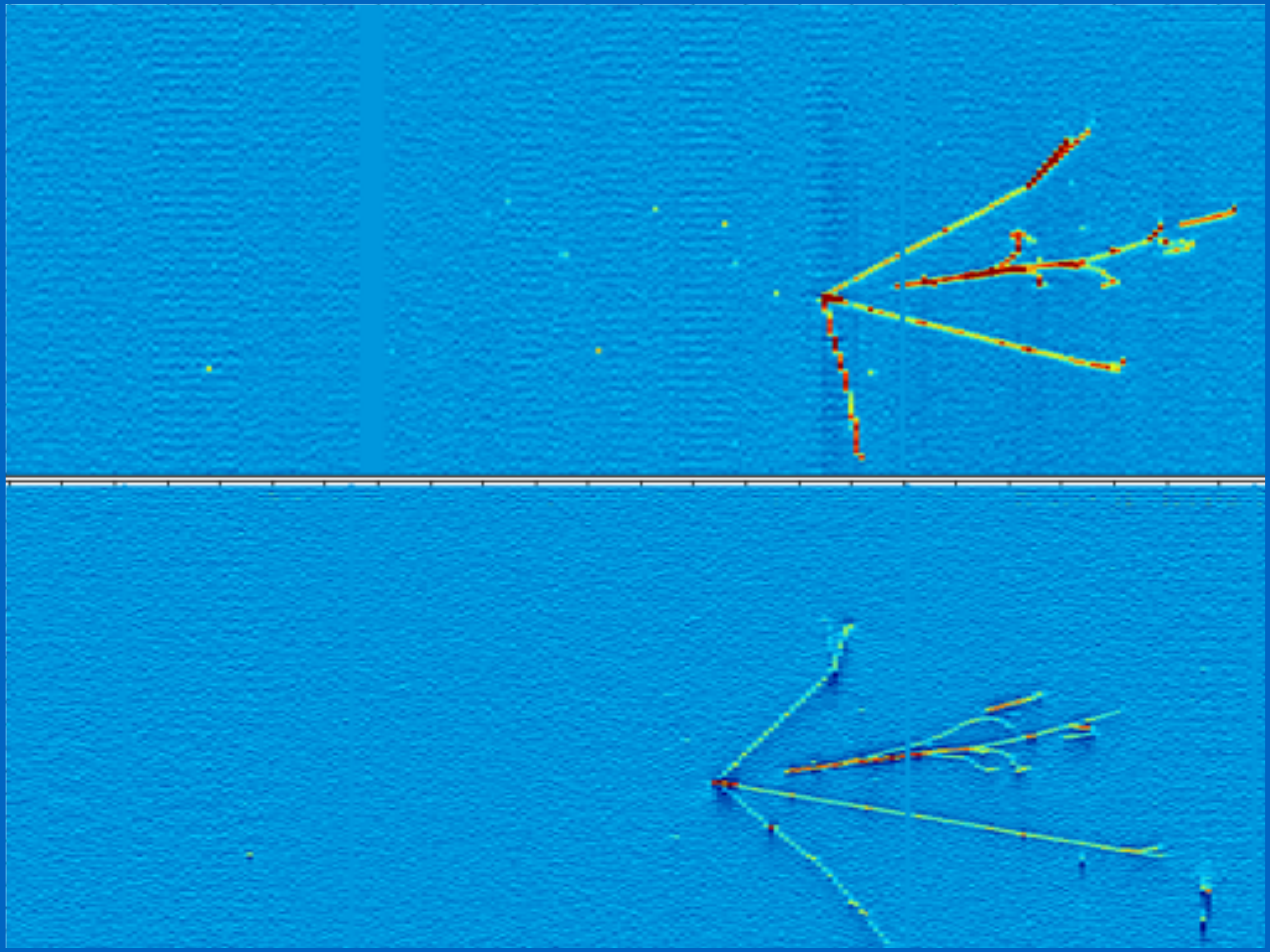
Liquid Argon Detectors

NuSTEC Lecture, part I

Mitch Soderberg
Syracuse University / Fermilab

What I'm going to talk about

This talk:
the technology of liquid argon neutrino detectors



Next talk:
the physics capabilities

Goals For This Lecture

- Familiarize everyone with detection principles of Liquid Argon Time Projection Chambers (LArTPCs).
- Get everyone thinking about some of the issues associated with designing, building, operating these detectors.

Goals For This Lecture

- Familiarize everyone with detection principles of Liquid Argon Time Projection Chambers (LArTPCs).
- Get everyone thinking about some of the issues associated with designing, building, operating these detectors.

Please ask questions at anytime!

Question #1 (To Help Me)

What do you work on?

Question #1 (To Help Me)

What do you work on?

A) Theory/Phenomenology

B) Cerenkov experiment (Super-K, IceCube, etc…)

C) Tracking Scintillator experiment (NOvA, MINERvA, etc…)

D) Liquid Argon experiment (ICARUS, MicroBooNE, etc…)

E) Something Else

Experimentalist Approach to Neutrino-Nucleus Interactions

$$N_{expected} = \sigma \otimes \mathscr{L} \otimes \epsilon$$

Event Sample

Cross-Section (Nature)

Exposure (Beam+Detector Mass)

Efficiency (Detector Specific)

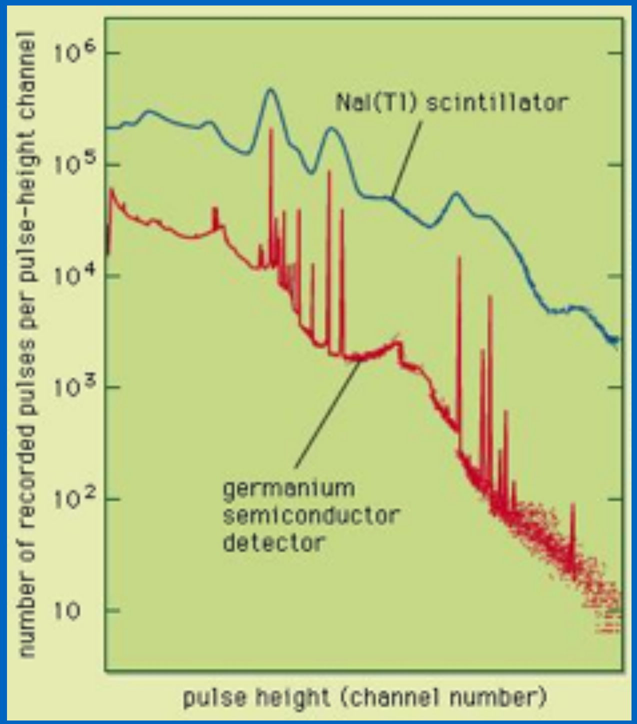
- Superficially, our job is to build experiments that can acquire enough statistics to learn something interesting.
- Statistics aren't everything though. We'd like to design experiments that provide deeper insight into the interactions we are studying while perhaps enabling new avenues of research.

Experimentalist Wishlist for Neutrino-Nucleus Scattering Detector

Refs:
1.) G.F. Knoll, *Radiation Detection and Measurement*, 2nd ed. (1989), John Wiley and Sons, Inc.

Experimentalist Wishlist for Neutrino-Nucleus Scattering Detector

☑ **Good Resolution!** Refined information enables advances in science.



Refs:
1.) G.F. Knoll, *Radiation Detection and Measurement*, 2nd ed. (1989), John Wiley and Sons, Inc.

Experimentalist Wishlist for Neutrino-Nucleus Scattering Detector

- ✓ **Good Resolution!** Refined information enables advances in science.

- ✓ **Big!** …enough to be suitable for the cross-section regime and beam you're working with.

Refs:
1.) G.F. Knoll, *Radiation Detection and Measurement*, 2nd ed. (1989), John Wiley and Sons, Inc.

Experimentalist Wishlist for Neutrino-Nucleus Scattering Detector

- ☑ **Good Resolution!** Refined information enables advances in science.
- ☑ **Big!** …enough to be suitable for the cross-section regime and beam you're working with.
- ☑ **Fast!** …enough to keep up with modern accelerator neutrino beam rep-rate.

Refs:
1.) G.F. Knoll, *Radiation Detection and Measurement*, 2nd ed. (1989), John Wiley and Sons, Inc.

Experimentalist Wishlist for Neutrino-Nucleus Scattering Detector

- ☑ **Good Resolution!** Refined information enables advances in science.
- ☑ **Big!** …enough to be suitable for the cross-section regime and beam you're working with.
- ☑ **Fast!** …enough to keep up with modern accelerator neutrino beam rep-rate.
- ☑ **Affordable!** Cost not so prohibitive that experiment will never be built.

Refs:
1.) G.F. Knoll, *Radiation Detection and Measurement*, 2nd ed. (1989), John Wiley and Sons, Inc.

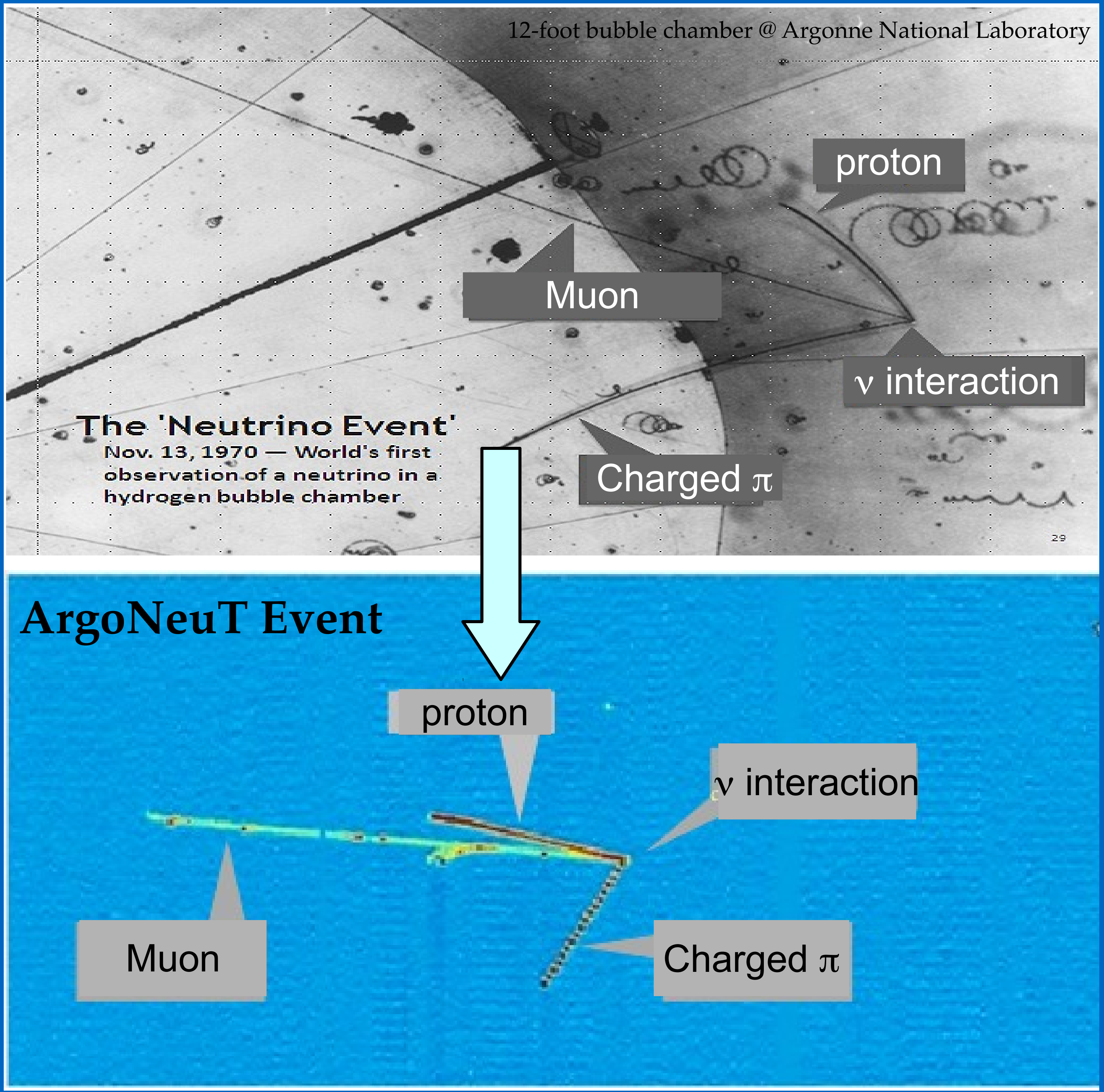
Experimentalist Wishlist for Neutrino-Nucleus Scattering Detector

- ✔ **Good Resolution!** Refined information enables advances in science.
- ✔ **Big!** …enough to be suitable for the cross-section regime and beam you're working with.
- ✔ **Fast!** …enough to keep up with modern accelerator neutrino beam rep-rate.
- ✔ **Affordable!** Cost not so prohibitive that experiment will never be built.
- ✔ **Versatile!** Potential to study many interaction types, and perhaps multiple nuclear targets.

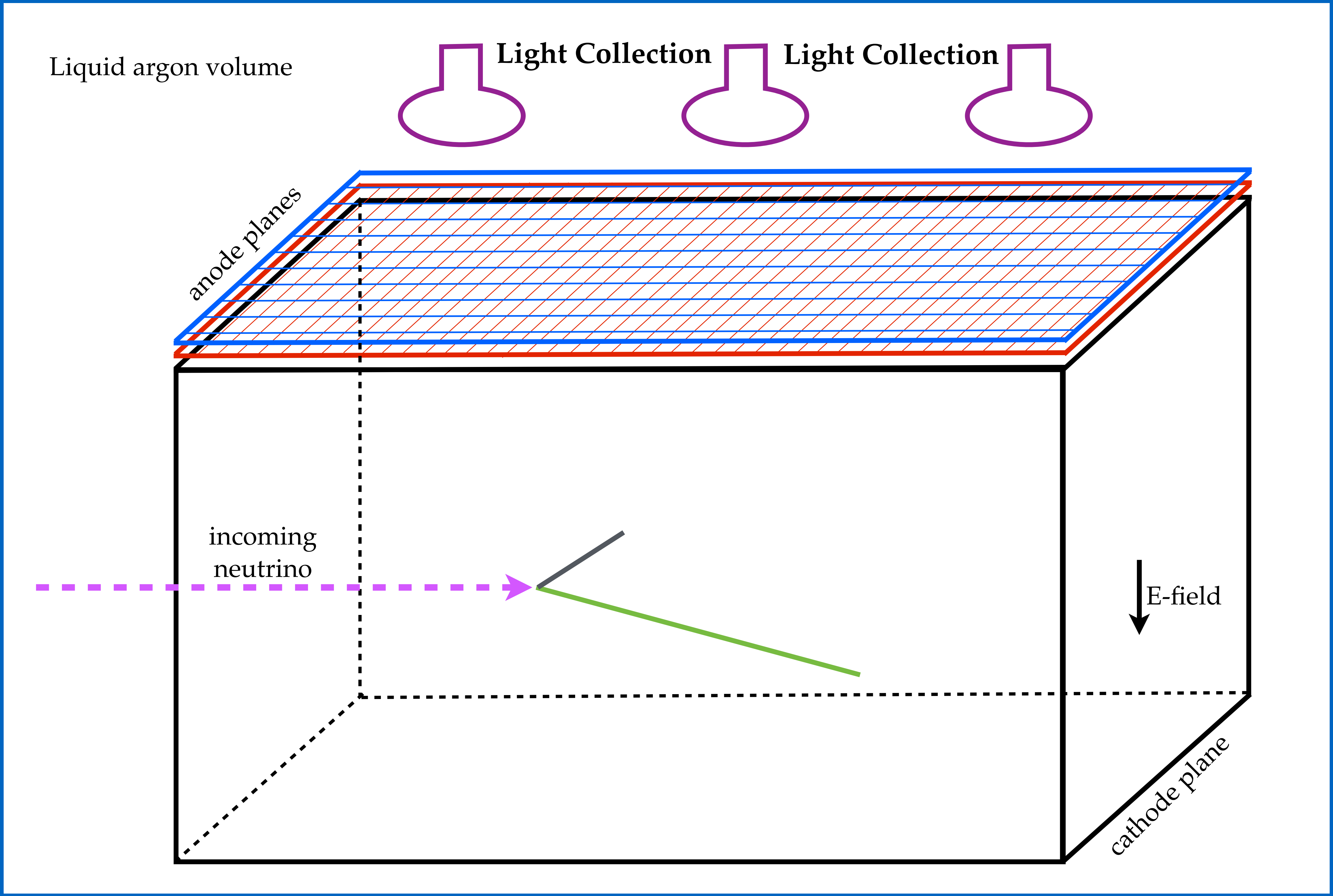
Refs:
1.) G.F. Knoll, *Radiation Detection and Measurement*, 2nd ed. (1989), John Wiley and Sons, Inc.

Why Liquid Argon Detectors?

- Has all the features desirable for studying neutrino-nucleus interactions.
- Bubble chamber quality images combined with calorimetry.

