First Science Results from the LUX Dark Matter Experiment

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Richard Gaitskell, LUX Co-Spokesperson, Brown University
on behalf of the LUX Collaboration
http://luxdarkmatter.org

Sanford Underground Research Facility

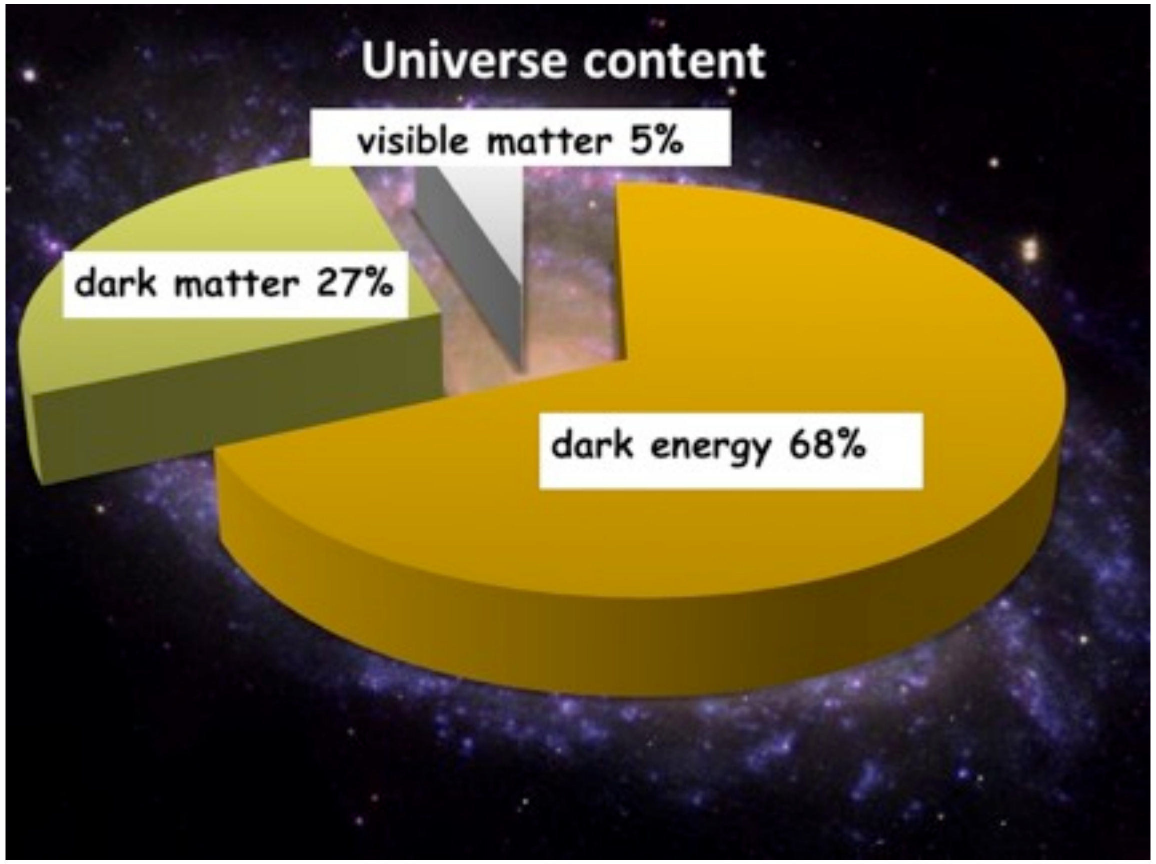
October 30, 2013

Composition of the Universe

The Higgs particle has been discovered, the last piece of the Standard Model.

But as successful as it has been, the Standard Model describes only 5% of the universe. The remaining 95% is in the form of dark energy and dark matter, whose fundamental nature is almost completely unknown.

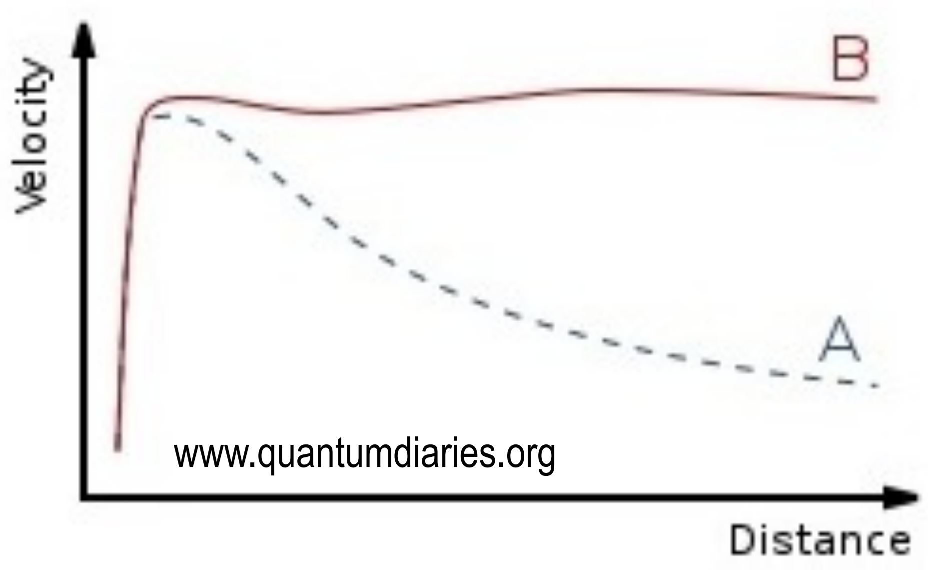
Image: X-ray: NASA/CXC/CfA/M.Markevitch et al.;
Optical: NASA/STScI; Magellan/U.Arizona/D.Clowe et al.;
Lensing Map: NASA/STScI; ESO WFI; Magellan/U.Arizona/D.Clowe et al.



www.quantumdiaries.org

Evidence for Dark Matter

Galaxy rotation curves



The cosmic microwave background

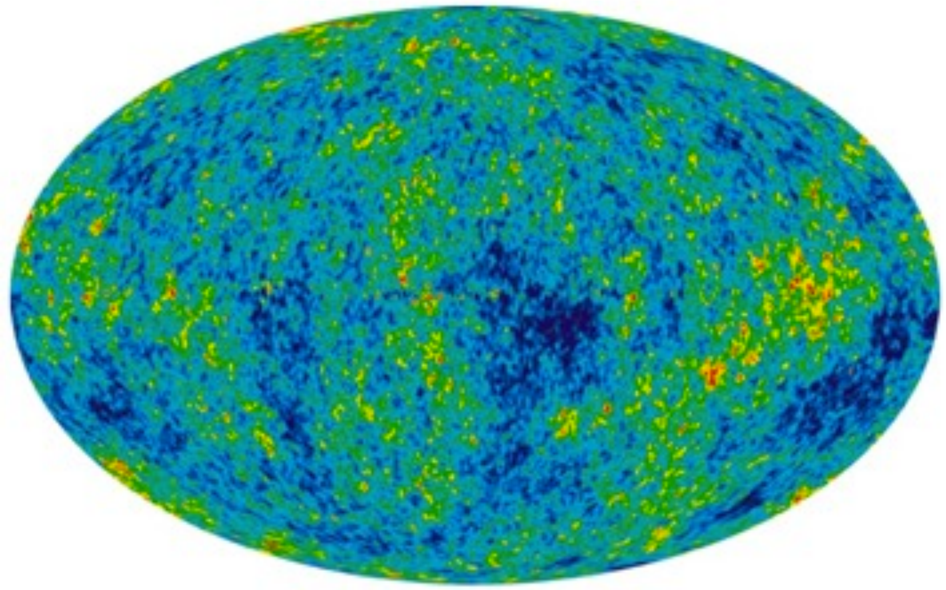
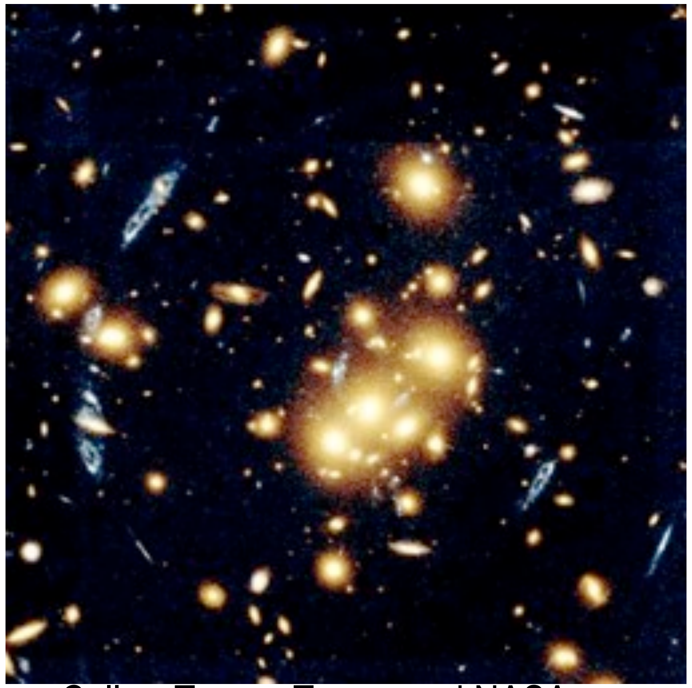


Image: ESA and the Planck collaboration

Gravitational lensing



Colley, Turner, Tyson, and NASA

- 27% of the energy composition of the universe
- Properties:
  - Stable and electrically neutral
  - Non-baryonic
  - Non-relativistic
- Estimated local density: $0.3 \pm 0.1 GeV \cdot cm^{-3}$
- Candidates: WIMPs, axions, dark photons,...

Weakly Interacting Massive Particles (WIMPs)

A new particle that only very weakly interacts with ordinary matter could form Cold Dark Matter

- Formed in massive amounts in the Big Bang.
- Non-relativistic freeze-out. Decouples from ordinary matter.
- Would exist today at densities of about $1000/m^3$.

Supersymmetry provides a natural candidate – the neutralino.

- Lowest mass superposition of photino, zino, higgsino
- Mass range from the proton mass to thousands of times the proton mass.
- Wide range of cross-sections with ordinary matter, from 10^{-40} to 10^{-50} cm^2.
- Charge neutral and stable!

Universal Extra Dimensions: predicts stable Kaluza-Klein (KK) particles

- Similar direct detection properties as neutralino
- Distinguishable from neutralinos at accelerators

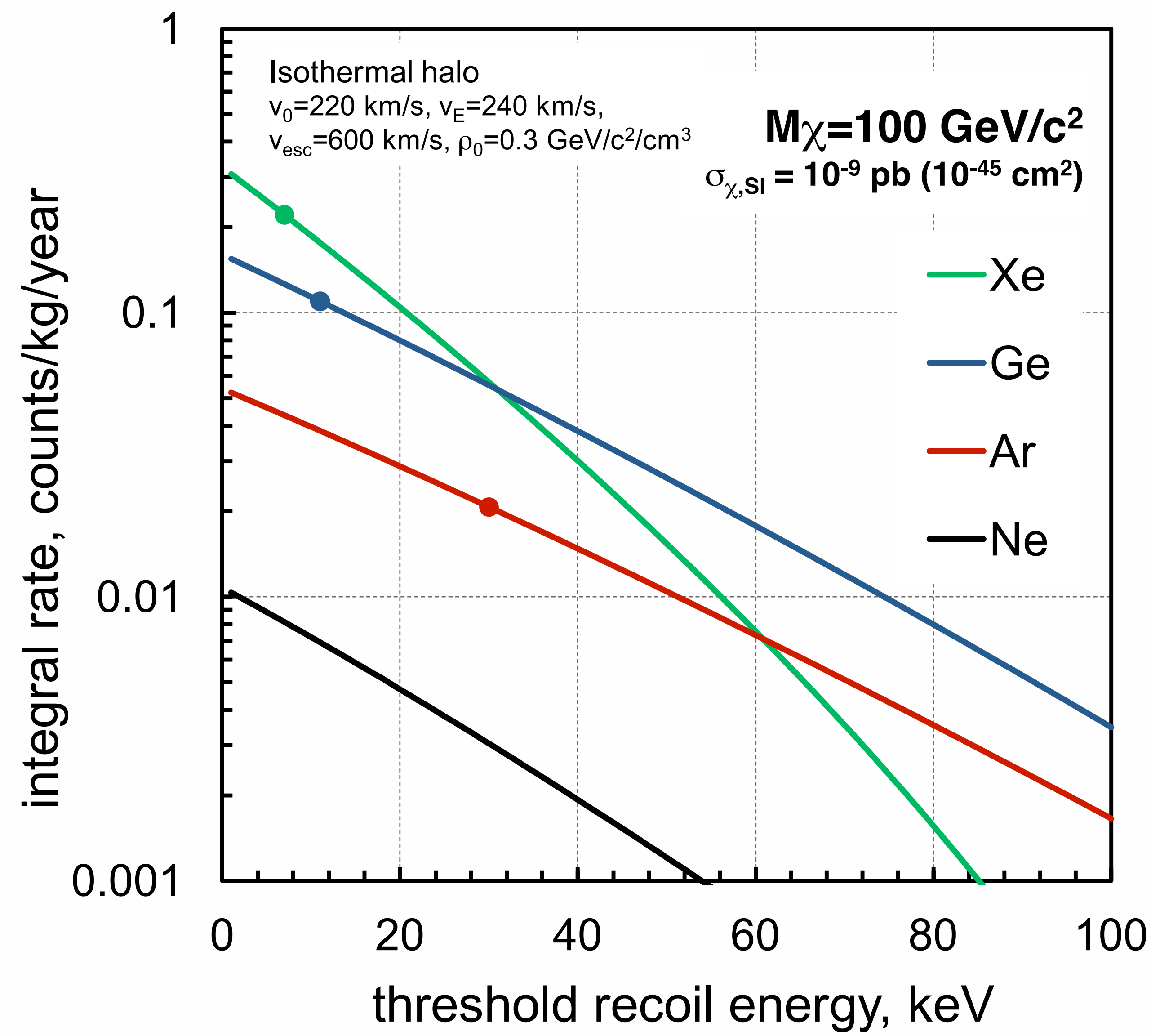
WIMP Direct Detection

Look for anomalous nuclear recoils in a low-background detector.

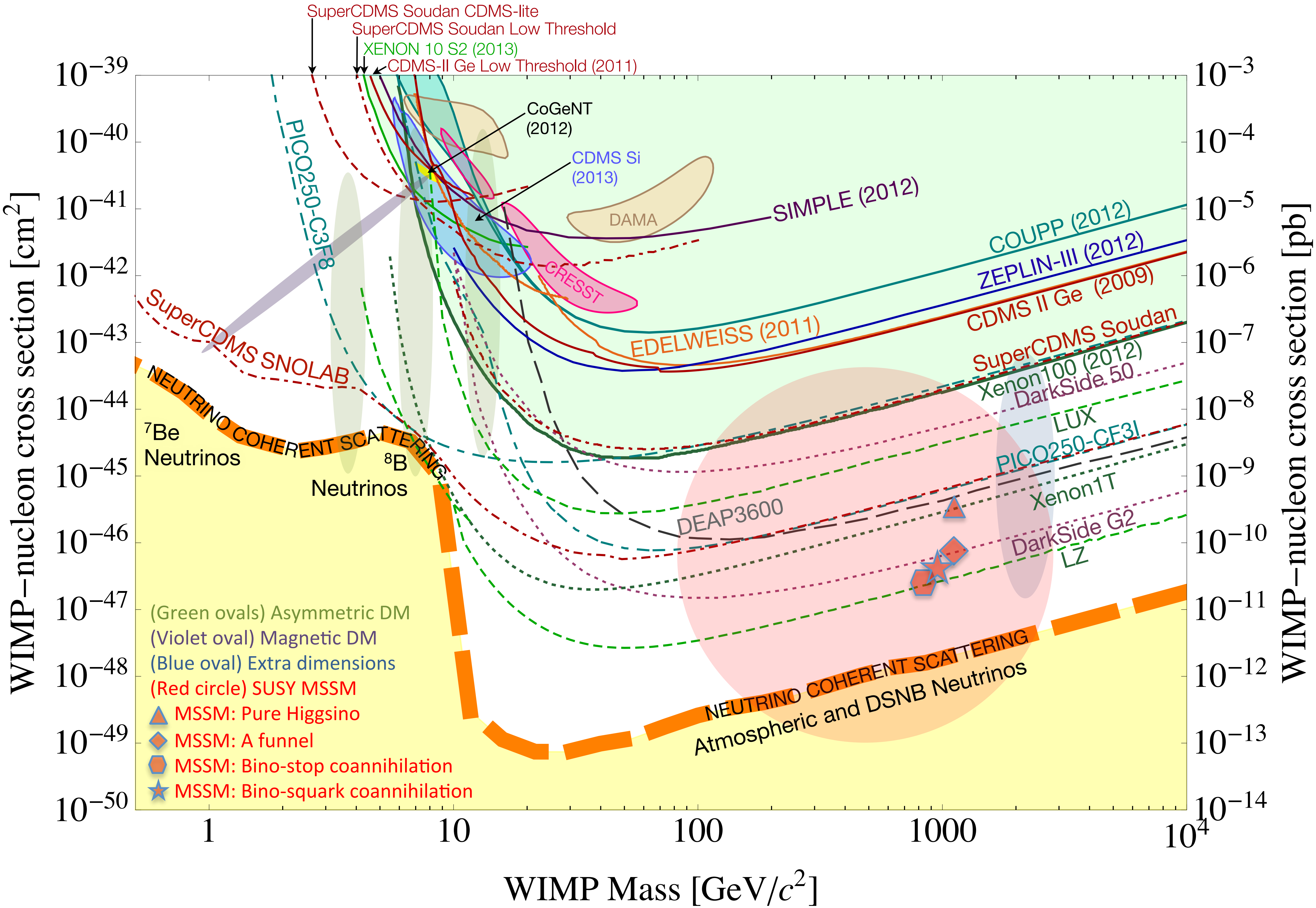
$R = N \rho \sigma \langle v \rangle$. From $\langle v \rangle$ = 220 km/s, get order of 10 keV deposited.

Requirements:

- Low radioactivity
- Low energy threshold
- Gamma ray rejection
- Scalability
- Deep underground laboratory



Current WIMP Cross-section Limits

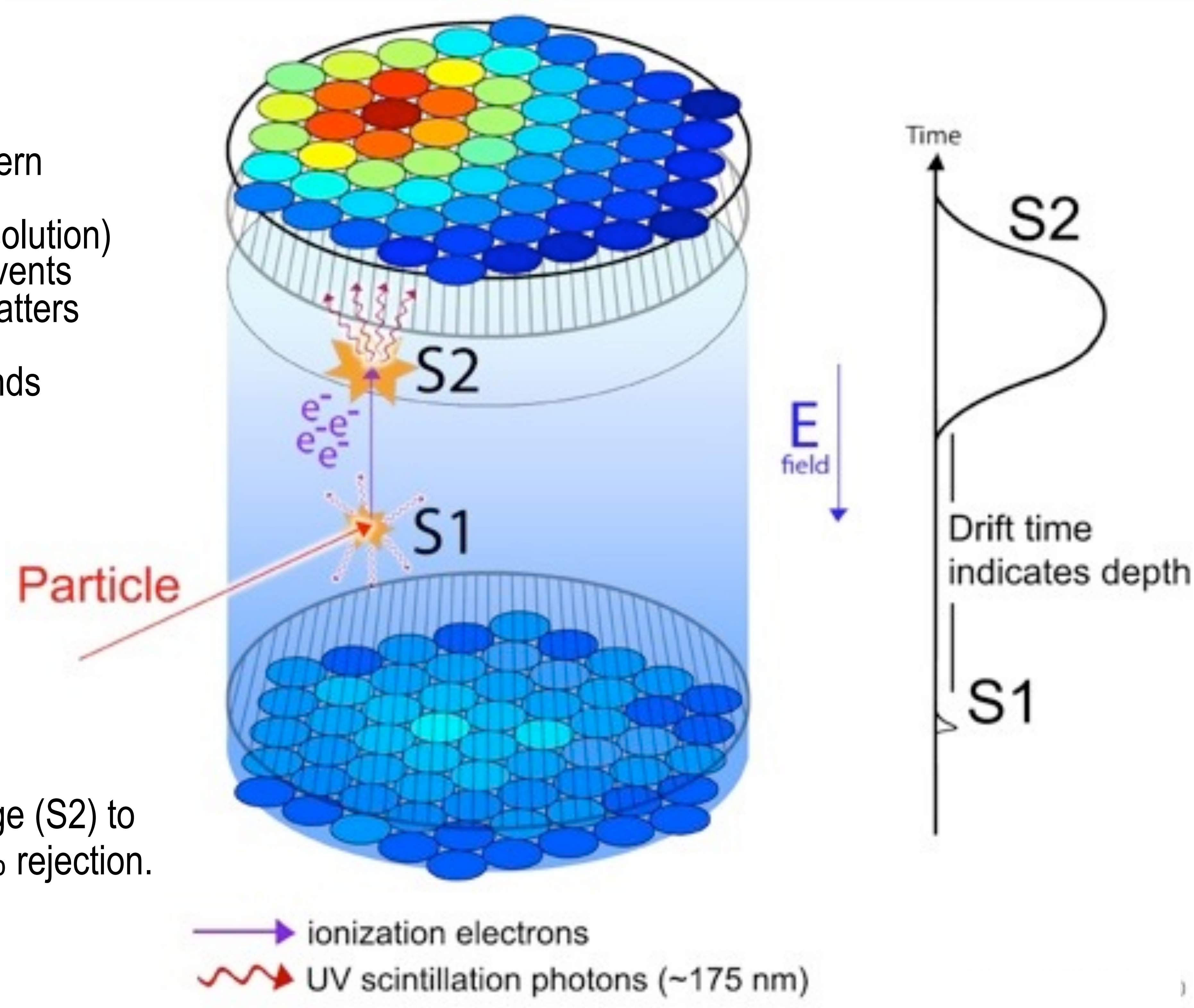


Two-phase Xenon WIMP Detectors

Z position from S1 – S2 timing
X-Y positions from S2 light pattern

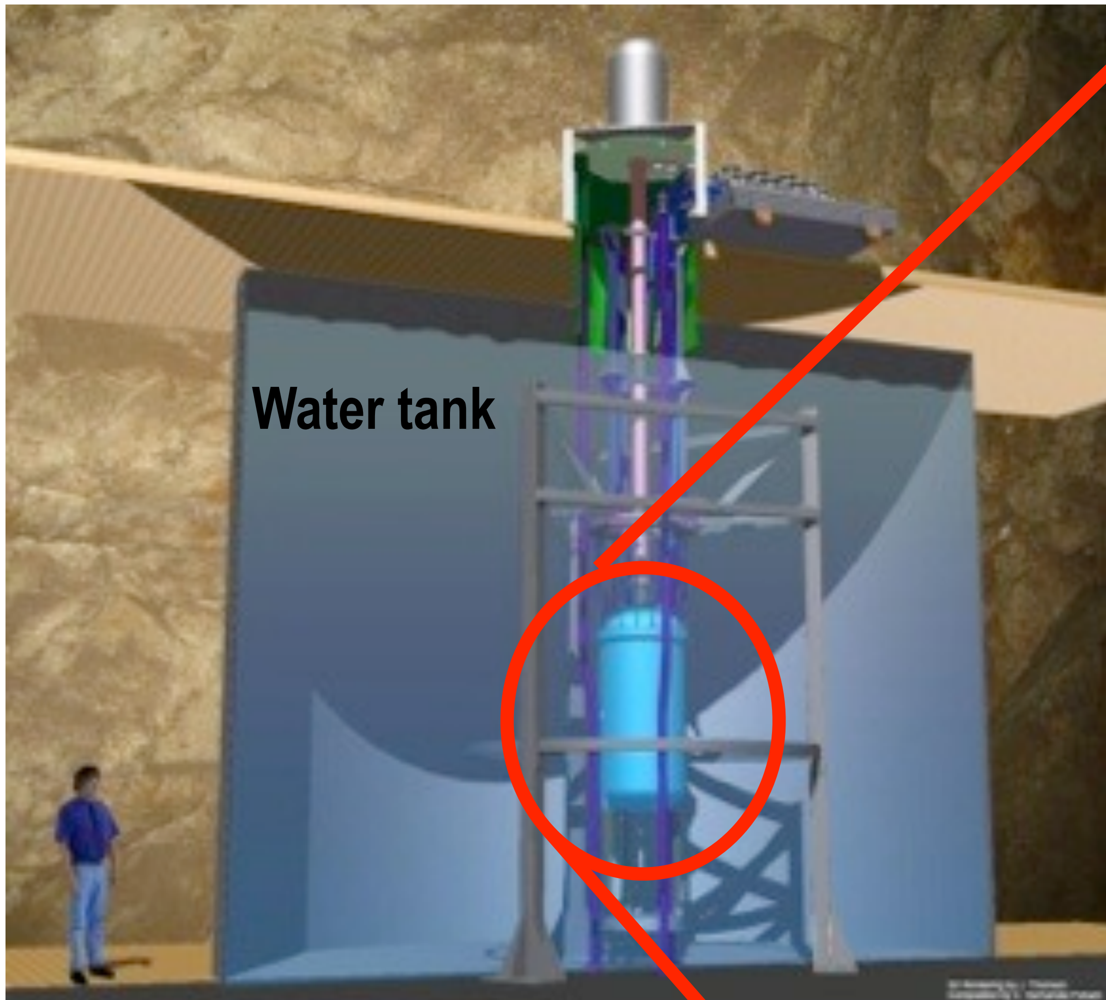
Excellent 3D imaging (~mm resolution)
- eliminates edge events
- rejects multiple scatters

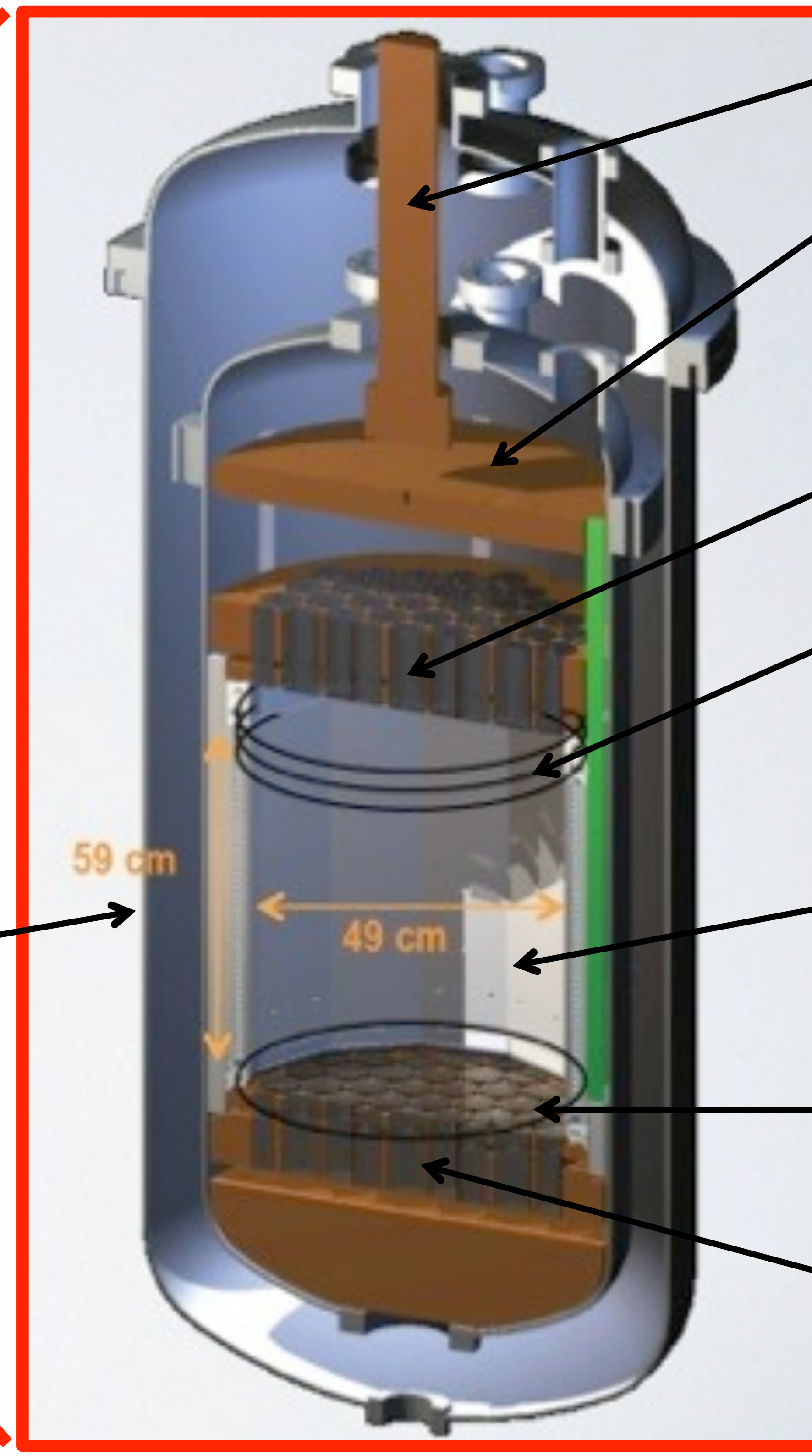
Gamma ray, neutron backgrounds reduced by self-shielding



Reject gammas, betas by charge (S2) to light (S1) ratio. Expect > 99.5% rejection.

