The LUX DIRECT DARK MATTER SEARCH

Alex Murphy

IPPP Senior Experimental Fellow

The LUX collaboration

Berkeley Lab / UC Berkeley

Bob Jacobsen	PI, Professor
Murdock Gilchriese	Senior Scientist
Kevin Lesko	Senior Scientist
Michael Witherell	Lab Director
Peter Sorensen	Scientist
Simon Fiorucci	Project Scientist
Attila Dobi	Postdoc
Daniel Hogan	Graduate Student
Kate Kamdin	Graduate Student
Kelsey Oliver-Mallory	Graduate Student

Brown University

Richard Gaitskell	PI, Professor
Samuel Chung	Graduate Student
Dongqing Huang	Graduate Student
Casey Rhyne	Graduate Student
Will Taylor	Graduate Student
James Verbus	Postdoc

University of Edinburgh, UK

Alex Murphy	PI, Professor
Paolo Beltrame	Research Fellow
Tom Davison	Graduate Student
Maria F. Marzioni	Graduate Student

Imperial College London, UK

Henrique Araujo	PI, Reader
Tim Sumner	Professor
Alastair Currie	Postdoc
Adam Bailey	Graduate Student
Khadeeja Yazdani	Graduate Student

Lawrence Livermore

Adam Bernstein	PI, Leader of Adv. Detectors Grp.
Kareem Kazkaz	Staff Physicist
Jingke Xu	Postdoc
Brian Lenardo	Graduate Student

LIP Coimbra, Portugal

Isabel Lopes	PI, Professor
Jose Pinto da	Assistant Professor
Vladimir Solovov	Senior Researcher
Francisco Neves	Auxiliary Researcher
Alexander Lindote	Postdoc
Claudio Silva	Postdoc
Paulo Bras	Graduate Student

SLAC Stanford (CWRU)

Dan Akerib	PI, Professor
Thomas Shutt	PI, Professor
Tomasz Biesiadzinski	Research Associate
Christina Ignarra	Research Associate
Wing To	Research Associate
Rosie Bramante	Graduate Student
Wei Ji	Graduate Student
T.J. Whitis	Graduate Student

SD Mines

Xinhua Bai	PI, Professor
Doug Tiedt	Graduate Student

SDSTA / Sanford Lab

David Taylor	Project Engineer
Markus Horn	Research Scientist
Dana Byram	Support Scientist

University at Albany

Matthew Szydagis	PI, Professor
Jeremy Mock	Postdoc
Sean Fallon	Graduate Student
Jack Genovesi	Graduate Student
Steven Young	Graduate Student

Texas A&M University

James White †	PI, Professor
Robert Webb	PI, Professor
Rachel Mannino	Graduate Student
Paul Terman	Graduate Student

UC Berkeley (Yale)

Daniel McKinsey	PI, Professor
Ethan Bernard	Project Scientist
Scott Hertel	Postdoc
Kevin O'Sullivan	Postdoc
Elizabeth Boulton	Graduate Student
Evan Pease	Graduate Student
Brian Tennyson	Graduate Student
Lucie Tvrznikova	Graduate Student
Nicole Larsen	Graduate Student

UC Davis

Mani Tripathi	PI, Professor
Britt Hollbrook	Senior Engineer
John Thomson	Development
Dave Hemer	Senior Machinist
Ray Gerhard	Electronics Engineer
Aaron Manalaysay	Project Scientist
Jacob Cutter	Graduate Student
James Morad	Graduate Student
Sergey Uvarov	Graduate Student

UC Santa Barbara

Harry Nelson	PI, Professor
Susanne Kyre	Engineer
Dean White	Engineer
Carmen Carmona	Postdoc
Scott Haselschwardt	Graduate Student
Curt Nehrkorn	Graduate Student
Melih Solmaz	Graduate Student

University College London, UK

Chamkaur Ghag	PI, Lecturer
James Dobson	Postdoc
Sally Shaw	Graduate Student

University of Maryland

Carter Hall	PI, Professor
Jon Balajthy	Graduate Student
Richard Knoche	Graduate Student

University of Rochester

Frank Wolfs	PI, Professor
Wojtek Skutski	Senior Scientist
Eryk Druszkiewicz	Graduate Student
Dev Ashish Khaitan	Graduate Student
Diktat Koyuncu	Graduate Student
M. Moongweluwan	Graduate Student
Jun Yin	Graduate Student

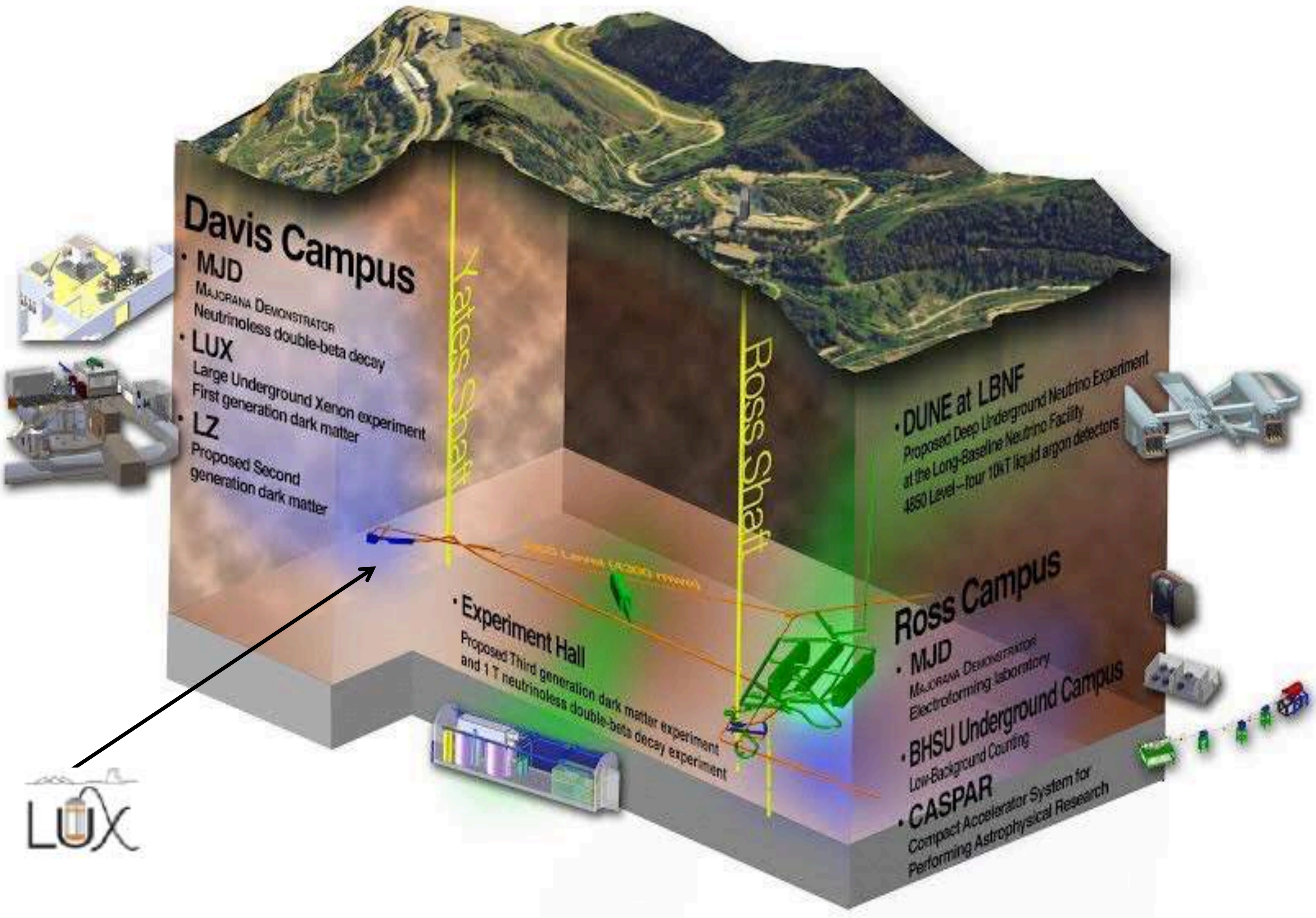
University of South Dakota

Dongming Mei	PI, Professor
Chao Zhang	Postdoc

University of Wisconsin

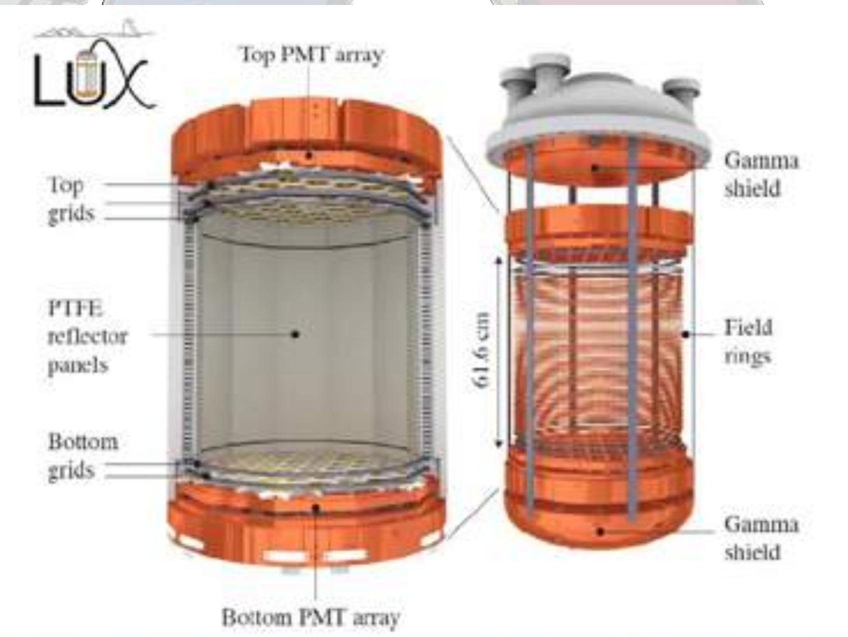
Kimberly Palladino	PI, Asst Professor
Shaun Alsum	Graduate Student

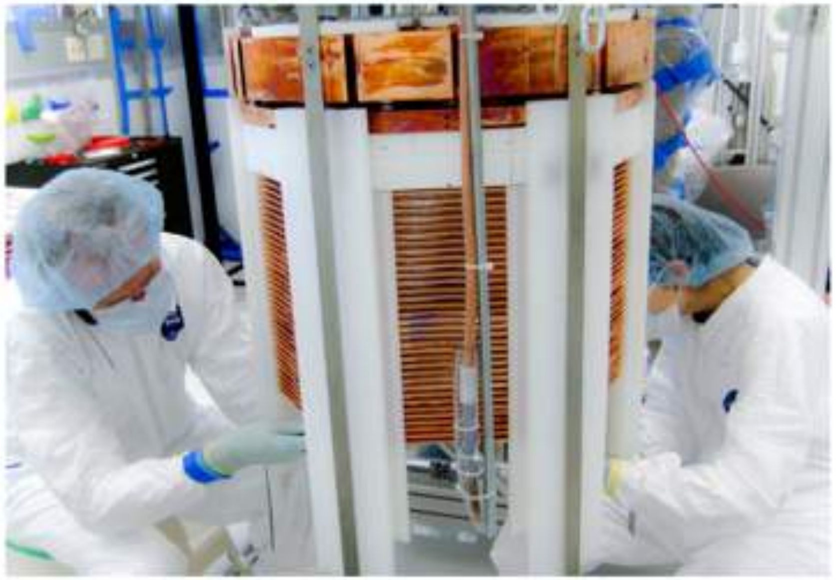

SOUTH DAKOTA
Minneapolis, MN
Sioux Falls
New York, NY
Chicago, IL
Denver, CO
Kansas City, MO
Los Angeles, CA
Dallas, TX

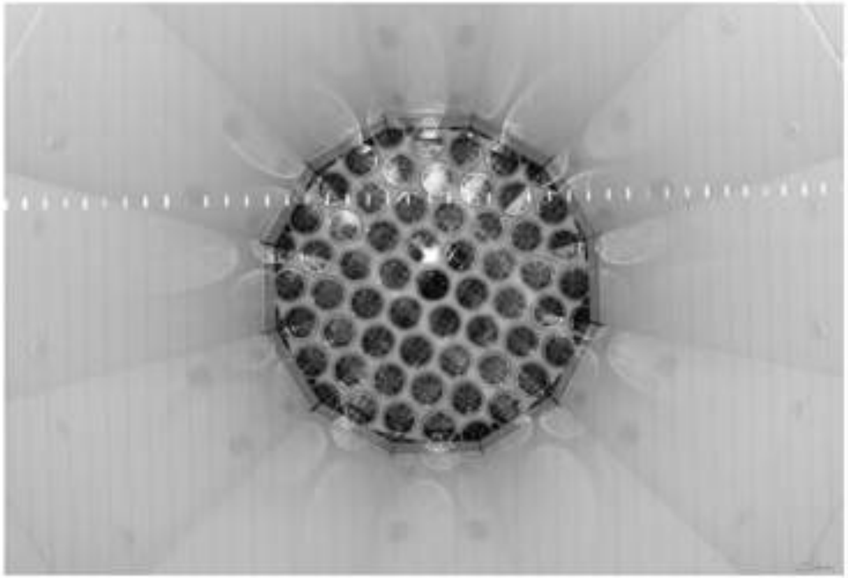


Davis Campus
• MJD
MAJORANA DEMONSTRATOR
Neutrinoless double-beta decay
• LUX
Large Underground Xenon experiment
First generation dark matter
• LZ
Proposed Second generation dark matter
Yates Shaft
Ross Shaft
• DUNE at LBNF
Proposed Deep Underground Neutrino Experiment at the Long-Baseline Neutrino Facility
4850 Level~four 10kT liquid argon detectors
• Experiment Hall
Proposed Third generation dark matter experiment and 1 T neutrinoless double-beta decay experiment
Ross Campus
• MJD
MAJORANA DEMONSTRATOR
Electroforming laboratory
• BHSU Underground Campus
Low-Background Counting
• CASPAR
Compact Accelerator System for Performing Astrophysical Research
LUX

The 8-m diameter LUX water tank (to contain LZ), Davis Campus, 4850-ft u/g level, Sanford Underground Research Facility


LUX
Top PMT array
Top grids
PTFE reflector panels
Bottom grids
Bottom PMT array
61.6 cm
Gamma shield
Field rings
Gamma shield



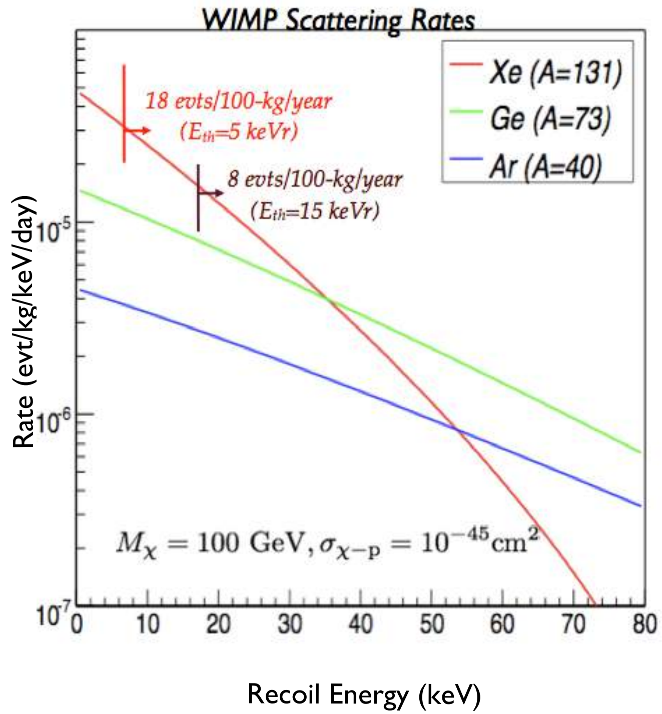


Liquid Xenon TPCs

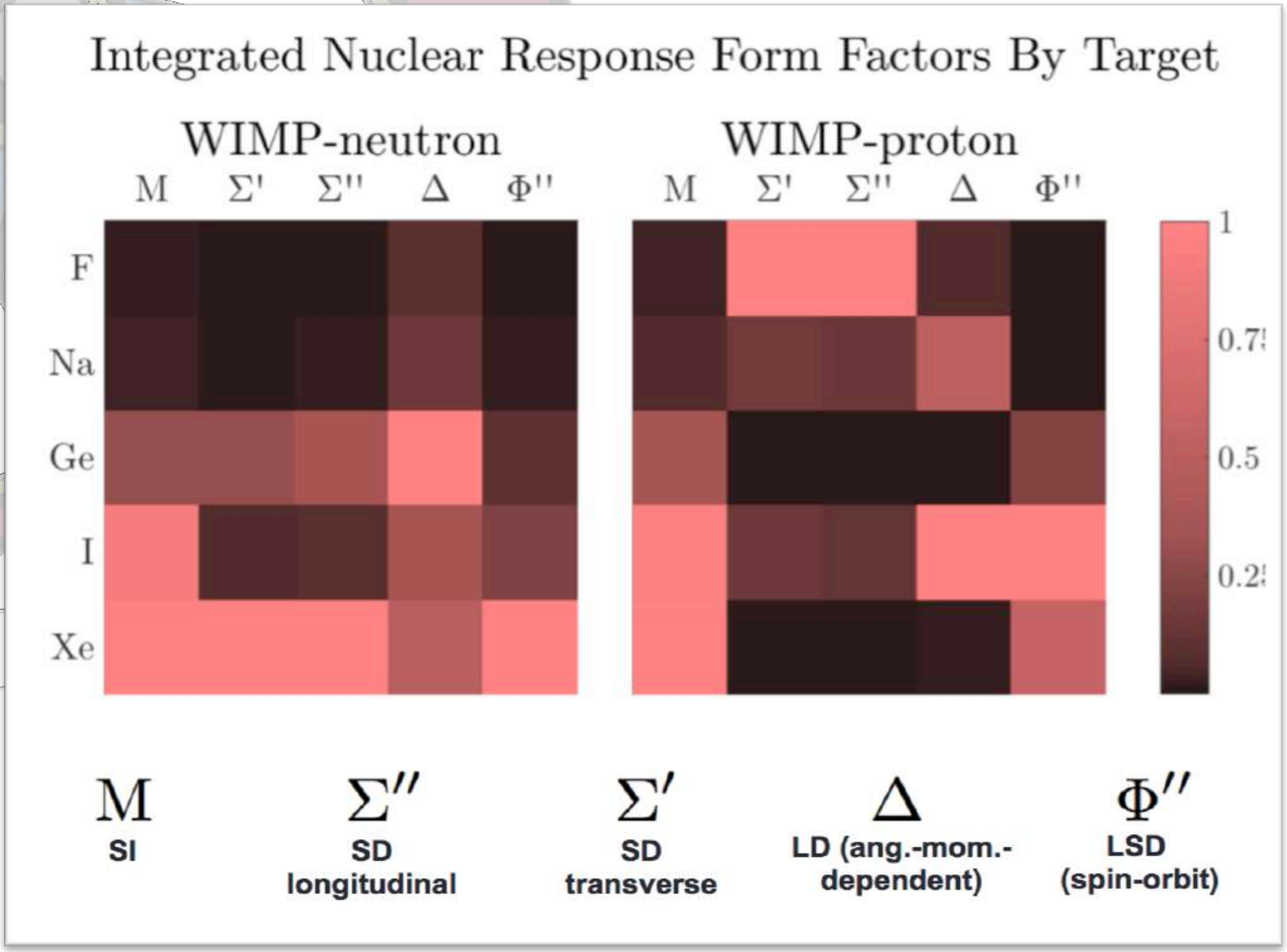
- **S1: LXe is an excellent scintillator**
  - Light yield: >60 ph/keV (0 field)
  - Scintillation light: 178 nm (VUV)

