PART-A (i)

External Cryogenic Distribution System for NBI

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Definitions:

C.B.	Cold Box
DAQ	Data Acquisition
ECDS	External Cryogenic Distribution system
FIM	Free Issue Material
GHe	Gaseous Helium
GN2	Gaseous Nitrogen
HX	Heat exchanger
LHe	Liquid Helium
LN2	Liquid Nitrogen
LNP	Liquid Nitrogen Pump
NBI	Neutral Beam Injector
PFD	Process Flow Diagram
PID	Piping and Instrumentation Diagram
PSV	Pressure Safety valve
SST-1	Steady state super conducting tokamak

List of Figures:

1 Introduction to SST-1 NBI:

Institute for Plasma Research (IPR) is involved in research and development activities related to the plasma science and fusion technology. The Steady State Superconducting Tokomak (SST-1) is an important project aimed at producing high temperature plasma. The Neutral Beam Injector (NBI) is a system required for the purpose of heating the plasma of SST-1 tokomak. NBI system generates a beam of energetic hydrogen atoms and then inserts them into the SST-1 plasma.

During the development stage of the NBI system, trial operations and characterization experiments were performed separately on a designated test-stand in the NBI hall. To achieve the final objective of integrating the NBI system with SST-1 tokomak, it is being transferred from the test stand (in NBI hall) to the SST-1 hall and will be coupled to the SST-1 tokomak. Finally the scientific objective of NBI can be accomplished by combining the operation of NBI along with that of the SST-1 tokomak.

The NBI system comprises of a huge vacuum vessel (20 m^3) with an Ion source and gate valve mounted on it. The vacuum vessel contains the following major 'internal components' such as the neutralizer, electromagnet, magnet liner, calorimeter, Ion dump and the cryo-condensation pumps. It also contains headers and distribution systems for liquid nitrogen, liquid helium and cooling water. The components outside the vacuum vessel are known as the 'external components'. They are the external vacuum pumping system, external cryogenic distribution system, external cooling water distribution system, HV deck, and the snubber deck.

The present document contains work description for installation of a cryogenic distribution system for NBI system at SST-1 hall. This distribution system will be used for operation of cryopumps in the NBI system (a) To transfer liquid nitrogen from the main tanks of IPR and (b) to transfer liquid helium from the liquid He plant of NBI.

1.1 External Cryogenic Distribution System (ECDS): Brief Description

Cryopumps in the vacuum vessel of NBI system are used for maintaining the necessary vacuum of 10^{-6} torr during operation of NBI. Cryopumps require supply of liquid nitrogen (LN2) and liquid helium (LHe) during the operation. The function of ECDS is to transfer LN2 from the IPR's main supply (of LN2) and LHe from the NBI's LHe plant. The required flow parameters and the relevant physical parameters for operation of ECDS are described in section 4. It is required to design and install the ECDS in the NBI hall, SST-1 hall and Cryo hall according to the functional requirements and specifications given by IPR.

The major components of the ECDS are LN2 tank/Dewar, LN2 & LHe transfer lines, flow control valves, Instrumentation for flow and pressure and safety valves. The work involves design and fabrication of certain sections, procurements of required components, and assembly of these components in SST-1 hall, Cryogenic hall and NBI hall. As a part of the work, it is required to disassemble some sections of the existing distribution –this system has been in operation with NBI test stand in NBI hall. A detailed account for the scope of disassembly work is given in section 3 and ECDS is given in section 4.

2 ECDS: Scope of Supply

This section presents the scope of supply along with salient points related to the execution. The detailed description of scope of work is given in sections 3, 4 and technical specifications & requirements are given sections 5, 6, and 7. Section 8 presents the schedule. Section 9 presents all the supporting drawings.

This document gives the conceptual design and the detailed design is the scope of the contractor.

2.1 Contractor's Scope of Supply:

The work is divided into two parts. First part is disassembly of few cryolines and connections of existing Nitrogen distribution system as a preparatory work. The second part is to build a new liquid nitrogen distribution system called External cryogenic distribution system (ECDS).

Part 1: Disassembly and preparation (refer section 3)

- **Disassembly of connections to existing 1000 litre liquid Nitrogen Dewar**
- **Disassembly of some of the existing lines**
- **Preparation for Installing ECDS**
  Part 1 is completely site work at IPR.

Part 2: ECDS work (refer section 4)

Part 2 work contains design, procurement, fabrication at factory, and site work.

- **Process design (PFD to PID)**
- **Detailed mechanical and thermal Design of ECDS as per the specifications**
- **Thermo hydraulic calculations, Instrumentation and lines details and sizing**
- **Drawings preparation (including layouts)**
- **Fabrication and/or procurement of different segments of Nitrogen lines**
- **Fabrication/procurement of 2000 litre LN2 tank with Instrumentation**
- **Design and fabrication of support platform for 2000 l Dewar**
- **Design and fabrication of Isolators boxes**
- **Procurement of Instrumentation [Valves (Control, On/Off, Manual), flow meters, pressure sensors, Safety valves, etc.]**
- **Data Acquisition(DAQ) junction box**
- **Delivery at the site of fabricated and procured items**
- **Erection and Installation of cryogenic lines, valves, instrumentation and storage tank. This work includes all necessary civil work including supports**
- **Commissioning and Acceptance tests of ECDS for performance**
- **Complete documentation including operating manuals (Soft and Hard copies)**
- **All the necessary spares and tools for future maintenance**

2.2 Salient Points for work execution:

- It is the responsibility of the contractor starting from the site visit to final acceptance test of the ECDS. **The contractor shall visit the site before submitting the quotation.**
- The contractor has to arrange/provide all the necessary tools, equipment, cables, material and all other provisions required to carry out the above job.

- It is the complete scope of contractor including all the minor details like supports, cables, wiring, electrical wiring, Helium gas, Vacuum pumps etc., to finish the above work.
- **The total work shall be completed within 7 months from the date of LOI.**
- **The site work at IPR will be agreed mutually and IPR will give site clearance accordingly. Site clearance for Part 1 and Part 2 activities will be given separately. Site work for part 1 and design and procurement activities of Part 2 may be carried out in parallel. Site work (under part 2) specific to the SST hall area shall be completed within 15 days.**

Note: IPR reserves the right to assess the contractor whether he is suitable for the job or not.

2.3 IPR Scope of supply:

- **FIM (Electrical isolators, Nexans lines, KENOL fittings, temperature sensors and monitor)**
- **Utilities (Water, Electricity, Instrument Air)**
- **Providing LN2 for commissioning and acceptance tests**
- **Implementation of control logic in IPR (NBI) PLC**

3 Existing Nitrogen system and Interconnections:

3.1 Existing Nitrogen system and Interconnections: Description

Figure 1 shows the existing Nitrogen system with the interconnections with the NBI system. 3D layouts are shown in Figure 5, Figure 6 and Figure 7

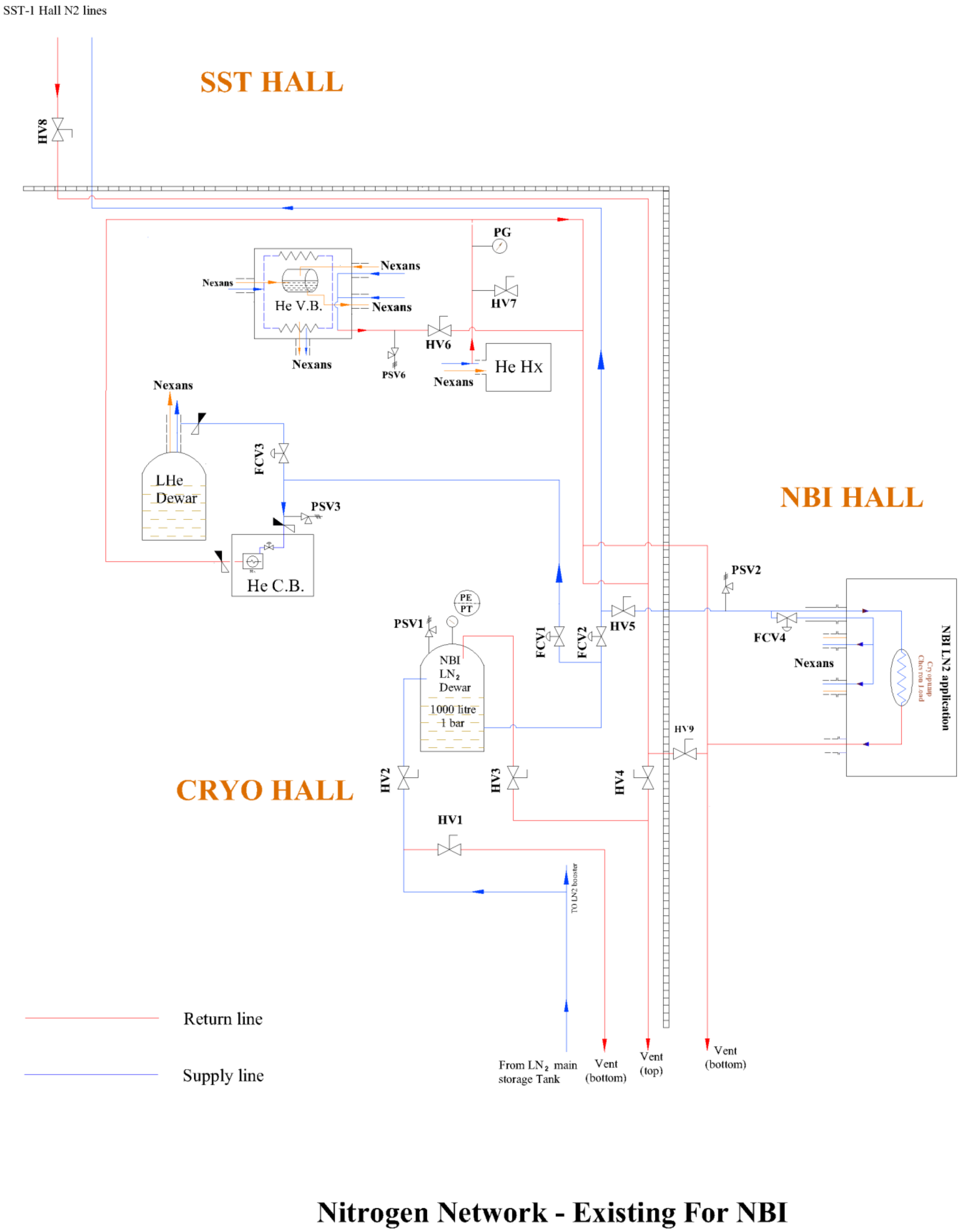


Figure 1 Process flow diagram: Existing Nitrogen Distribution System

Main Components:

- **1000 l liquid Nitrogen Dewar**
- **LN2 lines**
- **Vents lines with insulation**
- **Control valves**
- **Manual valves**
- **LN2 Shielded LHe Nexans coaxial lines (between valve box and NBI vessel)**
- **Instrumentation connections**

As mentioned in section 1.1, existing Nitrogen system is connected to the cryopumps inside the NBI vessel at NBI hall and also to the LHe Plant cold box and Nexans lines shielding.

The Existing Nitrogen system consists of a 1000 litre Dewar which is filled from 3 x 35000 litre (refer Figure 8). These LN2 tanks are located 300 m away at IPR tank/storage area. The existing distribution system along with 1000 l Dewar also contains few control valves, instrumentation and lines. This system is located mainly in Cryo hall and some parts in NBI hall.

NBI system will be moved to SST-1 hall to integrate the system with the tokamak. This integration requires a new few LN2 lines, valves, instrumentation, electrical isolator boxes and disassembly of part of the existing system.

3.2 Existing Nitrogen system and Interconnections: Disassembly work description

The Disassembly work as marked in Figure 2 mainly consist of:

- **Disassembly of connections to 1000 litre (liquid Nitrogen) Dewar**
- **Disassembly connections from 1000 litre Dewar**
- **Cutting and disassembly of LN2 lines**
- **Cutting and disassembly Vents lines with insulation**
- **Cutting and Removal of Control valves**
- **Cutting and Removal of Manual valves**
- **Removal of Instrumentation piping and electrical connections**
- **Removal of old insulation and New insulation on the vent lines marked**

Figure 2 **shows the disassembly work of existing system as a preparation to ECDS work.**

The present 1000 l NBI Dewar is not sufficient for 6 pumps stable operation. Functionally, this Dewar will be replaced by a 2000 l Dewar to fulfil the requirements of NBI nitrogen distribution. The disassembly of this 1000 l Dewar is not in the scope of contractor.

All the disassembled lines, valves and the Instrumentation shall be kept outside the Cryogenic hall or at the location identified by IPR in the premises.

