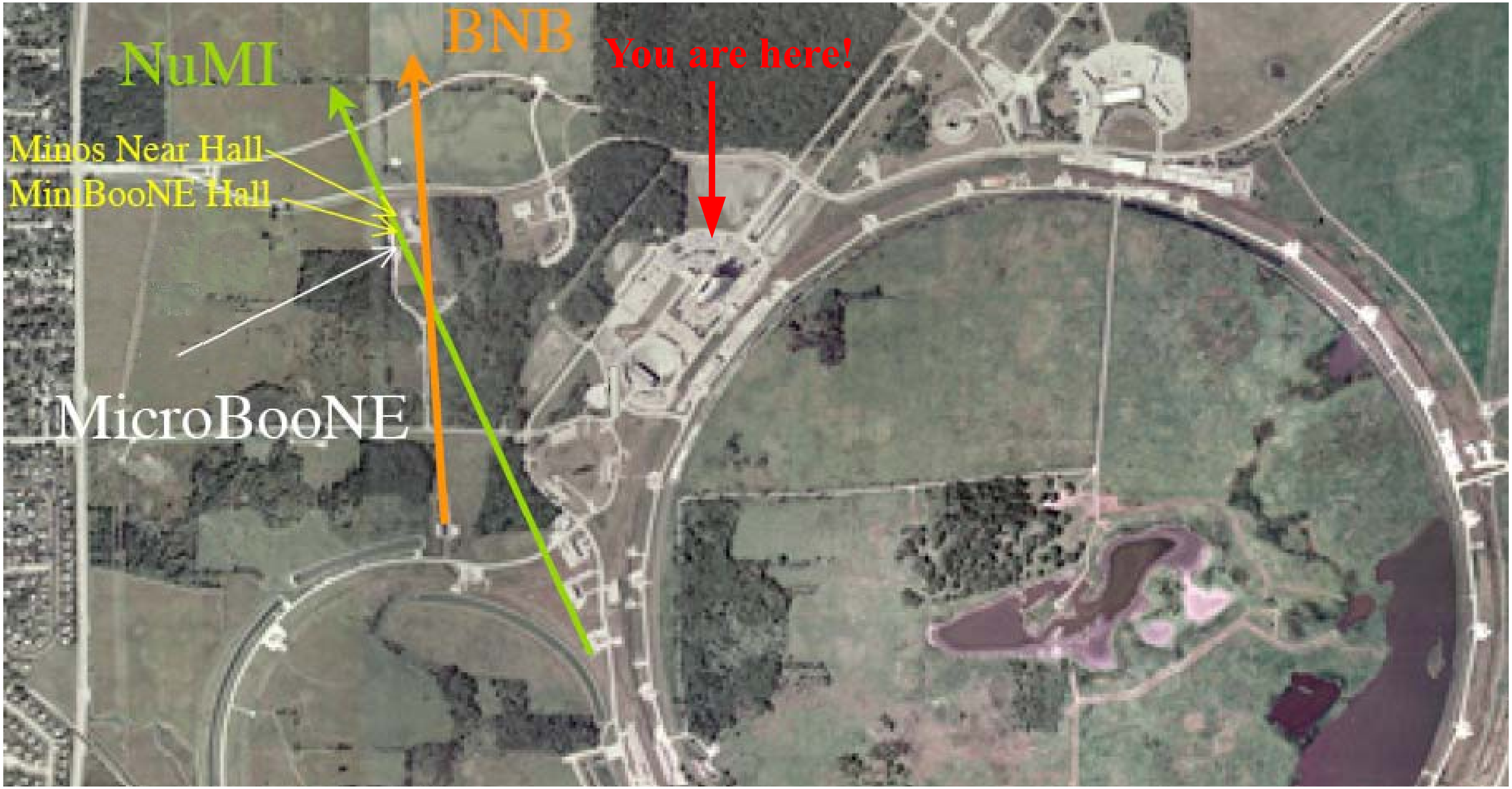
MicroBooNE

Christina Ignarra
MIT
Fermilab Users Meeting
June 1, 2011

Location



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

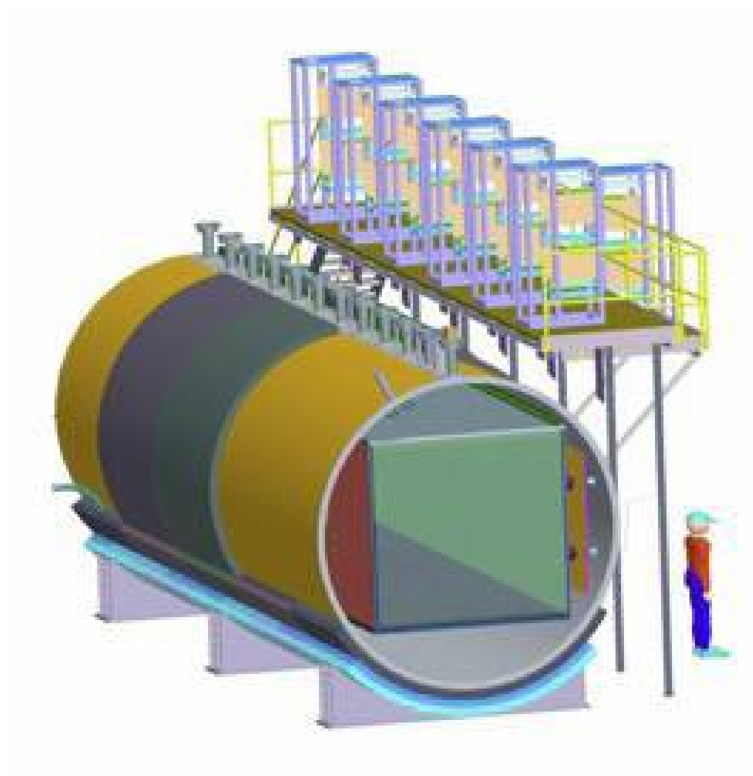
MicroBooNE: First Liquid Argon Time Projection chamber to do beam physics

Detector Overview

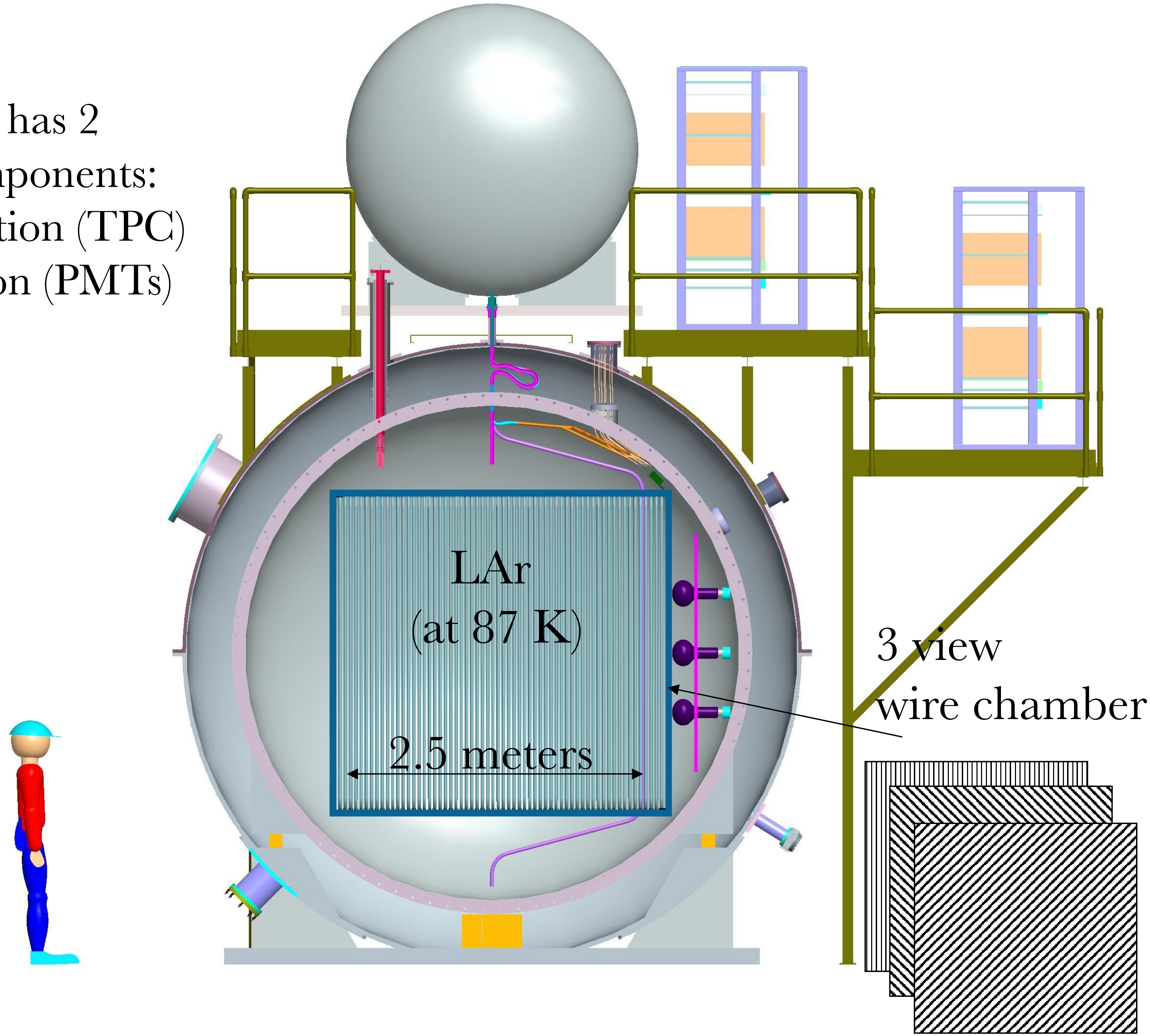
MicroBooNE is a Liquid Argon (LAr) Time Projection Chamber (TPC)

LAr TPC's have 6 times more sensitivity than Cherenkov detectors, meaning smaller detectors for the same physics!

