

THE DEAP 3600 DARK MATTER SEARCH IN SNOLAB

A.L. Hallin for the DEAP-3600 Collaboration

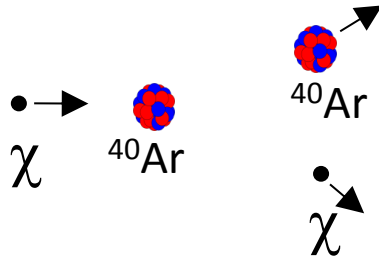
University of Alberta

NDM 2015, Jyvaskyla

June 2015

DEAP-3600 Dark Matter Search

Liquid Argon for DM (Single-phase)



Scattered nucleus (several 10's of keV) is detected via scintillation in LAr

Good Pulse-shape discrimination between b/g and nuclear recoils with scintillation

Argon is easy to purify

Very large target masses possible, no absorption of UV scintillation photons in argon, no pileup until beyond tonne-scale

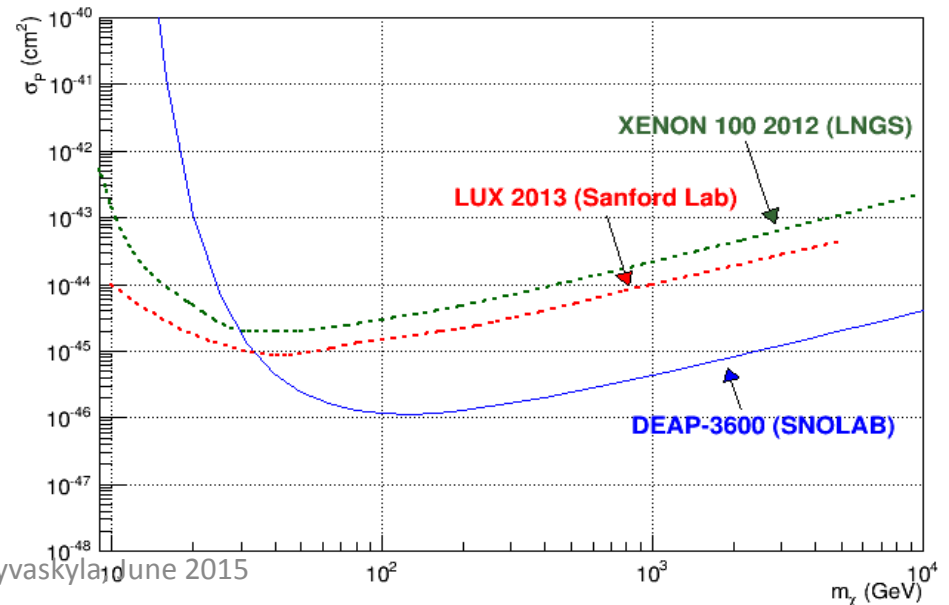
Position reconstruction based on photon detection allows mitigation of backgrounds from surfaces

Project Overview

3600 kg liquid argon in ultraclean acrylic vessel,
255 8-inch HQE PMTs

1000 kg fiducial mass designed for
< 0.2 background events/year

10^{-46} cm^2 sensitivity for $\sim 100\text{-GeV}$ WIMP with 3-year exposure



DEAP-3600 Detector

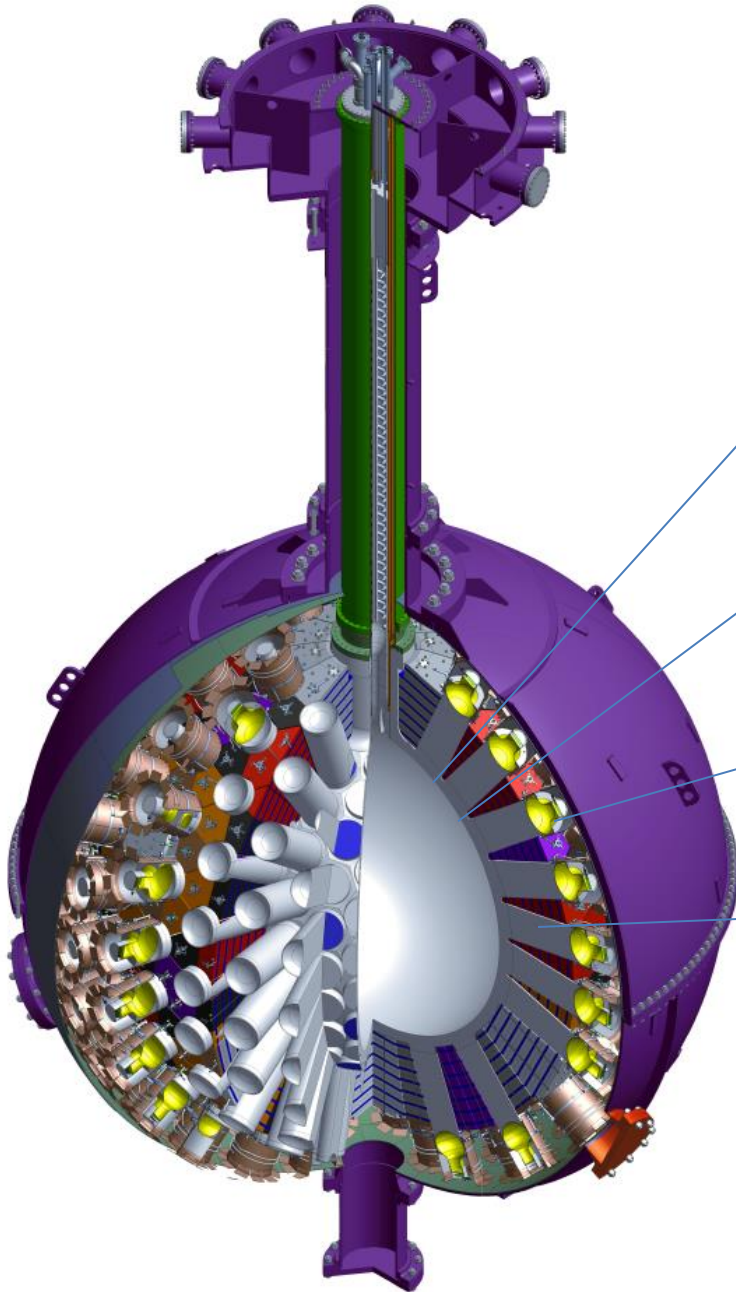
3600 kg argon target
(1000 kg fiducial)
in sealed ultraclean
Acrylic Vessel

Vessel is “resurfaced” in-situ to remove
deposited Rn daughters after
construction
TPB coating for wavelength shifting

255 Hamamatsu
R5912 HQE PMTs 8-inch
(32% QE, 71% coverage)

50 cm light guides +
PE shielding provide neutron
moderation

Steel Shell immersed in 8 m water shield
at SNOLAB



Background Budget 1000 kg-years Exposure

Background	Events in WIMP Energy Range	Events dominated by prompt light (singlet scintillation) in Fiducial Volume	Mitigation
Neutrons	30	<0.2	Detector designed as passive neutron shielding, SNOLAB location, water tank, materials selection
Surface alpha's	150	<0.2	Material selection, resurfacing, controlled exposure to radon, neck and liquid argon flow guide design
³⁹ Ar betas, other electromagnetic events	1.6×10^9	<0.2	Argon scintillation properties (PSD)

