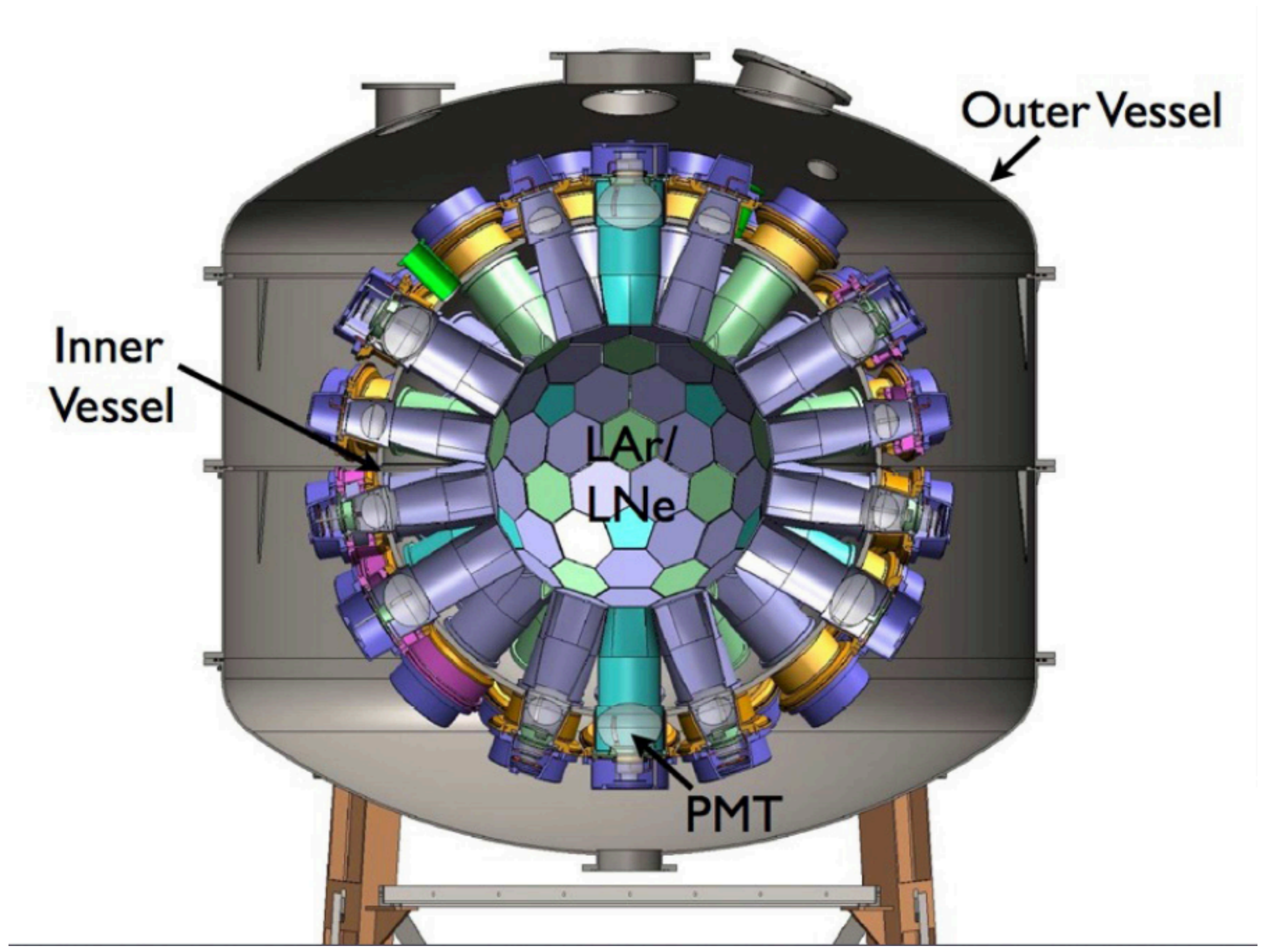
The MiniCLEAN Dark Matter Project

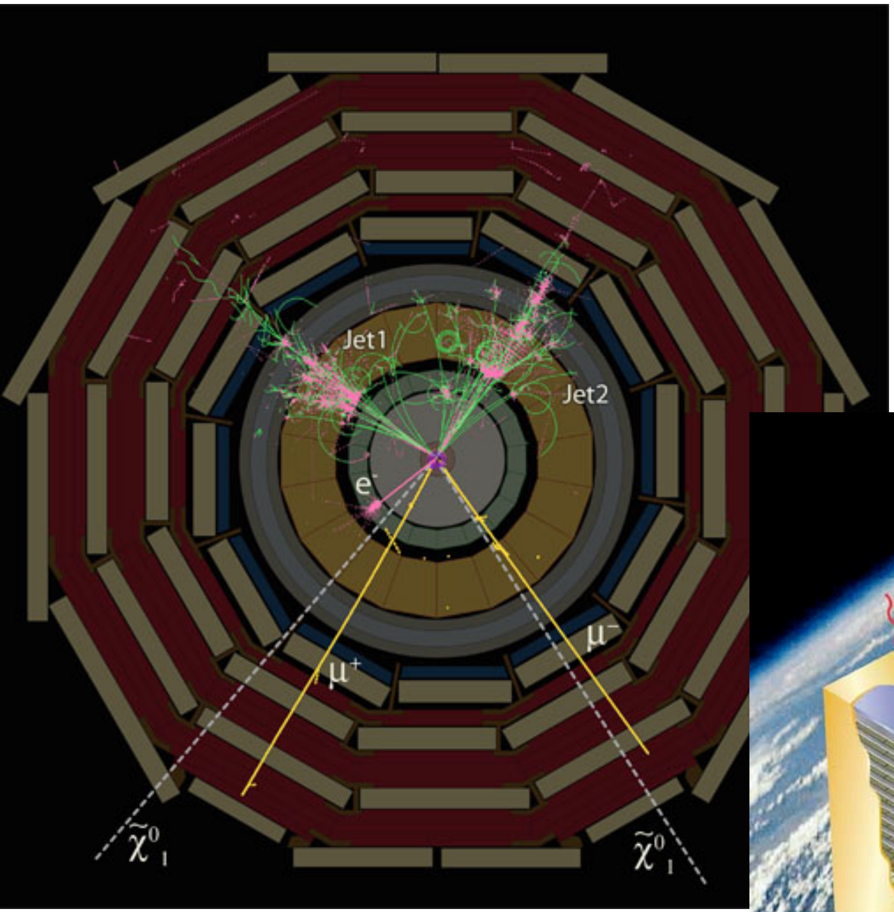


Raul Hennings-Yeomans
Los Alamos National Laboratory
for the DEAP/CLEAN collaboration

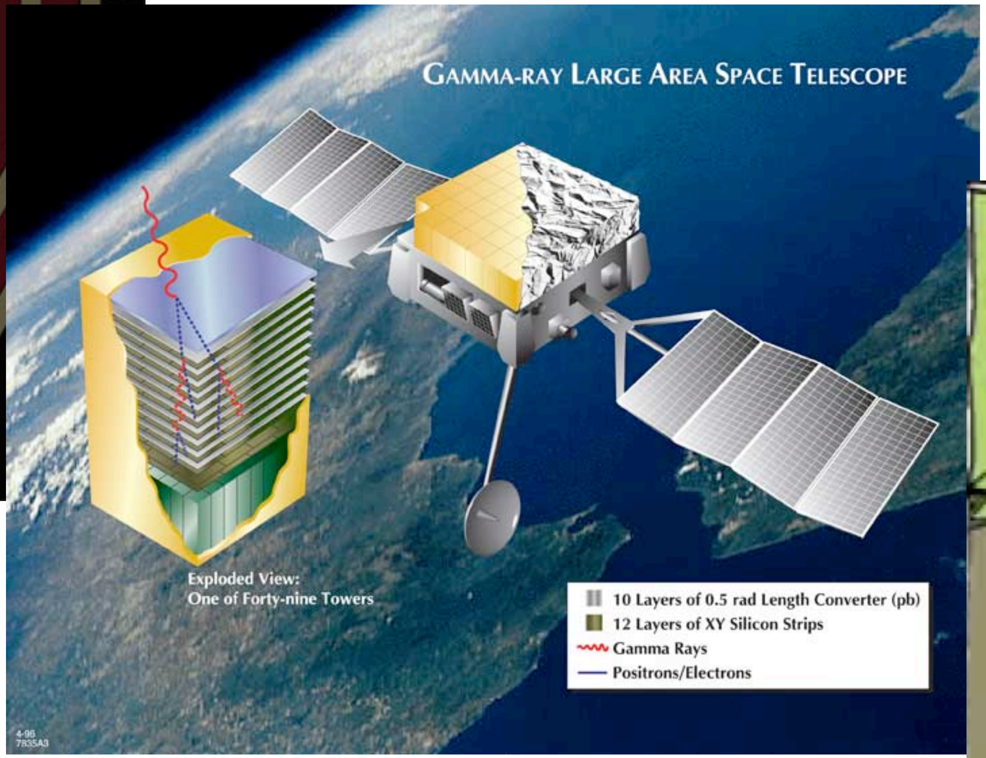
Phenomenology Symposium 2011
Madison, Wisconsin

Where are we looking for Dark Matter?

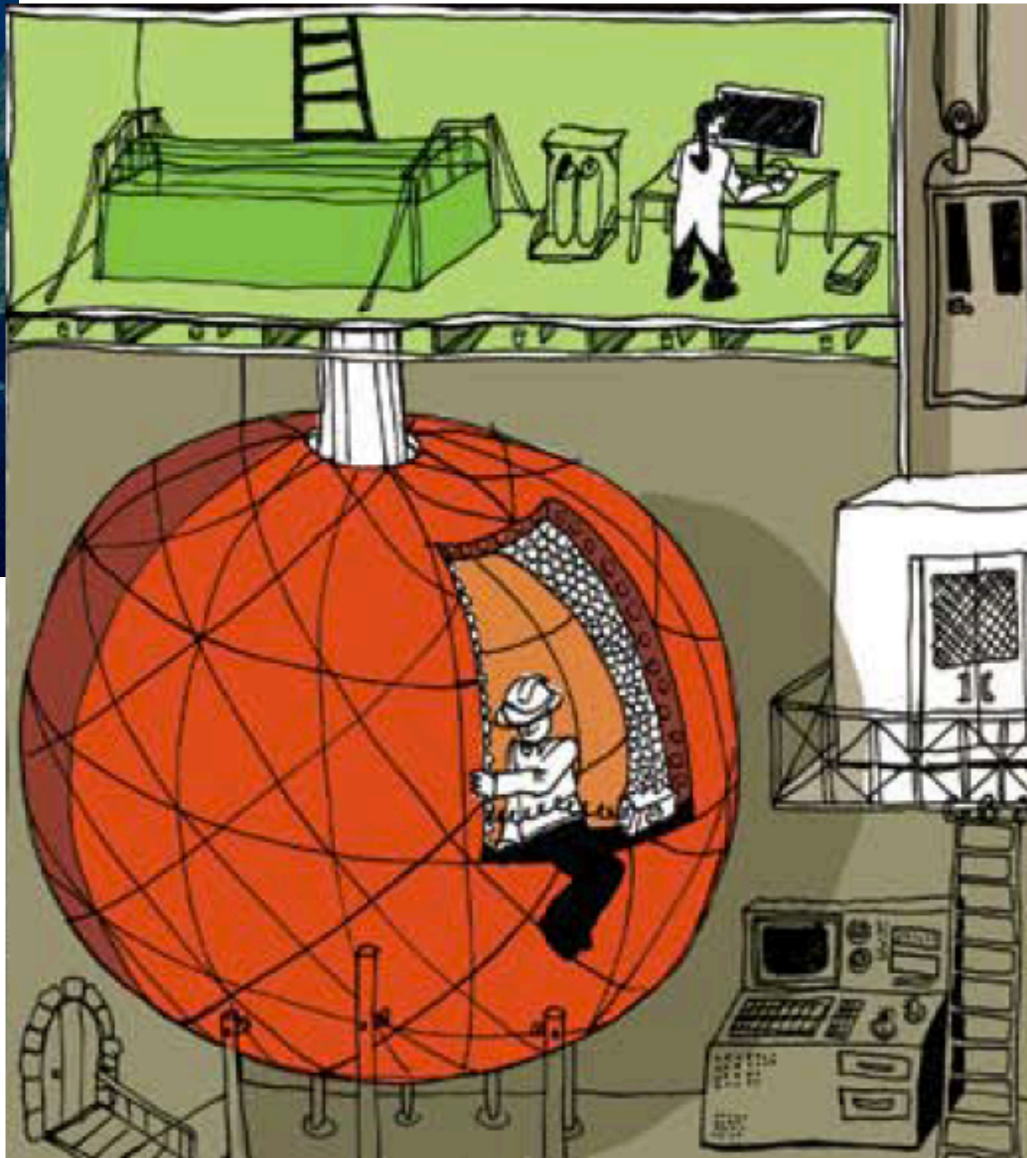
MAKE IT IN THE LABORATORY (LHC)



