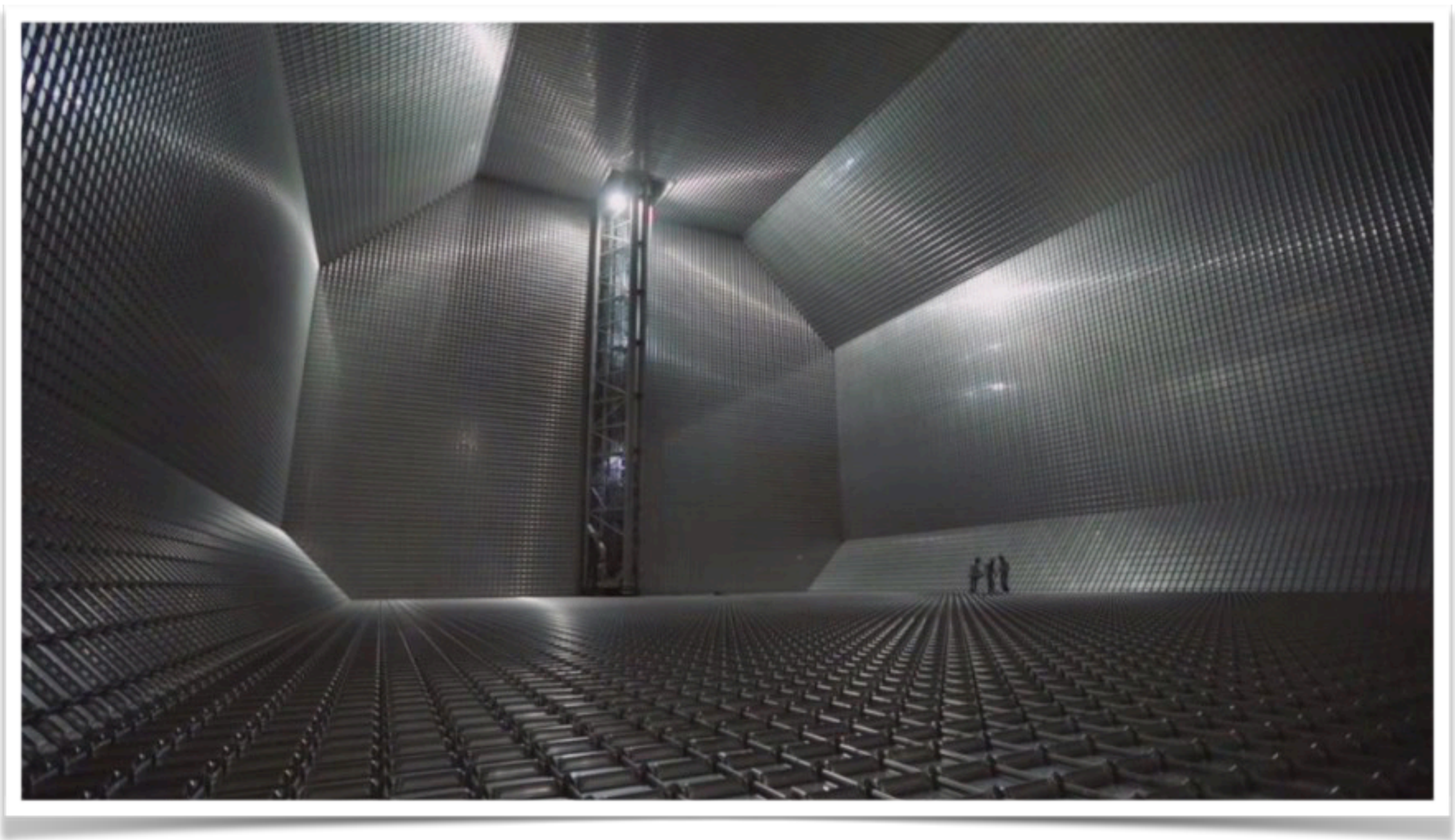
Cryostat Internal Outfitting

Filippo Resnati (CERN)

FS Integration/Installation Workshop - Kartause Ittingen - 3rd February 2020

The technology

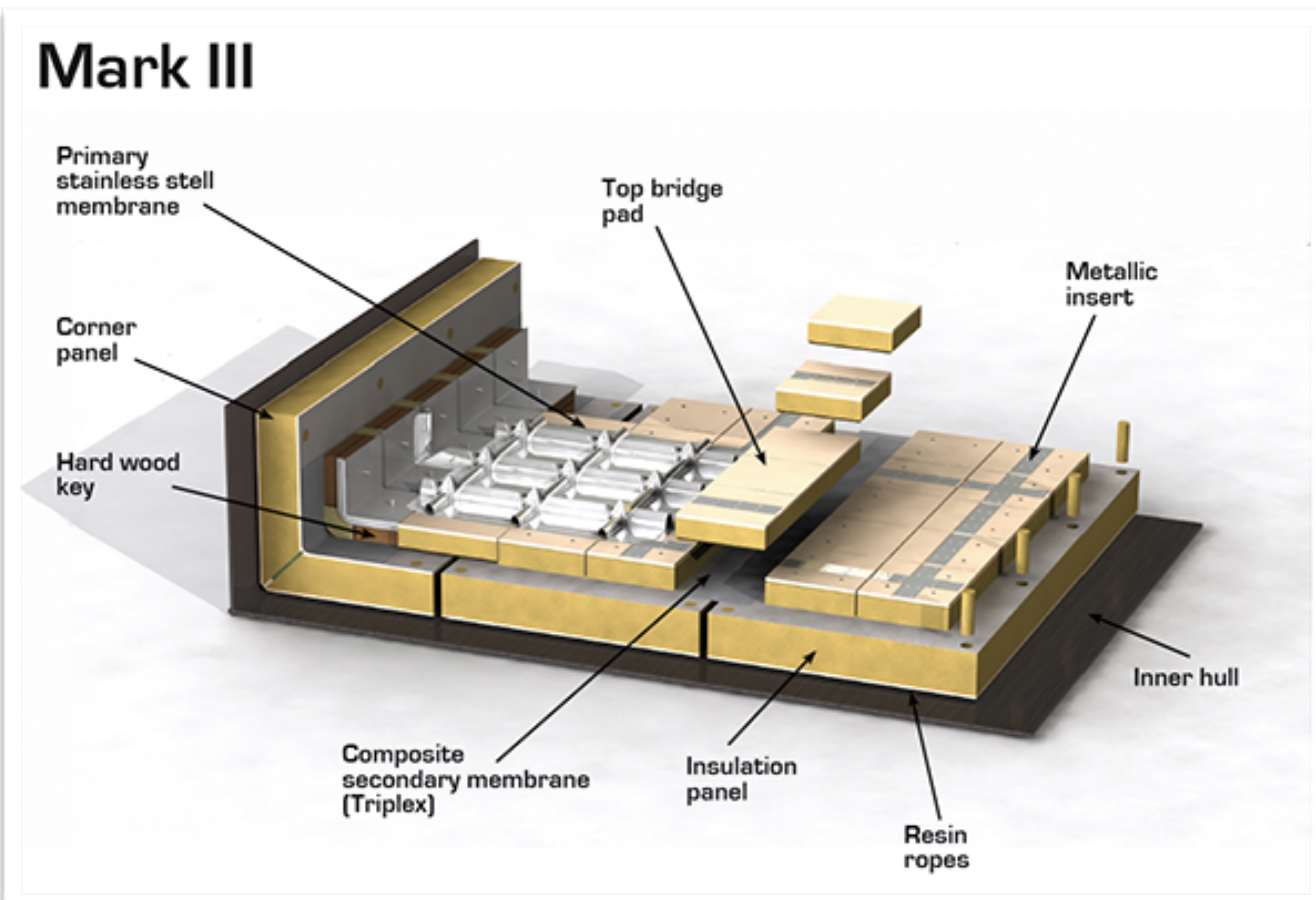
Royalties owner: GTT (France)
Construction licensee: among several Gabadi (construction of ProtoDUNEs)
Applications:
- LNG carriers (>200000 m^3 in 5 sub-tanks)
- Floating storages and re-gasification vessels
- Land storage tanks
- Fuel tank for vessels
- *Cryostats for liquid argon Time Projection Chambers*