Critical Elements of the Design

- Acrylic cryostat with lightguides and filler blocks.
 - Very low radioactivity (on order of ppt U and thorium)
 - Good neutron moderator (requires 50 cm of acrylic to reduce neutrons from PMTs to background budget levels)
 - Good visible light transmission- moves the light from the ultraclean fiducial volume to the relatively “dirty” PMT’s/electronics/outer detector
 - Added bonus: thermal insulation is sufficient to allow use of room temperature PMT’s which are better understood than cryogenic PMTs. We need to understand PMT behaviour- especially light sources within PMTs at the level of one pulse/255 PMTs/3 years.
- Completely radon-tight inner volume that can be remotely resurfaced in a radon-controlled atmosphere and then sealed to prevent further exposure to airborne radon.
- Liquid argon active region
 - “Easily” purified (liquid noble)
 - Well defined and homogeneous background model
 - Exceptional PSD because of singlet (6 ns)/triplet (1.5 μ s) lifetime difference

Acrylic Cryostat Design

- Measured mechanical (Young's modulus, tensile strength) properties of bonded and unbonded



Figure 1: First principal stress for a neck and bottom supported acrylic vessel. The maximum is 11.9

Fabrication and Assay of DEAP Acrylic

- Fabrication from pure MMA monomer at RPTAsia (Thailand), strict control of radon exposure for all steps
- DEAP Collaborators present during fabrication
- Control to $< 10^{-20}$ g/g ^{210}Pb from radon exposure
- Developed system to vaporize and assay large quantities of acrylic (10 kg samples), count residue with Ge well detector for ^{210}Pb peak, and with alpha counter for ^{210}Po ; (Corina Nantais M.Sc. Thesis)



Monomer cast at RPT Asia



Thermoformed Panel at RPT Colorado



The journey of the acrylic vessel begins in Thailand, where acrylic sheets are poured from clean acrylic monomer.

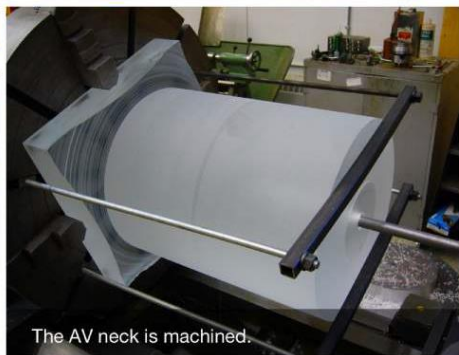
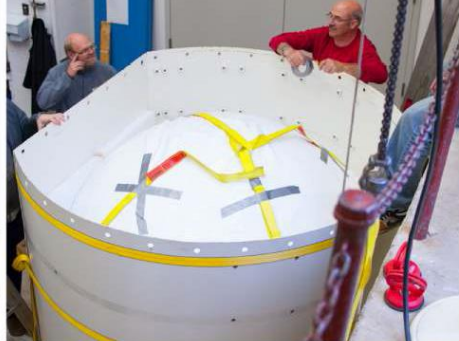


The sheets are thermoformed and machined into 'orange slices'.





lar is machined.



The AV neck is machined.



' thick shell controls thermal stress. Stubs move bond to low stress regions.

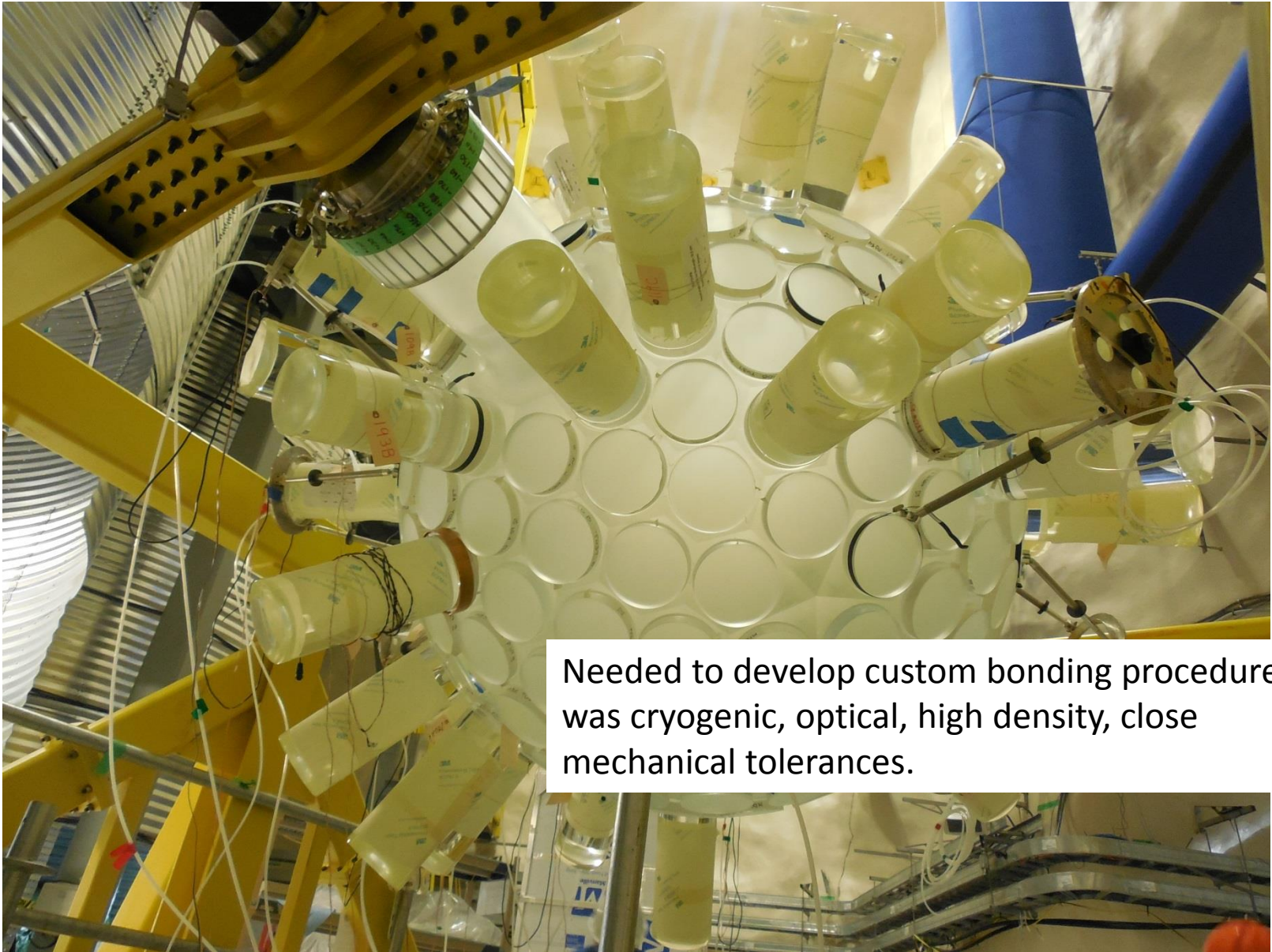


In several passes, stubs are precision machined out of the main AV sphere.

