

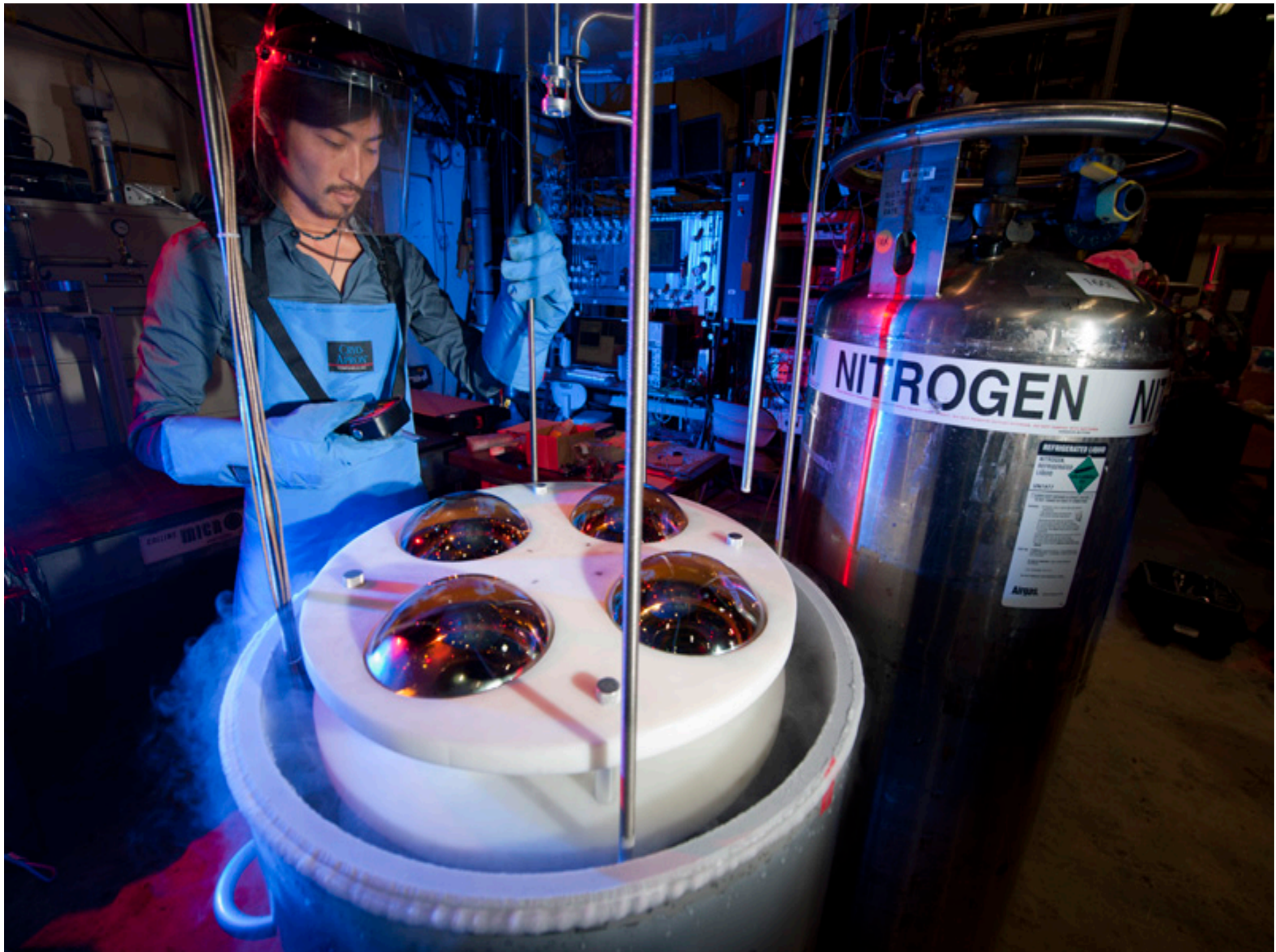
Nuclear Physics and Astrophysics

SPA6309

Dr. Teppei Katori

Lecture 22 – Detector designing, MicroBooNE PMT system





Dr. Teppei Katori

Radiation Detector



Motivation – What kind of physics do you want to study?

→ What kind of detector do you need?

Particle Physics (Lecture 2)

Physics of radiation mechanism – What kind of signal do you expect?

→ What is the signature of signal by this detector?

Particle Propagation (Lecture 3,4)

Detector mechanism – What is the character of signal?

→ What is the character of background and noise? how to distinguish

→ Precise specification of the detector

Detector concept (Lecture 6)

Signal processing – How to identify the physics you want to study?

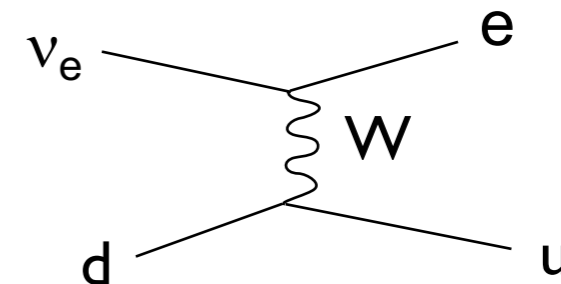
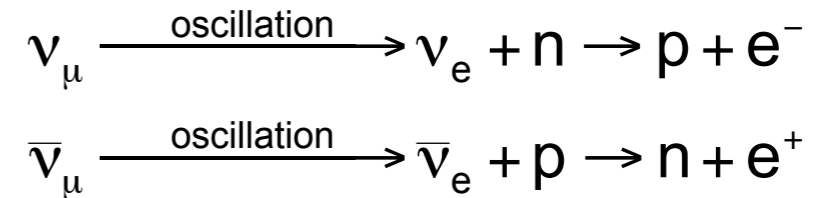
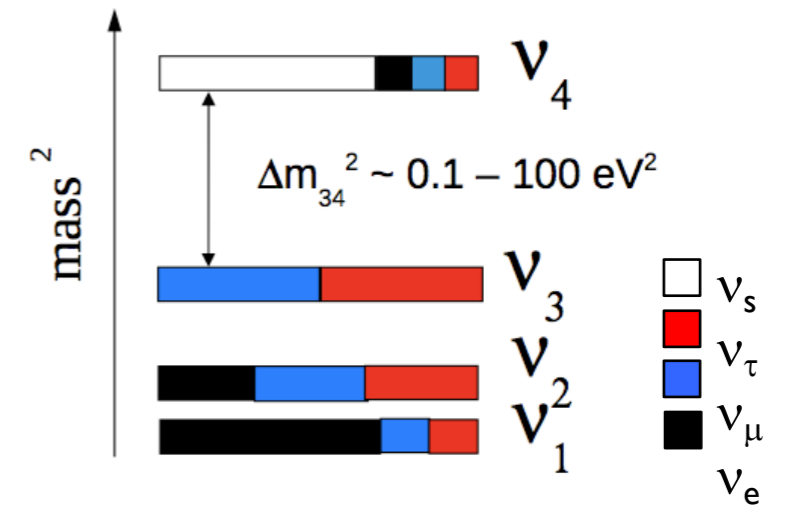
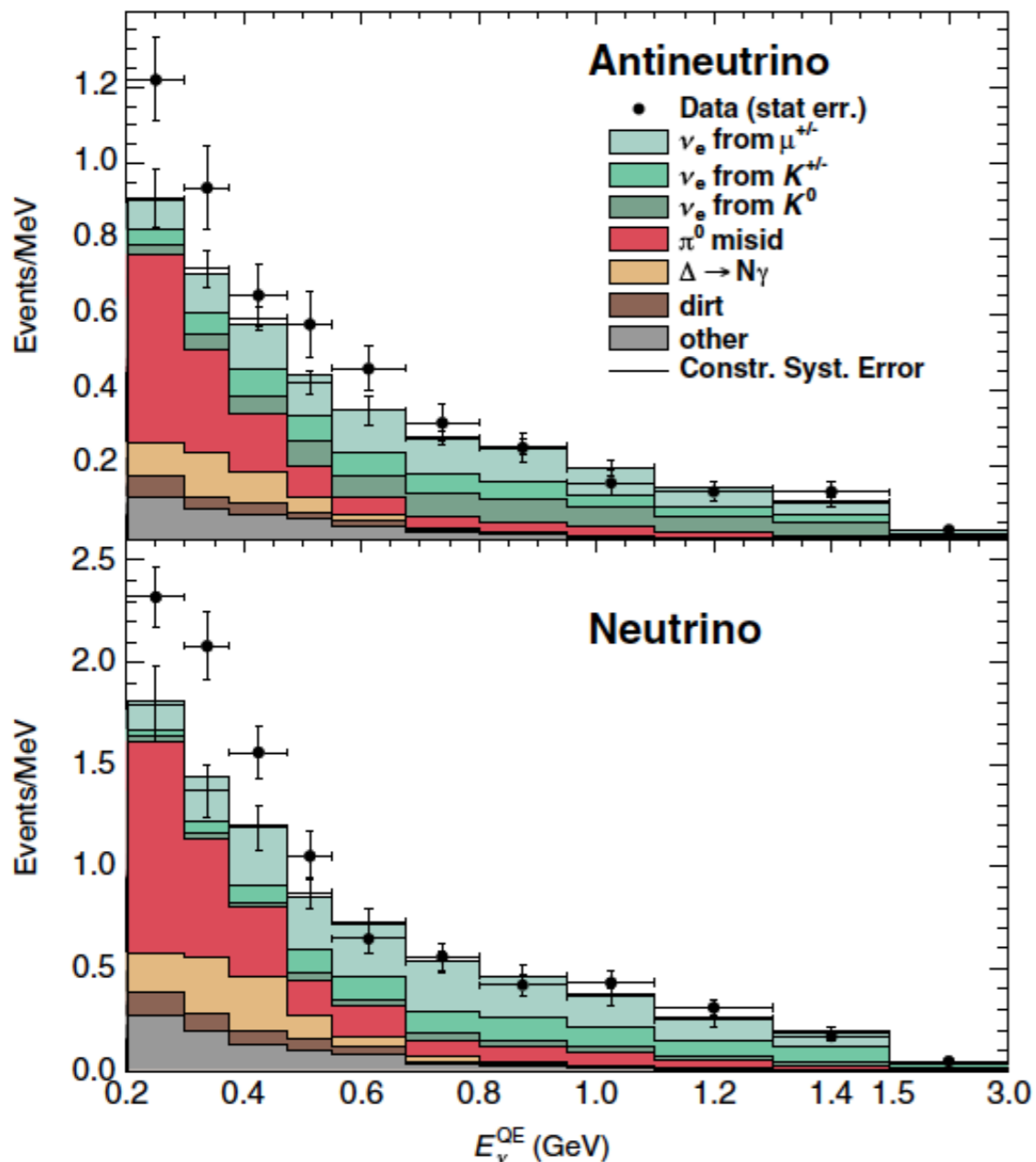
→ How to observe the phenomena exactly?

Statistics (Lecture 5)

Signal transmission (Lecture 7)

Signal processing (Lecture 8)

Goal of MicroBooNE is to find sterile neutrinos from muon neutrino to electron neutrino oscillations, by detecting single isolated electron/positron in the detector from charged-current weak interaction.



Particle Physics (Lecture 2)
Astrophysics
Medical application etc

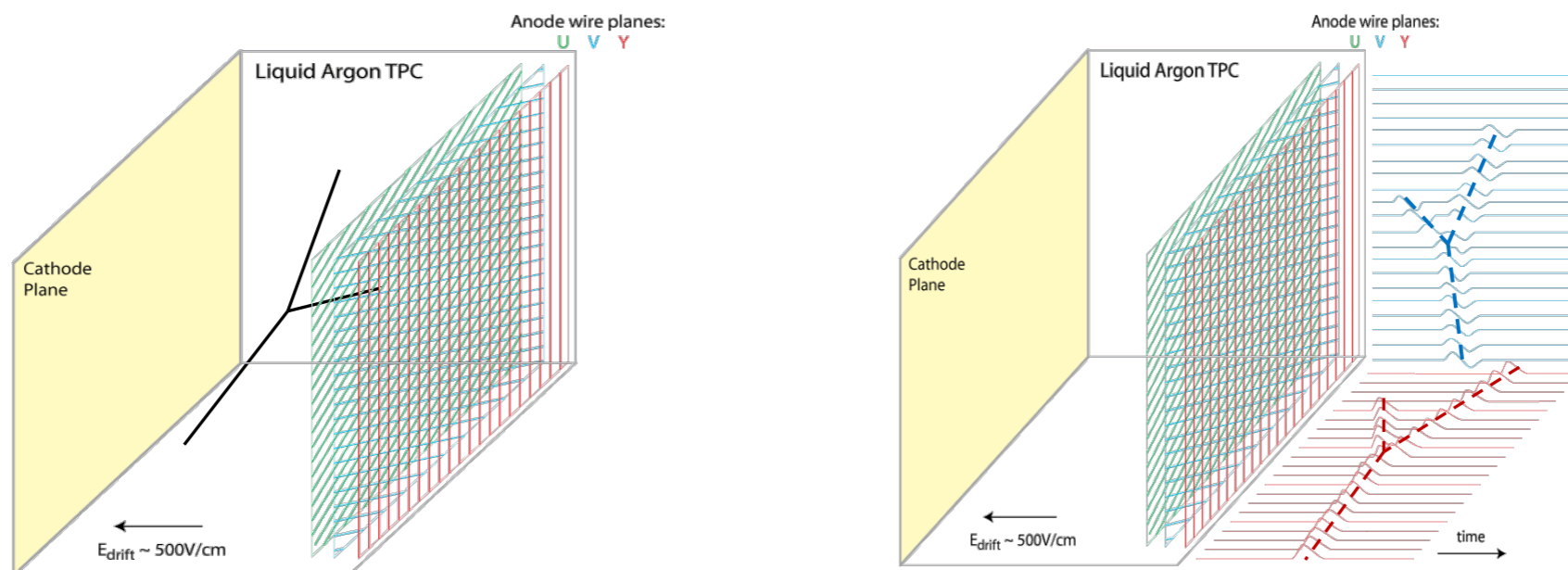
For this purpose, detector is required to

- measure and identify electron/positron
- distinguish it from gamma ray (background)

Therefore, MicroBooNE uses liquid argon time projection chamber (LArTPC)

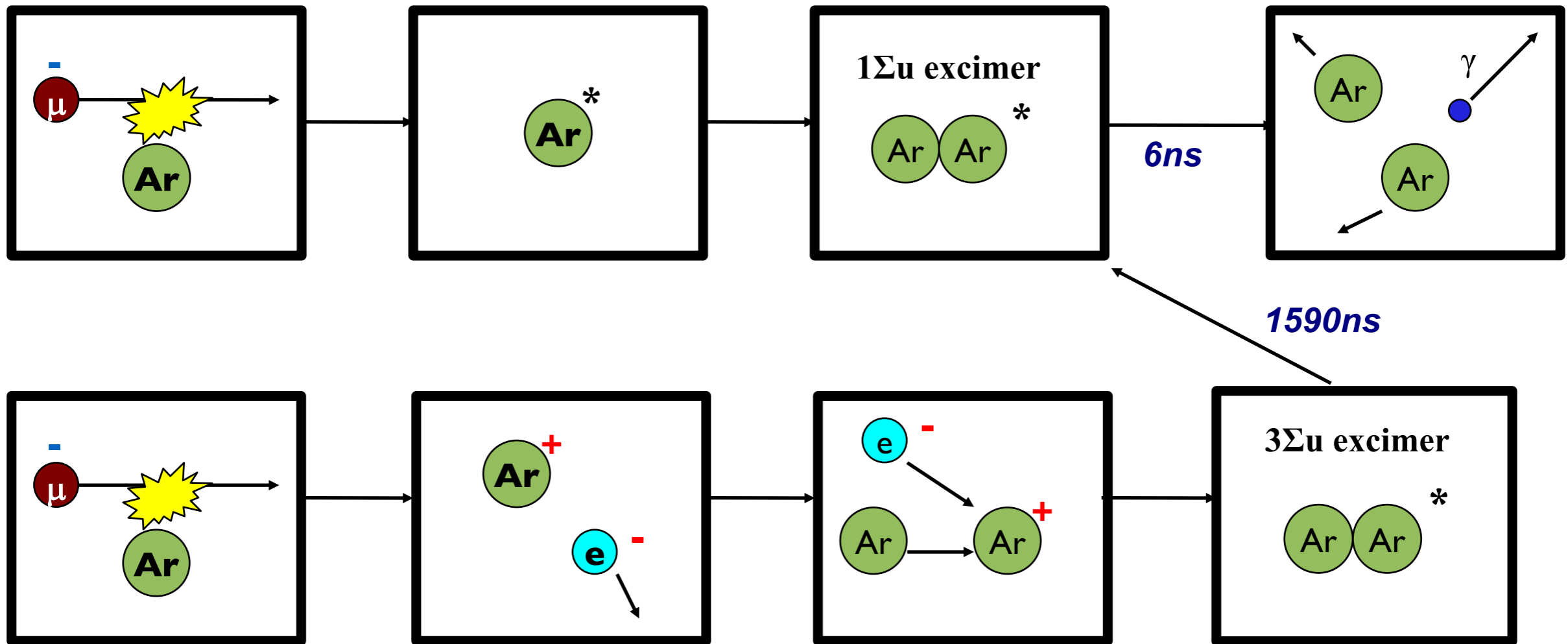
- it can reconstruct electron/positron and measure their energies.
- it can reject gamma ray background

However, LArTPC is slow detector and other detector needs to tell when interactions happen → we need PMT system to measure scintillation light



Particle Physics (Lecture 2)
Astrophysics
Medical application etc

Scintillation light are generated from argon atoms by ionizations of charged particles.



