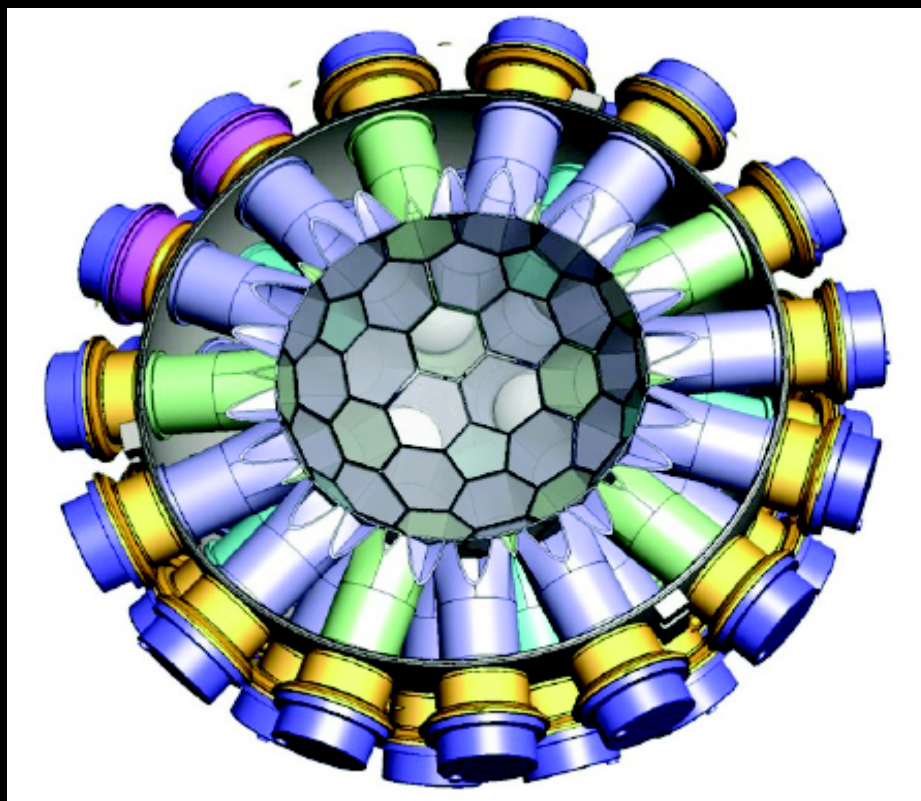


Status of the MiniCLEAN Experiment

Tom Caldwell
University of Pennsylvania

DPF – August 7, 2015



MiniCLEAN Collaboration



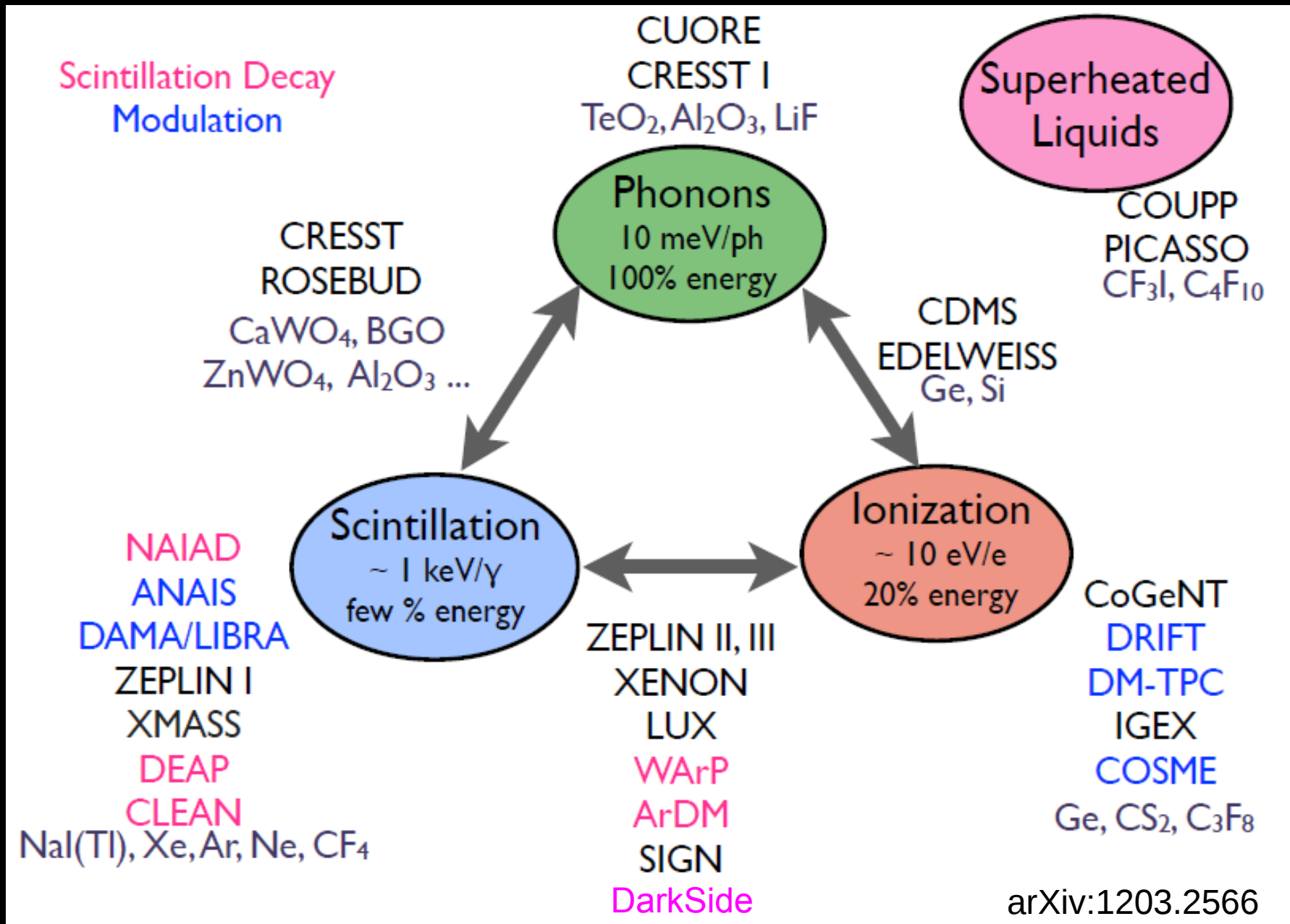
Massachusetts Institute of Technology



U.S. DEPARTMENT OF
ENERGY

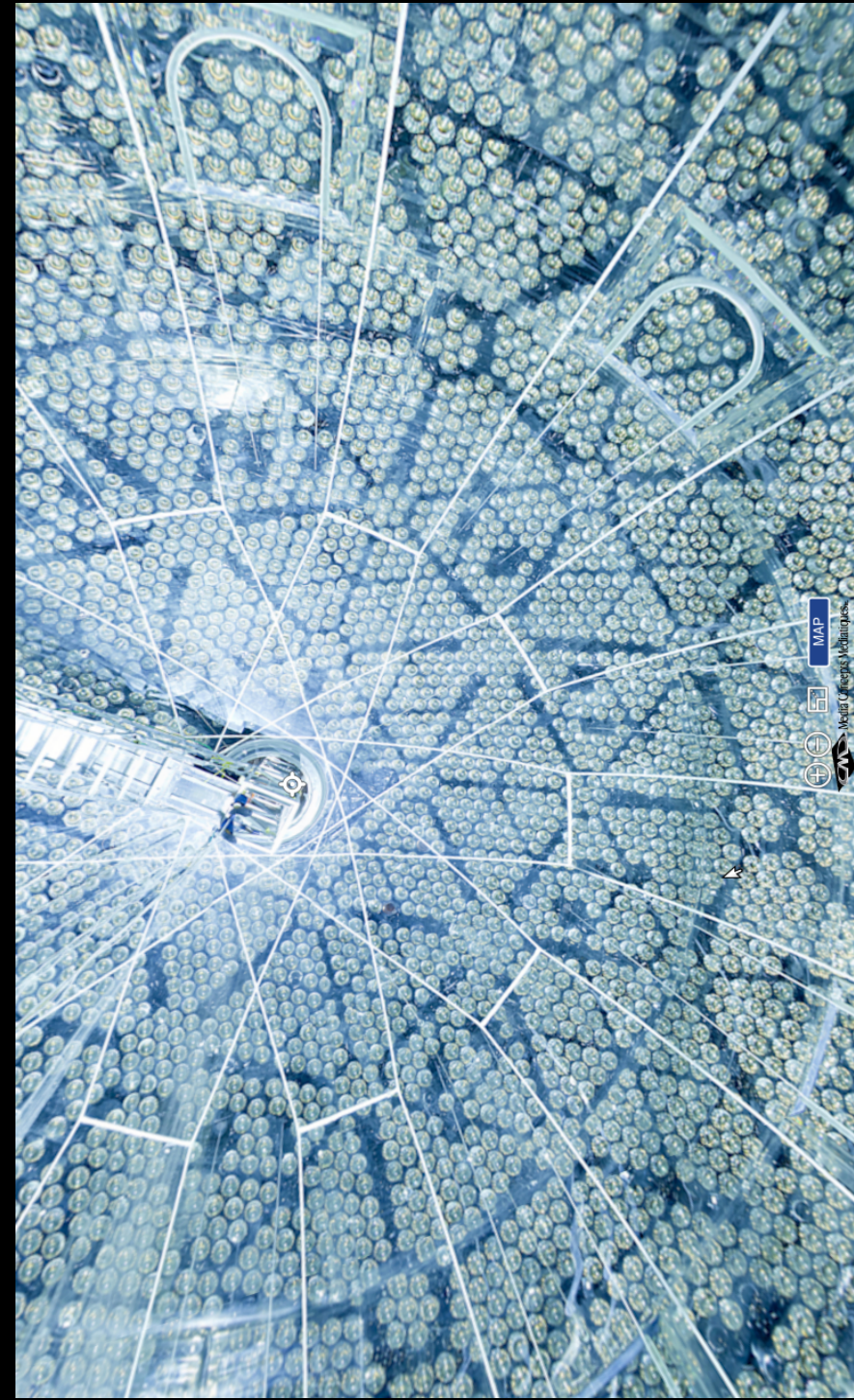
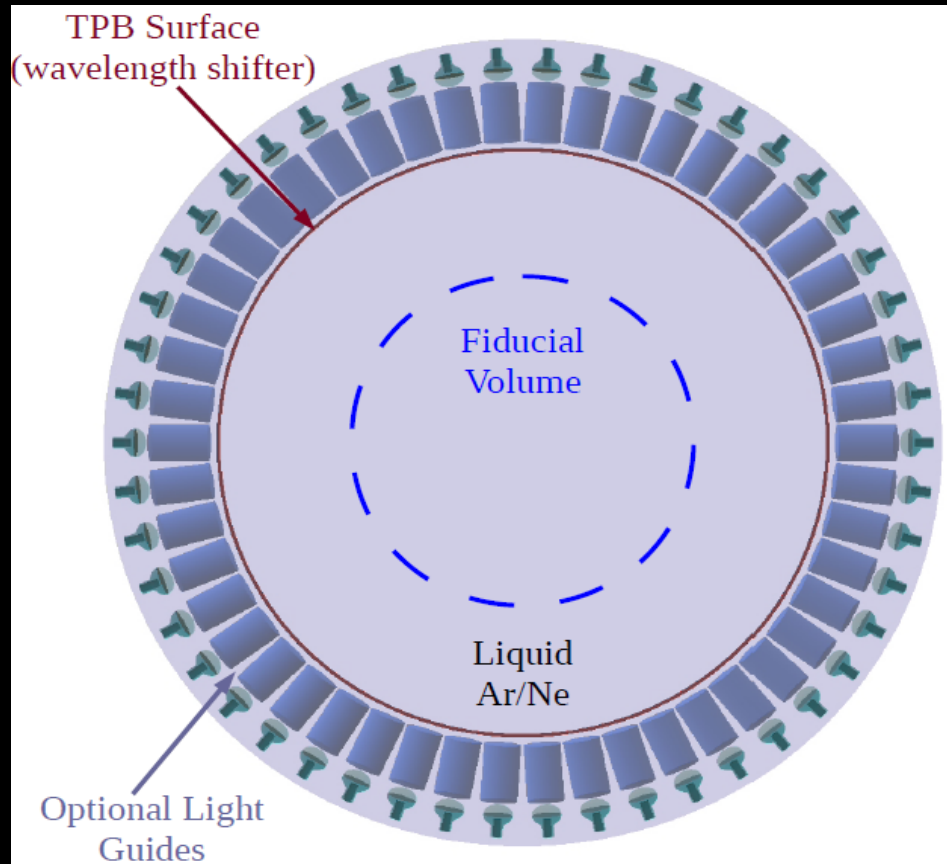
Office of
Science

