Noble Travails: LUX @ Sanford Lab

http://luxdarkmatter.org

Rick Gaitskell,
Joint Spokesperson,
LUX Collaboration

Particle Astrophysics Group, Brown University, Department of Physics (Supported by US DOE HEP)
http://particleastro.brown.edu

23 years in dark matter

CDMS II: Winter
@Soudan Minnesota

Sanford Lab
LUX @Homestake,
South Dakota

PHYSICS ITALIAN
STYLE XENON10
@ Gran Sasso

Gaitskell / Brown University

Dark Matter Underground Searches - Silver Jubilee

- First publication on an underground experimental search for cold dark matter (Ahlen et al. 1987. PLB 195, 603-608).

http://www.pnnl.gov/physics/darkmattersymp.stm

Volume 195, number 4 PHYSICS LETTERS B 17 September 1987

LIMITS ON COLD DARK MATTER CANDIDATES FROM AN ULTRALOW BACKGROUND GERMANIUM SPECTROMETER

S.P. AHLEN [a], F.T. AVIGNONE III [b], R.L. BRODZINSKI [c], A.K. DRUKIER [d,e], G. GELMINI [f,g,1] and D.N. SPERGEL [d,h]

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Received 5 May 1987

An ultralow background spectrometer is used as a detector of cold dark matter candidates from the halo of our galaxy Using a realistic model for the galactic halo, large regions of the mass–cross section space are excluded for important halo component particles. In particular, a halo dominated by heavy standard Dirac neutrinos (taken as an example of particles with spin-independent Z^0 exchange interactions) with masses between 20 GeV and 1 TeV is excluded. The local density of heavy standard Dirac neutrinos is <0.4 GeV/cm^3 for masses between 17.5 GeV and 2 5 TeV, at the 68% confidence level.

- 1986 operating a 0.8 kg Ge ionization detector at Homestake Mine, SD (adjacent to Ray Davis's operating Solar Neutrino Experiment)

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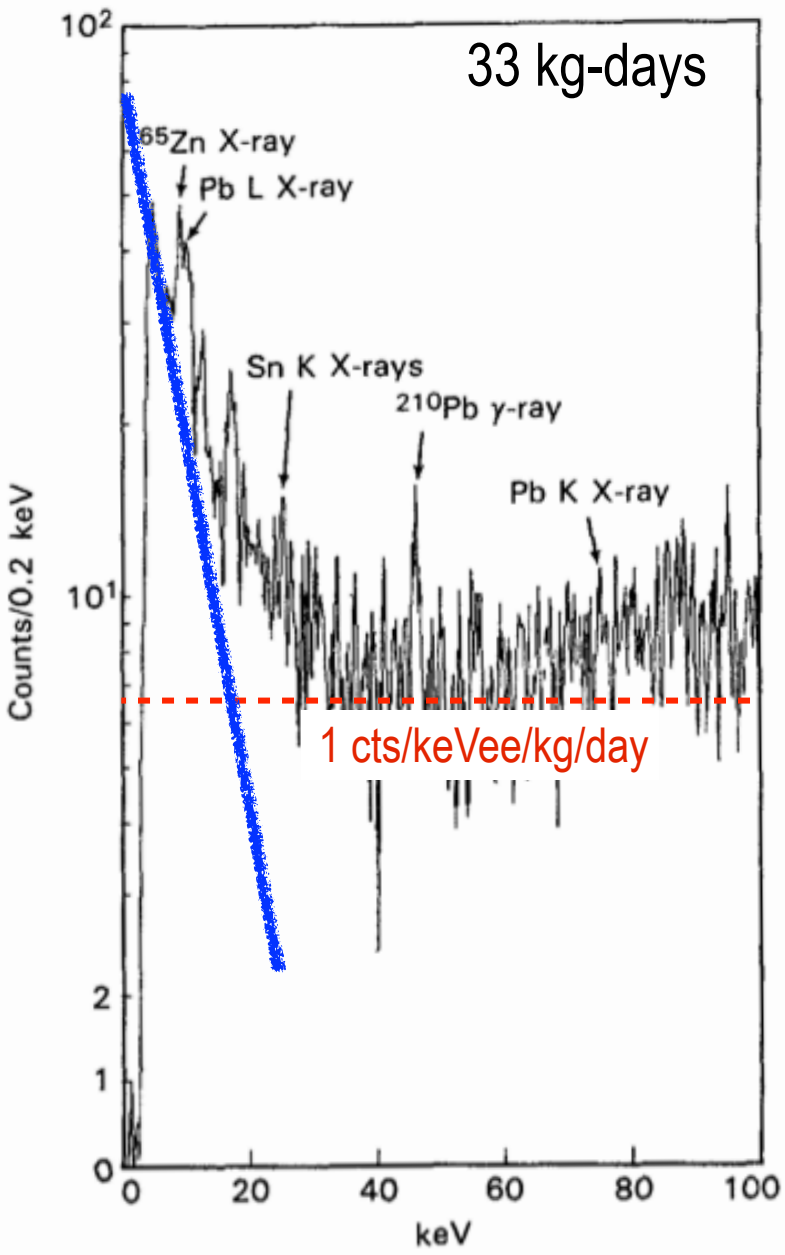

