Searching for dark matter in the Black Hills of South Dakota:
First results from the LUX experiment

Dr. Chamkaur Ghag
University College London
Early evidence for Dark Matter

- Fritz Zwicky (1930s) and Vera Rubin (1970s) measure rotational velocities of galaxies and clusters
- Expect Keplerian fall-off, but observe flat rotation curves
  - Galaxies are rotating too fast
  - Implies presence of much more mass in systems
Much much more evidence since then

BBN

Gravitation lensing

Large scale structure → CDM

CMB + BAO: precision tests of ΛCDM

D. Clowe, et al.
Much much more evidence since then

**BBN**

- Fraction of critical density vs. Baryon density
- Number relative to H

**Large scale structure → CDM**

**BAO + SNe + CMB**

- Union2.1 SN Ia Compilation
- CMB
- BAO
- SNe
- No Big Bang

**Gravitation lensing**

**CMB + BAO: precision tests of ΛCDM**

- Planck TT spectrum
- Multipole ℓ

D. Clowe, et al.
Much much more evidence since then

**Universe content**

- **visible matter** 5%
- **dark matter** 27%
- **dark energy** 68%

**BBN**

Fractions of critical density for different elements:
- $^3\text{He}$
- $^7\text{Li}$

**BAO + SNe + CMB**

Cosmological parameters estimated from BAO, SNe, and CMB observations.

**Gravitation lensing**

D. Clowe et al.

**Large scale structure → CDM**

CDM paradigm: Cold dark matter framework leading to the formation of large scale structures.

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Much much more evidence since then

BBN

Large scale structure → CDM

Universe content
visible matter 5%
dark matter 27%
dark energy 68%

Gravitation lensing

D. Clowe, et al.

BAO + SNe + CMB

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Slide 6
Dark Matter properties

- Interacts only **weakly** with normal matter
- Expected to be **neutral** in most scenarios
- **Cold**: Non-relativistic freeze-out
- **WIMPs** favoured candidates for Cold Dark Matter
  *(alternatives: axions, sterile neutrinos, ...)*
- Requires **beyond standard model** physics:
  - Super-symmetry: LSP neutralino, $10^{-40}$ to $10^{-50}$ cm$^2$, Mass range GeV→TeV
  - Universal Extra Dimensions: Stable KK, similar detection properties as neutralino
Detecting Dark Matter

\[ \chi \rightarrow \text{NC weak-scale?} \]

- Direct
- Indirect

production

SM

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Slide 8
Direct detection of galactic dark matter

- Elastic scattering of galactic WIMPs off target nuclei in terrestrial detector
- WIMP speed ~ 220 km/s
  expect recoils O(10 keV)
- Spin-independent cross section \( \propto A^2 \)
- Expect ~ 1 event/kg/year
- Requires SM backgrounds \(~0\) (underground operation)

![Diagram of dark matter detection](image)

**Graph**

- **Integral rate, counts/kg/year**
- **Threshold recoil energy, keV**
- **Integral rate, counts/kg/year**
- **Threshold recoil energy, keV**

- **Isothermal halo**
  \( v_0=220 \text{ km/s}, \ v_e=240 \text{ km/s}, \ v_w=600 \text{ km/s}, \ \rho_0=0.3 \text{ GeV/cm}^2 \)

- **WIMP with** \( M_{\chi}=100 \text{ GeV/c}^2 \)
  \( \sigma_{\chi,\text{SI}}=10^{-9} \text{ pb (10}^{-45} \text{ cm}^2) \)

- **Graph labels**
  - \( Xe \)
  - \( Ge \)
  - \( Ar \)
  - \( Ne \)
Direct detection techniques

- Requirements: large mass, low-radioactivity, low-energy threshold, high acceptance, discrimination

Figure 1.11: Past and present direct WIMP searches classified by excitation channel measured. Figure from [Plante, 2012].

