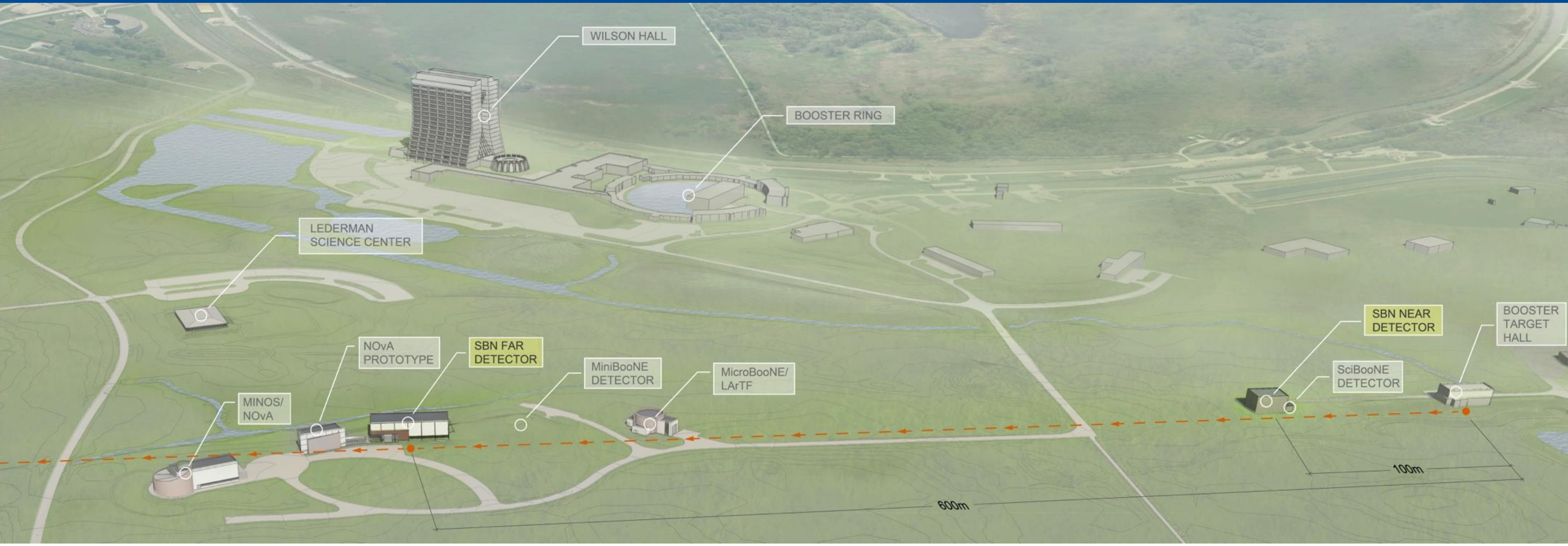
Fermilab U.S. DEPARTMENT OF ENERGY Office of Science




# SBND Installation and Integration

Joe Howell

Director's Progress Review of SBN

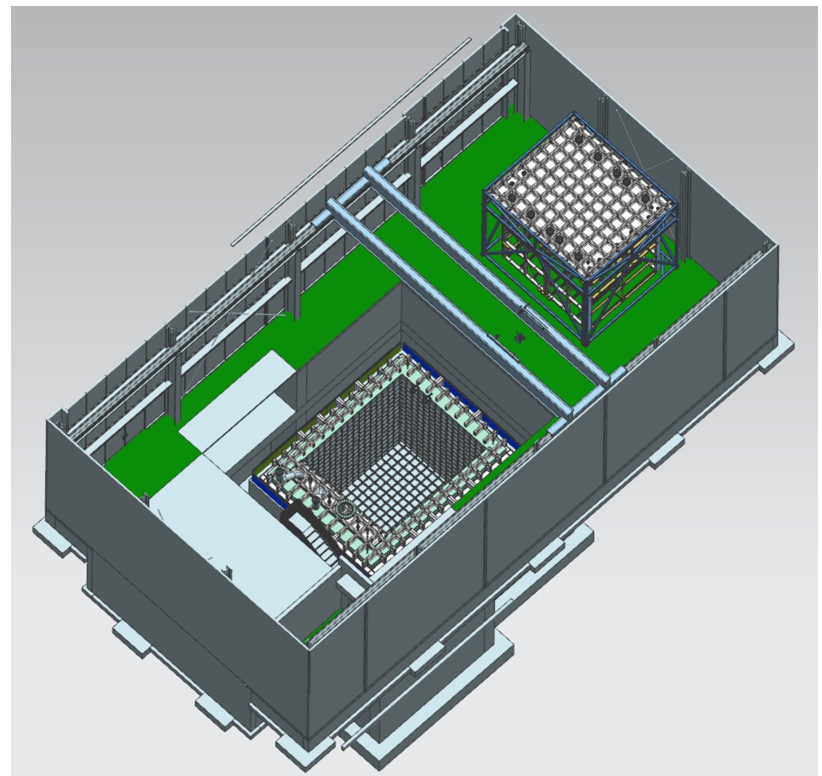
15-17 December 2015

# Outline

- System Overview
- Interfaces
- Resources
- Basis of Estimate (for DOE costs)
- Cost and Schedule Summary
- ES&H and QA (Environment, Safety & Health and Quality Assurance)
- Response to TPC technical review recommendations
- Status of design

# SBND installation and integration scope

The scope is the installation and integration of the TPC and Cosmic Ray Tagger at the Near Detector Building and the warm detector commissioning. The scope also includes the assembly of the TPC at DAB and transportation to the Near Detector Building



# SBND installation and integration scope elements

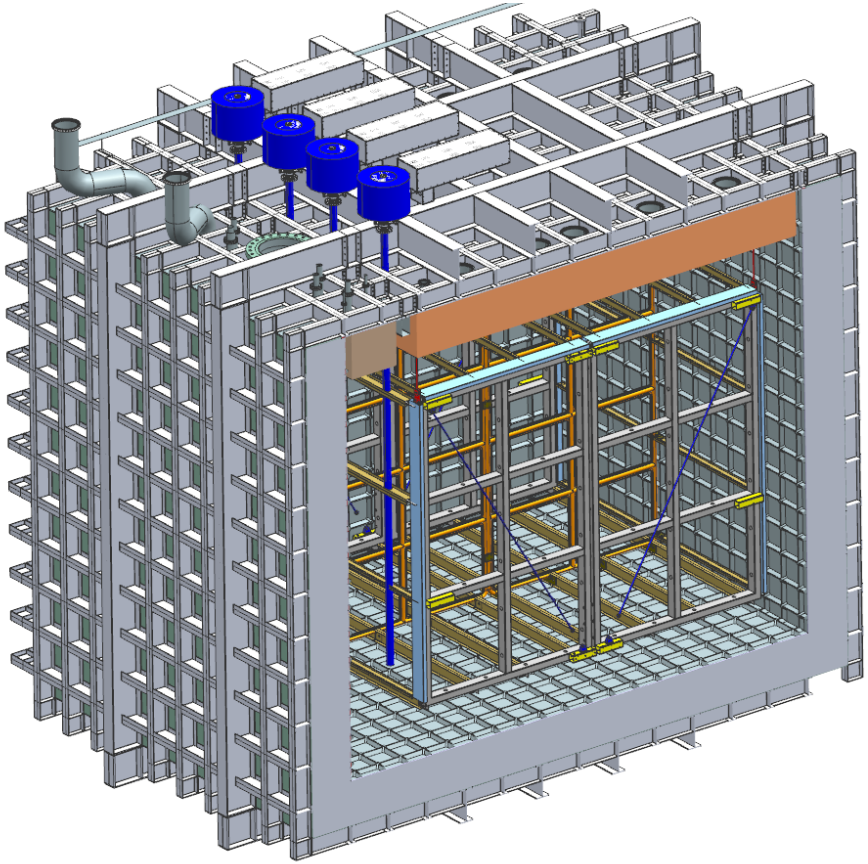
- Detector installation planning
- Installation equipment design and procurement
- Design and procurement of TPC hanger supports
- Design and procurement of upper Cosmic Ray Tagger support structure
- Setup of Near Detector Assembly Facility at DAB
- Near Detector Assembly
- Transportation of TPC from DAB to the Near Detector Bldg.
- Installation of TPC with Light Detectors into Cryostat
- Installation of the Cosmic-Ray tagger
- Warm detector checkout and commissioning

# System Requirements

| | |
|---|---|
| Installation and transportation scope | Provide the labor and equipment for the transportation from DAB and installation into the cryostat |
| Limits on TPC deflection during transportation and installation | 3 mm deflection of CPA relative to APA when side Field Cage panels are connected. Larger ( need to specify maximum) if side field cage panels are removed |
| TPC support design load | TPC and LDS load (4235 kg reference design, higher for SS tube FC) docdb 552 |
| Acceleration loads during transport and installation | Using measured values from MicroBooNE for now |
| Survey of TPC elements | ~0.2 mm for wire fiducials relative to APA frames<br>YY mm APA frames relative to cryostat<br>ZZ cryostat fiducials relative to detector building network<br>(values under discussion) |
| LDS UV light protection | Protect any UV sensitive LDS elements during installation |
| Program ES&H requirements | See ES&H slide |

