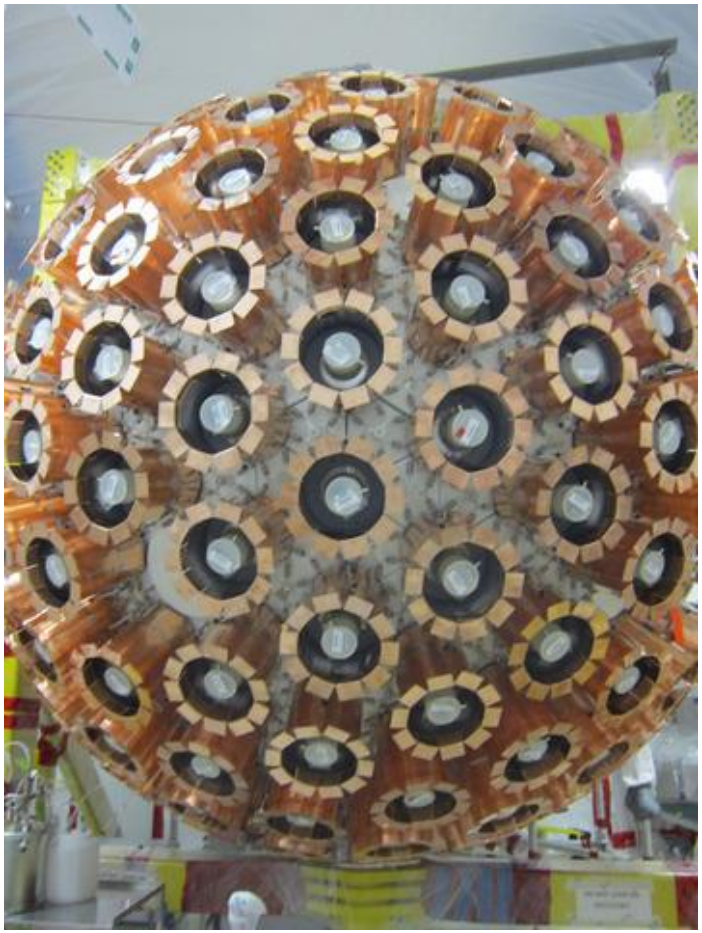
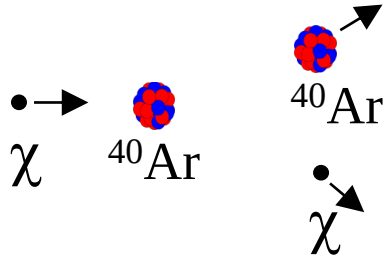
DEAP-3600 Dark Matter Search at SNOLAB



Mark Boulay
Carleton University
Queen's University

DEAP-3600 Dark Matter Search

Liquid Argon for DM (Single-phase)



Scattered nucleus detected via scintillation in LA

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

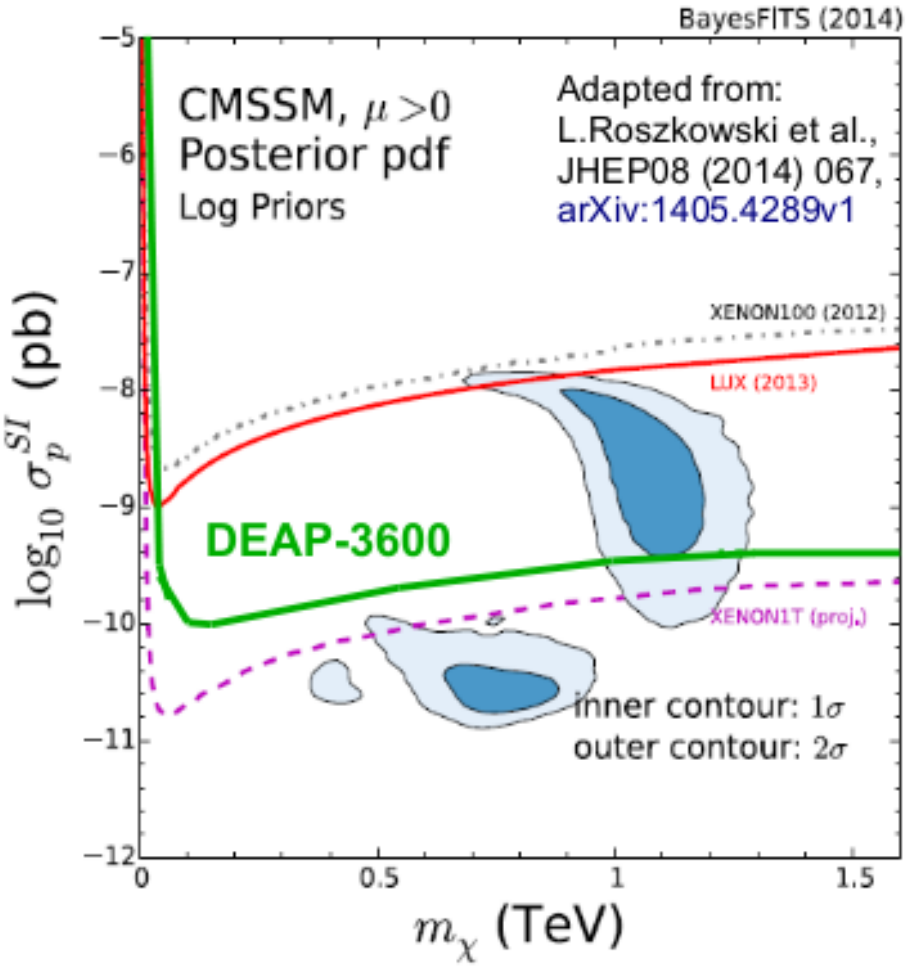
Argon is **easy to purify**

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

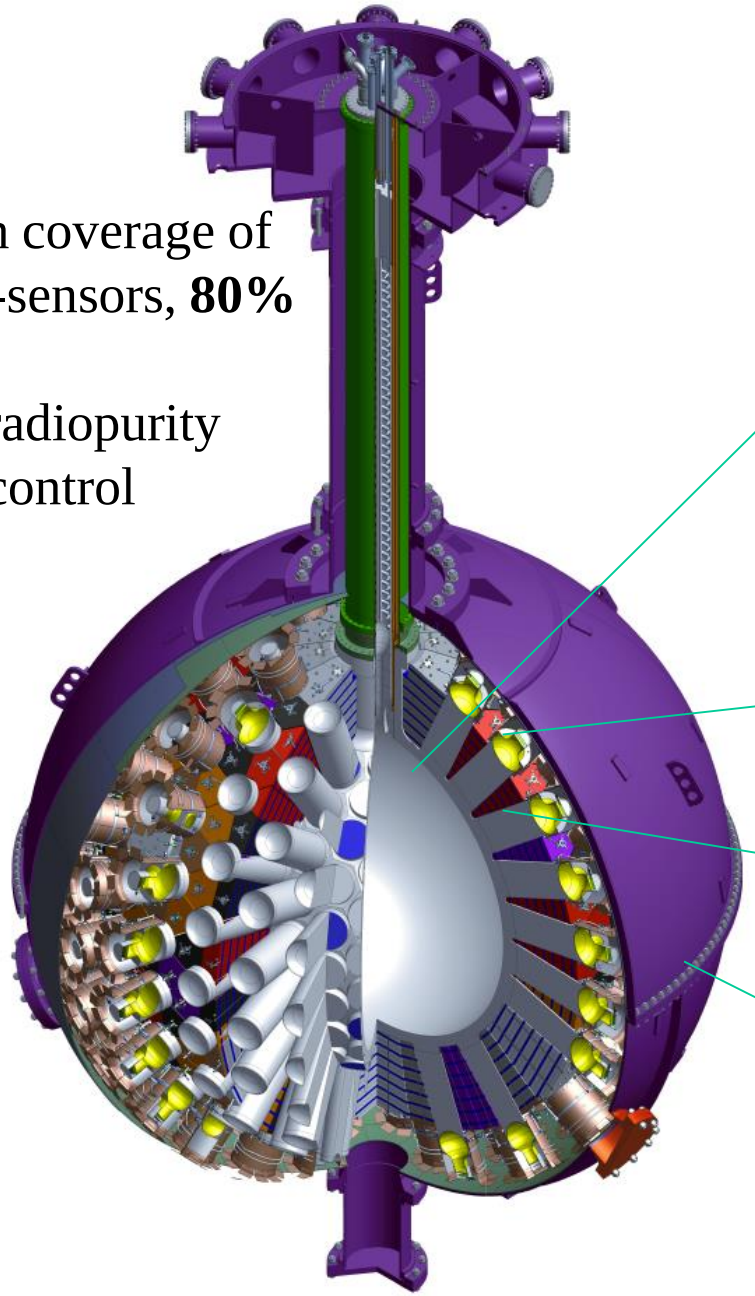
1 tonne fiducial mass (3.6 tonnes total) designed for < 0.2 background events/year with 60 keVr threshold



DEAP-3600 Detector

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

strict radiopurity control



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)

