Liquid Argon Time Projection Chambers and Project X

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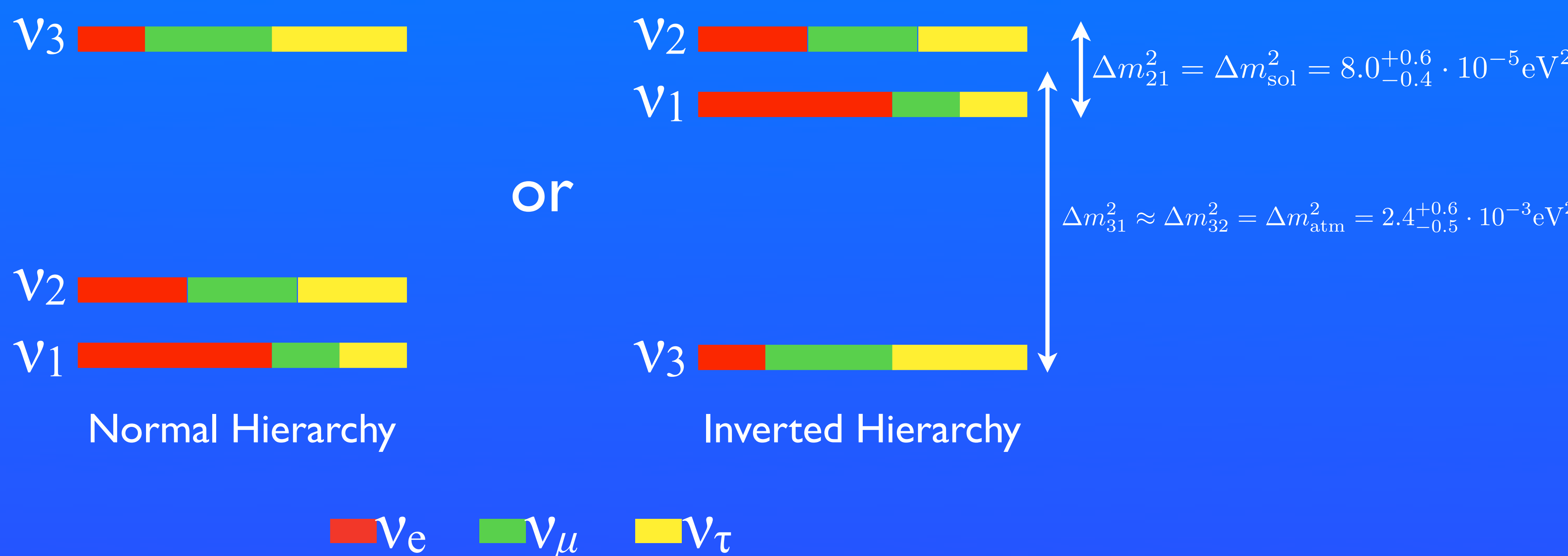
Introduction

- Physics Goals (accelerator and non-accelerator)
- Liquid Argon Time Projection Chambers (LAr TPCs)
- Current LAr TPC Work (focus on the U.S.)
- LAr TPCs possiblities in the Project X and DUSEL Era

Physics Goals

Accelerator Based

- Observe $\nu_\mu \rightarrow \nu_e$ transitions, measure θ_{13}
- Determine Mass Hierarchy
- Measure the CP-violating phase, δ_{CP}



Non Accelerator Based

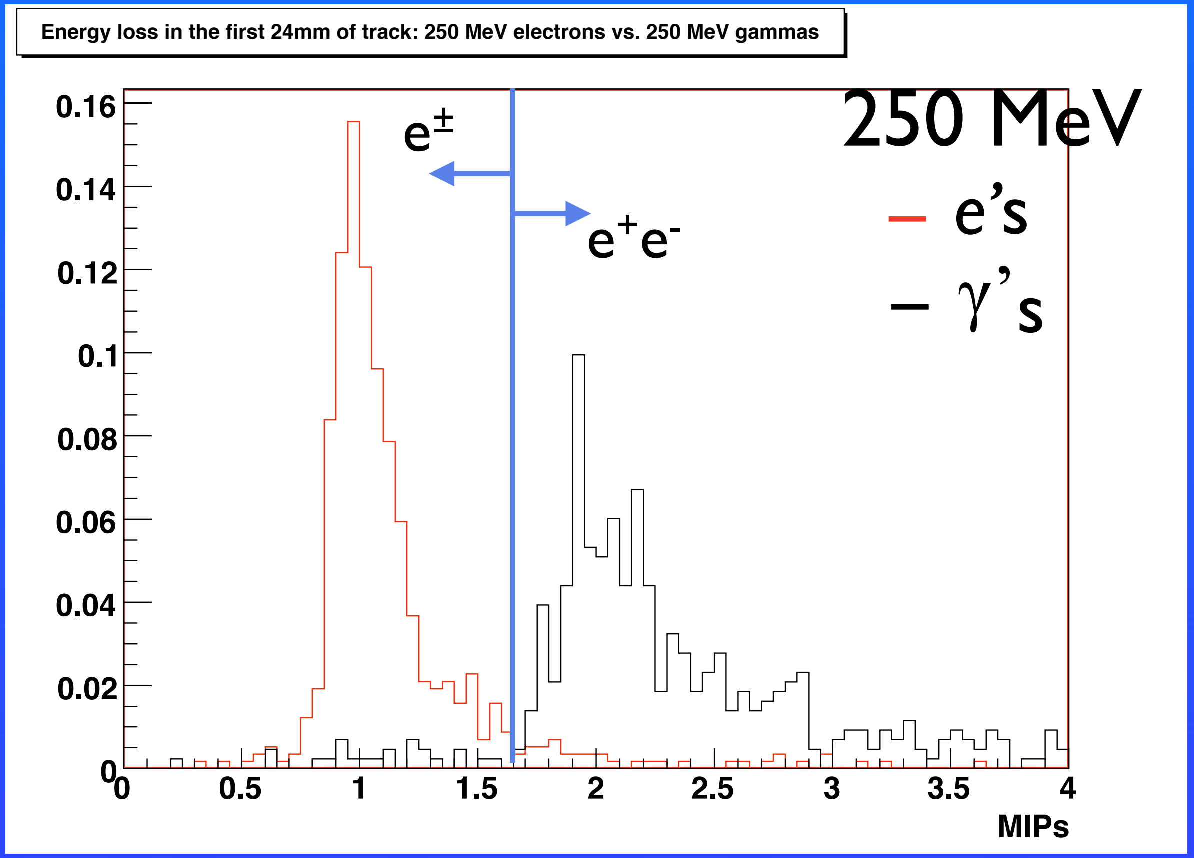
- Proton Decay (e.g. - $p \rightarrow K^+ \nu_\mu$)
- Supernovae searches
- Solar neutrinos

