I'm improving the search for dark matter

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1. Neutron Discrimination by Double Scattering
   Zeplin II Example!

2. Methods to "Probe" DM
   - Multi 'A' Detectors Needed

3. Methods to Estimate the WIMP Mass
   - Very High Mass WIMP Detection

Summary
Diagram and Text notes:

- Lead Shield
- Liquid Xenon Target
- Active Veto
- The Central Detector
- Copper Carbon Target Vessel
- Vessel Vessel
- Stainless Steel Cast
- Cooling and Feed-Through

**ZERPLIN II System Setup**

- Zerplin II System
- Data Name - New Detector Trigger
- Liquid Xenon
ZEPLIN II Operation Underground at Boulby Mine, UK

- Detector fully operational
- Physics data taking in progress (expect 300kg-day mid May)
- Data analysis in progress
ZEPLIN II Electron Lifetime and Light Collection in Liquid Xenon

- Liquid purification well understood
- Greater than 1-ms electron lifetime typical
- 1.6 photoelectron/keV at zero field

57Co

103pe/122keV

Light yield vs Purity

1000

e-lifetime (μs)

5 day

Elena Apoll, Columbia University
The detectors working under ground

\[ \frac{S_2}{S_1} \approx A + B/E_{\text{im}} \]  (like WARP)

[Not understood] BEPND/E/xFnuw/WARP

Low energy \( n \) interactions detected!
Note $S_2$ is very sensitive to low energy processes - $Xe \times Xe$ scatter like multiple $n$ scatter.

We see many cases of 2 scatter in the calibration data (in 40%) (we see 20.4 scatter in data) with the active data. Thus, it will provide strong evidence that a signal is not due to neutrino.

These detectors impreg with size!
$\Xi\Pi$ Started

Blind Analysis

Data Taking

in June 2006

will continue to

study 10% of

Data to see that

Detector is operating

correctly. Paper in "works"

Hope to collect > 5000 kg - day
data
# How to Prove that Dark Matter has been Detected

<table>
<thead>
<tr>
<th>Measurement</th>
<th>Comment</th>
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<tbody>
<tr>
<td>1. Observation of Annual Variation with Discriminated Signal</td>
<td>Effect is few percent. Detection requires great stability over long time.</td>
</tr>
<tr>
<td>Very hard to do.</td>
<td></td>
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<tr>
<td>2. Observation of Directional Signal</td>
<td>Requires a very large DRIFT like detector. We don't know the size until $\sigma_w$ measured ($\sigma_w \sim 10^{-10} pb$) as big as this building.</td>
</tr>
<tr>
<td>Very, very hard to do.</td>
<td></td>
</tr>
<tr>
<td>3. Careful observation of the $\sigma_p$ $A^2$ dependence</td>
<td>Requires range of Target A Detectors. All at the same time, if possible.</td>
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<tr>
<td>For Xenon/Argon $A^2 ratio \sim 9.$</td>
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Space Base detector $g, \gamma, \psi, \phi$

* Measure the Form Factors for Xe, Ar, Au, S... |

Need on array of Powerful Detector with different $A$

There are 5 Powerful Detector Undergrand Now Searching for WIMPs: ZEPLIN II, WARP, CDMS-I, CDMS-II, XENON
Figure 1: Count rate of 60 GeV WIMPs in a NaI detector such as DAMA as a function of recoil energy. The dotted lines (towards the left) indicate the count rate due to Galactic halo WIMPs alone for an isothermal halo. The solid and dashed lines indicate the step in the count rate that arises if we include the WIMPs in the Sgr stream for $v_{\text{str}} = 300$ km/sec in the direction $(l,b) = (90^\circ, -76^\circ)$ with a stream velocity dispersion of 20 km/sec. The plot assumes that the Sgr stream contributes an additional 20% of the local Galactic halo density. The solid and dashed lines are for June 28 and December 27 respectively, the dates at which the annual modulation of the stream is maximized and minimized.
Detector Materials

Differential Rate Comparison

Rate \sim 9 \text{ R Ar per kg}

\begin{align*}
\text{Rate (kg keV/day)} & \\
0 & \sim A^2
\end{align*}

\begin{itemize}
\item 131 Xe
\item 40 Ar
\item 73 Ge
\item 28 Si
\end{itemize}

Recoil Energy (keV)
Fig. 3. Schematic of the halo velocity distribution with minimal velocities for CDMS, DAMA and ZEPLIN II; the figure is modified from A. Green, P.R.D. 68, 023004 (2003) (Reference 5).
The term is sensitive to WIMP mass if different A used.

\[
\frac{MA}{(M + A)^2}
\]

\[M \gg A \Rightarrow \frac{A}{M}\] Very high masses

\[A > M \Rightarrow \frac{M}{A}\] Tov

Using different A targets one could fit to this term and determine M.

Also kinematic effects depend on M_w.
**Ultra High Mass SUSY**

A sensitivity study around $\sqrt{s}$.

- **300 GeV**
- **1000 GeV**
- **10,000 GeV**

**Ultra High Mass WIMP**

By **Dirac Detector**

At UCSD we are studying a 10 Ton Xe Detector using Nano Technology Institute Help.
Figure 13: Top panel: the 2-dimensional probability density $p(m_x, \sigma_p^{SI}|d)$, with the contours containing 68% and 95% probability also marked. Bottom panel: the mean quality of fit (likelihood) with the same 68% and 95% probability contours as in the top panel to facilitate the comparison. Current 90% experimental upper limits are also shown.

Dimensional regions encompassing 68% and 95% of the total probability:

\[
1.0 \times 10^{-10} \text{ pb} < \sigma_p^{SI} < 1.0 \times 10^{-8} \text{ pb} \quad (68\% \text{ region}),
\]

\[
0.5 \times 10^{-10} \text{ pb} < \sigma_p^{SI} < 3.2 \times 10^{-8} \text{ pb} \quad (95\% \text{ region}).
\]
Proposal for INPAC
Joint Analysis 2
Multi Detector Signals

- Assume Ga, Xo, Ar
  Detector
  (as CDMS II, ZEPLIN II
  [[WARP C140 kg]]
  => Similar to LEP Studies...]

- Look for $A^2$ effect

- Look for Reduced Mass Effects

Can we (a) Pine DM detector
(b) Extract WIMP
Mass
Summary

After many years of work ZEPLIN III (32 kg) is taking good data.
We hope to get > 5000 kg day of Data in the next year.
Data is Blinded now!

- Other detectors are also taking data. NEXT Two Years will be very interesting.
In a one year we may reach the level $7 \sim 10^{-8} \text{pb}$

If a Signal is seen we will need to prove it to DM
$A^2$ effects could be crucial.