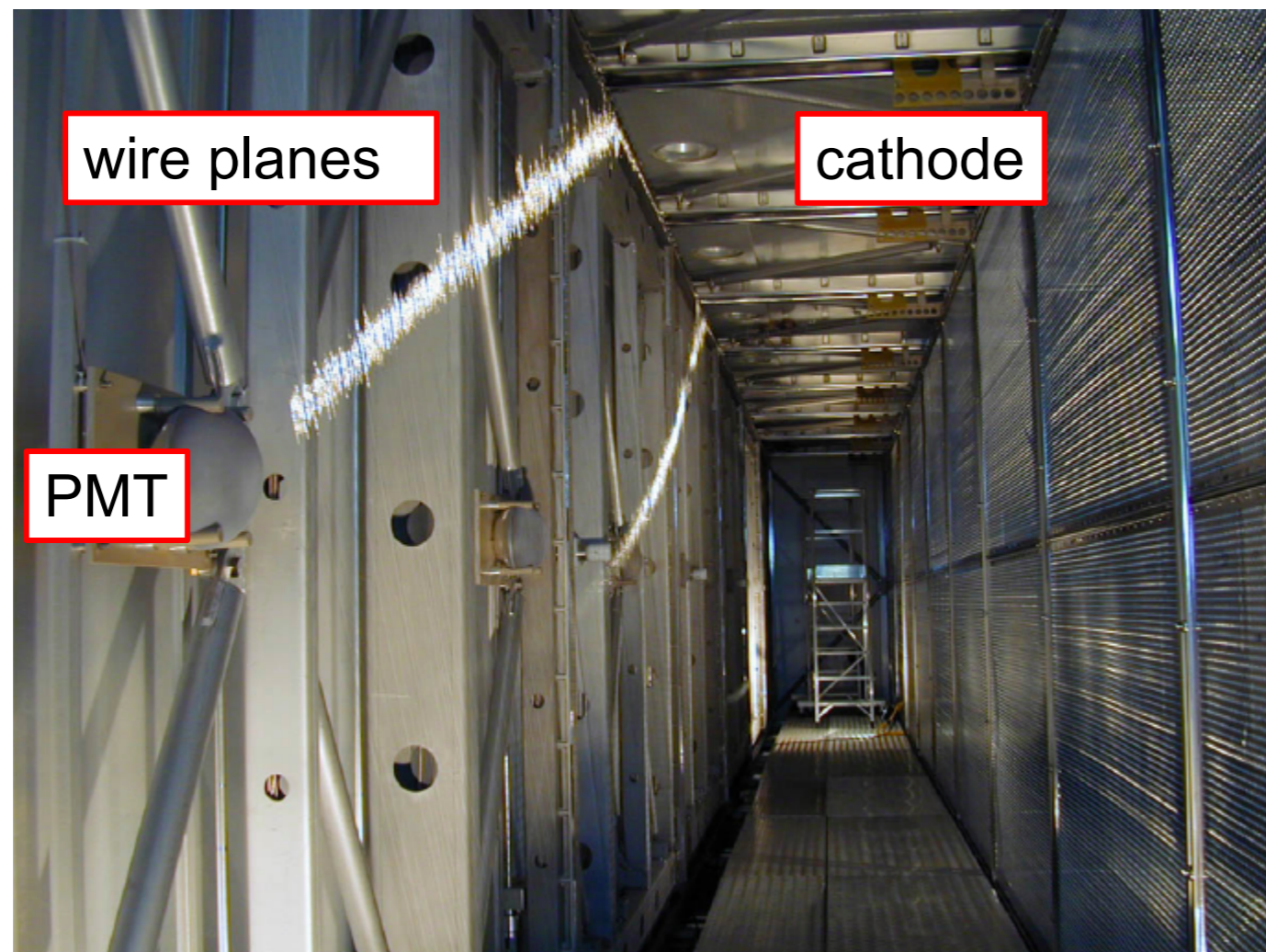
**Particle Propagation (Lecture 3,4)
Scintillation (Lecture 9)**

We took basic features of ICARUS T600 PMT system design and modified

ICARUS T600 photon detection system

- ETL 12 stage 8-inch bi-alkali PMT with Pt-coating
- 54 of PMTs to cover T300 3.6m x 3.9m x 19.6m volume (~0.5% photo-cathode coverage)
- PMTs are located 5mm behind of collection wire plane
- PMT windows are sand blasted to spray TPB solution
- Negative HV operation, custom made base directly soldered on PMT
- PEEK rod PMT mount

Inside of half module of ICARUS T300



We took basic features of ICARUS T600 PMT system design and modified

ICARUS T600 photon detection system vs MicroBooNE photon detection system

- ETL 12 stage 8-inch bi-alkali PMT with Pt-coating
- 54 of PMTs to cover T300 3.6m x 3.9m x 19.6m volume ($\sim 0.5\%$ photo-cathode coverage)
- PMTs are located 5mm behind of collection wire plane
- PMT windows are sand blasted to spray TPB solution
- Negative HV operation, custom made base directly soldered on PMT
- PEEK rod PMT mount

Detector concept (Lecture 6)
Photo-multiplier tubes (Lecture 10)

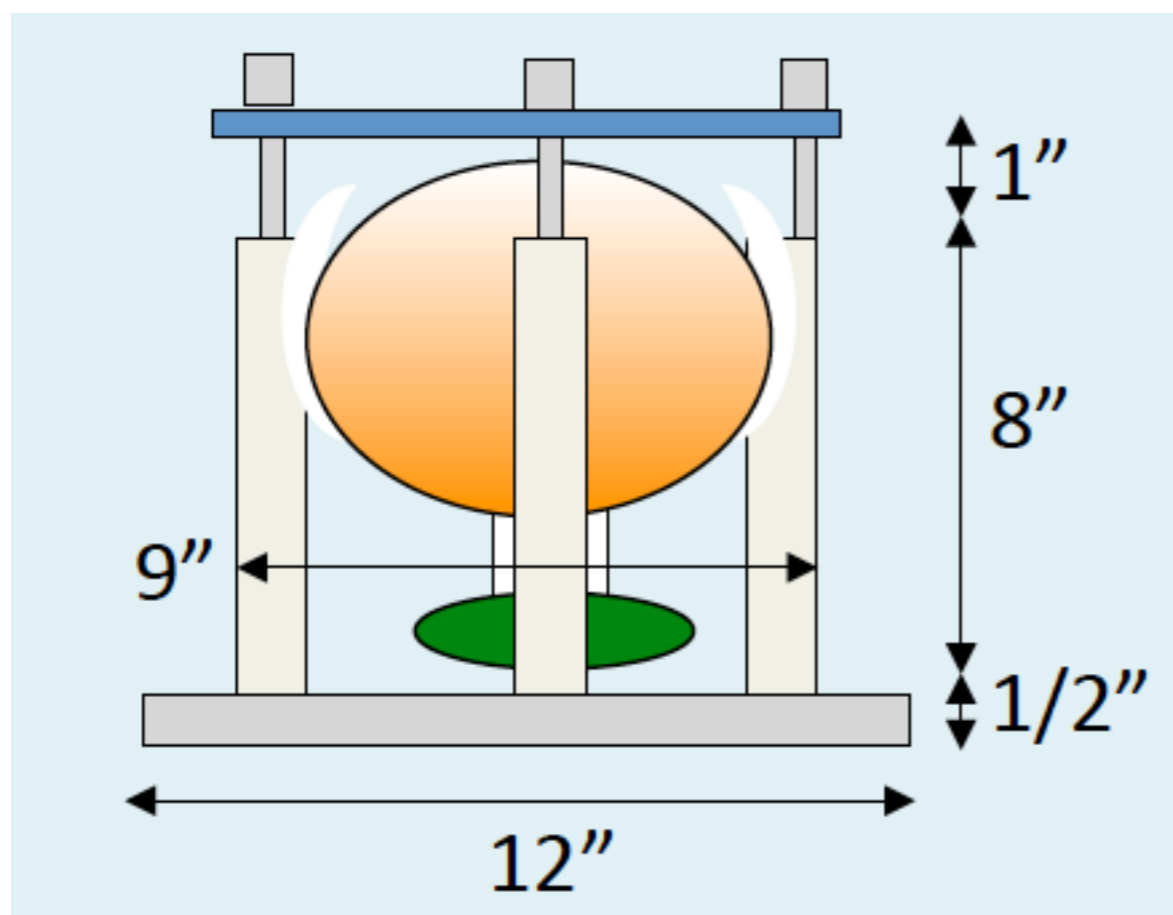
We took basic features of ICARUS T600 PMT system design and modified

ICARUS T600 photon detection system vs MicroBooNE photon detection system

- ETL 12 stage 8-inch bi-alkali PMT with Pt-coating
 - Hamamatsu 8-inch tube
- 54 of PMTs to cover T300 3.6m x 3.9m x 19.6m volume (~0.5% photo-cathode coverage)
 - 0.85% photocathode coverage
- PMTs are located 5mm behind of collection wire plane
 - ~20cm behind of collection wire plane
- PMT windows are sand blasted to spray TPB solution
 - TPB plate equipped in front of PMT
- Negative HV operation, custom made base directly soldered on PMT
 - positive HV operation
- PEEK rod PMT mount
 - spring loaded wire mount

Detector concept (Lecture 6)
Photo-multiplier tubes (Lecture 10)

PMT unit mechanical model



Each PMT unit consists of 4 pieces

- PMT and base
- TPB plate
- PMT mount
- Cryogenic mu-metal shield

2009/03/09

Detector concept (Lecture 6)
Photo-multiplier tubes (Lecture 10)

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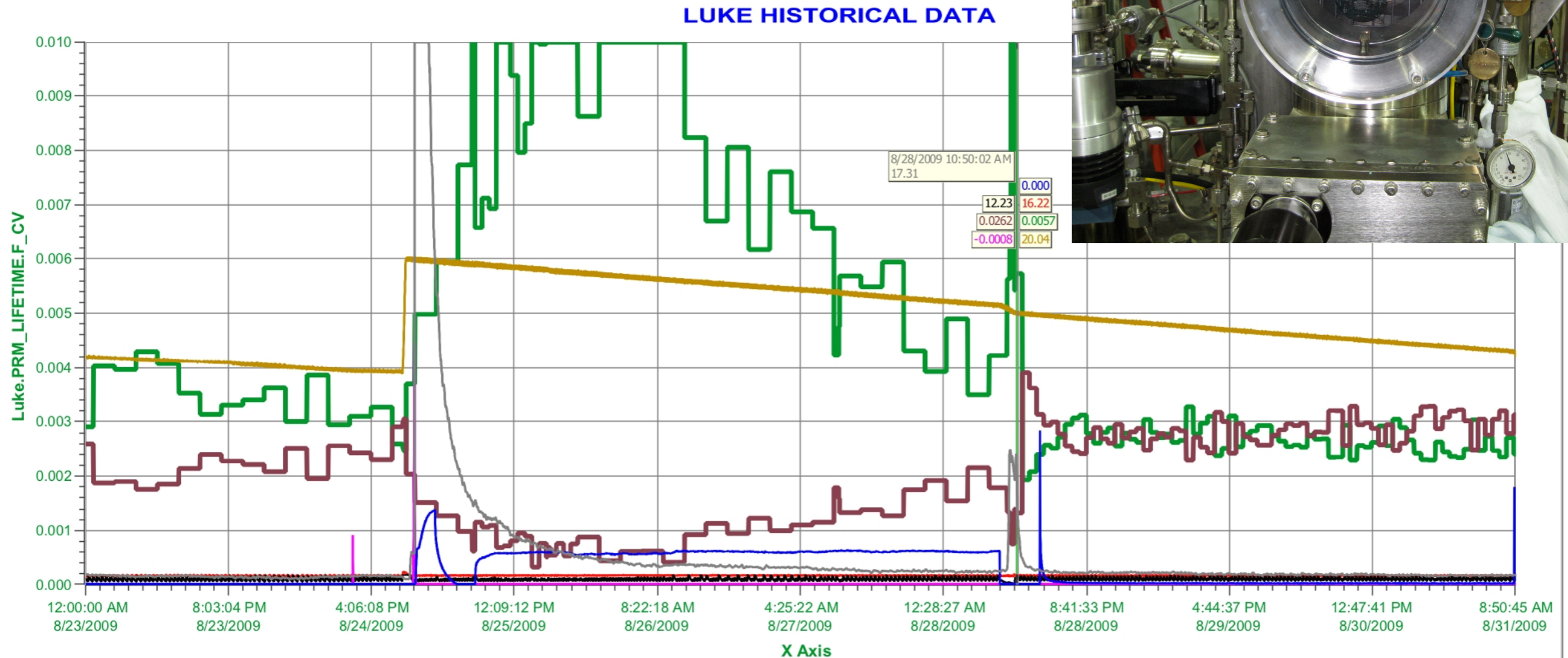
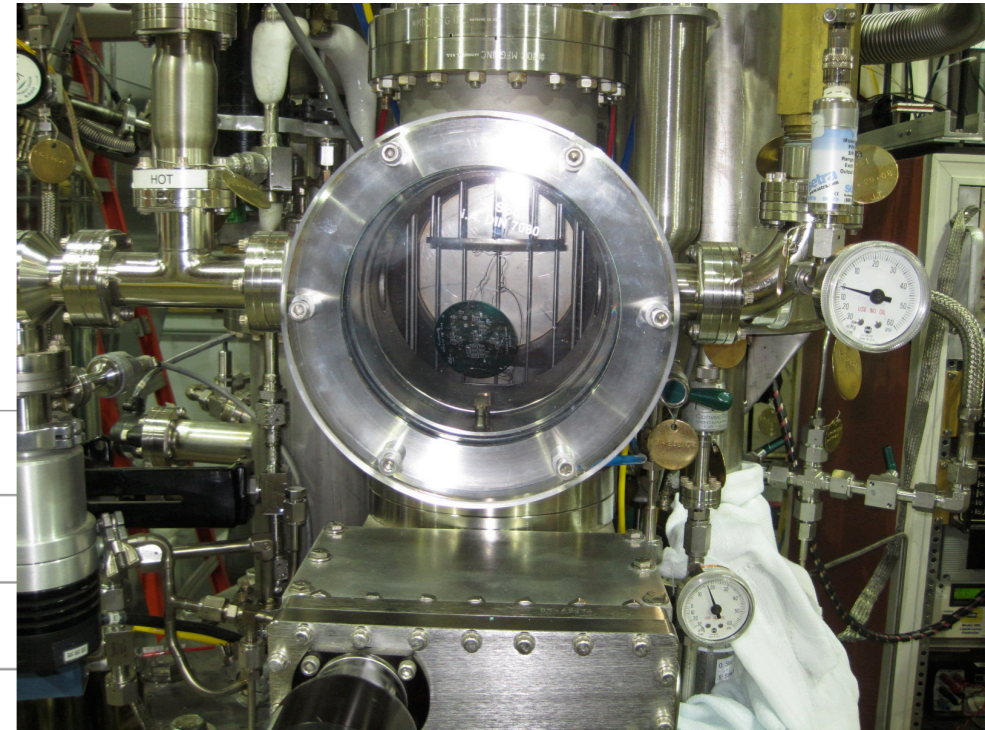
2013/03/21

Detector concept (Lecture 6)
Photo-multiplier tubes (Lecture 10)

Material impurity test



LAr requires high purity. Surface contamination (especially for fiber glass) is a big problem.