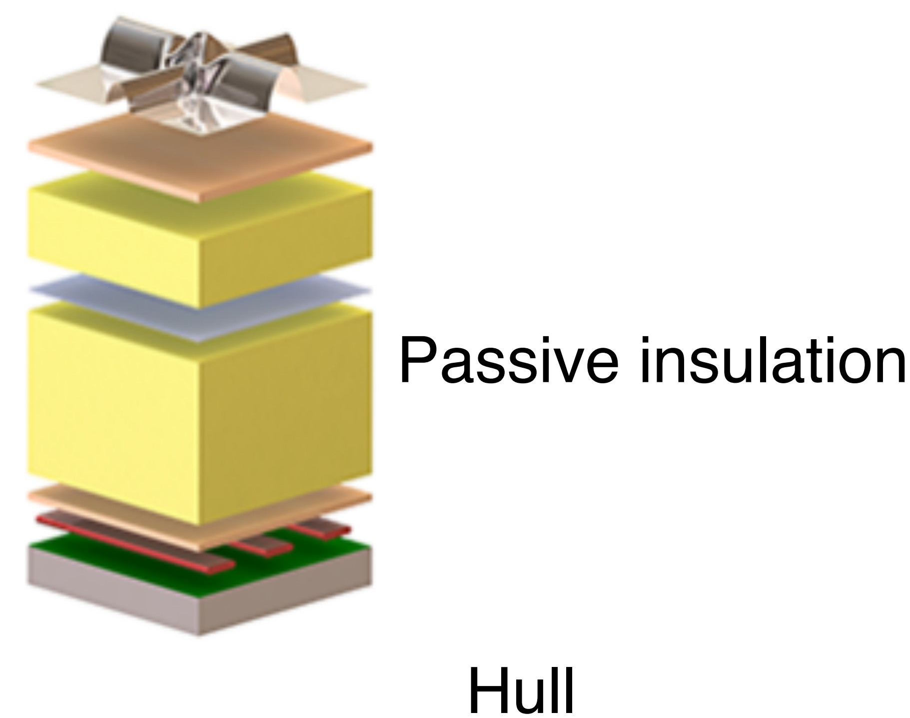
www.gtt.fr

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, modular, in between and directly connected to the primary membrane and the *hull*.
Hull: the warm structure, sustains and support the entire system.