- **S2: Even better ionisation detector**
  - S1+S2 allows mm vertex reconstruction
  - Sensitive to single ionisation electrons

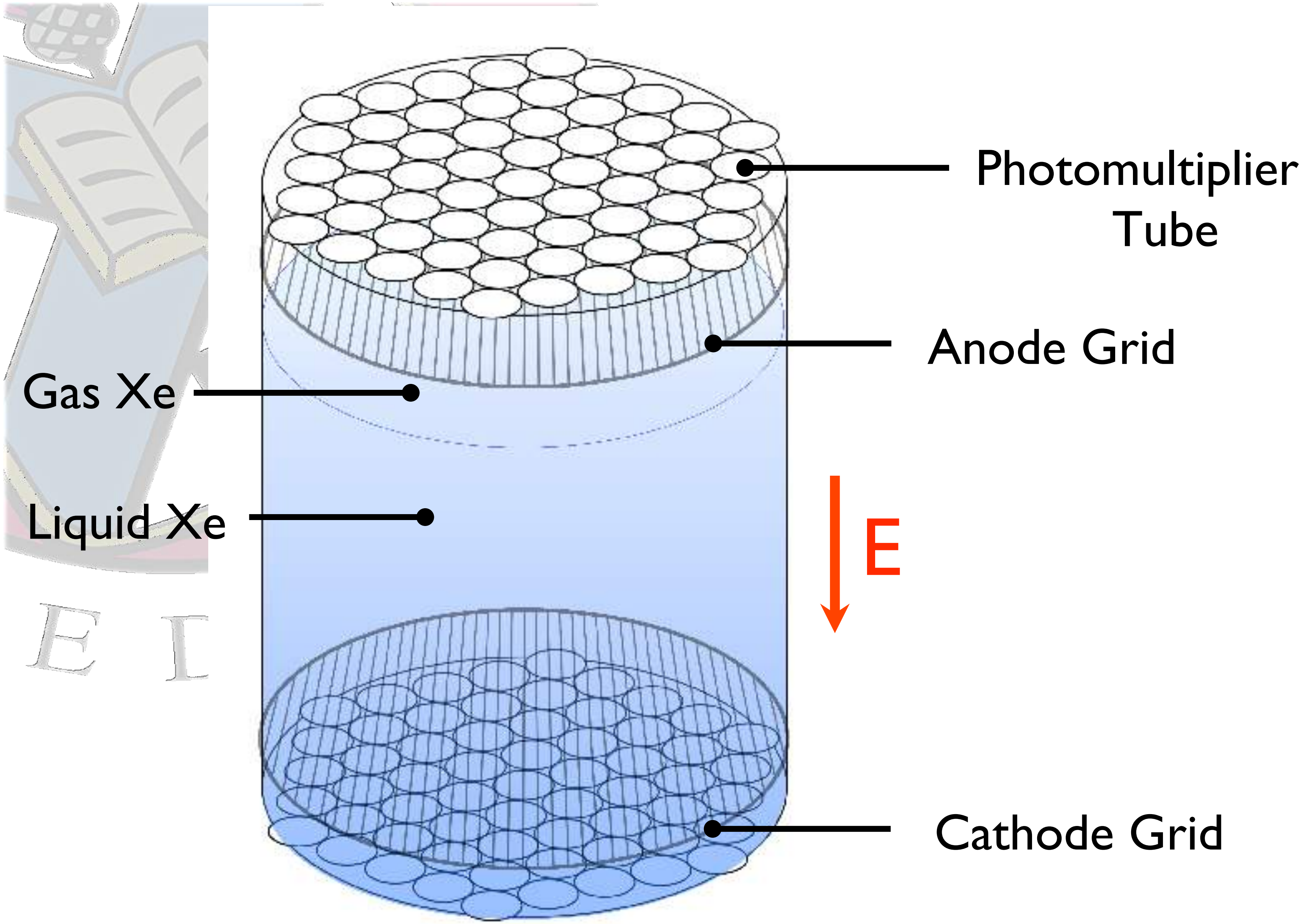
- **Well suited to WIMP searches**
  - Density: 3 g/cm^3
  - Scalar WIMP-nucleon scattering rate dR/dE~A^2
  - Odd-neutron isotopes (^{129}Xe, ^{131}Xe) enable spin-dependent sensitivity
  - Excellent ionisation threshold: 'light WIMP' searches using S2 only
  - No intrinsic backgrounds (^{85}Kr can be removed, low rate from ^{136}Xe $2\nu\beta\beta$)
  - Easily scaled with no loss of performance (actually improves!)

