Dark matter **E**xperiment using **A**rgon **P**ulse-shape discrimination: DEAP-3600

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for the DEAP Collaboration

Symmetries in Subatomic Physics
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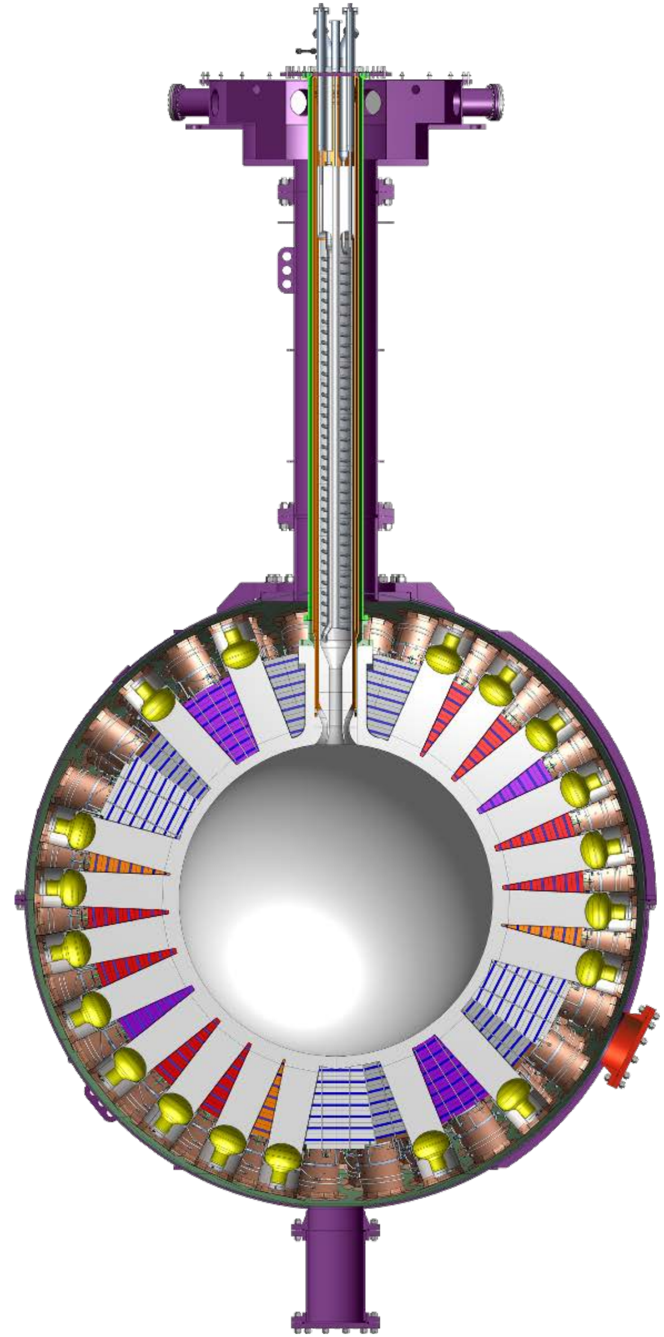
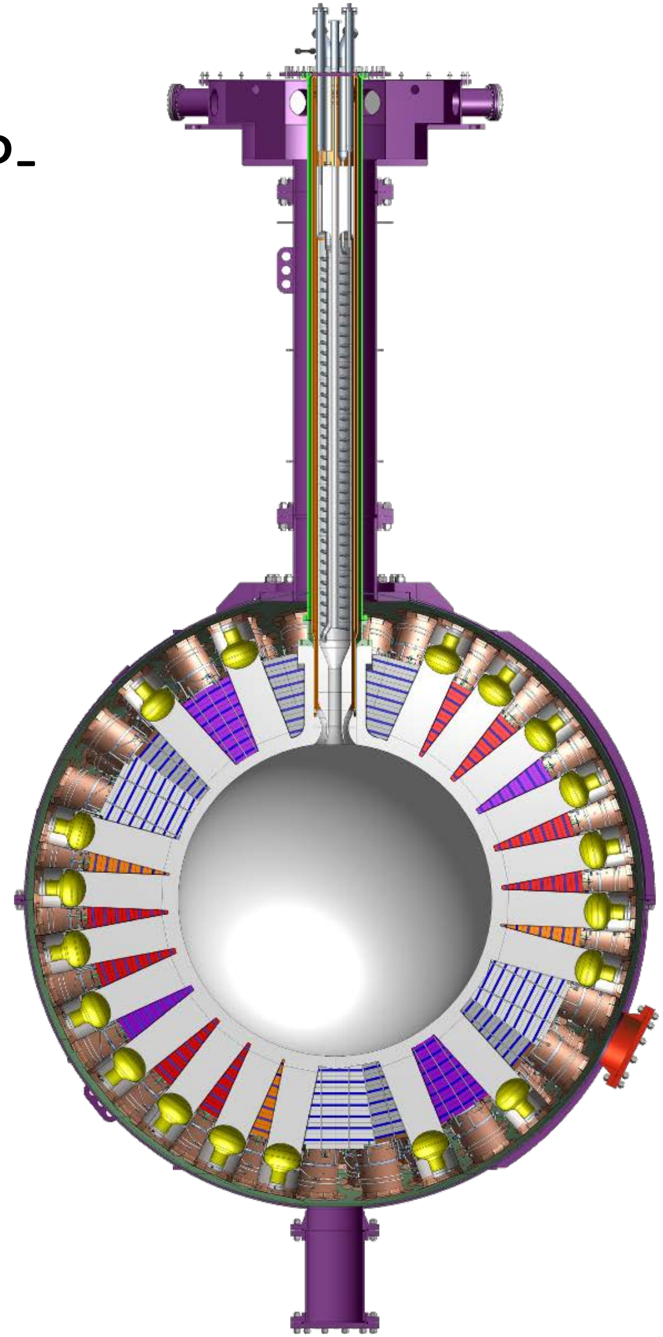
DEAP-3600 was designed from the inside out to achieve WIMP-nucleon recoil sensitivity of **10^{-46} cm^2 at 100 GeV** in 3 tonne-years using <u>single-phase liquid argon</u>.



Liquid argon is a good target for coherent WIMP-nucleon scattering



Diffraction effects are small.

Mass 40 gives sensitivity to lower-mass WIMPS.

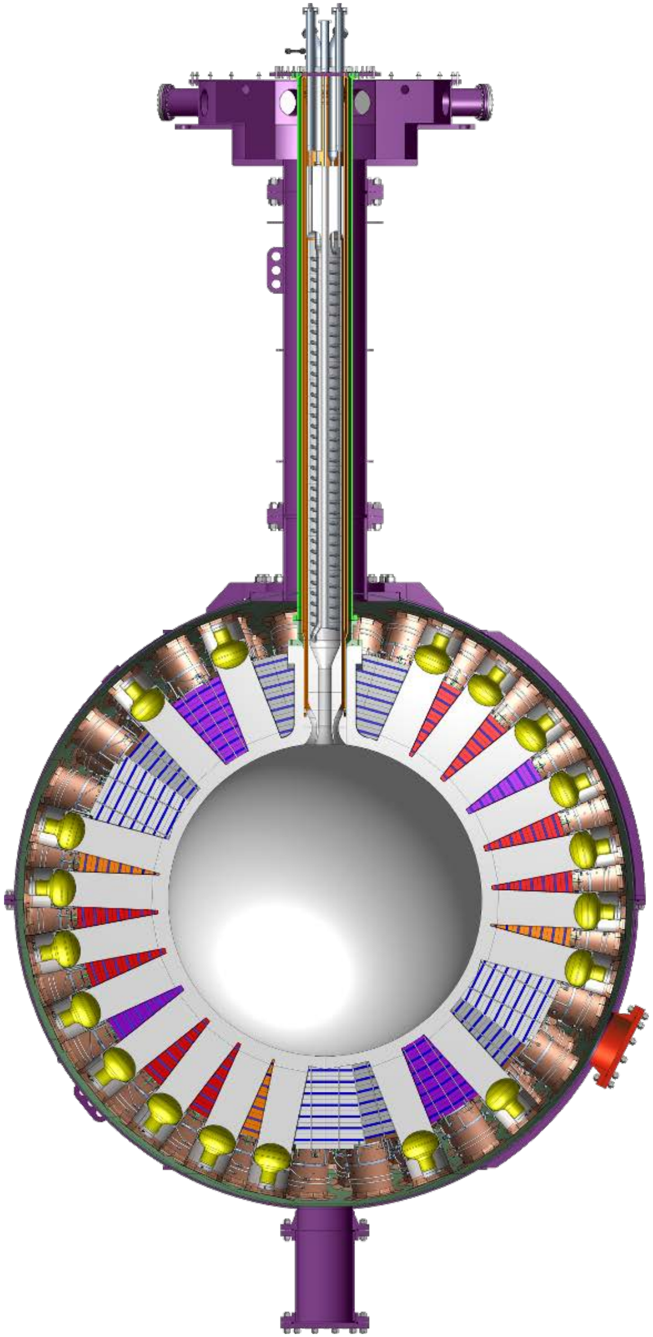
But must contend with Ar-39 beta decays at 1 Bq/kg.

Surface backgrounds,

fast neutrons, and

electromagnetic backgrounds

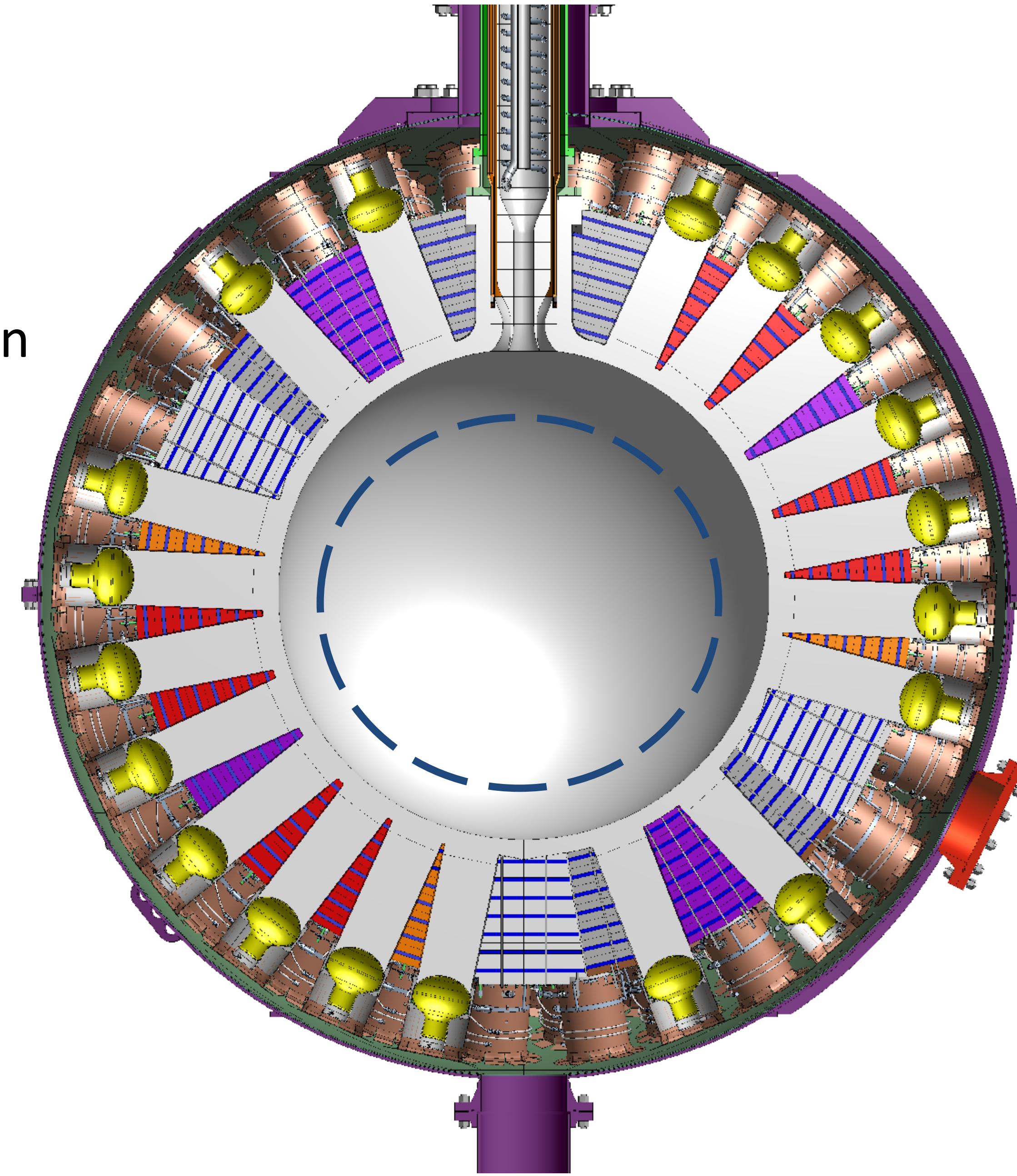
controlled to **<0.2/ 3 year/tonne** each.