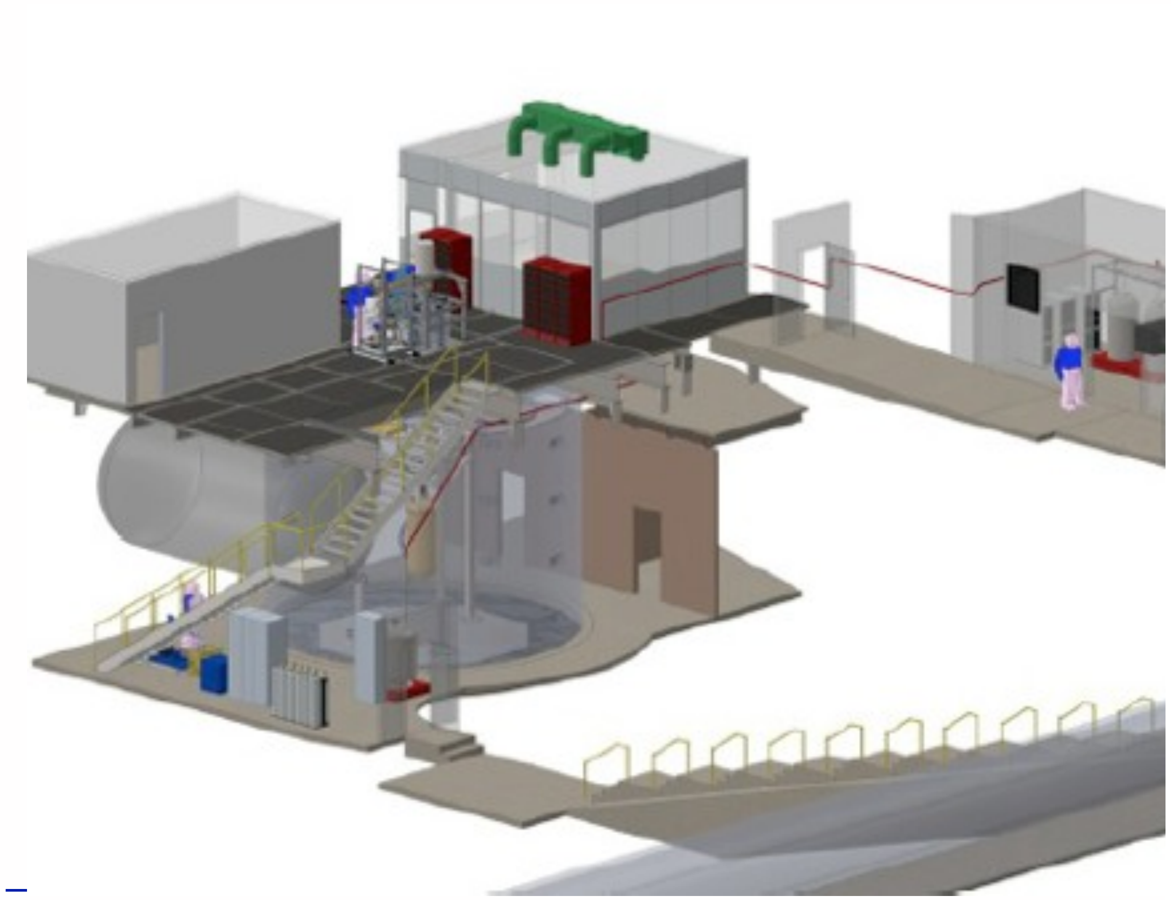
The LUX Detector

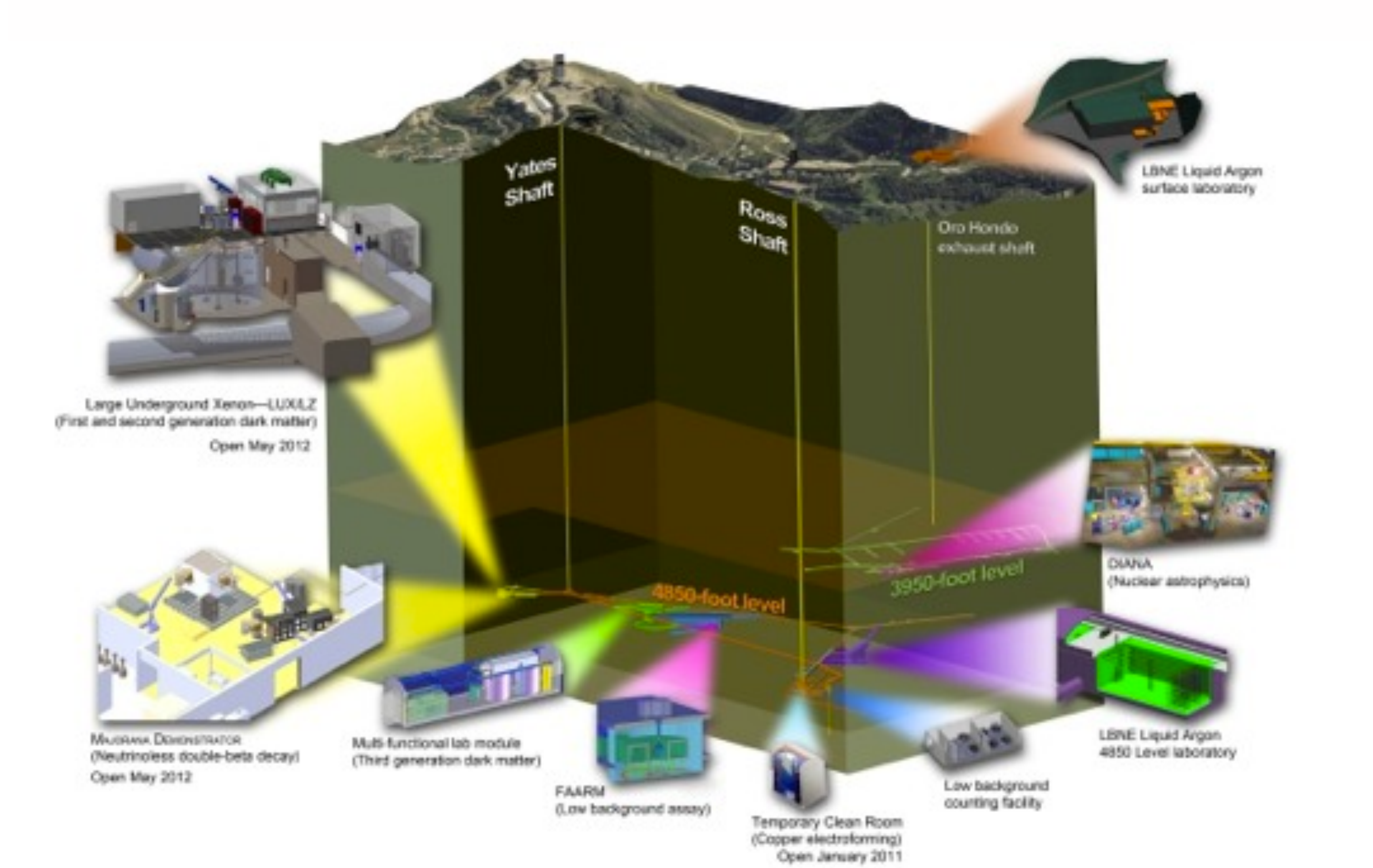




370 kg total xenon mass
250 kg active liquid xenon
118 kg fiducial mass

LUX Benefits from an Exceptional Lab and Exceptional Lab Support





LUX Dark Matter Experiment / Sanford Lab

The LUX Collaboration: ~100 researchers from 17 institutions

Brown

Richard Gaitskell	PI, Professor
Simon Fiorucci	Research Associate
Monica Pangilinan	Postdoc
Jeremy Chapman	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
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 Sumner	Professor
Alastair Currie	Postdoc
Adam Bailey	Graduate Student

Lawrence Berkeley + UC Berkeley

Bob Jacobsen	PI, Professor
Murdock Gilchriese	Senior Scientist
Kevin Lesko	Senior Scientist
Carlos Hernandez Faham	Postdoc
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 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

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 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
Carmen Carmona	Postdoc
Curt Nehrkorn	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
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 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

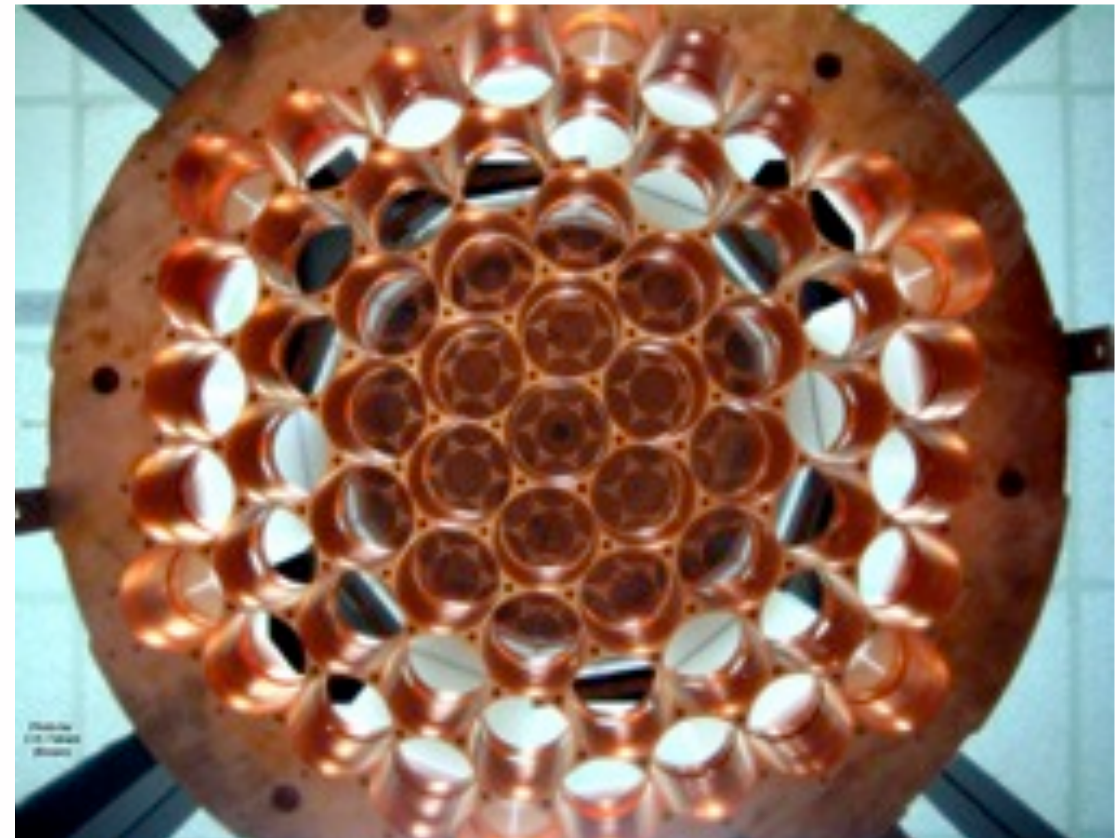
Yale

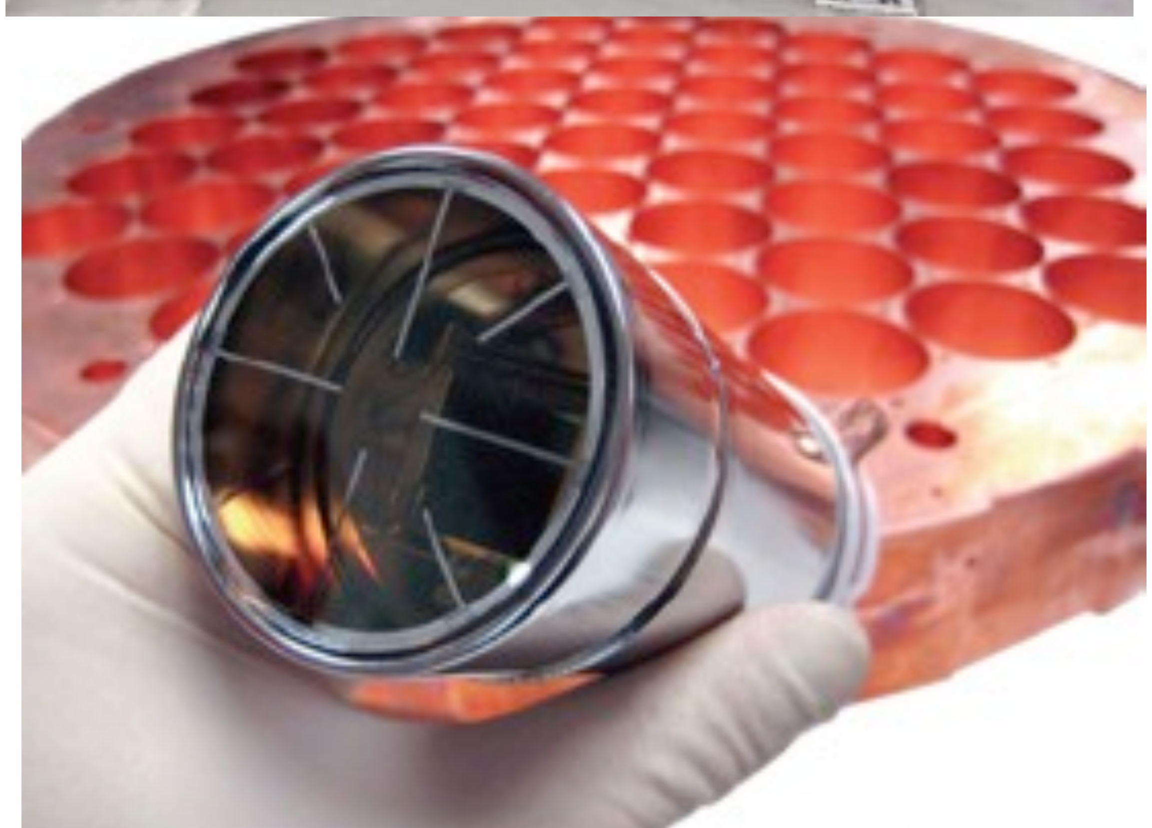
Daniel McKinsey	PI, Professor
Peter Parker	Professor
Sidney Cahn	Lecturer/Research Scientist
Ethan Bernard	Postdoc
Markus Horn	Postdoc
Blair Edwards	Postdoc
Scott Hertel	Postdoc
Kevin O'Sullivan	Postdoc
Nicole Larsen	Graduate Student
Evan Pease	Graduate Student
Brian Tennyson	Graduate Student
Ariana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

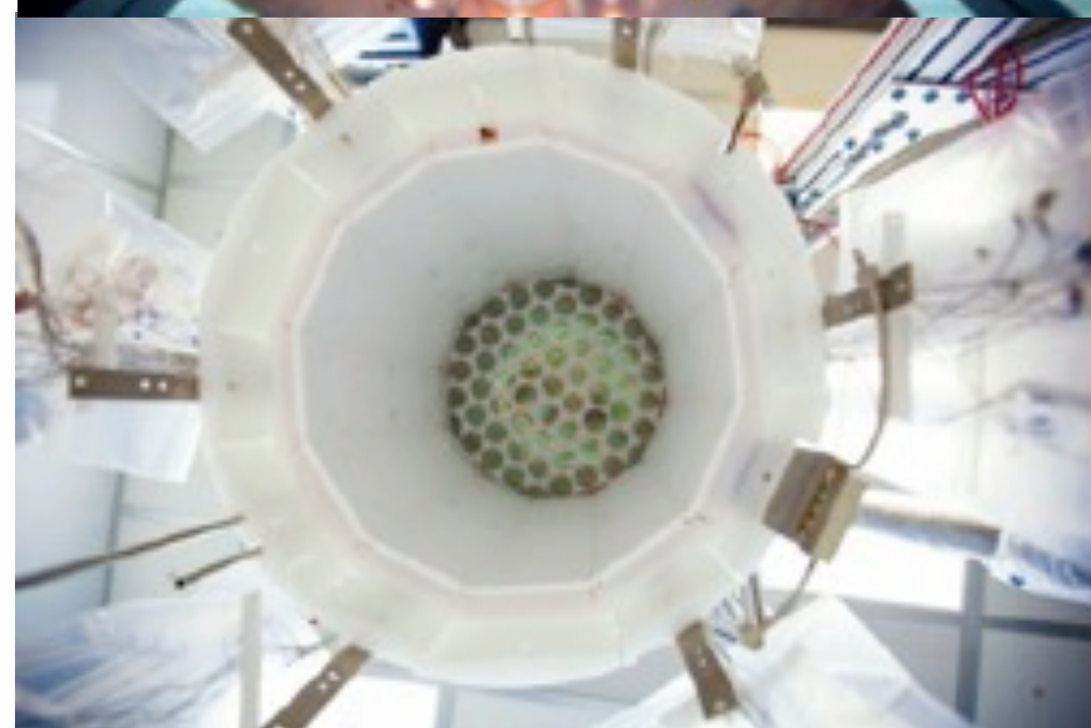
In Memoriam – Dr. James White

A key innovator in xenon dark matter detector technology, a creator of LUX, and a dearly missed colleague

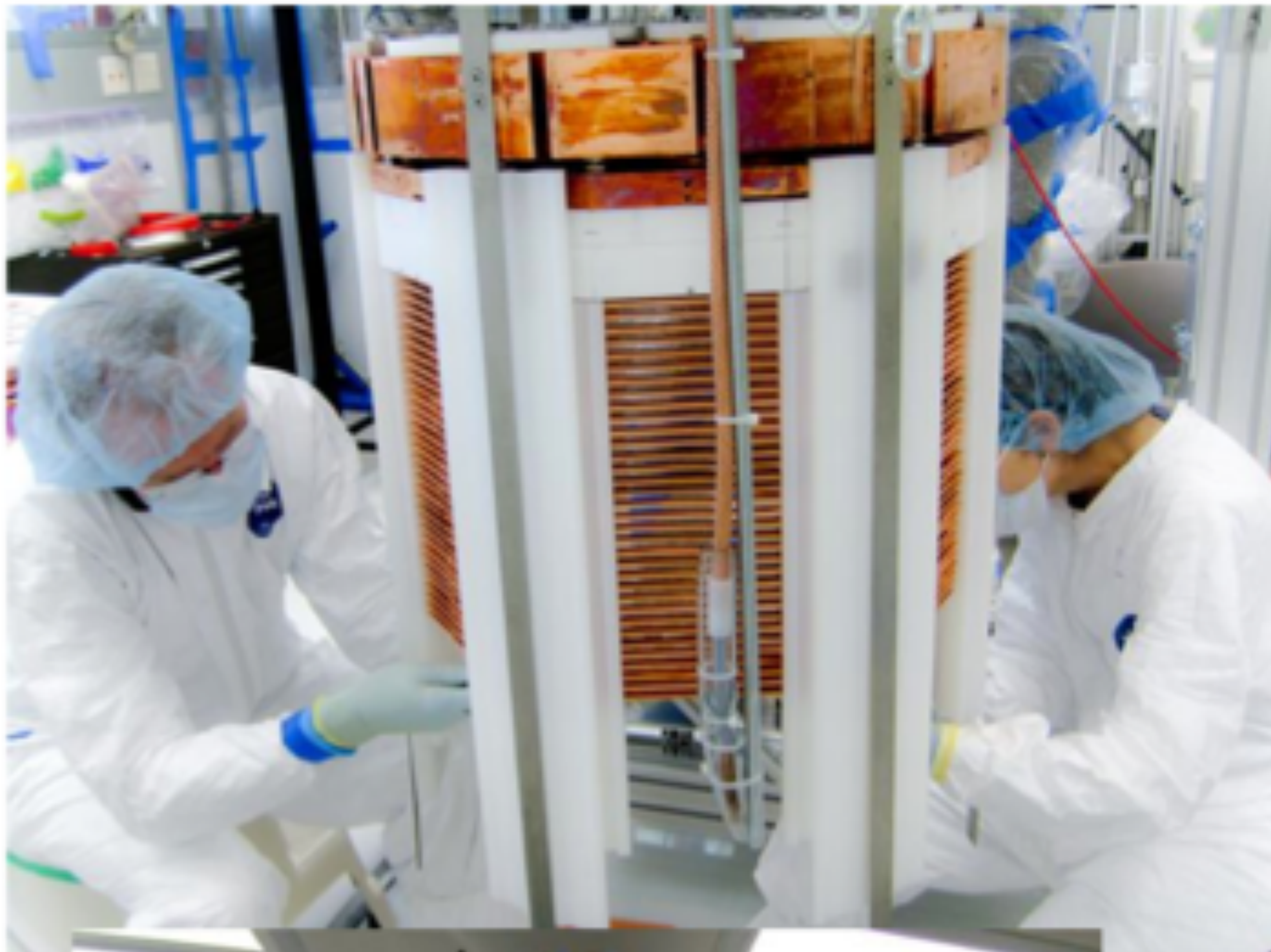
LUX – the Instrument

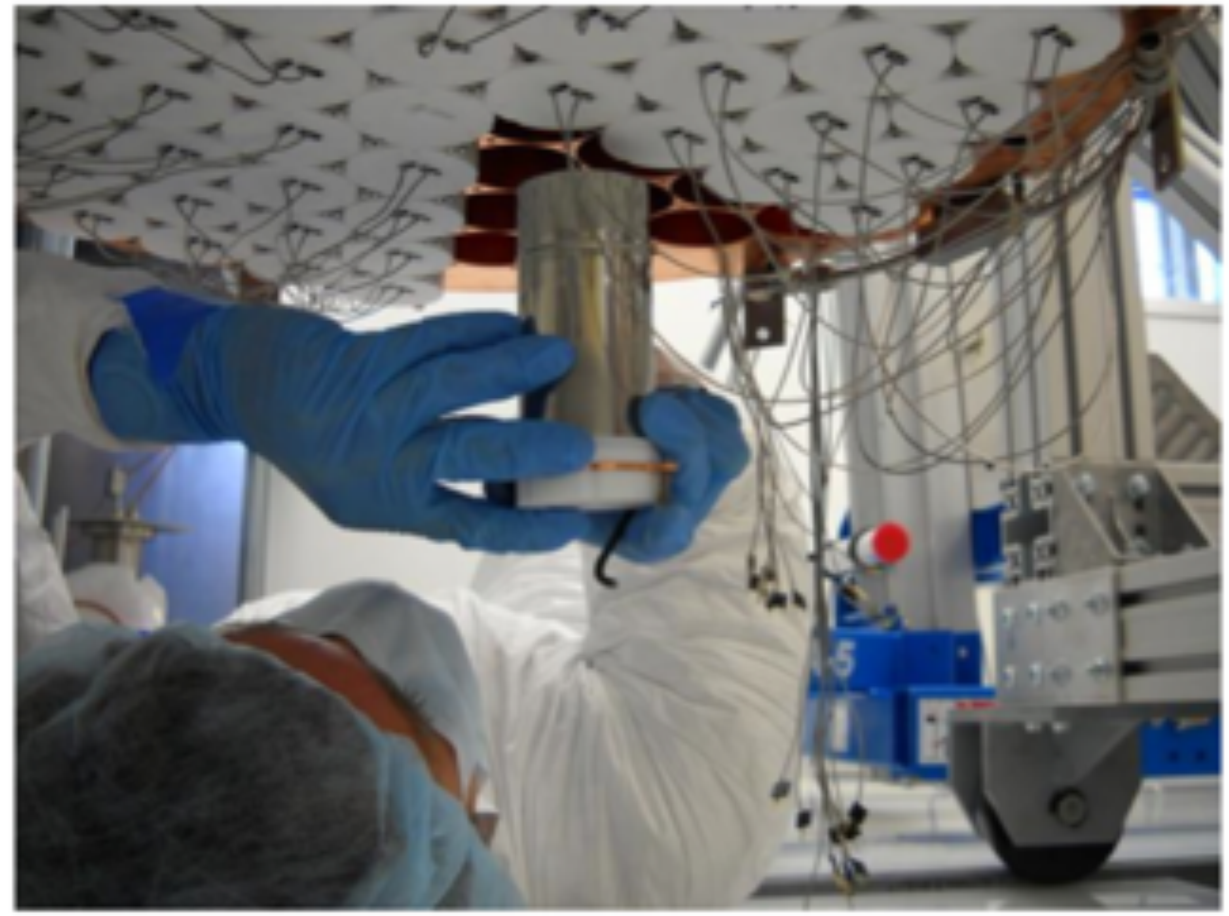






LUX Construction





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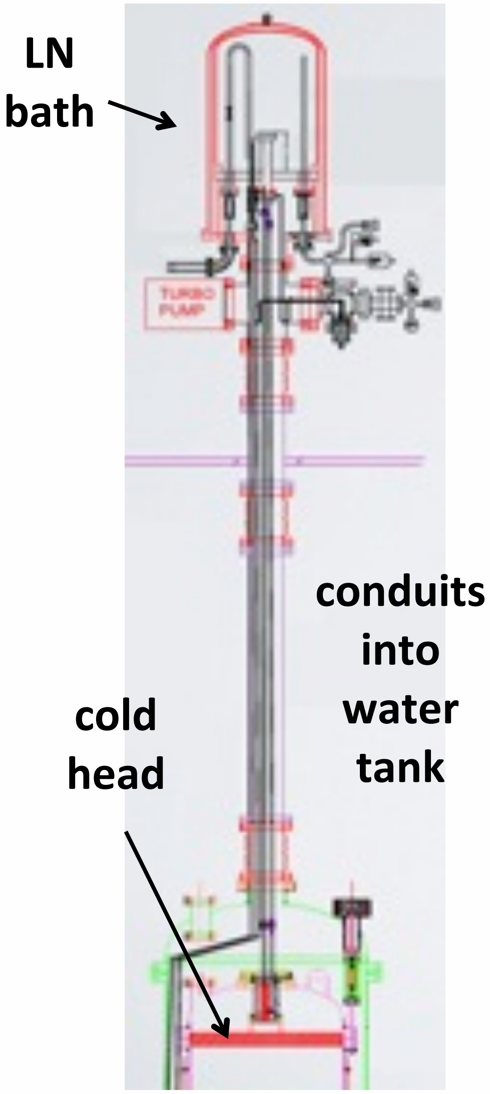
LUX – Supporting Systems

Xenon gas handling and sampling

Cathode HV feedthrough

Thermosyphon cryogenics



LUX Thermosyphon

Xe storage and recovery

LUX Timeline

LUX funded in 2008 by DOE and NSF

Above-ground laboratory completed at SURF in 2011
    LUX assembled; above-ground commissioning runs completed

Underground laboratory completed at SURF in 2012.
    LUX moves underground in July to its new home in the Davis cavern.

Detector cooldown and gas phase testing completed early February 2013

Xenon condensation completed mid February 2013

Detector commissioning completed April 2013

Initial (3-month) WIMP search. First results presented today!

Full year-long WIMP search to begin in 2014. Result in 2015

LUX Has Exceptional Technical Performance

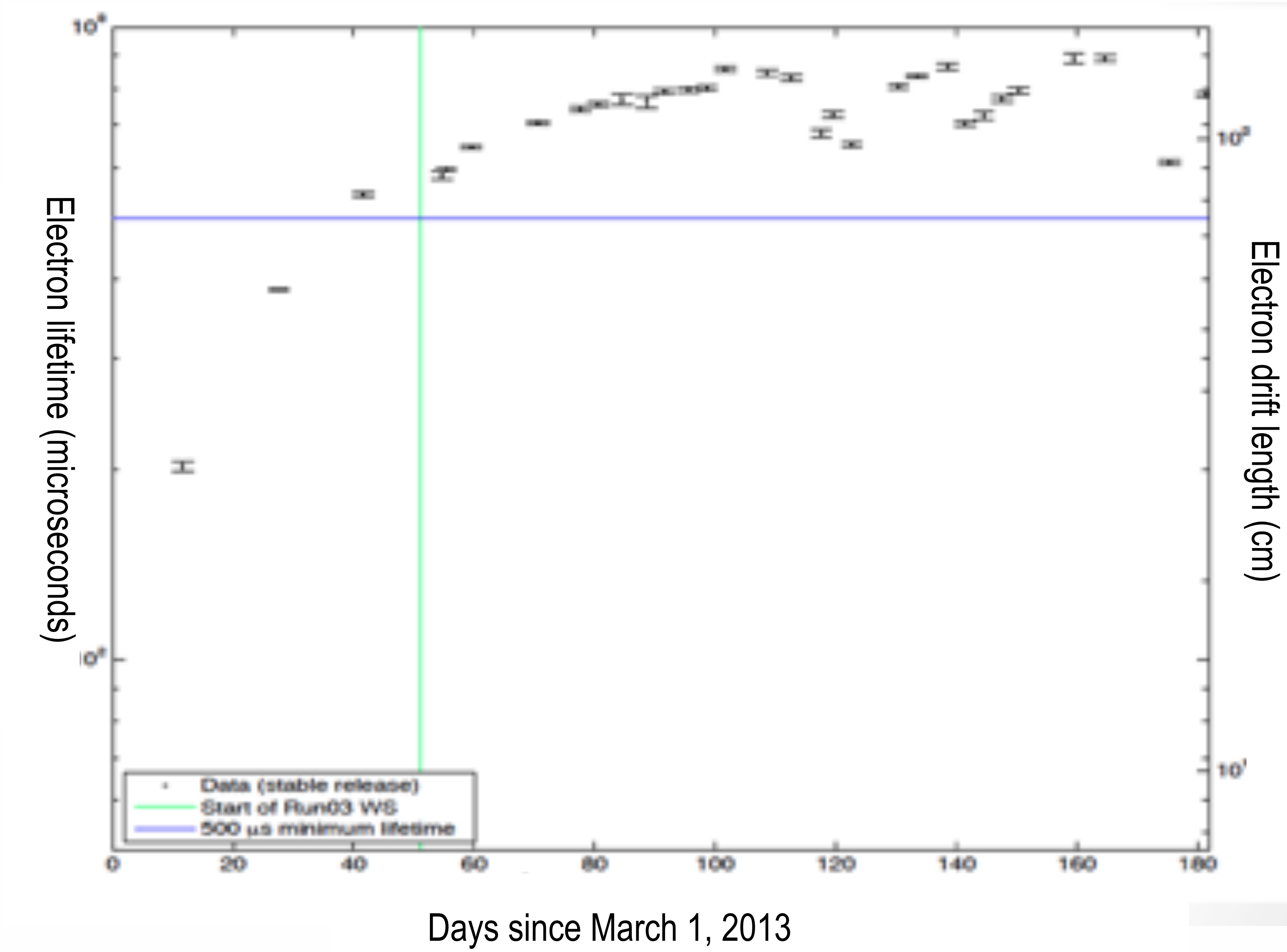
Low-energy electron recoil rate of 3e-3 events/keV/kg/day.

