# The LUX Dark Matter Experiment

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Yale University


8th Patras Workshop on Axions, WIMPs, and WISPs , July 18th, 2012

# Xenon as a WIMP Target

Inert

High density (3g/cm$^3$ for liquid)

High $A^2$ increases spin-independent cross-section

Some isotopes sensitive to spin-dependent interactions

Bright scintillator with fast (~ns) response

High electron mobility

Long ionization drift lengths (several meters) demonstrated

No long-lived radioactive isotopes

Low cost (~$1000/kg) and readily available in large quantities

Easy to scale

# Direct WIMP Detection with Liquid Xenon

Goal: observe recoils between a WIMP and a target nucleus

Equation for WIMP interaction cross section

$$\frac{dN}{dE_R} \propto \left( \frac{e^{-E_R/(E_0 r)}}{E_0 r} \right) \cdot \left( F^2(E_R) \cdot I \right)$$

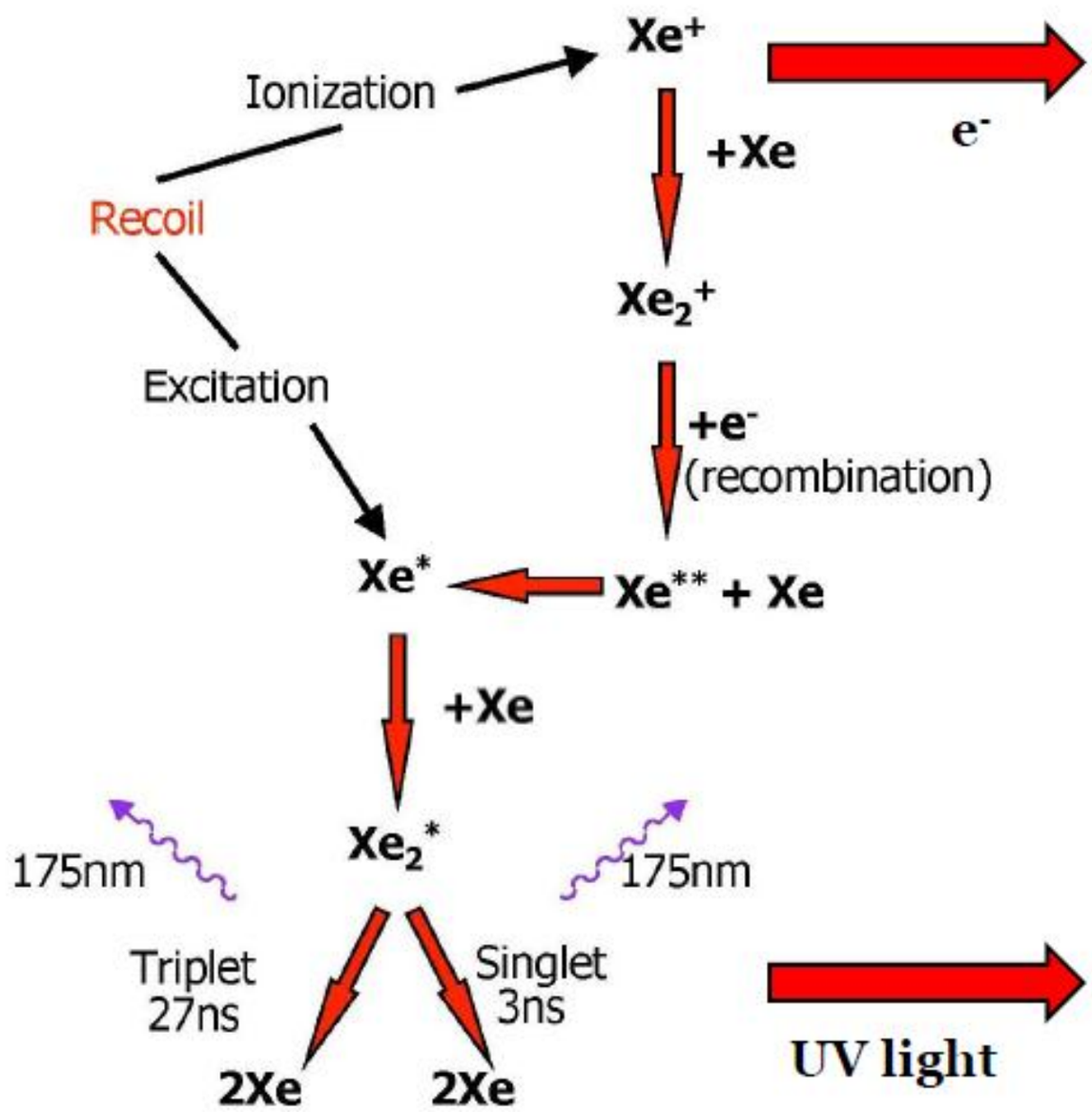
$$I \propto A^2 \quad \text{(for S.I. interactions)}$$

Recoil energy deposited in three channels:

Scintillation (photons)

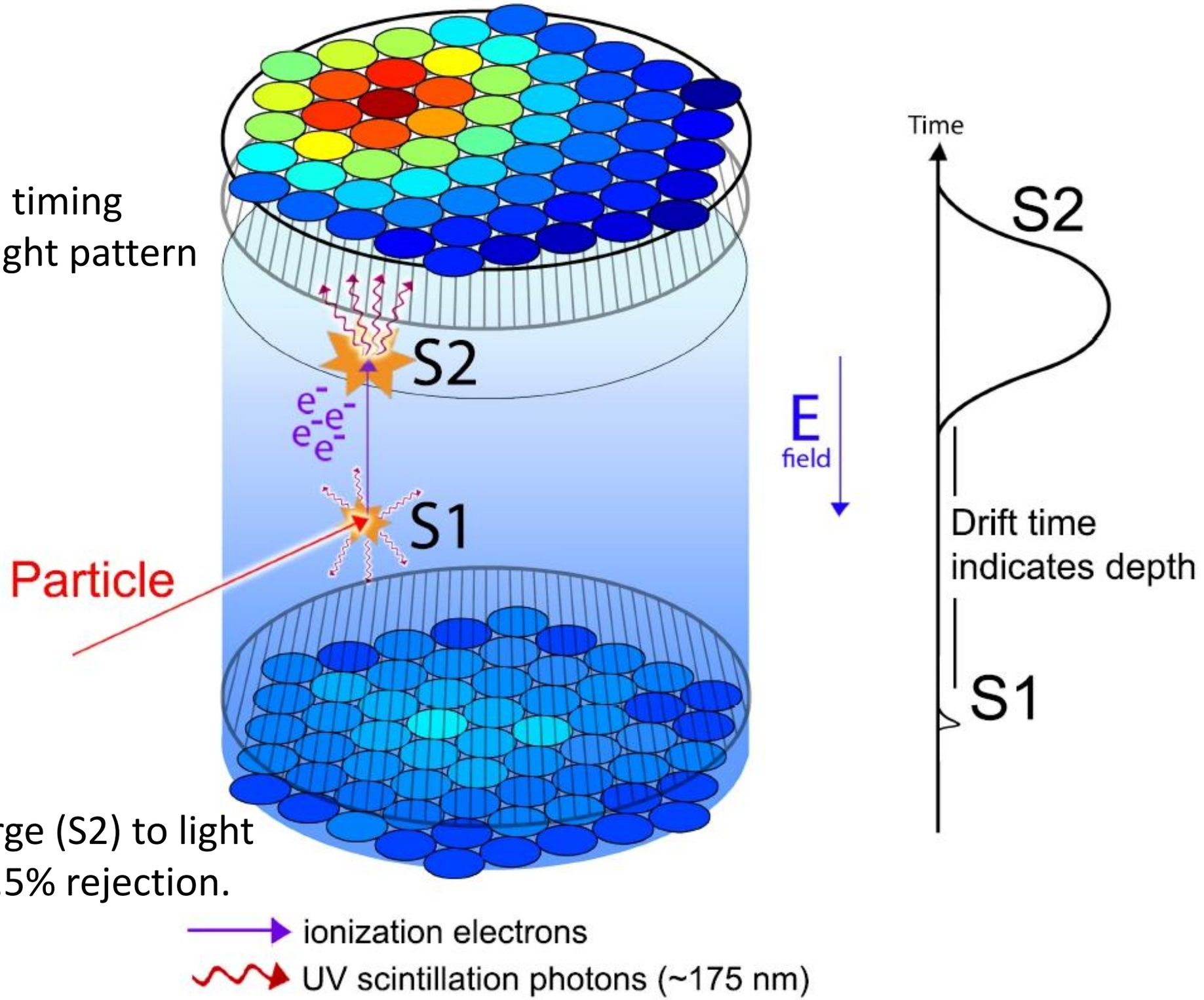
Ionization (charge)

Heat (phonons)



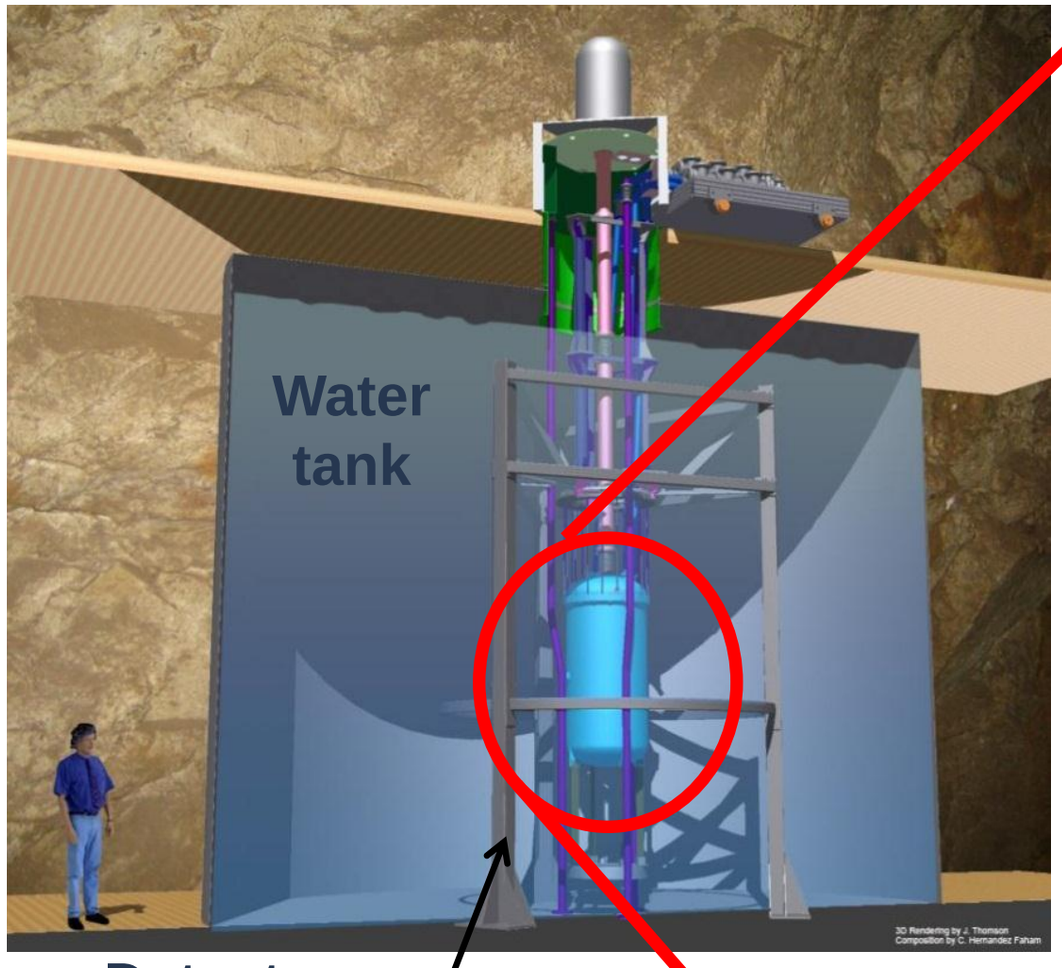
# LUX is a two-phase xenon WIMP detector

