LUX – Zeplin (LZ)
(G2 direct dark matter detection proposal)

Harry Nelson

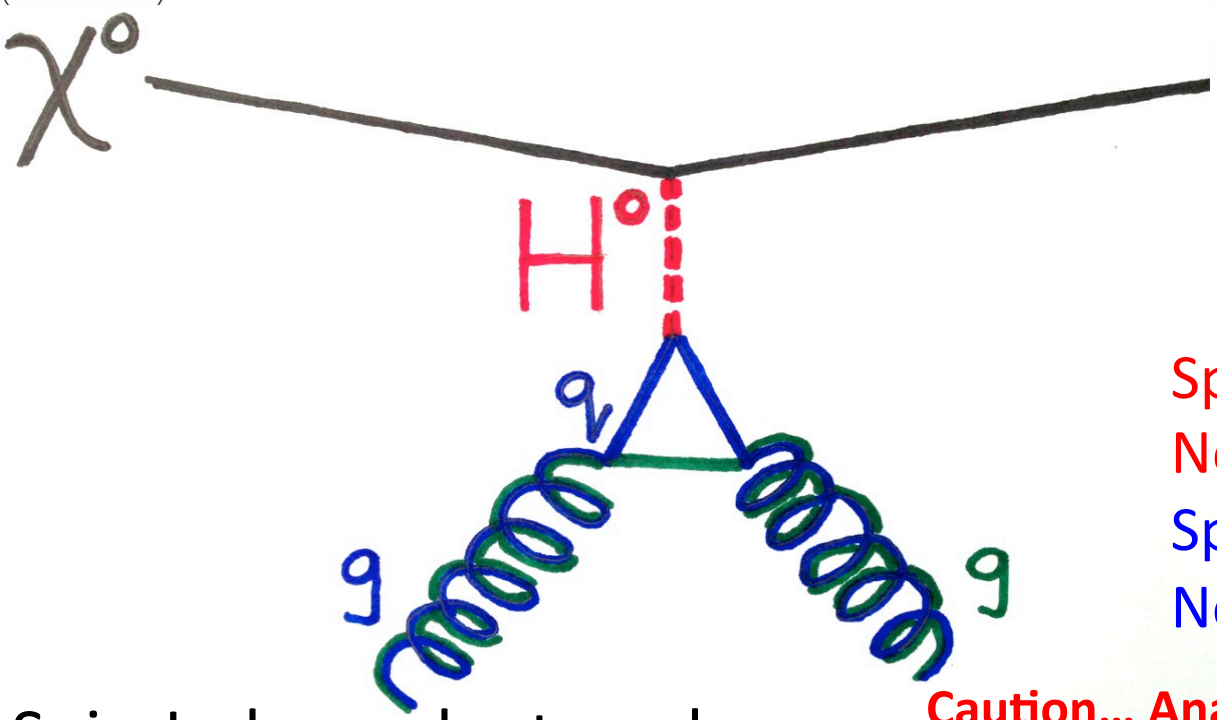
LZ Spokesperson

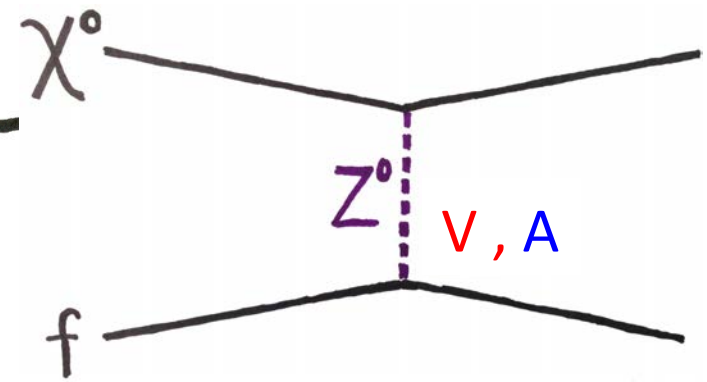
DOE HEP PI Meeting

Rockville, Maryland

June 16-17, 2014

Simplest Diagrams





Spin-Independent Vector
Non-zero for Dirac χ^0
Spin-Dependent Axial Vector
Non-zero for Majorana

Spin-Independent, scalar
Non-zero for Majorana & Dirac χ^0
Glue n/p indifferent, ≈ A^2

$$\sigma_{\rm SI} = 8 \times 10^{-45}\ {\rm cm}^2 \left(\frac{c_{h\chi\chi}}{0.1}\right)^2$$

Cheung, Hall, Pinner, Ruderman 2013

Caution… Anand, Fitzpartrick, Haxton (2014)

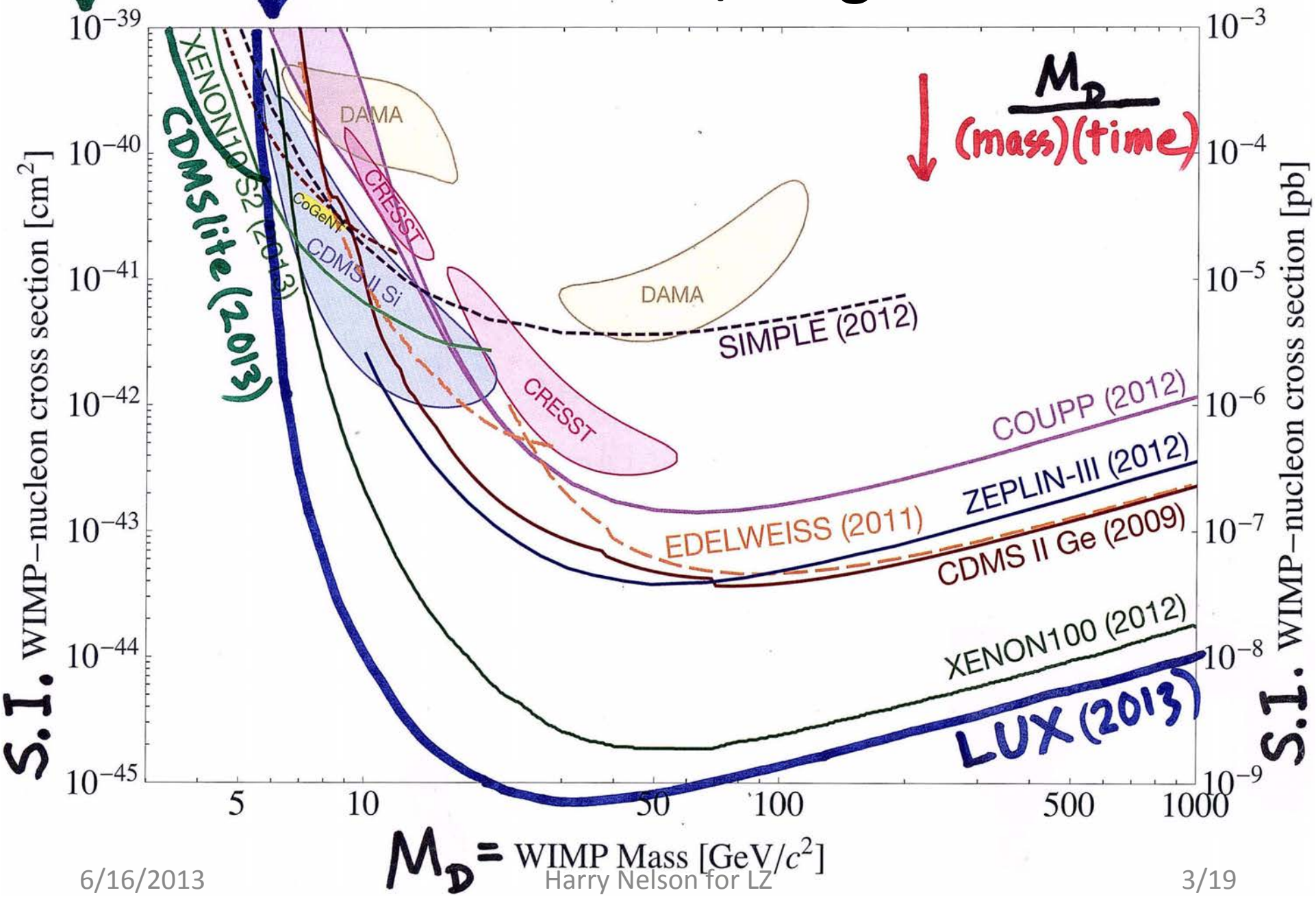
$$R^{\tau\tau'}_{\Sigma''}(\vec{v}_T^{\perp 2}, \frac{\vec{q}^2}{m_N^2}) = \frac{\vec{q}^2}{4m_N^2} c_{10}^\tau c_{10}^{\tau'} + \frac{j_\chi(j_\chi+1)}{12}\Big[c_4^\tau c_4^{\tau'} + \frac{\vec{q}^2}{m_N^2}(c_4^\tau c_6^{\tau'} + c_6^\tau c_4^{\tau'}) + \frac{\vec{q}^4}{m_N^4} c_6^\tau c_6^{\tau'} + \vec{v}$$

