A Dark Matter Tool on the Web

http://pisrv0.pit.physik.uni-tuebingen.de/darkmatter/

R. Lemrani, ILIAS-N3 Dark Matter Network / CEA Saclay
A word on ILIAS

Integrated Large Infrastructures for Astroparticle Science

European tool: I3 structure (Integrated Infrastructure Initiative) of FP6
Participants: 21 Contractors (70 laboratories), 14 European Countries
Start date: April 1st 2004 for 5 years
Web site: ilias.in2p3.fr

Prime areas: Double Beta Decay, Dark Matter, Gravitational Waves

Infrastructures: - Deep Underground Laboratories
- Gravitational Wave Interferometers

“… to produce a focused, coherent and integrated project to improve the existing infrastructures and their operation as well as to organise and structure the scientific community to prepare the best infrastructures for the future.”
A word on ILIAS-N3 Dark Matter Network

Web site: http://ilias-darkmatter.uni-tuebingen.de/

Working groups

- Cryogenic Detectors and Cryostat
- Non cryogenic Detectors and liquid Xenon
- Germanium and NaI Detectors
- Advanced Detectors including directional Concepts

Detection Concepts

- Axion Searches
- Background Simulation, Neutron-Shield and Muon-Vetos
- High Radiopurity Materials and Materials Purification

Common Activities

Convergence on the optimum strategy for large scale detector based on each of the alternatives

1st, 2nd, 3rd, 4th Year

Input for ASPERA Roadmap

http://pisrv0.pit.physik.uni-tuebingen.de/darkmatter/
Web tool: Purpose

- Build a web interface for dark matter calculations: Expected spectra, limits extraction, ...

- Handling different detection techniques

- Handling different theoretical assumptions

- Cross check methods and codes

- Available to the whole dark matter community

- Allowing comparisons of experimental strategies using the same theoretical inputs and varying them
Welcome to the

DArk
Matter
Network
Exclusion
Diagram
tool web page

Direct detection:

Spectra: Experimental energy spectra
Limits: Experimental limits on WIMP-nucleon cross sections
SuSy: Direct detection of Neutralinos

ILIAS related Links
Dark Matter N3 network
ILIAS web site
Database on radiopurity of materials
Database on purification of materials

External Links
Dark Matter Limit Plot Generator
DarkSUSY
SPF by G.Jungman
SoftSUSY - Micromegas - Suspect
Upper Limit Software by Yellin
Pole software: Confidence intervals with systematic uncertainties
Berkeley Twiki - F.Mayet's Portal

http://pisrv0.pit.physik.uni-tuebingen.de/darkmatter/
Direct Search for WIMPs

**WIMP nature : ie Neutralino**

\[ \sigma = \text{WIMP-nucleus cross section (point-like)} \]
\[ m_\chi = \text{WIMP mass} \]
\[ \mu = \text{WIMP-nucleus reduced mass} \]

**Galactic Halo**

\[ \rho = \text{density} \]
\[ f(v) = \text{velocity distribution} \]

**Detection rate :**

\[ \frac{dN}{dE} = \frac{\sigma \rho}{2 \mu^2 m_\chi} F^2 \int_{V_{\text{min}(E_r)}}^{V_{\text{esc}}} \frac{f(v)dv}{v} \times \frac{\varepsilon(E)}{q(E) \otimes r(E)} \]

**Nucleus**

\[ F = \text{Nuclear form factor} \]
\[ \mu = \text{WIMP-nucleus reduced mass} \]

**Detection**

\[ q(E) = \text{quenching} \]
\[ \varepsilon(E) = \text{efficiency} \]
\[ r(E) = \text{resolution} \]

Example: Dependence on WIMP Mass

All parameters are entered in a form: The outputs are figures and tables.