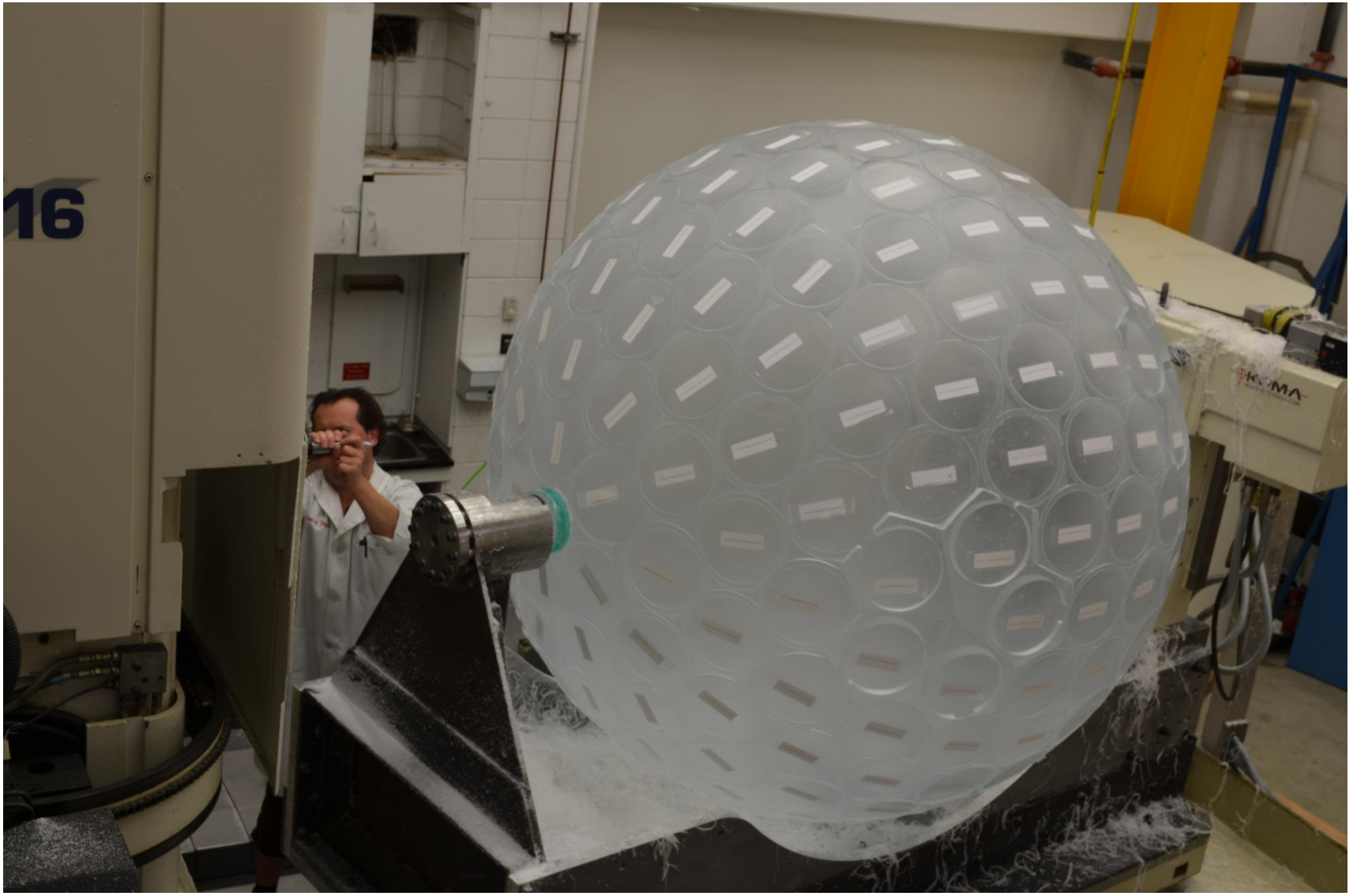
Monomer cast at RPT Asia, 2010

Thermoformed Panel at RPT Colorado

DEAP Acrylic Vessel, Panel Sections at Reynolds Polymer, Colorado

Mark Boulay

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



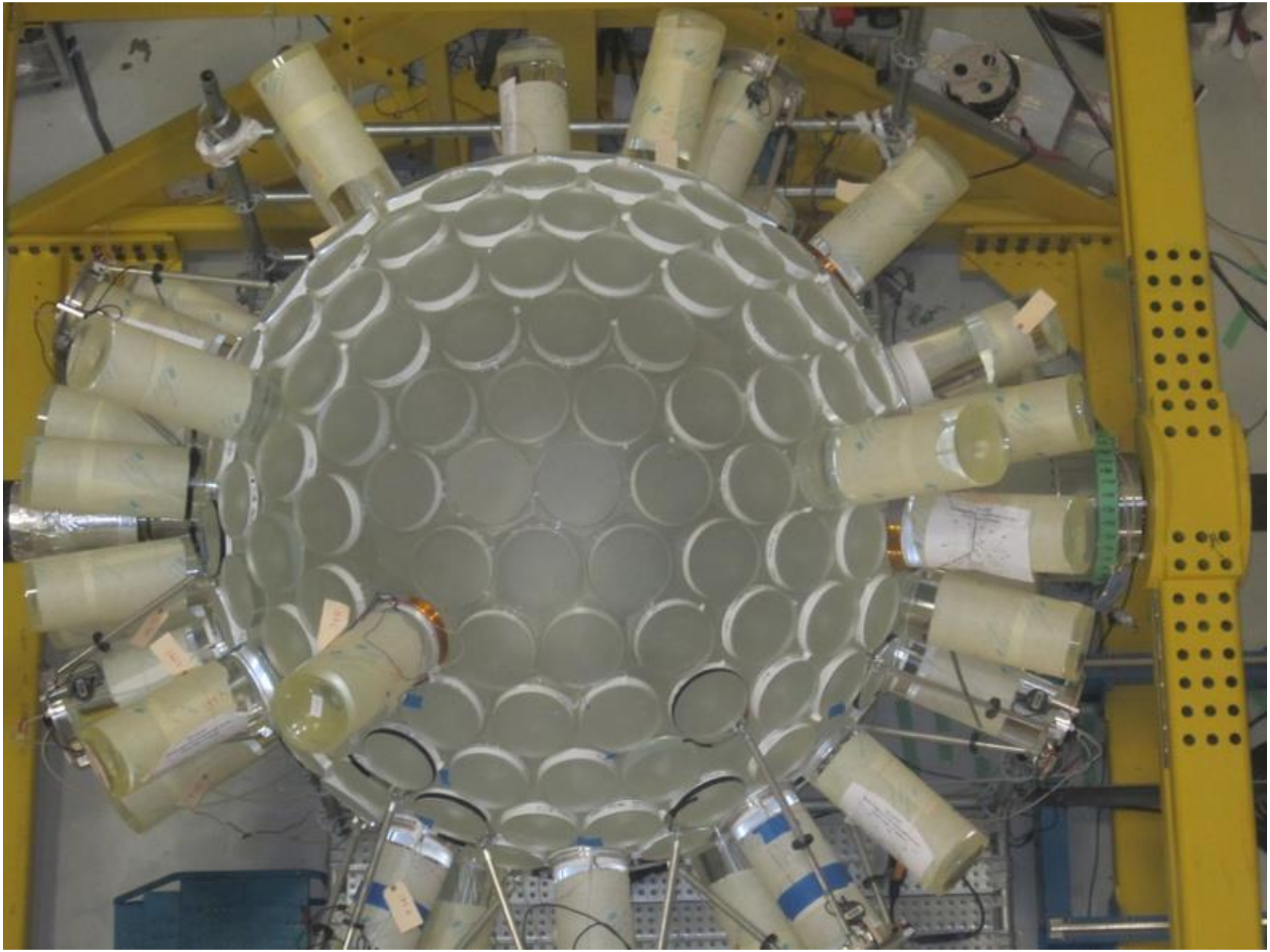
Mark Boulay

Mark Boulay

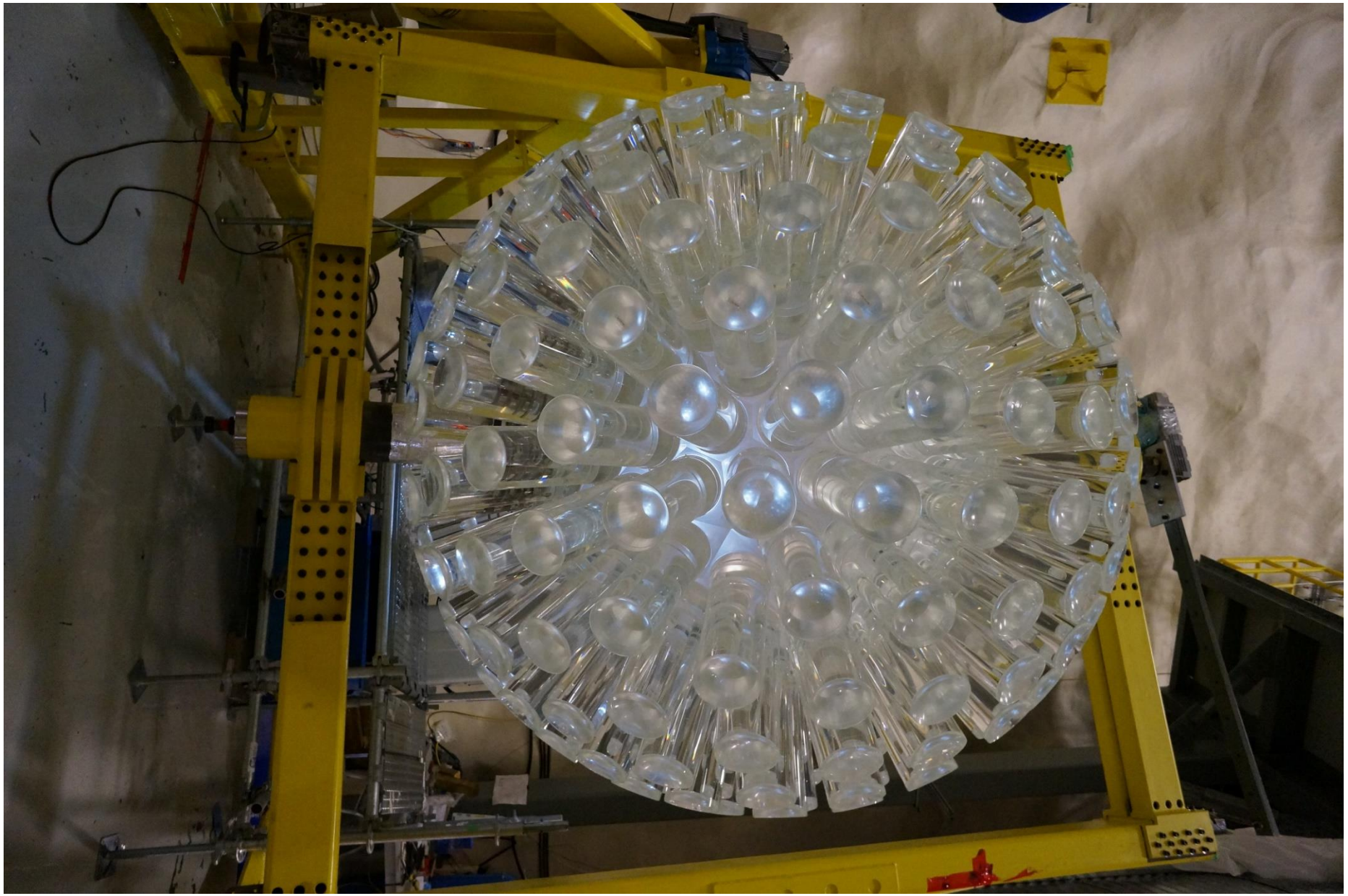
AV neck bonding underground (December 2012-January 2013)

Mark Boulay

Bonding light guides to the DEAP AV, underground at SNOLAB



DEAP Acrylic Vessel (2013)



