DEAP-3600 Dark Matter Search at SNOLAB

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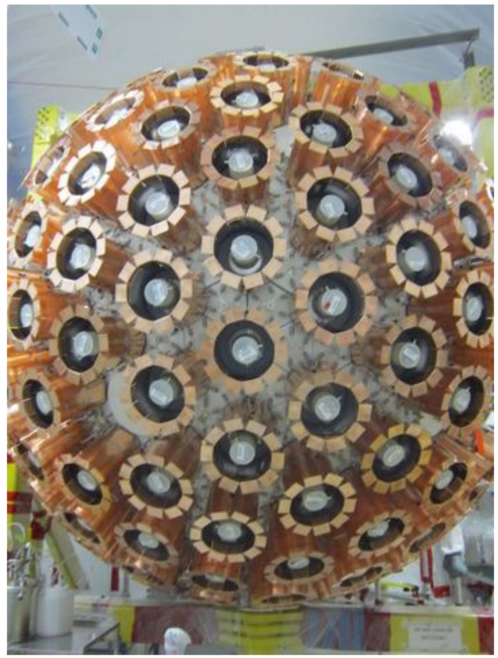

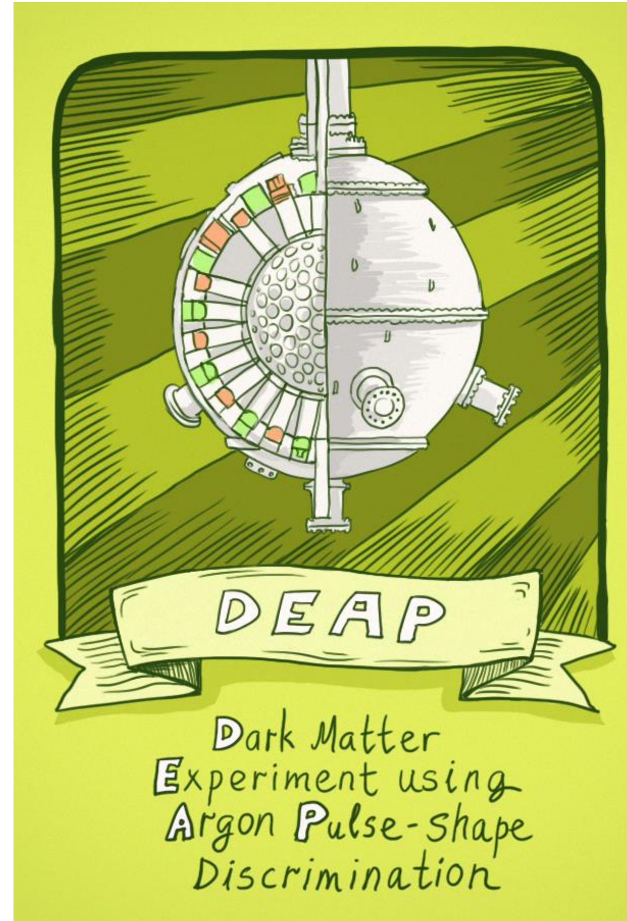

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Queen's University, Kingston

DEAP Collaboration

University of Alberta

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SNOLAB/Laurentian

B. Cleveland, F. Duncan, **R. Ford**, **C.J. Jillings,E. Vazquez Jauregui,** 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

Rutherford Appleton Laboratory

P. Majewski

Royal Holloway University of London

J. Monroe, J. Walding, A. Butcher

University of Sussex

Simon Peeters

Collaboration Demographics

13 Faculty/PIs in Canada (+ 3 PIs UK)

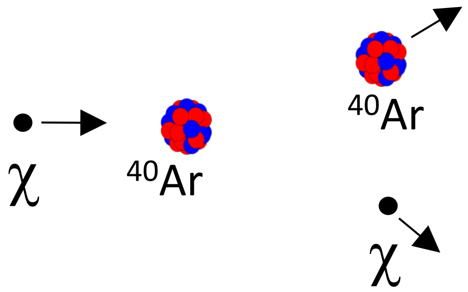
8.5 PDFs/RAs
8 GRAs
~5 undergraduates

Site Installation Staff (5+1 supervisor for construction phase)

~9 technical support

Substantial support from MRS personnel and TRIUMF

Liquid argon as a dark matter target



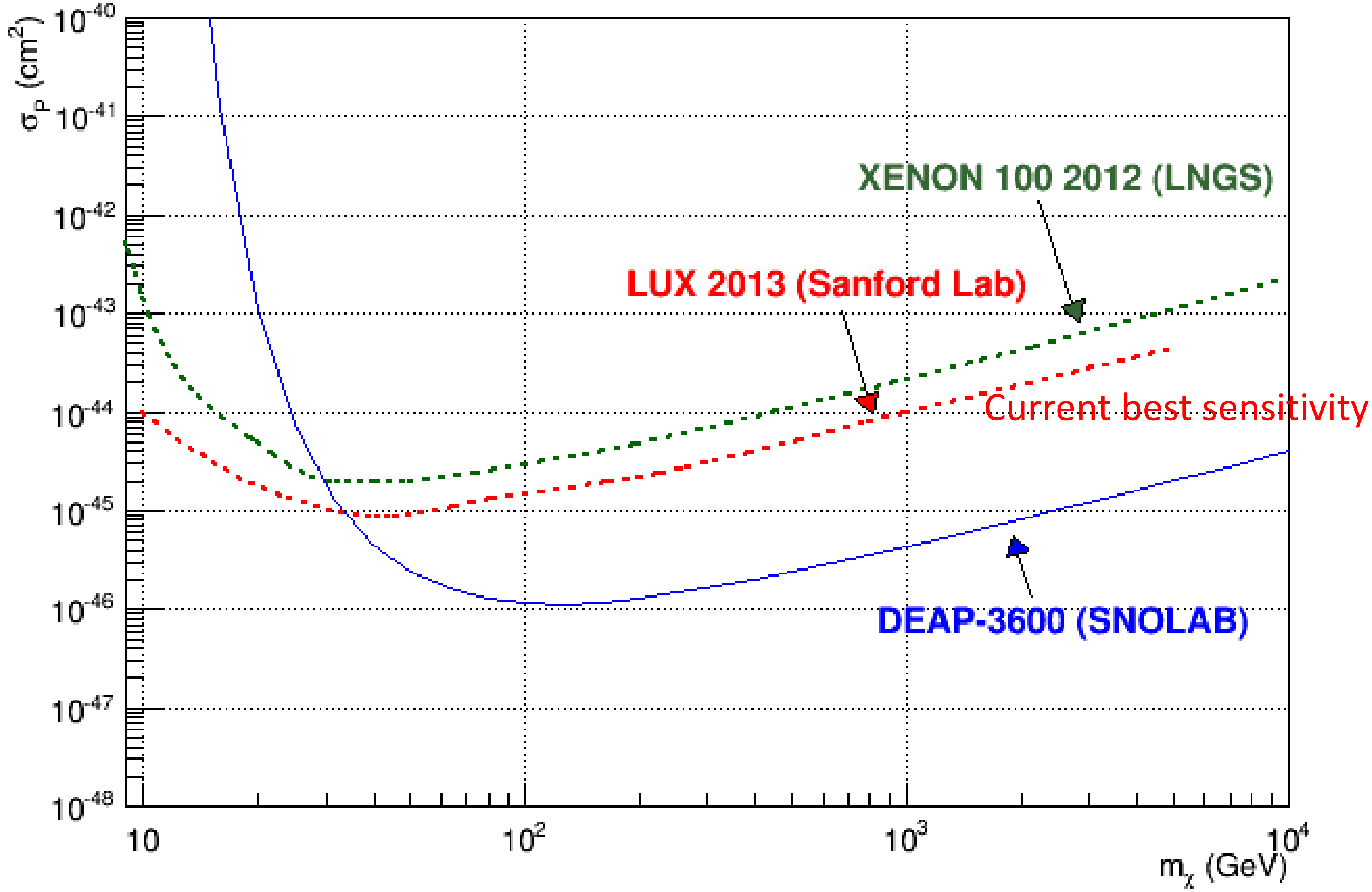
Scattered nucleus (with several 10's of keV) is detected via scintillation in liquid argon.

