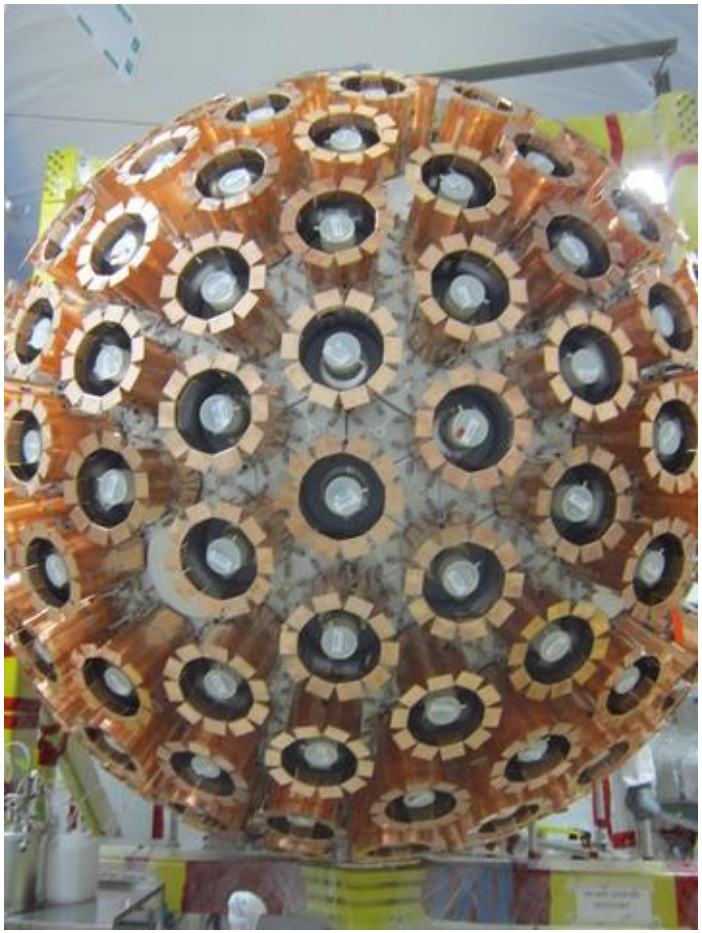
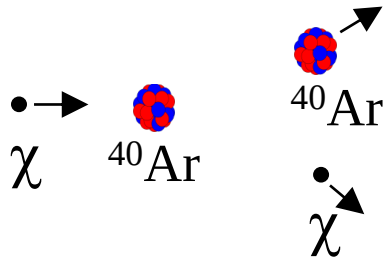
DEAP-3600 Dark Matter Search at SNOLAB



Mark Boulay
Carleton University
Queen's University

DEAP-3600 Dark Matter Search

Liquid Argon for DM (Single-phase)



Scattered nucleus detected via scintillation in LAr

Good Pulse-shape discrimination between β/γ and nuclear recoils with scintillation

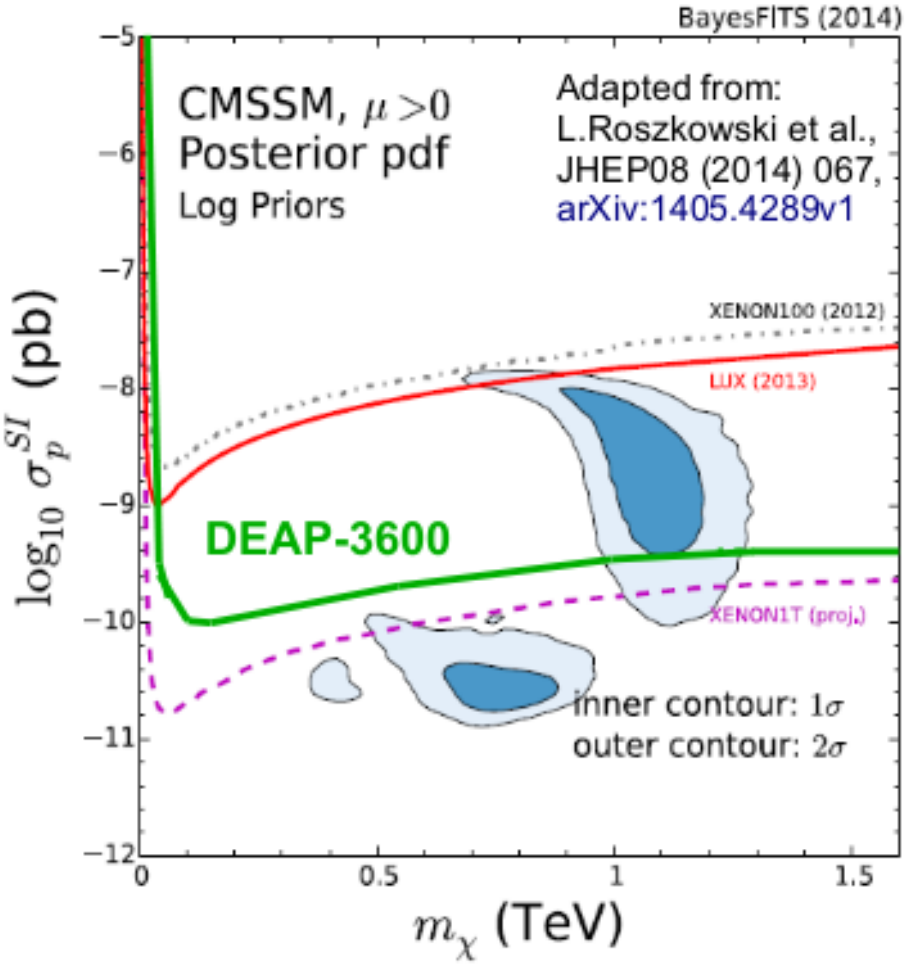
Argon is **easy to purify**

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

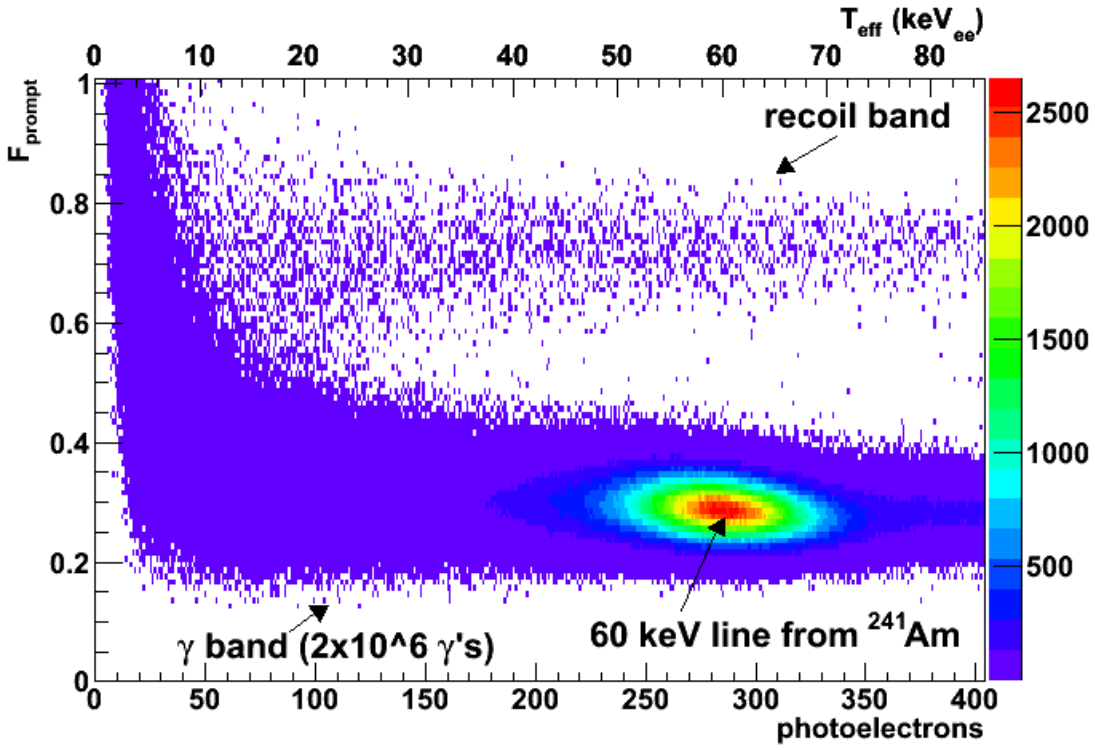
Position reconstruction allows surface background removal, based on photon detection (~5 cm resolution allows removal of radon daughter events from analysis)