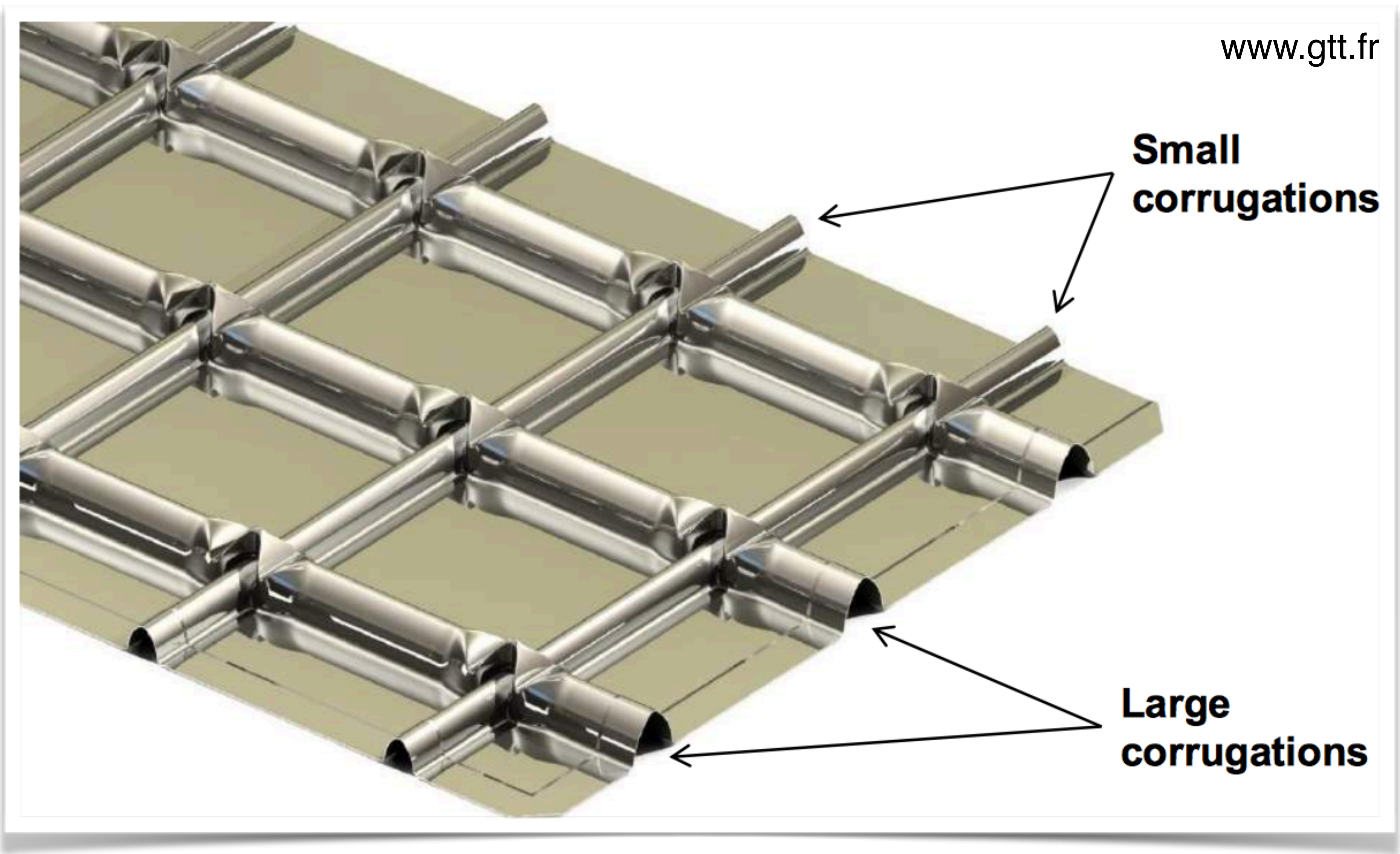


www.gtt.fr



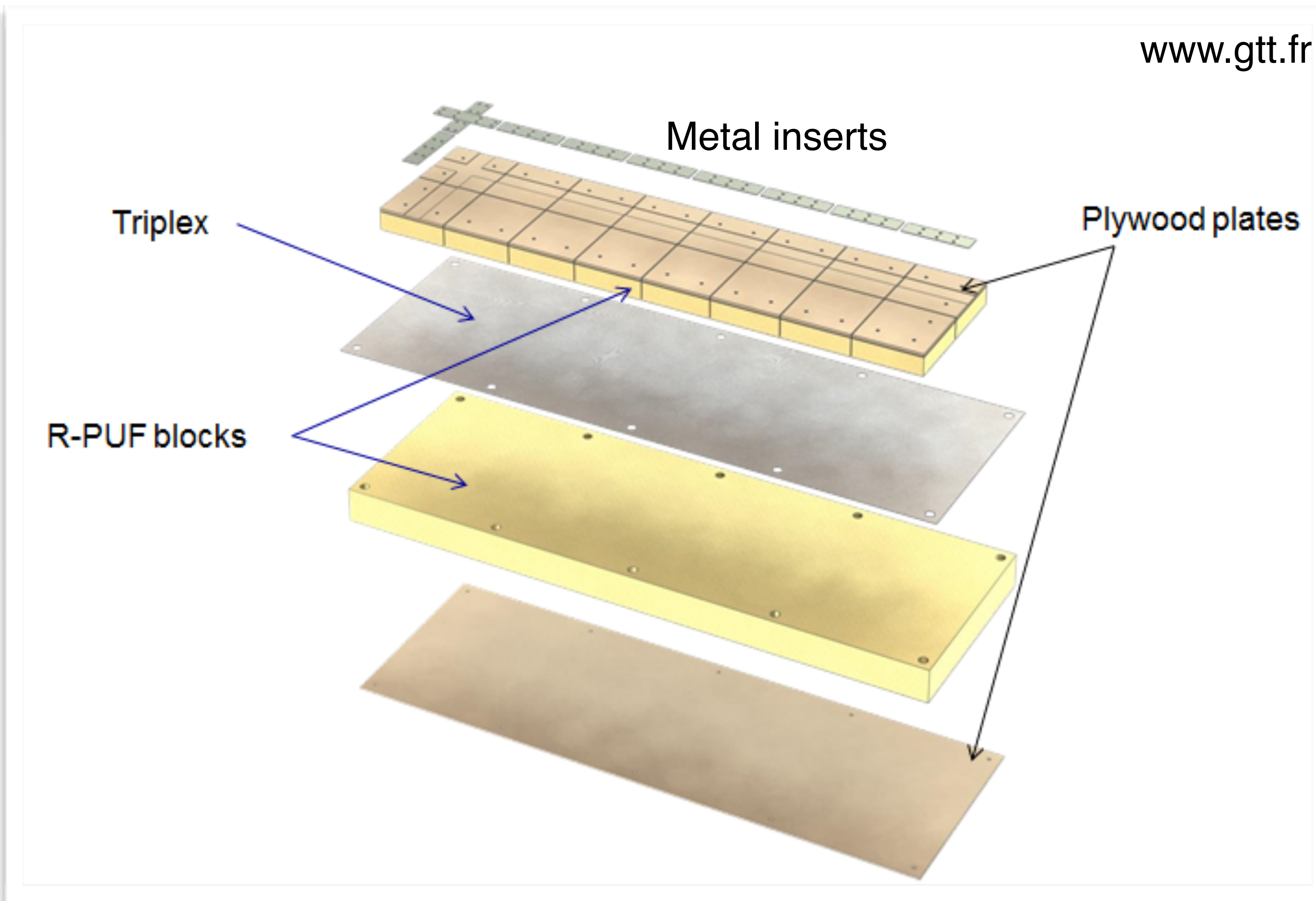
GTT Mark III technology

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, Protego valves, and roof penetrations.



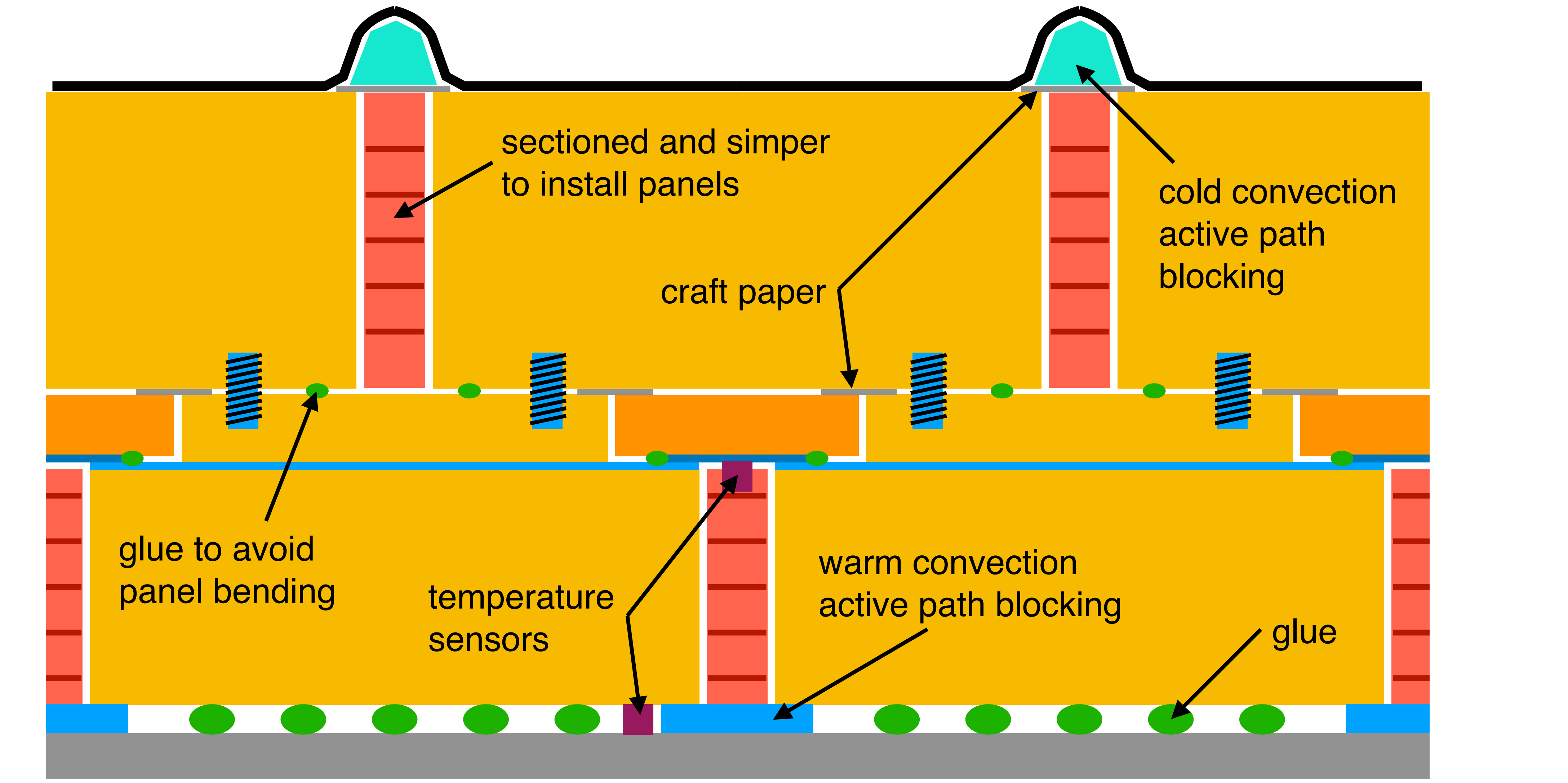
GTT Mark III technology

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, Protego valves, and roof penetrations.