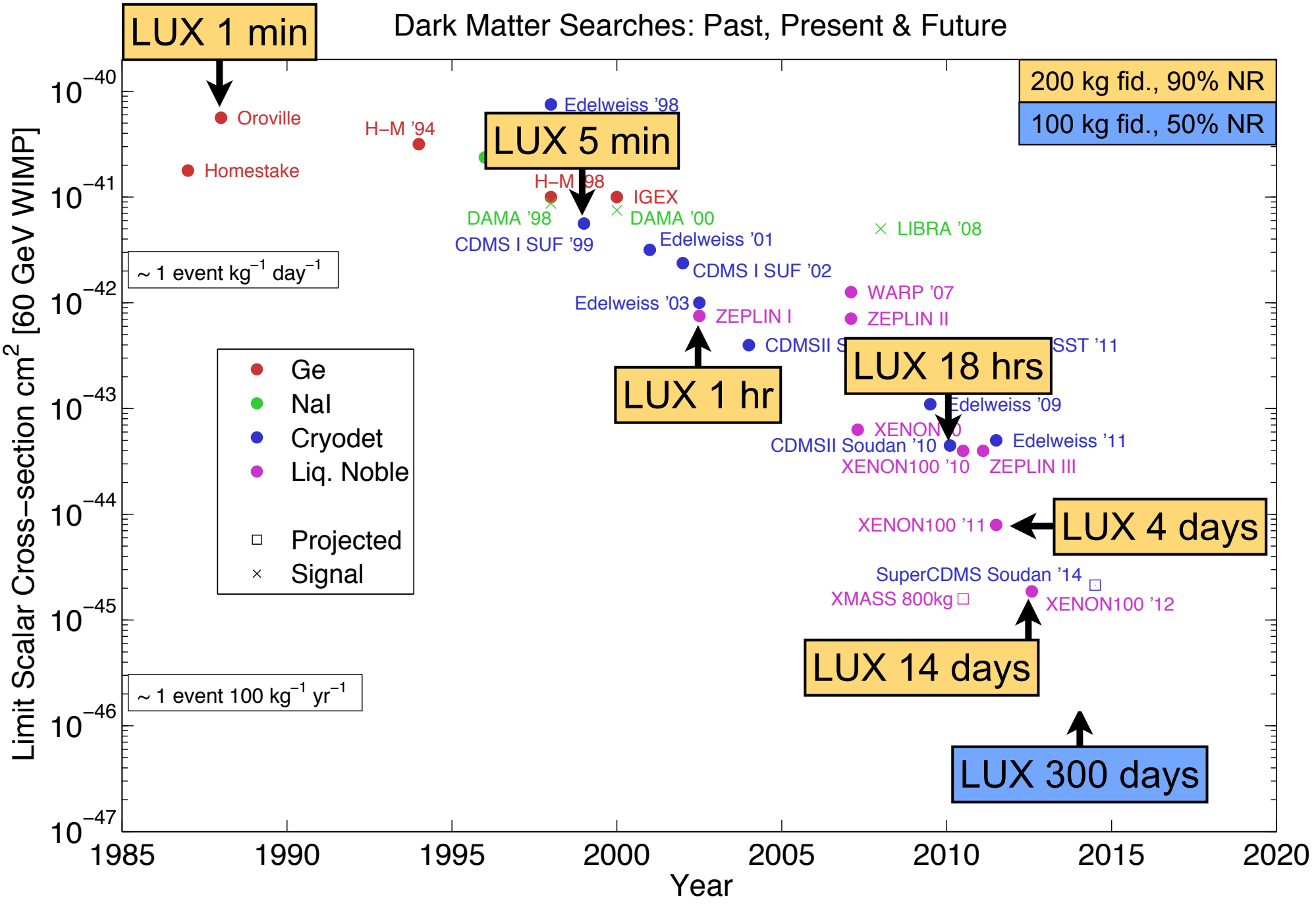

Thanks to Carlos Hernandez Faham (Brown) for work on slides

LUX @ Sanford Lab

The LUX Collaboration

Brown

Richard Gaitskell	PI, Professor
Simon Fiorucci	Research Associate
Monica Pangilinan	Postdoc
Jeremy Chapman	Graduate Student
Carlos Hernandez Faham	Graduate Student
David Malling	Graduate Student
James Verbus	Graduate Student
Samuel Chang	Graduate Student
Dongqing Huang	Graduate Student

Case Western Reserve

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Dan Akerib	PI, Professor
Mike Dragowsky	Research Associate Professor
Tom Coffey	Research Associate
Carmen Carmona	Postdoc
Karen Gibson	Postdoc
Adam Bradley	Graduate Student
Patrick Phelps	Graduate Student
Chang Lee	Graduate Student
Kati Pech	Graduate Student
Tim Ivancic	Graduate Student

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Alastair Currie	Postdoc

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Victor Gehman	Scientist
David Taylor	Engineer
Mia ihm	Graduate Student

Lawrence Livermore

Adam Bernstein	PI, Leader of Adv. Detectors
Dennis Carr	Mechanical Technician
Kareem Kazkaz	Staff Physicist
Peter Sorensen	Staff Physicist
John Bower	Engineer

LIP Coimbra

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Vladimir Solovov	Senior Researcher
Luiz de Viveiros	Postdoc
Alexander Lindote	Postdoc
Francisco Neves	Postdoc
Claudio Silva	Postdoc

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Robert Webb	Professor
Rachel Mannino	Graduate Student
Clement Sofka	Graduate Student

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Robert Svoboda	Professor
Richard Lander	Professor
Britt Hollbrook	Senior Engineer
John Thomson	Senior Machinist
Matthew Szydagis	Postdoc
Richard Ott	Postdoc
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James Morad	Graduate Student
Nick Walsh	Graduate Student
Michael Woods	Graduate Student
Sergey Uvarov	Graduate Student

UC Santa Barbara

Harry Nelson	PI, Professor
Mike Witherell	Professor
Dean White	Engineer
Susanne Kyre	Engineer
Curt Nehrkorn	Graduate Student

University College London

Chamkaur Ghag	PI, Lecturer

University of Edinburgh

Alex Murphy	PI, Reader
James Dobson	Postdoc
Lea Reichhart	Graduate student

University of Maryland

Carter Hall	PI, Professor
Attila Dobi	Graduate Student
Richard Knoche	Graduate Student

Collaboration Meeting, UCSB March 2012

University of Rochester

Frank Wolfs	PI, Professor
Wojtek Skutski	Senior Scientist
Eryk Druszkiewicz	Graduate Student
Mongkol Moongweluwan	Graduate Student

University of South Dakota

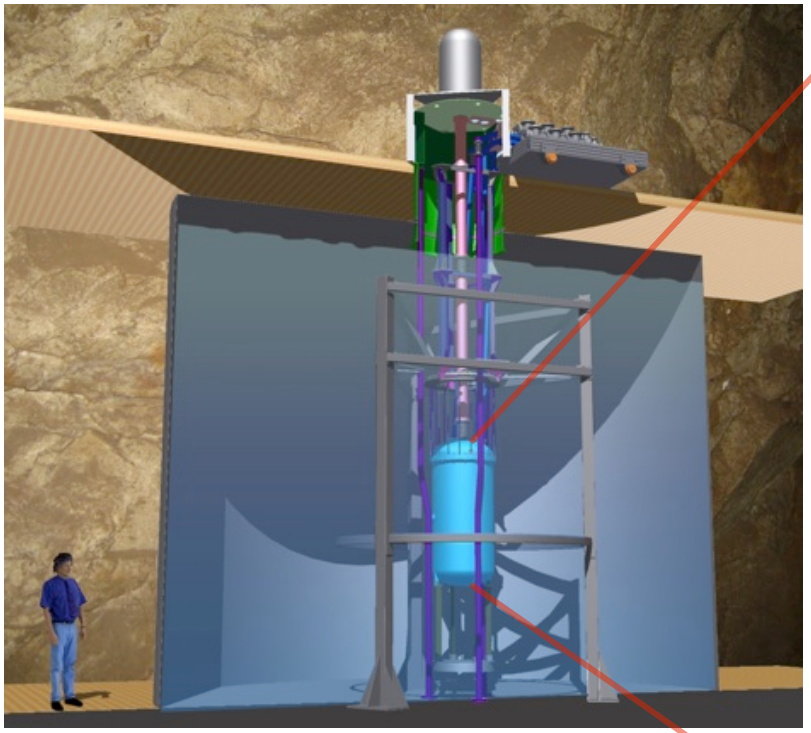
Dongming Mei	PI, Professor
Chao Zhang	Postdoc
Dana Byram	Graduate Student
Chris Chiller	Graduate Student
Angela Chiller	Graduate Student

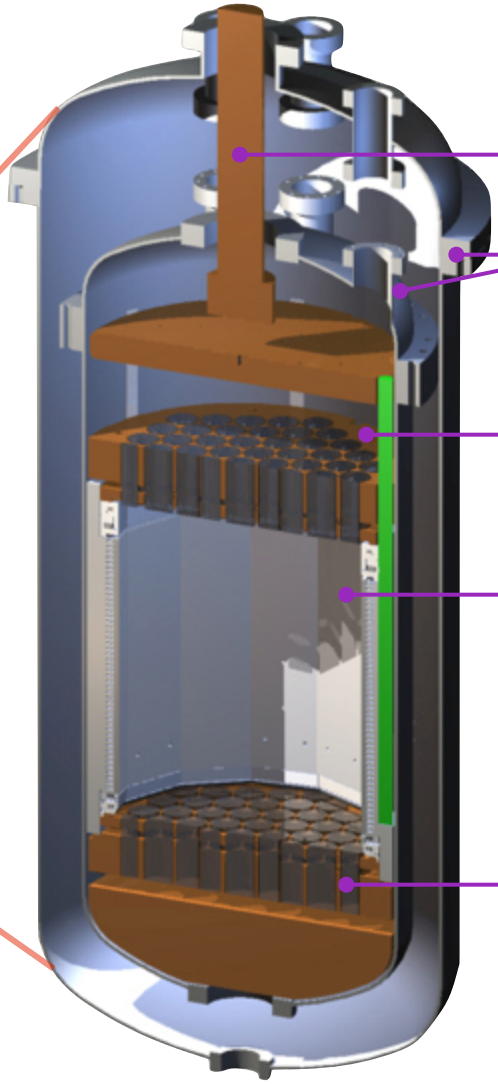
Yale

Daniel McKinsey	PI, Professor
Peter Parker	Professor
James Nikkel	Research Scientist
Sidney Cahn	Lecturer/Research Scientist
Alexey Lyashenko	Postdoc
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

Collaboration was formed in 2007 and fully funded by DOE and NSF in 2008.