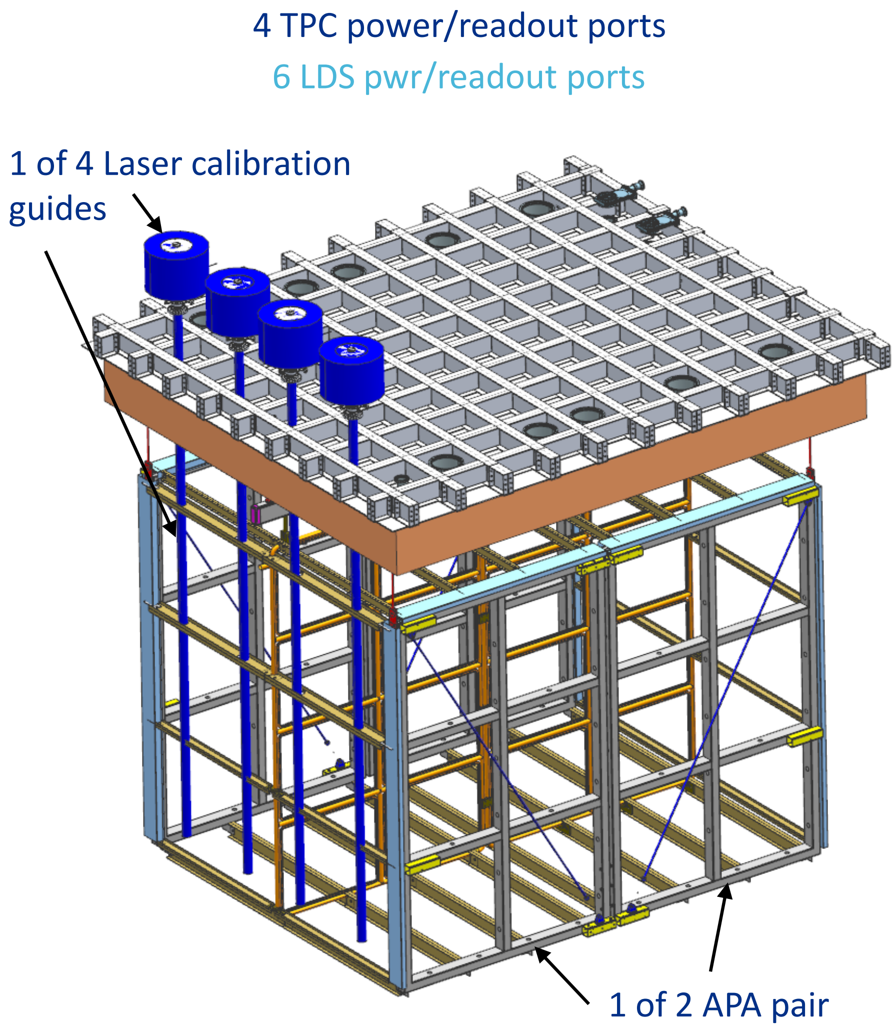
# Scope - Near Detector Integration

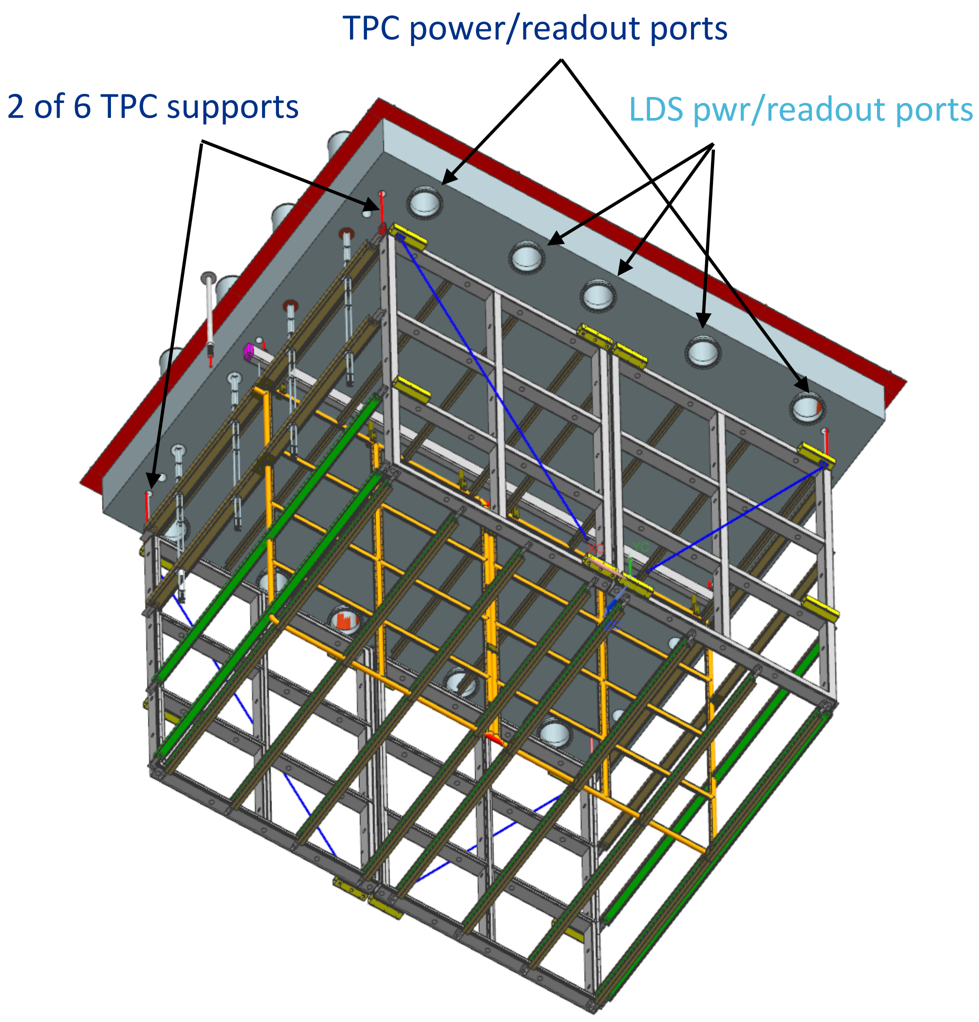
- Cryostat
- TPC
- Light Detection System
- Laser Calibration System
- Camera System
- Cosmic Ray Tagger
- Program Grounding Plan



Cryogenics integration part of Infrastructure but the same designer is working on the Detector and Cryo-system

