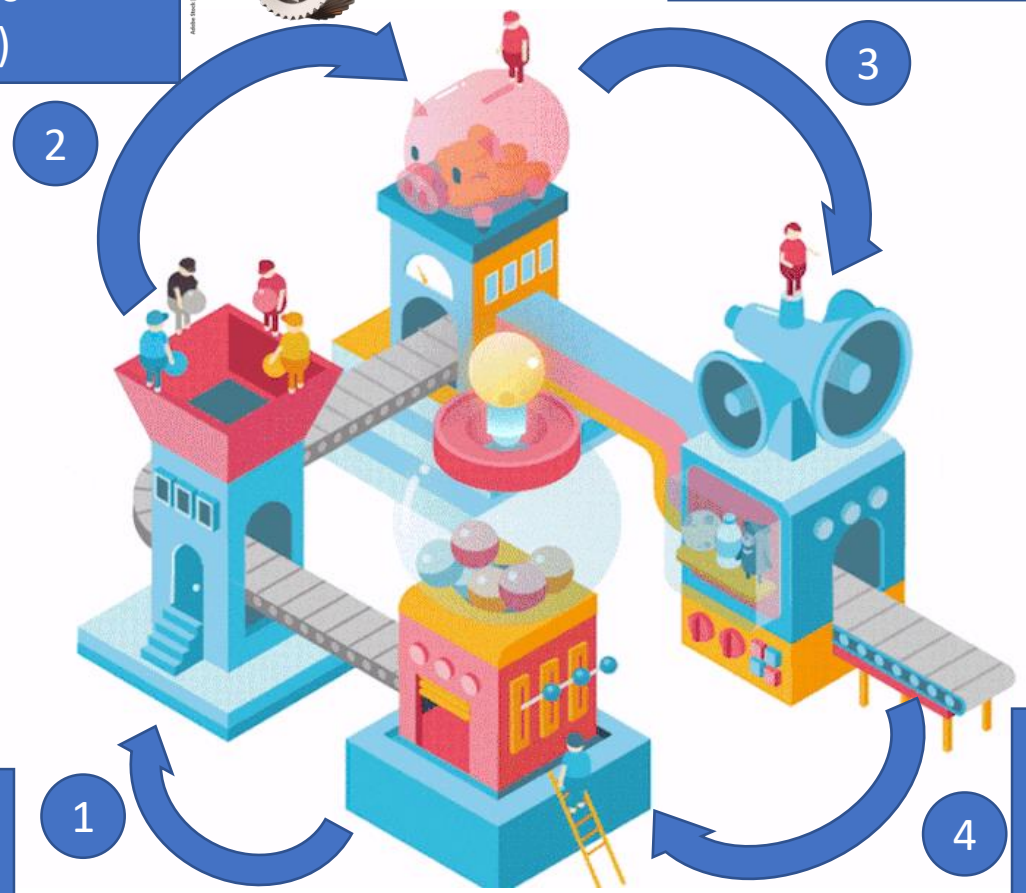
…Plusieurs sources d’erreur possibles

Défauts de conception ou dimensionnement (difficultés d’assemblage voire fragilités)





Mauvaise interprétation de l’idée de départ



Erreur lors de la production

Les itérations permettent souvent de corriger les erreurs constatées

La production HGCal

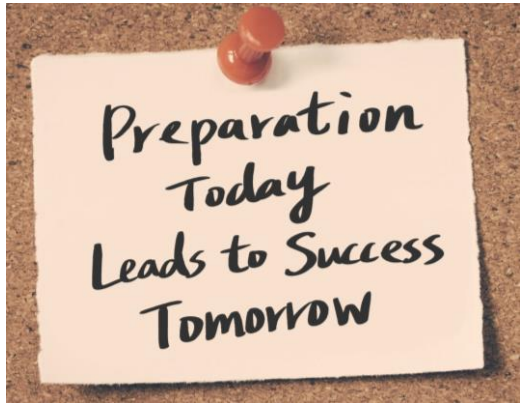
Un projet de longue haleine

SUCCESS **SUCCESS**

what people think it looks like

what it really looks like

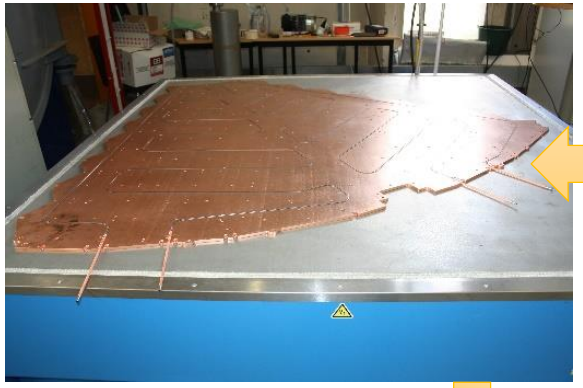
10 années de préparation du service



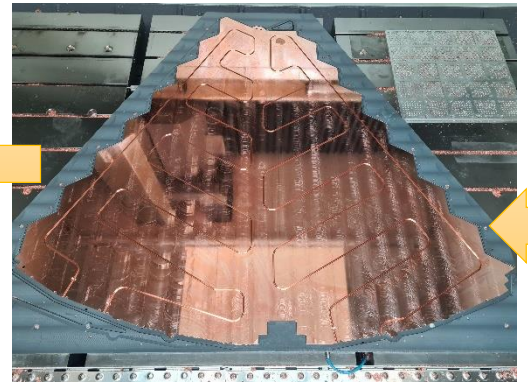
- Après 10 années d'études
- Une dizaine de marchés (PUMA et marchés publiques)
- 4 années de reconfiguration de l'atelier

➔ L'atelier est désormais prêt pour la production

10 années : de la CAO à la réalité

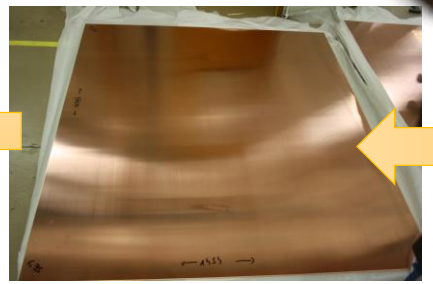


Preparation for soldering (4h)



First machining step (4h)

Water jet cut (market 2)

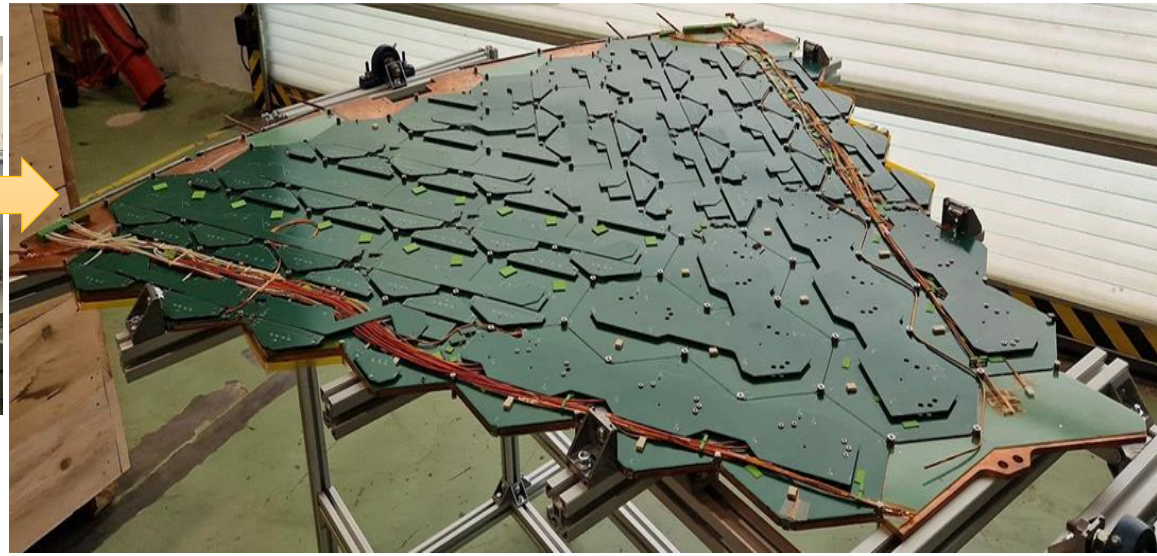


Raw plate (market 1)

Perform soldering (12h)

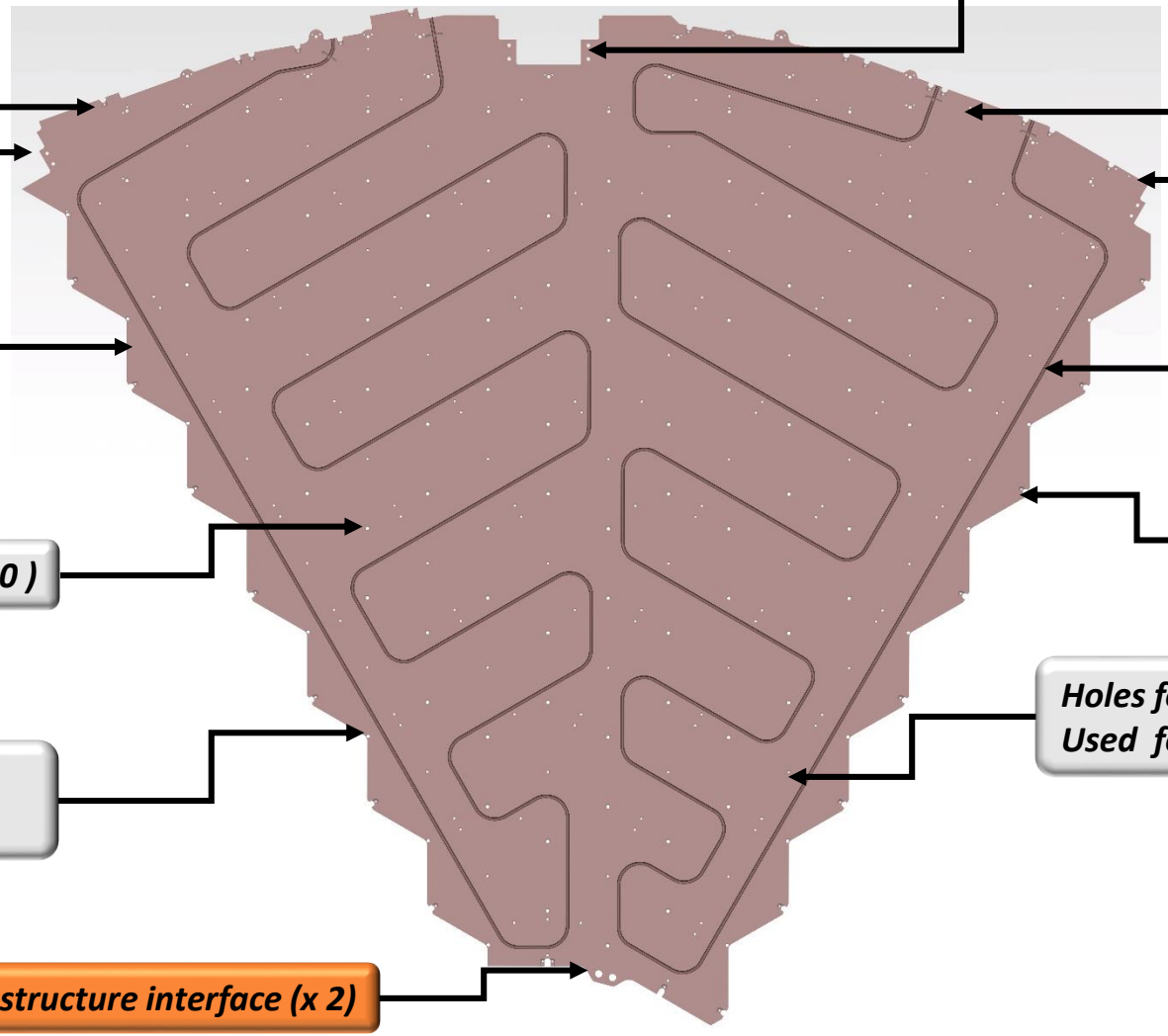
Second machining step (4h)

CMM (5h)



~30 heures de travail nécessaire par plaque

CE-E Cooling Plate



Interface for central Zbar (x 1)

Additional hole shims at the tilling boarder (~ x 30)

Interface for cables strain relief bars (x 14)

Interface for dry gas pipe (x1)

Interconnecting Zbar area (x 2)

Cooling groove (x 2)

Dry gas sealing foil (x 1)

Threaded holes for central spacers (~ x 100)

Interface for edge spacers for 1 module (~ x 15)

Holes for locating pins (~ 100)
Used for module locating and orientation

Interface for edge spacers for 2 modules (~ x 15)

Holes for inner support structure interface (x 2)

Electrical and optical services

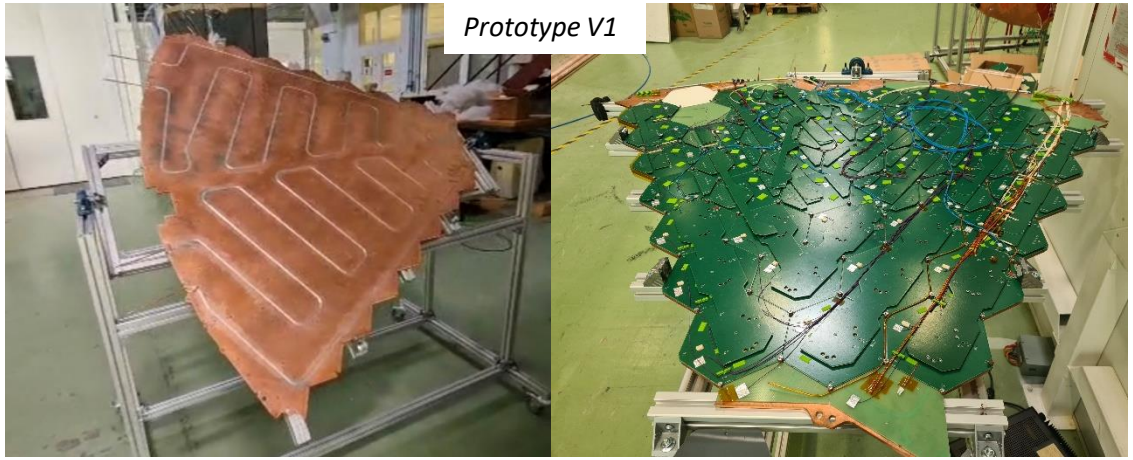
CE-E mechanical interfaces

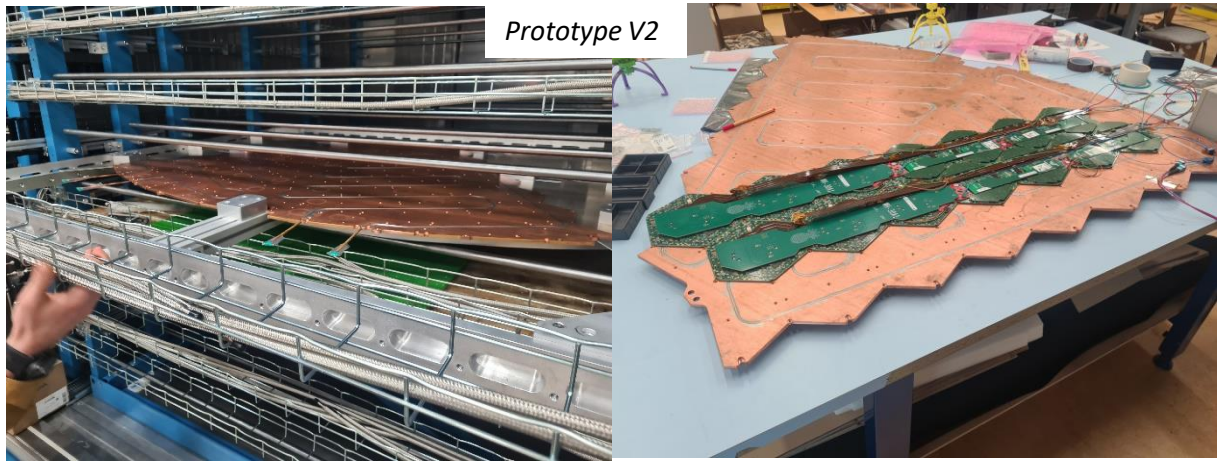
Fluid and cooling handling

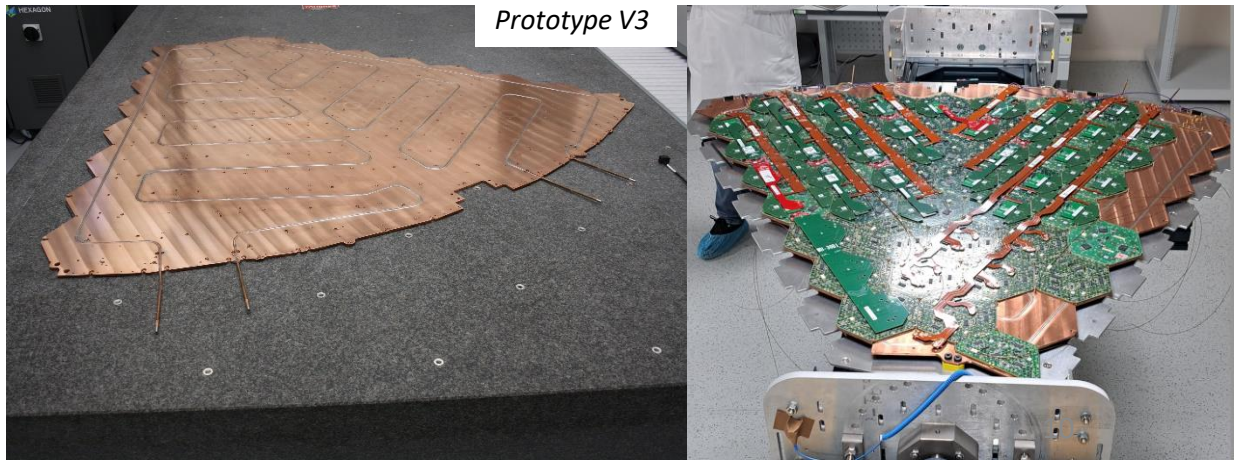
Module tilling and fixation

Pré-production des refroidisseurs

- 3 prototypes intégralement produits au LLR
  - 1er proto livré en Juin 2023 et utilisé pour les tests d'assemblage au bâtiment 86.
  - 2nd proto livré en Avril 2024 utilisé pour l'insertion en chambre froide et pour les premiers tests d'intégration d'électronique (initialement livre au P5 puis transféré au bâtiment 27
  - 3ème proto livré au CERN en Février 2025 et utilisé comme proto d'assemblage de pré série







