

The DEAP Search For Dark Matter

49th Rencontres De Moriond: Cosmology

Dr Joseph Walding
Royal Holloway, University of London

28th March 2014
On Behalf of the DEAP-3600 Collaboration

Outline

- The DEAP Program
- Calibration Systems & first ex - situ data
- Construction Status
- Outlook



Collaboration

- University of Alberta
- Carleton University
- Queens University
- SNOLAB/Laurentian
- SNOLAB
- TRIUMF
- Rutherford Appleton Laboratory
- Royal Holloway, University of London
- University of Sussex

70 collaborators

Me



Yesterday morning at breakfast...

Me: *Hello*

Jack Steinberger: *Hello, are you QCD?*

Me: *No, I'm dark matter*

Yesterday morning at breakfast...

Me: *Hello*

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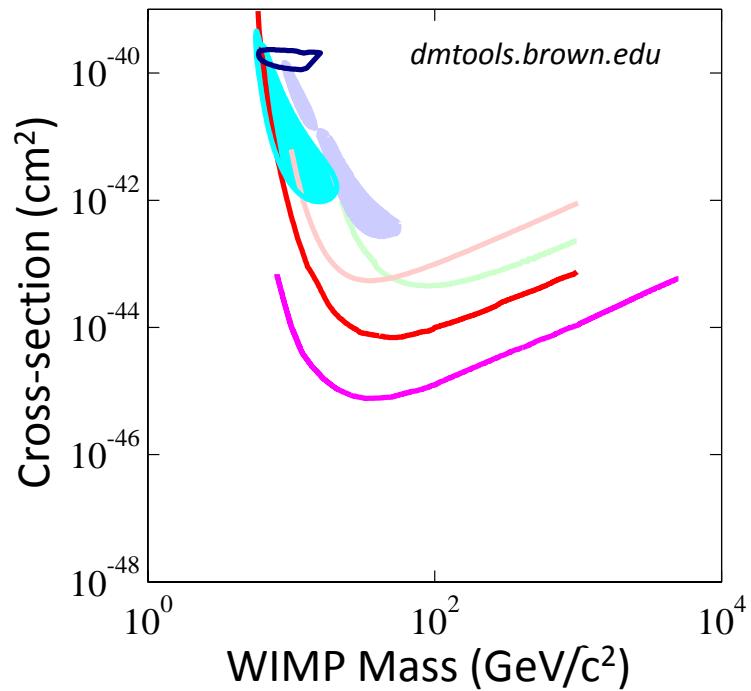
Me: *No, I'm dark matter*

JS: *Oh, so you know nothing then!*

Me: **hangs head**

Current Dark Matter Picture

- Dark matter proposed to explain astronomical observations
- Planck* measurement recently increased amount of dark matter in the Universe to 27%!
- Weakly interacting massive particles (WIMPs) are a leading candidate
- Require very low and well understood backgrounds



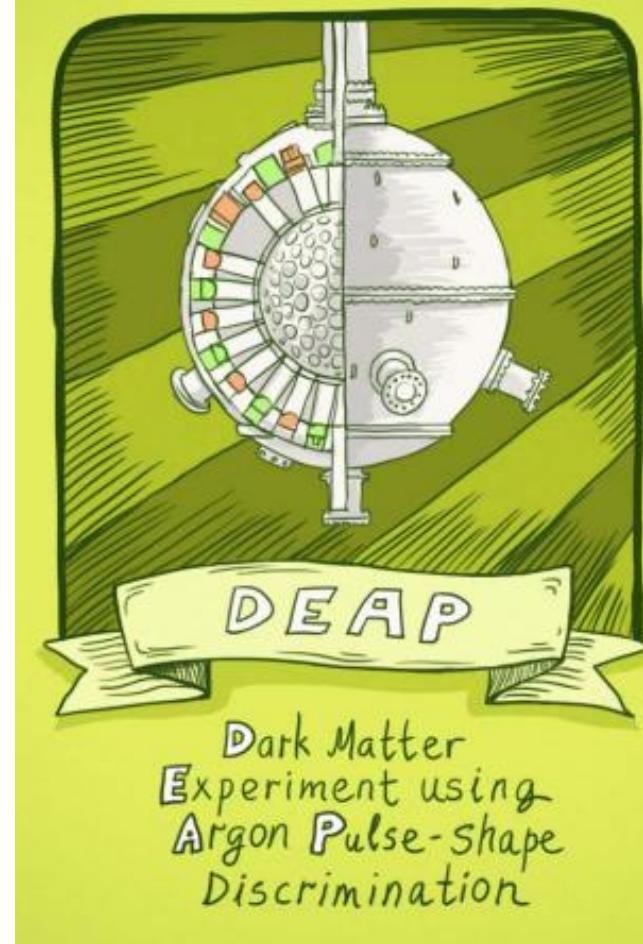
DATA listed top to bottom on plot
DAMA region, 90% C.L., Hooper PRD 2010
CDMS-II Soudan Silicon SI Result, R125-128, contour 90% C.L.
CRESST-II 2-sigma Allowed Region part 1, 730kg-days data
XENON10 2007, measured Leff from Xe cube
Edelweiss II Final result (March 25 2011)
Xenon 100 (2011)
LUX (2013) 90% U.L.

*arXiv:1303.5076

What is DEAP-3600?