LUX Anatomy



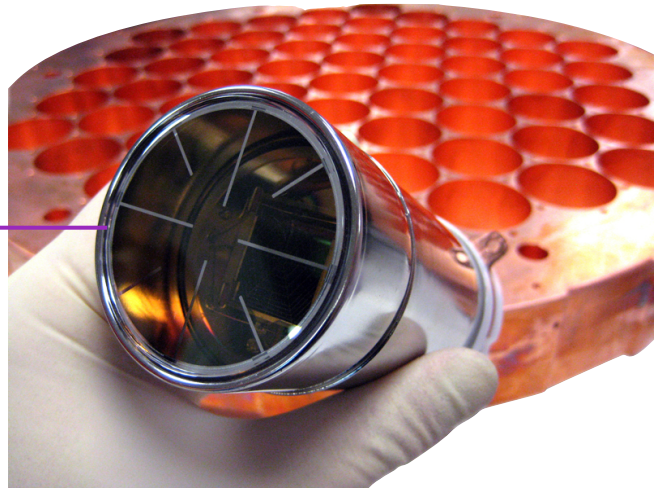


Thermosyphon

Titanium Vessels

PMT Holder Copper Plates

Dodecagonal field cage
+ PTFE reflector panels

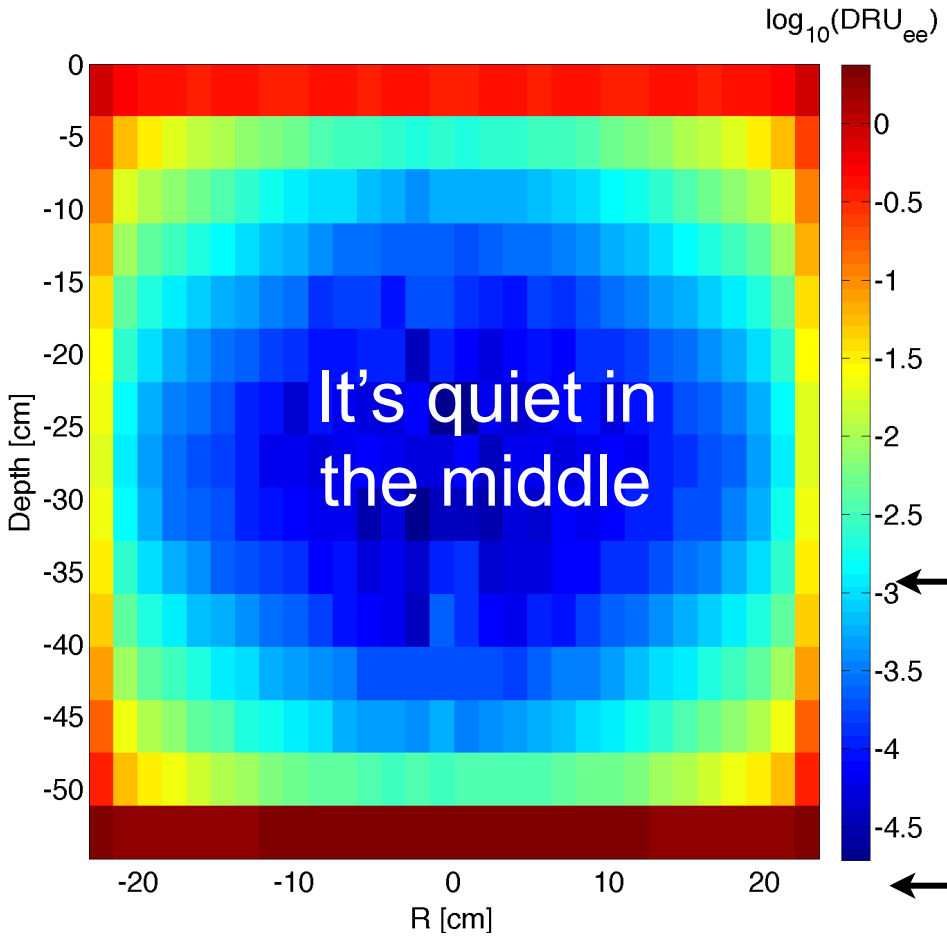


2” Hamamatsu R8778
Photomultiplier Tubes (PMTs)

- 370 kg (300 kg active) LXe
- 122 PMTs (2” round)
- Low-background Ti cryostat
- PTFE reflector cage
- Thermosyphon used for cooling (>1 kW)