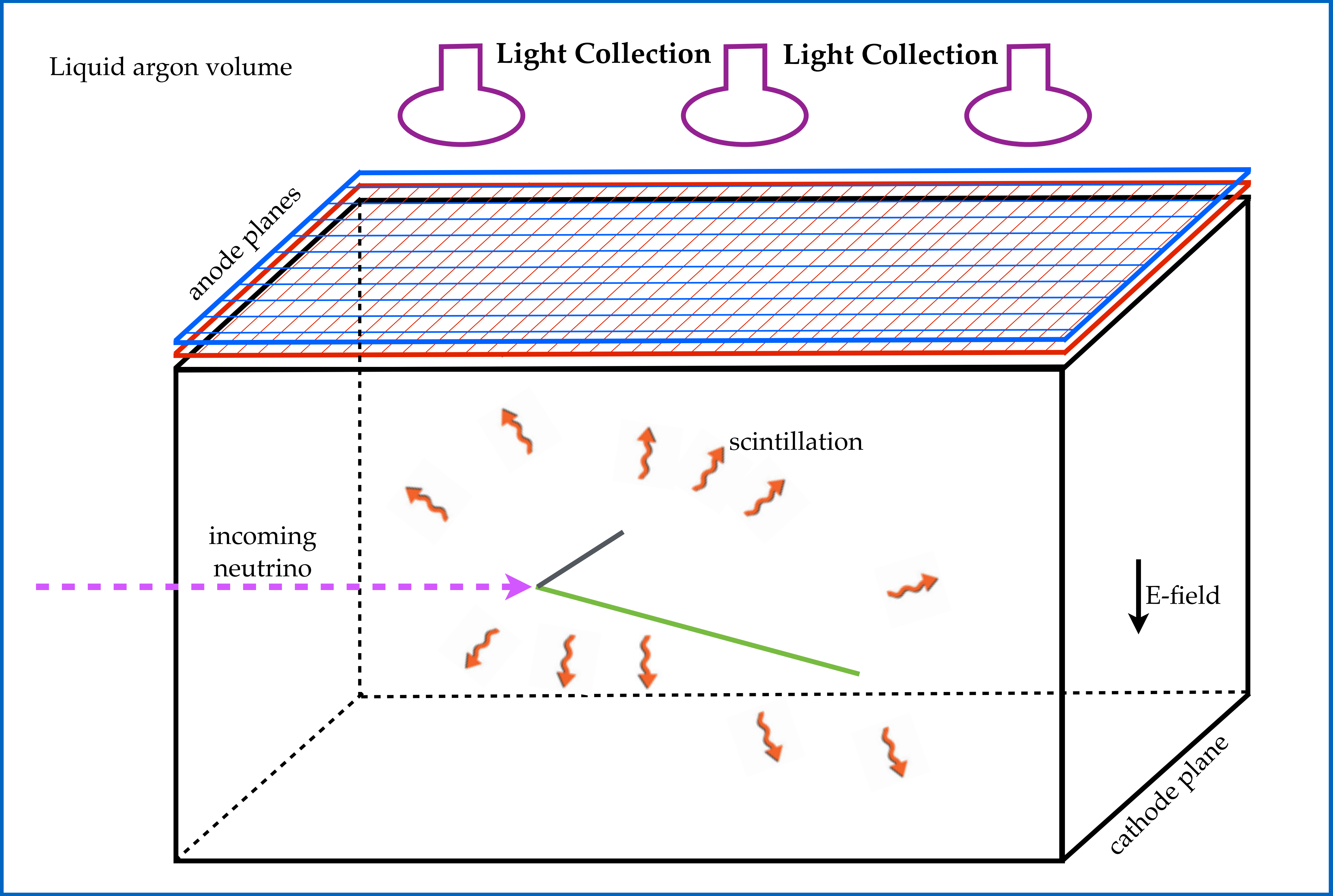


LArTPC Principle



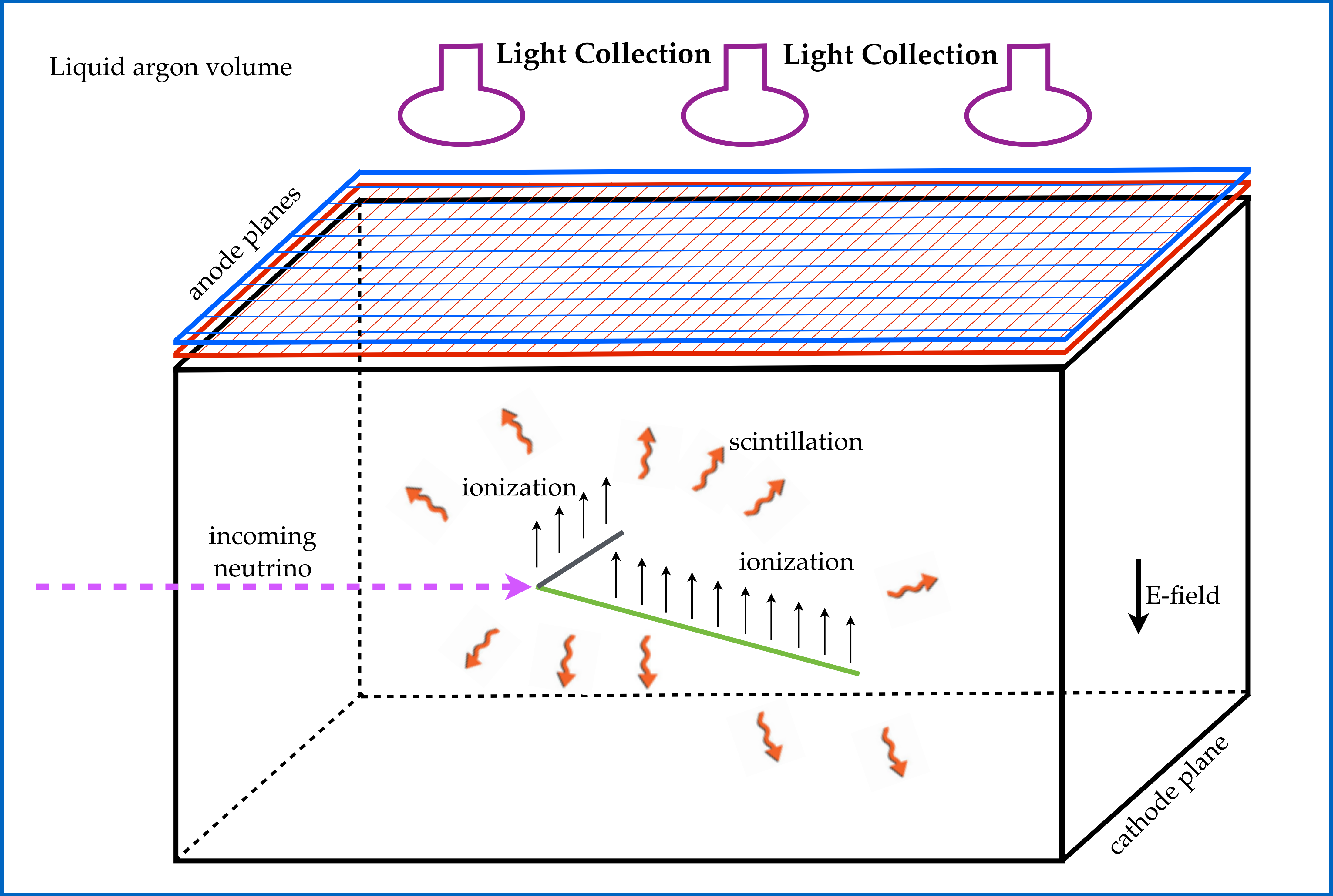
Refs:
1.) *Liquid-argon ionization chambers as total-absorption detectors*, W. Willis and V. Radeka, Nuclear Instruments and Methods 120 (1974), no. 2, 221-236.
2.) *The Liquid-argon time projection chamber: a new concept for Neutrino Detector*, C. Rubbia, CERN-EP/77-08 (1977)

LArTPC Principle



Refs:
1.) *Liquid-argon ionization chambers as total-absorption detectors*, W. Willis and V. Radeka, Nuclear Instruments and Methods 120 (1974), no. 2, 221-236.
2.) *The Liquid-argon time projection chamber: a new concept for Neutrino Detector*, C. Rubbia, CERN-EP/77-08 (1977)

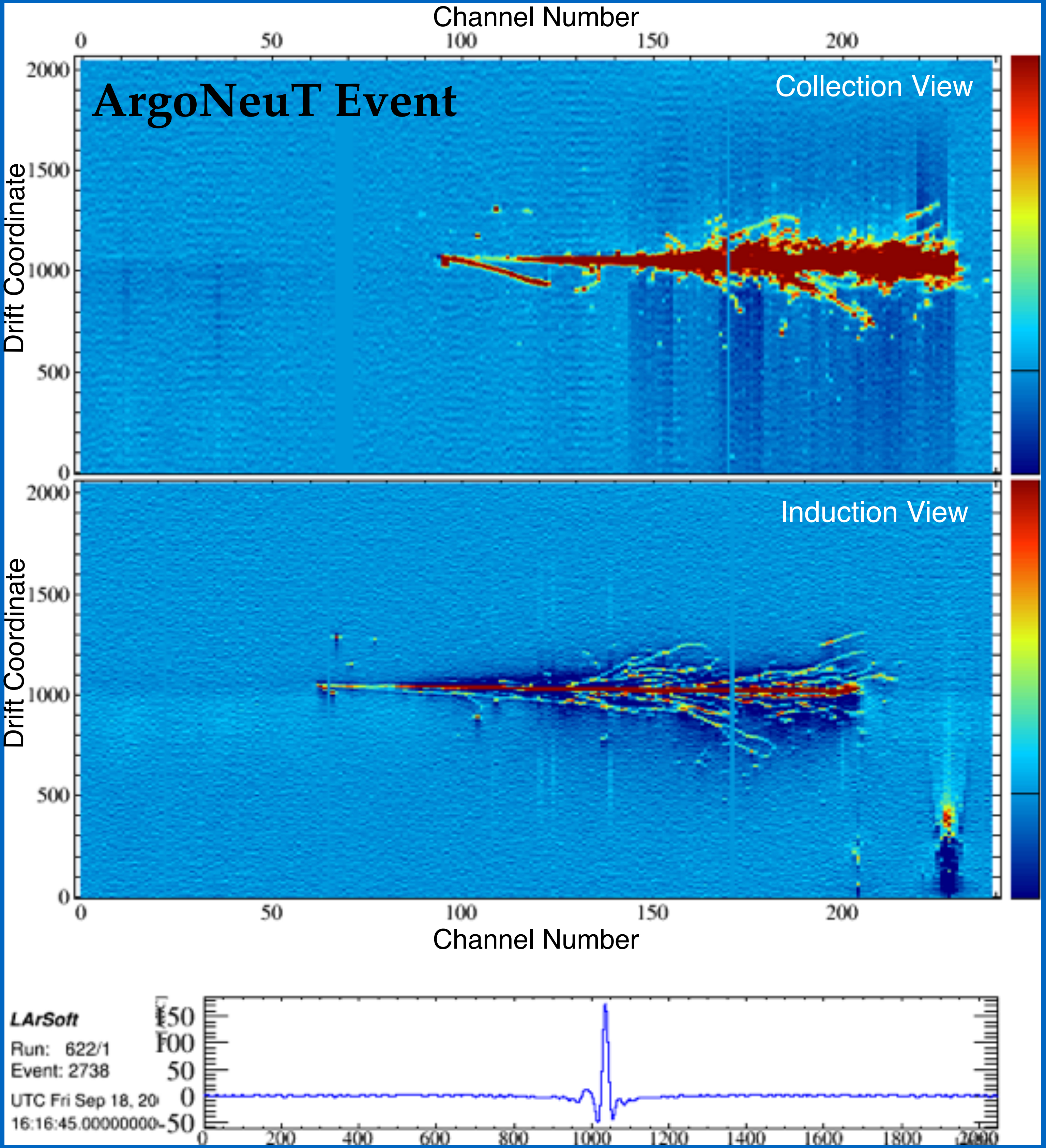
LArTPC Principle



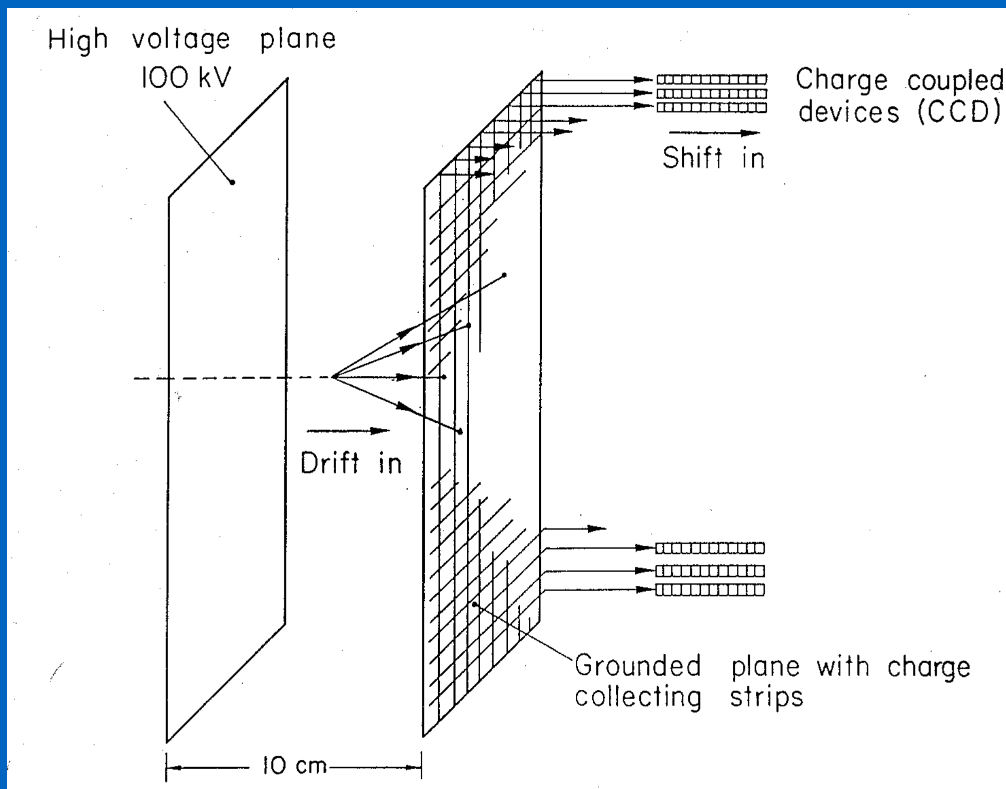
Refs:
1.) *Liquid-argon ionization chambers as total-absorption detectors*, W. Willis and V. Radeka, Nuclear Instruments and Methods 120 (1974), no. 2, 221-236.
2.) *The Liquid-argon time projection chamber: a new concept for Neutrino Detector*, C. Rubbia, CERN-EP/77-08 (1977)

LArTPC Principle

- Imaging detector… our eyes can readily see features that are quite challenging to train a software algorithm to do.
- More on extracting physics from these images in the next lecture.



LArTPC History



EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

EP Internal Report 77-8
16 May 1977

THE LIQUID-ARGON TIME PROJECTION CHAMBER:

A NEW CONCEPT FOR NEUTRINO DETECTORS

C. Rubbia

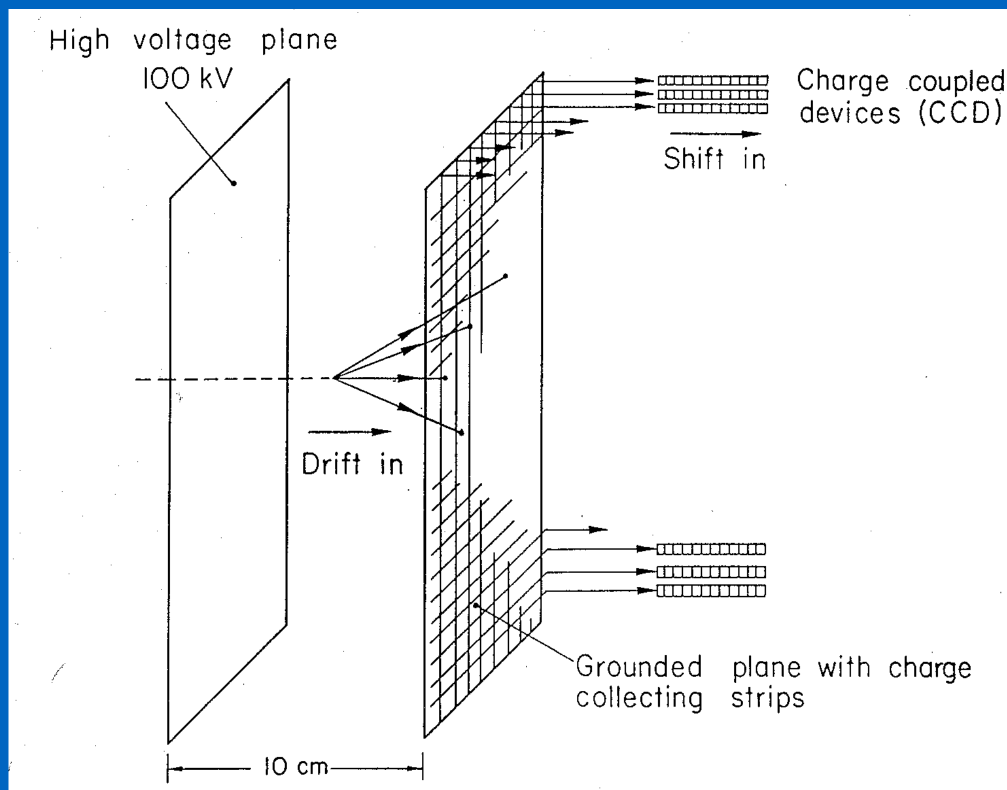
ABSTRACT

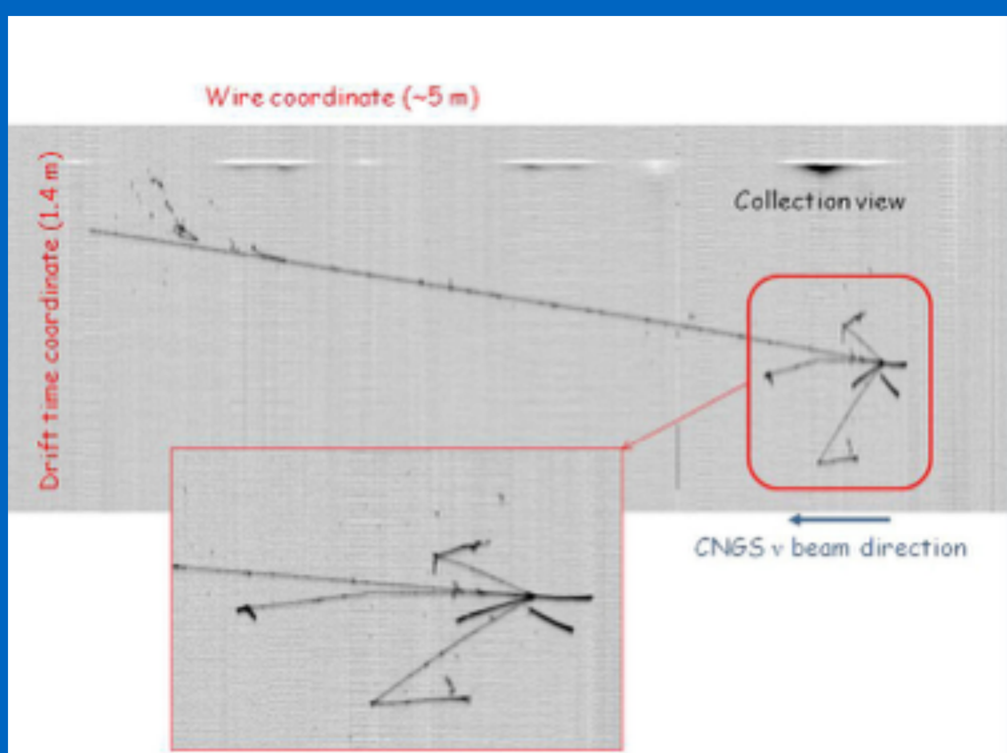
It appears possible to realize a Liquid-Argon Time Projection Chamber (LAPC) which gives an ultimate volume sensitivity of 1 mm^3 and a drift length as long as 30 cm. Purity of the argon is the main technological problem. Preliminary investigations seem to indicate that this would be feasible with simple techniques. In this case a multi-hundred-ton neutrino detector with good vertex detection capabilities could be realized.

G E N E V A

1977

LArTPC History





Neutrino interaction in ICARUS
~30 years after Rubbia's paper.

EUROPEAN ORGANIZATION FOR NUCLEAR RESEARCH

EP Internal Report 77-8
16 May 1977

THE LIQUID-ARGON TIME PROJECTION CHAMBER:

A NEW CONCEPT FOR NEUTRINO DETECTORS

C. Rubbia

ABSTRACT

It appears possible to realize a Liquid-Argon Time Projection Chamber (LAPC) which gives an ultimate volume sensitivity of 1 mm^3 and a drift length as long as 30 cm. Purity of the argon is the main technological problem. Preliminary investigations seem to indicate that this would be feasible with simple techniques. In this case a multi-hundred-ton neutrino detector with good vertex detection capabilities could be realized.