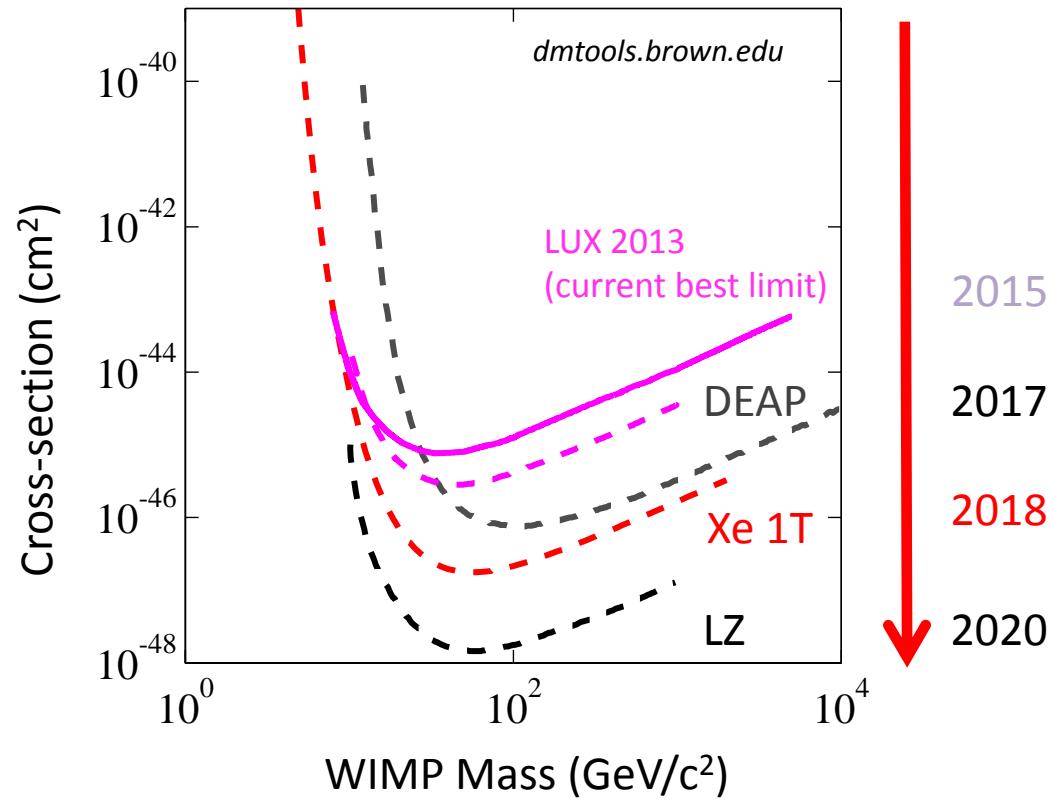
- Dark matter Experiment using Argon Pulse-shape discrimination
- DEAP-3600: Liquid Argon (LAr) detector
 - 3600 kg LAr, 1000 kg fiducial mass
 - SNOLAB – Sudbury, Ontario
 - 6800 feet underground = 6000 m.w.e
 - Single phase detector
- Single phase – No gaseous amplification region
 - No electron drift requirements
 - 4π PMT coverage
 - ➔ Detector scalability to O(kTonne)
- Why Argon?
 - Ar transparent to 128nm scintillation photons
 - Large fiducial masses
 - Well separated singlet and triplet state lifetimes
 - Easy to purify and inexpensive

1000 kg argon target & 3 year run allows $\sim 10^{-46} \text{ cm}^2$ sensitivity (SI) with
 $\sim 15 \text{ keVee}$ (60 keVr) threshold (bkgd limit)



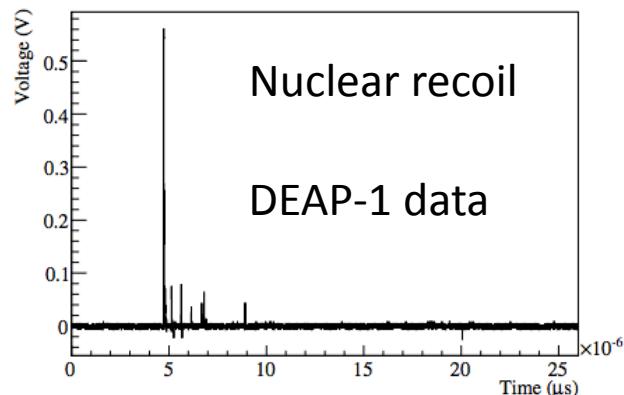
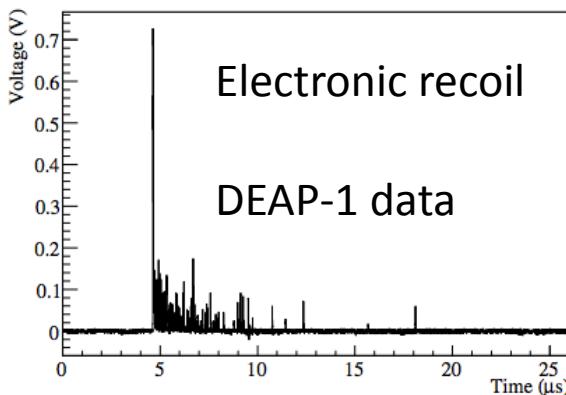
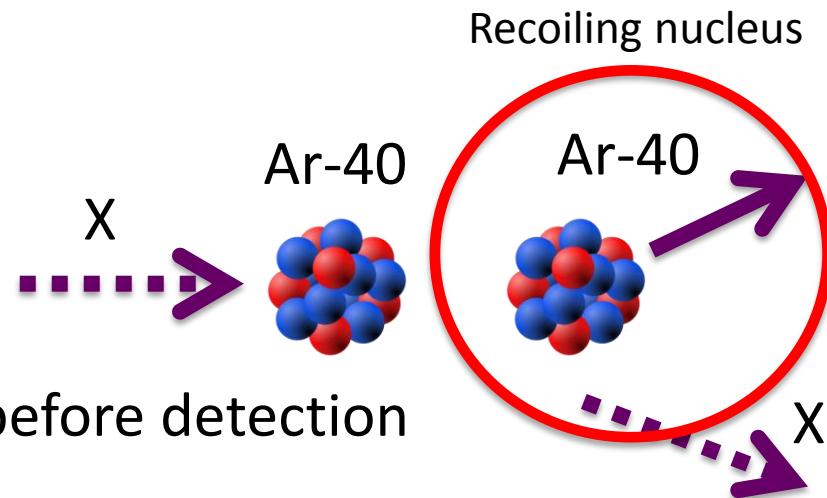
How does DEAP-3600 fit in?

- Will set a worlds best spin independent measurement on a competitive timescale:
 - 10^{-46} cm^2 for 100 GeV WIMP mass (3 years)
 - Current best limit: LUX 2013
 - 1 month to exceed Xe-100
 - 1 year to exceed LUX projected final sensitivity



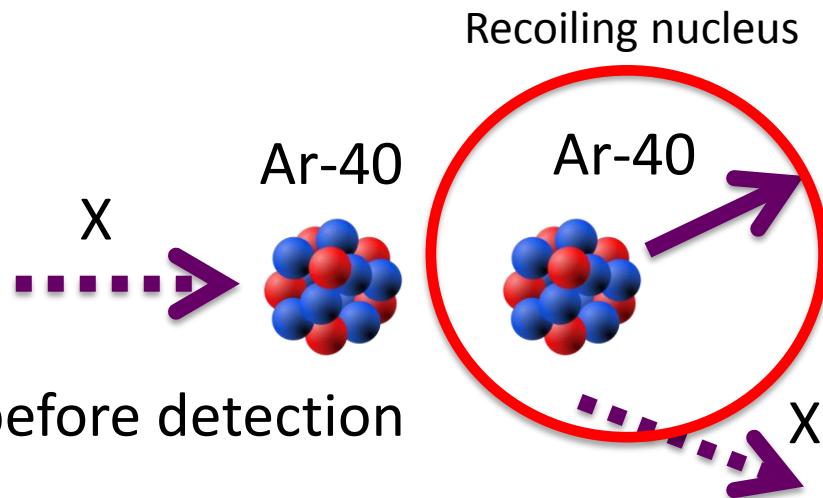
DEAP-3600 Signal

- What do we see?
 - Ionisation from recoiling nucleus
 - 128nm light wavelength shifted before detection by photomultipliers
- Ar singlet and triplet excited states have well separated lifetimes (7ns vs. 1.5us)
- Electronic and nuclear recoils produce different ratios of singlet and triplet states therefore...

