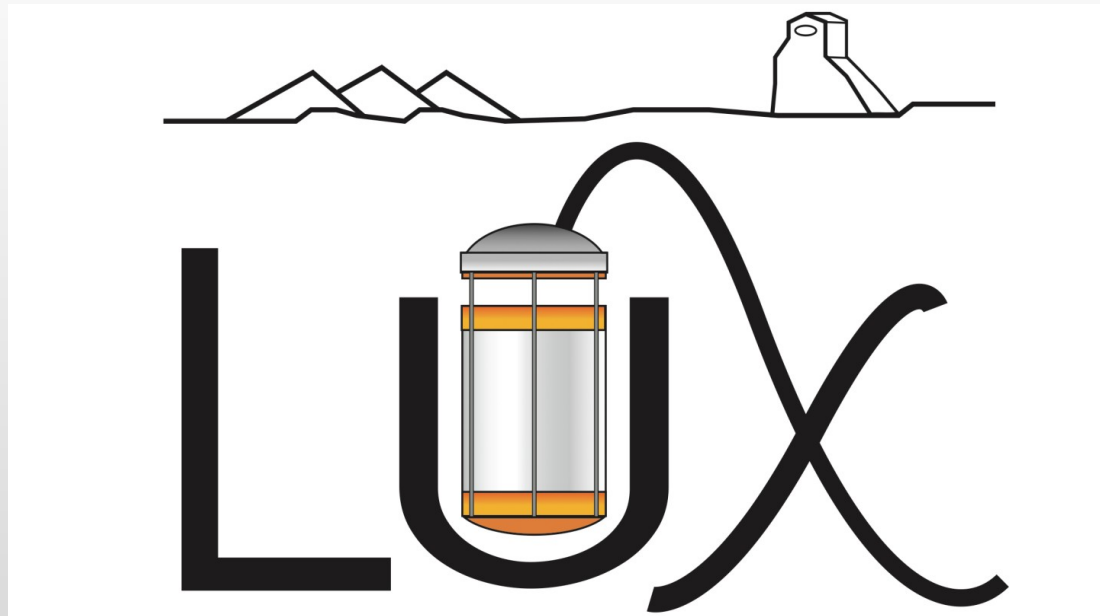


First Results from LUX Dark Matter Experiment



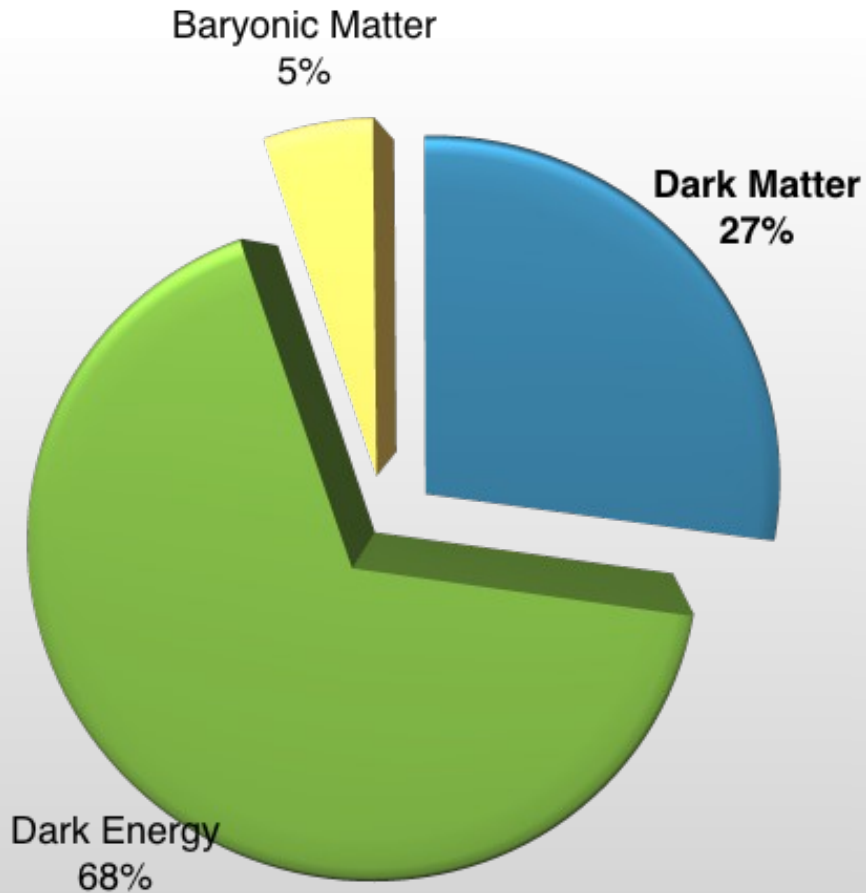
V. Solovov – *LIP Coimbra, Portugal*
on behalf of the LUX Collaboration



XXX-th International Workshop on High Energy Physics

Protvino, Russia, June 23-27 2014

Dark Matter



Evidence:

- Galaxy cluster dynamics
- Galaxy rotation curves
- Gravitational lensing
- Cosmological evidence
 - CMB
 - Supernovae
 - LS structure formation

Far away, we can see it

Through the “weak lensing” effect

Galaxy cluster CL0024+17



Bullet cluster



Dark matter candidates

MOND (Modified Newtonian Dynamics)

- explains galaxy rotation curves,
- but does not explain gravitational lensing

Hot dark matter - neutrinos

- too light to explain the dark matter density
- HDM disfavoured in scenarios of large scale structure formation

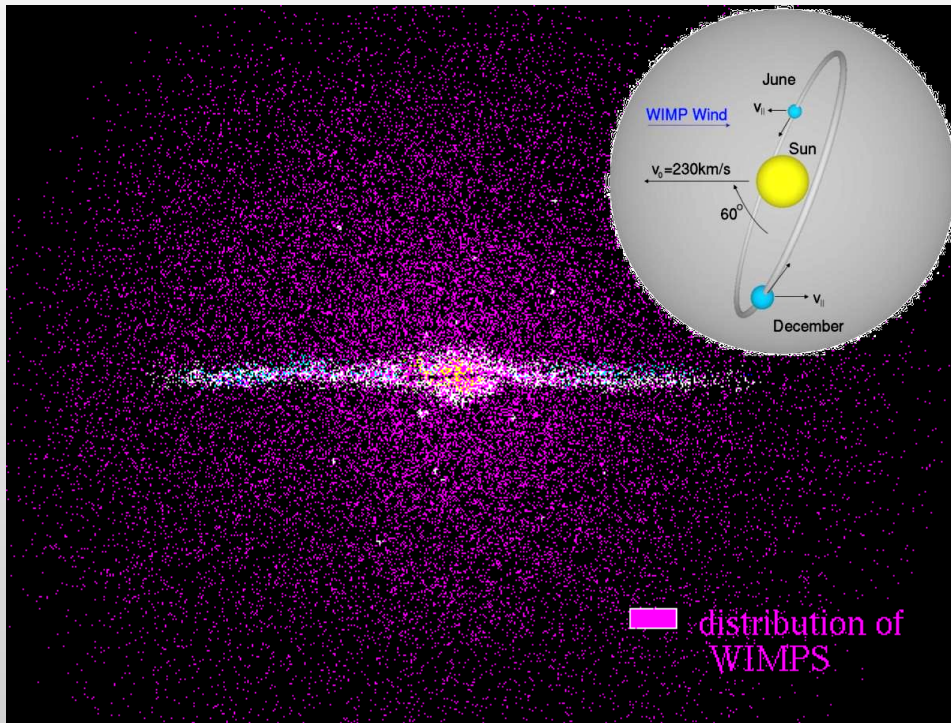
Cold dark matter

- **Axions**: have an (upper) experimental mass constraint.
- **WIMPs**: Weakly Interacting Massive Particles
(also predicted by SUSY: neutralinos)

WIMPs

WIMP properties (educated guess):

- Not affected neither by strong nor electromagnetic forces
- Mass scale: 10 GeV ... 1 TeV (assuming it is neutralino)
- Moves with the Galaxy => average velocity of ~ 300 km/s is expected

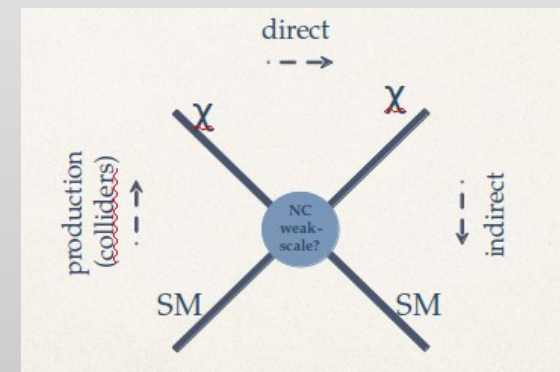


Interaction with nucleus:

- Spin-independent : $\sigma \sim A^2$
- Spin-dependent: $\sigma \sim J(J+1)$

How to search:

- **Production** – collider experiments
- **Indirectly** – e.g. looking for high-energy neutrinos from WIMP annihilation
- **Directly** – looking for nuclear recoils from WIMPs



Direct DM search

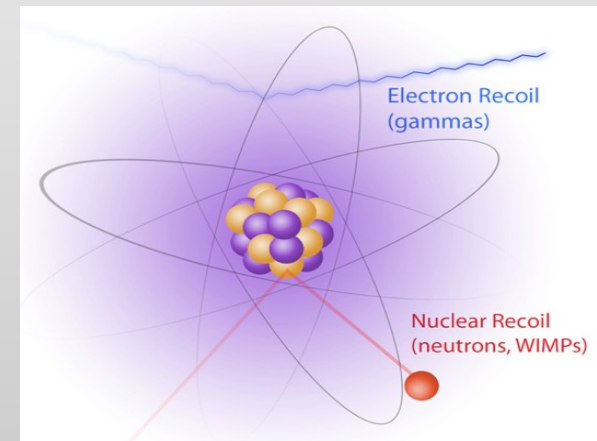


Challenges:

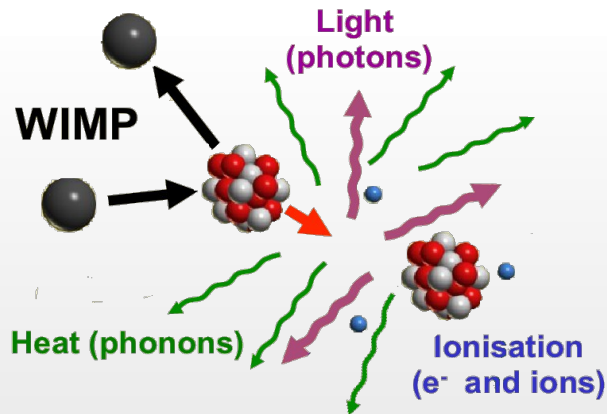
- Very low event rate: less than 10^{-3} ev/kg/day
- High background from natural radioactivity and cosmic rays
- Low energy nuclear recoils (<100 keV)

Solutions:

- Reduce background
 - Low-background materials
 - Passive shielding
 - Active shielding
- Reject background
 - Discriminate between electron and nuclear recoils



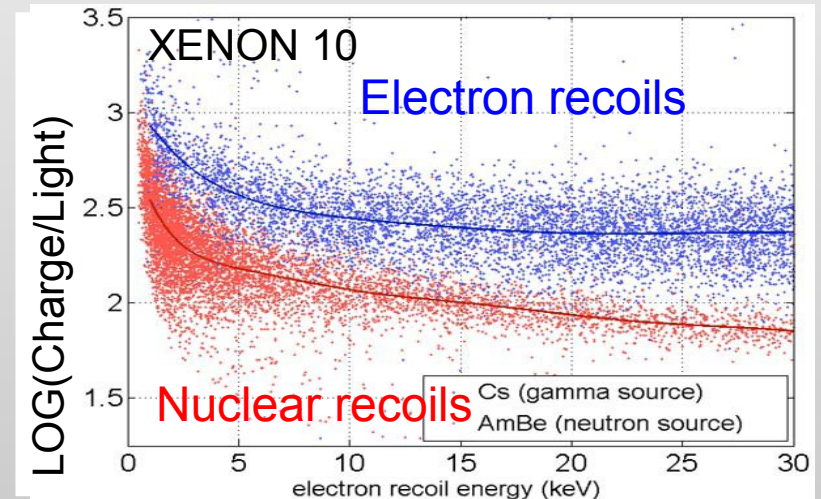
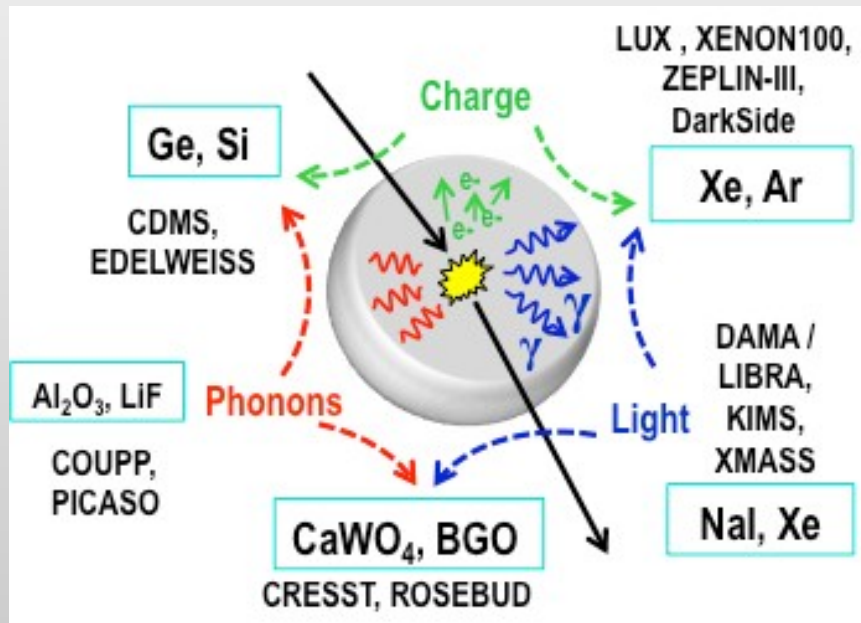
How discrimination works



Recoil energy dissipates through three channels:

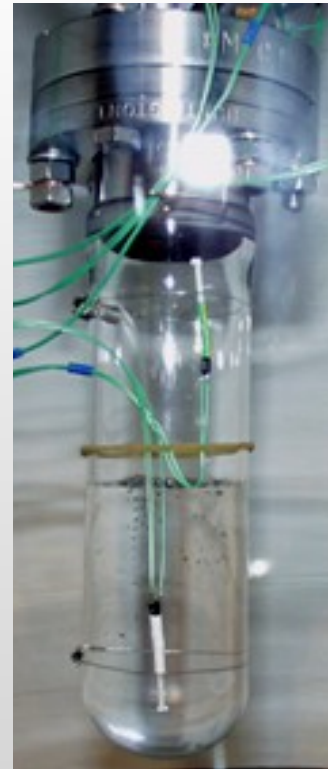
- Ionisation
- Scintillation
- Phonons

The ratio between these channels strongly depends on recoil type



Why we love liquid Xe

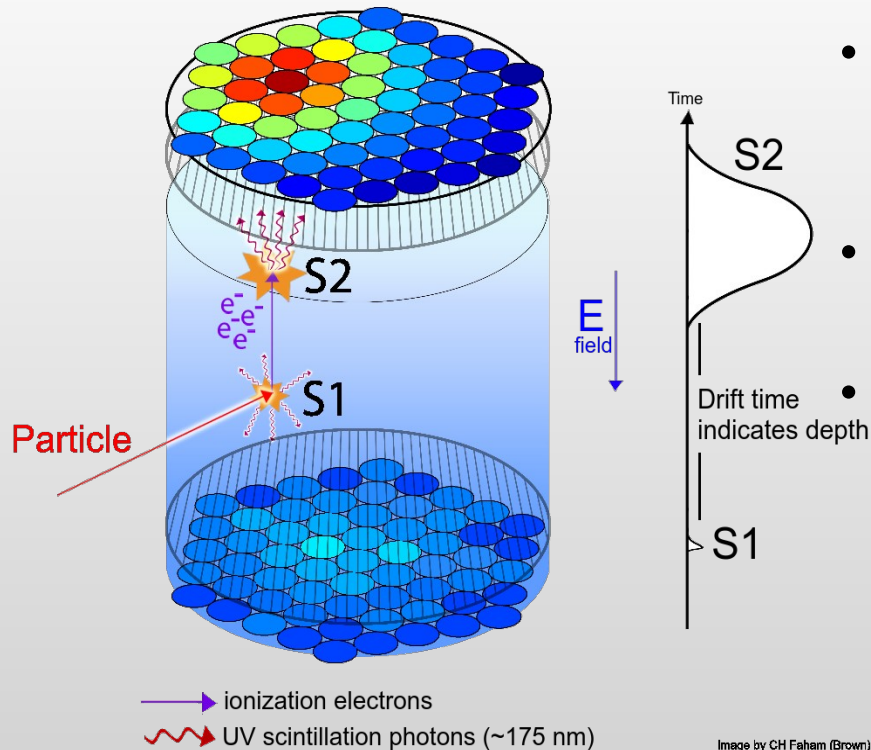
- Relatively high density (2.9 g/cm³)
- High atomic mass ($A=131$ g/mol)
- Spin-dependent sensitive isotopes
- High light output and fast response
- Long electron drift lengths (~ 1 m)
- No intrinsic backgrounds
- Self-shielding capability
- Two channel (light+charge) output
- Scalable to multi-ton size



Used in

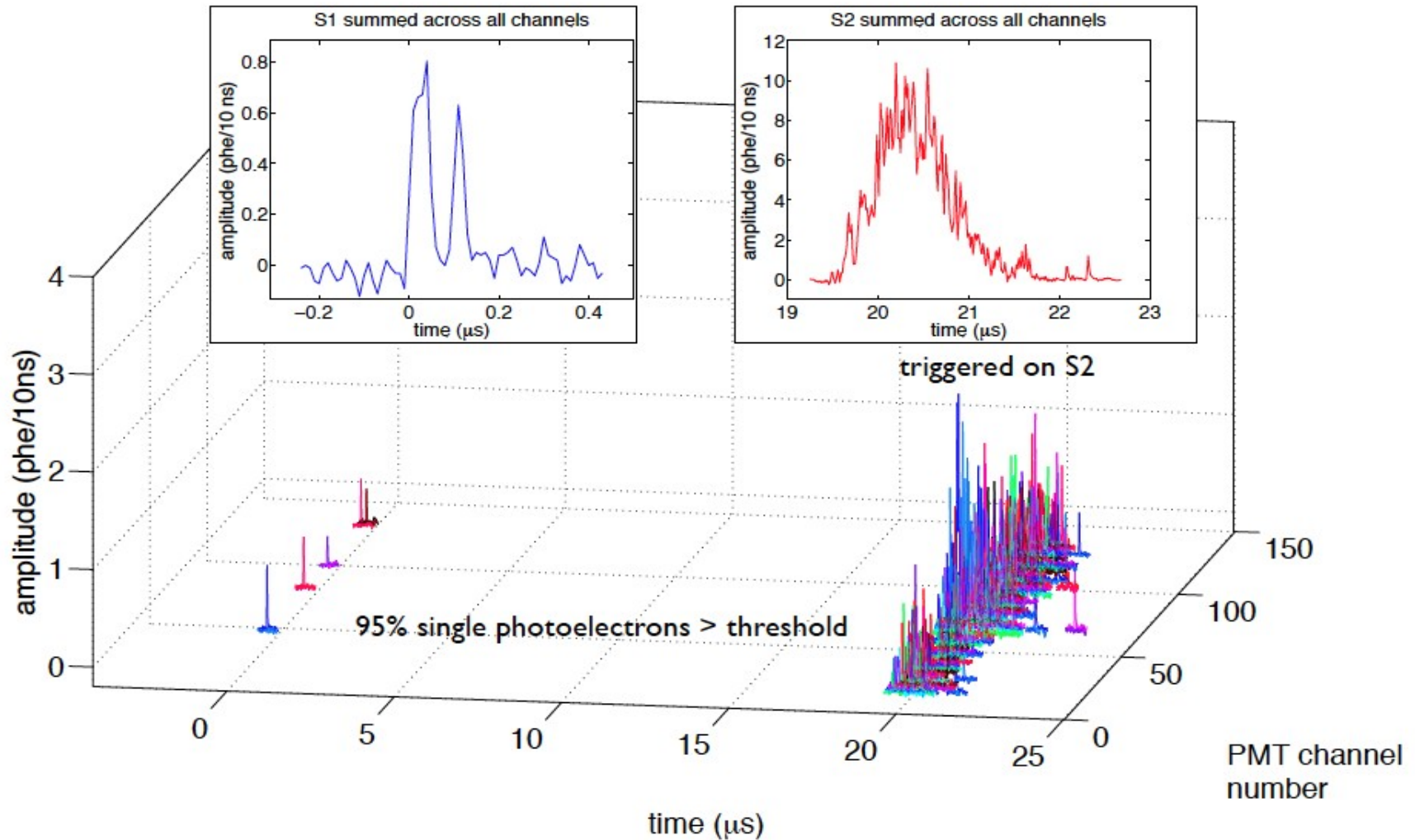
- ZEPLIN I
- ZEPLIN II
- XENON 10
- ZEPLIN III
- XENON 100
- LUX
- X-MASS
- XENON 1T
- PANDA-X
- LZ