Kr/Xe ratio of 3.5 ppt.

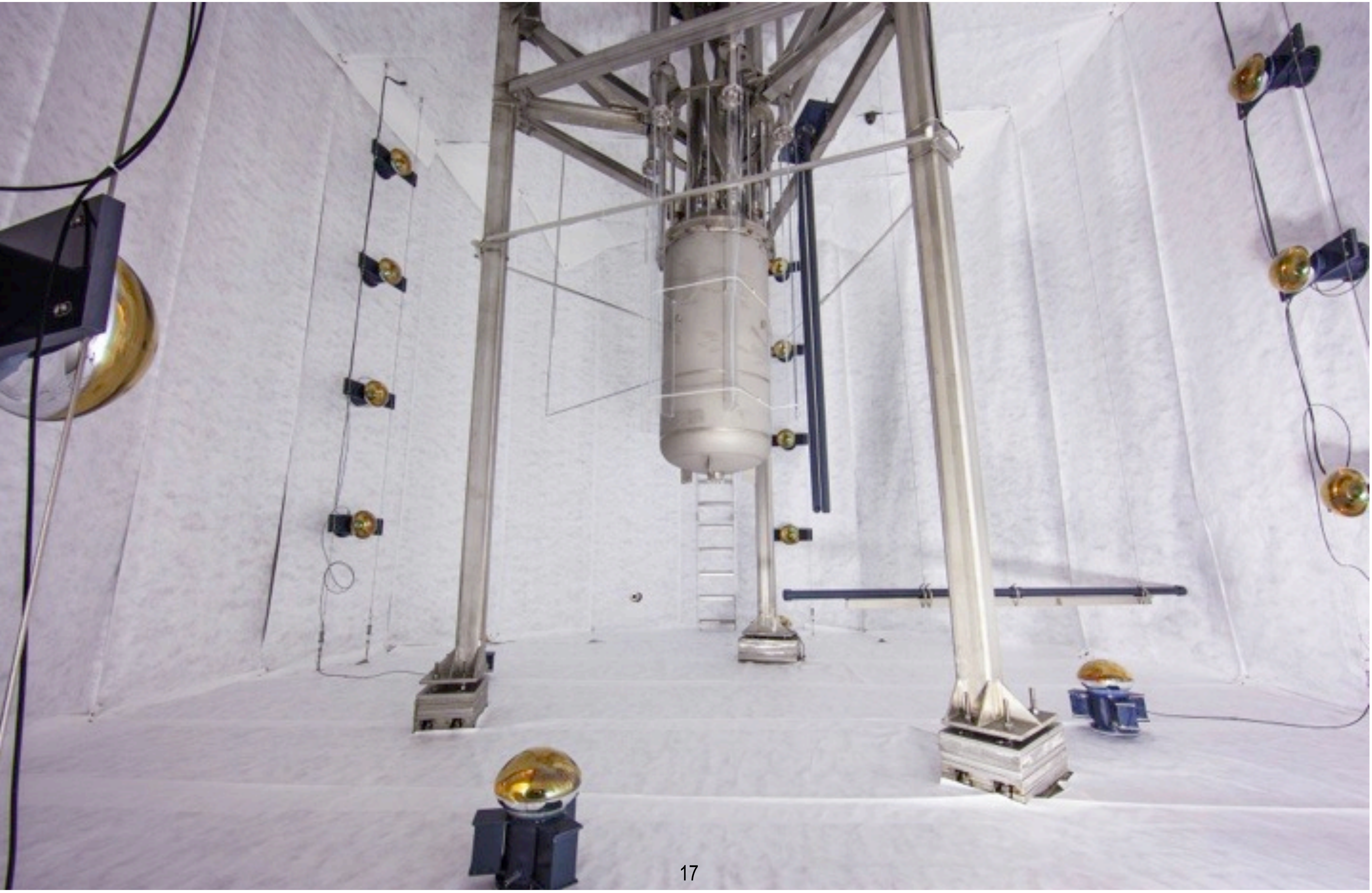
Electron drift length longer than 130 cm.

Light detection efficiency of 14%.

Electron recoil discrimination of 99.6%, with drift field of 181 V/cm.



LUX installed in its water tank shield, a mile underground at SURF



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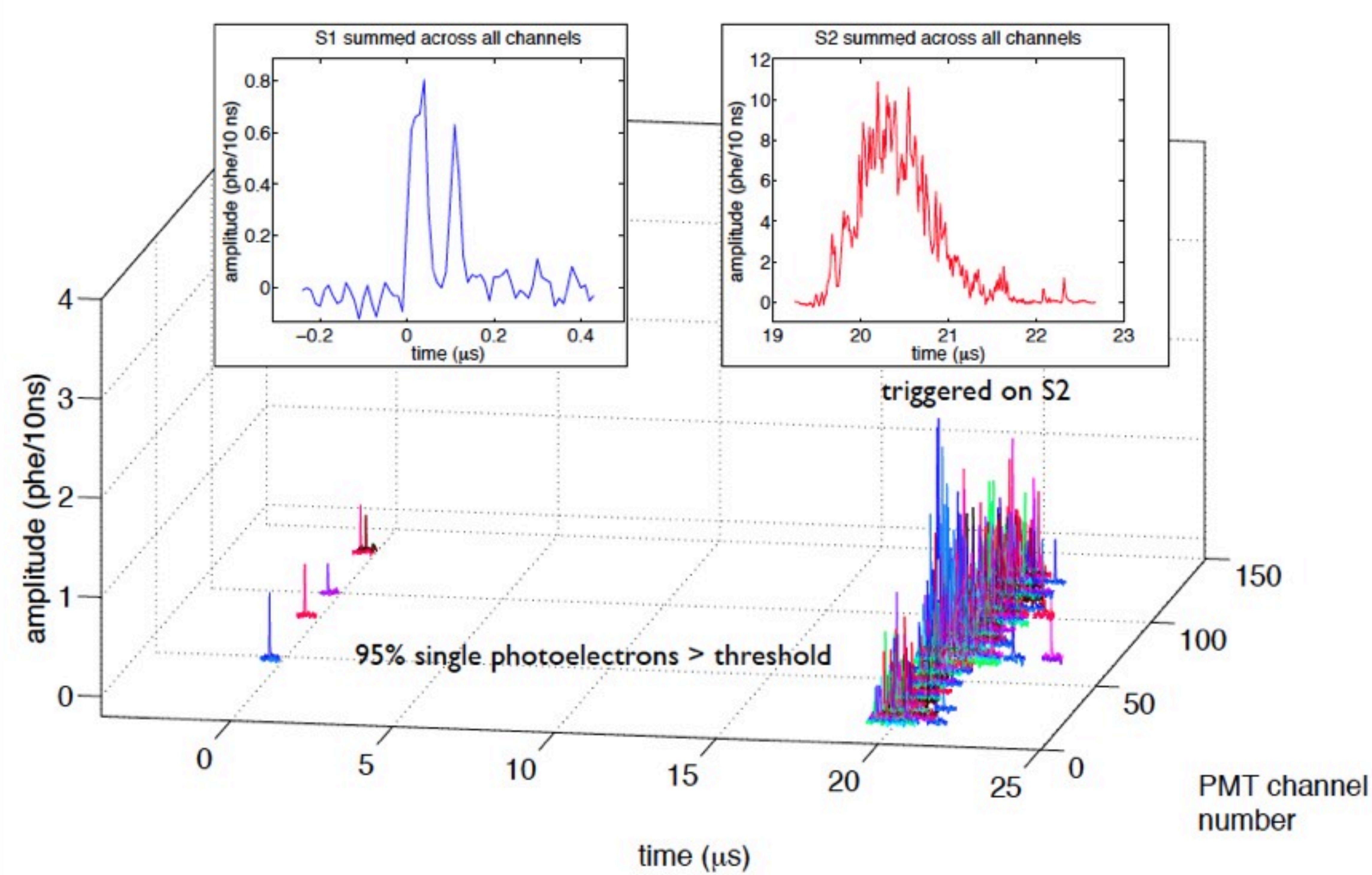
Typical Event in LUX

1.5 keV gamma ray scattering event



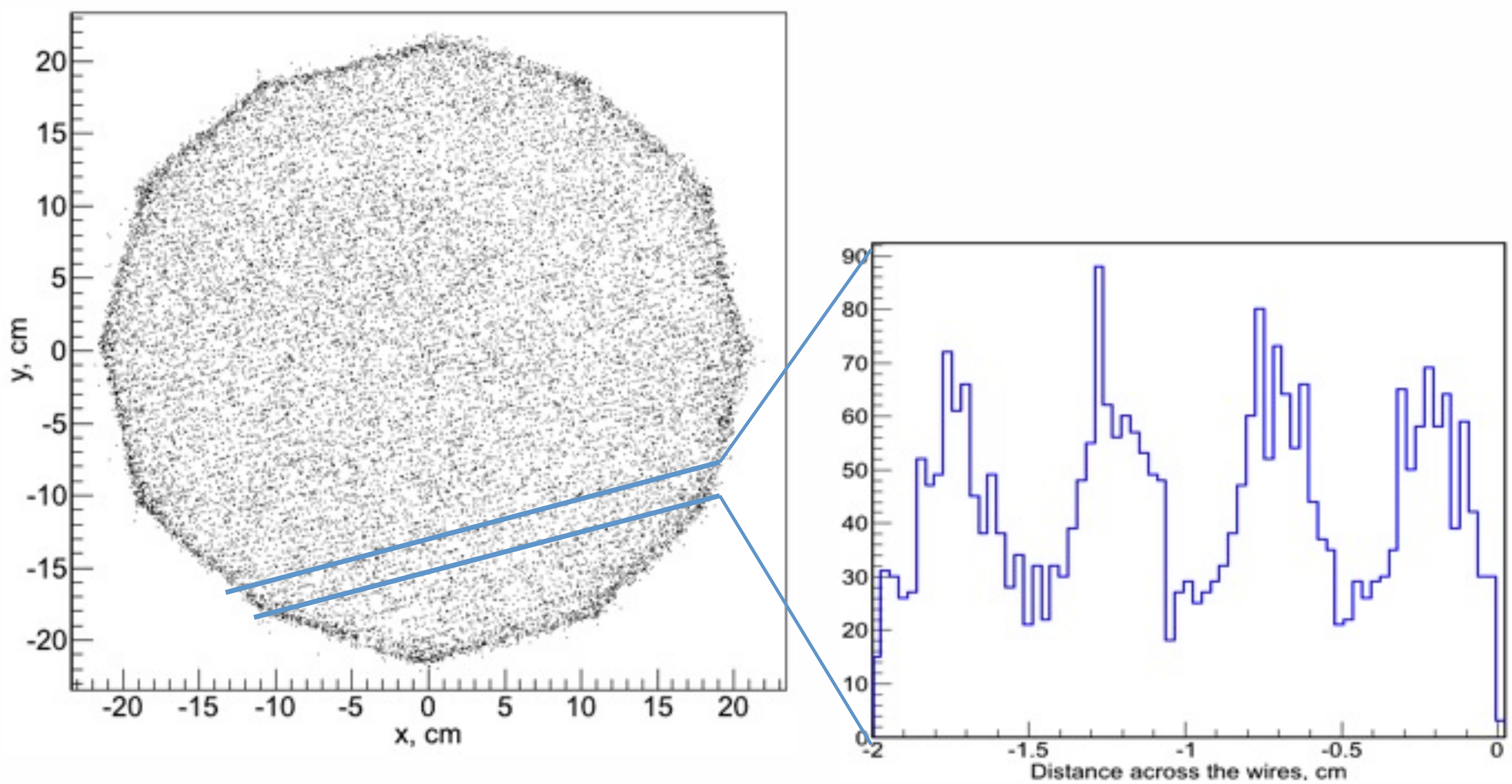
XYZ Position Reconstruction

Z coordinate is determined by the time between S1 and S2 (electron drift speed of 1.51 mm/microsecond)

Light Response Functions (LRFs) are found by iteratively fitting the distribution of S2 signal for each PMT.

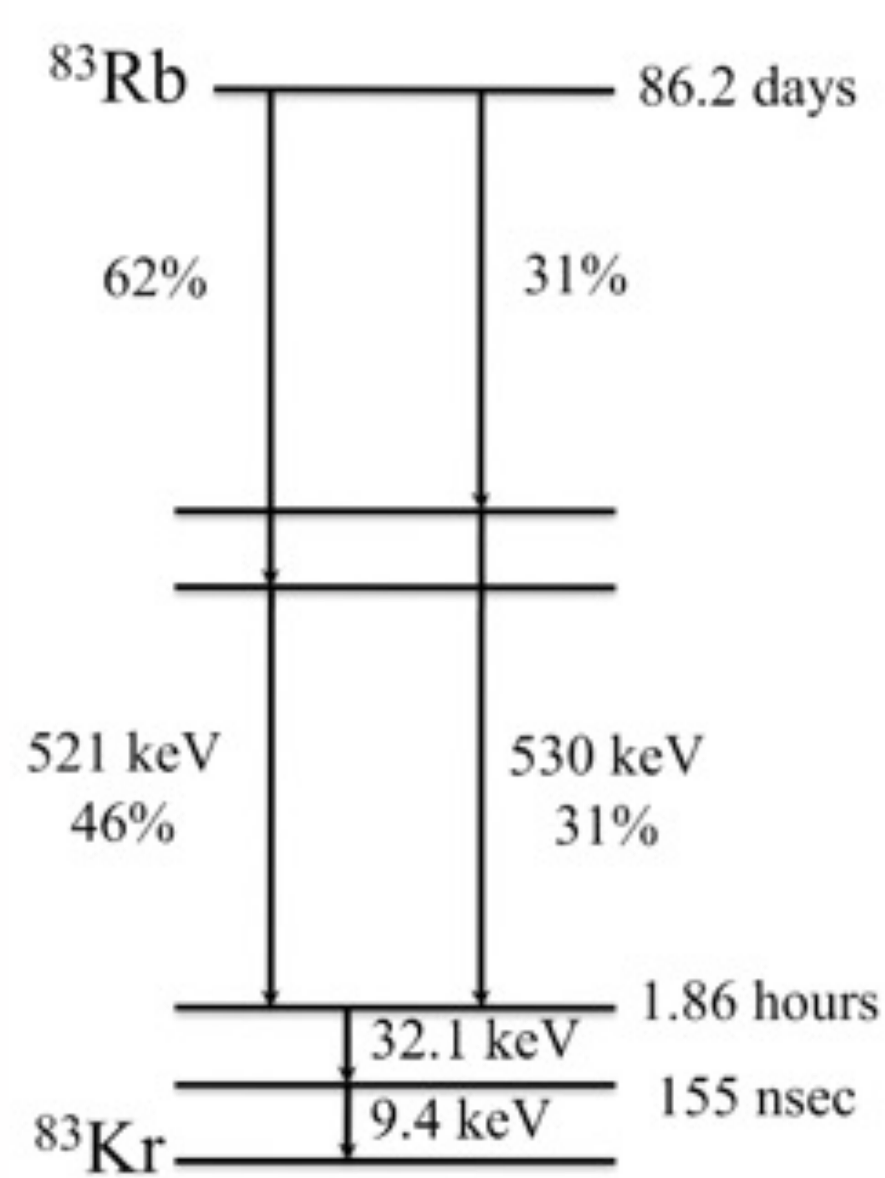
XY position is determined by fitting the S2 hit pattern relative to the LRFs.

Reconstruction of XY from events near the anode grid resolves grid wires with 5 mm pitch.

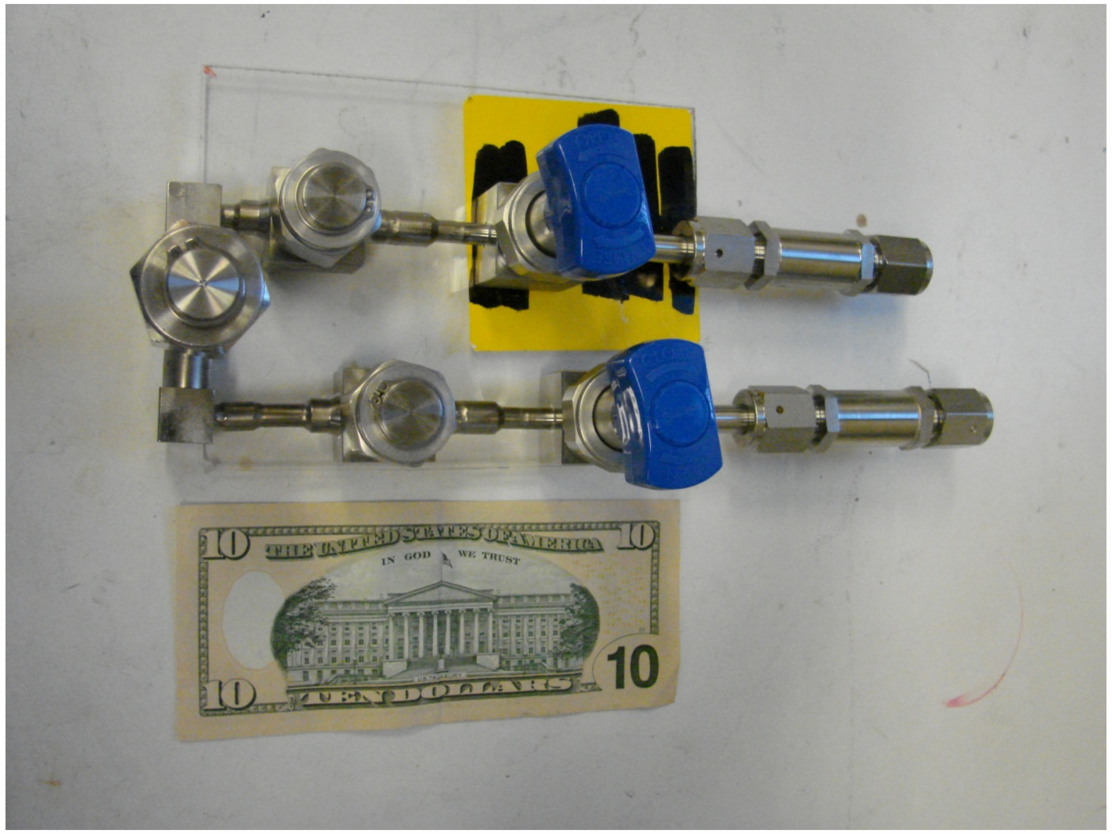


Kr-83m Calibration

- Rb-83 produces Kr-83m when it decays; this krypton gas can then be flushed into the LUX gas system to calibrate the detector as a function of position.
- Provides reliable, efficient, homogeneous calibration of both S1 and S2 signals, which then decays away in a few hours, restoring low-background operation..



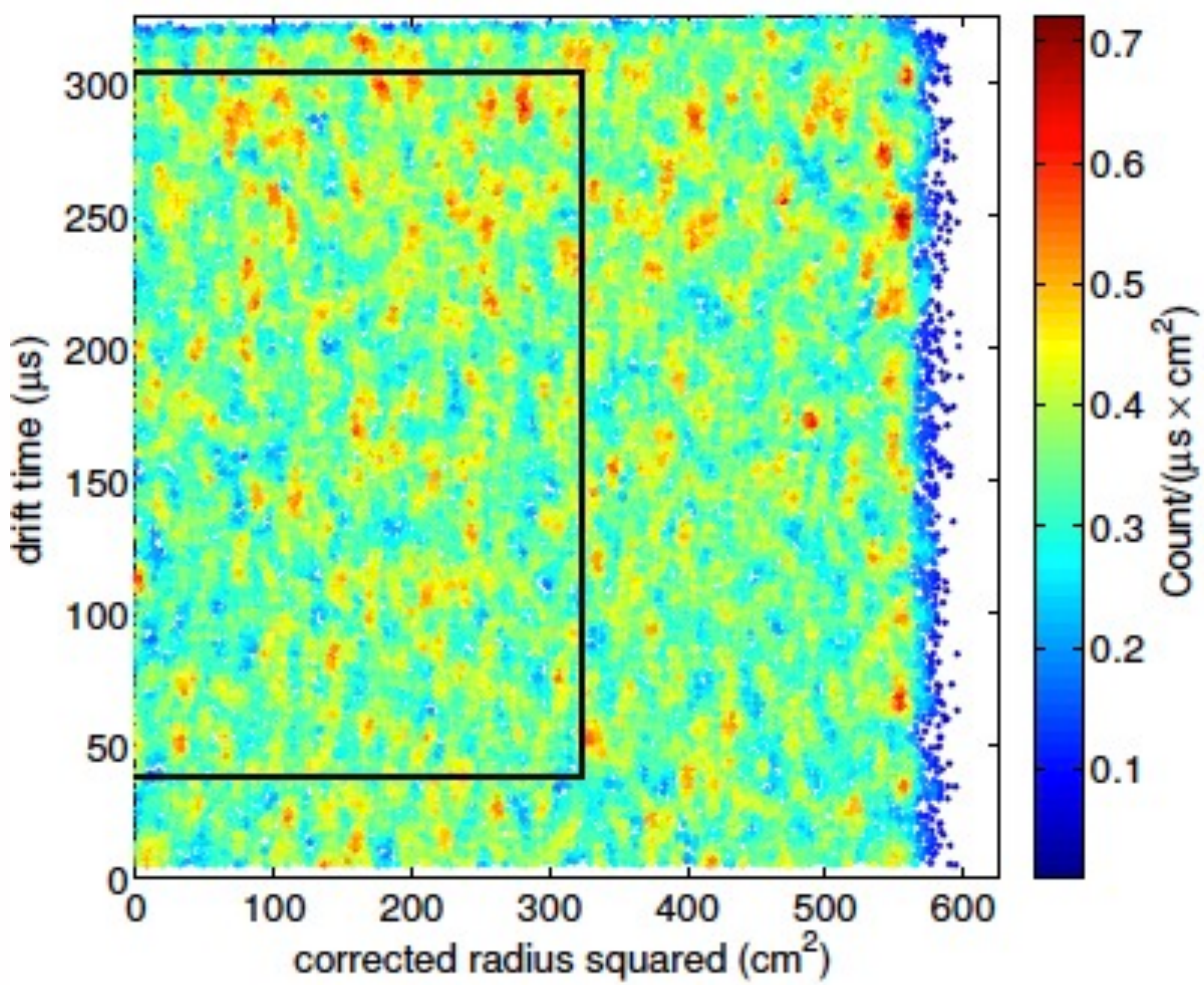
Kr-83m source (Rb-83 coated on charcoal, within xenon gas plumbing)



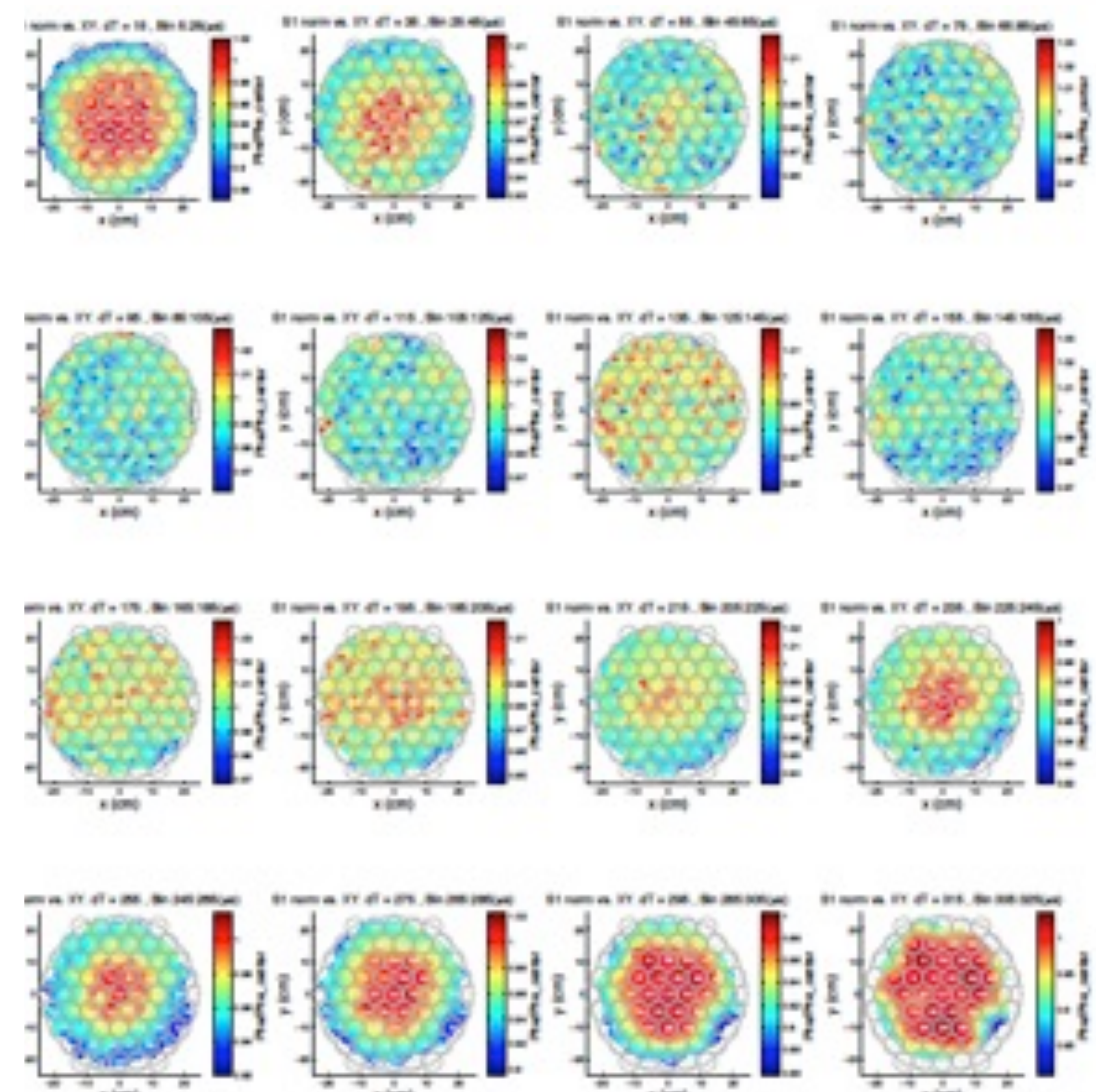
Kr-83m Calibration

- Over 1 million Kr-83m events, spread uniformly through the detector.

