The DEAP-3600 Dark Matter Experiment

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for the DEAP-3600 Collaboration

Queen's University

DEAP: **D**ark matter **E**xperiment using **A**rgon **P**ulse-shape discrimination

The DEAP-3600 Detector

Single phase liquid argon dark matter direct detection, 3600 kg target mass (1000 kg fiducial)

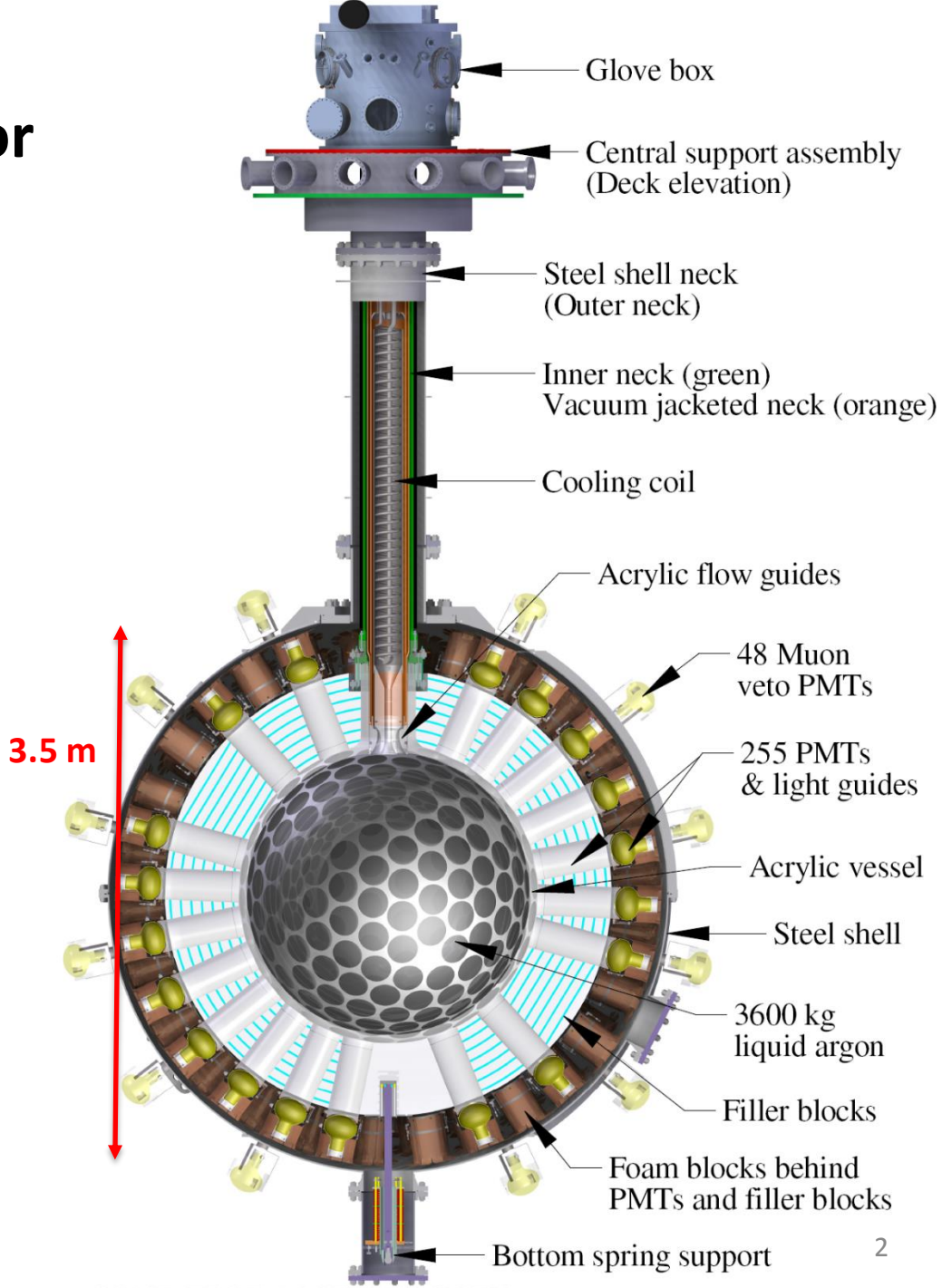
Located at SNOLAB, 2 km underground in Sudbury, Canada

Ultraclean acrylic vessel, "resurfaced" in-situ

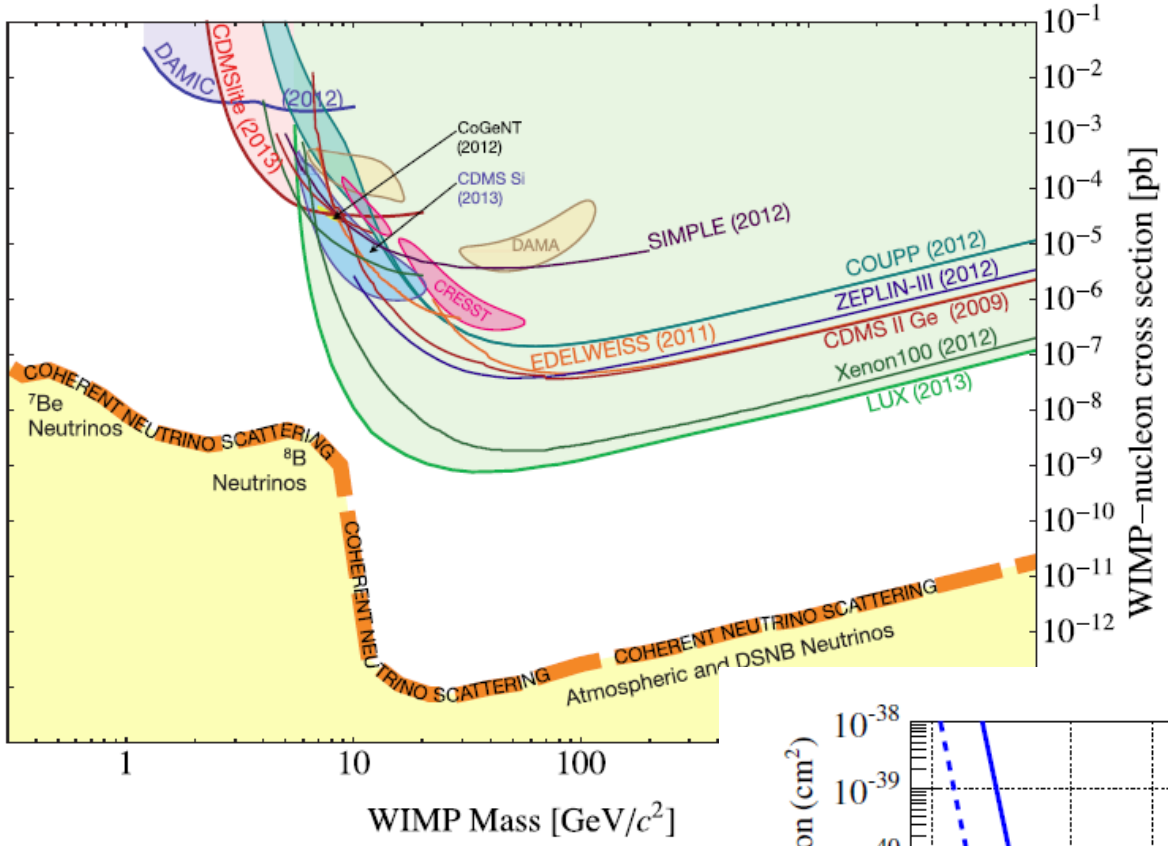
255 Hamamatsu R5912 HQE PMTs 8-inch (32% QE, 71% coverage)

50 cm light guides + PE shielding provide neutron moderation

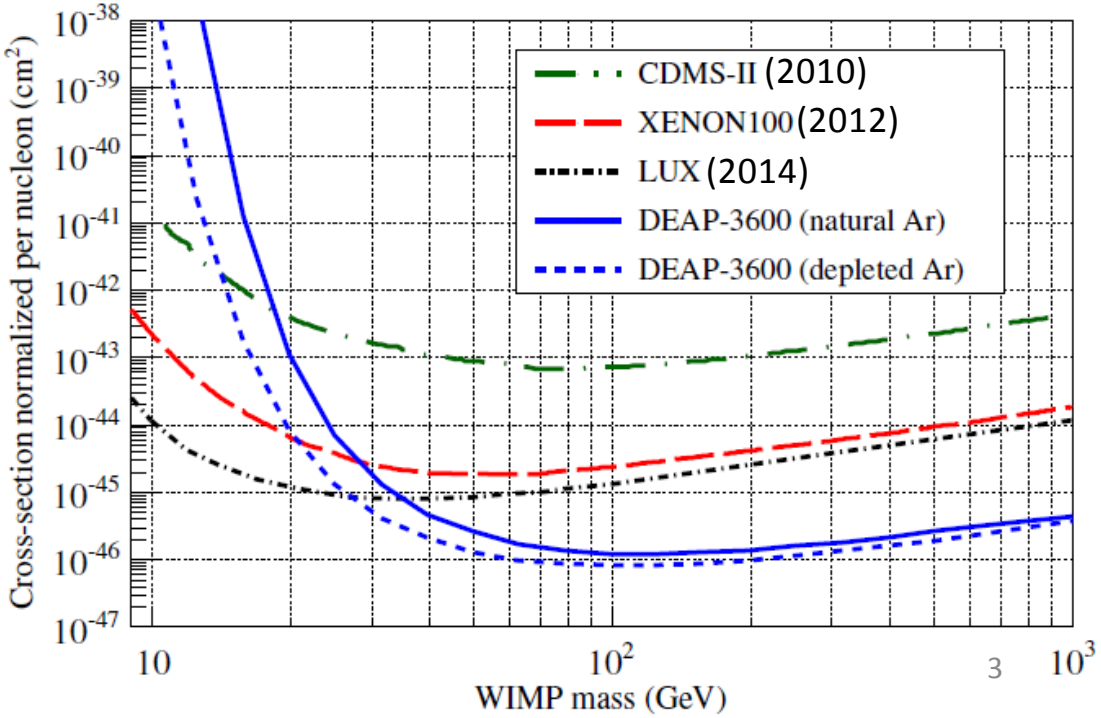
Steel Shell immersed in 8 m water shield



Spin-independent WIMP-nucleon cross section



J. Billard et al, Phys. Rev. D 89, 023524 (2014)



arxiv.org:1410.7673

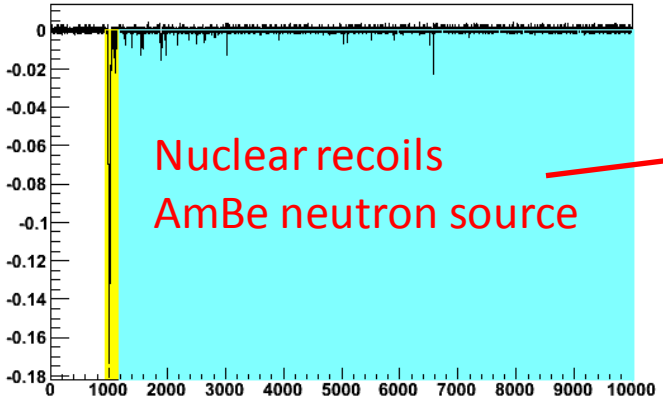
Critical elements of the design

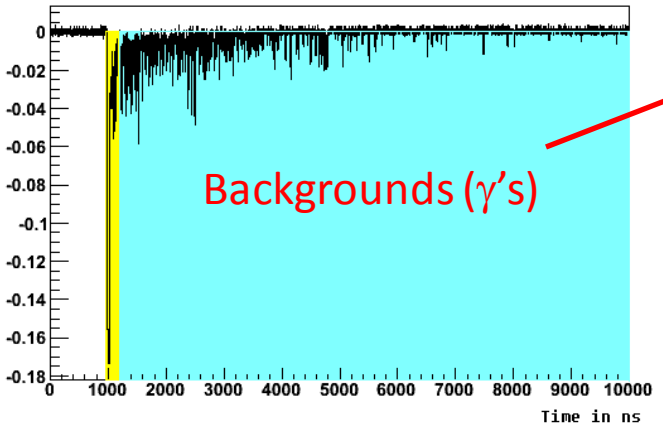
- Ultrapure cryogenic acrylic vessel bonded underground
- Large stainless steel pressure vessel welded underground
- Argon purification system with extremely low target levels of radon emanation
- Large target of liquid argon viewed by low-radioactivity HQE PMTs near room temperature
- Custom large-scale robotic resurfacer for radon control
- Custom large-scale (10 m^2!) in-situ thin-film deposition device