- Well-separated singlet and triplet lifetimes in argon allow for good pulse-shape discrimination (PSD) of β/γ's using only scintillation time information, projected to 10^{-10} at 15 keV_{ee}
  (see Astroparticle Physics 25, 179 (2006) and arxiv/0904.2930)

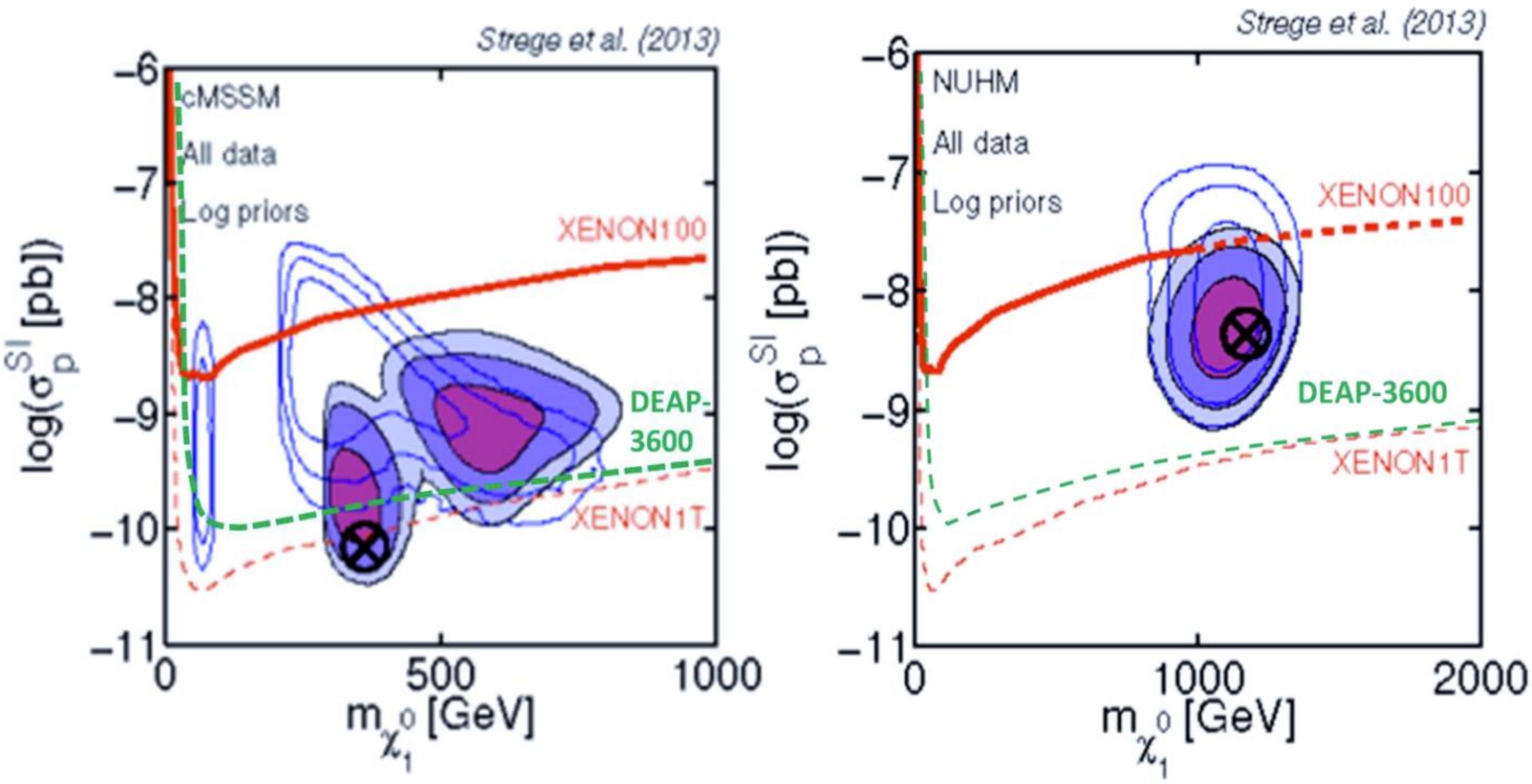
- Very large target masses possible, since no absorption of UV scintillation photons in argon, and no e-drift requirements.

- **1000 kg** argon target allows **10^{-46} cm^2** sensitivity (SI) with ~15 keV_{ee} (60 keVr) threshold, 3-year run

