Title: The LUX Dark Matter Search Program

Date: Jun 12, 2009 09:40 AM

URL: http://pirsa.org/09060050

Abstract: LUX (Large Underground Xenon) is a two-phase Time Projection Chamber that will instrument 350 kg of Xenon, 100 kg of which will form a fiducially active target for WIMP interactions. It will be deployed at the Sanford Underground Science and Engineering Lab at the Homestake Mine in Lead, South Dakota. The Early Implementation Program of Sanford Lab is providing space at the 4850 feet level for LUX. The first detector with 120 photomultiplier tubes is being constructed and is projected to start collecting data in late 2009. Estimated background rates and LUX sensitivity to WIMP like Dark Matter particles will be presented. At the same time, we are engaged in planning for future detectors of this kind. Besides scaling to larger target masses, several new technological avenues are also being pursued. Status of LUX and plans for a roadmap for the future will be presented.

Large Underground Xenon Experiment

Mani Tripathi, Perimeter Institute, June 12, 2009

Large Underground Xenon Experiment

Mani Tripathi, Perimeter Institute, June 12, 2009

LUX Collaboration

1 Member Institutions (incl. 2 National Labs)

~20 Senior Personnel, ~5 Engineers, ~7 Postdocs, ~15 Students.

Steadily growing. (Not shown below: Moscow Engineering Physics Institute)

QuickTime™ and a
decompressor
are needed to see this picture.

Large Underground Xenon Experiment

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Large Underground Xenon Experiment

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Brown
R. Gaitskell

CWRU
A. Bolozdynya
T. Shutt
M. Dragowsky
D. Akerib

LBNL
K. Lesko

LLNL
A. Bernstein
B. Svoboda

Maryland
C. Hall

UC Davis
R. Lander
B. Svoboda

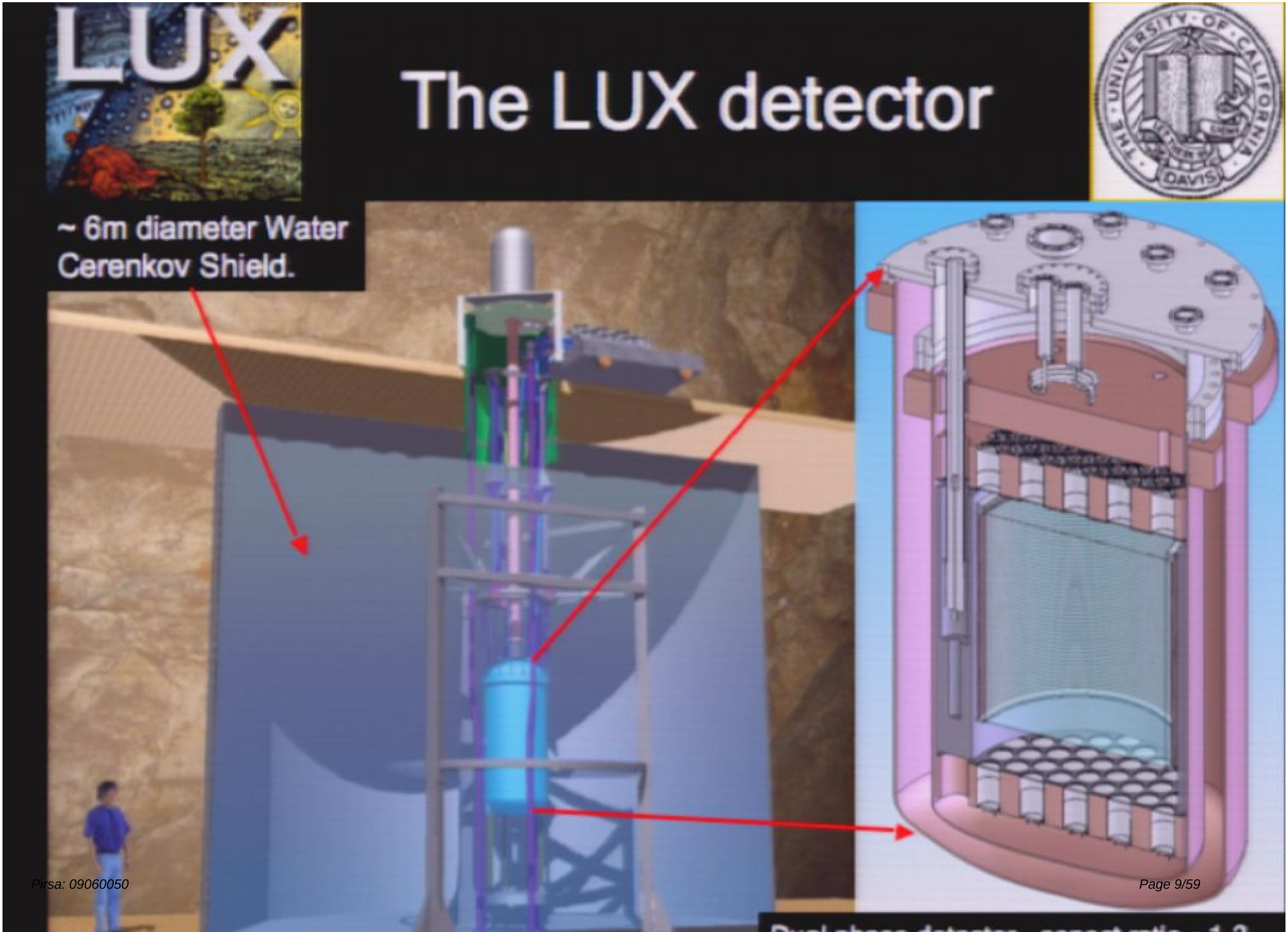
Rochester
T. Ferbel
U. Schroeder

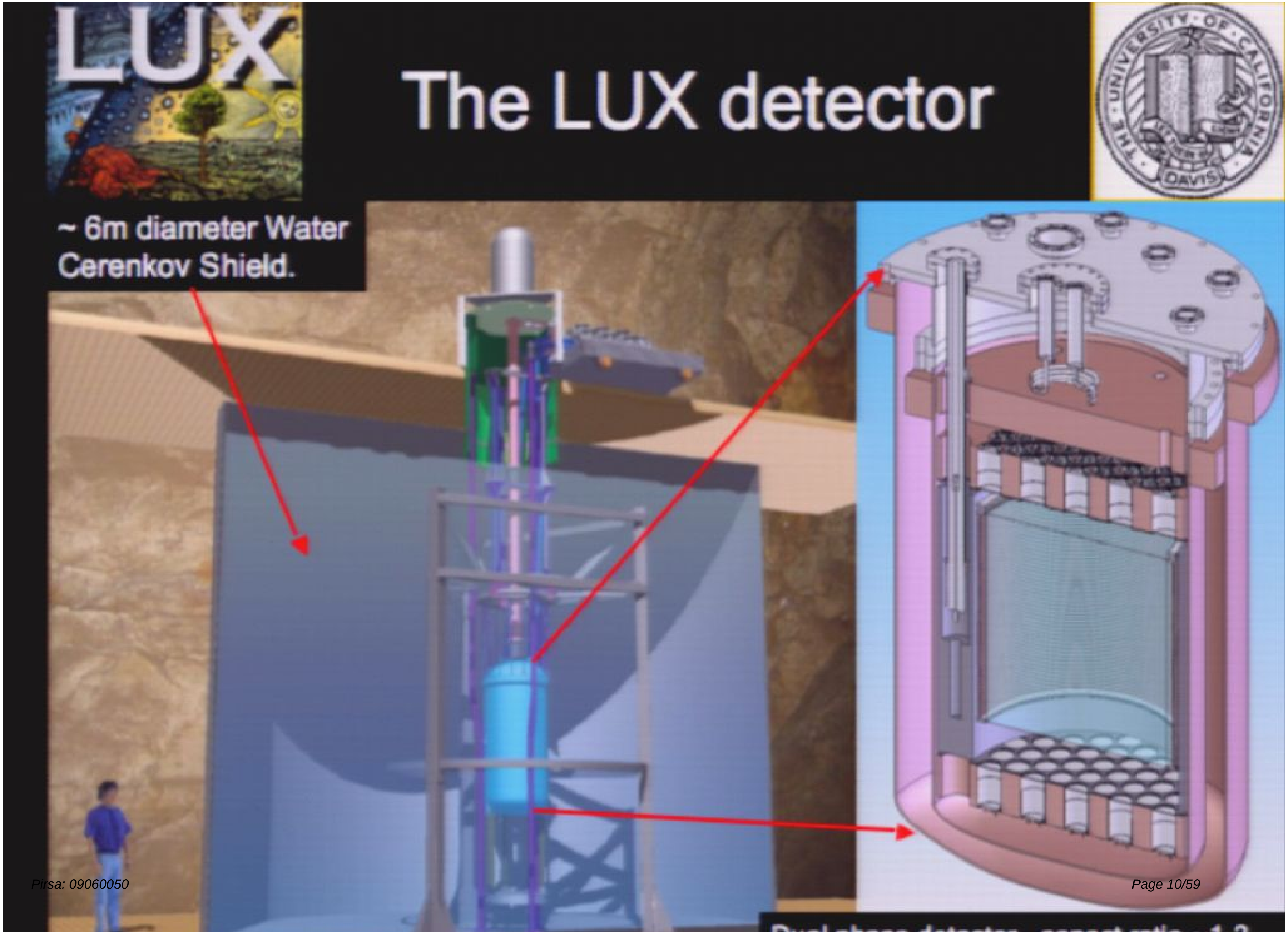
U. SouthDakota
D.Mei

TAMU
J. White

Yale
D. McKinsey

LUX Collaboration


LUX
The LUX detector
~ 6m diameter Water Cerenkov Shield.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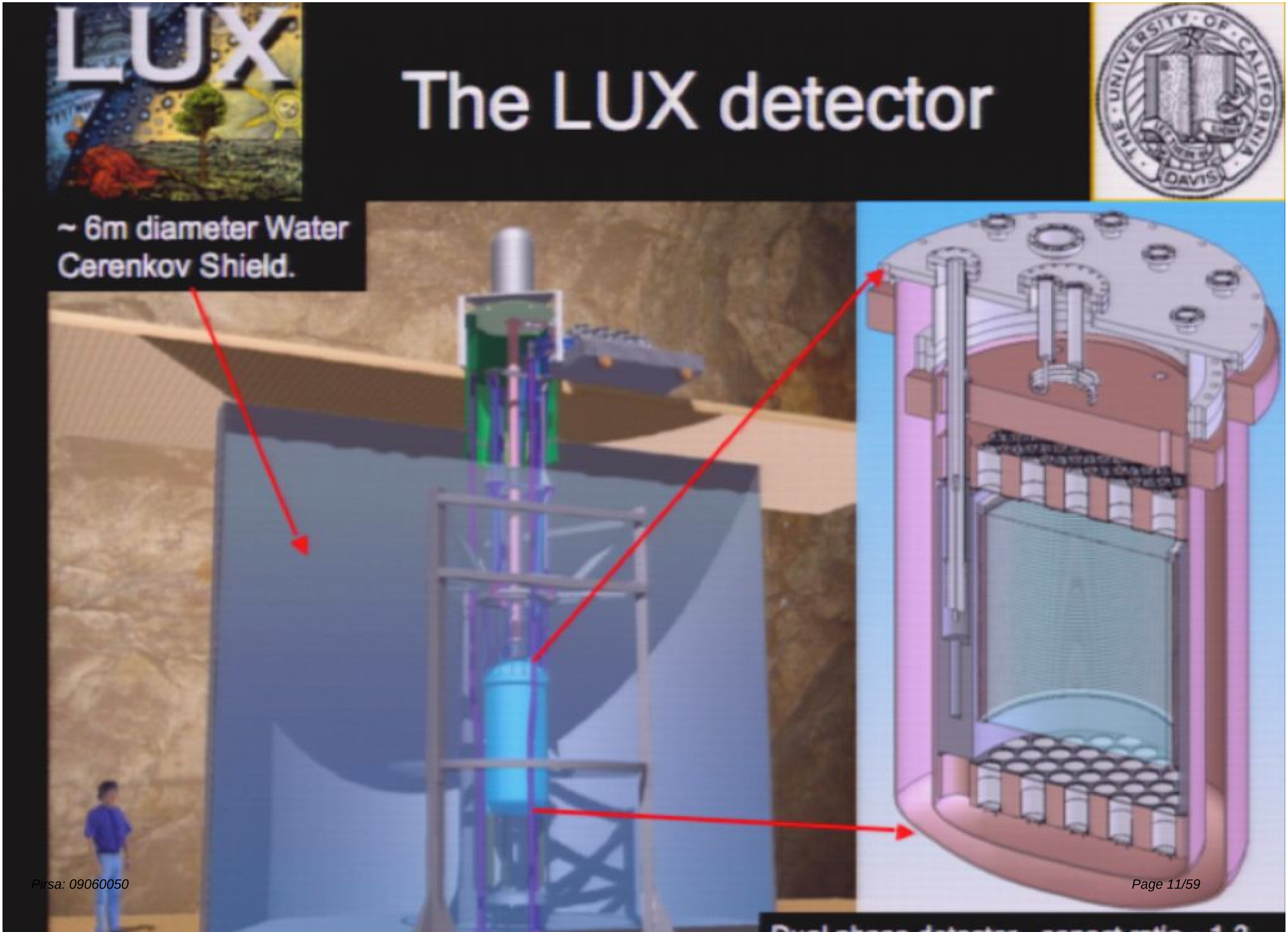
THE UNIVERSITY OF CALIFORNIA
DAVIS


LUX
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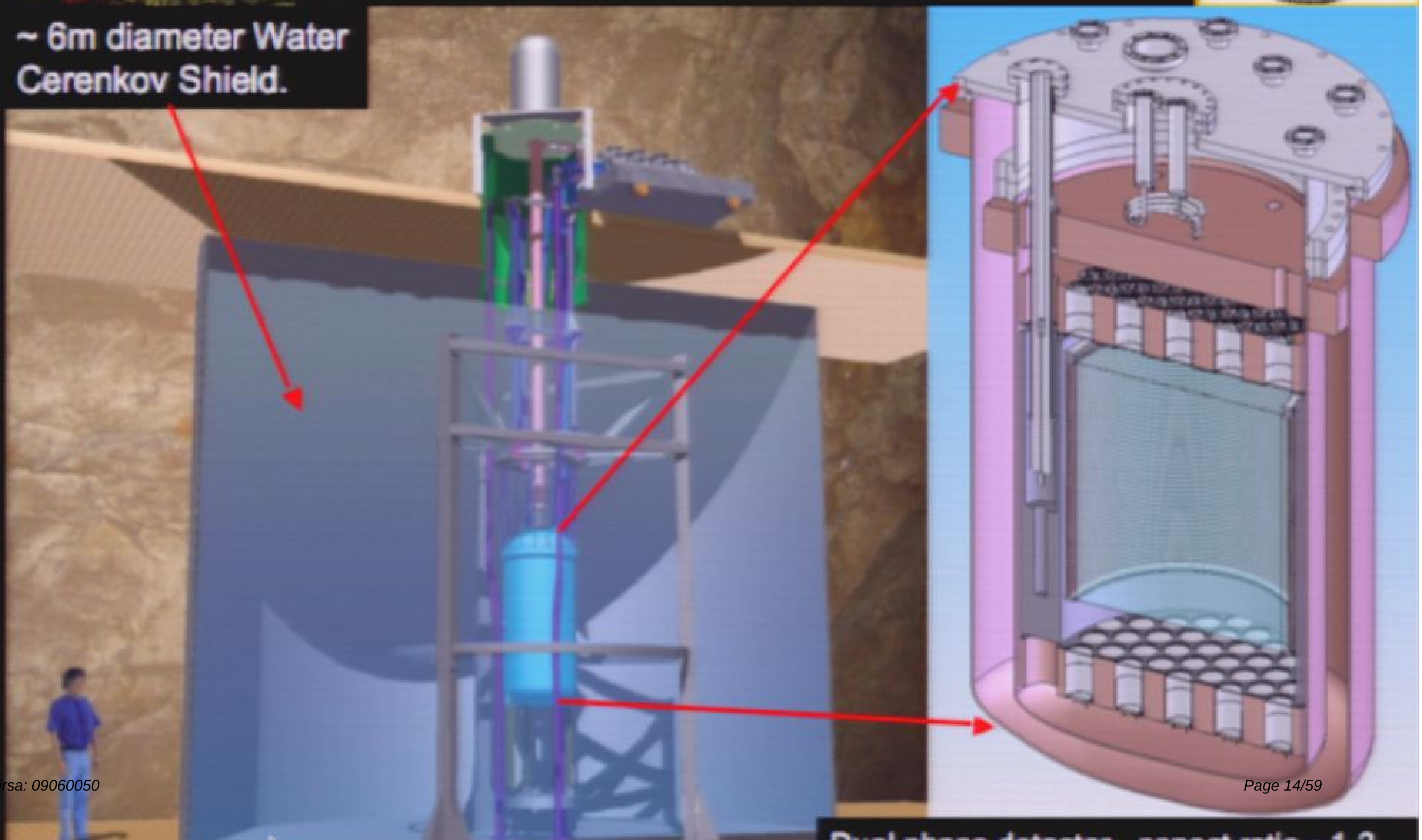
THE UNIVERSITY OF CALIFORNIA
DAVIS

