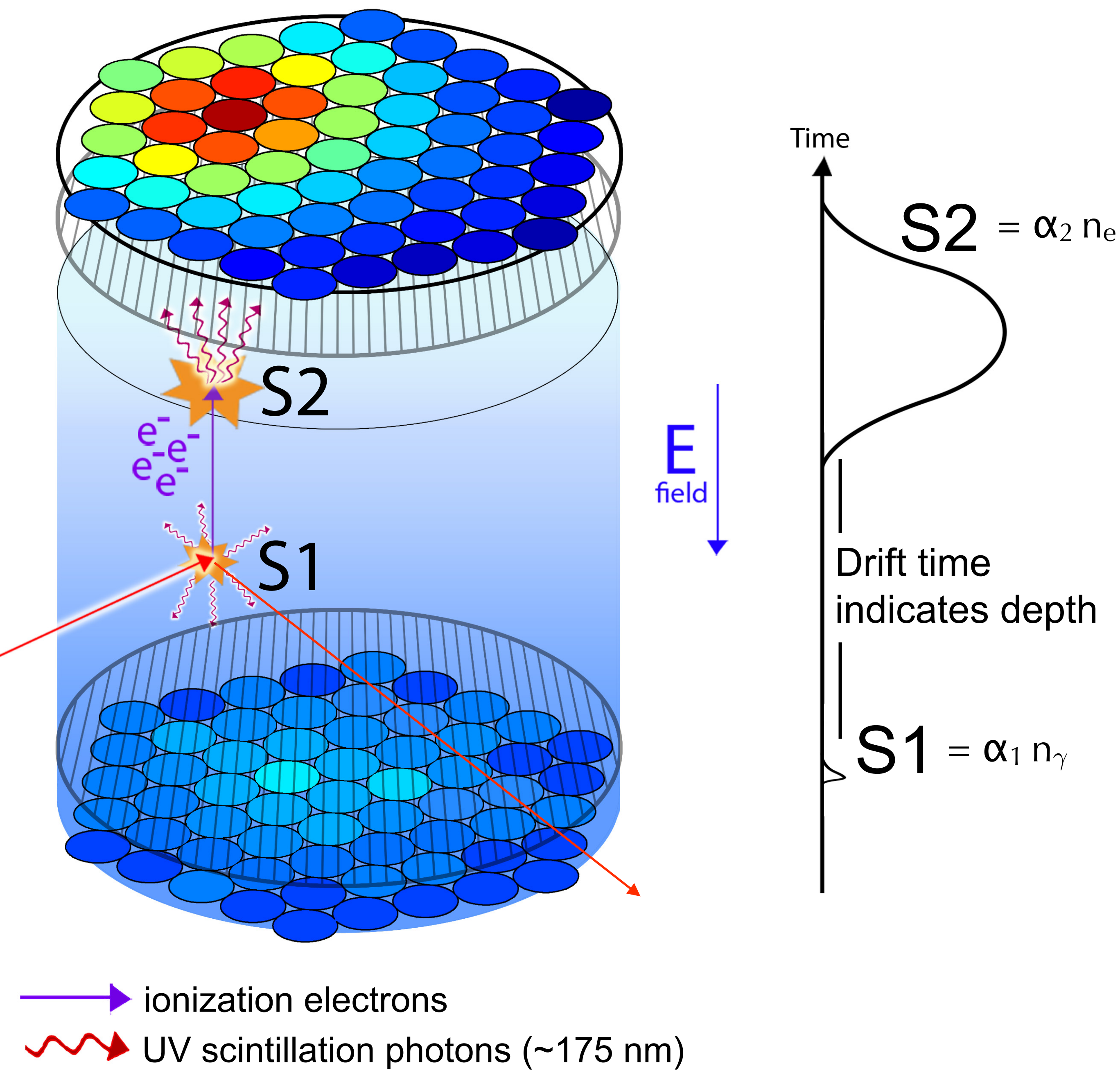
# FIRST RESULTS FROM LUX: TOWARDS DIRECT DETECTION OF DARK MATTER

peter sorensen on behalf of the LUX Collaboration

## what is LUX?

- a particle detector
- a monolithic, "wall-less," radiopure, ~370 kg xenon TPC
- viewed by 122 Photomultiplier Tubes
- able to reconstruct (x,y,z) for each event
- self-shielding

LUX, Nucl. Instr. Meth. A 668 1 (2012)

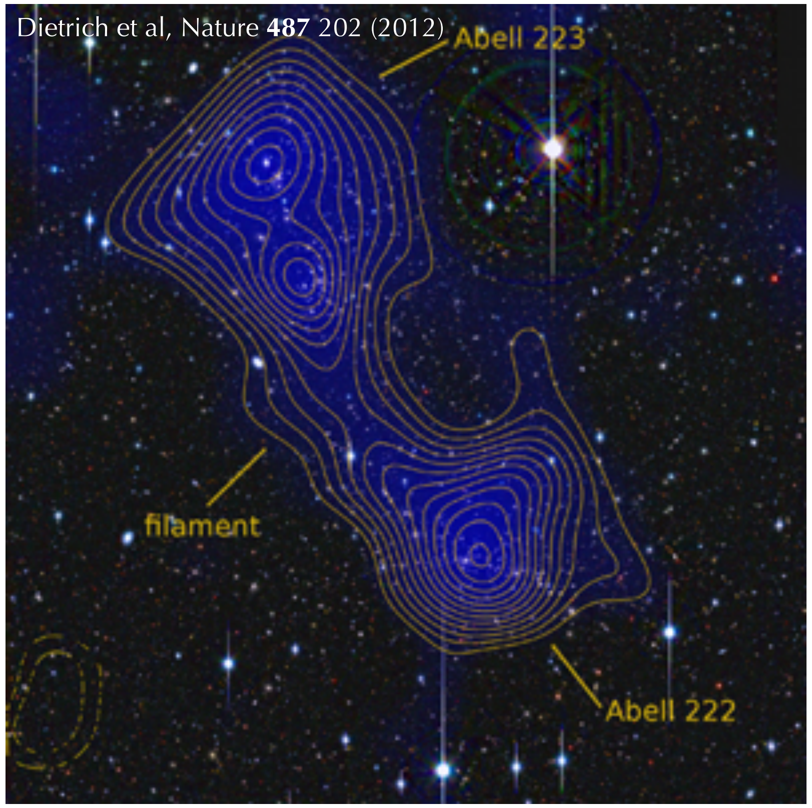



## how would LUX see dark matter?

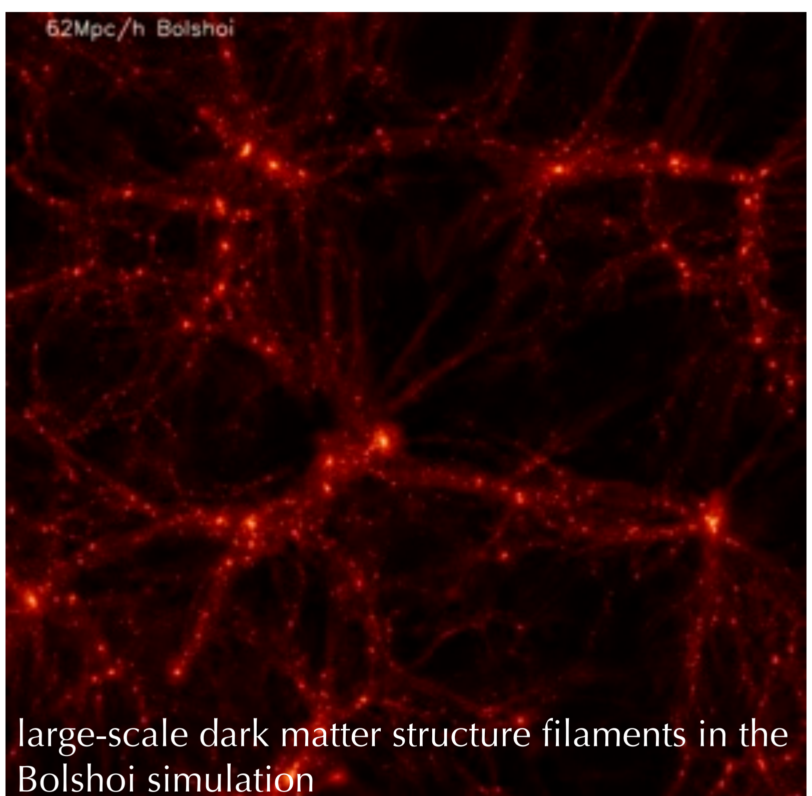
- it detects scintillation photons and ionized electrons created by particle interactions
- if dark matter interacted with a xenon atom, energy transferred to that atom would be visible to LUX
- $\alpha_1 \sim O(0.10)$ and $\alpha_2 \sim O(10)$ are the probabilities for detection of each quanta

- $n_\gamma$ and $n_e$ are the fundamental measured quantities

# WE KNOW THERE IS DARK MATTER OUT THERE: WE CAN "SEE" IT!



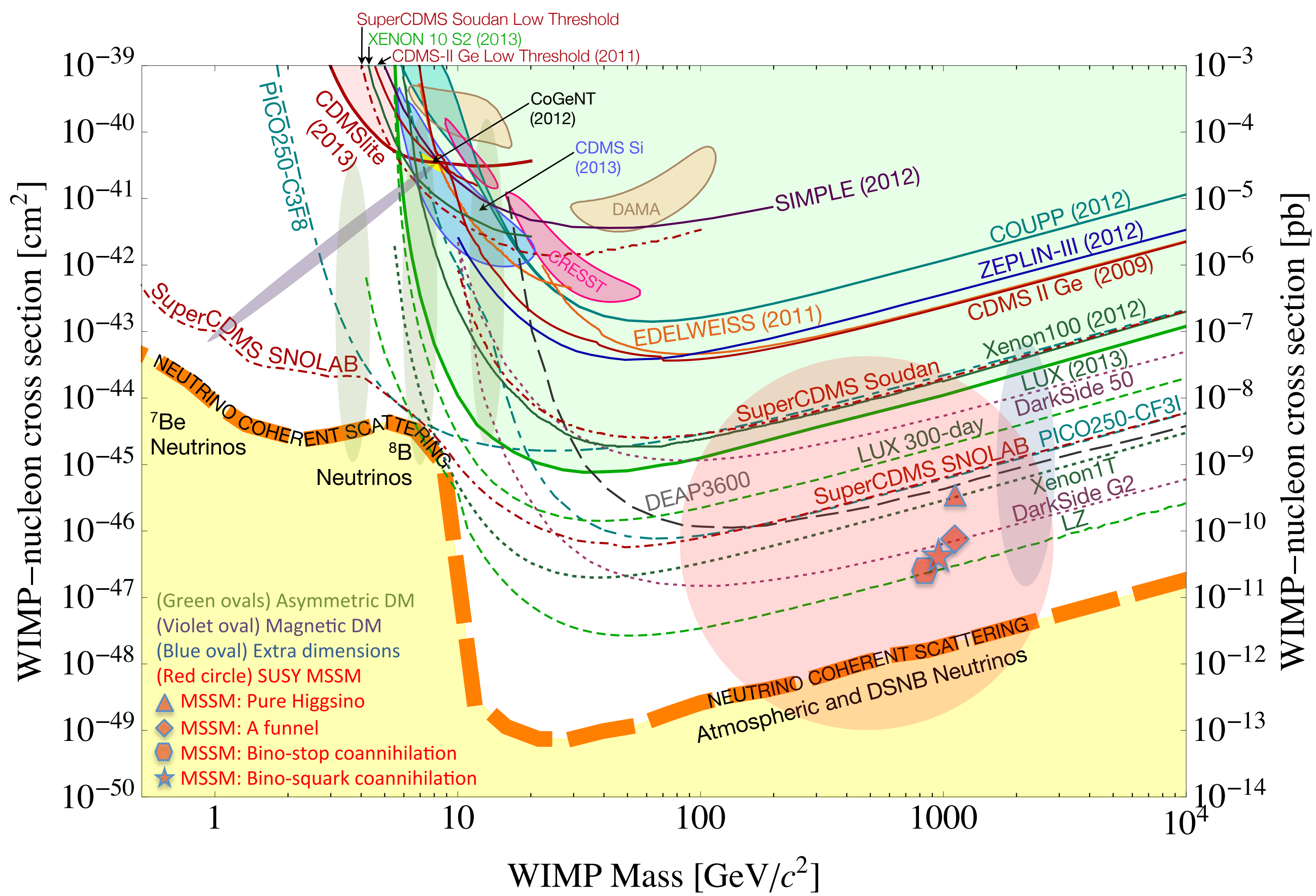

(above) weak-lensing mass reconstruction of a dark matter filament stretching between two clusters, separated by ~15 Mpc/h



