LUX

DARK MATTER SEARCH

Carter Hall

UNIVERSITY OF MARYLAND

The Collaboration

Co-spokespersons Thomas Shutt and Richard Gaitskell

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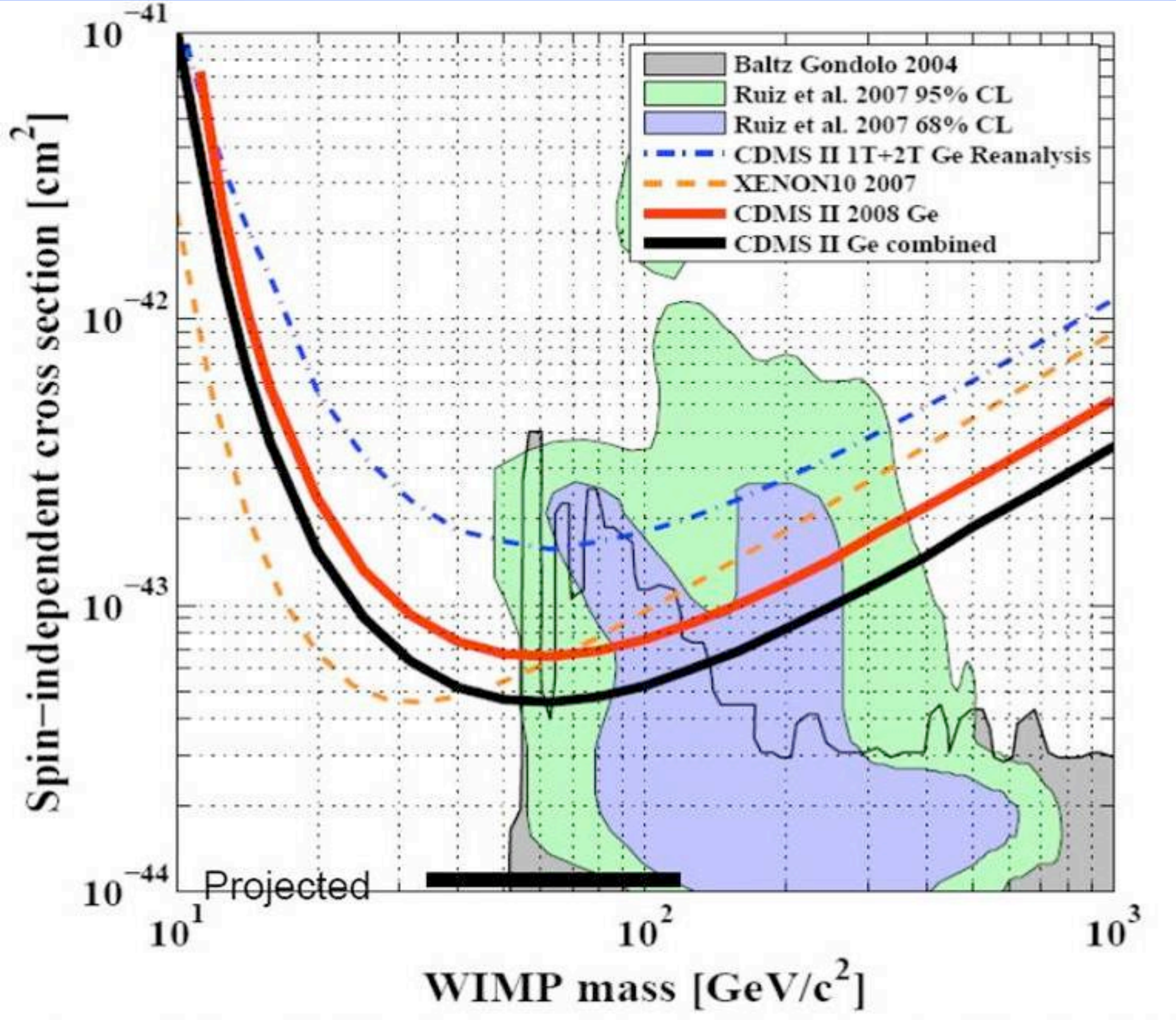
Texas A&M
J. White

Yale
D. McKinsey

Maryland
C. Hall

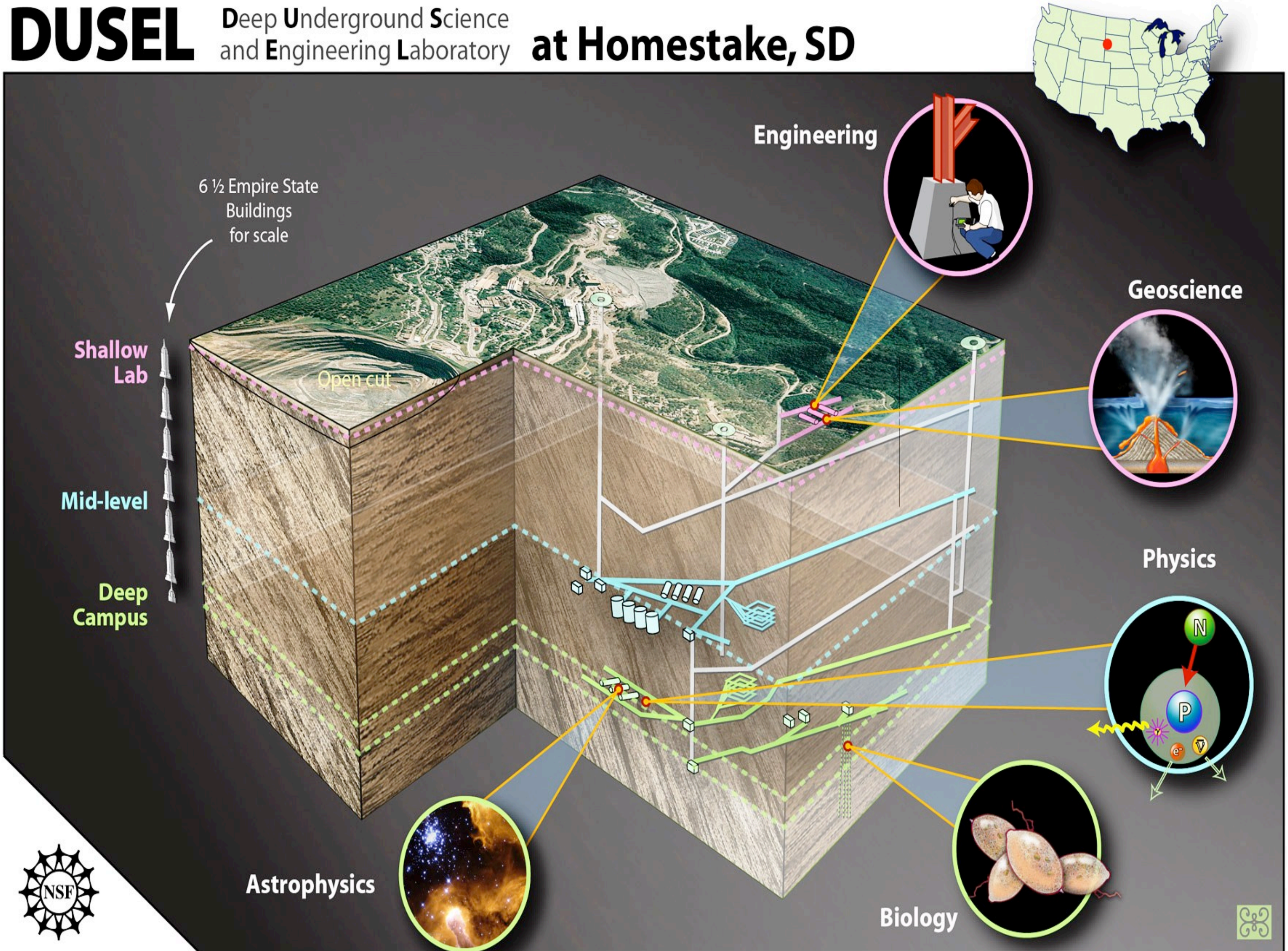
Collaboration meeting @ Homestake mine, March 1, 2009

Hunting for WIMPs in parametric space

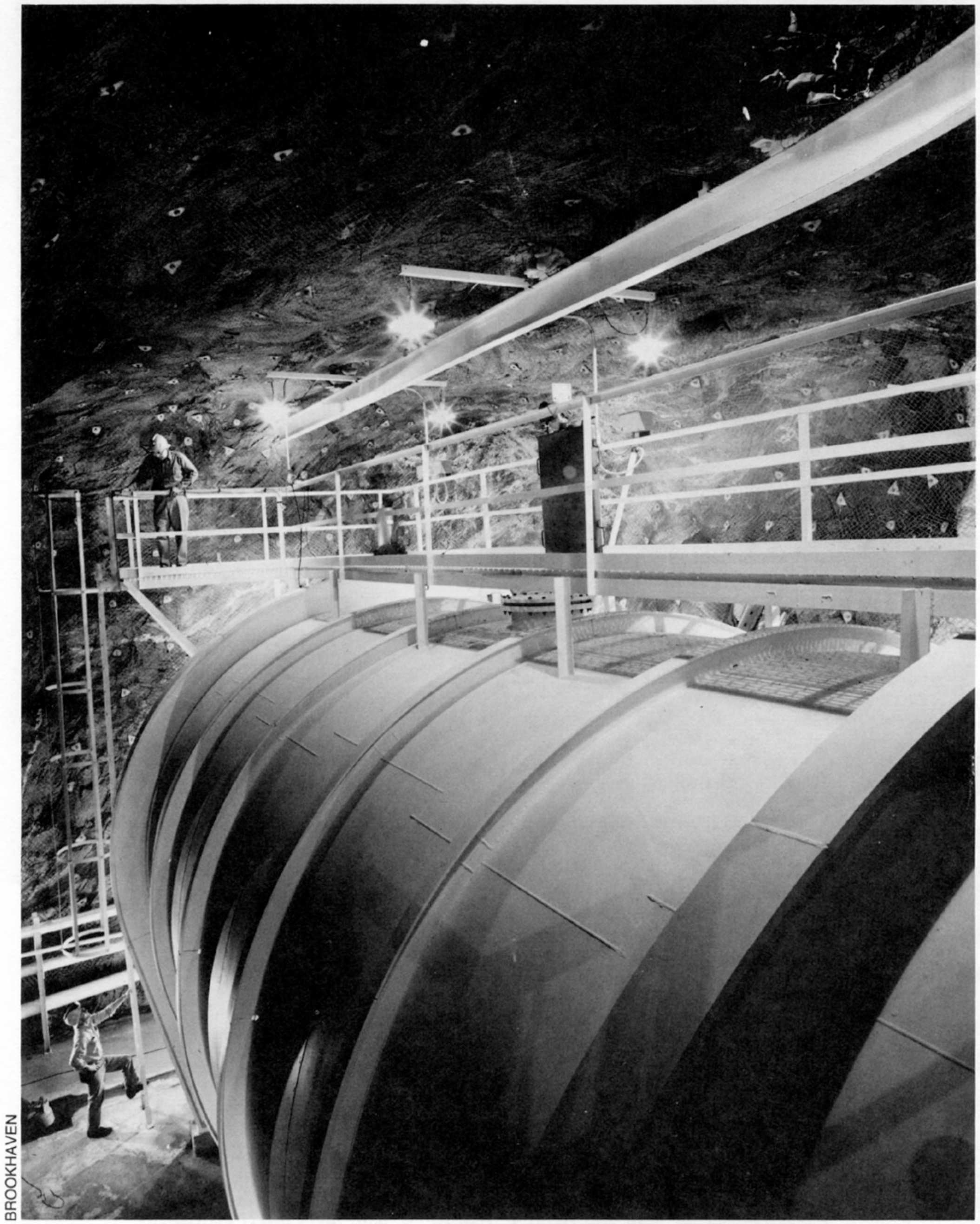



The Hunters Hut
Homestake (SD)

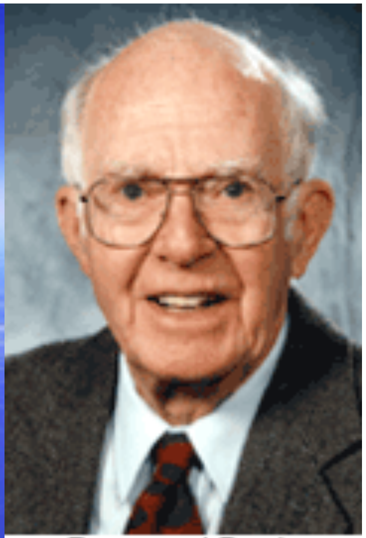
DUSEL Deep Underground Science and Engineering Laboratory at Homestake, SD