Pen Name	Description	Value	Eng Units	High Over Range	Low Over Range
— Luke.PRM_LIFETIME.F_CV	Luke.PRM_LIFETIME.F_CV	0.00573	sec	0.02420	0.00192
— Luke.PRM_IMPURITIES.F_CV	Luke.PRM_IMPURITIES.F_CV	0.0262	Imps	0.0780	0.0062
— PAB_S1.CRYOSTAT_PRESSURE_PSI...	Luke Vapor Pressure	16.22	psig	22.87	13.00
— PAB_S1.LT_10_N2.F_CV	Luke Condenser LN2 Level Probe (F_CV)	12.23	inches	17.51	0.78
— PAB_S1.LT_13_AR_REAL.F_CV	Luke Argon Level Probe	20.04	inches	24.18	15.55
— PAB_S1.AE_350_AR_REAL.F_CV	Nano Trace oxygen analyzer output (F_CV)	-0.001	ppm	0.022	-0.003
— PAB_S1.AE_311_AR_REAL.F_CV	Oxygen monitor connected to air lock purge	0.000	ppm	0.284	0.000
— PAB_S1.AE_423_AR_REAL.F_CV	HALO H2O meter (F_CV)	17.31	ppb	100.00	0.88

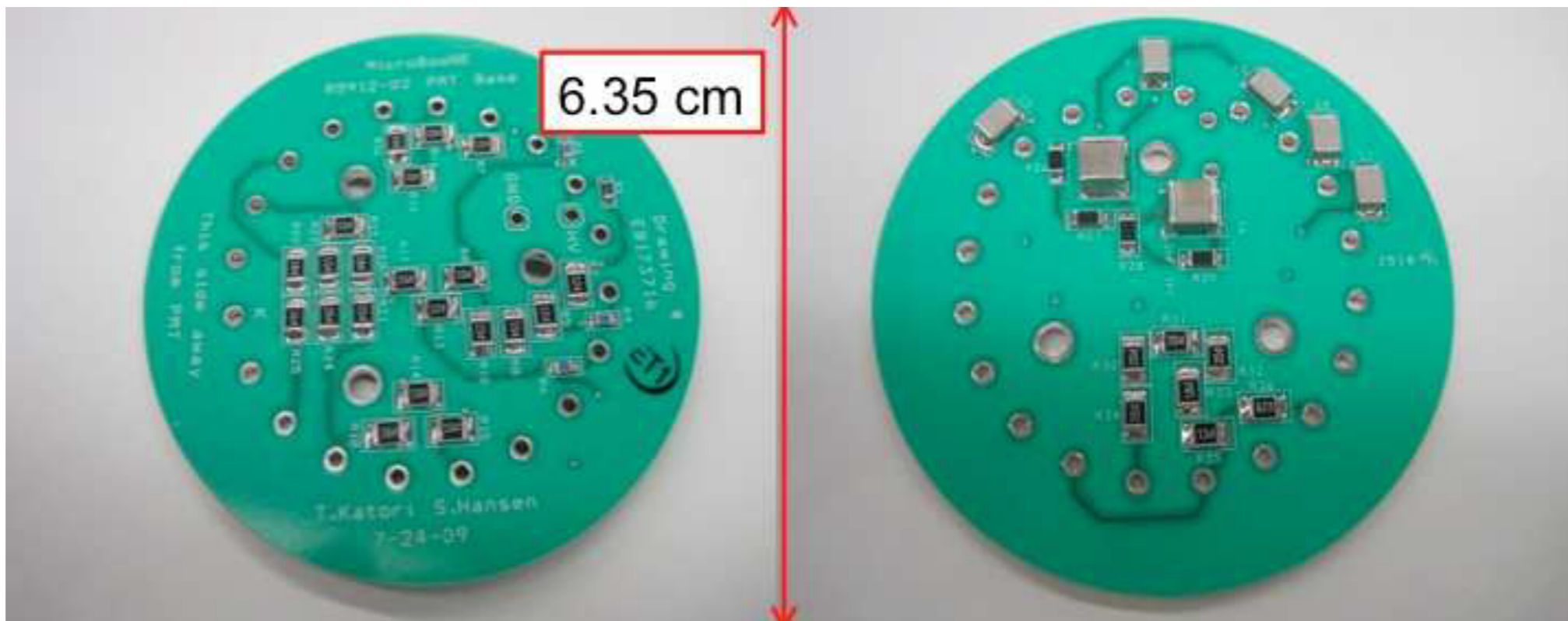
Hamamatsu R5912-02mod

- 14 stage high gain, 8-inch hemi-spherical photocathode, Pt-coating
- 32 PMTs to cover 2.5m x 2.4m x 10.6m volume (0.85% photocathode coverage)
- All PMTs are tested at PMT test stand (next)

Cryogenic base

- Metal film resistor, NP0/C0G capacitor, glass reinforced PC board, Teflon cable, etc
- Naked board (LAr is good insulator)
- Positive HV operation → One cable carries both signal and HV
- Total heat ~ 0.5W

MicroBooNE PMT base circuit



Hamamatsu R5912-02mod

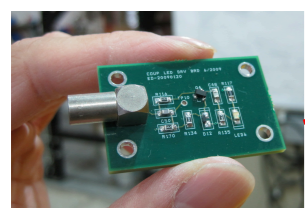
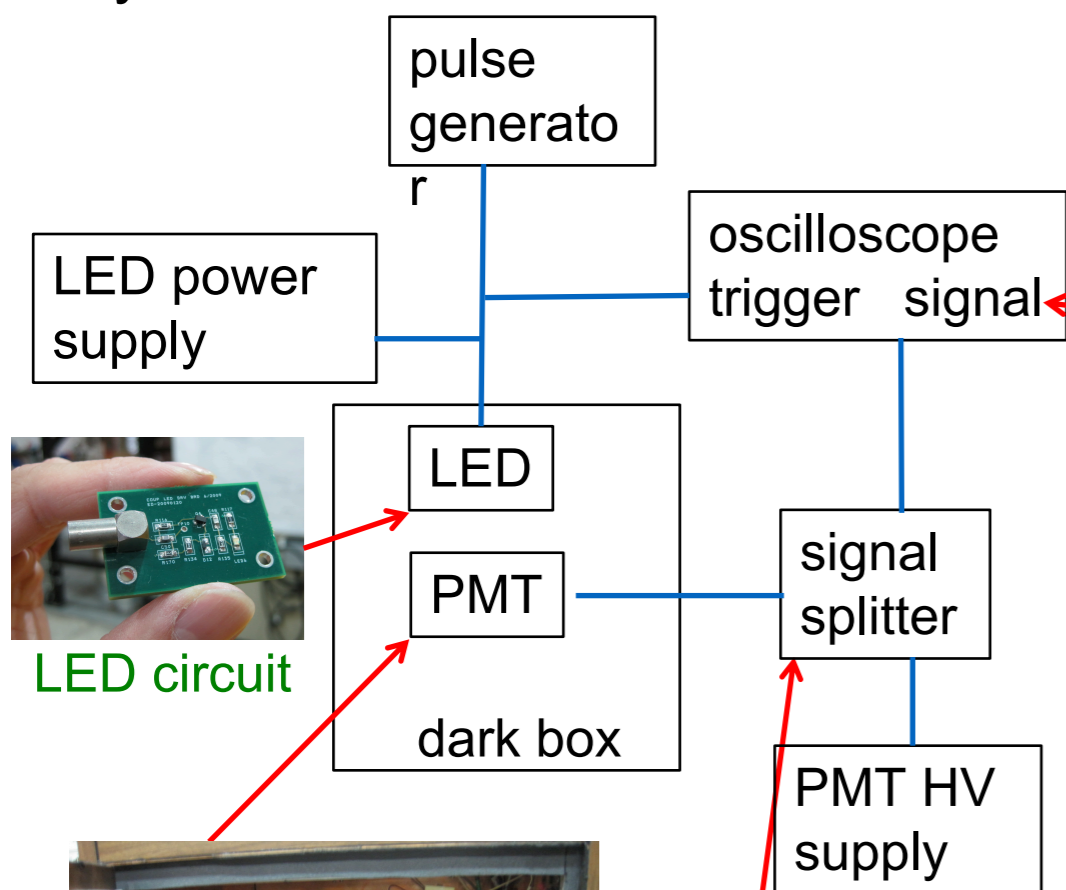
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Cryogenic base

- Metal film resistor, NP0/C0G capacitor, glass reinforced PC board, Teflon cable, etc
- Naked board (LAr is good insulator)
- Positive HV operation → One cable carries both signal and HV
- Total heat ~ 0.5W



Every PMTs are tested before installation



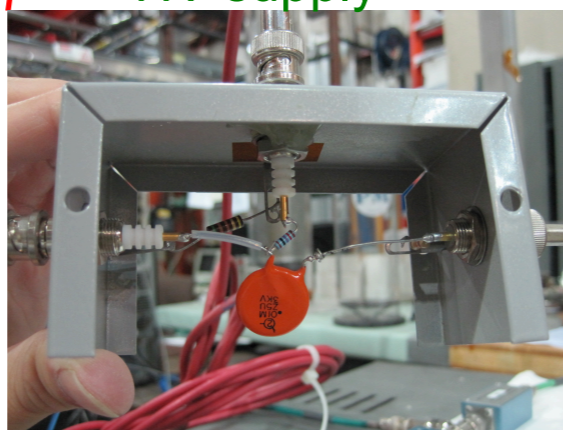
LED circuit



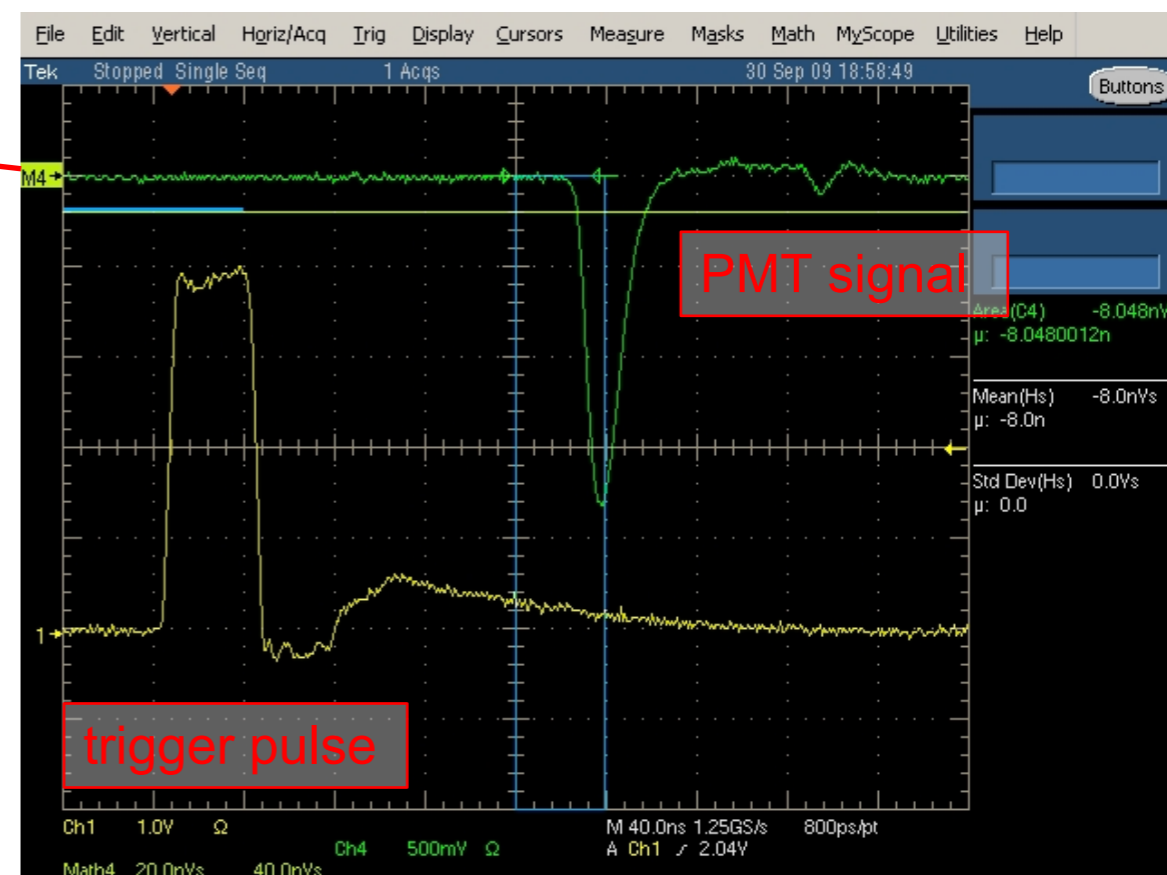
PMT with base

PMT signal

HV supply



output



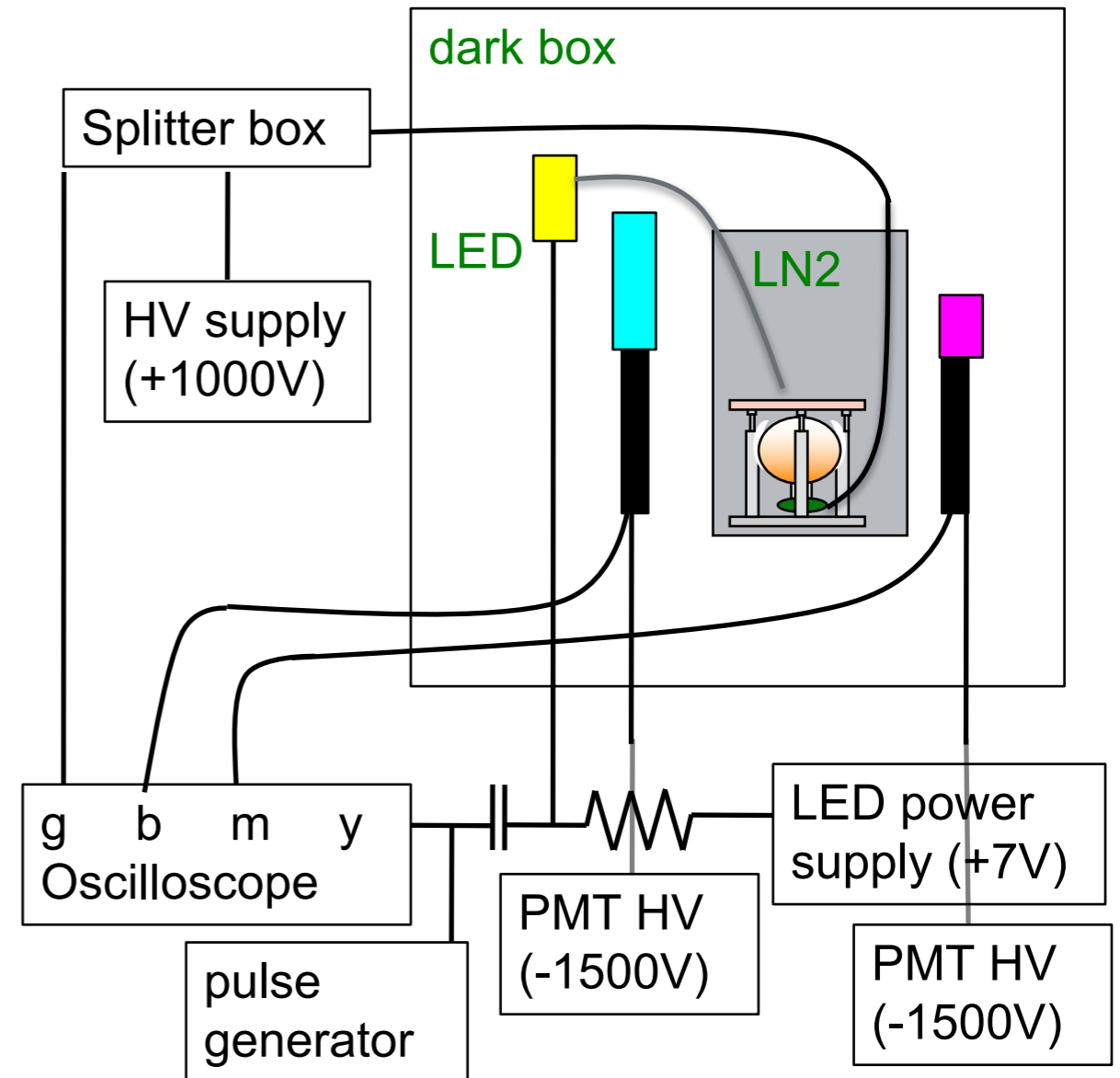
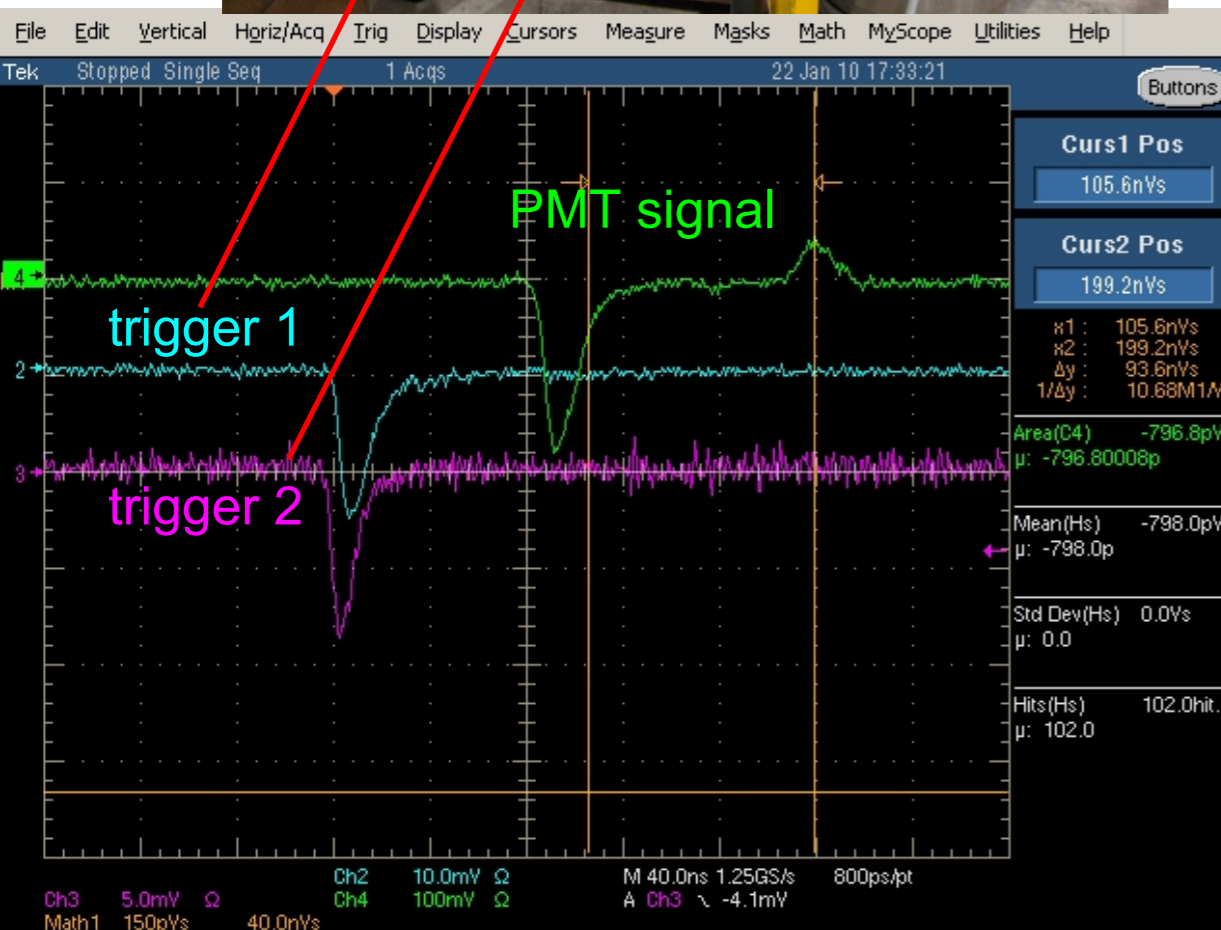
PMT pulse is observed.
PMT+base+splitter work fine in room temperature.

