Colorado State University

ENHANCED LIGHT COLLECTION FOR A WATER ĈERENKOV DETECTOR AT LBNE

Norm Buchanan
Colorado State University
(On behalf of the LBNE Light Collector Group)

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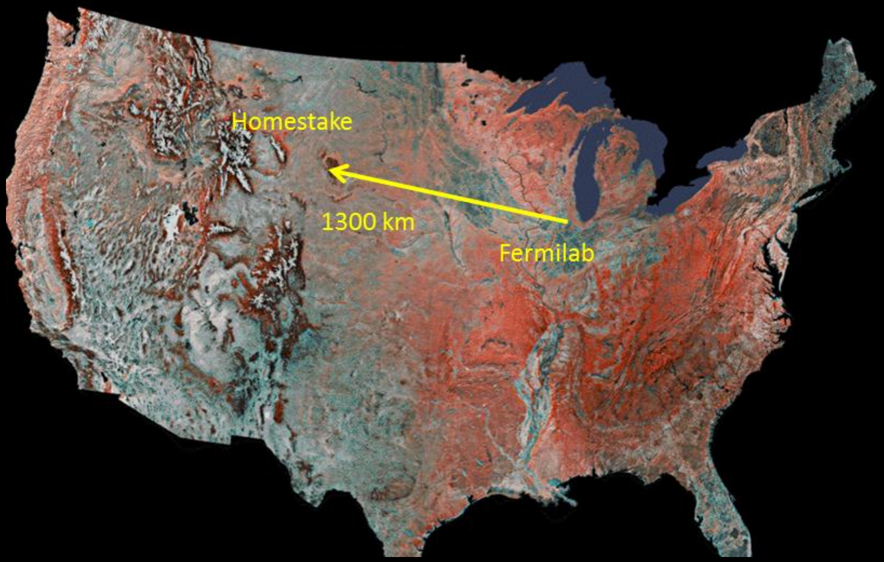
Technology and Instrumentation in Particle Physics
TIPP 2011

Long-Baseline Neutrino Experiment



- Wide-band neutrino oscillation experiment between FNAL and Homestake, SD.
- Physics goals include measurement of CP violating phase δ_{CP}, precision measurement (or discovery) of θ_{13}, SN burst neutrinos, etc…

- Two detector technologies under study for use in far detector
  - 200 kton Water Cerenkov at 4850′ depth
  - 34 kton Liquid Argon TPC at 400′ level

Motivation

- PMTs significant portion of LBNE WCD total cost
  - PMT (+Base) cost (estimate): ~$3000/channel
  - Additional costs for cabling and mounting

Geometry	Fiducial Vol. (kT)	Coverage (%)	# PMTs	Per channel Cost (M$)
Right cylinder	100	20	57,129	171.4
Right cylinder	150	20	73,012	219.0
Right cylinder	200 (2 x 100)	20	114,258	342.8
Mailbox	150	20	84,466	253.4

Eg. LBNE far detector with 20% coverage. PMT numbers (not costs) taken from John Felde (UC Davis) for LBNE far detector simulation (cost estimates and coverage #s for illustrative purpose only)

- Even 10% less PMTs leads to significant cost reduction.
- Improved light collection efficiency is potential solution – other experiments have used or studied possible approaches
  - Reflective cones (used in SNO)
  - WS plates (used in IMB, and SuperK outer detector)
  - WS PMT coatings investigated for IceCube