DM Sensitivity

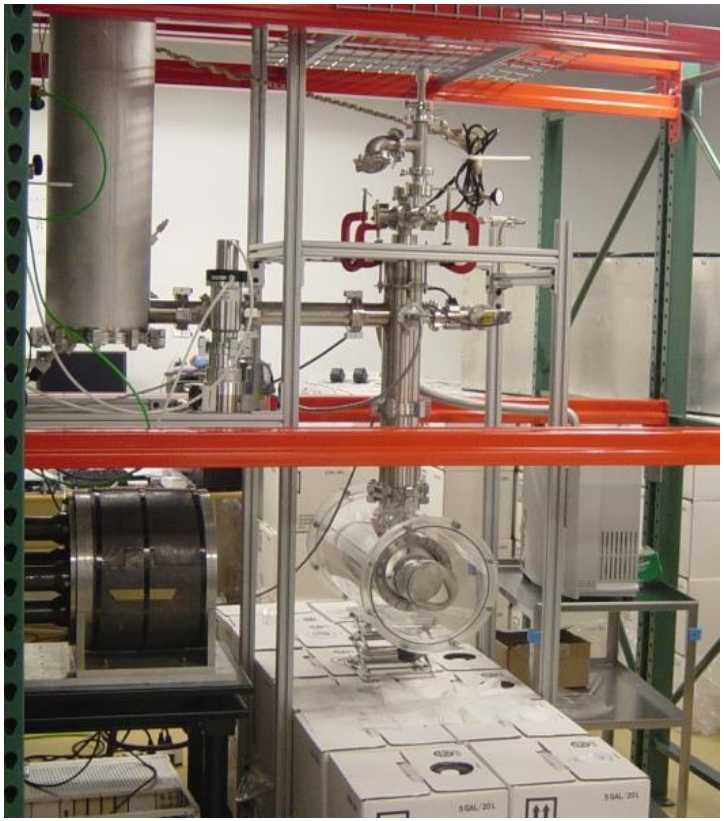
1 tonne fiducial mass (3.6 tonnes total) designed for < 0.2 background events/year with 60 keVr threshold



Pulse-shape discrimination (PSD) in argon



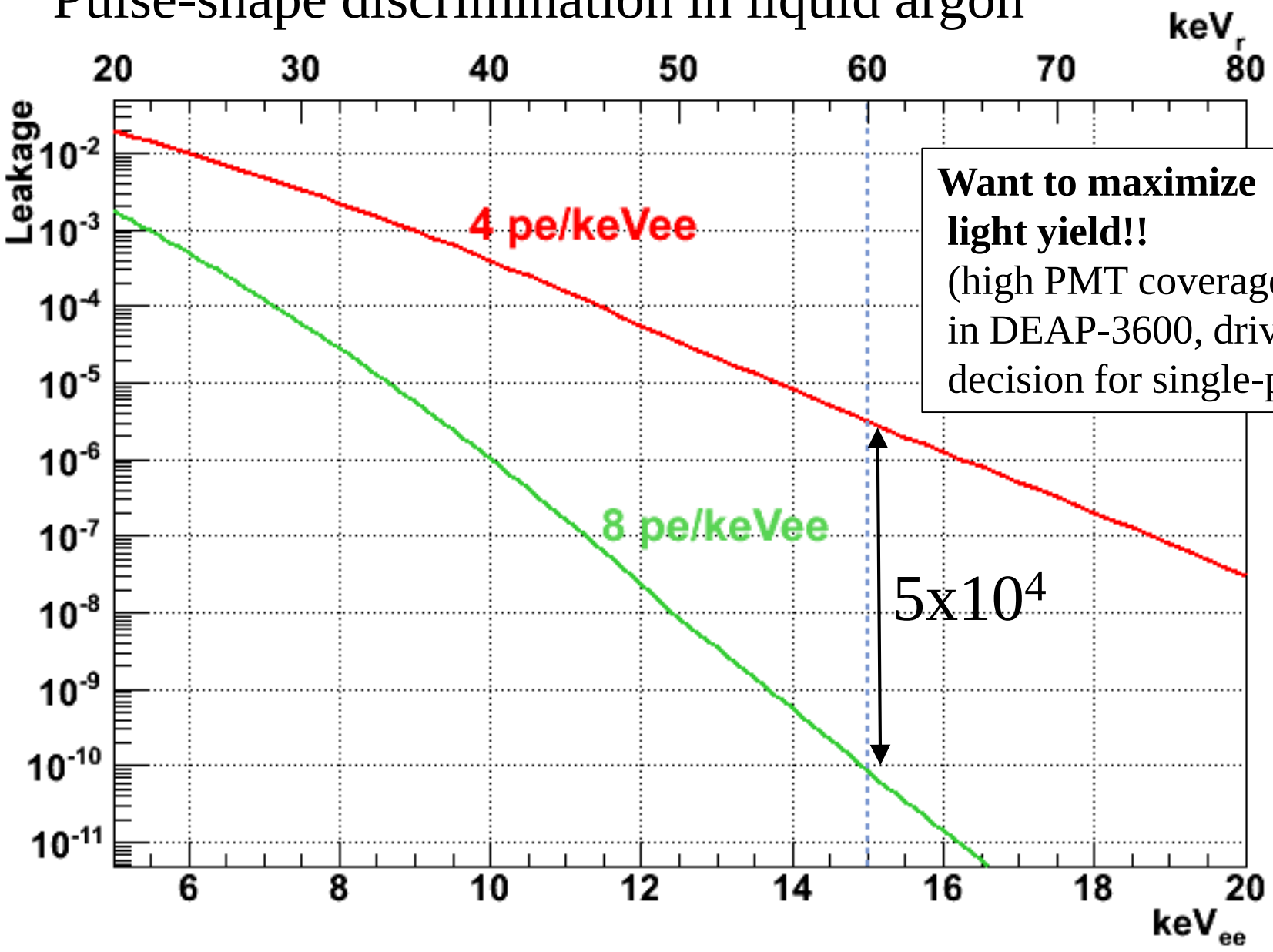
PSD in DEAP-1 prototype using AmBe neutron source



DEAP-1 started 2005

only purify argon while filling, stable for full run, order (year)

