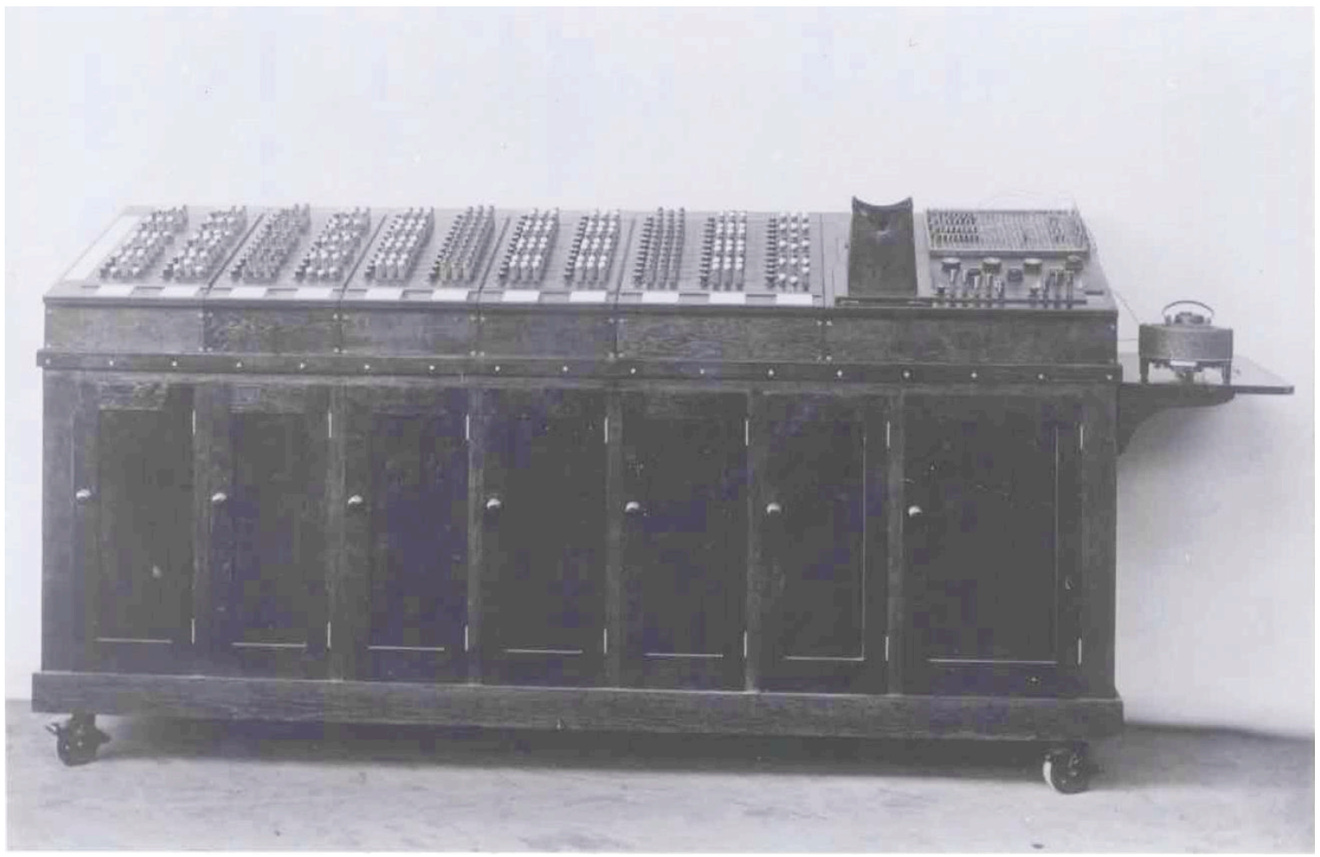
The Large Underground Xenon (LUX) experiment and NERSC

Carlos Hernandez Faham
LBNL

NERSC@40
Feb 5, 2014

Then and now...



The Malloc machine, 1933

Edison, 2014

Solved 10 simultaneous differential equations

Can do that, too

Then...

“Who the devil are you?”

When researchers talk about neutron stars, dark matter and gravitational lenses, they all start the same way: "Zwicky noticed this problem in the 1930s. Back then, nobody listened . . ."

Stephen Maurer

- Coined term "supernova" (he personally discovered 122)
- Worked on jet propulsion, Aerojet Engineering Corp (>50 patents)
- Proposed using SN as standard candles (though was skeptical of space expansion)
- Postulated that galaxy clusters could act as gravitational lenses
- ***Dunkle Materie***: Virial theorem applied to Coma cluster in **1933** revealed a large discrepancy between luminous mass and kinematic mass

Now...

