Acrylic Lightguides for Use in Liquid Argon Time Projection Chambers

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Liquid Argon Time Projection Chambers (LArTPCs)

In a LArTPC, **time** and **location** of interactions are reconstructed from two detection events:

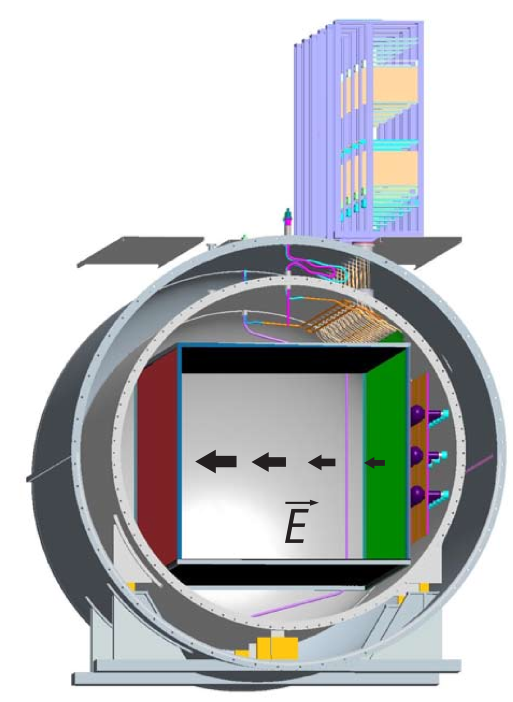
- Photomultiplier tubes (PMTs) detect light from the interaction.
- A wire chamber detects electrons ionized by energetic, charged particles moving through the detector.

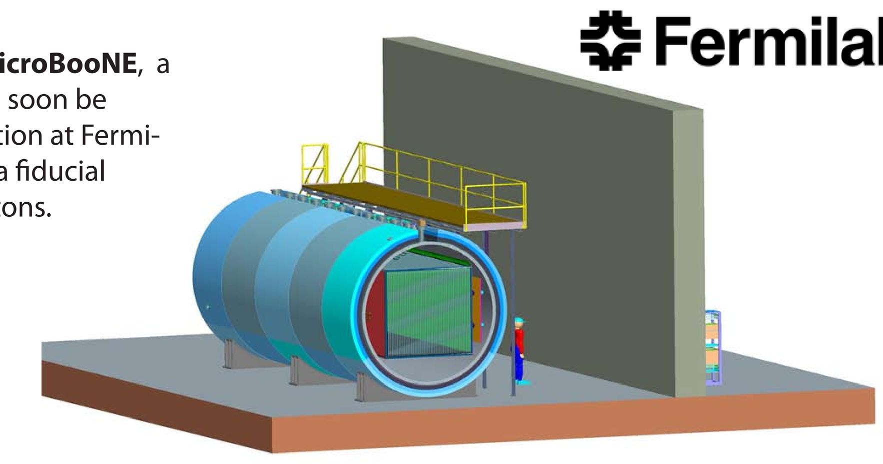
We can reconstruct the paths of the products of neutrino interactions:

$$\nu_e + n \rightarrow e^- + p$$

$$\nu_\mu + n \rightarrow \mu^- + p$$

LArTPCs are ideal for neutrino experiments because of their **sensitivity** and **scalability**.





Side views of **MicroBooNE**, a LArTPC that will soon be under construction at Fermilab. It will have a fiducial volume of ~70 tons.

Fermilab

In order to see more events, we hope to build bigger LArTPCs without losing event coordinate precision.

