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Managed by Fermi Research Alliance, LLC for the U.S. Department of Energy Office of Science

Short-baseline Neutrino Program

Peter Wilson

Fermilab Physics Advisory Committee

22 June 2015

Outline

- Introduction
  - Brief Overview of SBN Program
- Organization
  - SBN Collaborations
  - SBN Program
  - Review process
- Detector progress
  - MicroBooNE – covered by Sam Zeller
  - ICARUS
  - SBND
  - Buildings
- BNB Upgrade – presentation by Alberto Marchionni
  - Motivation

Brief History of Fermilab SBN Program

2003-13 - 1st gen. BNB experiments: MiniBooNE and SciBooNE

2015-18 - 2nd gen. BNB experiment: MicroBooNE

Jan. 2014 – Two new proposals to Fermilab PAC for next phase at BNB:

P-1052: ICARUS@FNAL

P-1053: LAr1-ND*

May 2014 – P5 recommendations

May 2014 – SBN Taskforce and working groups start developing joint proposal

Jan. 2015 – Joint proposal presented to PAC, recommends Stage 1 approval

Feb. 2015 – Director grants Stage 1 approval

* March 2015: LAr1-ND ➔ Short-Baseline Near Detector (SBND)

The SBN Proposal

- Returned to the January 2015 PAC meeting with an updated proposal:

A Proposal for a Three Detector Short-Baseline Neutrino Oscillation Program in the Fermilab Booster Neutrino Beam

Submitted jointly by ICARUS, MicroBooNE and SBND (LAr1-ND)
http://arxiv.org/abs/1503.01520

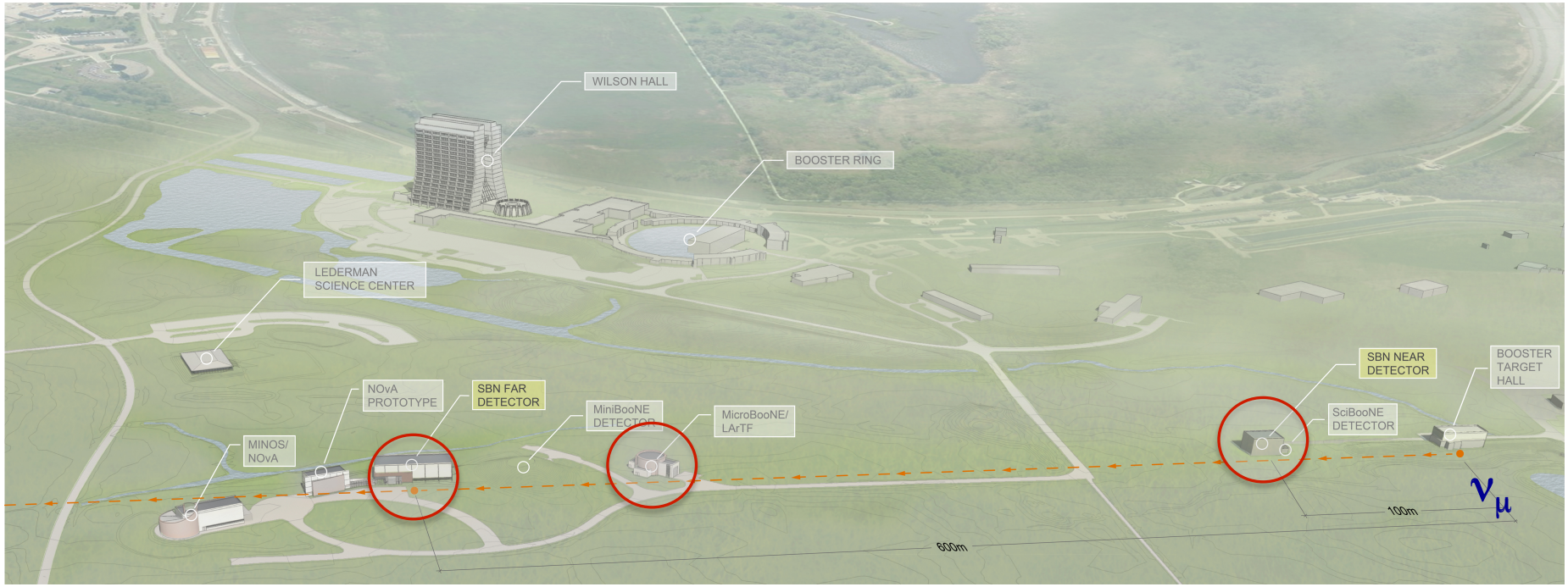
- Measure νe appearance and $\nu \mu$ disappearance in one program
- Detailed analysis for program sensitivities (e.g.):
  - Cosmogenic and beam based backgrounds ("Dirt" events)
  - Systematics from flux minimized by use of near detector
  - Detector systematics reduced by use of common technology
- To address cosmics from surface operation need: overburden, fast light detection and external cosmic tagger systems
- Technology development for LBNF/DUNE

GOAL : Operate in 2018

Program Overview

- Booster Neutrino Beam :
  - 8 GeV Booster protons produce ~1 GeV neutrino beam
  - Max. rep. rate : 5 Hz; typical : 2 Hz (when NuMI operating)
  - 5×10^{12} POT/spill; ~2 – 3 $\times 10^{20}$ POT/yr with current configuration
- Three detector physics program :
  - MicroBooNE
  - Far Detector – ICARUS T-600
  - Near Detector – SBND
- Important program for LAr detector development
- Challenge to simultaneously deliver physics and advance the technology
  - Necessity given our strategic vision for tackling neutrinos!!

SBN Program – Three detectors with one mission



	ICARUS	MicroBooNE	SBND	Produce
ν_μ Disappearance	Fewer ν_μ ?	Fewer ν_μ ?	ν_μ	ν_μ
ν_e Appearance	More ν_e?	More ν_e?	~1% ν_e	~1% ν_e

110m

470m

600m

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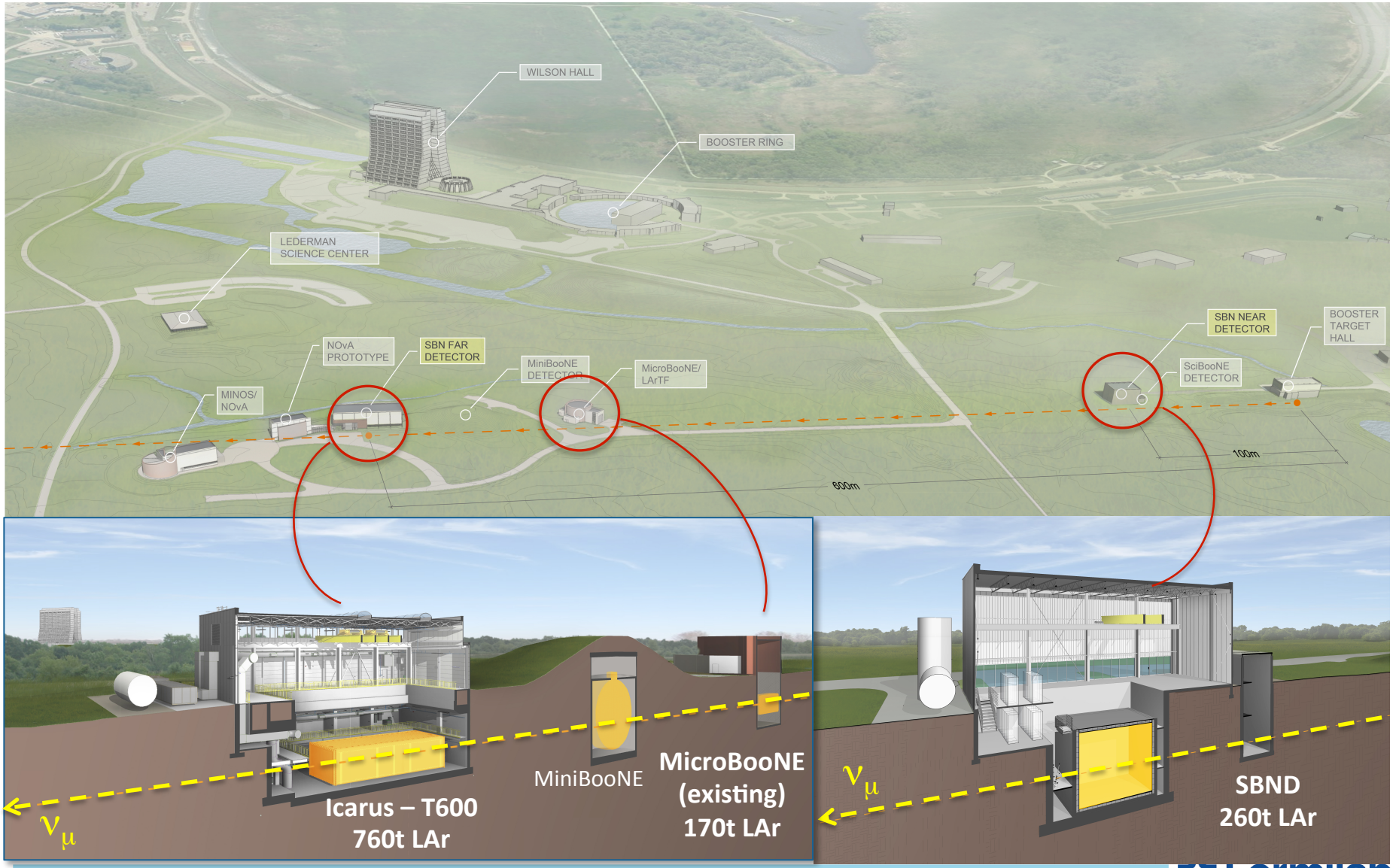
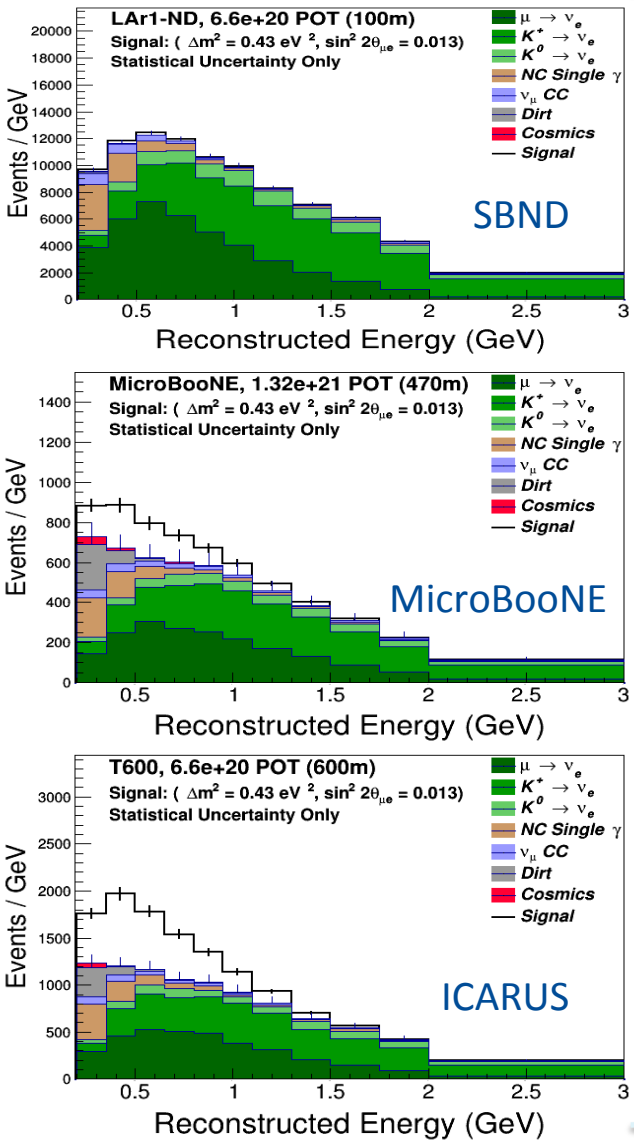
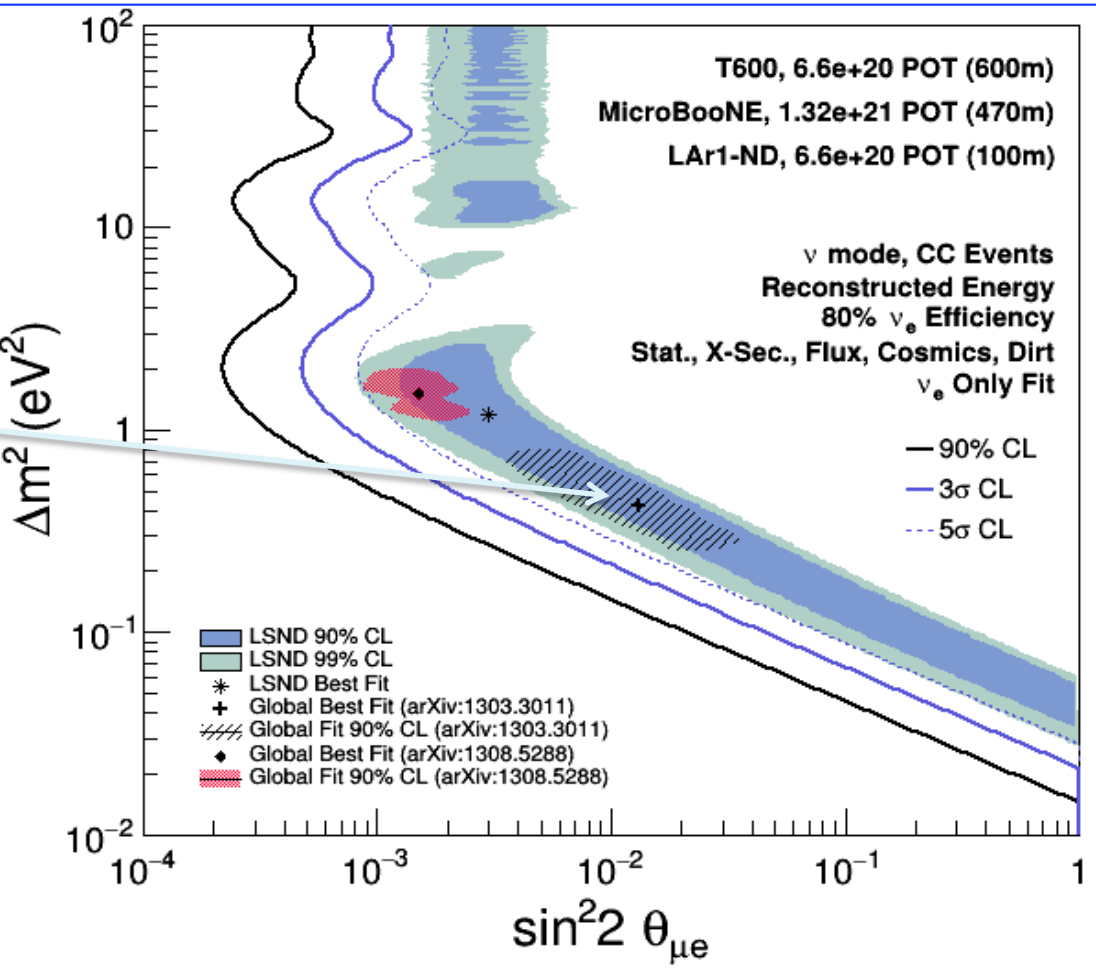
SBN Program – Three detectors with one mission