INDIRECT DETECTION: By measuring gamma rays, neutrinos, positrons, antiprotons, anti-deuterons, etc. produced by WIMP annihilation



DIRECT DETECTION: Measuring WIMP nuclear recoils in the underground labs

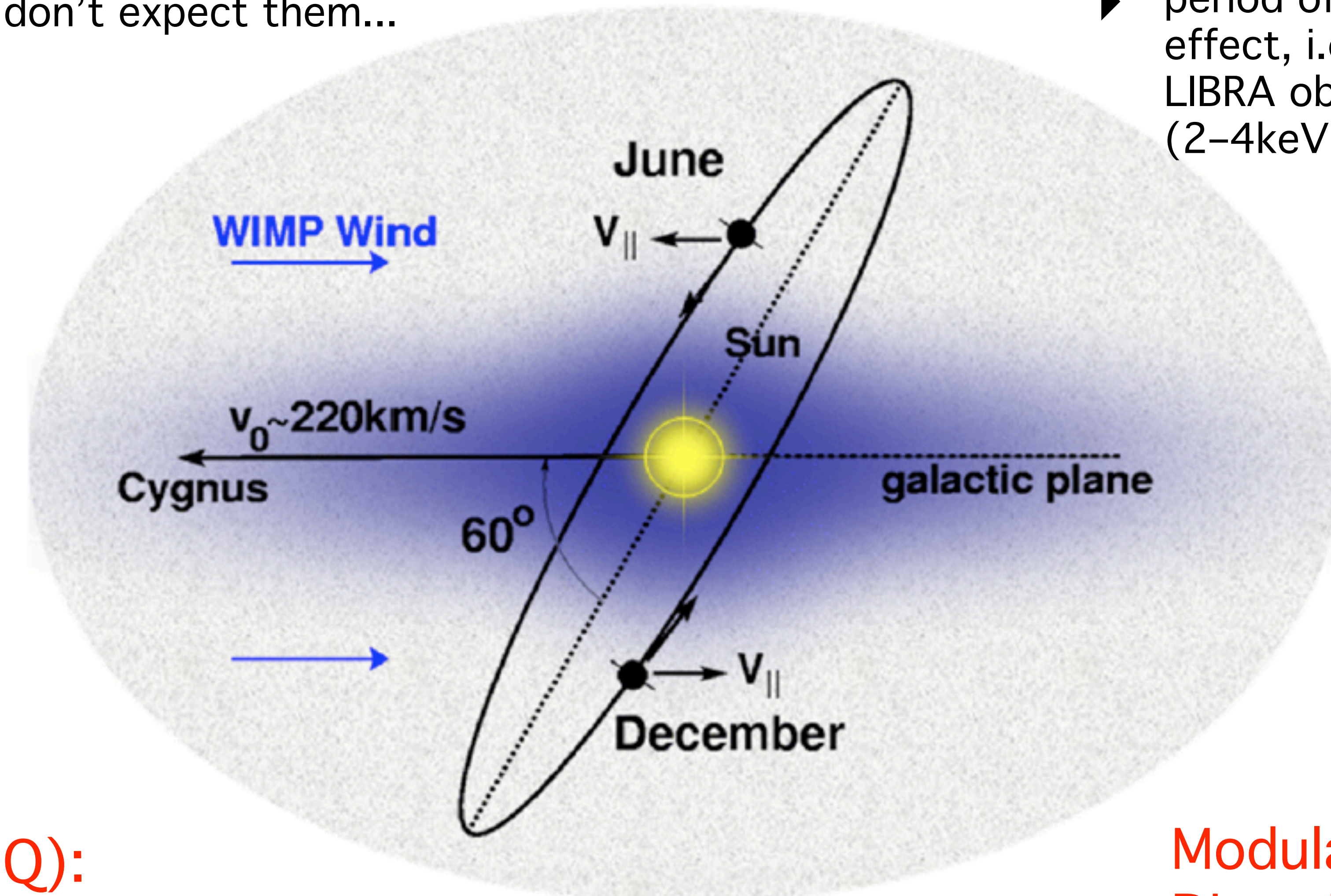


We expect that ‘something’ (DM) will be observed within the next few years to a decade in one or more of these experiments...

Direct Detection Signals

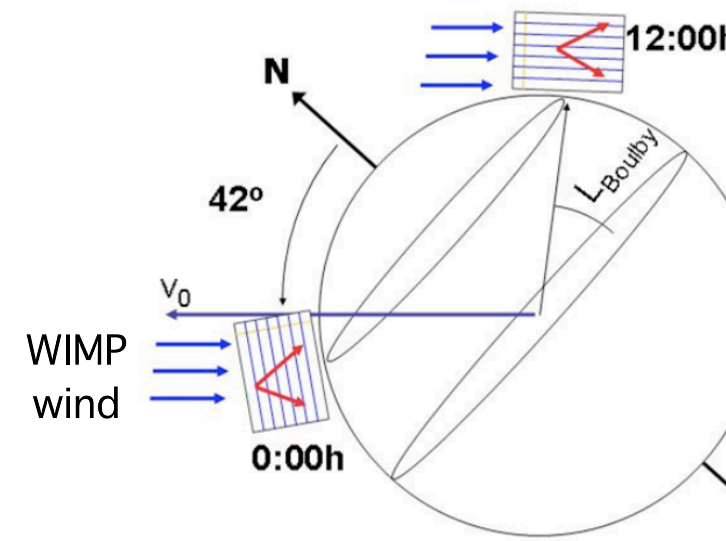
Nuclear Recoils:

- single nuclear recoils distributed uniformly within the detector fiducial volume
- neutron detectors (through nuclear recoils) where we don't expect them...



Anual Modulation of the Event Rate:

- movement of the Earth around the Sun, relative to the WIMP halo produces annual modulation of the event rate
- period of 1 year and phase~6/2 (only a 3% effect, i.e. requires many kg-y) DAMA/LIBRA observes modulation with ~8σ (2–4keV)



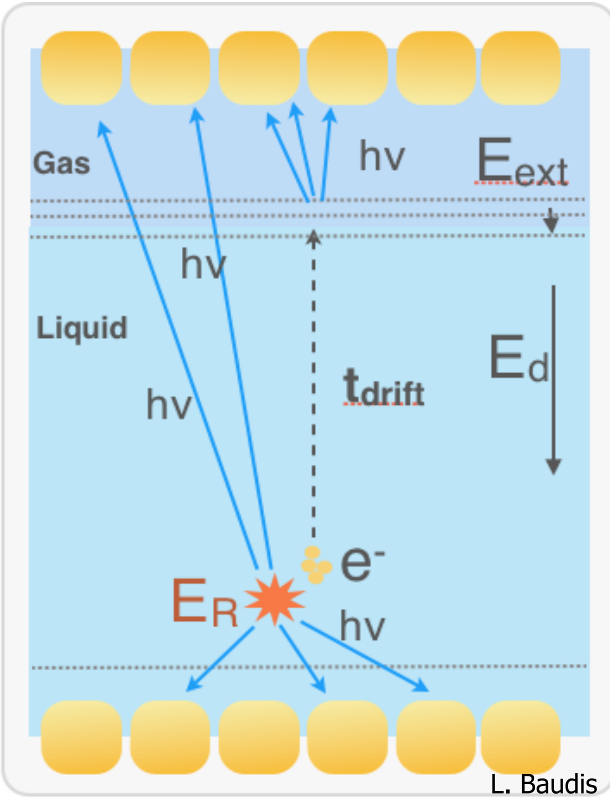
A^2 and F(Q):

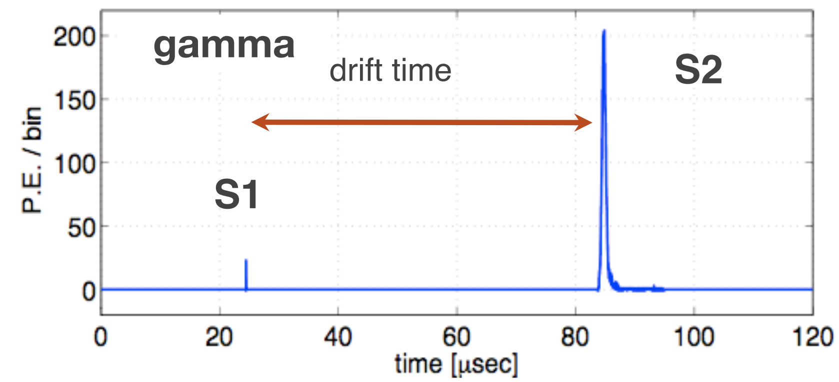
- Use different detector targets to cross check rate and systematics (Ge/Si like CDMS, Ar/Ne like MiniCLEAN)

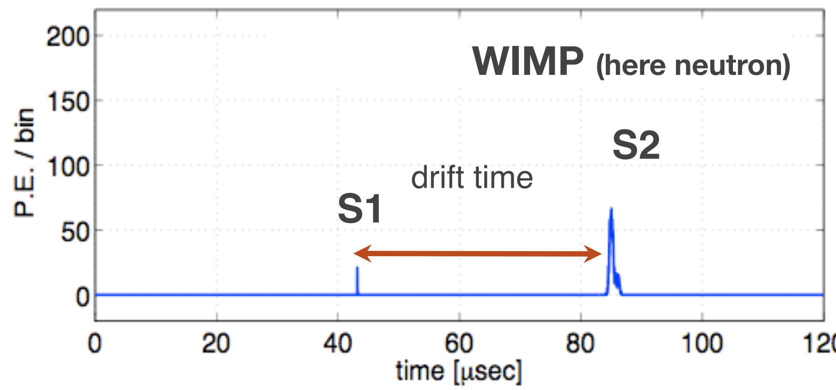
Modulation of the Recoil Direction (Diurnal)

- movement of the Earth around its own axis produces a modulation of the nuclear recoils π/2 every 12hrs

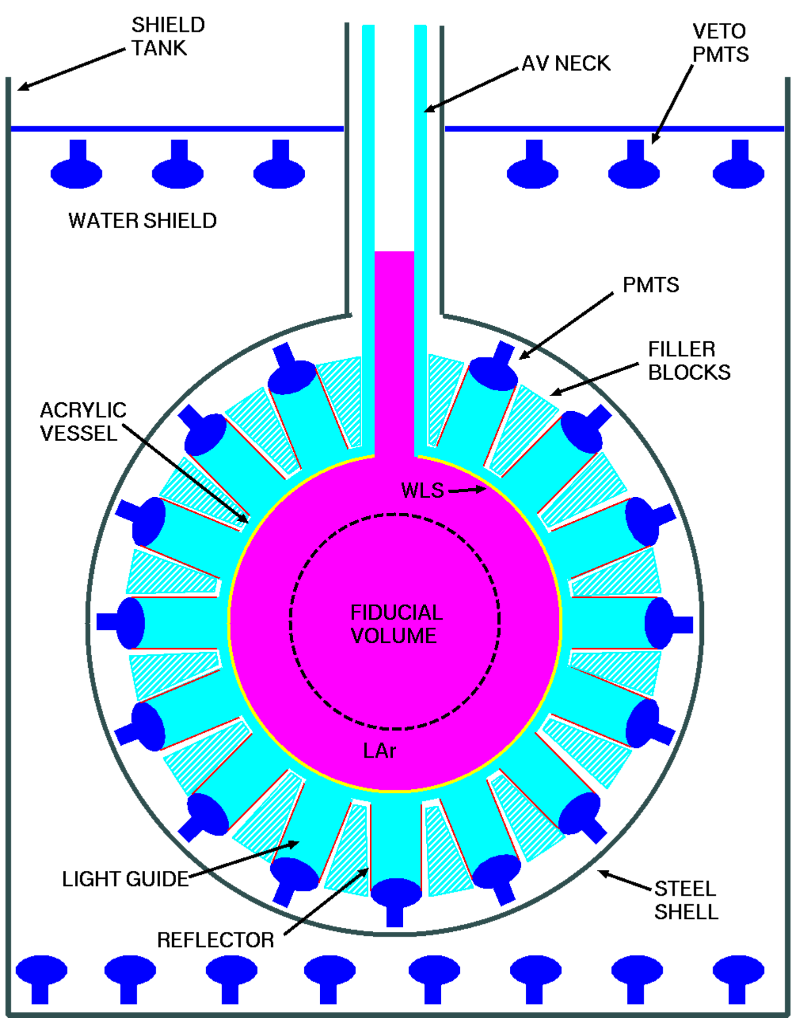
Dual Phase vs. Single Phase Noble Liquid Dark Matter Detectors