Production HGCal au LLR : planning

		JULY	AUGUST	SEPTEMBER	OCTOBER	NOVEMBER	DECEMBER	JANUARY	FEBRUARY	MARCH	APRIL	MAY	JUNE	JUL
1	**Raw copper from BIKAR company**													
1.1	Raw copper plate stock at CERN	140 140 105 105	70 70 70 70	35 35 35 35										
1.2	Pickup of copper samples by LLR													
1.3	Pickup by VJP for Water Jet Cutting (WJC)	35	35	35	35									
2	**Water jet cutting by VJP**													
2.1	Return of copper plates to CERN after WJC			35	35	35	35							
2.2	Total WJC copper plates at CERN			35 35 35 35	70 60 60 60	95 95 83	83 118	118 118 108	108 108 108	108 108 108	108 96 96	96 96 96	96 84 84	84 84 72 72 72 72 60 60 60
3	**Cooling plates machining at LLR (Senario 1)**													
3.1	Copper plates at LLR													
3.2	WJC of the copper plates batch at VJP													
3.3	WJC copper plates returned to LLR			39 33 27	21									
3.4	Copper plate machining Layer LL at LLR			L13 L12 L11										
3.6	**Cassette plate shipping to CERN**			L13 L12	L11									
3.7	**Copper plate Layer Lxx pickup from CERN**			L10, L9	L8,L7	L6,L5	L4,L3	L2,L1	L10, L9	L8,L7	L6,L5	L4,L3	L2,L1	
3.8	**Copper plate machining Layer Lxx at LLR**	L13/Al	L13 L12	L11		L10,L9	L8,L7	L6,L5	L4,L3	L2,L1	L13	L12,L11	L10,L9	L8,L7
3.9	**Cassette plate return to CERN**			L13 L12	L11		L10, L9	L8,L7	L6,L5	L4,L3	L2,L1	L13	L12,L11	L10, L9
3.10	**Cassette Assembly at CERN's CAF**			L13		L12,L11	L10, L9	L8,L7	L6,L5	L4,L3	L2,L1		L13	L12,L11
3.11	**Cassette CR test at CERN's CAF-Cold Box 1**					L12	L10	L8	L6	L4	L2			L12
3.12	**Cassette CR test at CERN's CAF-Cold Box 2**				L13	L13	L11	L9	L7	L5	L3	L1	E1-out L13	

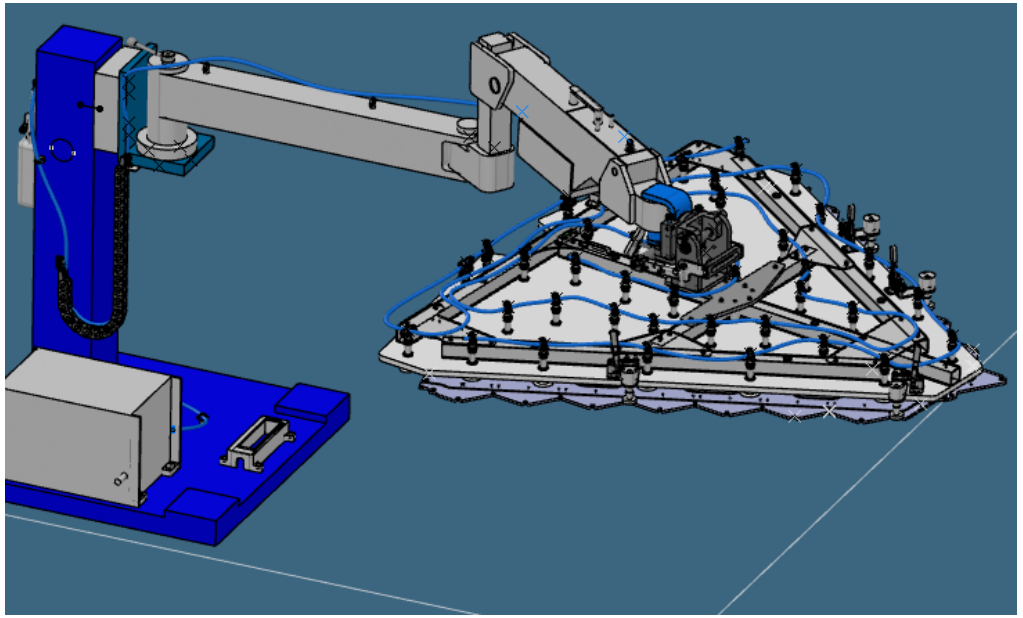
- L'ensemble des 180 plaques de cuivre a été reçu
- 1/5 des plaques déjà découpées
- Lancement de la production cet été
- Aujourd'hui la cadence de production doit être augmentée de 2 plaques/semaine à 3 plaques/semaine pour tenir les délais
  - Nous devons faire plus avec un effectif atelier réduit

Production HGCal au LLR : outillages

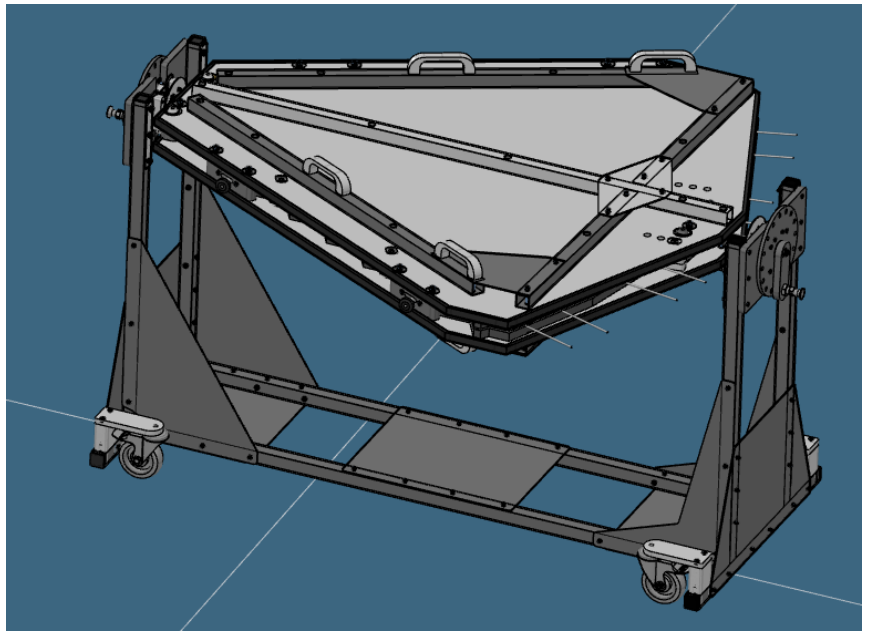
- La production et la mise en service des cassettes d'HGCAL fait apparaitre des contraintes et des besoins spécifiques …

➢Comment manipuler des plaques de cuivres de 6mm sans les déformer ?
➢Comment maintenir la cassette en position durant l'usinage ?
➢Comment transporter les cassettes jusqu'au CERN sans les abimer ?
➢Comment assembler toutes les cassettes une fois livrées ?
➢ ETC …

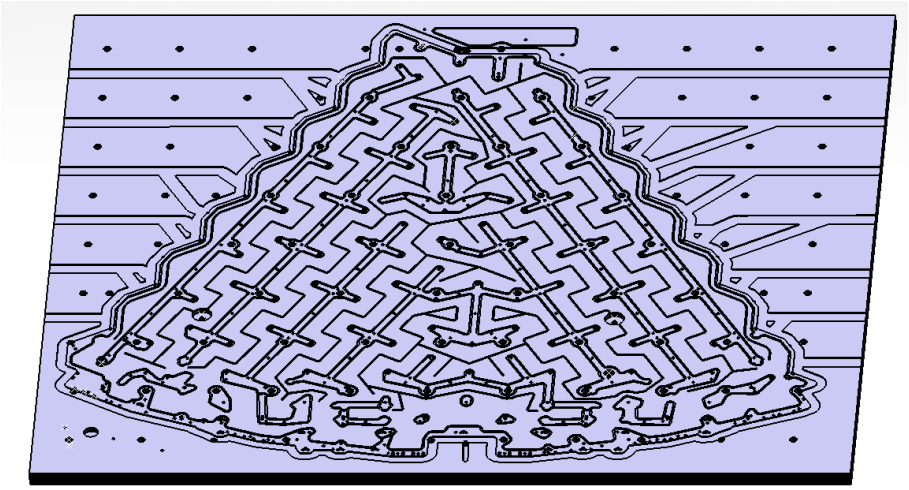
→ **Développement d'outillages spécifiques**



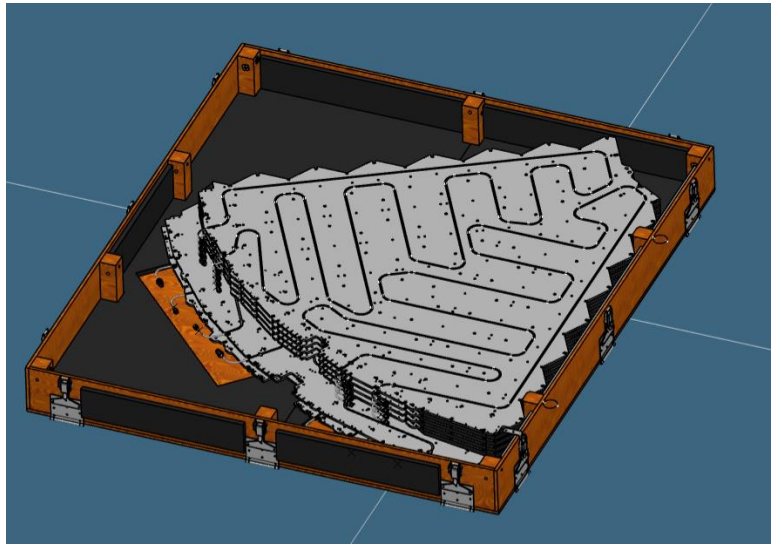
→ Palonnier : manipule les plaques de cuivres sur poste



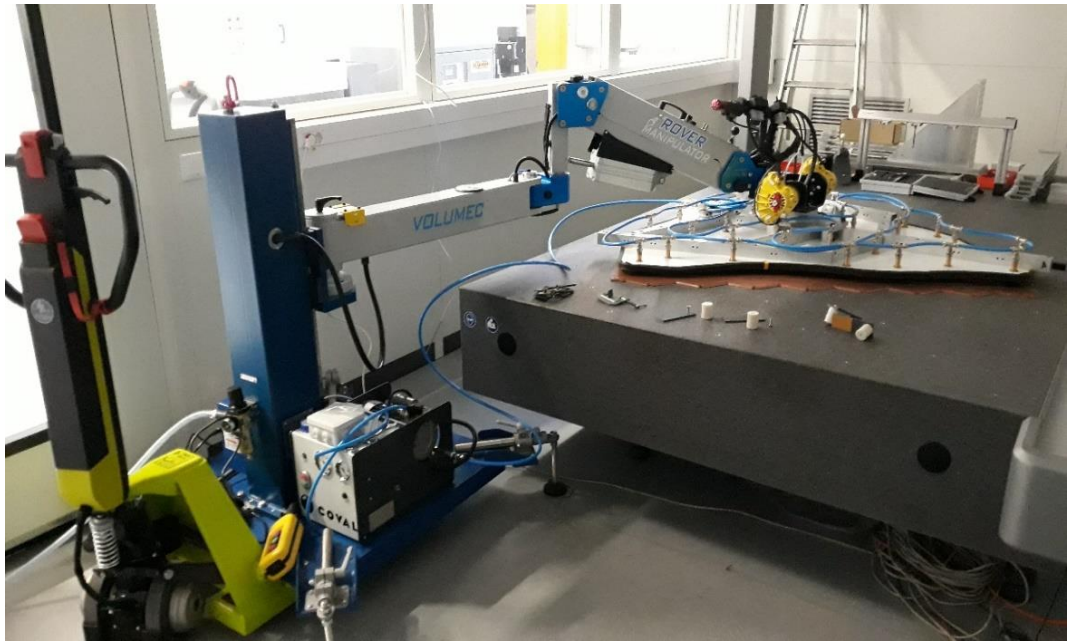
→ Chevalet : retourne les plaques de cuivres sur poste, transporte les plaques d'un poste à l'autre



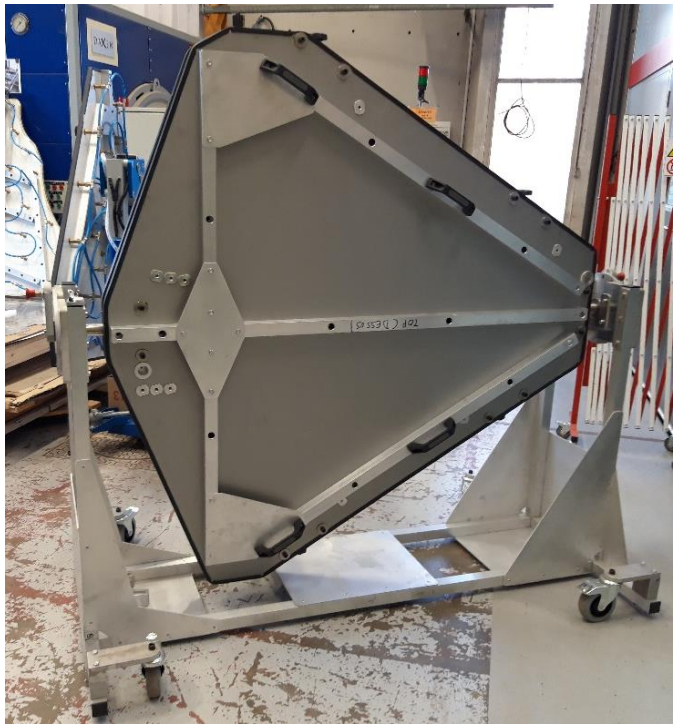
→ Plateau aspirant : maintient la cassette en position durant l'usinage



