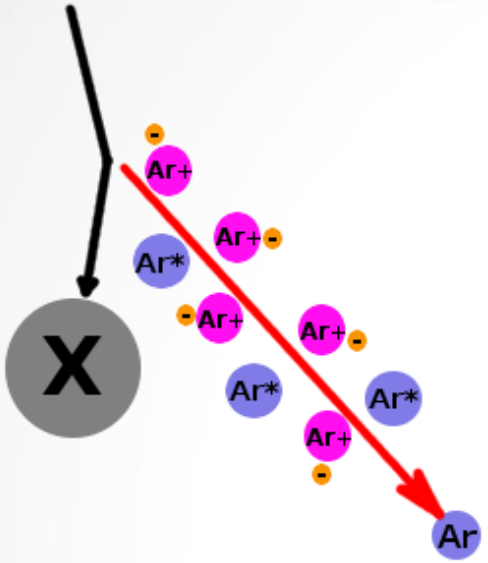
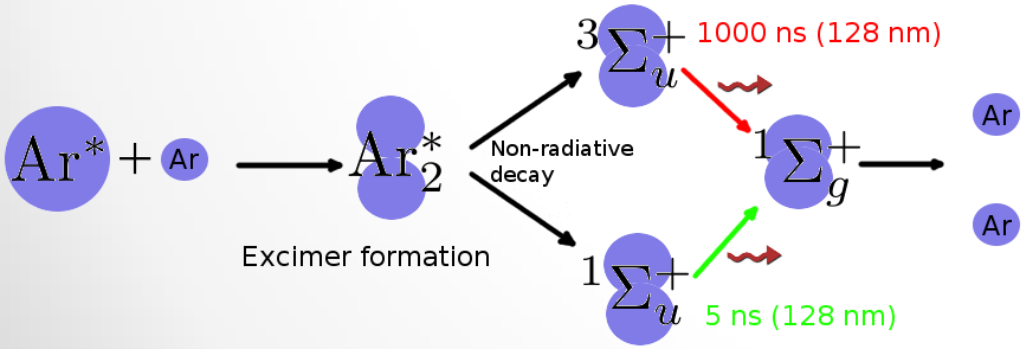
Dark-matter Experiment using Argon Pulse Shape Discrimination

Chris Ouellet – Carleton University, on Behalf of the DEAP Collaboration

Ar Scintillation

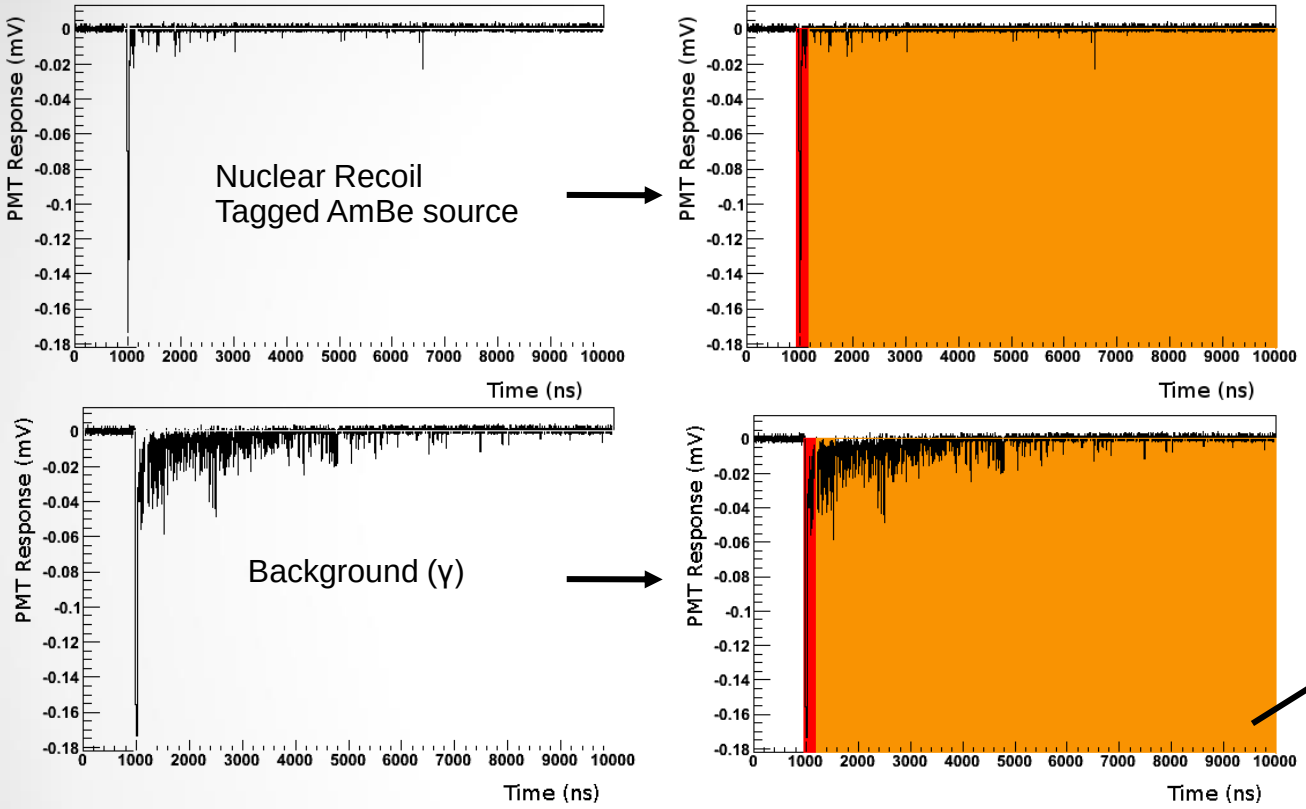


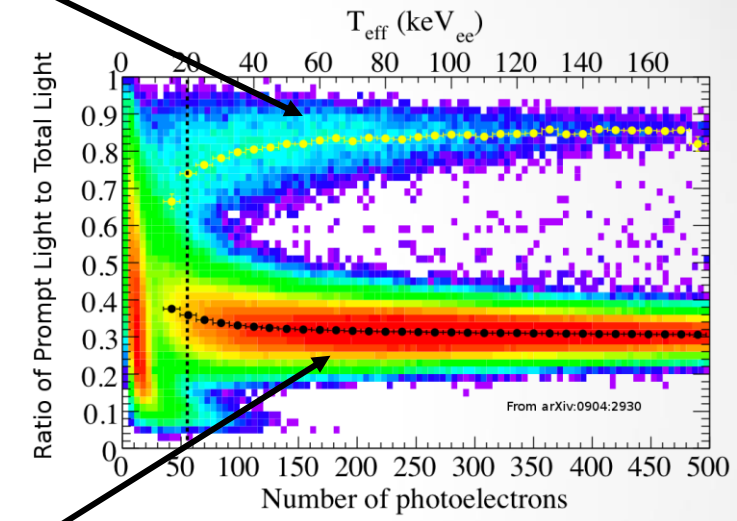
$$Ar^* + Ar \longrightarrow Ar_2^* \longrightarrow 2Ar + \gamma$$
$$Ar^+ + Ar \longrightarrow Ar_2^+ + e^- \rightarrow Ar_2^* \longrightarrow 2Ar + \gamma$$



