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Nano-Explosive Detector

– => Dark Matter

=> Neutrino Geology

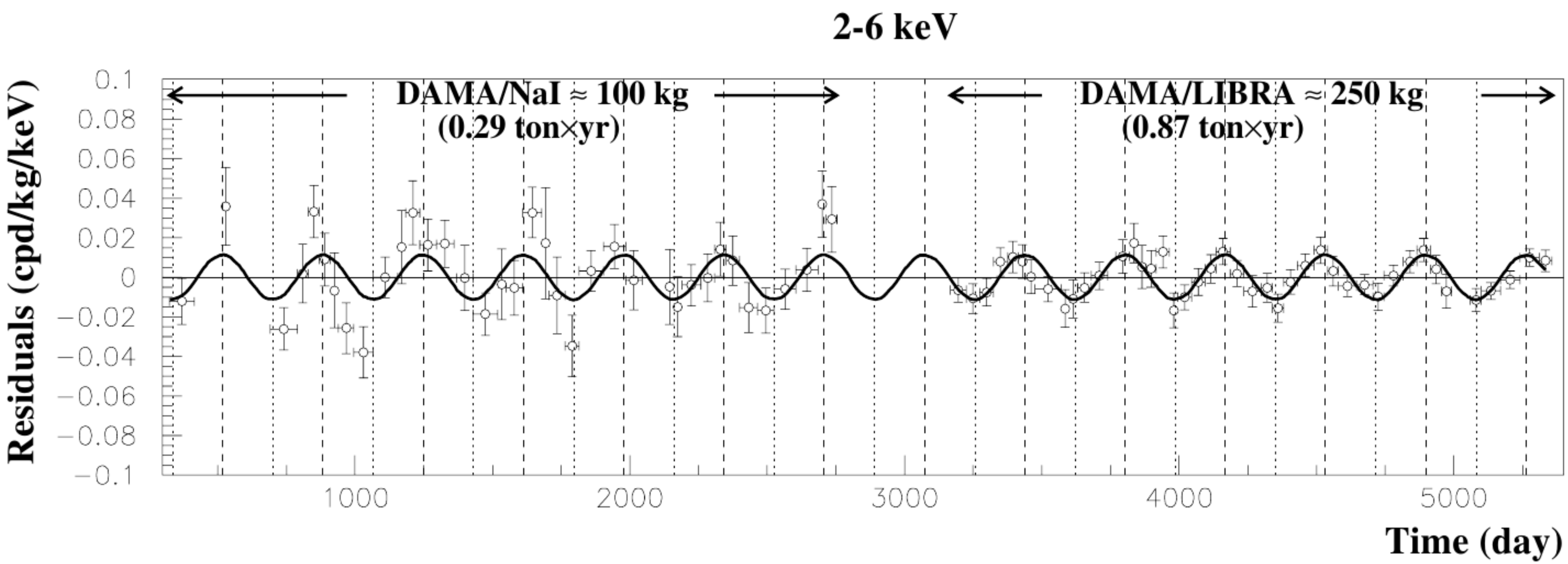
What we need

New class of detectors for neutral particles:
Neutrons, Neutrinos, Dark Matter candidates (WIMPs)

Neutrons => Homeland Security, Neutron Microscopy

Neutrinos => Fermi Lab, Neutrino Geology

Dark Matter => Low mass WIMPS (< 10 GeV/c^2).
Very high Mass WIMPs (> 400 GeV/c^2)
Spin dependent interactions (Li, F, Al)
<u>New SIGNATURES</u>



2-6 keV
DAMA/NaI ≈ 100 kg
(0.29 ton×yr)
DAMA/LIBRA ≈ 250 kg
(0.87 ton×yr)
Residuals (cpd/kg/keV)
Time (day)
0.1
0.08
0.06
0.04
0.02
0
−0.02
−0.04
−0.06
−0.08
−0.1
1000
2000
3000
4000
5000