Discrimination ability between WIMPs and electromagnetic background can be improved significantly. Since the interactions in the detection medium depend on the incident particle type and its energy, electromagnetic background interactions deposit energy in the detection medium in a different manner than do WIMP interactions. This results in the energy deposit partition through different channels of electromagnetic background interactions to be different than that from WIMP-induced interactions. Hence, the usage of signal from one channel to signal from the other channel can be used as a good discriminant for the electromagnetic background rejection. A good example is making use of ionization signals in a solid-state detector by applying electric field, in addition to the use of the phonon signal.

The Cryogenic Dark Matter Search (CDMS II) had reported discrimination of WIMP-like signal from electromagnetic background with a rejection power of \( >10^4 \), using the ratio of ionization signal to the phonon signal [Ahmed et al., 2009].
WIMP search status < 30th October 2013

![Graph showing WIMP mass vs. WIMP-nucleon cross section]
WIMP search status < 30th October 2013

![Graph showing WIMP search results]

- **XENON100 (2012)**
  - Observed limit (90% CL)
  - Expected limit of this run:
    - ± 1σ expected
    - ± 2σ expected

- **DAMA/Na**
- **CoGeNT**
- **DAMA/I**
- **SIMPLE (2012)**
- **CRESST-II (2012)**
- **ZEPLIN-III (2012)**
- **COUPP (2012)**
- **EDELWEISS (2011/12)**
- **CDMS (2010/11)**
- **XENON100 (2011)**
- **XENON100 (2011)**
WIMP search status < 30th October 2013
The Large Underground Xenon (LUX) experiment

The world’s largest dual-phase xenon time-projection chamber
### The LUX collaboration

**SD School of Mines**
- Xinhua Bai, PI, Professor
- Tyler Liebsch, Graduate Student
- Doug Tiedt, Graduate Student

**SDSTA**
- David Taylor, Project Engineer
- Mark Hanhardt, Support Scientist

**Texas A&M**
- James White, PI, Professor
- Robert Webb, PI, Professor
- Rachel Mannino, Graduate Student
- Clement Sofia, Graduate Student

**UC Davis**
- Mani Tripathi, PI, Professor
- Bob Svoboda, Professor
- Richard Lander, Professor
- Britt Holbrook, Senior Engineer
- John Thomson, Senior Machinist
- Ray Gerhard, Electronics Engineer
- Aaron Manalaysay, Postdoc
- Matthew Szadzis, Postdoc
- Richard Ott, Postdoc
- Jeremy Mock, Graduate Student
- James Morad, Graduate Student
- Nick Walsh, Graduate Student
- Michael Woods, Graduate Student
- Sergey Uvarov, Graduate Student
- Brian Lenardo, Graduate Student

**University of Edinburgh**
- Alex Murphy, PI, Reader
- Paolo Beltrame, Research Fellow
- James Dobson, Postdoc

**University of Maryland**
- Carter Hall, PI, Professor
- Attila Dobi, Graduate Student
- Richard Knoche, Graduate Student
- Jon Balajthy, Graduate Student

**University of Rochester**
- Frank Wolfs, PI, Professor
- Wojtek Skutski, Senior Scientist
- Eryk Drzuzkiewicz, Graduate Student
- Mongkol, Graduate Student

**University of South Dakota**
- Dongming Mei, PI, Professor
- Chao Zhang, Postdoc
- Angela Chiller, Graduate Student
- Chris Chiller, Graduate Student
- Dana Byram, *Now at SDSTA*

**Yale**
- Daniel McKinsey, PI, Professor
- Peter Parker, Professor
- Sidney Cahn, Lecturer/Researcher
- Ethan Bernard, Postdoc
- Markus Horn, Postdoc
- Blair Edwards, Postdoc
- Scott Hertel, Postdoc
- Kevin O’Sullivan, Postdoc
- Nicole Larsen, Graduate Student
- Evan Pease, Graduate Student
- Brian Tennyson, Graduate Student
- Ariana Hackenburg, Graduate Student
- Elizabeth Boulton, Graduate Student