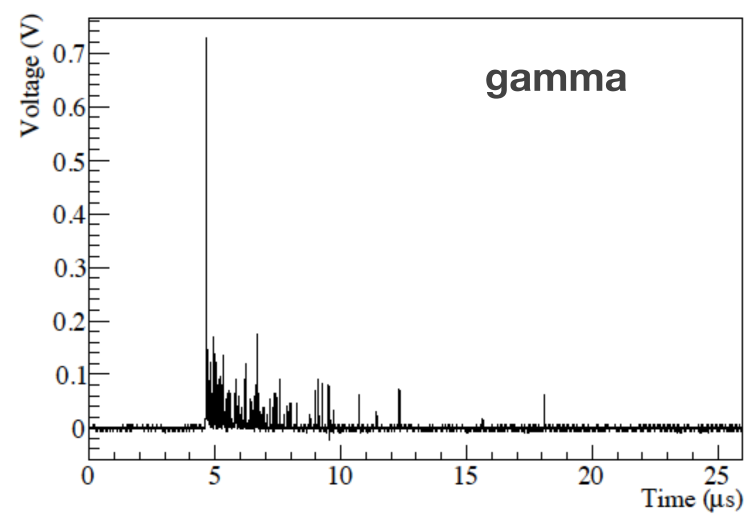


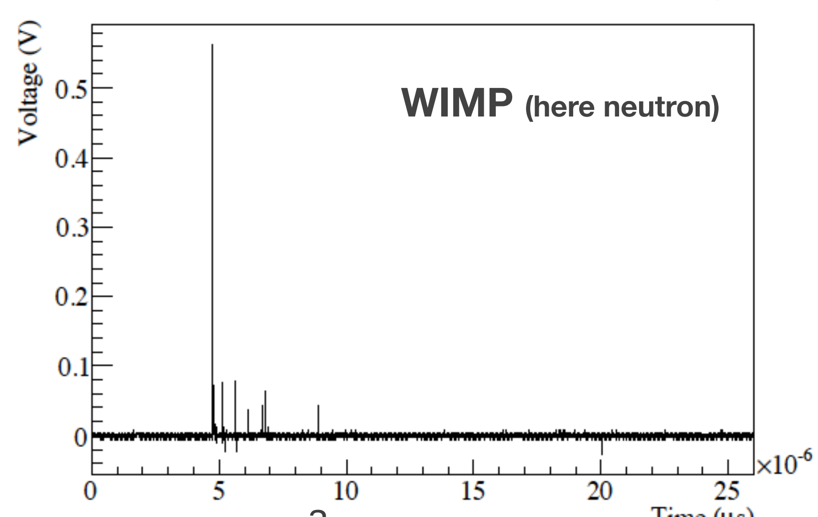




- Position reconstruction of few mm i.e. superior position reconstruction (mm vs. cm
- Scaling dificult due to long electron drift times or loss of signal on target impurities
- Ton scale LAr option only viable with depleted Ar
- Latest Xenon100 results leading the field on SI WIMP-nucleon Xsec limits

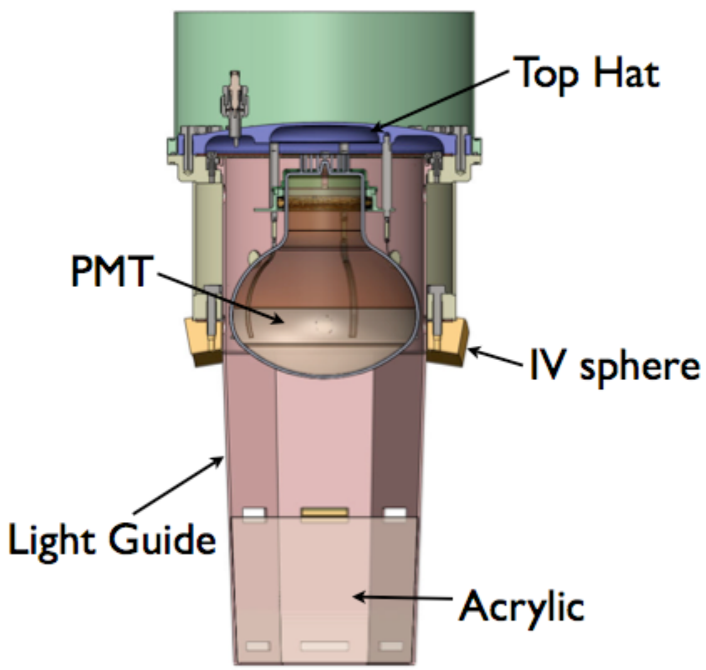


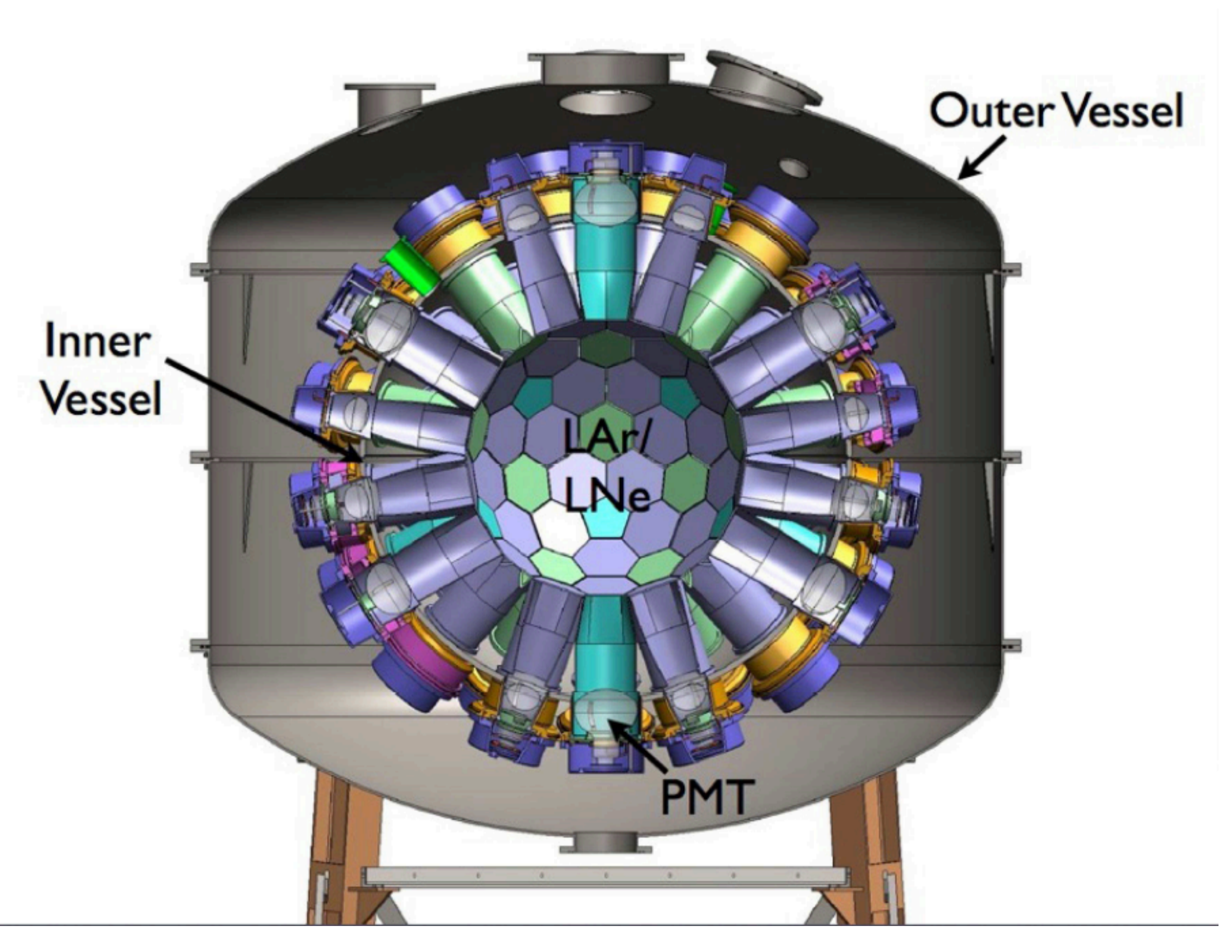




- Maximize light collection in order to use PSD techniques (4π coverage)
- Modular design & radon-free assembly
- Capability to run with Argon and Neon in order to test scaling of rates S/B
- When collecting only the fast scintillation component there is less chance of pile-up when the experiment is scaled up
- We believe it is a technique worth pursuing given the potentially simple and economic path to the multi-ton scale

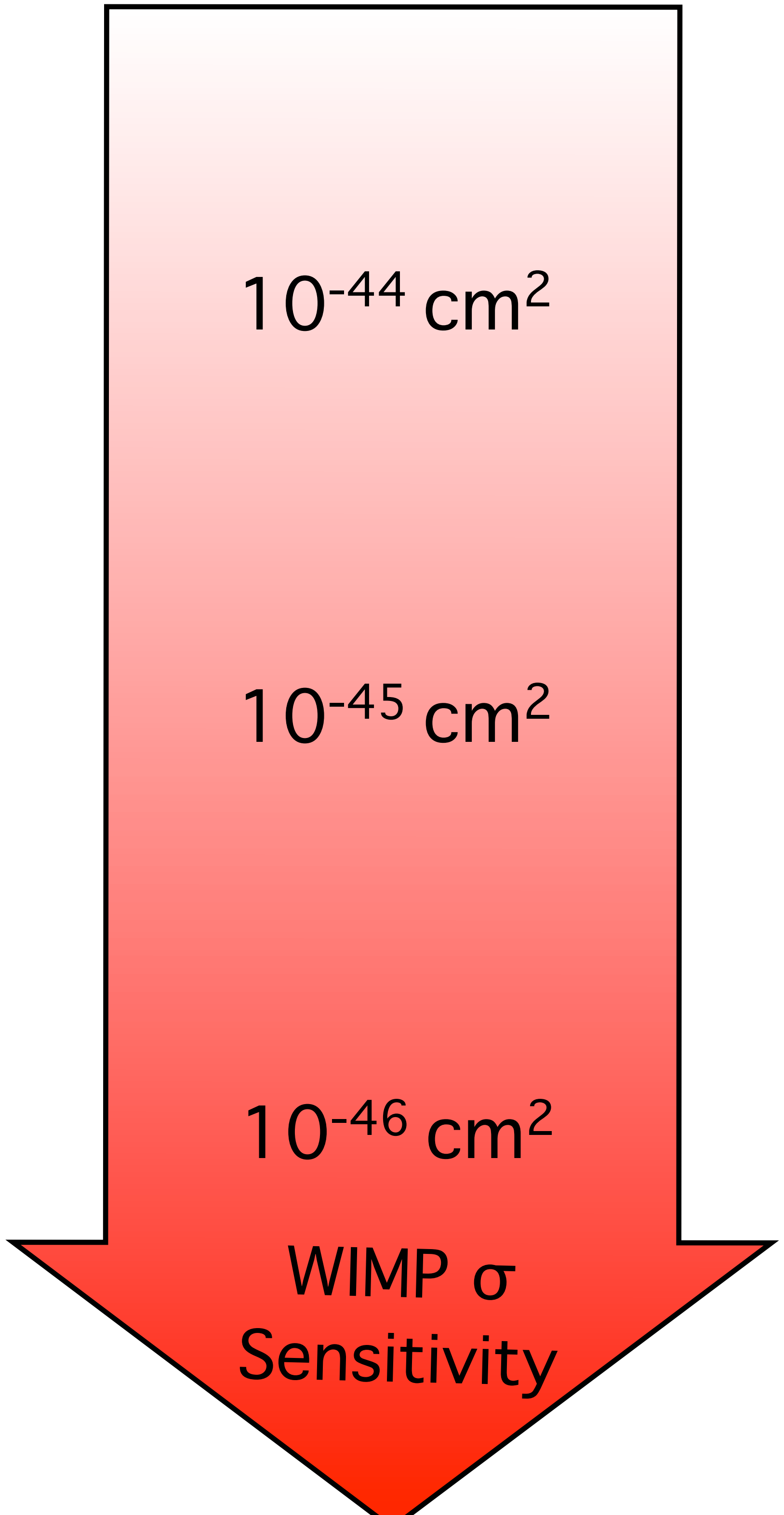
MiniCLEAN
Single Phase LAr and LNe Program





