The DEAP-3600 Dark Matter Experiment

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for the DEAP-3600 Collaboration

DEAP: Dark matter Experiment using Argon Pulse-shape discrimination
Direct WIMP detection with liquid argon

• Energy transfer in liquid argon leads to formation of excited dimers
• Dimer molecules are in either singlet or triplet states, and the lifetimes are well-separated:
  - ~ 6 ns for singlet state (prompt)
  - ~ 1.5 µs for triplet state (delayed)
• Fraction of dimers in singlet or triplet states depends on the incident particle type

Excellent pulse-shape discrimination (PSD) between electron recoils and nuclear recoils
Good scintillator (40 photons/keV)
Inexpensive and easy to purify
Single-phase detector, easy to scale up
PSD in liquid argon with DEAP-1

Yellow: Prompt light region
Blue: Late light region

Nuclear recoils
AmBe neutron source

Backgrounds (γ’s)

\[ F_{\text{prompt}} = \frac{\text{Prompt PE}(150 \text{ ns})}{\text{Total PE}(9 \mu \text{s})} \]
β/γ background suppression in liquid argon

- γ suppression better than $3 \times 10^{-8}$ in 43-86 keVee achieved at SNOLAB
- Simple model of photon statistics predicts $10^{-10}$ suppression at 15 keVee, allowing for sufficient background rejection of $^{39}\text{Ar}$ in DEAP-3600
The DEAP-3600 Detector

Located at SNOLAB, 2 km underground in Sudbury, Ontario

3600 kg argon target (1000 kg fiducial) in ultraclean Acrylic Vessel

Vessel is “resurfaced” in-situ to remove deposited Rn daughters after construction

255 Hamamatsu R5912 HQE PMTs 8-inch (32% QE, 71% coverage)

50 cm light guides + PE shielding provide neutron moderation

Steel Shell immersed in 8 m water shield
Critical elements of the design

- Ultrapure cryogenic acrylic vessel bonded underground
- Large stainless steel pressure vessel welded underground
- Argon purification system with extremely low target levels of radon emanation
- Large target of liquid argon viewed by low-radioactivity HQE PMTs near room temperature
- Custom large-scale robotic resurfacer for radon control
- Custom large-scale (10 m²!) in-situ thin-film deposition device
Spin-independent WIMP-nucleon cross section


arxiv.org:1410.7673
Backgrounds in DEAP-3600

- **β/γ backgrounds**
  - Dominated by $^{39}$Ar (1 Bq/kg)
  - Pulse-shape discrimination
  - Depleted argon after natural argon run

- **Neutron backgrounds**
  - Clean materials and shielding
  - Muon suppression at SNOLAB

- **Surface contamination**
  - Clean detector surface (resurfacer device)
  - Vertex reconstruction for fiducial volume
Fabrication and assay of DEAP acrylic

- Fabrication from pure MMA monomer at RPT Asia Thailand, strict control of radon exposure for all steps
- DEAP Collaborators present during fabrication
- Control to $<2.2 \times 10^{-19} \text{ g/g } ^{210}\text{Pb}$ from radon exposure
- Developed system to vaporize and assay large quantities of acrylic (10 kg samples), count residue with Ge well detector for $^{210}\text{Pb}$ peak, and with alpha counter for $^{210}\text{Po}$ (C. Nantais MSc thesis)
Monomer cast at RPT Asia 2011

Thermoformed panel at RPT Colorado 2012
AV arrives at SNOLAB (Oct 2012)

AV slung down the shaft (Dec 2012)
AV shoulder bond (RPT at SNOLAB Jan 2013)
AV neck bond (RPT at SNOLAB Feb 2013)
4th anneal after underground machining (June 2013)
Vessel sealed and purged, approx. 50 LGs bonded (September 2013)
Light guide bonding completed (November 2013)
Reflectors on light guides

All PMTs installed, cabled, most foam insulation in place Dec 2014

PMT installation Oct 2014
Completed inner detector

Steel Shell in shield tank

Detector ready for Final Lift onto neck

Steel Shell closing Dec 2014

Veto PMTs installed Mar 2015
The Resurfacer
Sanding head assembly

3M 6002J M74 diamond sanding pads, 200 grit, recommended by RPT, durable and good acrylic removal rate
Background reduction with resurfacer

• AV radon exposure:
  – 9 months surface, 6 months mine air, 1 month radon reduced air
  – $5 \times 10^4 \alpha$/day/m$^2$ on AV surface before resurfacing

• 200 hours of resurfacing

• Removed all radon daughters deposited on surface

• Estimated order of $10 \alpha$/day/m$^2$ on AV surface after resurfacing
Current status of DEAP-3600

• Acrylic vessel resurfacing was completed at the end of 2014
• Detector optical calibration, PMT and electronics commissioning ongoing (winter 2014/spring 2015)
• Commissioning cryogenic system (winter 2014/spring 2015)
• Vacuum-baked acrylic vessel (spring 2015)
• Completion of shield tank components, calibration hardware, veto PMT system (late spring 2015)
• Inner wavelength shifter is being deposited on the AV
• Next steps are commissioning with argon gas followed by cool down/liquid argon fill (starting summer 2015)
• Fill the shield tank with ultrapure water (July 2015)
TPB wavelength shifter deposition
Process system

Cryocoolers and LN2 dewar

Cooling coils being prepared for final acid bath

Ar purification getter and charcoal trap

Ar dewar
DEAP-3600 argon cooling system

Commissioning at 86 K, June 11, 2014
Data acquisition system

CAEN V1720

Digitiser & trigger module

PMT cables

LED driver

Neck veto cables

PMT cables
Calibration Systems

Calibrations tubes (x3) (AmBe, 5000n/s)
Water tank with liner
Magnetometers
Magnetic field compensation coils (x4)
Calibration tube ($^{22}$Na, 3.7MBq)

Courtesy: M. Ward
Light injection through fibers
Single photo-electron spectra

Low light intensity

High light intensity
A high energy event

Run: 9406  Subrun: 3  Event: 300460
Total energy: 1520 PE
High event rate: \( \sim 1 \) event/day
Expected muon rate: 1.6 muons/day

preliminary
Conclusion

• DEAP-3600 will search for dark matter interactions on argon starting summer 2015 with sensitivity to spin-independent WIMP-nucleon cross section >20 times better to current limits

• Construction is completed, currently depositing wavelength shifter and preparing for argon running

• Have been commissioning PMTs and electronics since late 2014, optical calibration ongoing

• Stay tuned
~60 collaborators in Canada, the UK, and Mexico

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DEAP presence at CAP

• Presentations (Tuesday afternoon)
  – DEAP-3600 trigger                  B. Smith
  – Optical data                     B. Beltran
  – Single photo-electron counting  T. McElroy
  – Neck alpha backgrounds          J. Bueno
  – Wavelength thickness studies     D. Cranshaw

• Posters (Wednesday evening)
  – Detector design and construction DEAP Collaboration
  – The resurfacer                   P. Giampa, B. Cai
  – Single PE calibration            C. Jillings, M. Kuzniak, T. Pollmann
  – Neck alpha backgrounds           C. Mielnichuk
  – $^{39}$Ar energy calibration     C. Stone, C. Jillings
Backup slides
Pulse-shape background discrimination