Detector concept (Lecture 6)
Signal transmission (Lecture 7)
Signal processing (Lecture 8)

Every PMTs are tested before installation

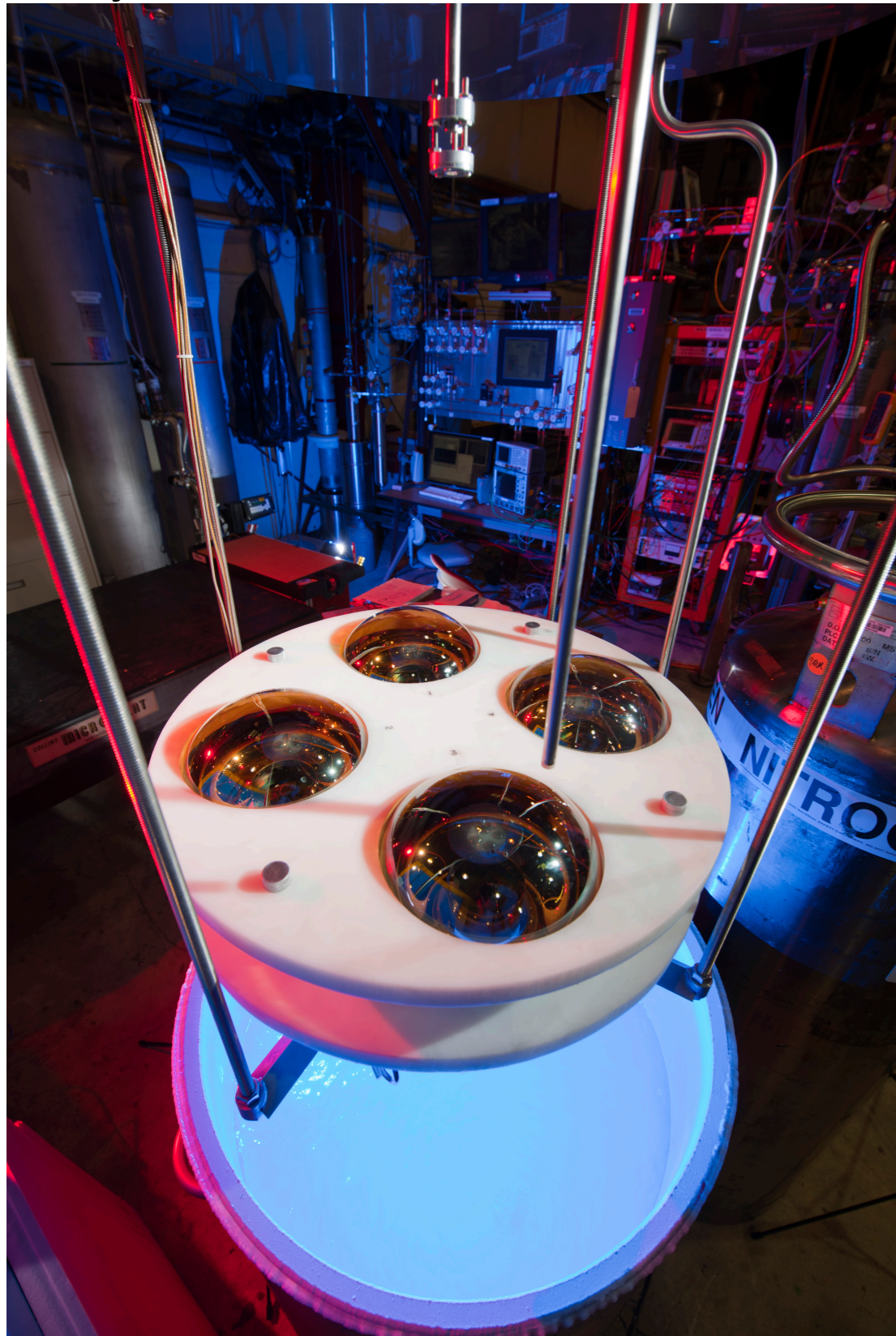


PMT LN2 running with counters
- PMT sees cosmic rays, too

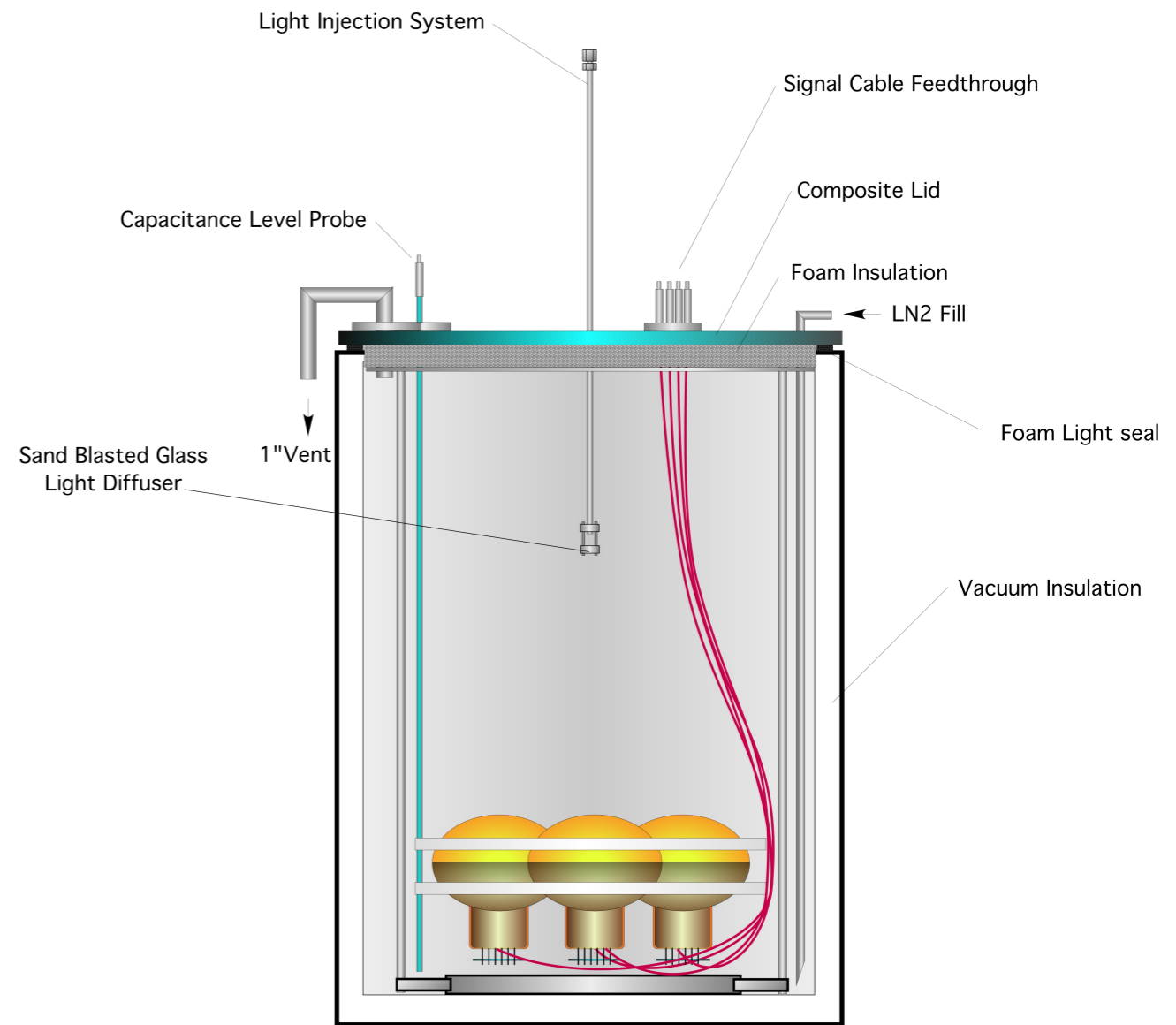


radiation Detector

Every PMTs are tested before installation



PMT TEST STAND



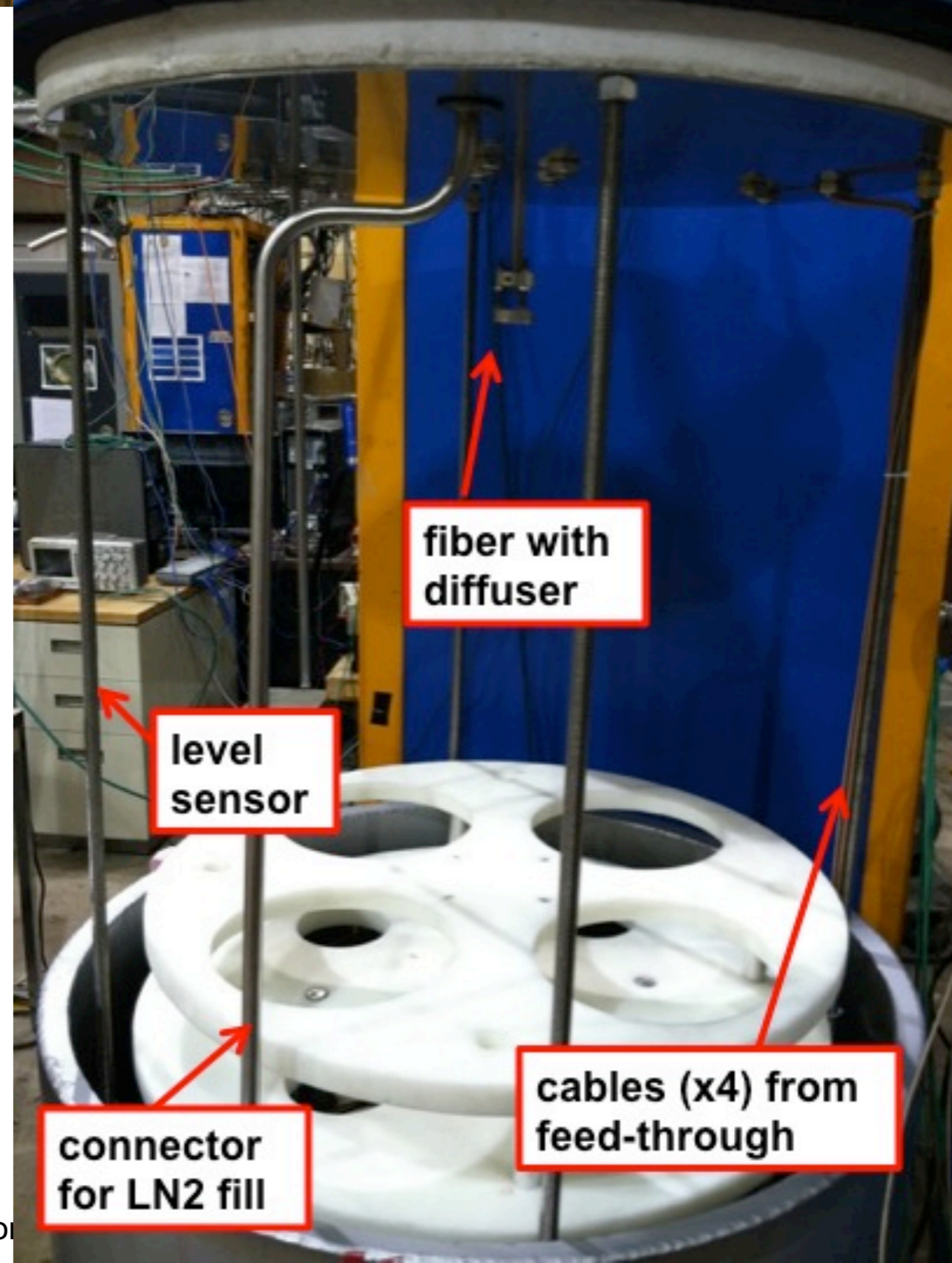
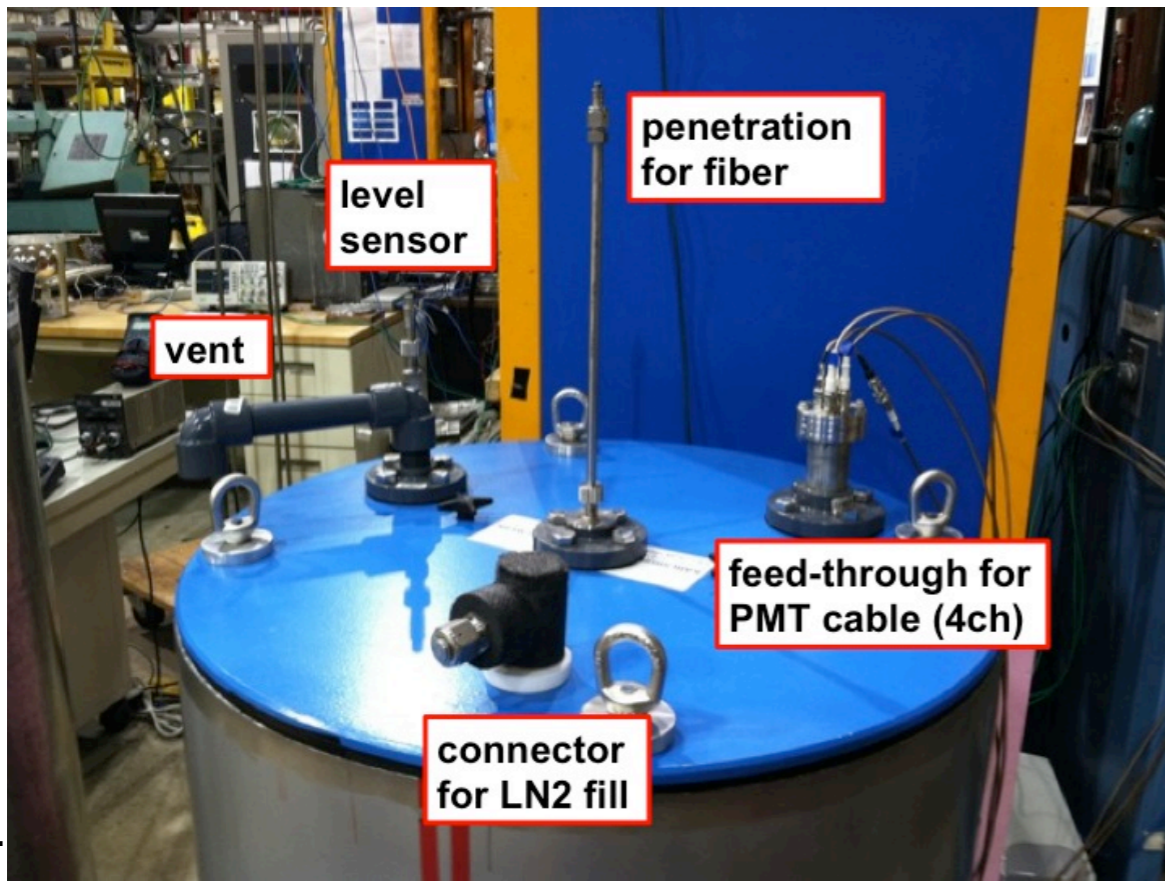
C.Kendziora 12.21.12

Every PMTs are tested before installation

Lid

- All structures are attached on glass fiber lid
- there are 5 penetrations
 - i. LN2 injection
 - ii. gas vent
 - iii. level sensor
 - iv. cable feed-through
 - v. light injection system

Fiber is coupled to LED outside of Dewar, sand blasted diffuser illuminate all PMTs