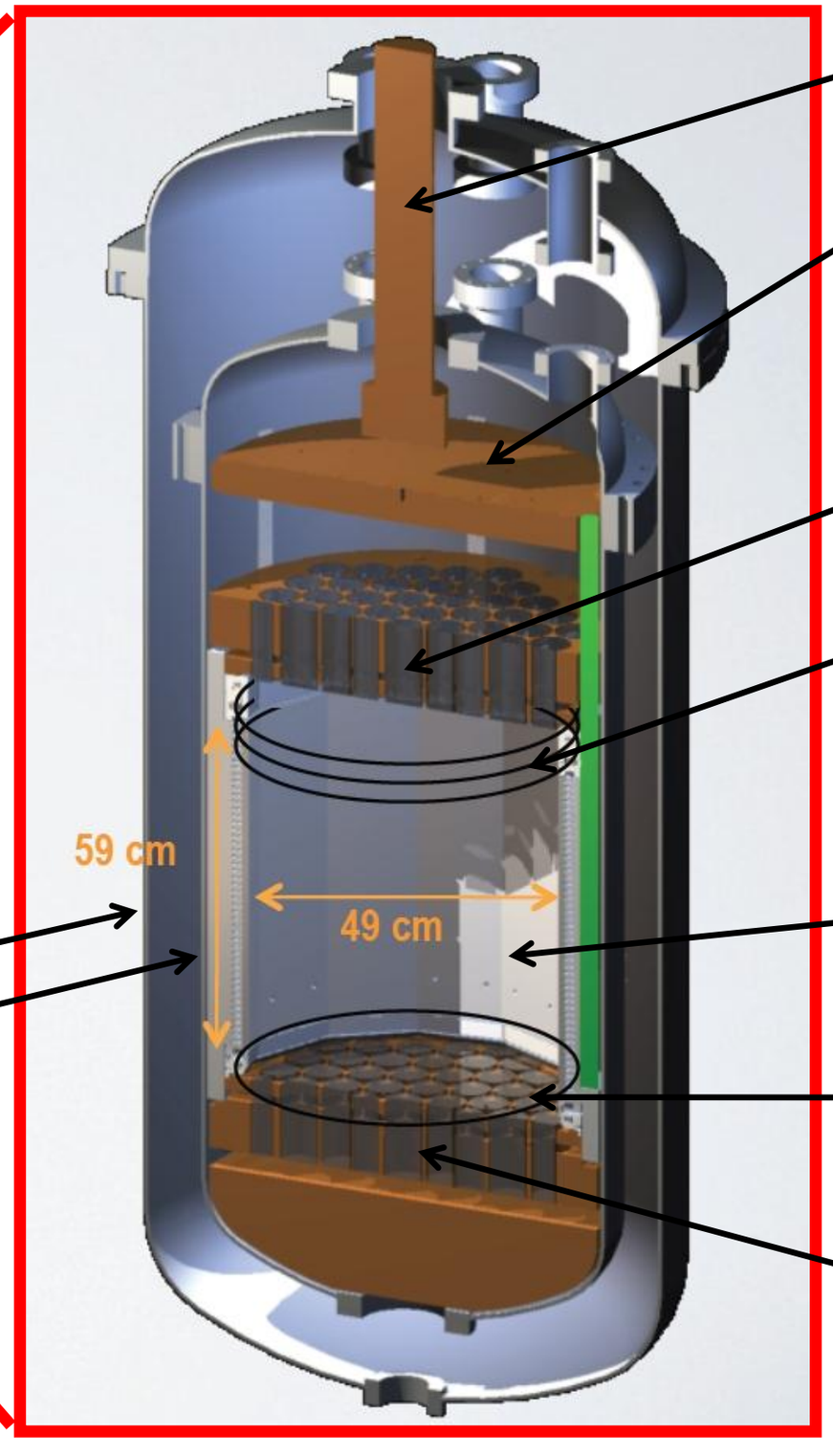
Z position from S1 – S2 timing
X-Y positions from S2 light pattern




Reject gammas by charge (S2) to light (S1) ratio.  Expect > 99.5% rejection.

# The LUX Detector




Thermosyphon

Copper shield

Top PMT array

Anode grid

PTFE reflector panels and field cage

Cathode grid

Bottom PMT array

350 kg xenon:
- 300 kg active region
- 100 kg fiducial

# 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 |

## Case Western

| | |
|---|---|
| Thomas Shutt | PI, Professor |
| 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 |

## University of Rochester

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

## Lawrence Livermore

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

## SD School of Mines

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|---|---|
| Xinhua Bai | PI, Professor |

## University of South Dakota

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

## University of Maryland

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

## Texas A&M

| | |
|---|---|
| James White | PI, Professor |
| Robert Webb | Professor |
| Rachel Mannino | Graduate Student |
| Clement Sofka | Graduate Student |

## UC Davis

| | |
|---|---|
| Mani Tripathi | PI, Professor |
| Robert Svoboda | Professor |
| Richard Lander | Professor |
| Britt Hollbrook | Senior Engineer |
| John Thomson | Senior Machinist |
| Matthew Szydagis | Postdoc |
| Richard Ott | Postdoc |
| Jeremy Mock | Graduate Student |
| James Morad | Graduate Student |
| Nick Walsh | Graduate Student |
| Michael Woods | Graduate Student |
| Sergey Uvarov | Graduate Student |

## Lawrence Berkeley + UC Berkeley

| | |
|---|---|
| Bob Jacobsen | PI, Professor |
| David Taylor | Engineer |
| Mia ihm | 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 |
| Nicole Larsen | Graduate Student |
| Evan Pease | Graduate Student |
| Brian Tennyson | Graduate Student |

## UC Santa Barbara

| | |
|---|---|
| Harry Nelson | PI, Professor |
| Mike Witherell | Professor |
| Dean White | Engineer |
| Susanne Kyre | Engineer |

## Imperial College London

| | |
|---|---|
| Henrique Araujo | PI, Senior Lecturer |
| Tim Sumner | Professor |
| Alastair Currie | Postdoc |

## University of Edinburgh

| | |
|---|---|
| Alex Murphy | PI, Reader |
| Lea Reichhart | Graduate student |

## University College London

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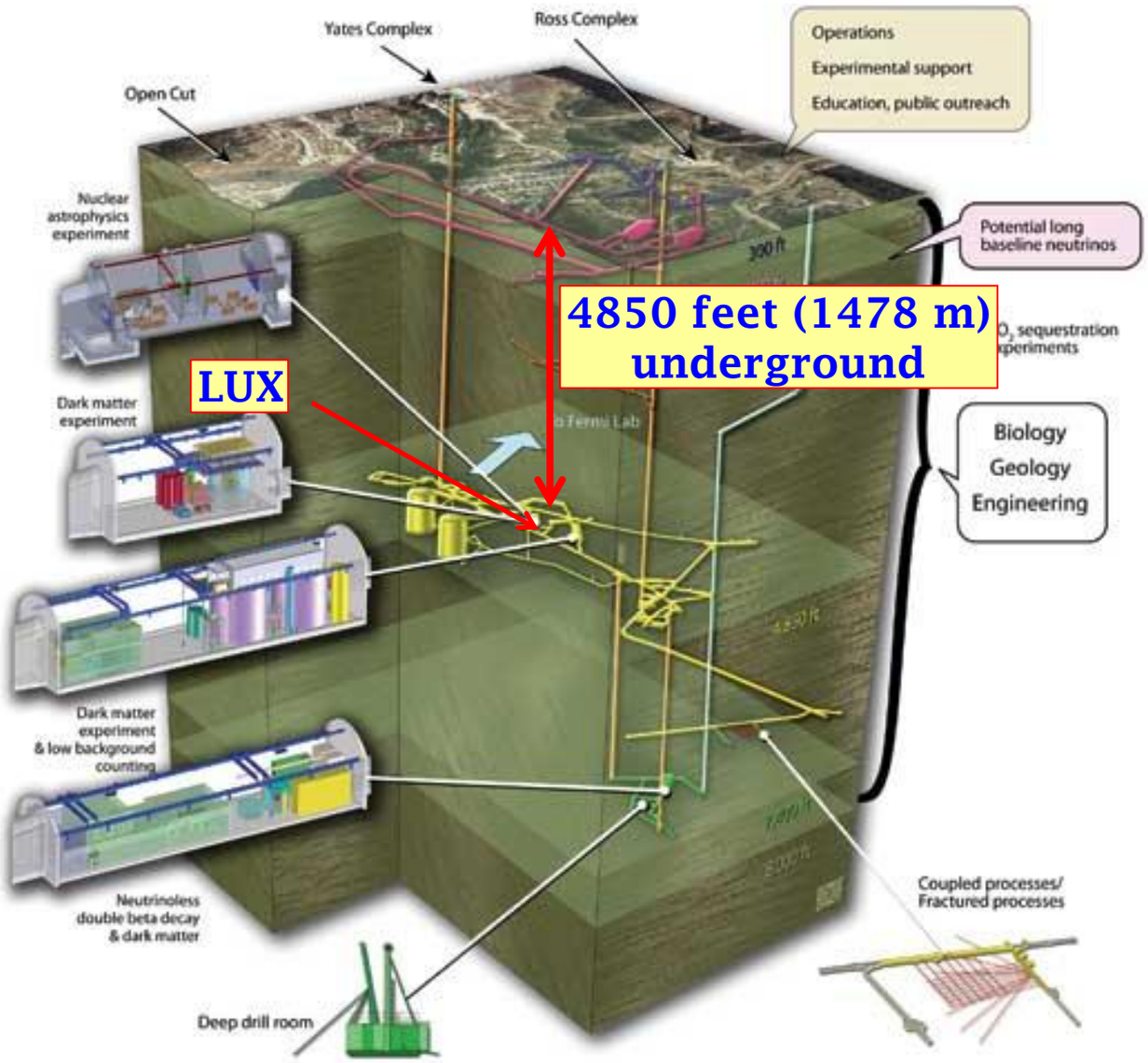
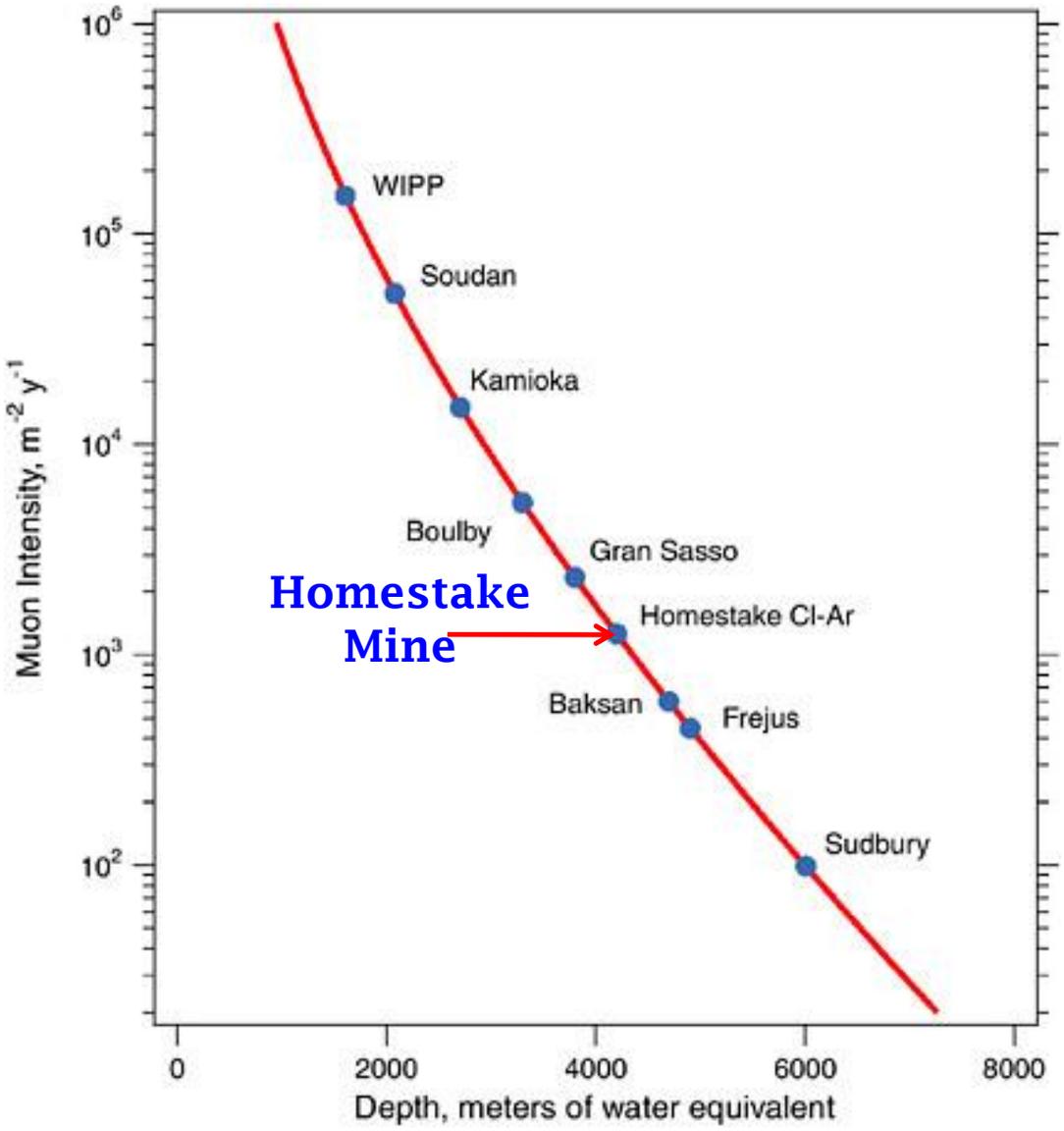
|---|---|
| Chamkaur Ghag | PI, Lecturer |

## LIP Coimbra

| | |
|---|---|
| Isabel Lopes | PI, Professor |
| Jose Pinto da Cunha | Assistant Professor |
| Vladimir Solovov | Senior Researcher |
| Luiz de Viveiros | Postdoc |
| Alexander Lindote | Postdoc |
| Francisco Neves | Postdoc |
| Claudio Silva | Postdoc |