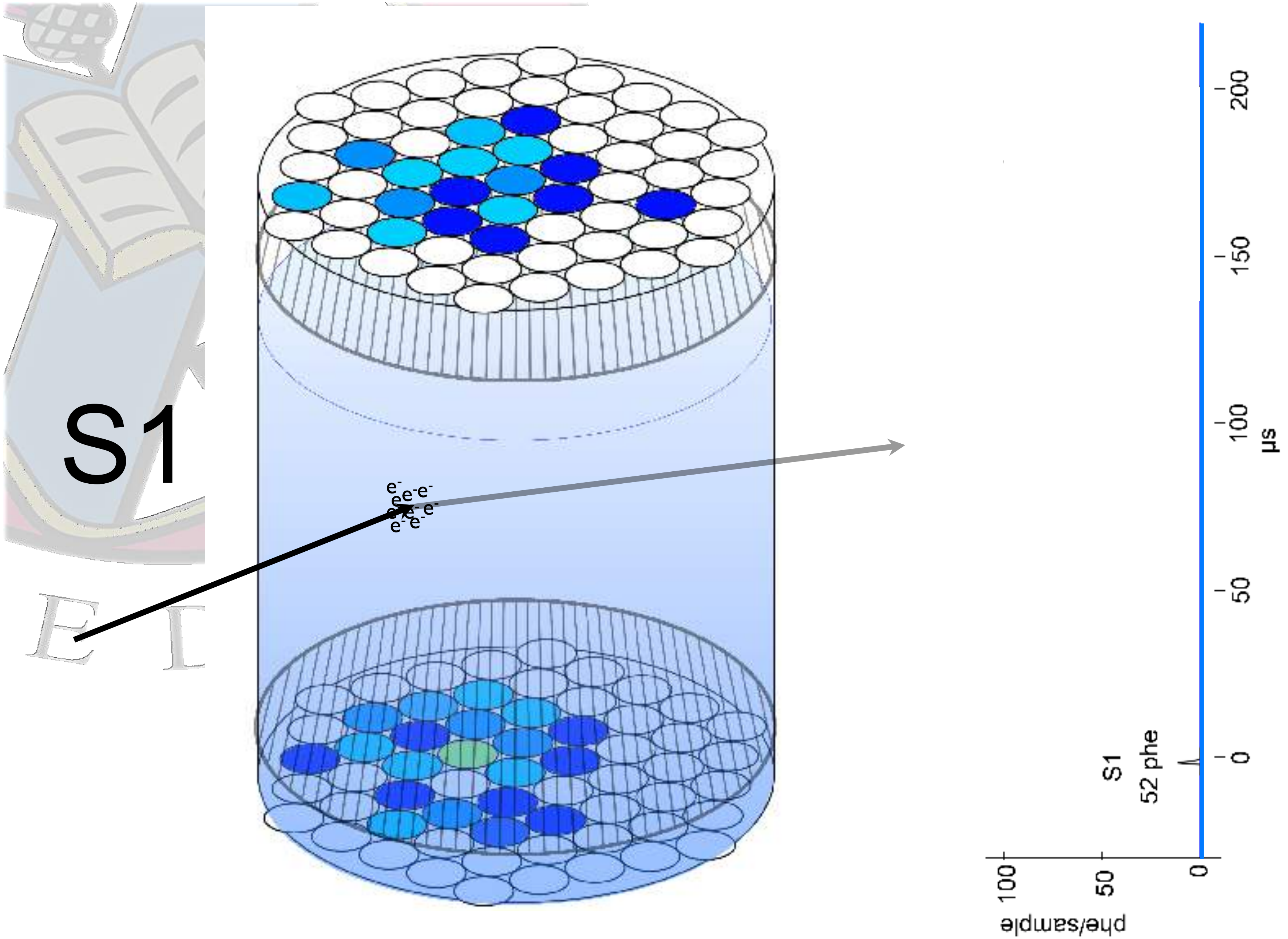


Liquid Xenon TPCs



N. Larsen, http://conference.ippp.dur.ac.uk/event/544/session/0/contribution/7/material/slides/0.pdf

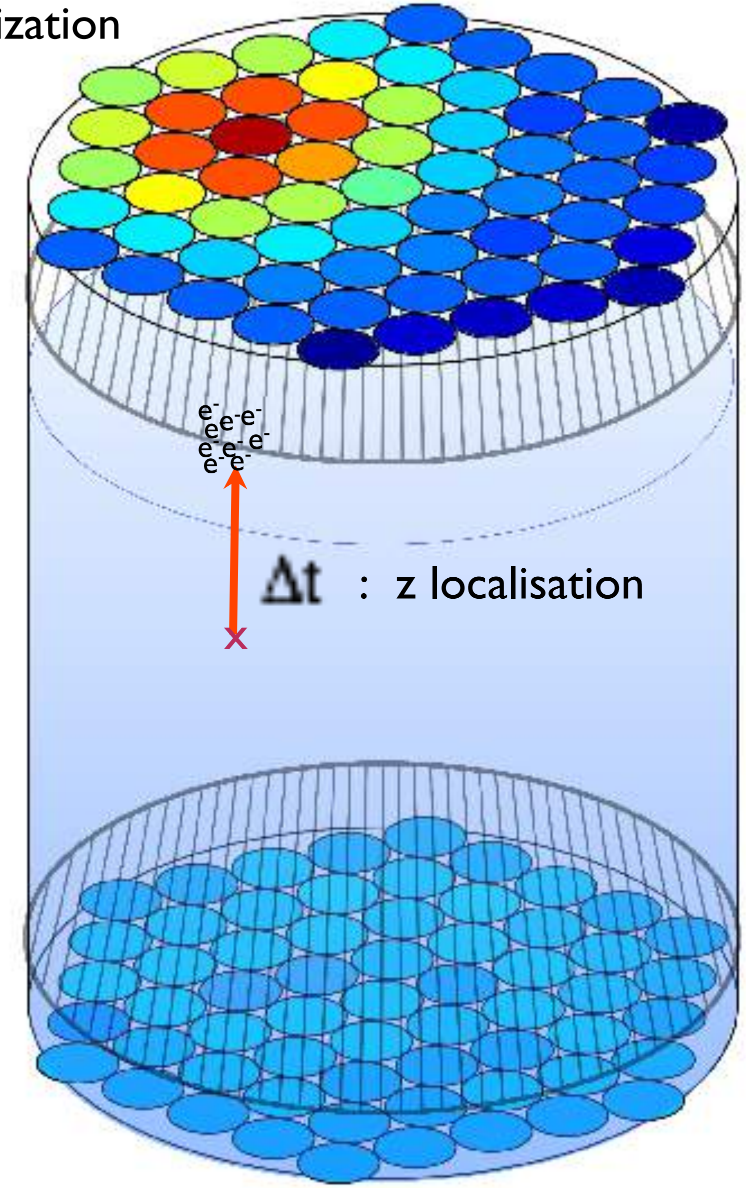

Photomultiplier
Tube
Anode Grid
Gas Xe
Liquid Xe
E
Cathode Grid

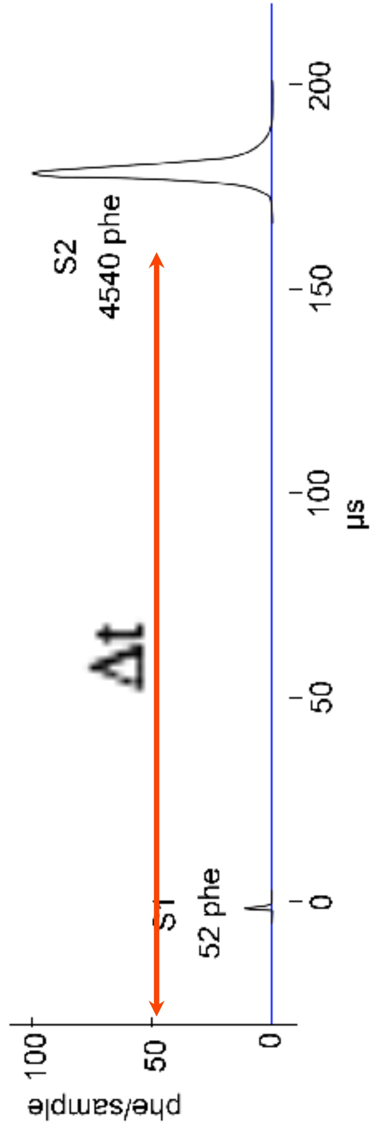


S1
e-
S1
52 phe
μs
phe/sample
0
50
100
150
200

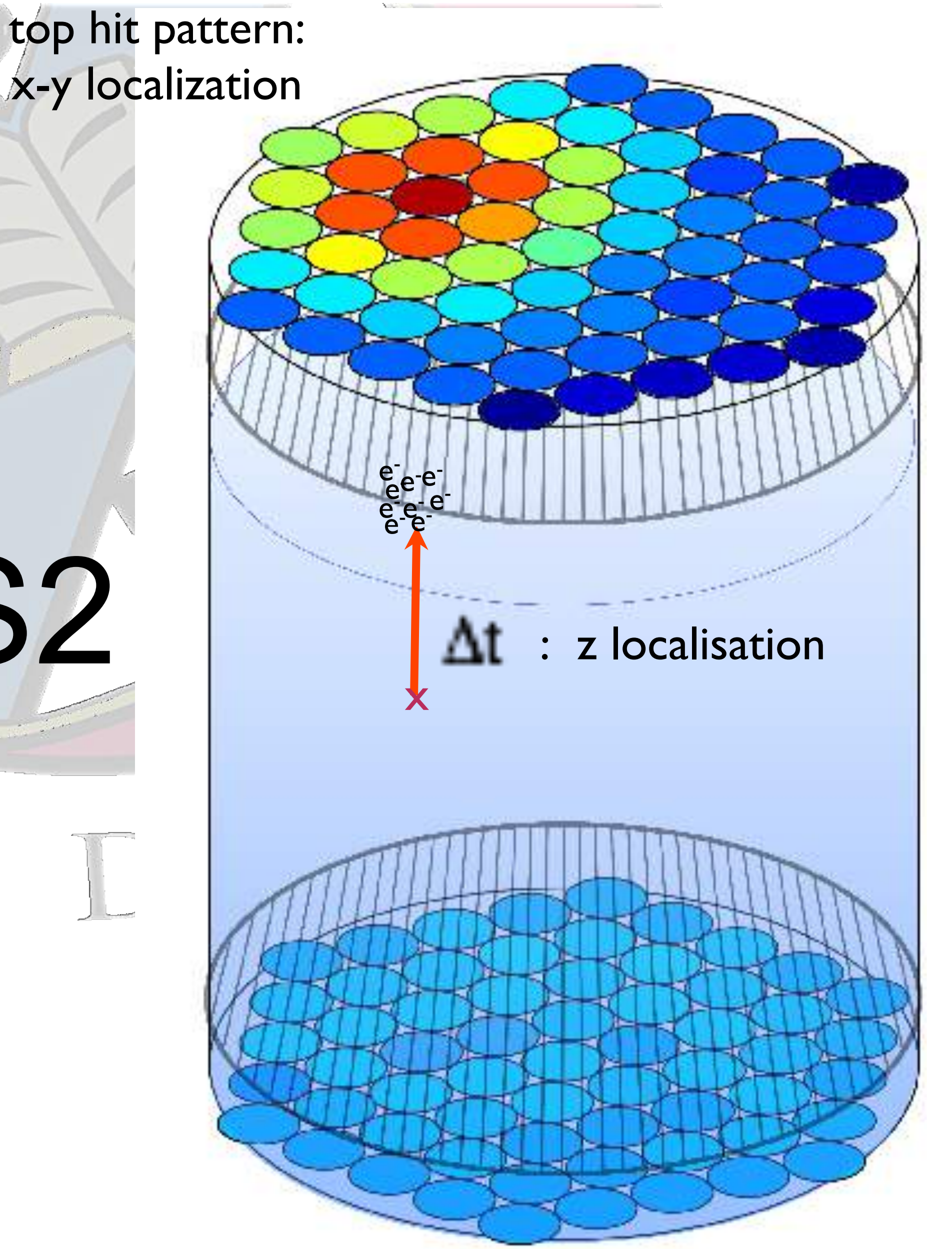
top hit pattern:
x-y localization

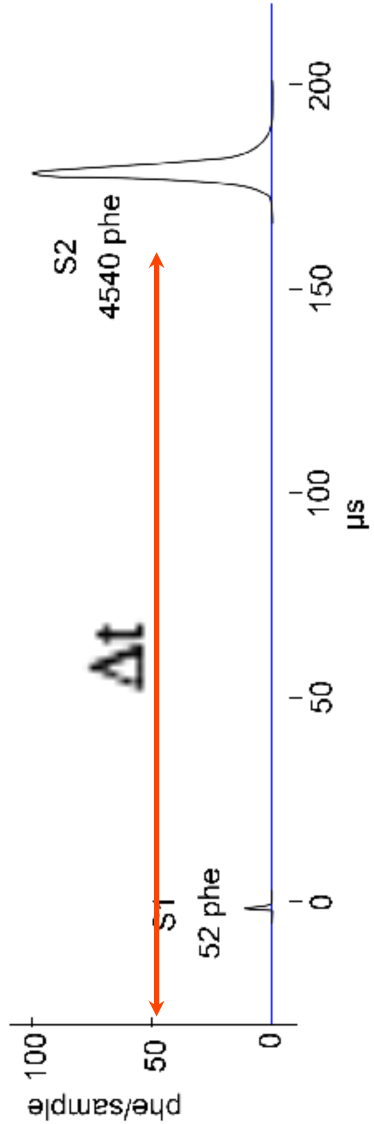
S2



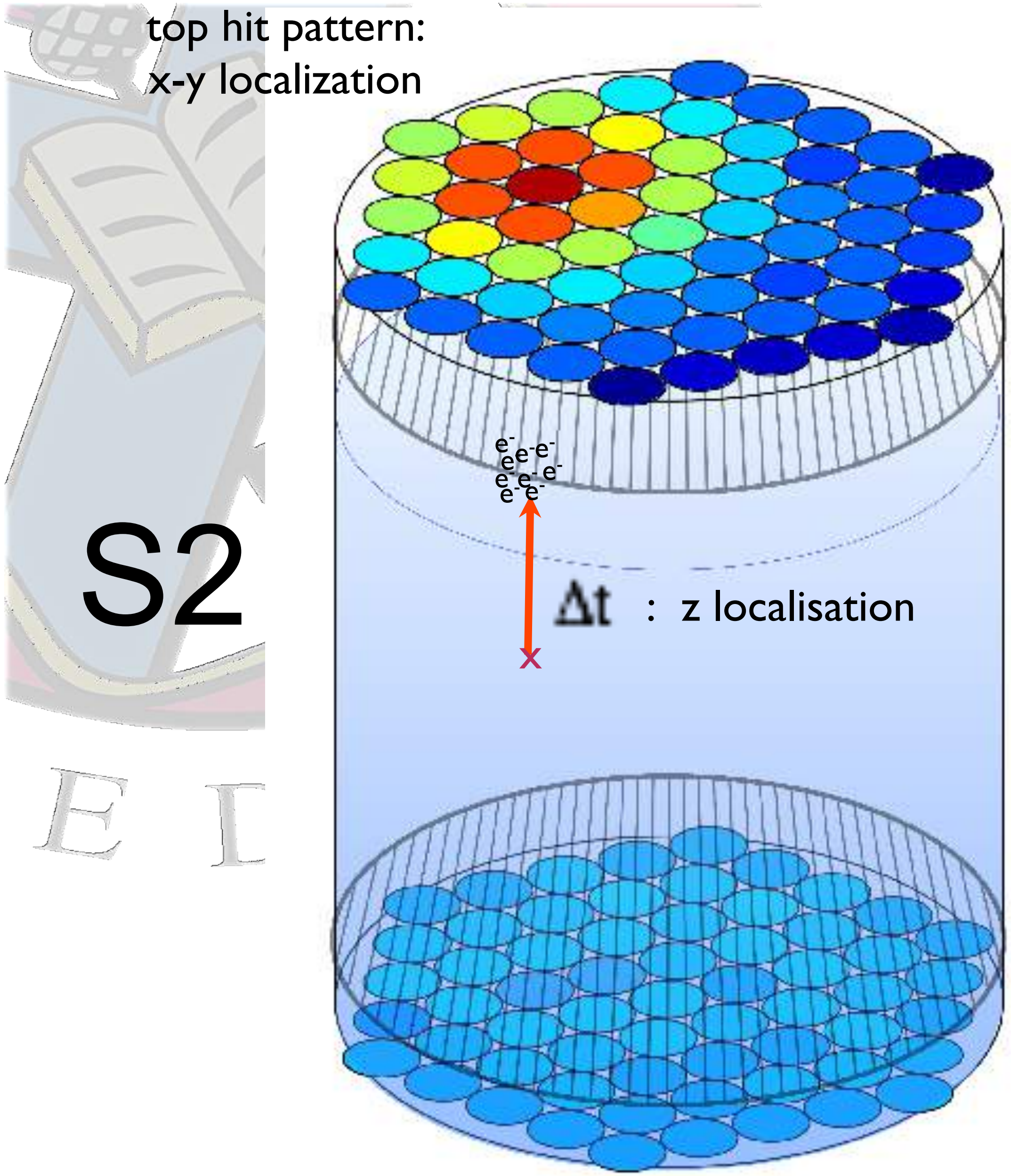


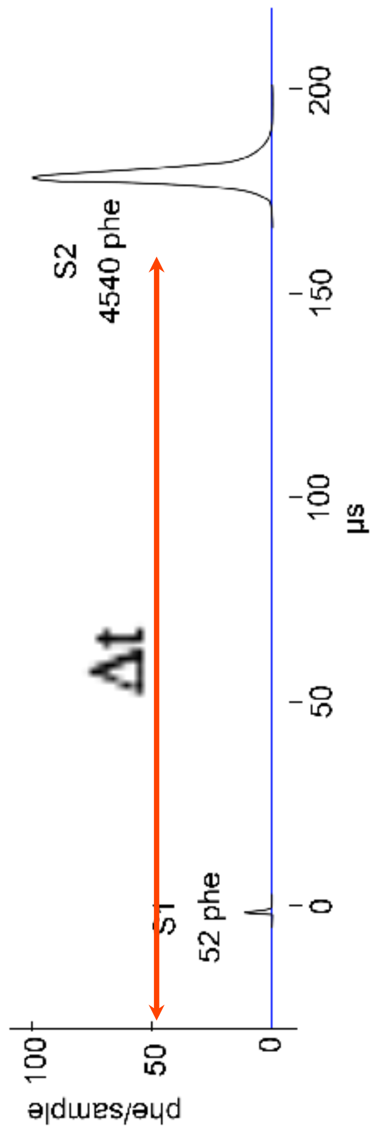
S2





Ratio of S2 to S1 depends on whether an electron or a neutron is recoiling.

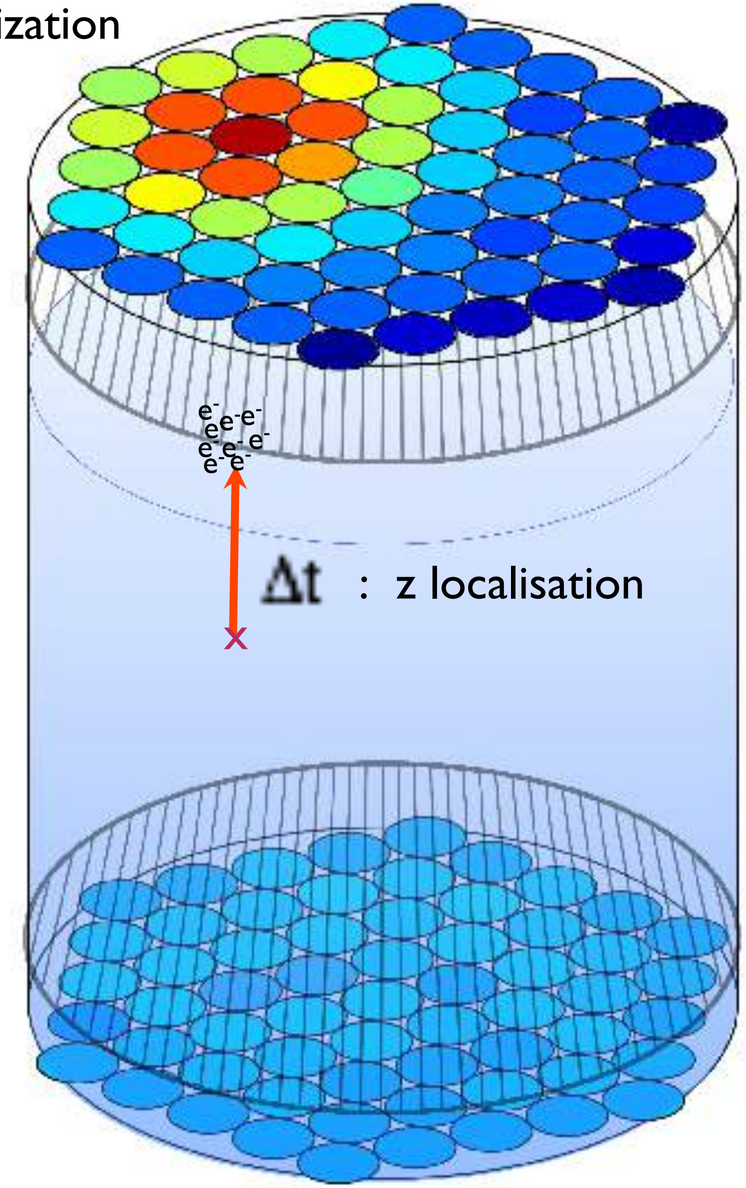


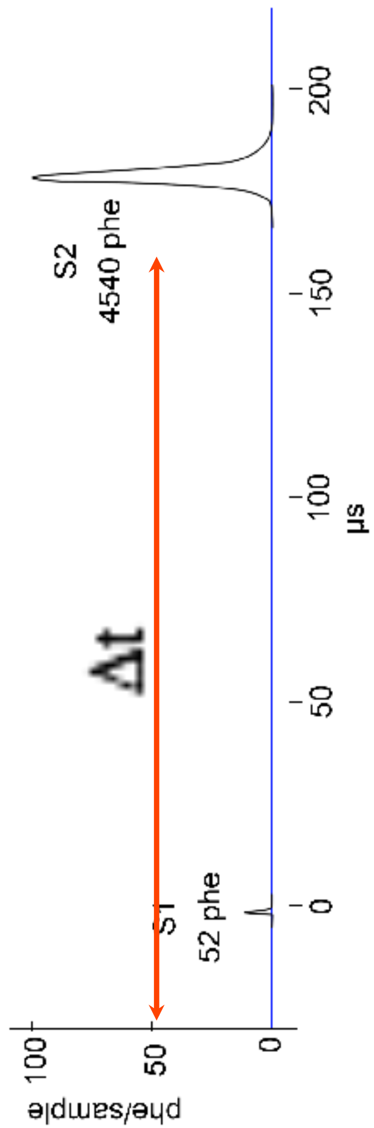


Most backgrounds are electron recoils(gamma-rays or beta particles)

top hit pattern:
x-y localization

S2

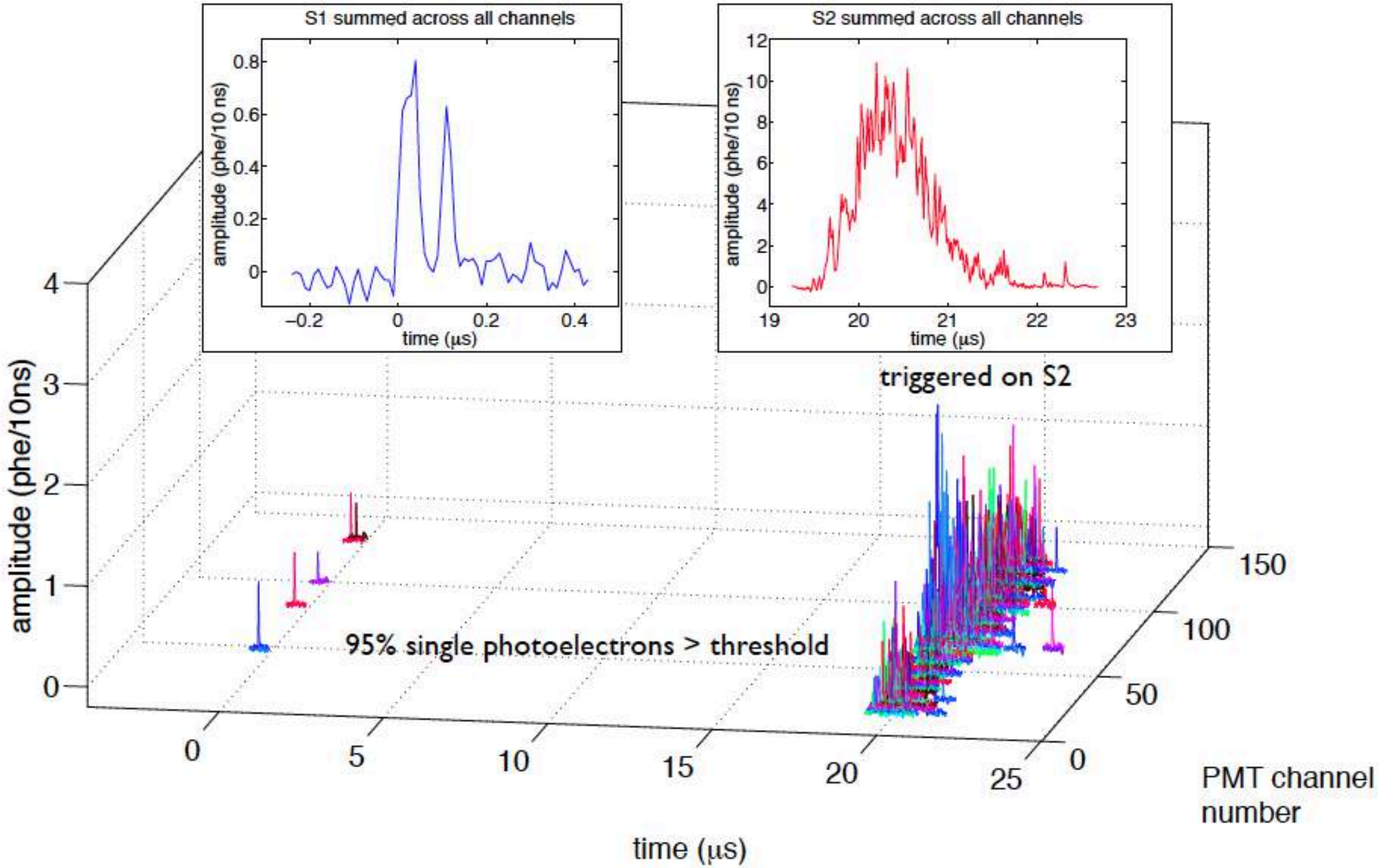




Allows us to reject >99.5% of background

A typical event…

A 1.5 keVee electron recoil
(combined energy reconstruction)



What have we done?

PRL 112, 091303 (2014) PHYSICAL REVIEW LETTERS week ending 7 MARCH 2014

First Results from the LUX Dark Matter Experiment at the Sanford Underground Research Facility

D. S. Akerib,[2] H. M. Araújo,[4] X. Bai,[8] A. J. Bailey,[4] J. Balajthy,[16] S. Bedikian,[19] E. Bernard,[19] A. Bernstein,[6] A. Bolozdynya,[2] A. Bradley,[2] D. Byram,[18] S. B. Cahn,[19] M. C. Carmona-Benitez,[2,14] C. Chan,[1] J. J. Chapman,[1] A. A. Chiller,[18] C. Chiller,[18] K. Clark,[2] T. Coffey,[2] A. Currie,[4] A. Curioni,[19] S. Dazeley,[6] L. de Viveiros,[7] A. Dobi,[16] J. Dobson,[15] E. M. Dragowsky,[2] E. Druszkiewicz,[17] B. Edwards,[19,†] C. H. Faham,[1,5] S. Fiorucci,[1] C. Flores,[13] R. J. Gaitskell,[1] V. M. Gehman,[5] C. Ghag,[11] K. R. Gibson,[2] M. G. D. Gilchriese,[5] C. Hall,[16] M. Hanhardt,[8,9] S. A. Hertel,[19] M. Horn,[19] D. Q. Huang,[1] M. Ihm,[12] R. G. Jacobsen,[12] L. Kastens,[19] K. Kazkaz,[6] R. Knoche,[16] S. Kyre,[14] R. Lander,[13] N. A. Larsen,[19] C. Lee,[2] D. S. Leonard,[16] K. T. Lesko,[5] A. Lindote,[7] M. I. Lopes,[7] A. Lyashenko,[19] D. C. Malling,[1] R. Mannino,[10] D. N. McKinsey,[19] D.-M. Mei,[18] J. Mock,[13] M. Moongweluwan,[17] J. Morad,[13] M. Morii,[3] A. St. J. Murphy,[15] C. Nehrkorn,[14] H. Nelson,[14] F. Neves,[7] J. A. Nikkel,[19] R. A. Ott,[13] M. Pangilinan,[1] P. D. Parker,[19] E. K. Pease,[19] K. Pech,[2] P. Phelps,[2] L. Reichhart,[11] T. Shutt,[2] C. Silva,[7] W. Skulski,[17] C. J. Sofka,[10] V. N. Solovov,[7] P. Sorensen,[6] T. Stiegler,[10] K. O'Sullivan,[19] T. J. Sumner,[4] R. Svoboda,[13] M. Sweany,[13] M. Szydagis,[13] D. Taylor,[9] B. Tennyson,[19] D. R. Tiedt,[8] M. Tripathi,[13] S. Uvarov,[13] J. R. Verbus,[1] N. Walsh,[13] R. Webb,[10] J. T. White,[10,*] D. White,[14] M. S. Witherell,[14] M. Wlasenko,[3] F. L. H. Wolfs,[17] M. Woods,[13] and C. Zhang[18]
(LUX Collaboration)

[1]*Department of Physics, Brown University, 182 Hope Street, Providence, Rhode Island 02912, USA*
[2]*Department of Physics, Case Western Reserve University, 10900 Euclid Avenue, Cleveland, Ohio 44106, USA*
[3]*Department of Physics, Harvard University, 17 Oxford Street, Cambridge, Massachusetts 02138, USA*
[4]*High Energy Physics, Imperial College London, Blackett Laboratory, London SW7 2BZ, United Kingdom*
[5]*Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, California 94720, USA*
[6]*Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, California 94550, USA*
[7]*LIP-Coimbra, Department of Physics, University of Coimbra, Rua Larga, 3004-516 Coimbra, Portugal*
[8]*South Dakota School of Mines and Technology, 501 East St Joseph Street, Rapid City, South Dakota 57701, USA*
[9]*South Dakota Science and Technology Authority, Sanford Underground Research Facility, Lead, South Dakota 57754, USA*
[10]*Department of Physics, Texas A & M University, College Station, Texas 77843, USA*
[11]*Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom*
[12]*Department of Physics, University of California Berkeley, Berkeley, California 94720, USA*
[13]*Department of Physics, University of California Davis, One Shields Avenue, Davis, California 95616, USA*
[14]*Department of Physics, University of California Santa Barbara, Santa Barbara, California 93106, USA*
[15]*SUPA, School of Physics and Astronomy, University of Edinburgh, Edinburgh, EH9 3JZ, United Kingdom*
[16]*Department of Physics, University of Maryland, College Park, Maryland 20742, USA*
[17]*Department of Physics and Astronomy, University of Rochester, Rochester, New York 14627, USA*
[18]*Department of Physics, University of South Dakota, 414E Clark Street, Vermillion, South Dakota 57069, USA*
[19]*Department of Physics, Yale University, 217 Prospect Street, New Haven, Connecticut 06511, USA*
(Received 30 October 2013; revised manuscript received 21 January 2014; published 4 March 2014)

The Large Underground Xenon (LUX) experiment is a dual-phase xenon time-projection chamber operating at the Sanford Underground Research Facility (Lead, South Dakota). The LUX cryostat was filled for the first time in the underground laboratory in February 2013. We report results of the first WIMP search data set, taken during the period from April to August 2013, presenting the analysis of 85.3 live days of data with a fiducial volume of 118 kg. A profile-likelihood analysis technique shows our data to be consistent with the background-only hypothesis, allowing 90% confidence limits to be set on spin-independent WIMP-nucleon elastic scattering with a minimum upper limit on the cross section of 7.6×10^{-46} cm^2 at a WIMP mass of 33 GeV/c^2. We find that the LUX data are in disagreement with low-mass WIMP signal interpretations of the results from several recent direct detection experiments.

