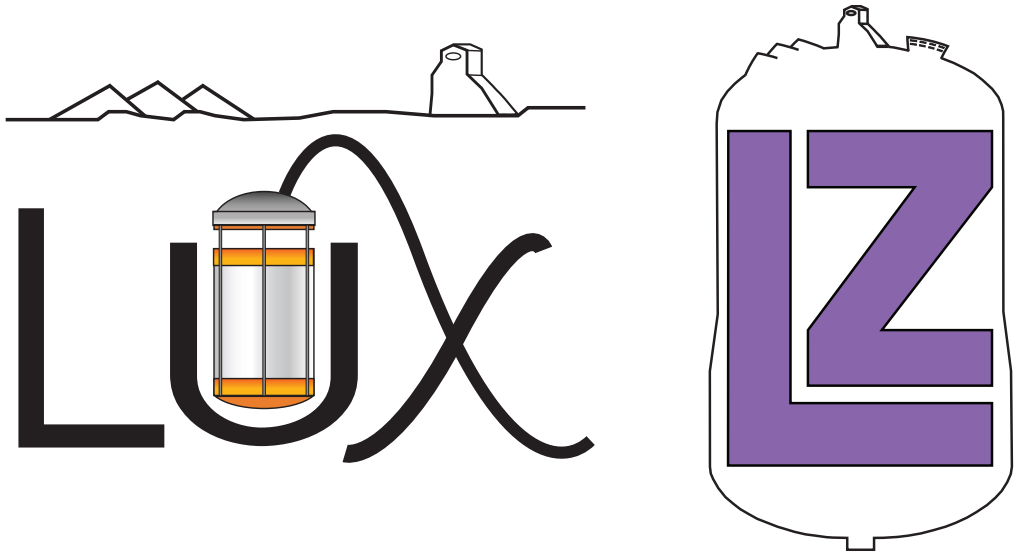


The LUX and LZ Dark Matter Experiments

Carlos H. Faham
Lawrence Berkeley National Laboratory

on behalf of the LUX and LZ collaborations

DBD2014 Workshop
Oct 6, 2014

LUX 30-second summary

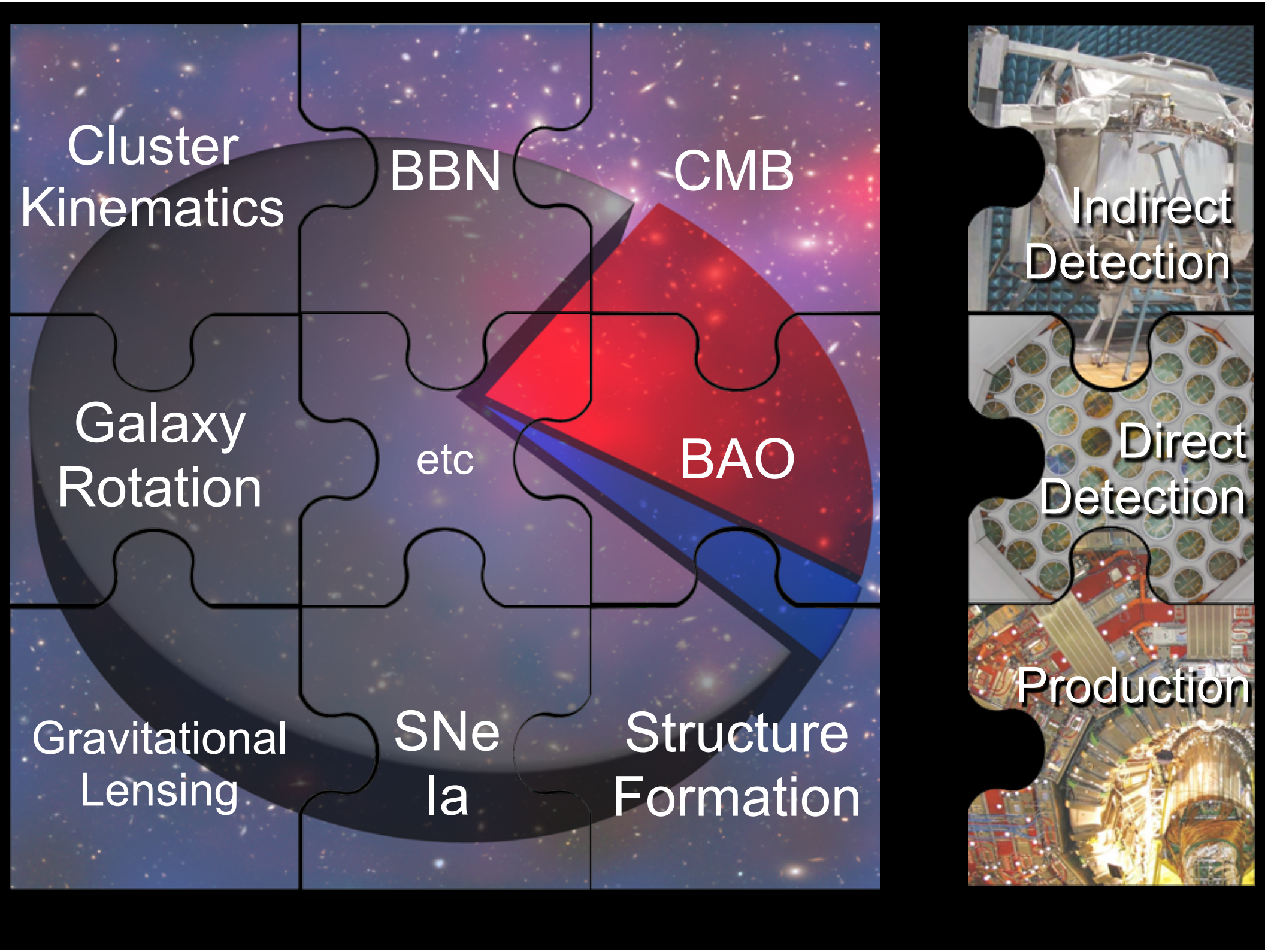
Large **U**nderground **X**enon (**LUX**)

- Ultra-low background, 1/3 tonne liquid xenon time-projection chamber.

- Operating at the Sanford Underground Research Facility, South Dakota, USA.

- In 3 months of WIMP data-taking in 2013, it became the most sensitive WIMP dark matter detector in the world on most of the mass range parameter space.

- After a period of more extensive calibrations, starting a new 300-day WIMP-search run in 2014.


Cluster Kinematics
BBN
CMB
Galaxy Rotation
etc
BAO
Gravitational Lensing
SNe Ia
Structure Formation
Indirect Detection
Direct Detection
Production

“Low Energy < 15 MeV neutrinos”

Matt Toups

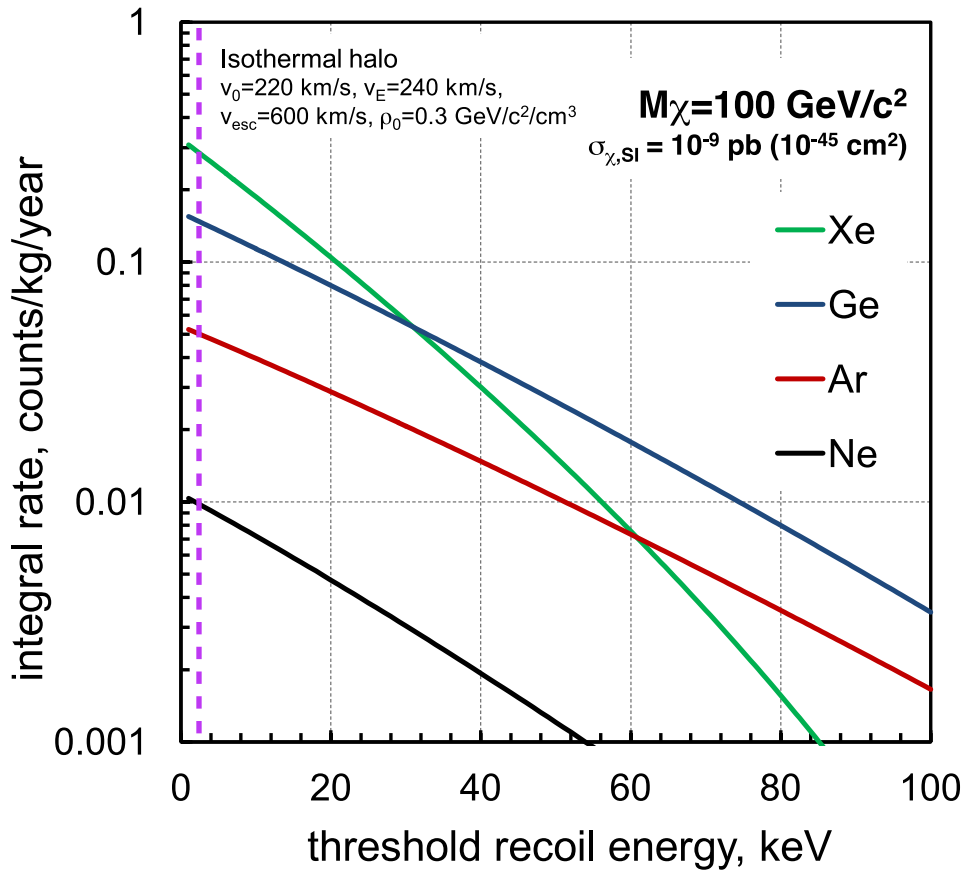
Weakly **I**nteracting **M**assive **P**articles (**WIMP**)

A leading candidate for dark matter.

Many extensions of the Standard Model predict a massive, weakly interacting long-lived particle. Weak scale is cosmologically significant for dark matter relic density.

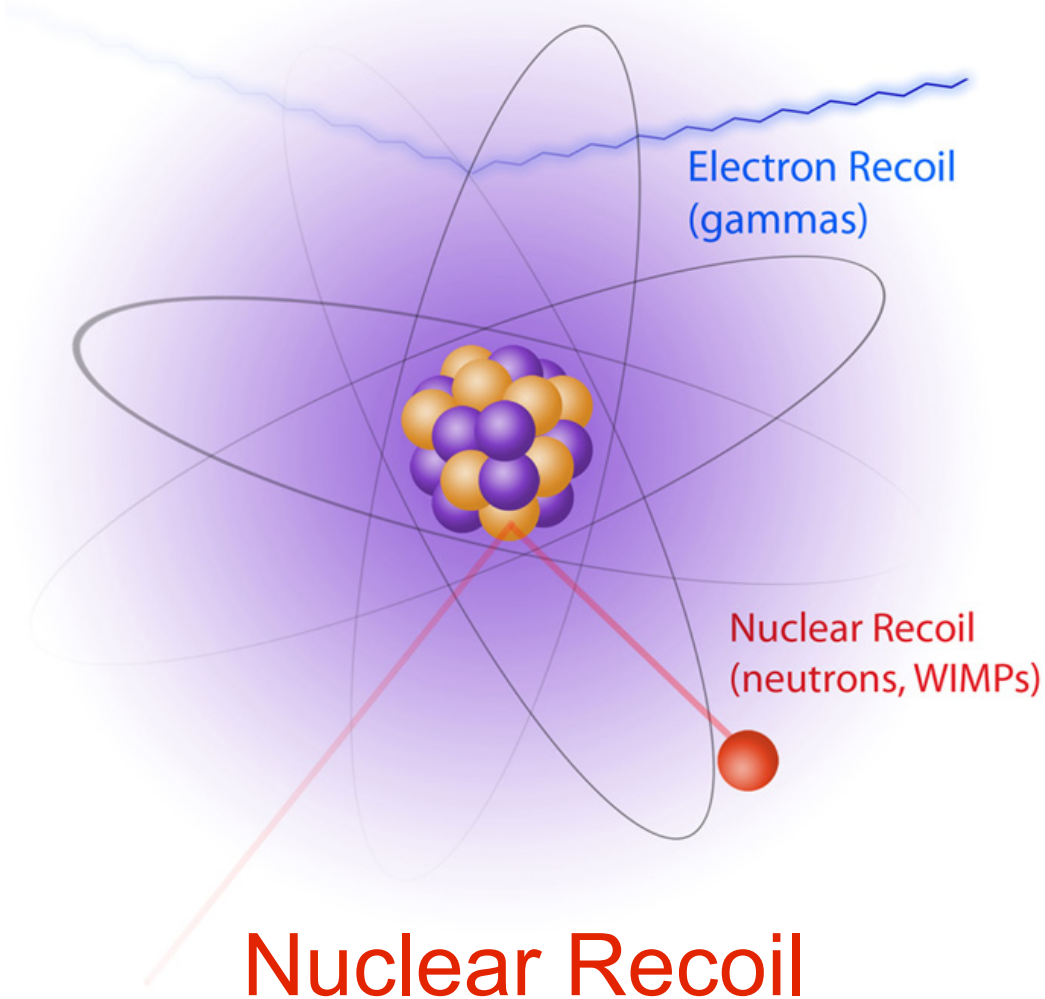
Detection mechanism consists of looking for nuclear recoils in a low-background detector.

A sensitive detector requires:
- Large mass
- Low radioactivity
- Electron recoil suppression/ discrimination
- Underground operation