SBN ν_e Appearance Sensitivity



~5σ coverage of LSND 99% CL Region for 6.6x10^{20} P.O.T. ~ 3 years (13.2x10^{20} for MicroBooNE)



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Program Organization

- Many Stakeholders :
  - Three collaborations,
  - Collaboration spokespeople
  - SBN Group in FNAL Neutrino Division, SBN Coordinator
  - CERN Neutrino Platform
  - Funding agencies, DOE Detector R&D
- Distinct (and overlapping) Program Phases :
  - Planning and Design
    - Simulations for detector design
  - Construction and Installation
  - Operations
  - Physics Simulations
  - Data Analysis

Three Collaborations ➔ One Program

The ICARUS-WA104 Collaboration

M. Antonello[16], B. Baibussinov[31], V. Bellini[5], P. Benetti[32], S. Bertolucci[6], H. Bilokon[15], F. Boffelli[32], M. Bonesini[17], J. Bremer[6], E. Calligarich[32], S. Centro[31], A.G. Cocco[19], A. Dermenev[20], A. Falcone[32], C. Farnese[31], A. Fava[31], A. Ferrari[6], D. Gibin[31], S. Gninenko[20], N. Golubev[20], A. Guglielmi[31], A. Ivashkin[20], M. Kirsanov[20], J. Kisiel[38], U. Kose[6], F. Mammoliti[5], G. Mannocchi[15], A. Menegolli[32], G. Meng[31], D. Mladenov[6], C. Montanari[32], M. Nessi[6], M. Nicoletto[31], F. Noto[6], P. Picchi[15], F. Pietropaolo[31], P.Płoński[42], R. Potenza[5], A. Rappoldi[32], G. L. Raselli[32], M. Rossella[32], C. Rubbia*[6,11,16], P. Sala[18], A. Scaramelli[18], J. Sobczyk[44], M. Spanu[32], D. Stefan[18], R. Suley[43], C.M. Sutera[5], M. Torti[32], F. Tortorici[5], F. Varanini[31], S. Ventura[31], C. Vignoli[16], T. Wachala[12], and A. Zani[32]

The LAr1-ND Collaboration

C. Adams[45], C. Andreopoulos[23], A. Ankowski[41], J. Asaadi[40], L. Bagby[10], B. Baller[10], N. Barros[33], M. Bass[30], S. Bertolucci[6], M. Bishai[3], A. Bitadze[25], J. Bremer[6], L. Bugel[26], L. Camilleri[9], F. Cavanna[a,10], H. Chen[3], C. Chi[9], E. Church[10], D. Cianci[7], G. Collin[26], J.M. Conrad[26], G. De Geronimo[3], R. Dharmapalan[1], Z. Djurcic[1], A. Ereditato[2], J. Esquivel[40], J. Evans[25], B.T. Fleming[45], W.M. Foreman[7], J. Freestone[25], T. Gamble[37], G. Garvey[24], V. Genty[9], D. Göldi[2], H. Greenlee[10], R. Guenette[30], A. Hackenburg[45], R. Hänni[2], J. Ho[7], J. Howell[10], C. James[10], C.M. Jen[41], B.J.P. Jones[26], L.M. Kalousis[41], G. Karagiorgi[25], W. Ketchum[24], J. Klein[33], J. Klinger[37], U. Kose[6], I. Kreslo[2], V.A. Kudryavtsev[37], D. Lissauer[3], P. Livesly[22], W.C. Louis[24], M. Lu□thi[2], C. Mariani[41], K. Mavrokoridis[23], N. McCauley[23], N. McConkey[37], I. Mercer[22], T. Miao[10], G.B. Mills[24], D. Mladenov[6], D. Montanari[10], J. Moon[26], Z. Moss[26], S. Mufson[14], M. Nessi[6], B. Norris[10], F. Noto[6], J. Nowak[22], S. Pal[37], O. Palamara*[,b,10], J. Pater[25], Z. Pavlovic[10], J. Perkin[37], G. Pulliam[40], X. Qian[3], L. Qiuguang[24], V. Radeka[3], R. Rameika[10], P.N. Ratoff[22], M. Richardson[37], C. Rudolf von Rohr[2], D.W. Schmitz*[,7], M.H. Shaevitz[9], B. Sippach[9], M. Soderberg[40], S. Söldner-Rembold[25], J. Spitz[26], N. Spooner[37], T. Strauss[2], A.M. Szelc[25,45], C.E. Taylor[24], K. Terao[9], M. Thiesse[37], L. Thompson[37], M. Thomson[4], C. Thorn[3], M. Toups[26], C. Touramanis[23], R.G. Van De Water[24], M. Weber[2], D. Whittington[14], T. Wongjirad[26], B. Yu[3], G.P. Zeller[10], and J. Zennamo[7]

The MicroBooNE Collaboration

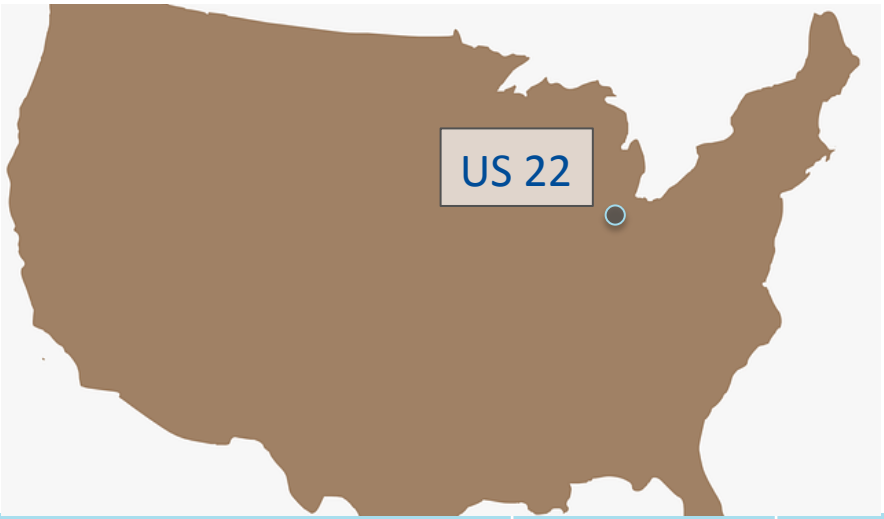
R. Acciarri[10], C. Adams[45], R. An[13], A. Ankowski[41], J. Asaadi[40], L. Bagby[10], B. Baller[10], G. Barr[30], M. Bass[30], M. Bishai[3], A. Blake[4], T. Bolton[21], C. Bromberg[27], L. Bugel[26], L. Camilleri[9], D. Caratelli[9], B. Carls[10], F. Cavanna[a,10], H. Chen[3], E. Church[10], G.H. Collin[26], J.M. Conrad[26], M. Convery[39], S. Dytman[34], B. Eberly[39], A. Ereditato[2], J. Esquivel[40], B.T. Fleming*[45], W.M. Foreman[7], V. Genty[9], D. Göldi[2], S. Gollapinni[21], M. Graham[39], E. Gramellini[45], H. Greenlee[10], R. Grosso[8], R. Guenette[30], A. Hackenburg[45], O. Hen[26], J. Hewes[25], J. Ho[7], G. Horton-Smith[21], C. James[10], C.M. Jen[41], R.A. Johnson[8], B.J.P. Jones[26], J. Joshi[3], H. Jostlein[10], D. Kaleko[9], L. Kalousis[41], G. Karagiorgi[25], W. Ketchum[24], B. Kirby[3], M. Kirby[10], T. Kobilarcik[10], I. Kreslo[2], Y. Li[3], B. Littlejohn[13], D. Lissauer[3], S. Lockwitz[10], W.C. Louis[24], M. Lu□thi[2], B. Lundberg[10], A. Marchionni[10], C. Mariani[41], J. Marshall[4], K. McDonald[35], V. Meddage[21], T. Miceli[28], G.B. Mills[24], J. Moon[26], M. Mooney[3], M.H. Moulai[26], R. Murrells[25], D. Naples[34], P. Nienaber[36], O. Palamara[b,10], V. Paolone[34], V. Papavassiliou[28], S. Pate[28], Z. Pavlovic[10], S. Pordes[10], G. Pulliam[40], X. Qian[3], J.L. Raaf[10], V. Radeka[3], R. Rameika[10], B. Rebel[10], L. Rochester[39], C. Rudolf von Rohr[2], B. Russell[45], D.W. Schmitz[7], A. Schukraft[10], W. Seligman[9], M. Shaevitz[9], M. Soderberg[40], J. Spitz[26], J. St. John[8], T. Strauss[2], A.M. Szelc[25,45], N. Tagg[29], K. Terao[9], M. Thomson[4], C. Thorn[3], M. Toups[26], Y. Tsai[39], T. Usher[39], R. Van de Water[24], M. Weber[2], S. Wolbers[10], T. Wongjirad[26], K. Woodruff[28], M. Xu[13], T. Yang[10], B. Yu[3], G.P. Zeller*[10], J. Zennamo[7], and C. Zhang[3]

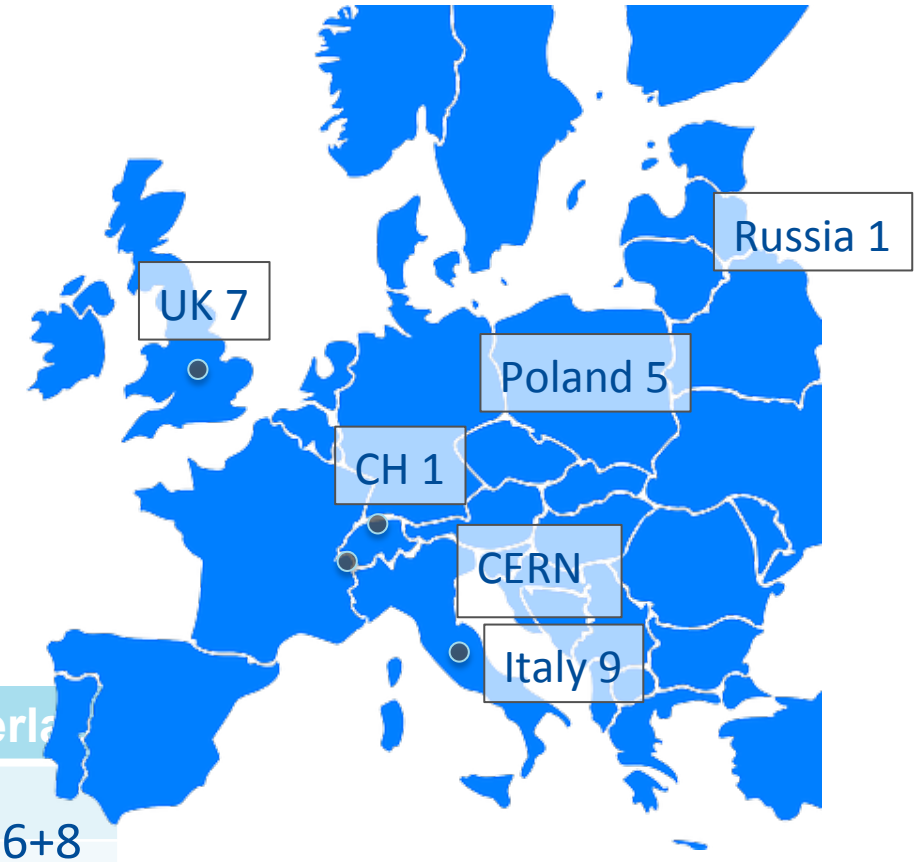
Additional Fermilab Contributors

W. Badgett[10], K. Biery[10], S. Brice[10], S. Dixon[10], M. Geynisman[10], E. Snider[10], and P. Wilson[10]

Collaboration spokespeople
Fermilab SBN Program Coordinator

SBN Institutions and Authors





Collaboration	Authors	Overla
ICARUS	~70	~6+8
SBND	112	~59
MicroBooNE	121	
All SBN (excl overlaps)	**~225**	

Recent addition of 6 U.S. institutions to ICARUS

Institutions	SBN	SBN-DUNE Overlap
US	22+2	20+2
Non-US	23	19

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U.S. Groups join ICARUS (ICAR-US)

Sunday, April 26, 2015 9:42 AM

Dear Colleagues

this is to let know that all the ICARUS participating groups have been formally consulted and have unanimously agreed to extend the ICARUS collaboration to you and your teams. Argonne National Laboratory, Colorado State University, Los Alamos National Laboratory, FermiLab, University of Pittsburgh and SLAC are presently new participants in the Collaboration.

Welcome in ICARUS !

