Liquid Argon Time Projection Chambers

R&D Towards Kiloton Class Detectors

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Big Questions in Neutrinos

- Observe $\nu_\mu \longrightarrow \nu_e$ transitions, measure θ_{13} $\sin^2(2\theta_{13}) < 0.19\ (90\%\mathrm{CL})$
- Determine Mass Hierarchy

$\Delta m^2_{21} = \Delta m^2_{\mathrm{sol}} = 8.0^{+0.6}_{-0.4} \cdot 10^{-5}\mathrm{eV}^2$

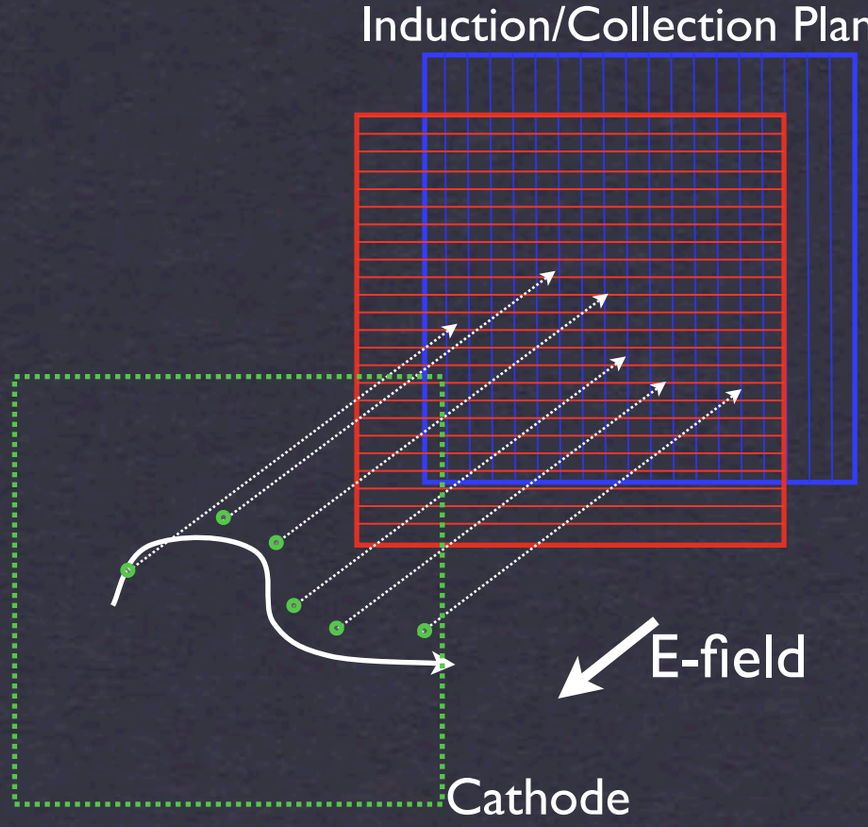
$\Delta m^2_{31} \approx \Delta m^2_{32} = \Delta m^2_{\mathrm{atm}} = 2.4^{+0.6}_{-0.5} \cdot 10^{-3}\mathrm{eV}^2$

- Measure a possible CP-violating phase, δ_{CP}

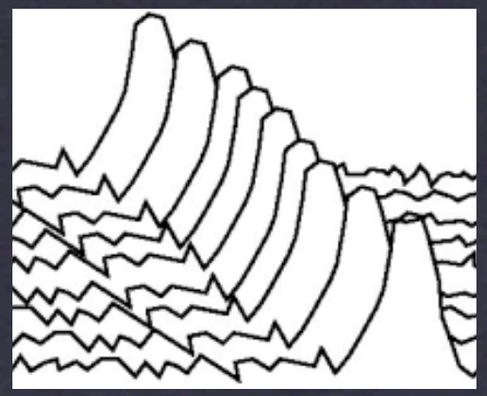
Liquid Argon TPC Idea

TPC = Time Projection Chamber

- Interactions in TPC produce ionization particles which drift along electric field lines to readout planes.
- Scintillation light also present, can be collected by PMTs and triggered on.
- Knowledge of drift speed, and T_0 of events, can be used to reconstruct interaction.