DEAP-3600 Projected Physics Sensitivity

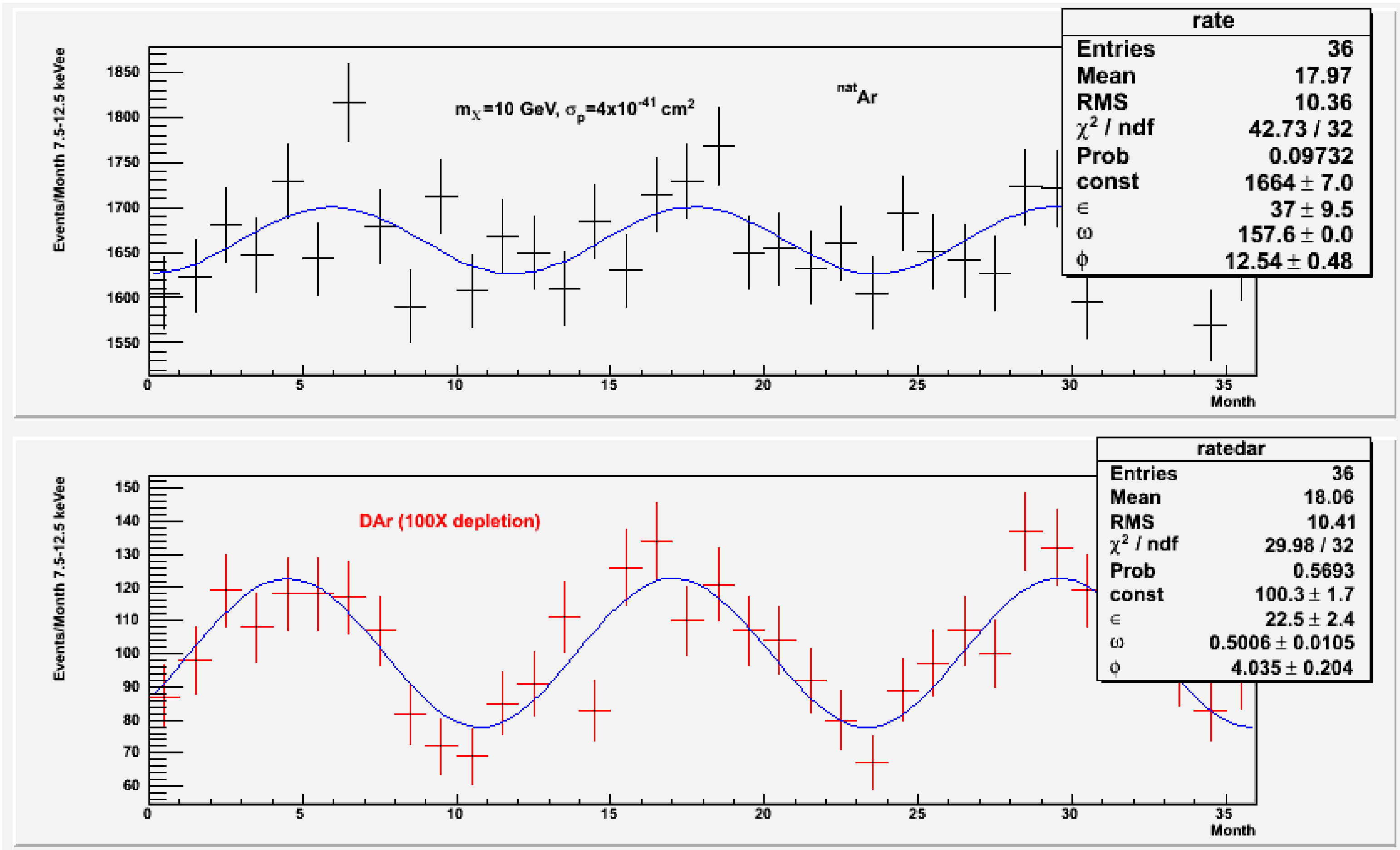


Physics Sensitivity



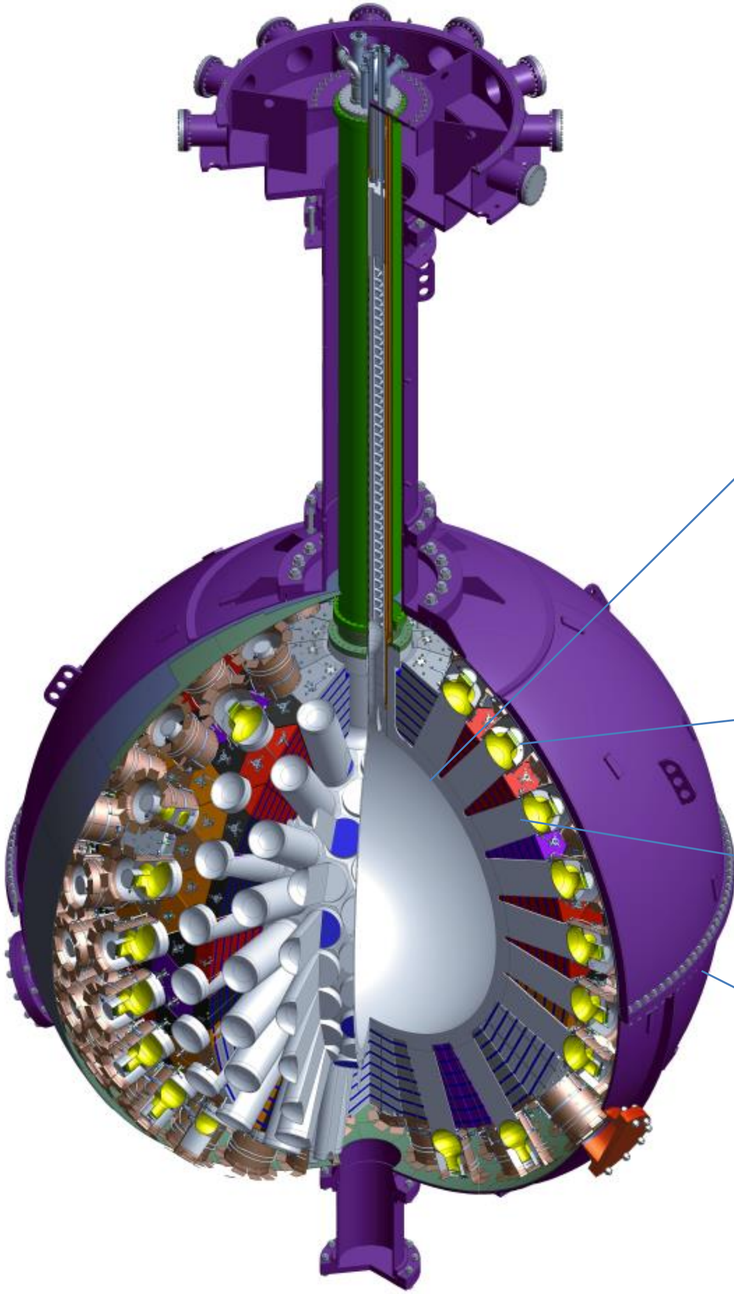
Sensitivity to parameters of simple SUSY models (cMSSM and NUHM)

Sensitivity to Low-Mass WIMPs in DEAP-3600



Annual modulation of detected rate provides sensitivity to low masses (~10 GeV)

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

255 Hamamatsu
R5912 HQE PMTs 8-inch
(32% QE, 75% coverage)

50 cm light guides +
PE shielding provide neutron
moderation

Steel Shell immersed in 8 m
water shield at SNOLAB

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DEAP-3600 Background Budget (3 year run)

Background	Raw No. Events in Energy ROI	Fiducial No. Events in Energy ROI
Neutrons	30	<0.2
Surface α's	150	<0.2
^{39}Ar β's (natural argon)	1.6×10^9	<0.2
^{39}Ar β's (depleted argon)	8.0×10^7	<0.01

Acr+H_2O shield

Resurfacer

PSD

Need to resurface inner vessel and ensure purity of acrylic.