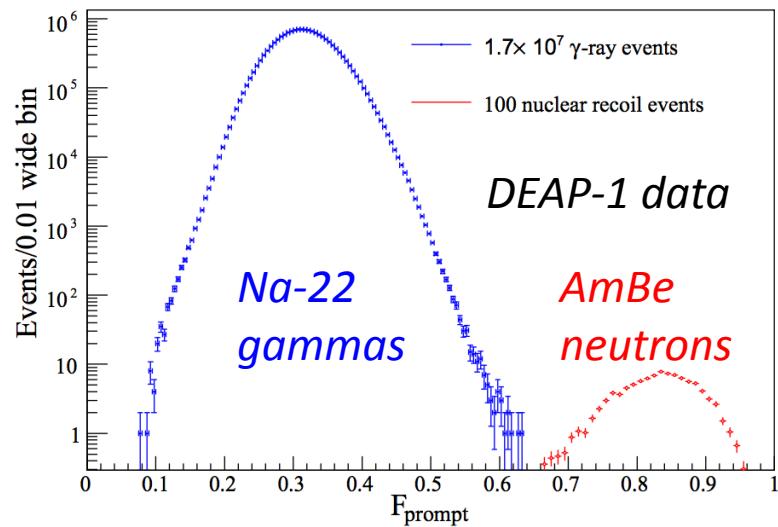


DEAP-3600 Signal

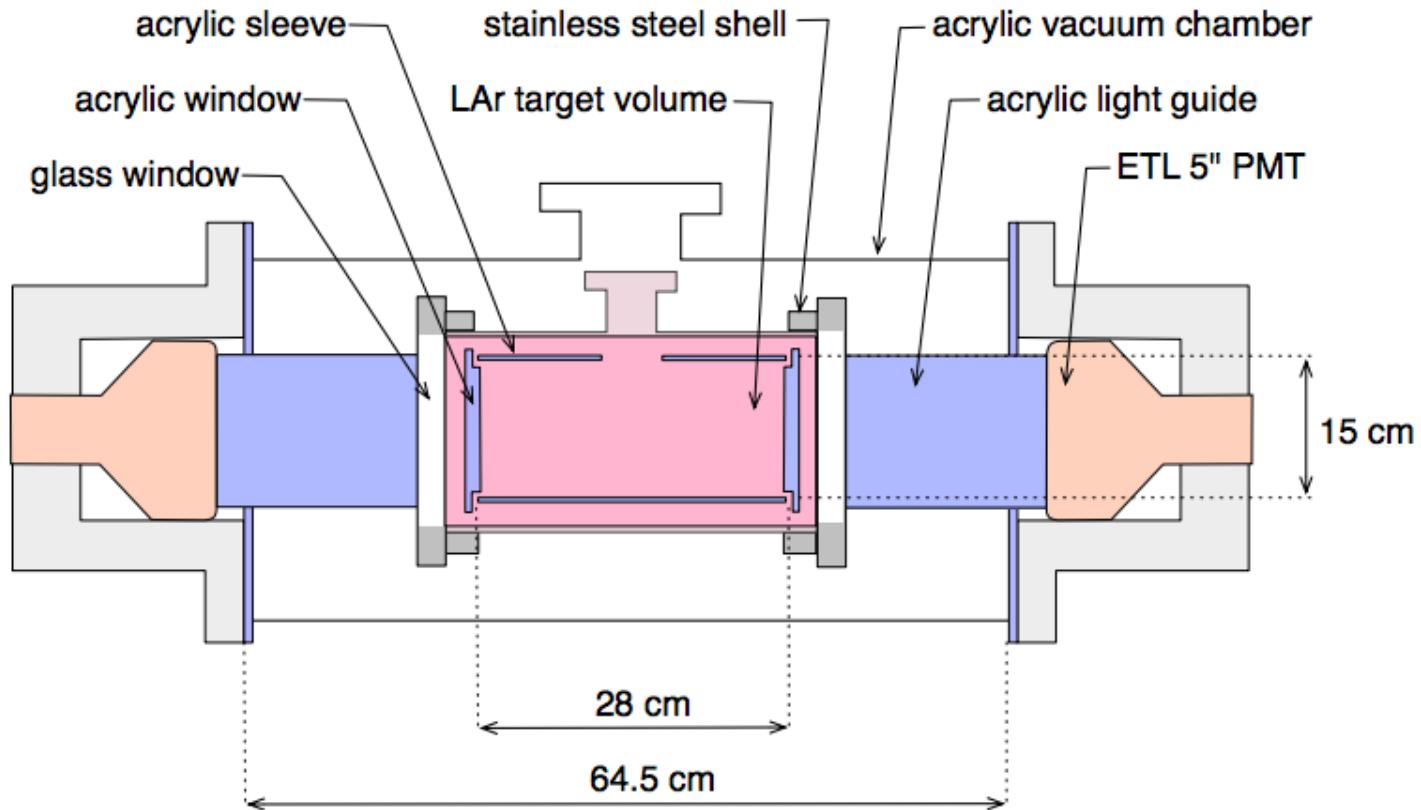
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- Pulse Shape Discrimination (**PSD**):
 - Separate electronic and nuclear recoils using timing
 - $F_{\text{prompt}} = \text{PE}_{\text{prompt}} / \text{PE}_{\text{total}}$
 - Prompt window: -50 ns → 150 ns