Direct Detection Techniques



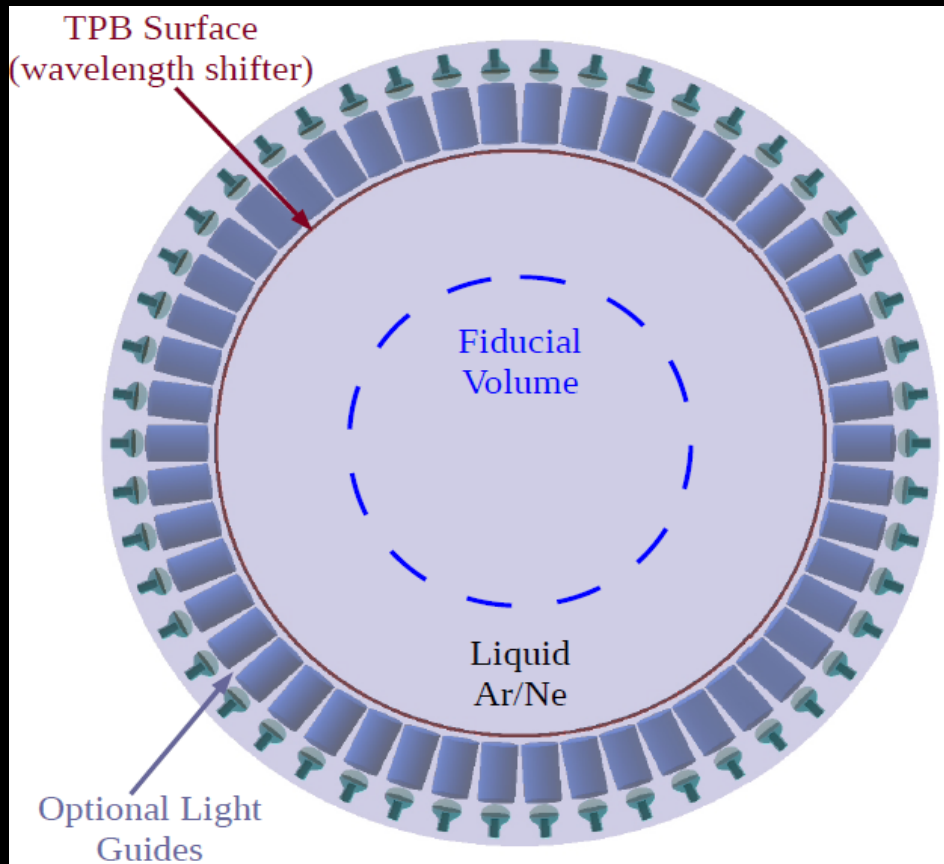
Single Phase Noble Liquid Concept

- Simple, scalable design (SNO/SNO+, Borexino, Kamiokande, etc)
- Detect only primary scintillation light from noble liquid
- 4π photomultiplier tube coverage



Single Phase Noble Liquid Concept

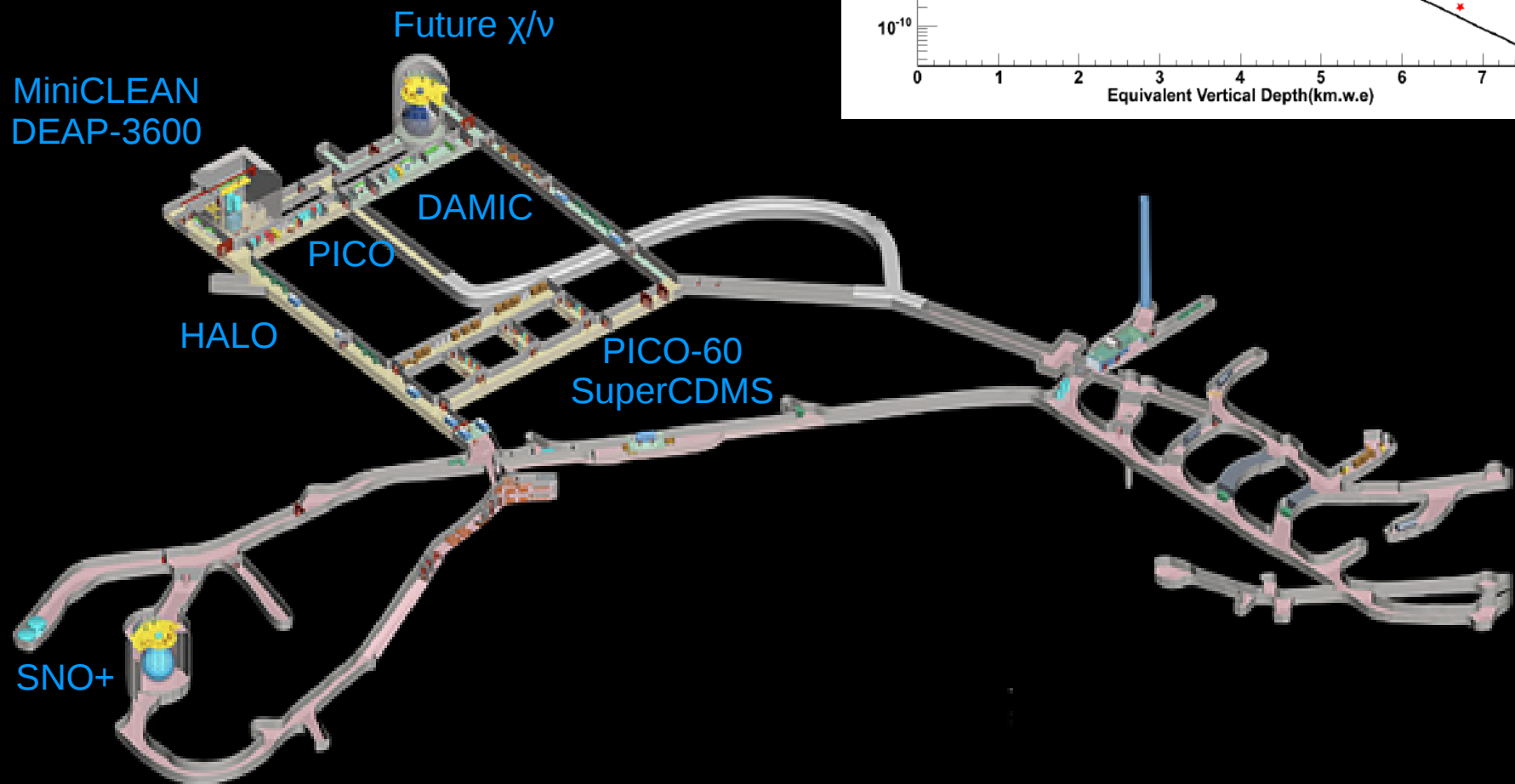
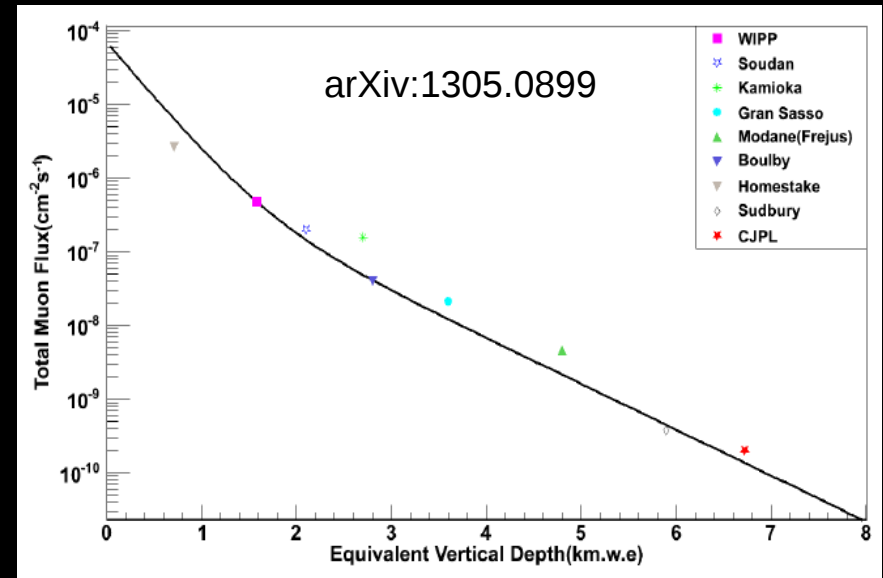
- Simple, scalable design (SNO/SNO+, Borexino, Kamiokande, etc)
- Detect only primary scintillation light from noble liquid
- 4π photomultiplier tube coverage



- Liquid argon:
 - Relatively affordable
 - Modest cryogenic requirements
 - Self-shielding of backgrounds
 - Efficient scintillators
 - Efficient particle identification