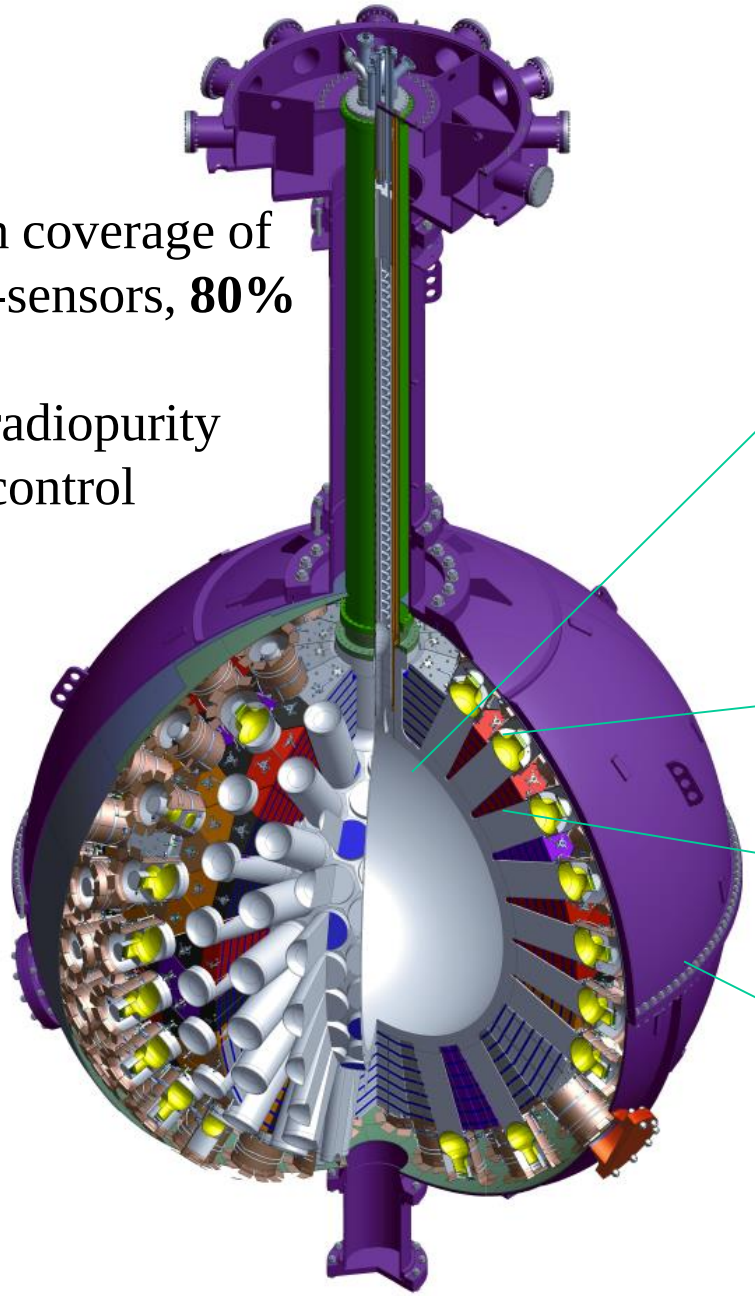
Pulse-shape discrimination in liquid argon



Want to maximize light yield!!
(high PMT coverage in DEAP-3600, drives decision for single-phase)

See J. Phys. (Conf. Ser.) 375 (2012) 012027

DEAP-3600 Detector



v. high coverage of light-sensors, **80%**

strict radiopurity control

3.5 meters

3600 kg argon in sealed ultraclean Acrylic Vessel (1.7 m ID)

Vessel is “resurfaced” in-situ to remove deposited Rn daughters after construction

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

50 cm light guides + PE shielding provide neutron moderation

Steel Shell immersed in 8 m water shield at SNOLAB

DEAP Collaboration: 65 researchers in Canada, UK, and Mexico

UNIVERSITY OF ALBERTA

Carleton UNIVERSITY

LaurentianUniversity
UniversitéLaurentienne

Queen's UNIVERSITY

ROYAL HOLLOWAY UNIVERSITY OF LONDON

Particle Physics
Rutherford Appleton Laboratory

SNOLAB
MINING FOR KNOWLEDGE
CREUSER POUR TROUVER... L'EXCELLENCE

US University of Sussex

TRIUMF

IF Instituto de Física

Fabrication and Assay of DEAP Acrylic

- Fabrication from pure MMA monomer at RPTAsia (Thailand), strict control of radon exposure for all steps, to < 10^{-20} g/g ^{210}Pb (RPT was fabricator of the SNO Acrylic Vessel)

- Assay of production acrylic < 2.2×10^{-19} g/g ^{210}Pb
  (Corina Nantais M.Sc. Thesis 2014, <0.2 bkg events/3 years)

Monomer cast at RPT Asia, 2010

Thermoformed Panel at RPT Colorado

DEAP Acrylic Vessel, Panel Sections at Reynolds Polymer, Colorado

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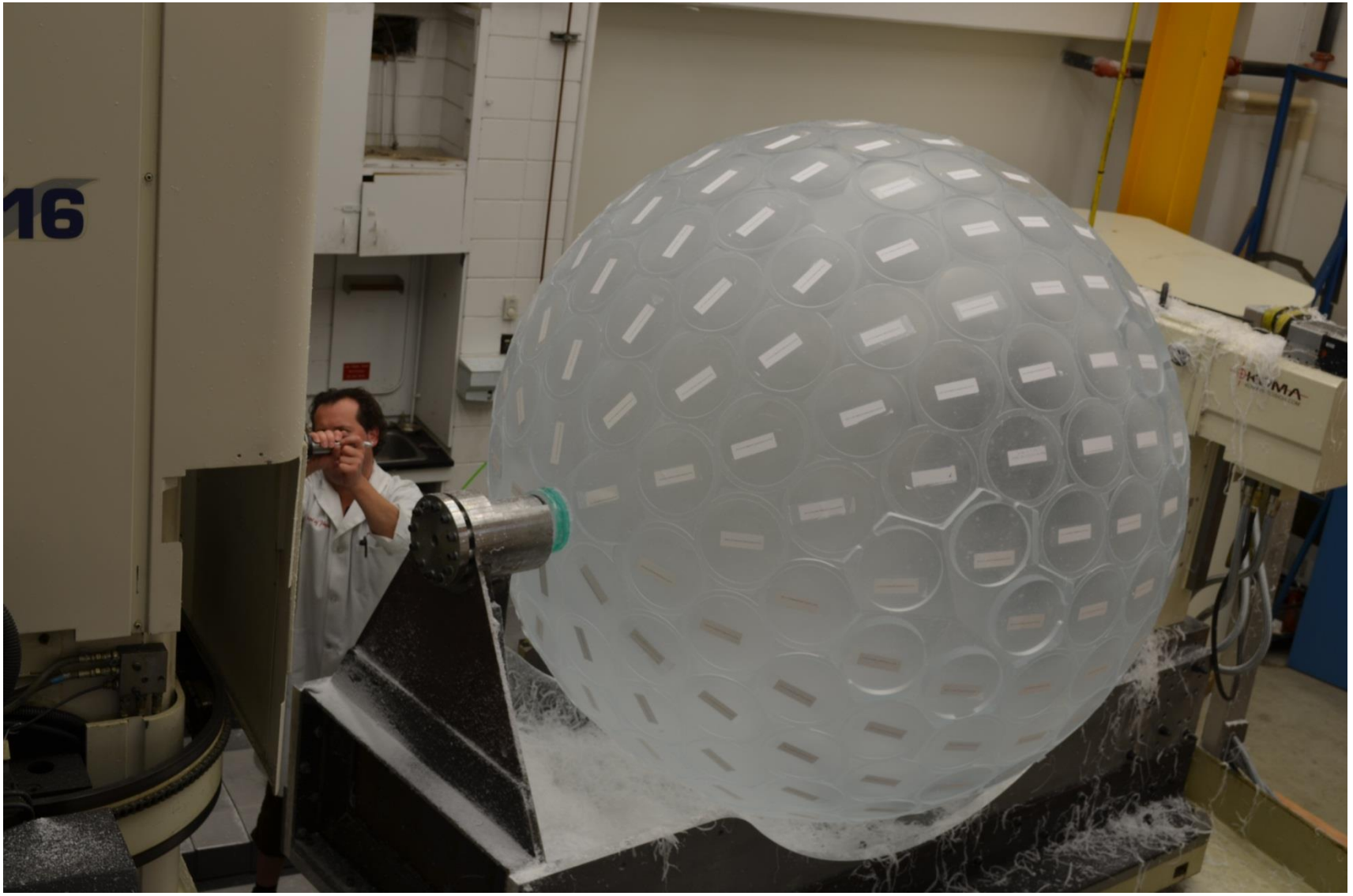
DEAP Acrylic Vessel with Light Guide "Stubs" July 2012, U Alberta



Mark Boulay

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AV neck bonding underground (December 2012-January 2013)