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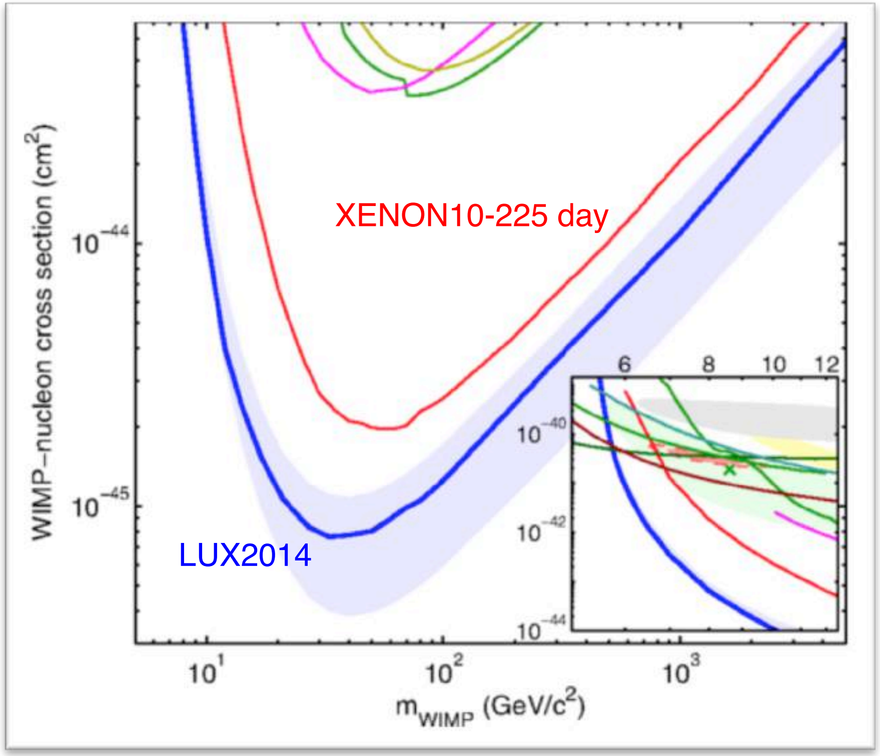
Convincing evidence for the existence of particle dark matter is derived from observations of the Universe on scales ranging from the galactic to the cosmological [1–3]. Increasingly detailed studies of the cosmic microwave background anisotropies have implied the abundance of dark matter with remarkable precision [4,5]. One favored

0031-9007/14/112(9)/091303(7) 091303-1

Physical Review Letters 112 (2014), 091303

Initial run Spin Independent results

118 kg
85.3 live days
AmBe and fixed source gamma ray calibrations
Enforced threshold at 3 keV_{NR}



PHYSICAL REVIEW D **93**, 072009 (2016)

Tritium calibration of the LUX dark matter experiment

D. S. Akerib,[1,2,3] H. M. Araújo,[4] X. Bai,[5] A. J. Bailey,[4] J. Balajthy,[6] P. Beltrame,[7] E. P. Bernard,[8] A. Bernstein,[9] T. P. Biesiadzinski,[1,2,3] E. M. Boulton,[8] A. Bradley,[1] R. Bramante,[1,2,3] S. B. Cahn,[8] M. C. Carmona-Benitez,[10] C. Chan,[11] J. J. Chapman,[11] A. A. Chiller,[12] C. Chiller,[12] A. Currie,[4] J. E. Cutter,[13] T. J. R. Davison,[7] L. de Viveiros,[14] A. Dobi,[15] J. E. Y. Dobson,[16] E. Druszkiewicz,[17] B. N. Edwards,[8] C. H. Faham,[15] S. Fiorucci,[11] R. J. Gaitskell,[11] V. M. Gehman,[15] C. Ghag,[16] K. R. Gibson,[1] M. G. D. Gilchriese,[15] C. R. Hall,[6] M. Hanhardt,[5,18] S. J. Haselschwardt,[10] S. A. Hertel,[19,8] D. P. Hogan,[19] M. Horn,[19,8] D. Q. Huang,[11] C. M. Ignarra,[2,3] M. Ihm,[19] R. G. Jacobsen,[19] W. Ji,[1,2,3] K. Kazkaz,[9] D. Khaitan,[17] R. Knoche,[6] N. A. Larsen,[8] C. Lee,[1,2,3] B. G. Lenardo,[13,9] K. T. Lesko,[15] A. Lindote,[14] M. I. Lopes,[14] D. C. Malling,[11] A. G. Manalaysay,[13] R. L. Mannino,[20] M. F. Marzioni,[7] D. N. McKinsey,[19,8] D.-M. Mei,[12] J. Mock,[21] M. Moongweluwan,[17] J. A. Morad,[13] A. St. J. Murphy,[7] C. Nehrkorn,[10] H. N. Nelson,[10] F. Neves,[14] K. O'Sullivan,[19,15,8] K. C. Oliver-Mallory,[19] R. A. Ott,[13] K. J. Palladino,[2,3] M. Pangilinan,[11] E. K. Pease,[8] P. Phelps,[1] L. Reichhart,[16] C. Rhyne,[11] S. Shaw,[16] T. A. Shutt,[1,2,3] C. Silva,[14] V. N. Solovov,[14] P. Sorensen,[15] S. Stephenson,[13] T. J. Sumner,[4] M. Szydagis,[21] D. J. Taylor,[18] W. Taylor,[11] B. P. Tennyson,[8] P. A. Terman,[20] D. R. Tiedt,[5] W. H. To,[1,2,3] M. Tripathi,[13] L. Tvrznikova,[8] S. Uvarov,[13] J. R. Verbus,[11] R. C. Webb,[20] J. T. White,[20] T. J. Whitis,[1,2,3] M. S. Witherell,[10] F. L. H. Wolfs,[17] S. K. Young,[21] and C. Zhang[12]

(LUX Collaboration)

[1]*Department of Physics, Case Western Reserve University, 10900 Euclid Avenue, Cleveland, Ohio 44106, USA*
[2]*SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, California 94205, USA*
[3]*Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, 452 Lomita Mall, Stanford, California 94309, USA*
[4]*High Energy Physics, Blackett Laboratory, Imperial College London, London SW7 2BZ, United Kingdom*
[5]*South Dakota School of Mines and Technology, 501 East Saint Joseph Street, Rapid City, South Dakota 57701, USA*
[6]*Department of Physics, University of Maryland, College Park, Maryland 20742, USA*
[7]*SUPA, School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3FD, United Kingdom*
[8]*Department of Physics, Yale University, 217 Prospect Street, New Haven, Connecticut 06511, USA*
[9]*Lawrence Livermore National Laboratory, 7000 East Avenue, Livermore, California 94551, USA*
[10]*Department of Physics, University of California Santa Barbara, Santa Barbara, California 93106, USA*
[11]*Department of Physics, Brown University, 182 Hope Street, Providence, Rhode Island 02912, USA*
[12]*Department of Physics, University of South Dakota, 414E Clark Street, Vermillion, South Dakota 57069, USA*
[13]*Department of Physics, University of California Davis, One Shields Avenue, Davis, California 95616, USA*
[14]*LIP-Coimbra, Department of Physics, University of Coimbra, Rua Larga, 3004-516 Coimbra, Portugal*
[15]*Lawrence Berkeley National Laboratory, 1 Cyclotron Road, Berkeley, California 94720, USA*
[16]*Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom*
[17]*Department of Physics and Astronomy, University of Rochester, Rochester, New York 14627, USA*
[18]*Sanford Underground Research Facility, South Dakota Science and Technology Authority, Lead, South Dakota 57754, USA*
[19]*Department of Physics, University of California Berkeley, Berkeley, California 94720, USA*
[20]*Department of Physics, Texas A&M University, College Station, Texas 77843, USA*
[21]*Department of Physics, University at Albany, State University of New York, 1400 Washington Avenue, Albany, New York 12222, USA*

(Received 9 December 2015; published 20 April 2016)

We present measurements of the electron-recoil (ER) response of the LUX dark matter detector based upon 170 000 highly pure and spatially uniform tritium decays. We reconstruct the tritium energy spectrum using the combined energy model and find good agreement with expectations. We report the average charge and light yields of ER events in liquid xenon at 180 and 105 V/cm and compare the results to the NEST model. We also measure the mean charge recombination fraction and its fluctuations, and we investigate the location and width of the LUX ER band. These results provide input to a reanalysis of the LUX run 3 weakly interacting massive particle search.

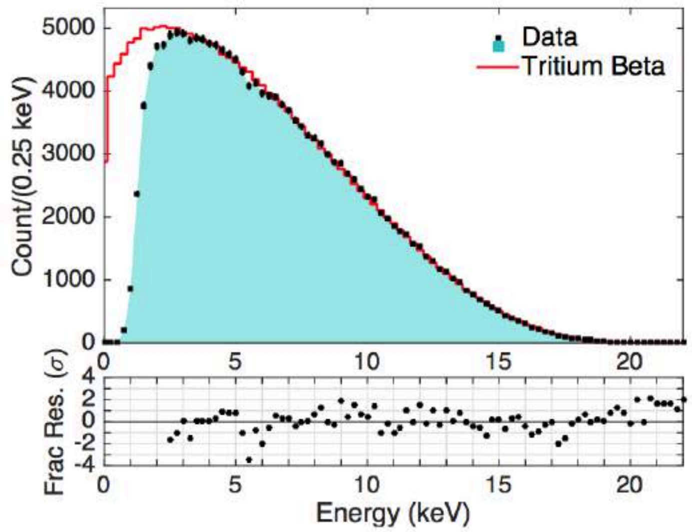
DOI: 10.1103/PhysRevD.93.072009

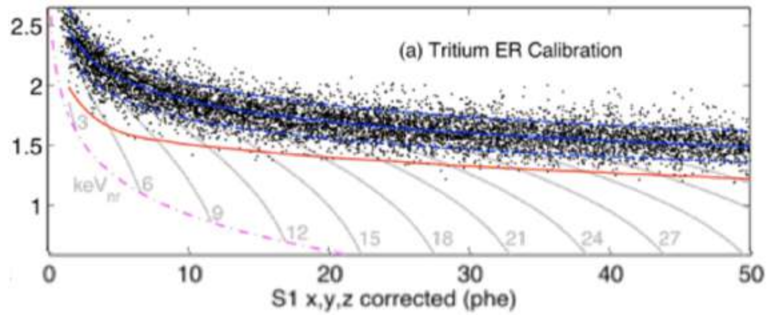
2470-0010/2016/93(7)/072009(12) 072009-1

Physical Review D 93 (2016), 072009

Dispersed tritium calibration

In situ measurement of ER response to low energies
Tritiated methane





Submitted Phys. Rev. C, arXiv:1608.05381

DD neutron generator calibration

Low energy NR response

Low-energy (0.7–74 keV) nuclear recoil calibration of the LUX dark matter experiment using D-D neutron scattering kinematics

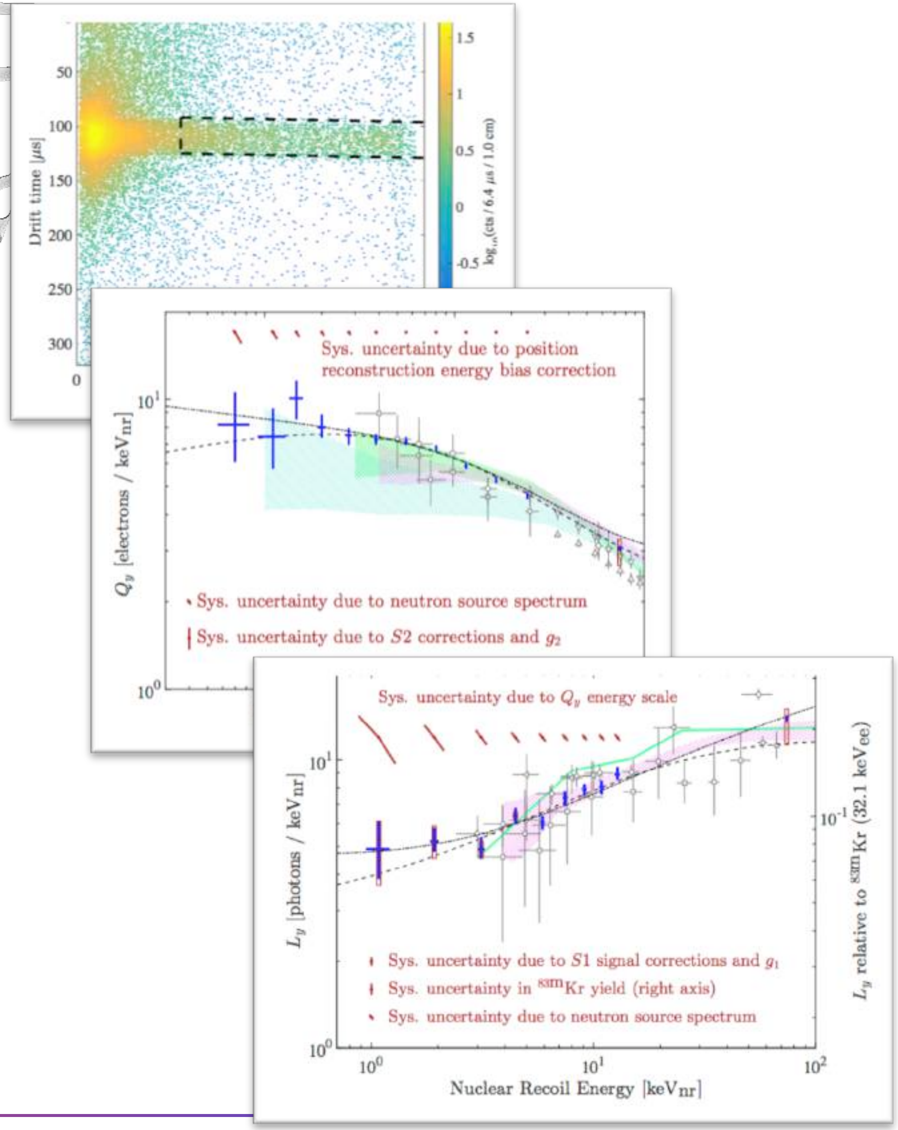
D.S. Akerib,[1,2,3] S. Alsum,[4] H.M. Araújo,[5] X. Bai,[6] A.J. Bailey,[5] J. Balajthy,[7] P. Beltrame,[8] E.P. Bernard,[9,10] A. Bernstein,[11] T.P. Biesiadzinski,[1,2,3] E.M. Boulton,[9,10] A. Bradley,[1] R. Bramante,[1,2,3] P. Brás,[12] D. Byram,[13,14] S.B. Cahn,[10] M.C. Carmona-Benitez,[15] C. Chan,[16] J.J. Chapman,[16] A.A. Chiller,[13] C. Chiller,[13] A. Currie,[5] J.E. Cutter,[17] T.J.R. Davison,[8] L. de Viveiros,[12] A. Dobi,[18] J.E.Y. Dobson,[19] E. Druszkiewicz,[20] B.N. Edwards,[10] C.H. Faham,[18] S. Fiorucci,[16,18] R.J. Gaitskell,[16] V.M. Gehman,[18] C. Ghag,[19] K.R. Gibson,[1] M.G.D. Gilchriese,[18] C.R. Hall,[7] M. Hanhardt,[6,14] S.J. Haselschwardt,[15] S.A. Hertel,[9,10] D.P. Hogan,[9] M. Horn,[14,9,10] D.Q. Huang,[16] C.M. Ignarra,[2,3] M. Ihm,[9] R.G. Jacobsen,[9] W. Ji,[1,2,3] K. Kamdin,[9] K. Kazkaz,[11] D. Khaitan,[20] R. Knoche,[7] N.A. Larsen,[10] C. Lee,[1,2,3] B.G. Lenardo,[17,11] K.T. Lesko,[18] A. Lindote,[12] M.I. Lopes,[12] D.C. Malling,[16] A. Manalaysay,[17] R.L. Mannino,[21] M.F. Marzioni,[8] D.N. McKinsey,[9,18,10] D.-M. Mei,[13] J. Mock,[22] M. Moongweluwan,[20] J.A. Morad,[17] A.St.J. Murphy,[8] C. Nehrkorn,[15] H.N. Nelson,[15] F. Neves,[12] K. O'Sullivan,[9,18,10] K.C. Oliver-Mallory,[9] K.J. Palladino,[4,2,3] M. Pangilinan,[16] E.K. Pease,[9,10] P. Phelps,[1] L. Reichhart,[19] C.A. Rhyne,[16] S. Shaw,[19] T.A. Shutt,[1,2,3] C. Silva,[12] M. Solmaz,[15] V.N. Solovov,[12] P. Sorensen,[18] S. Stephenson,[17] T.J. Sumner,[5] M. Szydagis,[22] D.J. Taylor,[14] W.C. Taylor,[16] B.P. Tennyson,[10] P.A. Terman,[21] D.R. Tiedt,[6] W.H. To,[1,2,3] M. Tripathi,[17] L. Tvrznikova,[9,10] S. Uvarov,[17] J.R. Verbus,[16,*] R.C. Webb,[21] J.T. White,[21] T.J. Whitis,[1,2,3] M.S. Witherell,[18] F.L.H. Wolfs,[20] J. Xu,[11] K. Yazdani,[5] S.K. Young,[22] and C. Zhang[13]

(LUX Collaboration)

[1]*Case Western Reserve University, Department of Physics, 10900 Euclid Ave, Cleveland, OH 44106, USA*
[2]*SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, CA 94205, USA*
[3]*Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, 452 Lomita Mall, Stanford, CA 94309, USA*
[4]*University of Wisconsin-Madison, Department of Physics, 1150 University Ave., Madison, WI 53706, USA*
[5]*Imperial College London, High Energy Physics, Blackett Laboratory, London SW7 2BZ, United Kingdom*
[6]*South Dakota School of Mines and Technology, 501 East St Joseph St., Rapid City, SD 57701, USA*
[7]*University of Maryland, Department of Physics, College Park, MD 20742, USA*
[8]*SUPA, School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3FD, United Kingdom*
[9]*University of California Berkeley, Department of Physics, Berkeley, CA 94720, USA*
[10]*Yale University, Department of Physics, 217 Prospect St., New Haven, CT 06511, USA*
[11]*Lawrence Livermore National Laboratory, 7000 East Ave., Livermore, CA 94551, USA*
[12]*LIP-Coimbra, Department of Physics, University of Coimbra, Rua Larga, 3004-516 Coimbra, Portugal*
[13]*University of South Dakota, Department of Physics, 414E Clark St., Vermillion, SD 57069, USA*
[14]*South Dakota Science and Technology Authority, Sanford Underground Research Facility, Lead, SD 57754, USA*
[15]*University of California Santa Barbara, Department of Physics, Santa Barbara, CA 93106, USA*
[16]*Brown University, Department of Physics, 182 Hope St., Providence, RI 02912, USA*
[17]*University of California Davis, Department of Physics, One Shields Ave., Davis, CA 95616, USA*
[18]*Lawrence Berkeley National Laboratory, 1 Cyclotron Rd., Berkeley, CA 94720, USA*
[19]*Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom*
[20]*University of Rochester, Department of Physics and Astronomy, Rochester, NY 14627, USA*
[21]*Texas A & M University, Department of Physics, College Station, TX 77843, USA*
[22]*University at Albany, State University of New York, Department of Physics, 1400 Washington Ave., Albany, NY 12222, USA*

(Dated: August 19, 2016)

The Large Underground Xenon (LUX) experiment is a dual-phase liquid xenon time projection chamber (TPC) operating at the Sanford Underground Research Facility in Lead, South Dakota. A calibration of nuclear recoils in liquid xenon was performed *in situ* in the LUX detector using a collimated beam of mono-energetic 2.45 MeV neutrons produced by a deuterium-deuterium (D-D) fusion source. The nuclear recoil energy from the first neutron scatter in the TPC was reconstructed using the measured scattering angle defined by double-scatter neutron events within the active xenon volume. We measured the absolute charge (Q_y) and light (L_y) yields at an average electric field of 180 V/cm for nuclear recoil energies spanning 0.7 to 74 keV and 1.1 to 74 keV, respectively. This calibration of the nuclear recoil signal yields will permit the further refinement of liquid xenon nuclear recoil signal models and, importantly for dark matter searches, clearly demonstrates measured ionization and scintillation signals in this medium at recoil energies down to $\mathcal{O}$(1 keV).