Starting with the liquid argon

Will use event reconstruction to create a one-tonne fiducial volume away from surfaces.

Will use pulse-shape discrimination (PSD) to eliminate electromagnetic backgrounds.



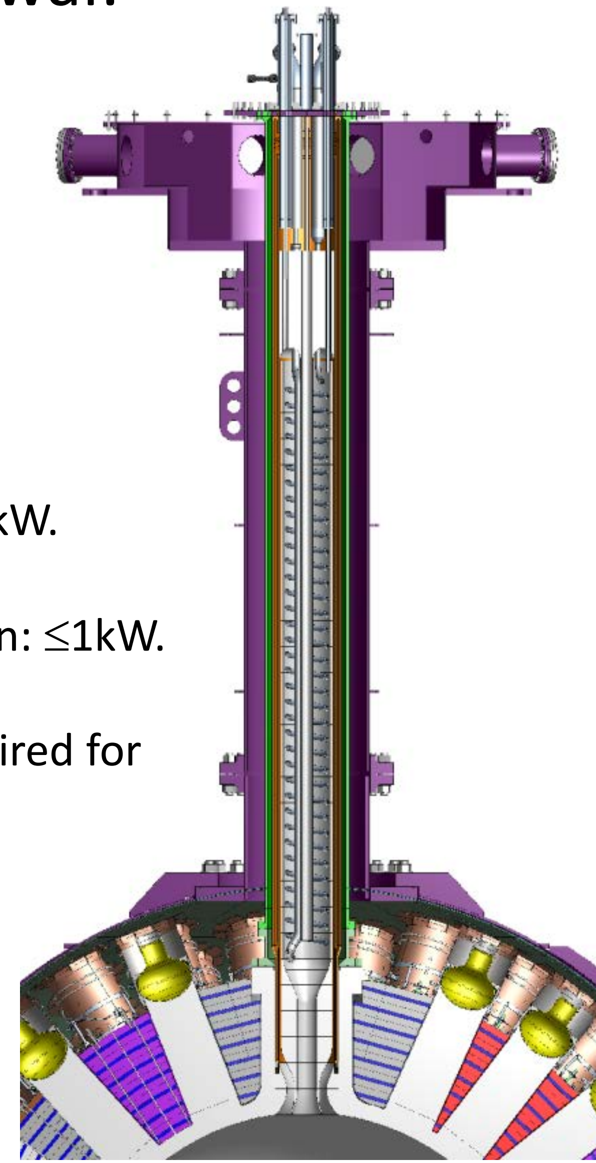
Cooling with coils in neck fed with liquid nitrogen in closed loop from a large dewar.

- CFD calculations demonstrate convective flow.
- Nitrogen cooling will last four days in power outage.
- Cooling coils tested with realistic heat loads.

Cooling system: 3kW.

Heat load on argon: ≤1kW.

(Cooling also required for radon trap.)

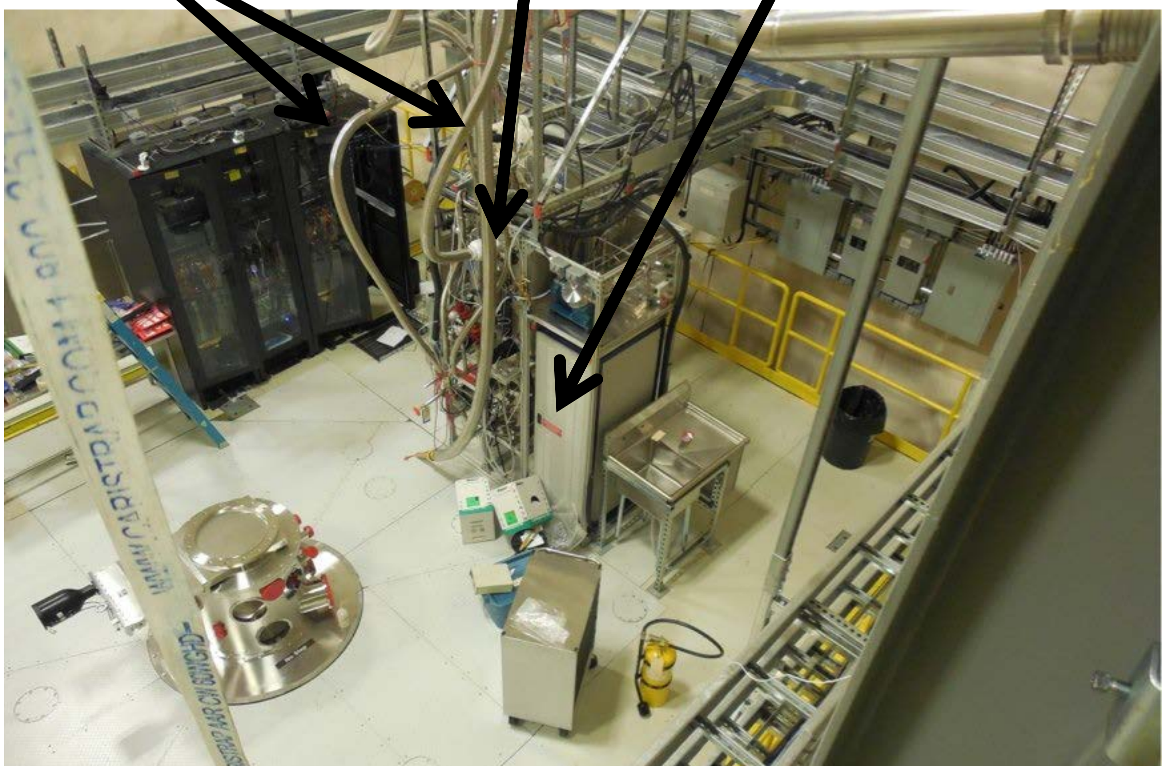


All Argon process system components tested for radon emanation. Cooling without pumping argon.

Process rack including Rn scrubber

Nitrogen cooling lines

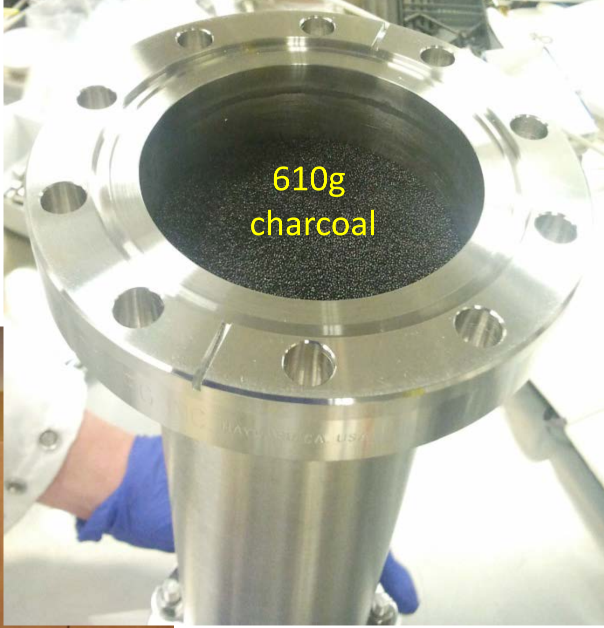
SAES getter: ppm impurity in; ppb out
Hot zirconium. Does not remove radon



Design of process systems based on minimizing sources of radon:

All valves and components considered a source of radon and justified against that risk.

Charcoal trap removes all radon: negligible punch through



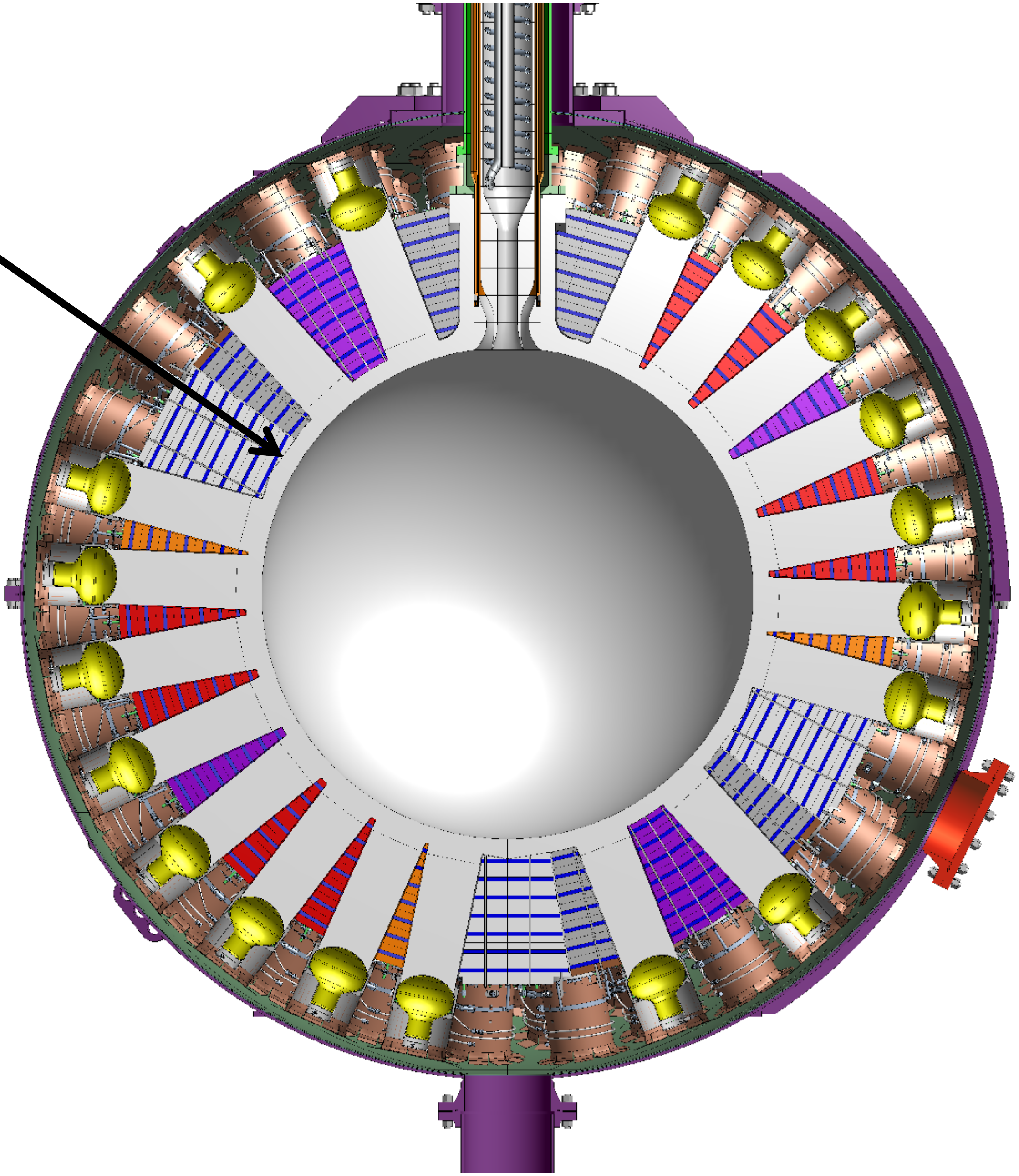
Operating Temperature: 110 K

The Acrylic Sphere

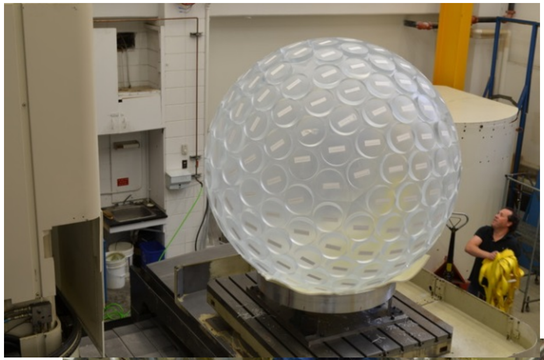
Nuclear recoils from radon progeny can create WIMP-like events in detector.

