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Neutrino Cryogenics Requirements Meeting Overall Summary of Our Discussions

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Neutrino Short Baseline Meeting

26 September 2014

Neutrino Cryogenics Requirements Meeting

- Our meeting began with Day 1 presentations reviewing the Cryostat and Cryogenic Systems work of the past, the now and the proposed future.

- We found the talks to be a good review of much of the field of LAr cryogenics and stimulated discussions that are indicative of a Collaborative effort headed in the right direction and taking a solid first step.

- Summary of Talks
- 35 ton Cryostat and Cryogenic Systems (including relation to LBNE)
- MicroBooNe Cryostat and Cryogenic Systems
- LAr1ND Cryostat and Cryogenic Systems Proposal
- 7 Years of Cryogenic R&D Experience at LHEP Bern
- The ICARUS Experience on LAr Cryogenics and Purification

Our Day 1 discussions can be summarized in a series of questions and comments as follows

Topic #1: Temperature Distribution Requirement

Maximum temperature gradients allowed in the sensitive volume (condition when steady state and filled)

- What is this maximum allowable temperature gradient?
- What will be the stratification in a large argon volume with a low heat input
- Is argon circulation (for purification purposes) breaking this stratification
- Should “ICARUS” wall cooling be implemented to break this stratification (has research been done?)

Discussion Points on Topic #1

- Steady State: 1 K temperature difference between any two points in the cryostat (both from ICARUS and LBNE).
- LBNE simulations show that 0.1 K is achievable (with 5 W/m^2 and all loads inside).
- BN: Overall transient stability for Temp/Press from control strategy.
- **No action needed forward is needed on this topic because the 1K requirement** is already achievable.
- Transient comment: TPC cool down gradient:
  - ICARUS: 10-15 K/m
  - BNL: 40 K/m

Topic #2: Argon Filtration

Which system to be foreseen for the argon purification?

- Barry asks: Does the choice of filtration material provide a key to long electron lifetime?
  - Active copper with “in place regeneration”
    - More flexibility since on-site regeneration
    - Fermilab approach in 35 ton, LAPD, MicroBooNe, Proposed LAr1ND initially
  - Commercial Hydrosorb/Oxisorb system, regenerated by the manufacturer.
    - What will be the interval between generations in cooling / filling sequence, and in normal operation
    - ICARUS and BERN approach

Conversation on Topic #2

- Report from ICARUS: Hydrosorb/Oxisorb → 20 ms in test chamber, 15 ms in T600. Copper 3 ms in test chamber.
- Report from FNAL: 6 ms lifetime in LAPD and 3 ms lifetime in 35 ton Phase 1 with Copper

- ***Which Oxygen removal system should we use?***

- Chromium may be an issue from the ES&H standpoint at FNAL. Need to discuss with FNAL Safety experts.

- What is the minimum lifetime requirement?
  - Comment from Claudio Montanari: 1-2 times the drift time.
- MN: What is the difference between Oxisorb and Copper??
  - Handling of chromium (byproduct of Oxysorb)
- PJW: How many times do they have to be regenerated?
  - CM: never regenerated the Oxysorb (only before the new run).
- **MN: make a study on capabilities of both.**
  - Is there any limit on size?
  - Is it possible to regenerate the Oxysorb in the US?
  - Oxysorb now handled by Air Liquide
  - What is the cost for using Oxysorb VS copper?

Topic #3: Ullage design and Purity Issues

- What should be foreseen for the cryostat ullage design? Which arrangement would benefit a request for increased purity in our designs?
  - Internal “warm oullage”
    - Advantage: “easy” feed throughs
    - Disadvantage: outgassing
  - Internal “cold ullage”
    - Advantage: diminish the outgassing of the cables and cryostat walls;
    - Disadvantage: What is the effect of “cooling jet” on purification process; which feed through shall be used?
  - External warm ullage:
    - Advantage: no outgassing in cryostat volume;
    - Disadvantage: cold feed throughs, second argon volume to be placed in neighbourhood of cryostat, how to cool the cryostat volume?

Conversation on Topic #3

- Original suggestion for LAr1ND included an external expansion can for separating the liquid volume from the gas ullage. Present idea models the 35 ton idea with an added idea to cool the ullage to 100 K or less.

