Cryostat installation sequence
&
QA for cold structure

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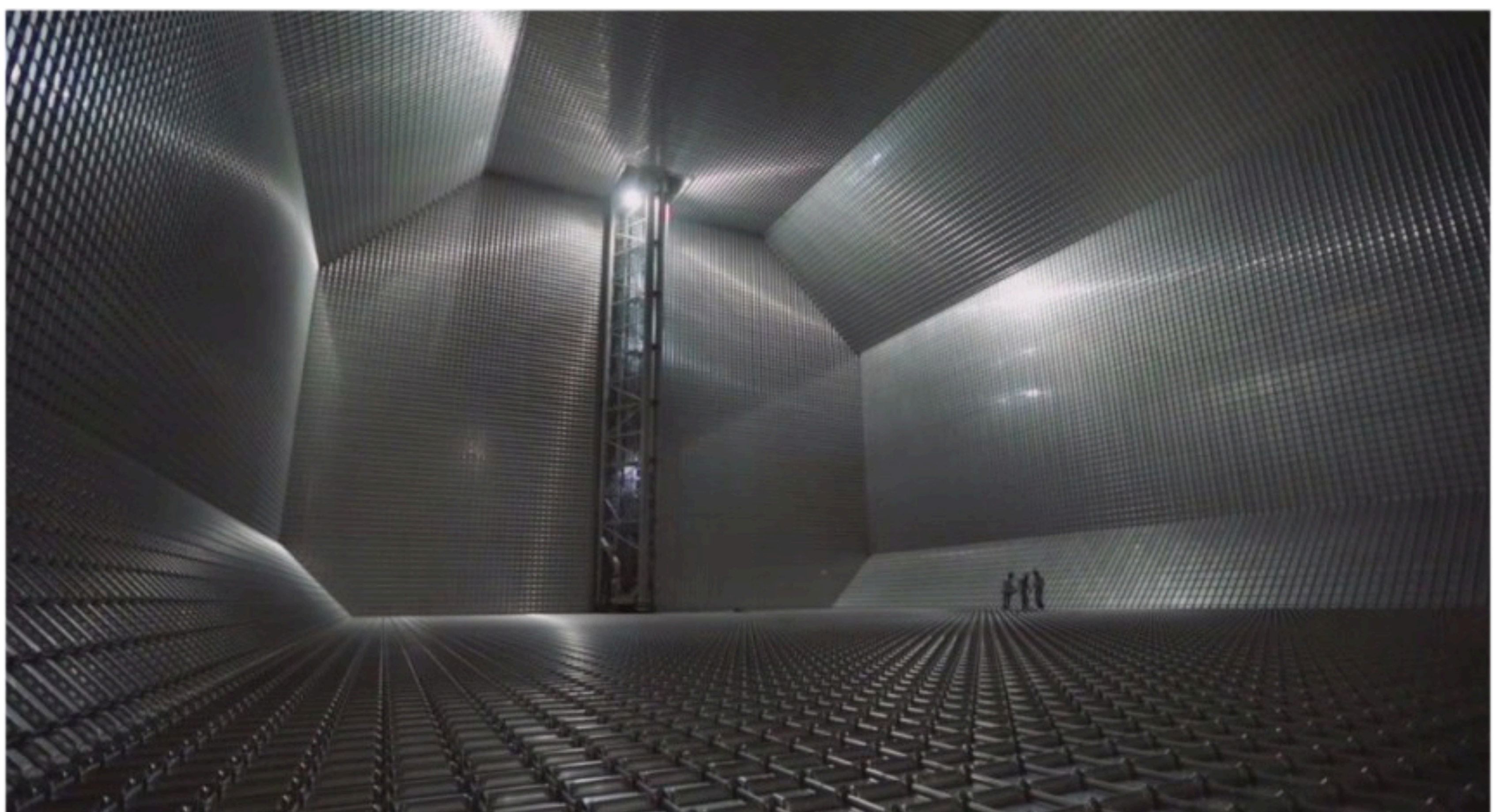
The technology

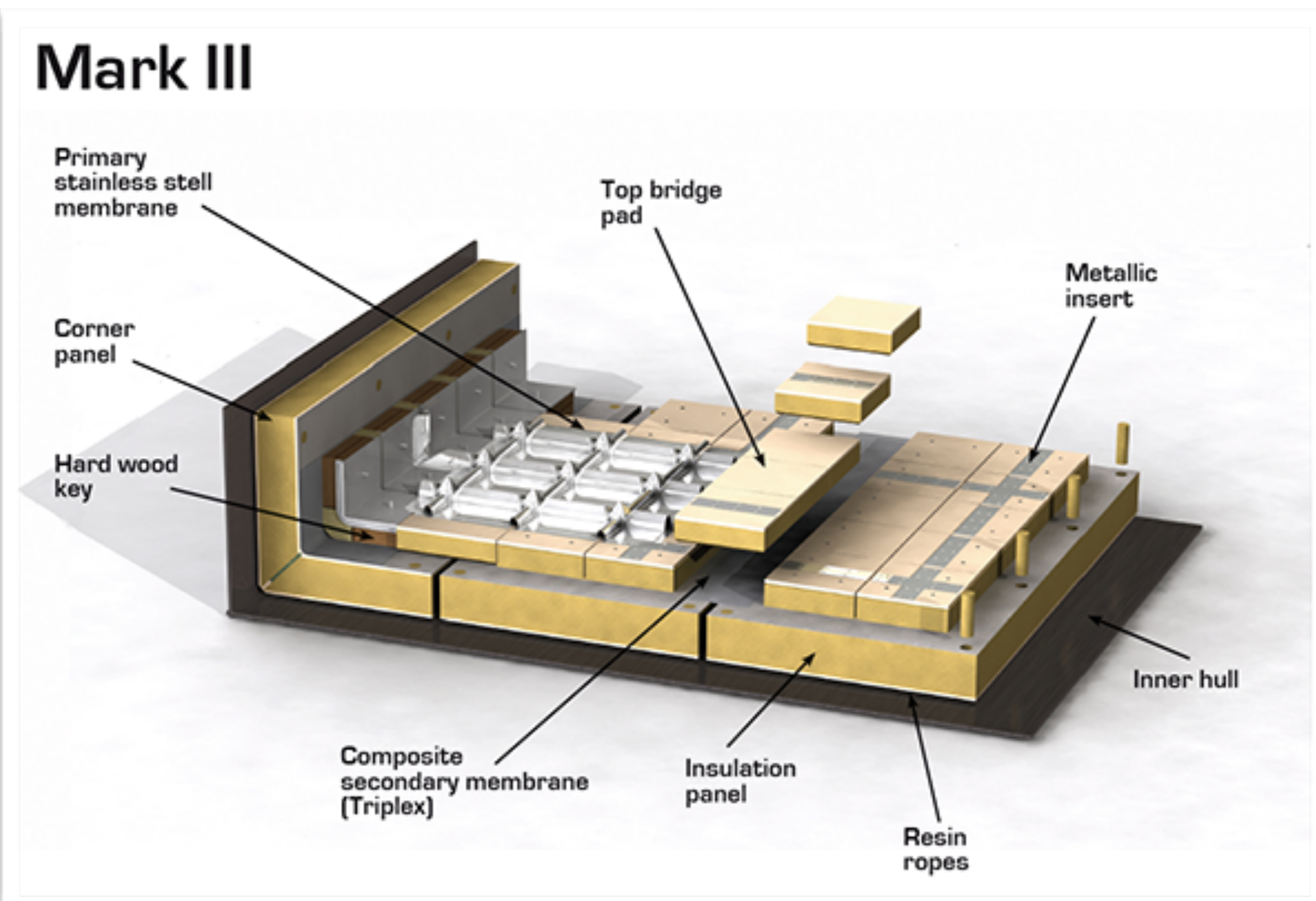
Royalties owner: GTT (France)
Construction licensee: among several Gabadi (construction of ProtoDUNEs)
Applications:

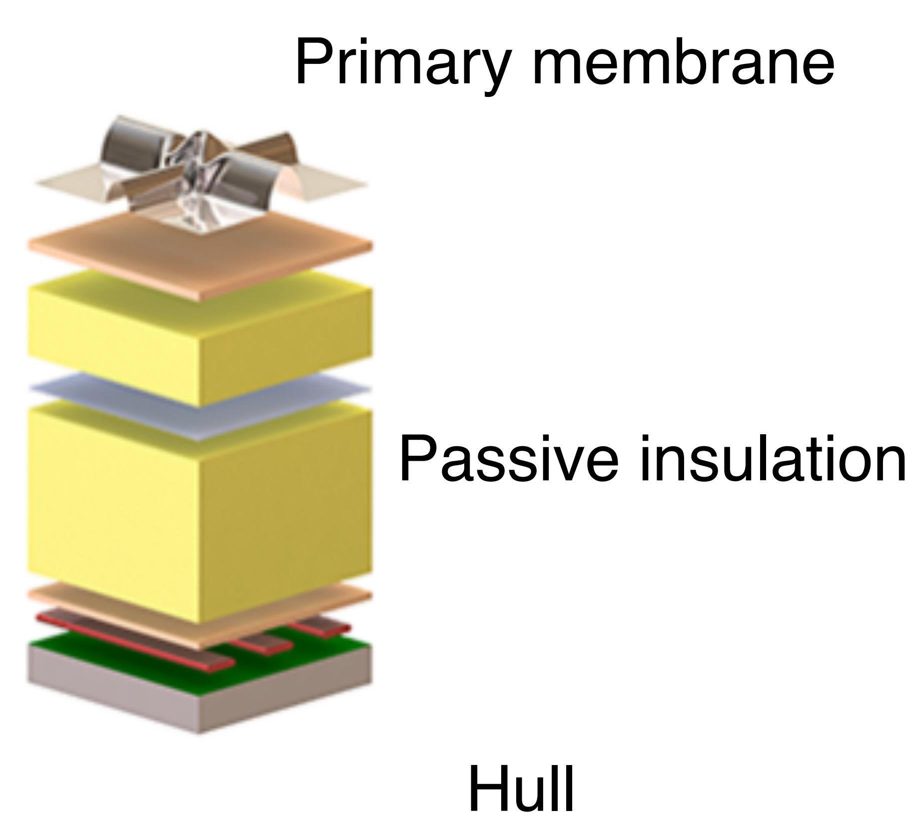
- LNG carriers (>200000 m^3 in 5 sub-tanks)
- Floating storages and re-gasification vessels
- Land storage tanks
- Fuel tank for vessels
- Cryostats for liquid argon time projection chambers