- Using Pulse Shape Discrimination in a single phase configuration in LAr allows a competitive WIMP search with 500kg (150kg fiducial) at the level of $10^{-45}cm^2$ (Spin-independent)
- Goal of MiniCLEAN is to reach a sensitivity in WIMP-nucleon cross section at $2x10^{-45}cm^2$ after 300 kg/y
- MiniCLEAN aims to demonstrate position reconstruction and neutron tagging
- Will measure the reach of the PSD technique up to $1:10^{10}$
- MiniCLEAN has to demonstrate that it can reduce radon daughter backgrounds at level of 1 alpha/m^2/day
- If WIMP-candidates appear, will swap to LNe as a cross check on background rate (A^2 dependance of WIMP rate)
- LNe will be used to test capability for a large pp solar neutrino detector

The DEAP and CLEAN Family of Detectors



Deap-0
Initial R&D detector
at LANL

Deap-1
7kg LAr
2 warm PMTs
At SNOLAB 2008

picoCLEAN
Initial R&D detector
at Yale

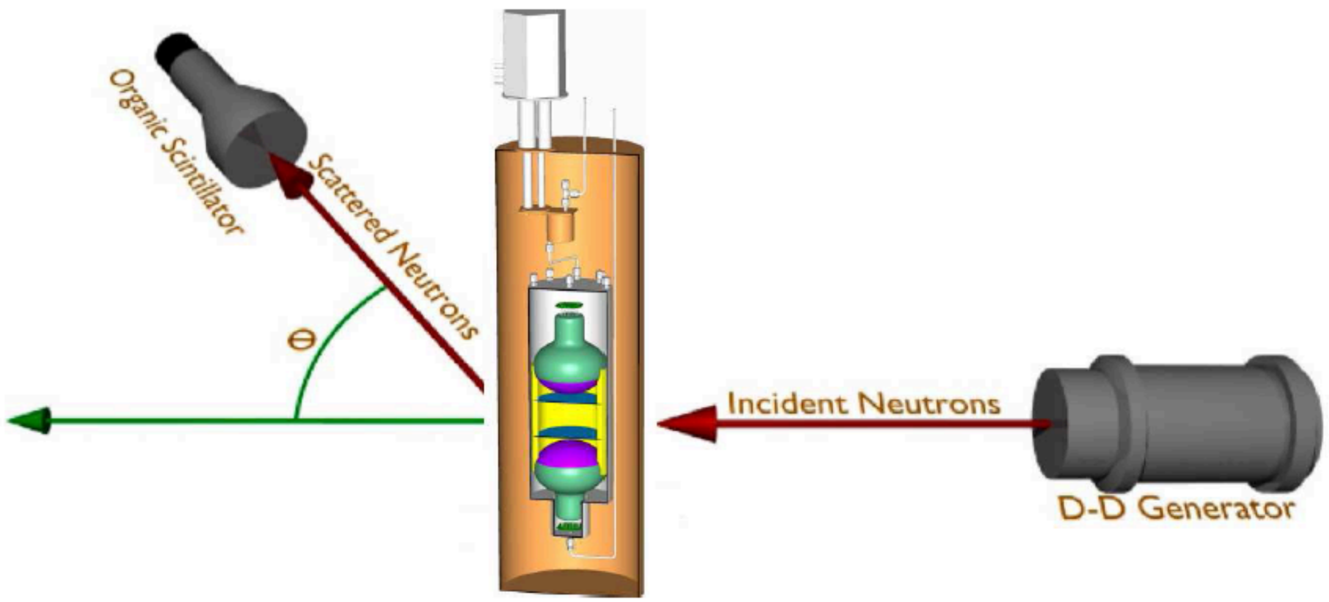
microCLEAN
4kg LAr or LNe
2 cold PMTs
surface tests at Yale

MiniCLEAN
500kg (150kg fiducial) LAr or LNe
92 cold PMTs
At SNOLAB early-2012

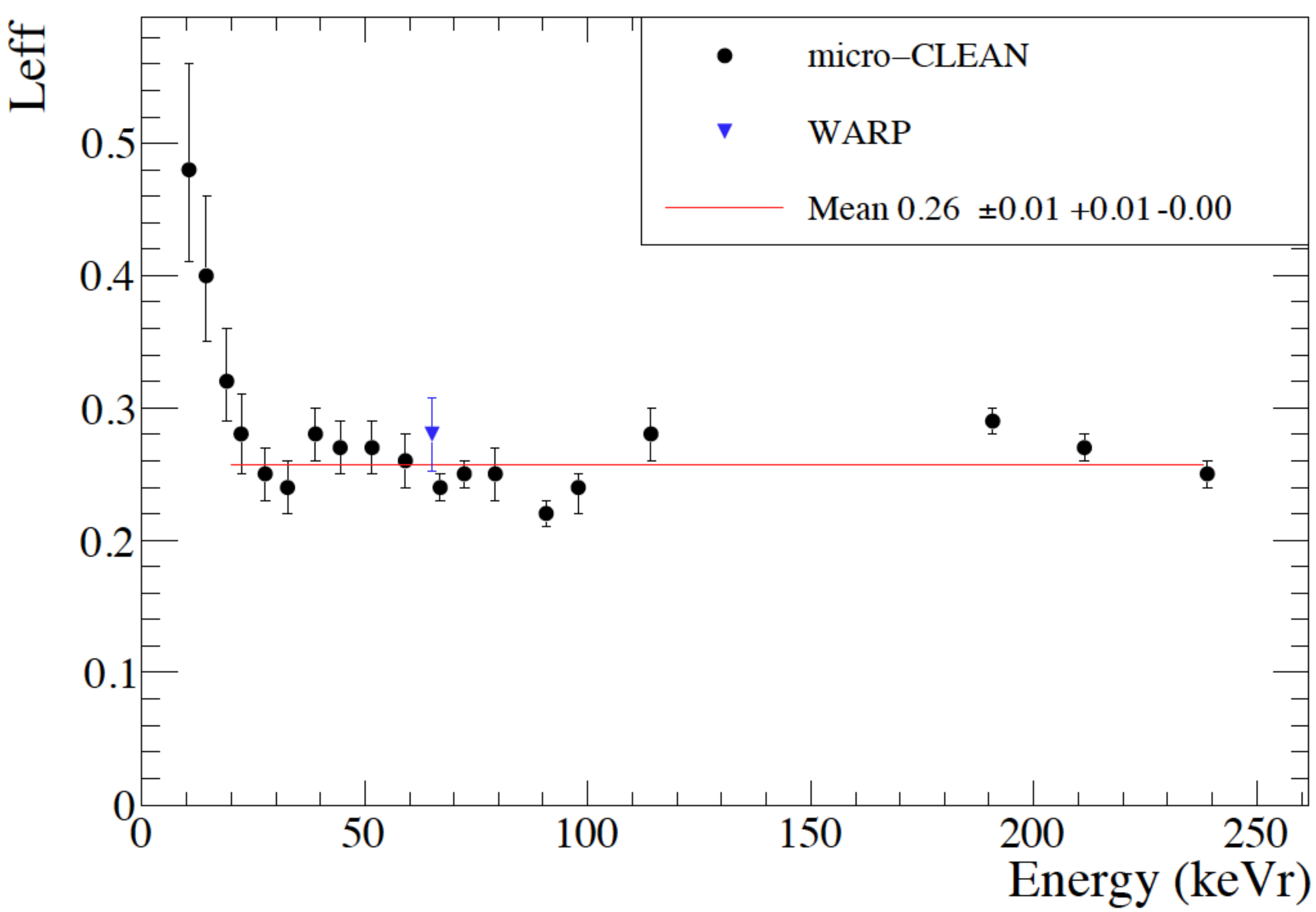
DEAP-3600
3600kg (1000kg fiducial) LAr
266 cold PMTs
At SNOLAB late 2012

50-tonne LAr/LNe Detector
pp-solar ν's, Supernova ν's, dark matter < 10^{-46}cm^2
At DUSEL ~2016?

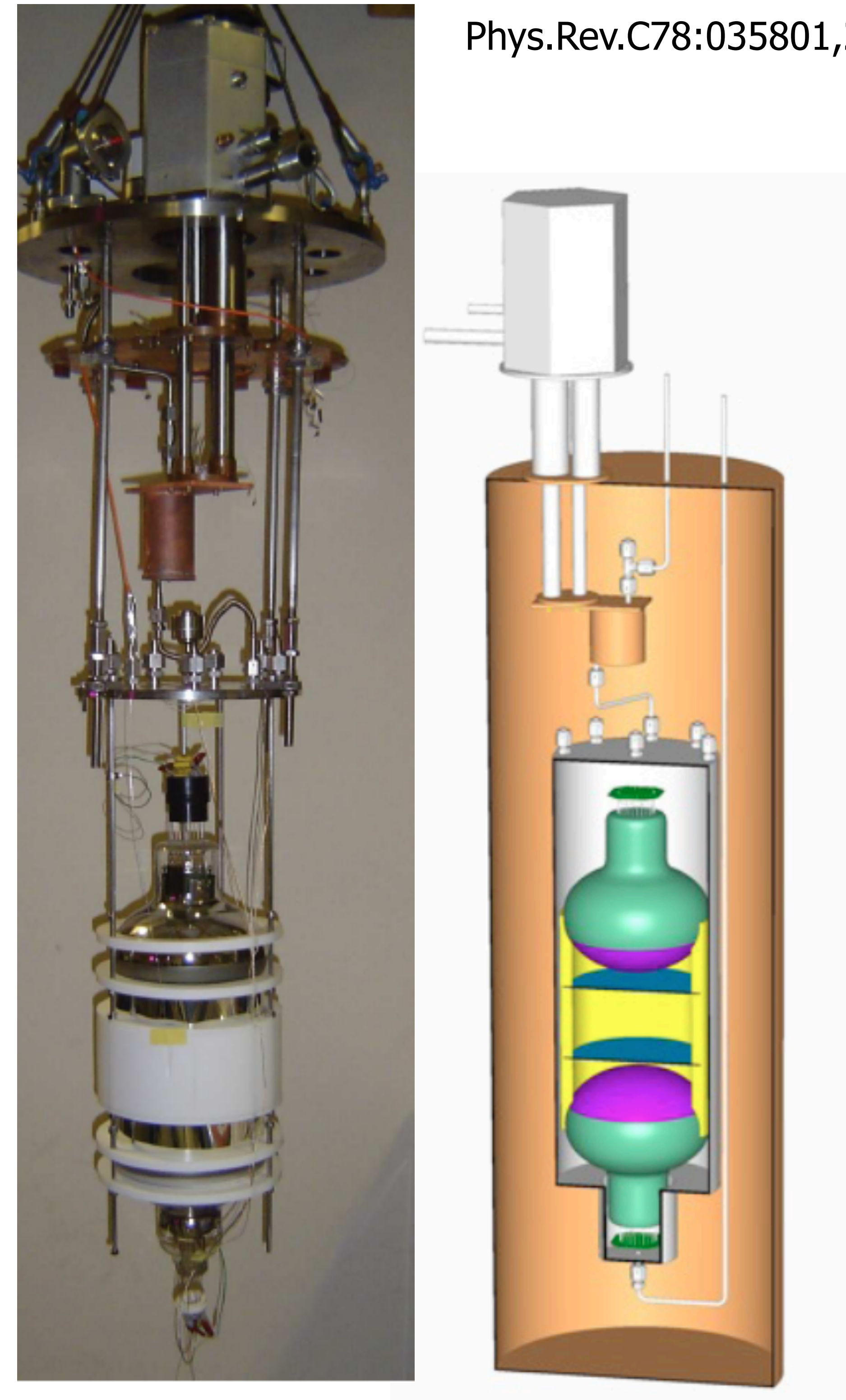
Summary of R&D: MicroCLEAN



$$E_{recoil} = \frac{2E}{(1+A)^2}\left(1 + A - \cos^2\theta - \cos\theta\sqrt{A^2 + \cos^2\theta - 1}\right)$$