Liquid Xenon Signal

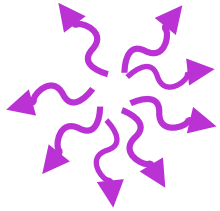
Electron Recoil



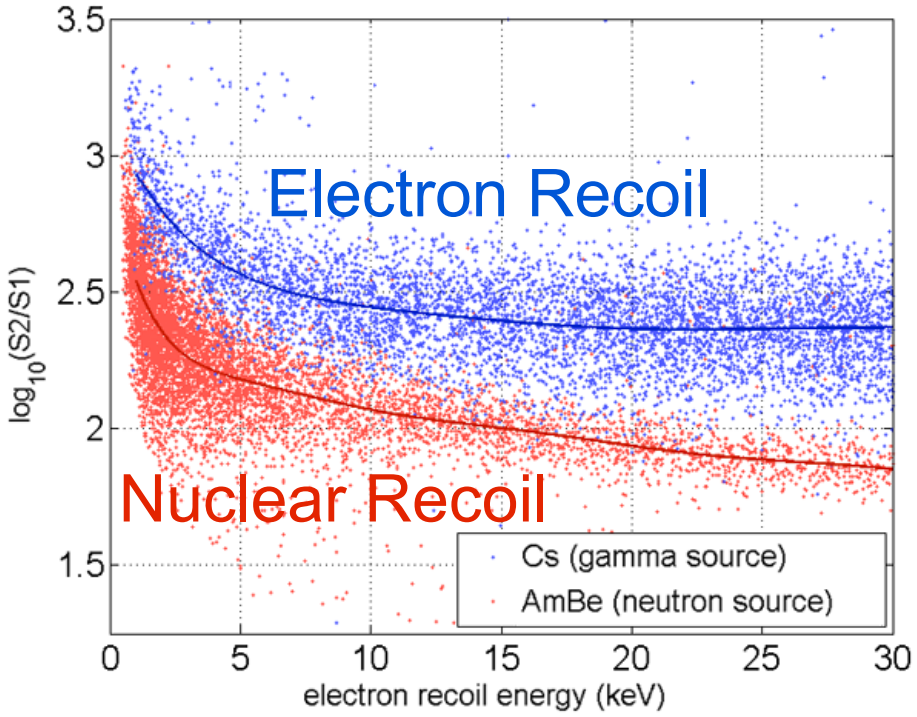
Nuclear Recoil

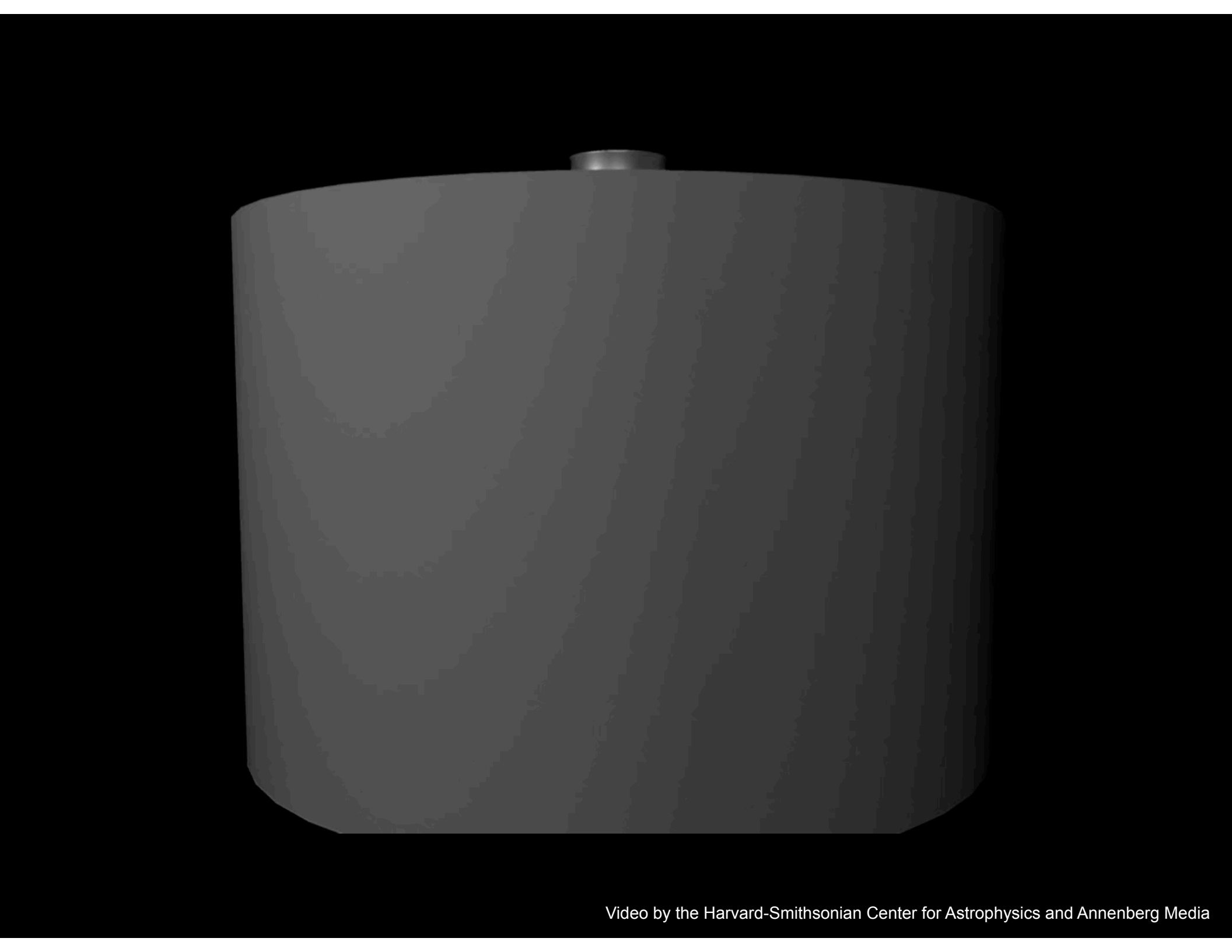
Two signals:

S1 **S2**



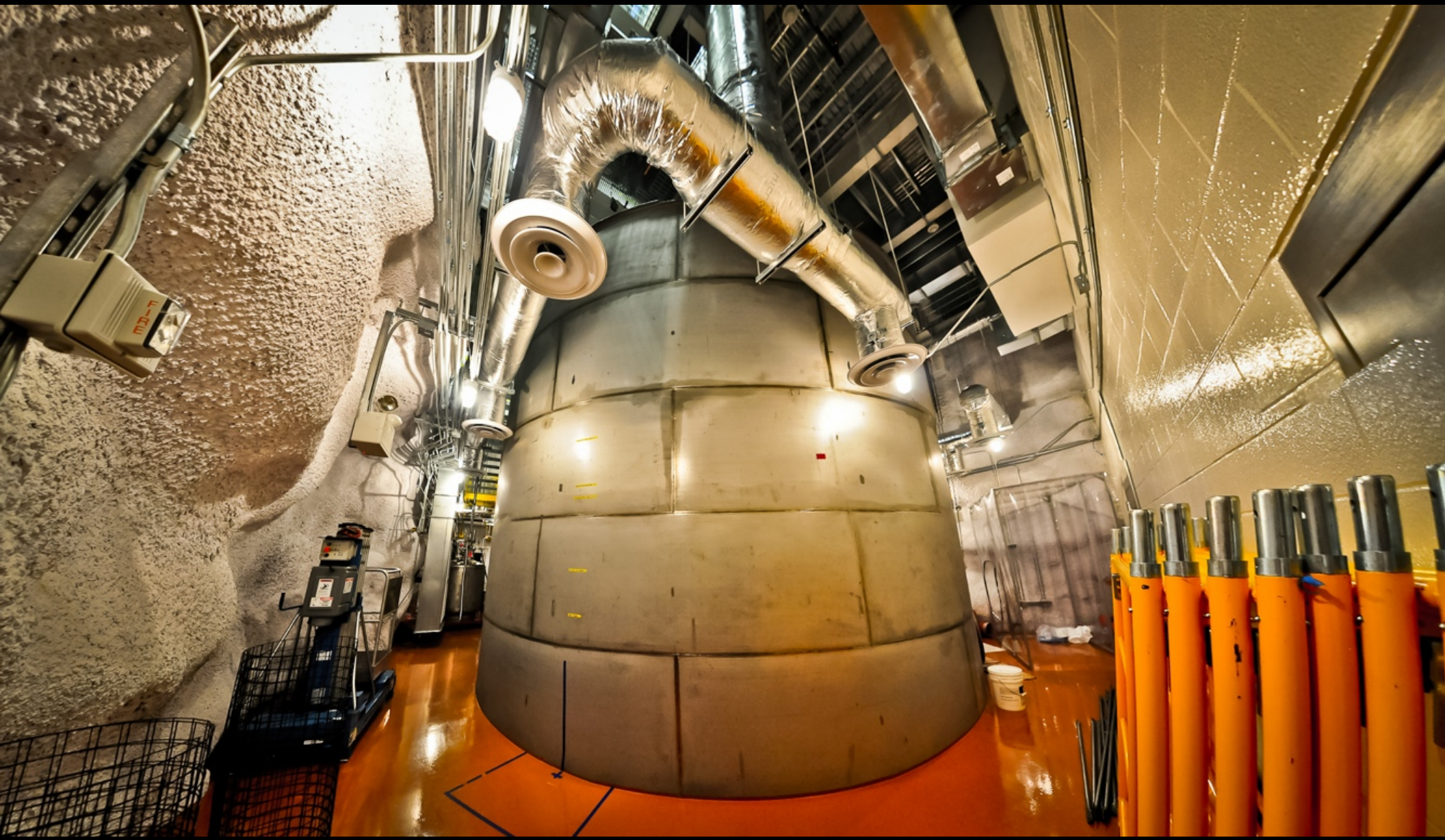
175 nm photons Electrons



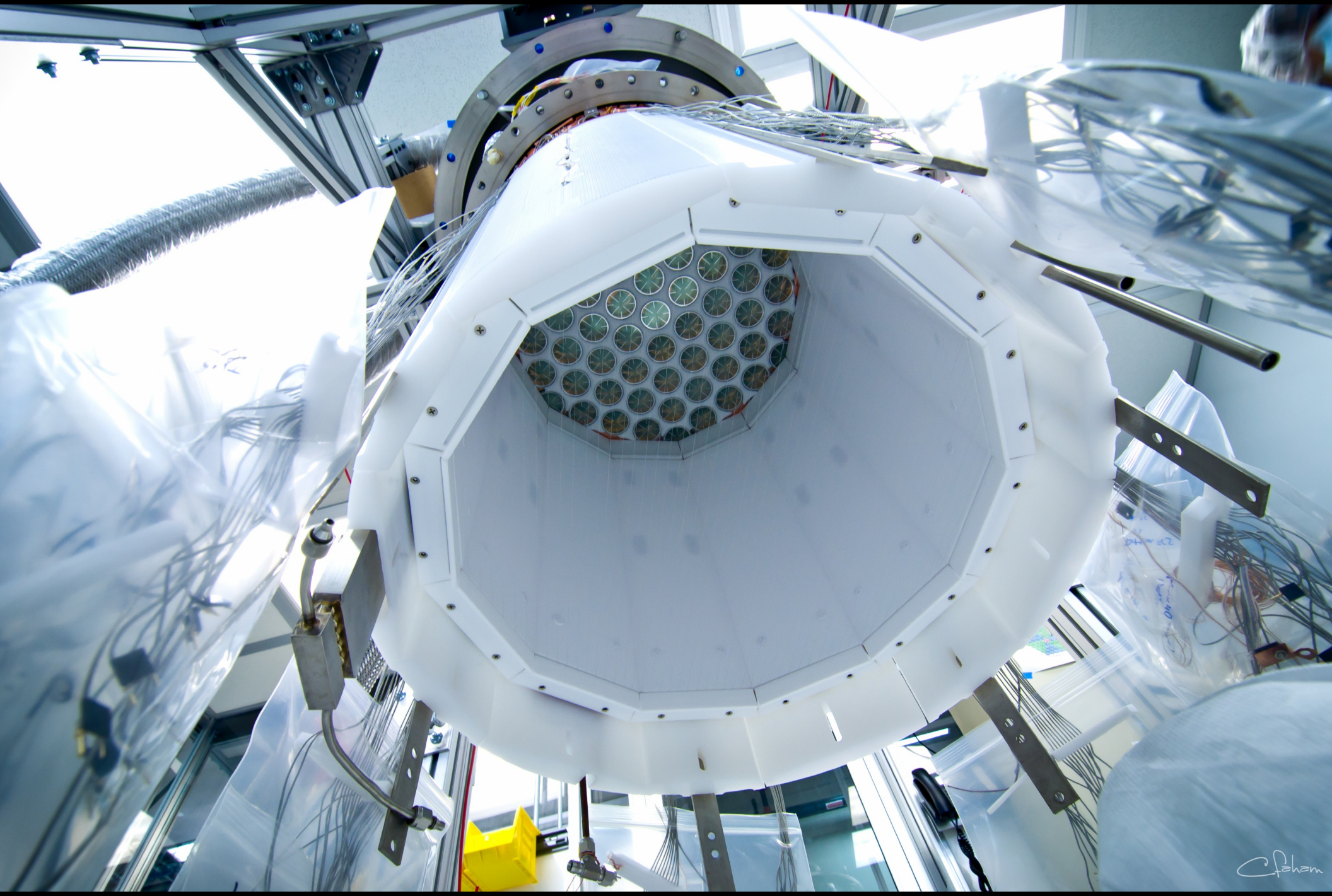


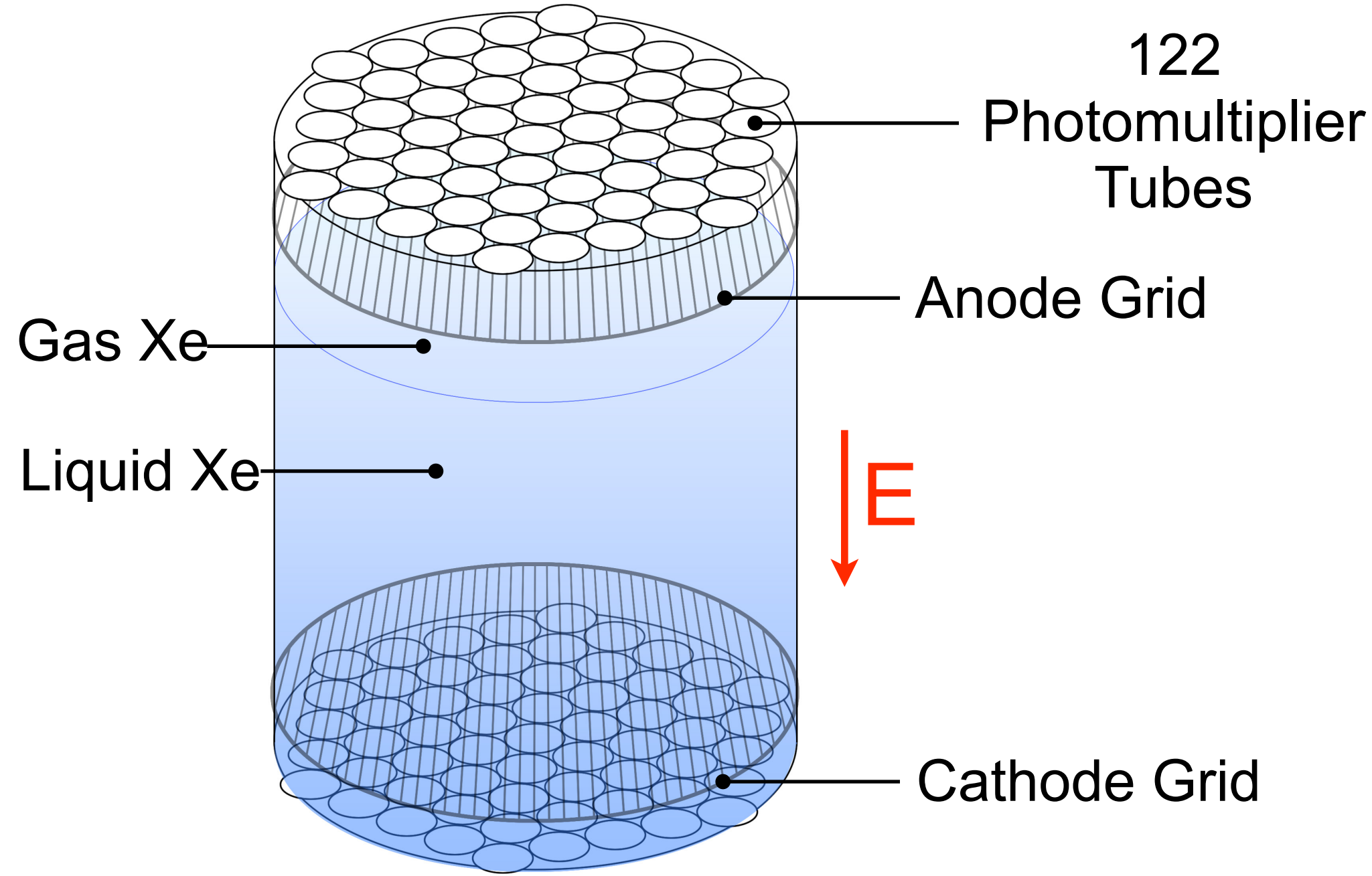
Video by the Harvard-Smithsonian Center for Astrophysics and Annenberg Media