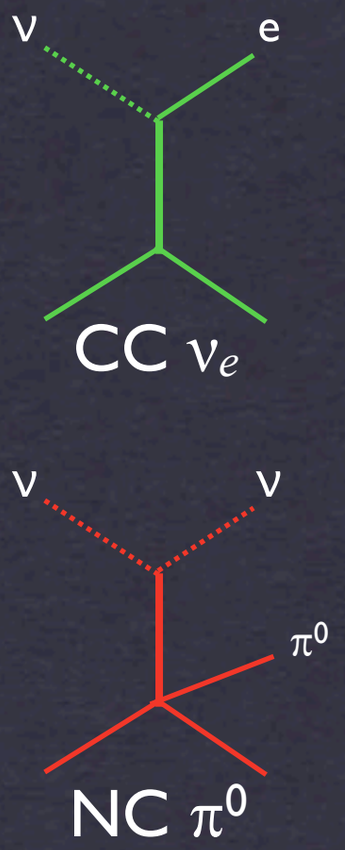
Train of pulses, with slight time offsets due to different drift lengths.

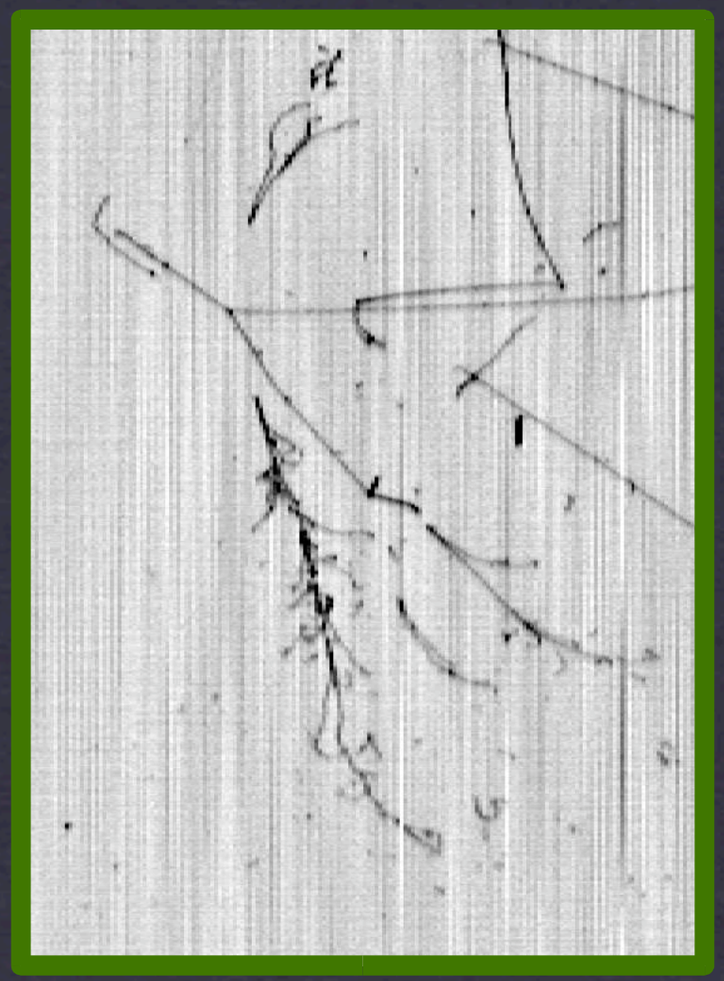


$$(t - T_0) = v_{drift} \cdot (x - x_{\mathrm{wire}})$$

LAr TPCs: Advantages

- Excellent π^0, electron discrimination (π^0's are big background in ν_e appearance expt.)
- 80% signal (CC ν_e) efficiency, ≈100% background (NC π^0) rejection
- Particle ID from dE/dx (proton/pion/kaon separation)
- Beautiful events:

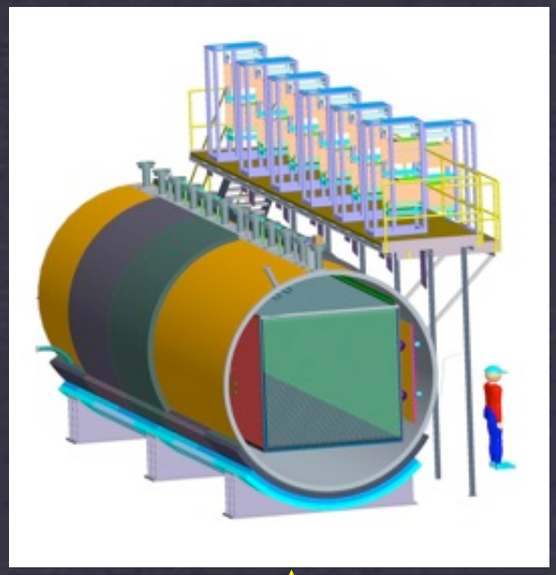




ICARUS Event

LAr TPCs (U.S.) : Past/Present/Future

Materials Test Stand



MicroBooNE

5 kTons

50-100 kTons

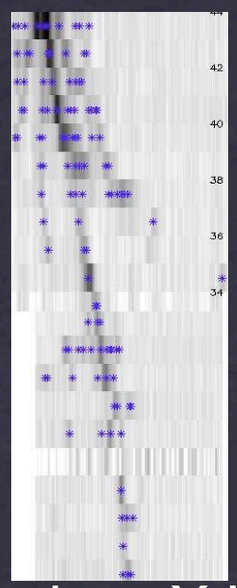
2007

2007

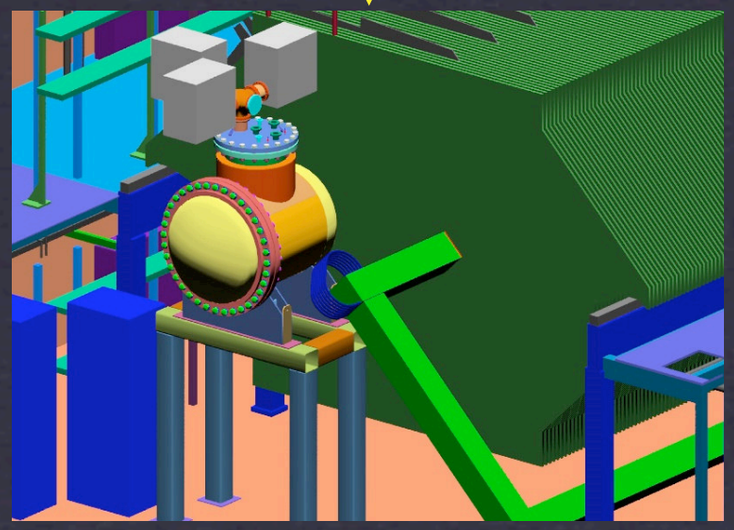
2008

2011?

201?