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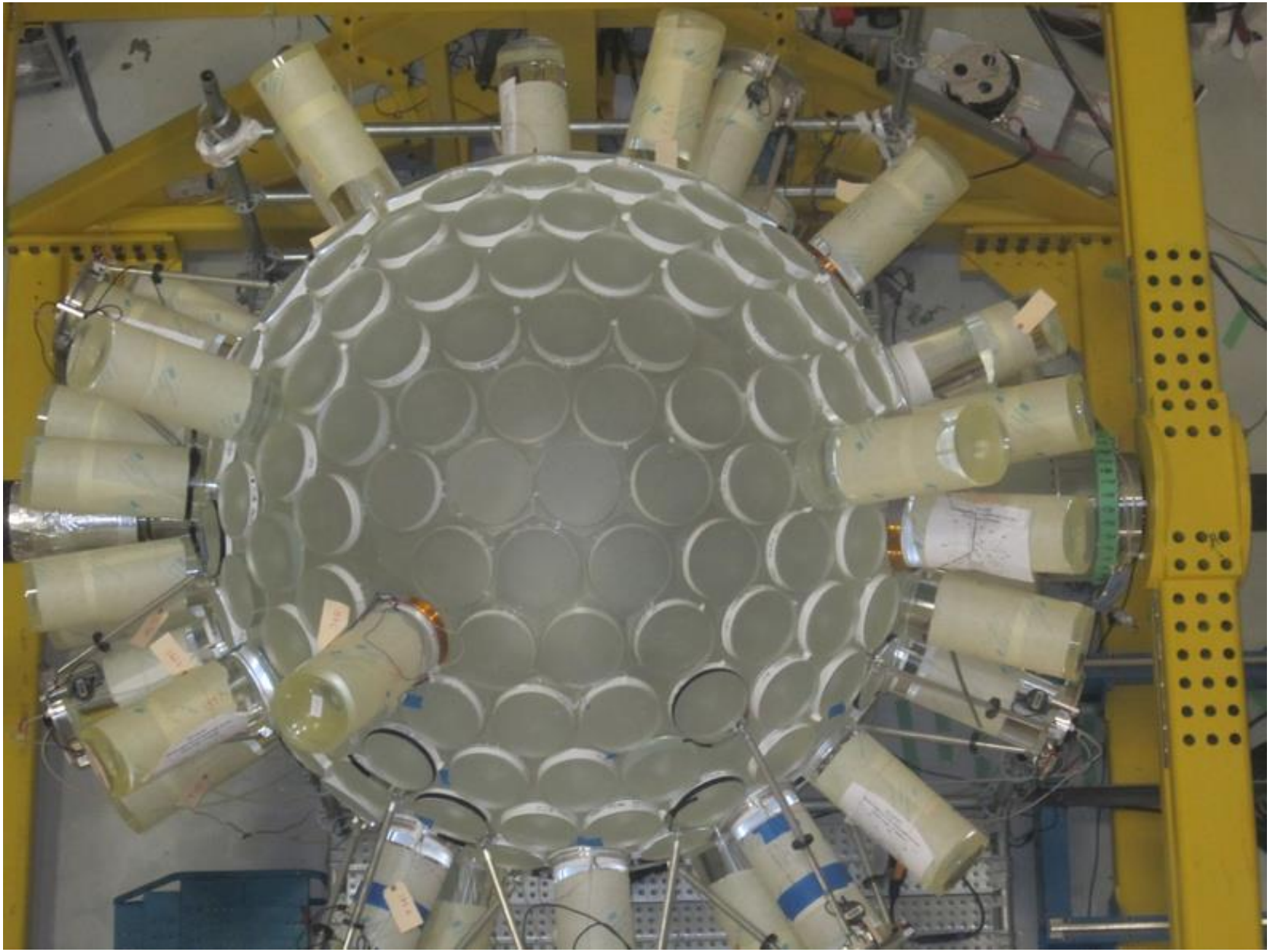
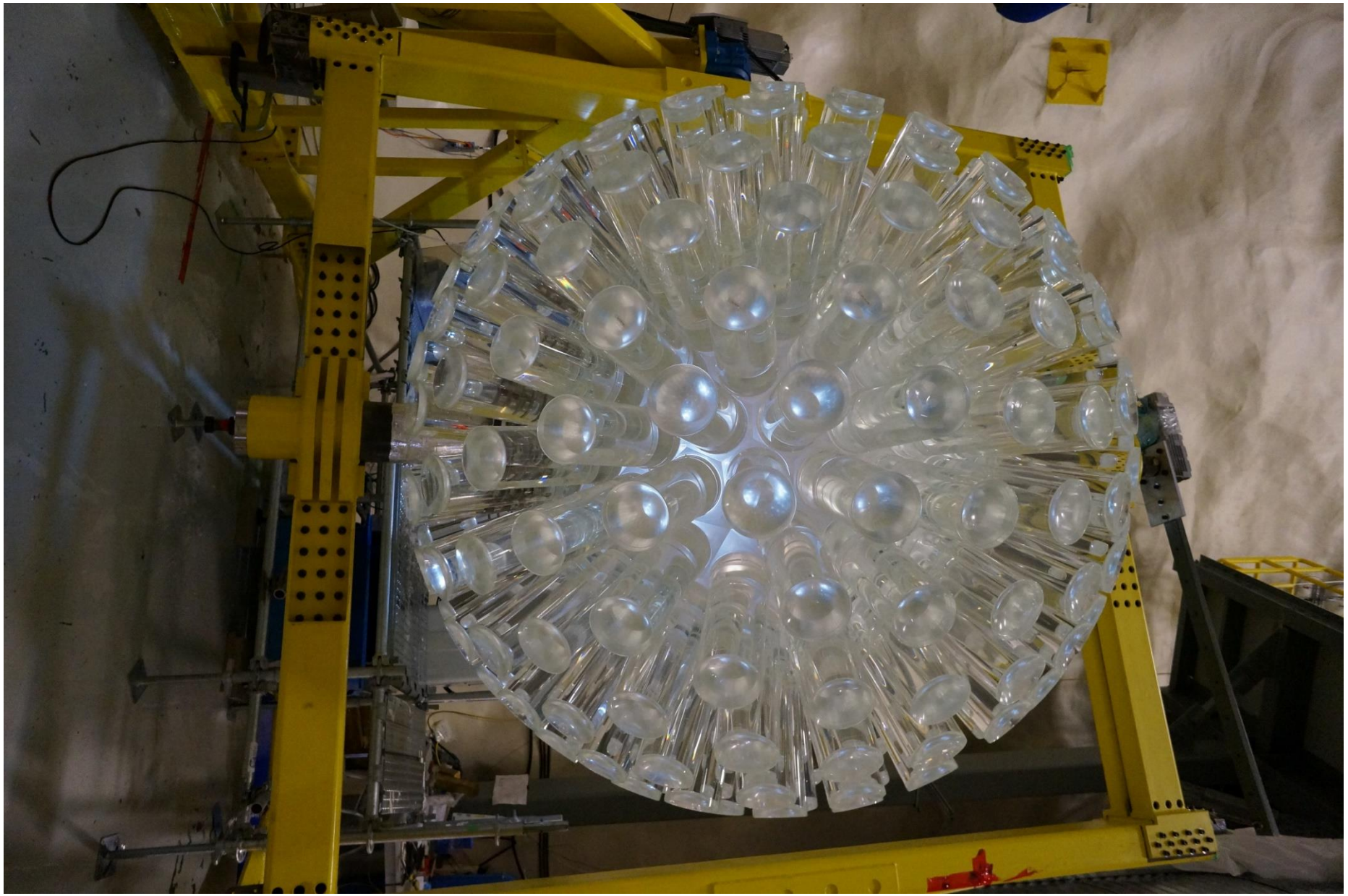
Bonding light guides to the DEAP AV, underground at SNOLAB



DEAP Acrylic Vessel (2013)



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Moving the AV into assembly room