Every PMTs are tested before installation

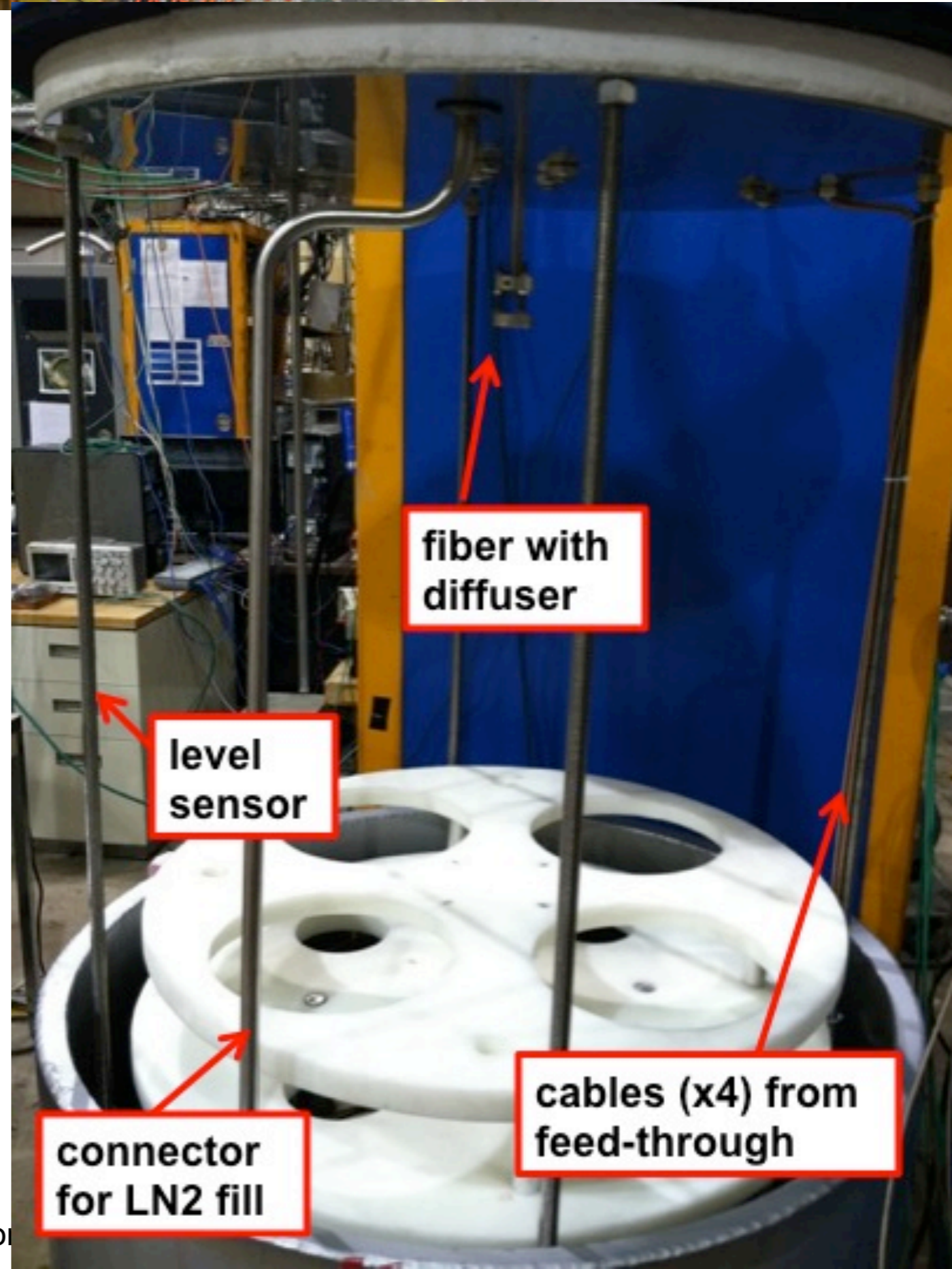
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PMT fixture

- In room temperature, PMTs sit on Delrin bottom fixture
- In LN2, PMTs float and fit in Delrin upper fixture
- There is a weight at the bottom of the structure



fiber with diffuser

level sensor

connector for LN2 fill

cables (x4) from feed-through

Every PMTs are tested before installation

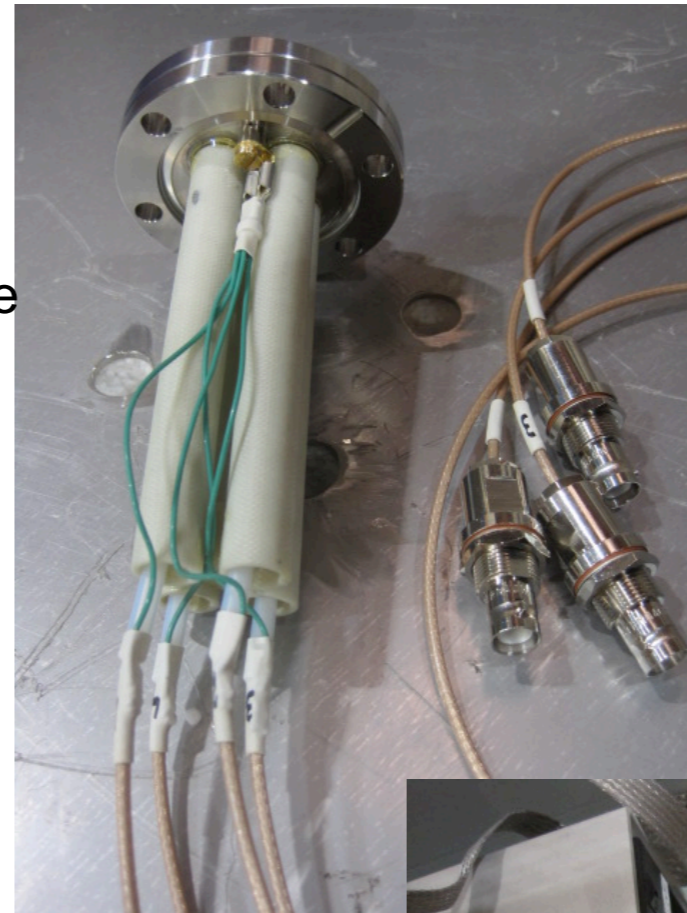
chief engineer, Nathan B.

light injection system

fiber injection



optical fiber penetrates (SMA connected to variable LED) lid, and sand-blast glass diffuser diffuses light.

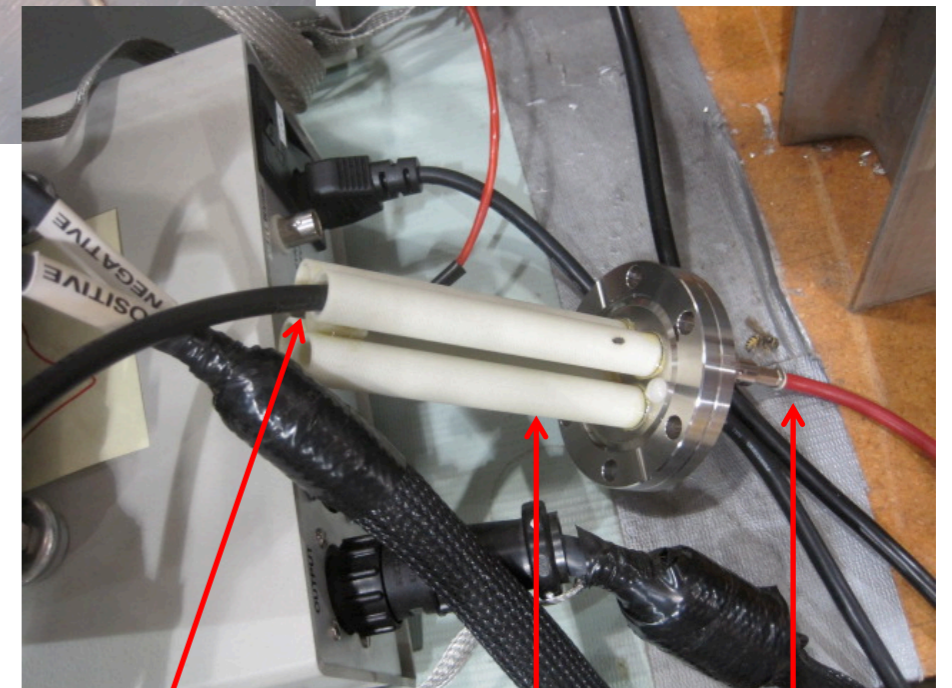
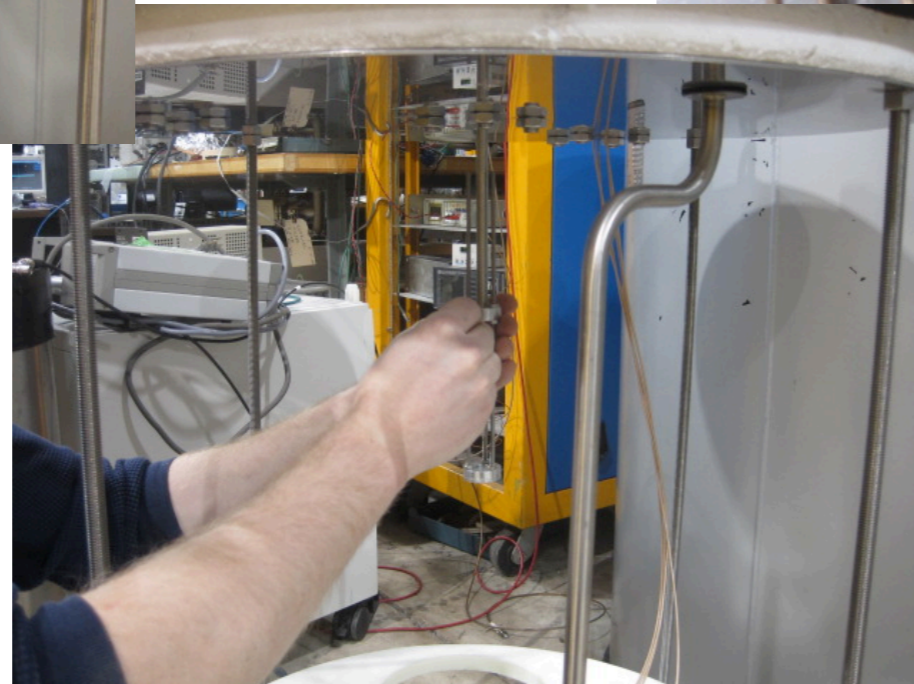


HV feed-through
Commercial SHV feed-through has 4 pig tails. The connectors are tested with 8kV with gas Argon.

fiber end

sand blasted glass diffuser

We can control the depth of the fiber and the distance to the diffuser



Argon gas

G10 spark protection

HV (8kV)

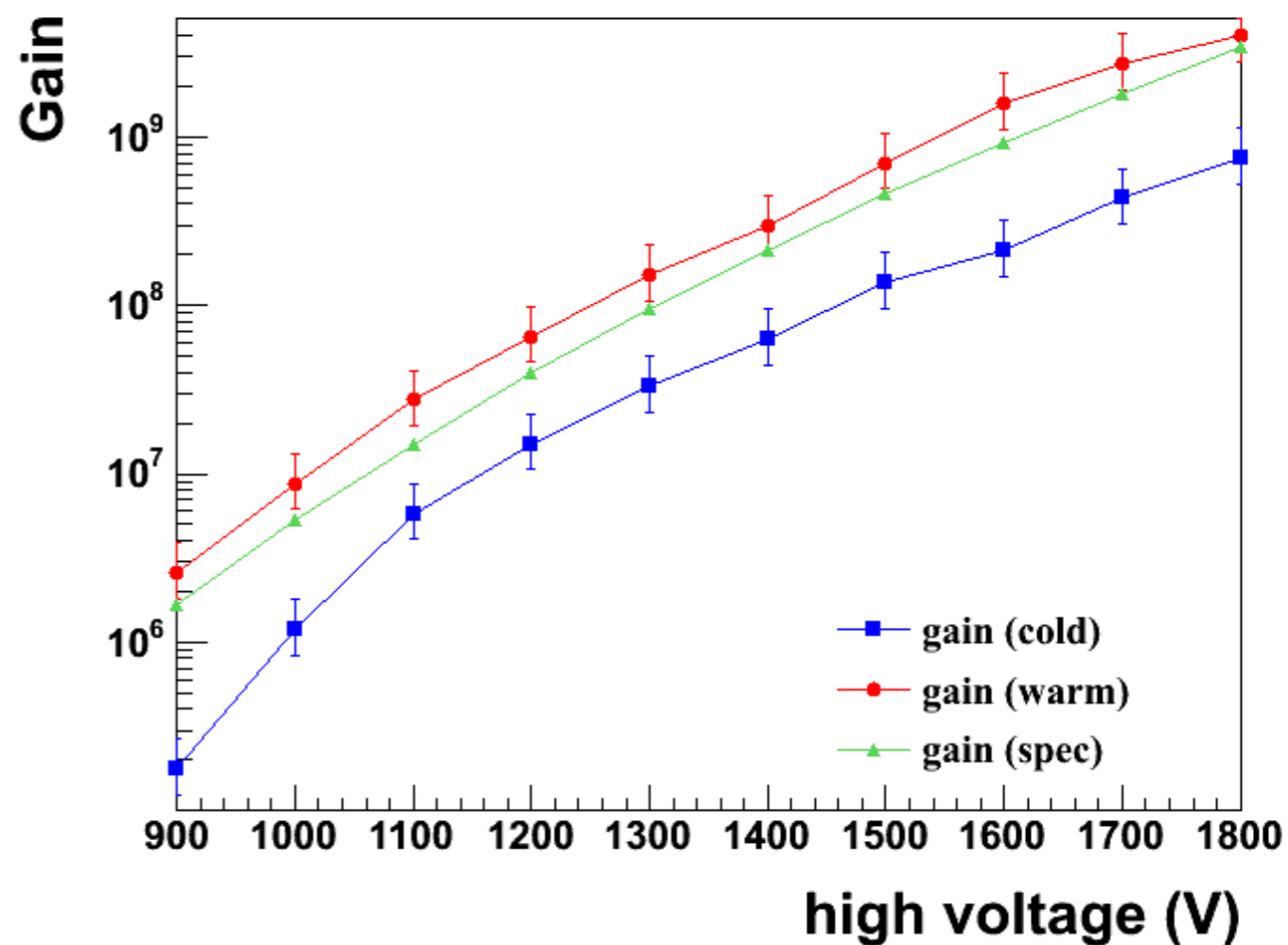
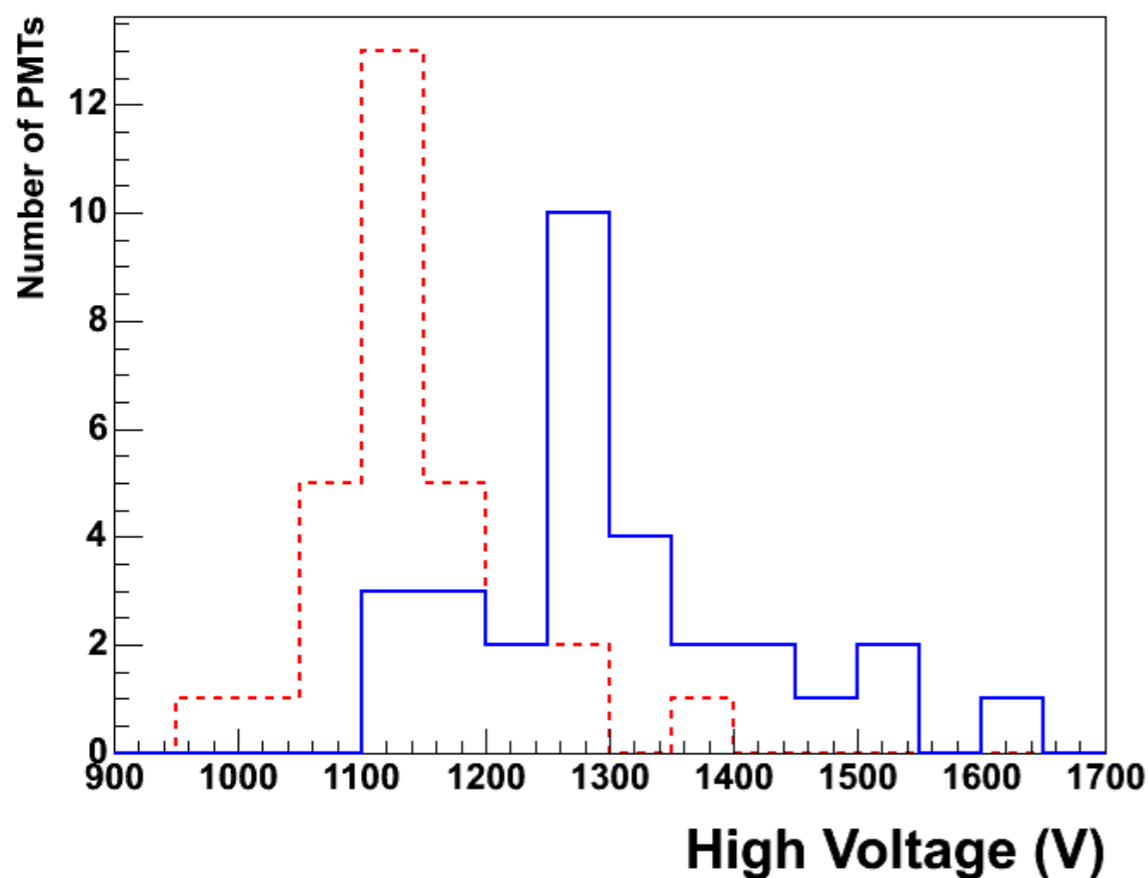
Every PMTs are tested before installation



Every PMTs are tested before installation

Basic properties of PMTs are tested

- Long term stability
- Cooling test (how fast to cool down?)
- Noise in cryogenic temperature
- Gain change in cryogenic temperature



Statistics (Lecture 5)

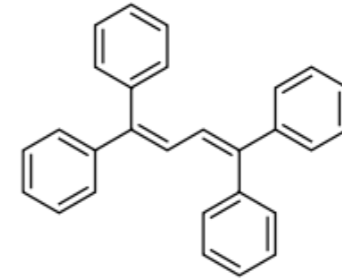
Tetra-Phenyl Butadiene (TPB)