# Sanford Underground Research Facility (SURF)




**55.2 $m^{-2} \cdot sec^{-1} \rightarrow 10^{-5}$ $m^{-2} \cdot sec^{-1}$**

**~$10^7$ fold muon flux suppression**

# Backgrounds in LUX

Davis Cavern at Homestake Mine is 4850’ below the surface

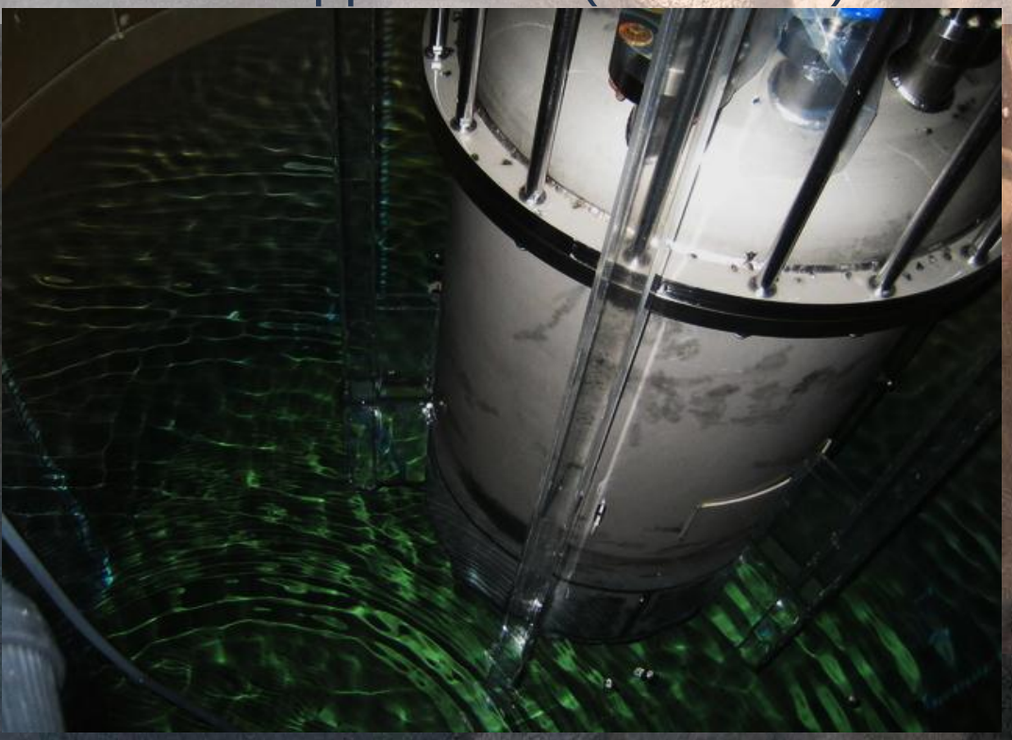
Reduces cosmic ray flux by $10^7$

## 300 ton water shield:

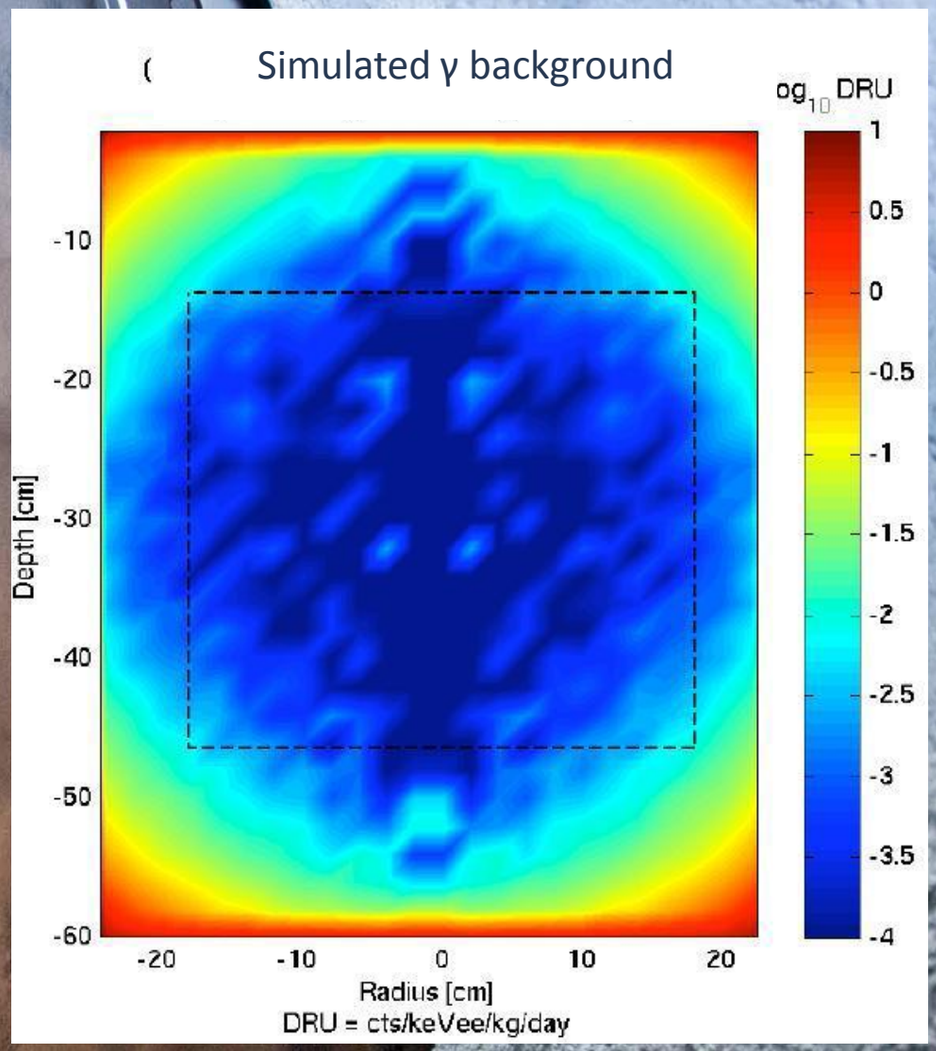
Gamma suppression: ~$10^7$

Neutron suppression (>10 MeV): ~$10^3$

Neutron suppression (<10 MeV): <$10^9$



## Self-Shielding:



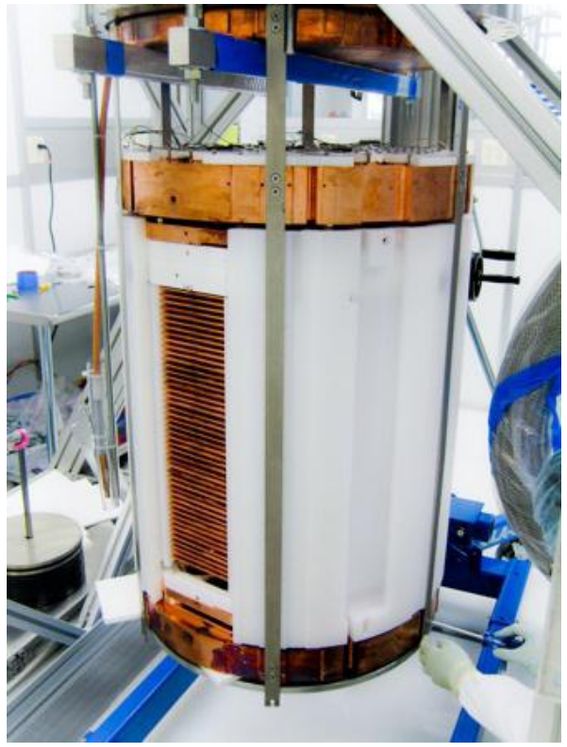

Continuous purge of internals limits Rn exposure

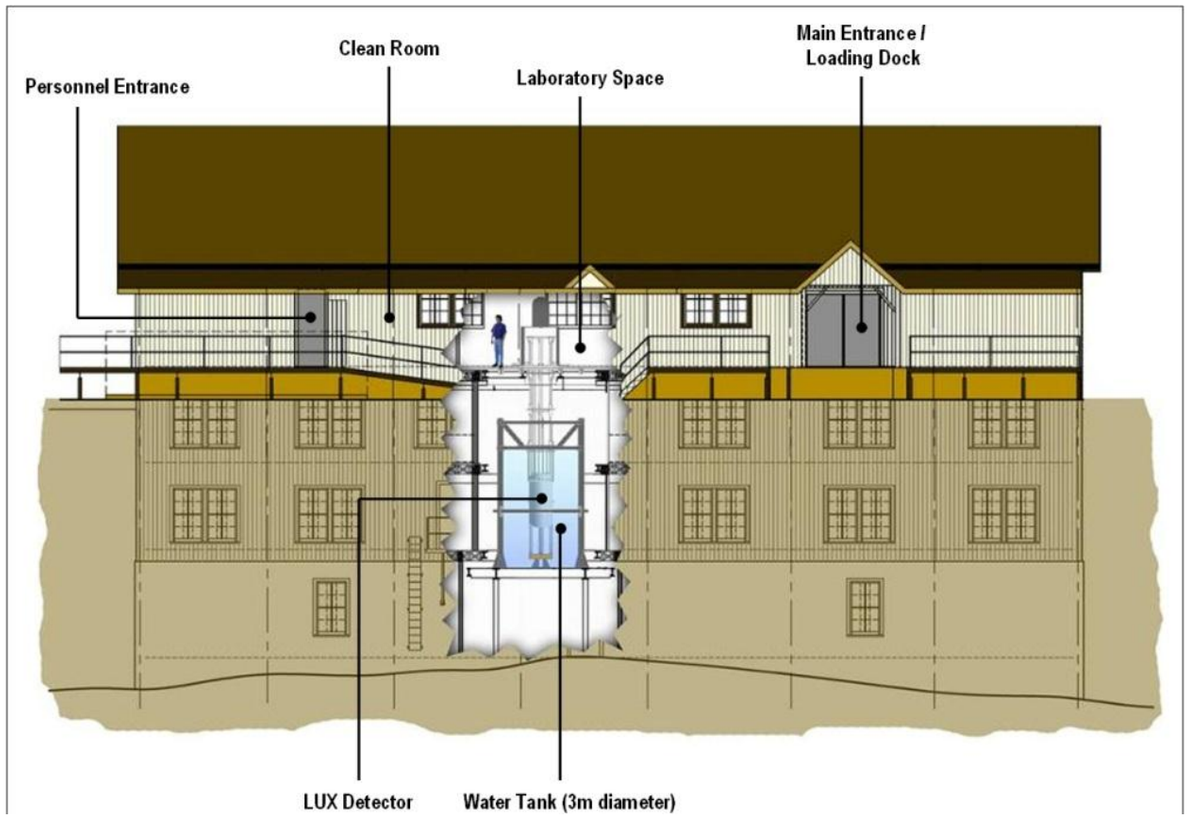
Kr removed using a charcoal column

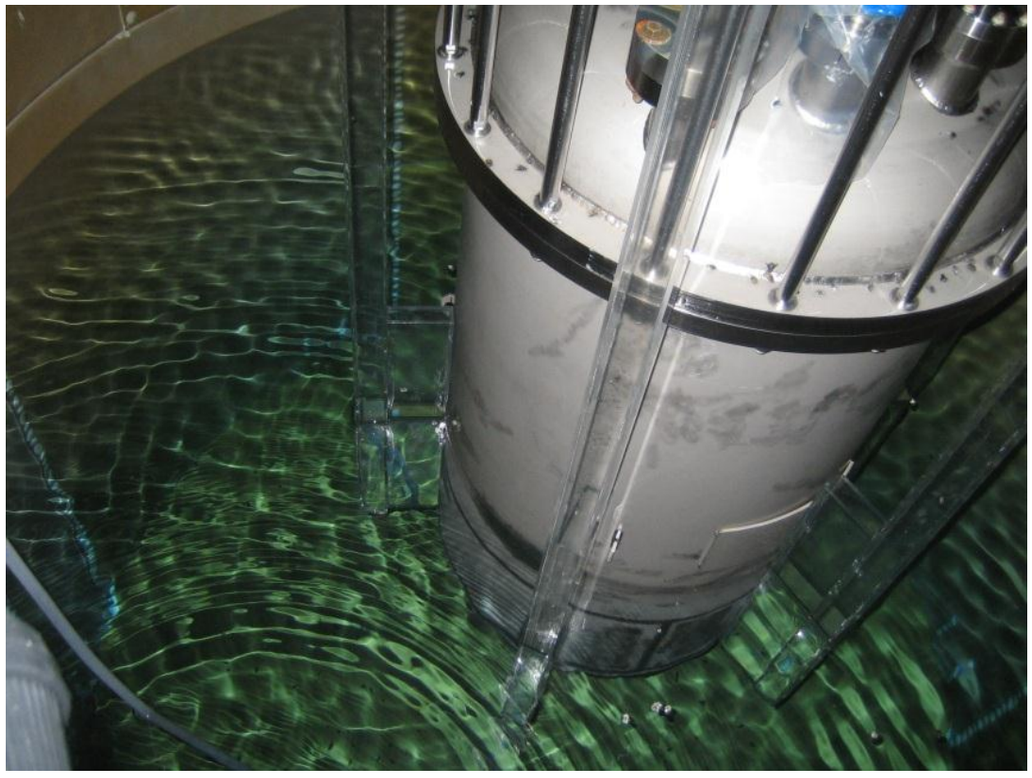
Internal background dominated by PMTs

# LUX Surface Run

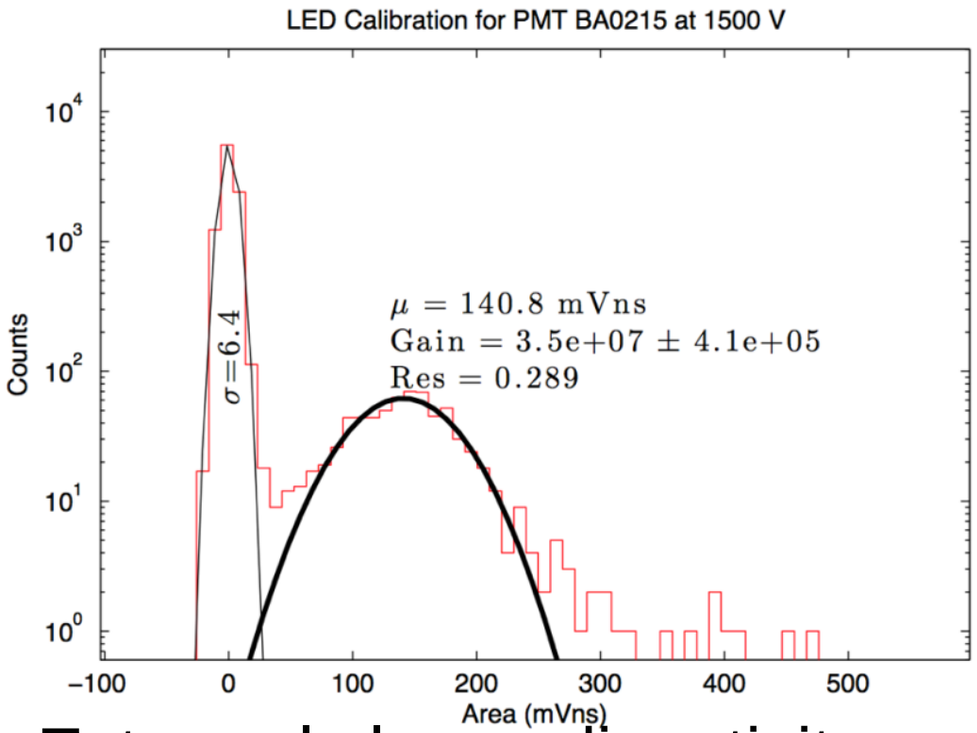
- Stable cryogenic operation for > 100 days