- Warm feed throughs in expansion volume, if penetrations are insulated. → Longer cables.

- BN: LBN(E) has put money aside to study the 100 K solution. We can assist with that study.

- BN: we could (if $ and time available) implement both internal and external ullage in a detector (LAr1ND?). Remember that an external ullage takes real estate, which is expensive underground and may not be a viable option for underground cavern in LBNF future.

- **Studies needed.**

Topic #4: Location of Liquid Pumps and Bottom Connections

- In recent operation of 35 ton Phase I there was a failure to an internal pump which has led LBNE to create a Value Engineering task asking if a large detector such as that proposed by LBNF should have its pumps located externally to the vessel rather than proposed internal.

- This would assist with maintenance issues and vibration effects.

- Liquid connection at the bottom of the cryostat seems to be necessary (liquid purification, emptying of cryostat,…) but how can such a connection be safely implemented? Oxygen deficiency concerns if a line break at bottom of vessel.

Discussion: **Study the feasibility using engineering analysis.**

- Question arose: Do we need to remove the LAr quickly?
- Answer from BN/DM: Not required in LBN(E).
- MN: I think it is necessary to have the possibility to remove LAr quickly from cryostat smaller than LBN.

Topic #5: Choice of Condenser Design

- What is the best re-condensing principle (stability in regulation):

- Cooling liquid evaporating at the internal of heat exchanger and condensing at the outside;

- Cooling liquid evaporating at the outside of the heat exchanger and condensing at the inside

- Discussion: FNAL and CERN engineers need to evaluate and decide which solution is best. Both are viable solutions.

Topic #6: Uniform Control System Strategy

- How to define the correct control system needed for such an installation?
- Operator friendly;
- “upgradable” (long term availability);
- One operating system for the complete cryogenic installation

Discussion on Controls

- Discussions Recognized the need to approach Controls from the First Step of Collaborative efforts.
- Upgradable and Operator friendly.
- **Guidelines from Fermilab for SBN-ND/FD since detectors at FNAL.**
- BN: Not just about hardware, we have to develop a control strategy also.
- JB: at CERN controls resources are integrated in the cryogenics group. They only do their specific work (cryogenic in this case). Makes sense to develop them at Fermilab, since the detectors will be there.

Topic #7: Purity Measurement/Electron Lifetime

- How to measure long life-time purities?

- Are the current monitors still “usable”
- Should the cryostats be equipped with internal monitors?

- Current purity monitors are limited in sensitivity and from an engineer’s viewpoint we feel the need to be able to actively measure the purity at parts per trillion levels since the field may be asking for higher requirements on lifetime on detectors.

- CM: it is possible to use laser to stimulate it and increase the sensitivity (reduced noise).
- FP: limit of the laser stimulated one is ~10 ms.
- Are we instrumenting the cryostats with purity monitors?

- **Action item: Scientists will look into the development of laser stimulated purity monitors.**

Topic #8: Purity Requirements vs. Hopeful Wishing

- Is it clear what is needed for the correct functioning of a neutrino detector (are we sure the input requirements are known?)
  - What should be the minimum lifetime the purification system has to be developed for?

On Day 2 David Montanari (FNAL) gave a talk with an attempt to begin outlining our work with an eye to prioritization.

The slides from that talk follow.

Current schedule

- The goal is to have the SBN-ND and SBN-FD ready for commissioning in the fall of 2017 and to take beam data in Apr 2018.
- Schedule for the cryogenic systems from the proposal submitted to the PAC in Jul 2014:

Milestone	Date
Cryogenic plant proposal submitted for peer review	Mar 2015
LAr1-ND technical proposal submitted for peer review	Mar 2015
Cryogenics procurement plans released and active	Sep 2015
Start cryogenic plant commissioning	Aug 2017
Start detectors cooling and commissioning	Nov 2017
Start data taking with beam	Apr 2018

In order to meet this schedule, we have to start now.

Goals

- We, as community, want to develop a **common strategy** to address LAr/LN2 cryogenics for SBN-ND/FD (short term), for LBN (long term) and other future generation detectors to come.

