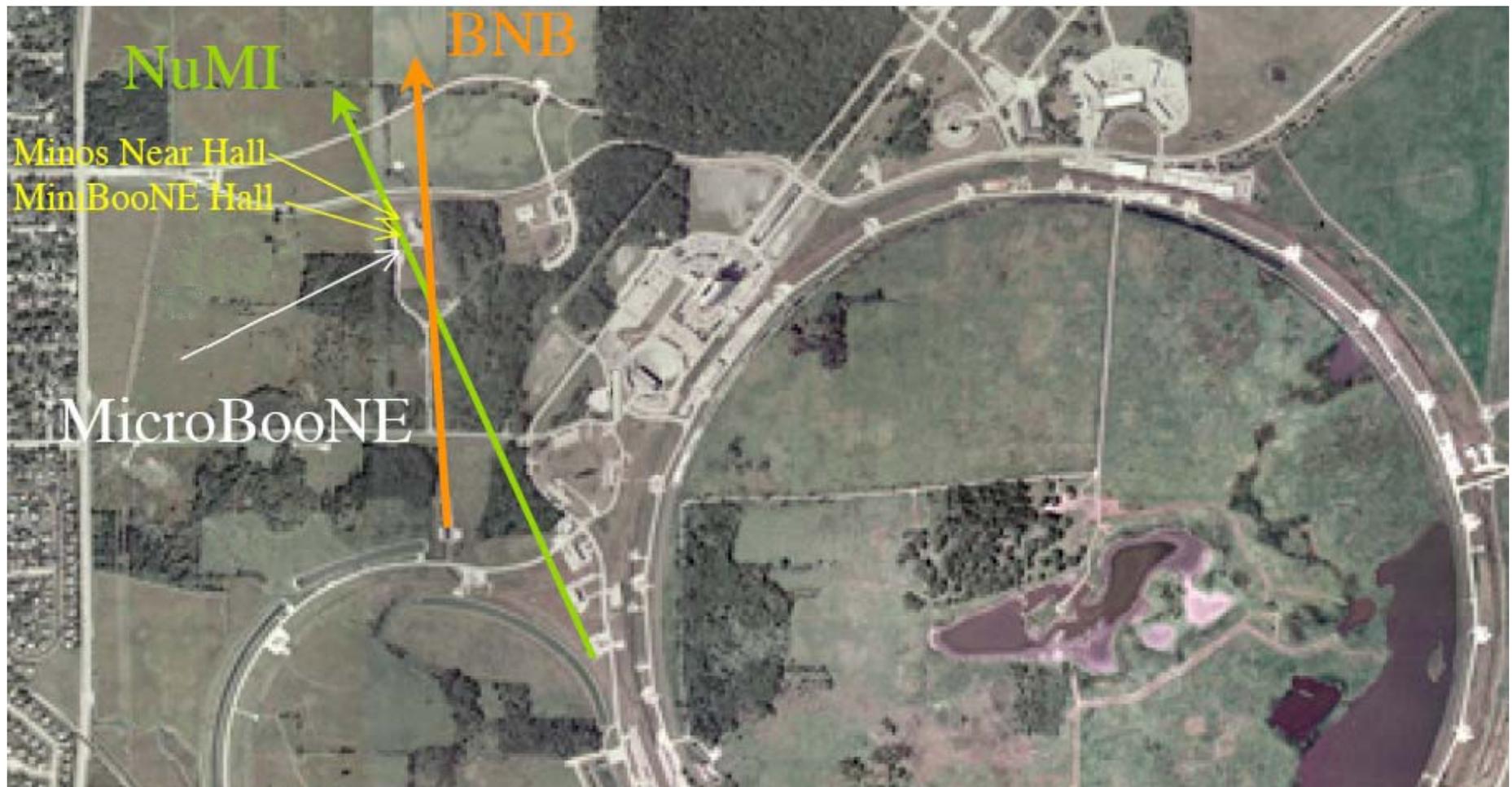


MicroBooNE

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MIT
DPF2011
August 12, 2011

Location



MiniBooNE: Cherenkov detector searching for electron neutrino appearance $\nu_{\mu} \rightarrow \nu_e$

MicroBooNE: First Liquid Argon Time Projection chamber to do beam physics

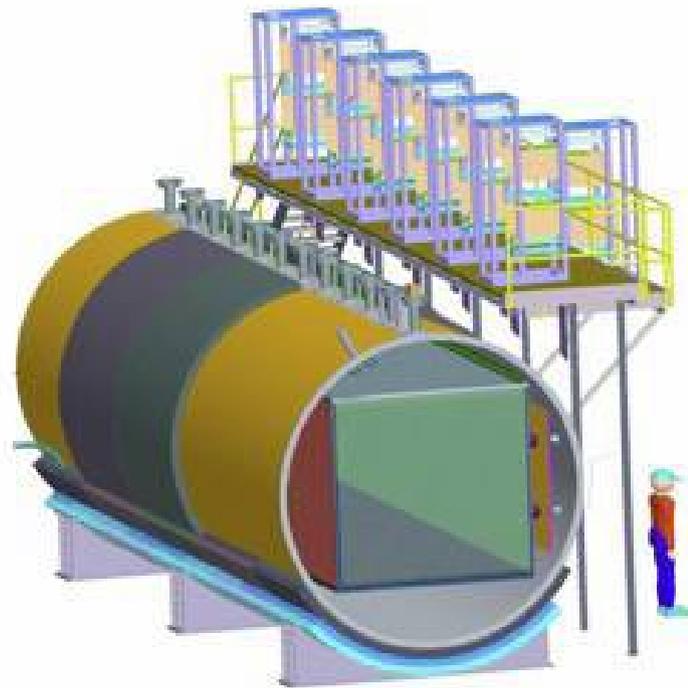
Detector Overview

MicroBooNE is a Liquid Argon (LAr) Time Projection Chamber (TPC)

LAr TPC's have 6 times more sensitivity than Cherenkov detectors, meaning smaller detectors for the same physics! They have a high signal efficiency and low background

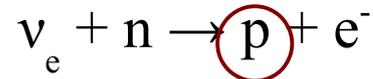
Two Detection components: charge collection (TPC) and light collection (PMTs)

Length: 10m
Radius: 4m
Fiducal volume:
~60 tons

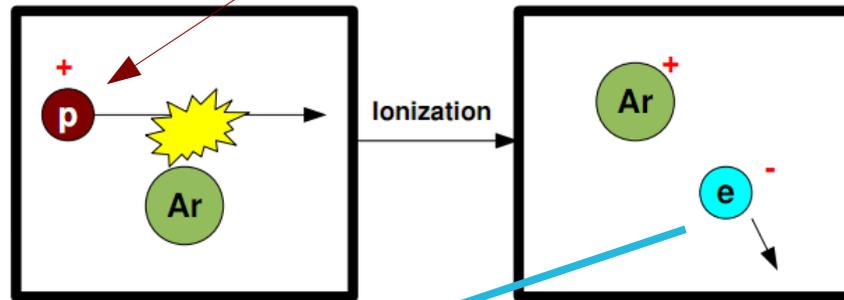


Charge in LAr

Charged particles are created in neutrino interactions, ex:



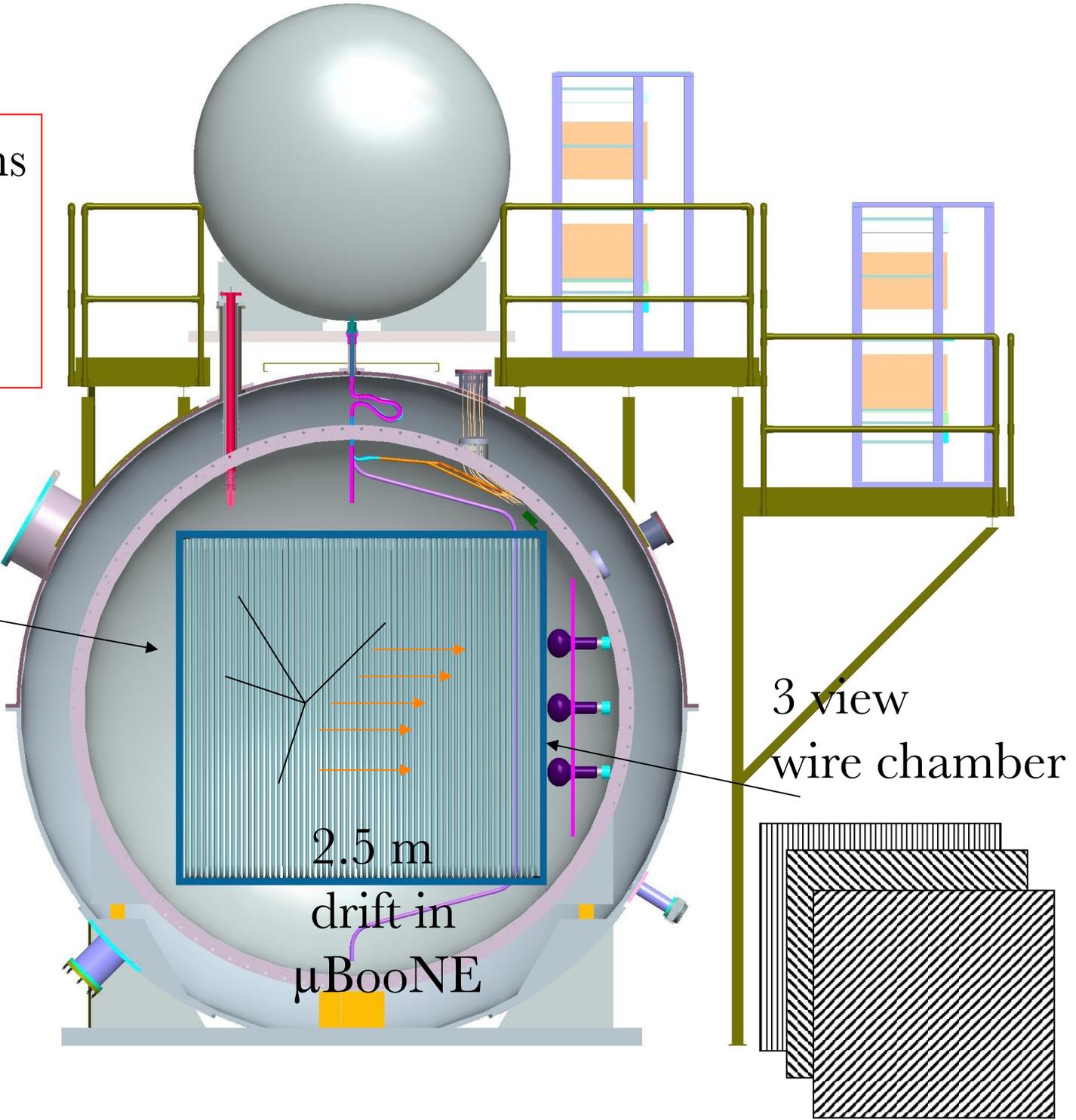
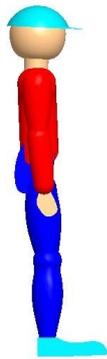
As these charged particles pass through the LAr, they ionize the Argon atoms:



Resulting “ionization electrons” drift due to an applied electric field

Ionized electrons drift slowly toward the chambers

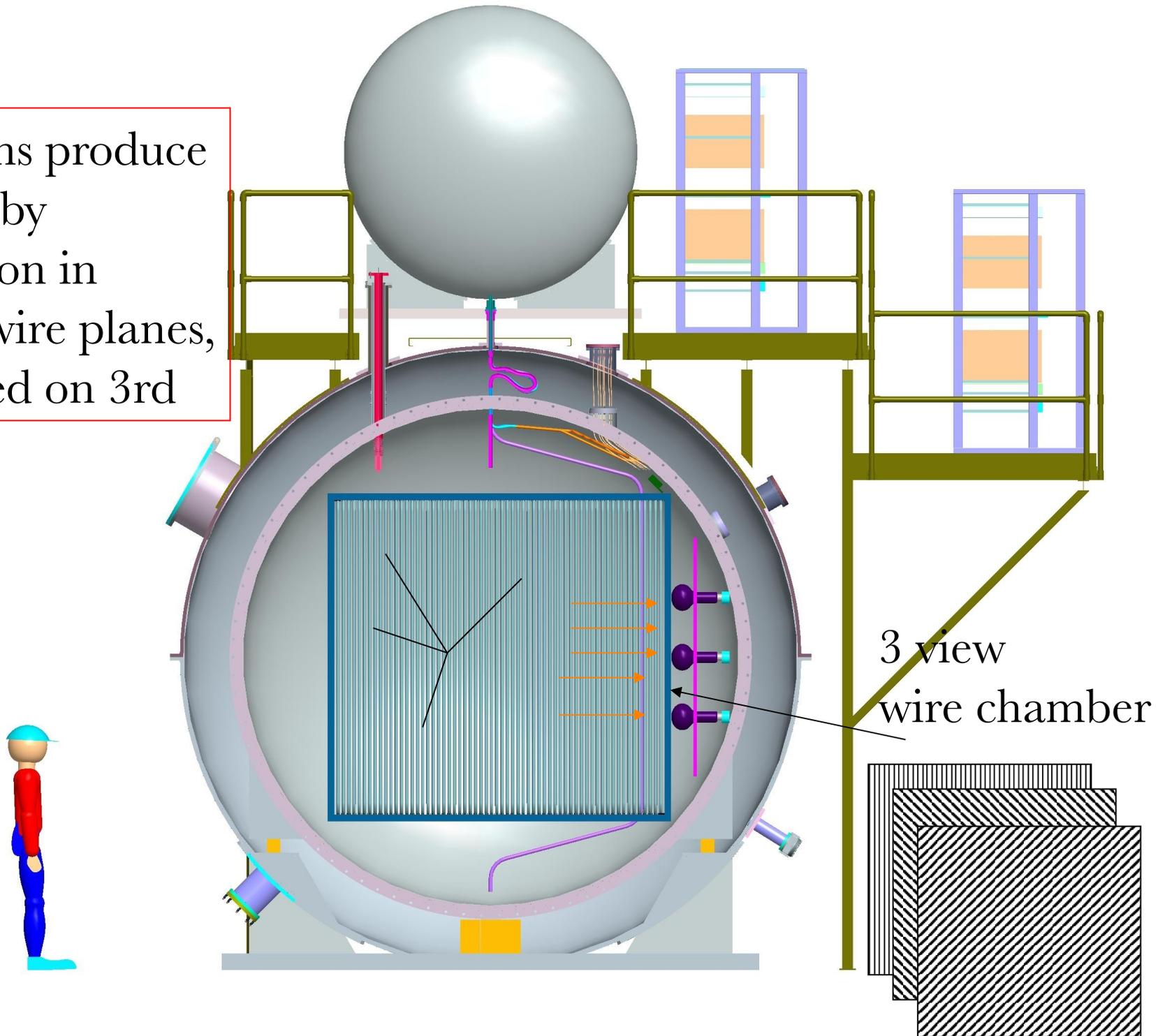
High Voltage, 125 kV



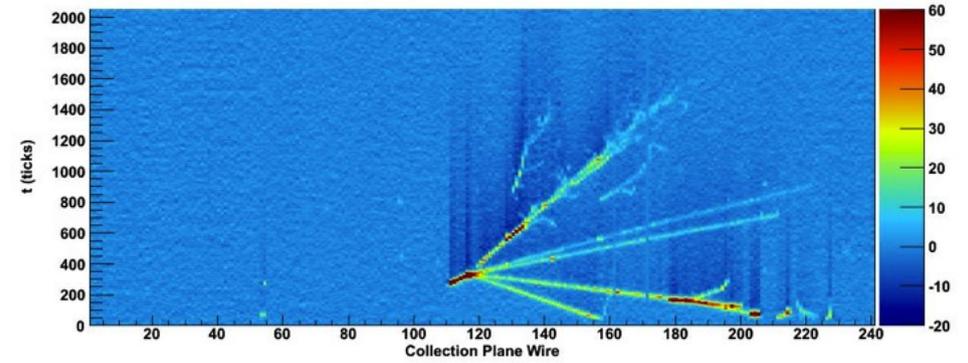
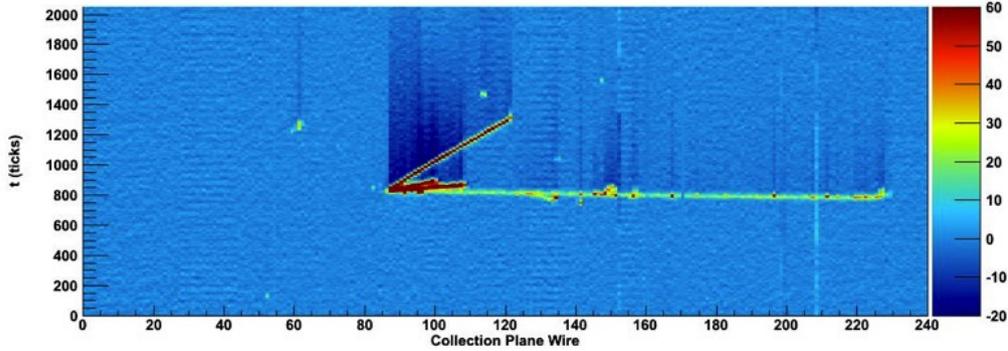
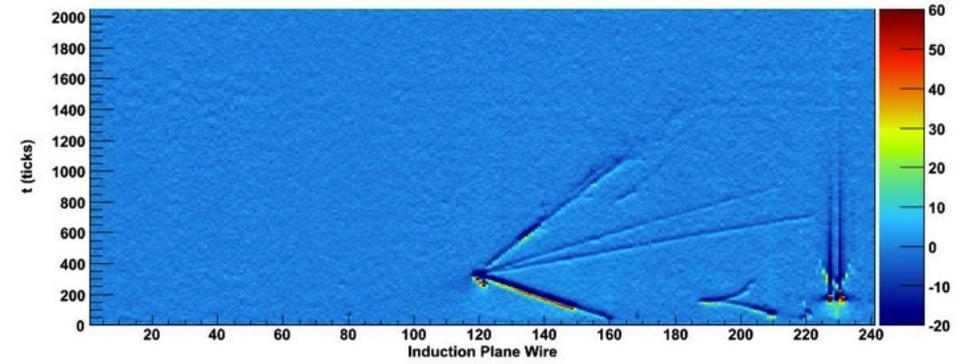
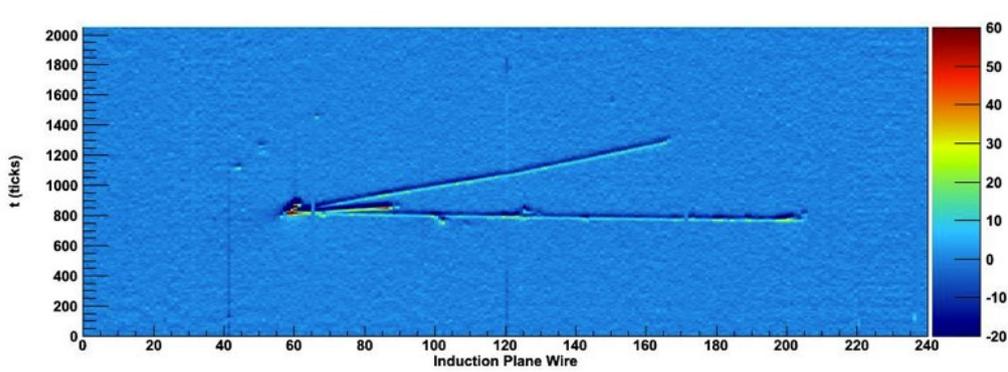
2.5 m drift in μ BooNE

3 view wire chamber

electrons produce signals by induction in first 2 wire planes, collected on 3rd



Event Displays (from ArgoNeut)



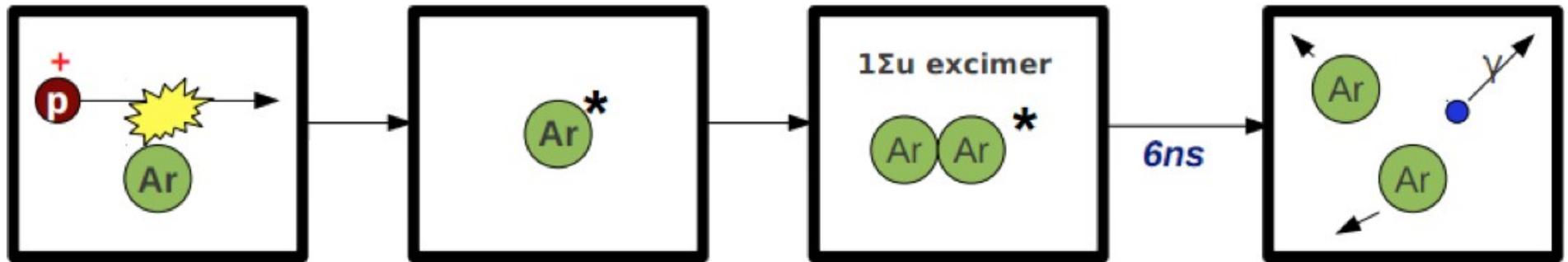
Why light detection in LAr is important

- Rejection of background by comparing interaction time with beam time structure (crucial for a surface detector!)
- Triggering on interesting non-beam events
- Correcting for charge losses and diffusion as a function of drift distance for a more accurate measurement of the energy deposits
- Reduce noise by comparing optical and TPC data