The DUNE case

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.
Improvements on the Mark III technology, developed from the ProtoDUNE experience:



Not to scale

ProtoDUNE experience

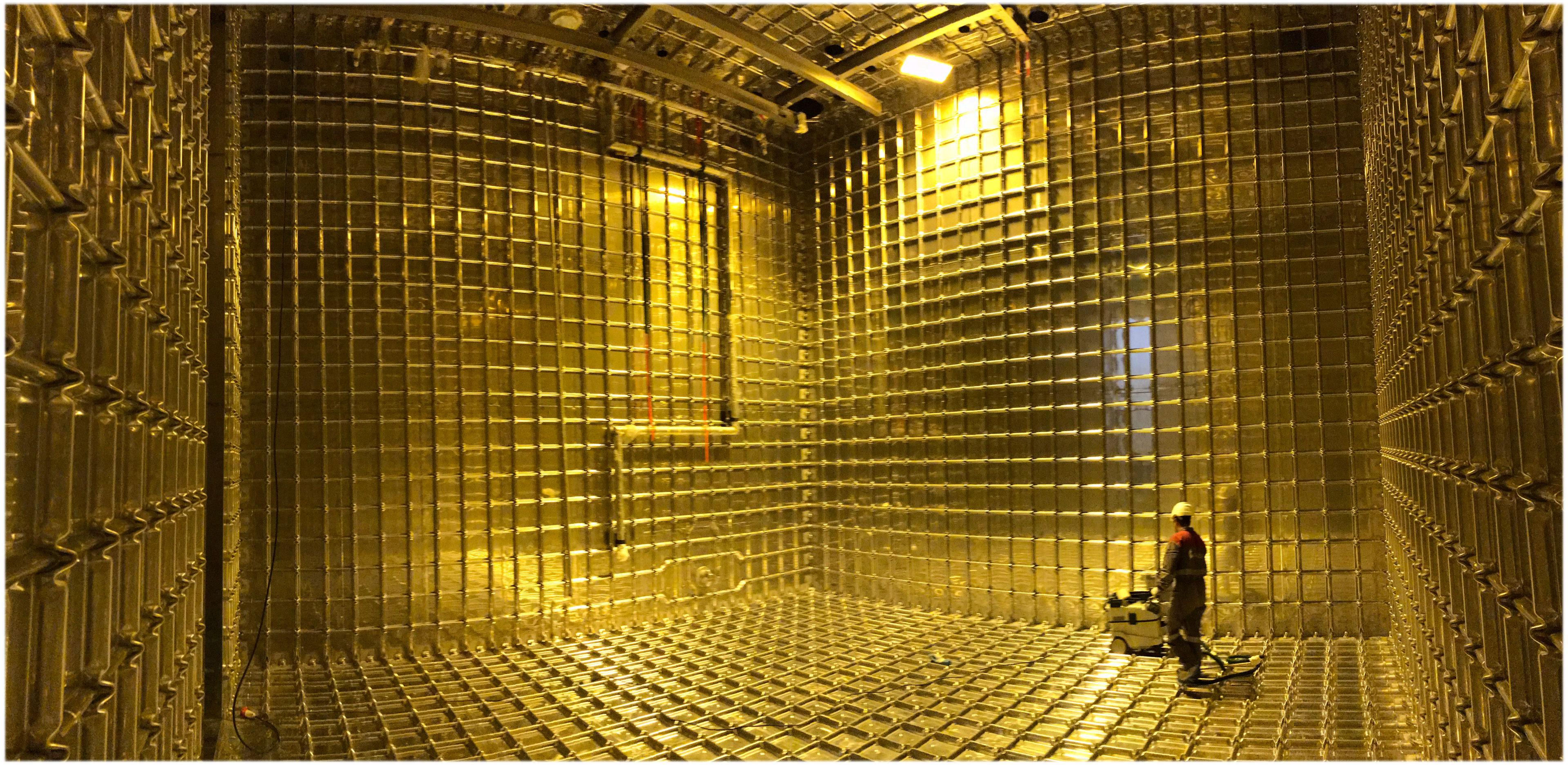
ProtoDUNEs:

In total ~40 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



Scaling to DUNE

Allocated time to outfit the cold cryostat components: 12 months (excluding the TCO closure)
This includes, leak testing, cleaning and DSS installation. Specialised personnel:

- 25 people for the major installation
- 10 people for the TCO closure

It’s very likely that external companies will want to work (1 or 2 shifts) 6 days per week.

		#										T-0													Time Units are in Quarters-3 months												
Task	Group	Month	-10	-9	-8	-7	-6	-5	-4	-3	-2	-1	0	3	6	9	12	15	18	21	24	27	30	33	36	39	42	45	48	51	54	57	60	63	66	69	72
Logistics Facility	DUNE										LF	Infra													Logistics Facilty Operations												
Excavation Cavern #1	CF	41								North Cavern & CUC		BSI	BSI																								
Excavation Cavern #3	CF	20											South Cavern			BSI																					
Install Warm Dec #1	CERN	15													Warm 1																						
CUC Infrastruc and DAQ	DUNE	20												CUC Infra			DAQ																				
Install Cold Dec #1	GTT	12																	Cold Struct. #1																		
Det #1 Installation Setup	DUNE	13																	Det #1 Setup																		
Assembly SP Dec #1	DUNE	10																					Detector #1 SP														
TCO Closing	CERN	2																							TCO												
Complete Detector #1	DUNE	3																																			
Purge/Fill Dec #1	CERN	18																									Pur										
Install Warm Dec #2	CERN	9																	Warm 1										Fill Det #1								
Install Cold Dec #2	GTT	12																					Cold Struct. #2														
Det #2 Installation Setup	DUNE	12																						Det #2 Setup													
Assembly Dec DP #2	DUNE	10																										Detector #2									
TCO Closing	CERN	2																													TCO						
Complete Detector #2	DUNE	3																																			
Purge/Fill Dec #2	CERN	20																															Pur	Fill Det #2			
Install Cryo Equipment	CERN	36																			Cryogenic Installation																
Estimated Number if FTEs Underground per shift-Assume 2 shifts per day																																					
CF-Day			80	80	80	80	80	80	80	80	80	90	90	80	80	40																					
CF-Night			70	70	70	70	70	70	70	70	70	90	90	70	70	35																					
LBNF/CERN-Warm-Day													25	25	25	25	25	25	25	25	20	20															
LBNF/CERN-Warm-Night													25	25	25	25	25	25	25	25	15	15															
GTT-Cold-Day																		25	25	25	25	25	25	25	25						10						
GTT-Cold-Night																		25	25	25	25	25	25	25	25						10						
LBNF/CERN-Cryo																10	10	20	20	20	20	20	20	20	20	20	20	4	4	4	4	4	4	4	4	4	4
JPO-Underground Day												11	28	28	28	28	30	30	30	30	30	30	30	30	30	30	30	30	30	30	29	29	29	29	29	29	29
JPO-Underground Night												11	28	28	28	28	30	30	30	30	30	30	30	30	30	30	30	30	30	30	29	29	29	29	29	29	29
DUNE-Consortia-Day														10	10	10	20	30	36	36	36	36	36	36	36	36	36	36	36	36	30	20	5	5	5	5	5
DUNE Consortia-Night														10	10	10	20	30	35	35	35	35	35	35	35	35	35	35	35	35	30	20	5	5	5	5	5
SURF-Day			15	15	15	15	15	15	15	15	15	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20	20
SURF-Night			5	5	5	5	5	5	5	5	5	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10	10
Total FTEs Underground per Day Shift			**95**	**95**	**95**	**95**	**95**	**95**	**95**	**95**	**95**	**121**	**163**	**163**	**163**	**133**	**105**	**150**	**155**	**155**	**150**	**150**	**130**	**130**	**130**	**105**	**105**	**89**	**89**	**89**	**93**	**73**	**58**	**58**	**58**	**58**	**58**
Total FTEs Underground per Night Shift			**75**	**75**	**75**	**75**	**75**	**75**	**75**	**75**	**75**	**###**	**###**	**###**	**###**	**###**	**85**	**###**	**###**	**###**	**###**	**###**	**99**	**99**	**99**	**74**	**74**	**74**	**74**	**74**	**79**	**59**	**44**	**44**	**44**	**44**	**44**