LUX Installed in Water Tank



LUX Water Tank - Outside View



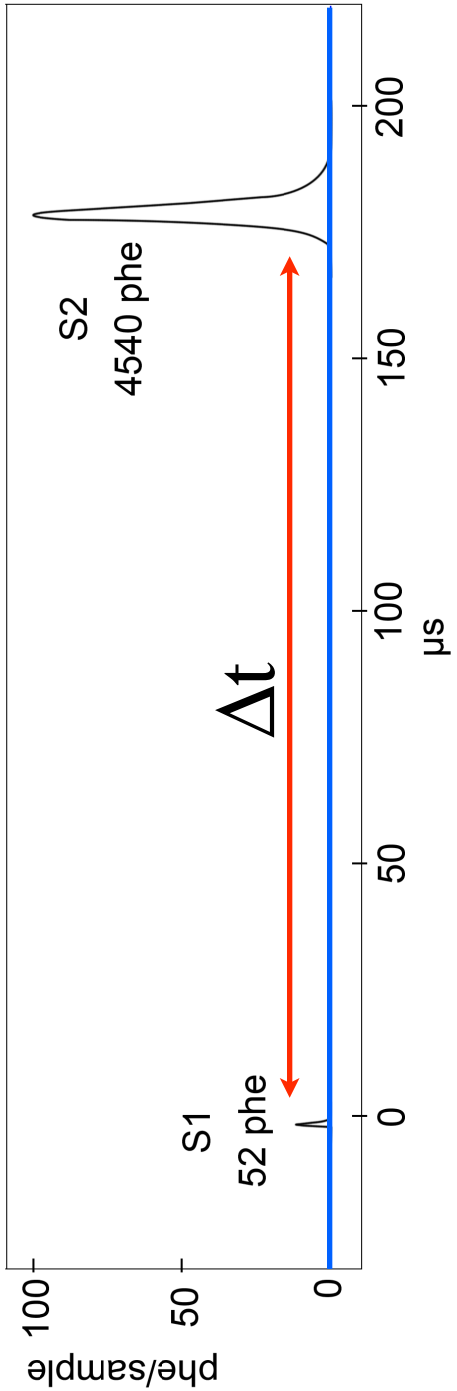

122
Photomultiplier
Tubes
Anode Grid
Gas Xe
Liquid Xe
E
Cathode Grid

top hit pattern:
x-y localization

S2

Δt z localization

E

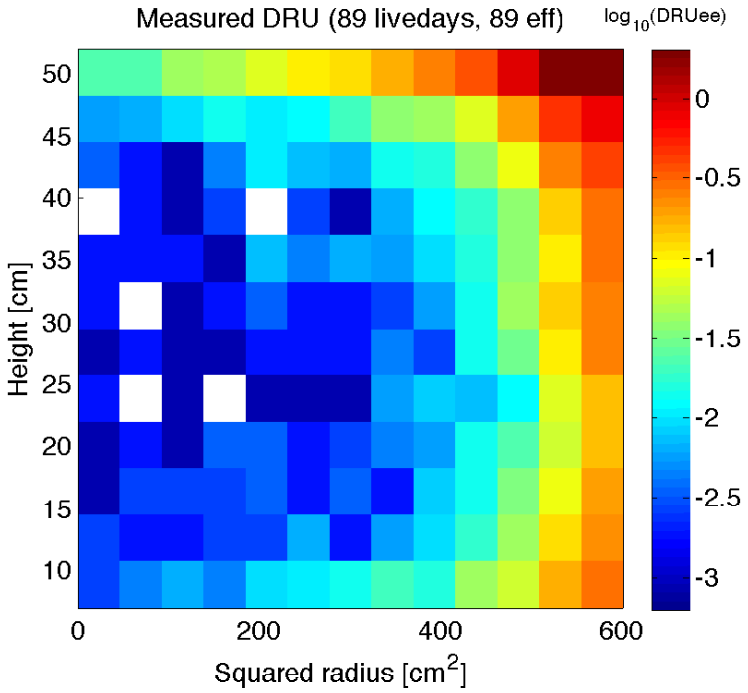


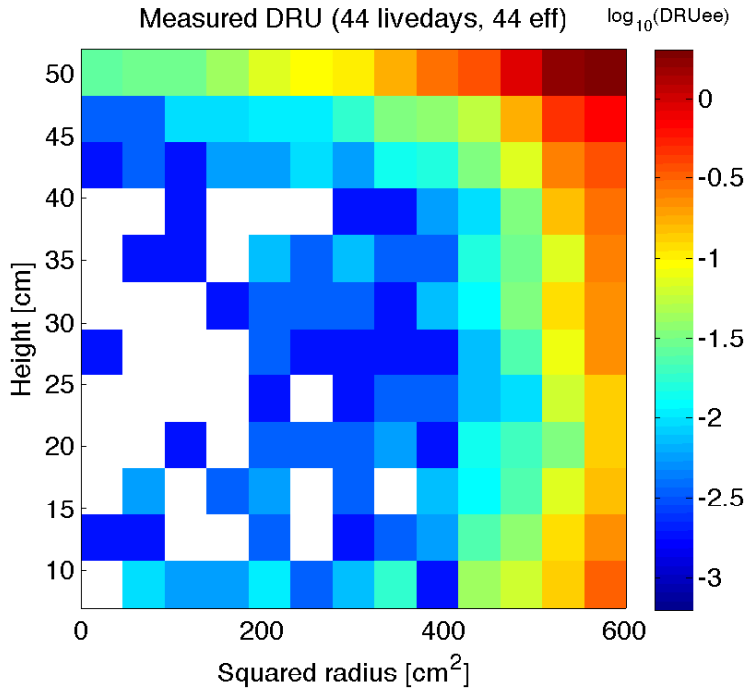
"BG-free experiment is the key to a successful program"

Bob McKeown

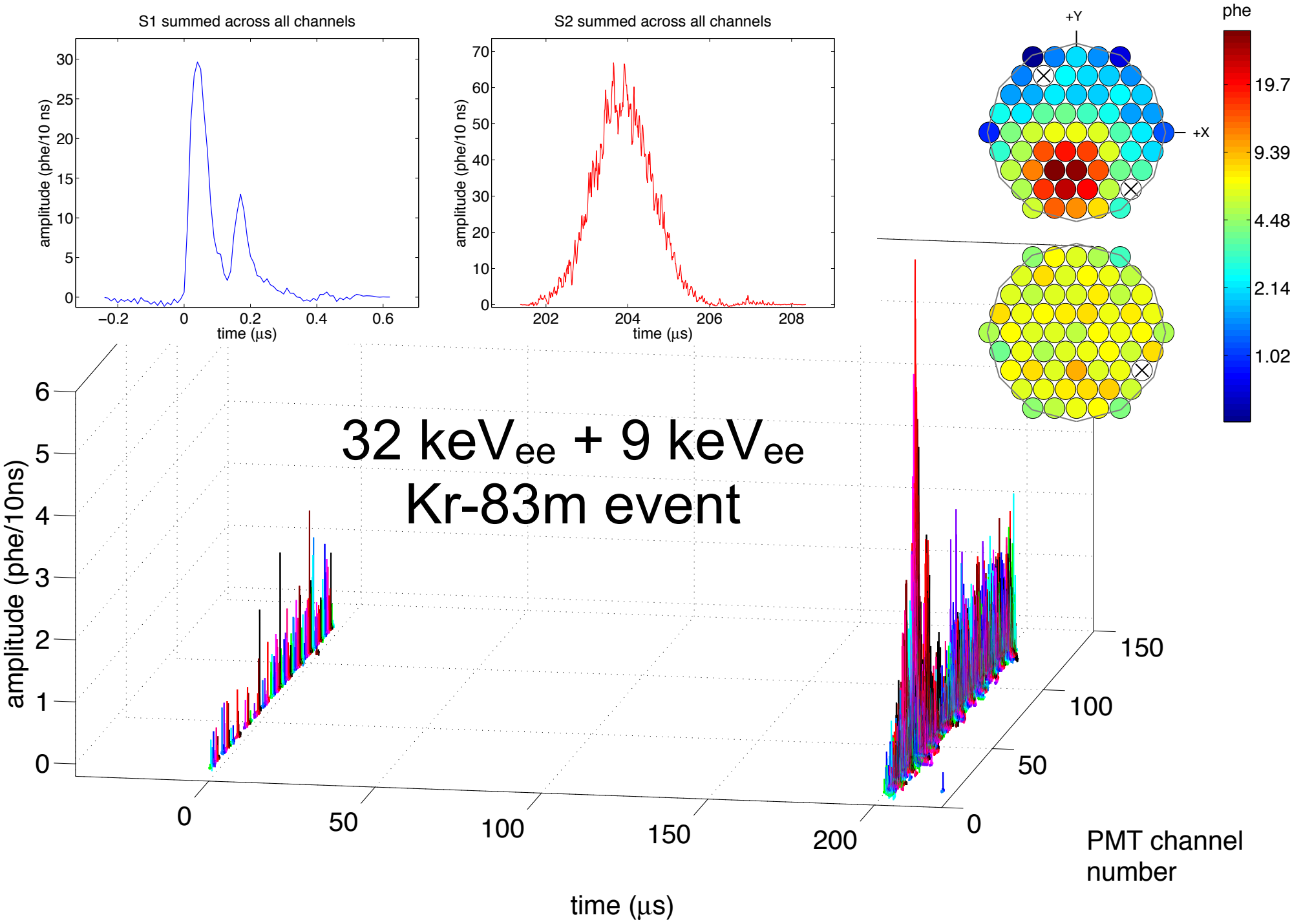
Detector Activity

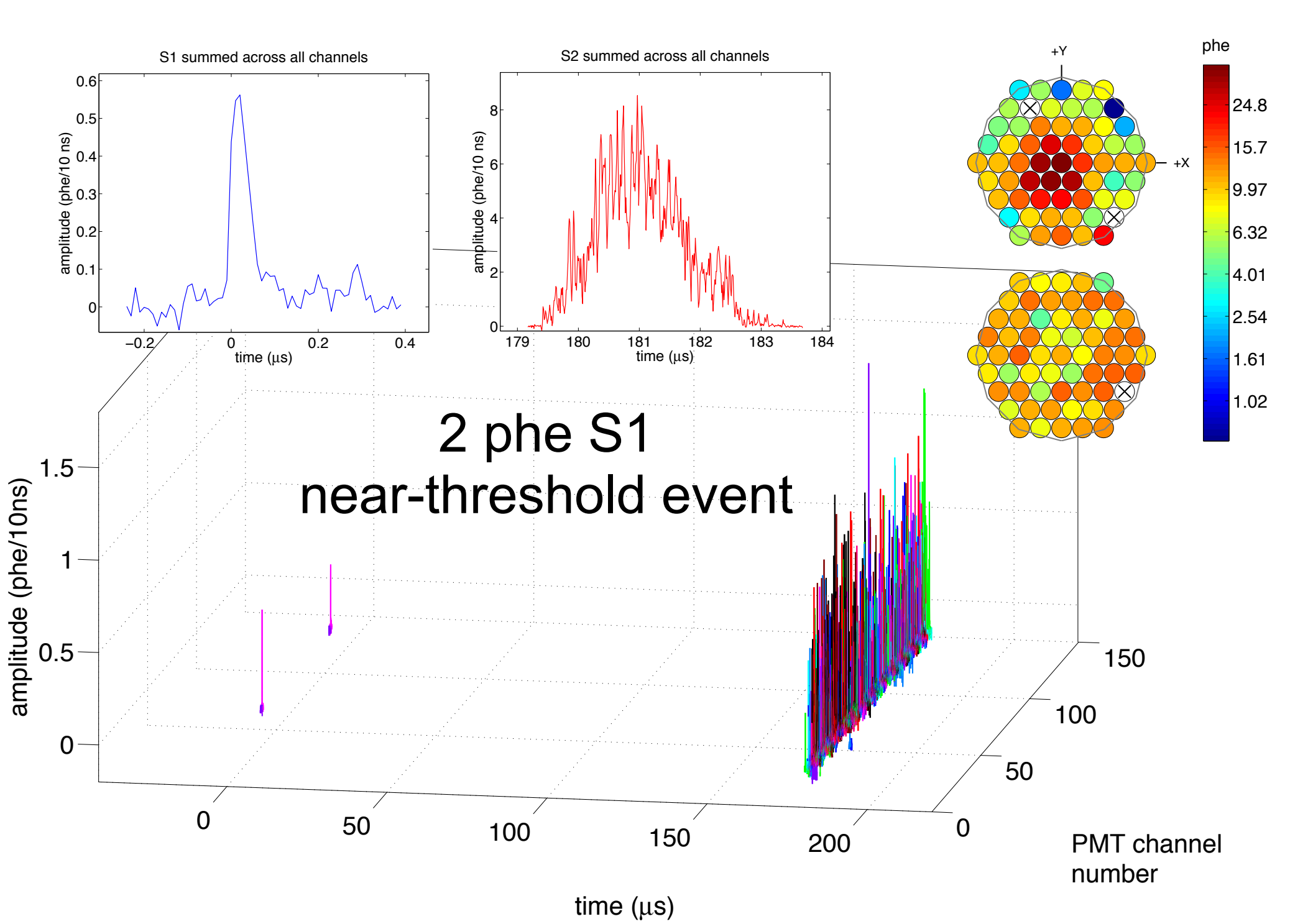
Total Electron Recoil Event Rate <5 keV_{ee}





Background	Source	10
γ-rays	Internal Components	1.8±0.2
127	Cosmogenic 0.87 -> 0.28	0.5±0.02
214	222	0.11-0.22
85	Reduced from 130 ppb to 3.5±1 ppt	0.13±0.07
	Total Predicted	**2.6±0.2**
	Total Observed	**3.1±0.2**


S1 summed across all channels
amplitude (phe/10 ns)
time (μs)
S2 summed across all channels
amplitude (phe/10 ns)
time (μs)
+Y
+X
phe
19.7
9.39
4.48
2.14
1.02
32 keV$_{ee}$ + 9 keV$_{ee}$
Kr-83m event
amplitude (phe/10ns)
time (μs)
PMT channel number


S1 summed across all channels
amplitude (phe/10 ns)
time (μs)
S2 summed across all channels
amplitude (phe/10 ns)
time (μs)
+Y
+X
phe
24.8
15.7
9.97
6.32
4.01
2.54
1.61
1.02
2 phe S1
near-threshold event
amplitude (phe/10ns)
time (μs)
PMT channel number

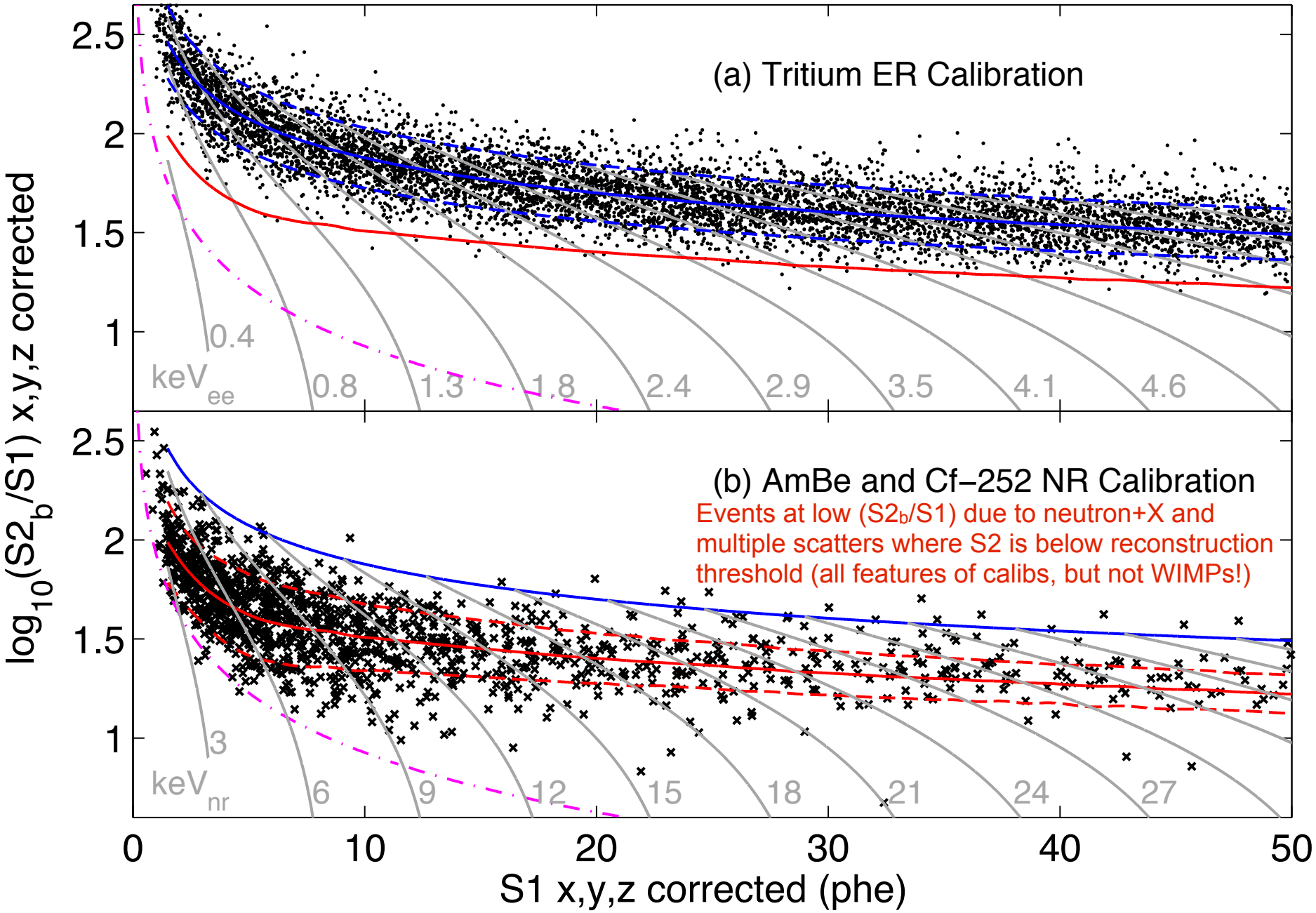

DEADWOOD
North Dakota
South Dakota
Michigan
Toronto
Wyoming
Nevada
Utah
Las Vegas
Arizona
Phoenix
Tucson
Sanford Underground Research Facility