  - Ended on Feb 2012, detector being moved underground
- First successful use of technologies proposed for tonne-scale detectors:
  - Biggest double phase Xe detector in operation: 350 kg, 122 PMTs
  - Low background Ti vessel, < 0.2 mBq/kg
    (arXiv:1112.1376)
  - Thermosyphon cooling
  - High flow Xe circulation (> 30 slpm)
  - Full scale deployment in water tank





# Hamamatsu R8778 PMTs

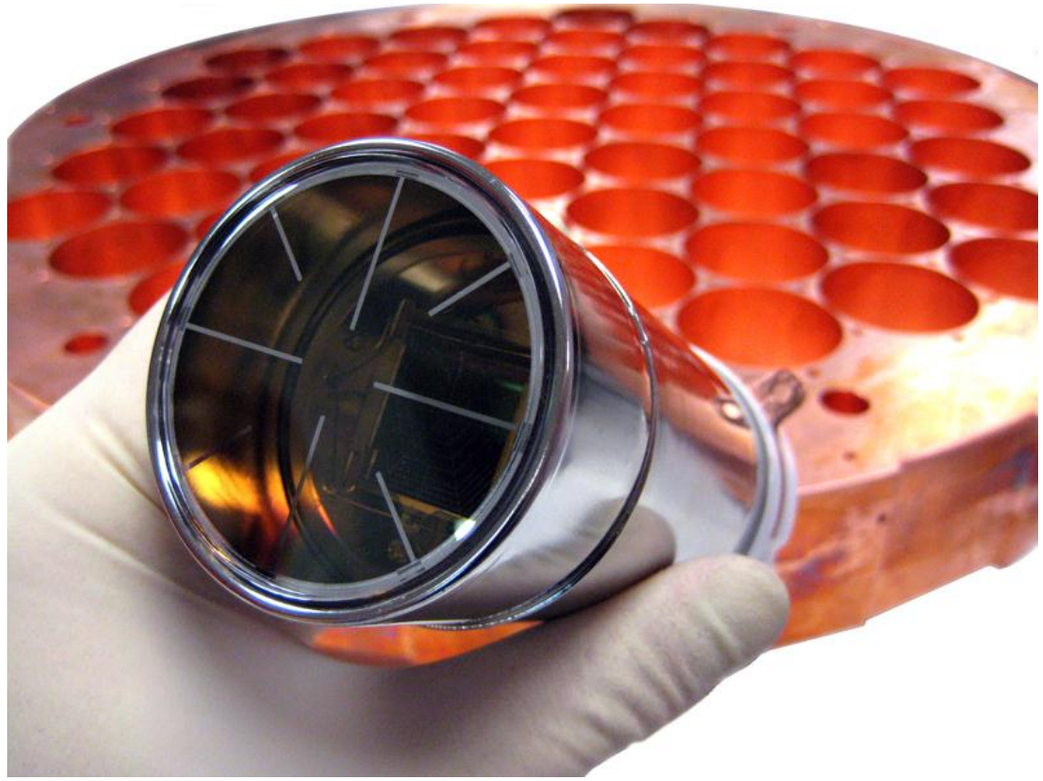



- Extremely low radioactivity:
  - < 9.5 mBq $^{238}$U / PMT
  - < 2.7 mBq $^{232}$Th / PMT
  - < 66 mBq $^{40}$K / PMT
- 33% quantum efficiency; 90% collection efficiency
- Gain = 3.3e6

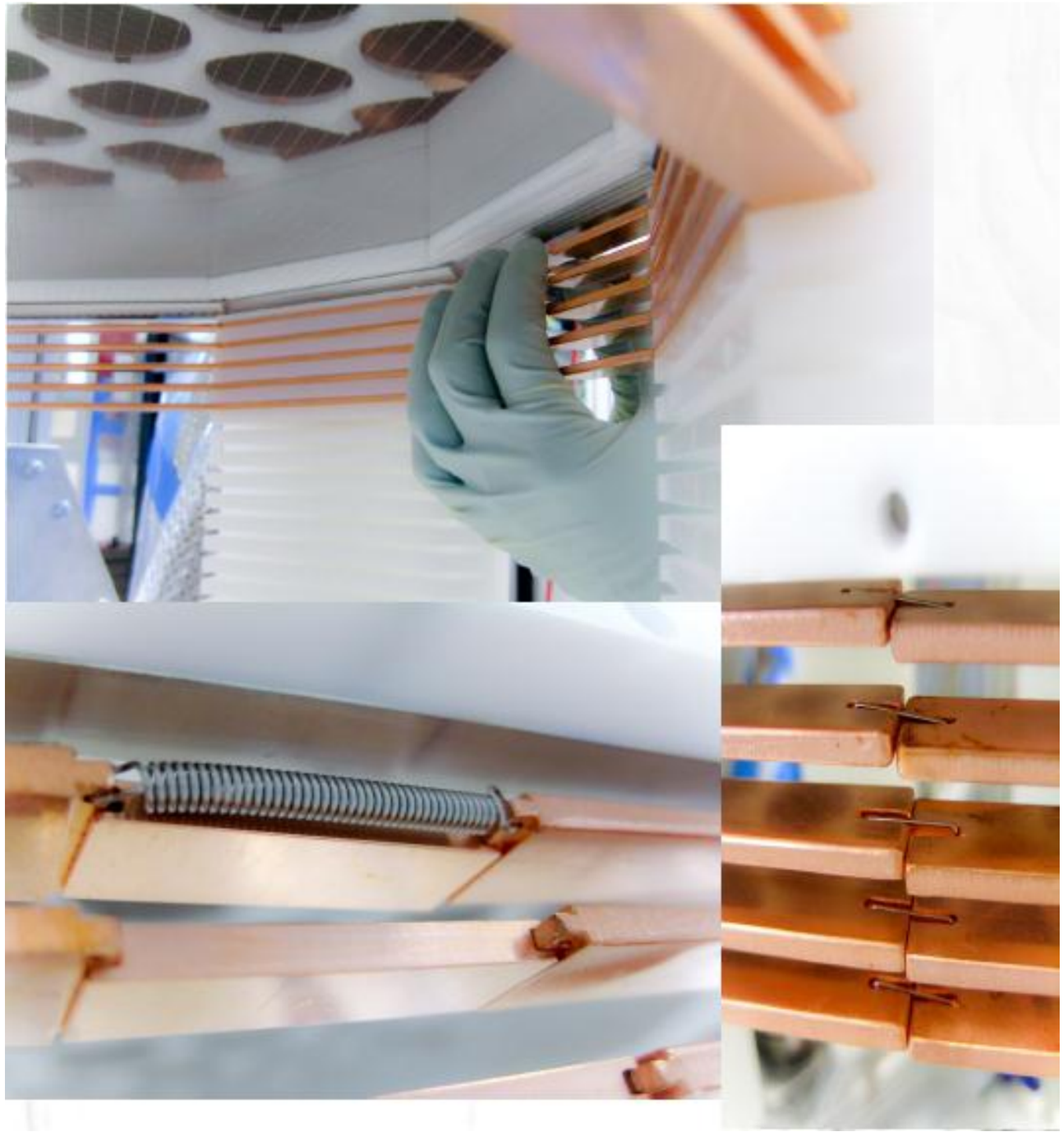
2” diameter provides high surface area coverage

Efficient detection of 178 nm light

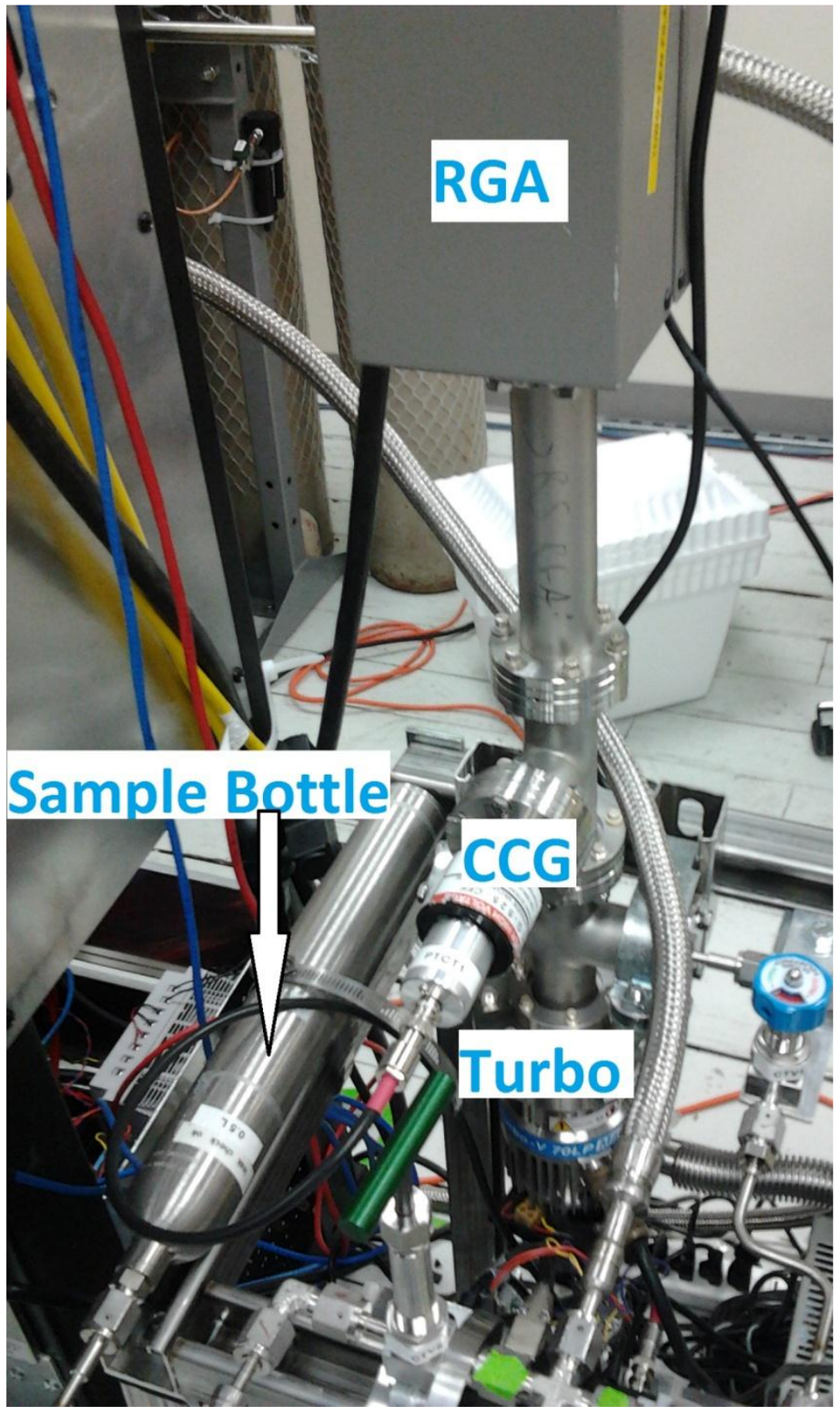
Operates in the LXe temperature range (165 - 180 K)