G E N E V A

1977

LArTPC History

NUCLEAR INSTRUMENTS AND METHODS 150 (1978) 585-588 ; © NORTH-HOLLAND PUBLISHING CO.

OBSERVATION OF IONIZATION ELECTRONS DRIFTING LARGE DISTANCES IN LIQUID ARGON*

HERBERT H. CHEN and JOHN F. LATHROP†

Department of Physics, University of California, Irvine, California 92717, U.S.A.

Received 26 September 1977 and in revised form 1 November 1977

Measurements using a ^{137}Cs internal conversion source demonstrate that ionization electrons will drift at least 35 cm in liquid argon in electric fields of a few kV/cm.

Liquid argon ionization detector technology is advancing at a rapid pace following the recent efforts of Willis[1]) and others[2,3]). The initial design of such detectors made use of inert inserts within the liquid argon, both as electrodes and as converters for electromagnetic and/or hadronic cascades. It was recognized early that these inserts degrade the energy resolution of such calorimeters. The first liquid argon shower counters were made with many thin converter sheets in order to minimize this effect. Eventually, the suggestion was made that inert converters should not be used at low energies to achieve optimal energy resolution, and wire planes were introduced as electrodes[4]). Such detectors have totally sensitive volumes and, *if sufficient spacial resolution could be achieved, these detectors would have unique capabilities and could be favorably compared with bubble chambers.*

This was recognized, and such a detector was proposed to Fermilab for a four fermion leptonic scattering experiment[5]). However, it was clear that spacial resolution of a few millimeters with closely spaced wire planes led to technical as well as financial difficulties. Thus, the idea of drifting ionization electrons over large distances in liquid argon and collecting the induced charge as a function of time[6]) was introduced and actively discussed.

The capability to drift electrons over large distances in liquid argon is basic to the feasibility of this idea. Information from detectors which collected ionization electrons over distances of a few millimeters, was encouraging[7]). It is well known that electronegative impurities, especially oxygen, must be at very low levels. Typically, oxygen levels of a few parts per million in argon[8]) can be tolerated in the shower counters. However, as yet undetermined impurities can seriously affect the performance of such detectors[9]). Thus, there is significant uncertainty as to whether ionization electrons will drift over distances of tens of centimeters even if oxygen is reduced to the appropriate levels, since such distances are at least an order of magnitude greater than had been attempted.

A detector, schematically shown in fig. 1, was designed to focus on the question of free ionization electron drift distance, λ_D [8]), in liquid argon.

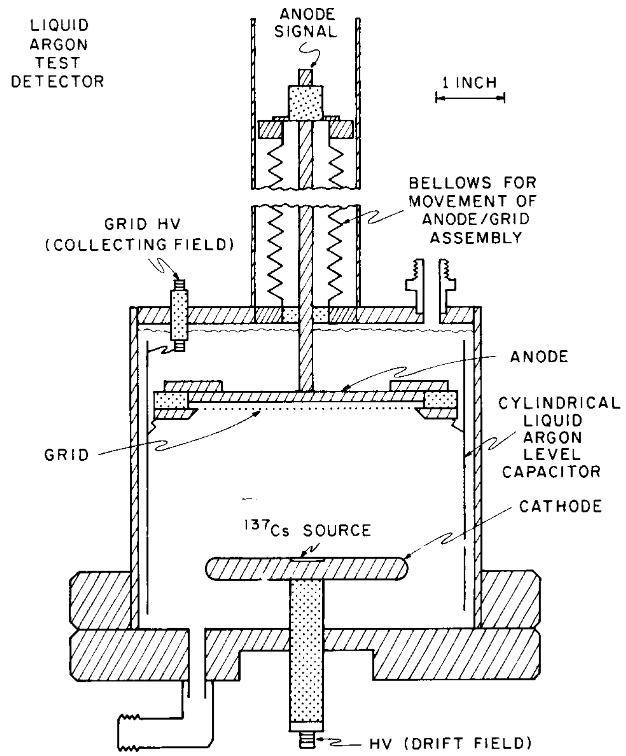


Fig. 1. Schematic of detector for measuring ionization electron drift distance in liquid argon.

* Research supported in part by the United States Energy Research and Development Administration.

† Now at Beckman Instruments, Inc., Scientific Instruments Division, Irvine, California, 92713, U.S.A.

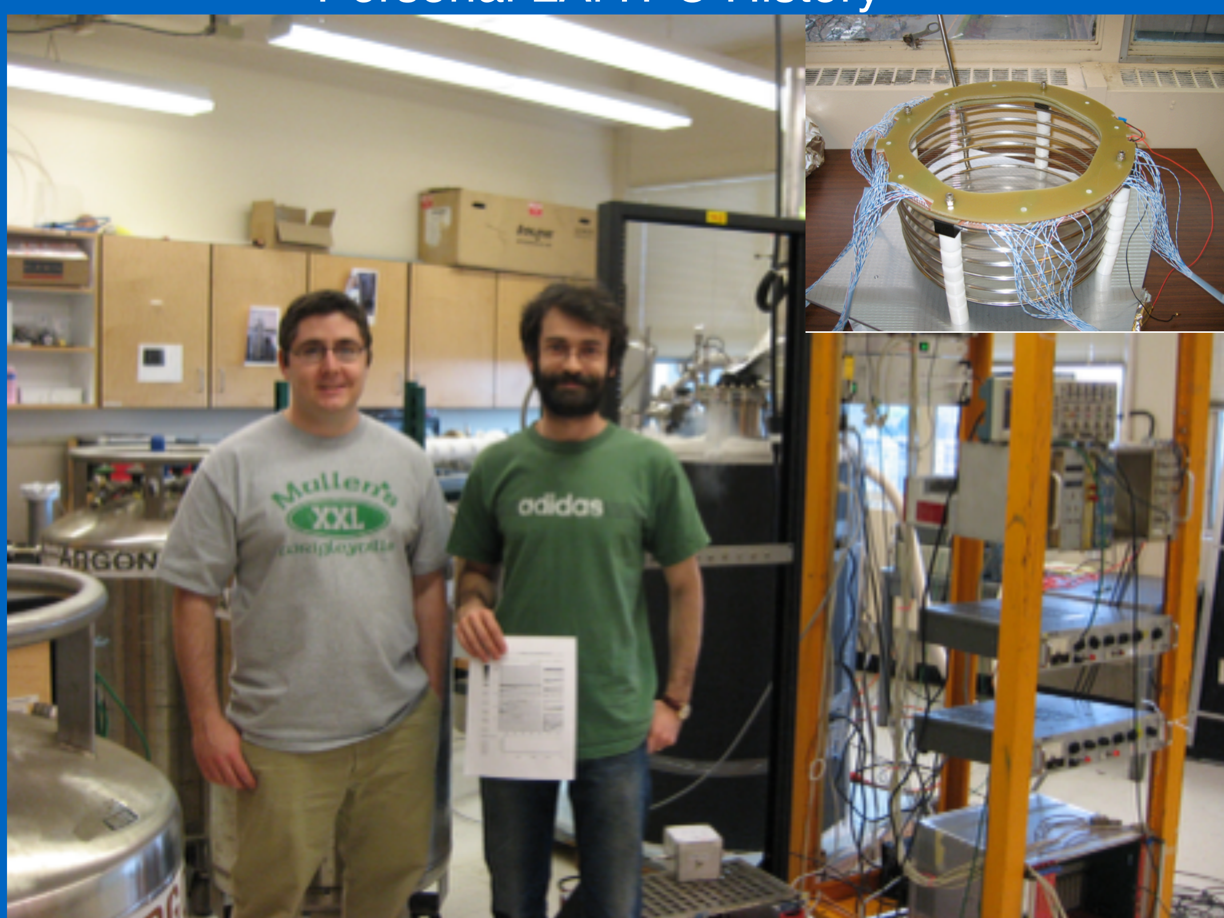
wire planes were introduced as electrodes[4]). Such detectors have totally sensitive volumes and, *if sufficient spacial resolution could be achieved, these detectors would have unique capabilities and could be favorably compared with bubble chambers.*

This was recognized, and such a detector was proposed to Fermilab for a four fermion leptonic scattering experiment[5]). However, it was clear that spacial resolution of a few millimeters with closely spaced wire planes led to technical as well as financial difficulties. Thus, the idea of drifting ionization electrons over large distances in liquid argon and collecting the induced charge as a function of time[6]) was introduced and actively discussed.

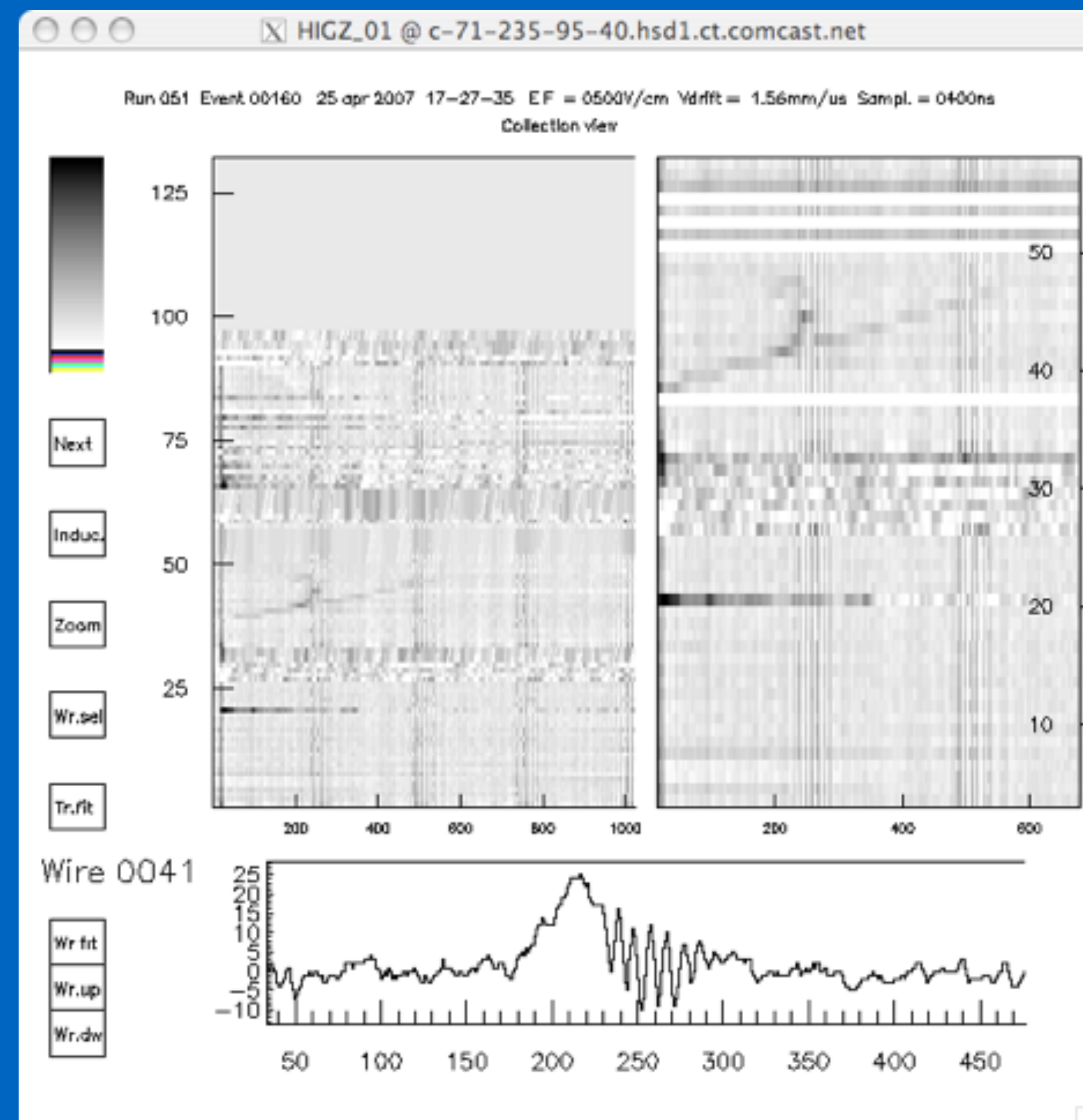
LArTPC Development

- Since those pioneering ideas, activities in Europe resulted in the ~600 ton ICARUS detector which operated in the CNGS beam from CERN.
- In last ~10 years there has been renewed and significant activity in the U.S. to develop LArTPCs for use in long-baseline oscillation experiments.

Personal LArTPC History



MS and Alessandro Curioni @ Yale in Fleming lab, April 2007



LAr Worldwide

Completed/Ongoing/Potential/Proposed/Suggested LAr Projects, separated by location of the detectors.

US

Materials Test Stand
ArgoNeuT
Liquid Argon Purity Demonstrator
MicroBooNE
LBNE
1 kTon LArTPC
Test-Beam @ FNAL (LArIAT)
Test-Beam @ Los Alamos (CAPTAIN)
GLADE
RADAR
LAr1-ND

Europe

3-ton prototype
50-liter @ CERN
10m^3
ICARUS
LArTPC in B-Field
LANDD @ CERN
ArgonTube @ Bern
UV Laser
GLACIER/LAGUNA
Double-LAr @ CERN-PS
LAr LEM-TPC
CERN 6m^3 (WA105)

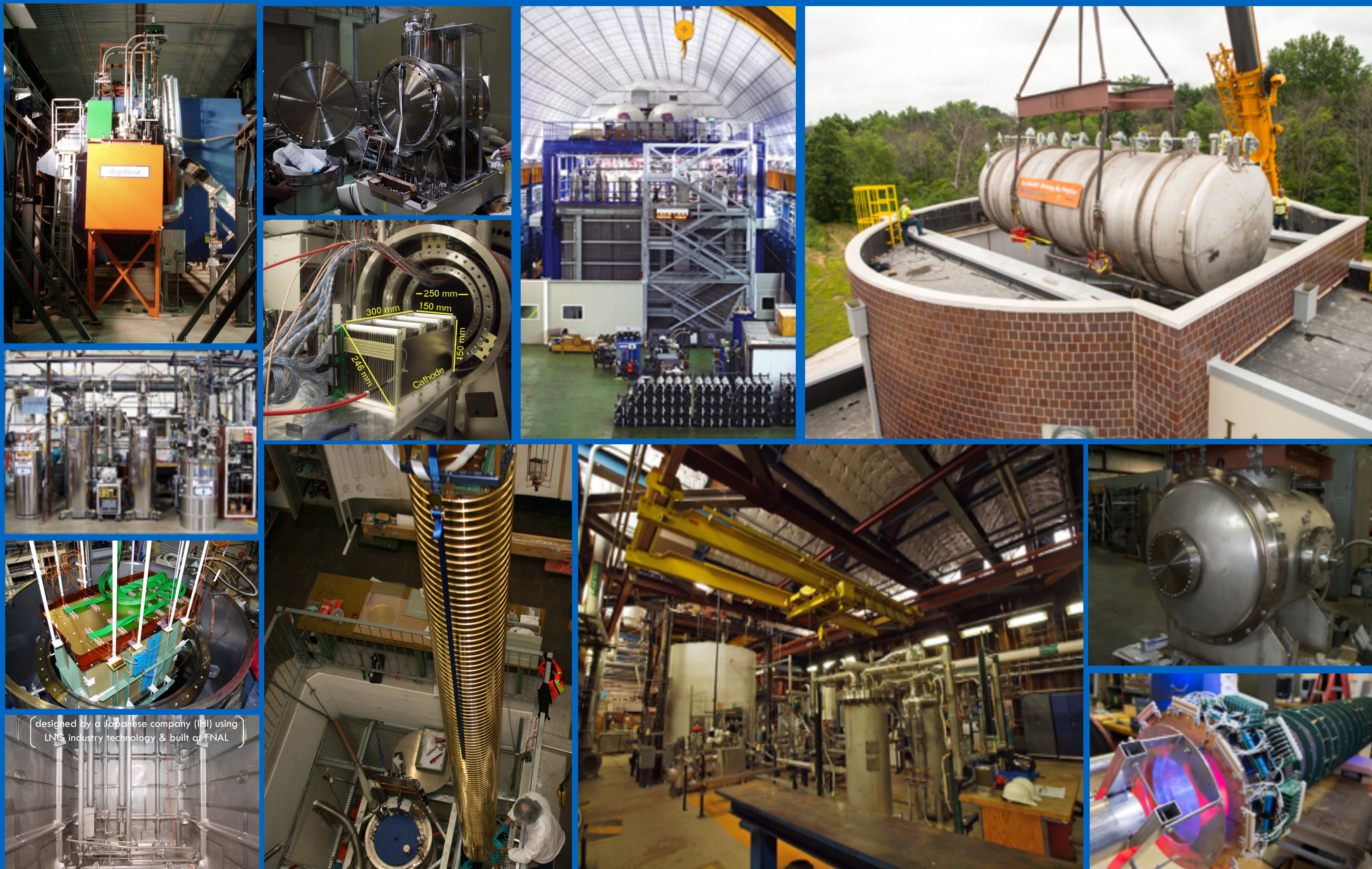
Japan

Test-Beam (T32) at J-PARC
100 kTon @ Okinoshima island

This isn't even a complete list!