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



MicroBooNE has 2 detection components:
Charge-detection (TPC)
Light collection (PMTs)

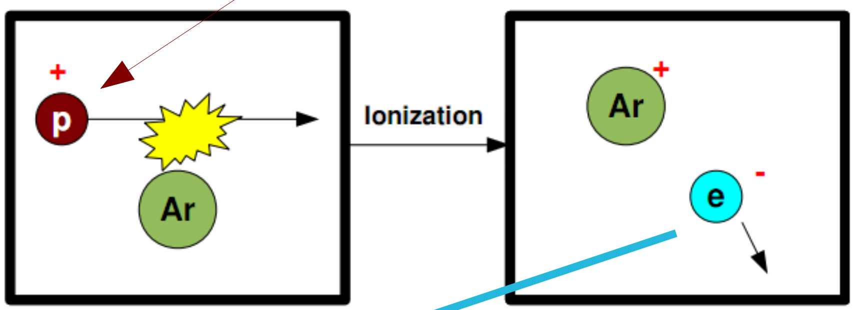


Charge in LAr

Charged particles are created in neutrino interactions, ex:

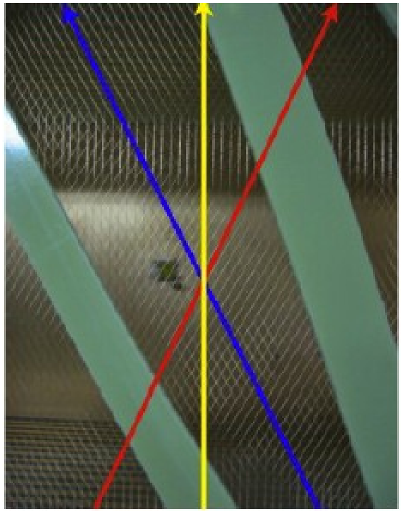
$$\nu_e + n \rightarrow p + e^-$$

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

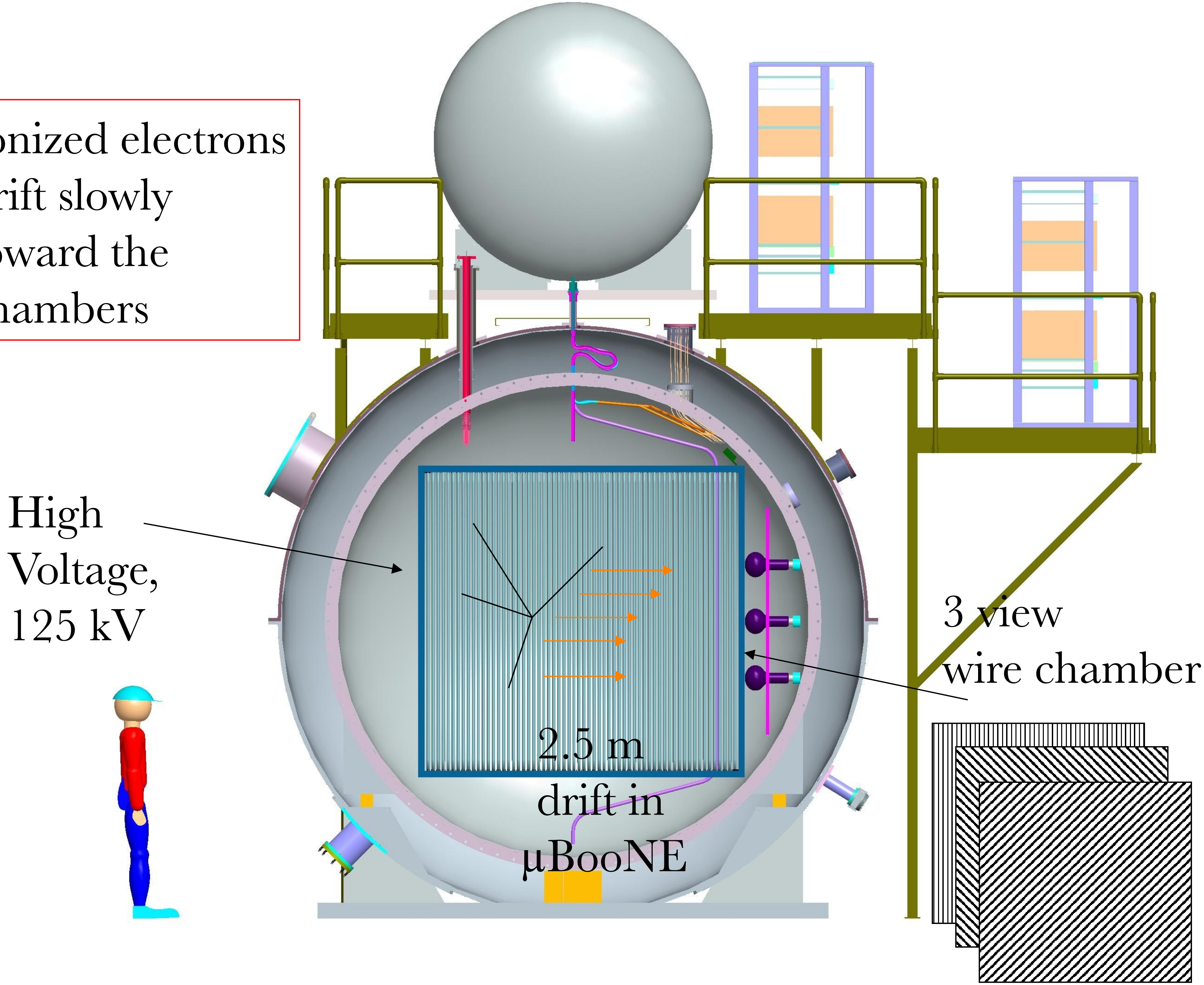


Resulting "ionization electrons" drift due to an applied electric field, and hit wires which are spaced 3mm apart arranged in 3 planes.

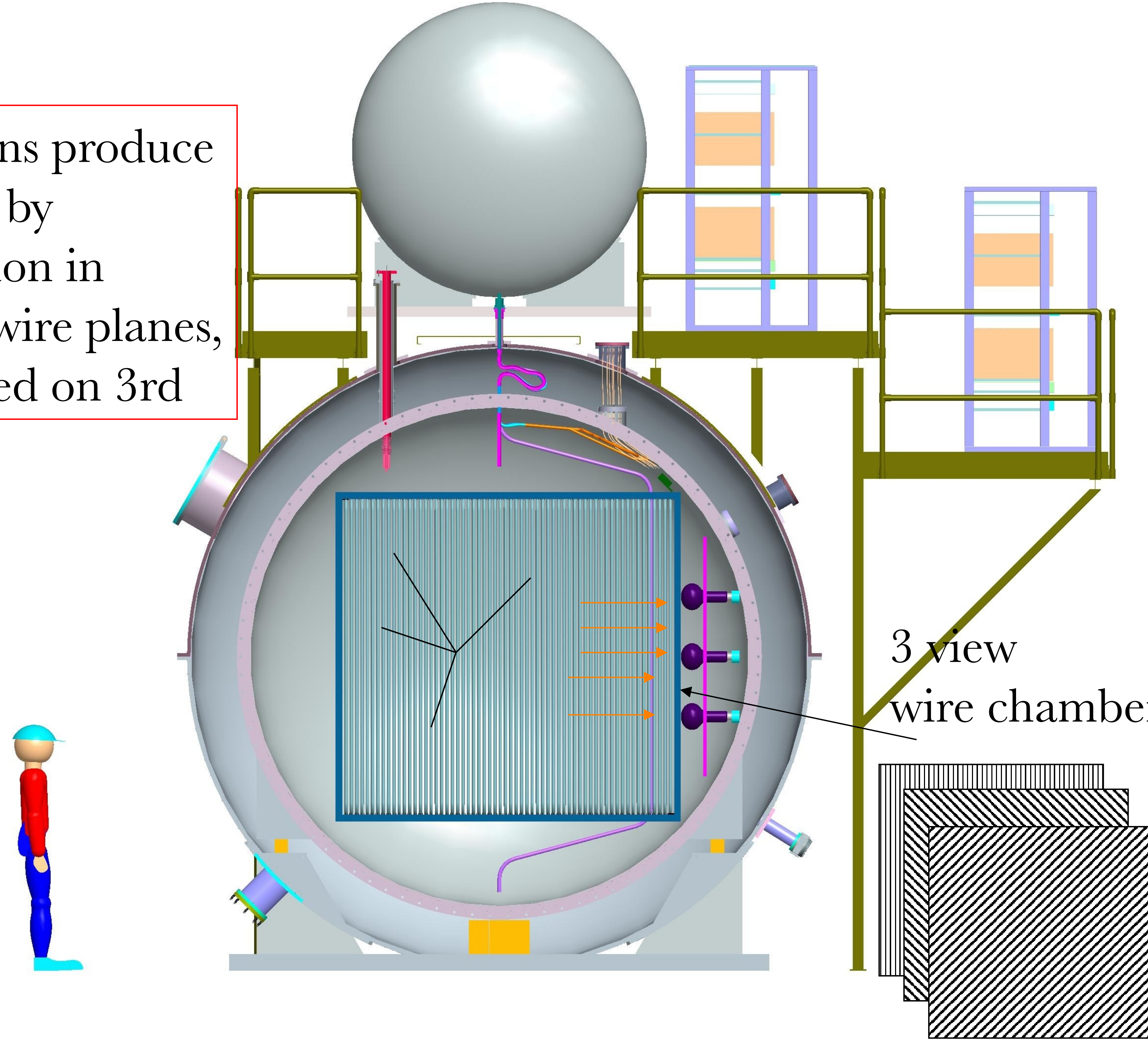
These wires measure the deposited energy in the detector