Xenon Self-shielding

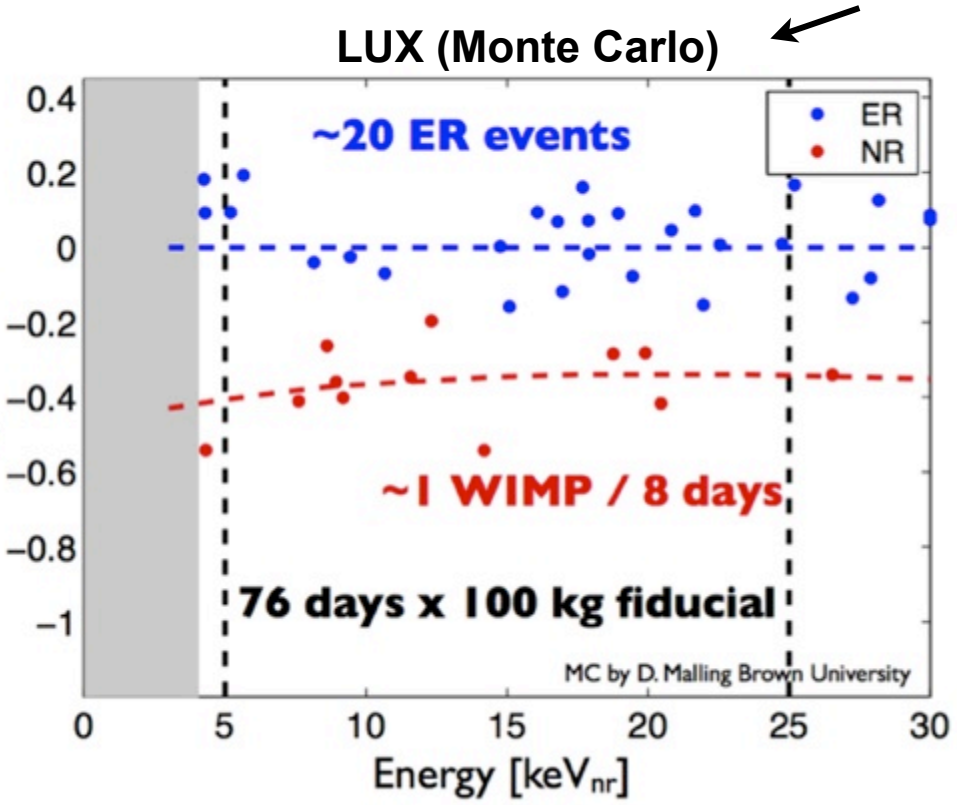
Single Scatter Events /keVee/kg/day

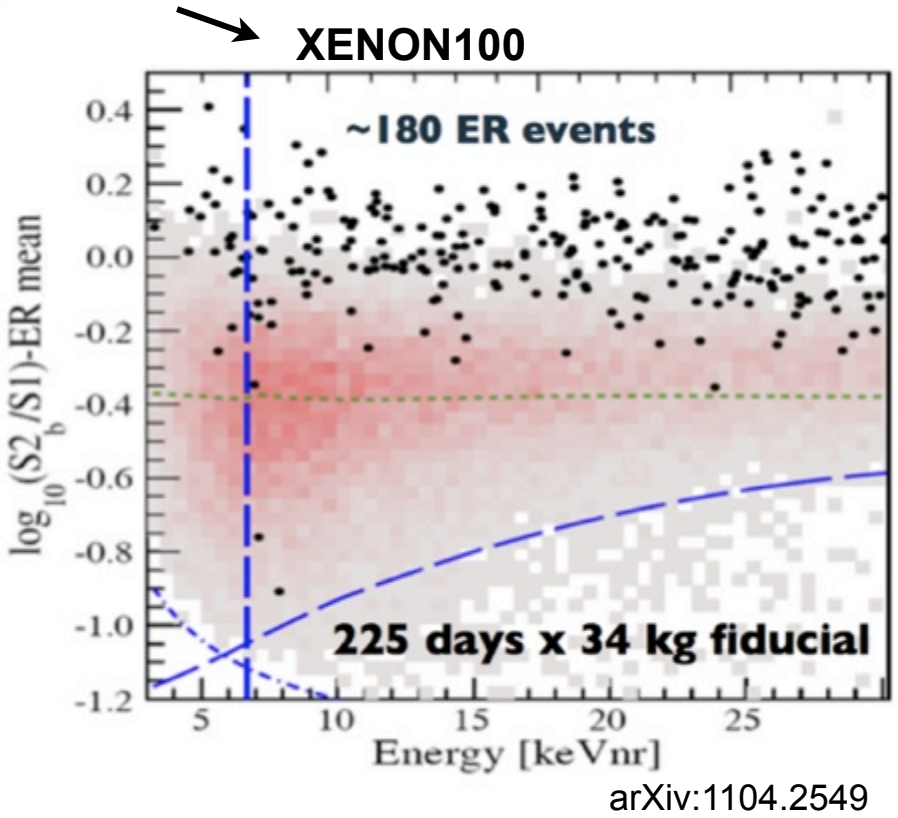


- Liquid xenon is a dense target at 3 g/cc.
- Self-shielding allows this technology to greatly benefit from scaling up.
- We expect ~1 ER in the fiducial volume/dm energy range every 4 days in LUX.

The first 76 days of LUX

Comparing nominally equivalent kg-days for 100 kg LUX fiducial versus 34 kg XENON fiducial but LUX has much greater sensitivity/kg-day because of cleaner signal/fewer BG events





arXiv:1104.2549

LUX signal and background expectation for 7,600 kg-days net exposure. WIMP events assume m = 100 GeV, σ = 3×10^{-45} cm^2. Assumes 100 kg fiducial. Given very low ER rate, can significantly increase fiducial in early running.

XENON100 7,600 kg-days result for comparison. Note higher ER rate - ~180 events primarily due to Compton scattering of external gamma background.