- removal of 1 mm acrylic
- $^{210}Pb < 1.1 \times 10^{-19}$ g/g for 0.1 events/3 years
  (strict control of Rn exposure)

Fabrication of DEAP Acrylic

- Fabrication from MMA monomer, strict control of radon exposure for all steps
- Moulds were prepped in a HEPA-filtered clean room made especially for DEAP (RPT Asia)
- DEAP Collaborators present during fabrication
- Control to < 10^{-20} g/g ^{210}Pb from radon exposure

DEAP Acrylic Panels at RPT Asia in 2010

Assay

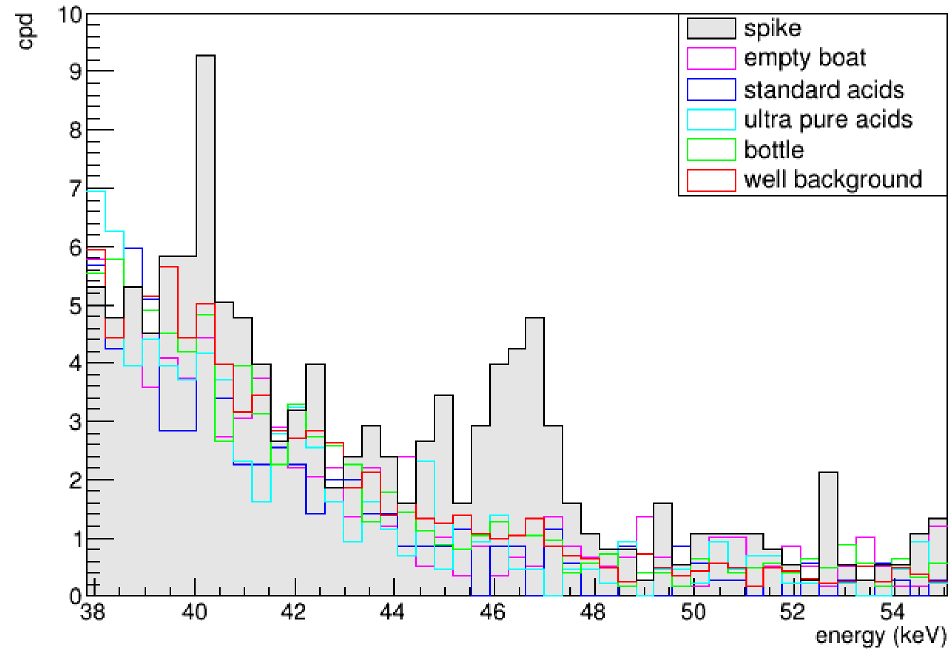
- Require assay of acrylic at levels of 10^{-20} g/g ^{210}Pb
- Requires vapourization to concentrate contaminants followed by chemical extraction followed by counting in a Germanium well detector or alpha-counter

New Furnace and extraction system developed for acrylic assay

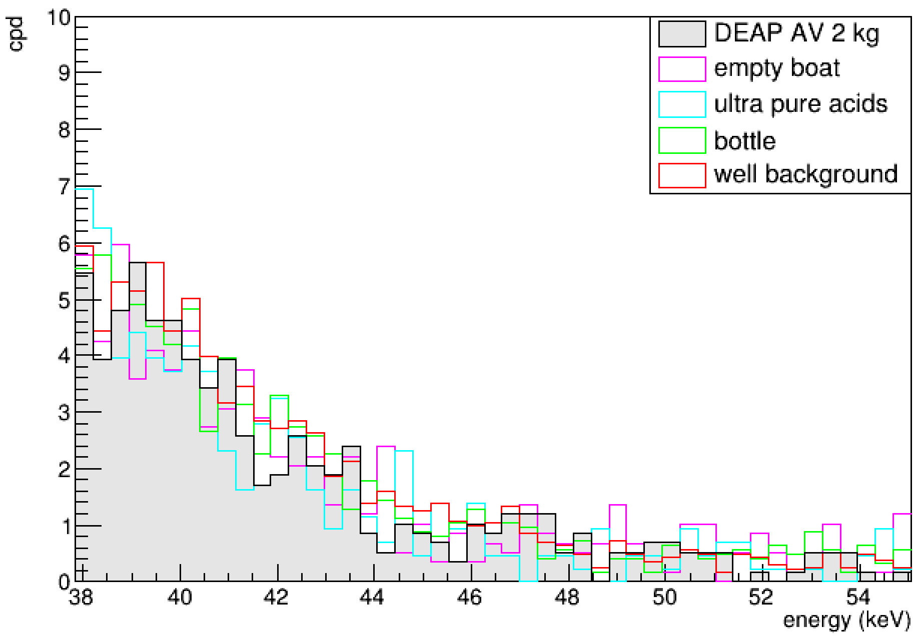
New Ge-well detector installed @ SNOLAB (~few counts per day for 46 keV line)

Also directly α-count ^{210}Po daughters after depositing on nickel

Spike with ^{222}Rn into acrylic cylinder



DEAP AV acrylic assay and backgrounds



Nantais M.Sc. Thesis result (Queen's, 2014):

^{210}Pb : $< 2.2 \times 10^{-19}$ g/g

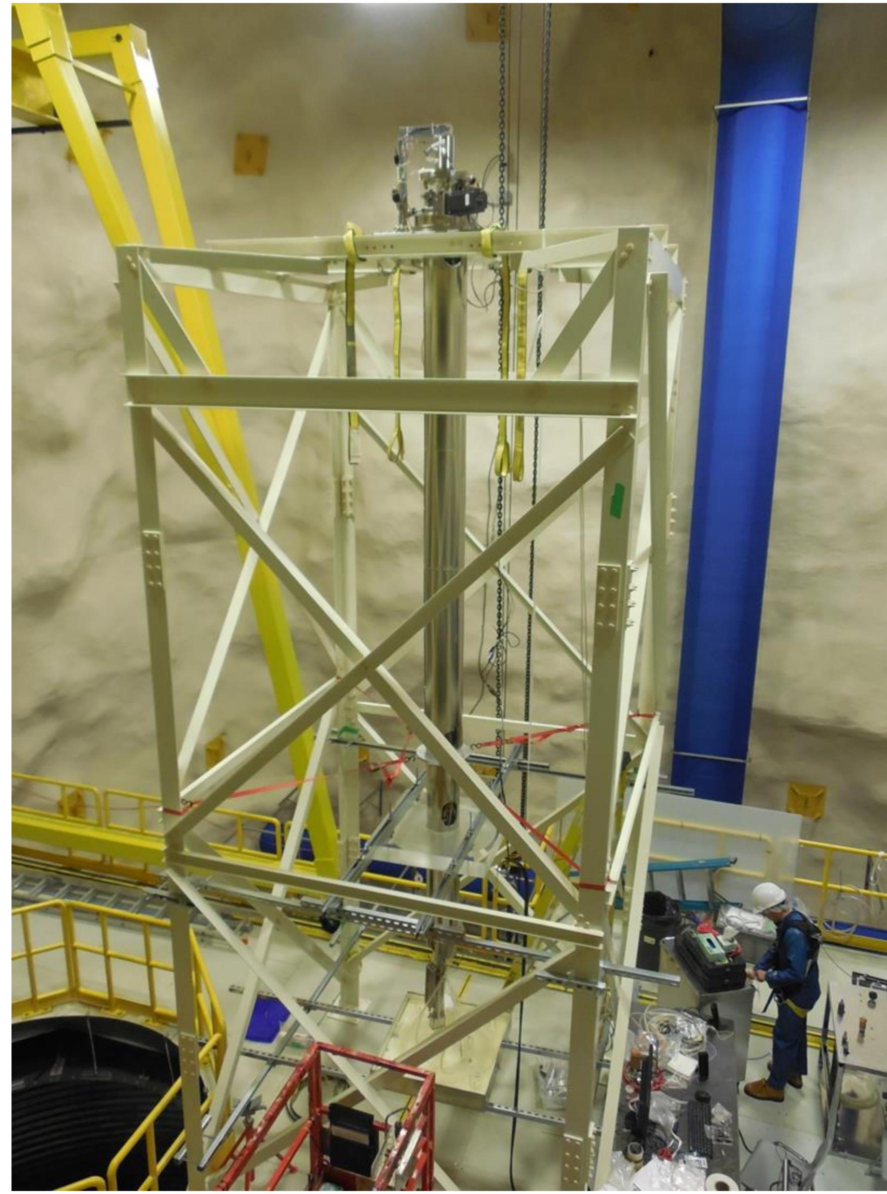
(<0.2 bkd events in 3 years)

