Alpha particle backgrounds from the neck of the DEAP-3600 dark matter detector

James Bueno, University of Alberta
for the DEAP-3600 collaboration

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Overview

- Neck region of the DEAP-3600 detector
- Radioactive contamination in DEAP-3600
- Mitigating neck alpha particle backgrounds:
  - Material selection and construction process
  - Choosing shape of components
  - Analysis of backgrounds
The DEAP-3600 detector

- Located at SNOLAB, 2 km below ground.
- Searching for WIMP nuclear recoils from 1 T liquid argon scintillator.
- Single phase operation with 255 PMTs (Hamamatsu R5912), 32% QE, 71% coverage.
- Cooled through a neck region.
The DEAP-3600 detector: neck region

- Very carefully designed geometry.
- Acrylic flow guides to direct warm liquid argon up and cool liquid argon down.
- Same acrylic as main vessel.
- No line of sight from steel to spherical acrylic vessel, except for the cooling coil.
  - Steel has $\sim 10^3$ more radioactivity than DEAP acrylic.
- Roughly 15 m of welds in contact with argon.
  - 5 m in cooling coil,
  - 10 m in neck steel.
Where do the alpha particle backgrounds come from?

**Bulk contamination** from $^{238}$U and $^{232}$Th chains in equilibrium.
- Clean acrylic monitored for years before construction.

Figure from J. Lidgard, 2008, Masters Thesis
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**Surface contamination**
- Exposure to air during construction.
- From liquid argon: none thanks to carbon trap.
- Weld emanation.

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Figure from J. Lidgard, 2008, Masters Thesis
Why do alpha particles cause a background?

- Radioactive decays in detector materials release alpha particles.
  - Energies are 4-9 MeV.
  - 5 MeV alpha’s have a range of ~35 µm in acrylic.

- Alpha particle in liquid argon produces 1000’s of photons.
  - Shadowed events with obstructed line of sight can look like WIMPs.
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- DEAP-3600 goal: < 0.2 alpha particle background events in 3 yrs.
Mitigation by GEANT4 tuning and analysis

- Flow guide geometry tuned by GEANT4 background simulations.
- Alpha particle decays in the neck have non-uniform position reconstruction.
Mitigation by GEANT4 tuning and analysis

- Flow guide geometry tuned by GEANT4 background simulations.
- Alpha particle decays in the neck have non-uniform position reconstruction.
- Radial cut removes most neck backgrounds, while maintaining a one-tonne fiducial.
- Pattern recognition using PMT light distribution and timing is under development.
  - See poster by Courtney Mielnichuk.
Machining neck flow guides

• Nov/Dec 2014: acrylic pieces machined in low radon environment at the University of Alberta and annealed in same air.
• Radon level ~0.3 Bq/m$^3$ compared to ~15 Bq/m$^3$ outside.
Covering up the acrylic vessel neck

- Spherical part of acrylic vessel was sanded with resurfacer.
- Neck of acrylic vessel was sanded with separate device.
- Gap between neck and outer flow guide was covered up.

Split ring, eliminates ~12 events in 3 years
Sanding flow guides

- Mar-Jun 2015: Hand sanded flow guide pieces in a nitrogen purged glovebox to remove embedded radon daughters.

Glovebox at Queen’s University

Flow guide pieces in glove box
Summary

• Gone to great lengths to minimize alpha particle backgrounds.
  • Selected clean materials.
  • Machined and sanded in clean environments.
  • Designed geometry carefully.

• Looking forward to argon data to verify the background rates.
The DEAP collaboration

~60 collaborators in Canada, the UK, and Mexico

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Backup: 232 Th chain

Figure 2.4: Thorium-232 decay chain

Figure from J. Lidgard, 2008, Masters Thesis