AV Neck Bond (Reynolds Polymer, Tech. (RPT) at SNOLAB Jan 2013)



Vessel sealed and purged, approx. 50 LGs bonded (September 2013)



Bonded underground, finish machined and then light guides attached:



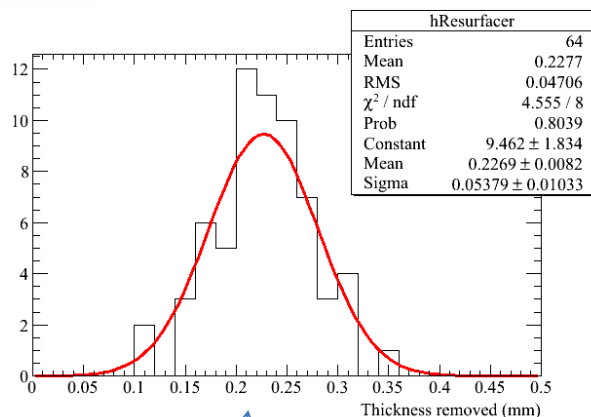
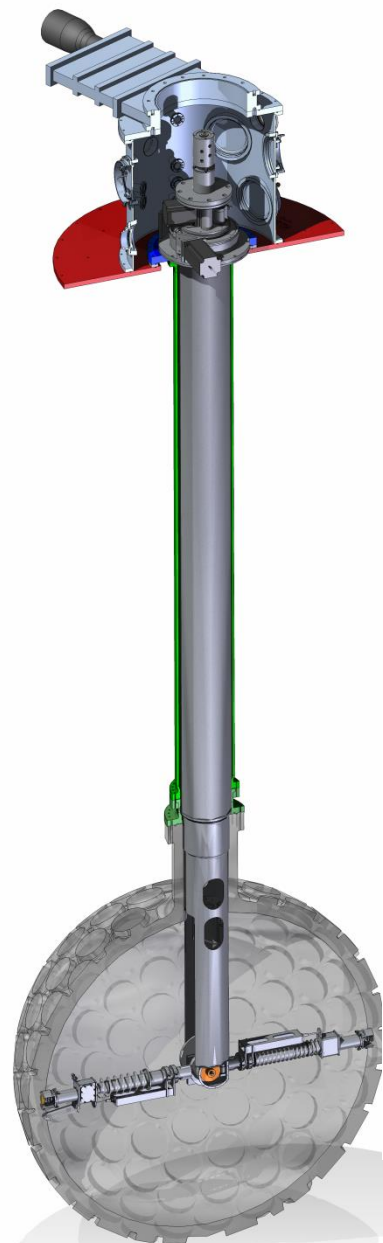
November, 2013