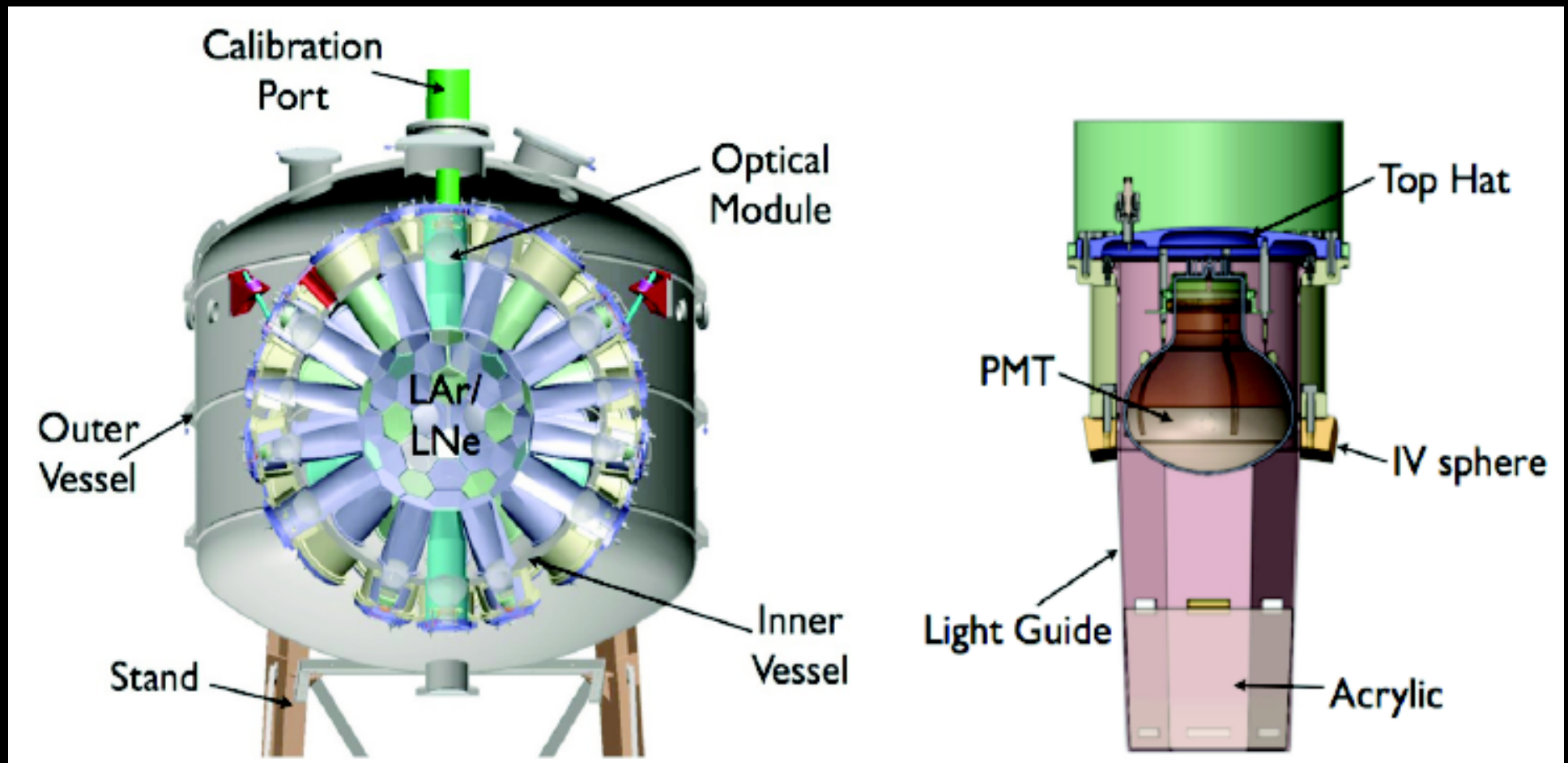
SNOLAB

- 6800 ft underground
- $0.29 \mu\text{m}^2/\text{day}$
- $34,340 \text{ m}^2$ clean facility



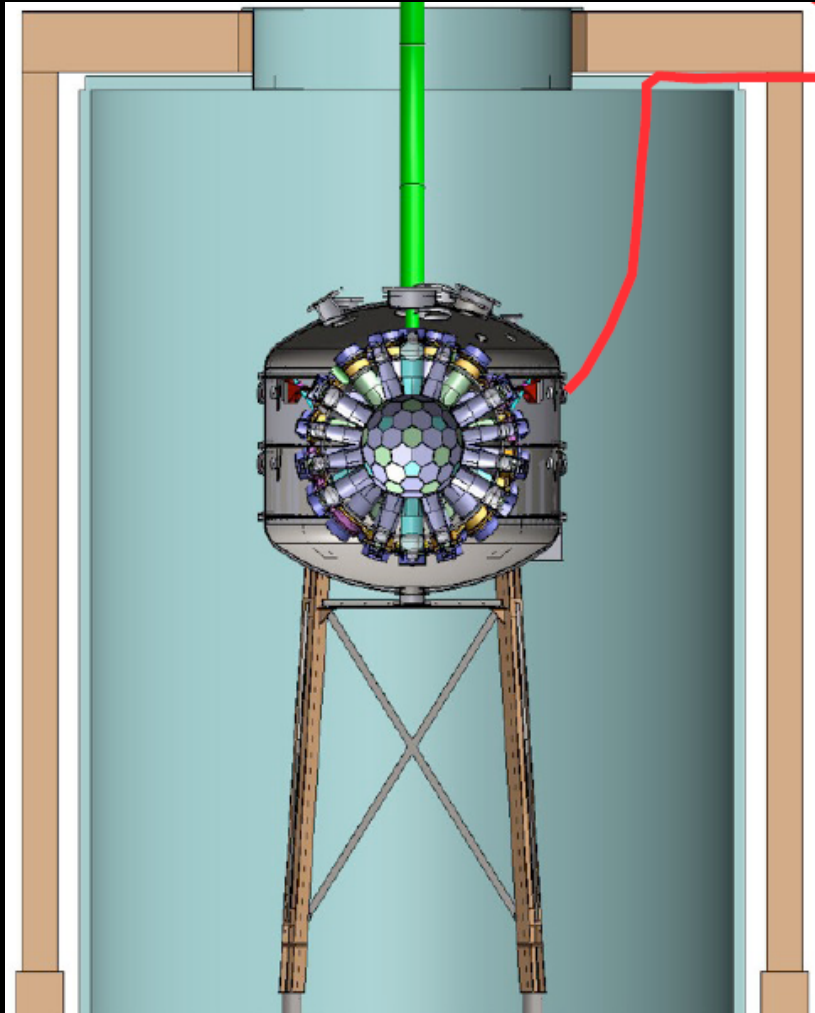
MiniCLEAN Detector

- 500 kg active LAr (or LNe) volume within inner vessel (IV)
- Tetraphenyl-butadiene (TPB) coated acrylic converts VUV LAr scintillation light to visible
- 92 optical cassettes with R5912-02-MOD 8" cryogenic PMTs
- Outer vacuum vessel (OV) for thermal insulation



MiniCLEAN Detector

- 18' diameter by 25' tall water tank for neutron/gamma shielding
- Hardware and PMTs in hand for installation of muon veto