Control with
1: Strict radio-purity regime for acrylic and wavelength-shifter coating

2: Event reconstruction

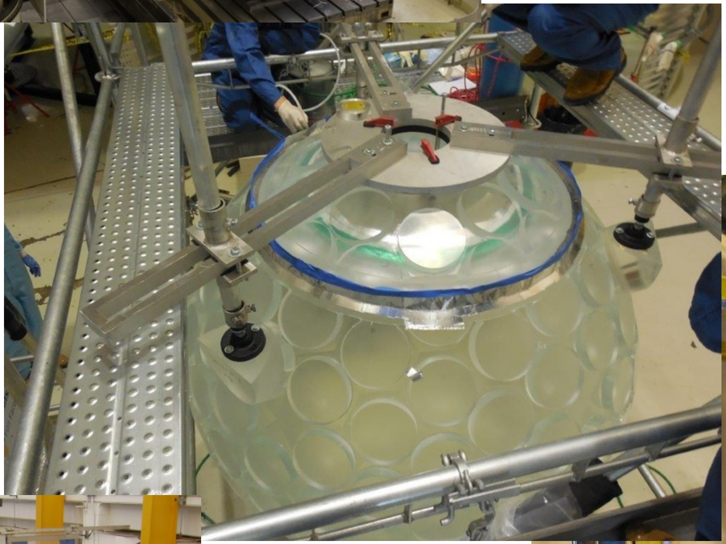


Radon History of **Acrylic Vessel** Tracked Throughout Production



University of Alberta

Reported at Low Radioactivity Techniques, LRT2013 at LNGS.
AIP Proceedings v1549



Reynolds Polymer CO, USA

SNOLAB

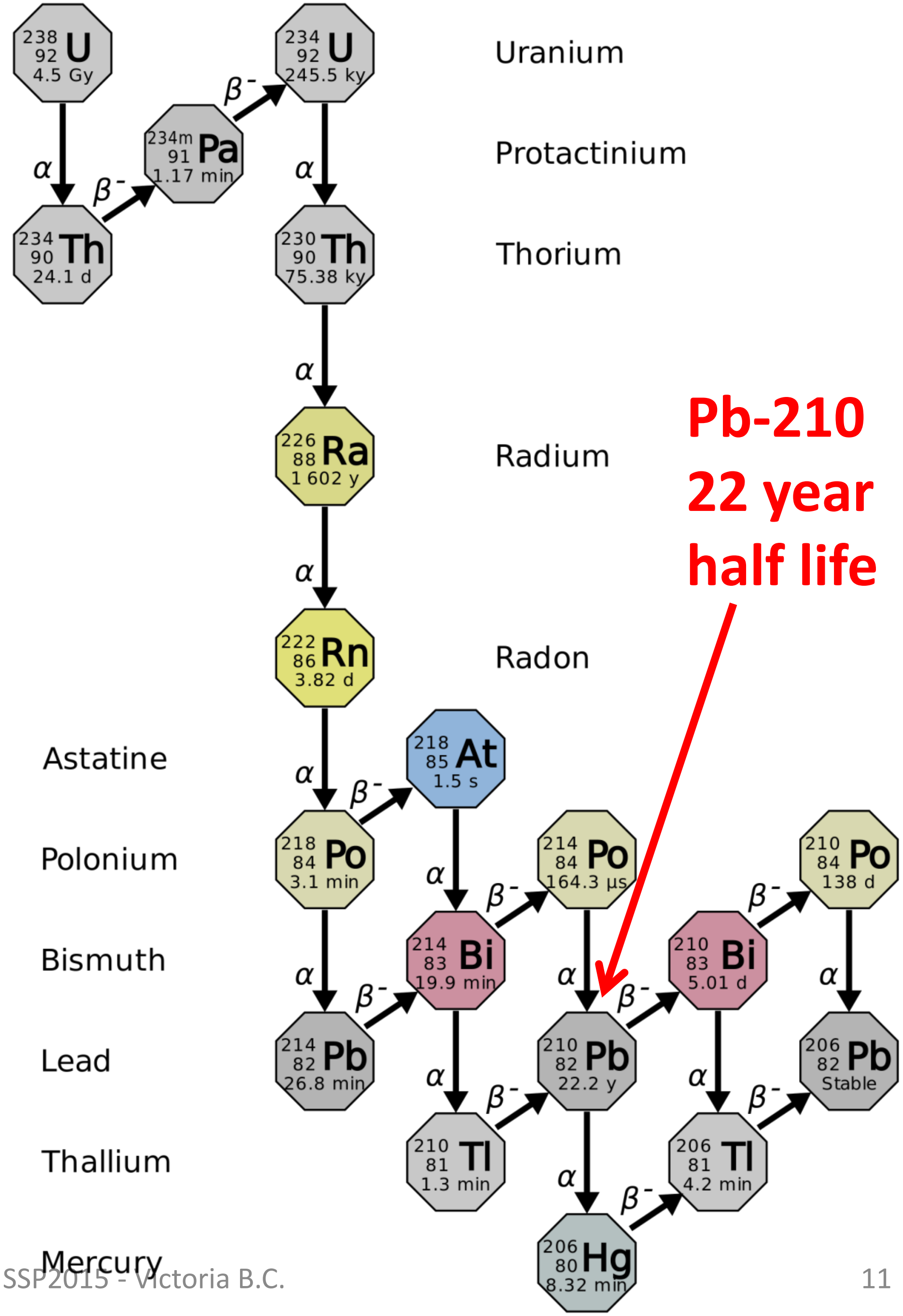
Acrylic purity tracked using conservative models of radon exposure during production.

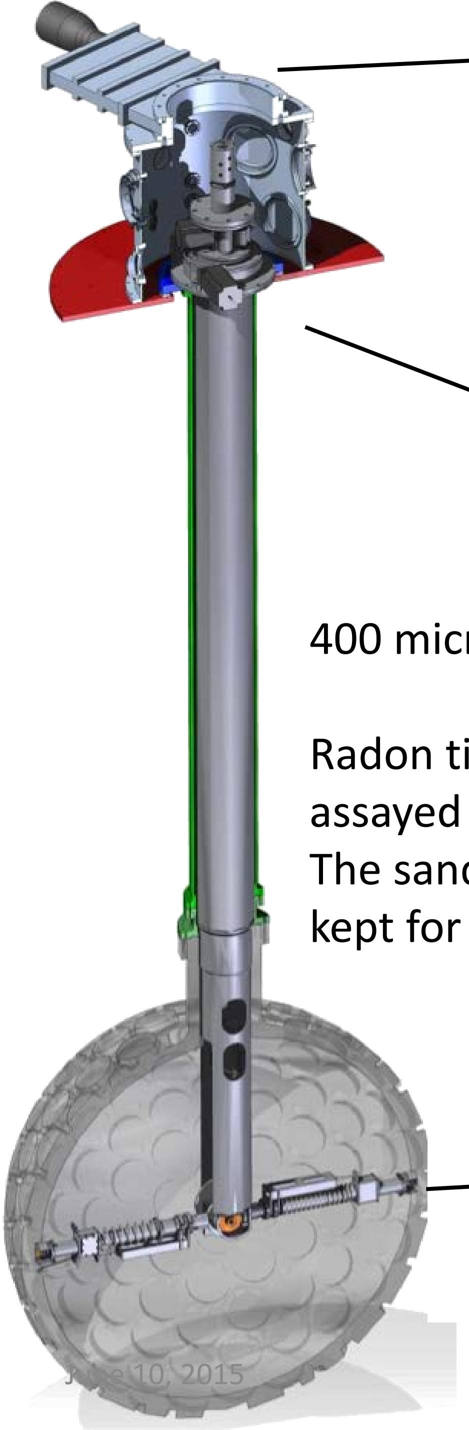
~10^{-20} g/g Pb-210

And acrylic from panels assayed for Pb-210

< 10^{-19} grams/gram Pb-210 contamination measured

in raw materials



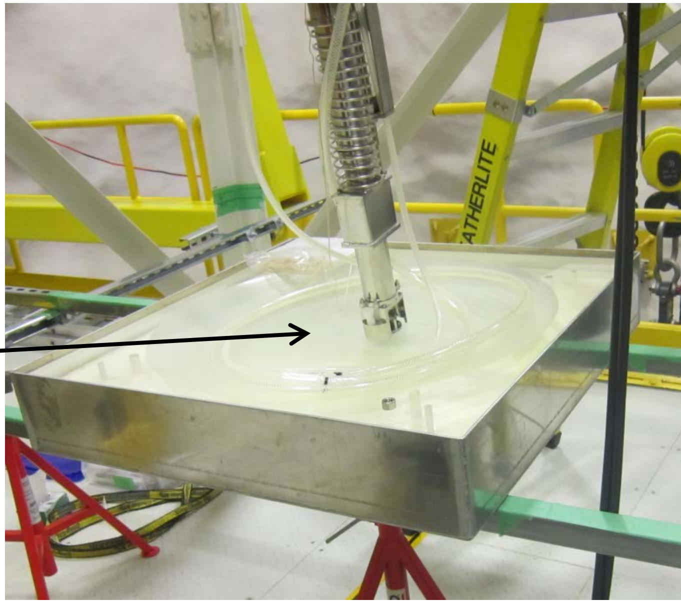


Radon can **diffuse into the acrylic** or decay near it during construction. Progeny radioactive.

<u>Resurfacing removed these progeny</u>.

400 microns of acrylic removed (mean).

Radon tight system. All components assayed for radon emanation.
The sanding residue was extracted and kept for assay.



SNOLAB air 120 Bq/m^3

UV Light Wavelength is Shifted to Blue at Acrylic Surface with a Thin Layer of T.P.B.

It is applied onto the vessel from a crucible inside a small heated sphere suspended at the center of the acrylic vessel.

High-quality vacuum is needed to ensure the mean free path of the TPB is large.

Heating coil

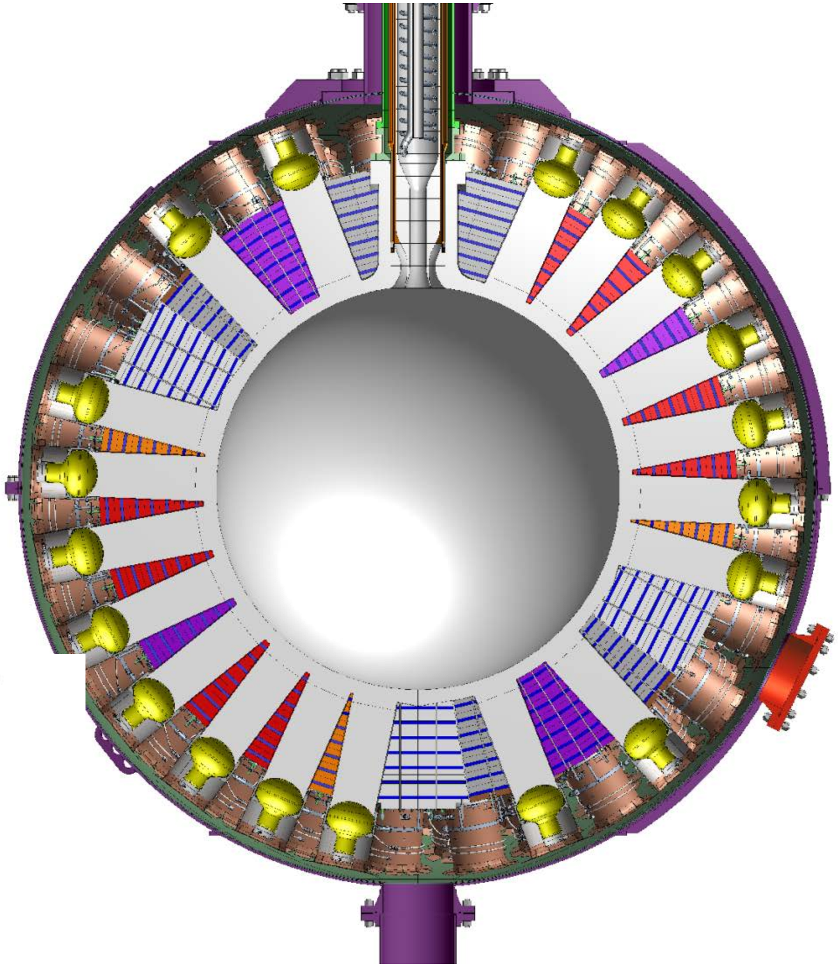
Crucible inside

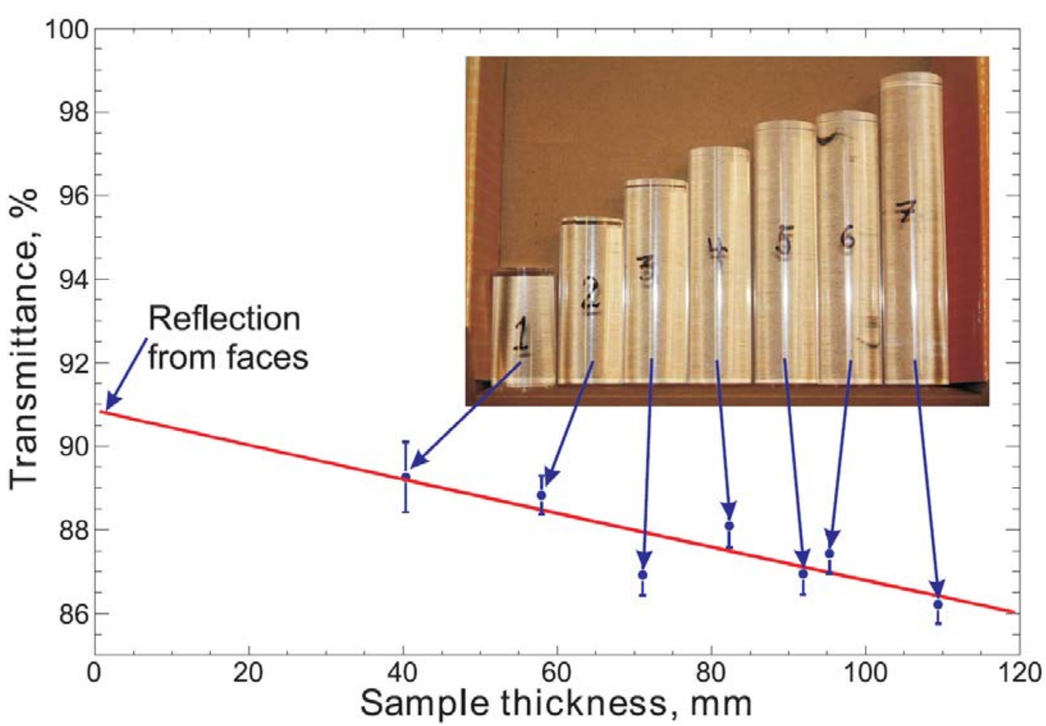
1,1,4,4-tetraphenyl-1,3-butadiene

The light guides allow the HQE PMTs to operate warm.