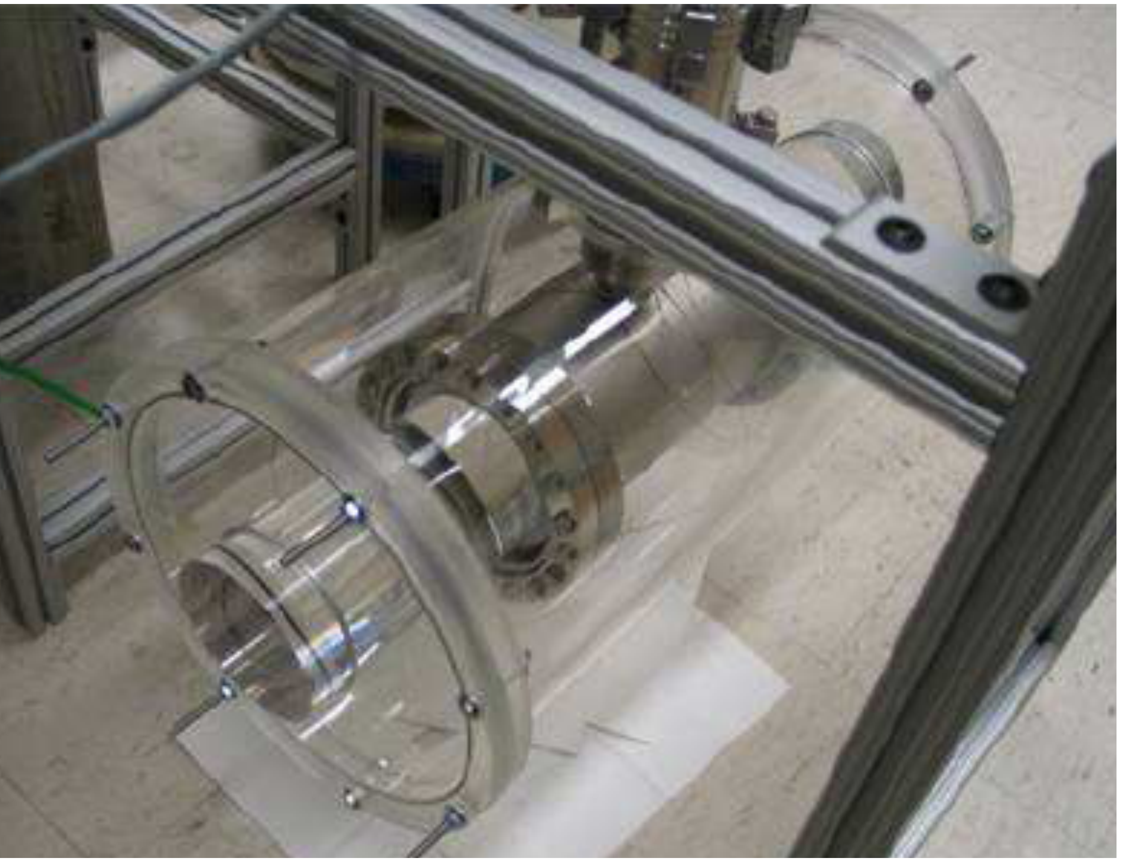


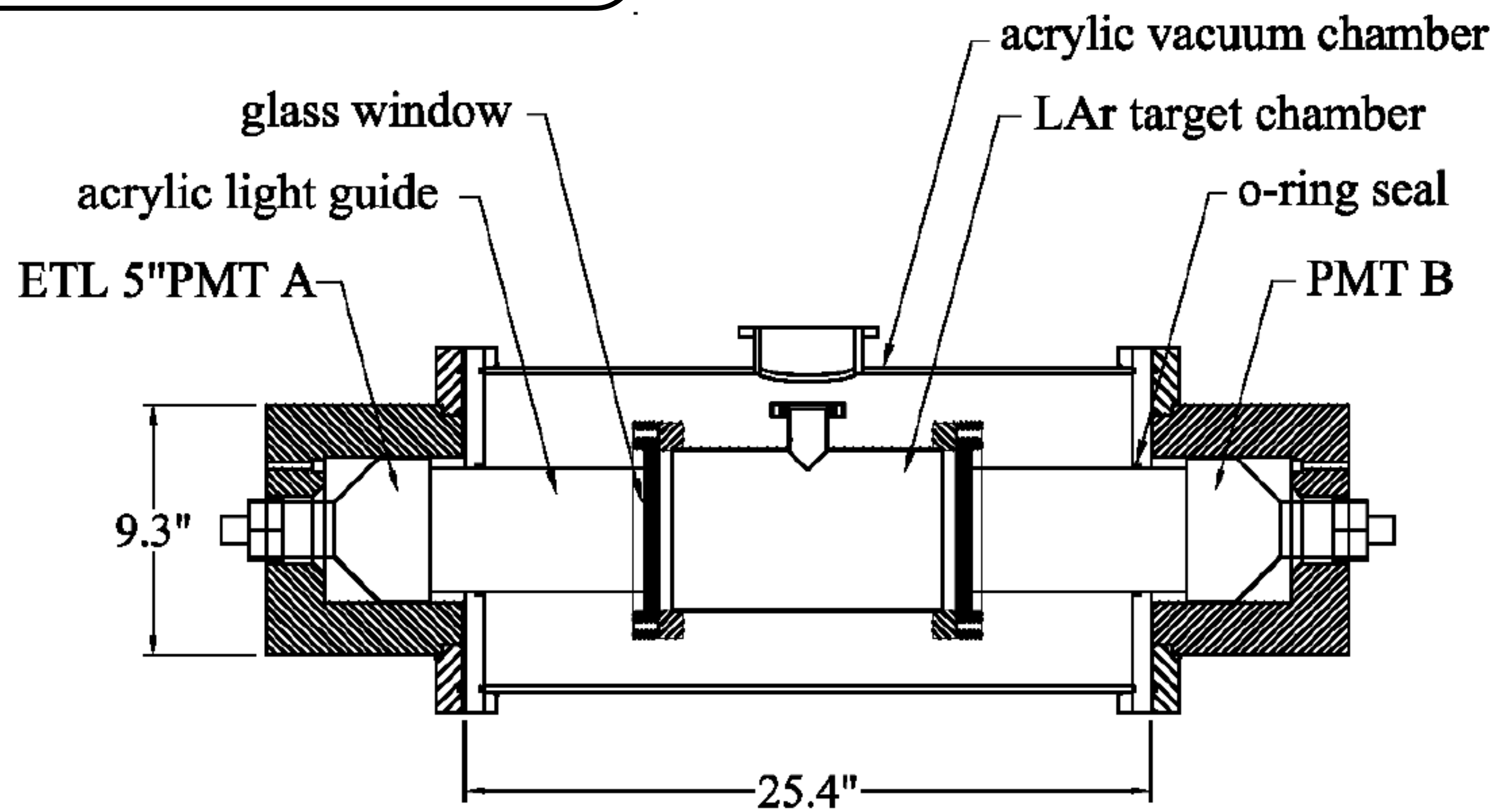
Phys.Rev.C78:035801,2008

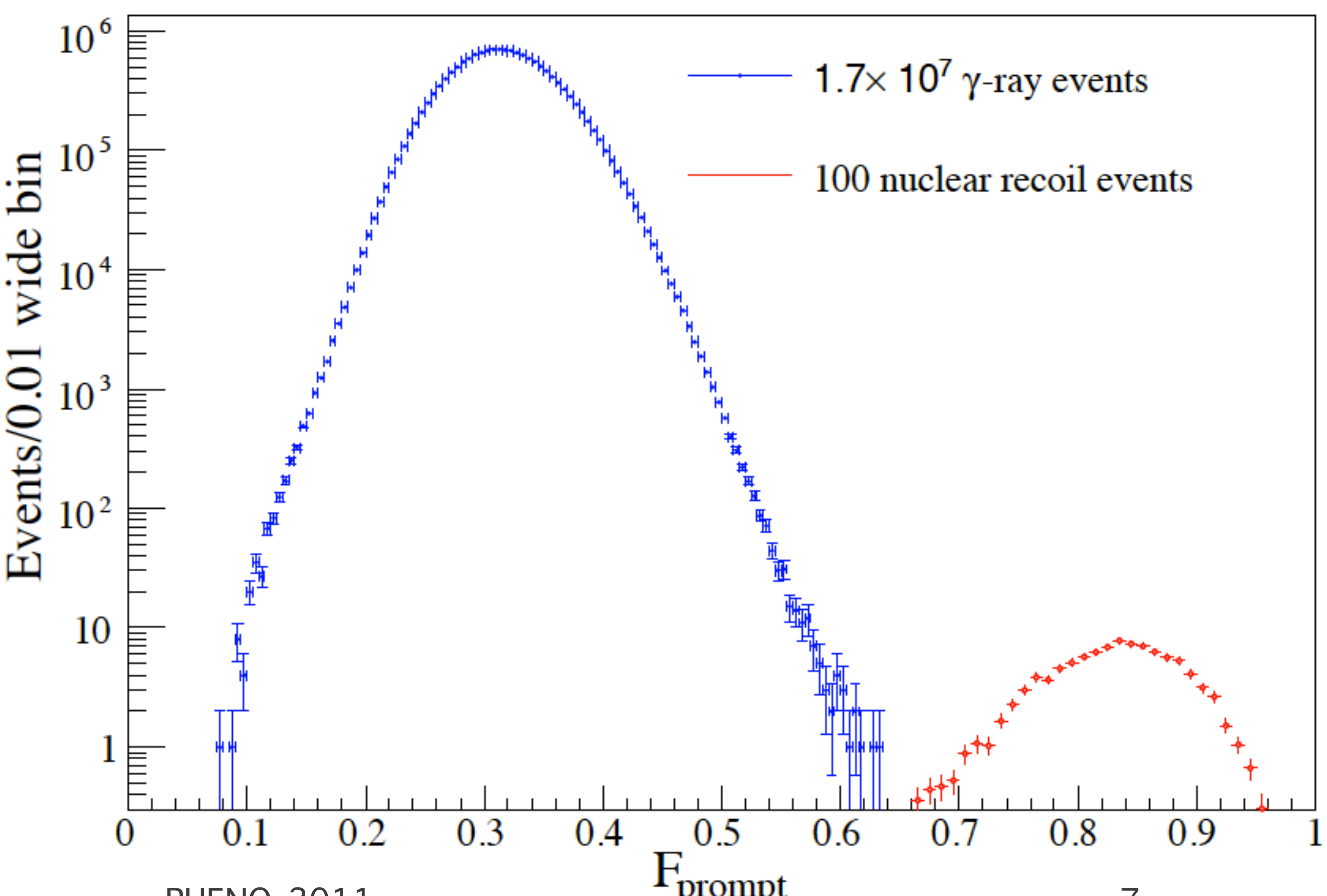


20cm PMTs immersed in liquid cryogen, all inner surfaces coated with TPB. White teflon cylinder contains active region.