(results from Corina Nantais, M.Sc. thesis work)

Acrylic Vessel Resurfacer

- Low-Radon emanation components
- Remove 1-mm surface *in situ*
- Cleans surface to bulk-level cleanliness

(100,000 cleaner than SNO AV surface for ^{210}Pb from radon / alphas)



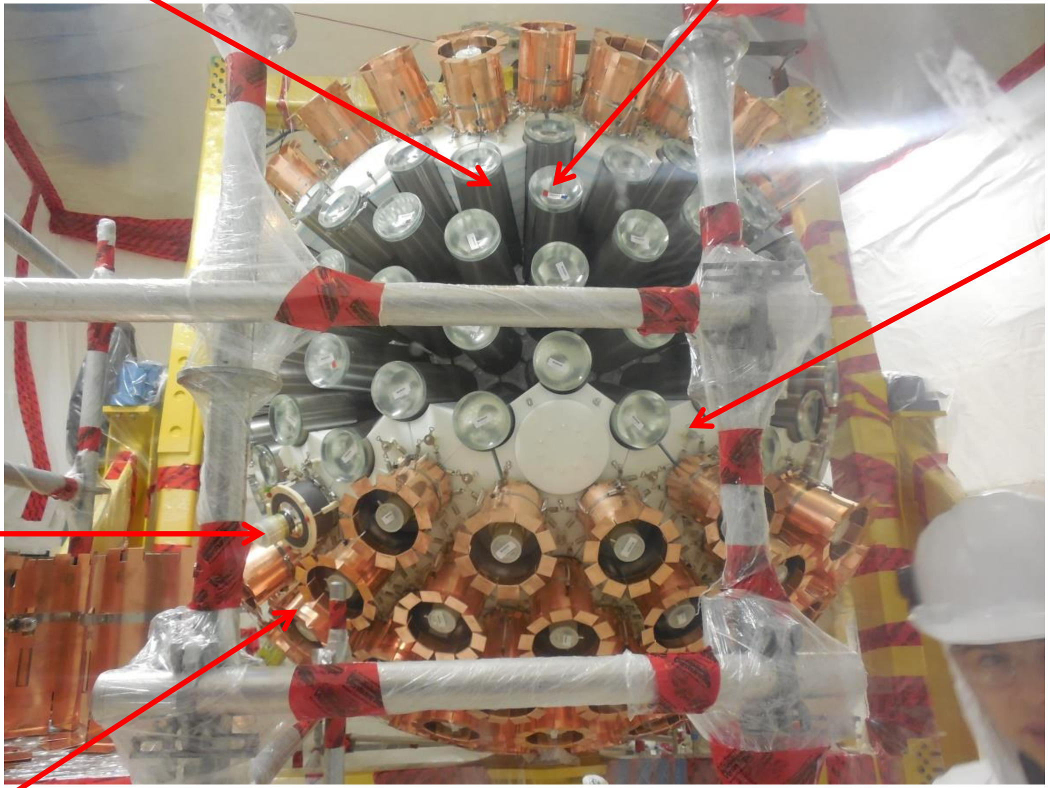
AV Fabrication (RPT Colorado and U of A)

AV neck bonding underground (December 2012-January 2013)

DEAP-3600 Detector Assembly

Acrylic Light Guide

Specular reflector + opaque wrap

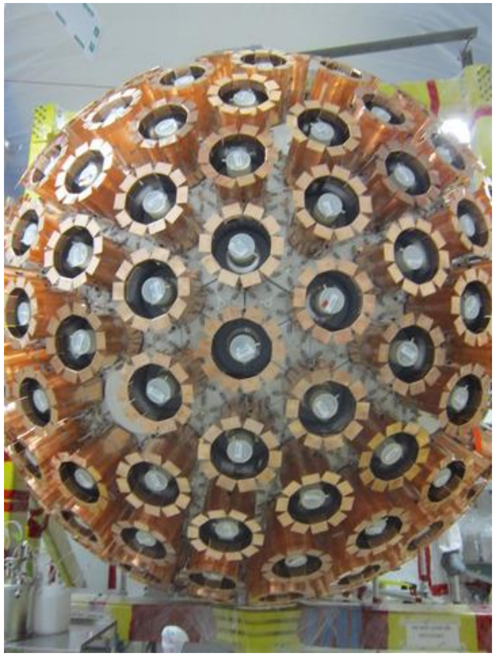


PE neutron
shielding "blocks"