"Nucleon Decay Searches with large Liquid Argon TPC Detectors at Shallow Depths: atmospheric neutrinos and cosmogenic backgrounds" - A. Bueno et. al, hep-ph/0701101

LAr TPC Advantages

e/γ separation → reduced ν_μ induced backgrounds (NC π^0)

- 80% signal (CC ν_e) efficiency, ≈96% background (NC π^0) rejection
- Topological cuts will also improve signal/background separation
- PID from dE/dx (proton/pion/kaon separation)



dE/dx for electrons and gammas in first 2.4 cm of track

New GEANT4 simulation... work in progress

Noble Liquids: Properties

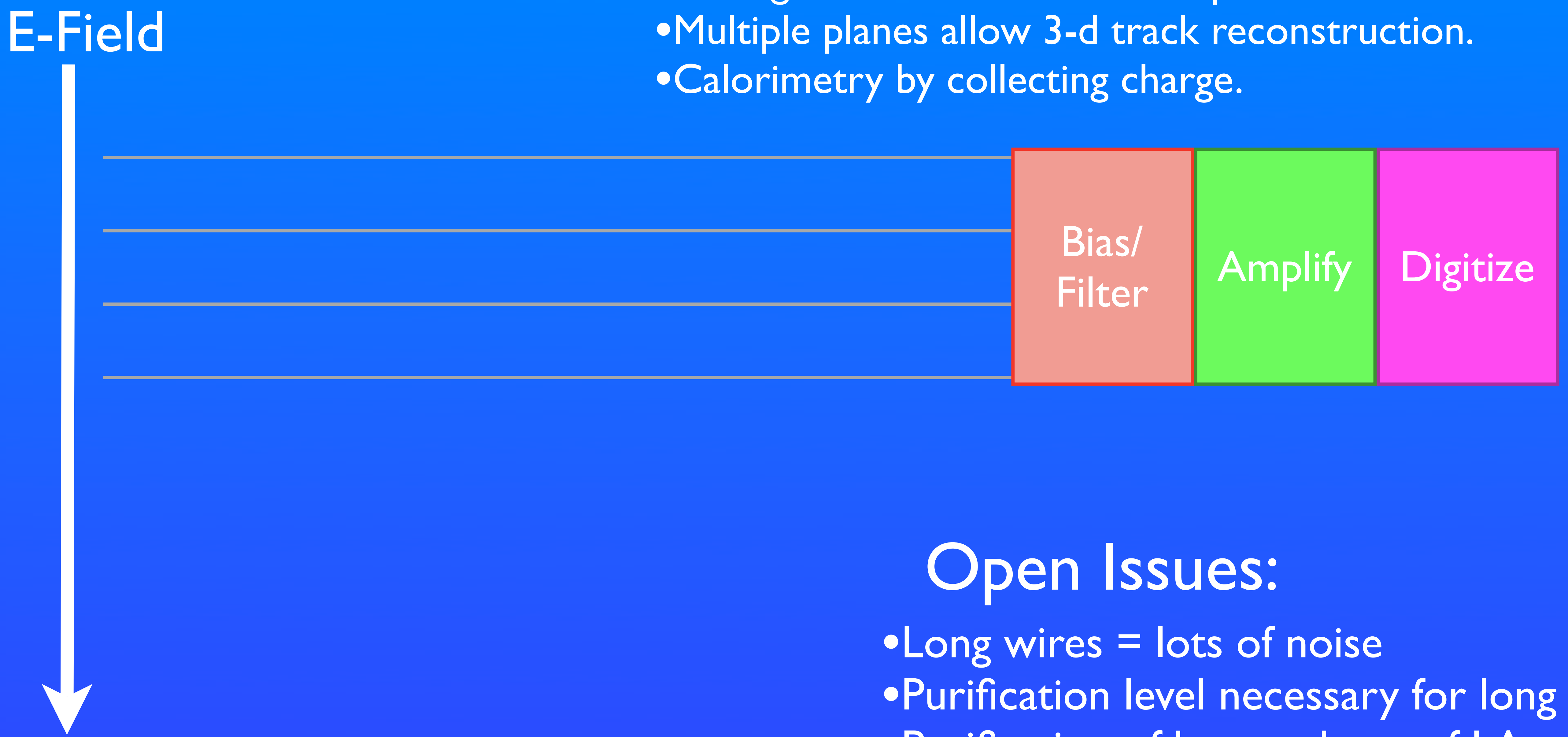
- Ionization and scintillation light used for detection (transparency to own scintillation).
- Ionization electrons can be drifted over long distances in these liquids.
- Very good dielectric properties allow high-voltages in detector.
- Argon is cheap and easy to obtain (1% of atmosphere).