# Integration with cryostat top



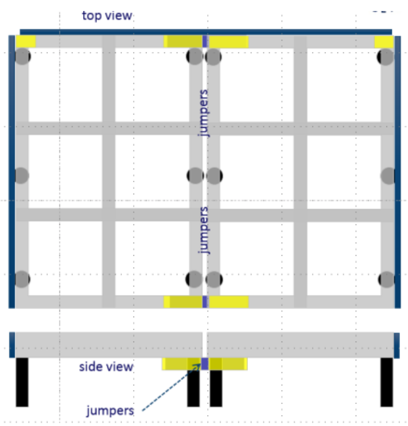
# Cryostat Ports

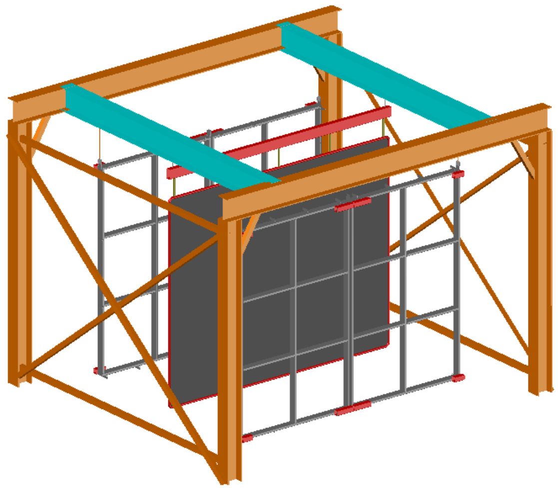
## Docdb 552

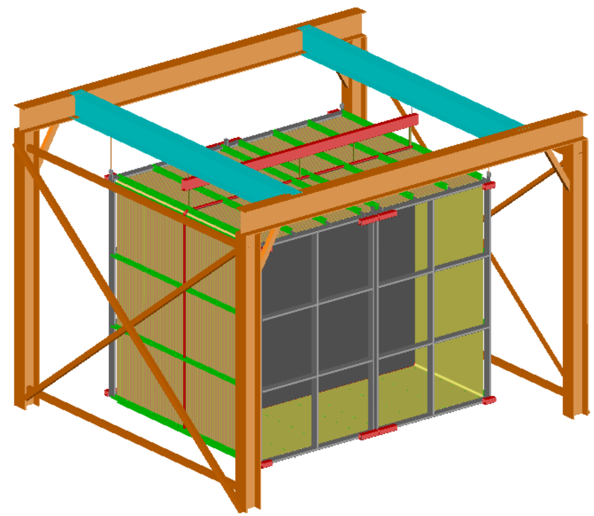
| Label | Function | Description | Tube size | Flange size | height above top plate | Quantity | Stay clear size | Location | Location flexibility | Notes |
|---|---|---|---|---|---|---|---|---|---|---|
| Removable top plate | | | | | | | | | | |
| | TPC support | port for TPC support hanger | 4" | 6" OD CF | needs more design development | 6 | | | ≤ 1 cm (on 1 Sept, location may be off by few cm) | support rod needs to structural connection to top plate structure |
| | TPC Signal/Power Feedthrough | Signal and power feedthrough for APA | 12" | 14" OD CF | keep minimnal for clearance above warm electronics | 4 | 30 cm above and 30 cm radius for wam electronics and enclosure | directly above APAs near ends | ≤ 10 cm transverse to beam direction; completely flexible in beam direction as long as TPC and LDS ports fit | |
| | LDS Signal/Power Feedthrough | Signal and power feedthrough for Light Detection System | 12" | 14" OD CF | needs more design development | 6 | currently show same size as TPC | directly above APAs | ≤ 10 cm transverse to beam direction; completely flexible in beam direction as long as TPC and LDS ports fit | |
| | Laser ports | port for steering head of laser calibration system | 6" | 8" OD CF | clearance for laser drive head | | 40 cm diameter (current steeing head diameter is 330 mm but design changes may require a large diameter) | along down stream edge of TPC behind field cage | ≤ 1 cm in the beam direction; ≤ 5 cm transverse to beam direction | two laser ports per drift: To reconstruct the electric field without ambiguity one needs two straight tracks crossing within the drift region at the same time. (Igor) |
| | Detector monitoring | T sensors from inside cryostat | 4" | 6" OD CF | flexible | 2 | 10 cm on each side | one on each side near APA edge | generally flexible but location should be in general area of upstream APA edges | for RTD's 1 port for each APA - feedthrough style like MicroBooNe (1 port in fixed portion of plate for cryostat) |
| | Radiation source deployment | Port with gate valve to allow temporaty insertion of a radiactive source | 6" | 8" OD CF | flexible | 2 | clearance for a gate valve | each at a different positions along the drift distance of one dirft volume | ≤ 5 cm in the beam direction; ≤ 20 cm transverse to beam direction (on 1 Sept general location is preliminary) | Is there a minimue distance from the FC because of HV breakdown considerations |
| | Cameras | cameras used to look for HV breakdown and observe LAr filling | | see notes | | | | | | cameras mounted to TPC will have feedthrough incorporated into LDS ports |

# TPC Assembly

## Design and tooling in WBS 2.3 (TPC) U of Chicago, BNL
## Technical labor in WBS 2.8



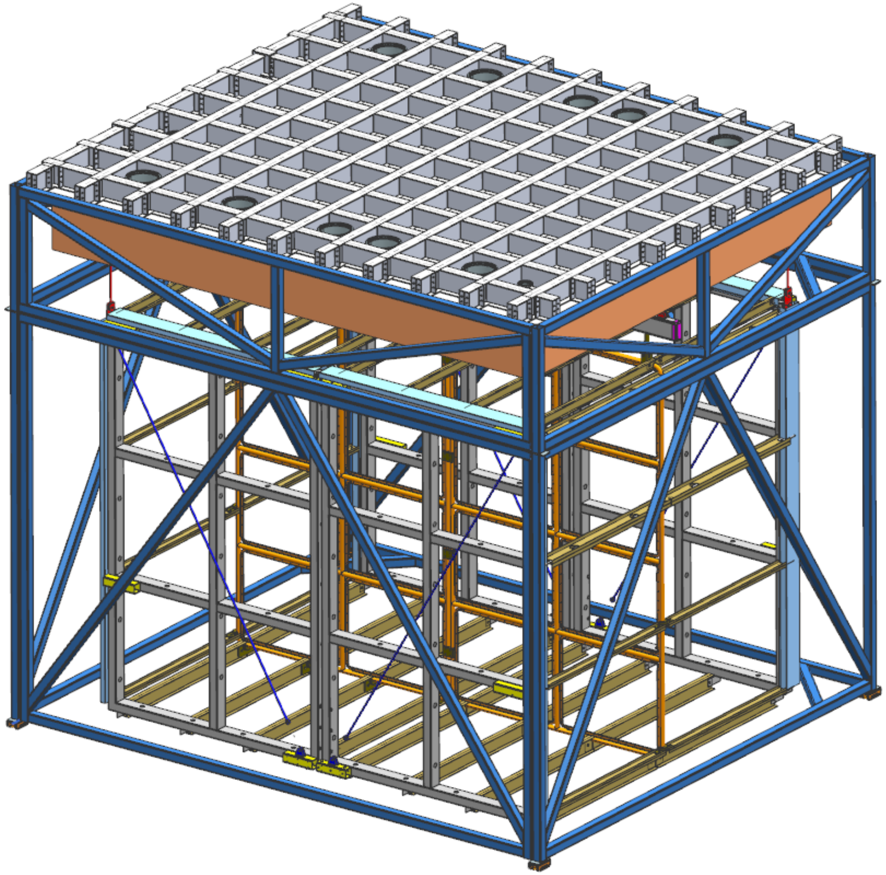


1. Join 2 APA side by side (while horizontal)
2. Install jumpers and
3. Rotate to vertical

4. Hang first APA pair from beams between MicroBooNE monorails
5. Hang intermediate cathode suspension beam and then two CPA sections
6. Hang second APA par

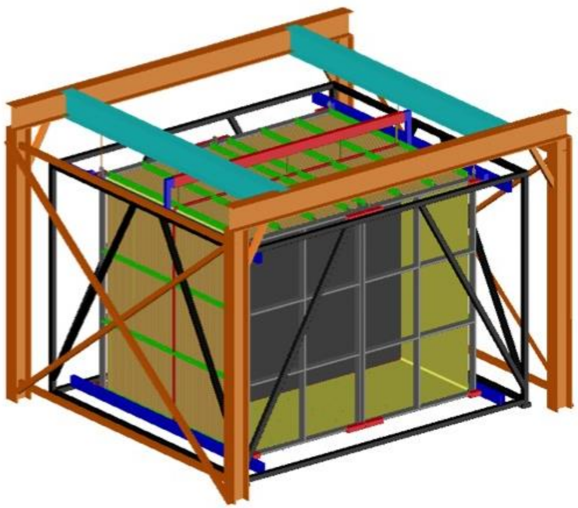
6. Attach field cage support beams
7. Install field cage panels (except side field cages)
8. Install FE electronics
9. Install LDS assemblies

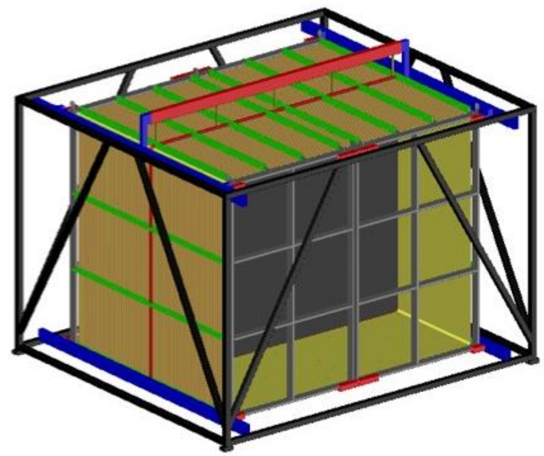
# Scope – TPC support and transport frame

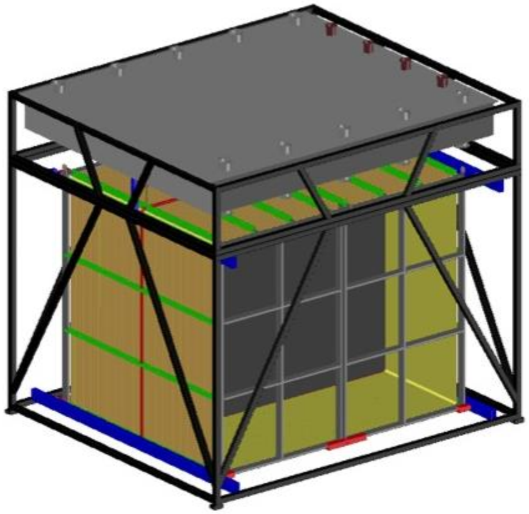


- Support TPC and cryostat top so the two can be connected at DAB in order to allow the electrical connections that will be inside the cryostat to be part of a readout system test
- Support TPC and cryostat top during transportation from DAB to near detector building
  - Rollers at the legs to allow the frame to be moved without a crane
  - Door height limits at DAB require the stand with TPC (with protective wrap) to be rolled out of building where it can be loaded with a mobile crane on to a truck

# Transfer to Transportation Frame







1. Push 3-sided transport frame around the TPC
2. Install back side of frame
3. Connect to TPC to transport frame
4. Disconnect TPC from MicroBooNE monorails
5. Pull out of MicroBooNE tent
6. Mount feedthrough flanges and test seals & connections
7. Lower cryostat top onto lower part of transport frame
8. Connection APAs/CPA to Cryostat top
9. Connect cold cables to feedthroughs and test

# Scope – TPC transport – (similar to MicroBooNE)



Maximum measured acceleration loads during the MicroBooNe transport was 1.2 g (in longitudinal direction) and 1.4 g (in vertical direction), respectively. These maximums were reached during the disconnection of the saddles from the LArTPC vessel, prior to lifting it at LArTF. Over-the-road transport of massive detectors or beamline components with an air-ride trailer has been shown to be quite stable and safe. One handling operation produced the largest load. No indication of resonance conditions