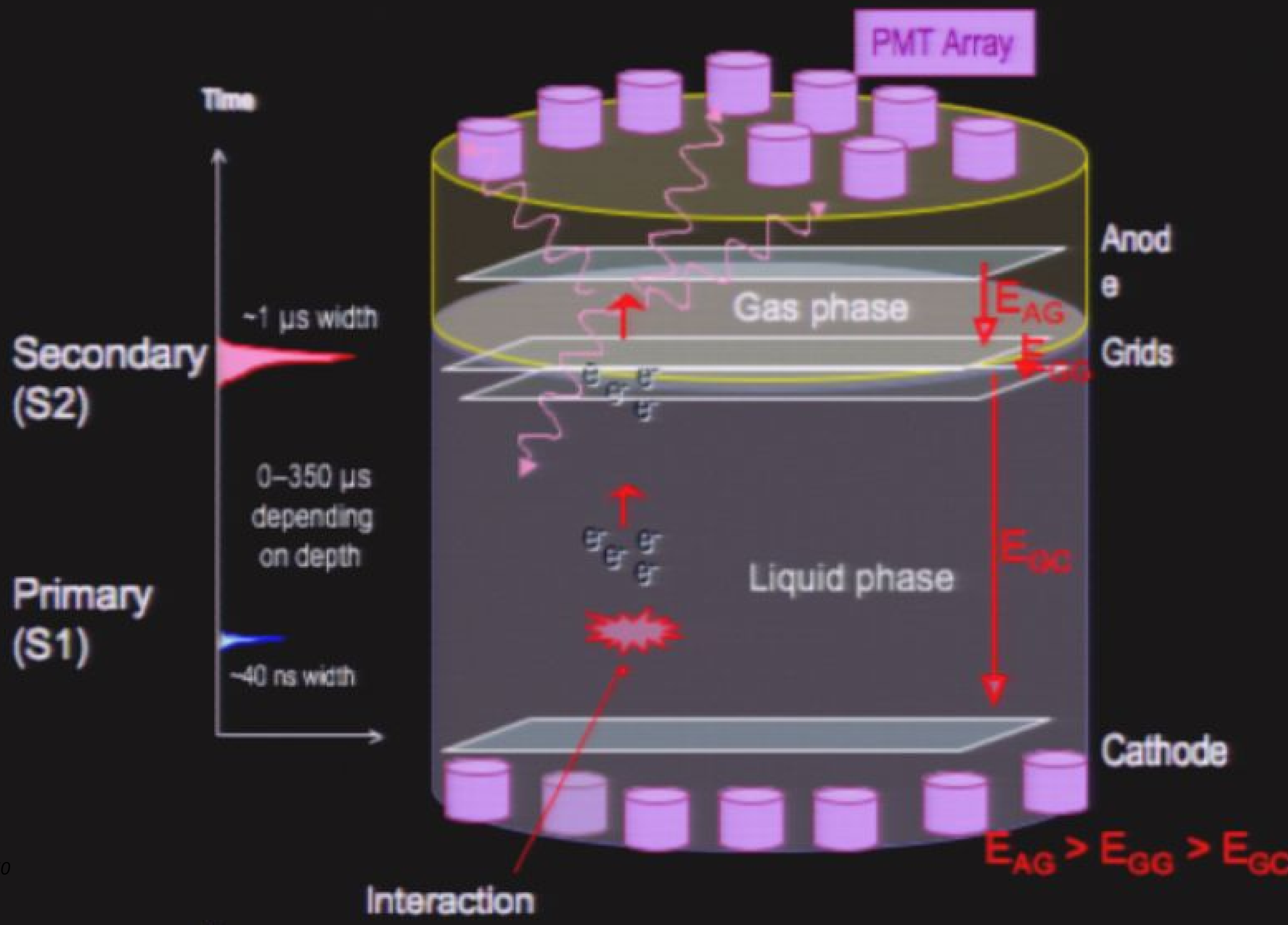
No Signa
VGA-1

No Signal
VGA-1

The LUX detector



Two Signal Technique

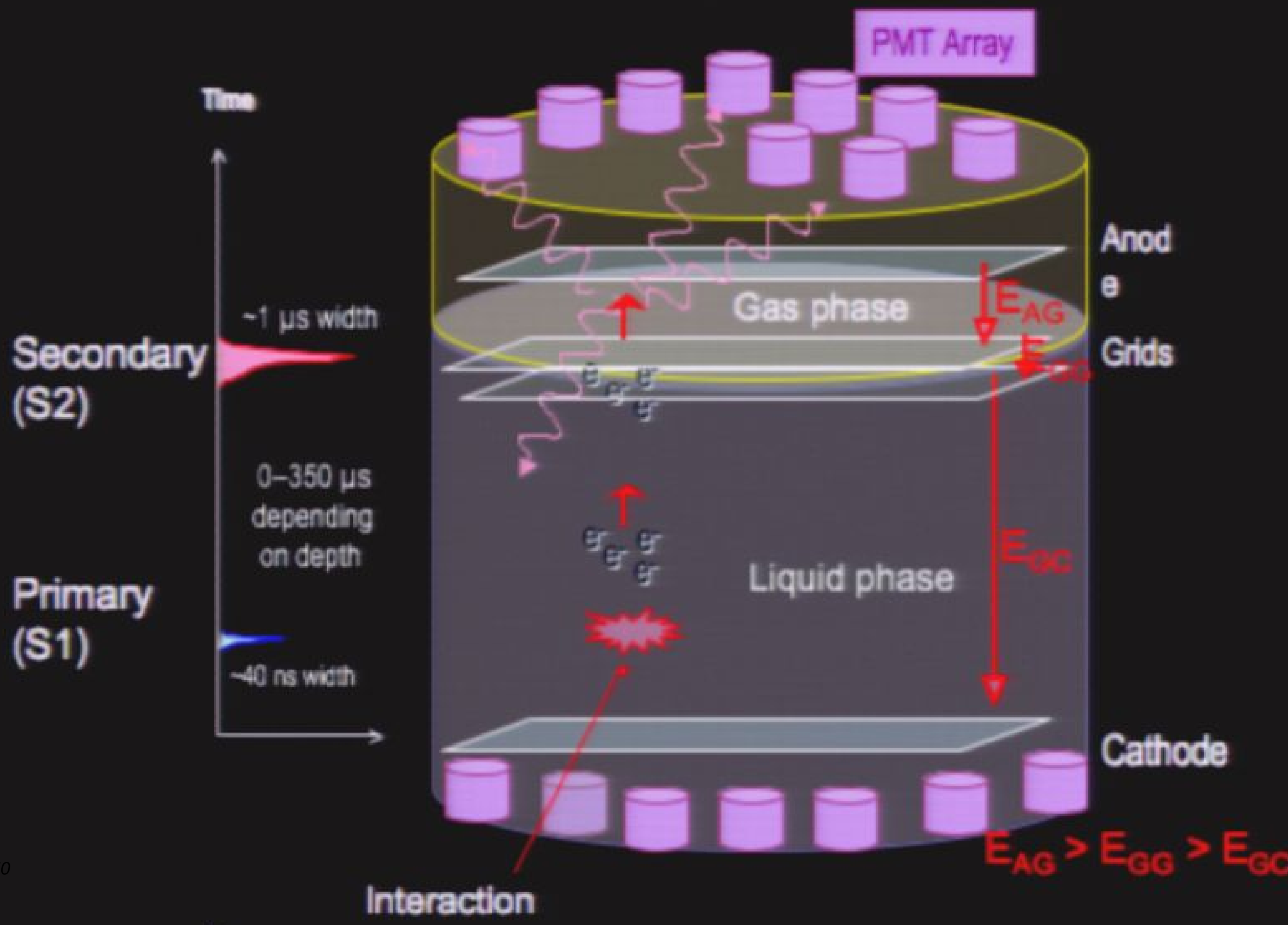


No Signa
VGA-1

No Signal

VGA-1

Two Signal Technique



LUX Approach to DM search

Maximise WIMP rate -- choice of Xe as target
large total mass of target ~100 kg fiducial

Minimize internal background sources -- new sensor developments
new materials -- titanium cryostat
purification techniques

Absorb/Tag external backgrounds -- active water cherenkov shield
active liquid scintillator bottle?

Maintain stable operations over long periods -- extensive monitoring
frequent calibrations

Well understood detector response -- in-situ Kr-83m calibration?

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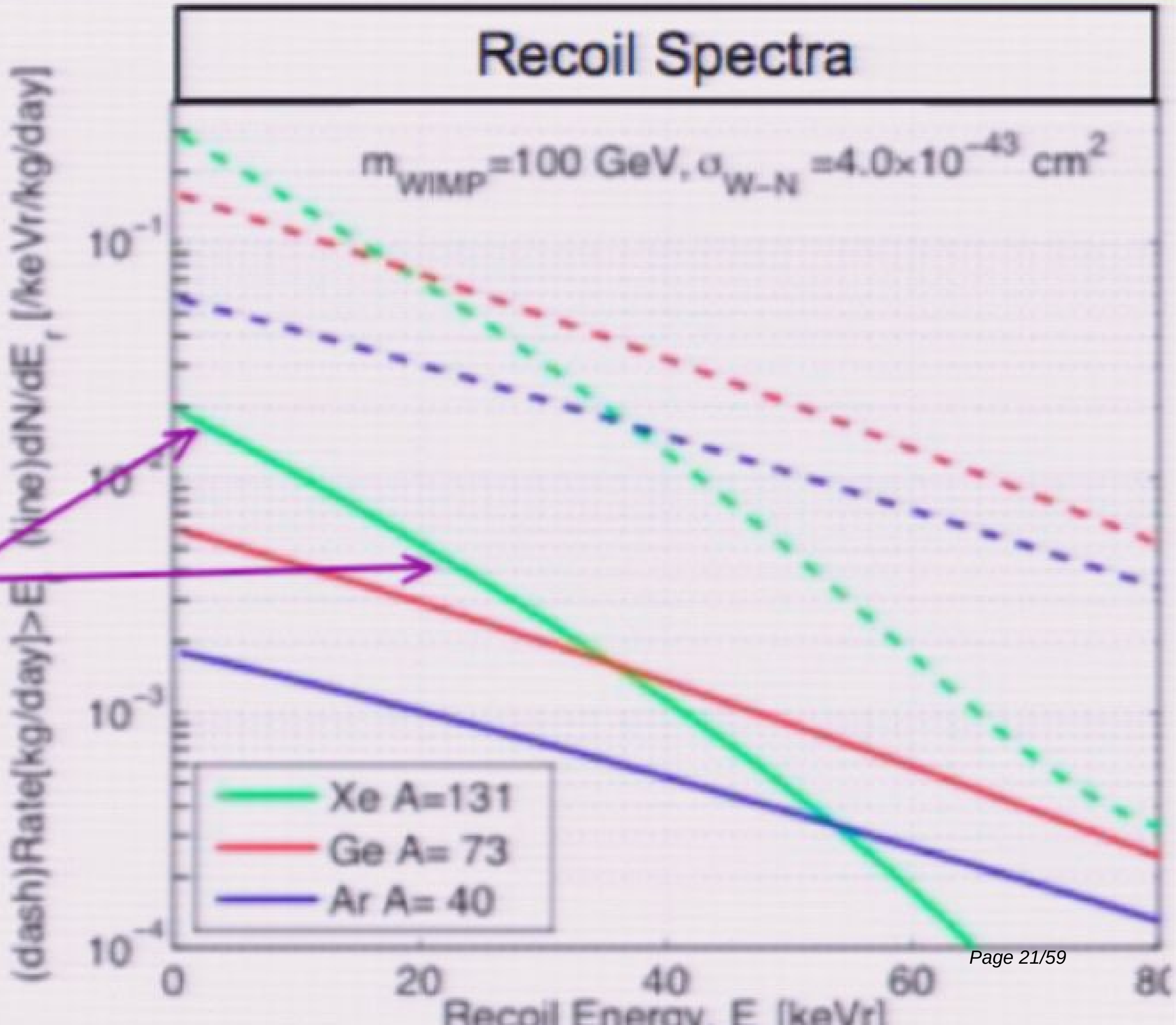
Why Xenon?

Higher Sensitivity
in the range
2keV < E < 20 keV.



Mani Tripathi, June 2009

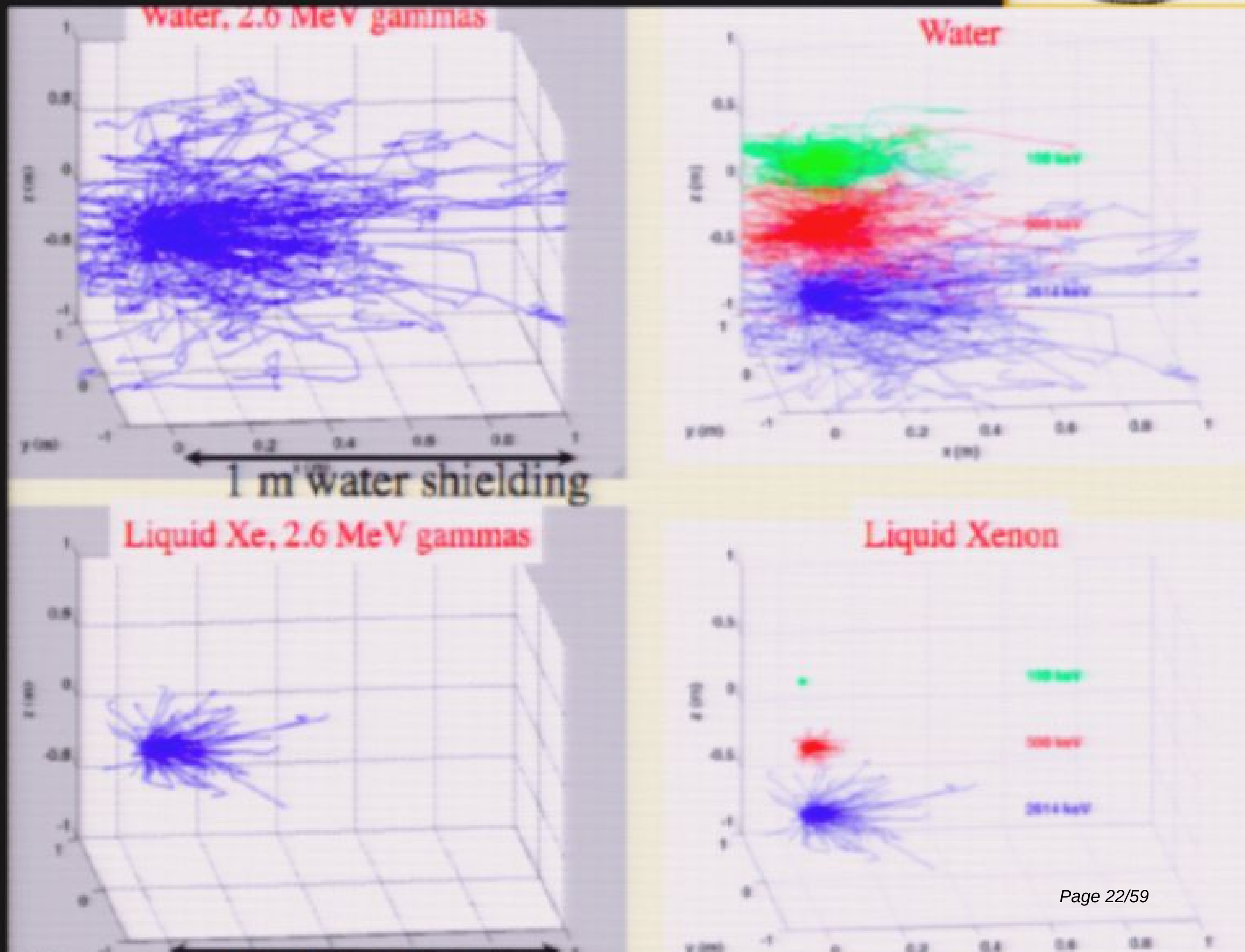
Why Xenon? (contd.)

Very powerful Self-shielding In Xe.

Effective when size > atten. length

=>

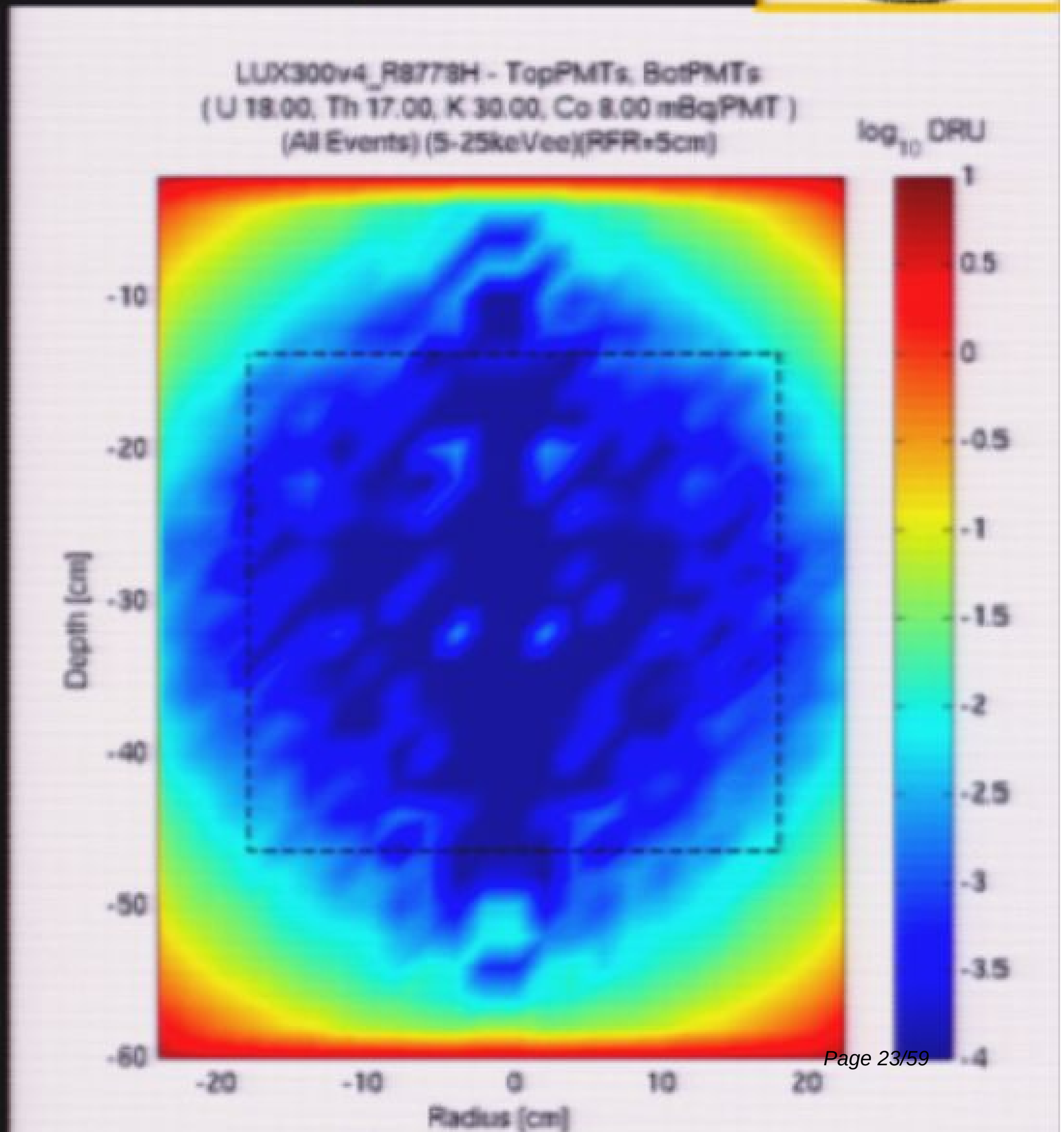
Mass > 300 kg.



Backgrounds (Gamma)

- Internal strong self-shielding against PMT activity (main source of background events). Double Compton scatters are rejected.