Light in LAr

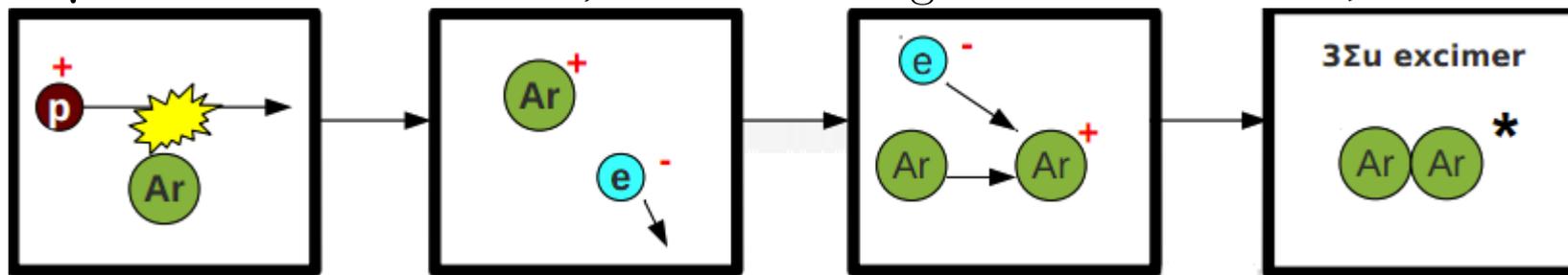
Fast scintillation path

~6ns after the interaction, 25% of the scintillation light



Slow scintillation path

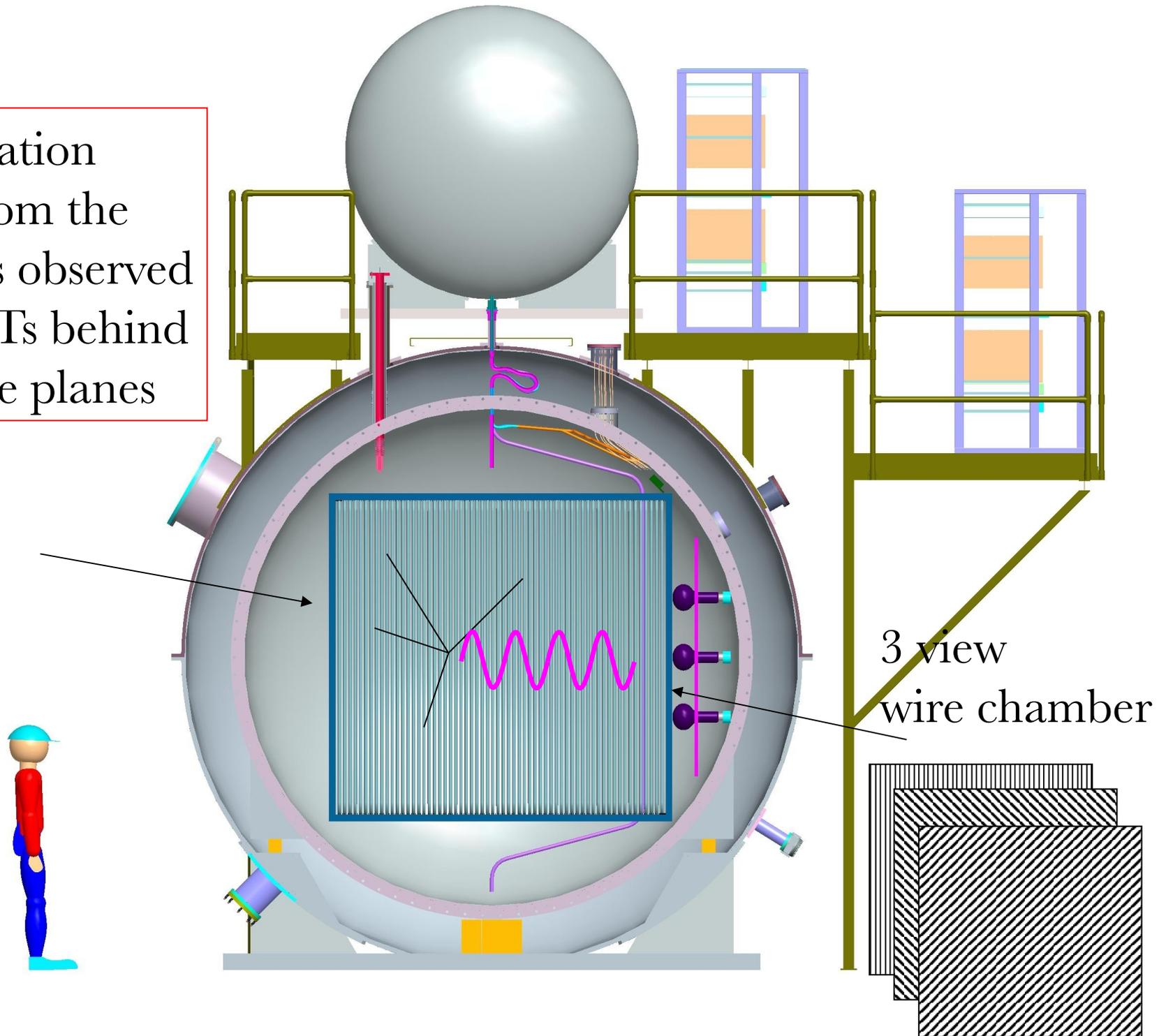
~1.6 μs after the interaction, 75% of the light



In both cases, this light is emitted at 128 nm, which our phototubes cannot see since it can not get through the glass

128 nm is in the “vacuum UV” so it doesn't even propagate through air!

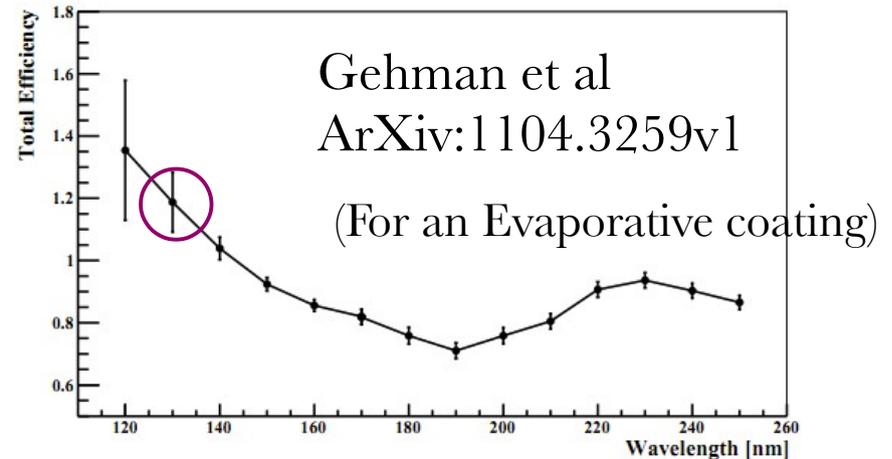
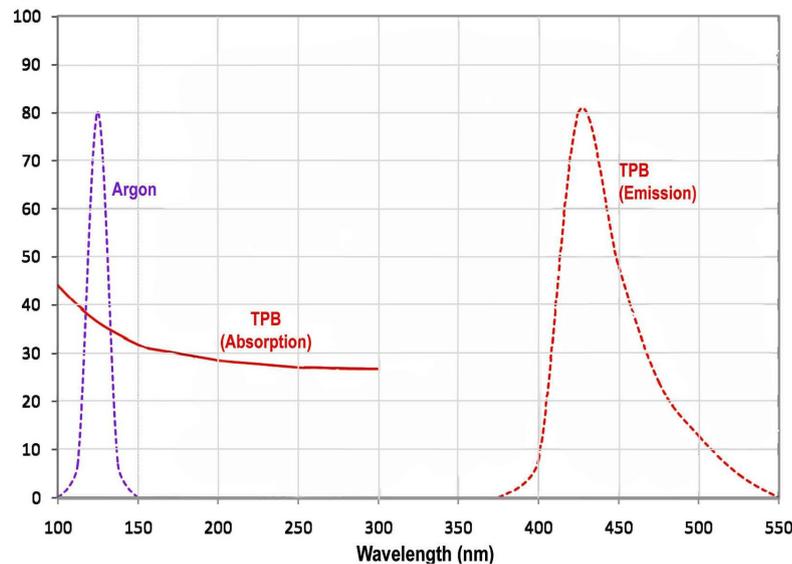
Scintillation light from the event is observed by PMTs behind the wire planes



3 view wire chamber

Seeing 128nm light

We use a wavelength shifting material called Tetrphenyl Butadiene (TPB) to coat plates which will go in front of the PMTs



We use a mixture of 50% TPB and 50% polystyrene (PS) for our plate coating (yields about 50% of the light as an evaporative coating)

We find that mixing the TPB in PS makes the plates more durable and is much more cost effective!

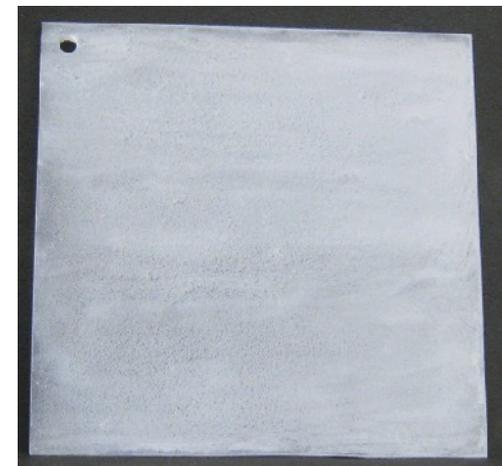
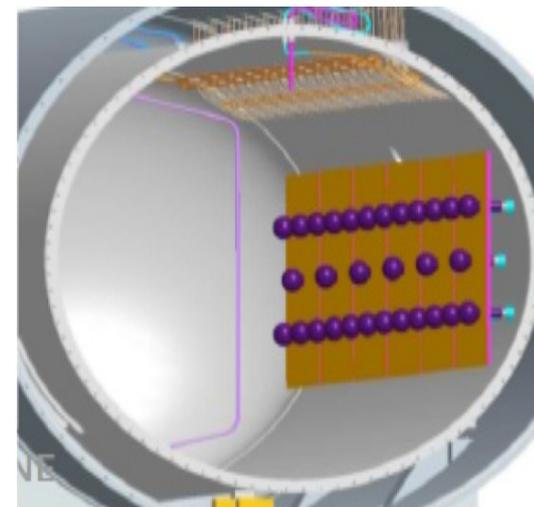
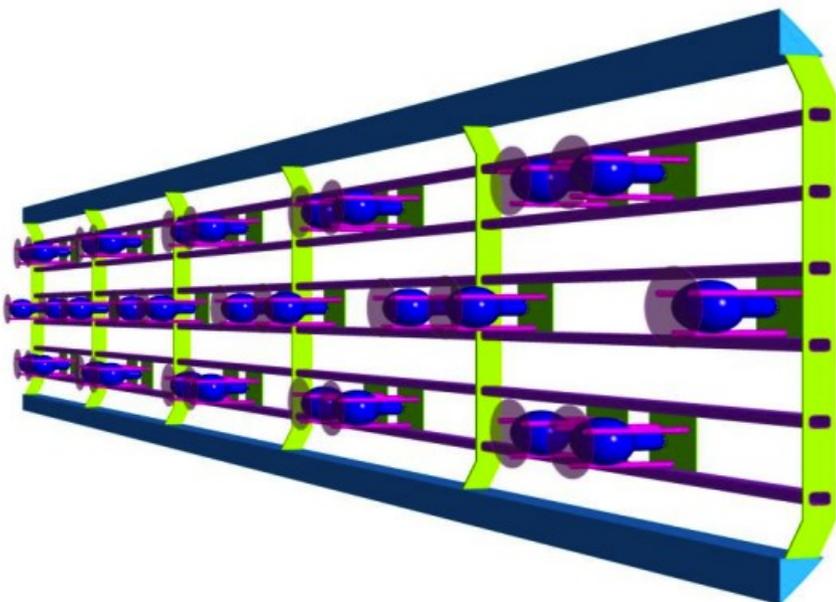
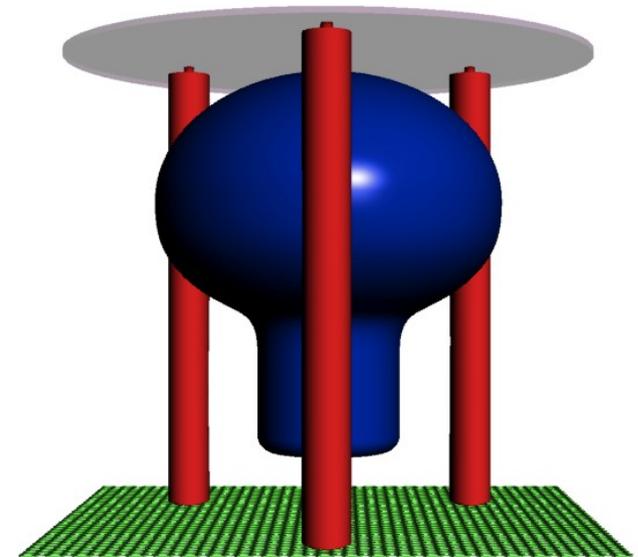