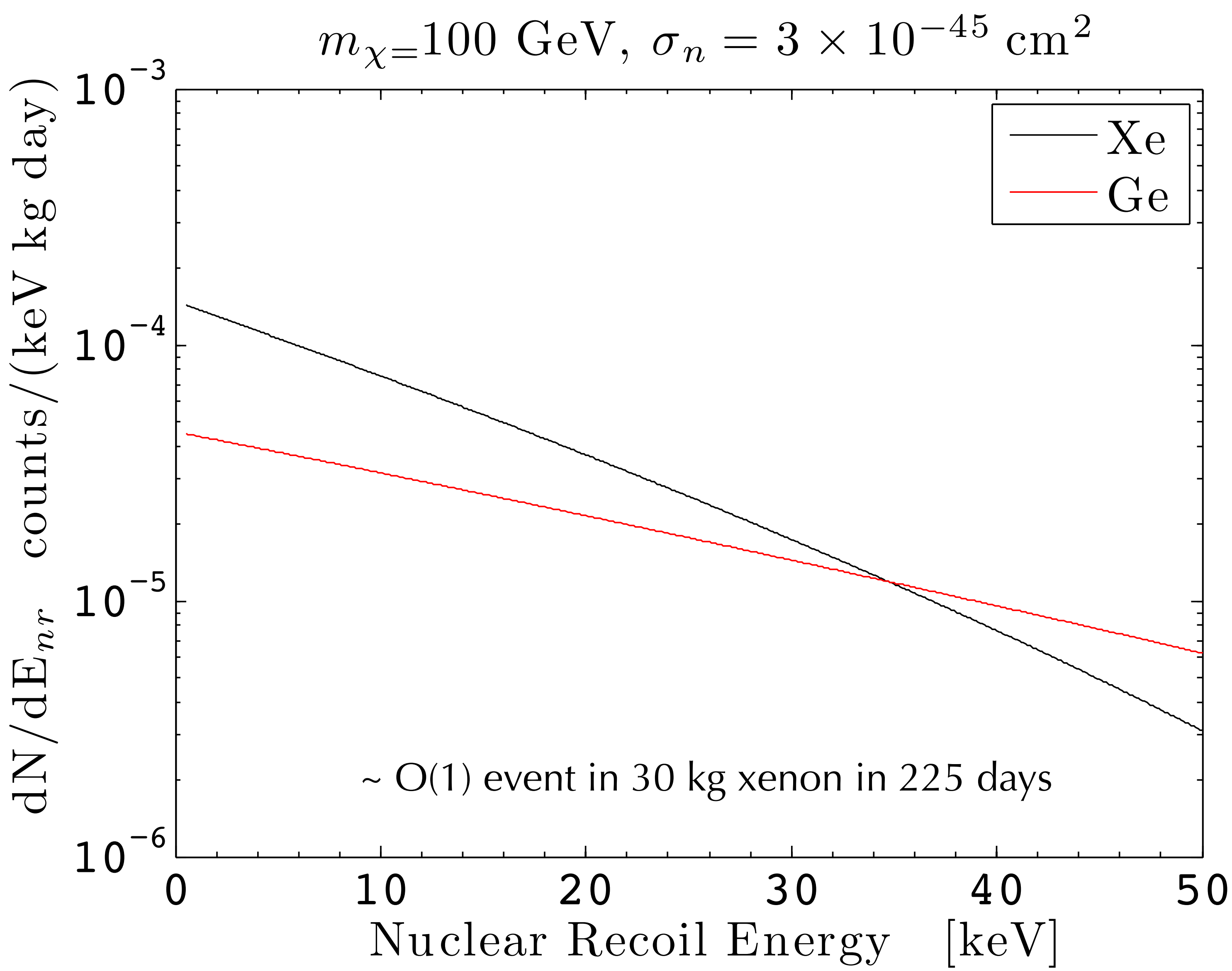

large-scale dark matter structure filaments in the Bolshoi simulation

## BUT, WHAT IS IT?

- Weakly Interacting Massive Particles are a prime candidate
- lots of effort to detect them (below, plot from Snowmass report)
- LUX presently the most sensitive search



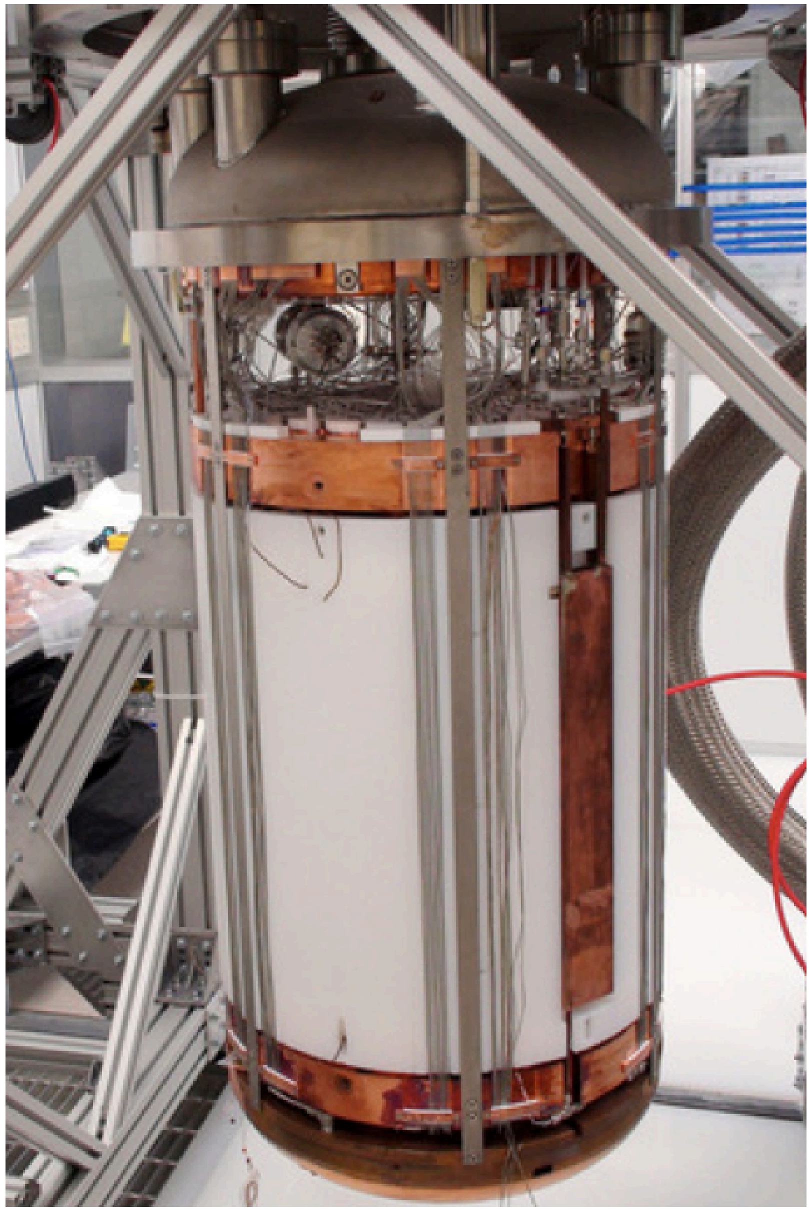
# MANY MODELS OF WIMP DARK MATTER. SIMPLEST CASE SPECTRUM IS ~EXP

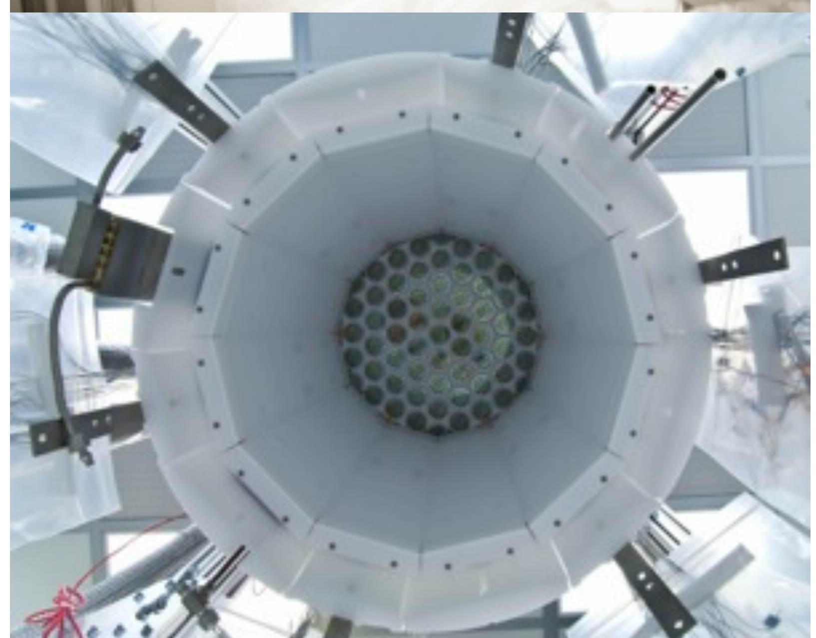


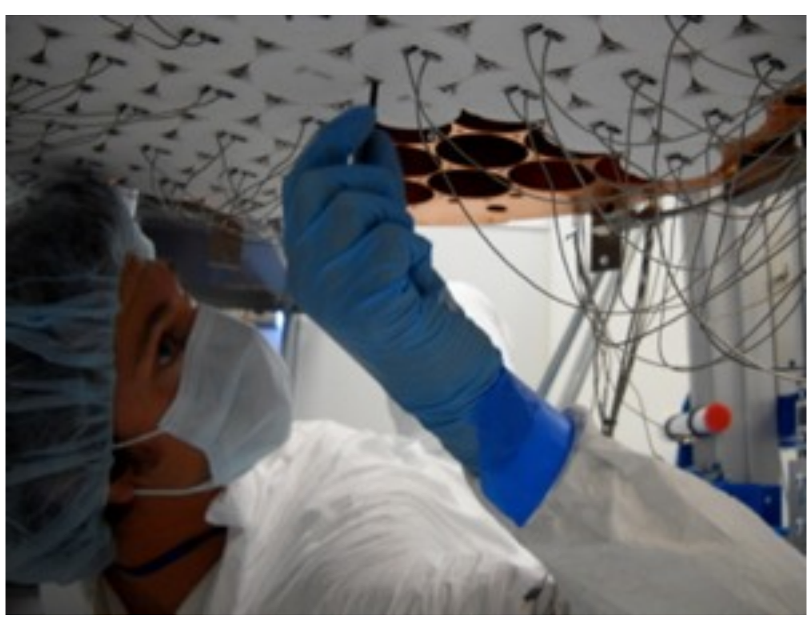
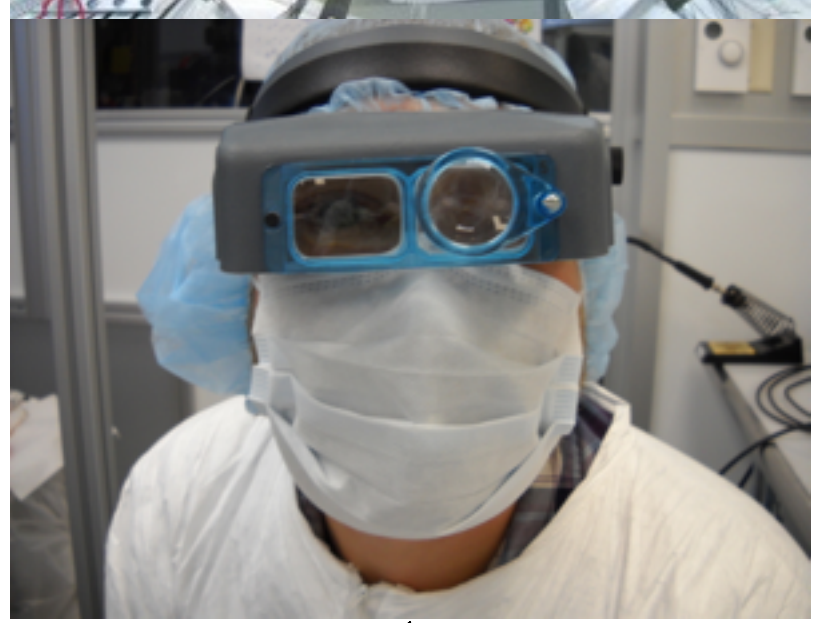

dark matter direct detection seems to require:

1. extremely low background
2. background rejection
3. lowest possible energy threshold
4. large target mass
5. patience

# LOTS OF WORK WENT INTO BUILDING LUX...



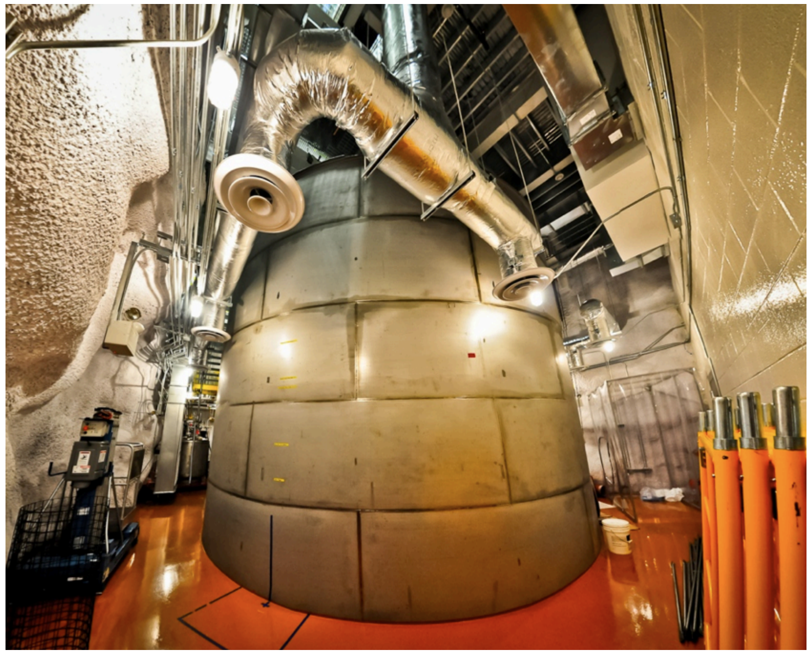



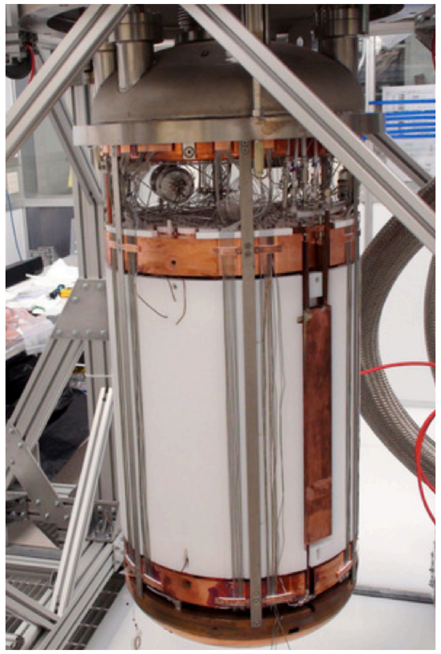



# WE'VE GOT EXTREMELY LOW BACKGROUND

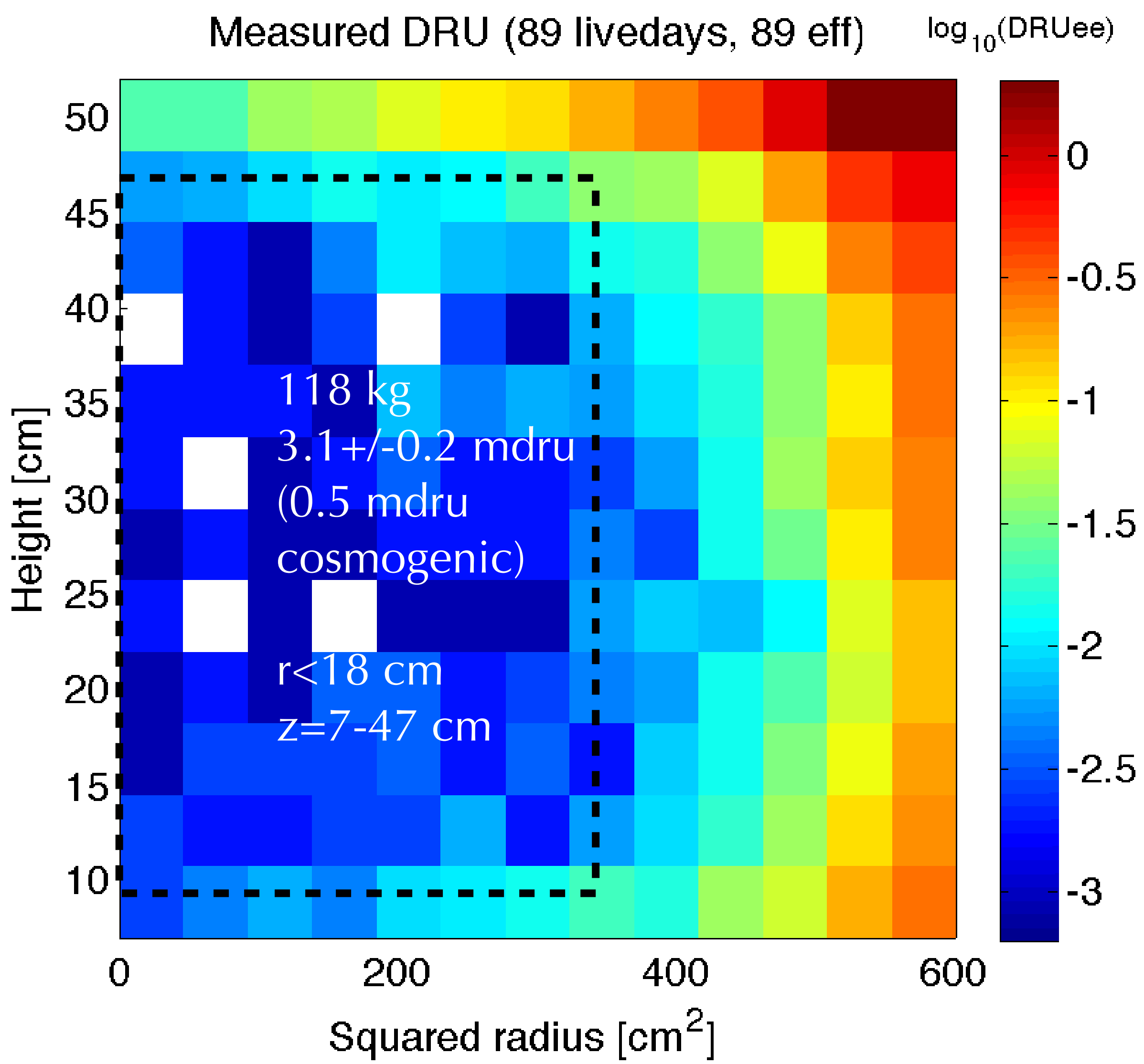
•4850 ft (1492 m) underground in the black hills of South Dakota (4300 meters water equiv.) ... reduces muon flux to <1 muon per day
•surrounded by a 7.6 m diameter water shield ... reduces gamma and neutron backgrounds to <1 projected event in 300 days of searching
•limiting factor is detector construction materials ... this limit is <2 background events per DAY in the central 118 kg target in the energy window of interest.. and **decreasing**

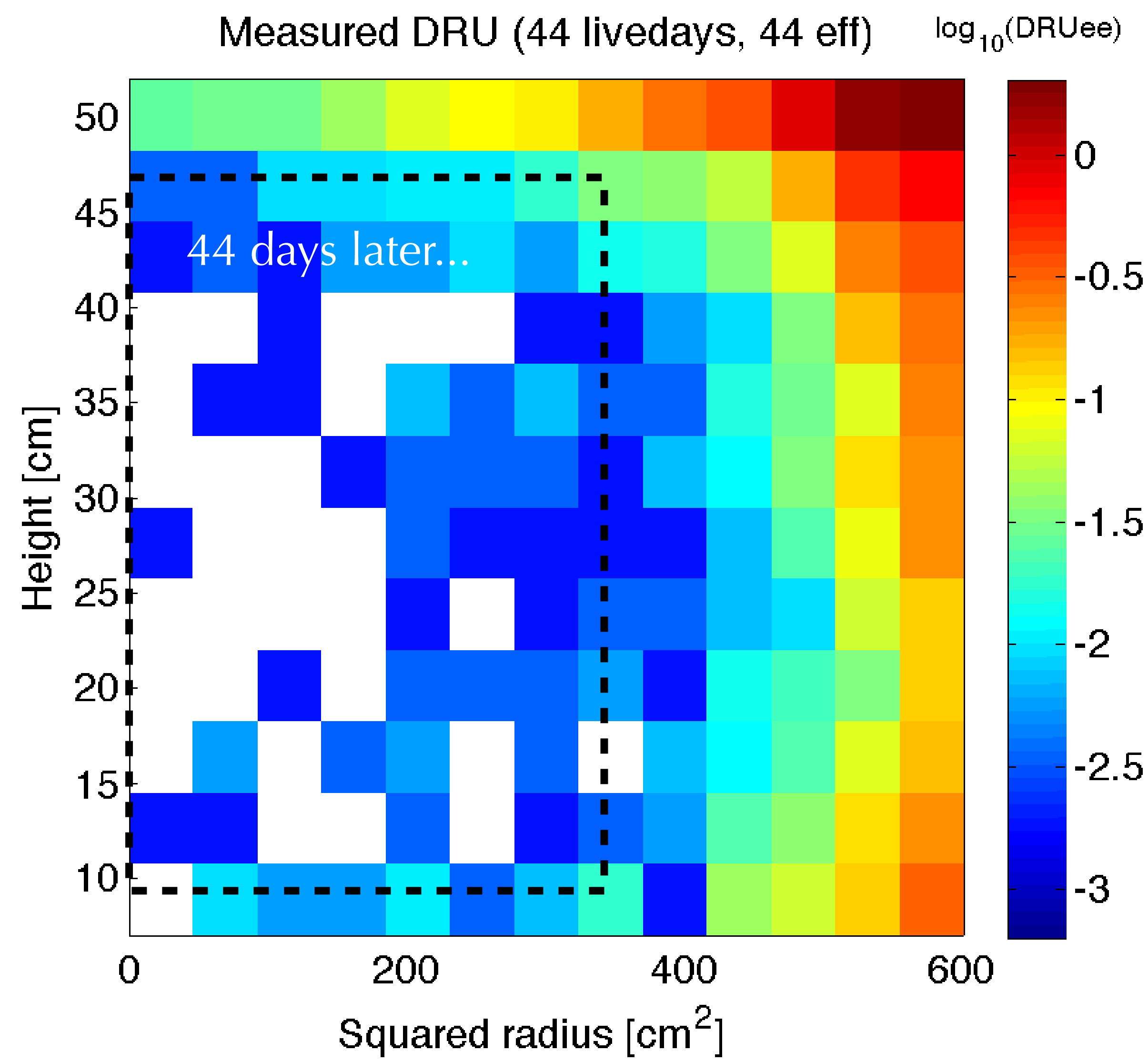
1492 meters below...