- External large water shield with muon veto. Very effective for cavern γ



Backgrounds (Neutrons)

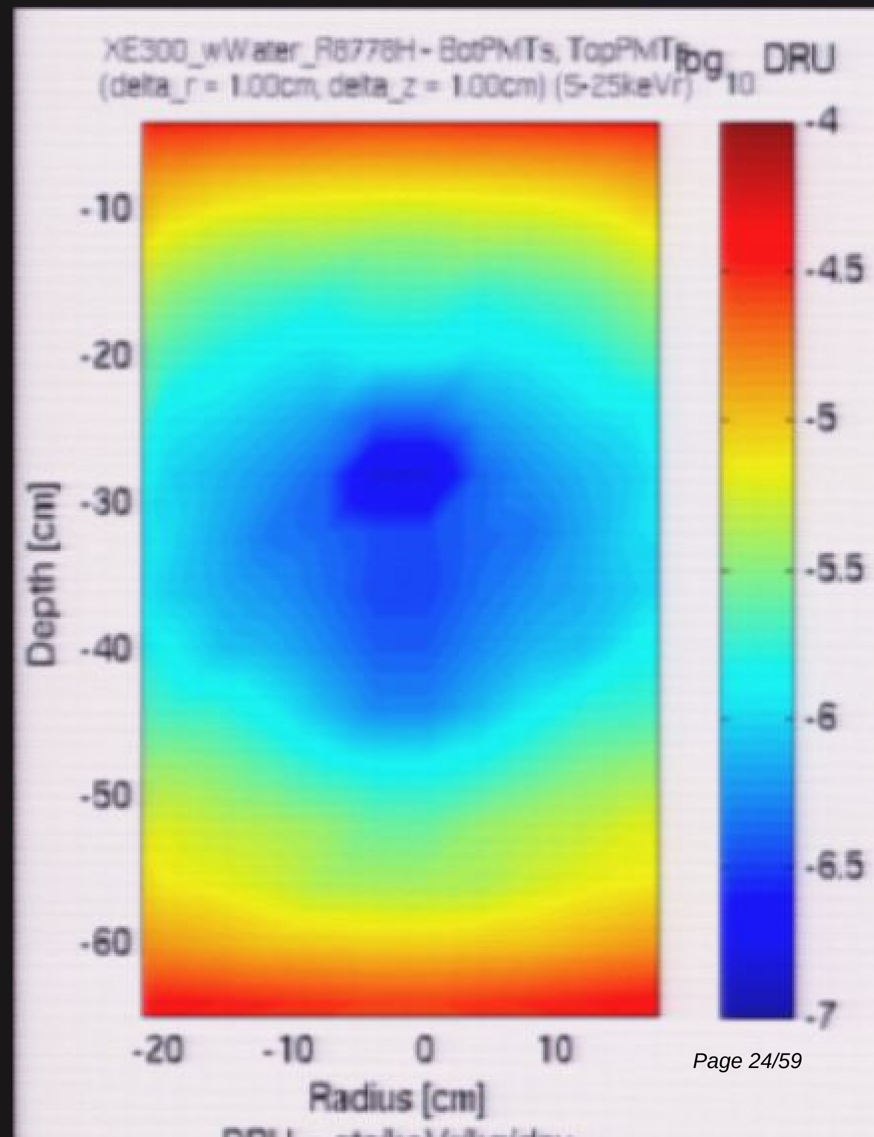
- <u>Internal</u>

  Neutrons (α,n) & fission << γ + β.

  ~65% double scatter.

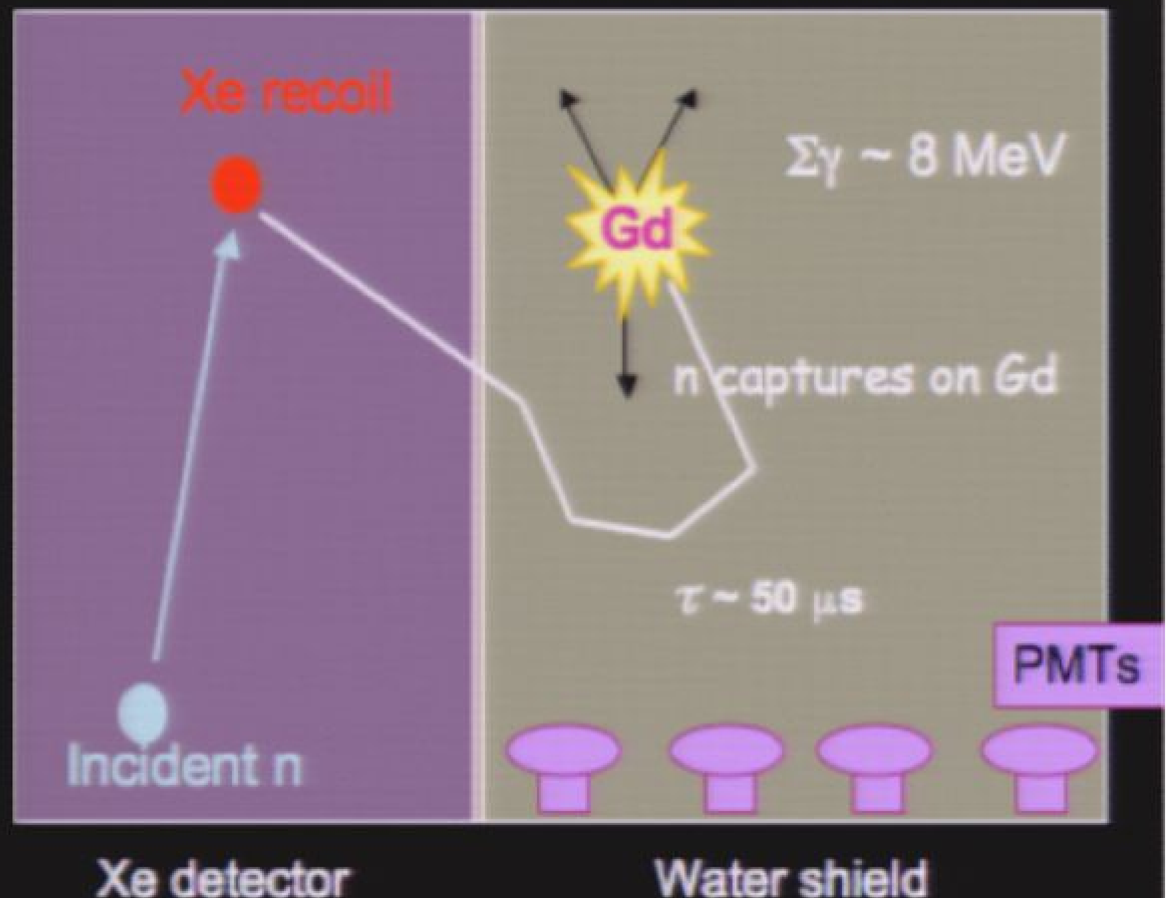
  (PMTs are the main source)

- <u>External</u> large water shield with muon veto.
  - Very effective for cavern n, and HE neutrons from muons
  - Possible <u>upgrade</u> of adding Gd to the water.

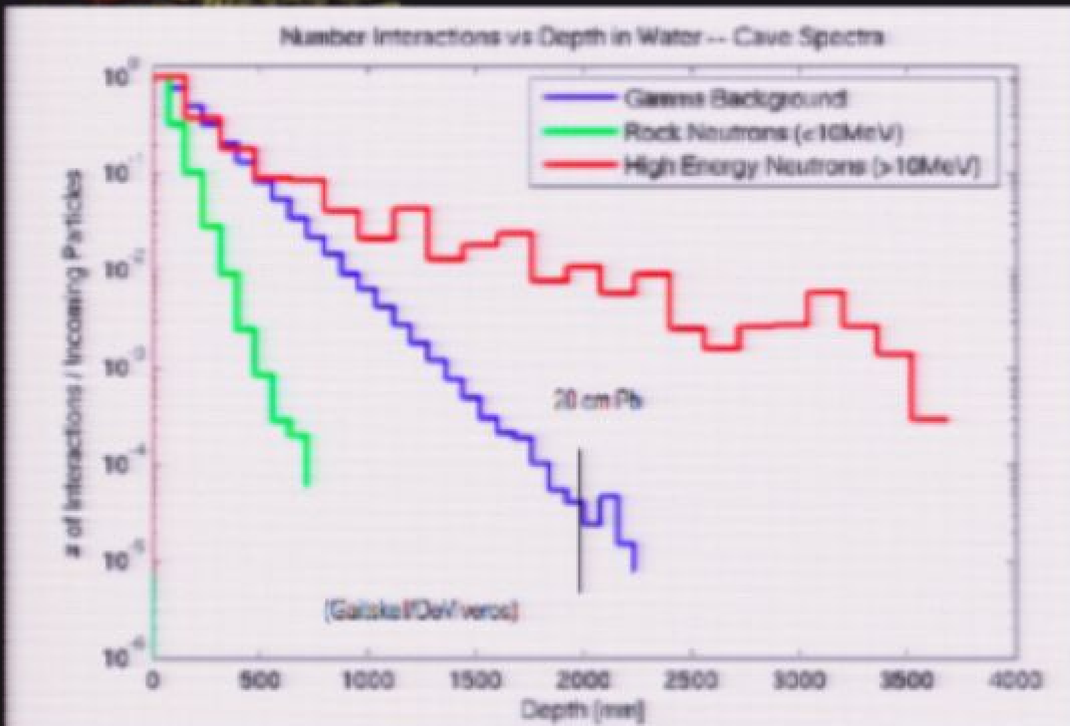


Water Shield & Veto

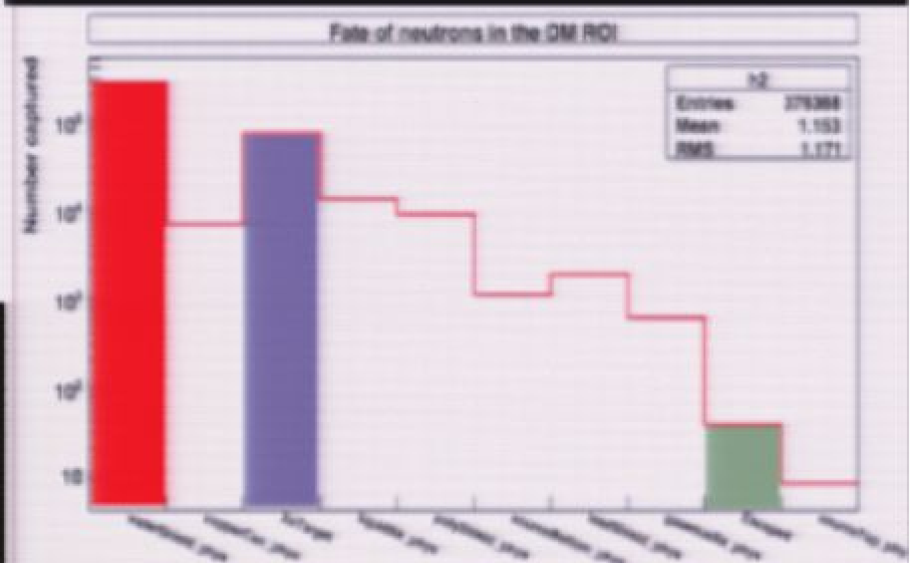
- Veto on incoming muons via Cherenkov light signal.
- Tag thermalized neutrons generated within the detector.
- Gd (0.2%) in water gives a capture efficiency of > 90% for thermal neutrons, followed by an 8 MeV gamma cascade.



Water Shield (Contd.)



Effective against fast neutrons.



Cost-effective and scalable. Very low gamma backgrounds with readily achievable $<10^{-11}$ g/g purity for water.

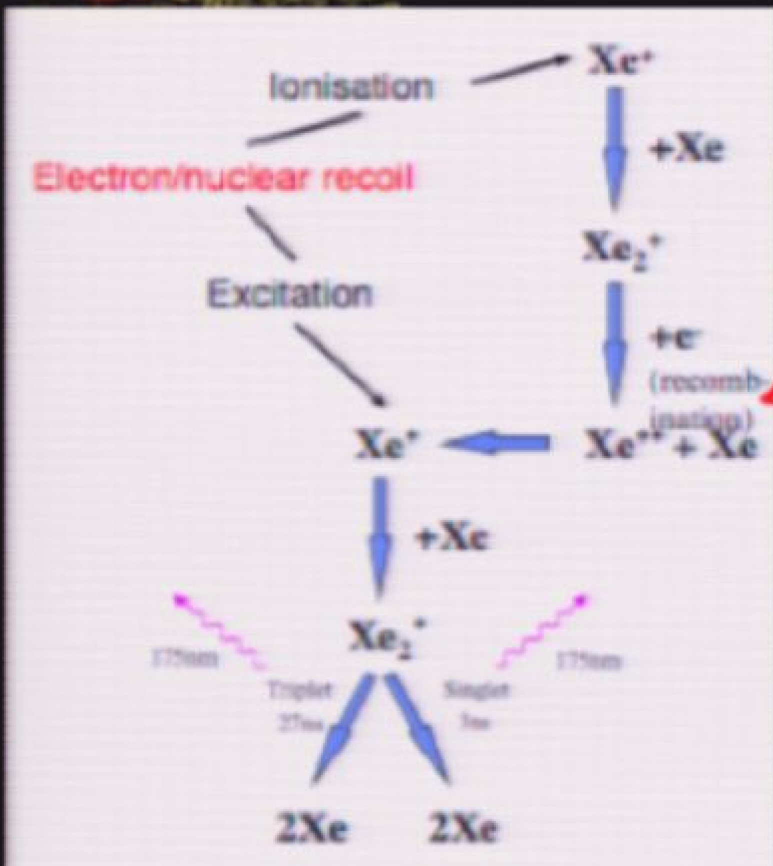
72% of ROI neutrons capture in the Gd-H_2O shield

19% of ROI neutrons capture in the active Xe target

LUX Parameters

- 350 kg Dual Phase liquid Xe TPC
- 2 KV/cm field in liquid, 5 KV/cm for extraction and 10 KV/cm field in gas phase
- 60 PMTs (Hamamatsu R8778) each in top and bottom arrays
- 3D-imaging TPC eliminates surface activity, defines fiducial
- ~100 kg achievable in the fiducial volume

γ/neutron Discrimination



Differences in recombination efficiency is exploited to discriminate between electron and nuclear recoils.

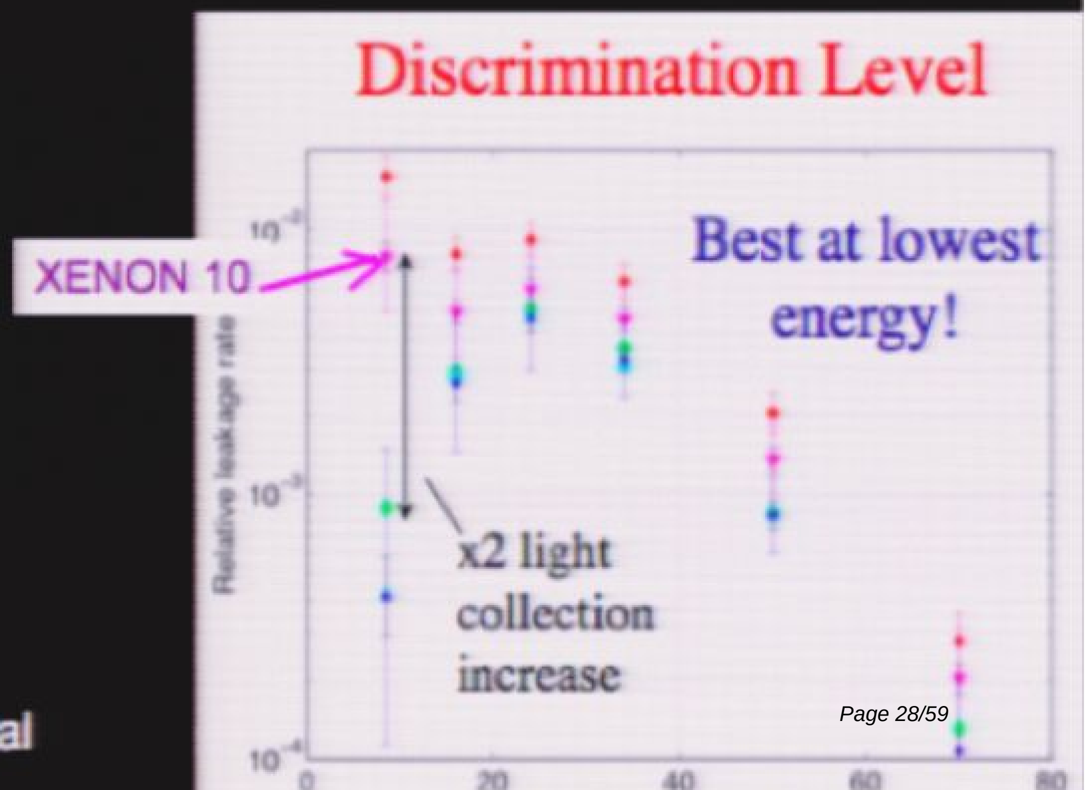
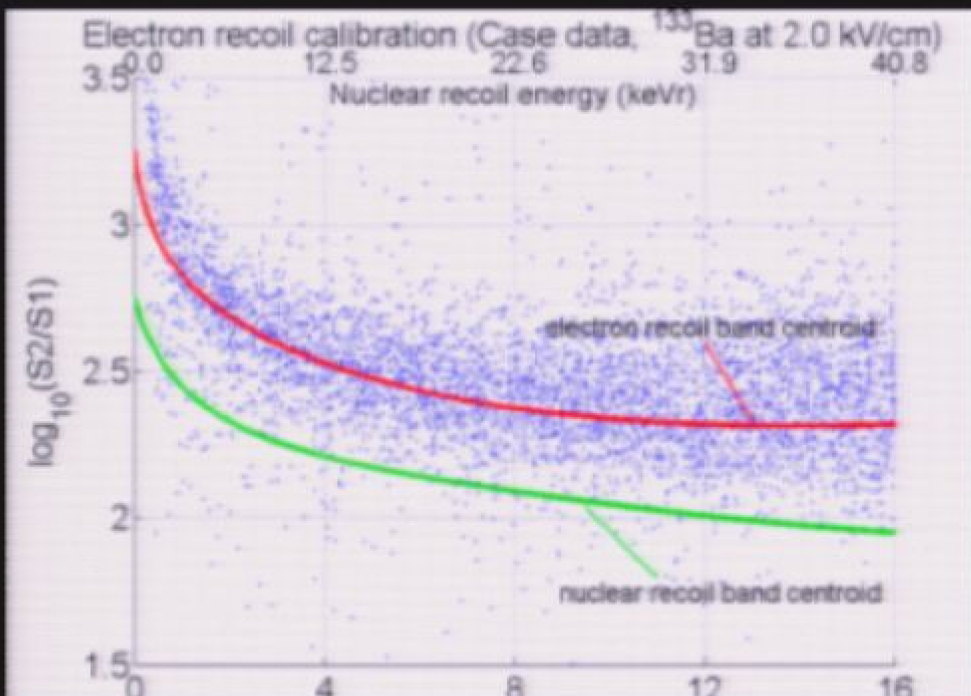