GTT Mark III technology

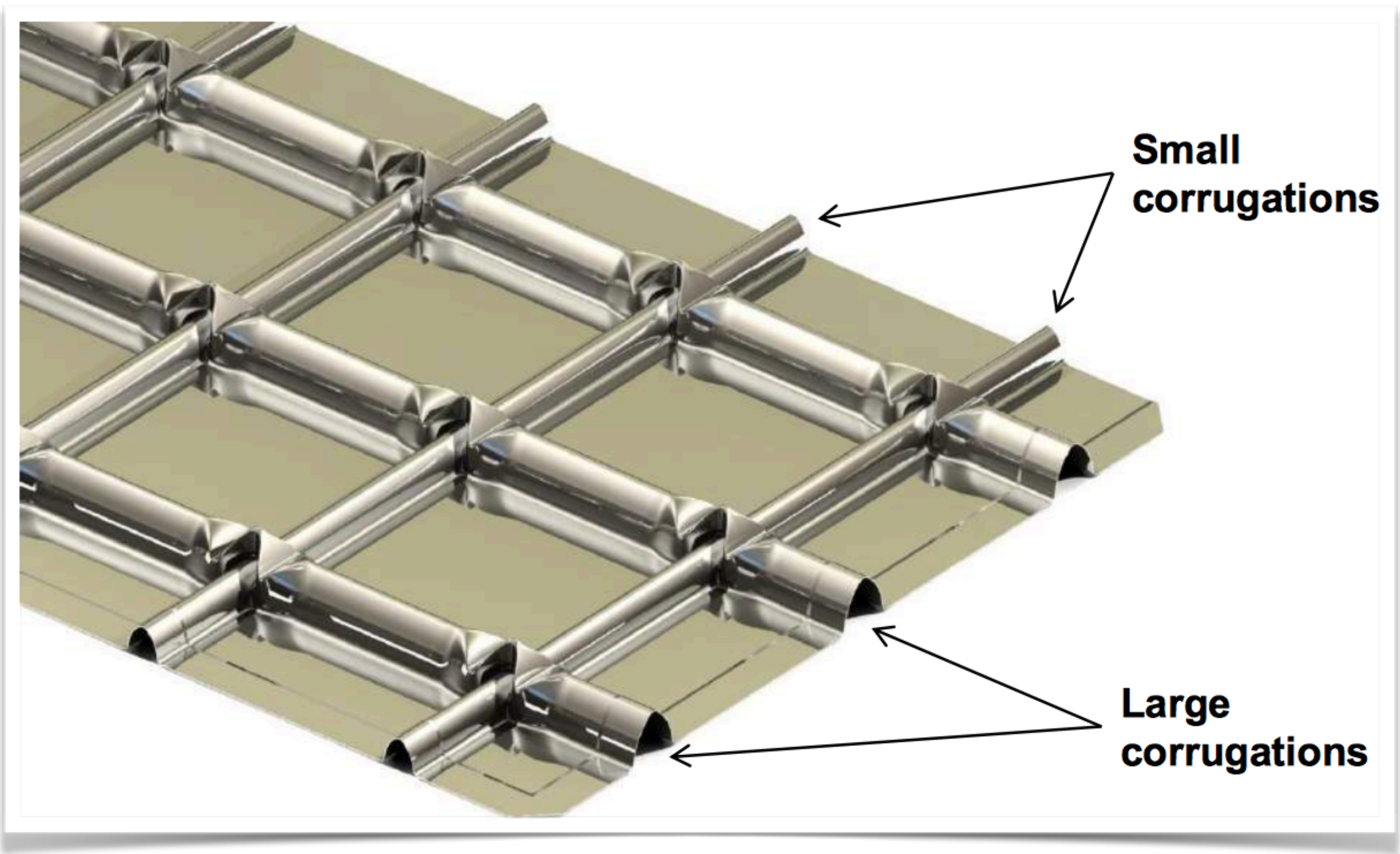
Primary membrane: in contact with the liquid. Flexible and elastic to accomodate wave impacts, vessel deformation, thermal expansion and contraction. Not self supporting.
Thermal insulation: passive, in between and directly connected to the primary membrane and the hull.
Hull: the warm structure, sustains and support the entire system.





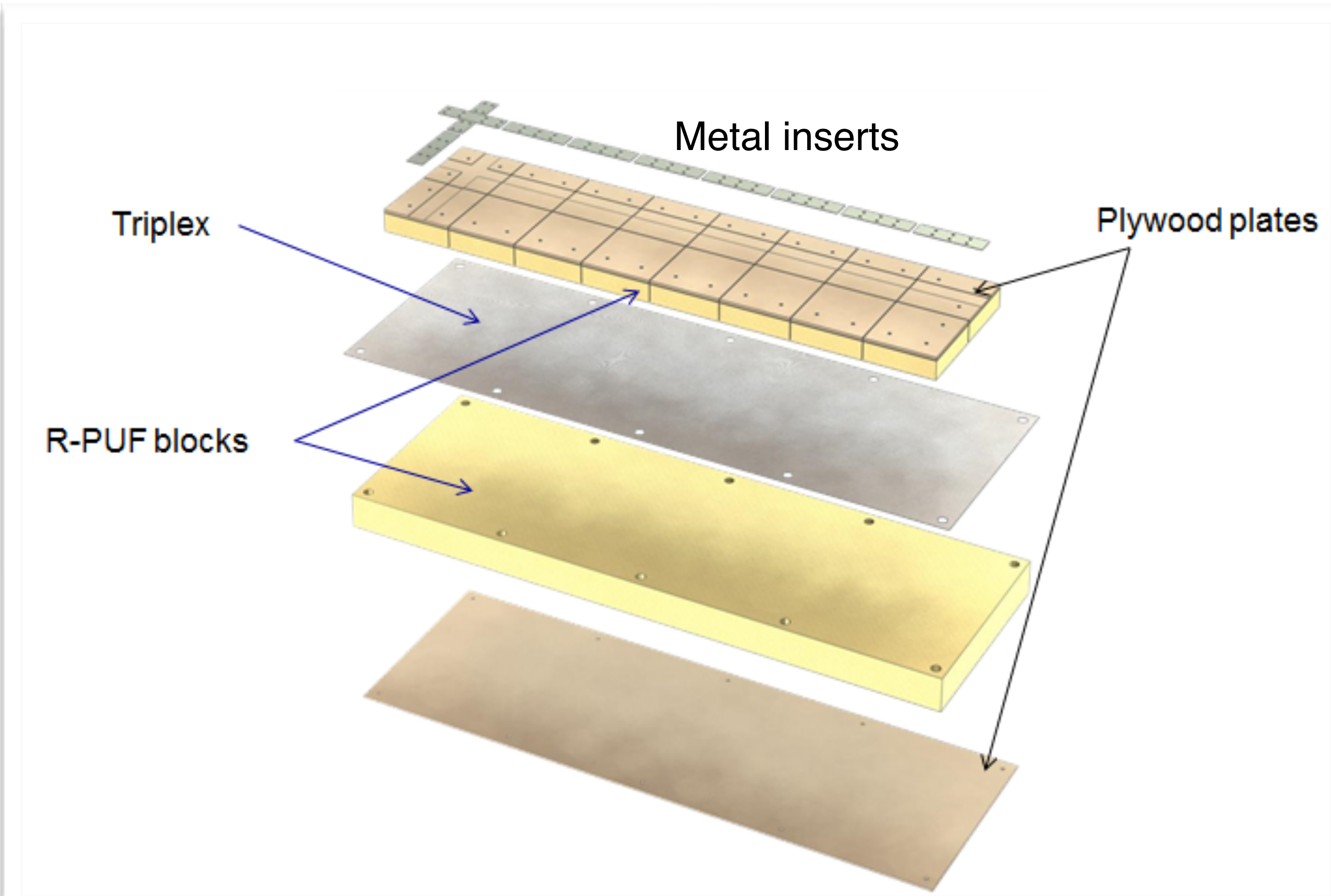
GTT Mark III technology

Primary membrane:
Stainless Steel 304L, 1.2 mm thick, ~1 m x ~3 m ‘tiles’ (eventually welded together), with corrugation (acting as springs) along the two orthogonal directions (340 mm pitch).
Highly standardised components, constructed in Korea.
Special components for angle and corner pieces and roof penetrations.