DEAP-3600 Acrylic Vessel Resurfacer

Removes ~1 mm acrylic
in-situ after construction

Radon-scrubbed N_2
purge gas and UPW
flushing to extract
residue

Surface contamination
returns to bulk purity
level



24% uniformity demonstrated

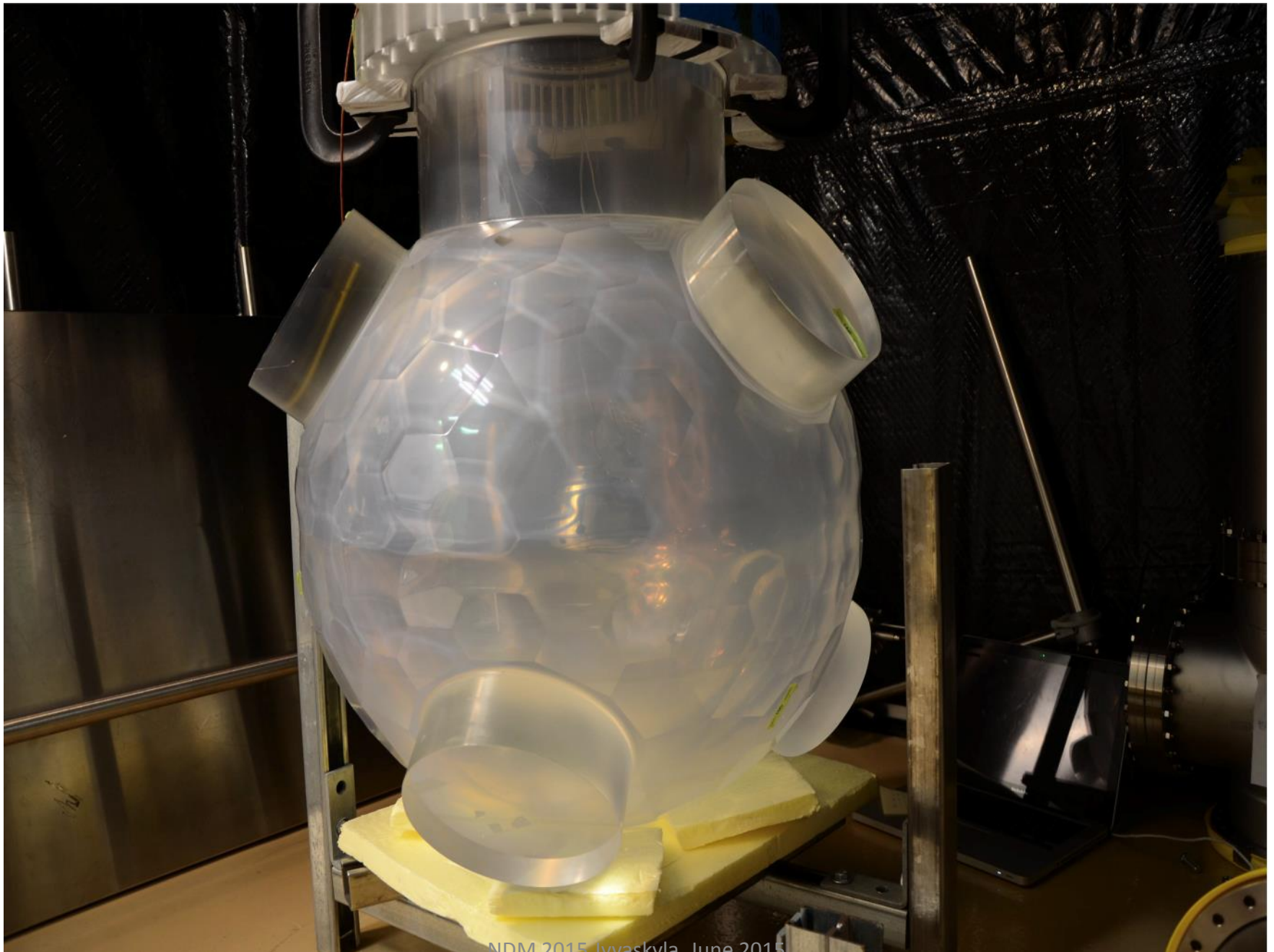


4π TPB (Organic WLS) deposition source developed for DEAP-3600