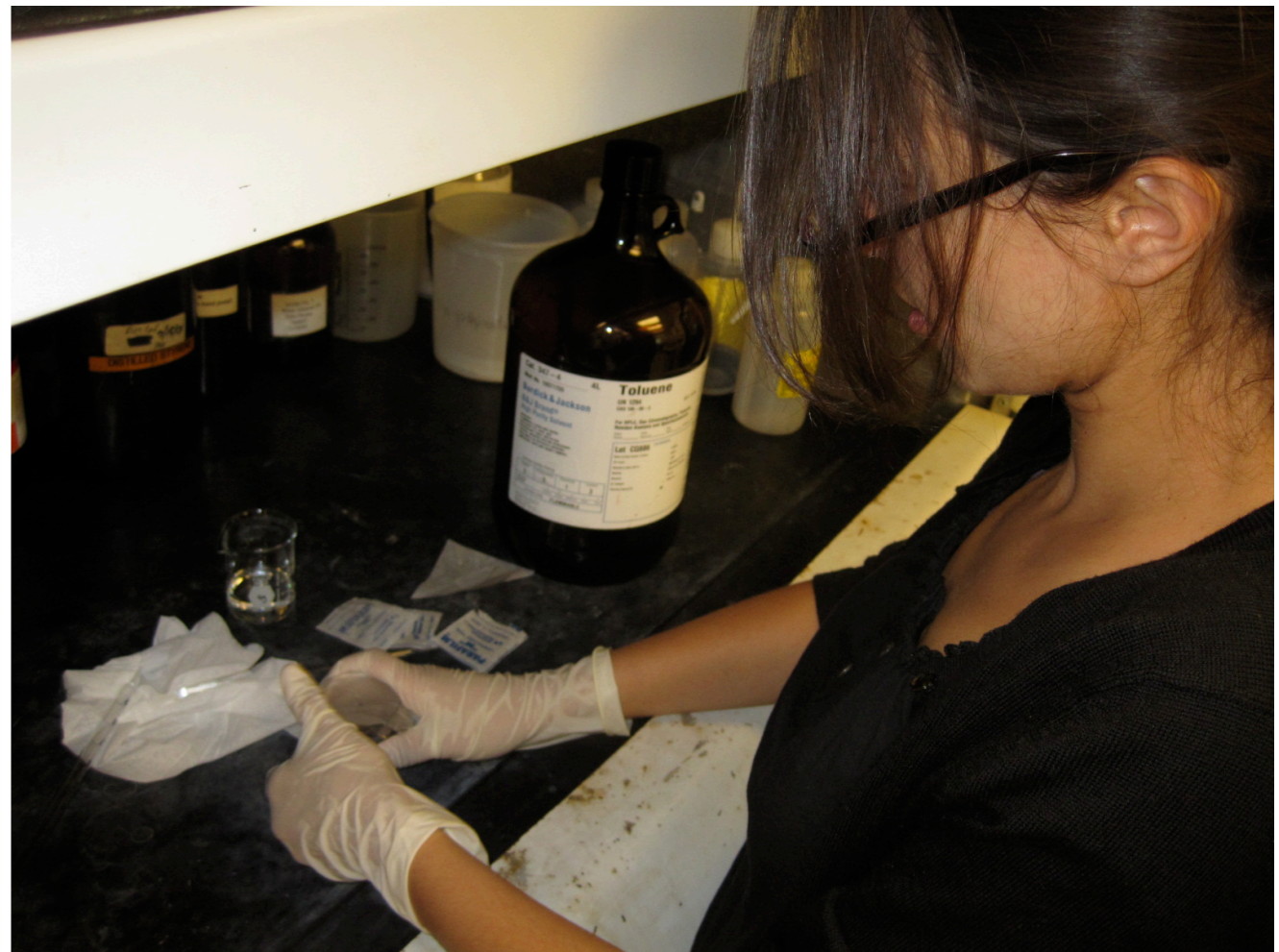
Scintillation of liquid argon is not visible by PMTs

TPB (tetraphenyl butadiene)

- convert 128nm to blue (efficiency > 100%?!)
- degrade by UV light (possibly by humidity, too)



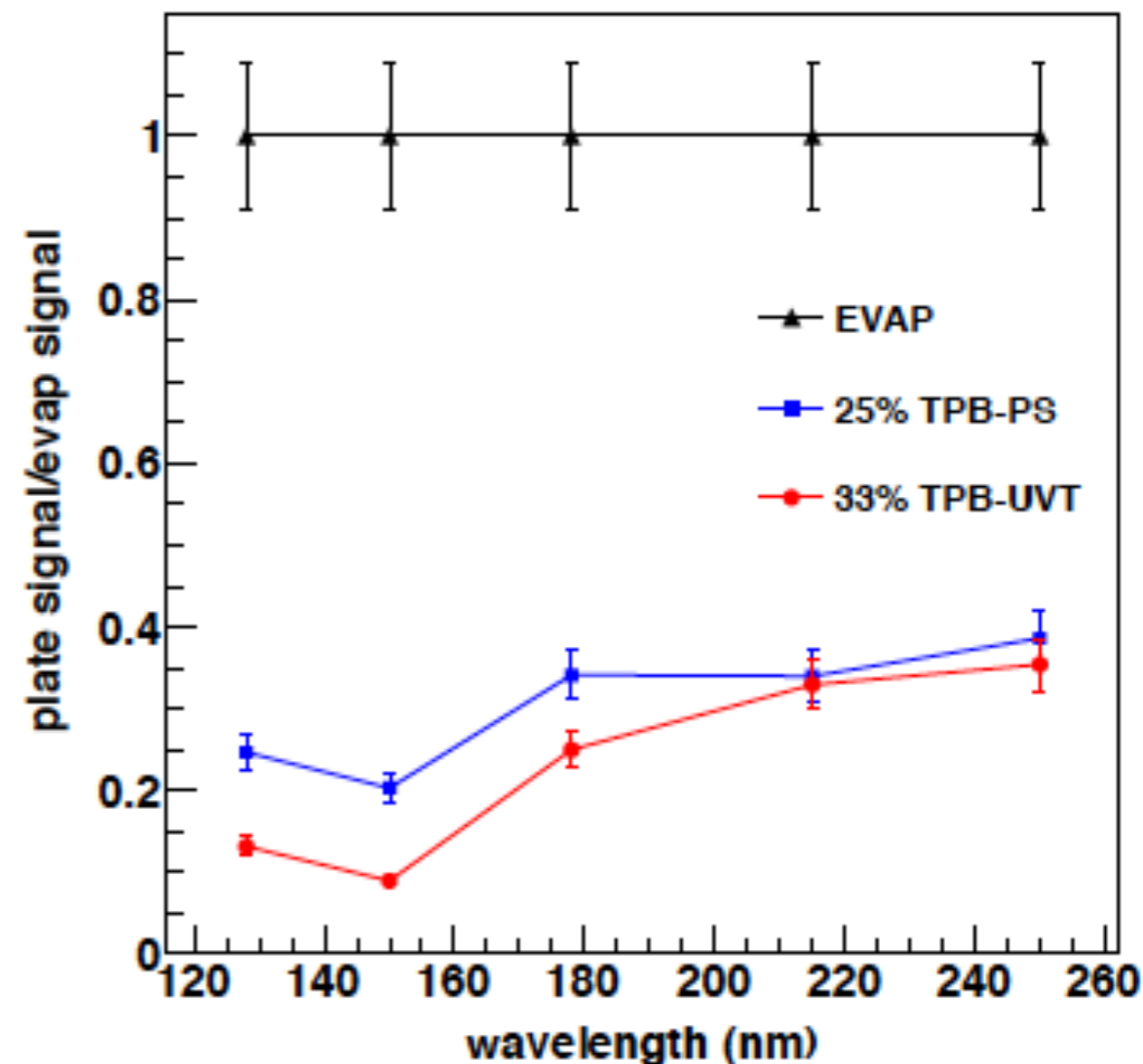
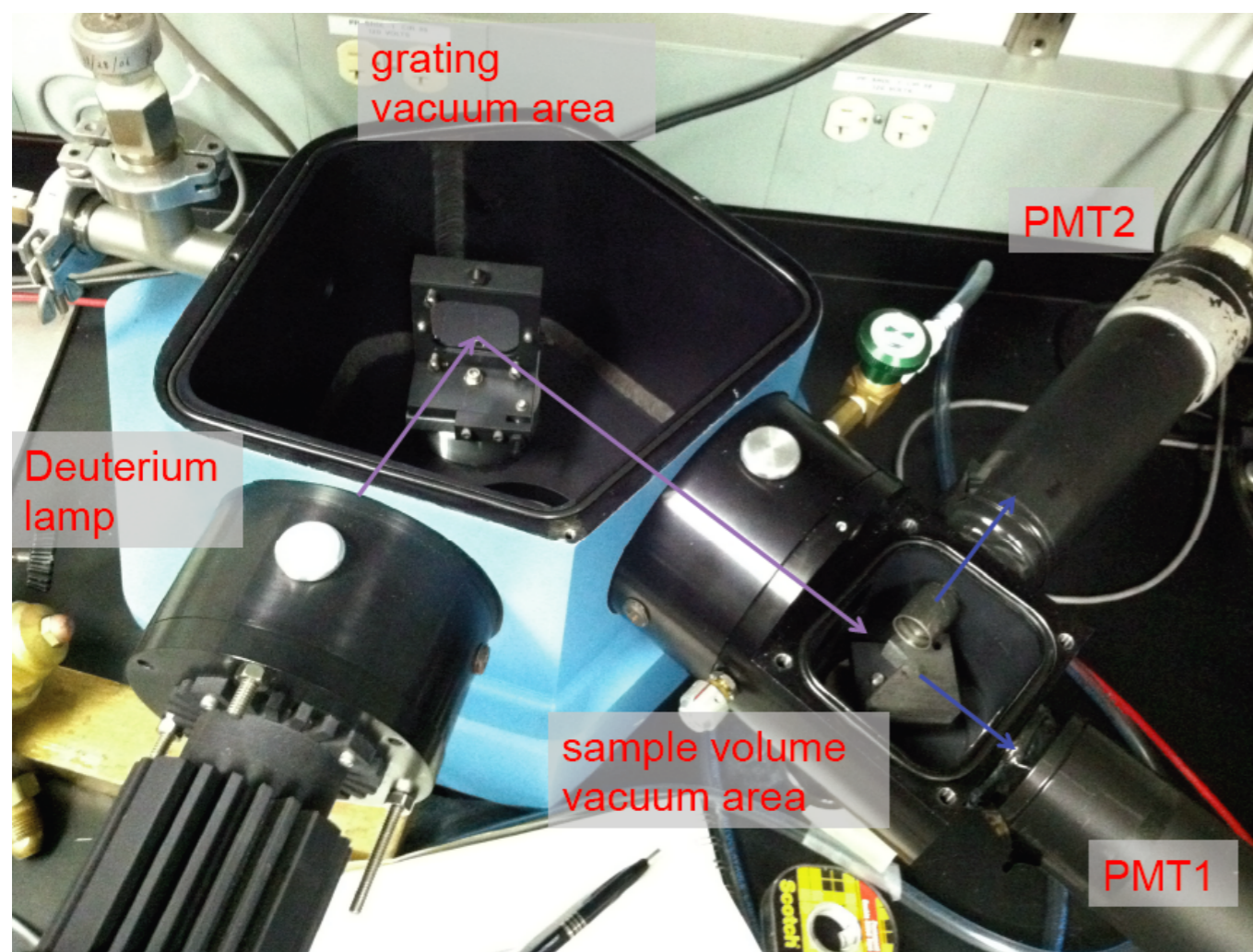
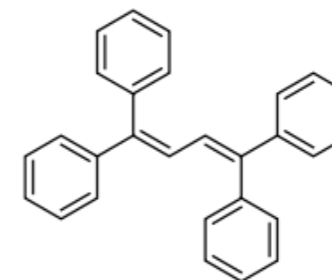
TPB plate sample



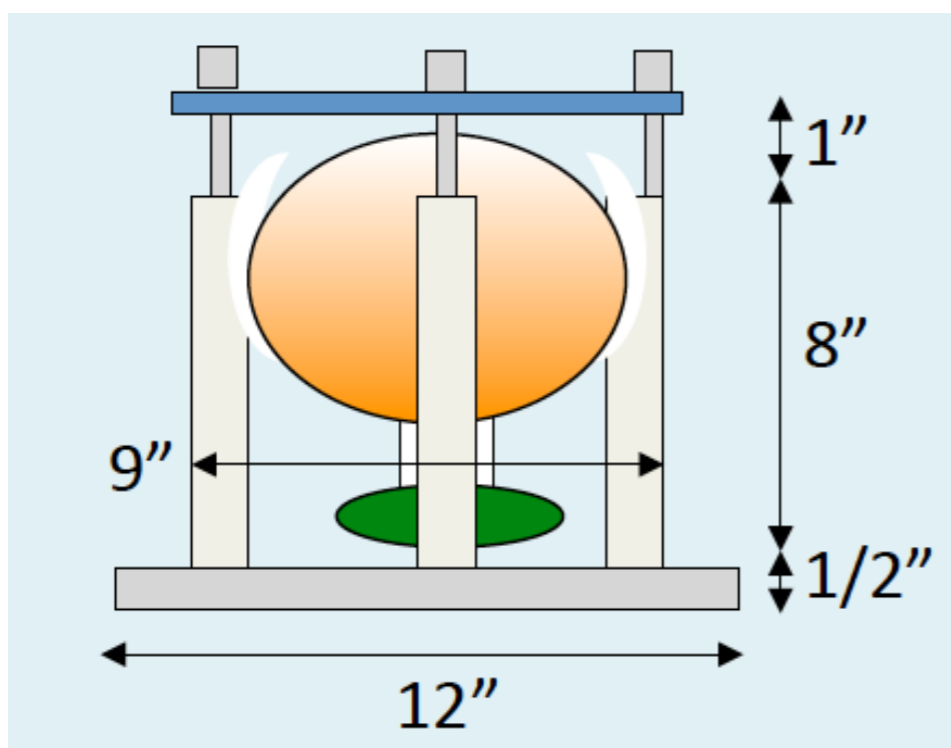
Scintillation of liquid argon is not visible by PMTs

TPB (tetraphenyl butadiene)

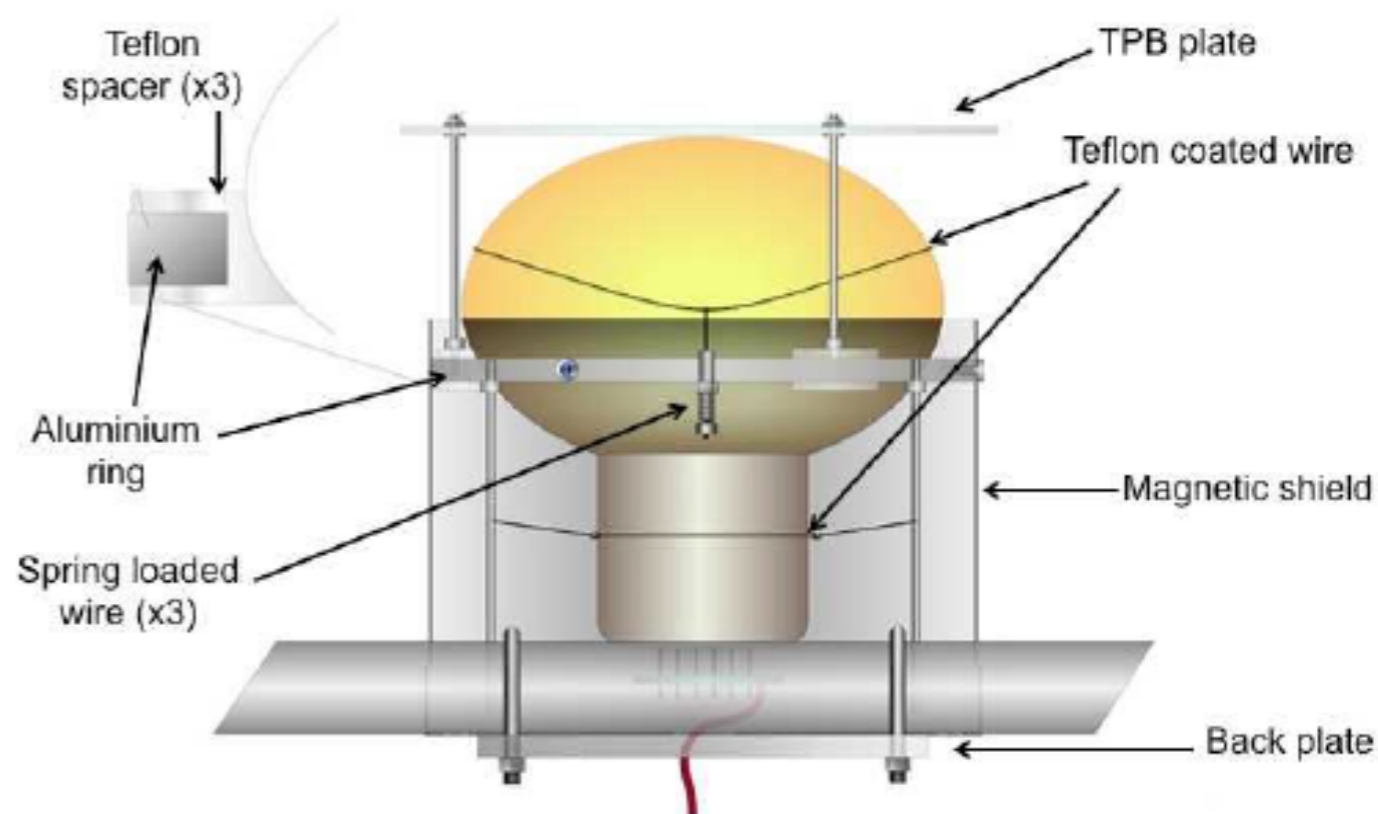
- convert 128nm to blue (efficiency > 100%?!)
- degrade by UV light (possibly by humidity, too)