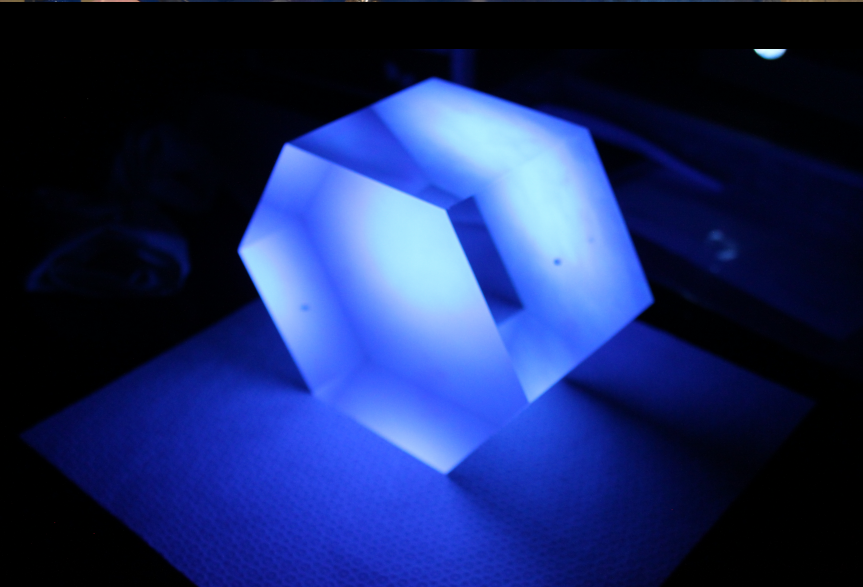


Inner Vessel Assembly

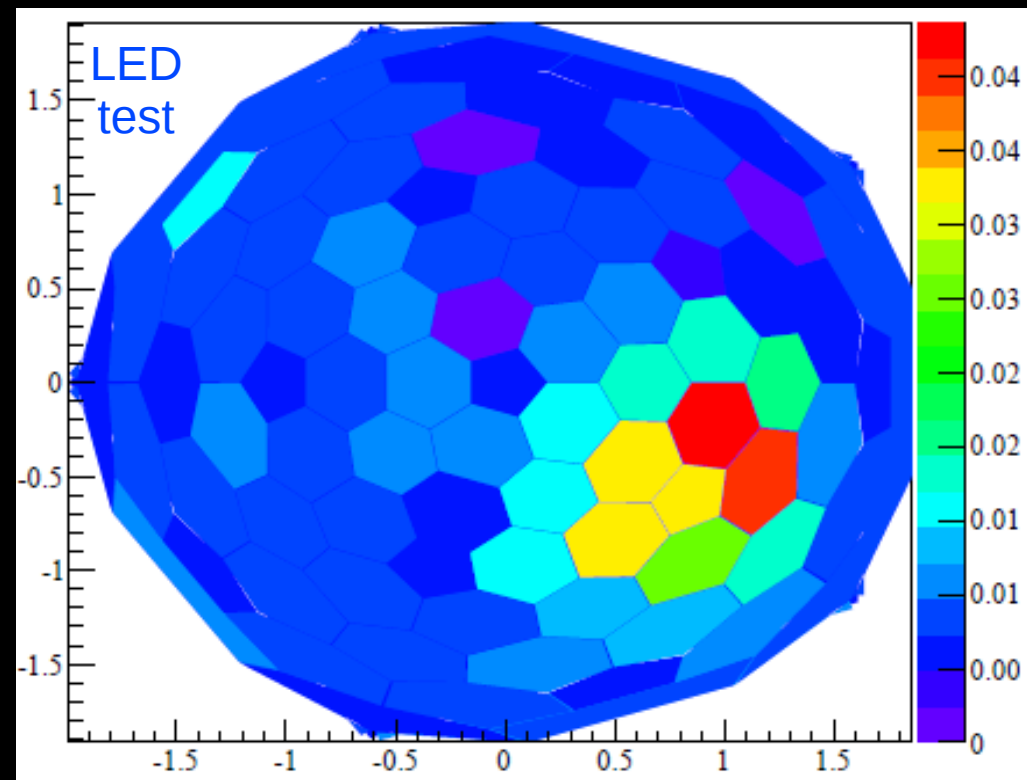
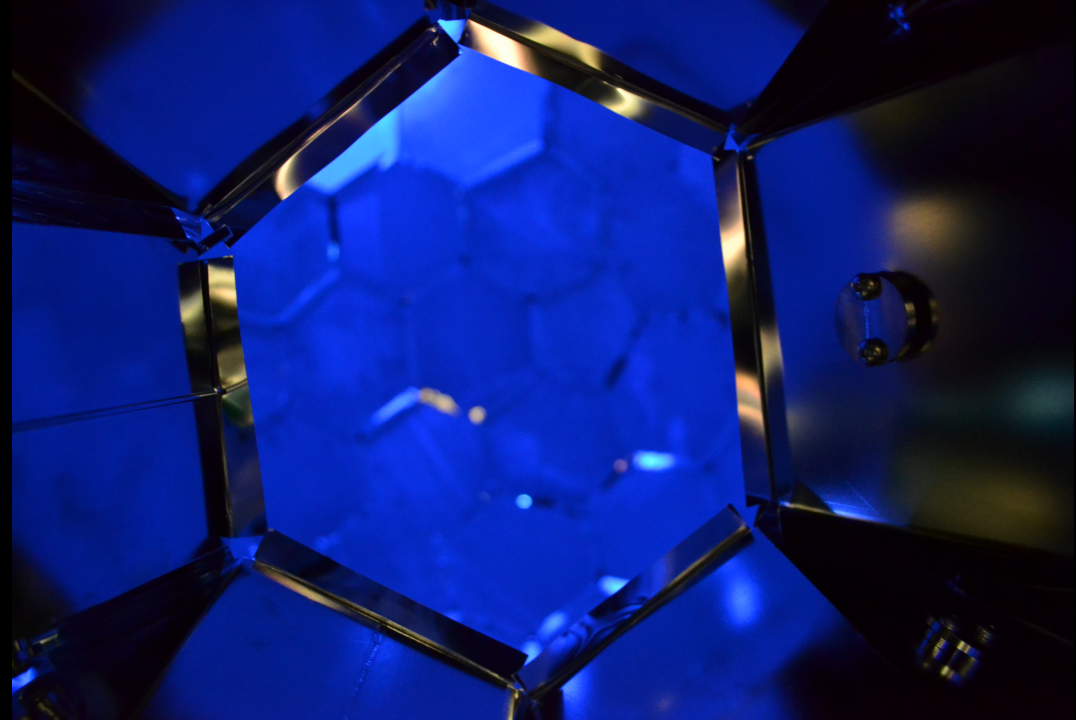
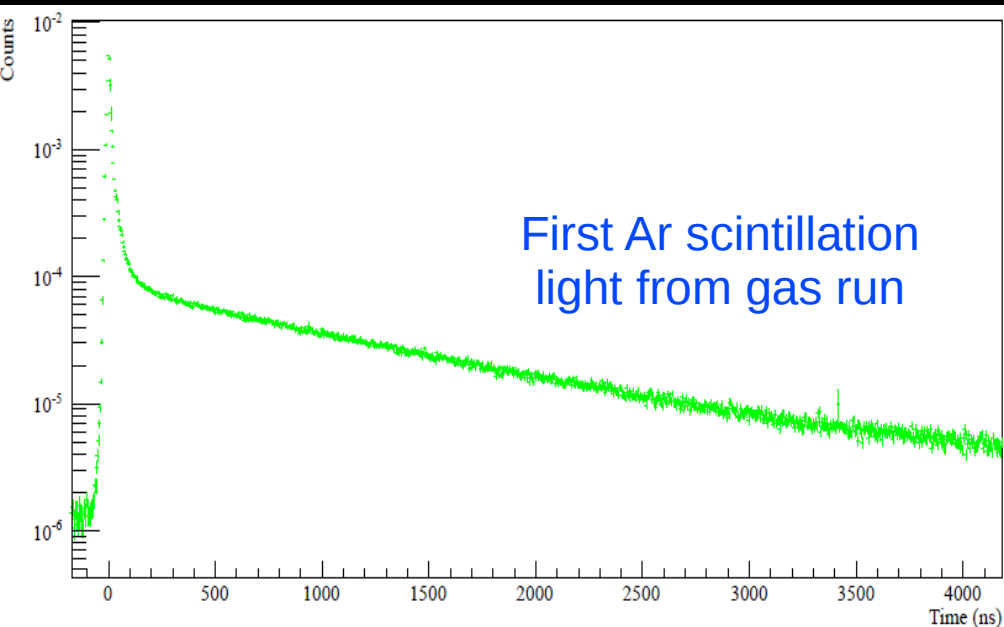
- IV assembled within radon reduced clean room in Cryopit
- Liquid nitrogen boil-off purge at all times to reduce radon exposure
- DAQ and Ar purification systems tested in Cryopit with IV complete



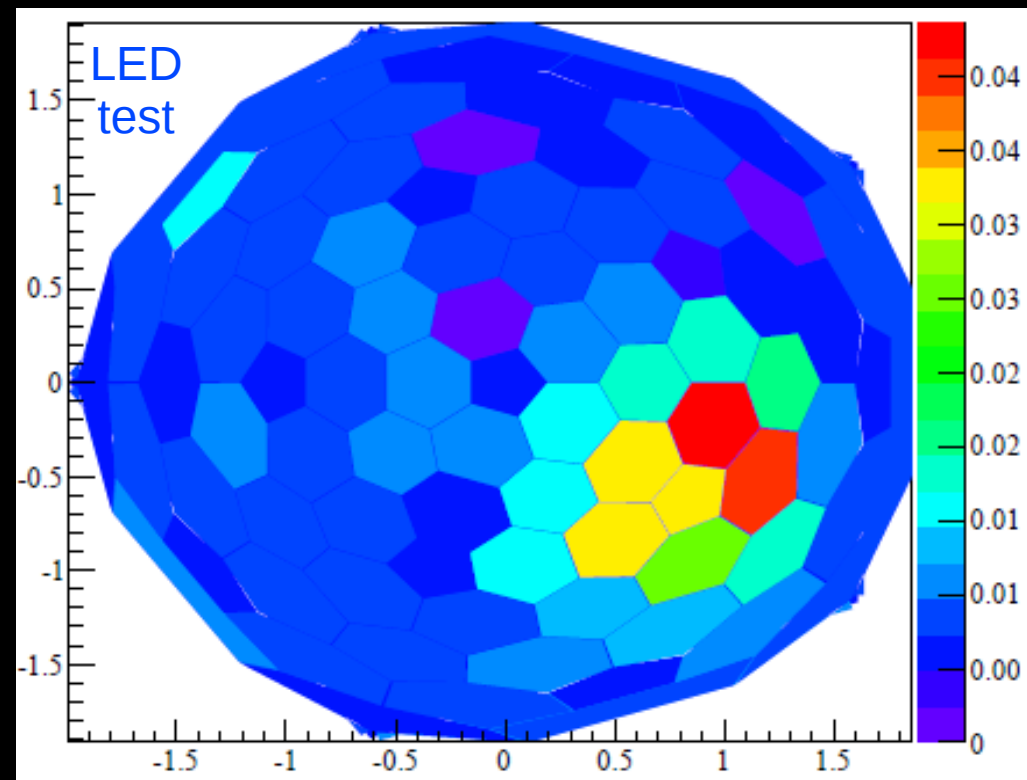
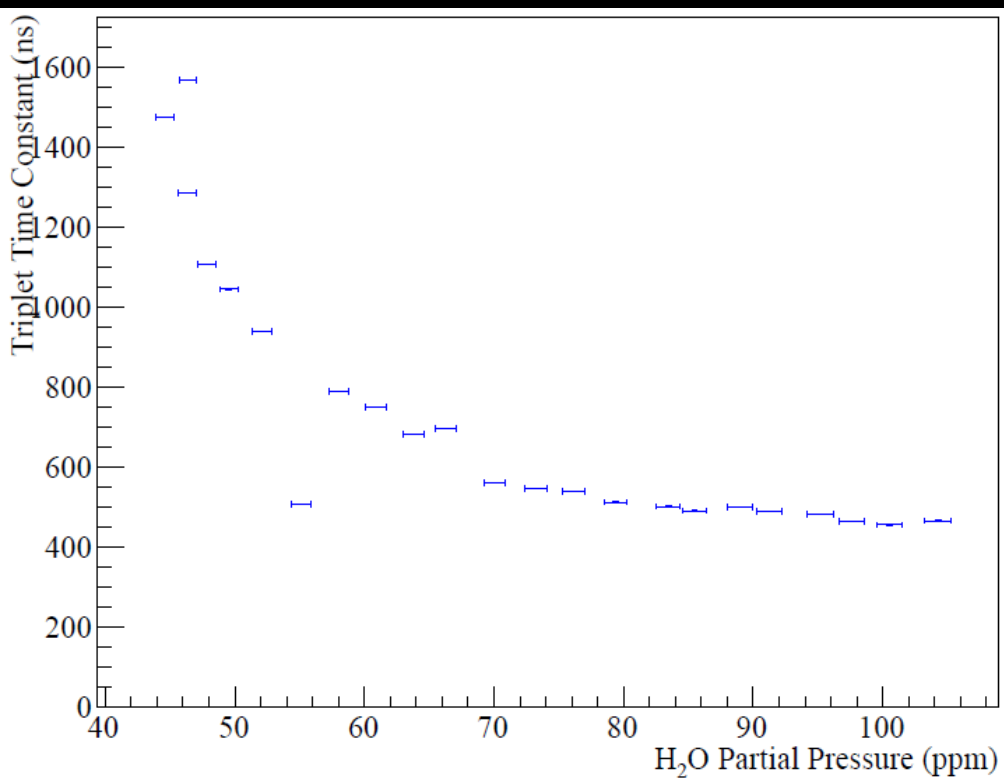
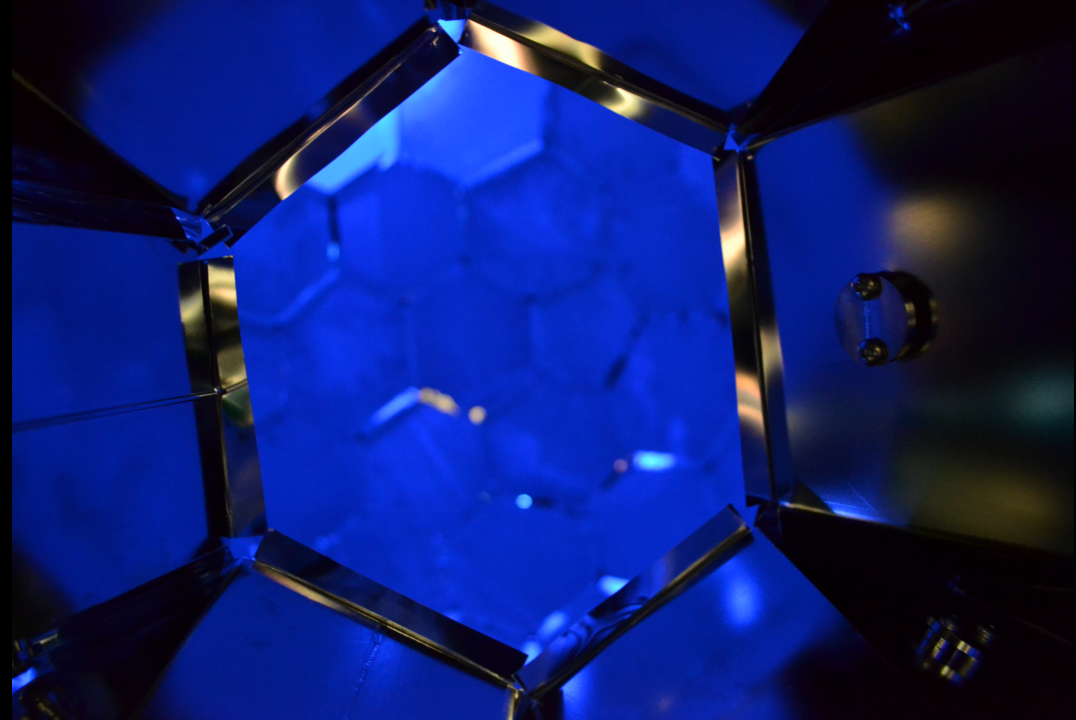
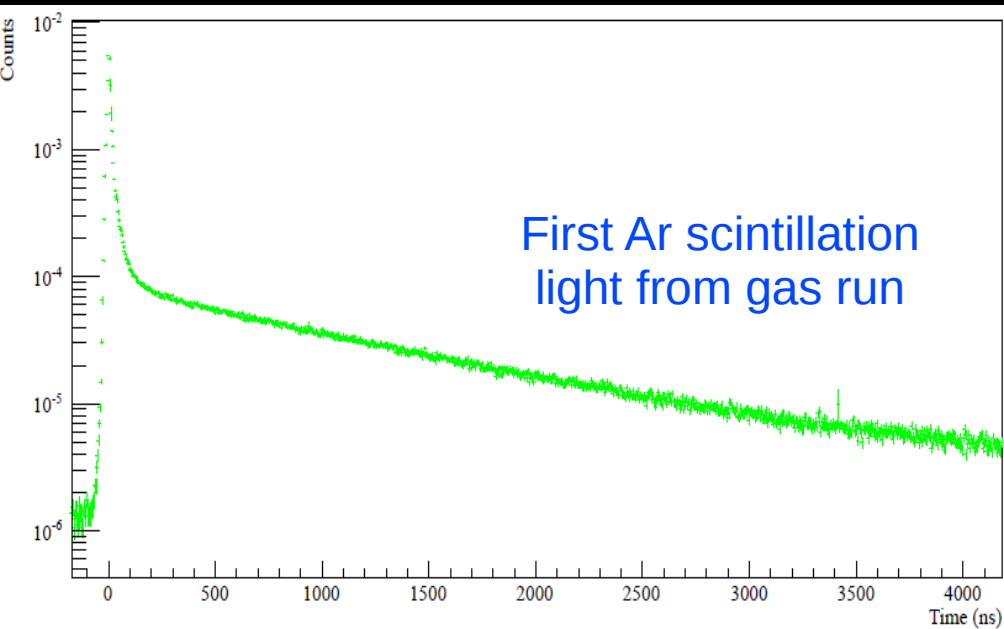
Inner Vessel Assembly