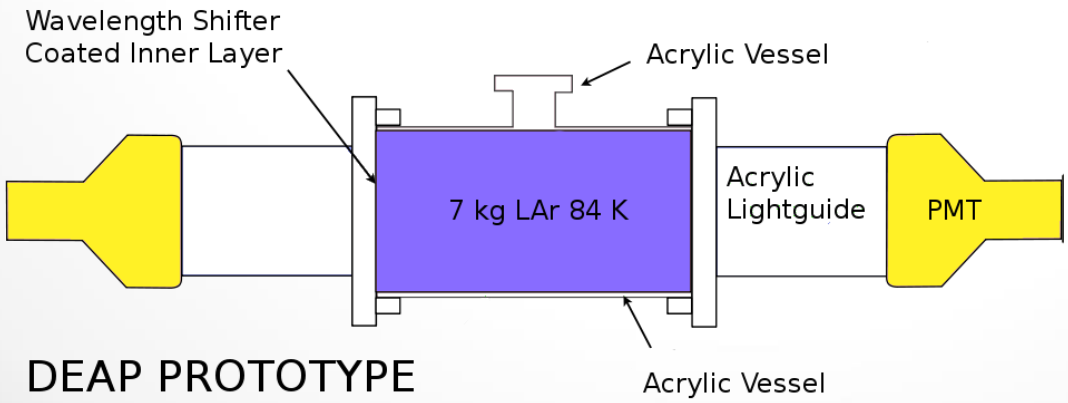
- Decay times of singlet and triplet states **do not** depend density of excited species along the track, linear energy transfer (LET)
- Intensity ratios of singlets to triplets **do** depend on (LET)
- Easily purified, inexpensive, accessible liquid temperature 87 K, very large detector mass possible
- 8 pe/keV light yield
- 128 nm molecular spectrum not absorbed by bulk Ar
- 128 nm light is deep UV, needs to be wavelength shifted for PMT detection