Plate sample with a 50% TPB-PS coating

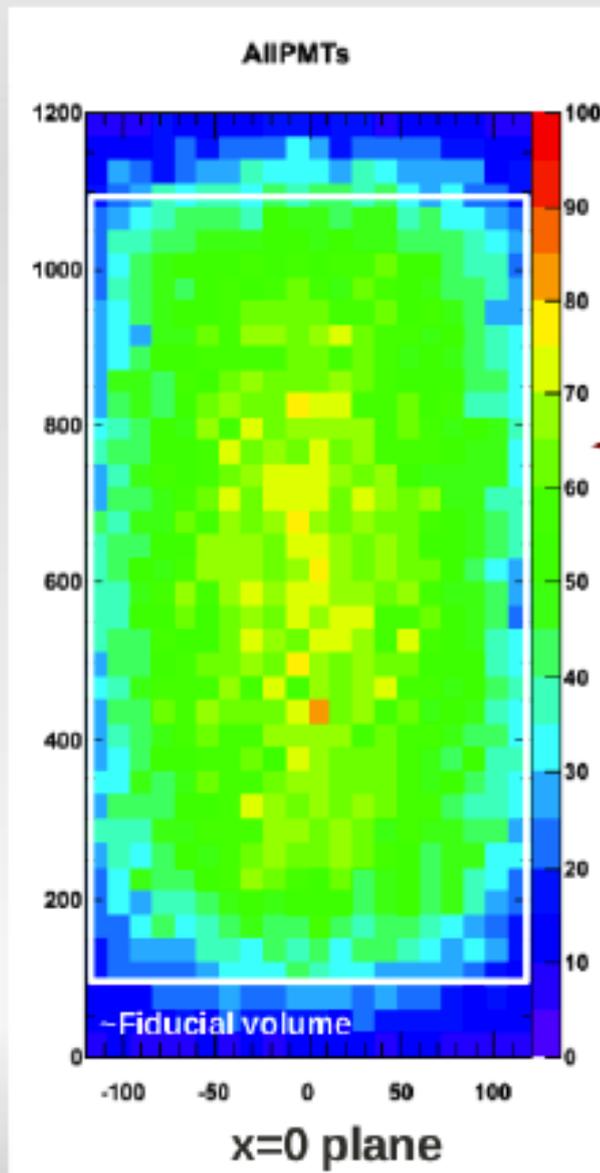
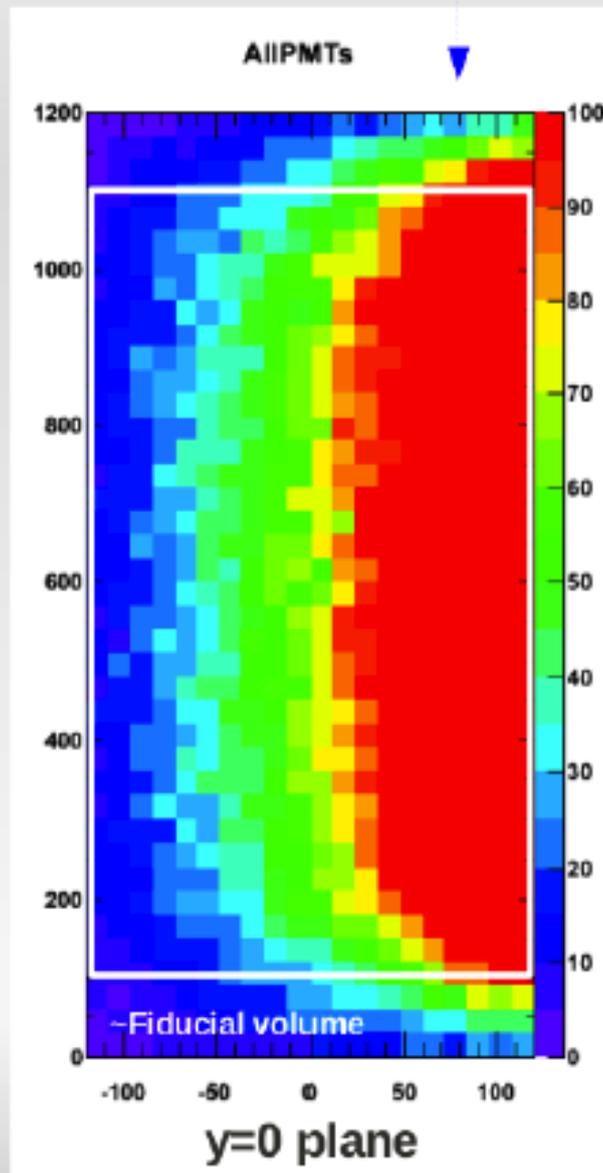
Light Collection System

These plates are then placed in front of 30 PMTs on the side of the cryostat.



30 PMTs facing TPC

Sensitivity map



A diagram showing a 2x2 grid of blue squares representing detector cells. To the right of the grid are four green ovals representing PMTs. A red arrow points from the bottom-right cell of the grid to the text below. A blue dashed arrow points from the top of the grid to the top of the y=0 plane plot.

Number of photoelectrons summed over all PMTs for point source of **5MeV** equivalent at different detector points

Trigger should be possible on 1 p.e. We are sensitive at all points on these plains within fiducial volume.

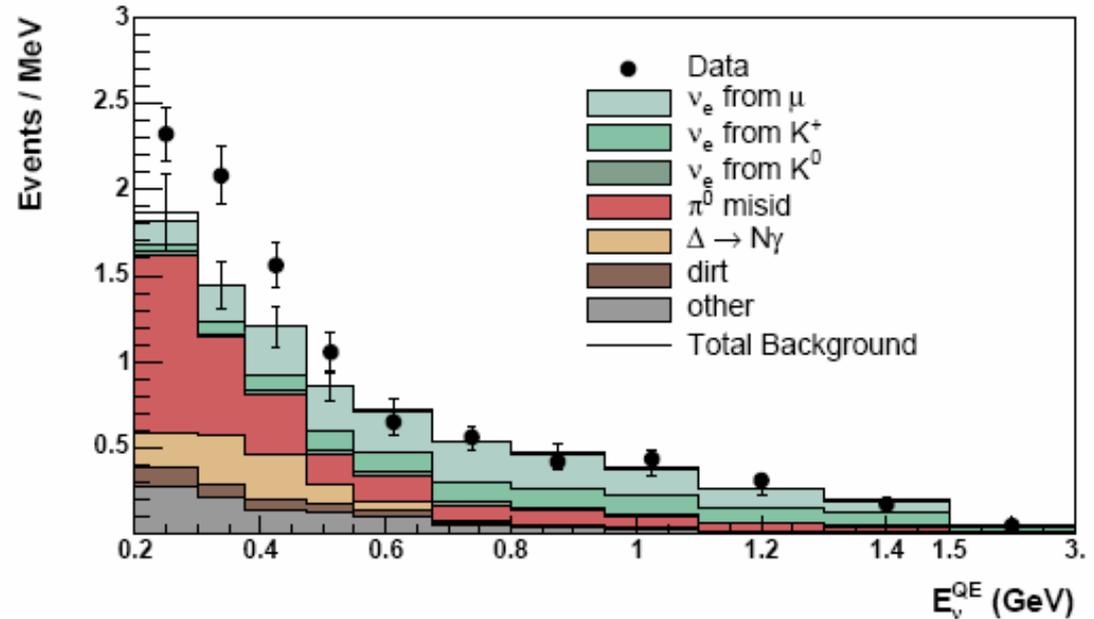
Motivation: MiniBooNE

MiniBooNE is a Cherenkov Detector, sees Cherenkov light from charged particles

3σ excess of electron-like events at low energies

Possibilities:

- Unexpected background
- New physics

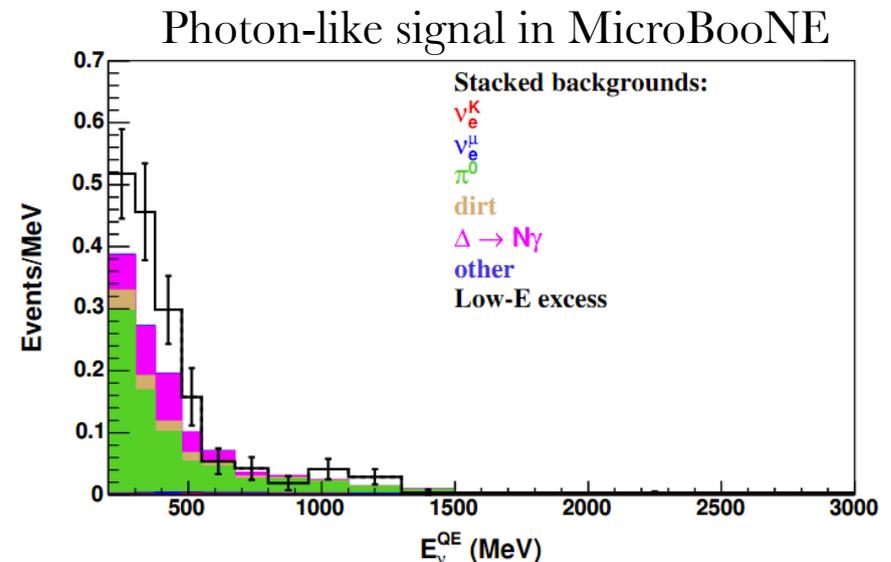
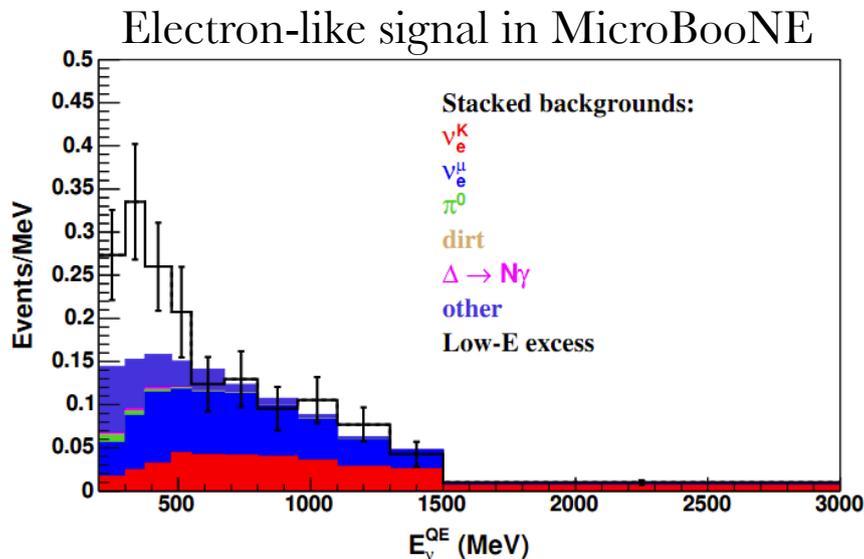
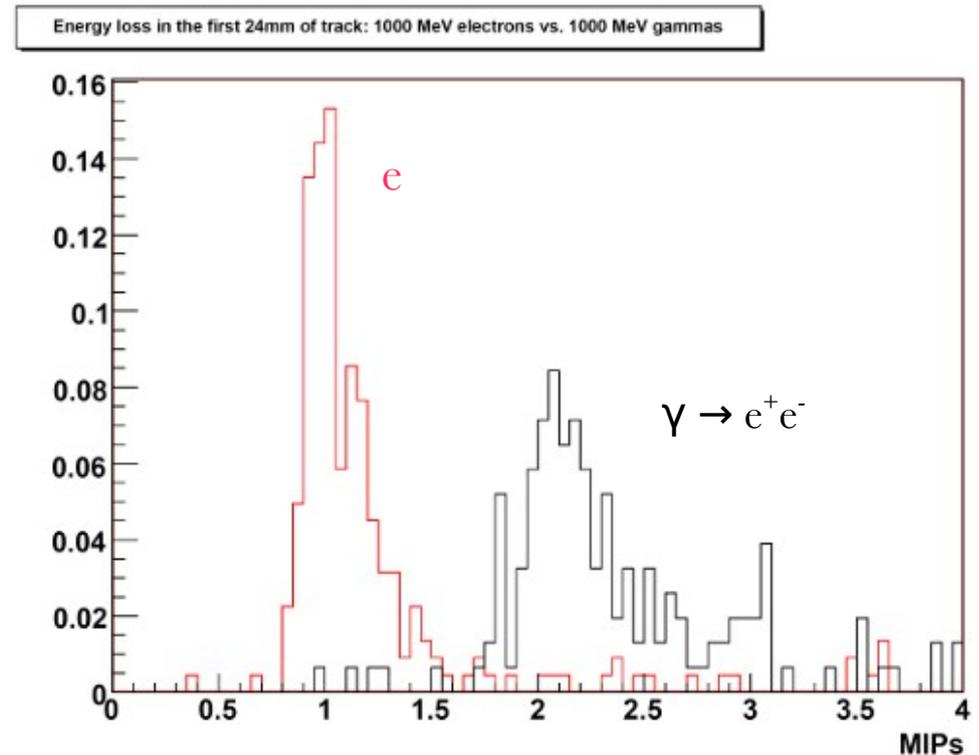


Cherenkov detectors cannot tell the difference between electrons and photons ($\gamma \rightarrow e^+e^-$), which are a large source of background

- Cherenkov detectors only have a ~ 20 cm vertex resolution, but 2cm is needed to distinguish γ 's from e^- 's

How MicroBooNE Can Help

- Can tell the difference between e's and γ 's – sensitive to the different amounts of energy they deposit
- High resolution reconstruction of events
- Predict ~ 50 MiniBooNE-like low energy excess events