Cluster Kinematics

BBN

CMB

Galaxy Rotation

etc

BAO

Gravitational Lensing

SNe Ia

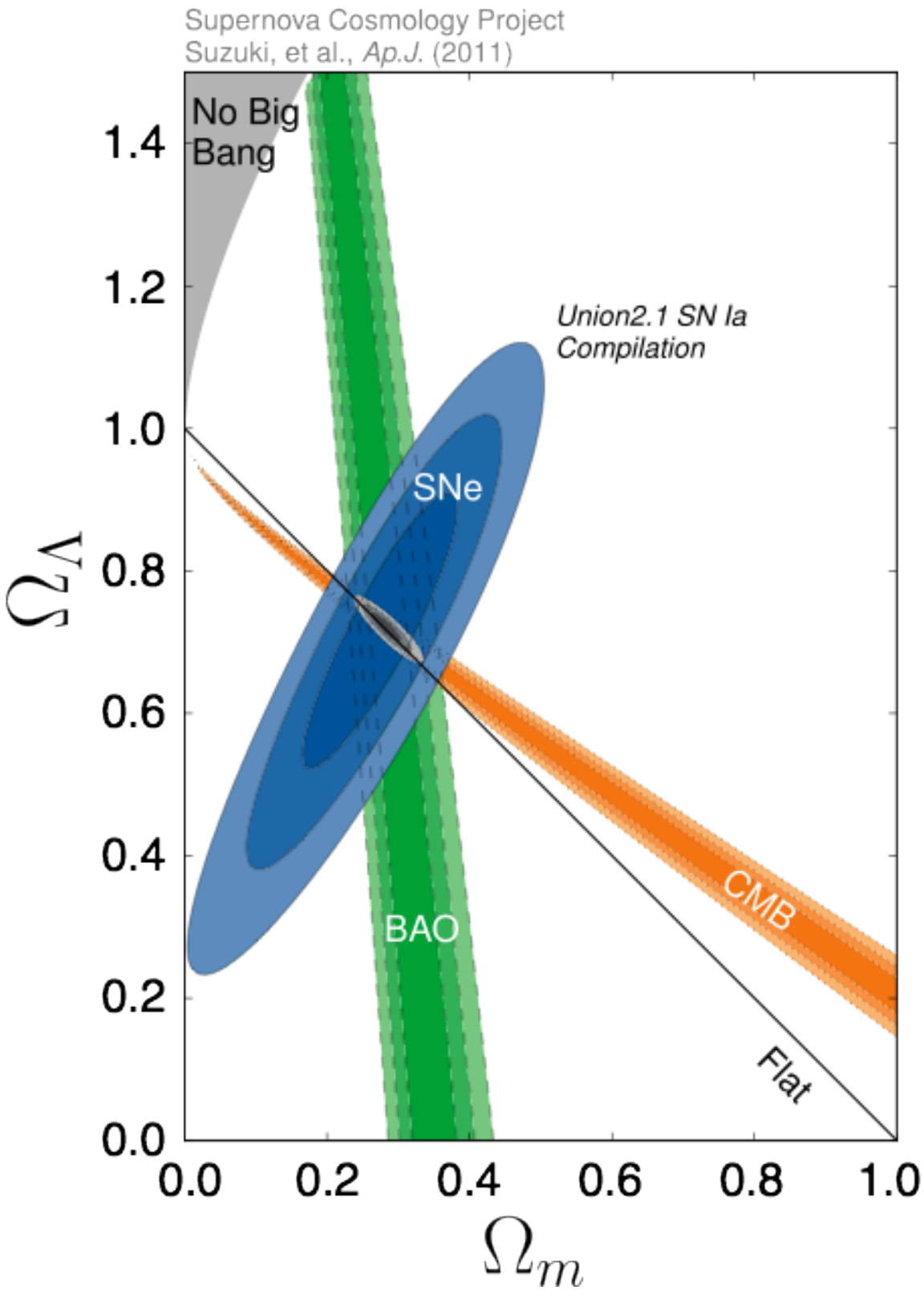
Structure Formation

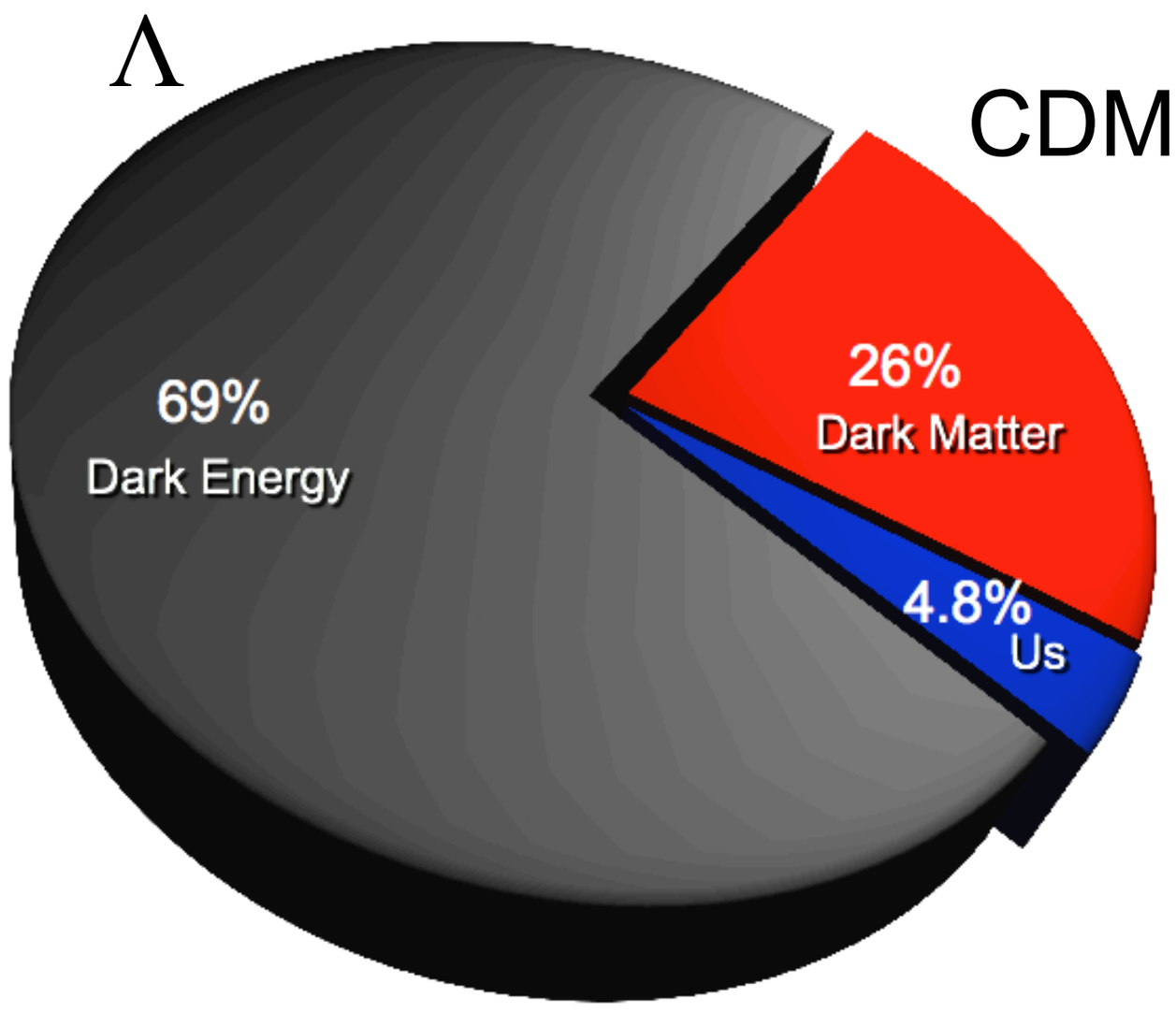
Indirect Detection

Direct Detection

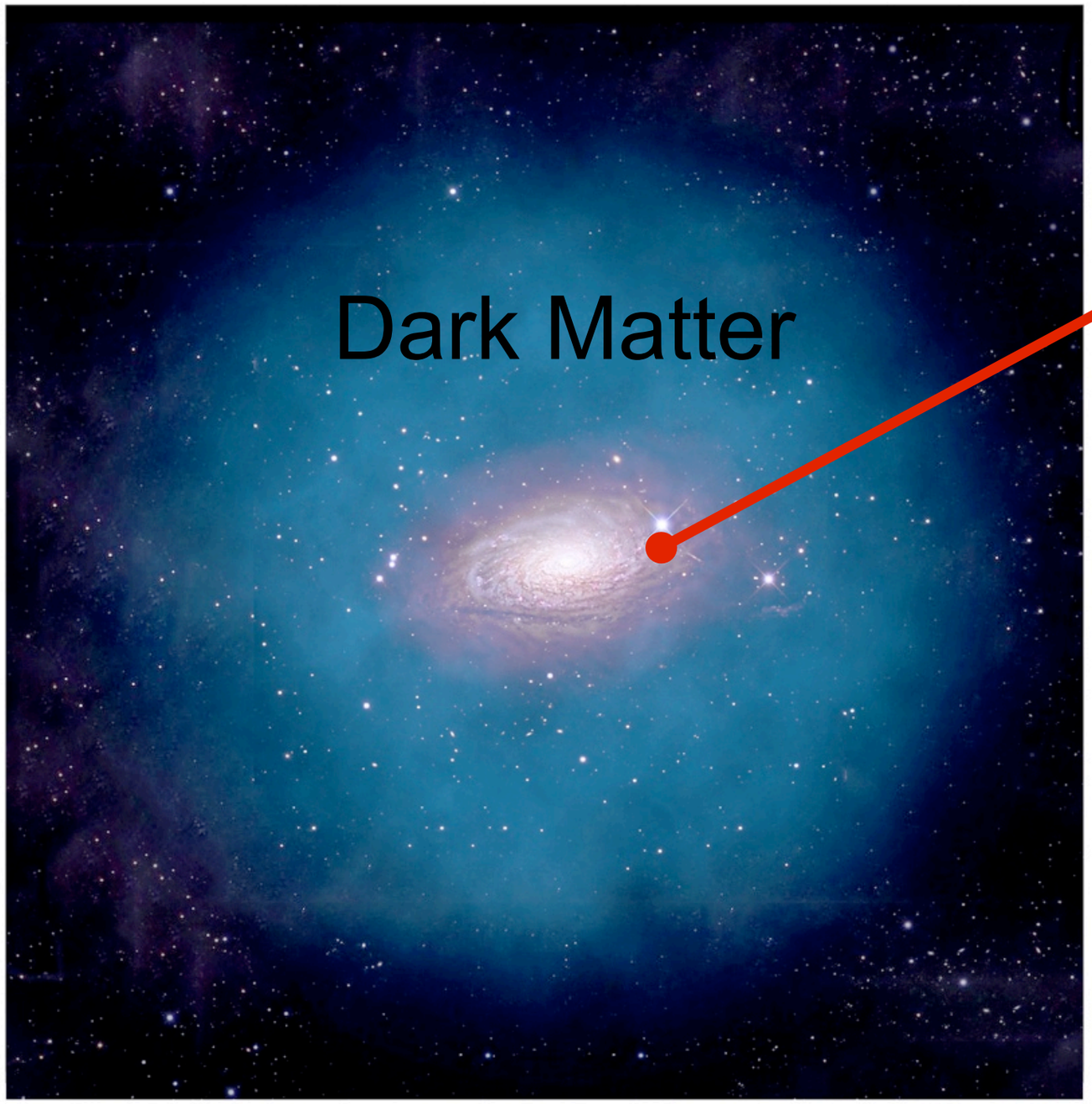
Production

ΛCDM Concordance Model

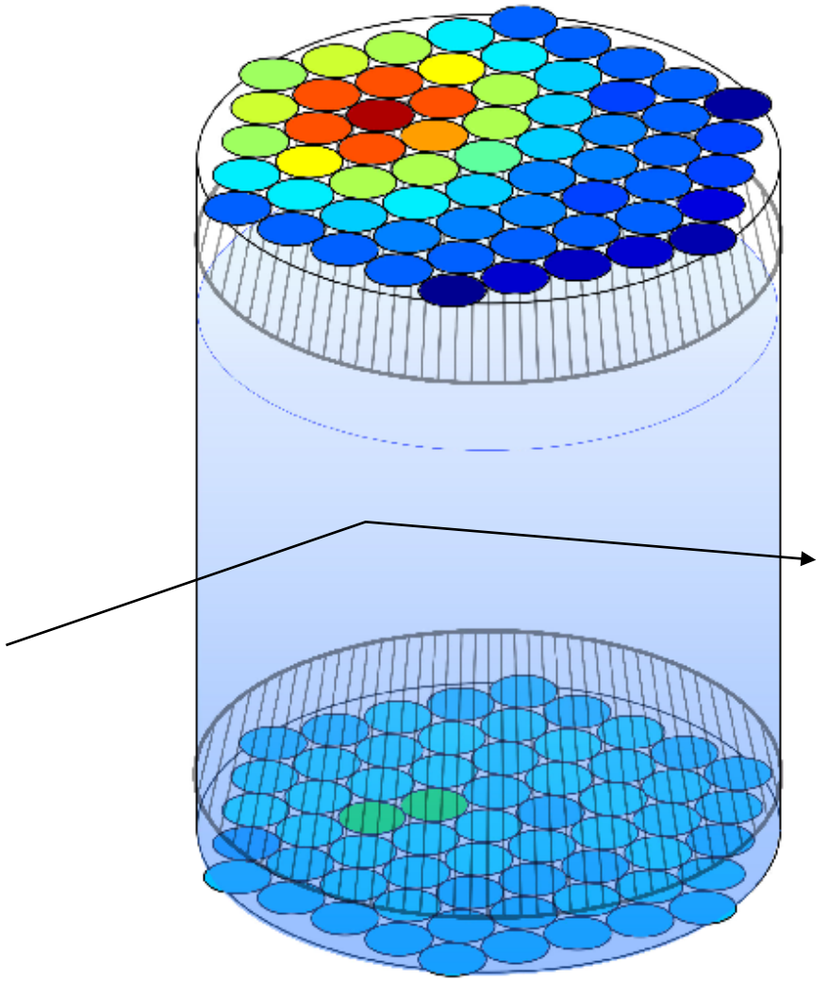


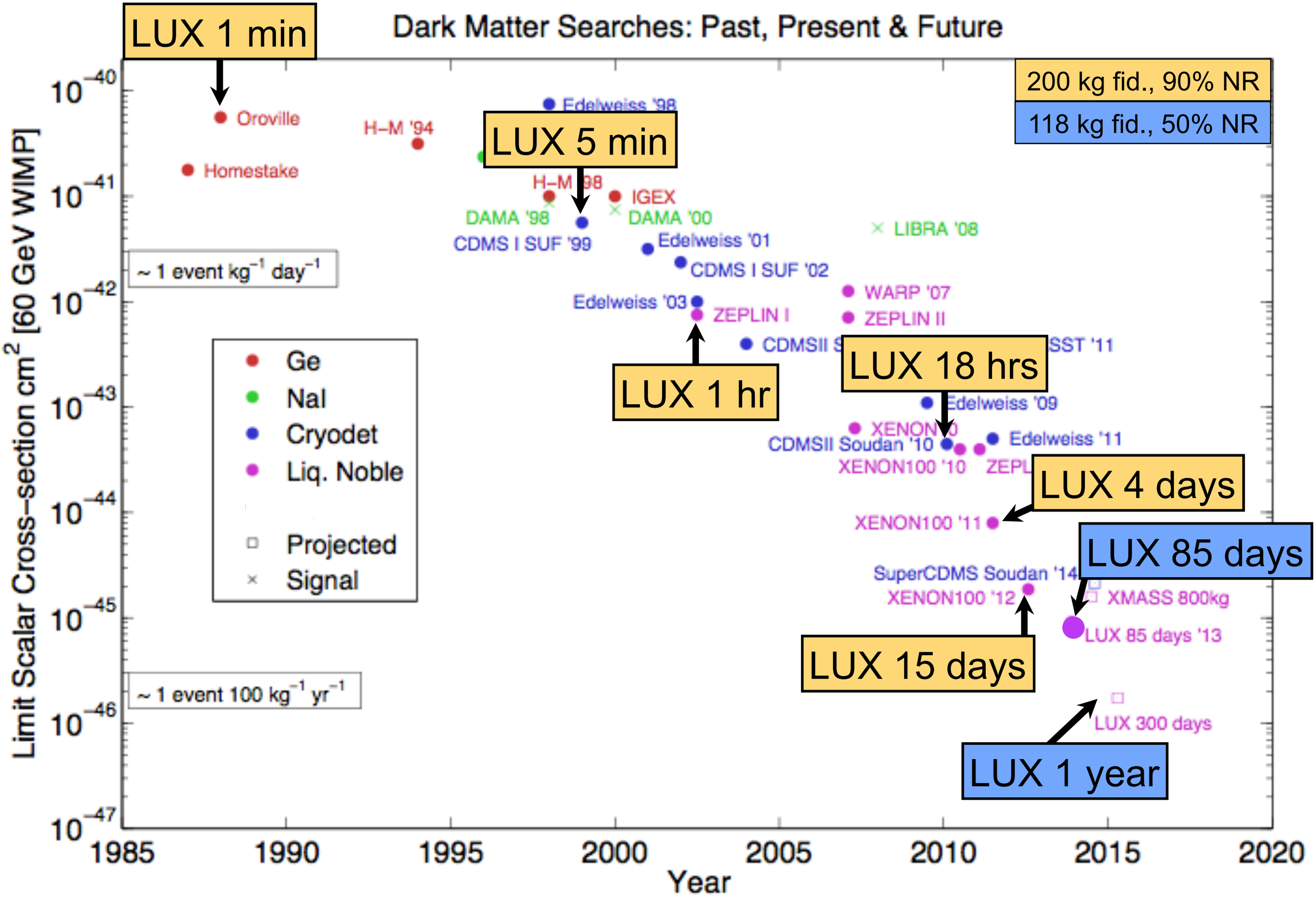


Dark Matter Detection On Earth



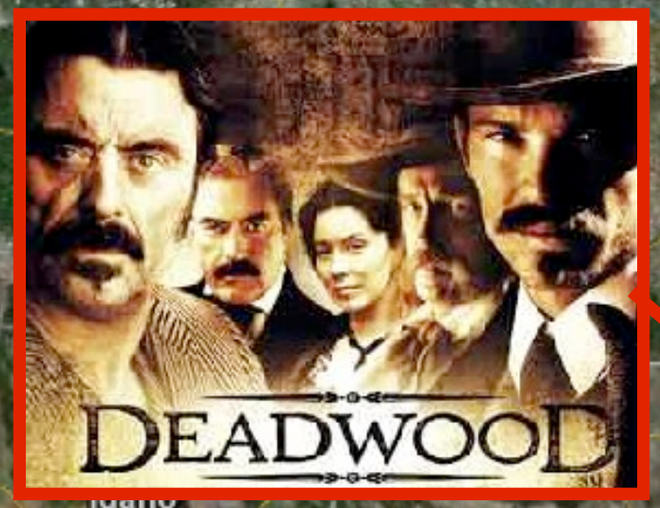
You are here




LUX 1 min
Dark Matter Searches: Past, Present & Future
200 kg fid., 90% NR
118 kg fid., 50% NR
LUX 5 min
LUX 1 hr
LUX 18 hrs
LUX 4 days
LUX 85 days
LUX 15 days
LUX 1 year
Oroville
Homestake
H–M '94
Edelweiss '98
H–M '98
IGEX
DAMA '98
DAMA '00
CDMS I SUF '99
Edelweiss '01
CDMS I SUF '02
LIBRA '08
WARP '07
ZEPLIN I
ZEPLIN II
Edelweiss '03
Edelweiss '09
XENON10
CDMSII Soudan '10
Edelweiss '11
XENON100 '10
XENON100 '11
SuperCDMS Soudan '14
XENON100 '12
XMASS 800kg
LUX 85 days '13
LUX 300 days
~ 1 event kg^{-1} day^{-1}
~ 1 event 100 kg^{-1} yr^{-1}
Ge
NaI
Cryodet
Liq. Noble
Projected
Signal
Limit Scalar Cross–section cm^2 [60 GeV WIMP]
10^{-40}
10^{-41}
10^{-42}
10^{-43}
10^{-44}
10^{-45}
10^{-46}
10^{-47}
1985
1990
1995
2000
2005
2010
2015
2020
Year


