CIPANP 2015

Commissioning the DEAP3600 Detector

Dr Mark Ward
Queen's University, Canada

On Behalf of the DEAP Collaboration

DEAP3600 Collaboration

Queen's University

Carleton University

Royal Holloway University of London

University of Alberta

Instituto de Física

Particle Physics
Rutherford Appleton Laboratory

TRIUMF

SNOLAB
Mining for knowledg
Creuser pour trouver... l'excellenc

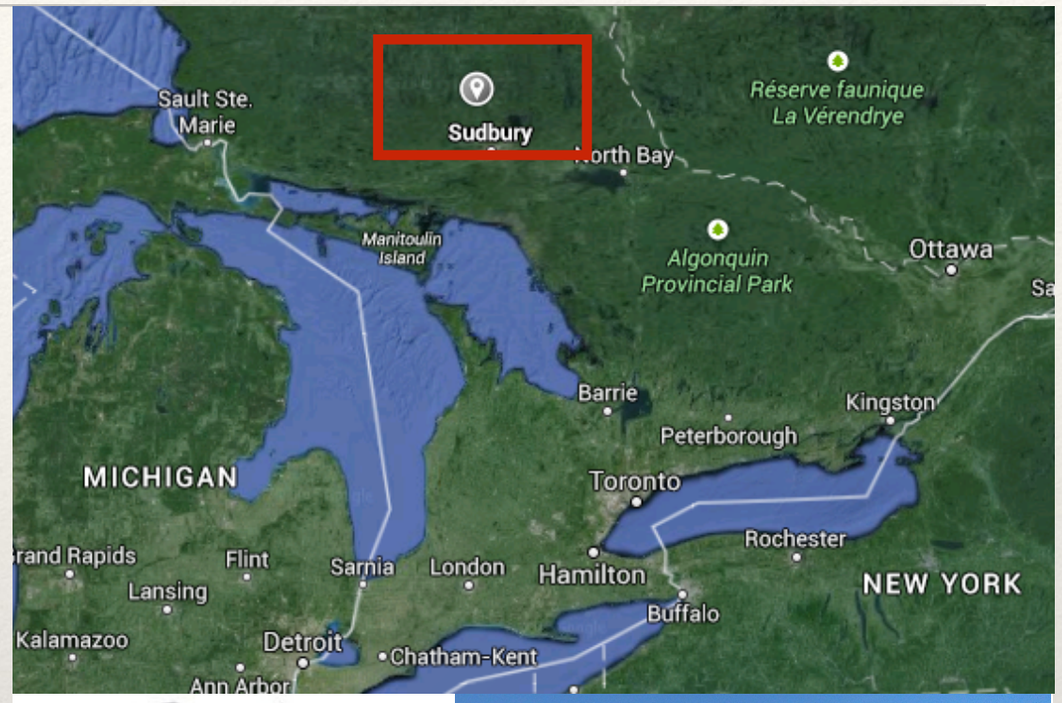
University of Sussex

Science & Technology Facilities Council

Laurentian University
Université Laurentienne

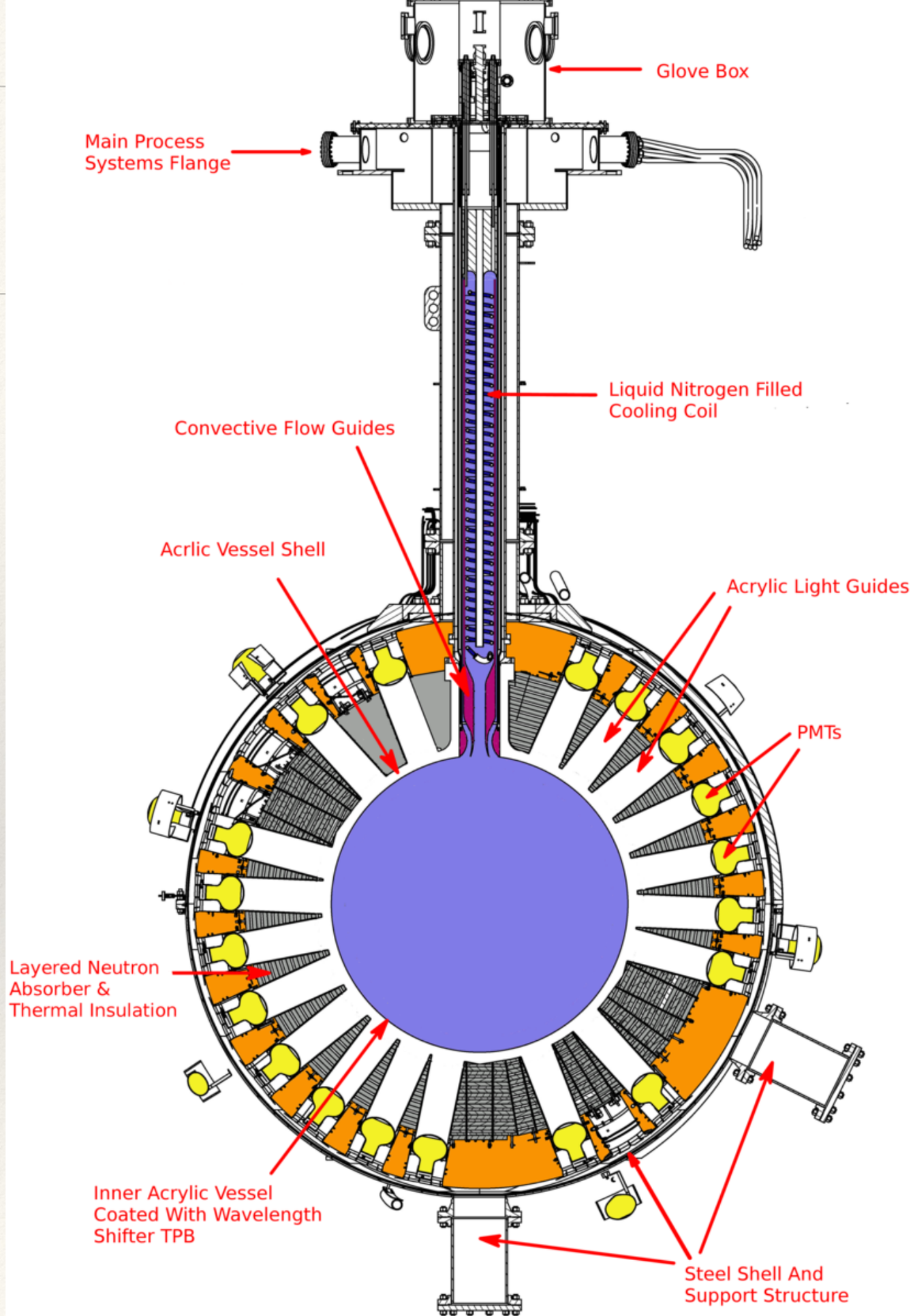
DEAP3600

- Single phase liquid argon (LAr) dark matter detector
- Located at SNOLAB, 2070m underground in Vale's Creighton mine, Sudbury Ontario, Canada

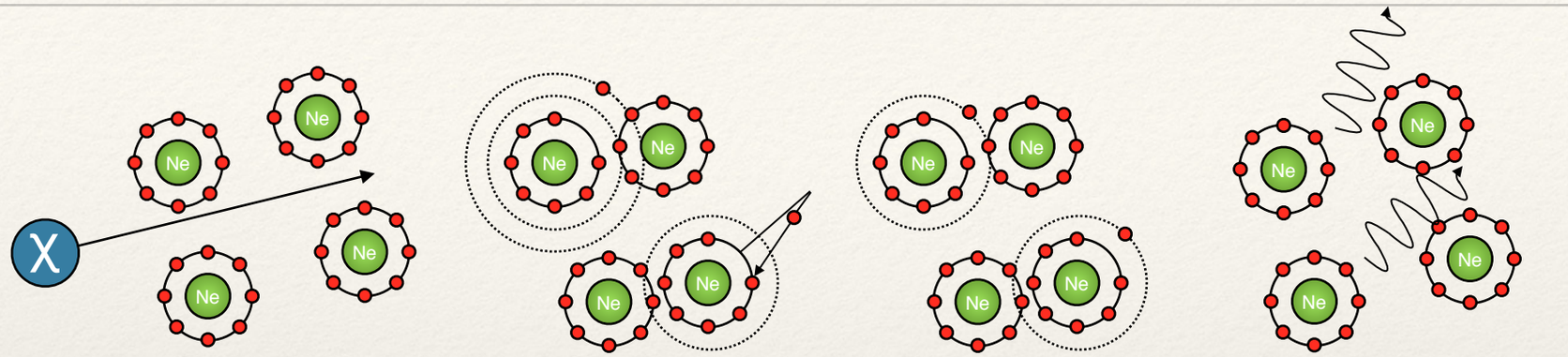


DEAP3600

- 3600 kg liquid argon target
  - 1000 kg fiducial
- Acrylic vessel
  - Ultra high purity acrylic
  - Resurfaced in-situ
- Vacuum deposited Tetraphenyl butadiene (TPB) wavelength shifter
- 255 PMTs
  - Mounted on 20 inch light guides
- Shielding
  - Acrylic light guides and high density polyethylene filler material
  - Water shield tank



