Testing

Isospin Violating Dark Matter

at CRESST, COUPP and KamLAND

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Isospin Violating Dark Matter

- as David showed, IVDM implies that event rates at direct detection experiments depend non-trivially on the material used
  - can reconcile DAMA, CoGeNT, and Xenon10/100
- makes harder the problem of comparing results from different experiments
- two related questions
  - how do we check signal from one experiment at another?
  - given some signals from experiments, is there a prediction for a different experiment?

- this talk will have two focusses
  - direct detection (CRESST, COUPP)
    - CRESST has a preliminary signal consistent with low mass dark matter
    - given the DAMA and CoGeNT signals, what is the implication for CRESST? COUPP?
  - neutrino detectors (KamLAND)
    - ideal place to cross-check IVDM

CRESST

- event rates from two different materials are sufficient to determine f_n , f_p
- to reconcile DAMA, CoGeNT we'd need $f_n / f_p \sim -0.7$
- if CRESST signal is dark matter, it's in the oxygen band
  - prediction for CRESST signal
- can parameterize as "normalized to nucleon," as they would report if assuming $f_n = f_p$

$$\sigma_A = \frac{\mu_A^2}{M_*^4}\left[f_p Z + f_n (A - Z)\right]^2$$

$$\sigma_N^Z = \sigma_p \frac{\sum_i \eta_i \mu_{A_i}^2 \left[Z + \left(f_n / f_p\right)(A - Z)\right]^2}{\sum_i \eta_i \mu_{A_i}^2 A_i^2}$$

$$\sigma_N^{Z=\mathrm{O}} \approx 8.5 \times \sigma_N^{Z=\mathrm{Ge}}$$

COUPP

- can play a similar game with COUPP
  - CF_3I detector
  - slightly tougher, since multiple elements
  - can separate iodine recoils from energy spectrum, but might be harder to separate carbon and fluorine recoils

- as with CRESST, can find the "normalized to nucleon" cross-section for carbon and fluorine
  - COUPP might report something between these
  - about the same as CRESST
  - a little higher than CoGeNT

$$\sigma_N^{Z=\mathrm{C}} \approx 8.4 \times \sigma_N^{Z=\mathrm{Ge}}$$

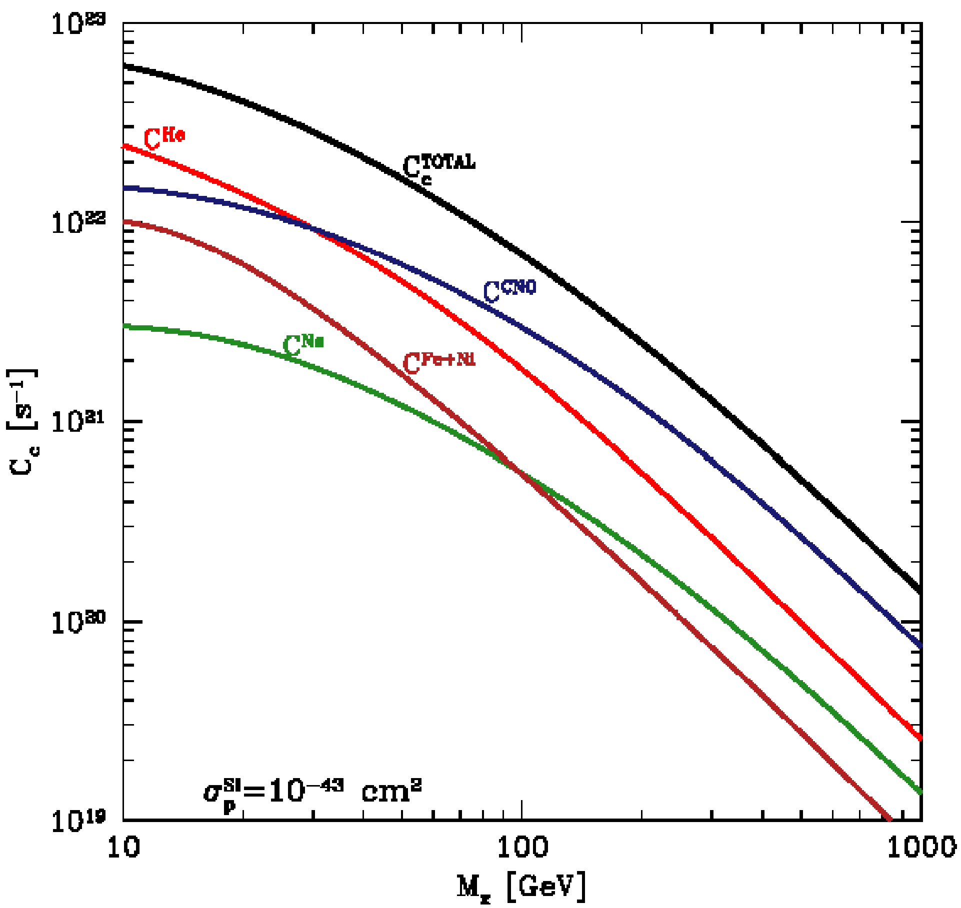
$$\sigma_N^{Z=\mathrm{F}} \approx 4.2 \times \sigma_N^{Z=\mathrm{Ge}}$$