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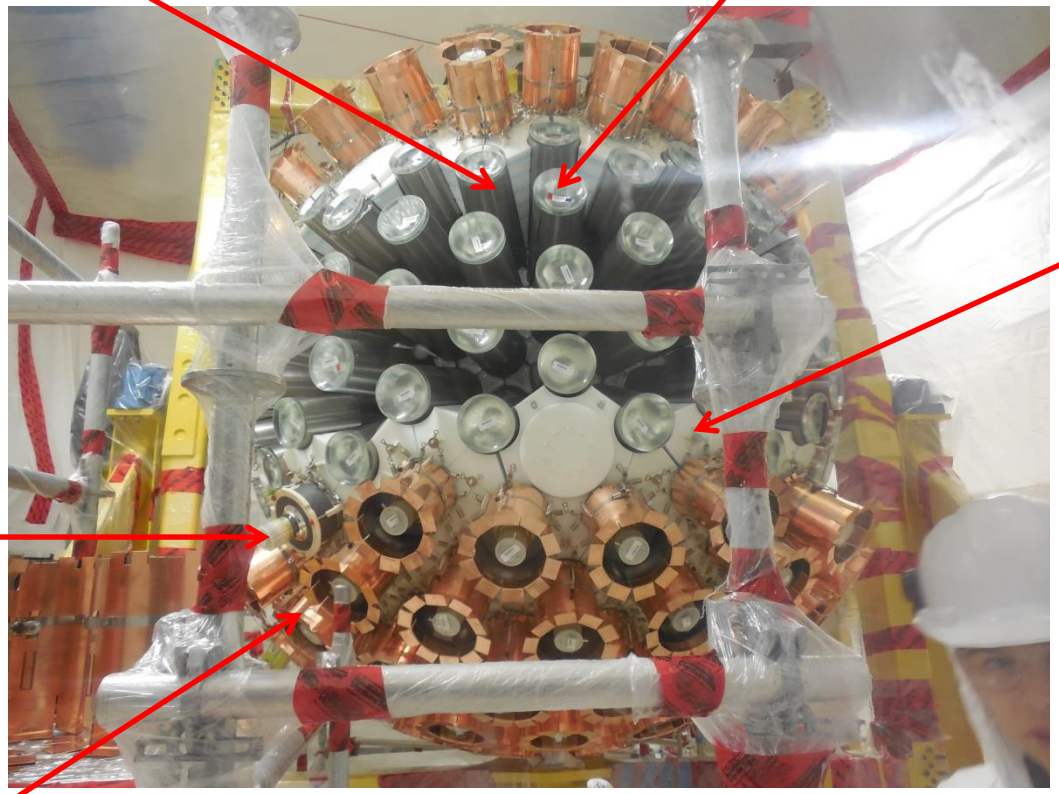
DEAP-3600 Detector Assembly

Specular reflector + opaque wrap

Acrylic Light Guide



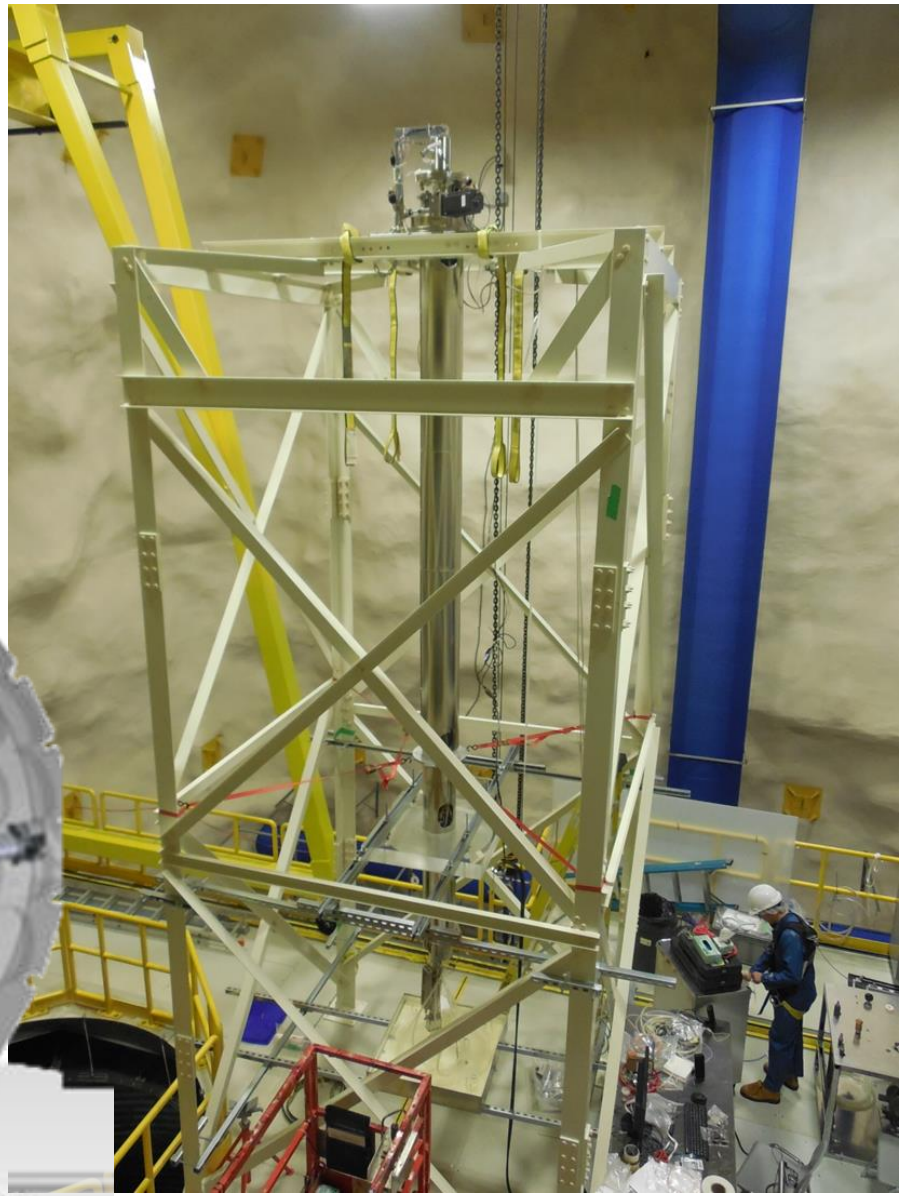
PE neutron shielding “blocks”

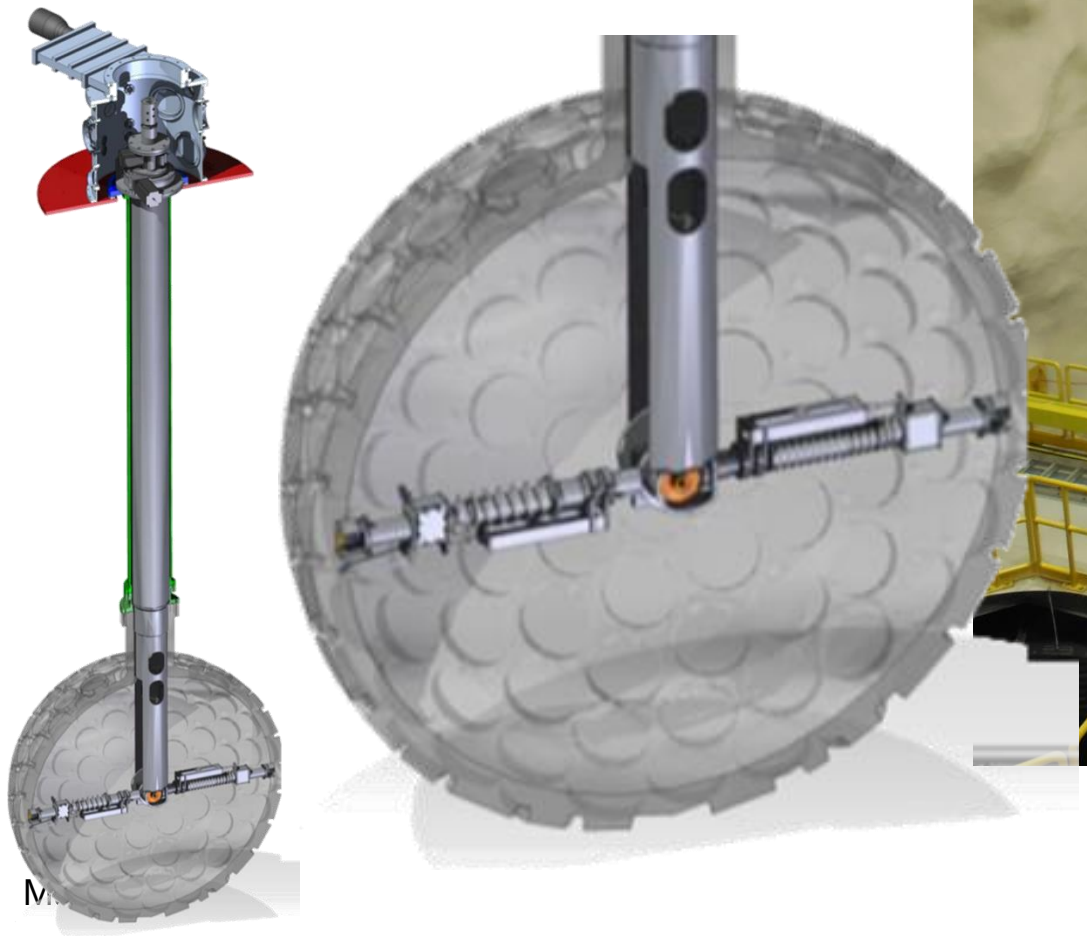
PMT with silicone oil coupling

Copper sleeve over PMT

Acrylic Vessel Resurfacer

- Mechanical sander to clean inner surface
- Components selected for low radon emanation
- Remove 0.5-mm surface *in situ* with N_2 purge
- Cleans surface to bulk-level impurities
  (order 100,000 cleaner than SNO vessel)



