30. DRILLING WITH COMPRESSED AIR, HOMESTAKE MINE, LEAD, S. D.

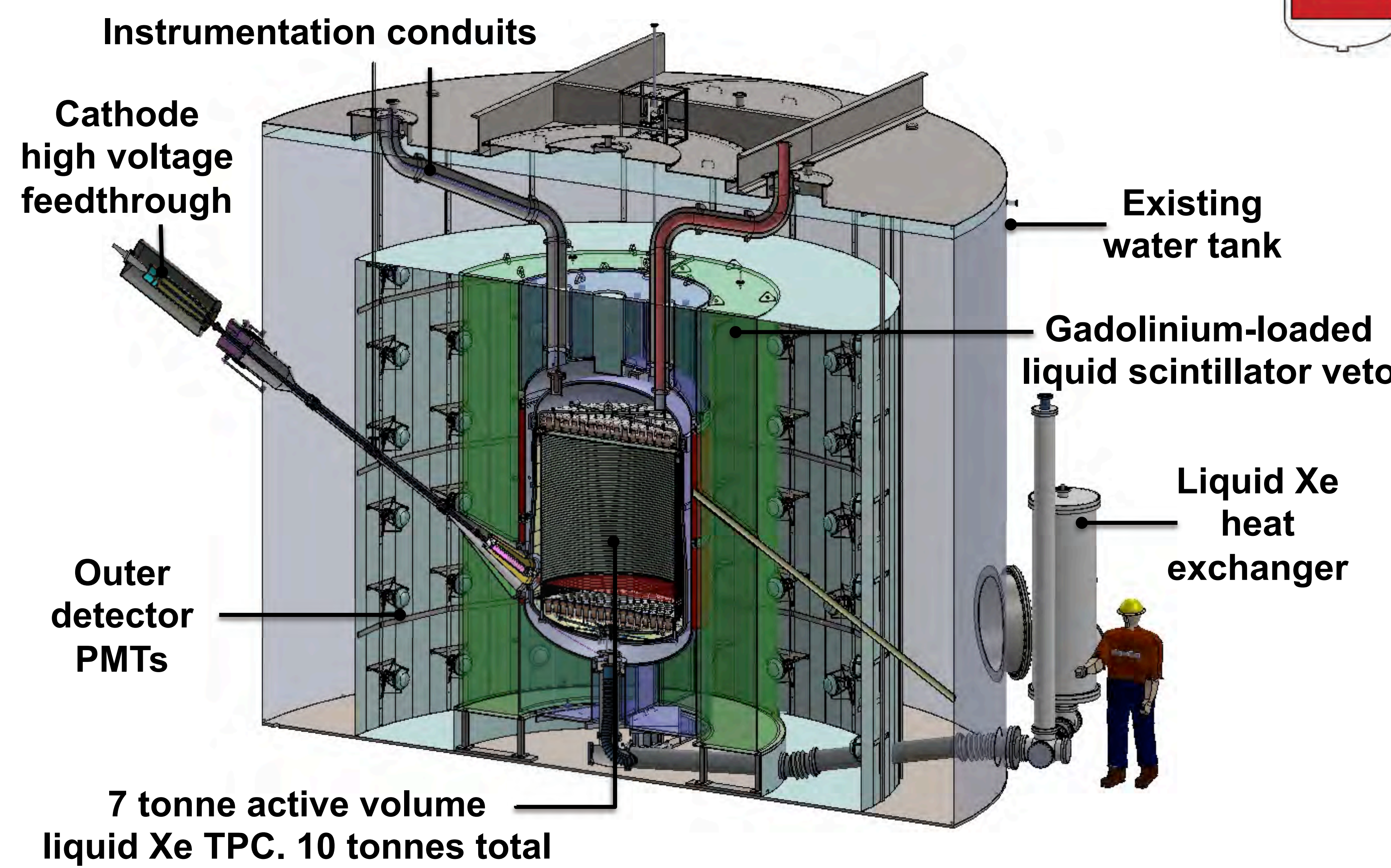
Low-mass dark matter searches with the LZ experiment