PRL 116, 161301 (2016) PHYSICAL REVIEW LETTERS week ending 22 APRIL 2016

Improved Limits on Scattering of Weakly Interacting Massive Particles from Reanalysis of 2013 LUX Data

D. S. Akerib,[1,2,3] H. M. Araújo,[4] X. Bai,[5] A. J. Bailey,[4] J. Balajthy,[6] P. Beltrame,[7] E. P. Bernard,[8] A. Bernstein,[9] T. P. Biesiadzinski,[1,2,3] E. M. Boulton,[8] A. Bradley,[1] R. Bramante,[1,2,3] S. B. Cahn,[8] M. C. Carmona-Benitez,[10] C. Chan,[11] J. J. Chapman,[11] A. A. Chiller,[12] C. Chiller,[12] A. Currie,[4,*] J. E. Cutter,[13] T. J. R. Davison,[7] L. de Viveiros,[14] A. Dobi,[15] J. E. Y. Dobson,[16] E. Druszkiewicz,[17] B. N. Edwards,[8] C. H. Faham,[15] S. Fiorucci,[15] R. J. Gaitskell,[11] V. M. Gehman,[15] C. Ghag,[16] K. R. Gibson,[1] M. G. D. Gilchriese,[15] C. R. Hall,[6] M. Hanhardt,[5,18] S. J. Haselschwardt,[10] S. A. Hertel,[19,8,15] D. P. Hogan,[19] M. Horn,[19,8,15] D. Q. Huang,[11] C. M. Ignarra,[2,3] M. Ihm,[19,15] R. G. Jacobsen,[19,15] W. Ji,[1,2,3] K. Kazkaz,[9] D. Khaitan,[17] R. Knoche,[6] N. A. Larsen,[8] C. Lee,[1,2,3] B. G. Lenardo,[13,9] K. T. Lesko,[15] A. Lindote,[14] M. I. Lopes,[14] D. C. Malling,[11] A. Manalaysay,[13] R. L. Mannino,[20] M. F. Marzioni,[7] D. N. McKinsey,[19,8,15] D.-M. Mei,[12] J. Mock,[21] M. Moongweluwan,[17] J. A. Morad,[13] A. St. J. Murphy,[7] C. Nehrkorn,[10] H. N. Nelson,[10] F. Neves,[14] K. O'Sullivan,[15,19,8] K. C. Oliver-Mallory,[19,15] R. A. Ott,[13] K. J. Palladino,[22,2,3] M. Pangilinan,[11] E. K. Pease,[19,8,15] P. Phelps,[1] L. Reichhart,[16] C. Rhyne,[11] S. Shaw,[16] T. A. Shutt,[1,2,3] C. Silva,[14] V. N. Solovov,[14] P. Sorensen,[15] S. Stephenson,[13] T. J. Sumner,[4] M. Szydagis,[21] D. J. Taylor,[18] W. Taylor,[11] B. P. Tennyson,[8] P. A. Terman,[20] D. R. Tiedt,[5] W. H. To,[1,2,3] M. Tripathi,[13] L. Tvrznikova,[19,8,15] S. Uvarov,[13] J. R. Verbus,[11] R. C. Webb,[20] J. T. White,[20] T. J. Whitis,[1,2,3] M. S. Witherell,[10] F. L. H. Wolfs,[17] K. Yazdani,[4] S. K. Young,[21] and C. Zhang[12]

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[4]*Imperial College London, High Energy Physics, Blackett Laboratory, London SW7 2BZ, United Kingdom*
[5]*South Dakota School of Mines and Technology, 501 East St Joseph St., Rapid City, South Dakota 57701, USA*
[6]*University of Maryland, Department of Physics, College Park, Maryland 20742, USA*
[7]*SUPA, School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3FD, United Kingdom*
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[10]*University of California Santa Barbara, Department of Physics, Santa Barbara, California 93106, USA*
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[12]*University of South Dakota, Department of Physics, 414E Clark St., Vermillion, South Dakota 57069, USA*
[13]*University of California Davis, Department of Physics, One Shields Ave., Davis, California 95616, USA*
[14]*LIP-Coimbra, Department of Physics, University of Coimbra, Rua Larga, 3004-516 Coimbra, Portugal*
[15]*Lawrence Berkeley National Laboratory, 1 Cyclotron Rd., Berkeley, California 94720, USA*
[16]*Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom*
[17]*University of Rochester, Department of Physics and Astronomy, Rochester, New York 14627, USA*
[18]*South Dakota Science and Technology Authority, Sanford Underground Research Facility, Lead, South Dakota 57754, USA*
[19]*University of California Berkeley, Department of Physics, Berkeley, California 94720, USA*
[20]*Texas A&M University, Department of Physics, College Station, Texas 77843, USA*
[21]*University at Albany, State University of New York, Department of Physics, 1400 Washington Avenue, Albany, New York 12222, USA*
[22]*University of Wisconsin-Madison, Department of Physics, 1150 University Avenue, Madison, Wisconsin 53706, USA*

(Received 12 December 2015; revised manuscript received 8 March 2016; published 20 April 2016)

We present constraints on weakly interacting massive particles (WIMP)-nucleus scattering from the 2013 data of the Large Underground Xenon dark matter experiment, including 1.4×10^4 kg day of search exposure. This new analysis incorporates several advances: single-photon calibration at the scintillation wavelength, improved event-reconstruction algorithms, a revised background model including events originating on the detector walls in an enlarged fiducial volume, and new calibrations from decays of an injected tritium β source and from kinematically constrained nuclear recoils down to 1.1 keV. Sensitivity, especially to low-mass WIMPs, is enhanced compared to our previous results which modeled the

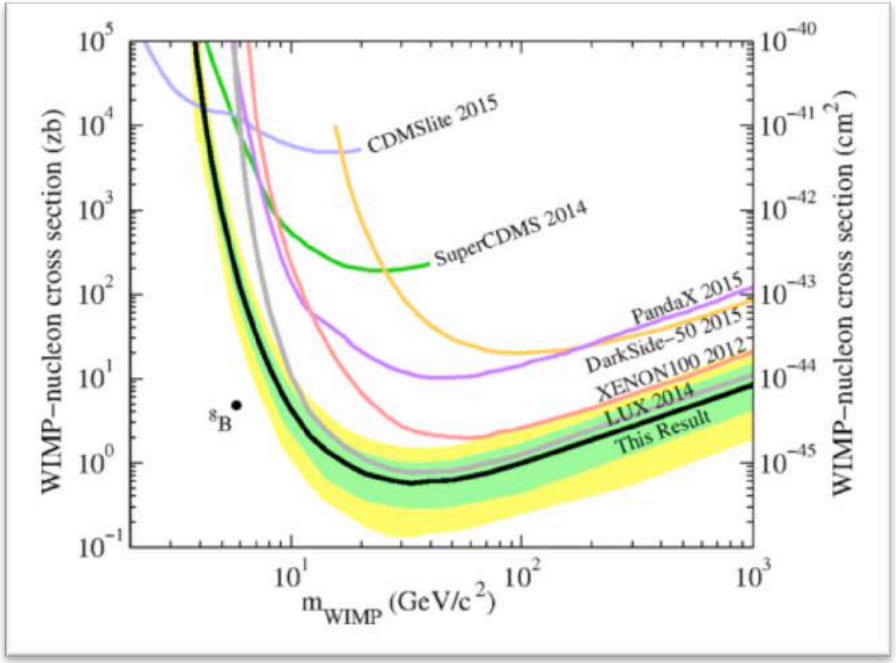
0031-9007/16/116(16)/161301(7) 161301-1

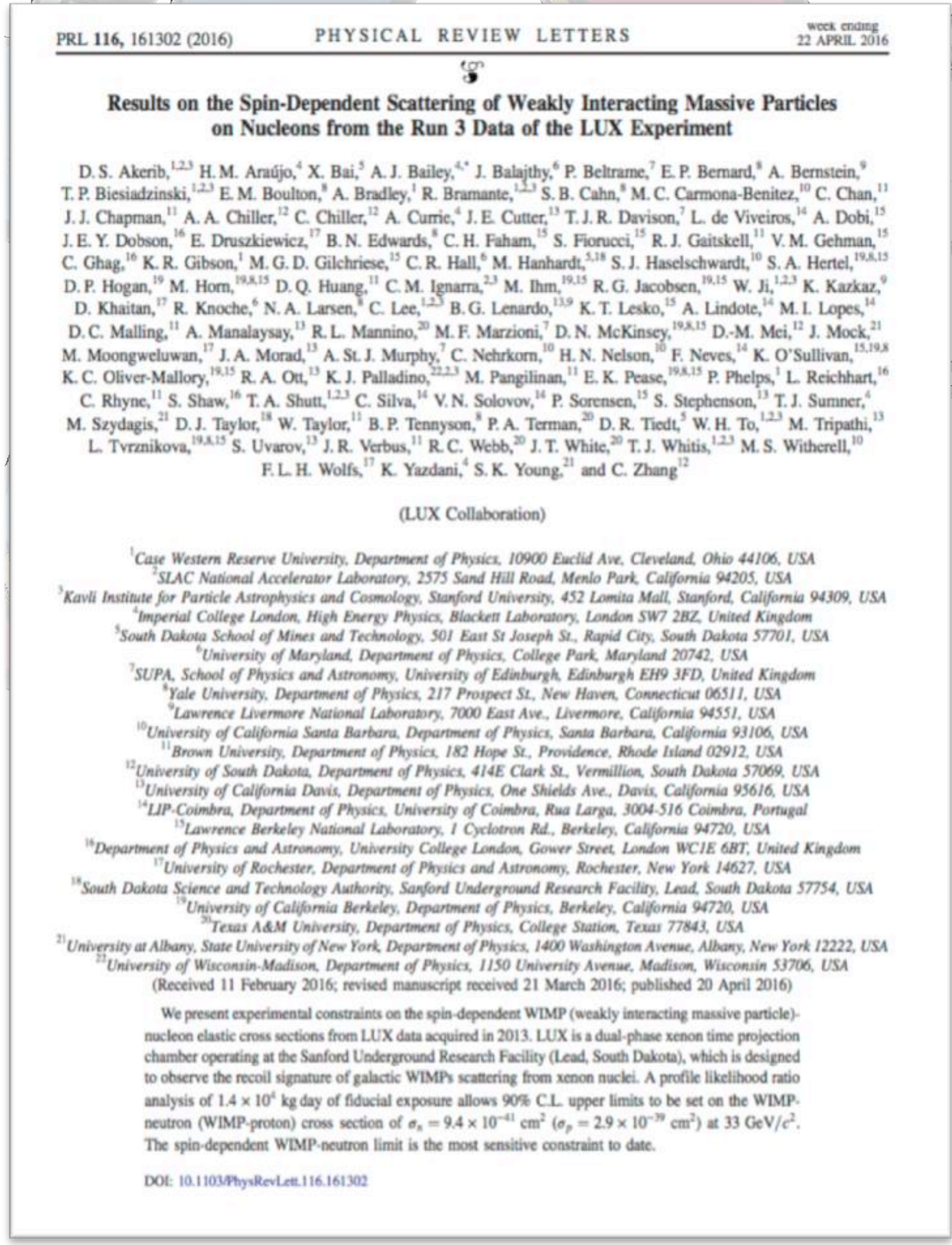
Physical Review Letters 116 (2016), 161301

Improved Spin Independent results

Additional DD and tritium calibrations used
Improved peak finding, analysis
145.4 kg
95 days
Threshold reduced to 1.1 keV_{NR}

Significant improvement for low masses





PRL 116, 161302 (2016) PHYSICAL REVIEW LETTERS week ending 22 APRIL 2016

Results on the Spin-Dependent Scattering of Weakly Interacting Massive Particles on Nucleons from the Run 3 Data of the LUX Experiment

D. S. Akerib,[1,2,3] H. M. Araújo,[4] X. Bai,[5] A. J. Bailey,[4,*] J. Balajthy,[6] P. Beltrame,[7] E. P. Bernard,[8] A. Bernstein,[9] T. P. Biesiadzinski,[1,2,3] E. M. Boulton,[8] A. Bradley,[1] R. Bramante,[1,2,3] S. B. Cahn,[8] M. C. Carmona-Benitez,[10] C. Chan,[11] J. J. Chapman,[11] A. A. Chiller,[12] C. Chiller,[12] A. Currie,[4] J. E. Cutter,[13] T. J. R. Davison,[7] L. de Viveiros,[14] A. Dobi,[15] J. E. Y. Dobson,[16] E. Druszkiewicz,[17] B. N. Edwards,[8] C. H. Faham,[15] S. Fiorucci,[15] R. J. Gaitskell,[11] V. M. Gehman,[15] C. Ghag,[16] K. R. Gibson,[1] M. G. D. Gilchriese,[15] C. R. Hall,[6] M. Hanhardt,[5,18] S. J. Haselschwardt,[10] S. A. Hertel,[19,8,15] D. P. Hogan,[19] M. Horn,[19,8,15] D. Q. Huang,[11] C. M. Ignarra,[2,3] M. Ihm,[19,15] R. G. Jacobsen,[19,15] W. Ji,[1,2,3] K. Kazkaz,[9] D. Khaitan,[17] R. Knoche,[6] N. A. Larsen,[8] C. Lee,[1,2,3] B. G. Lenardo,[13,9] K. T. Lesko,[15] A. Lindote,[14] M. I. Lopes,[14] D. C. Malling,[11] A. Manalaysay,[13] R. L. Mannino,[20] M. F. Marzioni,[7] D. N. McKinsey,[19,8,15] D.-M. Mei,[12] J. Mock,[21] M. Moongweluwan,[17] J. A. Morad,[13] A. St. J. Murphy,[7] C. Nehrkorn,[10] H. N. Nelson,[10] F. Neves,[14] K. O'Sullivan,[15,19,8] K. C. Oliver-Mallory,[19,15] R. A. Ott,[13] K. J. Palladino,[22,2,3] M. Pangilinan,[11] E. K. Pease,[19,8,15] P. Phelps,[1] L. Reichhart,[16] C. Rhyne,[11] S. Shaw,[16] T. A. Shutt,[1,2,3] C. Silva,[14] V. N. Solovov,[14] P. Sorensen,[15] S. Stephenson,[13] T. J. Sumner,[4] M. Szydagis,[21] D. J. Taylor,[18] W. Taylor,[11] B. P. Tennyson,[8] P. A. Terman,[20] D. R. Tiedt,[5] W. H. To,[1,2,3] M. Tripathi,[13] L. Tvrznikova,[19,8,15] S. Uvarov,[13] J. R. Verbus,[11] R. C. Webb,[20] J. T. White,[20] T. J. Whitis,[1,2,3] M. S. Witherell,[10] F. L. H. Wolfs,[17] K. Yazdani,[4] S. K. Young,[21] and C. Zhang[12]

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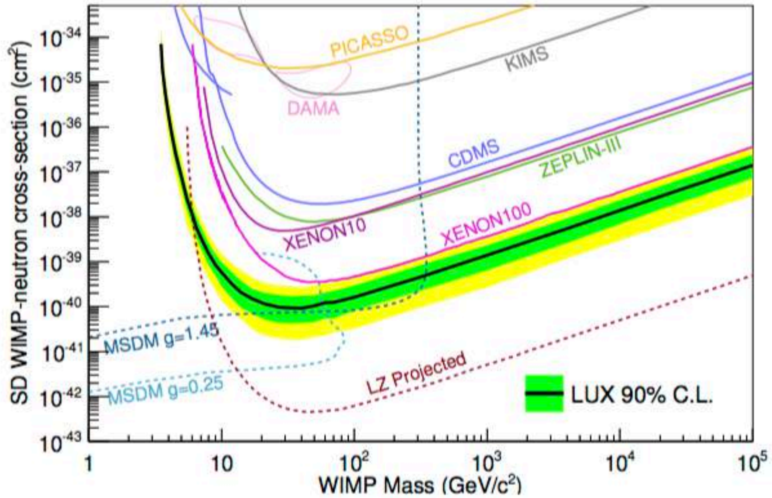
(Received 11 February 2016; revised manuscript received 21 March 2016; published 20 April 2016)

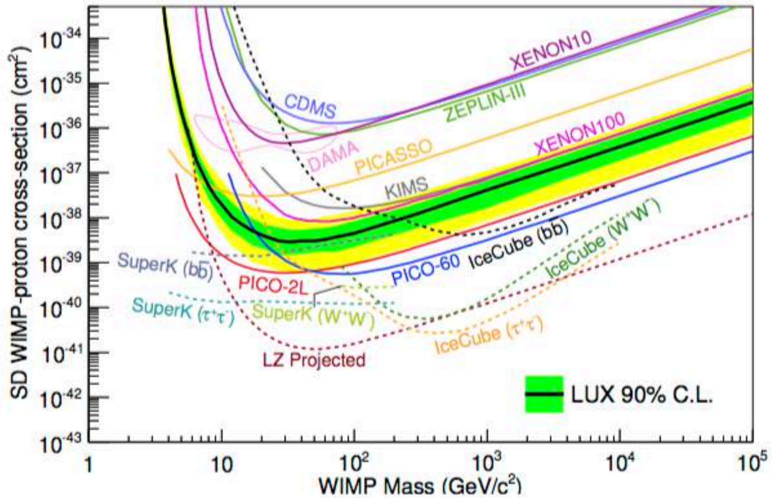
We present experimental constraints on the spin-dependent WIMP (weakly interacting massive particle)-nucleon elastic cross sections from LUX data acquired in 2013. LUX is a dual-phase xenon time projection chamber operating at the Sanford Underground Research Facility (Lead, South Dakota), which is designed to observe the recoil signature of galactic WIMPs scattering from xenon nuclei. A profile likelihood ratio analysis of 1.4×10^4 kg day of fiducial exposure allows 90% C.L. upper limits to be set on the WIMP-neutron (WIMP-proton) cross section of $\sigma_n = 9.4 \times 10^{-41}$ cm^2 ($\sigma_p = 2.9 \times 10^{-39}$ cm^2) at 33 GeV/c^2. The spin-dependent WIMP-neutron limit is the most sensitive constraint to date.

DOI: 10.1103/PhysRevLett.116.161302

Physical Review Letters 116 (2016), 161302

Spin Dependent results
from the 'Improved' 2013 data set



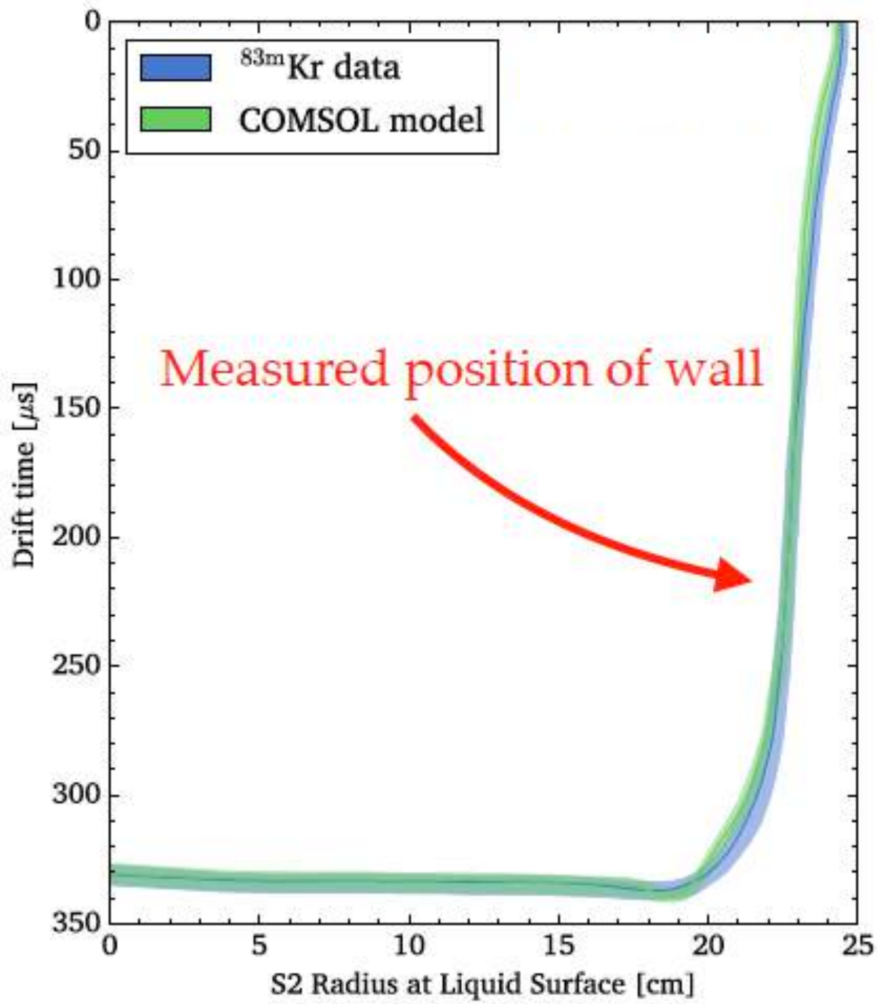


Maximal exploitation
“300 live days of data”