The LUX Program

LUX0.1 CWRU

2007 - 2009

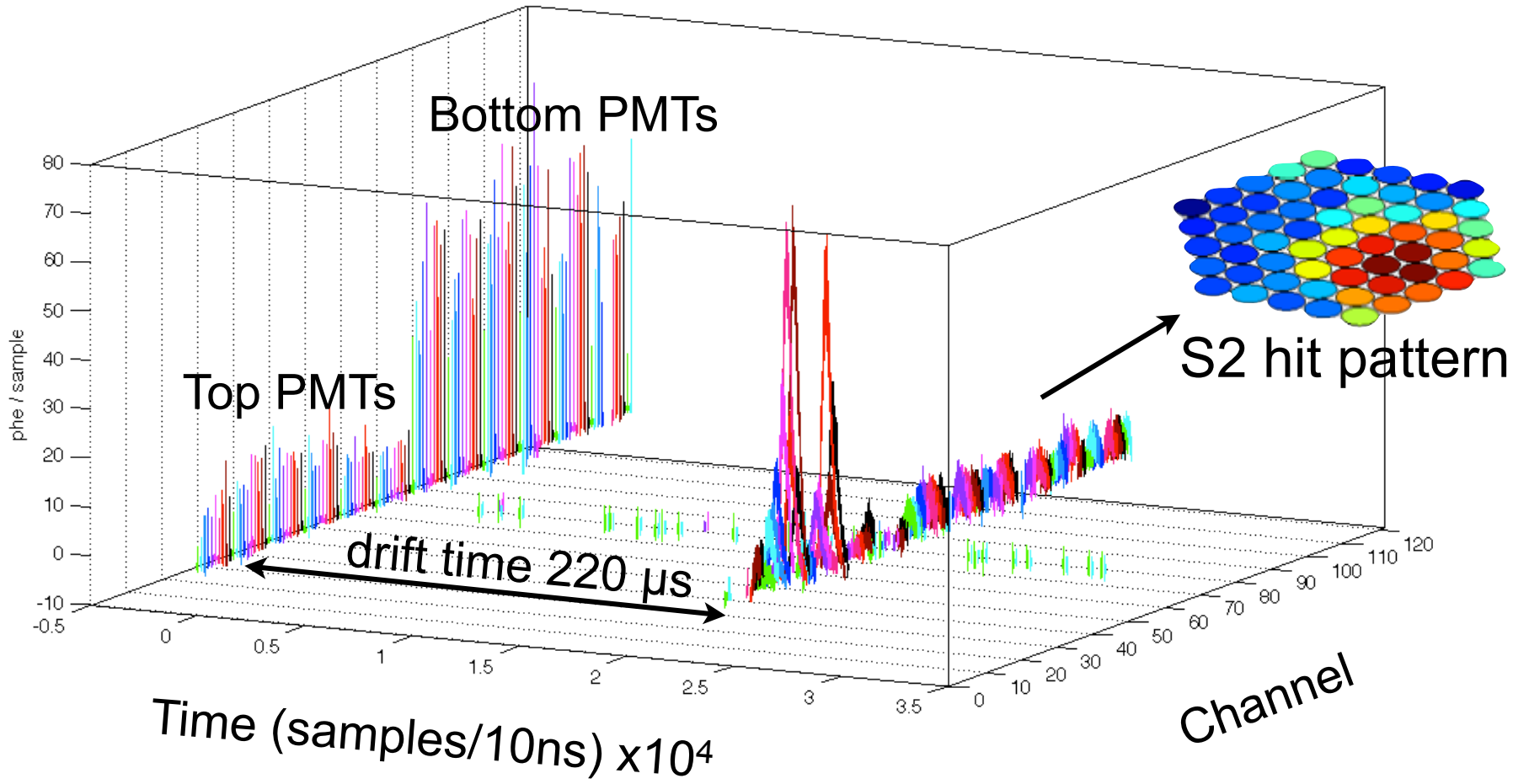
LUX Surface

Oct 2009 - Jun 2012

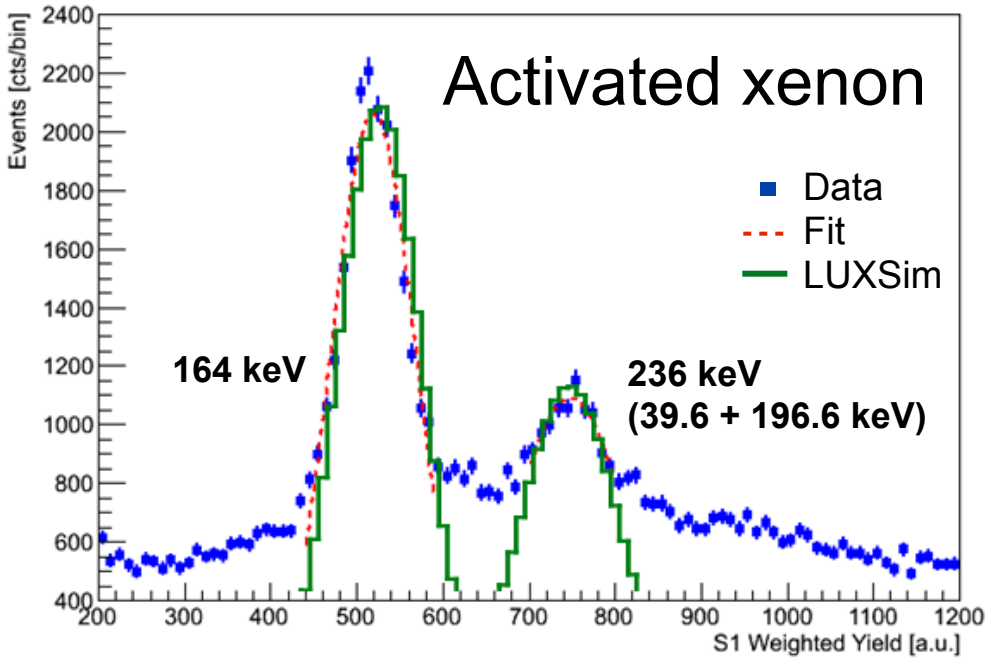
LUX Underground

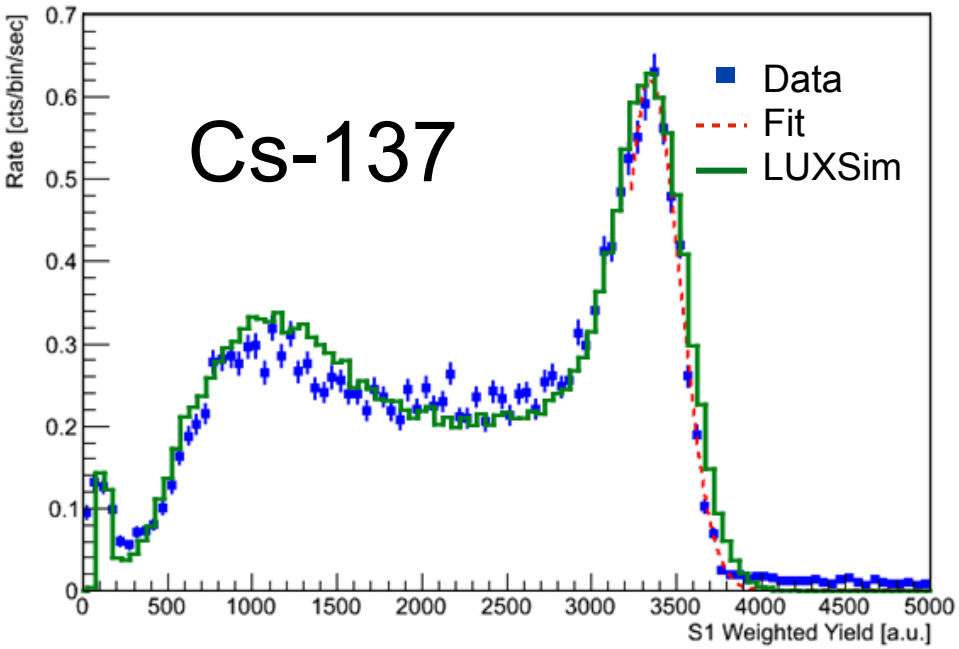
July 2012+

Example of alpha particle in middle of LUX detector



Light Collection





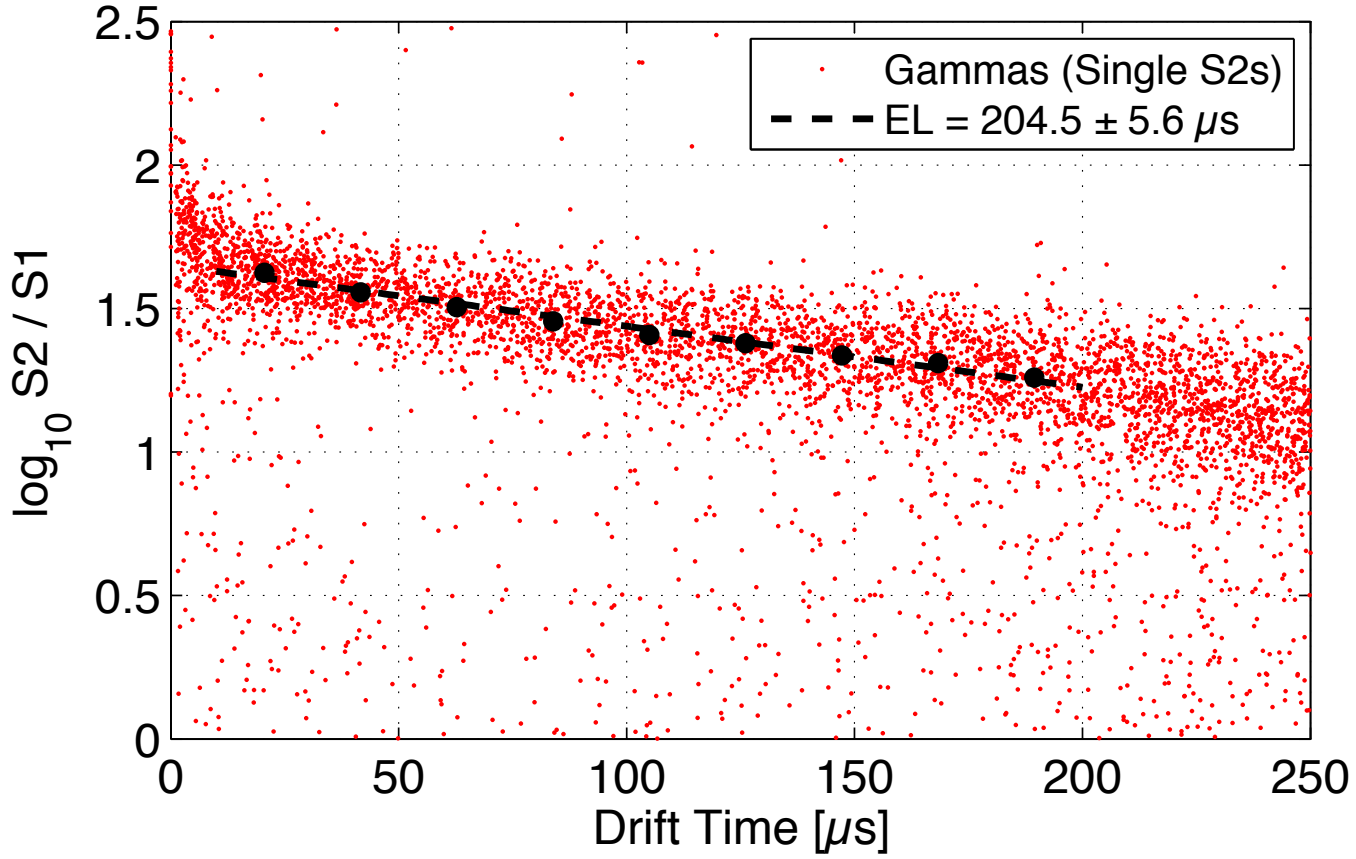
- Achieved **8 phe/keV$_{ee}$** light collection for 662 keV gammas at the center of the detector, zero field

- The light collection for 122 keV at 500 V/cm is 4 phe/keV$_{ee}$
  - This is **~x3** as good as XENON100

