Liquid Underground Xenon (LUX) experiment

Direct Dark Matter detection

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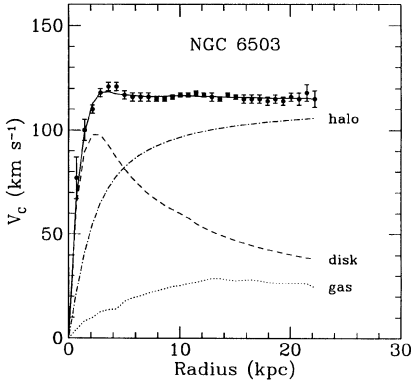
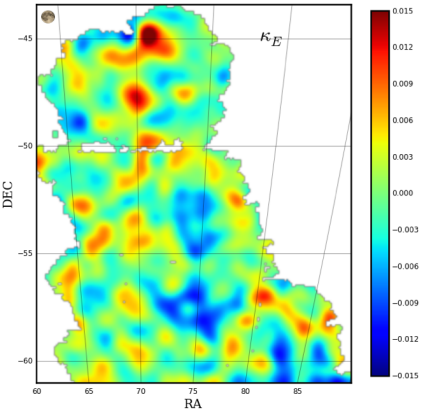
Outline

- Motivation
- ΛCDM model of the Universe
- Current candidates for dark matter
- Direct detection
- LUX detector
- Detector calibration
- First results and future experiments

Dark Matter discovery

Galaxy rotation curve/Fermilab DES DM map

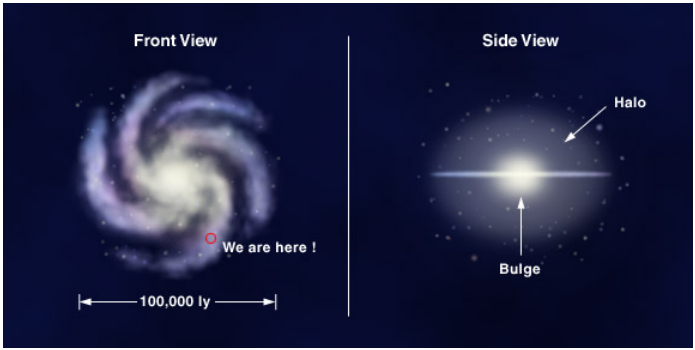




1. DM is concentrated in galactic halos and on large scale
2. DM makes up to 25% of matter in the Universe

Dark Matter discovery

A typical spiral galaxy



1. Simulations show the early Universe was filled with slow weakly interacting objects
2. DM makes up to 25% of matter in the Universe

Current Dark Matter candidates

Baryonic candidates

1. Cold neutron stars (Universe is too young)
2. Black holes (How they formed?)
3. Dwarf stars, massive planet-like objects, rocks (Not seen nearby)

Non-baryonic candidates

1. Massive neutrinos (Not massive enough)
2. Cosmic strings (No evidence of existense so far)
3. Modified gravity (Why not seen on smaller scale?)
4. Weakly interacting massive particles (WIMPs) (Cosmology and Supersymmetry)
5. Extra dimensions (No evidence of existense so far)
6. WIMPzillas, Q-balls, gravitinos, axions (Exotic)

Direct detection of Dark Matter

WIMPs

1. SUSY models predict GeV-scale particles (just what we are looking for!)
2. Can be possibly produced at LHC
3. Should have seasonal variations in flux
4. May recoil in matter

Nuclei recoil (NR)

1. Phonons/heat (100% energy)
2. Ionization (10% energy)
3. Scintillation light (1% energy)

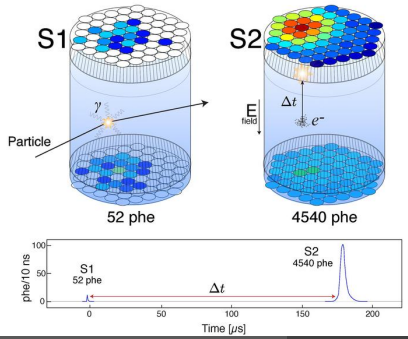
Liquid gas detector (2 and 3 combined)