arXiv:0904.2930

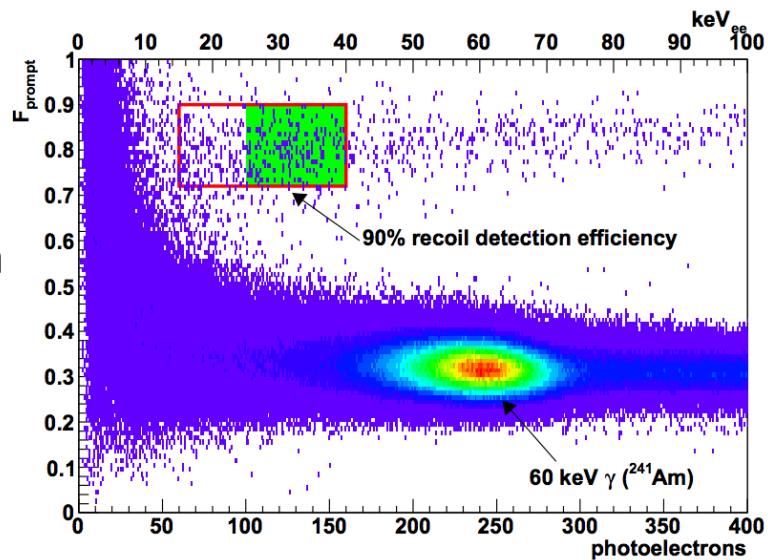


DEAP-1: 7kg LAr Prototype Detector



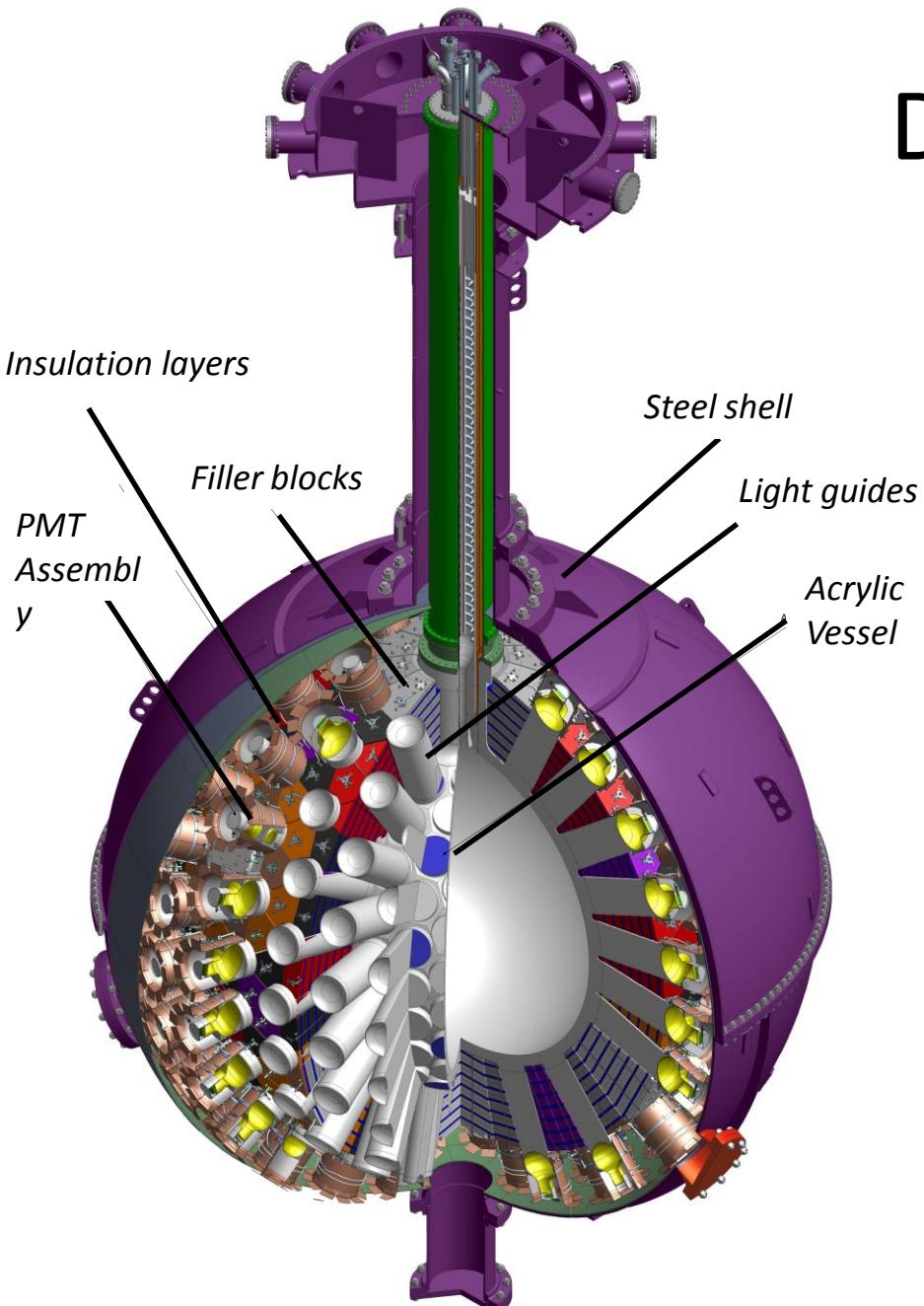
DEAP-1

- PSD (*Updated result of arXiv:0904.2930*):
 - 3×10^{-8} suppression (stat. limited) of γ 's seen in DEAP-1 (25 keVee)
 - light yield of ~ 4 PE/keV
 - Region of interest: 100 – 160 PE, $F_{\text{prompt}} > 0.7$
- Backgrounds (*arXiv:1211.0909*):
 - Principle backgrounds from Rn-222 decay chain coming from Uranium decay chain
 - Rn-222: 3.83 day lifetime (~ 20 minute Ar cycling)
 - Surface background $< 100 \mu\text{Bq}/\text{m}^2$ achieved in DEAP-1
 - Material assays $\times 10$ lower limit in DEAP-3600