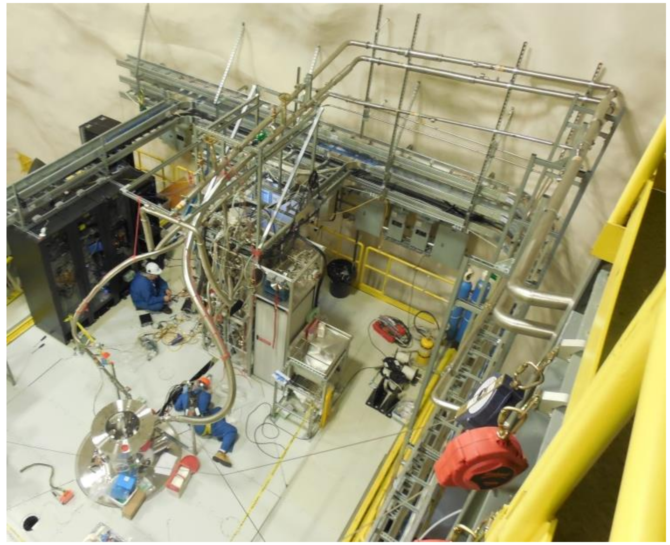
PMT with
silicone oil
coupling

Copper sleeve over PMT

Status of DEAP-3600 Installation at SNOLAB



Completed inner detector



Cryosystem, electronics

Detector ready for Final Lift onto Neck

Steel Shell in shield tank

View down detector neck

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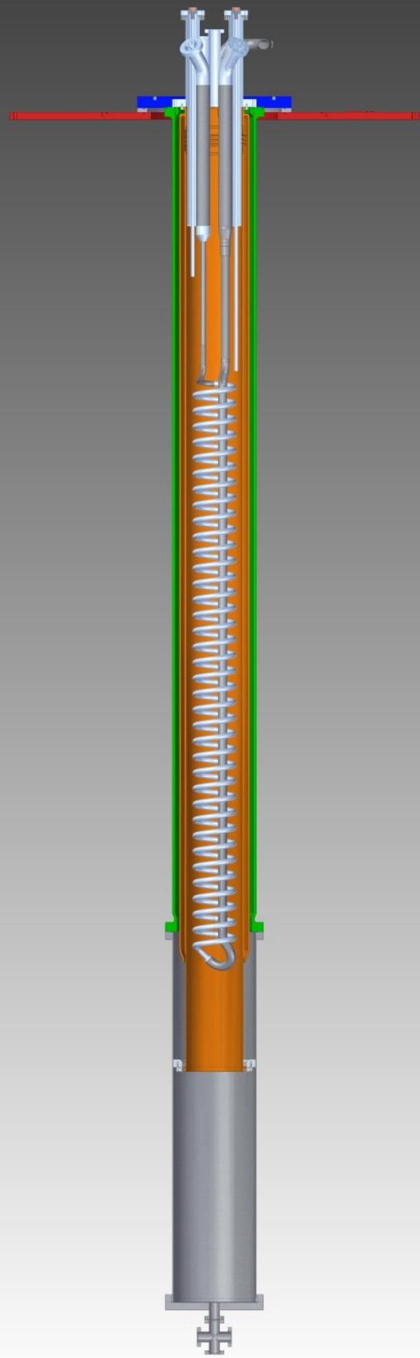
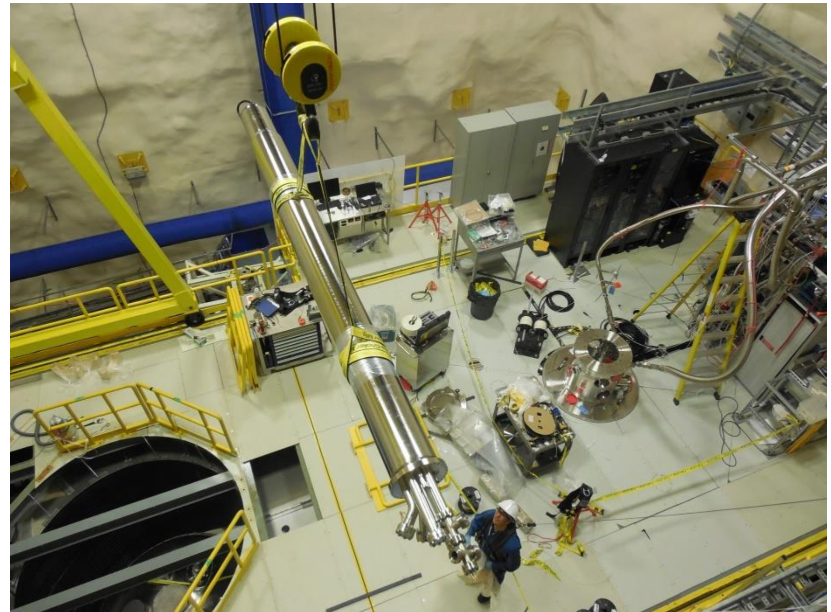
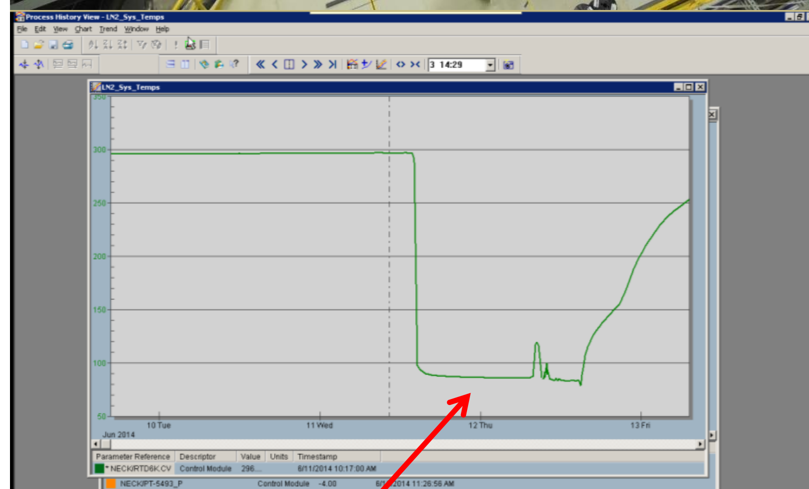
DEAP-3600 Argon Cooling System







Commissioning at 86K, June 11 2014

IPP AGM M. Boulay June 15 '14

DEAP-3600 Development Highlights

- Development of acrylic thermoforming and fabrication of spherical acrylic vessel (R&D in collaboration with Reynolds Polymer – thickness/curvature ratio beyond what had been fabricated previously); qualification of acrylic for cryogenic use

- Development of acrylic bonding technique for in-situ bonding of large diameter Light Guides to Acrylic Vessel (255 bonds underground)

- Ultrahigh purity and radon control for acrylic panel and light guide fabrication; development of new assay technique for ^{210}Pb in acrylic at the 10^{-20} g/g level; Observation of Rayleigh scattering in acrylic due to locked in stress and remediation through high-temperature annealing; demonstration of large-scale fabrication of acrylic with optics near the Rayleigh limit

- Development of PMT to acrylic lightguide coupling with o-ring seals and silicone oil coupling fluid

- Radon control in welded Stainless Steel; development of stainless steel citric acid passivation for radon emanation control (in argon purification system)

DEAP-3600 Development Highlights

- Ultrahigh purity materials selection (acrylic, stainless steel, polyethylene, cables, connectors, various components – several years of materials assays)
- Mechanical sanding robot (the Resurfacer) with controlled radon emanation
- Development of argon purification and radon filter for ultralow background argon; development of large-scale cryogenic cooling system for argon
- Seismic protection and Oxygen Deficiency mitigation for multi-tonne argon target underground
- Fabrication of a large (21,000 L) vacuum vessel with sealing flanges welded together *in-situ* underground
- Development of large-area (10 m^2) 4π thin-film vacuum deposition technique
- Characterization of readout with HQE PMTs and development of high-rate digitizing electronics and trigger
- Extensive calibration and simulations program; detailed modeling of surface effects and pulse-shape discrimination with comparisons to data (DEAP-1)