Liquid Argon Scintillation

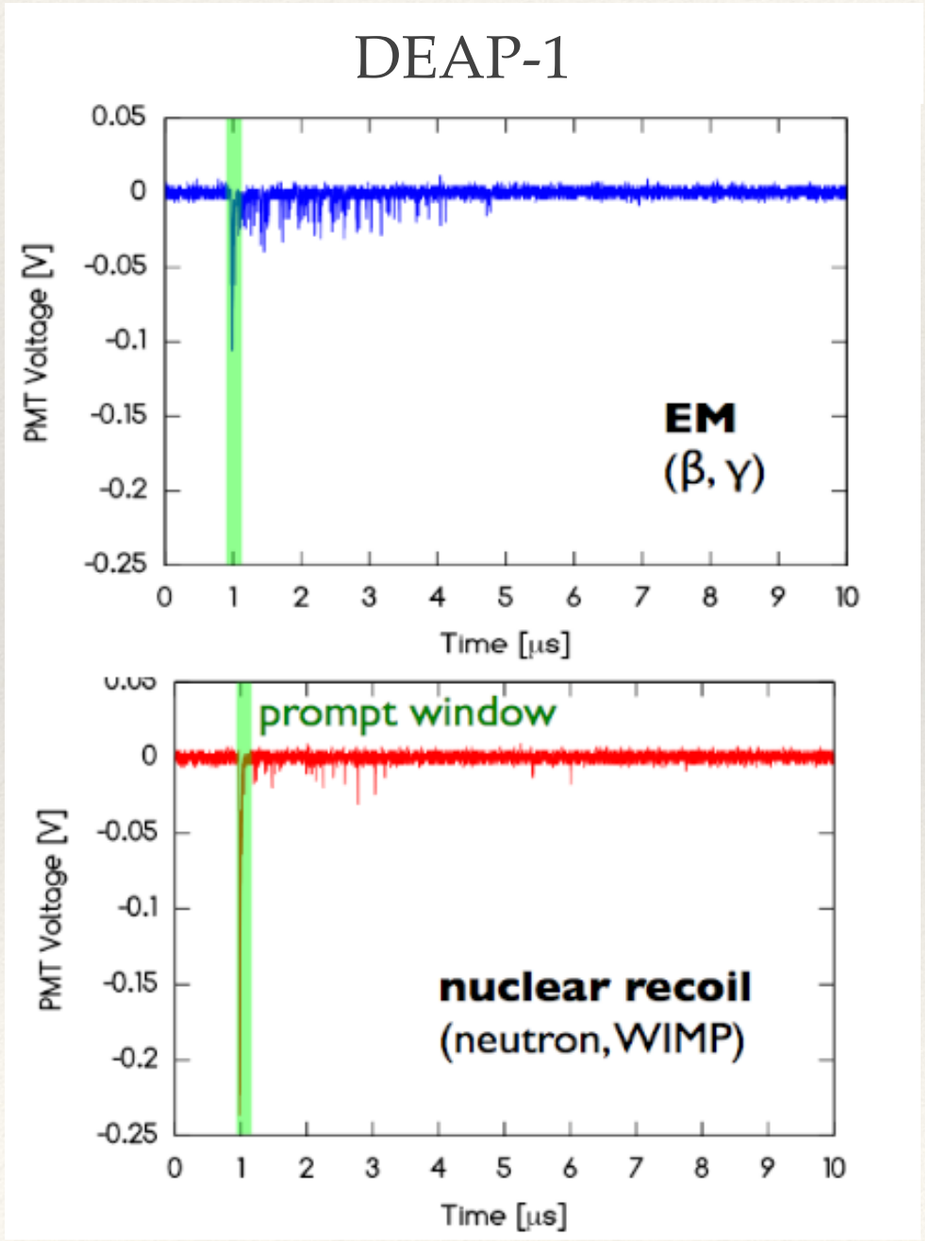


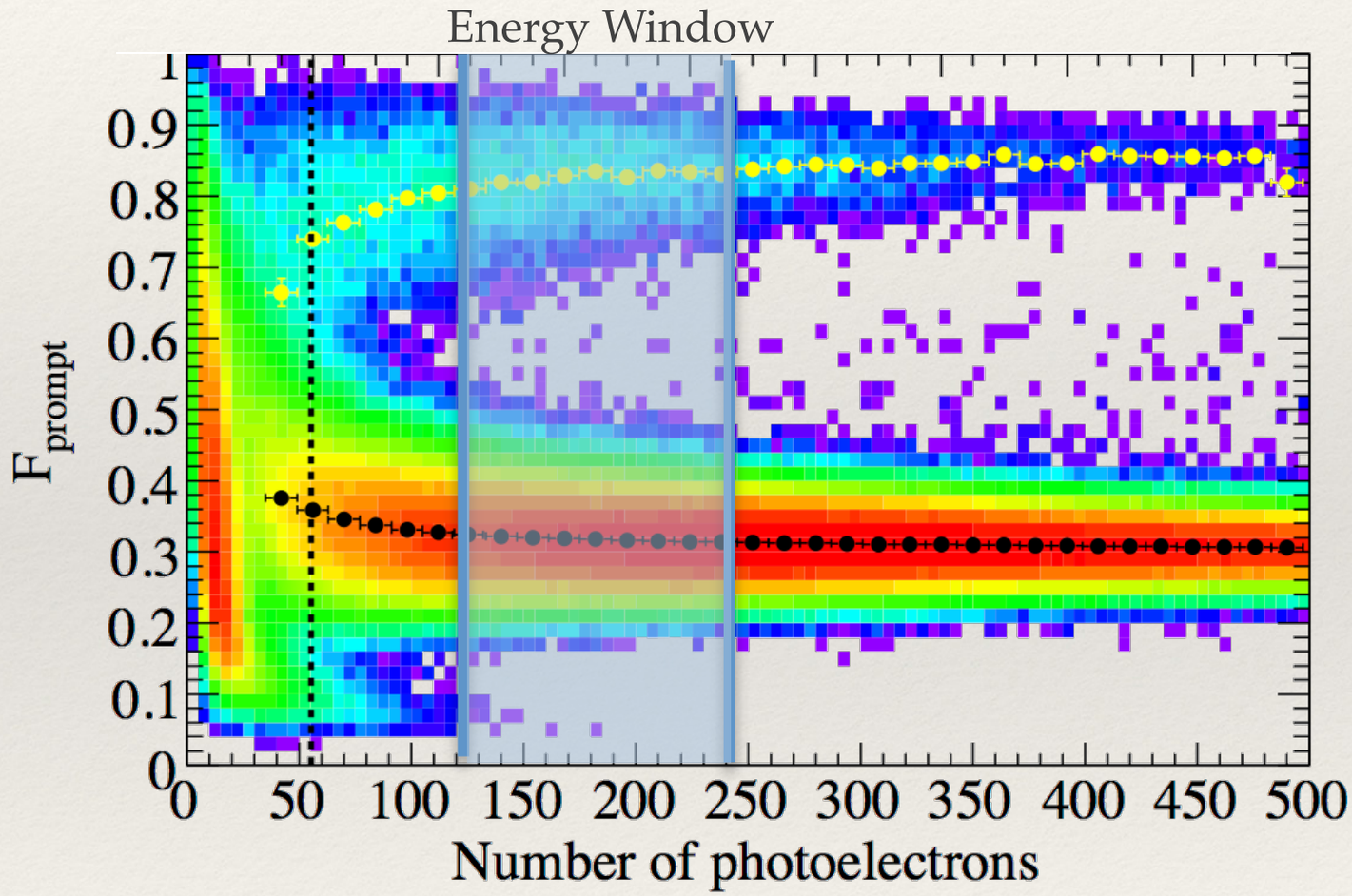
Excitation and ionisation | excimer formation | de-excitation | radiative decay

- Ionization of ultra high purity argon allows the production of excited dimers
- Formation of singlet and triplet states which have well separated lifetimes (7ns versus 1.5μs)
- Ratio of singlet and triplet states are exploited to produce excellent pulse shape discrimination (PSD)
- Radiative decay produces 128 nm light
- Projected light yield of 8 pe/keV$_{ee}$

Pulse Shape Discrimination

- Electronic and nuclear recoils produce different ratios of singlet and triplet states.





$$F_{\text{prompt}} = \frac{N_{\text{prompt}}}{N_{\text{total}}}$$

DEAP-1 Data

arXiv:0904.2930

Backgrounds

Budget for 3 year run <0.6 events

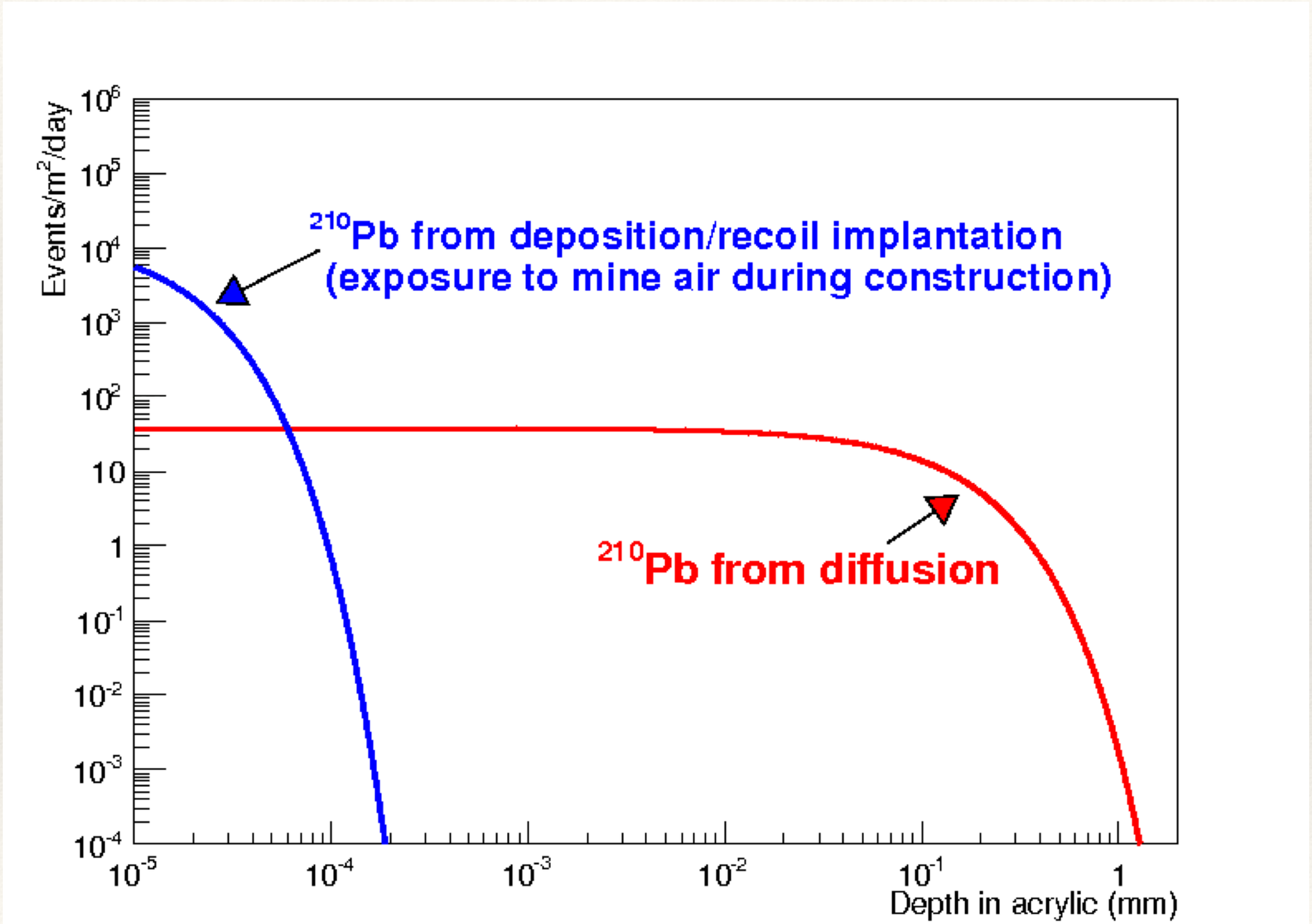
Background	Raw No. Events in Energy ROI	Fiducial No. Events in Energy ROI
Neutrons	30	<0.2
Surface α	150	<0.2
^{39}Ar β (natural)	1.6×10^9	<0.2
^{39}Ar β (depleted)*	8.0×10^7	<0.01