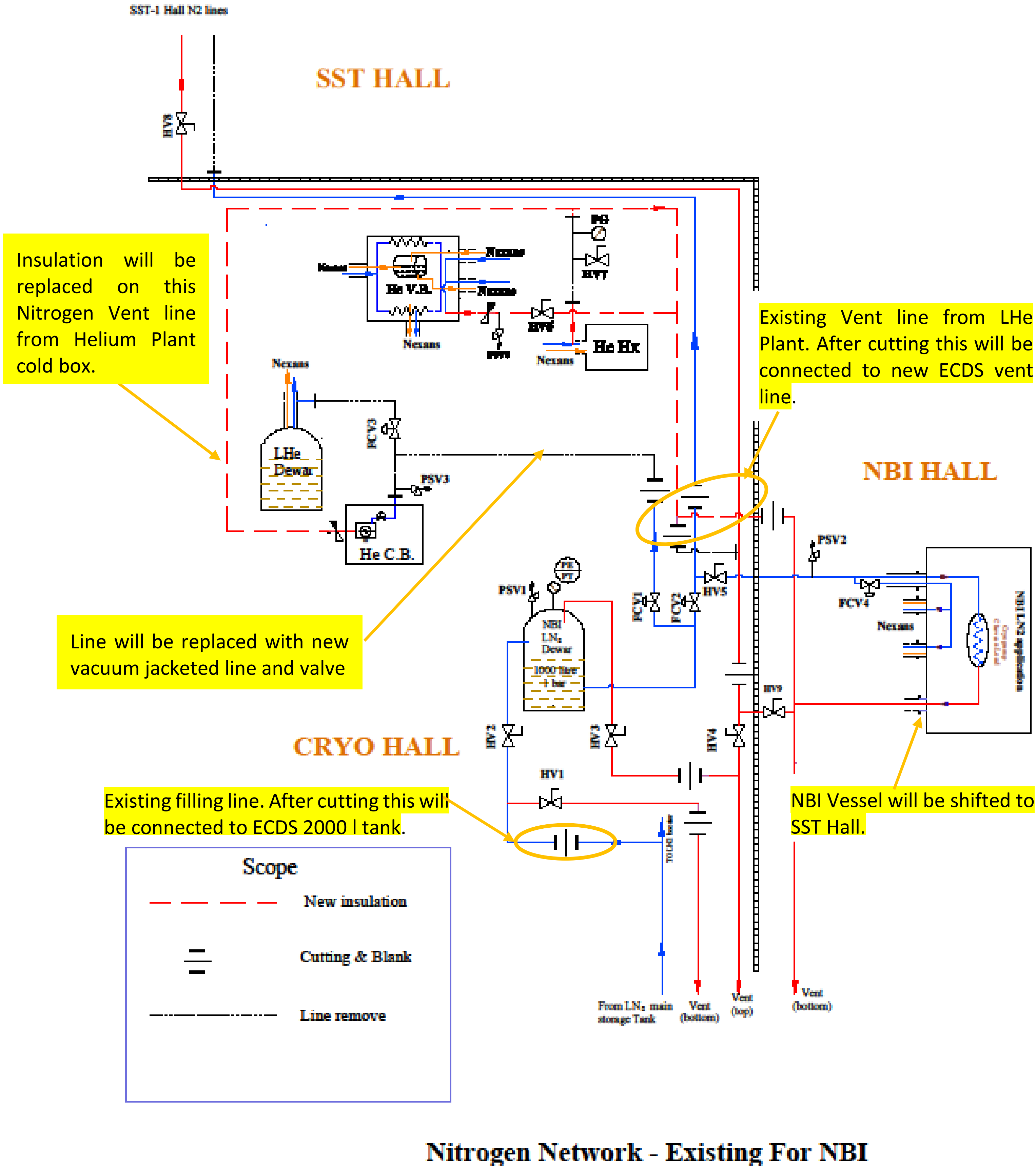


Figure 2 Process flow diagram: Existing Nitrogen Distribution System **Disassembly work**

4 ECDS:

4.1 ECDS: Main Components

The ECDS mainly consist of:

- **1x LN2 tank 2000 l with support platform and instrumentation**
- **Cryogenic lines with vacuum jacket**
- **Cryogenic lines with insulation**
- **Control and On/Off valves**
- **Manual valves**
- **Flow and pressure sensors and monitors**
- **Pressure sensors and monitors**
- **Temperature sensors (FIM)**
- **Safety relief valves (PSVs)**
- **Isolator boxes**
- **Ceramic Isolators (FIM)**
- **Nexans lines (FIM)**
- **KENOL fittings(FIM)**
- **DAQ junction box**

ECDS PFD in the. Figure 3 is showing the concept with required flows.

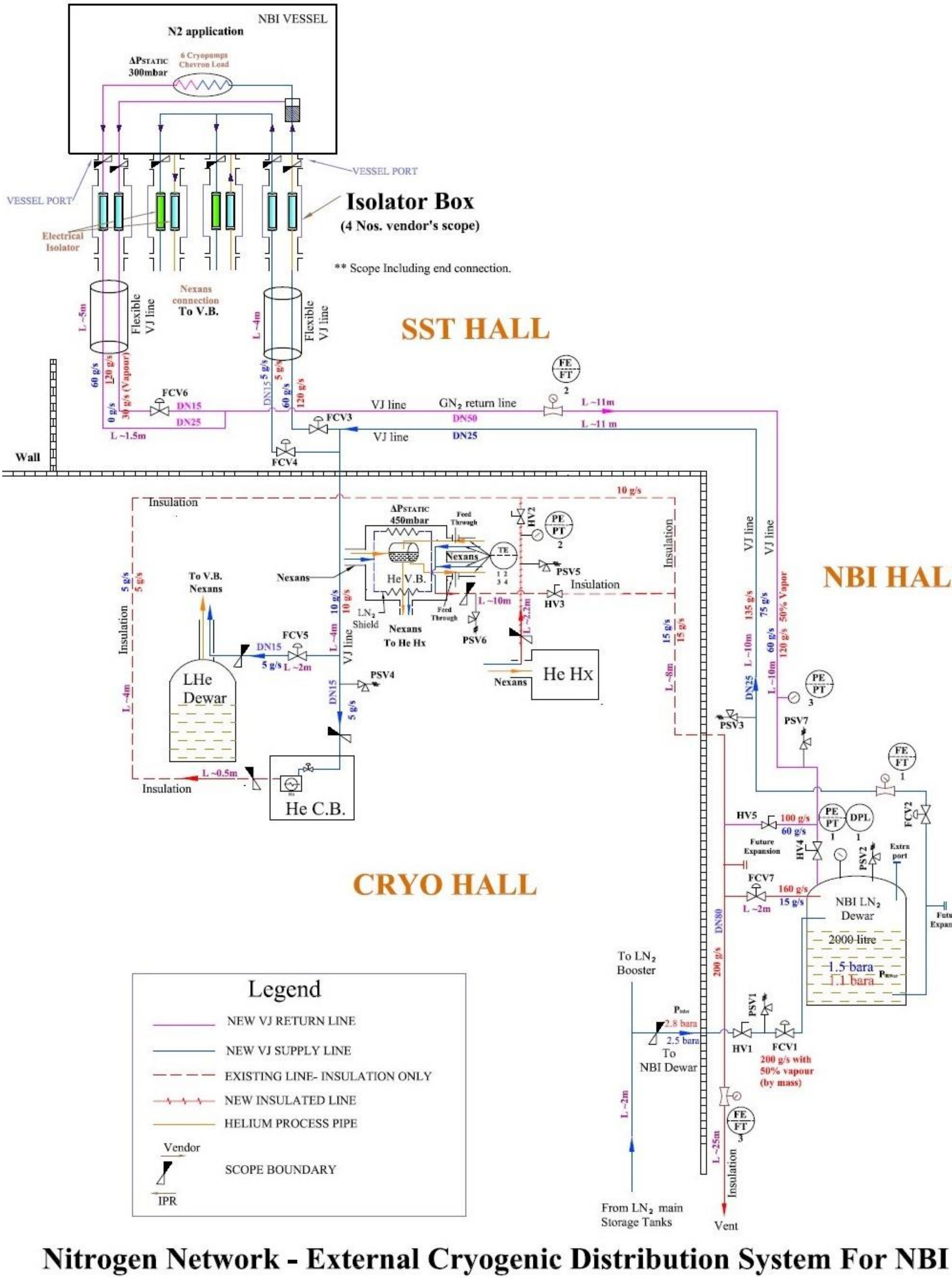
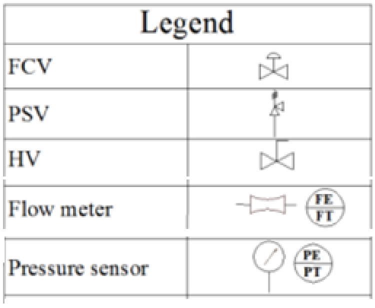


Figure 3 PFD: ECDS

Diameters shown in the figure are indicative only. Diameters will be finalised after Process design and calculations (contractor's scope)



4.2 ECDS: Description of Function

The PFD is shown in Figure 3 and the 3D layout is shown in the Figure 9. The connecting interface equipment is shown for clarity and understanding.

The ECDS supplies Nitrogen to the chevron baffles of cryopumps inside NBI vacuum vessel and to the shields of liquid Helium lines, LN2 pre cooler of LHe Plant. The flow rates bifurcation is as shown in the PFD. The mass of the chevron baffles is 1800 kg (mainly copper). The chevrons baffles which are at 80 K during normal operation receives heat load of 12 kW from the vessel walls. The ECDS requires to cooldown the chevron baffles gradually from room temperature to 80 K.

The 2000 l LN2 tank is continuously filled from common main tanks of IPR (3x 35000 l) at 0.5 barg. These tanks are located at ~300 m from the NBI LN2 tank. The level of 2000 l tank shall be maintained using the control valve (FCV1) and level transmitter. The tank needs a pressurising system.

NBI cryopumps need forced flow of LN2 during cooldown and also to maintain uniform temperature during operation. This requires force flow of liquid occasionally.

The LN2 tank return connections shall be sufficiently sized so that there will not be any pressure rise in the tank during all operational modes.

Flow, pressure and temperature sensors and transmitters are envisaged to control the flow and also for inventory management and diagnostics.

Electrical isolator boxes are required to isolate the NBI system and ECDS electrically.

The technical specifications of individual components are as given in Section 5.

4.3 ECDS: Work Description

The contractor is responsible for the performance of the ECDS system as per IPR requirements including operational requirements like cool down and dynamic operation. The mechanical and thermal design to satisfy the all the above requirements (including site conditions) are in the scope of the contractor.
Any design suggestions and improvements for simplification, performance improvement and cost optimisation shall be submitted to IPR approval during the quotation process itself.

4.3.1 Design: Process design and Thermo-mechanical design (refer Figure 3):

The PFDs and PIDs and lay out drawings including isometrics are in the scope of the contractor. The contractor shall foresee necessary iterations till the approval. Process data sheets shall be submitted for the all components/equipment for IPR approval. Before procurement, technical specifications documents shall be submitted to IPR for approval.

The ECDs shall be designed to operate in completely automatic mode from NBI control room. The system shall be operated for at least one year without any maintenance.

Thermo hydraulic calculations for the sizing of lines, valves, safety valves, flow meters and other instrumentation is in the scope of the contractor. The contractor has to submit the design details for IPR approval before procurement/fabrication. The heat and mass balance details shall be submitted. The details of pressure drop across each segment/component and allowable pressure drop balance shall be detailed.

The minimum design pressure of the system is 5 bar. The thermo mechanical design shall be compatible for cool down and normal operation. Flexibility analysis shall be carried out based on the layout.

4.3.2 2000 l LN2 Dewar/tank:

The 2000 l tank replaces function of existing 1000 l Dewar. The 2000 l tank will be connected to the existing filling line through a control valve (FCV1). The contractor shall do necessary cutting of the existing line and connecting to the 2000 l tank with the control valve. The tank has supply and return connections to/from the users. The 2000 l tank with all the connections shall be mounted in NBI hall at an elevation of 3.5 m (refer Figure 12) on a supporting platform. The tank needs an external pressurising system. The support platform is in the scope of the contractor. The contractor shall submit the design of platform for IPR approval.

The Contractor shall submit the PID and all engineering details of the tank for IPR approval before fabrication/procurement. In case of procurement, necessary conformance certificate shall be obtained and submitted before delivery.
As volume of liquid inside the Dewar is an important parameter, the contractor shall provide the correspondence between percentage of level and volume of liquid inside the tank.

The tank is a process vessel and declaration with PESO will be taken up by contractor.

4.3.3 Supply and return lines to 2000 l tank and Vent lines:

The supply line is connected to the users via a control valve (FCV2) with the tank is maintained at ~1.5 bara. The contractor shall design and size of the valves and all the connecting cryogenic lines and shall be submitted to IPR for approval.

The flash vapour from the tank and return vapour are sent to the vent line. The LN2 tank is connected to vent line through a control valve FCV7. FCV7 will also be used to maintain the pressure in the tank if it is necessary. The return from cryopumps is connected to vent through hand valve HV5 (HV4 is closed).

The vent lines from the LHe Plant shall be cut and connected to the Vent line as marked in the Figure 3. Some of the vent lines from the LHe Plant need replacement of insulation to avoid frosting.

The main vent line is through NBI hall and shall leave the NBI at an elevation shown in Figure 3. This shall be insulated to avoid frosting.

The contractor shall implement the approved routing of the lines. Necessary tools to carry out erection and fabrication work at site is in the scope of the contractor. All the supports shall be prepared as per approved drawings.

4.3.4 Connecting Helium Plant valve box with Nexans lines:

The scope of work also includes connecting a set of Nexans lines (FIM) as shown in Figure 15 to the LHe Plant valve box. The Nexans lines (please see the link www.nexans.de for detailed information) are coaxial lines (liquid Helium line is protected by liquid Nitrogen jacket). The lines are having vacuum barriers at both sides and flexible end connections of 300 mm for liquid helium and liquid nitrogen connections. These lines will be connected to electrical isolator boxes on the other side. It is responsibility of the contractor for layout and routing with supports of the Nexans lines. The allowable minimum bending radius of these lines is 1m.

4.3.5 Electrical Isolator boxes and connections:

Contractor has to carry out detailed design and fabricate 4 numbers of electrical isolator boxes. The conceptual design drawings with details are given in Figure 16, Figure 17 and Figure 18. The contractor's detail design shall ensure isolator box withstands external force with vacuum inside. A safety valve shall be installed on the box as a protection in case of vacuum loss inside.

The purpose of isolator boxes is to electrically separate high voltage side (NBI vessel side) and NBI cryogenics side. The construction of isolator boxes is similar to two pipe vacuum jacketed line with ceramic pipe isolators for fluid transfer. Two boxes shall be connected to Nexans lines on one side and NBI vessel on the other side. The third box will be connected to LN2 supply line and the fourth box will be connected to the GN2 return from the Chevron baffles of cryopumps and internal buffer. The isolator boxes will be placed on the Platform in SST-1 hall as shown in Figure 9 and Figure 13. Eight number of isolators will be provided as FIM. The isolators are made of ceramic and need specific care during fabrication and cooling down to avoid stresses.

Please submit a separate price for the isolator boxes. IPR may exclude this from the scope.

4.3.6 Instrumentation:

Flow meters and transmitters have been envisaged in the supply and return lines. Pressure sensors and transmitters and pressure gauges have been identified at few locations. Four temperature sensors are envisaged on the interface between valve box and Nexans lines. Two temperature sensors will be mounted on the Nitrogen lines and two sensors will be mounted on the Helium lines of supply and return.
The specifications of valves and instrumentation are given in Section. 5.