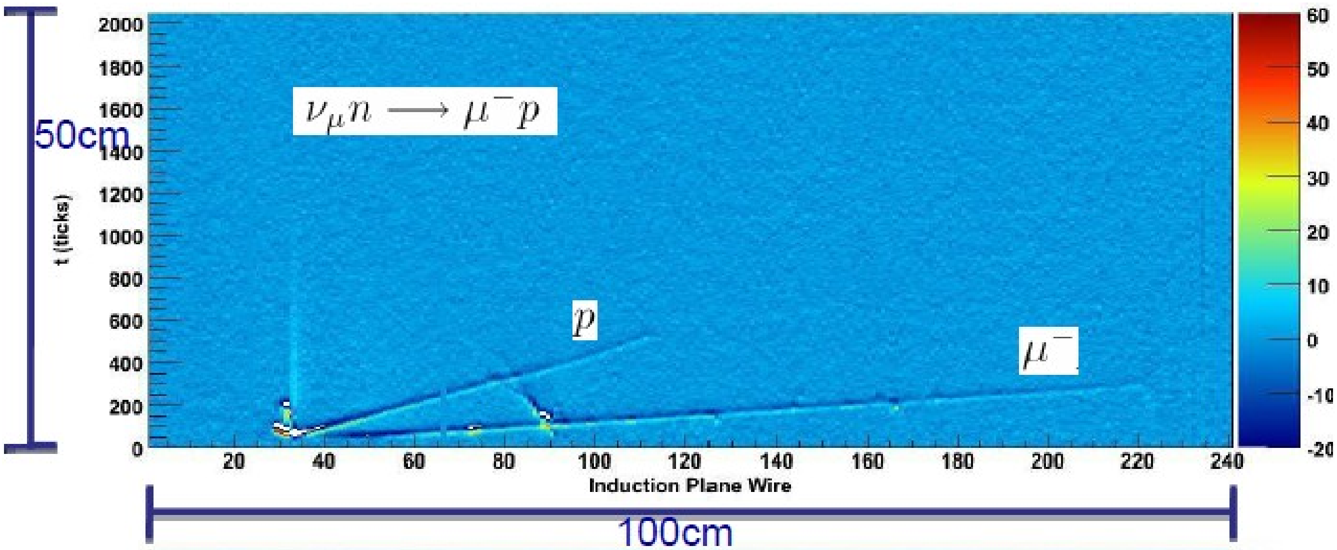
Ionized electrons drift slowly toward the chambers



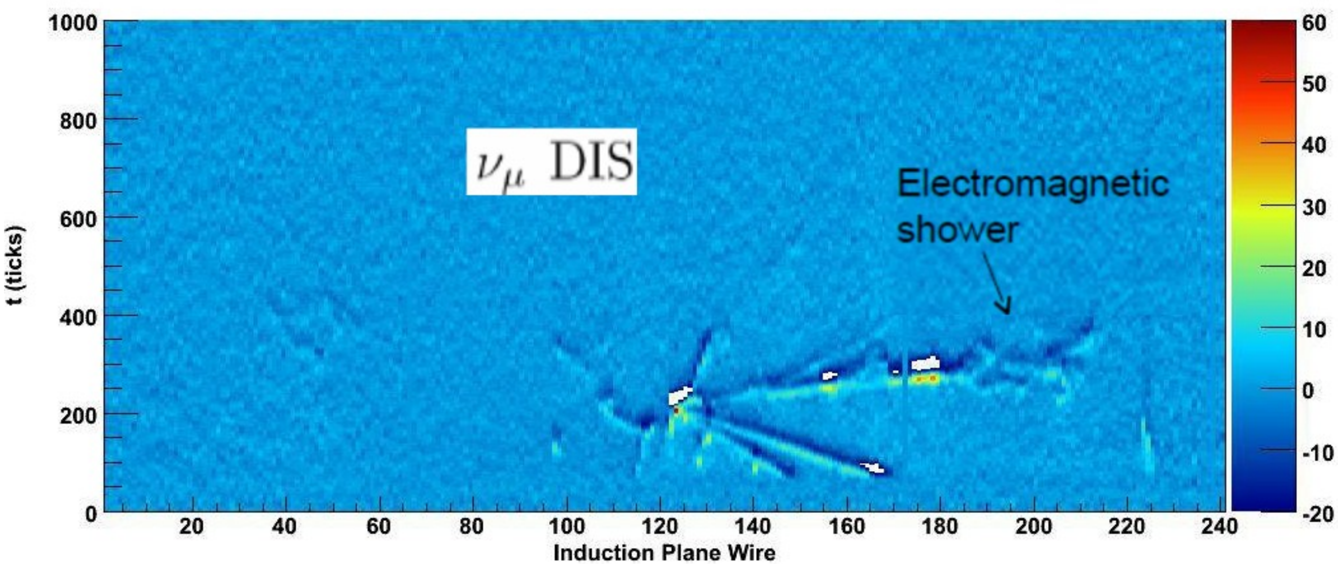
electrons produce
signals by
induction in
first 2 wire planes,
collected on 3rd



Event Displays



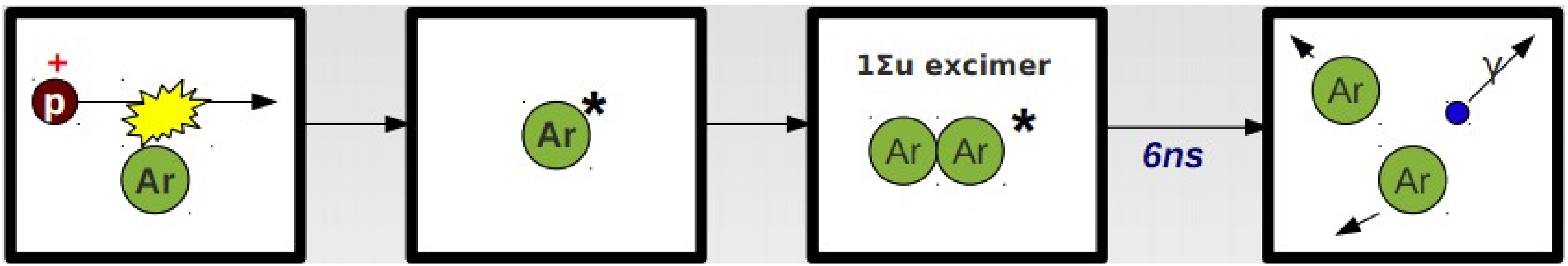
Quasielastic charged current event in ArgoNeuT



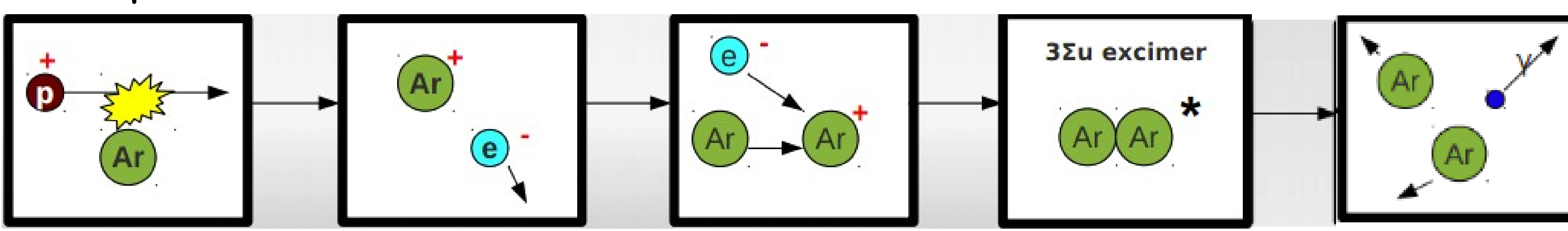
Deep Inelastic scattering event in ArgoNeuT