Inner Vessel Assembly

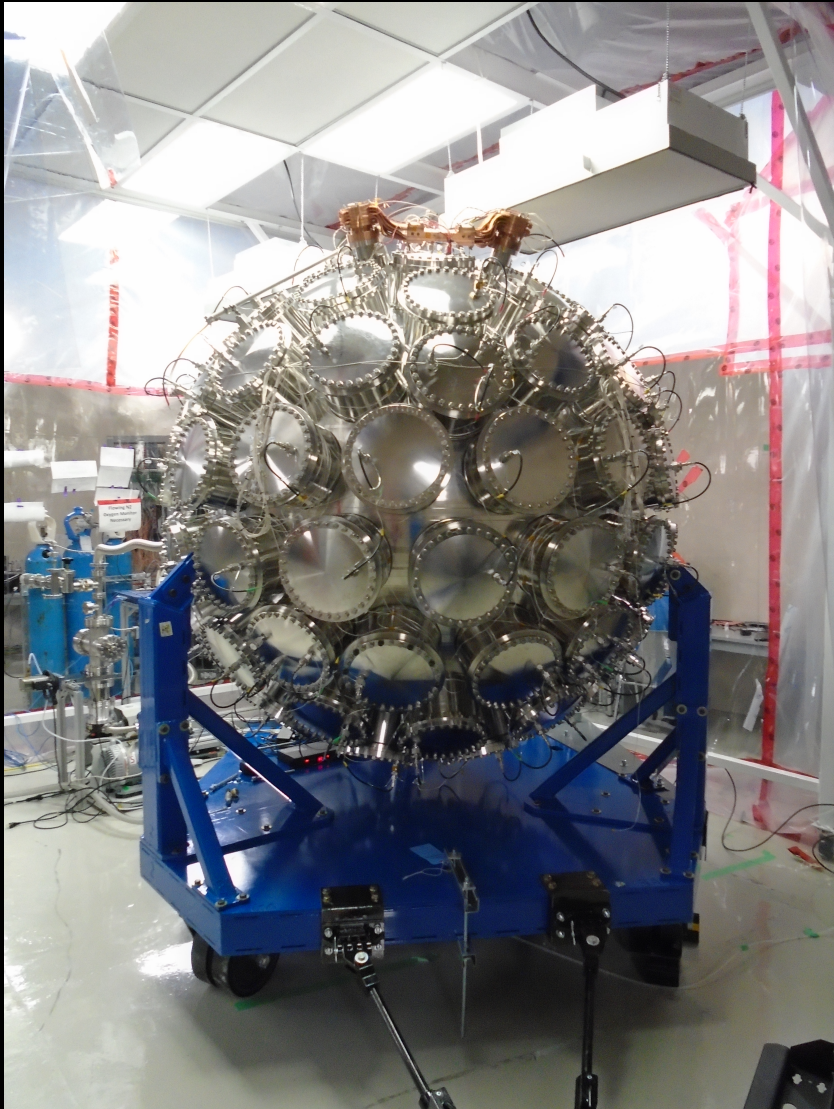


Inner Vessel Assembly

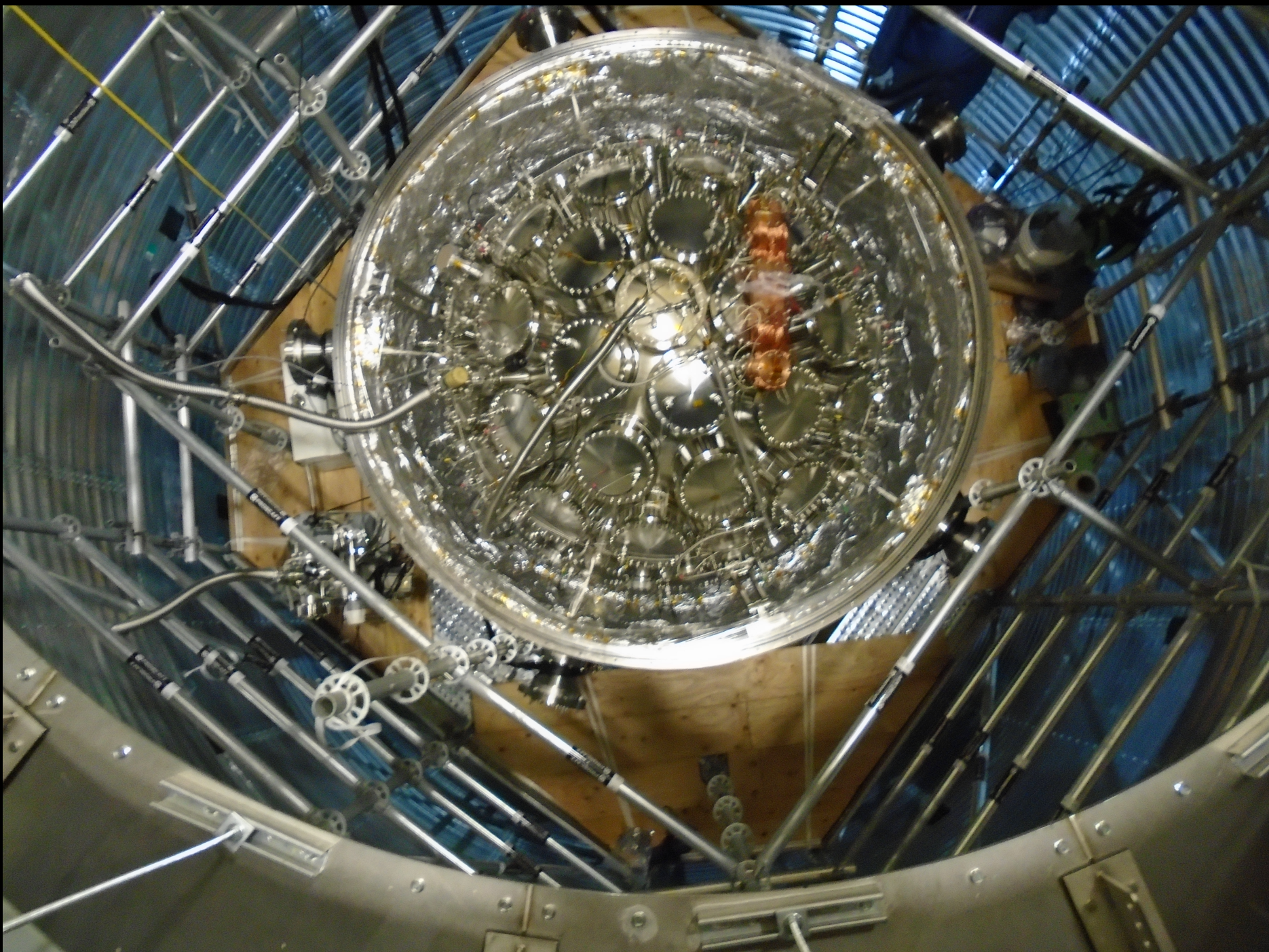


Installation in Outer Vessel

- With assembly/testing complete, IV only exposed to purified argon
- IV installed in the outer vessel December 2014