$$R^{\tau\tau'}_{\Sigma'}(\vec{v}_T^{\perp 2}, \frac{\vec{q}^2}{m_N^2}) = \frac{1}{8}\left[\frac{\vec{q}^2}{m_N^2}\vec{v}_T^{\perp 2} c_3^\tau c_3^{\tau'} + \vec{v}_T^{\perp 2} c_7^\tau c_7^{\tau'}\right] + \frac{j_\chi(}{}\ \frac{\vec{q}^2}{m_N^2} c_9^\tau c_9^{\tau'} + \frac{\vec{v}_T^{\perp 2}}{2}\left(c_{12}^\tau - \frac{\vec{q}^2}{m_N^2} c_{15}^\tau\right)($$

$$R^{\tau\tau'}_{\Delta}(\vec{v}_T^{\perp 2}, \frac{\vec{q}^2}{m_N^2}) = \frac{j_\chi(j_\chi+1)}{3}\left[\frac{\vec{q}^2}{m_N^2} c_5^\tau c_5^{\tau'} + c_8^\tau c_8^{\tau'}\right]$$

$$R^{\tau\tau'}_{\Delta\Sigma'}(\vec{v}_T^{\perp 2}, \frac{\vec{q}^2}{m_N^2}) = \frac{j_\chi(j_\chi+1)}{3}\left[c_5^\tau c_4^{\tau'} - c_8^\tau c_9^{\tau'}\right].$$

Current Limits / Regions of Interest

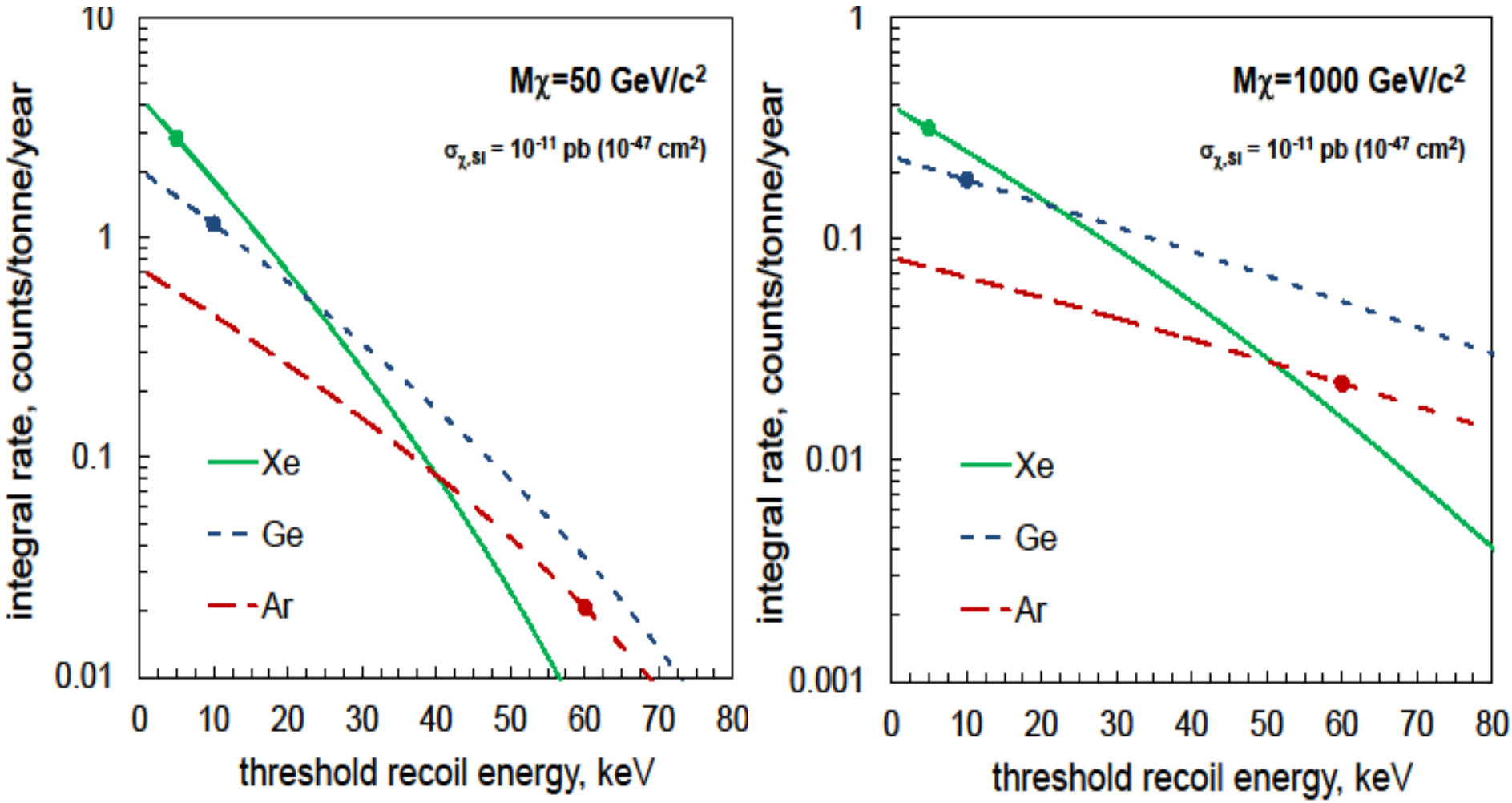


Xenon Properties

- Scintillates, comparison with ionization allows `discrimination' of signal and background
- Plenty of signal ≈1 keV
- Liquid ρ≈3 gm/cm^3, purity
- No long-lived radioisotopes
- 9 stable isotopes
- 2 with odd neutron

^{A}Z	$\tau_{1/2}$ or f	J^p
^{122}Xe	20 h	0^+
^{123}Xe	2.1 h	$(1/2)^+$
^{124}Xe	0.10 %	0^+
^{125}Xe	17 h	$(1/2)^+$
^{126}Xe	0.09 %	0^+
^{127}Xe	**36 d**	**$(1/2)^+$**
^{128}Xe	1.91 %	0^+
^{129}Xe	**26.4 %**	**$(1/2)^+$**
^{130}Xe	4.1 %	0^+
^{131}Xe	**21.2 %**	**$(3/2)^+$**
^{132}Xe	26.9 %	0^+
^{133}Xe	5.2 d	$(3/2)^+$
^{134}Xe	10.4 %	0^+
^{135}Xe	9.1 h	$(3/2)^+$
^{136}Xe	8.9 %	0^+

Per tonne, Xenon Most Sensitive (SI)