4.3.7 Data acquisition and control (Hardware and logic):

All the instrumentation will be connected to a junction box located in NBI hall.

The control logic has to be defined by the contractor and which shall be implemented in NBI PLC by IPR personnel.

The Contractor shall ensure proper supports and mounting scheme for the equipment, lines and instrumentation.

A junction box is foreseen and is in the scope of contractor and the specifications are given in 5.10. All the required cabling is in the scope of the contractor.

4.3.8 Tools and Spares:

The contractor has to identify a list of spares and shall be submitted along with the quotation. The contractor shall submit a separate price for the spares.

IPR has foreseen the following spares:

Spare: One Positioner for each type of valve

Spare: Soft parts for the valves

Tools: Tools for vacuum pumping of cryolines

4.3.9 Documentation:

Note: Starting from the quotation process contractor has to submit documentation for IPR approval before going to next step.

The documentation shall consist of (but not limited to);

- Documentation with quotation (for design, execution, quality and schedule)
- Documentation for the process design and thermo mechanical design
- Documentation for the layouts and isometrics
- Documentation for design approval before fabrication/ procurement
- Documentation for quality and test plan during fabrication
- Documentation for various stages of fabrication
- Documentation for the instrumentation
- Documentation for test certificates (material, calibration, etc.)
- Documentation for pressure tests, leak tests and NDT
- Documentation for factory acceptance test and final acceptance tests.
- Documentation for schedule

4.3.10 Work Execution at IPR:

The contractor shall carry out the erection, installation and commissioning after the procurement/ fabrication of all components/equipment and delivery at IPR site. List of acceptance tests are given in section 4.4.

The total work execution time (work at factory, procurement and work at IPR) is 7 months from the date of PO/LOI. The work at IPR is mainly in the areas of NBI hall, Cryogenic hall and SST hall. The work in the SST hall shall be finished in 15 days. A separate work slot will be given to carry out the work in SST hall.

The contractor shall follow all safety measures during the execution to protect the personnel and investment.

The tasks, milestones, List of deliverables and schedule break up is given in section 8.

4.3.11 Scope of supply: Components summary

Name	Quantity	Remarks
Flow control valves	6	Details in section 5.1
Flow valves (On/Off type)	1	Details in section 5.1
Hand valves	4	Details in section 5.1
Safety valves	5	Details in section 5.2
Flow meters	3	1 Venturi and 2 Coriolis. Details in section 5.4
Pressure transmitters	2	Details in section 5.5
Temperature sensors	4 **(FIM)**	Details in section 5.6
LN2 tank with pressure transmitter and level transmitter	1	2000 l. Details in section 5.3
Vacuum Jacketed line	90 m	Details in section 5.7
Insulated line	40 m	Details in section 5.8
Only insulation work	30 m	Details in section 5.8
DAQ junction box	1	Details in section 5.10
Isolator boxes	4	Details in section 4.3.5 and 5.9
Tools and spares	1 lot	Details in section 4.3.8

4.4 ECDS: Factory tests, Installation & Commissioning and Acceptance tests

4.4.1 ECDS: Factory tests

Factory tests for the all the components/equipment and instrumentation shall include tests as per the applicable codes of construction. All the factory test certificates shall be submitted along with the delivery.

- Factory tests of the valves shall be submitted to IPR for approval. The tests shall include leak tightness test, seat leak tightness test, and calibration of the valve with positioner.
- Factory tests of flow meters shall be submitted to IPR approval prior to despatch. As a minimum conformance to design specifications shall be submitted.
- Factory tests of pressure sensors and transmitters meters shall be submitted to IPR approval prior to despatch. Calibration tests shall be done and certificates shall be produced.
- Cryolines: The material tests for the pipes and welding material, leak tests, radiography tests shall be submitted. If the lines are procured, a conformance certificates satisfying the design specifications shall be submitted.
- 2000 l tank: If the tank is fabricated at the factory, all the required tests starting from material qualification, welding qualification, leak tests, other NDT tests shall be carried out. If the tank is procured, all details of fabrication and factory tests shall be submitted for IPR approval. This shall include the tests for instrumentation. A separate quote shall be given for ASME certification or equivalent certification.

4.4.2 ECDS: Site acceptance tests (Installation & Commissioning and Acceptance tests)

The Contractor shall carry out the commissioning of the integrated system and shall carry out the acceptance tests to demonstrate the performance of ECDS.

The following tests have been identified by IPR:

- Radiography and NDT including pressure tests during fabrication
- Leak tests and pressure tests after integration at IPR
- Evaporation rate of LN2 tank
- Complete flow testing with actual loads (cryopumps) or dummy loads (like using heaters and/or water bath) at IPR. Contractor shall make a proposal for discussion and mutual agreement during quotation process.
- Testing of Instrumentation and valves for the range specified

The performance acceptance test for global and individual components shall be conducted after integrating the whole system. Failing to satisfy the performance requirements, the contractor shall replace the components/equipment with free of cost and the tests shall be repeated.

The contractor has to submit a detailed test plan for the factory tests as well as satisfying ECDS functional requirements along with the quotation.

5 Technical specifications of ECDS components

5.1 Technical specifications: Valves

The sizing, design and selection of the valves is the scope of the contractor.

Valve	Operating conditions	Fluid	Type	Flow characteristic	Heat leak
FCV-1	Normally close	LN2	VJ	Linear	
FCV-2	Normally close	LN2	VJ	On/Off	
FCV-3	Normally close	LN2	VJ	Linear	
FCV-4	Normally open	LN2	VJ	Linear	
FCV-5	Normally close	LN2	VJ	Linear	
FCV-6	Normally close	LN2	VJ	Linear	
FCV-7	Normally close	GN2	w/o VJ long stem	Linear	
HV-1	manual	LN2	VJ	Linear	
HV-2	manual	GN2	w/o VJ long stem	On/Off	
HV-3	manual	GN2	w/o VJ long stem	On/Off	**Not in scope**
HV-4	manual	GN2	w/o VJ long stem	Linear	
HV-5	manual	GN2	w/o VJ long stem	On/Off	

General Specifications:

- Valve Body; SS 304L or better grade
- Valve sealing: Preferably Bellowed sealed type
- Heat leak : < 5W for each valve
- Rangeability : To be defined by Contractor as a part of design
- Leak tightness details shall be given by contractor for approval (refer section 6.1)

Preferred makes:

On/Off, control and Manual Valves	Weka, Velan, ACME, Herose
Valves controllers	Emerson, Siemens, ABB

5.2 Technical specifications: Safety Valves (PSVs)

PSV-1	Safety	LN2/GN2	
PSV-2	Safety	GN2	**Part of the tank**
PSV-3	Safety	LN2/GN2	
PSV-4	Safety	LN2/GN2	
PSV-5	Safety	LN2/GN2	
PSV-6	Safety	LN2/GN2	Not in scope
PSV-7	Safety	LN2/GN2	

General Specifications:

- Leak tightness see section 6.1
- Heat leak to be specified contractor for IPR approval
- Valve Body and assembly; SS 304L or suitable grade
- Some of the locations have been identified by IPR.
- Contractor has to submit the details of these valves for IPR approval.
- Contractor has to size the PSVs as per the flow rates and line diameters

Preferred makes:

M/s Leser Gmbh, M/s Weir, M/s Tyco, M/s Circle seal

5.3 Technical Specifications: LN2 tank

LN2 tank Specifications	Value/ requirement
Capacity	2000 l
Boil off rate	2 % per day
Maximum Operating pressure	3 bar abs
DP Level detector and transmitter	Yes
Pressure sensor and transmitter	Yes
Pressure gauge	With big dial
All Standard safety devices as per ASME code or equivalent code	Yes
Construction	All stainless steel or subject to IPR approval
All the inlet and outlet ports	As per design and subsequent PID approval
Construction codes	As per ASME or EN or equivalent codes
In vessel Insulation	MLI
Vacuum port for evacuation	Yes
Orientation	Horizontal
Self-pressurisation system (External type)	Required

The contractor shall provide the correspondence between percentage of level and volume of liquid inside the tank.

Note: The contractor shall guarantee for the vacuum (holding) of the Dewar atleast for two years.

This tank will be declared as a process vessel and will be declared accordingly with PESO by IPR if required. The contractor shall prepare necessary supporting documents for processing with PESO by IPR. A separate price shall be given for this activity.

5.4 Technical Specifications: Flow meters and transmitters

Flow meters and transmitters FE/FT1 to 3

Flow meters Specification	Value/requirement
Fluid	Liquid/ Vapour/two phase Nitrogen
Pressure and Temp.	As per location of flow meter
FE/FT1 **(Coriolis type flow meter)**	Max flow. 150 g/s
FE/FT2 **(Coriolis type flow meter)**	Max flow. 120 g/s
FE/FT3 **(Venturi flow meter)**	Max flow. 300 g/s
Type	Venturi (Orifice may be considered as an option) and Coriolis
Mass flow measurement	Multivariable type for venturi (Shall be able to provide flow, pressure and temp. Signals)
Mass flow unit	g/s
Pressure unit	bar
Temperature unit	K
Transmitter output	4-20 mA
Local display	Yes
Body material	SS 304L or better grade

- Preferred makes: M/s. Emerson, M/s Badger meter Inc., M/s. Yokogawa, M/s Siemens(Any other makes shall be submitted to IPR for approval)
- The accuracy and resolution details shall be submitted along with quotation.

5.5 Technical Specifications: Pressure sensors and transmitters

- Quantity: 3 (PE/PT 1, PE/PT 2, PE/PT 3)
- Type: Capacitance/ Piezo resistive type (any other type subject to IPR approval)
- Type: To be defined by contractor. Shall be compatible with the application
- Range: 0-6 bar
- Transmitter output: 4-20 mA
- Local digital display
- Display Unit: bar
- The accuracy and resolution details shall be submitted along with quotation.
- The complete details of the sensor and transmitters shall be submitted to IPR for approval
- Preferred makes: M/s. Emerson, M/s Keller, M/s. Yokogawa, M/s Siemens
  (Any other makes shall be submitted to IPR for approval)

5.6 Technical Specifications: Temperature sensors/transmitters, Feed throughs

- Quantity: 4 Diode (DT 470 lakeshore make) sensors (FIM), 2 feed throughs on two different Nexans line.
- Measurement Type: Diode (for 4.2 K and 80 K)
- No. Wire: 4 wire method
- Temperature Range : 77 K to 330 K and 4 K to 330 K
- Diode sensors will be connected to IPR Lakeshore monitors model
- Feed throughs (contractor scope) shall be vacuum compatible with CF flange.
- Wiring upto the Junction box is in contractor’s scope

5.7 Technical Specifications: Cryogenic Vacuum Jacketed line

- Design and sizing of the lines as per the flow, temperature and pressure requirements
- The design shall ensure enough flexibility preferably using bellows or internal hoses.
- The Contractor shall submit the design details for IPR approval
- The lines should be fabricated in segments with all the standard tests of vacuum jacketed line
- The fabrication of the lines shall be as per applicable ASME or equivalent standards.
- The material shall be 304L or better grade. The pipes shall be seam less.
- The segments shall be assembled at the site with valves and other instrumentation
- Each segment shall be equipped with vacuum pumping port. The contractor shall provide plunger for evacuation.
- The quality of each segment shall be such that after first pumping and sealing it shall hold the static vacuum for minimum 2 years. Vendor shall give guarantee for this.
- The leak rate for each weld and overall segment is as defined in section 6.1
- The heat leak rate shall be 2 W/m max. These values shall be submitted for approval.
- Flow velocity max. 20 m/s
- MLI shall be used as Insulation on the inner line. The make of this MLI shall be submitted for IPR approval.
- Contractor has to provide vacuum pumping tools along with the lines
- Length of Vacuum Jacketed (LN2) Line :- ~60 m
    a) 75 g/s – ~30 m
    b) 60 g/s - ~10 m
    c) 5 g/s - ~20 m
- Length of vapour line (120 g/s , 50 % vapour)– 30 m
- The Contractor shall keep 10% margin for the lengths. The Contractor shall quote for unit rate for additional lengths, if any after detailed layout and measurements.

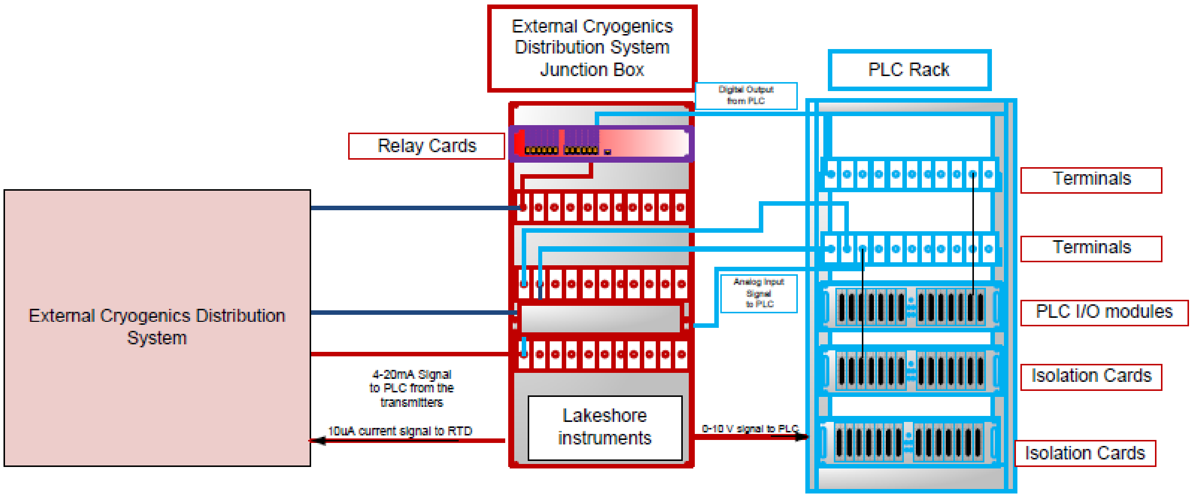
5.8 Technical Specifications: Insulated line

- Design and sizing of the lines as per the flow, temperature and pressure requirements
- The material shall be 304L or better grade. The pipes shall be seam less.
- No formation ice or any condensation on the surface
- The material used shall be as per safety norms for indoor applications
- Insulation type (Armaflex or better grade) and method of applying shall be submitted to IPR for approval during quotation process. The details and compatibility of insulation at cryogenics temperature shall be submitted to IPR.
- The material shall be 304L or better grade.
- Length of Gaseous Line :- ~30m existing line need insulation only
  ~40m new line with outer insulation
- The Contractor shall keep 10% margin for the lengths. The Contractor shall quote for unit rate for additional lengths, if any after detailed layout and measurements.