* Factor of 20 reduction
- Possible factor of 100

Energy ROI : 60 - 120 KeVr

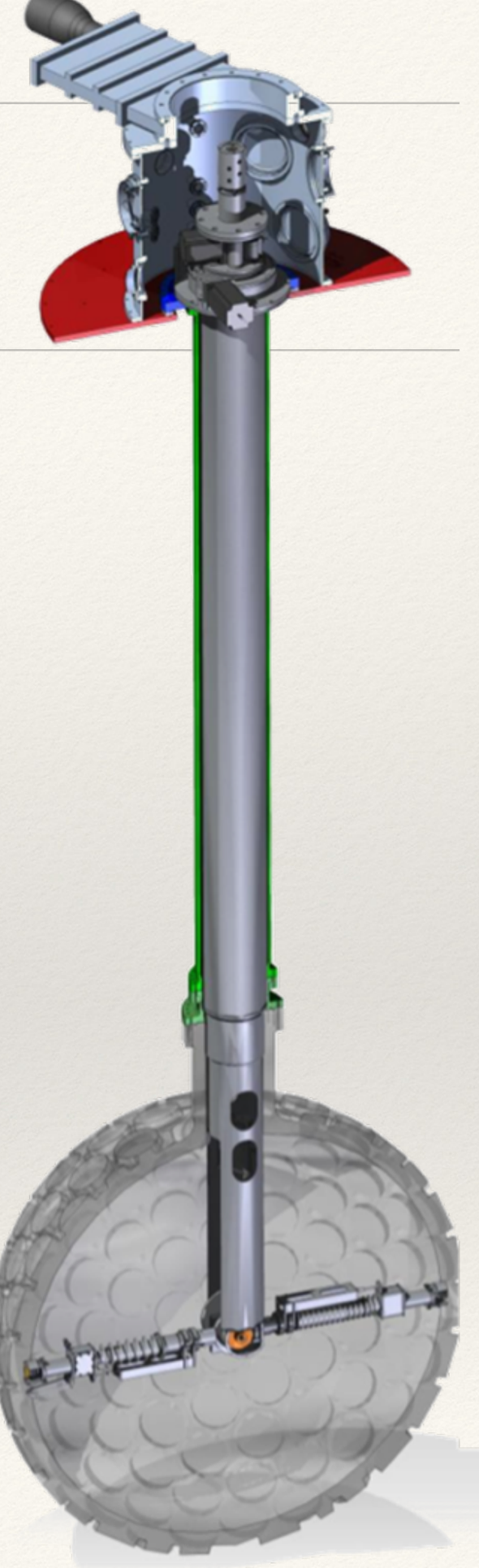
- Neutron recoils : (α,n) fission and μ-induced
  - Controlled by strict material screening and assay
  - Shielding (Acrylic + HDPE + Water)
- Surfaces : Rn daughters and contamination
  - Resurfacing acrylic vessel to reach bulk background levels
  - Passivation of all argon wetted surfaces
  - Fiducialisation
- β/γ events : ^{39}Ar
  - 1 Bq/kg
  - Predicted PSD reduction > 10^{-10}

AV alpha background reduction



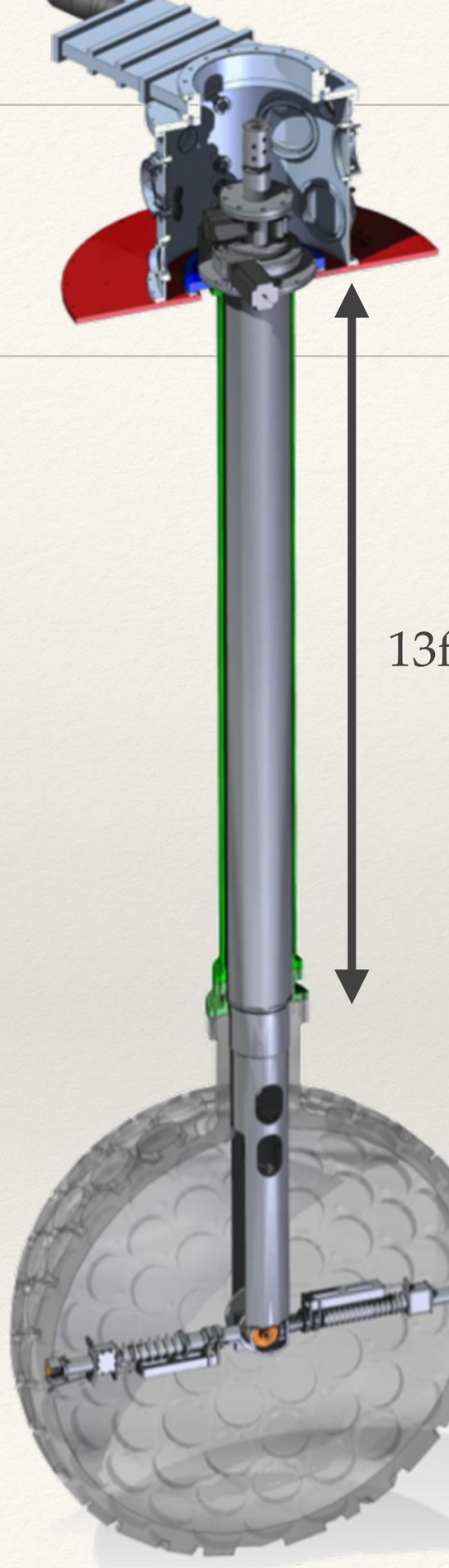
- Acrylic ^{210}Pb purity < 1.1×10^{-19} g/g - 0.1 events/3 years