LXe Time Projection Chamber



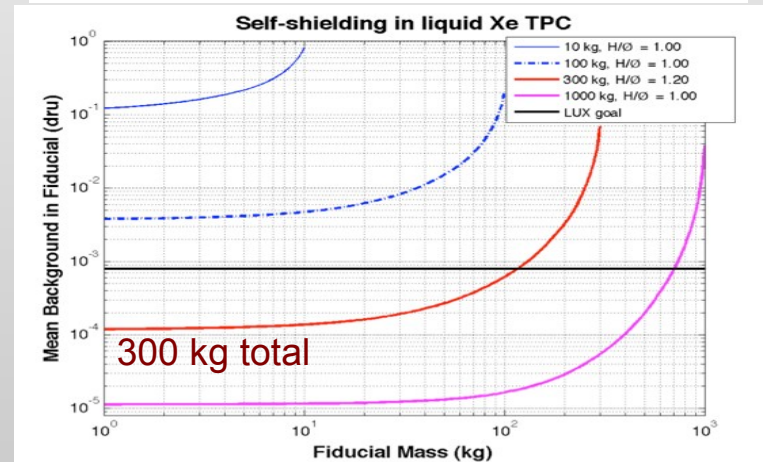
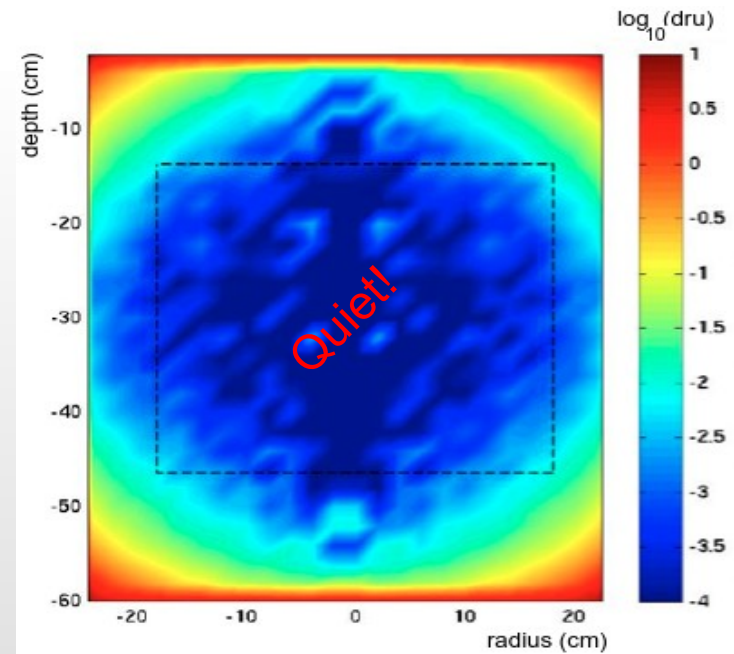
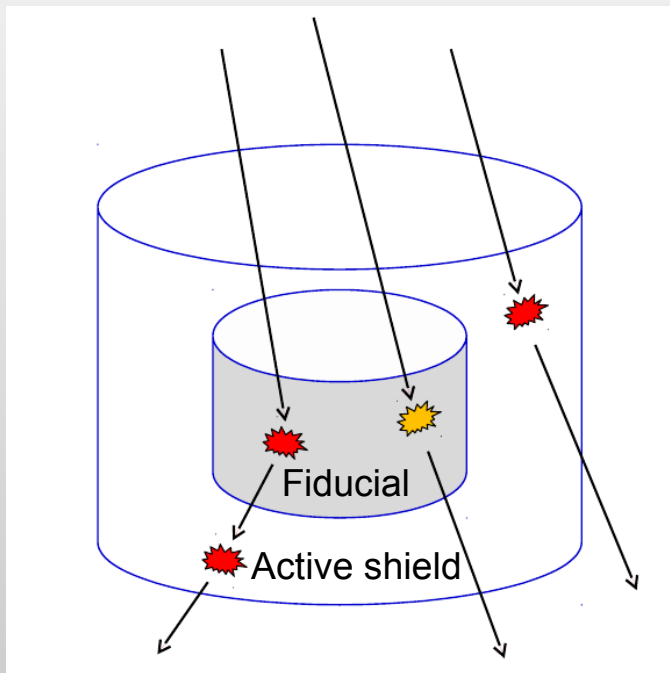
- Prompt scintillation (**S1**): energy scale (keVee)
- Proportional scintillation (**S2**): measurement of the e^- charge extracted from the liquid to the gas
- **S2/S1** ratio depends on the recoil type
- Position sensitivity:
 - **X** and **Y** from the S2 light distribution across the PMT array
 - **Z** from drift time (delay between S1 and S2)

1.5 keV electron recoil in LUX



Self-shielding

- Look for events only in the inner (fiducial) volume
- Use the outer volume as an active shield



The LUX Collaboration



Brown

Richard Gaitskell	PI, Professor
Simon Fiorucci	Research Associate
Monica Pangilinan	Postdoc
Jeremy Chapman	Graduate Student
Carlos Hernandez Faham	Graduate Student
David Malling	Graduate Student
James Verbus	Graduate Student
Samuel Chung Chan	Graduate Student
Dongqing Huang	Graduate Student



Case Western

Thomas Shutt	PI, Professor
Dan Akerib	PI, Professor
Carmen Carmona	Postdoc
Karen Gibson	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 Sumner	Professor
Alastair Currie	Postdoc
Adam Bailey	Graduate Student



Lawrence Berkeley + UC Berkeley

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Murdock Gilchriese	Senior Scientist
Kevin Lesko	Senior Scientist
Victor Gehman	Scientist
Mia Ihm	Graduate Student



Lawrence Livermore

Adam Bernstein	PI, Leader of Adv. Detectors Group
Dennis Carr	Mechanical Technician
Kareem Kazkaz	Staff Physicist
Peter Sorensen	Staff Physicist
John Bowder	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



SD School of Mines

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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 Sofka	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 Szydagis	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



UC Santa Barbara

Harry Nelson	PI, Professor
Mike Witherell	Professor
Dean White	Engineer
Susanne Kyre	Engineer
Curt Nehr Korn	Graduate Student
Scott Haselschwardt	Graduate Student



University College London

Chamkaur Ghag	PI, Lecturer
Lea Reichhart	Postdoc



Collaboration Meeting,
Sanford Lab, April 2013



University of Edinburgh

Alex Murphy	PI, Reader
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 Druszkiewicz	Graduate Student
Mongkol Moongweluwan	Graduate Student



University of South Dakota

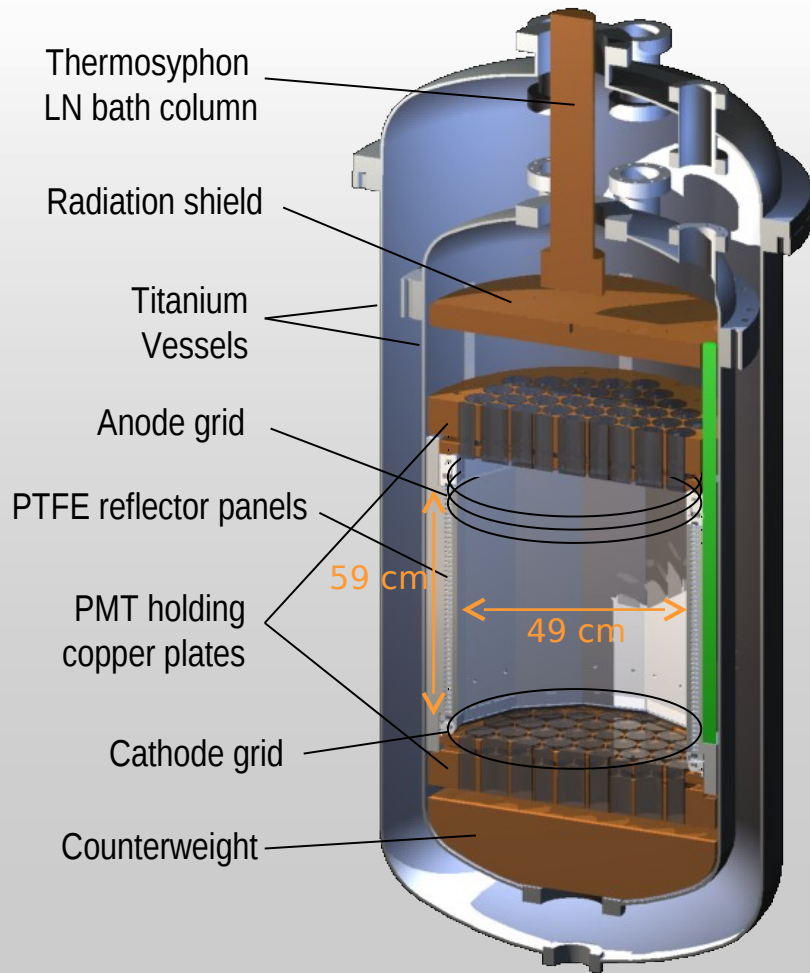
Dongming Mei	PI, Professor
Chao Zhang	Postdoc
Angela Chiller	Graduate Student
Chris Chiller	Graduate Student
Dana Byram	*Now at SDSTA



Yale

Daniel McKinsey	PI, Professor
Peter Parker	Professor
Sidney Cahn	Lecturer/Research Scientist
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

