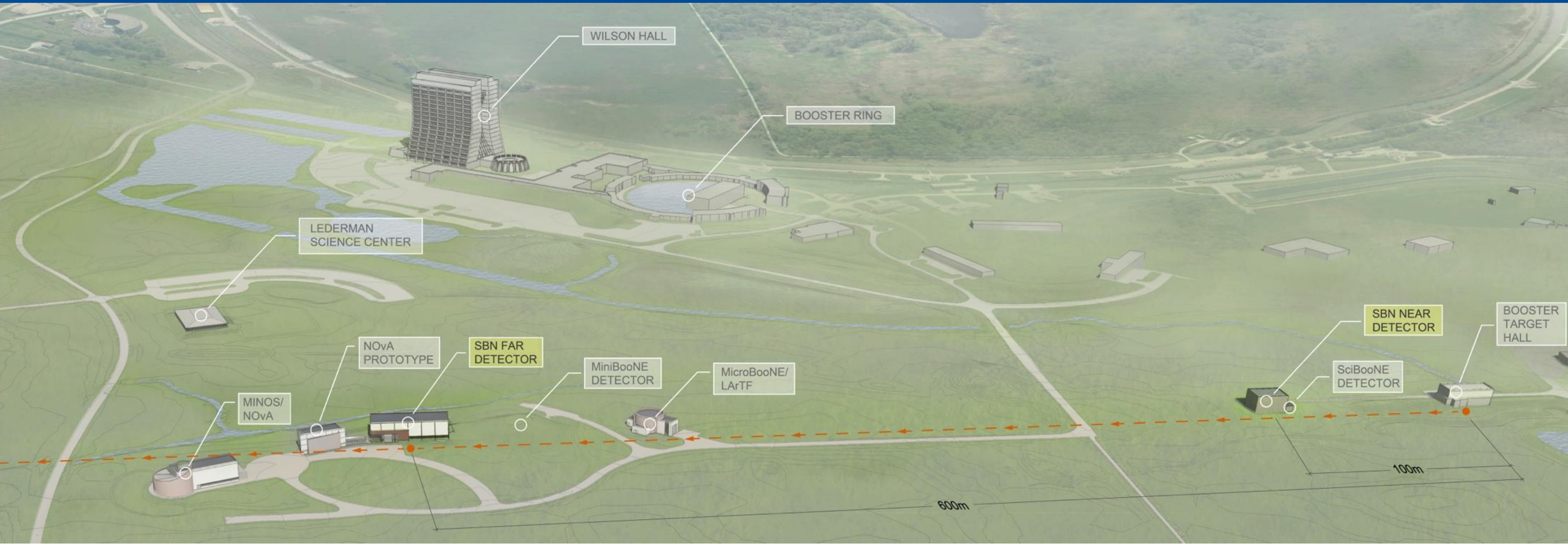

Requirements for SBN Cryogenics

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Director’s Progress Review of SBN

15-17 December 2015

Outline

- Scope of Cryogenic Systems for ND and FD
- Reviewing Requirements for ND and FD
- Overview of Process Flow Diagrams (PFD) for Both Experiments
- List of References
- Conclusions