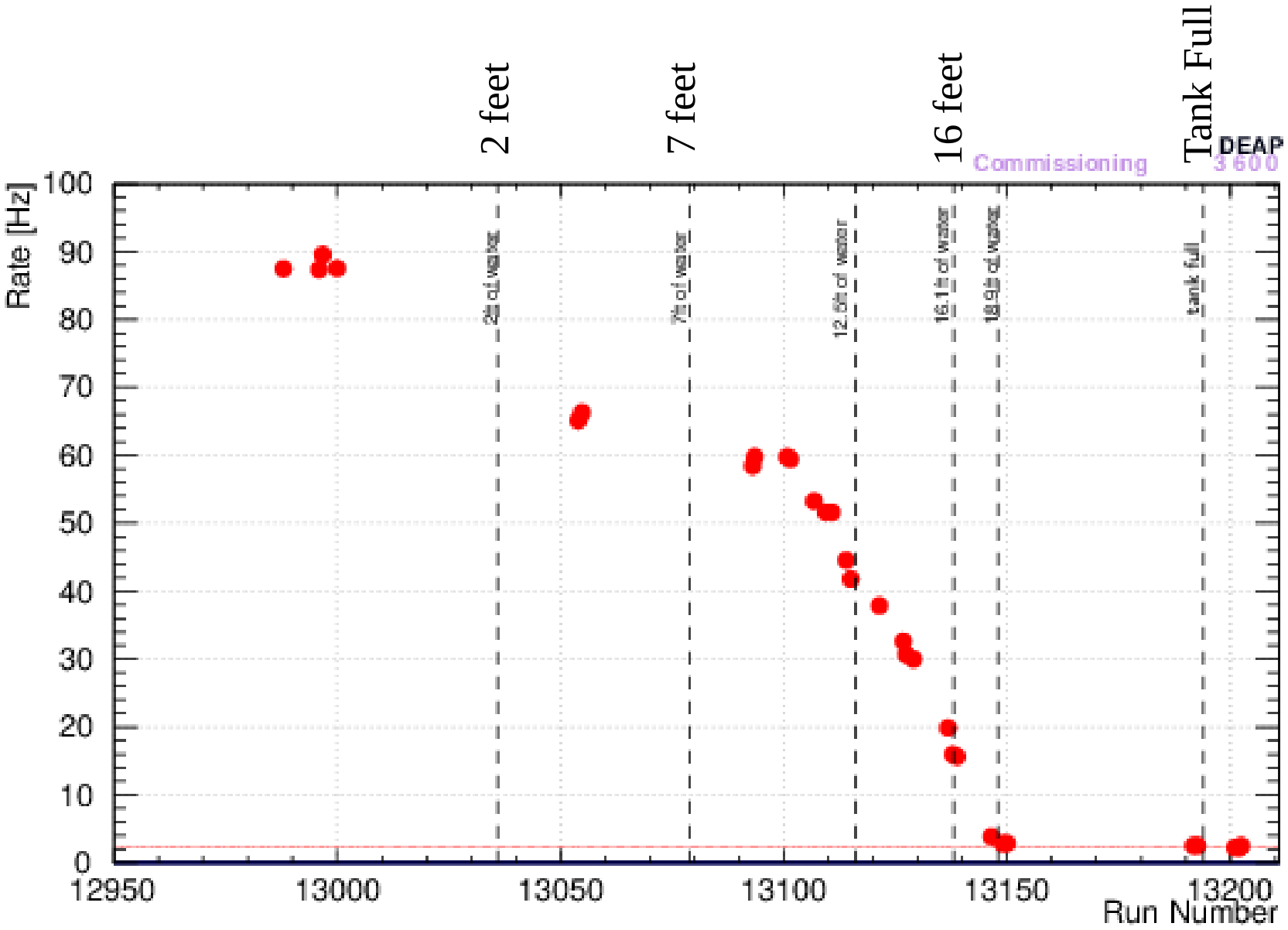


Completed Detector and Shield Tank

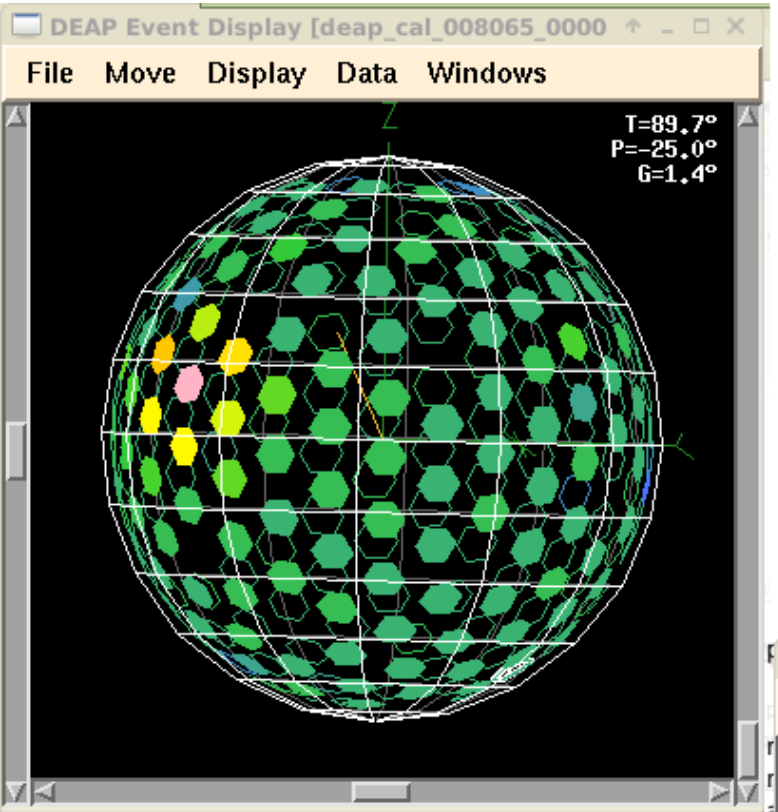
Completed Detector: Steel Shell, calibration tubes, muon veto in Shield Tank (fall 2015)

Shield Tank and emergency vent lines, tank was filled with water Oct 2015

Detector event rate during shield tank water fill

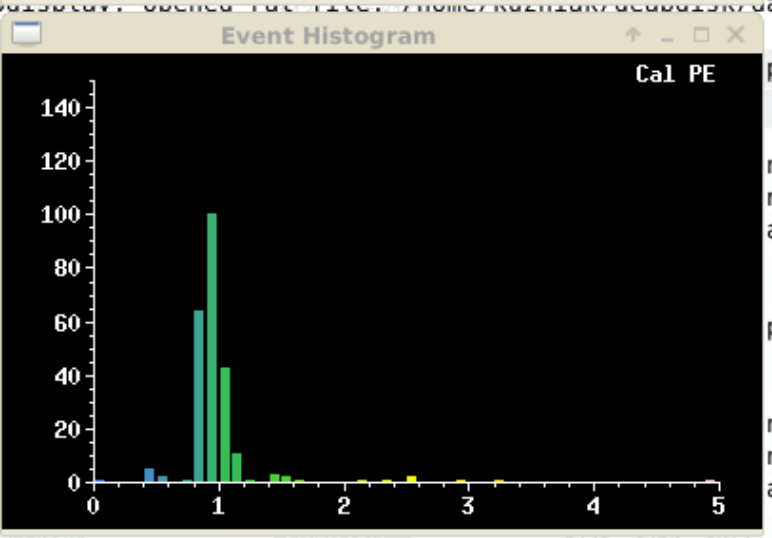


(Filled October 2015)