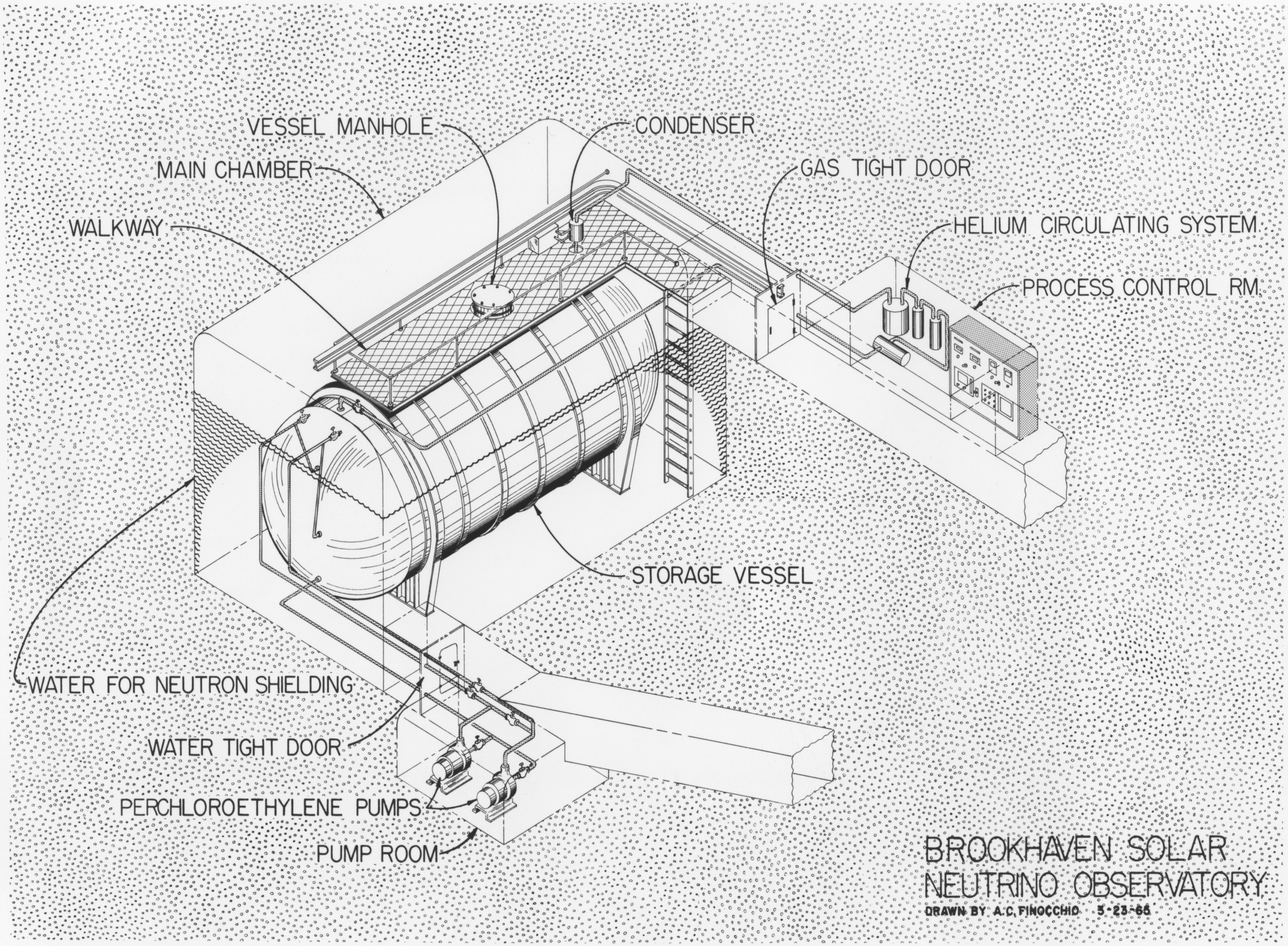
2002



Davis' neutrino detection apparatus one kilometer underground in the Homestake Gold Mine, Lead, South Dakota. The tank contains 400,000 liters of perchloroethylene.

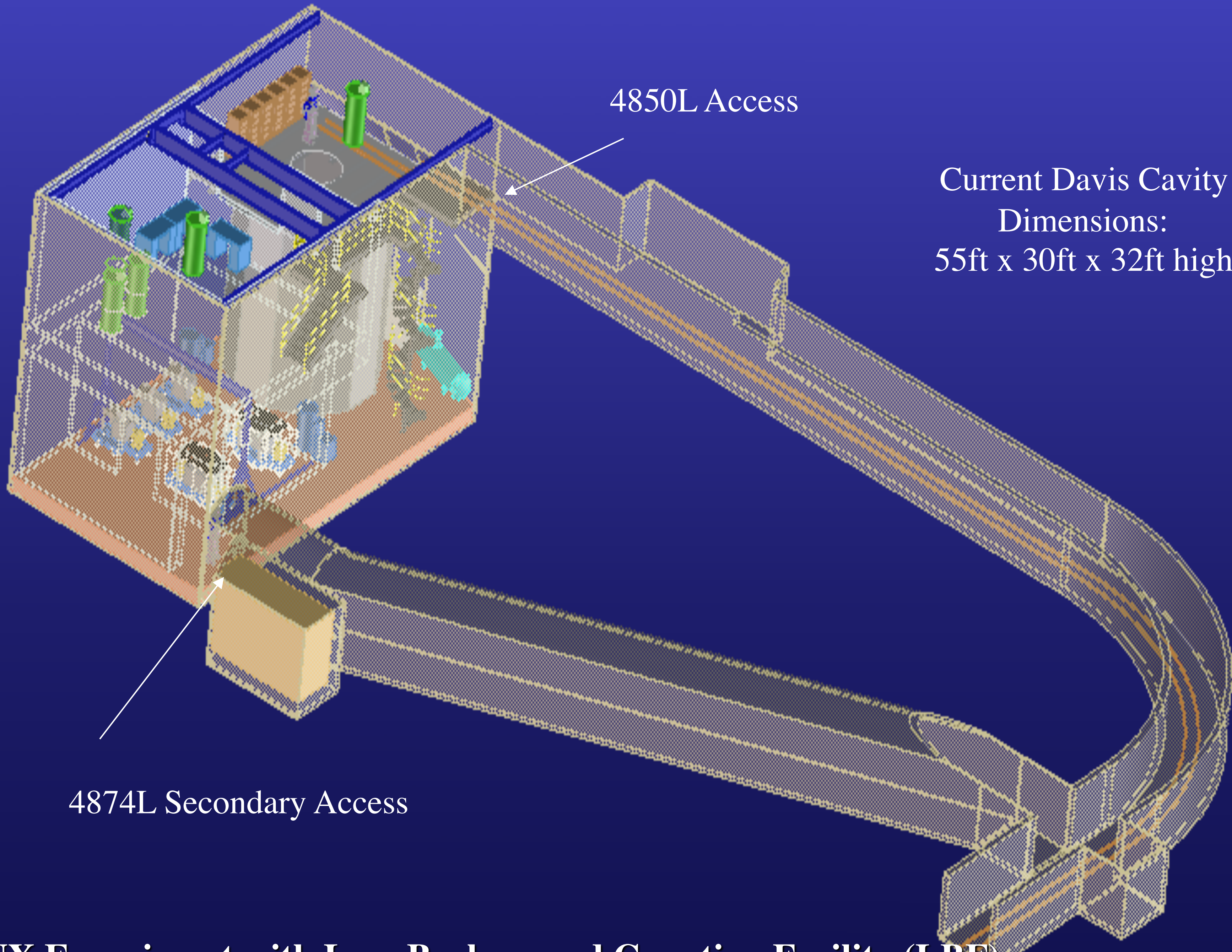


Raymond Davis

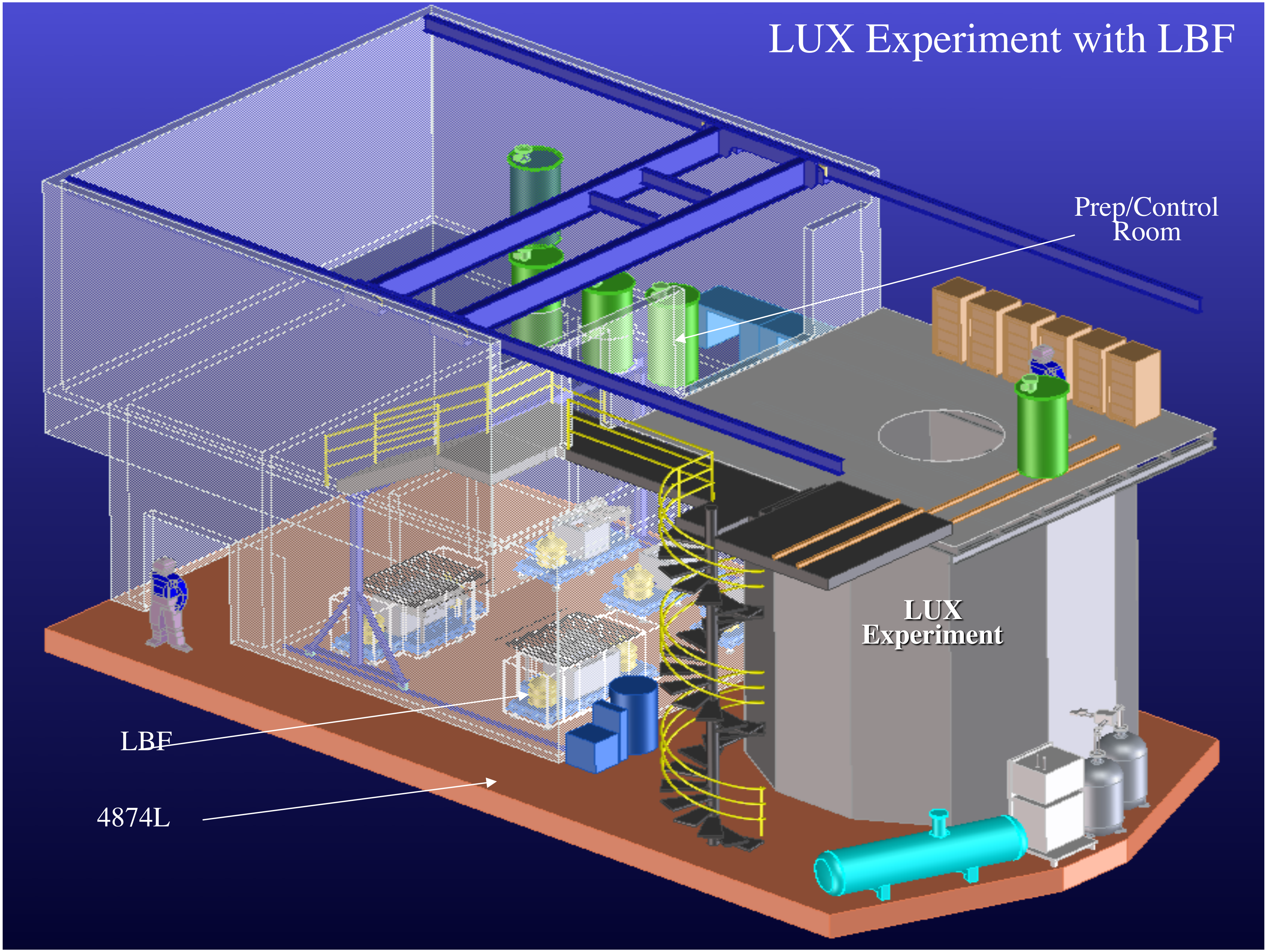


BROOKHAVEN SOLAR NEUTRINO OBSERVATORY

DRAWN BY A.C. FINOCCHIO 5-23-66

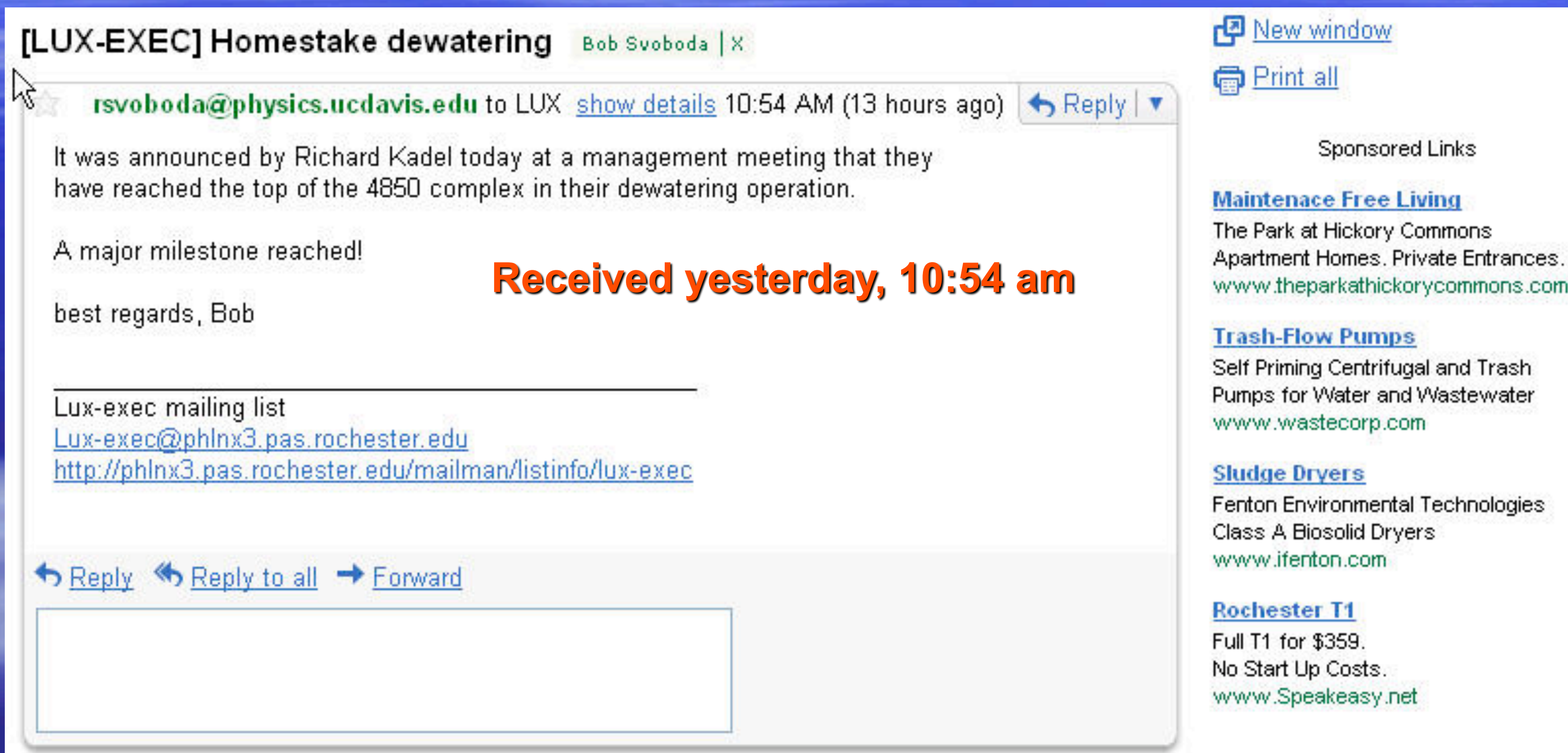


LUX Experiment with Low-Background Counting Facility (LBF)



LUX Experiment with LBF
Prep/Control Room
LUX Experiment
LBF
4874L

De-watering almost complete!