→ Boîte : permet le transport d'un lot de cassettes jusqu'au CERN



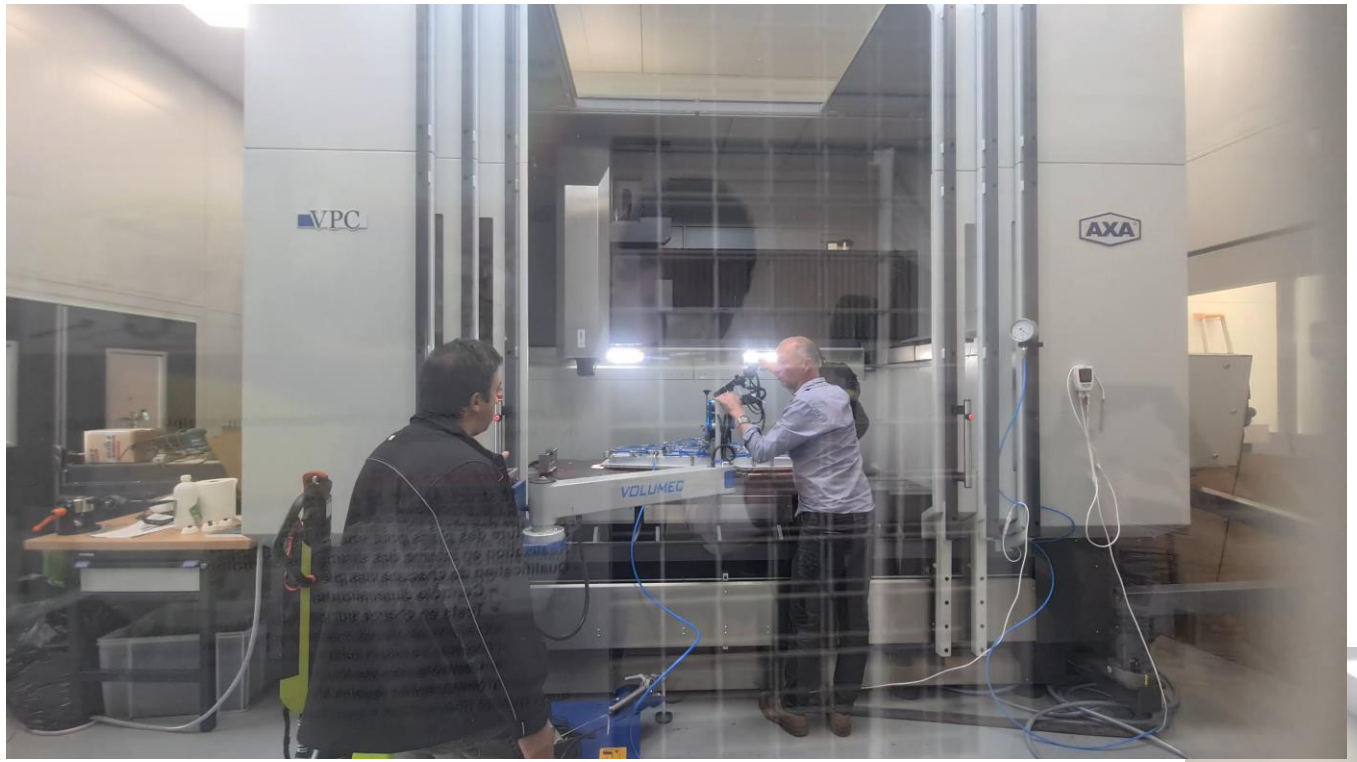
→ 2 versions réalisées, la version finale en cours



→ Réalisé et testé

→ Usinage aujourd'hui en cours

→ En production dans les prochaines semaines



Manutention de la cassette en fin d'usinage

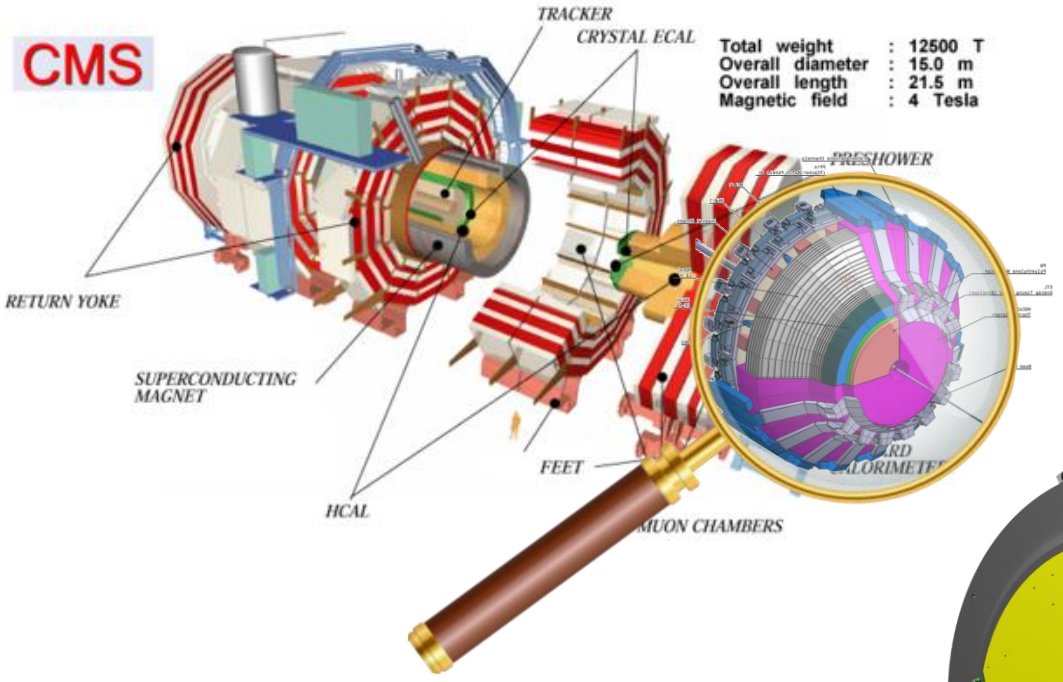
Manutention de la cassette avant métrologie

→ Distance entre les 2 postes : 5m

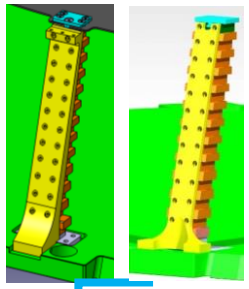
→ Beaucoup d'efforts « juste » pour passer d'un poste à l'autre

→ 3 postes de travails : AXA, MMT et table chauffante

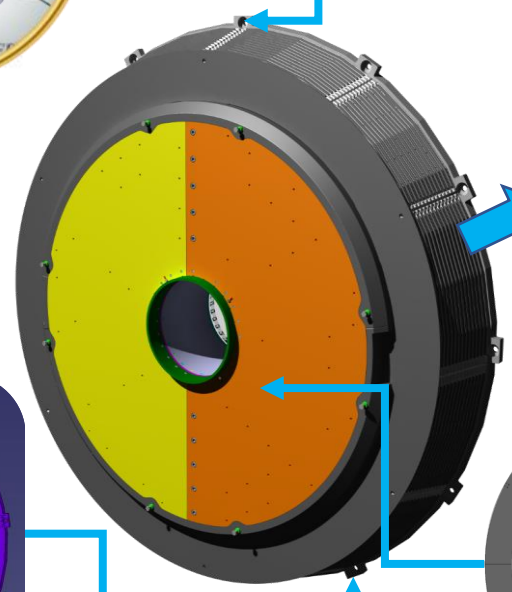
La production des cassettes, mais pas que …

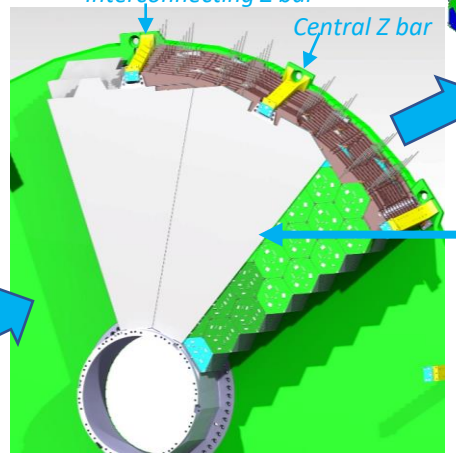


[Click to see 2023 HGCAL assembly animation]

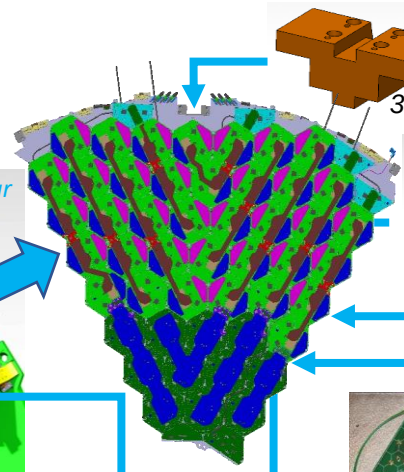


2 types of Z bars (x 12)
-Interconnecting Zbar (x6) -Central Zbar (x6)

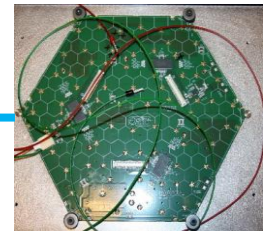




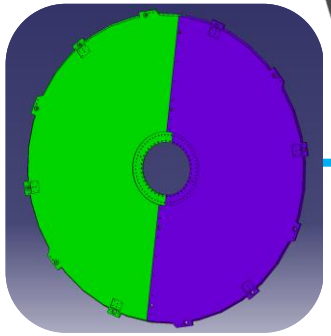
Central bracket (x 78)



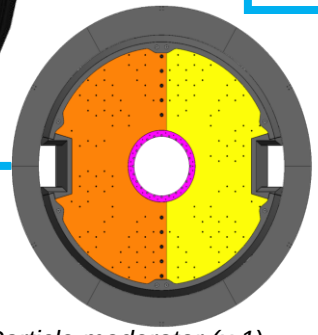
3 major types of Spacers ~6200



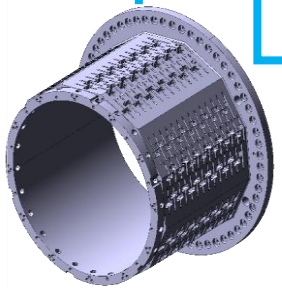
Several module types (~6200)



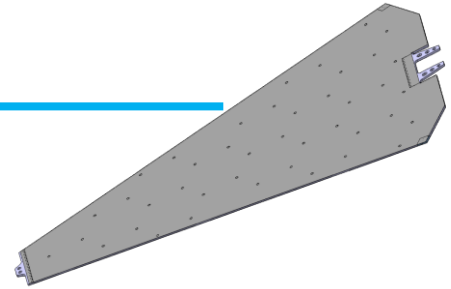
CE-E back plate (x 1)



Particle moderator (x 1)

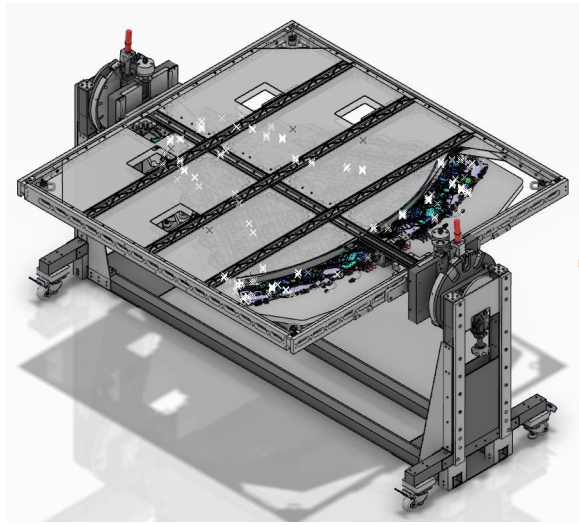


Central support structure (x 1)

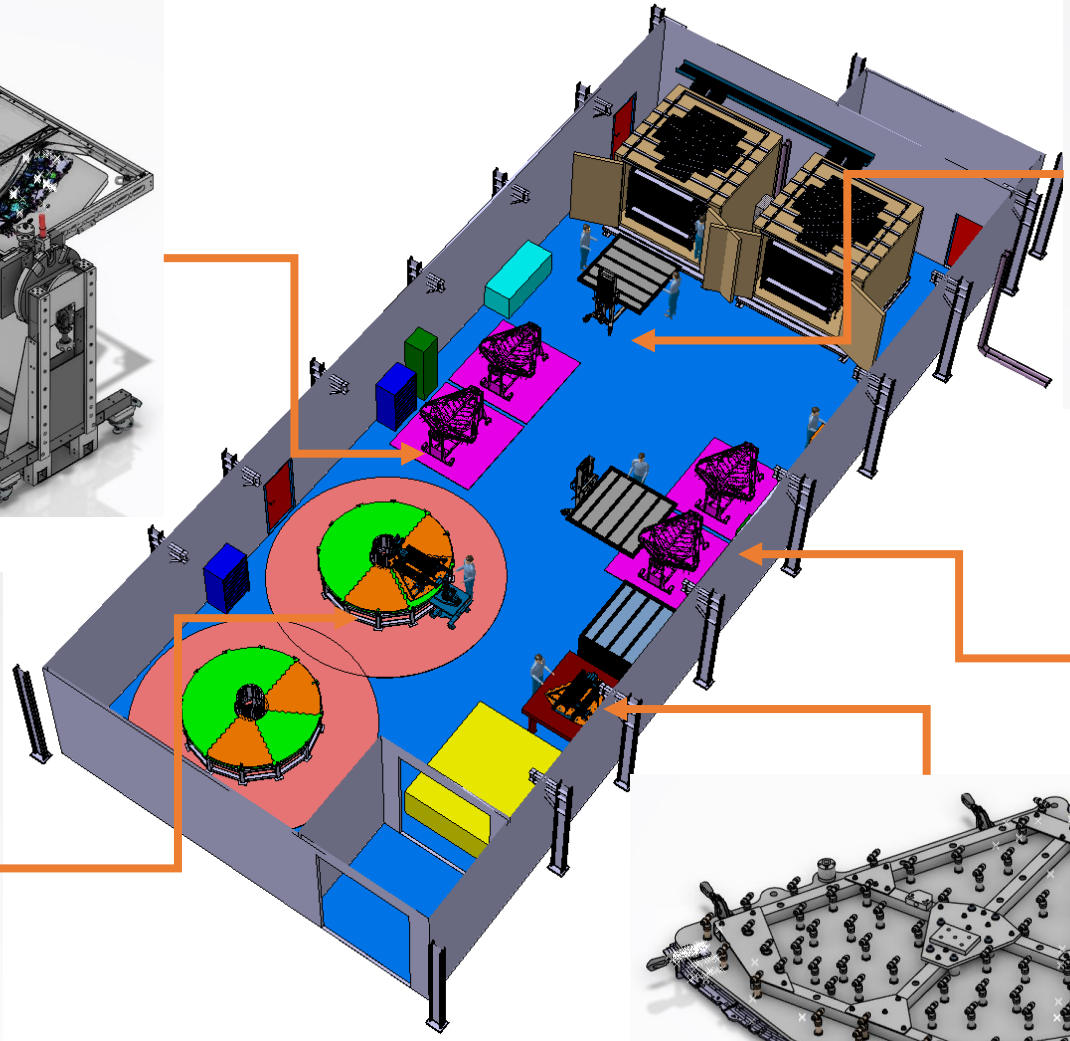


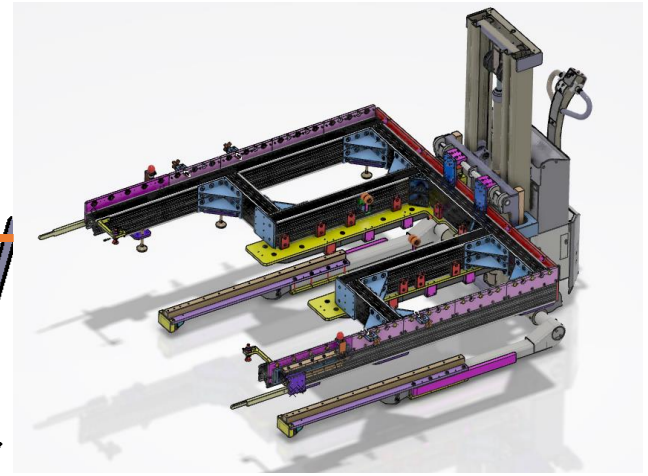
Lead sandwich absorber (x 156)