Sincerely

Carlo Rubbia

ICAR-US

- Institutions and PIs
  - ANL : Z. Djurcic
  - FNAL : A. Fava (WF), Rameika, Wilson + several other senior scientists
  - LANL : G. Mills, B. Louis, R. van de Water
  - SLAC : M. Convery, T. Usher
  - Colorado State : R. Wilson (+ 2 students, 1 engineer)
  - Pittsburgh : V. Paolone (+student, post-doc)
- Potential tasks are :
  - Cosmic ray tagger, associated electronics
  - PMT readout electronics
  - Data Acquisition
- Initial meeting of US institutions with key members of ICARUS at Fermilab on May 20.
- Contributions being discussed; technical and manpower resources first, to be followed by discussion of how funding could work
- Regular meetings among US institutions over past 2 months

Building towards a single science collaboration

- Common systems
  - Infrastructure related :
    - slow controls, DAQ
    - Cryogenics
- Software and Analysis Tools
- What it will take :
  - Trust
  - Agreements

Communication

It is in progress but will take time

SBN Executive Board

- SBN Executive Board formed consisting of the collaboration spokespeople, deputy spokesperson and SBN coordinator:
  Carlo Rubbia, Sandro Centro, Bonnie Fleming, Sam Zeller, Dave Schmitz, Ornella Palamara and Peter Wilson
- First meeting held May 20 at Fermilab with Gina Rameika also in attendance.
  - Discussion of joint workshops on analysis and software
- Planning for next face-to-face meeting in July at time of building groundbreaking

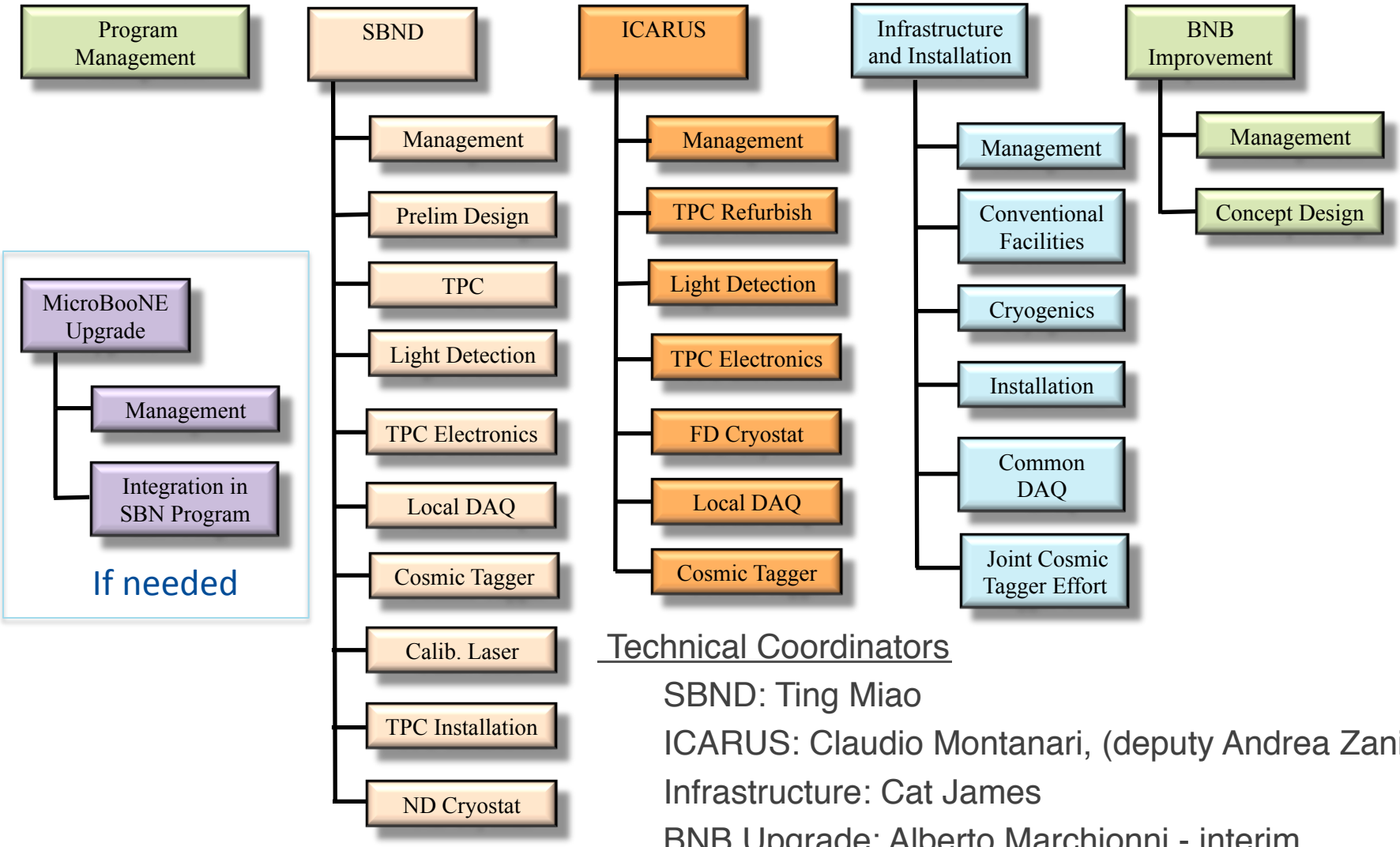
Physics and software coordination

- Critical to achieving the physics sensitivity will be close coordination of the software tools and analysis
- SBND and MicroBooNE already use the same software platform and share many software experts
- A next step is an ICARUS software workshop scheduled for July 20-24 at CERN including new US members who are experts on LArSoft, *art* and *artdaq* .
- Next stage will be workshops and working groups including all three collaborations
- Once these tools are in place it will be possible to more thoroughly examine issues of calibration and systematics across the program

Program Organization - SBN Program Office

- Program Coordinator – Peter Wilson
- Deputy Coordinator – Catherine James
- Program Mechanical Engineer
  - SBND interim – Joseph Howell
- Program Electrical Engineer – Linda Bagby
- ES&H Coordinator – Eric McHugh
- CERN-INFN-Fermilab Safety Coordination:
  - CERN Technical Safety POC – Olga Beltramello (CERN)
  - Fermilab Technical Safety POC – Min Jong Kim
- Project Controls – Richard Krull
- Financial Officer – Molly Anderson (ND FFM)
- Admin Support – Etta Johnson

SBN WBS



Technical Coordinators

SBND: Ting Miao

ICARUS: Claudio Montanari, (deputy Andrea Zani)

Infrastructure: Cat James

BNB Upgrade: Alberto Marchionni - interim

SBN Review Process

- SBN is not funded as a DOE project:
  - Collection of GPP, DOE funds and non-DOE funds (NSF, CERN, INFN, SNSF, STFC)
- Therefore, not managed as a DOE 413.3A project
  - For example: no critical decision (CD) process
- Instead, manage with a lightweight project management using a resource loaded schedule, milestones and technical reviews
- Coordinating with Office of the Chief Project Officer (Mike Lindgren) on the review process and appropriate “project” documentation
- Director’s reviews will assess the cost, schedule and risk of the program plan
- Technical design reviews organized by the SBN program to ensure that systems will meet the scientific and technical requirements of the program
  - Reports provided to Director’s review

Director's Reviews

- Organized by Chief Project Officer Office
  - DOE are participants. Other funding agencies will be invited.
- Plan for first review in October 2015
- For most systems intend this to be akin to DOE CD-2 Review – baseline of cost and schedule; management plan
  - Cover Design, Construction and Installation
  - Funding and staffing profile
  - "CD-3a" already happened for buildings under GPP process
- Follow-up Review(s) in 2016
  - Director's: Status on design, construction and installation
  - Plan for commission and operations (need to decide on forum)

SBN Technical Design Reviews

- Using new guidelines developed by Office of Chief Project Officer
  - Flexible template for use by projects
  - Defines series of reviews from requirements through operational readiness
- Adapt to needs of the SBN program
- Document development of design with requirements documents and technical design document for each subsystem rather than a single global TDR.
- Update technical design document at each review stage as appropriate
- Review by subsystem (L2) combining where appropriate.

Review Schedule

2015

- June-July: ad hoc reviews to examine specific requirements and conceptual design topics
- July-Sept: Design reviews of subsystems
- Oct: Director's Review of cost and schedule

Late 2015-16

- Final Design and Procurement Reviews for each subsystem
- Spring 2016(?): Director's Status Review

- In process of creating design review schedule for SBND. Next step will be to define necessary reviews for ICARUS.

Main SBN Funding Sources

U.S. DEPARTMENT OF ENERGY | Office of Science

NSF

INFN

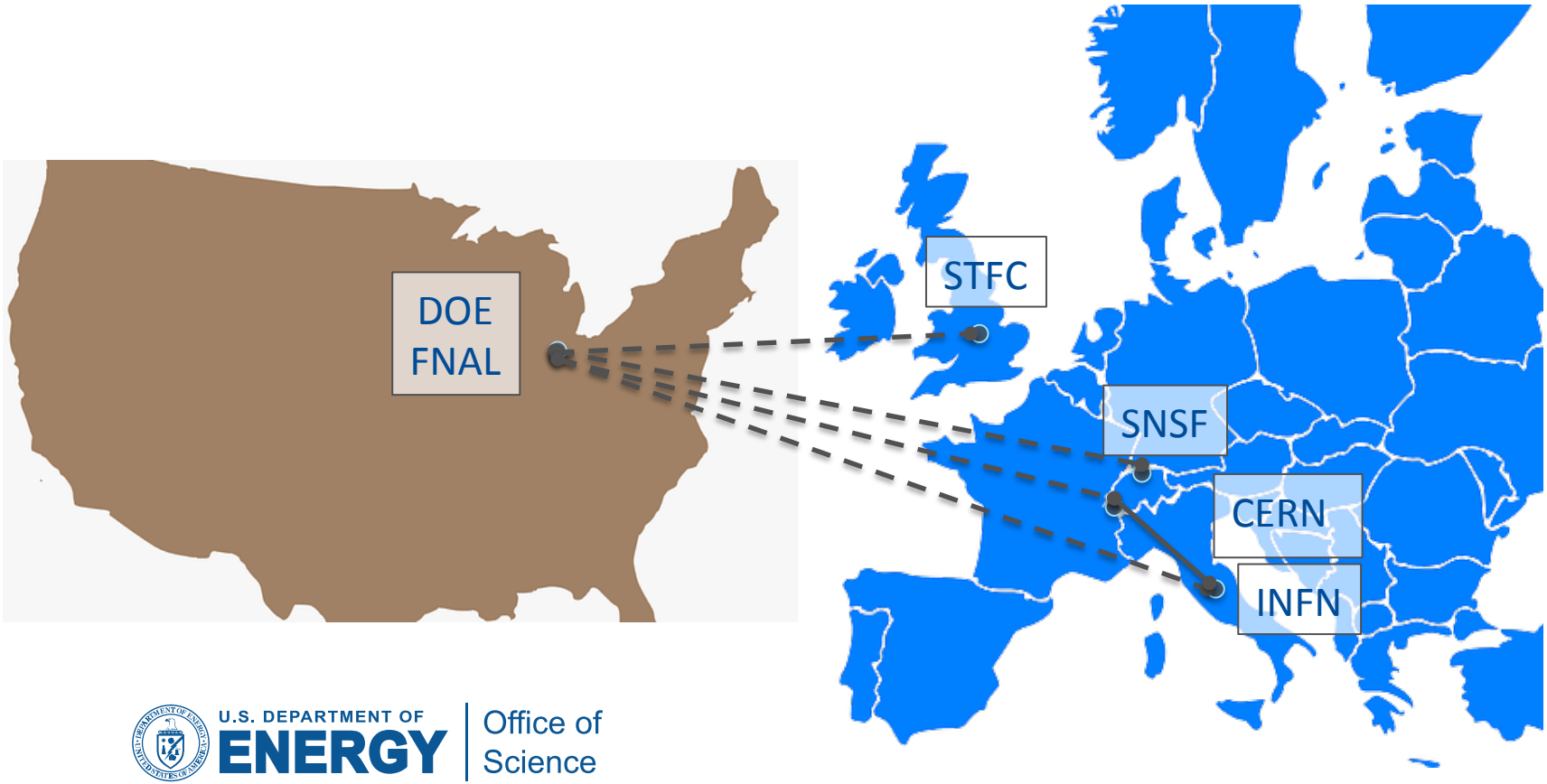
CERN

Science & Technology Facilities Council

FNSNF
Swiss National Science Foundation

Fermilab

Main International Agreements



U.S. DEPARTMENT OF ENERGY | Office of Science

Agreement Status
— Signed
- - In discussion

NSF

INFN

CERN

Science & Technology Facilities Council

FNSNF
Swiss National Science Foundation

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ICARUS refurbishment at CERN (WA-104)

Addendum No. 02

to the
Memorandum of Understanding
for Collaboration in the Neutrino Program

WA104

Improving the ICARUS T600 Liquid Argon Time Projection Chamber (LAr TPC) in order to prepare for its operation at shallow neutrino depths.

Version_22-11-2014

The European Organization for Nuclear Research (CERN)

and

The INFN, on behalf of the WA104 Collaboration

endorse the Present Addendum to the Memorandum of Understanding with the indicated improvements of ICARUS T600 and with the related R&D on Liquid Argon Time Projection Chamber (LAr TPC).

for CERN 25/11/2014

The Director of Reasearch and Computing

Sergio Bertolucci

For INFN, on behalf of INFN participating Institutes

The President

ISTITUTO NAZIONALE DI FISICA NUCLEARE
IL PRESIDENTE
Prof. Fernando Ferroni

Signature

Place and Date

ROMA, 28 NOV. 2014

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CERN – Fermilab Coordination on SBN Infrastructure

- Scope of shared work on infrastructure captured in draft agreement
- Fermilab engineer (David Montanari) based at CERN since January
  - Interface between Fermilab engineering and CERN engineering

Agreement between CERN and Fermilab on activities in support of the Fermilab Short Baseline Neutrino Program

CERN and Fermilab have agreed to cooperate on the development of LArTPCs and necessary infrastructures for future neutrino experiments. We describe here the areas of joint effort between the two laboratories on Fermilab Short Baseline Neutrino Program (SBN).

The primary areas of CERN contribution to the SBN program will be in support infrastructure, integration, logistics and installation. The systems include:

- Detector cryostats
- Cryogenic systems
- Installation support
- Cryogenic controls
- Data acquisition hardware and software

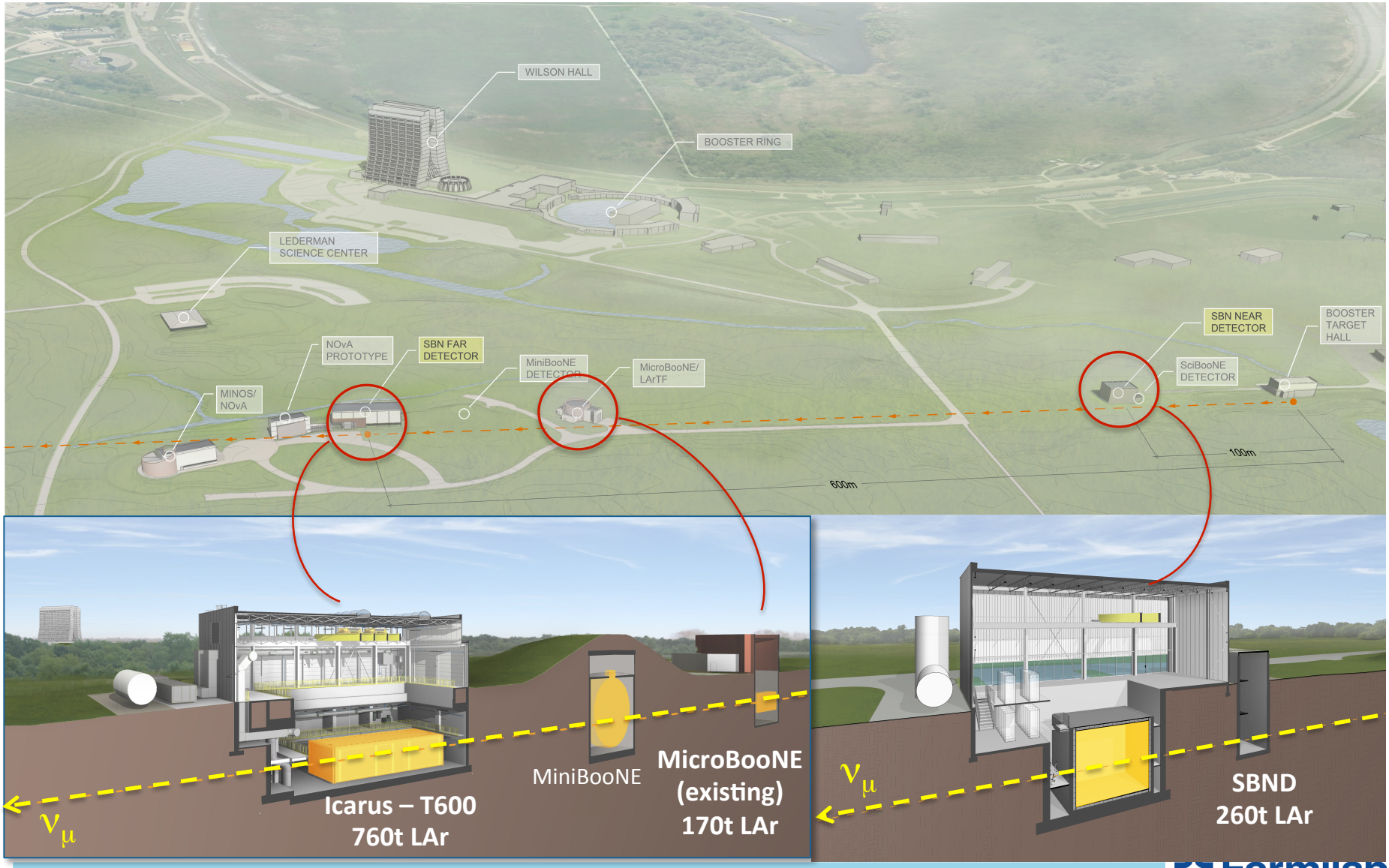
At this time we focus on deliverables for cryostats, cryogenics and installation support. We note that there are very similar tasks for cryostats, cryogenics and controls for WA105 and the DUNE single-phase prototype at CERN. The size of these systems is very similar to ICARUS and with a very similar schedule for operations.