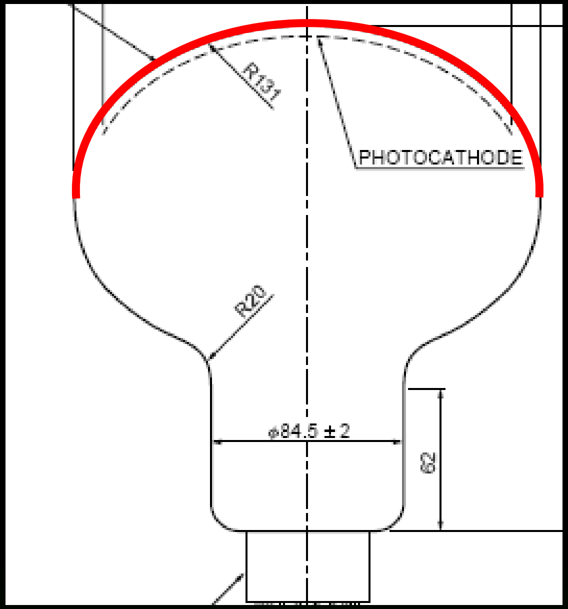
Investigating Three Options

- Wavelength-shifting coating on PMT face
  - investigated for IceCube
  - shifts Ĉerenkov spectrum into PMT detection spectrum
  - can be used with other light collection methods
- Wavelength-shifting plate
  - used in IMB (and outer detector of Super Kamiokande)
  - very configurable (dopant, thickness, radius)
  - relatively easy to manufacture – can be cast in desired shape
- Reflective Winston cone
  - used in SNO (heavy water D_2O)
  - minimal wavelength dependence
  - reflected light doesn't introduce delays

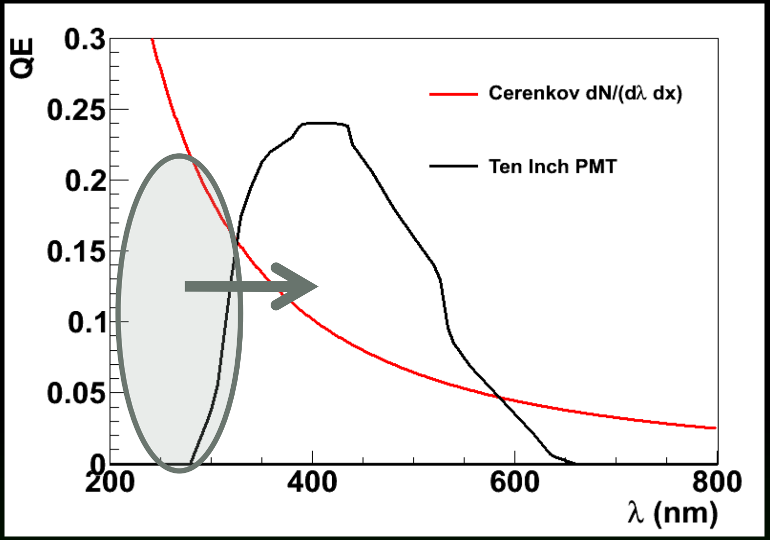
Cost of both WS plate and Winston cone ~$100/unit

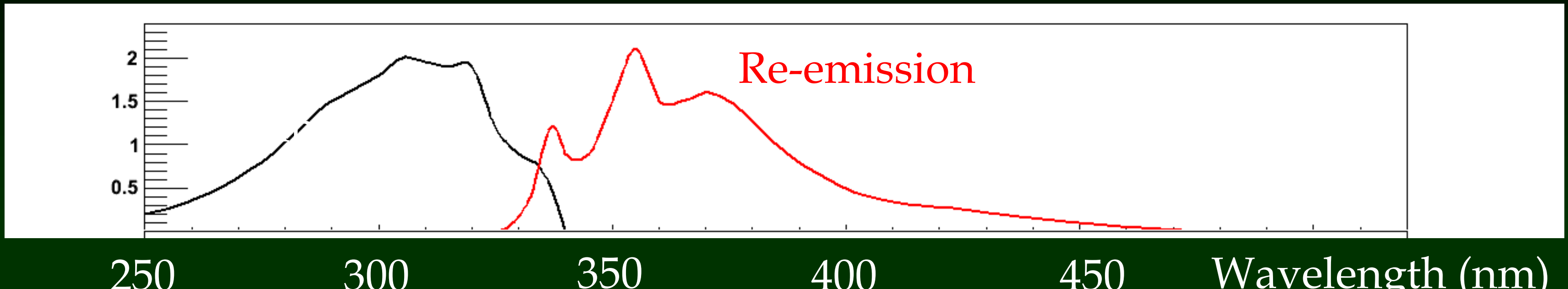
WS Films

Xin Qian et al (Caltech)

