Status of Dark Matter Search with HDMS and GENINO

Dark Matter 2000, Marina del Ray
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The GENIUS Collaboration
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Outline:

1. The present situation

2. The HDMS experiment

3. Results from the prototype detector

4. GENIUS and GENINO

5. Outlook and Conclusion
The present situation:

Evidence for WIMP dark matter (P. Belli this conference) through the signature of annual modulation in the spectrum of 100 kg NaI detector.

\[ \sigma_{W-N, \text{scalar}} \text{ [pb]} \]

- Very important to check with independent measurement signal and signature
The Heidelberg Dark Matter Search (HDMS)

Idea of further background reduction:

→ Multiple scattered events can be considered as background

Simulations show: Reduction up to a factor of 20.

L. Baudis et al. NIM A 385(1997)265
The prototype detector:

The prototype detector was running for a period of 362.91 days from March 1998 until July 1999.

Technical data of the detector:

<table>
<thead>
<tr>
<th>Property</th>
<th>Inner Detector</th>
<th>Outer Detector</th>
</tr>
</thead>
<tbody>
<tr>
<td>Crystal Type</td>
<td>p-type</td>
<td>n-type</td>
</tr>
<tr>
<td>Mass [g]</td>
<td>202</td>
<td>2111</td>
</tr>
<tr>
<td>Active Volume [cc]</td>
<td>37</td>
<td>383</td>
</tr>
<tr>
<td>Crystal diameter [mm]</td>
<td>35.2</td>
<td>84.4</td>
</tr>
<tr>
<td>Crystal length [mm]</td>
<td>40.3</td>
<td>86.2</td>
</tr>
<tr>
<td>Operation Bias</td>
<td>+2500</td>
<td>-1500</td>
</tr>
<tr>
<td>FWHM (1332 keV) [keV]</td>
<td>1.87</td>
<td>4.45</td>
</tr>
<tr>
<td>Threshold [keV]</td>
<td>2.5</td>
<td>7.5</td>
</tr>
</tbody>
</table>
Spectrum of outer detector after 362.91 days:

Identified peaks result from U/Th decay chains, $^{40}\text{K}$ and cosmogens

Also seen: $\alpha$'s → contamination from soldering tin
Spectrum of inner detector after 362.91 days:

Identified Peaks:

<table>
<thead>
<tr>
<th></th>
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</tr>
</thead>
<tbody>
<tr>
<td>10.37</td>
<td>1803 ± 48</td>
<td>2.00 ± 0.06</td>
<td>$^{68}$Ga and other X-rays</td>
</tr>
<tr>
<td>32.46 ± 0.25</td>
<td>110 ± 16</td>
<td>2.63 ± 0.50</td>
<td>?</td>
</tr>
<tr>
<td>122.06</td>
<td>45 ± 11</td>
<td>1.78 ± 0.50</td>
<td>$^{57}$Co</td>
</tr>
<tr>
<td>136.47</td>
<td>48 ± 17</td>
<td>7.48 ± 4.02</td>
<td>$^{57}$Co</td>
</tr>
<tr>
<td>143.58</td>
<td>45 ± 10</td>
<td>1.417 ± 0.39</td>
<td>$^{57}$Co</td>
</tr>
<tr>
<td>238.63</td>
<td>40 ± 12</td>
<td>3.35 ± 1.21</td>
<td>$^{212}$Pb, $^{224}$Ra, $^{214}$Pb</td>
</tr>
<tr>
<td>240.99</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>241.98</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>511.00</td>
<td>284 ± 18</td>
<td>2.82 ± 0.16</td>
<td>annihil.</td>
</tr>
<tr>
<td>834.84</td>
<td>35 ± 8</td>
<td>6.46 ± 1.80</td>
<td>$^{58}$Mn</td>
</tr>
<tr>
<td>1173.24</td>
<td>28 ± 6</td>
<td>2.22 ± 0.45</td>
<td>$^{60}$Co</td>
</tr>
<tr>
<td>1332.50</td>
<td>20 ± 5</td>
<td>2.25 ± 0.59</td>
<td>$^{60}$Co</td>
</tr>
</tbody>
</table>
Anticoincidence spectrum:

last 114.95 days of measurement

→ Suppression of \( \sim \) factor 4 (outer detector too thin).