South Dakota

Sanford Underground Research Facility

Davis Cavern 1480 m
(4200 mwe)
LUX Water Tank

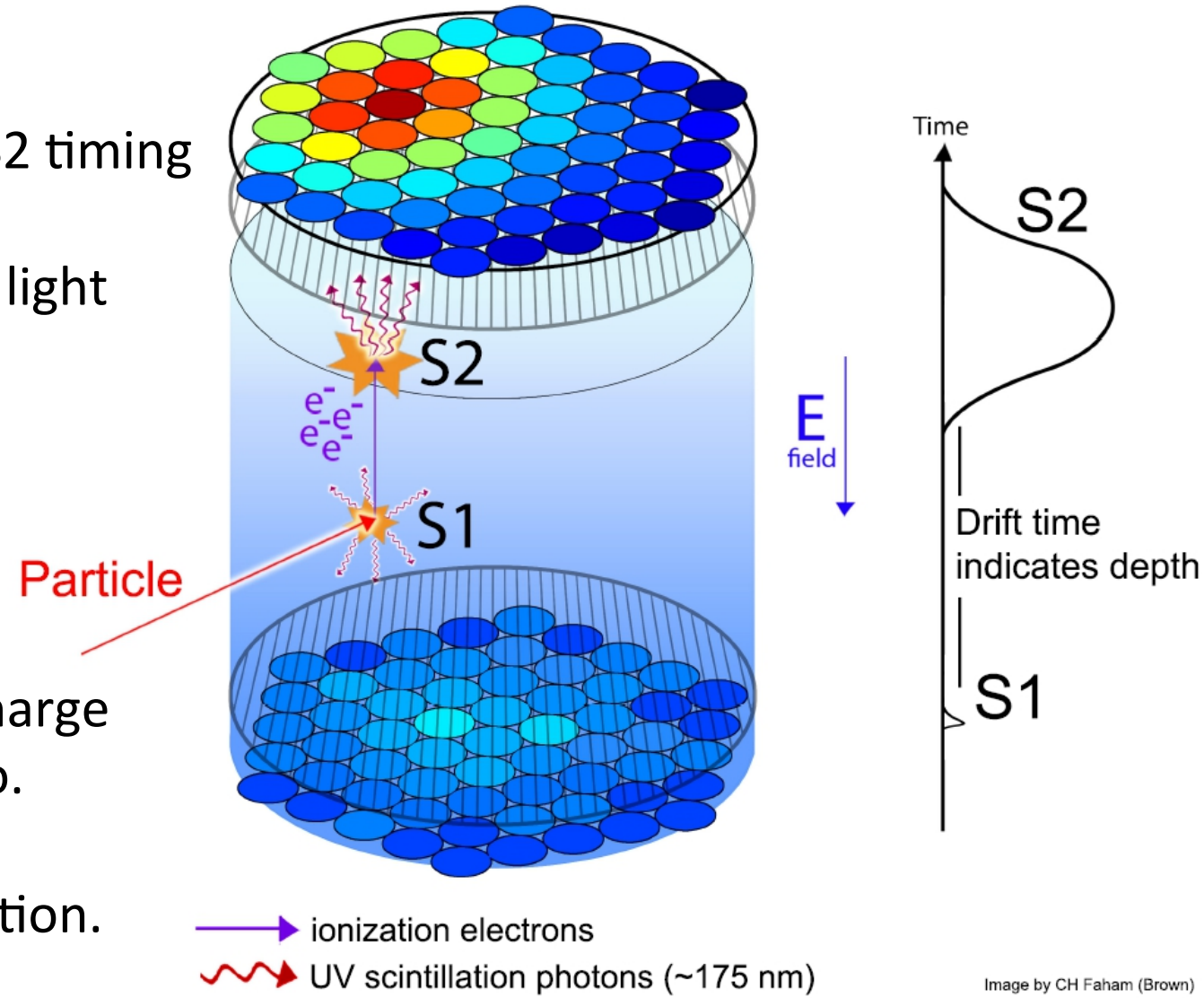
Liquid Xenon TPC Principle

Z position from S1 – S2 timing

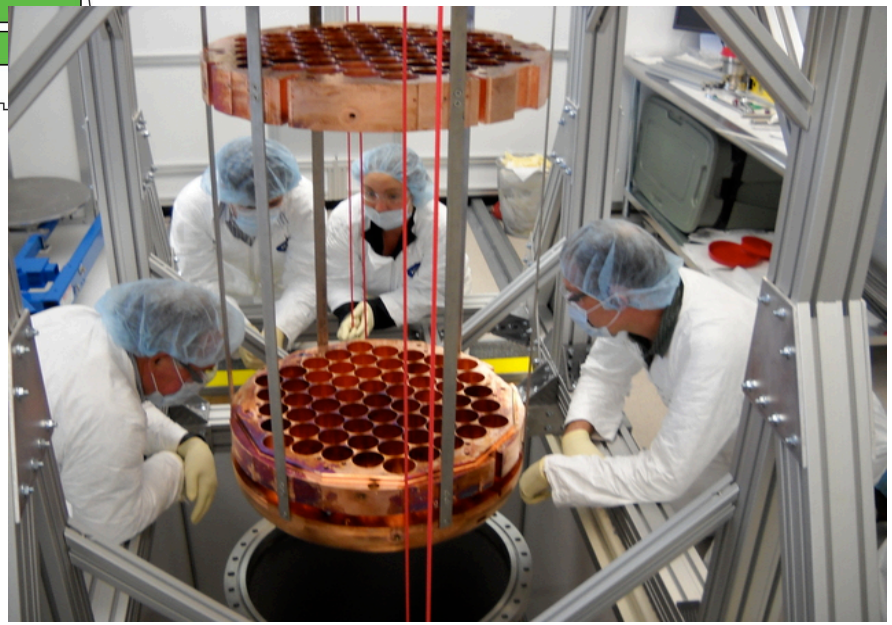
X-Y positions from S2 light pattern

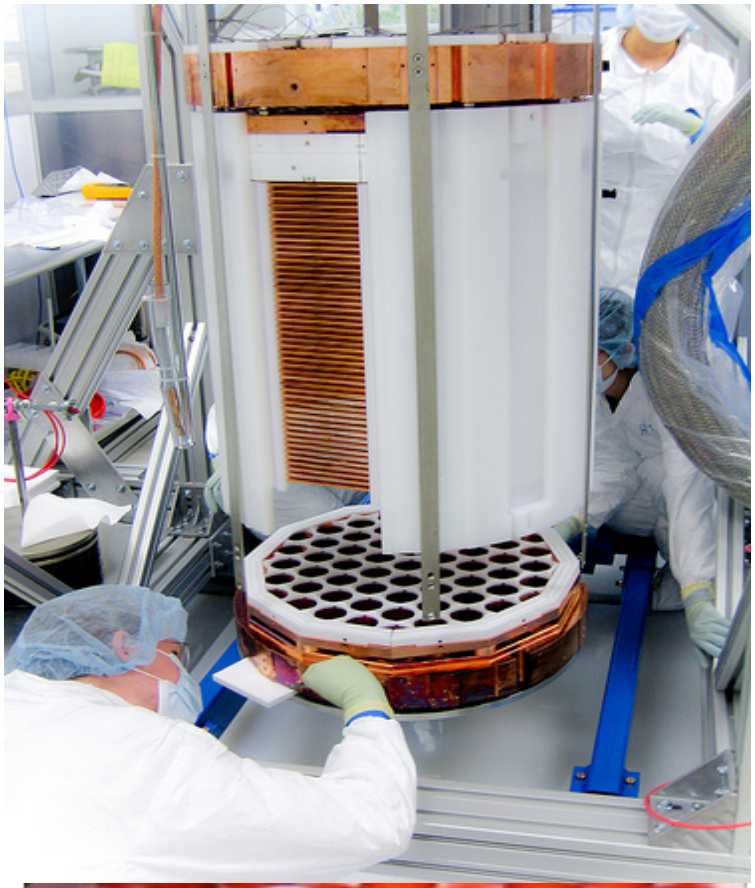
Reject gammas by charge (S2) to light (S1) ratio.