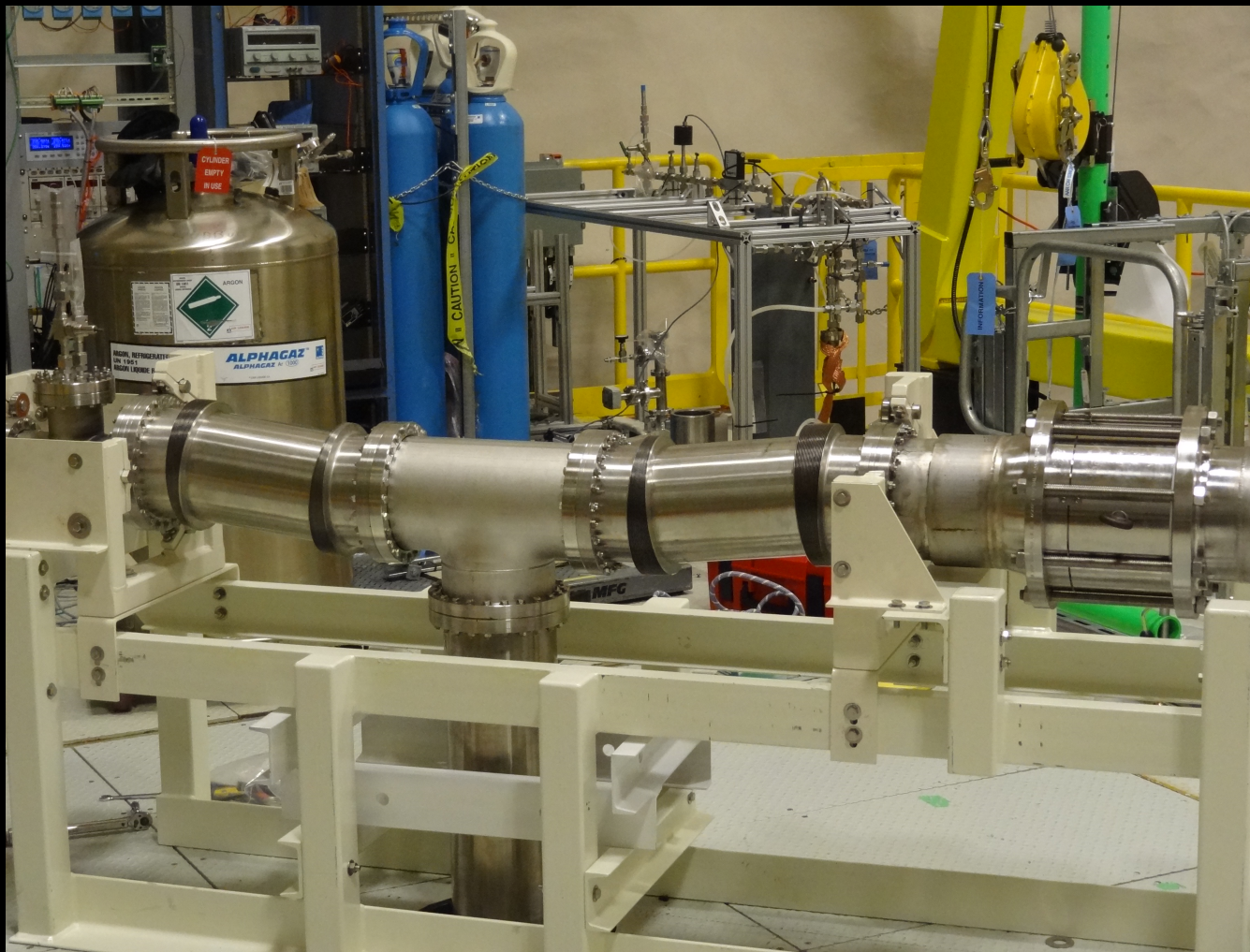


Installation in Outer Vessel



Detector Commissioning

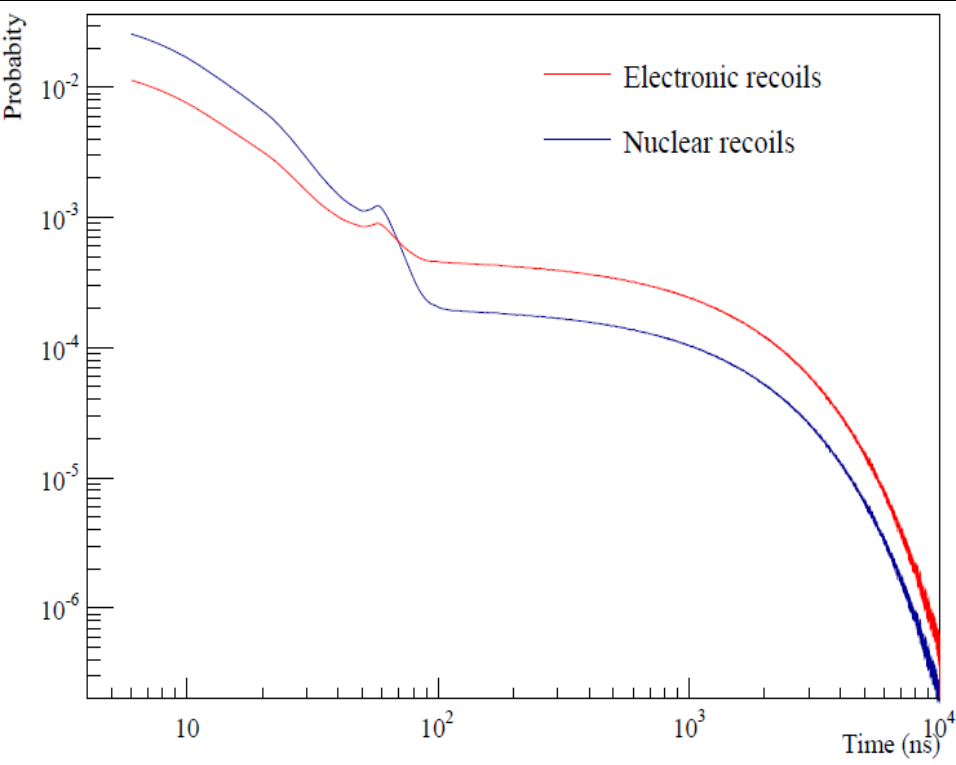
- Piping to IV and OV completed up to Cube Hall deck
- 30 day cool down started Wednesday
- 50 day fill with purification in gas phase before liquefaction in IV
- 1-2 month atmospheric argon run
- ^{39}Ar spike run for pulse-shape discrimination demonstration



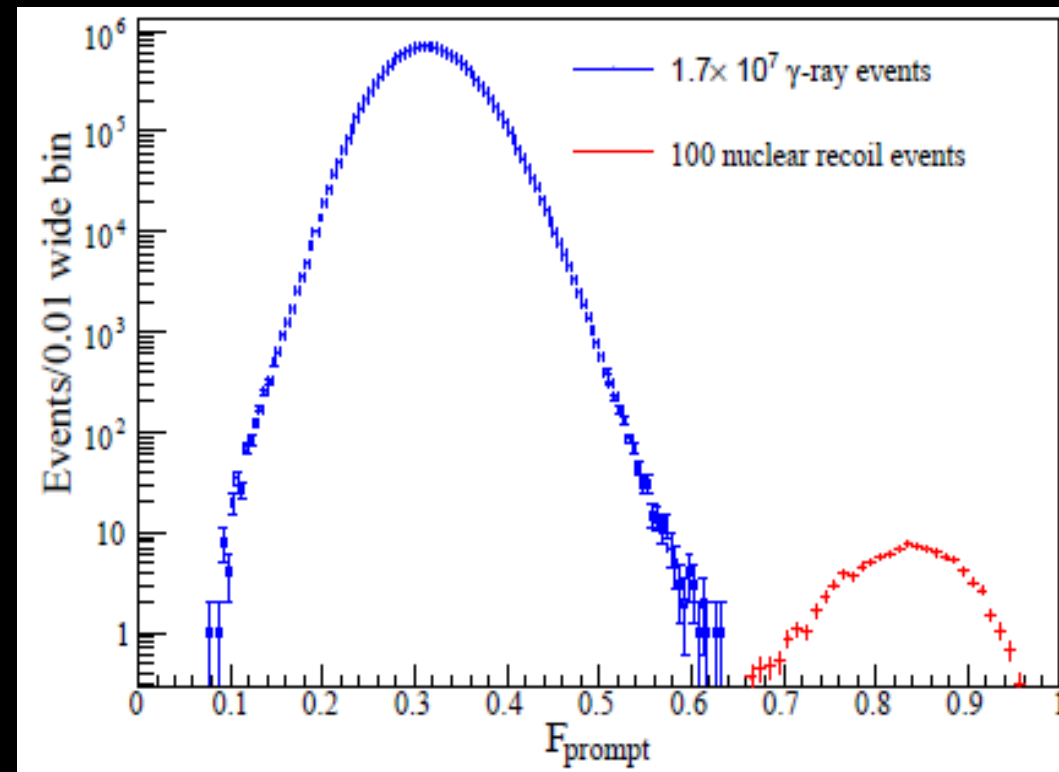
³⁹Ar Spike

- Atmospheric argon contains 1 Bq/kg of ³⁹Ar, a beta decay isotope with 269 yr half life, 565 keV endpoint
- LAr scintillation has 7 ns singlet state and 1600 ns triplet state
- dE/dx dependence of scintillation state production results in excellent separation of electronic recoils from nuclear recoils
- Demonstrated pulse shape discrimination to levels of 10⁸