Figure of merit derived from plots of:

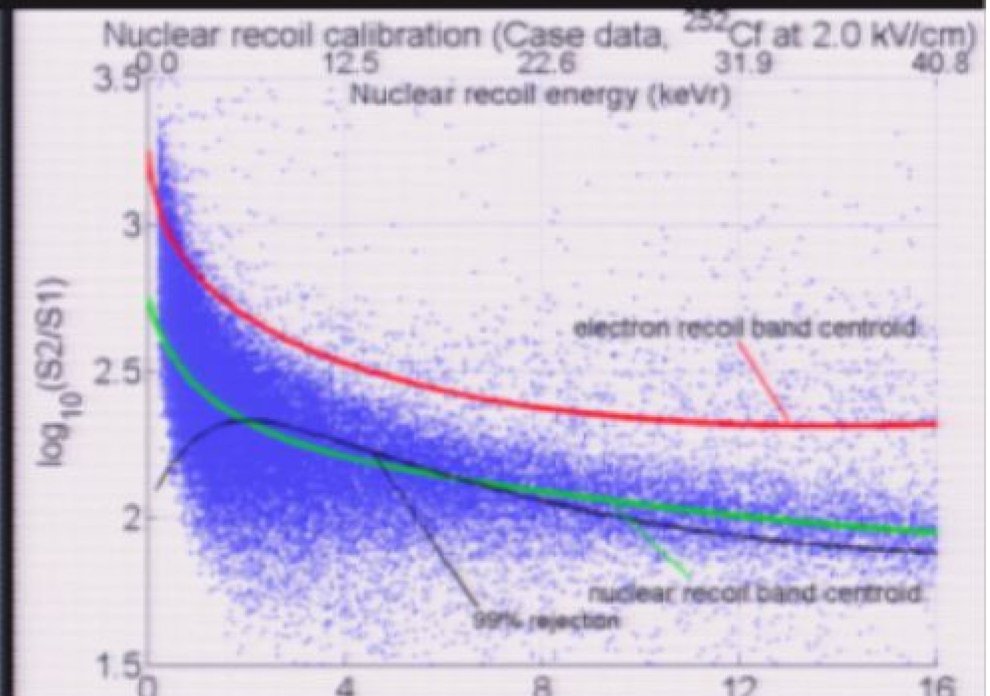
Log (charge escaping recombination/total

Calibration Data (Prototype Cell at Case)

^{133}Ba Electrons



^{252}Cf Neutrons



Recoil Energy (keVr)

Recoil Energy (keVr)

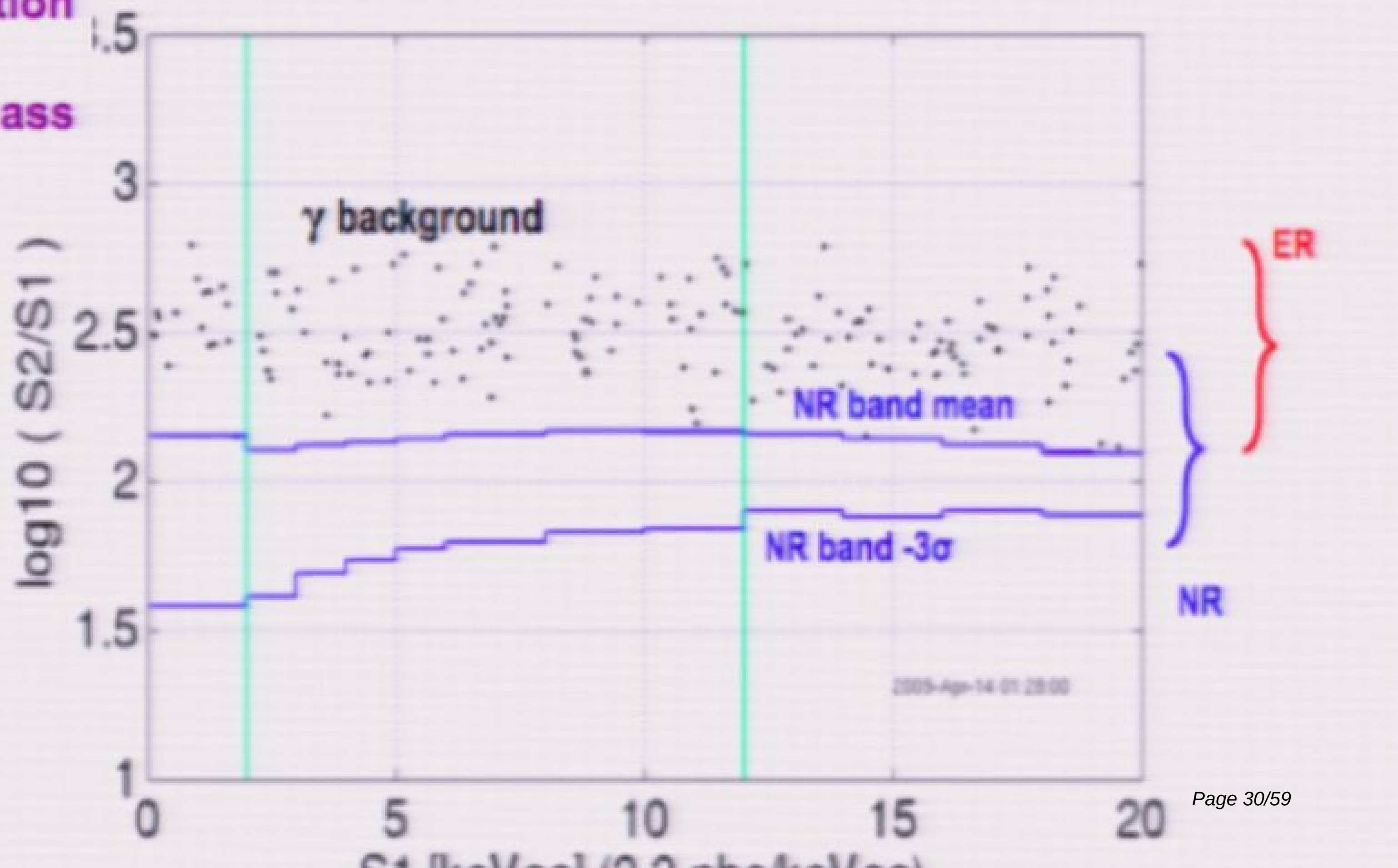
These measurements were made above ground, but agree well with Xenon10 experience.

Simulated Signal in LUX

Electron recoil background ~2.6×10^{-4} dru (based on screening of materials)

300 days acquisition

100 kg fiducial mass

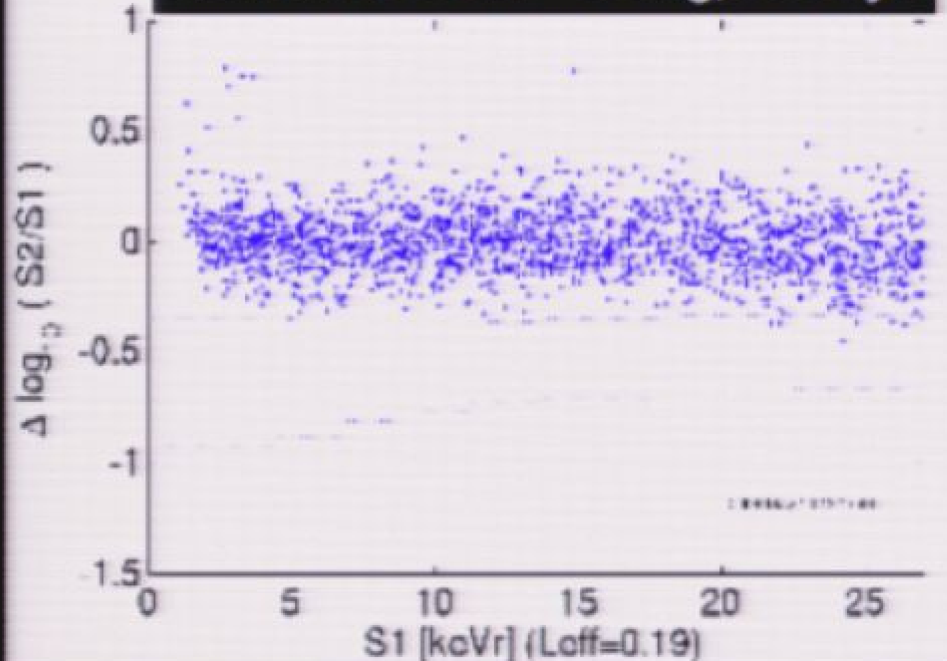


$L_{eff} = 0.19$

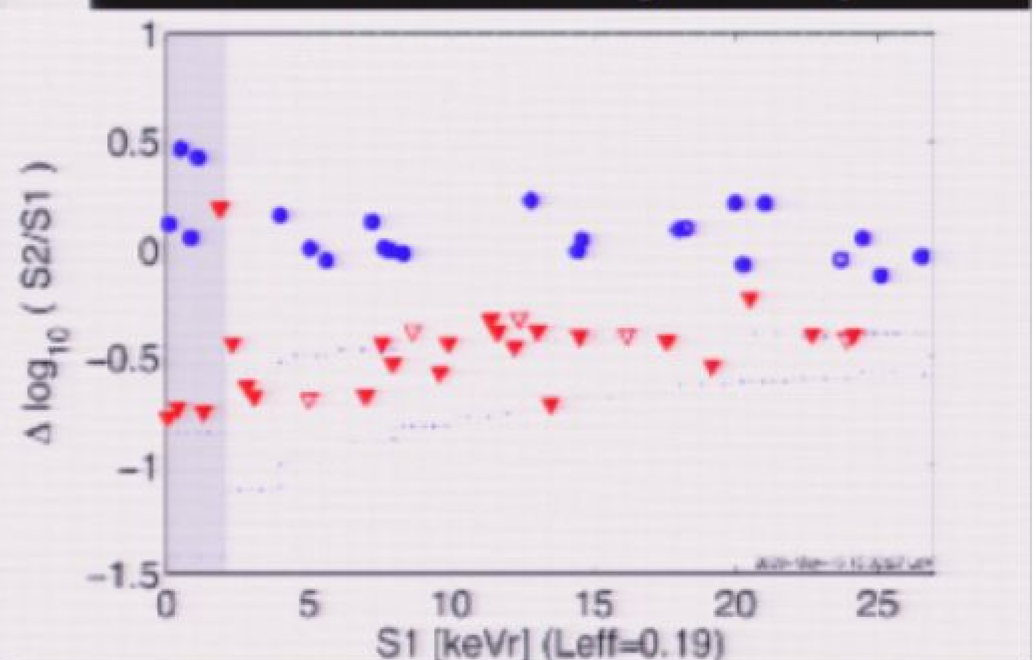
Using same
ER and NR bands

Power of self-shielding

XENON10 Data -- 5.4 kg, 59 days



LUX Simulation -- 100 kg, 100 days



Red points are for a simulated signal of 100 GeV WIMP and a cross section $5x10^{-45}$ cm^2

Calibration Data (Prototype Cell at Case)

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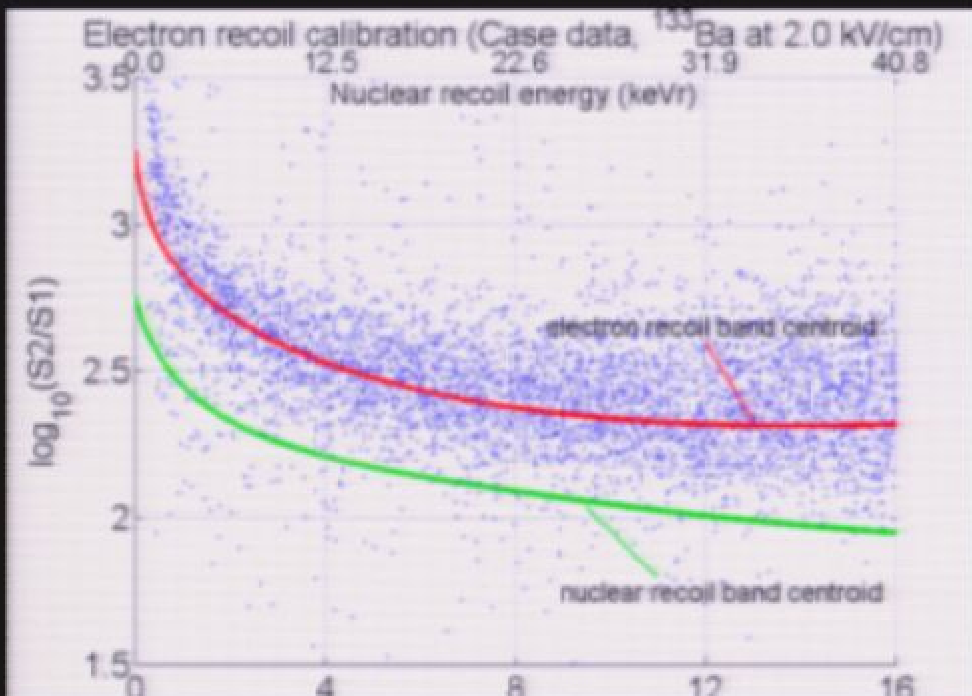

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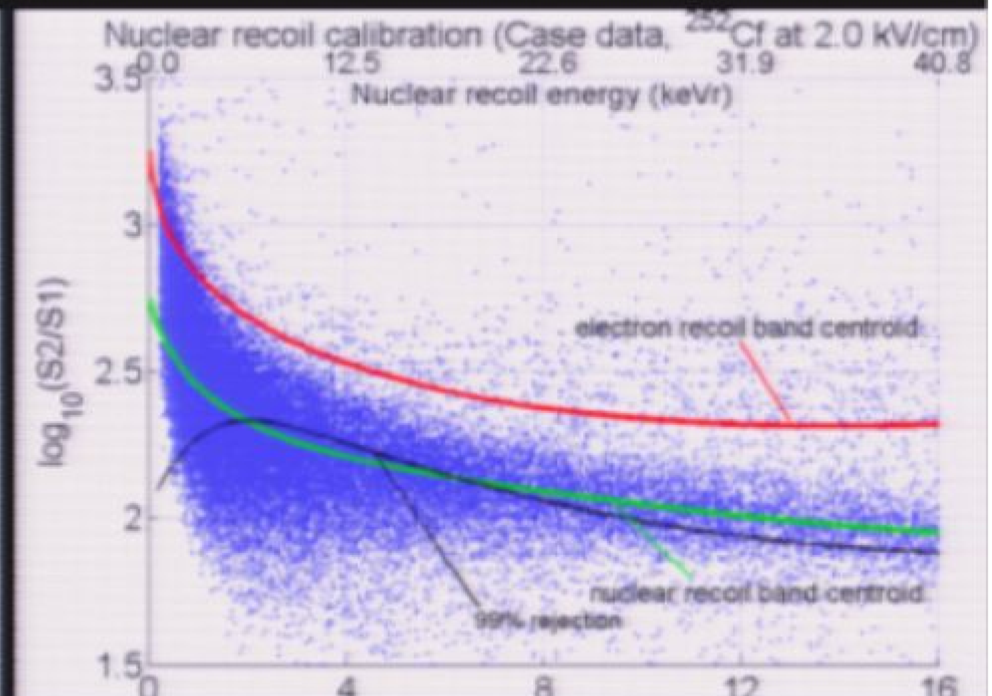

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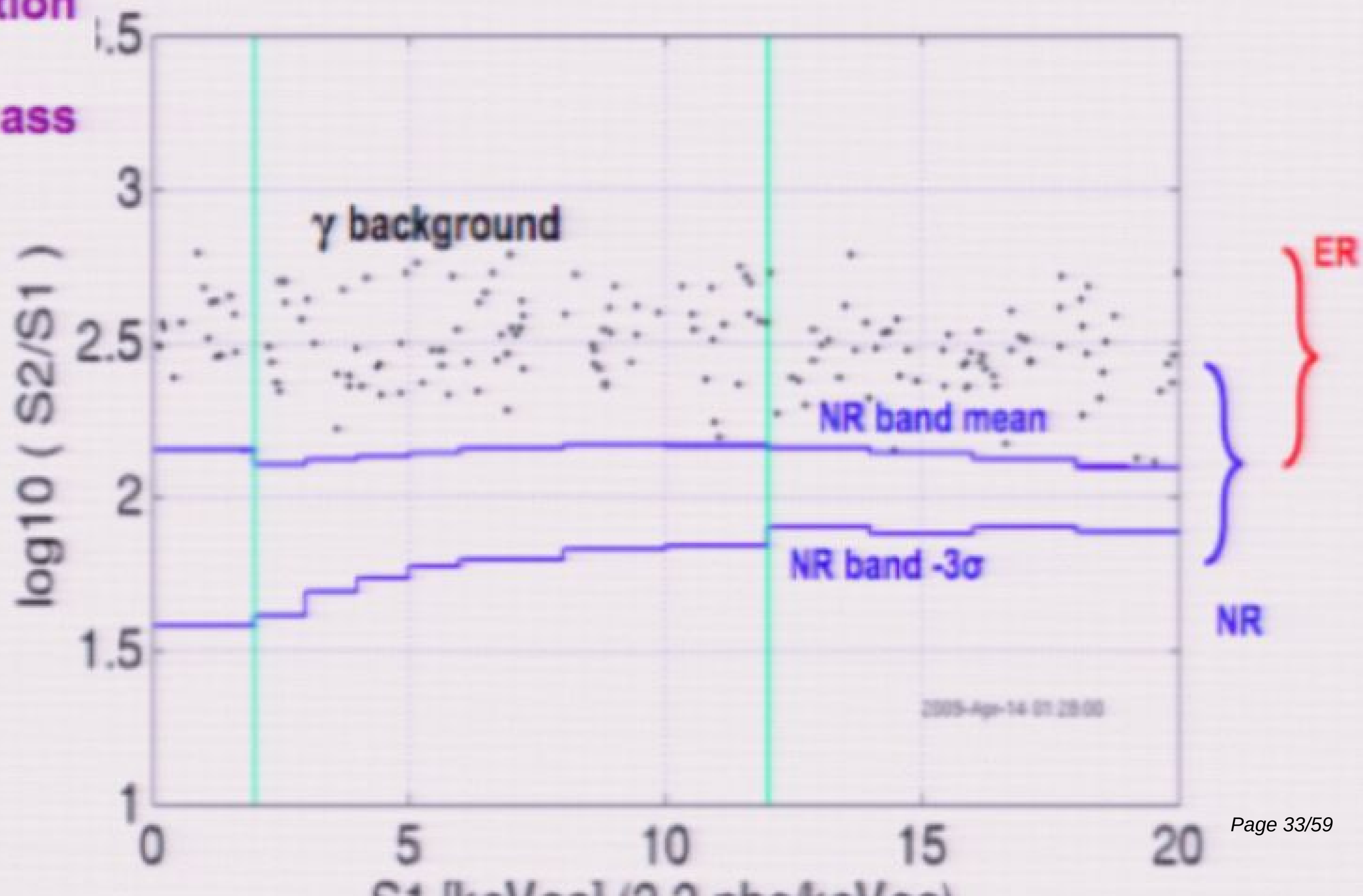