[LUX-EXEC] Homestake dewatering   Bob Svoboda | X

rsvoboda@physics.ucdavis.edu to LUX show details 10:54 AM (13 hours ago)   Reply

It was announced by Richard Kadel today at a management meeting that they have reached the top of the 4850 complex in their dewatering operation.

A major milestone reached!

best regards, Bob

____
Lux-exec mailing list
Lux-exec@phlnx3.pas.rochester.edu
http://phlnx3.pas.rochester.edu/mailman/listinfo/lux-exec

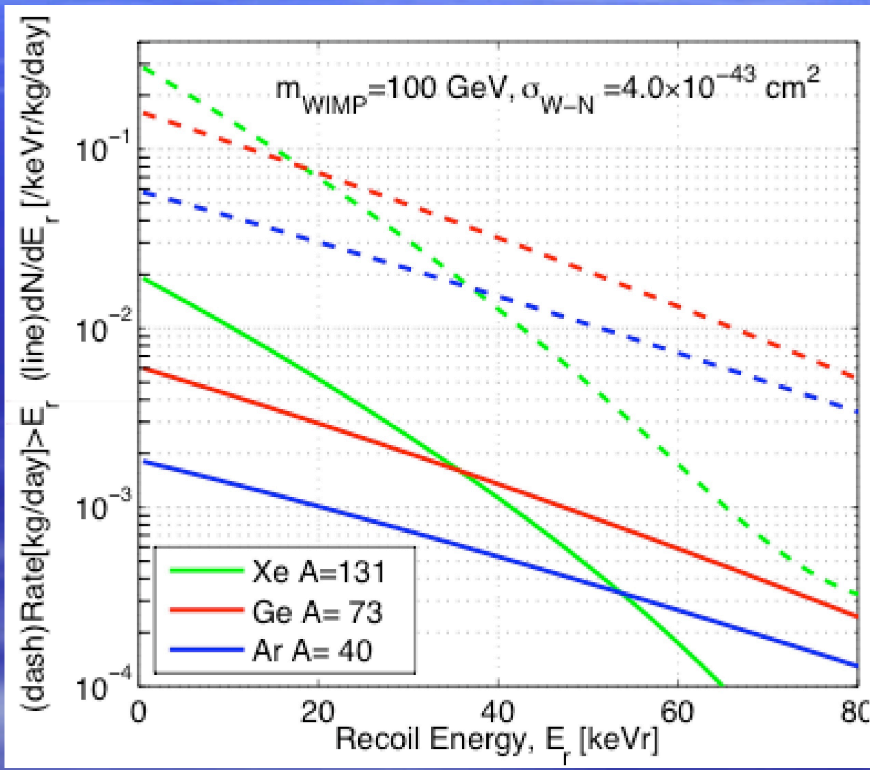
Reply   Reply to all   Forward

New window
Print all

Received yesterday, 10:54 am

Liquid Noble Detectors

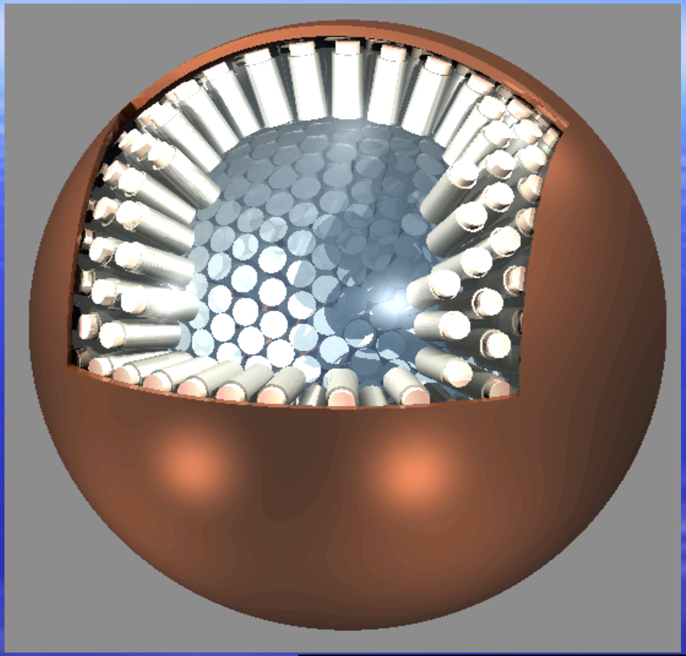
- Liquid target:
  - Readily purified
  - *Scalable to large masses*
- Liquid scintillator: 14C fatal for dark matter
  - Even in petroleum - 10-18
  - 14C: U->*a* + rock -> n -> 14N(n,p)14C
- Xe, Ar, Ne(?)
  - Xe: 165 K, λ=175 nm
  - Ar: 87.3 K, λ =128 nm, 39Ar - 1 Bq/kg.
  - Ne: 27.1 K, λ =80 nm, bubbles ->
    - slow charge drift
- Signals: ionization & scintillation
  - Single photons, electrons readily measured

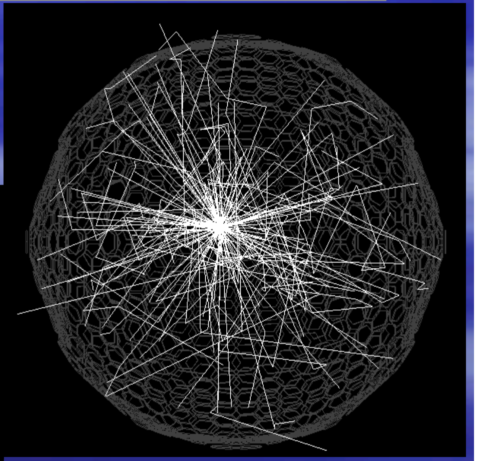


Single Phase detectors

- Scintillation signal.
  - Cryogenic versions of Chooz, Kamland, Borexino.
- Rayleigh scattering:
  - Position reconstruction poor.
  - Need large volume to reject large rate of Rn-daughter background on surface.
  - Multiple-vertex events hard to distinguish.
- PMTs: highly radioactive
  - Self-shielding in large detector
  - LXe best for this

XMASS: 800 kg total, 100 kg fiducial



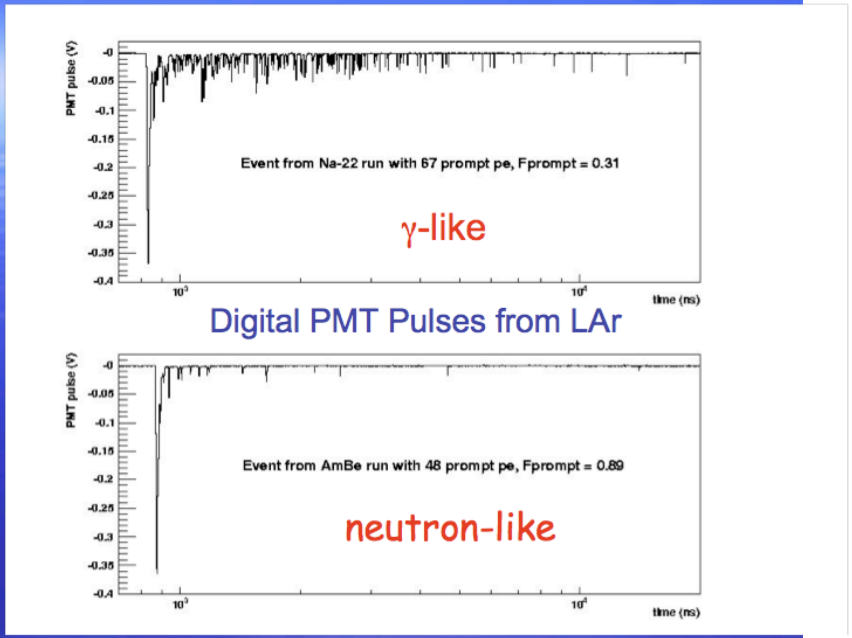


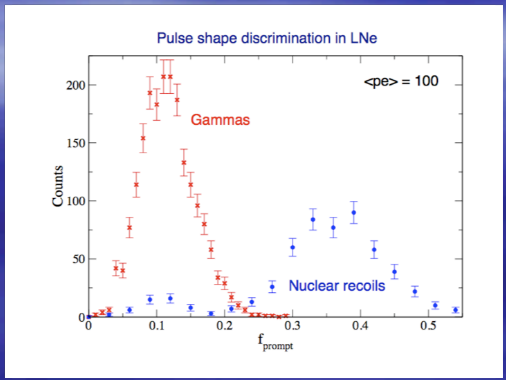
(Seidel, Lanou, Yao, 2002)

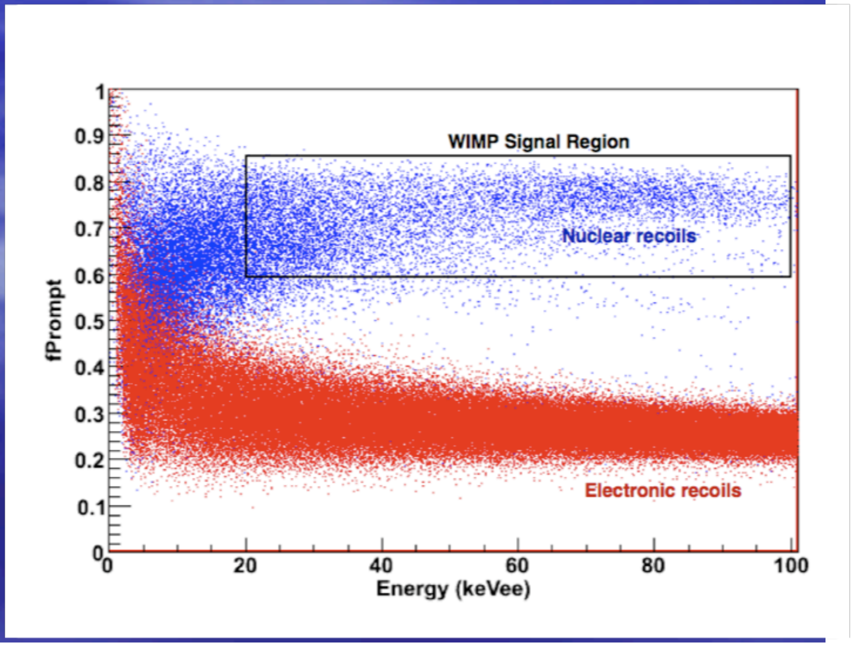
	λ (nm)	*L* theory (cm)	*L* exp (cm)
Ne	78	60	
Ar	128	90	66
Xe	174	30	30-50

Scintillation pulse shape discrimination

- Scintillation from excimer state:
  - Ar*+Ar -> Ar2*
  - Triplet (long lived)
  - Single (short lived)
- Discrimination of electron recoil backgrounds:
  - Nuclear recoils don't populate triplet
  - No one knows why
- Ar system by far most favorable