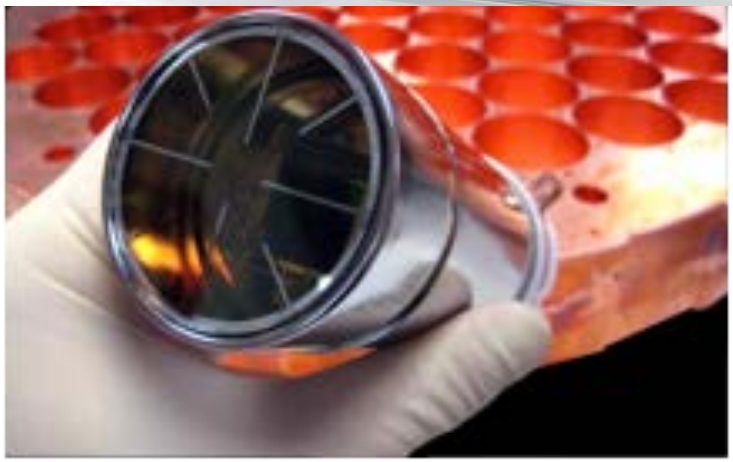
Expect > 99.5% rejection.



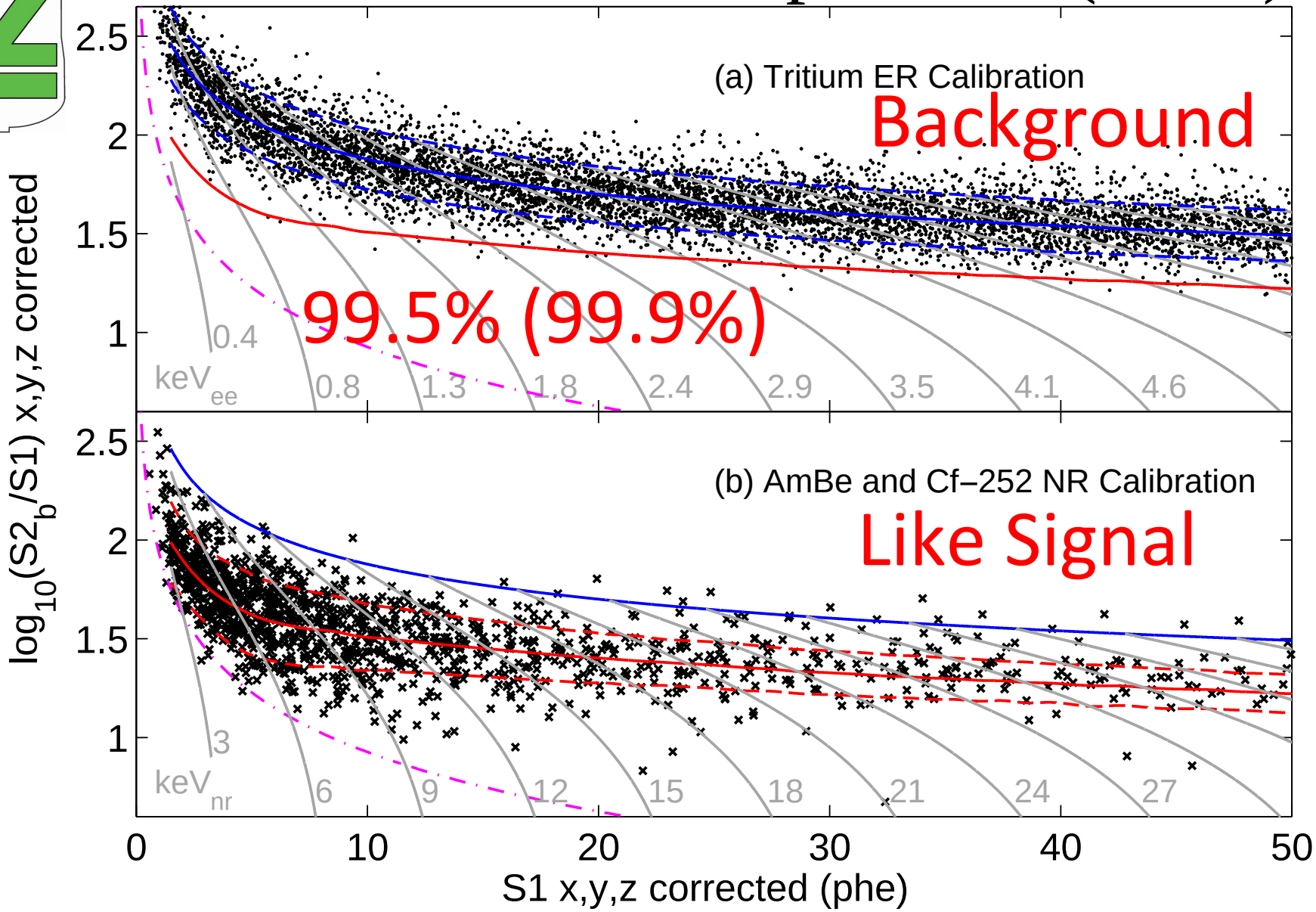
LUX being built







Separation (LUX)