Tracks at Yale*



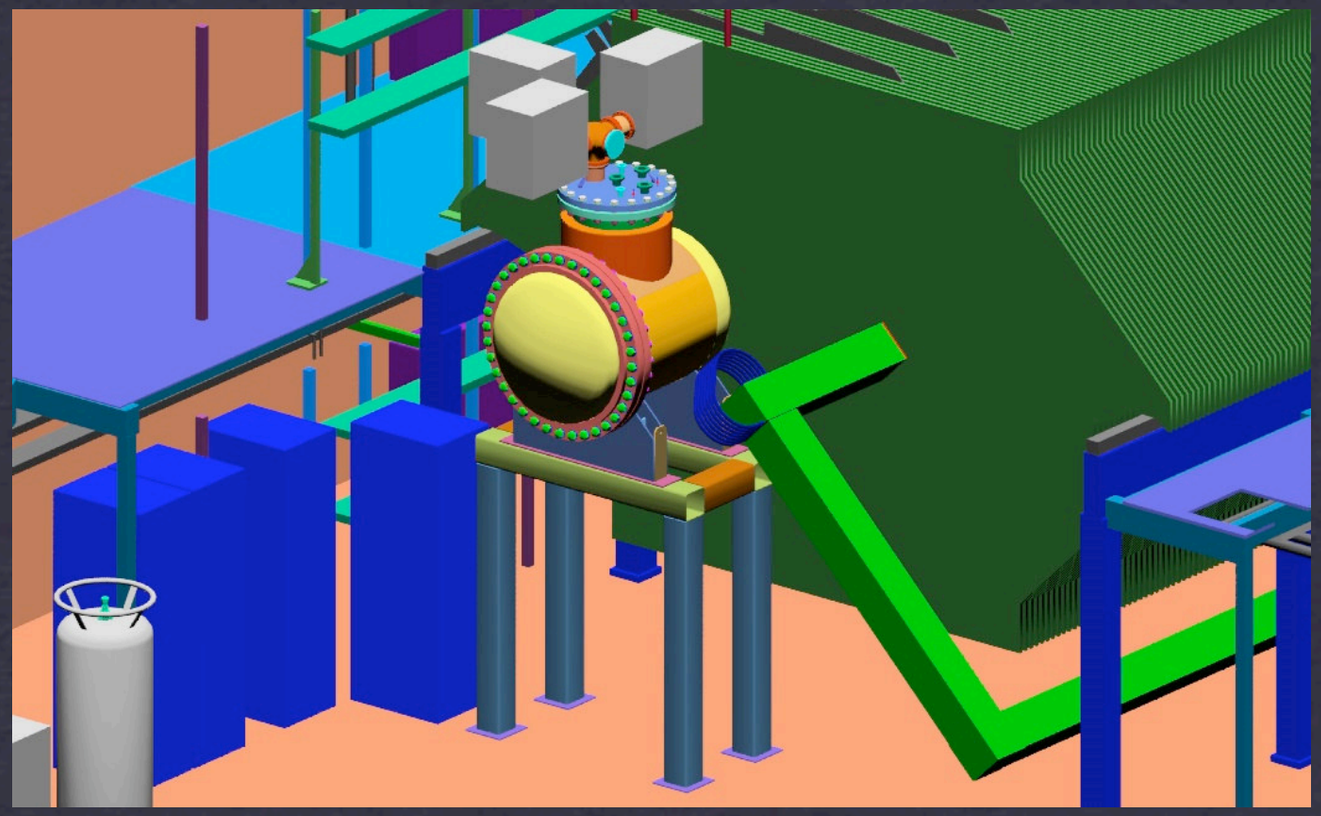
ArgoNeuT

Massive LArTPCs:
FLARE
GLACIER
LANNDD
MODULAR

* - arXiv:0708.0875v1 - "*The Yale LAr TPC*"

ArgoNeuT

- Collaboration of Fermilab, Gran Sasso, L'Aquila, Michigan State, UT Austin, Yale
- Small (~175 liter TPC) LArTPC in Fermilab's NuMI beamline.
- Real neutrino events in an LArTPC.
- Invaluable learning experience before attempting larger detector.