UNDERGROUND
THE
LURE
OF THE
UNDERGROUND


Symmetry Magazine
1
2
3
4850 ft
LUX experiment

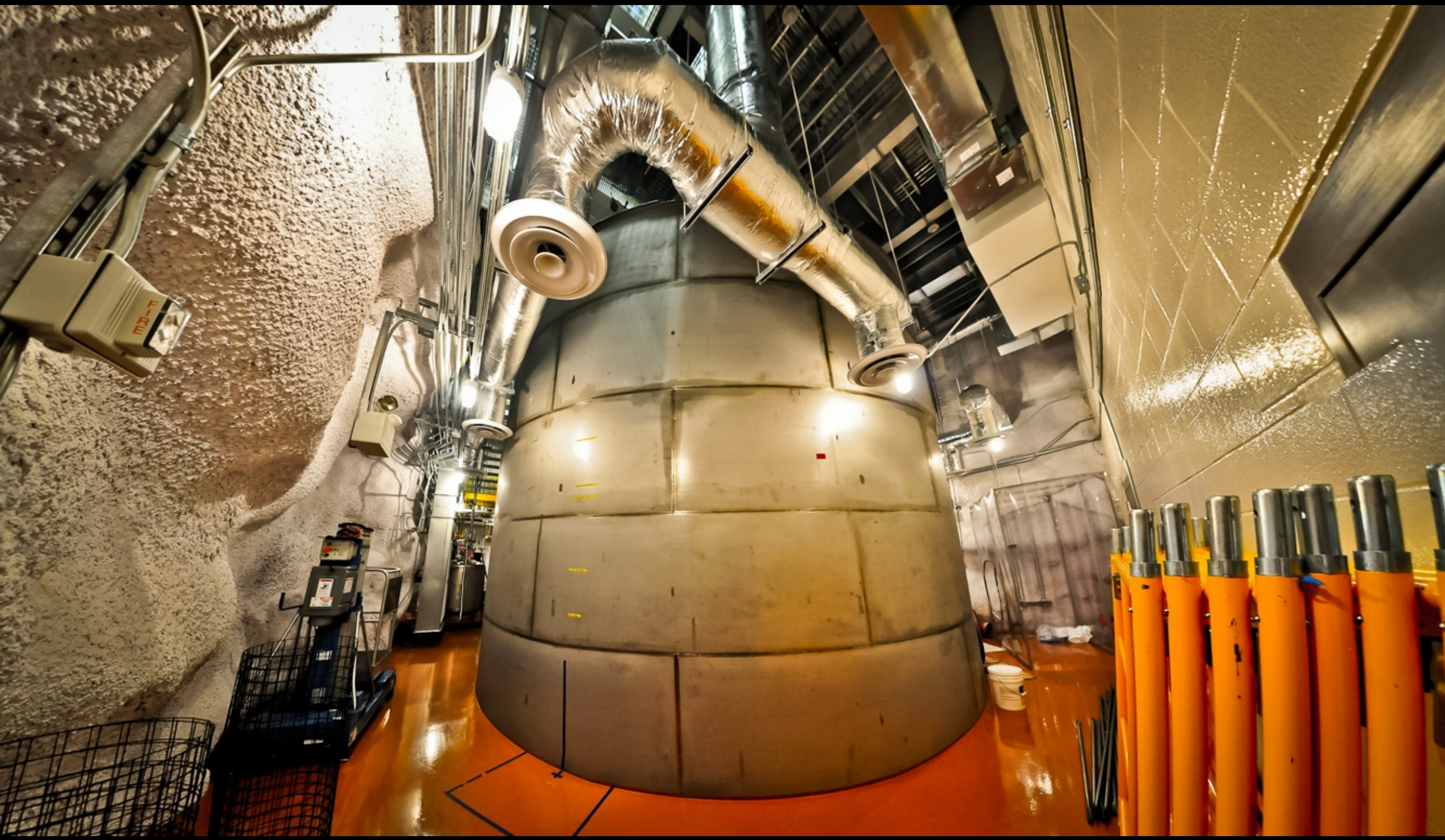

DEADWOOD

“Eager Graduate Students”

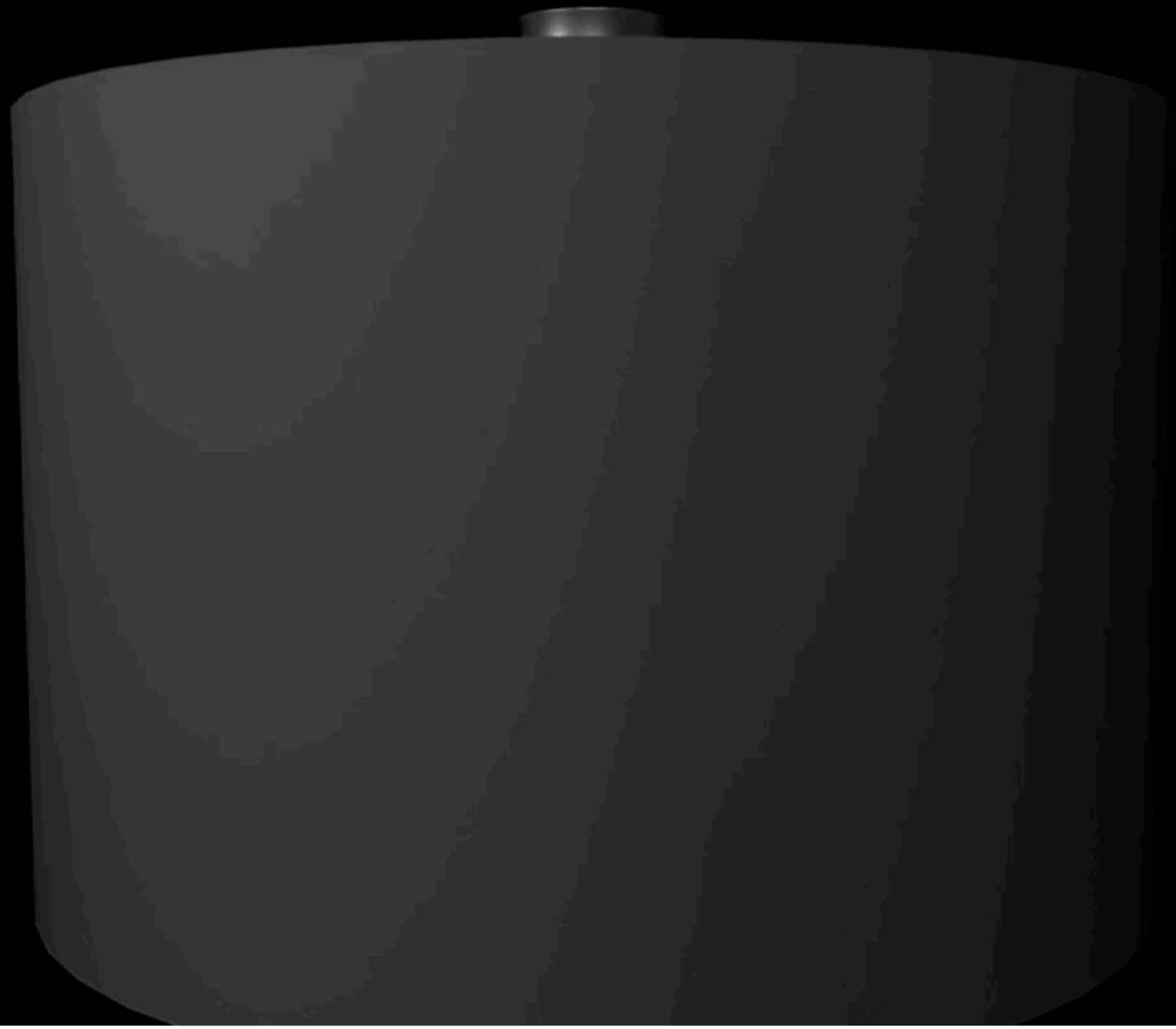
Davis Cavern, Oct 2011

“Busy Graduate Students”