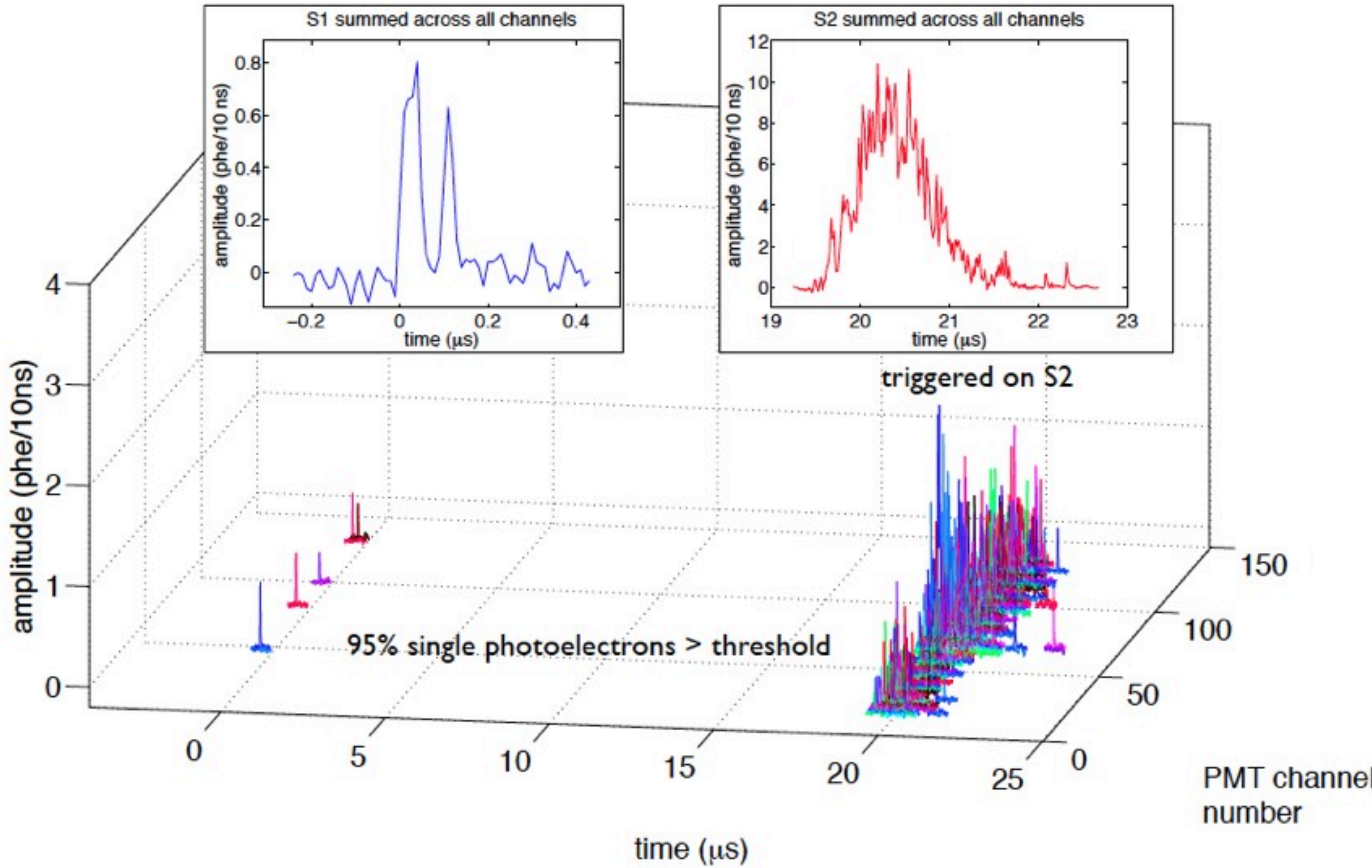
# AND, THE BACKGROUND RATE IS DECREASING!