- We want to minimize the effort and design and fabricate a **standard system** that could be “enlarged” and adapted for future short/mid/long term needs.

- We want to design a **portable system** that could be fabricated and tested in one place and installed at destination in another.

- We want to **test all features** that might be relevant/of interest for present and future detectors: external LAr pumps, cold roof (< 100 K), external ullage concept, etc. and the possibility to **turn them on/off** to compare.

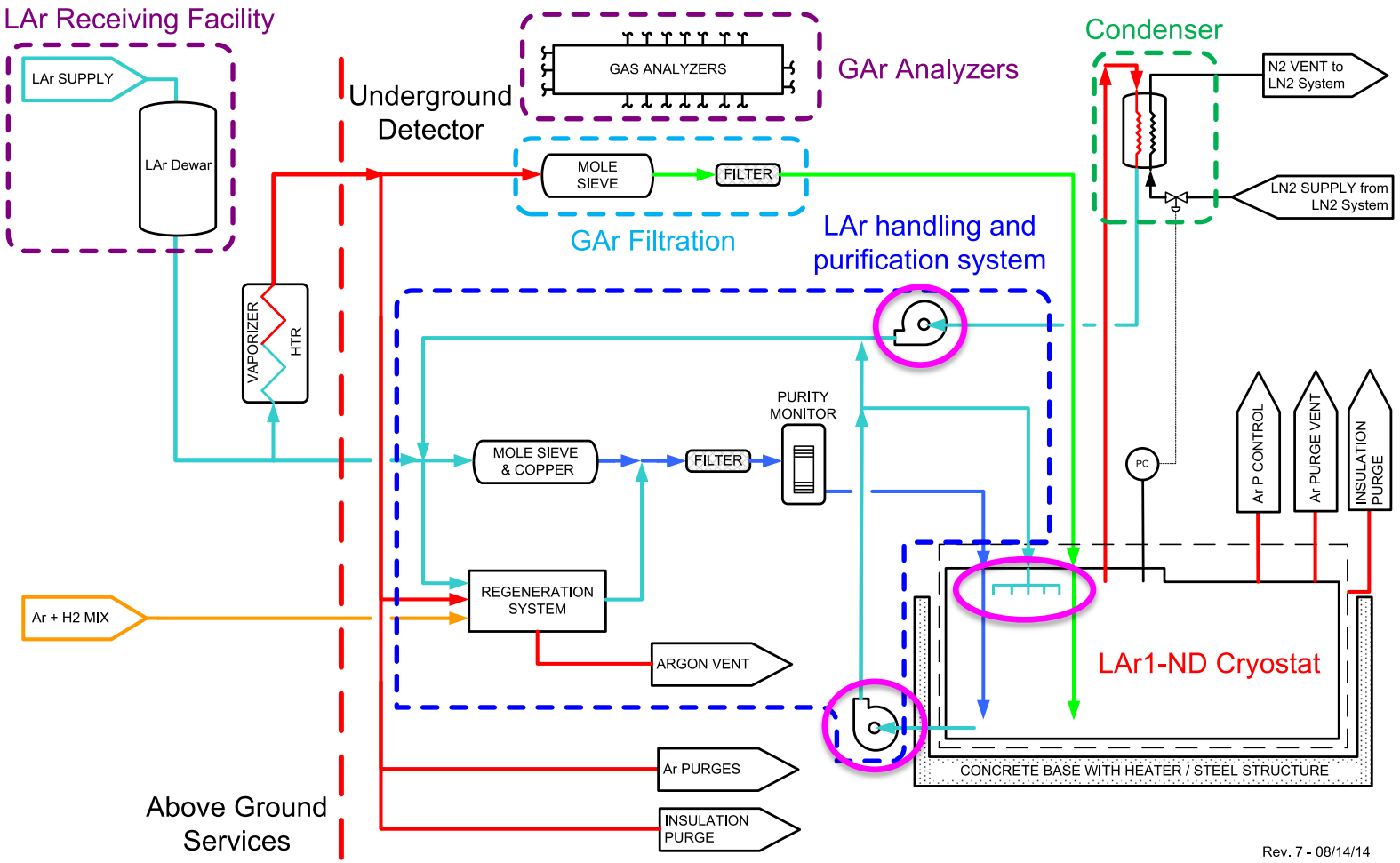
Outstanding issues – DRAFT Proposal of prioritization