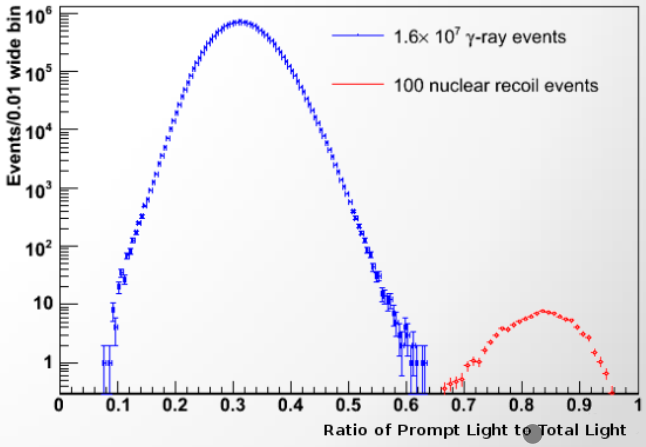
Pulse Shape Discrimination



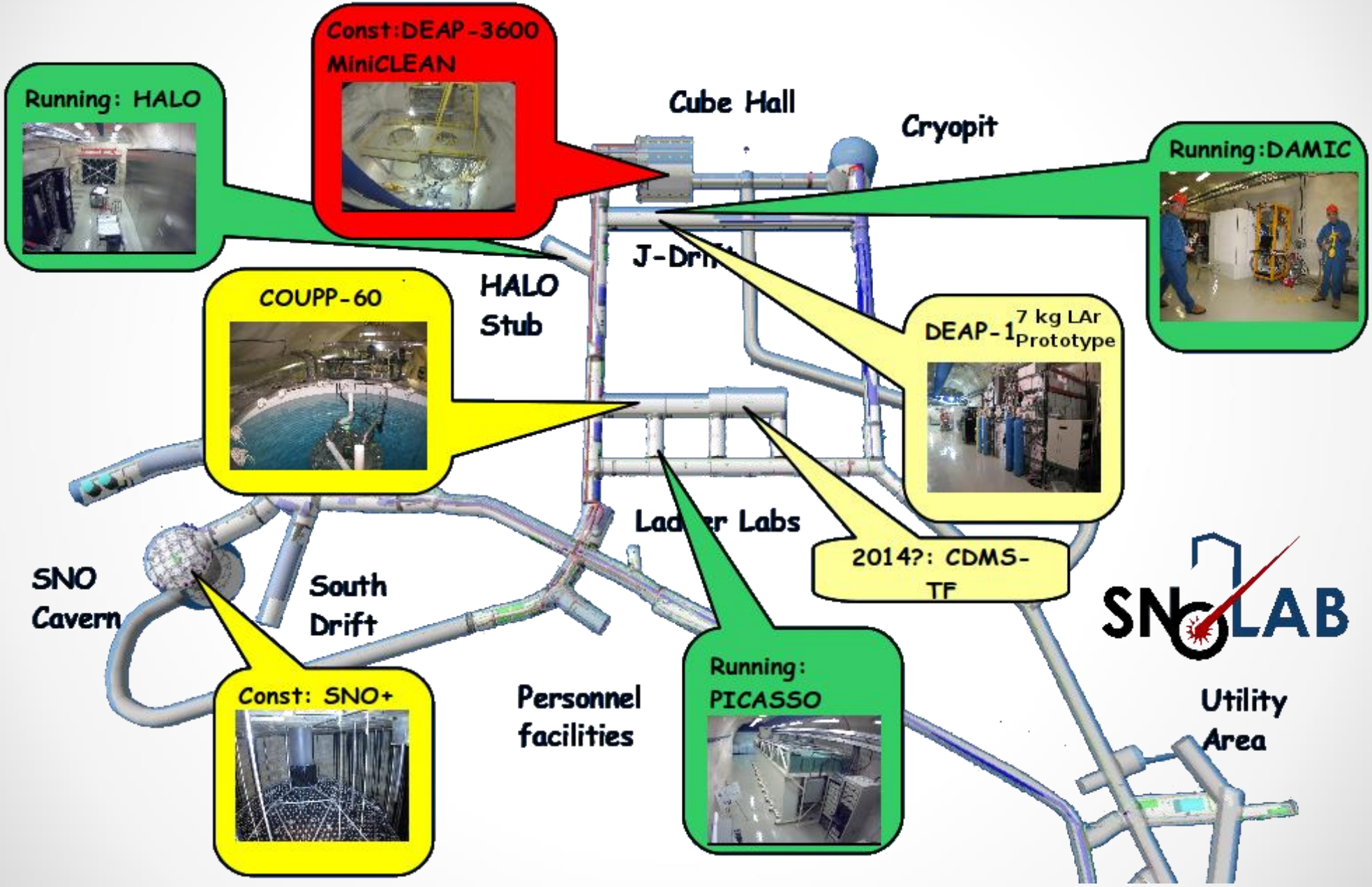


120-240 PE = 60 keV Recoil
Suppression > $3x10^{-8}$

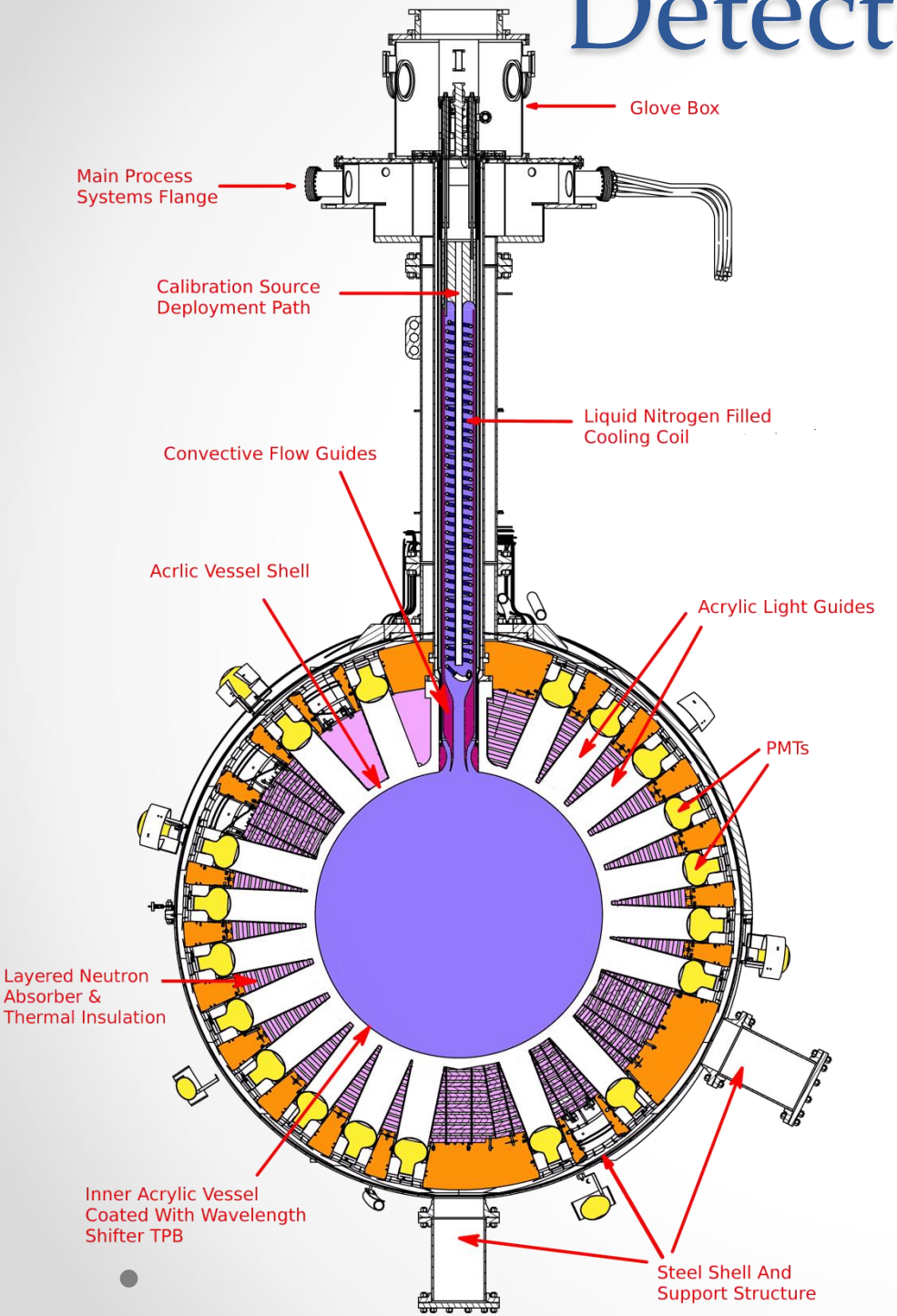




Experiments at SNOLAB



Detector Schematic



- 3600 kg – 1000 kg fiducial single phase liquid Ar
- 85 cm radius sphere
- 255 8 inch PMTs (warm) Hamamatsu R5912 HQE (32% QE, 75% coverage)
- 50 cm light-guides (neutron shielding from glass, thermal insulation for PMTs)
- Interior has only argon and wavelength shifter
- Filler blocks for neutron shielding
- Detector surrounded by 8 m water shield

Detector Backgrounds

- Background rate goal in sensitive region is ~0.1/tonne/year
- Fast neutrons from (a,n) activity in acrylic, TPB, PMT glass, steel shell and surrounding rock
- Cosmic ray induced neutrons
- β from ^{39}Ar and other β and γ emitters
- Radon gas and its daughters

Background Mitigation Strategy

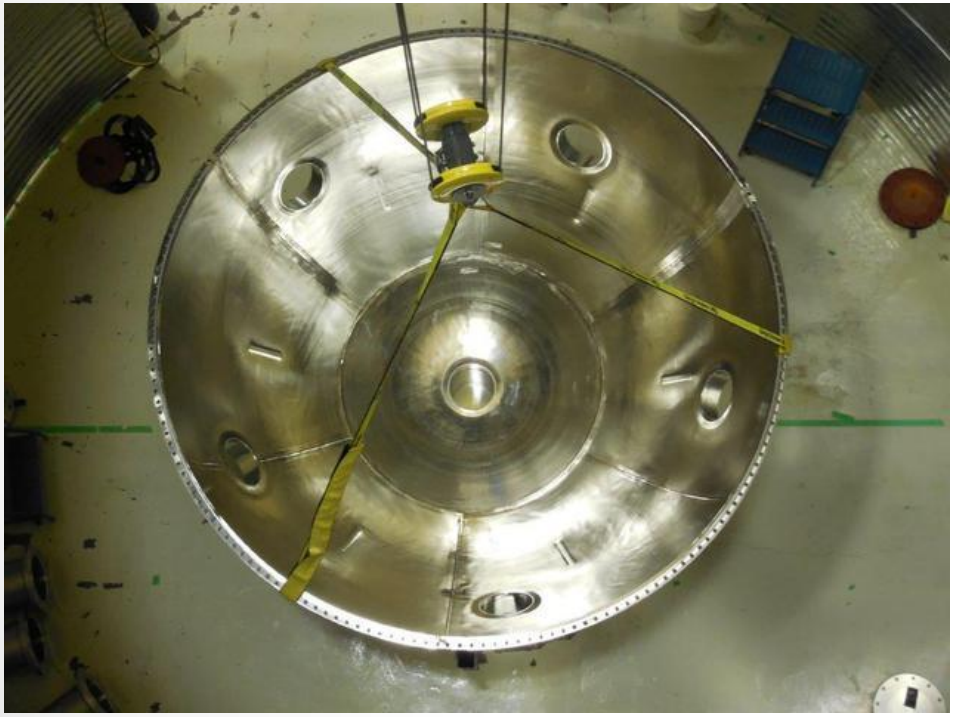
- DEAP has 6000 mwe overburden and active muon veto
- 8 m water shielding surrounding steel shell
- Selection of materials for:
  - Low U and Th content (acrylic)
  - Neutron absorption (light guides, filler blocks)
  - High reflectivity to enhance PSD
  - Reduced emanation (process systems <5μBq of ^{222}Rn)
- SEAS getter and cold radon-trap filtration of Ar
- Specific construction steps against Radon daughters
- Potential move to depleted Ar - factor of x10 β reduction over natural Ar (1 Bq/kg)

