The DEAP-3600 Experiment

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10th April 2013
IOP HEPP & APP Conference

Outline
• Dark Matter and DEAP-3600
• Calibration System
• Construction Status
Collaboration

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

70 collaborators

Me again
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
What is DEAP-3600?

• **Dark matter Experiment using Argon Pulse-shape discrimination**

• DEAP-3600: Liquid Argon (LAr) detector
  – 3600kg LAr, 100kg 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

• Why Argon?
  – Ar transparent to 128nm scintillation photons
    • Large fiducial masses
  – Well separated singlet and triplet state lifetimes
The Detector

- LAr housed in sealed ultraclean acrylic vessel
- 255 8-inch Hamamatsu R5912 HQE PMTs
  - 32% QE, 75% coverage
- Acrylic vessel & light-guides provide neutron shielding
- Tetraphenyl-butadiene (TPB) used as wavelength shifter (128nm to 430nm)
- Detector submerged in 8m water tank
  - Cosmic veto
DEAP-3600 Signal

- What do we see?
  - Ionisation from recoiling nucleus
  - 128nm light detected by photomultipliers
- Ar singlet and triplet excited states have well separated lifetimes (4ns vs. 1.5us)
- Electronic and nuclear recoils produce different ratios of singlet and triplet states therefore...

![Electronic recoil](chart1.png)

![Nuclear recoil](chart2.png)
DEAP-3600 Signal

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

• Pulse Shape Discrimination:
  – Separate electronic and nuclear recoils using timing
  – $F_{\text{prompt}} = \frac{\text{PE}_{\text{prompt}}}{\text{PE}_{\text{total}}}$
DEAP-3600 Backgrounds

- Major background is Ar-39 beta decays – 1Bq/kg in Argon
- PSD allows reduction in fiducial volume to 2pBq/kg!

<table>
<thead>
<tr>
<th>Background (in Fid Vol)</th>
<th>DEAP-3600 Goal</th>
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<tbody>
<tr>
<td>Radon in Ar</td>
<td>&lt; 1.4 nBq/kg</td>
</tr>
<tr>
<td>Surface α’s</td>
<td>&lt; 100 μBq/m²</td>
</tr>
<tr>
<td>Neutrons (all sources)</td>
<td>&lt; 2 pBq/kg</td>
</tr>
<tr>
<td>Background Events (Ar-39)</td>
<td>&lt; 2 pBq/kg</td>
</tr>
<tr>
<td>Total (3 tonne-year in Fid Vol in ROI)</td>
<td>&lt; 0.6 events</td>
</tr>
</tbody>
</table>
How does DEAP-3600 fit in?

- Will set a world's best spin independent measurement on a competitive timescale:
  - $10^{-46}$ cm$^2$ for 100 GeV WIMP mass (3 years)
  - Xe-100: Current best limit

- DEAP will exceed Xe-100 sensitivity with 1 month of data
  - 1 year - Exceed LUX
Calibration Systems

• Three calibrations systems
• Optical, gamma source and neutron source
  – UK responsible for delivery
• And one for free: Ar-39

• What do we want to calibrate?
  – Energy scale (PE/keVee): Gamma, Ar-39, Optical
  – Radial reconstruction: Neutron, Gamma
  – Prompt photon fraction: Gamma, Ar-39
  – Detector uniformity & stability: Optical, Ar-39
  – ROI validity: Neutron, Ar-39

• Calibration data vital during commissioning and data run
Optical Calibration

*University of Sussex*

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

- PMT timing & gain calibration/monitoring
- AV/light guide monitoring
- Run during commissioning and physics run
Gamma Calibration

**RAL**

- Tagged Na-22 source lowered in external calibration tubes
- Map detector with well understood gamma spectrum
- Used to calibrate PMTs

Tagged NA-22 source canister
Neutron Source Calibration

**RHUL**

- Neutrons irreducible dark matter background
- Deploying a neutron source allows study of detector response to neutrons
  - Multiple scatters
  - ROI leakage
- System built to deploy tagged AmBe (α-n) source at various locations around detector
- Deployment system is constructed and tested
  - 4.5mm deployment precision
- Studies ongoing to determine neutron tagging method
• Construction and installation underground progressing well

• Acrylic vessel (AV) shipped underground: Dec 8, 2012

• AV prepped & annealed for bonding: Dec 2012 - Jan 2013

• Steel shell and structural steelwork completed. Steel shell is in final installation position hanging from deck

• Detector filling date early January 2014
Summary

• DEAP-3600 due to switch on in early 2014
• Will make worlds best spin independent dark matter measurement
  – Cross-section sensitivity: \(10^{-46} \text{ cm}^2\) at 100 GeV
• UK responsible for delivering calibration systems
  – Calibration data > 99% of all data taken... 100% if we don’t see Dark Matter!
Backup
Gamma Source Calibration - RAL

Hamamatsu R9880U:
gain $10^6$
QE: (380/420 nm) 35/30 %

Saint-Gobin LYSO / BrilLanCe 380
crystal 20 mm diam x 2 mm

PTFE coated cable
2+2 signal/HV cables
2 stainless steel safety wire

Na-22 source from High Technology Sources Ltd
Optical Calibration
University of Sussex

• Calibrate detector components during construction, commissioning and data-taking
  – LAr, TPB, Acrylic vessel, Light-guides, PMTs
  – Continuous monitoring

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

• Vertical cavity surface emitting laser (VCSEL) diffused in quartz flask
• Lowered into DEAP through neck
• Deployed before and after TPB deposition
• Calibrate Light-guide pre-TPB
• Determine TPB thickness
Optical Calibration

University of Sussex

• Calibrate detector components during construction, commissioning and data-taking
  – LAr, TPB, Acrylic vessel, Light-guides, PMTs
  – Continuous monitoring

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

  • Monitor TPB properties
  • Measure LAr scattering
  • Run during commissioning and physics run