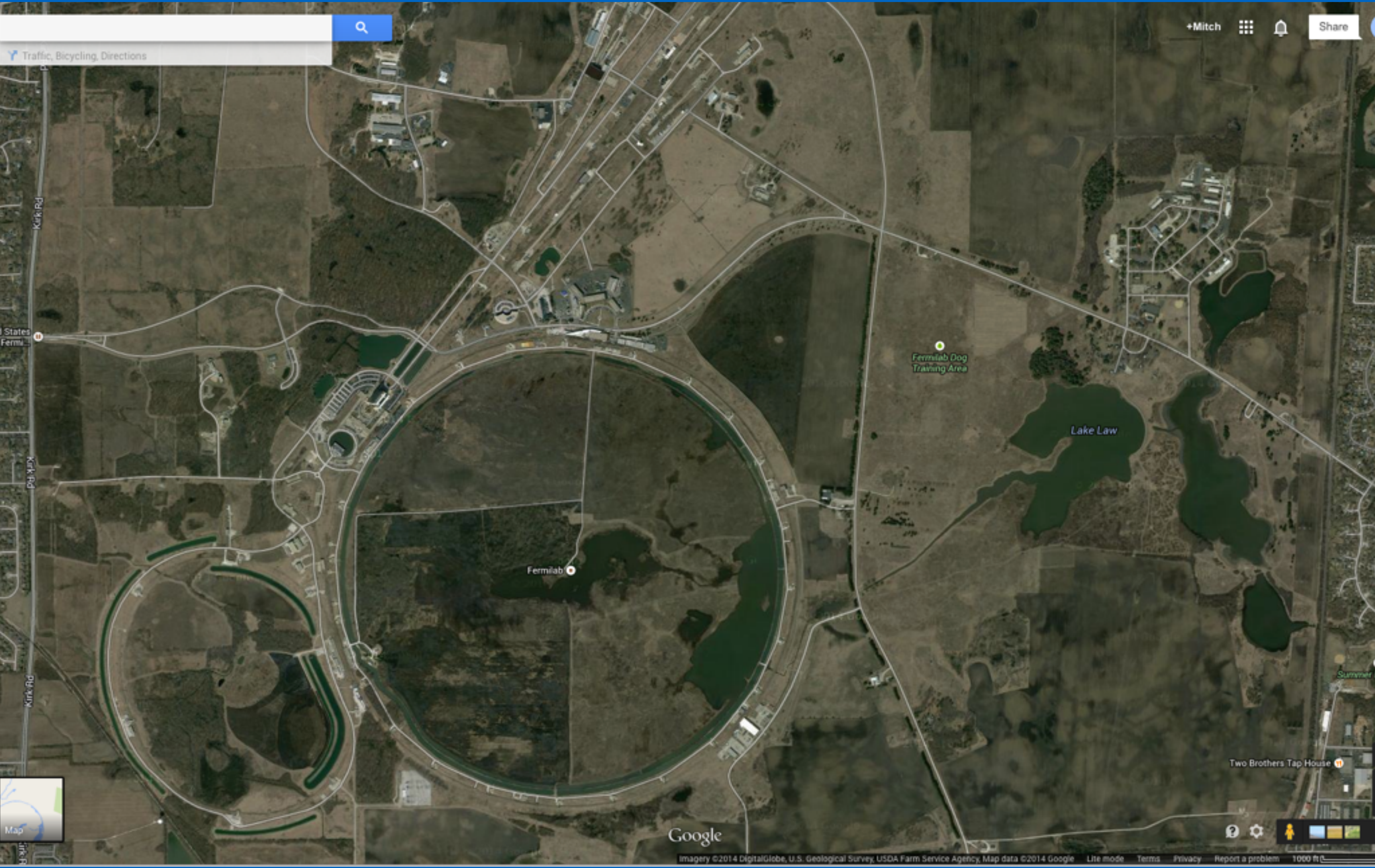
*LAr also pursued for Dark Matter: DarkSide, ArDM, DEAP/CLEAN, WARP, Depleted Argon, ...

LAr Worldwide



Far too much activity to cover each of these, so I'll focus on the general aspects of LArTPCs

FermiLAb



Traffic, Bicycling, Directions
+Mitch
Share
Kirk Rd
Fermilab Dog Training Area
Lake Law
Fermilab
Two Brothers Tap House
Google
Imagery ©2014 DigitalGlobe, U.S. Geological Survey, USDA Farm Service Agency, Map data ©2014 Google
Lite mode
Terms
Privacy
Report a problem
1000 ft

FermiLArb

1. Lab 6 - LArIAT/ArgoNeuT construction
2. D0 - MicroBooNE construction/D0 Calorimeter
3. Future ICARUS home?
4. NuMI Tunnel - Former ArgoNeuT Home, Future CAPTAIN home?
5. LArTF - MicroBooNE Home
6. SciBooNE Enclosure - Future LAr1-ND Home
7. M-Center - LArIAT Home
8. PAB - Hub of LArTPC R&D
9. PC4 - LAPD/LBNE 35-ton Home
10. Two Brothers - Try the fish tacos.

Question #2

Which item is not featured in outdoor "art" at Fermilab?

Question #2

Which item is not featured in outdoor “art” at Fermilab?

A) 15-foot diameter bubble chamber

B) Cyclotron magnet

C) Mobius strip

D) The symbol for “pi”.

E) A giant metal bean

Question #2

Which item is not featured in outdoor “art” at Fermilab?

A) 15-foot diameter bubble chamber

B) Cyclotron magnet

C) Mobius strip

D) The symbol for “pi”.

E) A giant metal bean

Noble Elements

Refs:
1.) image from periodtable.com

Noble Elements

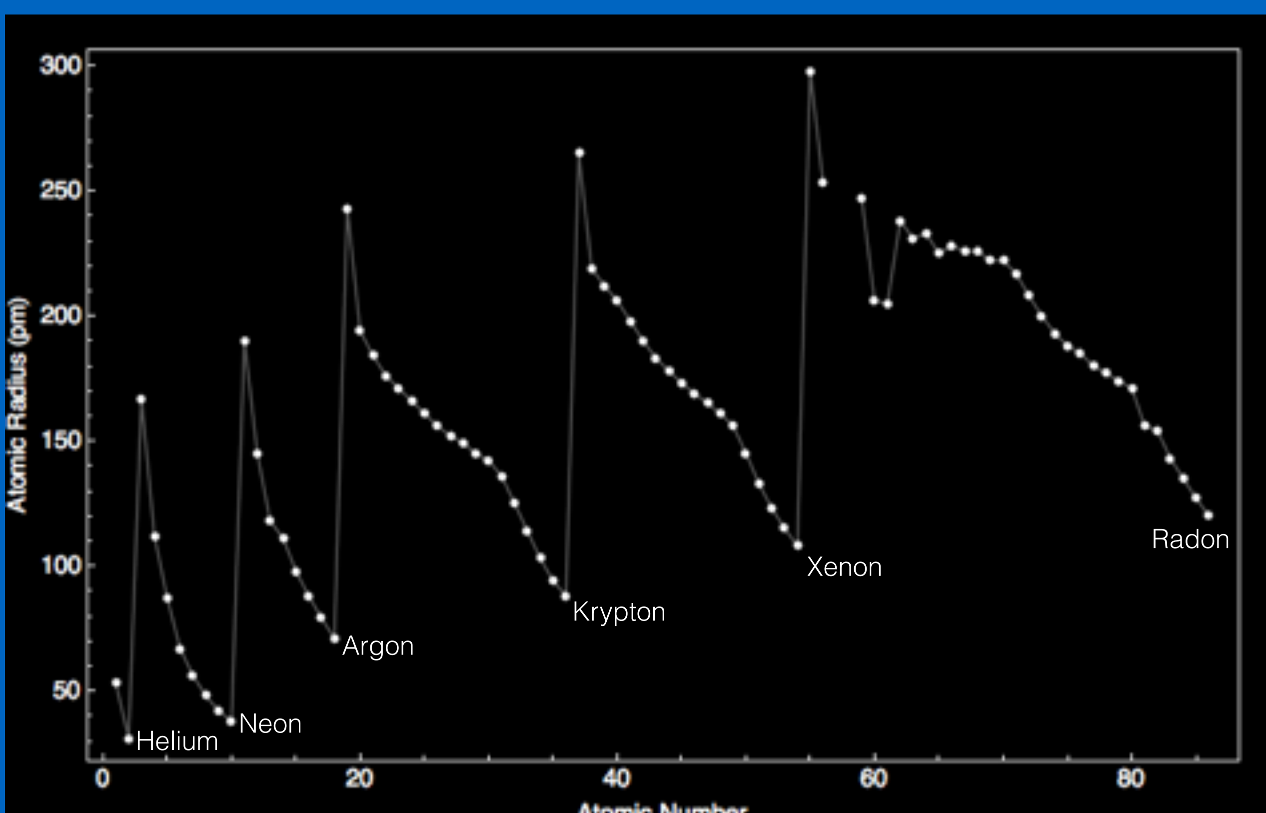
- The Noble elements are characterized by their inertness, which is a reflection of their completely filled valence shells. 

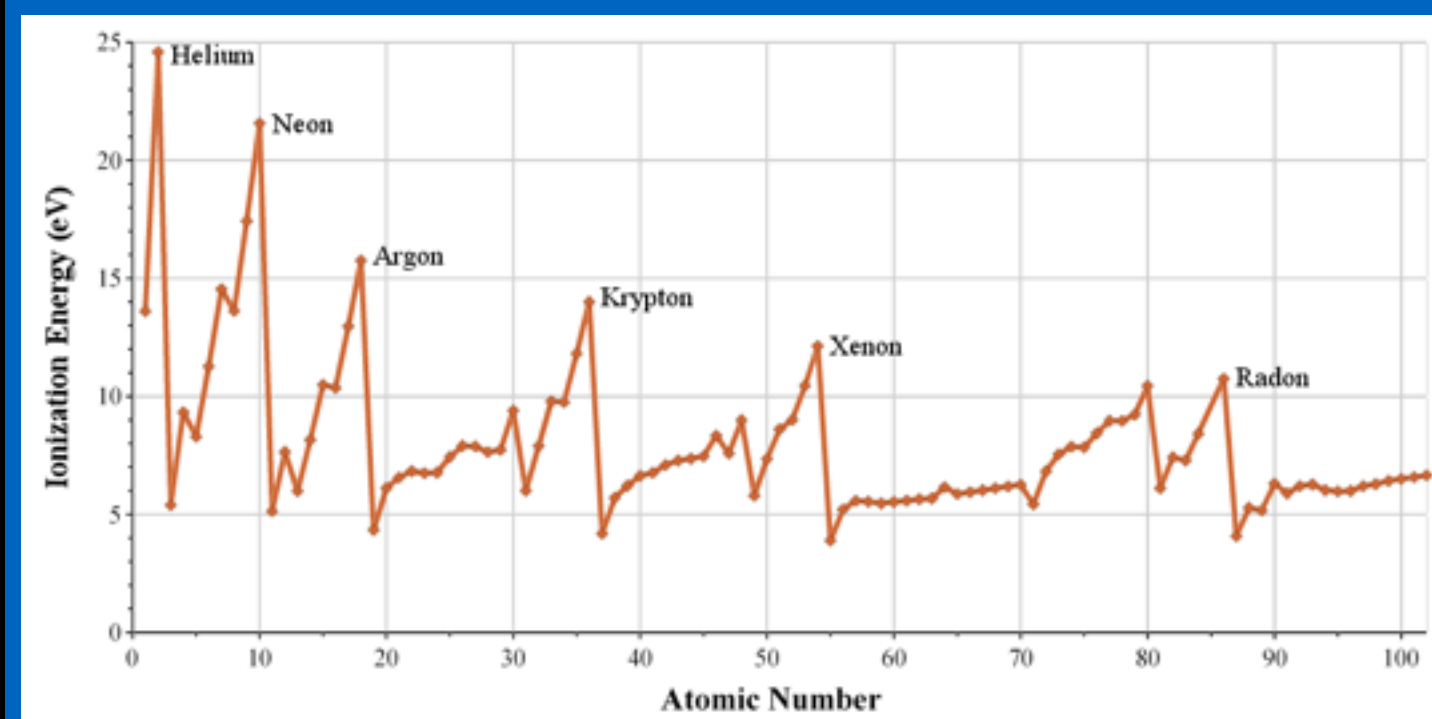
Refs:
1.) image from periodtable.com

Noble Elements

- The Noble elements are characterized by their inertness, which is a reflection of their completely filled valence shells. 

- These are compact atoms that hold on to their electrons tightly.





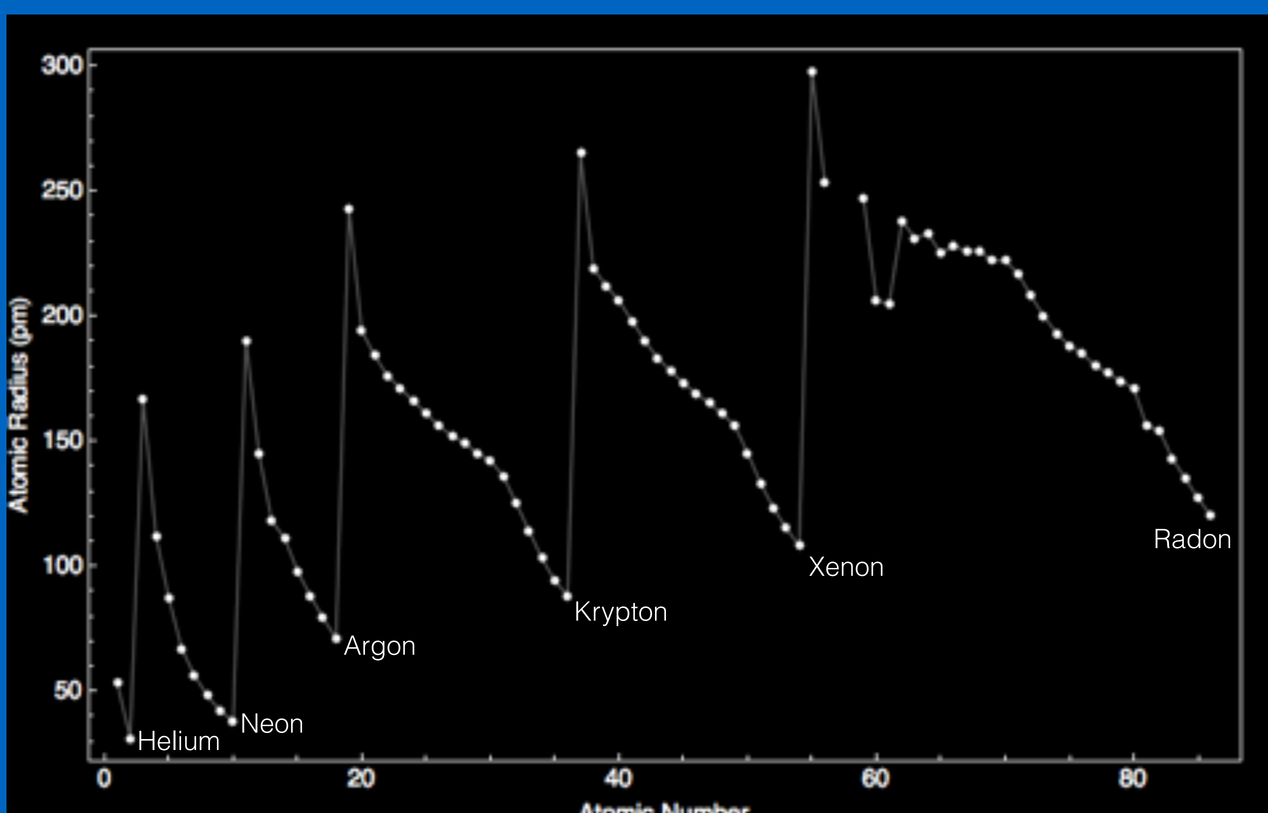
Refs:
1.) image from periodtable.com

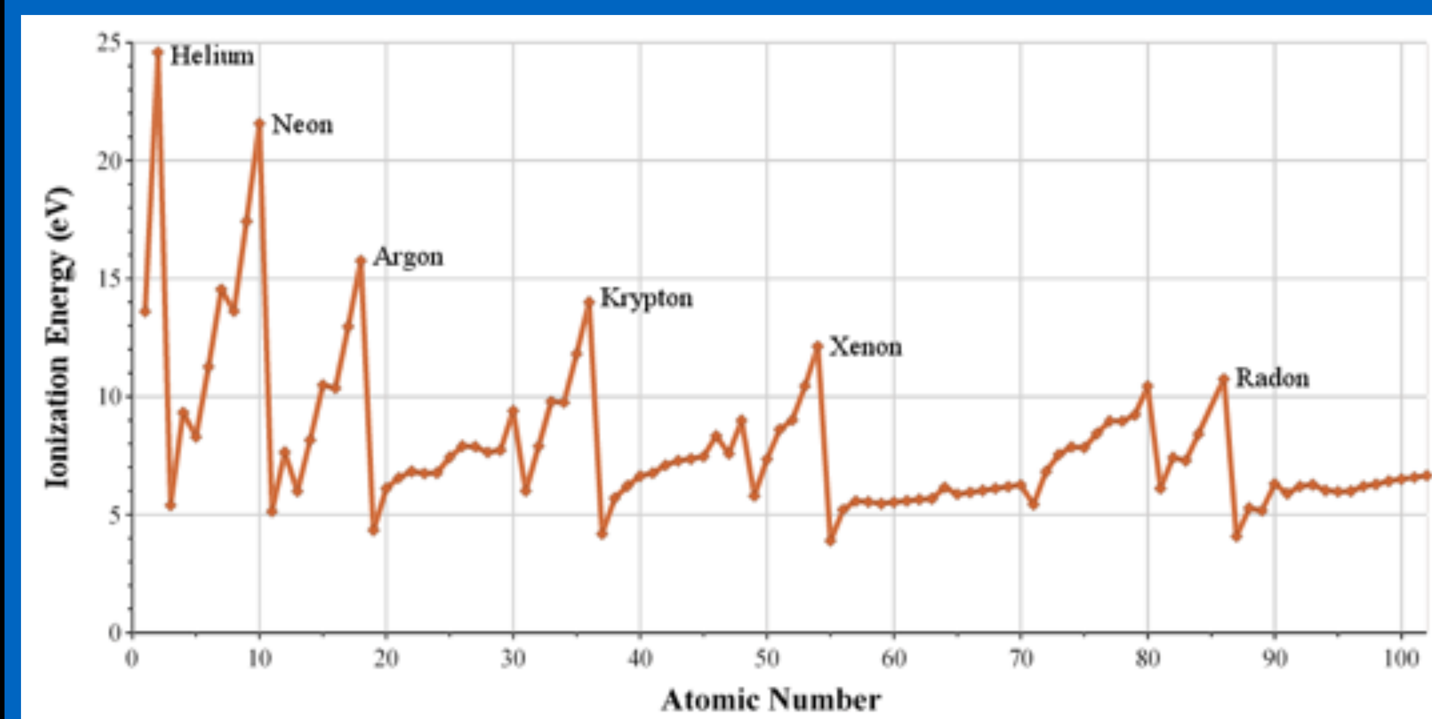
Noble Elements

- The Noble elements are characterized by their inertness, which is a reflection of their completely filled valence shells. 

- These are compact atoms that hold on to their electrons tightly.

- Their almost nonexistent electron affinity indicates that free electrons in a highly purified noble liquid environment will be capable of traveling long distances under the influence of an electric-field.