LUX underground commissioning, 2012

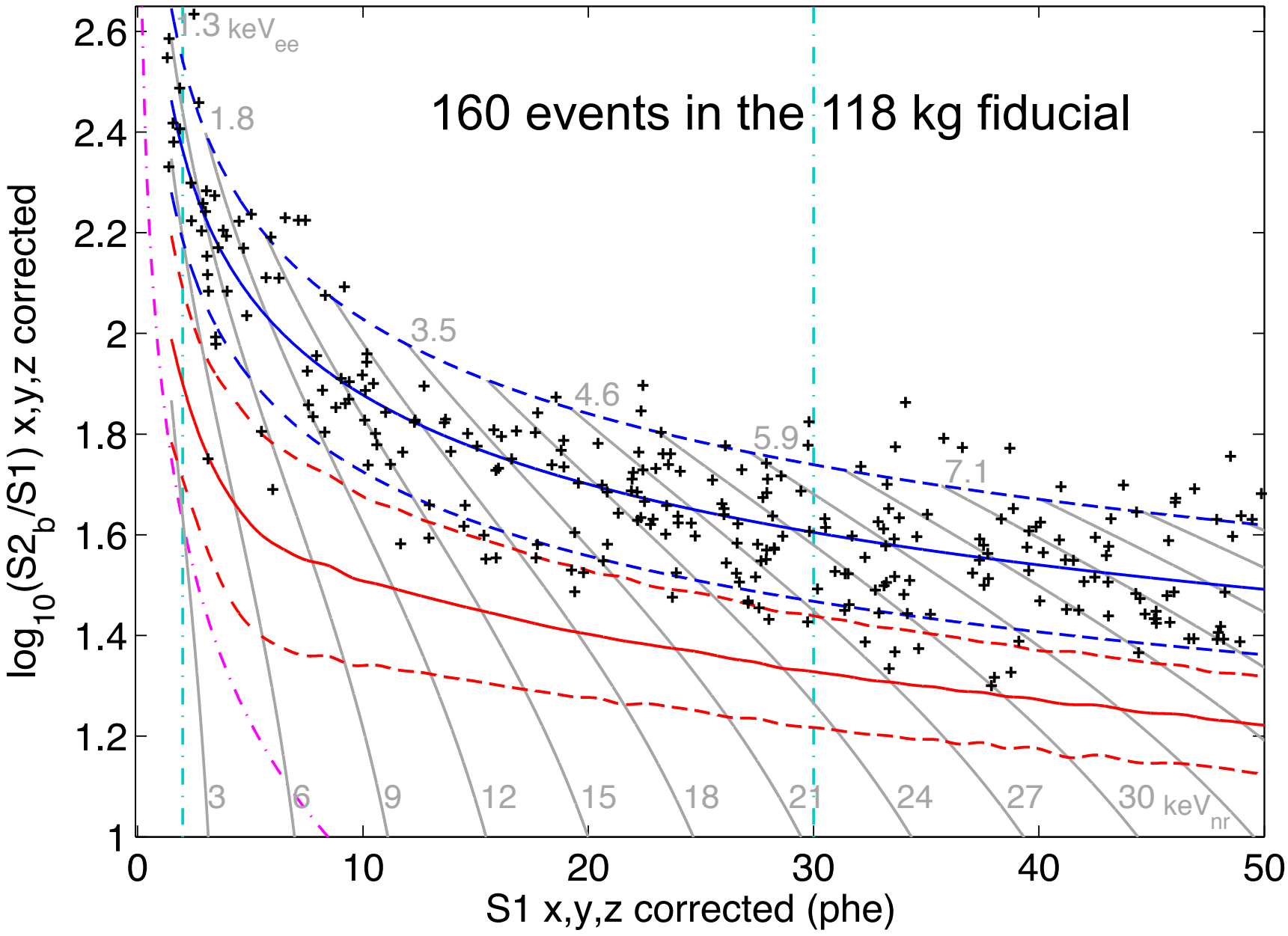
LUX

100+ collaborators
18 institutions
1 Yeti

LUX Calibrations

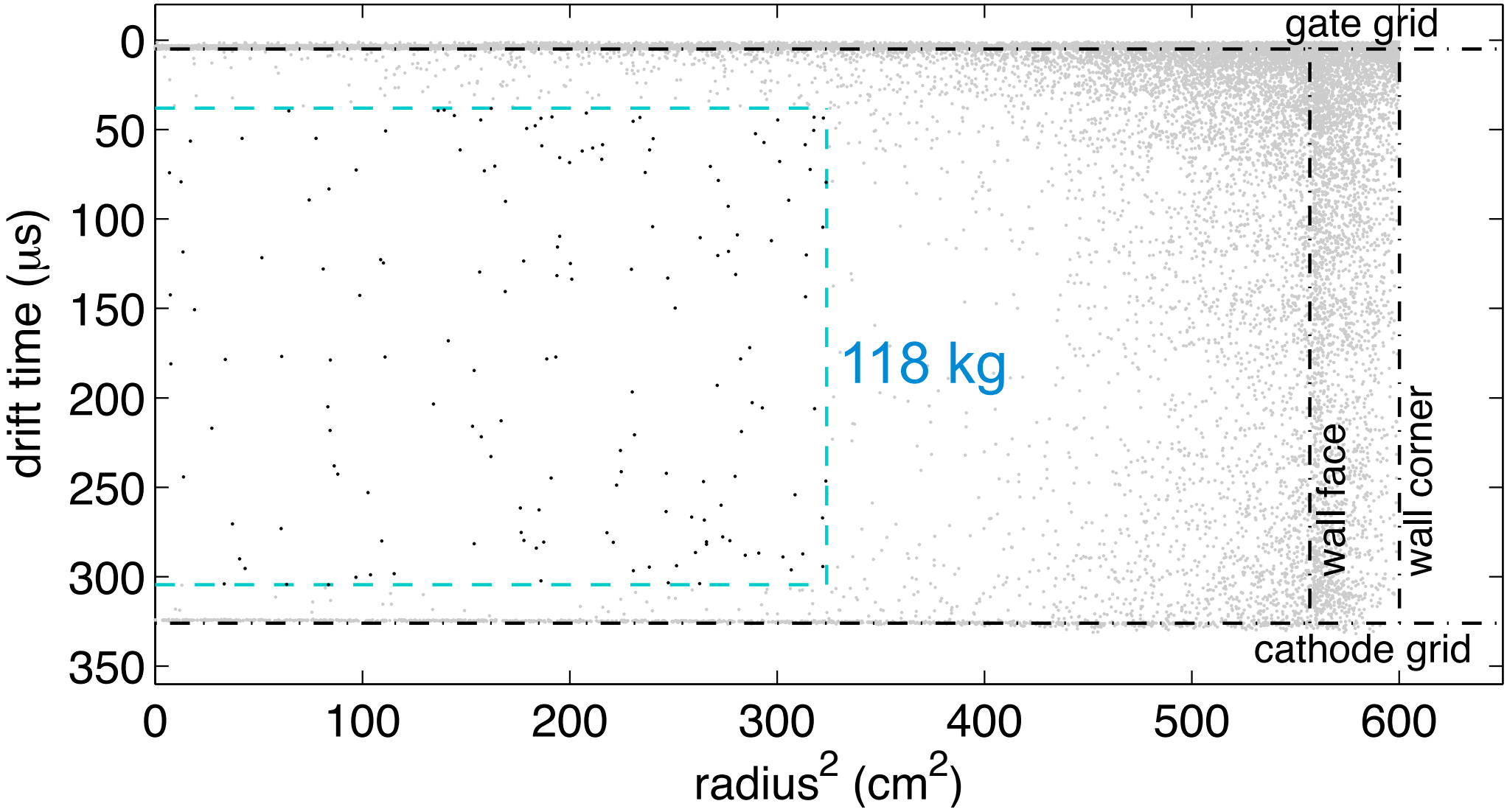


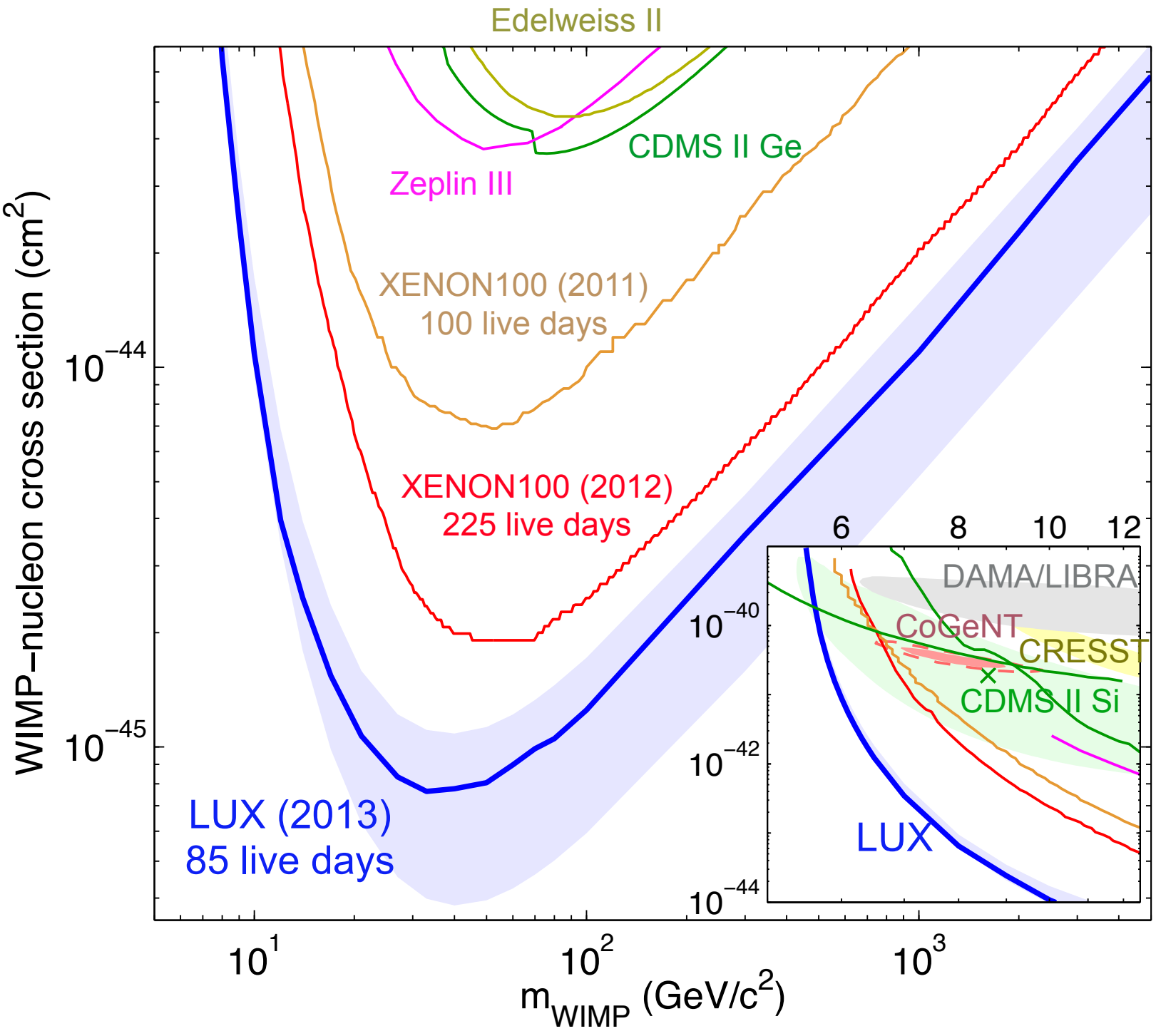
First Results - WIMP search

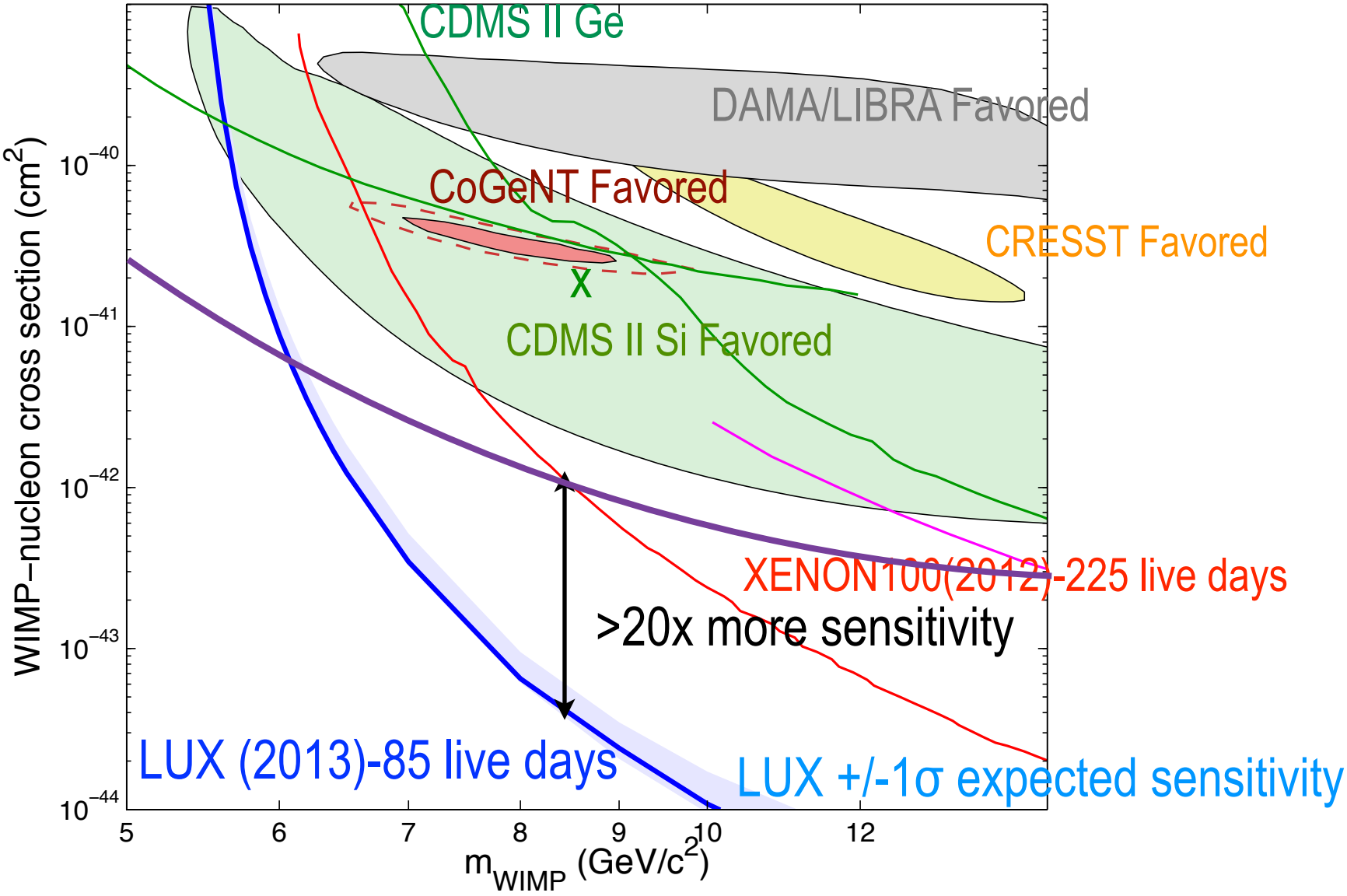


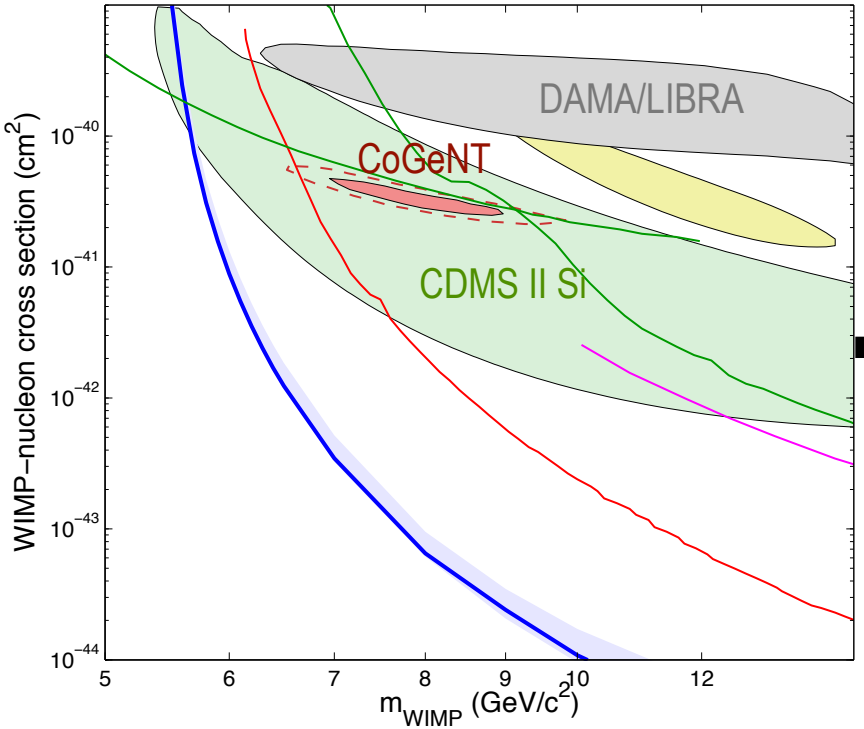
160 events in the center in 85 days (~2 events day!)

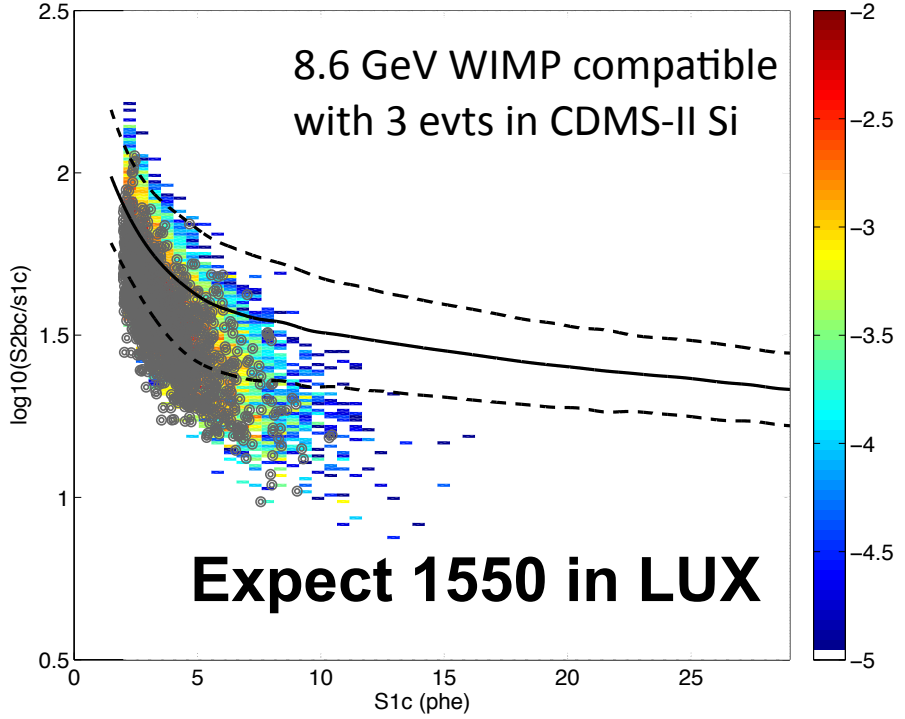
Profile-likelihood analysis shows events consistent with background-only hypothesis with p-value = 0.35

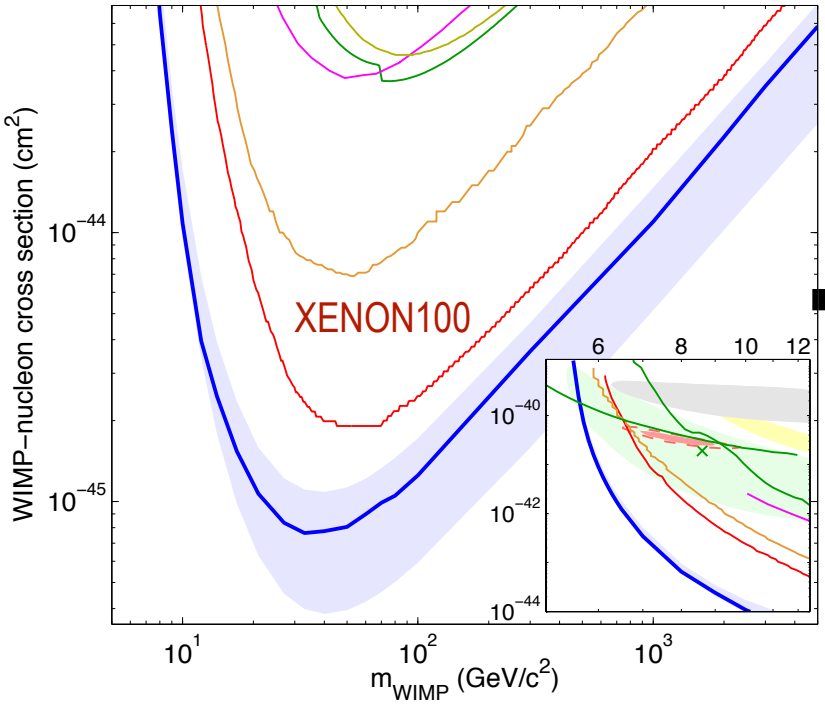


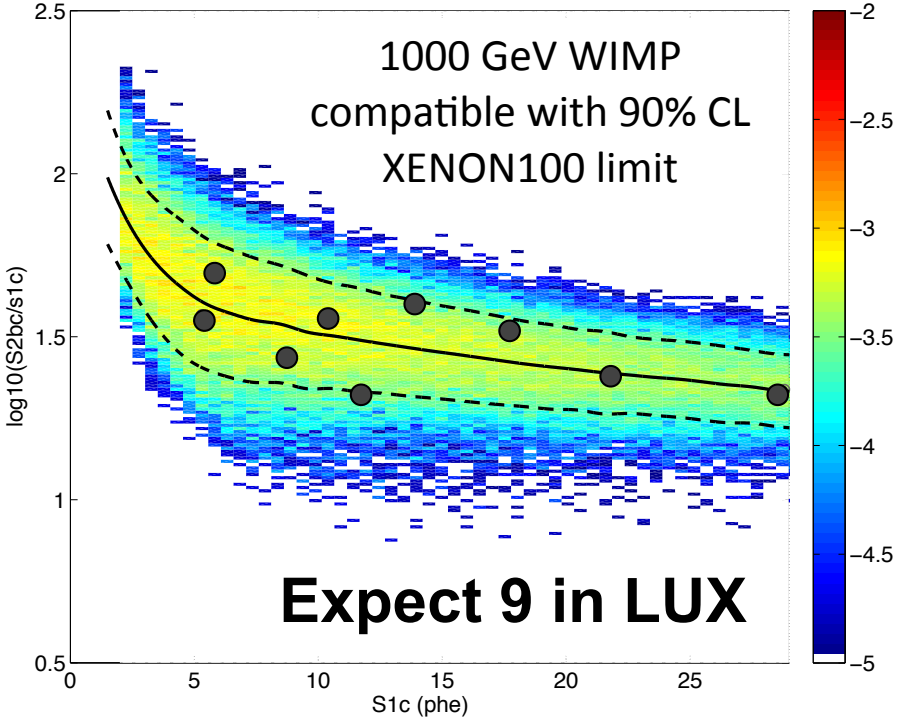

Edelweiss II
CDMS II Ge
Zeplin III
XENON100 (2011)
100 live days
XENON100 (2012)
225 live days
LUX (2013)
85 live days
DAMA/LIBRA