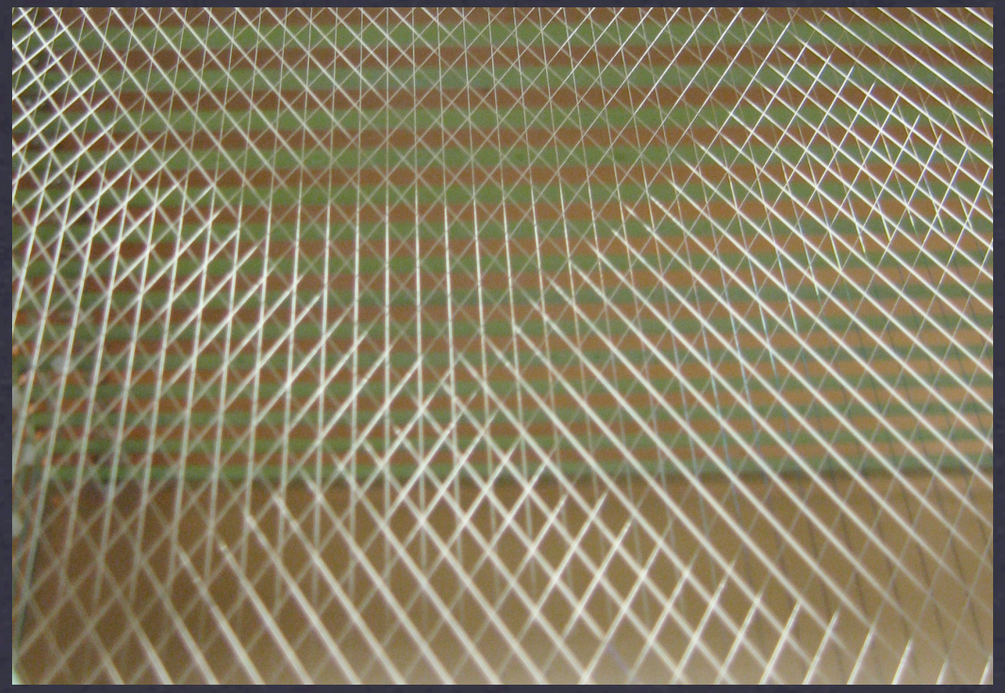


ArgoNeuT in front of MINOS

Cryostat

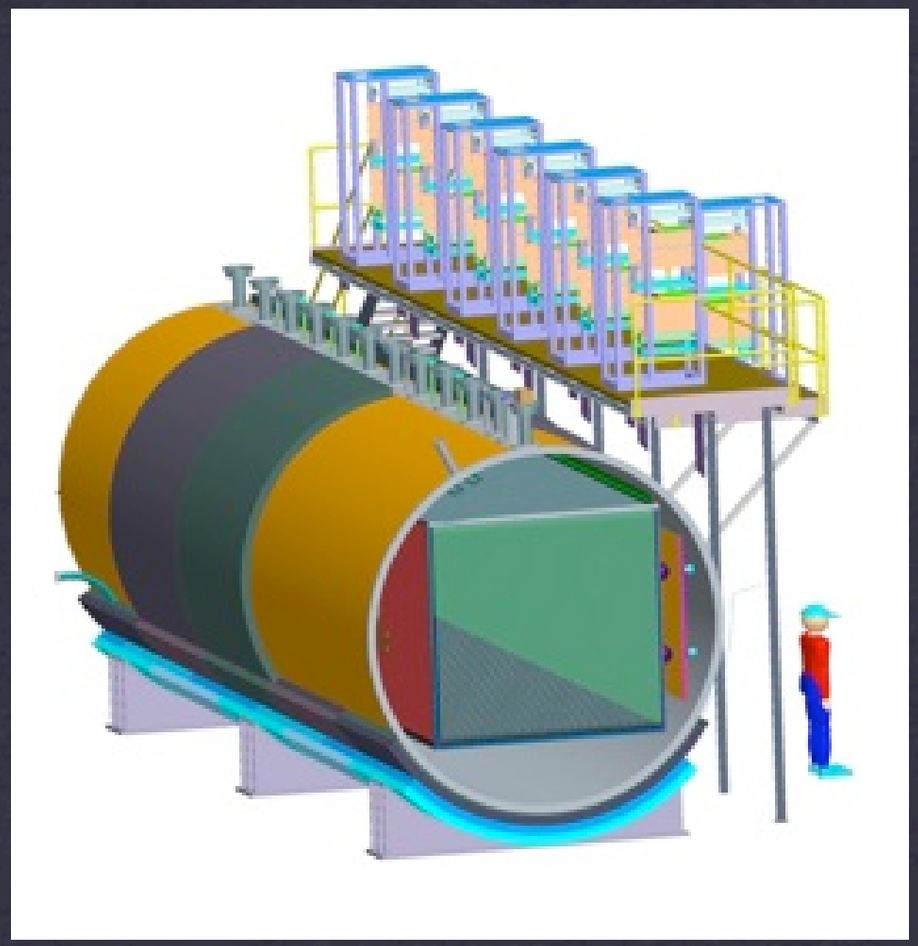
ArgoNeuT Detector

- TPC has 480 channels of readout spread over two planes.
- Collection/Induction wires at 60º angles.
- Max. drift distance is ~50cm.
- 2048 samples over 400μs
- MSU electronics are first U.S. built LArTPC electronics.



