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# **SBN Overview & Roadmap**

Catherine James PITT PACC Workshop on Short Baseline Oscillation Physics 27 January 2016

#### Outline



- History / Background / Goals
- Current Status

**SBN** 

Upcoming Challenges



# History – to January 2014

- 2003-13 MiniBooNE and SciBooNE: 1st Generation on the Booster Neutrino Beam
- 2009-15 Construct and install MicroBooNE (address the MiniBooNE anomaly)
- 2009-13 Proposals for vs search using multiple LArTPC detectors:

ICARUS@CERN: declined - no v beam at CERN

LAr1@FNAL: declined - too expensive

Jan 2014 Two proposals to Fermilab for next phase at BNB

P-1052: Updated ICARUS-T600 + new T150 (near detector) vs search

Proposal to relocate the existing ICARUS-T600 LArTPC detector to the BNB and to construct a new one-fourth scale detector based on the same design to serve as a near detector for oscillation searches

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P-1053: LAr1-ND\* + MicroBooNE (add later a kton scale far detector)

#### "The PAC encourages the [groups] to formulate a common Short-Baseline Neutrino Experimental program for FNAL."

\* LAr1-ND later renamed SBND

#### **A few months later - P5 Recommendations**

Recommendation 12: In collaboration with international partners, develop a coherent short- and long-baseline neutrino program hosted at Fermilab.

Recommendation 15: Select and perform in the short term a set of small-scale short-baseline experiments that can conclusively address experimental hints of physics beyond the three-neutrino paradigm. Some of these experiments should use liquid argon to advance the technology and build the international community for LBNF at Fermilab.



Building for Discovery Strategic Plan for U.S. Particle Physics in the Global Context

P5 Report, May 2014



### **2014 – Joint Proposal Development**

2014 Soon after the January PAC, proponents of the LAr1-ND and ICARUS proposals, members of the MicroBooNE collaboration, as well as representatives from Fermilab, INFN, and CERN started working together to develop a plan for a coherent SBN physics program

Efforts organized in a set of four Working Groups

flux and systematics, cosmics ; cryogenic and building infrastructures

Jan 2015 SBN Proposal presented jointly to PAC by ICARUS, MicroBooNE and SBND\*

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

http://arxiv.org/abs/1503.01520

Stage 1 Approval in February 2015 Target: Operations with beam by 2018

\* Name change: LAr1-ND Short Baseline Near Detector (SBND)



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#### Three Collaborations -> One Program

Jan 2015 proposal author list

#### The ICARUS-WA104 Collaboration

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#### The LAr1-ND Collaboration

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#### **SBN Institutions and Authors**



**‡**Fermilab

#### **SBN**

## **SBN Science Goals**

- Directly follow up on the <u>MiniBooNE neutrino anomaly</u> by utilizing the LArTPC technology to determine the composition of the observed excess as electrons or photons (MicroBooNE during Phase I)
- Apply the advantages of the LArTPC technology and multiple detectors at different baselines to the question of high-∆m<sup>2</sup> sterile neutrino oscillations for the first time, testing current allowed oscillation parameters at ≥5σ (Phase II)
- Study v-Argon interaction physics using <u>millions of events</u> from both the Booster and Main Injector neutrino beams at Fermilab
- Further <u>develop the LArTPC technology</u> toward the aim of applying it at very large scales for long-baseline physics in DUNE



# Phase I Goal : MiniBooNE → MicroBooNE

- MiniBooNE is a Cherenkov detector
  - Scintillator oil

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- Single electron indistinguishable from single photon
- 540 m from the beam target



MicroBooNE's core mission is to follow up on the anomalous excess of electromagnetic events observed by MiniBooNE and determine its composition as electrons or photons

- MicroBooNE is a LArTPC 70 tons fiducial
- Single electron distinguishable from single photon
- 470 m from the beam target



MicroBooNE parameters (mass, run plan, etc.) were chosen to observe the specific MiniBooNE excess with  $\sim 5\sigma$  significance over expected backgrounds