5.9 Technical Specifications: Isolator boxes

- Vacuum jacket material: SS304L
- Pipes material: SS316 L seamless
- Kenol Couplers : FIM
- Electric isolators for LN2 and LHe process pipes: FIM
- Isolator box shall be equipped with a vacuum port for evacuation
- Safety valve to avoid pressure build in case of vacuum loss
- MLI shall be wrapped above the isolators assembly.
- Isolator boxes shall be supported on the platform.

5.10 Technical Specifications: DAQ Junction Box



Contractor's Scope of Work:

- **Development of control logic as per process requirements**
- **Installation of the junction box**
- **Wiring (signal and power) of all the instruments to the ECDS junction box.**
- **Installation of relay cards for valves operation**
- Installation of lakeshore temperature monitors (model number 218) (FIM).

IPR's Scope of Work:

- **Wiring from ECDS junction box to PLC rack**
- **Control logic implementation in PLC**
- **SCADA development**
- **Data acquisition & user interface**
- **PLC powering and cabling between ECDS junction box and NBI PLC rack**

5.10.1 Technical Specifications: DAQ Junction Box: Signals Summary

Sr. No.	Name	Quantity	ECDS: DAQ Junction Box (Vendor's Scope of Work)	NBI PLC Junction Box (IPR's Scope of Work)	Type of PLC Signal	Remarks
1.	Flow Control Valves	06	4-20mA signal	4-20mA signal	Analog Output From PLC	
2.	Flow Control Valves ON/OFF)	01	24V DC Signal	24V DC Signal	Digital Output from PLC	
3.	Flow Meters	03	4-20mA signal	4-20mA signal	Analog Input to PLC	
4.	Pressure Transmitters	03	4-20mA signal	4-20mA signal	Analog Input to PLC	
5.	Temperature Transmitters	02	0-10V signal	0-10V signal	Analog Input to PLC	4 temperatures sensors will be connected to these two transmitters. Lakeshore instruments installation in the ECDS DAQ Junction Box is in the Vendor's scope of work.
6.	LN2 Tank Pressure and level	02	4-20mA signal	4-20mA signal	Analog input to PLC	

Note:

1) **Analog signal to/from the ECDS DAQ junction box will go to the NBI PLC Junction Box. Isolation card for the analog input/output signals will be installed in the NBI PLC Junction Box i.e. IPR's scope of work**
2) **Digital Output signal (24V DC) from PLC will go to the relay cards installed in the cryogenics junction box (scope of vendor).**
3) **The relay cards to be used in the ECDS junction box depend on the operating parameters (voltage and current requirements) for the valves.**
4) **Also for the analog output signals (4-20mA) from the PLC to the flow control valves (type and specifications for the flow control valve is in vendor's scope of work).**

6 Technical Requirements of ECDS

6.1 Technical Requirements: Leaks and Leak testing

System/ Component	Maximum Leak Rate
Individual leak rate from the weld joints	10^{-9} mbar l/s
Global leak rate from VJ line to atmosphere	Better than 10^{-6} mbar l/s
Individual leakage across valve seats (at design pressure and room temperature)	10^{-4} mbar l/s
Leakage from valves and Instrumentation to atmosphere	10^{-7} mbar l/s
Leakage from flanges	10^{-7} mbar l/s

- All components shall be leak tested, under helium at maximum operating pressure, as far as possible during fabrication/ manufacturing phase. The contractor/contractor shall leak test the rest of the system after assembly at site. This leak test shall be combined with pressure test after integration at site.
- The contractor shall submit a complete leak testing procedure in this regard for IPR approval.
- The contractor/ sub-contractor shall have experience in leak testing and shall have all the equipment to carry out the leak detection. It is the scope of the contractor arranging all the leak detection equipment.

6.2 Technical Requirements: Welding and Radiography

- Filler material shall be compatible with piping material
- All the weld joints shall be made of TIG welding
- 100% radiography of all the lines joints. Wherever radiography is not possible contractor shall submit alternate procedure for IPR approval
- All joints shall qualify radiography
- The welder shall be qualified and experienced for carrying out similar jobs
- The welding procedures shall follow AWS and/or ASME standards or equivalents standards
- The contractor shall make all necessary arrangements to carry out welding at site
- No weld defects are acceptable
- The repaired welds shall undergo radiography for qualification
- Weld joints shall be passivized after welding
- The joints shall be cleaned thoroughly after passivation

6.3 Technical Requirements: Pipes and Flanges

- All the piping (pipes, bends, Tees) and flanges shall be SS 304L or better grade
- The contractor shall submit material and test certificates conforming ASME/ASTM
- All the pipes used shall be seamless
- The sealing gaskets shall be compatible with the application

6.4 Technical Requirements: Site conditions

- SST Hall is Air conditioned (Temp 20 to 30 deg C)
- Cryogenic Hall is Non A/c (Temp 25 to 40 deg C)
- Seismic zone V

6.5 Technical Requirements: Cleanliness

The fabrication shall be carried out in clean environment/atmosphere as the work is related to vacuum and cryogenics.

The inside and outside surfaces shall be thoroughly cleaned before and after fabrication.

Dust protection cover during mechanical work - Contractor will cover working area to ensure that grinding dust should not go inside other parts of system.

Cleaning of worksite, workplace mandatory on daily basis after completion of routine works by the contractor.

Contractor should also keep workplace, surroundings clean and tidy from rubbish, scrap, surplus materials unwanted tools and equipment.

All passages to entry/exit doors, electrical switches, fire points, first aid boxes etc. shall be kept free by the contractor. Welding and electrical cables shall be routed properly so as to allow safe traffic by all concerned.

6.6 Technical Requirements: General: Design to Acceptance

- **The Contractor shall visit the site before quotation to understand the space constraints and about the existing system.**
- The contractor shall have experience in handling similar works. The contractor and/or his subcontractor shall have experience in the area for which they are responsible. The contractor shall submit the list of sub-contractors if any for IPR approval along with the quotation.
- **ASME or equivalent code shall be followed at the various stages of design, fabrication, inspection and testing wherever applicable. Shall be submitted as a part of QA/QC along with quotation.**
- The Contractor shall submit a detailed list of codes and standards to be followed for ECDS design, fabrication and testing along with the quotation.
- The contractor shall prepare and submit PFDs, PIDs and layouts (3D and isometrics) for IPR approval.
- The PFDs given in this document are baseline. The contractor may propose alternate schemes for IPR approval along with the quotation. Any changes after the purchase order are not acceptable.
- The contractor shall make the design calculations and shall be submitted to IPR for approval. The design shall include thermal, mechanical, vacuum, process and control.
- The design shall ensure safety of equipment and human for all the operational modes including power failure.
- The design shall include flexibility analysis of the piping as per the approved layout and drawings.
- IPR reserves the right to carryout stage wise inspection during fabrication.
- The ECDS components shall be suitable for the application and to the environment where they will be installed.
- **Supports in the SST-1 hall shall be non-magnetic near the tokamak.**
- All the surfaces that are exposed to high vacuum shall have 2 delta surface finish after electro-polishing/buffing except at sealing faces.
- In case of any failure of the subassembly/assembly/component to comply with/meet an inspection or test required/specified, the contractor shall notify the purchaser about it. Without purchaser’s written permission, contractor shall not undertake the repair of the fault.
- The ECDS will be installed in areas where other equipment have already been installed. The contractor shall take utmost care so that there will not be any damage to existing equipment. The contractor is responsible for such incidents causing the damages.
- All repair welds shall be re-examined and tested as per the requirements of the original weld and shall meet the requirements and acceptance criteria of the same.
- Ensure human and component safety during assembly and erection Works
- The material, fabrication, testing shall comply with all currently available statues, regulations and safety code in the locality where system is fabricated and installed.
- Dye/liquid penetration test is not allowed.

7 QA/QC procedures and Warranty/Guarantee

7.1 QA/QC Procedures:

The contractor is responsible for the quality of the ECDS throughout all phases of execution whether the work is performed by the contractor or Sub-contractors or Contractors.

The contractor has to submit detailed QA/QC procedures for the following:

- Design
- Fabrication
- Erection and Installation
- Leak testing
- Materials
- Acceptances
- Resources
- Documentation
- Codes and standards for the complete ECDS

7.2 Warranty/Guarantee:

The contractor shall give 12 months warranty/guarantee from the date of final acceptance by IPR.

The warranty/guarantee shall be for the individual components and also for the workman ship.

All the defective components shall be replaced at free of cost. All the repairs shall be done at free of cost. The performance shall not be degraded after the replacement and repair.

8 Tasks, Milestones, List of deliverables and schedule break up:

Task	List of deliverables** (under each task)	Applicable sections***	Duration	Milestone reached after task completion	Remarks
Task -1	*Contractor's Scope of Supply:* *Part 1: Disassembly and preparation*	Section 2.1, section 3 and section 8	1 month	Milestone -1	**This activity can be initiated and carried out in parallel with tasks 2 and/or 3.**
Task-2	Contractor's Scope of Supply *Part 2: Design and approval (Process design, thermal and mechanical design, etc..)*	Section 2.1 and sections 4, 5, 6, 7 and section 8	1.5 months	Milestone-2	The contractor will be given 2 weeks time to initiate the work from the date of LOI. The contractor shall submit the design, drawings and layouts to IPR for final approval within 45 days from the date of LOI. All iterations with IPR shall include in this period. IPR will give a final approval within two weeks.
Task-3	Contractor's Scope of Supply *Part 2: ECDS work:* *Procurement/Fabrication of components and delivery at IPR site*	Section 2.1, sections 4, 5, 6, 7 and section 8	3 months	Milestone-3	This activity shall be started immediately after approval of task 2
Task-4	Contractor's Scope of Supply *Part 2: ECDS work:* Erection, Installation & commissioning.	Sections 2.1 , Section 4 and section 8	2 months	Milestone-4	This activity shall be started only after task 1, task 2 and task 3
Task-5	Contractor's Scope of Supply *Part 2: ECDS work:* Site acceptance tests	Section 2.1 and section 4.4	0.5 month (15 days)	Milestone-5	This activity shall be started only after task 4