neutrino detectors

- more generally, though, we can see the upshot
- standard assumption of coherent scattering is constructive interference
  - bigger nucleus = bigger enhancement
- so IVDM can suppress signal... the question is how much
  - affects heavy nuclei (like xenon) the most
- let's take this DAMA/CoGeNT region, with f_n / f_p ~ -0.7
  - neutron-rich nuclei hurt
  - ideal detector would be made of hydrogen
- fortunately, we have such a detector available
  - the sun

dark matter annihilation in the sun

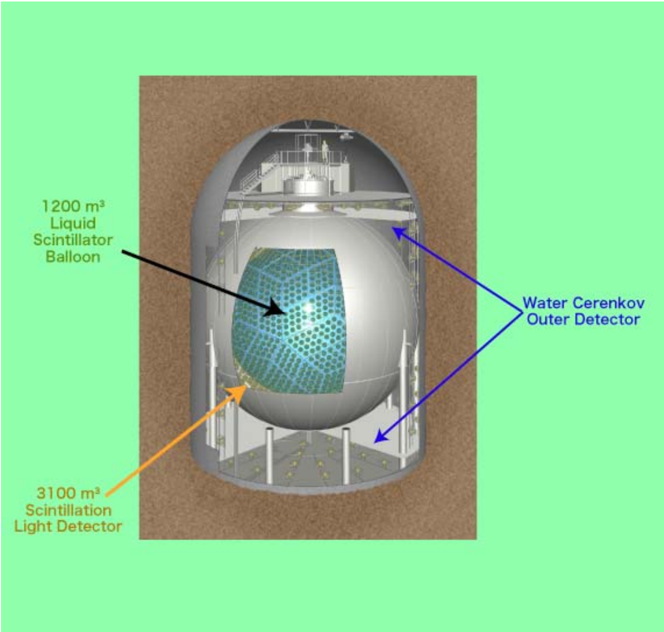
- basic assumptions
  - DM captured by the sun through elastic scattering
  - DM annihilates to SM matter
  - SM matter showers off neutrinos, which are seen at detector
  - DM in equilibrium → $\Gamma_C = 2\Gamma_A$
  - so neutrino event rate probes DM capture rate (and σ_{SI} ,σ_{SD})
- at low mass, ~ 3-10% of Γ_C is from scattering off hydrogen (if $f_n=f_p$)
- best for IVDM....



A. Zentner, arXiv:0907.3448

KamLAND

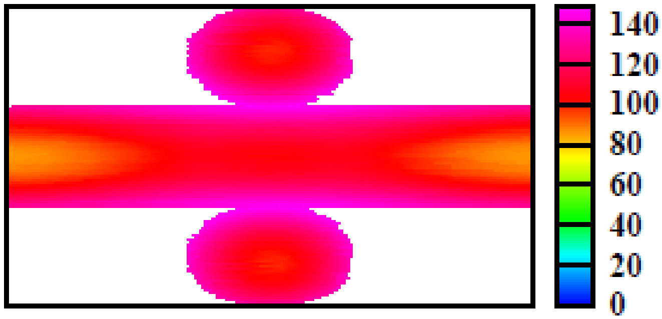
- 1 kT liquid scintillator detector
  - what we're looking at is the lepton produced from charged-current interaction