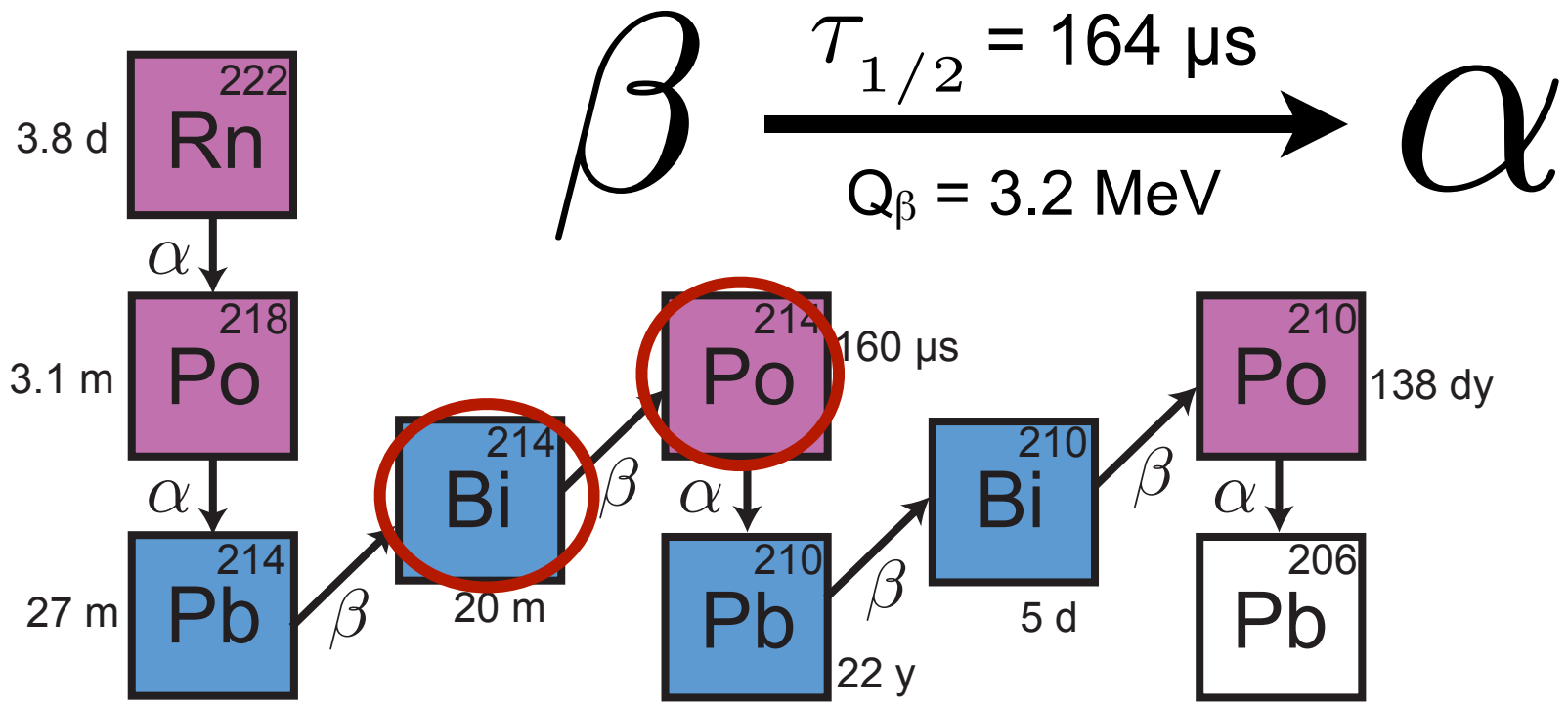
- PTFE reflectivity in liquid xenon measured to be **> 98%** at 1-sigma level

Xenon purification

200 μs electron lifetime achieved



Beta-Alpha Physics from BiPo

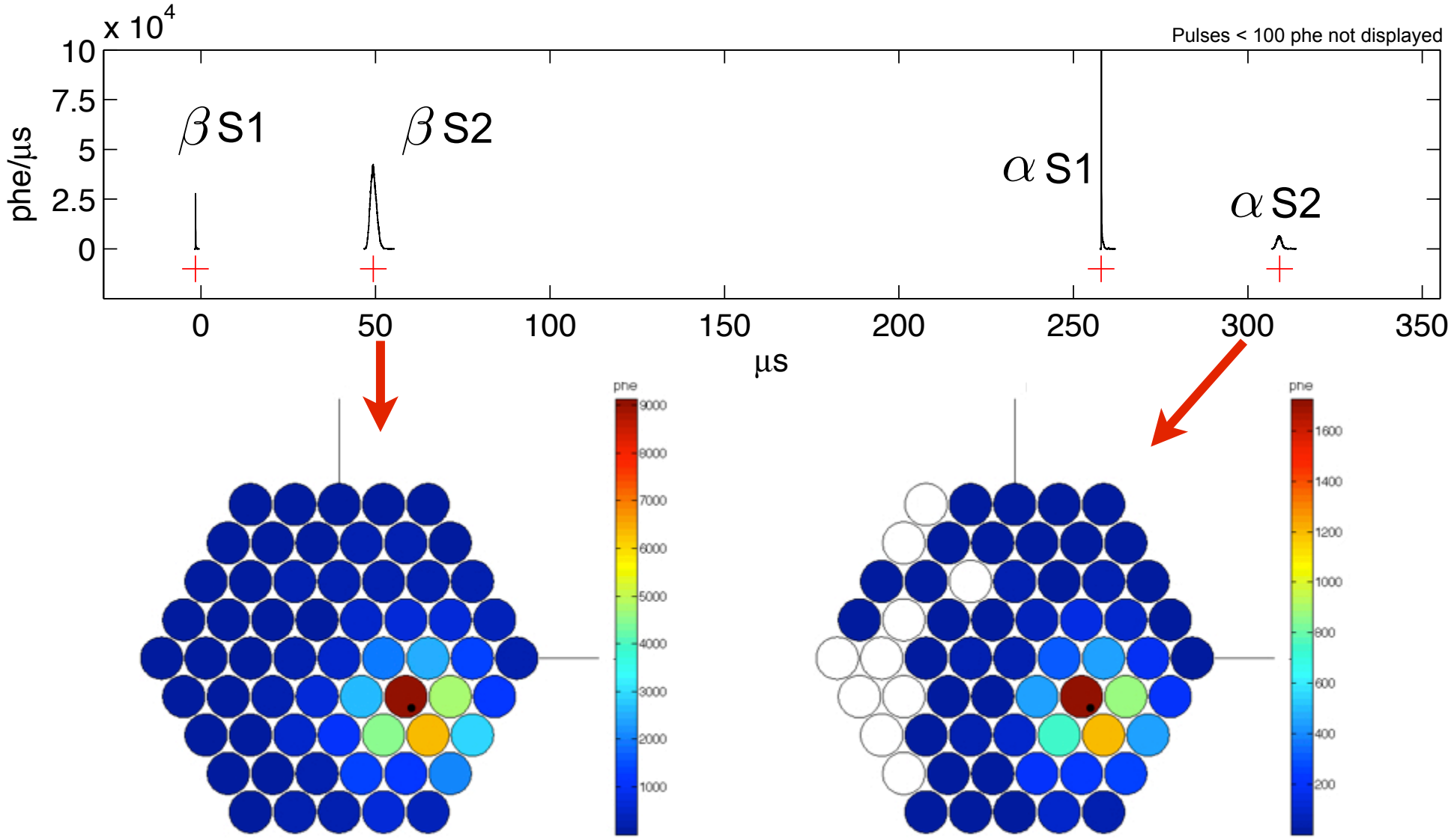


Beta range (E_{mean} = 642 keV)
in LXe is ~1.5 mm

Alpha range
in LXe is ~50 μm

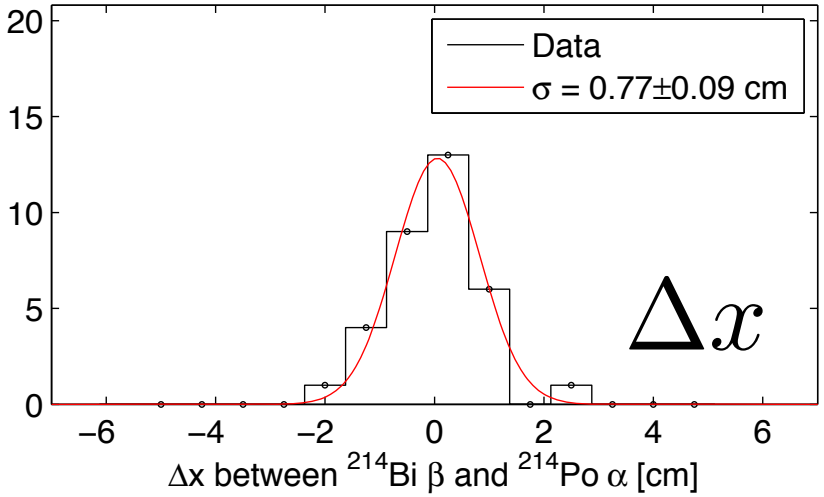
This coincidence event is highly localized in x,y,z