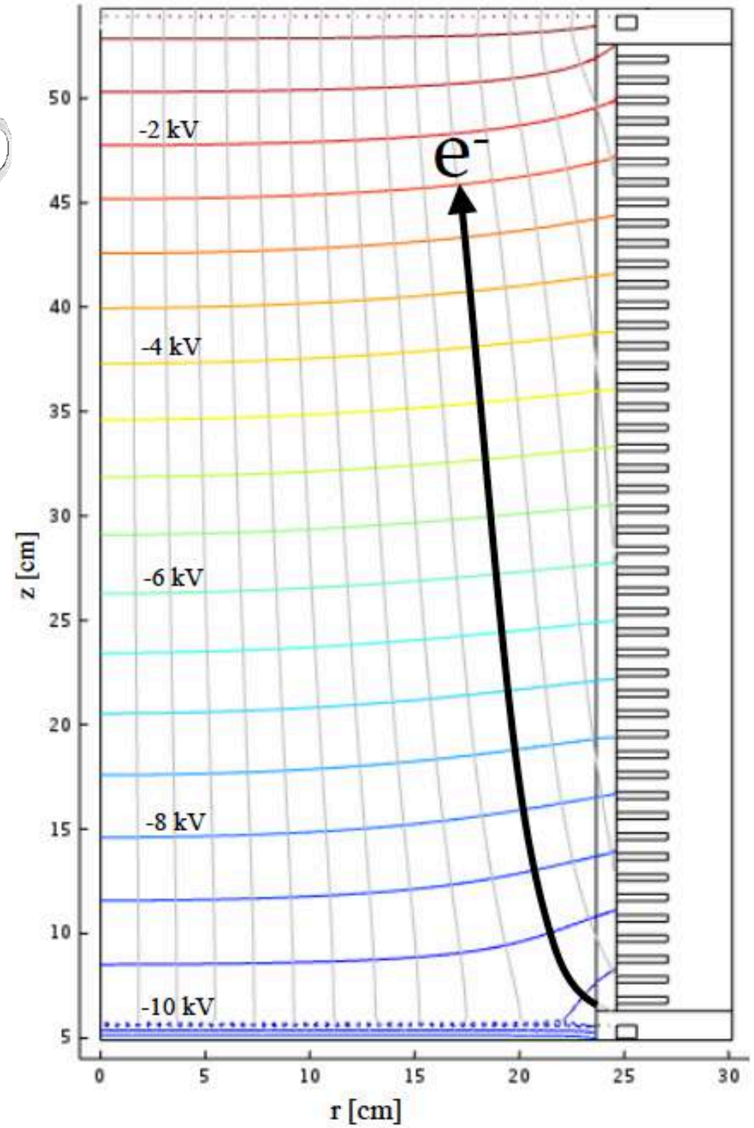
Improve electron extraction

Was ~50% in initial data

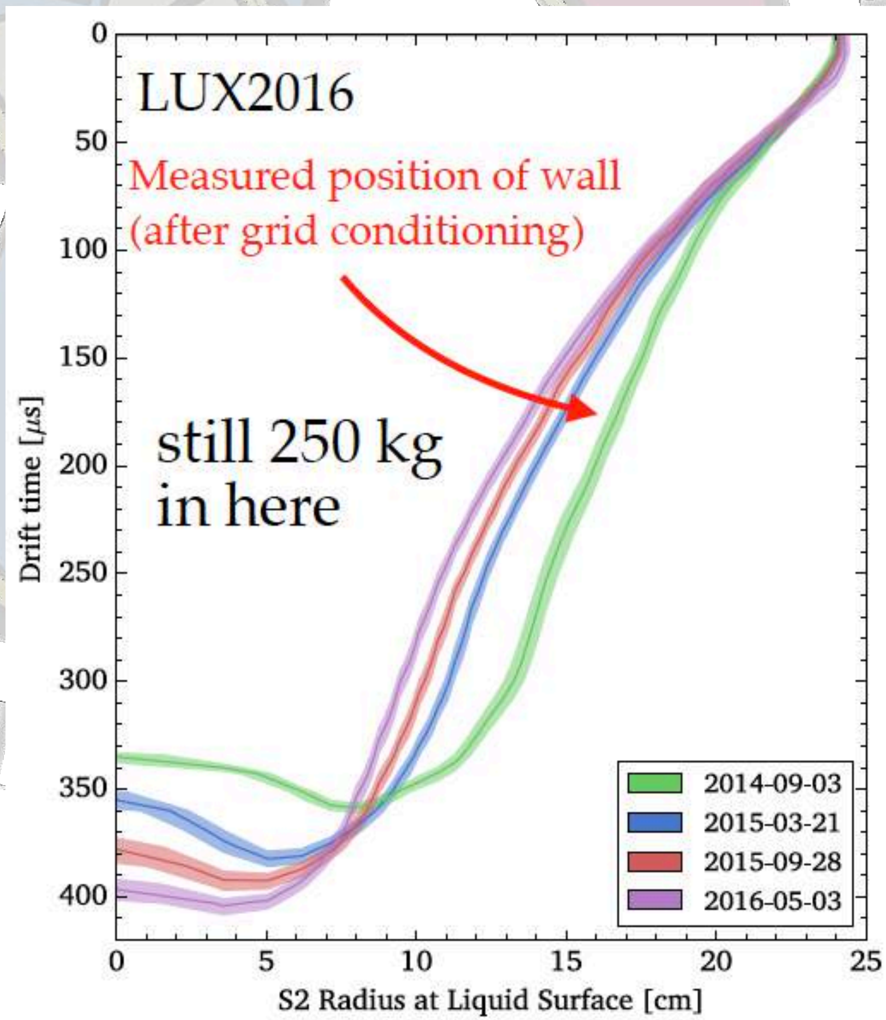
- Conditioning campaign
- Voltage on electrodes raised, until significant current was drawn, for extended period
- Successfully raised electron extraction efficiency to ~75%
- Commenced run (11 September 2014)
- But…

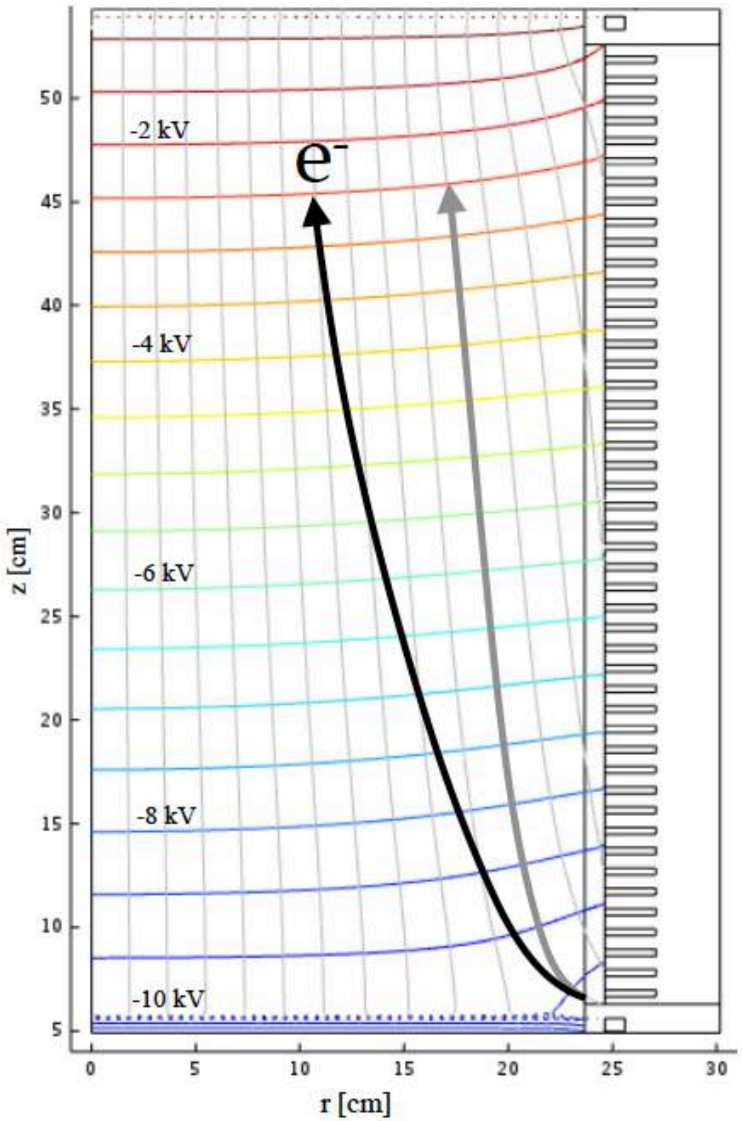


^{83m}Kr data
COMSOL model
Measured position of wall
Drift time [μs]
S2 Radius at Liquid Surface [cm]
0
50
100
150
200
250
300
350
0
5
10
15
20
25



e-
-2 kV
-4 kV
-6 kV
-8 kV
-10 kV
z [cm]
r [cm]
5
10
15
20
25
30
35
40
45
50
0
5
10
15
20
25
30





- Note: full FV is *still* active
- Deep events are being reconstructed at smaller radii than shallow events

Charge build up on PTFE

Understood in terms of build up of negative charge on internal PTFE walls

- Detailed COMSOL™ model developed
- Magnitude of effect continued to evolve during run
- Roughly rotational symmetry, but strong depth dependence

300 live days of blinded data completed 03 May 2016

Photo 28 April 2016

300 live days of blinded data completed 03 May 2016

Photo 28 April 2016

Data Analysis

- Considered data set as 4 time bins and 4 volumes.
- Each segment then has its own model for ER and NR response
- Likelihood analysis performed on S1 and S2 observables
- S1 and S2 modelled with the Noble Element Simulation Technique (NEST, http://www.albany.edu/physics/NEST.shtml)
- NEST is "tuned" to each of the 16 detectors by varying the applied field until we see a match between model and calibration data.
- Periodic CH3T, Kr, DD calibrations throughout run
- Background estimates... (^{127}Xe has now decayed away)
- Cuts… Efficiencies…

Background expectations

Background source	Expected number below NR median
External Gamma rays	1.5 +/- 0.2
Internal beta particles	1.2 +/- 0.06
Radon plate out (wall background)	8.7 +/- 3.5
Accidental S1-S2 coincidences	0.34 +/- 0.10
^{8}B solar neutrinos (CNNS)	0.16 +/- 0.03

← Indicative only: we use PLR

} In the bulk, but n/γ discrimination

} Low energy wall events, but PLR gives these low $\mathcal{L}(\text{signal})$

} In the bulk, low energy, NR band

+ ~ **0.3** single scatter neutrons, e.g. from (α, n), not included in PLR

Salting of data

- Injected substantial (unknown) number fake signal events ("salt") to the data stream
- Injected at the level of raw waveforms, and are built from calibration data (not simulation)
- Mitigates bias while allowing scrutiny of individual events.
- Previously used by neutrino experiments and searches for fractional charge.

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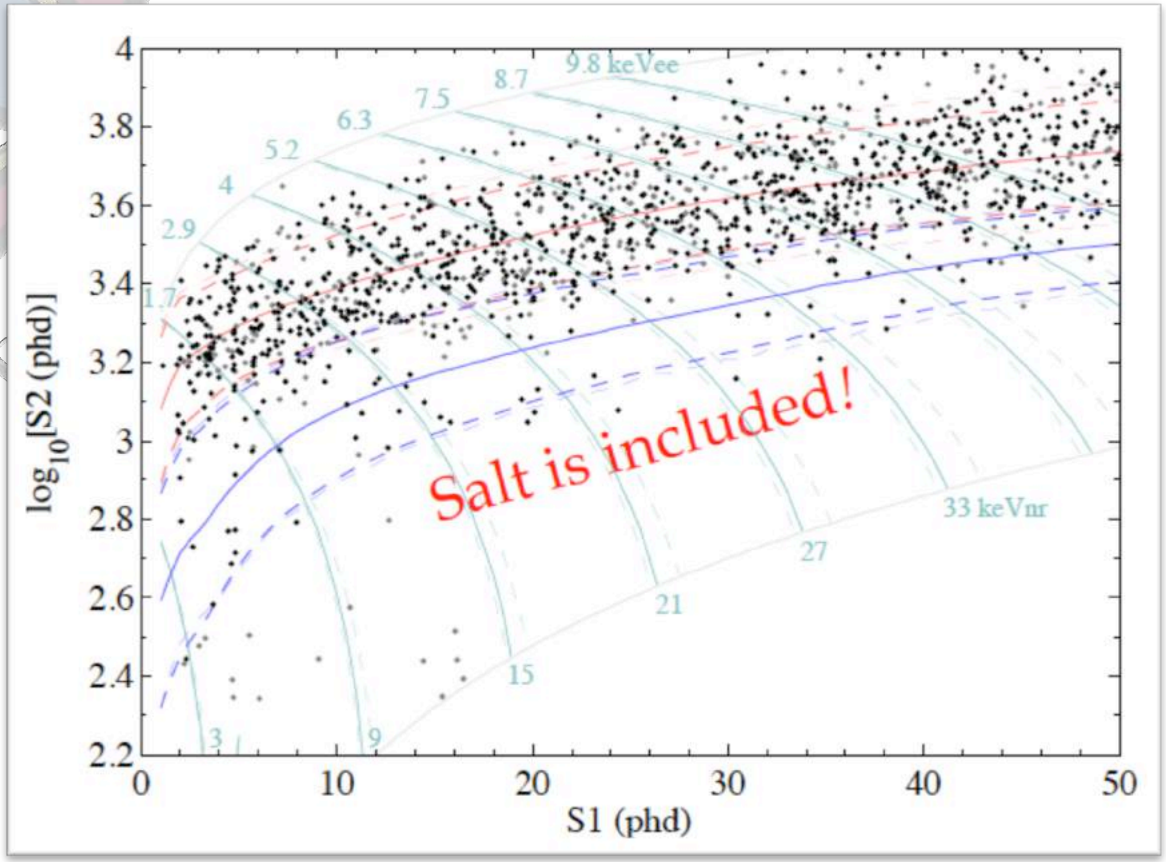


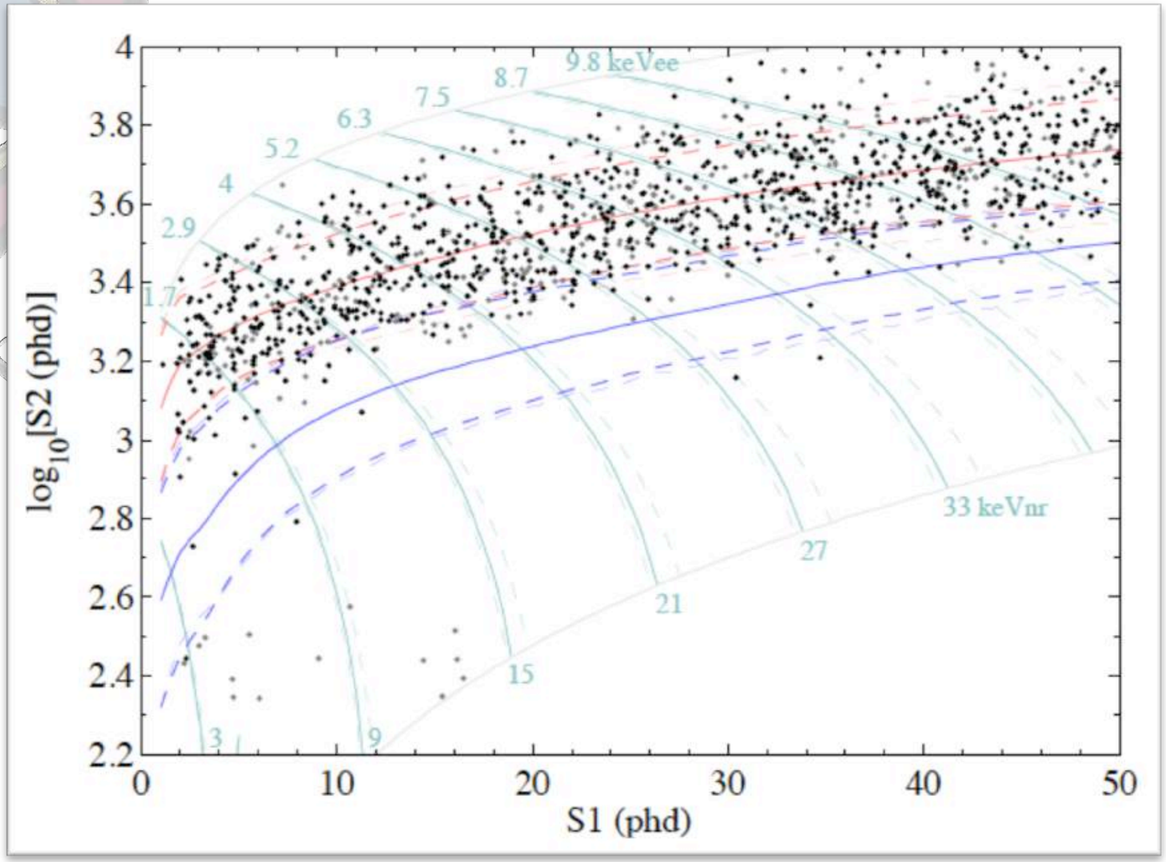
Unsalting…

Plot shows the data from all 16 "detectors"

Dots are events:

- Gray: within 1cm of our fiducial boundary
- Black: bulk events
- Red and blue curves are the ER and NR bands,

Salt removed



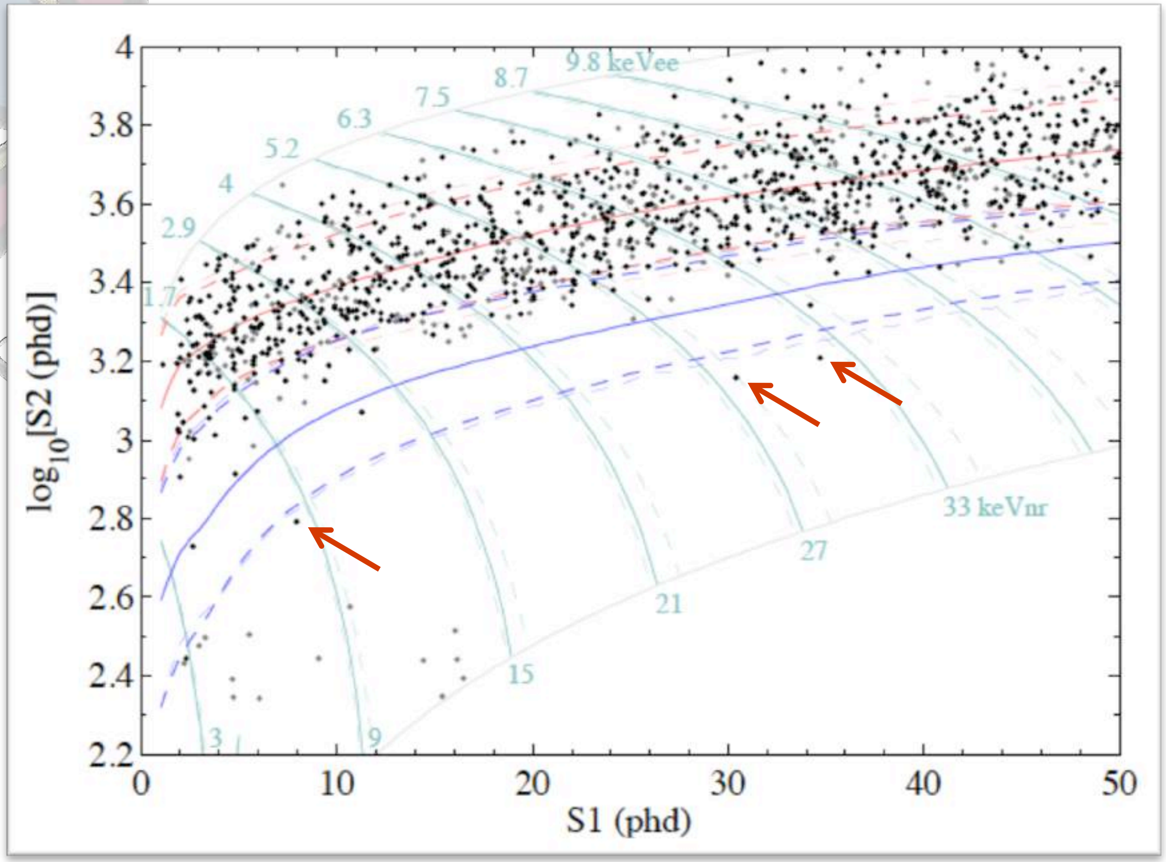
Additional scrutiny

Plot shows the data from all 16 “detectors”