	Water	He	Ne	Ar	Kr	Xe
Boiling Point [K] @ 1atm	373	4.2	27.1	87.3	120.0	165.0
Density [g/cm^3]	1	0.125	1.2	1.4	2.4	3.0
Radiation Length [cm]	36.1	755.2	24.0	14.0	4.9	2.8
Scintillation [γ /MeV]	-	19,000	30,000	40,000	25,000	42,000
dE/dx [MeV/cm]	1.9		1.4	2.1	3.0	3.8
Scintillation λ [nm]		80	78	128	150	175

LAr TPCs can be scaled to massive sizes.

How LAr TPCs Work

- Drift velocity controlled by E-field.
- Timing + wire location = track position.
- Multiple planes allow 3-d track reconstruction.
- Calorimetry by collecting charge.



Open Issues:

- Long wires = lots of noise
- Purification level necessary for long drift
- Purification of large volume of LAr
- Surface cosmic-ray rates

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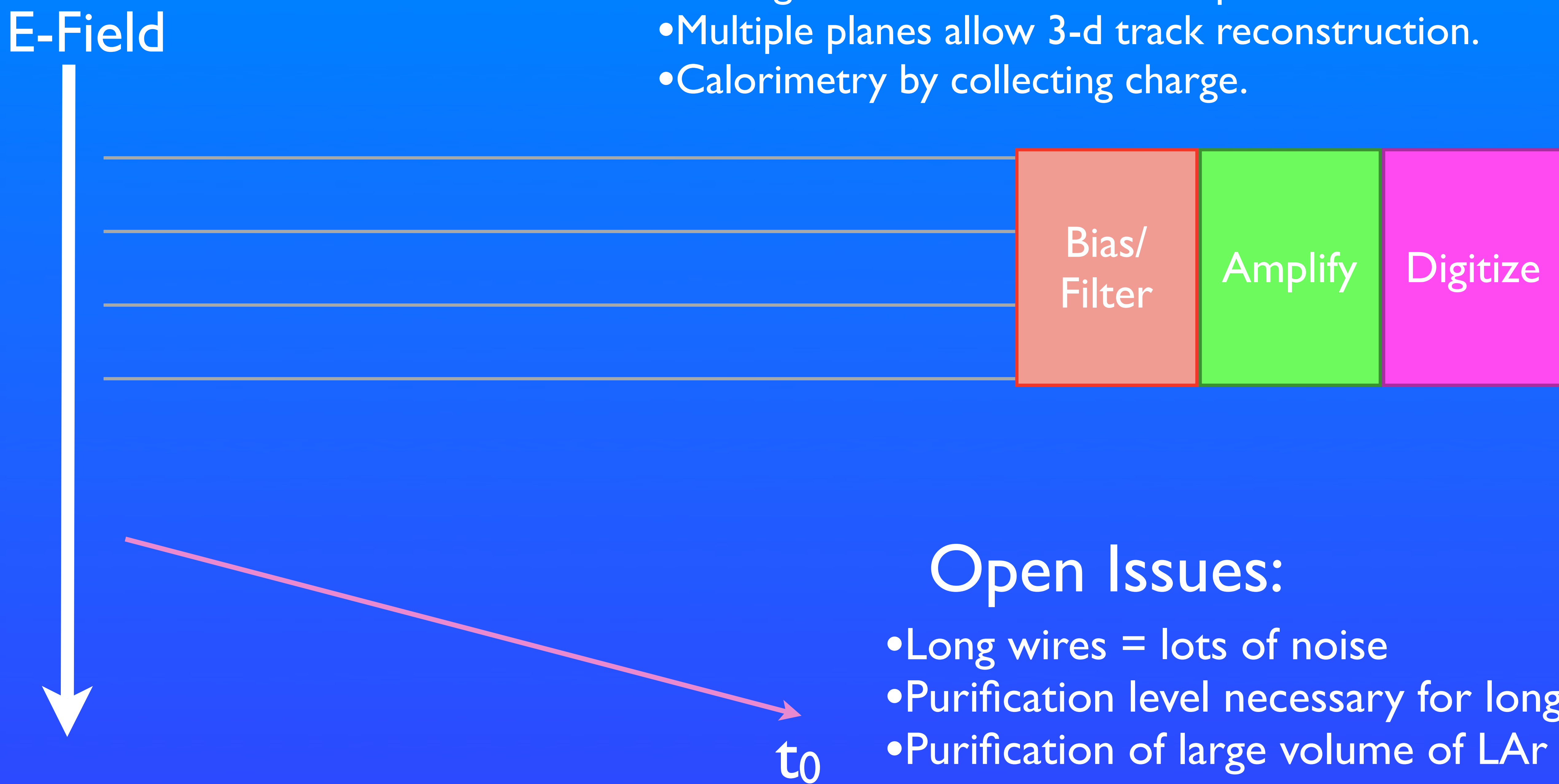

