Status of the PICASSO Dark Matter Search Experiment

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Seitz theory of phase transition of superheated liquids

\[ E_{\text{dep}} = \frac{dE}{dx} \cdot R_{\text{crit}} \geq E_{\text{min}} \]

Superheated droplet technique

Liquid-to-vapour phase transition

- **Incoming particle**
- **Liquid Droplet**
- **Nuclear recoil**
- **Gas Bubble**
- **Direct energy deposition**
- **Recoiling nucleus**
- **Shock wave**
The PICASSO Collaboration

Project in Canada to Search for Supersymmetric Objects


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*Bubble Technology Industries, Canada*
1) **Polymerized Aqueous Gel Matrix**

**Inert Component**

Droplet sizes: 5μm to 100 μm

2) **Freon C₄F₁₀ Droplets**

**Active Component**

Picture taken with a microscope

- Fabrication technique based on the Bubble Detectors produced by *Bubble Technology Industries*

- Modified to customize the detectors for the Dark Matter Search (Larger, Cleaner)

- Gel ingredients: water, acrylamide, bis-acrylamide... **Cesium Chloride** (to equalize densities)

- ~Ambient temperature operation (freon superheated)
Neutralino interaction with matter:

\[
\sigma_A = 4G_F^2 \left( \frac{M_\chi M_A}{M_\chi + M_A} \right)^2 C_A
\]

Enhancement factor

Depending on the type of target nucleus and neutralino composition

Spin independent interaction \( (C_A \propto A^2) \)

Spin dependent interaction

\[
C_A = \left( \frac{8}{\pi} \right) (a_p <S_p> + a_n <S_n>)^2 (J+1)/J
\]

\[ \lambda \]

Spin of the nucleus is approximately the spin of the unpaired proton or neutron

<table>
<thead>
<tr>
<th>Isotope</th>
<th>Spin</th>
<th>Unpaired</th>
<th>( \lambda^2 )</th>
</tr>
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<tbody>
<tr>
<td>( ^7 \text{Li} )</td>
<td>3/2</td>
<td>p</td>
<td>0.11</td>
</tr>
<tr>
<td>( ^{19} \text{F} )</td>
<td>1/2</td>
<td>p</td>
<td>0.863</td>
</tr>
<tr>
<td>( ^{23} \text{Na} )</td>
<td>3/2</td>
<td>p</td>
<td>0.011</td>
</tr>
<tr>
<td>( ^{29} \text{Si} )</td>
<td>1/2</td>
<td>n</td>
<td>0.084</td>
</tr>
<tr>
<td>( ^{73} \text{Ge} )</td>
<td>9/2</td>
<td>n</td>
<td>0.0026</td>
</tr>
<tr>
<td>( ^{127} \text{I} )</td>
<td>5/2</td>
<td>p</td>
<td>0.0026</td>
</tr>
<tr>
<td>( ^{131} \text{Xe} )</td>
<td>3/2</td>
<td>n</td>
<td>0.0147</td>
</tr>
</tbody>
</table>

**Why \( C_4F_{10} \)? Spin Dependent**
Energy Thresholds of the PICASSO Detectors

200 keV neutrons

Neutron beam calibrations

400 keV neutrons

Monte Carlo Simulations

M.H. Genest
Thresholds & Efficiency

Energy Thresholds

Efficiency
Evolution of the energy threshold for $^{19}$F recoils (1.23 bar)

Sensitivity to keV recoils
Detector Operation

**Operation cycle**

**Data taking:** (> 30h)
Temperature range: ~15 C to ~55 C
Relative pressure: 0 psi

**Recompression:** (~10h)
Relative pressure: ~ 90 psi

**Duty Cycle:** ~80%

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M.-H Genest

The Hunt for Dark Matter, FermiLab – May 10, 2007
**Backgrounds**

- **Cosmic ray muons** → induce high energy **neutrons** (E > 10 MeV)

- Radioactivity from the environment  **neutrons** → (E < 10 MeV)

- MIPS → Mostly suppressed at the operating temperature range (better than $10^7$ at $E_{rec} = 6$ keV)

- **α-particles are the dominant background (for WIMP runs, mainly from CsCl)**

**Simulations indicate that the shape of the curve is independent of the droplet distribution and the type of the contaminant**