Light in LAr

Fast scintillation path (This is what we trigger on!)
~6ns, 25% of the scintillation light



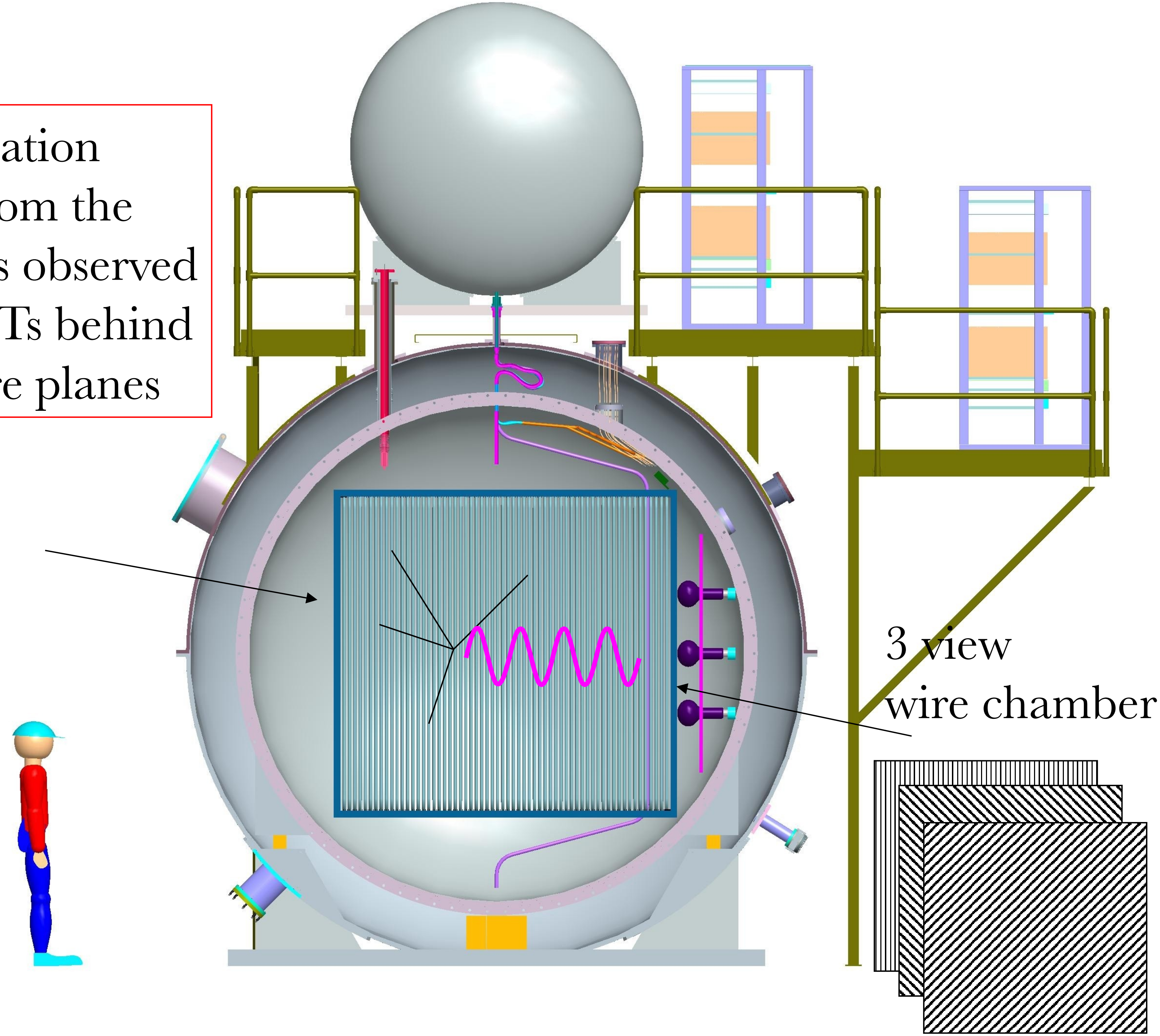
Slow scintillation path (bonus light!)
~1.6 µs after the interaction



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

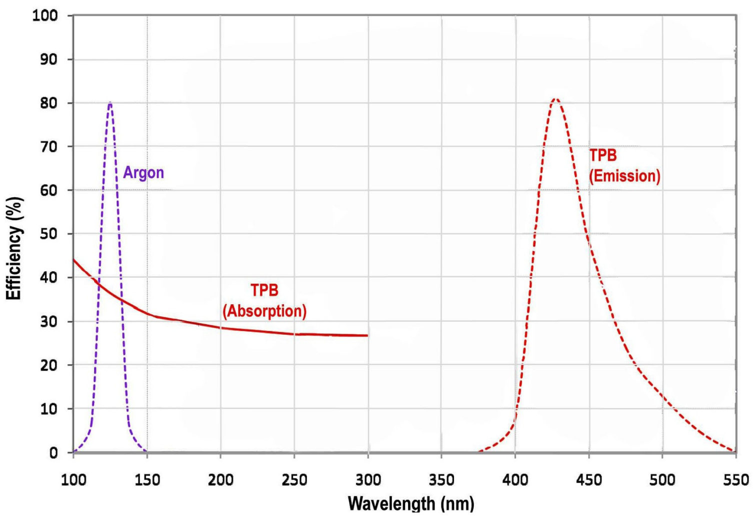


Why light detection in LAr is important

- 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 Collection

We use a wavelength shifting material called Tetraphenyl 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