# Field Rings



# Circulation, Sampling and Storage



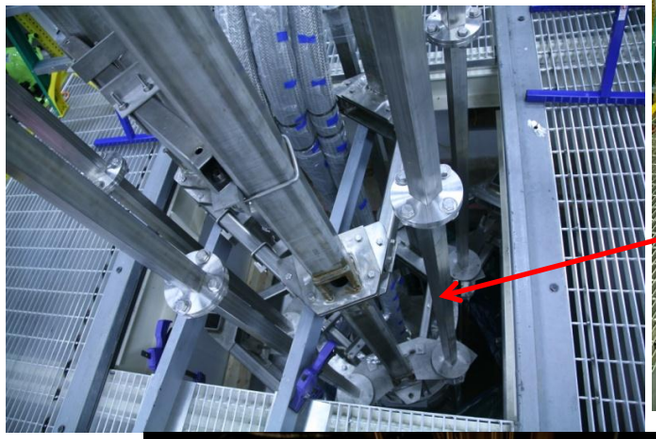

Circulation at 35 SLPM through purifier by diaphragm pump

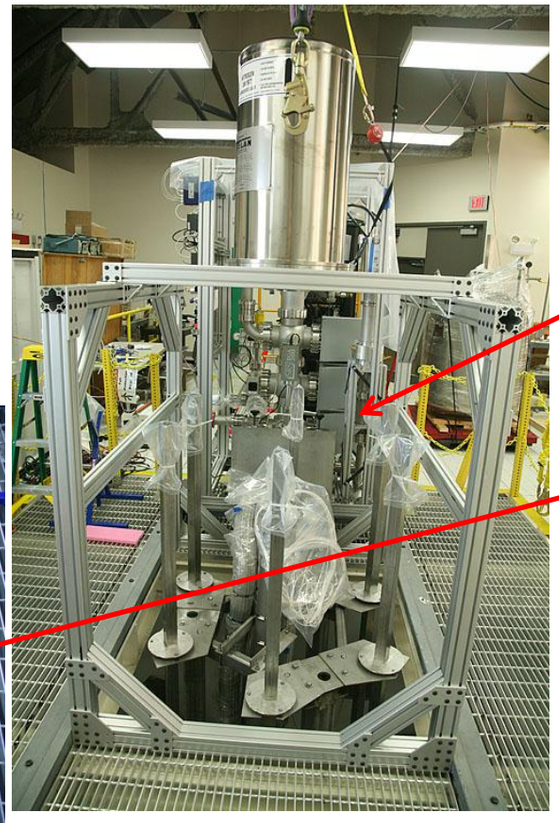
Xenon recoverable to Storage and Recovery Vessel (SRV)

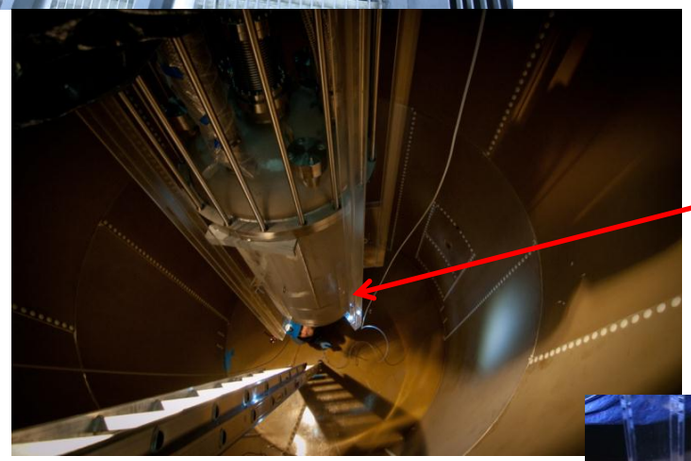
In-situ xenon sample RGA analysis[1] sensitivity:
0.7 ppb $O_2$ mol / mol, 0.5 ppt Kr mol / mol

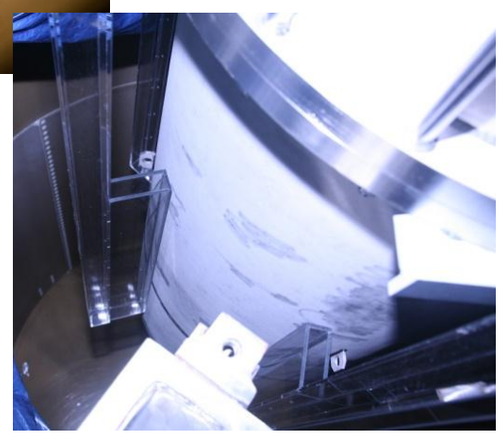
1) A. Dobi et al., NIM-A, Vol. 675, 40-46 (2012) [arXiv:1109.1046]

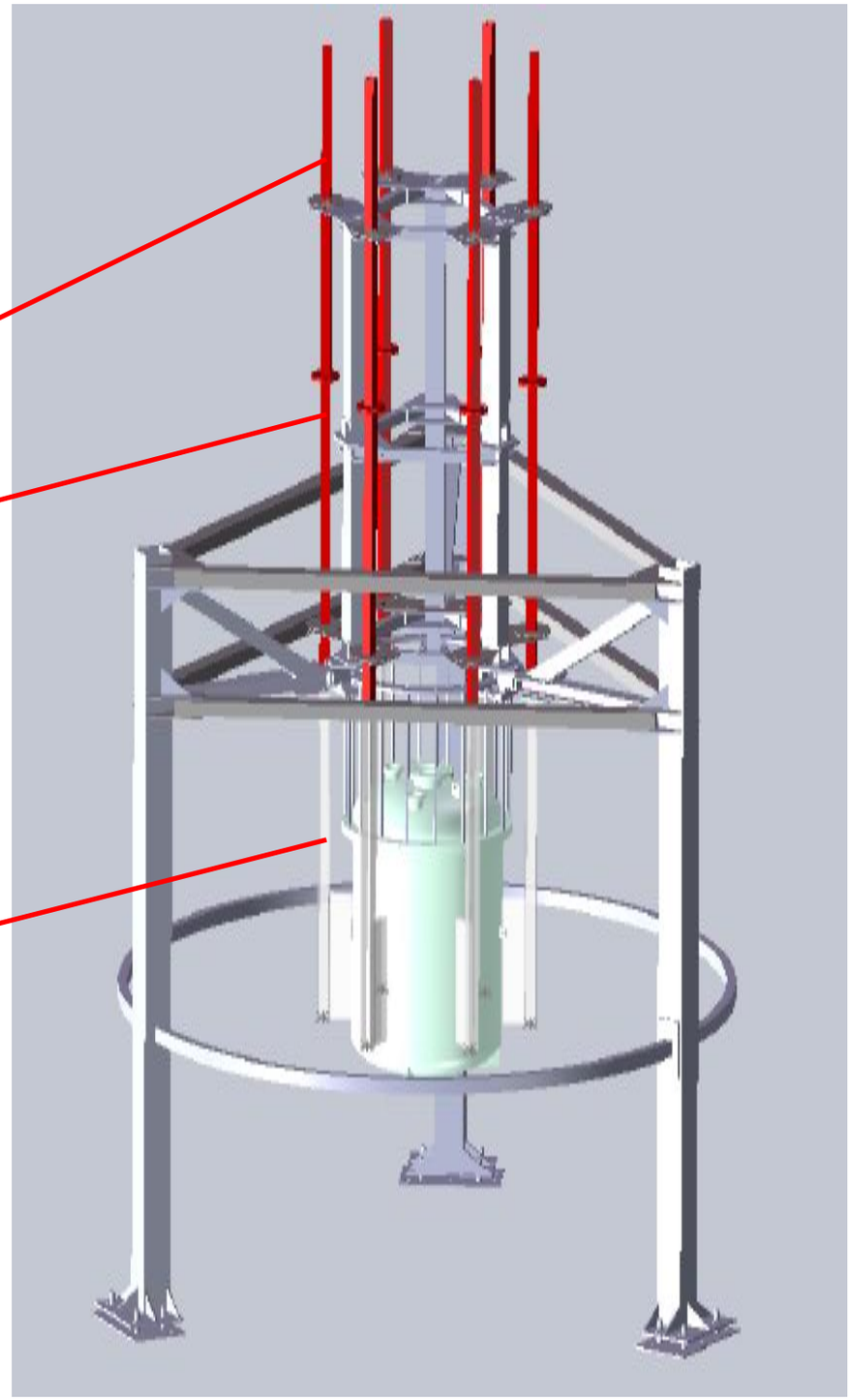
# LUX calibration system: source tubes







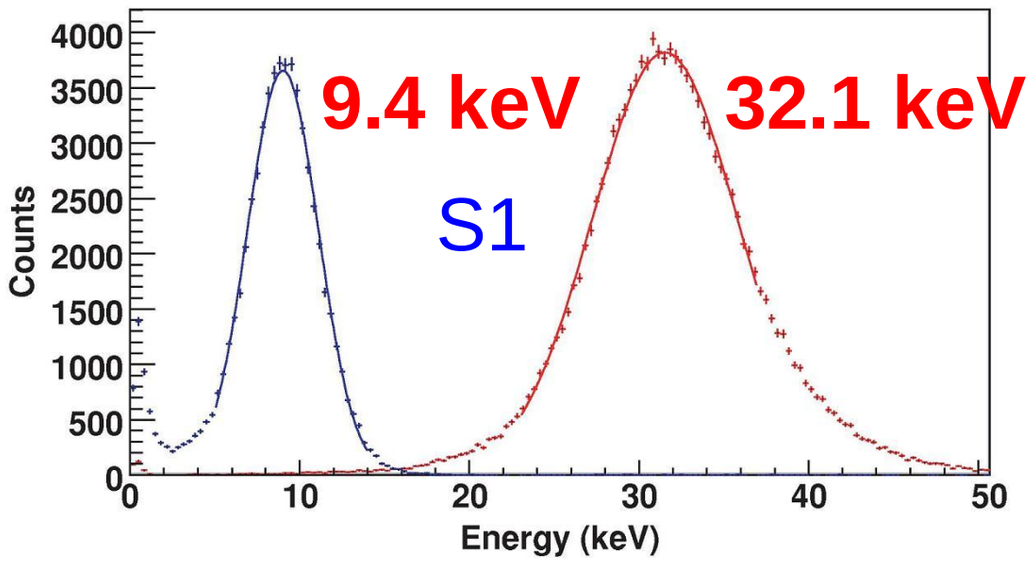




$^{133}$Ba, $^{137}$Cs, $^{22}$Na, $^{208}$Tl (collimated):
S1 LY, ER energy bands, $e^-$ lifetime
$^{241}$Am/Be: NR band