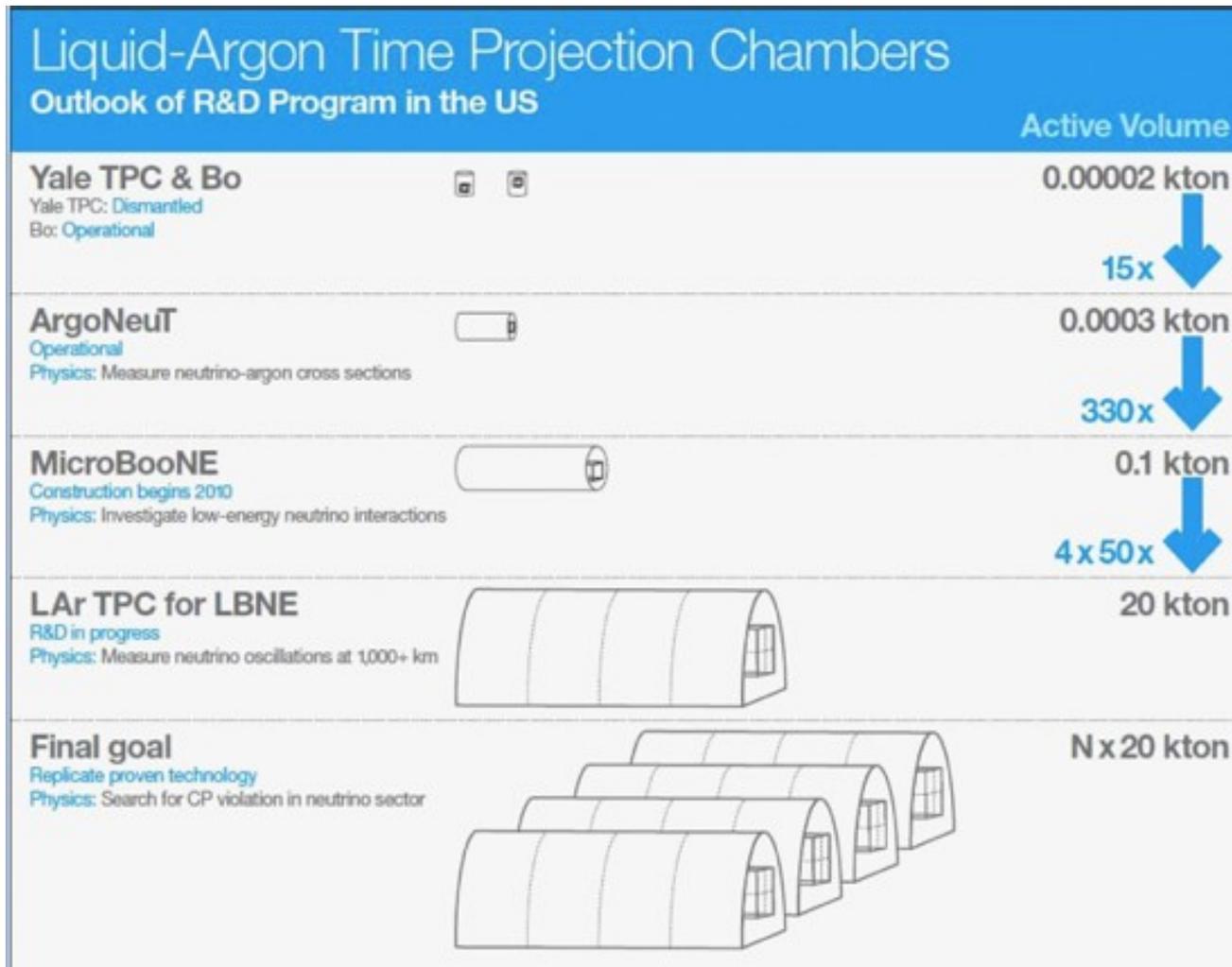


R&D for Future LAr Detectors

Goal: Make LAr a viable option for future large detectors

- Need to understand cross sections in LAr
- Demonstrate scalability of technology
- Cold electronics
- Purity
- Analysis tools

R&D for Future LAr Detectors

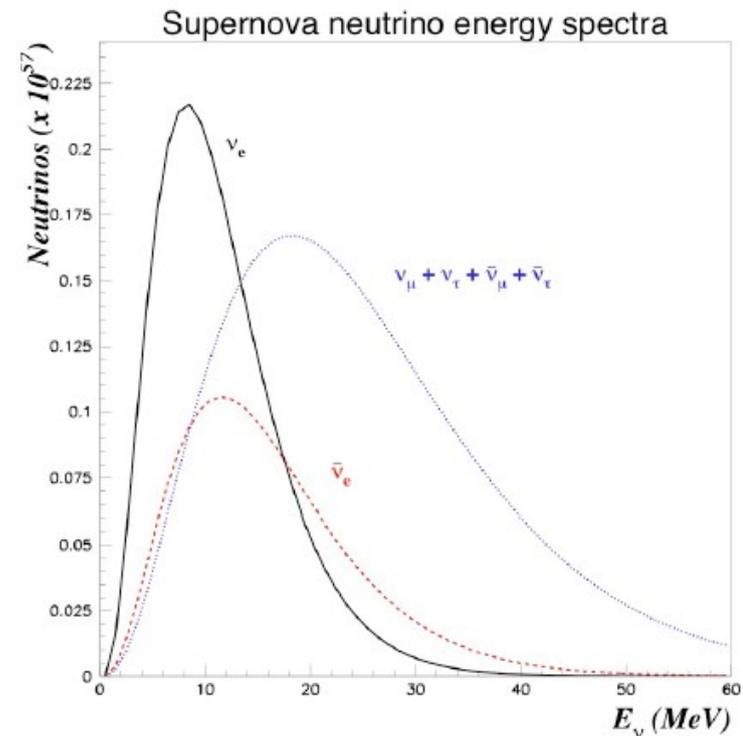


Other Physics Goals

- Low energy cross section measurements
 - Important for everyone!
 - Can't study neutrino interactions until we understand their cross sections
 - How do we model neutrino interactions on different nuclei?
 - Independent particle models?
 - Multi-nucleon correlations?

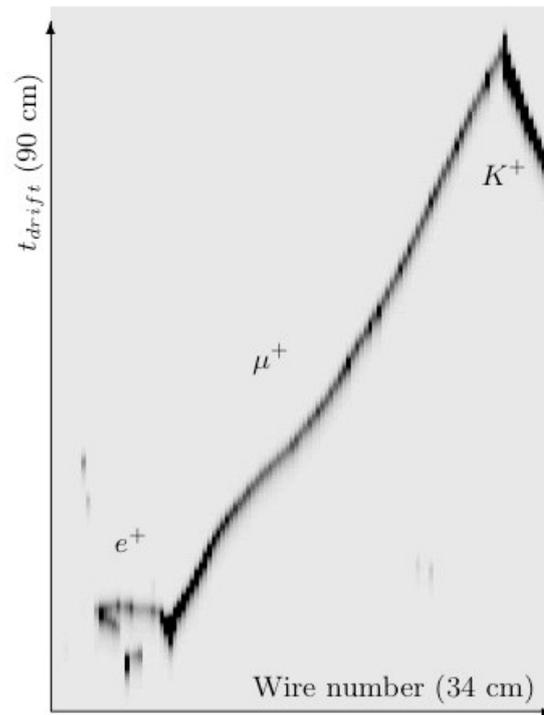
Other Physics Goals

- Burst supernova detection capability
 - Neutrinos are the only way we can see what's going on in the core of a supernova! Window to nucleosynthesis, black hole and neutron star formation, etc
 - MicroBooNE is sensitive to all neutrino species for elastic scattering, charged current, and neutral current events
 - Sensitive to low enough energies
 - Planning on data buffer



Other Physics Goals

- Prepare for future proton decay searches ($p^+ \rightarrow K^+ \nu$)
 - Invisible to Cherenkov detectors
 - We're not big enough to actually search for this yet but can develop PID, triggers, and understand background



Simulated Proton
decay event in LAr

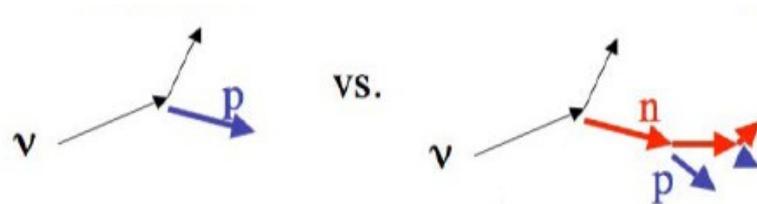
FIG. 17: Simulated $p \rightarrow K^+ \bar{\nu}$ event. The displayed area covers $34 \times 90 \text{ cm}^2$.

Other Physics Goals

- Sensitive to ΔS (fraction of proton spin carried by strange quark)

$$R_{NC/CC} = \frac{\sigma(\nu p \rightarrow \nu p)}{\sigma(\nu n \rightarrow \mu^- p)}$$

- May help us to better understand proton spin
- Input for spin-dependent WIMP searches
- Information on final states for modeling events in LAr
- This is impossible for most detectors because it is hard to tell protons from neutrons



MicroBooNE may be able to! It can measure the energy of the outgoing proton and may be able to see the disconnected neutron-proton vertex 21

Other Physics Goals

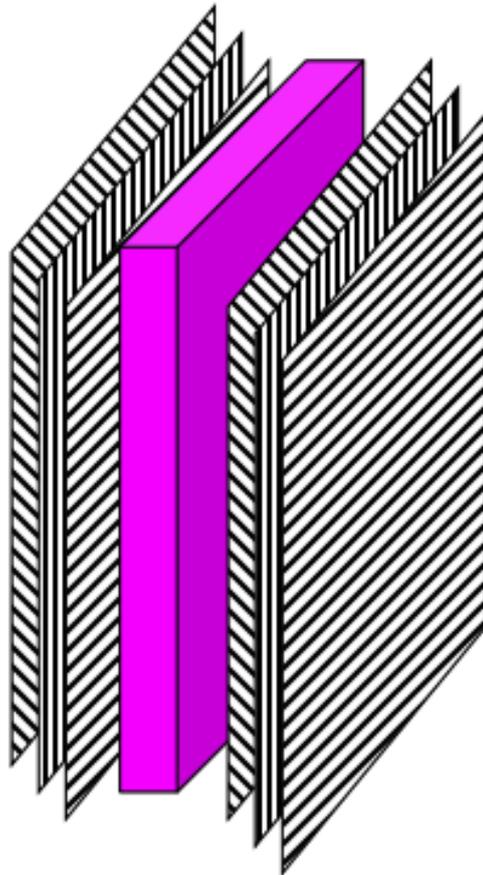
- Searches for exotic physics
 - Sensitive to decays such as Neutral Heavy Leptons, Axions, Paraphotons
 - Lorentz violation
 - Various models out there predict exotic physics... We have to be open to the possibility of seeing something unexpected, especially in a field where every experiment seems to have a new anomaly!

Some light collection R&D at MIT...

Scaling up to multi kton detectors

Light detection along the outside edge of detector unlikely to work.
Rayleigh scattering leads to a high chance that interior light
will hit wires and be absorbed.