![Response curve from a $^{238}$U spiked detector](image)

(Bckg. values: integrated from 6 keV – 1 MeV)
Signal $\times$ Background shape

Neutralino Signal Effect

- $\alpha$-fit
- $\alpha$-fit + $M_\chi = 50$ GeV, $\sigma_\chi = 15$ pb
- $\alpha$-fit + $M_\chi = 50$ GeV, $\sigma_\chi = 5$ pb
- $\alpha$-fit + $M_\chi = 50$ GeV, $\sigma_\chi = 2$ pb

(Bckg. values: integrated from 6 keV – 1 MeV)
- First experiment at SNOLAB
- 4.5 L Detector Modules: 32
- Total net detector volume: ~ 150 L
- Total active mass (C₄F₁₀): ~ 2.6 kg
- Acoustic channels: 288 (9 channels per detector)
- Expected exposure: ~280 Kg·day (Six-month period)
### Improved fabrication Method: The 4.5L detector

1. **Reduction of the internal background:** Cleaner materials

2. **Improved fabrication procedure – Defect-free gel & Homogeneous distribution of droplets**

3. **Reduction of the internal background - Purification of the ingredients**

   (PICASSO Collaboration technology)

<table>
<thead>
<tr>
<th>Exp-ID</th>
<th>PZS50A</th>
<th>PZS50B</th>
<th>PZS50D</th>
<th>PZS60B&amp;C</th>
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<tbody>
<tr>
<td>CsCl concentration</td>
<td>50%</td>
<td>50%</td>
<td>60%</td>
<td>60%</td>
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<tr>
<td>HZrO concentration</td>
<td>2 g Zr/L</td>
<td>0.28 g Zr/L</td>
<td>0.05 g Zr/L</td>
<td>0.13 g Zr/L</td>
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<tr>
<td>Extraction efficiency</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>$^{228}\text{Th}$</td>
<td>$&gt;99.7%$</td>
<td>$&gt;98.8%$</td>
<td>99.8±0.4%</td>
<td>99.1±1.5%</td>
</tr>
<tr>
<td>$^{224}\text{Ra}$</td>
<td>$&gt;99.6%$</td>
<td>99.2±0.8%</td>
<td>-</td>
<td>97.0±1.2%</td>
</tr>
<tr>
<td>$^{226}\text{Ra}$</td>
<td>$&gt;99.5%$</td>
<td>97.3±1.1%</td>
<td>64.9±3.8%</td>
<td>97.1±0.6%</td>
</tr>
<tr>
<td>$^{212}\text{Pb}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>96.1±0.8%</td>
</tr>
<tr>
<td>$^{212}\text{Bi}$</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>92.8±1.6%</td>
</tr>
</tbody>
</table>

$\Rightarrow$ New method: co-precipitation of Th, Ra and Pb with (HZrO) Hydrous Zirconium Oxide
The greater the droplet’s radius, the smaller the alpha response – for the same active mass ("Geometric Purification")

The response varies like \( (R_{\text{droplet}})^{-1} \)

M.-H Genest

Production of the 4.5L detectors

Detector's response to the alpha internal background
Production of the 4.5L detectors

Expected performance of the 4.5L PICASSO detector’s production

→ Droplet Distribution

1-Litre

Active Mass: ~ 7g/L
Loading = 0.5%

4.5-Litre

Active Mass: ~ 19g/L detector
Loading = 1.2%

300 X less background

→ Higher loading
Data taking & Calibrations

- Performance
  - All piezos sensors see individual events
  - No dead regions
  - **Localization of events**

- Switchable on site neutron calibration source

- Optimized data taking strategy

- Optimized filters and signal recognition strategy

- **New beam line for neutron calibration/characterization of the detectors**
Installation @ SNOLab
Conclusions

• PICASSO uses superheated droplets detectors for the direct search of dark matter

• The SDD response to different background sources has been studied extensively

• For the this phase we expect that the increase in mass and purity improve the sensitivity dramatically

• Installation of major infrastructure has been completed and the first four modules are presently taking data (more will be added progressively)

• Data analysis of the first four modules is in progress and results will be available for the end of 2007