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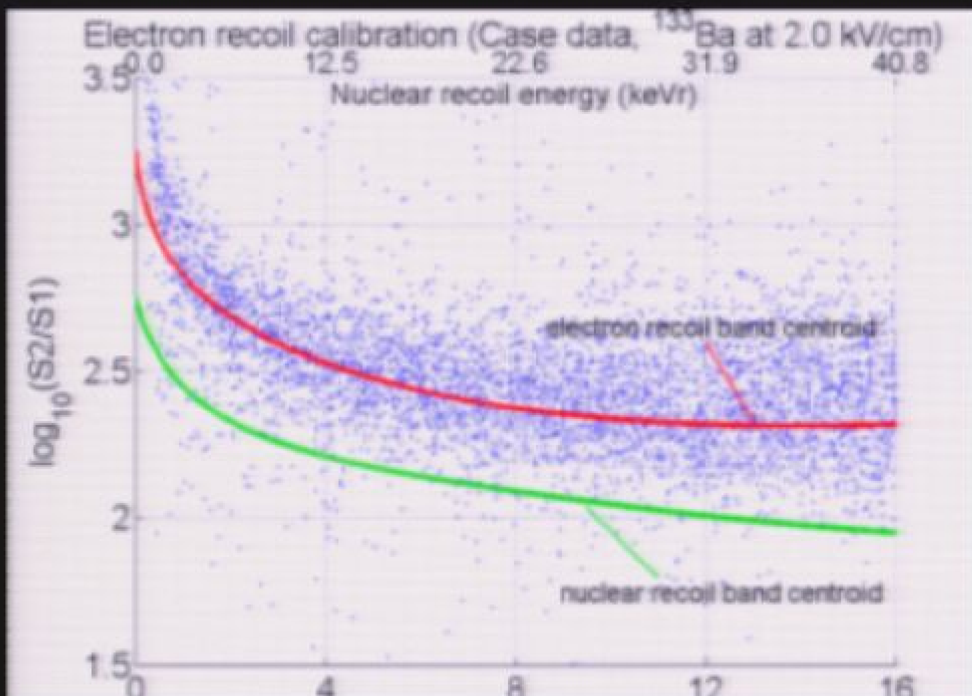

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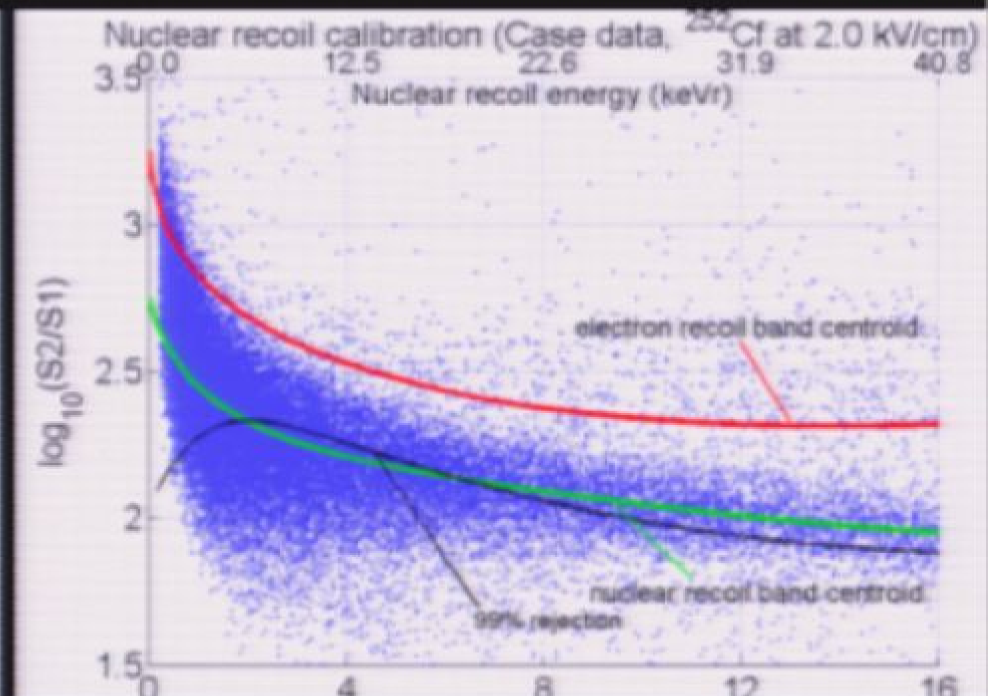

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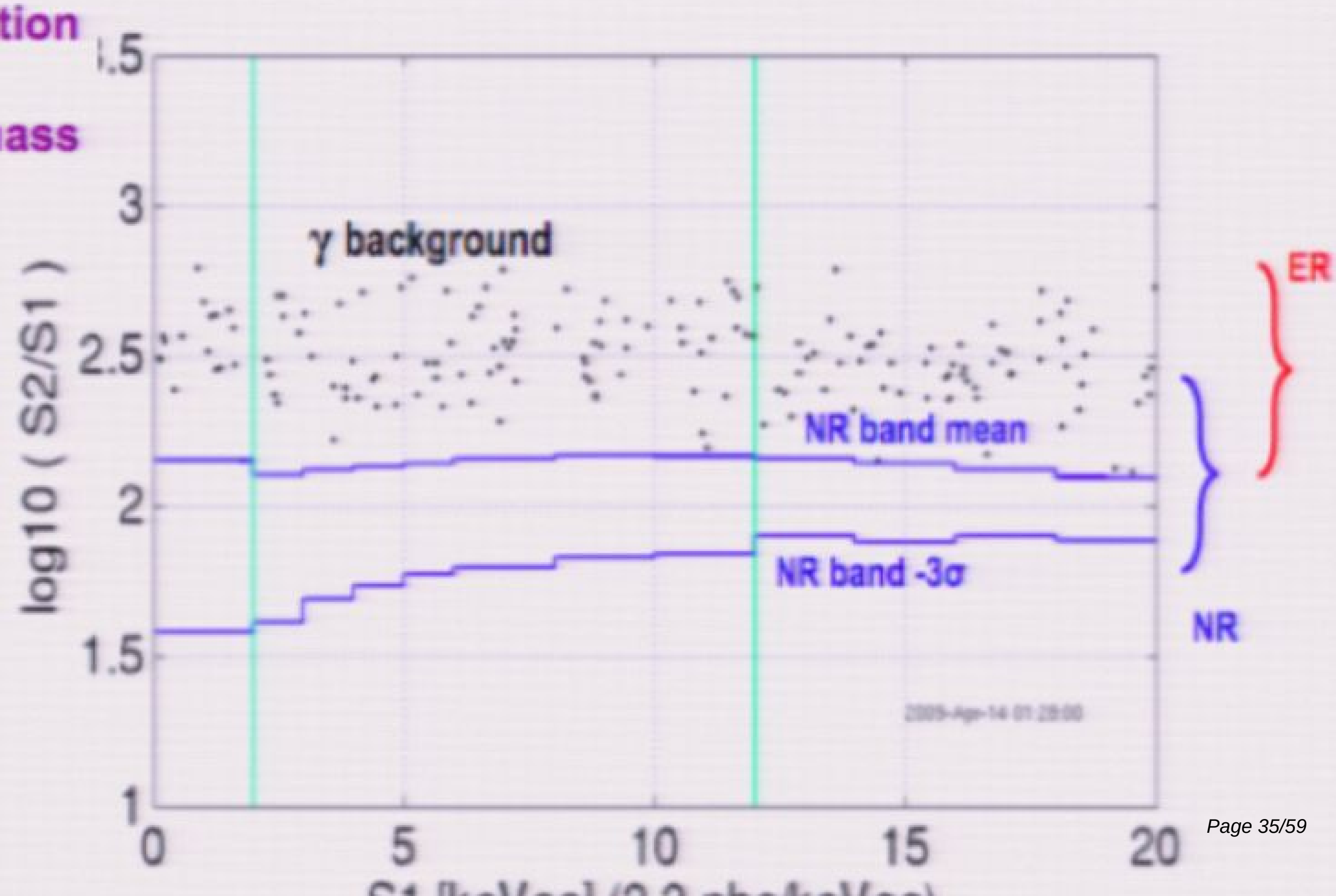

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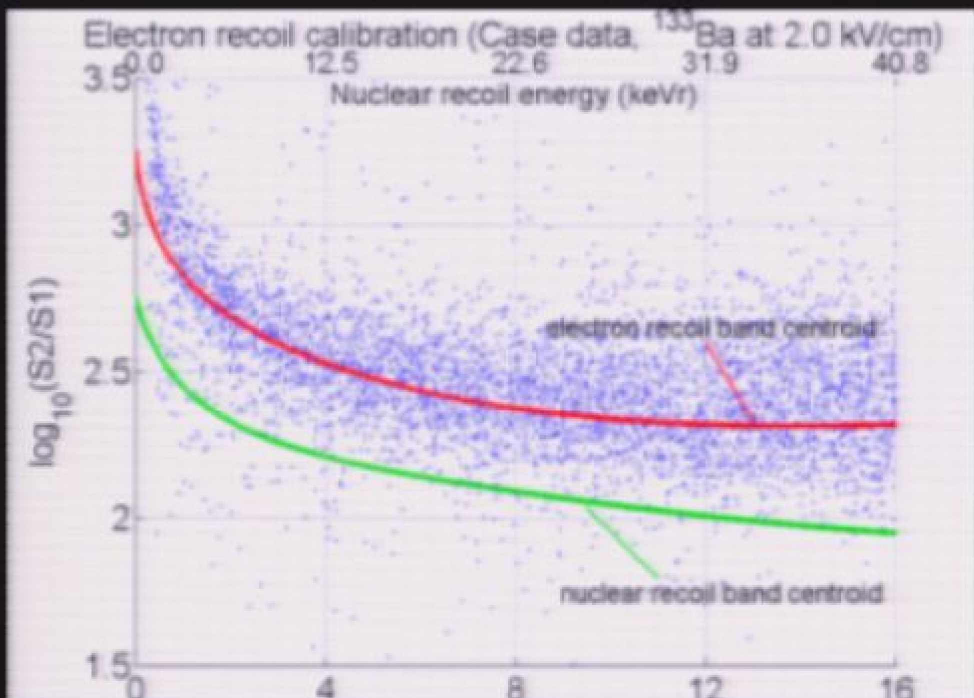

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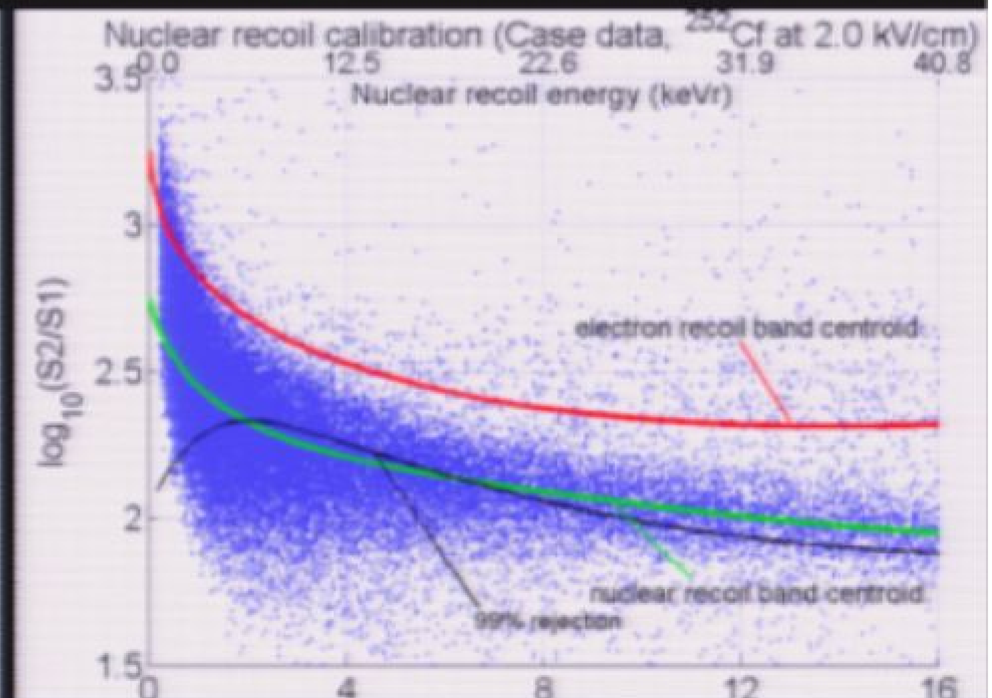

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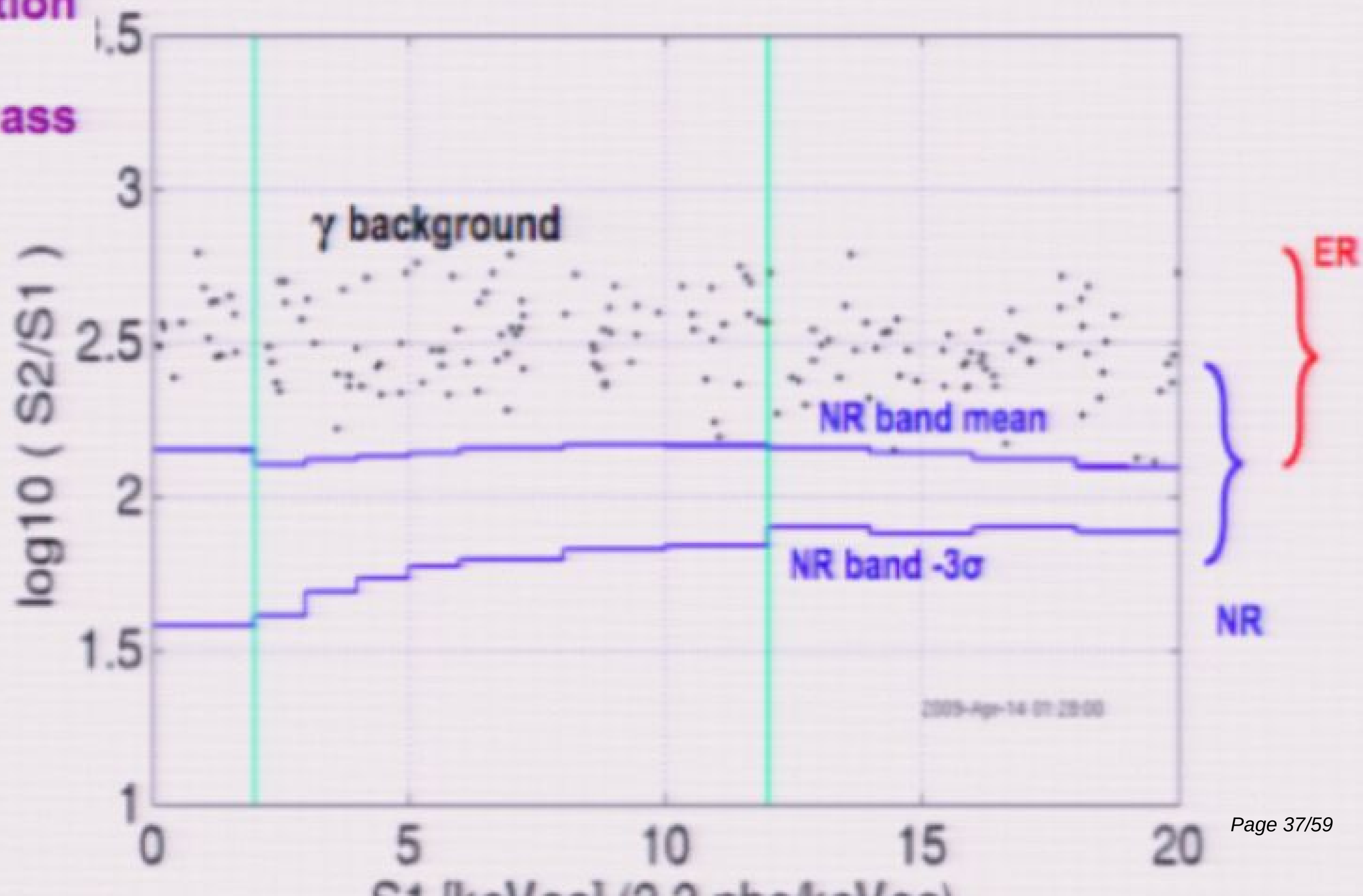