- LS detectors → good lepton direction measurement from timing of first photons

- use electron neutrinos
  - ν_e produces an electron shower which is completely contained
  - much less atm. ν_e background

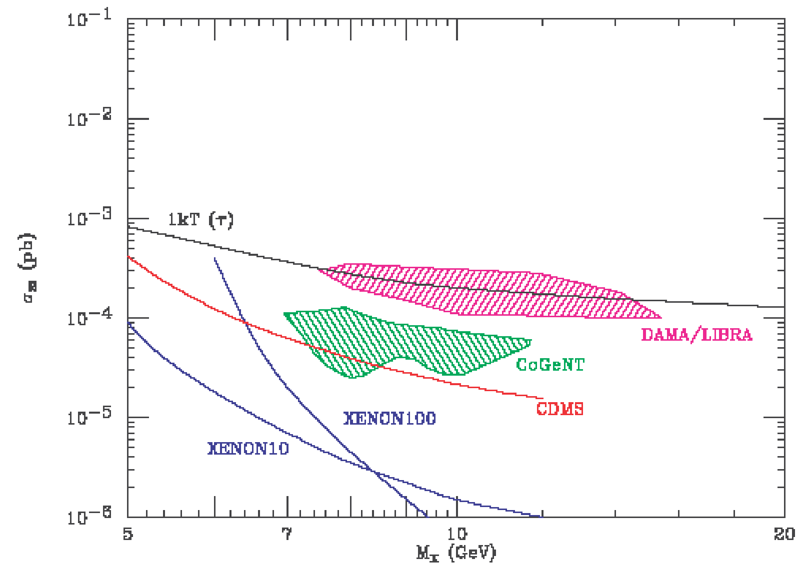
J. Learned, arXiv:0902.4009



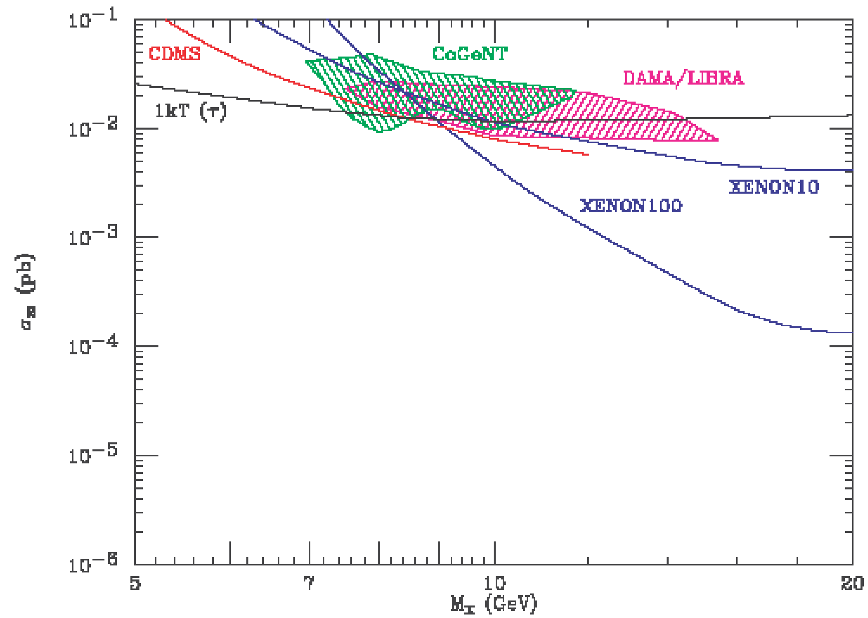
unrolled PMT time plot

IVDM bounds

- KamLAND bound from 2135 live-days (E_{thr} = 1.5 GeV)
- atm. ν_e bgd. ~ 5 events
  - 10 events for detection
- capture rate and neutrino spectrum → DarkSUSY
- IVDM
  - conservative estimate... scattering off hydrogen
  - same as SD capture rate
  - bounds from KamLAND become competitive
  - test Goodenough/Hooper model