<table>
<thead>
<tr>
<th>Label</th>
<th>WIMP mass (GeV)</th>
<th>A of Target</th>
<th>Exposure (kg.days)</th>
<th>WIMP-nucleon cross section (pb)</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>10GeV</td>
<td>10</td>
<td>72.6</td>
<td>1E-7</td>
</tr>
<tr>
<td>2</td>
<td>20GeV</td>
<td>20</td>
<td>72.6</td>
<td>1E-7</td>
</tr>
<tr>
<td>3</td>
<td>50 GeV</td>
<td>50</td>
<td>72.6</td>
<td>1E-7</td>
</tr>
<tr>
<td>4</td>
<td>100GeV</td>
<td>1000</td>
<td>72.6</td>
<td>1E-7</td>
</tr>
</tbody>
</table>

Using ddmc tool (by J. Gascon, V. Sanglard and R.L.)

```
<table>
<thead>
<tr>
<th>Energy (keV)</th>
<th>10GeV</th>
<th>20GeV</th>
<th>50GeV</th>
<th>100GeV</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>1.18E-01</td>
<td>6.97E-02</td>
<td>2.87E-02</td>
<td>1.42E-03</td>
</tr>
<tr>
<td>3</td>
<td>4.59E-02</td>
<td>5.18E-02</td>
<td>2.58E-02</td>
<td>1.35E-03</td>
</tr>
<tr>
<td>5</td>
<td>1.59E-02</td>
<td>3.77E-02</td>
<td>2.31E-02</td>
<td>1.28E-03</td>
</tr>
<tr>
<td>7</td>
<td>5.09E-03</td>
<td>2.71E-02</td>
<td>2.06E-02</td>
<td>1.22E-03</td>
</tr>
<tr>
<td>9</td>
<td>1.50E-03</td>
<td>1.93E-02</td>
<td>1.84E-02</td>
<td>1.16E-03</td>
</tr>
<tr>
<td>11</td>
<td>3.65E-04</td>
<td>1.35E-02</td>
<td>1.64E-02</td>
<td>1.10E-03</td>
</tr>
<tr>
<td>13</td>
<td>3.55E-05</td>
<td>9.40E-03</td>
<td>1.46E-02</td>
<td>1.04E-03</td>
</tr>
<tr>
<td>15</td>
<td>0.00E+00</td>
<td>6.49E-03</td>
<td>1.30E-02</td>
<td>9.87E-04</td>
</tr>
<tr>
<td>17</td>
<td>0.00E+00</td>
<td>4.43E-03</td>
<td>1.15E-02</td>
<td>9.36E-04</td>
</tr>
<tr>
<td>19</td>
<td>0.00E+00</td>
<td>3.01E-03</td>
<td>1.02E-02</td>
<td>8.87E-04</td>
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<tr>
<td>21</td>
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<td>2.03E-03</td>
<td>9.01E-03</td>
<td>8.41E-04</td>
</tr>
<tr>
<td>23</td>
<td>0.00E+00</td>
<td>1.35E-03</td>
<td>7.95E-03</td>
<td>7.97E-04</td>
</tr>
<tr>
<td>25</td>
<td>0.00E+00</td>
<td>8.94E-04</td>
<td>7.02E-03</td>
<td>7.55E-04</td>
</tr>
</tbody>
</table>
```
How it works

When leaving the webpage or starting new figures the session is destroyed before leaving copy the created figures and tables
Experimental parameters

Quenching, Resolution, Efficiency as a function of energy with 2 types of inputs:
- Binned entry
- Parametrised function
  For quenching Lindhard parametrisation

**HOW TO:**
- enter binned values:
  \[ N_{\text{bins}} \quad \text{Bins edges} \quad (N_{\text{bins}} + 1 \text{ numbers}) \quad \text{Efficiencies} \quad (N_{\text{bins}} \text{ numbers}) \]

- enter compound target:
  Example NaI: \( N_{\text{target}} N_{\text{stoich}} \quad A \quad Z \quad N_{\text{stoich}} \quad A \quad Z \)
  \[
  \begin{array}{ccc}
  2 & 1 & 23 \\
  1 & 11 & 127 \\
  \end{array}
  \]

Overview

I-1 Quenching

<table>
<thead>
<tr>
<th>Type</th>
<th>Q = a \times b \quad (for b=0 \text{ quenching=constant=a})</th>
</tr>
</thead>
<tbody>
<tr>
<td>next</td>
<td>0.36 0.36</td>
</tr>
</tbody>
</table>

I-1-a Quenching

<table>
<thead>
<tr>
<th>a \quad b</th>
</tr>
</thead>
<tbody>
<tr>
<td>0.36 0.36</td>
</tr>
</tbody>
</table>