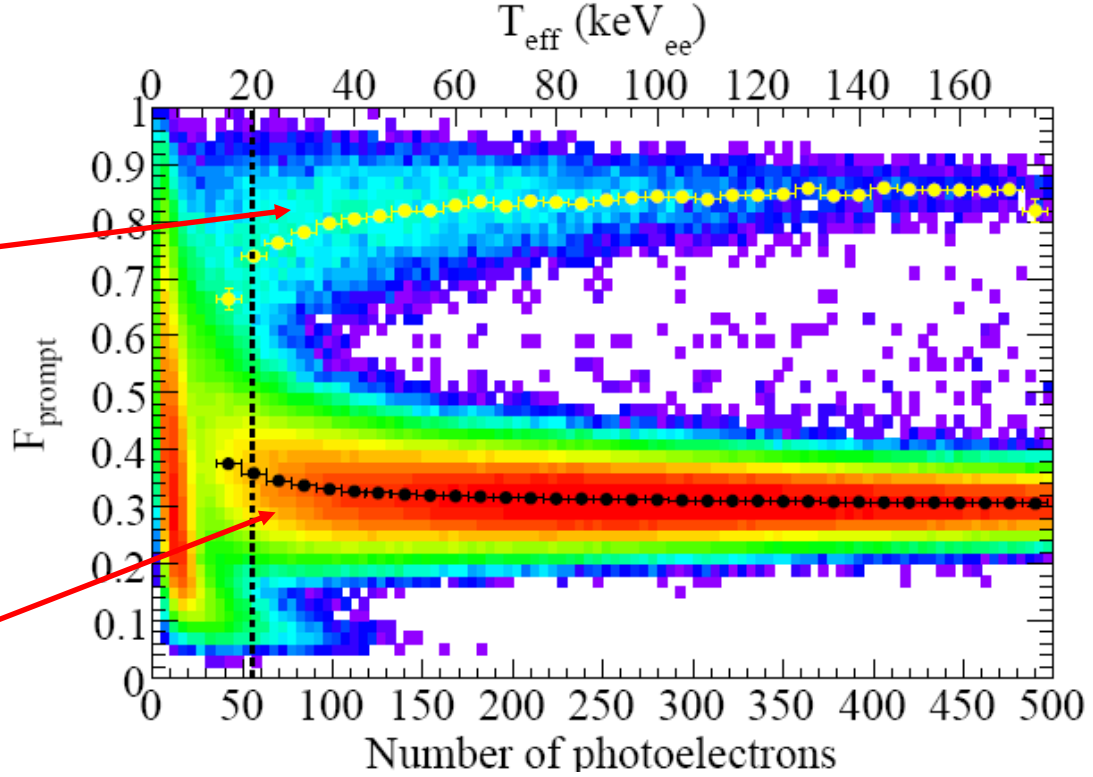
Backgrounds in DEAP-3600

- β/γ backgrounds
  - Dominated by ^{39}Ar (1 Bq/kg)
  - Pulse-shape discrimination
  - Depleted argon after natural argon run
- Neutron backgrounds
  - Extensive assay program for selecting clean materials
  - Sufficient neutron shielding
  - Muon suppression at SNOLAB
- Surface contamination
  - Clean detector surface (resurfacer device)
  - Vertex reconstruction for fiducial volume

PSD in liquid argon with DEAP-1

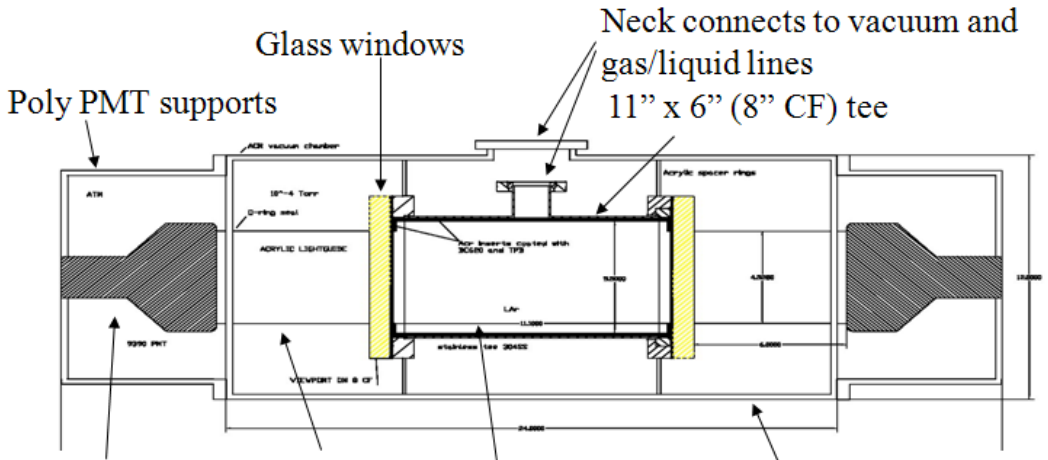






Yellow: Prompt light region
Blue: Late light region

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



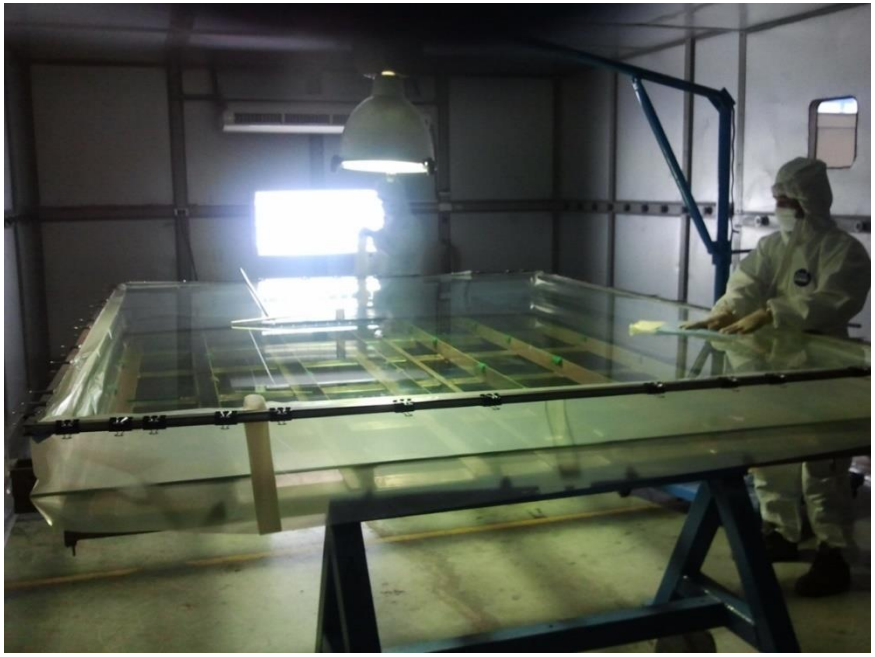
ET 9390B PMT 5"

7 kg LAr

Inner surface 97% diffuse reflector, covered with TPB wavelength shifter

Fabrication and assay of DEAP acrylic

- Fabrication from pure MMA monomer at RPT Asia 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
- C. Nantais M.Sc. Thesis result (Queen's 2014)
  - ^{210}Pb : $< 2.2 \times 10^{-19}$ g/g
  - < 0.2 background events in 3 years



Monomer cast at RPT Asia 2011

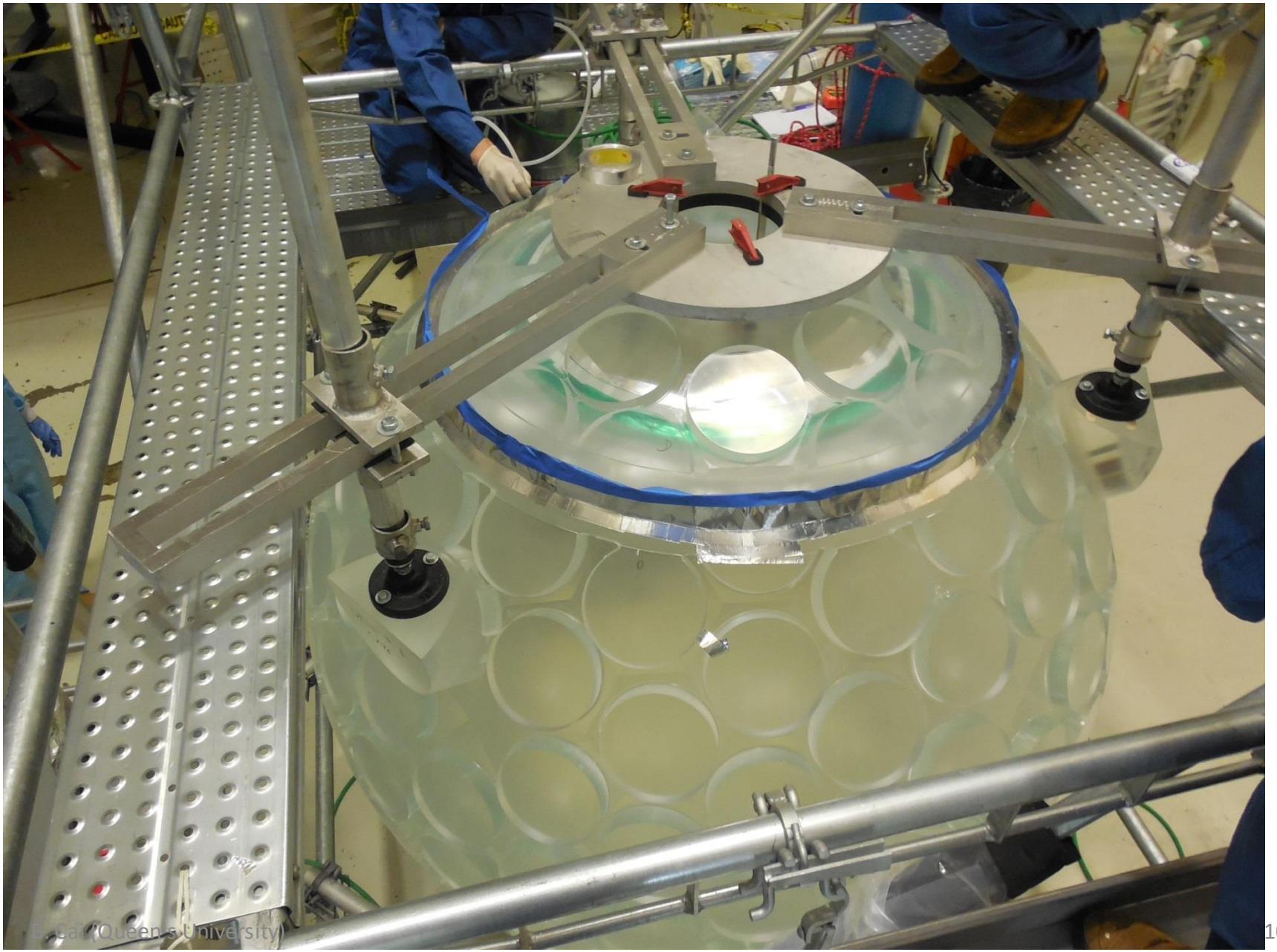
Thermoformed panel at RPT Colorado 2012

AV neck machining
(U of Alberta, Jul 2012)