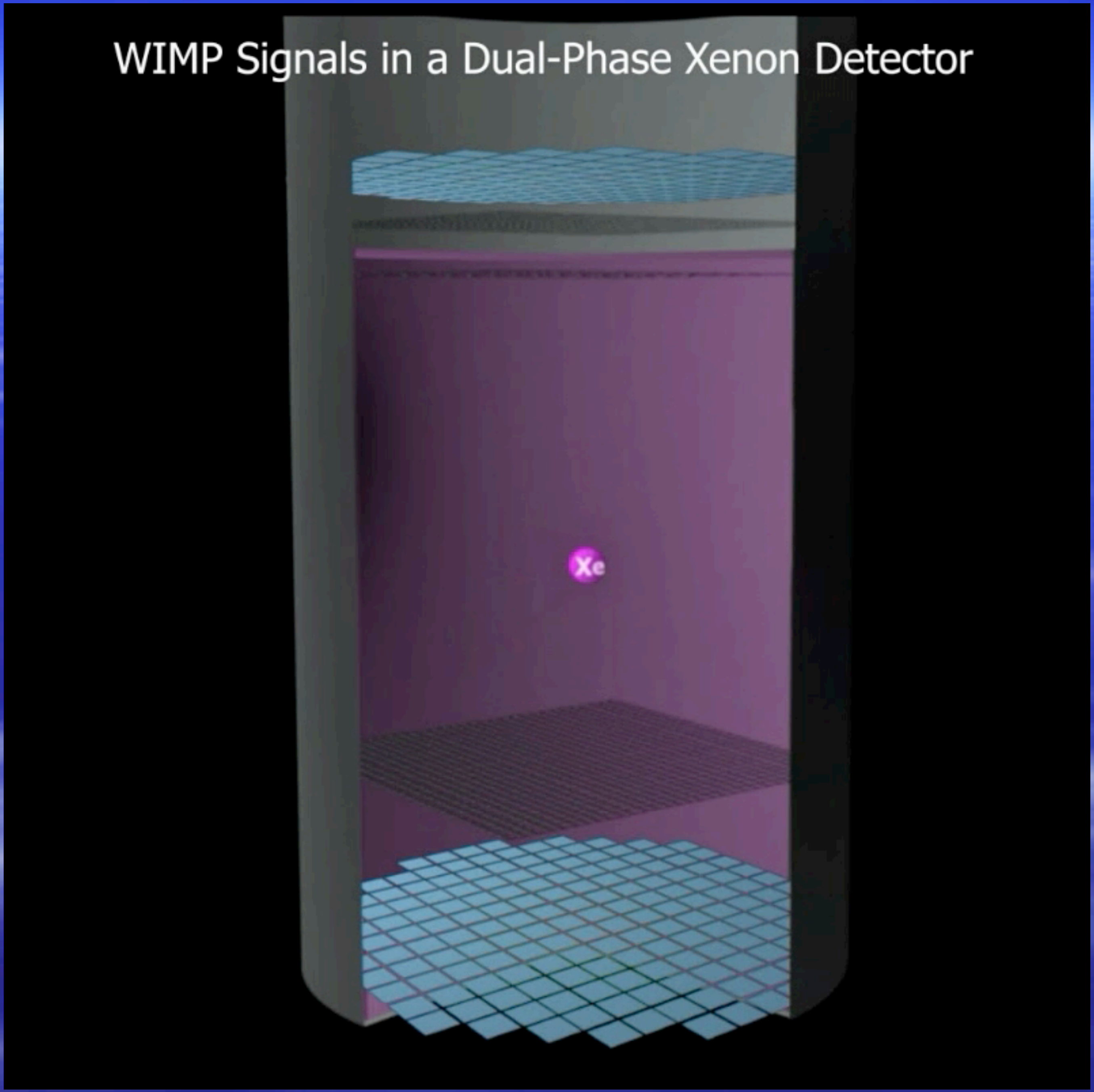




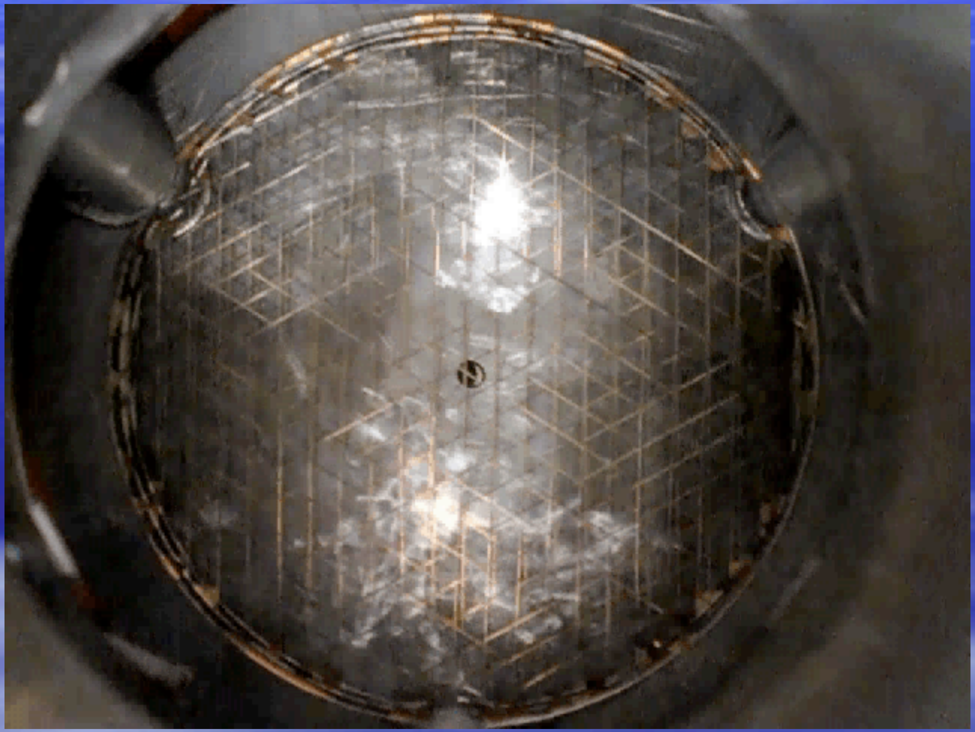


Why Xenon?

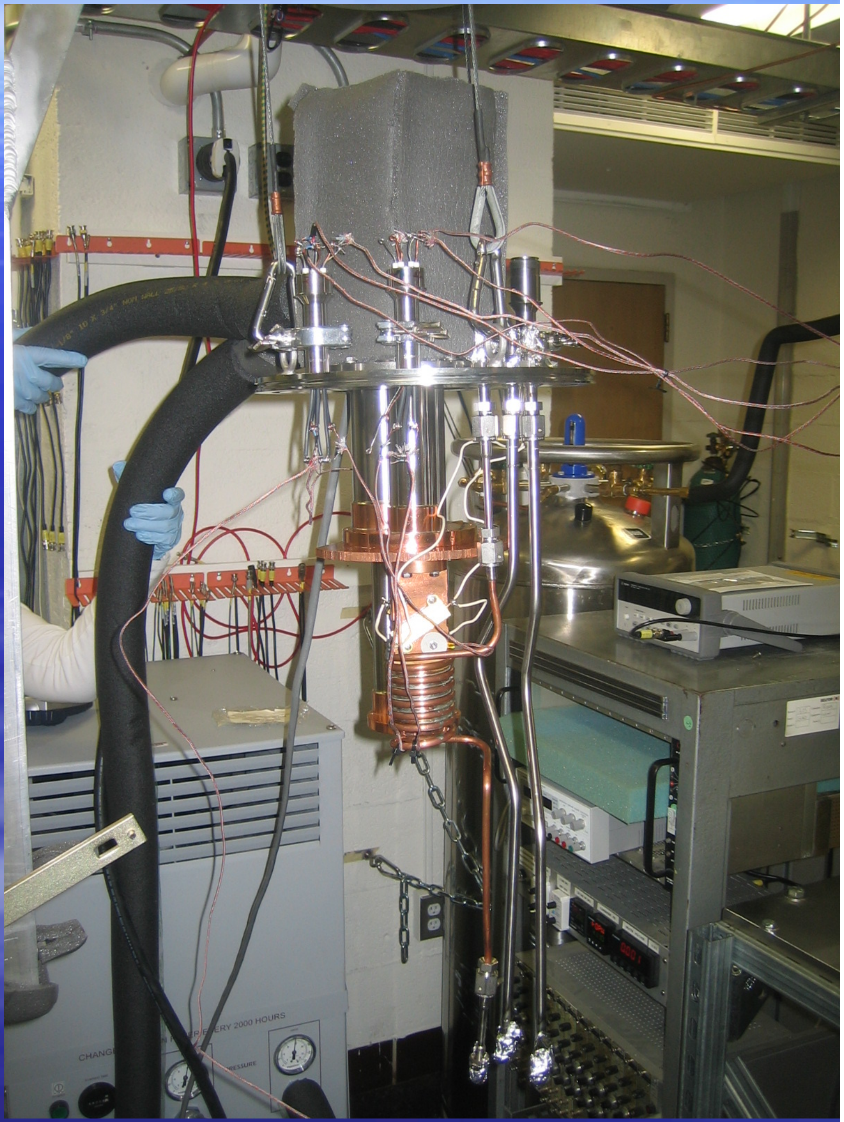
- High Z → Self shielding → "Wall-less detector"
- Scintillation + ionization (+ phonons for SXe)
- Scintillation light wavelength good match for QE PMTs
- Low natural radioactivity
- Easy to purify
- Good gamma/neutron discrimination (>10^2)
- High atomic mass
  - Coherent scattering cross-section $\propto A^2$
  - Good WIMP energy transfer in the range of ~100 GeV/c^2
- Low cost (~$1500/kg)