- **Portability/Scalability** *(Base Idea)***:** studies on portability and how to design a portable/scalable system that can serve present and future generation detectors of any size.
- **Accessibility** *(In parallel with everything else):*
  - Ability to make modifications after run for 5 years.
- **Safety** of existing components of SBN-FD to be relocated **at FNAL** *(In parallel with everything else).*
- **Process Controls** *(In parallel with everything else).*
- Studies on **LN2 system** design to be common (to the extent possible) to T600 (FD). Will be different than that of larger systems because of cost of LN2 refrigeration (Urgent).
- Studies on **cryostat ullage** (internal, external, cold, warm) (Urgent).
- Studies on how to measure **long lifetime purity**. (Urgent).
- Studies on how to minimize **noise** in the vicinity of the wires. It may also be coming from piping layout. (Less Urgent).
- **LAr Pump (Outside)** Less Urgent**.**
  - Need to see how to isolate the pump electrically and mechanically from the TPC to reduce issues with electronic noise and microphonics.

Engineering Design choices – DRAFT Proposal of prioritization

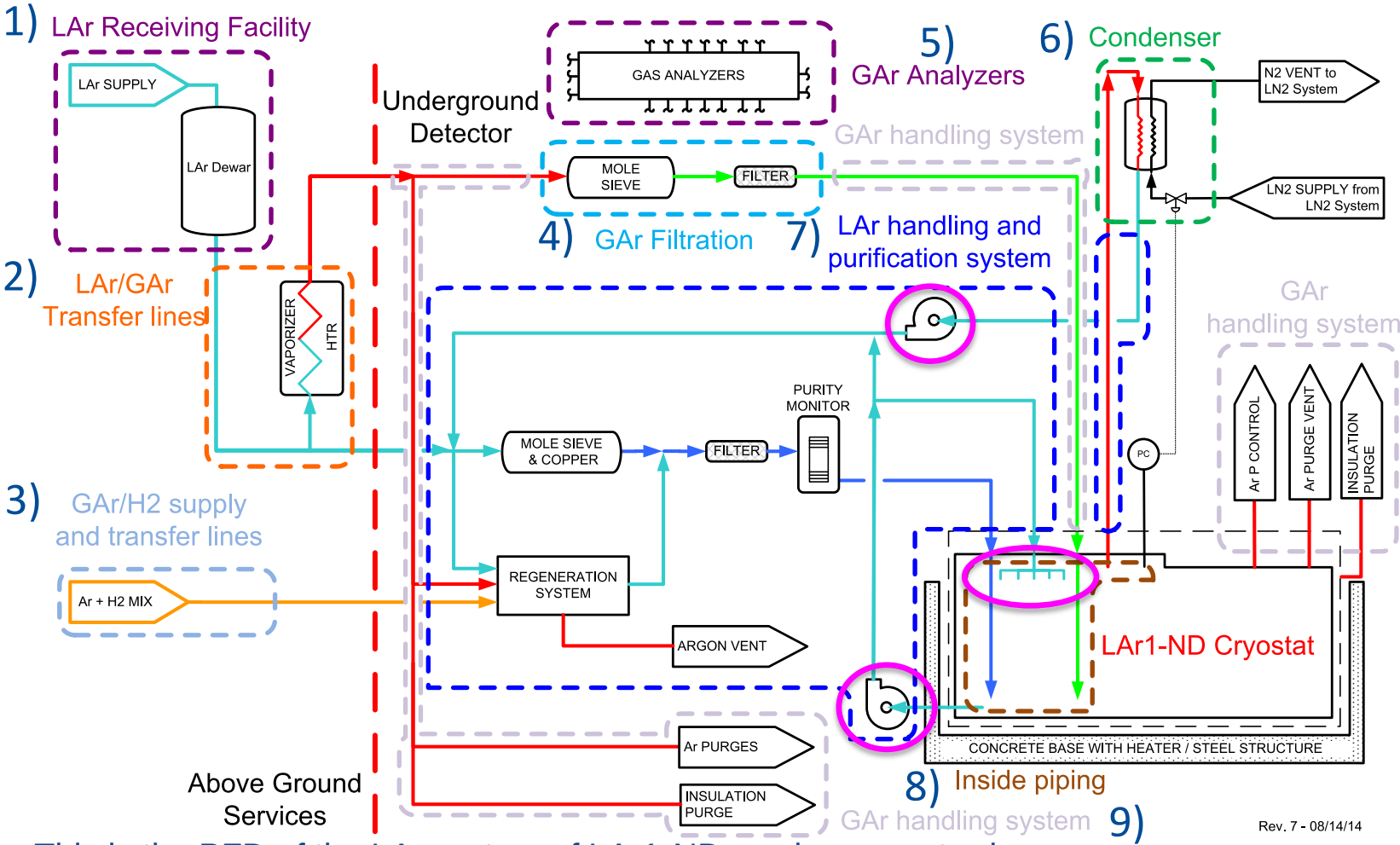
- Process controls strategy (Urgent).
- Which LAr condenser (Urgent) ??
  - Ar in tube and LN2 in shell
  - Ar in shell and LN2 in tube
- LAr filtration after condenser (Urgent) ??
  - Mixed with LAr from tank
  - Stand alone system
- Which interface with cryostat (Less Urgent) ??
  - Bayonet fittings.
  - Flanged connections.
  - Where is the boundary.
- Which LAr filtration system (Less Urgent) ??
  - Copper beds.
  - Oxysorb.