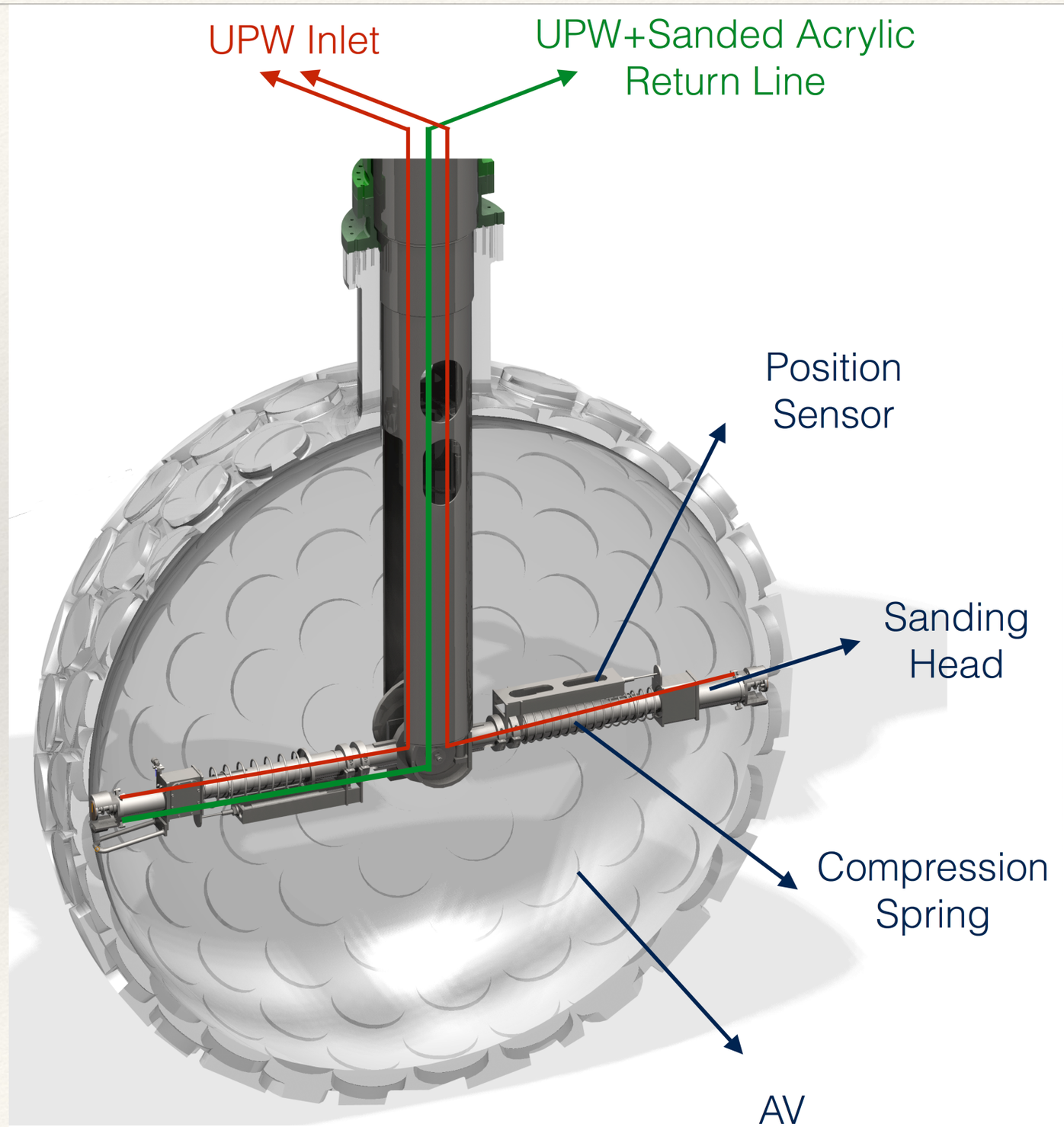
DEAP3600 Resurfacer



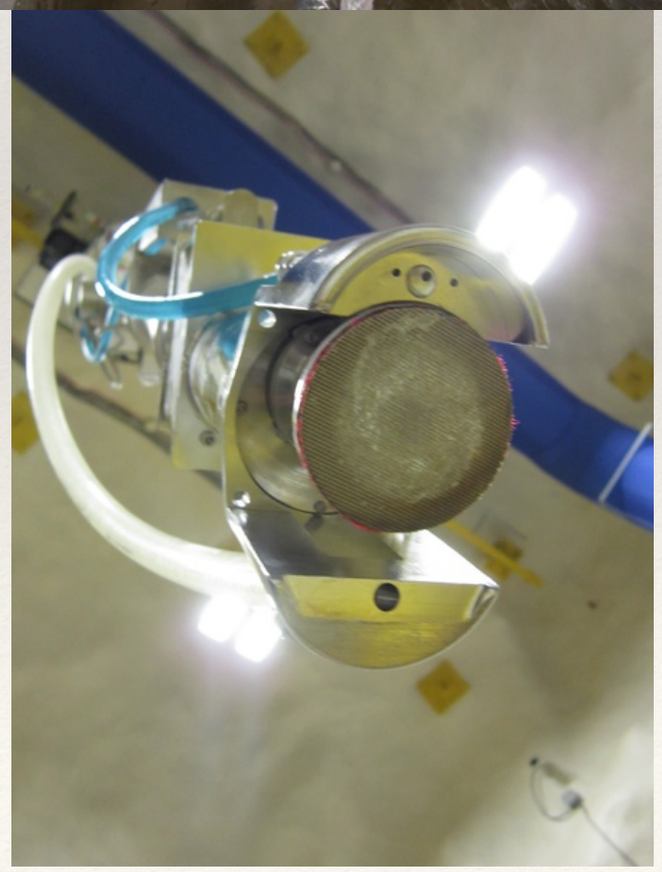
- Designed for 0.1-1mm acrylic removal inner AV
- Radon scrubbed N_2 purge gas and UPW controls Rn levels during operation.
- Surface contamination reduced to bulk purity levels
- Deployed September 2014
- Completed 200 hr operation.

DEAP3600 Resurfacer





DEAP3600 Resurfacer

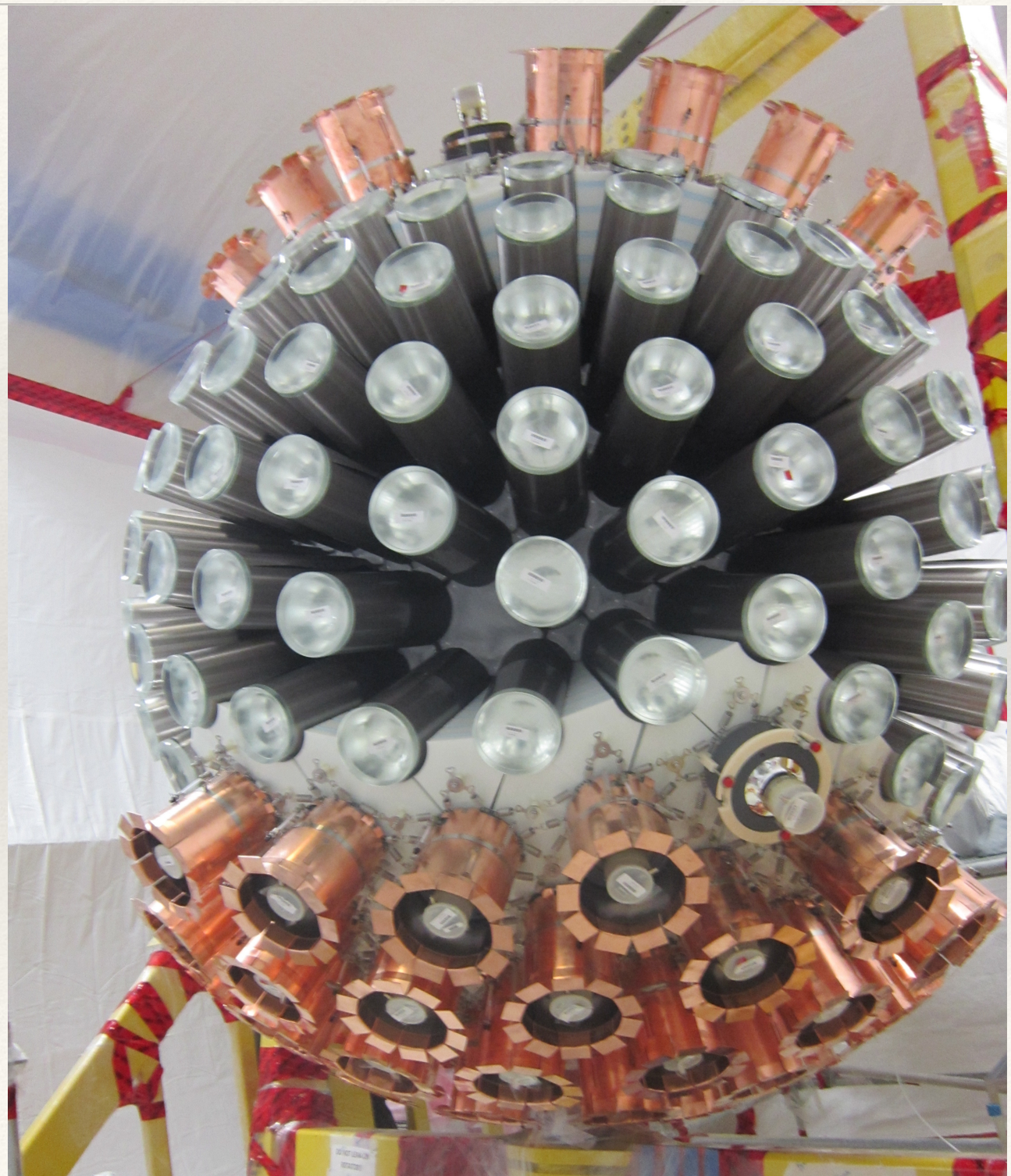


Construction Milestones

- **Acrylic Vessel completed November 2013**
- Installation of inner detector instrumentation through to June 2014
- AV installed in final location July 2014
- AV Complete November 2014
- Steel Shell and Veto PMTs completed April 2015

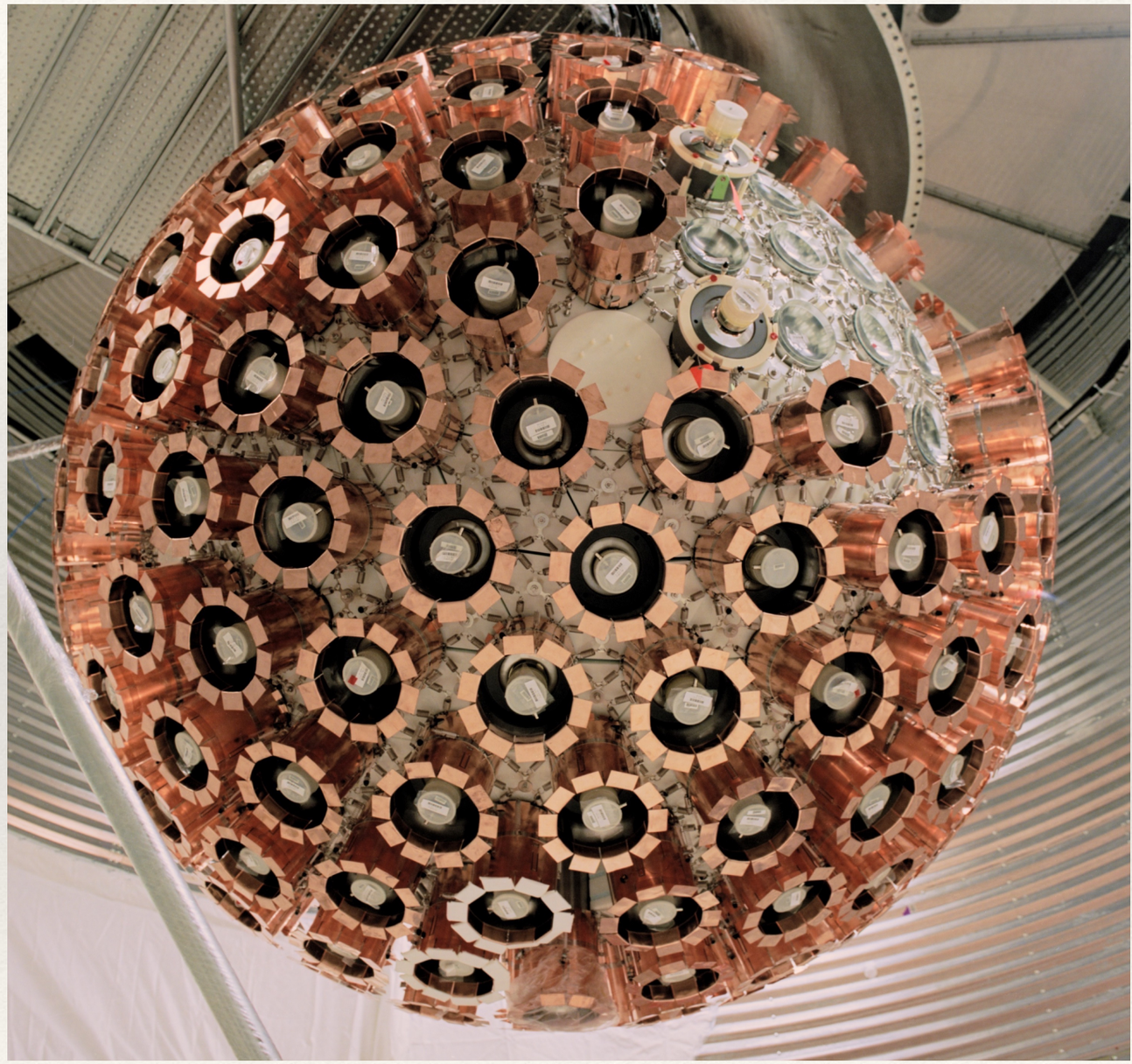
Construction Milestones

- Acrylic Vessel completed November 2013
- **Installation of inner detector instrumentation through to June 2014**
- AV installed in final location July 2014
- AV Complete November 2014
- Steel Shell and Veto PMTs completed April 2015