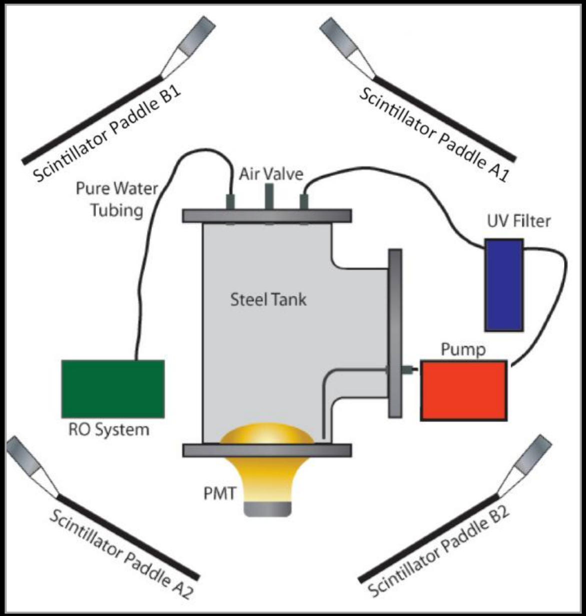


Motivated by initial investigations from IceCube reported in 1995 (15% increase in efficiency)





WS Film R&D

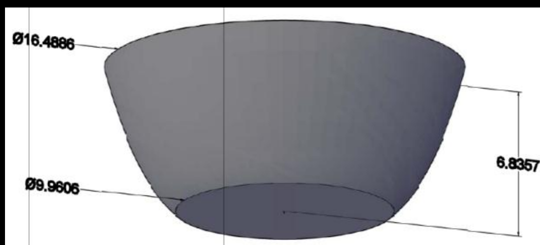


- WS film added to PMT face achieves an increase in light collection of about 11%
- The nature of the WS film allow it to be combined with the either of the other approaches so R&D focus has moved to the reflective cones and WS plates.

Reflective (Winston) Cones

Jelena Maricic et al (Drexel)

$$\frac{(r-d)^2}{a^2} + \frac{z^2}{b^2} = 1$$

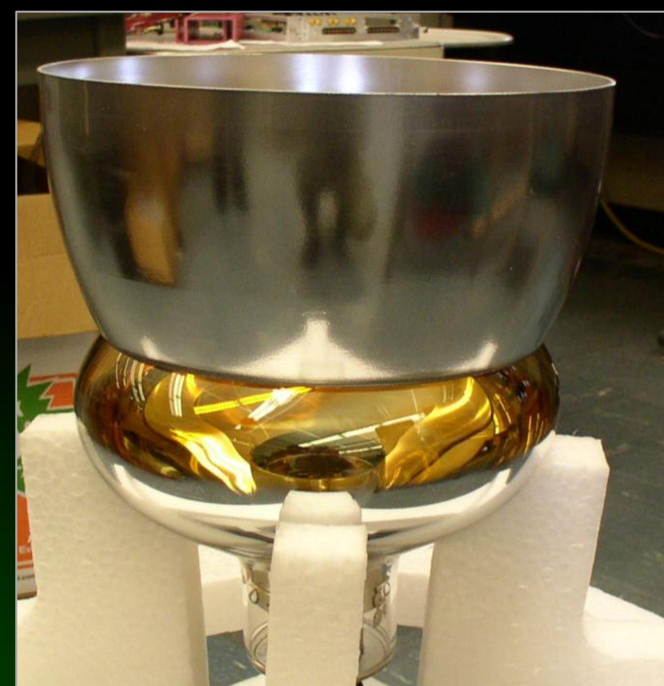


(ellipse with semi-axes a,b centered on (d,0) in r-z plane)