### Phase I Goal : MiniBooNE → MicroBooNE



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#### **Phase 2 Goal – explore** $v_s$ oscillation parameters

#### **Three Detectors**



#### Phase 2 Goal – explore vs oscillation parameters

- Oscillation sensitivity of the three-detector SBN system has been evaluated in a joint effort by the three collaborations
  - based on full simulations of all known backgrounds and systematic uncertainties for all detectors using common BNB flux generators



#### $v_e$ appearance

#### $v_{\mu}$ disappearance

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#### Phase 2 Goal – explore vs oscillation parameters



#### SBN Systematic Uncertainties Corey Adams' Talk later today



Analysis methods / strategies are the subject of several talks in this Workshop



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#### **Goals - Neutrino Cross Sections, Analysis Development**

- SBN detectors will collect <u>huge data sets on</u> <u>argon</u> from the BNB on-axis and the NuMI off-axis fluxes
  - SBND will record ~1.5M neutrino interactions  $(7,000 v_e)$  in the fiducial volume per 2.2e20 POT (~year running)
  - Large complementary samples in T600 and MicroBooNE (already started!)
  - Order 100k NuMI off-axis events in the T600 per year
- Precision studies of neutrino-argon interaction physics
  - Even rare channels like coherent scattering, strange production, v-e elastic scattering, etc.
- Large data sets will push development of LAr reconstruction and analysis techniques, having direct impact for long-baseline physics using LAr in the future





## **Current Status - SBN Program Coordination**

- Program benefited enormously by a dedicated **SBN Program Office** within Neutrino Division at Fermilab
  - Coordinator: Peter Wilson

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- Deputy Coordinator: Cat James
- Program mechanical and electrical engineering support
- Program-wide schedule and cost/resource tracking and resource allocation
- Program is managed as a combination of in-kind contributions from collaborating institutions and DOE deliverables funded through Fermilab
  - Major infrastructure contributions by FNAL in civil construction, electrical design, and installation support – and by CERN/FNAL in cryostats and cryogenics
- The Program Office also assists with coordination between the collaborations, plans reviews, and interfaces with supporting agencies



The Fermilab Short-Baseline Neutrino Program emerged from a joint proposal by three collaborations to use their detectors to perform sensitive searches for  $v_e$  appearance and  $v_p$  disappearance in the Booster Neutrino Beam. All of the detectors utilize LArTPCs - liquid argon time projection chambers - and each contribute to the development of this technology for the long-baseline DUNE experiment. The joint scientific goals are outlined in the proposal, available on the HEP arxiv. The proposal was submitted to the Fermilab PAC and granted Stage 1 approval in early 2015. The web sites of the three SBN Program collaborations and the SBN Program Office are linked below.

#### SBN Program Office

The SBN Program Office provides coordination among all stakeholders the collaborations and funding institutions - and also provides oversight and integration of joint systems and facilities. The Program Office site holds information and links on program organization, events, and reviews.

comprised of two 300-ton LAr-TPC modules with photodetectors, will serve as the Short-Baseline Program Far Detector, farthest from the BNB primary target. The T-600 is currently being refurbished at CERN following successful operation at the Gran Saso laboratory from 2010-2014. The T-600 detector will be moved to Fermilab in 2017.

**ICARUS T-600** 

The ICARUS T-600 detector.

#### MicroBooNE

MicroBooNE is located 470m from the BNB primary target, and consists of a 8250-wire TPC and 32 photomultiplier tubes in 170-tons of liquid argon. The cryostat was filled in mid-2015 and the detector is currently operating.

#### Short-Baseline Near Detector

Short-Baseline Near Detector - SBND will be located 110m from the BNB primary target, and will consist of a 260-ton liquid argon TPC supplemented by light detection systems. The SBND cryostat is a membrane type, envisioned for use by the future DUNE far detectors.