Electronics and trigger system operational for over a year (CAEN v1720s)

- Commissioning, electronics calibration
- Optical calibration with internal fibers (AARFs) and deployed diffusing laserball source

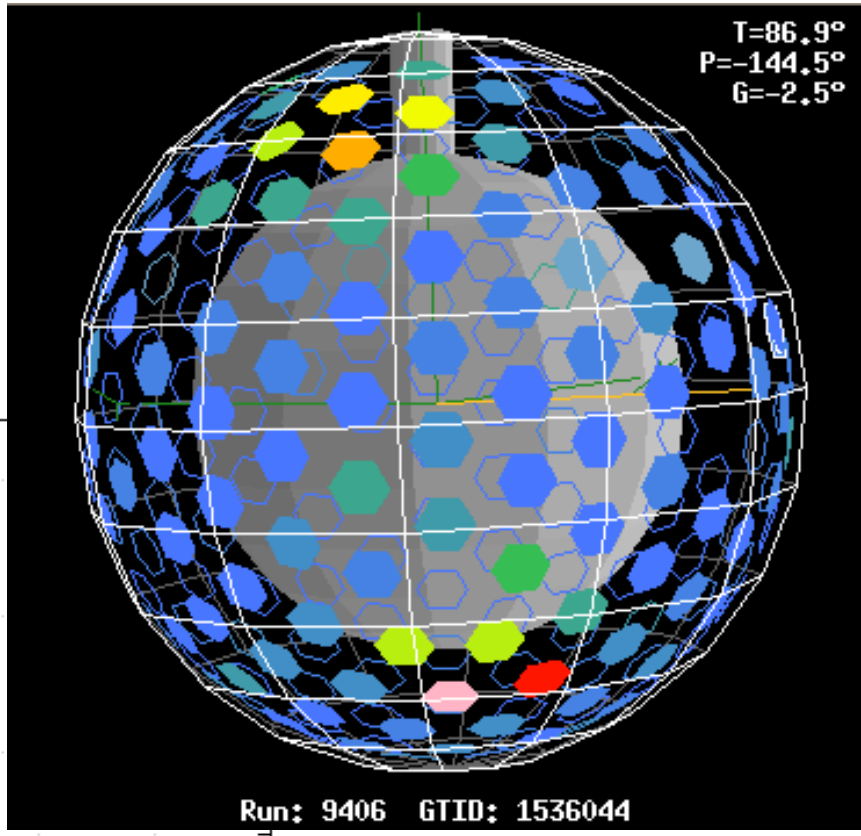


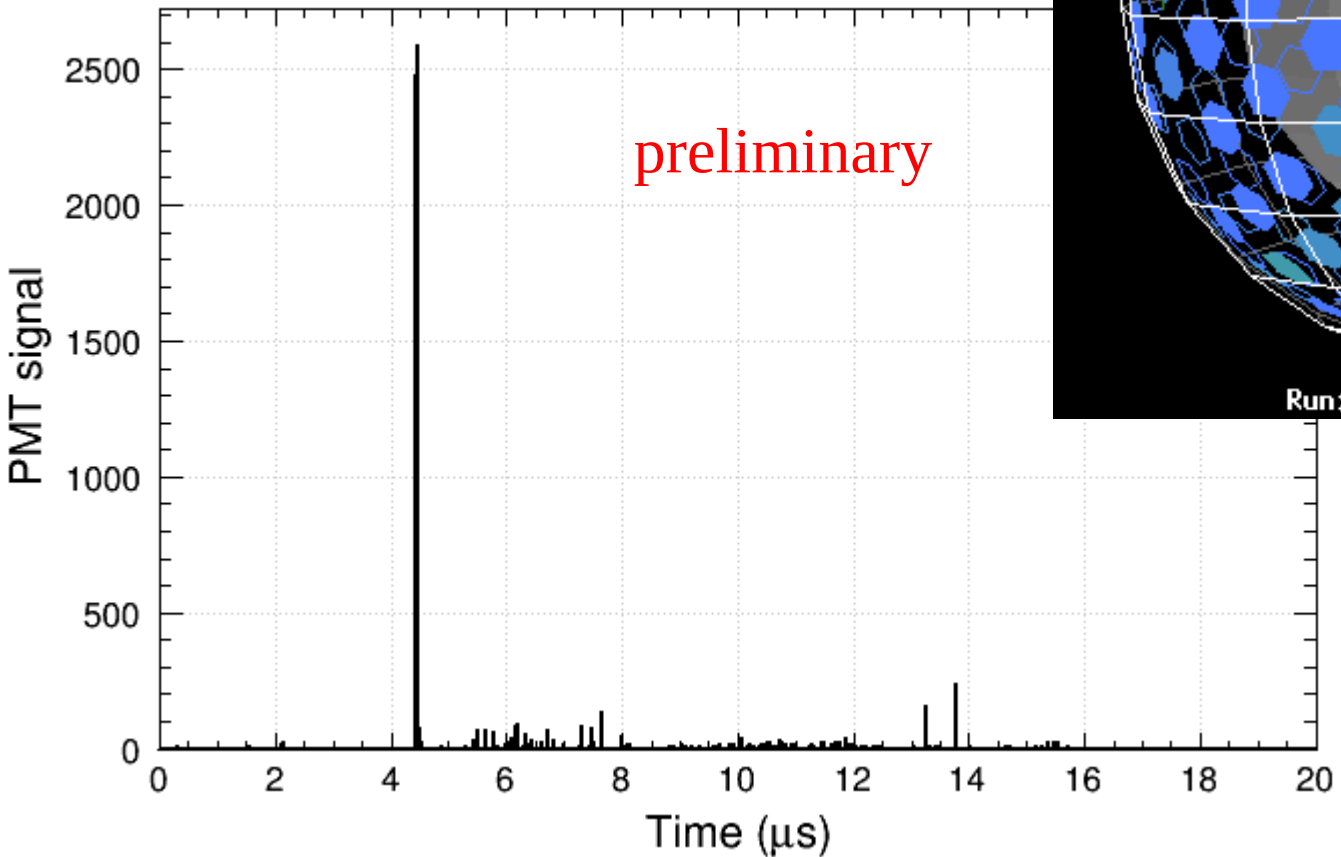
A high energy event (Commissioning running, Spring 2015)