Uses off-axis parabola to re-direct photons missing PMT onto photocathode

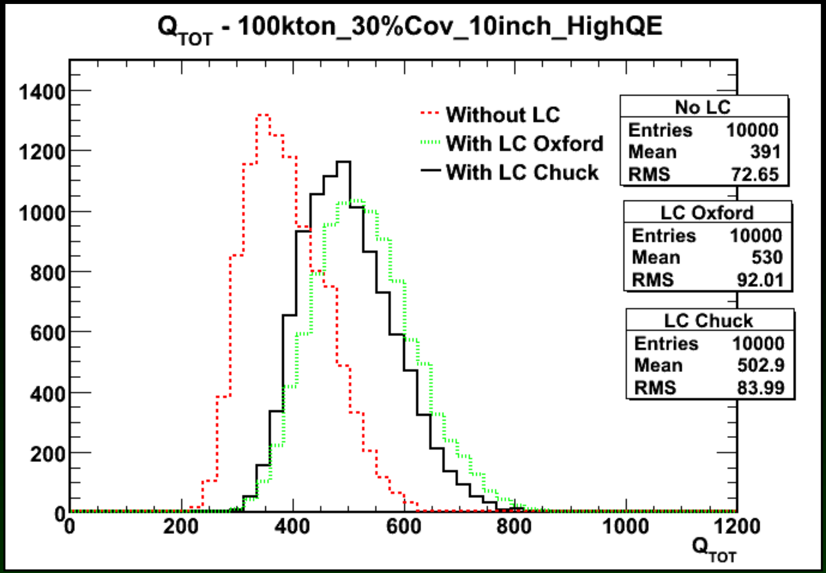
(2 prototypes with slightly different shapes examined)

Al coated prototype

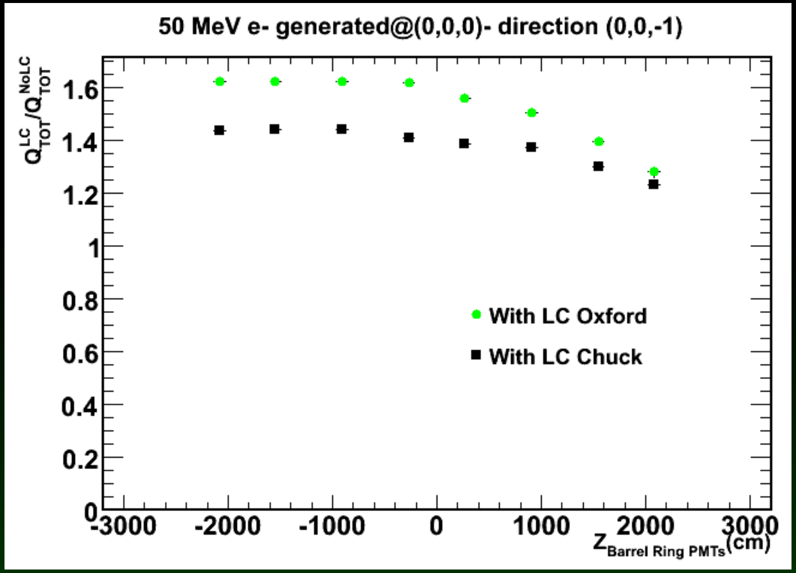


Studies on Prototypes

- Simulation (WCSim) with Winston cone reflector shows 50% increase in light collection
- Increasing the size of the Winston cone can increase collection enhancement
    - Need to balance increase light collection with reduction of fiducial volume when increasing size of cone.



Collected Charge



Fractional improvement vs Z pos.