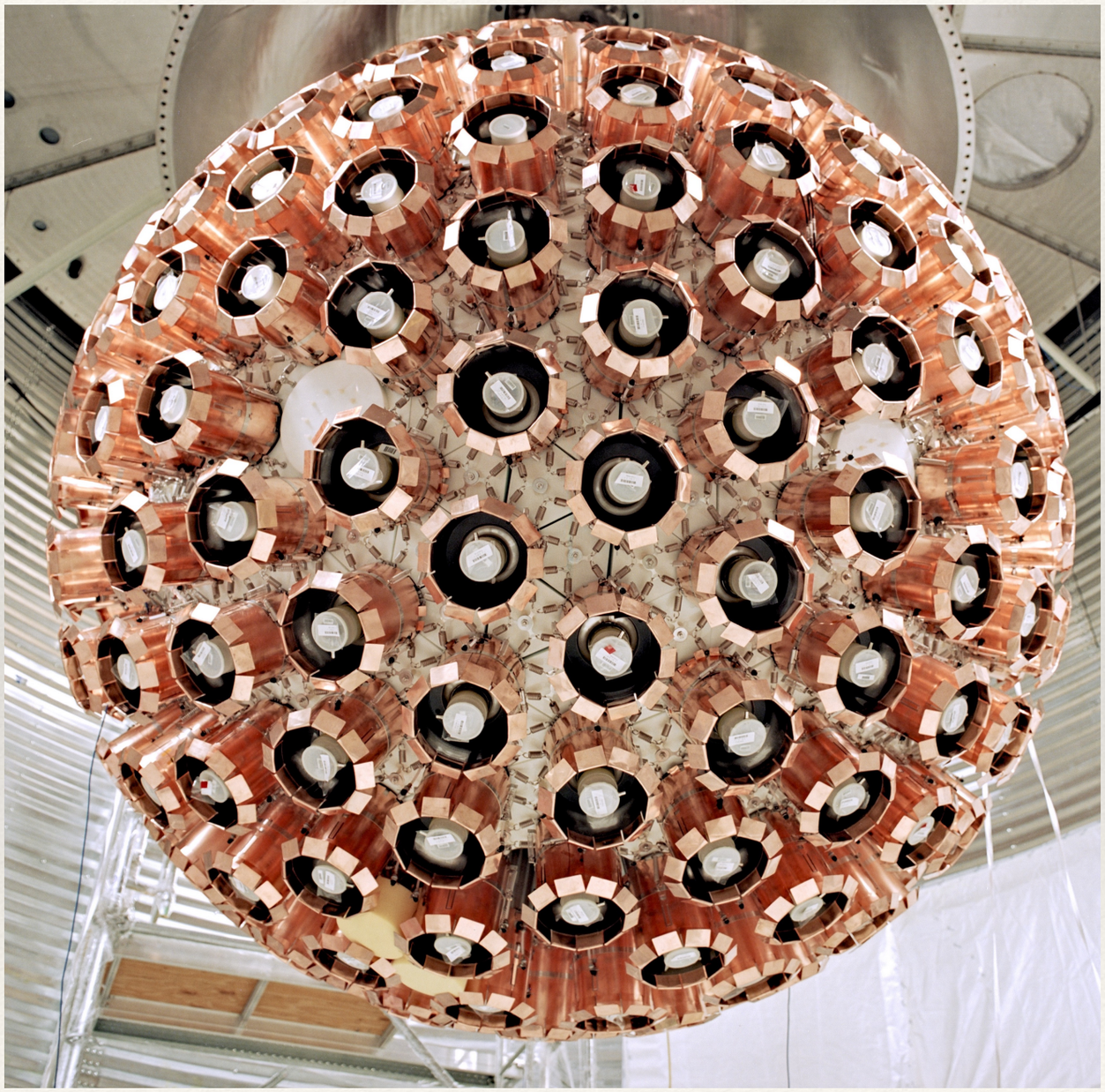
Construction Milestones

- Acrylic Vessel completed November 2013
- Installation of inner detector instrumentation through to June 2014
- **AV installed in final location July 2014**
- AV Complete November 2014
- Steel Shell and Veto PMTs completed April 2015



Construction Milestones

- Acrylic Vessel completed November 2013
- Installation of inner detector instrumentation through to June 2014
- AV installed in final location July 2014
- **AV Complete November 2014**
- Steel Shell and Veto PMTs completed April 2015

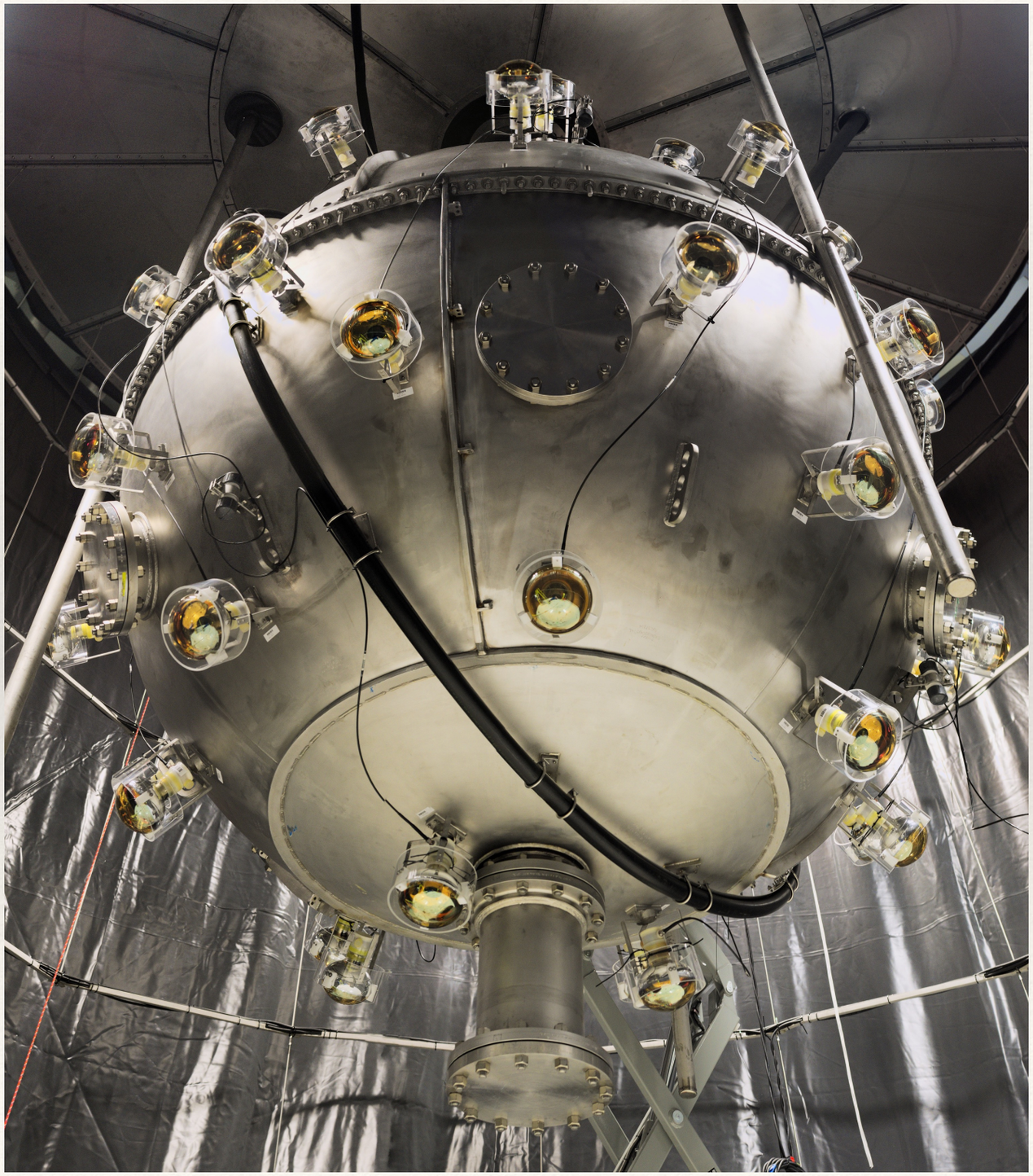


Construction Milestones

- Acrylic Vessel completed November 2013
- Installation of inner detector instrumentation through to June 2014
- AV installed in final location July 2014
- **AV Complete November 2014**
- Steel Shell and Veto PMTs completed April 2015

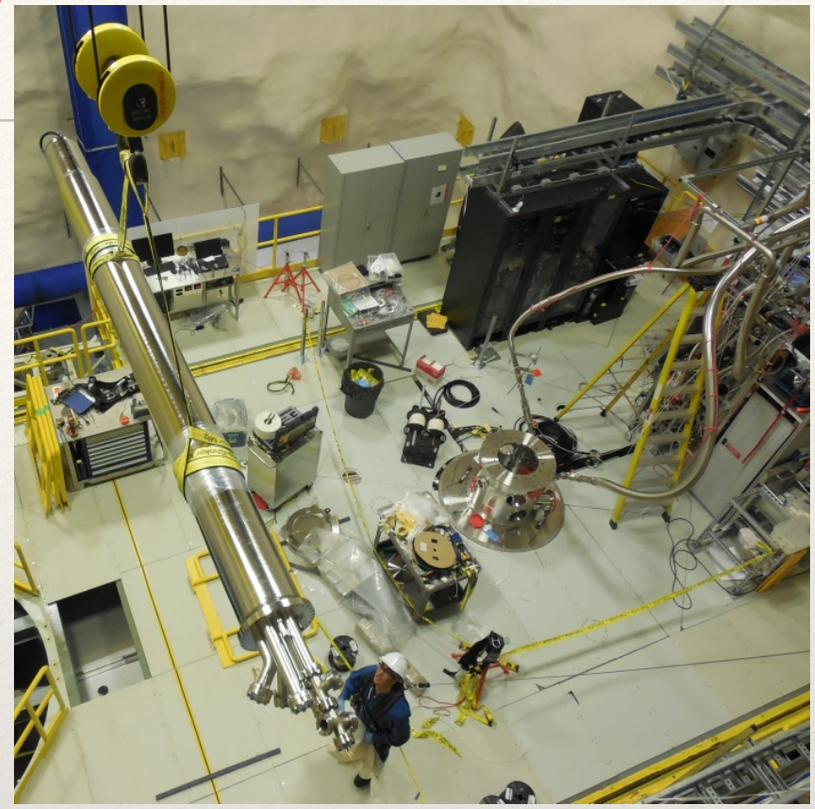
Construction Milestones

- Acrylic Vessel completed November 2013
- Installation of inner detector instrumentation through to June 2014
- AV installed in final location July 2014
- AV Complete November 2014
- **Steel Shell and Veto PMTs completed April 2015**