La production des cassettes, mais pas que …

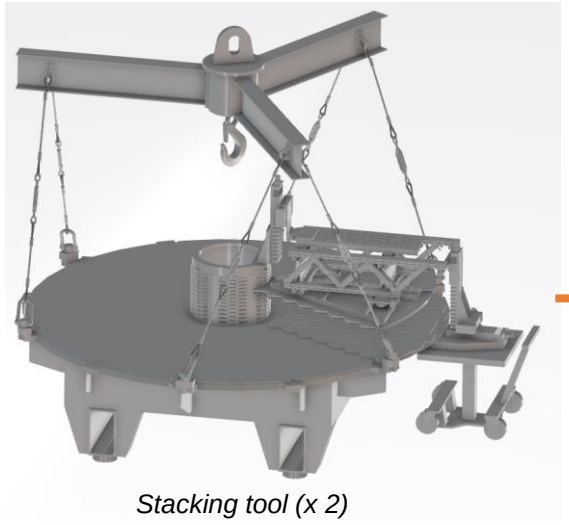


Assembly station (x 6)

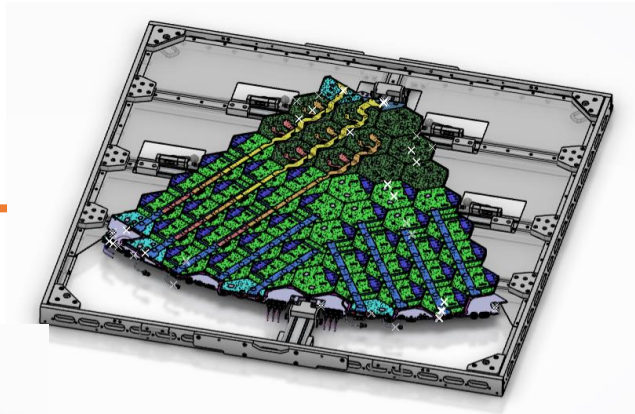




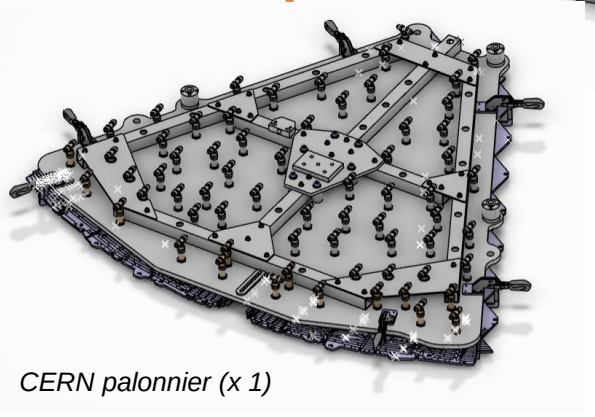
Specific Forklift (x 1)



Stacking tool (x 2)



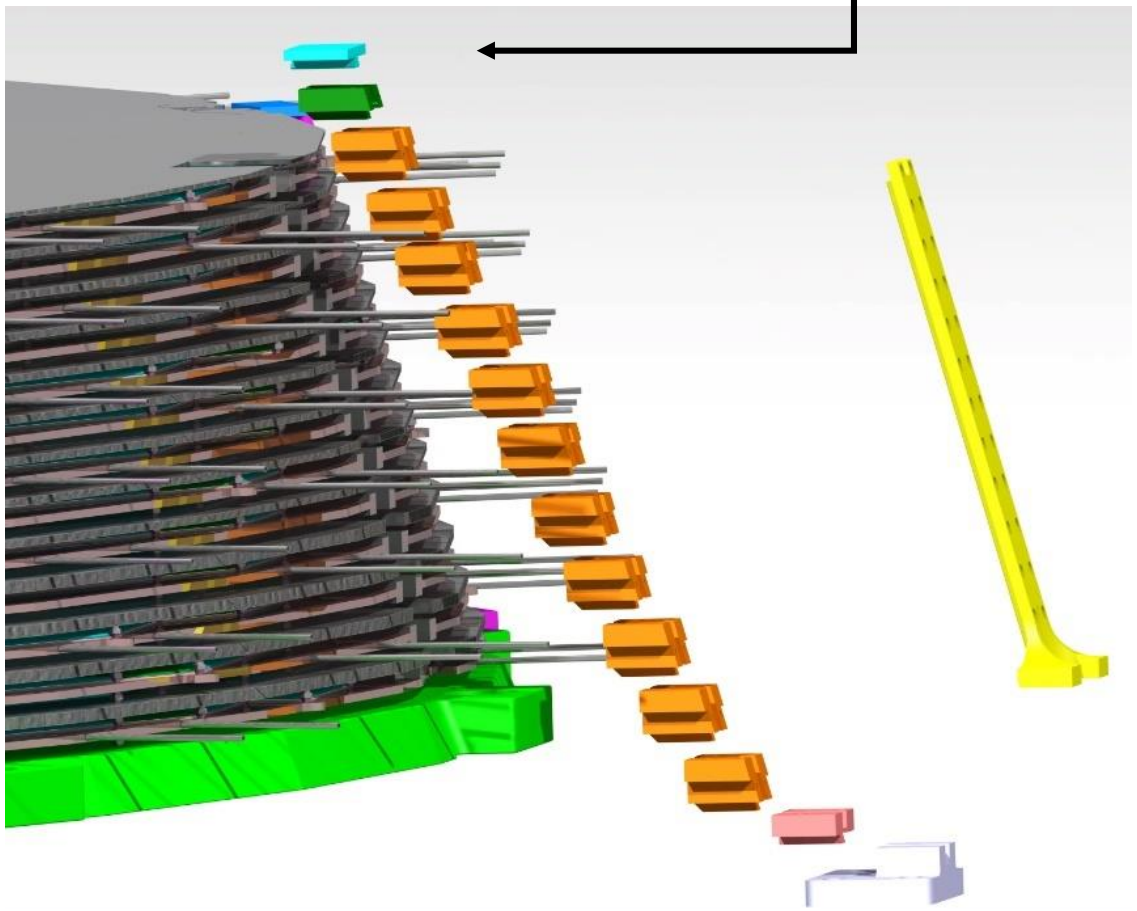
CEE Frames (x ~20)

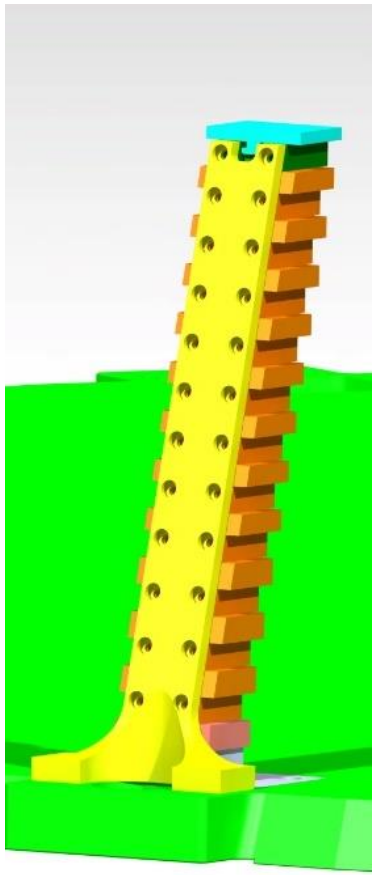


CERN palonnier (x 1)

Back up

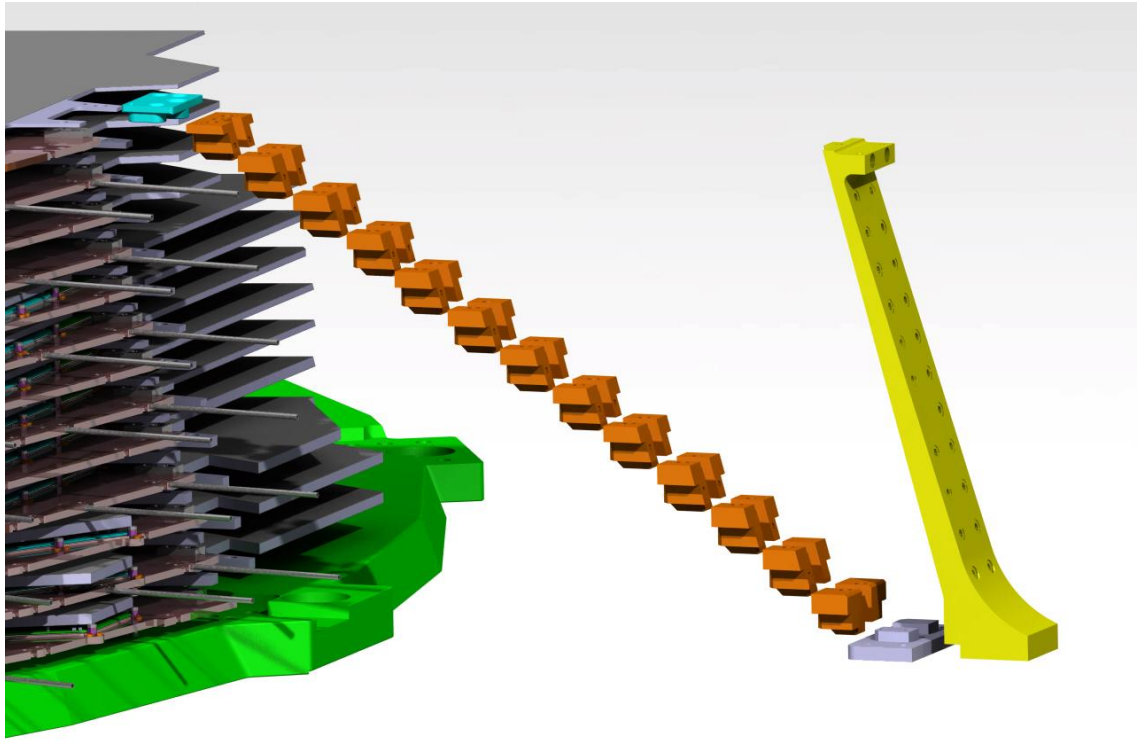
Cooling plate description





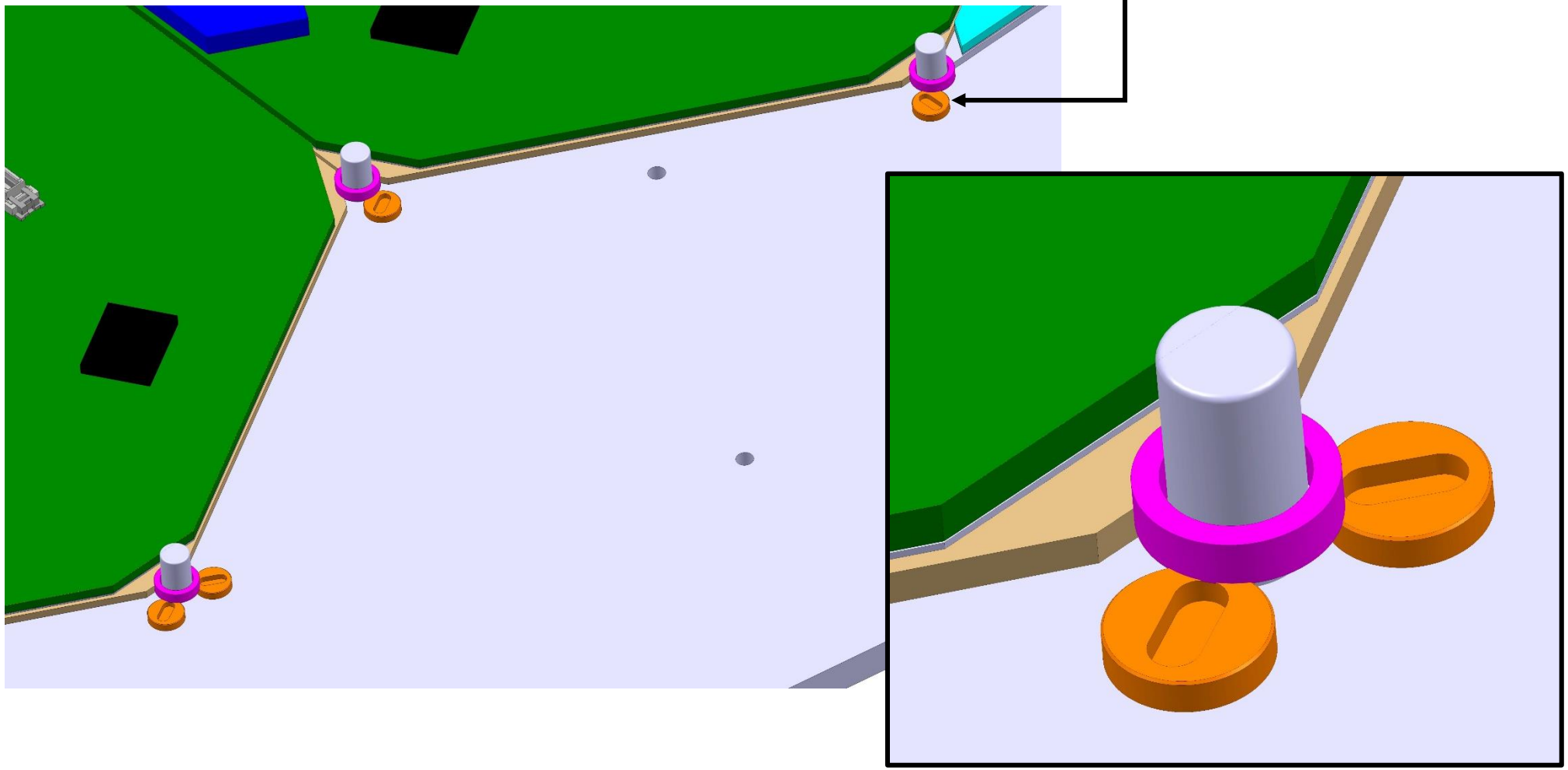
Cooling plate description

Interconnecting Zbar area (x 2)

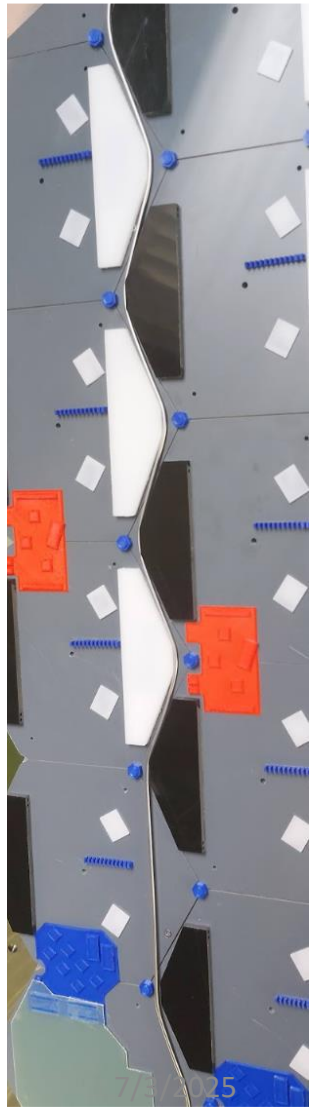


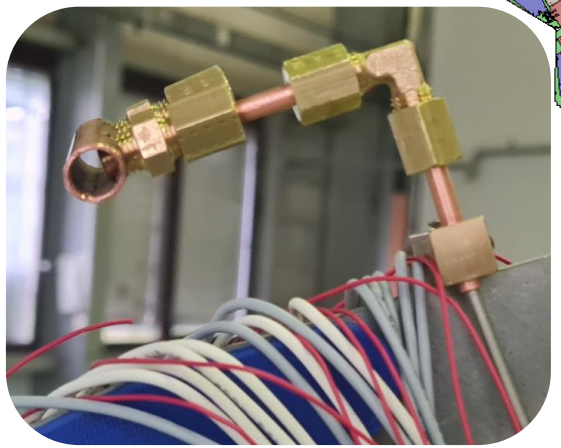
- This one is based on the same principle as the central Z bar.
- It is located in between 2 cassettes