Last modified: 10/30/2015 email Fermilab



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http://sbn.fnal.gov/



### **Current Status – Supporting Institutions / Agencies**



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### **Current Status – Organizing ourselves**



#### **Current Status - MicroBooNE Detector**

- 170 ton LArTPC (total mass)
- 8256 wires (3 mm pitch)
  - 3456 collection channels (vertical)
  - 4800 induction channels (±60°)
- Cold front-end TPC electronics
- 32 8" Cryogenic PMTs to collect scintillation photons
- UV laser calibration system
- Now taking data

More in Bryce Littlejohn's talk









# **Current Status - ICARUS-T600**

- The T600 is the first and the largest LArTPC ever built
  - Three-year physics run in the CNGS neutrino beam at the Gran Sasso Laboratory
- Currently the detector is at CERN for refurbishment (INFN and CERN project, WA104) in preparation for transport to Fermilab
  - First module complete end of 2015
  - Second module prepared in 2016
  - Installation at Fermilab in 2017

#### More in Andrea Zani's talk





# **Current Status - Cryogenic Systems**

- A necessary bit of infrastructure
  - Rebuild ICARUS cryogenic system
  - New SBND cryogenic system
- Joint CERN-Fermilab responsibility
- Worked out partitioning:
  - Internal : inside the cryostat
    - ICARUS CERN-INFN scope
    - SBND Fermilab scope
  - Proximity : Argon circulation & filtering
    - SBND & ICARUS CERN scope
  - External : Nitrogen & Argon delivery
    - SBND & ICARUS Fermilab scope
  - Controls Fermilab scope

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A precursor of a similar joint effort by CERN-Fermilab for DUNE



#### **Current Status – Civil Construction**



# **Far Detector Building**

- 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
- Milestones:

- ✓ Aug 2014 Start preliminary design
- ✓ Mar 2015 Design complete
- ✓ April 2015 Construction contract bidding
- ✓ July 2015 Construction Start
- ✓ Sept 2015 Excavation complete
- □ Jan 2016 Concrete complete
- □ June 2016 Building envelope complete
- □ Oct 2016 Beneficial Occupancy







#### **Far Detector Building – construction progress**





## **Near Detector Building**

- Designed for 3m concrete overburden inside building to mitigate cosmogenic backgrounds for near surface operation
- Milestones:

- ✓ Jan 2015 Design start
- ✓ May 2015 60% Design complete
- ✓ July 2015 Final design review
- ✓ Aug 2015 Design complete
- ✓ Oct 2015 Bidding complete
- ✓ Jan 2016 Notice to proceed
- □ Feb 2016 Construction start
- □ Nov 2016 Beneficial Occupancy







# **Current Status - SBND**

- Completely new detector incorporating experience from ICARUS, MicroBooNE, LBNE 35 ton
- Scope of work:

- TPC design and construction
  - SBND is a 4m (W) x 4m (H) x 5m (L) 112 ton LArTPC
- PMT (8") system
- Laser Calibration system
- Cold TPC readout electronics
- DAQ (and electronics infra)
- Membrane cryostat





## **Current Status - The SBND TPC**



SBND TPC design and construction is a joint **US-NSF** and **UK-STFC** project

| Chicago, Sheffield                  |
|-------------------------------------|
| Manchester,<br>Syracuse             |
| Liverpool                           |
| BNL, Yale                           |
| UCL, Yale                           |
| Lancaster                           |
| Chicago, BNL,<br>Fermilab           |
| al design phase<br>struction in 201 |
|                                     |

# **SBND TPC Electronics**

- Cold front-end & warm readout electronics will be upgrades from components used in MicroBooNE system
  - Signal digitization moves into the cold
- FE/ADC ASIC design now a joint SBND-DUNE effort
  - Coordination meeting Aug 20 at BNL
  - Cost and resource sharing agreed
  - 2 prototype ASIC runs scheduled for 2016
  - Production run early 2017

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 Collaboration institutes are getting involved in the QA/QC test-stand efforts



### **SBND Cryostat, and Photon Detectors**

- Cryostat design being developed at CERN following WA105 experience
- Photon detection in SBND

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- 112 8" PMTs (as in ICARUS & MicroBooNE) mounted to backside of APA frames directly behind wires
- planning to use the same type of PMT as ICARUS



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#### **Current Status - Booster Neutrino Beam Improvements**