20-inch test vessel, 1/3 scale

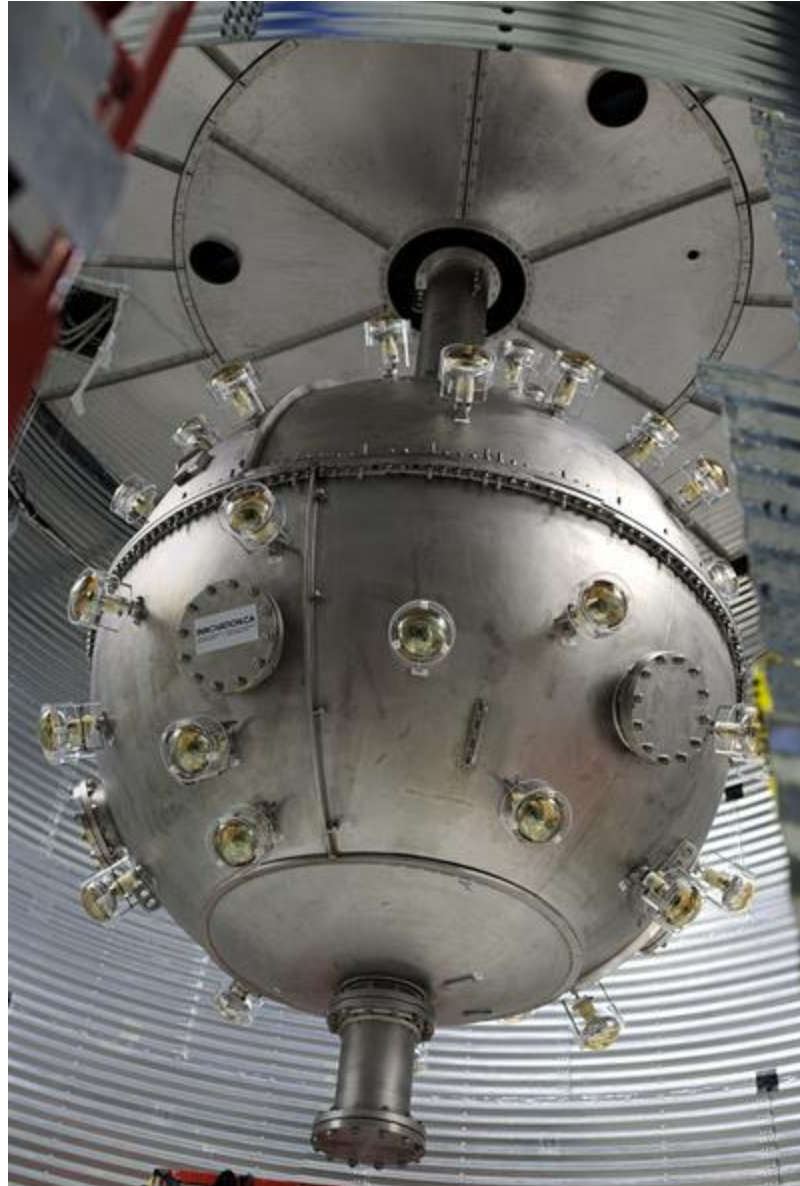
NDM 2015 Jyvaskyla, June 2015



NDM 2015 Jyväskylä, June 2015



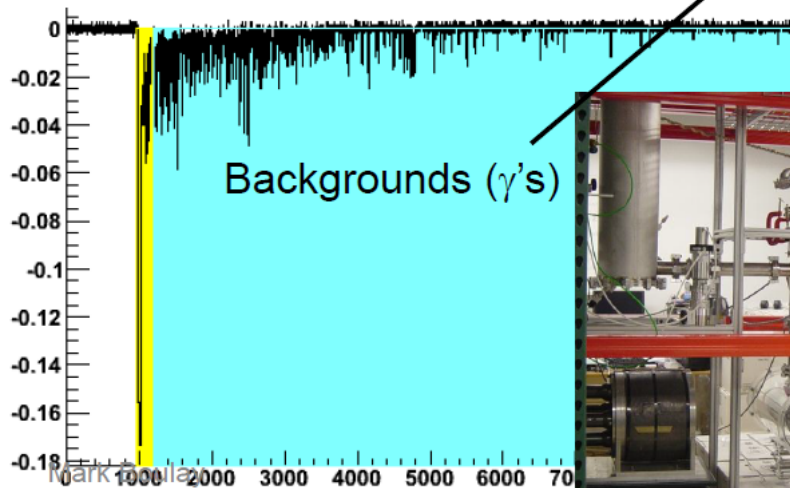
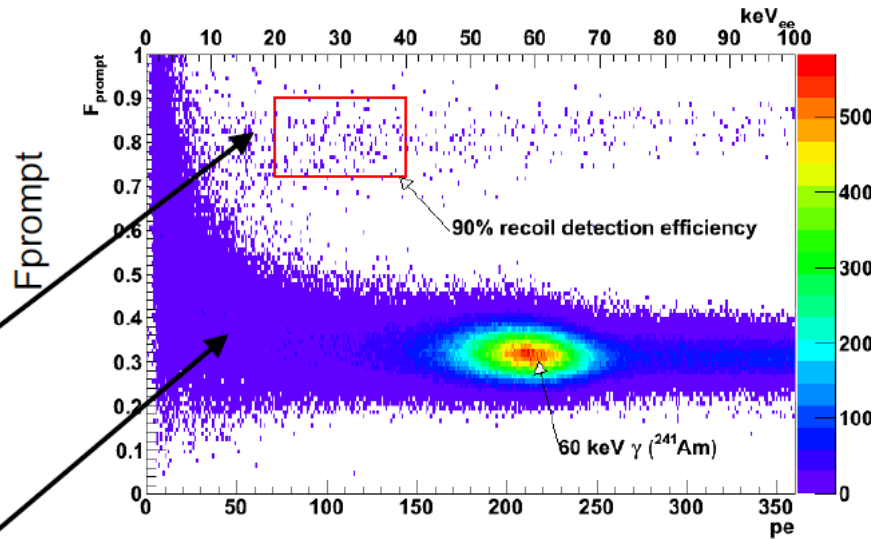
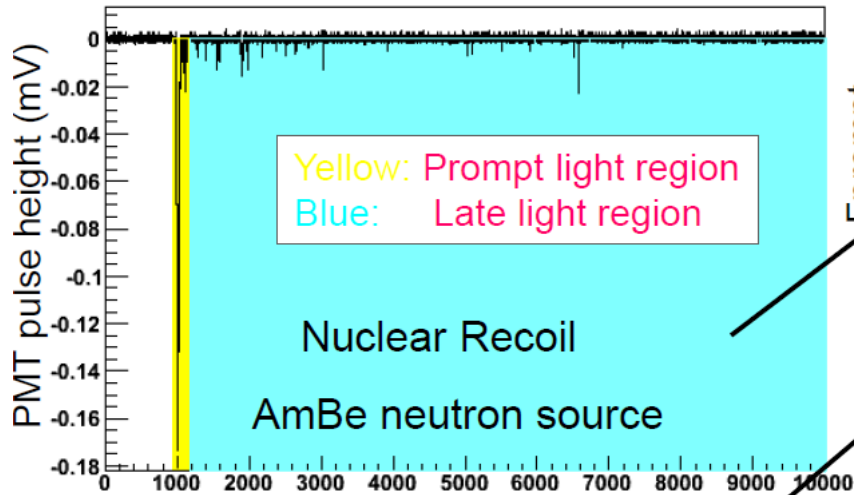
13
11
KSC 2015-06-01-001-001 June 2015