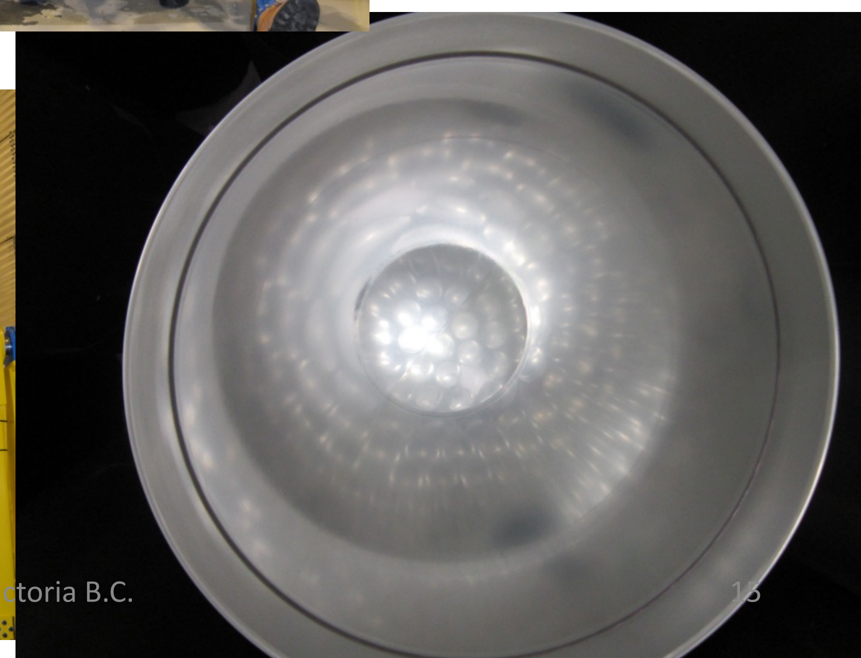
Light guide acrylic tested for transparency as PSD depends exponentially on light yield.

They provide shielding from PMT neutrons.

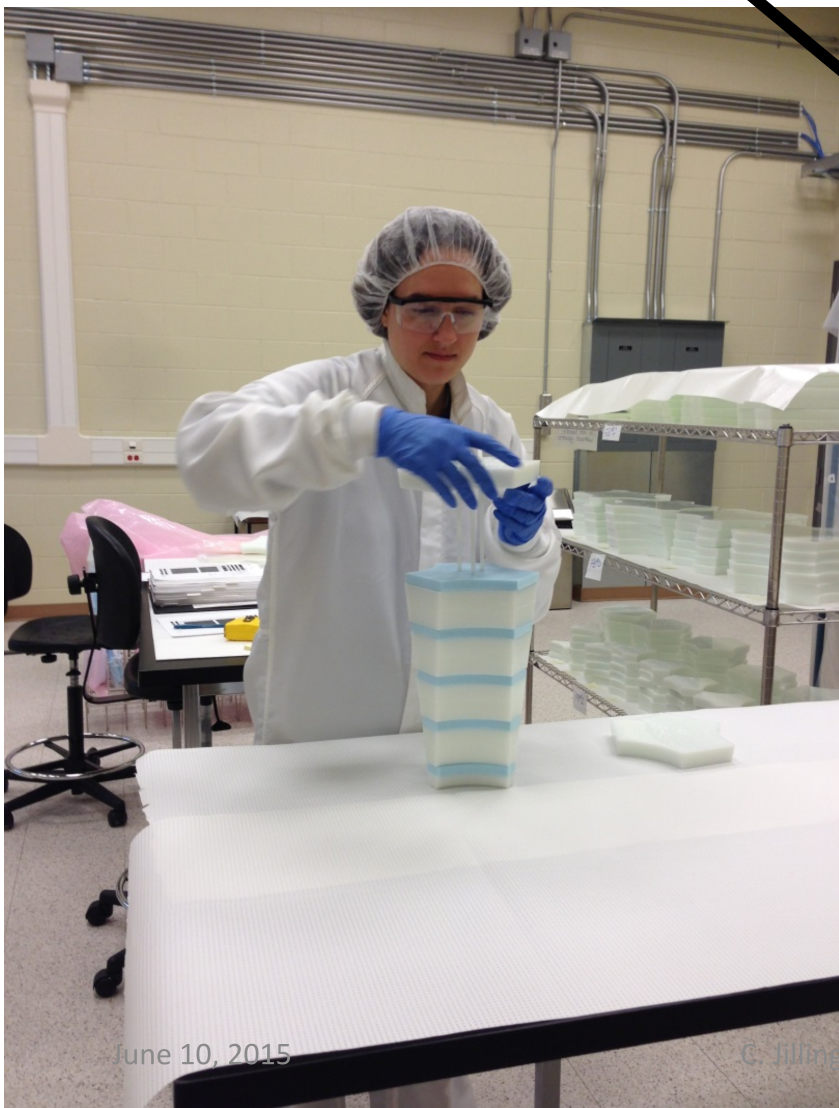


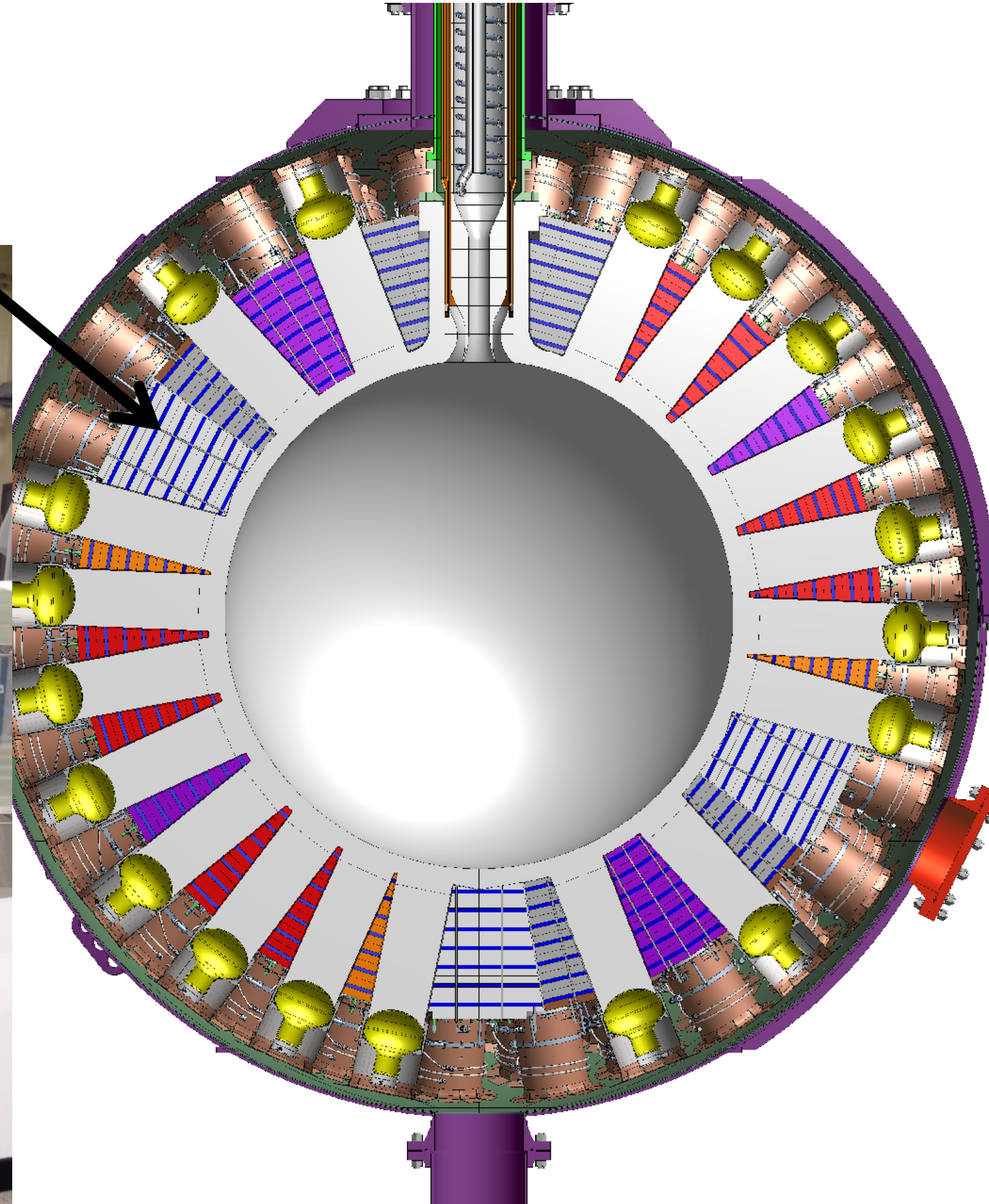


Hundreds of measurements such as this at various wavelengths on different samples.



The Filler Blocks are alternating layers or HDPE and polystyrene.