MiniCLEAN Simulation



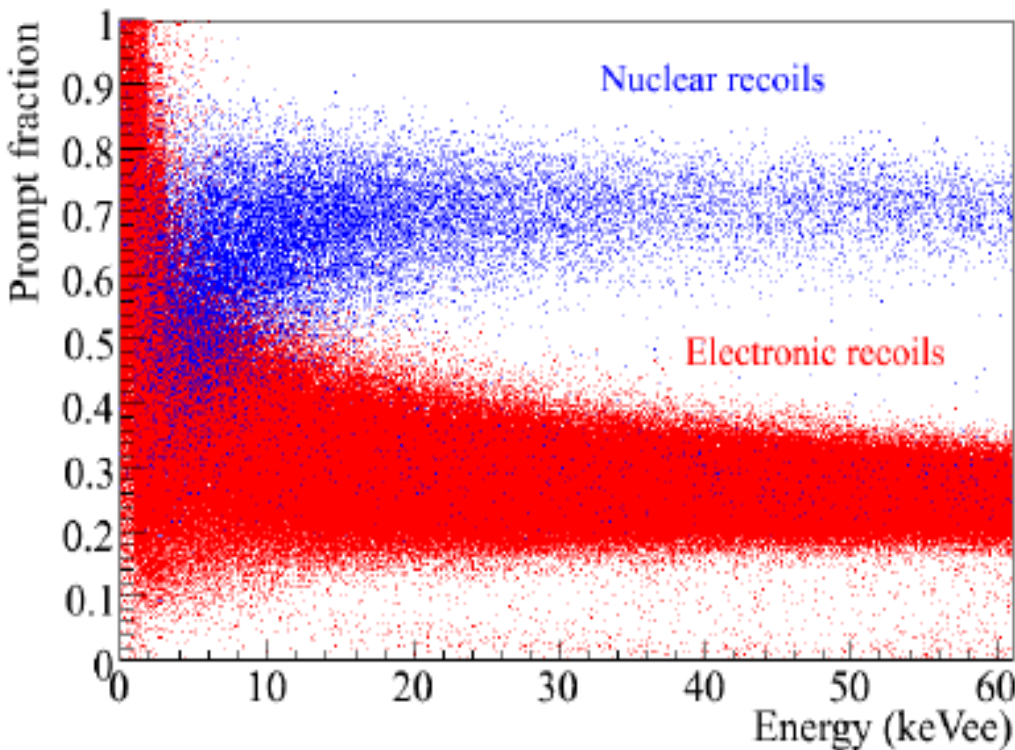
DEAP-1 arXiv:0904.2930



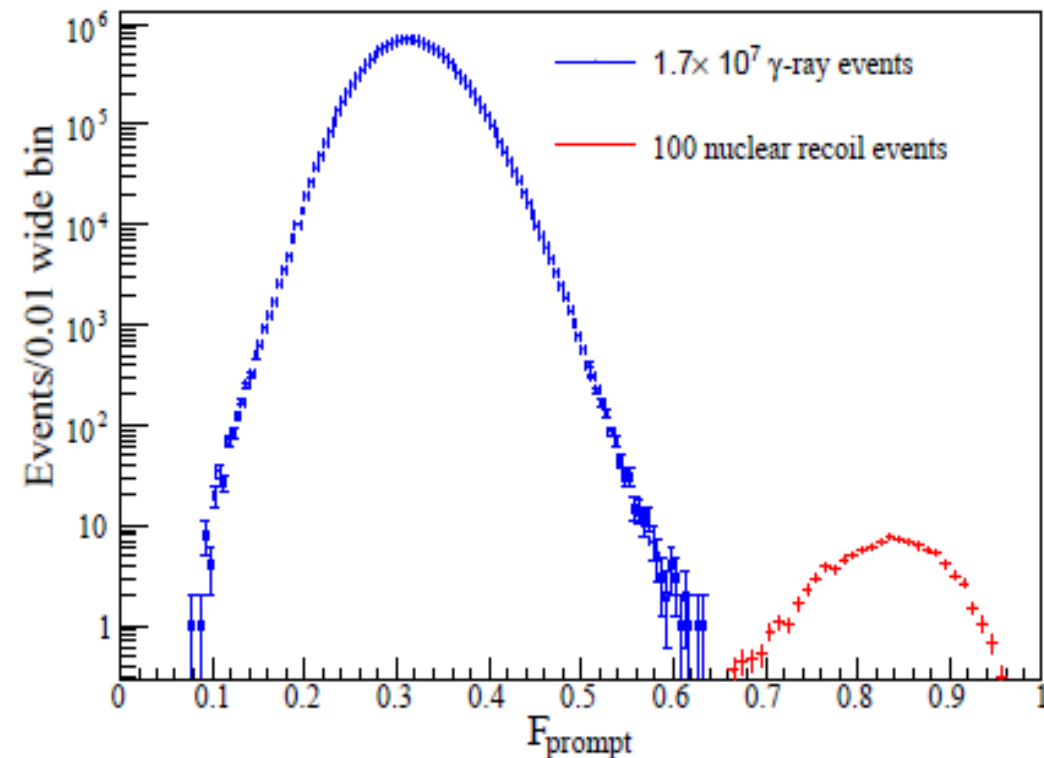
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- dE/dx dependence of scintillation state production results in excellent separation of electronic recoils from nuclear recoils
- Demonstrated pulse shape discrimination to levels of 10^8

MicroCLEAN Phys. Rev. C78, 035801 (2008)



DEAP-1 arXiv:0904.2930



PSD Degradation Mechanisms

- With the LAr singlet and triplet time constants separated by orders of magnitude, the fraction of the light in the first ~ 80 ns of the waveform is a highly effective pulse shape discriminant
- At low energies various mechanisms degrade the PSD reach
- Improved discriminants can allow the analysis threshold to be lowered which results in exponentially improved WIMP sensitivity

*GPU based toy MiniCLEAN MC
12.5 keVee apparent energy only*

Improved with increased
detector light yield

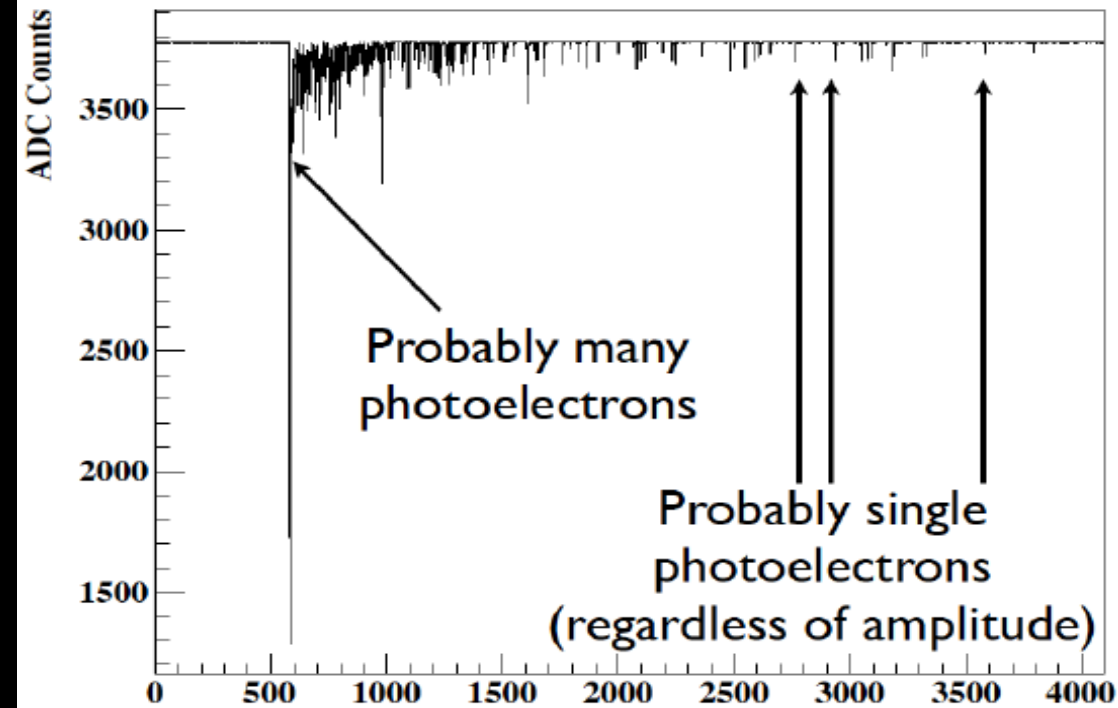
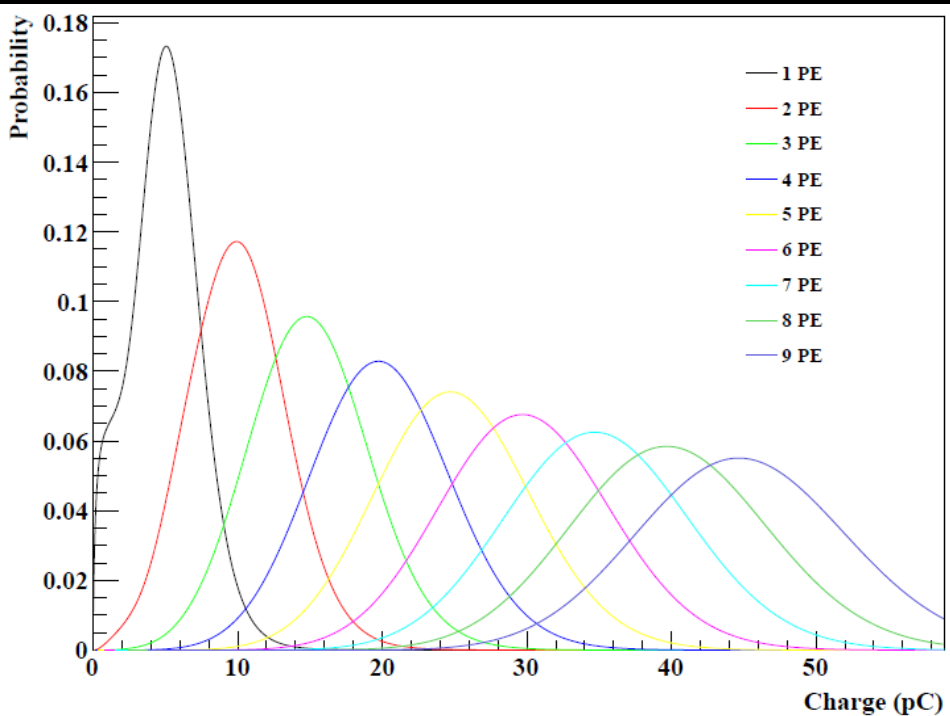
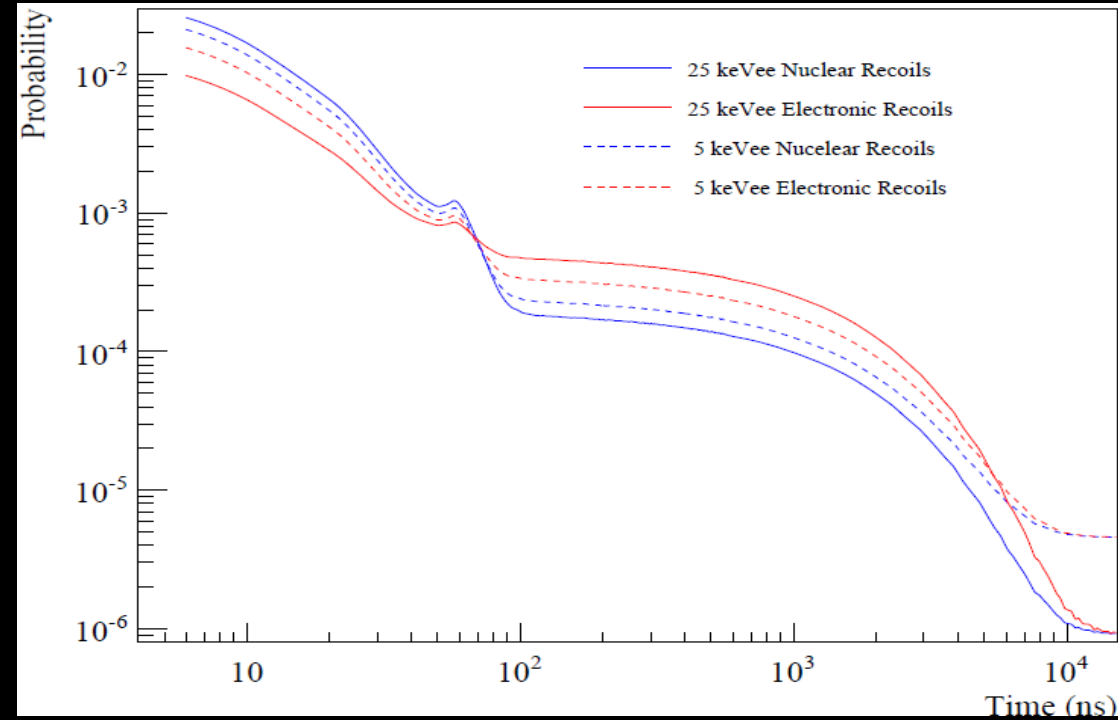
Improved with
better waveform
analysis techniques

Detector Effect	f_p leakage
Binomial Fluctuations	3.9×10^{-11}
Scintillation Time Profile	2.9×10^{-10}
^{39}Ar Distrib. + Energy Res.	2.3×10^{-9}
PMT Response	7.1×10^{-8}
PMT Dark Current	1.2×10^{-7}
Digitizer Noise	4.2×10^{-6}