** Documentation is mandatory with the progress of the project for records and necessary approvals.

*** Only main sections are listed. All appropriate sections and drawings are applicable.

9 Supporting Figures/Drawings

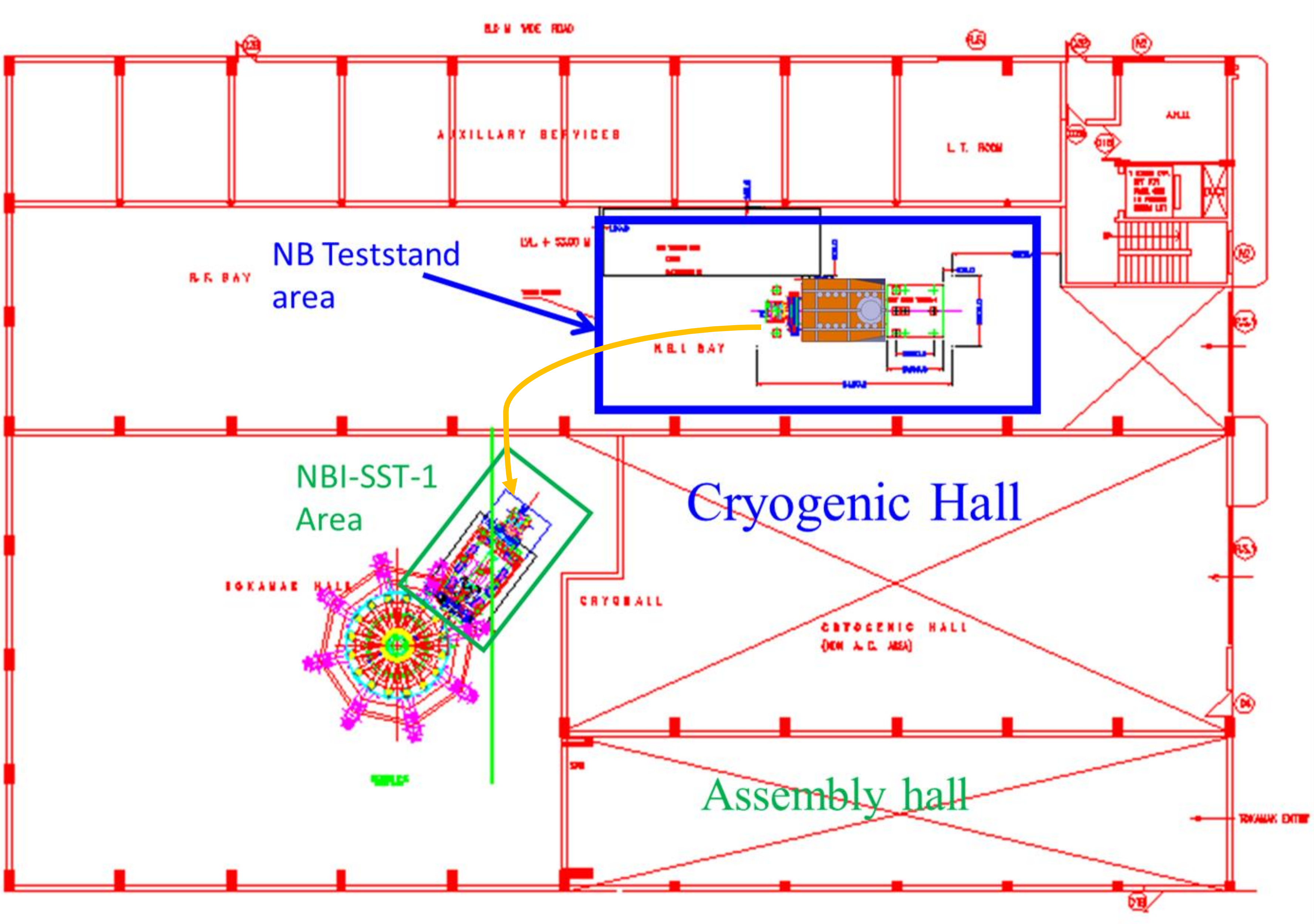


Figure 4 Layout showing NBI Vessel movement from NBI hall to SST hall

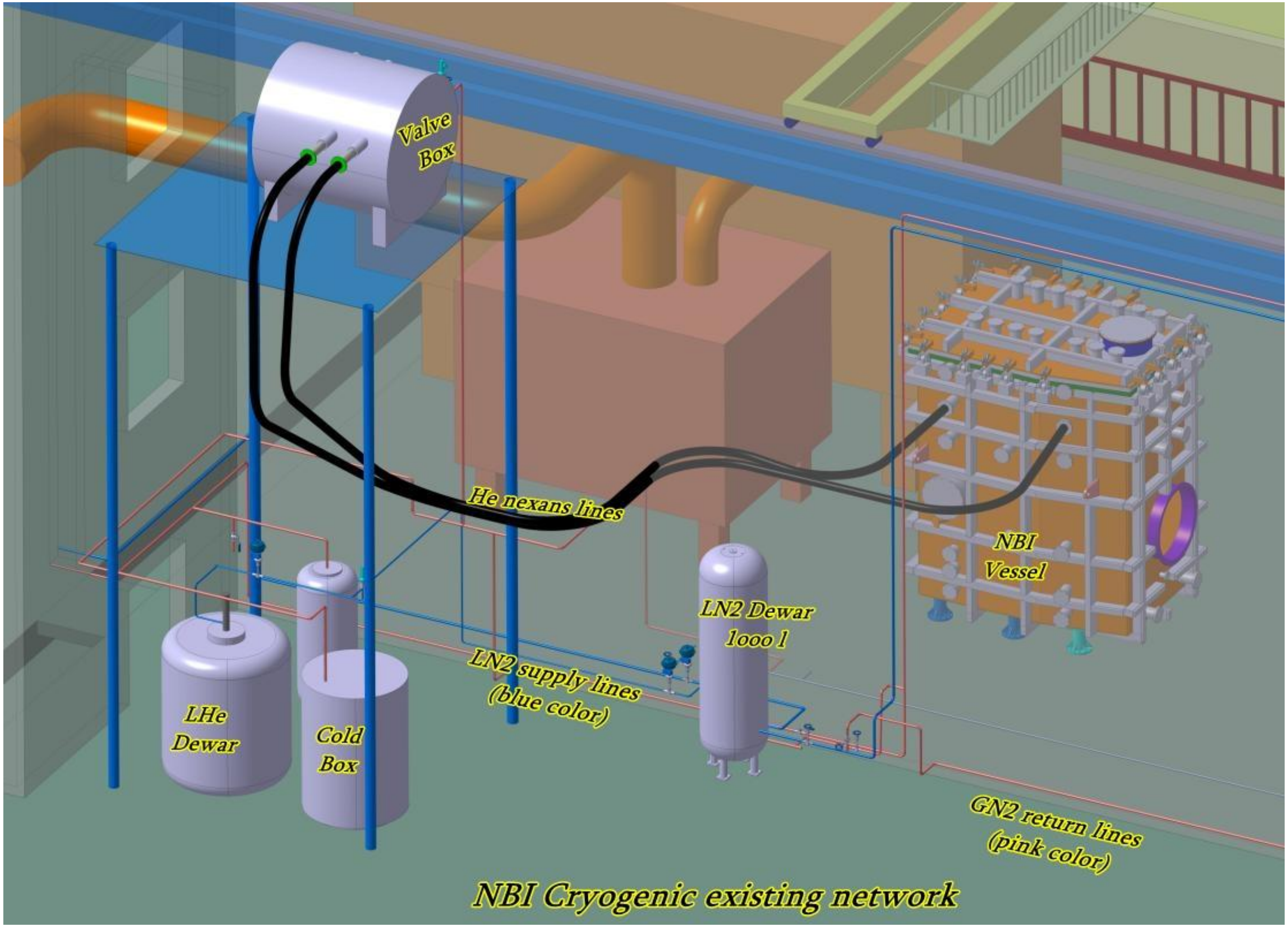


Figure 5 Existing Cryogenic System

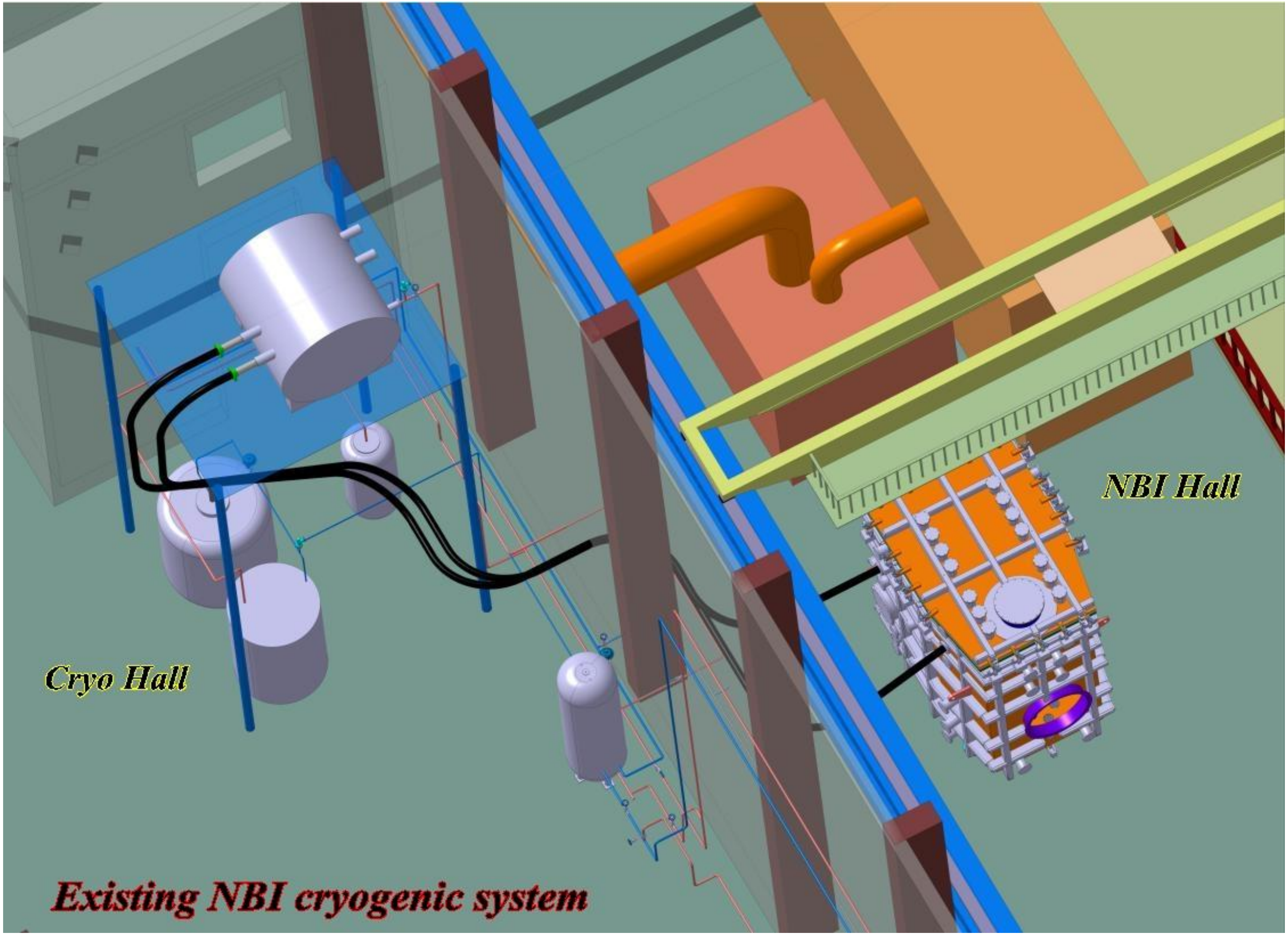


Figure 6 Existing cryogenic system (View 2)

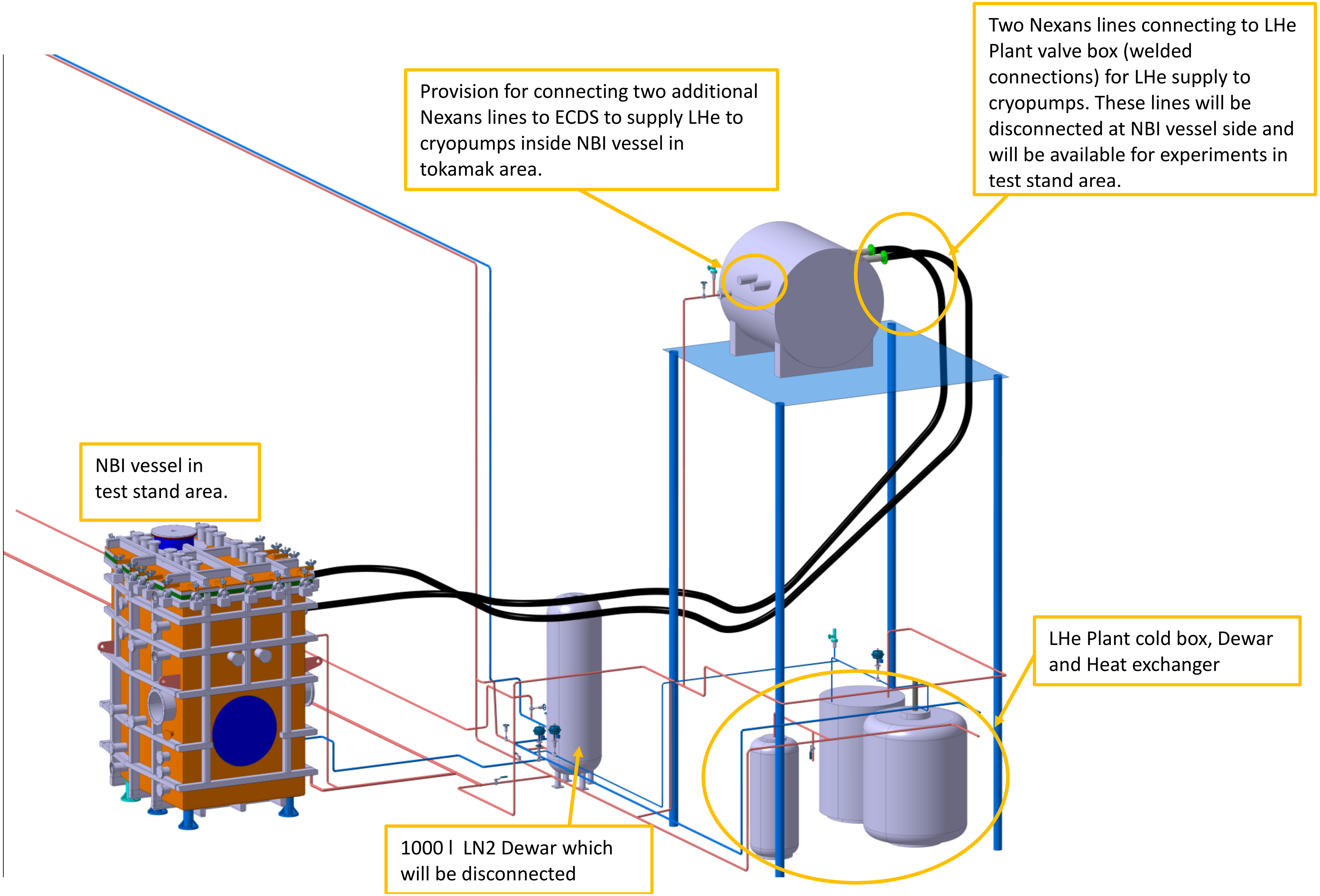


Figure 7 Existing Cryogenic system (view 3)

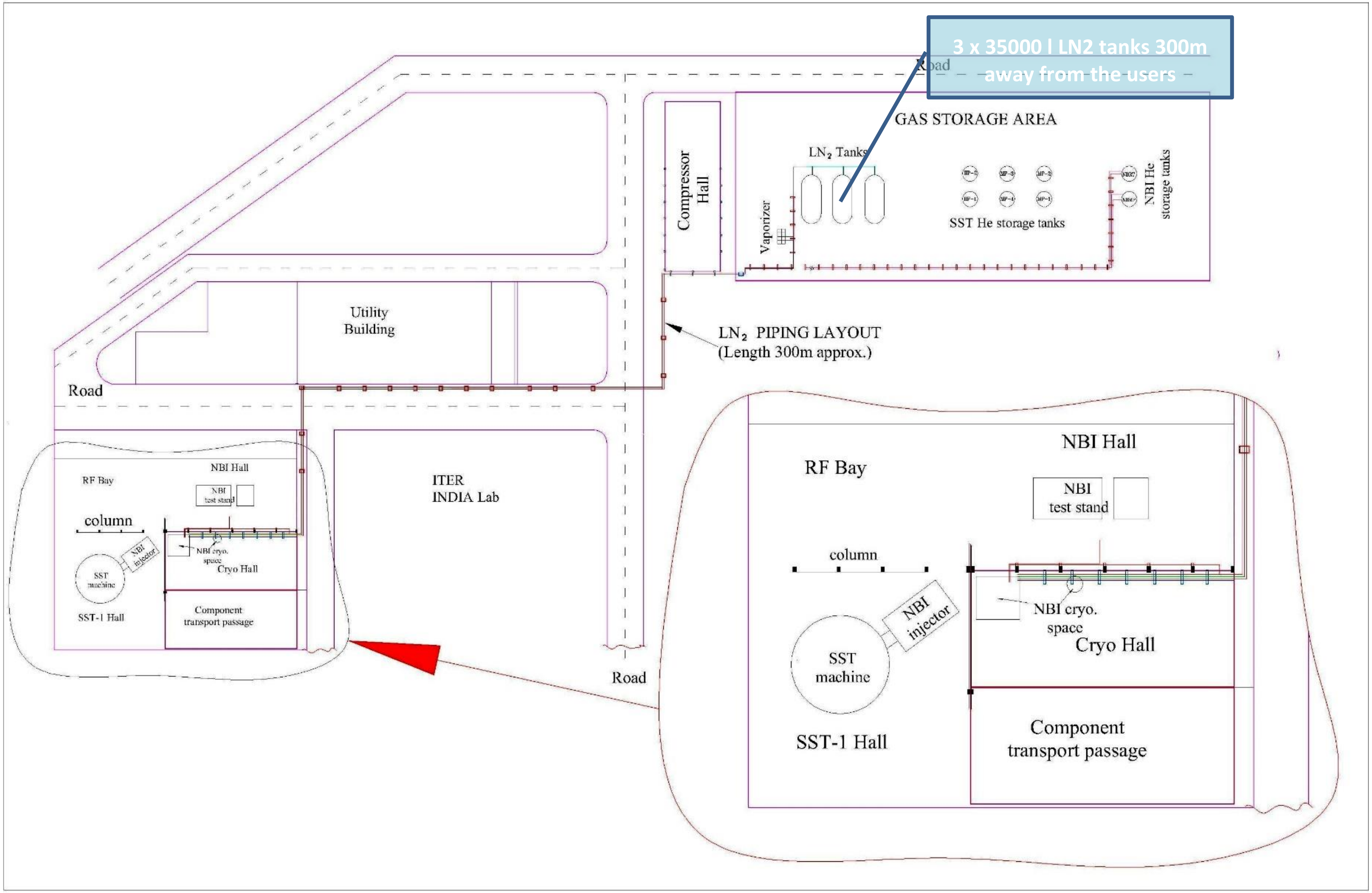


Figure 8 Layout showing LN2 storage tanks location with respect to NBI hall, Cryo hall and SST hall