Fiducial volume determination



Position-based S1 corrections

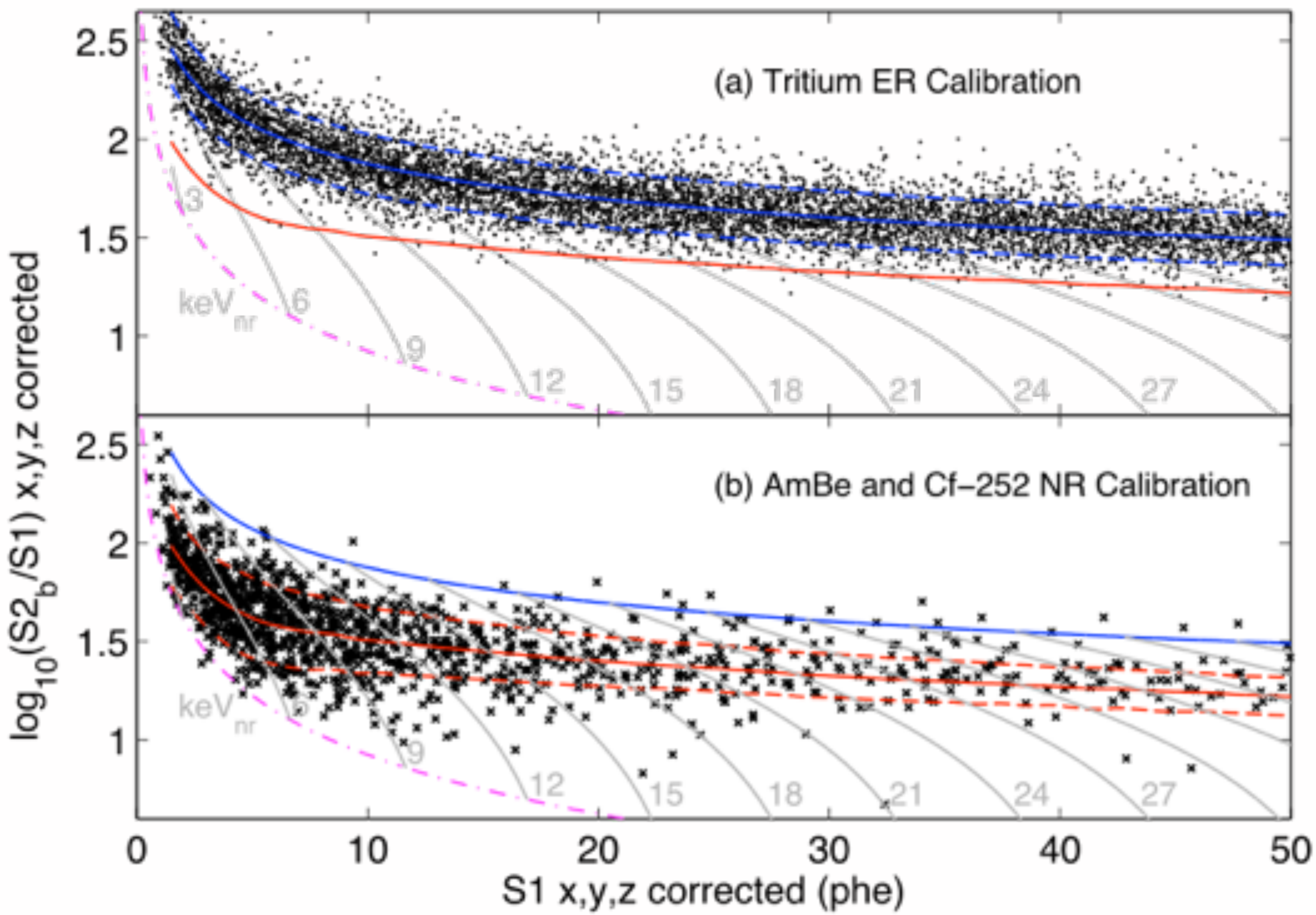


Tritiated Methane Calibration

- LUX uses tritiated methane, doped into the detector, to accurately calibrate the efficiency of background rejection.
- This beta source (endpoint energy 18 keV) allows electron recoil S2/S1 band calibration with unprecedented accuracy
- The tritiated methane is then fully removed by circulating the xenon through the getter
- Parametrization of the electron recoil band from the high-statistics tritiated methane data is then used to characterize the background model.

Electron Recoil and Nuclear Recoil Bands

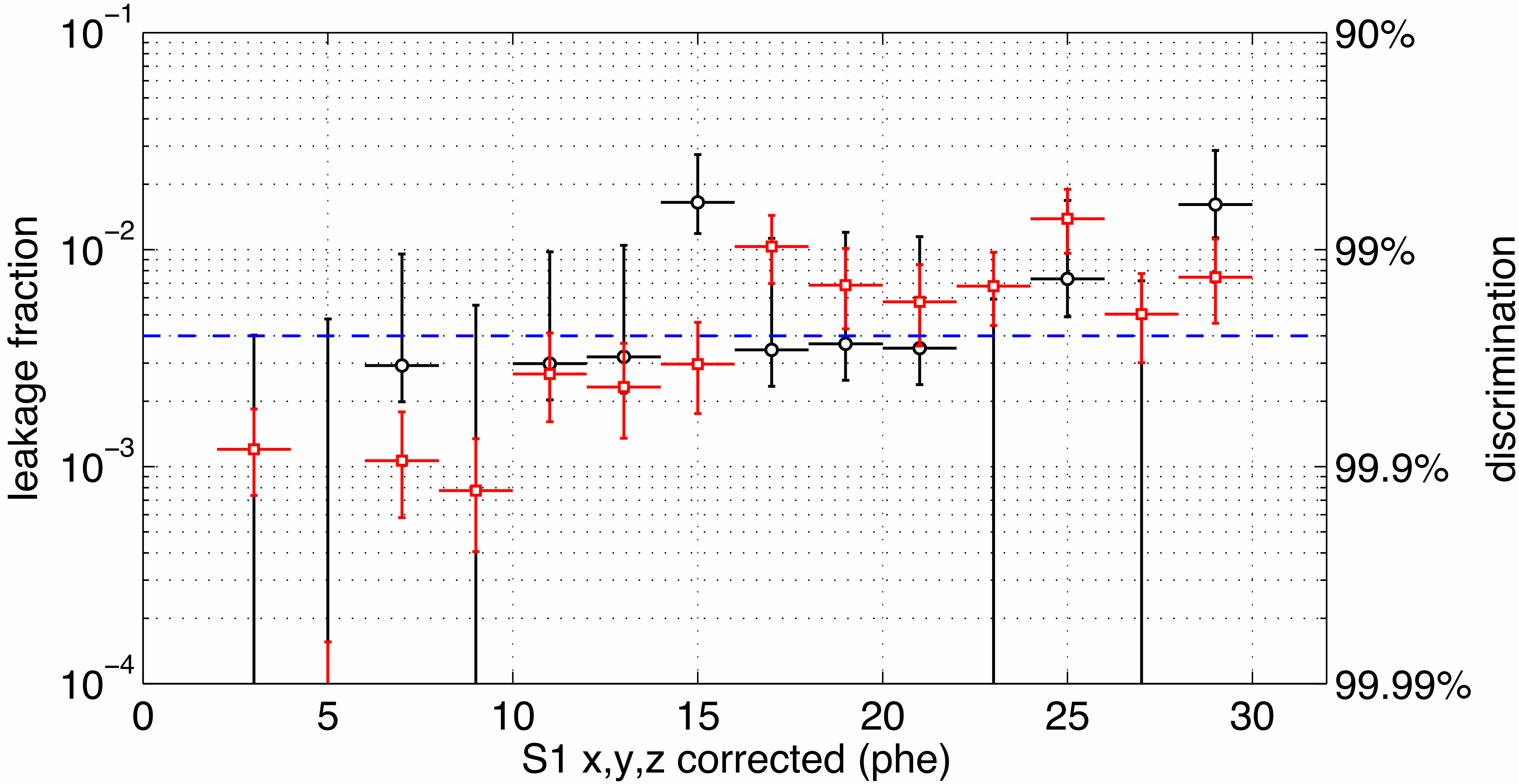
Tritium provides very high statistics electron recoil calibration (200 events/phe)
Neutron calibration is consistent with NEST + simulations



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

Electron Recoil Discrimination

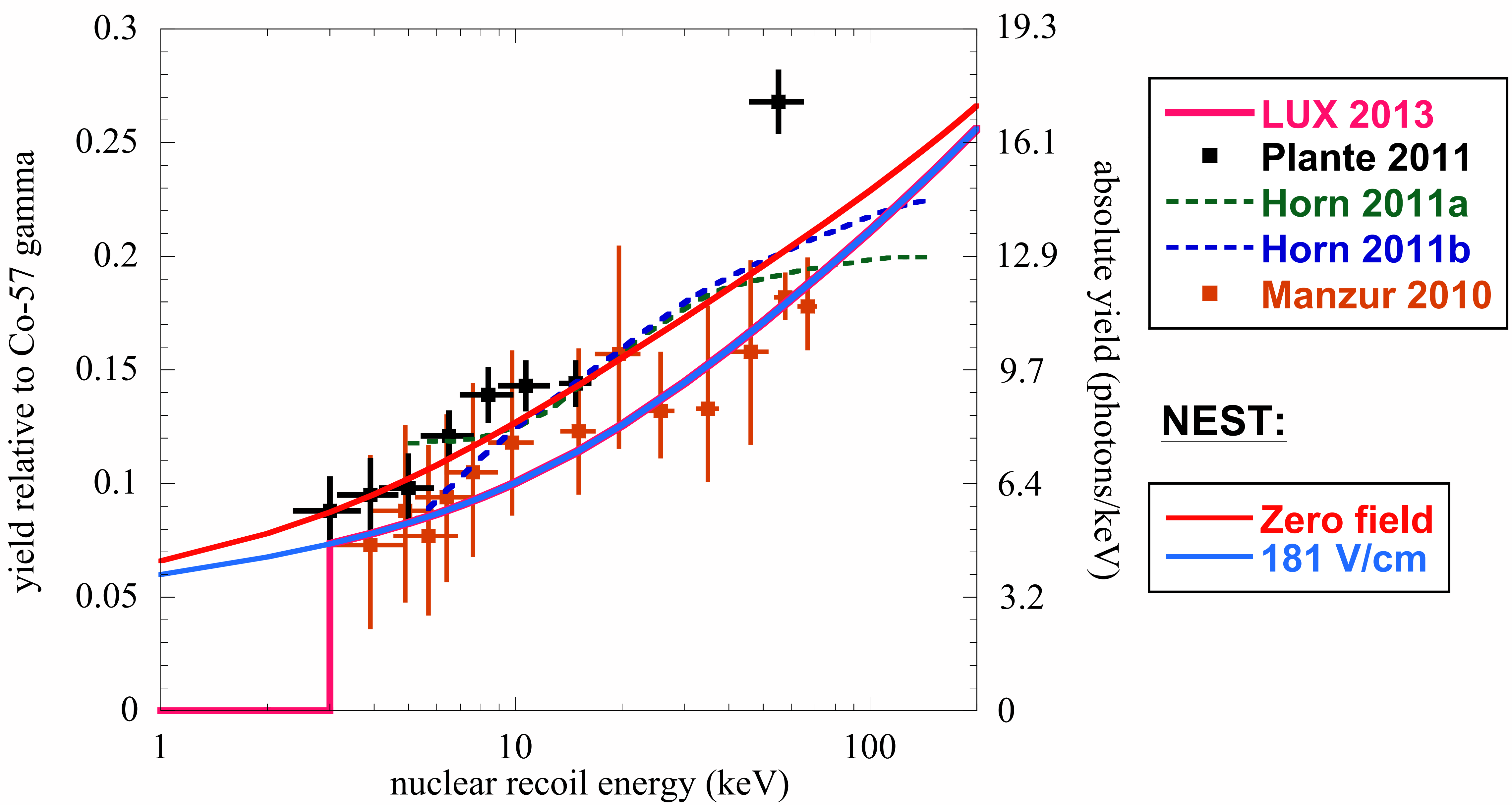
Average discrimination from 2-30 S1 photoelectrons
measured to be 99.6% (with 50% nuclear recoil acceptance)



Black circles show leakage from counting events from the dataset
Red circles show projections of Gaussian fits below the nuclear recoil band mean

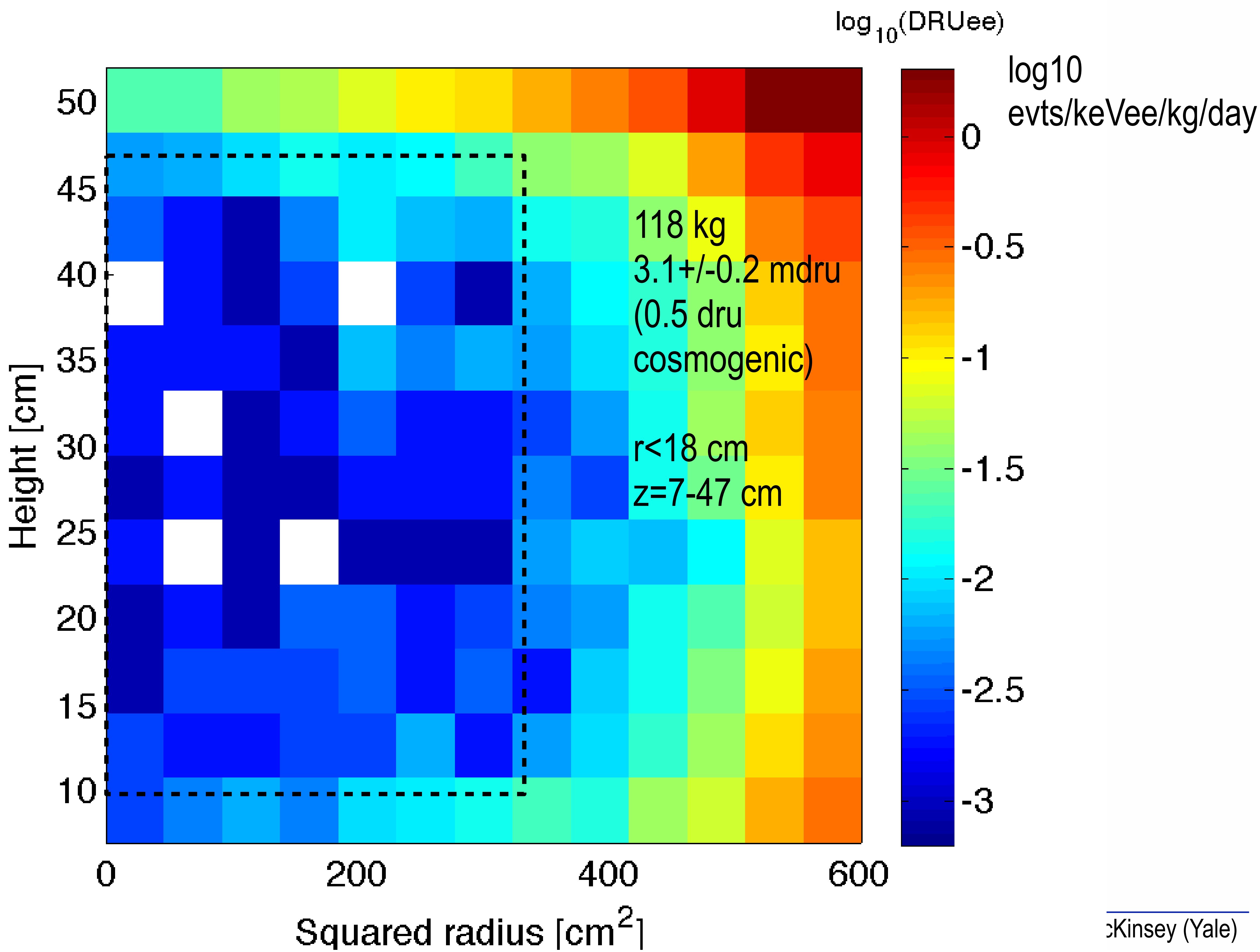
Light and Charge Yields in LUX

- Modeled Using Noble Element Simulation Technique (NEST).
- NEST based on canon of existing experimental data.
- Artificial cutoff in light and charge yields assumed below 3 keVnr, to be conservative.
- Includes predicted electric field quenching of light signal, to 77-82% of the zero field light yield

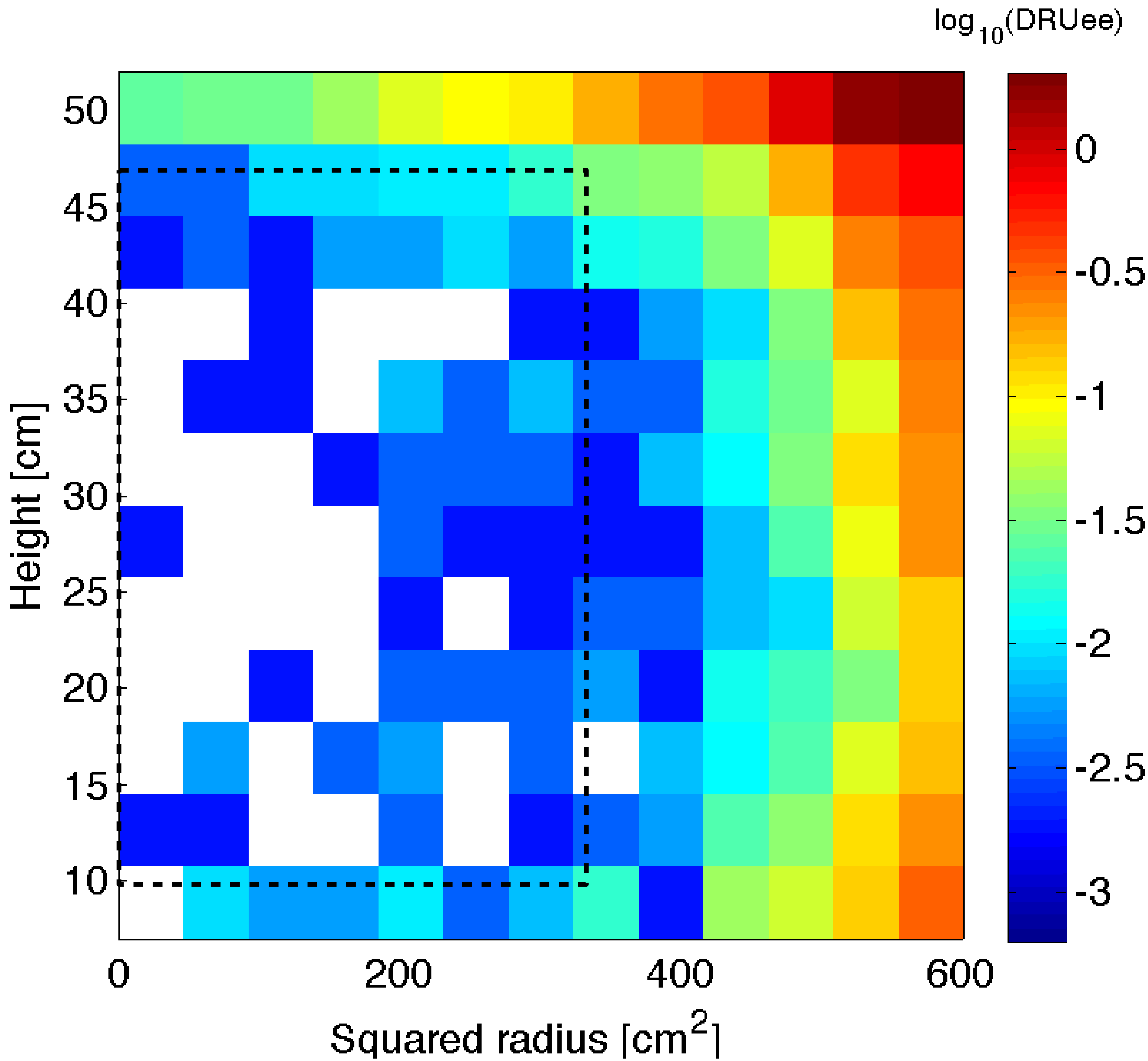


The center of LUX, measured at low energies, is the radioactively quietest place in the world.

Total Electron Recoil Event Rate <5 keVee



And it continues to get quieter - Xe Cosmogenic Activity cools (rate in 44 days)



How Quiet is it in the LUX Detector?

When we ran it above ground the energy being deposited in the detector can be though of as:

Standing in the middle of the Super Bowl at the start of a game and listening to the noise generate by 75,000 people clapping for their team (twice a second)

Once we took LUX underground the energy deposited by backgrounds in the inner Fiducial Volume at the center of the detector becomes:

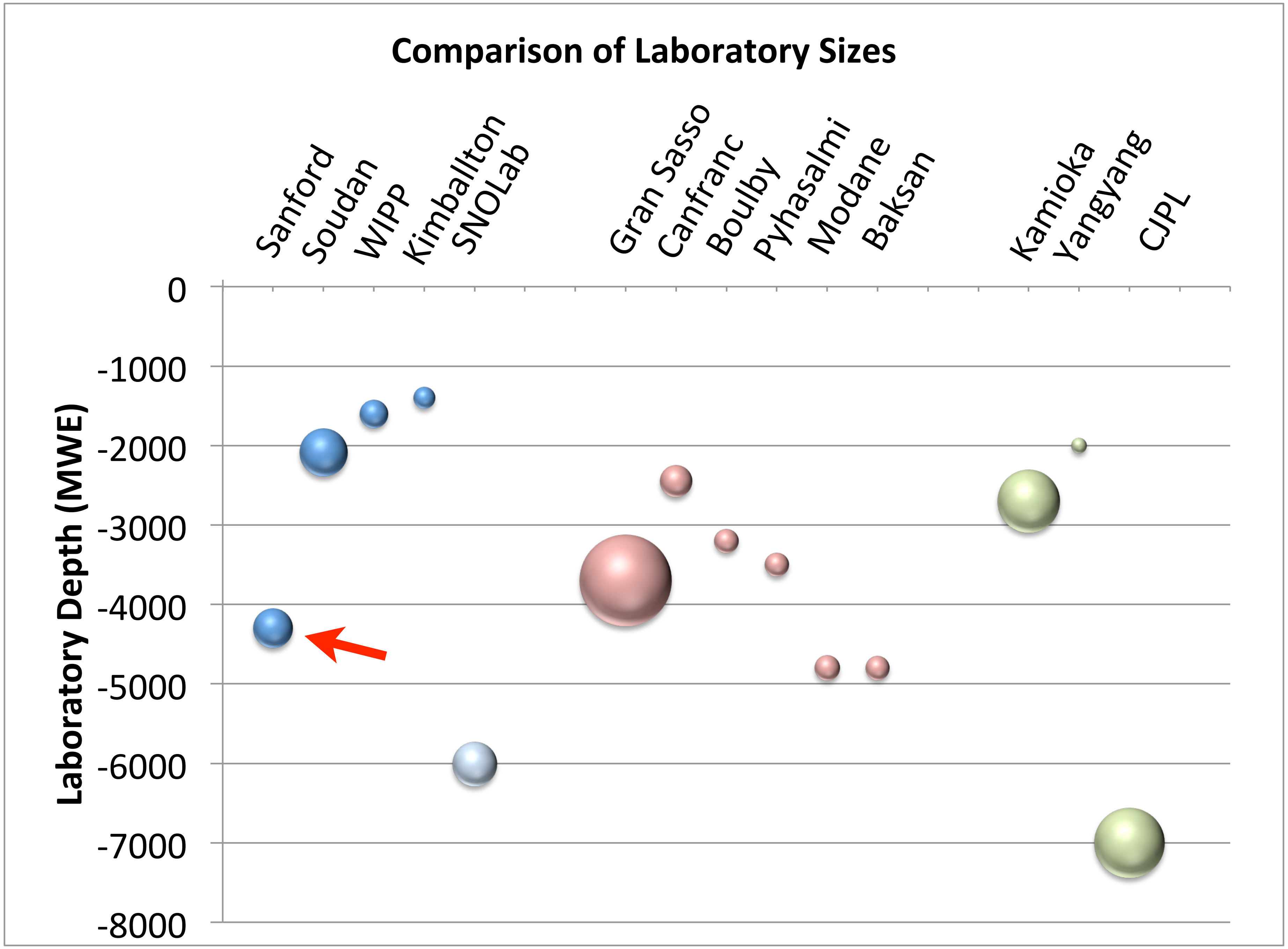
Listening to one person clapping from the stands every 1 minute

The WIMP signal is even lower energy:

It is like listening for someone taking the occasional a breath

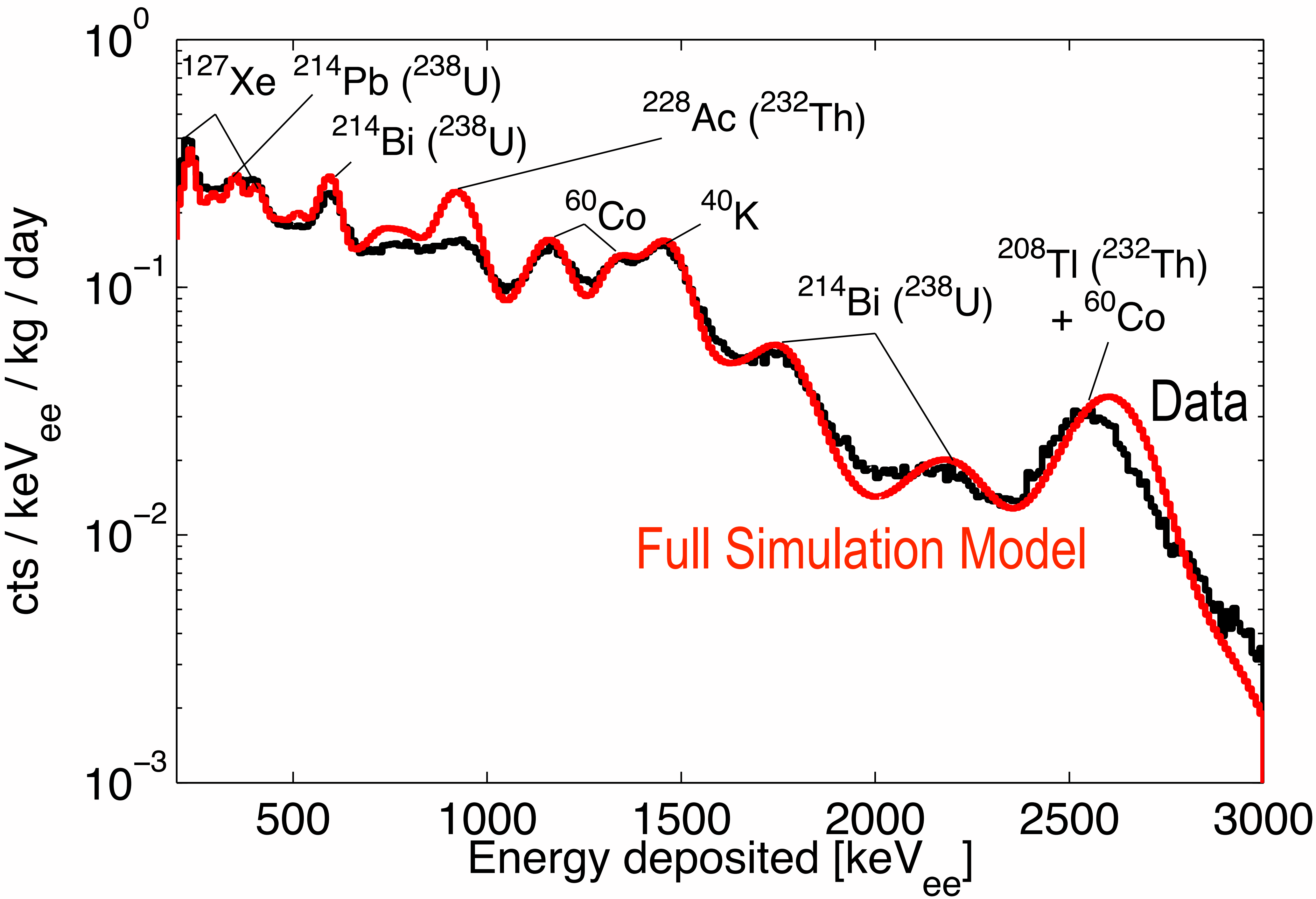
4850ft Depth Reduces Muon Flux by 3 million

- At Sanford Lab LUX's first run we don't have to worry about signals from subterranean muons