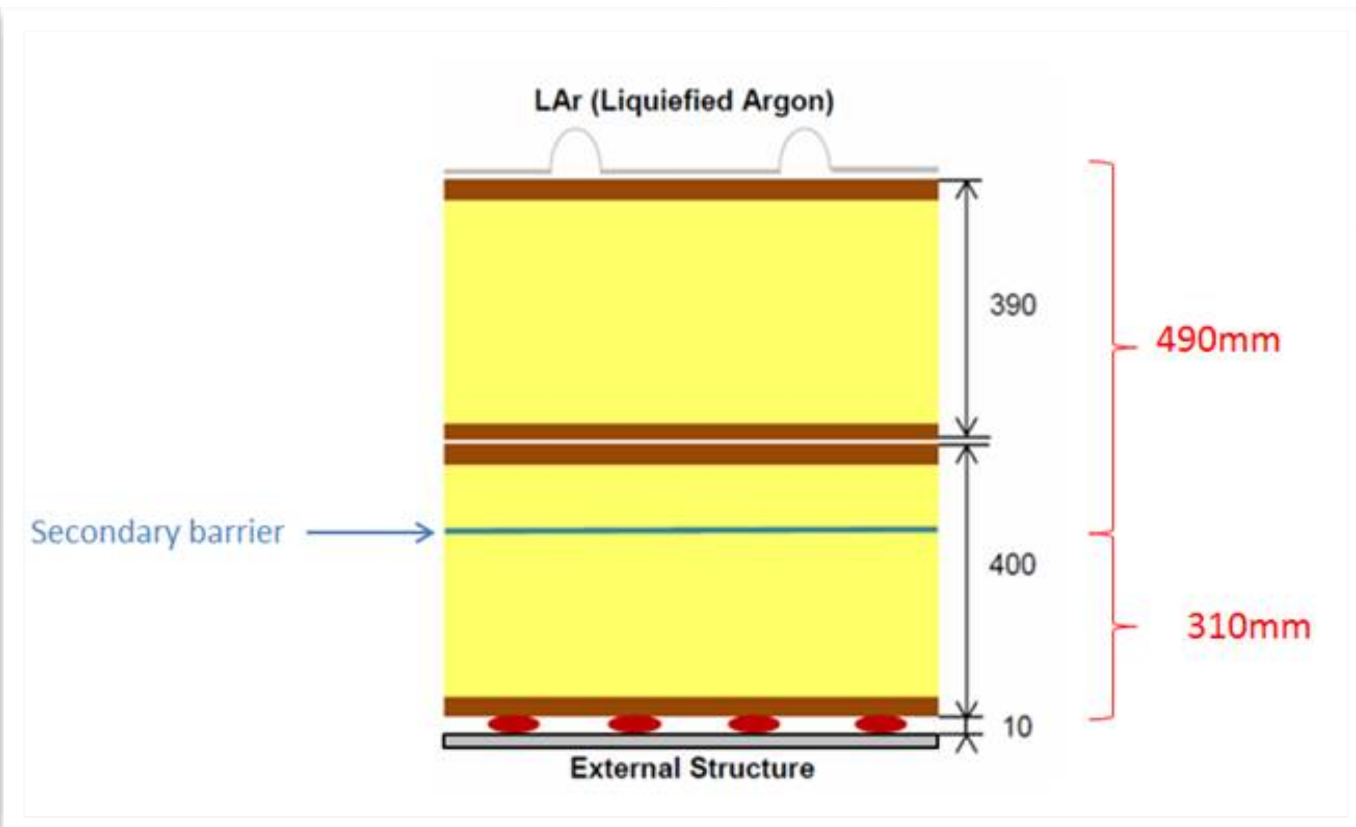
GTT Mark III technology

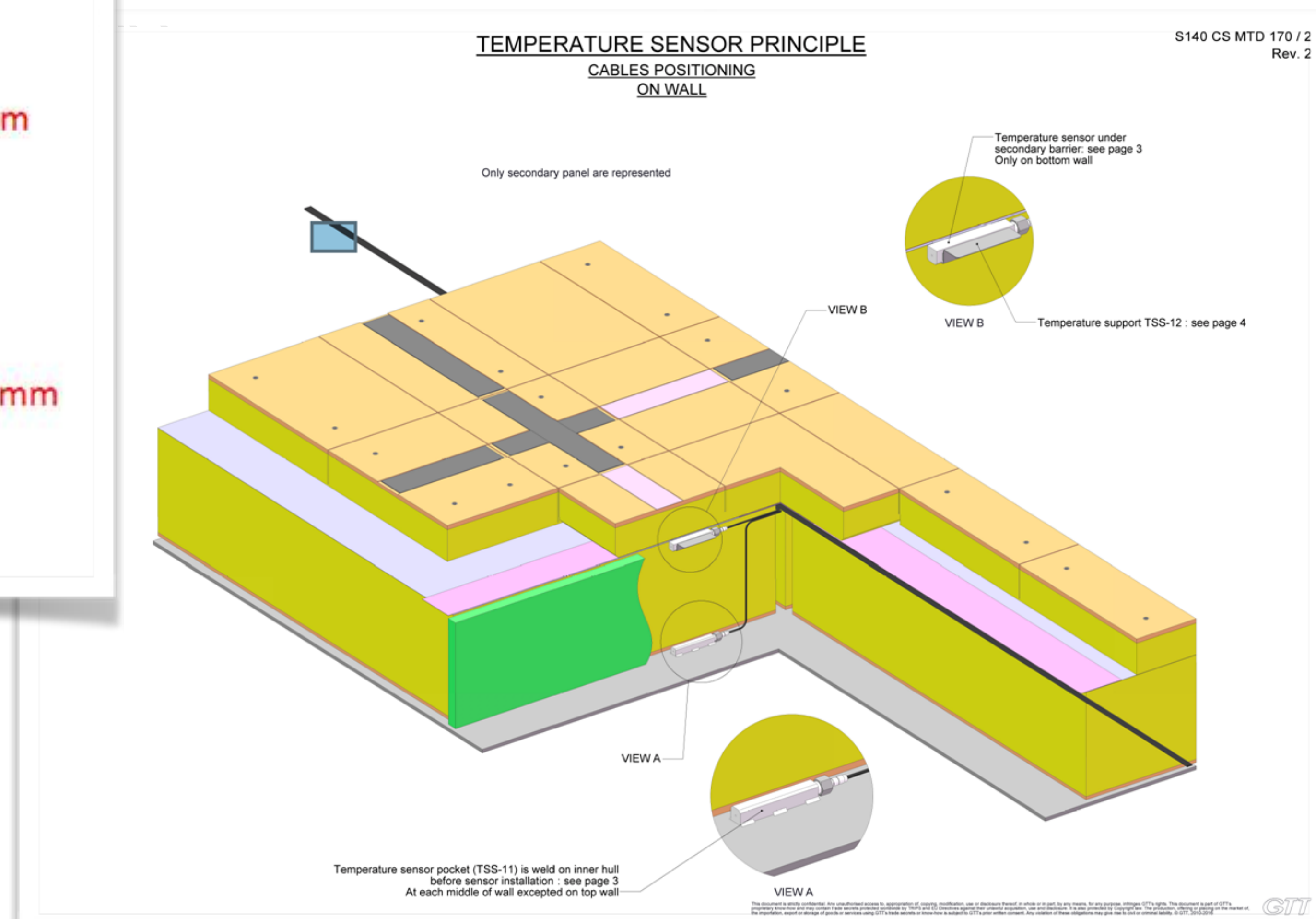
Insulation:
Two layers of polyurethane foam (90 kg/m^3) separated by the secondary membrane.
Metal inserts on the plywood serve as welding points for the primary membrane.
No direct metal contact between warm structure and primary membrane.
Highly standardised prefabricated components, constructed in Korea.
Special components for angle and corner pieces and roof penetrations.



Insulation for DUNE

Thickness increased to 790 mm to meet the heat input requirements (same as ProtoDUNEs)
Two layers of insulation panels (400 mm + 390 mm) installed subsequently
The outermost panels contain the secondary containment system
Temperature sensors in contact with the warm structure and secondary membrane installed in strategic spots to monitor the cool down and filling





Insulation and membrane

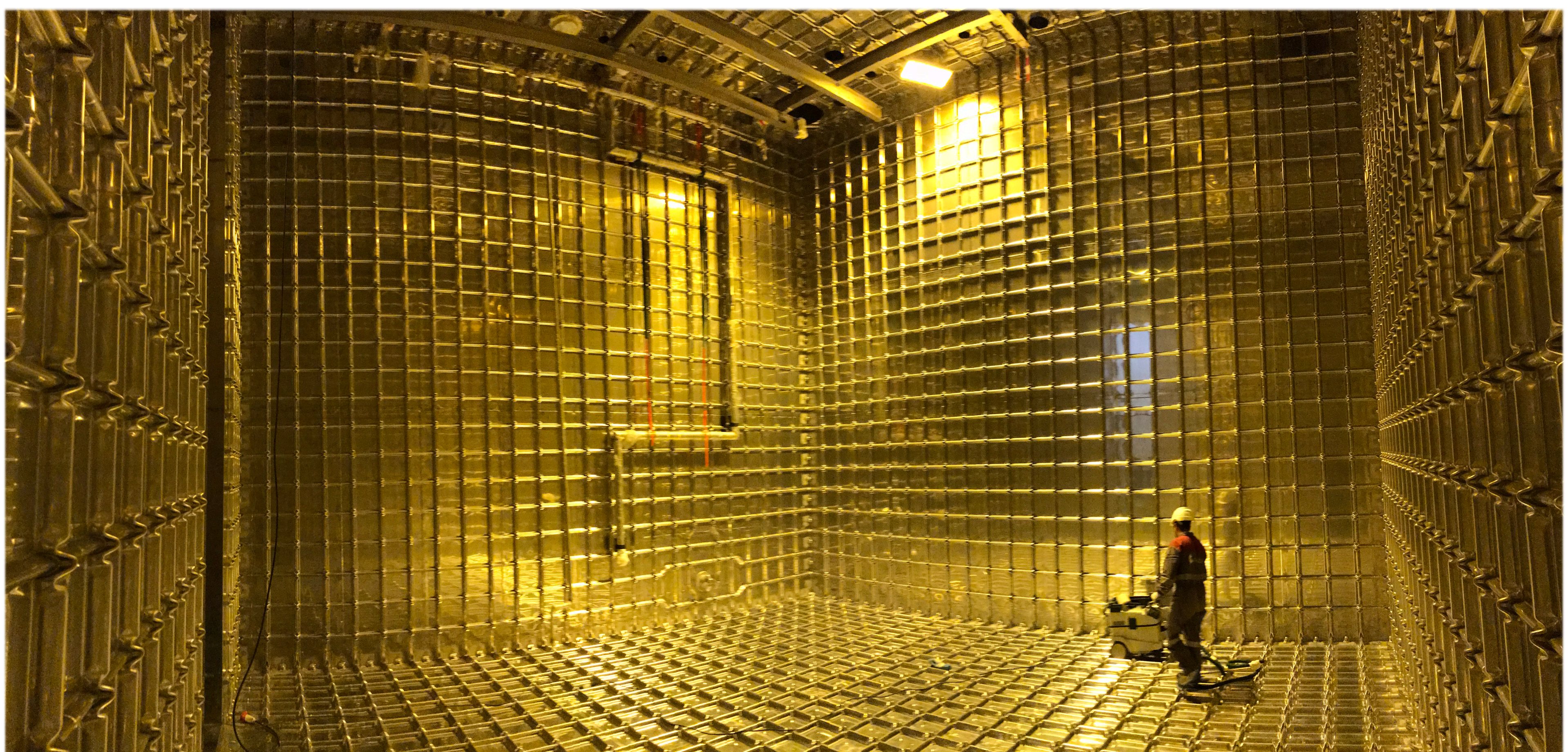
ProtoDUNEs:

Up to about ~50 workers (engineers, carpenters, welders, foreman, technicians, scaffolders):

- Gabadi for construction work, welding, and management
- GTT for quality control and supervision

NP04 (handover on 7th January 2017)
start date 9th of January
last welding 1st September (34 weeks)
Scaffolding removal 11th October

NP02 (handover on 13th March 2017)
start date 13th of March
last welding 22nd September (28 weeks)
Scaffolding removal 10th October



Construction sequence

Assuming no co-activity inside of the cryostat and 'easy access' to the cryostat (may conflict in some occasions with the clean room construction):
- Survey of the walls/floor/ceiling of the warm structure
- Installation of the scaffolding
- Marking and positioning of studs on the warm structure
- Installation of the first insulation layer (time consuming) including temperature sensors, pipes for GN_2, …
- Sealing with *triplex* bonding of the secondary membrane
- Test with vacuum boxes the secondary membrane
- Completion of the first insulation layer
- Installation of the second insulation layer (time consuming)
- Fitting of the corrugated membrane and weld it vacuum tight
- Test of the corrugated membrane (global vacuum test) and helium sniffing
- Same for the TCO closure, but in small and confined space

Needed equipment

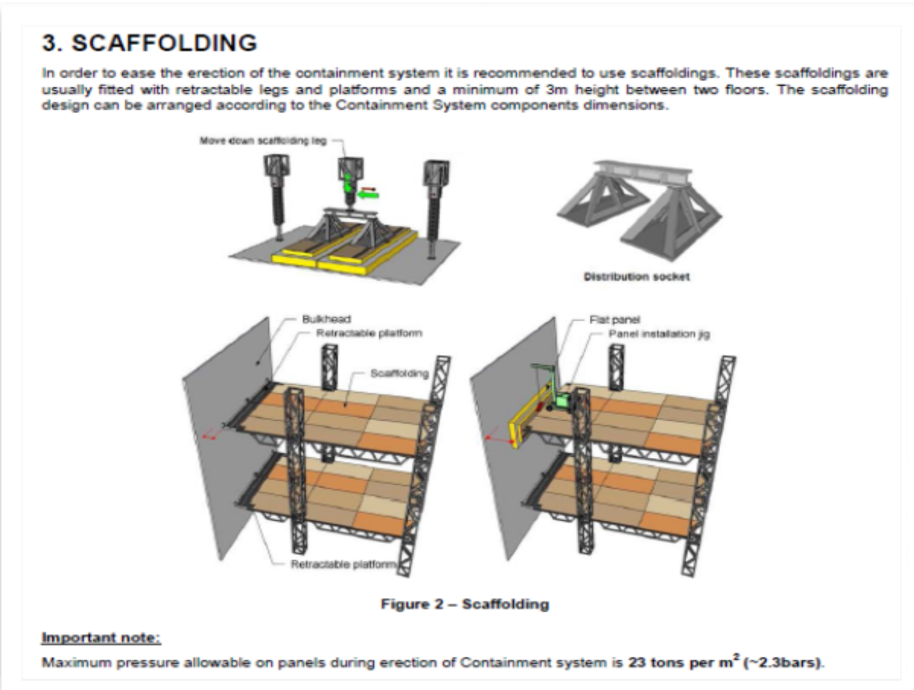
Number and type defined by the company selected to construct the cryostat insulation and containment system.
The company is in charge of the procurement of this material.

Type of equipment used at ProtoDUNEs:

- Standard equipment (grinders, jigsaws, planners, drillers, sanders, stud welding machines, TIG welding machines, …)
- Scaffolding and electric hoist
- Pallet trucks and carts
- Mastic mixing machines
- Triplex bonding machines
- Lifting hoists on the scaffolding and lifting fixtures
- Vacuum pumps and pressure sensors

Scaffolding

Laying on the floor (at most 23 ton/m^2)



3. SCAFFOLDING

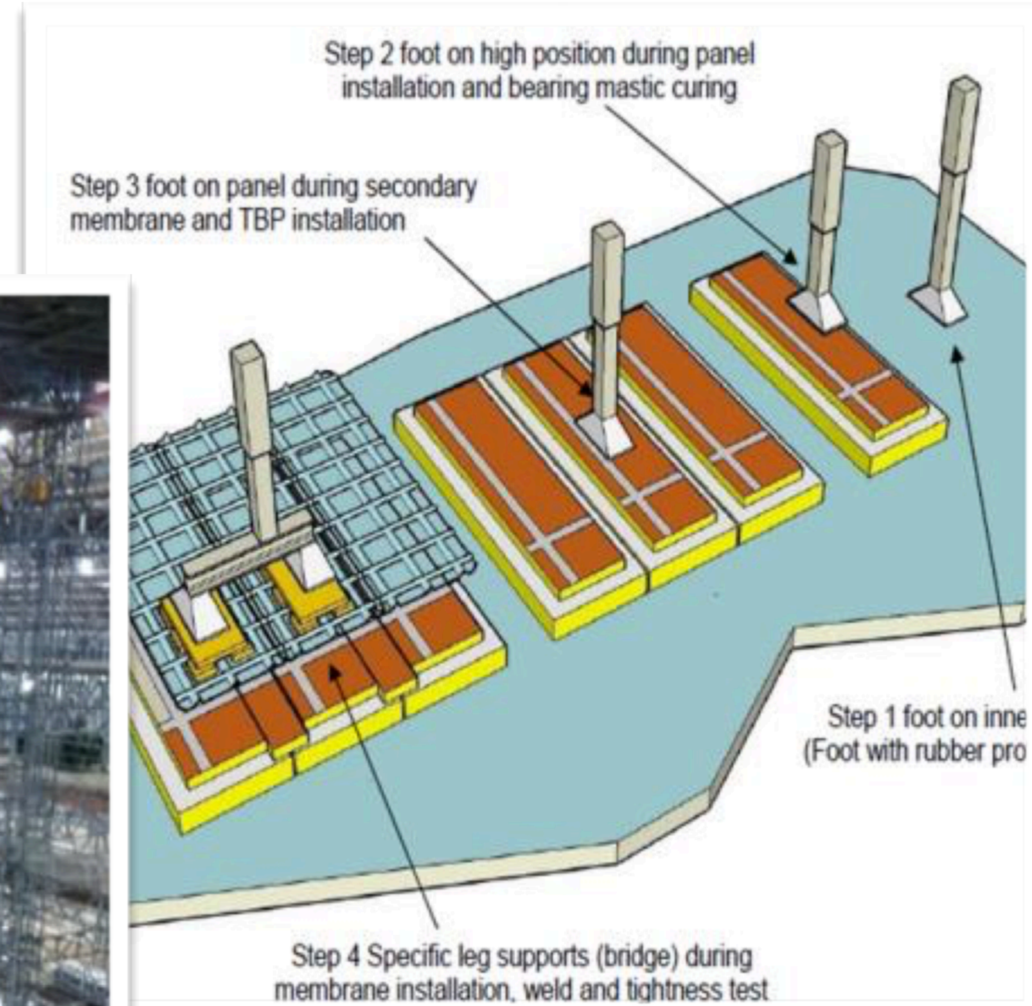
In order to ease the erection of the containment system it is recommended to use scaffoldings. These scaffoldings are usually fitted with retractable legs and platforms and a minimum of 3m height between two floors. The scaffolding design can be arranged according to the Containment System components dimensions.