Central Xenon – 5600 kg Fiducial

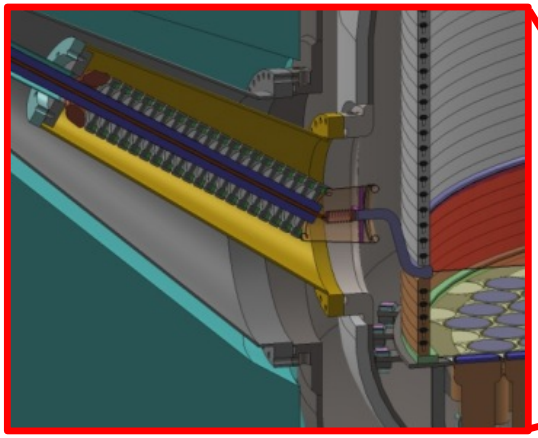
241 PMTs

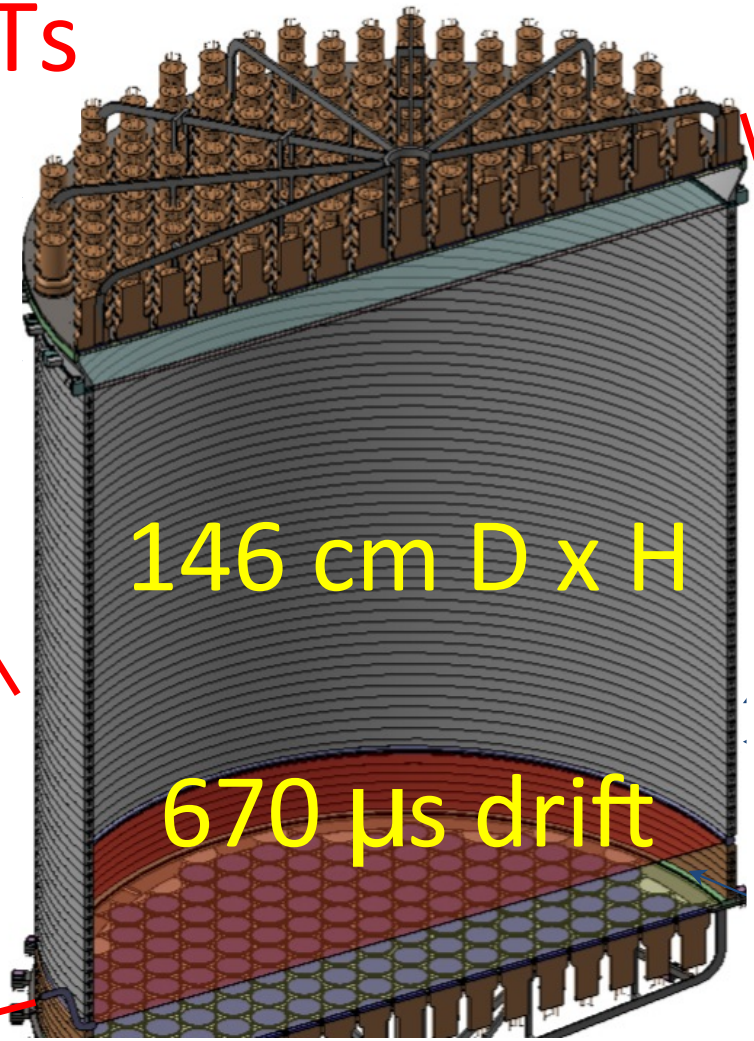
R11410

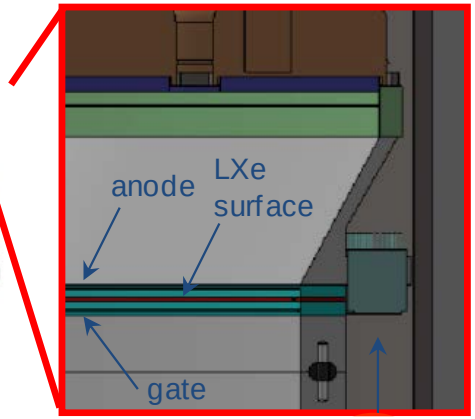
(110 skin PMTs)