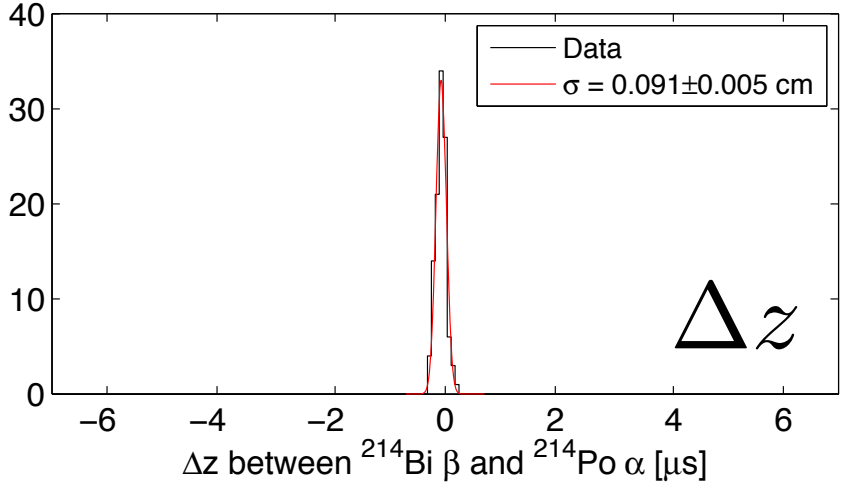
Sample β-α Bi-Po event in surface data

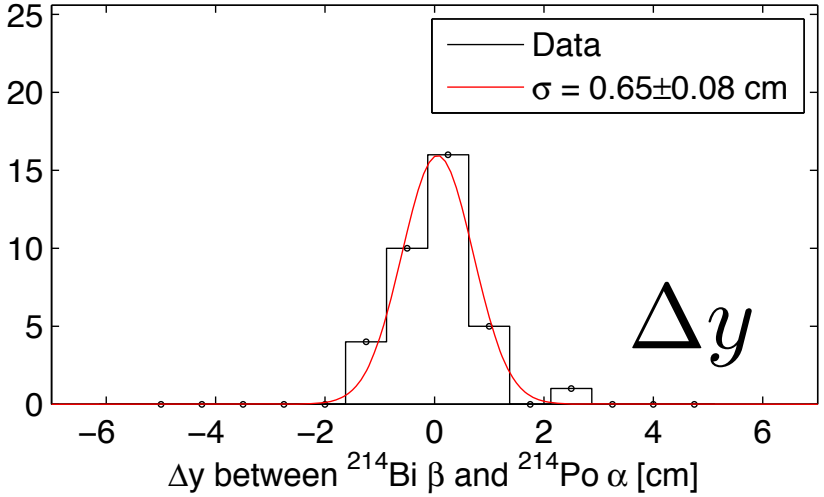


Position reconstruction computed with Zeplin III Mercury algorithm

Statistical position resolution







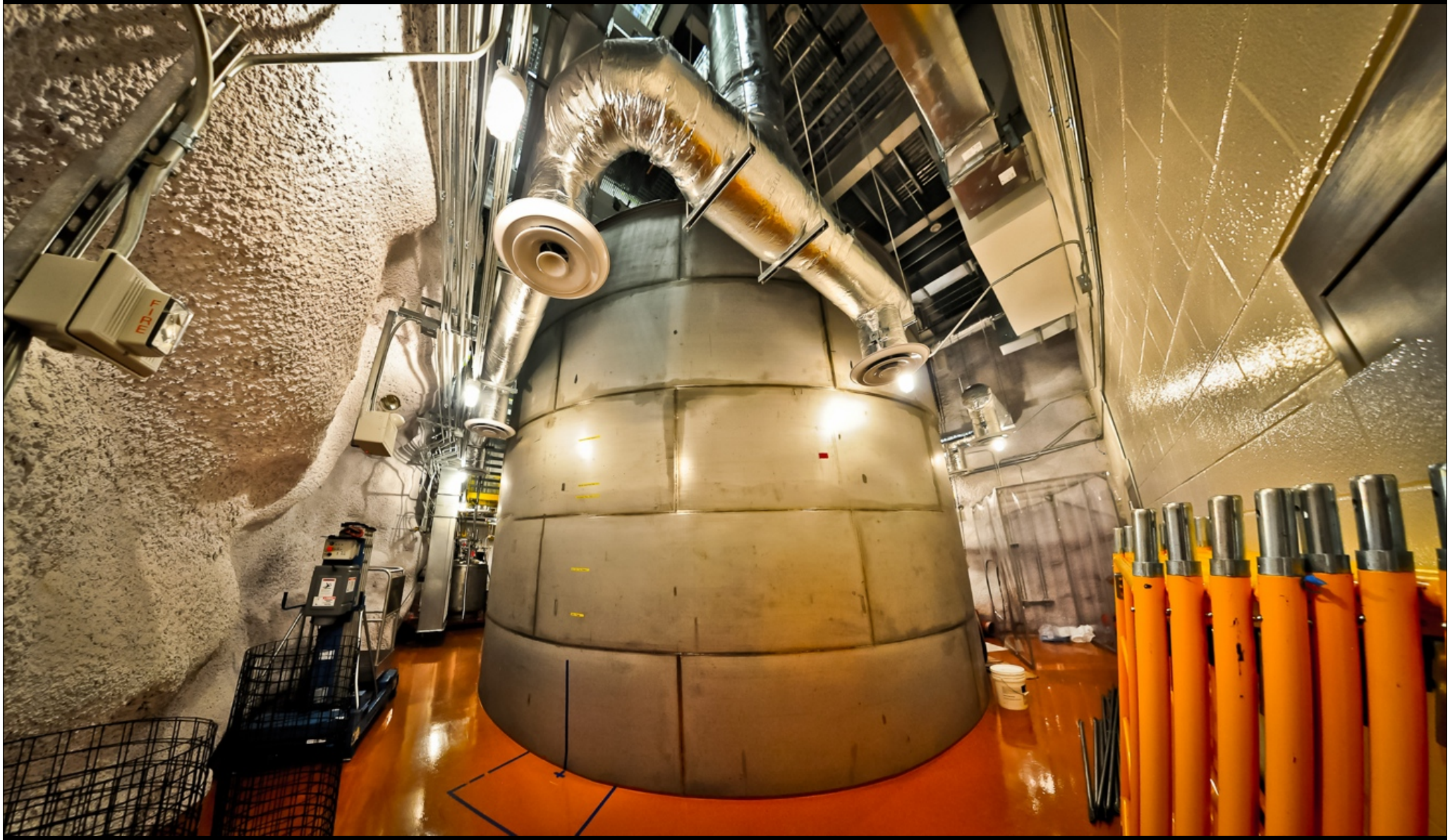
- Alpha S2 signal equivalent to ER gamma S2(z=0) < 20 keV_{ee}
- The statistical resolution in z is 0.09 cm
- The statistical resolution in x or y is 0.7 cm

LUX Davis Campus @ Sanford Lab

“Eager Graduate Students”
Davis Cavern, Oct 2011

“Busy Graduate Students”