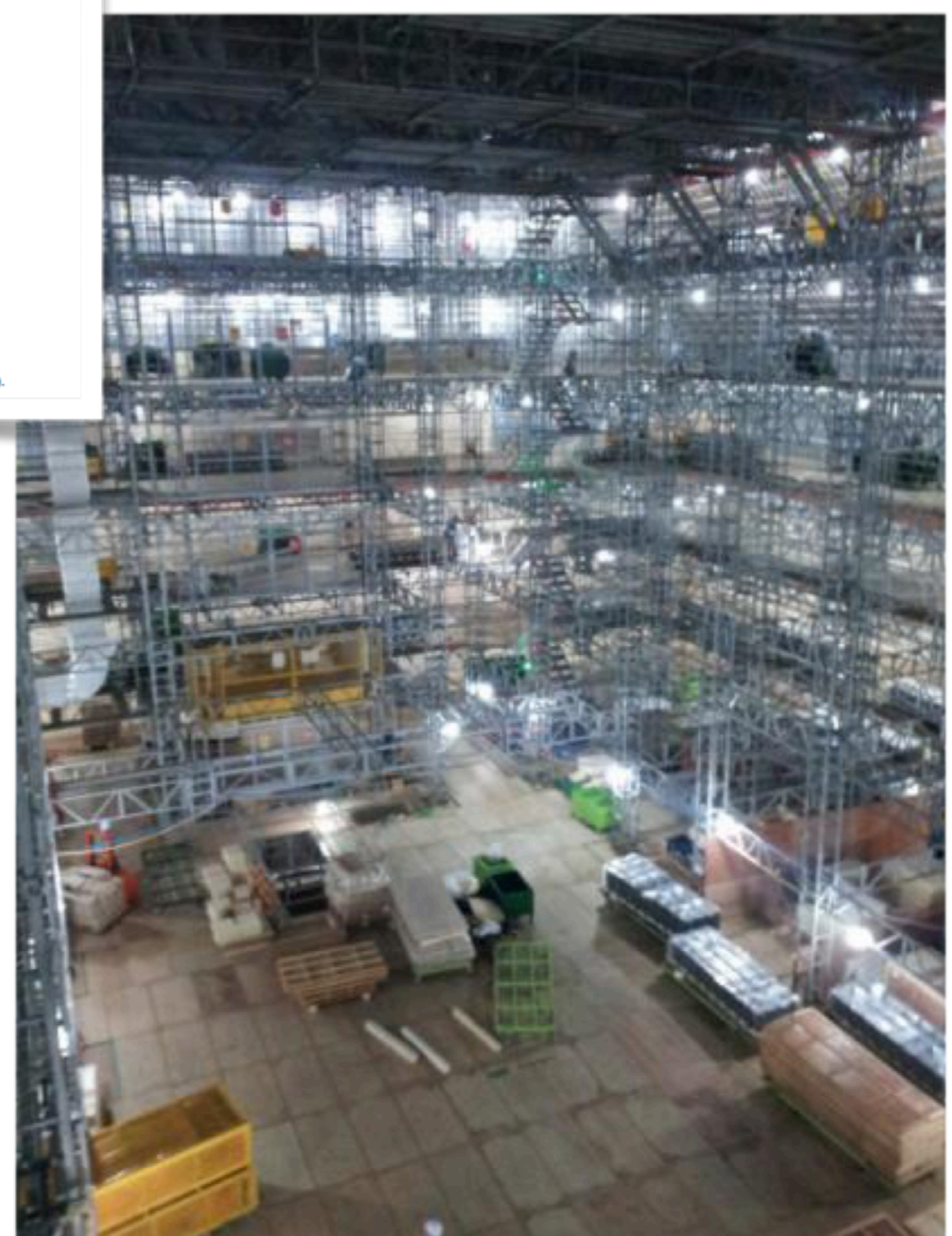
Figure 2 – Scaffolding

Important note:

Maximum pressure allowable on panels during erection of Containment system is **23 tons per m^2 (~2.3bars)**.

Retractable feet





Allow to reach 100%
of surface at the same time:
Possibility to work in parallel
on different places

Mastic application

Manual (ProtoDUNEs)

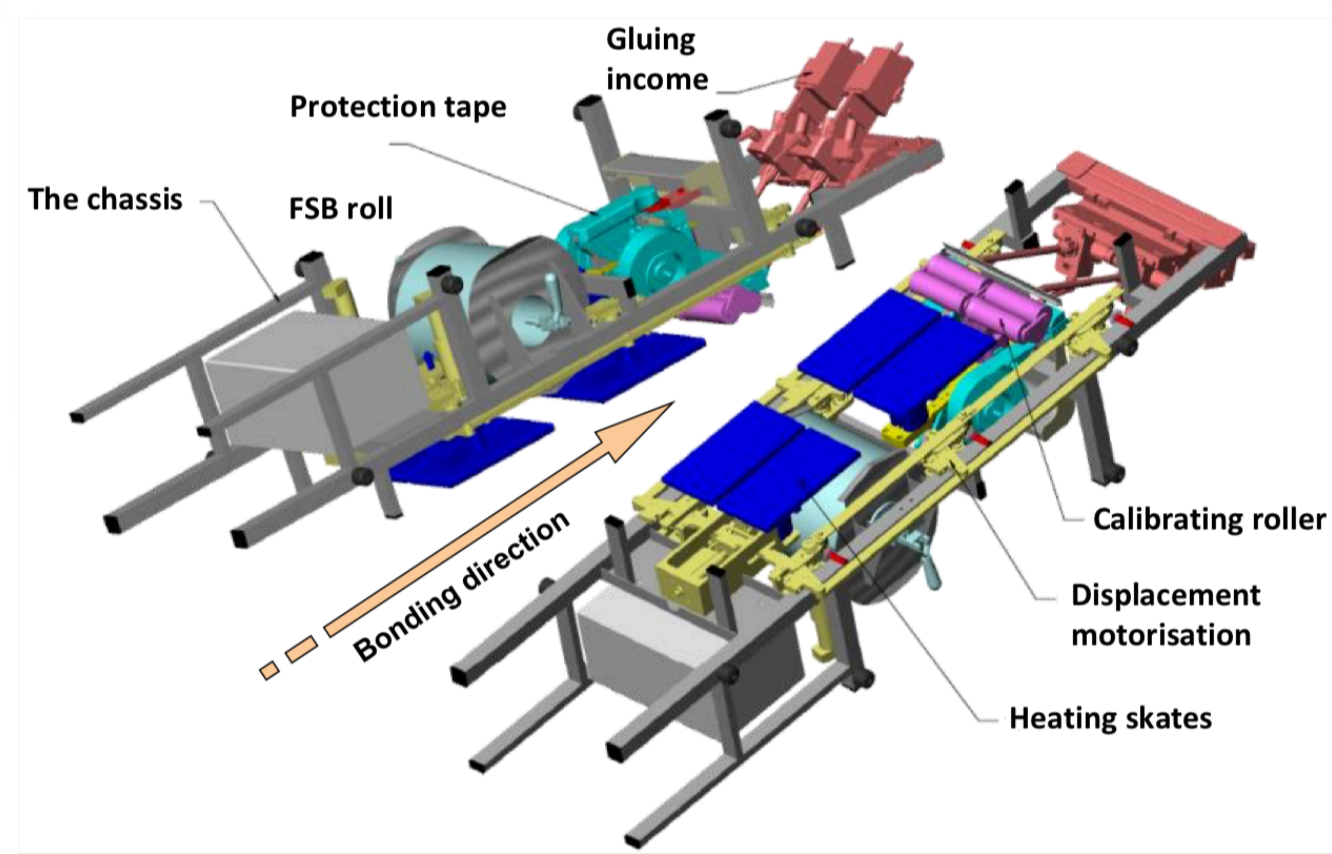
Automatic

Amount of mastic depends on the position: defined from the survey of the warm structure

Triplex bonding machine

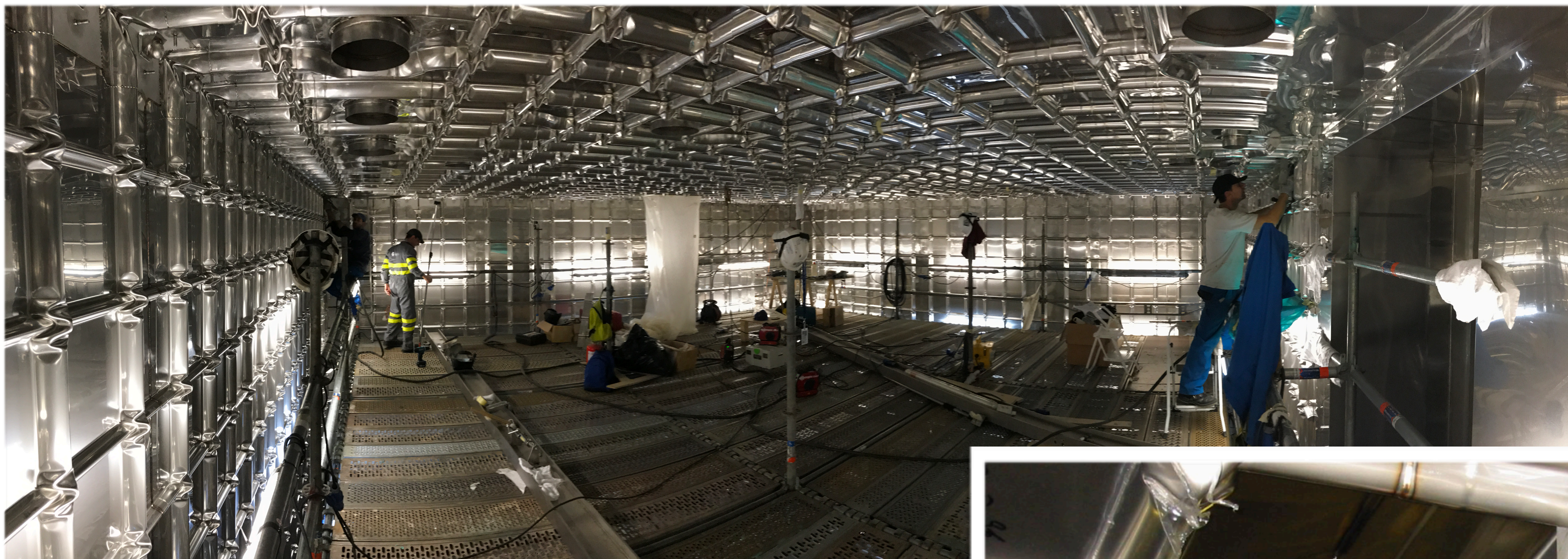
Manual (needed for the corner pieces)