Presentations at CAP

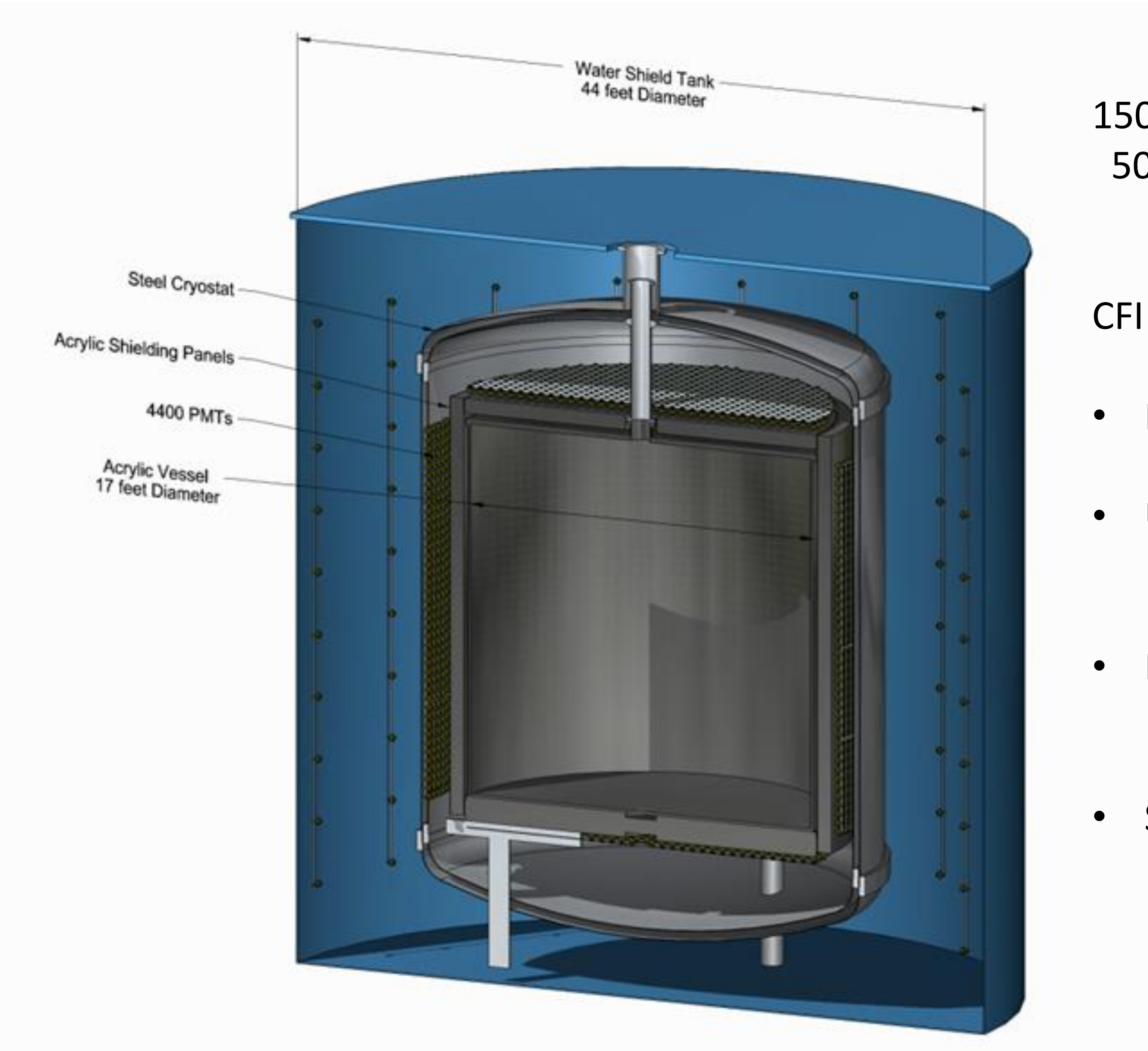
DEAP-3600 Dark Matter Detector	Aksel Hallin, Alberta (W2-7)
Organic Thin Film Deposition System for DEAP-3600	Ben Broerman, Queen's (W2-7)
Surface Alpha Background Mitigation in DEAP-3600	Joshua Bonnat, Queen's (R1-9)
Characterization of DEAP-3600 PMTs	Paradorn Pasuthip, Queen's (R1-9)
DEAP-3600 Resurfacer Deployment and Testing	Pietro Giampa, Queen's (F1-5)
Cryogenic Liquid Safety for DEAP-3600	Tom Sonley, Queen's (F1-5)
DEAP-3600 Light Guide Bonding	Thomas McElroy, Alberta (POS-28)
DEAP-3600 Optical Calibration Systems	Pietro Giampa, Queen's (POS-29)
DEAP-3600 Argon Process Systems	Mark Ward, Queen's (POS-33)

Also, several posters and components setup for display at the experiment underground in the SNOLAB Cube Hall

DEAP-3600 Project Timeline

Milestone	Date
Installation of Detector under Neck	June 23, 2014
Start of Resurfacing	July 2014
Calibrations and commissioning (warm)	Aug 2014
Start of Physics Data Collection	Oct-Nov, 2014

DEAP-50T: Follow-up with 50-tonnes of liquid argon (Development Proposal)