AV shoulder machining
(Sep 2012)

AV stub machining
(Fall 2012)

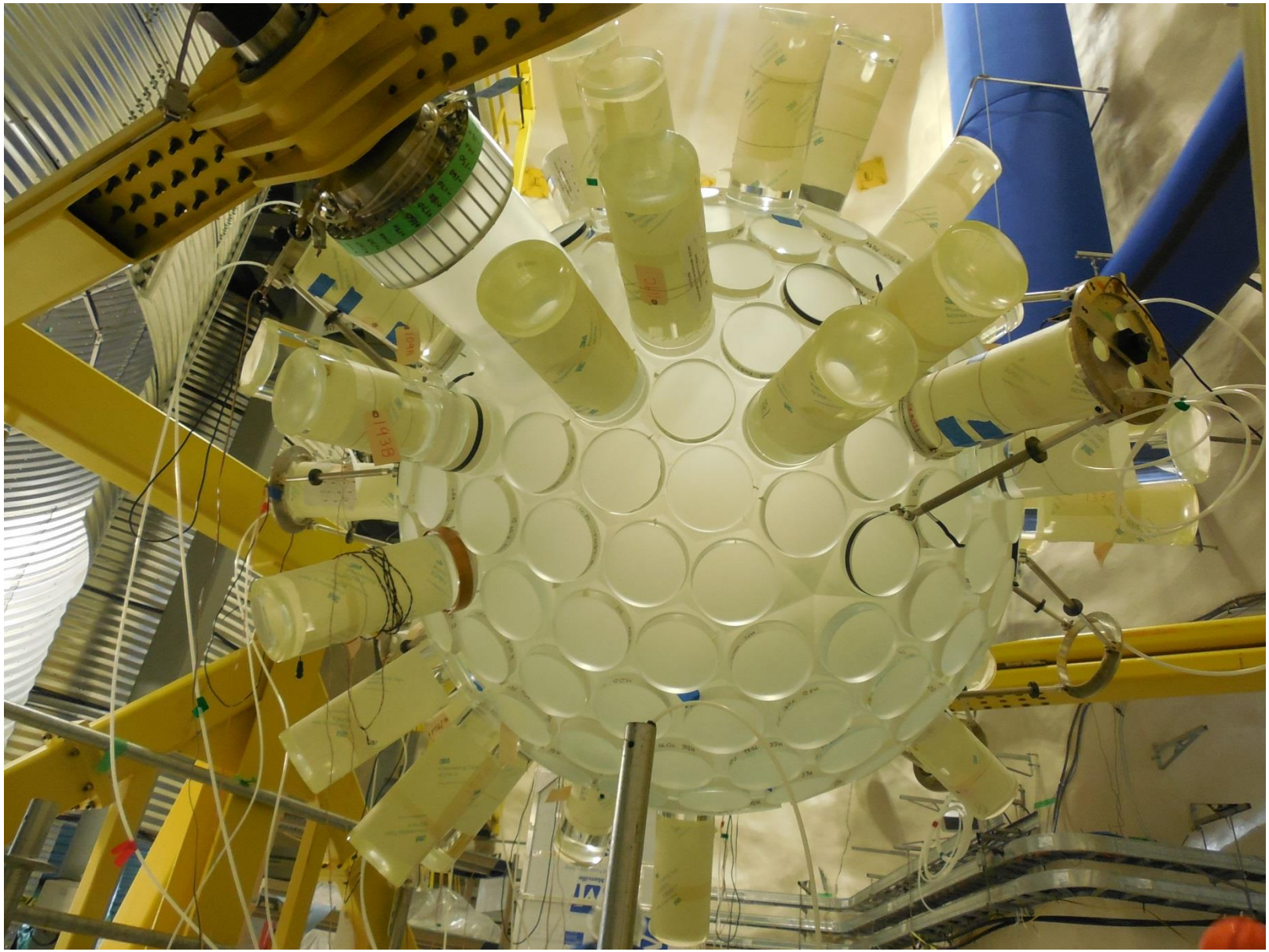
AV shoulder bond (RPT at SNOLAB Jan 2013)



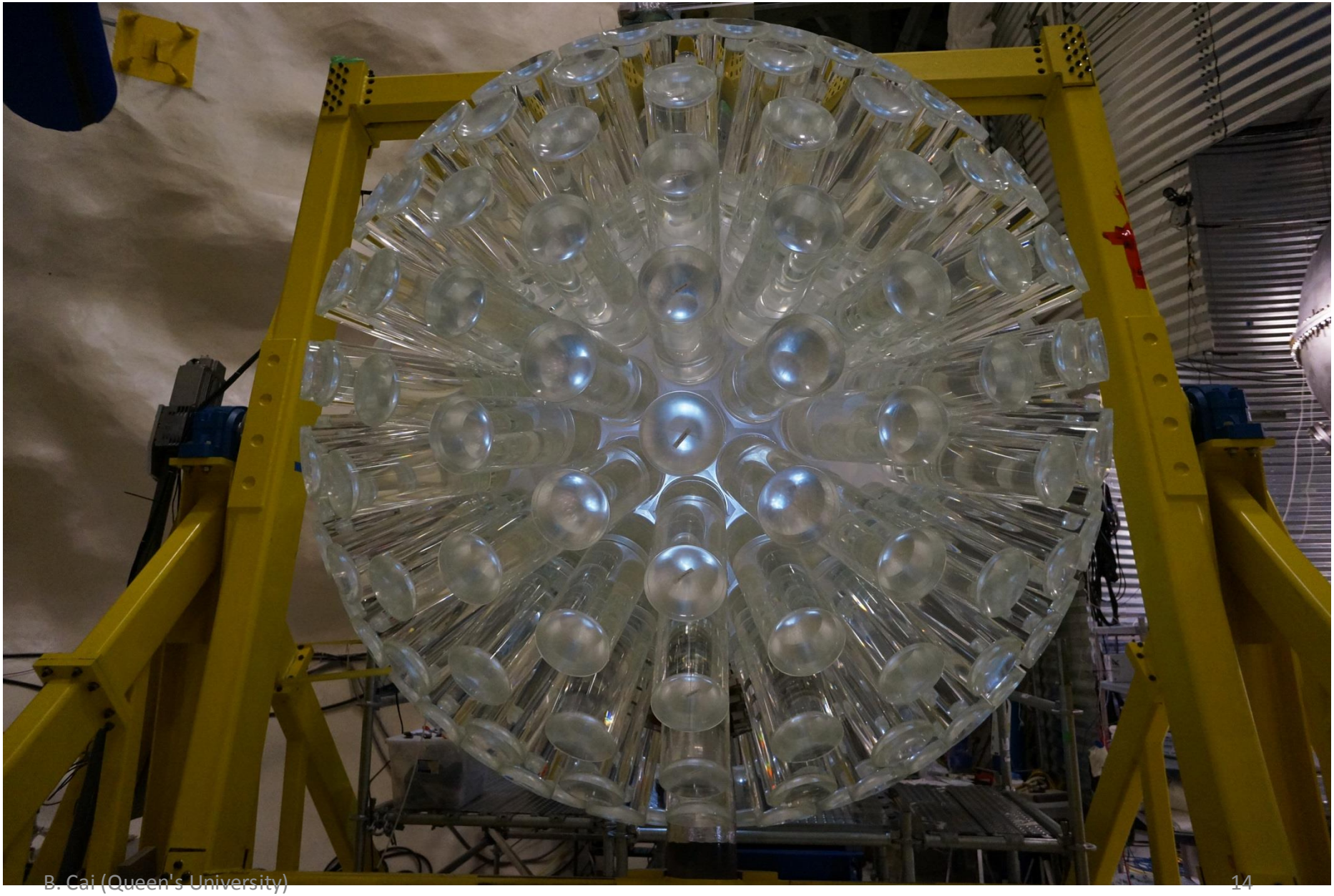
AV neck bond (RPT at SNOLAB Feb 2013)

4th anneal after underground machining (June 2013)

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

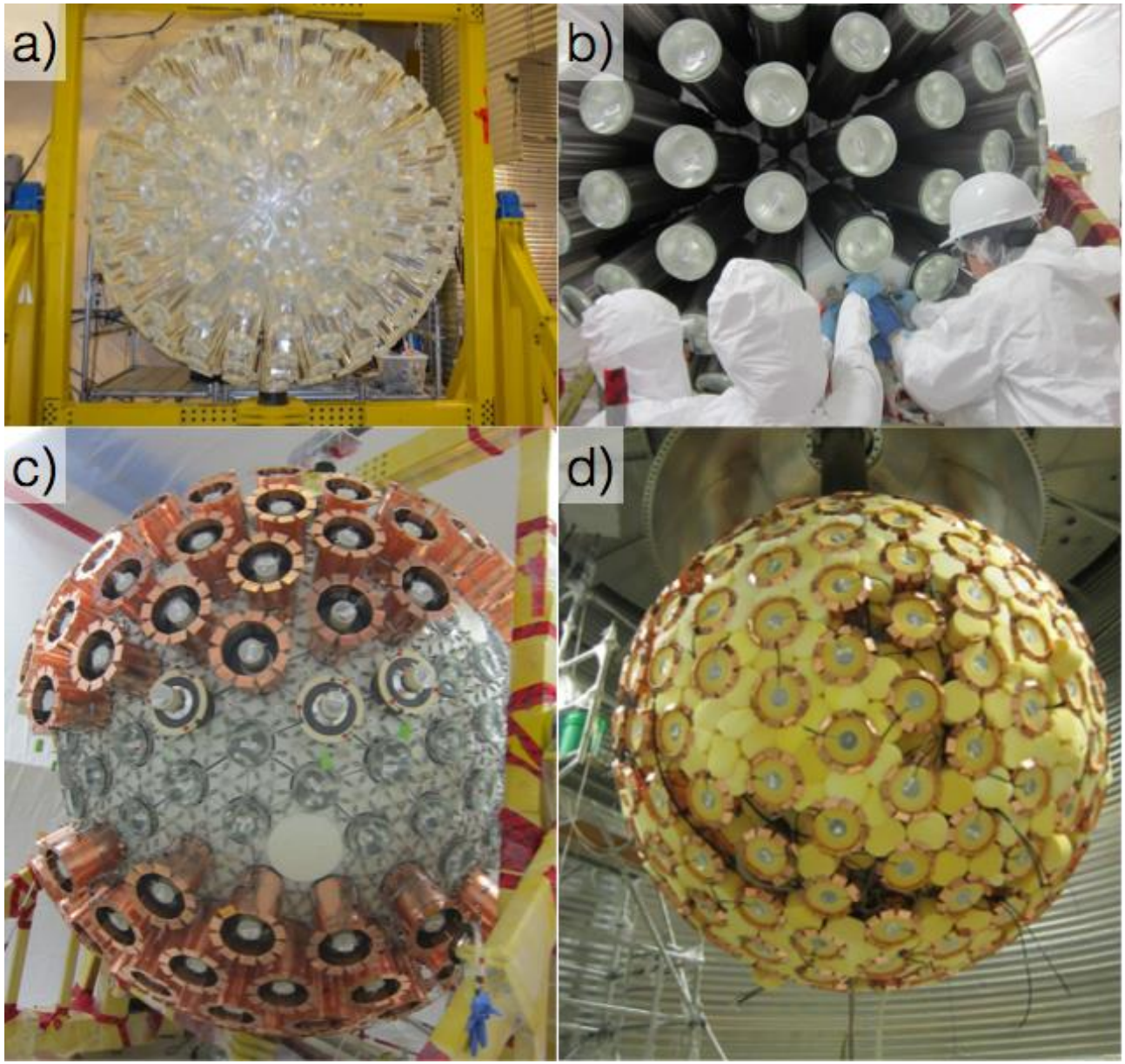


Light guide bonding completed (November 2013)