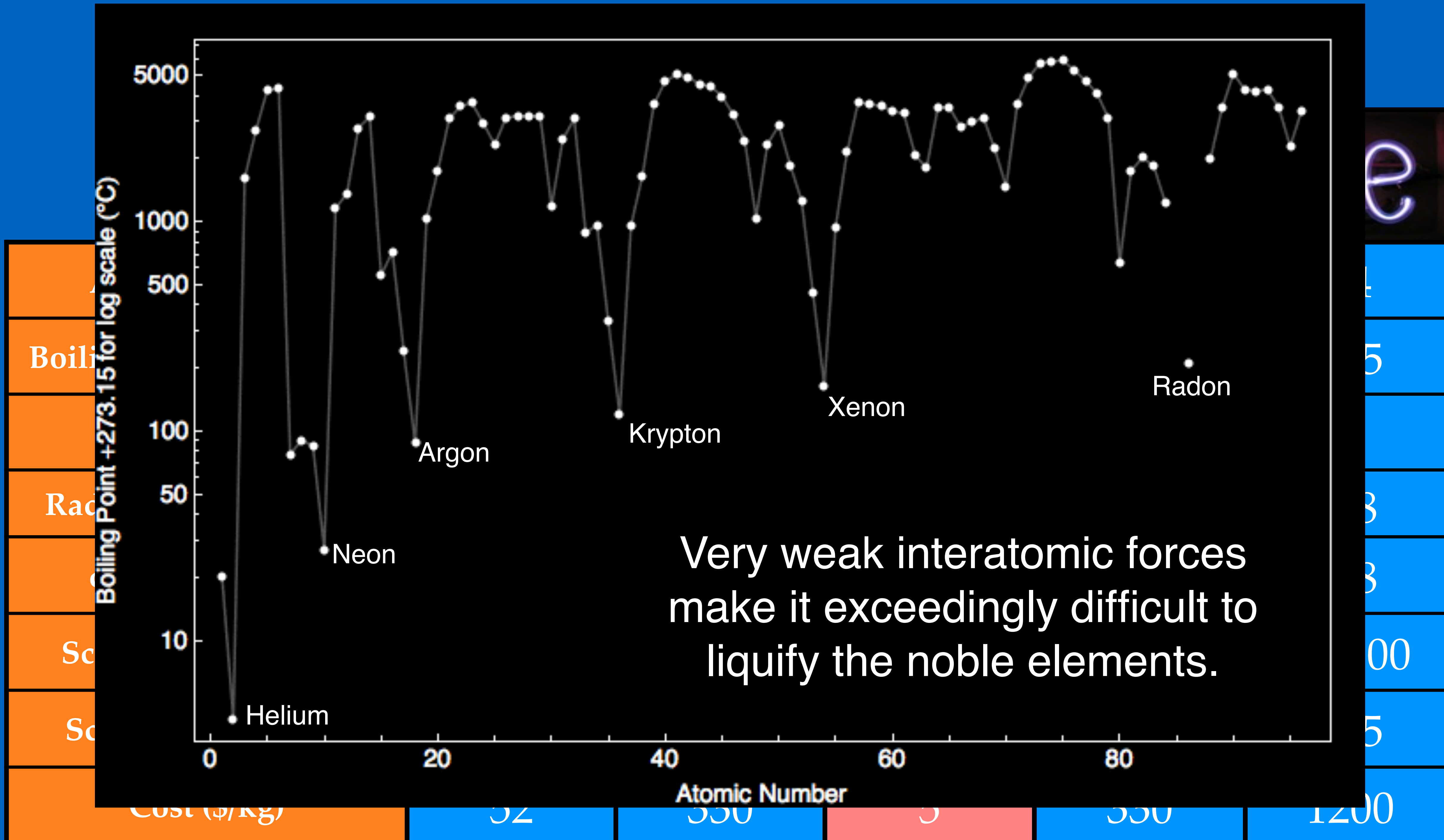
Refs:
1.) image from periodtable.com

Noble Liquids

	He	Ne	Ar	Kr	Xe
Atomic Number	2	10	18	36	54
Boiling Point [K] @ 1atm	4.2	27.1	87.3	120	165
Density [g/cm	0.125	1.2	1.4	2.4	3
Radiation Length [cm]	755.2	24	14	4.9	2.8
dE/dx [MeV/cm]	0.24	1.4	2.1	3	3.8
Scintillation [γ/MeV]	19,000	30,000	40,000	25,000	42,000
Scintillation λ [nm]	80	78	128	150	175
Cost ($/kg)	52	330	5	330	1200

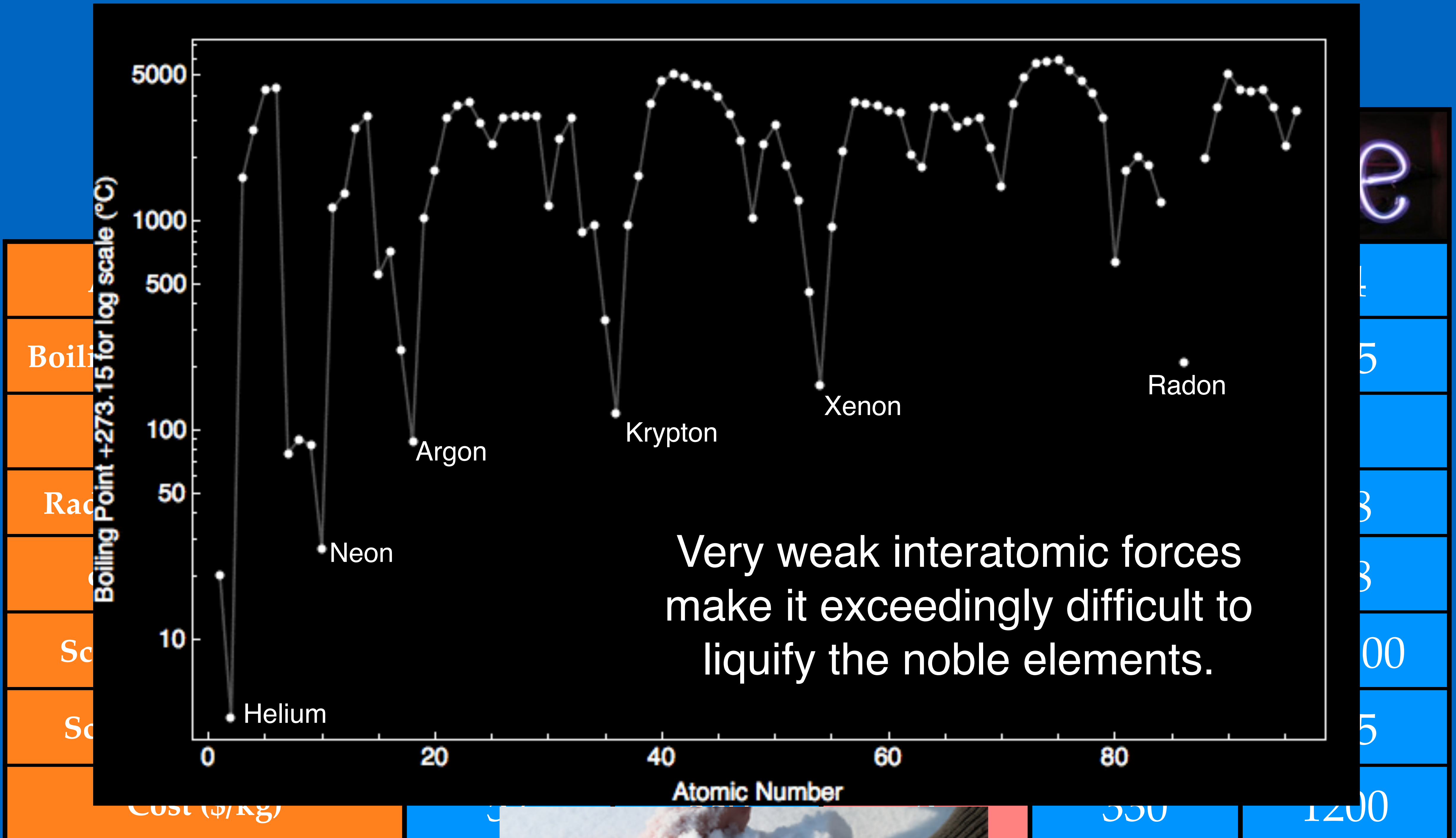
Refs:
1.) images from periodtable.com

Noble Liquids



Refs:
1.) images from periodtable.com

Noble Liquids



Kind of like making a snowball out of very "powdery" snow.

Refs:
1.) images from periodtable.com

A Bit More About Argon

Don't "get" argon? This sixth-grader does!

Middle schooler, Abby Hardin, tests four different Noble gases against each other for their conductive properties.

Posted *February 22 2010* *in* *Holler Blog*

Abby Knows Argon!

Argon

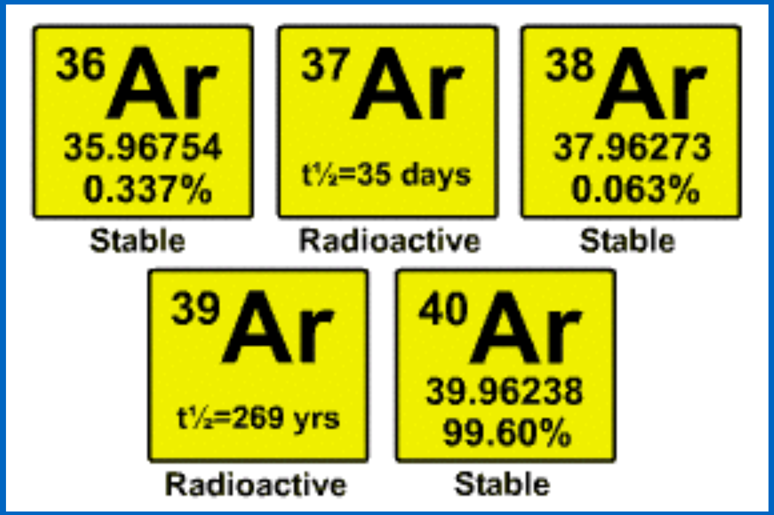
Argon

- Most abundant isotope of argon in universe? Ar36

"Crab" Nebula (supernova remnant).
^{36}Ar-Hydrogen molecules observed.

Argon

- Most abundant isotope of argon in universe? Ar36
- Most abundant isotope of argon on Earth? Ar40

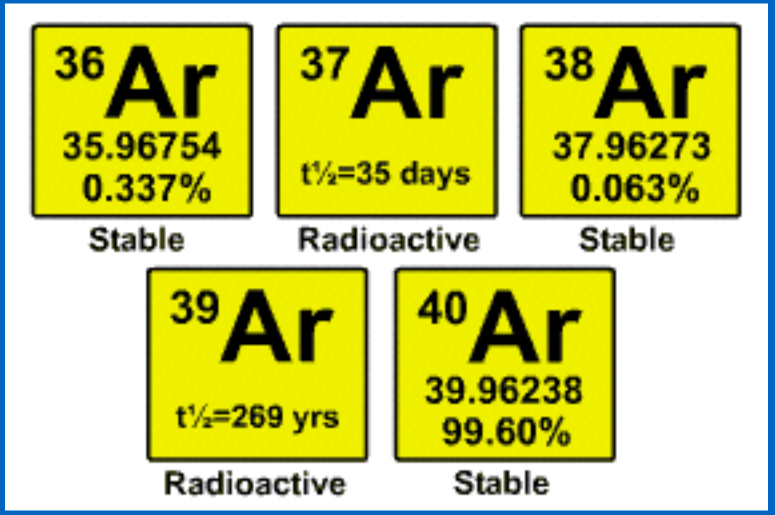


"Crab" Nebula (supernova remnant). ^{36}Ar-Hydrogen molecules observed.

Argon

- Most abundant isotope of argon in universe? Ar36
- Most abundant isotope of argon on Earth? Ar40
- Ar40 is primarily produced by decay (electron capture) of potassium in Earth's crust. This K→Ar mode is the basis for K-Ar radiometric dating.

$$ {}^{40}_{19}K + {}^{0}_{-1}e^{-} \rightarrow {}^{40}_{18}Ar + \nu_e $$



"Crab" Nebula (supernova remnant). ^{36}Ar-Hydrogen molecules observed.

Question #3

About how many liters of LAr could we extract from the air in this auditorium? (Order of magnitude estimate.)

Question #3

About how many liters of LAr could we extract from the air in this auditorium? (Order of magnitude estimate.)

Reminders: Argon is 1% of the atmosphere. LAr is ~850 denser than room temperature GAr. $1m^3$=1000 liters.

Question #3

About how many liters of LAr could we extract from the air in this auditorium? (Order of magnitude estimate.)

Reminders: Argon is 1% of the atmosphere. LAr is ~850 denser than room temperature GAr. $1 m^3 = 1000$ liters.

A) 0.001 Liters

B) 100 Liters

C) 1,000,000 Liters

Question #3

About how many liters of LAr could we extract from the air in this auditorium? (Order of magnitude estimate.)

Reminders: Argon is 1% of the atmosphere. LAr is ~850 denser than room temperature GAr. $1m^3$=1000 liters.

A) 0.001 Liters

B) 100 Liters

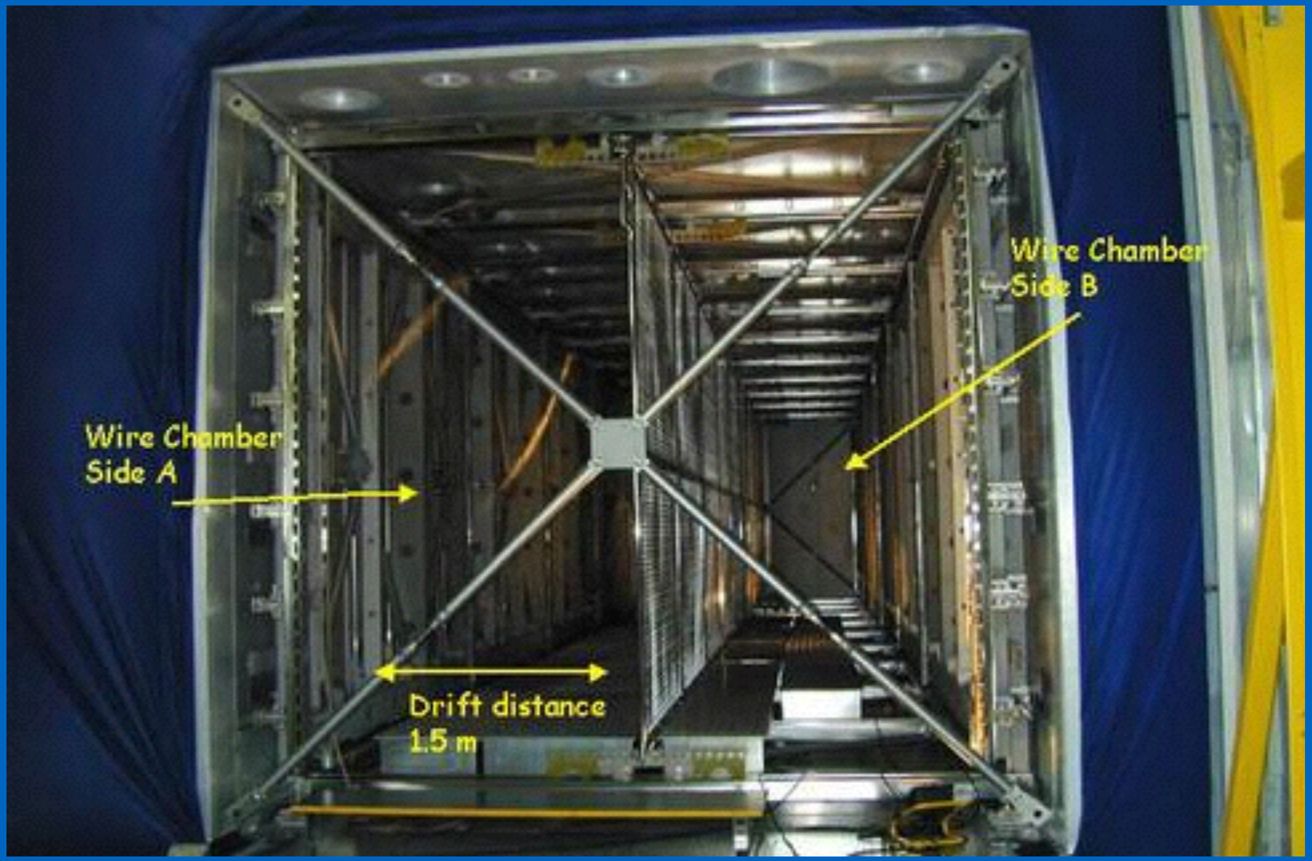
C) 1,000,000 Liters

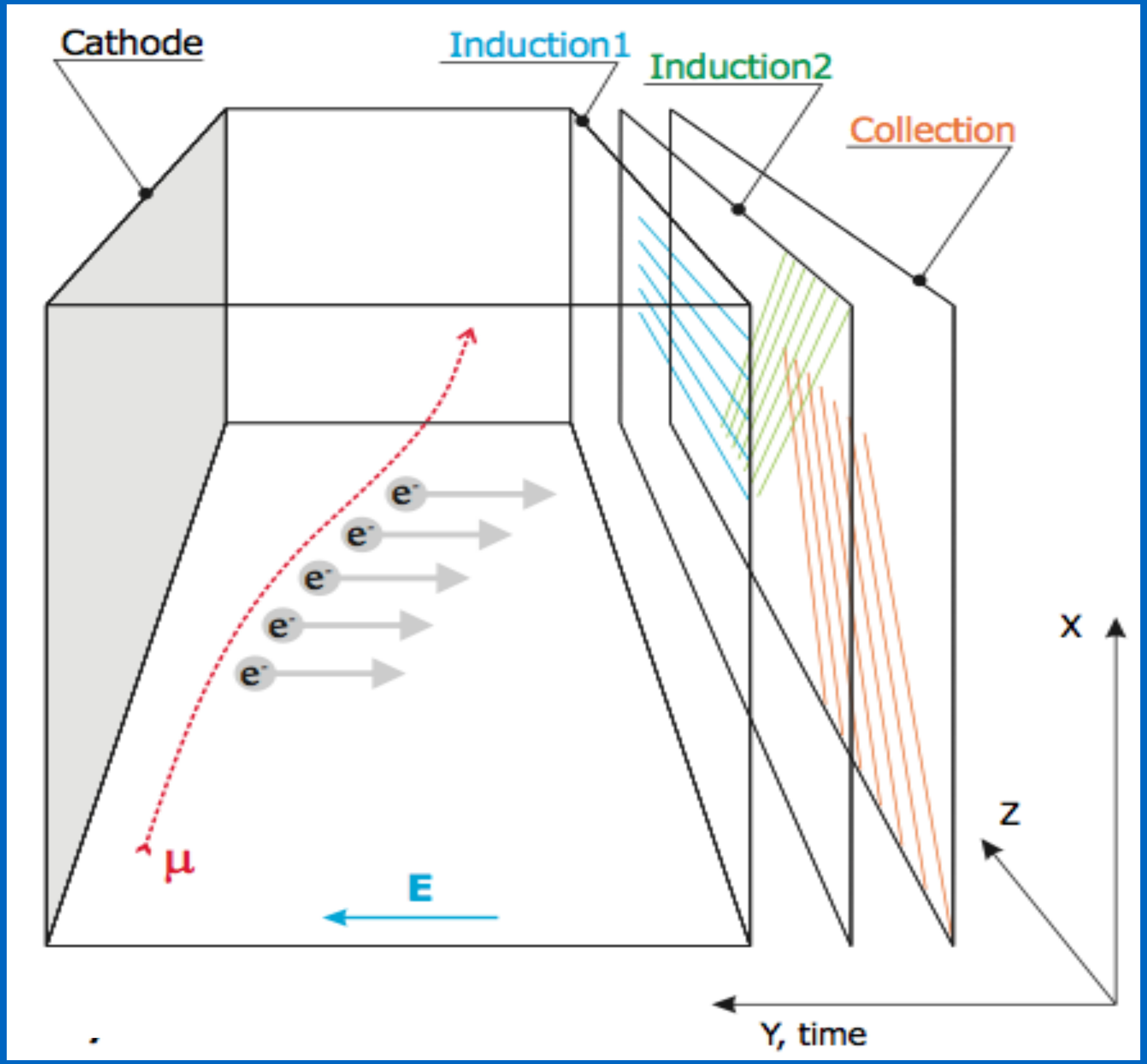
"Argon must not be deemed rare. A large hall may easily contain a greater weight of it than a man can carry."
- Lord Rayleigh (co-discover of argon, Nobel Lecture,1904)