Bayesian Identification of Single Photoelectrons

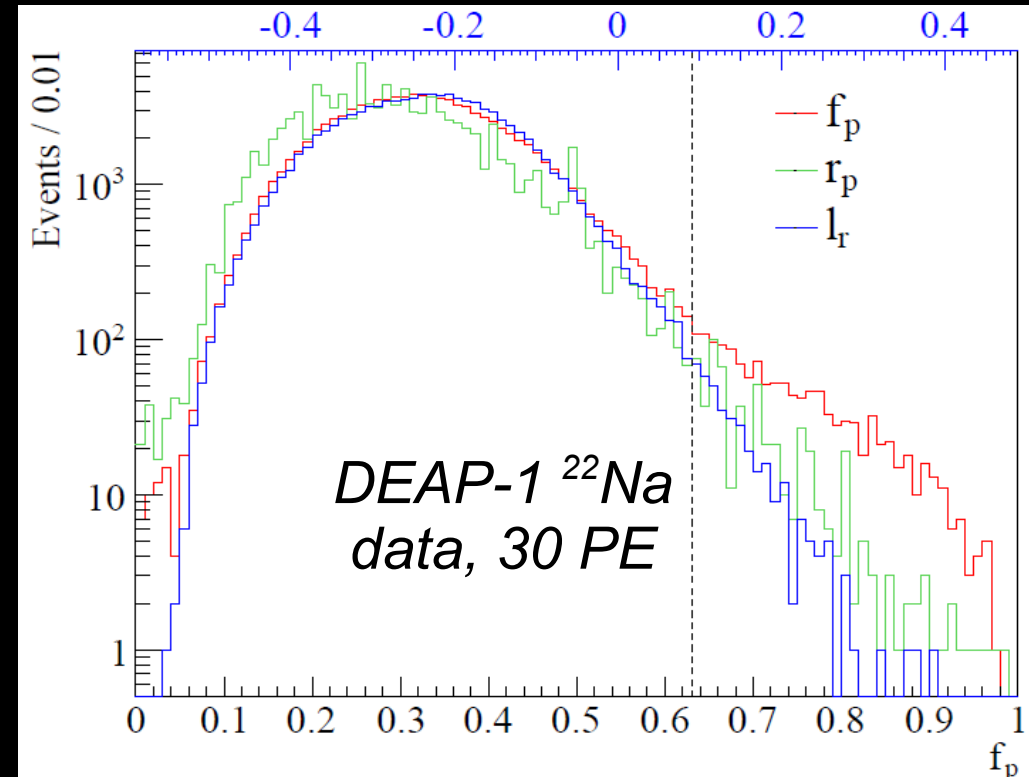
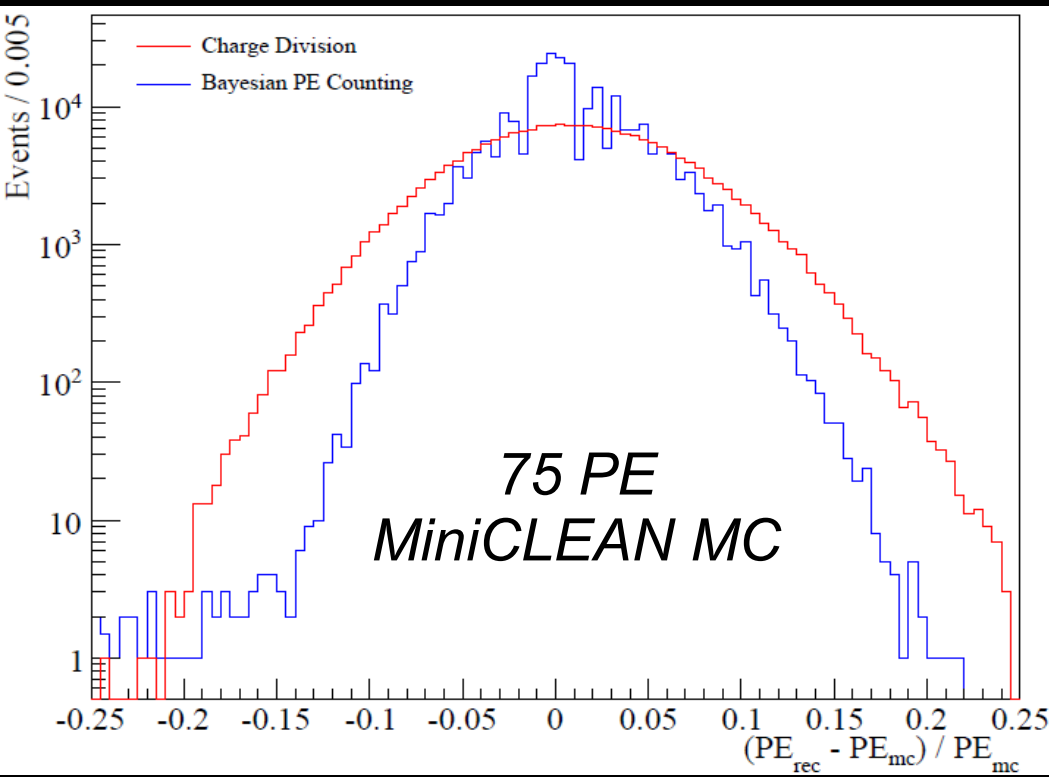
$$P_N(n|q, t_1, t_2) = \frac{P_Q(q|n)P_N(n|t_1, t_2)}{P_Q(q|t_1, t_2)}$$
$$= \frac{P_Q(q|n)P_N(n|t_1, t_2)}{\sum_{i=0}^{\infty} P_Q(q|i)P_N(i|t_1, t_2)}$$

$$l_r = \frac{1}{m} \sum_{t \in \mathcal{T}} (\log P_n(t|E) - \log P_e(t|E))$$



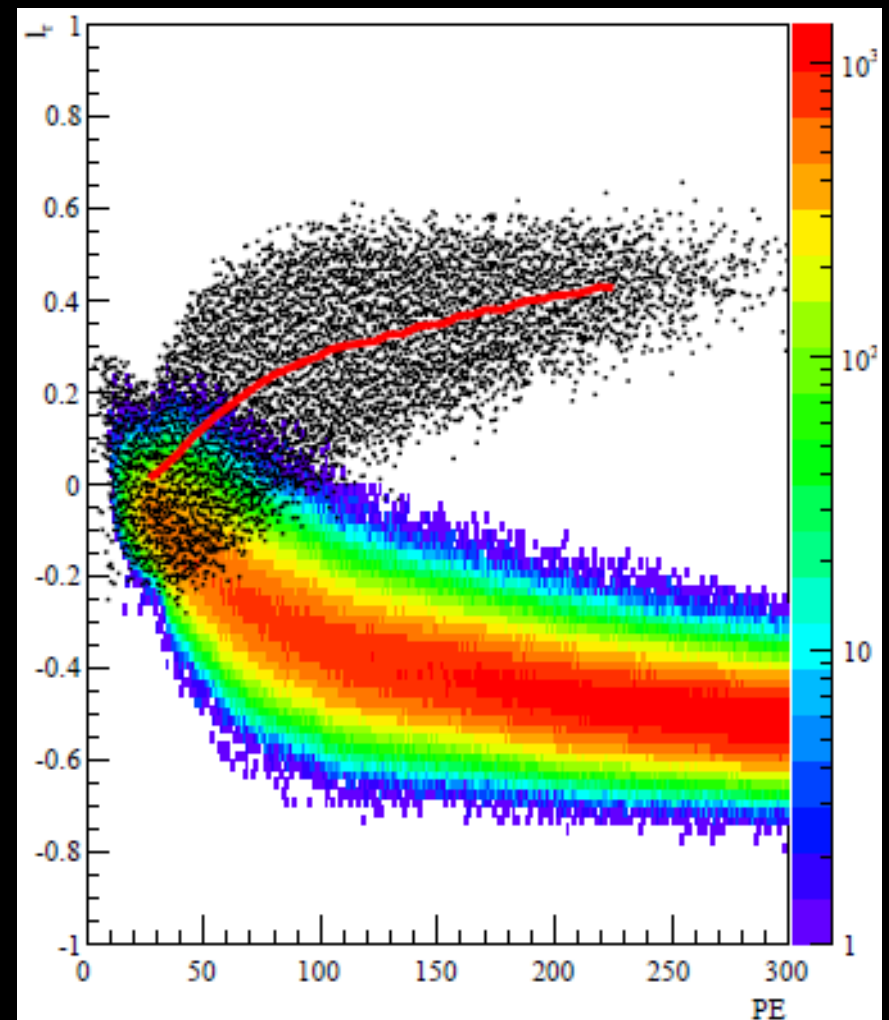
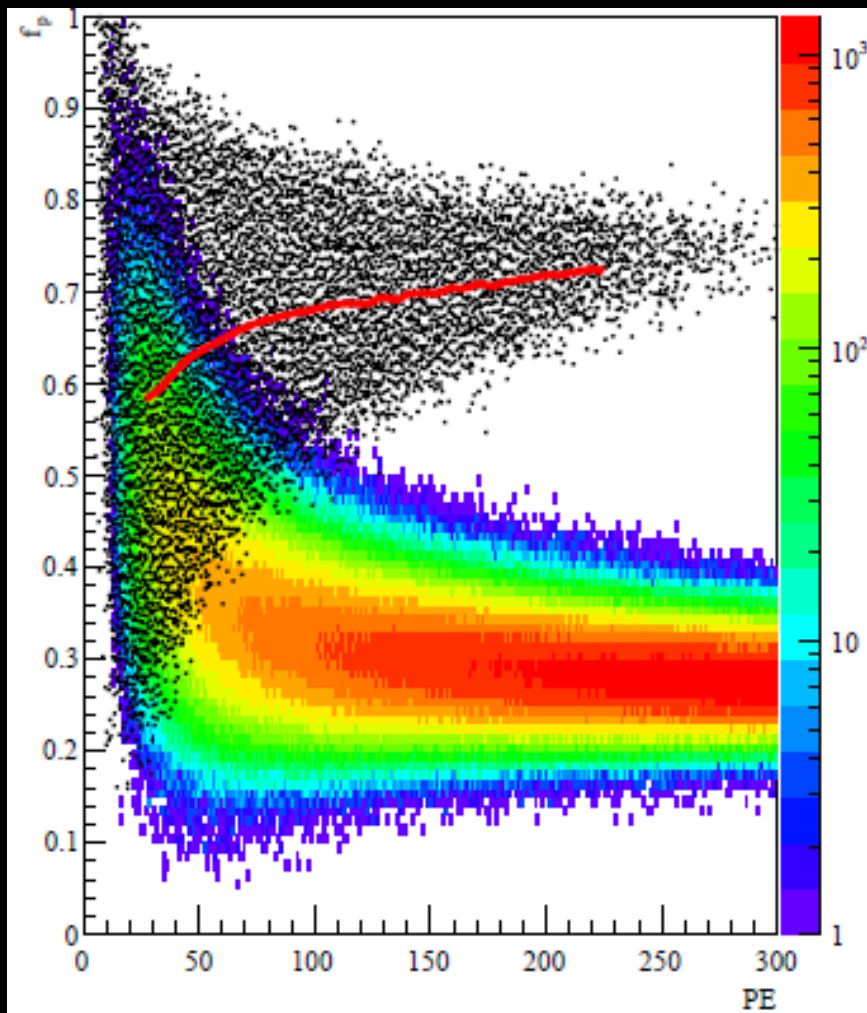
Bayesian Identification of Single Photoelectrons

- Number of photoelectrons identified in the Bayesian procedure improves both energy and position reconstruction
- Likelihood ratio pulse shape discriminant significantly improves rejection of electronic recoils at low energies
- Details in Astroparticle Physics 65, (2014) 40-54



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Conclusion and Outlook

- MiniCLEAN construction complete
- IV completed, tested, and operated in Cryopit
- Currently commissioning cryogenics and cool down has begun
- ~80 days until first LAr data
- ^{39}Ar spike to measure PSD capability of single phase LAr detectors at the scale of 10-100 tonnes
- Improved particle ID techniques, which are applicable to a wide range of scintillation detectors, will be used to lower the energy threshold achievable in LAr detectors