DEAP-1 results used to project DEAP-3600 sensitivity

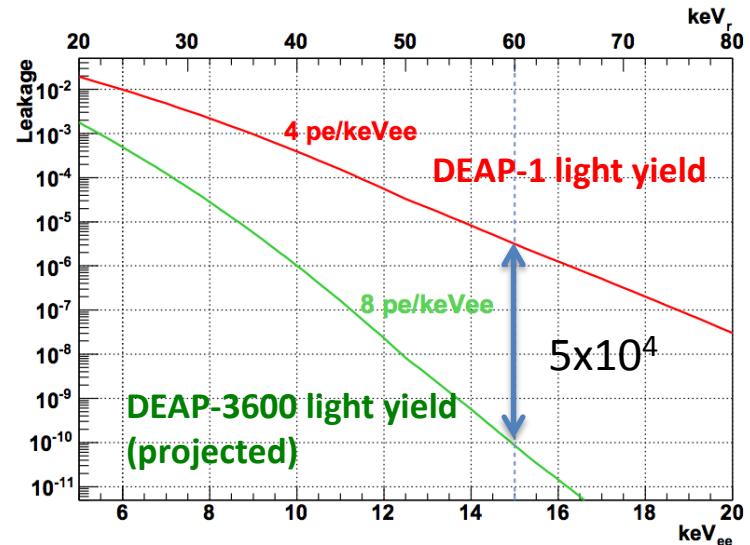
DEAP-3600 Detector



- LAr housed in sealed ultraclean acrylic vessel
- 255 8-inch Hamamatsu R5912 HQE PMTs
 - 32% QE, 75% coverage
- Acrylic vessel & light-guides provide PMT neutron shielding
- Tetraphenyl-butadiene (TPB) used as wavelength shifter (128nm to 430nm)
- Cosmic veto
 - SNOLAB (2km underground)
 - Detector submerged in 8m diameter water tank

DEAP-3600 Backgrounds

- **β/γ events:**
 - Ar-39 dominant rate – 1 Bq/kg.
Removal using PSD
 - Leakage scales with light yield
- **Neutron recoils:**
 - (α, n) - very strict material controls:
achieved with ex-situ material assays
 - Muon induced – SNOLAB ~2km
underground + active cosmic veto
- **Surface alphas:**
 - Rn daughters and other surface
impurities.
 - Resurface acrylic surface in-situ,
fiducial volume cuts, limit radon (trap)

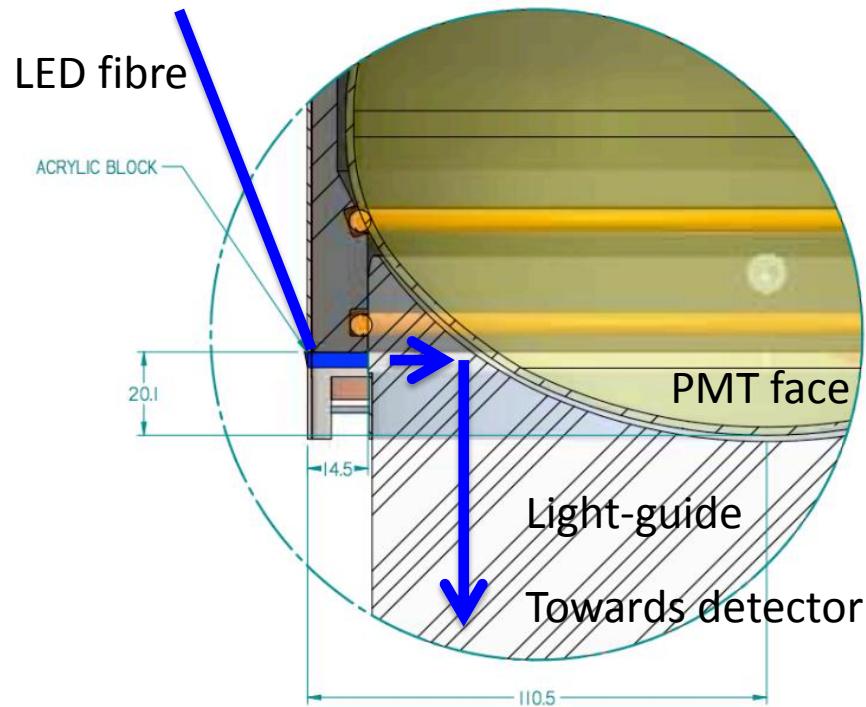


Background (in Fid Vol)	DEAP-3600 Goal
Radon in Ar	< 1.4 nBq/kg
Surface α 's	< 100 μ Bq/m ²
Neutrons (all sources)	< 2 pBq/kg
Ar-39	< 2 pBq/kg
Total (3 tonne-yr)	< 0.6 events

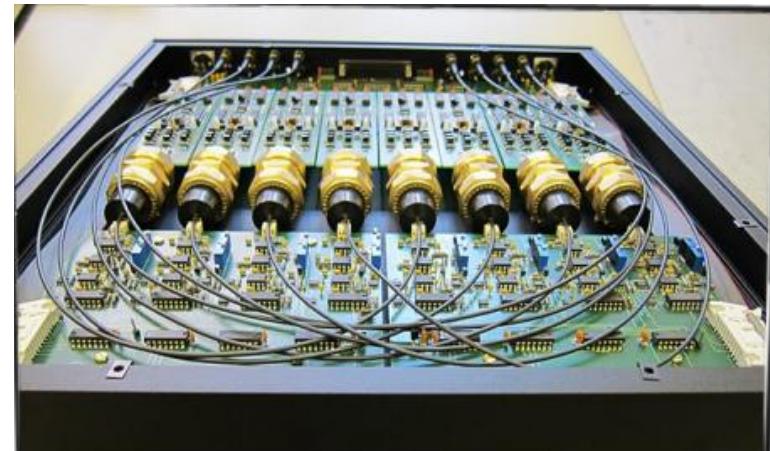
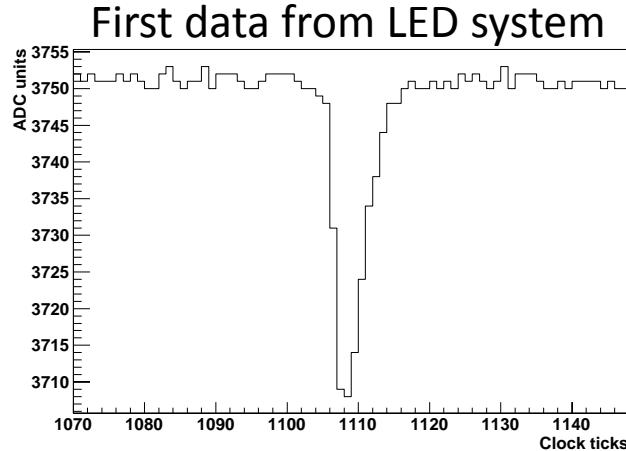
For 10^{-46} cm² sensitivity over 3 year exposure (1000 kg fiducial volume)
requires < 0.6 background events

