“Whither WIMPs:”
Direct Detection of SUSY Cold Dark Matter
One Tonne - Have we got what it takes?
Has NUSEL got what we need?

WORKING GROUP LEADERS:
Rick Gaitskell (Brown University)
& Dick Arnowitt (Texas A&M University)

useful information at
http://www.physics.umd.edu/ness02/
- follow working group link
http://gaitskell.brown.edu/physics/NeSS2002/web_darkmatter/
Dark Matter Working Group

Thanks to the working group

Rick Gaitskell, Brown
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John Ellis, CERN
Jonathan Feng, UC Irvine
Gilles Gerbier, Saclay
Alexander Kusenko, UCLA
Kirk MacDonald, Princeton
Jeff Martoff, Temple
Richard Schnee, CWRU
Nigel Smith, RAL
Andy Warhol - Pop Artist 1960’s - “Exactly”
Gerald M. Edelman *Bright Air, Brilliant Fire* (1992)

The pop artist Andy Warhol once approached me at a party and told me that he collected scientific journals, but he couldn't understand them.

He drifted away, then came back and said, "Do you mind if I ask you a question?... Why does science take so long?"

I said, "Mr. Warhol, when you do a picture of Marilyn Monroe, does it have to be exactly like her, as close as you can make it?"

He said, "Oh no."

I said, "Well, in science it has to be exact, as exact as you can make it."

He looked at me with sympathy and said, "Isn't that terrible?"
>20 Experiments currently operating underground
Only 1 is located u/g in the US

Dark Matter Experiments (Worldwide/affiliations)
(Running/Active Collaboration)

- UK
  - NaIAD
  - ZEPLIN I
  - ZEPLIN II
  - ZEPLIN III
  - DRIFT I
- France
  - Edelweiss II
  - Simple
- Germany
  - HDMS/Genino
  - Picasso
- Italy
  - Xenon
  - Cuoricino
- Japan
  - XMASS(DM)
  - LiF
  - Elegant V&VI
- Russia
  - Majorana(DM)
  - IGEX
- Canada
  - XENON
- Canada
- Spain
  - Russia
  - Spain
  - XMASS(DM)
  - LiF
  - Elegant V&VI
- Taiwan
  - Taiwan
- US
  - CDMS II
  - XENON
  - Majorana(DM)
  - IGEX
  - ANAIS
  - Rosebud
  - CsI

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Direct Detection: History & Future

90% CL Limit on Cross section for 60 GeV WIMP (scalar coupling)

[Diagram with data points and technology indicators]

Different Colours Indicate Different Technologies

- Ge
- NaI
- Cryodet
- Liq Xe
- Gas CS₂
- Target
- Signal

Not meant to be a complete list - see http://dmtools.berkeley.edu

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[Note: m = ?? GeV - if significantly better limit obtained at different mass]
Some of Current (2001-) and Projected Experiments (2005-)

**Not a complete list, experiments reported at meeting**

<table>
<thead>
<tr>
<th>Technology /Collab. Name</th>
<th>CURRENT Fiducial Mass Goal / (Now)</th>
<th>(2001-) Funding source</th>
<th>Location</th>
<th>PROJECTED Mass Goal</th>
<th>(2005-) Location</th>
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</thead>
<tbody>
<tr>
<td>Liquid Xe</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>XENON</td>
<td>100 kg (-)</td>
<td>US</td>
<td>**</td>
<td>1000 kg</td>
<td>**</td>
</tr>
<tr>
<td>ZEPLIN</td>
<td>30 kg (3 kg)</td>
<td>UK/US</td>
<td>Boulby,UK</td>
<td>1000 kg</td>
<td>Boulby,UK</td>
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<tr>
<td>XMASS</td>
<td>20 kg (1 kg)</td>
<td>Japan</td>
<td>Kamioka,Japan</td>
<td>1000 kg</td>
<td>**</td>
</tr>
<tr>
<td>Cryogenic (T&lt;1K)</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>CDMS/CryoArray</td>
<td>7 kg (1 kg)</td>
<td>US</td>
<td>Soudan,US</td>
<td>1000 kg</td>
<td>**</td>
</tr>
<tr>
<td>EDELWEISS</td>
<td>7 kg (0.7 kg)</td>
<td>France</td>
<td>Frejus,France</td>
<td>35 kg</td>
<td>Frejus,France</td>
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<tr>
<td>EuroCryo Collab</td>
<td></td>
<td>Europe</td>
<td>**</td>
<td>1000 kg</td>
<td>**</td>
</tr>
<tr>
<td>Gas TPC</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>DRIFT</td>
<td>1 kg (0.2 kg)</td>
<td>US/UK</td>
<td>Boulby,UK</td>
<td>100 kg</td>
<td>**</td>
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<tr>
<td>HP Ge</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>MAJORANA</td>
<td>40 kg (2 kg)</td>
<td>US</td>
<td>**</td>
<td>500 kg</td>
<td>**</td>
</tr>
<tr>
<td>GENIUS</td>
<td>40 kg (5 kg)</td>
<td>Europe</td>
<td>Gran Sasso,Itty</td>
<td>1000 kg</td>
<td>Gran Sasso,Itty</td>
</tr>
</tbody>
</table>