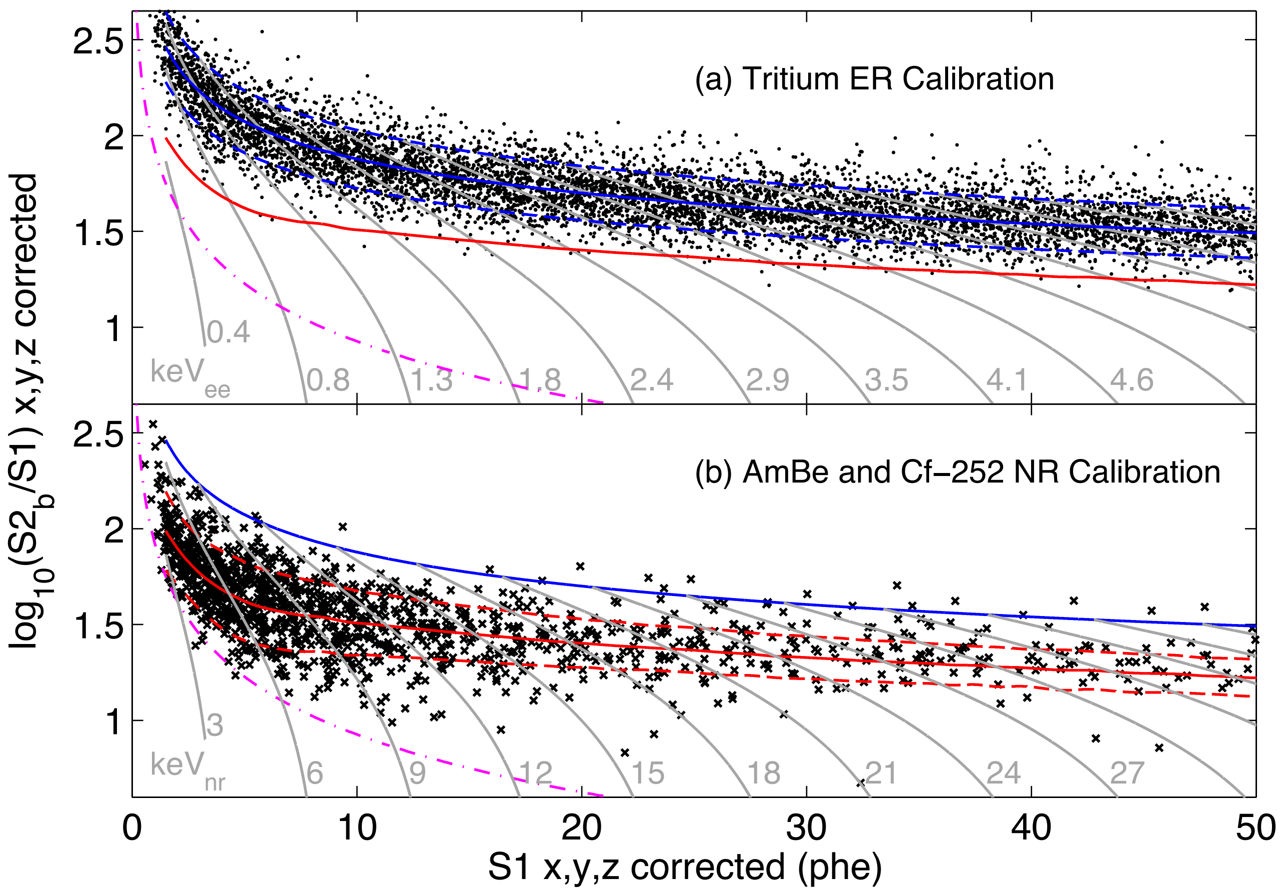




SHOWING EVENT RATE 0-5 KEV

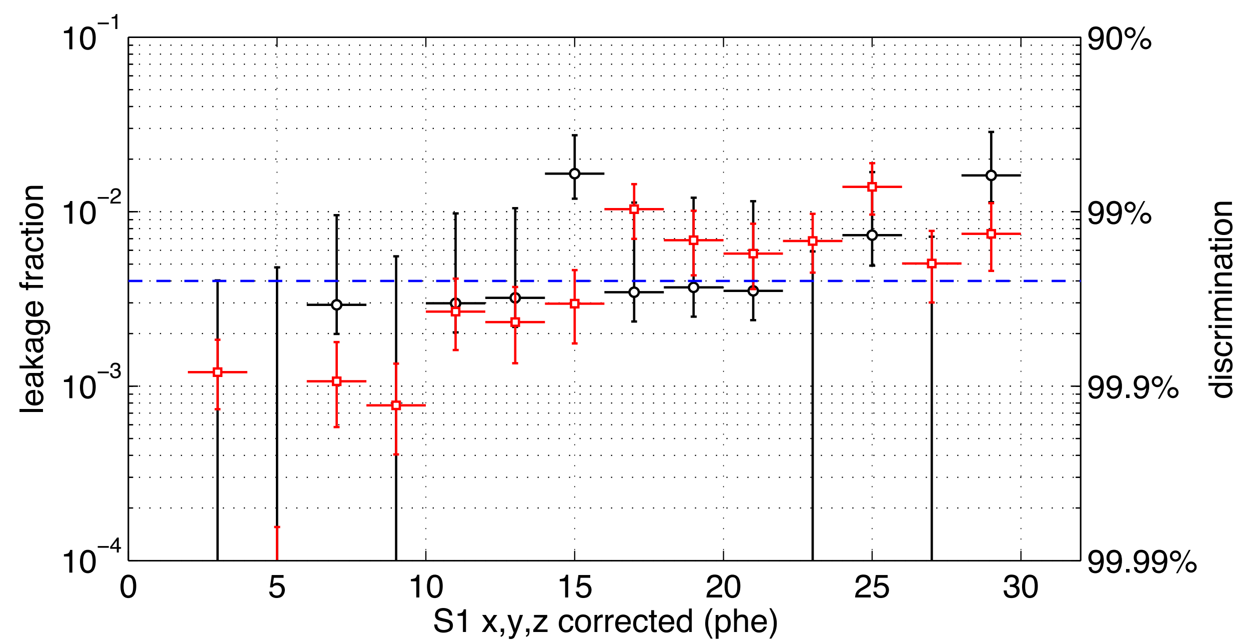
# A TYPICAL BACKGROUND EVENT AT 1.5 KEV



# WE'VE GOT BACKGROUND REJECTION!




99.6% background rejection in low energy region of interest

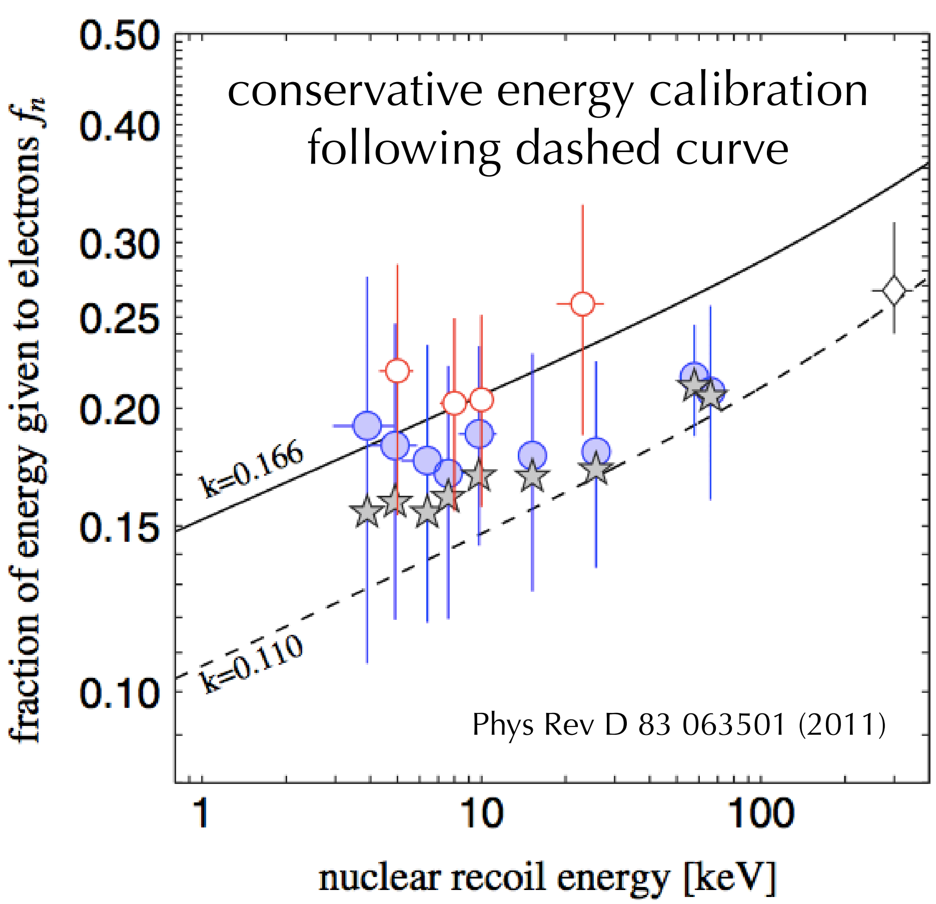


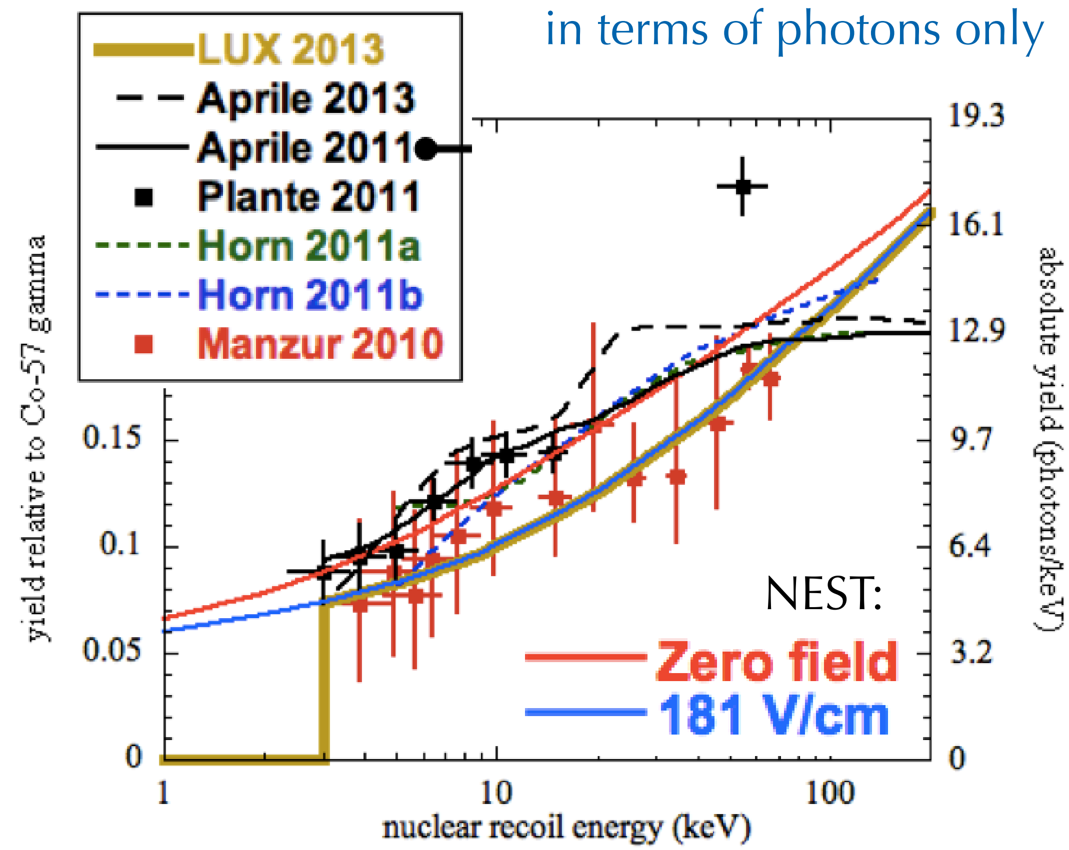

NB: data reduction built on robust event identification and extremely minimal software cuts

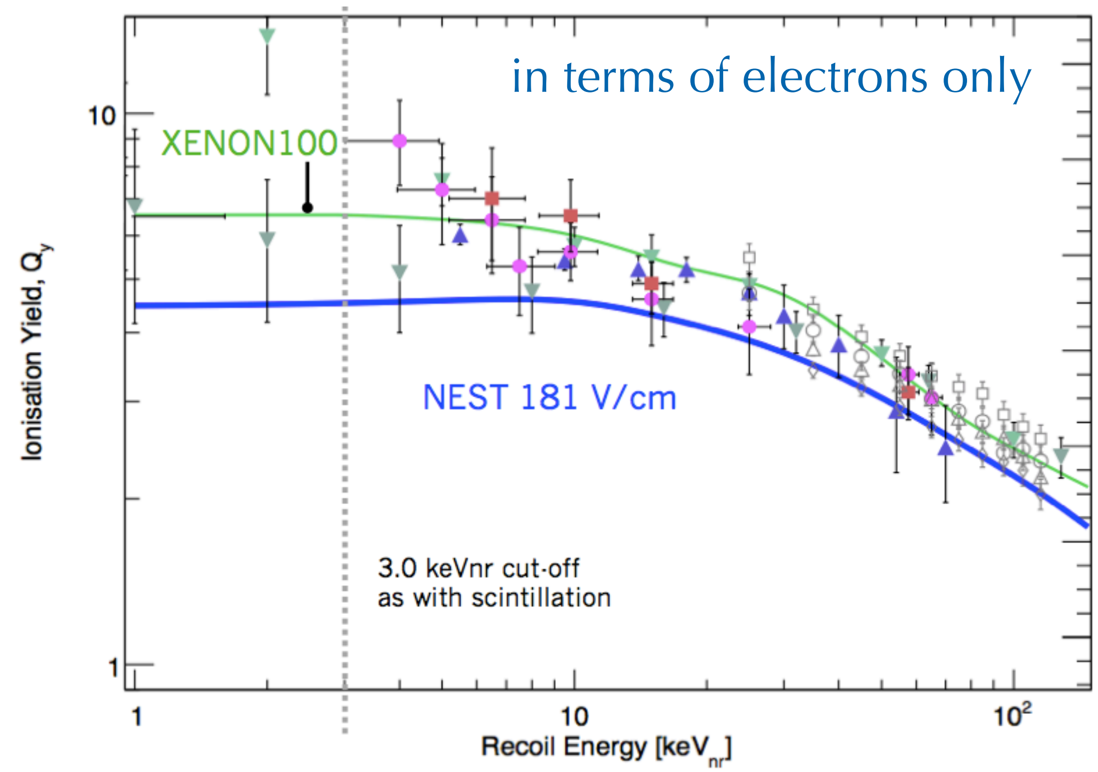
# AND, AN ENERGY THRESHOLD OF ~3 KEV

=> (ENERGY OF RECOILING XENON ATOM)

Total signal (electrons + photons)