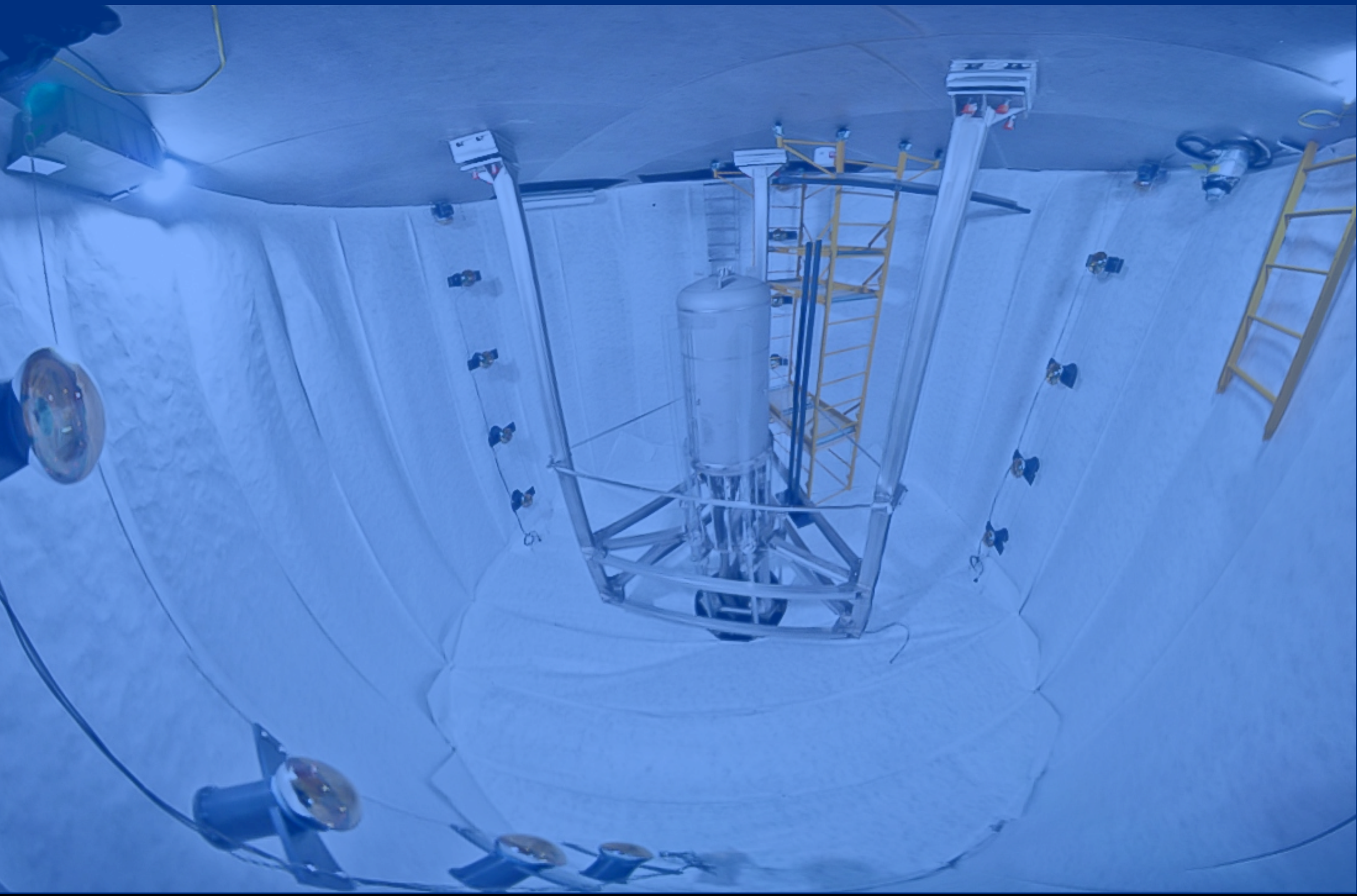
Davis Cavern, Sep 2012

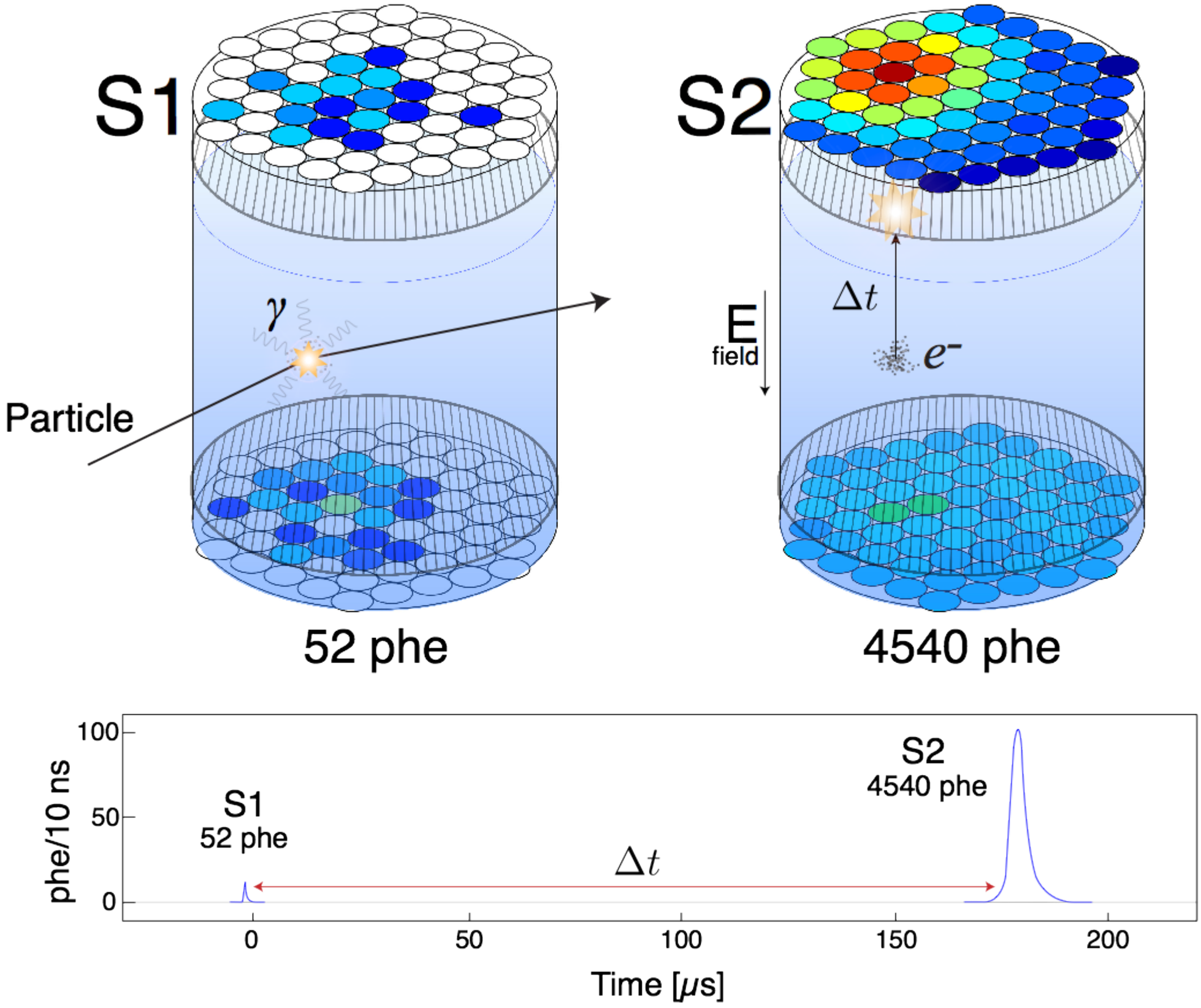


LUX Water Tank - Outside View



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

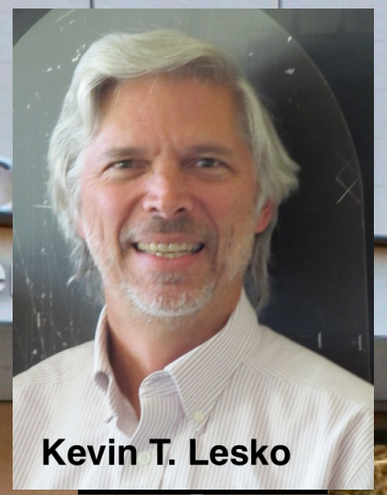



S1
S2
γ
Particle
Δt
E
field
e^-
52 phe
4540 phe
100
50
0
phe/10 ns
S1
52 phe
S2
4540 phe
Δt
0
50
100
150
200
Time [μs]


Carlos Faham


Vic Gehman


M. Gilchriese


Kevin T. Lesko


Bob Jacobsen


Who the devil are you?


Mia Ihm

First Results from LUX, October 30 2013

Science »

Dark matter hunt nears final pha
BBC News - 20 minutes ago
Scientists could be nearing the final phase enigmatic substance thought to make up a
BBC News

Earth-sized 'lava world' discover
BBC News - 14 minutes ago
A doomed "lava world" with a similar mass discovered orbiting a star 400 light-years a
BBC News

Newly discovered humpback do
USA TODAY - 3 minutes ago
(NEWSER) - A species of dolphin that live so new to science that it doesn't have a na
The Indep...

More Science stories

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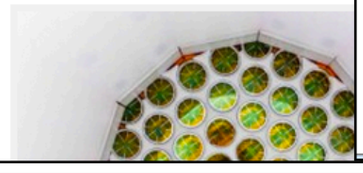
5 LinkedIn Strategies

TECH | 11/07/2013 @ 1:44PM | 3,143 views

Why The LUX Results M Dark Matter - And To W

+ Comment Now + Follow Comments

Reading through the coverage of the first results from most sensitive search for dark matter, the Large Under Xenon (LUX), you'd be forgiven for thinking that resea working on dark matter had either discovered nothing were on the verge of laying their (metaphorical) hands stuff. As with so much scientific research though, thing never as simple as they seem.



With the Higgs boson safely tucked under one arm, the next great hunt for physicists is the search for dark matter

The Economist | World politics | Business & finance | Economics | Science & technology | Cultu

Dark matter

Absence of evidence, or evidence of absence?

Physicists are learning more about what dark matter isn't. That will help them find out what it is

Nov 2nd 2013 | From the print edition

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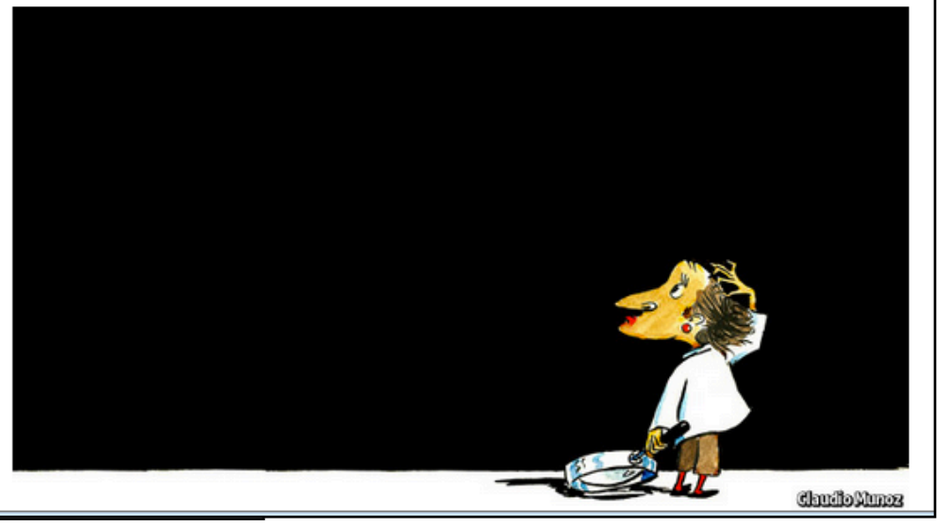
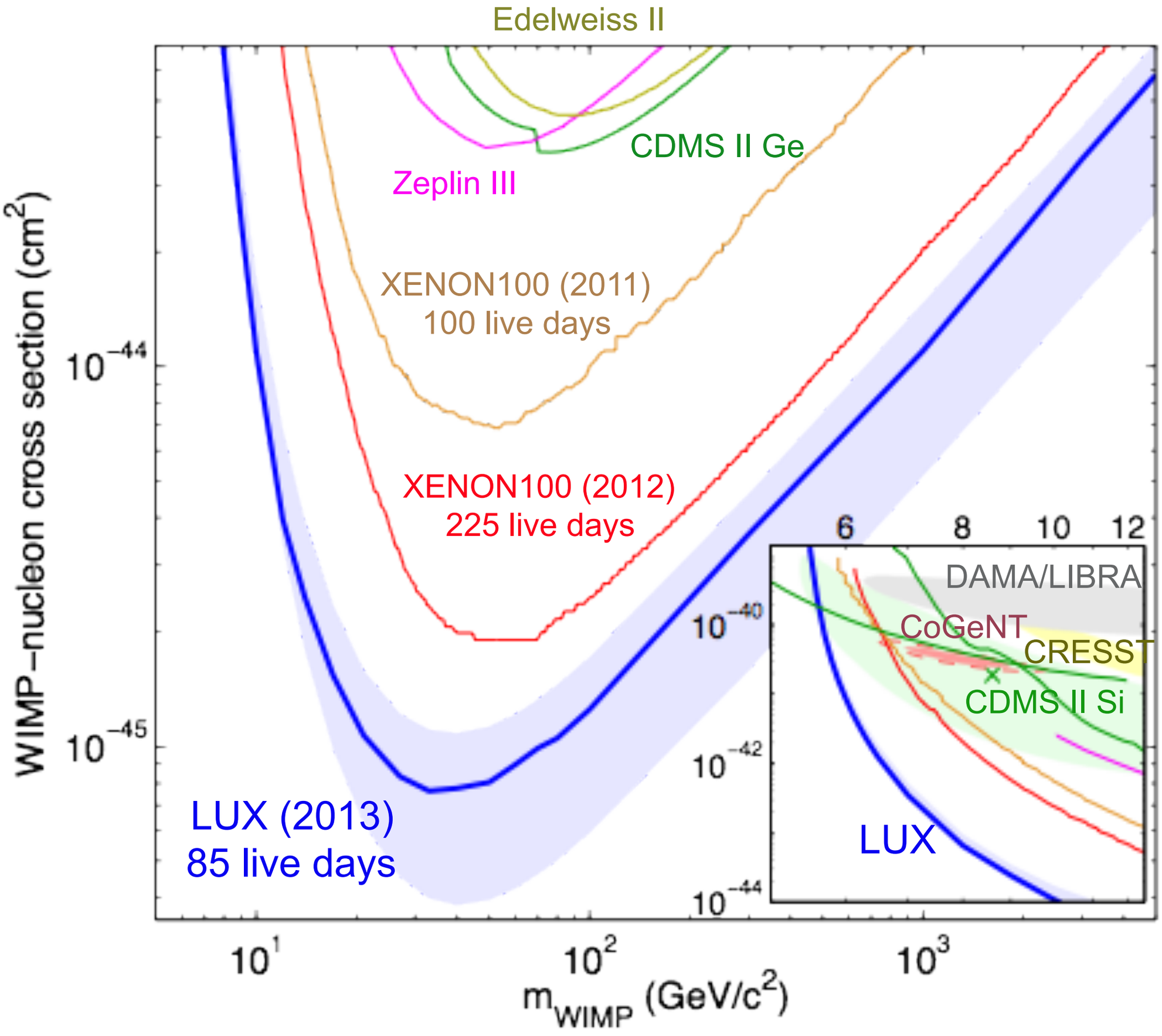
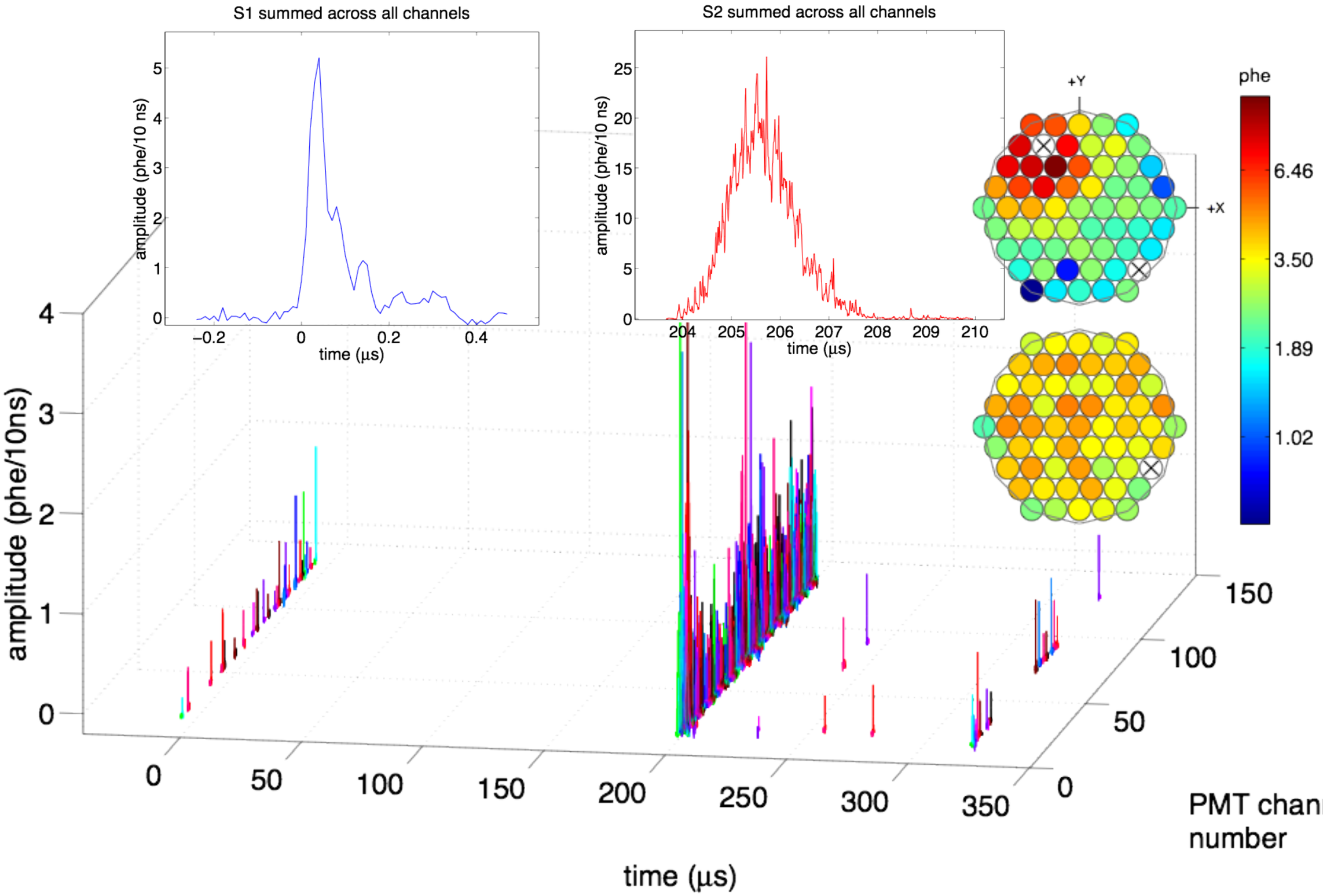