MicroBooNE

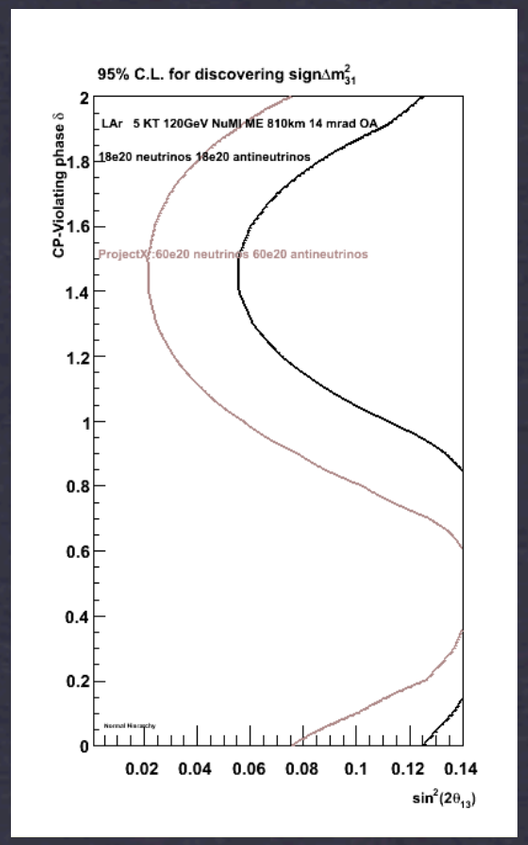
- Next generation TPC which will sit in Booster neutrino beam at Fermilab.
- 170 ton cryostat with ~70 ton fiducial volume TPC
- MicroBooNE can study MiniBooNE low-energy excess, as well as numerous cross-section measurements.
- Many R&D aspects which will benefit in design of very large detectors