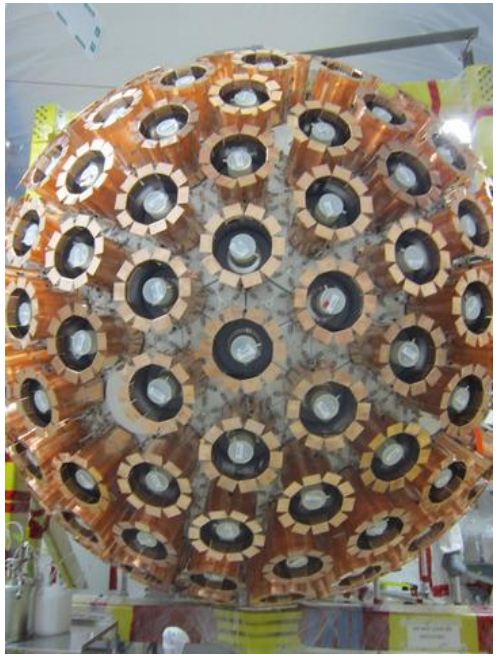
Light guides on AV

Reflectors on light guides



PMT installation Oct 2014

All PMTs installed, cabled, most foam insulation in place Dec 2014

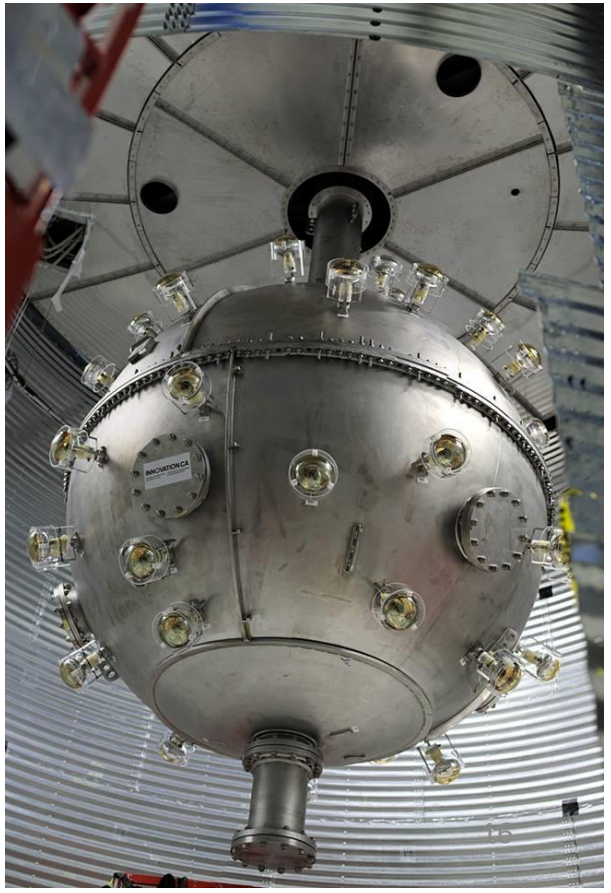


Completed inner detector

Detector ready for Final Lift onto neck

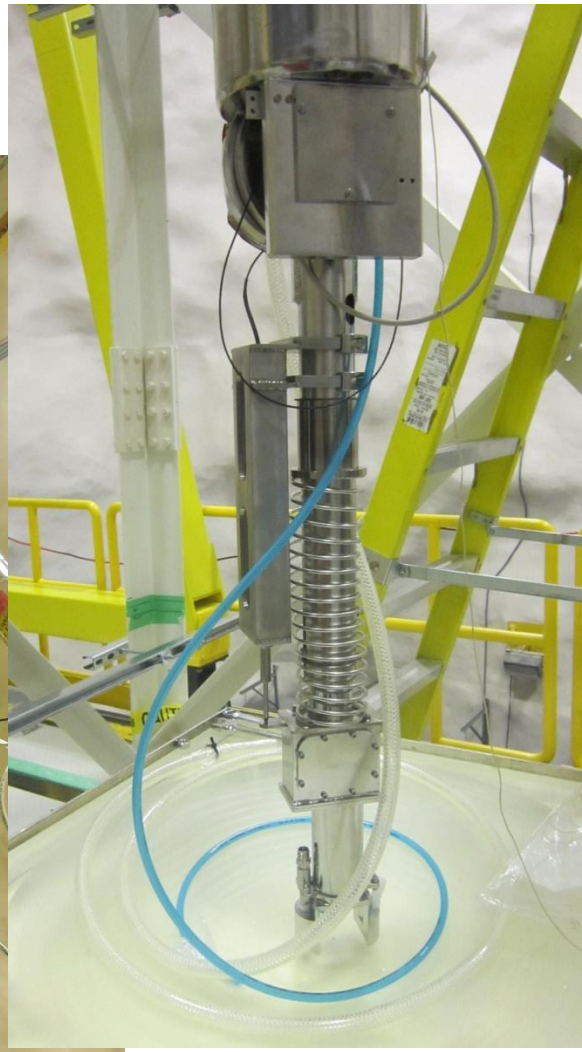
Steel Shell closing Dec 2014

Steel Shell in shield tank

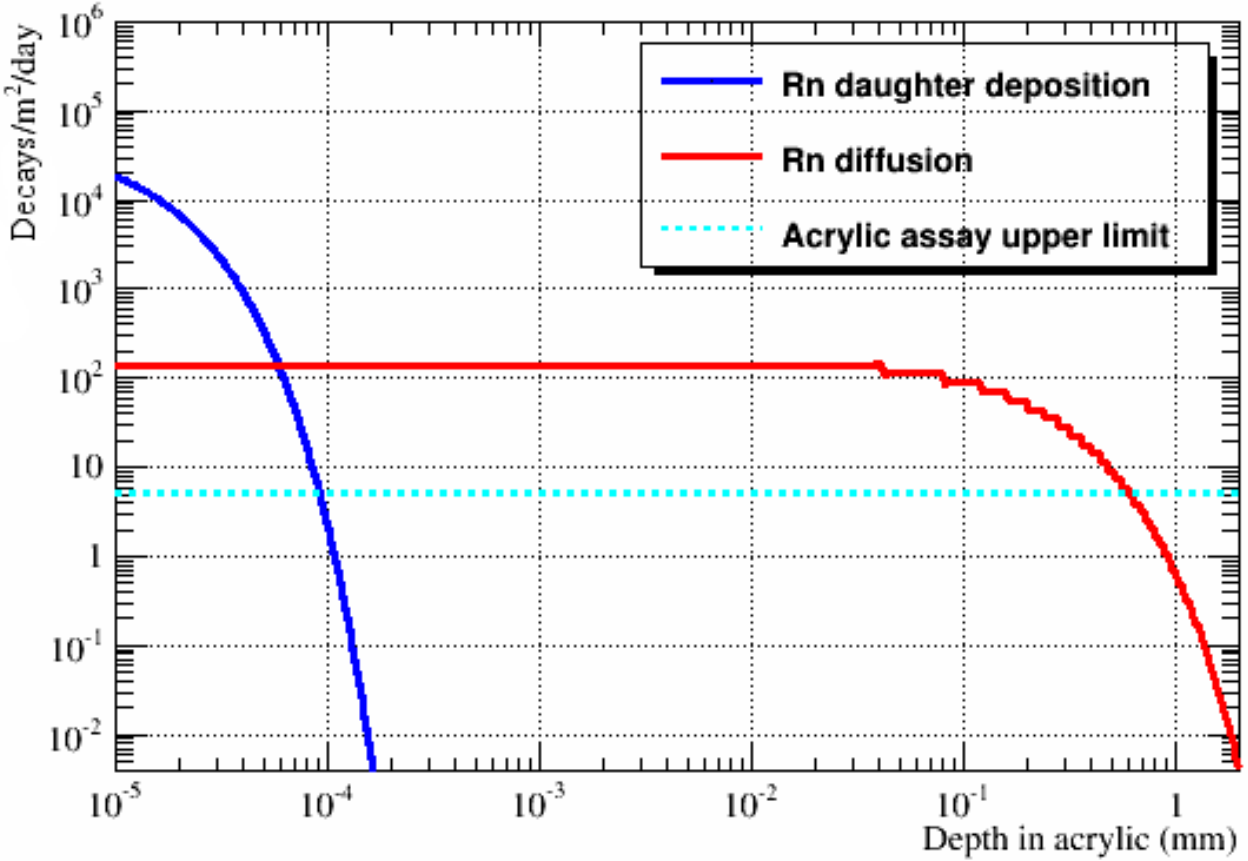


Veto PMTs installed Mar 2015

The Resurfacer



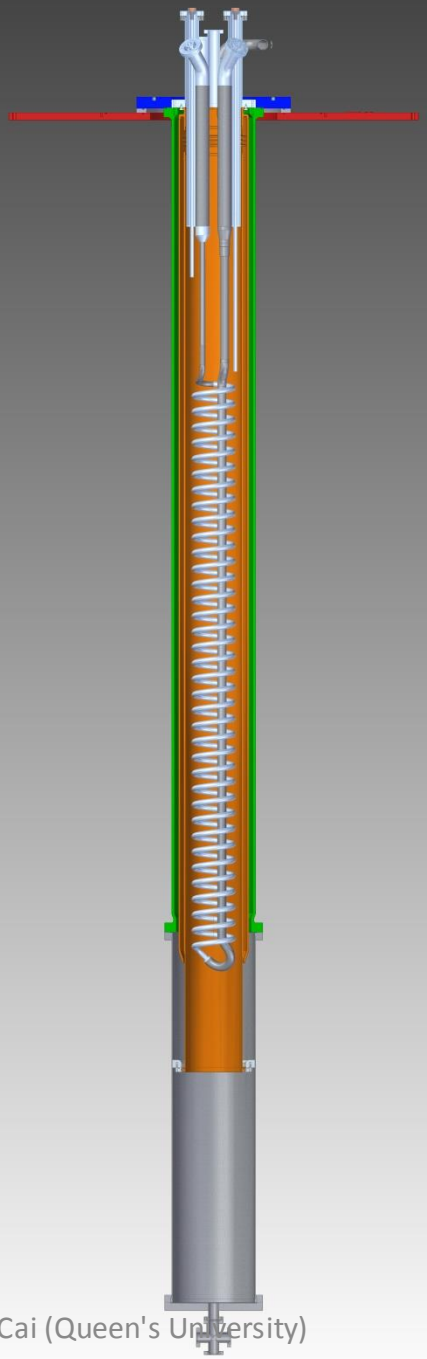
Calculated ^{210}Pb distribution in acrylic vessel