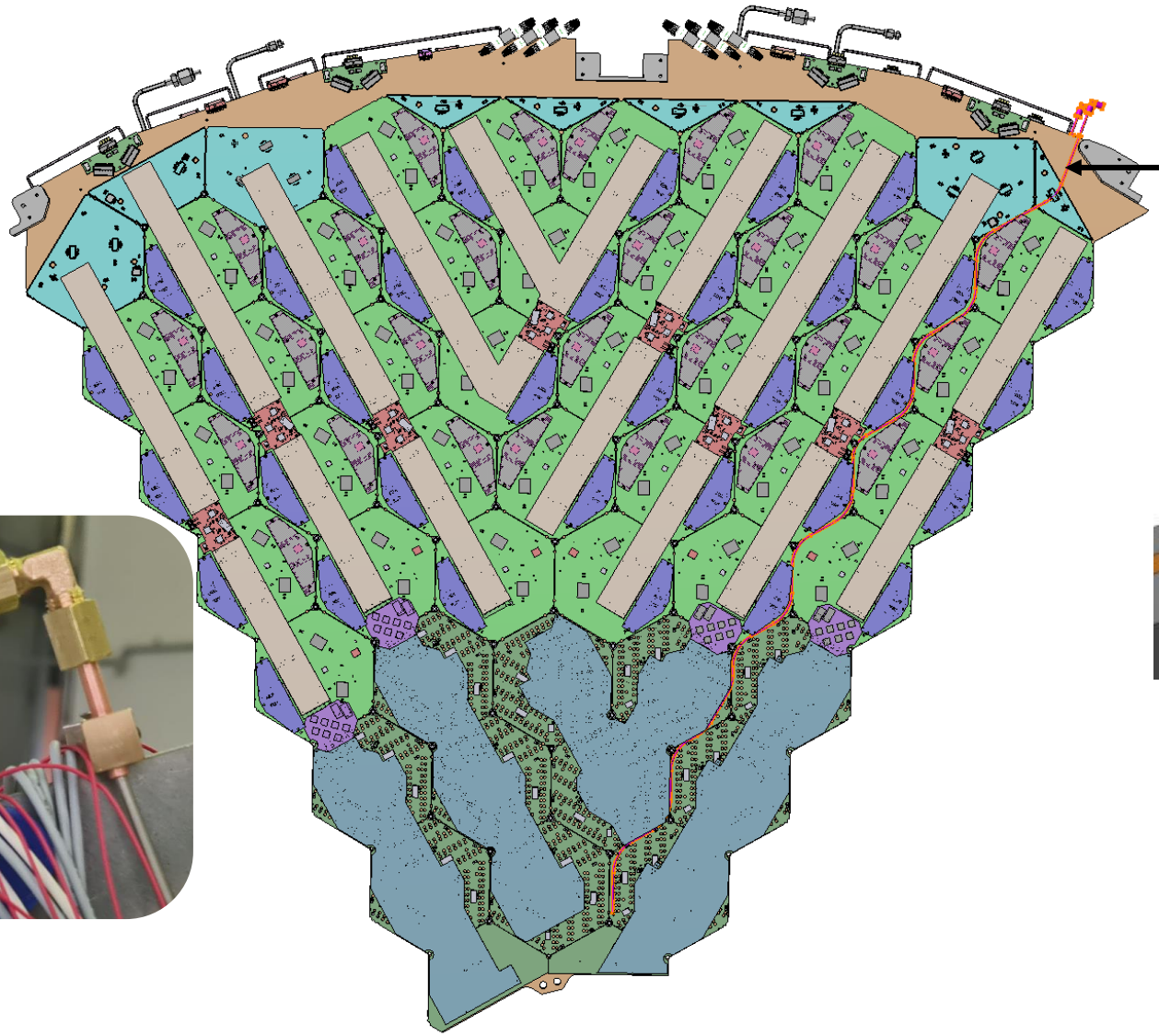
Cooling plate description



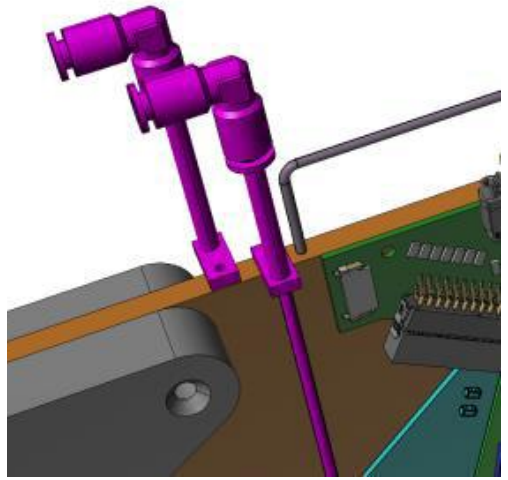
Cooling plate description



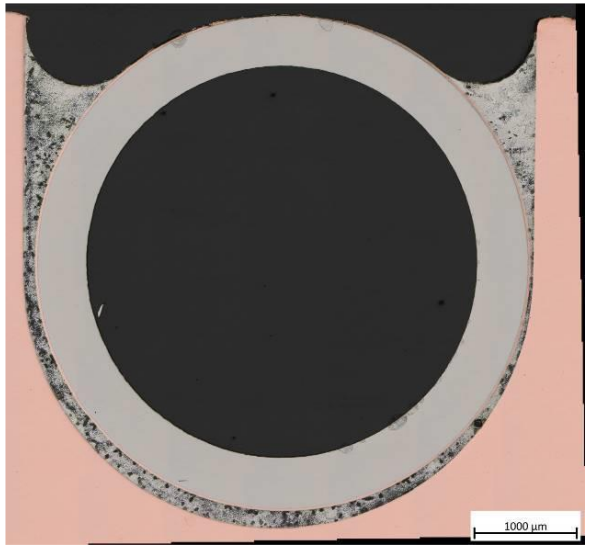


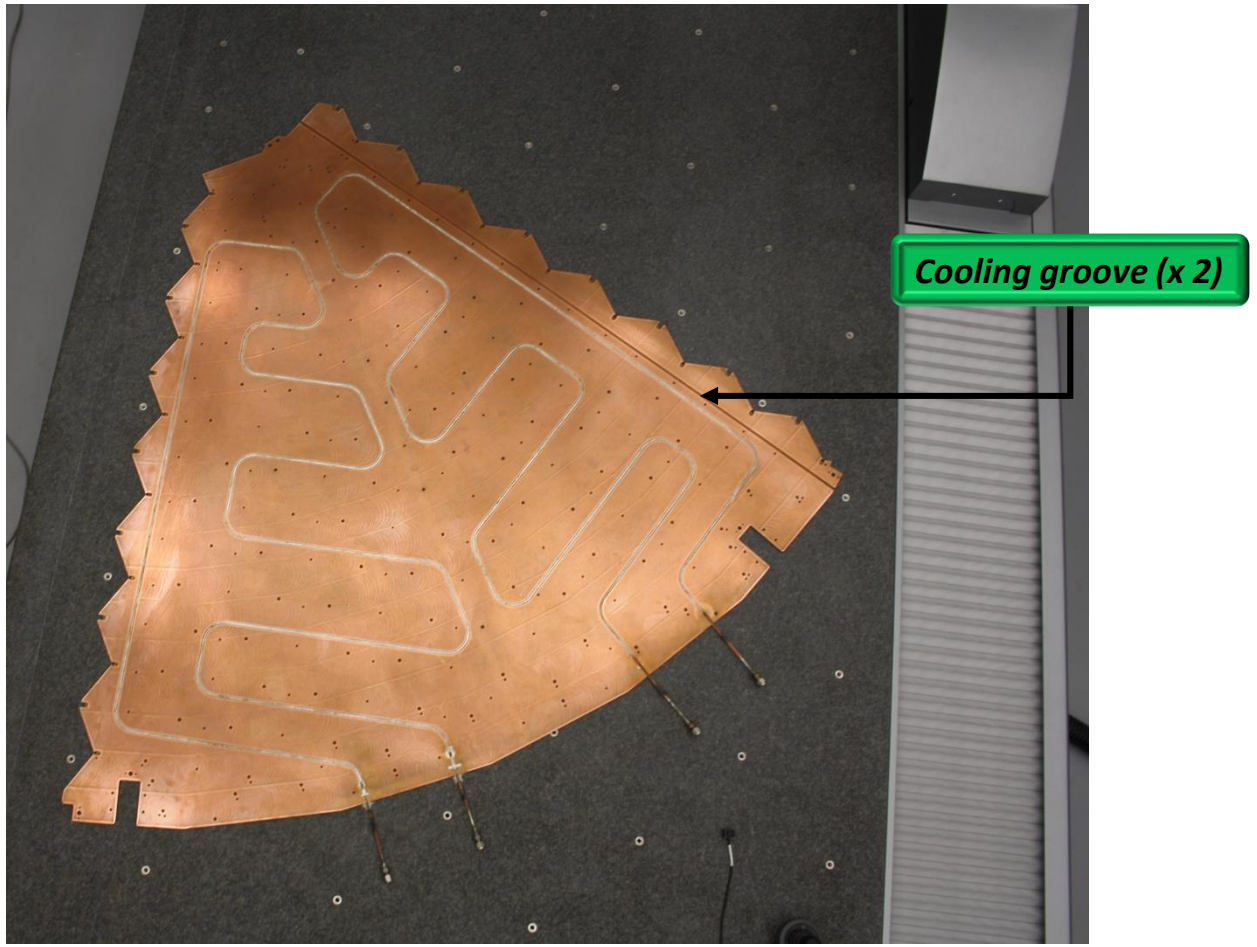


Interface for dry gas pipe (x1)



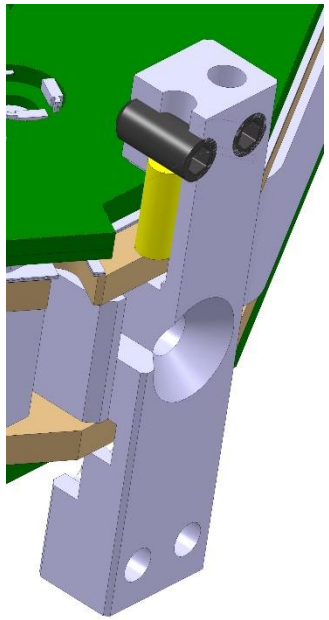
Cooling plate description

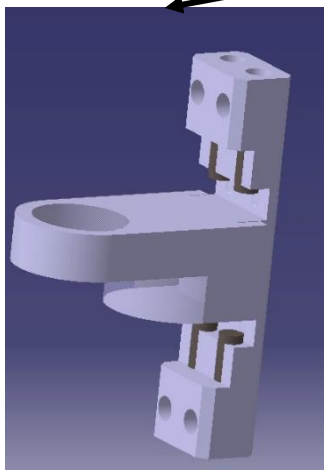




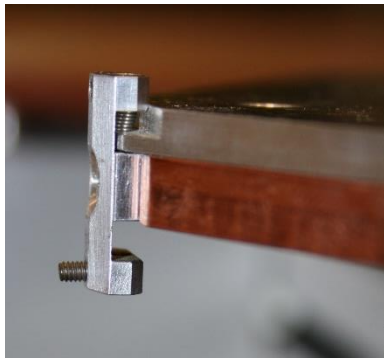
Cooling plate description

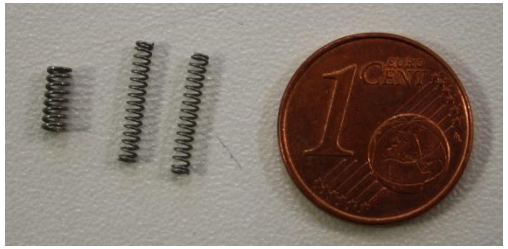
Several options developed

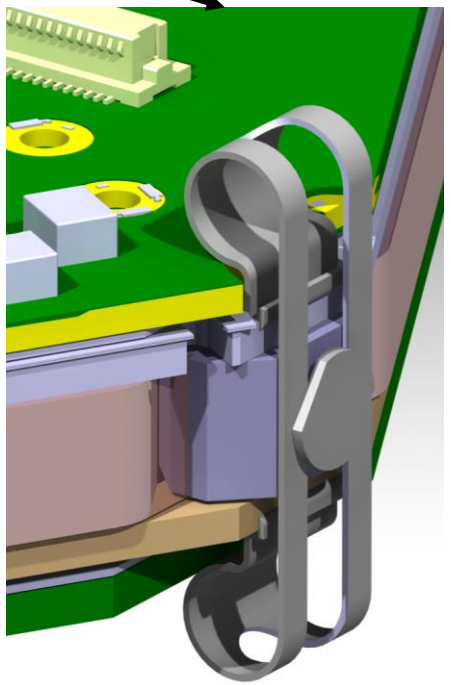




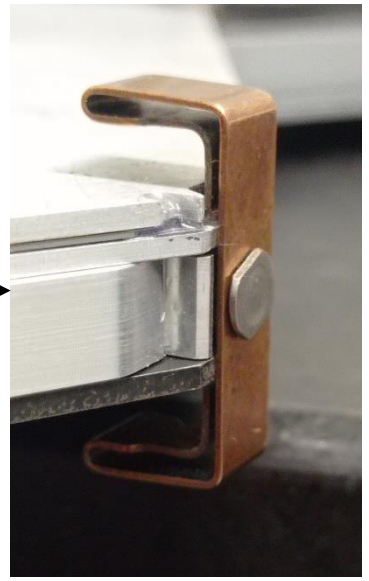
Option 1

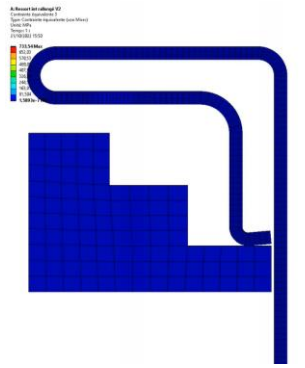






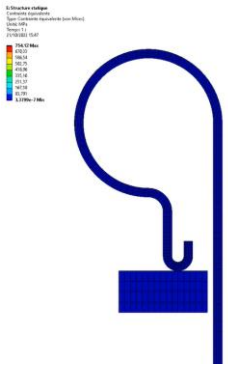
Option 2



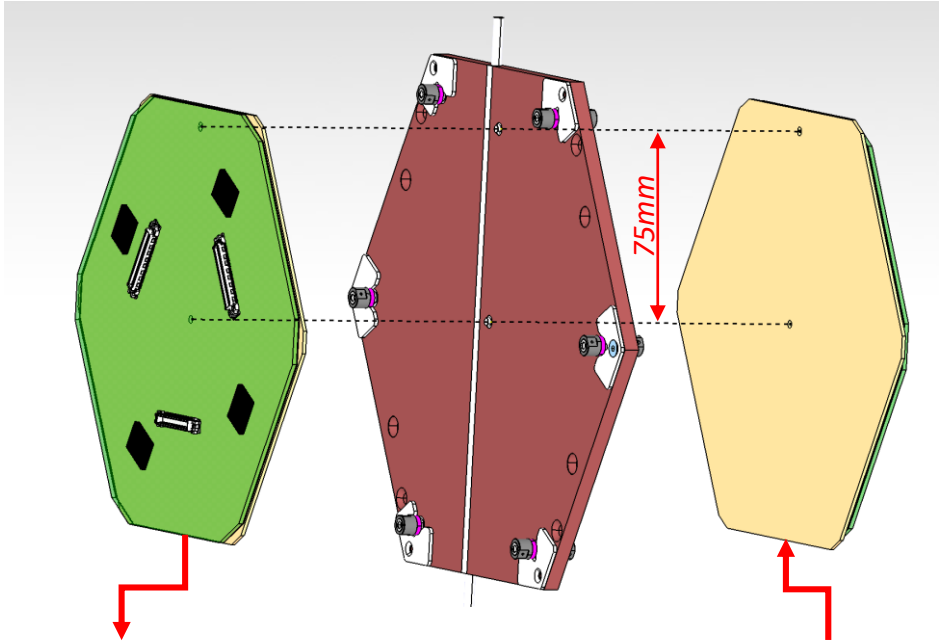


Option 3 (actual baseline)