Optical Calibration

- 3 systems:
 - LED fibre system
 - LED/Laser-ball
 - Neck laser

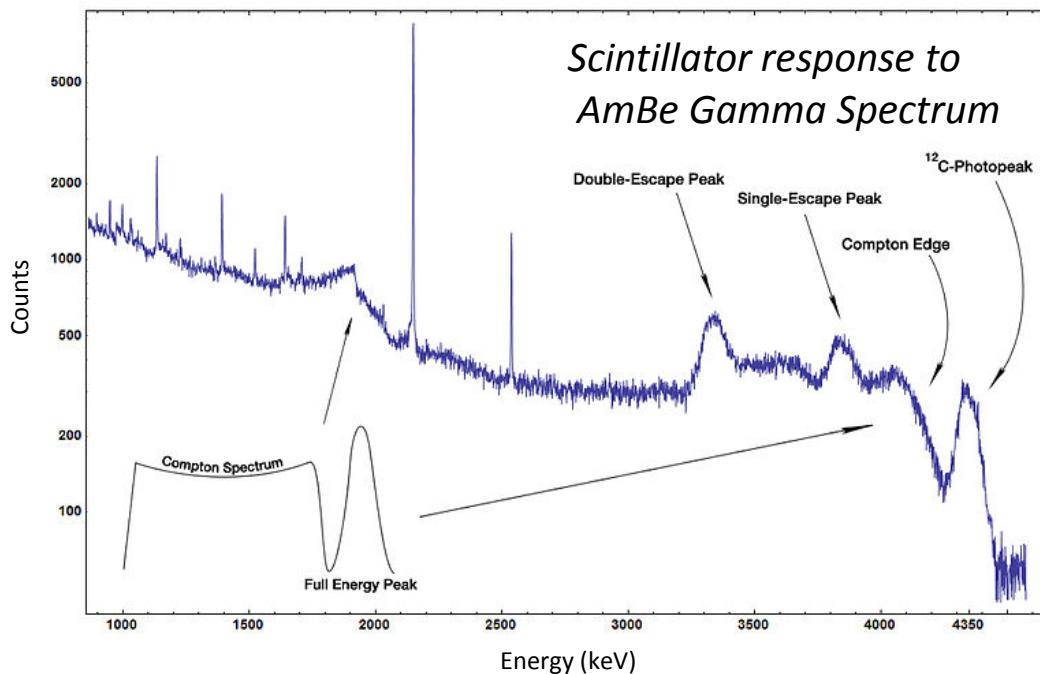


- PMT timing & gain calibration/monitoring
 - Fast rise time (1 clock tick = 4ns)
- AV/light guide monitoring
- Run during commissioning and physics run



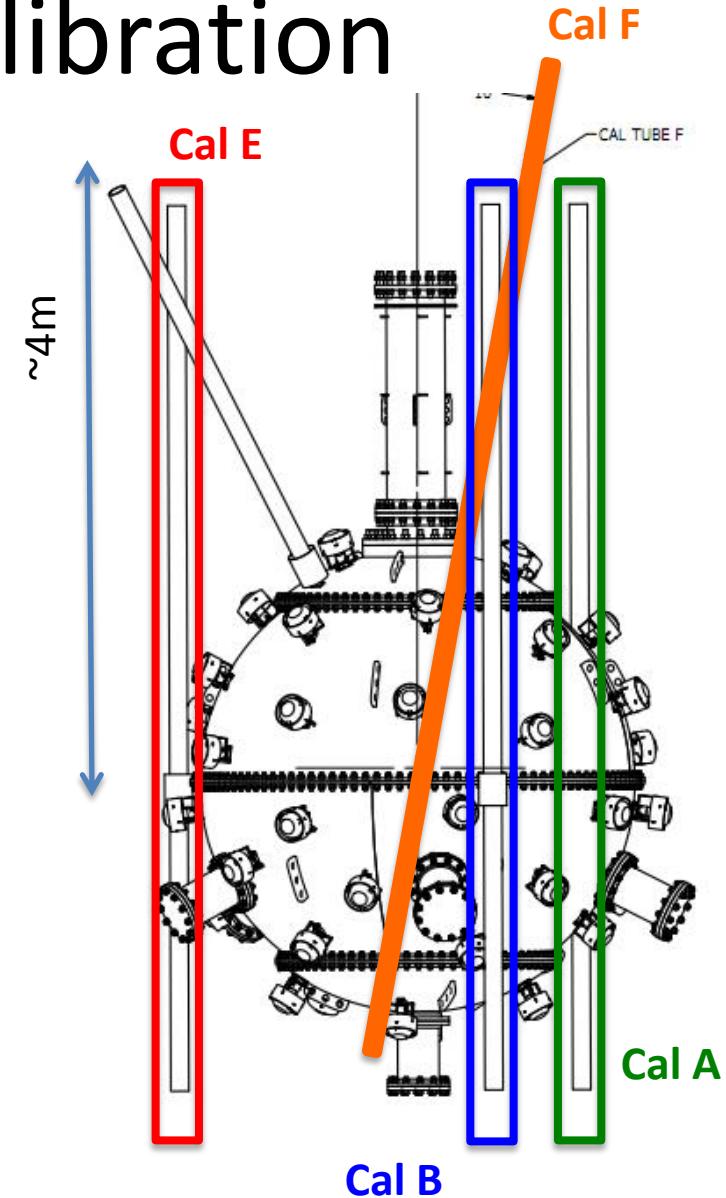
Gamma & Neutron Calibration

- Tagged Na-22 and AmBe-neutron sources
- Na-22: Map detector with well understood gamma spectrum
 - Cal F loops around detector
- AmBe: Populate detector with WIMP-like recoil events