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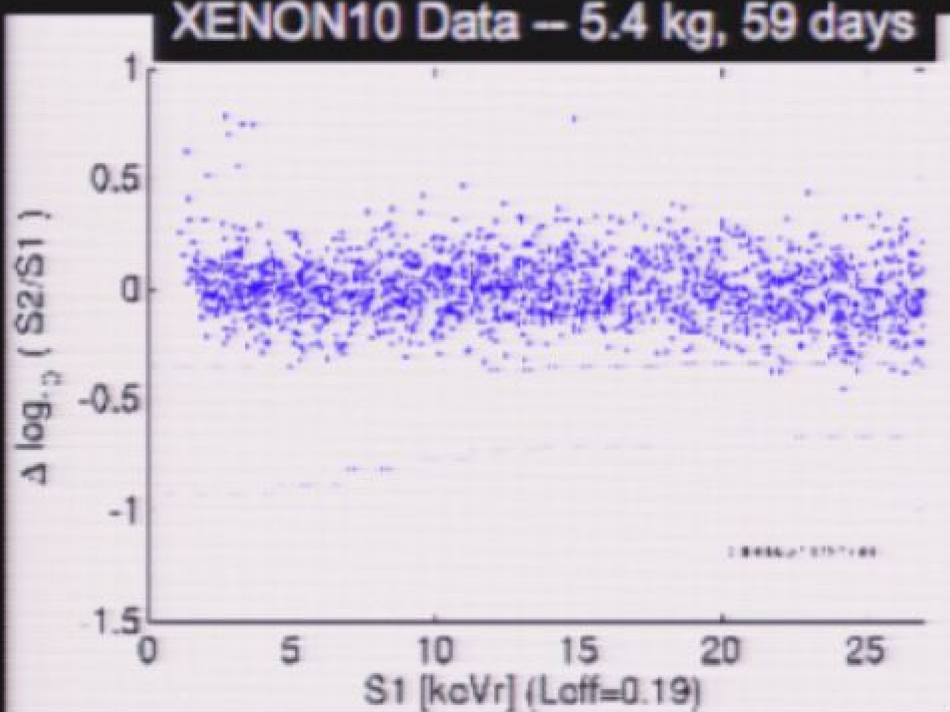
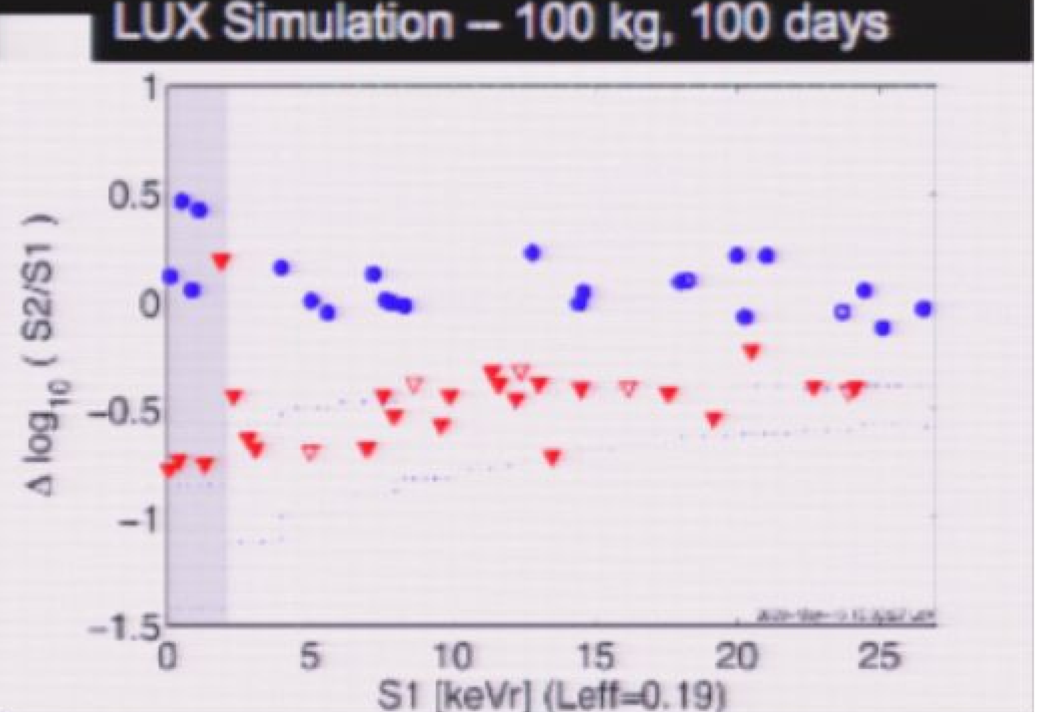


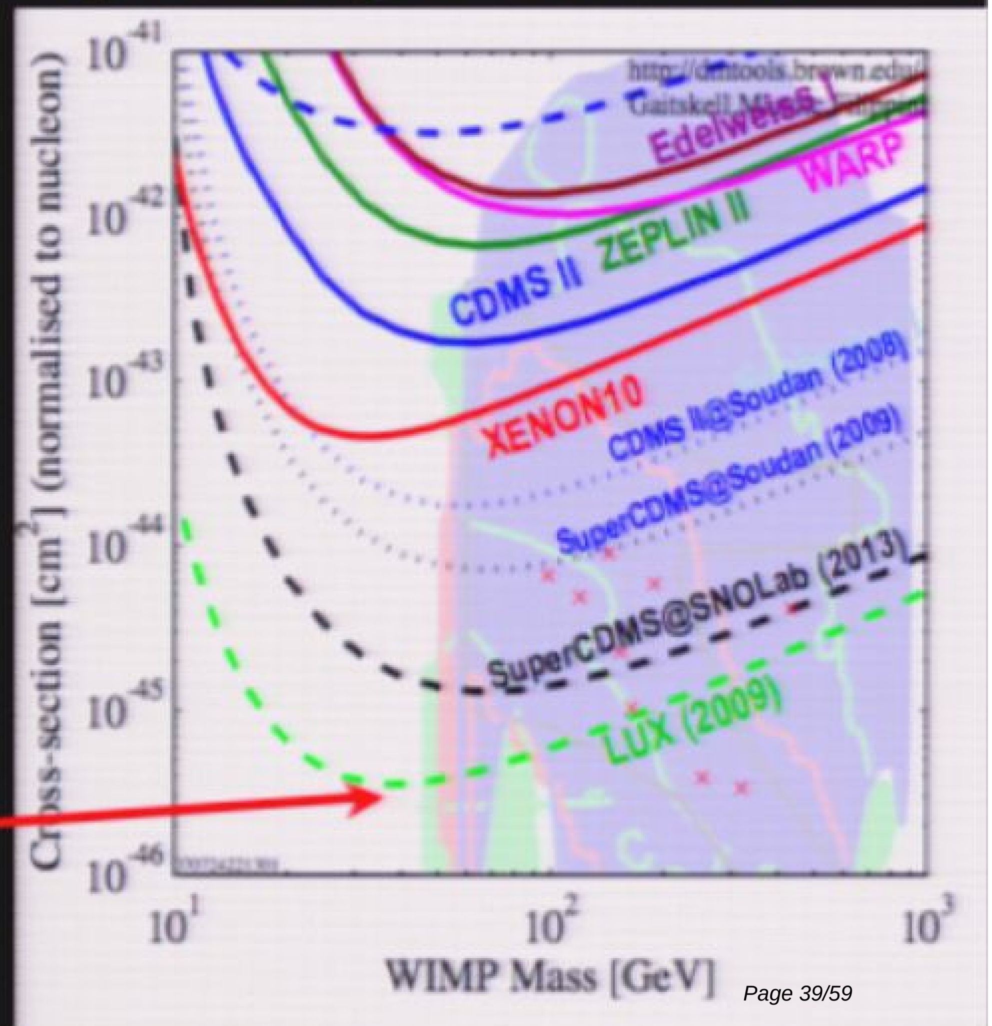


Red points are for a simulated signal of 100 GeV WIMP and a cross section 5×10^{-45} cm^2

LUX Goals

- 99.3 – 99.9% Electron Recoil background rejection for 50% Neutron Recoil acceptance, in the range 5 keVr < E < 25 keV
- $\gamma + \beta$ rate $< 8 \times 10^{-4}$ events/kg/keVee/day with 99.4% rejection (conservative)
- 10 month run w/ 50% NR acceptance (net 15,000 kg-days)
- <u>DM reach</u> $\sigma \sim 4\times10^{-46}$ cm^2

(Equivalent to an event rate of ~0.4/100kg/month in 100kg fiducial)



Goals (Contd.)

GOAL FOR WIMP SIGNAL SENSITIVTY AND REFERENCE LEVELS (UPPER LIMITS) FOR BACKGROUNDS (5–25 keVr, 1.3-8 keVee)	NR Avg. Diff. Rate evts/keVr/kg/day	ER Avg. Diff. Rate evts/keVee/kg/day	Total Rate for a FV exposure of 30,000 kg-days (net live)
WIMP (m = 100 GeV, $\sigma = 7\text{x}10^{-46}$ cm^2)	$1.4\text{x}10^{-5}$		8.6
WIMP (after NR acceptance of 45%)	$6.5\text{x}10^{-6}$		3.9
ER Flat Spectrum (before ER rej.)		$8.3\text{x}10^{-4}$	180
ER Flat Spectrum (after ER rej. 99.4%)		$4.8\text{x}10^{-6}$	1.0
NR Neutron Spectrum	$3.7\text{x}10^{-6}$		2.2
NR Neutron Spectrum (after NR acceptance of 45%)	$1.7\text{x}10^{-6}$		1.0

Conservative

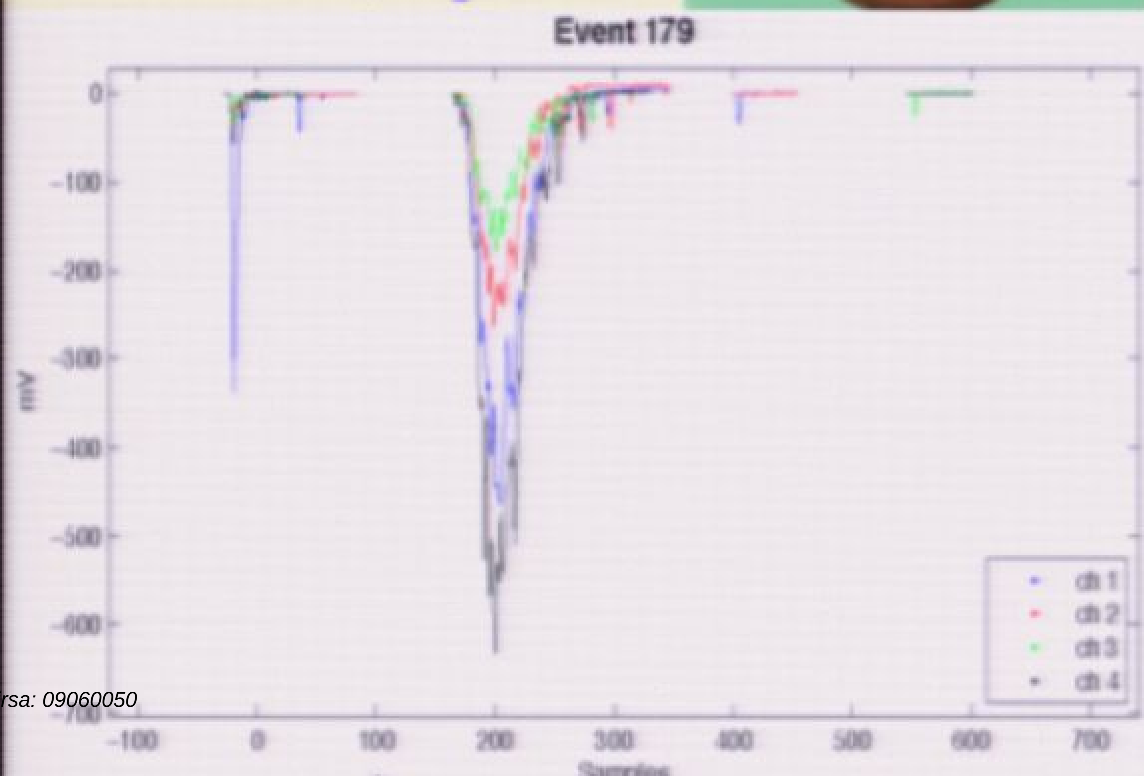
Mani Tripathi, June 2009

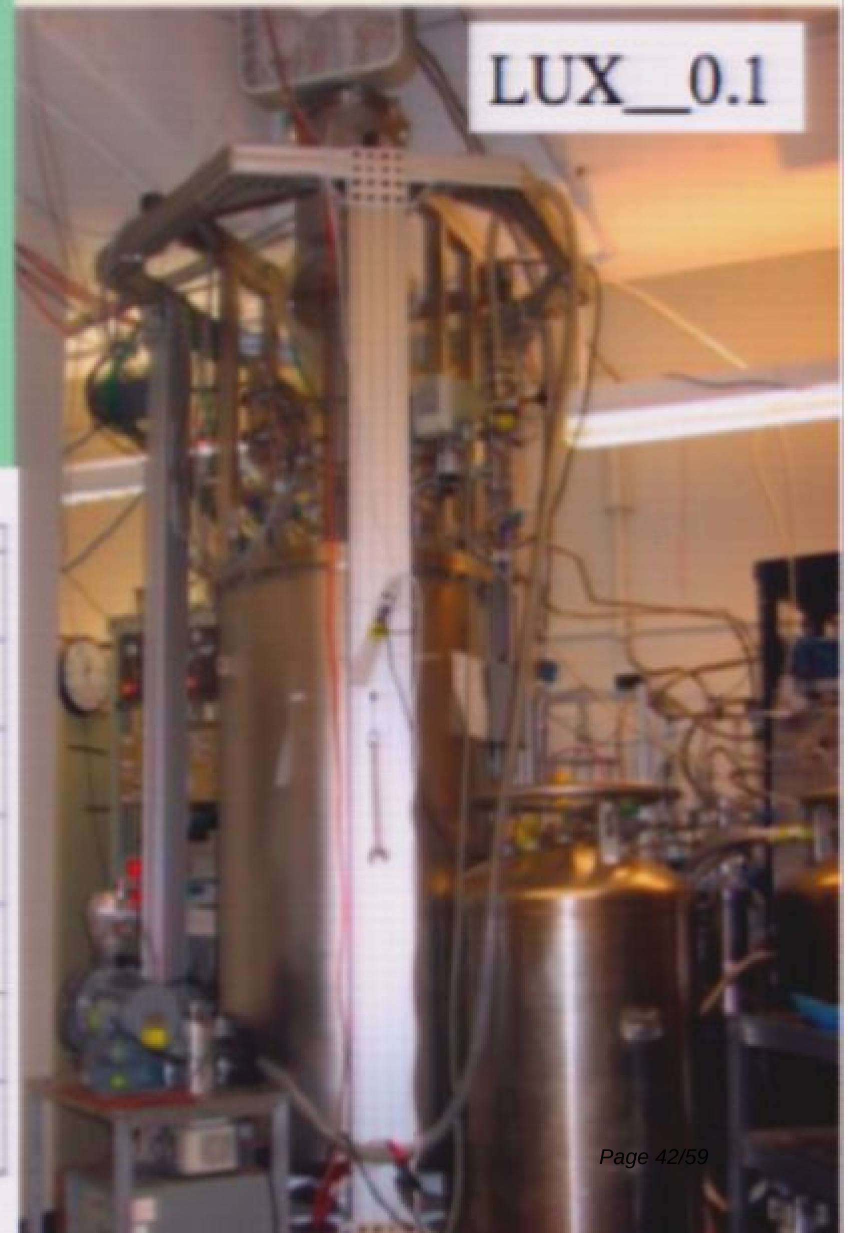
Status

- NSF/DoE funding received in 2008.
- DUSEL site selection => LUX can deploy as part of Homestake's Early Implementation Program => Sanford Lab.
- Detector components have been all designed and are in various stages of production.
- A surface facility at Sanford Lab for assembling LUX will become available ~Oct 2009.
- Deployment underground anticipated ~Feb 2010.

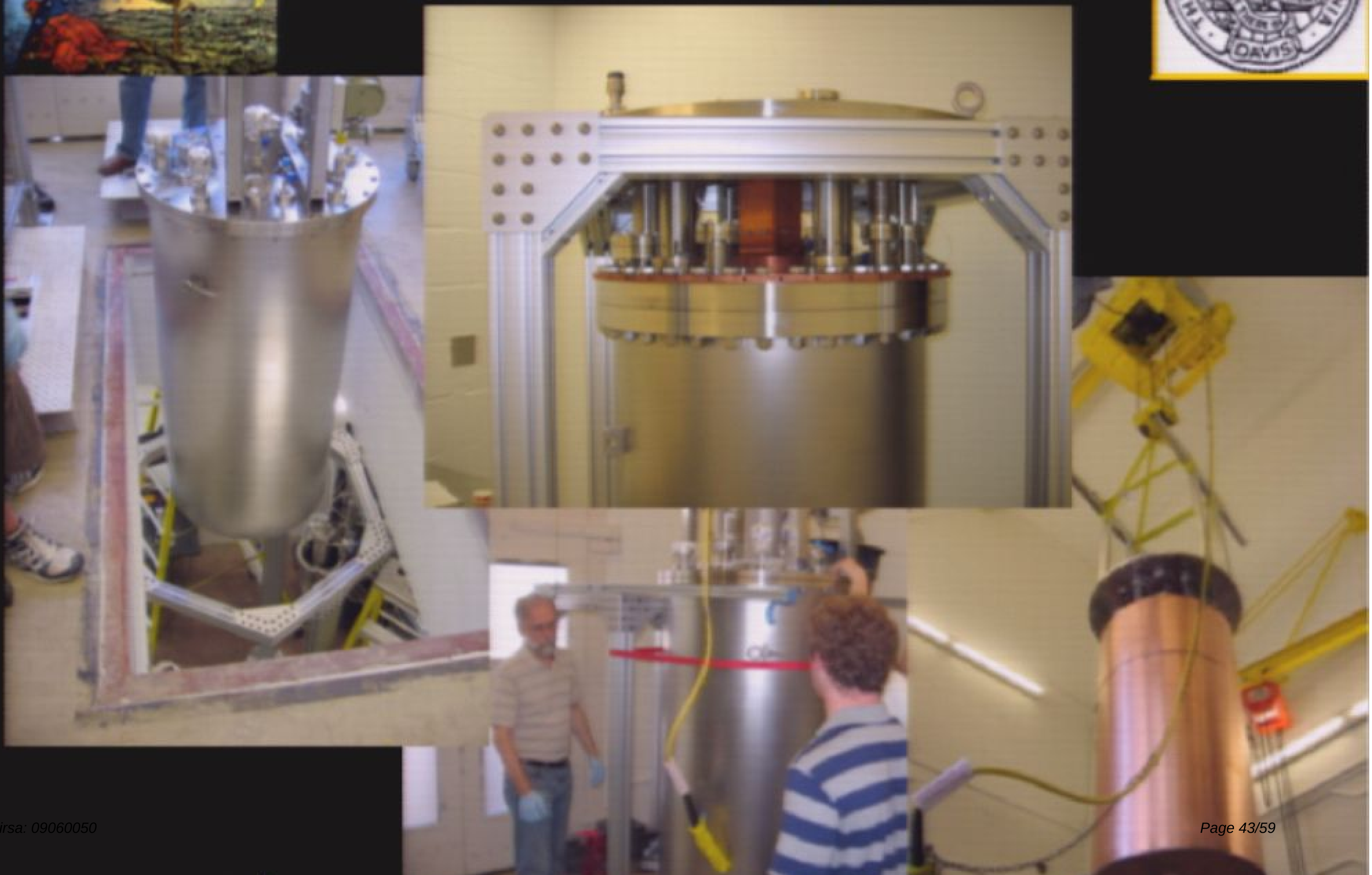
LUX Detector

- Full scale prototype cryostat with 60 kg Xe under test
- Final, Ti cryostat, internal parts under fabrication
- Integration at Sanford lab surface, Sept 09.