- PMT sits in spring-loaded structure
- avoid direct glass-metal contact by teflon
- cryogenic magnetic shield

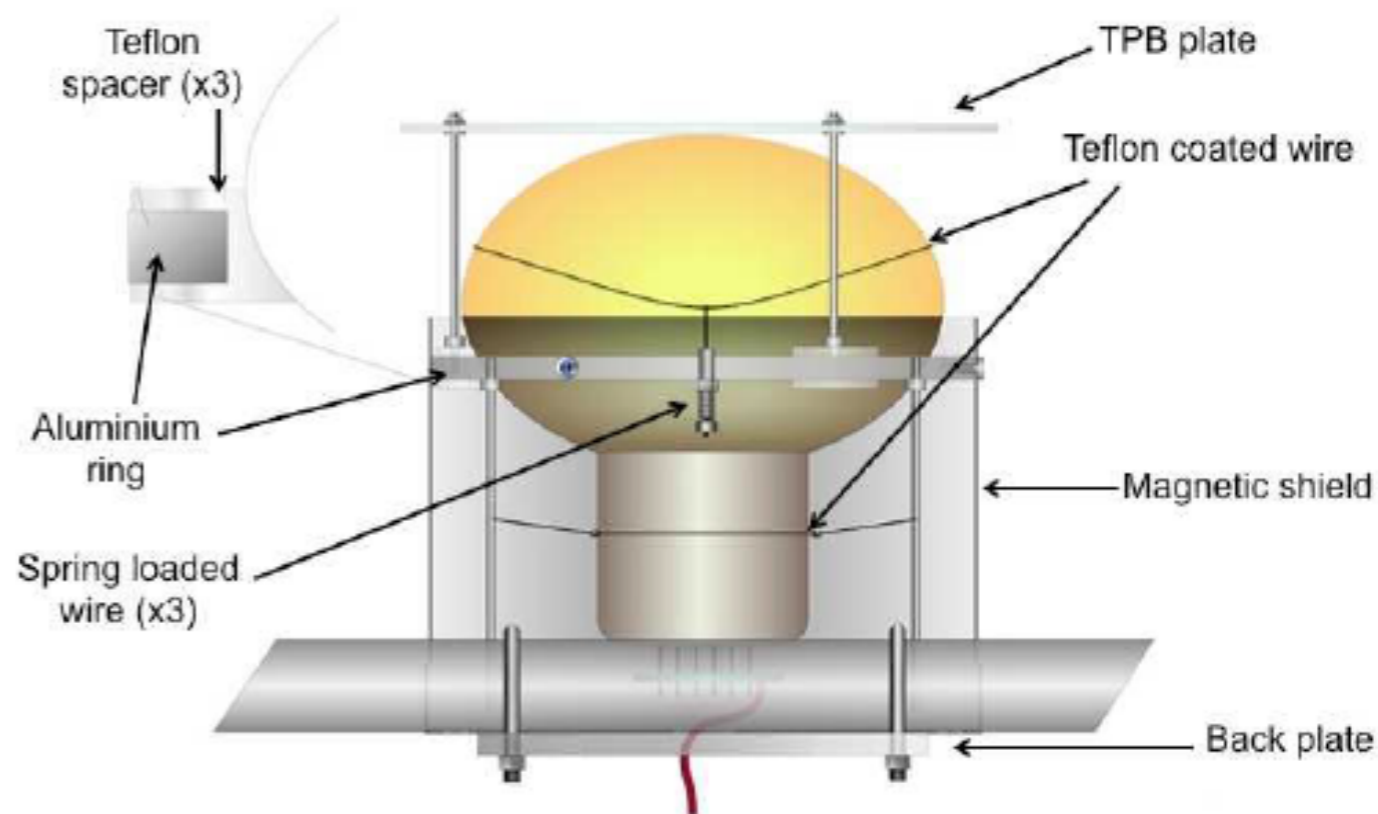
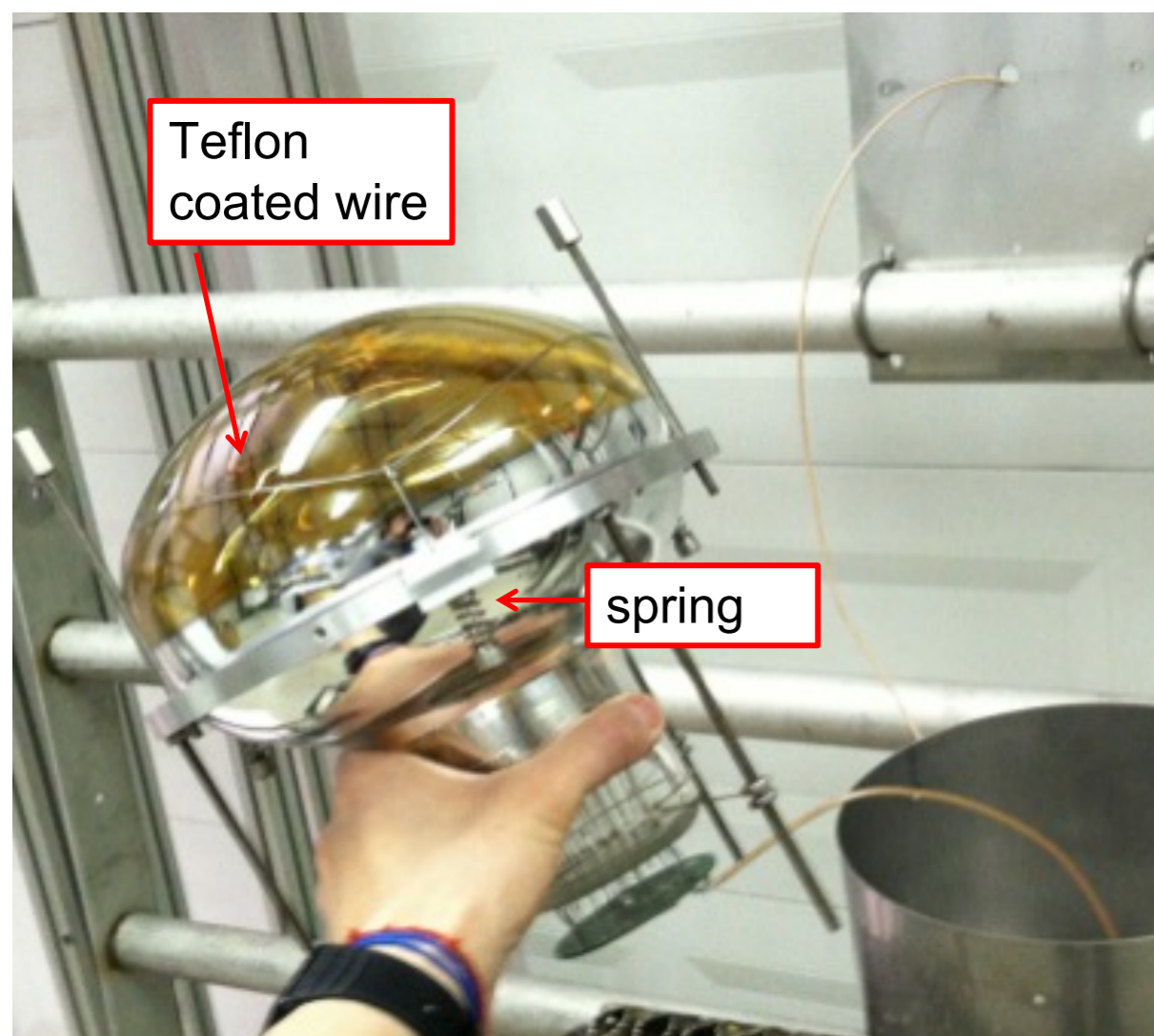


My design



Designed by engineer

- PMT sits in spring-loaded structure
- avoid direct glass-metal contact by teflon
- cryogenic magnetic shield



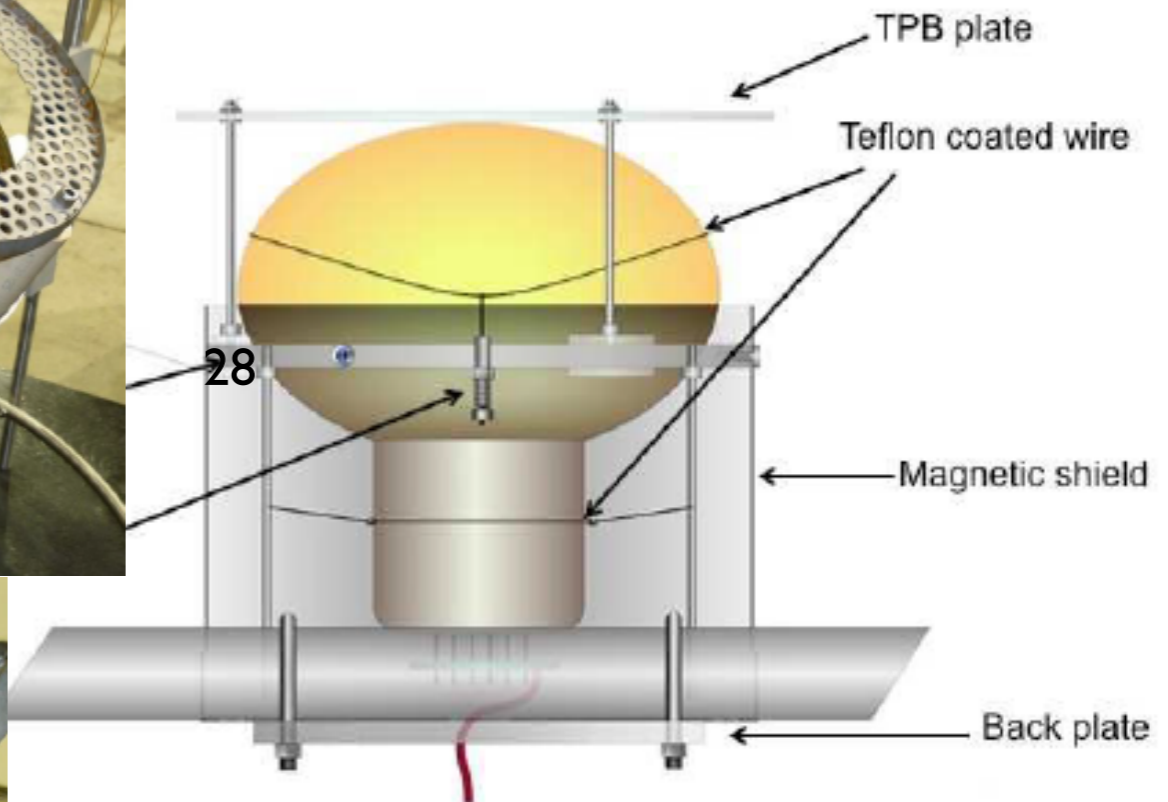
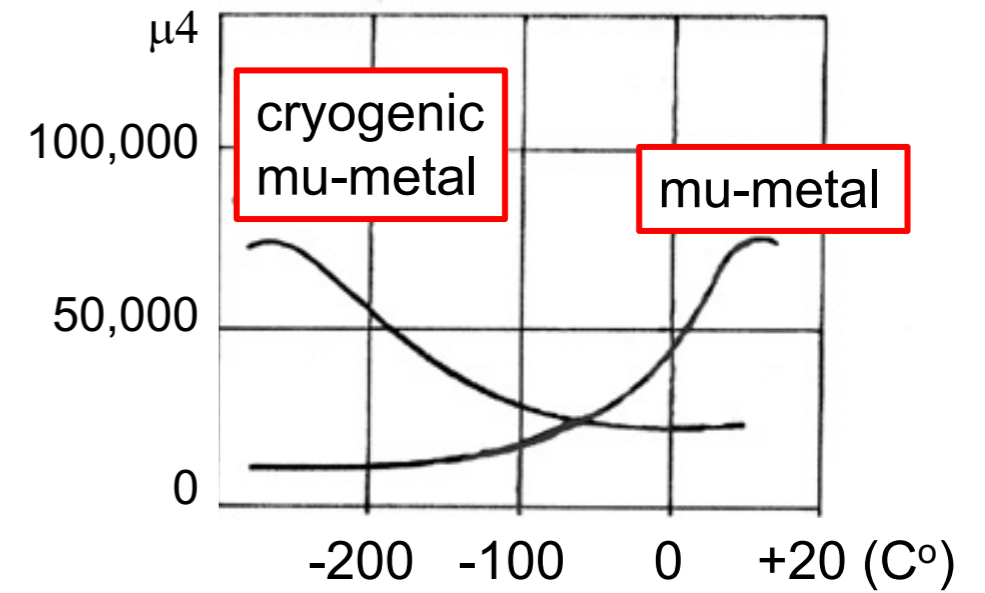
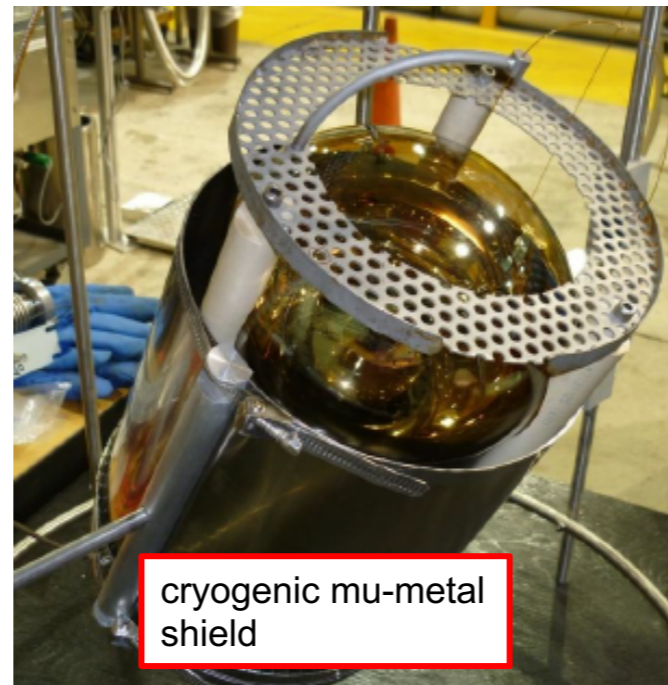
Designed by engineer

Cryogenic magnetic shield



- PMT sits in spring-loaded structure
- avoid direct glass-metal contact by teflon
- cryogenic magnetic shield