Maria Elena Monzani
on behalf of the LZ Collaboration

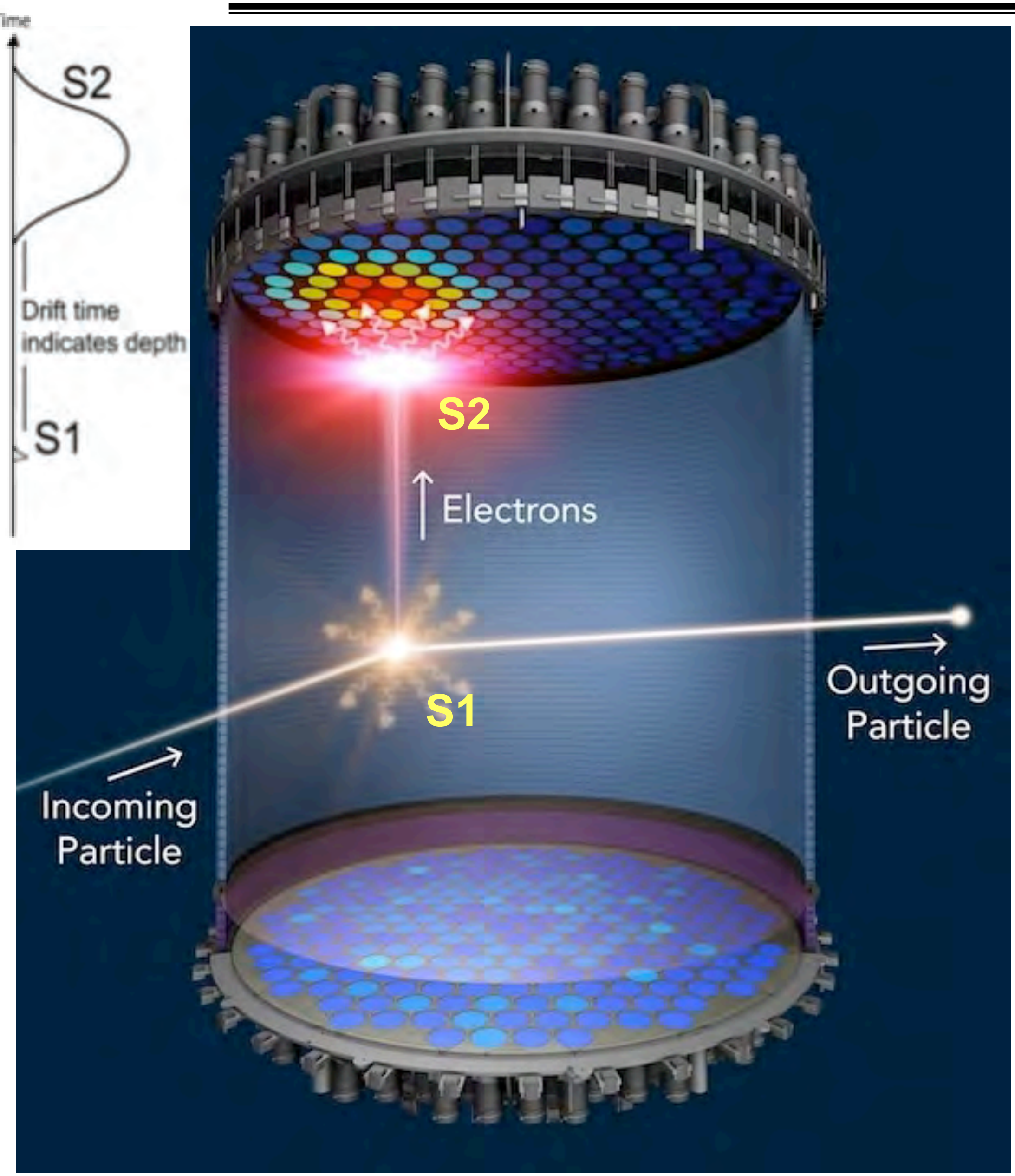
SLAC
NATIONAL ACCELERATOR LABORATORY

SLAC, Apr 29, 2016

LZ Detector Overview

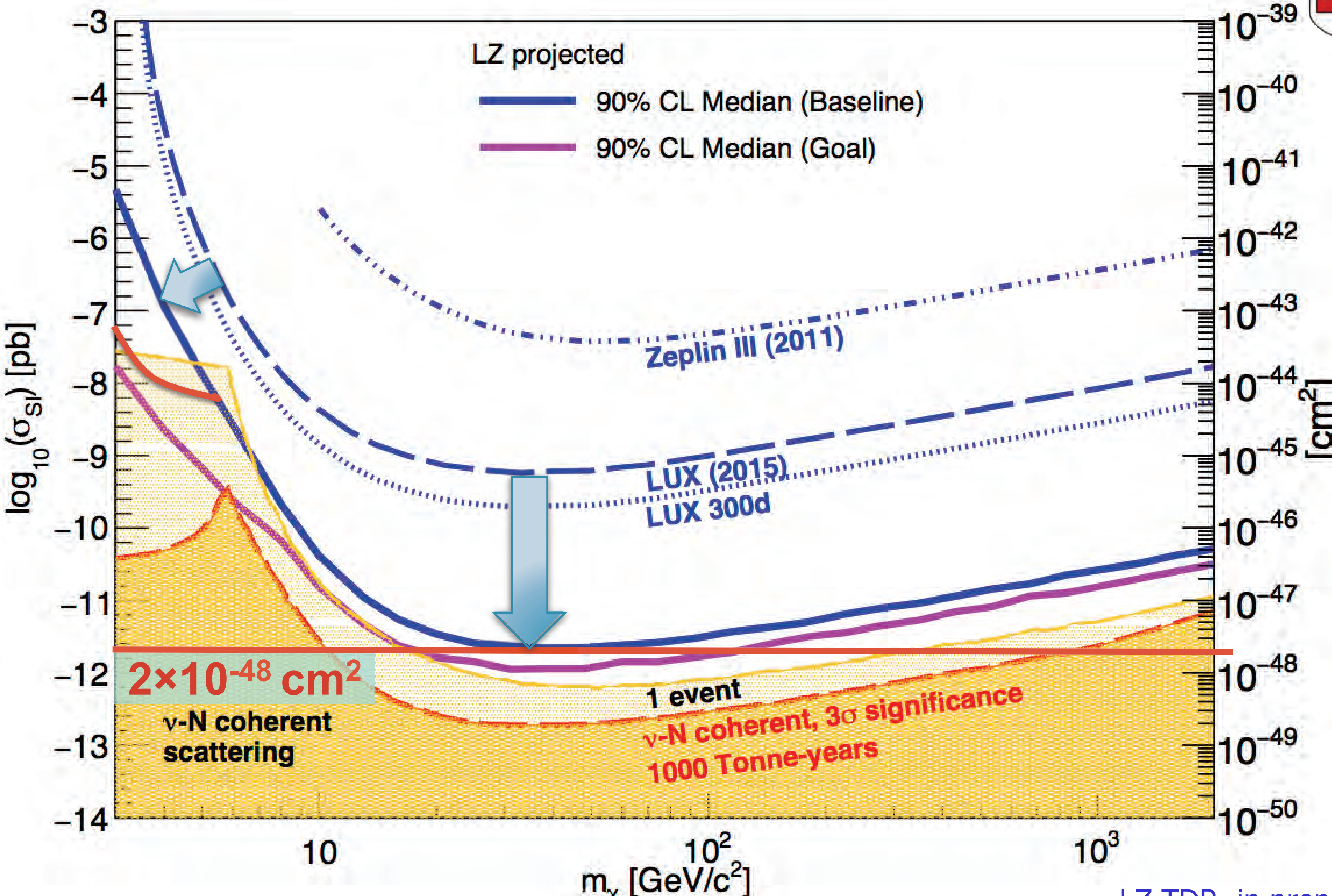