Summary of R&D: DEAP-1





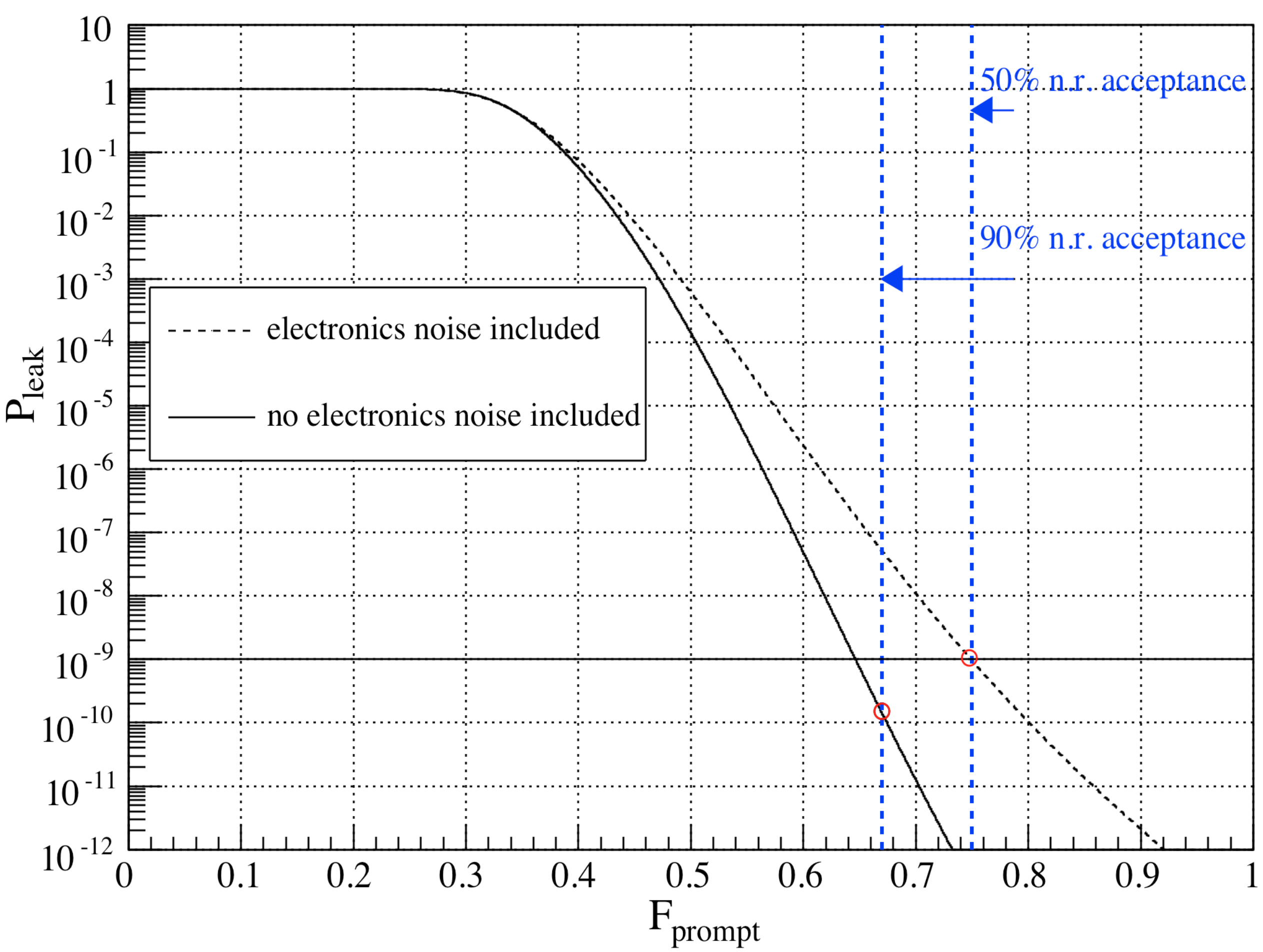


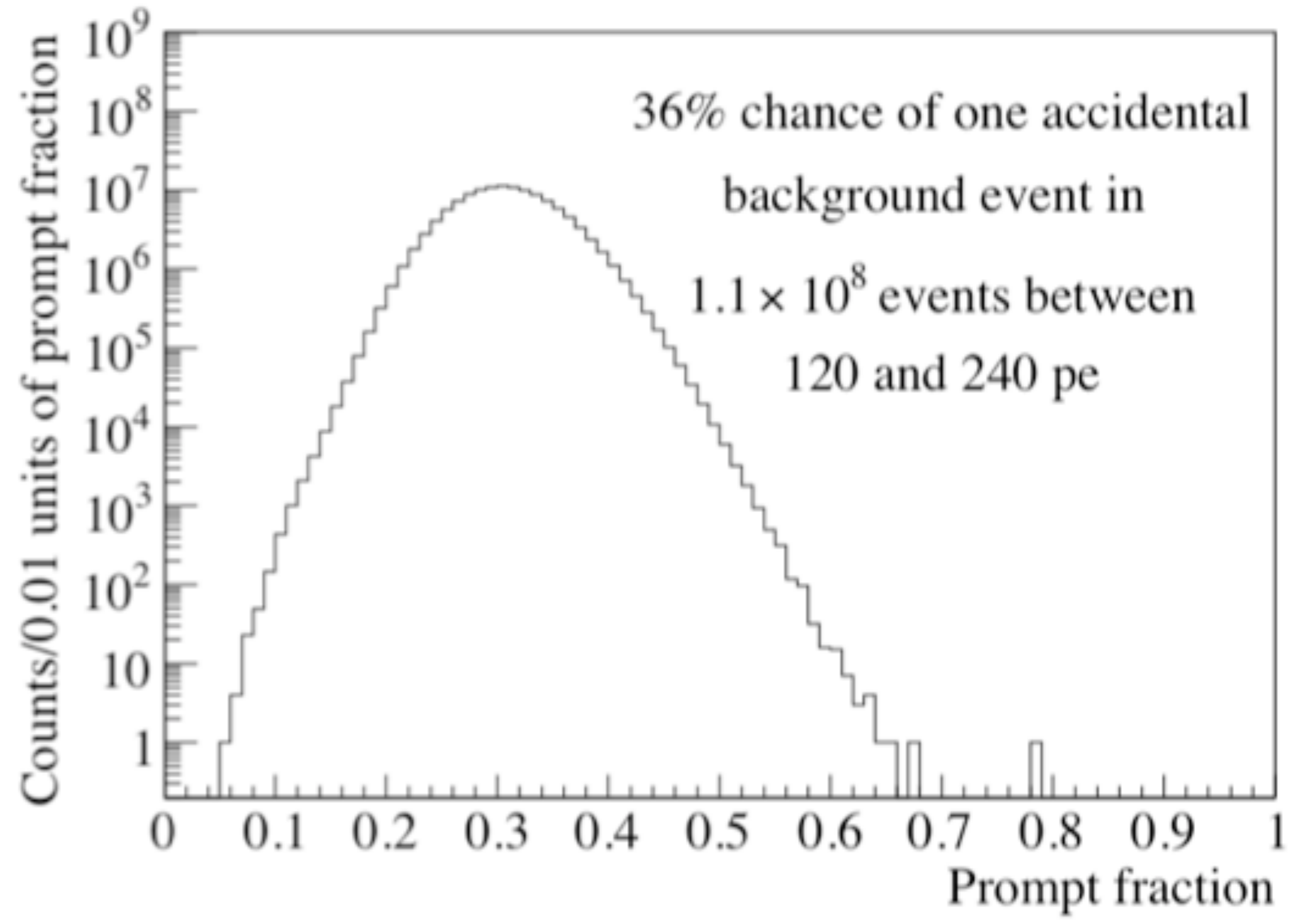
- Run at Queen's U. at surface
- Utilized a ^{22}Na source
- Light yield of 2.8 pe/keV
- No leakage observed for a sample of 1.7×10^{7} events
- For a neutron eff. of 50% and between 25–86 keV_{ee} measured a PSD of 4.7×10^{-8}
- DEAP-1 now underground at SNOLAB

Boulay et al., arXiv:0904.2930v1 [astro-ph.IM]

Summary of R&D: DEAP-1

- With modest improvements on Rn and surface event contamination, DEAP-1 at SNOLAB has reached...

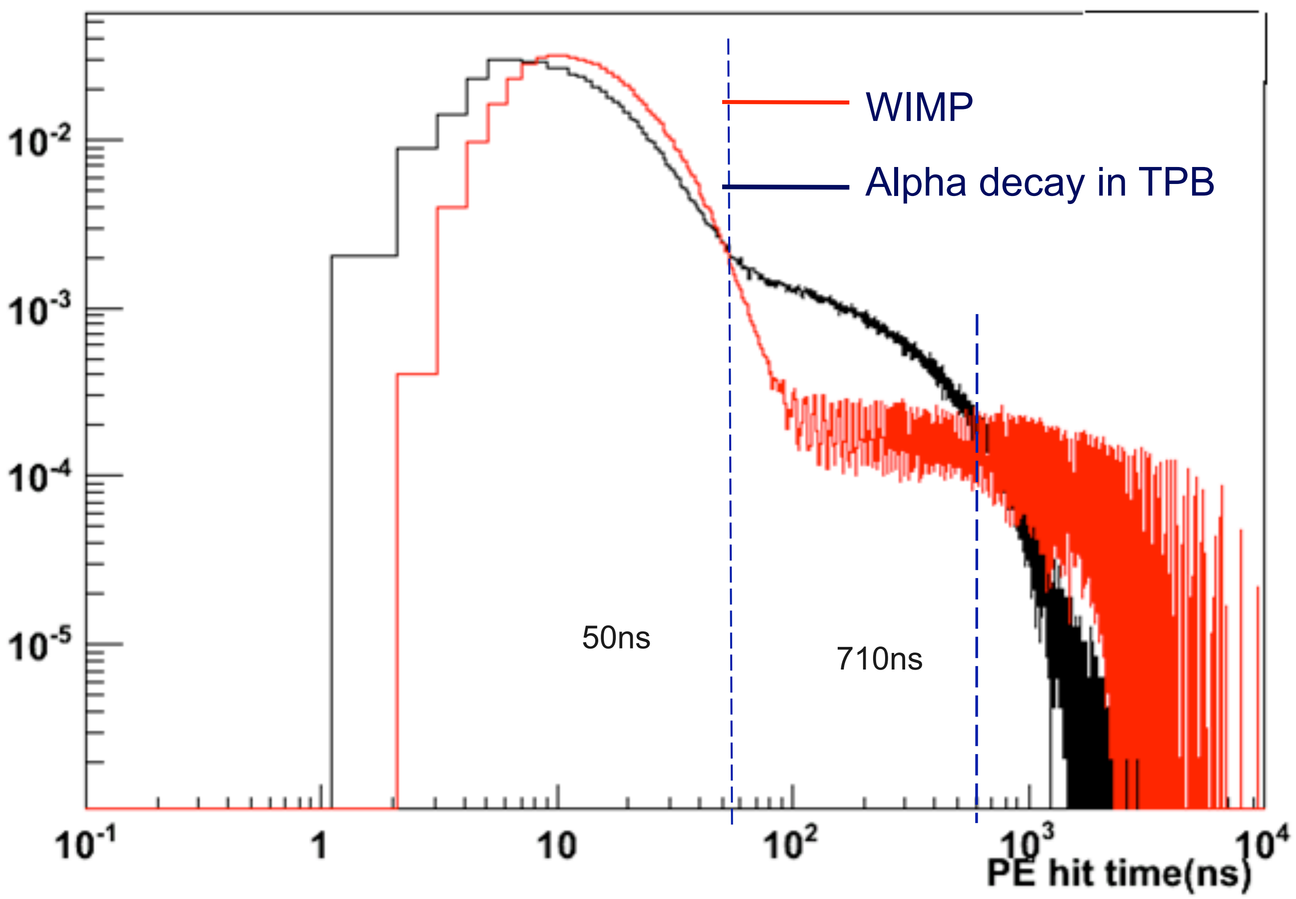




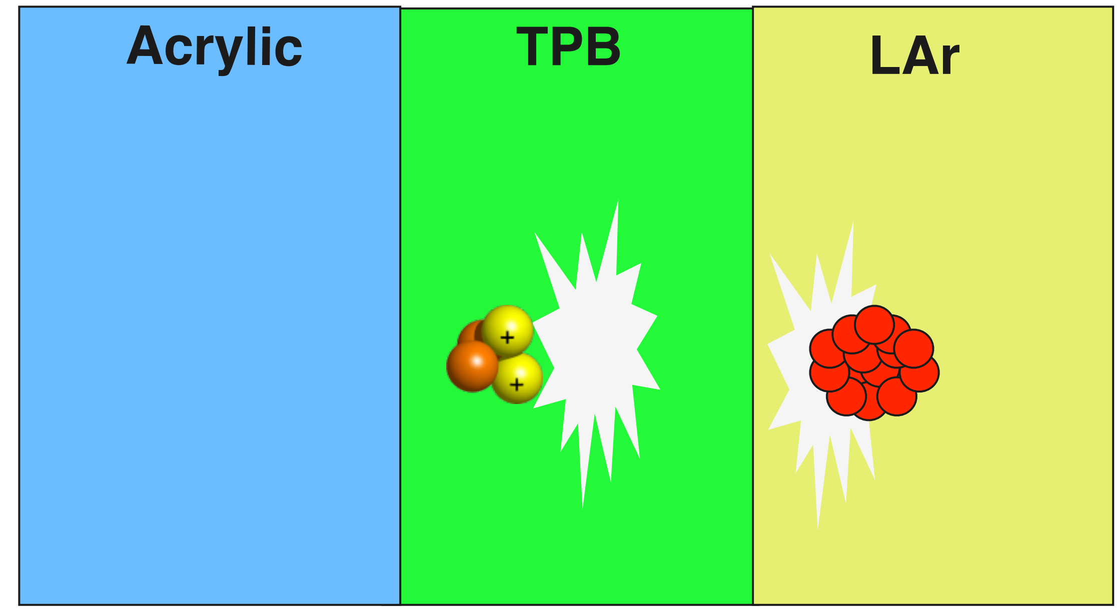
- 1 Event consistent with accidental backgrounds in the nuclear recoil region of interest ... 9.3×10^{-9}
- We are within a factor of ~5 for what is needed for MiniCLEAN and now it is likely to demonstrate that with MiniCLEAN and 3-D position reconstruction against Rn.