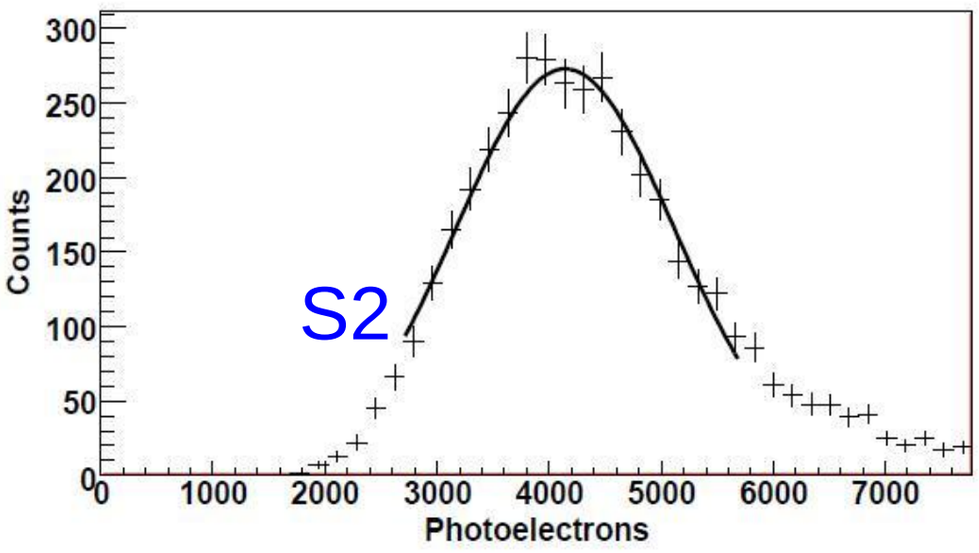
# LUX Internal Sources

## $^{83m}$Kr (half-life 1.86 hours)

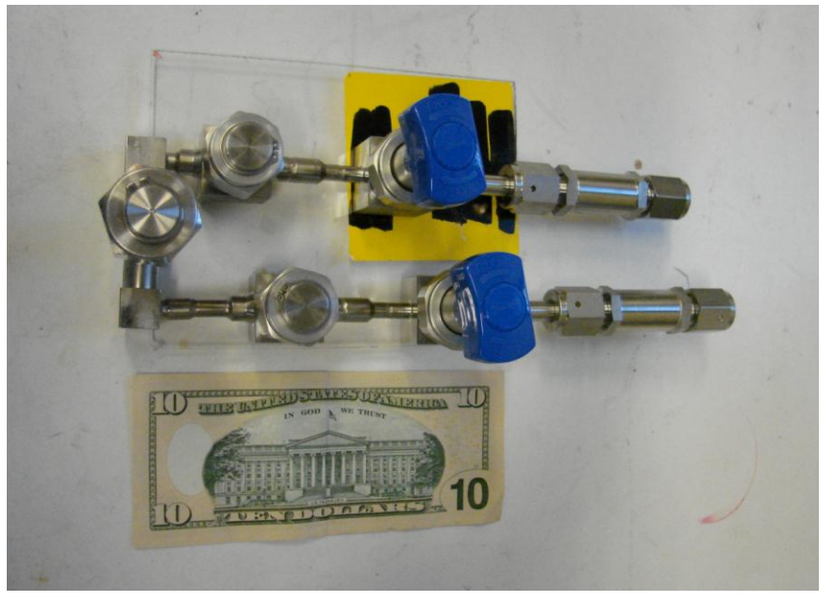


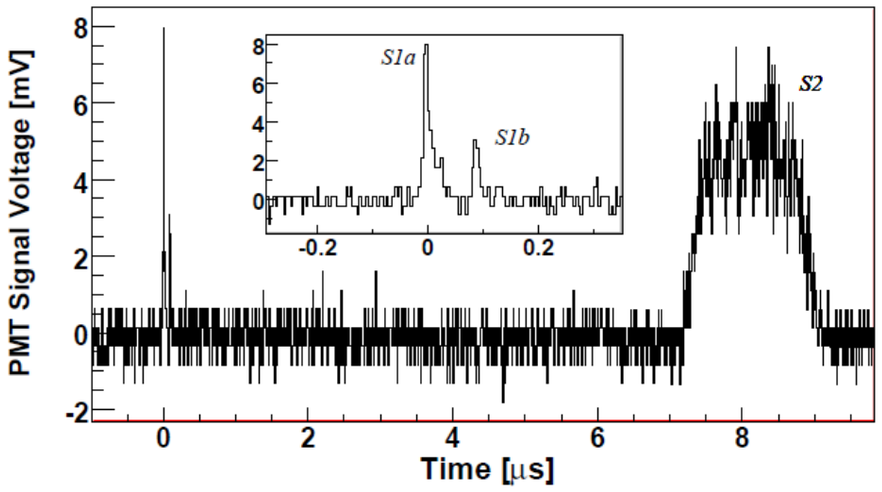

**Conversion electrons**

- **S1 LY and keVee, $e^-$ lifetime**
- **Fills entire fiducial volume**




L. Kastens et al., Phys. Rev. C80: 045809 (2009).
A. Manalaysay et al., Rev. Sci. Instr. **81**, 073303 (2010)

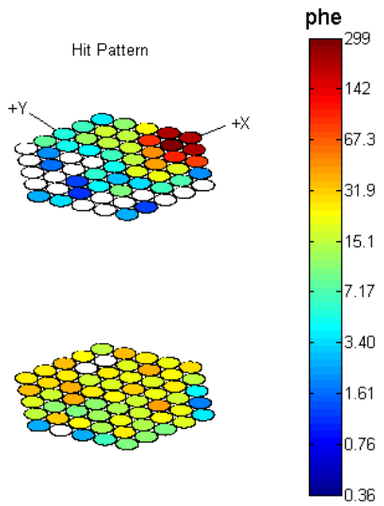





**Tritium (half-life 12.3 yrs)**

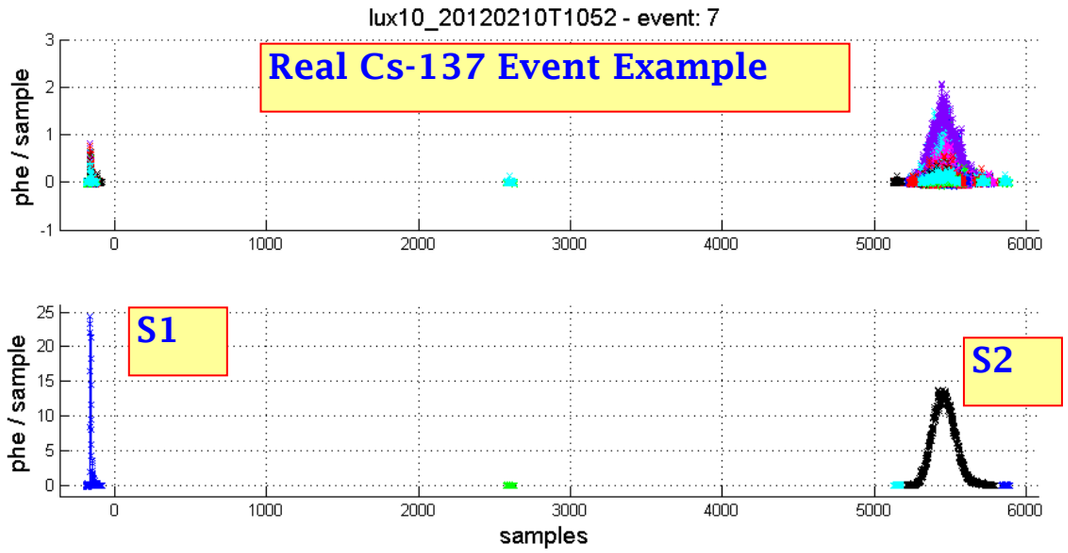
- **Injected as $CH_3T$**
- **Beta source, up to 18.6 keV**
- **Removed by purification system**
- **S2/S1 ER band**
- **Fills entire fiducial volume**

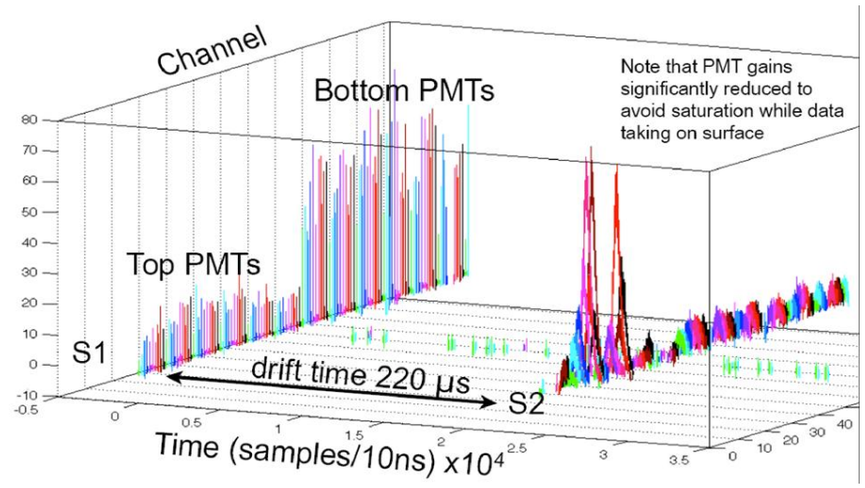
# LUX Surface run highlights

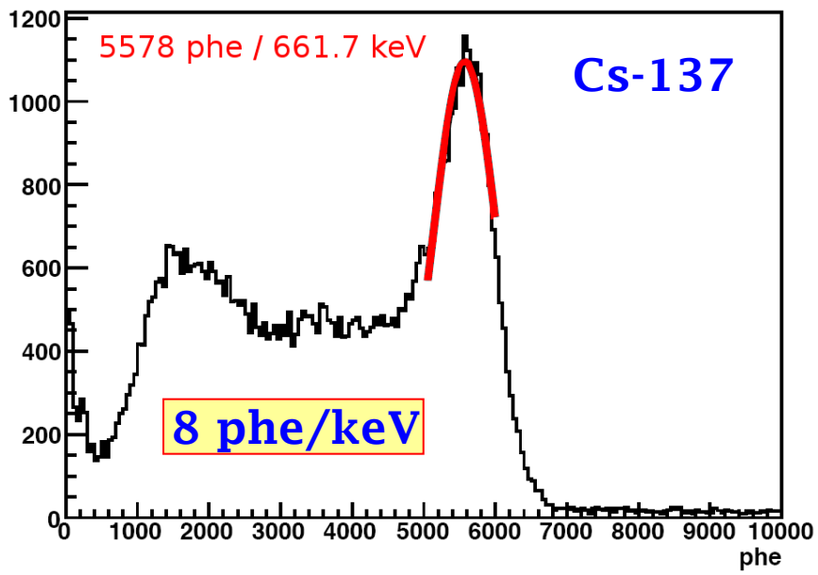




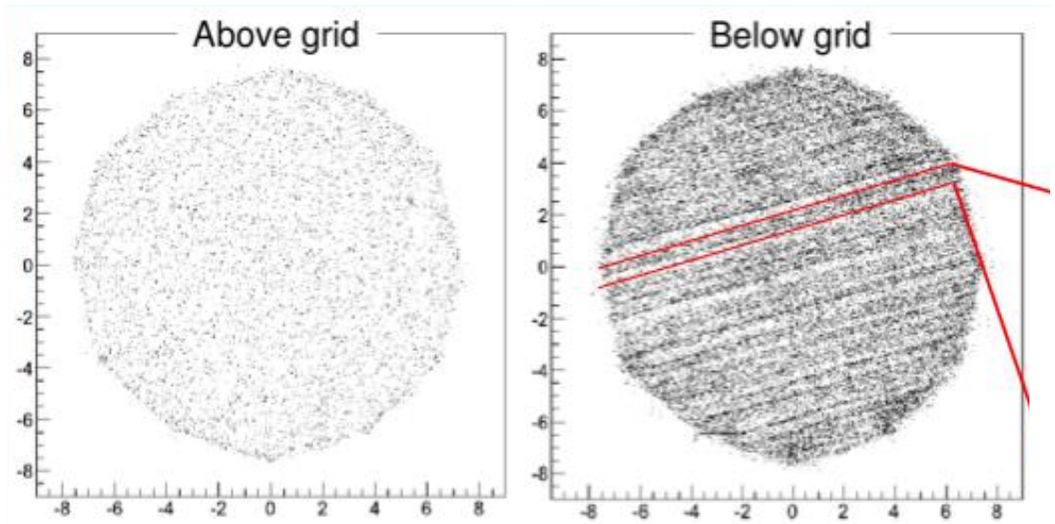


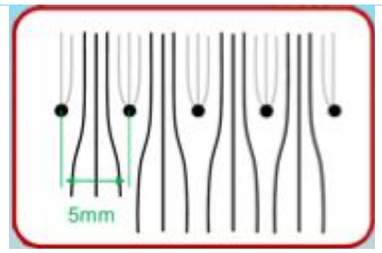


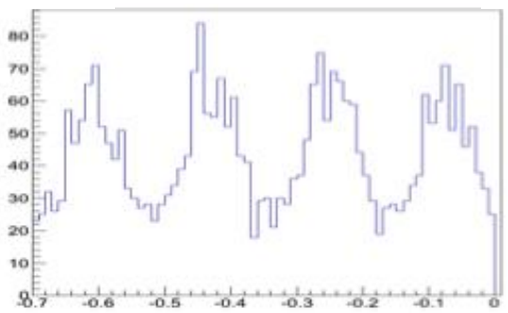




PTFE reflectivity >95% in LXe and >65% in gas Xe, $\lambda_{abs}$>5m (from comparison with MC simulations)