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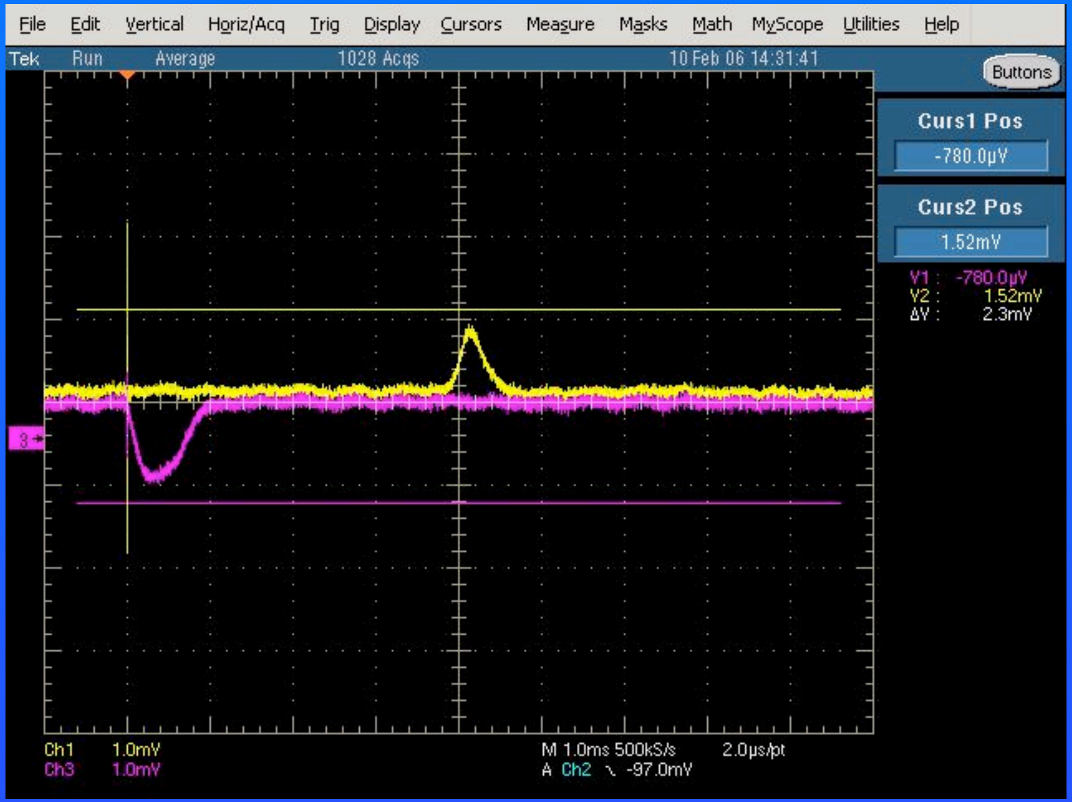
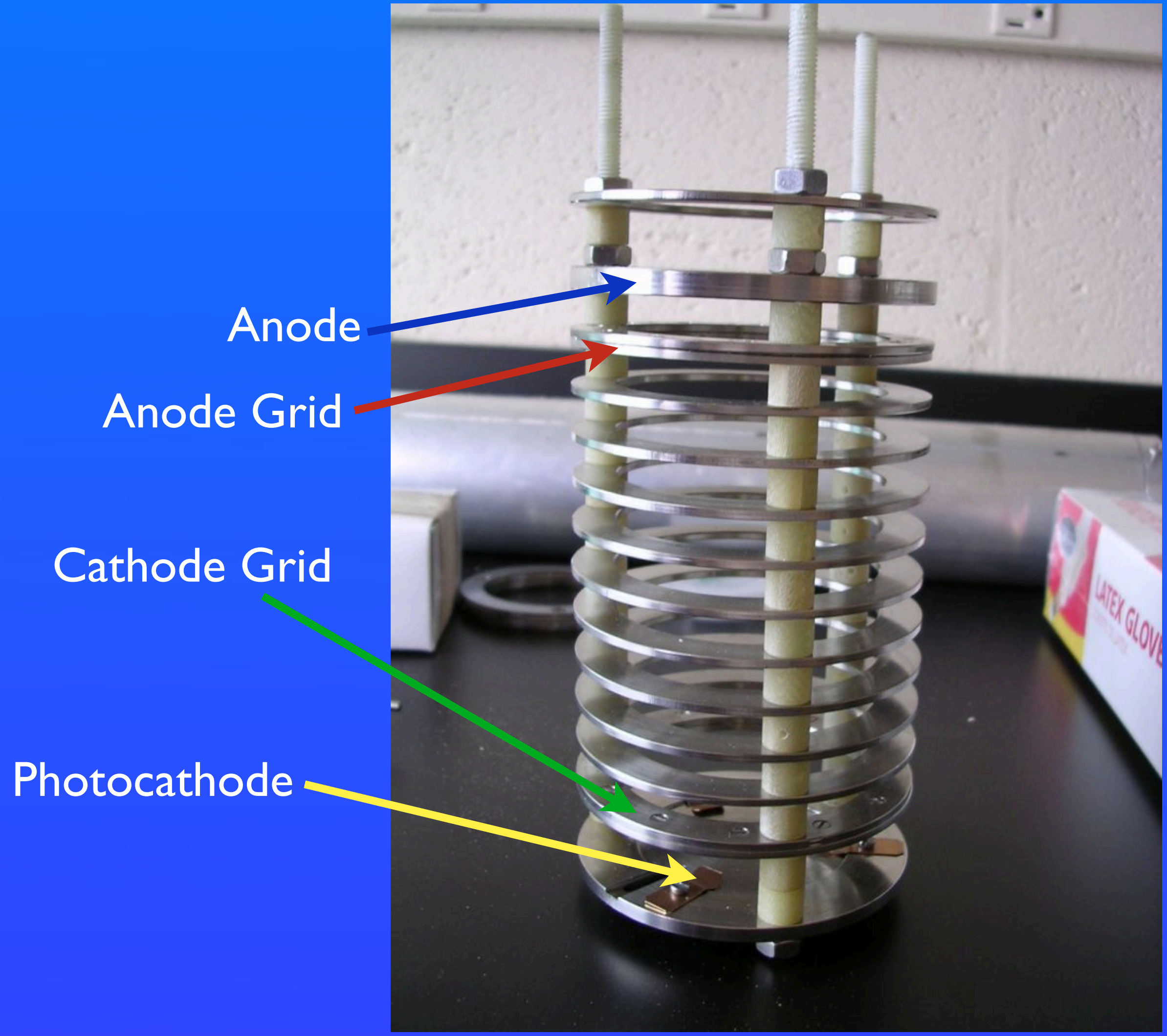
Argon Purity