From Bill

Construction sequence

Assuming no co-activity inside of the cryostat and *simple 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, flat joint panels, temperature sensors, pipes for GN_2 circulation, …
- 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

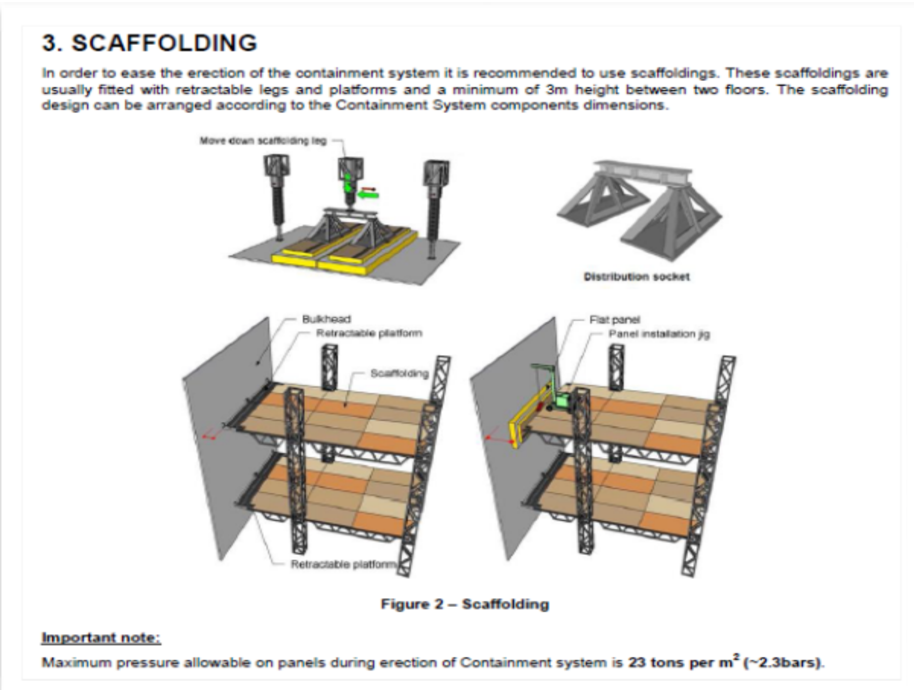
Needed equipment

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 hoists
- 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/m²)



3. SCAFFOLDING

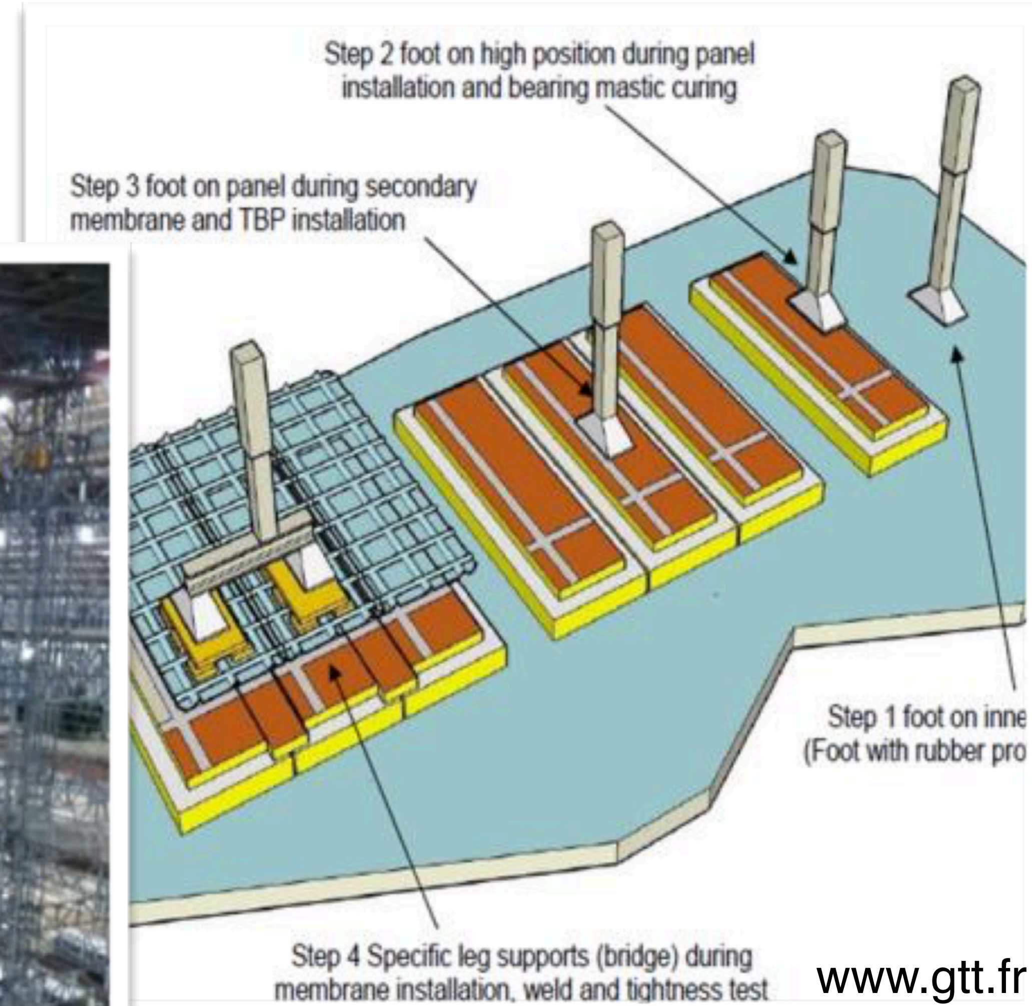
In order to ease the erection of the containment system it is recommended to use scaffoldings. These scaffoldings are usually fitted with retractable legs and platforms and a minimum of 3m height between two floors. The scaffolding design can be arranged according to the Containment System components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

