CLEAN Detection of Dark Matter

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LAUR-11-10659
Pulse-Shape Discrimination in LAr

Example Pulses from DEAP-0

Event from Na-22 run with 67 prompt pe, $F_{\text{prompt}} = 0.31$

Event from AmBe run with 48 prompt pe, $F_{\text{prompt}} = 0.89$
Approach

Keep it conceptually simple & scalable ...
MiniCLEAN Modular Design

- Radon-free assembly ...
- “Cold” design allows both LAr & LNe ...
- $4\pi$ coverage to maximize light-yield at threshold ...
  - 3D Position Reconstruction
  - Particle-ID via Pulse-shape discrimination
- No electric fields ... PMTs only active component ...
- Fast signals ($\tau_3 = 1.6 \, \mu s$) avoid pulse-pileup in LAr ...
Sensitivity

Backgrounds

$^{39}$Ar in Target
Fast Neutrons from PMTs
Surface Radon Progeny

Particle-ID
Fiducialization & Tagging
Fiducialization & Particle-ID

Pulse Shape Discrimination
Position Reconstruction

Light Yield
Progress on PSD

microCLEAN at Yale

W.H. Lippincott et al.

DEAP-1 at SNOLAB

36% chance of one accidental background event in
1.1 x 10^8 events between 120 and 240 pe
# photoelectrons

\( \text{DEAP-1 Upper Bound} \)

\( \text{Integral Leakage < } 3 \times 10^{-8} \)
Differential Leakage

Energy (keV_{ee})

# photoelectrons (pe)

DEAP-1 Upper Bound
Integral Leakage < 3 \times 10^{-8}

MiniCLEAN
1 event/150kg/year

L_{\text{recoil}}
99.99 \%

F_{\text{prompt}}
99.99 \%

50 \%

99.99 \%

F_{\text{prompt}}

1 event/150kg/year
A Comment on Discovery Potential

We are entering an “era of discovery” of SUSY WIMPs with interaction cross-section below $10^{-44}$ cm$^2$ ...

Discovery will require experiments with robust means for differentiating signal from background and confirming backgrounds with redundant methods ...

Discovery will require verification & consistency amongst different experiments ...

... technical approach (attack on backgrounds)

... target sensitivity to WIMP parameters (eg. $A^2$)

We need scalable and affordable detector technologies ...
$^{39}$Ar Spike & Target Exchange in MiniCLEAN

Natural Ar Run  

Events in ROI?  

Y  

Enriched $^{39}$Ar Run  

$^{39}$Ar BGND Leakage  

Y  

Rate $\times 10$?  

N  

Evidence for WIMPs  

N  

Neon Run  

Rate $\times 1/10$?  

Y  

Confirm Evidence for WIMPs  

N  

PSD Demonstrated WIMP Upper Limit
$^{39}$Ar Spike & Target Exchange in MiniCLEAN

1. Natural Ar Run
   - Events in ROI?
     - Yes: Enriched $^{39}$Ar Run
     - No: PSD Demonstrated WIMP Upper Limit
2. $^{39}$Ar BGND Leakage
   - Yes: $^{39}$Ar BGND Leakage
   - No: Neon Run
3. Neon Run
   - Rate X 10?
     - Yes: Confirm Evidence for WIMPs
     - No: Evidence for WIMPs
4. Neutron or Radon BGND
   - Yes: Confirm Evidence for WIMPs
   - No: Informs Larger LAr Detector
From MiniCLEAN to CLEAN

500 kg  50000 kg

Inner Vessel
x3

Outer Vessel
x2

Scale-up using “conventional” SS pressure vessels & maintain LAr/LNe capability
Should we be considering an intermediate step for CLEAN?
Thank You
### DEAP/CLEAN Collaborators

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<thead>
<tr>
<th>University of Alberta</th>
<th>University of Pennsylvania</th>
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<tr>
<td><strong>Boston University</strong></td>
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Andrew Hime Dark Matter 2012
DEAP-3600

DEAP-3600
3.6 T LAr in Acrylic Vessel

Steel Shell

Acrylic Vessel

Water Tank 2m Shielding

Liquid Argon

255 room temp PMTs
50cm light guides
# MiniCLEAN & DEAP-3600

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<th>G1 MiniCLEAN</th>
<th>G2 DEAP-3600</th>
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<tr>
<td><strong>Target Capability</strong></td>
<td>LAr &amp; LNe</td>
<td>LAr</td>
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<tr>
<td><strong>Target Radius (cm)</strong></td>
<td>45 cm</td>
<td>85 cm</td>
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<tr>
<td><strong>Target Mass (kg)</strong></td>
<td>500</td>
<td>3600</td>
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<tr>
<td><strong>Fiducial Mass (kg)</strong></td>
<td>150</td>
<td>1000</td>
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<td><strong>Light Collection</strong></td>
<td>92 Modular Optical Cassettes with PMTs Submerged “Cold”</td>
<td>266 “Warm” PMTs outside of Cryogen</td>
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<tr>
<td><strong>Cryogenic Containment</strong></td>
<td>Code Stamped Stainless Steel Pressure Vessel</td>
<td>Monolithic Acrylic Vessel</td>
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<td><strong>Neutron Shielding</strong></td>
<td>30 cm of Acrylic &amp; Cryogen</td>
<td>50 cm Acrylic</td>
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<td><strong>Surface Radon Mitigation</strong></td>
<td>Modular Cassettes Assembled in Vacuum</td>
<td>In Situ Resurfacing of inner Acrylic Vessel Surface</td>
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<td>LN-Cooled Thermal Siphon</td>
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