1. Originally proposed for cosmic rays in 70s
2. Relatively easy to build
3. Large fiducial volume

LUX - dual phase liquid noble gas detector

1. Located 4,850 ft (about 1 mile) underground at the Sanford Underground Laboratory
2. Utilizes a 370 kg liquid xenon
3. Interactions in xenon produce 175 nm light that is detected by PMT arrays

1. Particle scatters off nuclei and produces photon(s) and electron(s)
2. Photons are detected with PMT and form (phe) S1 signal
3. Electrons are dragged by applied electric field into the gas phase where they scintillate
4. Scintillation light is detected as S2 signal

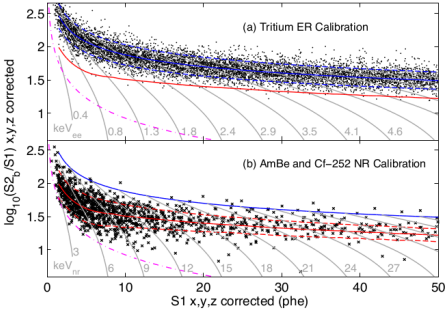


Challenges in detection

1. Photons can experience Compton scattering resulting in electron recoils (ER)
2. Need a way to distinguish between ER and NR

Calibration

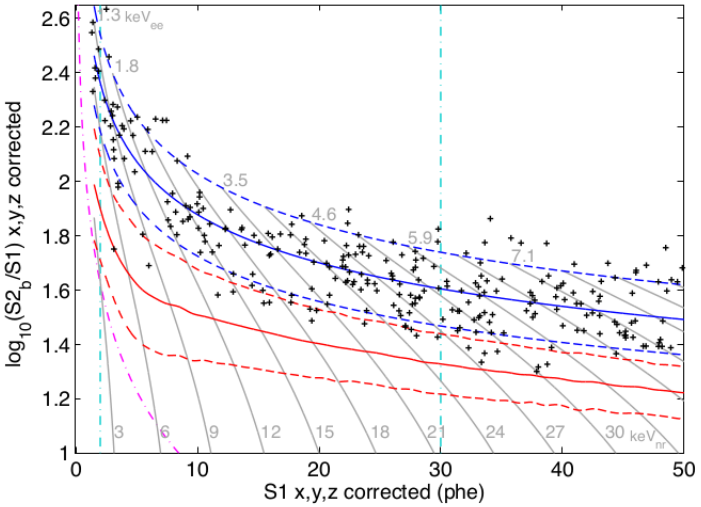
1. ER calibration with dissolved tritium in xenon
2. NR calibration with AmBe and Cf-252 neutron sources
3. ER and NR signal can be separated



Phys. Rev. Lett. **112**, 091303 (2014)

The LUX WIMP signal region

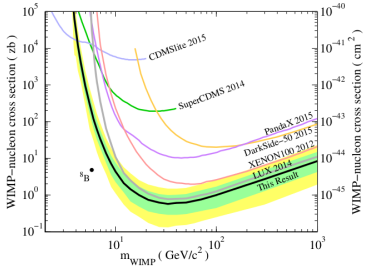
118 kg fiducial volume during the 85.3 live-day exposure



Phys. Rev. Lett. **112**, 091303 (2014)

First results

1. 160 events observed in the region of interest are consistent with predicted ER background
2. The WIMP NR signals were modelled assuming Maxwellian velocity distribution with $v_0 = 220 km/s$
3. The background-only model (no DM particles) gives a good fit to the data