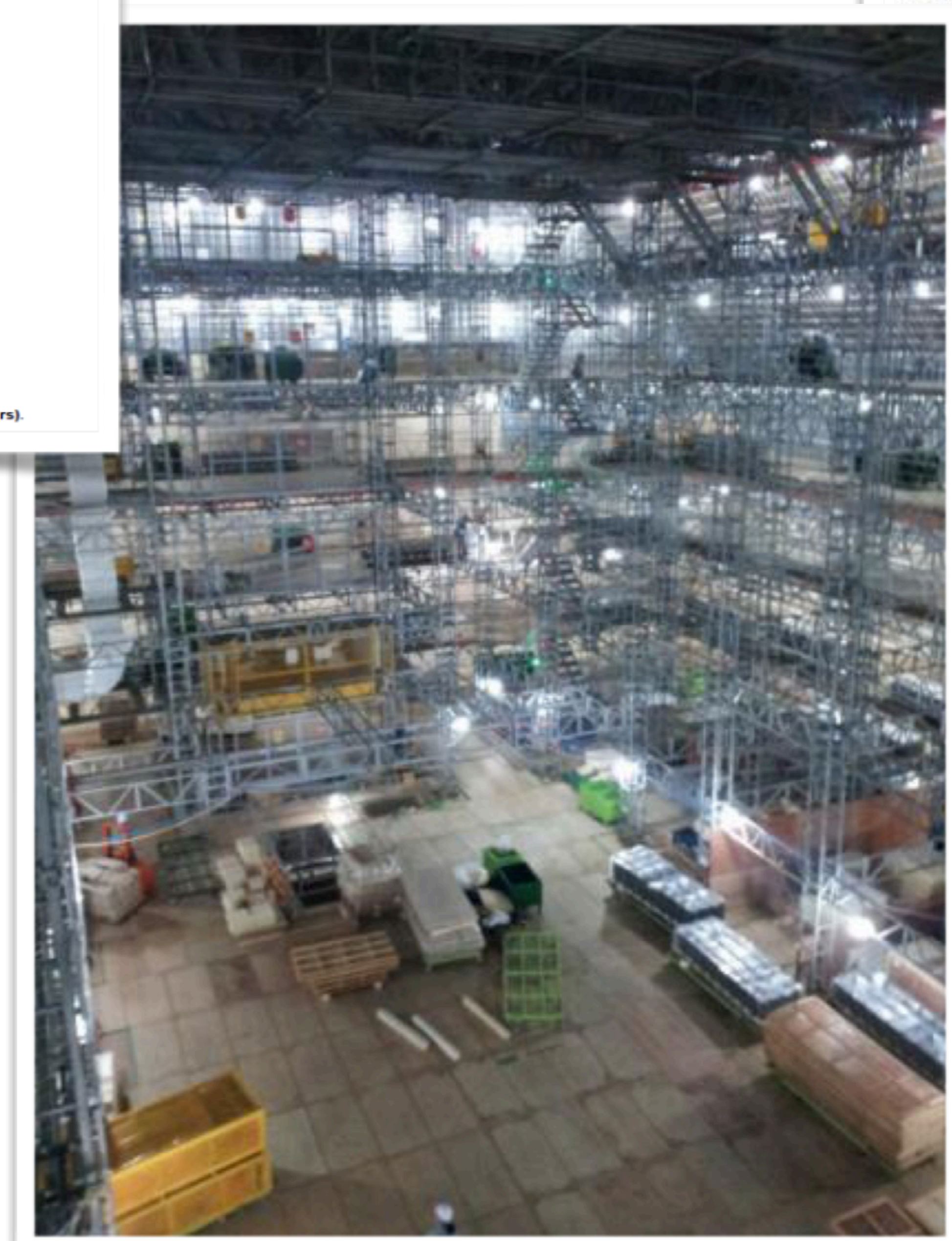
Figure 2 – Scaffolding

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

Humidity and temperature sensitive process: samples of actually used glue analysed for QC

Manual (ProtoDUNEs)

Automatic

www.gtt.fr

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

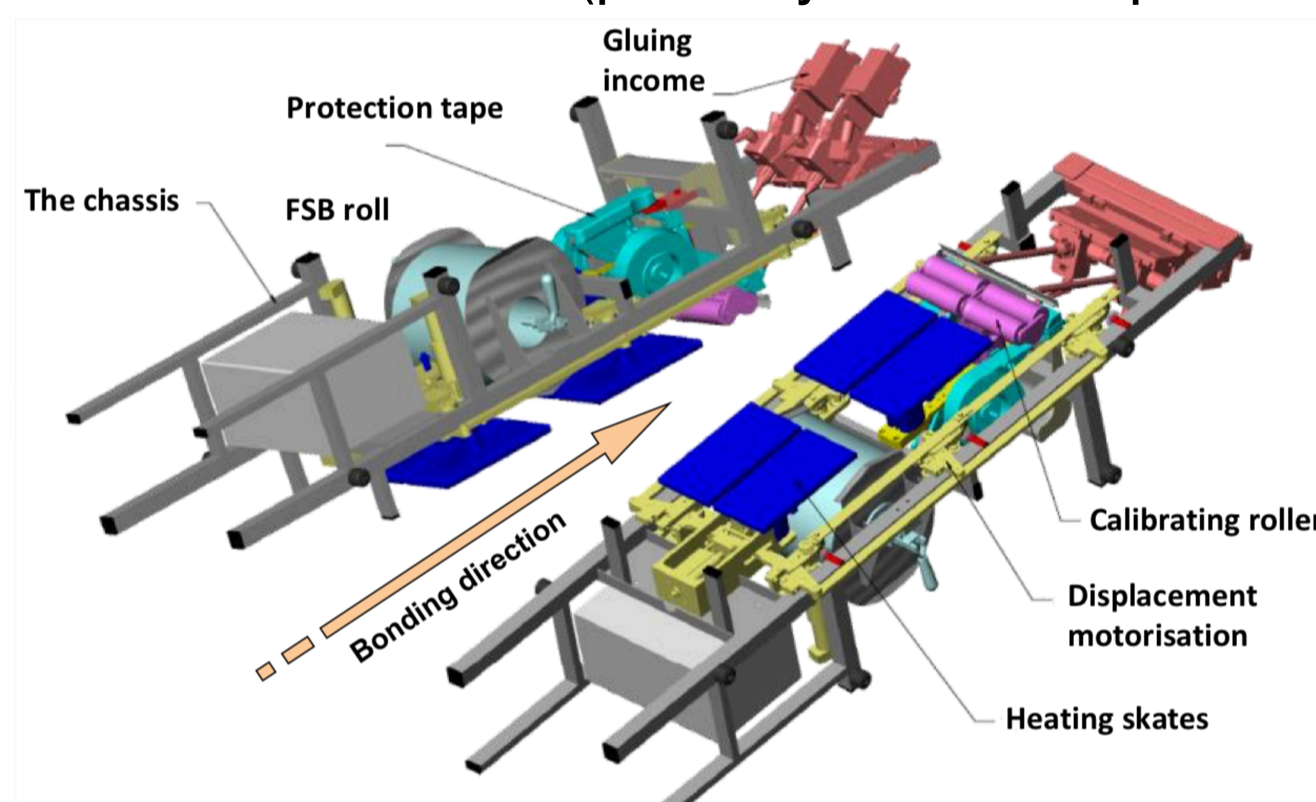
Mastic will be distributed onto the panels to increase the impedance to the GN_2 flow.

Triplex bonding machine

Manual (needed for the corner pieces)

- 100% of the glued sections visually inspected by GTT experts.
- Samples of the actually used glue are analysed.
- 100% of the glued sections tested with vacuum bags technique.