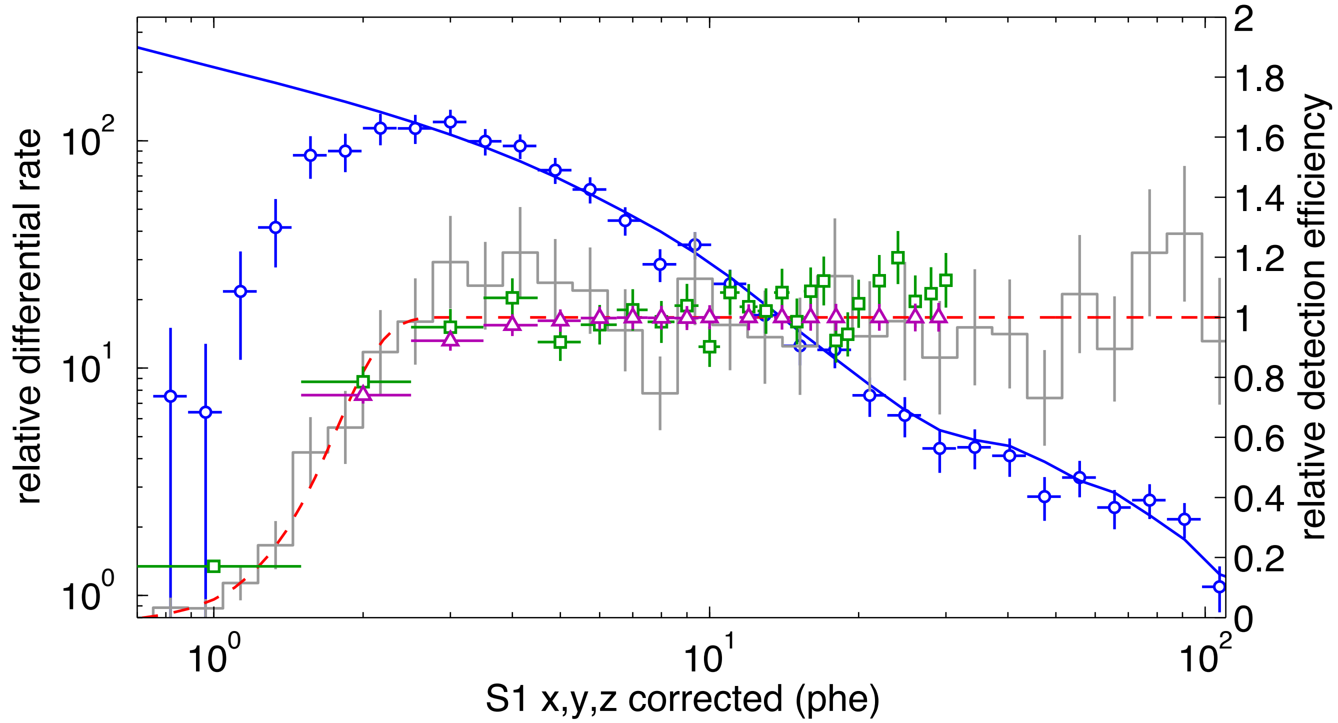


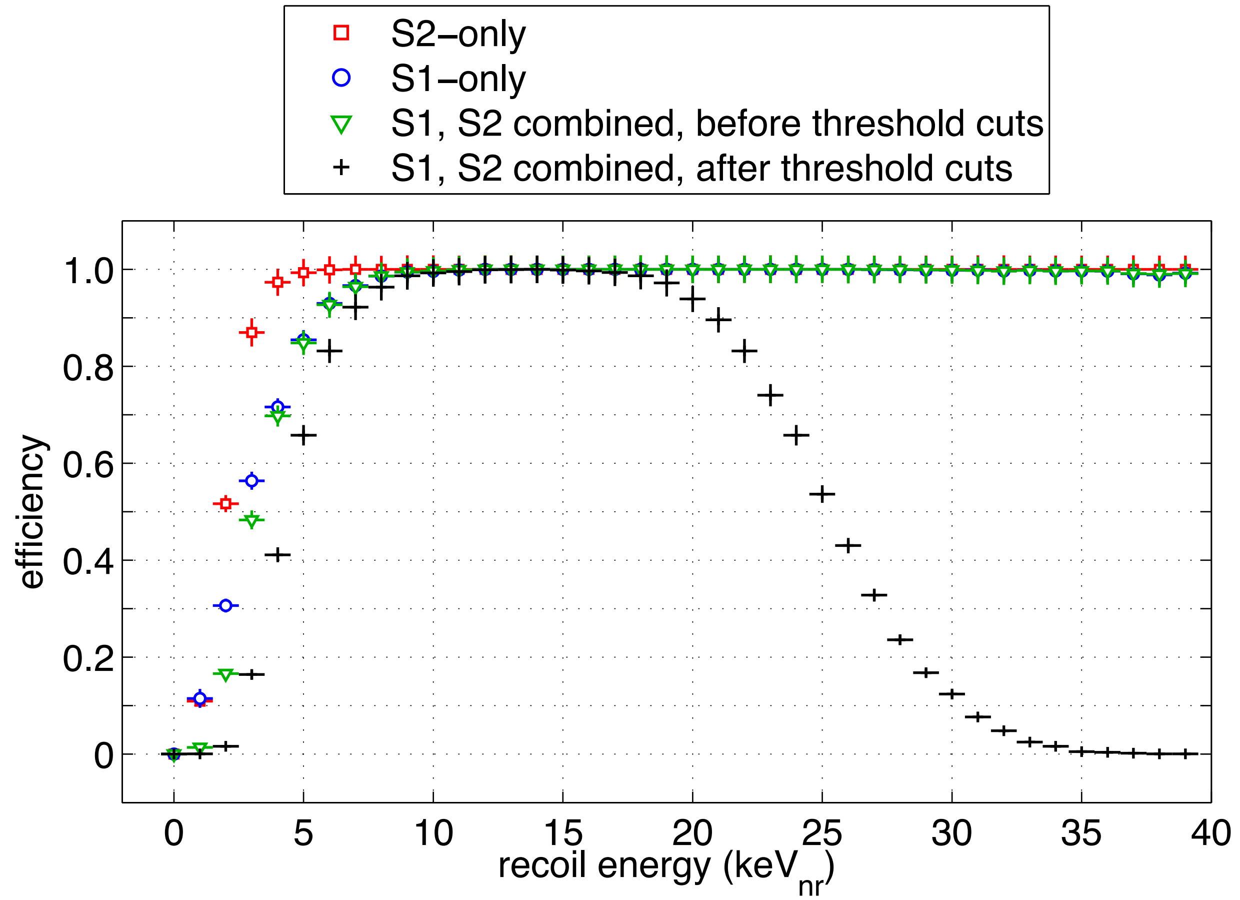




** for details about NEST see e.g. arxiv:1307.6601

# Signal detection efficiency is robust

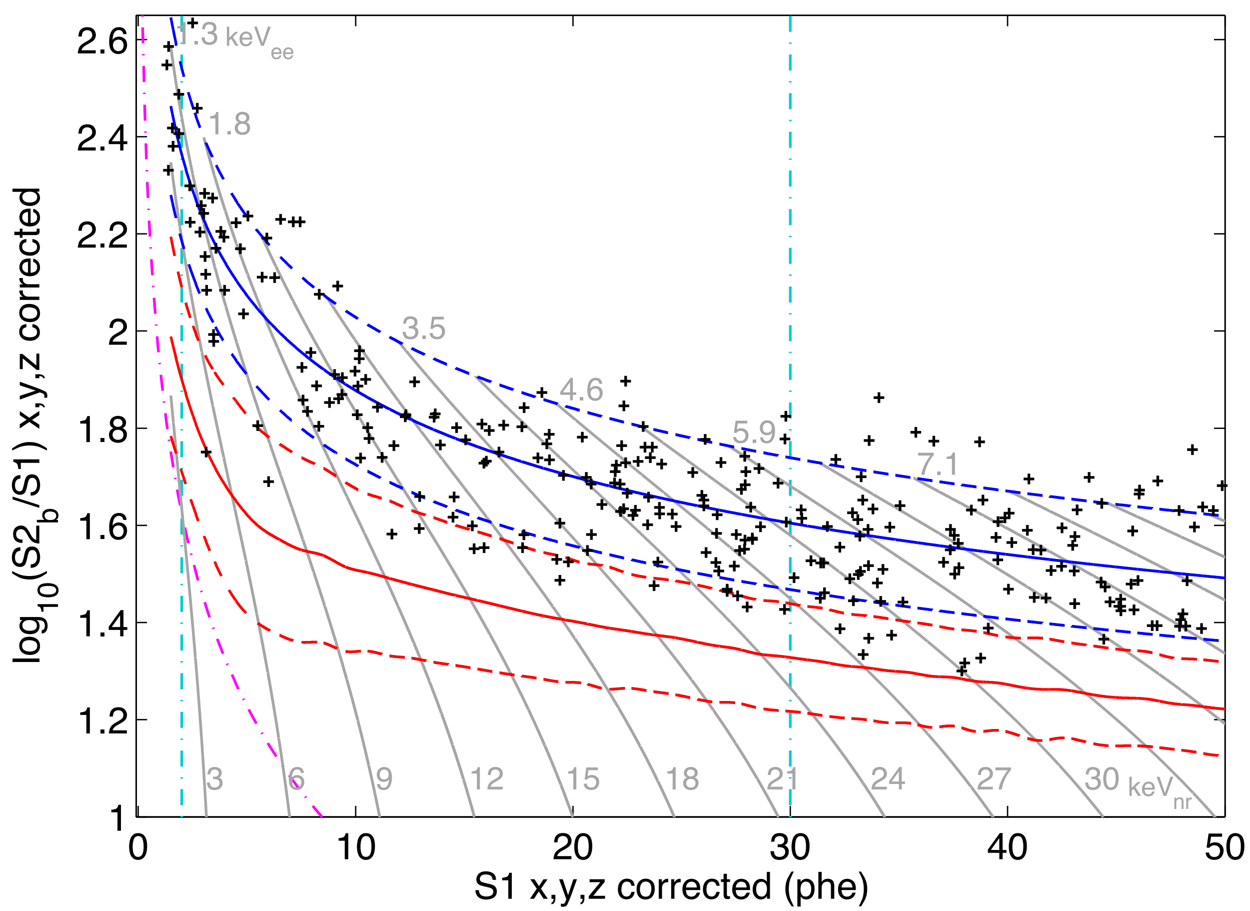


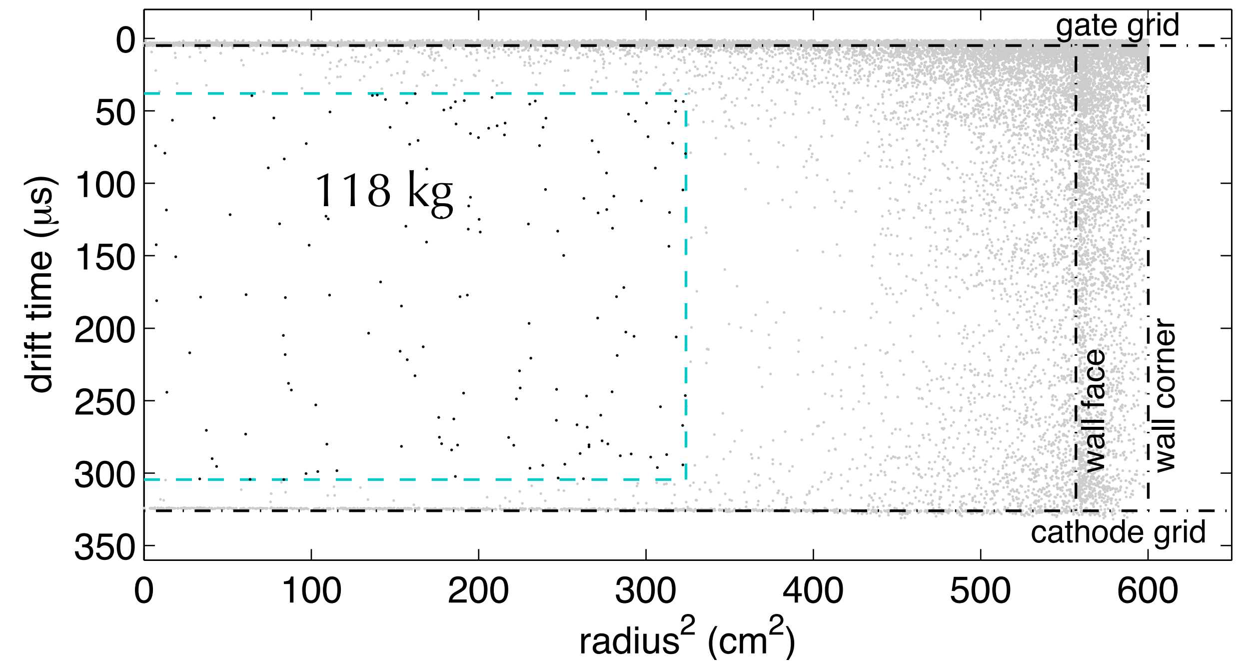

- (left)
- well understood
- limited by scintillation photon (S1) detection
- geometrical
- two-fold coincidence in xxx ns




- (right)
- same efficiency curve as a function of recoil energy
- fall-off at 20 keV due to search window defined in S1