28/03/2014

49th Rencontres De Moriond - The DEAP-3600 Experiment - Dr. Joseph Walding



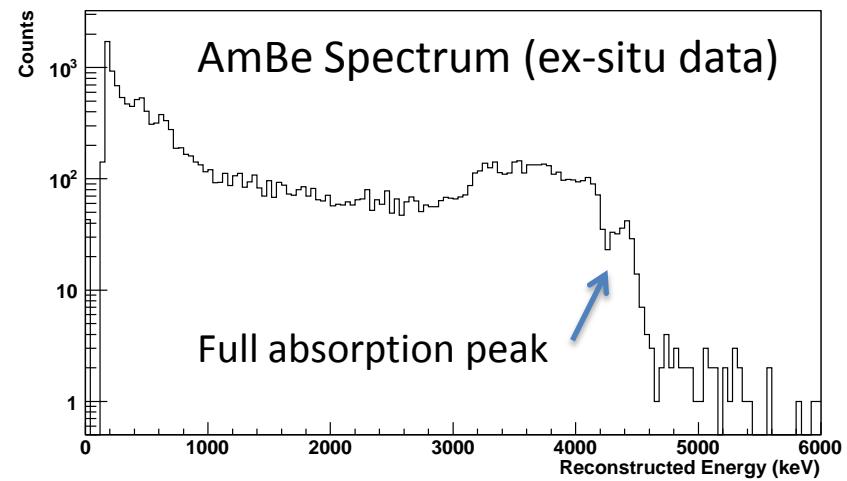
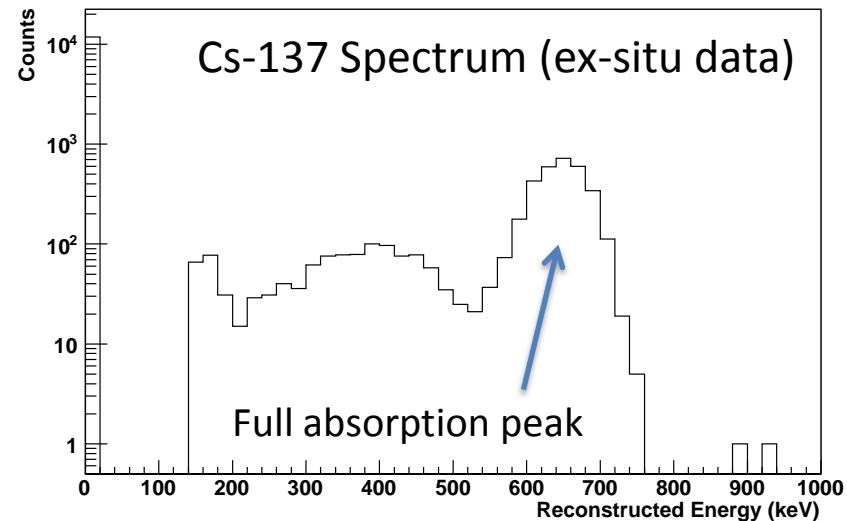
Neutron Calibration Ex-situ data

- Tagged 74 MBq AmBe source



4.4MeV from C^{12*} de-excitation

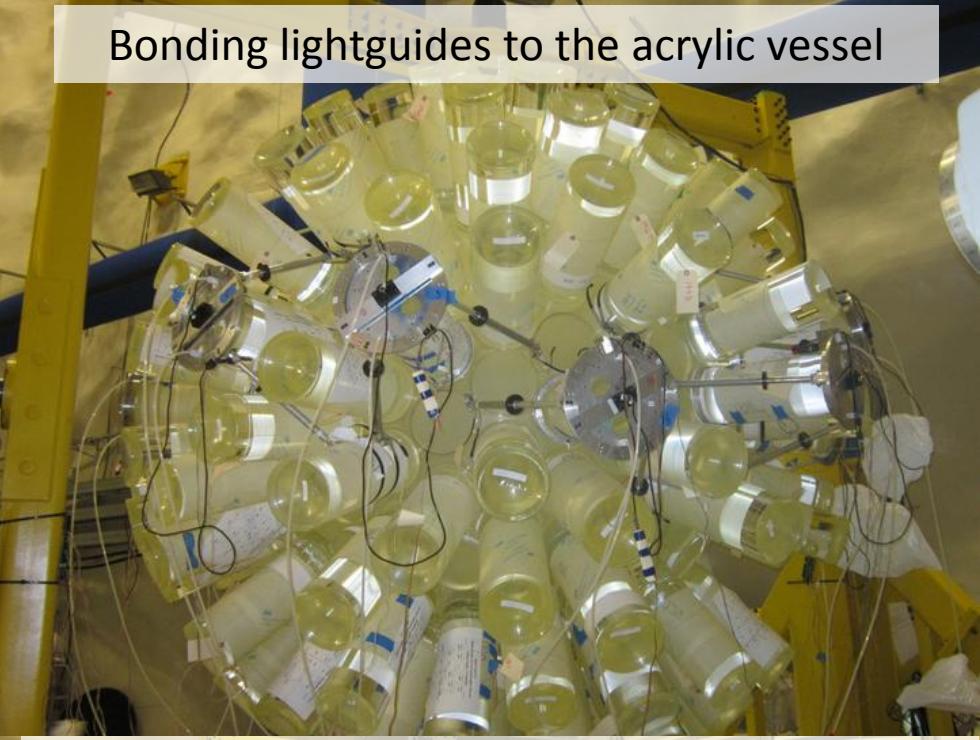
- Two 5x4cm NaI crystals encapsulate source
- Simulation estimate: 100 hours to get 10,000 single neutron scatters in DEAP
- Expect ~20% gammas (AmBe) to deposit > 500keV energy in NaI crystal
- Ex-situ measurement of efficiency in agreement with simulation



Vacuum testing the steel shell



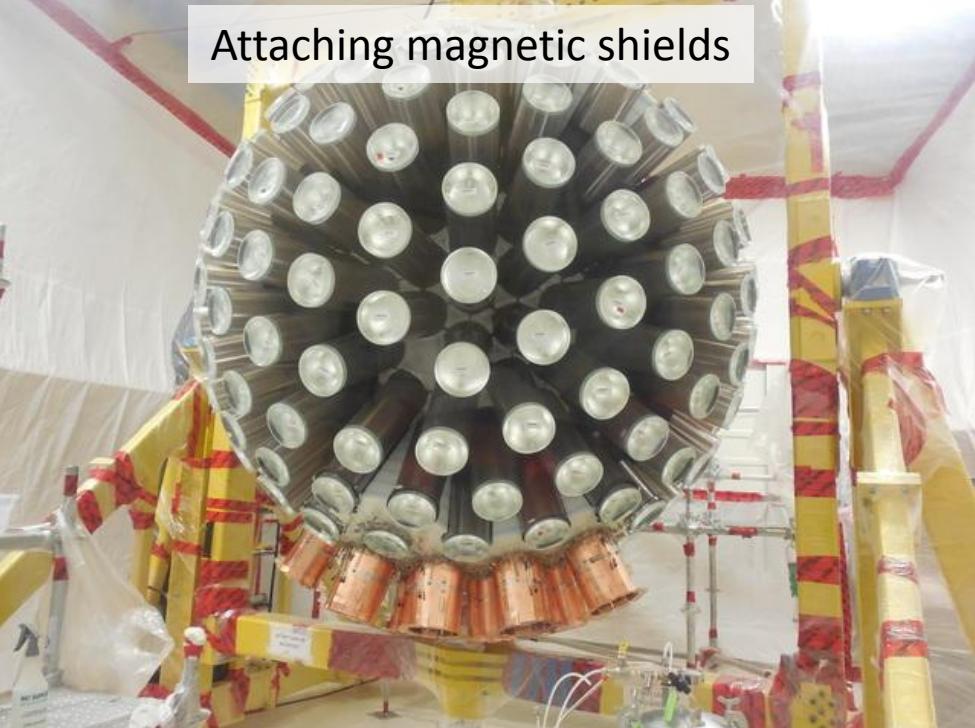
Bonding lightguides to the acrylic vessel