---

**Brown University College London**
- Richard Gaitskell, PI, Professor
- Simon Fiorucci, Research Associate
- Monica Pangilinan, Postdoc
- Jeremy Chapman, Graduate Student
- David Mallings, Graduate Student
- James Verbus, Graduate Student
- Samuel Chung Chan, Graduate Student
- Dongqiing Huang, Graduate Student

**Case Western University**
- Thomas Shutt, PI, Professor
- Dan Akerib, PI, Professor
- Karen Gibson, Postdoc
- Tomasz Biesiadzinski, Postdoc
- Wing H To, Postdoc
- Adam Bradley, Graduate Student
- Patrick Phelps, Graduate Student
- Chang Lee, Graduate Student
- Kati Pech, Graduate Student

**Imperial College London**
- Henrique Araujo, PI, Reader
- Tim Sunner, Professor
- Alastair Currie, Postdoc
- Adam Bailey, Graduate Student

**Lawrence Berkeley National Laboratory**
- Bob Jacobsen, PI, Professor
- Murdock Gilchriese, Senior Scientist
- Kevin Lesko, Senior Scientist
- Carlos Hernandez, Postdoc
- Victor Gehman, Scientist
- Mia Ihm, Graduate Student

**Lawrence Livermore National Laboratory**
- Adam Bernstein, PI, Leader of Adv.
- Dennis Carr, Mechanical Technician
- Kareem Kaskaz, Staff Physicist
- Peter Sorensen, Staff Physicist
- John Bower, Engineer

**LIP Coimbra**
- Isabel Lopes, PI, Professor
- Jose Pinto da Cunha, Assistant Professor
- Vladimir Solovov, Senior Researcher
- Luiz de Viveiros, Postdoc
- Alexander Lindote, Postdoc
- Francisco Neves, Postdoc
- Claudio Silva, Postdoc

---

**University College London**
- Chamkaur Ghag, PI, Lecturer
- Lea Reichhart, Postdoc

**University of California San Diego**
- SDSTA
- David Taylor, Project Engineer
- Mark Hanhardt, Support Scientist

**University of California Santa Barbara**
- Harry Nelson, PI, Professor
- Mike Witherell, Professor
- Dean White, Engineer
- Susanne Kyre, Engineer
- Carmen Carmona, Postdoc
- Curt Nehrkorn, Graduate Student
- Scott HaselSchwartz, Graduate Student

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Sanford Underground Research Facility (SURF)

Sanford Underground Research Facility (SURF)

Former Homestake gold mine - refurbished for science only

Lead, SD, located in Black Hills

Muon flux at 4850' level reduced by $10^7$

$55.2 \text{ m}^{-2}\text{s}^{-1} \rightarrow 1 \times 10^{-5} \text{ m}^{-2}\text{s}^{-1}$
An ultra low background environment

Figure 3: Overview of the LUX detector system installed in the Davis Cavern. Shown are the water tank and the central cryostat. The PMTs of the muon-veto system are not shown.
The LUX cryostat

- Top thermosyphon
- Feedthroughs
- Low background titanium cryostats
- Anode and electron extraction grids
- Xenon recirculation and heat exchanger
- Photomultiplier tubes
- PTFE reflector panels
- Bottom thermosyphon
- 250 kg active liquid xenon (370 kg total)
- Cathode grid

Hamamatsu R8778 PMTs (61 top, 61 bottom)

Figure 5: Cross-sectional view of the LUX cryostats. The vertical distance between the inner faces of the top and bottom PMT arrays is 61.6 cm.
The active region of LUX