WS Light Collector Plates

Norm Buchanan et al (CSU)

Prototype 1 (BC-499-76)

UV → blue

ID: 10″, OD 20″, 5 mm thick

Polyvinyl toluene (PVT) base

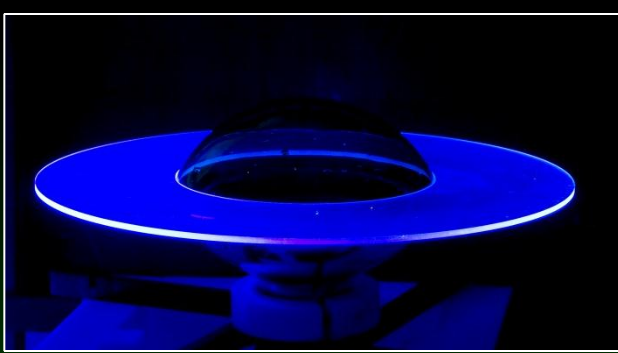
Fluor: POPOP + ??

Index of refraction = 1.58

Density = 1.04 g/cm^3

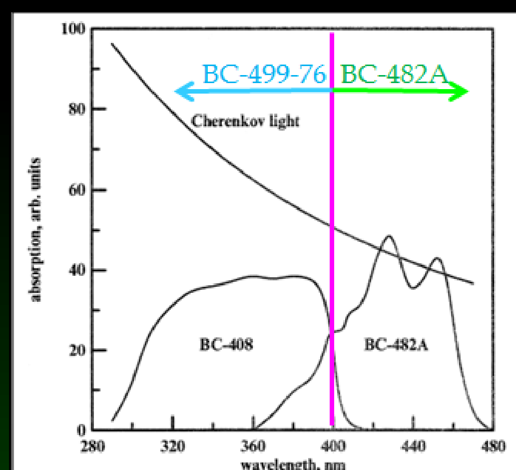
Decay time = 2.1 ns

Vendor: Saint-Gobain



PMT area: 78.5 in^2

Plate area: 235.6 in^2



Prototype 2 (BC-482A)

blue → green

ID: 10″, OD 20″, 10 mm thick

Polyvinyl toluene (PVT) base

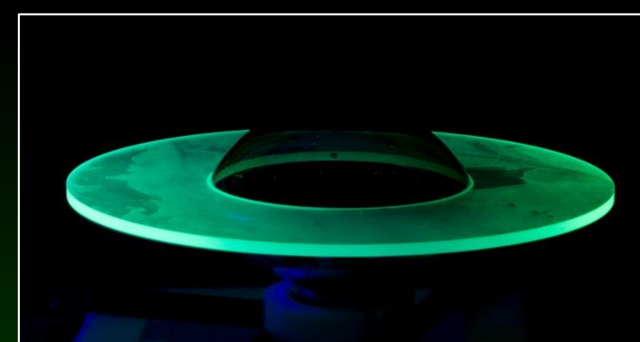
Fluor: BBQ?