WIMP Signals in a Dual-Phase Xenon Detector
Xe

UMD Liquid Xenon Lab

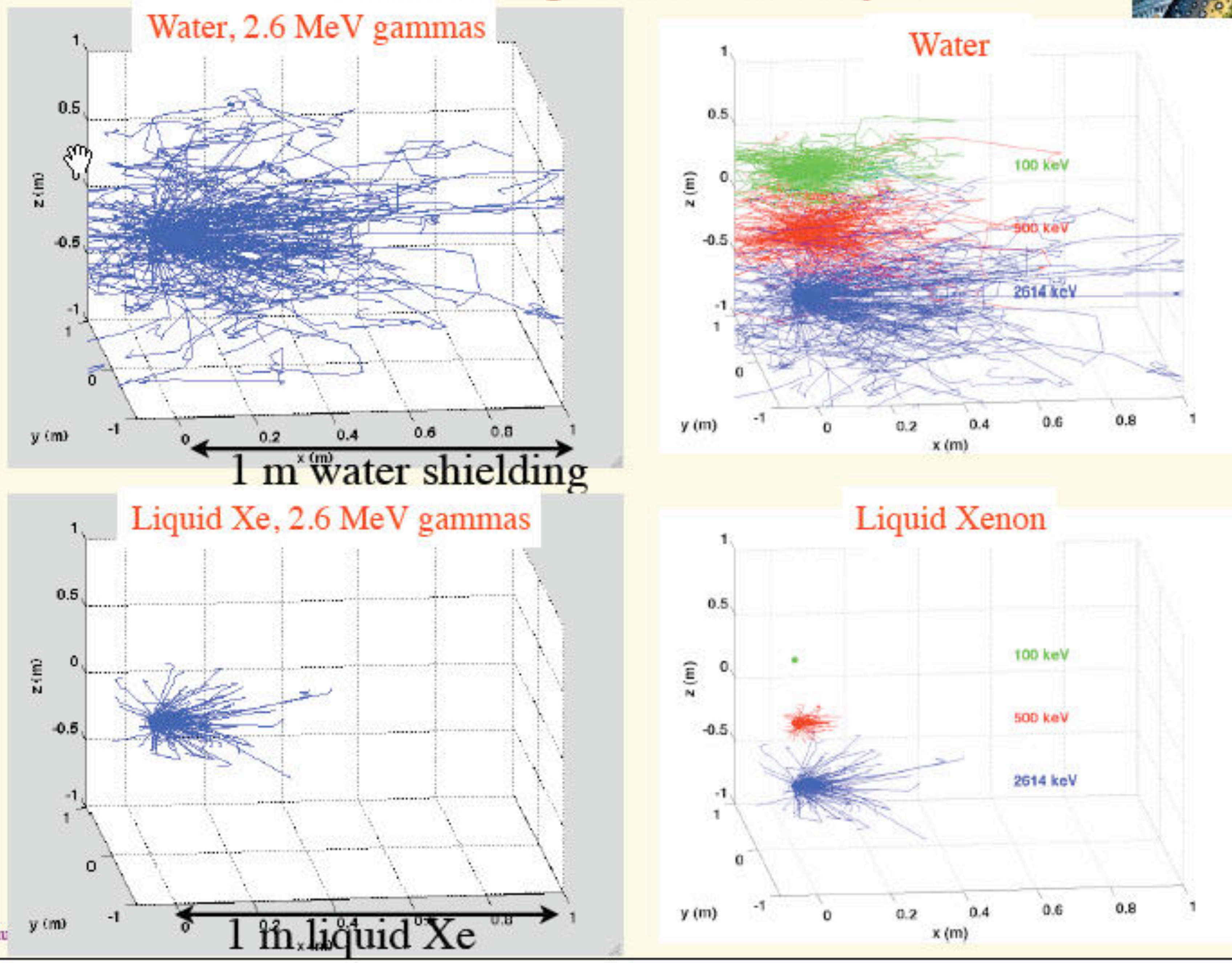


Liquid xenon detector R&D @ UMD



UMD Xenon condenser

Shielding Gamma Rays



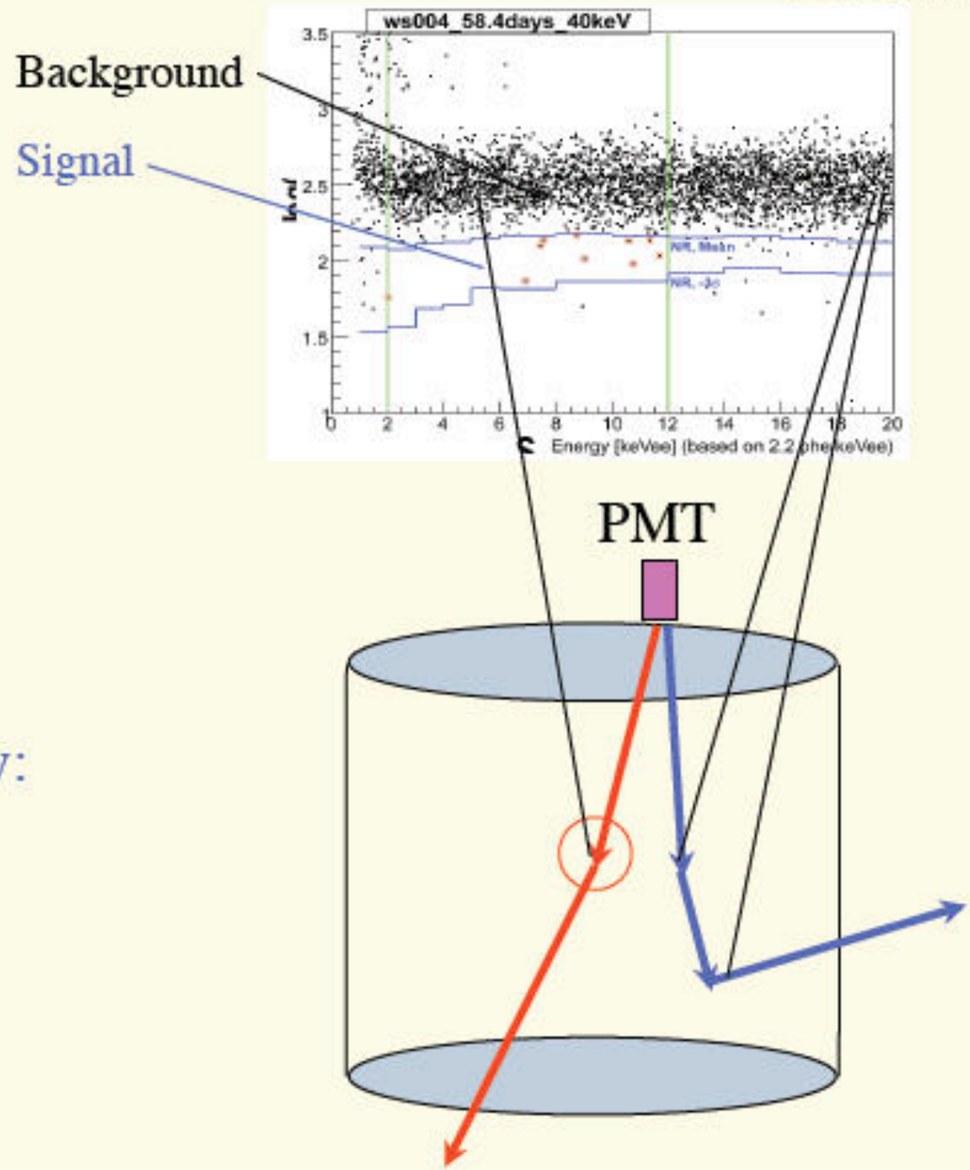
Single Scatters of MeV photons

- Dominant background in foreseeable future

- Rare

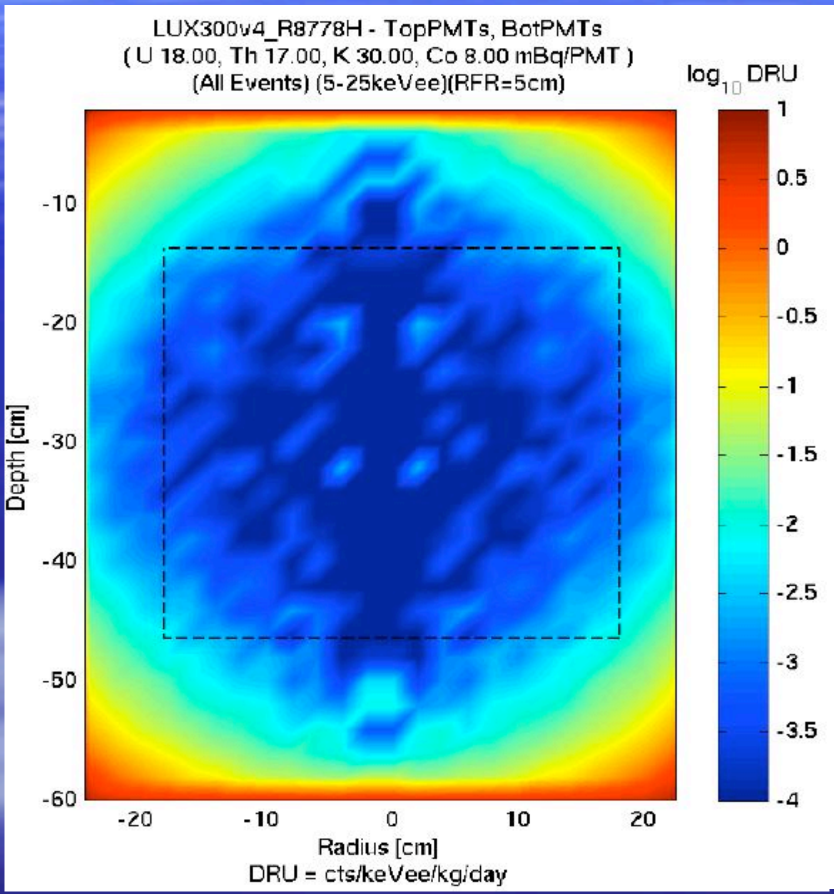
- Can approximate analytically:

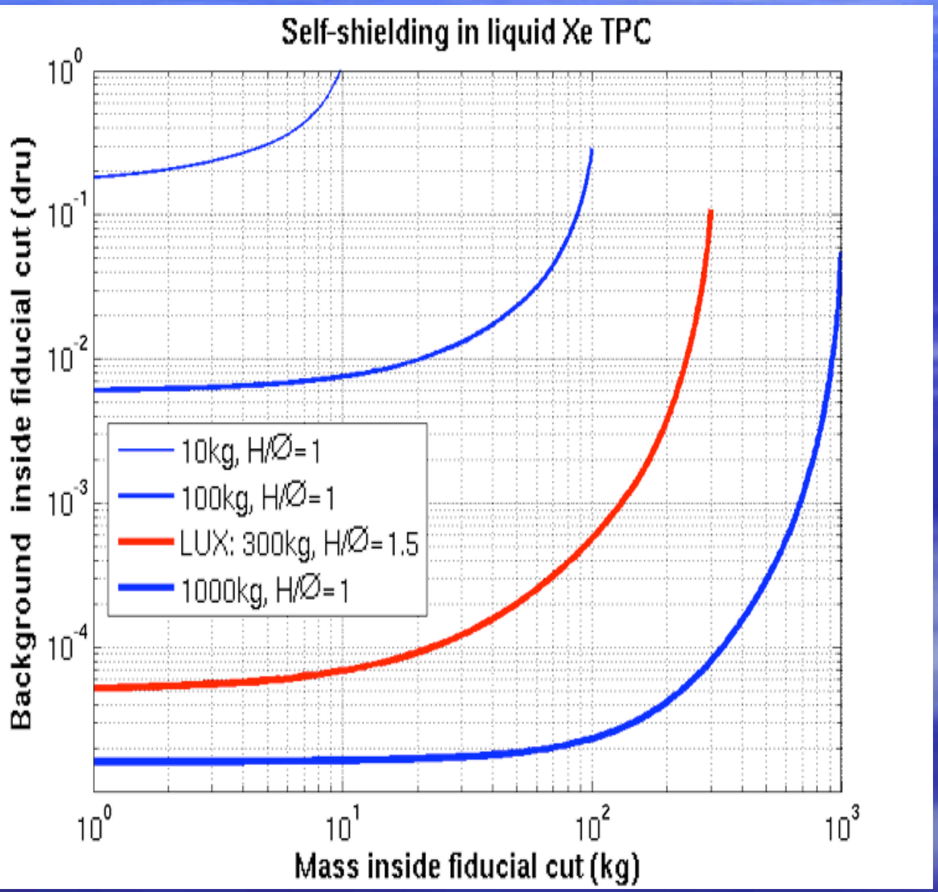
$$P(L) \cong \frac{L}{\lambda} e^{-\frac{L}{\lambda}}$$



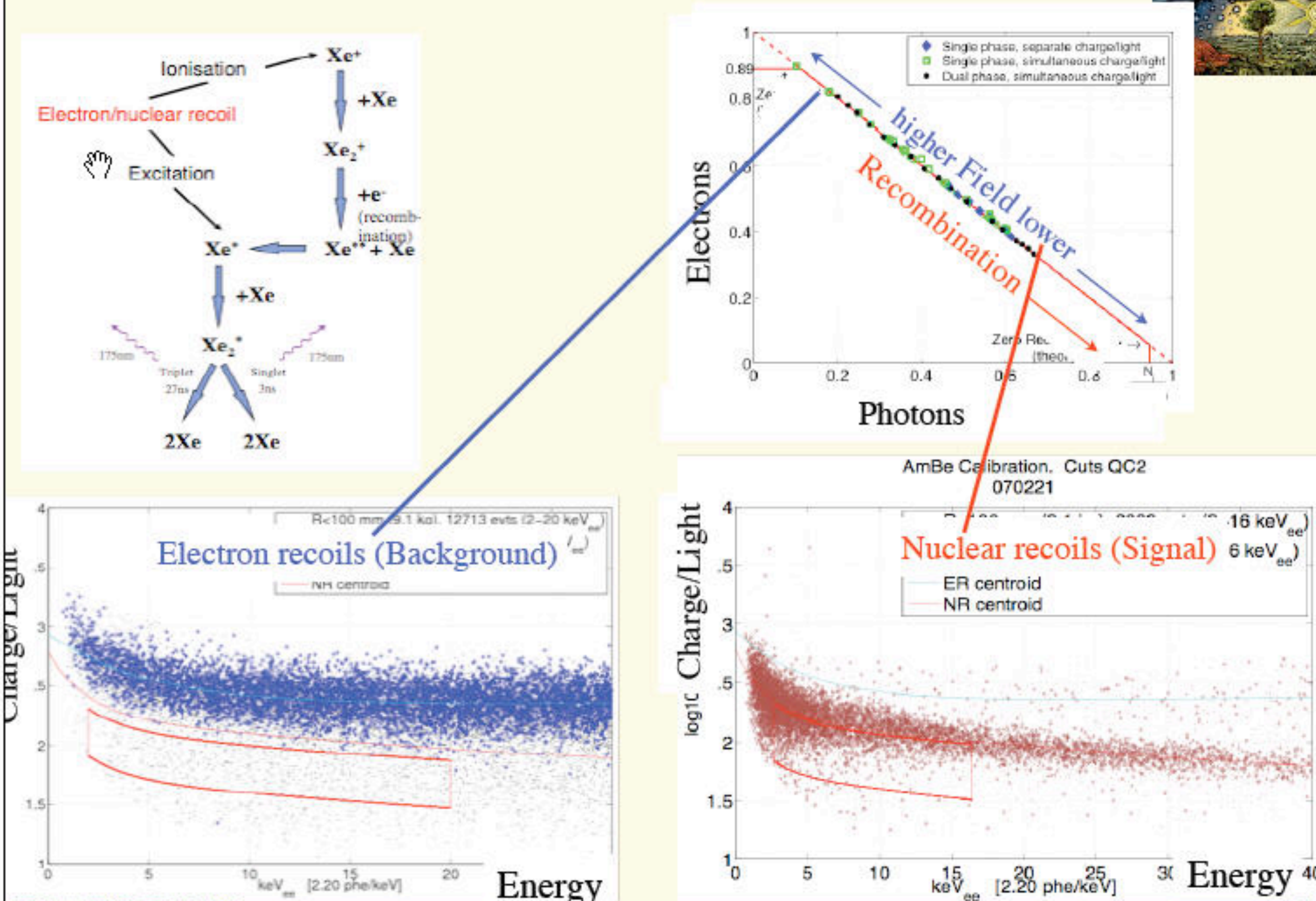
Self-shielding effect

- Sensitivity vs volume greater than linear



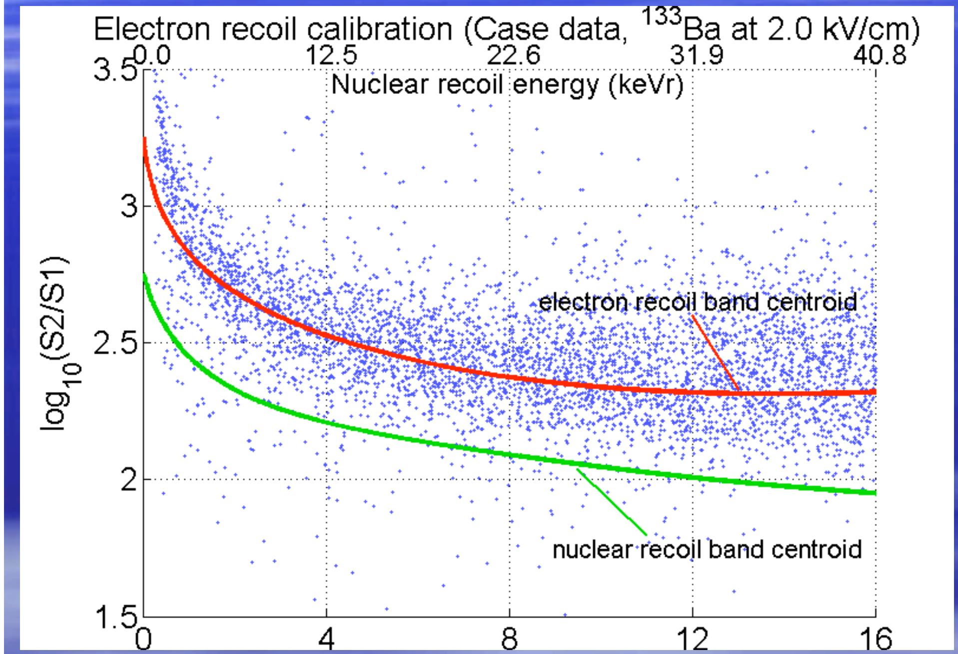


Recombination - based discrimination



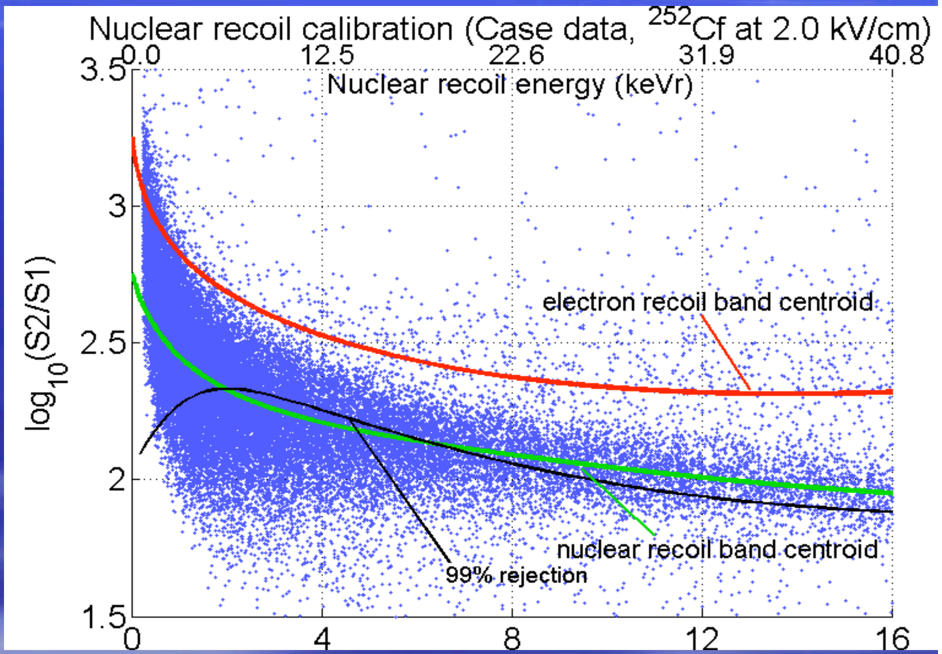
Gamma/neutron discrimination

^{133}Ba Electrons



Recoil Energy (keVr)