Cryostat Assembly at Case



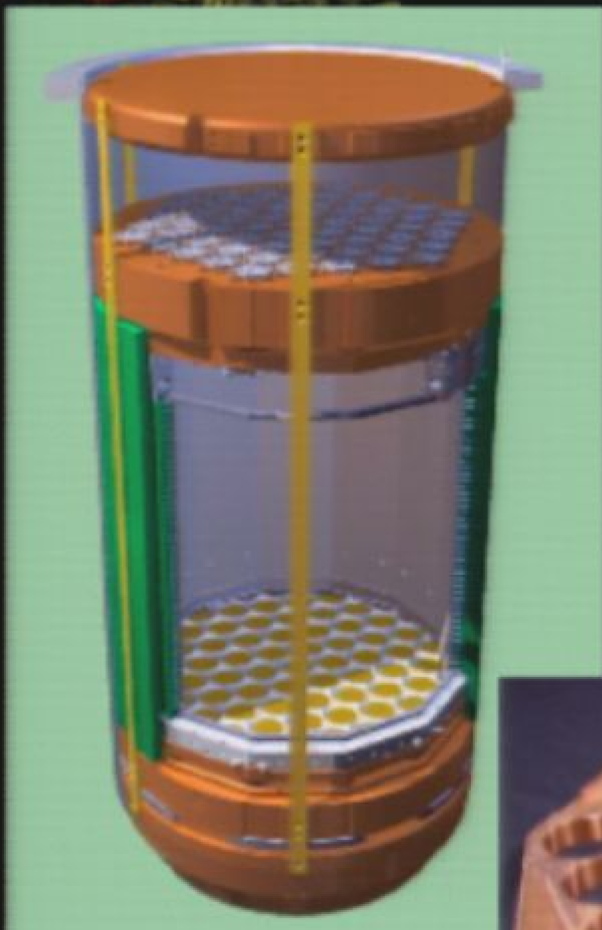
Titanium

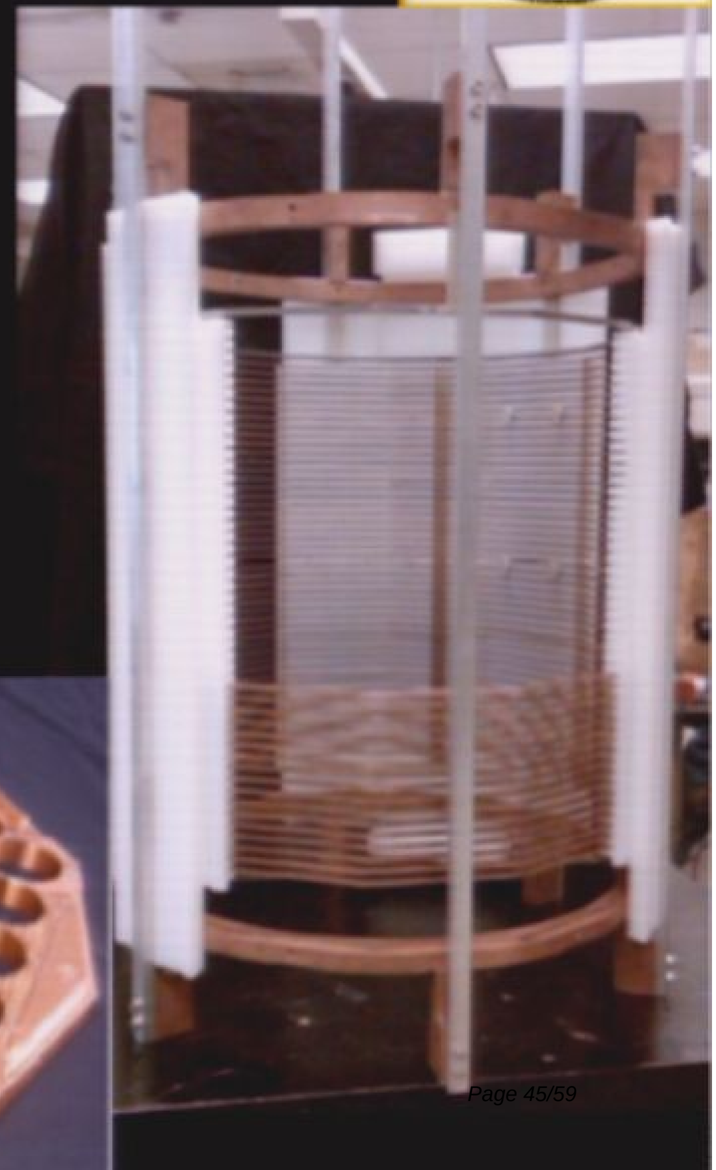
Grade CP1 generally good.
CP2 had high counts in 2 samples.

Sample activated in air transport
Not a problem for construction
Materials. 86 days half-life

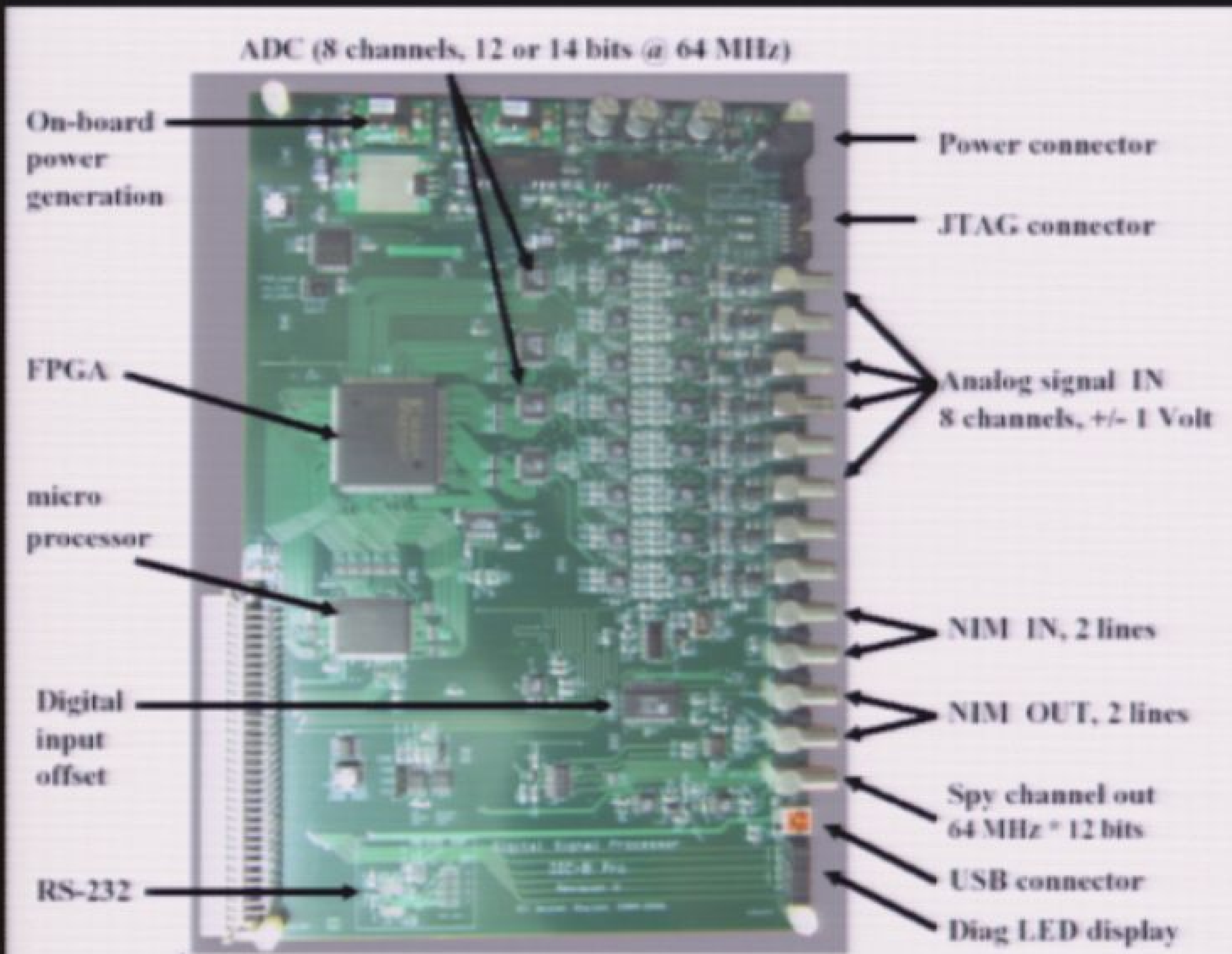
	Sample Type	Grade	Dim.	# of piece	Total weight	Counted At	U		Th		K-40		Sc-46
							ppb	mBq /kg	ppb	mBq /kg	ppm	mBq/ kg	mBq/ kg
Ti1	3/8" plate	CP1	2.5" x 6"	4	1.87 kg	Oroville	<0.2	< 2.5	<0.4	< 1.6	<0.2	< 6.2	4.8
Ti2	3/16" plate	CP2	4" x 6"	20	7.55 kg	SOLO	10.4	130	17.5	70		--	
Ti3	0.358" plate	CP2	~ 1.3" x 6"	8	1.55 kg	SOLO		85		35			
Ti6	3/16" plate	CP1	4" x 6"	20	7.98 kg	Oroville	<0.03	<0.4	< 0.2	<0.8	<0.05	<1.6	23
Ti7	1" plate	CP1	2" x 6"	8	7.201 kg	Oroville	<0.02		<0.05		<0.04		2.5
Ti8	0.063" sheet	CP1	4" x 6"	40	4.399	Oroville	<0.1		<0.4		<0.3		6

Internal Assembly





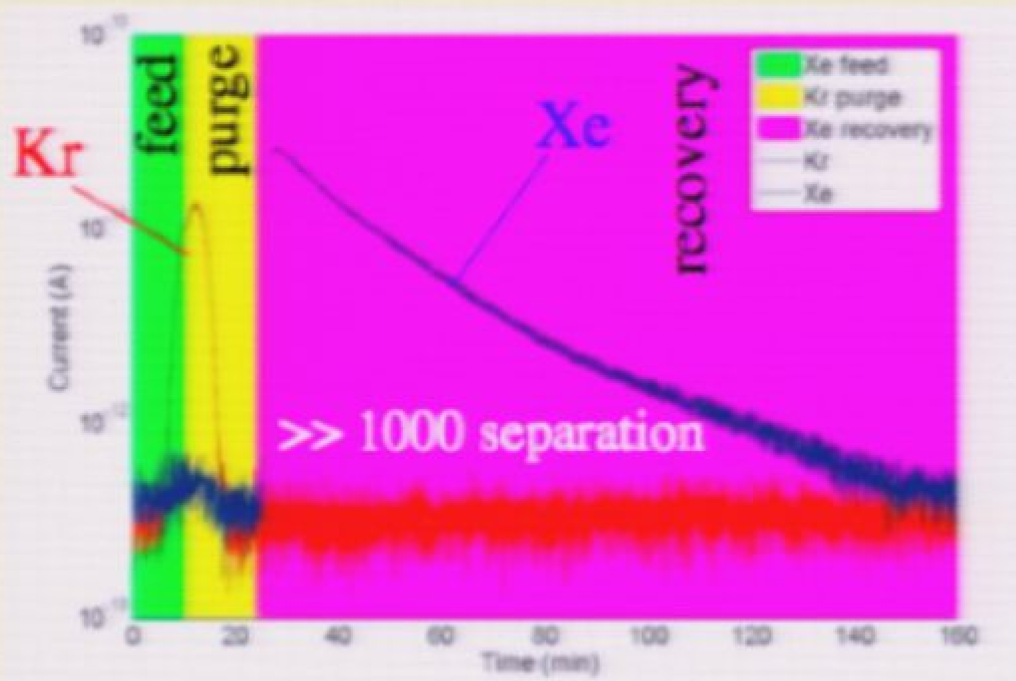
Real Time Pulse Finding in Trigger



Internal Backgrounds

- ^{85}Kr - beta decay
  - Goal for 20 tons scale: 10^{-14} Kr/Xe.
  - Chromatographic system: < ~2 ppt to date

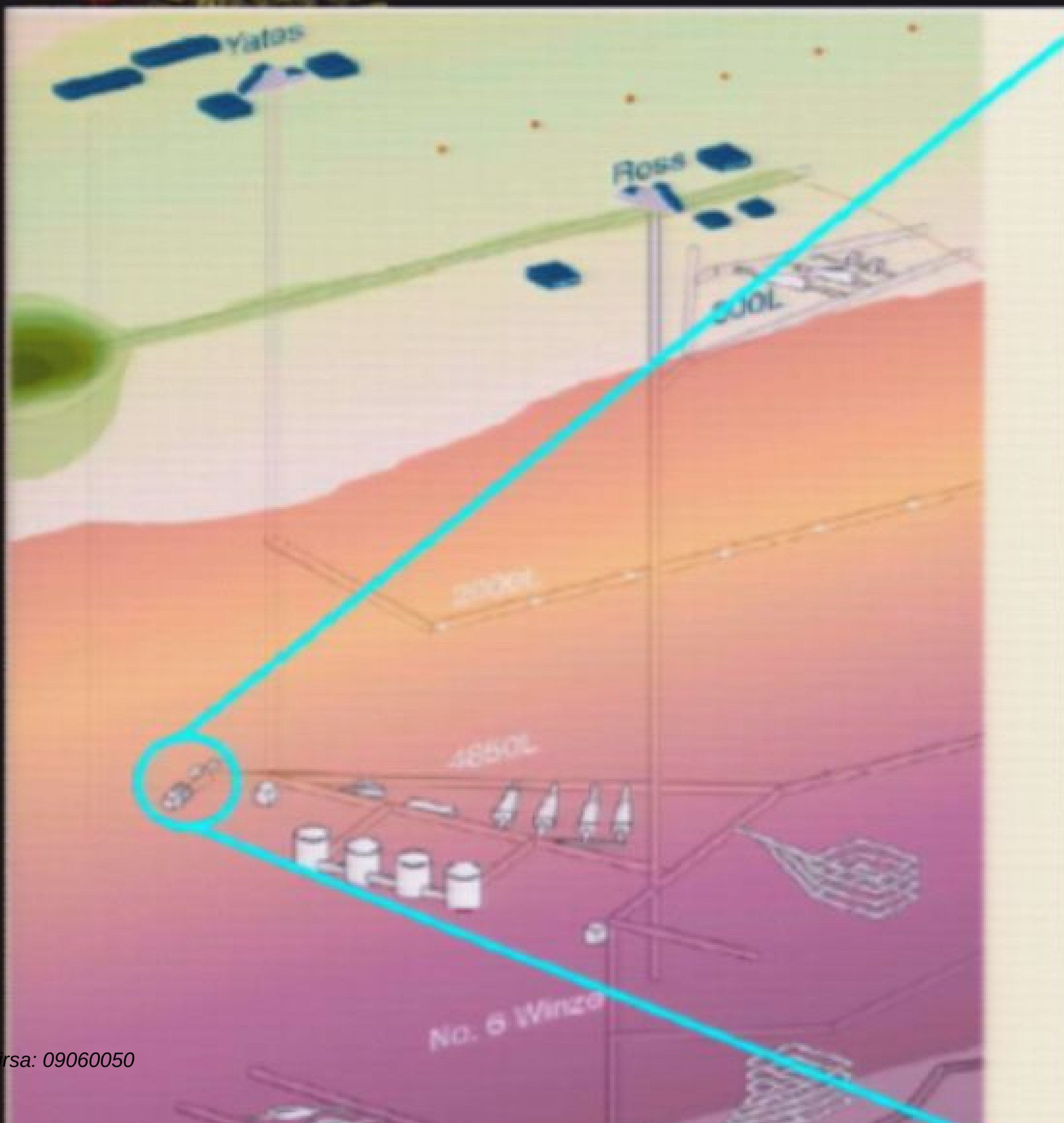
System at Case has achieved 2 kg/day.



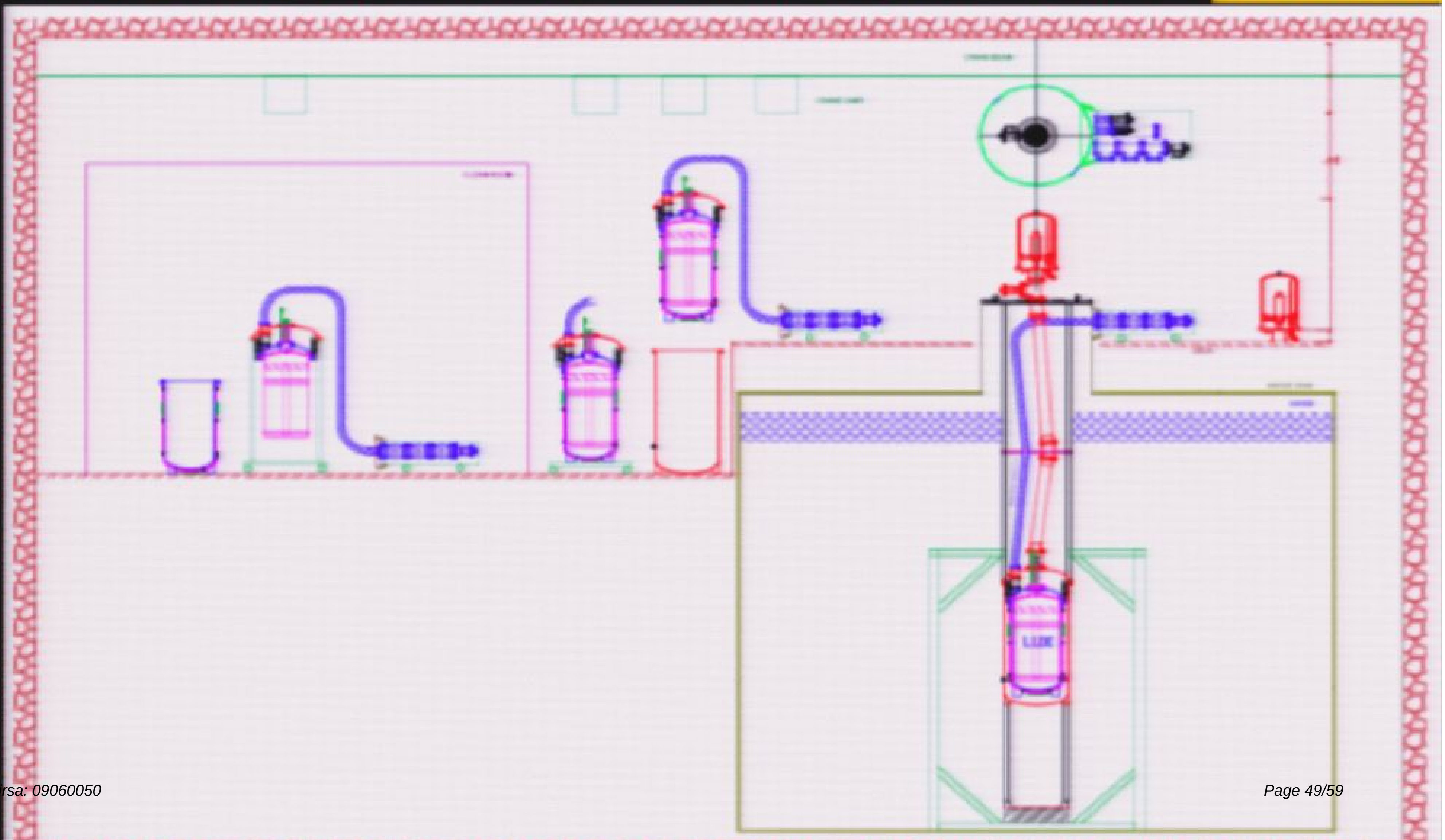
- Rn: require ~ < mBq total.
- Other gasses: ^{3}H, ^{14}C. Should be manageable

LUX

Davis Cavern



Plans for Davis Cavern



De-watering Milestone


LUX
Sanford
Lab

LZ3/LZ20 Collaboration

Merger with ZEPLIN-III collaboration. Plus, some new US groups joining in. New members:

A. Murphy, C. Ghag, E. Barnes, A. Hollingsworth, P. Scovell
Edinburgh University, United Kingdom

T. Sumner, H. Araujo, J. Quenby, M. Horn, K. Lyons, R. Walker, A. Currie, B. Edwards
Imperial College London, United Kingdom

N. Smith, G. Kalmus, P. Smith, P. Majewski, B. Edwards
STFC Rutherford Appleton Lab, United Kingdom

I. Lopes, V. Chepel, J. Pinto da Cunha, F. Neves, A. Lindote, V. Solovov, C. Silva
LIP - Coimbra, Portugal

D. Akimov, V. Belov, A. Burenkov, A. Kobyakin, A. Kolvalenko, V. Stekanhov
ITEP - Moscow, Russia

J. Siegrist
Lawrence Berkeley National Laboratory

H. Nelson

Future Program: Scaling Up

- Purity for charge and light
  - Required purity demonstrated.
  - LUX attacking engineering to achieve high reliability.
- Light collection
  - Current understanding -> 20 ton scale ok.
  - Better measurements
- Backgrounds
  - Scaling current technology, dominated by PMTs: LZ20 ~60% fiducial
    - PMTs: x10 improvement likely. (Currently demonstrated for XMASS).
  - Active shield: 99% neutron tag, 90-99% gamma tag
  - Goal: increase fiducial mass to ~80% at 3 ton scale, ~90% at 20 ton scale.
  - Purity requirements for Xe (primarily Rn, Kr) near state of art: SNO Borexino
- Mechanics, safety: LUX is dry run for 20 ton scale.
- Xe procurement.