CoGeNT
CRESST
CDMS II Si
LUX
WIMP–nucleon cross section (cm^2)
10^{-44}
10^{-45}
10^{-40}
10^{-42}
10^{-44}
6
8
10
12
10^1
10^2
10^3
m_{WIMP} (GeV/c^2)


CDMS II Ge
DAMA/LIBRA Favored
CoGeNT Favored
CRESST Favored
CDMS II Si Favored
XENON100(2012)-225 live days
>20x more sensitivity
LUX (2013)-85 live days
LUX +/-1σ expected sensitivity
WIMP–nucleon cross section (cm^2)
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
5
6
7
8
9
10
12
m_{WIMP} (GeV/c^2)


DAMA/LIBRA
CoGeNT
CDMS II Si
WIMP–nucleon cross section (cm^2)
m_{WIMP} (GeV/c^2)

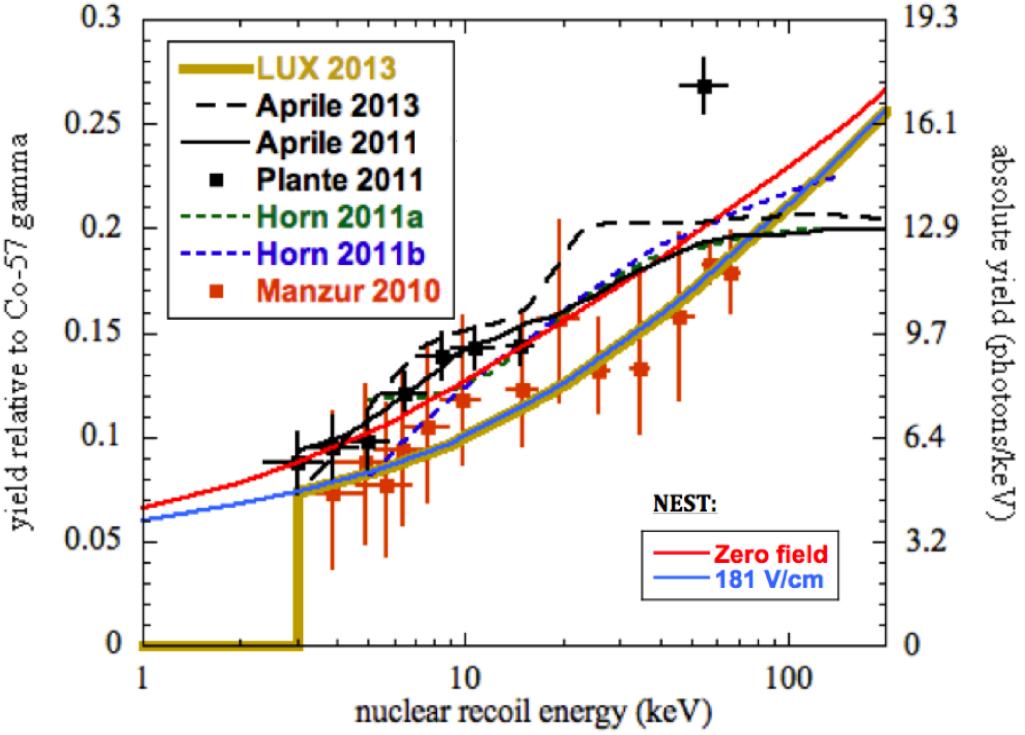

8.6 GeV WIMP compatible
with 3 evts in CDMS-II Si
Expect 1550 in LUX
log10(S2bc/s1c)
S1c (phe)


XENON100
WIMP–nucleon cross section (cm^2)
m_{WIMP} (GeV/c^2)