NDM 2015 Jyvaskyla, June 2015

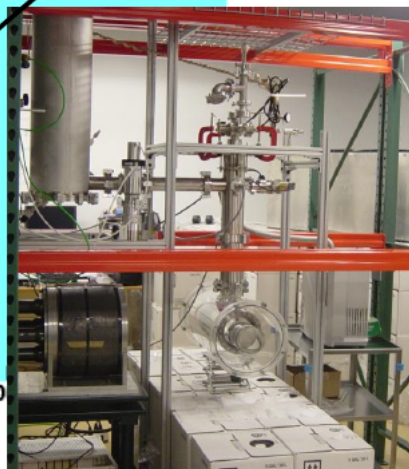
DEAP-3600 Dark Matter Search

Background suppression with PSD in DEAP-1



$$F_{\text{prompt}} = \frac{\text{PromptPE}(150\text{ns})}{\text{TotalPE}(9\mu\text{s})}$$

γ suppression better than
 3×10^{-8} (45-89 keV_{ee},
 120-240 pe)
 using tagged γ source



Liquid Argon Target Transfer



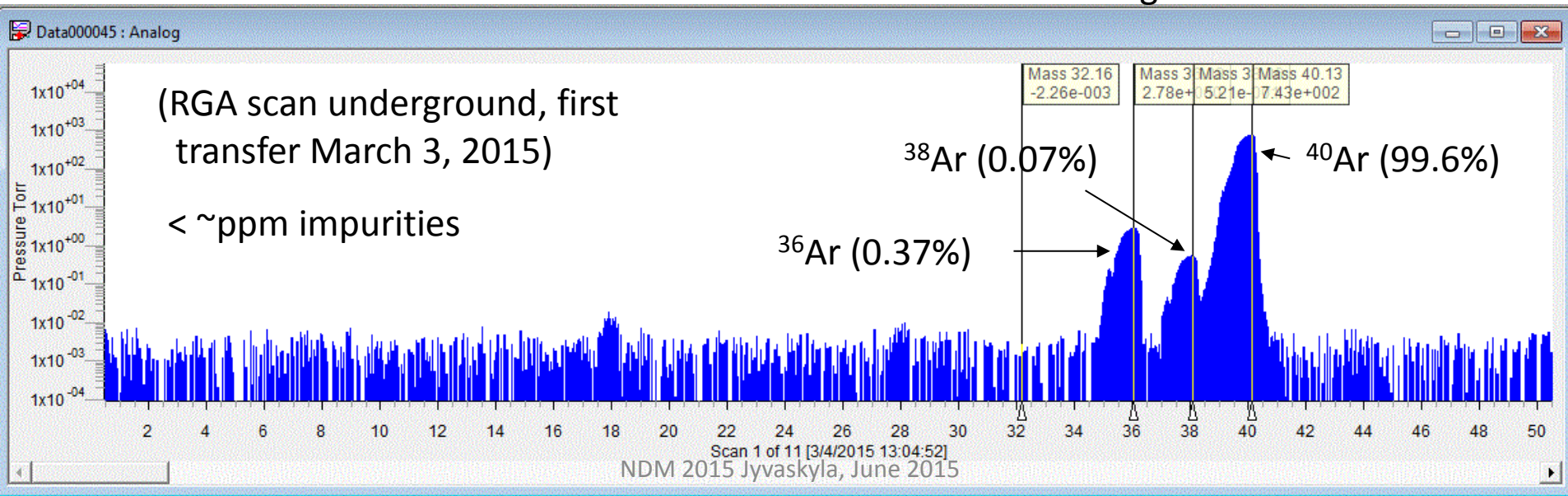
Bulk LAr storage on surface



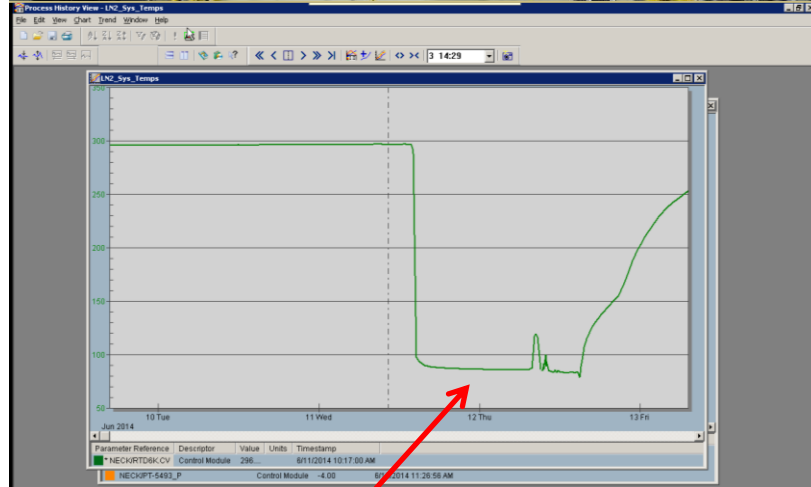
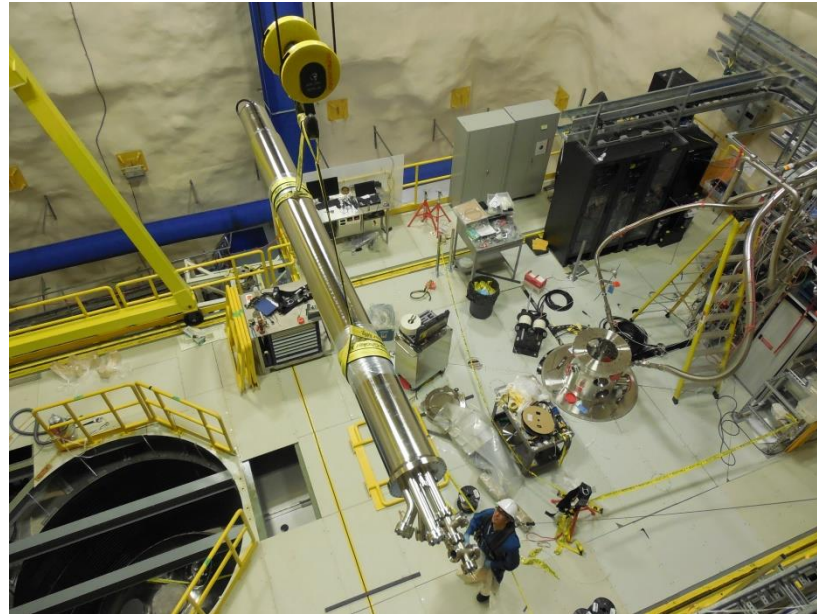
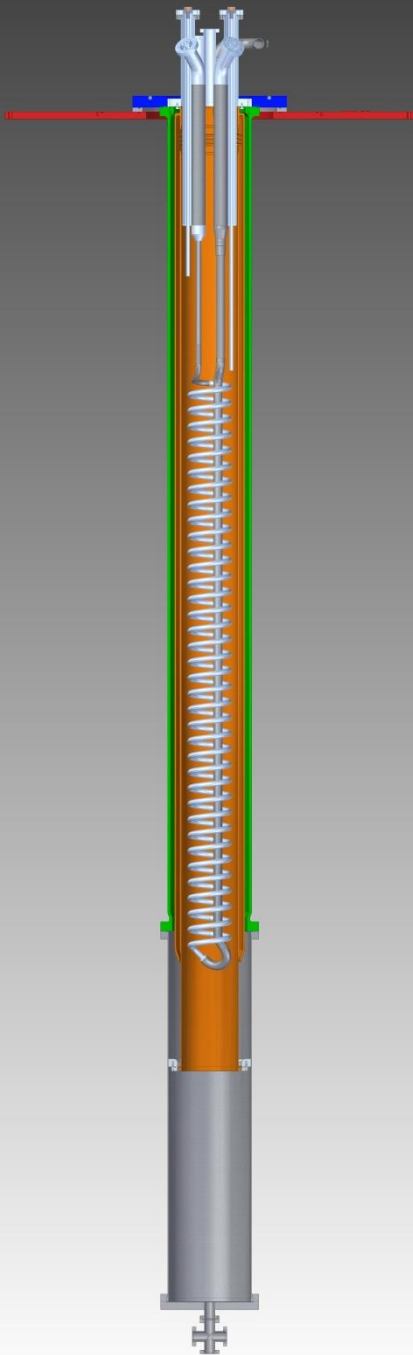
2x240L
(transfer)



