Scintillation Light Detection in SBND

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Neutrino Oscillation

\[ \nu_\mu \rightarrow \nu_e \]

\text{distance } L
Neutrino Oscillation – Short-Baseline Anomalies

Lots of tension!

New (sterile) neutrino?


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LSND

MiniBooNE

Lots of tension!
Short-Baseline Neutrino (SBN) programme at Fermilab consist of 3 LArTPCs at different baseline to probe $\Delta m^2 \sim 1eV^2$.BOOSTER NEUTRINO BEAM

SBN Far Detector
MicroBooNE
SBN Near Detector

BNB neutrinos
SBN Far Detector
ICARUS

BNB neutrinos
SBN Near Detector
SBND

Short-Baseline Neutrino Programme
Short-Baseline Near Detector (SBND)

SBND → A 112 t active volume Liquid Argon Time Projection Chamber at 110 m from target

arXiv:1503.01520
What Physics can SBND do?

- Measure unoscillated neutrino flux for SBN
  - Crucial for the sensitivity of oscillation measurement
  - Highly correlated interactions in near and far detectors (same detector technology and target)
  - Control systematic uncertainties for sterile neutrino search

- Become the world’s highest statistics cross-section on LAr with ~7 Millions of $\nu_\mu$ interactions in 3 years
  - Allows precision measurements of exclusive event topologies
  - Quantify nuclear effects in $\nu$-Ar scattering

- BSM Physics (examples for SBND):
  - Sub-GeV Dark Matter (electron-scattering)
  - Neutrino and dark trident (arXiv:1406.2332)
  - Probing the Higgs Portal (arXiv:1909.1167)
Liquid Argon Time Projection Chambers

Ionization signals:

- Localizing neutrino events (MicroBooNE)

Scintillation signals:

- Very good scintillator (40,000/MeV at E=0)
- Triggering (beam vs background events)
- Localizing neutrino events (MicroBooNE)

VUV scintillation emission pathways in L-Ar.

Excitation:

\[ \text{Ar} \rightarrow \text{Ar}^+ \rightarrow \text{Ar}_2^+ \rightarrow \text{Ar} + \text{Ar} \]

Ionization:

\[ \text{Ar}^+ \rightarrow \text{Ar}_2^+ \rightarrow \text{Ar}_2^+ \rightarrow \text{Ar}_2^+ \]
**SBND Photon Detection System (PDS)**

- **Active elements:**
  - Baseline: 120 8” Hamamatsu PMT’s (96 TPB coated)
  - R&D: X-ARAPUCA + ARAPUCA

- **Passive element:**
  - Wavelength-Shifting Reflective foils.
  - Total surface area of \(~38 \text{ m}^2\) to cover on cathode (Largest area to date!)
(X-)ARAPUCAS are light traps that increases the effective area of SiPMs using a combination of wavelength-shifters (WLS) and a dichroic filter.

\[ \lambda_{VUV} < \lambda_1 < \lambda_2 \text{ [nm]} \]
- PMT VUV + visible sensitive
- PMT visible sensitive
- X-ARAPUCA VUV sensitive
- X-ARAPUCA visible sensitive
- ARAPUCA (VUV sensitive)
- ARAPUCA (visible sensitive)
Wavelength-Shifting Reflective Foils

- 3M DF2000MA (38 um) laminated on 0.8 mm FR4 (lamination performed at IIT).
- 64 plates are required for SBND coverage (128 evaporations for double-sided)
- Evaporations split between Manchester and Unicamp.
• VUV scintillation (128 nm) is absorbed by most material (except liquid argon itself).

• Rayleigh scattering (~55 to 110 cm) and absorption (~30 m).

Rayleigh scattering of visible light is longer than VUV.
SBND High Light Yield + Coverage Physics

Improve energy resolution and calorimetry (ionization + scintillation)

Determine position in drift direction at the trigger time using both light (only)

Improve cosmic rejection

Perform calibration and particle identification

Allow lower trigger thresholds
SBND Current Status

- Warm cryostat steel structure installation: November
- TPC assembly: ongoing winter/spring 2020
- Membrane cryostat installation: begin spring 2020
- Moving and installing detector: fall 2020
- Filling and commissioning: 2021
• SBND’s high coverage diverse photon detection system will have a large impact to both SBN physics and R&D for future LArTPCs in a neutrino beam.

• Sensitivity to both VUV direct and VIS reflected light through PDS + Wavelength-shifting foils.

• SBND’s PDS status:
  • PMTs tested at LANL and will be on their way early 2020
  • ARAPUCA/X-ARAPUCA are in production and will be installed with PMTs
  • Wavelength-shifting reflective plates and mesh assemblies are ready for installation on cathode.

• Busy next year(s) for SBND!
244 Total Collaborators

198 Scientific Collaborators (faculty/scientists, postdocs, PhD students)

39 Institutions

23 US Institutions
  4 DOE national laboratories
  19 US universities

16 International Institutions
  5 Brazilian universities
  1 Paraguayan university
  1 Spanish university, 1 national lab
  1 Swiss university
  6 UK universities
  CERN
A diffuser system installed at the cathode using a laser (Q1-B semiconductor laser class 3B) with two wavelengths (211 nm and 537 nm) will be used to calibrate the PDS.
• 120 sandblasted 8” Hamamatsu R5912-mod PMTs readout by CAEN V1730 will make the primary PDS of SBND (60 per TPC side).

• 96 are covered with TPB to wavelength shift VUV light (sensitive to both VUV and VIS).

• 24 are non-coated making them only sensitive to visible reflected light.

Test in CCM: 0.5PE/keV response
Summary of scintillation light in liquid argon

1. Emission:
   • Excited argon dimer dexcites to emits 128 nm photons (VUV).

2. Propagation:
   • VUV scintillation is absorbed by most material (except liquid argon itself).
   • Rayleigh scattering (~55 to 110 cm) and absorption (~30 m).

3. Detection:
   • Typical PMTs and SiPMs are blind to VUV scintillation which makes the detection challenging.
   • Solution? use Wavelength shifting compounds, like Tetra-Phenyl Butadiene (TPB).

![Diagram of scintillation process](image)
• Light travelling to the TPB coated cathode will be remitted and reflected.
• That light will travel to the PMTs and transmit through the glass window.
• ~60% of the blue light will transmit.
• 64 plates are required for SBND coverage (128 evaporations for double-sided) + spares.

• Heating up slowly the TPB filled cup up to 245°C and evaporate on plate.

• Manchester and Unicamp have split the task (both have the same evaporation setup).
• Cool down (with LN2) the frame to shrink.
• Screw the mesh-foil-mesh configuration in before subframes warms up.
• Let the assembly expand and lock in place.

Repeat 16 times!
Installation on SBND cathode

Mesh

Foil plates

• Metal mesh to keep electrical field uniform and constant.
• N6.0 argon with alpha source in vacuum chamber with a PMT.
• Foil sample located above the PMT.