Radiopurity of Materials

*** More detail in Corina's talk for vaporization/assay of acrylic

- Extensive and enormous effort
- Acrylic, polymethal-meth-acrylate, sourced, counted in-situ and followed through every step from distillation to thermoforming pure MMA monomer sheets (Thai MMA)
- Electropolishing of metal surfaces including interior of the steel shell to reduce radon emanation
- Seamless tubing and where unavoidable welds in process system performed with non-thoriated TIG welding to reduce radon emanation
- Developed vaporization system for acrylic assays, ultra low background emanation chamber to qualify process systems materials and cleaning methods

Radiopurity of Materials



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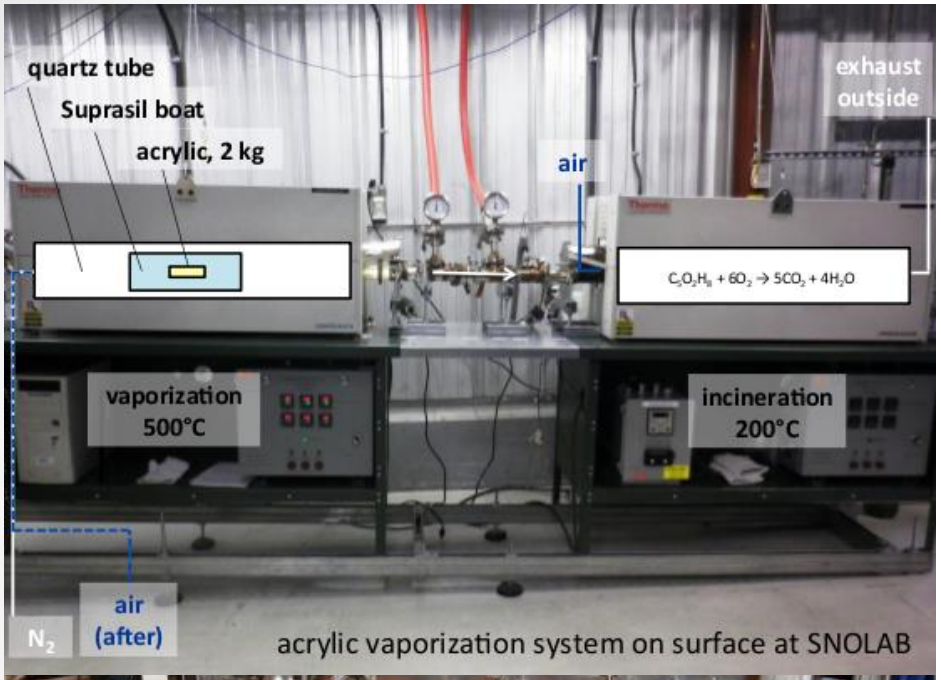
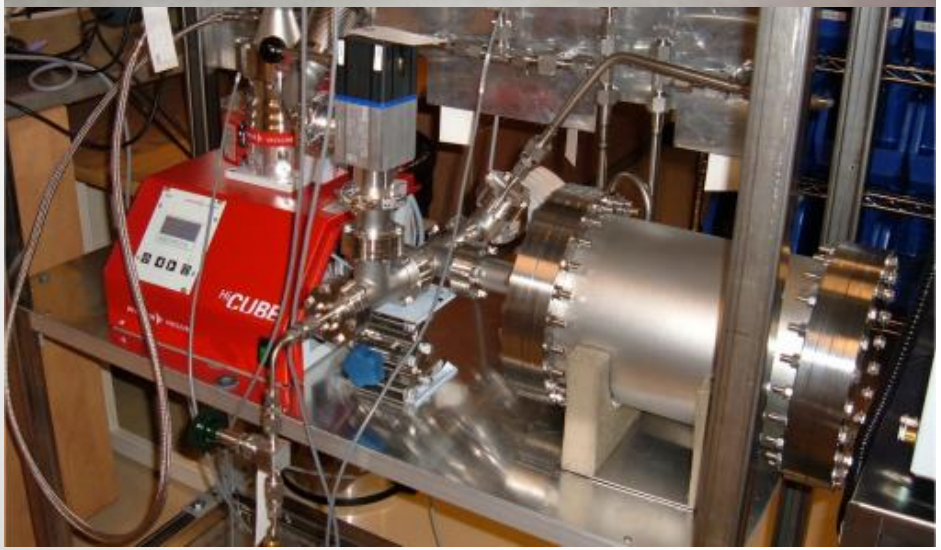


acrylic vaporization system on surface at SNOLAB



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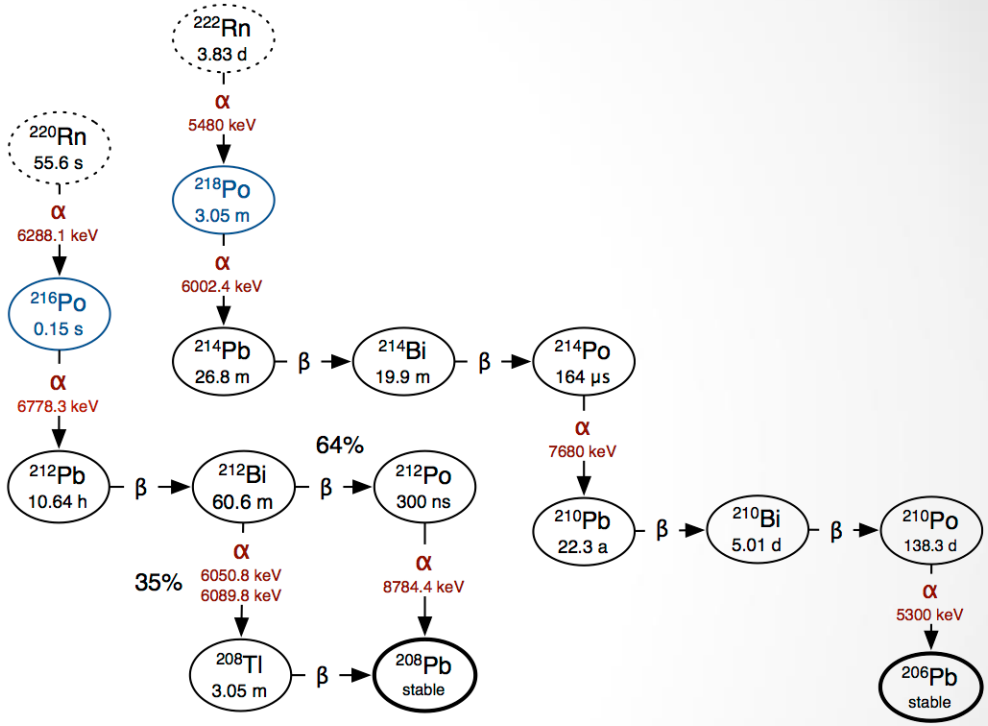
Radon Mitigation