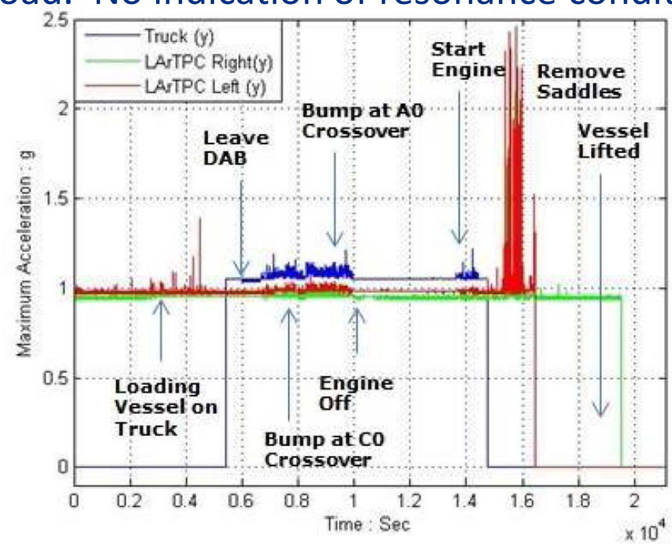
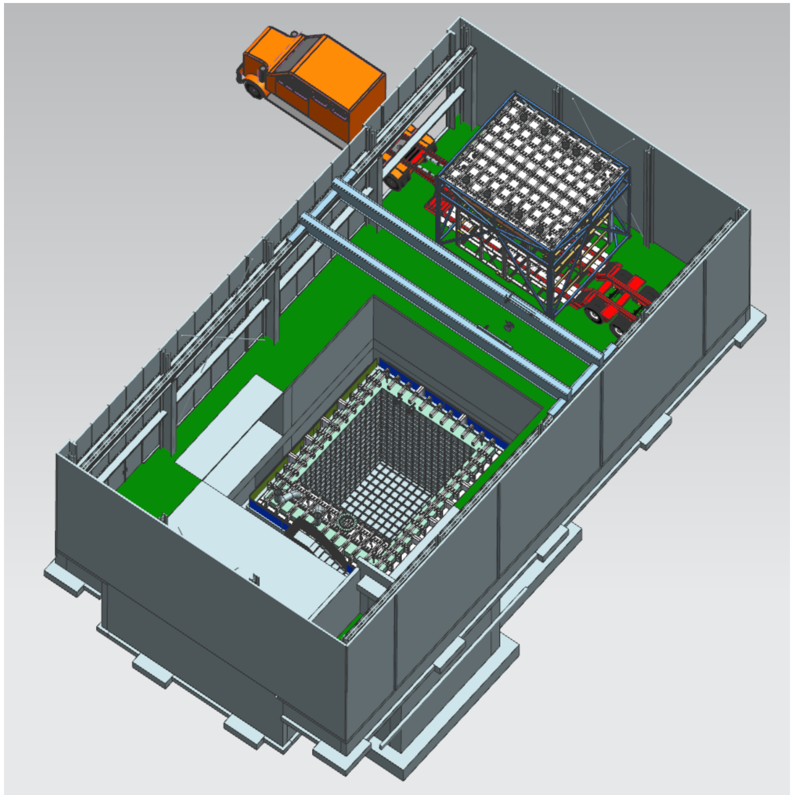
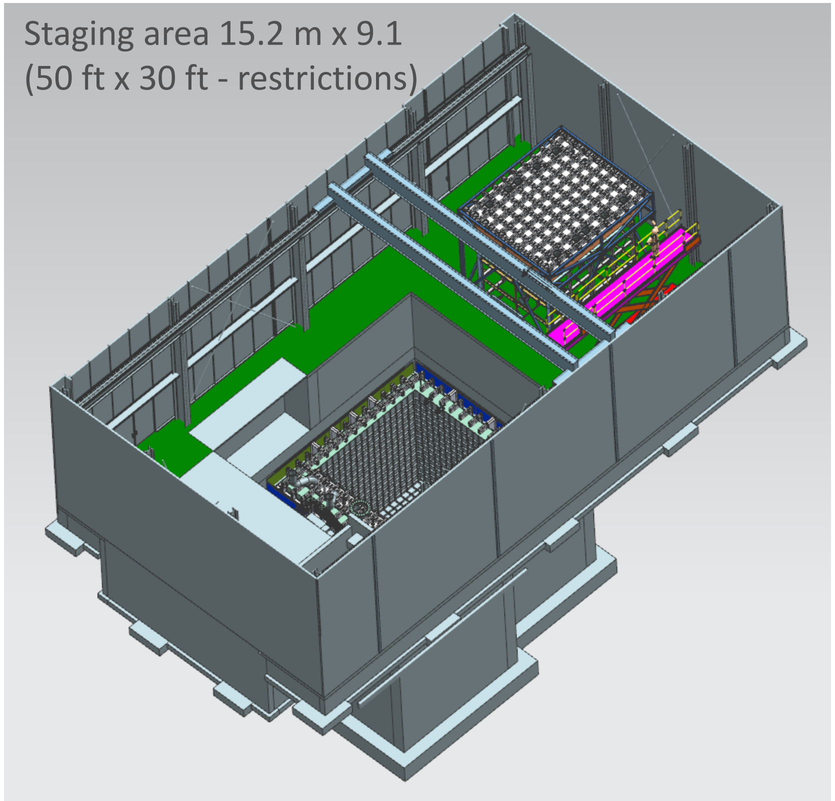



**Figure 13:** Vertical GP1 device acceleration loads during all three phases of transport.

# Delivery to Near Detector Building

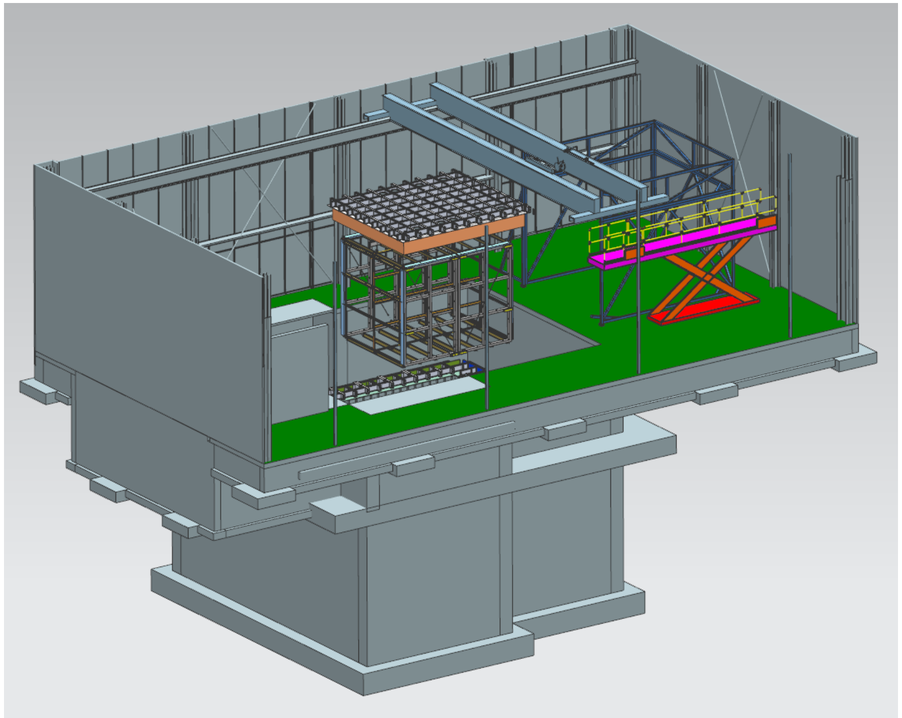


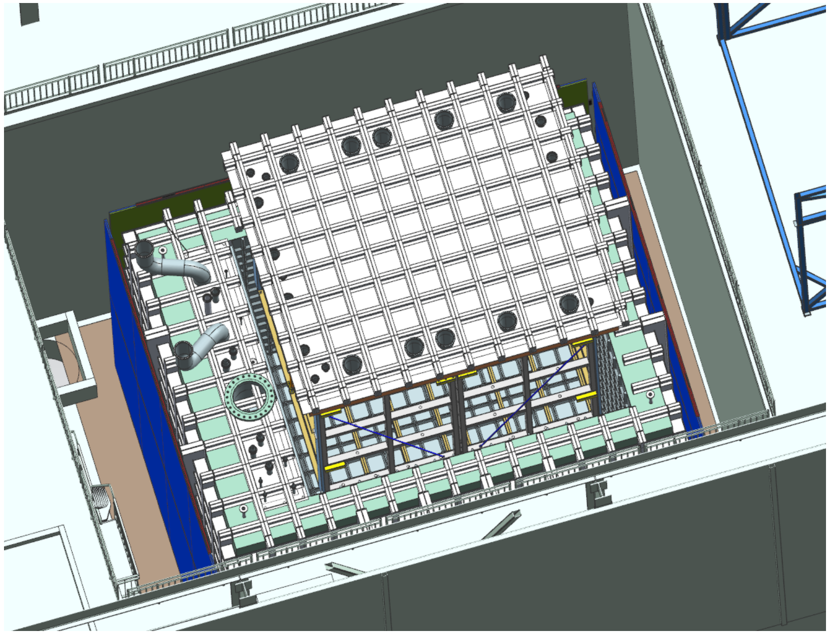



Deliver TPC on transportation frame with protective wrap into building

- Install LDS if not done at DAB
- Install side field cage
- Test/Retest entire detector readout