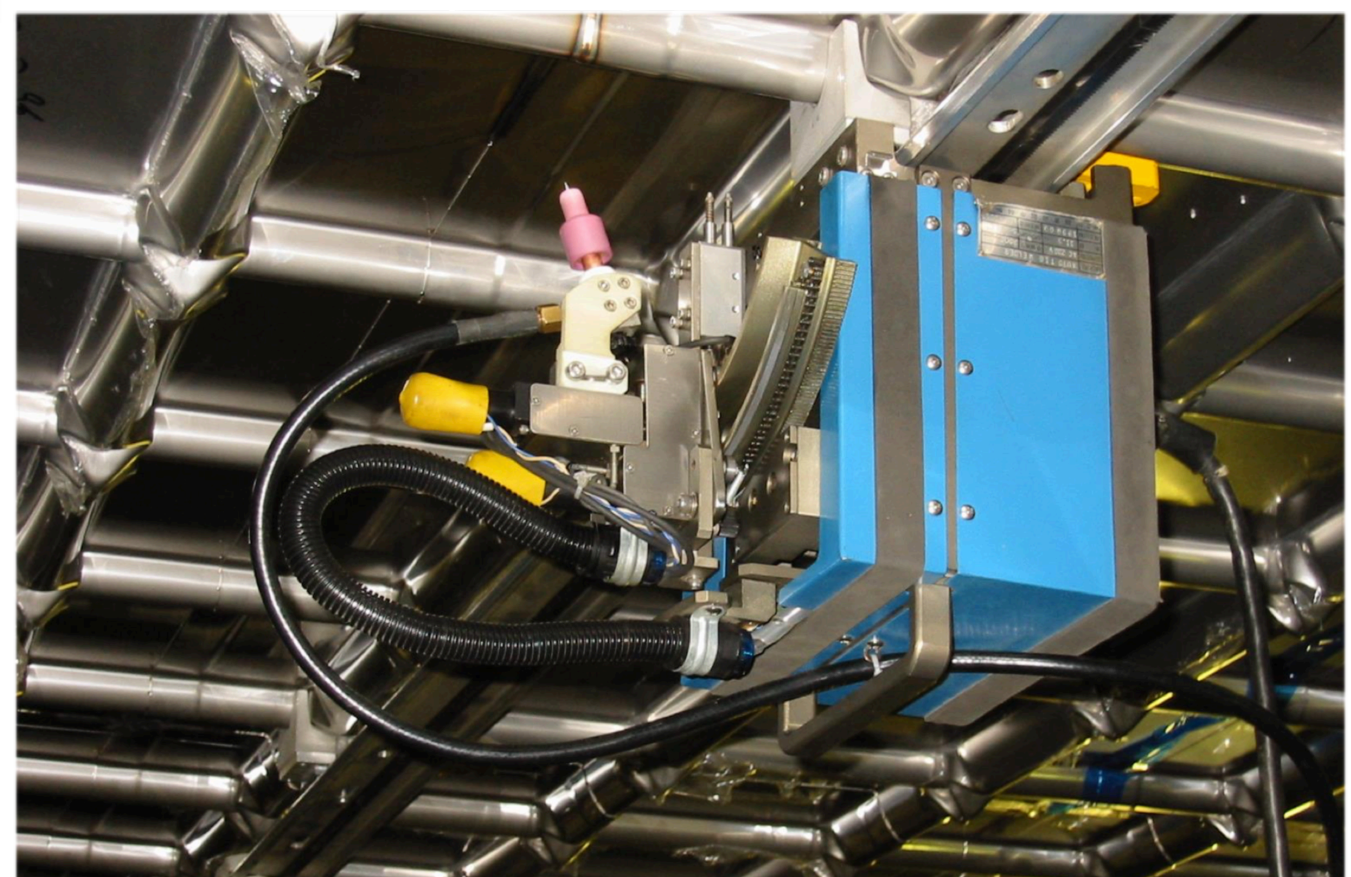
Automatic machine (possibly within flat panels)



Welding primary membrane

Manual (ProtoDUNEs)

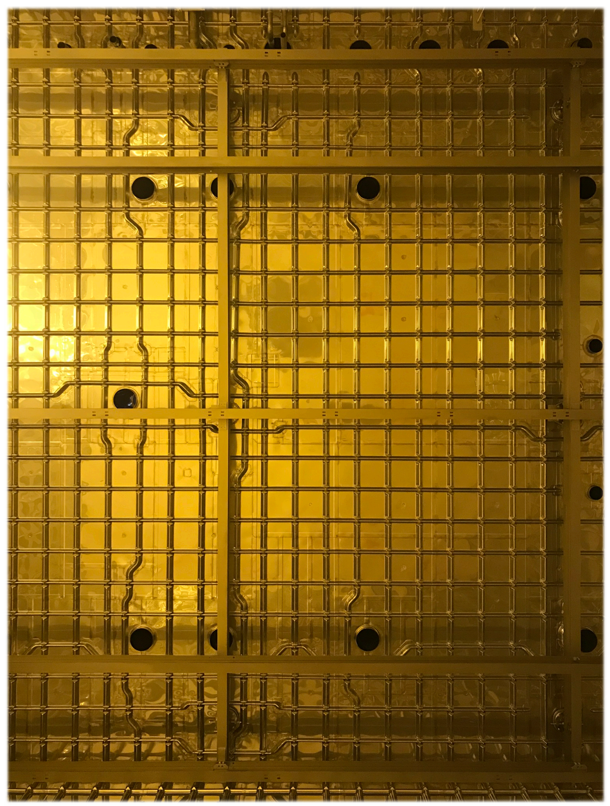




Depending on the contractor company, automatic machines may be a possibility
Probably is a mandatory tool to meet the schedule constraints

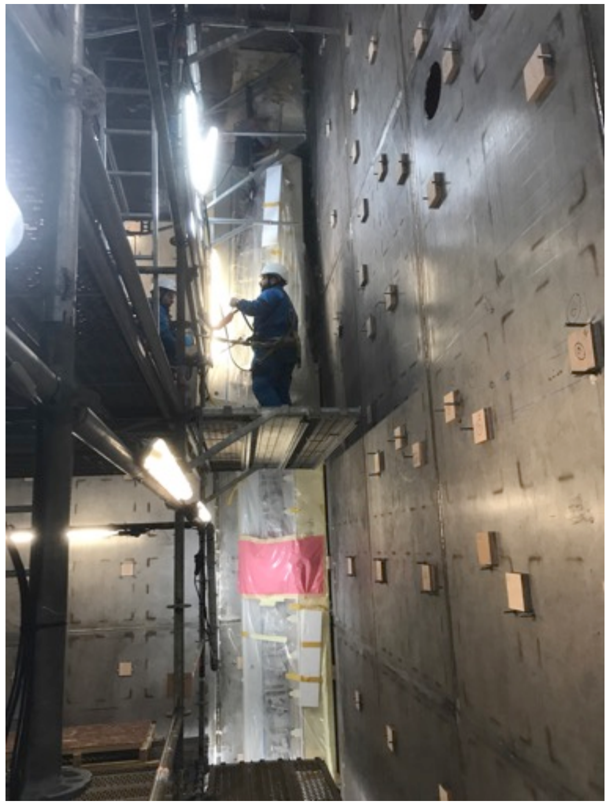
Installation supports

Hanging from dedicated feedthroughs

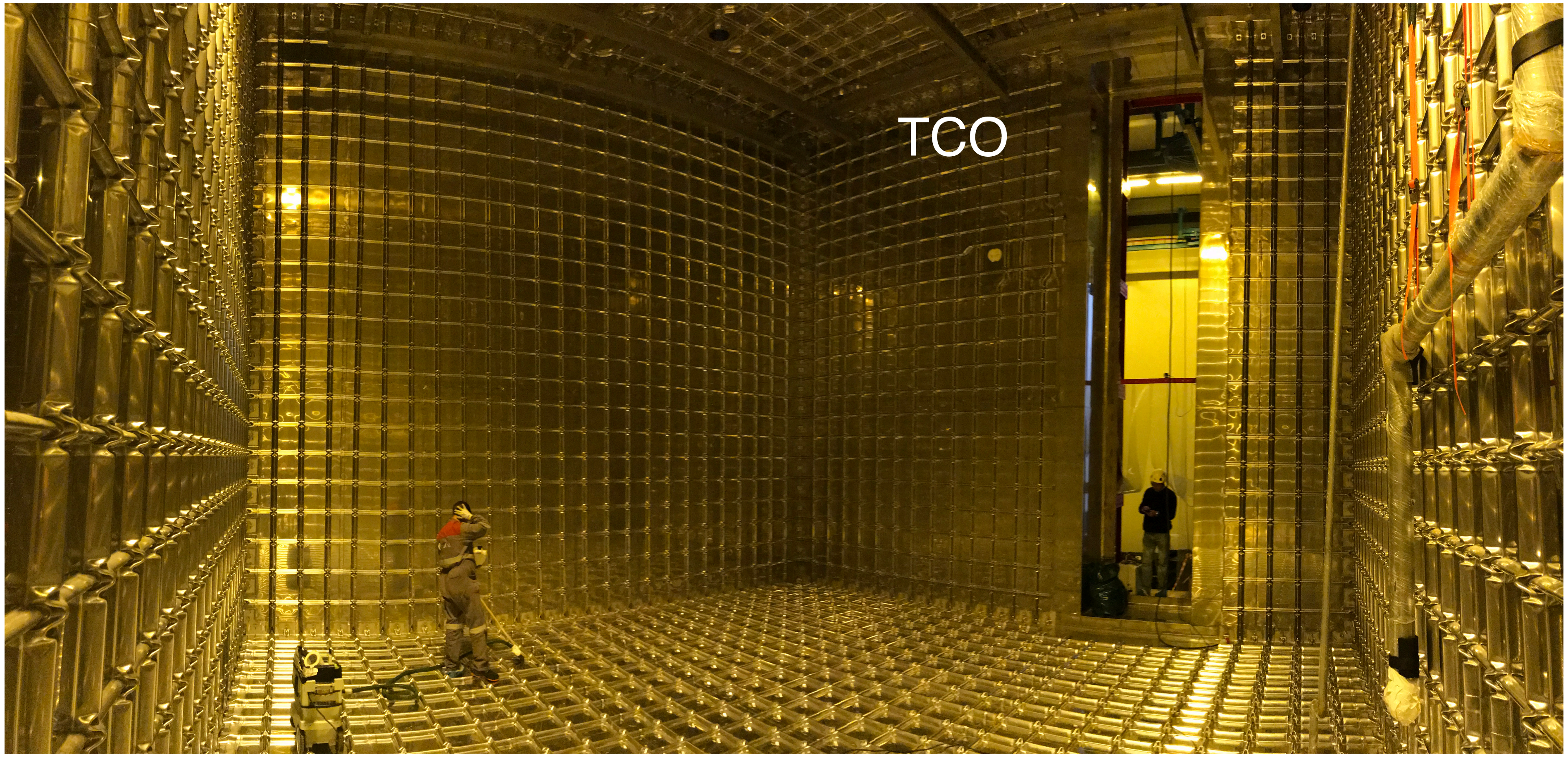


DSS installation:
DSS beams must be lifted up in position with ropes going through the roof penetration.
- Scaffolding may be used to move the DSS components in the right positions (NP04 like)/
- Without scaffolding, ropes arriving at the floor and man lifts to reach the ceiling (CRPs in NP02).