Scope of Each Cryogenic System – SBND & SBN-FD

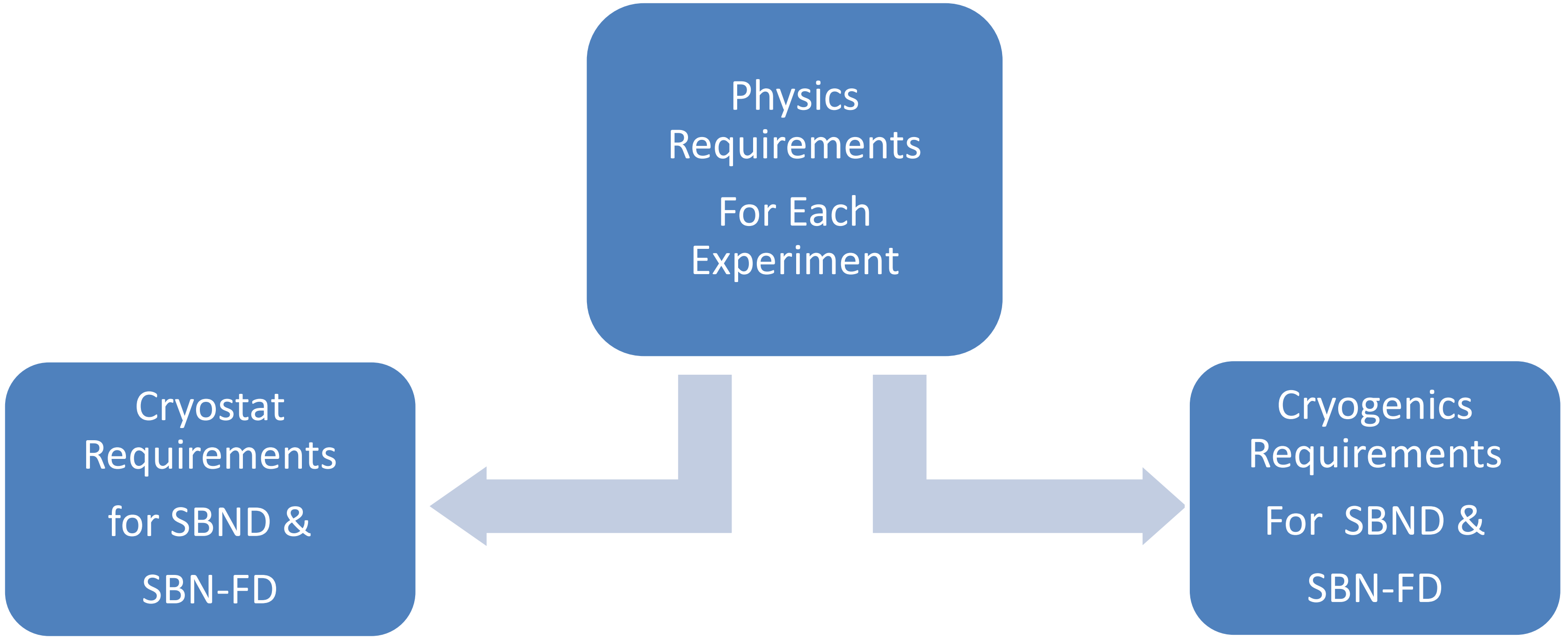
The scope of the cryogenics system includes all sub-systems necessary to receive, transfer, store and purify the LAr

Include systems for:

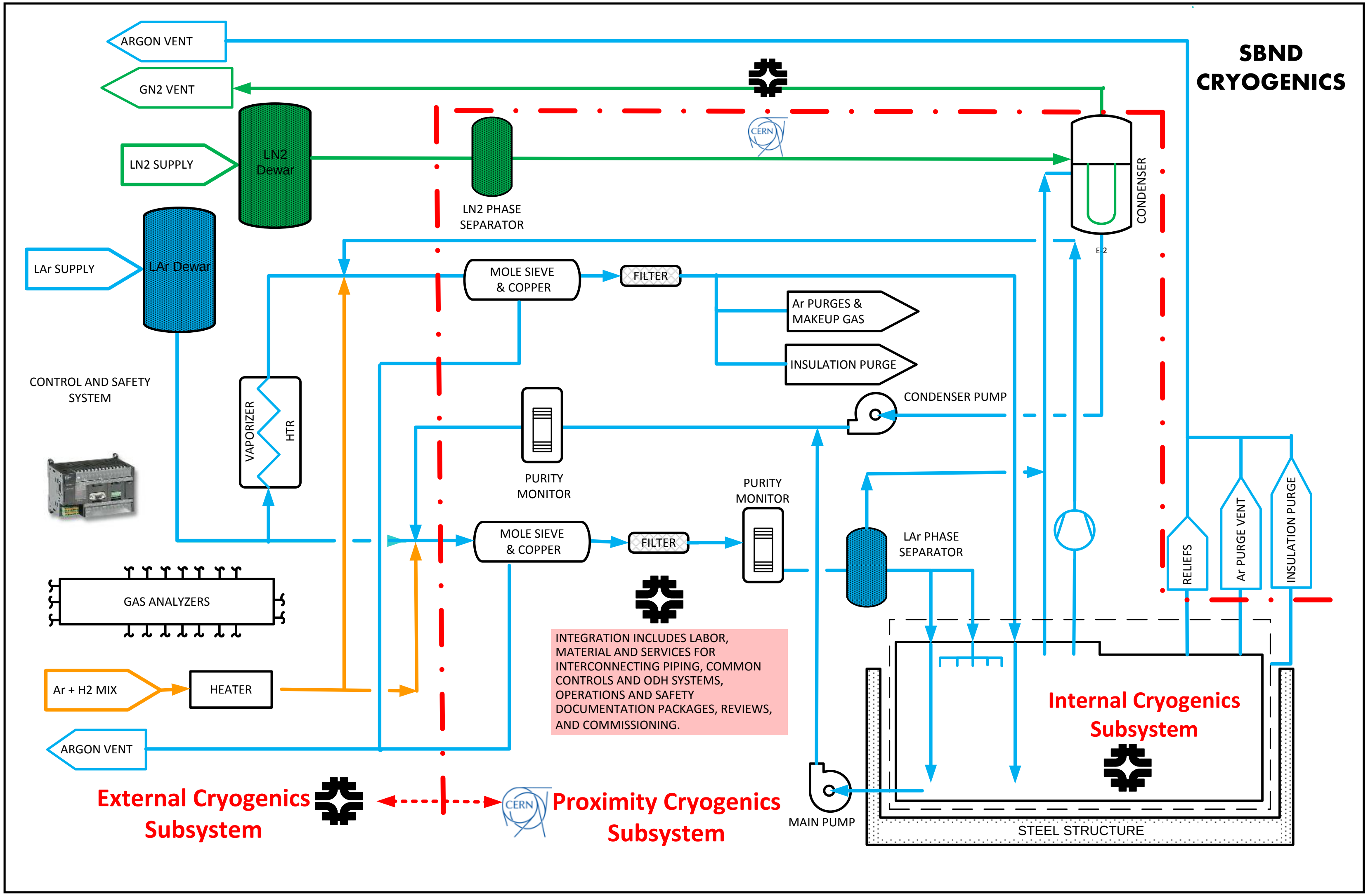
- Receipt of LAr and LN2
- LAr acceptance testing
- LAr transport piping to cryostat
- GAr recovery to re-condensing and filtration to LAr
- LAr recirculation and purification

- Requirements for SBND and SBN-FD cryogenics flow down from physics requirements and requirements for the cryostat and TPC.

- Scope and design of Cryogenics/Cryostats was identified and reviewed during Oct 2015 Technical Meeting at CERN.



SBND Process Flow Diagram and Subsystem Definitions



Requirements for **SBND** Cryogenics – TPC and Cryostat

Requirements from Cryostat	Value
Type of structure	Membrane cryostat (5% ullage at <100K) -> 2-3% ullage per most recent discussion)
Membrane material	SS 304/304L, 316/316L or equivalent.
Fluid	Liquid Argon (LAr)
Outside reinforcement (Support structure)	Self standing steel enclosure. Might include embedded heaters to prevent steel from freezing (Floor + Sides)
Minimum inner dimensions cryostat	5,202 mm (Transv) x 7,027 mm (Para) x 5,423 mm (H) * (flat plate to flat plate)
TPC size (with field cage and frame)	Width: 4,312 mm (Transvers to beam) Length: 2 x 2,656 = 5,312 mm (Parallel to beam) Height: 4,294 mm
Depth of LAr above TPC	400 mm (Above the CPA frame)
Minimum depth of liquid argon	5,164 mm (From the floor)
Membrane leak tightness	1E-6 mbar*l/sec
Maximum static heat leak	15 W/m^2 (Sides/Floor) 20 W/m^2 (Roof)