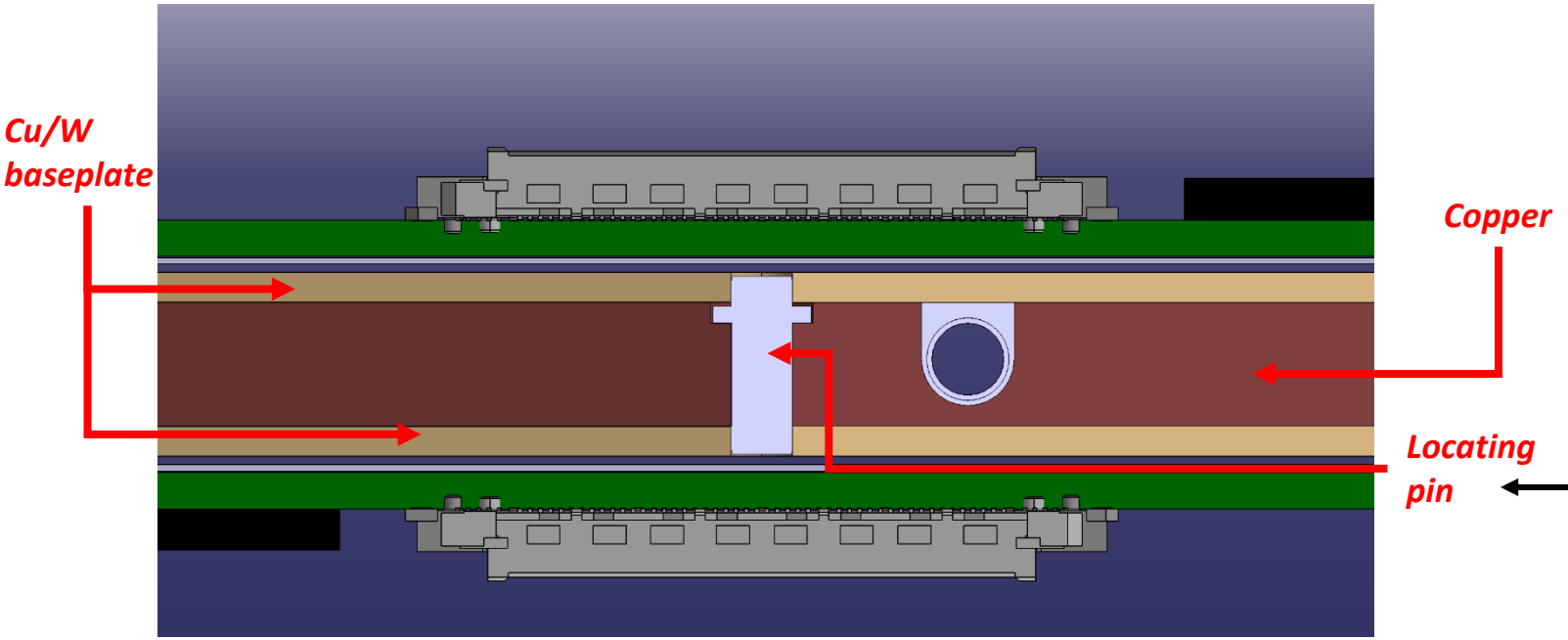
Interface for edge spacers for 1 module (~ x 15)



Cooling plate description

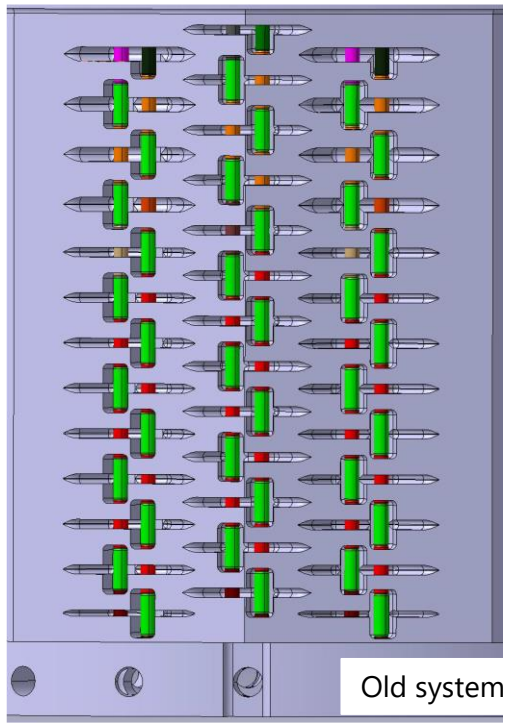


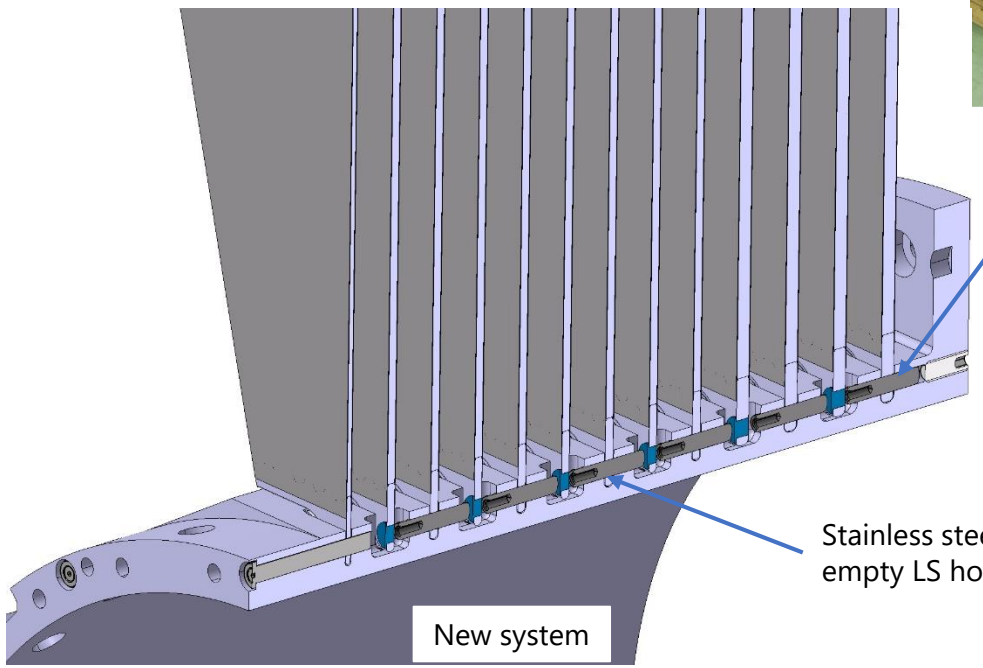
Once you defined the orientation of module on one side, you automatically set the orientation of the associated pair.
How many modules could work in pairs like this and how many don't?

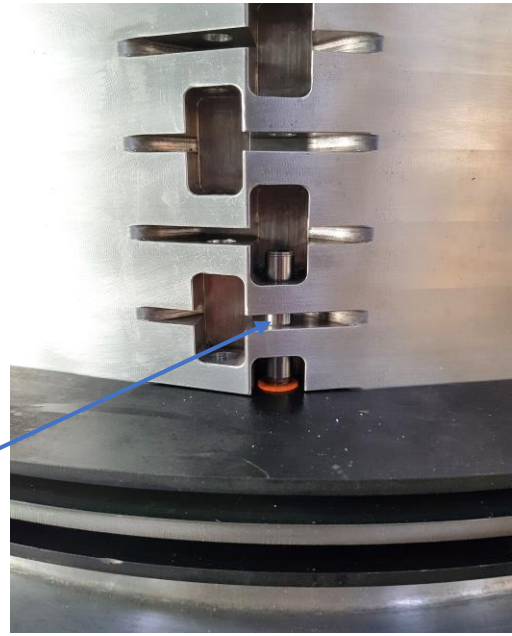


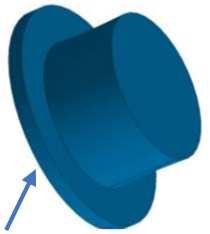
Holes for locating pins (~ 100)
Used for module locating and orientation

Cooling plate description

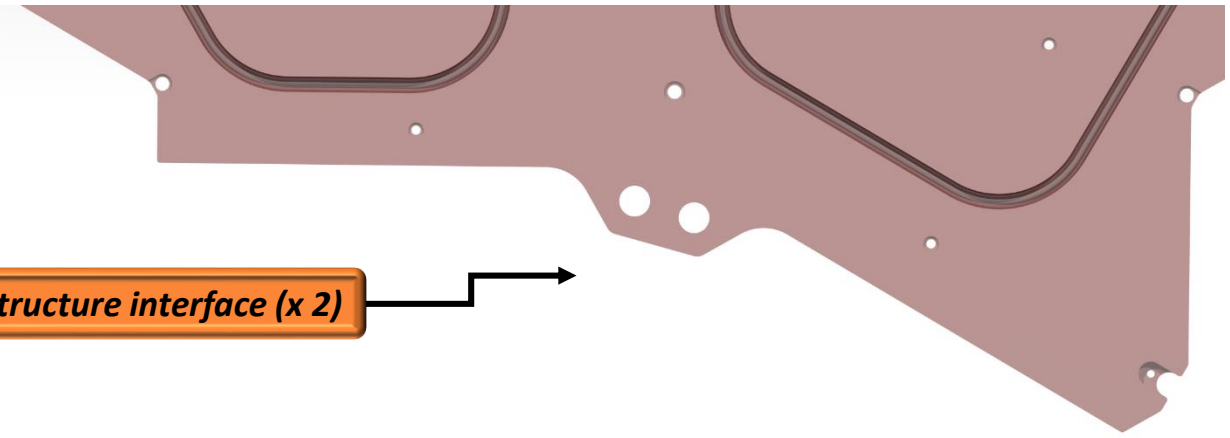






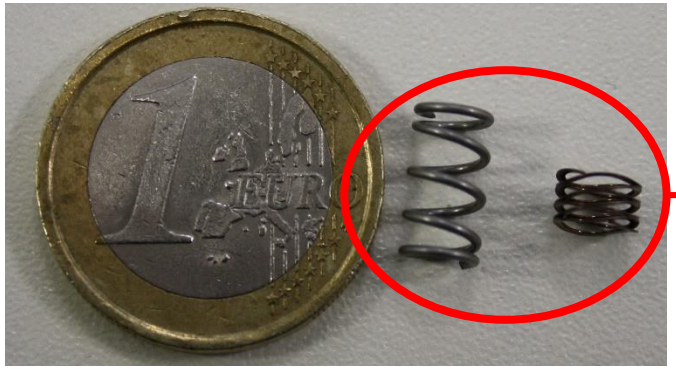


Stainless steel plug glued to the empty LS hole

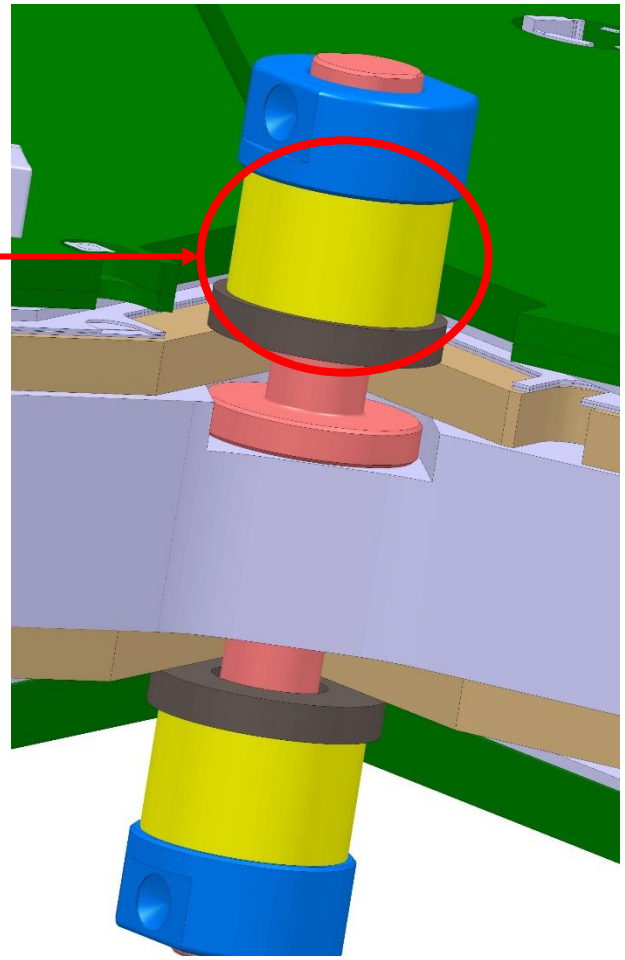


Holes for inner support structure interface (x 2)

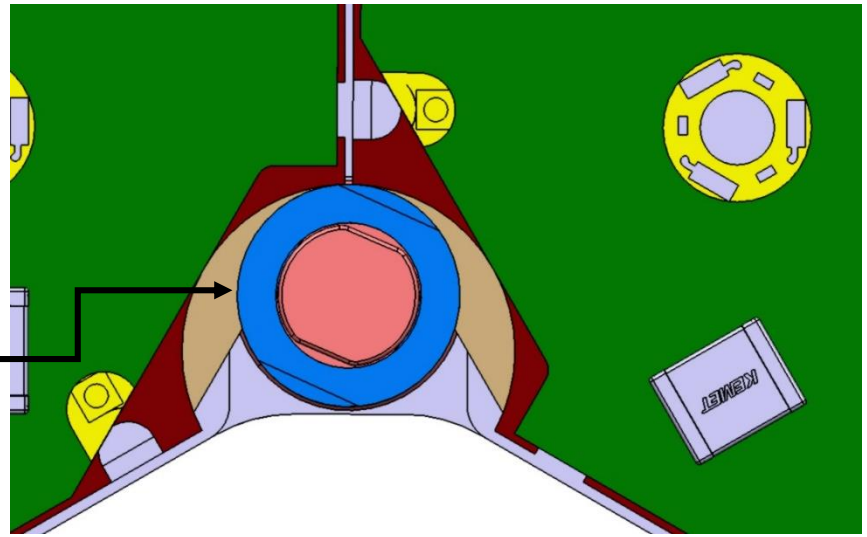
Cooling plate description



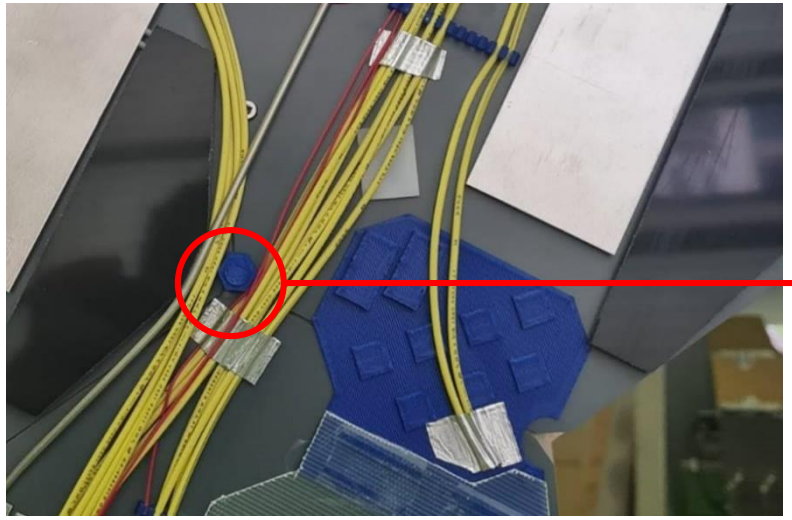
Several spring options to adjust compression force



Interface for edge spacers for 2 modules (~ x 15)

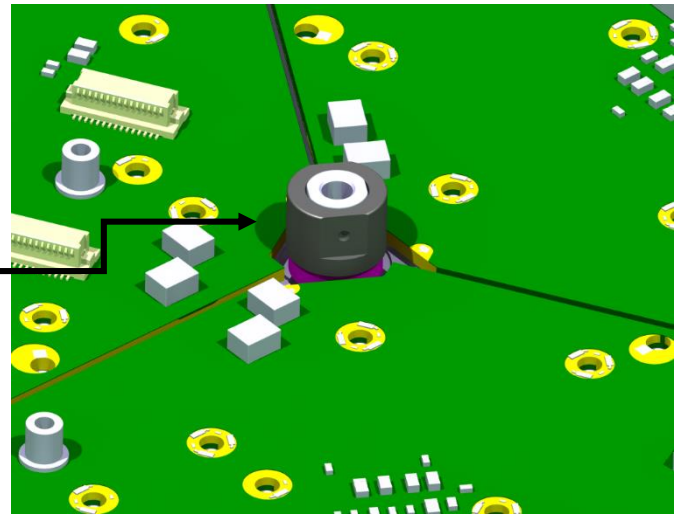


Cooling plate description



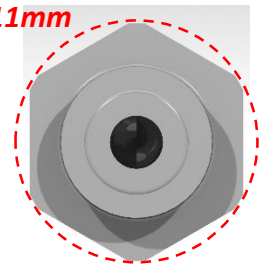
2 options to deal with services identified choke points