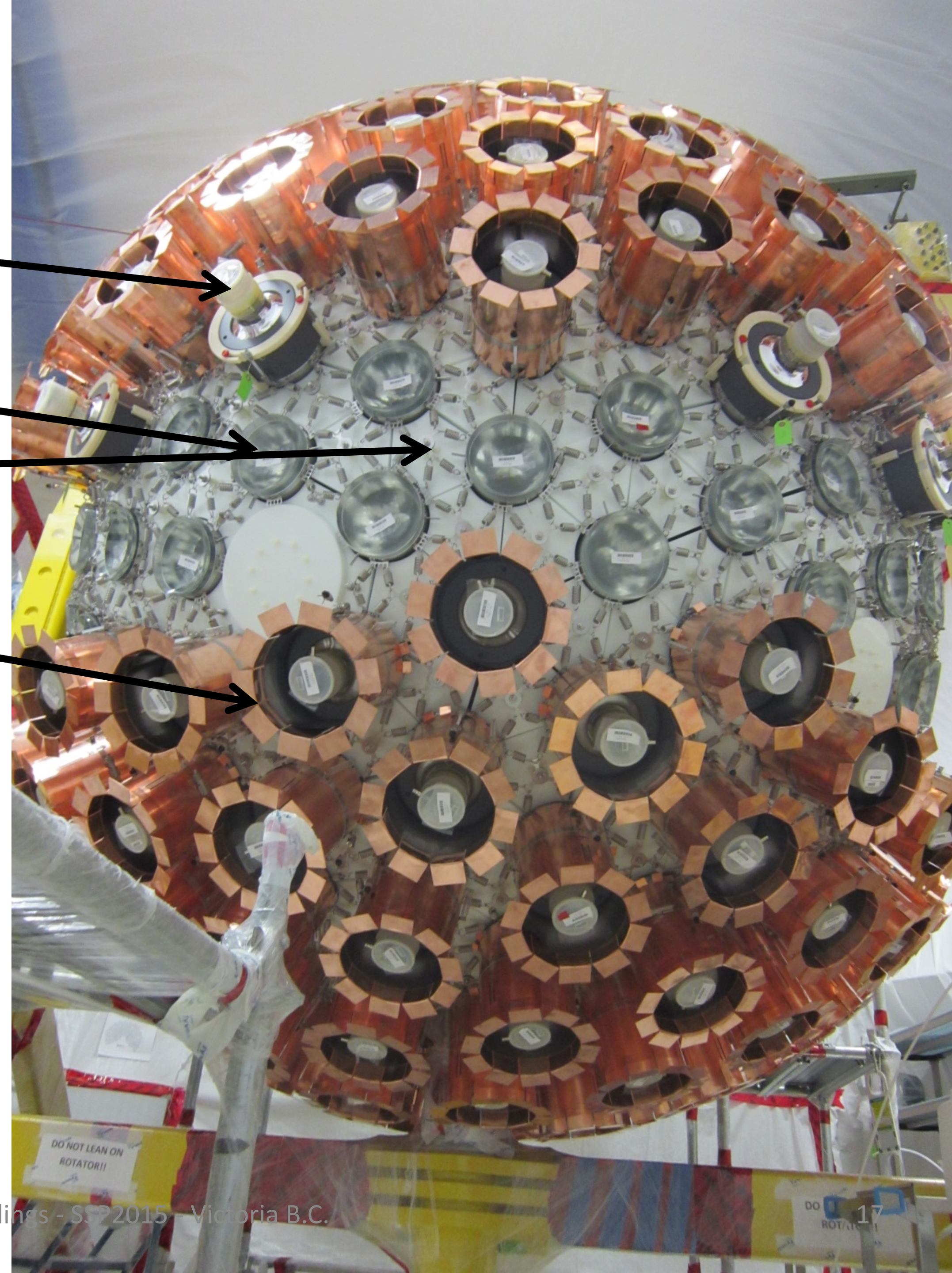
The near-final assembly

PMTs

light guides

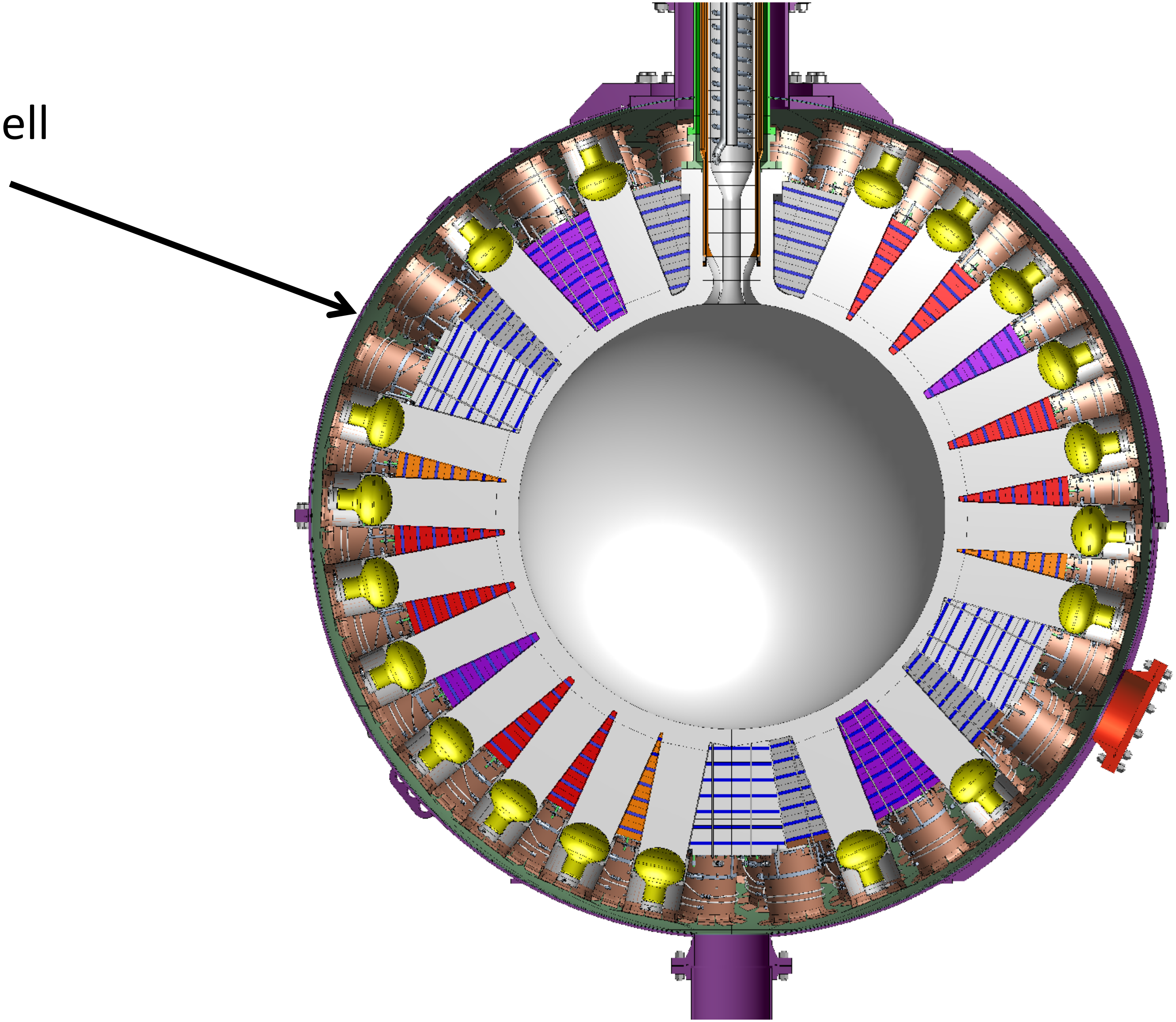
filler blocks

Copper thermal shorts around PMT



Held together w/ springs

The Steel Shell



The Steel Shell is a Section-8 Pressure Vessel designed for human safety in event of upset conditions

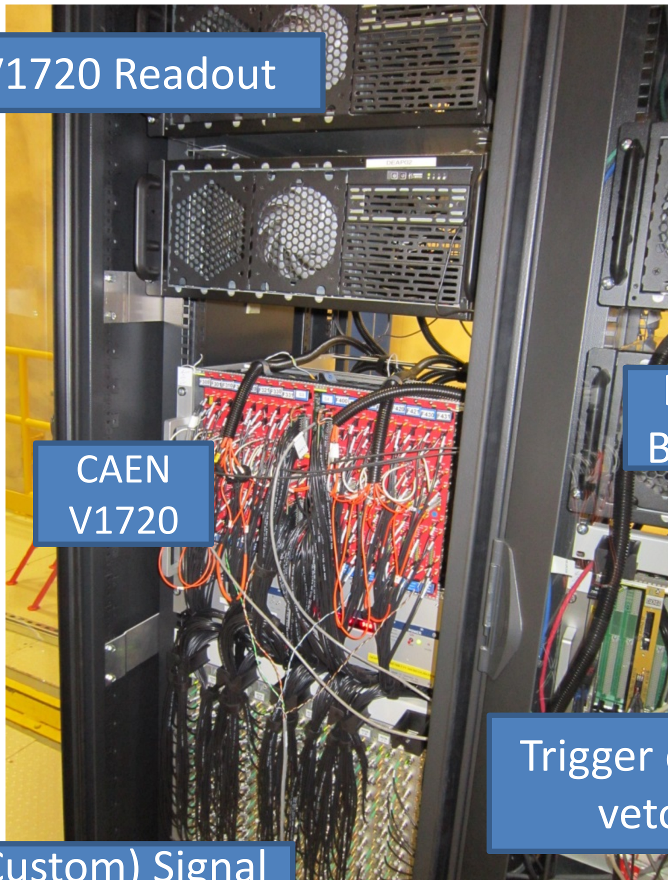
A large bladder lines the water tank.

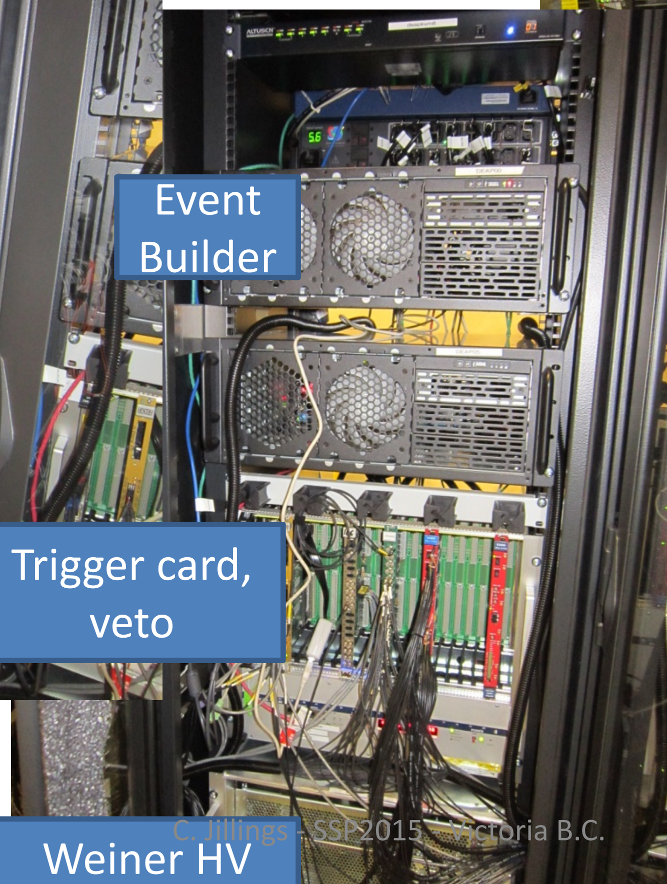
Magnetic compensation coils increase PMT collection efficiency and light yield.

Veto PMTs are a Cherenkov veto for cosmic rays. (2.9/m^2/day at SNOLAB)

Electronics and DAQ must reduce in hardware the data from 10^{10}Argon betas while measuring a few WIMPS.

3 racks on deck + disk in u/g control room



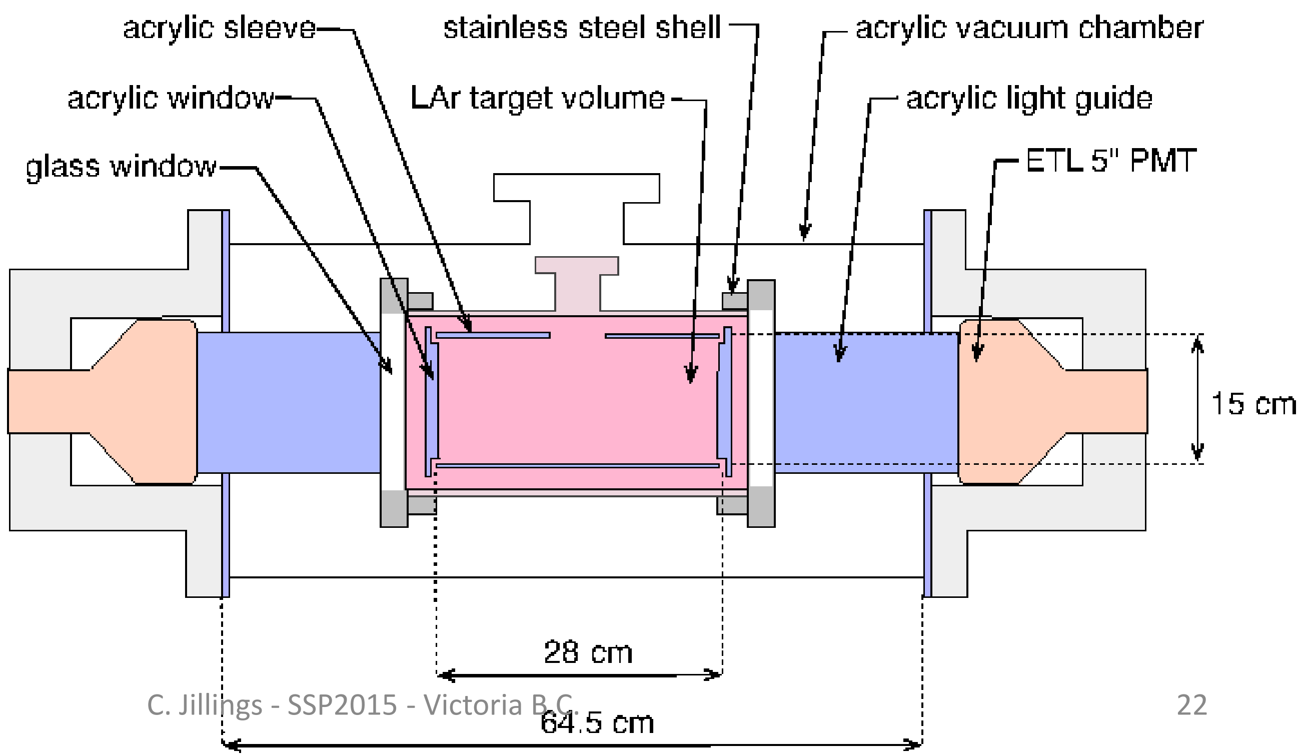


Calibration sources inserted into detector are a contamination risk: No sources to be placed in Argon