Mark Boulay

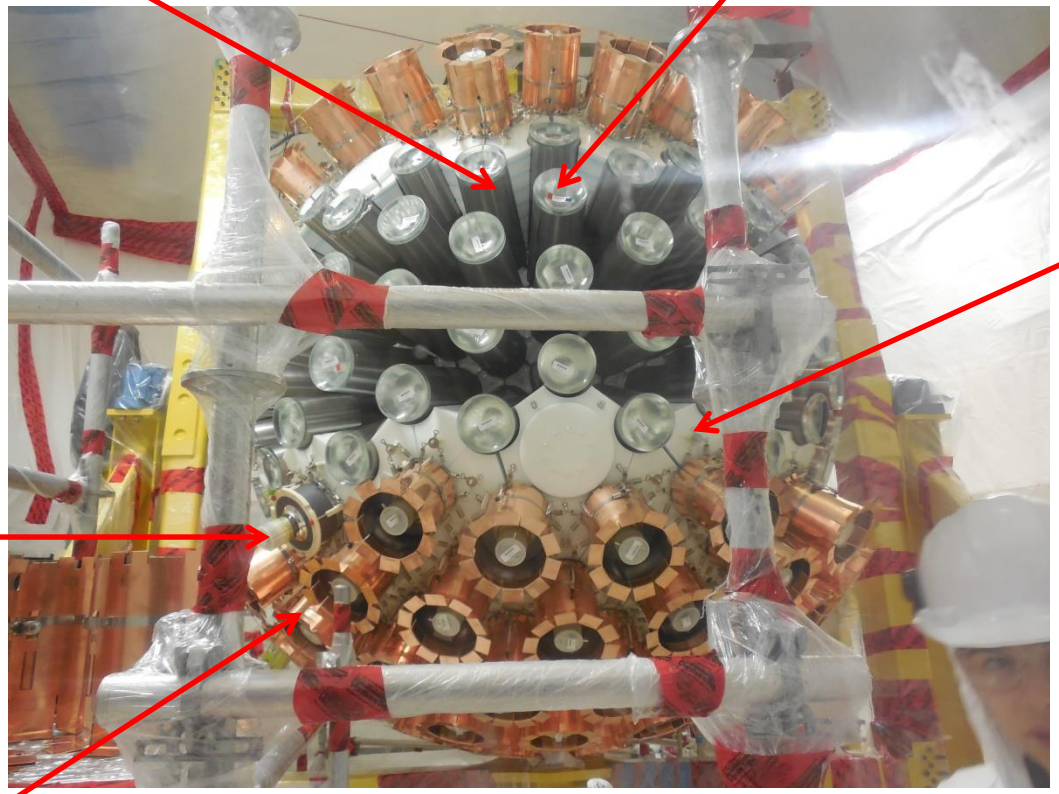
Moving the AV into assembly room

Mark Boulay

DEAP-3600 Detector Assembly

Specular reflector + opaque wrap

Acrylic Light Guide



PE neutron shielding “blocks”

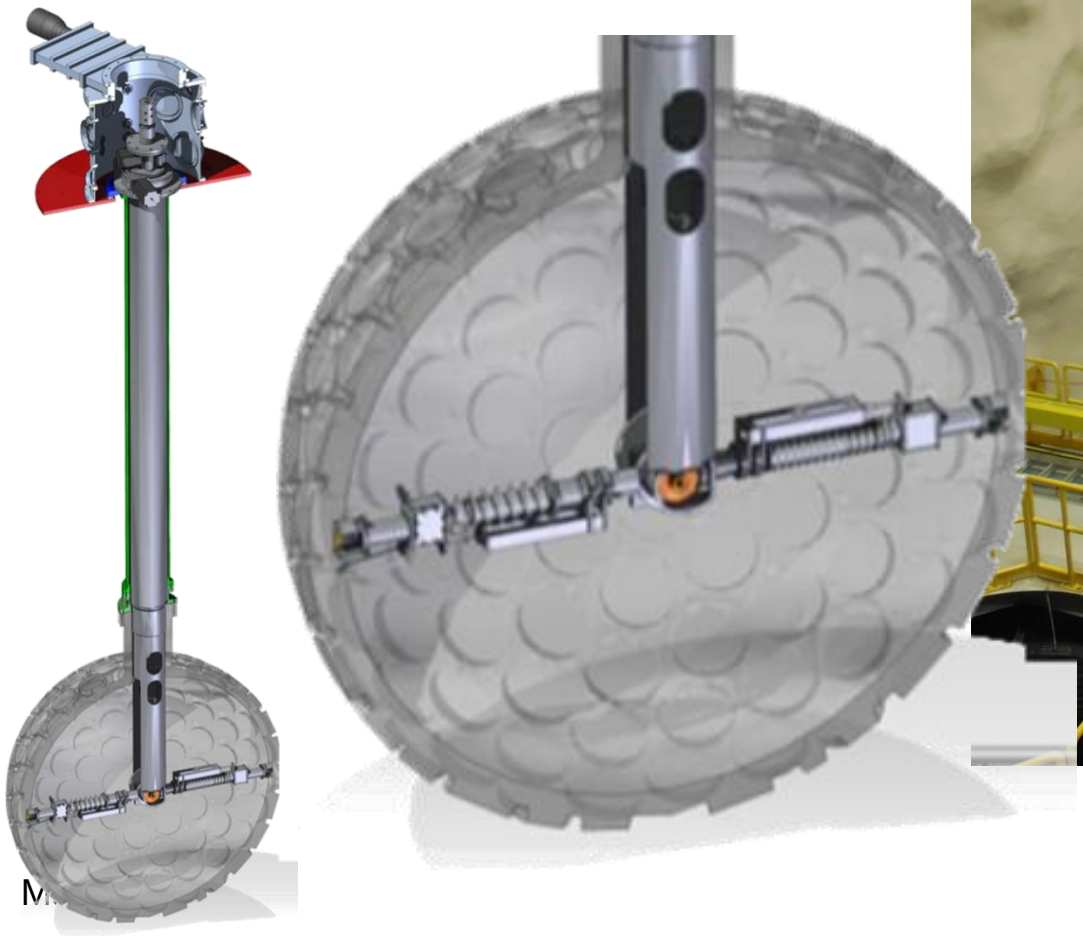
PMT with silicone oil coupling

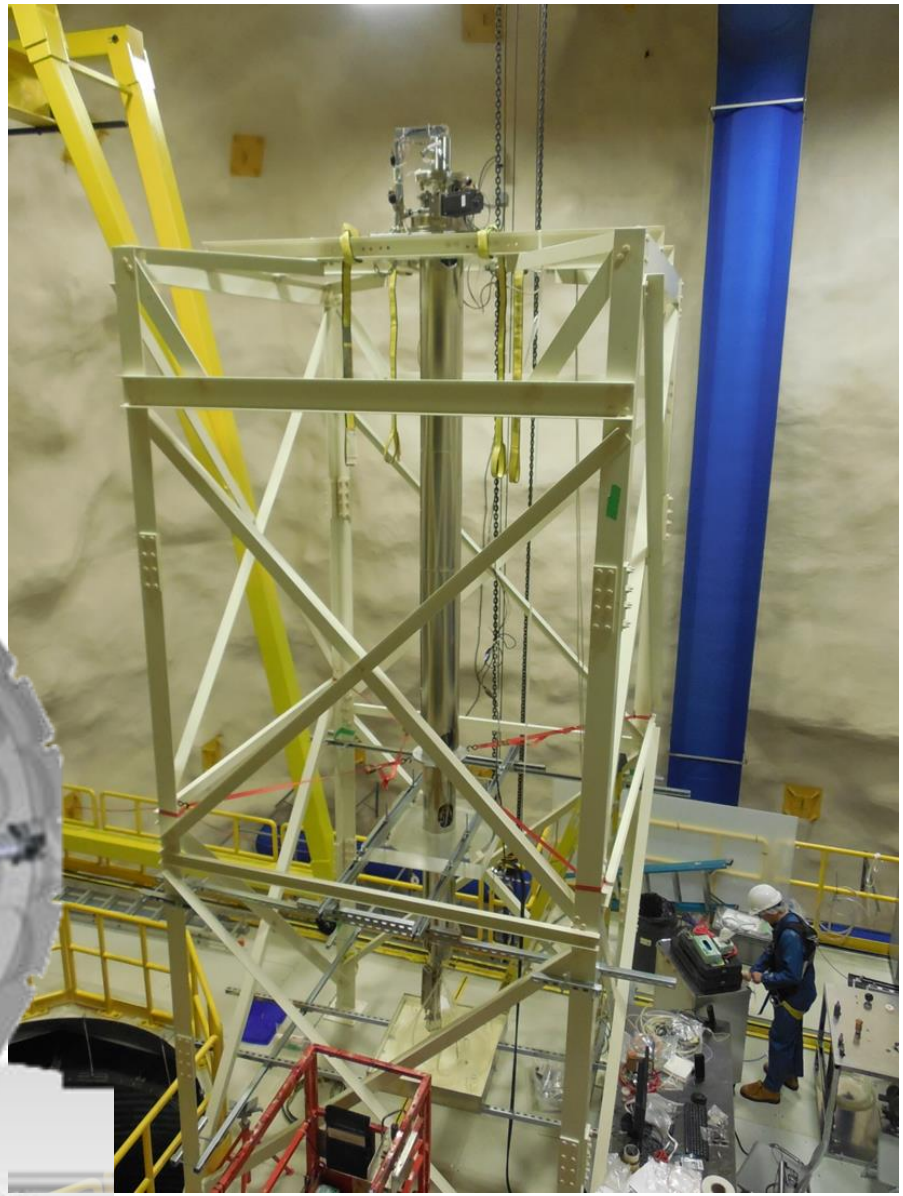
Copper sleeve over PMT

2,500 person-weeks of assembly (students, faculty, PDFs, technicians, engineers)

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)