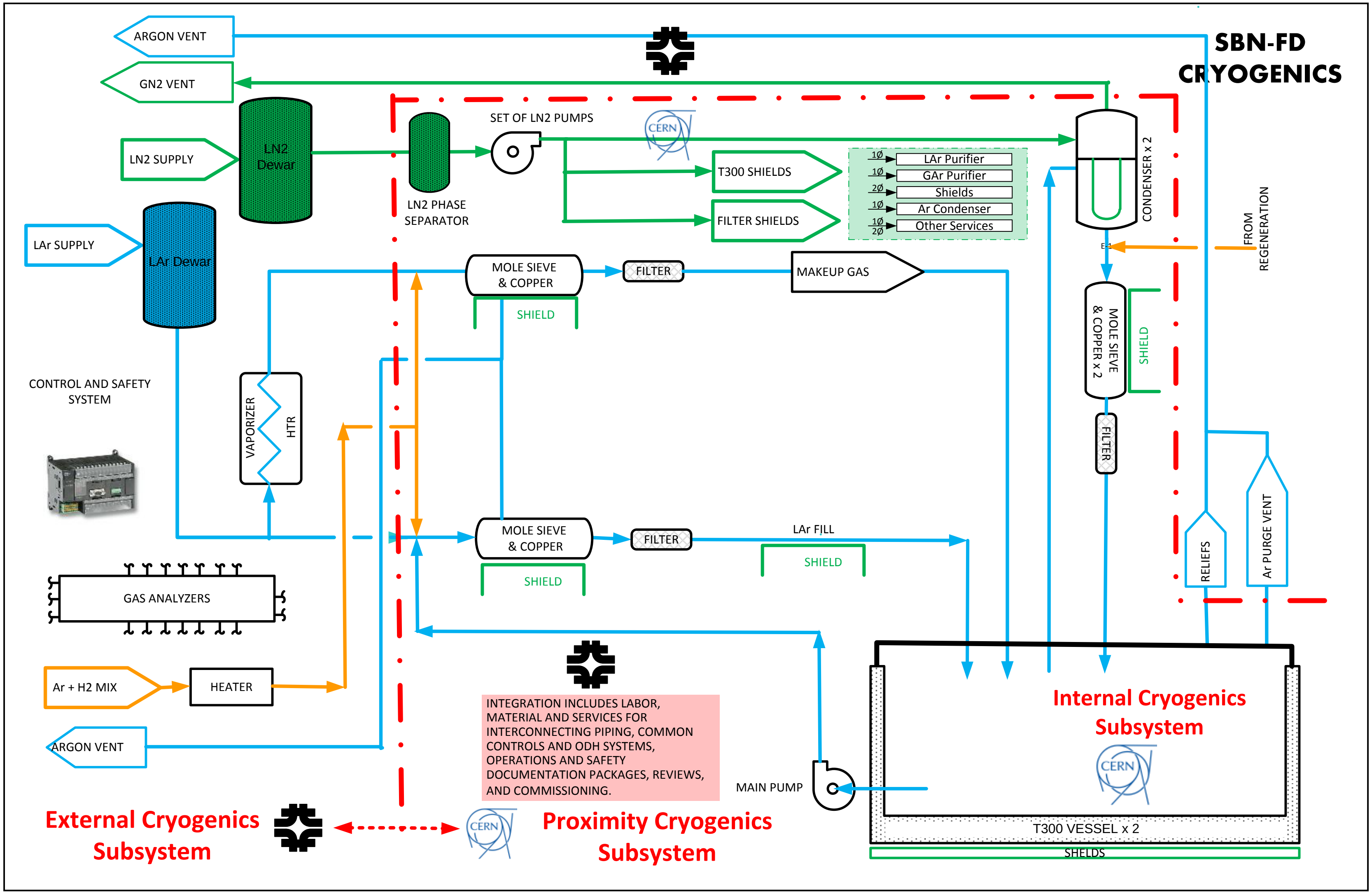
Requirements for **SBND** Cryogenics - Cryogenics

Requirements for Cryogenics	Rationale
Include systems for: • receipt of LAr and LN2 • LAr acceptance • LAr transport to cryostat • GAr recovery to LAr • LAr recirculation • Continuous argon purification	The scope of the cryogenics system should include all sub-systems necessary to receive, transfer, store and purify the LAr
Verifiable contamination levels for LAr delivery	O_2 < 1 ppm, H_2O < 1 ppm, N_2 < 2 ppm (to coincide with T600)
Cooldown rate	The detector cool-down rate shall be chosen to ensure that temperature induced differential stresses in the detector do not exceed the yield stress of the detector components
LAr recirculation rate	The system shall allow recirculation and purification of the liquid argon inventory to achieve the needed LAr purity to meet the scientific requirements
Cryogenic System Noise Control	The cryogenics system shall be designed so as not to introduce unwanted noise into the electronics
Piston-Purge technique	The cryostat and cryogenic systems shall be designed for using the piston-purge technique (introducing heavy gas at the bottom and taking out exhaust from the top) for removing initial electronegative impurities
LAr flow speeds	The liquid argon shall have local flow speeds low enough to prevent distortion of the electron drift trajectories