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

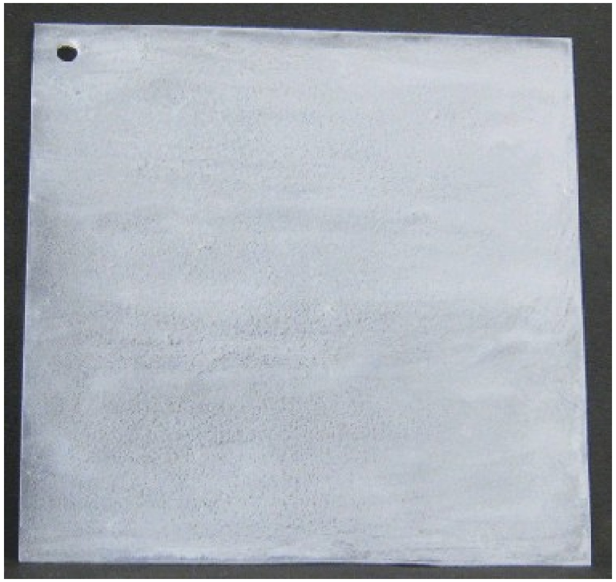


Plate sample with a 50% TPB-PS coating

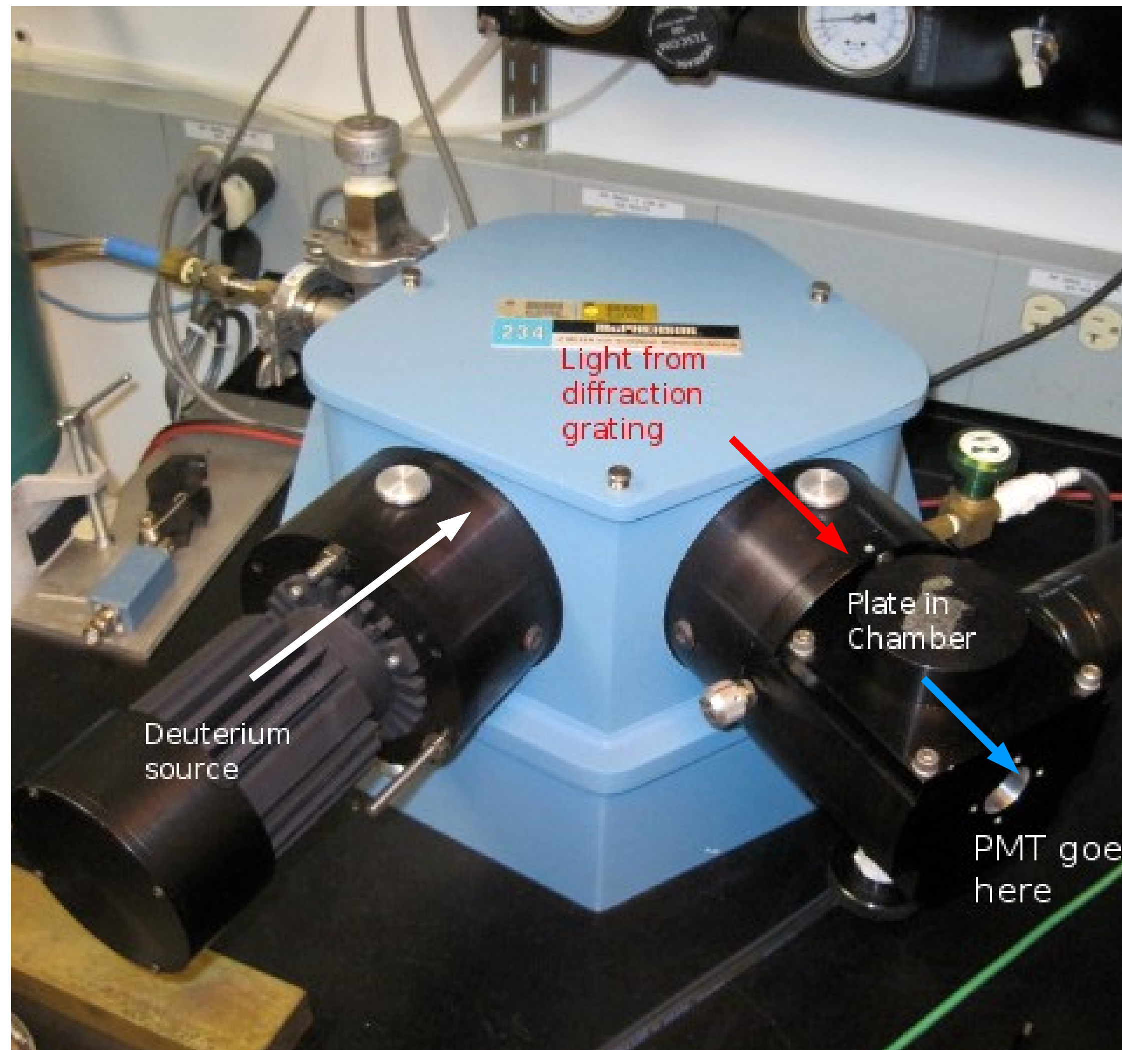
Comparison of coating methods

Vacuum setup at Fermilab

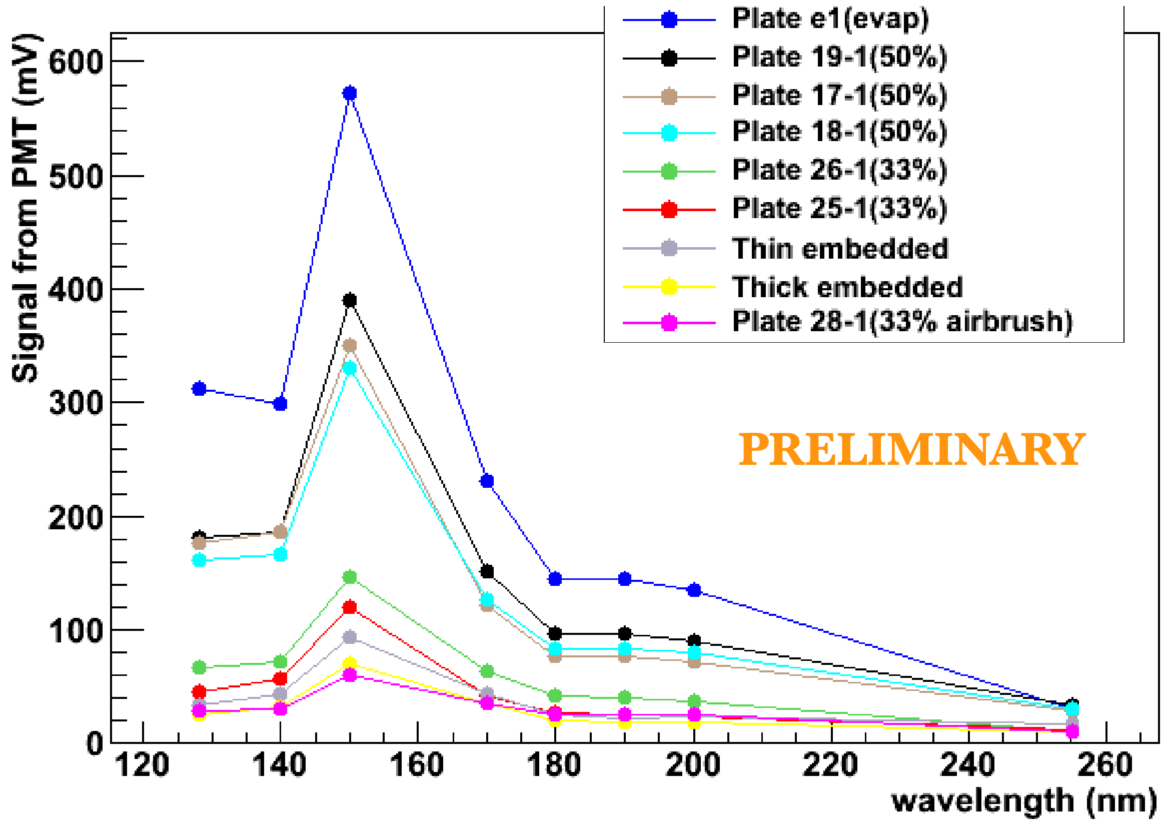
- McPherson 234 vacuum monochrometer
- McPherson model 632 UV Deuterium Lamp as light source
- Light from diffraction grating hits the plate and the output is measured by the PMT on the other side