Dots are events:

- Gray: within 1cm of our fiducial boundary
- Black: bulk events
- Red and blue curves are the ER and NR bands,

Salt removed

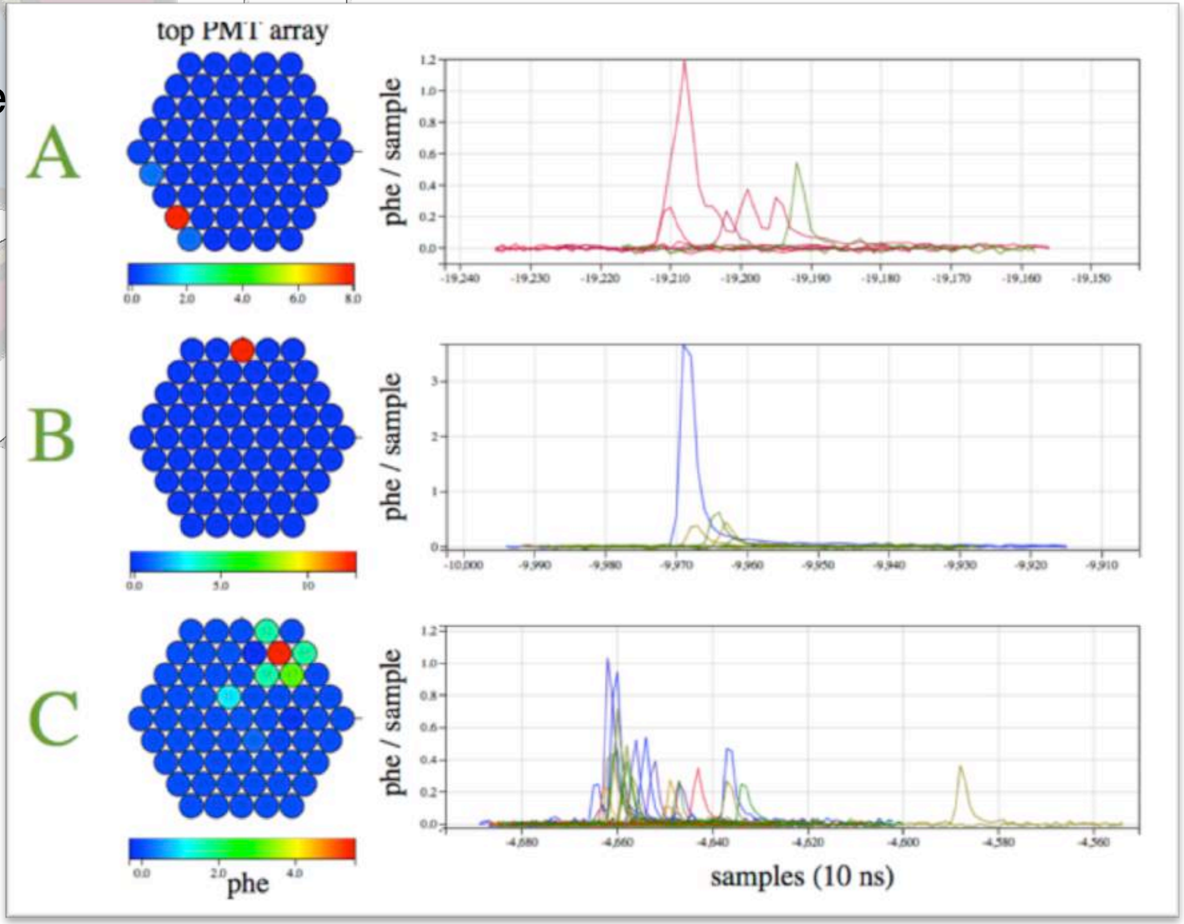


Additional scrutiny revealed 3 events have highly unlikely PMT hit patterns

After unsalting...

Two events have ~80% of the light in a single top edge PMT. Consistent with energy deposited outside the TPC, and light leaking through a gap near the edge of the PMT array.

One event has light concentrated under a few top PMTs and has time structure consistent with gas scintillation emission.
 - Also, this event came after high rate in the preceding 1 second.



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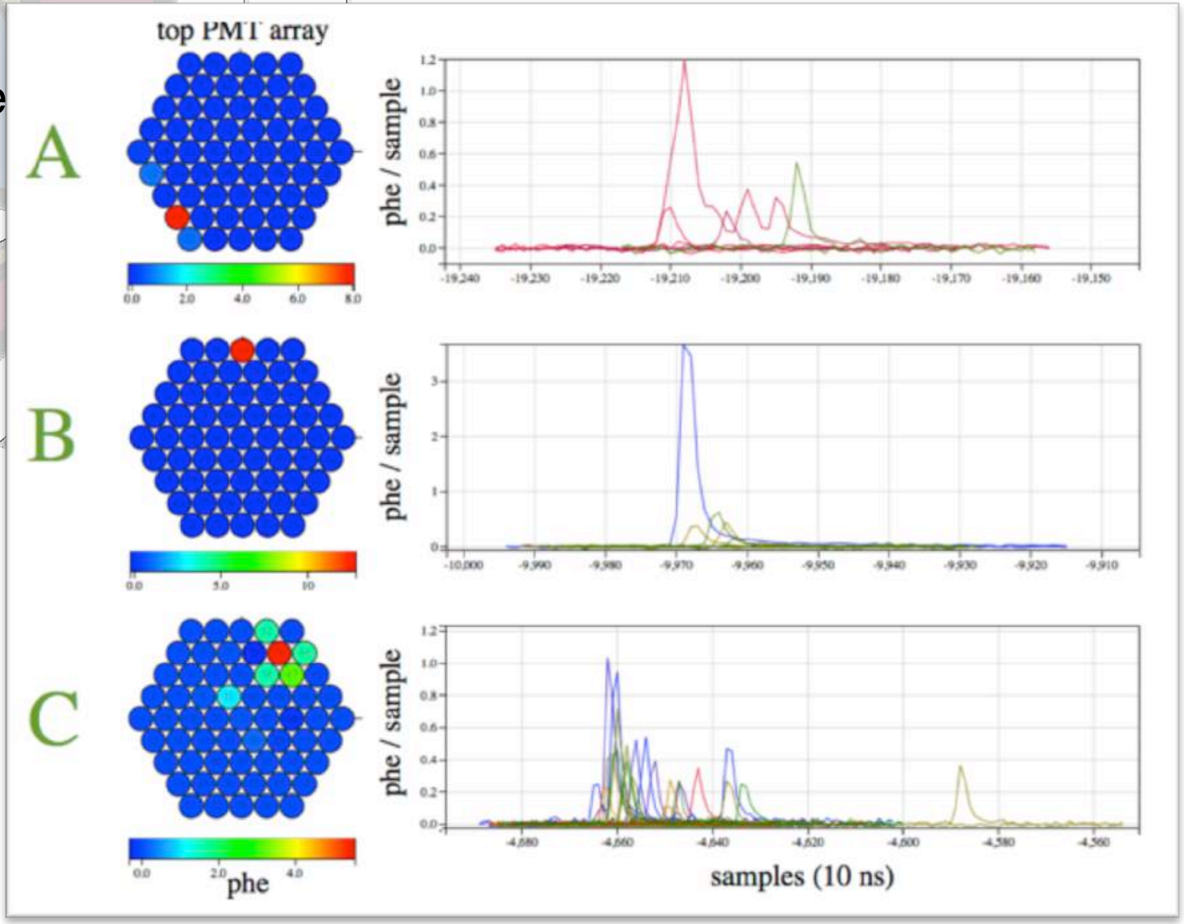
Two events have ~80% of the light in a single top edge PMT. Consistent with energy deposited outside the TPC, and light leaking through a gap near the edge of the PMT array.

One event has light concentrated under a few top PMTs and has time structure consistent with gas scintillation emission.
- Also, this event came after high rate in the preceding 1 second



Since these events do not correspond to interactions in the TPC, we developed additional (post-unsalting) cuts to target them

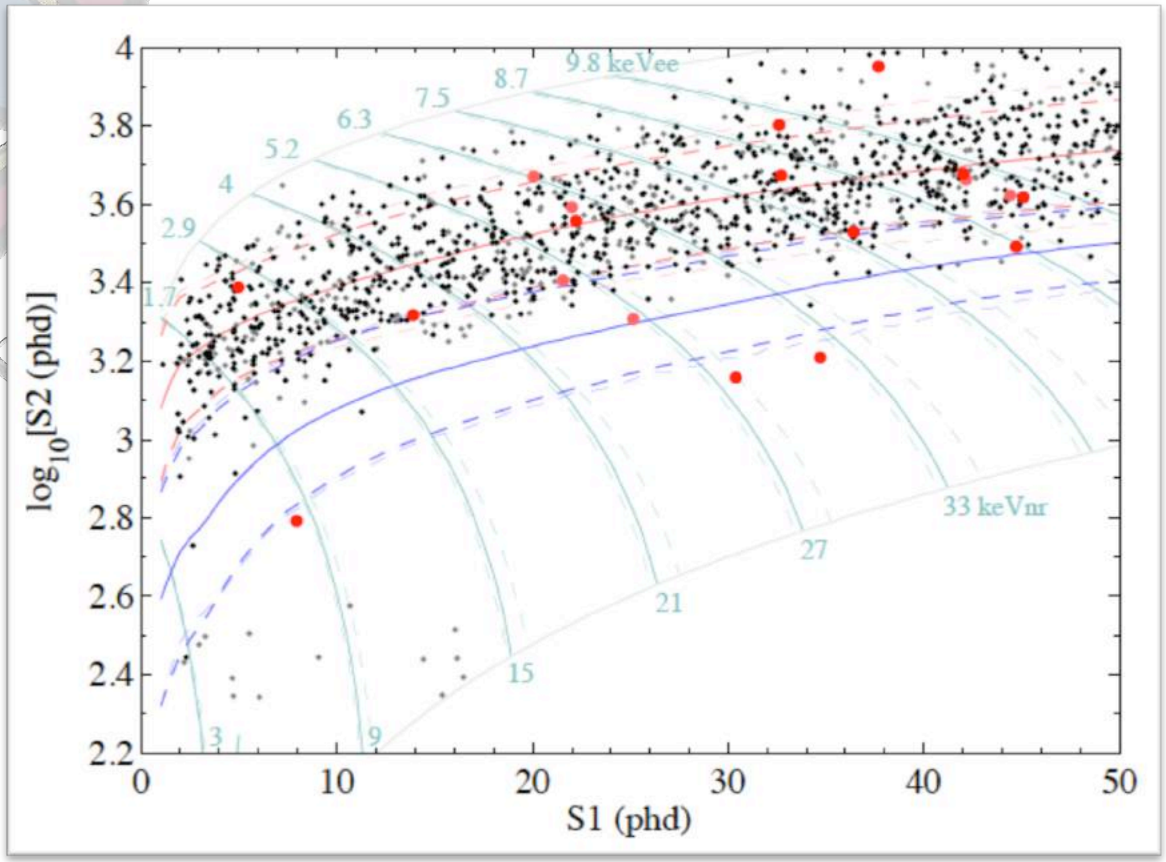
Additional cuts

Post unsalting cuts applied

Red dots show additional cuts do not unduly target WS candidate events

~Flat efficiency of 98.5%

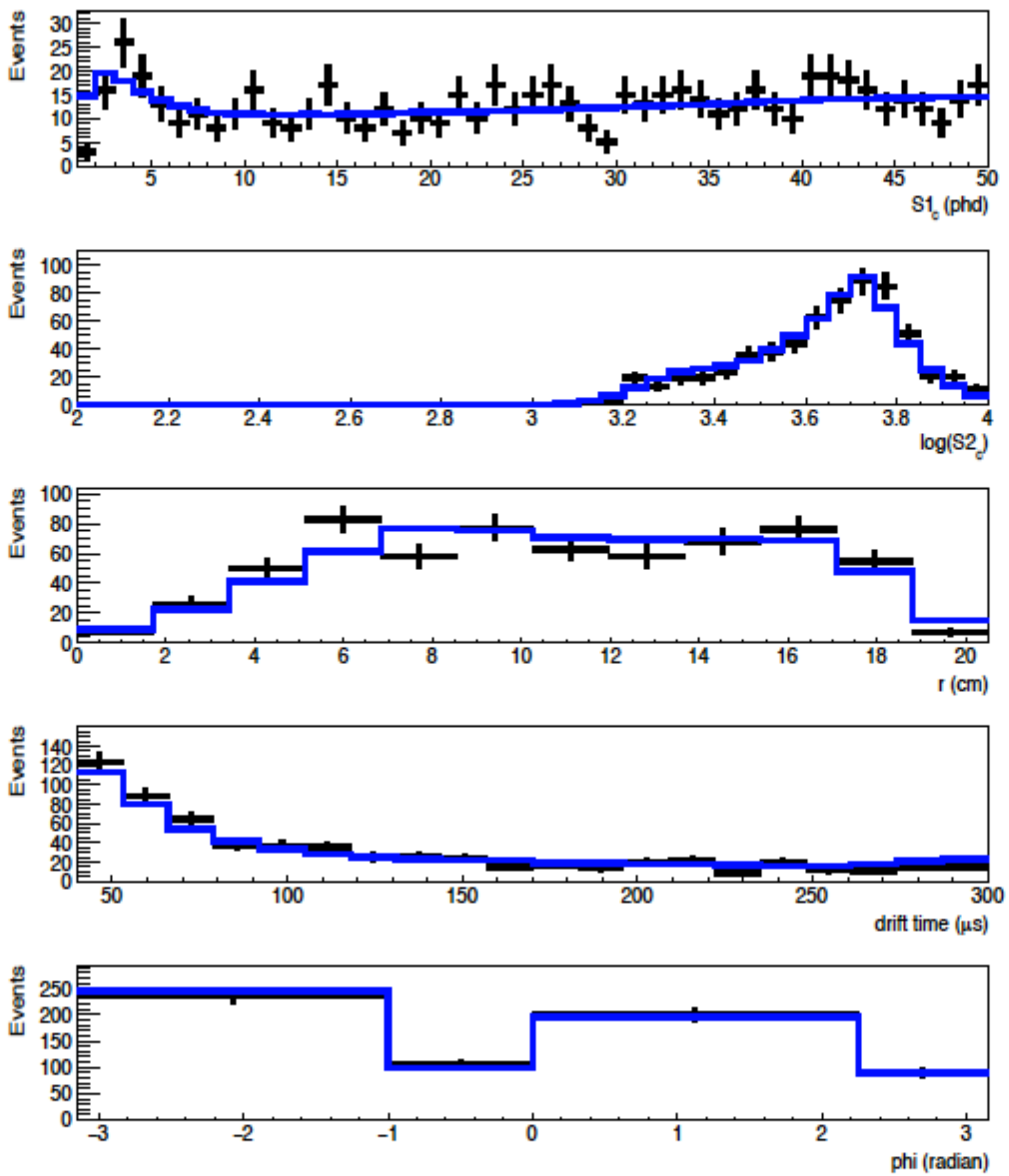
Salt removed



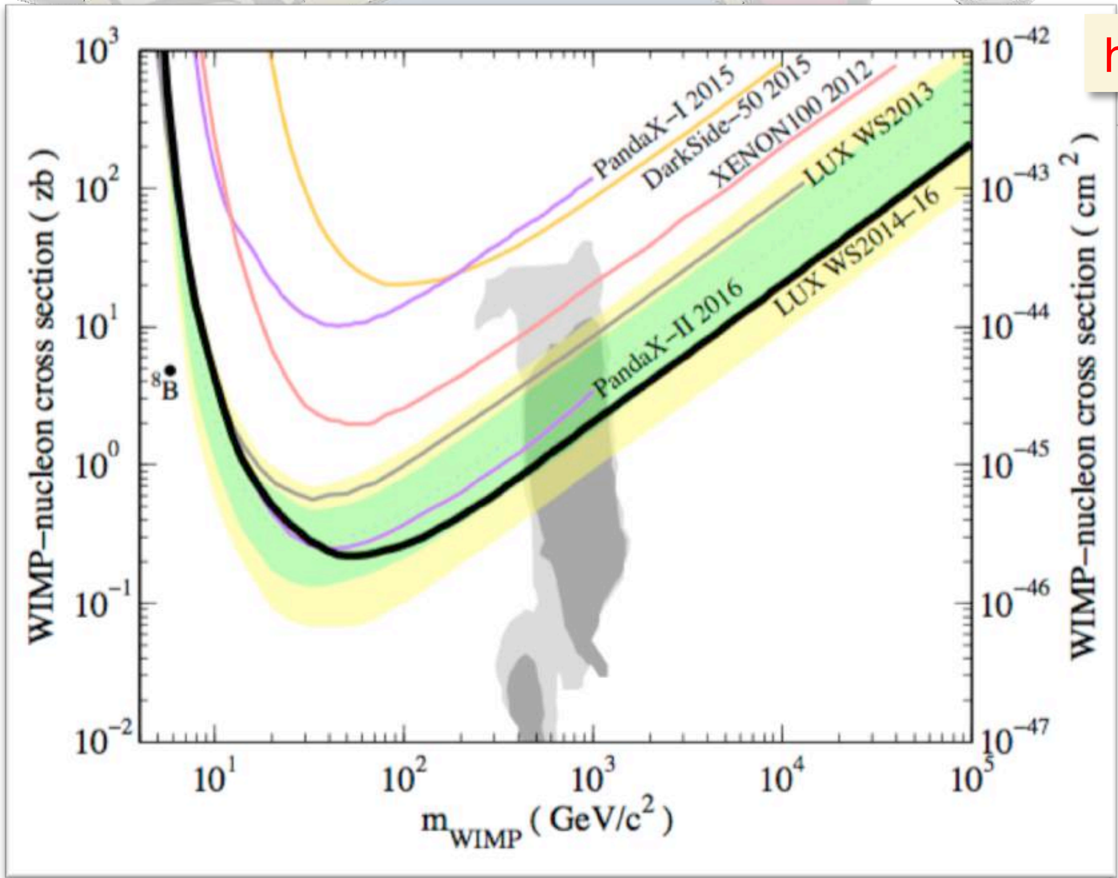
PLR analysis

Two-sided PLR

- 5 un-binned PLR dimensions: r, ϕ, drift-time, S1, log10(S2)
- 1 binned PLR dimension: Event date
- Good agreement with background-only model, p-value >0.6 for each projection