LAr1-ND PFD of LAr systems (as shown in Sept 24 talk)



- This is the PFD of the LAr system of LAr1-ND as shown yesterday.
- The one for SBN-FD has a **stand alone filtration for the LAr coming from the condenser**, instead of a connection to the main stream of LAr coming from the cryostat.

Categorizing the LAr1-ND PFD of LAr systems into 'Objects'



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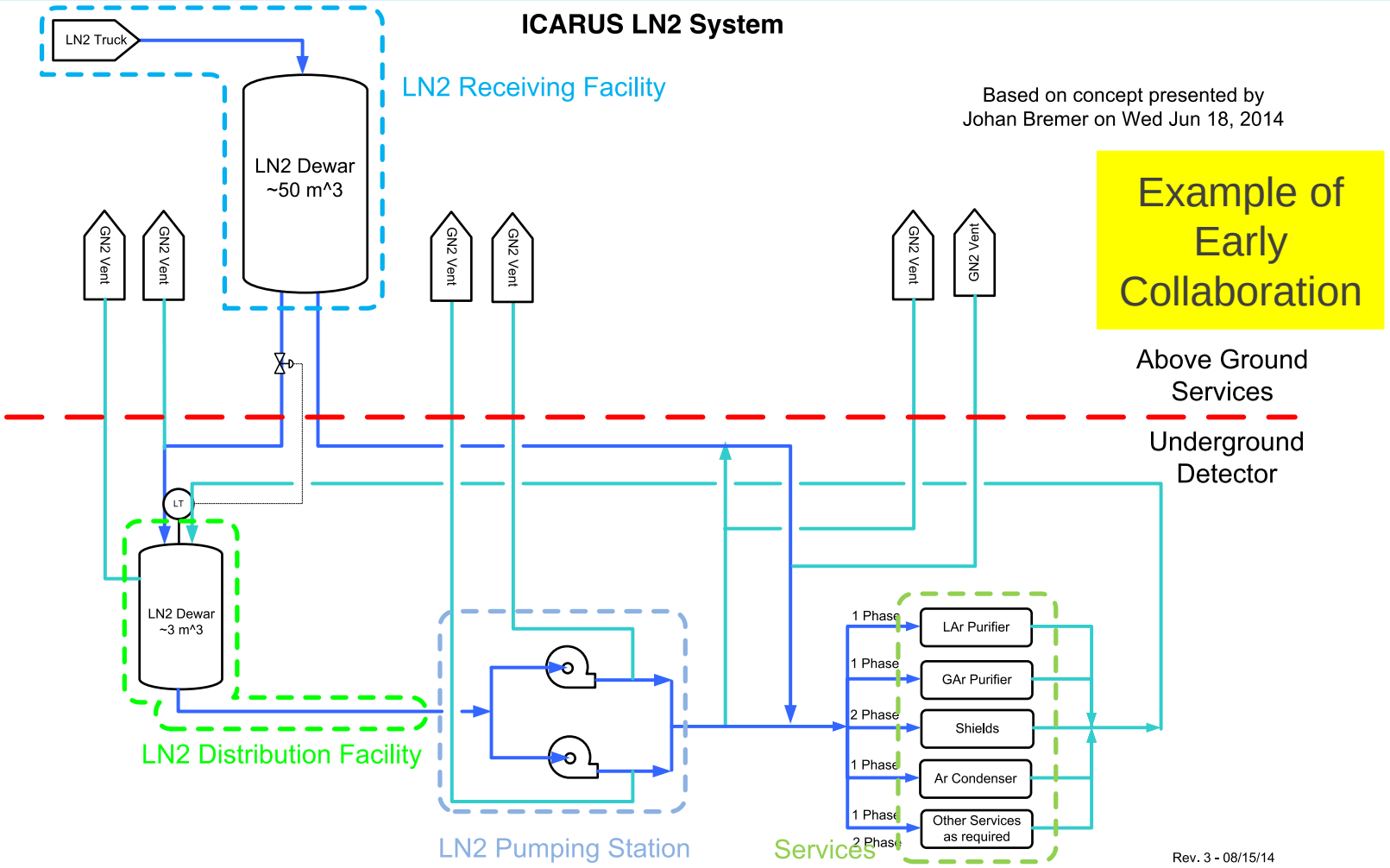
SBN-ND/FD LAr systems – DRAFT Proposal