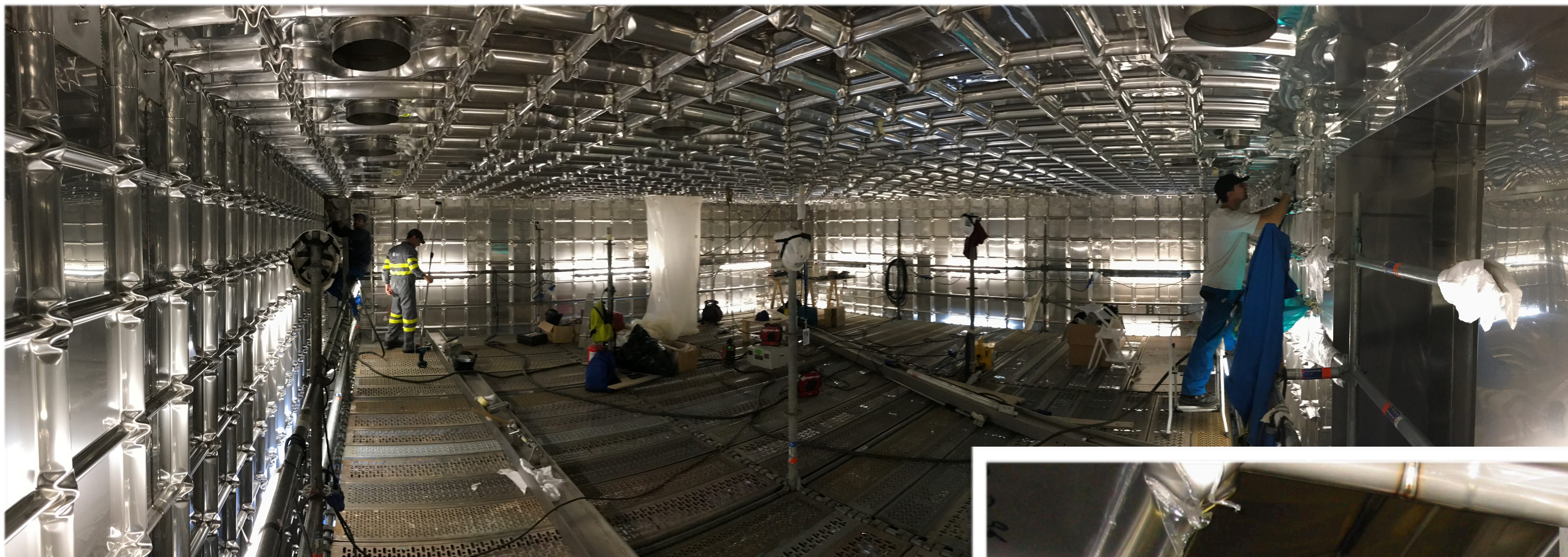
Automatic machine (possibly within flat panels)

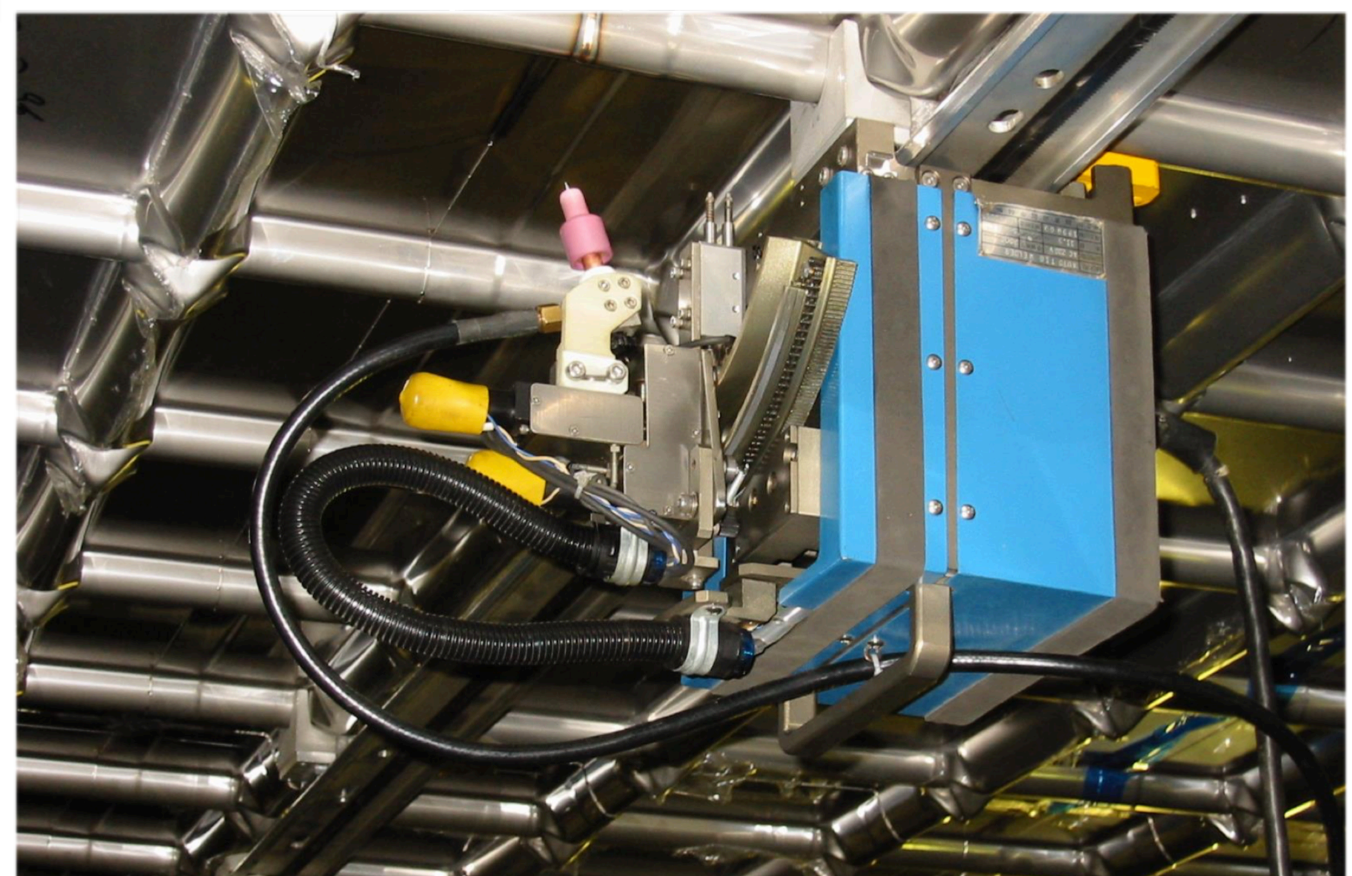


www.gtt.fr

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 (requirement). Internal cryo pipes should be installed during the welding of the corrugated membrane