# Insertion into cryostat

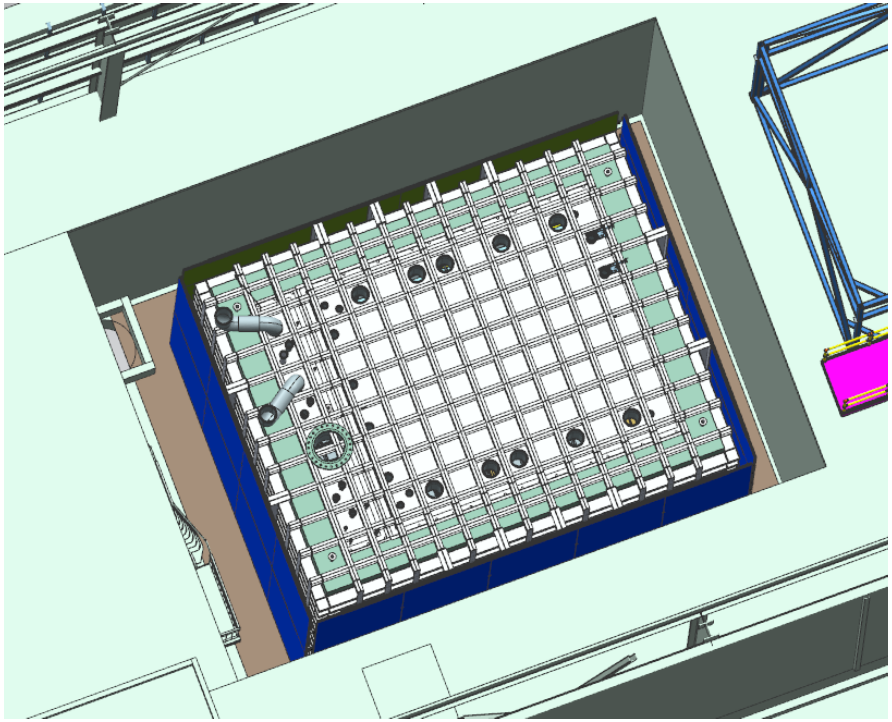


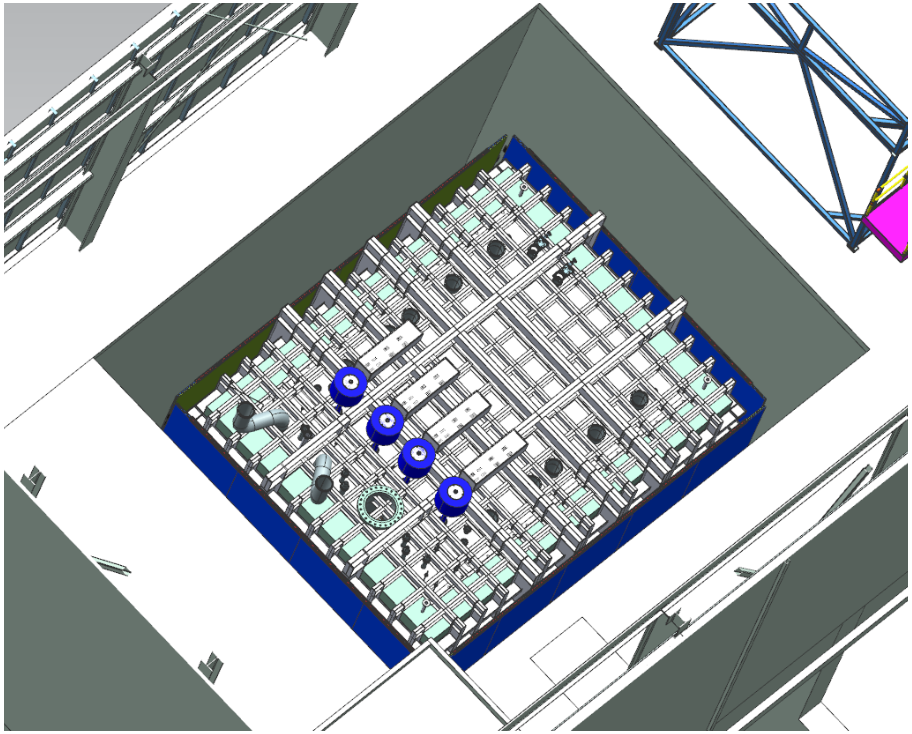


- Brace sides of transportation frame and remove one end
- Use building crane to lift TPC with cryostat top from frame

- Lower detector into cryostat with building crane
- Use laser pointer guides to avoid lateral movements of crane after insertion begins

# After insertion into cryostat



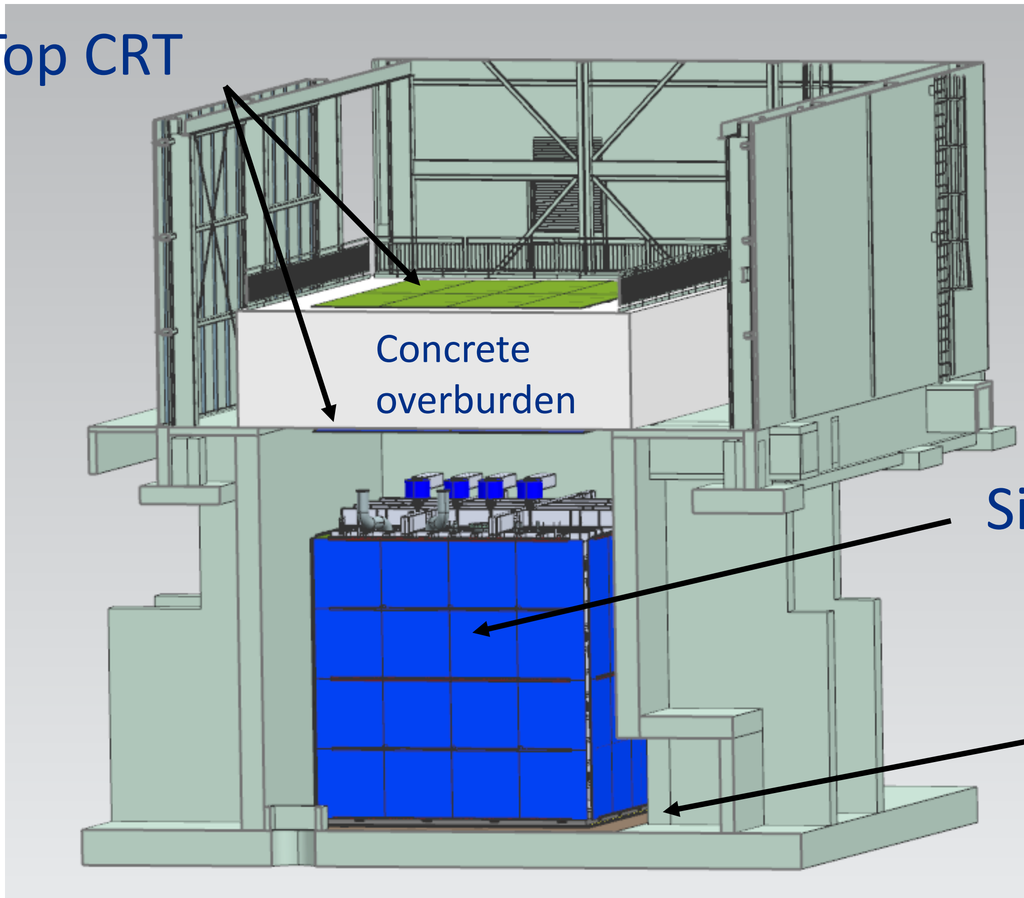


- Add laser calibration steering assemblies
- Add HV probe
- Connect all warm cables
- Check detector readout

- Attach large beams
- Install laser heads

Beams on cryostat top have removable sections for access to top seal weld zone. Timing of the weld operation TBD

# CRT and shielding installation

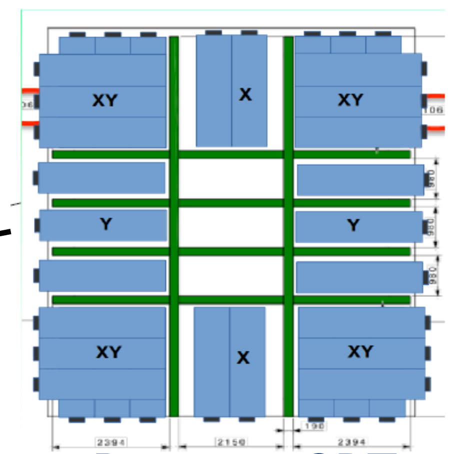



Installed in 3 stages

Bottom - before cryostat

Sides - after cryostat body

Top – after filling with LAr




Bottom CRT

# Interfaces

| | |
|---|---|
| Near Detector Building | Overhead crane, door size, staging area, building power and ground |
| Cryostat top plate | Cryostat feedthrough ports, TPC supports connections and ports, Lifting features, overall height for transport clearance |
| TPC | TPC support loads and attachment, transportation deflection and acceleration loading limits, survey requirements and fiducial features, assembly tooling and procedure guidance |
| Light Detection System | UV light exposure requirements, load on TPC supports, clearances for installation into cryostat, general handling requirements |
| Detector grounding plan | Linda Bagby's presentation on program grounding plan in docdb 589 and 684 |
| Cosmic Ray Tagger | Module loads on supports, handling features/fixture, support connection points |