I-2 Resolution

<table>
<thead>
<tr>
<th>Type</th>
<th>FWMH = a + b E^{0.5}</th>
</tr>
</thead>
<tbody>
<tr>
<td>next</td>
<td>0 9.8</td>
</tr>
</tbody>
</table>

I-2-a Resolution

<table>
<thead>
<tr>
<th>a \quad b</th>
</tr>
</thead>
<tbody>
<tr>
<td>0 9.8</td>
</tr>
</tbody>
</table>

I-3 Efficiency

<table>
<thead>
<tr>
<th>Efficiency in bins</th>
</tr>
</thead>
<tbody>
<tr>
<td>next 10</td>
</tr>
</tbody>
</table>

Efficiency in bins

<table>
<thead>
<tr>
<th>Example</th>
<th>n \times N \quad A \quad Z \quad n \times N \quad A \quad Z</th>
</tr>
</thead>
<tbody>
<tr>
<td>next 3 5 20 0.5 0 0.5 0 0.5</td>
<td></td>
</tr>
</tbody>
</table>
Example: Experimental parameters

**Effect of resolution**

- Low resolution => flattens the spectra but worsens efficiency (discrimination)

**Xenon vs Germanium**

- lower threshold for Xe
  => Sensitivity 5x higher for Xe
Example: Combine experimental conditions

Option available to combine recursively with previous outputs
Extraction of limits

When no signal is observed:

⇒ limit on the WIMP-nucleon cross-section as a function of the WIMP mass

- Feldman-Cousin: known background

  The limit on the rate depends on the number of observed events and the number of expected background events.


- Yellin: unknown background

  The list of the energies of the observed events are entered. The method takes advantage of signal-unlikely events.

Example: Experimental limits

Approximate treatment with respect to full experimental analysis i.e. multidimensional efficiencies
Neutralino

Neutralino-nucleon cross-section

<table>
<thead>
<tr>
<th>m_0</th>
<th>m_{1/2}</th>
<th>μ sign</th>
<th>tan β</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>500</td>
<td>+</td>
<td>40</td>
</tr>
<tr>
<td>2</td>
<td>1000</td>
<td>+</td>
<td>50</td>
</tr>
<tr>
<td>3</td>
<td>2000</td>
<td>+</td>
<td>55</td>
</tr>
<tr>
<td>4</td>
<td>4000</td>
<td>+</td>
<td>55</td>
</tr>
</tbody>
</table>

Cross-section and WIMP mass

1. 2E-08 pb, 97 GeV
2. 2E-08 pb, 98 GeV
3. 2E-07 pb, 139 GeV
4. 4E-08 pb, 340 GeV

From DMtools

=> Cross sections and WIMP mass vary with assumed SUSY model

SuSy scan (isasugra) following:
H. Baer et al JCAP09(2003)007
Example: Neutralino on $^{73}$Ge

Inputs: SUSY parameters and experimental parameters

Outputs: Spin independent, Spin dependent cross sections, WIMP mass (using DarkSUSY) and experimental spectra

using:

<table>
<thead>
<tr>
<th></th>
<th>$m_0$</th>
<th>$m_{1/2}$</th>
<th>$\mu$</th>
<th>sign</th>
<th>$\tan(\beta)$</th>
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</thead>
<tbody>
<tr>
<td>1</td>
<td>500</td>
<td>250</td>
<td>+</td>
<td>40</td>
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<td>2</td>
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<td>250</td>
<td>+</td>
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<tr>
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<tr>
<td>4</td>
<td>4000</td>
<td>900</td>
<td>+</td>
<td>55</td>
<td></td>
</tr>
</tbody>
</table>

Linear scale

Only a few targets are available so far for spin-dependent interactions
Conclusion and Outlook

- Expected recoil spectra and exclusion plots
- Generic WIMPS or SUSY Neutralino
- Experimental strategy: quenching, resolution and efficiency
- Combines experimental conditions
- Statistical treatment: Feldman Cousin, Yellin

OUTLOOK

- Different theoretical models (galactic halos...)
- Complementarity with indirect dark matter searches
- Complementarity with LHC
- Interpretation of experimental results