As host laboratory, Fermilab has primary responsibility for providing the safety review of all the systems.

Near Detector Cryostat

The SBN near detector will use the membrane cryostat technology developed for transport and storage of liquefied natural gas. This technology is being explored for far detectors at the Long Baseline Neutrino Facility. Worldwide there are two suppliers of the technology: GTT of France and IHI of Japan. Fermilab gained experience with the technology with the construction of cryostat containing 35t of LAr as part of the LBNE project R&D. This cryostat was designed and fabricated by IHI in 2012. The first membrane cryostat at CERN is being designed and constructed by GTT for a small two-phase LArTPC prototype as part of the WA105 collaboration with installation anticipated in mid-2015. In addition to differing in vendor for the membrane technology these installations differ in design of the warm cryostat support technology. The outer cryostat structure (aka warm cryostat) for

Three detectors with one technology: Liquid Argon TPC



Strategy for SBN Detectors

- Far Detector: ICARUS T-600
  - Exists
  - Has operated
  - Being upgraded
- Middle Detector: MicroBooNE
  - Exists
  - Now commissioning
  - Upgrade if needed
- Near Detector: SBND
  - Doesn't exist
  - Needs to be designed, built, installed and operated, …
  - Needs to incorporate lessons learned as well as new ideas; in particular ones that will inform us how to scale to larger detector mass
  - Funding available from a variety of sources, for a variety of reasons :
    - Physics, international collaboration,…

Not a construction project;
Not R&D;
Install and commission
as Detector Operations

We are developing a construction plan funded by a variety of sources; manage it using standard PM Principles;
Commissioning
will be Detector Operations

T600 Milestones and Funding Plan: CERN-INFN agreement

Version_22-11-2014

ANNEX 5: Project Milestones

1. First T600 TPC transport to CERN: November 2014
2. Second T600 TPC transport to CERN: December 2014
3. First T600 aluminum vessel ready at CERN: October 2015
4. Second T600 aluminum vessel ready at CERN: October 2016
5. First T600 TPC ready for insertion in the new cold vessel: November 2015
6. Second T600 TPC ready for insertion in the new cold vessel: November 2016
7. T600 ready for transport to FNAL: beginning 2017

Includes:
- PMT replacement
- Limited cosmic ray tagger
- No TPC or PMT electronics

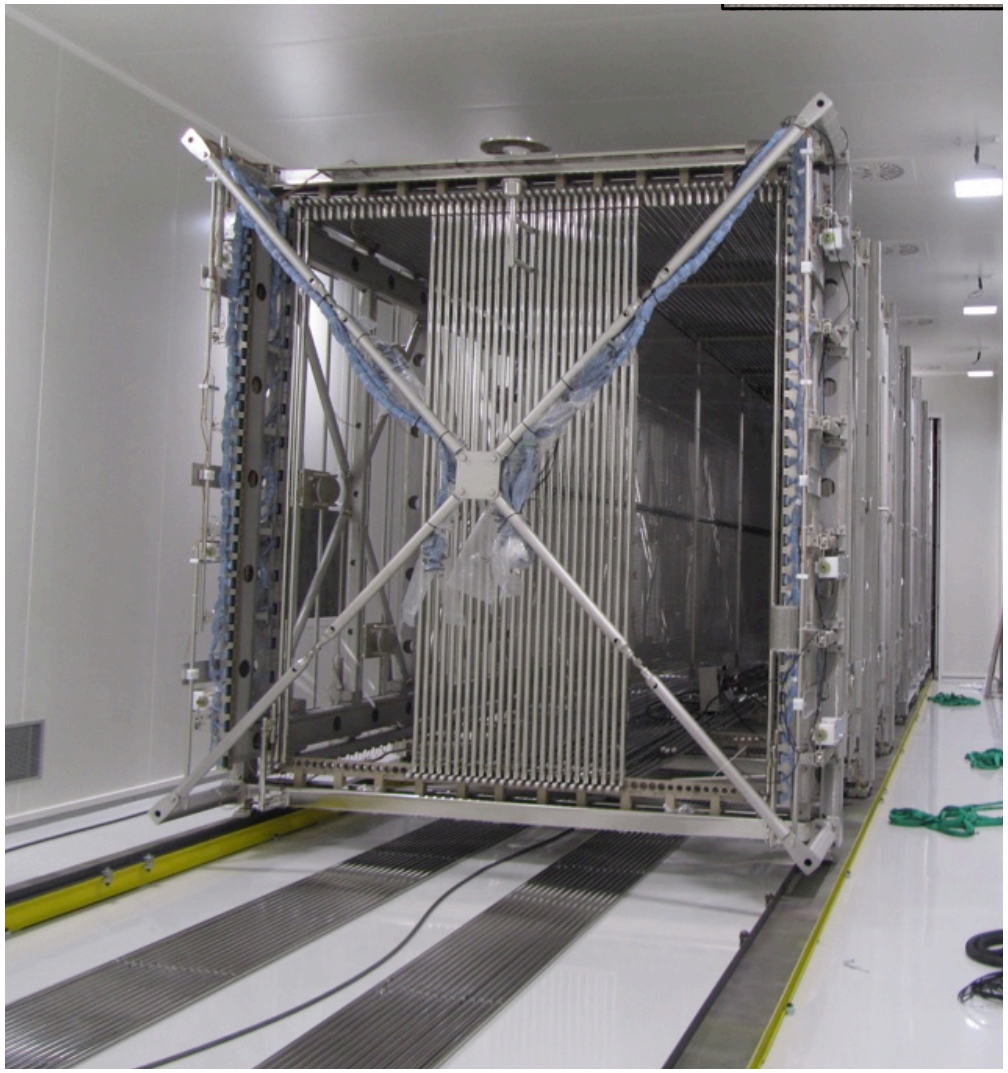
Task	TotalCost (KCHF)	CERN	INFN
Movement to CERN	1227	504	723
Cryostats	3951	2082	1869
Cryogenics	1108	1108	0
Refurbishing	2531	663	1868
Slow controls and DAQ	115	115	0
Veto counters procurement and pre-assembly	1200	600	600
Total	**10132**	**5072**	**5060**

Core Costs

ICARUS transport to CERN

FIG. 23: *The transport vessel on its way to CERN.*

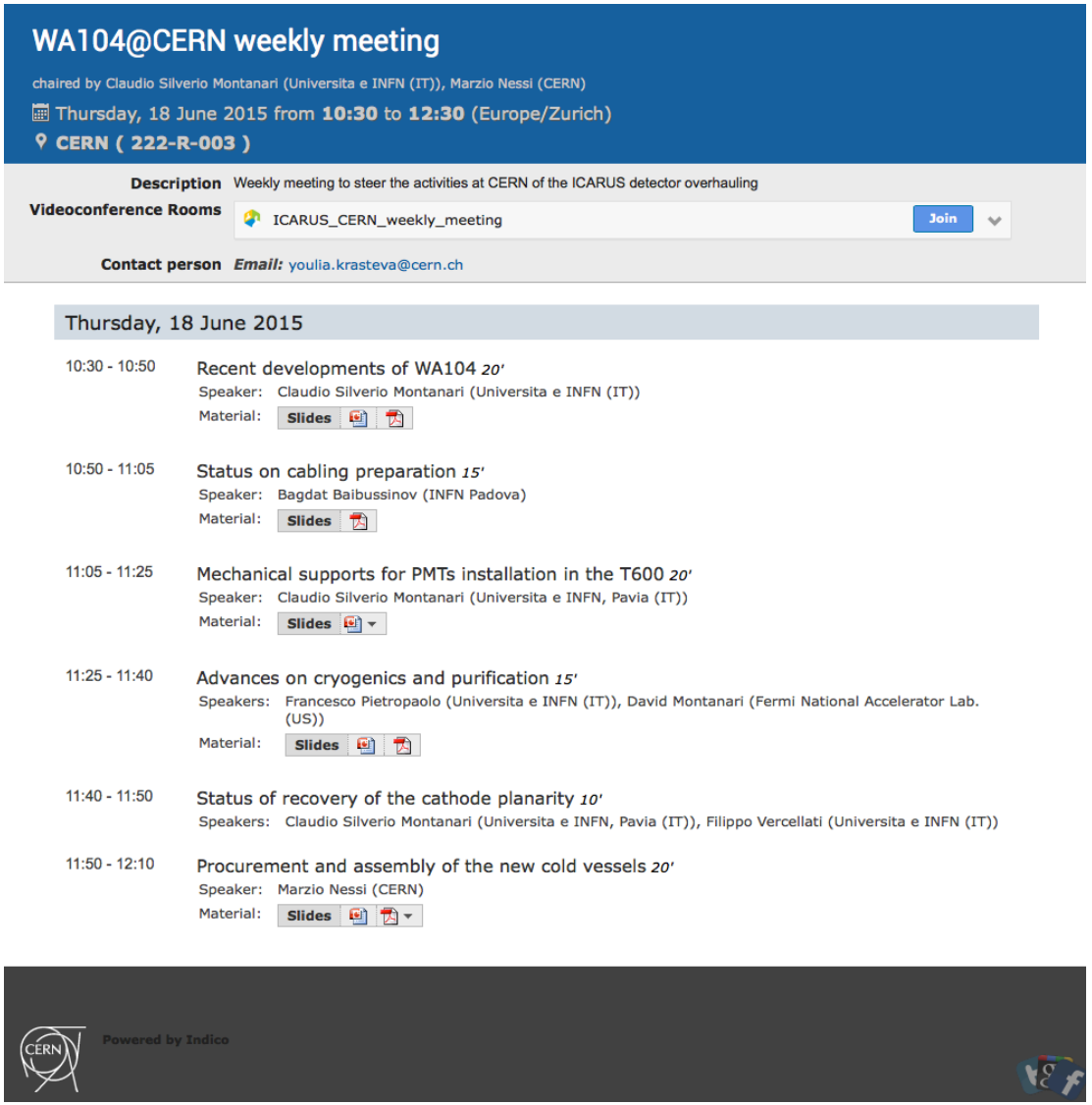
1st T-300 TPC in clean room



- Tasks in progress (WA104)
  - New cryostats
  - Rebuild cryogenics
  - Replace internal TPC cabling
  - Flattening cathode planes
  - PMTs : 90 new 8” tubes behind each wire plane (360 total)
- Other tasks under discussion
  - Upgrade of TPC front-end electronics
  - Electronics and readout for PMTs
  - Construction of a cosmic ray tagger

T600 Refurbishing

- Regular WA104 meeting chaired by Claudio Montanari (TC) covering refurbishing topics
- Preparing for purchase of new PMTs and TPC cabling
- Preparing final plans for cold cryostat vessels: first vessel fall 2015
- Working to schedule for delivery of both T300 TPCs to Fermilab when building is ready in early FY17



WA104@CERN weekly meeting

chaired by Claudio Silverio Montanari (Universita e INFN (IT)), Marzio Nessi (CERN)

Thursday, 18 June 2015 from **10:30** to **12:30** (Europe/Zurich)

CERN (222-R-003)

Description Weekly meeting to steer the activities at CERN of the ICARUS detector overhauling

Videoconference Rooms ICARUS_CERN_weekly_meeting — Join

Contact person ***Email:*** youlia.krasteva@cern.ch

Thursday, 18 June 2015

10:30 - 10:50 Recent developments of WA104 *20'*
Speaker: Claudio Silverio Montanari (Universita e INFN (IT))
Material: Slides

10:50 - 11:05 Status on cabling preparation *15'*
Speaker: Bagdat Baibussinov (INFN Padova)
Material: Slides

11:05 - 11:25 Mechanical supports for PMTs installation in the T600 *20'*
Speaker: Claudio Silverio Montanari (Universita e INFN, Pavia (IT))
Material: Slides