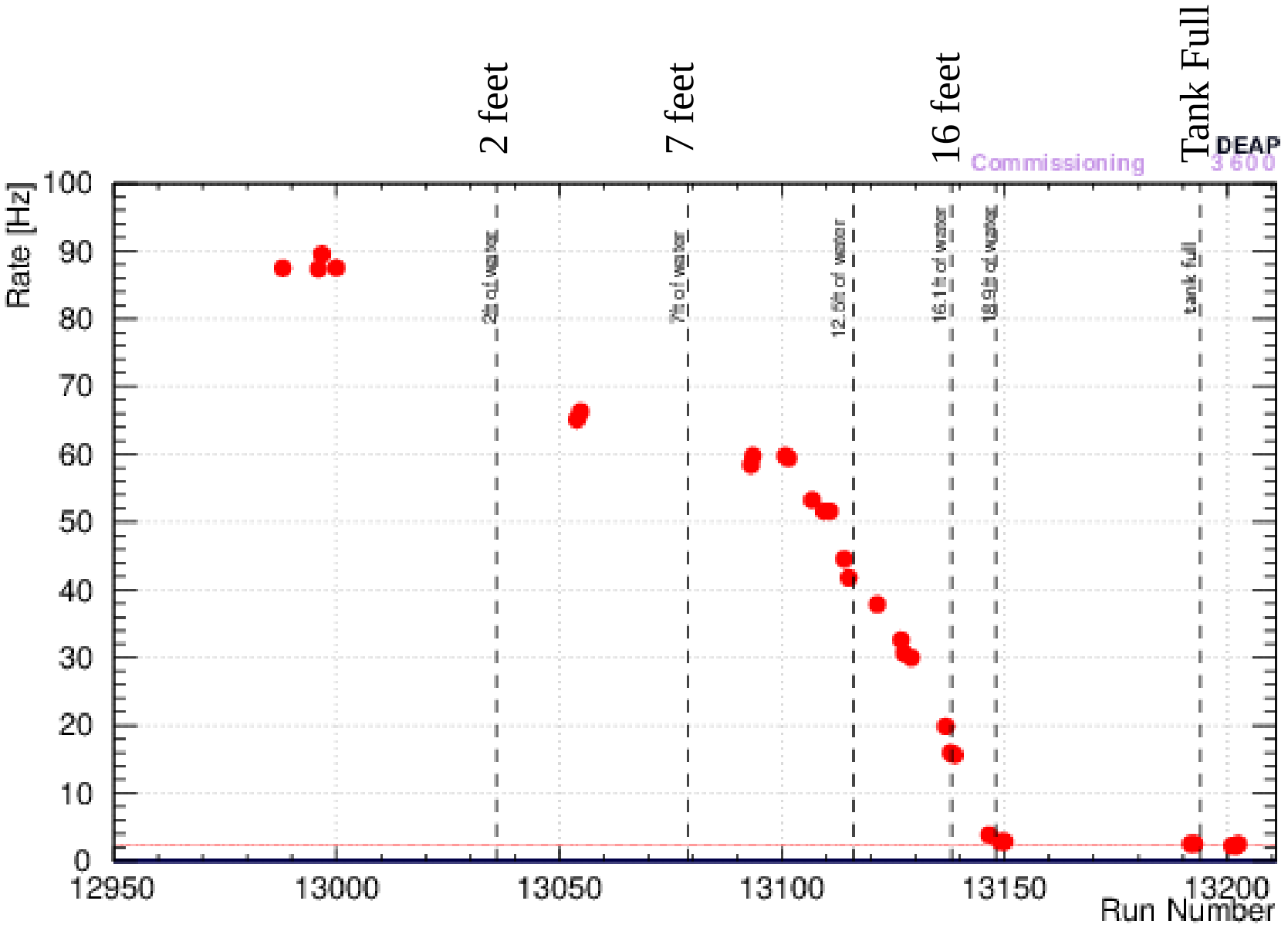


Completed Detector and Shield Tank

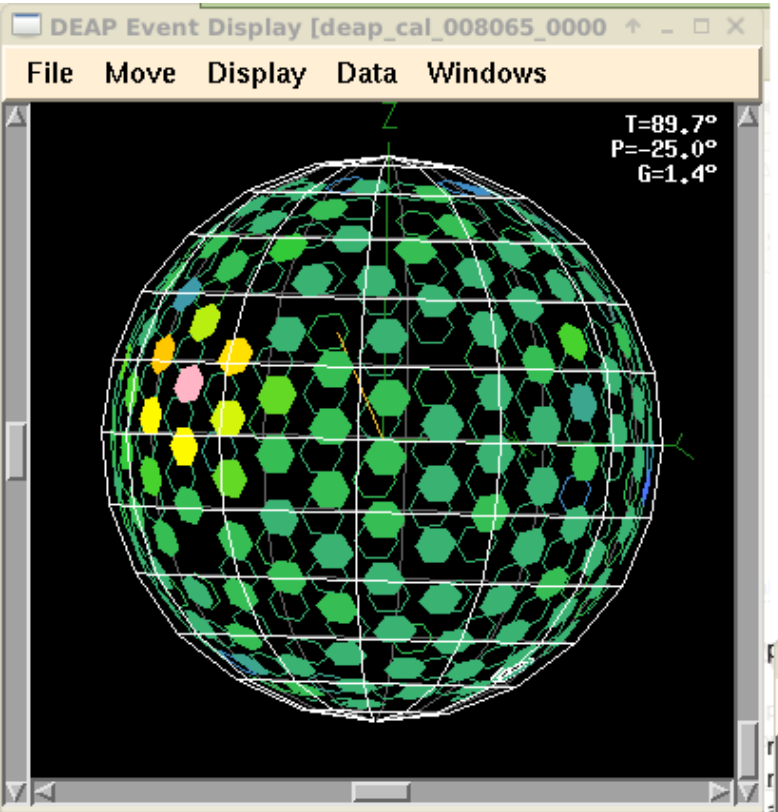
Completed Detector: Steel Shell, calibration tubes, muon veto in Shield Tank (fall 2015)

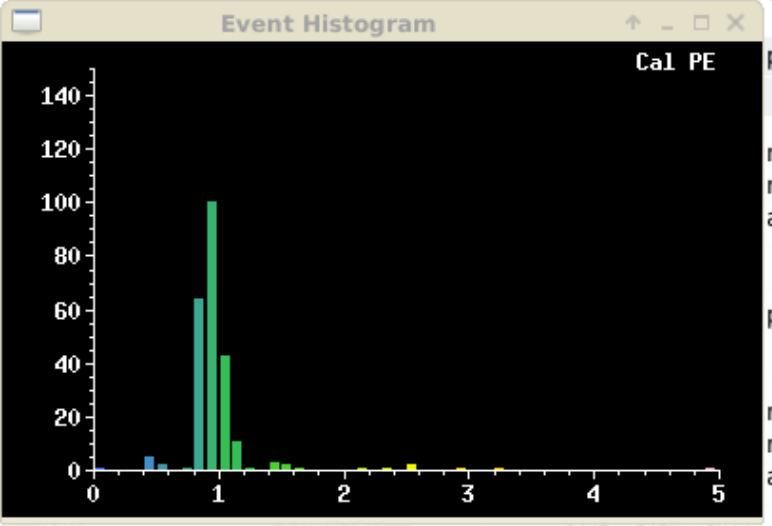
Shield Tank and emergency vent lines, tank was filled with water Oct 2015

Detector event rate during shield tank water fill



(Filled October 2015)

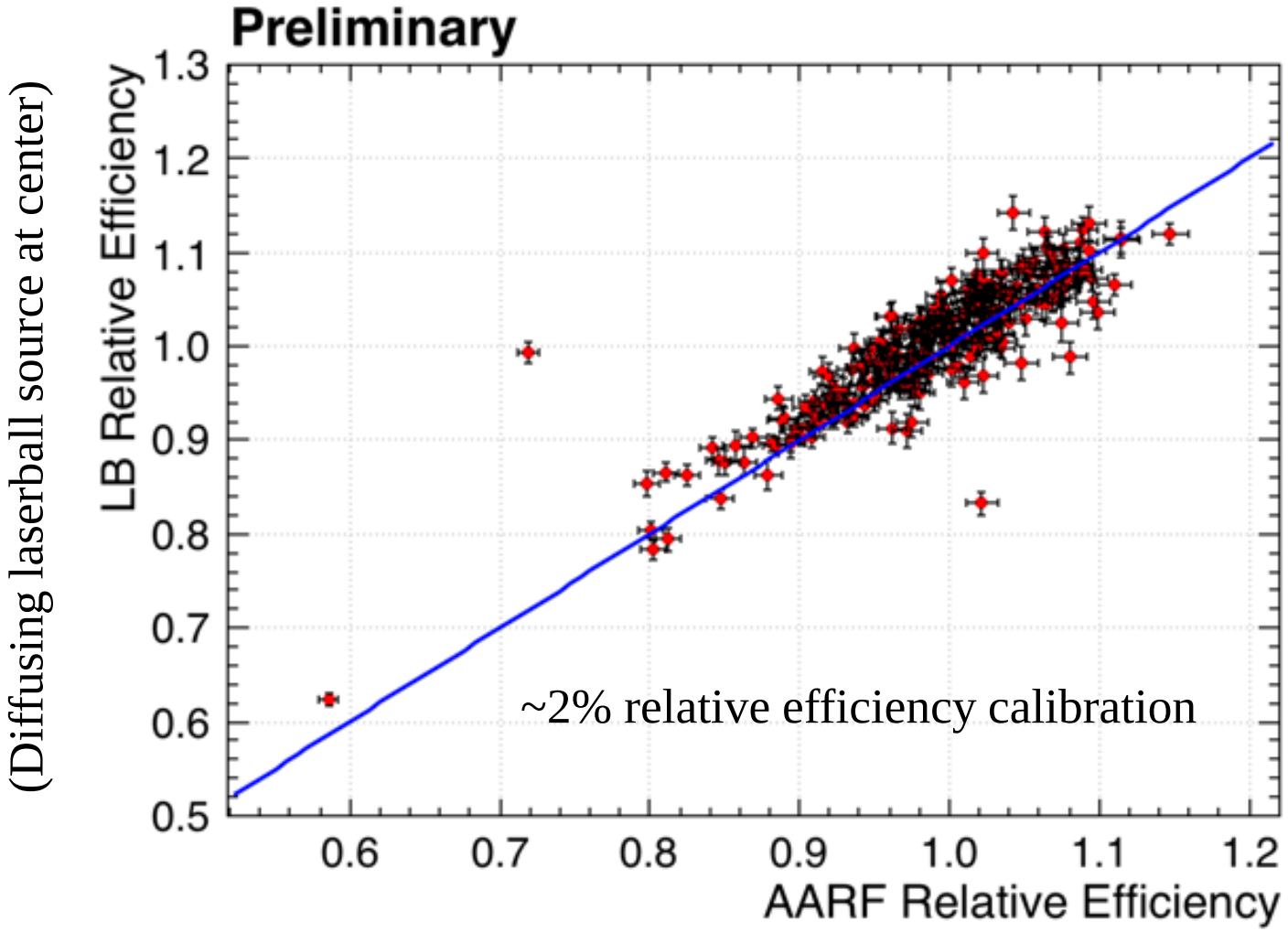




Electronics and trigger system operational for over a year (CAEN v1720s)