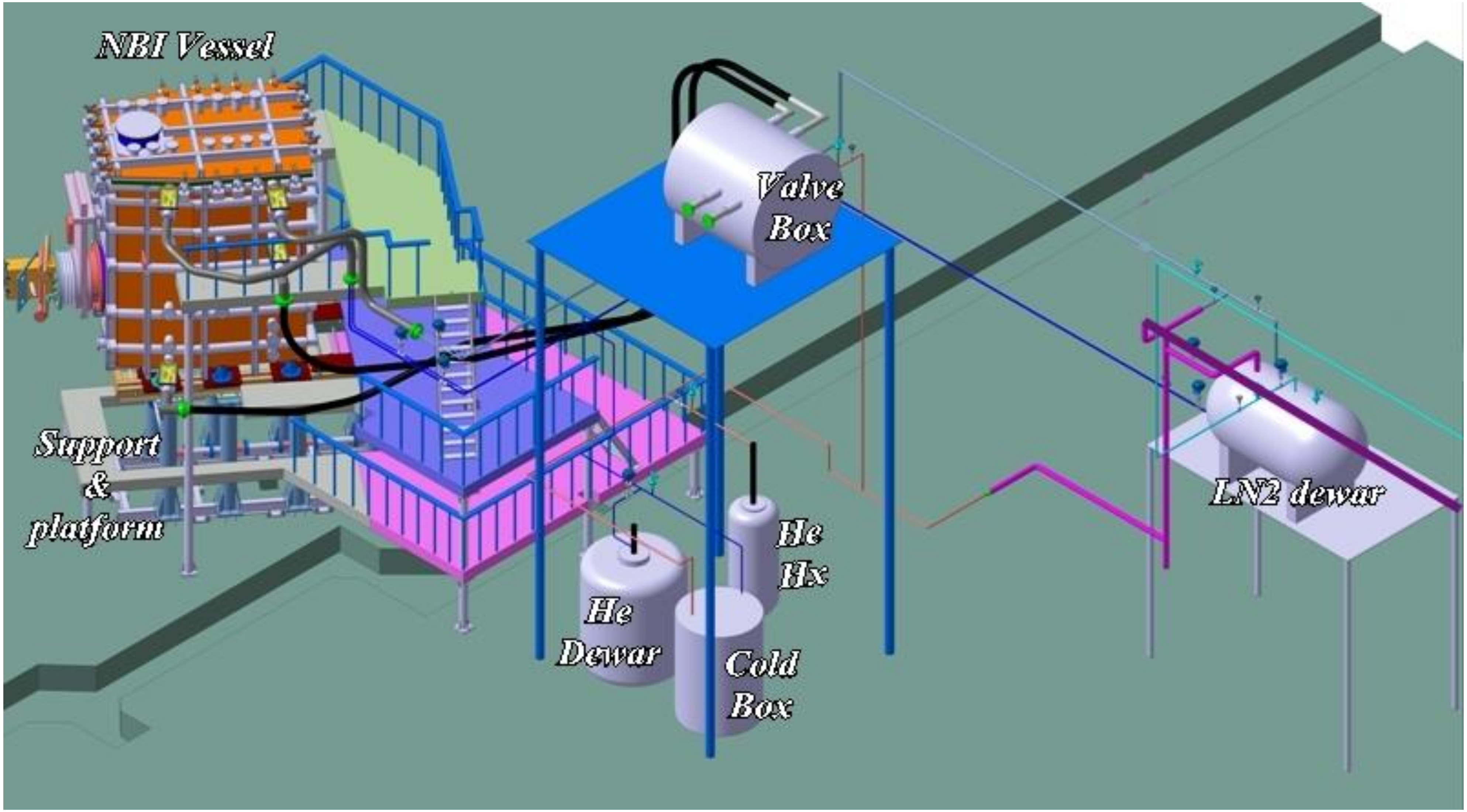


Figure 9 ECDS 3D layout

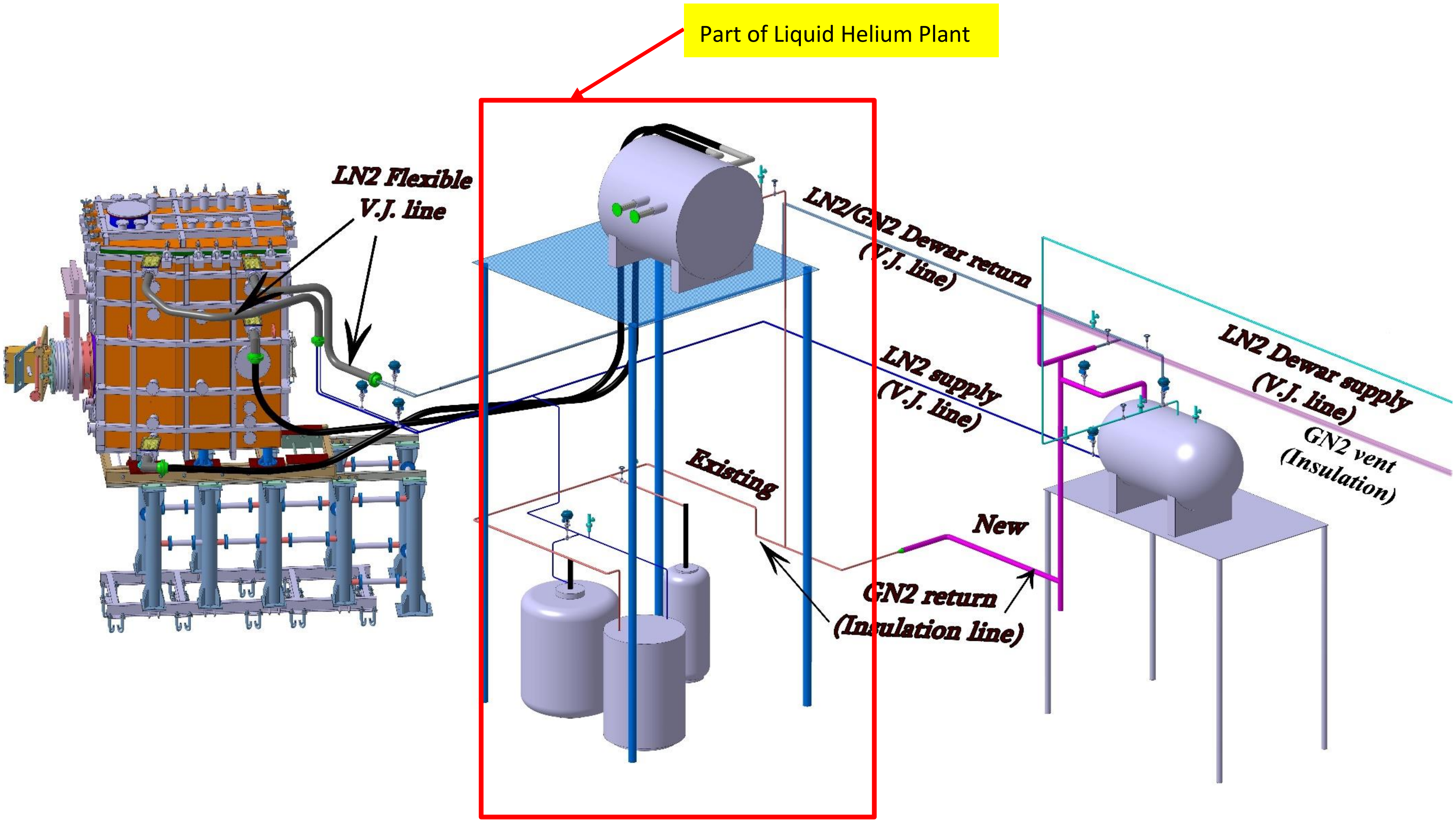


Figure 10 ECDS: 3D layout (Platforms in SST hall not shown for clarity)