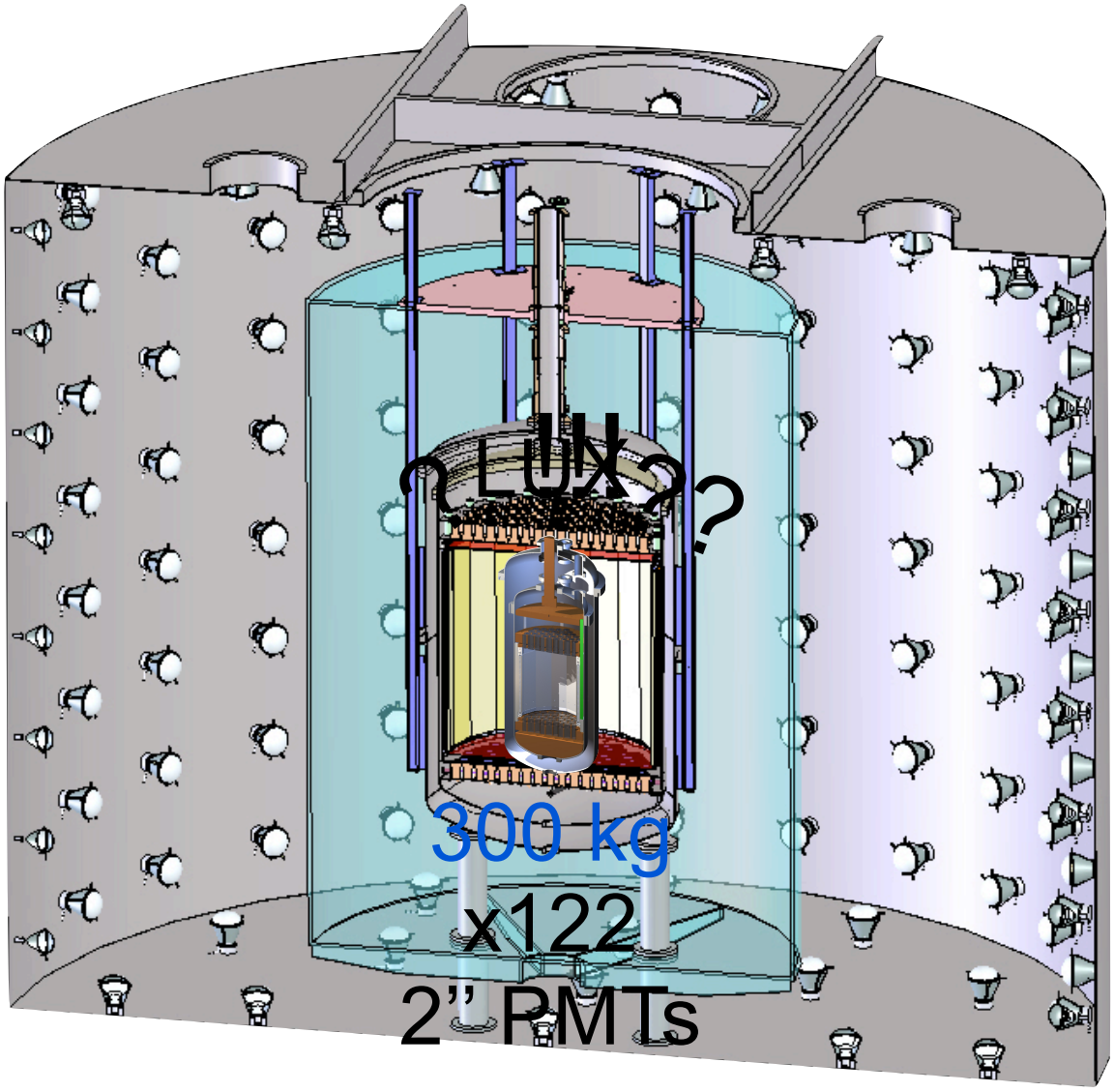
Davis Cavern, Sep 2012



LUX Water Tank - Outside View

LUX Water Tank - Inside View

LUX+ZEPLIN = LZ



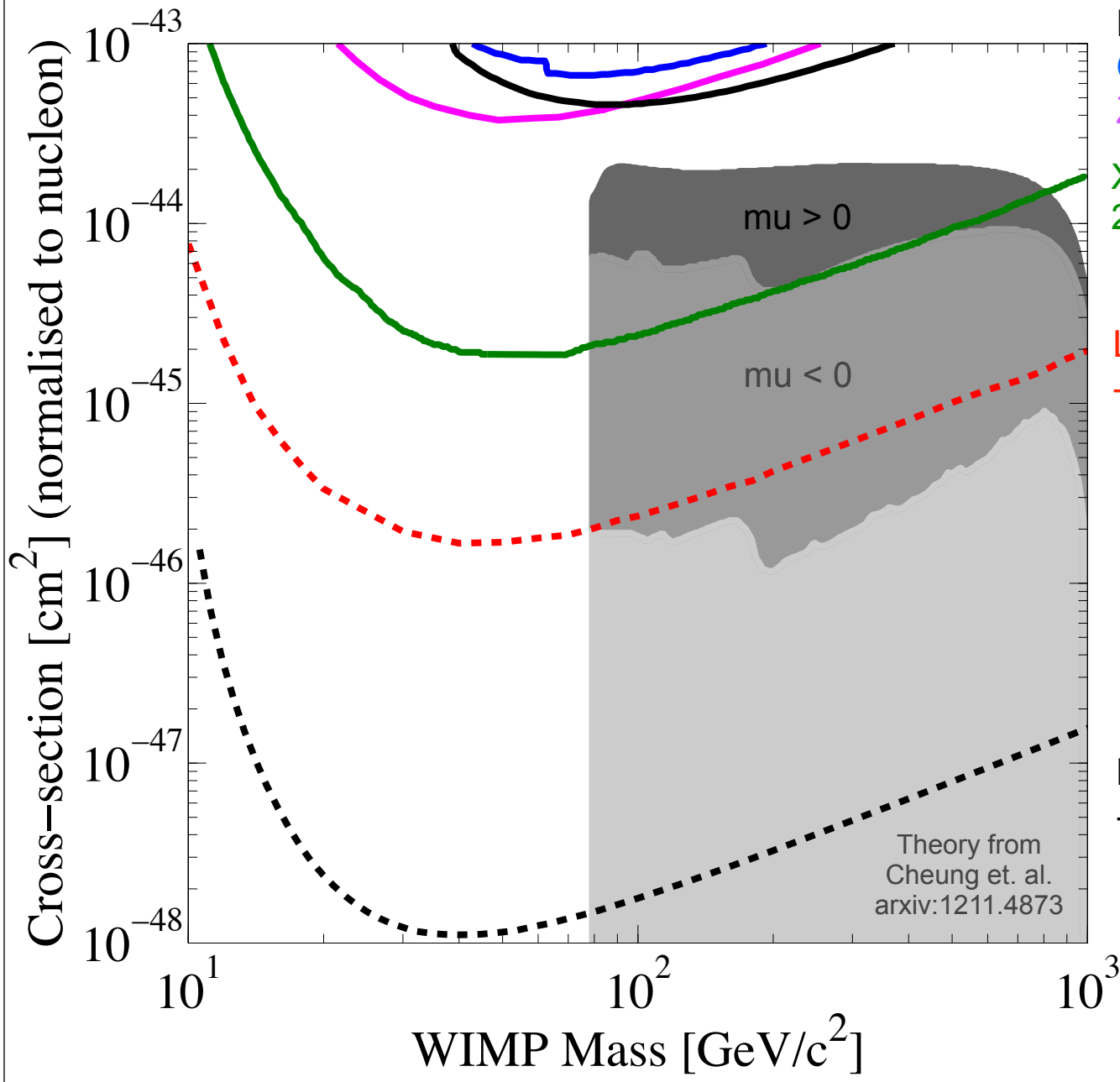
LZ

7 tonnes

x482

3” PMTs

Expected sensitivity



Edelweiss II
CDMS II
ZEPLIN III

XENON100 (2012)
225 day x 34 kg fid. Xe

LUX 300 days x 100 kg fid. Xe
- goal zero background

LZ 1000 days x 5 tonne fid. Xe
- goal zero background

- LUX detector moved to from surface lab to underground lab @ Sanford July 2012
  - All detector/safety system commissioned and checkouts passed
  - Water shield / Muon veto - filled and operational
  - Experiment is working closely with Sanford Lab personnel who are focused on science mission
- Dec 2012: Warm Xe gas to perform preliminary checks
  - Internal calibration with 83Kr to check circulation path / data taking
- Now: Detector Cooldown and Condensation of 370 kg liquid Xe (low ^{85}Kr<5 ppt)
  - Authorization to proceed from Lab
- During 2013
  - Full checkout of all systems cold / circulation to achieve purity (collection of S2 throughout volume)
  - Calibrations to establish detector response at low energy
  - Unblinded ~2 month run to demonstrate dark matter sensitivity
- Ultimate Science Goal is to take 300 days of live data
  - Expect to continue data-taking/calibration studies until the LZ experiment (7 tonnes) is ready to be installed.
  - G2 down select - DOE/NSF is funding LZ development in 2013, will compete in field downselect end 2013