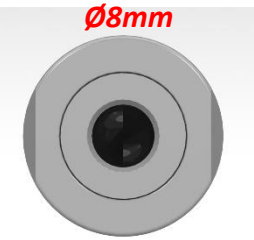
Threaded holes for central spacers (~ x 100)

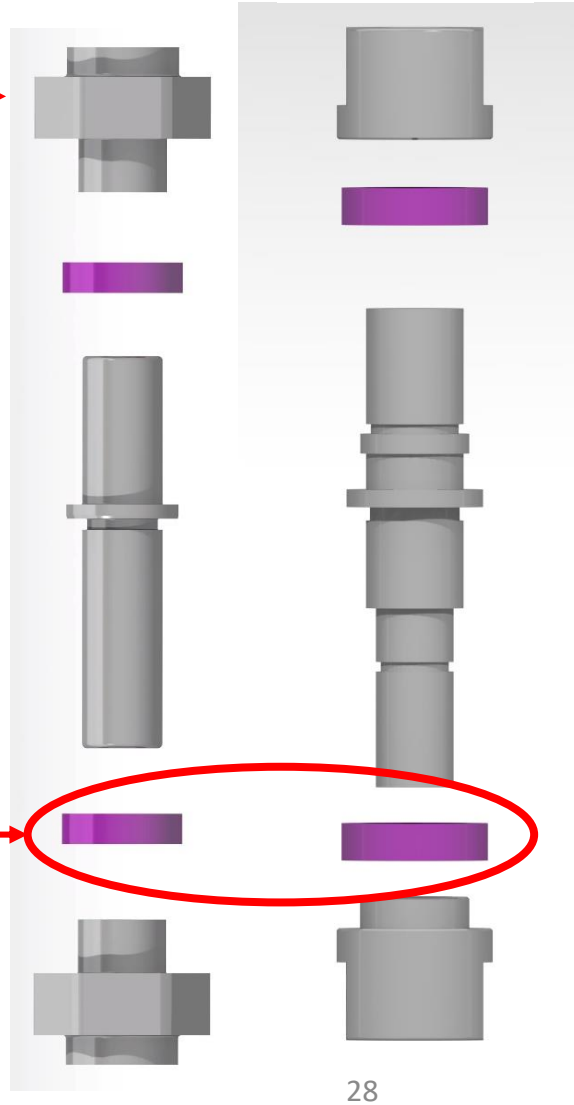


Central spacer body provide hard stops in Z which is the only way to control the overall CE-E thickness.
Torelance applied in length directly affects the overall CE-E thickness tolerance

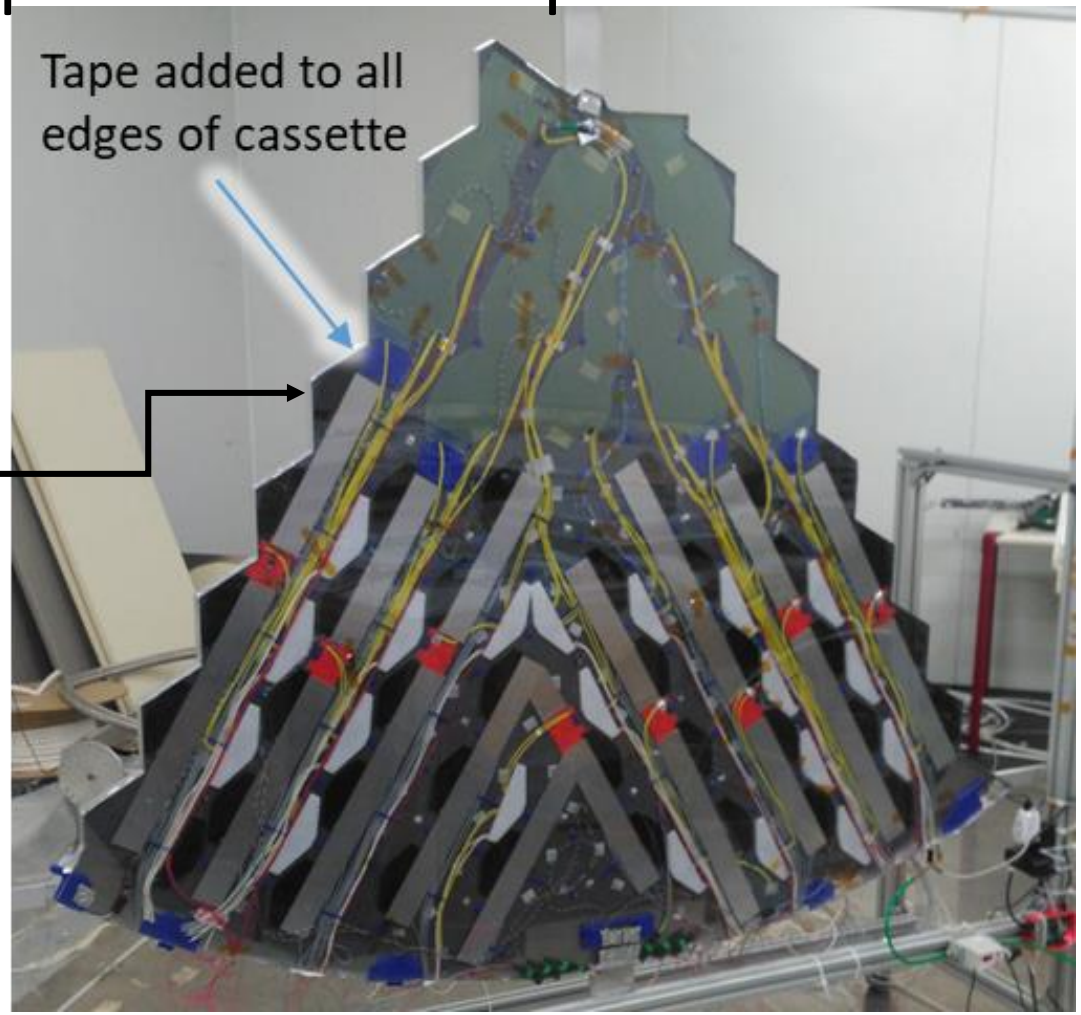
Several spring options to adjust compression force



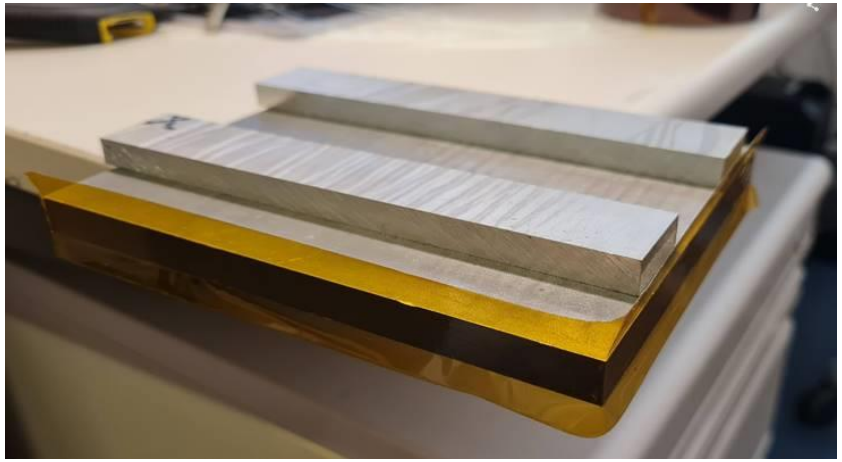




Cooling plate description

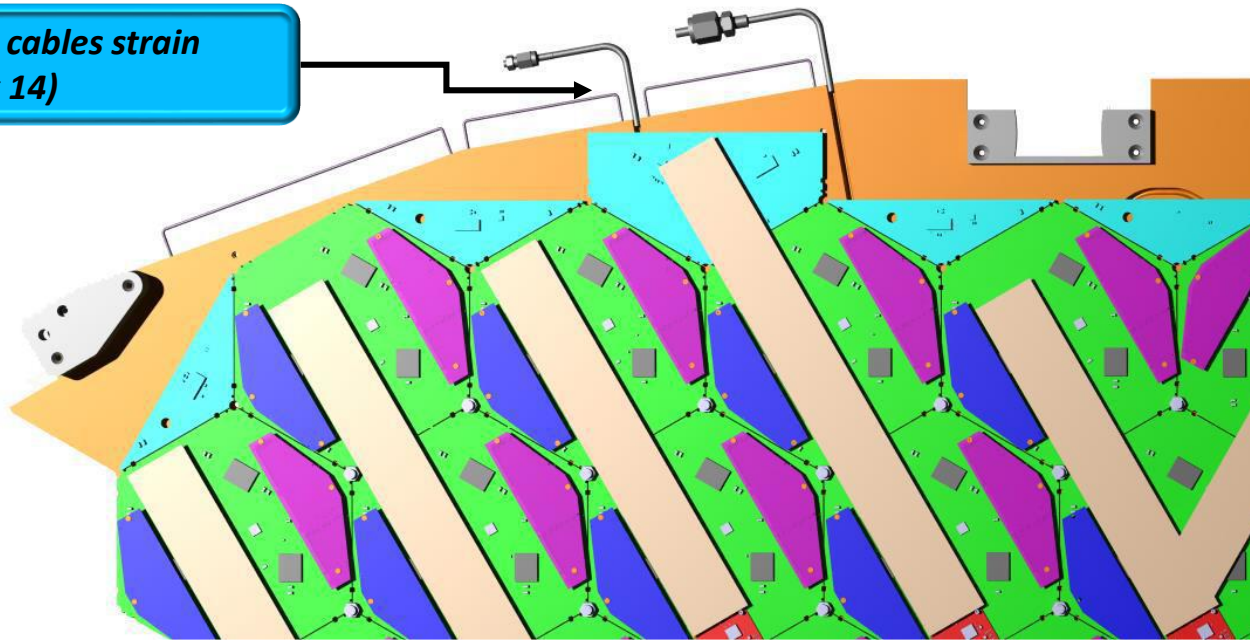


Dry gas sealing foil (x 1)



Cooling plate description

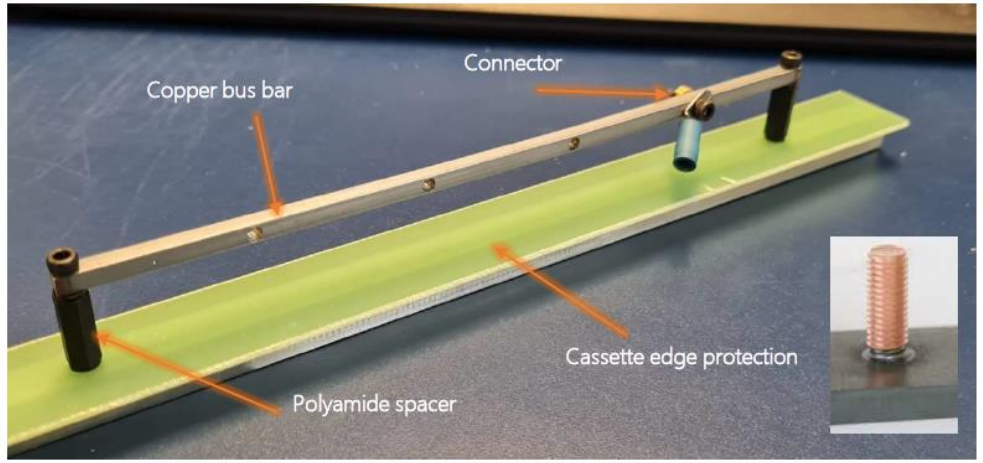
Interface for cables strain relief bars (x 14)

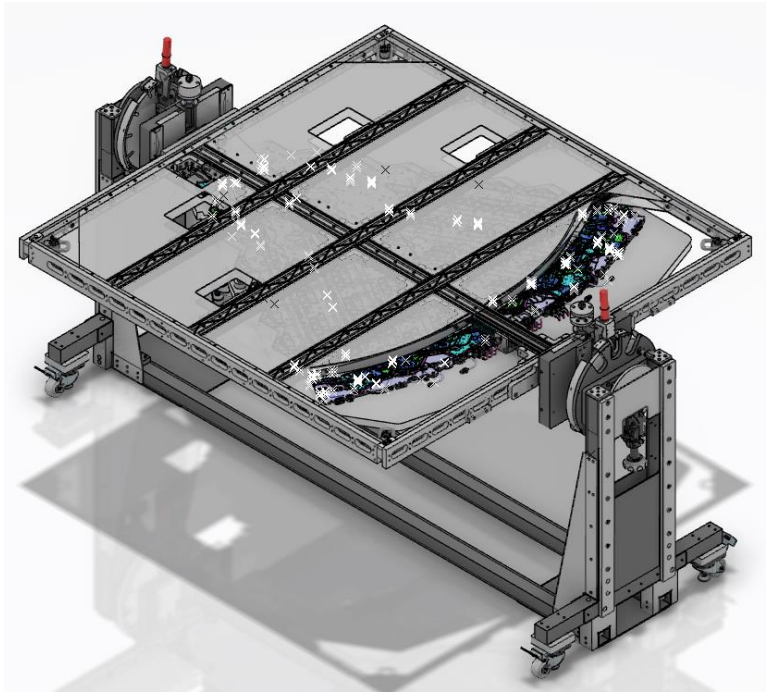


4) Cassette edge status:

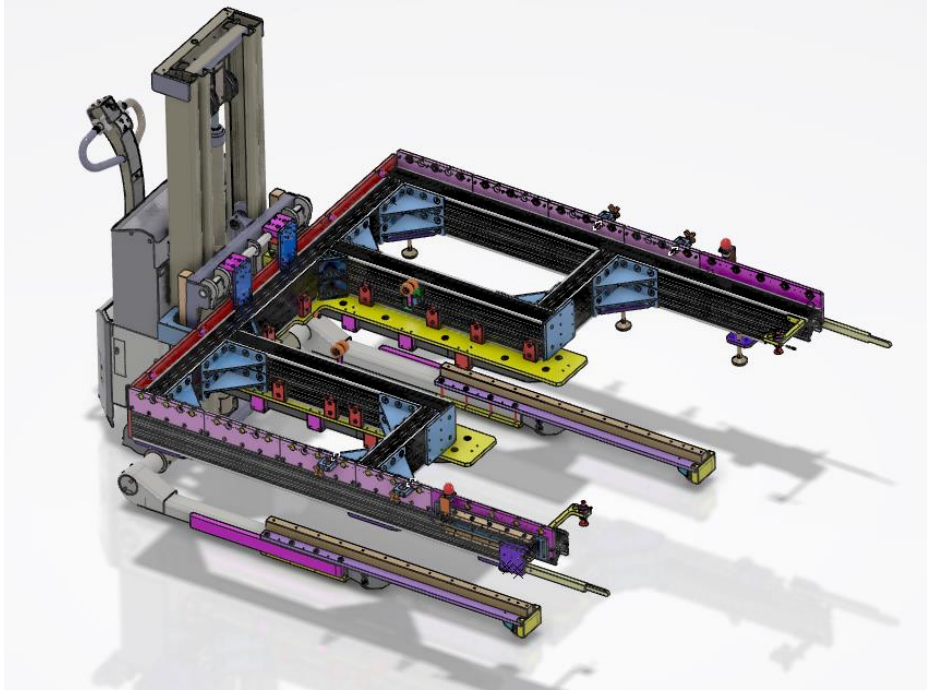
Grounding concept based on the bus bar is being studied. Since cassette internal space is tight possibility of integrating bus bar design and services strains relief (including cassette protection) is being checked.