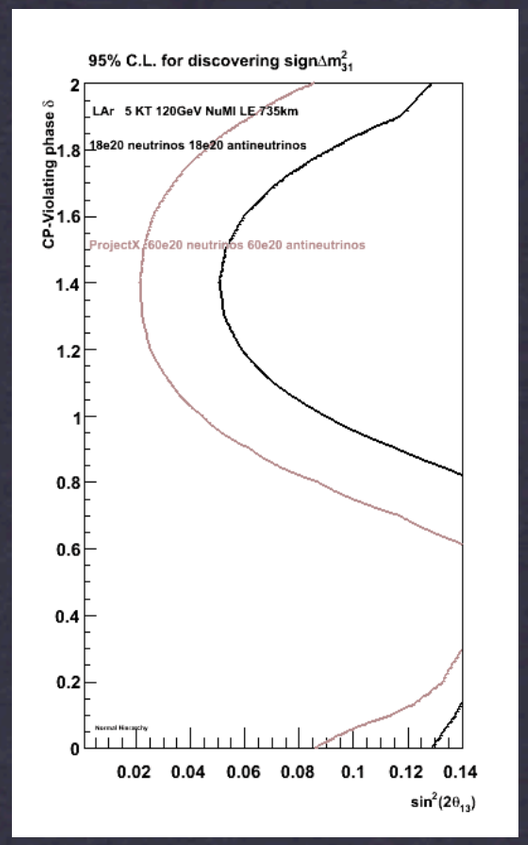
LAr5

- Growing interest/discussion regarding a 5 kiloTon LAr TPC.
- Possible siting options at Ash River, Soudan Mine, DUSEL
- Possible beams include NuMI or Project X from Fermilab.
- LAr5 would capitalize on knowledge gained from ArgoNeuT/MicroBooNE/etc...
- Physics potential: ex. - Mass hierarchy sensitivity:

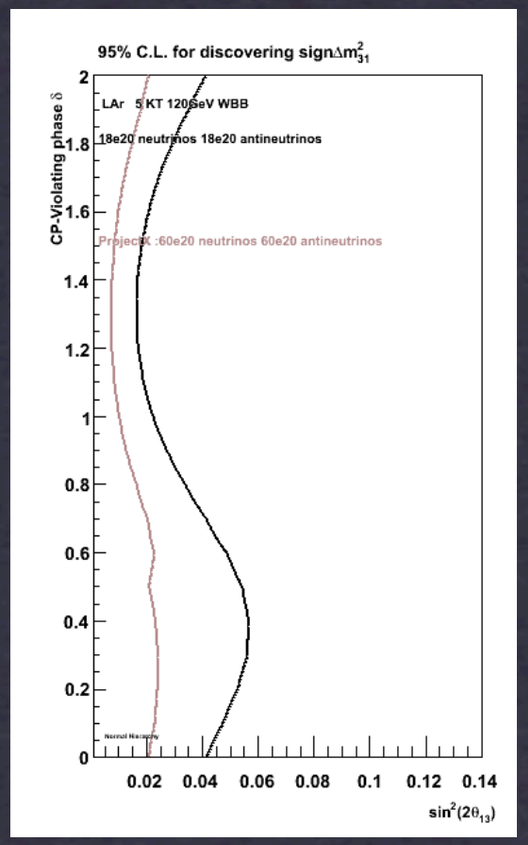
PLOTS FROM G. RAMEIKA



ASH RIVER/
NUMI(ME)



SOUDAN/
NUMI(LE)