Cryogenics and Process Systems

- Purification Systems
  - Delivered and installed
- Liquid Nitrogen Systems
  - Storage capable of maintaining AV for 4 days
  - Commissioned and been operating since June 2014
- Liquid Argon Storage
  - Began transfers between surface and SNOLAB March 2015
- Detector Cooling
  - Delivered and commissioned June 2014

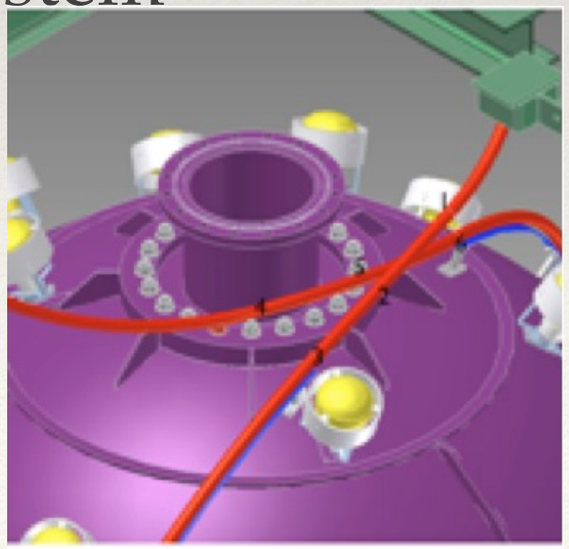


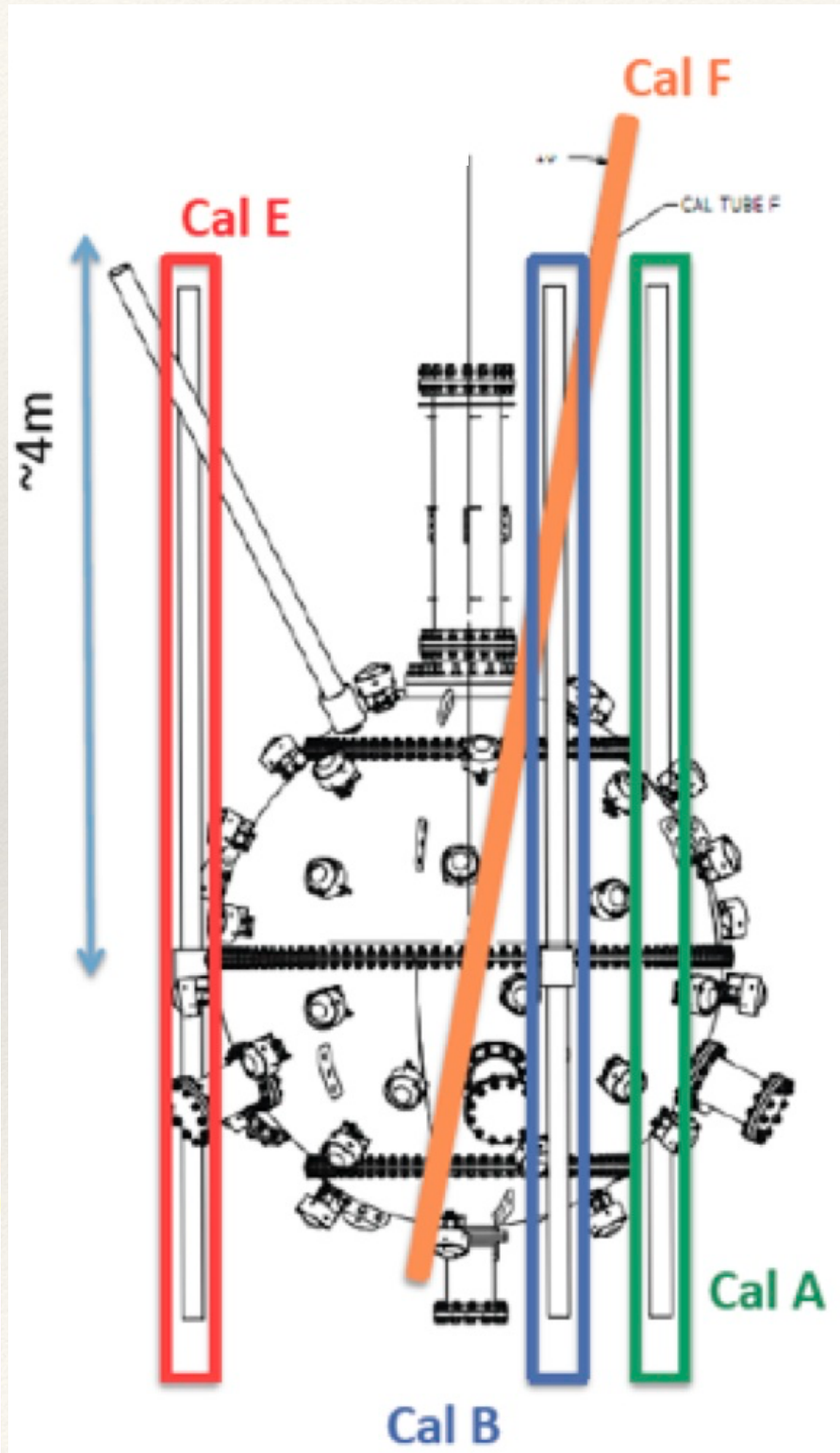
Calibration Commissioning

- Successful high voltage ramping of all 255 PMTs
- Exercised DAQ processing chain
- Signal injection
- Light injection system
  - Acrylic and Aluminium Reflectors and Fibre Optics Systems (AARFS) operated
  - Laserball before cold data
- Neutron and Gamma calibration
  - Deployment hardware complete

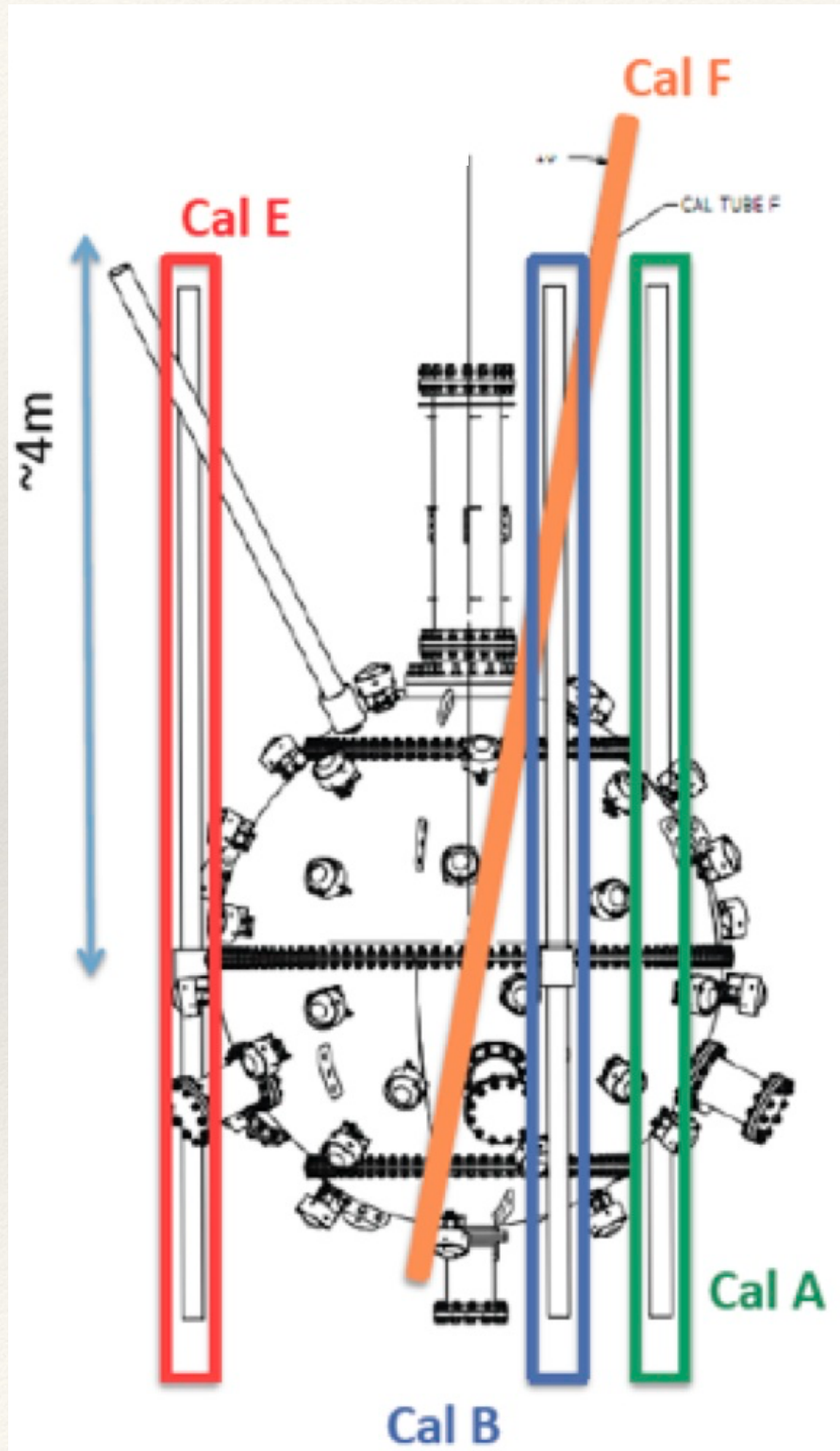
Neutron and Gamma Calibration

- Equator calibration via Cal A, B and E
  - Provides equal distance calibration set at different ϕ
- Looped tube Cal F
  - Provides equal distance calibration set at different θ
  - Calibration of neck region
- Calibration tubes and race track served by stepper motor positioning system
- Calibration via tagged AmBe and ^{22}Na sources