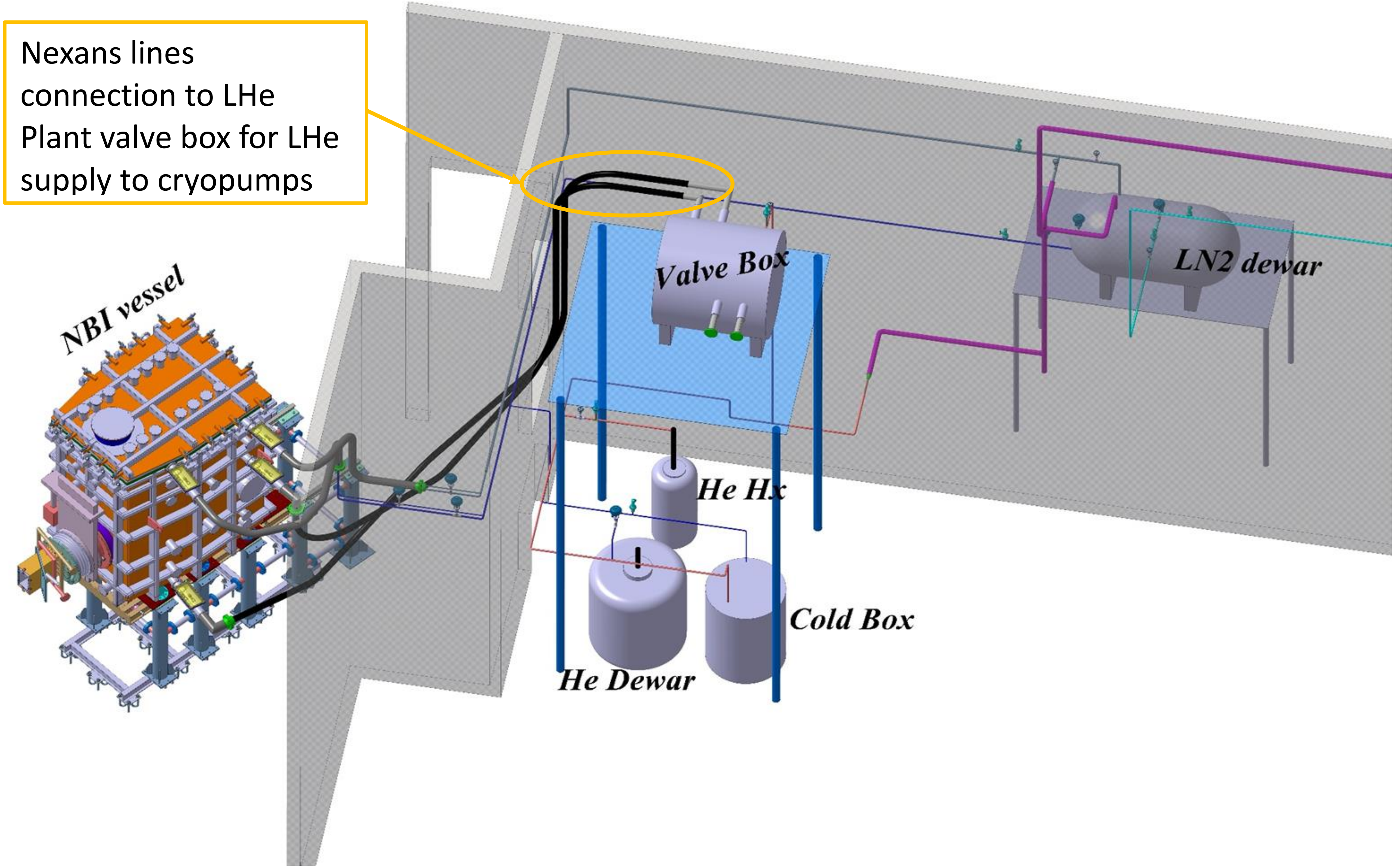


Figure 11 ECDS:Other View

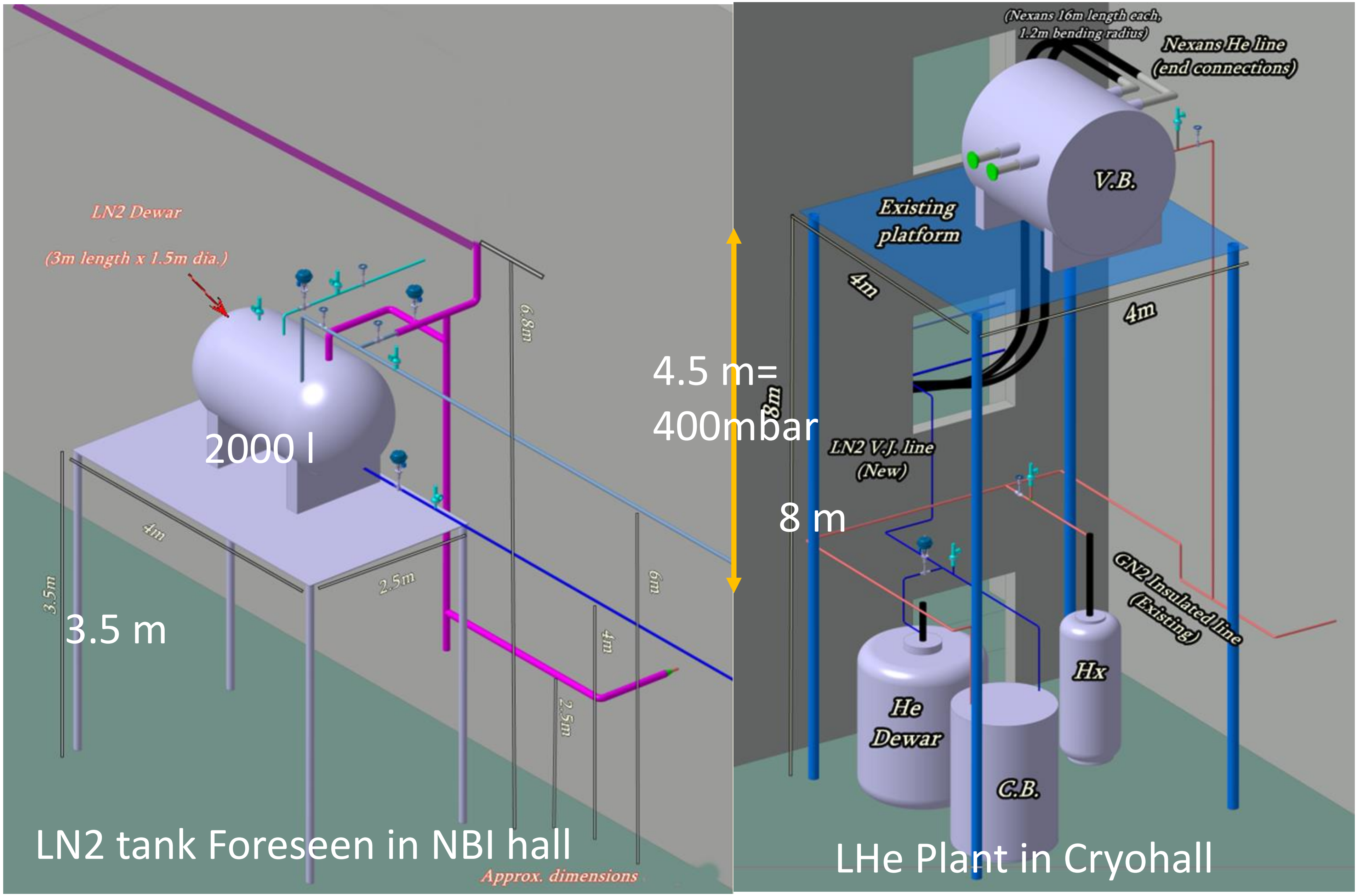


Figure 12 ECDS:Elevations: NBI 2000 l Dewar in NBI hall and Valve box in Cryogenic hall

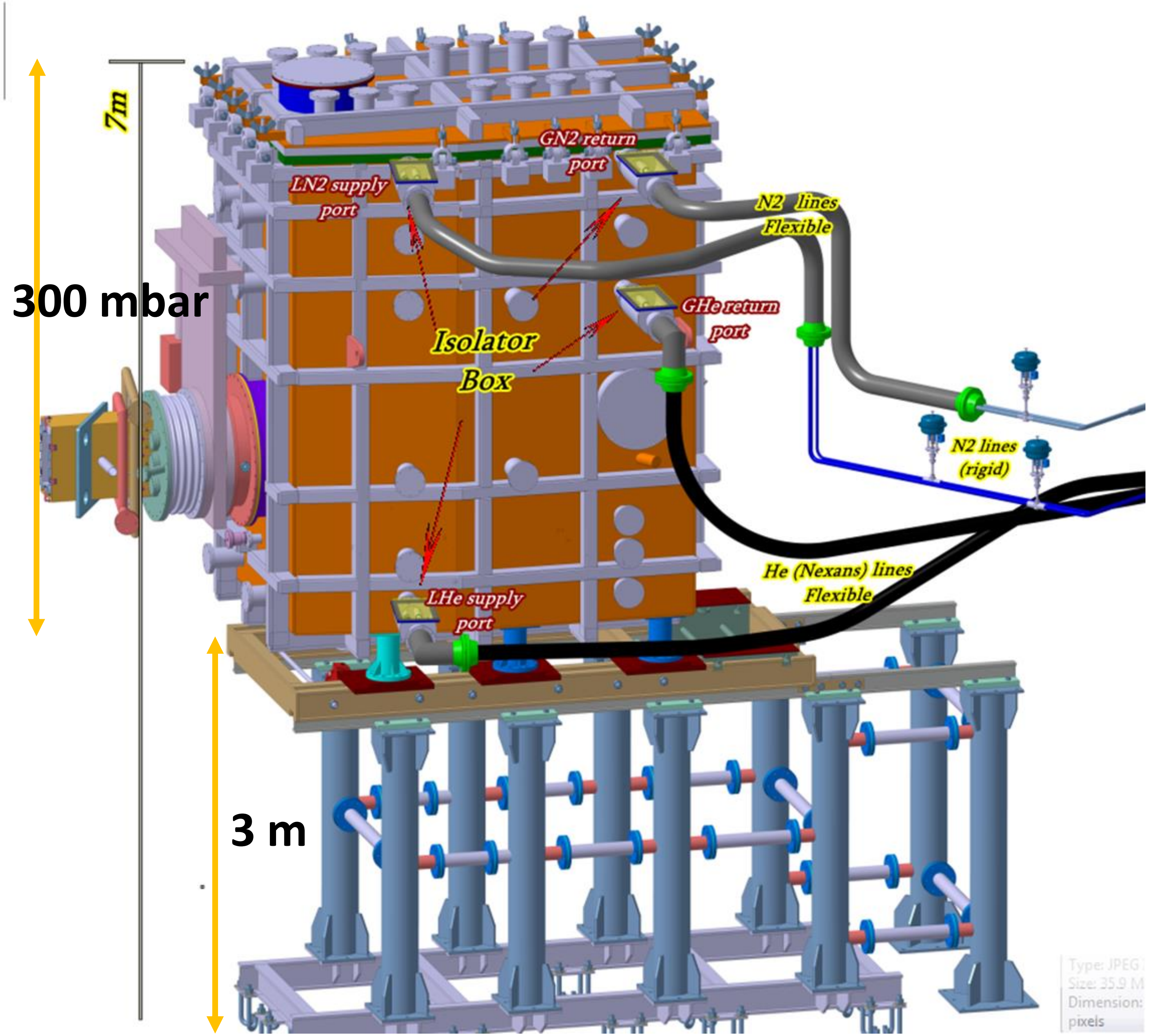


Figure 13 NBI vessel Elevation in SST hall

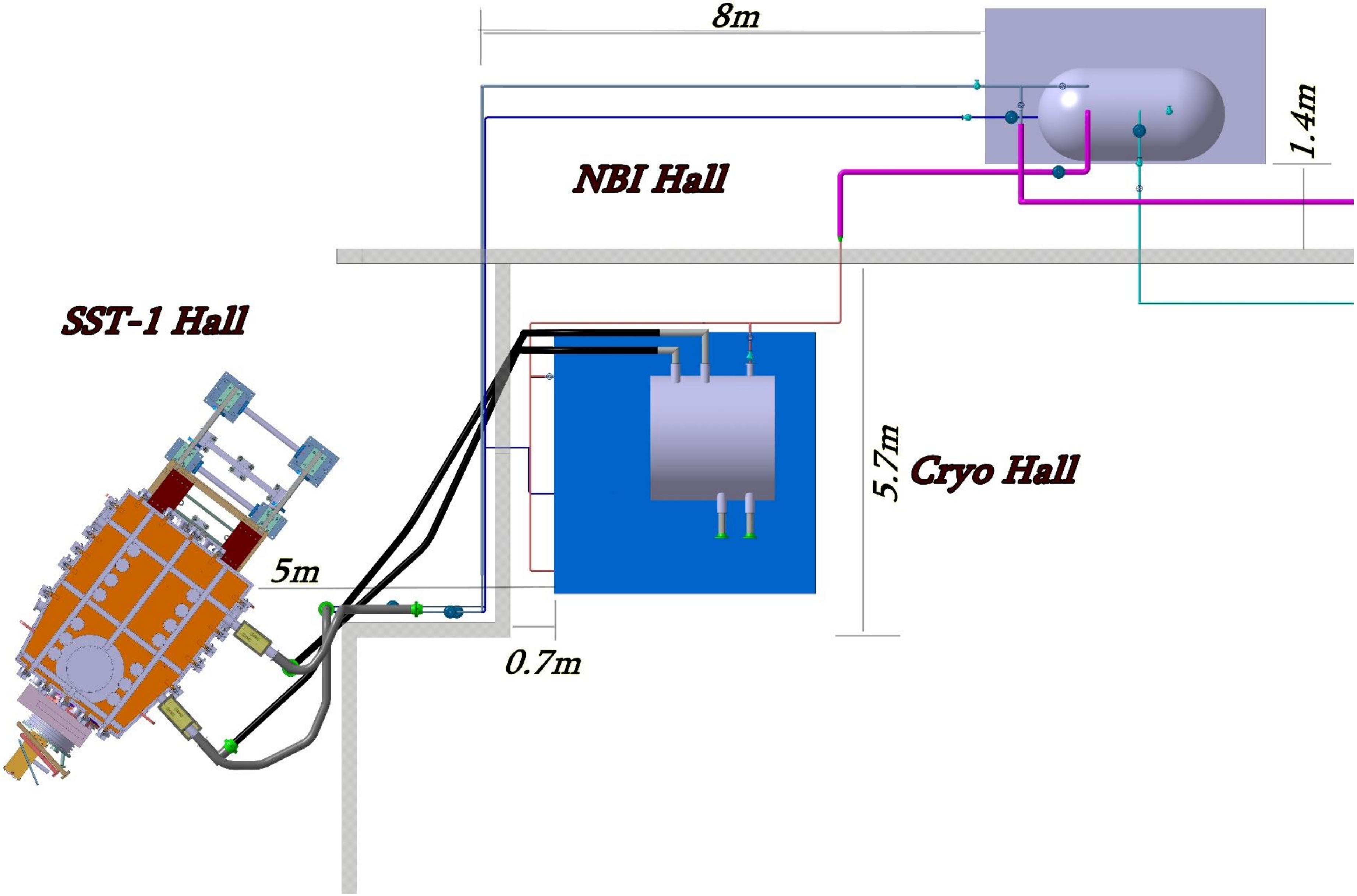


Figure 14 ECDS: Top view

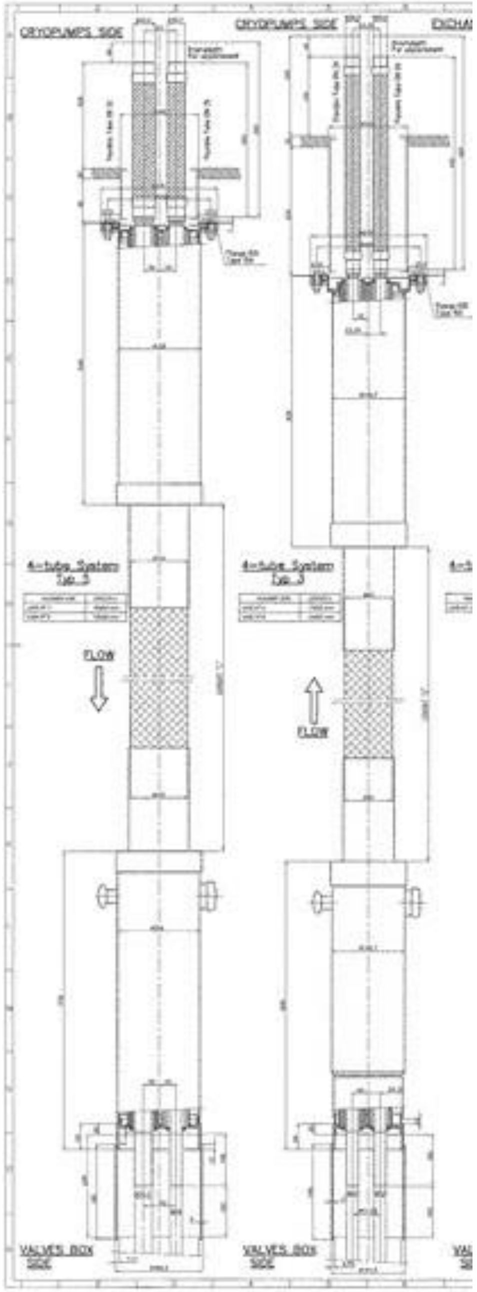


Figure 15 Nexans lines (Line numbers 8 Supply, 9 Return)