Index of refraction = 1.58

Density = 1.04 g/cm^3

Decay time = 12 ns

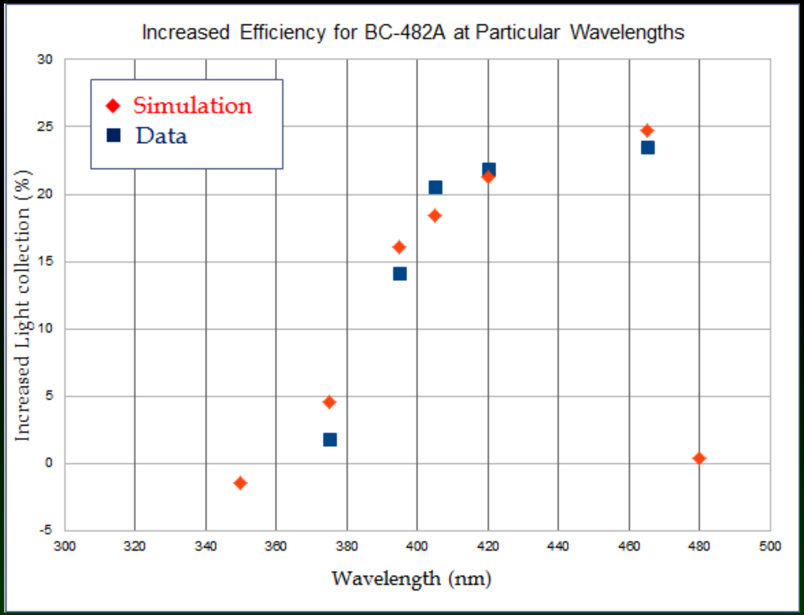
Vendor: Saint-Gobain



Studies on Prototypes

- Due to the nature of the WS plastic (very different absorption/emission spectra) two experimental setups are being used to study the prototypes.
  - “Green” prototype studied in a dark barrel with various LEDs
  - “Blue” prototype studied in a large water Ĉerenkov tank (Auger tank)
- Tests on green prototype show good agreement between data and simulation
- Tests on blue prototype in WC facility just getting underway (results soon)

Tank for Cerenkov facility (May 2011)



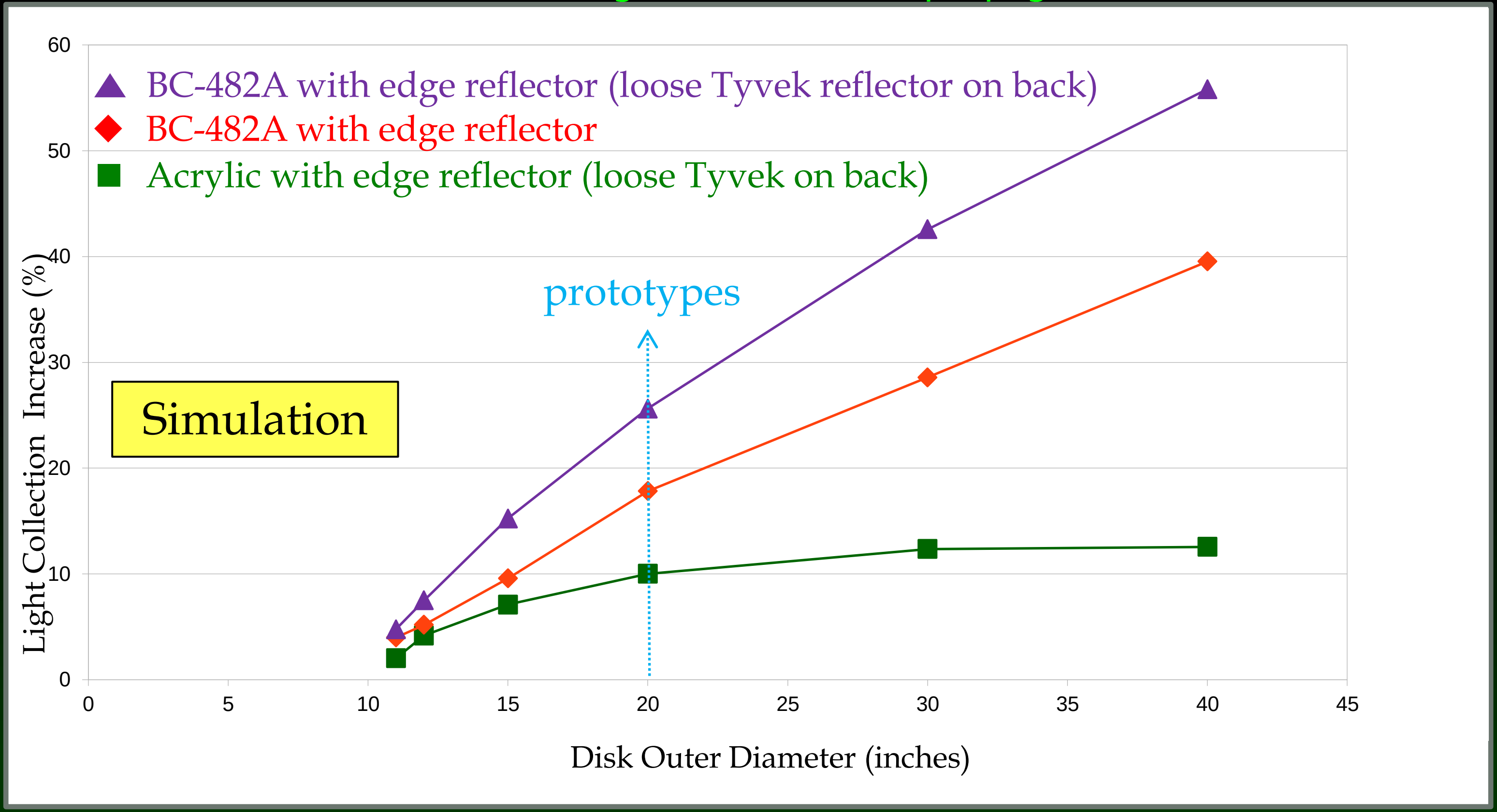
Light collection increase (%)