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

In-situ calibration of relative PMT efficiencies



(Diffusing laserball source at center)

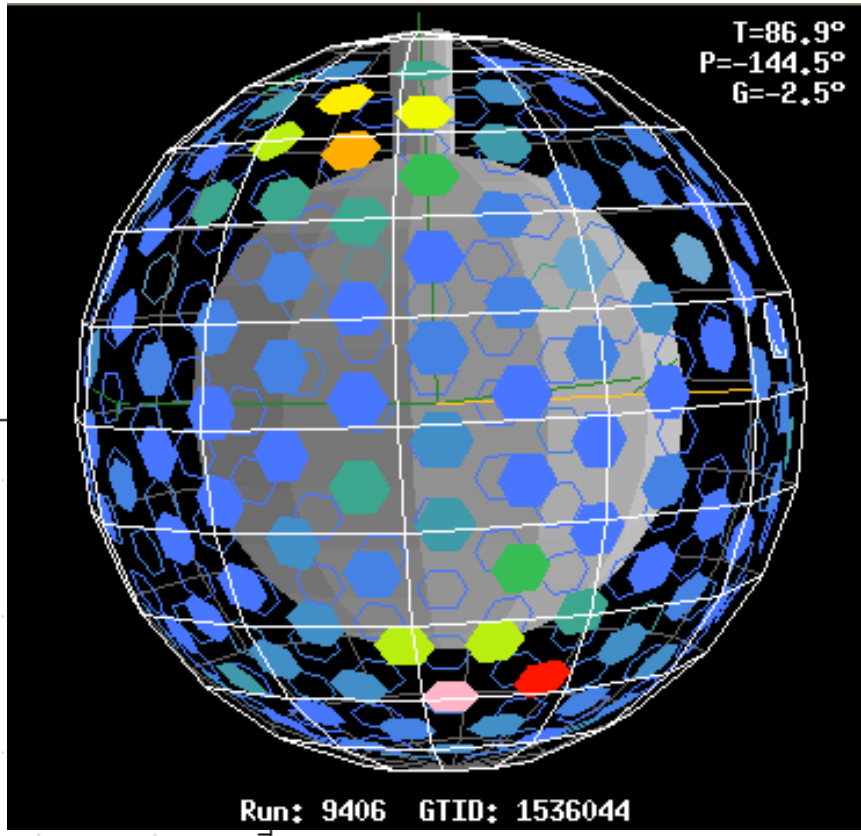
Internal fiber system (20 fibers into light guides)

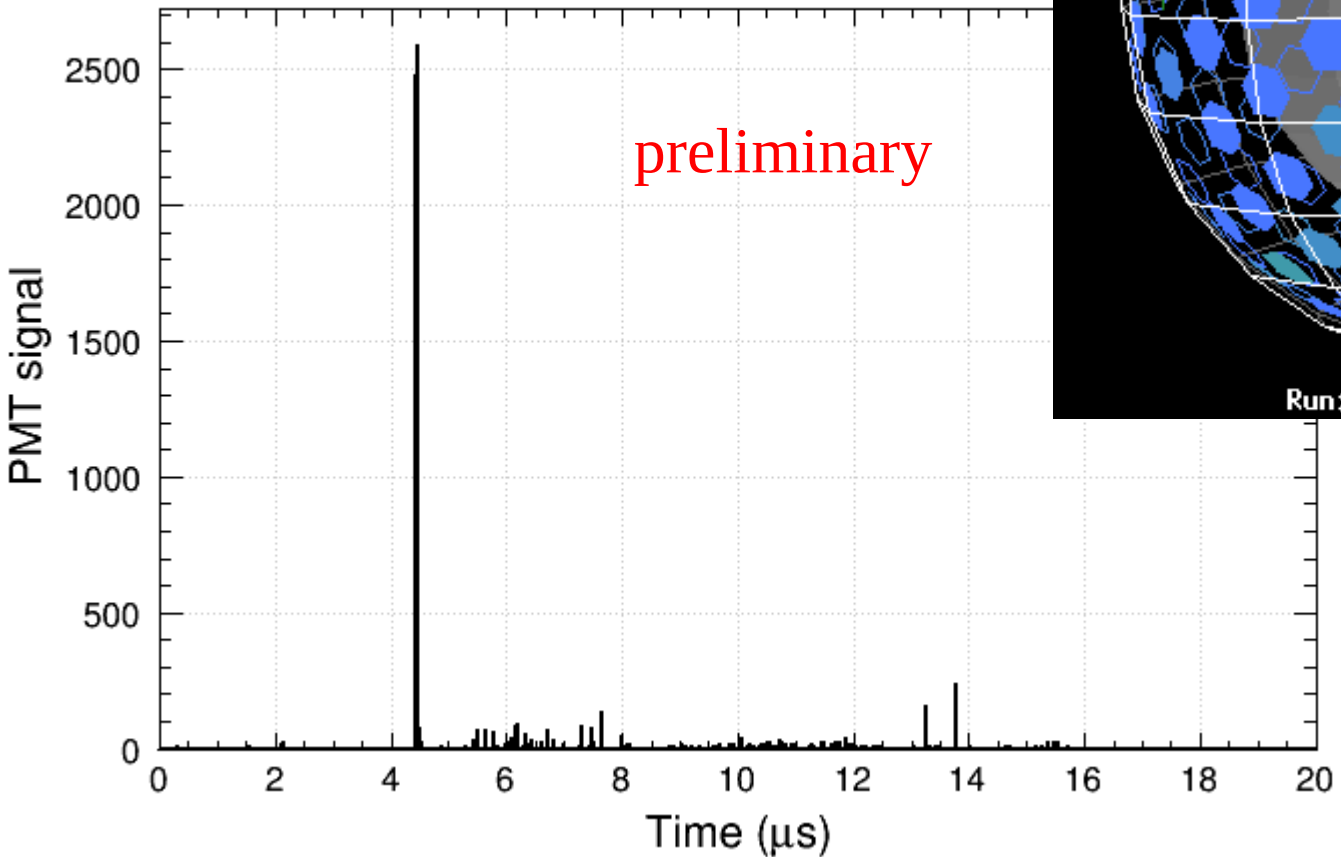
A high energy event (Commissioning running, Spring 2015)