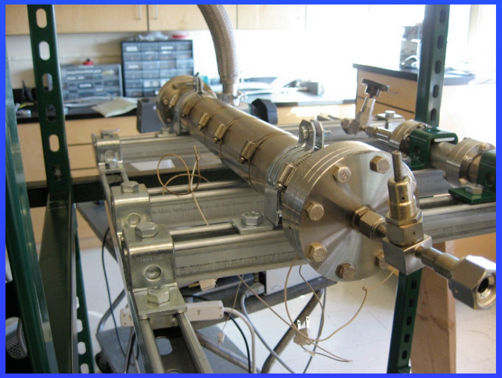
- To drift electrons through argon, impurities (primarily Oxygen) must be removed from delivered LAr to increase ionization electron lifetimes.
- Pass LAr through filter before sending it into detector vessel.
- Drift charges through filtered LAr to measure purity.
- Fermilab has developed its own reusable filters for liquid argon.



Very nice FNAL Purity signal (4ms)



ICARUS style Purity Monitor

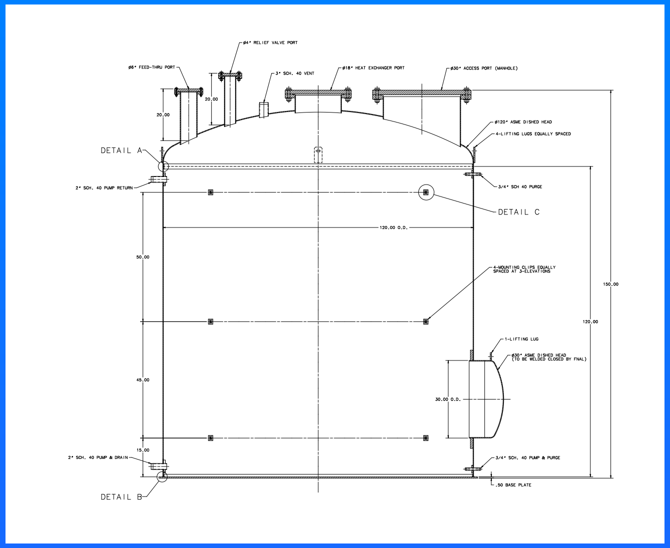


FNAL TRIGON Filter

LAr TPC Roadmap

Materials Test Stand

20 Ton Purity Demonstration



Poster Session

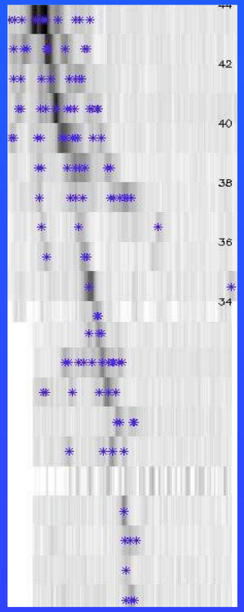
"R&D on Liquid Argon Time Projection Chambers and Physics Potential for Future Neutrino Oscillation Experiments"
-Niki Saoulidou (Fermilab), Dave Finley (Fermilab)