R8520

100-200 kV

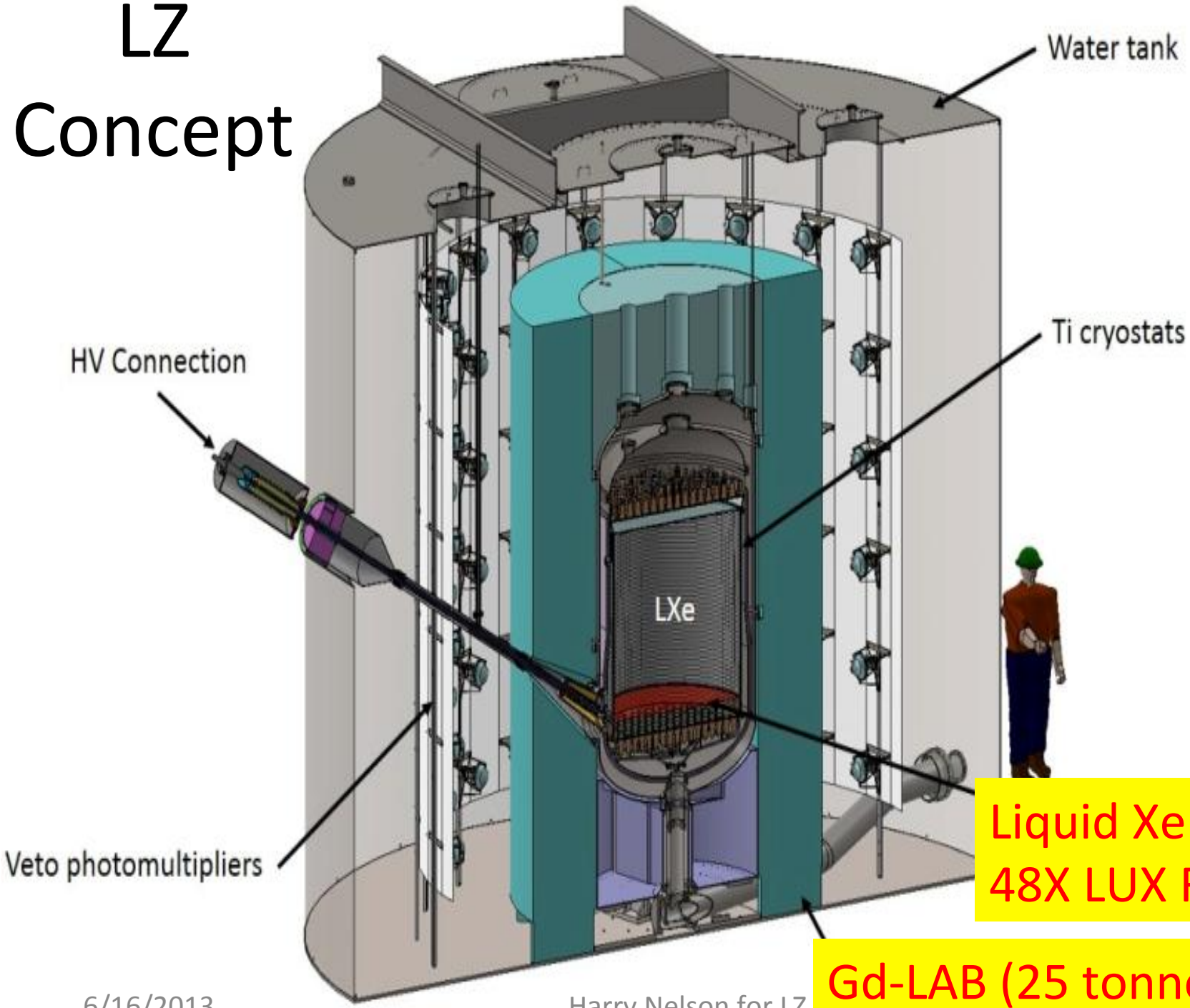






241 PMTs

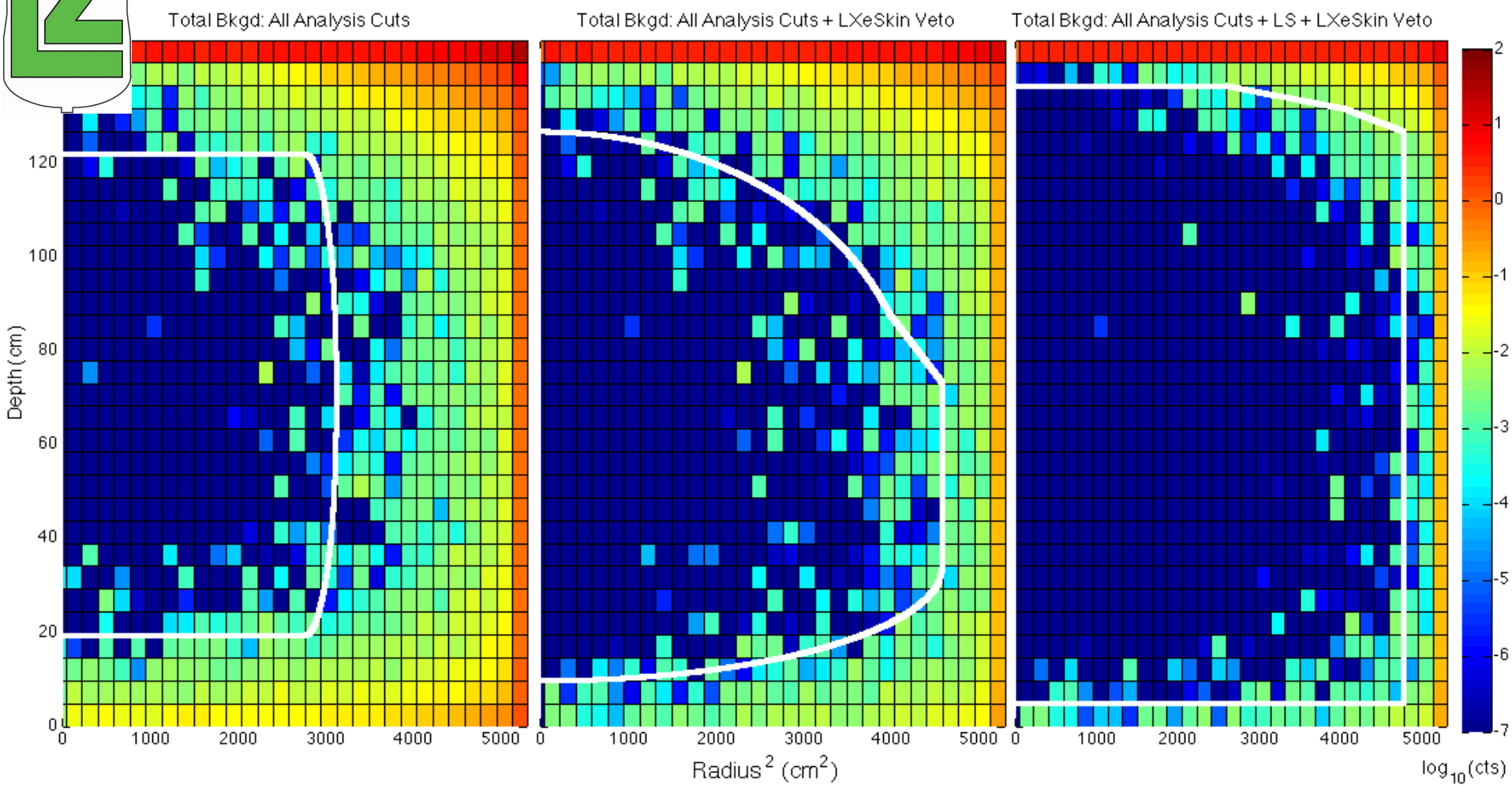
LZ Concept



Liquid Xenon: 7T
48X LUX Fiducial

Gd-LAB (25 tonne)

Self Shielding, Veto… Calibrate?