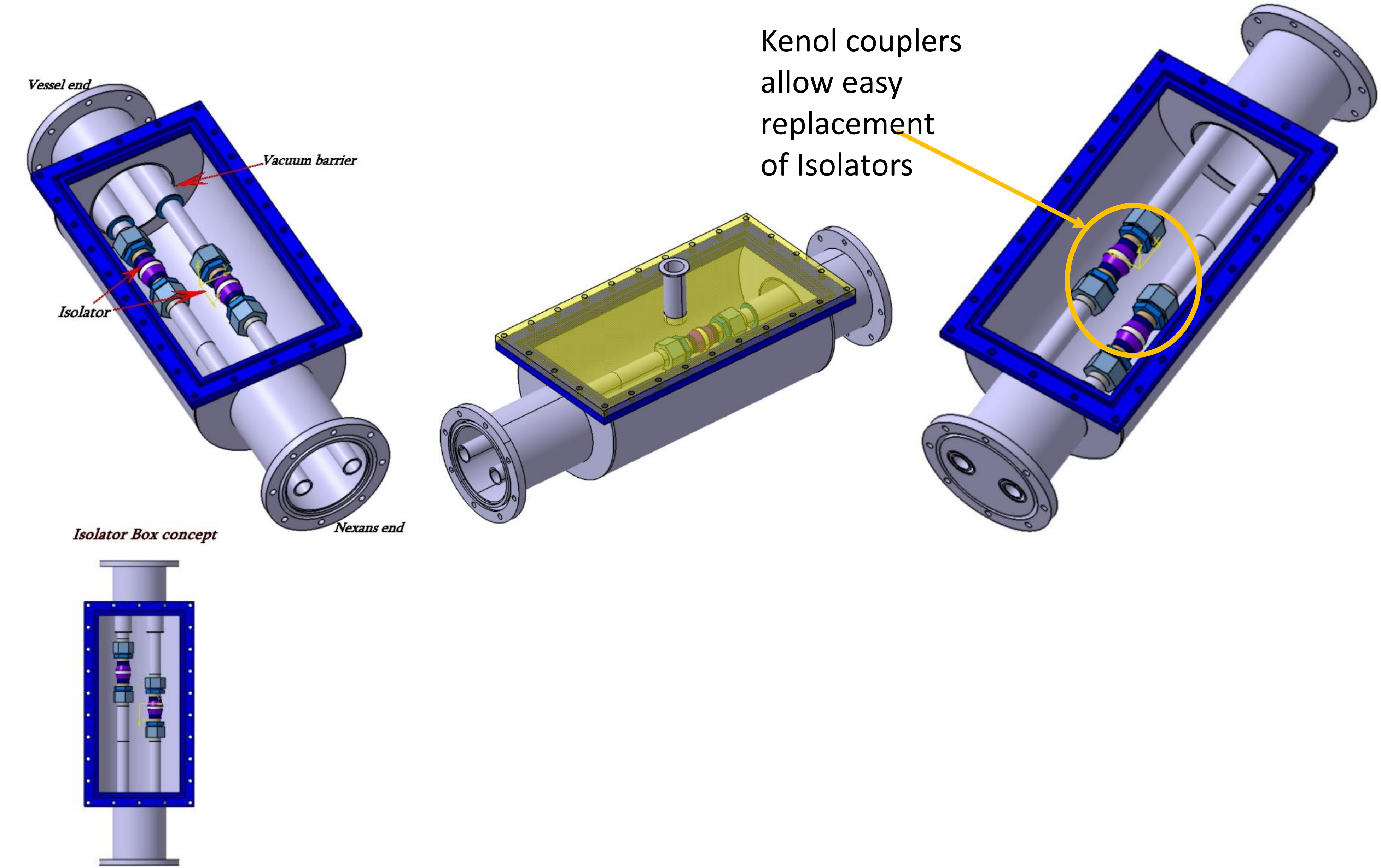


Figure 16 ECDS: Isolator boxes concept

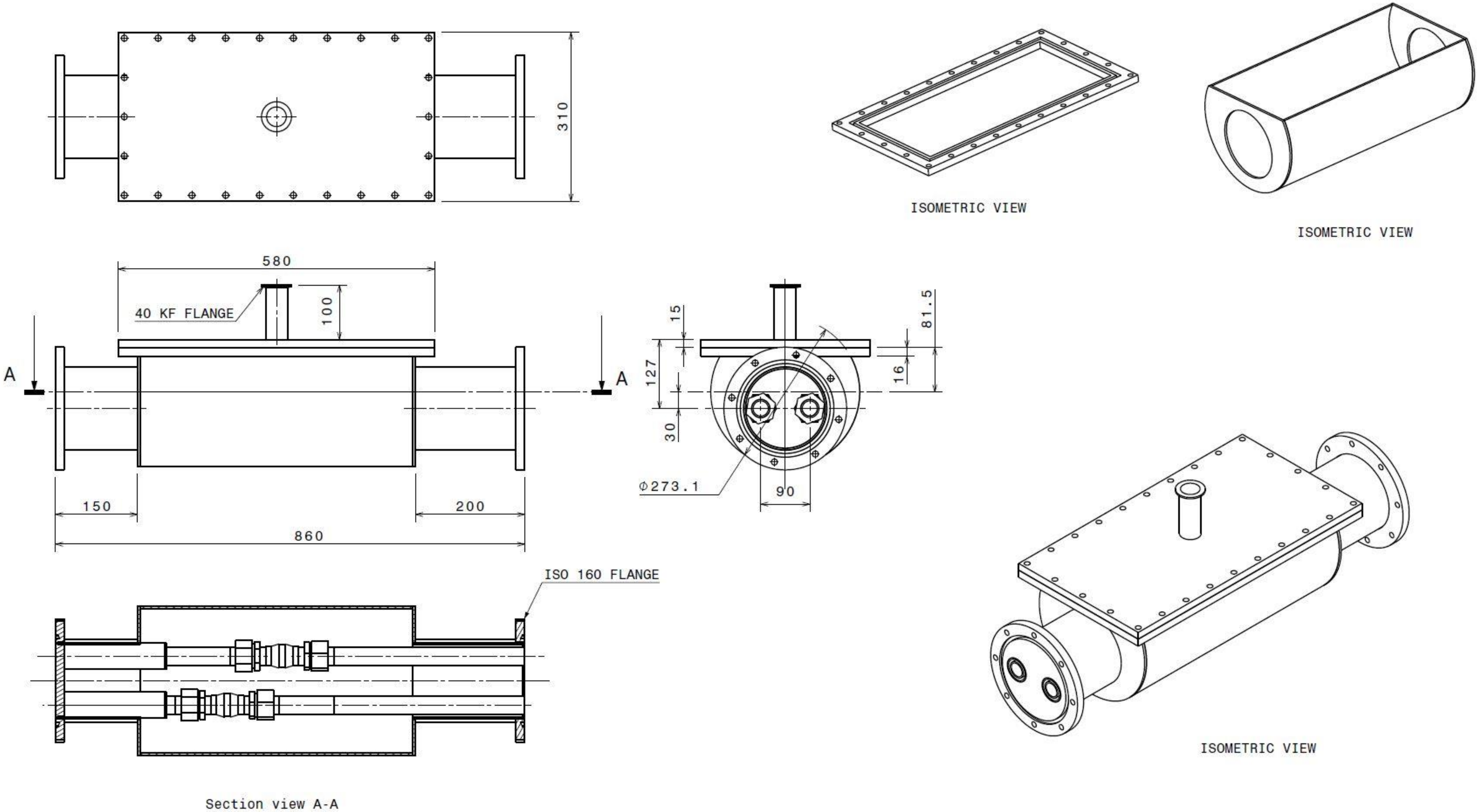


Figure 17 ECDS: Isolator box drawing

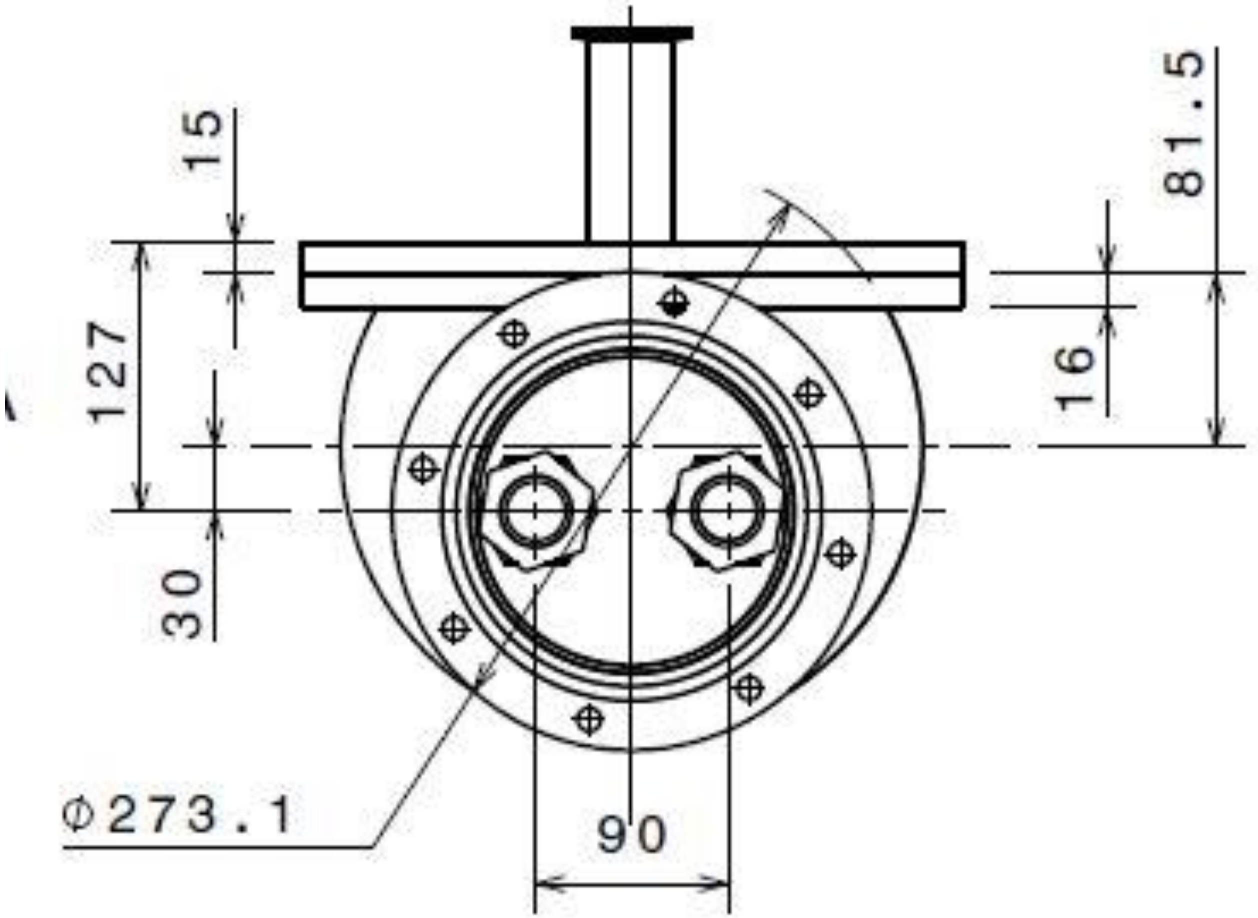


Figure 18 ECDS: Isolator box flange details

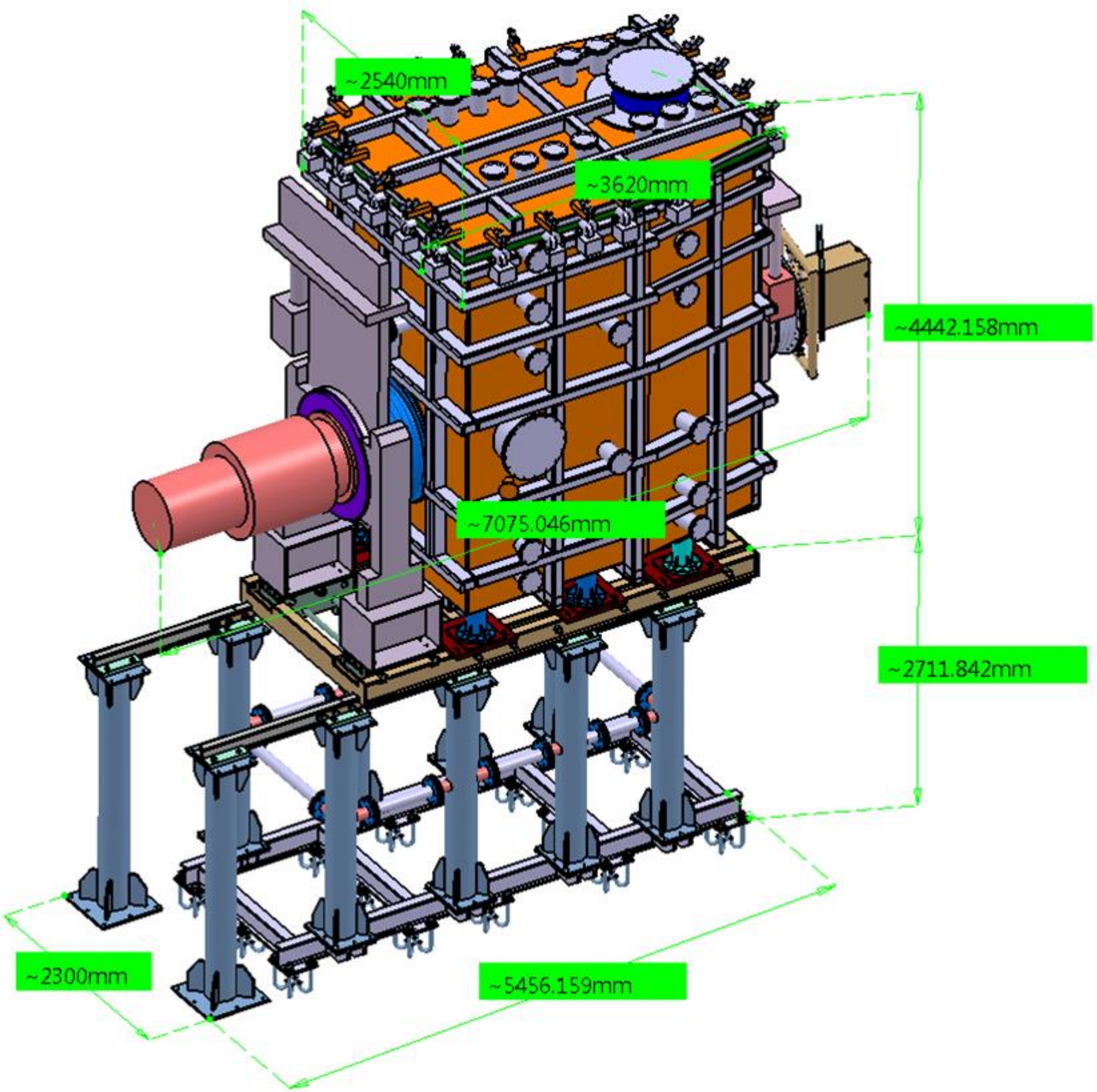


Figure 19 NBI vessel and supports (SST-1 hall) dimensions