#### Future Upgrades will come under the SBN Program umbrella

- Far detector statistics are key to  $\nu_{e}$  appearance sensitivity
  - (Detector mass) x (Neutrino flux) x (Time)
- Possible BNB upgrade paths:

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- 1. Increase focusing efficiency of target/horn system
  - Optimize horn length, inner conductor, and current
- 2. Increase rate at which horn system is capable of running
  - Booster can operate at 15 Hz, existing horn at 5 Hz (limited by mechanical integrity and power supply)
- Detailed study carried out by design team at FNAL



#### see Zarko's talk from yesterday



### Current Status – Reviews to tell us how we're doing

- Directors Review, December 2015 Summary & Highlights
  - SBN is a Program not a DOE 413 project
    - Pros and cons to this approach
    - Don't have to wait through the Project CD process to get equipment funds
    - But the DOE funding is less certain from year to year than for a 413 Project
- Review Committee found the Program "well conceived, well managed and is proceeding satisfactorily toward timely completion and installation of the two detectors"
- Challenges include :

- Building SBND a completely new detector (though design is based on experience from ICARUS, MicroBooNE and the DUNE 35 ton)
  - Working schedule is very aggressive presently is technically-driven
  - Funding profile doesn't quite match the work plan; current schedule runs into a funding limitation in FY17; there's no contingency to cover the unexpected
- Finalizing the CRT implementation details for all detectors
  - Not all funding for the ICARUS CRT is identified yet



#### **Challenges – Schedule & Coordination**



## **Challenges - Cosmogenic Backgrounds**



The problem: 1000x longer charge drift time than the beam spill time!
 1.6 μs beam spill vs. 1-2 ms TPC drift time



More in Joseph Zenamo's talk



# **Cosmic Ray Taggers Design**

- The SBN proposal assumed a 3m concrete overburden and a CRT detector for both SBND and ICARUS.
  - the three collaborations performed independent simulations to study the impact of cosmics and the need for overburden and CRT systems
  - these simulations have been refined by all three collaborations over the past year to compare / validate those initial results and push on new studies
    - What are the requirements on spatial and time resolutions, number of layers?
    - What is the optimal configuration of the CRT systems for tagging the most problematic muons?



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# **SBN Task Force on Cosmics Mitigation**

Joint Task Force formed in Nov 2015 to define requirements and implementation of the overburden and CRT systems

- representatives from each collaboration
- Main questions

- cross-check the accuracy of the simulation geometries
- impact and necessary thickness (1, 2, or 3 m) of overburden
- CRT configurations and performance requirements (spatial granularity, time resolution, number of layers)
- Additional rejection from the CRT relative to internal light collection
- impact of activity on the CRT from secondary particles (cosmic or beam source)
- Identify areas where common technical solutions could be used for the three detectors
  - the designed and tested SBND CRT readout can be used for all
  - utilize common scintillator strip size & configuration where possible



# **Ongoing - Detector Hardware Coordination**

• DAQ

- Lots of activity involving SBND, MicroBooNE, and ICARUS DAQ experts to consider common DAQ software solutions, data formats, etc.
- One-day SBN-DUNE workshop held in November to explore possible synergies within DAQ and readout electronics.
- Photon Detection
  - SBND working with ICARUS on PMT-based photon detection system
  - SBND to use same PMTs, 8" Hamamatsu R5912
  - Plan to send SBND PMTs to CERN for wavelength shifter coating and performance testing/characterization in same facility used for ICARUS tubes
  - Working together to decide on similar electronics and DAQ system
- Already mentioned -
  - Common parts among the SBN detectors CRT systems, portions of cryogenics
  - Synergies with DUNE: Cold electronics, membrane cryostat



## Summary

#### One year after approval, the SBN Program is advancing rapidly

- Buildings are progressing; construction completion before then end of this year
- Progress on ICARUS refurbishment (later talk...)
- SBND nearing the final stages of design

Continue the pace!

This year

- move into final designs and parts procurement
- finalize CRT requirements and start building
- finalize installation planning

Next year

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• installation of ICARUS, assembly and installation of SBND