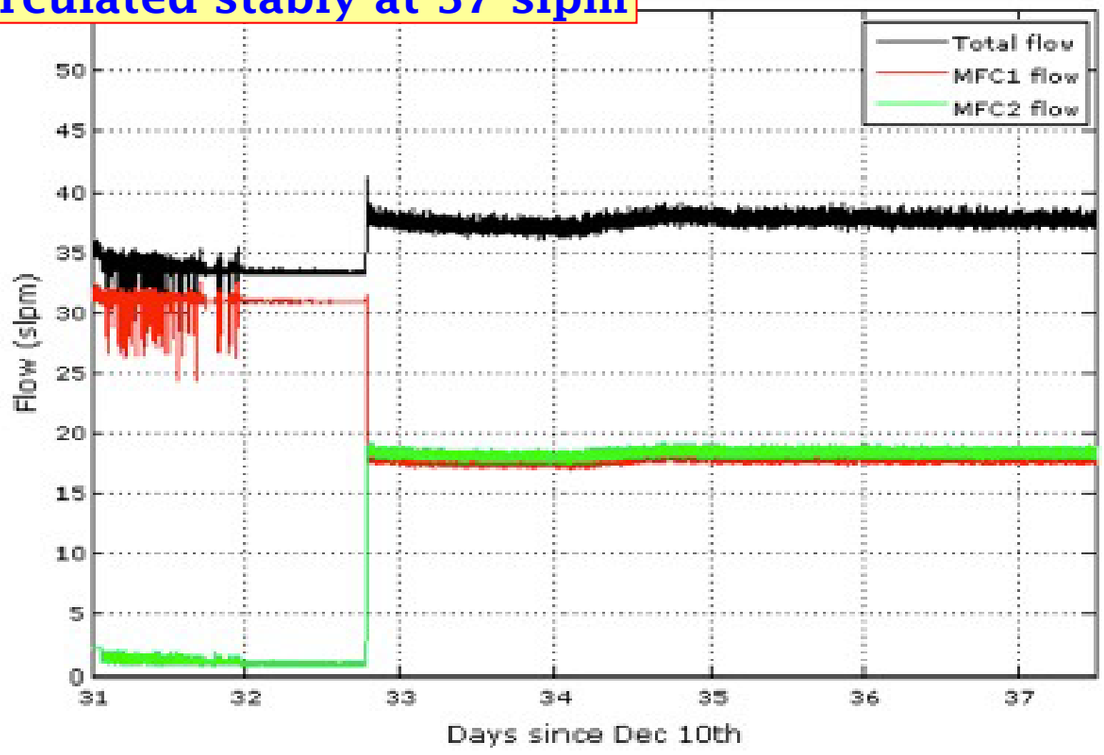



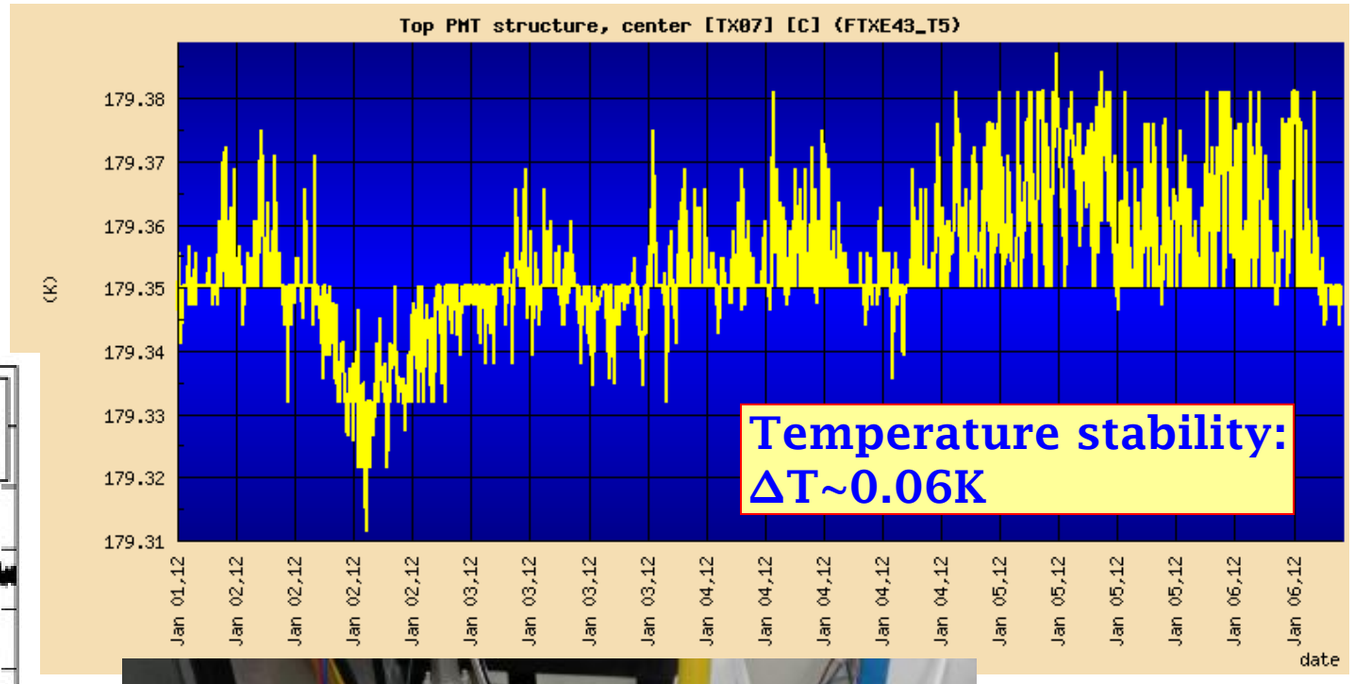



Position reconstruction algorithms demonstrated successfully!

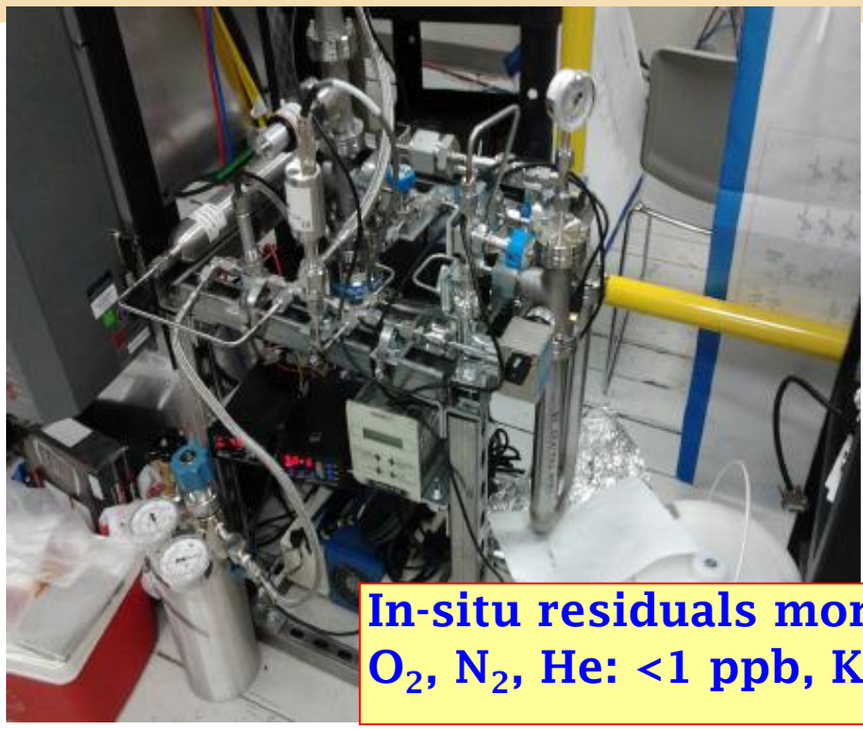
# LUX Surface run highlights

**Circulated stably at 37 slpm**




**Temperature stability: ΔT~0.06K**



**In-situ residuals monitoring: $O_2$, $N_2$, He: <1 ppb, Kr < 200 ppb**

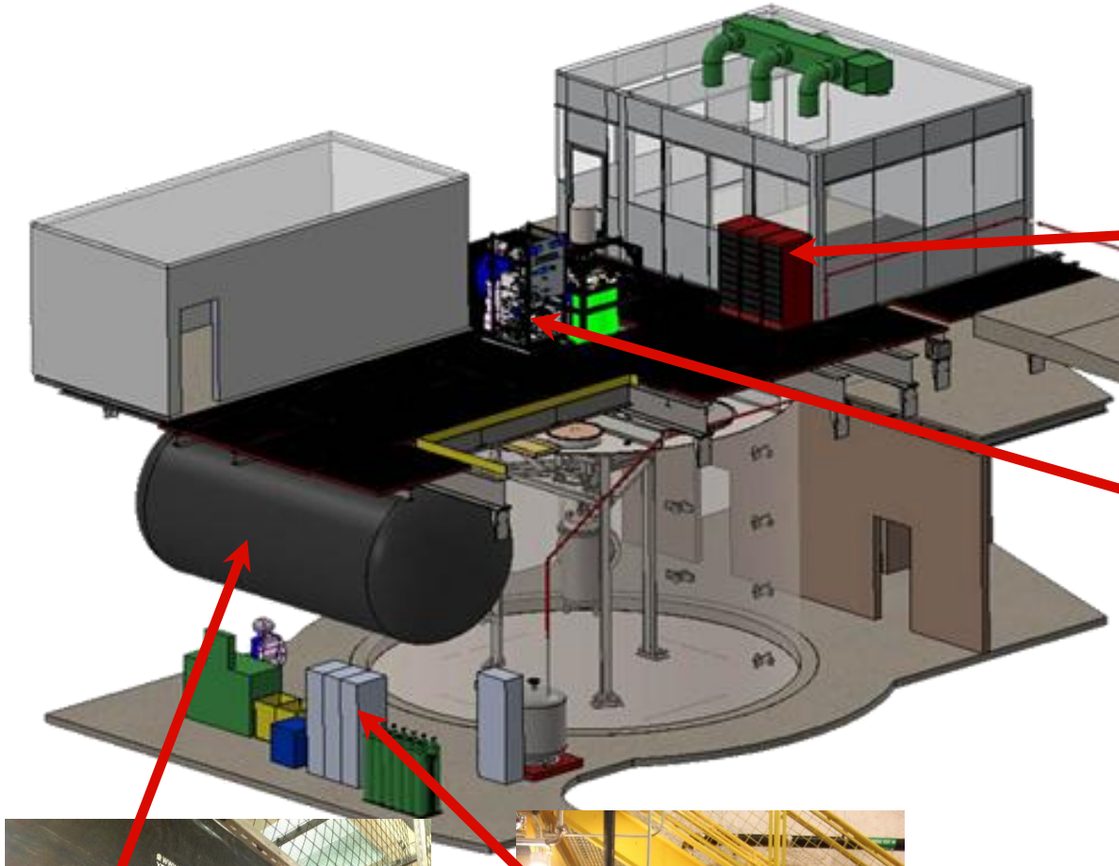
# System Upgrades/Fixes

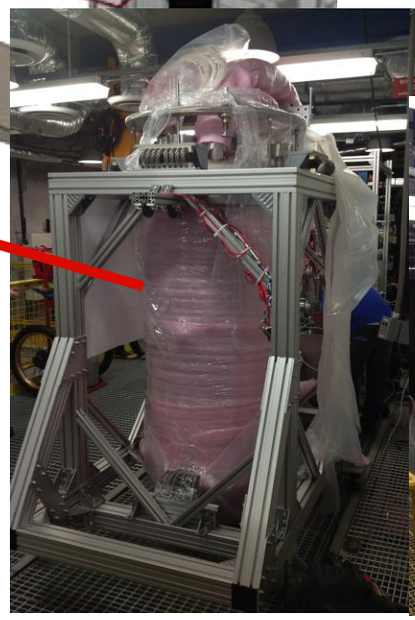
- Disconnect in the internal circulation line repaired and made more robust.
- Cathode High Voltage feedthrough replaced with a new design. Feedthrough design tested up to 100 kV for over a month with no sign of breakdown.
- Drift field was limited to 120 V/cm by electroluminescence on the wires. Cathode grid replaced to mitigate the problem.
- Upgrades to gas system (including implementation of pump safety features).
- The single failed PMT was replaced.
- Sampling system upgraded for automated operation.