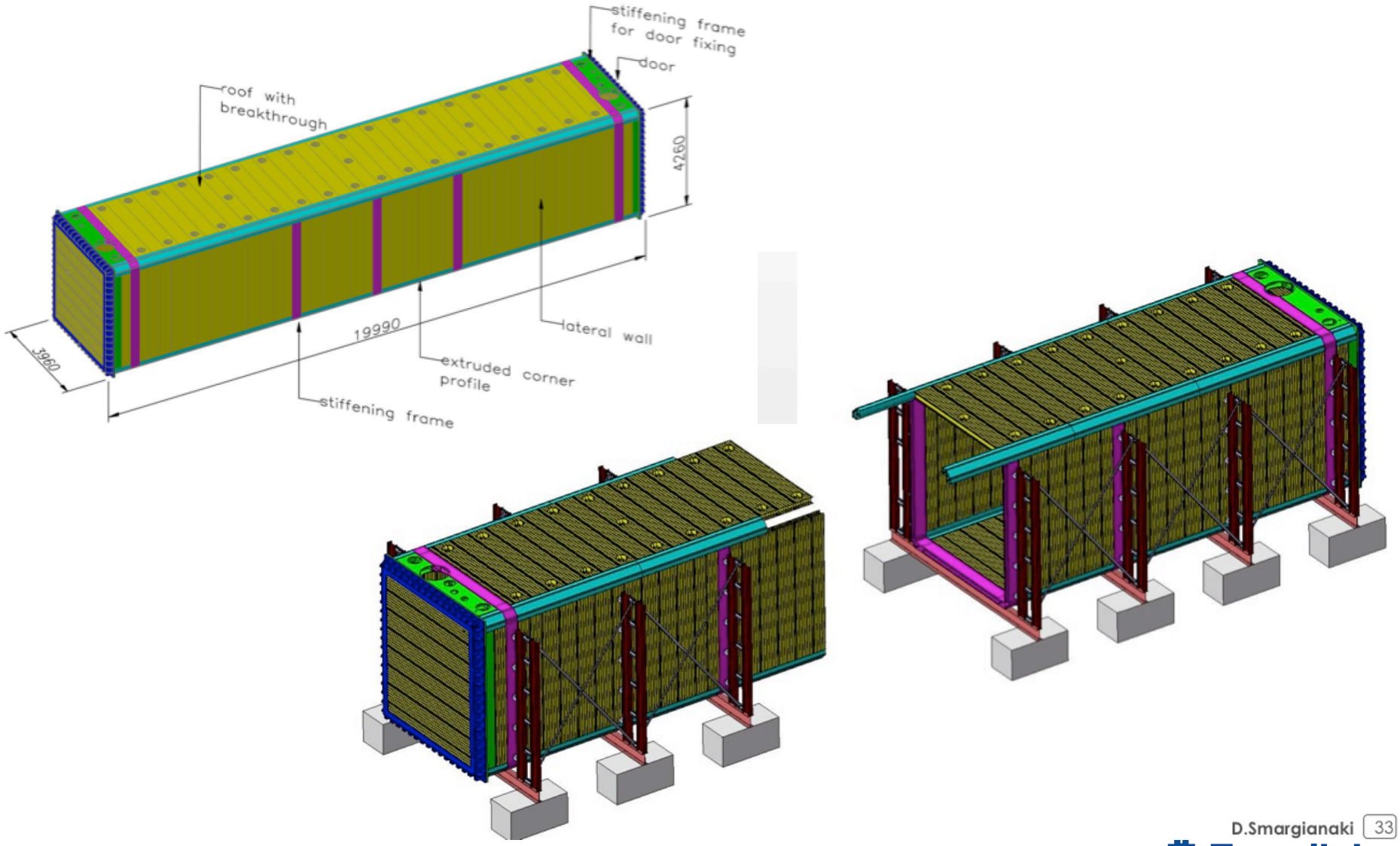
11:25 - 11:40 Advances on cryogenics and purification *15'*
Speakers: Francesco Pietropaolo (Universita e INFN (IT)), David Montanari (Fermi National Accelerator Lab. (US))
Material: Slides

11:40 - 11:50 Status of recovery of the cathode planarity *10'*
Speakers: Claudio Silverio Montanari (Universita e INFN, Pavia (IT)), Filippo Vercellati (Universita e INFN (IT))

11:50 - 12:10 Procurement and assembly of the new cold vessels *20'*
Speaker: Marzio Nessi (CERN)
Material: Slides

CERN Powered by Indico

Example: Cold cryostat assembly plans

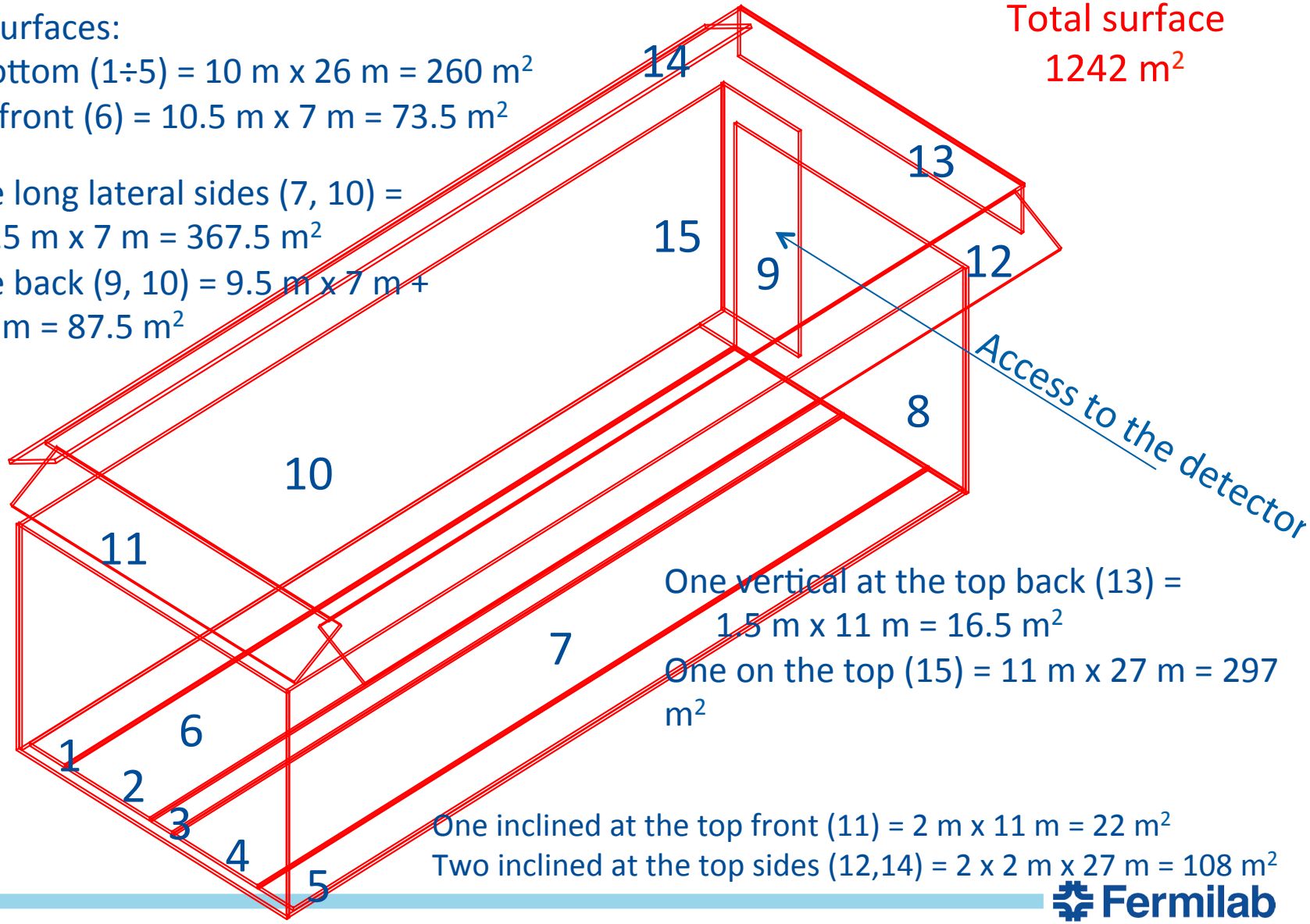


Concept for ICARUS Cosmic Rays Tagger

15 planar surfaces:
5 on the bottom (1÷5) = 10 m x 26 m = 260 m^2
one at the front (6) = 10.5 m x 7 m = 73.5 m^2

Two on the long lateral sides (7, 10) =
2 x 26.25 m x 7 m = 367.5 m^2
Two on the back (9, 10) = 9.5 m x 7 m +
3 m x 7 m = 87.5 m^2

Total surface
1242 m^2

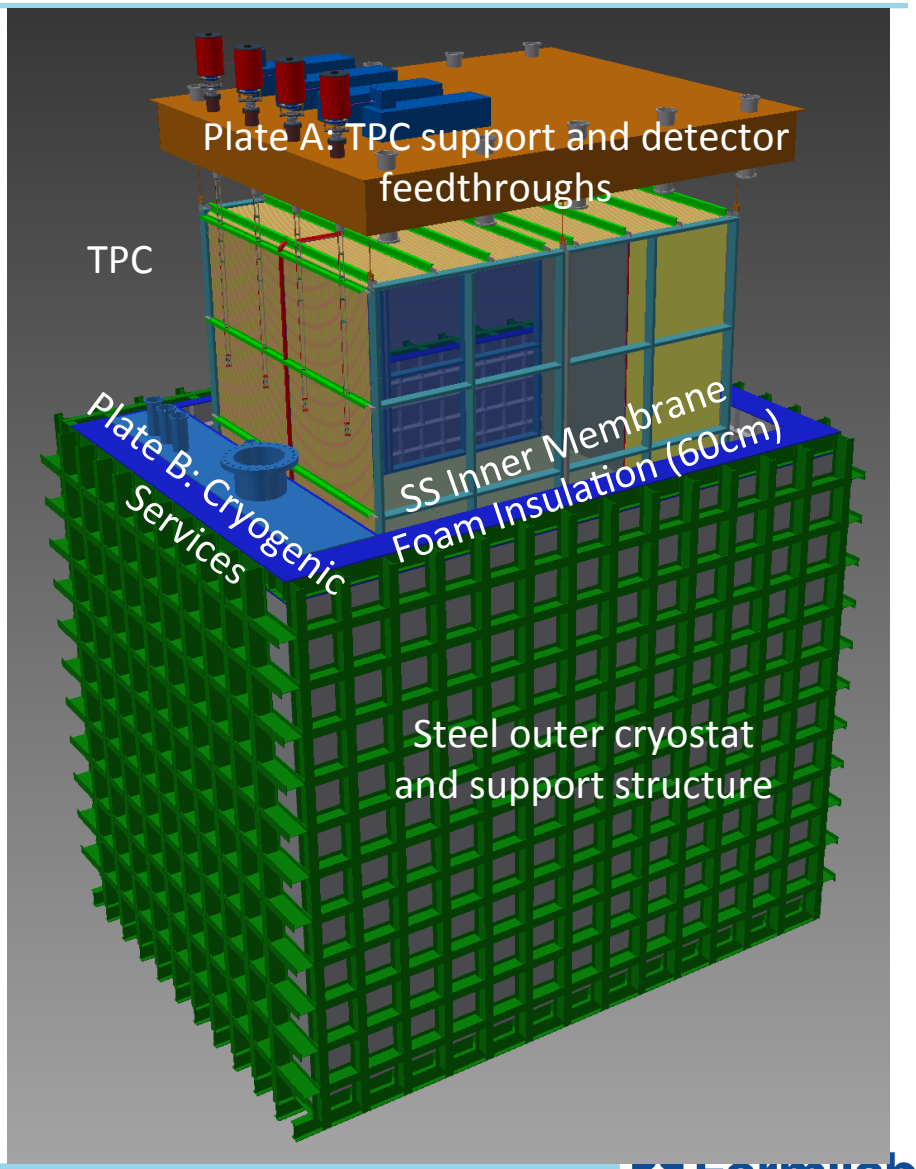


One vertical at the top back (13) =
1.5 m x 11 m = 16.5 m^2
One on the top (15) = 11 m x 27 m = 297 m^2

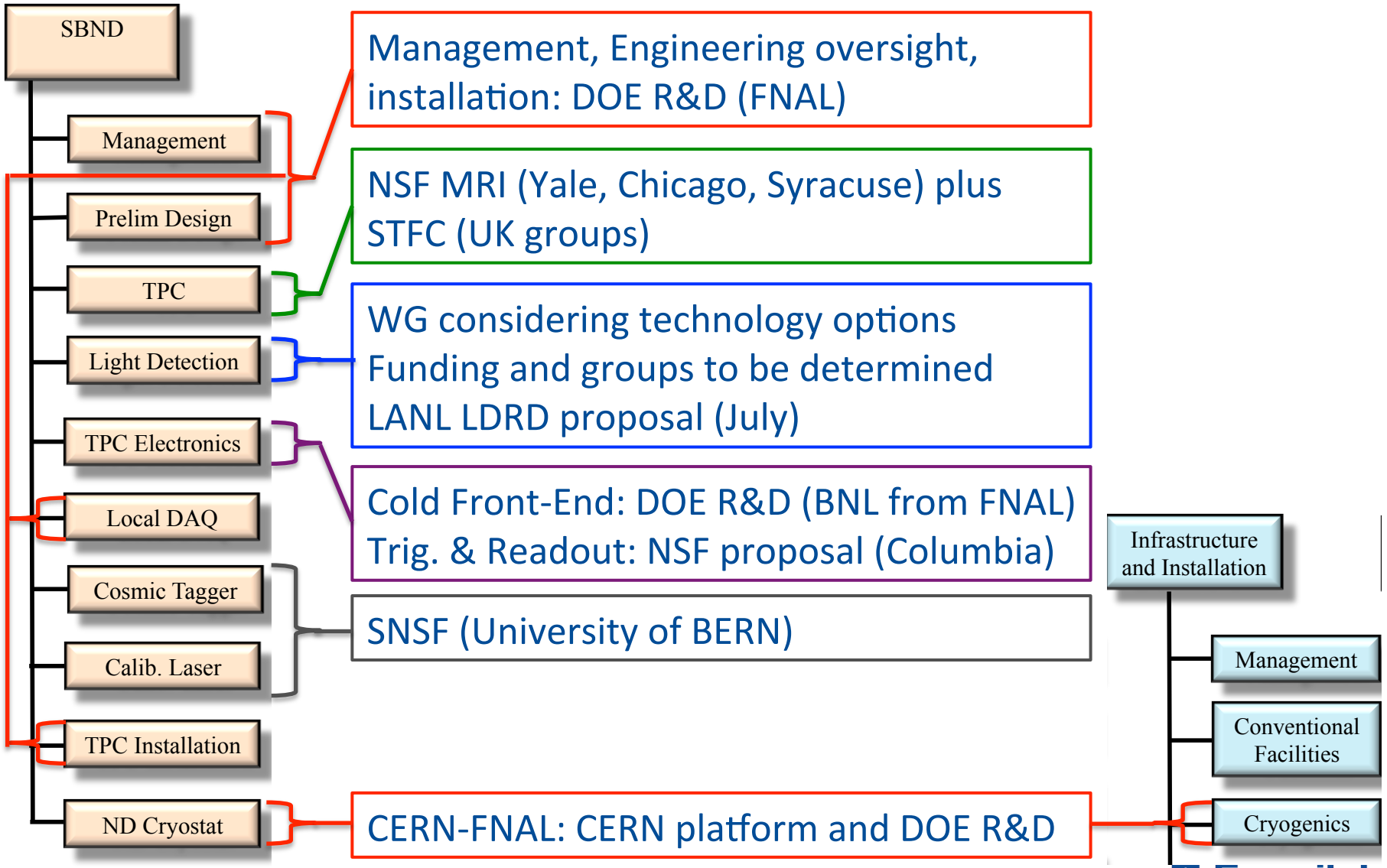
One inclined at the top front (11) = 2 m x 11 m = 22 m^2
Two inclined at the top sides (12,14) = 2 x 2 m x 27 m = 108 m^2