LUX High Energy Gamma Background in 220 kg

- Full gamma Spectrum, excluding region ±2 cm from top/bottom grids

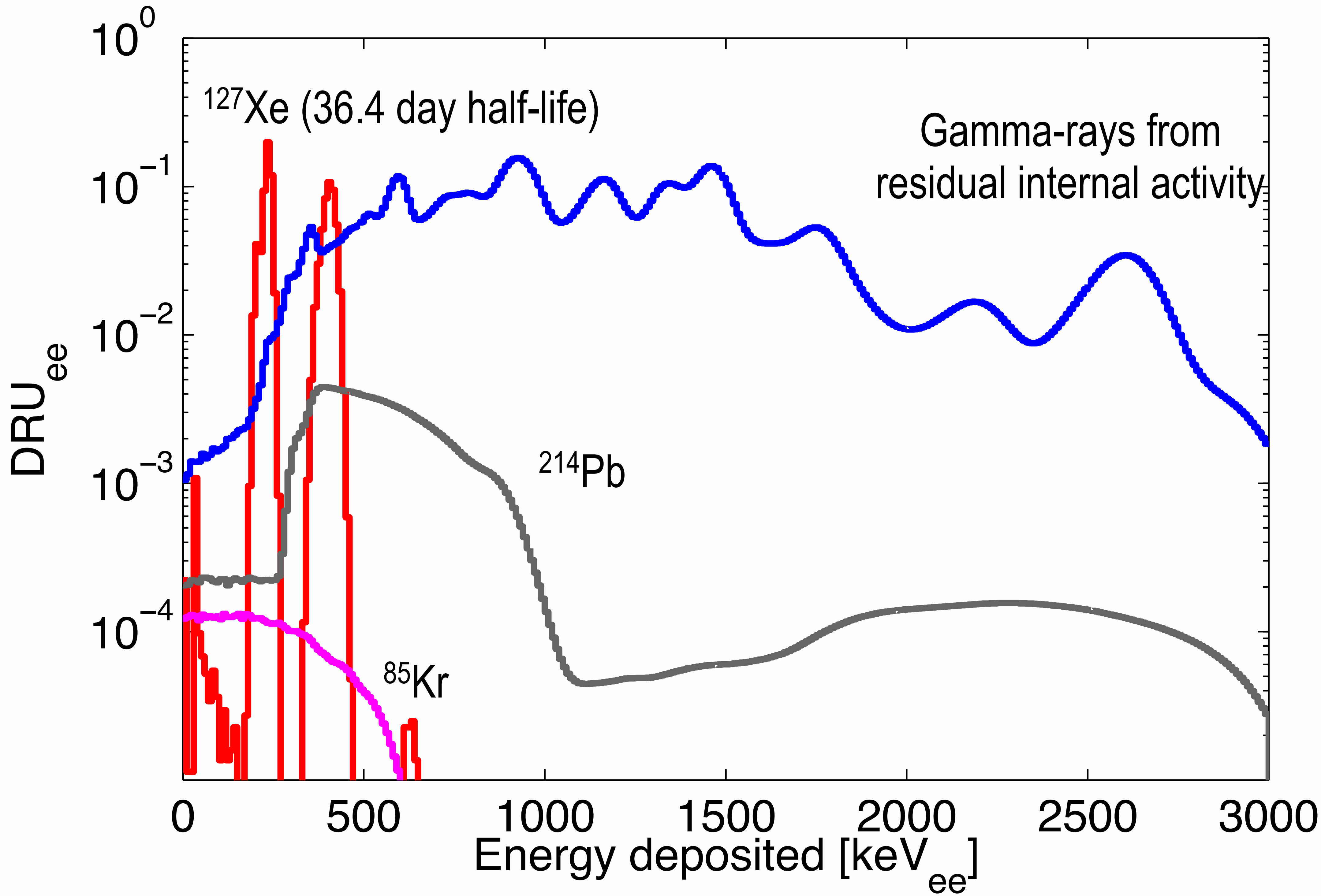


Background Summary for 118 kg Fiducial

- Average levels over period April-August WIMP Search Run

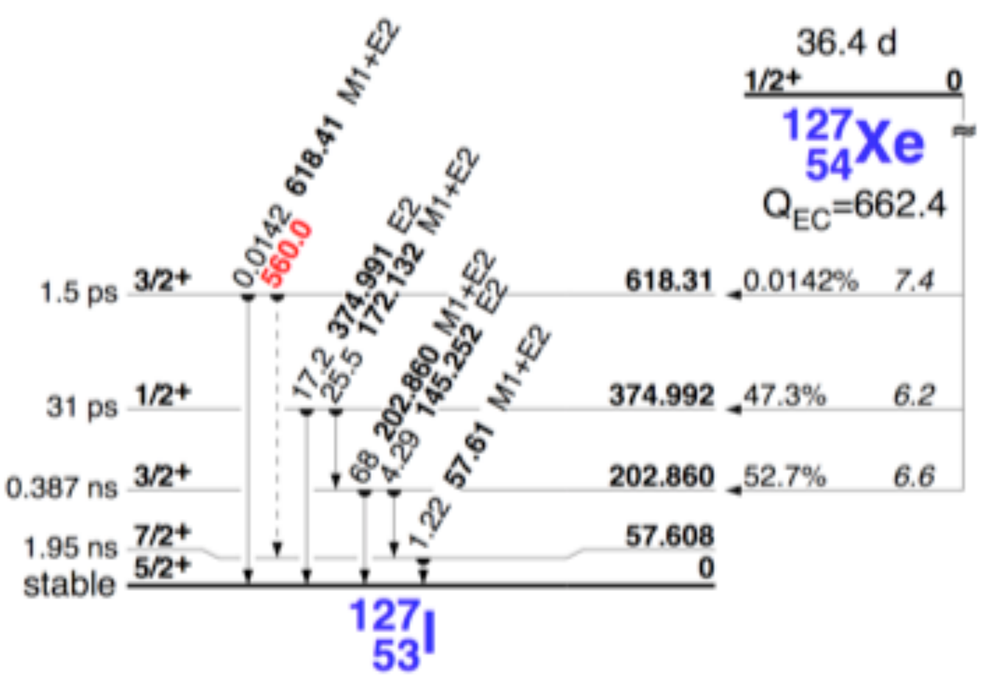
Background Component	Source	10^{-3} x evts/keVee/kg/day
Gamma-rays	Internal Components including PMTS (80%), Cryostat, Teflon	$1.8 \pm 0.2_{stat} \pm 0.3_{sys}$
^{127}Xe (36.4 day half-life)	Cosmogenic 0.87 -> 0.28 during run	$0.5 \pm 0.02_{stat} \pm 0.1_{sys}$
^{214}Pb	222Rn	0.11-0.22(90% CL)
^{85}Kr	Reduced from 130 ppb to 3.5±1 ppt	$0.13 \pm 0.07_{sys}$
Predicted	Total	$2.6 \pm 0.2_{stat} \pm 0.4_{sys}$
Observed	Total	$3.1 \pm 0.2_{stat}$

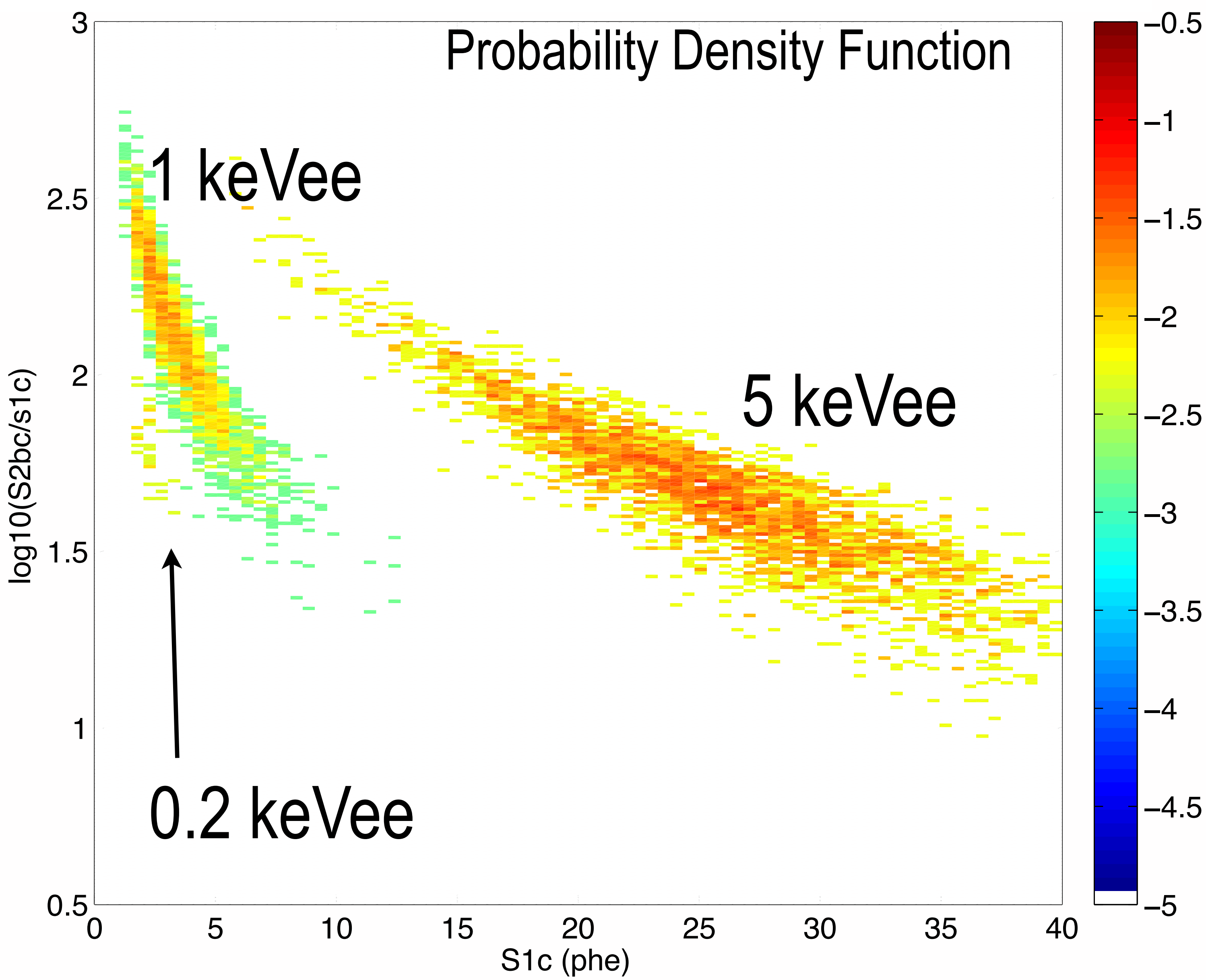
Full Background Model Fits ER Data Over Entire Range



127Xe Electron Capture - Simulation

- x-ray line emission in center of detector following full escape of gamma associated with nuclear excited state





LUX WIMP Search Summary - How did you spend your summer?

- April 21 - August 8, 2013 - 110 calendar days
  - 85.3 live days of WIMP Search
  - 118.3+/-6.5 kg fiducial mass

- Calibrations
  - Frequent injected ^{83m}Kr calibration to correct for any S1 or S2 gain shifts
  - AmBe&Cf calibrations+Sims to define NR band
  - Injected Tritiated Methane defines full ER band at all relevant energies

- Efficiency
  - Efficiency for WIMP event detection was studied using data from calibration sets using multiple techniques and all were all shown to be consistent with one another

"The Sensitivity of a Dark Matter Experiment Scales as its Mass"

"The problems scale as its Surface Area"

LUX WIMP Search Summary /2

- Data Analysis and Blinding Discussion
  - The Xe Target inner fiducial volume is very simple, it sits inside a larger volume of Xe with only a “virtual” surface dividing them
    - Modeling of extrinsic and intrinsic background signals in large monolithic Xe volume has low systematics
  - No blinding was imposed for the first WIMP data analysis
    - We aimed to apply minimum set of cuts in order to reduce any tuning of event cuts/acceptance.
    - The cuts list is very short ...
  - Fiducial Volume was selected based on requirement to keep low energy events from grid and teflon surface out of WS data. Primarily alpha-decay events.
    - Low energy alpha-parent nuclear recoil events generate small S2 + S1 events. Studies position reconstruction resolution. Tested using data outside WIMP search S1 energy range. This ensured that position reconstruction for sets were similar, and definition of fiducial was not biased.
  - Use of Profile Likelihood Ratio (PLR) analysis means we don’t have to draw acceptance boxes
    - This avoids potential bias in data analysis from selecting regions in S1,S2 signal-space
  - Inputs for Profile Likelihood Ratio analysis were developed using high statistics in situ calibrations, with some simulations to cross check

Event & Cuts Summary: 85 live days

Cut	Explanation	Events Remaining
All Triggers	S2 Trigger >99% for $S2_{raw}$>200 phe	83,673,413
Detector Stability	Cut periods of excursion for Xe Gas Pressure, Xe Liquid Level, Grid Voltages	82,918,901
Single Scatter Events	Identification of S1 and S2. Single Scatter cut.	6,585,686
S1 energy	Accept 2-30 phe (energy ~ 0.9-5.3 keVee, ~3-18 keVnr)	26,824
S2 energy	Accept 200-3300 phe (>8 extracted electrons) Removes single electron / small S2 edge events	20,989
S2 Single Electron Quiet Cut	Cut if >100 phe outside S1+S2 identified +/-0.5 ms around trigger (0.8% drop in livetime)	19,796
Drift Time Cut away from grids	Cutting away from cathode and gate regions, 60 < drift time < 324 us	8731
Fiducial Volume radius and drift cut	Radius < 18 cm, 38 < drift time < 305 us, 118 kg fiducial	160

- ~11.5 Hz of S2-like triggers
  - >99% efficiency for events S2area>200 phe

keVnr = keV nuclear recoil
keVee = keV electron equivalent

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Fiducial Volume radius and drift cut	Radius < 18 cm, 38 < drift time < 305 us, 118 kg fiducial	160

- <0.8% of run time lost to instabilities

Event & Cuts Summary: 85 live days

Cut	Explanation	Events Remaining
All Triggers	S2 Trigger >99% for $S2_{raw}$>200 phe	83,673,413
Detector Stability	Cut periods of excursion for Xe Gas Pressure, Xe Liquid Level, Grid Voltages	82,918,901
Single Scatter Events	Identification of S1 and S2. Single Scatter cut.	6,585,686
S1 energy	Accept 2-30 phe (energy ~ 0.9-5.3 keVee, ~3-18 keVnr)	26,824
S2 energy	Accept 200-3300 phe (>8 extracted electrons) Removes single electron / small S2 edge events	20,989
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- Primary method of defining energy range of analysis
  - Note S1 analysis threshold of S1area >=2 phe. Expected S1 for a 3 keVnr event is 1.94 phe.
  - This threshold is very low, and provides high sensitivity over full WIMP mass range

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- Low energy efficiency is dominated by S1 acceptance
    - S2 area cut is looser constraint on WIMP energy range

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- The aftermath of large S2 events in the detector can lead to additional single electron events, for periods ~0.1-1 ms afterwards
  - Events that coincide with periods of non-quiescence can be cut by simply demanding <4 extracted electron events (<100 phe) of spurious signal occurs during +/-0.5 ms around the primary S1 and S2 event
  - This cut causes < 0.8% dead time

Event & Cuts Summary: 85 live days

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- Events from residual radioactivity on cathode and gate grids lead to significant number of events in energy region of interest. Use a simple drift time cut to remove them.

Event & Cuts Summary: 85 live days

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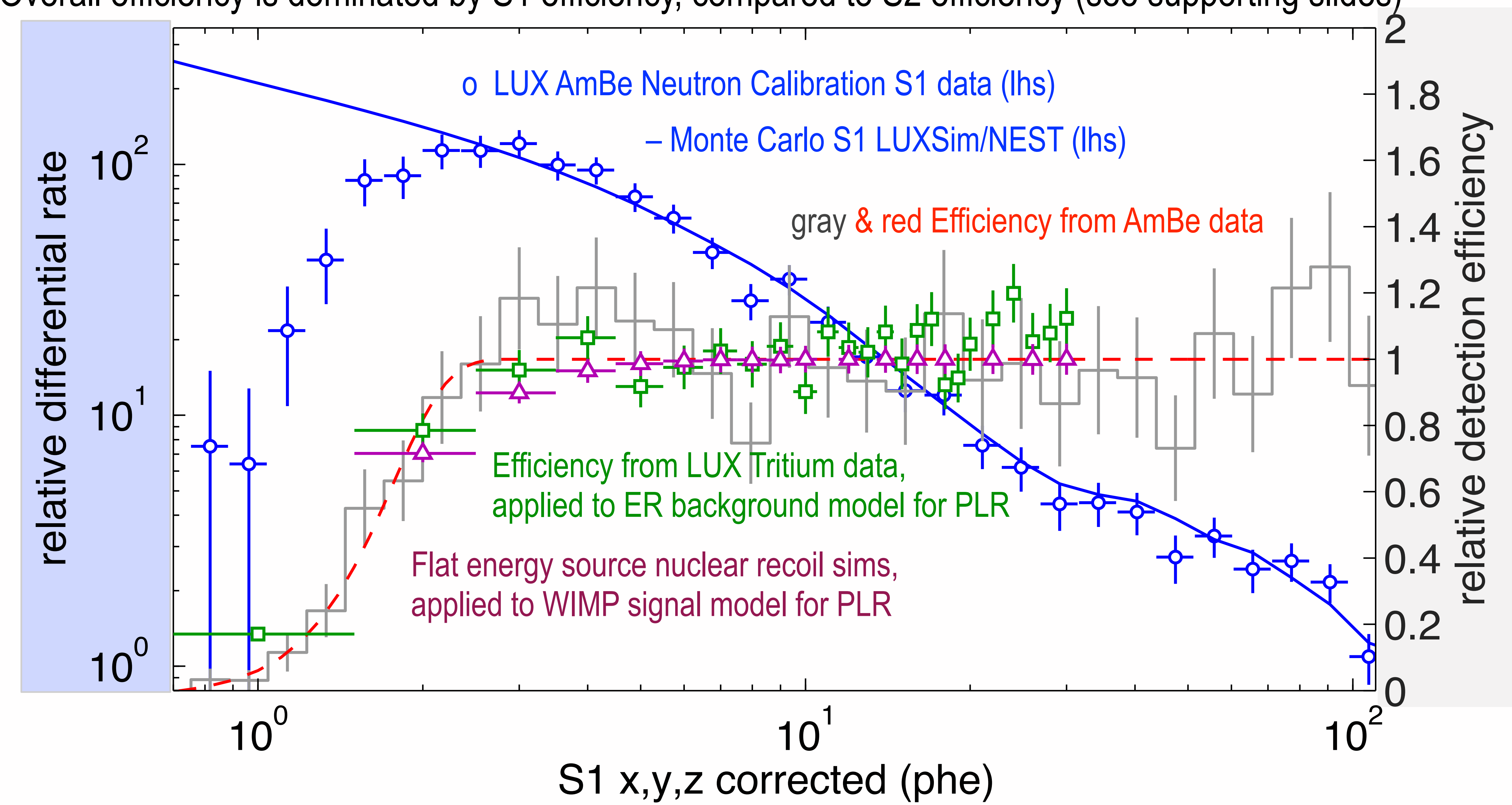
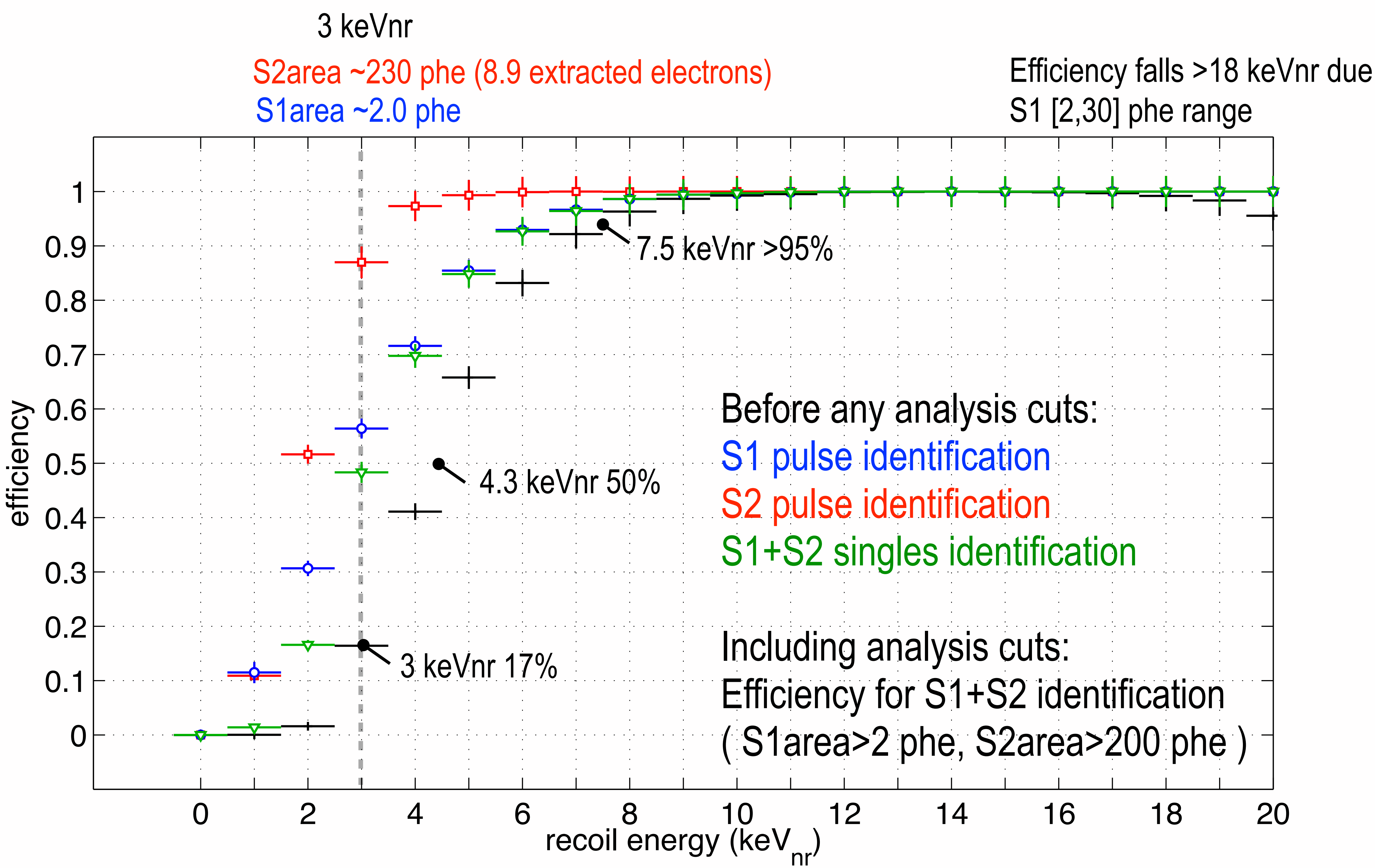
- Define a Fiducial Volume of 118 kg using combination of radius and drift time cut
  - Low energy alpha-parent nuclear recoil events generate small S2 + S1 events. The radius and drift time cuts were set using population of events which had S1's outside of the WIMP signal search range, but with S2's of a comparable size to lower S1 events in same population. This ensured that position reconstruction for sets were similar, and definition of fiducial was not biased.
- Cuts also remove corner regions where ER event rates are proportionally very high

S1 Efficiency For WIMP Detection

- S1 efficiency was studied in detail using
  - AmBe NR calibration
  - Tritiated-Methane calibration
  - Full Monte Carlo sim of NR events (S1+S2 processed by same analysis chain)
- Overall efficiency is dominated by S1 efficiency, compared to S2 efficiency (see supporting slides)



WIMP Detection Efficiency - True Recoil Energy

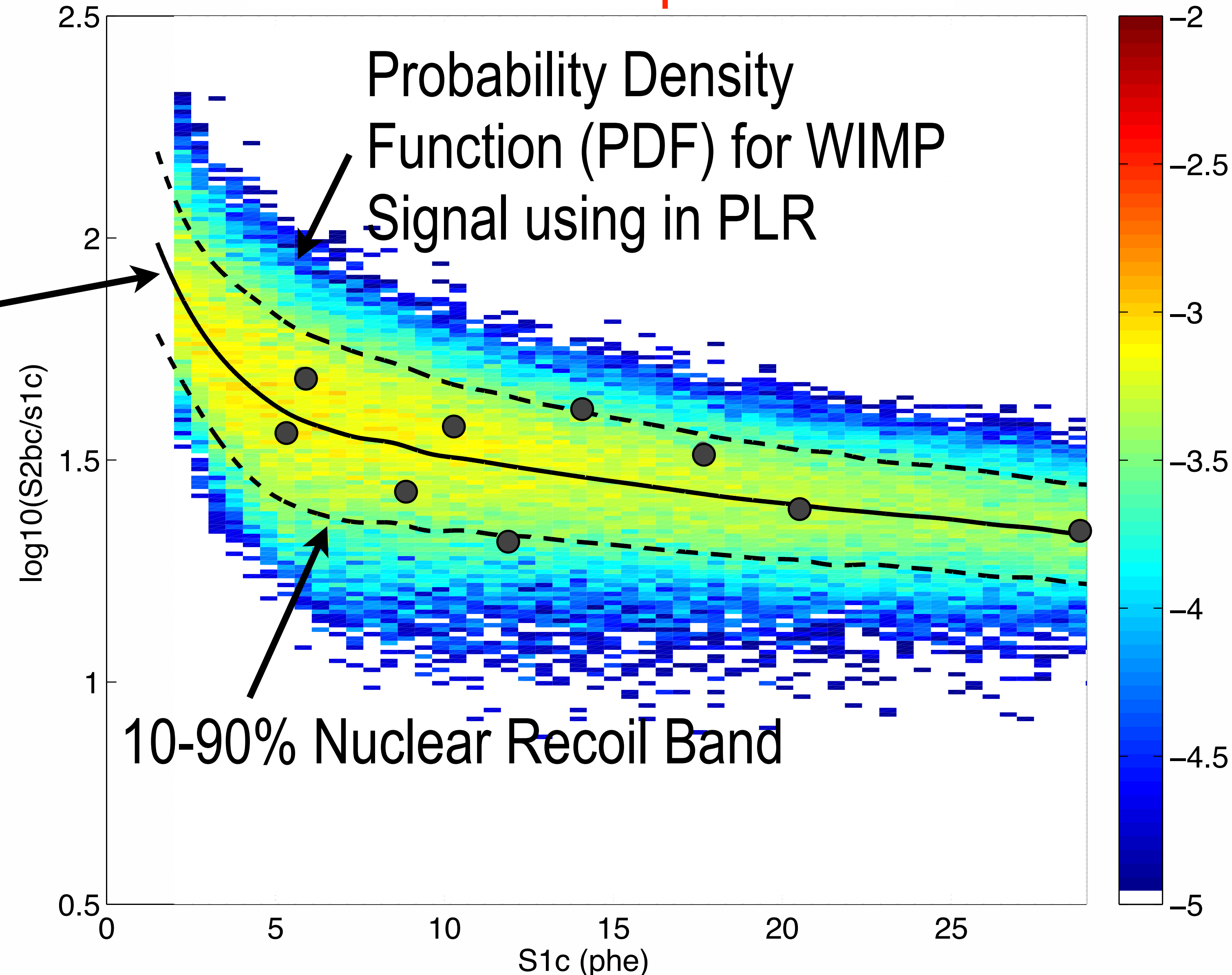


True Recoil Energy equivalence based on LUX 2013 Neutron Calibration/NEST Model

Simulated WIMP Signals for 85 days, 118 kg

- Pick a mass of 1000 GeV and cross section at the existing XENON100 90% CL Sensitivity 1.9×10^{-44} cm^2 - Would expect 9 WIMPs in LUX Search

Conservatively assume no signal generated for recoils < 3 keVnr to reflect lowest energy for which NR calibration is available.

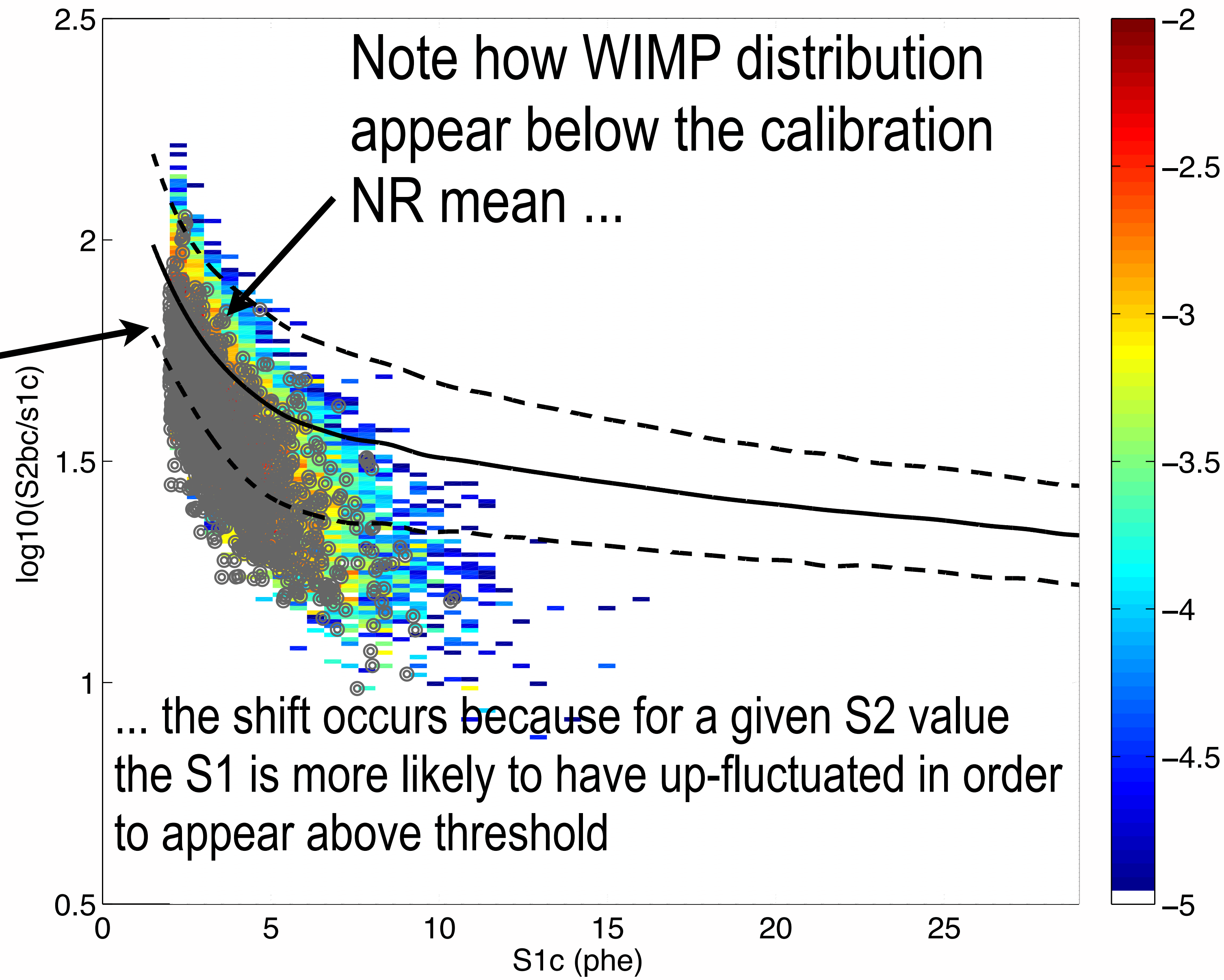


- PDF assumes Standard Milky Way Halo parameters as described in Savage, Freese, Gondolo (2006) v_0=220 km/s, v_{escape} = 544 km/s, ρ_0 = 0.3 GeV/c^2, v_{earth} = 245 km/s
  - Helm Form Factor.