"MicroBooNE" - Joshua Spitz (Yale)

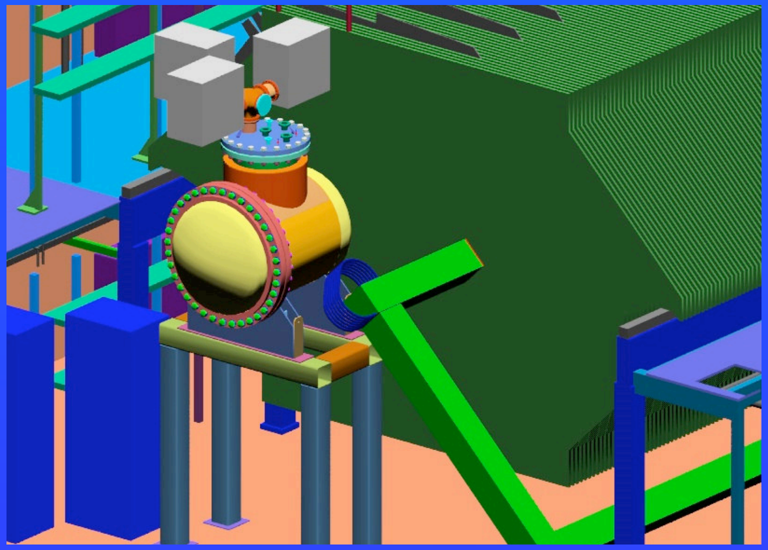
2007 | 2007 | 2008 | 2008 | 2010/11? | 201?

5 kTons

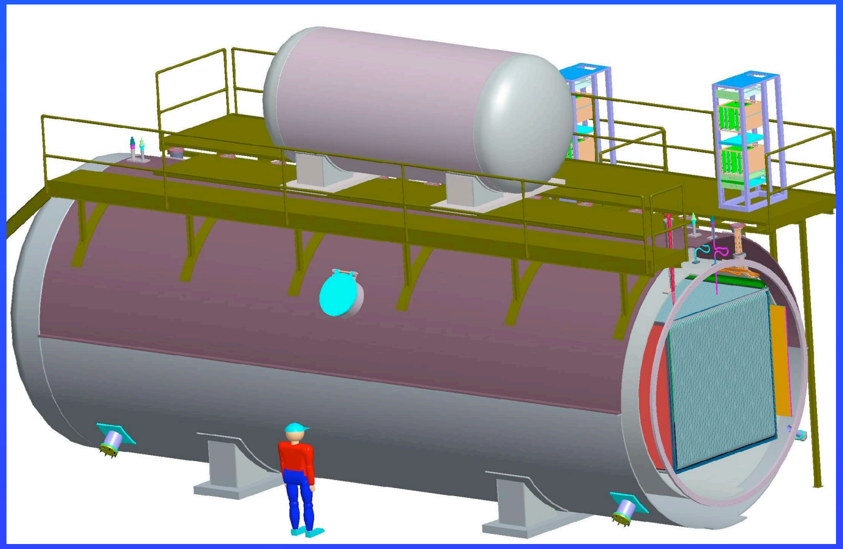
50-100 kTons



Tracks at Yale

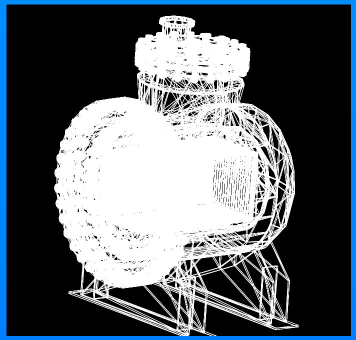


ArgoNeuT: ~175 Liter TPC in NUMI beam.