SBN Near Detector: SBND (formerly known as LAr1-ND)

- **Detector Development** : Build on experience and lessons learned from ICARUS, MicroBooNE, LBNE 35 ton prototype
- **Detector Development** : incorporate ideas being discussed for DUNE
- **Physics** : size and location to provide best control of systematics for ν_e appearance
- **Schedule** : make decisions in a timely manner to be ready when far detector is ready
- **Cost** : use multiple funding sources to cover required scope



SBND Scope of Work and Funding



SBND Coordination

Integration meetings since Dec 2014:

ND Installation Design 27May2015

SBN-doc-#	Title	Author(s)	Topic(s)	Last Updated
424-v2	TPC suspension concepts	Rich Northrop *et al.*	Integration	27 May 2015
427-v1	Cold vs Warm Ullage Discussion May 21 2015	Michael Geynisman	Cryostat Cryogenics Near Detector	26 May 2015
407-v4	LAr1-ND cryostat top FEA - TPC load & 5 psi ullage pressure	Joe Howell *et al.*	Near Detector	26 May 2015

First Technical Board meeting:

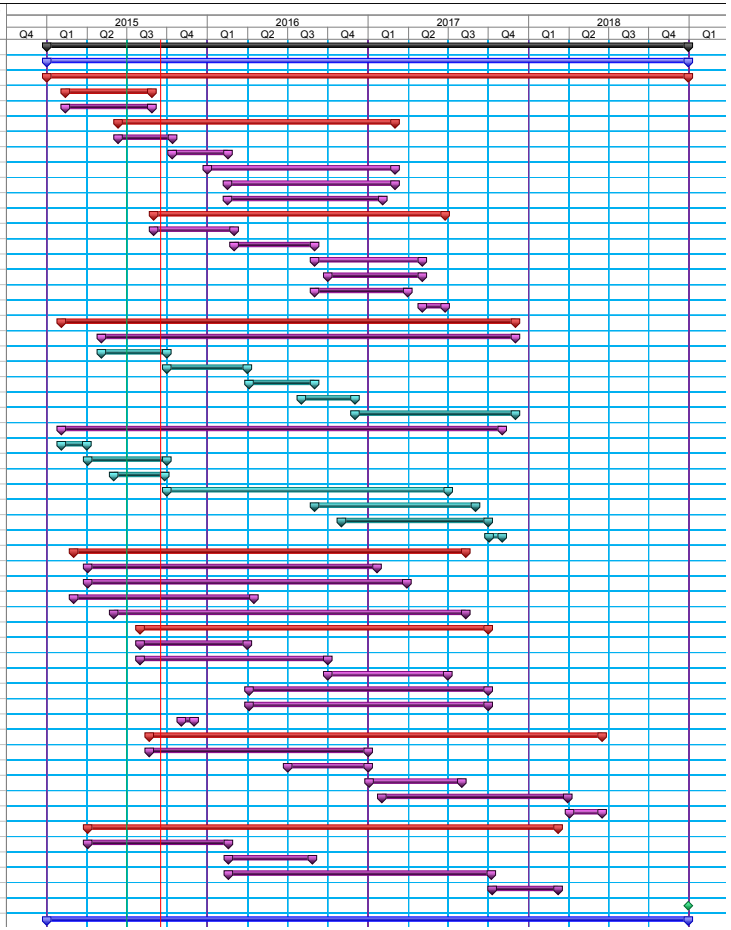
ND Technical Board Meeting June 3, 2015

SBN-doc-#	Title	Author(s)	Topic(s)	Last Updated
445-v2	TPC Preliminary Gantt Chart	Kostas Mavrokoridis	TPC	03 Jun 2015
442-v2	June-3-2015 ND Technical Board Meeting	Ting Miao	Near Detector	03 Jun 2015
446-v1	Liverpool TPC Engineers' Meeting Preliminary Agenda	Kostas Mavrokoridis	TPC	03 Jun 2015
444-v1	Nevis Electronics Status	Leslie Camilleri	Electronics	03 Jun 2015
443-v1	DAQ Tech Board slide	Eric D Church	Program Management	03 Jun 2015
441-v1	SBND Cryostat and Cryogenics - Technical Board Jun 3 2015	David Montanari	Cryostat Cryogenics Near Detector	03 Jun 2015
440-v1	TPC Cold Electronics Advancement Plan and SBND Strategy	Hucheng Chen	Electronics	03 Jun 2015
439-v1	CRT and Laser calibration status - brief & full	Igor Kreslo	Electronics External Tracking System Laser Calibration Cosmic Tagger	03 Jun 2015

SBND Schedule

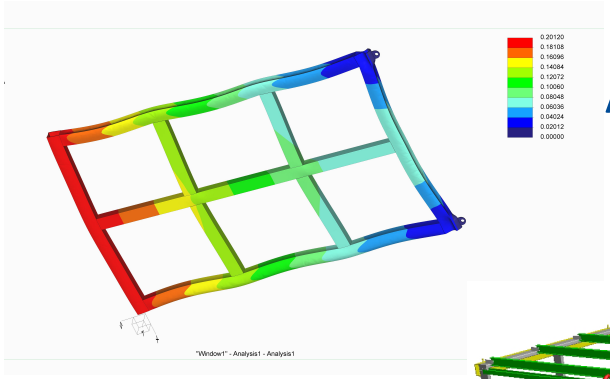
First complete schedule for detector WBS

UID	ID	WBS	Name	Start	Finish	Duration	% Complete
1	1	40SBN	Short Baseline Neutrino (SBN)	10/1/14	9/28/18	1003 d	0%
2	44	40SBN/2	Short Baseline Neutrino Near Detector (SBN-ND)	10/1/14	9/28/18	1003 d	0%
3	45	40SBN/2.1	Program Management (SBN-ND-PM)	10/1/14	9/28/18	1003 d	0%
14	79	40SBN/2.2	Preliminary Detector Design (SBN-ND-PDD)	11/11/14	5/27/15	133 d	0%
191	80	40SBN/2.2.1	Preliminary Detector Design & Installation (SBN-ND-PDD)	11/11/14	5/27/15	133 d	0%
98	93	40SBN/2.3	TPC Construction (SBN-ND-TPCC)	3/12/15	11/30/16	435 d	0%
99	94	40SBN/2.3.1	TPC Preliminary Design (SBN-ND-TPCC)	3/12/15	7/13/15	86 d	0%
1820	114	40SBN/2.3.2	TPC Final Design (SBN-ND-TPCC)	7/13/15	11/16/15	90 d	0%
1828	127	40SBN/2.3.3	TPC Component Fabrication - UK (SBN-ND-TPCC)	10/1/15	11/30/16	293 d	0%
1848	131	40SBN/2.3.4	TPC Component Fabrication - US (SBN-ND-TPCC)	11/16/15	11/30/16	261 d	0%
1824	136	40SBN/2.3.5	TPC Assembly and Installation Preparations (SBN-ND-TPCC)	11/16/15	11/2/16	243 d	0%
101	138	40SBN/2.4	Light Detector Construction (SBN-ND-LDC)	6/1/15	3/24/17	456 d	0%
102	139	40SBN/2.4.1	Light Detector Design (SBN-ND-LDC)	6/1/15	11/30/15	127 d	0%
1574	152	40SBN/2.4.2	Light Detector Signal Feed Through and Installation Support Productions (SBN-ND-LDC)	12/1/15	5/31/16	125 d	0%
1576	159	40SBN/2.4.3	Light Guide Bar System Assembly (SBN-ND-LDC)	6/1/16	1/31/17	166 d	0%
1578	168	40SBN/2.4.4	PMT System Assembly (SBN-ND-LDC)	7/1/16	1/31/17	144 d	0%
1580	177	40SBN/2.4.5	Light Detector Readout (SBN-ND-LDC)	6/1/16	12/29/16	146 d	0%
1582	188	40SBN/2.4.6	Light Detector Installation (SBN-ND-LDC)	2/1/17	3/24/17	38 d	0%
104	195	40SBN/2.5	Laser Calibration System and Cosmic-Ray Detector Construction (SBN-ND-LCC)	11/3/14	8/31/17	710 d	0%
105	196	40SBN/2.5.1	Laser Calibration System (SBN-ND-LCC)	2/2/15	8/31/17	652 d	0%
106	197	40SBN/2.5.1.1	Adaptation of the MicroBooNE Laser Calibration to LAR1ND Cryostat (SBN-ND-LCC)	2/2/15	6/30/15	106 d	0%
997	208	40SBN/2.5.1.2	Fabrication of Components of Laser Calibration System (SBN-ND-LCC)	7/1/15	12/30/15	125 d	0%
998	222	40SBN/2.5.1.3	Assembly and Test of Laser Calibration System at Bern (SBN-ND-LCC)	1/4/16	5/31/16	105 d	0%
999	236	40SBN/2.5.1.4	Laser Calibration System Delivery to Fermilab (SBN-ND-LCC)	5/2/16	8/31/16	86 d	0%
1000	243	40SBN/2.5.1.5	Laser Calibration Installation (SBN-ND-LCC)	9/1/16	8/31/17	251 d	0%
1652	248	40SBN/2.5.2	Cosmic Ray Tagger Construction (SBN-ND-LCC)	11/3/14	8/1/17	688 d	0%
1653	249	40SBN/2.5.2.1	Preparation of Requirement Documents (SBN-ND-LCC)	11/3/14	12/30/14	38 d	0%
1654	254	40SBN/2.5.2.2	Preliminary Design and Tests (SBN-ND-LCC)	1/2/15	6/30/15	126 d	0%
1655	268	40SBN/2.5.2.3	Production of Module #0 and Tests (SBN-ND-LCC)	3/2/15	6/25/15	83 d	0%
1656	279	40SBN/2.5.2.4	Mass Production of Planes #1 - #7 (SBN-ND-LCC)	7/1/15	3/31/17	439 d	0%
1657	292	40SBN/2.5.2.5	Modules Delivery to Fermilab (SBN-ND-LCC)	6/1/16	6/1/17	252 d	0%
1658	302	40SBN/2.5.2.6	Installation of CRT Modules at the Detector (SBN-ND-LCC)	8/1/16	6/30/17	231 d	0%
1659	306	40SBN/2.5.2.7	CRT Commissioning (SBN-ND-LCC)	7/3/17	8/1/17	21 d	0%
107	310	40SBN/2.6	TPC Electronics (SBN-ND-TPCE)	12/1/14	5/10/17	613 d	0%
108	311	40SBN/2.6.1	TPC Cold Electronics (SBN-ND-TPCE)	1/2/15	10/20/16	456 d	0%
820	362	40SBN/2.6.2	TPC Warm Interface Electronics (SBN-ND-TPCE)	1/2/15	12/27/16	500 d	0%
821	395	40SBN/2.6.3	TPC Readout Signal Feed-through and Cold Cable (SBN-ND-TPCE)	12/1/14	1/14/16	280 d	0%
954	444	40SBN/2.6.4	Nevis TPC Readout Electronics Design (SBN-ND-TPCE)	3/2/15	5/10/17	553 d	0%
110	486	40SBN/2.7	DAQ (SBN-ND-DAQ)	5/1/15	6/30/17	545 d	0%
111	487	40SBN/2.7.1	Readout and DAQ Integration Design (SBN-ND-DAQ)	5/1/15	12/30/15	167 d	0%
1047	504	40SBN/2.7.2	Readout Power Supplies and Cabling Designs (SBN-ND-DAQ)	5/1/15	6/30/16	294 d	0%
1049	526	40SBN/2.7.3	Production of Power Supplies, Cabling and Relay Racks (SBN-ND-DAQ)	7/1/16	3/30/17	186 d	0%
1051	533	40SBN/2.7.4	DAQ Trigger Electronics Integration Design and Installation (SBN-ND-DAQ)	1/4/16	6/30/17	378 d	0%
1053	544	40SBN/2.7.5	Detector Control System (SBN-ND-DAQ)	1/4/16	6/30/17	378 d	0%
1798	555	40SBN/2.7.6	Production of DAQ Teststand (SBN-ND-DAQ)	8/3/15	8/31/15	21 d	0%
113	558	40SBN/2.8	Installation Coordination (SBN-ND-IC)	5/22/15	3/16/18	706 d	0%
114	559	40SBN/2.8.1	Near Detector Installation Design (SBN-ND-IC)	5/22/15	9/30/16	343 d	0%
1099	581	40SBN/2.8.2	Near Detector Assembly Facility Setup (SBN-ND-IC)	4/1/16	9/30/16	128 d	0%
1097	593	40SBN/2.8.3	Near Detector Assembly (SBN-ND-IC)	10/3/16	5/1/17	144 d	0%
1095	620	40SBN/2.8.4	Near Detector Installation (SBN-ND-IC)	11/1/16	12/28/17	289 d	0%
1093	651	40SBN/2.8.5	Warm Detector Commissioning (SBN-ND-IC)	1/2/18	3/16/18	53 d	0%
138	659	40SBN/2.9	Near Detector Cryostat (SBN-ND-C)	1/2/15	12/6/17	738 d	0%
141	660	40SBN/2.9.1	Preliminary Design of Near Detector Cryostat (SBN-ND-C)	1/2/15	11/17/15	224 d	0%
253	679	40SBN/2.9.2	Final Design of Near Detector Cryostat (SBN-ND-C)	11/18/15	5/26/16	130 d	0%
255	695	40SBN/2.9.3	Procurement and Installation of Near Detector Cryostat (SBN-ND-C)	11/17/15	7/7/17	409 d	0%
257	721	40SBN/2.9.4	Commissioning Cool-down of Near Detector Cryostat (SBN-ND-C)	7/10/17	12/6/17	105 d	0%
73	727	40SBN/2.10	(T3) - [End WBS2] - End of Near Detector (SBN-ND)	9/28/18	9/28/18	0 d	0%
75	807	40SBN/4	Short Baseline Neutrino Infrastructure and Installation (SBN-II)	10/1/14	9/28/18	1003 d	0%



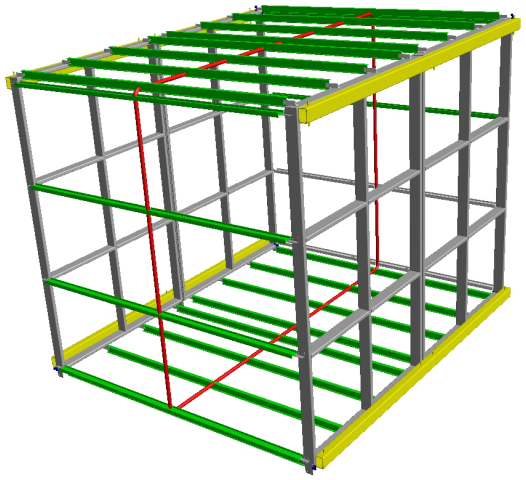
SBND TPC

- Responsibilities of collaborating institutes defined (UK-US)
- Workshop this week in Liverpool
- Advancing design:



Anode Plane FEA

TPC Structure Concept



Liverpool TPC Engineers' Meeting Preliminary Agenda

Venue: Stephenson Institute For Renewable Energy (SIRE) seminar room

Monday 22/6/15

10:00 - 12:00 Unofficial Interactive Eng. Modeling session at Peter Sutcliffe's office (Designers only, meet at my office 307, 3rd floor, Physics Department, Oliver Lodge building)

12:00 Formal start at the Stephenson Institute seminar room

12:00 -12:30 Overview on preliminary design status and plan – Bo Yu

12:30 – 13:30 CPA review -Liverpool

(Working lunch 13:00)

13:30 - 14:30 APA Frame review -Sheffield/BNL

14:30 -15:30 APA winding UK process review -Manchester

15:30 -16:00 Coffee break

16:00 - 16:30 US APA winding tooling and plans -Syracuse/BNL

16:30 -17:00 Electronic FEB Board status and APA mounting requirements -Hucheng?