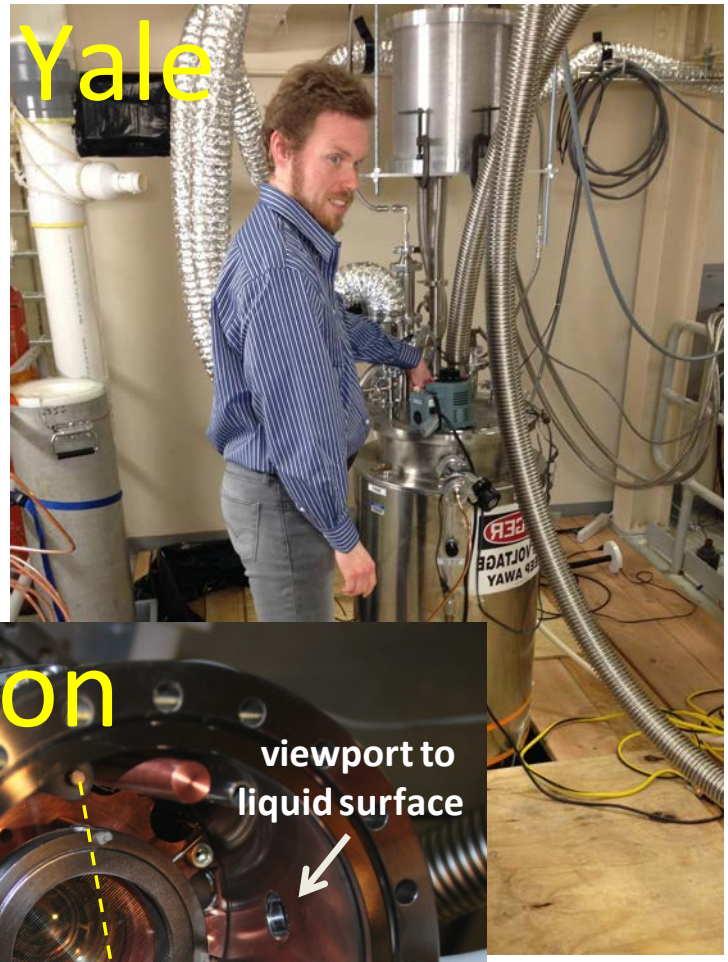
2.8 Tonne

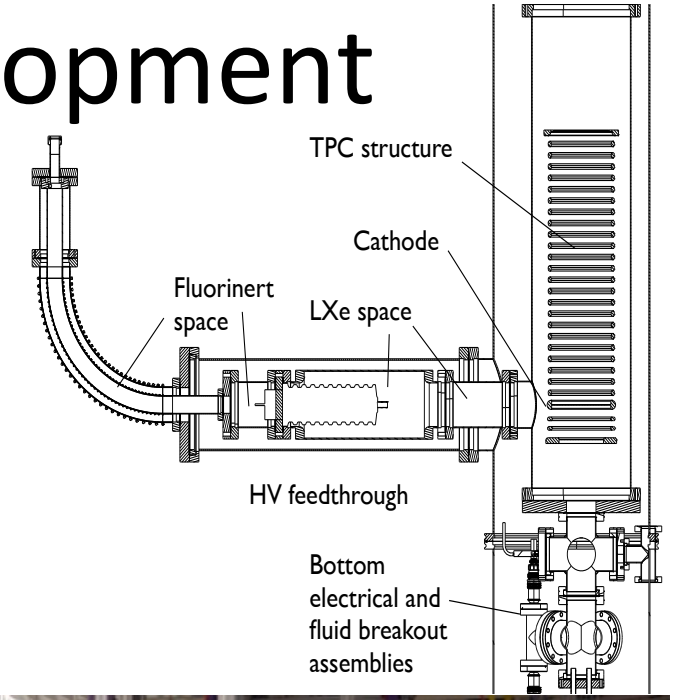
Skin Veto
4.1 Tonne

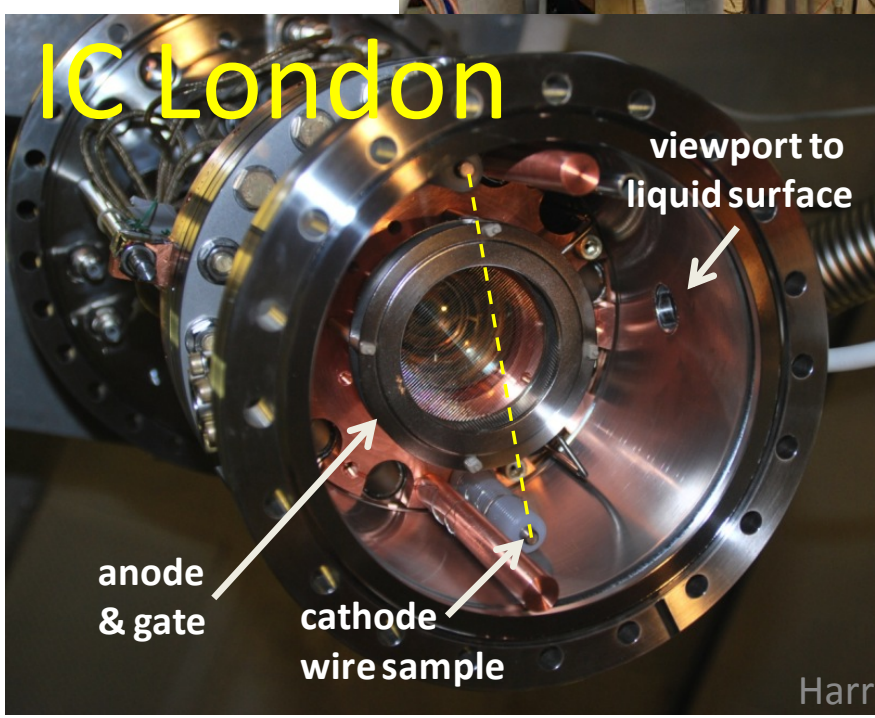
+ Gd-LAB
5.6 Tonne

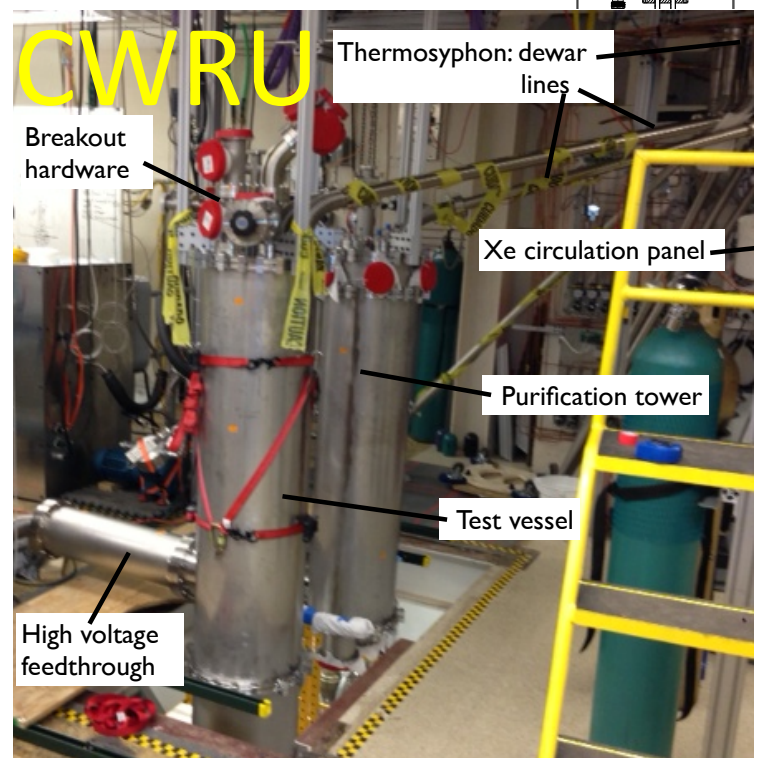
LUX

LZ Development









Estimated Background

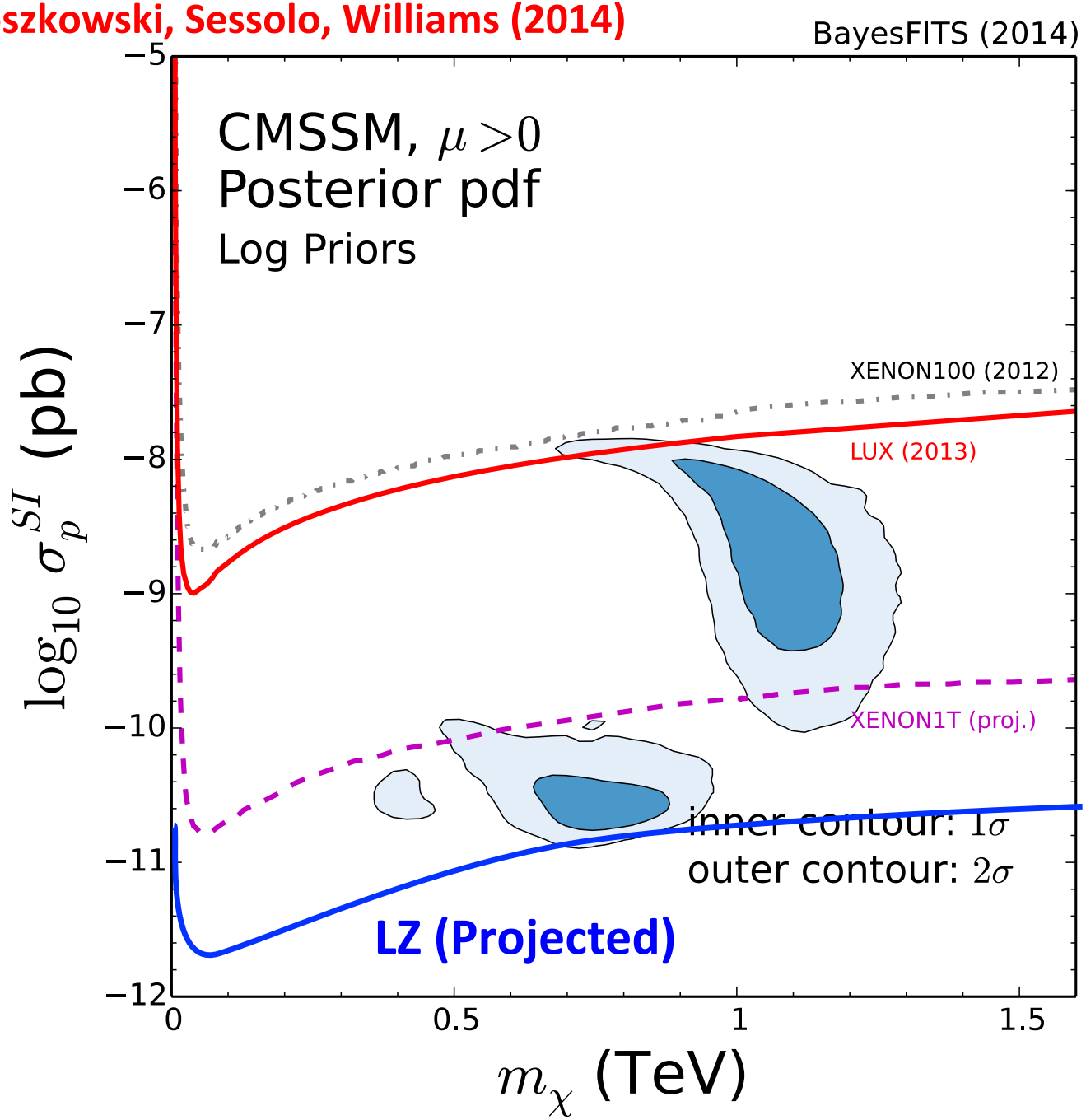
				ER	NR
Extra-TPC Subtotal				(11) 14 (40)	(0.05) 0.10 (0.35)
Kr + Rn				46	
Neutrinos				234	0.61
Totals	Raw			(291) 294 (312)	(0.66) 0.71 (0.96)
	99.5% ER rejection, 50% NR acceptance			(1.46) 1.47 (1.56)	(0.33) 0.36 (0.48)
	Combined			**(1.79) 1.83 (2.04)**	