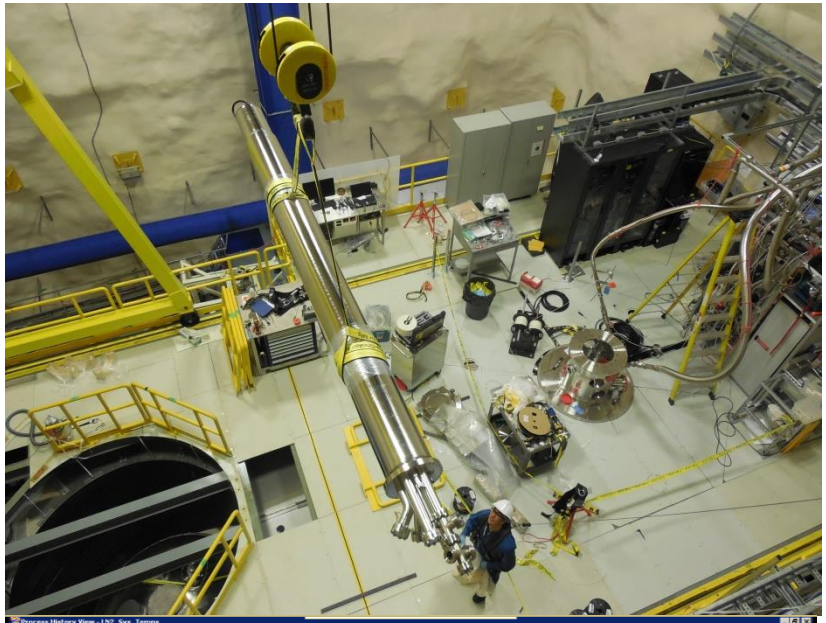
- 200 hours of resurfacing
- Removed all radon daughters deposited on surface
- ~10 α/day/m^2 on AV surface after resurfacing

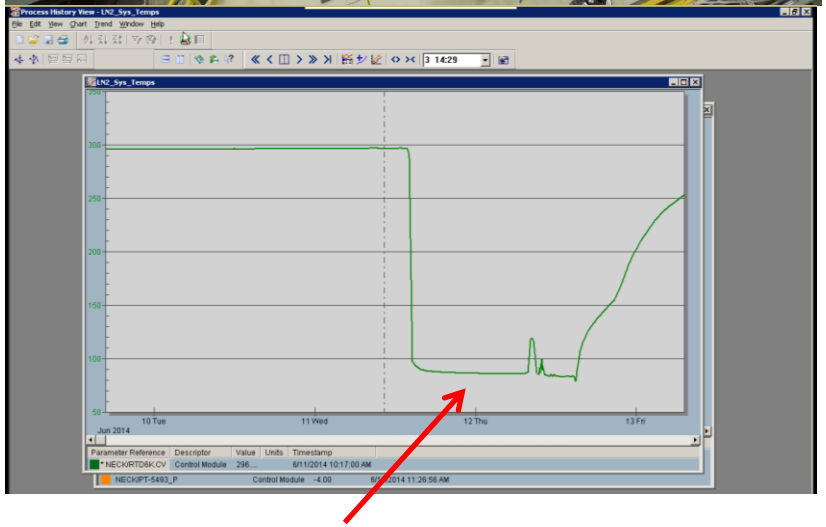
Current status of DEAP-3600

- Acrylic vessel resurfacing was completed at the end of 2014
- Vacuum-baked acrylic vessel (spring 2015)
- TPB wavelength shifter was deposited in June 2015
- Laserball calibration in July 2015
- Detector optical calibration, PMT and electronics commissioning ongoing (winter 2014/spring 2015)
- Commissioning cryogenic system (winter 2014/spring 2015)
- Completion of shield tank components, calibration hardware, veto PMT system (summer 2015)
- Next steps are commissioning with argon gas followed by cool down/liquid argon fill (starting summer 2015)
- Fill the shield tank with ultrapure water (Aug 2015)