17:00 -18:00 Discussion and remarks of the day -All

Tuesday 23/06/2015

Daresbury Lab visit 9:00 - 11:00 (Meet 8:00 am outside Physics, two cars available)

12:00 -12:30 UK Cold tests design status –Lancaster

12:30 - 13:00 Bridged APAs connection design, deflection board status and geometry boards –BNL

(Working lunch 13:00)

13:00 - 13:30 HV feedthrough review UCL/Yale

13:30- 14:30 Field Cage review BNL/Yale

14:30 -15:30 TPC assembly and support structure review -Chicago/BNL

15:30 - 16:00 Coffee break

16:00 – 16:30 TPC required cryostat ports -BNL

16:30 -17:00 Towards final design: engineering design issues - Peter Sutcliffe

17:00 -18:00 Discussion and final remarks of the day -All

Cryogenics – ICARUS (report from David Montanari)

- The WA104 Cryogenics has been preliminarily divided between CERN and Fermilab:
  - WA104 → Internal Cryogenics (inside the cryostat).
  - CERN → Proximity Cryogenics (LAr filtration, Ar Condenser, LAr recirculation pump and associated piping and instrumentation).
  - Fermilab → External Cryogenics (LAr/LN2 receiving facilities, LAr/LN2 transfer lines and GAr/GN2 returns).
- Preliminary P&IDs have been drawn (based on the previous ICARUS configuration) to facilitate the discussion.
- Exact division of responsibilities are being discussed.
- Deliverables (with cost and schedule) being prepared for discussion.
- Interface documents for the various parts will need to be prepared for discussion.
- Components need to be sized (will start with existing values).
- 3D modeling can then start.

Cryogenics - SBND

- SBND Cryogenics follows similar plan to ICARUS with a to has been preliminarily divided between CERN and Fermilab:
  - Femilab → Internal Cryogenics (inside the cryostat).
  - CERN → Proximity Cryogenics (LAr filtration, Ar Condenser, LAr recirculation pump and associated piping and instrumentation).
  - Fermilab → External Cryogenics (LAr/LN2 receiving facilities, LAr/LN2 transfer lines and GAr/GN2 returns).
- Exact division of responsibilities is being discussed (draft CERN/FNAL agreement)

Cryogenics - Strategy

- Components will be skid mounted and cold tested, ready for installation and final connections in the field.
- Pipe sections may be prefabricated and cold tested, ready for installation and final connections in the field.
- Need to look at available ICARUS components and decide what can be reused (eg LAr pumps, valves, vessels?).

Conventional Facilities for Near and Far Detectors

Budget from GPP funds FY14 - 16

	FY14	FY15	FY16	Total
Site Preparation		1500	695	2195
Near Detector Building		1700	3645	5345
Far Detector Building	1000	5298	3502	9800
Total GPP Budget				17340

Budget to cover :

- EDIA
- Construction Contract
- Management reserve

($2,190K additional to what in initial plans; extra added in FY16)

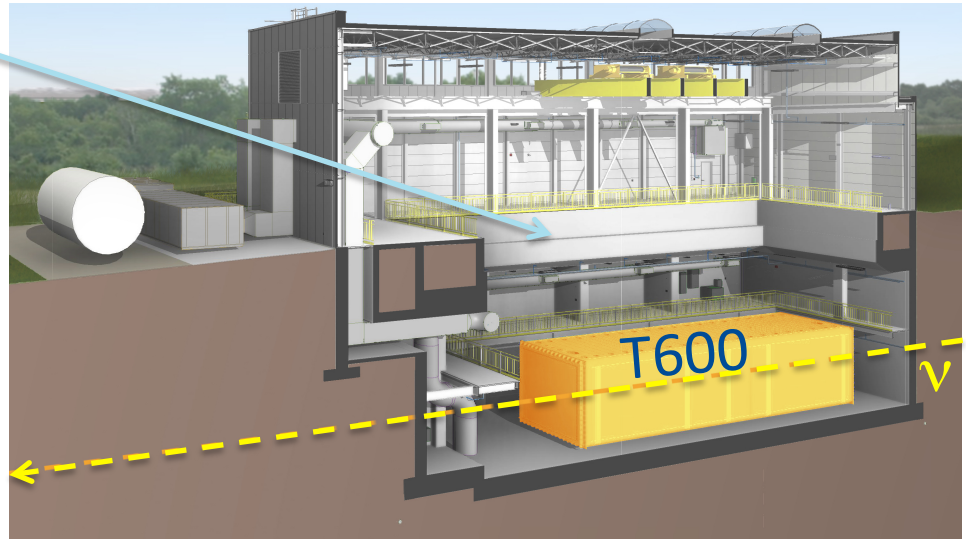
Far Detector


Near Detector

Fermilab

Far Detector Building

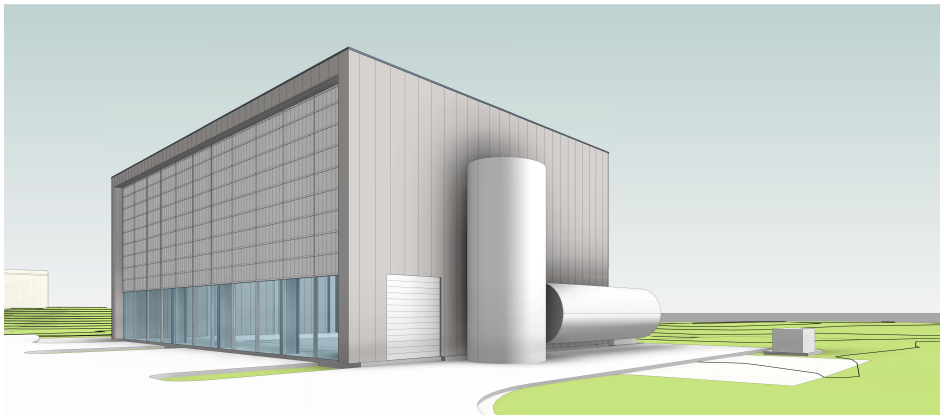
- Preliminary design started summer 2014
- Close cooperation between ICARUS, CERN and Fermilab on design requirements and review.
- Designed for 3m concrete overburden over detector to mitigate cosmogenic backgrounds for near surface operation



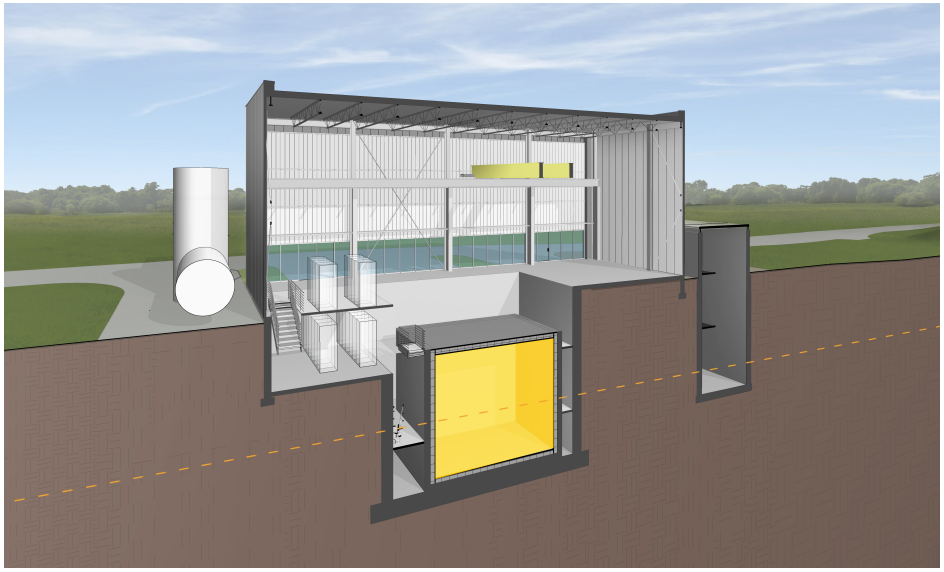
- Timeline:
  - ✓ January 2015 - 60% Design Review
  - ✓ March 2015 – Final Design Review
  - ✓ March 2015 - Design complete
  - ✓ April 2015 - Construction contract bidding (complete May 2015)
  - – July 2015 - Construction start
  - – Nov 2016 - Beneficial occupancy

Near Detector Building

- Design started January 2015
- Designed for 3m concrete overburden inside building to mitigate cosmogenic backgrounds for near surface operation

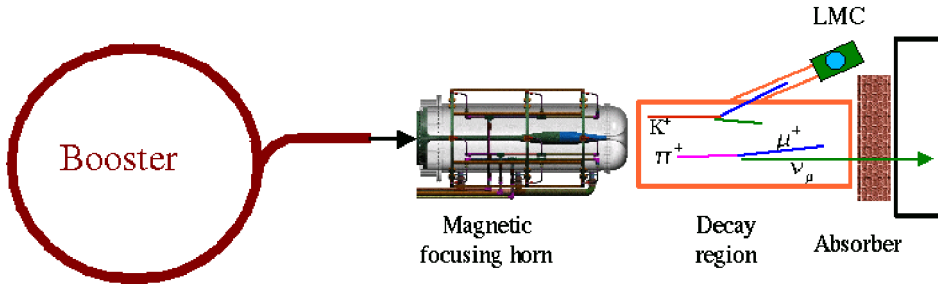


- Timeline:
  - ✓ March 2015 - 60% Design review and cost estimate
  - ✓ May 2015 – revised 60% design
  - – July 2015 – Final design review
  - – August 2015 - Design complete
  - – October 2015 - Construction start
  - – Nov 2016 - Beneficial occupancy



Booster Neutrino Beamline Improvements

- This sterile ν search is limited by far detector statistics
  - Neutrino flux X detector mass
  - Detector is expensive ($10M for building alone)
- Increased ν flux would further secure the program sensitivity
  - Higher ν production efficiency
  - More protons on target (P.O.T.)



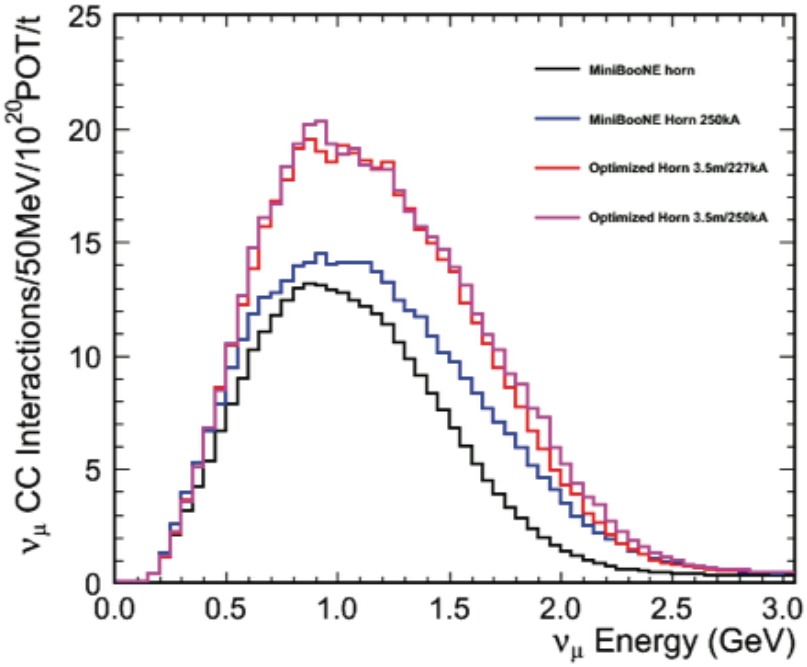
- Current BNB ν energy distribution optimized for MiniBooNE
  - LAr-TPCs more tolerant of high energy tail (distinguish NC π^0 background)
  - Allows for reconsideration of target and horn design
  - First studies in 2014 exploring one horn and two horn designs indicate an improvements 30-100% are possible
- P.O.T. is presently limited to 5 Hz average
  - After PIP, Booster up to 15 Hz when NUMI beam (and Muon program) is off
  - Upgraded power supply would permit more opportunistic use of beam pulses

Booster Neutrino Beam Upgrade

Since January PAC meeting we have developed a Pre-Conceptual design with estimated cost of ~$6.5M

Two options span a range of improvements and cost:

1. Short, improved MiniBooNE-style horn + PS mods
2. New horn, max. length (3.5m) + PS mods



Interaction yield with a 3.5m long Horn (Option 2) compare to present yield

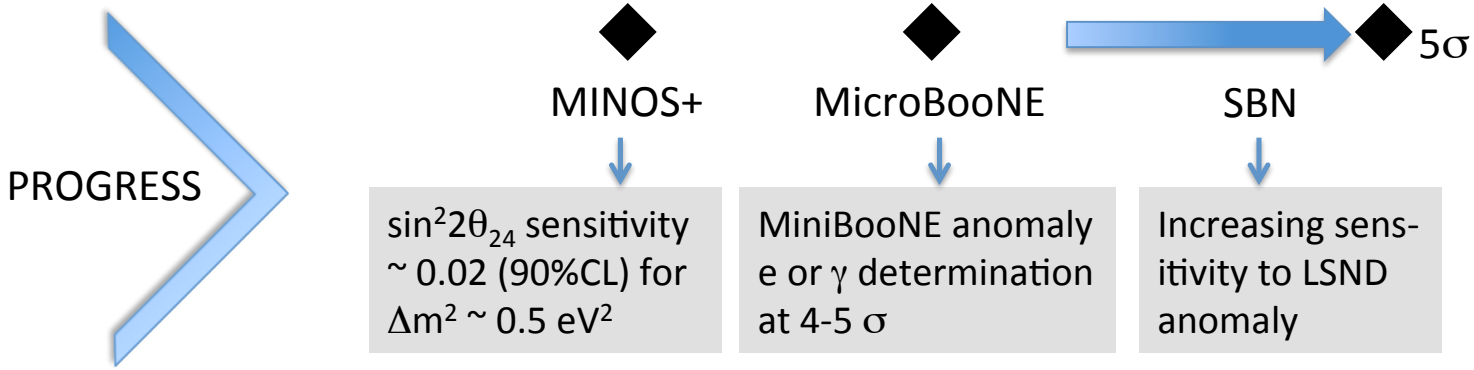
+70% efficiency (not incl. more booster cycles)

Plan to complete conceptual design in 2016

Details in Alberto's Talk

SBN Program Timeline

EPOC	EXPT	2015	2016	2017	2018	2019	2020	
NOW	MINOS+	RUN						
NOW	MicroBooNE		RUN 1			RUN - SBN		
NEXT	SBND		BUILD + INSTALL *			RUN - SBN		
NEXT	ICARUS		REFURBISH+INSTALL*			RUN - SBN		
NEXT+	?						decide	????