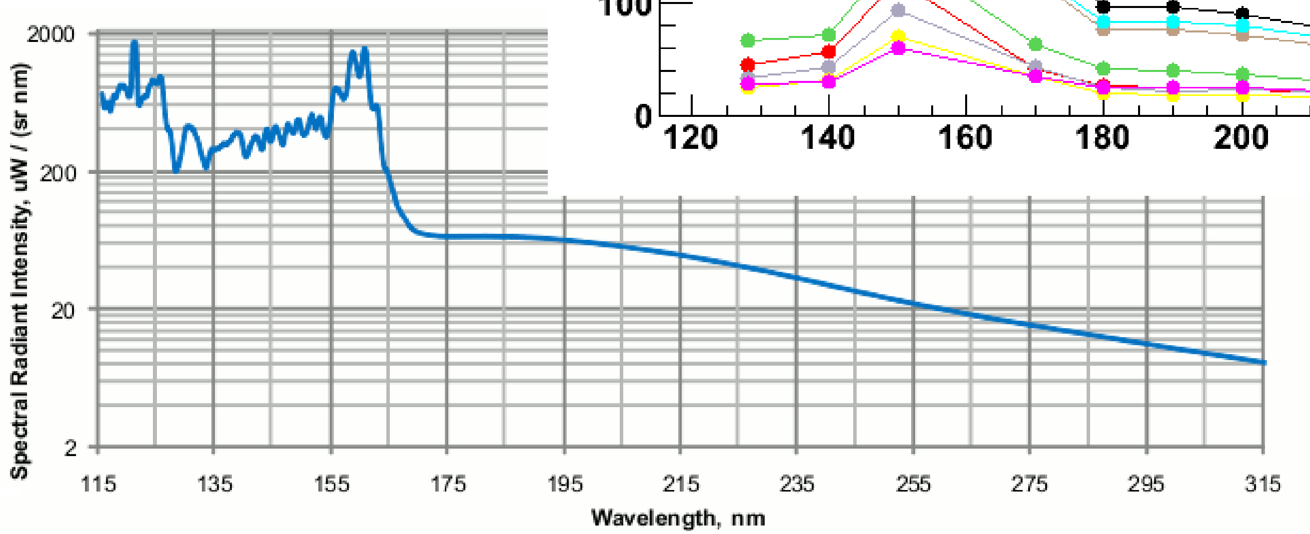
Compare

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



Comparison of coating methods

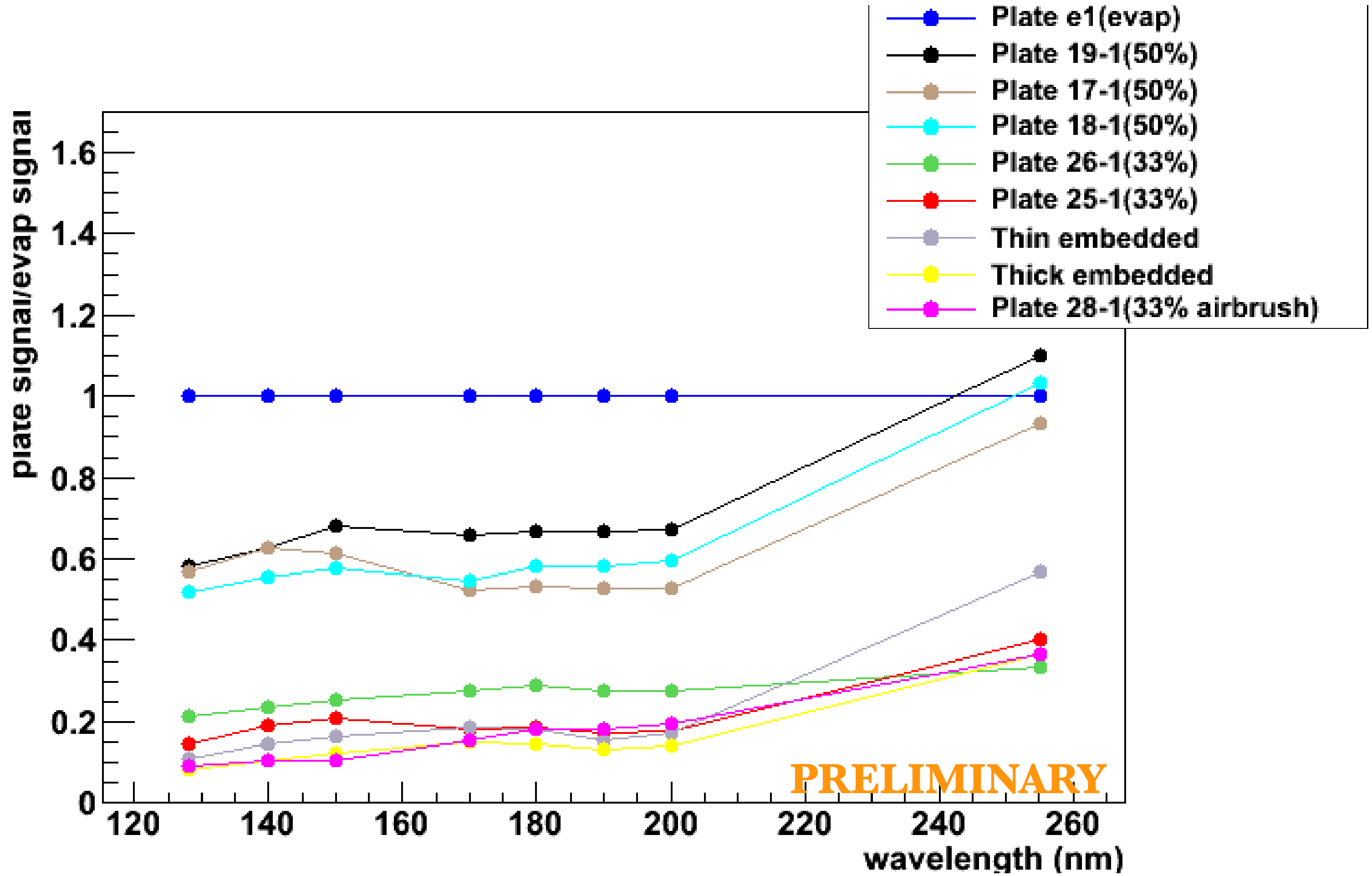




McPherson model 632 UV Deuterium Lamp (Logarithmic scale)

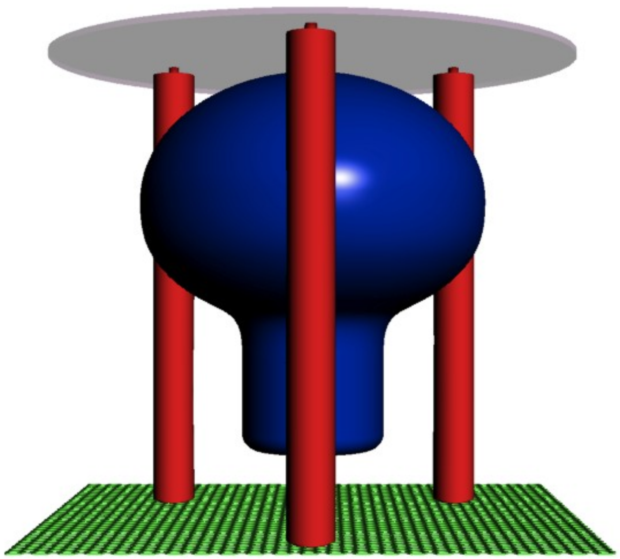
Comparison of coating methods

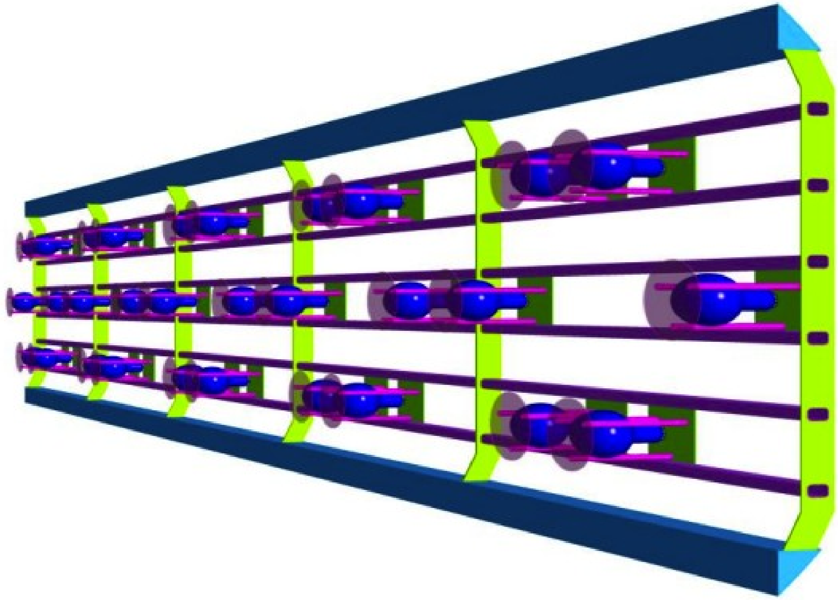
Normalized to evaporatively coated plate

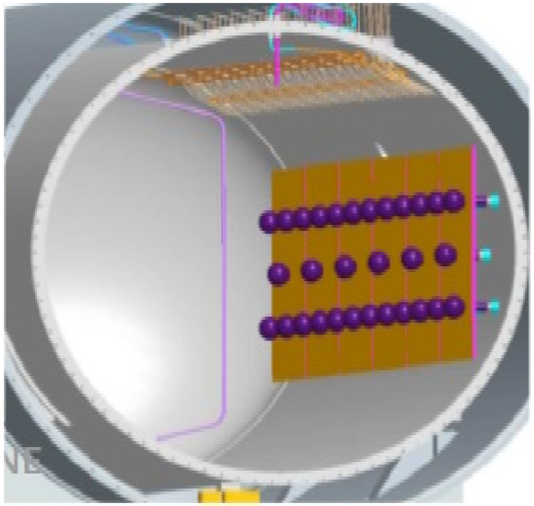


Light Collection System

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

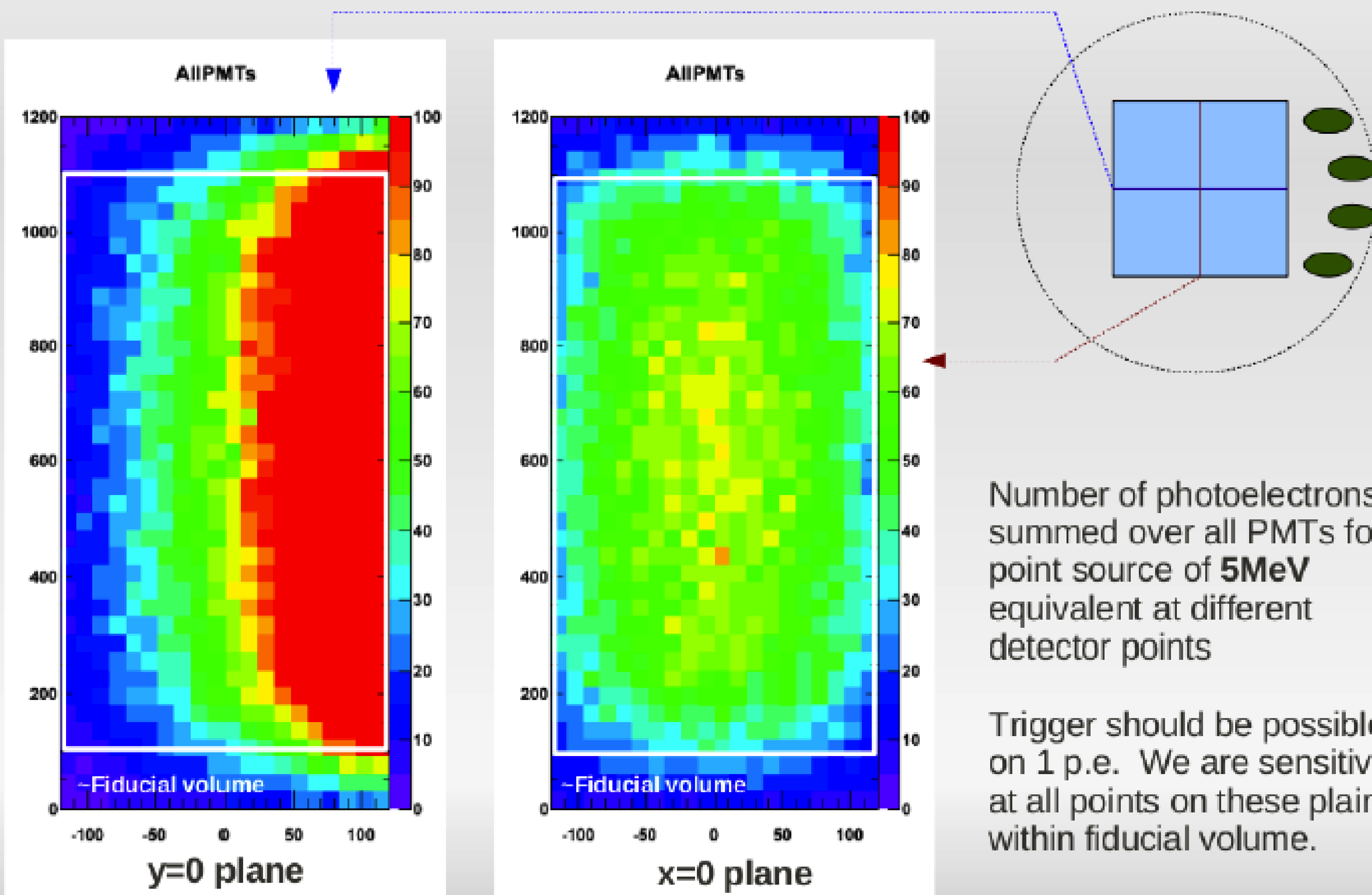






30 PMTs facing TPC

Sensitivity map



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.