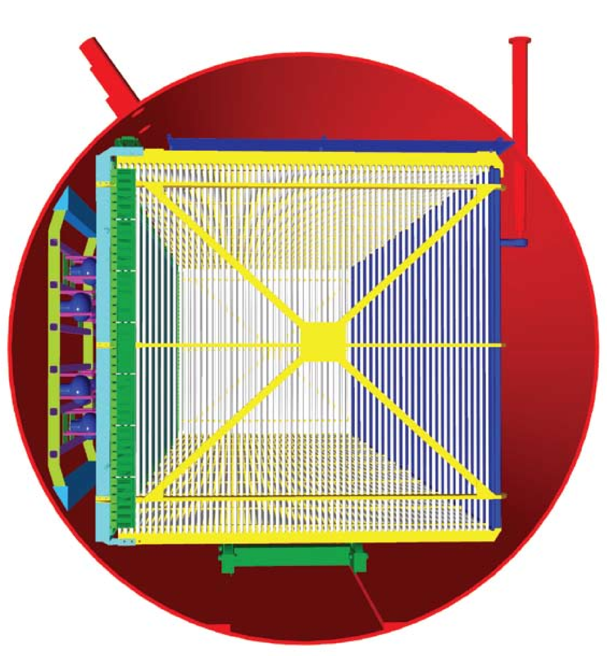
Light Detection Challenges in LArTPCs

- Photomultiplier tubes (**PMTs**) **cannot be used in strong electric fields**, which LArTPCs utilize to drift and detect ionized electrons.

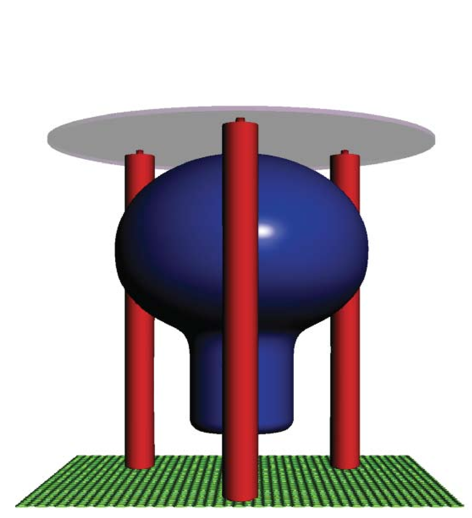
  $\Rightarrow$ *Light detection coverage limited to field free regions of chamber.*

- 128nm UV light is created by bonding and seperation of argon dimers. Glass of **PMTs** is **opaque to UV**.

  $\Rightarrow$ *Need to shift UV light to visible spectrum so it can be detected.*

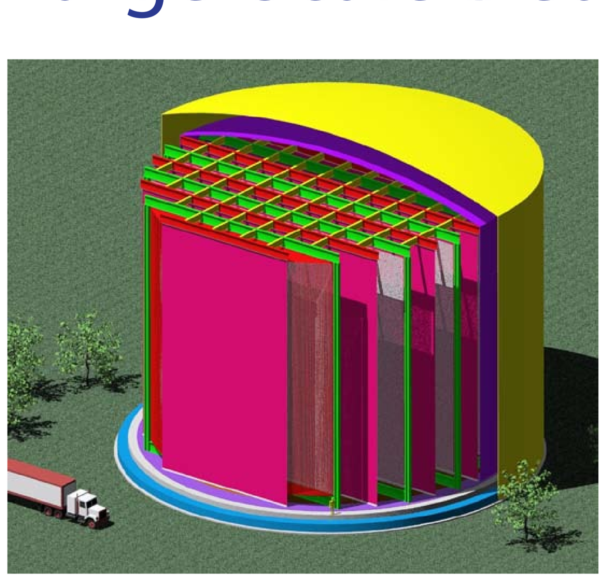


PMTs in MicroBooNE can only be placed in the zero field side of the chamber, behind the wire planes. This lack of coverage limits the ability to detect light events in the detector.



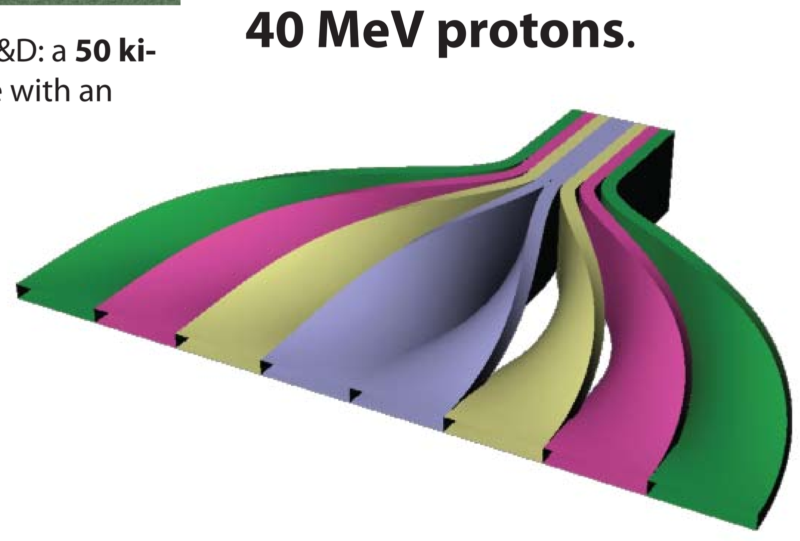
Current design for PMT module in MicroBooNE. A plate (in gray) coated with a wavelength shifter is fastened in front of PMT to shift UV light to blue light.