# Interfaces – Information management

- Feature specific documents
  ex. Cryostat ports list
- CAD file exchange
- Weekly meetings
  - Installation and integration design meeting
  - TPC meeting
- Data captured in SBN docdb

Docdb 552

| Label | Function | Description | Tube size | Flange size | height above top plate | Quantity | Stay clear size | Locat |
|---|---|---|---|---|---|---|---|---|
| Removable top plate | | | | | | | | |
| | TPC support | port for TPC support hanger | 4" | 6" OD CF | needs more design development | 6 | | |
| | TPC Signal/Power Feedthrough | Signal and power feedthrough for APA | 12" | 14" OD CF | keep minimnal for clearance above warm electronics | 4 | 30 cm above and 30 cm radius for wam electronics and enclosure | directly abo near ends |
| | LDS Signal/Power Feedthrough | Signal and power feedthrough for Light Detection System | 12" | 14" OD CF | needs more design development | 6 | currently show same size as TPC | directly abo |
| | Laser ports | port for steering head of laser calibration system | 6" | 8" OD CF | clearance for laser drive head | | 40 cm diameter (current steeing head diameter is 330 mm but design changes may require a large diameter) | along down edge of TPC field cage |
| | | T sensors from inside cryostat | 4" | 6" OD CF | flexible | 2 | 10 cm on each side | one on each APA edge |

# Resources

- Planning
  - Manager – Joe Howell
  - SBN Program EE – Linda Bagby
  - Engineering – Jim Kilmer, Bob Woods
  - Design Integration - Steve Hentschel
  - Fixture Design - Rick Reinert
- Assembly (setup and all crane operations) and Installation
  - PPD Experiment Installation group – John Voirin Ldr.
- Survey and alignment
  - PPD Alignment – O'Sheg Oshinowo

- Collaboration – Scientist, Engineering and student participation

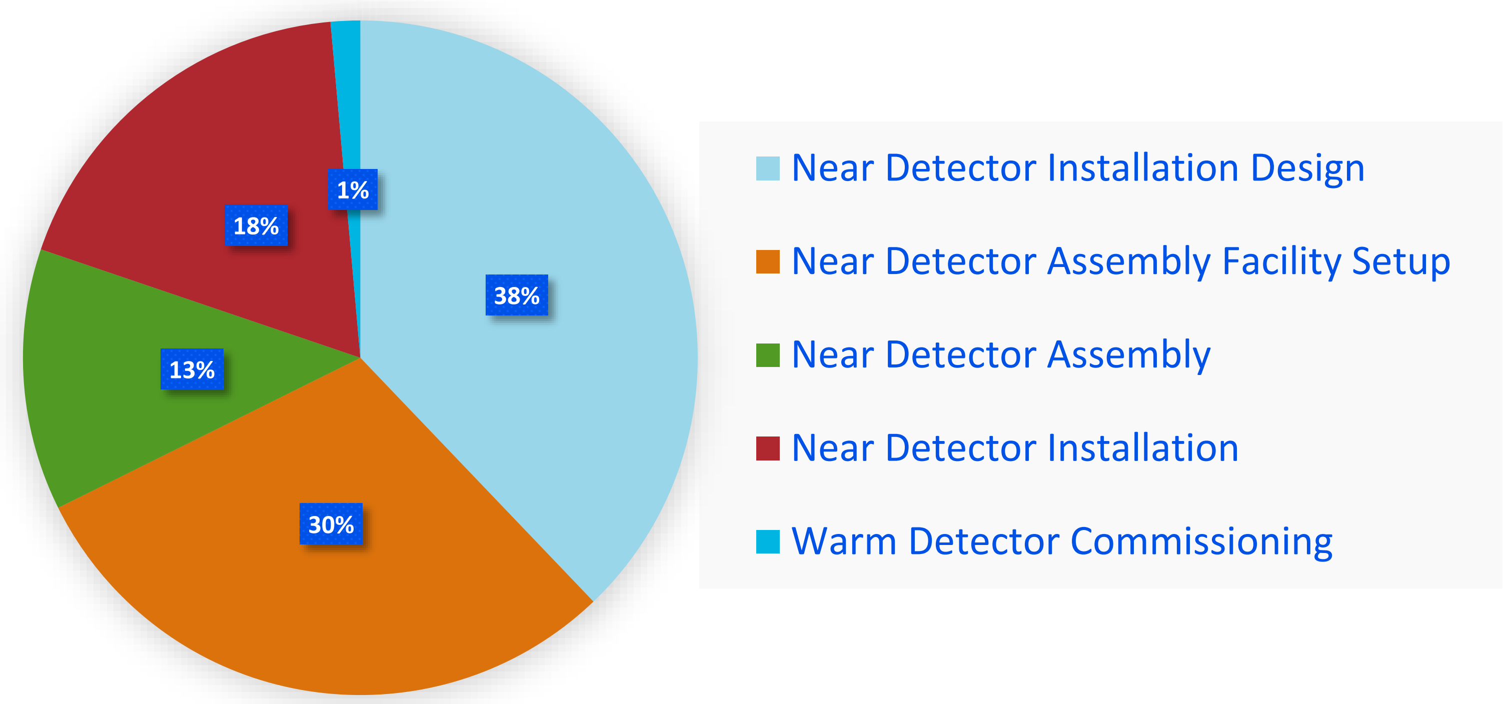
# Basis of Estimate

- Design labor
  - Equipment and task list
  - Previous experience with similar tasks
- Installation Labor
  - Previous experience
  - Data mining from MicroBooNE and interviews with assembly and installation managers (Jen Raaf and John Voirin)
- Installation equipment M&S
  - Previous experience
  - Rules of thumb for welded assemblies
  - Catalog prices

| WBS 2.8 Base Cost | | |
|---|---|---|
| Total | Labor | M&S |
| 1497 K$ | 1106 k$ | 391K$ |
| | 74% | 26% |

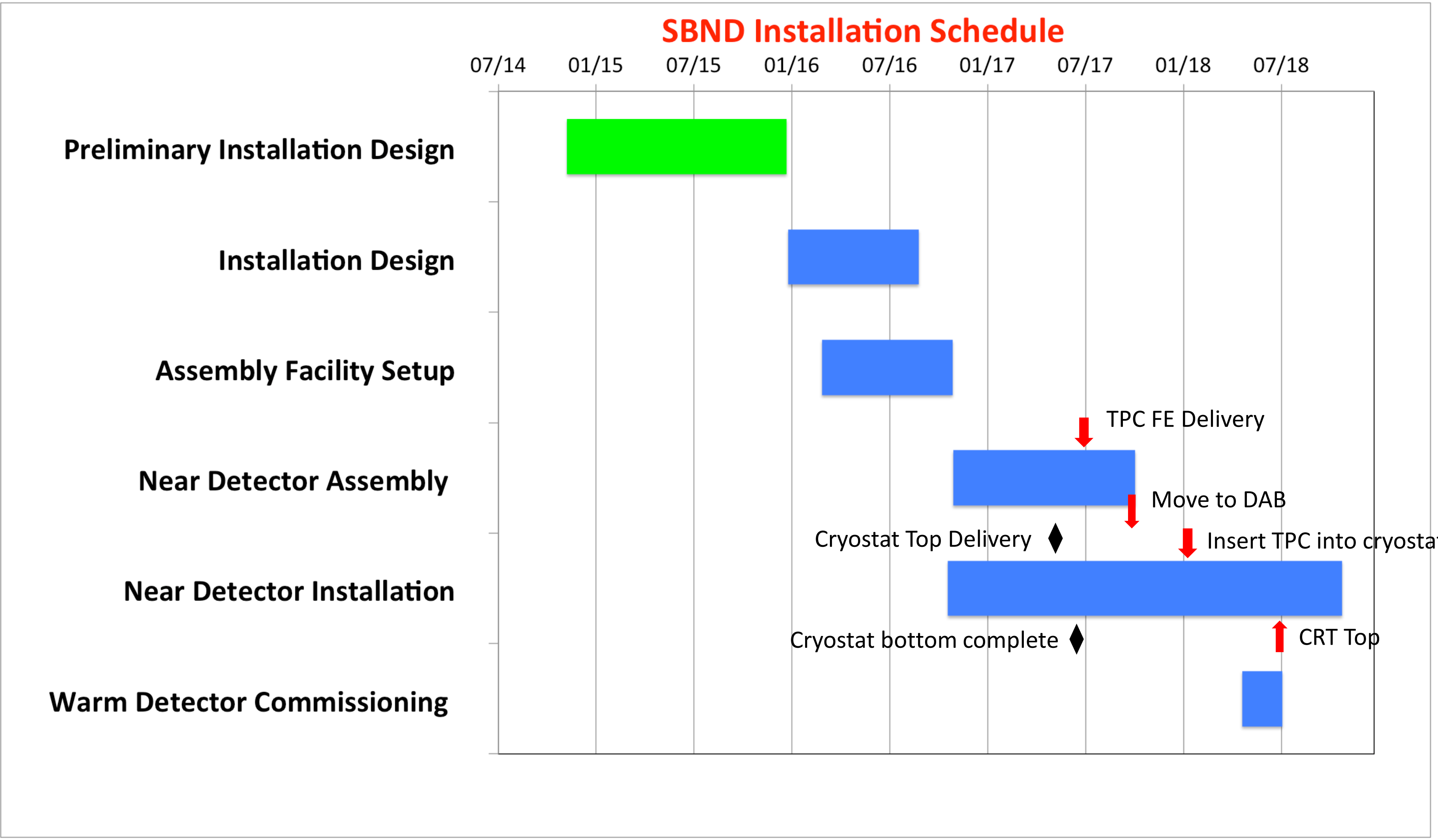
| Labor Type | WBS Tasks | FTE-Year |
|---|---|---|
| Senior Mech. Engineer | Manager of 2.2 & 2.8 | 1.5 |
| Mech. Engineer | Installation design -2.2 & 2.8 | 0.85 |
| Mech. Designer | Installation design - 2.2 & 2.8 | 1 |
| Mech. Technician | Assembly and installation - 2.8 | 2.25 |
| Alignment & survey | Assembly and installation - 2.8 | 0.46 |
| | Total (FTE-year) | 6.06 |