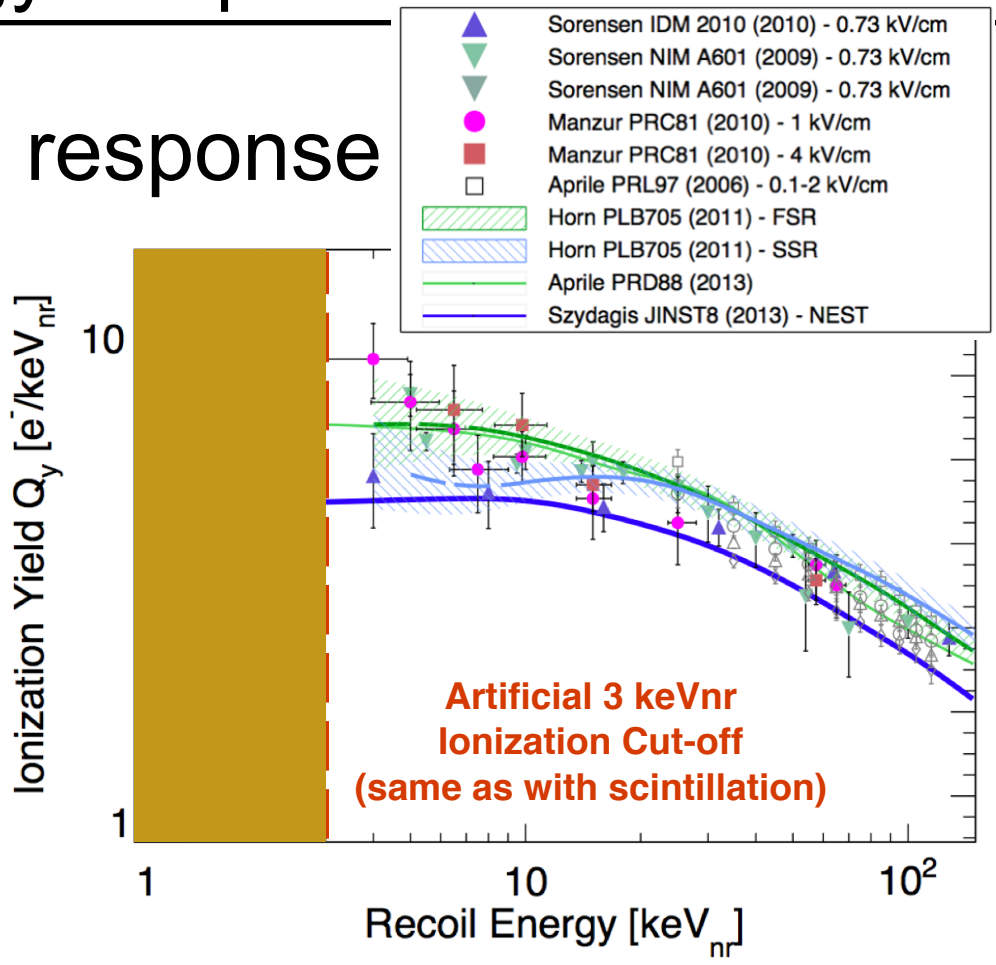

1000 GeV WIMP
compatible with 90% CL
XENON100 limit
Expect 9 in LUX
log10(S2bc/s1c)
S1c (phe)

Conservative Energy Response Cut

S1 response

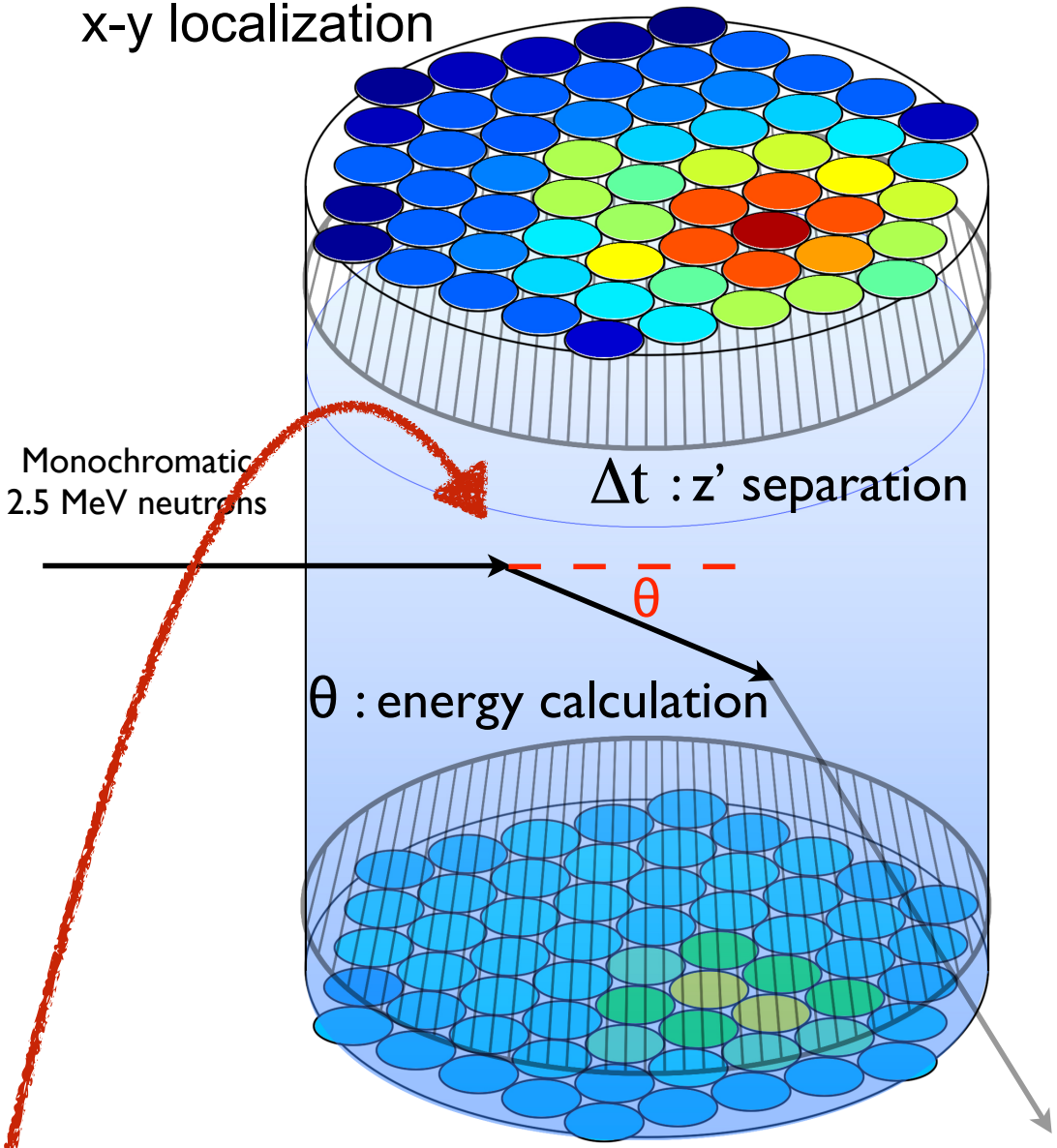


S2 response

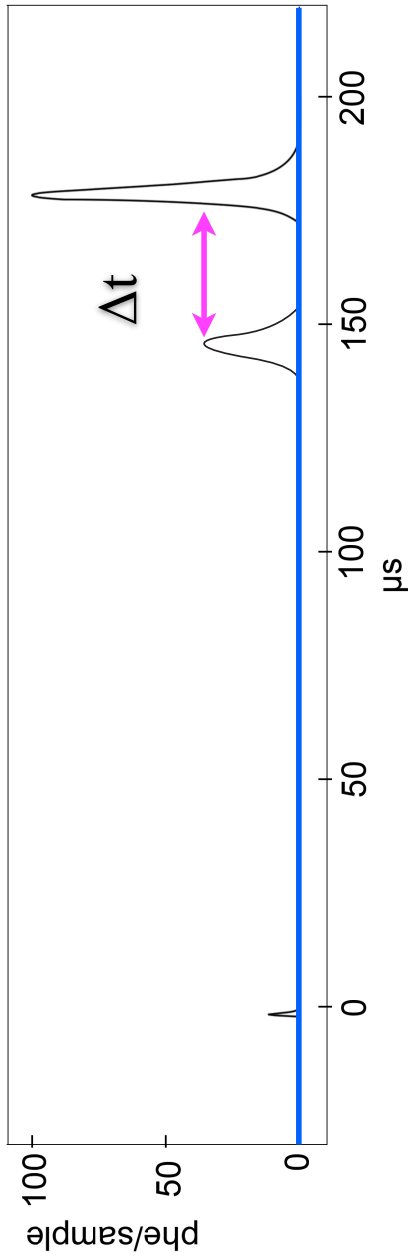


- Conservative assumption for first LUX limit: LXe has no response below the lowest calibration data point available (3 keV$_{nr}$).
- Response now shown with LUX DD neutron calibration to extend well below 3 keV$_{nr}$.

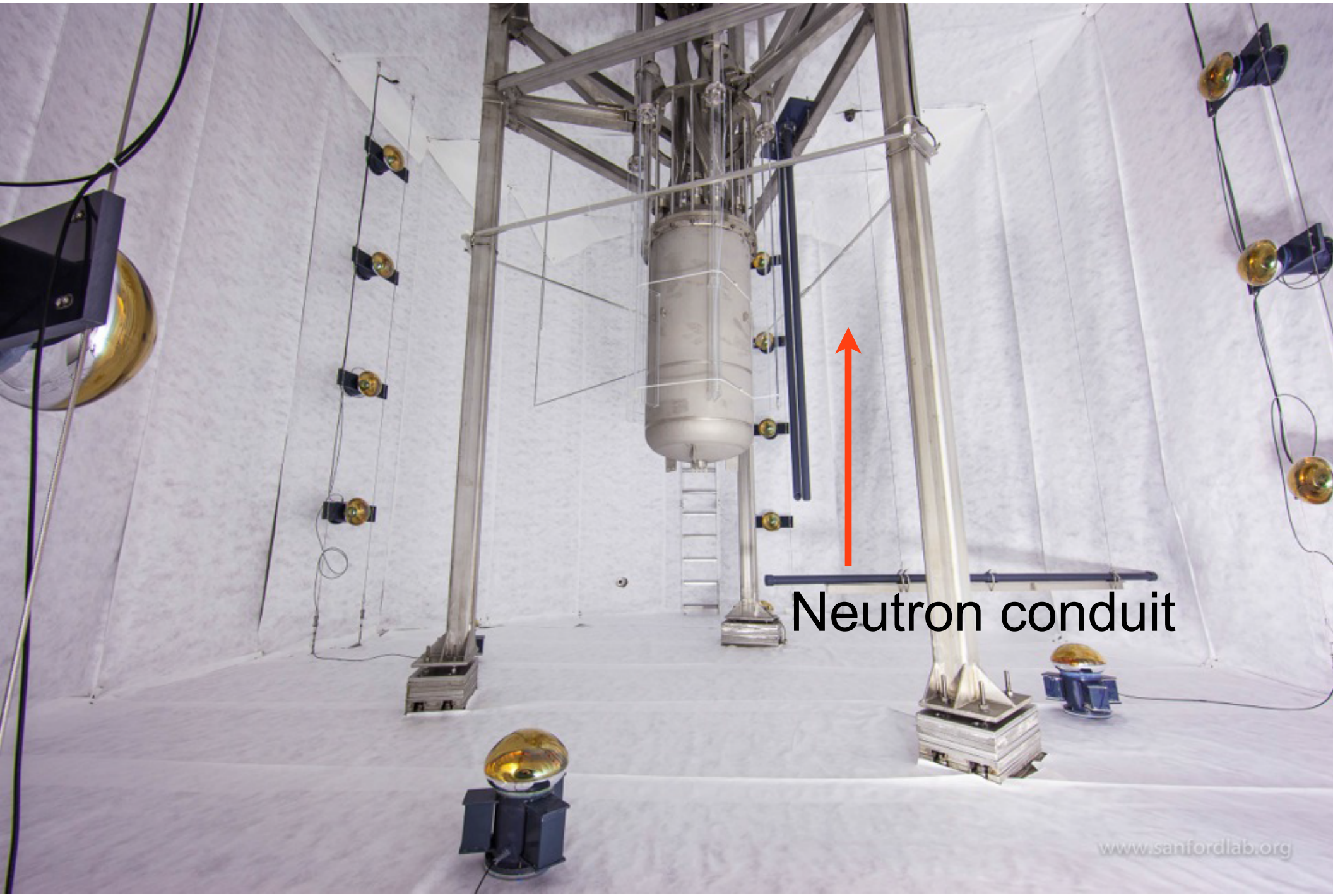
top hit pattern:
x-y localization



$$E_r = E_n \frac{4 m_n m_{Xe}}{(m_n + m_{Xe})^2} \frac{1 - \cos\theta}{2}$$

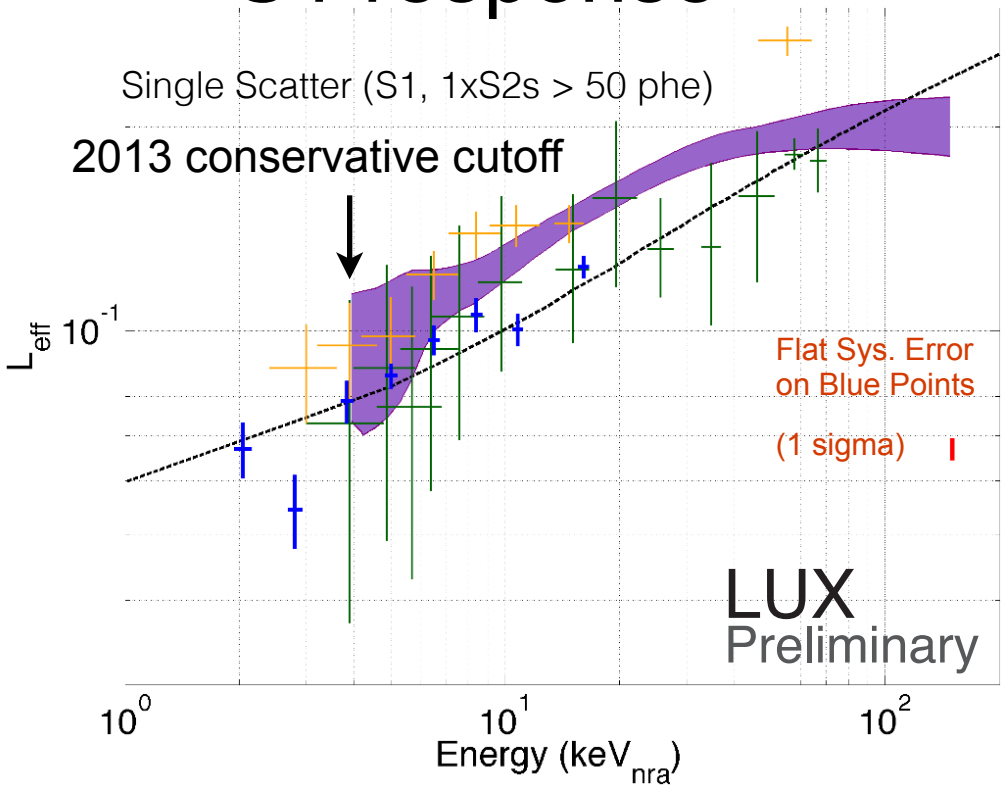


Samuel Chan, Carlos Faham for the LUX Collaboration


Neutron conduit
www.sanfordlab.org

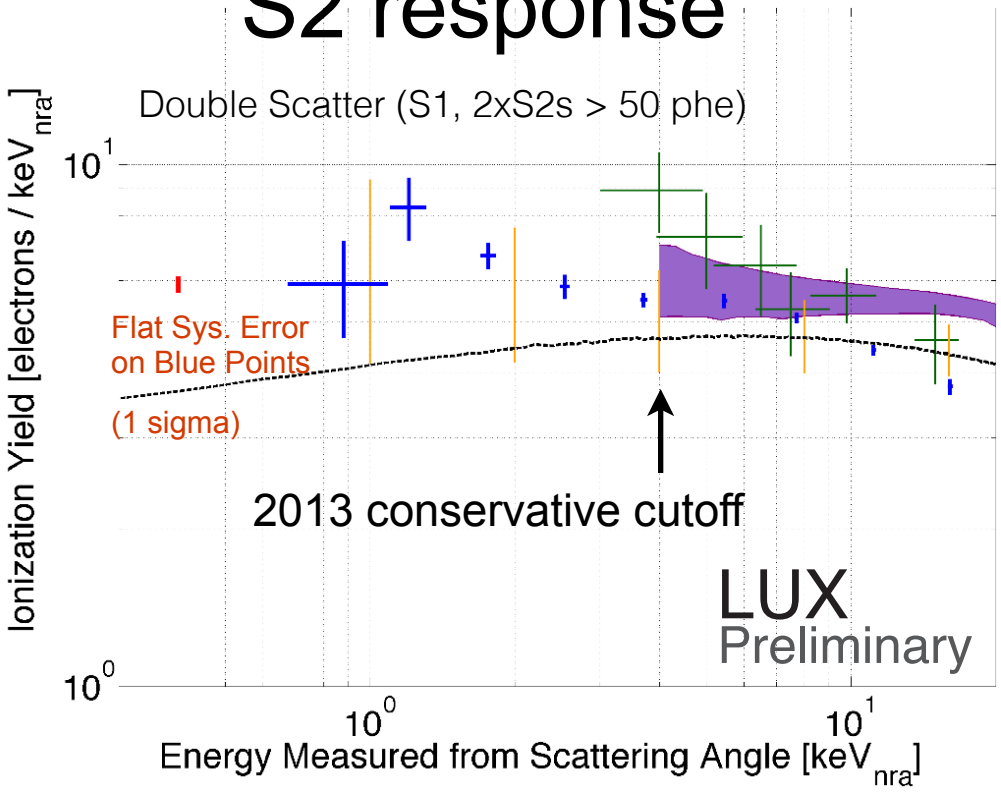
New In-Situ Calibration Results

S1 response



+ LUX DD result (181 V/cm)
— NEST model for LUX (181 V/cm)
+ Manzur 2010 (0 V/cm)
■ Horn Zeplin III (scaled to 0 V/cm)
| Plante 2011 (0 V/cm)