Calibration Tools	Optical Response	Energy Reconstruction	Radius Reconstruction	Detector response and stability vs time
LED, lasers, in-situ single PE tails	✔	✔		✔
Gamma sources (tagged ^{22}Na)		✔	✔	✔
Neutron source (AmBe)		✔	✔	✔
In-situ ^{39}Ar	✔	✔	✔	✔

Table from P. Gorel (Rencontres Moriand)

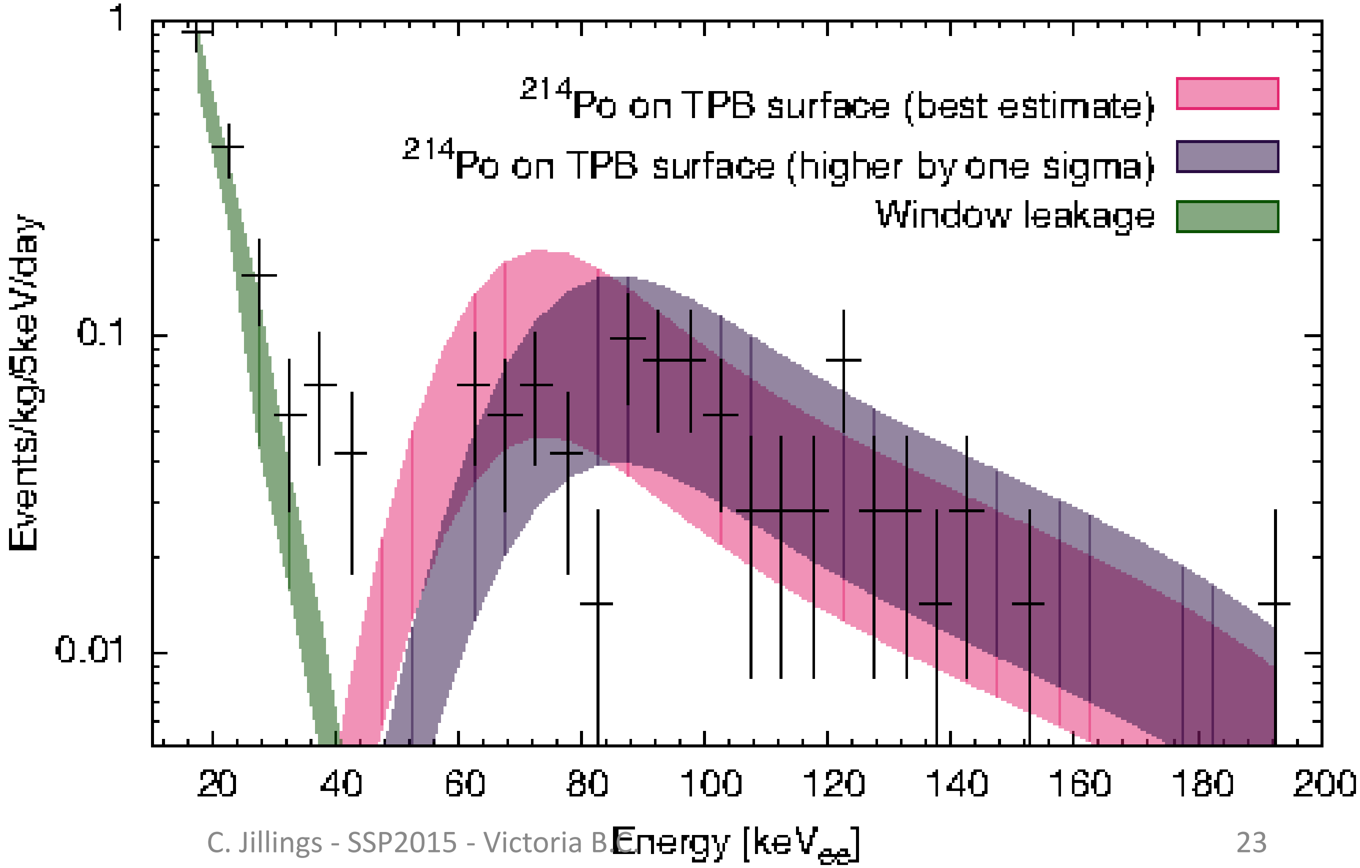
DEAP-1, our prototype, was run at Queen's University and at SNOLAB



DEAP-1 demonstrated low rates of Radon and backgrounds from surface alphas

Acrylic surface activity < 1.6 x 10^{-19} g/g ^{210}Pb

Radon decay rate of 16 to 26 micro Bq/kg



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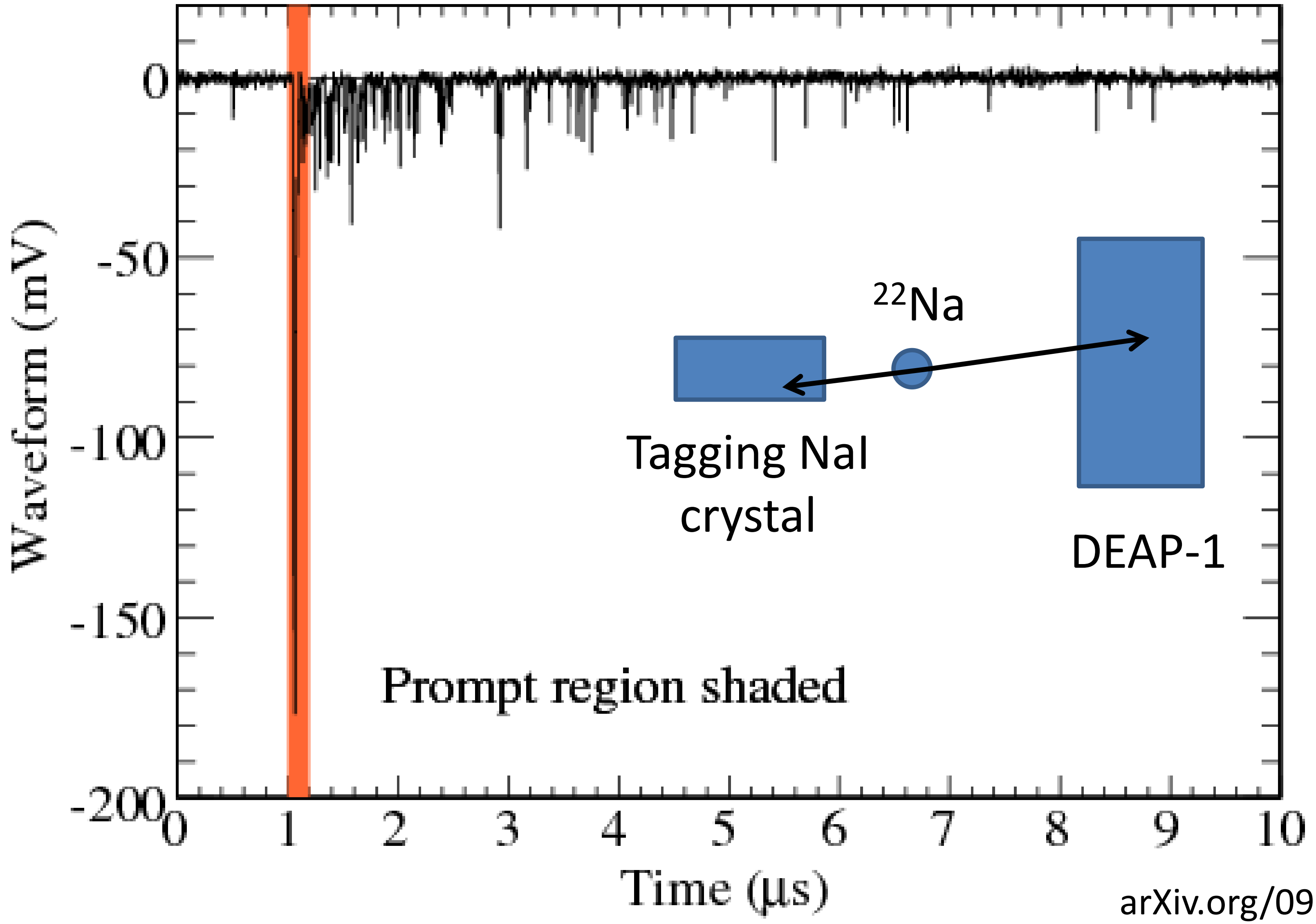
DEAP-1 Pulse Shape Discrimination



arXiv.org/0904.2930

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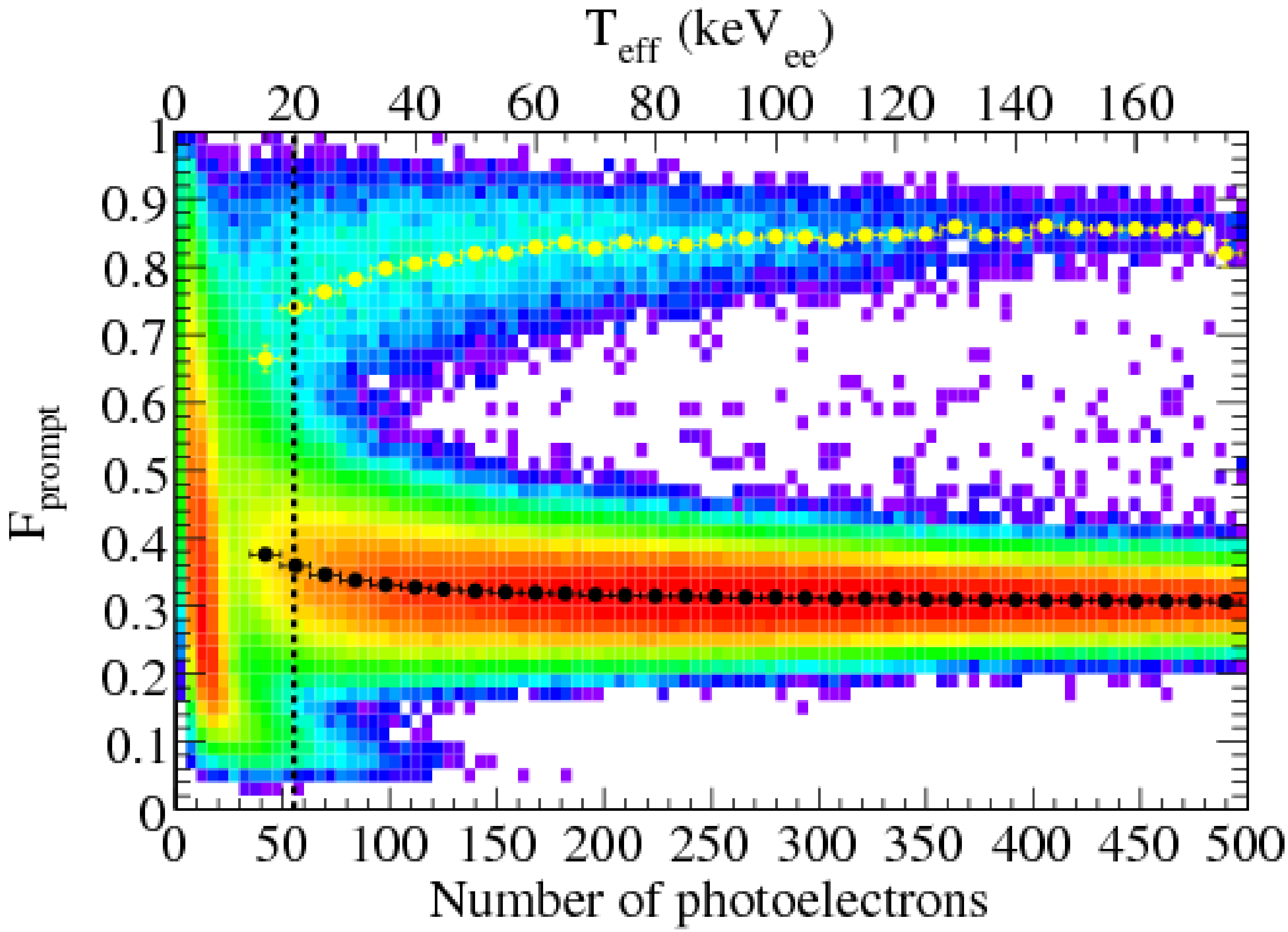

