“The relevance of XENON10 constraints in this low-mass region has been questioned [15]”

C.E. Aalseth et al. arXiv:1001.2834v1

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on behalf of the XENON10 Collaboration

at
UC Davis HEFTI Workshop
“Light Dark Matter 2010”
Historical Note: last HEFTI workshop

Some concluding remarks

**ON DAMA:**
- what does the modulation signal look like in individual detectors? Is it similar in all 25 modules?
- what if pulse-shape discrimination is employed (to select NR)?
  - what about the quenching for nuclear recoils?
- what about a “blank” run with a different scintillator (or none at all)? (idea credit: J Collar)
- what does the modulation signal look like 1-2 keV?

**What to look for in 2009:**
- new results from XENON100 (mid-2009 ?)
- new results from LUX (late 2009 - early 2010 ?)
- longer exposure / deeper / more shielding results from CoGeNT (?)
- analysis of CDMS ER data (axions?)

**Some predictions:**
- possible observation of channeling effect in laboratory scattering experiments (?)
- ruling out all DAMA-allowed regions**, with or without channeling
- continued emphasis of alternative dark matter candidates / non-standard halo models

** for standard MB halo models / neutralino dark matter particles

Thank You
XENON10 detector

14 kg Xe

S2: secondary scintillation

S1: primary scintillation

S2 hit pattern gives (x, y)

\[ t_{S2} - t_{S1} \text{ gives } z \]
Discrimination (old news)

What determines threshold?

“...incorporating the S2 threshold, resulting in an energy-dependent acceptance at low energies ... is complicated.”

M Kuhlen, N Weiner et al. JCAP02 (2010) 030

PRD 80 115005 (2009)

reminder: $\text{keVr} = \text{phe}$ in this case, i.e. assumption that $L_{\text{eff}} = 0.19$
S1 detection efficiency in XENON10

- we measure 7 eV photons (175 nm)
- roughly 10% total detection efficiency for scintillation photon => PMT photo-electron
- require n-fold PMT coincidence:
  - XENON10: n>1
  - ZEPLIN III: n>2
- efficiency predicted by Poisson stats. in PMT photo-electrons (simulation)

red (x) curve originally appeared in:

S1 detection limits threshold...
what about S2?
Single electron pulses ~25 phe

Figure 4.6: The summed event record for a typical ~ 4 keVee background γ scatter, showing a 61 μs drift time between S1 and S2, and also an isolated 25 phe single-electron S2 pulse at 103 μs. The primary S2 pulse (at 80 μs) triggered the DAQ in this event, however the S2 trigger was sensitive to single-electron S2 pulses as small as ~ 10 phe (see Fig. ??). The PMT hit-patterns are indicated for each pulse; the lower subplots show a zoom (and PMT hits on individual channels) on each pulse.
Recent work on S2 calibration & threshold

from XENON10 neutron calibration (AmBe).
The calibration, analysis, etc already described in (with focus on S1 signal):


S2 trigger efficiency

S2 (electron) response to nuclear recoils, rather than S1 (scintillation) response

S2 energy resolution assumed Poisson in number of electrons
The $Q_y$ curve allows us to assign a keVr value to every event, based on its $S_2$.

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E = 730 V/cm

energy scaling obtained from scattering angle

energy scaling obtained from $S_1$, via Leff

energy scaling obtained from $S_2$

systematic uncertainty

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Result of monte carlo best fit

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Nuclear recoils from AmBe neutrons

all valid events in the 5.4 kg target

the same data after all cuts
Coherent neutrino scattering

P.S. Barbeau, J.I. Collar et al.
IEEE TRANSACTIONS ON NUCLEAR SCIENCE, VOL. 50, NO. 5, OCTOBER 2003

~ 1 keVr, assuming ~0.15 quenching of ionization signal...

Fig. 1. Detectable signal in different gases from neutral-current nuclear scattering of reactor antineutrinos \(10^{13} \bar{\nu} \text{ cm}^{-2} \text{ s}^{-1}\), obtained by folding of the differential cross section in [8] with the reactor spectrum in [24] and applying quenching factors derived from SRIM [25]. The tradeoff between endpoint energy and rate with increasing atomic mass is evident. Table: total coherent recoil rate in different gases under the same conditions.

Yikes.
single-scatter Compton background in XENON10

(above coherent neutrino scatter threshold)

clear need for a mono-energetic energy calibration at low energy

same data as previously reported in
PRD 80 115005 (2009)
PRL 100 021303 (2008)
except no S2/S1 discrimination
(hence Compton-dominated)

same data scaled to keVr

green/red show +/- 1sigma uncertainty in energy calibration
Typical Events at threshold

ADC samples [105 MHz]

224 phe

ADC samples [105 MHz]

209 phe

phe / sample

phe / sample
For each nuclear recoil:
- assign a keVr value based on S2, with scaling taken from
  - PRC 81 025808 (2010), or
  - the present work (very similar results either way)
- obtain $L_{\text{eff}}$ from the S1 data, via the usual formula

\[
L_{\text{eff}} = \frac{S_1 S_n 1}{L_y S_e E_{\text{nr}}}
\]
S1 detection efficiency (scaled to keVr)

Same curve as in slide 5, scaled to keVr via Leff

Ratio of histogram in slide 7

Conservative assumption
Spin-independent sensitivity doesn’t change (much)

solid curve: $S_1$ efficiency assumed constant above threshold

dashed curves: $S_1$ efficiency taken from “conservative assumption” on slide 10
Comparing...

JCAP02 (2010) 014  (appears overly optimistic)
Coming full-circle
and around again

- energy range 1.5 - 20 keVr
- flat 0.35 cts/keVr/kg.day
- red curve: efficiency falling <4 keVr
- 58.6 live days
- 8.6 kg target
- Poisson 90% C.L. upper limit

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log_{10}(\sigma_n) [cm^2]
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XENON10 S2-only (no discrimination)
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XENON10 PRD with S1 detection efficiency
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CoGeNT 2008
CoGeNT 2010

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30 Apr 2010
End