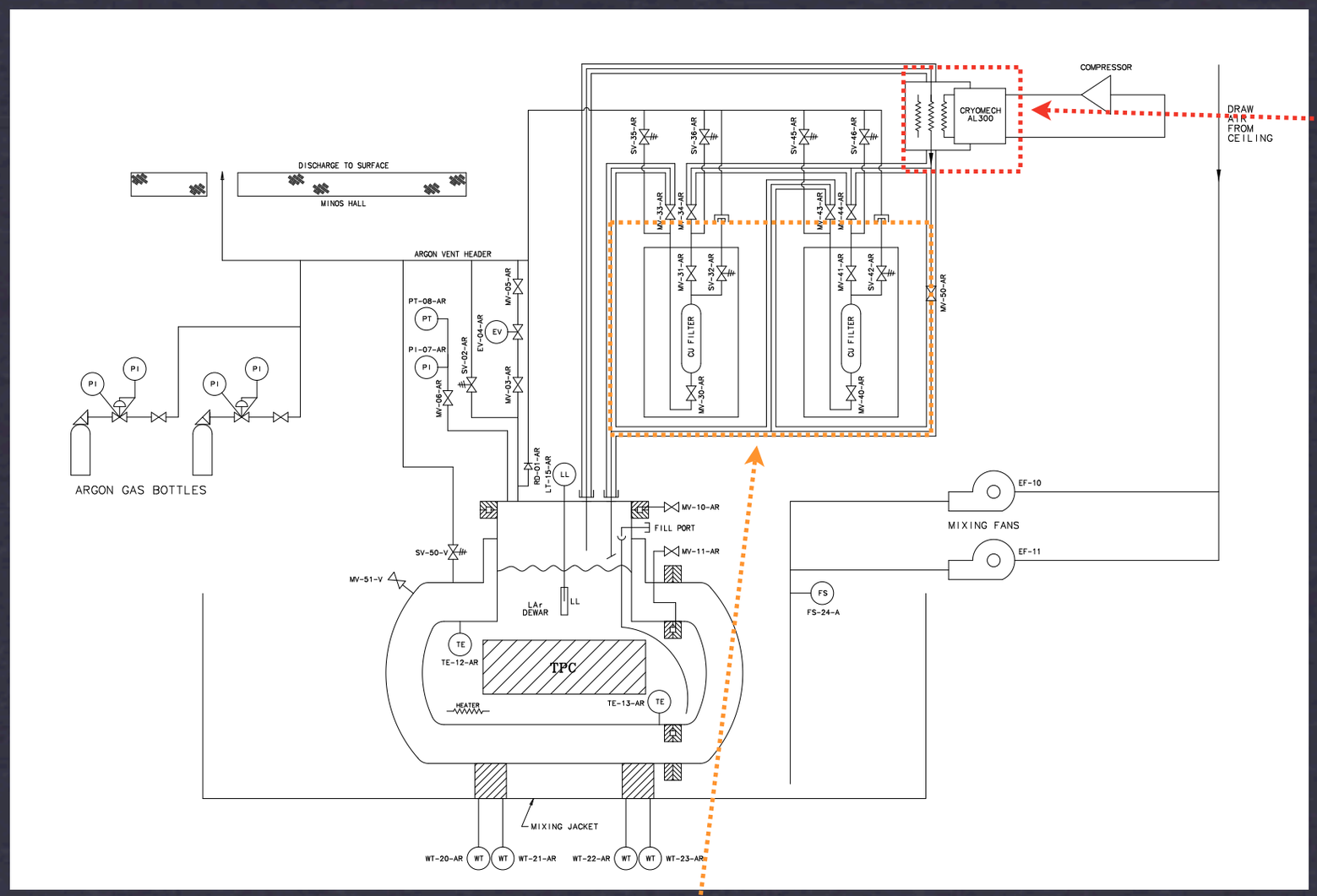


DUSEL/
PROJECT X

Conclusion

- LAr TPCs are an exciting technology for massive next generation neutrino detectors.
- ArgoNeuT will be a great proving ground for LAr TPCs in a real beam environment.
- MicroBooNE can do timely physics, such as studying the MiniBooNE low-energy excess, and R&D.
- Massive (>5kTon) LAr TPCs could someday answer the major questions of neutrino oscillation physics.

ArgoNeuT Cryogenics



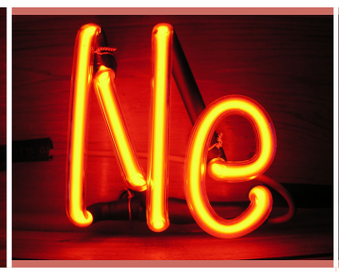
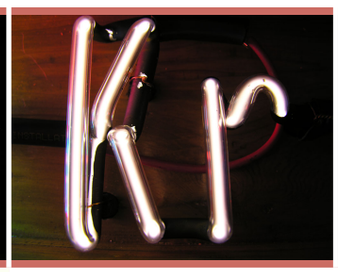
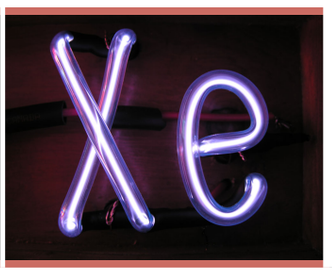
300W Cryocooler

Bathtub Containment

- Recirculation System will have two filters to allow for continuous operation.
- Complete volume exchange every ~4 days.
- Many safety features to minimize chances of argon escaping into tunnel.

Noble Liquids

- 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					
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.