Needs a flat system that can be inserted in interior, w/i wire planes



Solution: lightguides
that slide
between the
wireplanes

Lightguides

- Can go places that phototubes can not such as in electric fields and tighter spaces
- More coverage so possibly less phototubes needed
- Takes up less space, so more fiducial volume for your detector

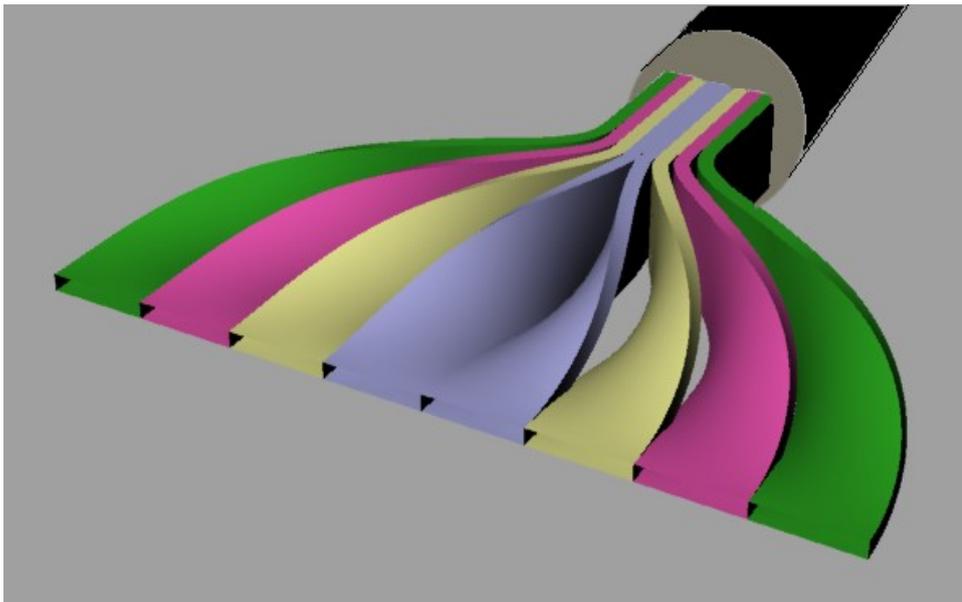


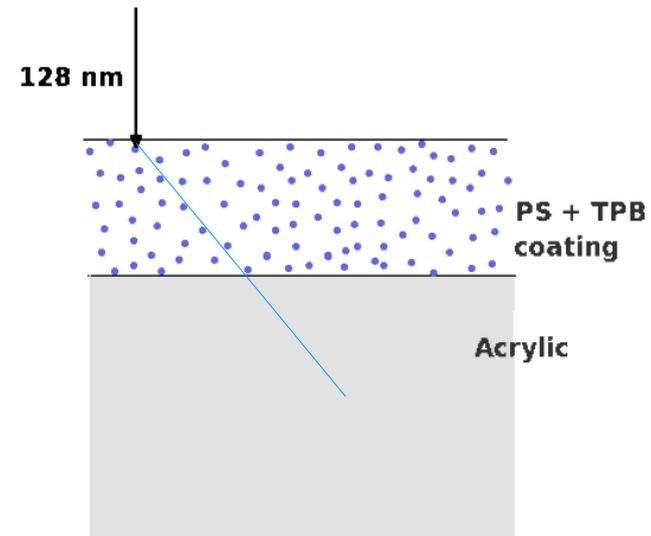
Illustration of paddle arrangement of lightguides



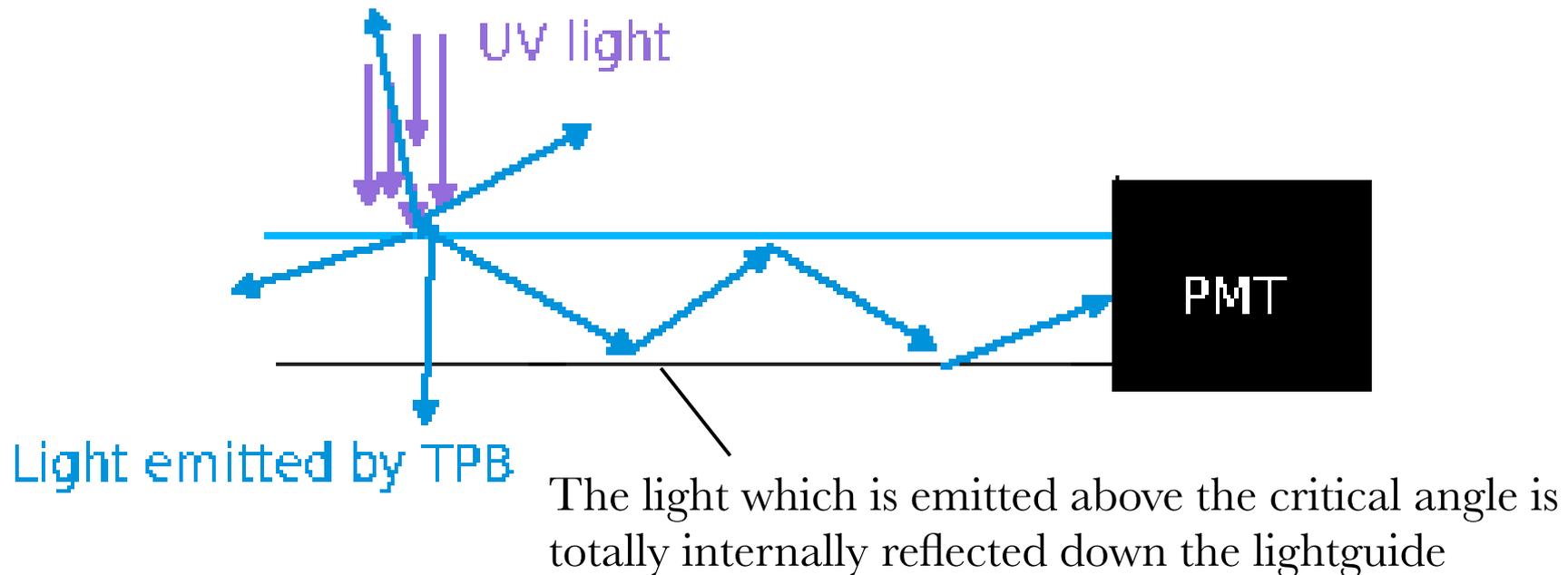
Adiabatic bending still allows light to be transmitted down the rod

Acrylic Rods as Light Guides

- TPB embedded in polystyrene (PS)
- Use 25% TPB in PS
 - Coating must be optically smooth
For better lightguiding properties

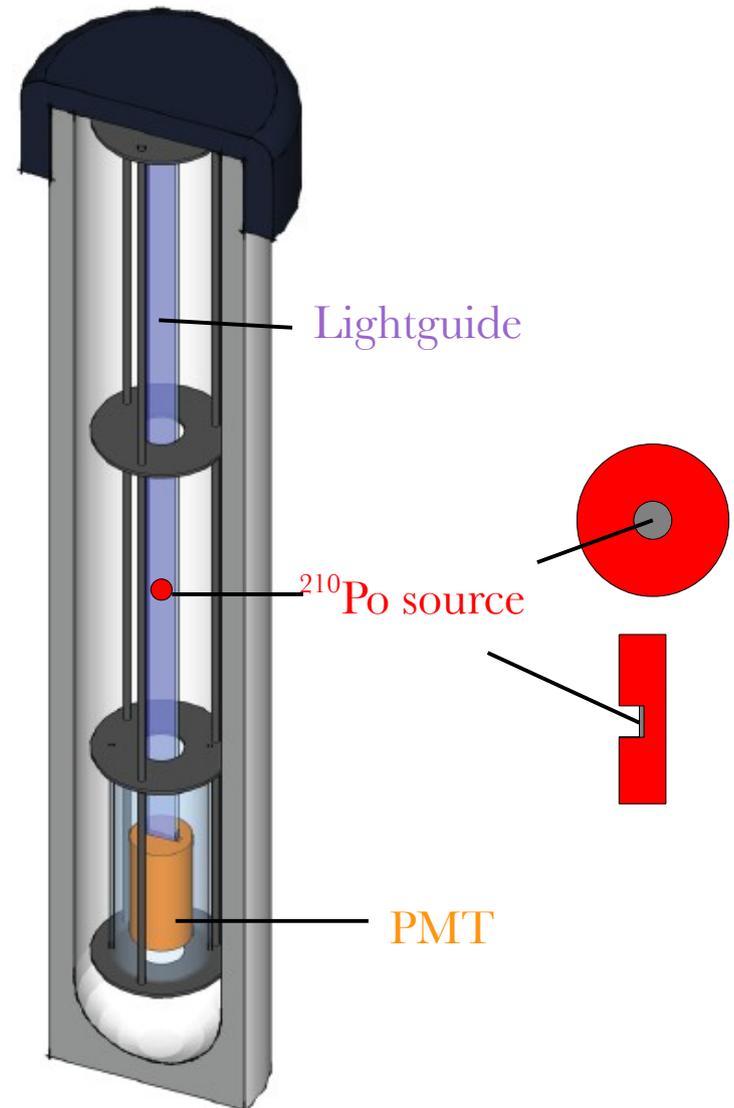


- PS is a good index of refraction match to acrylic
- Light emitted by the TPB coating is essentially produced inside the

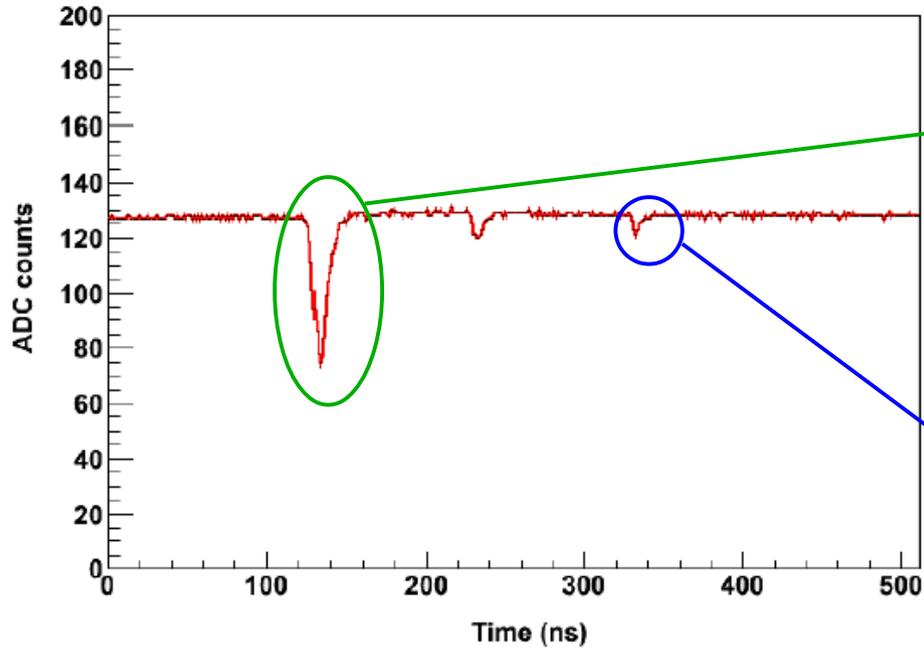


Testing

- The lightguides are tested using a ^{210}Po source which produces 5.3 MeV α particles
- The α particles travel 50 μm in Argon and produce photons along this path, some of which hit the lightguide and are transmitted to the PMT
- Source is located ~ 5 mm from the rod



PMT Response



Pulse of light from an alpha particle. Quantized by number of photoelectrons

We would like to know how many photoelectrons!

A one photoelectron pulse

We use an AlazarTech ATS9870 digitizer for data acquisition

Calibration

- Two ways: Late light:
 - Define one photoelectron (p.e.) so we know how many ADC counts it corresponds to
 - We can use this information to find out how many p.e. are in an early light pulse
- Spacing between peaks in data:
 - Data forms peaks, representative of a Poisson distribution around each number of p.e. that a pulse can have
 - Fit to equally spaced Gaussians, with spacing allowed to float
- Both methods yield same answer

Results from our paper

- Resulting fits (arXiv:1101.3013) yield an average of ~ 8 pe and an attenuation length of ~ 75 cm.
- Using 1 m paddles (8 lightguides curving into a 2 in PMT), we would need 27 paddles to detect a 40 MeV photon (5 p.e.) in MicroBooNE (doable! Though not as good as the MicroBooNE system)
- 650 of these paddles needed for a 5 MeV electron (such as from supernova)... not quite there yet!

As of 2 weeks ago!