Lightguides in Large-Scale Detectors



The ultimate goal of LArTPC R&D: a **50 kiloton chamber,** pictured here with an 18-wheeler for scale.

Our results, indicate that in order to trigger off of 5 PE in a detector the size of MicroBooNE (70 tons of argon), we would need **30 lightguide paddles to trigger off of 40 MeV protons**.

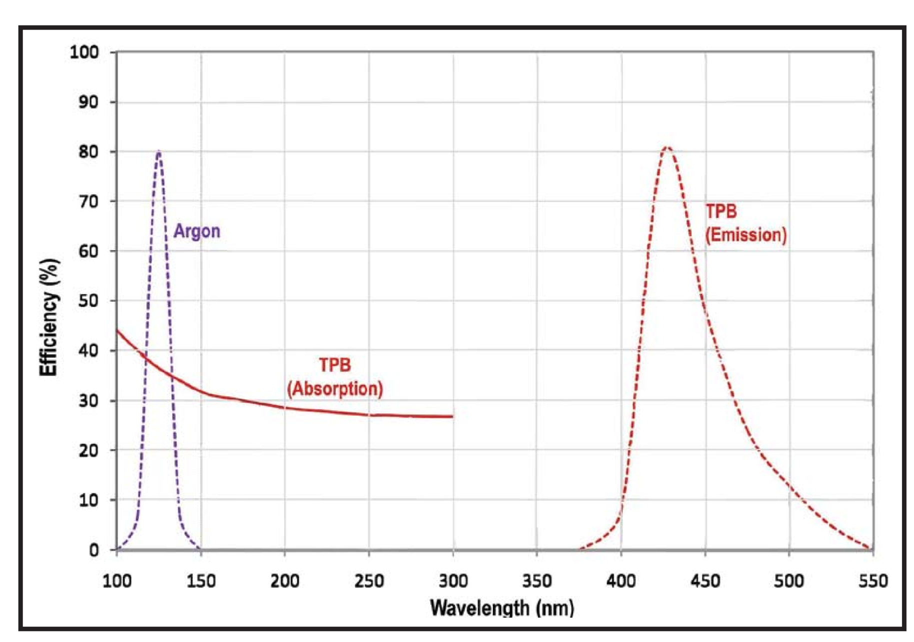


8 lightguides can be bent to form an adiabatic paddle and connect to a 2" PMT face. This gives a detection area of 0.1 m^2 (1.2 ft^2).

Acrylic Lightguides

Acrylic lightguides relay light events that occur in electric field intensive areas of the detector to a PMT.