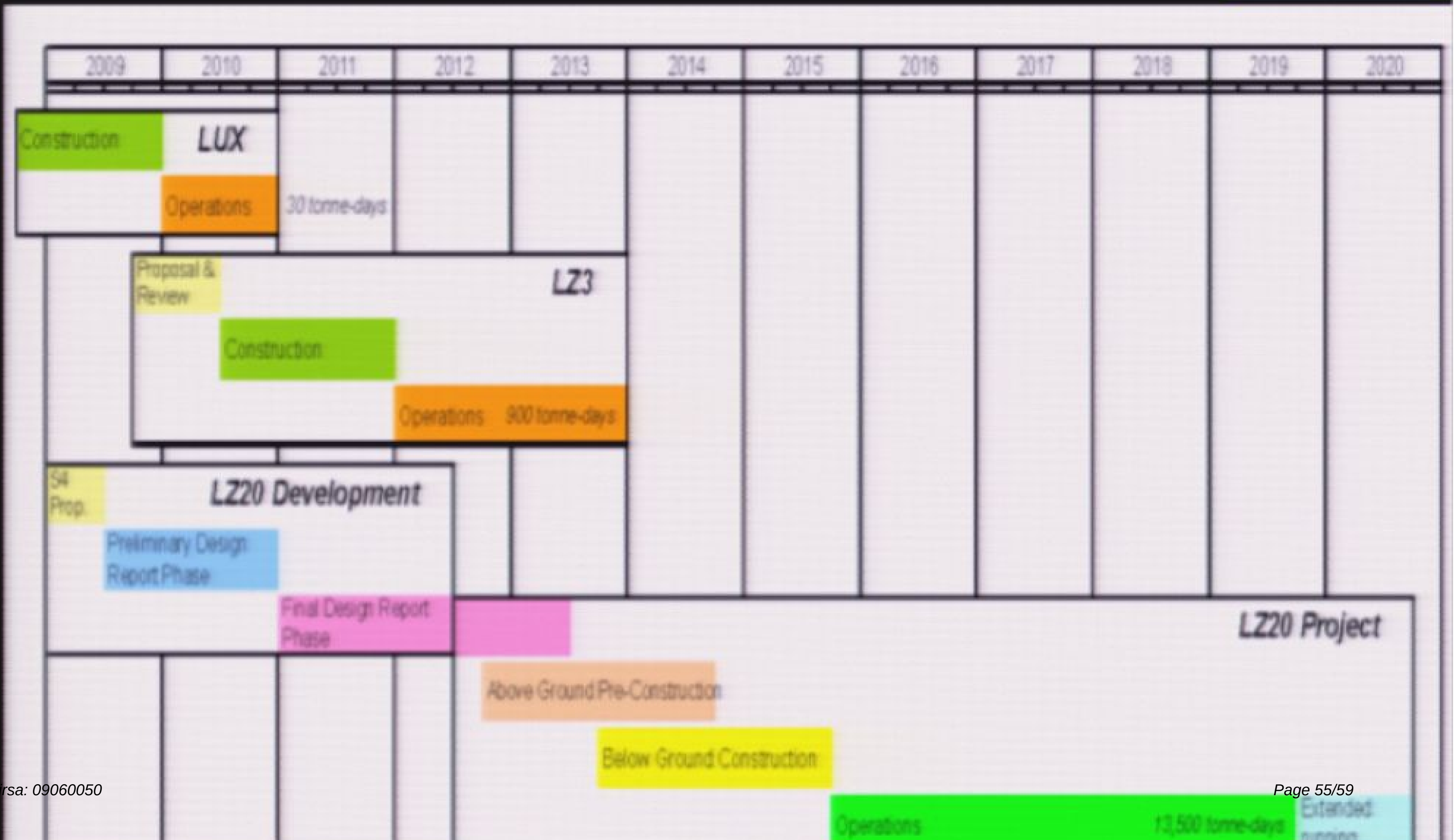
Estimate of Target Sensitivities

(Assume 100 GeV, 4E-45 cm^2)

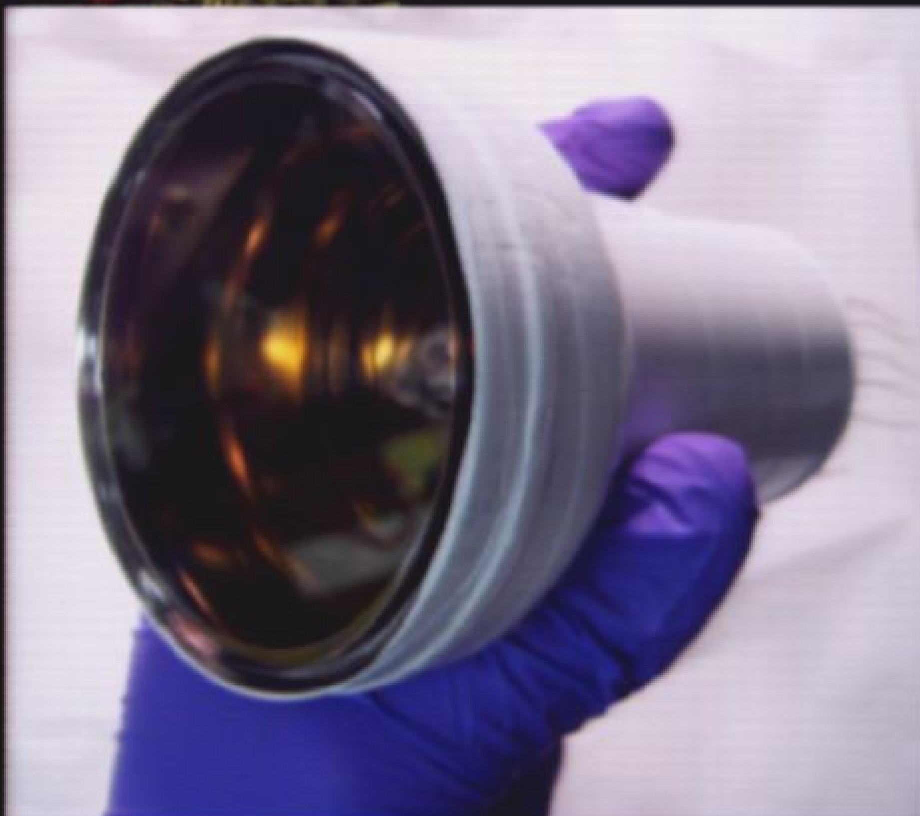
Akerib, Gaitskell et al (assume natural Ar)

Target	Energy Threshold * / assumed signal acceptance	Fiducial Mass required for 25 WIMP events in 100 live-days ††	Total number of ER events in Fiducial Mass for 100 live-days **	Max acceptable leakage in ER Rejection
Xe TPC	2 keVr / 80%	100 kg	17	0.05
Ar (†)	40 keVr / 90%	1.5 tonnes	2×10^{8}	5×10^{-9}
Ar (†)	80 keVr / 90%	6.5 tonnes	8×10^{8}	1×10^{-10}
Ge (CDMS)	10 keVr / 50%	350 kg	2×10^{5}	5×10^{-6}

Long Term (contd.)



LZ Program R&D

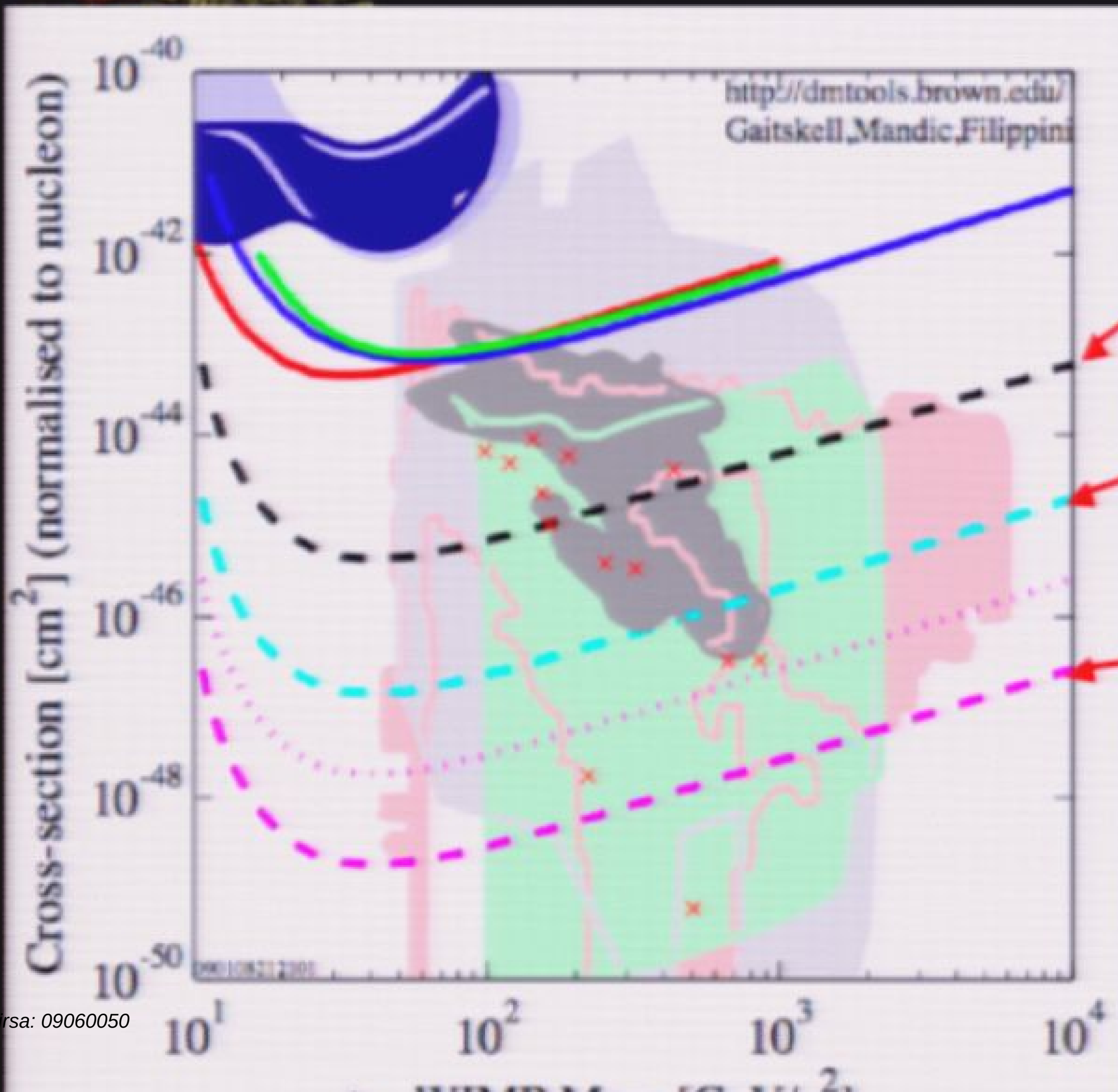


New 3" PMTs -- Hamamatsu R11065
With x2 collection area of R8778.

Background target for U/Th of 1/1 mBq.

Single p.e. resolution obtained from first articles of Hamamatsu R11065.

Long Term Program



LUX (construction 2008-2009, data in 2010)

LZ3 (construction 2010-2011, data in 2012-2013)

LZ20 (construction 2013-2015, data in 2016-2019)

Summary

The LUX collaboration is firmly in place with a sound management structure and requisite funding.

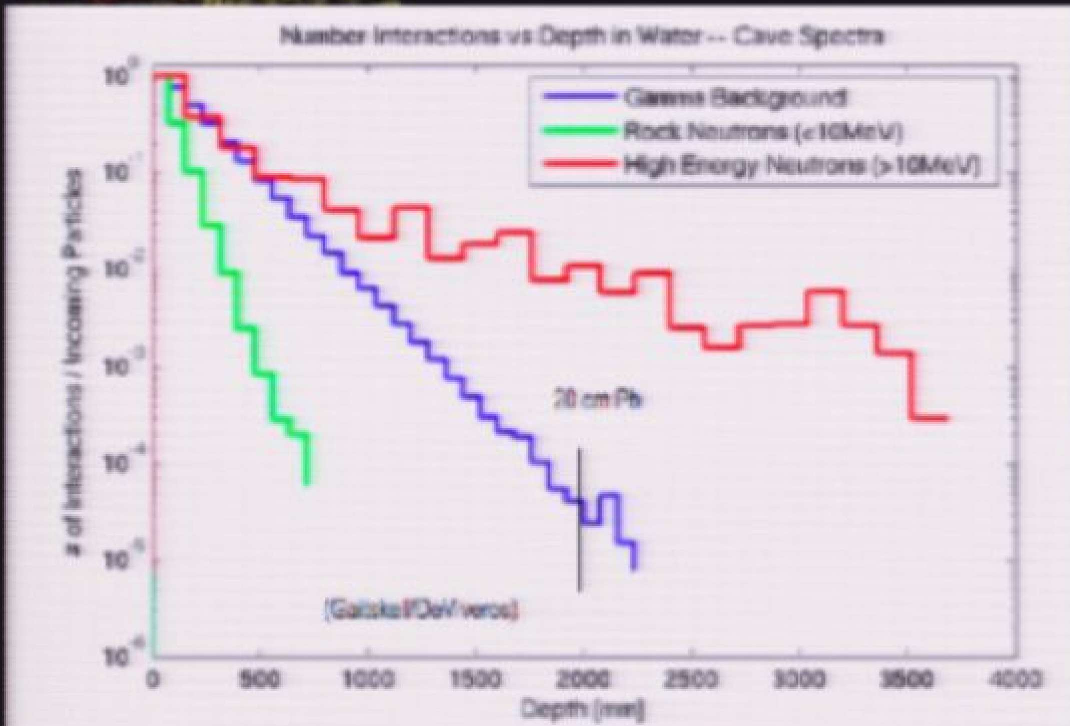
Detector design is complete.

Cryostat, components, sub-systems, electronics etc are being produced.

Sanford Lab is projecting surface facility availability in Oct-Nov 2009 and Underground facility in Feb-mar 2009.

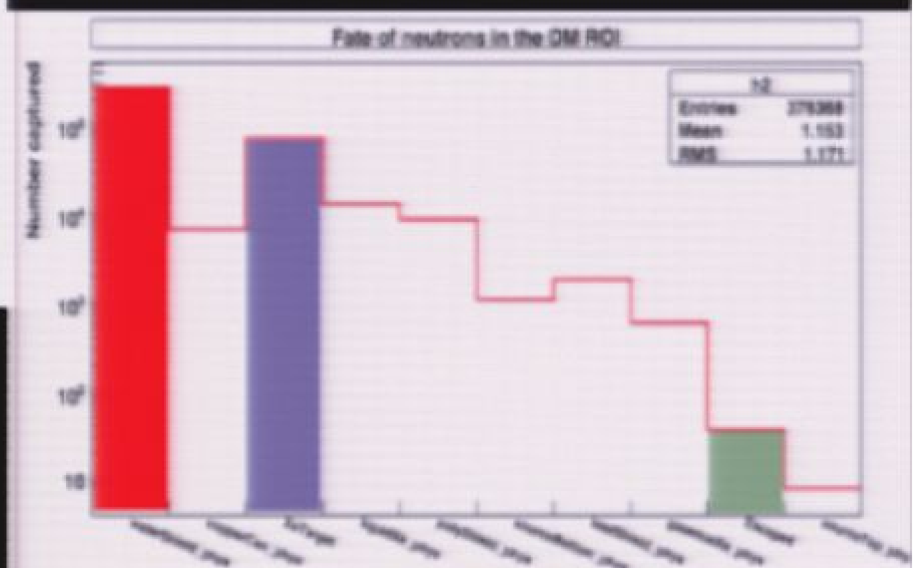
LUX and ZEPLIN groups are together proposing a future program at DUSEL.

Water Shield (Contd.)



Effective against fast neutrons.

Cost-effective and scalable. Very low gamma backgrounds with readily achievable $<10^{-11}$ g/g purity for water.



72% of ROI neutrons capture in the Gd-H_2O shield

19% of ROI neutrons capture in the active Xe target