#	Task Name	Service Type	Location	Responsible	Funds
1	LAr Receiving Facility	Cryo	AG	FNAL	FNAL
2	LAr/GAr Transfer Lines	Cryo/No Cryo	S	FNAL	FNAL
3	GAr/H2 Supply and Transfer Lines	Non Cryo	AG	FNAL	FNAL
4	GAr Filtration	Non Cryo	UG	CERN/FNAL	??
5	GAr Analyzers	Non Cryo	UG	CERN/FNAL	??
6	Condenser	Cryo	UG	CERN/FNAL	CERN
7	LAr handling and purification system	Cryo	UG	CERN/FNAL	CERN
8	Inside piping	Cryo/Non Cryo	C	CERN/FNAL	CERN
9	GAr handling system	Non Cryo	UG	CERN/FNAL	CERN

- Point n. 7 may include a stand alone LAr purification system for LAr from condenser (see FD).

- AG = Above Ground
- S = Shaft
- UG = Underground
- C = Inside Cryostat

SBN-ND/FD PFD of LN2 system (based on Johan B.)



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- The one for the **ND is identical**, but only has the last two “Services”.

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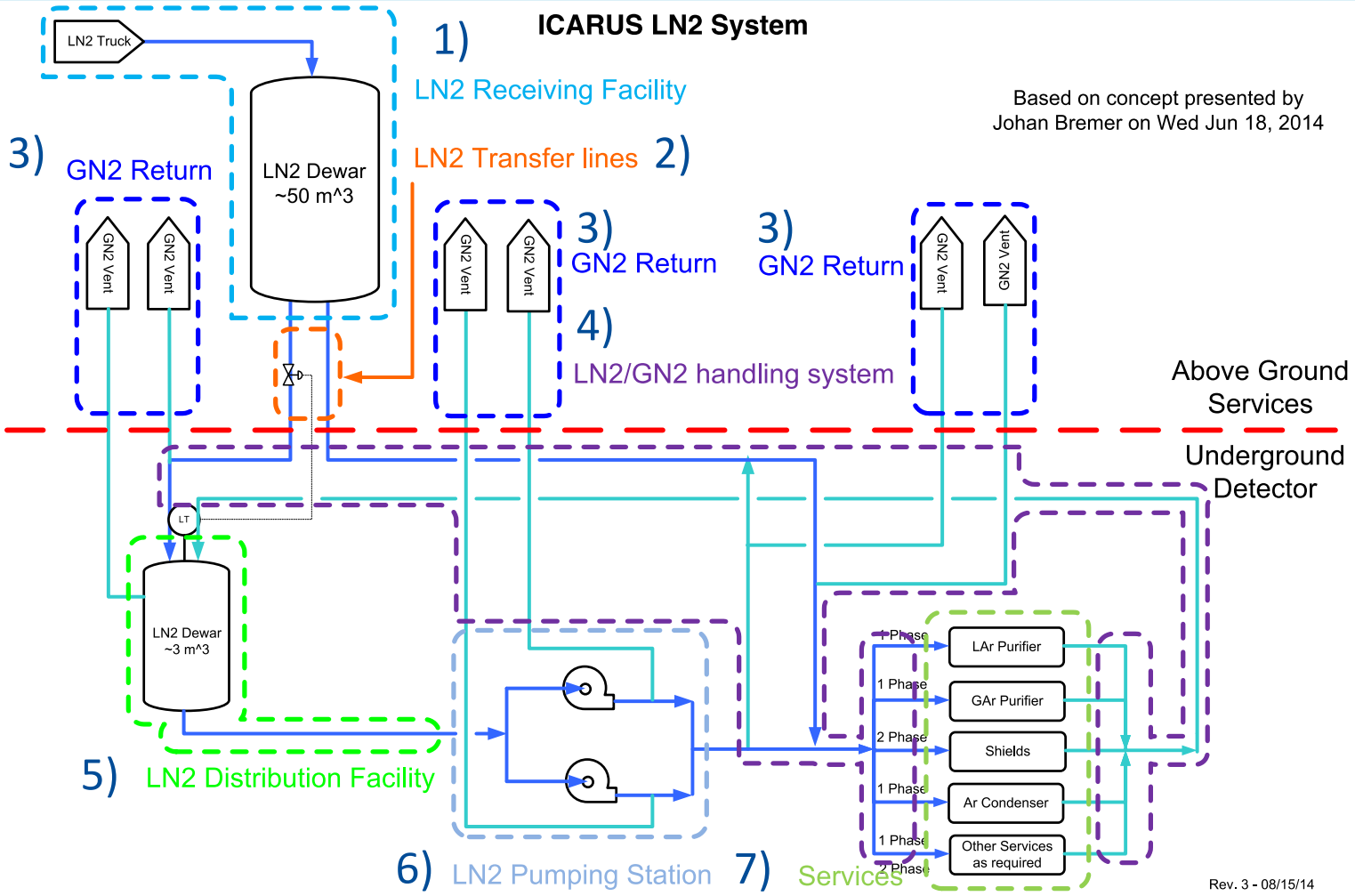

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1	LN2 Receiving Facility	Cryo	AG	FNAL	FNAL
2	LN2 Transfer Lines	Cryo	S	FNAL	FNAL
3	GN2 returns	Non Cryo	AG	CERN	CERN
4	LN2/GN2 handling system	Cryo/Non Cryo	UG	CERN	CERN
5	LN2 Distribution Facility	Cryo	UG	CERN	CERN
6	LN2 Pumping Station	Cryo	UG	CERN	CERN
7	Services	Cryo	UG	CERN/FNAL	CERN

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SBN-ND/FD Additional items – DRAFT Proposal

#	Task Name	Service Type	Responsible	Funds
1	Process Controls	Non Cryo	FNAL	FNAL
2	Design/Drafting	Non Cryo	FNAL/CERN	FNAL/CERN
3	Smart P&IDs	Cryo/Non Cryo	FNAL/CERN	FNAL/CERN
4	Safety aspects of cryogenic installation at Fermilab	Cryo	FNAL	FNAL

Concluding Remarks

- A two day meeting has led to good presentations and discussions concerning a Collaborative effort on issues related to Cryostats/Cryogenics in liquid argon detectors.

- This has been a good first step to going forward internationally in efforts for the SBN program as well as the future Long baseline program(s).

- A set of questions have been identified and openly discussed with the agreement that the Collaboration will move forward to answer these questions.

- A first pass prioritization plan for the SBN detectors has been presented.

- Final point: in order to meet the SBN milestone schedule, the cryogenics/cryostat design needs to start now. **LAr Cryogenic Groups are forming based at FNAL and CERN and will collaborate.** Statement to Community: Science requirements which inform the engineering must be finalized soon.