- Pervasive gas, in higher concentration underground than surface (100 vs 10 Bq/m^3)
- Can diffuse into materials, particularly acrylic (~100 μm depth)
- Daughter product Polonium of particular concern, plates out on metal and TPB
- ^{214}Po major portion of DEAP prototype low energy background
- Control of lab air exposure of inner surface of AV
- Re-surfacing inner surface of AV before TPB deposition (1mm removal)
- ^{210}Po and Pb controlled to10^{-20} g/g



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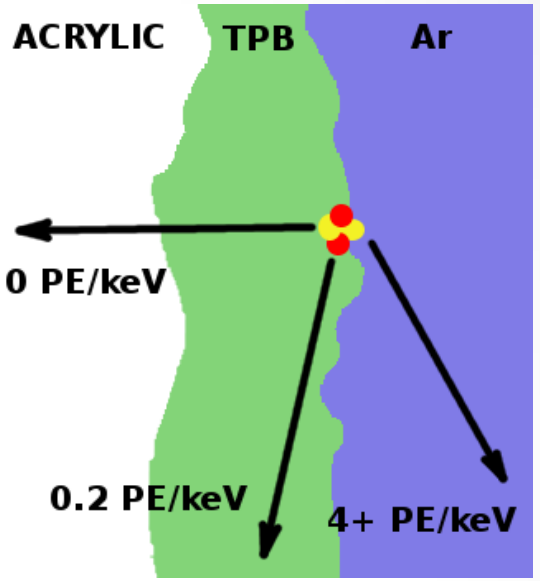

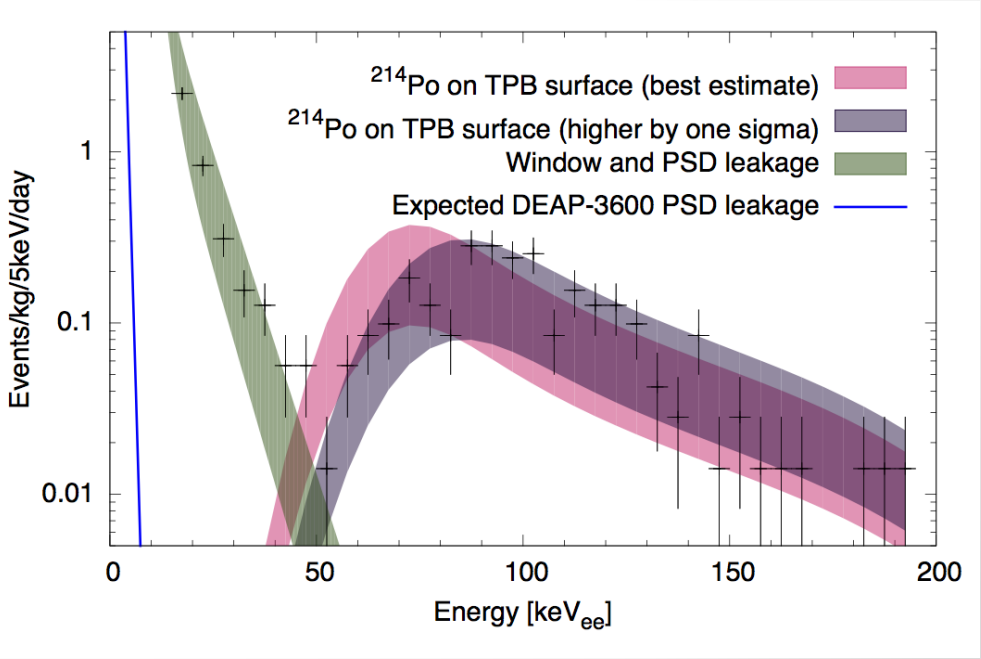

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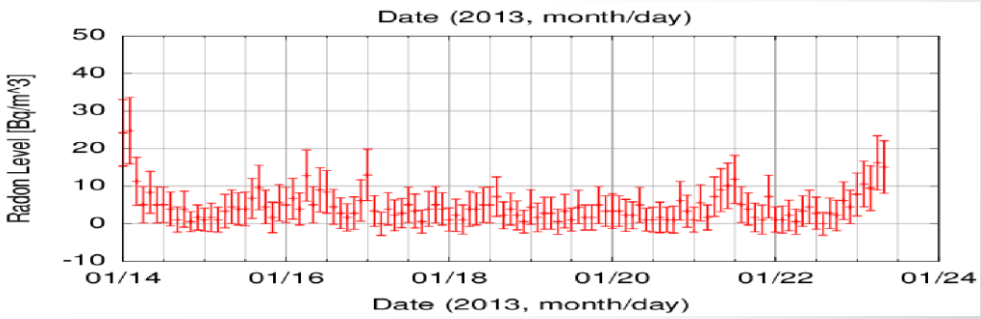

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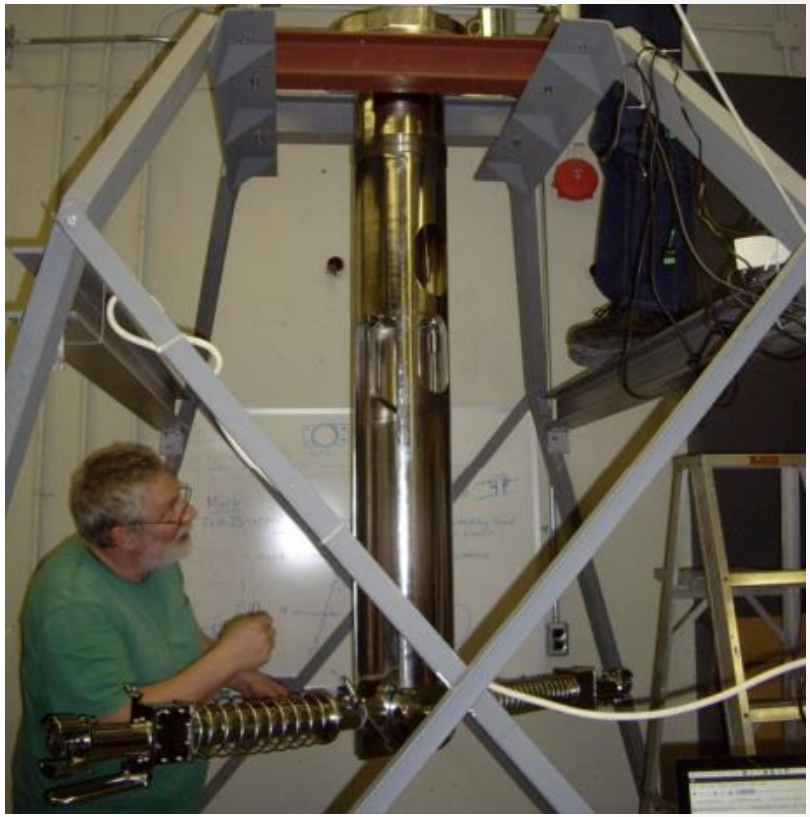