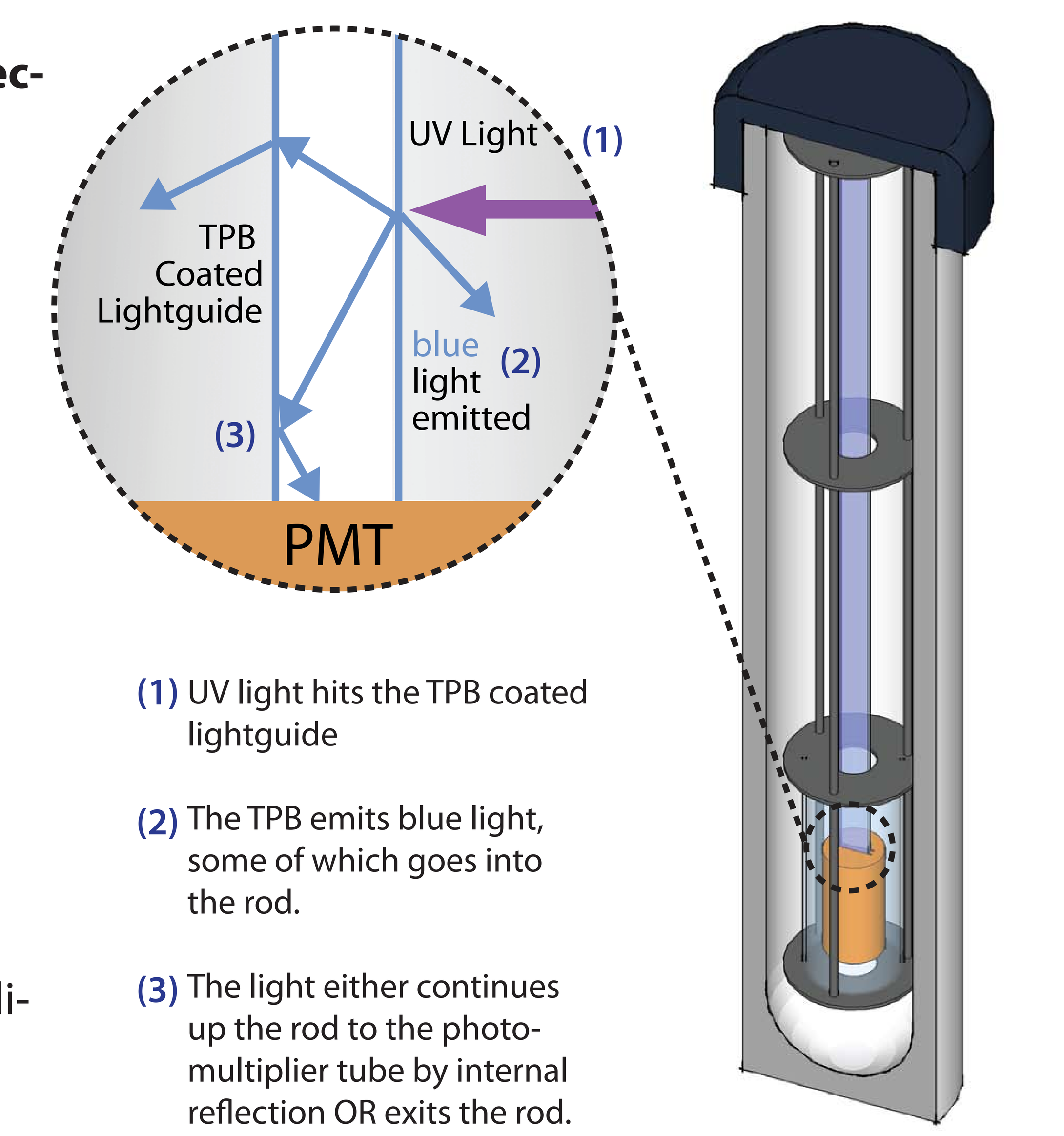
Acrylic is inexpensive and can withstand liquid argon temperatures.



The lightguides are coated with **TPB** (Tetraphenyl-butadiene) and polystyrene.

TPB shifts **UV light to blue light** and polystyrene has an index of refraction that matches that of acrylic.

Setup for testing lightguides



(1) UV light hits the TPB coated lightguide

(2) The TPB emits blue light, some of which goes into the rod.

(3) The light either continues up the rod to the photomultiplier tube by internal reflection OR exits the rod.

Testing the Lightguides

To test the efficiency of the lightguides, we

- Measure photoelectrons (PE) detected from UV light produced by polonium 210 α's
- Compare to a calculated ideal response.

"Ideal response" is calculated by accounting for TPB coating quality, PMT efficiency, and lightguide geometry.

0.1% Efficient
(Detected/UV emitted)
Ideal: 10 $\pm$ 3 PE
Measured: 7.5 $\pm$ 2.5 PE

Manfacturing concerns in making lightguides:

- **Attenuation**
  Light signal degrades in acrylic.
  Attentuation depends on acrlyic quality.
- **Coating smoothness and optical clarity**
  Bumps in coating result in light exiting the rod, never reaching PMT.
  Coating efficiency increases with TPB but more TPB reduced optical clarity.

Three lightguides with 3, 2, and 1 coat(s) of 1:3 TPB to polystyrene coating.

Conclusion

Lightguides are a **cost effective** method for increasing light detection coverage in LArTPCs.

Our current light guides are already sufficiently efficient to be used in large-scale detectors.

We are investigating **better coating techniques** and ways to **improve attenuation length**.

Future tests of the lightguides include measuring the lifetime of muons in liquid argon.

The dewar we will use to measure muon lifetime in liquid argon.

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