- **Funding Profile - current experiments (investment in det R&D >10 yr)**
  - Construction Capital 5-15M$ ; Operating 2-4M$/yr , Personnel FTE 15-40

- **Funding Profile - Projected Experiments (1 tonne)**
  - Construction Capital 20-50+M$ ; Operating 4-8M$/yr , Personnel FTE 30-60
WIMP Dark Matter Physics

• Physics Motivation
  □ Cosmology: Need for Non-Baryonic Dark Matter
    • $\Omega_{\text{unknown matter}} = 0.27 +/- 0.04$ [Turner]
  □ Particle Physics: Naturally generates solution
    • SUSY [Ellis]
    • Non-Pointlike DM [Kusenko]
    • Kaluza-Klein Extra Dimensions [Feng]

• Existing Direct Detection Experiments:
  □ Testing some models
  □ As sensitivity improves - will continue to test more models

• Recent/current accelerator constraints shrinking SUSY bounds
  □ Mainly constrained UPPER bound of cross-section
  □ g-2 [BNL] can provide constraint on LOWER bound (for $\mu > 0$) if tentative disagreement is due to SUSY
Greatest Experimental Challenges

- Construction & Operation of Detector Arrays Underground
  - Many of experiments experiencing “delays” associated with construction/operation
    - “Project Risk”
  - All Groups would benefit greatly from infrastructure/support of Underground Lab
    - Knowledgeable Technical/Engineering Assistance
- Achieving Detector Discrimination Performance (free of systematics)
  - Demanding Background Discrimination >>99%
- Improvements needed in Screening Facilities
  - Dark Matter has new concerns, beyond those of Current Low Background Experiments
    - 0-100 keV & Surface Contamination
  - To reduce internal radioactivity
    - Experiments >2005 clearly demand access to systems beyond simple HPGe screening
      - $10^{-12}$ g/g U/Th
    - Surface/low energy radioactivity screening (Providing Input to NUSL -> Screen Fac Initiative)
      - $1 \text{ m}^2 \text{ day}^{-1}$
  - Scale of “intermediate” collaboration has difficulty meeting all screening requirements
- Fabrication of some target/construction materials underground
  - Ge crystal growth / Electroformed Cu
- Purification / Isotopic enrichment of target materials (e.g. Xe)
Dark Matter Depth Requirements

• Site Depth Requirement
  □ Dominated by need to reduce high energy neutrons (50-600 MeV), generated by muons, that cannot be moderated directly using poly
  □ Shallow ~1700 mwe (1 muons/m²/minute)
    • Just satisfactory for 10 kg scale experiments (~10⁻⁸ pb)
    • 1 tonne experiments would require large additional active shield (>1 m thick)
      – >99% veto Risk associated with systematic misidentification
  □ Intermediate ~3800 mwe
    • Factor ~50x reduction in muons/HE neutrons compared to shallow
    • Additional comfort factor, general consensus that 1 tonne experiments can function comfortably wrt to HE neutrons from muons (~10⁻¹⁰ pb)
    • Depth may be necessary for gas target given much large surface area to shield
    • Satisfactory for cosmogenic activation
    • Muons passing through detector array can be vetoed by simple muon veto (>99% being achieved)
  □ Deep ~6000 mwe (Further factor ~50x reduction in muon/HE neutrons)
    • Does not appear to be necessary for 1 tonne (~10⁻¹⁰ pb), but eliminates any risk, and will allow next-next generation
WIMP SUSY Dark Matter Conclusion

- Planned Projects for sensitivity -> 1 event /100 kg/year $\sim 10^{-46}$ cm$^2$
  - Target masses of 1 tonne
  - Data from existing round of detectors will be used to inform design
- Support of Underground Laboratory will be vital for their successful construction and operation
  - "Intermediate Scale Experiments
  - Significant extra burden bringing full resource requirements to hole in ground
- Next Generation 2005-: complementary TeV / LHC SUSY signal
- If signal is discovered then range of large detectors can be used to do WIMP astronomy and study SUSY / Dark Matter physics
  - Different target materials
    - study coupling / kinematics on different nuclei
  - Directional Detectors
    - WIMP Velocity distribution
  - SUSY Parameters that can’t be determined in accelerators (R-Parity)
  - Tests models of particle generation in Big Bang

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