3.3. Grids, fields, and light reflecting cage

The LUX Time-Projection Chamber (TPC) is a dodecagonal structure enclosing an active region with approximately 300 kg of liquid xenon. The active region is viewed from above and below by arrays of 61 PMTs, as illustrated in Fig. 7. Monte Carlo optimization of background rejection and fiducial volume resulted in a design with a drift distance of 49 cm, a diameter of 50 cm, and a buffer distance of 5 cm between the cathode and the bottom PMT array. The inner walls of the TPC consist of twelve polytetrafluoroethylene (PTFE) reflector panels that cover forty-eight copper field rings, supported by Ultra High Molecular Weight Polyethylene (UHMW) panels. All PTFE components are made from ultrahigh purity grade materials and all copper components are C101 OFHC grade. The field cage includes five grids, supported by PTFE structures, that maximize light collection and minimize the leakage of scintillation light from xenon outside the TPC into the viewing region. The entire structure is supported...
Principle of detection: dual phase xenon TPC

- Primary scintillation (S1) and secondary ionization signal from electroluminescence (S2)
- 3D position (mm resolution)
- S2/S1 particle discrimination
- Recoil energy correlated to S1 and S2
- Powerful Xe self-shielding

Electron/Nuclear recoil

Excitation

Ionisation

S1

S2

E field

Drift time indicates depth

Powerful Xe self-shielding

Circulation gas and sampling

**Thermosyphon**

- LN bath
- cold head
- conduits into water tank

**Cathode HV feedthrough**

- LUX Thermosyphon

**Kr removal facility**

- 130 ppb to 3.5 ppt!

**Xe storage**

- Rick Gaitskell (Brown) / Dan McKinsey (Yale)
- LUX Dark Matter Experiment / Sanford Lab

**Kr removal facility**

- Research grade Xenon: ~100 ppb Kr ⇒ 10^4 to 10^5 reduction needed
- August 2012 - January 2013: Kr removal at dedicated facility
- Chromatographic separation system
- Kr concentration reduced from 130 ppb to 3.5 ± 1 ppt, (factor of 35000)
- 1 ppt is achievable (useful for next-generation detectors)

*arXiv:1103.2714*
Calibrating LUX

- External sources via source tubes:
  - Americium-beryllium (AmBe) and $^{252}$Cf: low energy neutrons → validating NR models and detector sims, NR efficiencies

- Xenon self-shielding → internal sources injected into circulation system:
  - $^{83m}$Kr: half-life ~1.8 hours, 32.1 + 9.4 keV betas → weekly purity & xyz maps; drift length >130 cm
  - Tritiated methane (CH3T): low energy betas (end point 18 keV) High stats, uniform and high purity → ER band, ER acceptance
First dark matter results from LUX

118 kg and 85.3 days of live-time data
Run 3 data-taking

- LUX moves underground in July 2012
- Detector cool-down January 2013, Xe condensed mid-February 2013
- Kr and AmBe calibrations throughout, CH3T after WIMP search
A LUX event - 1.5 keV electron recoil

S1 summed across all channels

S2 summed across all channels

95% single photoelectrons > threshold

Triggered on S2
Position reconstruction

- Drift time (1.5 mm/µs) for Z-position,
- XY position fitting S2 hit pattern with LRFs from internal calibrations
## Backgrounds in LUX

The most radioactively quiet place in the world!

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<thead>
<tr>
<th>Source</th>
<th>Background rate, mDRU&lt;sub&gt;ee&lt;/sub&gt;</th>
</tr>
</thead>
<tbody>
<tr>
<td>$\gamma$-rays</td>
<td>$1.8 \pm 0.2_{\text{stat}} \pm 0.3_{\text{sys}}$</td>
</tr>
<tr>
<td>$^{127}$Xe</td>
<td>$0.5 \pm 0.02_{\text{stat}} \pm 0.1_{\text{sys}}$</td>
</tr>
<tr>
<td>$^{214}$Pb</td>
<td>$0.11-0.22$ (90% C.L.)</td>
</tr>
<tr>
<td>$^{85}$Kr</td>
<td>$0.13 \pm 0.07_{\text{sys}}$</td>
</tr>
</tbody>
</table>

Total predicted: $2.6 \pm 0.2_{\text{stat}} \pm 0.4_{\text{sys}}$

Total observed: $3.1 \pm 0.2_{\text{stat}}$

Measured DRU (89 livedays, 89 eff)

- 118 kg
- 3.1 +/- 0.2 mDru
- r < 18 cm
- z = 7-47 cm

Log<sub>10</sub>(DRU<sub>ee</sub>)

Squared radius [cm$^2$]
...and still dropping!