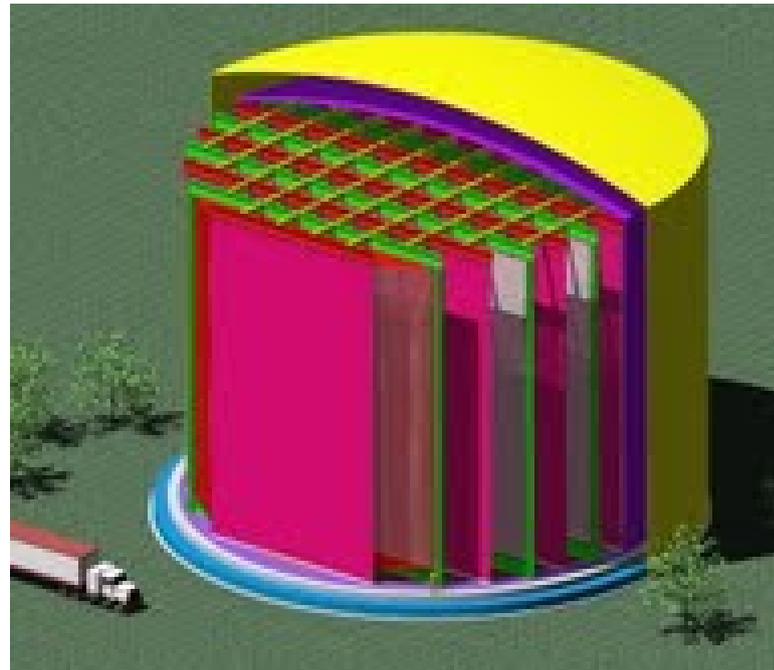
- Switched to using UV transmitting acrylic for our coating to embed the TPB
- Switched to using cast acrylic instead of extruded acrylic (both from McMaster Carr)
- With these new rods, seeing an average of 35 p.e. Per alpha! This is a factor of 4 more light!
- In addition, we are not seeing much of an attenuation (measuring out to 50cm), so we are looking at significantly longer attenuation lengths as well ($\gg 50\text{cm}$)!

Our Demonstration Detector

- Plan to set up at MIT this fall
- Phototubes ringing top with paddles hanging down
- Only need one side of rods coated with TPB
- Goals:
 - See Michel electrons
 - Address some of the things we will see in MicroBooNE and future large LAr detectors



Our Demo detector



100 kTon Next Generation LAr detector

Conclusions

- MicroBooNE is an important stage in the development of future large LAr TPCs
- It will also help our understanding of the MiniBooNE experiment as well as making other physics contributions!
- New lightguide R&D looking very promising!

Backup Slides

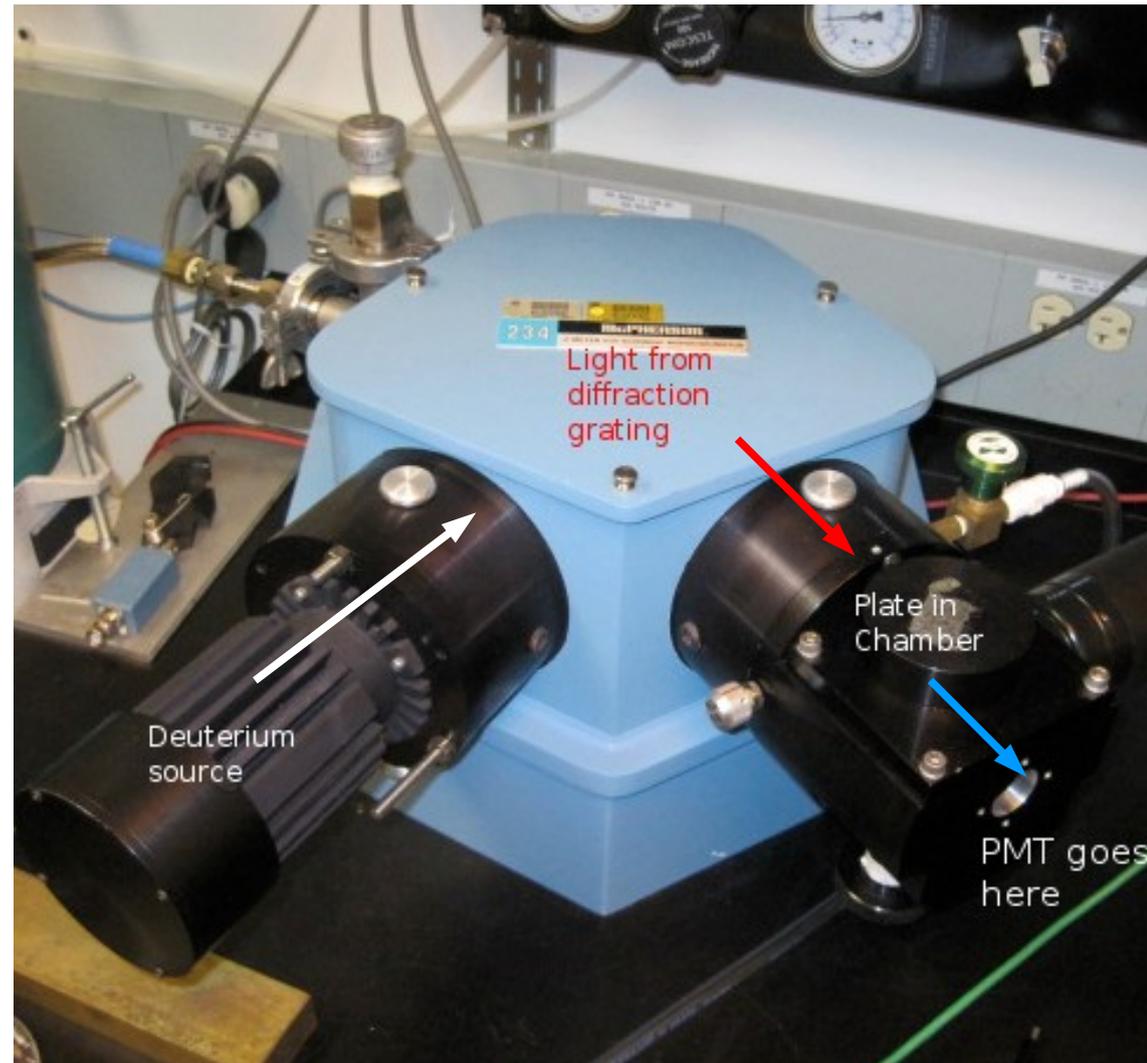
Comparison of coating methods

Vacuum setup at Fermilab

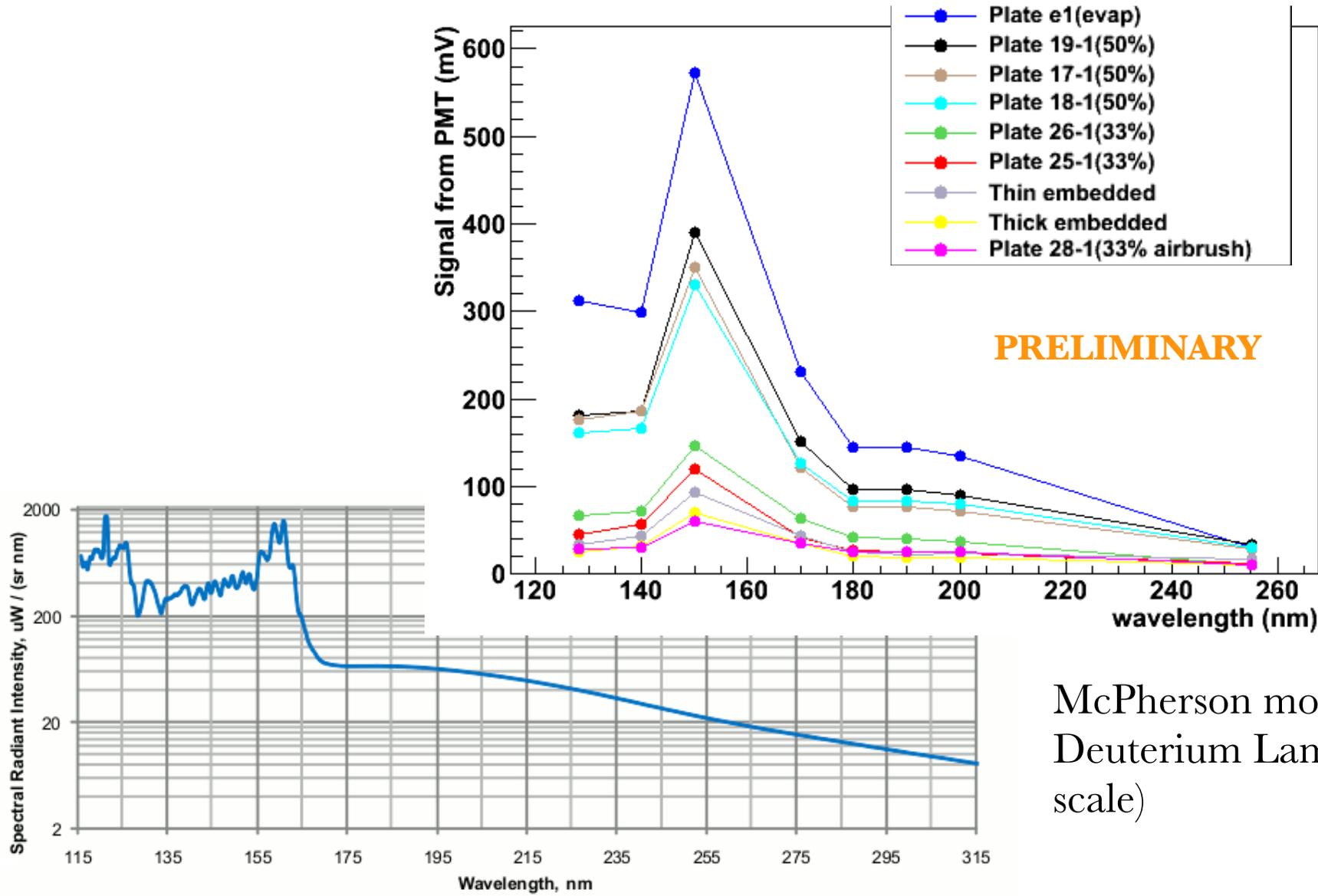
- McPherson 234 vacuum monochromator
- McPherson model 632 UV Deuterium Lamp as light source
- Light from diffraction grating hits the plate and the output is measured by the PMT on the other side

Compare

- 33% TPB in PS plates
- 50% TPB in PS plates
- evaporatively coated plates
- TPB embedded plates