Run: 9406 Subrun: 3 Event: 300460

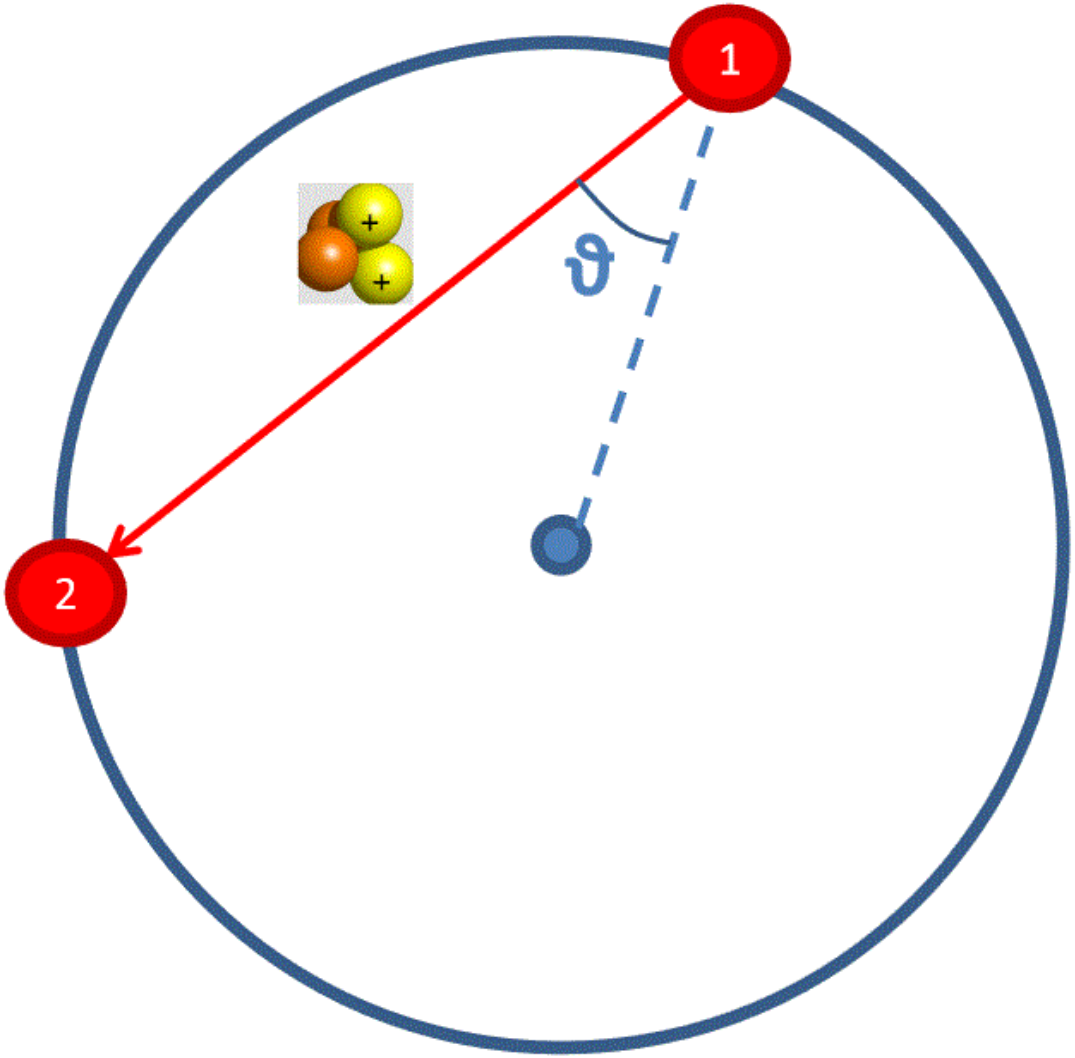
High-E event rate: ~1 event/day

Expected muon rate: 1.6 muons/day

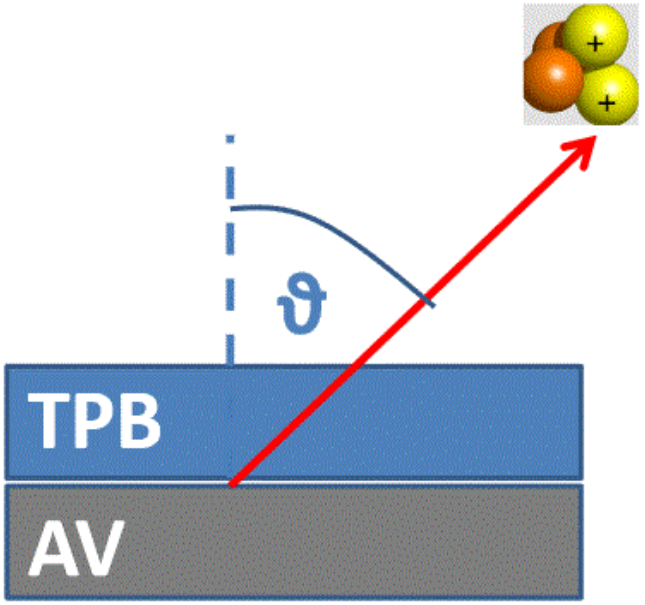




Angle definition

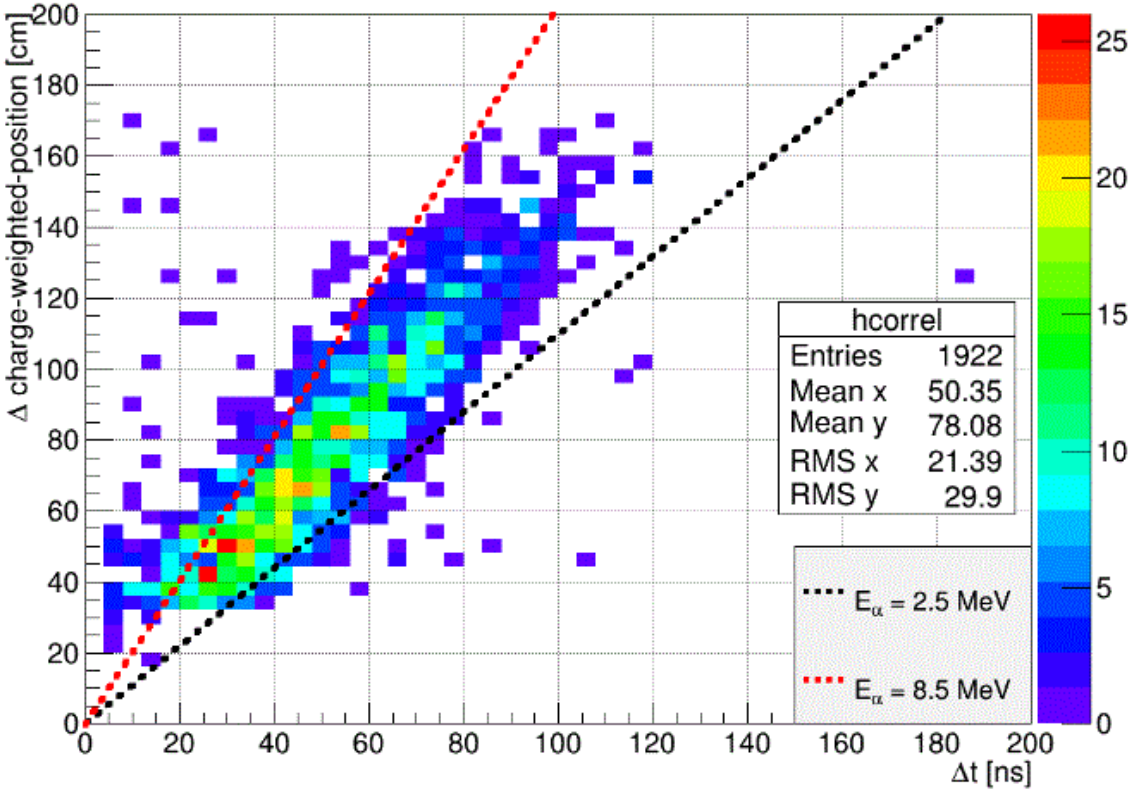


Angle is w.r.t vector from cluster 1 to center.

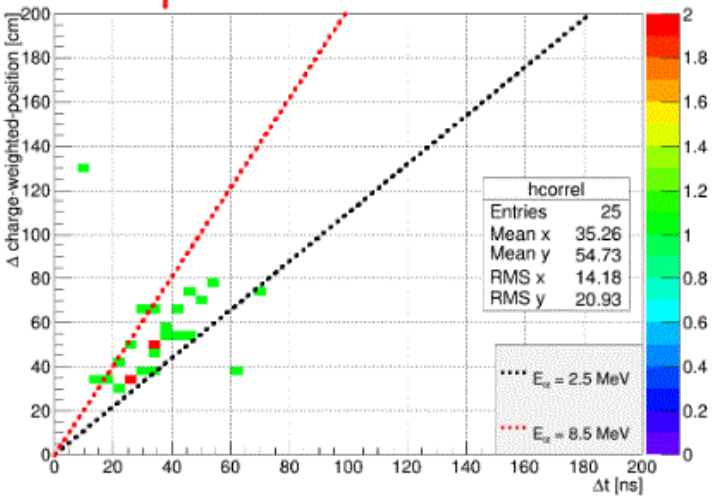


Identify alpha events from scintillation in TPB

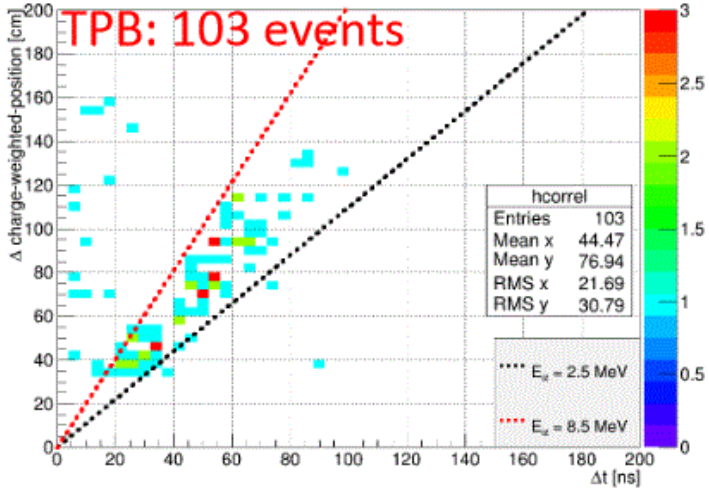
And the correlation between distance & t?