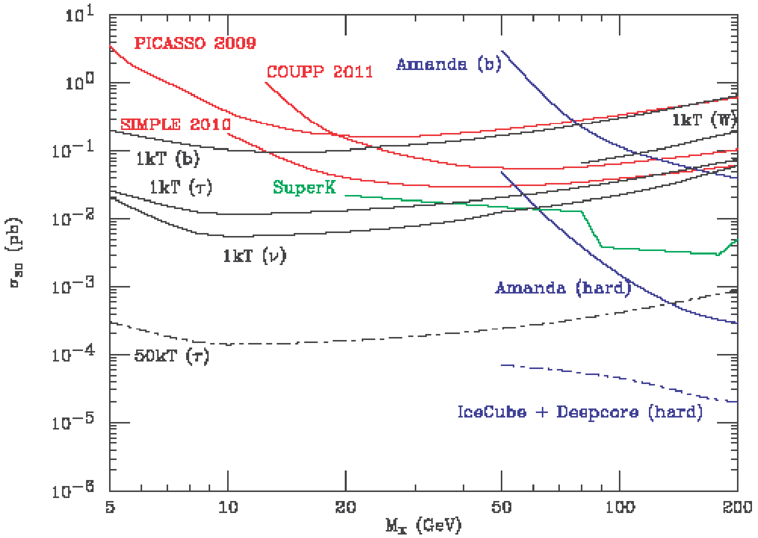
f_n/f_p~1



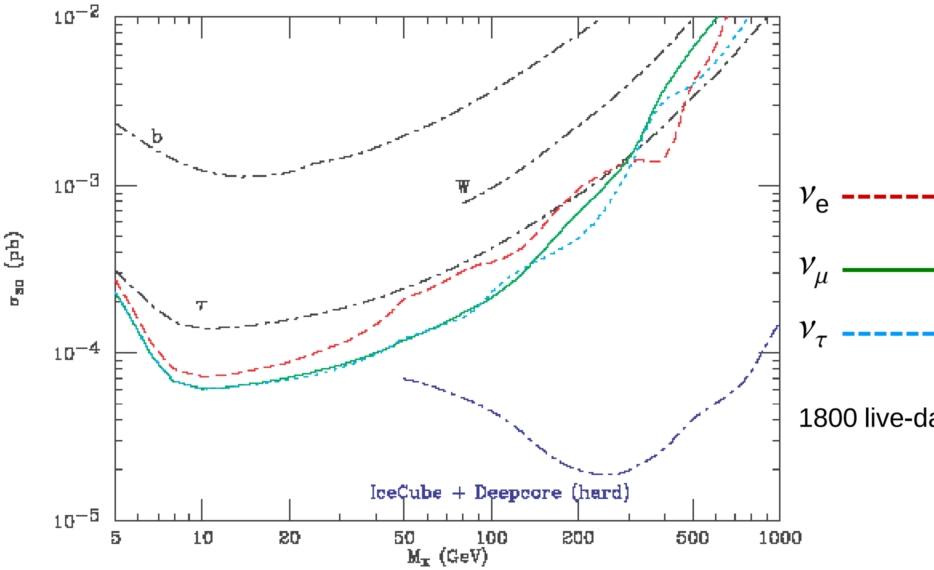
f_n/f_p~-0.7

while we're at it... σ_{SD} bounds

- KamLAND can also bound σ_{SD}
- for $m_X < 20$ GeV, KamLAND sensitivity competitive with direct detection and other experiments
- below 4 GeV, WIMP evaporation hurts sensitivity
- future detectors (LENA, HanoHano) can improve sensitivity by 2 orders of magnitude
  - competitive below 50 GeV
- with one year of running, could probe same low-mass



2135 live-days



1800 live-days

Conclusion

- Isospin Violating Dark Matter can potentially explain data from DAMA and CoGeNT, consistent with bounds from Xenon10/100
- prediction for favored region for CRESST
- ideal way to test this... neutrino experiments
- KamLAND can probe the interesting IVDM region with data already taken

Mahalo!