S2 response

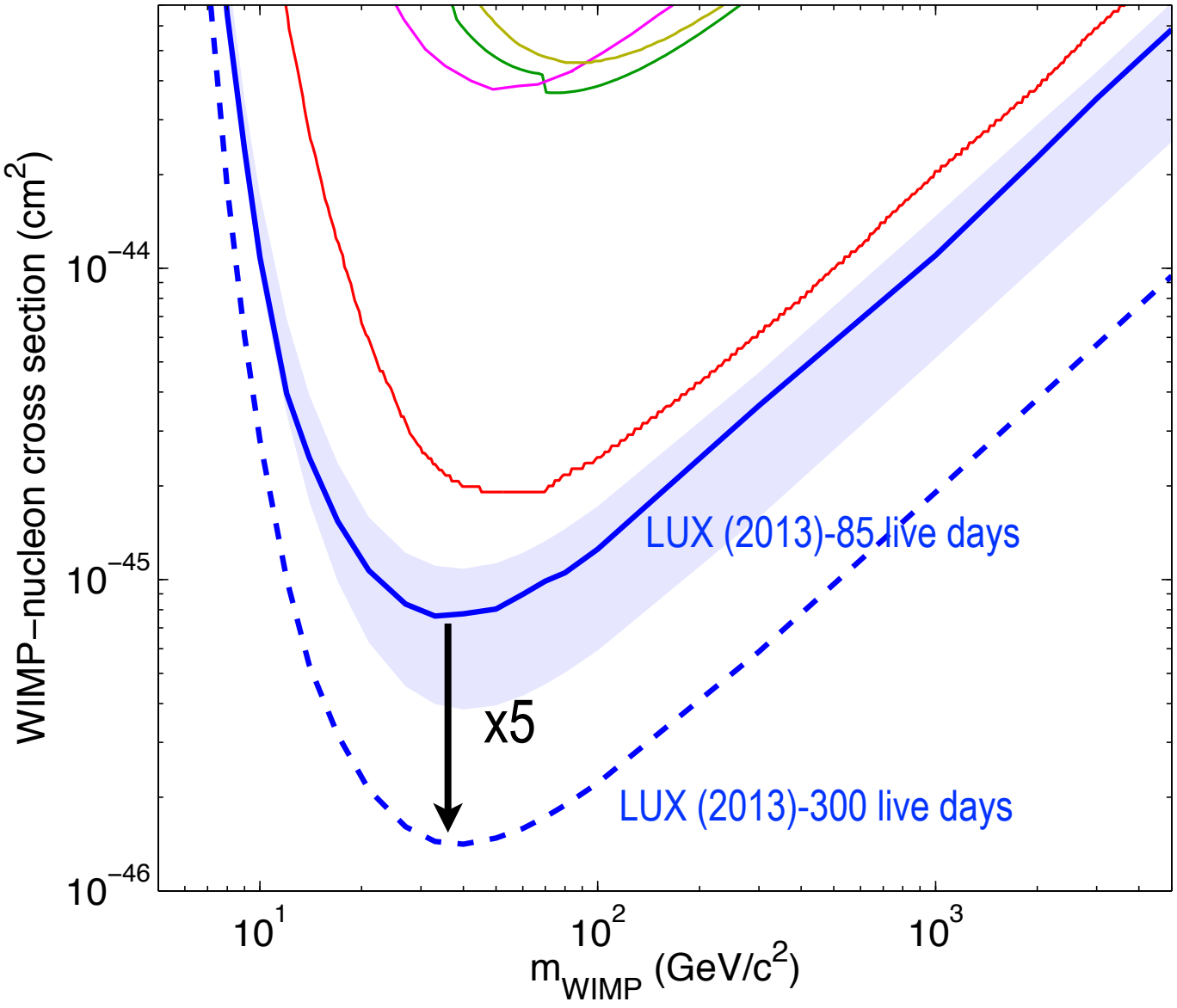


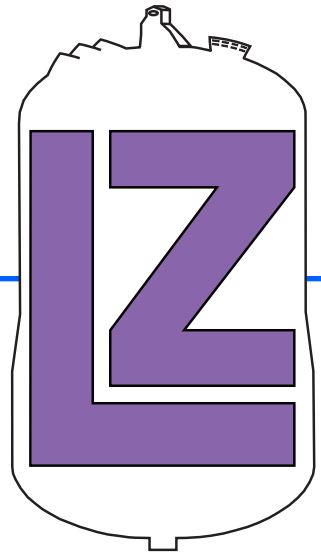
+ LUX DD result (181 V/cm)
— NEST model for LUX (181 V/cm)
+ Manzur 2010 (1 kV/cm)
■ Horn Zeplin III (3.6 kV/cm)
| Sorensen IDM 2010 (0.73 kV/cm)

LUX Current Status

- Re-analysis of 86-day data from 2013
  - Lower threshold
  - Using newly measured xenon signal yields at low energy (lower cutoff than conservative 3 keVnr)
  - This will result in better sensitivity to lower WIMP masses
- Now finishing more extensive detector calibrations (DD neutron, high-stat tritium)
- New run 300-day run starting very soon (2014)

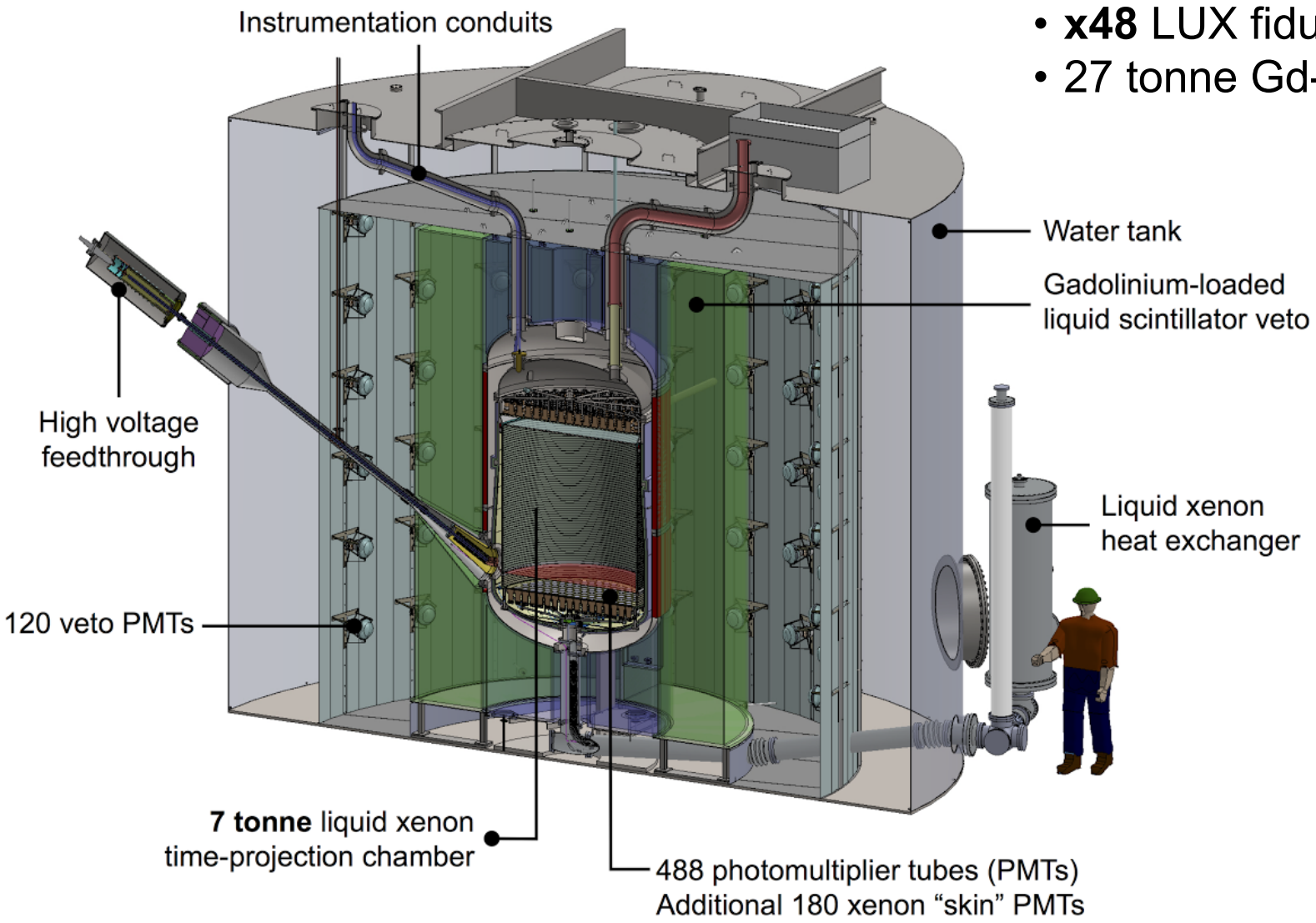
New 300 day run in 2014





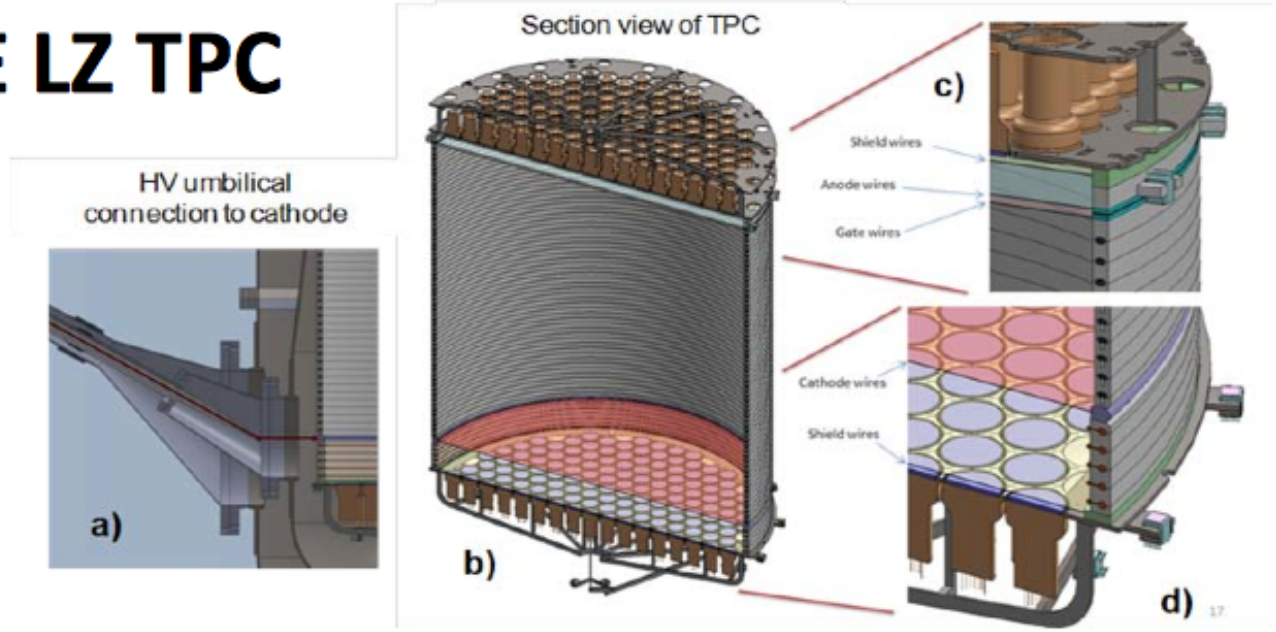
The LZ Dark Matter Experiment

- **x48** LUX fiducial
- 27 tonne Gd-LAB veto



LZ: Key Parameters

THE LZ TPC



- **TPC PARAMETERS**
  - 1.5 m diameter/length (3x LUX)
  - 7 tonne active LXe mass (28x LUX)
  - 2x 241 3-inch PMTs (4x LUX)
  - Highly reflective PTFE field cage
  - 100 kV cathode HV (10x LUX)
  - Electron lifetime 3 ms (3x LUX)

H. ARAUJO

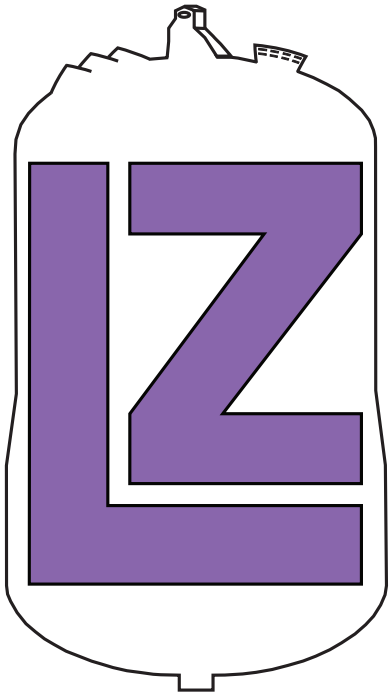
PHYSICS PARAMETERS

- 5.8 keVr S1 threshold (4.5 keVr LUX)
- 0.7 kV/cm drift field, 99.5% ER/NR disc. (already surpassed in LUX at 0.2 kV/cm)

TPC CALIBRATION

- ER: Dispersed sources: Kr-83m, CH_3T
- NR: AmBe, YBe, D-D generator

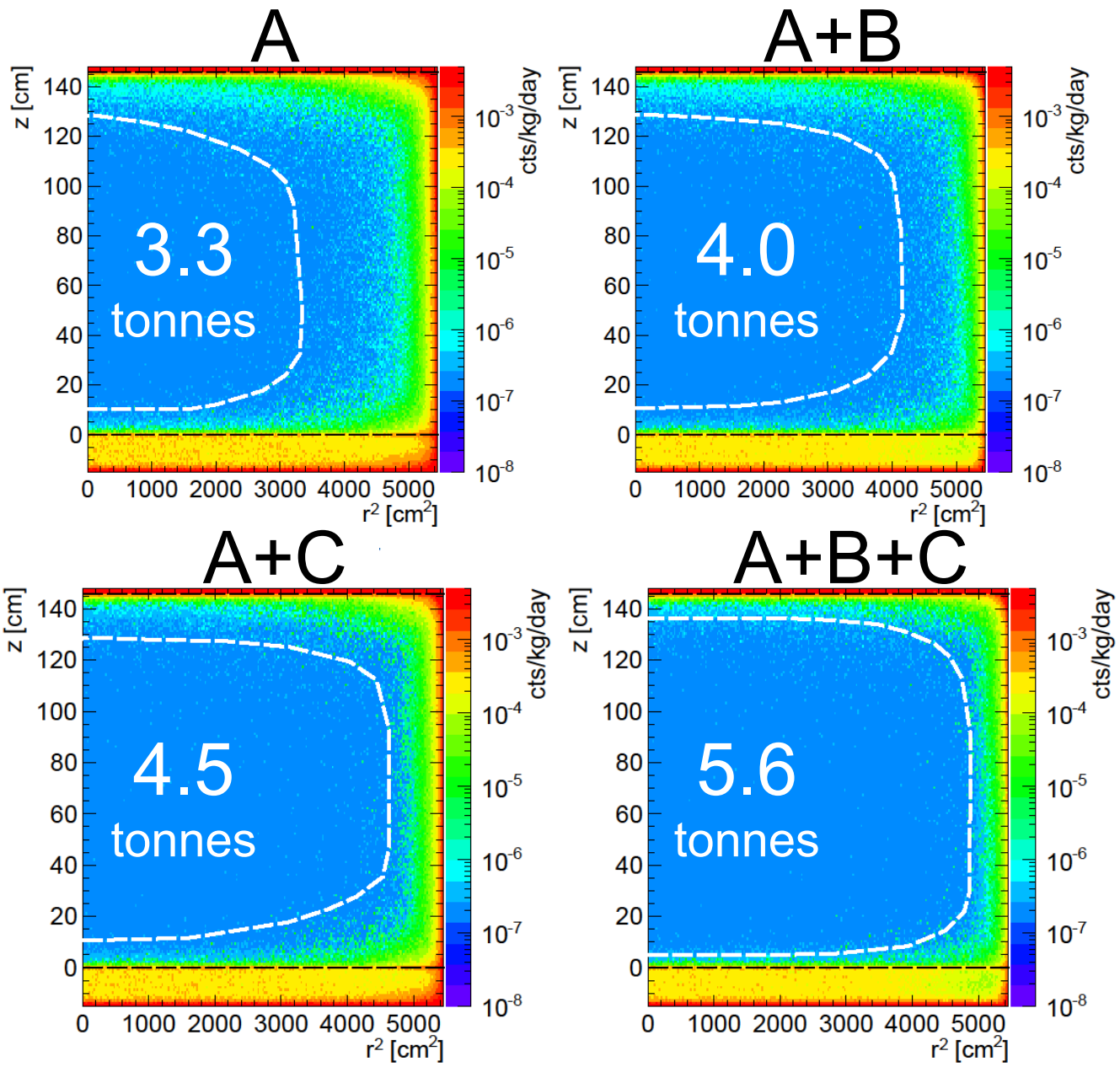
Collaboration



LIP Coimbra (Portugal)
STFC Daresbury Laboratory
Edinburgh University (UK)
University of Liverpool (UK)
Imperial College London (UK)
University College London (UK)
MEPhI (Russia)
University of Oxford (UK)

Rutherford Appleton Laboratory (UK)
University of Sheffield (UK)
University of Alabama (US)
University at Albany SUNY (US)
Lawrence Berkeley Lab, UC Berkeley (US)
Brookhaven National Laboratory (US)
Brown University (US)
Case Western Reserve University (US)
University of California, Davis (US)
Lawrence Livermore National Lab (US)
University of Maryland (US)
University of Rochester (US)
University of California, Santa Barbara (US)
University of South Dakota (US)
South Dakota School of Mines & Technology (US)
South Dakota Science and Technology Authority (US)
SLAC National Accelerator Laboratory (US)
Texas A&M (US)
Washington University (US)
University of Wisconsin (US)
Yale University (US)

External Backgrounds - Fiducial Volume



Simulation

Total NR background plus ER leakage from sources external to the liquid xenon in the TPC, 6-30 keV

ER discrimination efficiency of 99.5%

A Single hit

B LXe skin

C Gd-LS veto

LZ Status

Next-generation dark matter experiments get the green light

Jul 16, 2014 by Kate Greene

The LZ water shield, currently housing the LUX experiment.