Requirements for **SBND** Cryogenics - Cryogenics

Required Parameter for Cryogenics	Value
LAr purity in cryostat	3 ms electron lifetime (100 ppt O2 equivalent)
Nitrogen contamination	Less than 2 ppm (to coincide with T600)
Design Pressure	345 mbarg (~5 psig)
Operating gas pressure	70 mbar (~1 psig) with +/- 5% (~0.05 psig)
GAr Piston purge rate of rise	1.2 m/hr
Membrane cool-down rate	From manufacturer (most likely < 10-15 K/hr)
TPCs cool-down rate	< 40 K/hr < 10 K/m (vertically)
Mechanical load on TPC	The LAr or the gas jet pressure shall not apply a mechanical load to the TPC greater than 200 Pascal
Nominal LAr purification flow rate (filling/ops)	1 volume change/day 7.9 m^3/hr = 35 gpm. Less circulation flow is allowed , e.g. 10 gpm, is rationale is verified. Similar to 1 change per 8 days for T600
All surfaces in the ullage during operations	< 100 K
Convective currents inside cryostat	< 10 cm/s
GAr purge within insulation (From LBNF)	1 volume change/day of the open space between insulation panels
Condenser cooling power	Based on fill with LAr (~25 kW)
Grounding and noise requirement	Electrical isolation from cryostat. Approval by SBND committee supervising detector and building grounding

SBN FD Process Flow Diagram and Subsystem Definitions



Requirements for **SBN FD** Cryogenics – TPC and Cryostat

Requirements from Cryostat	Value
Type of structure	Pressure vessel cryostat (**2**% ullage)
LAr containers material	Aluminum EN 6082 T6.
Fluid	Liquid Argon (LAr)
Outside reinforcement (Support structure)	SS vessel with passive insulation (GTT) and active cooling with LN2
Minimum inner dimensions cryostat	**3600** mm (Transv) x **19600** mm (Para) x **3900** mm (H) (-0 mm +10mm for all dimensions)
TPC size (with field cage and frame)	Width: **3543.5** mm (Transvers to beam) Length: **19538** mm (Parallel to beam) Height: **3805.5** mm
Depth of LAr above TPC	**207.5** mm (Above the race-tracks)
Minimum depth of liquid argon	**3783** mm (From the floor)
Maximum static heat leak	**<10** W/m^2 (Sides/Floor) **10** W/m^2 (Roof)

Requirements for **SBN FD** Cryogenics - Cryogenics

Requirements for Cryogenics	Rationale
Include systems for: • receipt of LAr and LN2 • LAr acceptance • LAr transport to cryostat • GAr recovery to LAr • LAr recirculation • Continuous purification	The scope of the cryogenics system should include all sub-systems necessary to receive, transfer, store and purify the LAr
Verifiable contamination levels for LAr delivery	O_2 < 1 ppm, H_2O < 1 ppm, N_2 < 2 ppm
Cooldown rate	≈ 2 K/hr
LAr recirculation rate	≈2 m^3/hr/T300 module (one volume / week)
Cryogenic System Noise Control	The cryogenics system shall be designed so as not to introduce unwanted noise into the electronics
Purification Technique	Pump down to vacuum and fill with purified LAr
LAr flow speeds	< 20 cm / sec

Requirements for **SBN FD** Cryogenics - Cryogenics

Required Parameter for Cryogenics	Value
LAr purity in cryostat	**15** ms electron lifetime (to replicate Icarus performance)
Nitrogen contamination	Less than 2 ppm
Design Pressure	**350** mbarg (~**5** psig)
Operating gas pressure	**150** mbar (~**2** psig) with +/- 5% (~0.1 psig)
TPCs max gradients	< **70** K < **50** K (vertically)
Mechanical load on TPC	no load on the TPC
Nominal LAr purification flow rate (filling/ops)	1 volume change/week **2** m^3/hr/T300 module ≈ **9** gpm.
All surfaces in the ullage during operations	≈ 87 K except for the cables inside the chimneys
Convective currents inside cryostat	< **20** cm/s
GAr purge within insulation (From LBNF)	**0.5** volume change/day of the open space between insulation panels
Condenser cooling power	~**2** kW / gas recirculation unit
Grounding and noise requirement	Electrical isolation from cryostat. Approval by SBN-FD committee supervising detector and building grounding