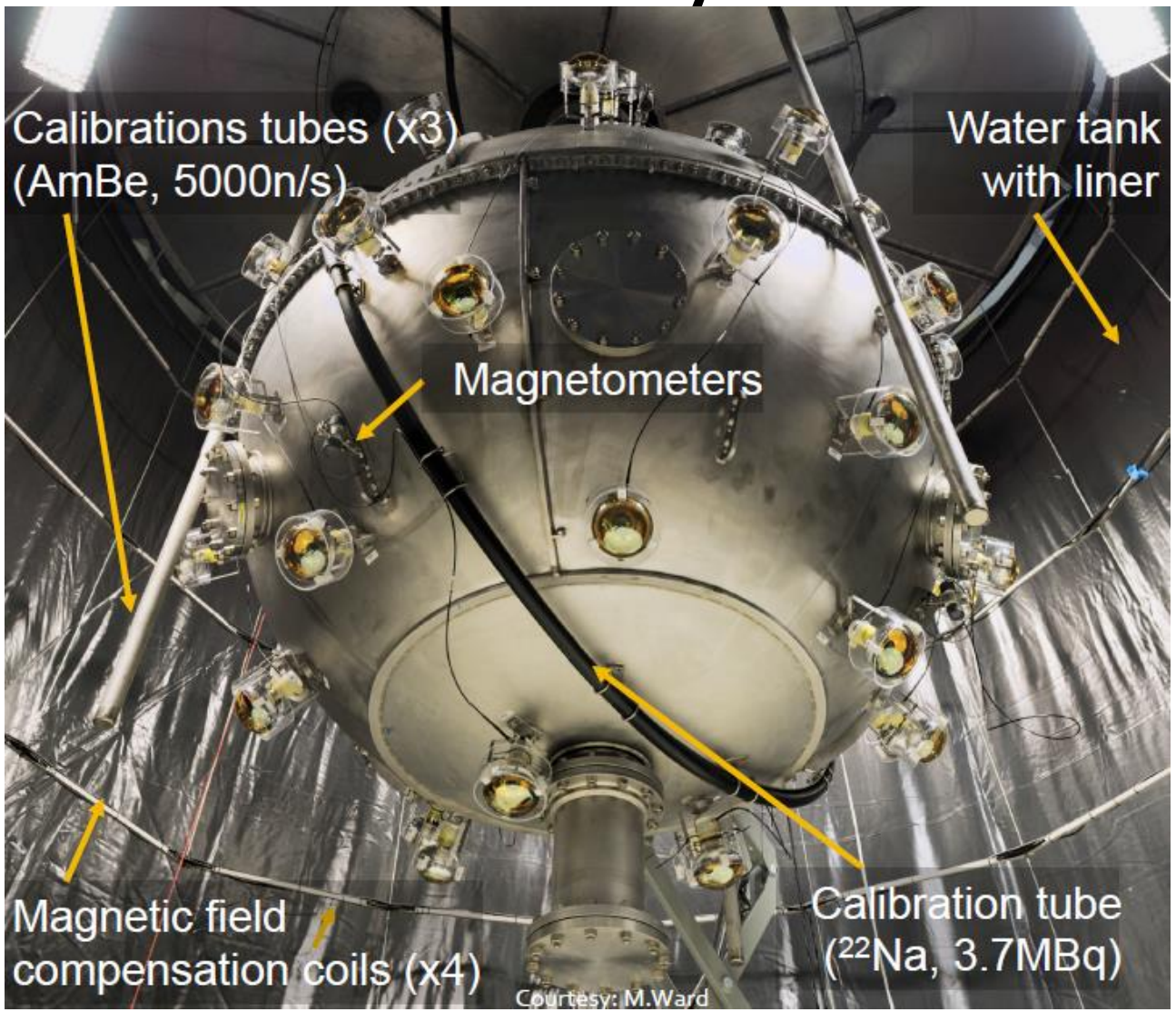
DEAP-3600 argon cooling system



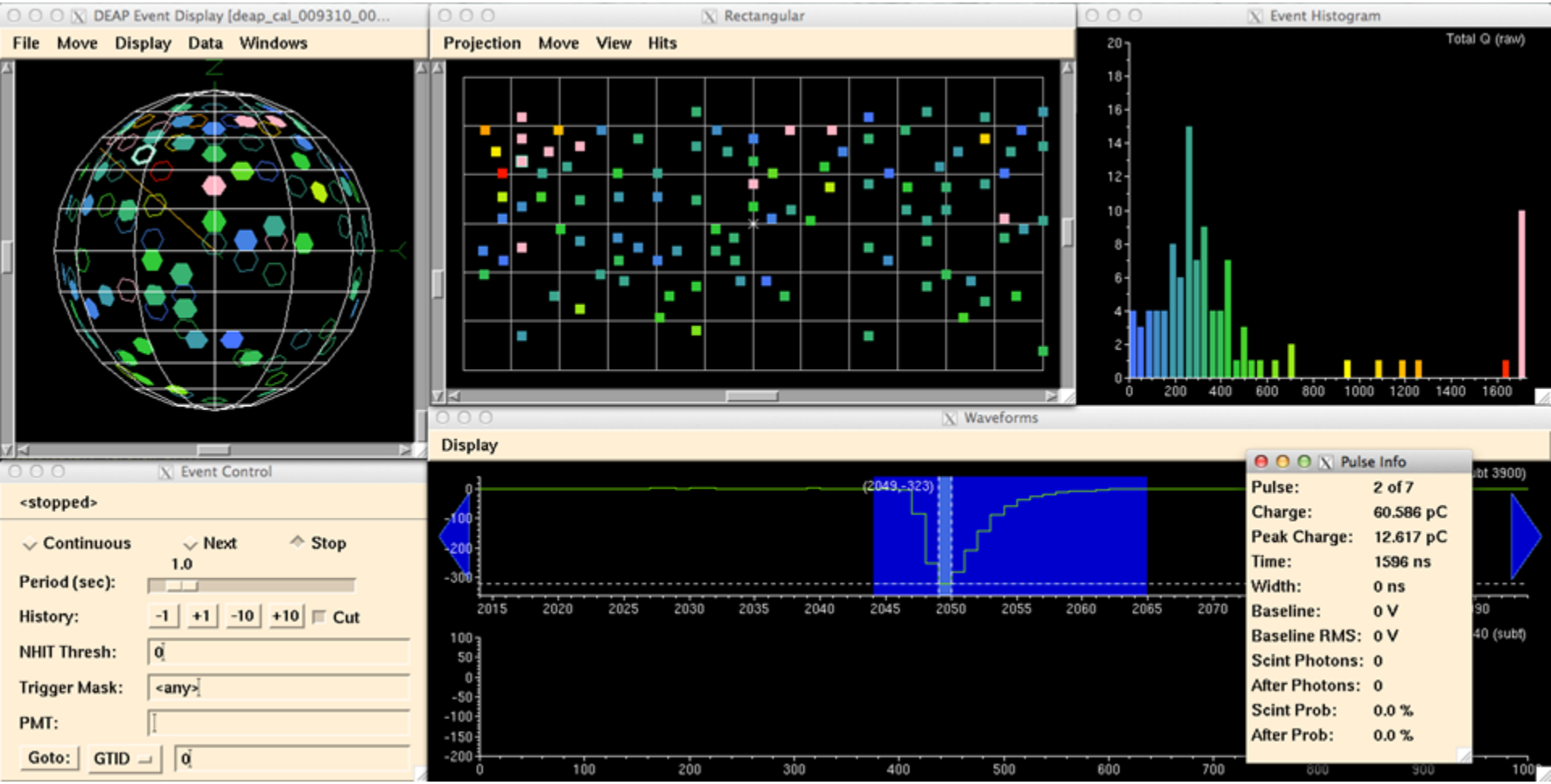


Commissioning at 86 K, June 11, 2014

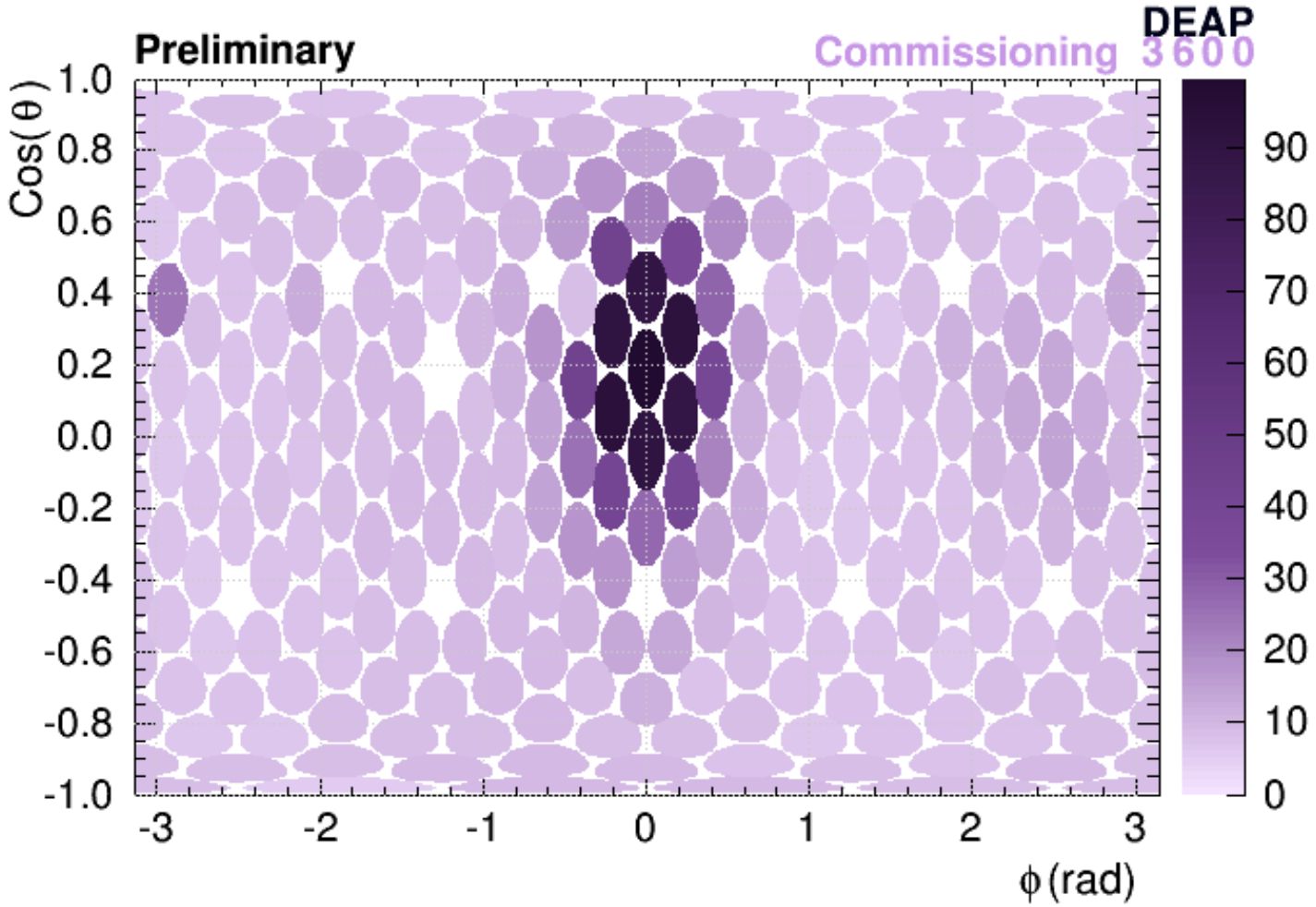
Calibration Systems



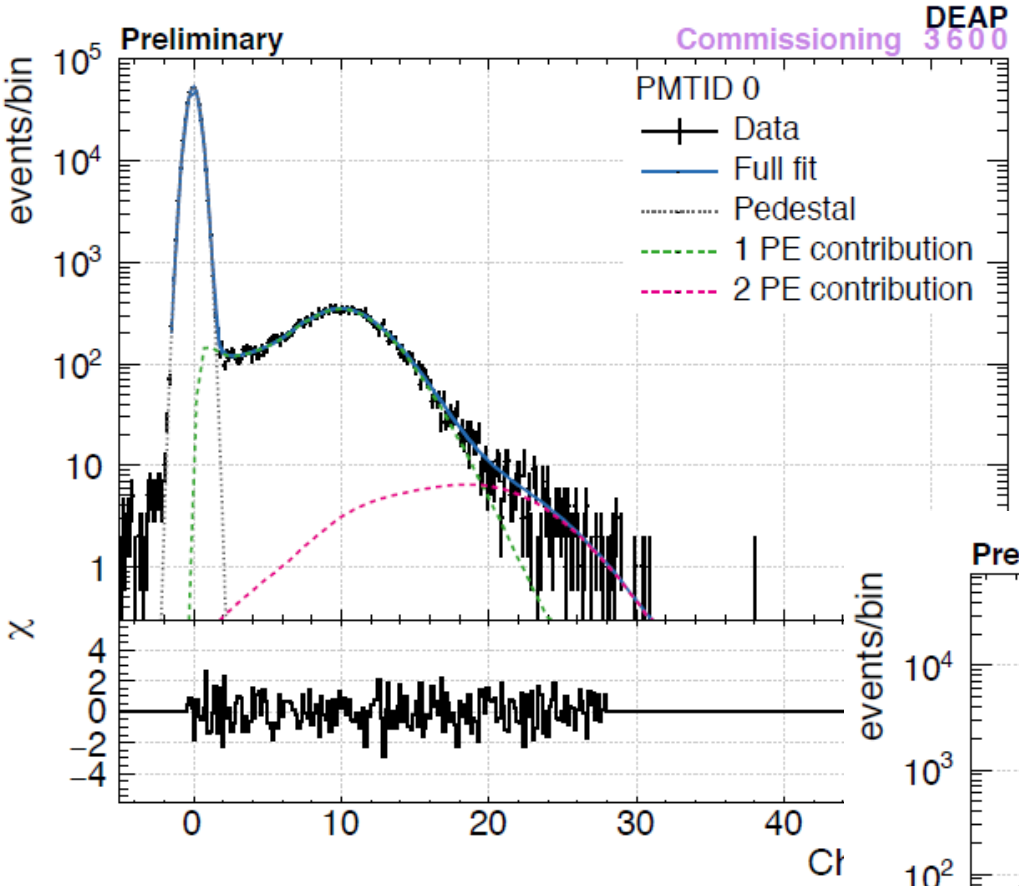
Light injection through fibers



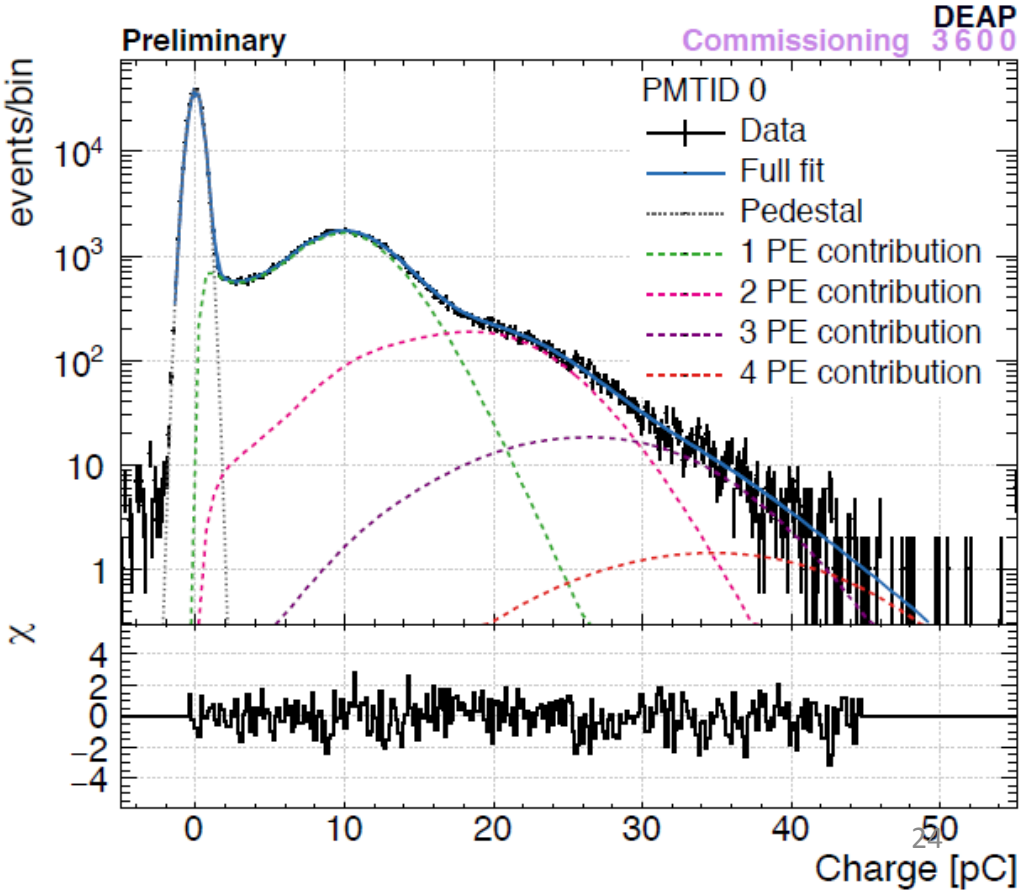
PMT occupancy in LED calibration



Single photo-electron spectra



Low light intensity



High light intensity

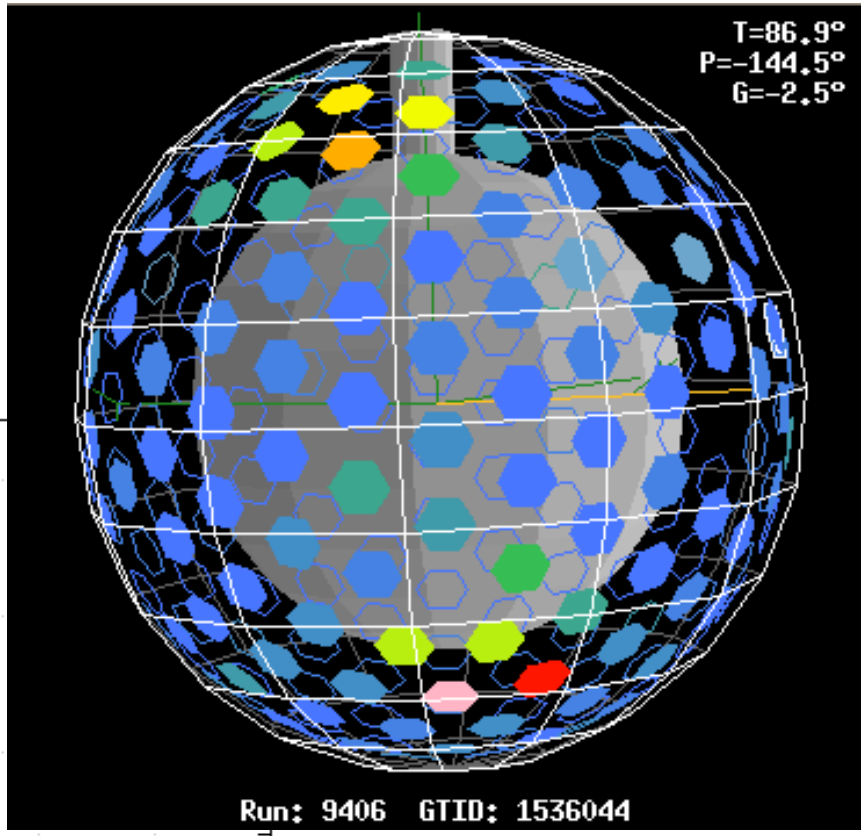
A high energy event

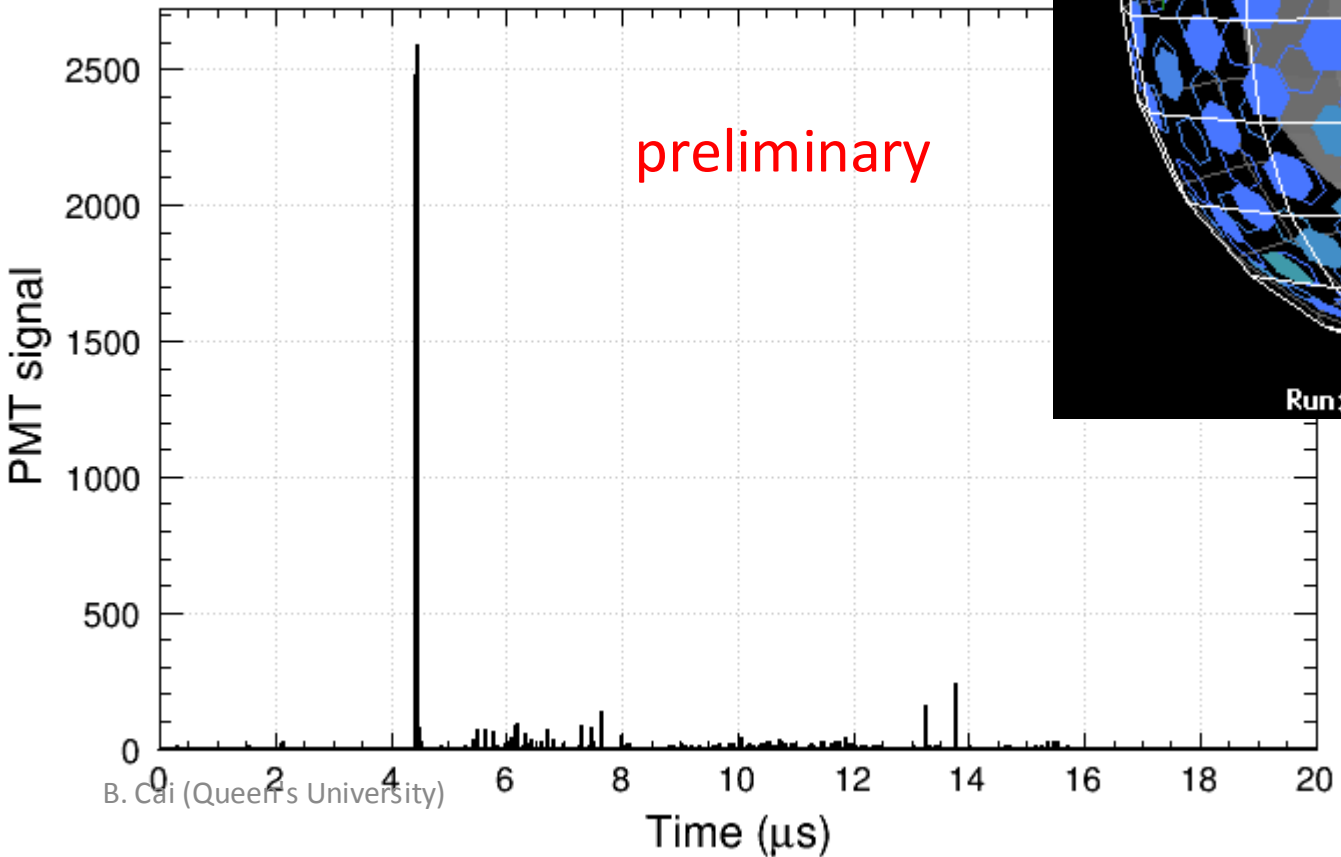
Run: 9406 Subrun: 3 Event: 300460

Total energy: 1520 PE

High event rate: ~1 event/day

Expected muon rate: 1.6 muons/day





Conclusion