Simulated WIMP Signals for 85 days, 118 kg

- At a mass of 8.6 GeV and cross section favored CDMS II Si (2012) cross section 2.0x10-41 cm2 - Expect 1550 WIMPs in LUX Search

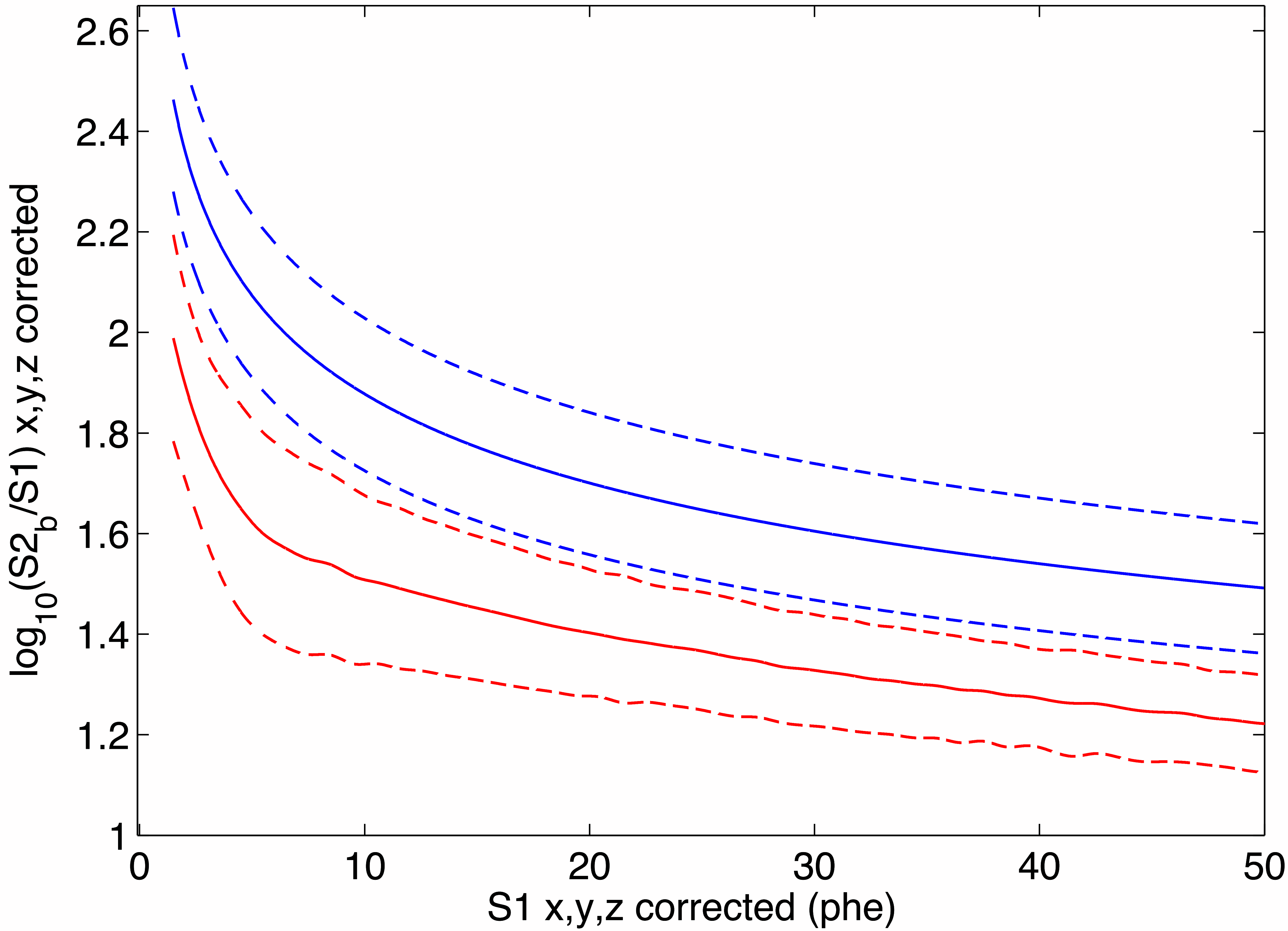
Conservatively assume no signal generated for recoils < 3 keVnr to reflect lowest energy for which NR calibration is available.



◆ The shift in the WIMP PDF downwards improves the effective ER event leakage fraction

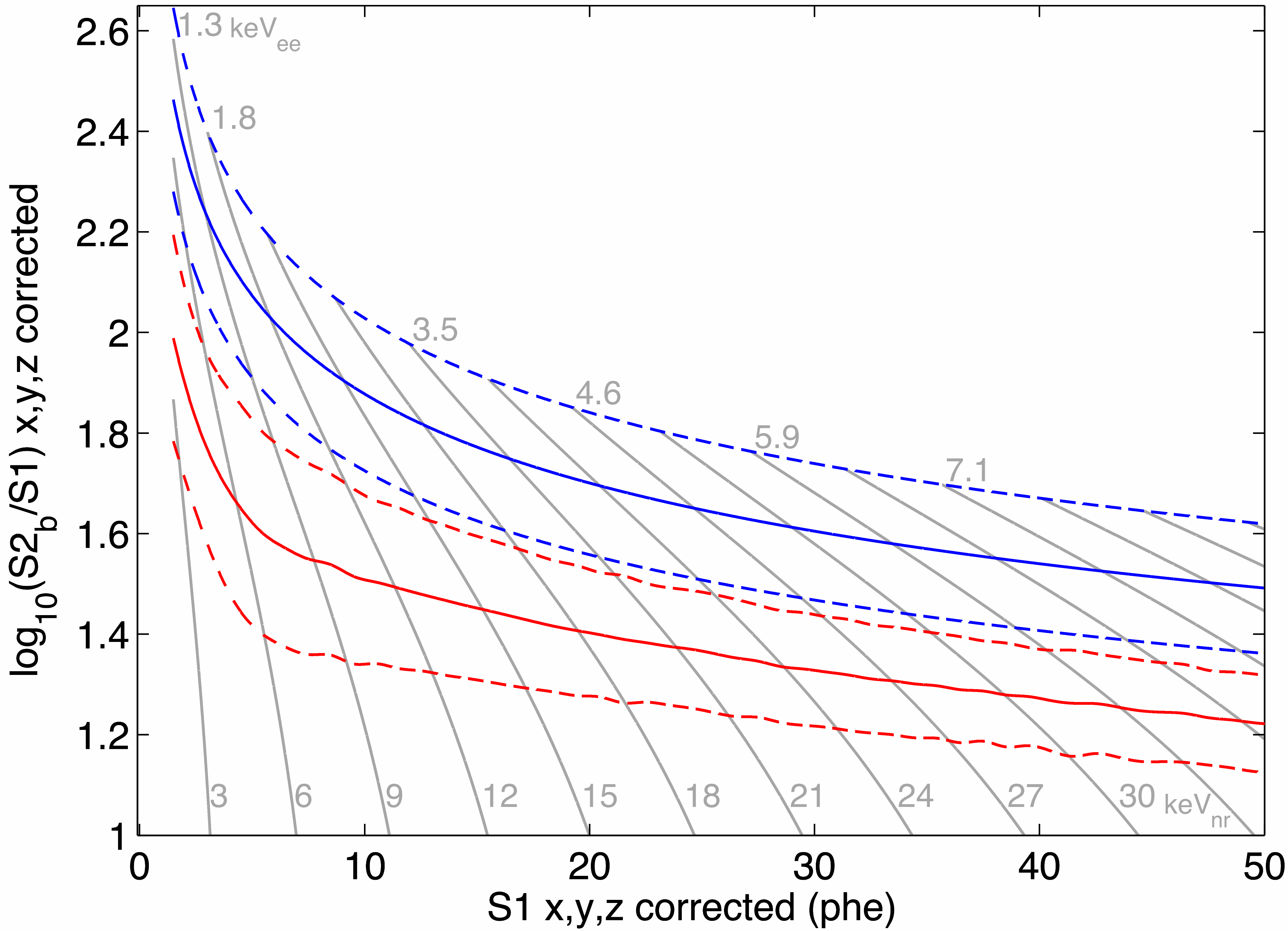
LUX WIMP Search, 85 live-days, 118 kg

- Electron Recoil and Nuclear Recoil Bands

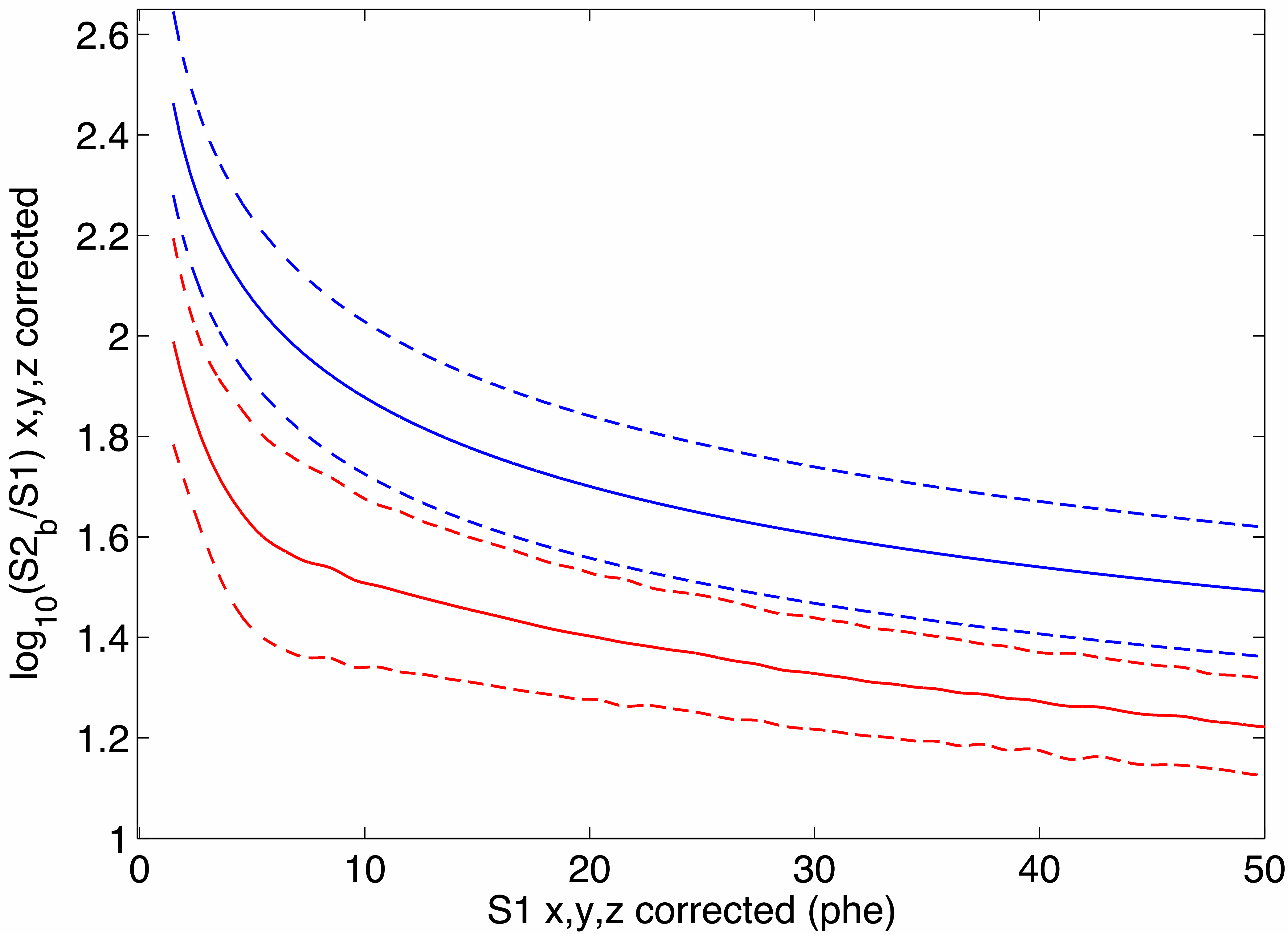


LUX WIMP Search, 85 live-days, 118 kg

- Event energies in keVee and keVnr

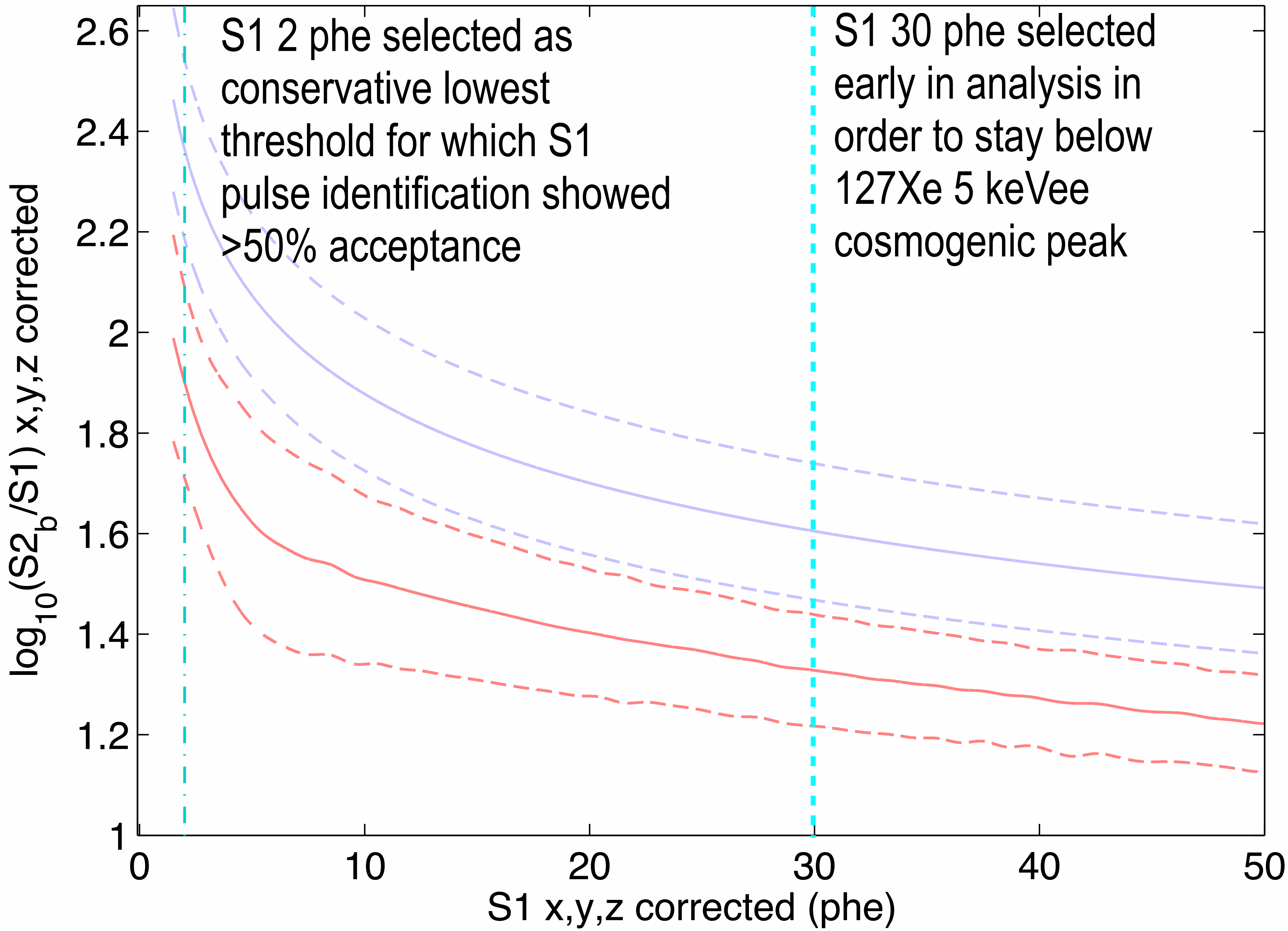


LUX WIMP Search, 85 live-days, 118 kg



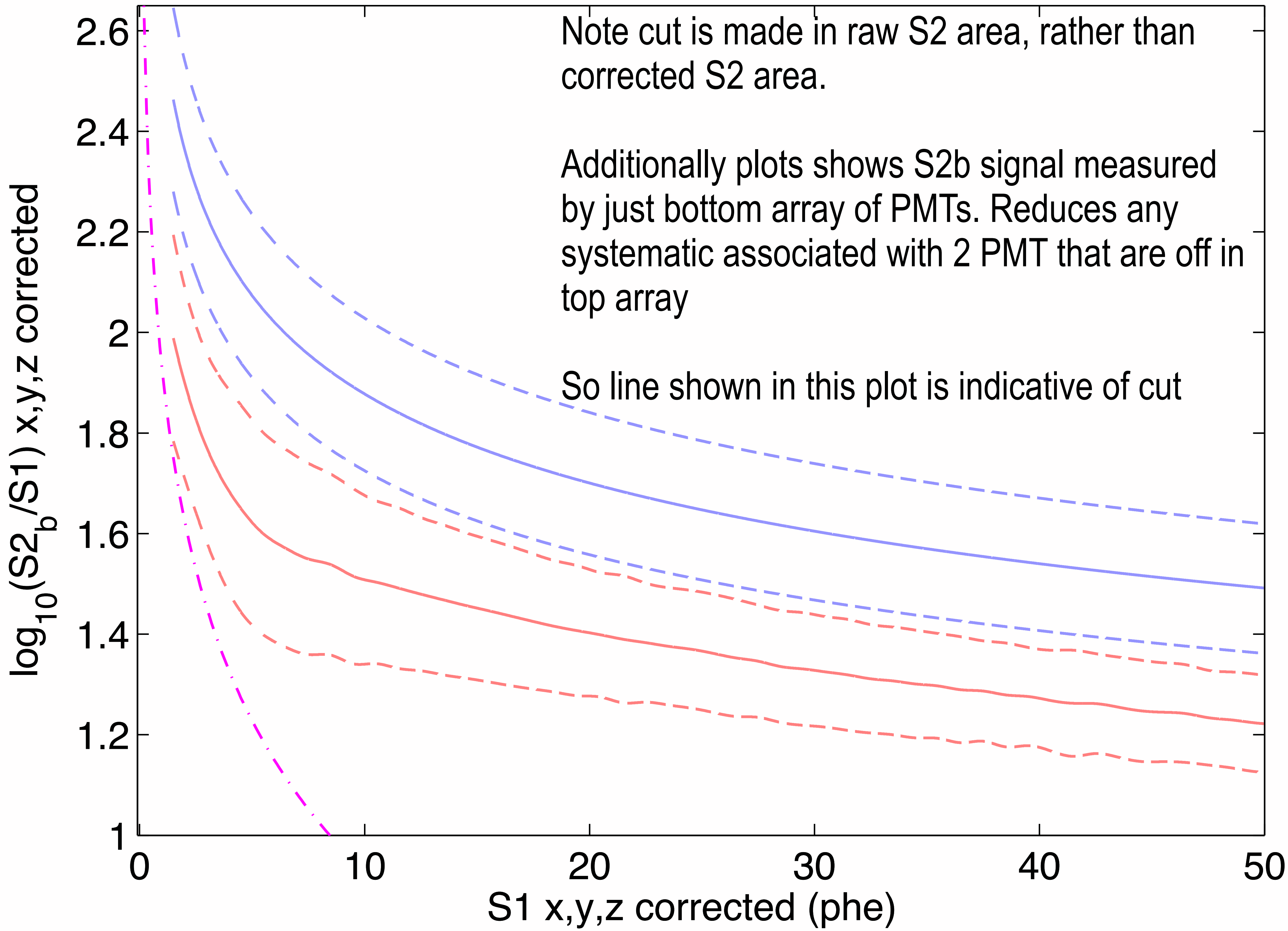
LUX WIMP Search, 85 live-days, 118 kg

- S1area >= 2 phe analysis threshold. S1area <= 30 phe



LUX WIMP Search, 85 live-days, 118 kg

- Total S2area >= 200 phe analysis threshold.

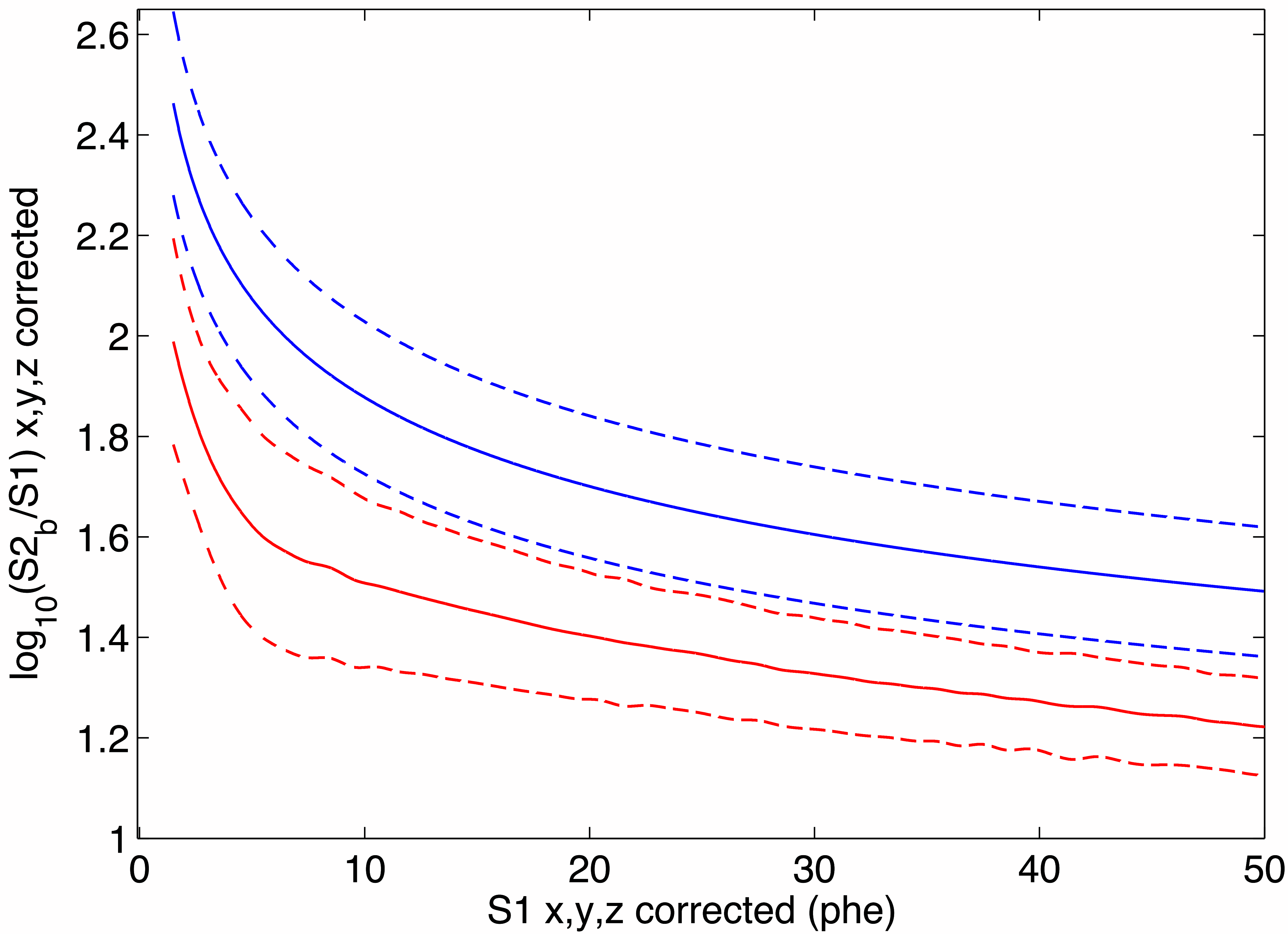


Note cut is made in raw S2 area, rather than corrected S2 area.

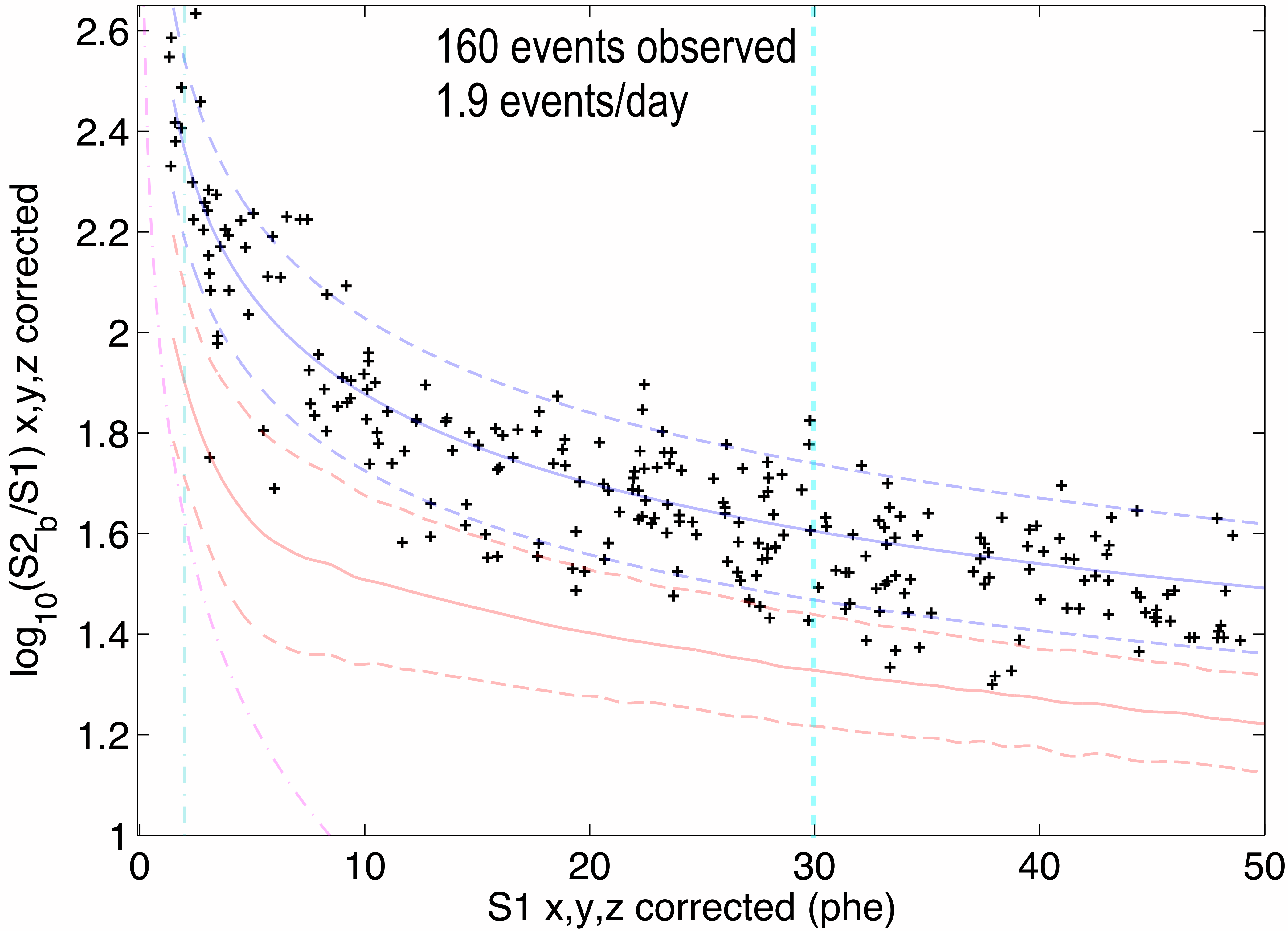
Additionally plots shows S2b signal measured by just bottom array of PMTs. Reduces any systematic associated with 2 PMT that are off in top array