1.4 µm of TPB: 25 events



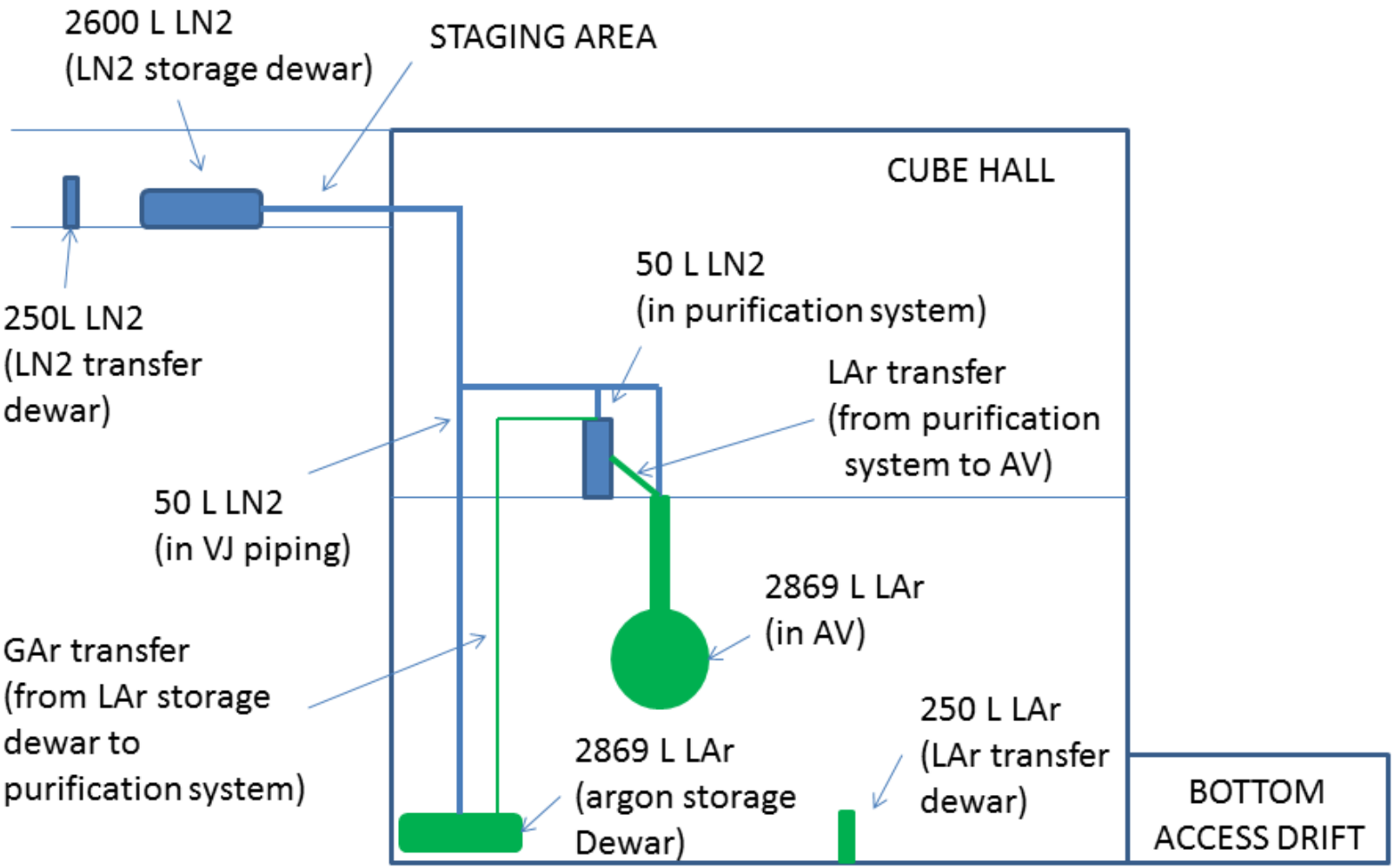
Old data with 3.0 µm of TPB: 103 events



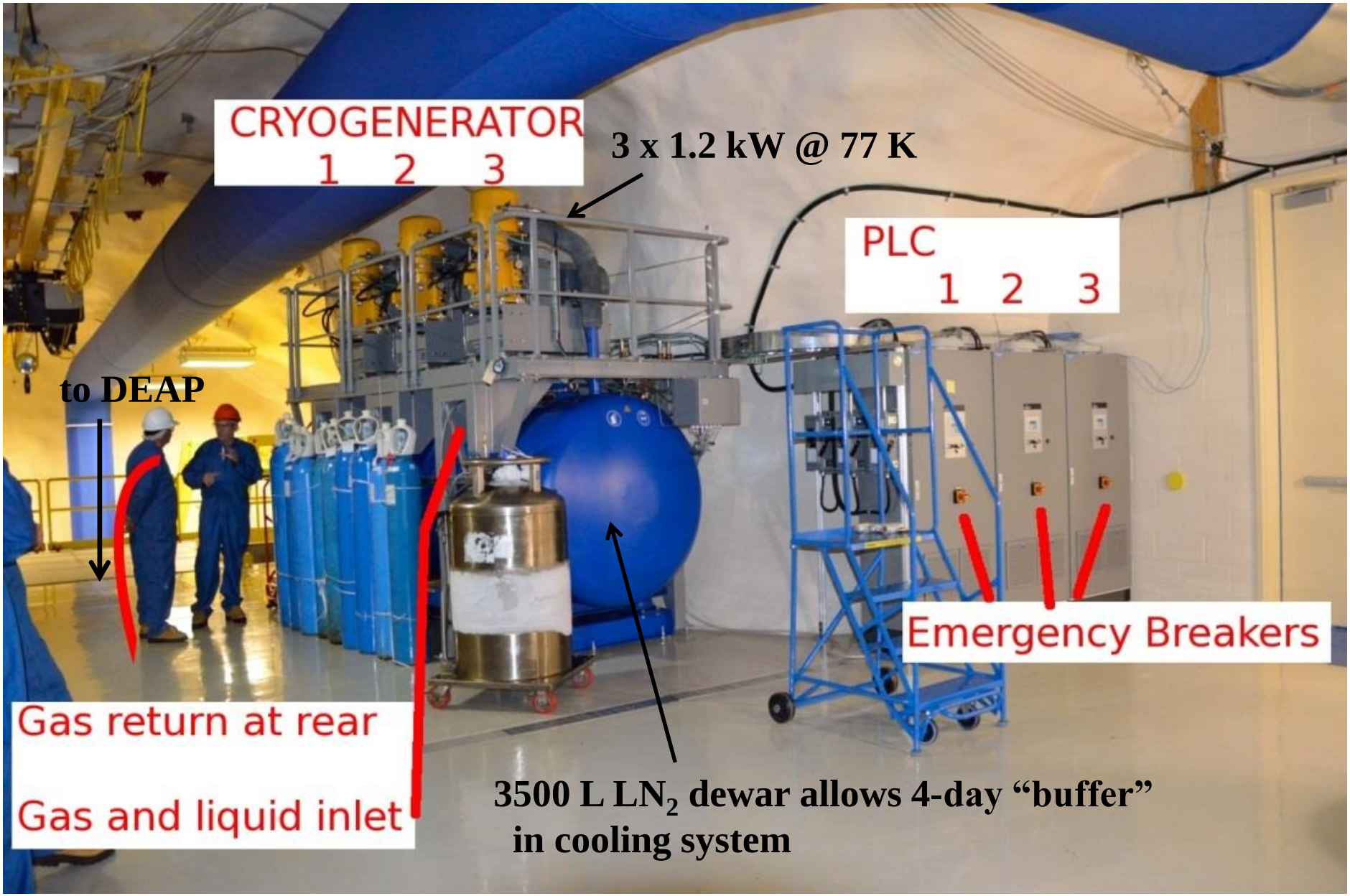
A handful of outliers in 2 months (Cherenkov mainly), otherwise the calculated energies are between 2.5 and 8.5 MeV.

PRELIMINARY – NOT FOR DISTRIBUTION!

DEAP-3600 Cryogenic Systems



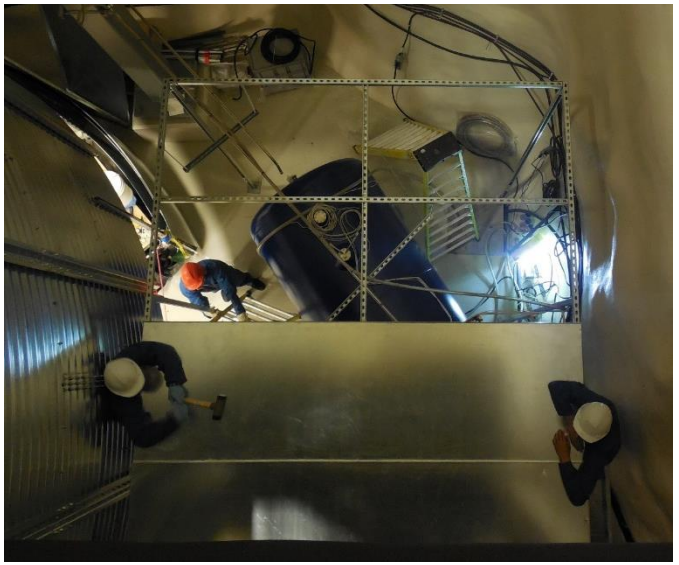
DEAP-3600 Cryocooler System Installed May 2012



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

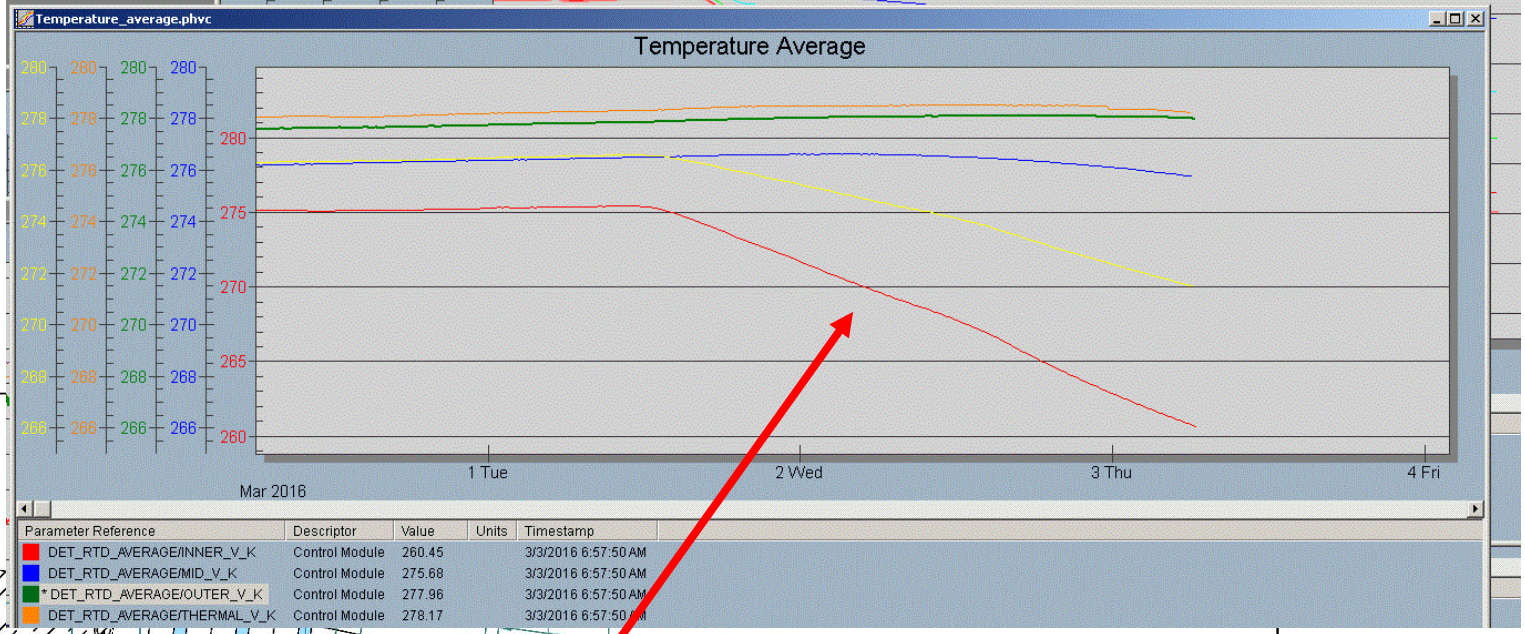
(<100 ppt after purification)

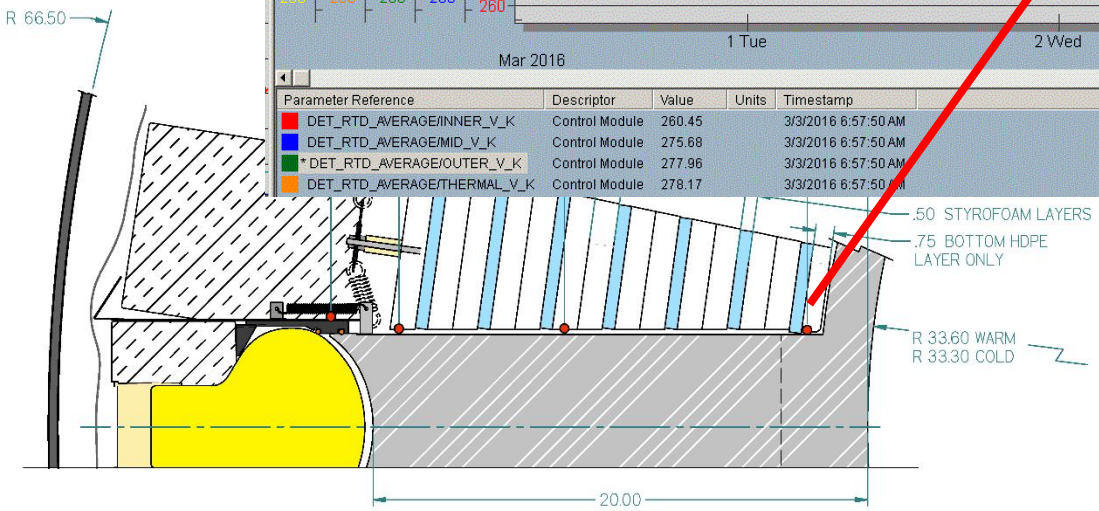
Argon Purification

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

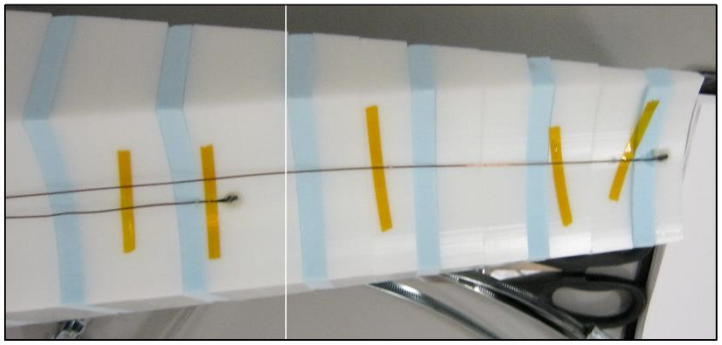
(Gettering, radon
and
particulate filtration)

AV cooldown started
Feb 2016

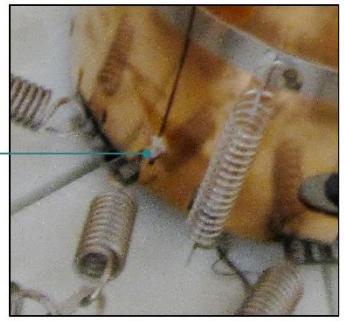




Refer to "Temperature Sensor Locations Rev G" for a visual map of all AV RTD locations.