Dual-Phase Xenon TPC



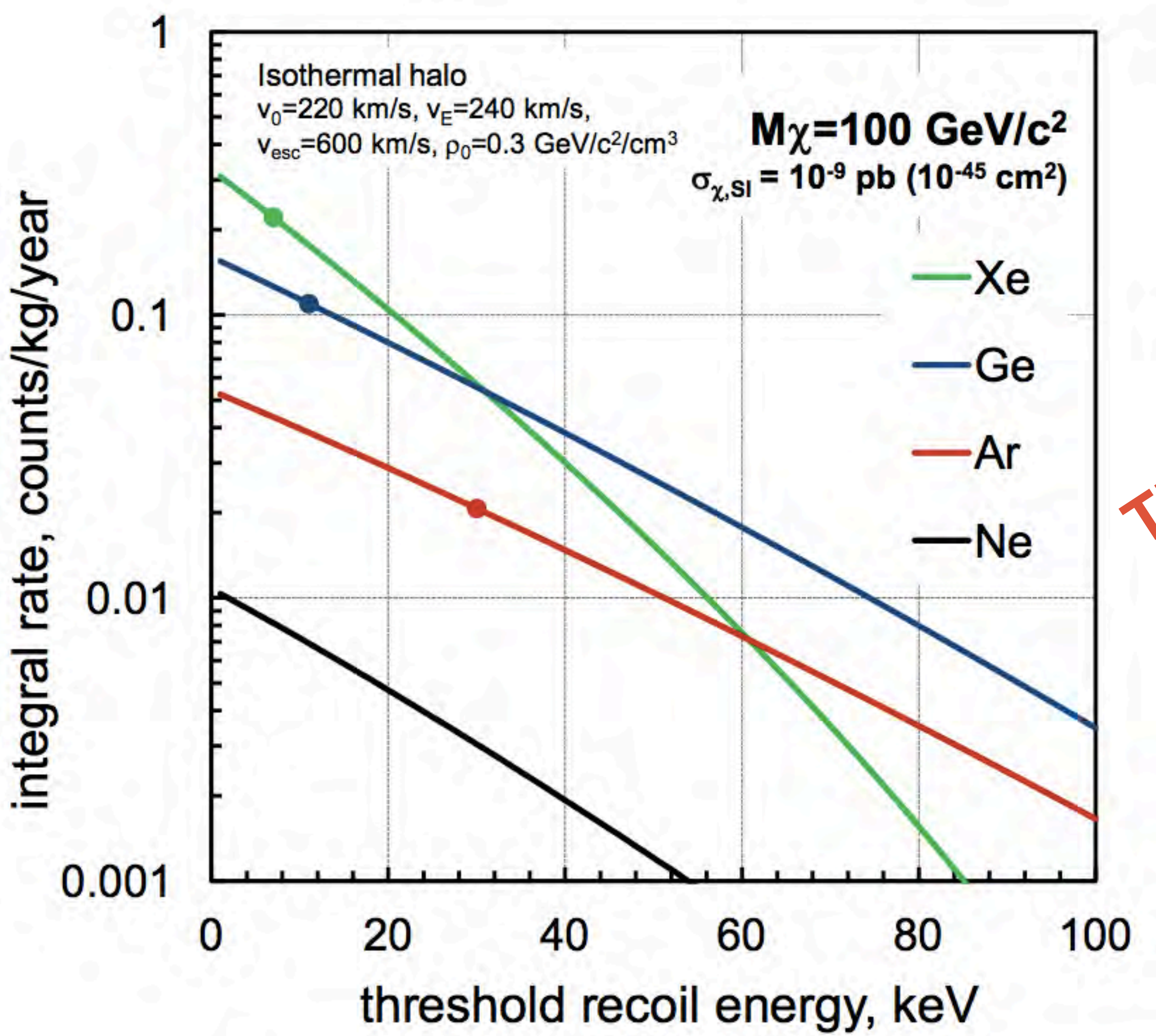
- Electron recoil (ER) background rejection:
  - Charge/light ratio (aka "S2/S1")
- 3D event reconstruction:
  - Vertical coordinate from drift time
  - Horizontal coordinates from S2 light pattern
- External backgrounds:
  - Fiducial volume cuts
- Neutron rejection:
  - Multiple scattering
  - Tagged in skin/veto