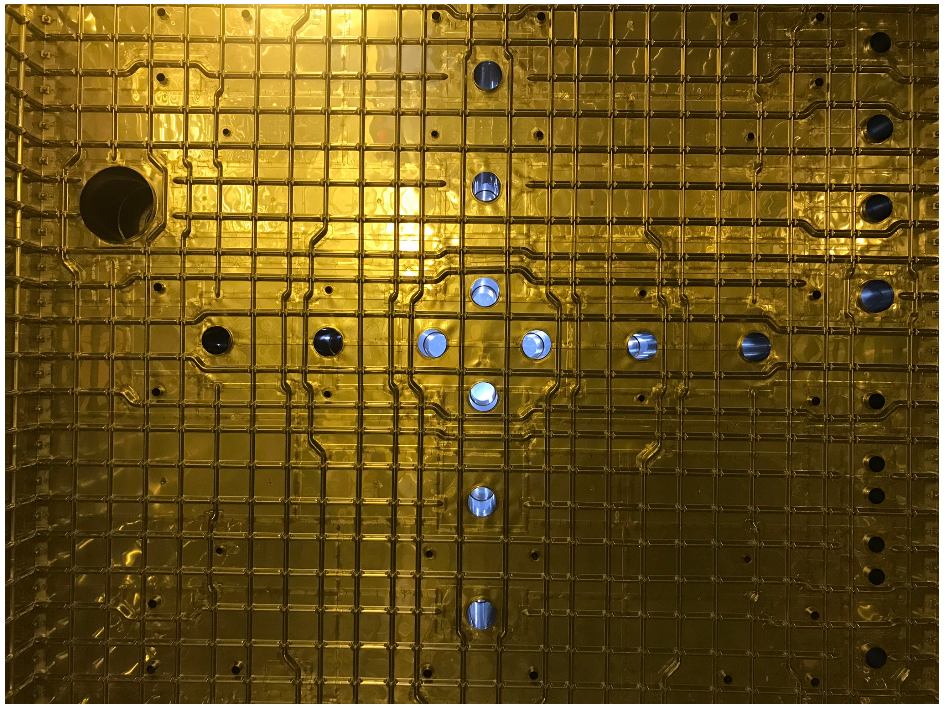
Corners and angles pieces:
No rating nor specification are given.
In NP02 and NP04, cryogenic piping and cable trays are attached here



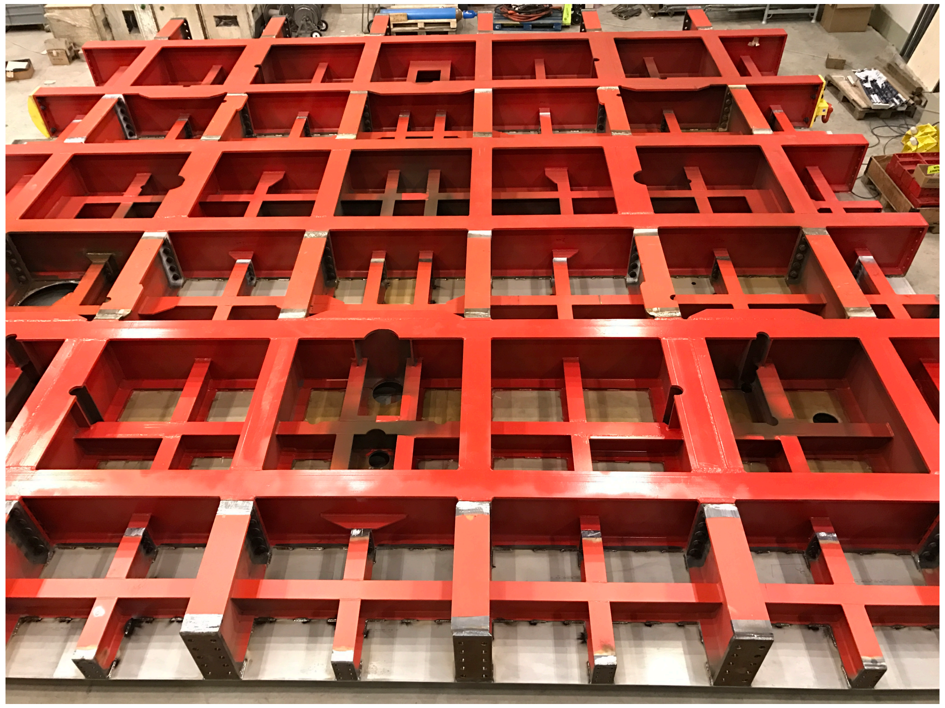

SCS-05



Roof openings (from inside)



Roof openings (from outside)



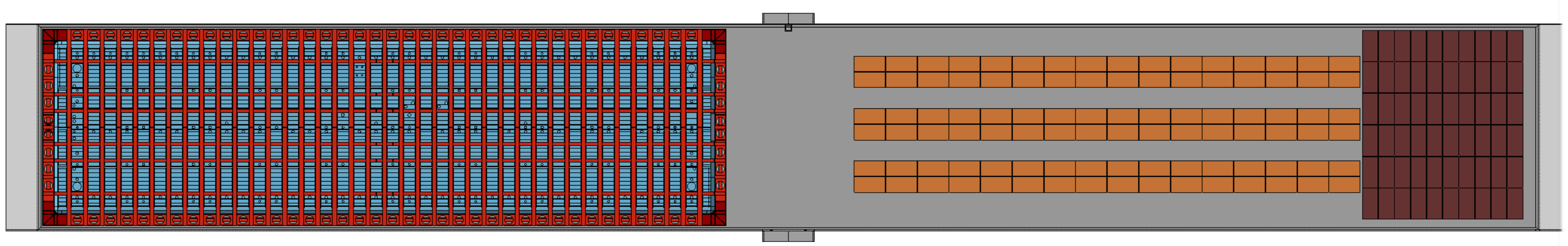
Material list

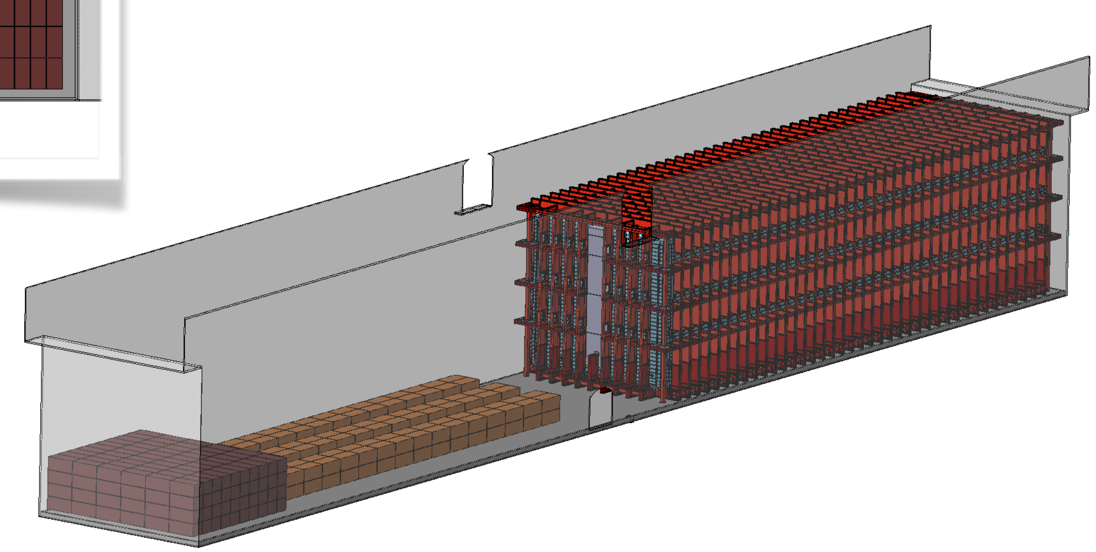
		Volume (m^3)	40" container number
including packing Insulation pannels and pads	Flat pannels	3823.71	80.93
	Corner Pieces	449.56	9.51
	Bridge Pad	281.64	5.96
	Trihedre	107.77	2.28
	Erection on Board	5.62	0.12
		53.89	1.14
Membrane	Membrane	521.61	11.04
	Angle Piece	12.08	0.26
	End Corrugation	0.32	0.01
Glasswool elements	FJ	278.70	5.90
Plugs	PG	29.54	0.63
Secondary barriers	SB	7.18	0.15
Thermal Protection	TP	2.42	0.05
Load bearing Mastic	Mastic	47.94	1.01
Adhesive for primary blocks and TBP Bonding	Adhésif	10.39	0.22
Glue for secondary barrier	Glue	4.07	0.09
Studs	studs	26.04	0.55

TANK DIMENSIONS

	S229				
	L (m)	l (m)	h (m)	surface (m2)	volume (m3)
Secondary	63.58	16.68	15.58	4,621.93	1,848.77
Primary	62.78	15.88	14.78	4,319.08	1,684.44
At membrane level	62.00	15.10	14.00	4,031.20	

Assuming a packing factor of 70% (for ProtoDUNE was 50%-60%):
- For the insulation: ~750 boxes 3x1.5x1.3 m^3
- For the membrane: <150 boxes 3x1.5x1.3 m^3