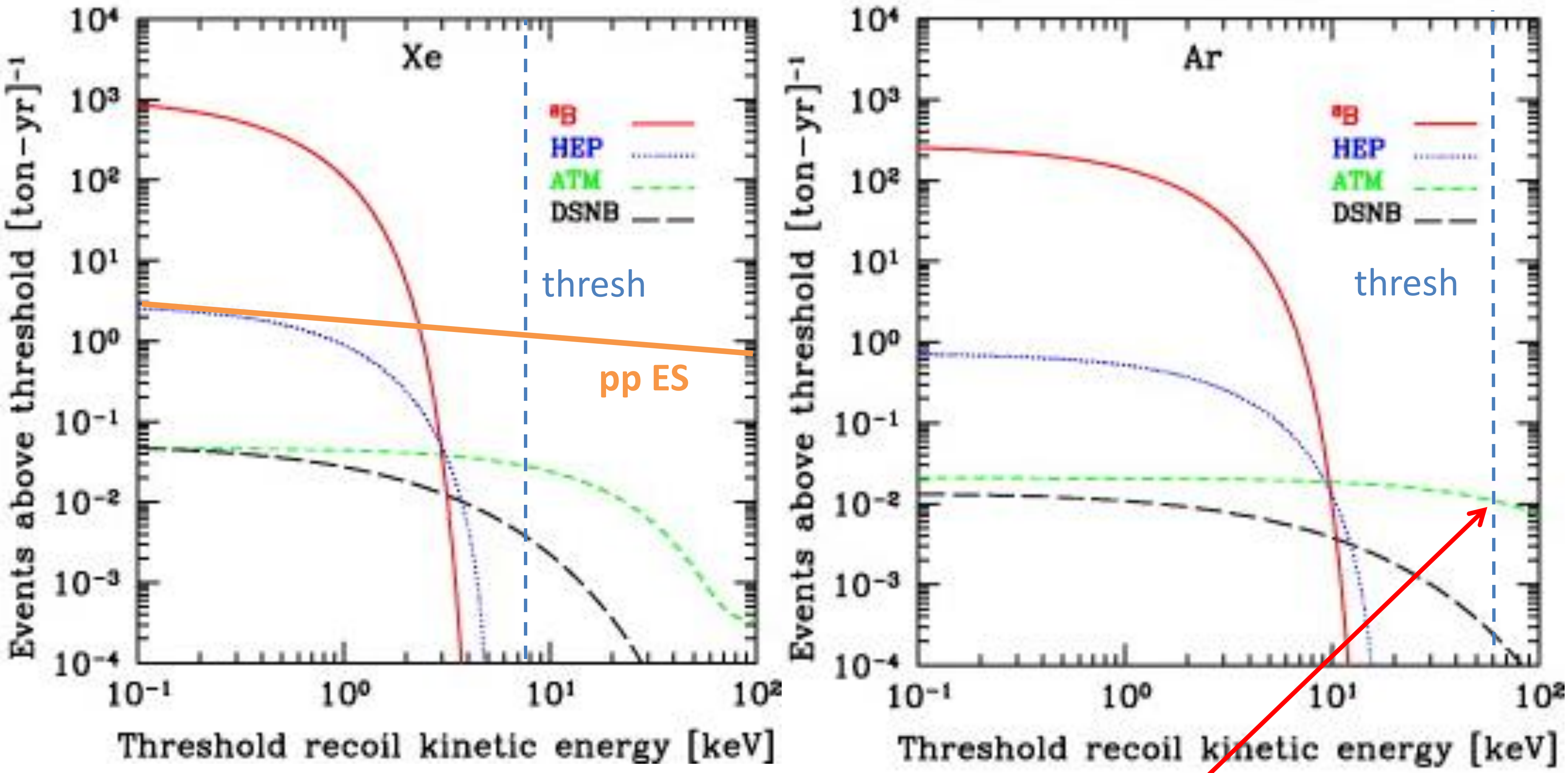


150-tonnes DAr in AV
50-tonne fiducial

CFI Proposal for development of:

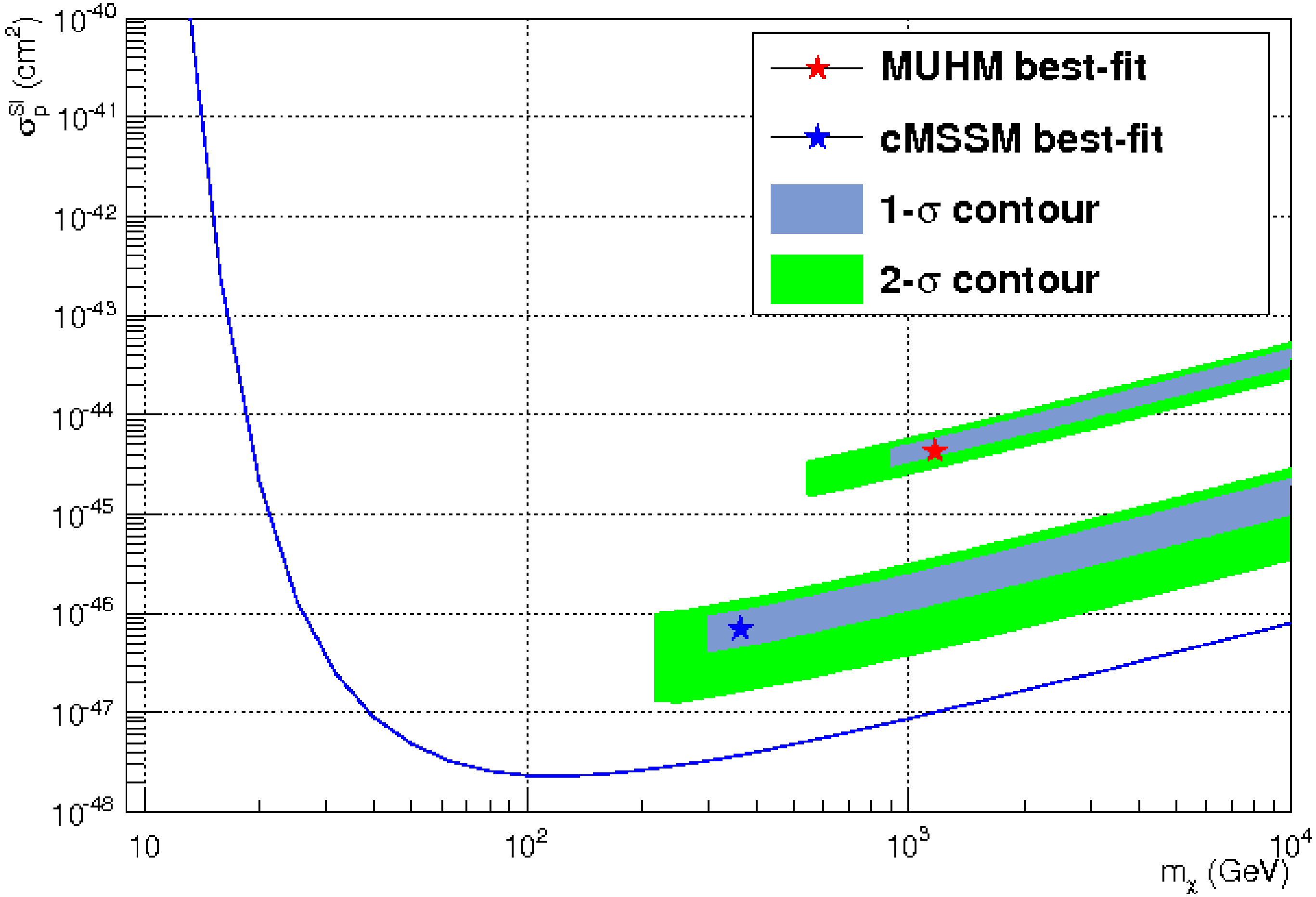
- Photodetector Development
- UG screening/storage of Low Radioactivity Argon
- Low Background Cryogenic Test Facility
- Seismic/safety engineering

Neutrino backgrounds in xenon and argon



Target sensitivity for **DEAP-50T** (50 Tonne Fiducial Argon) is
at ultimate limit set by atmospheric neutrinos

Physics Sensitivity with DEAP-50T:



Sensitivity at "Floor" set by irreducible background from atm. neutrinos

Summary

- DEAP-3600 sensitive to SI DM interactions at 10^{-46} cm^2; factor of 23X improvement at high WIMP mass over current LUX leading result

- Start of Physics Collection at SNOLAB Fall 2014

- Proposal being developed for 50T follow-up program, reaches ultimate DM sensitivity limit from atmospheric neutrinos