Surface Backgrounds: Recent Milestones

Alpha decays from ^{238}U, ^{232}Th, ^{222}Rn daugher
$^{210}Po \longrightarrow$ alpha(5.3MeV) + ^{206}Pb(103keV)



Surface surrounding LAr

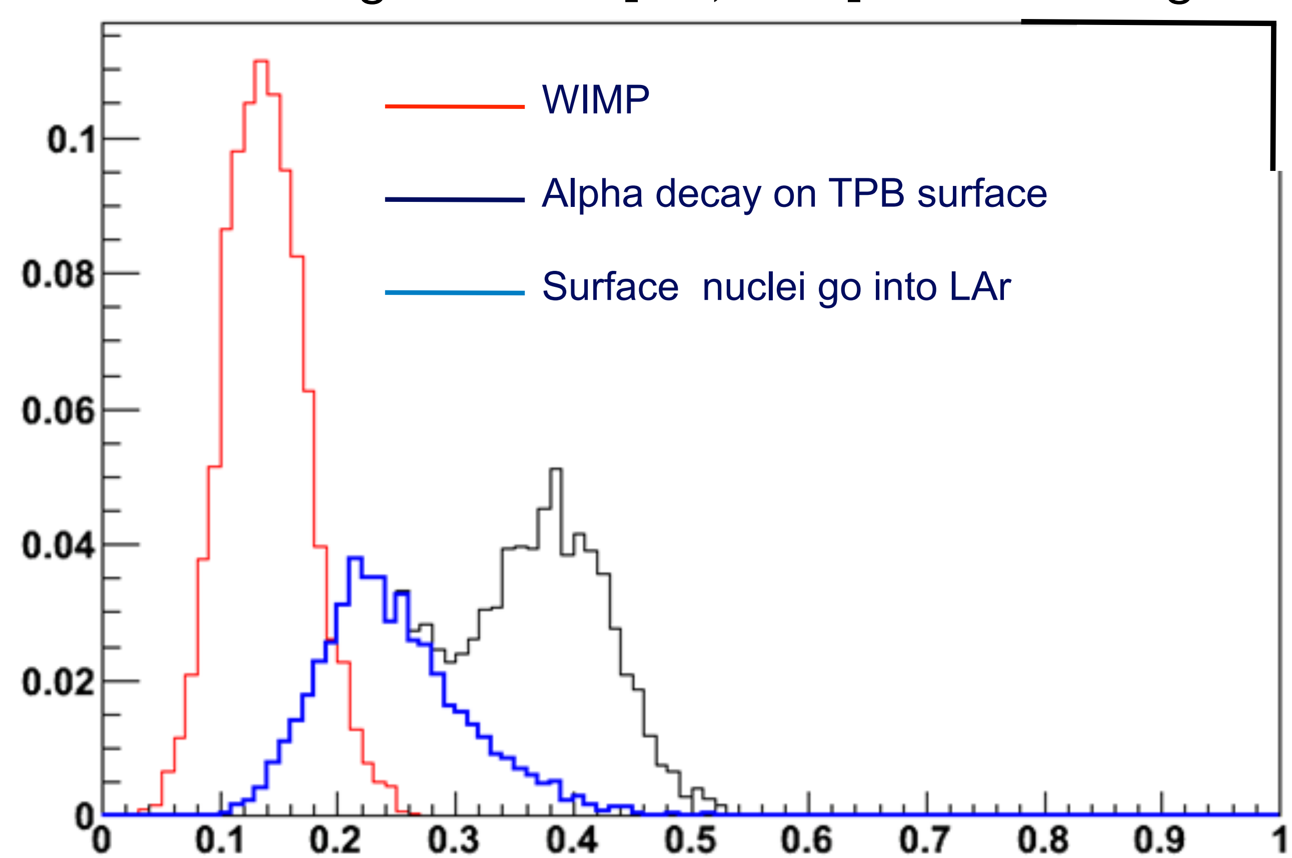


Handles against surface backgrounds:

- Energy range 75-150 p.e. (~20-40keVee)
- Pulse Shape Discrimination (~50-710ns)
- Position reconstruction (30% fiducial volume)
- Previous screening of materials, acrylic surface machining under vacuum, clean assembly

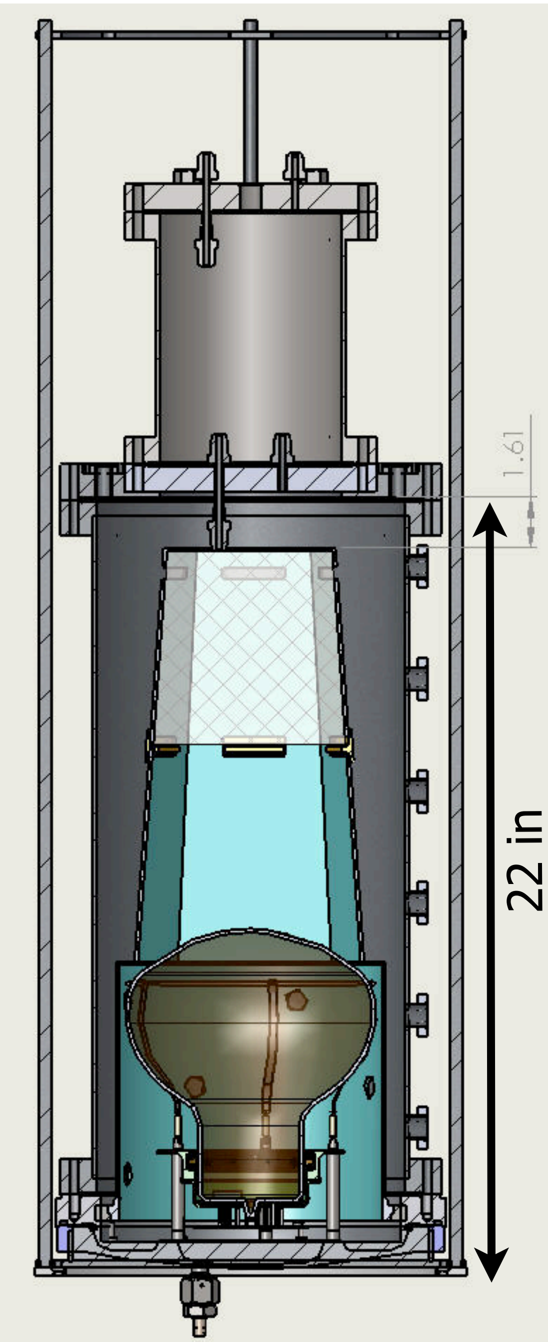
Boulay and Hime, Astropart. Phys. 25, 179 (2006)
Pollmann, Boulay, Kuzniak arXiv:1011.1012v1
K. Coakley, MiniCLEAN Workshop Jan 2011.
B. Wang and R.W. Schnee April APS mtg (2011)

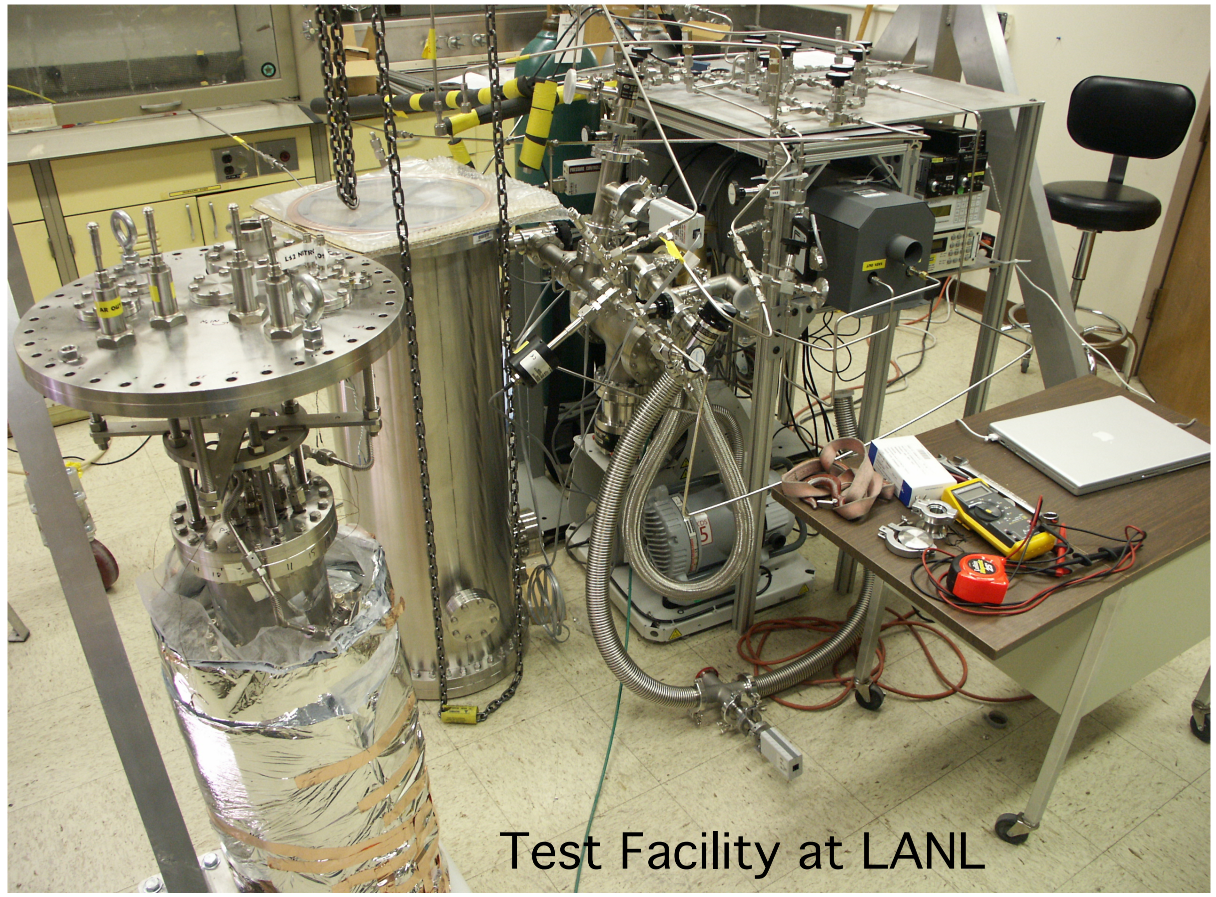
PSD discriminator
ratio of light within [50, 710]ns to total light