^{252}Cf Neutrons



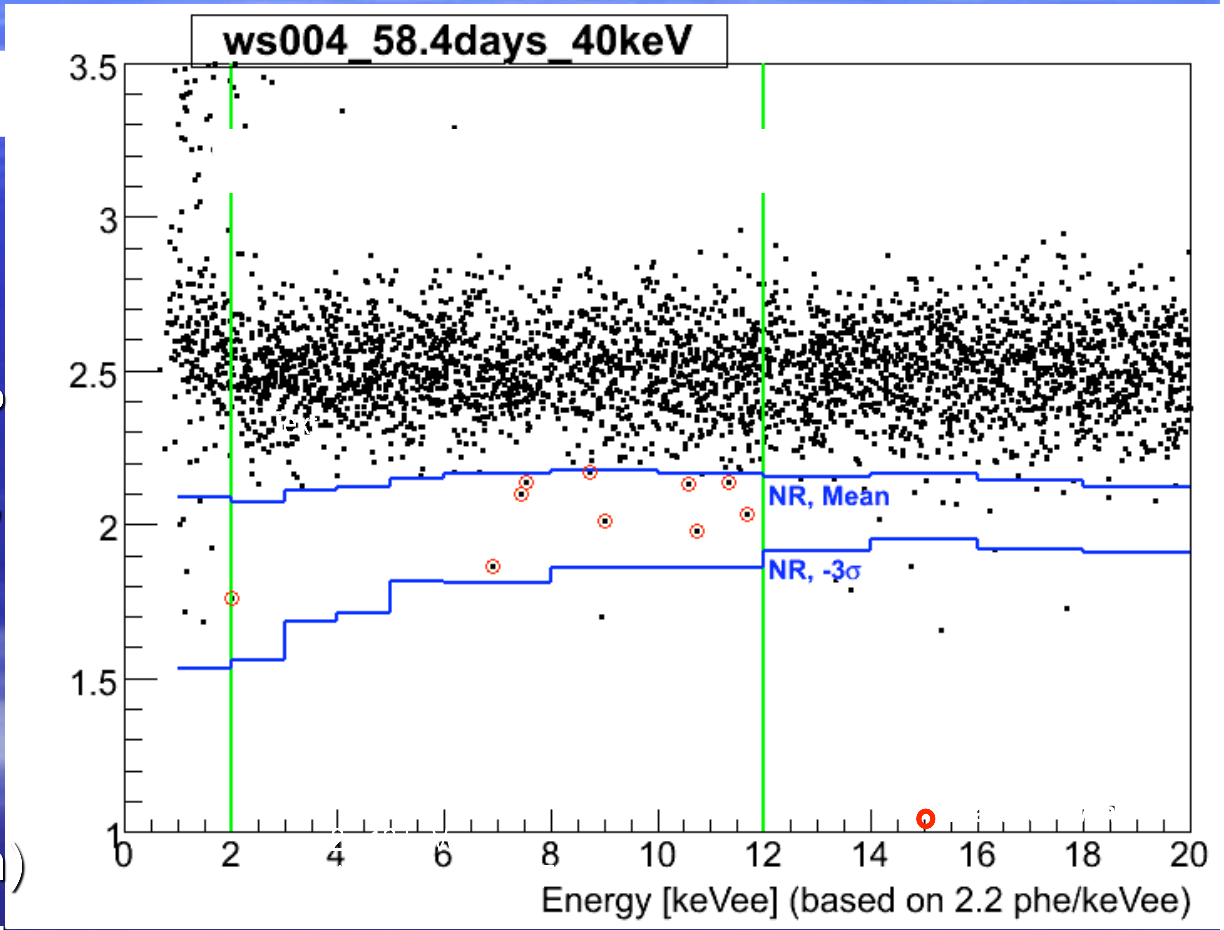
Recoil Energy (keVr)

Measurements above ground

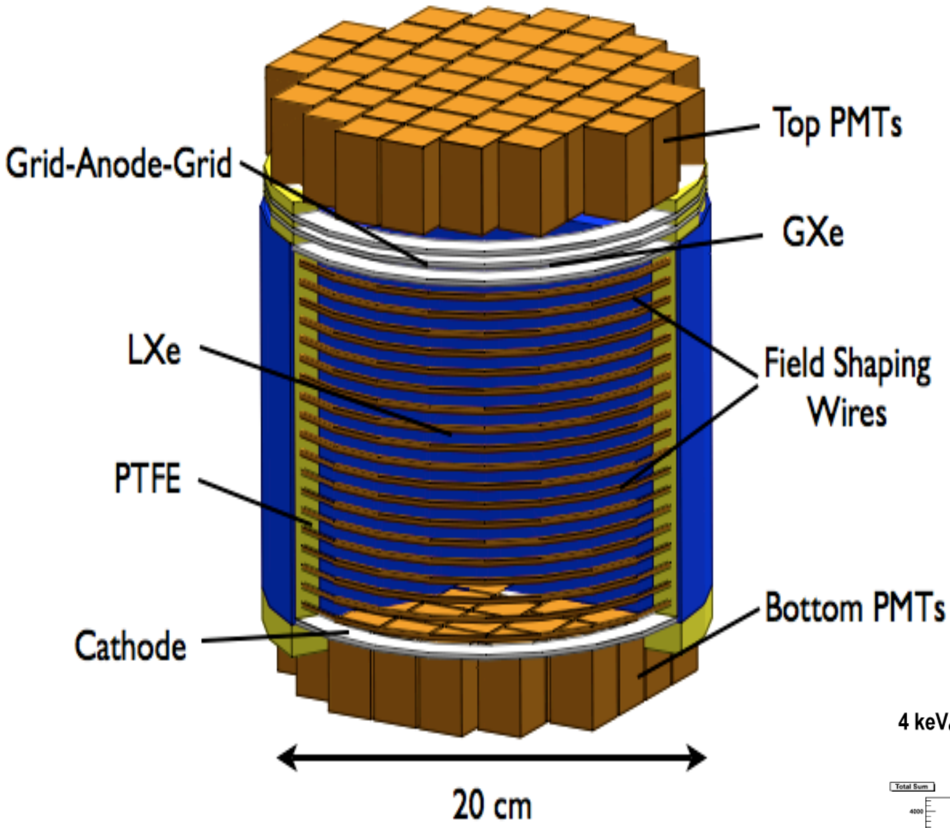
XENON10 WIMP search data

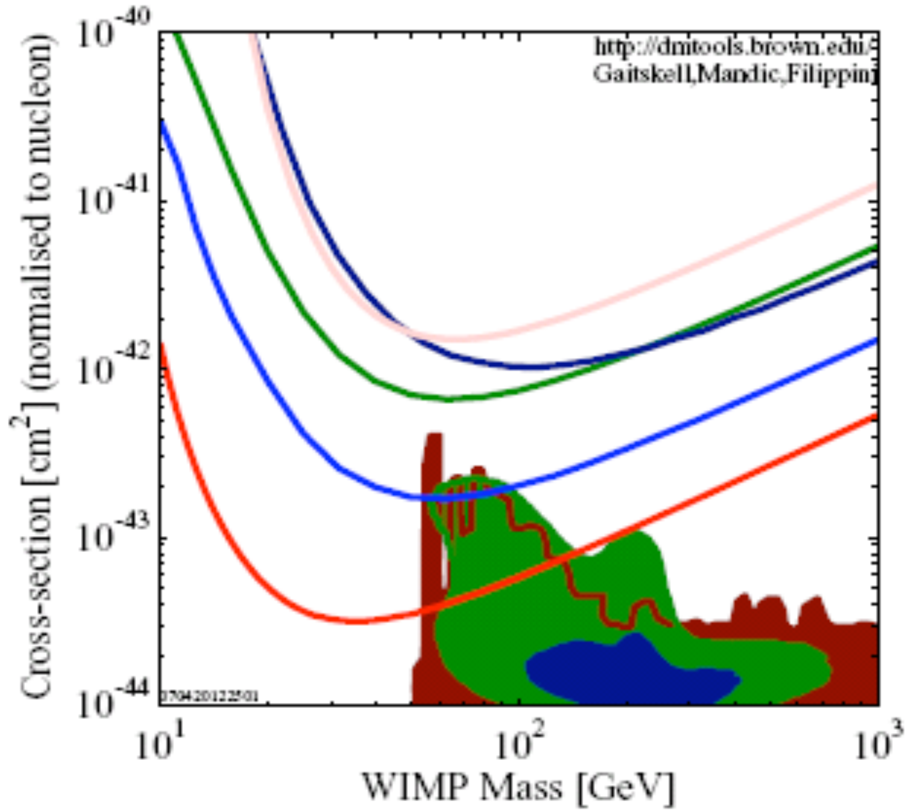
- Blind Analysis
- 58.6 days, 5.4 kg fiducial
- ~50% acceptance of Nuclear Recoils
- 2-12keVee / 4.5-27 keVr
  - Assuming QF 19% 4.5-27 keVr
- 10 events in the "box" after all primary analysis blind cuts
  - Calibration expectation: 7.0 +2.1-1.0 (gaussian)
  - Data: 5 ~gaussian; 5 non-gaussian

"Straightened ER Scale"