Edelweiss II
CDMS II Ge
Zeplin III
XENON100 (2011)
100 live days
XENON100 (2012)
225 live days
LUX (2013)
85 live days
DAMA/LIBRA
CoGeNT
CRESST
CDMS II Si
LUX
WIMP–nucleon cross section (cm^2)
10^{-44}
10^{-45}
10^{-40}
10^{-42}
10^{-44}
6
8
10
12
10^1
10^2
10^3
m_{WIMP} (GeV/c^2)

LUX Data


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
6.46
3.50
1.89
1.02
amplitude (phe/10ns)
time (μs)
PMT channel number

Keep Everything / Find Anything

Keep everything

High efficiency

In 85 days:

- 50+ TB waveforms
- 25 TB reduced quantities

Find anything

Rare event search

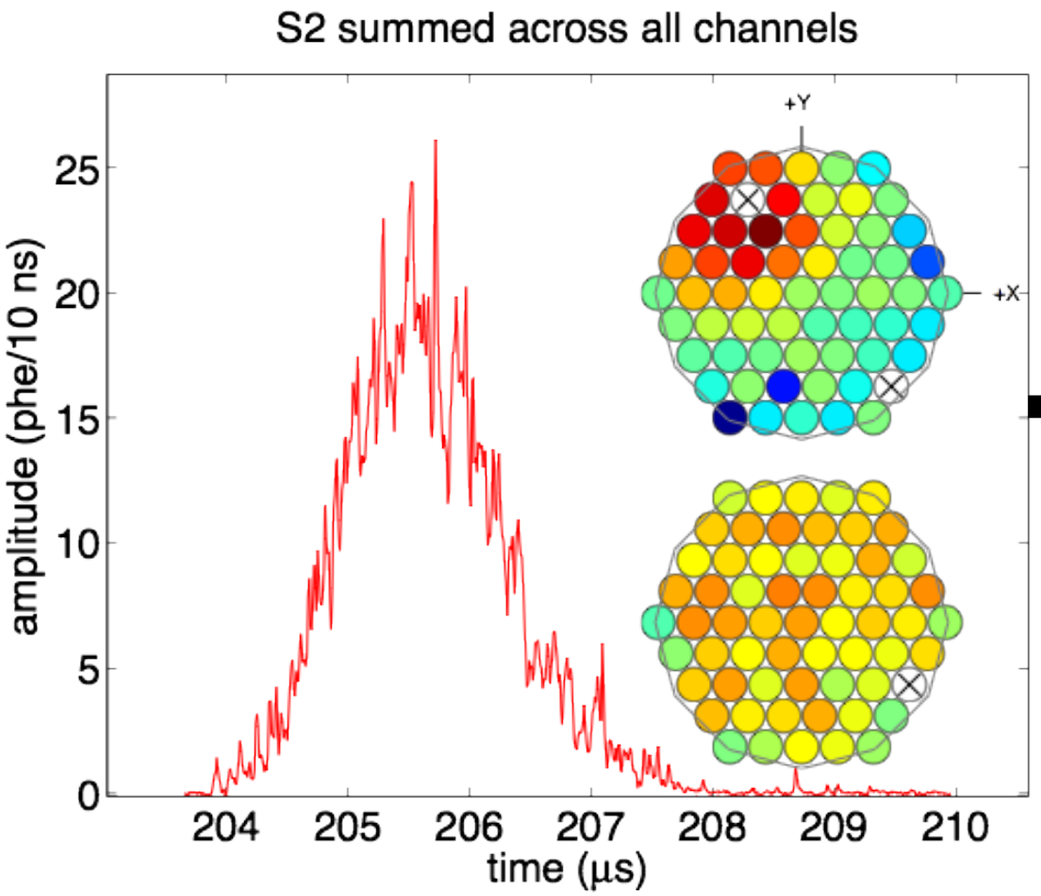
Many possible signatures

- WIMP dark matter
- Axion dark matter
- Inelastic dark matter
- Double electron capture
- Double-beta decay (LZ)
- Coherent neutrino scattering (LZ)
- Pushing detector thresholds

- Detector calibrations:
- Nuclear recoil response
- Electron recoil response,
- Detector response uniformity, light yield, threshold...

Data Processing

Waveform Data



Reduced Quantities (RQ)

- energy reconstruction
- number of electrons/photons
- x,y position reconstruction
- electron drift time (z)
- pulse height
- pulse width
- pulse asymmetry
- digital filter outputs
- pulse clustering
- pulse type classification
- pulse quality
- ...

Monte Carlo simulation output also runs through DP

Rare event search

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)	Radius < 18 cm, 38 < drift time < 305 us, 118 kg fiducial	160

LUX NERSC Resources

Computing

- Carver - Data Intensive Pilot Program
  - Data processing, simulations
- PDSF node acquisition
  - Data processing, simulations

Storage

- GPFS
  - Processed waveform
  - Reduced quantities
- HPSS
  - Raw waveforms

Transfer

- Globus

Exciting Projects Ahead @ NERSC

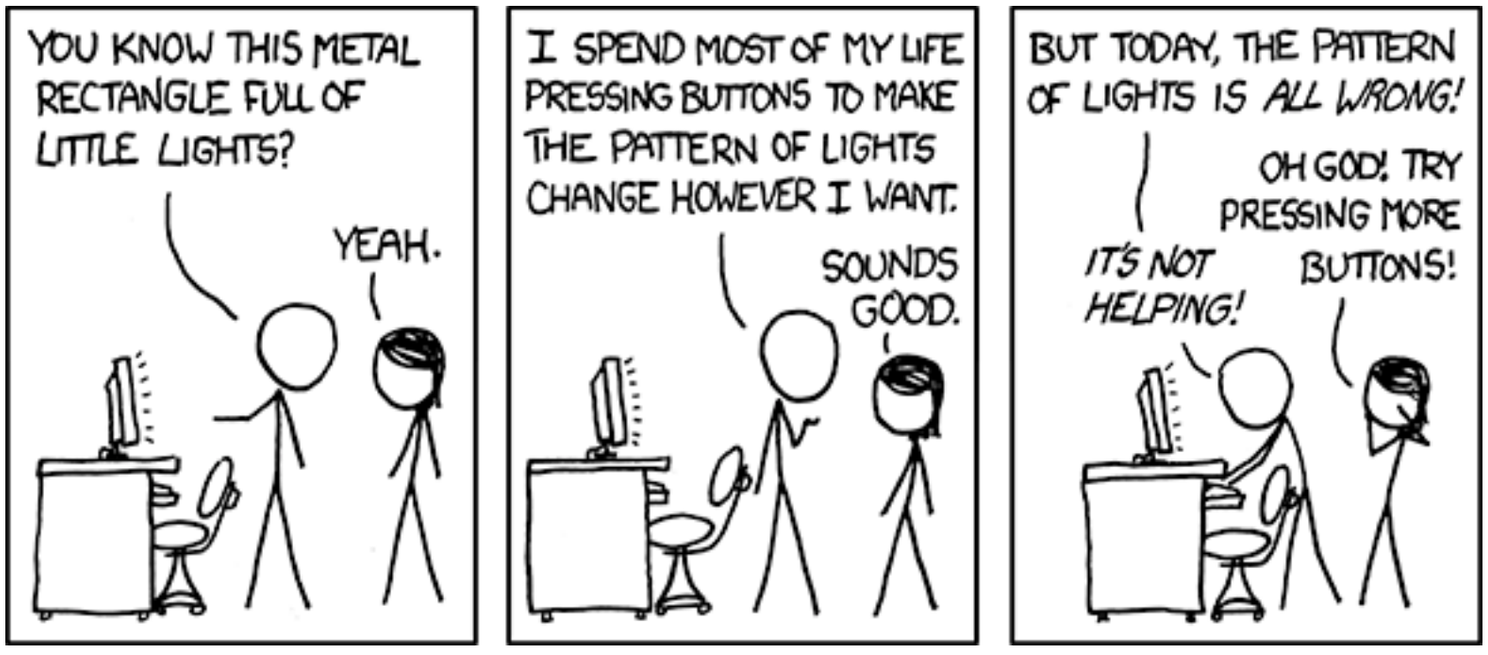
SciDB data analysis

SciDB +django LUX Online Event Viewer

File system analysis model

File system-based analysis works for small datasets, but quickly becomes cumbersome.

- Poor data management
- Slow search (file-by-file loading), especially for rare-events
- Large-scale analytics and time-trends difficult
- Not easily replicated, shared



lux10_20130424T1740_f011654_cp05388.rq.gz
lux10_20130424T1740_f011660_cp05388.rq.gz
lux10_20130424T1740_f011661_cp05388.rq.gz
lux10_20130424T1740_f011664_cp05388.rq.gz
lux10_20130424T1740_f011671_cp05388.rq.gz
lux10_20130424T1740_f011674_cp05388.rq.gz
lux10_20130424T1740_f011681_cp05388.rq.gz
lux10_20130424T1740_f011684_cp05388.rq.gz
lux10_20130424T1740_f011691_cp05388.rq.gz
lux10_20130424T1740_f011694_cp05388.rq.gz
lux10_20130424T1740_f011701_cp05388.rq.gz
lux10_20130424T1740_f011704_cp05388.rq.gz
lux10_20130424T1740_f011711_cp05388.rq.gz
lux10_20130424T1740_f011721_cp05388.rq.gz
lux10_20130424T1740_f011724_cp05388.rq.gz
lux10_20130424T1740_f011731_cp05388.rq.gz
lux10_20130424T1740_f011741_cp05388.rq.gz
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lux10_20130424T1740_f011811_cp05388.rq.gz
lux10_20130424T1740_f011831_cp05388.rq.gz
lux10_20130424T1740_f011841_cp05388.rq.gz
lux10_20130424T1740_f011851_cp05388.rq.gz
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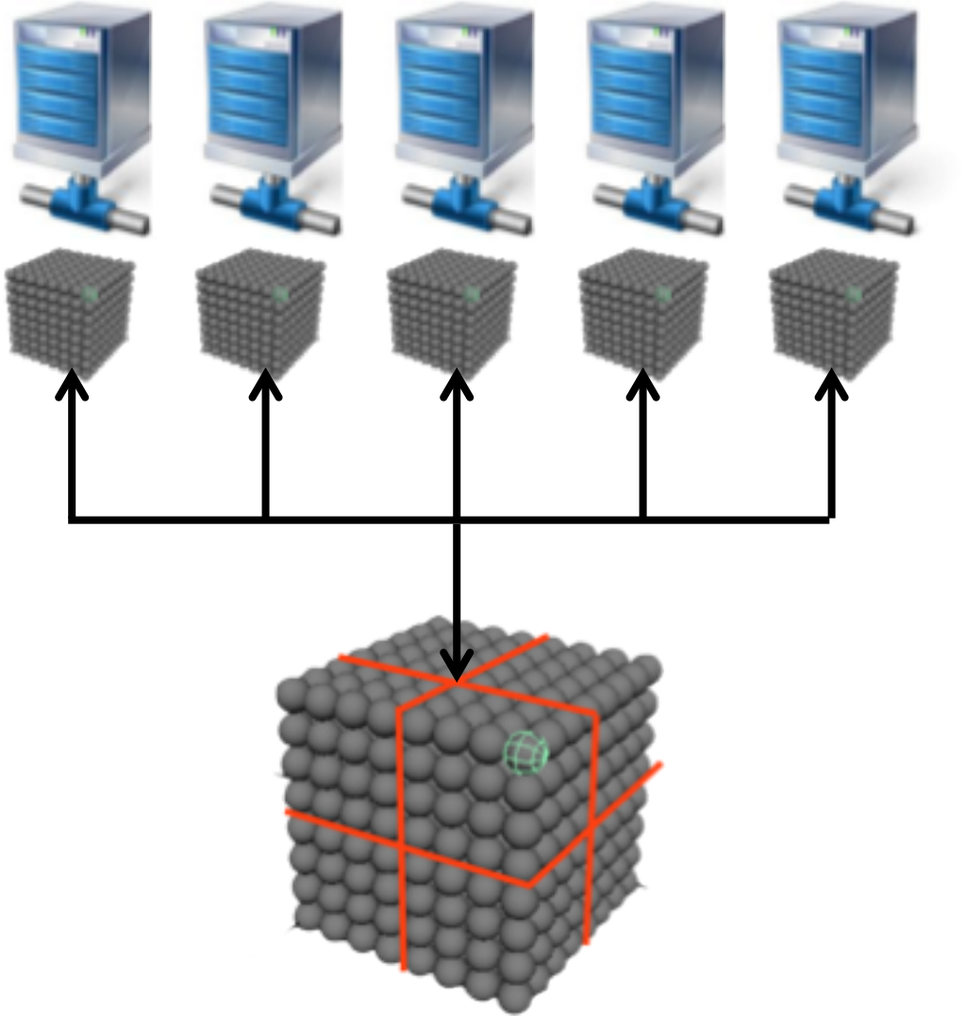
lux10_20130424T1740_f011871_cp05388.rq.gz
lux10_20130424T1740_f011881_cp05388.rq.gz
lux10_20130424T1740_f011891_cp05388.rq.gz
lux10_20130424T1740_f011901_cp05388.rq.gz
lux10_20130424T1740_f011911_cp05388.rq.gz
lux10_20130424T1740_f011921_cp05388.rq.gz
lux10_20130424T1740_f011941_cp05388.rq.gz
lux10_20130424T1740_f011951_cp05388.rq.gz