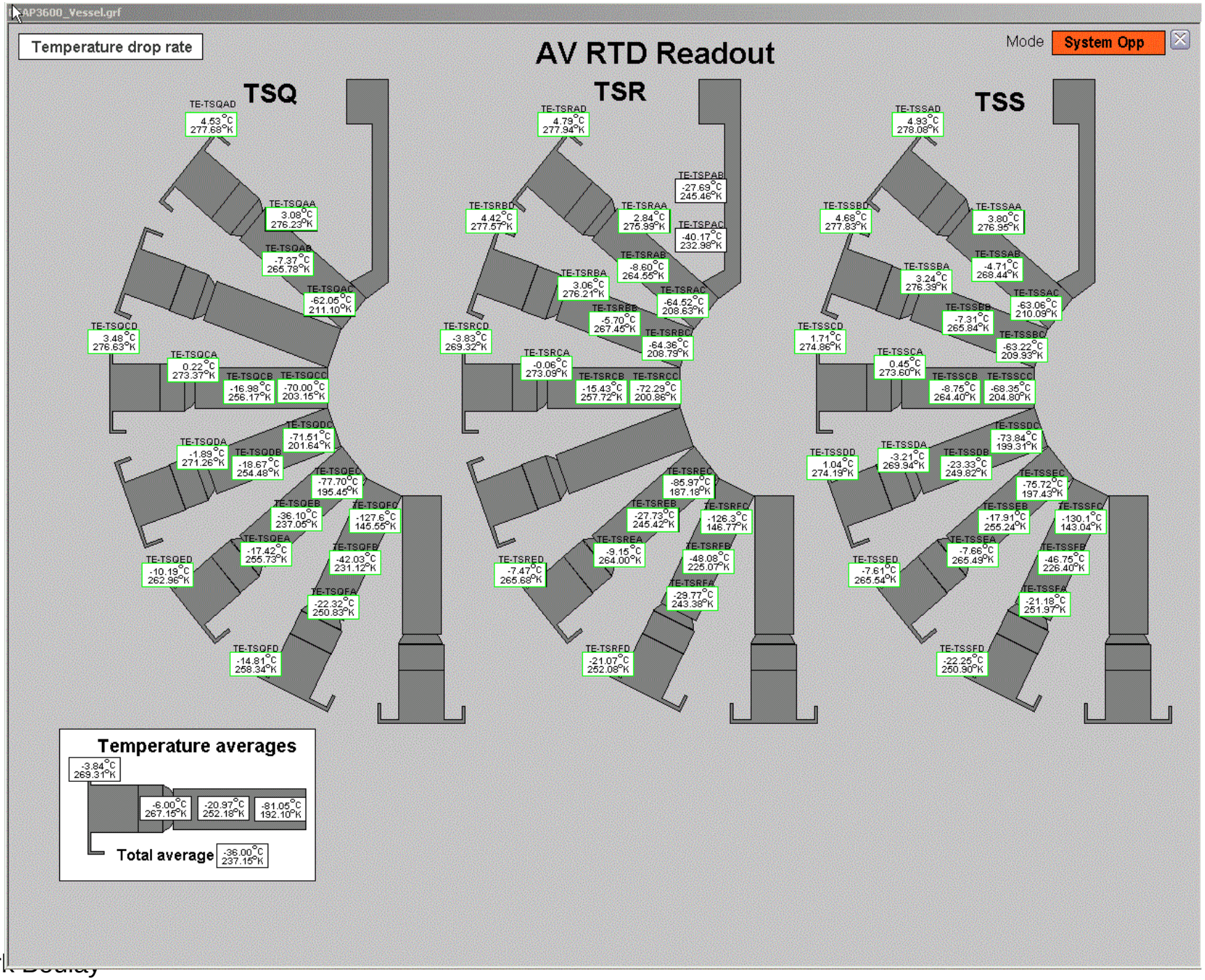
RTD on PMT



SHEET 3 TYPICAL FILLER BLOCK RTD ARRANGEMENT

DRAWN: KOBY DERING | DATE: 18 FEB 2016
UNLESS OTHERWISE SPECIFIED
DIMENSIONS ARE IN INCHES
DECIMALS .XX ± 0.01 .XXX = 0.005
ANGLES ± 1°
ROUNDS AND FILLETS 0.313 INCHES
SURFACE FINISH 125 µINCHES

DEAP
Queen's University. Physics Department
TITLE: DETECTOR RTD ARRANGEMENT
SIZE: B | DWG NO QUDO-DEC-AR-7216-03 | REV: B
SCALE: AS % OF | WEIGHT: | SHEET 3 OF 5


AP3600_Vessel.grf
Temperature drop rate
AV RTD Readout
Mode
System Opp
TSQ
TE-TSQAD 4.53°C 277.68°K
TE-TSQAA 3.08°C 276.23°K
TE-TSQAB -7.37°C 265.78°K
TE-TSQAC -62.05°C 211.10°K
TE-TSQCD 3.48°C 276.63°K
TE-TSQCA 0.22°C 273.37°K
TE-TSQCB -16.98°C 256.17°K
TE-TSQCC -70.00°C 203.15°K
TE-TSQDC -71.51°C 201.64°K
TE-TSQDA -1.89°C 271.26°K
TE-TSQDB -18.67°C 254.48°K
TE-TSQEC -77.70°C 195.45°K
TE-TSQEB -36.10°C 237.05°K
TE-TSQFC -127.6°C 145.55°K
TE-TSQEA -17.42°C 255.73°K
TE-TSQED -10.19°C 262.96°K
TE-TSQEB -42.03°C 231.12°K
TE-TSQFA -22.32°C 250.83°K
TE-TSQFD -14.81°C 258.34°K
TSR
TE-TSRAD 4.79°C 277.94°K
TE-TSRBD 4.42°C 277.57°K
TE-TSRAA 2.84°C 275.99°K
TE-TSPAB -27.69°C 245.46°K
TE-TSPAC -40.17°C 232.98°K
TE-TSRAB -8.60°C 264.55°K
TE-TSRBA 3.06°C 276.21°K
TE-TSRAC -64.52°C 208.63°K
TE-TSRBB -5.70°C 267.45°K
TE-TSRBC -64.36°C 208.79°K
TE-TSRCD -3.83°C 269.32°K
TE-TSRCA -0.06°C 273.09°K
TE-TSRCB -15.43°C 257.72°K
TE-TSRCC -72.29°C 200.86°K
TE-TSREC -85.97°C 187.18°K
TE-TSREB -27.73°C 245.42°K
TE-TSRFC -126.3°C 146.77°K
TE-TSREA -9.15°C 264.00°K
TE-TSRED -7.47°C 265.68°K
TE-TSRFB -48.08°C 225.07°K
TE-TSRFA -29.77°C 243.38°K
TE-TSRFD -21.07°C 252.08°K
TSS
TE-TSSAD 4.93°C 278.08°K
TE-TSSBD 4.68°C 277.83°K
TE-TSSAA 3.80°C 276.95°K
TE-TSSAB -4.71°C 268.44°K
TE-TSSBA 3.24°C 276.38°K
TE-TSSAC -63.06°C 210.09°K
TE-TSSBB -7.31°C 265.84°K
TE-TSSBC -63.22°C 209.93°K
TE-TSSCD 1.71°C 274.86°K
TE-TSSCA 0.45°C 273.60°K
TE-TSSCB -8.75°C 264.40°K
TE-TSSCC -68.35°C 204.80°K
TE-TSSDC -73.84°C 199.31°K
TE-TSSDD 1.04°C 274.19°K
TE-TSSDA -3.21°C 269.94°K
TE-TSSDB -23.33°C 249.82°K
TE-TSSEC -75.72°C 197.43°K
TE-TSSEB -17.91°C 255.24°K
TE-TSSFC -130.1°C 143.04°K
TE-TSSEA -7.66°C 265.49°K
TE-TSSED -7.61°C 265.54°K
TE-TSSFB -46.75°C 226.40°K
TE-TSSFA -21.18°C 251.97°K
TE-TSSFD -22.25°C 250.90°K
Temperature averages
-3.84°C 269.31°K
-6.00°C 267.15°K
-20.97°C 252.18°K
-81.05°C 192.10°K
Total average -36.00°C 237.15°K

Mark Boulay

DEAP-3600 Analysis Groups

Working group leader	Institution	Group
Marcin Kuzniak	Carleton	Analysis Coordinator
James Bueno	Alberta	Gamma/other backgrounds
Berta Beltran	Alberta	Position reconstruction
Chris Ouellet	Carleton	Global backgrounds, Run Selection
Chris Jillings	Laurentian	PMTs
Rashid Medyev	Carleton	Efficiency/optical calibration
Tina Pollmann	Laurentian	PSD
Ben Smith	TRIUMF	Low-level calibration (electronics)
Joe Walding	RHUL	Neutron calibration
Nasim Fatemighomi	RHUL	Energy response
Eric Vazquez Jauregui	UNAM	Neutron backgrounds

Working group structure, additional students/scientists contribute to various working groups, require additional effort on reconstruction, mu-veto calibration, surface backgrounds, optical calibration

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, detector calibration and analysis well advanced

- Start of detector cooldown Feb 2016, start of liquid filling June 11, 2016

- Expecting first physics data summer 2016

END