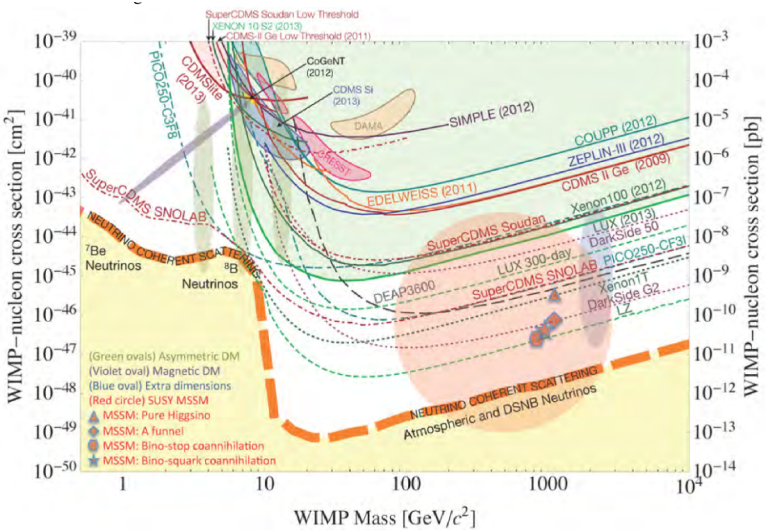


Phys.Rev.Lett. **116**, 161301 (2016)

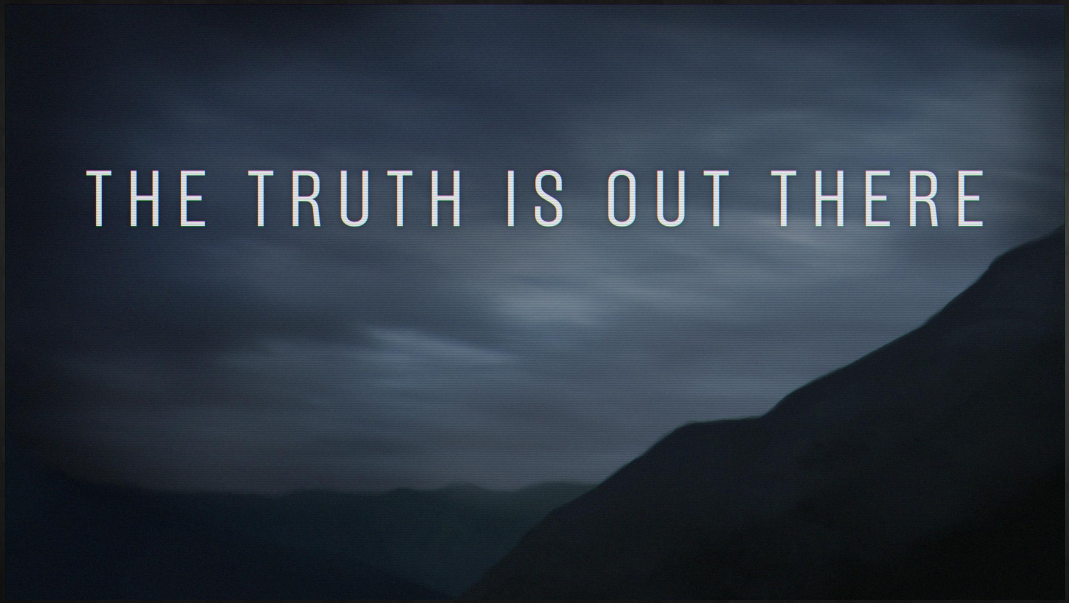
Conclusions

1. Current experiment show no evidence of spin-independent isospin-invariant WIMP-nucleon couplings with minimum upper limit on the cross-section of $5.6 \times 10^{-46} cm^2$ at a WIMP mass of 33 GeV/c^2
2. The achieved sensitivity is much better than in previous experiments
3. The constraints on spin-dependent WIMP scattering were published a week ago(!) **Phys.Rev.Lett. 116, 161302 (2016)**
4. New LZ 7-tonne detector is under construction http://lz.lbl.gov

Current WIMP results combined



LZ Conceptual Design Report, arXiv:1509.02910


THE TRUTH IS OUT THERE