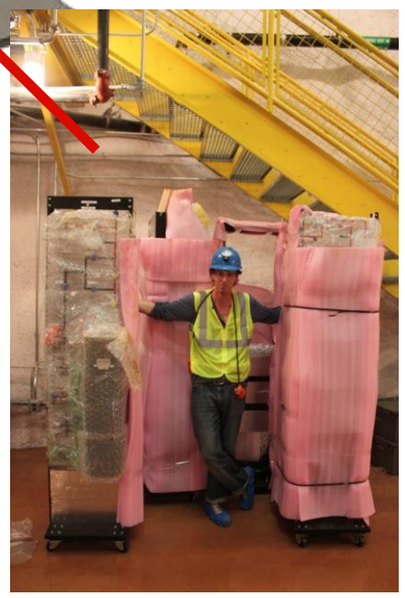
# Current Status


- **LUX was successfully moved UG last week!!**

# Current Status



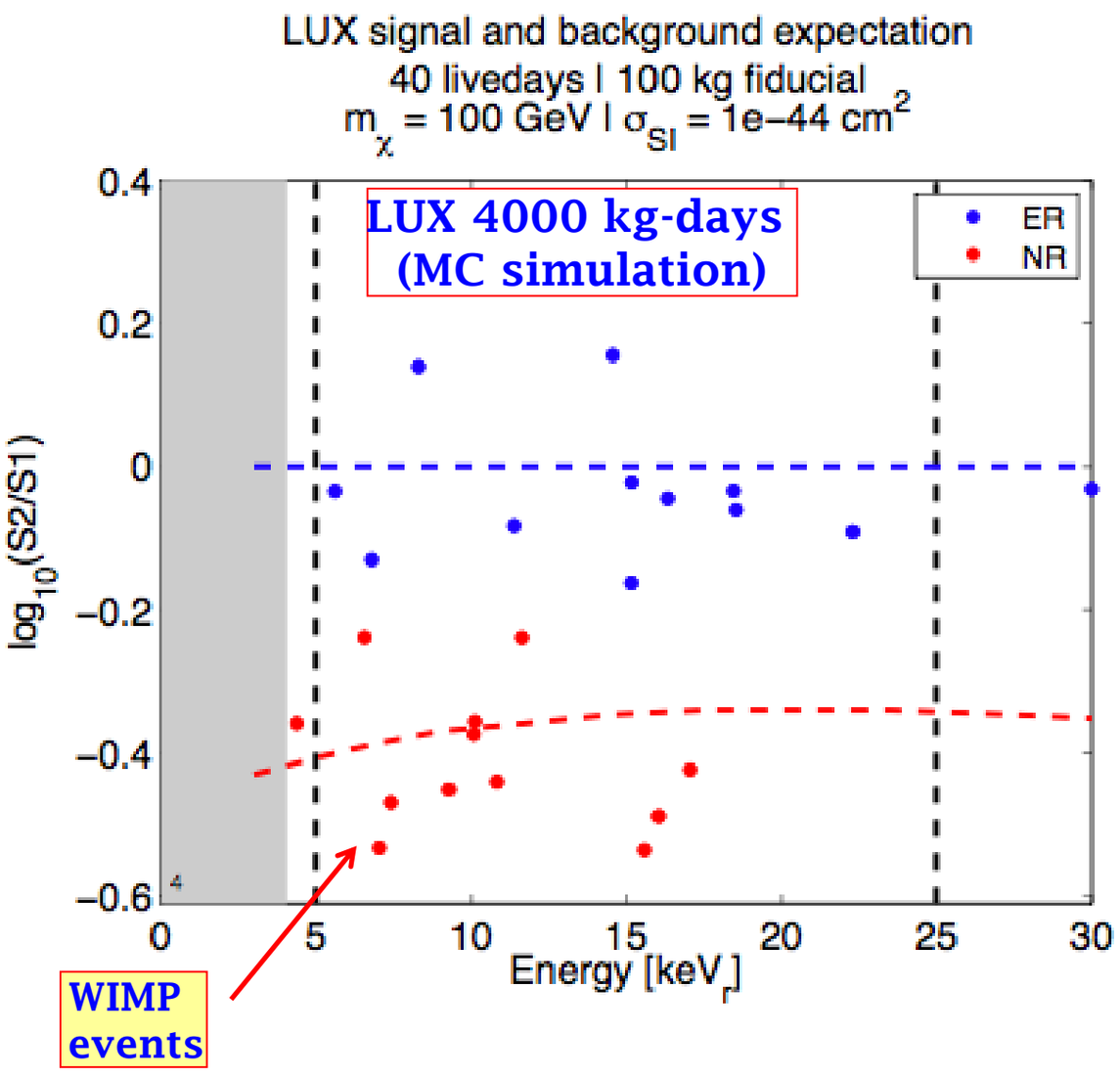


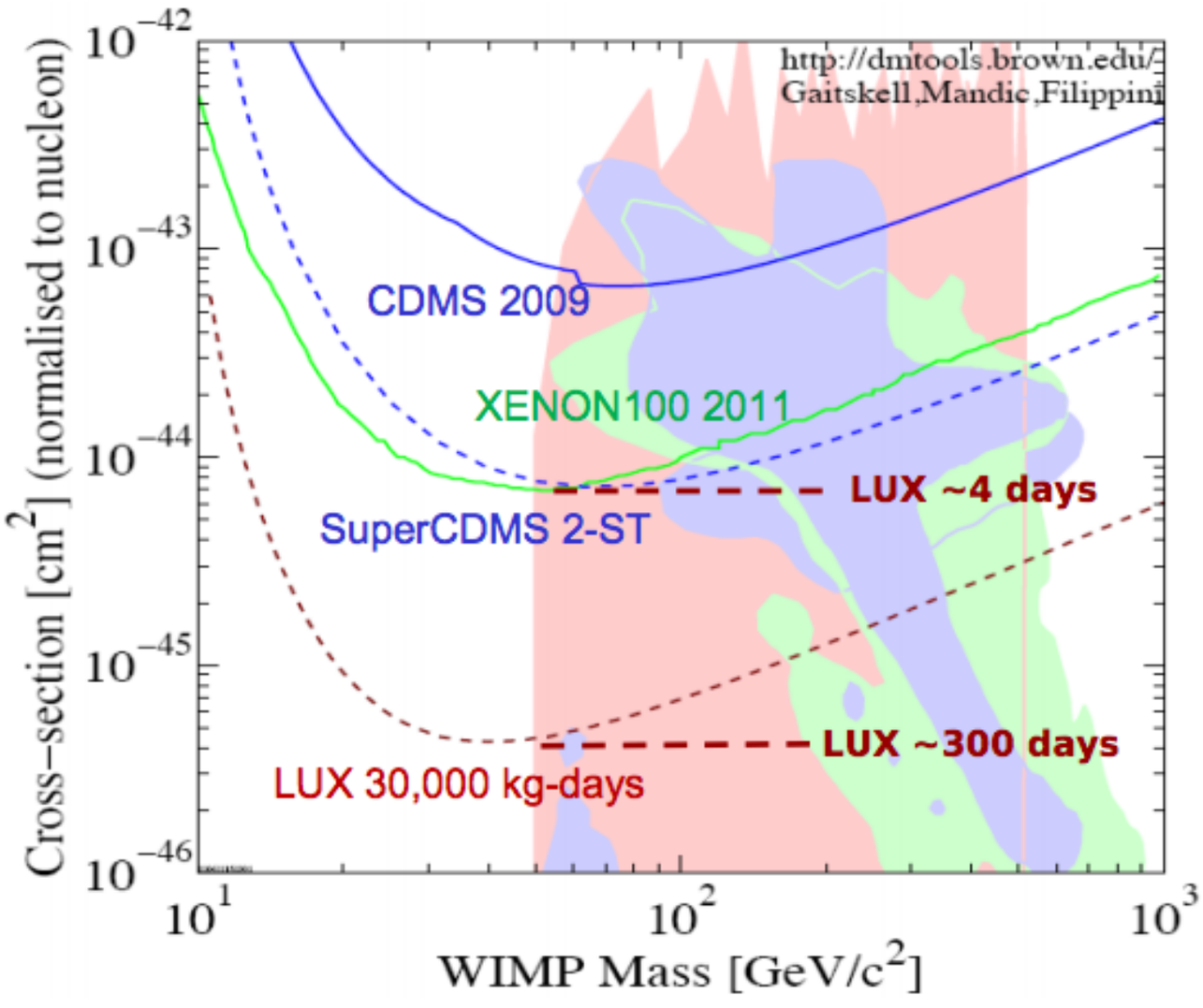


- Davis Cavern now fully occupied by LUX.
- Most major subsystems now underground.
- Installation of subsystems underway.
- Should be running by the end of the year.

# Water tank / Veto

# LUX Expected Sensitivity



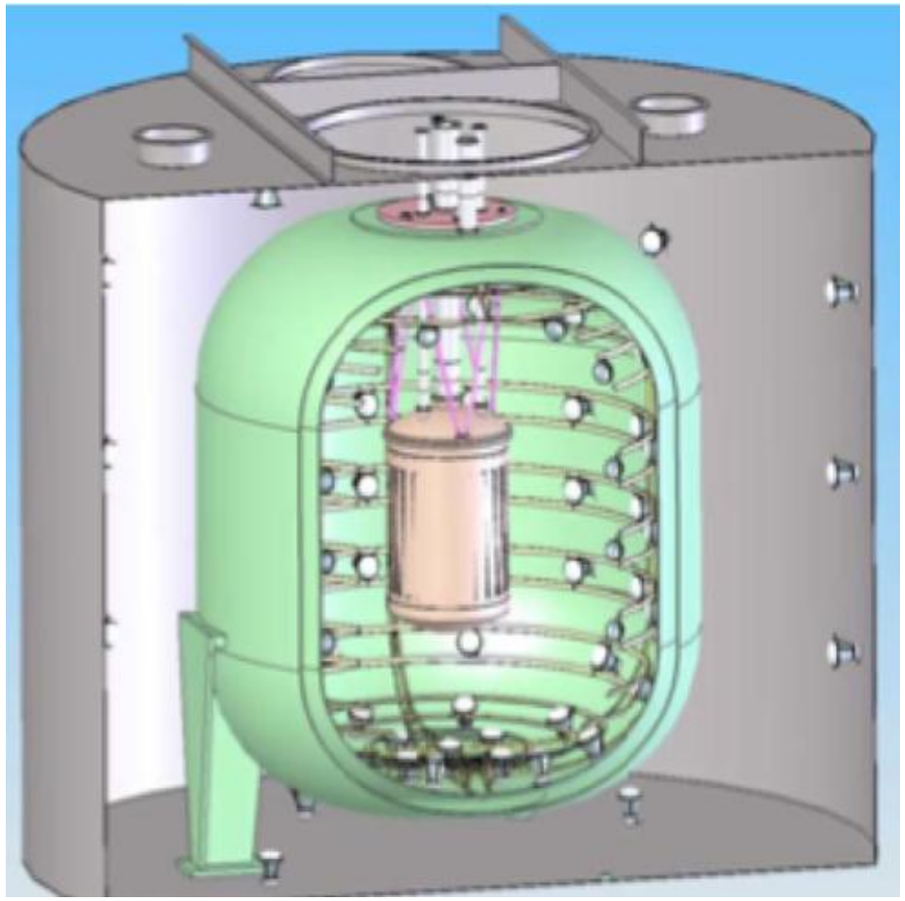

Fewer than 1 NR event in the fiducial volume in 300 days!

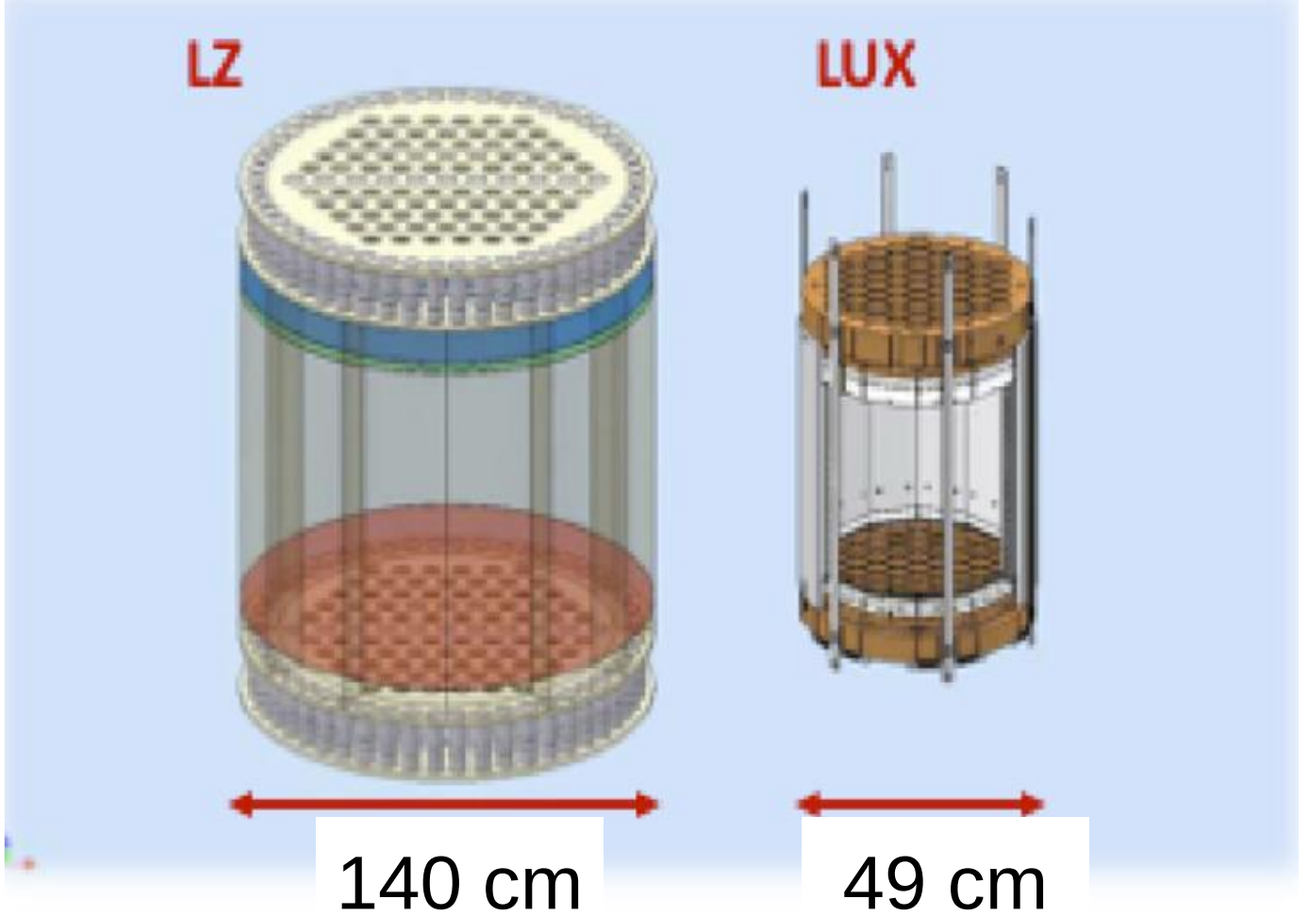
Targeting at $7 \cdot 10^{-46}$ cm² (@ 100GeV)

**LUX – strong emphasis on WIMP discovery**

# What's next: **LZ**

- **LZ = joint collaboration of LUX and ZEPLIN**
- **LZ (Sanford) ~7000 kg, with 5000 kg fiducial mass**
- **LUX infrastructure designed to accommodate LZ**
- **Liquid scintillator veto**
- **Construction 2014–2016, operation 2016…**
- **$\sigma_\chi = 2\times10^{-48}\ cm^2$ in 3 years**





# Summary

- LUX demonstrated operation of all subsystems during surface run.
- Demonstrated xenon purification.
- Excellent light collection shown (8 phe/keVee)!
- Minor fixes and upgrades completed.
- LUX successfully moved underground!
- UG installation underway.
- Expect to be running by the end of the year.