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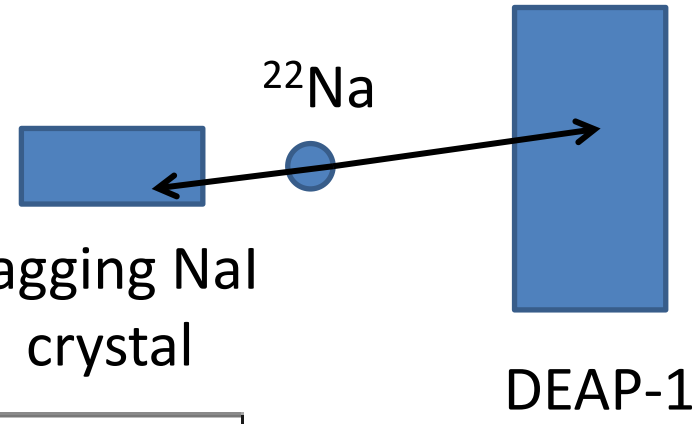
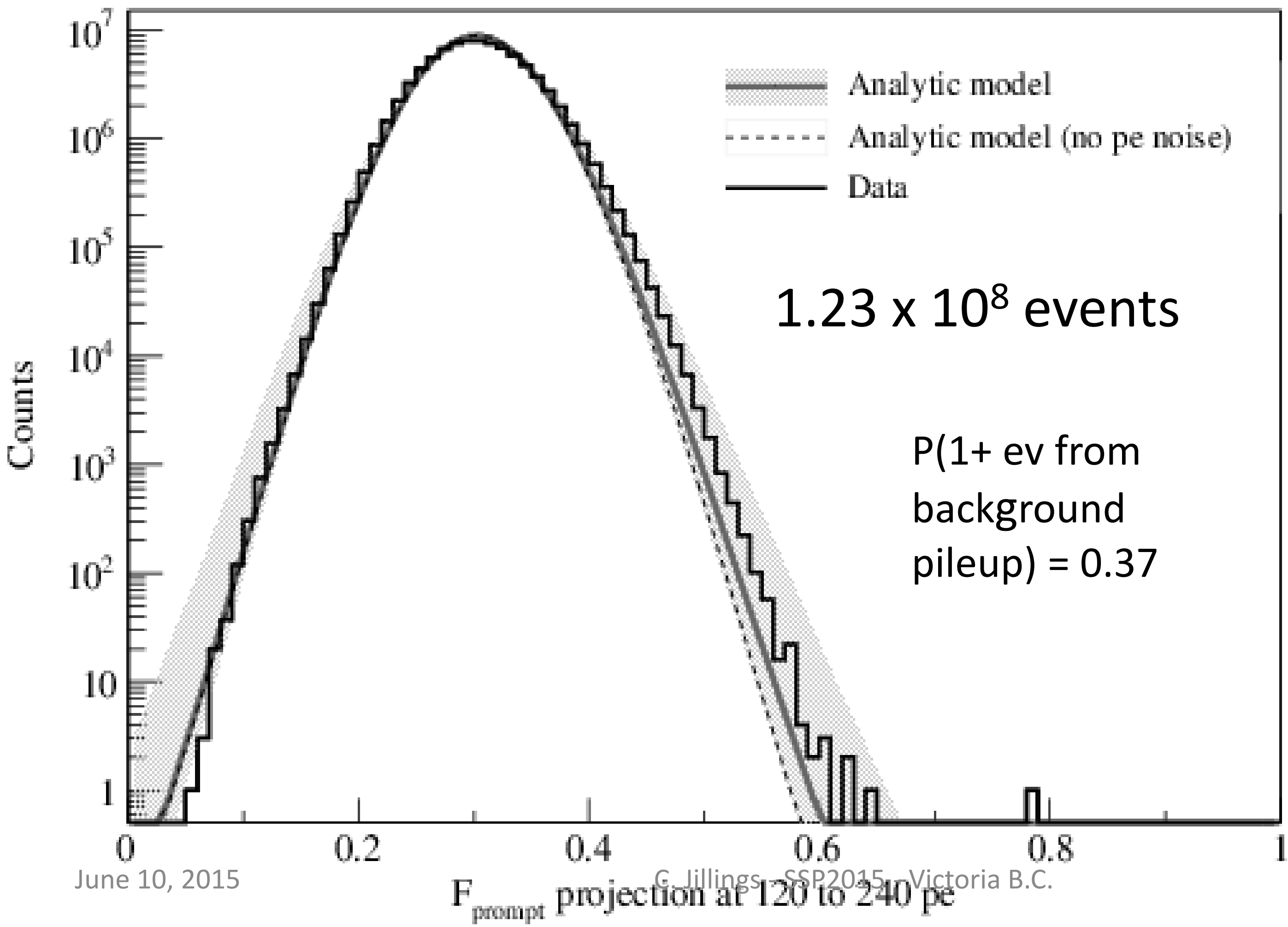
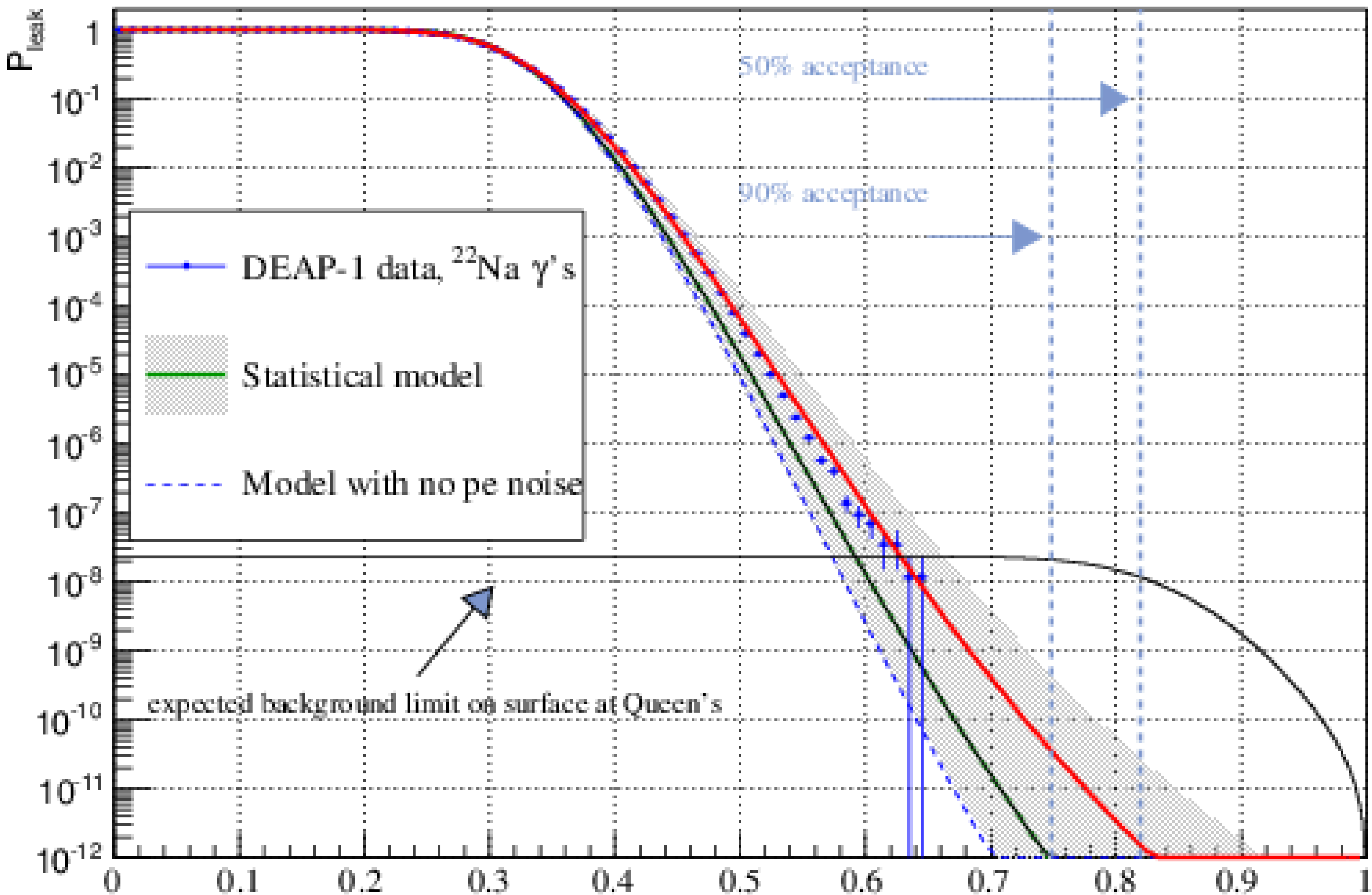




1.23 x 10^8 events

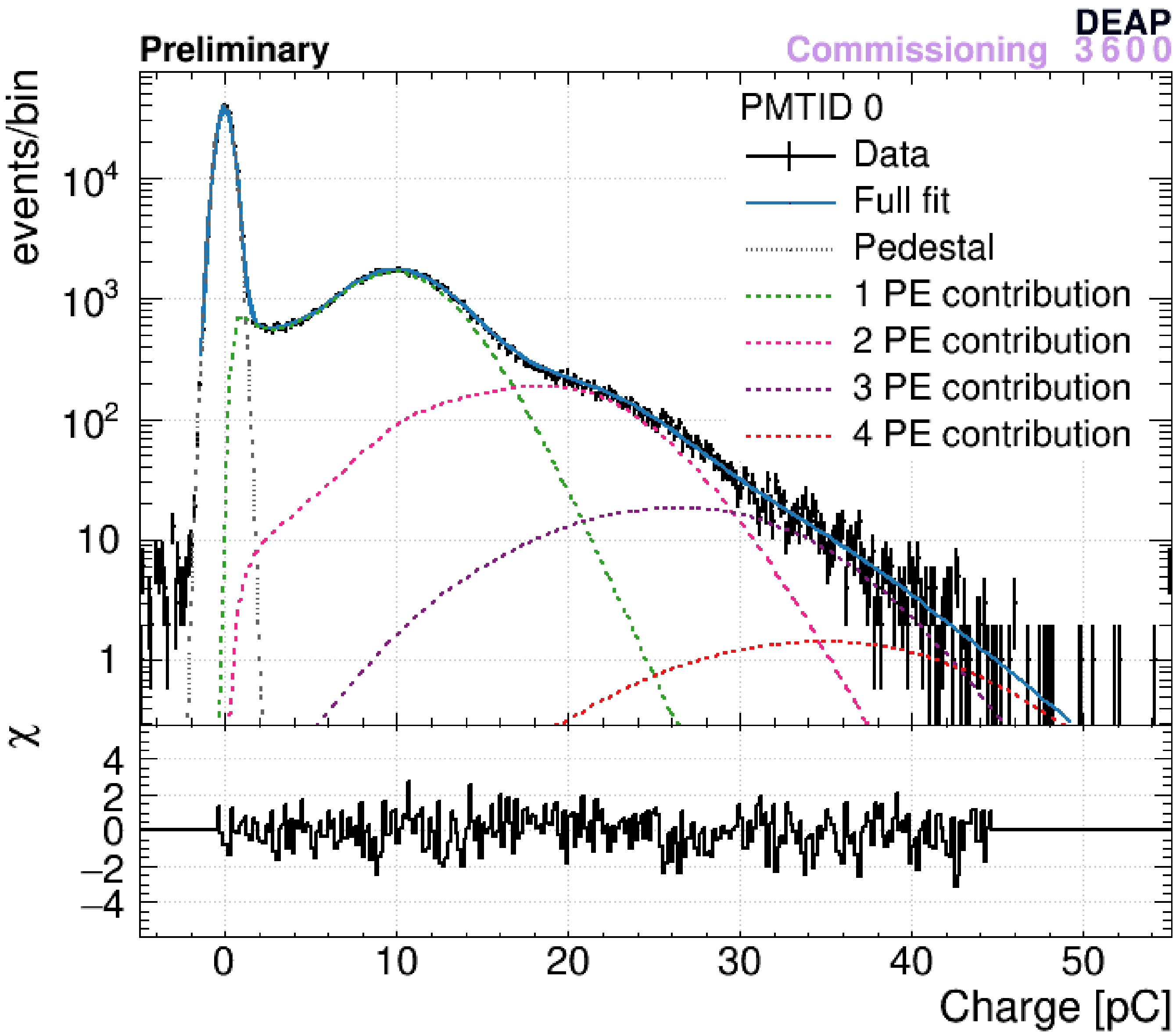
P(1+ ev from background pileup) = 0.37

DEAP-1 PSD measurements agree with a model based on counting statistics and measured noise parameters. The model was applied to DEAP-3600 parameters.



Commissioning of DEAP-3600 has started.

PMT
1: Gain-vs-HV,
2: Afterpulsing, and
3: effect of threshold on pulse-counting efficiency measured in situ



Optical LED/Fibre System Fully Commissioned

Able to introduce light into detector at 21 different light guides and in neck.

Able to dial in intensities to calibrate PMTs.

High-statistics data taken before TPB (wavelength shifter) application.