240 brown boxes for insulation (~30%)
192 orange boxes for primary membrane

Additional boxes for special parts and tools

Quality assurance

During construction, GTT is in charge of ensuring that the insulation and the containment systems are installed according to the specification:

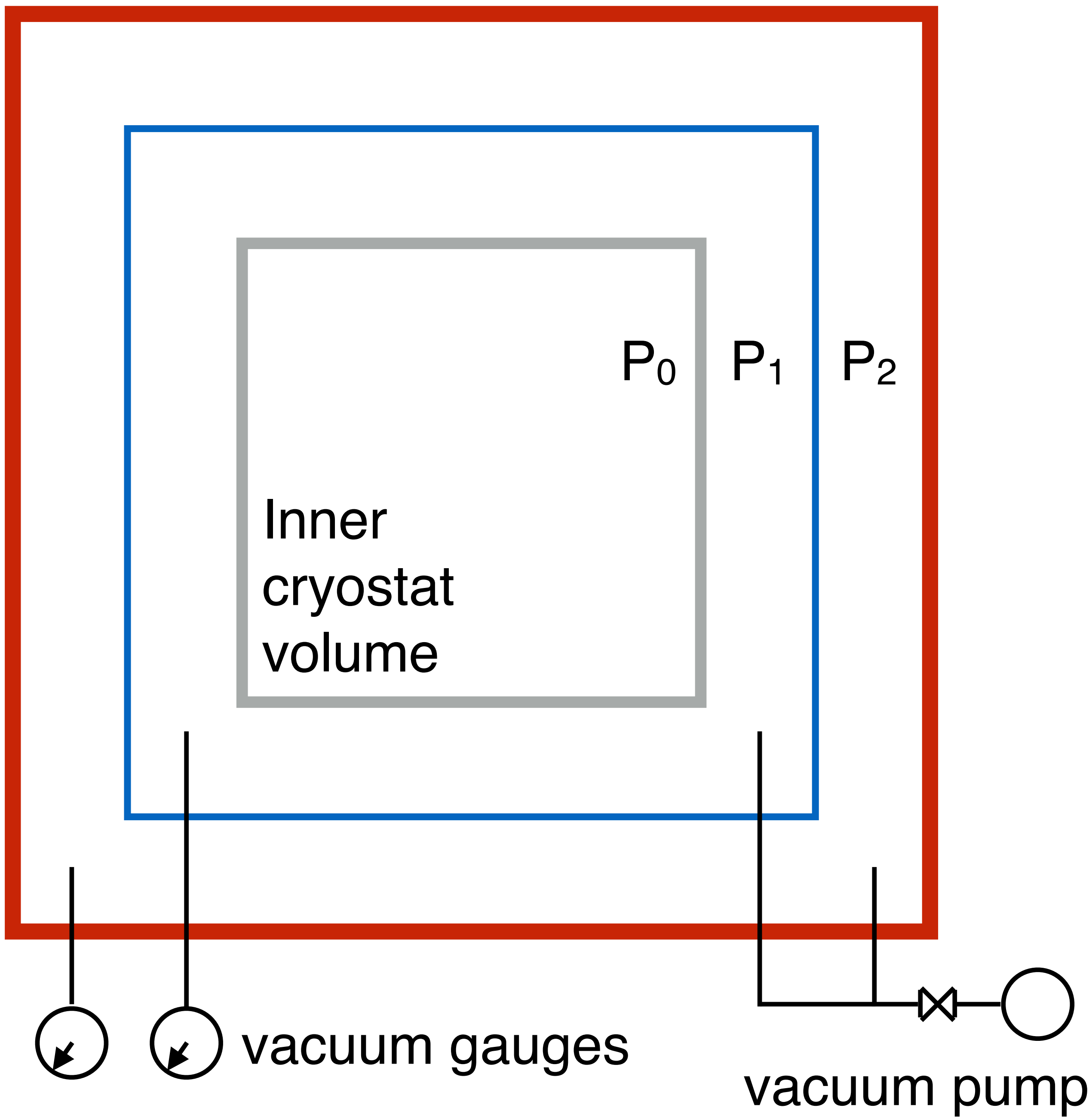
- Controls of the gaps within the panels, adherence checks of panels and of secondary membrane, laboratory tests of samples of the glue actually used.
- Test of the tightness of the secondary and primary membrane.

In addition:

- Constantly monitor the insulation pressure (leaks developing during detector construction)
- Helium leak tests of all the penetrations, flanges, and feedthroughs
- Helium leak tests with vacuum bags of corrugated membrane
- Pressure test at 200 mbar (approved document by Fermilab)

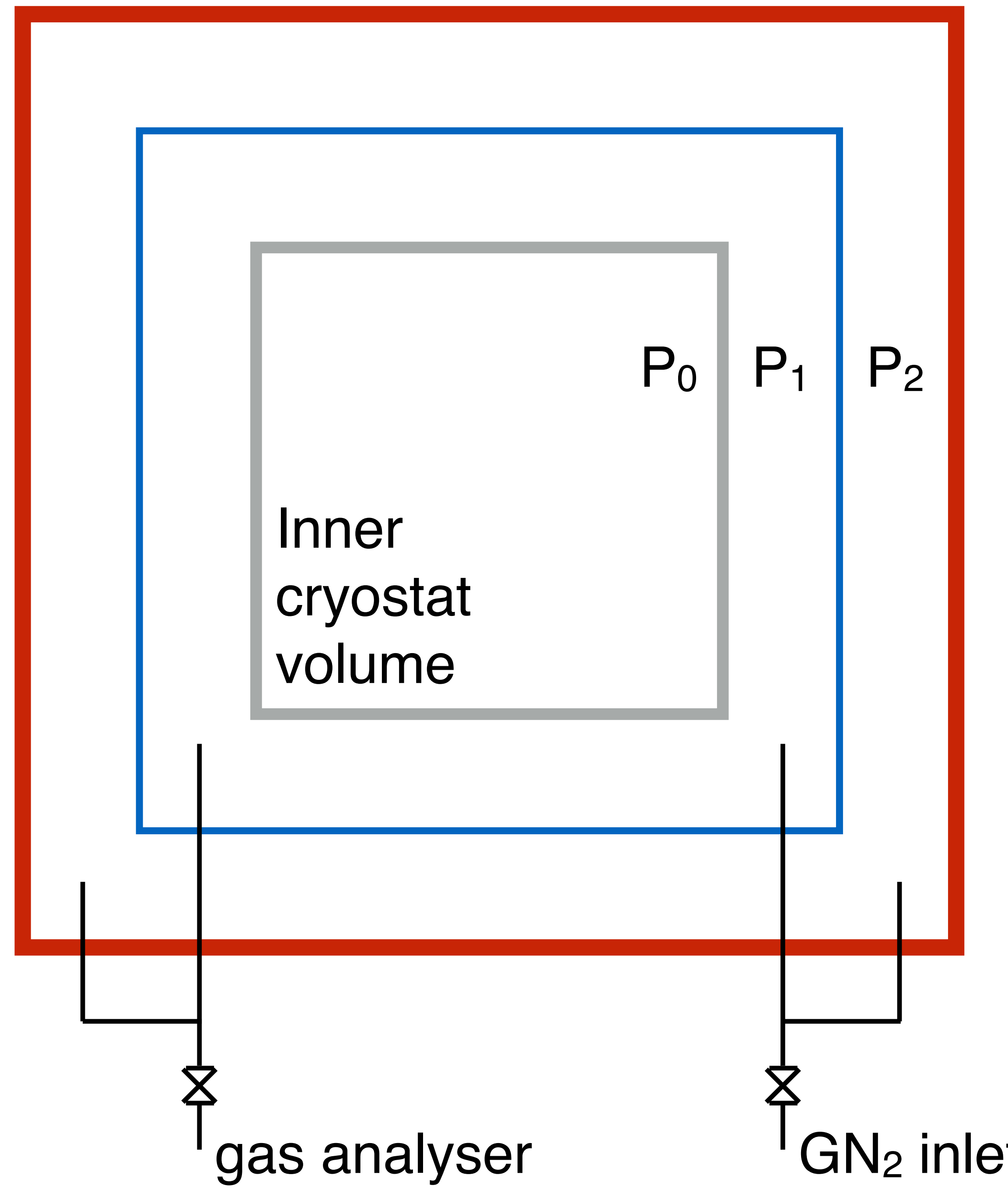
Insulation space

During detector installation



P_0 = atm
$P_1 = P_2 \sim 800$ mbara
Constantly monitor P_1 and P_2

During detector operation



$P_0 >$ P1 and $P_0 < 350$ mbarg
$P_1 = P_2 \sim 5$ - 15 mbarg
Pressures regulated with valves

Leak checks

Warm structure:
All the weldings were checked spraying helium from one side and sniffing from the other

Secondary barrier:
Under-pressure tests were performed before continuing the installation of the insulation

Primary membrane:
- Under-pressure tests of the primary and secondary insulation spaces
- Insulation spaces filled with helium and sniffing 100% of the welding (ProtoDUNE ~1 km/cryostat)
- Few welding imperfections found (very typical) fixed and inspected with dye penetrant
- Second round of He sniffing found no leaks
- He leak checking with 'vacuum bags' on most of the weldings (GTT will adopt this method)
- Sensitivity between 5×10^{-9} - 5×10^{-8} mbar l/s over a welding length of 40 cm
- No leak found in NP04 and NP02 with this method.

Cleaning campaign

Cleaning of the internal membrane once the leak check campaign is finished:
- Installation of the false floor in the cryostat and insertion of man-lifts
- Cleaning with pressurised demineralise water+solvents and acids
(need water -to be quantified yet- and need to pump it up once the cleaning is finished)
- Remove sharpie marks, silicon traces, possible glue traces, clean weldings and degrease

Declaration of the cryostat as clean room:
- Maintain the cleanliness of the cryostat with regular cleaning campaign
- During detector installation, further cleaning and protection of parts difficult to reach