LUX detector

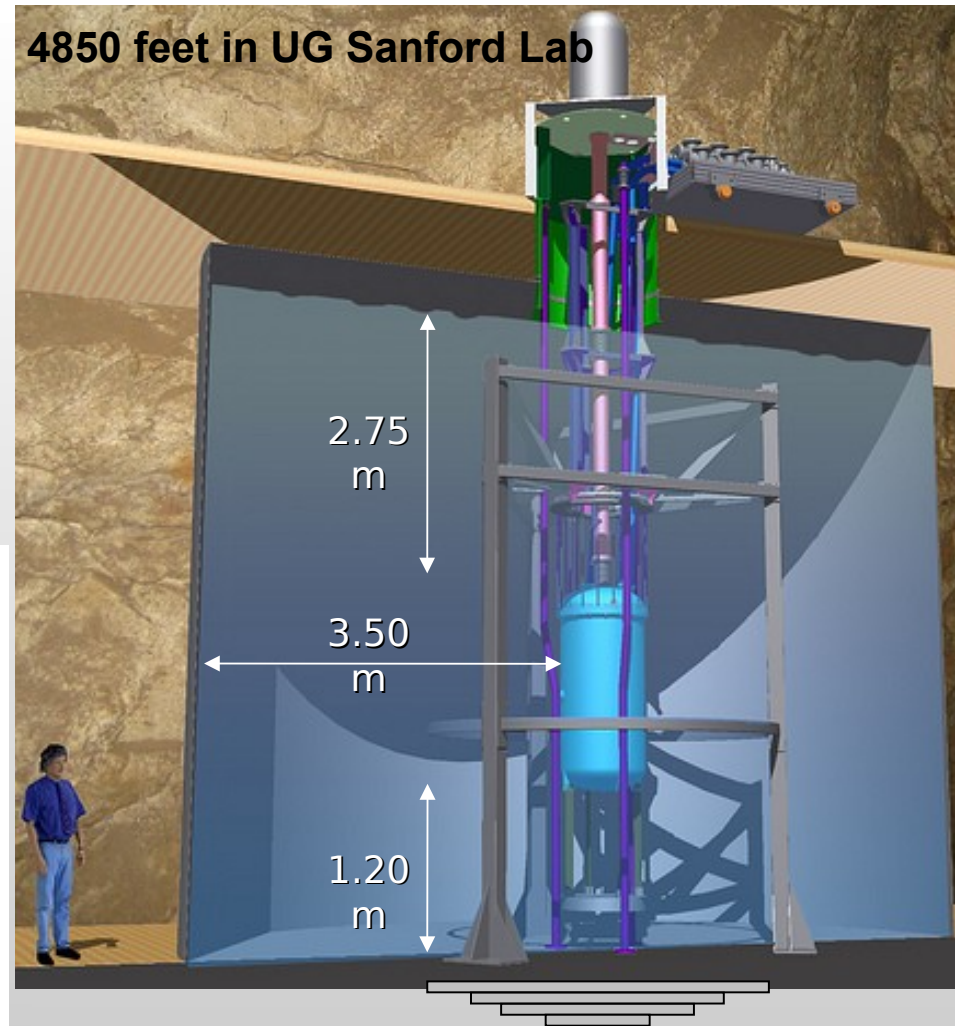
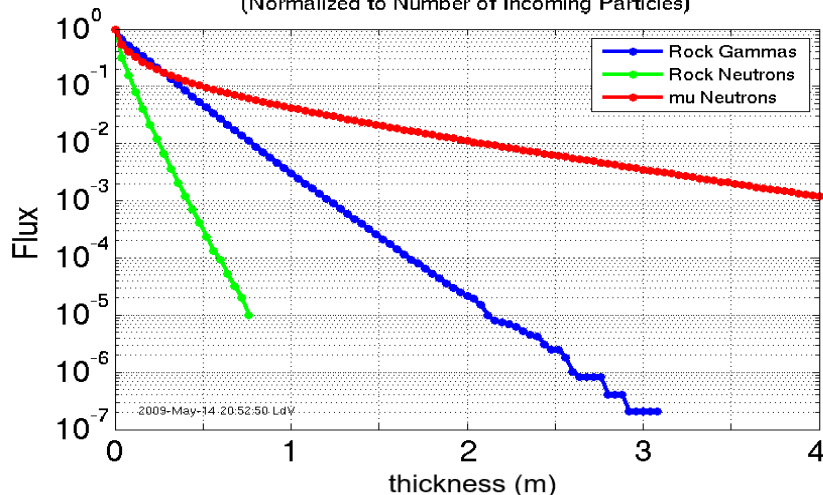


- 350 kg of xenon (300 kg active, expected ~100 kg fiducial);
- 122 Ultra low background PMTs (12 mBq/PMT);
- Radio-pure titanium cryostat (<0.2 mBq/kg);
- Internal copper shield;
- Active region defined by PTFE slabs (high reflectivity for xenon scintillation light);
- Maximum drift length: 49 cm;
- High flow plumbing and heat exchanger for rapid (~25 SLPM) circulation through external purifier;

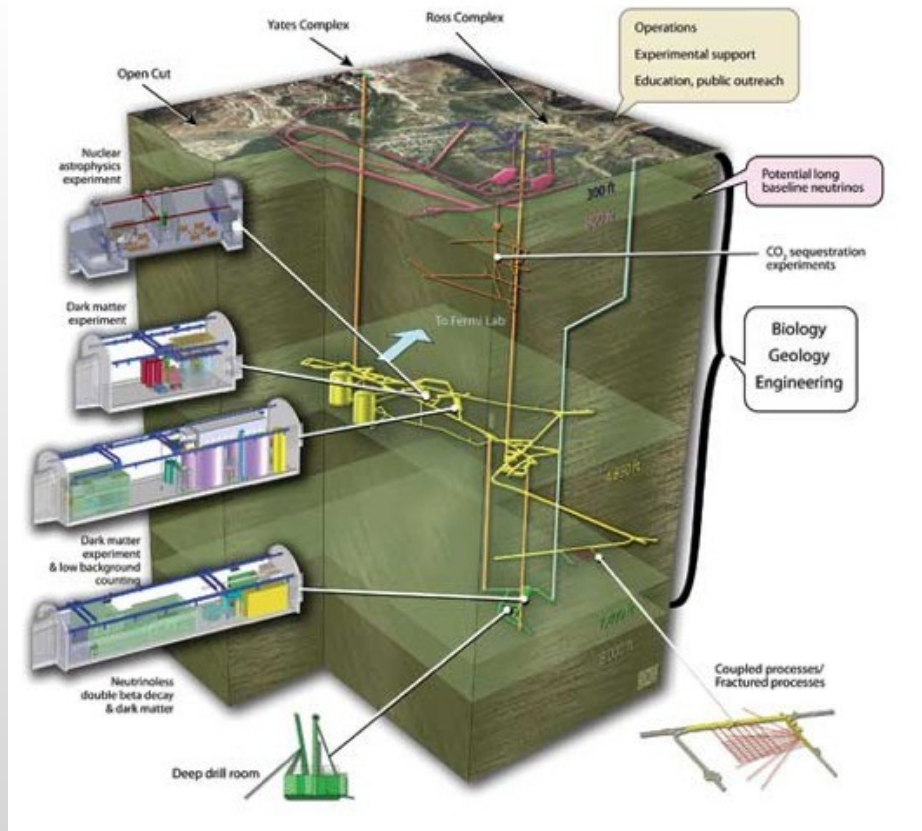
Shielding: Water tank

- 8m diameter, 6m high
- 300 tonnes of purified water
- Background suppression:
 - 10^9 for gammas
 - 10^3 for neutrons
- Instrumented with Cherenkov muon veto (20 PMTs)

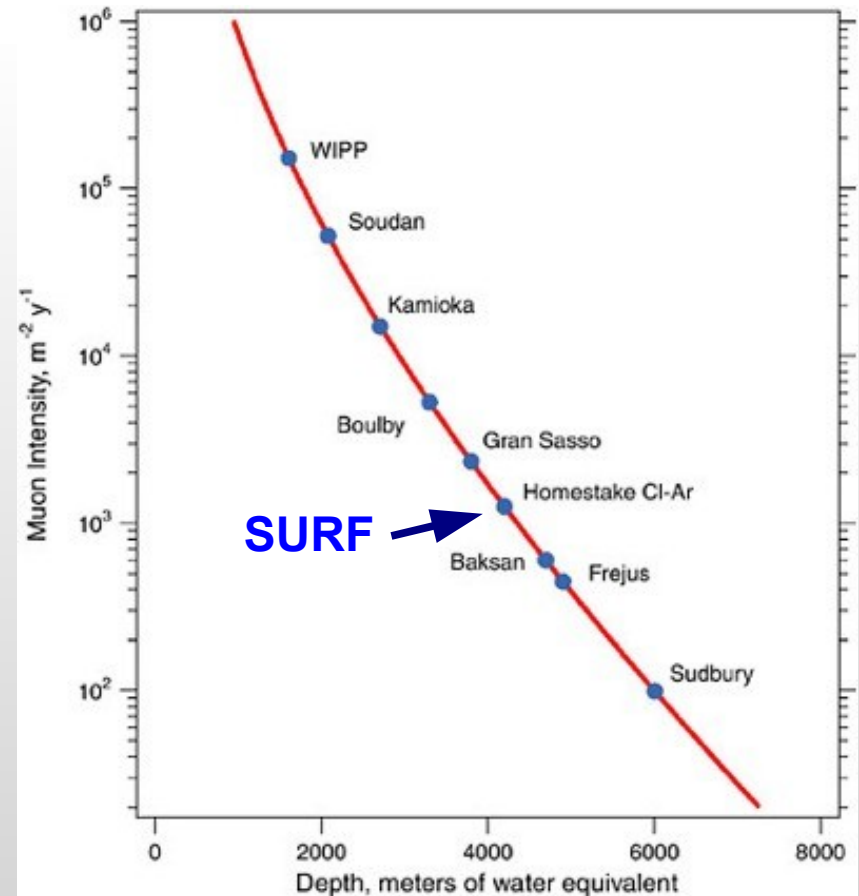
Flux Attenuation in Water
(Normalized to Number of Incoming Particles)