Queen's University

Construction Status I

RPT Colorado

Construction Status I

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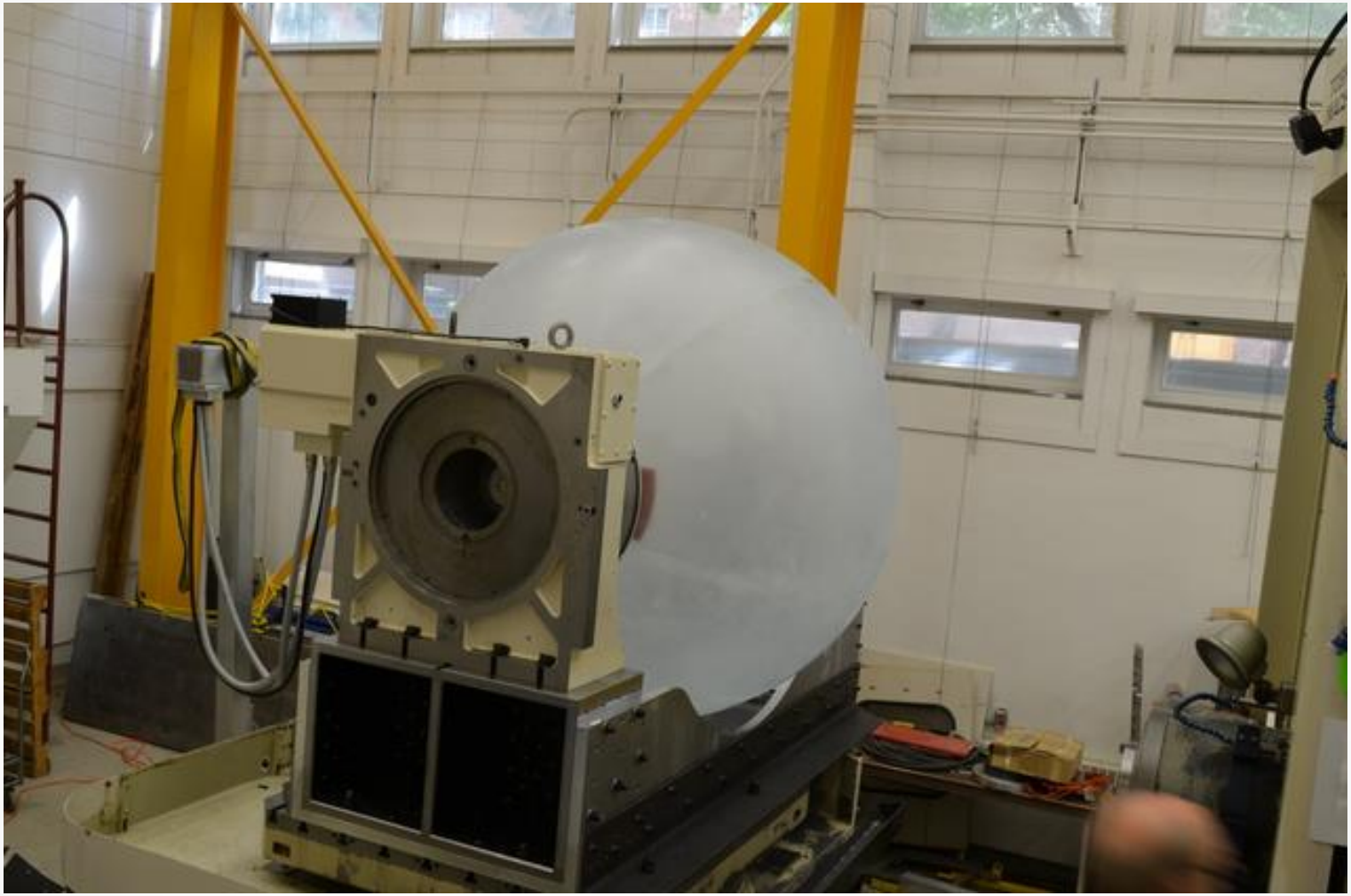

Construction Status I

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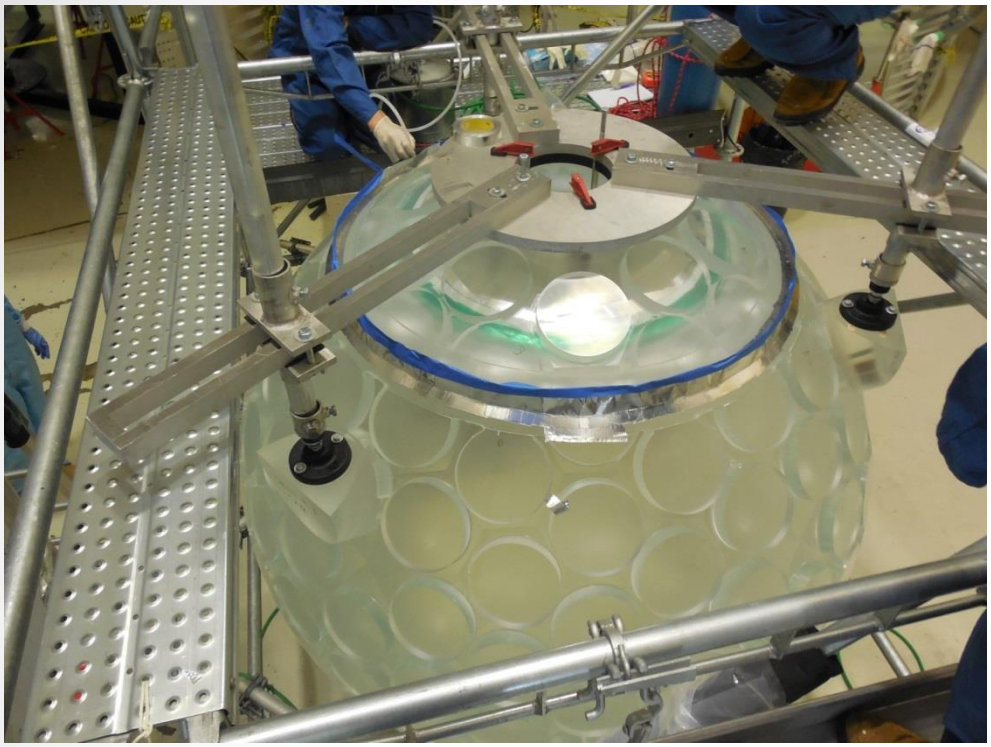
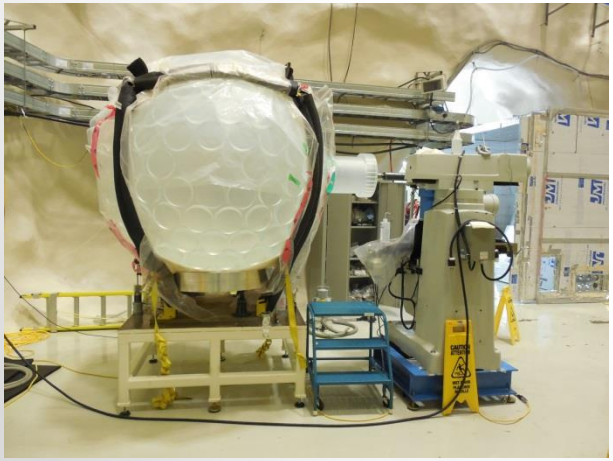
Construction Status II