SciDB: Massive database with array-oriented data model. Share-nothing, parallel data access

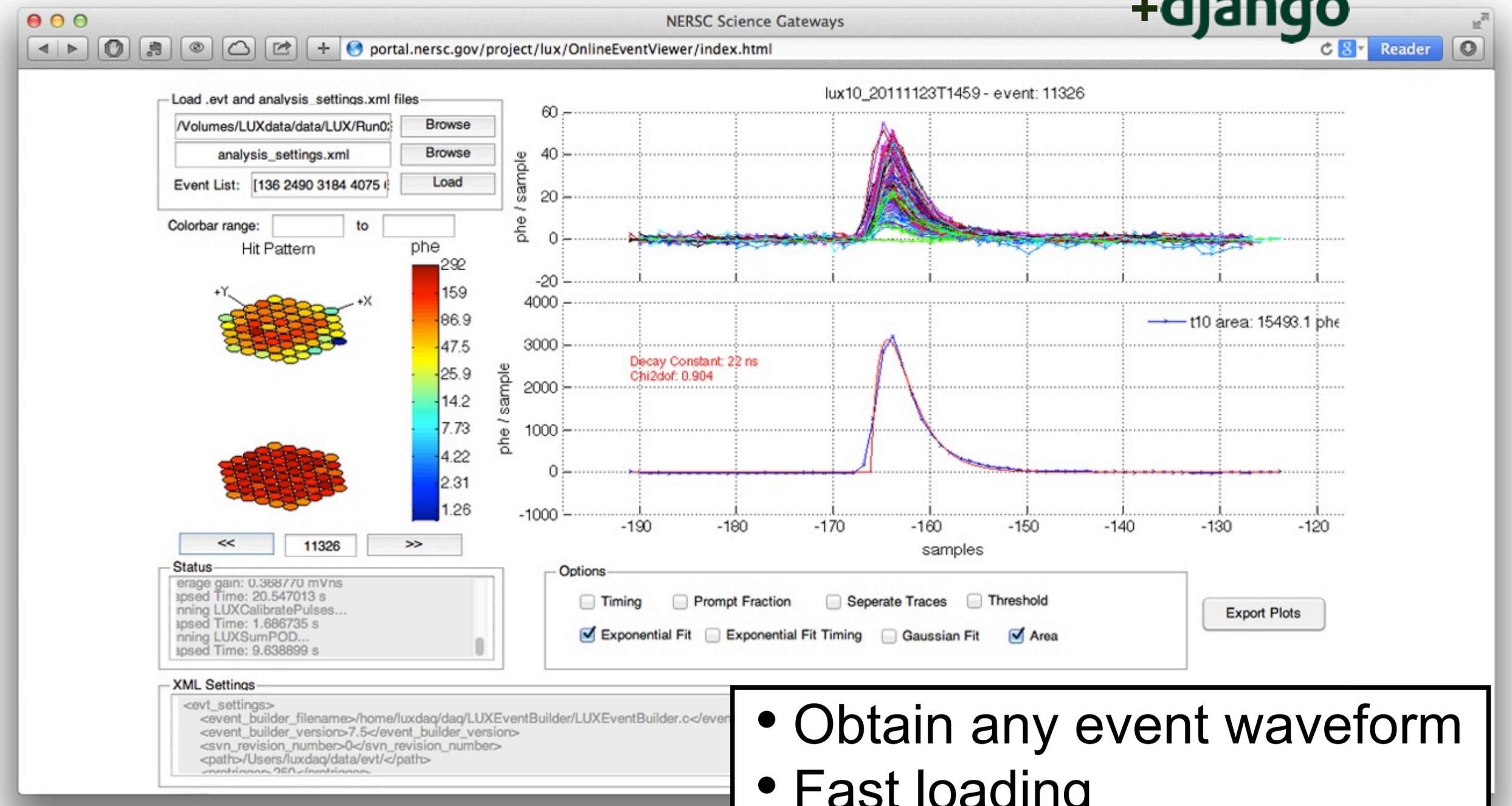


Evaluating SciDB as a data analysis tool:

- Fast query of specific event topologies, rare events
- Fast plotting of key detector performance parameters over time
- Store waveform data as well

LUX Online Event Viewer

SciDB +django



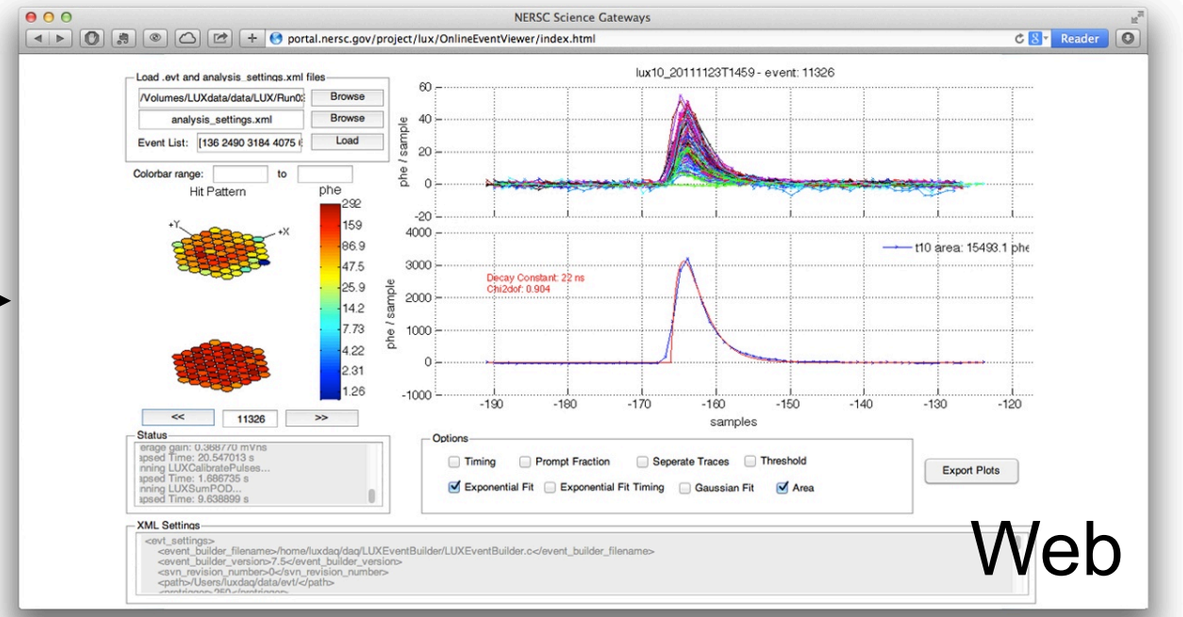
- Obtain any event waveform
- Fast loading
- Platform-independent