Shielding: Underground facility



SURF – Sanford Underground Research Facility, South Dakota, USA

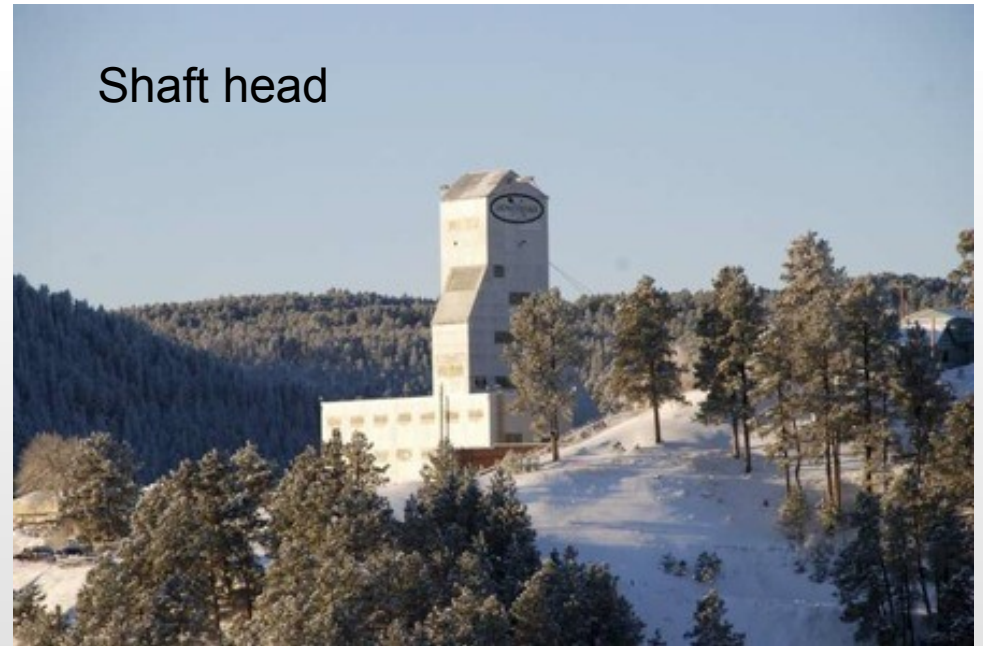


Muon flux is reduced by $\sim 10^7$ compared to surface

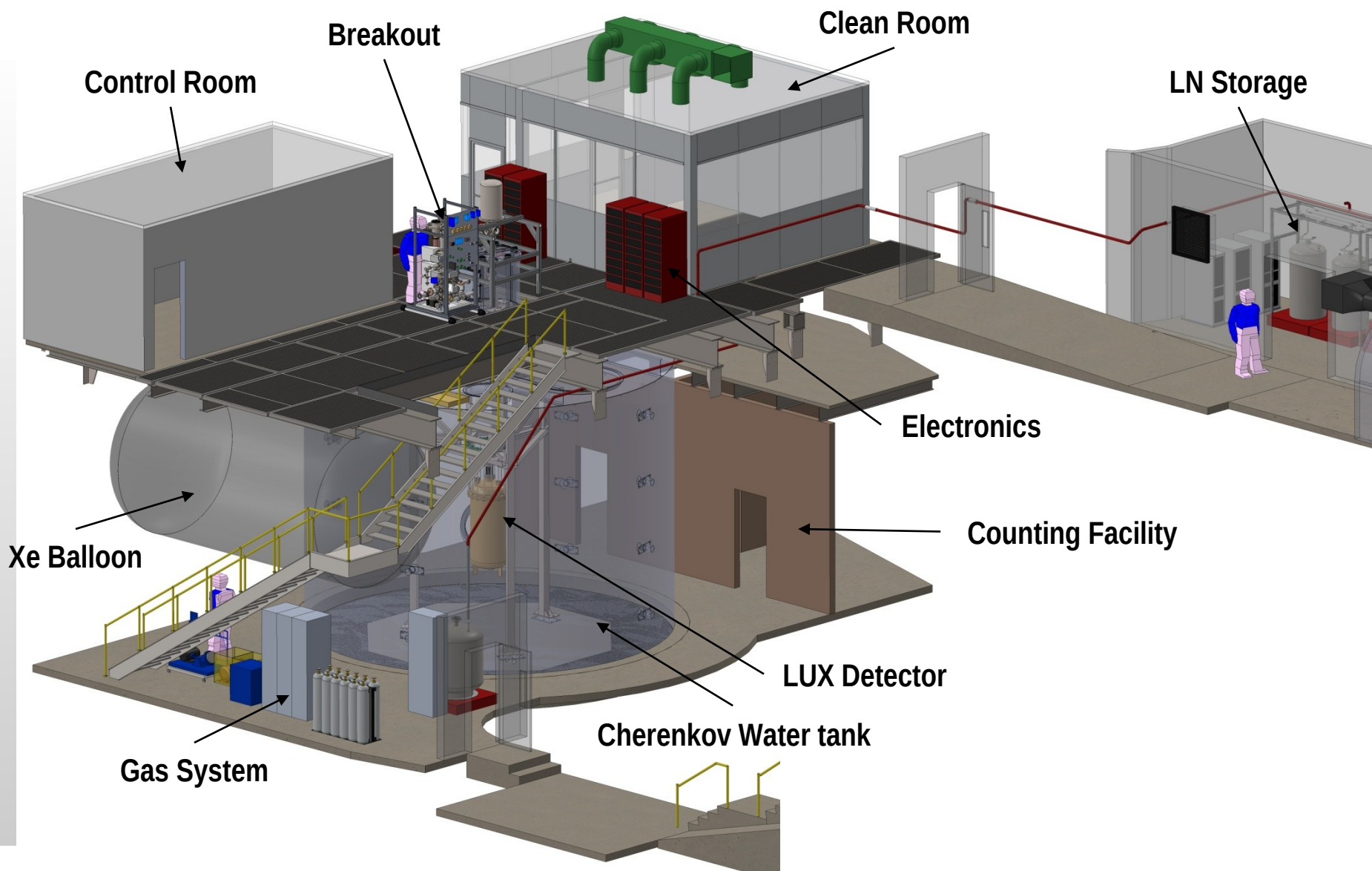
Sanford Lab at Homestake mine



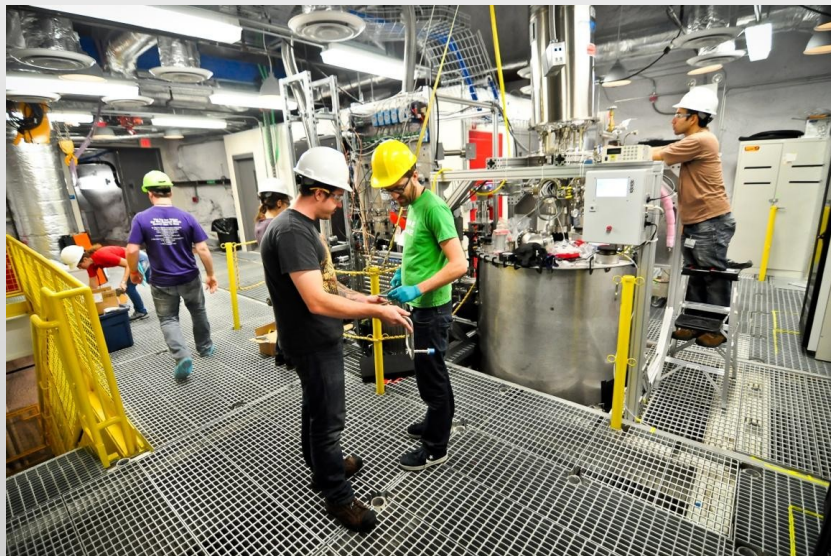
- Was the deepest gold mine in North America
- 1970-1994 – home of Davis solar neutrino experiment
- Located in a spectacular Black Hills region



Davis Lab



Underground deployment



Detector in place

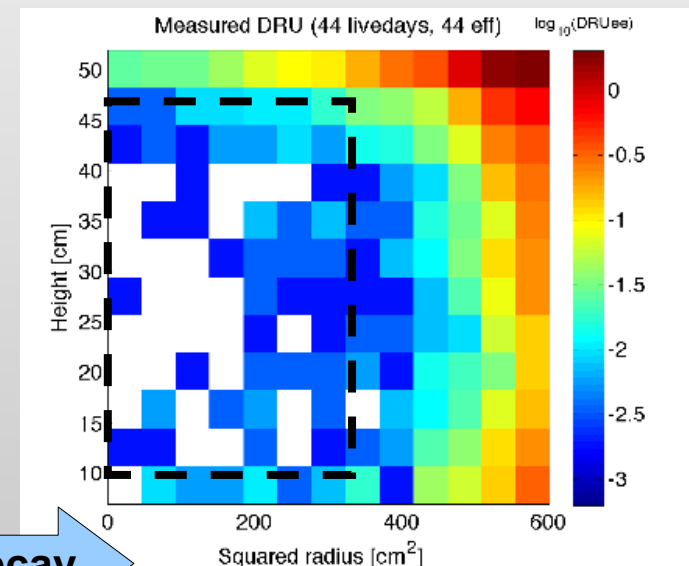
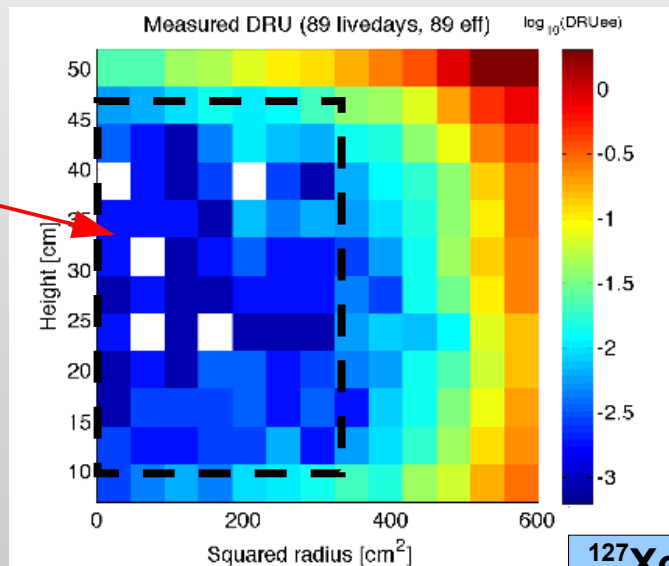