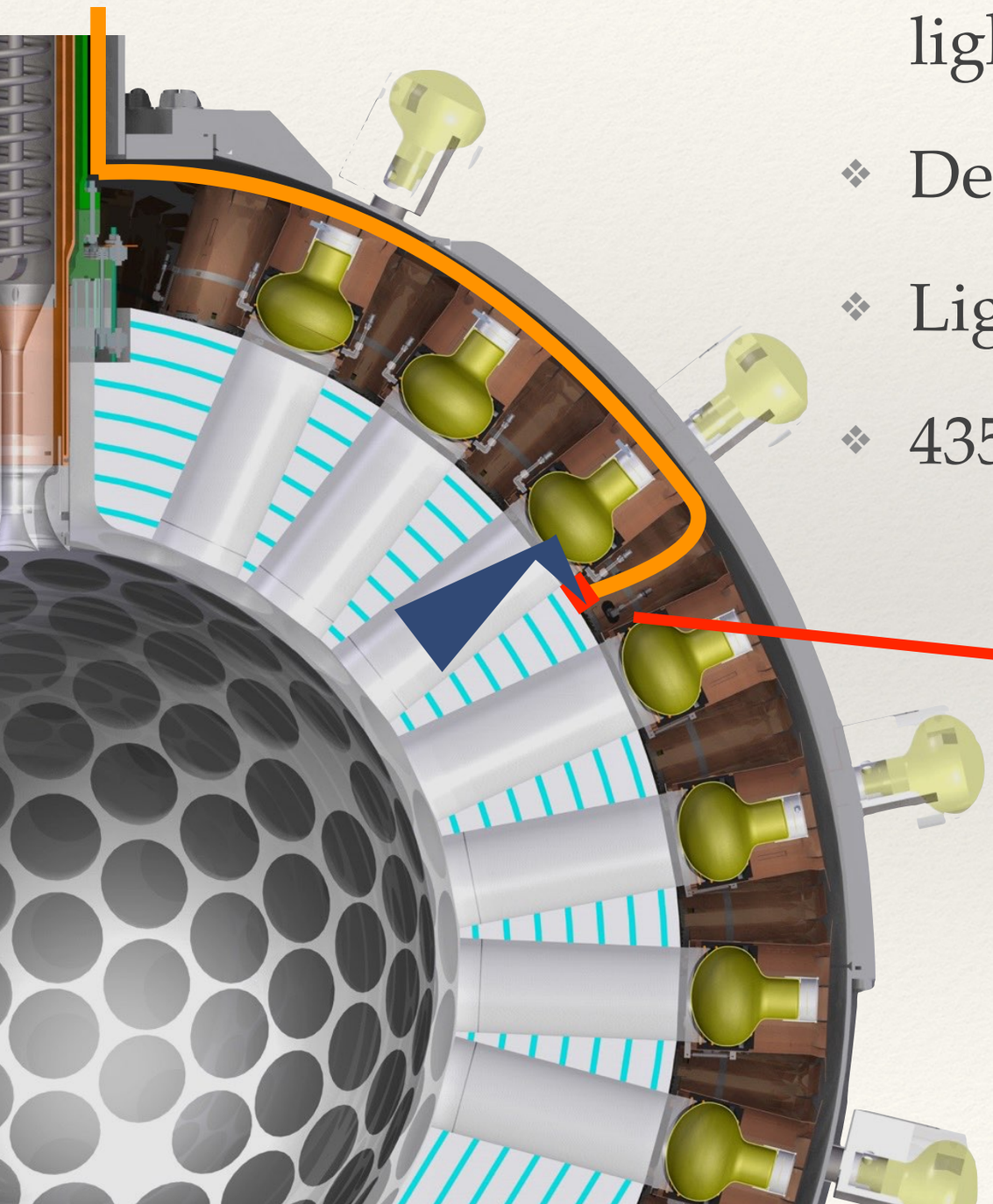




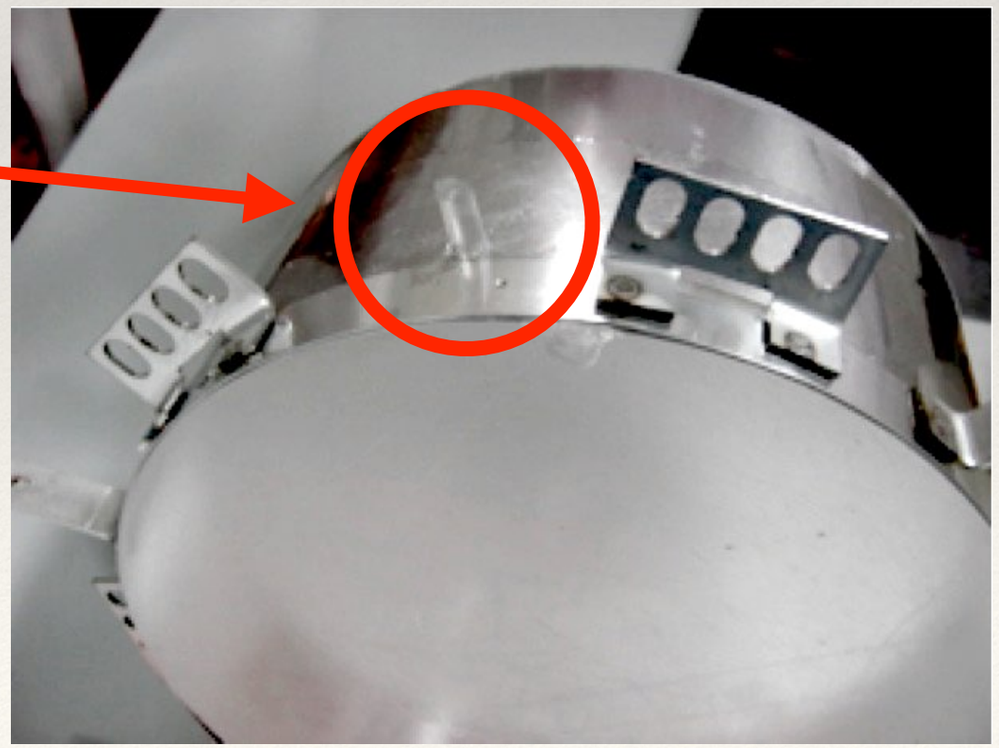
Neutron and Gamma Calibration



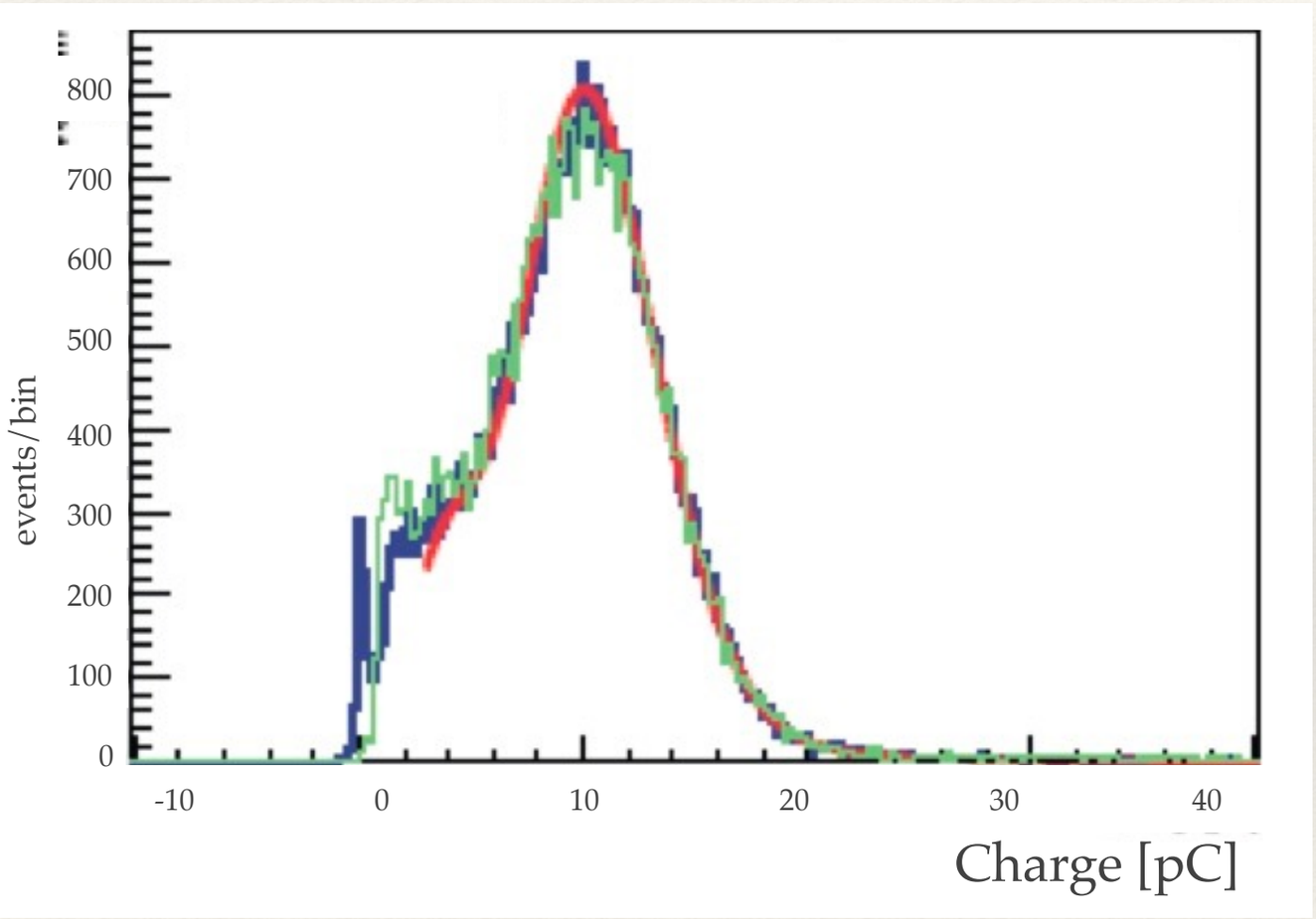
AARFS



- Aluminium coated stubs bonded to 20 light guides around the detector
- Deliver light via fibres directed at the PMT
- Light is reflected into the detector
- 435nm LED and 445nm laser