332 Live days result



https://arxiv.org/pdf/1608.07648.pdf

arXiv:1608.07648v1 [astro-ph.CO] 27 Aug 2016

Results from a search for dark matter in LUX with 332 live days of exposure

D.S. Akerib,[1,2,3] S. Alsum,[4] H.M. Araújo,[5] X. Bai,[6] A.J. Bailey,[5] J. Balajthy,[7] P. Beltrame,[8] E.P. Bernard,[9,10] A. Bernstein,[11] T.P. Biesiadzinski,[1,2,3] E.M. Boulton,[9,10] R. Bramante,[1,2,3] P. Brás,[12] D. Byram,[13,14] S.B. Cahn,[10] M.C. Carmona-Benitez,[15] C. Chan,[16] A.A. Chiller,[13] C. Chiller,[13] A. Currie,[5] J.E. Cutter,[17] T.J.R. Davison,[8] A. Dobi,[18] J.E.Y. Dobson,[19] E. Druszkiewicz,[20] B.N. Edwards,[10] C.H. Faham,[18] S. Fiorucci,[16,18] R.J. Gaitskell,[16] V.M. Gehman,[18] C. Ghag,[19] K.R. Gibson,[1] M.G.D. Gilchriese,[18] C.R. Hall,[7] M. Hanhardt,[6,14] S.J. Haselschwardt,[15] S.A. Hertel,[9,10,*] D.P. Hogan,[9] M. Horn,[14,9,10] D.Q. Huang,[16] C.M. Ignarra,[2,3] M. Ihm,[9] R.G. Jacobsen,[9] W. Ji,[1,2,3] K. Kamdin,[9] K. Kazkaz,[11] D. Khaitan,[20] R. Knoche,[7] N.A. Larsen,[10] C. Lee,[1,2,3] B.G. Lenardo,[17,11] K.T. Lesko,[18] A. Lindote,[12] M.I. Lopes,[12] A. Manalaysay,[17,†] R.L. Mannino,[21] M.F. Marzioni,[8] D.N. McKinsey,[9,18,10] D.-M. Mei,[13] J. Mock,[22] M. Moongweluwan,[20] J.A. Morad,[17] A.St.J. Murphy,[8] C. Nehrkorn,[15] H.N. Nelson,[15] F. Neves,[12] K. O'Sullivan,[9,18,10] K.C. Oliver-Mallory,[9] K.J. Palladino,[4,2,3] E.K. Pease,[9,18,10] P. Phelps,[1] L. Reichhart,[19] C. Rhyne,[16] S. Shaw,[19] T.A. Shutt,[1,2,3] C. Silva,[12] M. Solmaz,[15] V.N. Solovov,[12] P. Sorensen,[18] S. Stephenson,[17] T.J. Sumner,[5] M. Szydagis,[22] D.J. Taylor,[14] W.C. Taylor,[16] B.P. Tennyson,[10] P.A. Terman,[21] D.R. Tiedt,[6] W.H. To,[1,2,3] M. Tripathi,[17] L. Tvrznikova,[9,10] S. Uvarov,[17] J.R. Verbus,[16] R.C. Webb,[21] J.T. White,[21] T.J. Whitis,[1,2,3] M.S. Witherell,[18] F.L.H. Wolfs,[20] J. Xu,[11] K. Yazdani,[5] S.K. Young,[22] and C. Zhang[13]

(LUX Collaboration)

[1] *Case Western Reserve University, Department of Physics, 10900 Euclid Ave, Cleveland, OH 44106, USA*
[2] *SLAC National Accelerator Laboratory, 2575 Sand Hill Road, Menlo Park, CA 94205, USA*
[3] *Kavli Institute for Particle Astrophysics and Cosmology, Stanford University, 452 Lomita Mall, Stanford, CA 94309, USA*
[4] *University of Wisconsin-Madison, Department of Physics, 1150 University Ave., Madison, WI 53706, USA*
[5] *Imperial College London, High Energy Physics, Blackett Laboratory, London SW7 2BZ, United Kingdom*
[6] *South Dakota School of Mines and Technology, 501 East St Joseph St., Rapid City, SD 57701, USA*
[7] *University of Maryland, Department of Physics, College Park, MD 20742, USA*
[8] *SUPA, School of Physics and Astronomy, University of Edinburgh, Edinburgh EH9 3FD, United Kingdom*
[9] *University of California Berkeley, Department of Physics, Berkeley, CA 94720, USA*
[10] *Yale University, Department of Physics, 217 Prospect St., New Haven, CT 06511, USA*
[11] *Lawrence Livermore National Laboratory, 7000 East Ave., Livermore, CA 94551, USA*
[12] *LIP-Coimbra, Department of Physics, University of Coimbra, Rua Larga, 3004-516 Coimbra, Portugal*
[13] *University of South Dakota, Department of Physics, 414E Clark St., Vermillion, SD 57069, USA*
[14] *South Dakota Science and Technology Authority, Sanford Underground Research Facility, Lead, SD 57754, USA*
[15] *University of California Santa Barbara, Department of Physics, Santa Barbara, CA 93106, USA*
[16] *Brown University, Department of Physics, 182 Hope St., Providence, RI 02912, USA*
[17] *University of California Davis, Department of Physics, One Shields Ave., Davis, CA 95616, USA*
[18] *Lawrence Berkeley National Laboratory, 1 Cyclotron Rd., Berkeley, CA 94720, USA*
[19] *Department of Physics and Astronomy, University College London, Gower Street, London WC1E 6BT, United Kingdom*
[20] *University of Rochester, Department of Physics and Astronomy, Rochester, NY 14627, USA*
[21] *Texas A & M University, Department of Physics, College Station, TX 77843, USA*
[22] *University at Albany, State University of New York, Department of Physics, 1400 Washington Ave., Albany, NY 12222, USA*

(Dated: August 30, 2016)

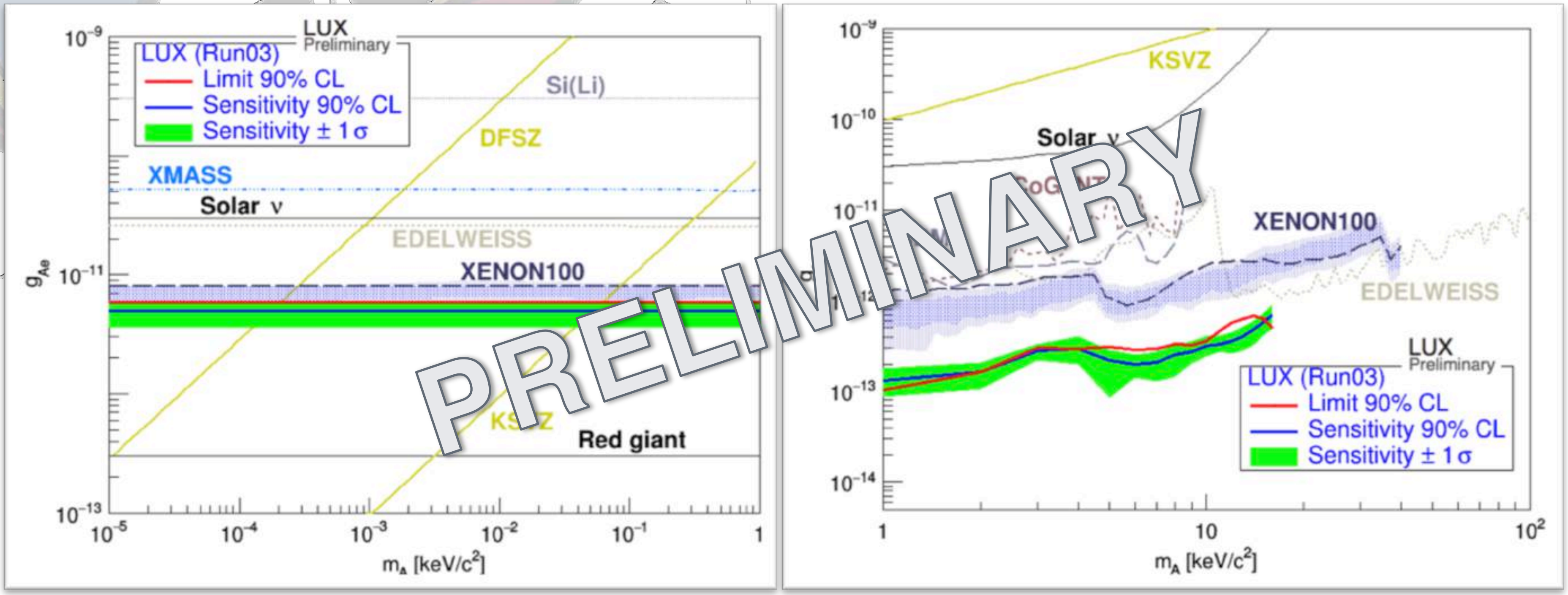
We report constraints on spin-independent weakly interacting massive particle (WIMP)-nucleon scattering using a 3.35×10^4 kg-day exposure of the Large Underground Xenon (LUX) experiment. A dual-phase xenon time projection chamber with 250 kg of active mass is operated at the Sanford Underground Research Facility under Lead, South Dakota (USA). With roughly four-fold improvement in sensitivity for high WIMP masses relative to our previous results, this search yields no evidence of WIMP nuclear recoils. At a WIMP mass of 50 GeV c^{-2}, WIMP-nucleon spin-independent cross sections above 2.2×10^{-46} cm^2 are excluded at the 90% confidence level.

* hertel@berkeley.edu
† aaronm@ucdavis.edu

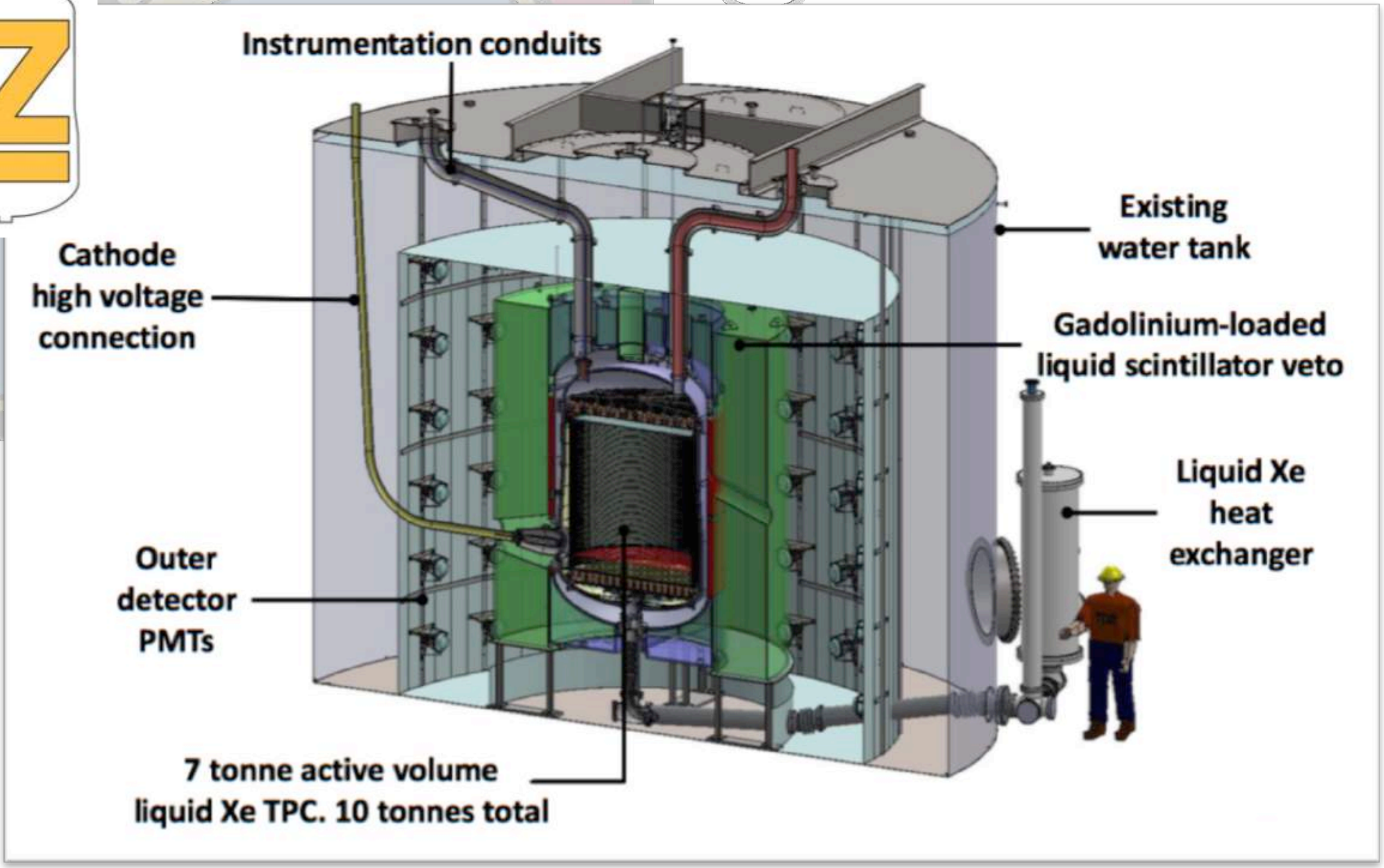
What’s next?

Axions

- Extends science beyond standard WIMP searches
- ER-band search
- …Extending background model



Longer term: Bigger is better!



See talk: "Status of LZ dark matter search experiment", Sridhara Dasu, 15.10 Friday

The LUX collaboration

Berkeley Lab / UC Berkeley

Bob Jacobsen	PI, Professor
Murdock Gilchriese	Senior Scientist
Kevin Lesko	Senior Scientist
Michael Witherell	Lab Director
Peter Sorensen	Scientist
Simon Fiorucci	Project Scientist
Attila Dobi	Postdoc
Daniel Hogan	Graduate Student
Kate Kamdin	Graduate Student
Kelsey Oliver-Mallory	Graduate Student

BROWN Brown Univer

Richard Gaitskell	PI, Profes
Samuel Chung	Graduate
Dongqing Huang	Graduate
Casey Rhyne	Graduate
Will Taylor	Graduate
James Verbus	Postdoc

University of Edinburgh, UK

Alex Murphy	PI, Professor
Paolo Beltrame	Research Fellow
Tom Davison	Graduate Student
Maria F. Marzioni	Graduate Student

Imperial College London — Imperial College London, UK

Henrique Araujo	PI, Reader
Tim Sumner	Professor
Alastair Currie	Postdoc
Adam Bailey	Graduate Student
Khadeeja Yazdani	Graduate Student

Lawrence Livermore

Adam Bernstein	PI, Leader of Adv. Detectors Grp.
Kareem Kazkaz	Staff Physicist
Jingke Xu	Postdoc
Brian Lenardo	Graduate Student

LIP Coimbra, Portugal

Isabel Lopes	PI, Professor
Jose Pinto da	Assistant Professor
Vladimir Solovov	Senior Researcher
Francisco Neves	Auxiliary Researcher
Alexander Lindote	Postdoc

Rosie Bramante	Graduate Student
Wei Ji	Graduate Student
T.J. Whitis	Graduate Student

SD Mines

Xinhua Bai	PI, Professor
Doug Tiedt	Graduate Student

SDSTA / Sanford Lab

David Taylor	Project Engineer
Markus Horn	Research Scientist
Dana Byram	Support Scientist

UAS University at Albany

Matthew Szydagis	PI, Professor
Jeremy Mock	Postdoc
Sean Fallon	Graduate Student
Jack Genovesi	Graduate Student
Steven Young	Graduate Student

Texas A&M University

James White †	PI, Professor
Robert Webb	PI, Professor
Rachel Mannino	Graduate Student
Paul Terman	Graduate Student

Berkeley UC Berkeley (Yale)

Nicole Larsen	Graduate Student

UCDAVIS UC Davis

Mani Tripathi	PI, Professor
Britt Hollbrook	Senior Engineer
John Thomson	Development
Dave Hemer	Senior Machinist
Ray Gerhard	Electronics Engineer
Aaron Manalaysay	Project Scientist
Jacob Cutter	Graduate Student
James Morad	Graduate Student
Sergey Uvarov	Graduate Student

UCSB UC Santa Barbara

Harry Nelson	PI, Professor
Susanne Kyre	Engineer
Dean White	Engineer
Carmen Carmona	Postdoc
Scott Haselschwardt	Graduate Student
Curt Nehrkorn	Graduate Student
Melih Solmaz	Graduate Student

UCL University College London, UK

Chamkaur Ghag	PI, Lecturer
James Dobson	Postdoc
Sally Shaw	Graduate Student

ersity of Maryland

	PI, Professor
	Graduate Student
e	Graduate Student

ersity of Rochester

	PI, Professor
i	Senior Scientist
Eryk Druszkiewicz	Graduate Student
Dev Ashish Khaitan	Graduate Student
Diktat Koyuncu	Graduate Student
M. Moongweluwan	Graduate Student
Jun Yin	Graduate Student

University of South Dakota

Dongming Mei	PI, Professor
Chao Zhang	Postdoc

University of Wisconsin

Kimberly Palladino	PI, Asst Professor
Shaun Alsum	Graduate Student

Thank You

Extra Slides

Extraction Efficiency:

We have three different measurements of the extraction in situ and all agree within errors.

- The value we quote comes from the Doke plot analysis.
- We can also measure our extraction efficiency by comparing the charge yield for alphas to previous work by Aprile.
- The third method performs a fit to the tritium spectrum floating g1 and g2.
- The agreement between the three different methods gives us confidence in that number.
- In addition, electric field simulations show that our extraction efficiency at this extraction field is consistent with the work of Gushkin.

Cuts

- Single S2 preceded by a single S1
- S1 in 2 or more PMTs
- upper threshold for the summed pulse area outside S1 and S2 within the trigger window
- S2 > 200 phd
- Events for which S2 > 104 phd, S1 > 50 phd, log10(S2) < medianNR – 5σNR or log10(S2) >medianER + 3σER are considered far from the region of interest and are ignored.
- FV 40-300 us
- Event located >3cm inward of median wall position

Efficiencies

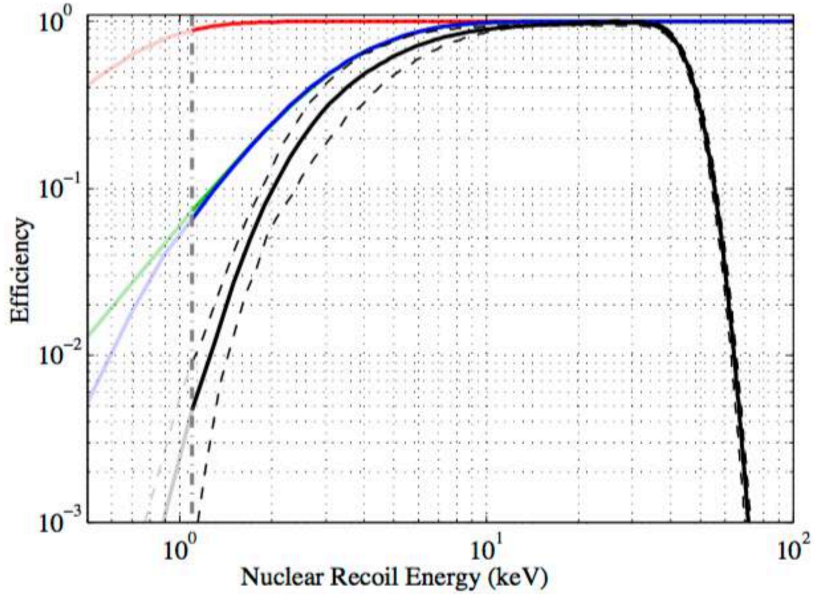


FIG. 2. Efficiencies for NR event detection, estimated using simulation with parameters tuned to calibration data. In descending order of efficiency—red: detection of an S2 (and classification as such by analysis); green: detection of an S1 ($\geq$2 PMTs detecting photons); blue: detection of both an S1 and an S2; black: detection passing analysis selection criteria. Solid curves indicate exposure-weighted means of the 16 calibrated models. The scale of model variation is illustrated by including the efficiencies of the date- and z-bins with highest and lowest total efficiency (black dashed curves). Below 1.1 keV nuclear recoil energy, the lowest energy for which light yield was measured in [11], efficiency is conservatively assumed to be zero.