So line shown in this plot is indicative of cut

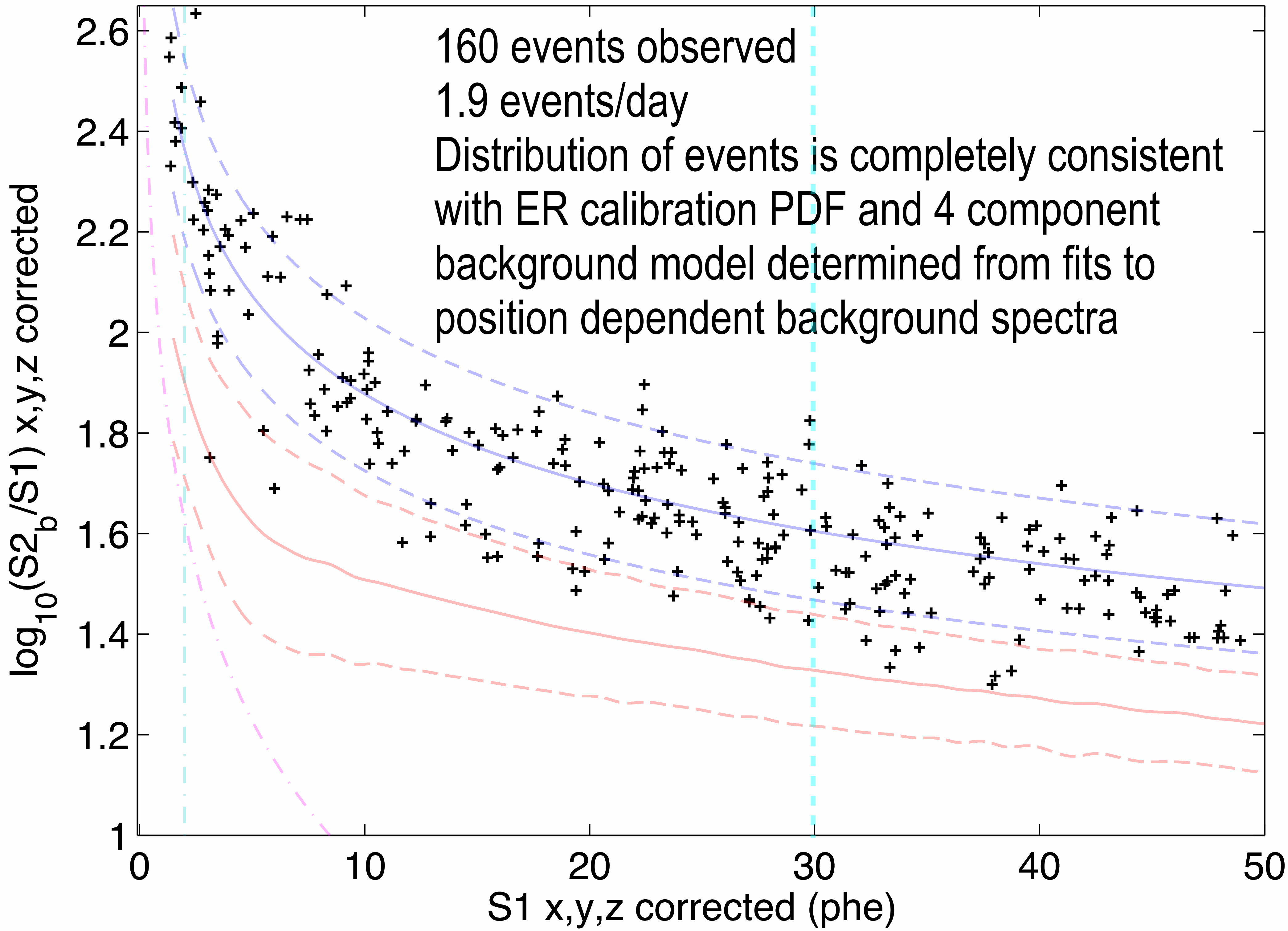
LUX WIMP Search, 85 live-days, 118 kg



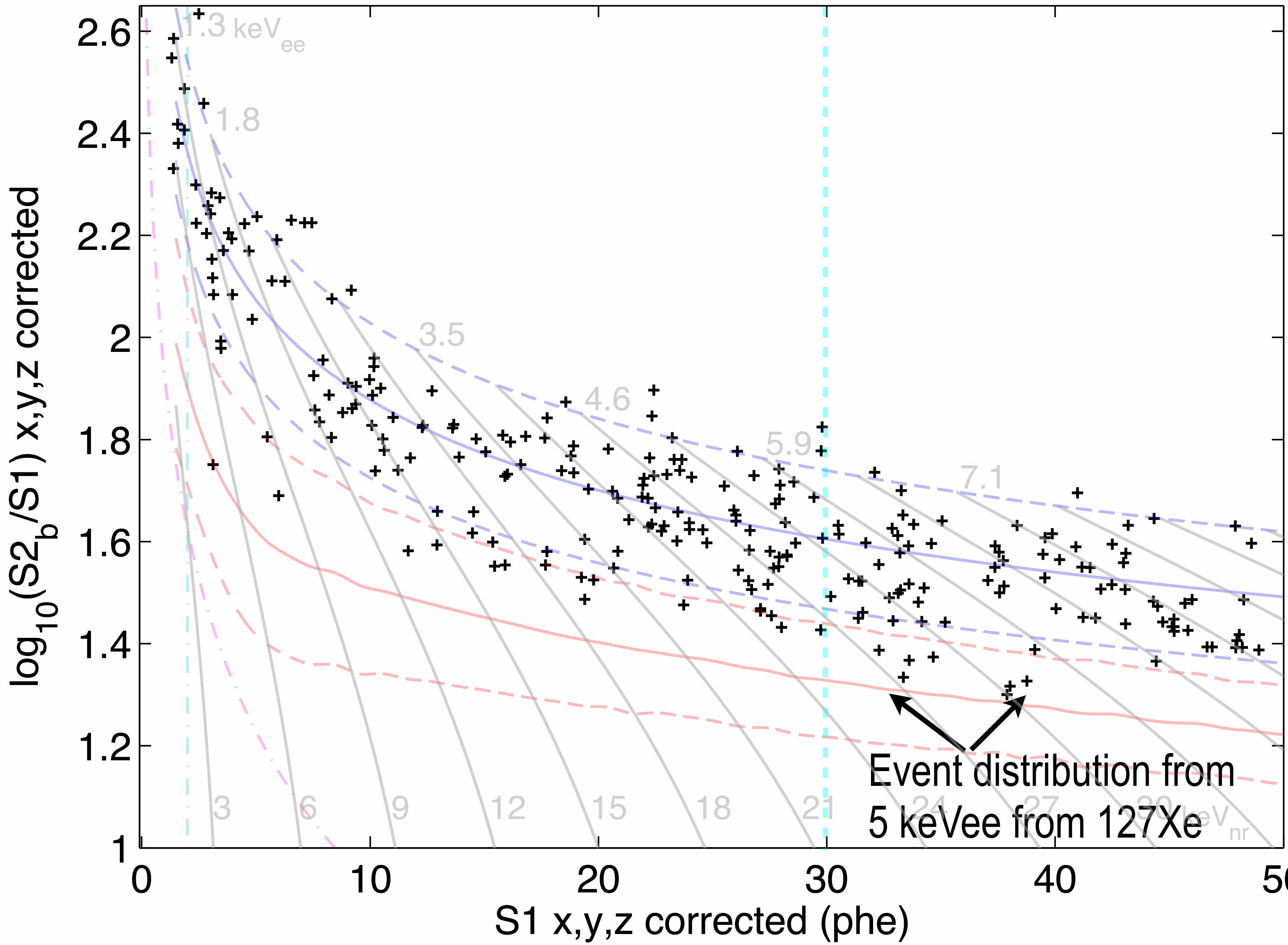
LUX WIMP Search, 85 live-days, 118 kg



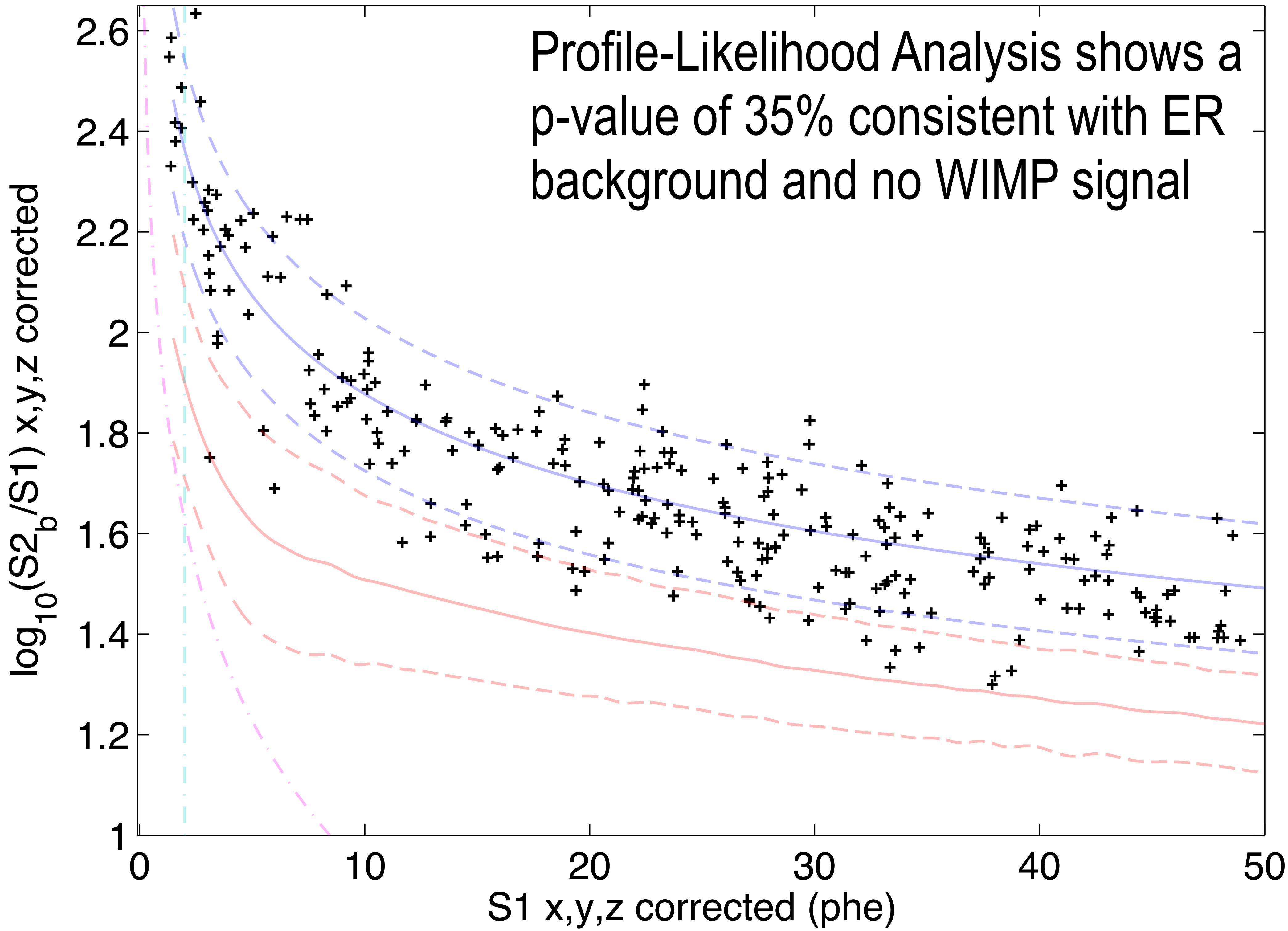
LUX WIMP Search, 85 live-days, 118 kg



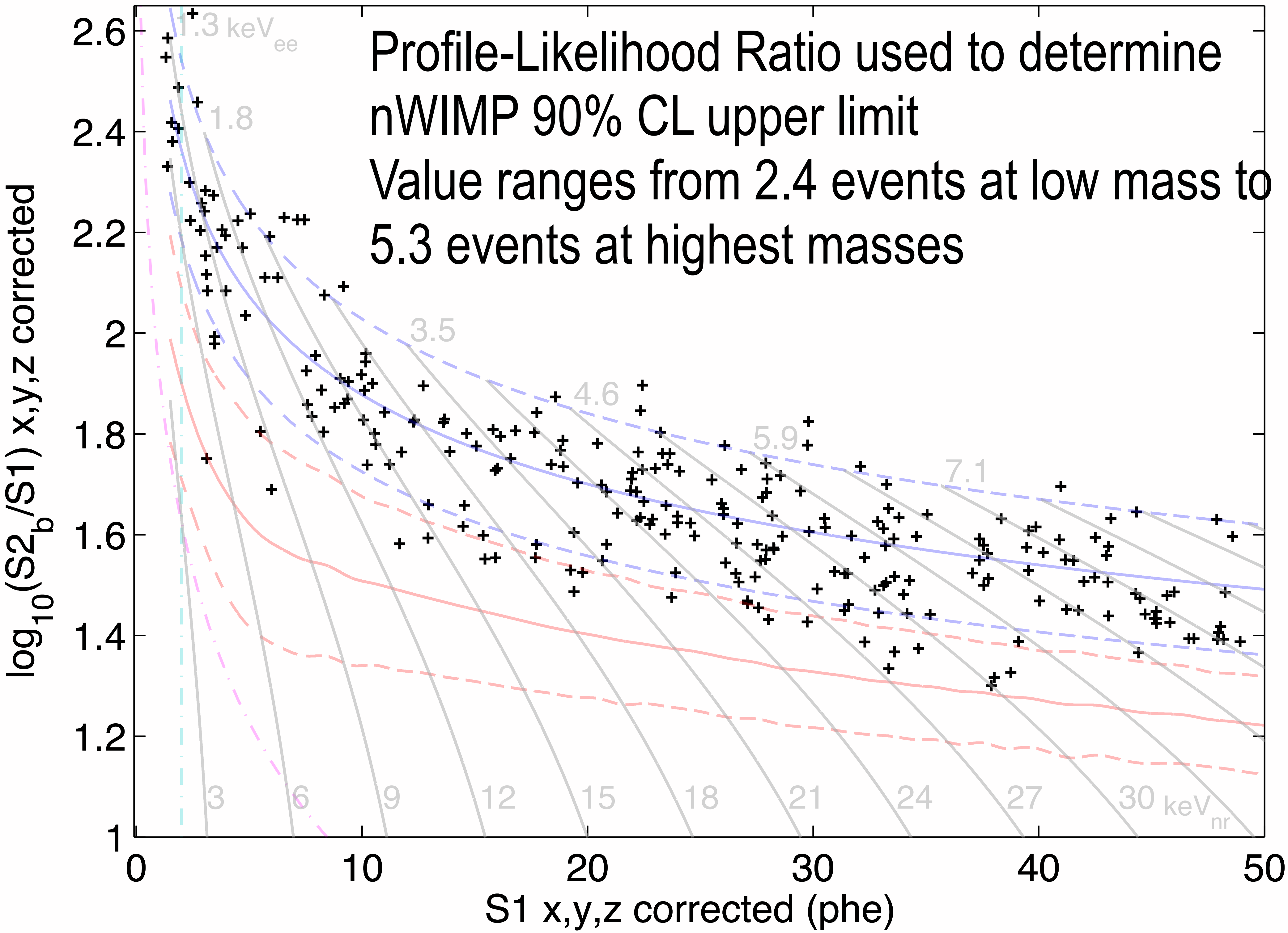
LUX WIMP Search, 85 live-days, 118 kg



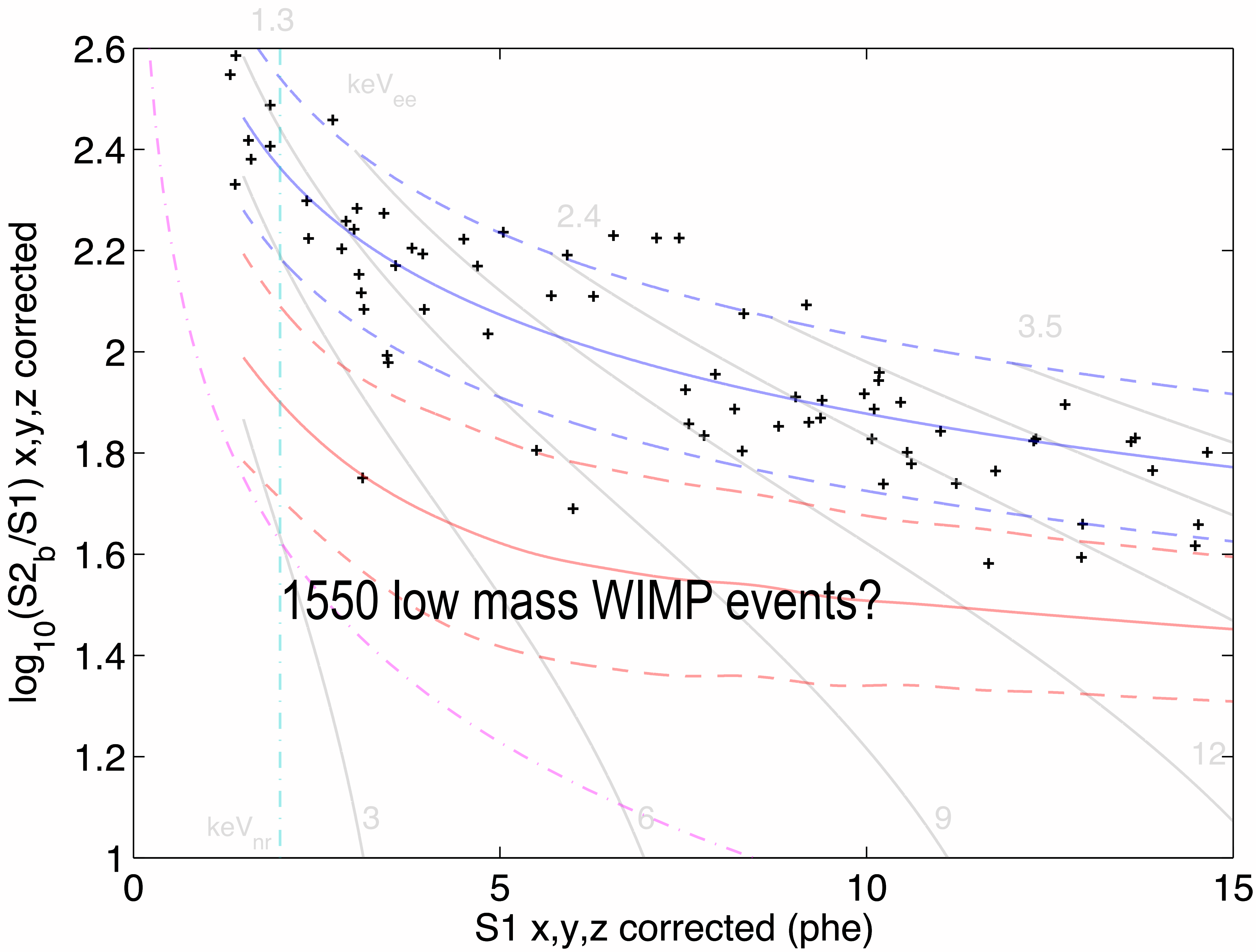
LUX WIMP Search, 85 live-days, 118 kg



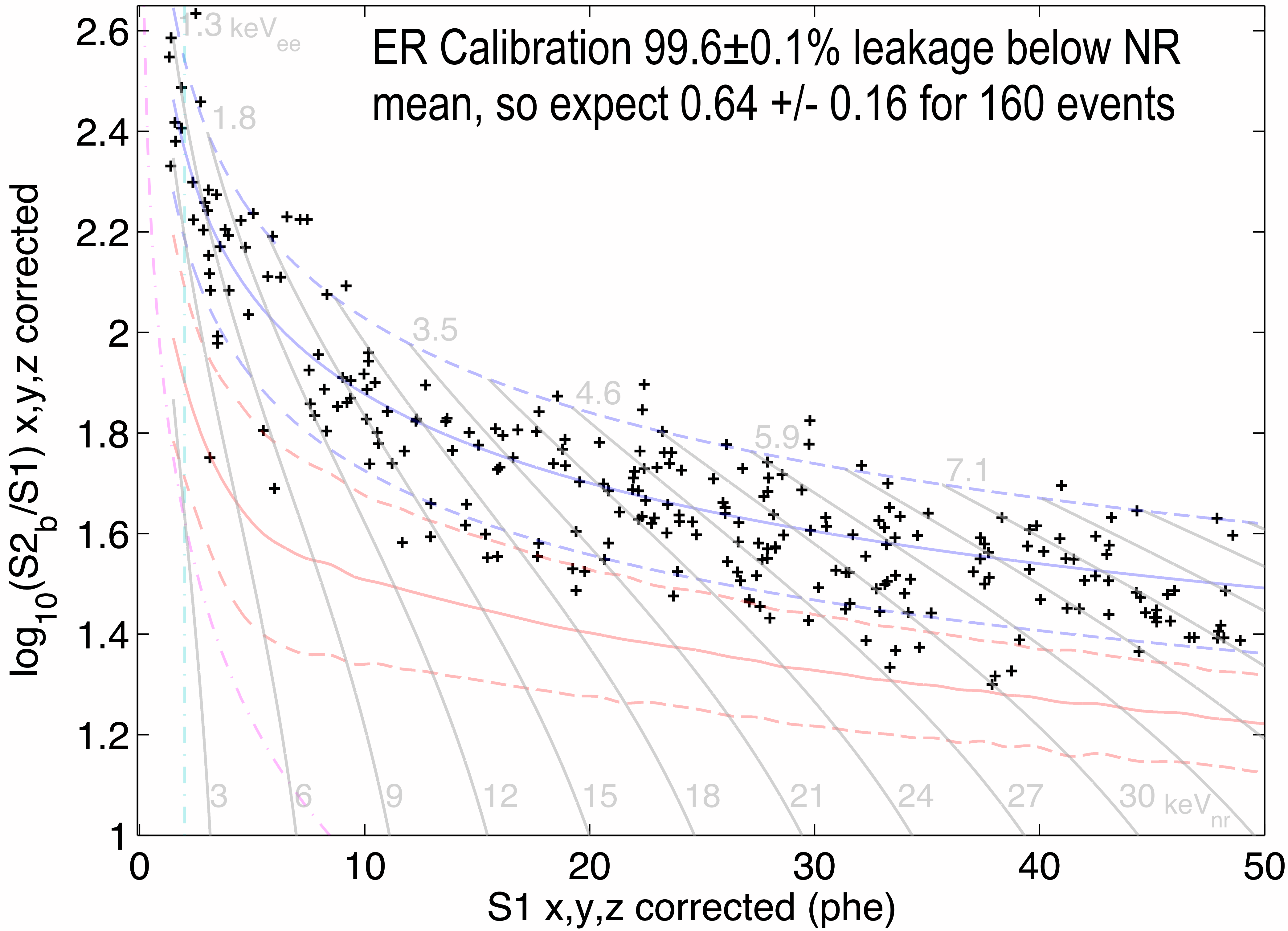
LUX WIMP Search, 85 live-days, 118 kg



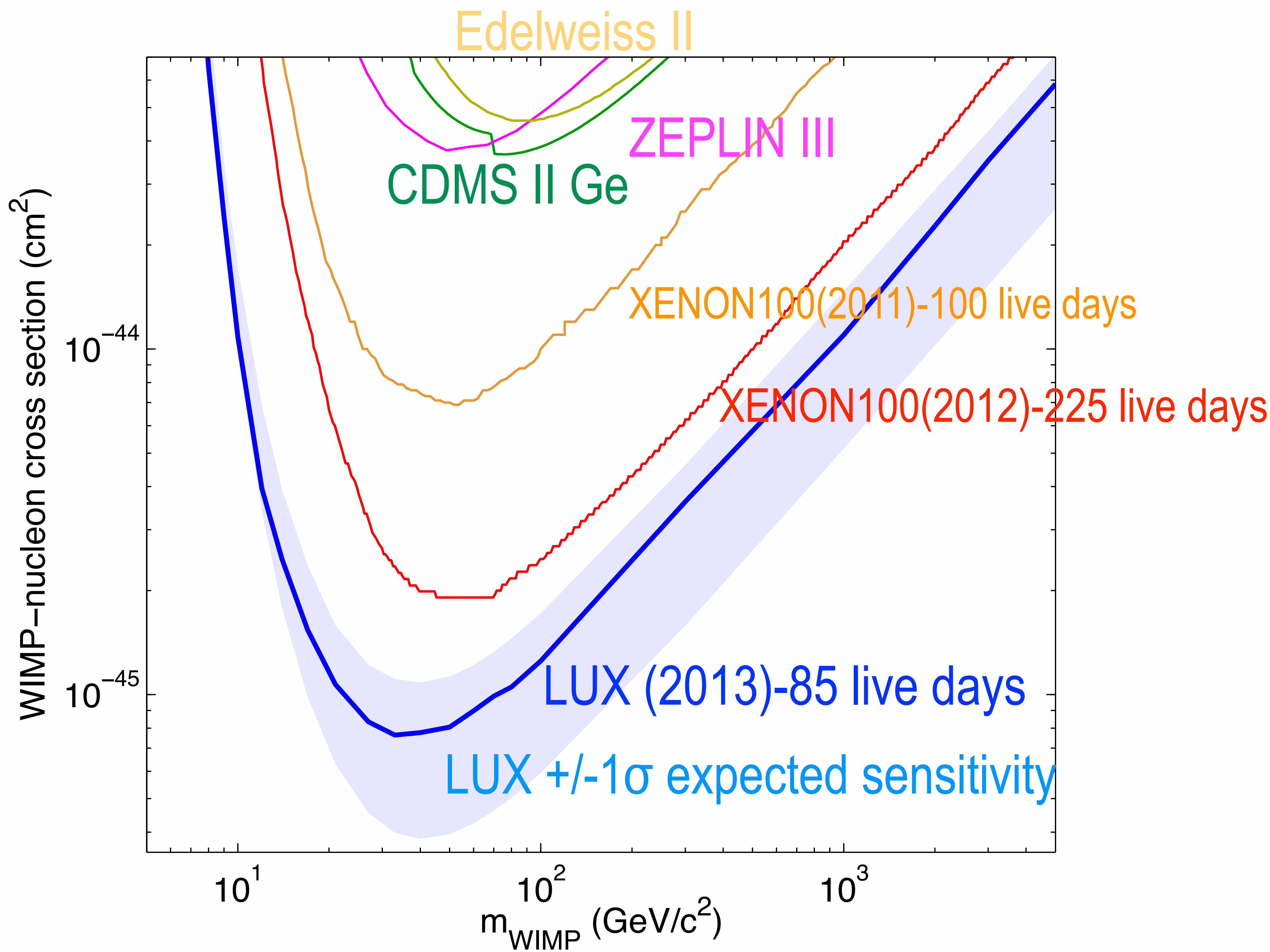
LUX WIMP Search, 85 live-days, 118 kg



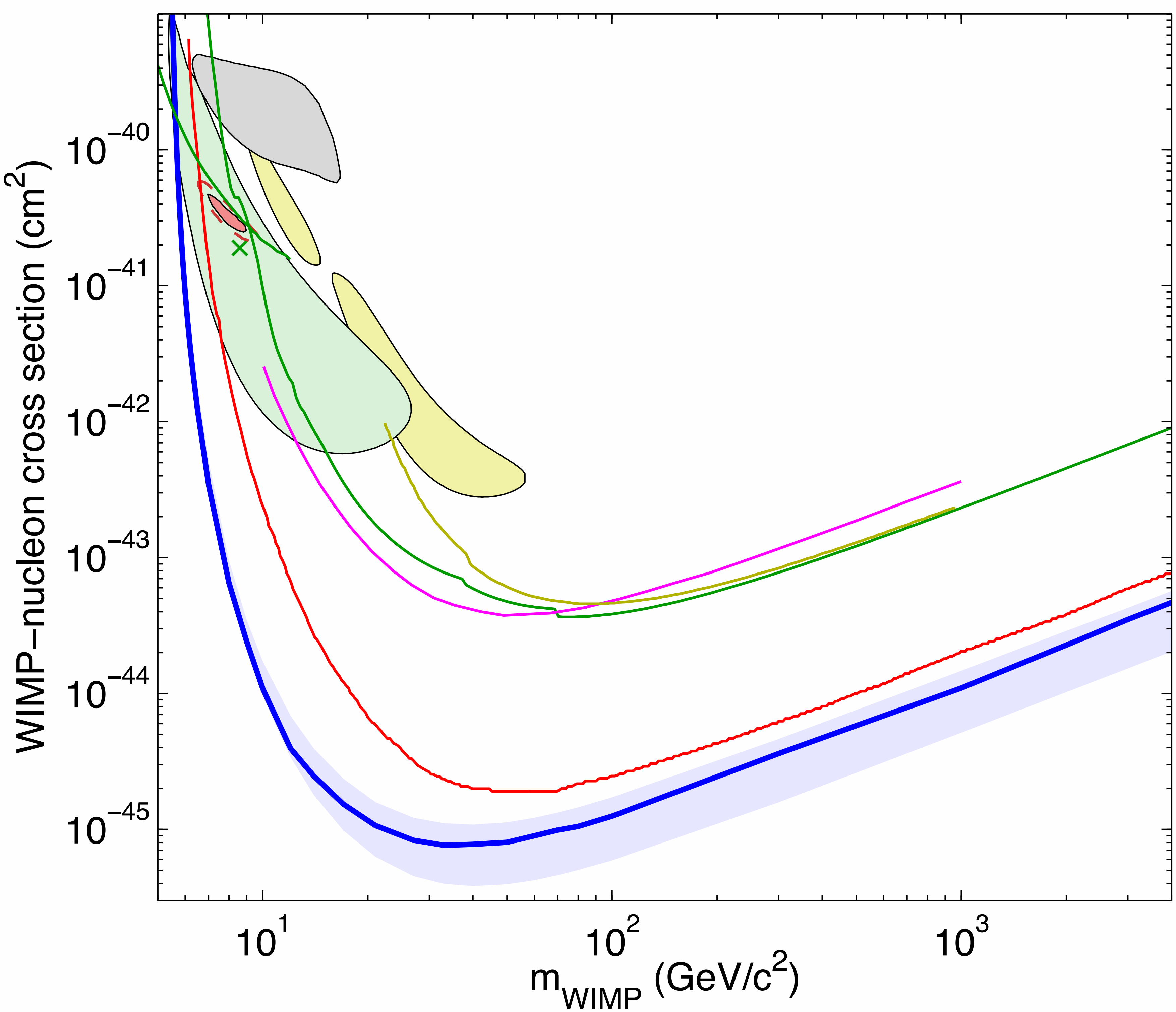
LUX WIMP Search, 85 live-days, 118 kg



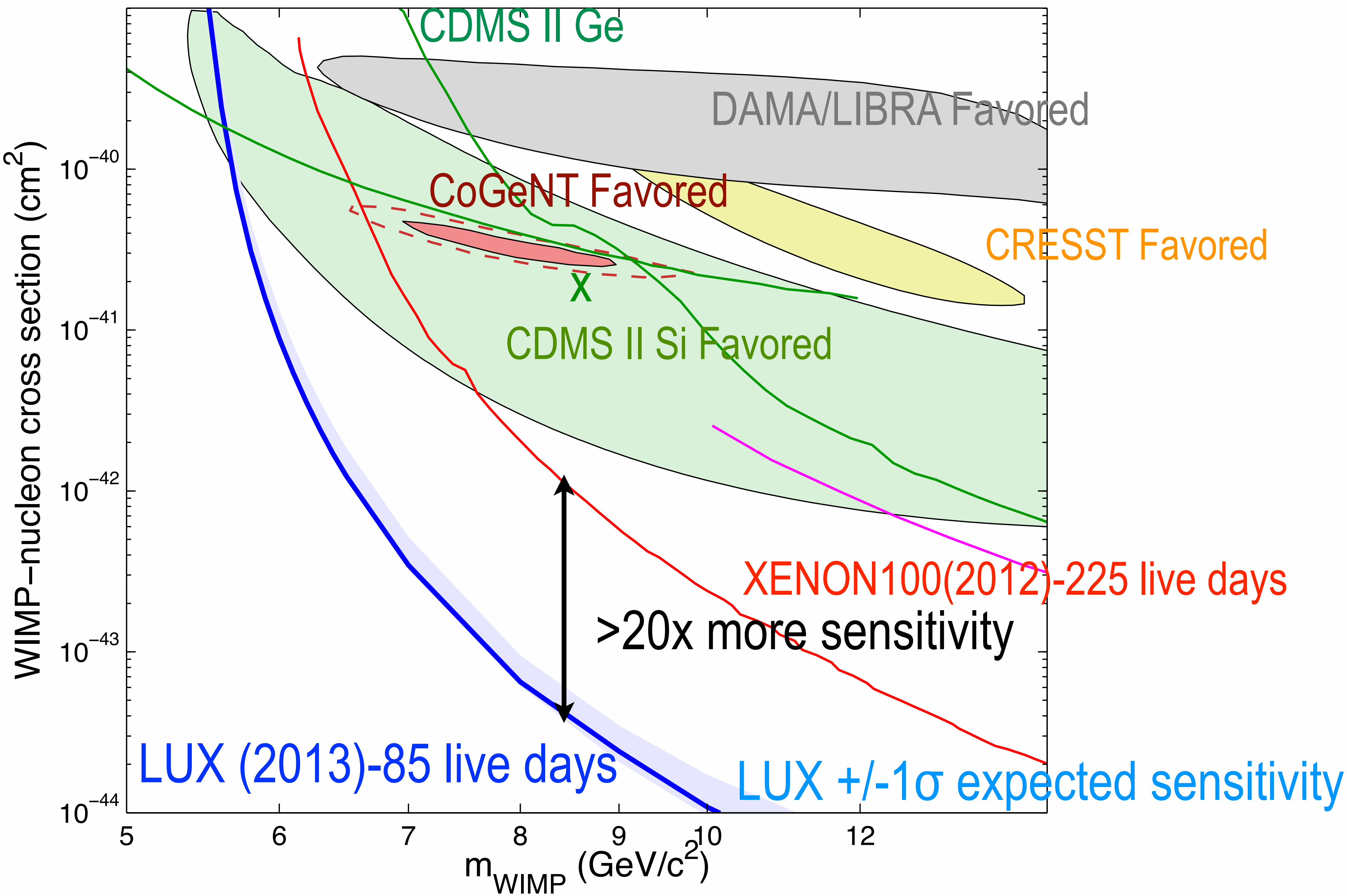
Spin Independent Sensitivity Plots



Spin Independent Sensitivity Plots

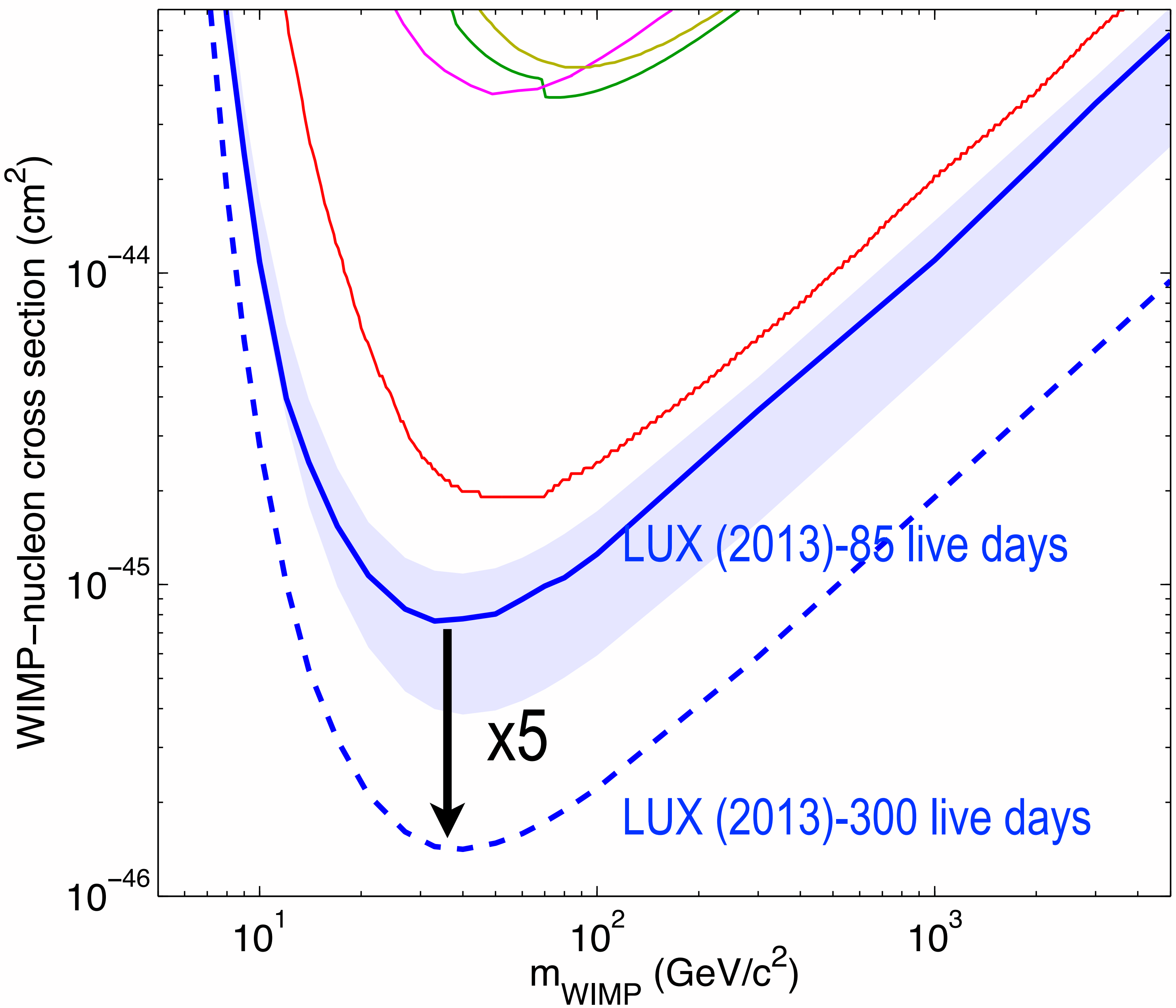


Low Mass WIMPs - Fully excluded by LUX



Projected LUX 300 day WIMP Search Run

- We intend to run LUX for a new run of 300 days in 2014/15
  - Extending sensitivity by another factor 5
  - Even though LUX sees no WIMP-like events in the current run, it is still quite possible to discover a signal when extending the reach
  - LUX does not exclude LUX



- WIMPs remain our favored quarry

- LZ 20x increase in target mass
  - If approved plans to be deployed in Davis Lab in 2016+
  - (Talk by Tom Shutt)

LUX Statistics

12,474 person-days on site at Sanford Lab so far ...

5.8 million feet travelled vertically

>1/2 million Wiki Page Reads
(that is reading all of War and Peace every day for over a year)

We started to estimate the number of USPS employees that would have been employed to move the 2 million+ P2P email messages, if messages were still carried by conventional means ... but then we realized we had talks to write

Conclusion

- LUX has made a WIMP Search run of 86 live-days and released the analysis + PRL submission within 9 months of first cooling in Davis Lab