Room Volume * 1% / 850

LArTPC Principle Revisited

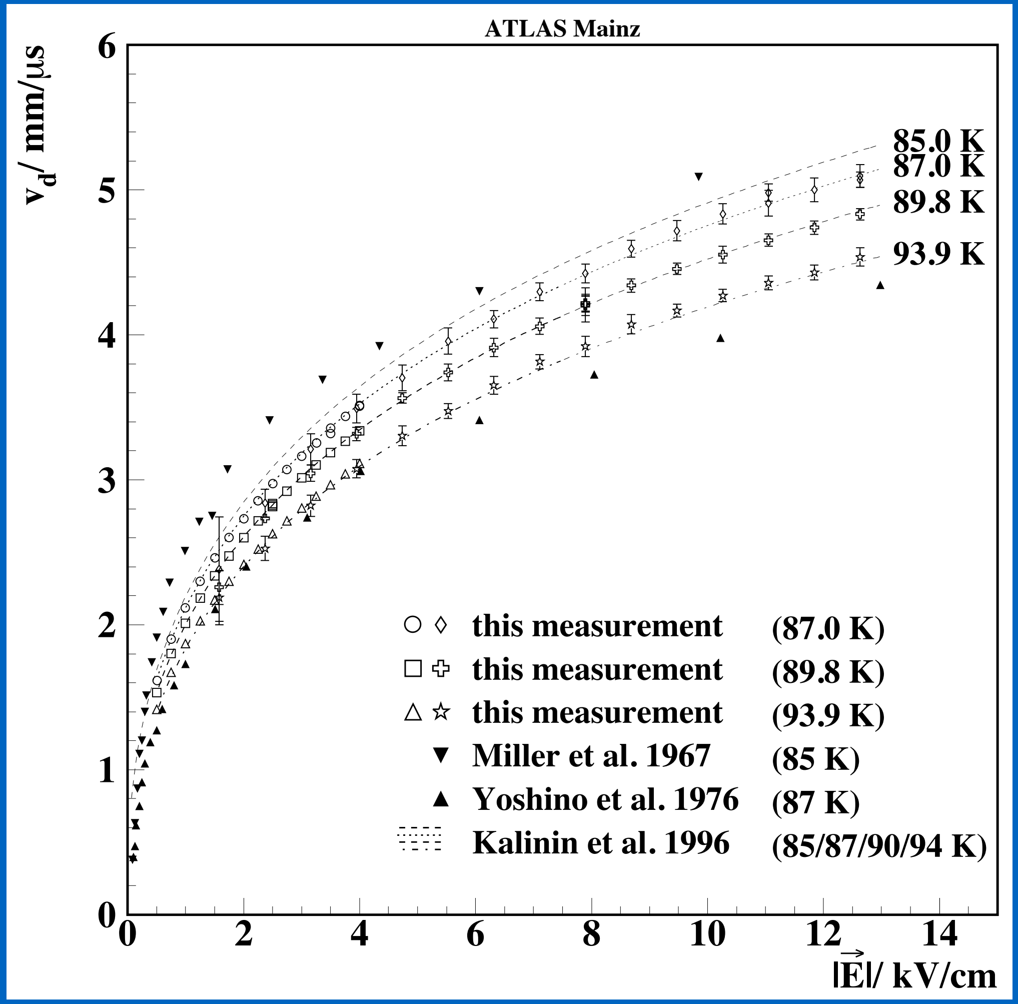
- One of the attractive aspects of this technology is we don't need to instrument the entire volume. Just drift liberated ionization over to anode plane.
- This allows us to scale the detector to very large sizes without the cost of electronics becoming prohibitive.
- The longer the drift length, the higher the demands on LAr purity and high-voltage capability.

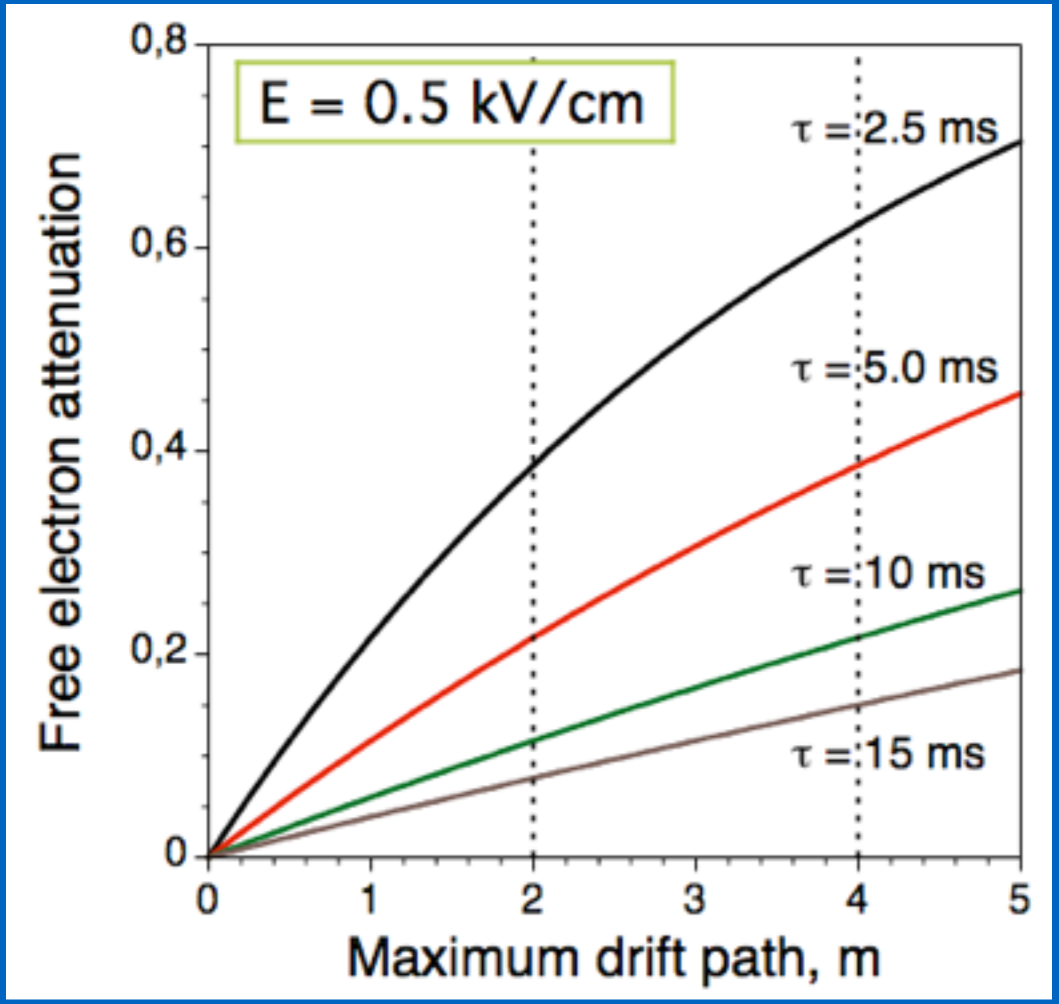




LAr Purity

- Perhaps the most important detector parameter we care about is *electron lifetime*, which is the half-life for electrons in the LAr environment.
- In 100% pure LAr, the electron lifetime should be almost infinite.
- Electronegative impurities, such as Oxygen and Water, will attach to electrons before they reach anode planes, reducing the recorded signal.

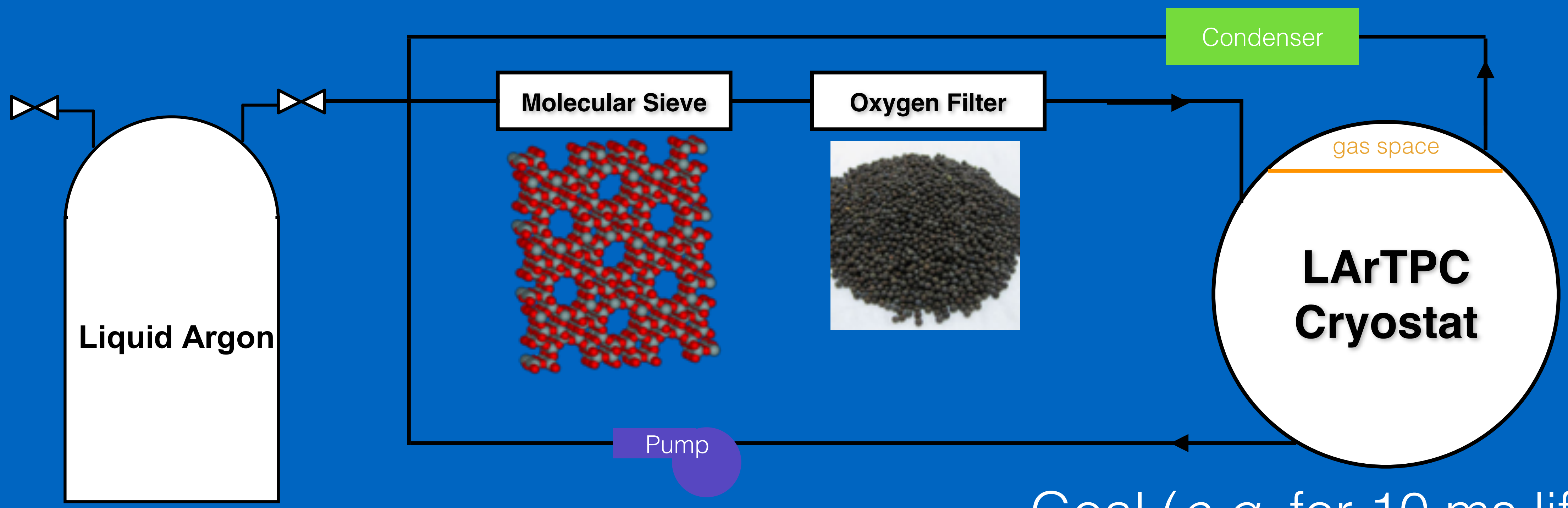




Refs:
1.) *Drift Velocity of Free Electrons in Liquid Argon*, W. Walkowiak, NIM A Vol. 449, July 2000, pp 288-294

LAr Purity

- Achieve desired purity level by passing argon through filters containing molecular sieve (to remove water) and copper (to remove oxygen).
- Detector components must also be chosen to minimize contamination.
- Continuous recirculation necessary to reach/maintain ultimate purity requirements.



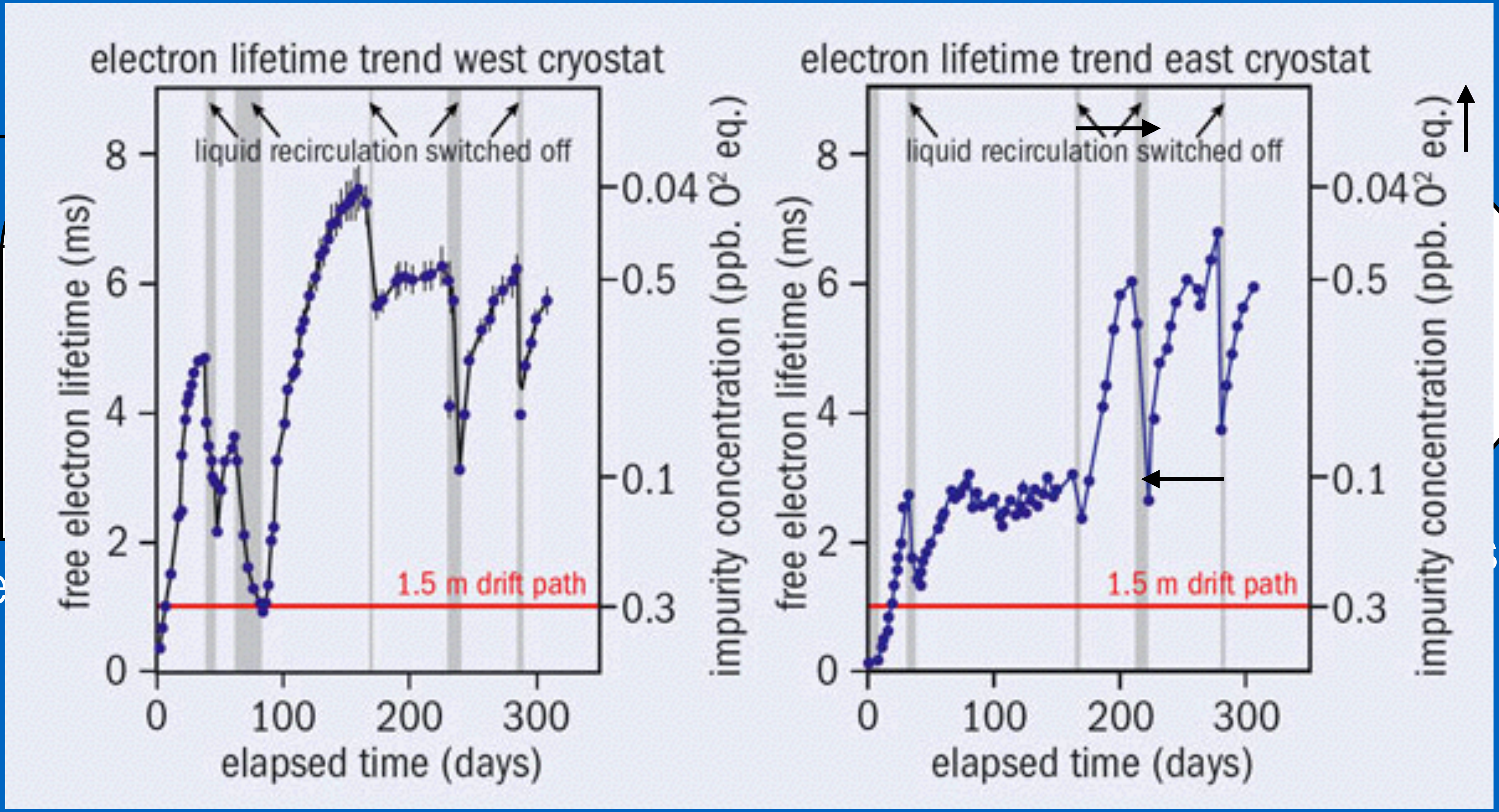
Delivered: 1ppm O_2

Goal (*e.g.* for 10 ms lifetime): 30 ppt O_2

Refs:
1.) *A Regenerable Filter for Liquid Argon Purification*, A. Curioni et al, NIM A Vol. 605, July 2009, pp 306-311
2.) *ICARUS takes flight beneath the Gran Sasso*, CERN Courier, July 2011

LAr Purity

- Achieve desired purity level by passing argon through filters containing molecular sieve (to remove water) and copper (to remove oxygen).
- Detector components must also be chosen to minimize contamination.
- Continuous recirculation necessary to reach/maintain ultimate purity requirements.



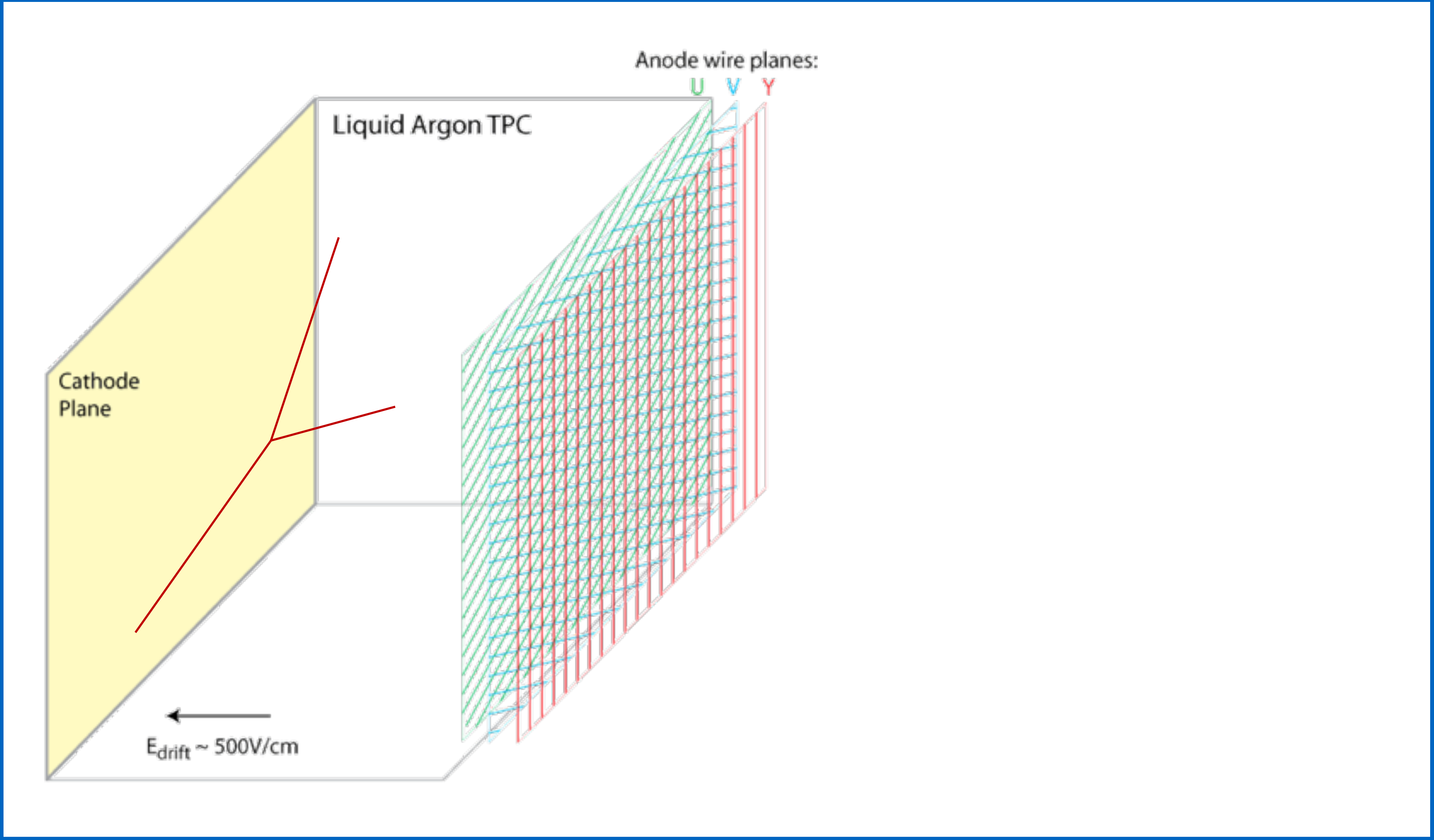
Delive

lifetime):

Refs:
1.) *A Regenerable Filter for Liquid Argon Purification*, A. Curioni et al, NIM A Vol. 605, July 2009, pp 306-311
2.) *ICARUS takes flight beneath the Gran Sasso*, CERN Courier, July 2011