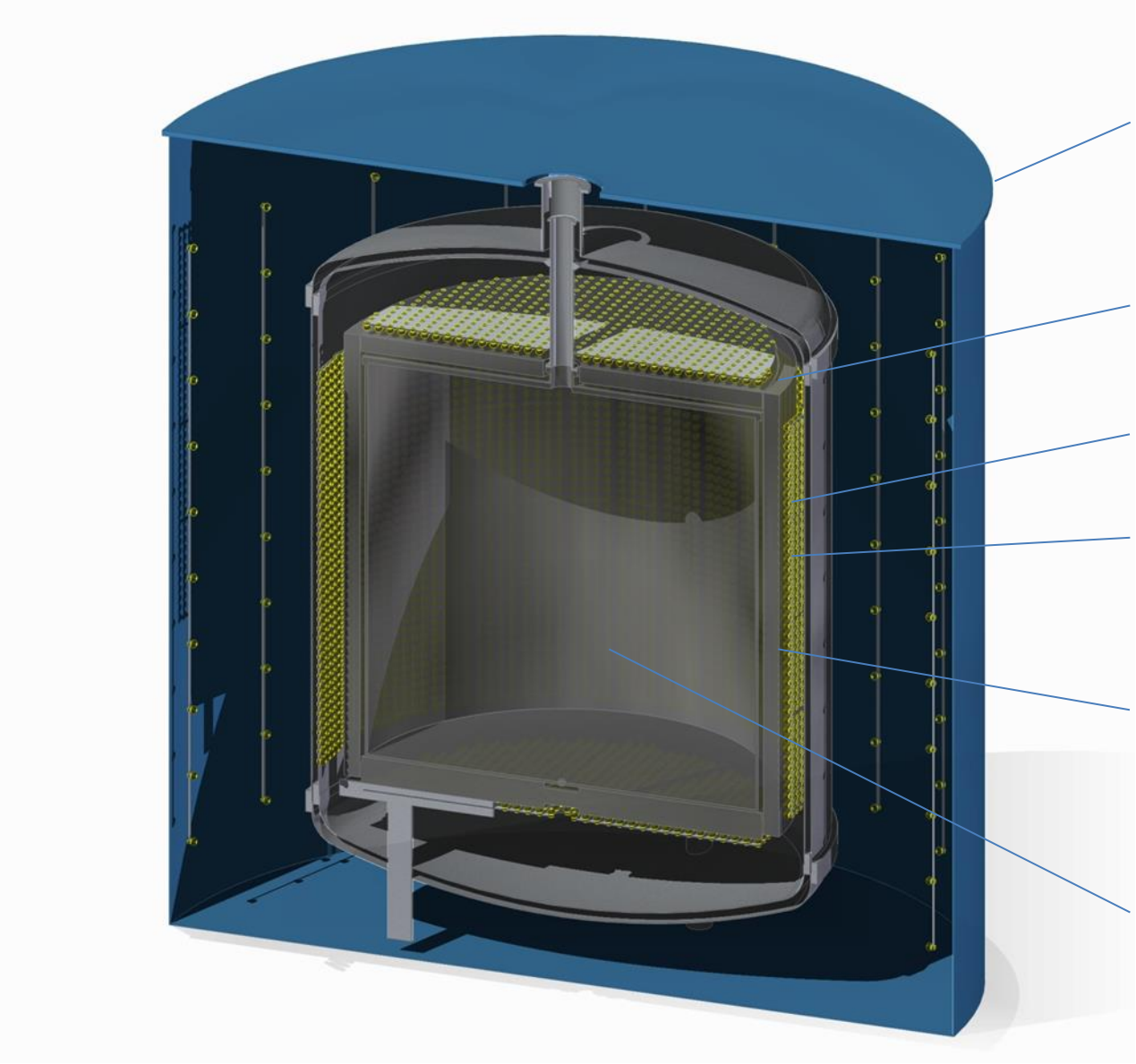
- DEAP-3600 will search for dark matter interactions on argon with sensitivity to spin-independent WIMP-nucleon cross section >20 times better to current limits
- Construction is completed, currently preparing for argon running starting summer 2015
- Have been commissioning PMTs and electronics since late 2014, optical calibration ongoing
- Working on developing a follow-up 50T detector

~60 collaborators in Canada, the UK, and Mexico

Thanks to CFI, NSERC, the provinces of Alberta and Ontario, and SNOLAB for funding and support

Backup slides

Large LAr Detector (Conceptual) 10^{-48} cm^2 Sensitivity…



44’ diam. water tank

24’ diam. Steel Shells
(inner and outer)