# 160 EVENTS IN 85 DAYS SEARCH WITH 118 KG TARGET



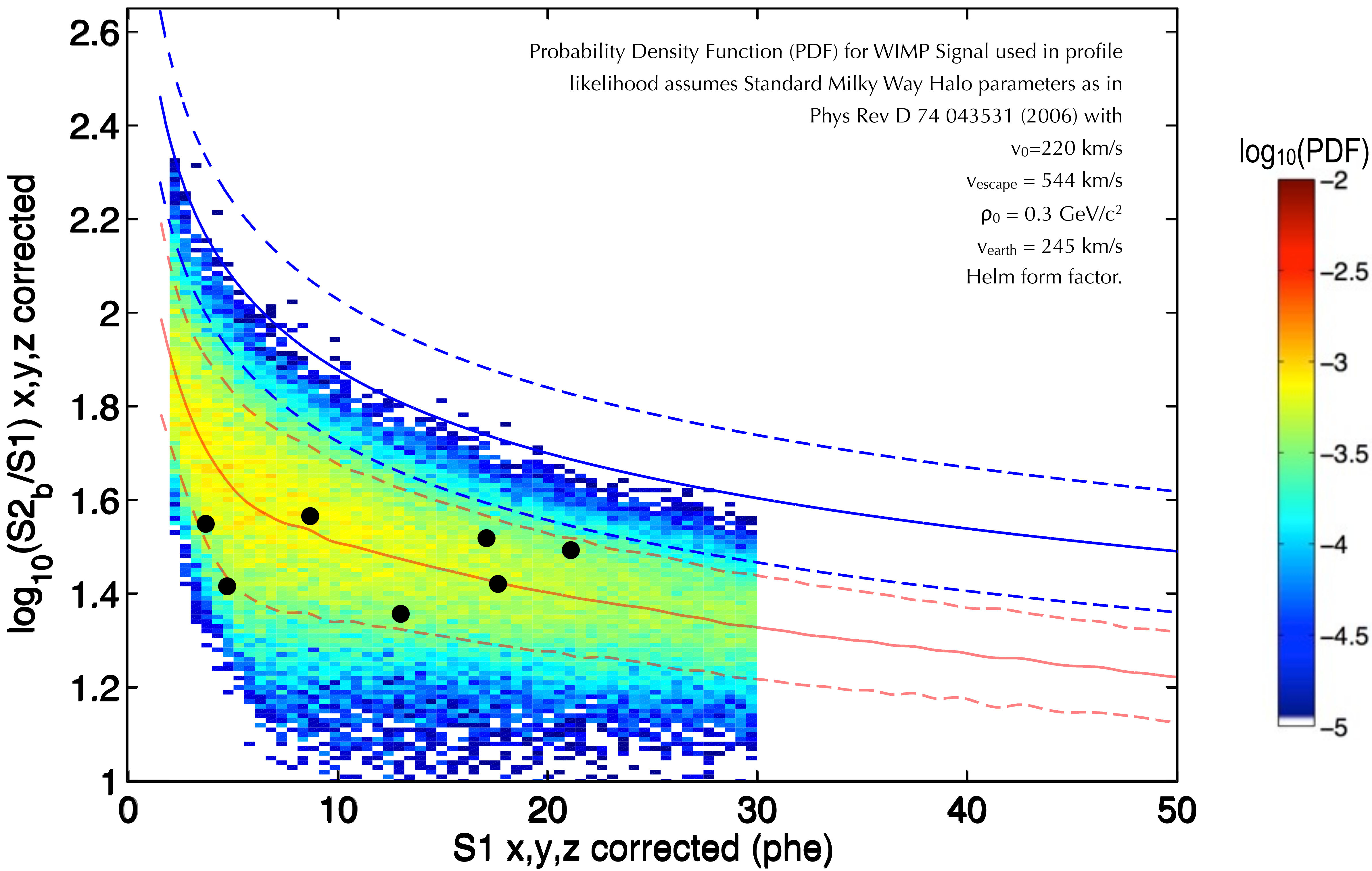

| Source | Background rate, mDRU$_{ee}$ |
|---|---|
| $\gamma$-rays | $1.8 \pm 0.2_{stat} \pm 0.3_{sys}$ |
| $^{127}$Xe | $0.5 \pm 0.02_{stat} \pm 0.1_{sys}$ |
| $^{214}$Pb | 0.11–0.22 (90% C. L.) |
| $^{85}$Kr | $0.13 \pm 0.07_{sys}$ |
| Total predicted | $2.6 \pm 0.2_{stat} \pm 0.4_{sys}$ |
| Total observed | $3.1 \pm 0.2_{stat}$ |

inset gray curves defined from $E_{nr} = \epsilon(n_\gamma + n_e)/f_n$

# SIMULATED WIMP SIGNAL FOR 1000 GEV MASS

At 1000 GeV particle mass and cross section at the existing XENON100 90% CL Sensitivity $1.9 \times 10^{-44}$ cm$^2$ ...

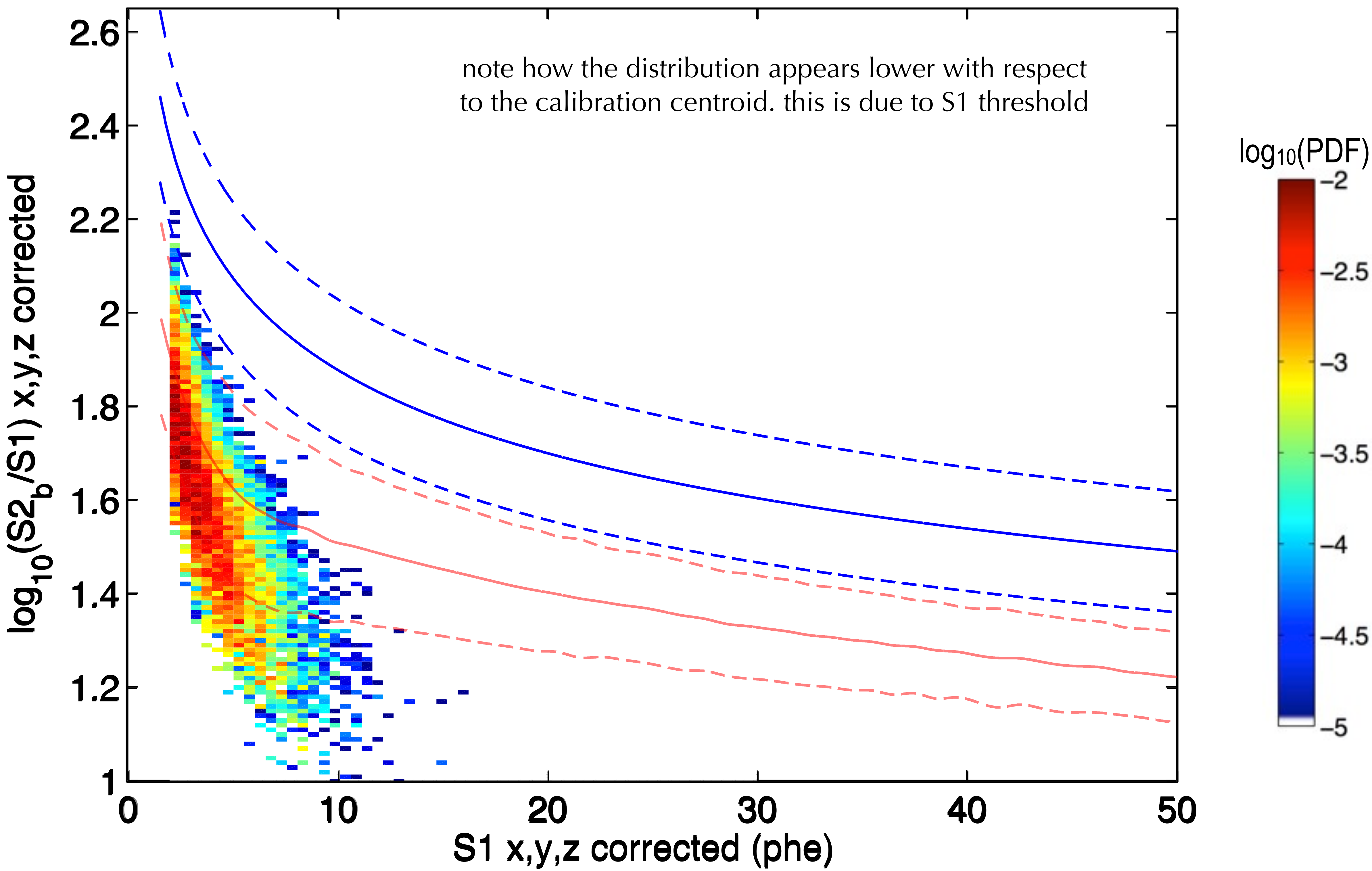
We would expect ~7 WIMPs in LUX Search (trial experiment shown as filled circles)



# SIMULATED WIMP SIGNAL FOR 8.6 GEV MASS

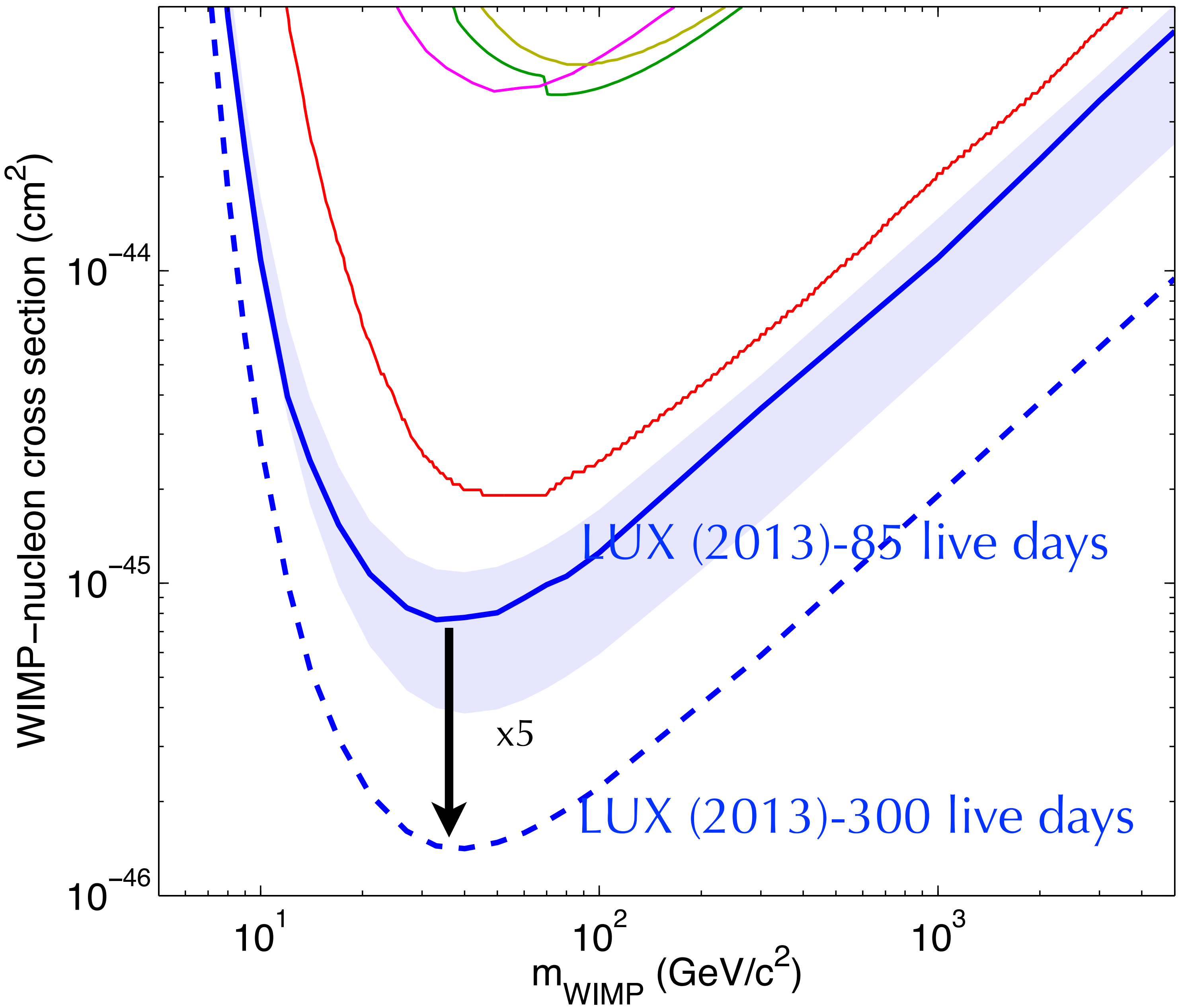
At 8.6 GeV particle mass and cross section favored by CDMS II silicon (2012) ~$2.0 \times 10^{-41}$ cm$^2$ ...