RPT SNOLAB

Construction Status II



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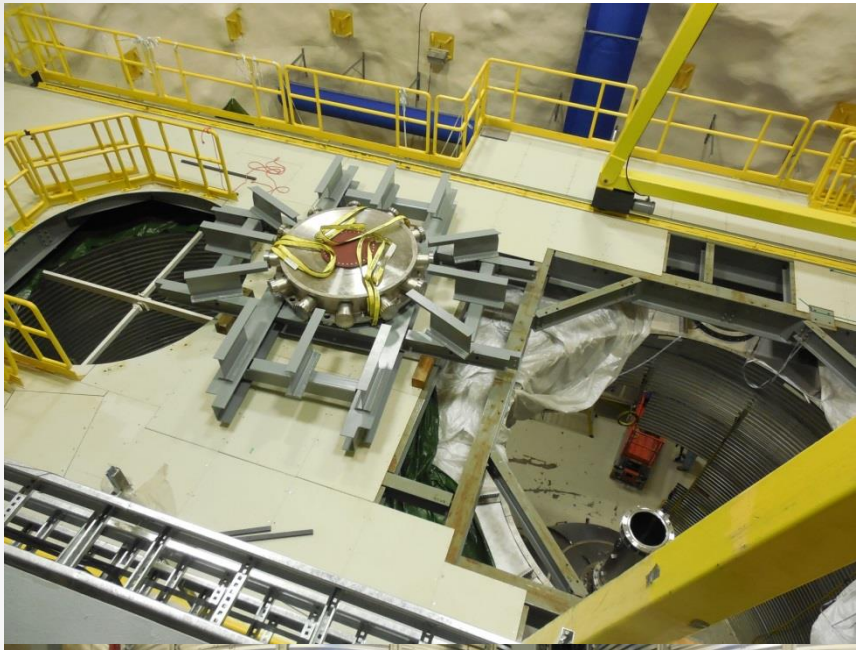

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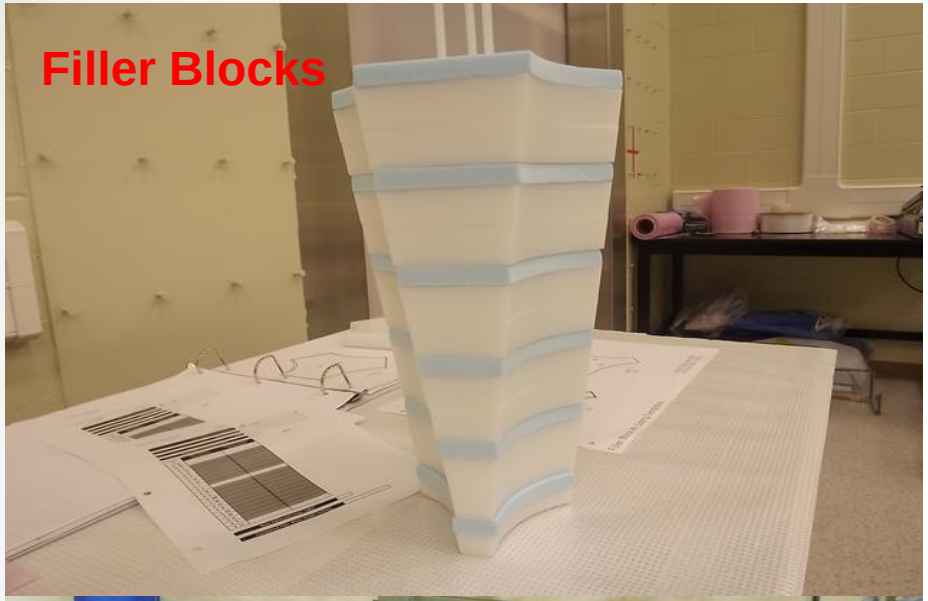
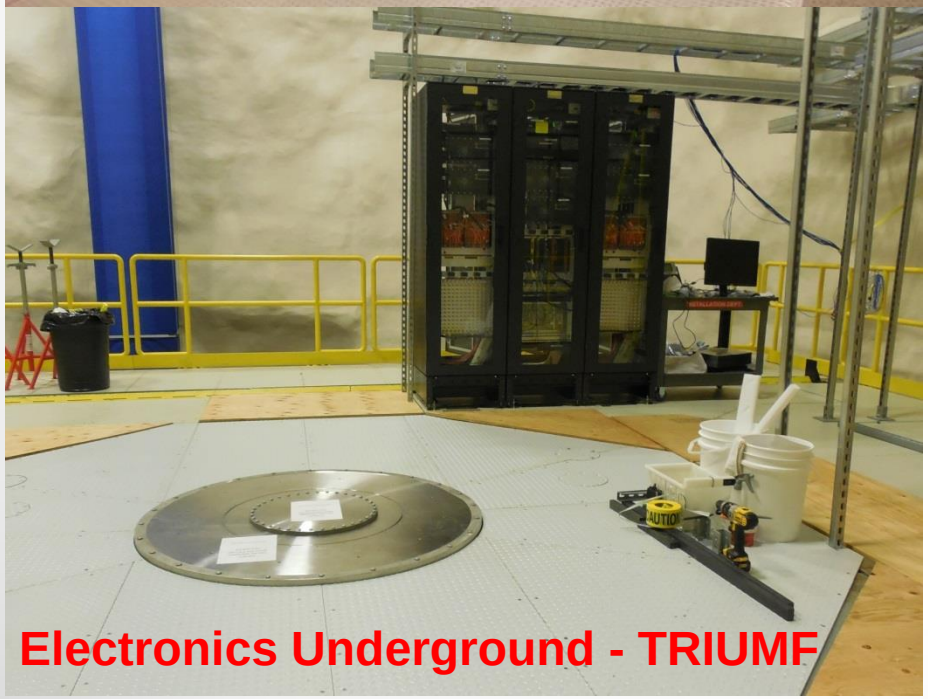
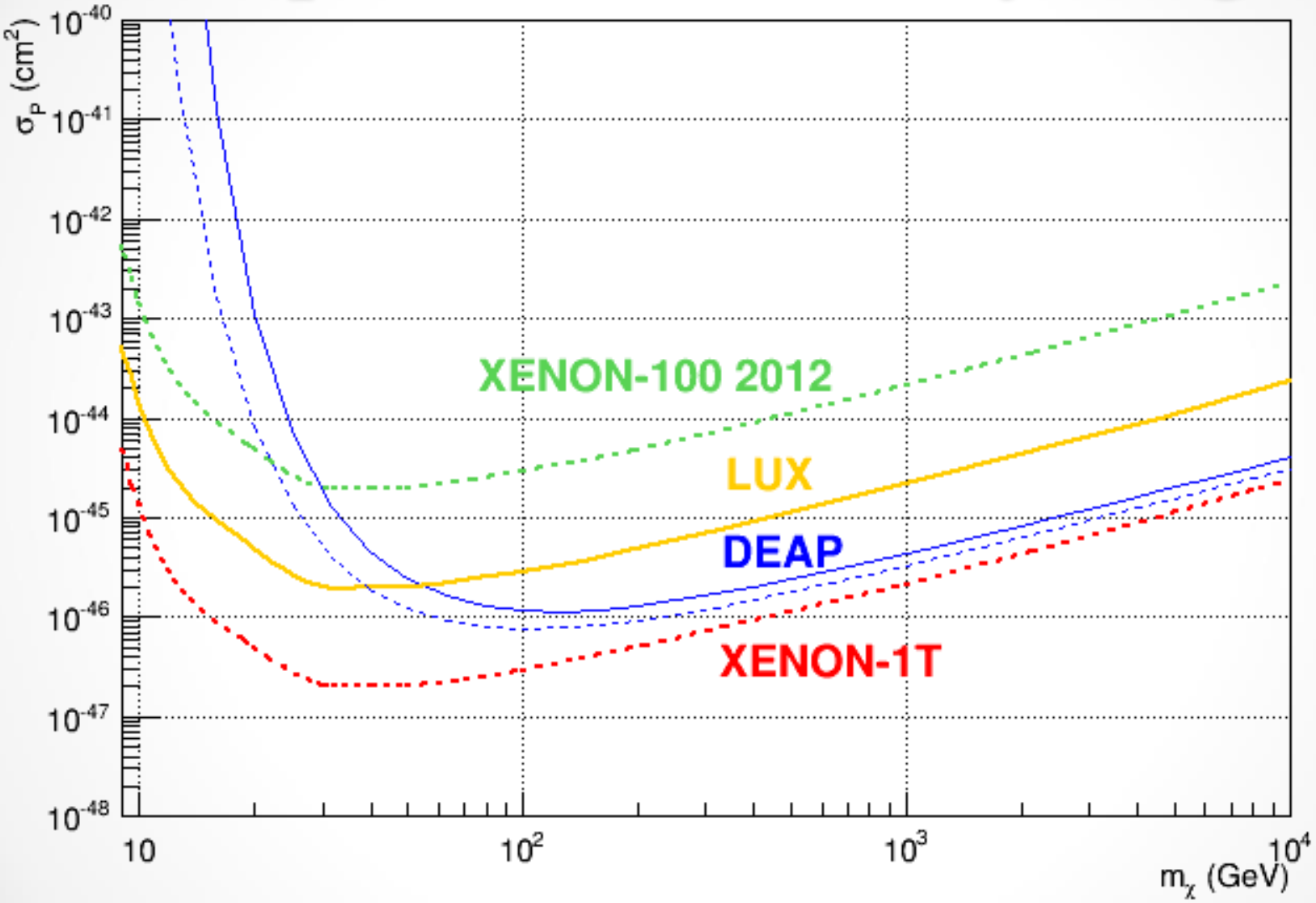