- Measured DRU (89 livedays, 89 eff)
  - $\log_{10}(\text{evts/keVee/kg/day})$
  - 118 kg
  - 3.1$\pm$0.2 mdru
  - $r<18$ cm
  - $z=7$-$47$ cm

- Measured DRU (44 livedays, 44 eff)
  - $\log_{10}(\text{DRUee})$

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Light and charge yields

\[ \text{yield relative to Co-57 gamma} \]

\[ \text{nuclear recoil energy (keV)} \]

\[ \text{absolute yield (photons/keV)} \]

\( \Rightarrow \) set hard threshold at 3 keVnr

Very conservative!

Photon detection efficiency: **14%**

Charge yield: **26 phe/e**
Tritium Calibration

\[ \log_{10}(S_{2b}/S_1)_{x,y,z \text{ corrected}} \]

S1 \( x,y,z \) corrected (phe)

keV\text{ee} 0.4 0.8 1.3 1.8 2.4 2.9 3.5 4.1 4.6 50
NeutronX and multiple scatters in calibration, but not WIMP data
program at the Soudan Low-Background Counting (summarized in Table I). Backgrounds from detector 5.3 keV channel. Additional, anti-correlated portioning into the ionization range 3–25 keV. A minimum of 0.77 and a maximum of 0.82 in the are consistent with an energy-dependent, non-monotonic scattering. Consequently, these data cannot be used obtained, accounting for their unique energy spectra. These e-scatters from AmBe and Cf reactions. In regions of di-scattering events (including those where scatters occur on each plot). The dot-dashed magenta line delineates the energies using an S1–S2 combined energy scale (same contours band mean and vice versa. Gray contours indicate constant profile likelihood analysis. The ER plot also shows the NR b-tritium data, with fits to simulated NR data shown in panel 2 mDRU. The observed ER background in the range 0.9–1.5 k shows fits to the high statistics 1.5–2.5 keV peaks of 0.4 and 0.8. The ratio of keV is 0.4 for S1 and 0.8 for S2. The concentration of 3
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Slide 32
* For 50% NR acceptance at 181 V/cm average discrimination 99.6%
S1 efficiency

* Independent measures using AmBe, tritium, LED calibrations and full MC simulation of NR events (includes analysis cuts)
NR acceptance

- S2–only
- S1–only
- S1, S2 combined, before threshold cuts
- S1, S2 combined, after threshold cuts

**FIG. 4.** WIMP detection efficiency as a function of nuclear recoil energy for events with a corrected S1 between 2 and 30 phe and a S2 signal greater than 200 phe (black +). This efficiency is used directly in the profile likelihood analysis. In addition, we show the efficiency for individually detecting an S2 (red squares) or S1 (blue circles) signal, respectively, without the application of any analysis thresholds. The detection efficiency for single scatter events (again applying no threshold cuts), shown by the green triangles, clearly demonstrate the dominant impact of the S1-only efficiency.