* Important contributions from CERN Neutrino Platform and European funding agencies (INFN, STFC, SNSF)

Source of information: January 2015 Fermilab PAC meeting; presentations & Report:

Steve Geer presented at ICFA Neutrino panel (18 April 2015)

Fermilab

Conclusions

- Since January we have made good progress in initiating this combined physics and R&D program
- Through this program we are exercising the components required to host a program in the U.S. where major contributions are coming from our international collaborators
- We have advanced designs for the conventional facilities
  - Groundbreaking for ICARUS this summer; SBND in fall
- ICARUS refurbishment at CERN is underway
  - Addition of the U.S. groups will enable our ability to install and integrate the ICARUS detector into our facilities
- Construction and commissioning of the SBND will provide a next-generation test bed (after MicroBooNE) for gaining the experience needed to construct and operate on the multi-kiloton scale
- Actual costs from MicroBooNE construction, installation and commissioning are informing our plan and budget requirements.

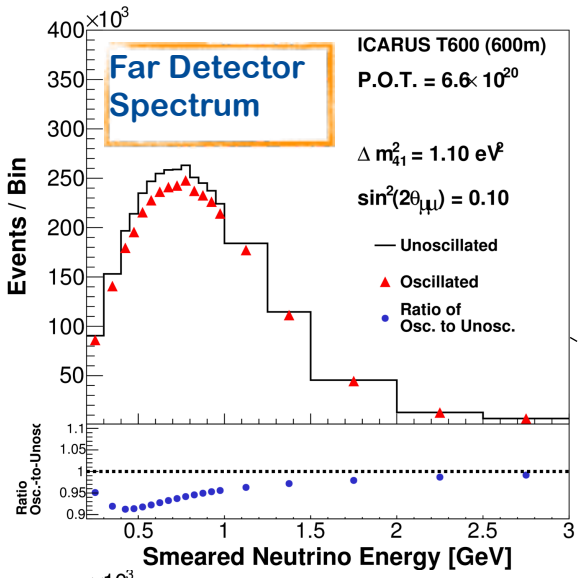
Response to PAC Charge (1)

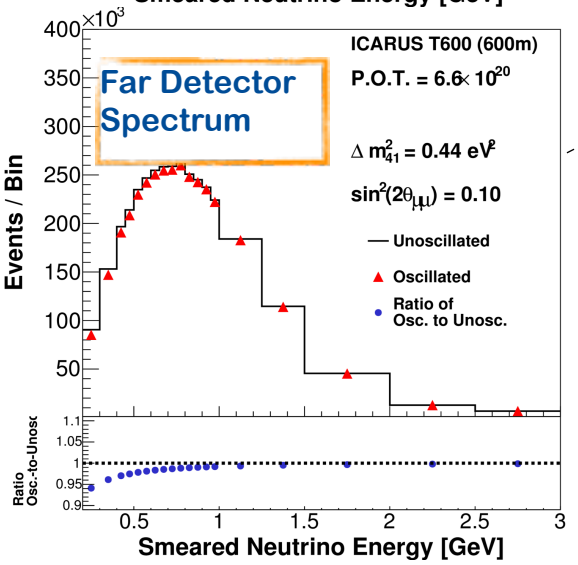
1. We ask the PAC to comment on the current situation and on the progress being made on MicroBooNE, SBND, and ICARUS
   - MicroBooNE is presently filling with liquid argon and will be full in ~2 weeks!
   - Both the far detector and near detector buildings are in advanced stages of design and construction will begin this summer.
   - Refurbishments/upgrades of the first ICARUS T300 module are on-going at CERN and scheduled to be completed by the end of 2015. Work on the second T300 to be completed by the end of 2016.
   - SBND designs for the cryostat, detector, and cosmic tagger system are all advancing well; TPC design meeting going on right now in Liverpool, UK.
2. Is the path to Stage 2 approval for SBND and ICARUS (and extended MicroBooNE running) clear and appropriate?
   - A SBN Director's Review is anticipated in October. Several technical reviews for ND systems being planned through the summer leading up to Director's Review.

Response to PAC Charge (2)

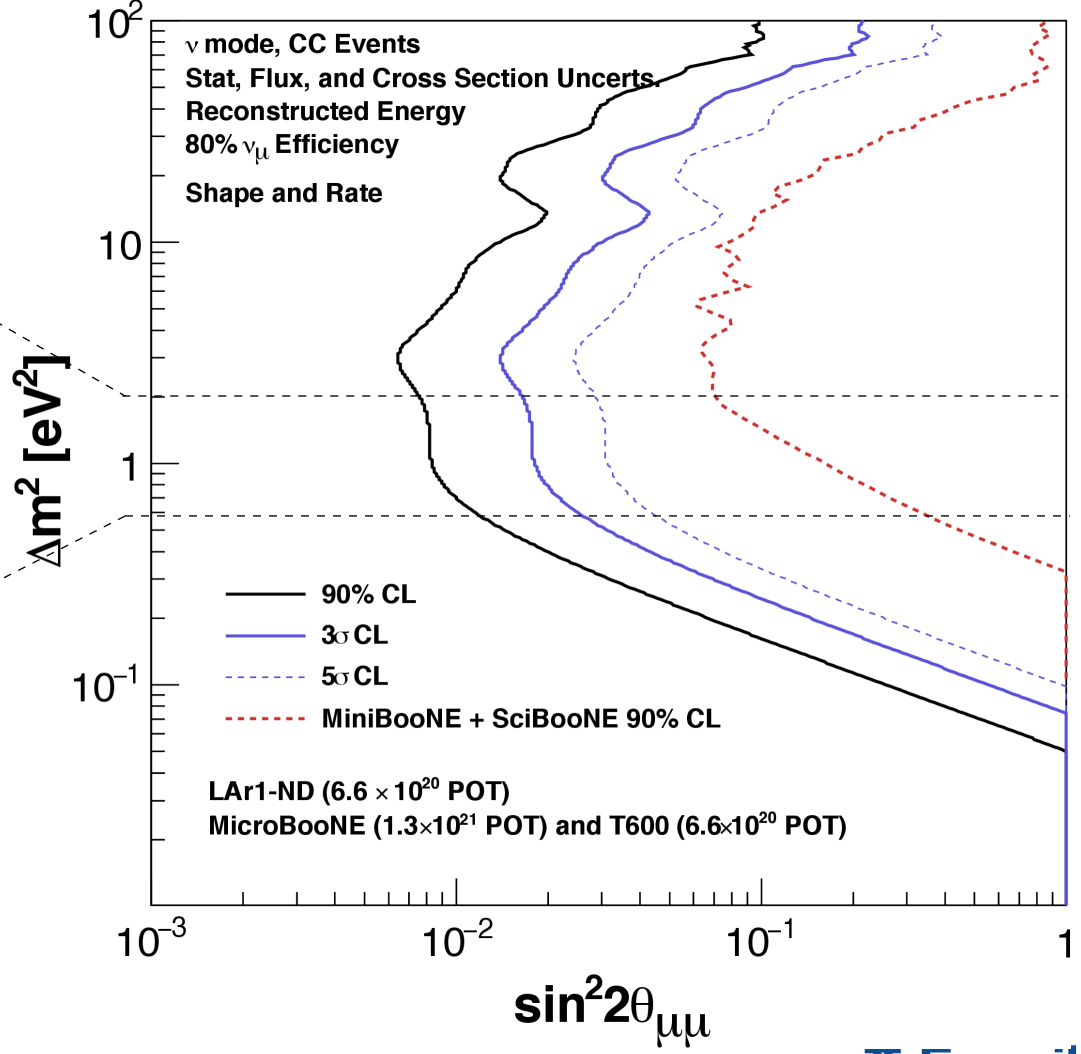
3. Is there an adequate plan for the three collaborations to develop a strategy of cross calibrations that will lead to an understanding of the relative acceptances at the required level?
   - To realize the maximum sensitivity to oscillations will require that data from the three detectors be analyzed in a consistent way using common analysis algorithms.
   - Planning efforts are underway now to work toward common solutions in software from DAQ, to offline software frameworks, to reconstruction algorithms.
   - MicroBooNE data, coming soon, will be extremely valuable to planning, preparing for data in other SBN detectors.

SBN ν_μ Disappearance Sensitivity





Improve on MiniBooNE+SciBooNE by factor of ~10



Design Review Stages

- Reviews follow stages of design and construction run by SBN program
  - Requirements and Specification
  - Conceptual Design (CDR - 20% design complete) – Pre-CD1
  - Preliminary Design (PDR - 50% design complete) – Pre-CD2
  - Final Design (FDR - 80-90% design complete)
  - Production Readiness (PRR) – post CD3
  - Installation Readiness (IRR)
  - Operational Readiness (ORR) – completion results in Operational Readiness Clearance (ORC)
- Where appropriate combine stages such as Requirements and Conceptual Design or Final Design and PRR
- Review program by subsystem (L2). May combine where appropriate.

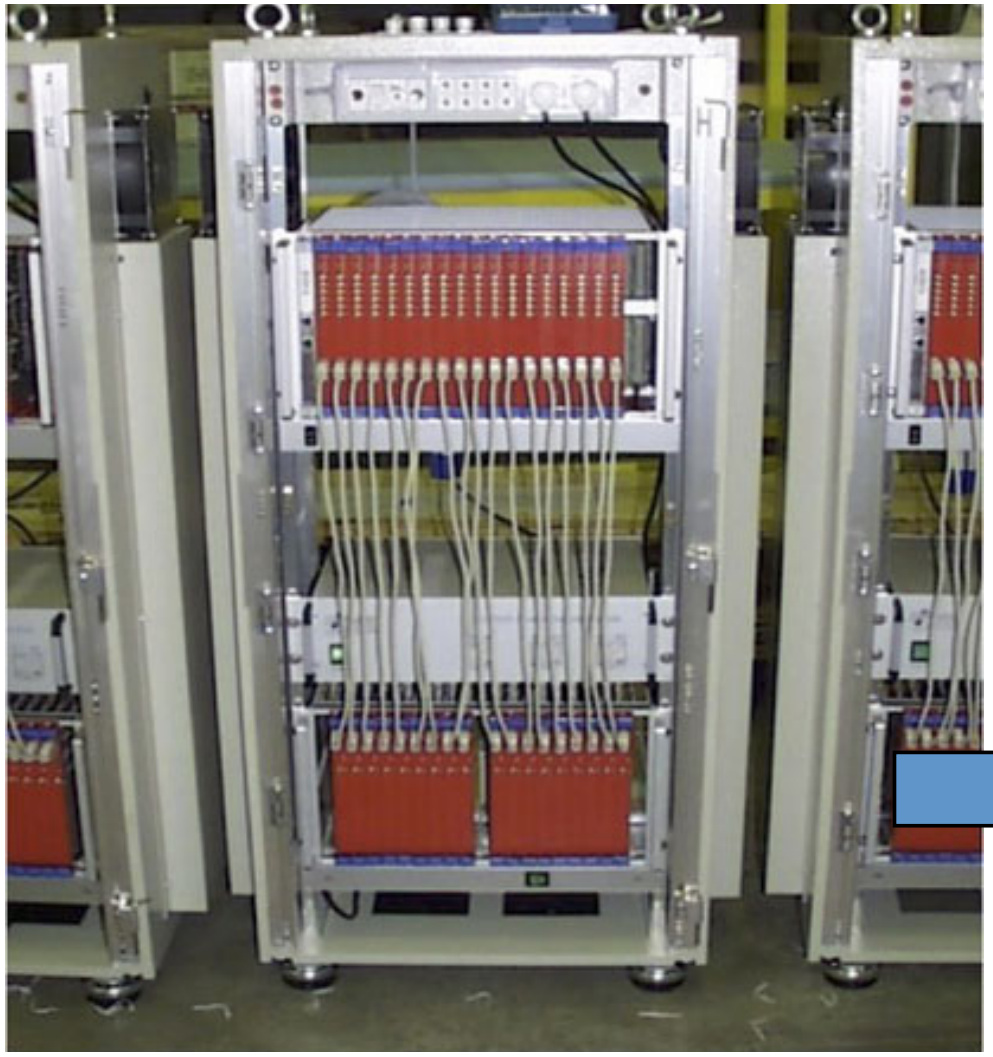
Proposal for electronics replacement

- In old T600 electronic readout scheme, it's possible to measure charge and energy deposition in only one view (Collection);
- For unfavorable event topology, ν_e identification not possible since in Collection too few wires are available to measure dE/dx;
- Large undershoot is detected in Ind2: the reconstruction of e.m. showers is very difficult;
- Moreover, due to VME architecture the data throughput is limited to 0.7 Hz;
- The timing of each board (32 wires) is not synchronized to each other -> 1 t-sample (~0.6 mm) uncertainty on drift coordinate is added. This effect is the dominant error, limiting resolution on the measurement of muon momentum by multiple scattering.

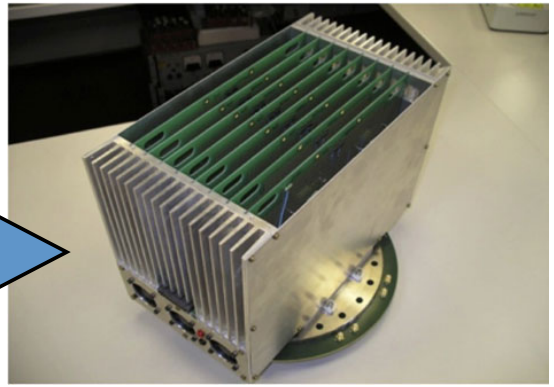
1. It is necessary to improve the electron identification and energy measure in the Ind2 view, allowing to increase ν_e identification efficiency in SBL events at FNAL by 12% with significant impact on physics reach, through different signal shaping;
2. The synchronization of boards would allow to improve muon momentum resolution by multiple scattering by ~20%;
3. The data throughput would increase to ~10 Hz.

ICARUS report

New design is compact



From 595 to 10 liters



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