LUX Online Event Viewer

NERSC Science Gateway

Django web framework

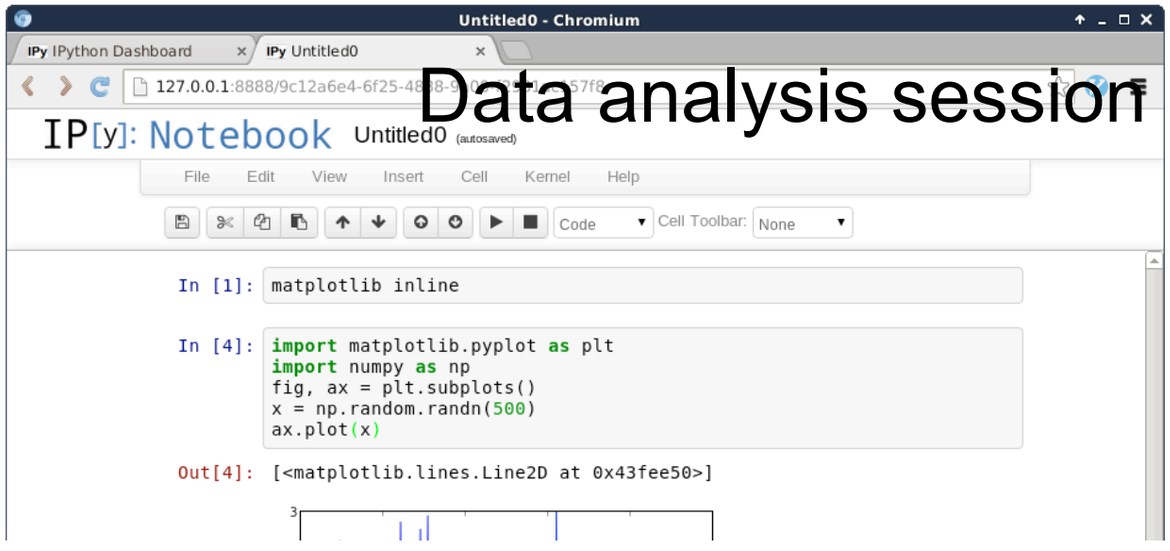
LUX waveforms



Web

LUX User

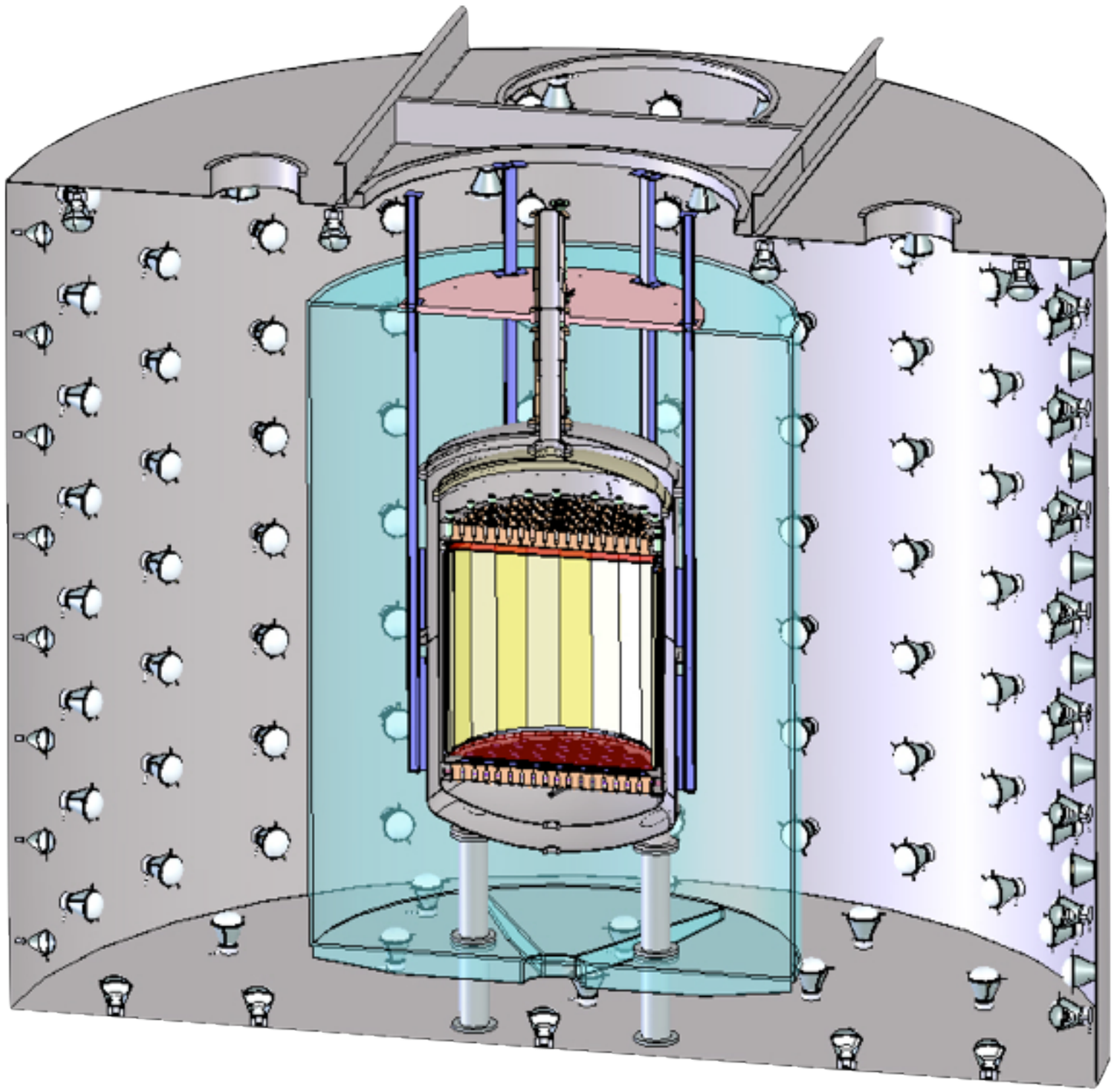
Data analysis session



LUX+ZEPLIN = LZ

LUX

370 kg
x122
2” PMTs



LZ

7 tonnes
x482
3” PMTs

Summary

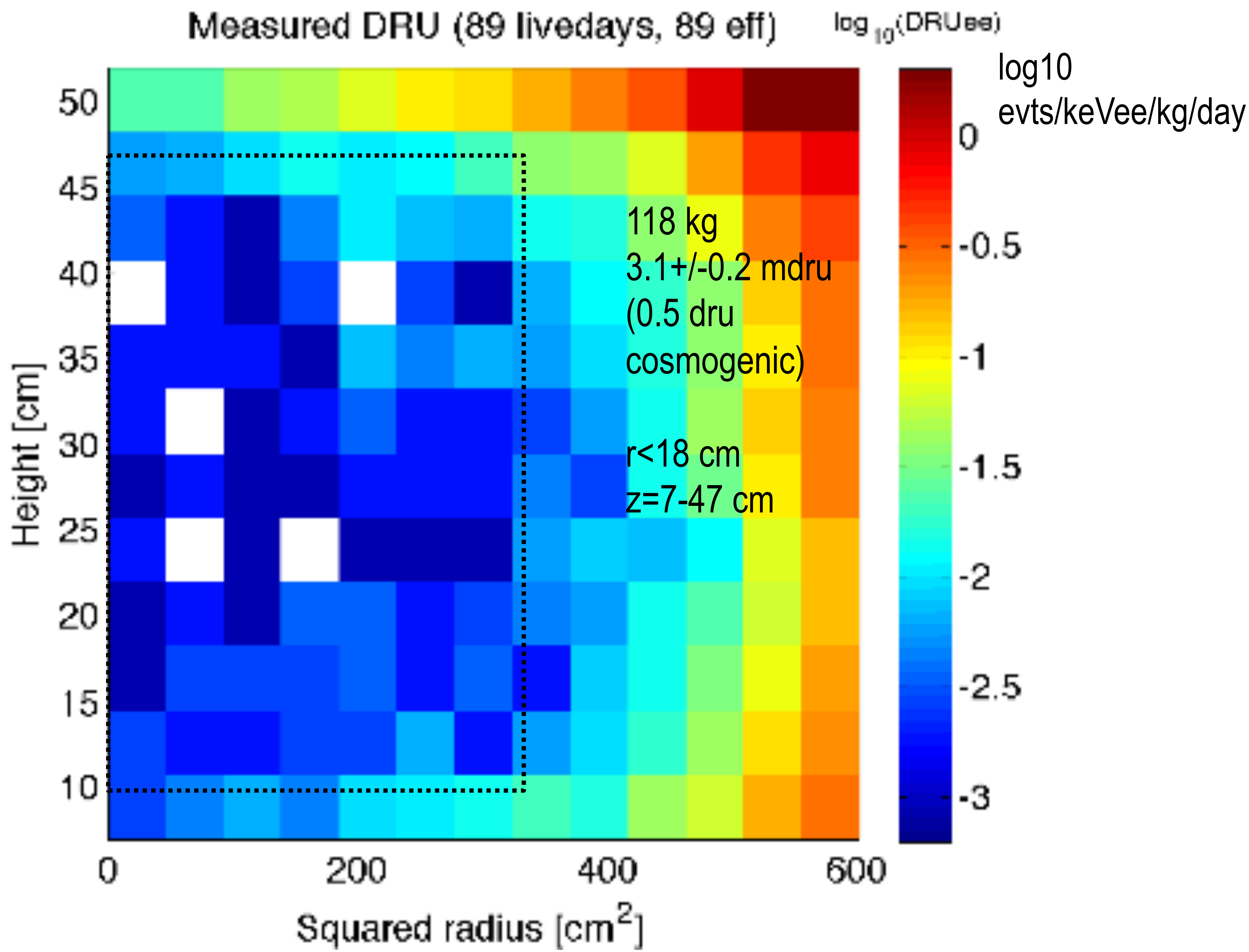
- LUX experiment data: “keep everything / find anything” model
  - Collect every pulse, look for WIMP dark matter signature and other models, perform high-stat detector calibrations.

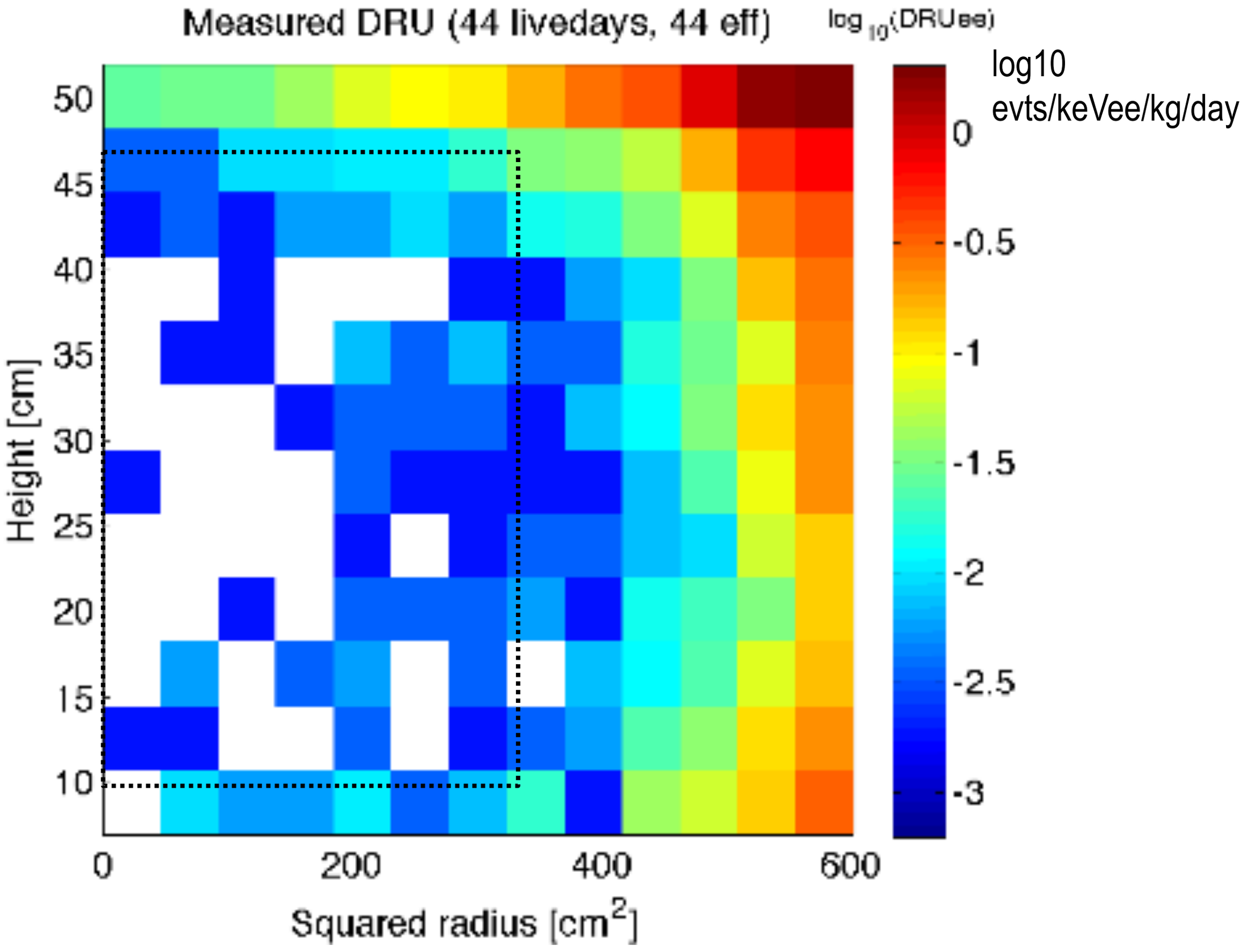
- LUX starting the long dark matter search soon
  - >200 TB raw data, simulation data and reduced quantities

- LUX starting to use NERSC available resources:
  - Carver (data pilot program) and PDSF (node acquisition)
  - GPFS and HPSS for raw and derived quantity data
  - Globus for data transfers

- LUX evaluating a massive, parallel database (SciDB) for data analysis and online event viewing

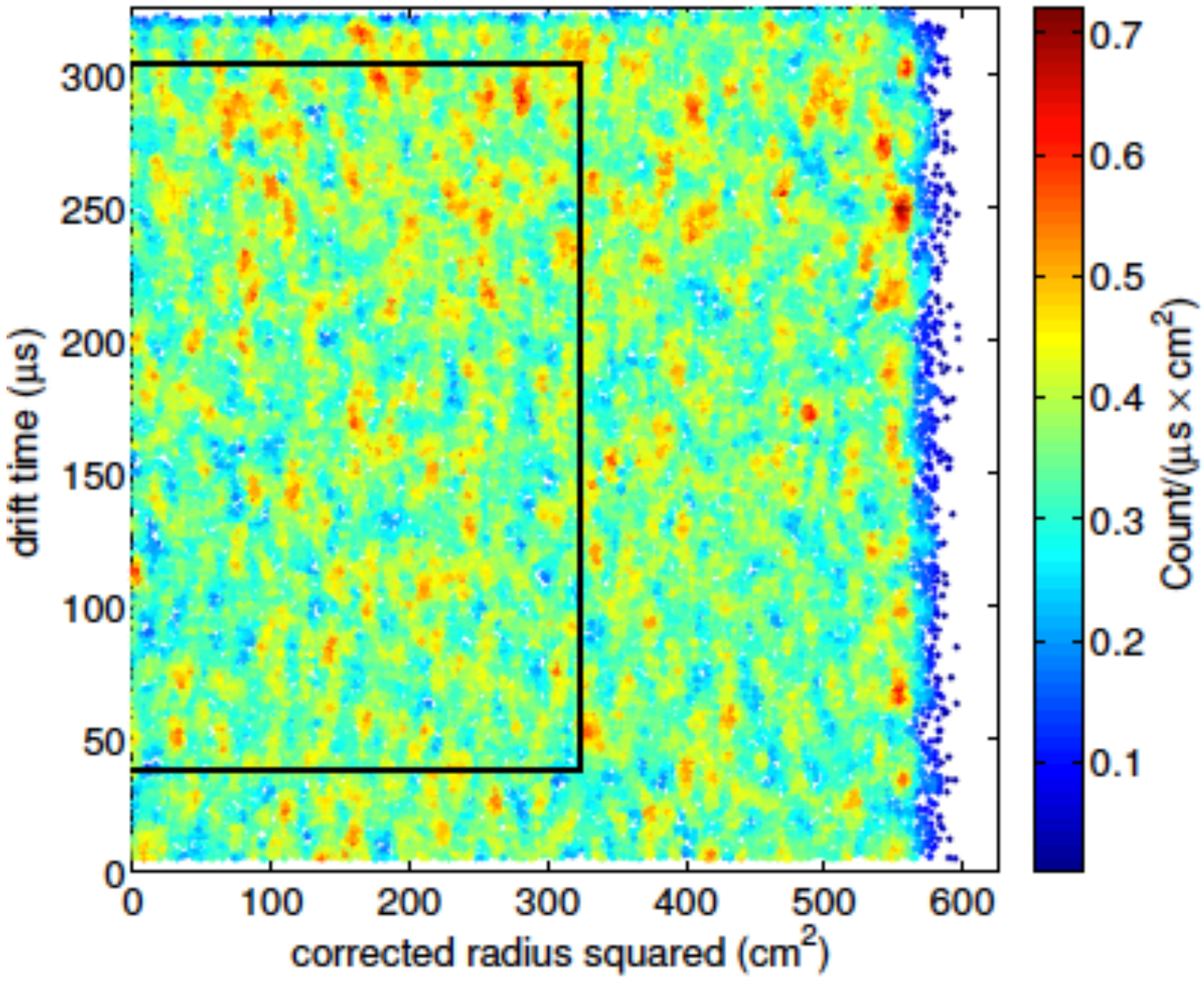
Back up slides


Measured DRU (89 livedays, 89 eff)
log10(DRUee)
log10
evts/keVee/kg/day
118 kg
3.1+/-0.2 mdru
(0.5 dru
cosmogenic)
r<18 cm
z=7-47 cm
Height [cm]
Squared radius [cm2]
50
45
40
35
30
25
20
15
10
0
200
400
600
0
-0.5
-1
-1.5
-2
-2.5
-3