  - Backgrounds as expected, inner fiducial ER rate <2 events/day in region of interest
  - Major advances in calibration techniques including ^{83m}Kr and Tritiated-CH_4 injected directly into Xe target
  - Very low energy threshold achieved 3 keVnr with no ambiguous/leakage events
  - ER rejection shown to be 99.6+/-0.1% in energy range of interest
- Intermediate and High Mass WIMPs
  - Extended sensitivity over existing experiments by x3 at 35 GeV and x2 at 1000 GeV
- Low Mass WIMP Favored Hypotheses ruled out
  - LUX WIMP Sensitivity 20x better
  - LUX does not observe 6-10 GeV WIMPs favored by earlier experiments
- Thanks to:
  - DOE and NSF
  - Governor and State of South Dakota and Denny Sanford
  - Sanford Lab for all their support to get to this world-leading result

LUX Results Paper

LUX Results Paper will be available at 10.15 am MT on

http://sanfordlab.org
http://luxdarkmatter.org

Will also be available on http://arXiv.org tonight.

Paper has been submitted to PRL

Welcome to **Club Sub Zepto** (*)

LUX is the first WIMP detector to reach below a zeptobarn cross section

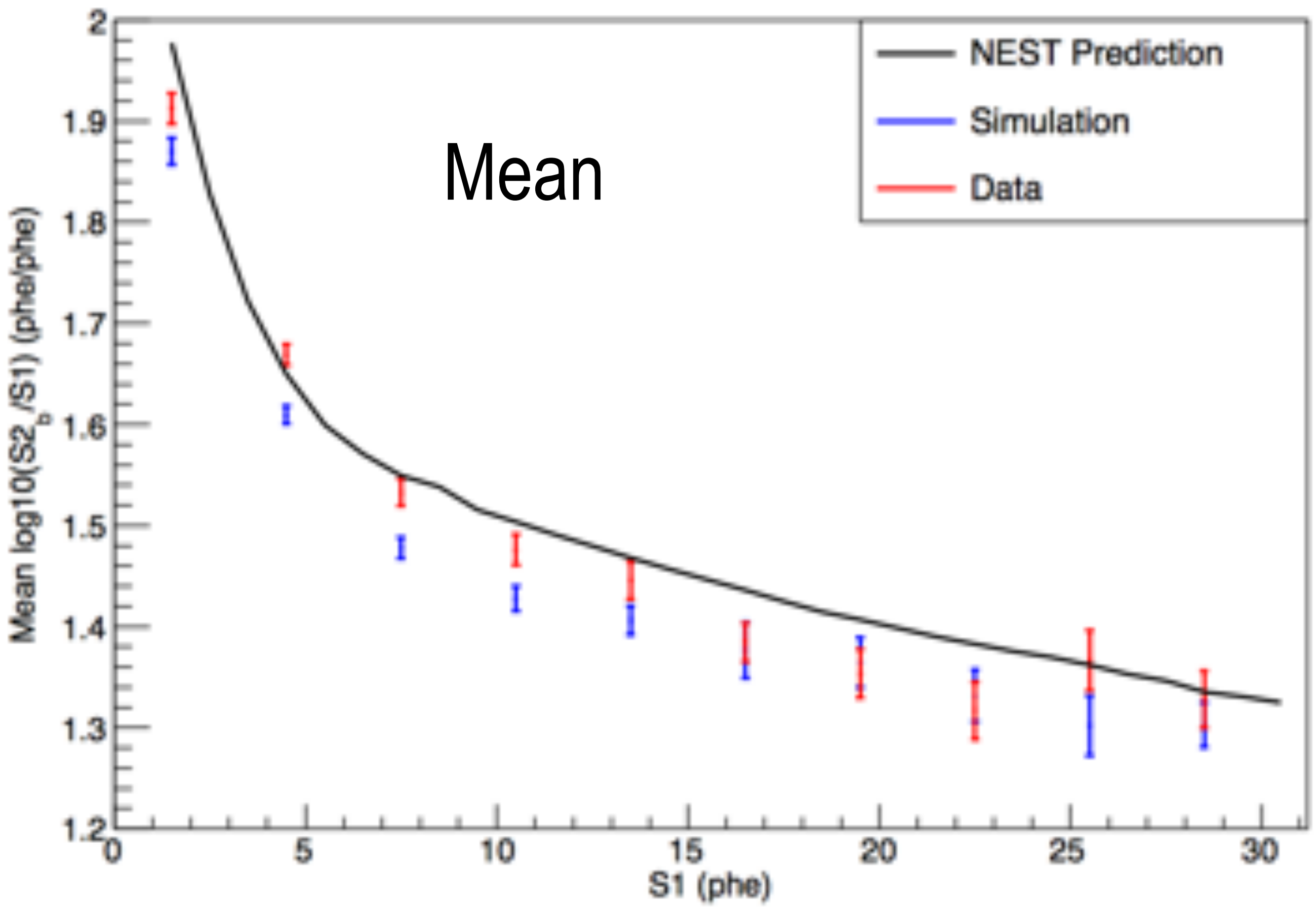
* zeptobarn is 10^{-45} cm^2

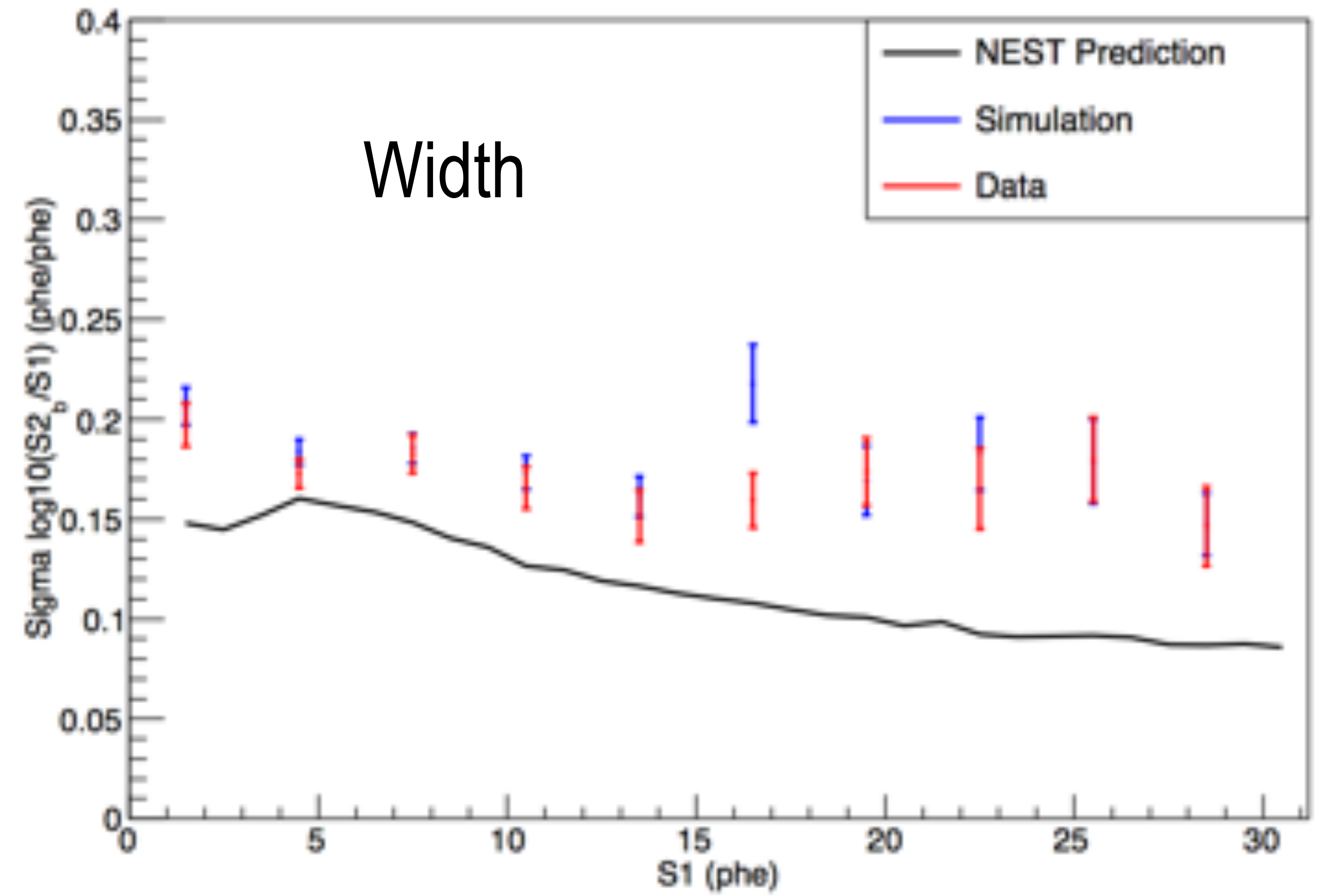
A barn is the size of barn door at nuclear scales!

[redacted]

- SUPPORTING MATERIAL

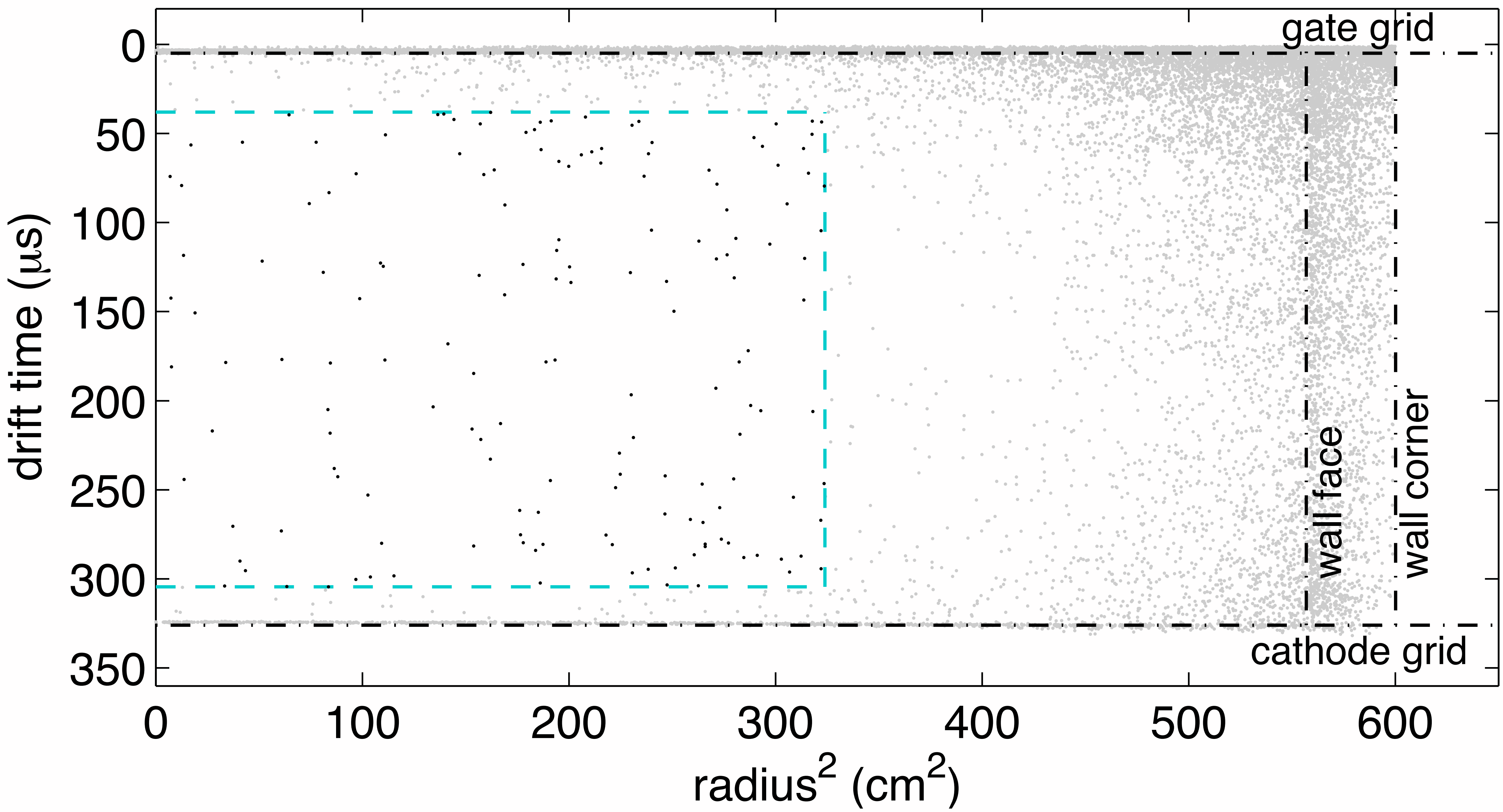
NR Calibrations





- Above plots show comparisons between simulation (blue), the NEST prediction (black), and data for the mean and width of the nuclear recoil band from AmBe calibrations
- The mean and width are different in the calibrations because the data contain ER contamination and neutron-X events, which are modeled well by the simulation

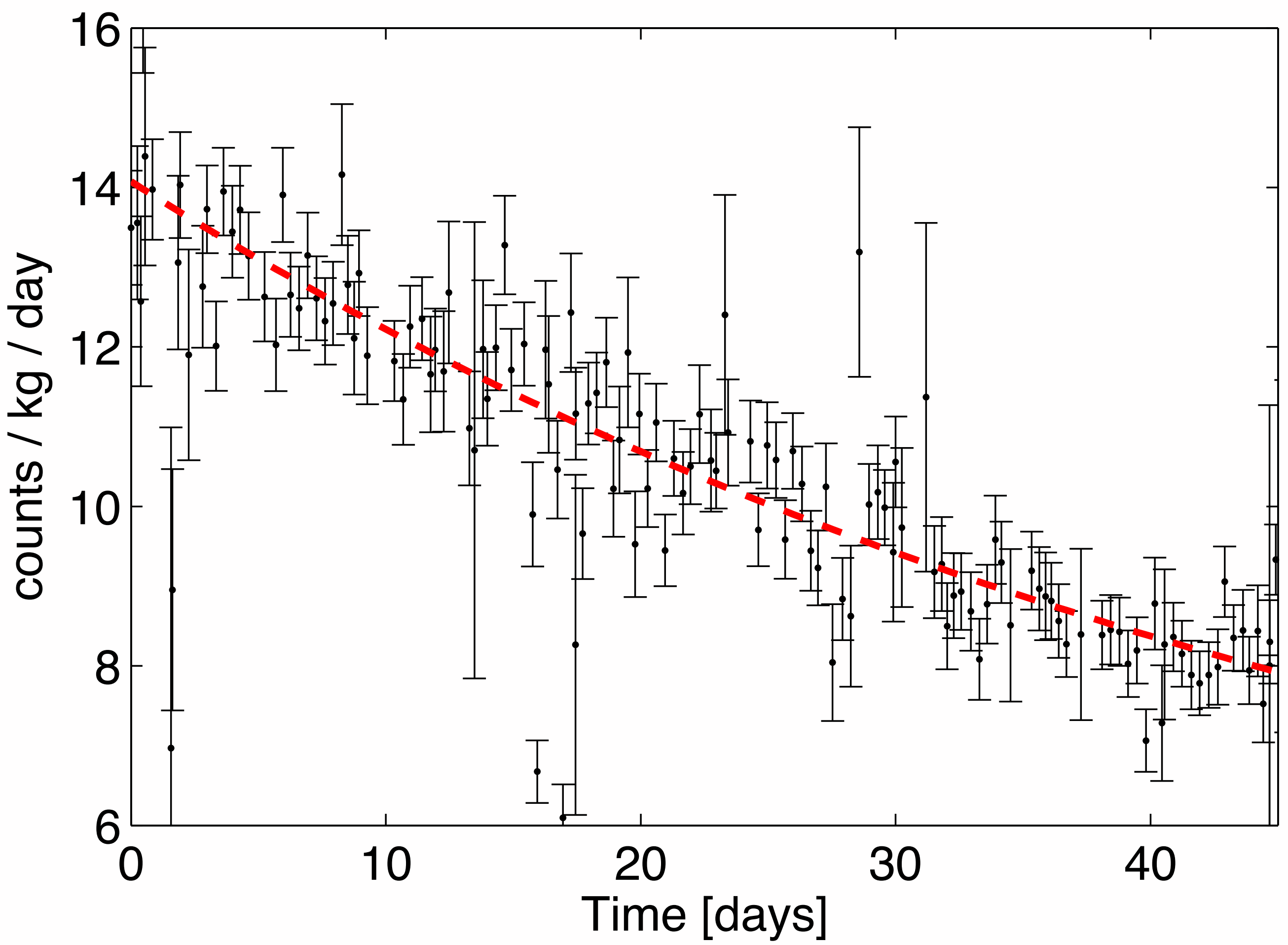
Position of Low Energy Events in 85 day Exposure

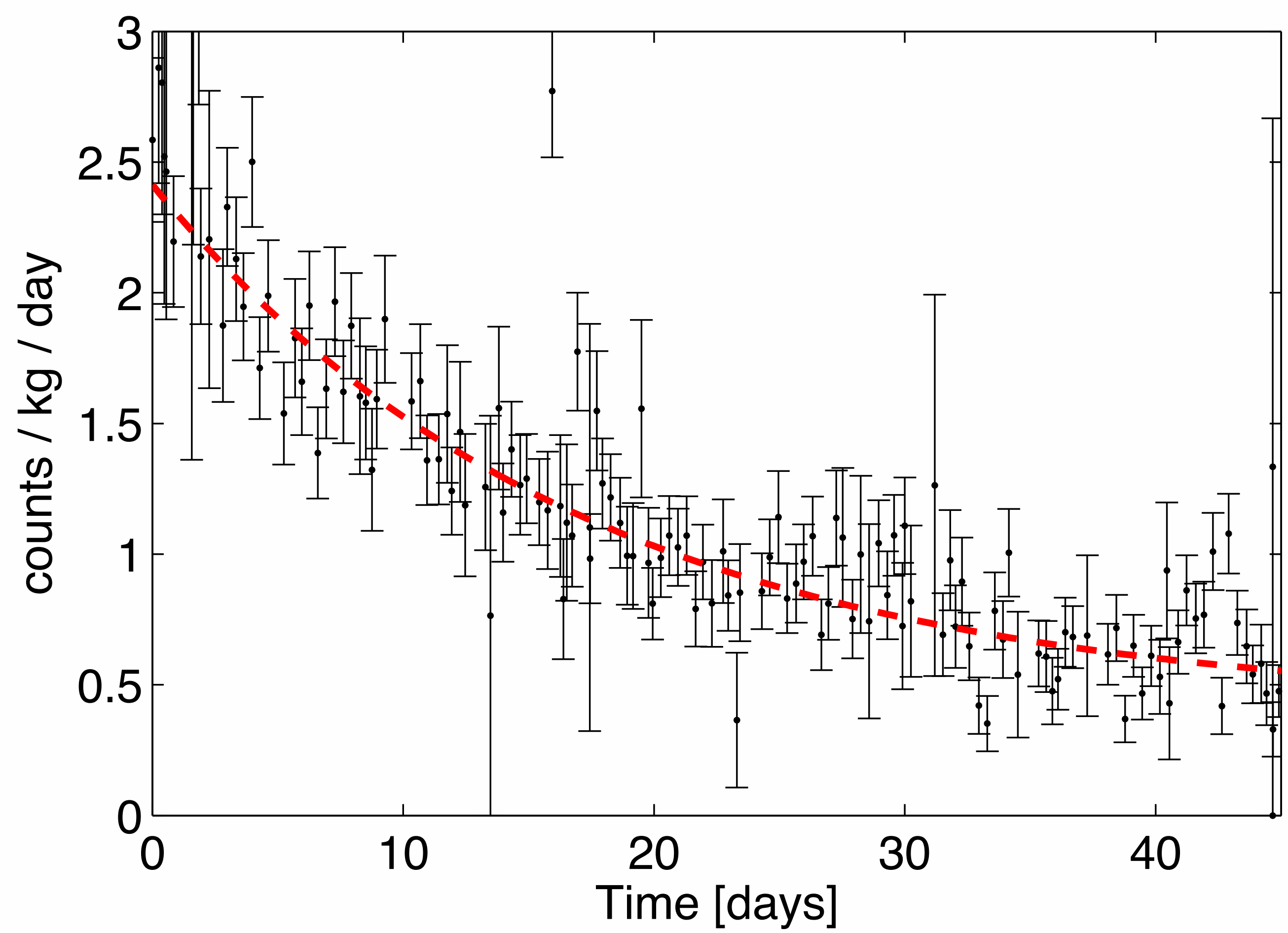


Cosmogenic Isotopes Decaying

- 127Xe Decay vs Time

131mXe Decay vs Time





AmBe S2 Calibration