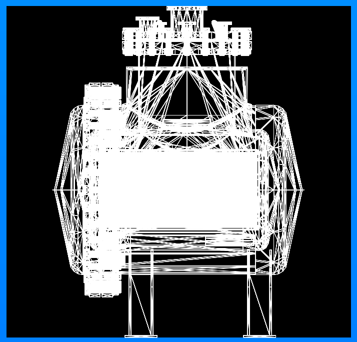
MicroBooNE

Massive LArTPCs:
FLARE
GLACIER
LANNDD
MODULAR

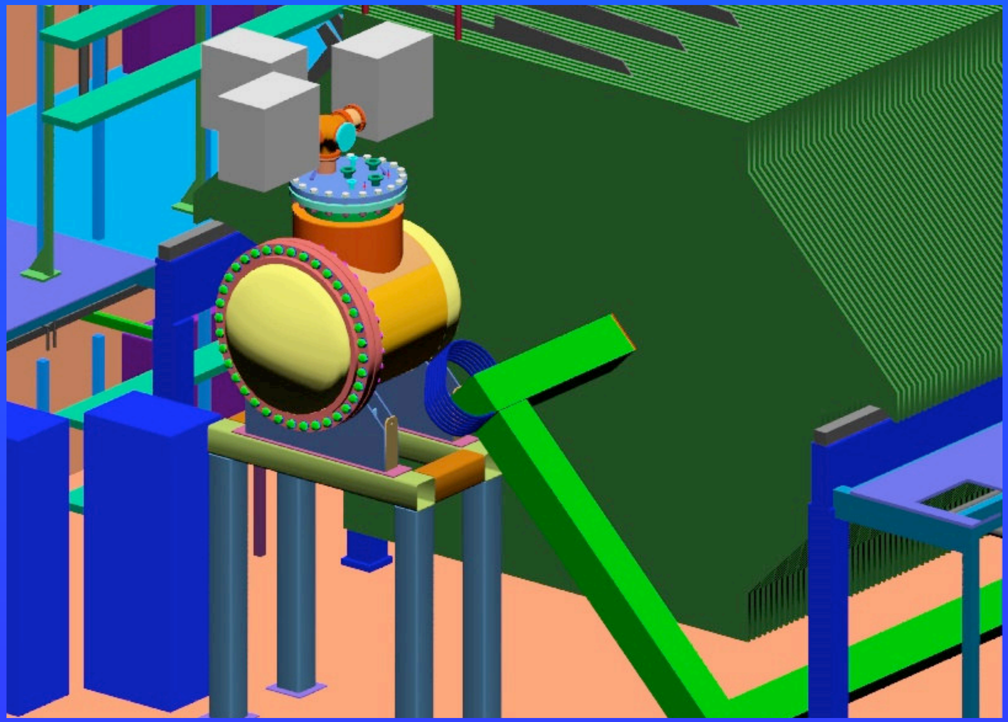


ArgoNeuT

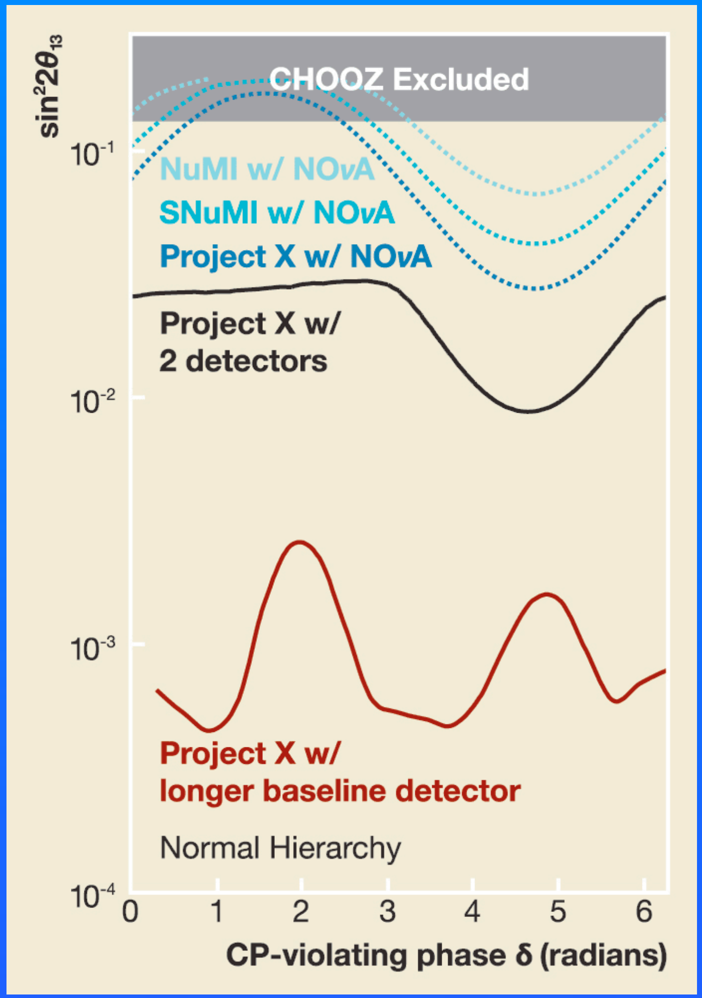
http://t962.fnal.gov



- ArgoNeuT = Argon Neutrino Test , scheduled to start running in Feb. 2008
- Fermilab, INFN, Michigan State, UT Austin, Yale ← International collaboration!
- ~175 Liter LAr TPC exposed to NUMI beam.
- 480 channels of readout, 4mm pitch
- Use Minos as muon catcher to calibrate, then move elsewhere in tunnel when Minerva arrives
- Excellent opportunity to gain experience (in the U.S.) with LArTPCs in a neutrino beam:
  - Recirculation system with Fermilab filters.
  - Electronics made in U.S. (by MSU)
  - Underground running and all its issues....
  - Develop GEANT4 Simulation