Run: 9406 Subrun: 3 Event: 300460

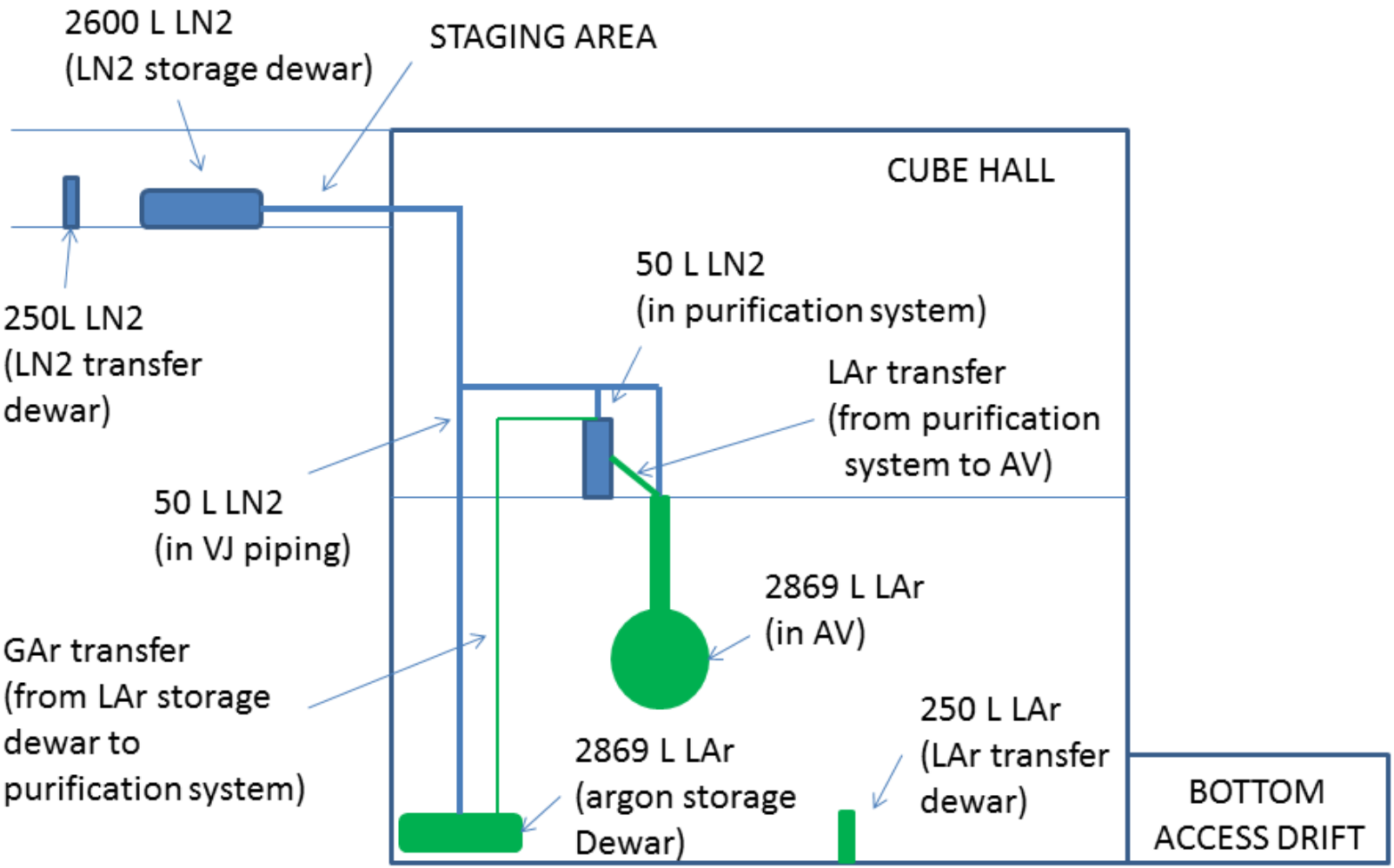
High-E event rate: ~1 event/day

Expected muon rate: 1.6 muons/day

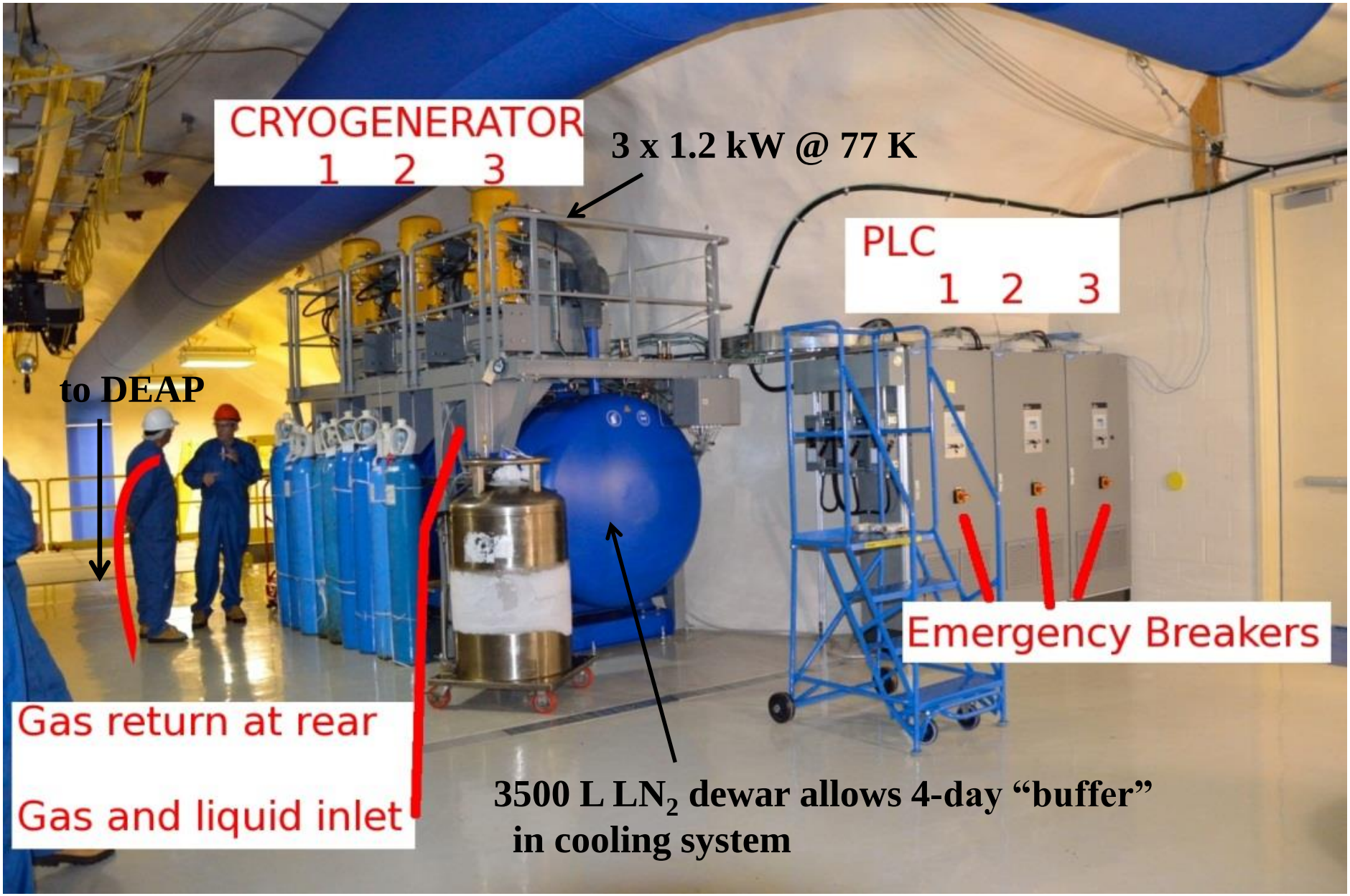




DEAP-3600 Cryogenic Systems



DEAP-3600 Cryocooler System Installed May 2012



Liquid Argon Target Transfer and Storage

Bulk LAr storage on surface

2x240L
(transfer)

LN_2-cooled storage dewar underground

Transferring underground started March 3, 2015

From RGA scans (before purification in the DEAP system):

$CH_4 < 10$ ppb, $H_2O < 10$ ppb, $N_2 < 4$ ppb, $O_2 < 6$ ppb

(<100 ppt after purification)

Argon Purification

Target stored as liquid,
boiled and purified
in gas phase,
then (re-)liquefied into AV

(Gettering, radon
and
particulate filtration)

150 lpm = ~380 kg/day

Currently running in
closed loop on argon
storage dewar, and
for filling AV with argon
during cooldown

AV cooldown started
Feb 17th, 2016 !

Summary

- DEAP-3600: 3.6 tonnes of liquid argon (1 tonne fiducial)
  >20X improvement in experimental sensitivity, excellent high WIMP mass sensitivity
  (similar sensitivity to XENON-1T for high WIMP mass)

- Collecting data in commissioning phase since early 2015

- Start of detector cooldown Feb 17th 2016!
  ~3 weeks cooldown + 3 weeks argon filling

- R&D towards larger detector:

  ~100 Tonnes of argon

  requires low-radioactivity (underground source) argon

  detector surface backgrounds (dominant concern in DEAP-3600) are **easier** to mitigate in larger detector

  good option to explore down to neutrino floor, complements xenon searches
  (also no concern in argon for pp neutrino ES backgrounds, ½-event per tonne-year in xenon)

END

Mark Boulay