Signatures

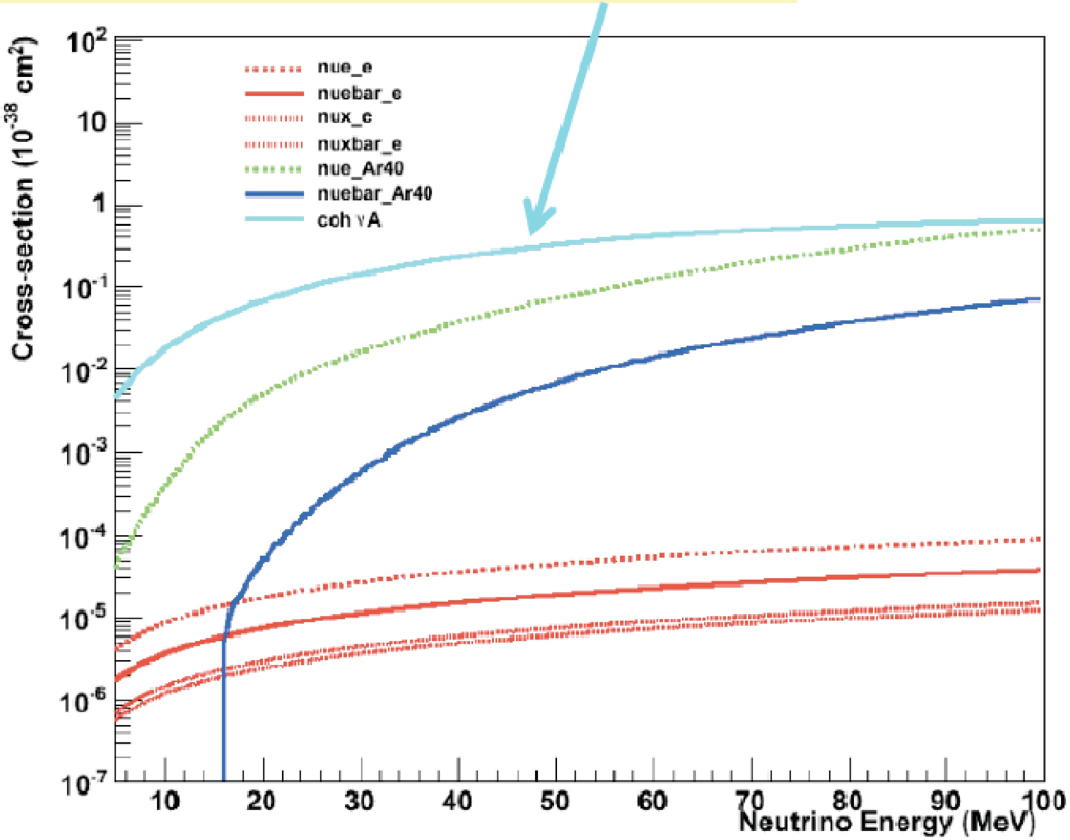
1) **N^2 dependence of the cross-section;**

2) **$(dE/dx)_{rn} >> (dE/dx)_{background}$**
=> Range of recoiling nuclei is O(10 nm);

3) **Particular ratio of FM = (TED/ETE)**
TED = Total energy deposited;
ETE = Energy transferred to electrons;

4) **Annual modulation effect (AME) ,**
Diurnal Modulation Effect (DME),
Other directional effects.

And the cross-section is *large!*



These are the cross sections used by Super-K etc. to detect solar neutrinos.

From Lindley Winslow, 18 Oct 2012, SLAC

Four detectors seem to see WIMPs, but

M_{WIMP} < O(10 GeV/c^2)

Due to Kinematics Exclusions are :

- **Liquid Xe only for M_{WIMP} > 15 GeV/c^2**
- **CDMS-Ge only for M_{WIMP} > 10 GeV/c^2.**
- **S1 in L. Xe small => E_{th} (S1) = O(10 keV)**
  Ionization in Ge low => E_{th}(ionization)= O(5 keV)

DAMA, CoGeNT, CDMS-Si, CRESST, CDMS-Ge, L.Xe

AGREE, only if

- MODEL 1 => $4.1 < M_{WIMP} < 6.8$ GeV/c^2
- MODEL 2 => $3.6 < M_{WIMP} < 5.8$ GeV/c^2.