Backgrounds in LUX

Background	Source	$10^{-3} \times \text{evts/keVee/kg/day}$
γ -rays	Internal Components	$1.8 \pm 0.2_{\text{stat}} \pm 0.3_{\text{sys}}$
^{127}Xe ($\lambda_{1/2} = 36.4\text{d}$)	Cosmogenic $0.87 \rightarrow 0.28$	$0.5 \pm 0.02_{\text{stat}} \pm 0.1_{\text{sys}}$
^{214}Pb	^{222}Rn chain	$0.11\text{-}0.22(90\% \text{ CL})$
^{85}Kr	$130 \text{ ppb} \rightarrow 3.5 \pm 1 \text{ ppt}$	$0.13 \pm 0.07_{\text{sys}}$
	Total Predicted:	$2.6 \pm 0.2_{\text{stat}} \pm 0.4_{\text{sys}}$
	Total Observed:	$3.1 \pm 0.2_{\text{stat}}$

Fiducial volume

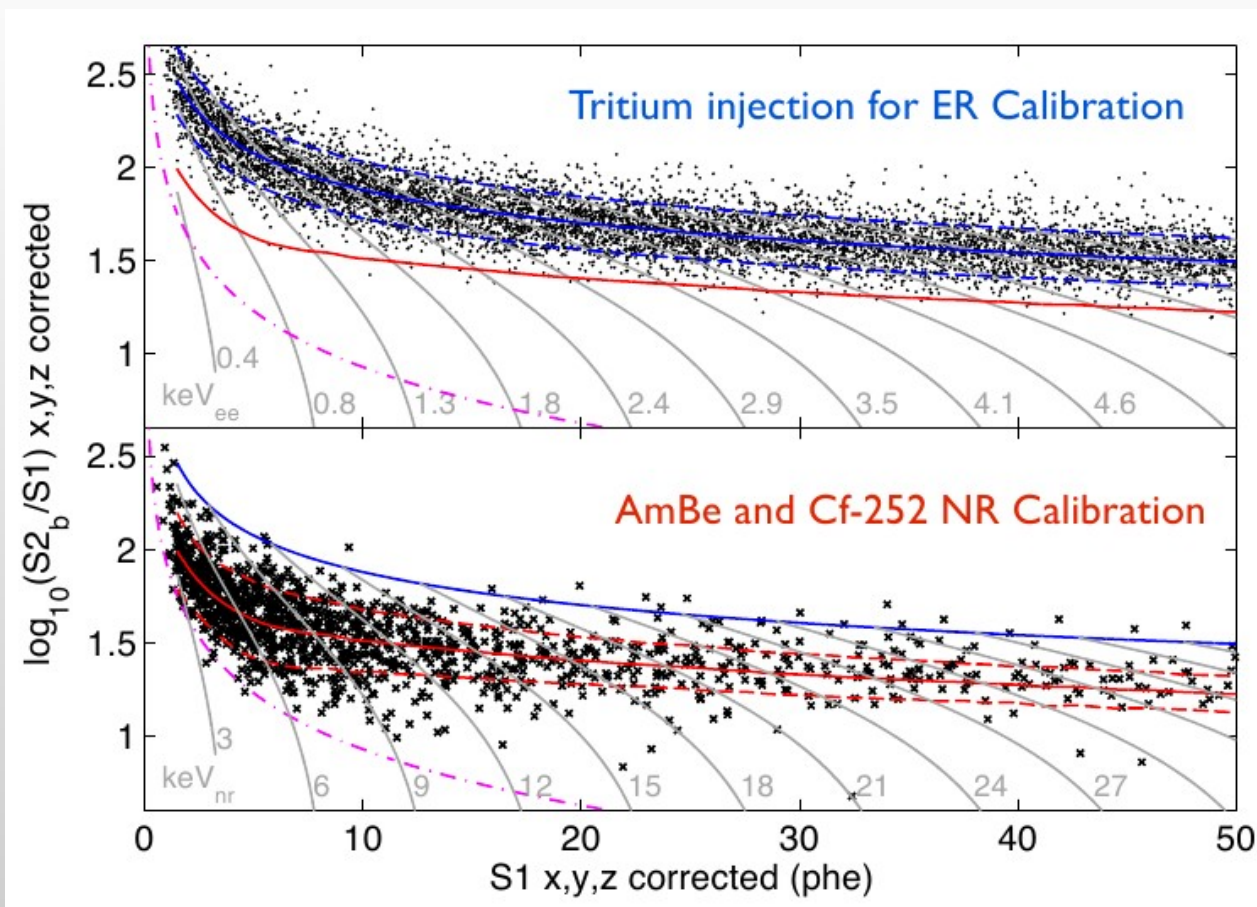
- 118 kg
- $r < 18 \text{ cm}$
- $7 < z < 47 \text{ cm}$
- $3.1 \pm 0.2 \text{ mdru}$



^{127}Xe decay

Calibration

- Tritium provides very high statistics electron recoil calibration (200 events/phe)
- Neutron calibration is consistent with NEST + simulations
- ER discrimination at 50% NR acceptance is 99.6%

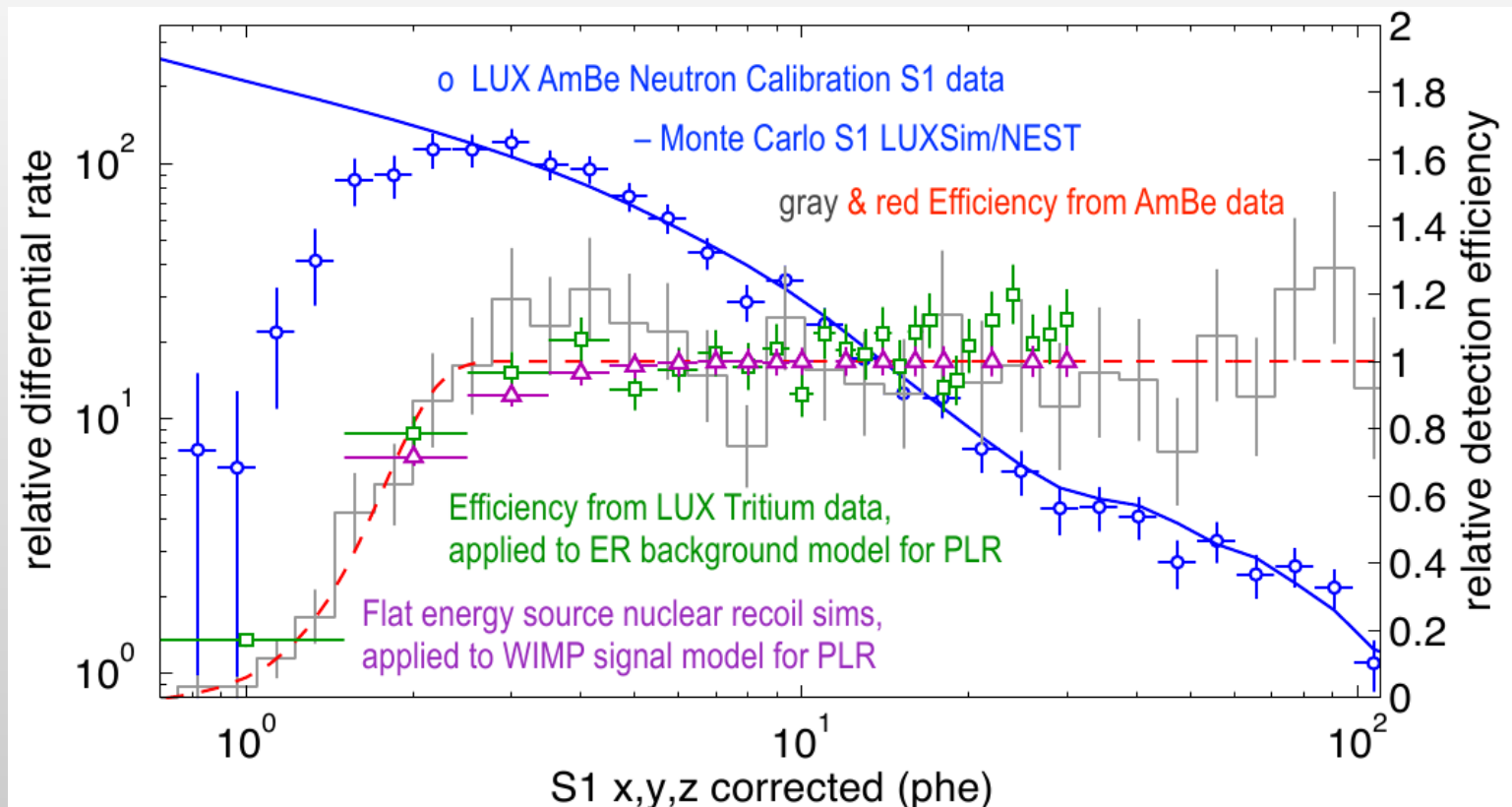


Gray contours indicate constant energies using a S1-S2 combined energy scale

Golden efficiency

Cumulative efficiency of: finding the S2 pulse, finding the S1 pulse, and finding (only) one of each in a given event

Measured independently using AmBe, Tritium, LED data and full NR simulations using a flat spectrum



WIMP search

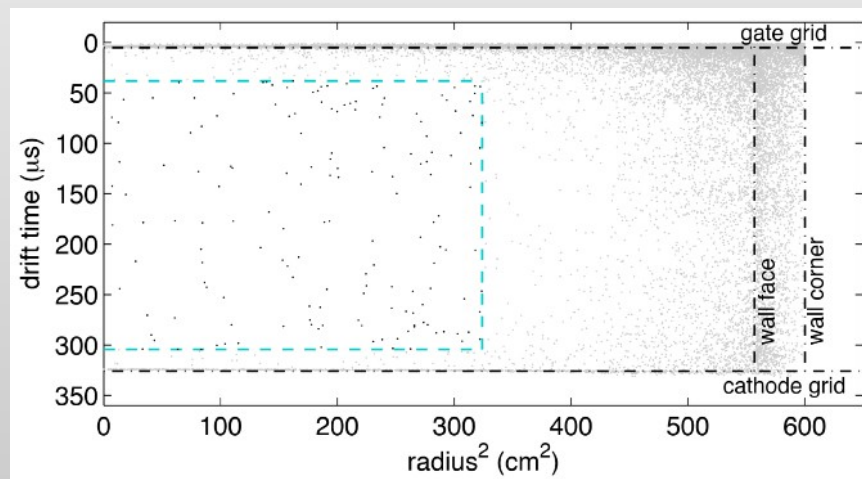
Timeline:

- July 2012: Detector transported underground
- July 2012 – January 2013: Underground deployment and commissioning
- January 2013 – detector cooldown
- February 2013 – Xe condensed
- March – April 2013 – finalizing run parameters
- April – August 2013 – WIMP search