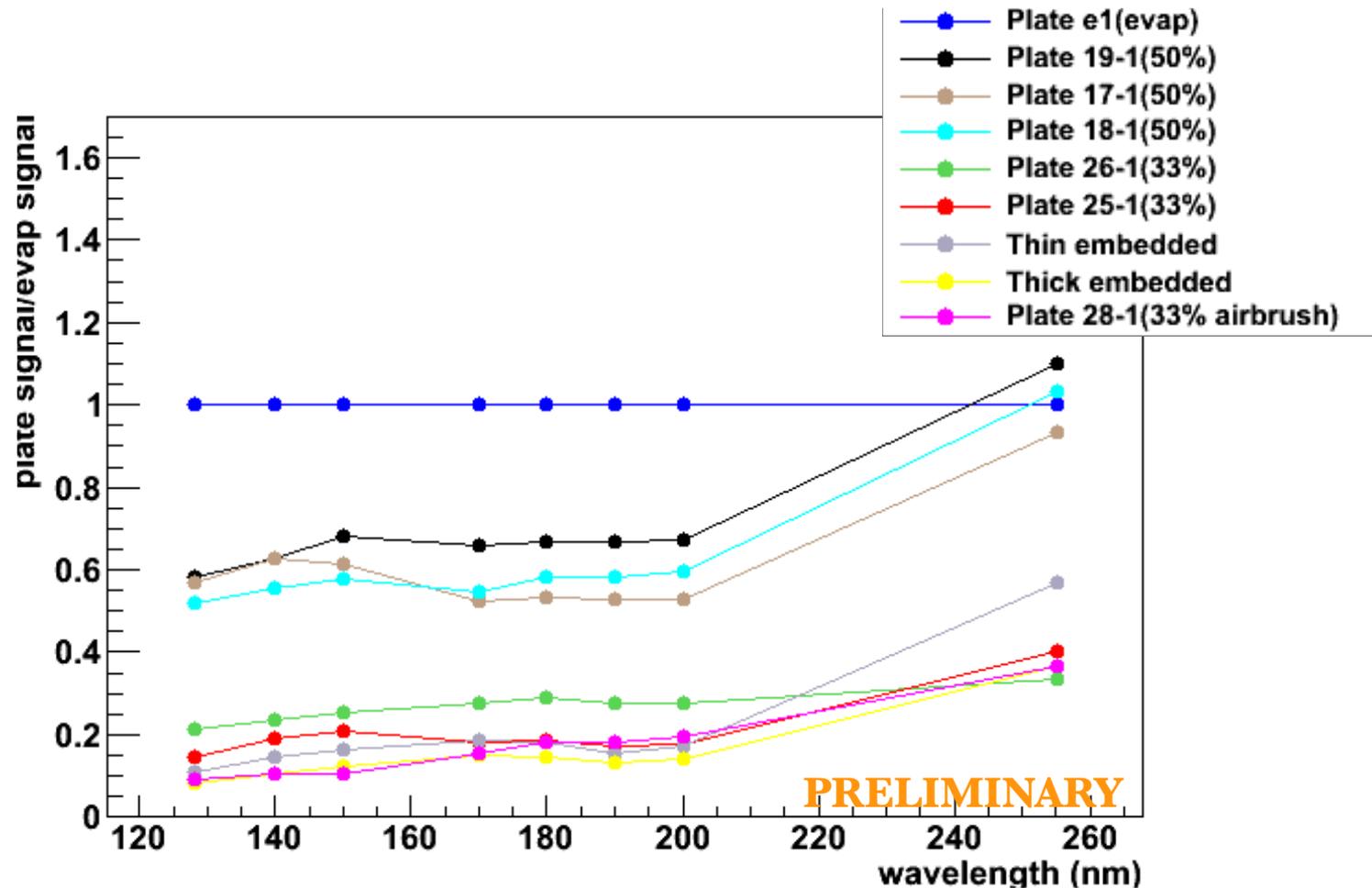
Comparison of coating methods



McPherson model 632 UV
Deuterium Lamp (Logarithmic
scale)

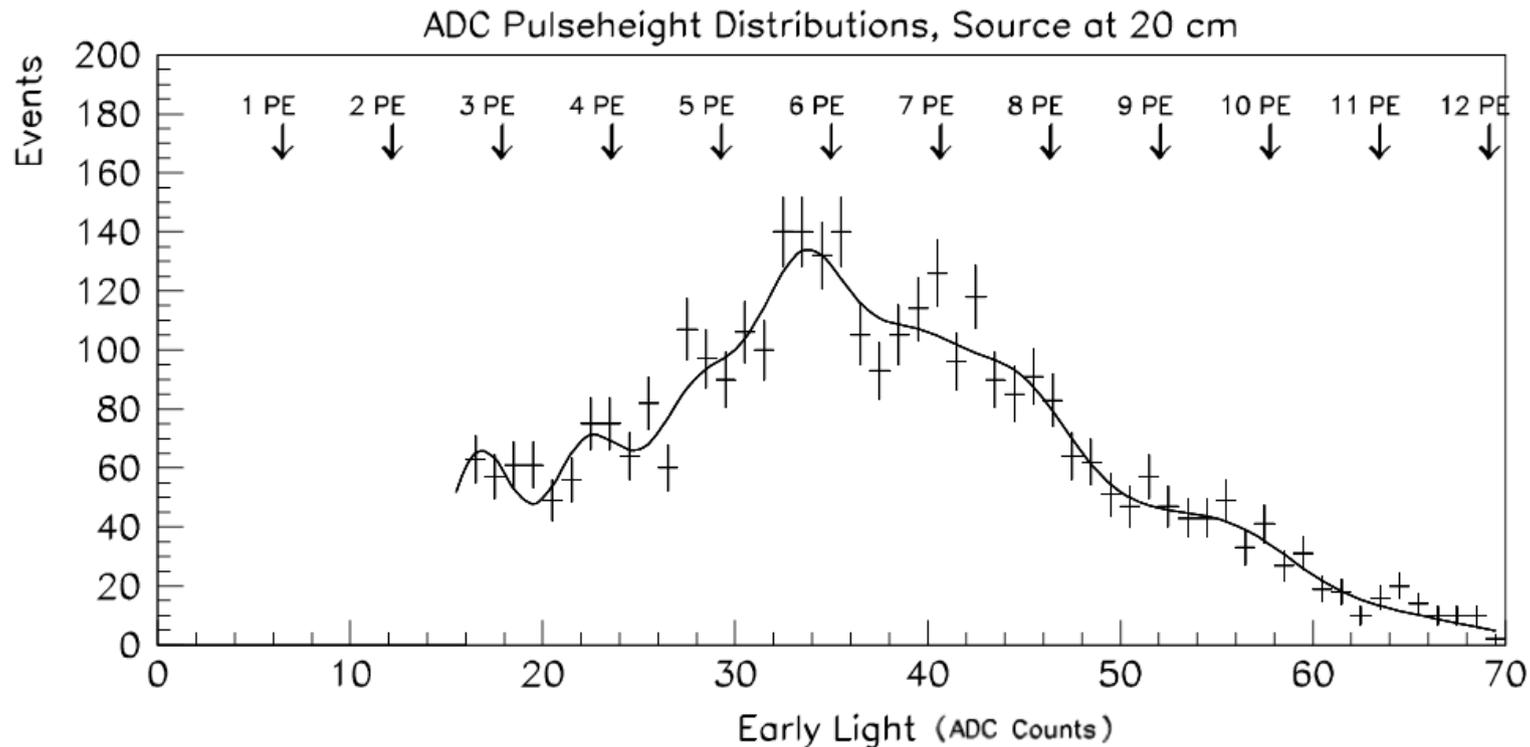
Comparison of coating methods

Normalized to evaporatively coated plate



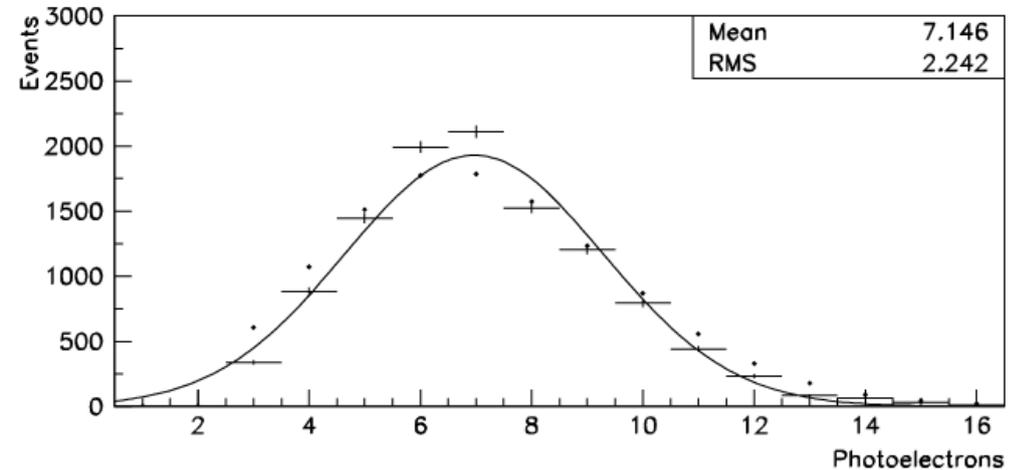
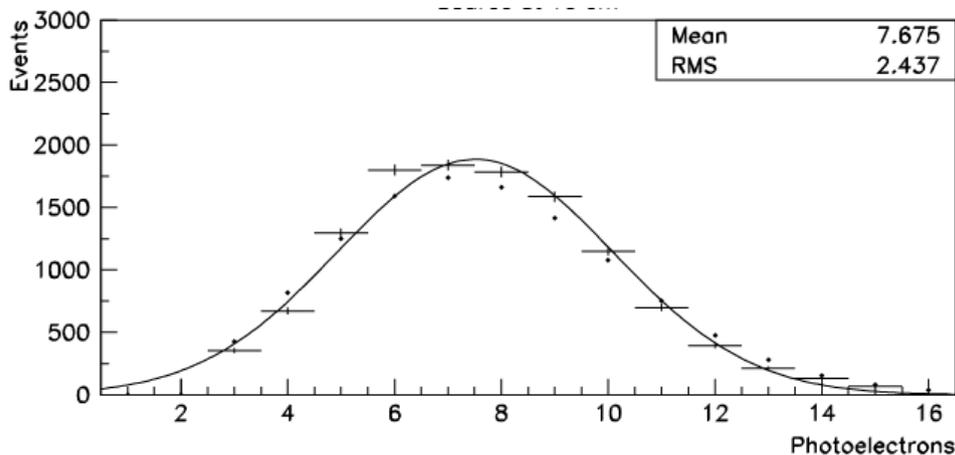
Example early light distribution

- Data forms peaks, representative of a Poisson distribution around each number of p.e. that a pulse can have
- Fit is to 10 equally spaced Gaussians, with spacing allowed to float
- In this case, resulting fit yields 5.7 ADC count spacing, which is in agreement with late light 1 p.e. peak
- Peaks formed by overlapping Gaussians



Variations in coating - Repeatability

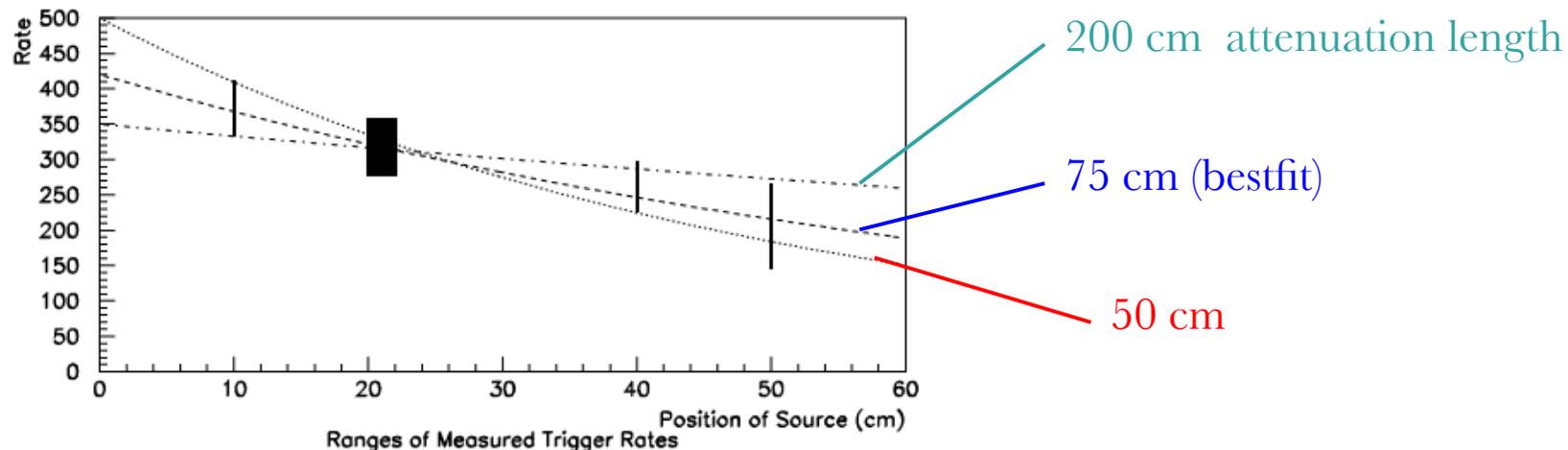
We find that our coating is pretty uneven, and are currently investigating new coating methods



Example of two measurements done at the “same” place on the lightguide, 10 cm away from the PMT

Attenuation lengths

- Measure attenuation length by comparing trigger rates at multiple points along the bar (subtracting cosmic ray background)
- Large error in attenuation length measurement due to variations in coating along the bar
- Very conservative: 50cm attenuation length (but we think we can do better!)



Co-extrusion R&D

- Production of lightguides through co-extrusion—PS bar with PS+TPB coating
- Testing with Bis-MSB (since it was readily available)
- Investigating possibilities and cost of doing this with TPB
- Smooth and consistent coatings possible

