DEAP-3600 trigger: dark matter from light

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1. DEAP-3600
2. Electronics and trigger
3. Trigger commissioning
DEAP-3600

- 2km below Sudbury, ON
- Uses liquid Ar to search for WIMPs
- ~60 collaborators from Canada, UK and Mexico

See detector hardware poster for more!
Detection principle

- Current evidence for dark matter is from gravitational interactions on large scales
- We're looking for direct evidence of interactions through the weak force
- Recoils in liquid argon cause scintillation
  - WIMPs cause nuclear recoils
  - Most backgrounds cause electron recoils
  - Pulse shapes are different!

![Nuclear recoil: more prompt light.](chart1)

![Electron recoil](chart2)
Expected sensitivity

- Expect world-leading sensitivity for $>0.1\text{TeV}$ WIMPs
**Expected event rates**

<table>
<thead>
<tr>
<th>Event type</th>
<th>Trigger rate (Hz)</th>
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</thead>
<tbody>
<tr>
<td>$^{39}$Ar $\beta$ decay</td>
<td>3600</td>
</tr>
<tr>
<td>Surface backgrounds</td>
<td>$&lt; 10^{-3}$</td>
</tr>
<tr>
<td>Cosmic muons</td>
<td>$&lt; 10^{-3}$</td>
</tr>
<tr>
<td><strong>WIMPs</strong></td>
<td>$&lt; 10^{-5}$</td>
</tr>
<tr>
<td>$^{222}$Rn decay</td>
<td>$&lt; 5 \times 10^{-6}$</td>
</tr>
<tr>
<td>Neutrons in Ar</td>
<td>$&lt; 10^{-6}$</td>
</tr>
</tbody>
</table>

- At least $10^8$ $\beta$ decays for each WIMP!
- Trigger needs to filter out most of these events, so offline analysis is feasible.
Electronics setup

- 255 LAr PMTs
- 22 signal conditioning boards (slow down the fast PMT pulses)
- 32 250MHz digitizers
- 4 62.5MHz digitizers
- Trigger signals
- SUM
- Readout PCs

PMTs: Hammamatsu R5912
SCBs: Custom TRIUMF/Alberta
DTM: Custom TRIUMF
250MHz digitizers: CAEN V1720
62.5MHz digitizers: CAEN V1740
Digitizer and trigger module

- Trigger is at the heart of the electronics
- Can trigger based on different sources
  - A timer (e.g. take data at 1kHz)
  - External signal (e.g. calibration system)
  - Analysing the PMT signals
- Each source is connected to one or more outputs
  - Which hardware to trigger
  - Whether to skip this event (to reduce trigger rate)
- This system is incredibly flexible and powerful
  - Can change the entire trigger scheme run-to-run
DEAP-3600 events

- Expect <1 pulse per PMT from a WIMP
- Digitizers configured to only save data near pulses
- Optical calibration uses simple "timer" trigger

Optical calibration: B Beltran talk next!
Energy and $F_{prompt}$

- "Physics" trigger looks at sum of all 255 PMTs
- Can distinguish $^{39}$Ar $\beta$ decays and WIMP-like nuclear recoils using $F_{prompt}$

Electronic and nuclear recoil calibration data from DEAP-1 (arXiv:0904.2930)

$E_{prompt} =$ charge in prompt window

$F_{prompt} =$ $E_{prompt}$ / $E_{wide}$
Energy and Fprompt

- The main physics trigger for DEAP-3600 will split up the energy/Fprompt phase-space into 6 regions
- Each region is connected to a different output
  - Keep all data for events in region 4 (WIMP-like!)
  - Ignore some events in region 5 ($\beta$ decays)
  - Ignore almost all events in region 1 (noise)
- Thresholds are being tuned during commissioning

![Phase-Space Diagram](image-url)
Latest commissioning results

- Trigger is calibrated
- Low-threshold data being used to tune MC noise model
- Lots of data taken to model trigger rates
The roadmap

- Need to optimize all the thresholds for the energy/Fprompt trigger
- Backgrounds change as the detector continues to be built
  - Add water to the veto tank – fewer "rock gammas"
  - Add wavelength-shifter – more $\alpha$ backgrounds
  - Install LAr flow guides in neck – more $\alpha$ backgrounds
  - Add gaseous Argon – start to understand $\beta$ rate
- Step-wise approach gives us great insight to the different background sources
- Final goal: 5MB/s, don't miss a single WIMP-like event
Summary

- DEAP-3600 expects to see at least $10^8$ times more $^{39}$Ar $\beta$ decay events than WIMPs.
- TRIUMF has developed a very flexible trigger module.
- Trigger scheme will be refined and optimised as we learn more about our detector.
- Aim to keep 100% of WIMP-like events, but greatly suppress $\beta$ decays and other backgrounds.
Backups
More about DEAP-3600

- Talks
  - Optical calibrations – Berta Beltran – next!
  - Photon counting – Thomas Mcelroy – this session!
  - Alpha backgrounds – James Bueno – today T3-4
  - Wavelength-shifter – Derek Cranshaw – today T3-4
  - Invited talk – Bei Cai – yesterday M2-7

- Posters – PPD poster session – tomorrow
  - Detector hardware – Pollman/Giampa/Dering
  - Resurfacer robot – Pietro Giampa
  - PMT calibration – Tina Pollman / Marcin Kuzniak
  - Neck alpha backgrounds - Courtney Mielnichuk
  - Energy calibration from beta decays – Connor Stone
Commissioning

- Trigger system is being used to collect lots of commissioning data
  - Light injection
  - PMT dark noise
  - Background characterisation

- Trigger is also used to monitor the health of PMTs