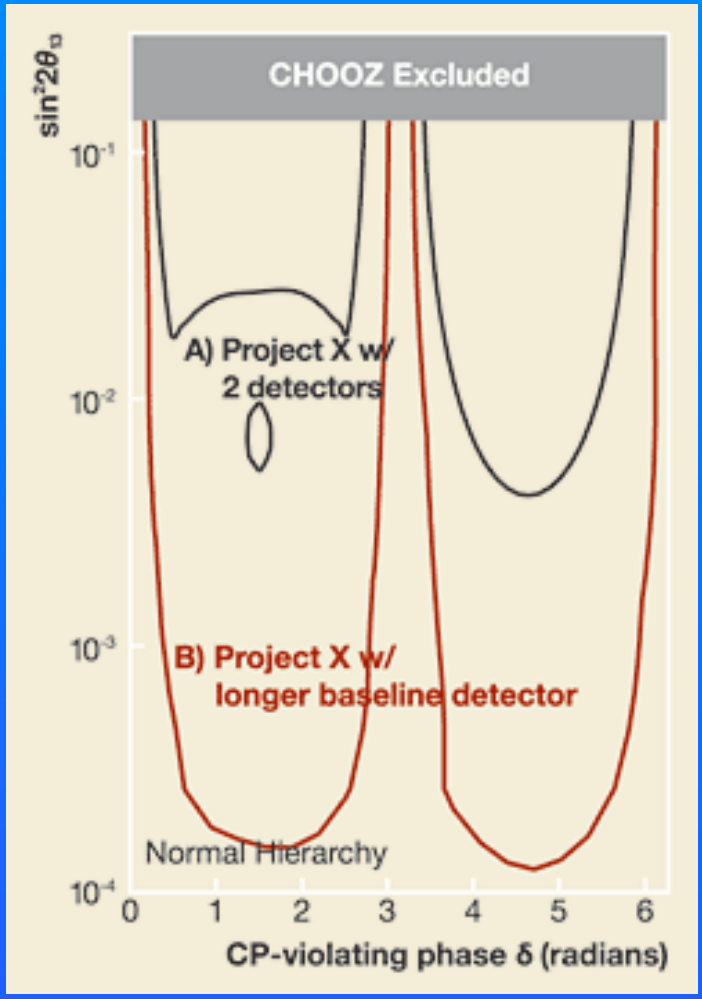
LArTPC Potential with Project X



Mass Ordering

- Scenarios assume 3 years neutrino + 3 years antineutrino
- LArTPC Curves Assume:
  - 80% signal efficiency and 80% beam ν_e selection efficiency
  - no NC π^0 background and 5% systematic on background.

From Steering Group Report
(Niki Saoulidou)



CP Violation

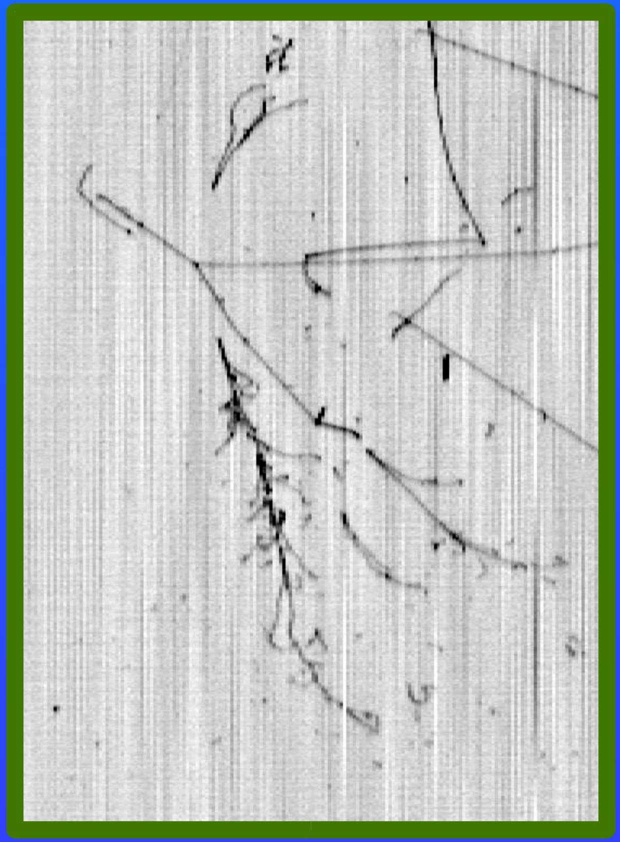
Curve	Beam	Detectors	POT/mode (10^{20})	Energy (GeV)
light cyan dotted	NuMI	NOvA	15	120
cyan dotted	sNuMI	NOvA	30	120
blue dotted	Project X	NOvA	60	120
black solid	Project X / NuMI	100kT LArTPC at 700km 100kT LArTPC at 810km	60	120
red solid	Project X / wideband	100kT at 1300km	120	60

Conclusions

- Liquid Argon TPCs are an exciting technology for next generation experiments.
- There are several LArTPC projects in progress, or in the proposal stage, all of which will ready the technology for the Project X /DUSEL era.

One of top 4 level recommendations from the NuSAG report, 2007:

"A phased program with milestones and using technology suitable for a 50-100kton detector is recommended for the liquid argon detector option. Upon completion of the existing R&D project to achieve purity sufficient for long drift times, to design low noise electronics, and to qualify materials, construction of a test module that could be exposed to a neutrino beam is recommended."



ICARUS Event