# Cost Distribution




| WBS | Task Name | All Labor (With OverHd) | All Materials (With OverHd) | Project Base Est Cost |
|---|---|---|---|---|
| | | $1,105,998 | $391,699 | $1,497,697 |
| 40SBN/2.8.1 | Near Detector Installation Design | $567,018 | $0 | $567,018 |
| 40SBN/2.8.2 | Near Detector Assembly Facility Setup | $130,886 | $315,457 | $446,343 |
| 40SBN/2.8.3 | Near Detector Assembly | $177,519 | $10,395 | $187,913 |
| 40SBN/2.8.4 | Near Detector Installation | $209,451 | $65,847 | $275,299 |
| 40SBN/2.8.5 | Warm Detector Commissioning | $21,124 | $0 | $21,124 |

# Schedule


SBND Installation Schedule
07/14
01/15
07/15
01/16
07/16
01/17
07/17
01/18
07/18
Preliminary Installation Design
Installation Design
Assembly Facility Setup
Near Detector Assembly
Near Detector Installation
Warm Detector Commissioning
TPC FE Delivery
Move to DAB
Cryostat Top Delivery
Insert TPC into cryostat
Cryostat bottom complete
CRT Top

# ES&H

FESHM (Fermilab ES&H manual)

- Below the hook lifting fixture standards
- Engineering notes for support structures
- Crane Operation Procedures
- Hazard Analysis for Installation Tasks
- Qualification for TPC support feedthrough for Cryostat Maximum Pressure

For work inside the cryostat (small portion of the installation task)

- Non-Permitted Confined Space
- Access & Egress Procedures
  - Personnel accountability (including sign-in and sign-out for cryostat entry)
  - Two person rule
  - Continuous communication
- Temporary Ventilation and Lighting for work inside cryostat
- Emergency Response Procedures
  - Rescue equipment
- Air quality monitoring

Fermilab Environment, Safety and Health Manual (FESHM) 5063
Confined Space - A space that:
1. Is large enough and so configured that an employee can bodily enter and perform assigned work; and
2. Has limited or restricted means for entry or exit; and
3. Is not designed for continuous employee occupancy

Non-Permit Confined Space - A confined space that does not contain or, with respect to atmospheric hazards, have the potential to contain any hazard capable of causing death or serious physical harm.

# Quality Assurance

- Work planning and training
  - Written procedures.
  - Experienced team leaders
- Detector system groups will be involved with checkout before and after installation (including an engineering run at DAB)
- Installation tracking database (including part ID and installation location)
- Cable mapping and labels
- Lessons learned from MicroBooNE and 35T installation and operation will be applied.
- Operational readiness clearance approval process
- If an isolated system is required for the ground plan a monitor with alarm will be used to assure the integrity of the detector ground during installation.

# Response to Review Recommendations 1 of 2

## From Sept 28 TPC preliminary design review

| Recommendation | Response |
|---|---|
| Review the process of transferring the TPC from being supported directly by the transport frame to being supported by the cryostat lid. Make sure the two sets of supports don't interfere with each other and that no part of the TPC is ever unsupported. | Likely not explained well at the review. The transfer of support to the cryostat will be very positive so that the TPC can be lifted from the frame support without any chance of the TPC being unsupported in the transition |
| Determine how the TPC will be brought from the assembly building to the detector building and then unloaded and installed while maintaining adequate cleanliness. | The entire transportation frame will be wrapped with a protective cover during the move from DAB to the near detector building |
| Check the process of removing the TPC from the transport frame at the detector building to make sure that it can be done with a single crane (or that a second is available if needed). | One side of the transport frame will be removed after the sides of the frame are braced. The TPC can then be lifted by a single crane for insertion into the cryostat |

# Response to Review Recommendations 2 of 2

| Recommendation | Response |
| --- | --- |
| Careful communication between light detection system and TPC is encouraged, particularly in final design stages for LDS, where interfaces for installation and assembly will be critical. | Members of the TPC team regularly attend the weekly SBND installation and integration meeting and the L2 installation manager attends the weekly TPC meeting. The LDS group is just starting to develop a mounting structure. |
| Set up meetings with FNAL survey/alignment group to identify which parts of detector will need as-found survey vs. alignment help during assembly and installation. | O'Sheg Oshinowo and Virgil Bocean of the survey and alignment department participated in an SBND installation meeting devoted to discussion of the survey and alignment tasks. Most of the tasks are as-found survey. Regular communication with O'Sheg and this will continue. |
| Develop plans for attaching the cryostat top outside of the D-Zero Assembly building. | At the time of the review the communication with CERN engineers on the cryostat top had just started. Since then a design of the cryostat top has been developed at CERN which will allow the cryostat top to be attached at DAB. The cryostat top can be attached at the Near Detector Building but that would involve some major schedule and effort penalties. |

# Status of Design

- Finalizing cryostat top features for near detector
- Updating integration model with Cryostat structure from CERN and Cosmic Ray Tagger Modules
- Will add Light Detection System as information is available
- Transportation frame design
  - Basic frame design done and analyzed
  - Adding features to aid detector assembly
- TPC support design initiated
- CRT upper layer support initiated
- Miscellaneous fixture list created but design not started
- Future Reviews
  - TPC transportation final design review ( Spring 2016)
  - TPC assembly readiness review
  - CRT installation readiness review
  - TPC installation readiness review

# Backup Slides

# System Scope - Survey

## Detector Building Monuments

1. LTCS:X,Y,Z system used to define Booster Neutrino BeamLine
2. Coordinates for key Near Detector Building points provided to FESS in LTCS:X,Y,H system by the Alignment group
3. Coordinates shown on FESS Drawings used for Near Detector Building construction. P1 and P2 are points on the beam line at opposite ends of the detector pit
4. Near Detector Building Construction
5. After Building construction is complete the Alignment group will install a network of monuments in the building for Detector survey tasks (it is expected that some monuments will be covered and not accessible after detector installation)
6. The Alignment group can snap a line to aid in the placement of the membrane cryostat

## Detector at DAB

1. APA Assembly
2. Survey wire positions relative to fiducials on APA frames
3. TPC Assembly at DAB
   - Align fixtures and APA pairs
4. Connect TPC to cryostat top plate
5. Survey APA fiducials relative to external support points on top of cryostat (some support alignment adjustment if necessary)
6. Transport TPC and cryostat top from DAB to Near Detector Building

## Detector after Installation

1. Install TPC into cryostat
2. Survey top ends of TPC support points relative to monuments in building (some support alignment adjustment if necessary)
3. Seal top plate of cryostat
4. Survey top ends of support points relative to monuments in building
5. Cool down TPC in cryostat
6. Survey top ends of support points relative to monuments in building

# Basis of Estimate Form and Rules

Short Baseline Neutrino Project
**BASIS of ESTIMATE FORM (BoE)**

| | | |
|---|---|---|
| Short Baseline Neutrino Project BASIS of ESTIMATE FORM (BoE) | | **SBN-docDB Number: 759**<br>**Date of Estimate: 3/5/2015**<br>**Prepared by: Ting Miao** |
| **WBS Number: 2.8** | **Control Account (CTC):** | **CAM: Joe Howell** |
| **WBS Title: Installation Coordination** | | |

**WBS Dictionary Definition:** This WBS element includes final installation and integration tasks for the detector hall installations of detector components including TPC, light detector, cosmic ray tagger, readout electronics and DAQ system.

| **Cost Type:** | **Cost Estimate Method:** | | |
|---|---|---|---|
| _x_ M&S _x_ Labor | __Engineering Estimate<br>__Vendor Quote or Vendor Survey | _x Prior Purchase or Experience Source: ____________<br>__Other (Please describe) : ____________ | __Catalog Price Source:____________ |