**FIG. 5.** Plot showing the leakage fraction (discrimination level) between electron and nuclear recoil populations, with 50% nuclear recoil acceptance (as calculated from flat-in-energy NR simulations), measured with the high-statistics tritium data. We show the leakage from counting events in the dataset (black circles) and from projections of Gaussian fits to the electron recoil population (red squares). An upper limit is shown for S1 bins without events. The blue dashed line indicates the total leakage fraction, 0.004, in the S1 range 2-30 phe. The leakage fraction is not used directly in the estimation of the WIMP signal.

\[ \text{efficiency} = 50\% \text{ @ } 4.3 \text{ keV}_{nr} \]

\[ \text{efficiency} = 17\% \text{ @ } 3 \text{ keV}_{nr} \]
Run 3 event selection and cuts

<table>
<thead>
<tr>
<th>Cut</th>
<th>Events Remaining</th>
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<tr>
<td>all triggers</td>
<td>83,673,413</td>
</tr>
<tr>
<td>detector stability</td>
<td>82,918,902</td>
</tr>
<tr>
<td>single scatter</td>
<td>6,585,686</td>
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<tr>
<td>S1 energy (2 – 30 phe)</td>
<td>26,824</td>
</tr>
<tr>
<td>S2 energy (200 – 3300 phe)</td>
<td>20,989</td>
</tr>
<tr>
<td>single electron background</td>
<td>19,796</td>
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<tr>
<td>fiducial volume</td>
<td>160</td>
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* Non-blind analysis!

* Hardware trigger: at least two trig. channels > 8 phe within 2 μs window (16 PMTs per trig. channel)

* > 99% efficient for raw S2 > 200 phe
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- Remove periods of live-time when liquid level, gas pressure or grid voltages were out of nominal ranges:
  - Less than 1.0% live-time loss!
## Run 3 event selection and cuts

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- Exactly 1 S2 and 1 S1 as identified by the pulse finding/classification:
  - Separate S1s from S2s using pulse shape and PMT hit distributions
  - S1s identification includes a two fold PMT coincidence requirement
Run 3 event selection and cuts

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- Accept events with S1 between 2-30 phe (0.9-5.3 keVee, ~3-18 keVnr):
  - 2 phe analysis threshold allows sensitivity down to low WIMP masses
  - Upper limit avoids $^{127}$Xe 5 keVee activation
Run 3 event selection and cuts

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* S2 threshold cuts subdominant to S1:
  * 200 phe ~ 8 single electrons
  * Removes small S2 edge events and single electron events
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* Require less than 100 phe (< 4 extracted electrons) of additional signal in 1 ms period around S1 and S2 signals:
  * Simple cut to removes additional single electron events in 0.1-1 ms following large S2 signals
  * Only 0.8% hit on live-time
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• 118 kg fiducial volume defined by:
  * Z cut: $38 < \text{drift time} < 305 \mu\text{s}$ ($320 \mu\text{s}$ is max drift time)
  * Reconstructed radial position $< 18 \text{ cm}$
After all selection cuts:
160 candidate events in fiducial ($r < 18 \text{ cm}$ and $7 \text{ cm} < z < 47 \text{ cm}$)
LUX WIMP search data, 85.3 live-days, 118 kg FV

- **S1 > 2 phe:**
  - Conservative S1 pulse identification > 50%

- **S1 < 30 phe:**
  - Avoid $^{127}$Xe 5 keVee activation

- **S2_b > 200 phe:**
  - Removes SE and small edge events

Graph showing log$_{10}$($S_{2b}/S_1$) vs. S1 x,y,z corrected (phe)
LUX WIMP search data! 85.3 live-days, 118 kg FV
LUX WIMP search data! 85.3 live-days, 118 kg FV

P-value of 35% consistent with ER BG and no WIMP signal
Simulated response for hypothetical WIMP signals

For 1000 GeV WIMP @ $1.9 \times 10^{-44}$ cm$^2$, XENON100 90% CL:

→ expect 9 WIMPs in LUX search
Simulated response for hypothetical WIMP signals

For 8.6 GeV WIMP @ $2.0 \times 10^{-41}$ cm$^2$, CDMS II Si (2012) 90% CL ....

→ expect 1550 WIMPs in LUX search
Profile likelihood ratio for limits

- Unbinned maximum likelihood compare data with prediction on event by event basis.