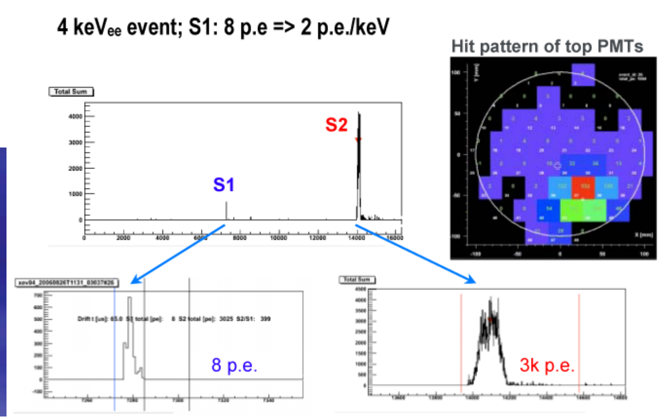


LUX Inspiration: Xenon 10 – New best limit in 2007





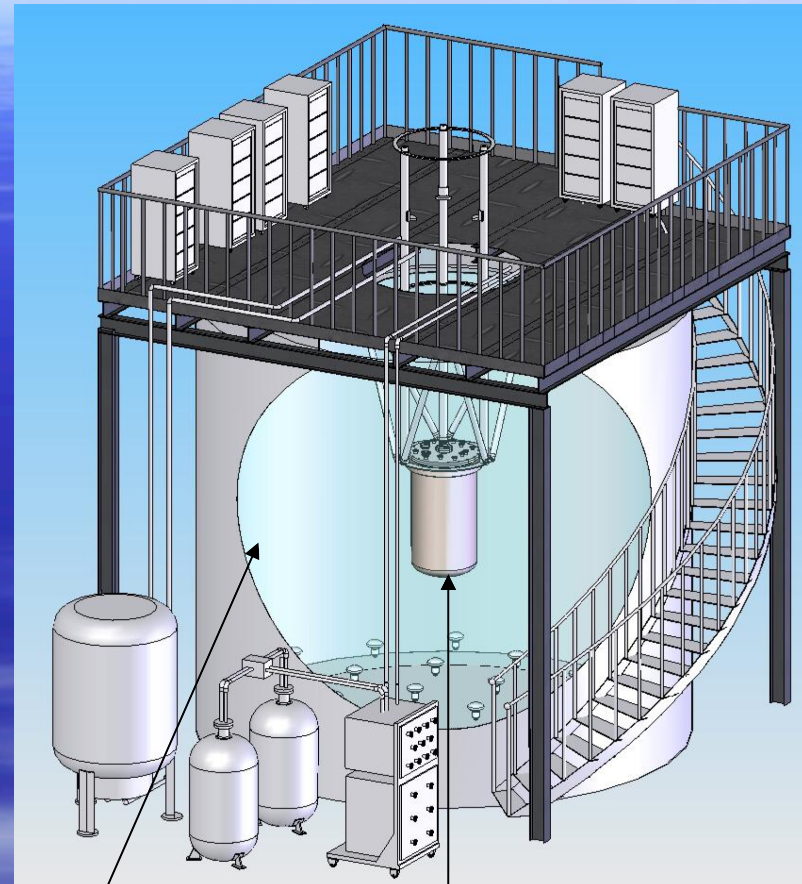
26 kg LXe




LUX

LUX Experiment

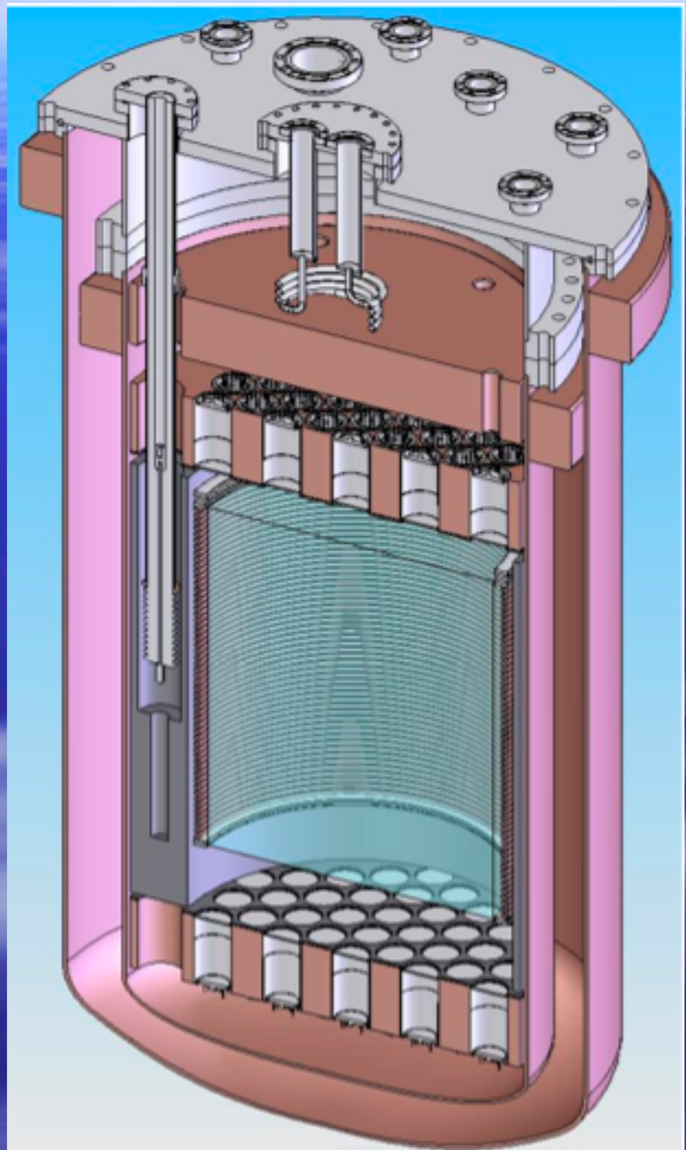
- **The LUX Concept**
  - 100 kg fiducial dual phase xenon detector, 300 kg total xenon mass
  - 2.5 m thick purified water shield
- **The Physics Goal -**
  - Detect (or exclude) WIMPs with a cross section of 7×10^{-46} cm^2 about 100 times more sensitive than current limit
- **Project Cost = 2.8 M$**



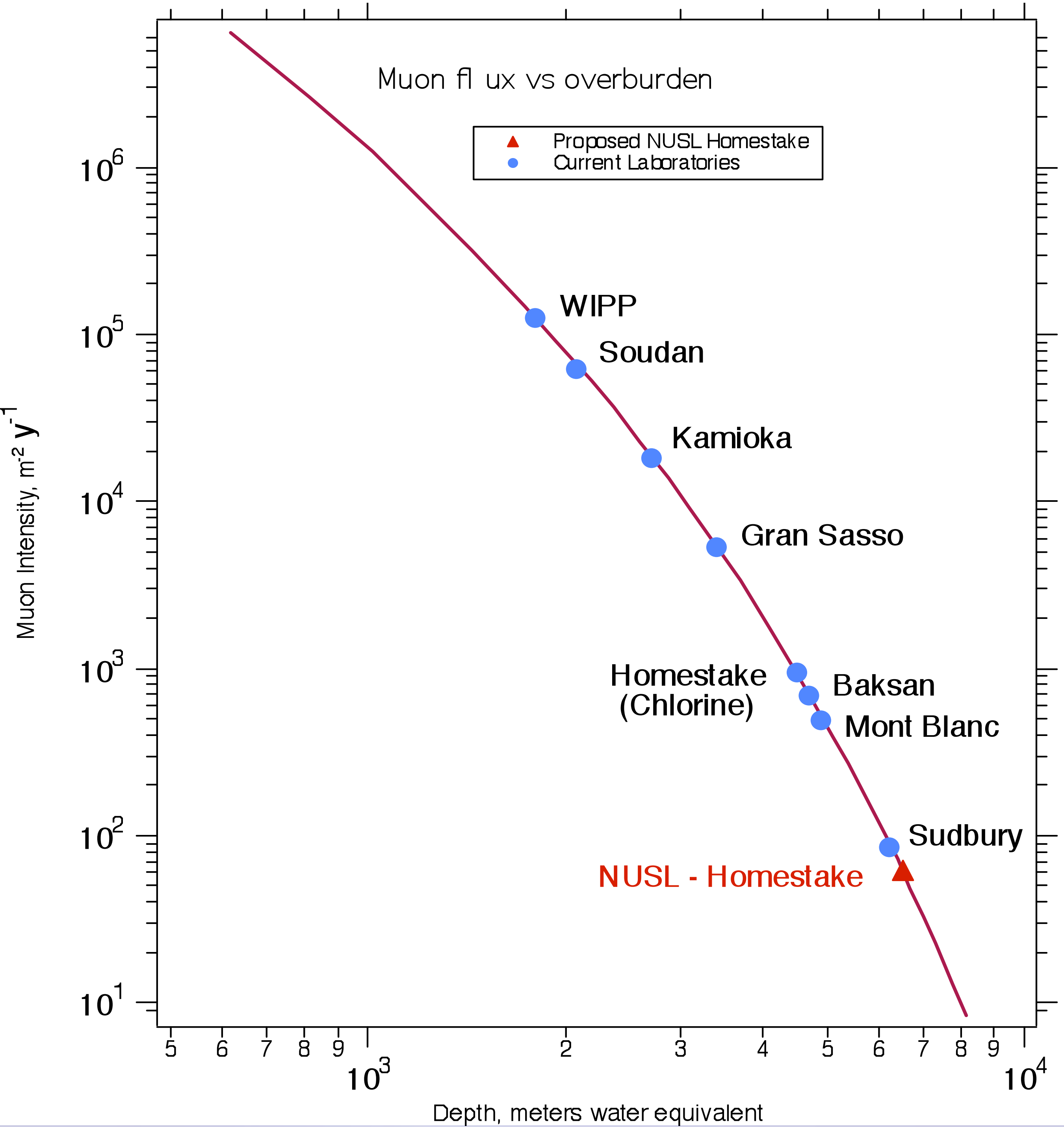
Water shield instrumented with PMTS

LXe emission detector 300 kg total 100 kg fiducial

LUX Detector

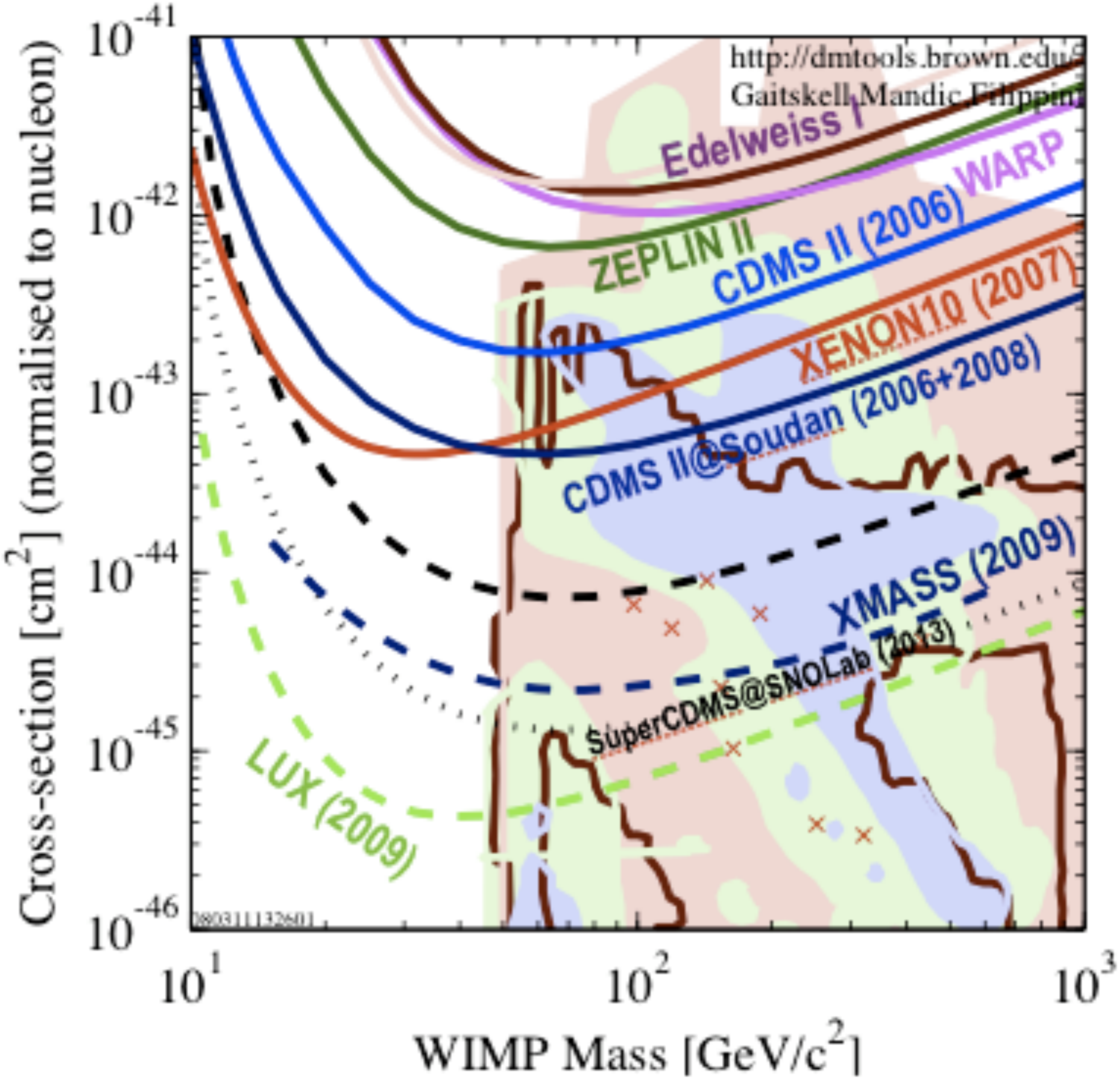


- Xenon Temperature 170K
- Gas Pressure 1.5bar
- 350 Kg of Xenon
- Drift Field 0.5kV/cm
- Active region ø50cm x 50cm


Muon fl ux vs overburden
Proposed NUSL Homestake
Current Laboratories
WIPP
Soudan
Kamioka
Gran Sasso
Homestake (Chlorine)
Baksan
Mont Blanc
Sudbury
NUSL - Homestake
Muon Intensity, m^-2 y^-1
Depth, meters water equivalent
10^1
10^2
10^3
10^4
10^5
10^6
5 6 7 8 9 10^3 2 3 4 5 6 7 8 9 10^4

LUX goal

Source	events in 300 day run (>99% rejection)
PMT gammas (for highest activity estimate, HM R8788 PMT)	1
PMT and other internal neutrons	0.1
L.b. cryostat/PTFE…	0.05
External "punch-through" neutrons	0.01
Muogenic neutrons in water (after 0.99 eff. Veto)	0.0025
External gammas	0.0002
Total Predicted Background in 300 days	<~1

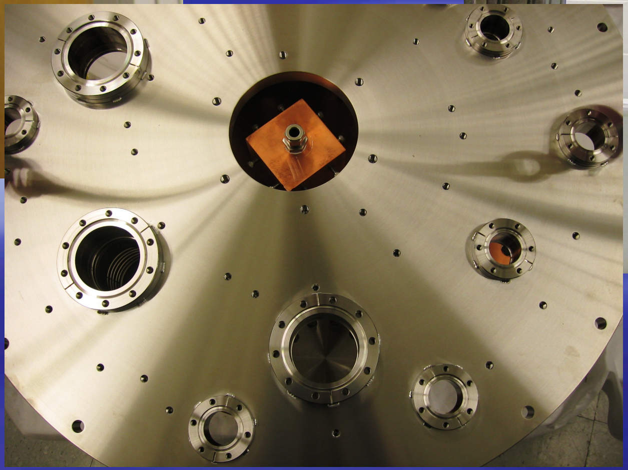


Predicted WIMP rate = 4 events in 300 day for $7 \cdot 10^{-46}$ cm^2 @ 100 GeV

LUX Deployment Plan

- **LUX-0.1 test unit - summer 2009**
- **DUSEL/SUSEL cavern renovation - late 2009**
- **Deployment LUX-1.0 in DUSEL/SUSEL - Dec 2009**
- **Run LUX-1.0 for ~ 1 year of 2009**