Trigger Commissioning Underway

Cherenkov Data used to measure effect of trigger thresholds for both a physics trigger with cuts on Fprompt and energy and a *minimum bias* trigger.

External trigger for optical system works well.

Next Steps

1: Evaporate TPB onto steel shell

Requires ~10^{-5} mBarr vacuum.

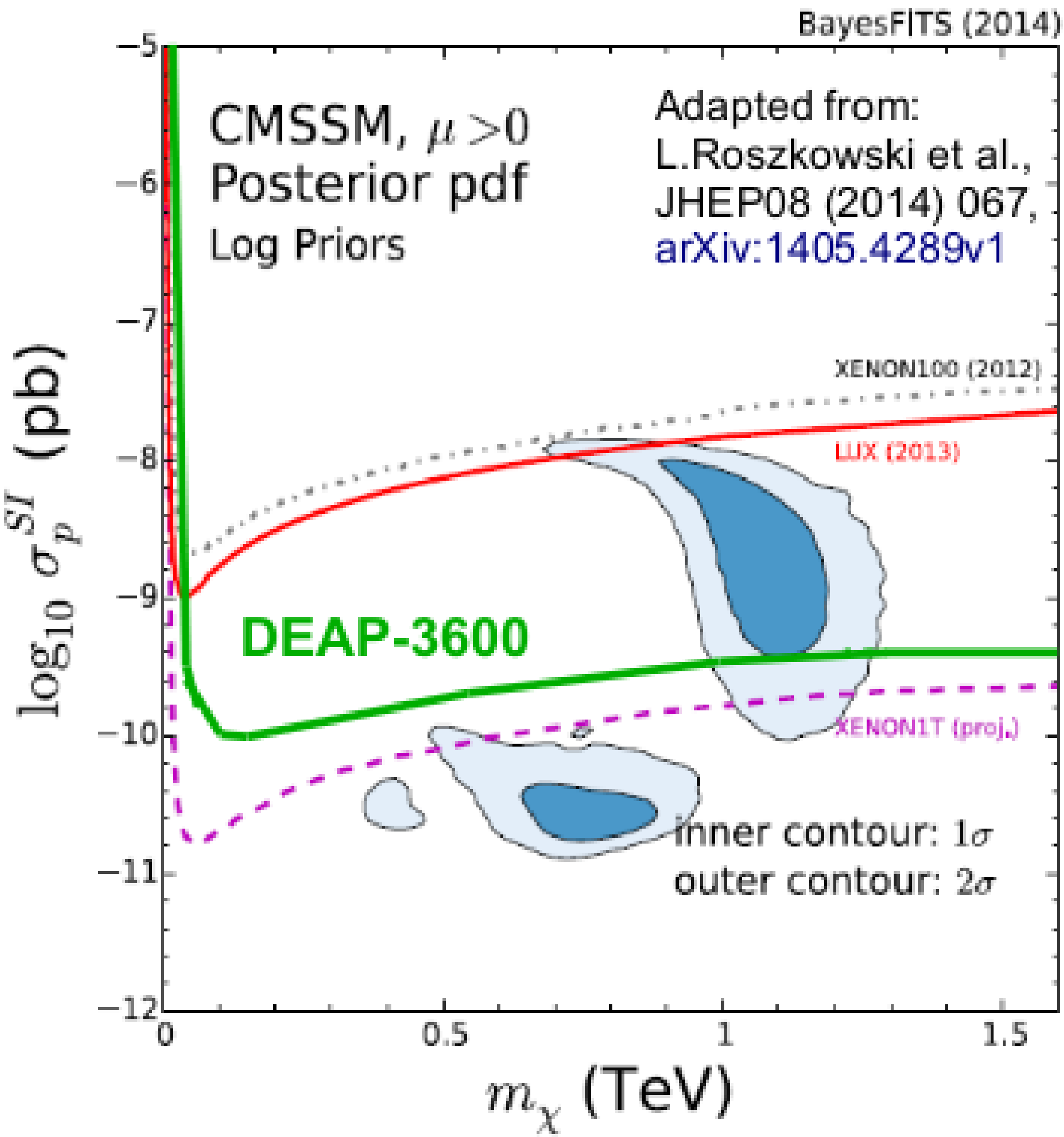
2: “Laserball” optical calibration

3: Cool with cold argon gas for 2-3 weeks

4: Start liquid fill

Leading Sensitivity After 2 months exposure (Plot assumes 3 tonne-years)

Background-free sensitivity with threshold at 60 keVr



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Particle Physics
Rutherford Appleton Laboratory

Carleton UNIVERSITY

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Instituto de Física

ROYAL HOLLOWAY UNIVERSITY OF LONDON

Queen's UNIVERSITY

TRIUMF

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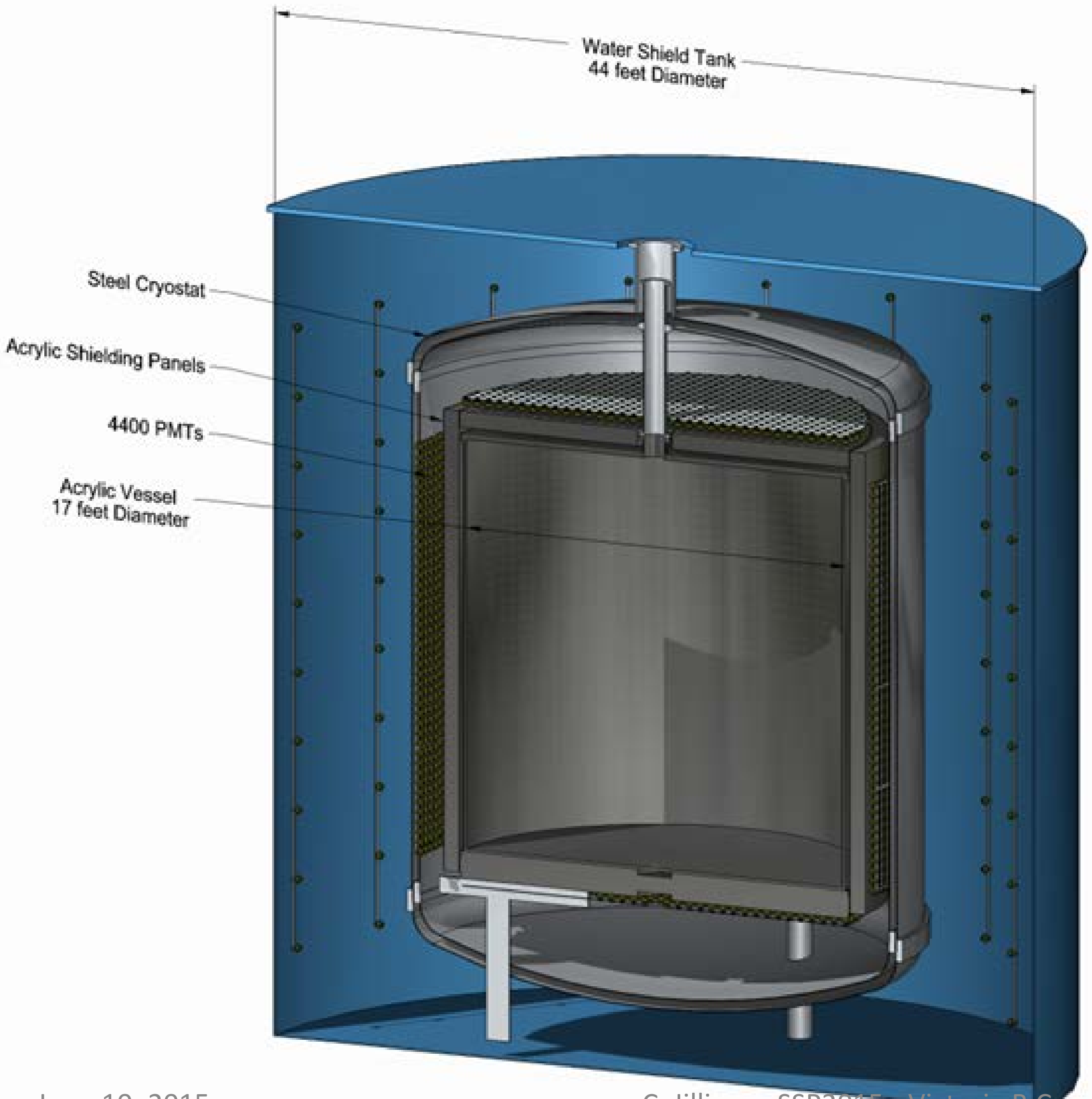
The support of SNOLAB and its staff is gratefully acknowledged.

Looking To the Future: Concept for 50 Tonne Detector



“Conventional” ultra-clean acrylic vessel, constructed UG

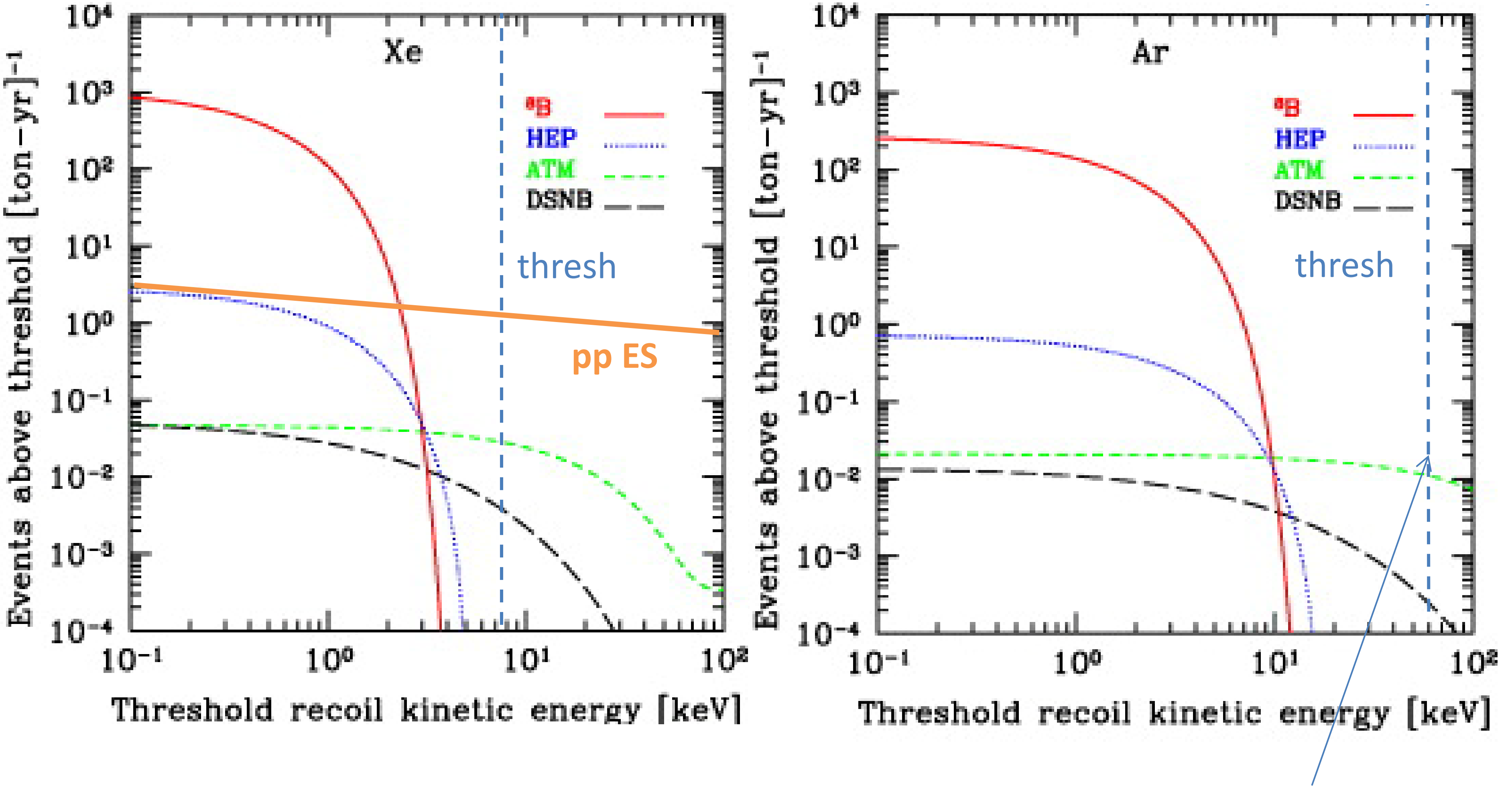
Sanded over ~months to remove deposited daughters, meets requirement

150-tonnes DAr in AV 50-tonne fiducial

Requires UG storage of argon target

Will investigate PMTs versus SiPMs

Neutrino backgrounds in 50-T argon are manageable



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