But: Already now reached a background comparable to Heidelberg-Moscow-Experiment.
exclusion plot:

main background components:

- Cosmogenics
- Copper of Crystal holder
- Soldering tin for contacts
Background model:

Monte Carlo Simulation (GEANT3.21) → Most background components identified:

Upper panel: outer detector, high energy spectrum
Middle: inner detector, high energy spectrum
Lower panel: inner detector, low energy spectrum

In principle it is possible to subtract background model → Further improvement of sensitivity by approximately factor 2.
In future:

Setup with $^{73}$Ge-inner crystal will start measurement in summer 2000.

Further background suppression with respect to prototype is expected through:

- $^{73}$Ge crystal → Supression of $^{68}$Ge production up to a factor of 500!
- New crystal holder out of carefully selected copper
- No use of soldering tin.

→ HDMS will be able to test DAMA evidence region within the next three years.
GENIUS

Reduction of background by 3-4 orders of magnitudes:

→New technology:

’naked’ HPGe-crystals in LN$_2$

- LN$_2$ can be produced very clean
- Removal of all dangerous contaminations
- Shielding from external activity
- Efficient cooling of detectors

GENINO
An intermediate size detector for Wimp Dark Matter search

We showed earlier: The concept of the GENIUS project is very powerful.

First verify feasibility in a smaller setup with the same target mass: 100 kg of natural Germanium.

GENINO proposal: reduce the size of the tank by replacing part of the nitrogen shield by substantially denser medium: commonly used boliden lead.

electronics, holder system and clean room facilities can be used in both setups!
If reasonable sensitivity has to be achieved:

→ Size of setup is determined by influence of vessel wall: steel, polystyrene foam and boli- den lead.
→ Amount of boliden lead is given by surrounding gammas.

Increase of sensitivity by factor 20 →

- Minimal liquid nitrogen tank size: 5m in diameter
- Thickness of lead shielding: ~ 25cm
New background simulations

Simulated components:

**A:** Internal activities
- Cosmogenics
- Holder system
- Liquid nitrogen
- vessel: steel, polystyrene, lead

**B:** External activities
- Gamma flux from surrounding
- Neutron flux
- Muons
Simulated components:
Resulting sum spectrum:

<table>
<thead>
<tr>
<th>Source</th>
<th>Component</th>
<th>Count rate (11-100 keV) [counts/(kg y keV)]</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen</td>
<td>U/Th/K/Rn</td>
<td>1×10⁻³</td>
</tr>
<tr>
<td>Steel vessel</td>
<td>U/Th</td>
<td>2.5×10⁻¹</td>
</tr>
<tr>
<td>Lead</td>
<td>U/Th</td>
<td>2×10⁻¹</td>
</tr>
<tr>
<td>Isolation</td>
<td>U/Th</td>
<td>7×10⁻²</td>
</tr>
<tr>
<td>Holder system</td>
<td>U/Th</td>
<td>1×10⁻²</td>
</tr>
<tr>
<td>Surrounding</td>
<td>Gammas(LE)</td>
<td>7×10⁻²</td>
</tr>
<tr>
<td></td>
<td>Gammas(HE)</td>
<td>5×10⁻³</td>
</tr>
<tr>
<td></td>
<td>Neutrons</td>
<td>8×10⁻³</td>
</tr>
<tr>
<td></td>
<td>Muon shower</td>
<td>2×10⁻²</td>
</tr>
<tr>
<td>Cosmogenics in Ge</td>
<td>⁵⁴Mn, ⁵⁷Co, ⁶⁰Co</td>
<td></td>
</tr>
<tr>
<td></td>
<td>⁶³Ni, ⁶⁵Zn, ⁶⁸Ge</td>
<td></td>
</tr>
<tr>
<td>Cosmogenics in N</td>
<td>⁷Be, ¹⁴C</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td>7.5×10⁻¹ counts/(kg y keV)</td>
</tr>
</tbody>
</table>
→ The WIMP signal suggested by the DAMA experiment can be tested

→ The background is small enough and the target mass is high enough to also test the signature (annual modulation, see Cebrián et al. hep-ph/9912394)

→ Direct test of DAMA evidence possible in near future!
Conclusions:

- HDMS prototype proves: *technique is working*

- Start of measurement this summer

- Independent test of DAMA evidence region with the HDMS experiment is expected within three years

- As a first step towards the realization of GENIUS project we propose the intermediate size *GENINO* setup

- With the *GENINO* setup a test of *signal and signature* of dark matter WIMPs suggested by DAMA can be made.