Cryostat at Case 2007/2008



Thermosyphon cooling system

Thermosyphon principle of operation

$$dQ/dt = k\,A\,(T_H - T_C) / L$$

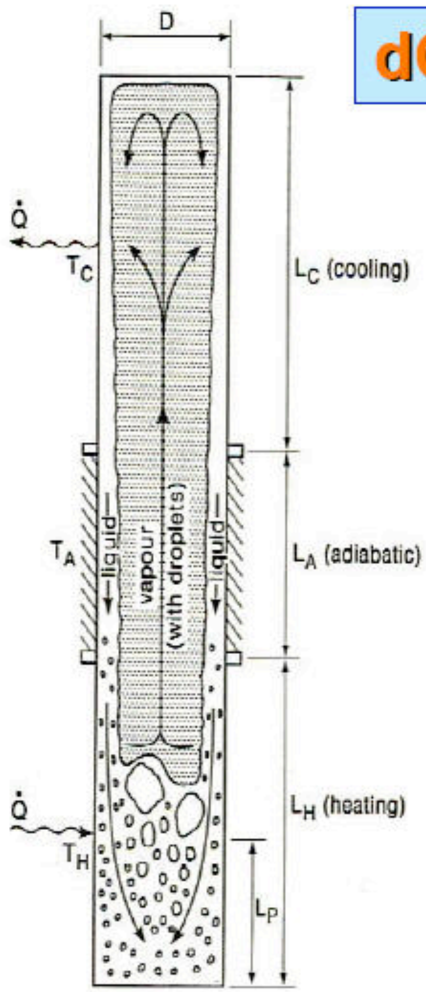


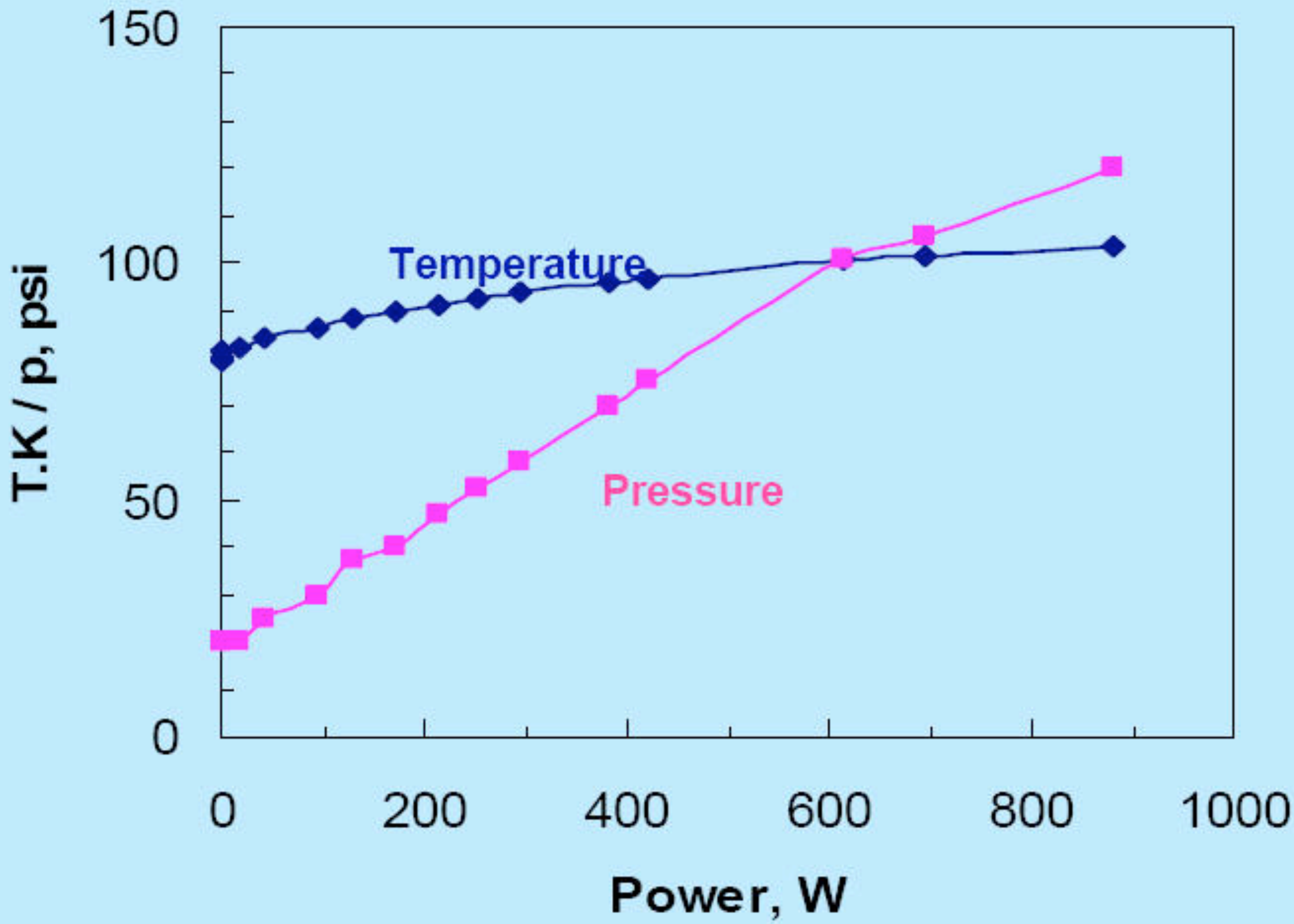
Fig. 3.13. Model of evaporative tubular thermosyphon standing vertical.

Thermosyphon cooling system

Thermal conductivity k = (ΔW/ΔT)(L/A) = 30 kW/Km

diamond 1-2 kW/Km

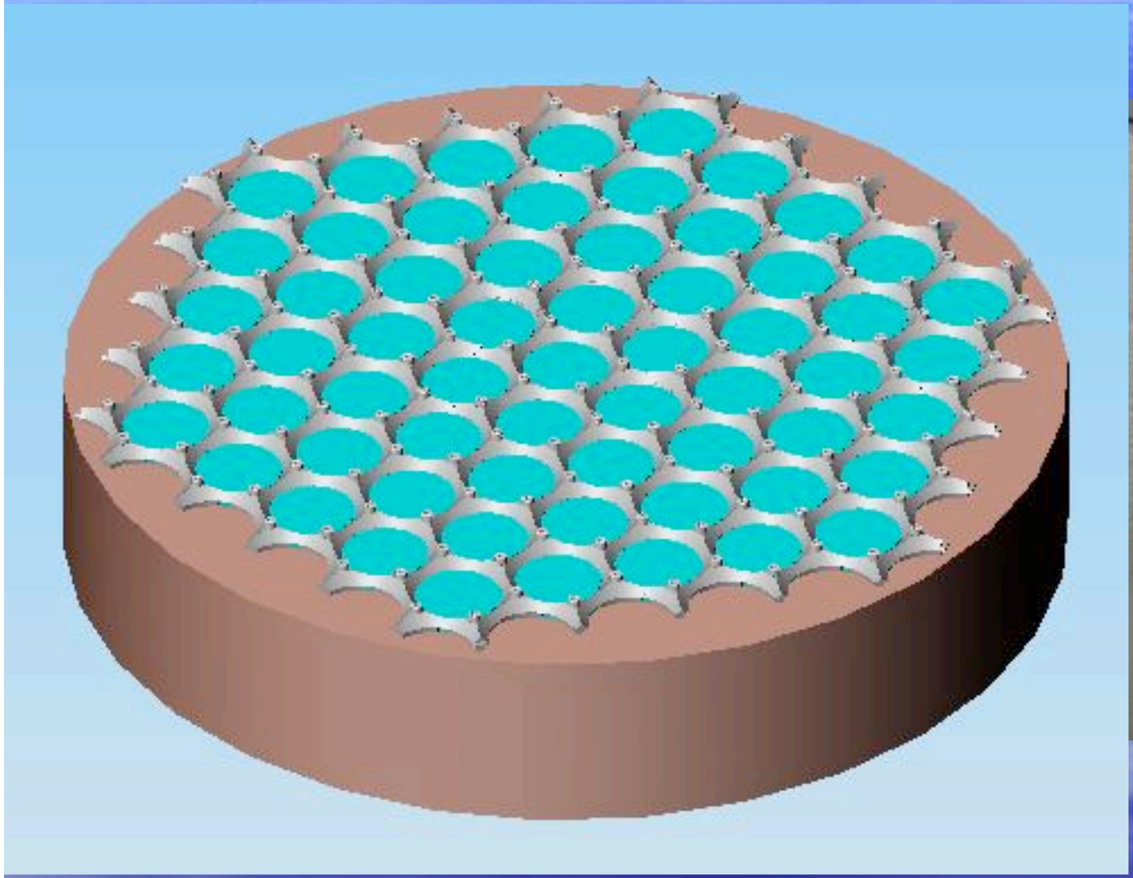
copper 0.4 kW/Km



Thermosyphons at oil-pipeline in North Russia

Photomultiplier Tubes

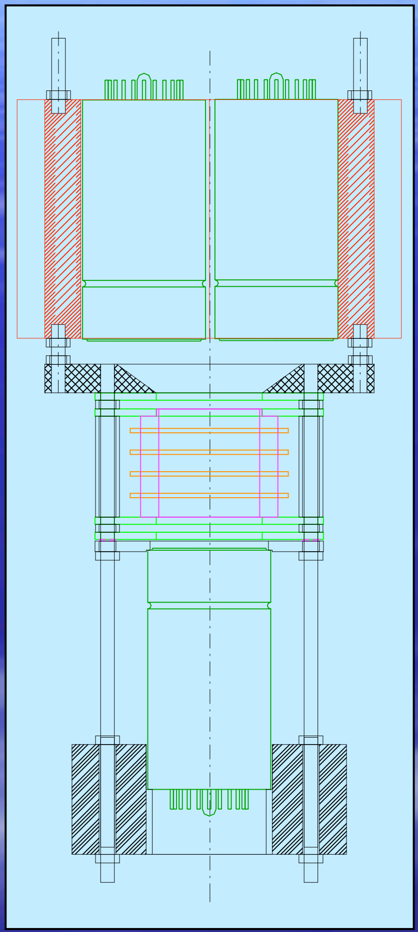
Hamamatsu R8778 : QE ~30% Background < 50mBq



LUX-0.1 PMT ASSEMBLY

LUX-1.0 PMT ASSEMBLY

LUX-0.1



Installation LUX-0.1:

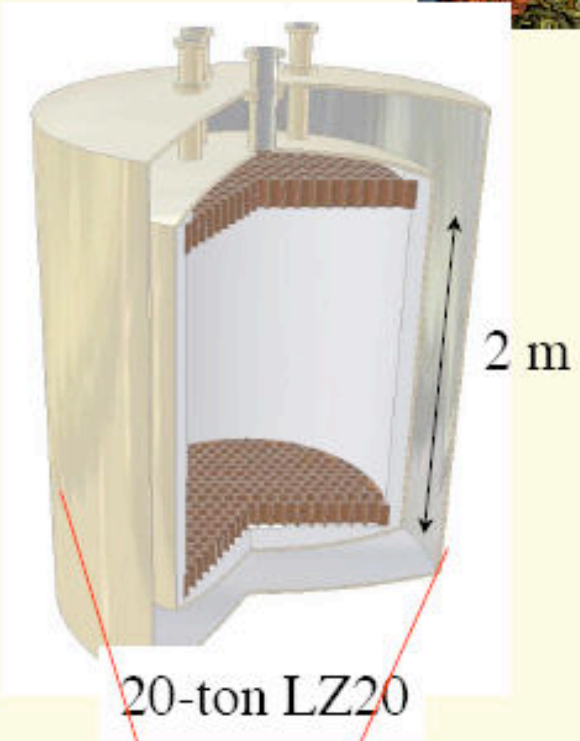
Aluminum filler to be replaced by LXe in LUX-1.0

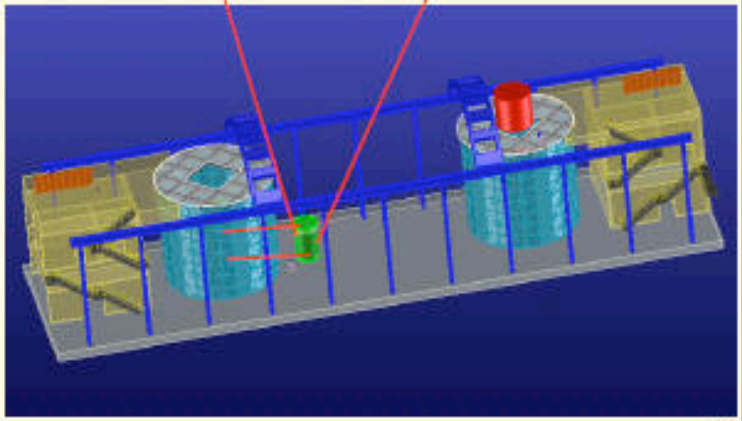
Summary

- Existing Cryostat at Case can support large mass LXe operations
- LUX-0.1 test platform is under operation
- LUX-1.0 components – in production
- Kr-85 removing system updated to process 350 kg Xe in 2008
- By the end of the year LUX should be installed at Homestake gold mine

LZ20

- New collaboration between LUX, and ZEPLIN III.
  - ZEPLIN III: largest European LXe dark matter collaboration: UK, Portugal, Russia
- LZ3: 3 ton, at Sanford Lab
  - Proposals: Sept. 09.
- LZ20: proposed part of ISE for DUSEL
  - 20 ton LXe mass
  - "ultimate" direct dark matter detection experiment





LZ20 in Context