This may suggest Asymmetric DM *a la* S. Nussinov,1985

ZOO of DETECTORS – Part I

Ordered by minimal velocity at $M_W = 10$ GeV/c^2

		Vmin
(1)	*Nano-explosives*	*20 km/sec*
(2)	*Enzymatic*	*50 km/sec*
(3)	*Be-SSDNA*	*100 km/sec*
(4)	*Be-SSC*	*100 km/sec*
(5)	*DAMA, CRESST, COGENT*	*250-300 km/sec*
(6)	*Freons*	*> 300 km/sec*
(7)	*CDMS-Ge*	*> 500 km/sec*
(8)	*L. Xenon*	*> 1,000 Km/sec*

Low Mass WIMP's Detection Challenge

Kinematics requires low mass targets *ergo* cross-section is very low (smaller effect of coherent scattering) and requires large mass.

$E_{threshold}$ must be very low (< 0.5 keV)

=> current methods of background rejection do not work

=> best spatial resolution to improve S/B ratio

=> importance of directionality to detect AME and DM (Annual and diurnal modulation)

NEED A NEW CLASS OF DETECTORS

Superheated Detectors

a) Bubble Chambers, Cloud Chambers – dx = O(1 mm)

b) Superconducting Granular detector – dx = O(10 microns)

c) Magnetic Nanotechnology detectors – dx = O(100 nm)

d) Explosive Nano-droplets detectors -- dx = O(5 nm)

One component-high explosives

- *Two components — Thermites*

- **Biological Detectors**

- I) DNA-based detectors;
- II) Enzymatic processes based detectors

Advantages of "New" Detectors

1. Room Temperature;
2. Low Cost and potentially very high mass;

3. Low mass targets (Li, Be, B, C, N, O, F) possible;
4. Very high mass targets (A > 175) possible;

5. Very low Energy threshold (0.1-0.5 keV);

6. New methods of background rejection;
7. Directionality.

MADE POSSIBLE BY NANOTECHNOLOGY

Properties of New Detectors

TYPE	Mass	E_{th} [keV]	Dir.	E_{stored}
Be-SSC	O(50 kg)	0.5-1.0	No	< 0.01
Be-ssDNA	O(100 kg)	0.3-0.6	YES	No
Enzymatic	O(1 T)	O(0.5 keV)	No	2
	|			
Explosives	O(50 T)	O(0.2 keV)	No	4
Thermites	O(10 T)	O(0.2 keV)	YES	3

Energy stored in units keV(nm^3); Dir = Directionality

Nano-Bolometry

Energy Losses

$dE/dX = Ax\ Z_1 x Z_2 /[\ (Z_1)^{0.666} + Z_2^{0.666})]^2$

Ranges

Muons= O(m), Electrons =O(mm),
Alphas = O(50 microns), Recoil = O(5 nm)

Specific Heat:

$C_v = a(T/T_{Debay})^3 + bT \Rightarrow O(10^{-5}\ keV/nm^3)$

"Explosive diode" for low Mass WIMP

The mixture of spherical grains is "symmetric".
Evaporated structures permit directionality

- Xx Xx
- Xx Xx
- Xx Xx
- Xx Xx
- ==>Xx Xx <== [Li, WO_3]
- Xx Xx
- Xx Xx
- Xx Xx

- X low A (F) x = high A (Ga)
- Low energy transfer High energy transfer
- Asymmetry is due to mismatch of target and WIMP mass, *i.e.* is kinematics dependent

Summary for nano-boom Detectors

- C^{14} will be a background – *ab ovo* synthesis need to use carbon from 1 mln years old petroleum;
- Need to well control stechiometry;
- Control of size important but not crucial;
- To diminish fast neutrons / Cosmic Rays => underground
- Efficient “nano-explosion readout” (magnetic, acoustic, optical) has been developed.

Backgrounds, backgrounds, backgrounds…

but

a) It’s a new class of “room temperature” detectors;

b) They have the high mass and low threshold;

c) It’s “elegant”;

d) *Nec Hercules contra plures*.