State of the Art and Projected Sensitivity



LZ TDR, in preparation

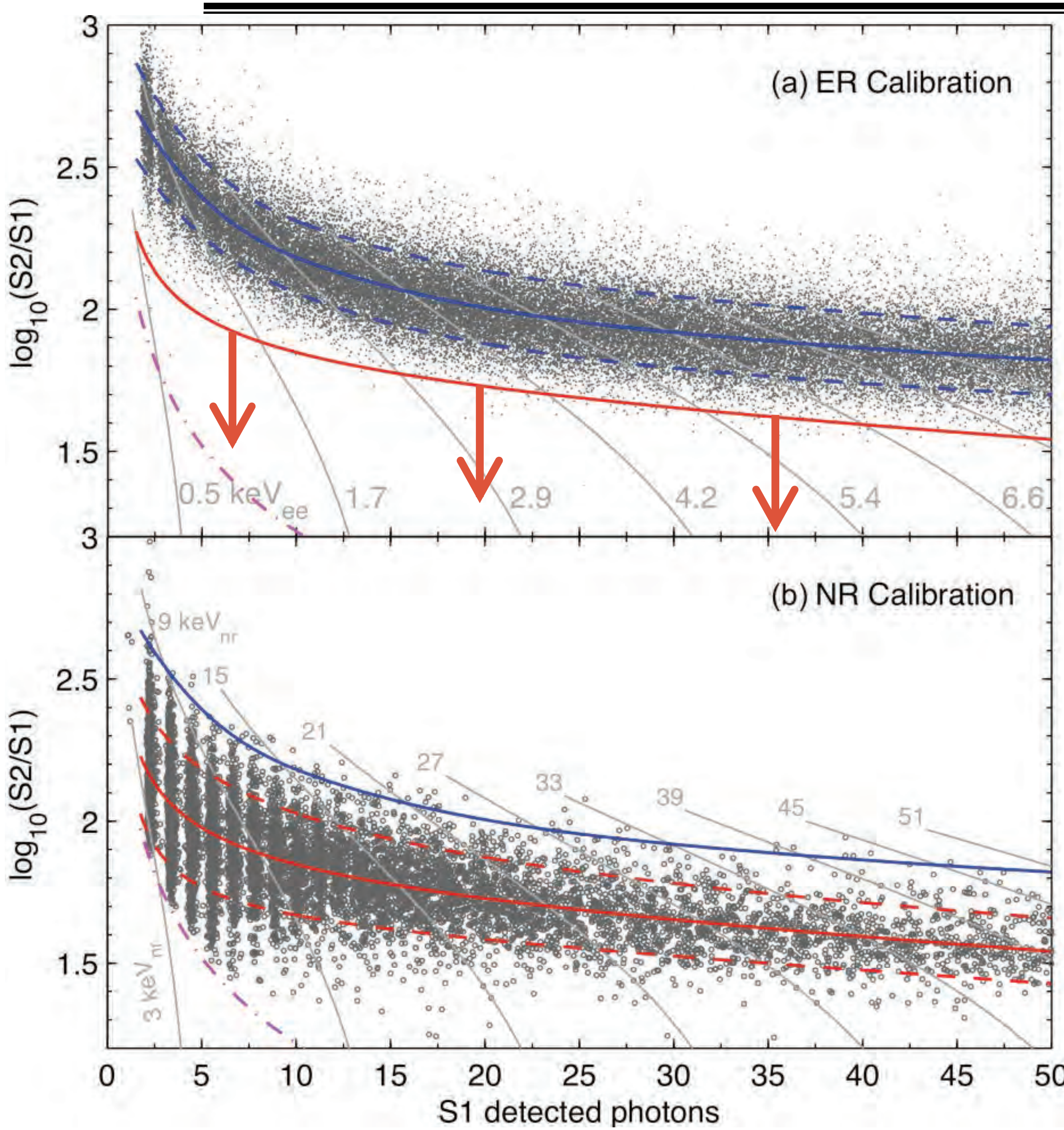
How to probe the low-mass range?