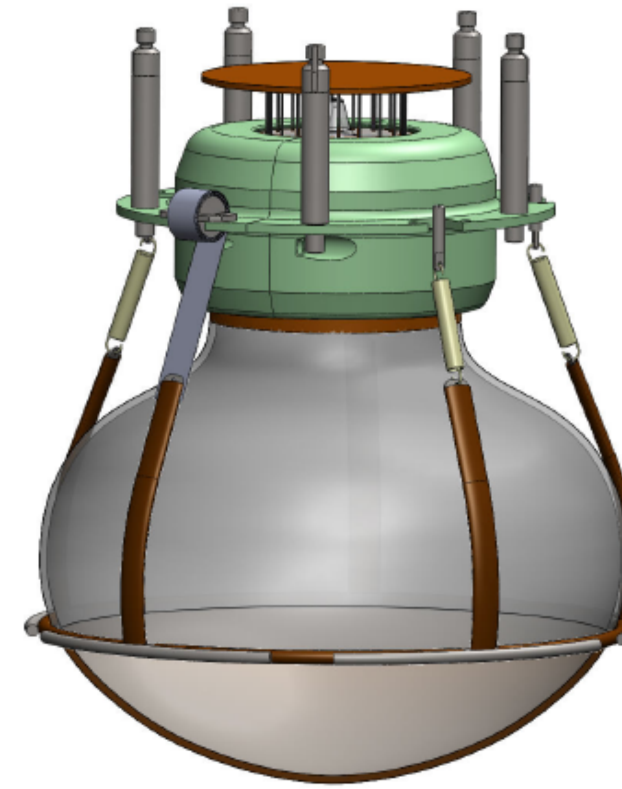


Optical Cassette Testing

Main design constraints: hold PMT under pressurized LAr and submerged (bouyant forces) in any direction, radioactivity from materials, installation and robustness




Test Facility at LANL



<u>Perform optical tests with a cassette prototype under pressurized LAr</u>

- Outfit the cassette prototype with sensors to measure strain and loads on certain components
- Determine the light collection
- Reflectivity of the aluminum (silver) coating as well as its integrity under pressurized LAr conditions
- Efficiency of the PMT
- Benchmark MiniCLEAN monte carlo simulations
- Use alpha source to benchmark surface background model

Fabrication Status

MiniCLEAN Inner Vessel

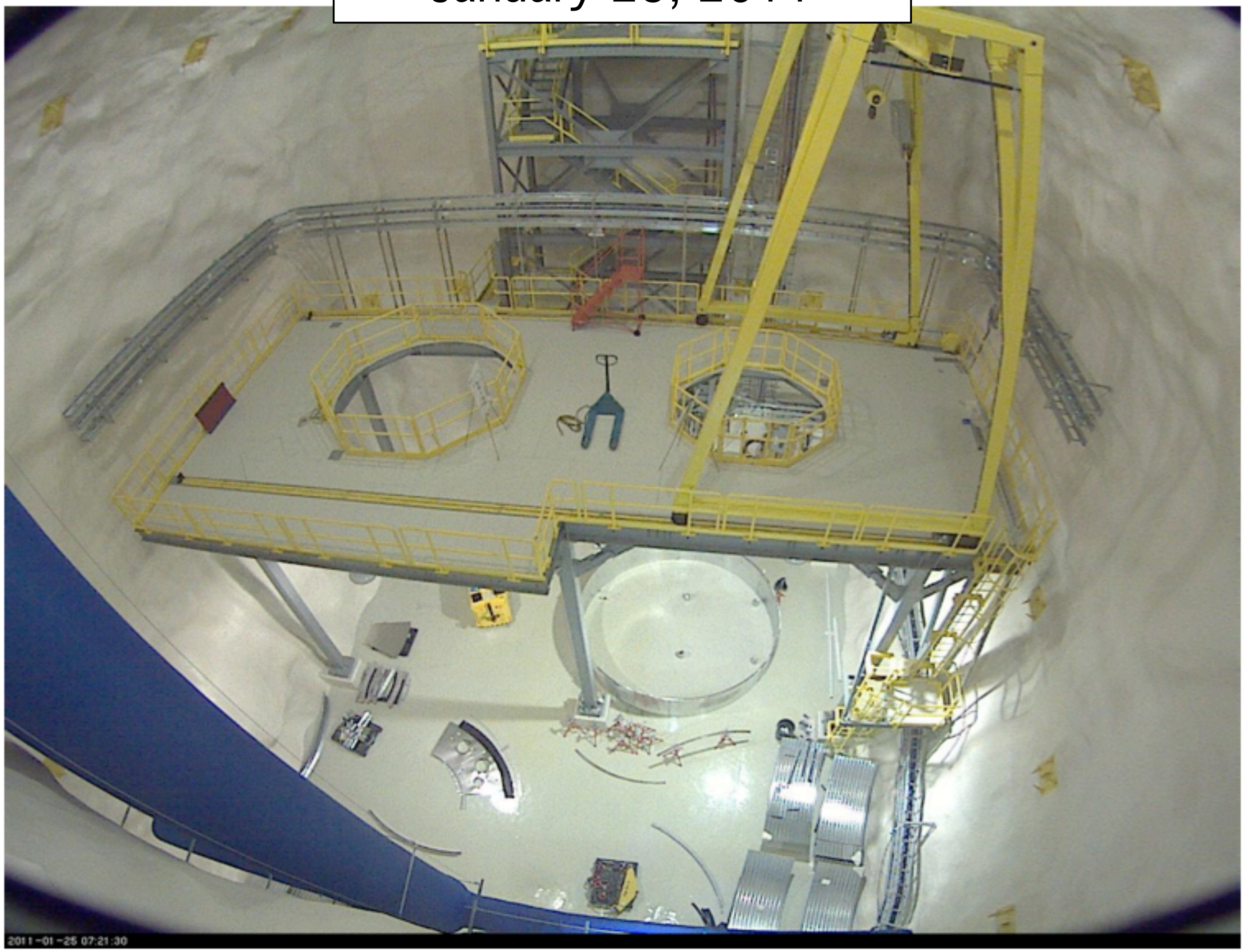
In Fabrication at Winchester
Precision Technologies
April 7, 2011

MiniCLEAN Outer Vessel

Engineered at LANL
Fabricated at PHPK Technologies, Columbus, OH

At the Lab ~6500 ft underground

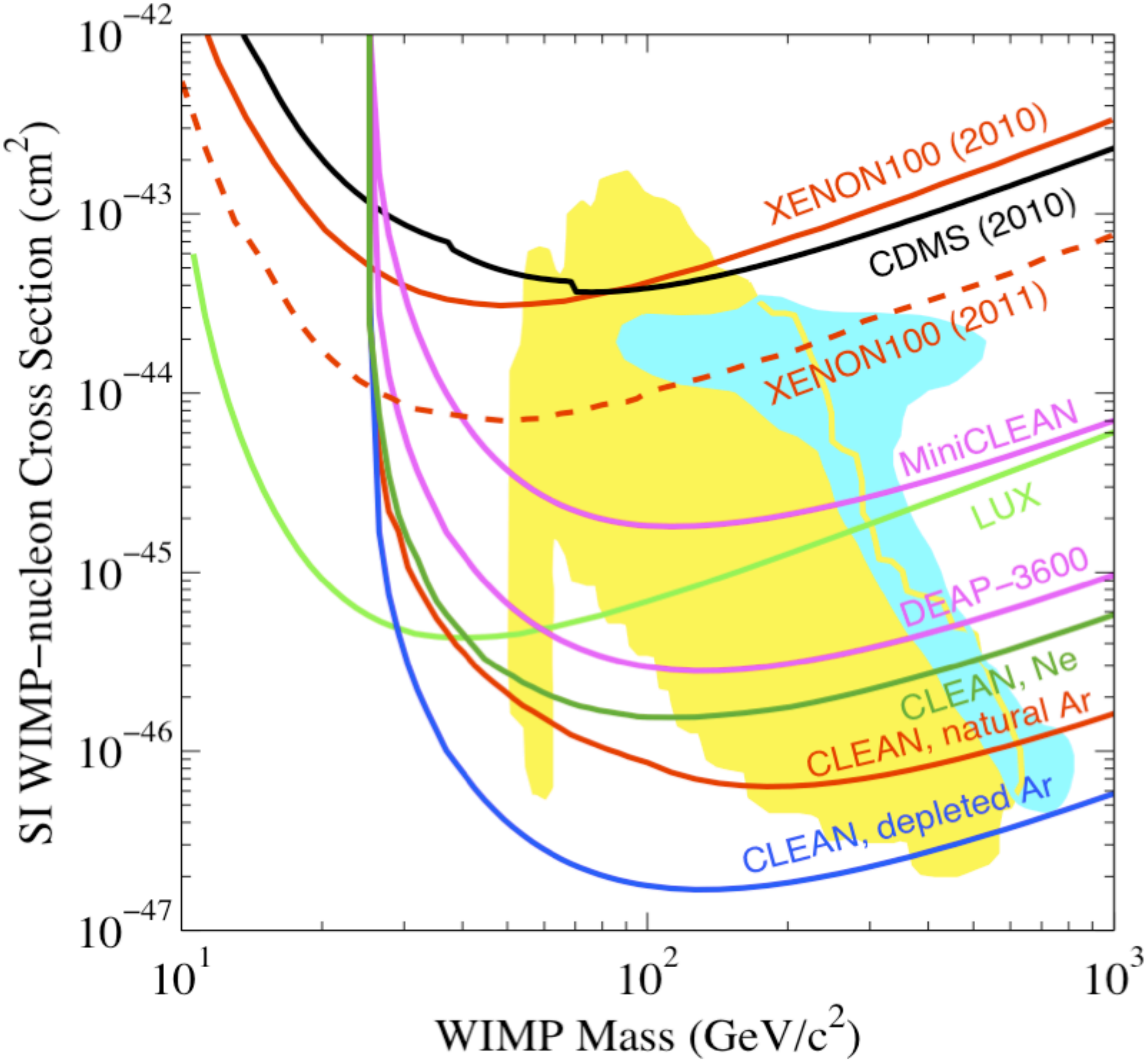
SNOLAB Cube-Hall – January 25, 2011



MiniCLEAN Water-Shield - April, 2011

With the water-shield tank assembled, the SNOLAB Cube Hall is ready for detector assembly.

MiniCLEAN Sensitivity Projections and Summary



- The use of noble liquids as scintillators in single and dual-phase detectors are some of the most promising scalable WIMP detectors
- Using single phase configuration with PSD allows for easy scalability and MiniCLEAN can use both LAr and LNe
- We believe MiniCLEAN has a sensitivity reach of ~ $2x10^{-45}cm^2$ after 300 kg/y for the LAr run
- Cassettes (PMT+Lightguide) have been designed and are in the process of testing to finalize the design
- Outer vessel going underground this summer
- Tank and deck are ready, inner vessel is being fabricated by Winchester Precision Technologies
- Assembly scheduled for late 2011

DEAP/CLEAN Collaborators

<u>University of Alberta</u>

B. Beltran, P. Gorel, A. Hallin, S. Liu, C. Ng, K.S. Olsen, J. Soukup

<u>Boston University</u>

D. Gastler, E. Kearns, S. Linden

<u>Carleton University</u>

M. Bowcock, K. Graham, P. Gravelle, C. Oullet

<u>Harvard University</u>

J. Doyle

<u>Los Alamos National Laboratory</u>

M. Akashi-Ronquest, R. Bingham, R. Bourque, E. Flores, V.M. Gehman, J. Griego, R. Hennings-Yeomans, A. Hime, S. Jaditz, F. Lopez, J. Oertel, K. Rielage, L. Rodriguez, D. Steele

<u>Massachusetts Institute of Technology</u>

L. Feng, J.A. Formaggio, J. Kelsey, J. Monroe, K. Palladino

<u>National Institute of Standards and Technology</u>

K. Coakley

<u>University of New Mexico</u>

M. Bodmer, F. Giuliani, M. Gold, D. Loomba, J. Wang

<u>University of North Carolina/TUNL</u>

R. Henning, S. MacMullin

<u>University of Pennsylvania</u>

T. Caldwell, J.R. Klein, A. Latorre, A. Mastbaum, G.D. Orebi Gann, S. Seibert

<u>Queen's University</u>

M. Boulay, B. Cai, M. Chen, S. Florian, R. Gagnon, V. Golovko, P. Harvey, M. Kuzniak, J. Lidgard, A. McDonald, T. Noble, P. Pasuthip, C. Pollman, W. Rau, P. Skensved, T. Sonley, M. Ward

<u>SNOLAB Institute</u>

M. Batygov, F.A. Duncan, C. Jillings, I. Lawson, O. Li, P. Liimatainen, K. McFarlane, T. O'Malley, E. Vazquez-Jauregi

<u>University of South Dakota</u>

V. Guiseppe, D.-M. Mei, G. Perumpilly, C. Zhang

<u>Syracuse University</u>

R. Bunker, Y. Chen, M.S. Kos, R.W. Schnee, B. Wang

<u>TRIUMF</u>

P.-A. Amaudruz, A. Muir, F. Retiere

<u>Yale University</u>

D.N. McKinsey, J.A. Nikkel, Y. Shin