**Supporting Documents:**

**Task Duration:**

| | |
|---|---|
| **Task M&S Cost** (FY15): **$277,000** | **Task Labor** (Resource type & work hours or % for duration of task): 10,002 hours total |
| **Task M&S Contingency** (% and the contingency rule applied): **40% and Rule M5** | **Task Labor Contingency** (% and the contingency rule applied): **40% and Rule L5** |

**Assumptions:**
- See SBN-doc-186 for project key assumptions
- Costs are in FY2015 dollars and do not include indirects.
- Durations are in working days.
- 85% efficiency assumed for labor hours. 1 FTE = 1768 hours for an average year.
- Add your assumptions here for the BOE

**Task Table**

| WBS | WBS TASK DESCRIPTION | M&S RESOURCES (FY15$) | LABOR RESOURCES | DURATION (DAYS) | Hours | M&S contingency (%) | Labor Contingency (%) |
|---|---|---|---|---|---|---|---|
| 2.8.1 | Near Detector Installation Design | | | 343 | | | |
| 2.8.1.1 | Overall layout of near detector in detector hall | | FNPD_MECH_DESIGNER[50%], FNPD_MECH_DRAFTER[50%] | 48 | 192 | 40% | 40% |
| 2.8.1.2 | Design of TPC support inside cryostat | | FNPD_MECH_DESIGN_EN[50%], FNPD_MECH_DESIGNER[50%], FNPD_MECH_DRAFTER[100%] | 48 | 576 | 40% | 40% |
| 2.8.1.3 | Design of TPC support during assembly and installation | | FNPD_MECH_DESIGN_EN[100%], FNPD_MECH_DESIGNER[100%], FNPD_MECH_DRAFTER[100%] | 41 | 656 | 40% | 40% |
| 2.8.1.4 | Design of light detector installation support during assembly and installation | | FNPD_MECH_DESIGN_EN[50%], FNPD_MECH_DESIGNER[[50%] | 39 | 312 | 40% | 40% |

## M&S Contingency Category

| | | | |
|---|---|---|---|
| M4 | Preliminary | 20%-40% | Items that can be readily estimated from a reasonably detailed but not completed design; items adapted from existing designs but with moderate modifications, which have documented costs from past projects. A recent vendor survey (e.g., budgetary quote, vendor RFI response) based on a preliminary design belongs here. |
| M5 | Conceptual | 40%-60% | Items with a documented conceptual level of design; items adapted from existing designs but with extensive modifications, which have documented costs from past projects |

## Labor Contingency Category

| | | | |
|---|---|---|---|
| L4 | Preliminary | 25%-40% | Based on direct experience with similar work. Development of activities, resource requirements, and schedule constraints are defined at a preliminary (beyond conceptual) design level. Technical requirements are achievable and with some precedent. |
| L5 | Conceptual | 40%-60% | Based on expert judgment using some experience as a reference. Development of activities, resource requirements, and schedule constraints are defined at a conceptual level. Technical requirements are moderately challenging. |

# Basis of Estimate Data

**Basis of Estimate for Tasks under**

| | |
|---|---|
| **Summary Task Name:** | **Installation Coordination (SBN-ND-IC)** |
| **Summary WBS:** | **40SBN/2.8** |
| **Summary Unique ID:** | **113** |
| **Summary BOE Number:** | **208** |

| WBS | UID | ID | Task Name | Duration in Days | Start Date | Finish Date | Fixed Cost M&S | All Labor (With OverHd) | All Materials (With OverHd) | Project Base Est Cost |
|---|---|---|---|---|---|---|---|---|---|---|
| 40SBN/2.8.1 | | | | | | | | $1,105,998 | $391,699 | $1,497,697 |
| | 114 | 725 | Near Detector Installation Design (SBN-ND-IC)(ID) | 166 | 11/05/15 | 07/06/16 | $0 | $567,018 | $0 | $567,018 |
| 40SBN/2.8.1.1 | 115 | 726 | Overall Layout of Near Detector in Detector Hall (FNAL - Labor) (SBN-ND-IC)(ID) | 49 | 11/05/15 | 01/21/16 | $0 | $40,252 | $0 | $40,252 |
| 40SBN/2.8.1.2 | 1101 | 727 | Overall Layout of Near Detector in Detector Hall (FNAL - M&S) (SBN-ND-IC)(ID) | 49 | 11/05/15 | 01/21/16 | $0 | $0 | $0 | $0 |
| 40SBN/2.8.1.3 | 1112 | 728 | Design of TPC Support Inside Cryostat (FNAL - Labor) (SBN-ND-IC)(ID) | 42 | 11/05/15 | 01/11/16 | $0 | $73,511 | $0 | $73,511 |
| 40SBN/2.8.1.4 | 1113 | 729 | Design of TPC Support Inside Cryostat (FNAL - M&S) (SBN-ND-IC)(ID) | 42 | 11/05/15 | 01/11/16 | $0 | $0 | $0 | $0 |
| 40SBN/2.8.1.5 | 1114 | 730 | Design of TPC Support During Assembly and Installation (FNAL - Labor) (SBN-ND-IC)(ID) | 65 | 11/05/15 | 02/12/16 | $0 | $117,549 | $0 | $117,549 |
| 40SBN/2.8.1.6 | 1115 | 731 | Design of TPC Support During Assembly and Installation (FNAL - M&S) (SBN-ND-IC)(ID) | 42 | 11/05/15 | 01/11/16 | $0 | $0 | $0 | $0 |
| 40SBN/2.8.1.7 | 1116 | 732 | Design of Light Detector Installation Support During Assembly and Installation (FNAL - Labor) (SBN-ND-IC)(ID | 41 | 01/12/16 | 03/09/16 | $0 | $42,989 | $0 | $42,989 |
| 40SBN/2.8.1.8 | 1117 | 733 | Design of Light Detector Installation Support During Assembly and Installation (FNAL - M&S) (SBN-ND-IC)(ID) | 41 | 01/12/16 | 03/09/16 | $0 | $0 | $0 | $0 |
| 40SBN/2.8.1.9 | 1118 | 734 | Design of TPC Assembly Tent Modification (FNAL - Labor) (SBN-ND-IC)(ID) | 39 | 11/05/15 | 01/06/16 | $0 | $81,784 | $0 | $81,784 |
| 40SBN/2.8.1.10 | 1119 | 735 | Design of TPC Assembly Tent Modification (FNAL - M&S) (SBN-ND-IC)(ID) | 39 | 11/05/15 | 01/06/16 | $0 | $0 | $0 | $0 |
| 40SBN/2.8.1.11 | 1120 | 736 | Design of ND Transportation and Installation Tooling (FNAL - Labor) (SBN-ND-IC)(ID) | 65 | 03/10/16 | 06/09/16 | $0 | $113,768 | $0 | $113,768 |
| 40SBN/2.8.1.12 | 1121 | 737 | Design of ND Transportation and Installation Tooling (FNAL - M&S) (SBN-ND-IC)(ID) | 65 | 03/10/16 | 06/09/16 | $0 | $0 | $0 | $0 |
| 40SBN/2.8.1.13 | 1122 | 738 | Design of Cosmic-Ray Shielding Installation (FNAL - Labor) (SBN-ND-IC)(ID) | 43 | 03/10/16 | 05/09/16 | $0 | $45,086 | $0 | $45,086 |
| 40SBN/2.8.1.14 | 1123 | 739 | Design of Cosmic-Ray Shielding Installation (FNAL - M&S) (SBN-ND-IC)(ID) | 43 | 03/10/16 | 05/09/16 | $0 | $0 | $0 | $0 |
| 40SBN/2.8.1.15 | 1124 | 740 | Design Readout Cable Tray Support and Layout (FNAL - Labor) (SBN-ND-IC)(ID) | 43 | 03/10/16 | 05/09/16 | $0 | $37,631 | $0 | $37,631 |
| 40SBN/2.8.1.16 | 1125 | 741 | Design Readout Cable Tray Support and Layout (FNAL - M&S) (SBN-ND-IC)(ID) | 43 | 03/10/16 | 05/09/16 | $0 | $0 | $0 | $0 |
| 40SBN/2.8.1.17 | 1126 | 742 | Fermilab Engineering Design Review of ND Assembly and Installation (FNAL - Labor) (SBN-ND-IC)(ID) | 40 | 05/10/16 | 07/06/16 | $0 | $7,224 | $0 | $7,224 |
| 40SBN/2.8.1.18 | 1127 | 743 | Fermilab Engineering Design Review of ND Assembly and Installation (FNAL - M&S) (SBN-ND-IC)(ID) | 40 | 05/10/16 | 07/06/16 | $0 | $0 | $0 | $0 |
| 40SBN/2.8.1.19 | 1128 | 744 | Fermilab Safety Review of ND Assembly and Installation (FNAL - Labor) (SBN-ND-IC)(ID) | 40 | 05/10/16 | 07/06/16 | $0 | $7,224 | $0 | $7,224 |
| 40SBN/2.8.1.20 | 1129 | 745 | Fermilab Safety Review of ND Assembly and Installation (FNAL - M&S) (SBN-ND-IC)(ID) | 40 | 05/10/16 | 07/06/16 | $0 | $0 | $0 | $0 |

Summary | M&S | Labor | Summary at L3 | labor by type | Equipment_list | M&S_backup_material | Labor_Backup_Notes | MicroBooNE_data

- Updates to the cost data in process to reflect the present state of the design
- Costs have been fairly stable with minor changes