Courtesy of NASA

breaking

July 11, 2014

US reveals its next generation of dark matter experiments

Together, the three experiments will search for a variety of types of dark matter particles.

By Kathryn Jepsen

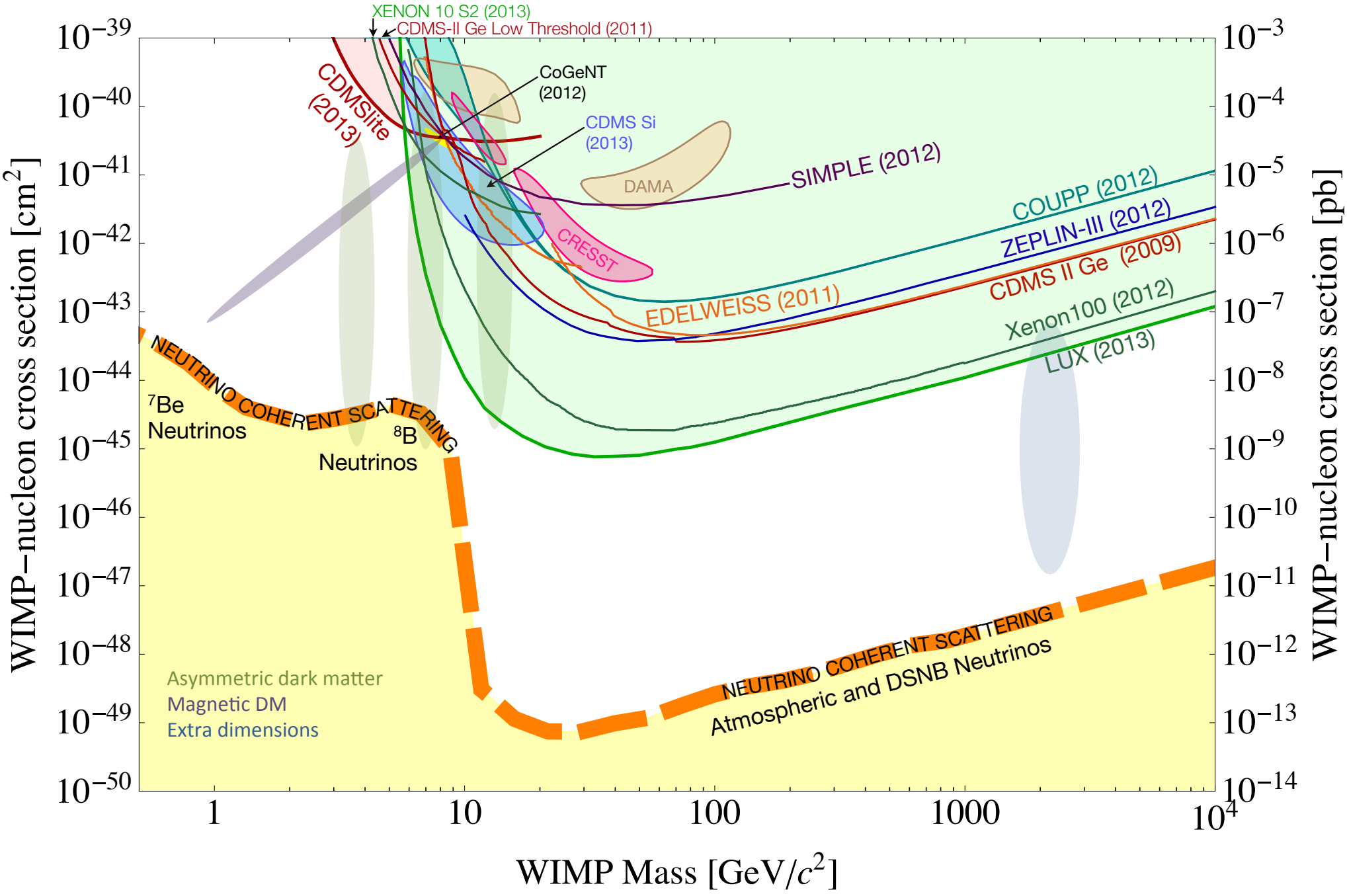
PDF download

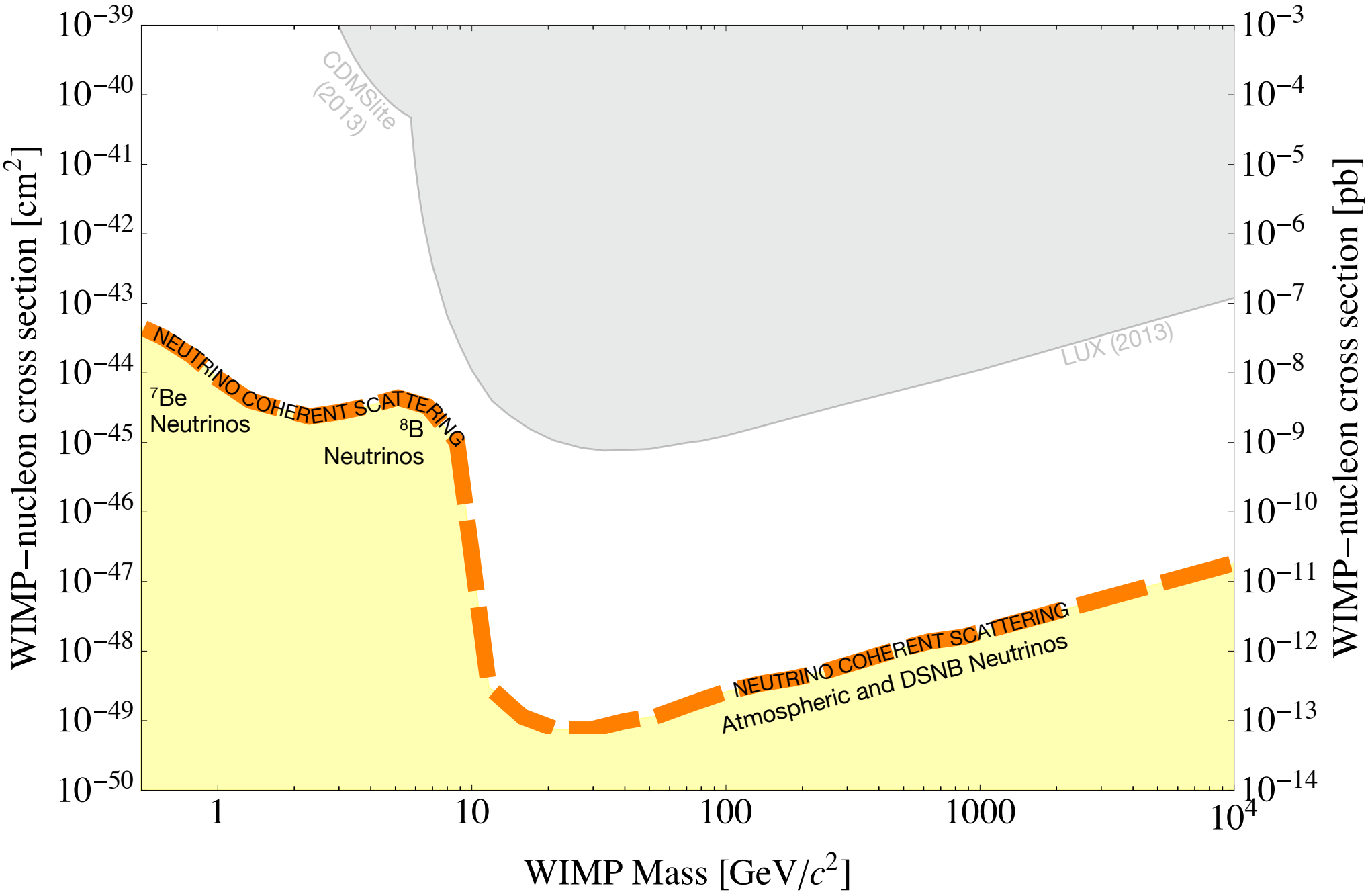
Related symmetry content

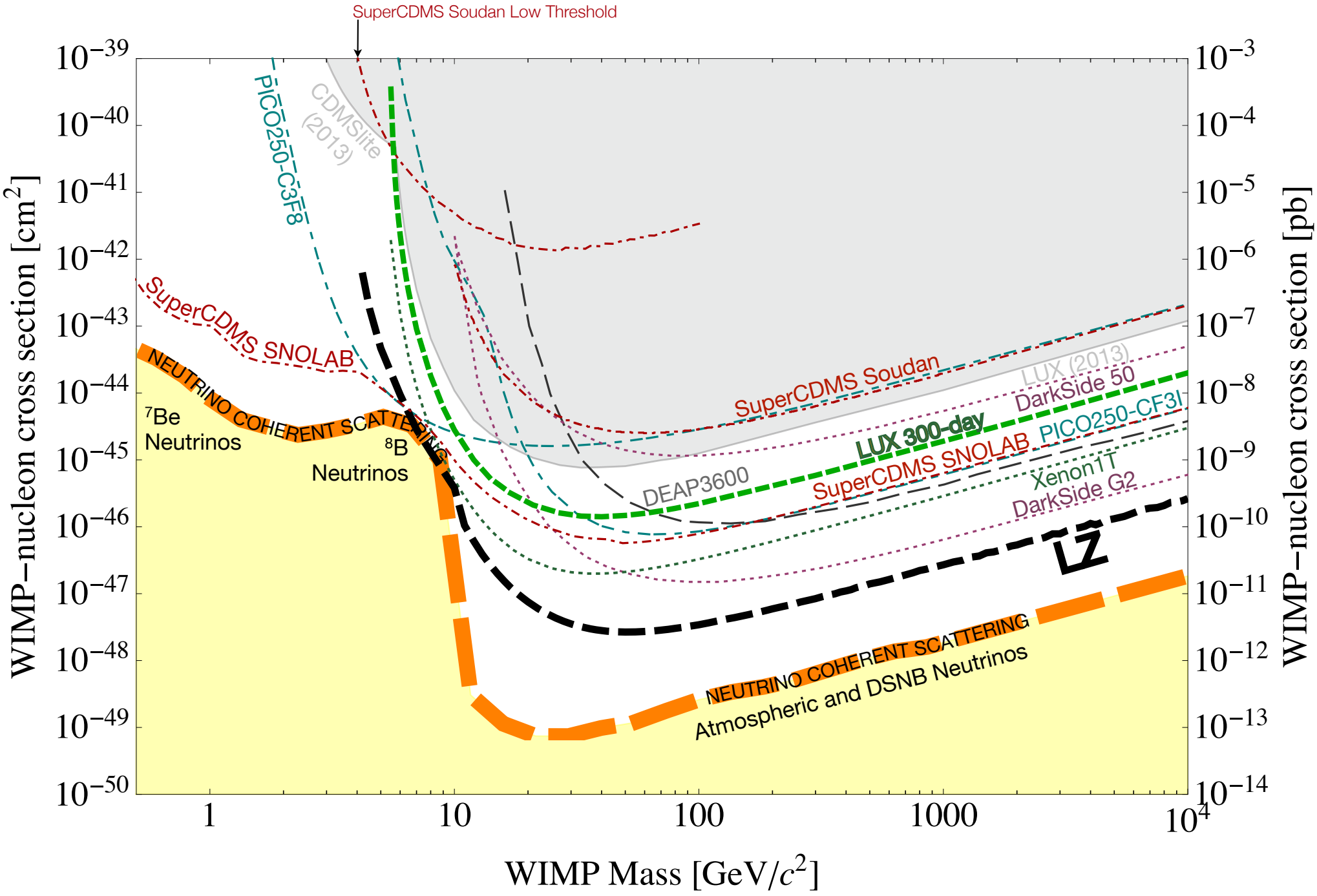
Two US federal funding agencies announced today which experiments they will support in the next generation of the search for dark matter.

The Department of Energy and National Science Foundation will back the Super Cryogenic Dark Matter Search-SNOLAB, or SuperCDMS; the LUX-Zeplin experiment, or LZ; and the next iteration of the Axion Dark Matter eXperiment, ADMX-Gen2.

- One of the 3 experiments approved for funding in the US DOE/NSF G2 down-select (with ADMX and SuperCDMS).
- Endorsed by DMUK consortium in the UK.
- Conceptual design nearly finished, upcoming CD1 review.
- Construction through 2017, operation from 2018.


XENON 10 S2 (2013)
CDMS-II Ge Low Threshold (2011)
CDMSlite (2013)
CoGeNT (2012)
CDMS Si (2013)
DAMA
SIMPLE (2012)
CRESST
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
EDELWEISS (2011)
Xenon100 (2012)
LUX (2013)
NEUTRINO COHERENT SCATTERING
^{7}Be Neutrinos
^{8}B Neutrinos
Asymmetric dark matter
Magnetic DM
Extra dimensions
NEUTRINO COHERENT SCATTERING
Atmospheric and DSNB Neutrinos
WIMP–nucleon cross section [cm^2]
WIMP–nucleon cross section [pb]
WIMP Mass [GeV/c^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
1
10
100
1000
10^4


WIMP–nucleon cross section [cm^2]
WIMP–nucleon cross section [pb]
WIMP Mass [GeV/c^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
1
10
100
1000
10^4
CDMSlite (2013)
LUX (2013)
NEUTRINO COHERENT SCATTERING
^{7}Be Neutrinos
^{8}B Neutrinos
NEUTRINO COHERENT SCATTERING
Atmospheric and DSNB Neutrinos


SuperCDMS Soudan Low Threshold
CDMSlite (2013)
PICO250-C3F8
SuperCDMS SNOLAB
NEUTRINO COHERENT SCATTERING
^{7}Be Neutrinos
^{8}B Neutrinos
SuperCDMS Soudan
LUX (2013)
DarkSide 50
LUX 300-day
SuperCDMS SNOLAB
PICO250-CF3I
DEAP3600
Xenon1T
DarkSide G2
LZ
NEUTRINO COHERENT SCATTERING
Atmospheric and DSNB Neutrinos
WIMP–nucleon cross section [cm^2]
WIMP–nucleon cross section [pb]
WIMP Mass [GeV/c^2]
10^{-39}
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
10^{-48}
10^{-49}
10^{-50}
10^{-3}
10^{-4}
10^{-5}
10^{-6}
10^{-7}
10^{-8}
10^{-9}
10^{-10}
10^{-11}
10^{-12}
10^{-13}
10^{-14}
1
10
100
1000
10^4

Plug

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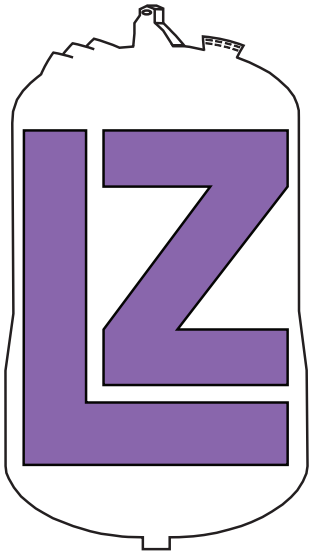

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Mahalo
Huli pau!
Aia i hea ka lua?