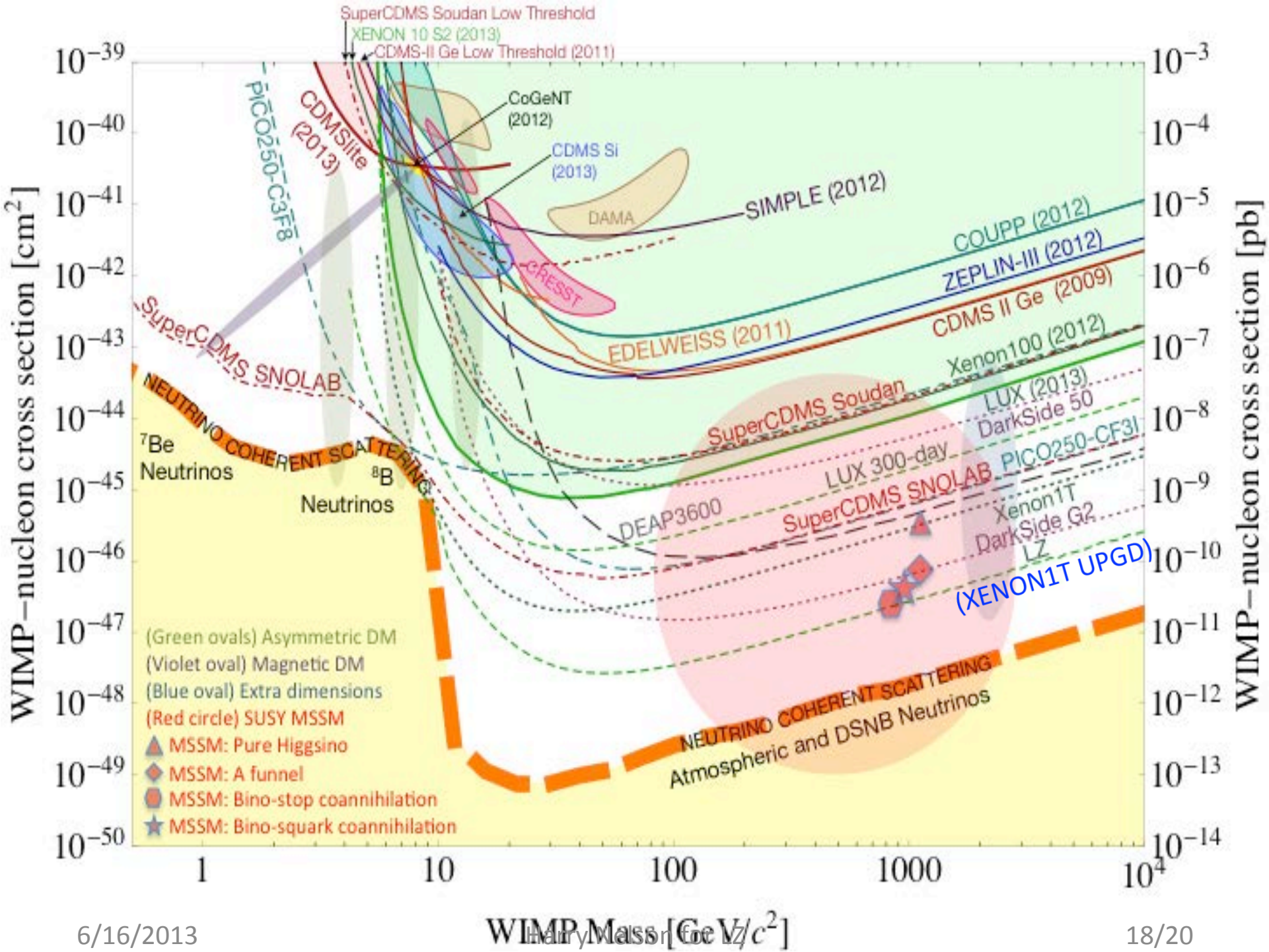
5.6 tonnes fiducial

1000 days

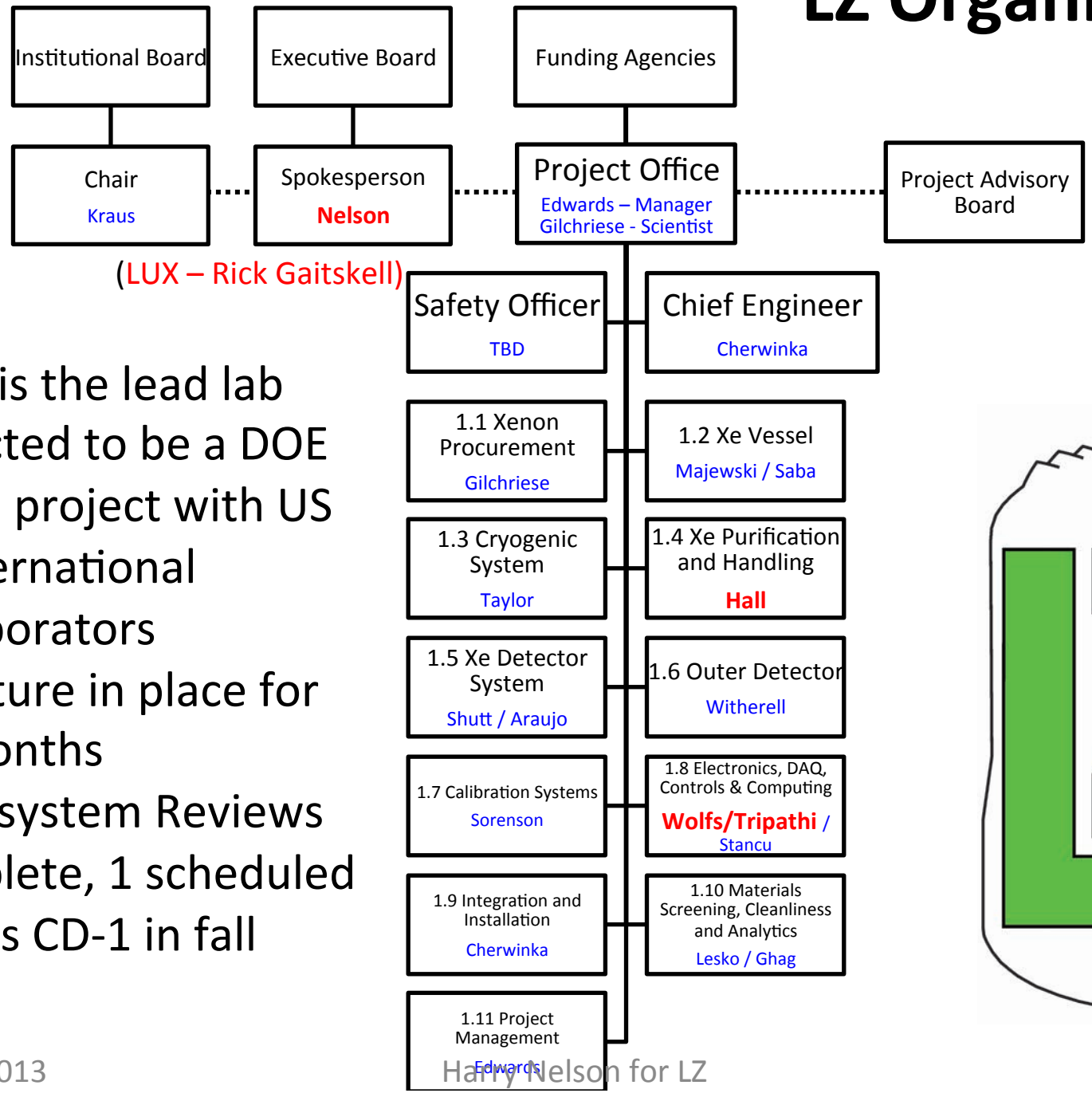
(best) baseline (pessimistic) – bkg of ϒ, n

Roszkowski, Sessolo, Williams (2014)




SuperCDMS Soudan Low Threshold
XENON 10 S2 (2013)
CDMS-II Ge Low Threshold (2011)
CoGeNT (2012)
CDMS Si (2013)
CDMSlite (2013)
PICO250-C3F8
DAMA
SIMPLE (2012)
CRESST
COUPP (2012)
ZEPLIN-III (2012)
CDMS II Ge (2009)
EDELWEISS (2011)
Xenon100 (2012)
SuperCDMS SNOLAB
SuperCDMS Soudan
LUX (2013)
DarkSide 50
LUX 300-day
PICO250-CF3I
SuperCDMS SNOLAB
Xenon1T
DarkSide G2
LZ
(XENON1T UPGD)
DEAP3600
NEUTRINO COHERENT SCATTERING
7Be Neutrinos
8B Neutrinos
NEUTRINO COHERENT SCATTERING
Atmospheric and DSNB Neutrinos
(Green ovals) Asymmetric DM
(Violet oval) Magnetic DM
(Blue oval) Extra dimensions
(Red circle) SUSY MSSM
MSSM: Pure Higgsino
MSSM: A funnel
MSSM: Bino-stop coannihilation
MSSM: Bino-squark coannihilation
WIMP–nucleon cross section [cm²]
WIMP–nucleon cross section [pb]
WIMP Mass [GeV/c²]

LZ Organization



- LBNL is the lead lab
- Expected to be a DOE (413) project with US & international collaborators
- Structure in place for 18 months
- 4 Subsystem Reviews Complete, 1 scheduled
- Goal is CD-1 in fall

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

LIP Coimbra (Portugal)
STFC Daresbury Laboratory (UK)
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)