TPCs

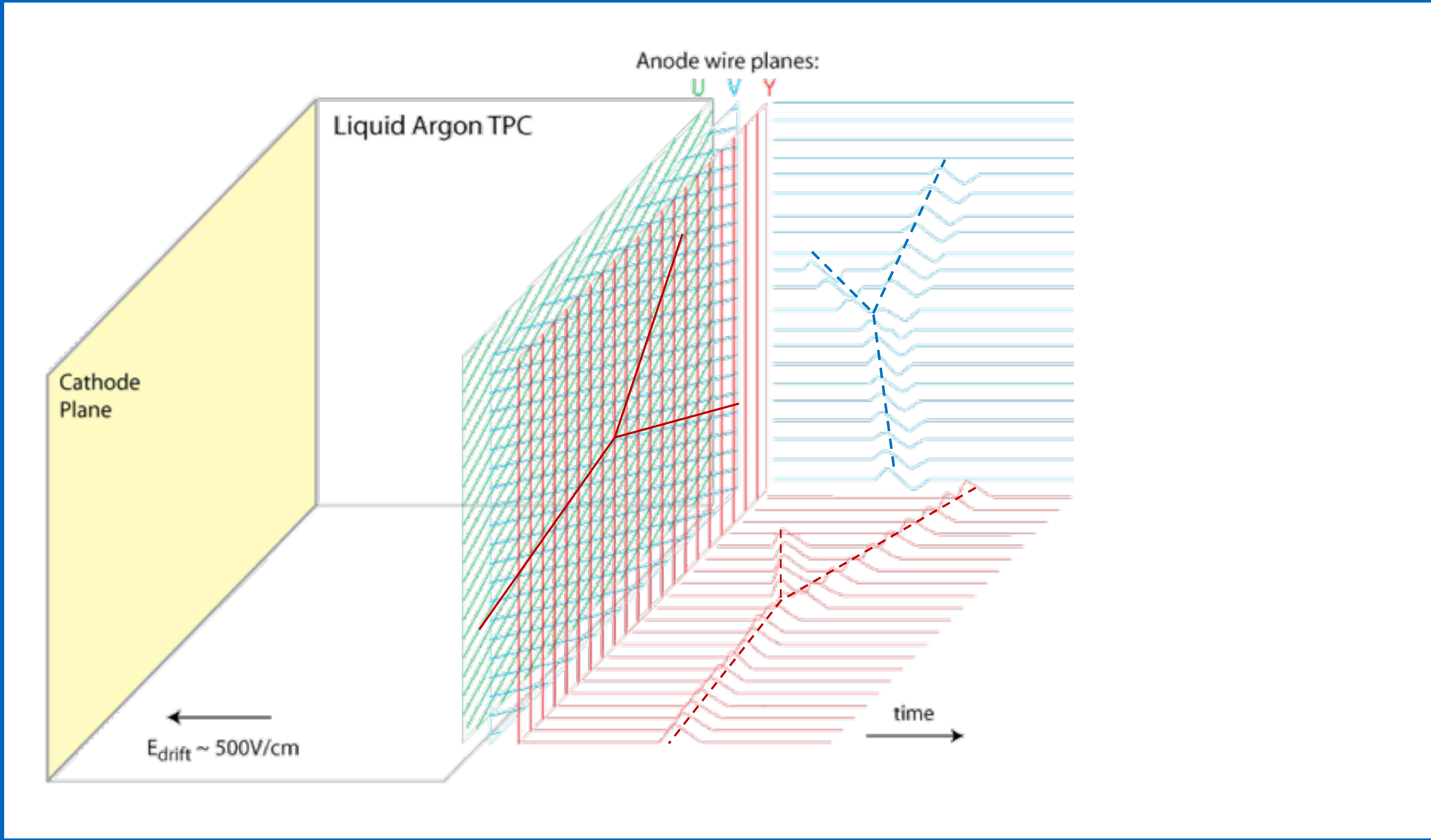
- Drifting charge induces current in wires it is approaching/receding from.
- Wireplanes act as “Frisch” grids that shield subsequent planes from drifting charge.
- Transparency of Induction planes, and opaqueness of Collection plane, is achieved through anode geometry and bias voltages applied to wires.



Refs:
1.) *Design of Grid Ionization Chambers*, Bunneman, Cranshaw,Harvey, Can. J. Res. 27 (1949) 191
2.) *Design of Large LArTPCs*, B. Yu, TIPP 2011

TPCs

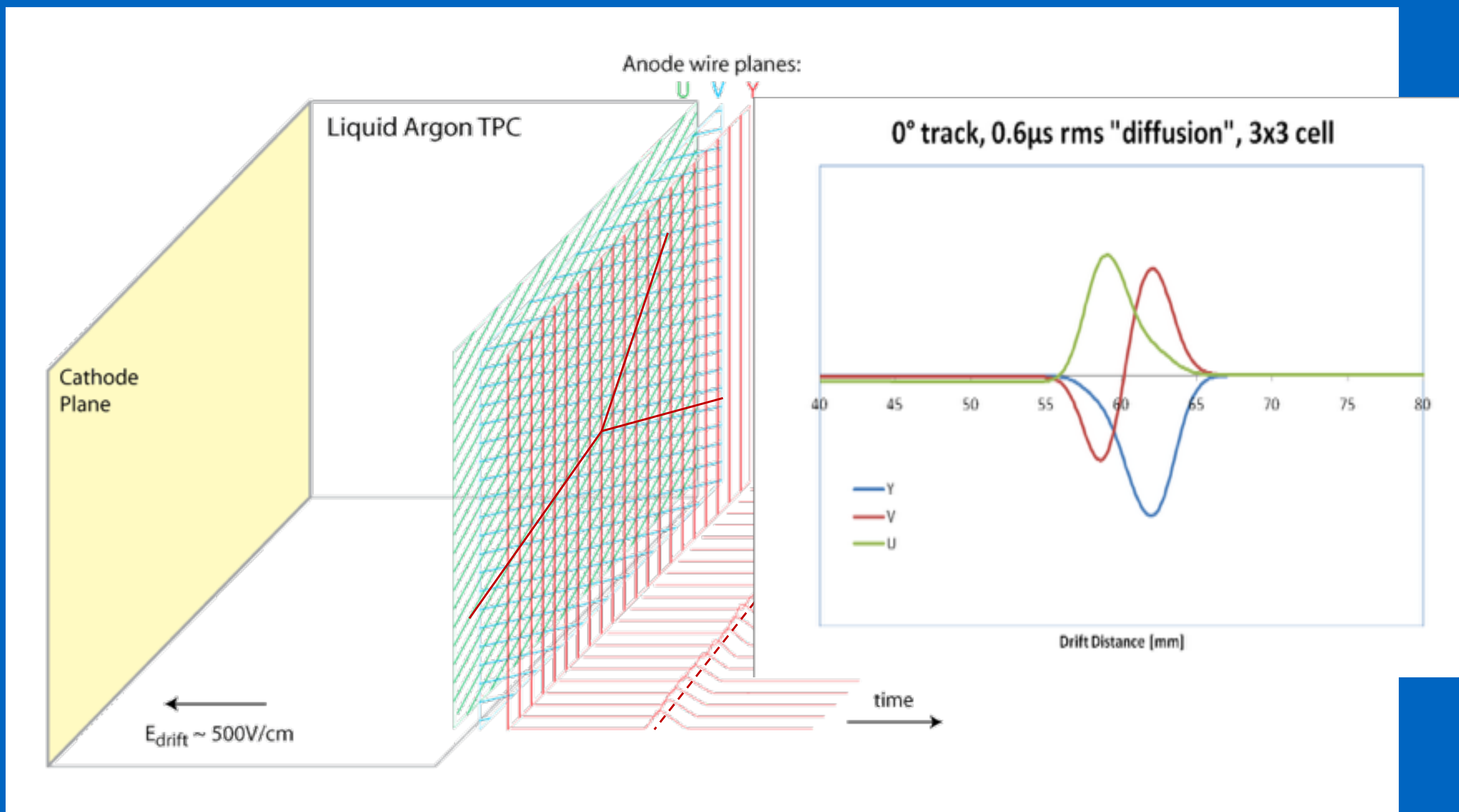
- Drifting charge induces current in wires it is approaching/receding from.
- Wireplanes act as “Frisch” grids that shield subsequent planes from drifting charge.
- Transparency of Induction planes, and opaqueness of Collection plane, is achieved through anode geometry and bias voltages applied to wires.



Refs:
1.) *Design of Grid Ionization Chambers*, Bunneman, Cranshaw,Harvey, Can. J. Res. 27 (1949) 191
2.) *Design of Large LArTPCs*, B. Yu, TIPP 2011

TPCs

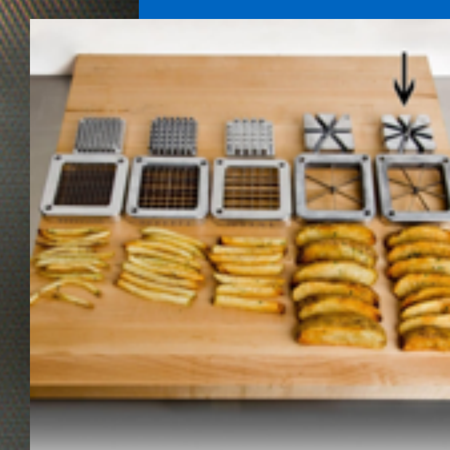
- Drifting charge induces current in wires it is approaching/receding from.
- Wireplanes act as “Frisch” grids that shield subsequent planes from drifting charge.
- Transparency of Induction planes, and opaqueness of Collection plane, is achieved through anode geometry and bias voltages applied to wires.



Refs:
1.) *Design of Grid Ionization Chambers*, Bunneman, Cranshaw,Harvey, Can. J. Res. 27 (1949) 191
2.) *Design of Large LArTPCs*, B. Yu, TIPP 2011

TPCs

- Single-phase readout (e.g. - wireplanes) or Two-phase readout (e.g. - LEMs) can be employed to detect signals.
- Wires in plane can be spaced closely to increase resolution, but there is a balance between too close (smaller signal, more resolution) and too far (bigger signal, less resolution).
- For long drift, diffusion of ionization will degrade resolution.



TPCs

Refs:
1.) *Dynamical behavior of free electrons in the recombination process in liquid argon, krypton, and xenon* , S.Kubota, M.Hishida, M.Suzuki, J.Ruan(Gen), Phys. Rev. B20 (1979), 3486

TPCs

- Excellent dielectric properties of noble liquids are ideal for sustaining high cathode voltages. Example: MicroBooNE has a 2.5m drift, so a 500V/cm field requires: 125,000V on Cathode.

Refs:
1.) *Dynamical behavior of free electrons in the recombination process in liquid argon, krypton, and xenon* , S.Kubota, M.Hishida, M.Suzuki, J.Ruan(Gen), Phys. Rev. B20 (1979), 3486

TPCs

- Excellent dielectric properties of noble liquids are ideal for sustaining high cathode voltages. Example: MicroBooNE has a 2.5m drift, so a 500V/cm field requires: 125,000V on Cathode.
- Field-cage of TPC creates uniform drift region.

Refs:
1.) *Dynamical behavior of free electrons in the recombination process in liquid argon, krypton, and xenon* , S.Kubota, M.Hishida, M.Suzuki, J.Ruan(Gen), Phys. Rev. B20 (1979), 3486

TPCs

- Excellent dielectric properties of noble liquids are ideal for sustaining high cathode voltages. Example: MicroBooNE has a 2.5m drift, so a 500V/cm field requires: 125,000V on Cathode.
- Field-cage of TPC creates uniform drift region.
- Recombination of electron-ion pairs diminishes signal. Can compensate by increasing field, but this increases demand on cathode voltage.

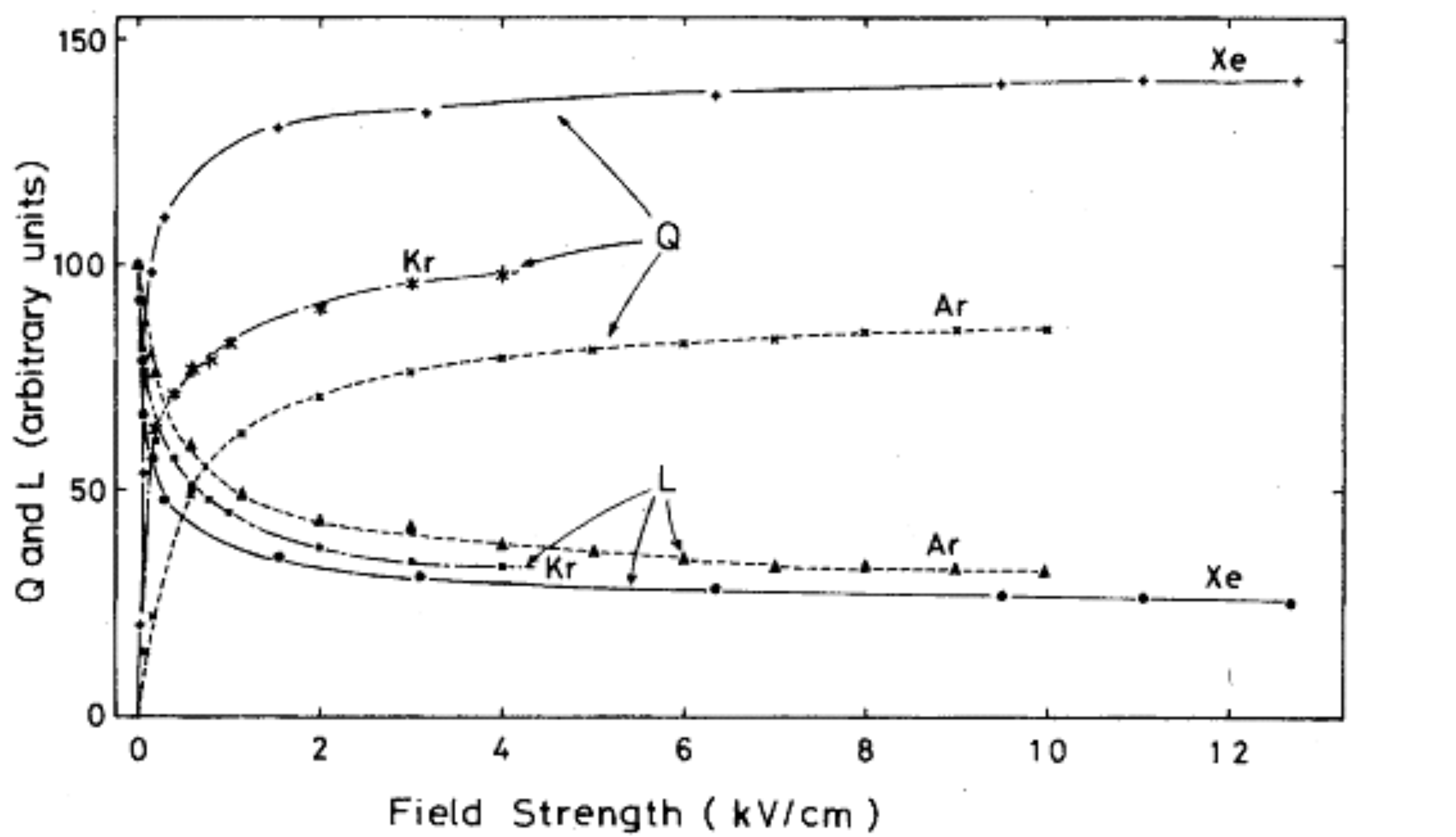
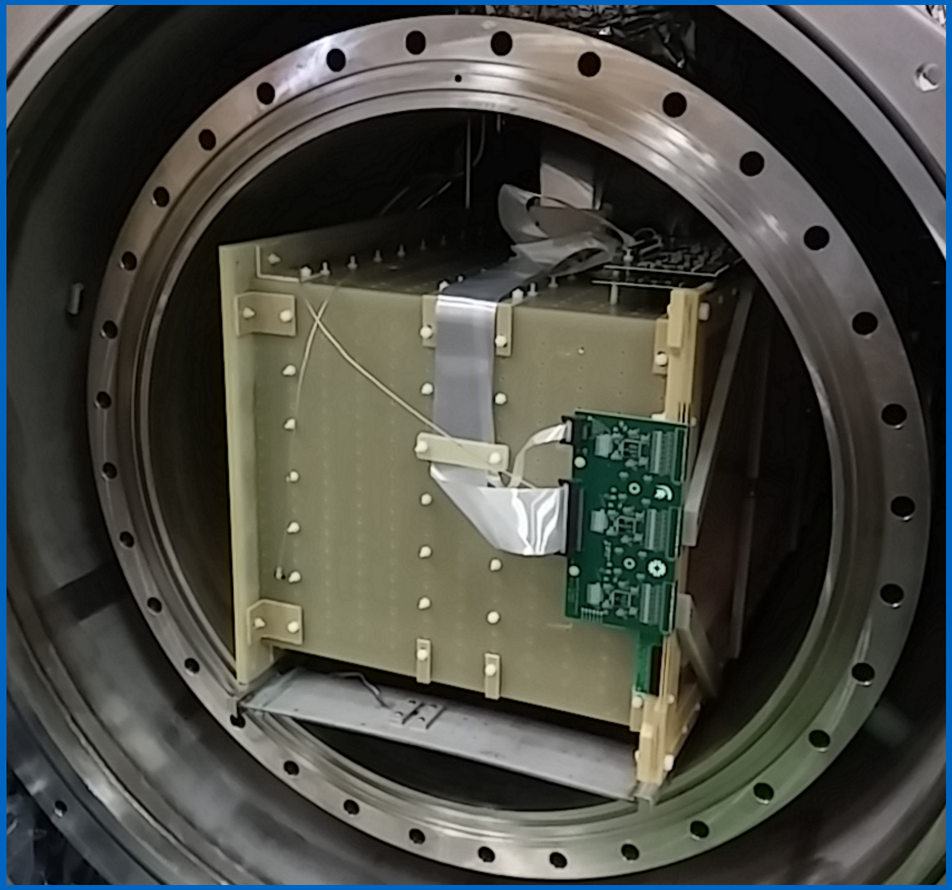


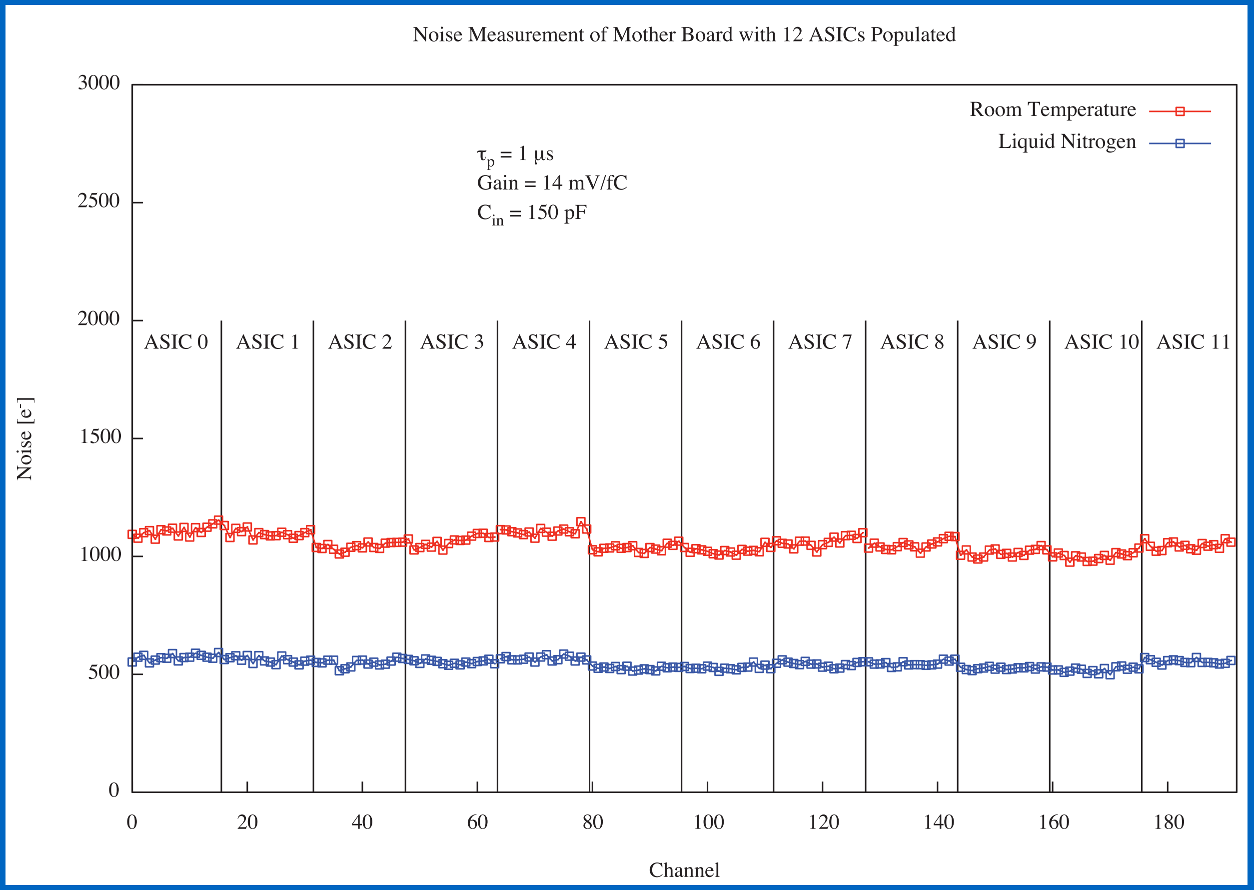
FIG. 2. Variation of relative luminescence intensity L and collected charge Q in liquid argon, krypton, and xenon vs applie electric-field strength for 0.976- and 1.05-MeV electrons.