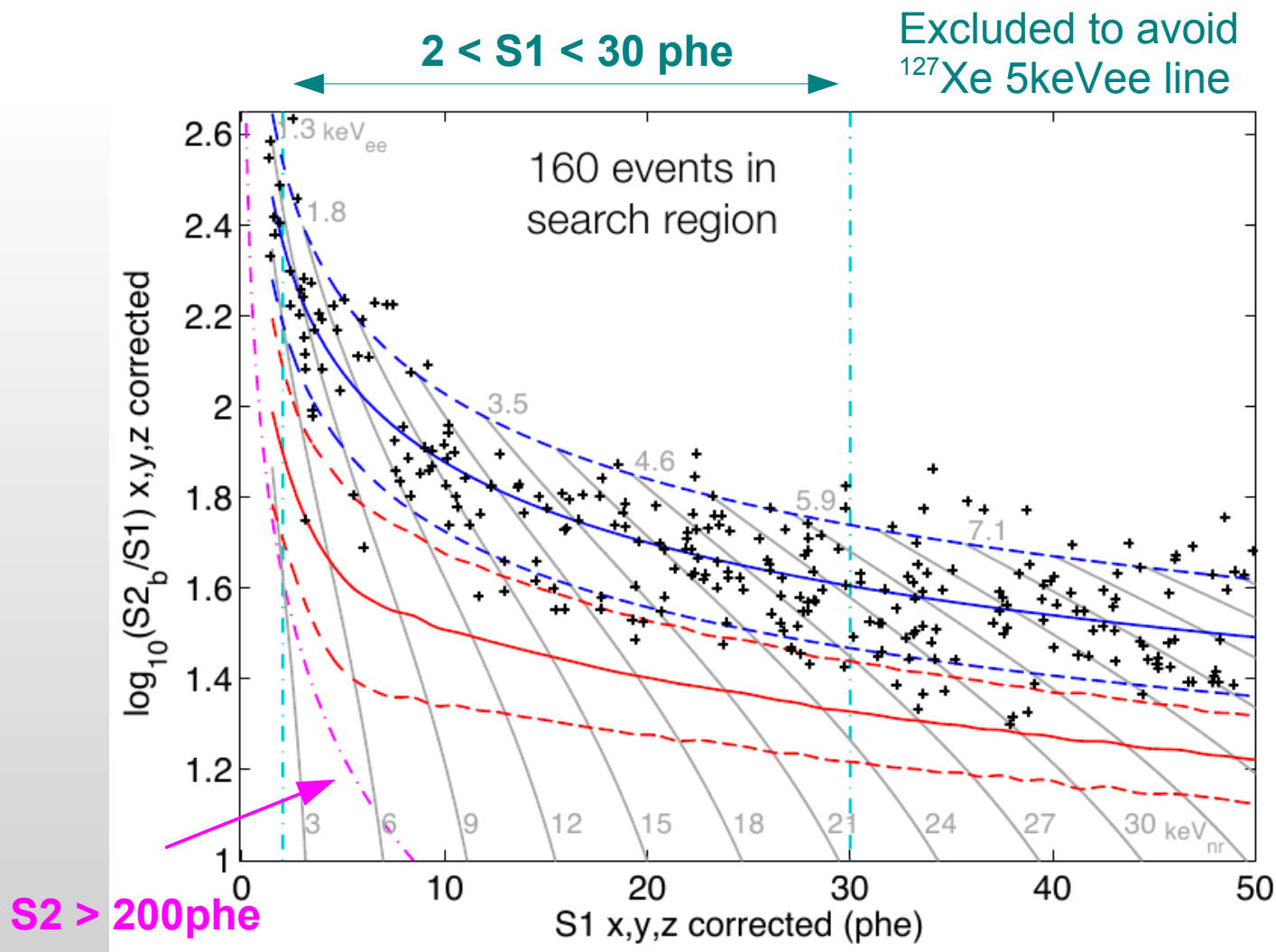
• **85.3 live days**
• **118 kg fiducial mass**

Event Selection

Cut	Events Remaining
All Triggers	83673413
Detector Stability	82918901
Single Scatter Events	6585686
S1 energy (Accept 2-30 phe)	26824
S2 energy	20989
S2 Single Electron Quiet Cut	19796
Drift Time Cut away from grids	8731
Fiducial Volume Cut	160