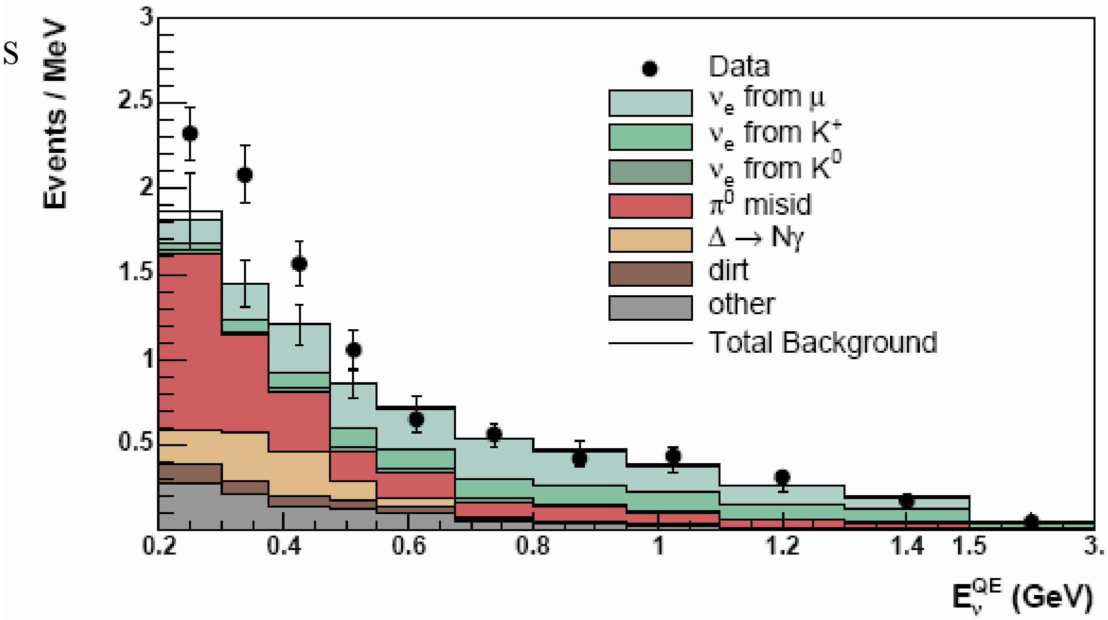
Motivation: MiniBooNE

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

3σ excess of electron-like events at low energies (not present with $\bar{\nu}$)

Possibilities:

- Unexpected background
- New physics

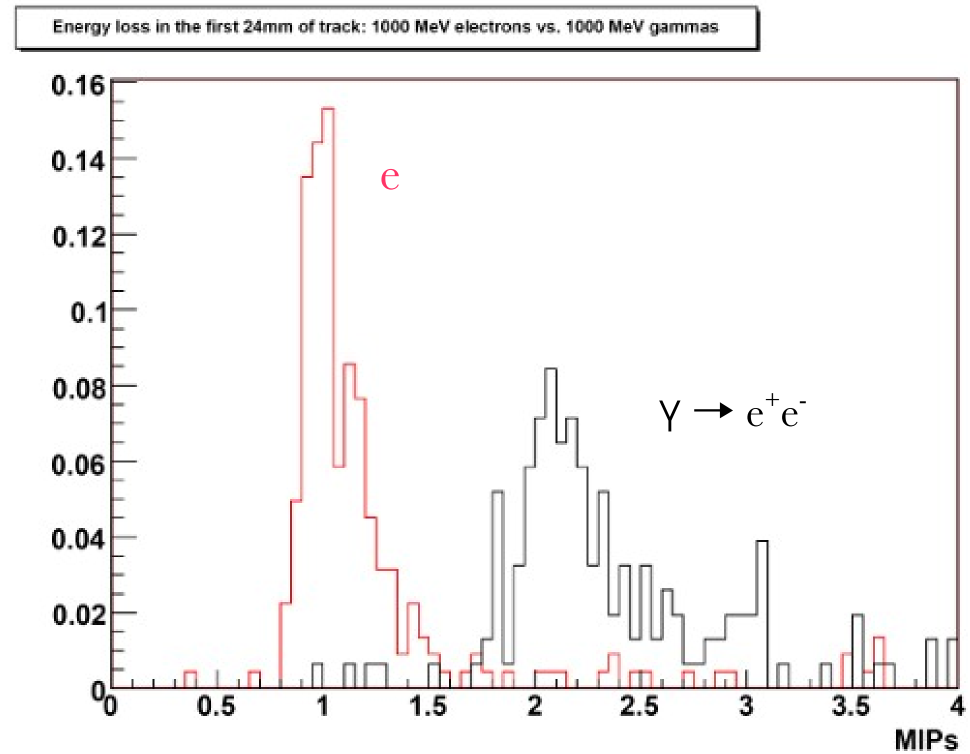


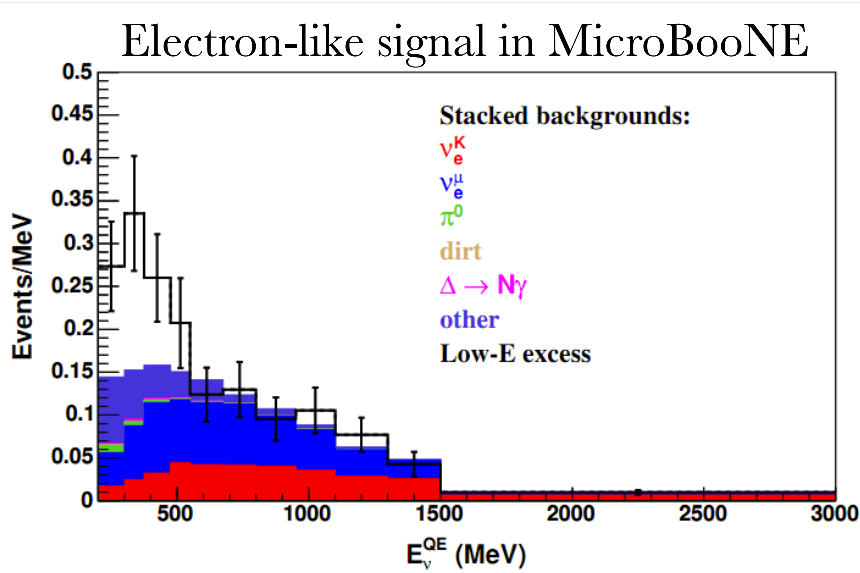
Cherenkov detectors cannot tell the difference between electrons and photons ($\gamma \rightarrow e^+e^-$), which are a large source of background

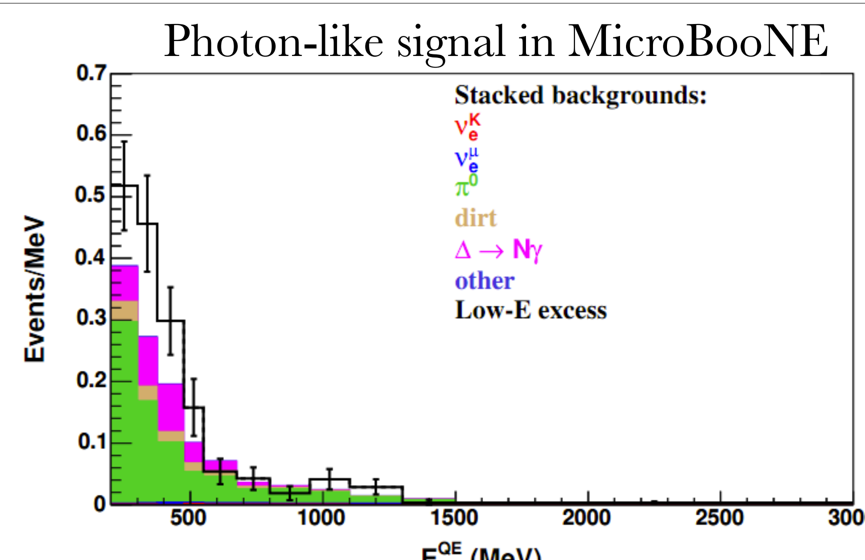
- Cherenkov detectors only have a ~20cm vertex resolution, but 2cm is needed to distinguish γ's from e^- 's