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

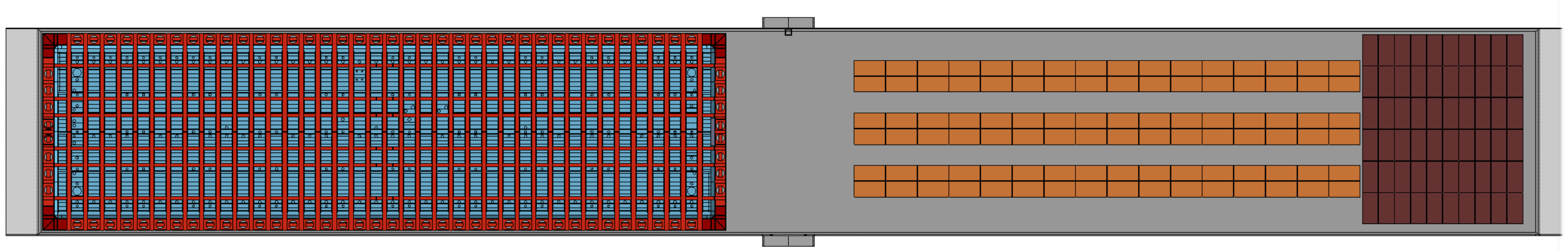
TANK DIMENSIONS

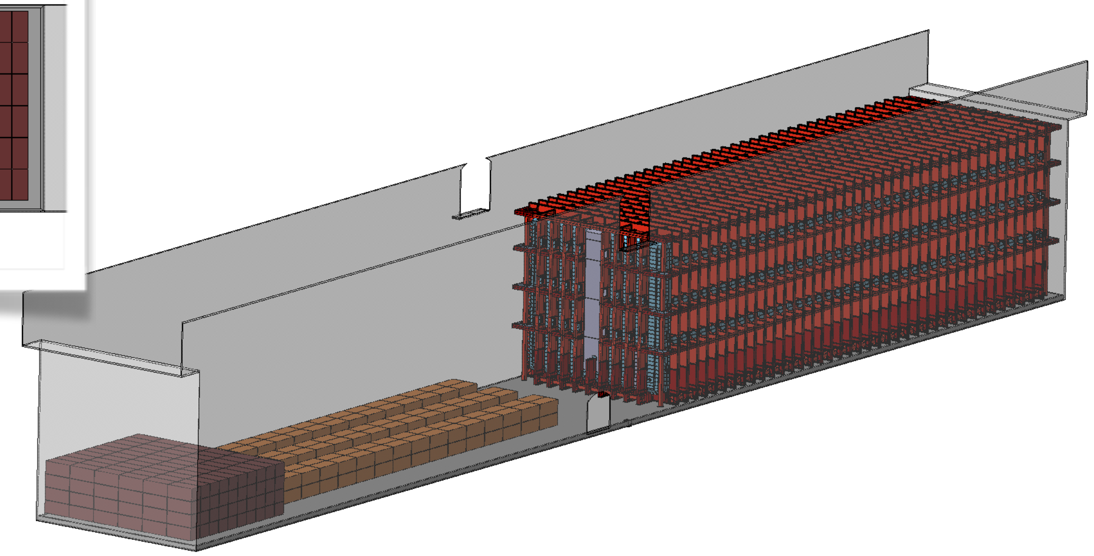
	S229				
	L (m)	l (m)	h (m)	surface (m2)	volume (m3)
Secondary	63.58	16.68	15.58	4,621.93	1,848.77
Primary	62.78	15.88	14.78	4,319.08	1,684.44
At membrane level	62.00	15.10	14.00	4,031.20	

Assuming a packing factor of 70% (for ProtoDUNE it was 50%-60%):

- For the insulation: ~750 boxes 3x1.5x1.3 m^3
- For the membrane: <150 boxes 3x1.5x1.3 m^3

Together with Ladia, to evaluate an alternative transportation solutions, investigating the possibility to bring the panels underground in boxes 1.22 m (L) x 1.02 m (W) x > 3 m (H).





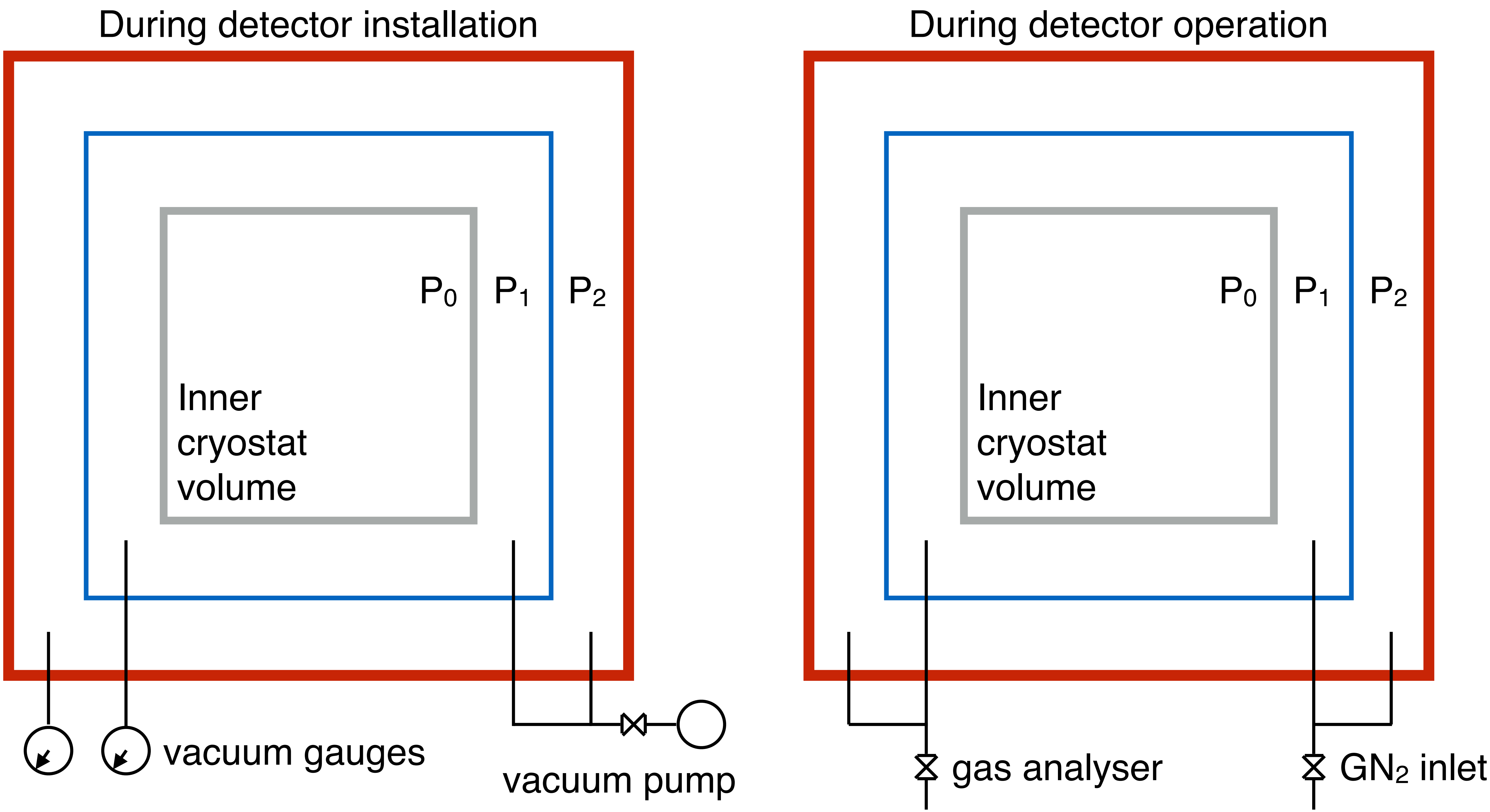
240 brown boxes for insulation (~30%)
192 orange boxes for primary membrane
Additional boxes for special parts and tools

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
- Final pressure tests

Insulation space



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

$P_0 > P1$ 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 a (partial) false floor in the cryostat and insertion of man-lifts
- Cleaning with pressurised demineralise water+solvents and acids
(need water -2 m^3 for ProtoDUNE- and need to pump it up once the cleaning is finished)
- Remove sharpie marks, silicon traces, possible glue traces, clean weldings and degrease

After 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