Threshold!

arXiv: 1310.8327

High Statistics Calibrations from LUX



Electron Recoil (ER) (Tritiated methane)

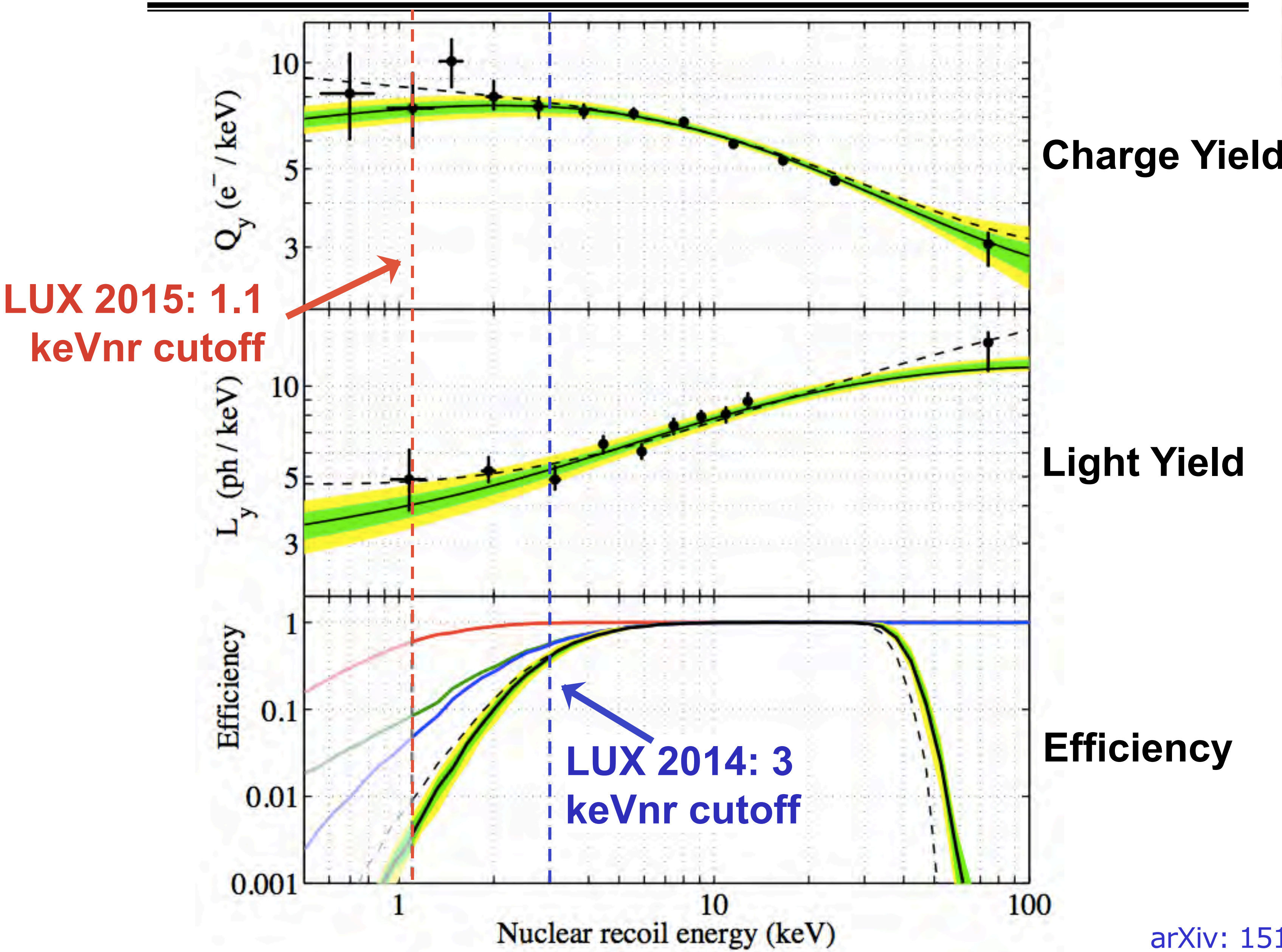
+

Nuclear Recoil (NR) (DD neutron gun)