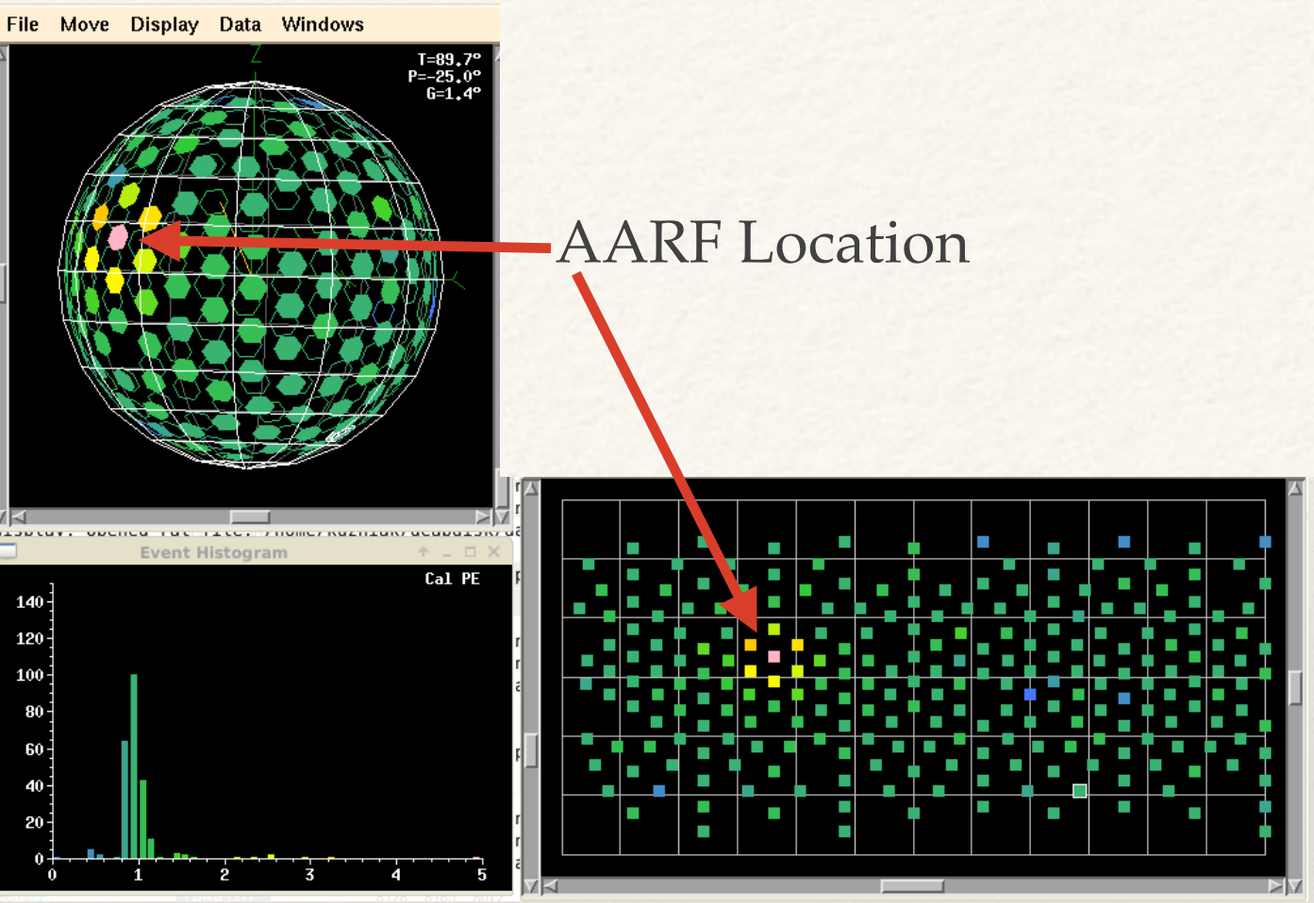
AARFS

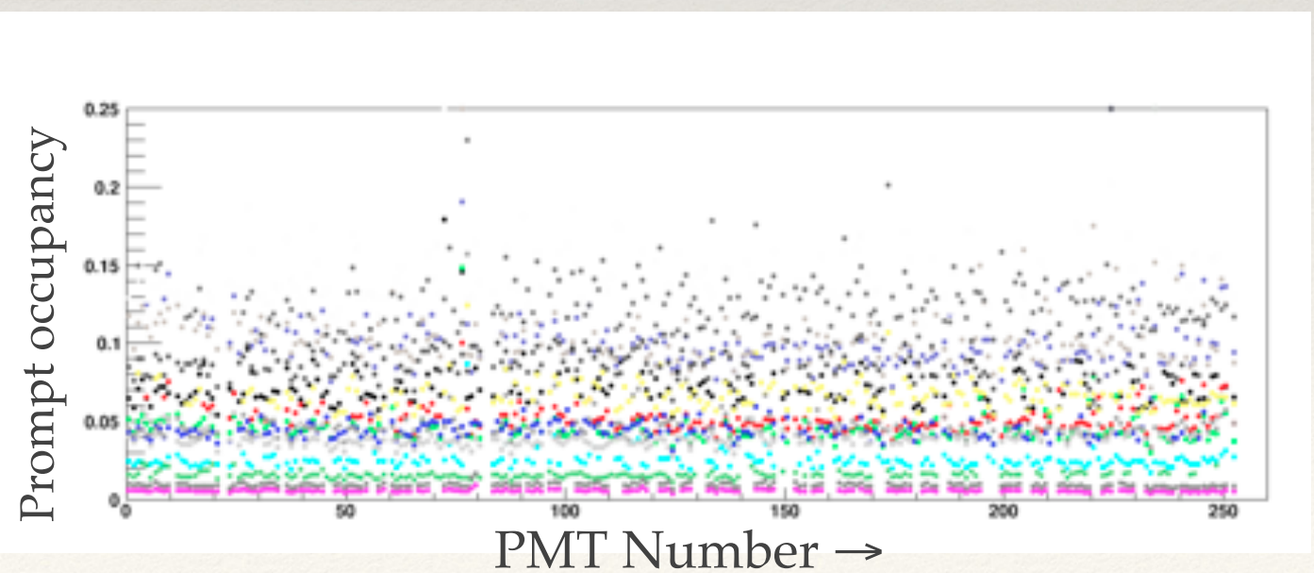


AARFS Low intensity
Dark Noise SPE

- PMT response
- SPE Calibration
  - Good dark noise and low light injection agreement
- PMT Timing
- Detector optics
  - Mature light transport models

AARFS



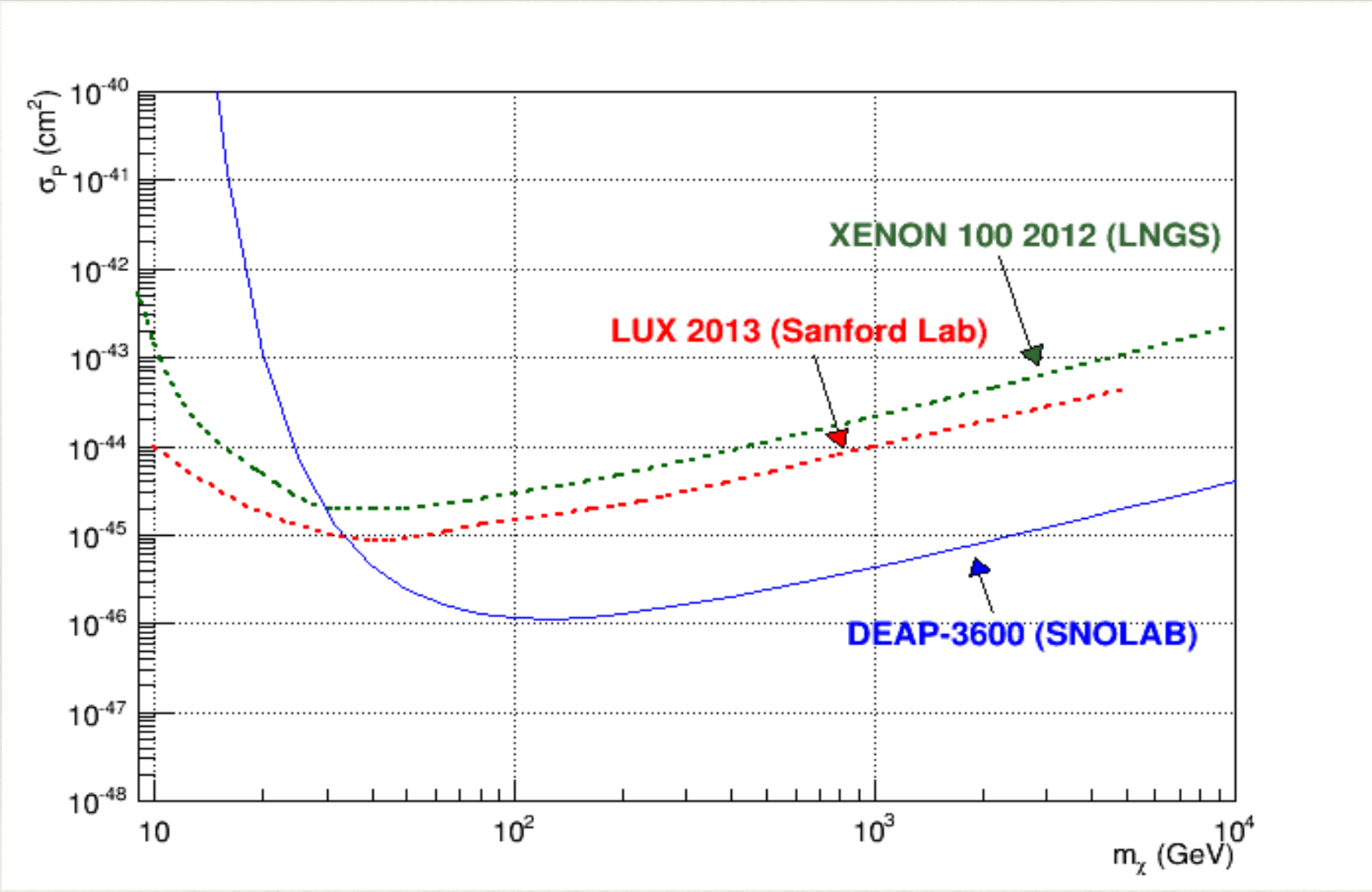


- PMT response
- SPE Calibration
  - Good dark noise and low light injection agreement
- PMT Timing
- Detector optics
  - Mature light transport models

Current and Future

- TPB vacuum deposition - May
- Laser ball optical calibration - May
- Vacuum + TPB data - June
- Installation of detector cooling coils - July
- Ultra high purity Argon gas fill and gas data - August onwards

Physics Reach



- 10^{-46} cm^2 sensitivity at 100 GeV for 3 years physics run
- First dark matter physics results 2016