LN₂-cooled storage dewar
underground



DEAP-3600 Argon Cooling System

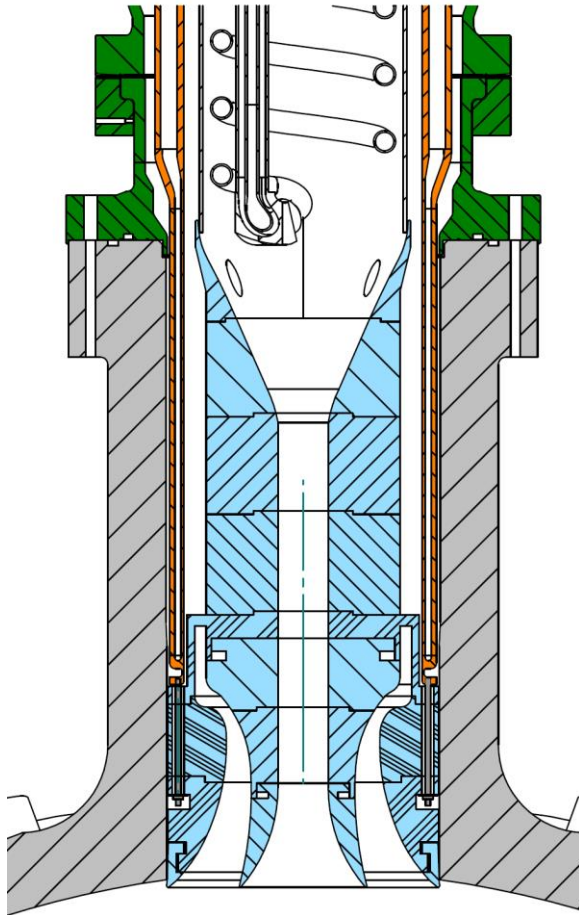


Commissioning at 86K, June 11 2014

LN2 system operating with cryogen since June 2014

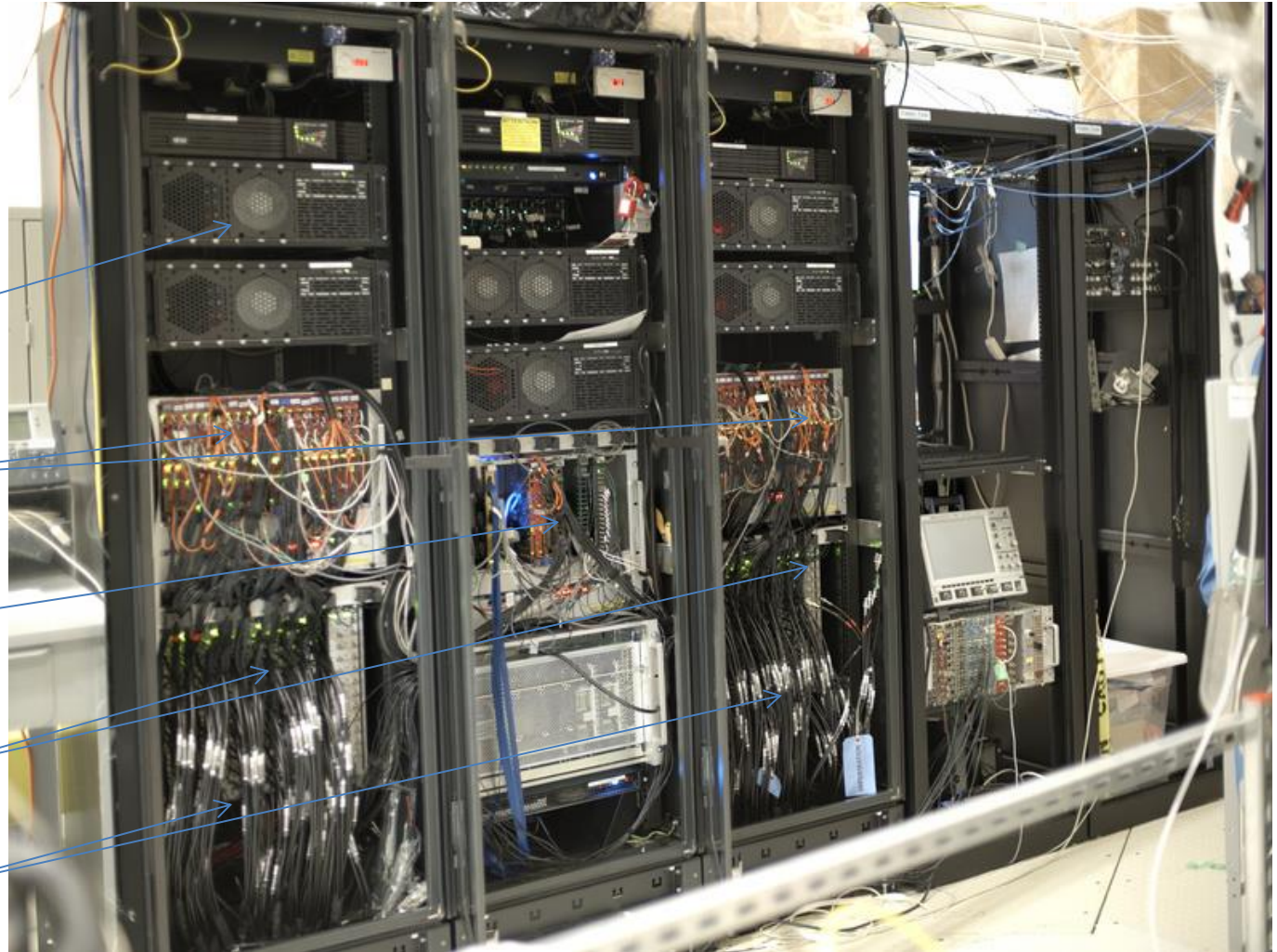
HDW-2015 Jyväskylä, June 2016

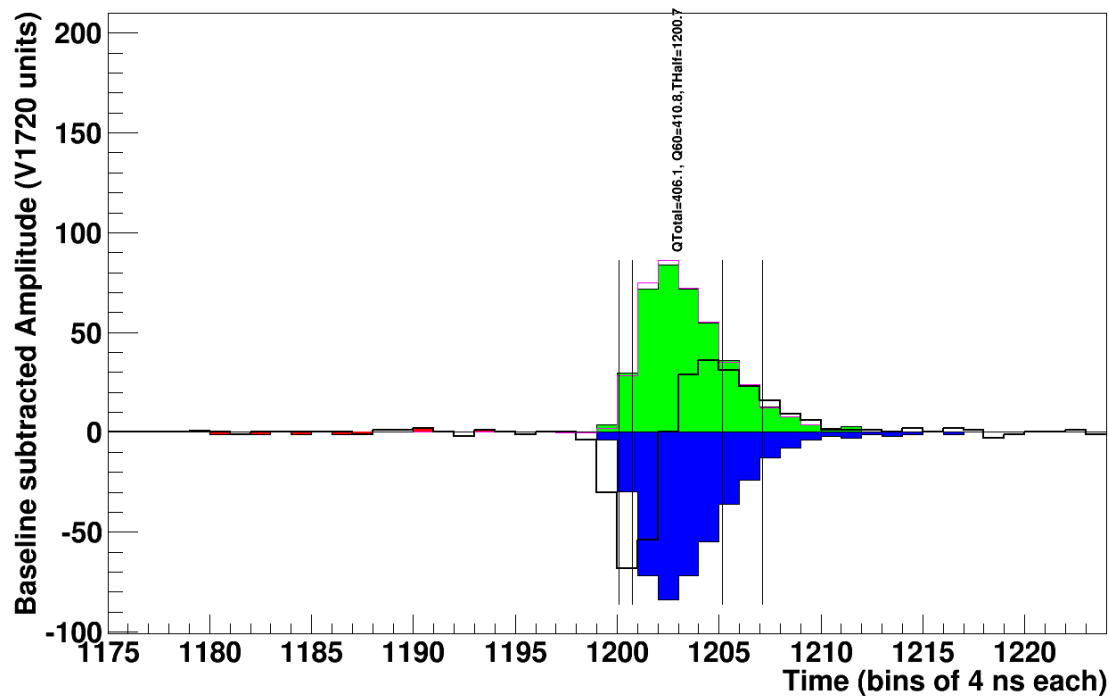
Flow Guides



- Design guides convection of warm liquid argon up, cold liquid argon down the neck
- UV scintillation light from surface contaminants on cooling coils, upper steel components, or acrylic neck is blocked from entering the main acrylic vessel.
- Iterations of GEANT calculations done to ensure shadowing will decrease topological backgrounds to an acceptable level
- Machined in low radon cleanroom and with radon exposure limited thereafter.