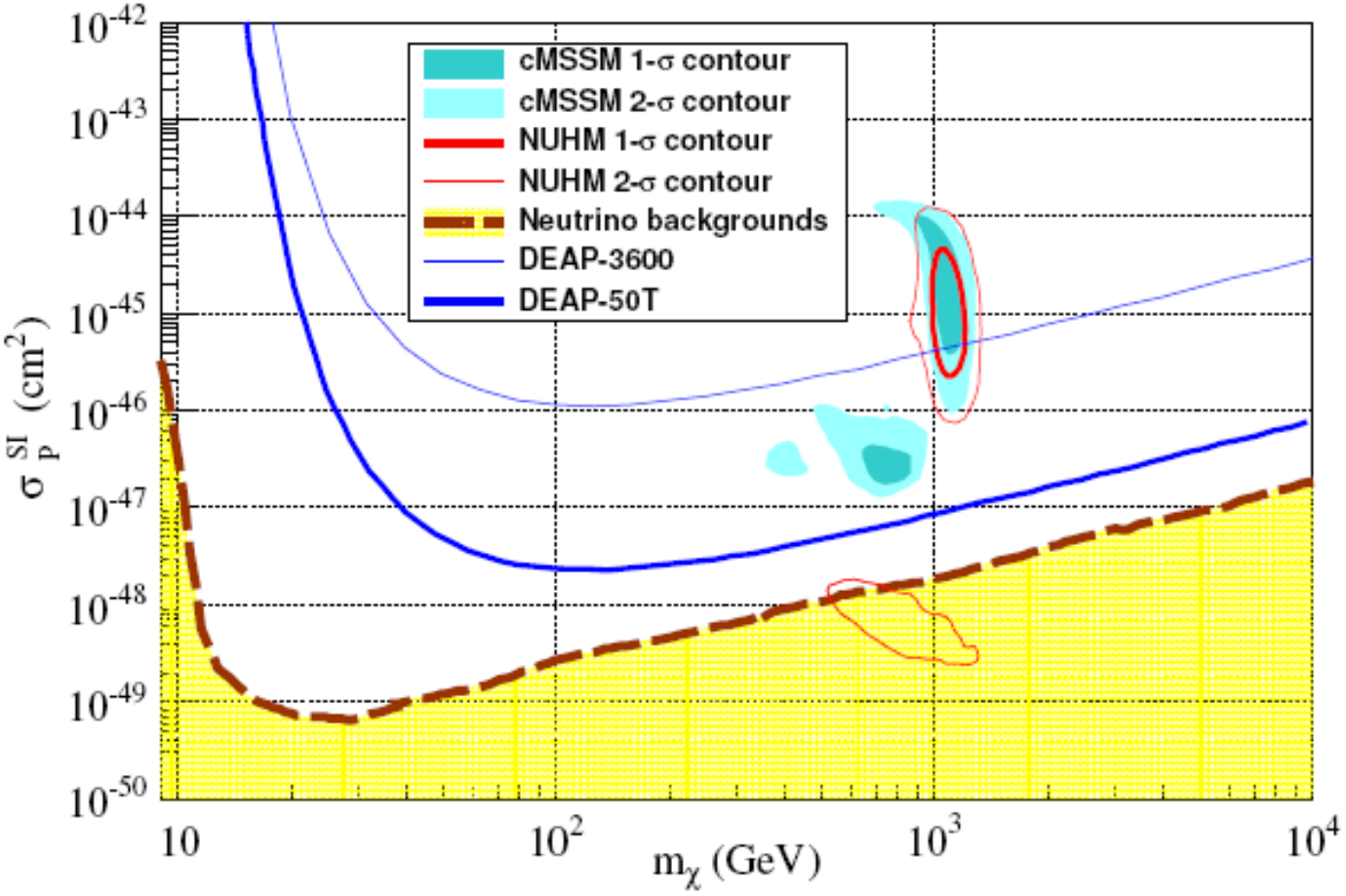
4400 8” HQE PMTs

12” acrylic shielding panels

17’ diam. 2” thick acrylic
vessel with flanged lid

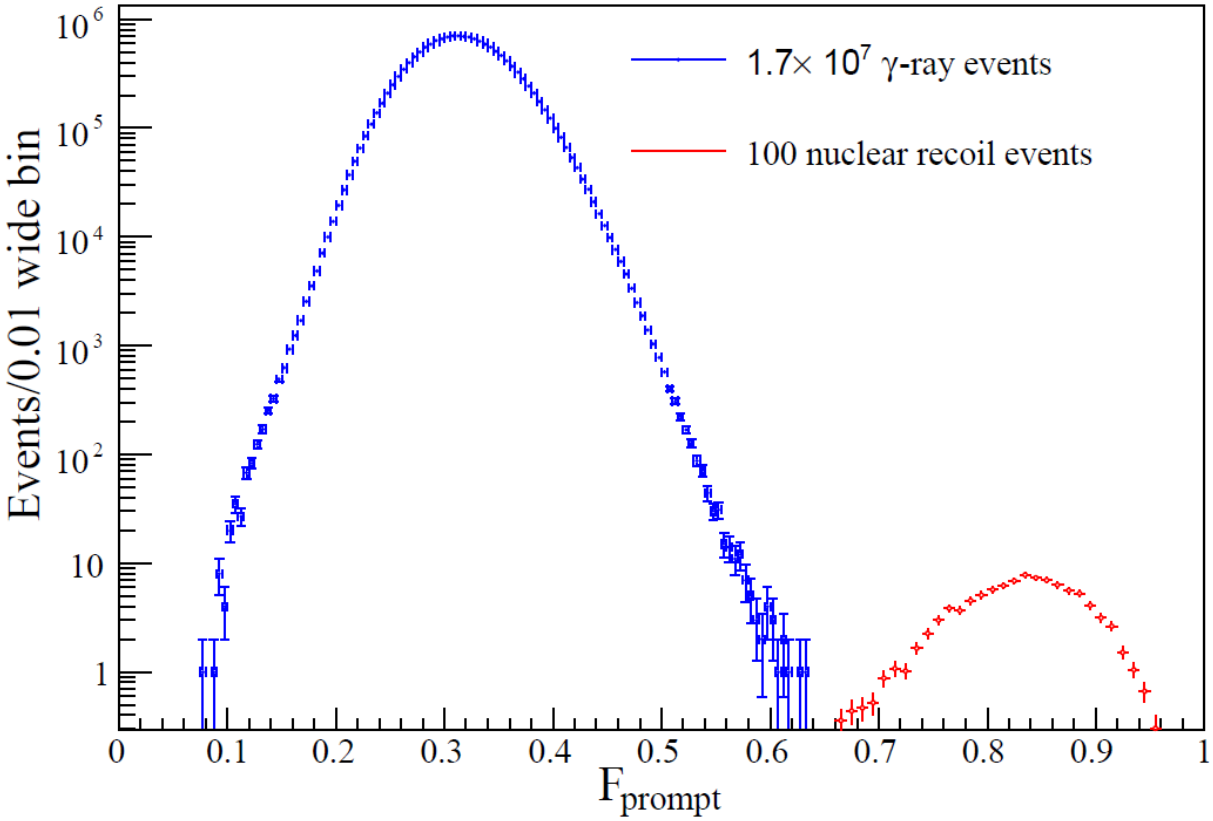
150 tonnes argon in AV
(50 tonnes fiducial)

Requires low ^{39}Ar activity



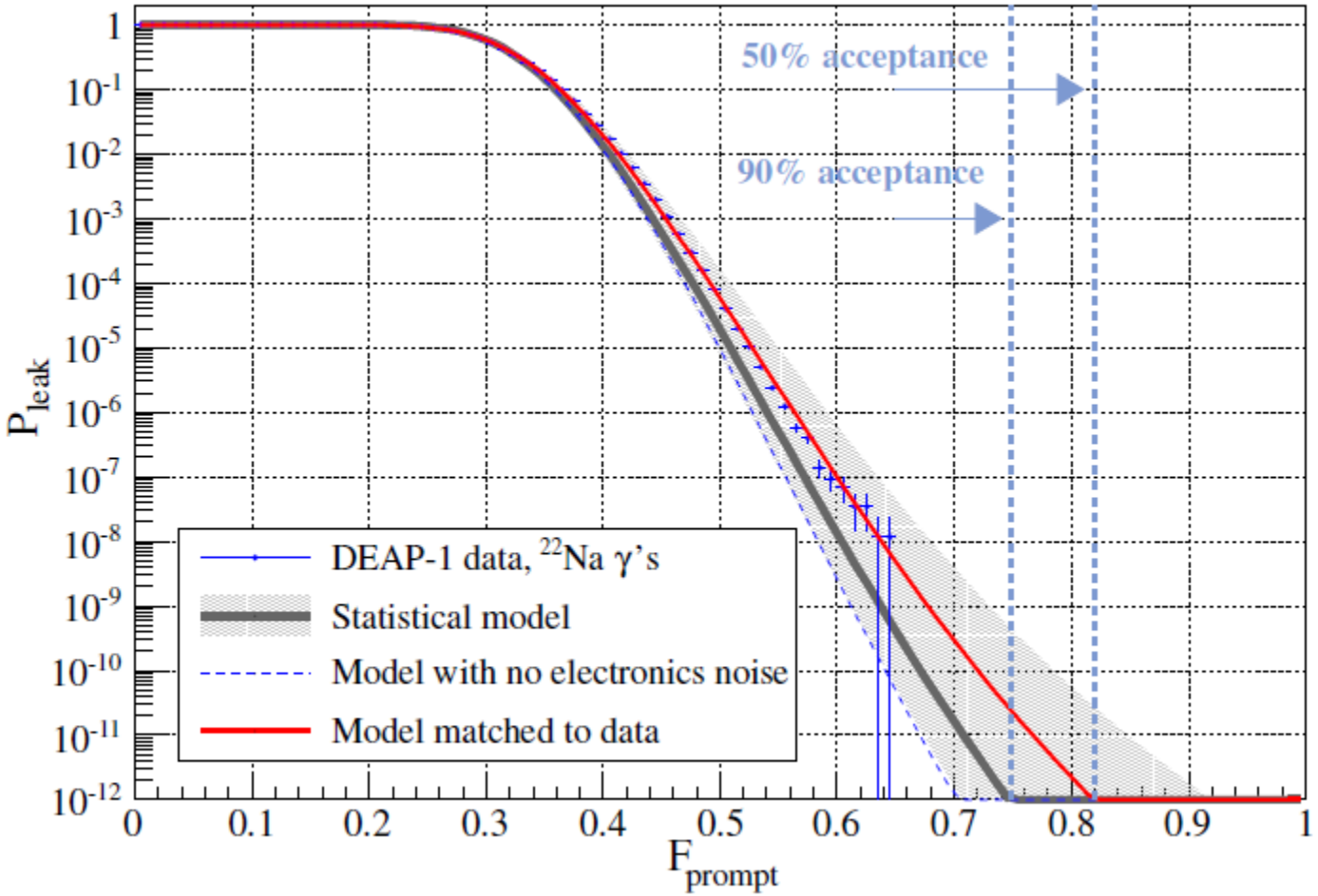
Exclusion sensitivity (90% C.L.) of the proposed DEAP-50T argon detector

β/γ background suppression in liquid argon

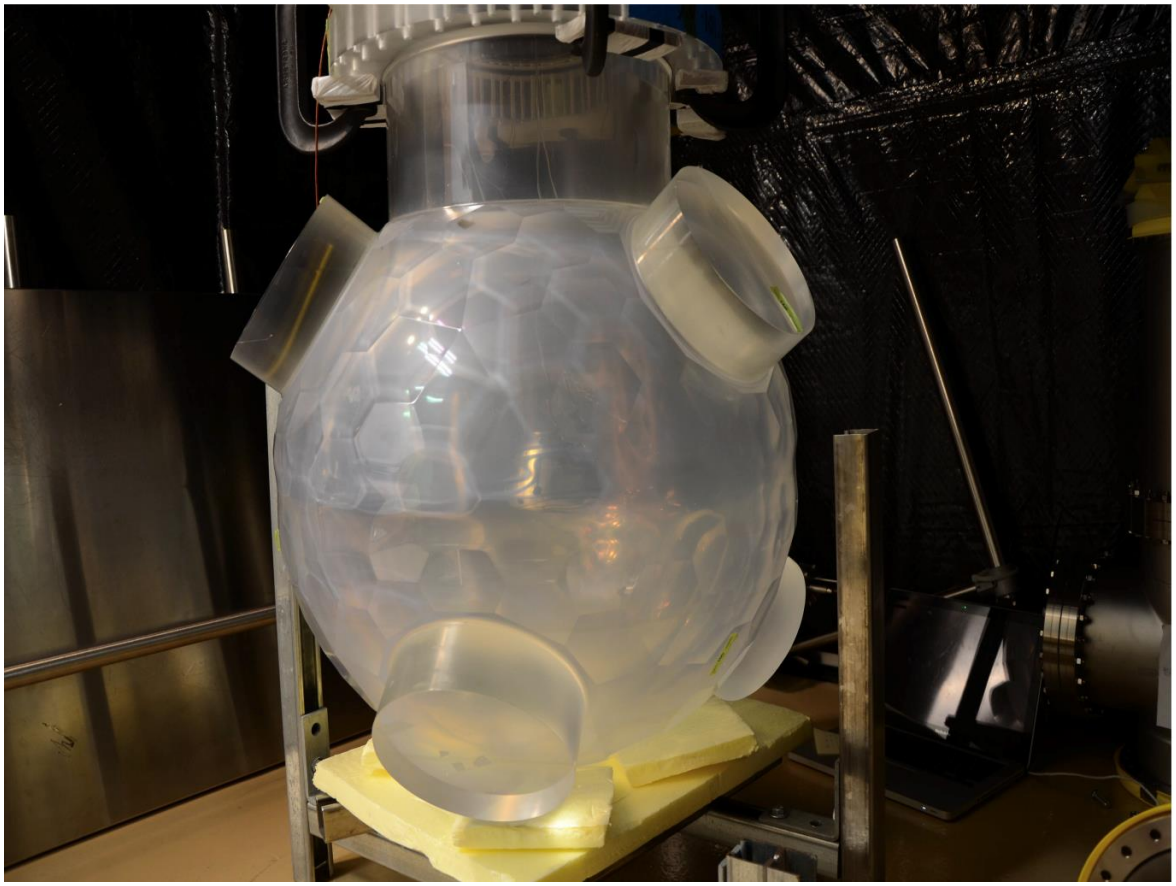


- γ suppression better than 3×10^{-8} in 43-86 keVee achieved at SNOLAB
- Simple model of photon statistics predicts 10^{-10} suppression at 15 keVee, allowing for sufficient background rejection of ^{39}Ar in DEAP-3600

Pulse-shape background discrimination



TPB wavelength shifter deposition



Process system

Ar purification getter and charcoal trap


Cryocoolers and LN2 dewar


Ar dewar


Cooling coils being prepared for final acid bath