Improvement with Disk Size

One of the two handles we have for improving the collection performance of the system is the diameter of the disk.

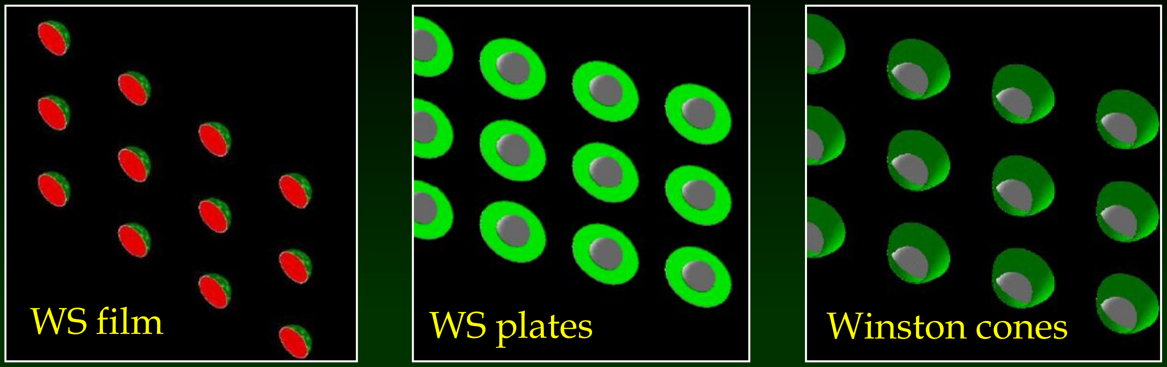
Building a scanner to help characterize the effect of the radial location on collection efficiency and timing degradation

Uniform Cerenkov light source (30 m propagation)



Simulation

- Simulation of devices and physics critical
  - important to understand the physical characteristics of devices (optical, timing) in order to have accurate physics simulation
  - all 3 technologies have been added into the full simulation of our WC detector (WCSim)
  - stand alone Geant4 simulation of WS plates used in conjunction with the lab testing
- What are the effects on the physics potential of LBNE?
  - is reconstruction compromised?
  - is π^0/electron separation measurably impacted
  - are we sending light back out into the active volume?



LC Geometries in WCSim

Outstanding Questions

- Reflective Winston cones
  - What is the effect on fiducial volume?
  - How does efficiency look at top/bottom of tank (angular dep.)?
  - How to they hold up in ultra-pure water at high pressure?
- WS plates
  - What is the effect of timing on physics?
  - Are reflections a problem? Can we deal with them algorithmically?
  - How to they hold up in ultra-pure water at high pressure?
- WS films
  - How can the films work together with other technologies?
  - How will they hold up in ultra-pure water at high pressure?

Summary

- Three light collection enhancement technologies candidates for potential use in a WC far detector at LBNE
- Prototypes in hand for all three technologies and studies ongoing
- Simulation work in parallel to answer critical physics questions
- Moving toward a choice of a baseline technology this year
- Working hard to ensure any chosen technology improves LC efficiency without destroying the physics potential of the experiment

THANK YOU!