Refs:
1.) *Dynamical behavior of free electrons in the recombination process in liquid argon, krypton, and xenon* , S.Kubota, M.Hishida, M.Suzuki, J.Ruan(Gen), Phys. Rev. B20 (1979), 3486

Electronics

- Signals from each wire are sampled/amplified/shaped/digitized for a duration longer than the maximum drift time (milliseconds). This is an eternity compared to usual HEP experiments.
- Small signal sizes demand low-noise electronics.
- Placing the amplification circuit in the LAr, directly on the TPC, increases S/N performance.

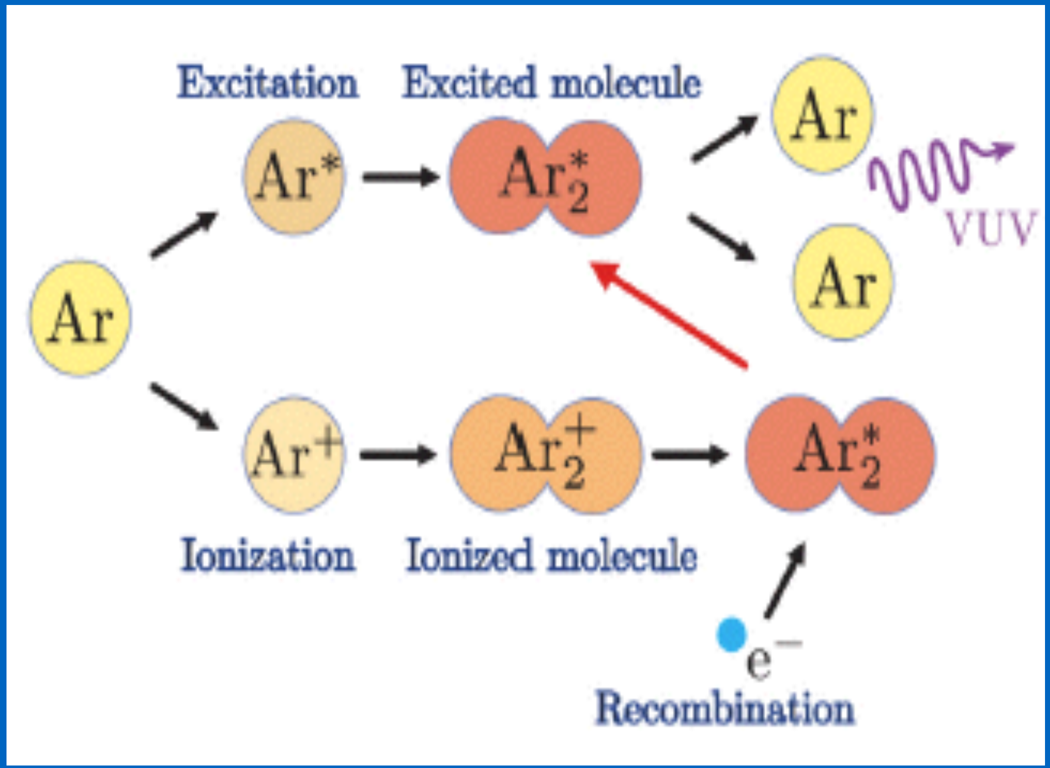


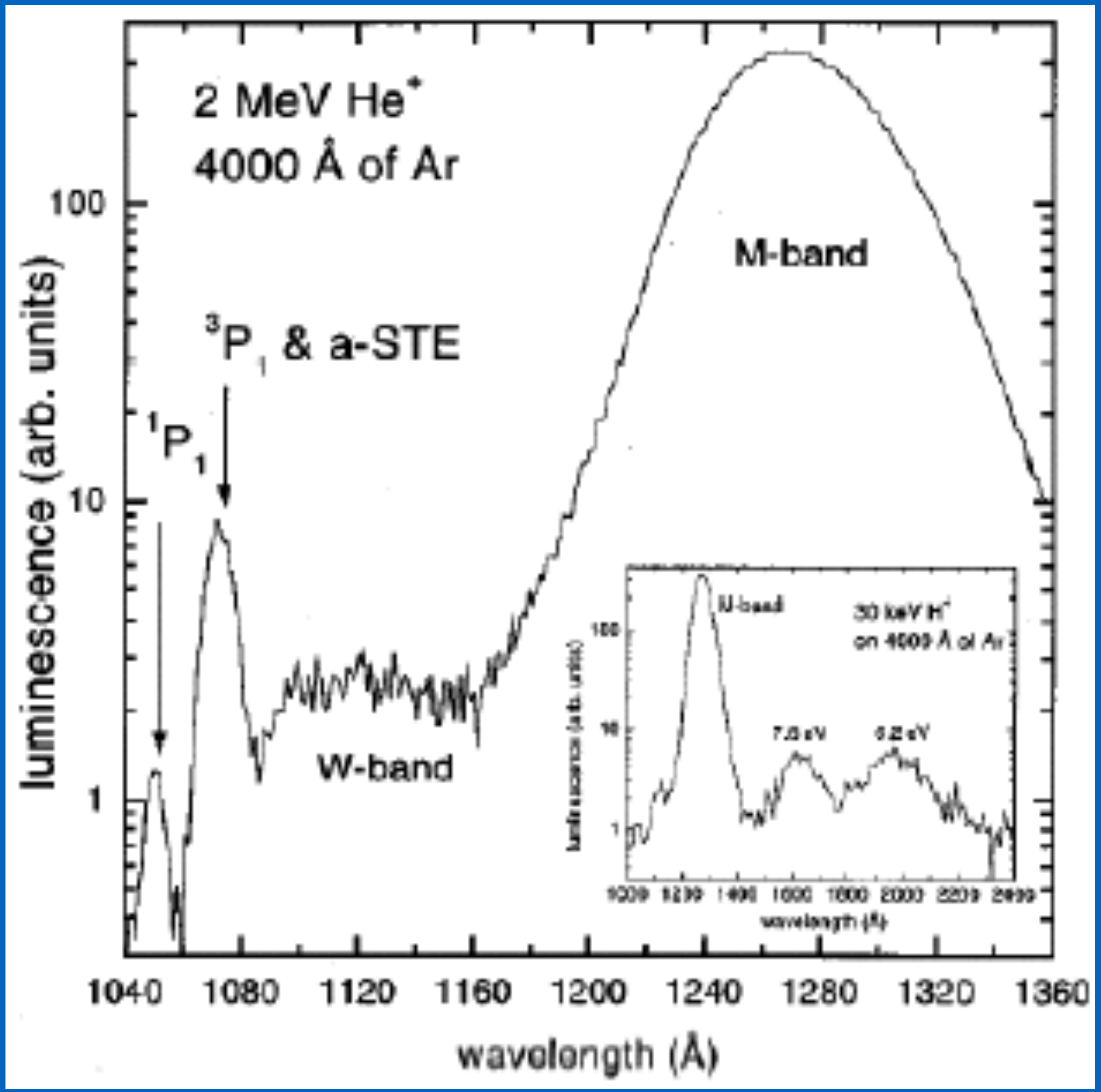


Refs:
1.) *Readout electronics for the MicroBooNE LAr TPC, with CMOS front end at 89K*, H. Chen et al, JINST 7 C12004, 2012

Light Production

- Prompt light from particles traversing the LArTPC allow determination of the t_0 of the interaction, as well as complimenting the TPC information during reconstruction.
- LAr is a very bright scintillator, though its predominant wavelength is deep in the UV (128nm).
- LAr is transparent to its own scintillation light (128 nm photon not enough energy to re-excite another Ar atom).

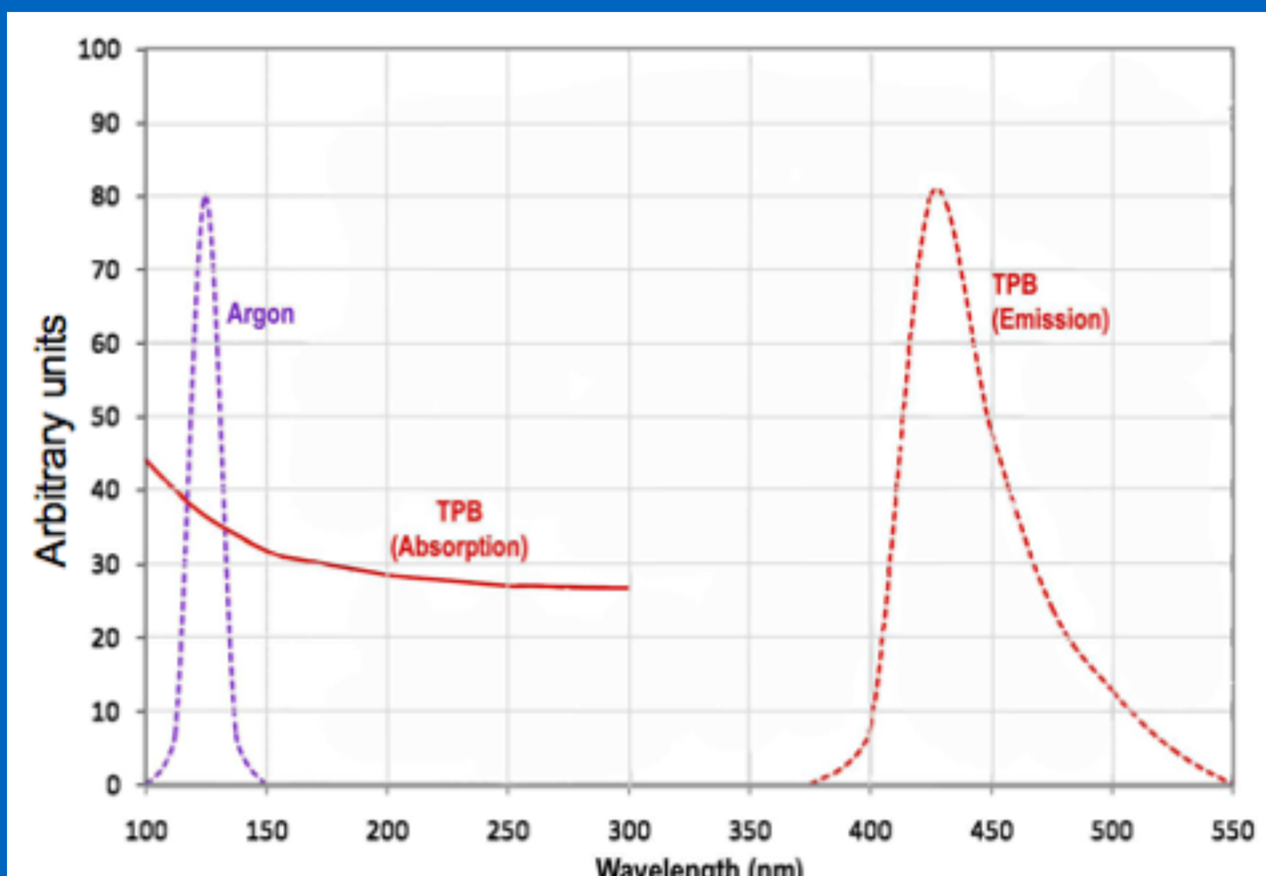




Light Collection

- Light collection devices (PMT, scintillator bar, SiPM, etc…) immersed in the LAr, which puts constraints on their robustness to cold.
- Argon scintillation light is deep in UV, so need to shift wavelength to regime where device has good efficiency.

MicroBooNE PMTs behind TPB-coated plates



Abosrption/Emission Spectrum of Tetraphenyl butadiene (TPB)

LArIAT TPC lined with TPB-coated foils

Refs:
1.)*MicroBooNE*, C. Ignarra, DPF 2011 Proceedings

Thinking Outside the Box

Thinking Outside the Box

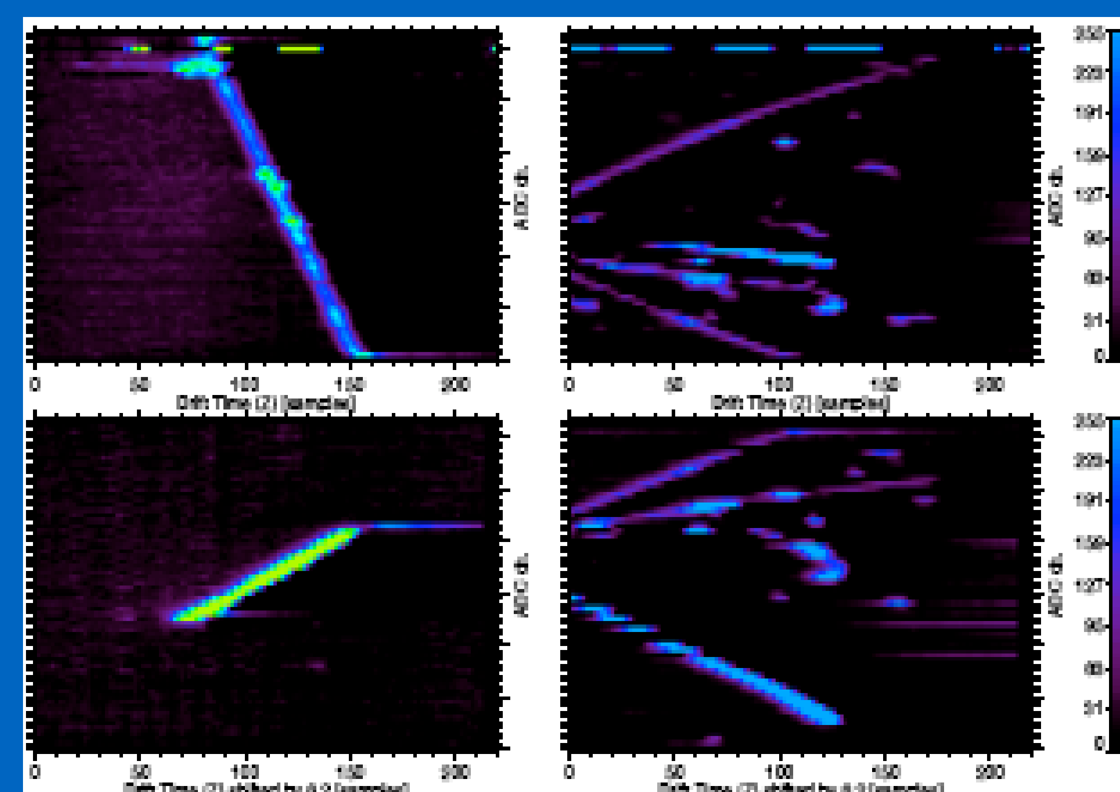
- With all the development going into LArTPCs, might we stumble on some unexpected uses for this technology?

Spinoffs

Thinking Outside the Box

- With all the development going into LArTPCs, might we stumble on some unexpected uses for this technology?
- Argon is certainly the most attractive element for large-scale experiments (>1 ton) based on cost. It is not the only noble liquid we can use for a TPC. Any interest/value to our neutrino-scattering community in a “small” TPC full of He, Ne, Kr, or Xe exposed to a neutrino beam?

Spinoffs



Tracks in LXeGRIT LXeTPC - Curioni, NuINT07

The Past

- Building neutrino detectors to study neutrino interactions has a rich history.
- Ray Davis's "argon detector" experiment had, in essence, the opposite purity requirements as I've discussed…as little argon as possible allowed!

"In order to forecast as accurately as possible the rate of solar neutrino capture in the Homestake detector, it was necessary to measure the production cross-sections of the neutrino-producing reactions, and derive their rates in the interior of the Sun. This great effort was largely carried out at the California Institute of Technology under the leadership of William A. Fowler (Nobel Prize in Physics, 1983). Many nuclear astrophysicists and astronomers contributed to the basic physics that supported this early effort in solar neutrino astronomy. <u>Our task at Brookhaven was far simpler and we (Don Harmer, Ken Hoffman, and myself) had the fun of building a large detector and making it work.</u>" - Ray Davis, Nobel Lecture 2002

Ray Davis Homestake Experiment

The Future

- Short-Baseline LArTPC experiments to measure a variety of cross-sections, and study anomalies.
- Really big LArTPC detectors deep underground to search for CP-violation, proton decay, astrophysics.



Conclusions

- LArTPCs are powerful detectors for studying neutrino interactions.

- Worldwide development effort is pushing the boundary of where we might go with this technology.

- If you are interested in learning more about any of the technical aspects I've discussed, you are at the right laboratory to find experts to speak with this week.