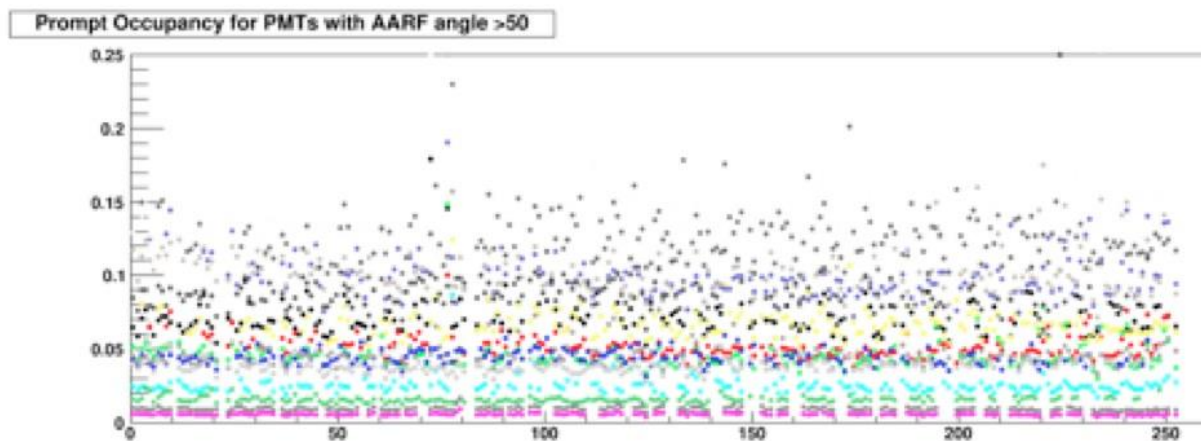
Electronics/DAQ



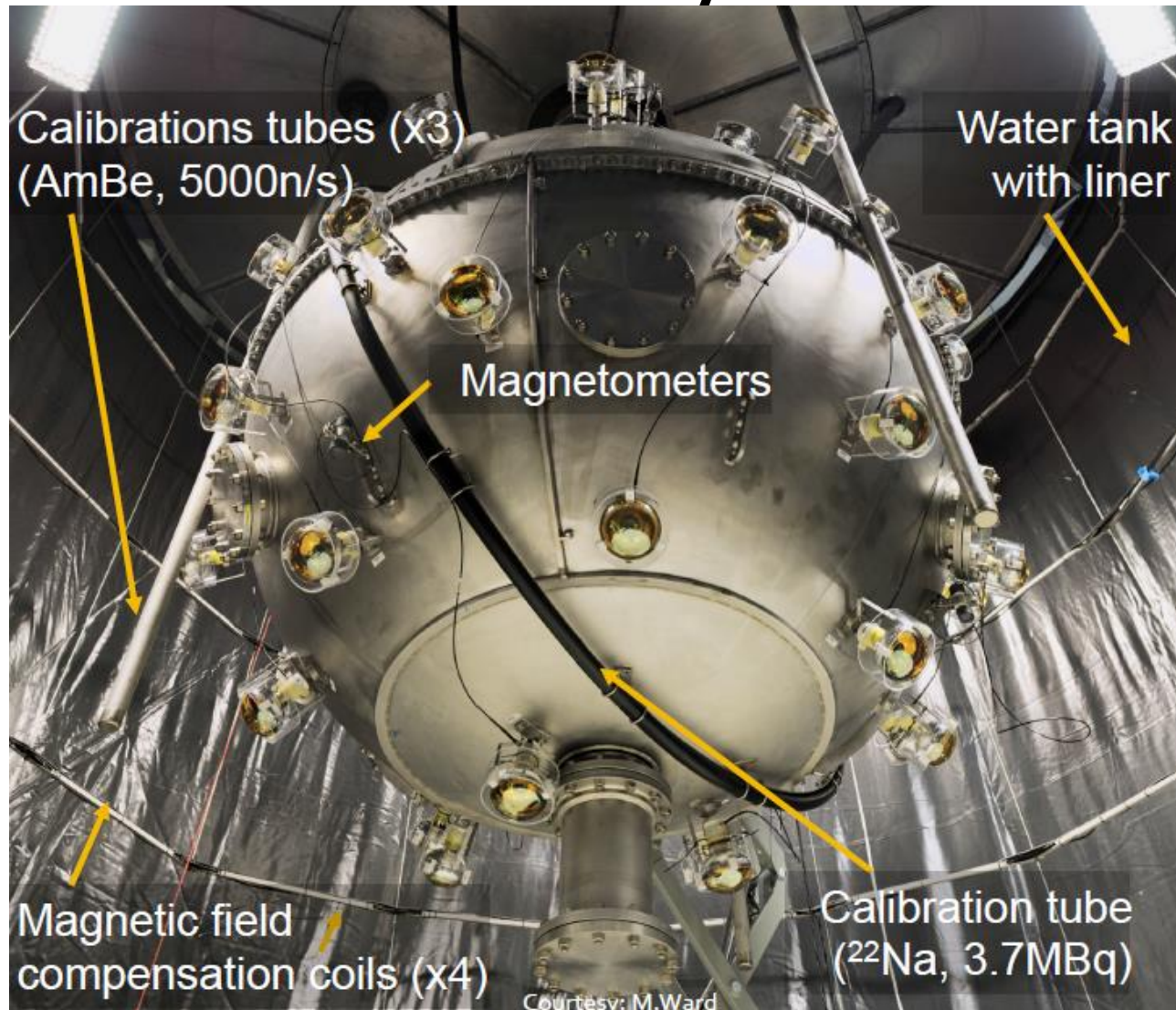


Starting to look at calibration pulses! This is a raw single photon pulse, from an LED flasher, as digitized (in blue), overlaid with derivative and various derived quantities.

Prompt occupancy for several flasher runs, looking at PMTs more than 50 degrees away from the LED flasher



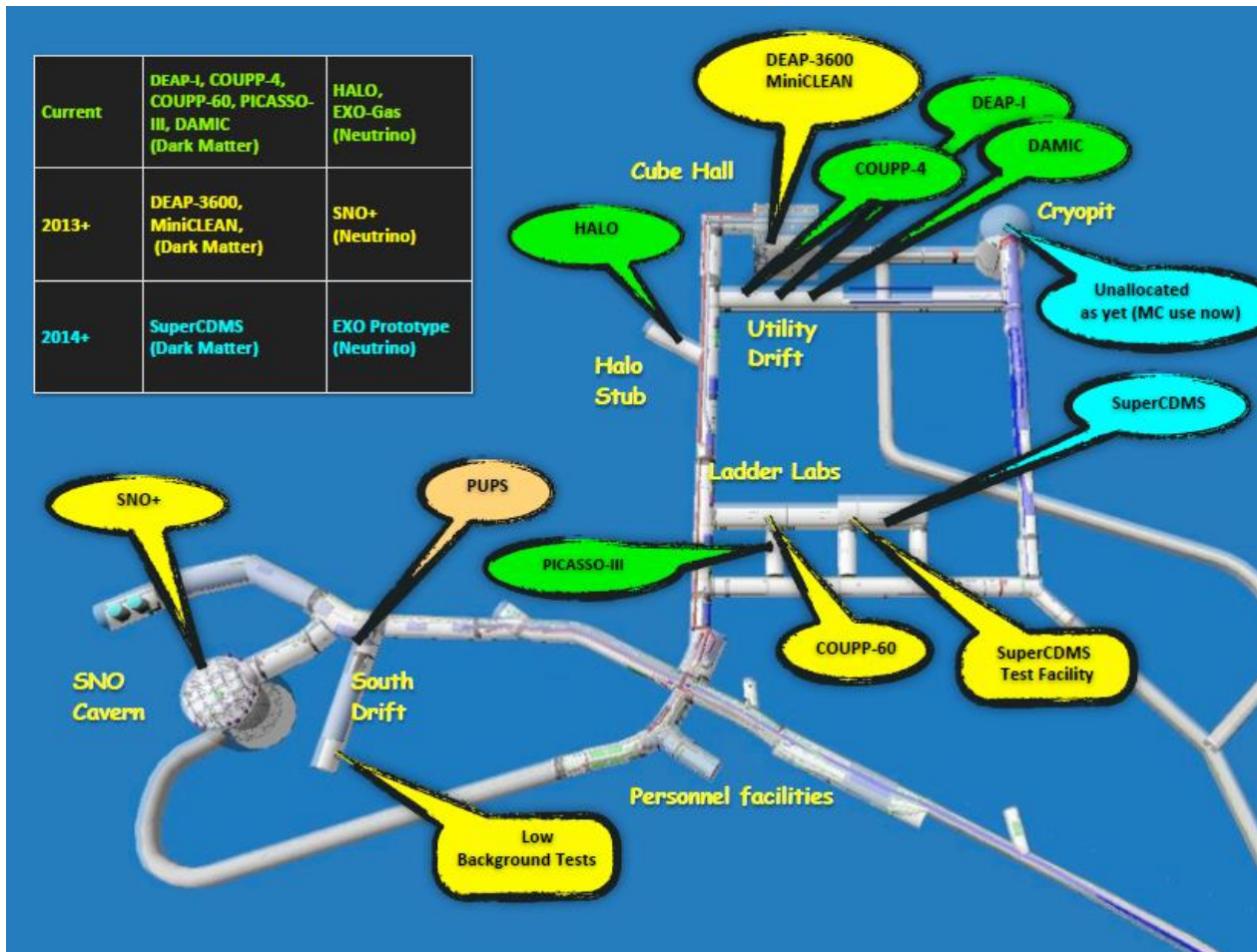
Calibration Systems





SNO LAB
MINING FOR KNOWLEDGE
CREUSER POUR TROUVER... L'EXCELLENCE

SNOLAB



Deap Status

- DEAP-3600 detector assembly completed, currently completing wavelength shifter coating. Detector will have 1000-kg fiducial liquid argon with < 0.2 background events/year background budget
- Extensive backgrounds and assay program, in particular ultralow background acrylic inner vessel and low radon emanation inner detector and purification system
- 10^{-46} cm² sensitivity for 100-GeV WIMP

DEAP Collaboration

University of Alberta

D. Grant, **P. Gorel**, **A. Hallin**, J. Soukup, C. Ng, **B. Beltran**, K. Olsen, R. Chouinard, T. McElroy, S. Crothers, S. Liu, P. Davis, and A. Viangreiro

Carleton University

K. Graham, **C. Ouellet**, Carl Brown

Queen's University

M. Boulay, **B. Cai**, D. B. Broerman, Bearse, J. Bonnat, K. Dering, **M. Chen**, S. Florian, R. Gagnon, **V.V. Golovko**, P. Harvey, **M. Kuzniak**, **A. McDonald**, C. Nantais, **A.J. Noble**, E. O'Dwyer, P. Pasuthip, L. Veloce, **W. Rau**, **T. Sonley**, **P. Skensved**, **M. Ward**

SNOLAB/Laurentian

B. Cleveland, **F. Duncan**, **R. Ford**, **C.J. Jillings**, **T. Pollmann**, **C. Stone**

SNOLAB

I. Lawson, K. McFarlane, P. Liimatainen, O. Li

TRIUMF

F. Retiere, **Alex Muir**, P-A. Amaudruz, D. Bishop, S. Chan, C. Lim, C. Ohlmann, K. Olchanski, V. Strickland

National Autonomous University of Mexico

E. Vazquez Jauregui

Rutherford Appleton Laboratory

P. Majewski

Royal Holloway University of London

J. Monroe, **J. Walding**, A. Butcher

University of Sussex

Simon Peeters



NDM 2015 Jyväskylä, June 2015