Completed acrylic vessel – lightguide assembly



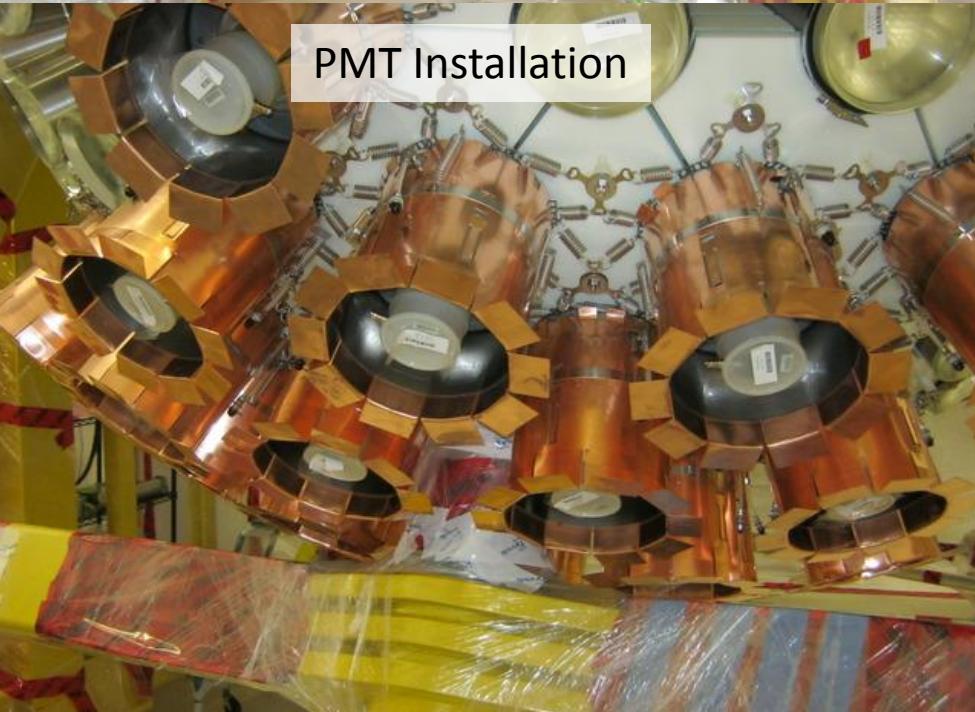
Attaching magnetic shields



Installing the filler blocks



PMT Installation



Installed LED fibre system reflector



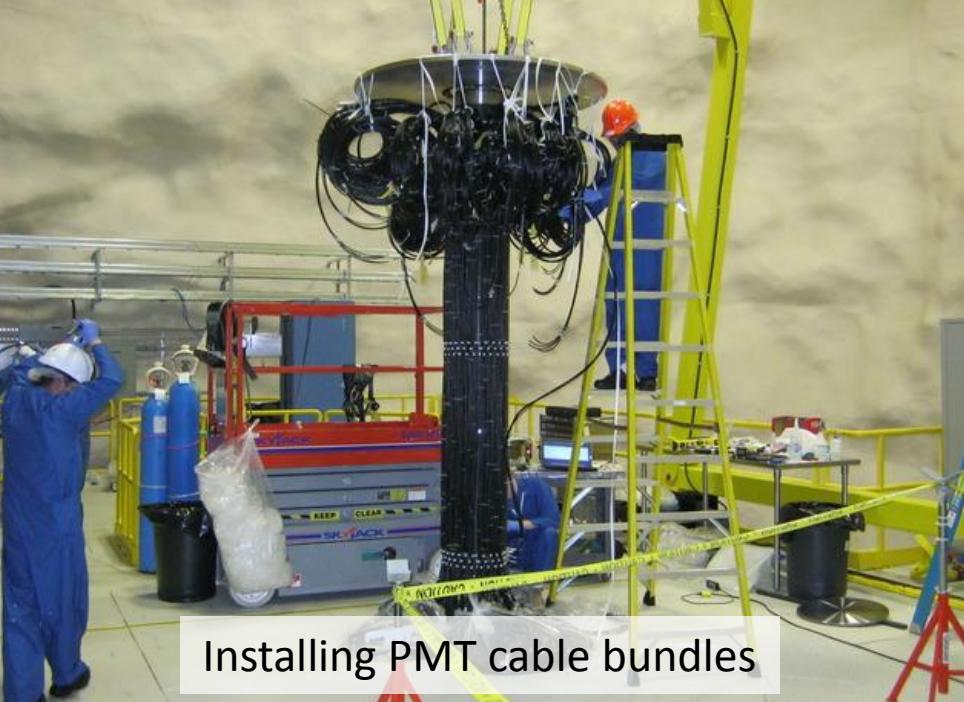
Acrylic vessel in the annealing oven



DEAP-3600 (r) and MiniCLEAN (l)
water tanks



Cryocoolers & argon storage dewar



Installing PMT cable bundles

Conclusions and Outlook

- May 7th: DEAP-3600 PMT installation completed and detector sealed
 - Start resurfacing
 - Start calibration commissioning of the detector with the optical fibre system
- Fill with gAr July
- 5 weeks to cooldown
- Commissioning May - September
- Begin physics run October 2014

First result early 2015!
Full sensitivity 3 years 10^{-46}cm^2

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Me: *No, I'm dark matter*

JS: *Oh, so you know nothing then!*

Me: ... *Yet!*

A wide-angle photograph of a snowy mountain range under a clear blue sky with scattered white clouds. In the foreground, a chairlift system with green and yellow seats is visible, running across a snow-covered slope. The mountains in the background are rugged and covered in thick snow, with some rocky outcrops exposed.

Thank you
Stay tuned!

Backup