Construction Completion Schedule

- Light Guide Bonding, May/July 2013
- Process systems and cooling coil commissioning
- Installation of magnetic compensation coils
- Shield tank water systems commissioning
- PMT and filler block installation
- Re-surfacing and TPB deposition
- First calibrations and cool-down end of 2013

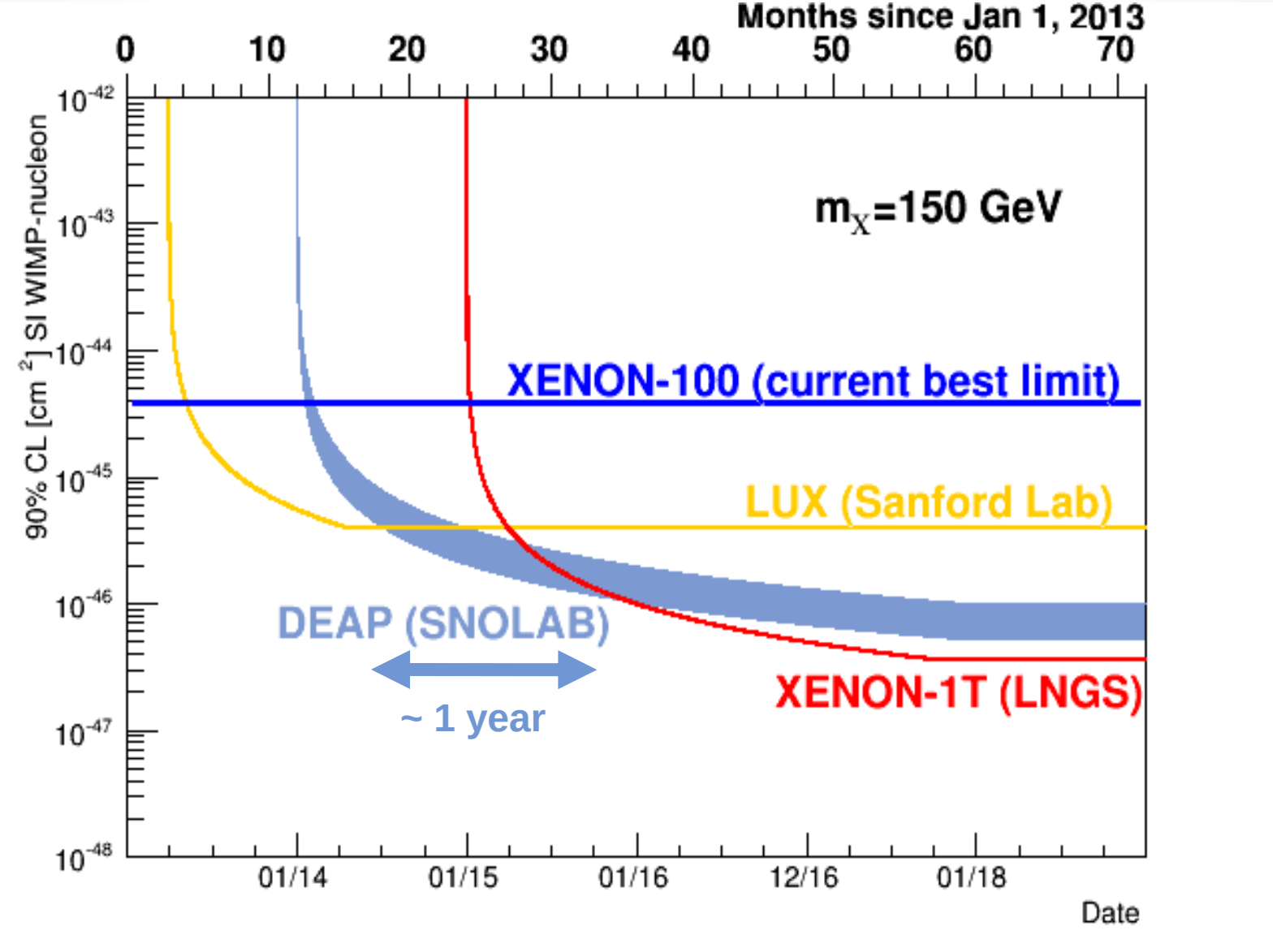
Anticipated Sensitivity Region



- Conservative effective resolution of 10 cm (predict x2 with better max likelihood fitter analysis)
- Attenuation length of at least 4 m
- 15keVee threshold (approx. 60 keV recoil energy), 3-yr exposure

Potential For World Leading Results

(Spin independent)



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Laurentian University
Université Laurentienne

Particle Physics
Rutherford Appleton Laboratory

Royal Holloway
University of London

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