4 observables: \( x = S_1, \log_{10}(S_2/S_1), r, z \)

\[
\mathcal{L}_{WS} = \frac{e^{-N_s - N_{\text{Compt}} - N_{\text{Xe-127}} - N_{\text{Rn-222}}} N!}{N_{\text{obs}}!} \prod_{i=1}^{N} N_s \mathcal{P}_s(x; \sigma, \theta_s) \mathcal{P}_\text{ER}(x; \theta_{\text{Compt}}) + N_{\text{Compt}} \mathcal{P}_\text{ER}(x; \theta_{\text{Compt}}) + N_{\text{Xe-127}} \mathcal{P}_\text{ER}(x; \theta_{\text{Xe-127}}) + N_{\text{Rn}} \mathcal{P}_\text{ER}(x; \theta_{\text{Rn}})
\]

WIMP signal PDF:
- WIMP dE/dR for given mass (see earlier)
- efficiency from validated NR sims
- \( N_s \) is parameter of interest

Backgrounds as nuisance parameters:
- detector efficiencies included
- 30% uncertainty on overall rate

Ratio of this to null hypothesis used to create test statistic and extract 90% CI upper limit
Spin-independent sensitivity

Upper limit @ 33 GeV/c² is $7.6 \times 10^{-46}$ cm² → first sub-zeptobarn WIMP detector!

WIMP–nucleon cross section (cm²)

$m_{\text{WIMP}}$ (GeV/c²)

XENON100 (2012)-225 live days
LUX (2013)-85 live days: 90% upper limit → $10^{-21}$ barn!
Low-mass WIMPs excluded

- **Low-mass WIMPs excluded**

- **WIMP–nucleon cross section (cm$^2$)**
  - $10^{-44}$
  - $10^{-43}$
  - $10^{-42}$
  - $10^{-41}$
  - $10^{-40}$

- **m$_{WIMP}$ (GeV/c$^2$)**
  - 5
  - 6
  - 7
  - 8
  - 9
  - 10
  - 12

- **CDMS II Ge**
- **DAMA/LIBRA Favored**
- **CoGeNT Favored**
- **CRESST Favored**
- **CDMS II Si Favored**
- **LUX (2013)-85 live days**
- **LUX +/-1σ expected sensitivity**
- **XENON100(2012)-225 live days**
- **>20x more sensitivity**
What’s next: LUX 300 day run

- 300 day run planned for 2014/2015
- Cosmogenic cool-down plus potential for further improvements (E-field, cals., …)
- Still not background limited and expect factor of ~5 improvement in sensitivity → discovery possible!
Longer term: LUX-ZEPLIN (LZ)

- 20 times LUX Xenon mass, active scintillator veto, Xe purity at sub ppt level
- Ultimate direct detection experiment - approaches coherent neutrino scattering backgrounds

Same water tank as LUX
Onwards and downwards

Figure from SNOMASS CF1 WIMP Dark Matter Detection summary
LZ Projections

Limit on Nucleon $s(0)$, 50 GeV WIMP

- Crystals
- Cryogenic
- Liquid xenon
- Liquid argon
- LUX and LZ
- LUX

50 GeV WIMP mass

Year:
- 1985
- 1995
- 2005
- 2015
- 2025

Limits decrease over time, with projections extending into the future.
LZ and all ‘G2’ Projections

![Graph showing limits on nucleon cross-sections for WIMP mass up to 50 GeV/year from 1985 to 2025.](image)
With 85.3 live-days LUX set world’s best limit on spin-independent scattering:

- 90% UL $7.6 \times 10^{-46} \text{ cm}^2 @ 33 \text{ GeV}/c^2 \rightarrow$ first sub-zeptobarn WIMP detector
- Low-mass WIMPs fully excluded by LUX
- Results paper submitted to PRL, expect more to follow

LUX at the frontier of dark matter direct detection - exciting times ahead with the 300 day run, WIMP discovery possible!

LUX-ZEPLIN proposed successor will approach irreducible background limit for direct detection experiments
THANKS FOR LISTENING

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