How MicroBooNE Can Help

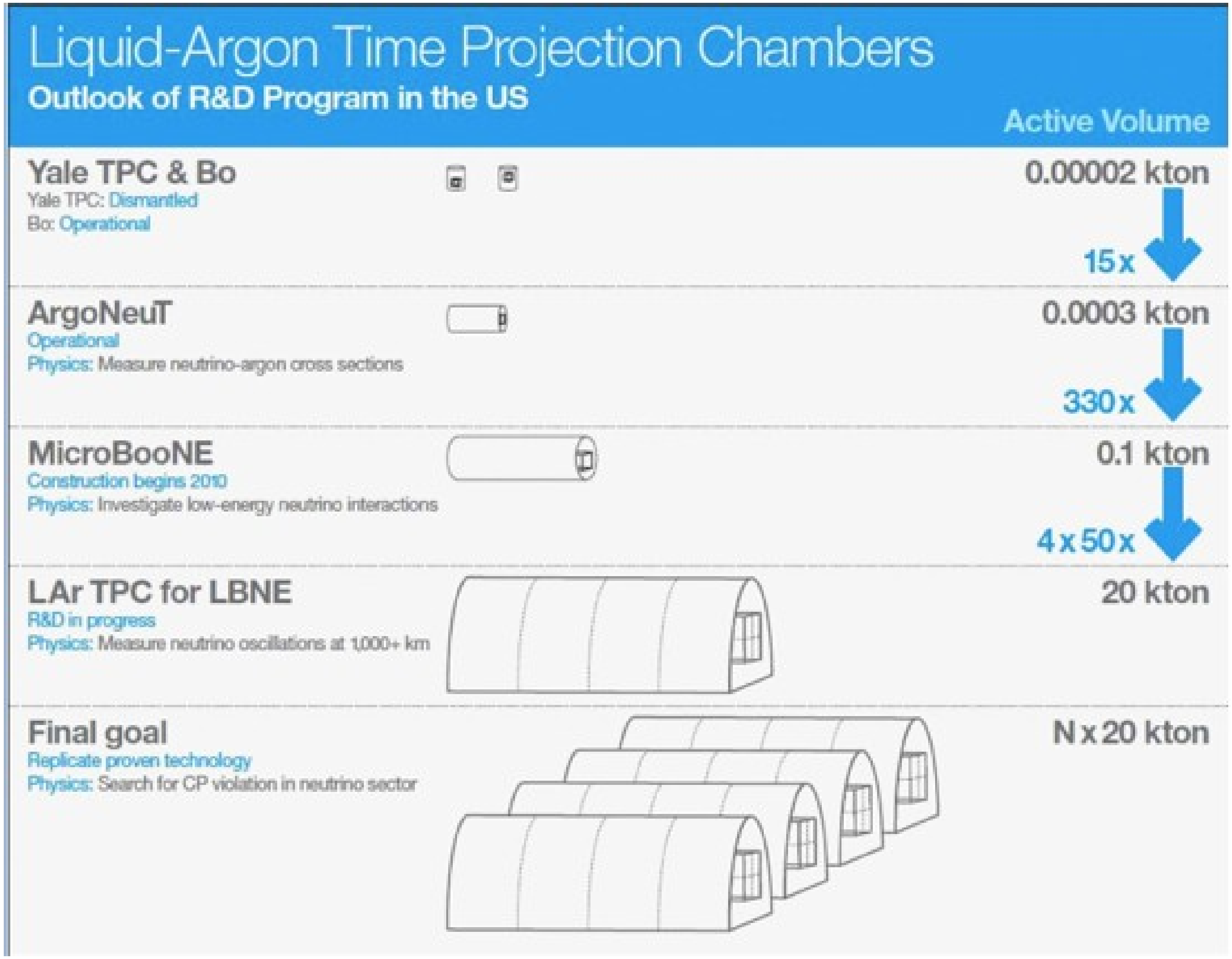
- Can tell the difference between e's and γ's – sensitive to the different amounts of energy they deposit
- High resolution reconstruction of events
- Predict ~50 MiniBooNE-like low energy excess events







R&D for Future LAr Detectors



R&D for Future LAr Detectors

Goal: Make LAr a viable option for future large detectors

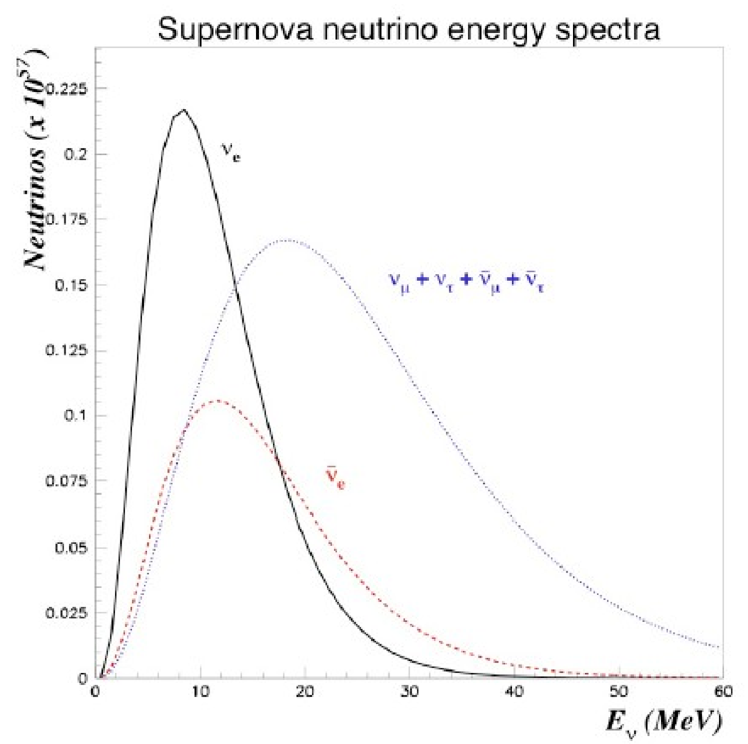
- Need to understand cross sections in LAr
- Demonstrate scalability of technology
- Cold electronics
- Purity
- Analysis tools

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

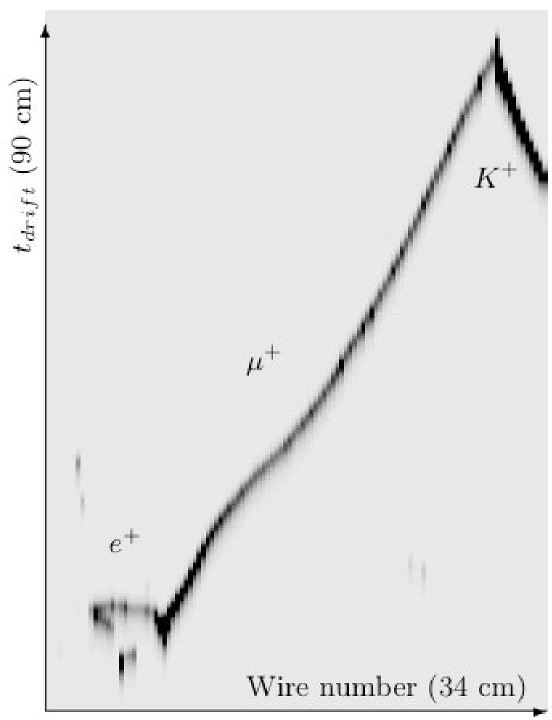


FIG. 17: Simulated $p \to K^+ \bar{\nu}$ event. The displayed area covers 34×90 cm^2.

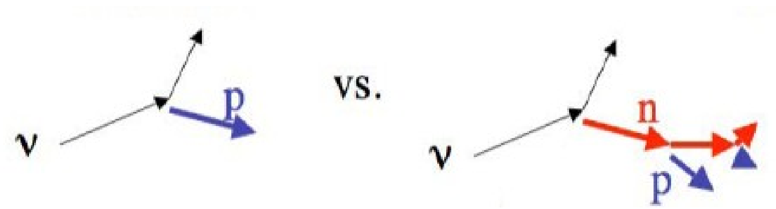
Simulated Proton decay event in LAr

Other Physics Goals

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

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

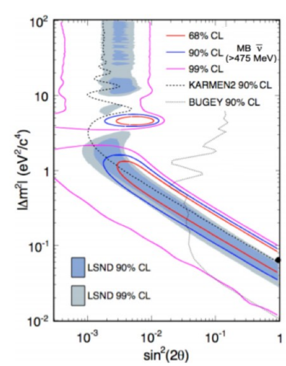
  - May help us to better understand proton spin
  - Input for spin-dependent WIMP searches
  - Information on final states for modeling events in LAr
  - This is impossible for most detectors because it is hard to tell protons from neutrons



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

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 (or old) anomaly!



If you don't recognize this plot, don't miss Joe Grange's talk tomorrow!

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!