MicriBooNE PMT rotator



Designed by engineer

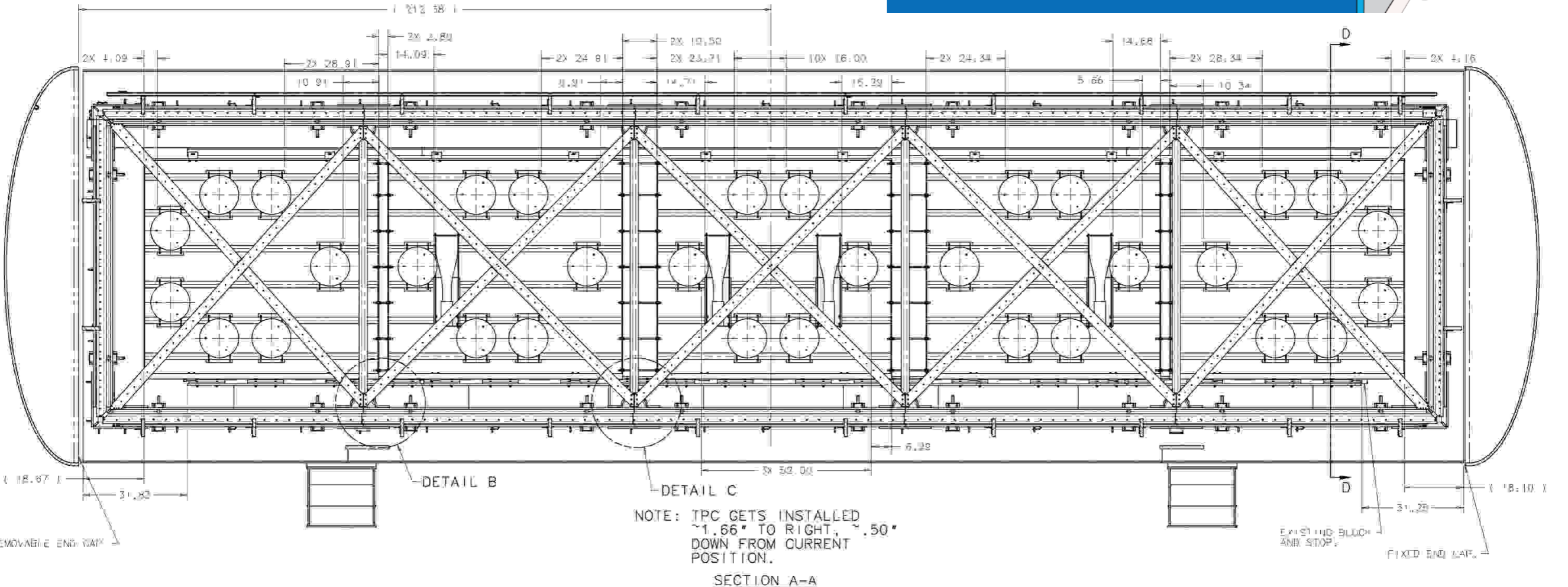
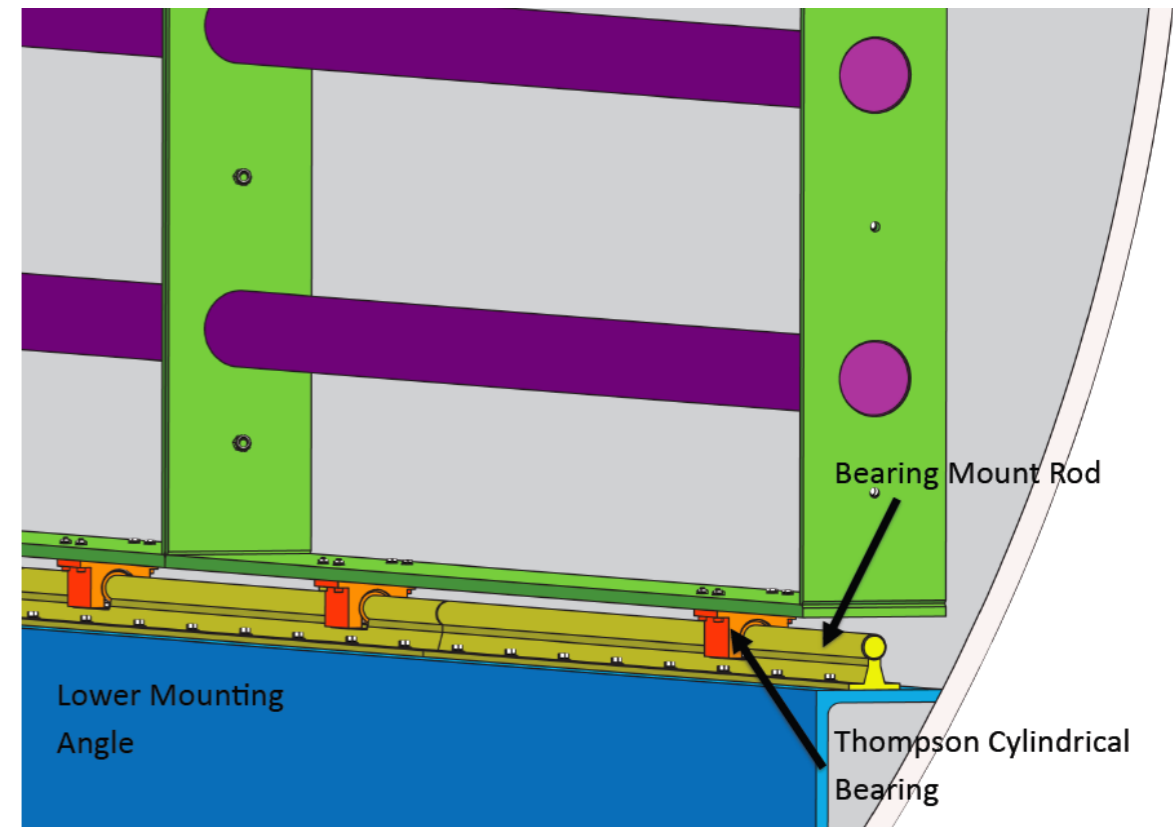
Frame design

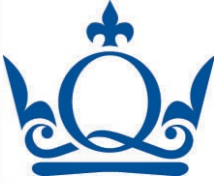


In ICARUS, PMTs need to be installed first, and sit months
→ there is a worry of degradation of TPB coating...

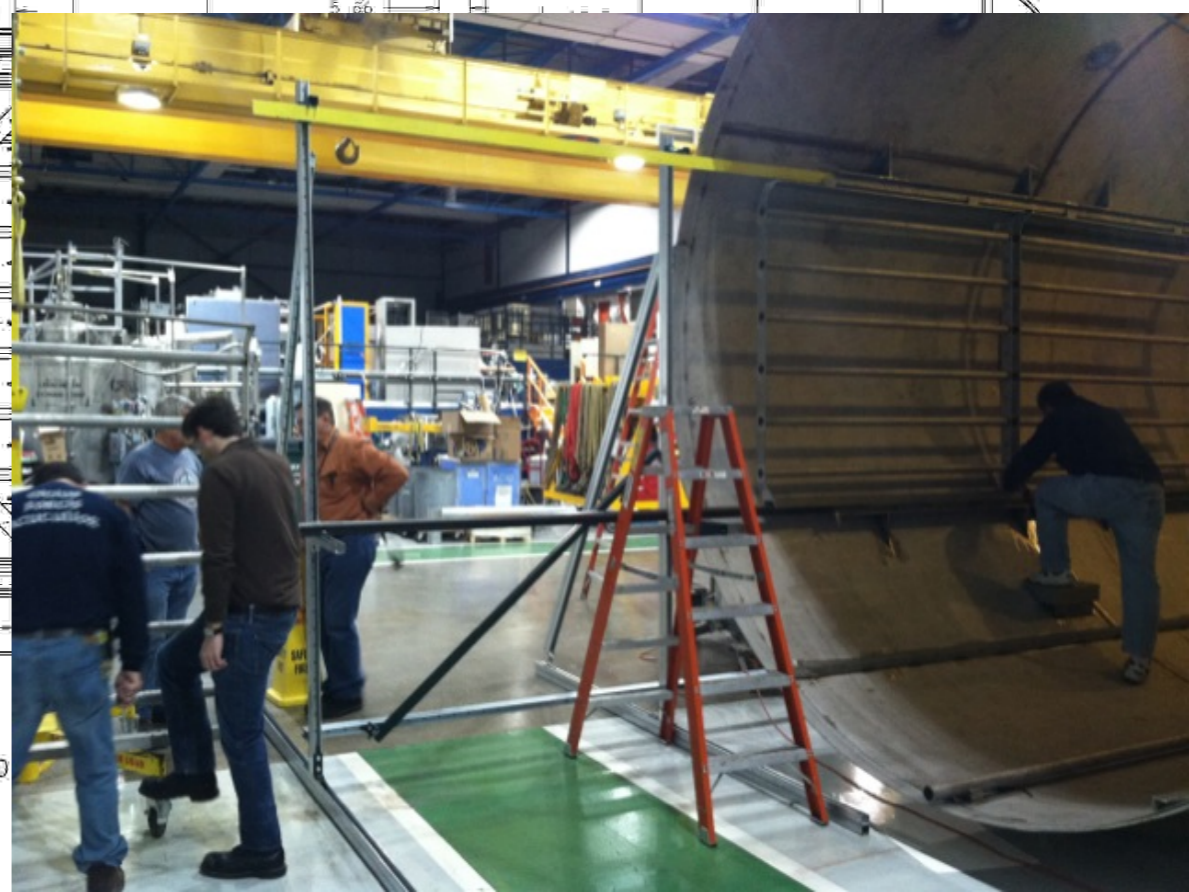
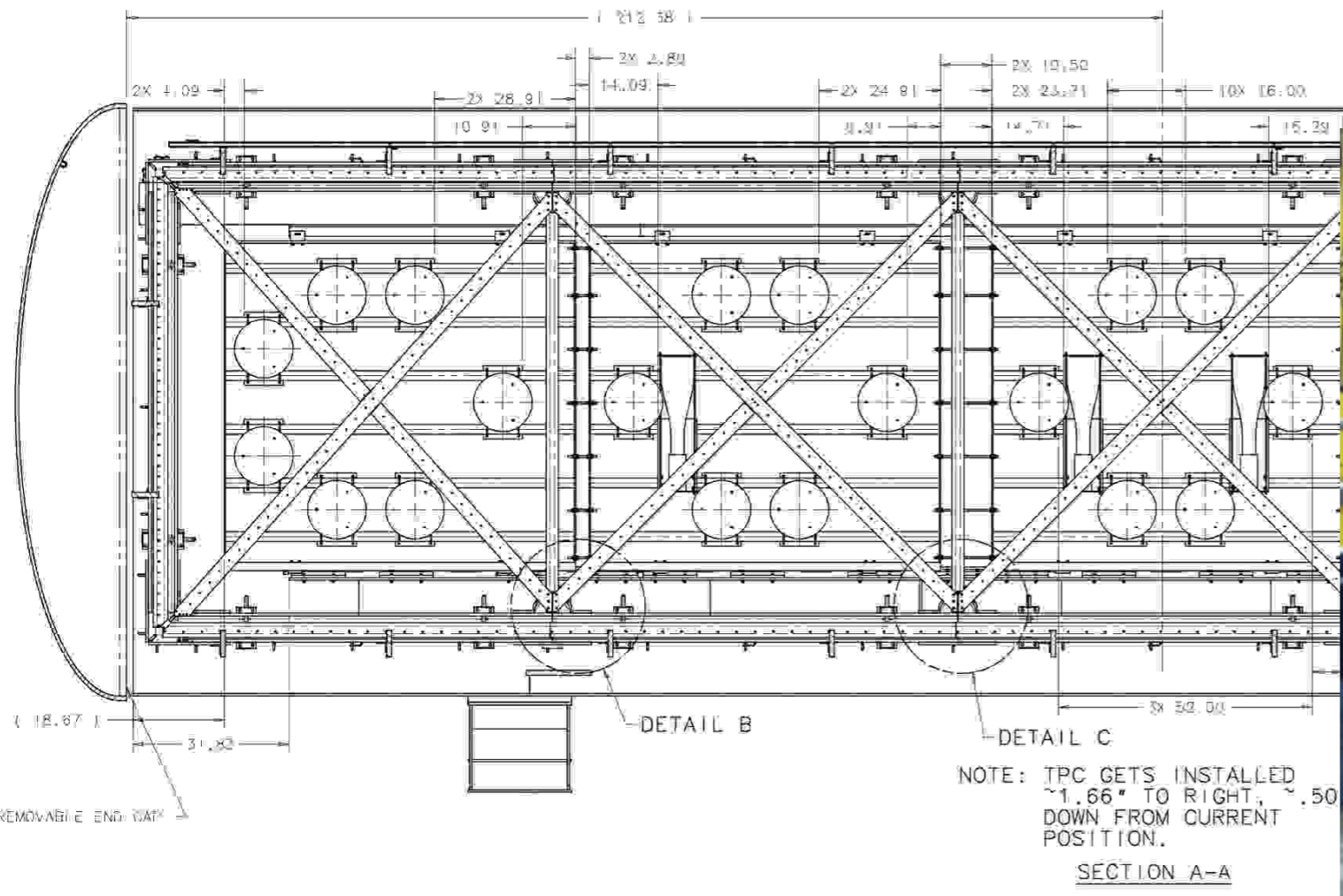
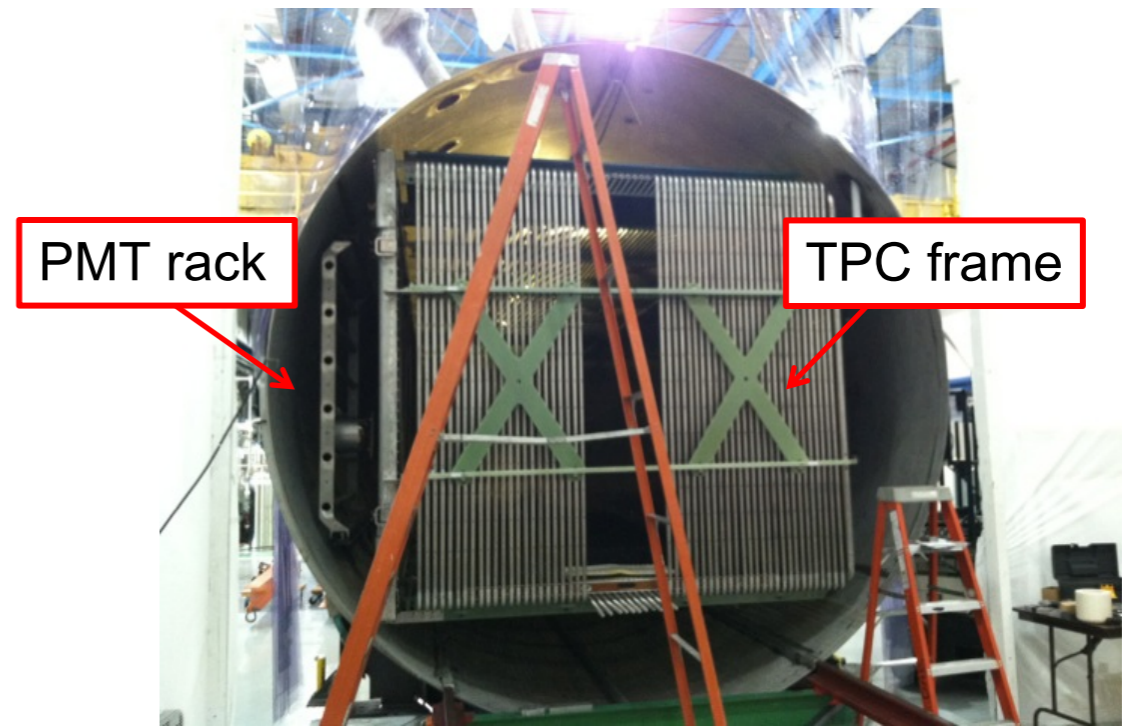
Oil-free linear (Thomson) bearing

- Racks slide in and out by Teflon coated Thomson bearing
- PMTs can be installed after TPC is installed

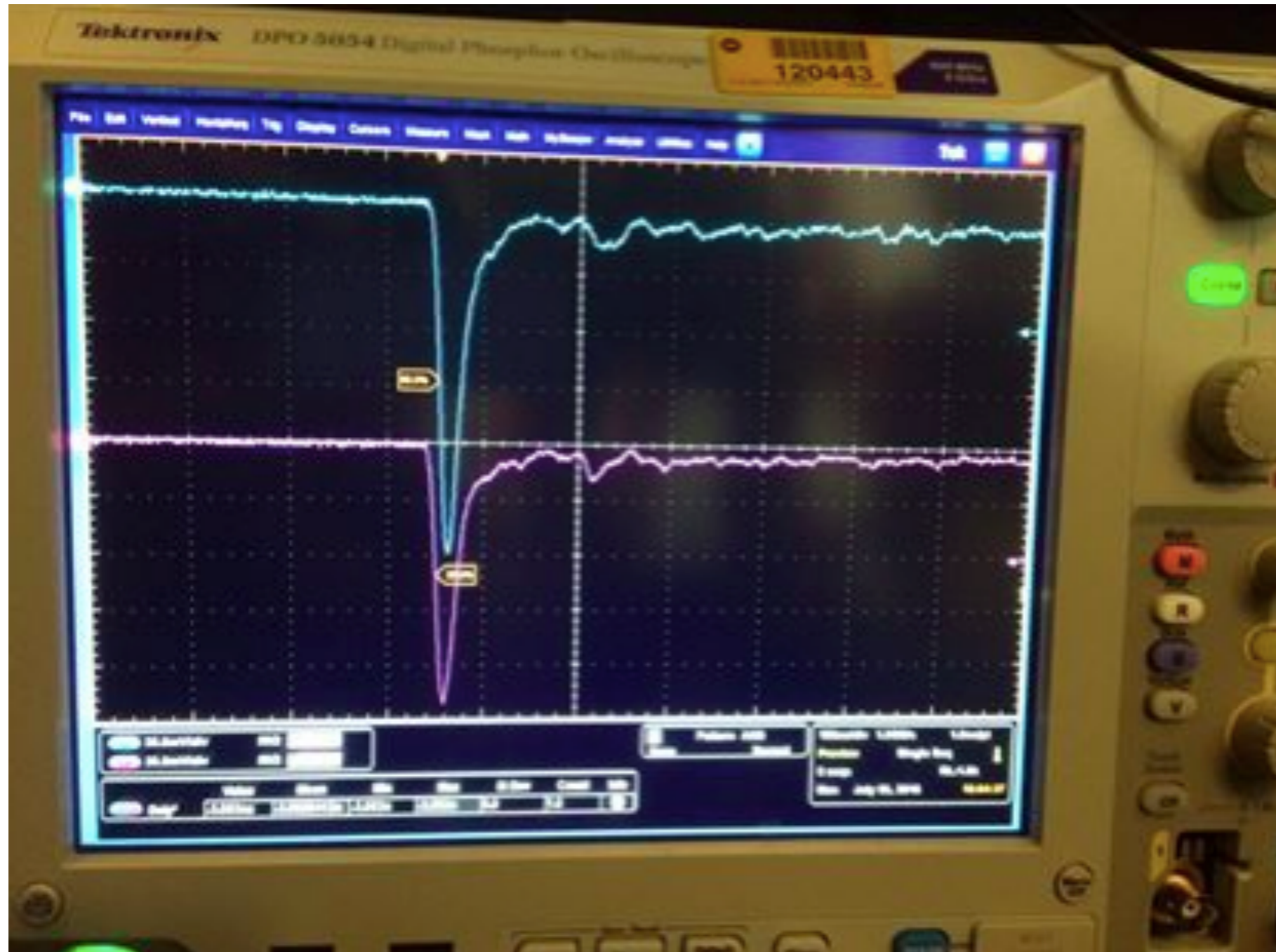




Always fun part...



First light (cosmic rays?) seen by MicroBooNE PMT system
- coincidence of 2 PMTs





Designing of an experiment (sub-detector)

1. Motivation

2. Physics of radiation mechanism

3. Detector design

- Detector mechanism

- specification

4. Performance