We would expect 1550 WIMPs in LUX Search (trial experiment NOT shown :)

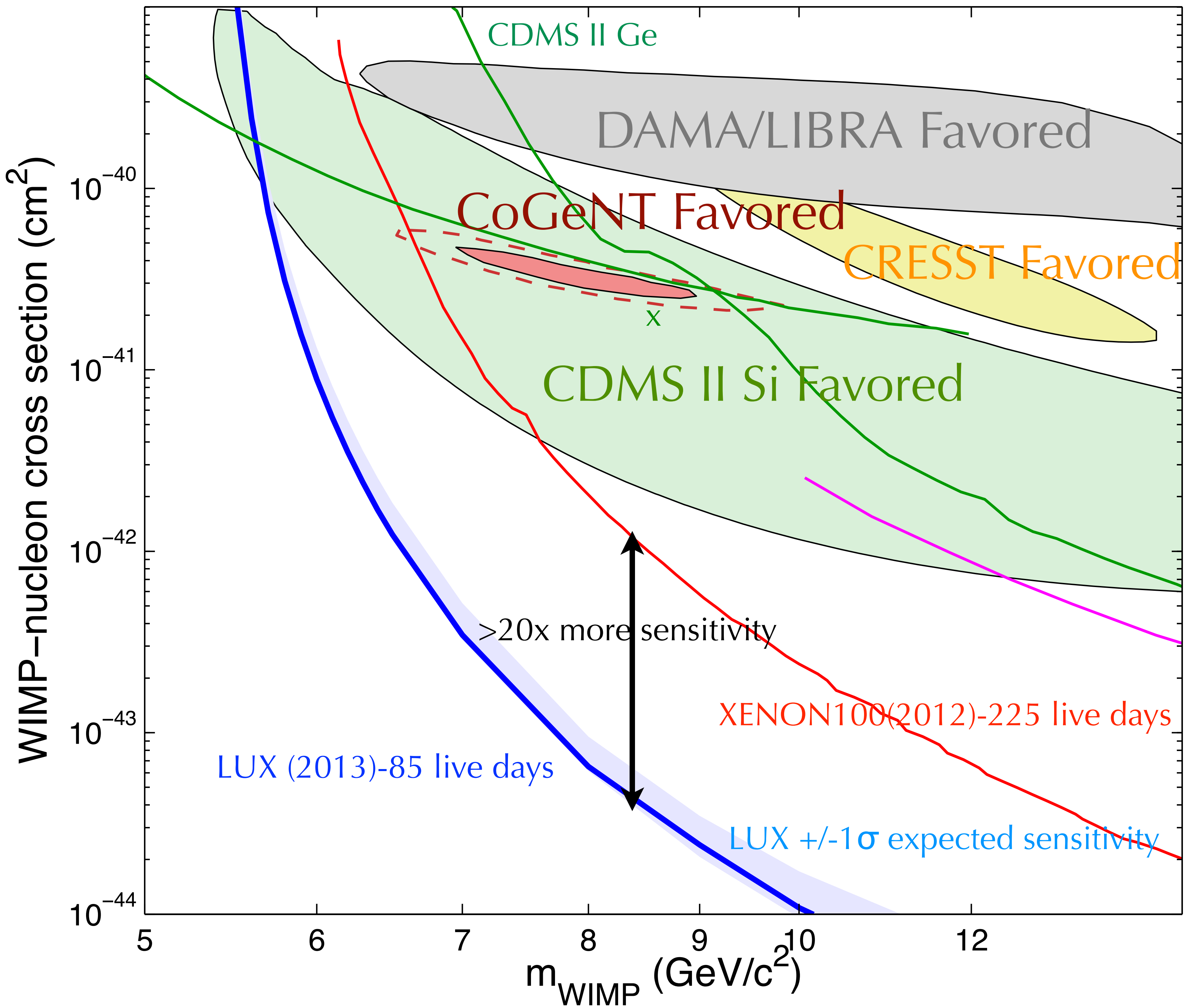


# LUX 85 live day search, and projected LUX 300 day WIMP search

- First results from LUX -- consistent with background-only hypothesis (p=0.35)
- additional dark matter search analyses under consideration
- 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"



# Low mass WIMPs - fully excluded by LUX



# CONCLUSION

- LUX has made an 85 live day WIMP search and released manuscript (arxiv:1310.8214) within 9 months of commissioning the detector underground at the Davis Lab at SURF
  - Low backgrounds as expected, inner fiducial (118 kg) ER rate <2 events/day in region of interest
  - New calibration techniques including $^{83m}$Kr and Tritiated-$CH_4$ injected directly into Xe target (not discussed in this talk)
  - 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

- Extended sensitivity over existing experiments by x3 at 35 GeV WIMP mass and x2 at 1000 GeV WIMP mass

- Low Mass WIMP Favored Hypotheses ruled out
  - LUX WIMP Sensitivity 20x better
  - LUX does not observe 6-10 GeV WIMPs favored by earlier experiments

- Results due to lots of great work by a large number of scientists!

# LUX COLLABORATION: ~100 SCIENTISTS 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 |

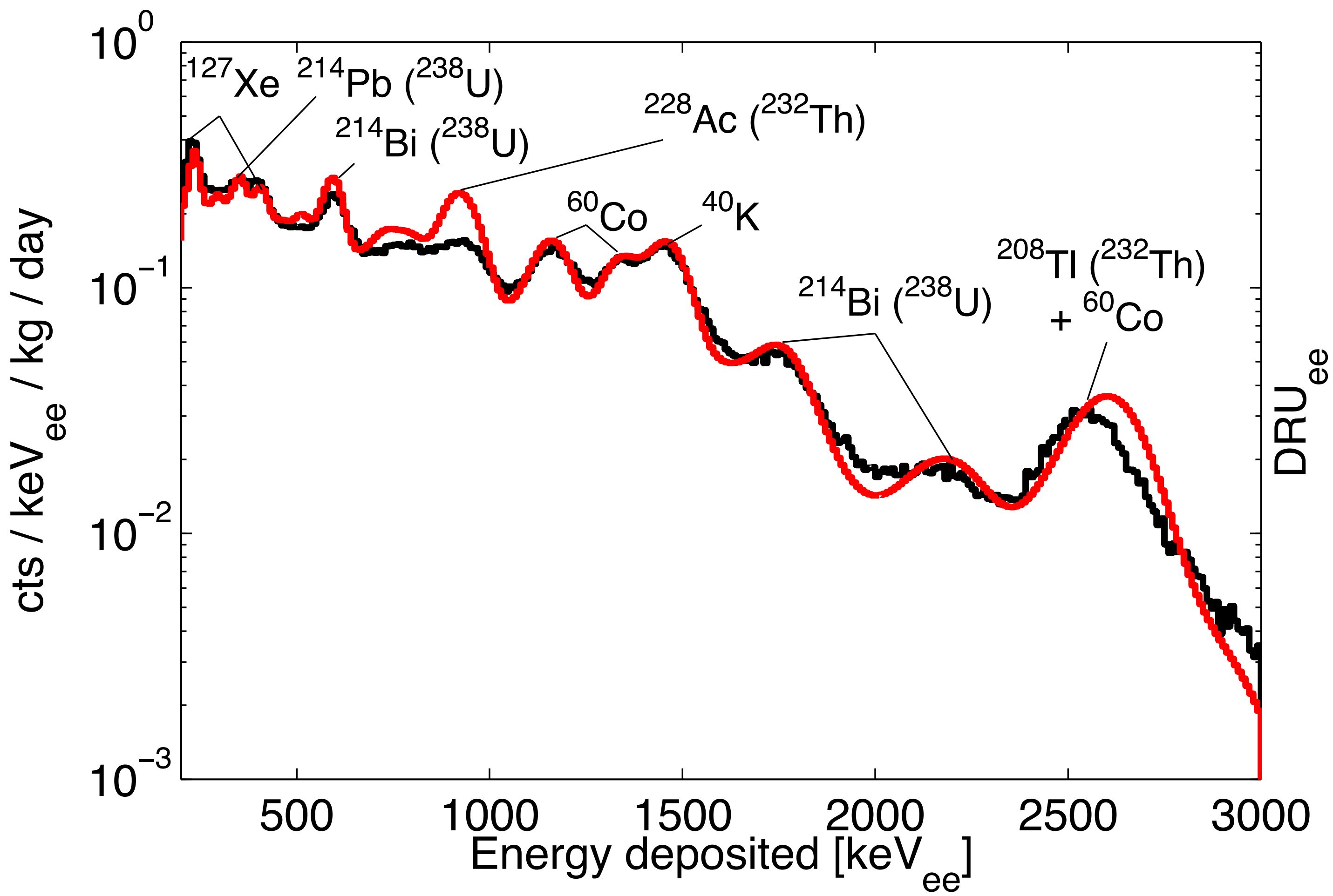
## University of South Dakota

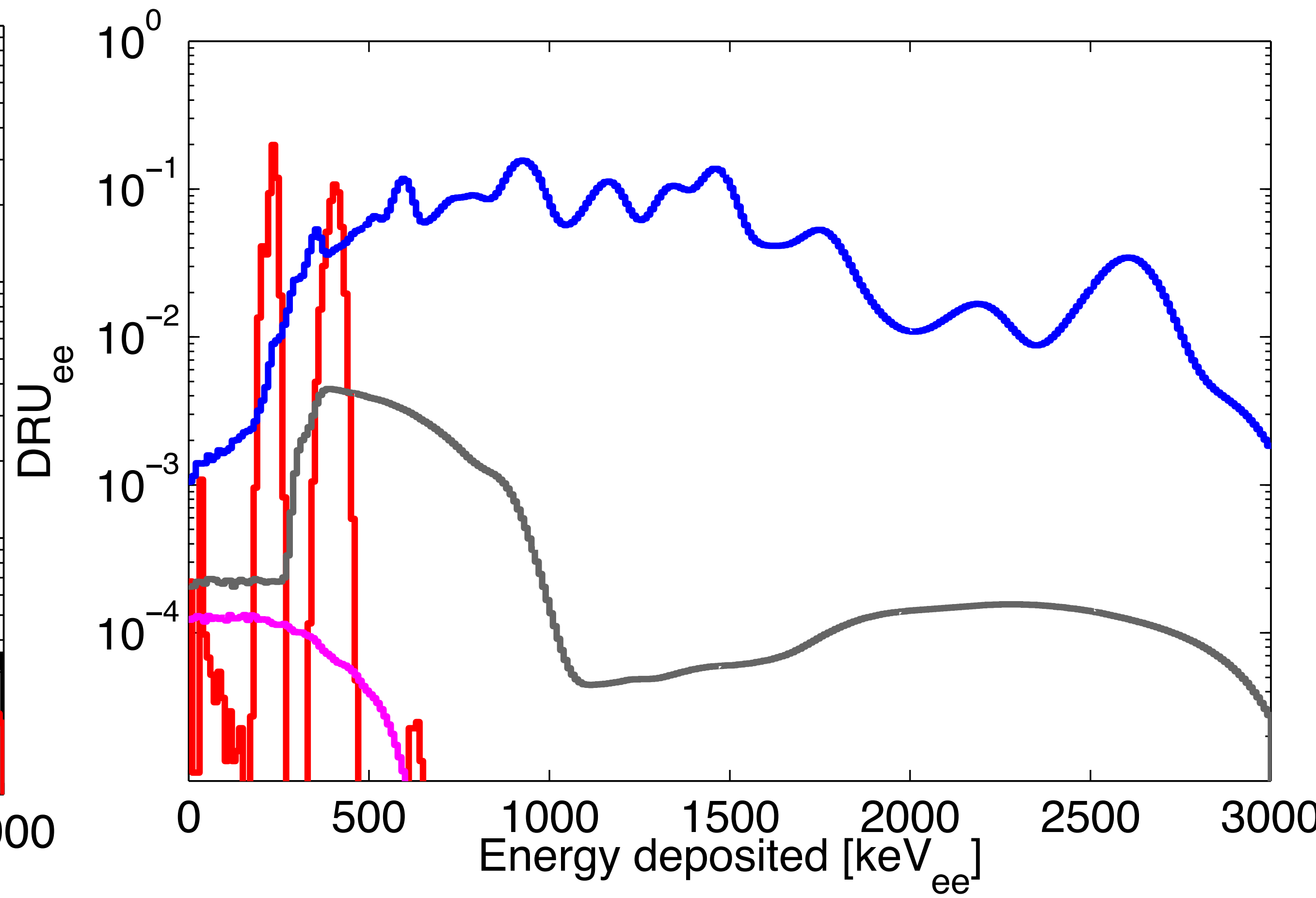
| | |
|---|---|
| Dongming Mei | PI, Professor |
| Chao Zhang | Postdoc |
| Angela Chiller | Graduate Student |
| Chris Chiller | Graduate Student |
| Dana Byram | *Now at SDSTA |

## 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 |

# Extra slide: backgrounds well understood



# Extra slide: background summary for 118 kg fiducial

| 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<br>0.87 -> 0.28 during run | $0.5 \pm 0.02_{stat} \pm 0.1_{sys}$ |
| $^{214}Pb$ | 222Rn | $0.11\text{-}0.22_{(90\%\ CL)}$ |
| $^{85}Kr$ | Reduced from<br>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 | $3.1 \pm 0.2_{stat}$ |