DEAP & CLEAN Detectors
for the Direct Detection of Dark Matter

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Elevator Statements

The existence of Dark Matter is firmly established and represents one of the most pressing problems in modern science.

The identification of Dark Matter is highly synergistic with the theoretical and experimental techniques at the intersection of the disciplines of Nuclear Physics, Particle Physics, Astrophysics, and Cosmology (NPAC).

A compelling explanation calls for Weakly Interacting Massive Particles (WIMPs) thought to be the cold, dark relics of the Big Bang.

How can INPAC serve as an Institute for the NPAC community engaged in the identification of Dark Matter?
Need Scalable Detector Technology with Ever-Increasing Reduction/Rejection of Background !!!
Exploiting Noble Liquids
DEAP - Dark matter Experiment with Argon and Pulse-shape-discrimination

![Graph showing prompt/singlet and late/triplet light with relative probability and time constant](image1)

**Basic Concept Demonstrated at LANL ... DEAP-0**

![Graph showing events/bin with simulated background](image2)
**Goals of the DEAP-1 Experiment**

→ Demonstrate basic & conceptually simple approach with “single-phase” technology
→ Demonstrate PSD at low-energy threshold & low-background
→ Perform 1’rst generation WIMP search competitive with other experiments at similar scale
CLEAN: Cryogenic Low Energy Astrophysics with Neon


- LNe contains no long-lived radioactive isotopes and is easily purified of $^{39}$Ar & $^{85}$Kr using conventional cold-traps.
- LNe is transparent to its own scintillation light and dense enough to act as a self-shielding medium.
- Position reconstruction via PMT charge & time distributions allows fiducialization of the central volume while avoiding the PMT background wall.
- LNe scintillates brightly in the EUV with ~30000 photons/MeV.

Low-Energy Threshold

- Pulse-Shape-Discrimination is possible using two distinct states of scintillation light, making possible a truly dual-purpose detector of low-energy solar neutrinos and WIMP dark matter.

Boulay, Hime, & Lidgard, nucl-ex/0410025
Projected Sensitivity with 40 ton CLEAN

<table>
<thead>
<tr>
<th></th>
<th>pp uncert. (%)</th>
<th>⁷Be uncert. (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1 y</td>
<td>5 y</td>
<td>1 y</td>
</tr>
<tr>
<td>Energy scale</td>
<td>0.34</td>
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<tr>
<td>Fiducial volume</td>
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<tr>
<td>Internal krypton</td>
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<tr>
<td>External backgrounds</td>
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<td>0.02</td>
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<tr>
<td>⁷Be ν’s</td>
<td>0.25</td>
<td>0.11</td>
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<tr>
<td>Total systematic</td>
<td>1.03</td>
<td>1.00</td>
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<tr>
<td>Statistics</td>
<td>0.86</td>
<td>0.38</td>
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<tr>
<td>Total</td>
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- Development & Design with LNe
- Dark Matter Search with LAr
Getting More Ambitious

Combine the attributes of LAr and LNe in the same detector at the “tonne” scale

♦ Sensitive search for WIMP dark matter with LAr ($\sigma_{100\text{ GeV}} \sim 10^{-46}\text{ cm}^2$)

♦ Exchange LAr with LNe for a “Beam-On/Beam-Off” WIMP experiment

$$S(\text{Ar}) \sim 10 \times S(\text{Ne})$$
$$B(\text{Ar}) \sim 1 \times B(\text{Ne})$$

♦ Prototype step to massive (~100 tonne) LNe detector for DM and low-energy ($pp$-fusion) solar neutrinos
“tonne-scale” DEAP/CLEAN participants

University of Alberta
Boston University
Carleton University
DUSEL
Los Alamos National Laboratory
University of New Mexico
NIST - Boulder
University of North Carolina
Queens University
University of South Dakota
SNOLAB
University of Texas - Austin
Yale University
Acrylic Vessel & Vacuum Cryostat Concept
Acrylic Vessel Concept
Neutralinos can be responsible for both Baryogenesis and Dark Matter

All parameter space is within reach of next generation km$^2$ neutrino telescopes and “tonne-scale” direct detection WIMP experiments.
Synergies

Baryon Asymmetry

SUSY EW Baryogenesis

Neutralino Cold Dark Matter

Next Generation Direct / Indirect
- Ton Scale Recoil Cryogenic Detectors
- km$^2$ Neutrino Telescopes - IceCube

Production at LHC / ILC

Next Generation Electric Dipole Moments
Opportunity

Under U.S. lead, novel and complementary developments in the NPAC community will extend the reach to identify the Dark Matter in the Universe by several orders of magnitude within the next decade.

Observation

Interest and support for the investigation into Dark Matter has fallen into niches mainly as a result of the traditional means for funding specific aspects of the research. The identification of Dark Matter is intrinsically intertwined with modern techniques that intersect the boundary of Nuclear physics, elementary Particle physics, Astrophysics, and Cosmology (NPAC). A combination of complementary and redundant efforts will be required to firmly establish the nature of Dark Matter.

Recommendation

INPAC should be designed and organized to unite the global community and to develop a concerted effort towards the identification and understanding of Dark Matter. It should further provide a voice to the funding agencies for achieving this goal and marking it as a high priority in U.S. science.