List of Document for Reviewers (For Cryogenic Infrastructure)

1. General (Program-related):

 ○ **SBN DocDB 269** A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam
 ○ **SBN DocDB 752** Report from SBN Assessment at CERN Oct 2015 (https://indico.cern.ch/event/446818)
 ○ **SBN DocDB 648** [CERN EDMS 1510390] SBN - SBND Cryogenics - WorkPackage Agreement (CERN-Fermilab)
 ○ **SBN DocDB 647** [CERN EDMS 1549951] SBN - T600 Cryogenics - WorkPackage Agreement (CERN-Fermilab)
 ○ **SBN DocDB 651** [CERN EDMS 1554082] Design, Fabrication, Installation and Testing of the LBNF/DUNE and SBND Membrane Cryostats

2. Cost and Schedule:

 ○ **SBN DocDB 737** [BOE] ND Cryogenics Preliminary Integration
 ○ **SBN DocDB 738** [BOE] ND Cryogenics Final Design
 ○ **SBN DocDB 739** [BOE] ND Cryogenics Construction
 ○ **SBN DocDB 740** [BOE] ND Cryogenics Installation
 ○ **SBN DocDB 736** [BOE] FD Cryogenics Preliminary Integration
 ○ **SBN DocDB 725** [BOE] FD Cryogenics Final Design
 ○ **SBN DocDB 724** [BOE] FD Cryogenics Construction
 ○ **SBN DocDB 735** [BOE] FD Cryogenics Installation
 ○ **SBN DocDB 753** Cryogenics Cost and Schedule

3. Safety:

 ○ **SBN DocDB 377** Preliminary Discussion of ODH setup for Short Baseline Near Detector and Far Detector buildings

List of Document for Reviewers (For Cryogenic Infrastructure)

4. Design/Engineering/Technical:

- **SBN DocDB 782** SBND P&ID
- **SBN DocDB 783** SBN-FD P&ID
- **SBN DocDB 780** Functional Requirements Specification for SBND Control System
- **SBN DocDB 769** Functional Requirements Specification for SBN-FD Control System
- **SBN DocDB 762** SBND Cryostat and Cryogenic Parameters Spreadsheet

Conclusions

- The Scope and proposed designs for the SBND and SBN-FD have been presented.
- PFD's have been developed (as well as preliminary P&ID's) which outline both the proposed strategies for cryogenics and the deliverables (external, proximity and internal cryogenics).
- Science requirements including electron lifetime and LAr properties have been defined in each detector which have led to design choices shown in the PFD and Engineering requirement tables.

Requirements for **SBND** Cryogenics - Physics

Requirements from Physics	Value
LAr purity in cryostat	3 ms electron lifetime (100 ppt O2 equivalent)
Nitrogen contamination	Less than 2 ppm
Design Pressure	345 mbarg (~5 psig)
Operating gas pressure	70 mbar (~1 psig) with +/- 5% (~0.05 psig)
Membrane cool-down rate	From manufacturer (most likely < 10-15 K/hr)
TPCs cool-down rate	< 40 K/hr < 10 K/m (vertically)
Lifetime	10 years (5 years of run + 5 years potential upgrade)
Thermal cycles	20 cool down and total warm-up

Requirements for **SBN FD** Cryogenics - Physics

Requirements from Physics	Value
LAr purity in cryostat	**>3** ms electron lifetime (**<100** ppt O2 equivalent)
Nitrogen contamination	Less than **2** ppm
Max Design Pressure	**350** mbarg (~**5** psig)
Operating gas pressure	**150** mbar (~**2** psig) with +/- 5% (~0.1 psig)
Cool-down rate	≈ 2 K/hr (5 days to cool to LAr temperature)
TPCs max gradients	< **70** K < **50** K (vertically)
Lifetime	10 years (5 years of run + 5 years potential upgrade)
Thermal cycles	20 cool down and total warm-up