DEAP
Dark-matter Experiment with Argon PSD

Andrew Hime
Physics Division, MS H803, Los Alamos National Laboratory
Los Alamos, NM 87545, USA
ahime@lanl.gov

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Signals

100 GeV WIMPs with $\sigma_p = 10^{-44}$ cm$^2$

pp solar $\nu$'s

$^7$Be solar $\nu$'s

CLEAN

Background

PMT backgrounds

pp neutrinos

$^7$Be neutrinos

$\sim 12$ keV

Energy Reconstruction

10 keV, $\sigma = 2.6$ keV

50 keV, $\sigma = 4.7$ keV

100 keV, $\sigma = 6.4$ keV

Position Reconstruction

10 keV, $\sigma = 66.7$ cm

100 keV, $\sigma = 17.0$ cm
Design Constraints for a WIMP Dark Matter and $pp$ Solar Neutrino Liquid Neon Scintillation Detector

M.G. Boulay*, A. Hime, and J. Lidgard

Physics Division
MS H803, Los Alamos National Laboratory
Los Alamos, NM, USA 87545

Detailed Monte-Carlo simulations were used to evaluate the performance of a liquid neon scintillation detector for dark matter and low-energy solar neutrino interactions. A maximum-likelihood event vertex fitter including PMT time information was developed, which significantly improves position resolution over spatial-only algorithms, and substantially decreases the required detector size and achievable analysis energy threshold. The ultimate sensitivity to WIMP dark matter and the $pp$ flux uncertainty are evaluated as a function of detector size. The dependence on the neon scintillation and PMT properties are evaluated. A 300 cm radius detector would allow a $\sim$13 keV threshold, a $pp$ flux uncertainty of $\sim$1%, and limits on the spin-independent WIMP-nucleon cross-section of $\sim 10^{-46}$ cm$^2$ for a 100 GeV WIMP, using commercially available PMTs. Detector response calibration and background requirements for a precision $pp$ measurement are defined. Internal radioactivity requirements for uranium, thorium, and krypton are specified, and it is shown that the PMT data could be used for an in-situ calibration of the troublesome $^{85}$Kr. A set of measurements of neon scintillation properties and PMT characteristics are outlined which will be needed in order to evaluate feasibility and fully optimize the design of a neon-based detector.
Pulse Shape Discrimination in a CLEAN Detector
Sensitivity to WIMPs and Neutrinos with Liquid Neon

Boulay, Hime, and Lidgard nucl-ex/0410025

WIMP sensitivity

\( \sim 10^{-46} \)

Detector size

300 cm

1 year livetime

pp statistical uncertainty

<1%
Direct WIMP Detection Using Scintillation Time Discrimination in Liquid Argon

M.G. Boulay and A. Hime

Physics Division, MS H803, Los Alamos National Laboratory, Los Alamos, NM 87545
(Dated: November 16, 2004)

Discrimination between electron and nuclear recoil events in a liquid argon scintillation detector has been demonstrated with simulations by using the differences in the scintillation photon time distribution between these classes of events. A discrimination power greater than $10^8$ is predicted for a liquid argon experiment with a 10 keV threshold, which would mitigate electron and $\gamma$-ray backgrounds, including $\beta$ decays of $^{39}$Ar and $^{42}$Ar in atmospheric argon. A dark matter search using a $\sim 2$ kg argon target viewed by immersed photomultiplier tubes would allow a sensitivity to a spin-independent WIMP-nucleon cross-section of $\sim 10^{-43}$ cm$^2$ for a 100 GeV WIMP, assuming a one-year exposure. This technique could be used to scale the target mass to the tonne scale, allowing a sensitivity of $\sim 10^{-46}$ cm$^2$. 
<table>
<thead>
<tr>
<th>Parameter</th>
<th>Ne</th>
<th>Ar</th>
<th>Xe</th>
</tr>
</thead>
<tbody>
<tr>
<td>Yield ($\times 10^4$ photons/MeV)</td>
<td>1.5</td>
<td>4.0</td>
<td>4.2</td>
</tr>
<tr>
<td>prompt time constant $\tau_1$ (ns)</td>
<td>2.2</td>
<td>6</td>
<td>2.2</td>
</tr>
<tr>
<td>late time constant $\tau_3$</td>
<td>2.9 μs</td>
<td>1.59 μs</td>
<td>21 ns</td>
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<tr>
<td>$I_1/I_3$ for electrons</td>
<td>0.3</td>
<td>0.3</td>
<td></td>
</tr>
<tr>
<td>$I_1/I_3$ for nuclear recoils</td>
<td>3</td>
<td>1.6</td>
<td></td>
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<tr>
<td>$\lambda$(peak) (nm)</td>
<td>77</td>
<td>128</td>
<td>174</td>
</tr>
<tr>
<td>Rayleigh scattering length (cm)</td>
<td>60</td>
<td>90</td>
<td>30</td>
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</table>
DEAP Simulation Parameters

• 6 pe/keV for 75% coverage, with
• 1500 Hz PMT noise
• Backgrounds from Ham. R9288 (approx. 70 mBq/PMT)
• 5 ns PMT resolution
• 20% photon detection efficiency
• 100 ns trigger window sets $T_0$
• $F_{\text{prompt}} = \text{Prompt hits(100 ns)}/\text{Total hits(15 μs)}$
• ~10 keV$_{ee}$ threshold (60 pe)
<table>
<thead>
<tr>
<th>Source</th>
<th>Rate (events/year)</th>
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</thead>
<tbody>
<tr>
<td>$^{39}\text{Ar}$</td>
<td>$1.26 \times 10^6$</td>
</tr>
<tr>
<td>$^{42}\text{Ar}$</td>
<td>76</td>
</tr>
<tr>
<td>U in PMTs</td>
<td>$2.65 \times 10^5$</td>
</tr>
<tr>
<td>Th in PMTs</td>
<td>$1.51 \times 10^5$</td>
</tr>
<tr>
<td>K in PMTs</td>
<td>$4.54 \times 10^5$</td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td>$2.13 \times 10^6$</td>
</tr>
</tbody>
</table>
Background rejection with LAr (simulation)

From simulation, rejection $> 10^8$
@ 10 keV

10^8 simulated e-'s
100 simulated WIMPs

Events/0.01 wide bin

F_{prompt}
Test-Cryostat for DEAP at LANL
<table>
<thead>
<tr>
<th>Target Mass (kg)</th>
<th>100 GeV WIMP-nucleon X-section (cm$^2$)</th>
</tr>
</thead>
<tbody>
<tr>
<td>100 GeV</td>
<td>100</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Detector Mass</th>
<th>10 kg</th>
<th>100 kg</th>
<th>1 t</th>
<th>5 t</th>
<th>10 t</th>
<th>40 t</th>
<th>135 t</th>
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</thead>
<tbody>
<tr>
<td>Detector Radius (cm)</td>
<td>12</td>
<td>26</td>
<td>56</td>
<td>100</td>
<td>200</td>
<td>300</td>
<td></td>
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</tbody>
</table>

CLEAN Fiducial Mass
\[ \sigma_{pp} \sim 1\% \]

CLEAN Total Mass
\[ \sigma_{pp} \sim 7\% \]

DEAP-I

DEAP-II

DEAP-III
Depth Sensitivity Relation for Dark Matter

D-M Mei & AH

[Graph showing the depth sensitivity relation for dark matter, with various sites like WIPP, Soudan, Kamioka, Boulby, Gran Sasso, and Sudbury, and the CDMS-II sensitivity curve.]
CLEAN

… get clean and go deep

DEAP