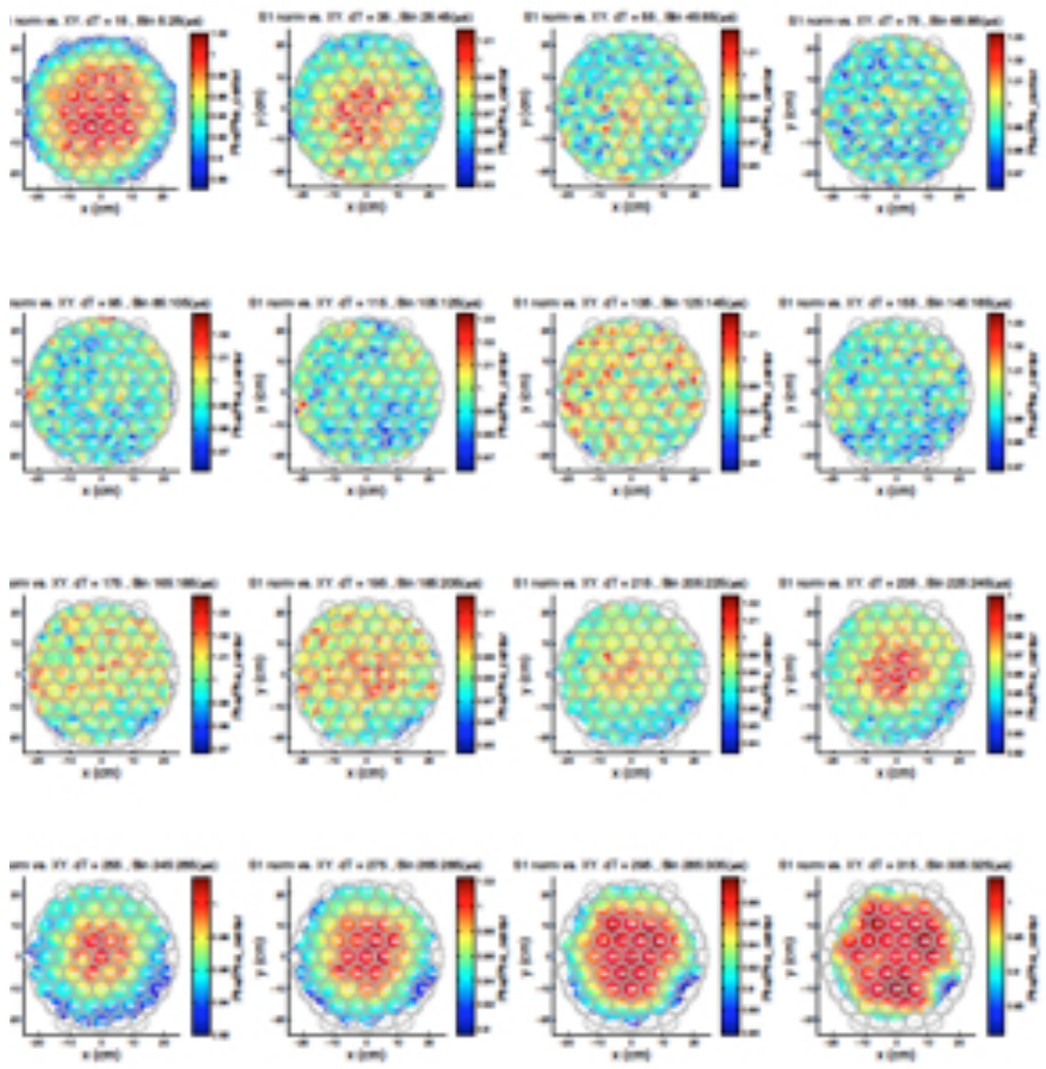

Measured DRU (44 livedays, 44 eff)
log10(DRU/kg/day)
log10
evts/keVee/kg/day
Height [cm]
50
45
40
35
30
25
20
15
10
0
200
400
600
Squared radius [cm^2]
0
-0.5
-1
-1.5
-2
-2.5
-3

Detector Corrections

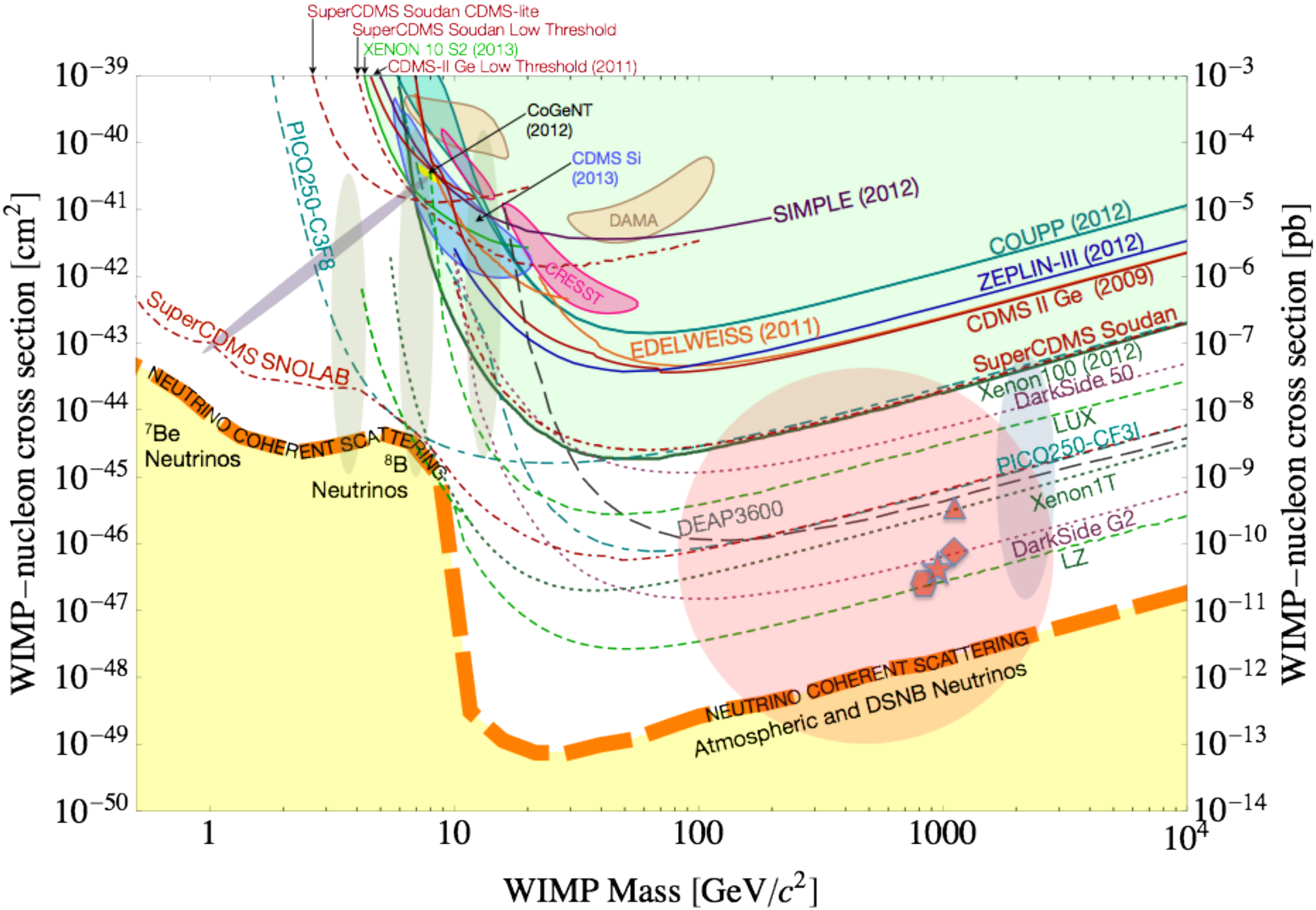
Fiducial volume determination



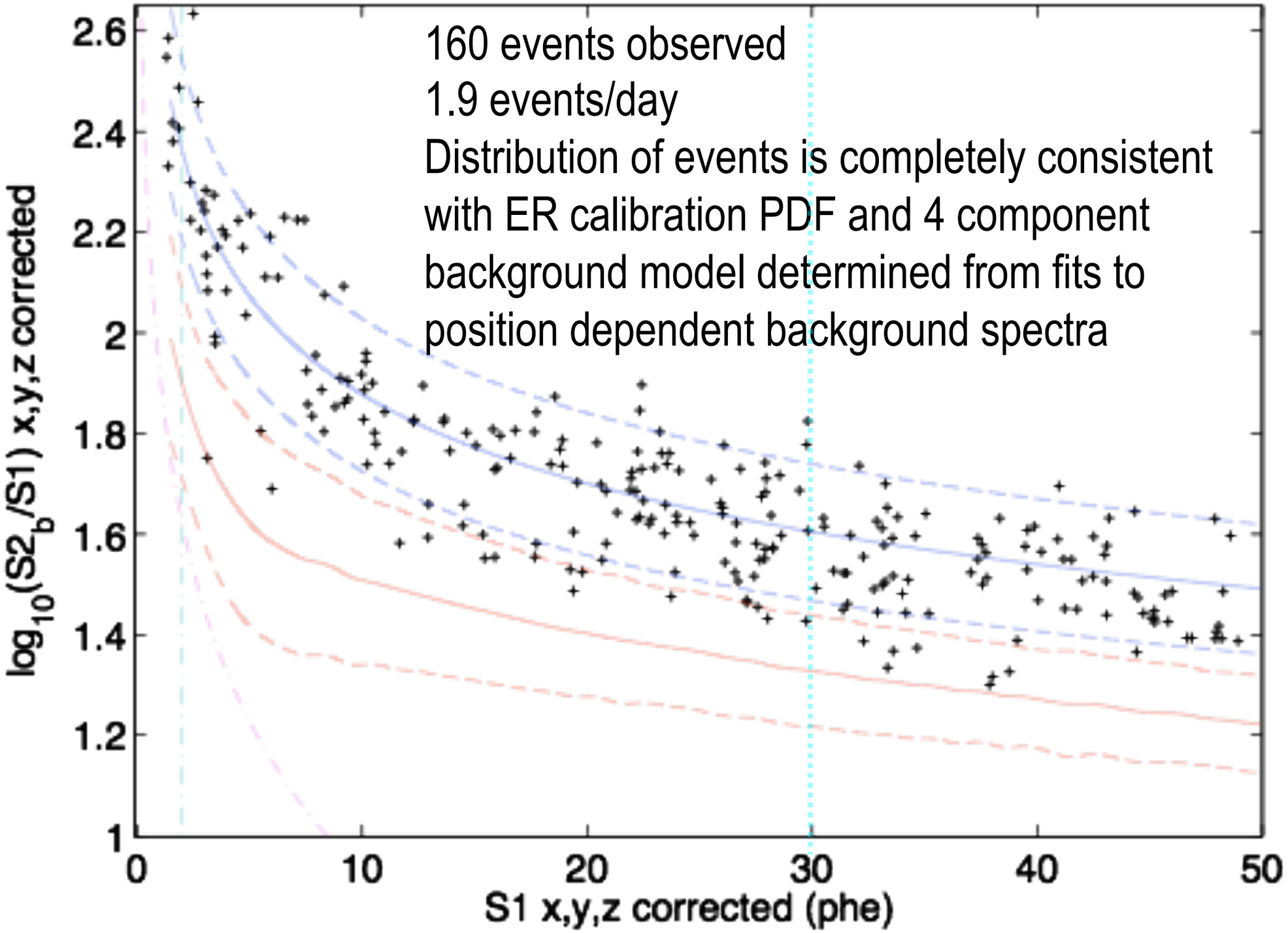
Position-based S1 corrections



The Field


SuperCDMS Soudan CDMS-lite
SuperCDMS Soudan Low Threshold
XENON 10 S2 (2013)
CDMS-II Ge Low Threshold (2011)
CoGeNT (2012)
CDMS Si (2013)
DAMA
SIMPLE (2012)
CRESST
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
EDELWEISS (2011)
SuperCDMS Soudan
Xenon100 (2012)
DarkSide 50
LUX
PICO250-CF3I
Xenon1T
DarkSide G2
LZ
DEAP3600
PICO250-C3F8
SuperCDMS SNOLAB
NEUTRINO COHERENT SCATTERING
^{7}Be Neutrinos
^{8}B Neutrinos
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

LUX Results


160 events observed
1.9 events/day
Distribution of events is completely consistent with ER calibration PDF and 4 component background model determined from fits to position dependent background spectra
log10(S2b/S1) x,y,z corrected
S1 x,y,z corrected (phe)
2.6
2.4
2.2
2
1.8
1.6
1.4
1.2
1
0
10
20
30
40
50

Modular Multi-Language Data Processing Framework