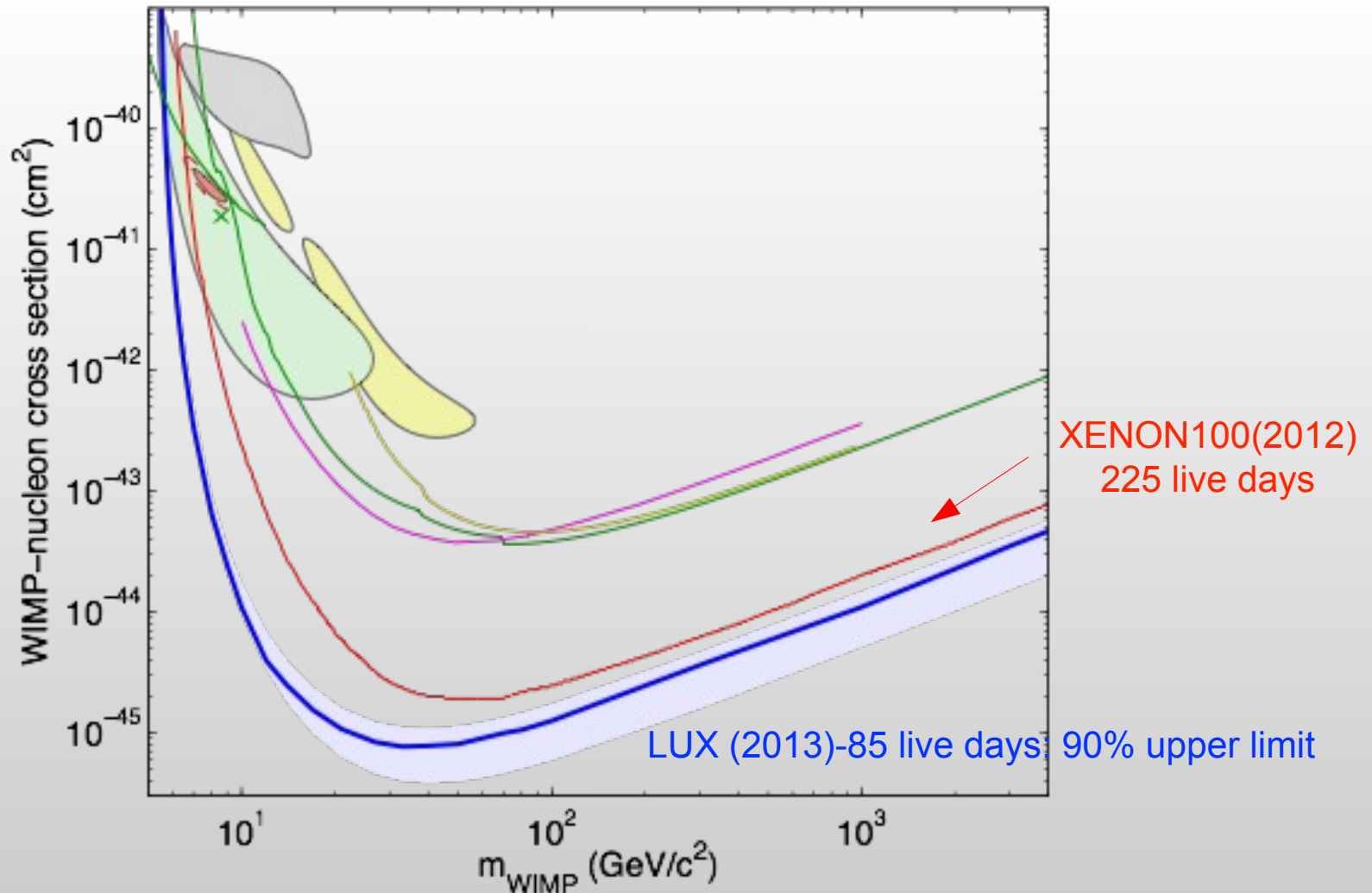


WIMP search data

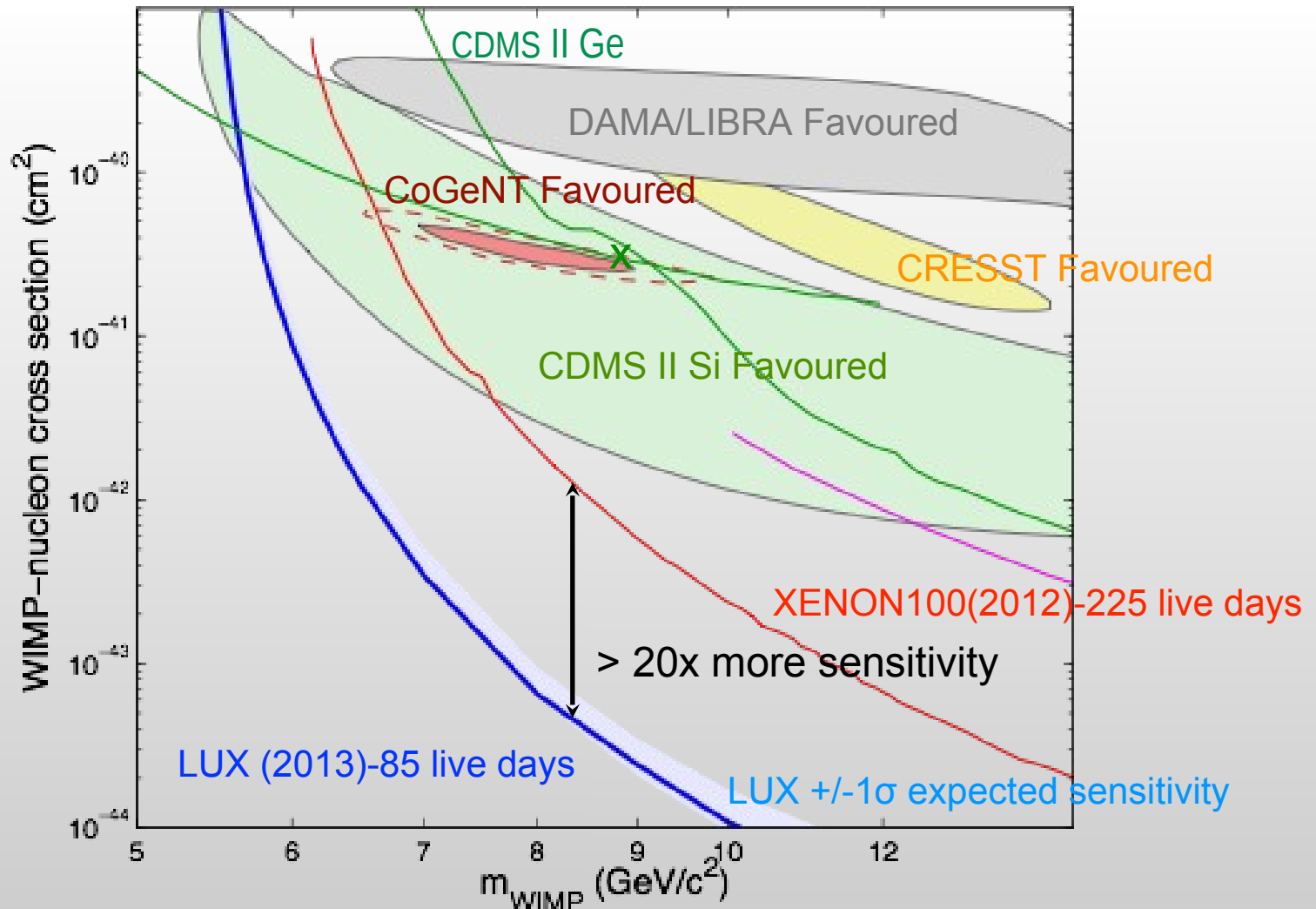


Profile likelihood analysis: P-value of 0.35 consistent with ER background and no WIMP signal

Spin-independent limit

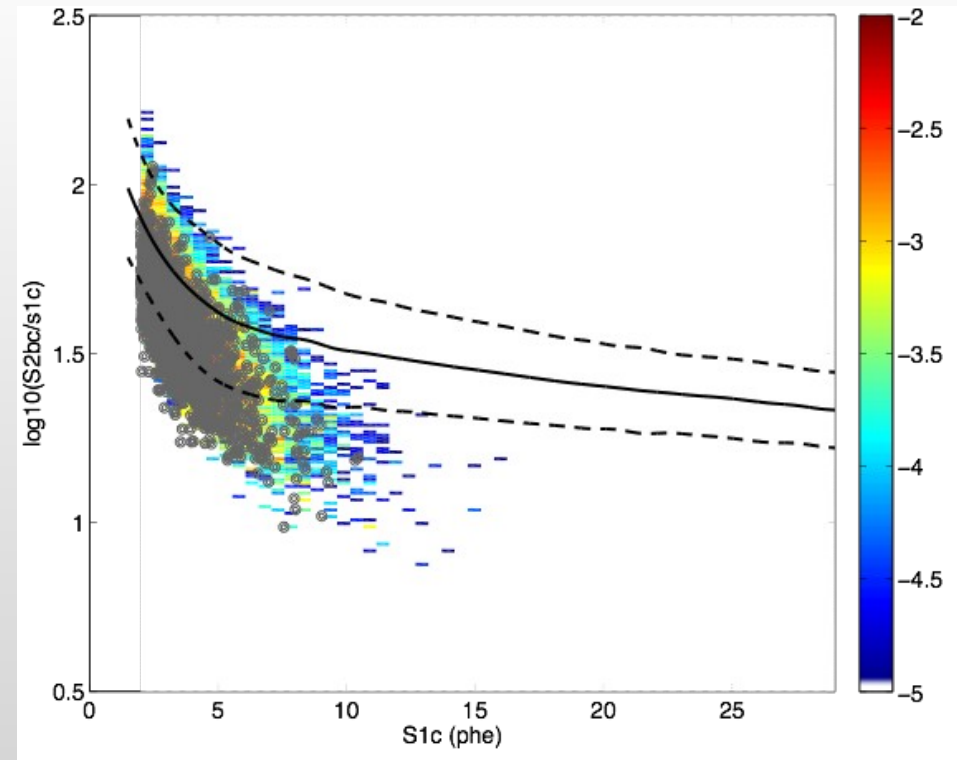
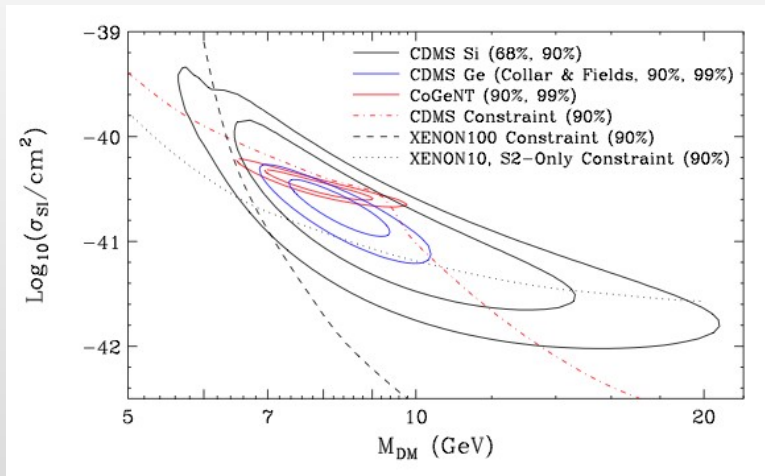


Low-mass WIMPs excluded



Simulated response to light WIMPs

For 8.6 GeV WIMP
compatible with 3
events in CDMS-II Si

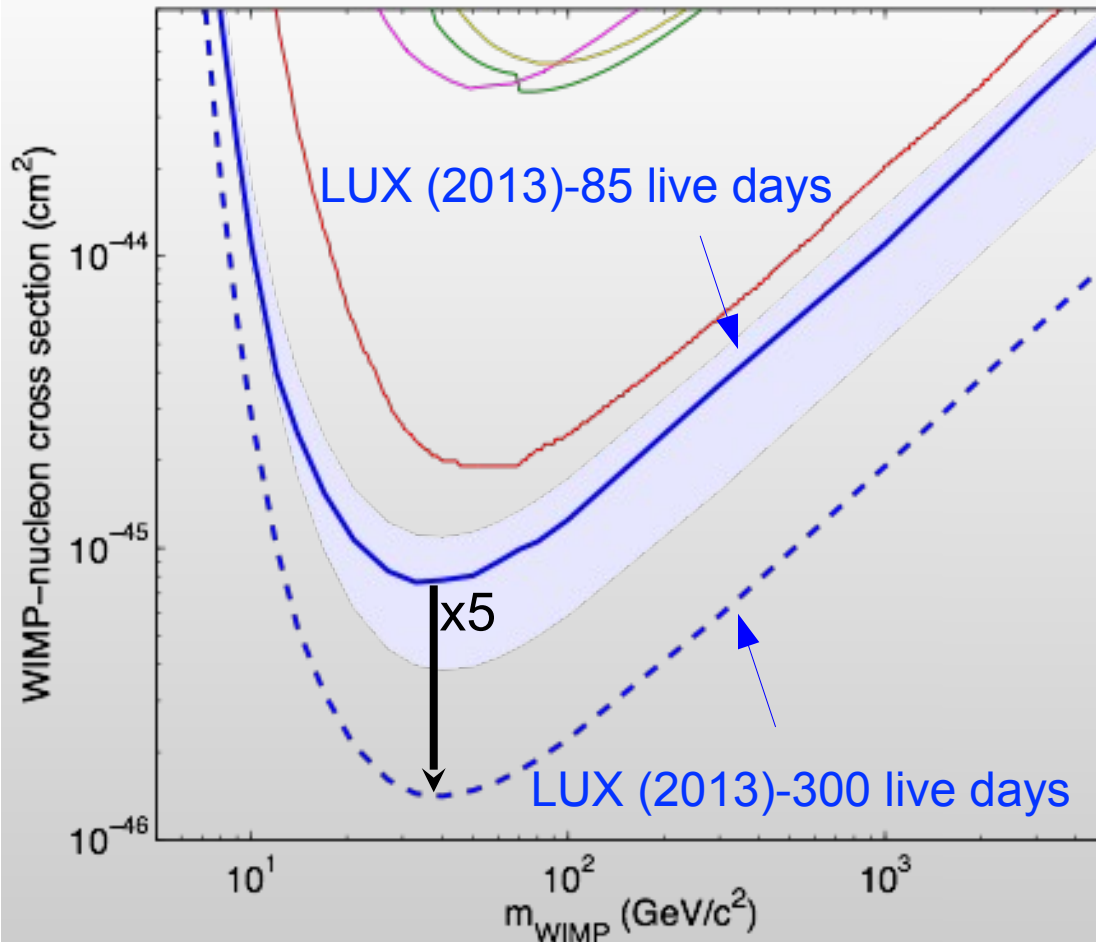


expect 1550 WIMPs in this run!

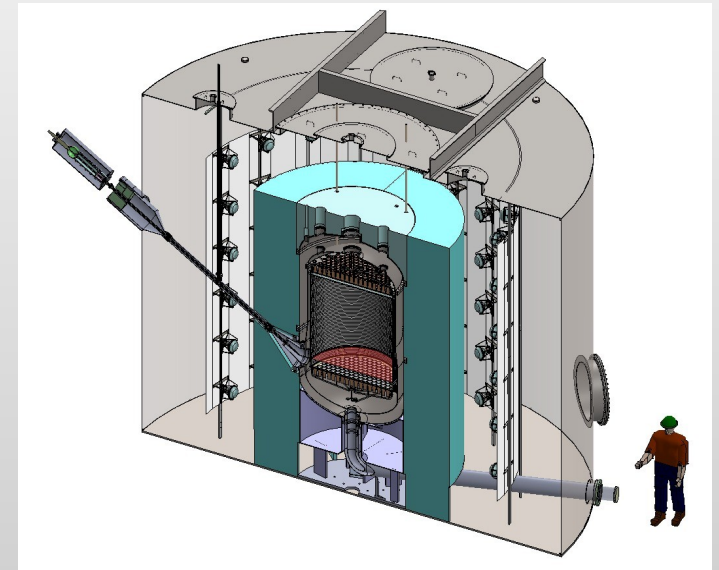
What's next?

300 day run planned for 2014/15

LZ = LUX & ZEPLIN



- More Xe: 7t total, 5t fiducial
- ~500 3" PMTs at ~1 mBq radioactivity level
- Construction planned 2015-17



Thank you!