Bus bar/services strain relief and cassette edge protection concept

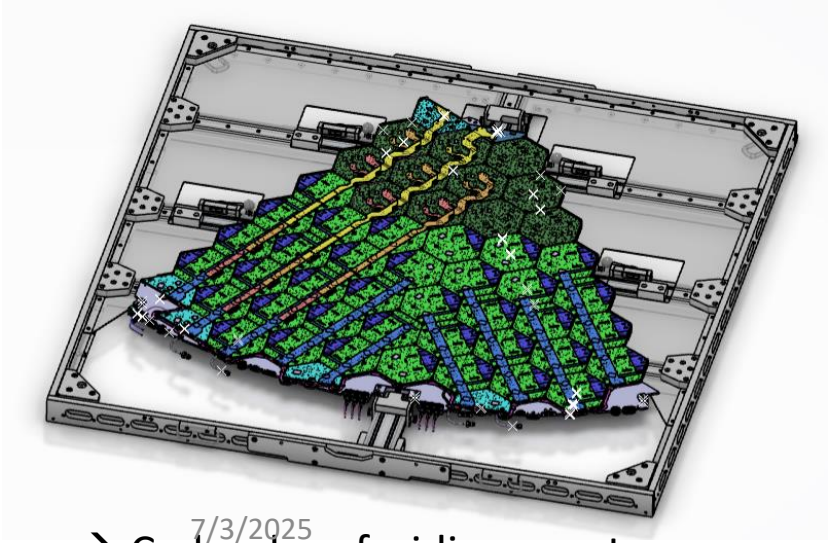




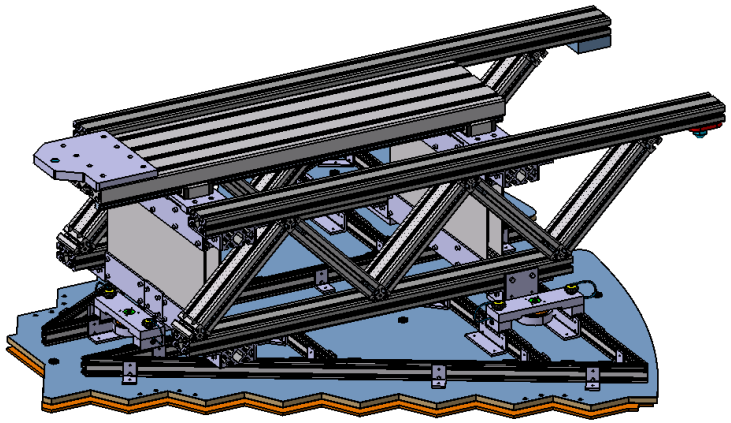
→ Station d’assemblage



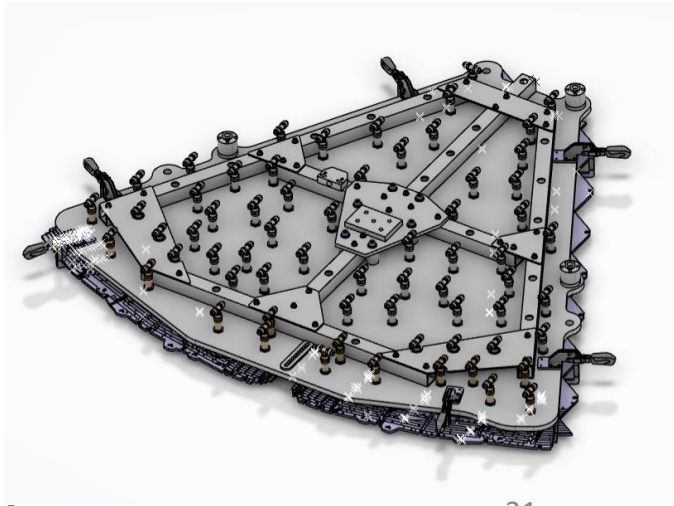
→ Gerbeur spécifique



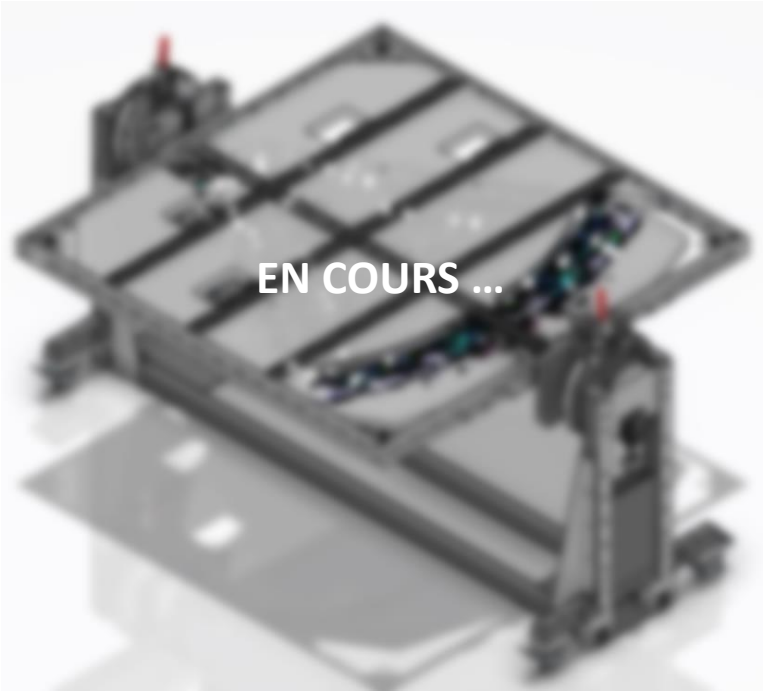
→ Cadre de refroidissement



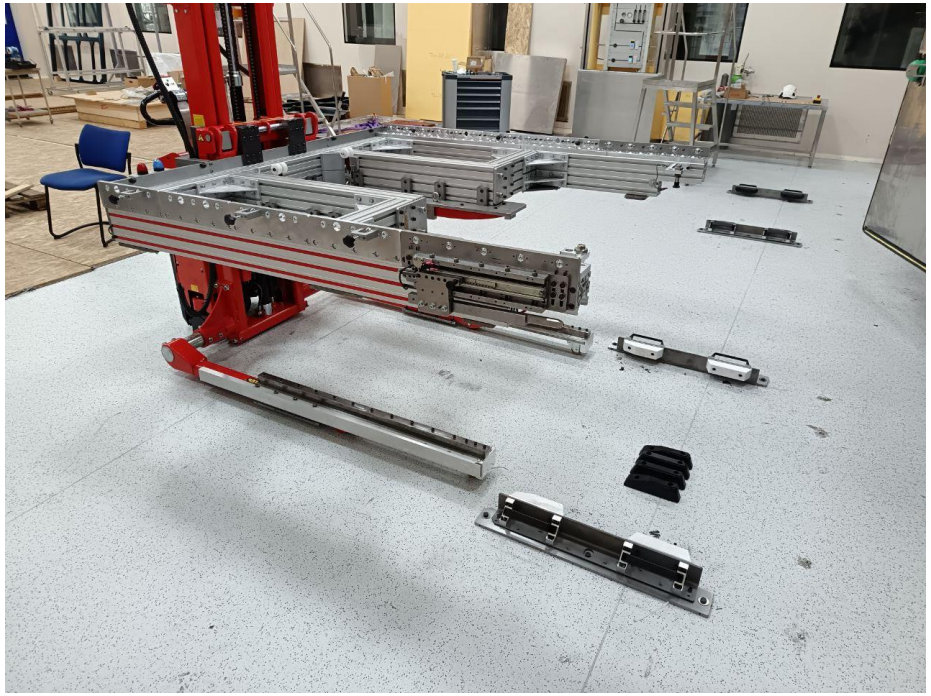
→ Outil d’insertion



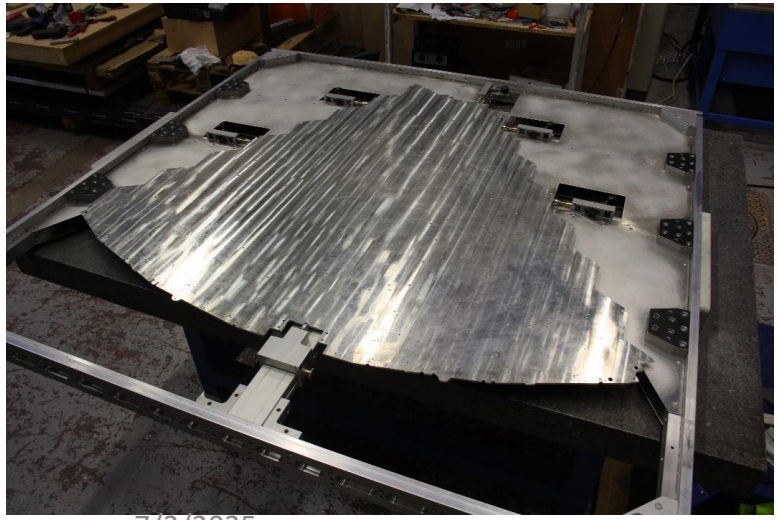
→ Palonnier version CERN



→ Station d’assemblage



→ Gerbeur spécifique

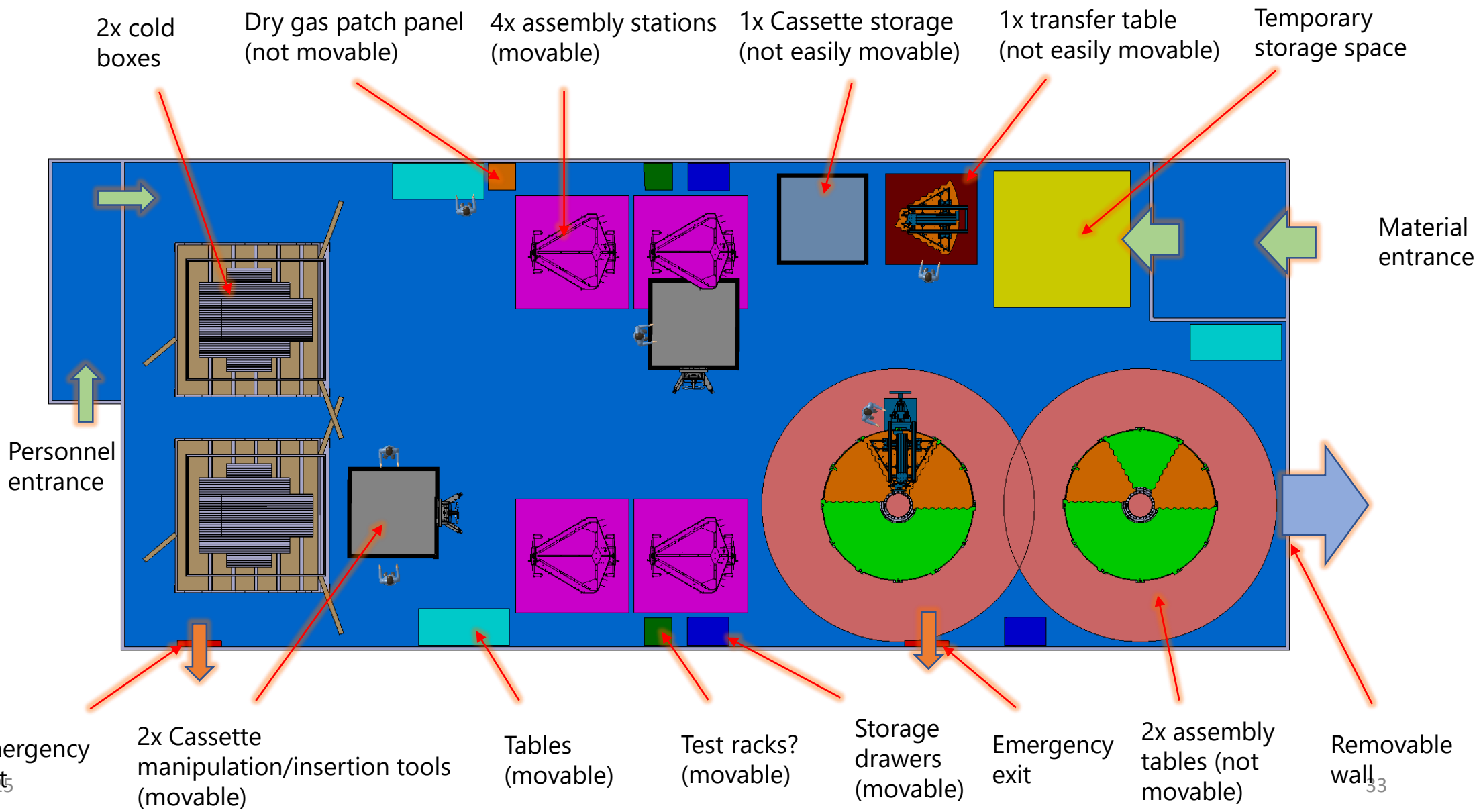
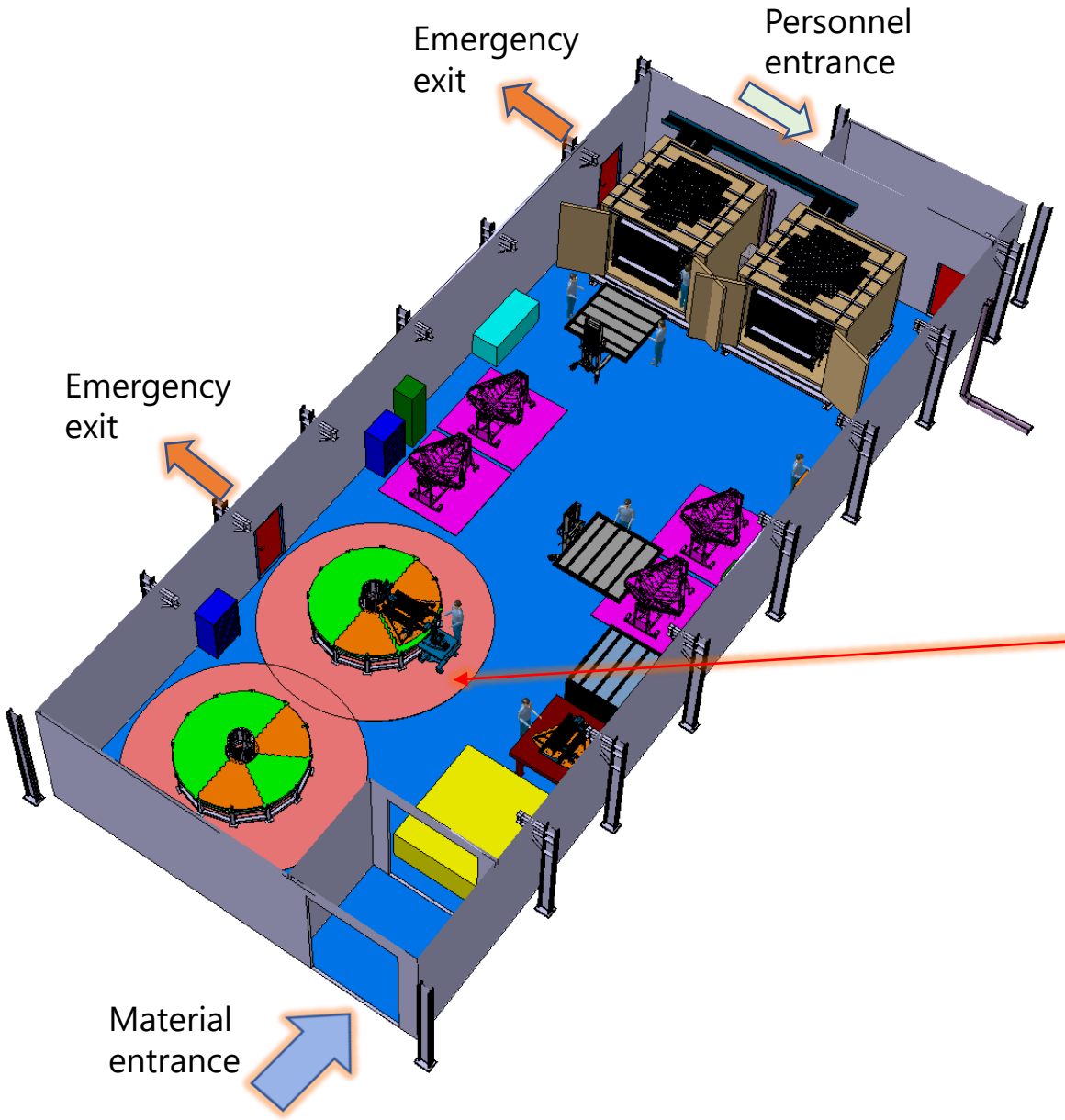


→ Cadre de refroidissement

→ Outil d’insertion

→ Palonnier version CERN

2. SXA5 Clean room layout



2. SXA5 Clean room layout