↓

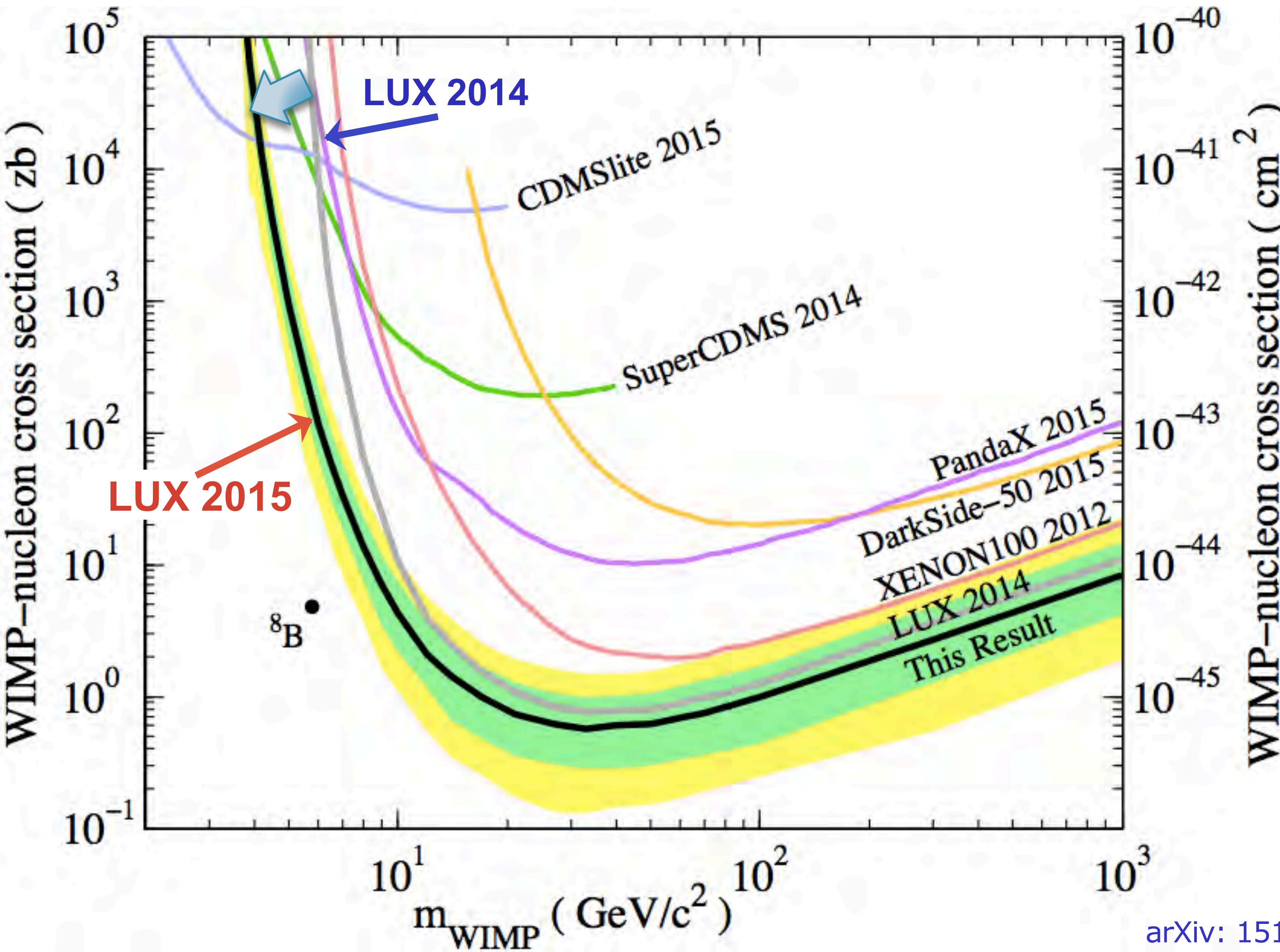
In-situ calibrations, unpreced. accuracy, lower NR threshold

NR Calibrations: towards Lower Threshold



arXiv: 1512.03506

WIMP Sensitivity with Lower Threshold



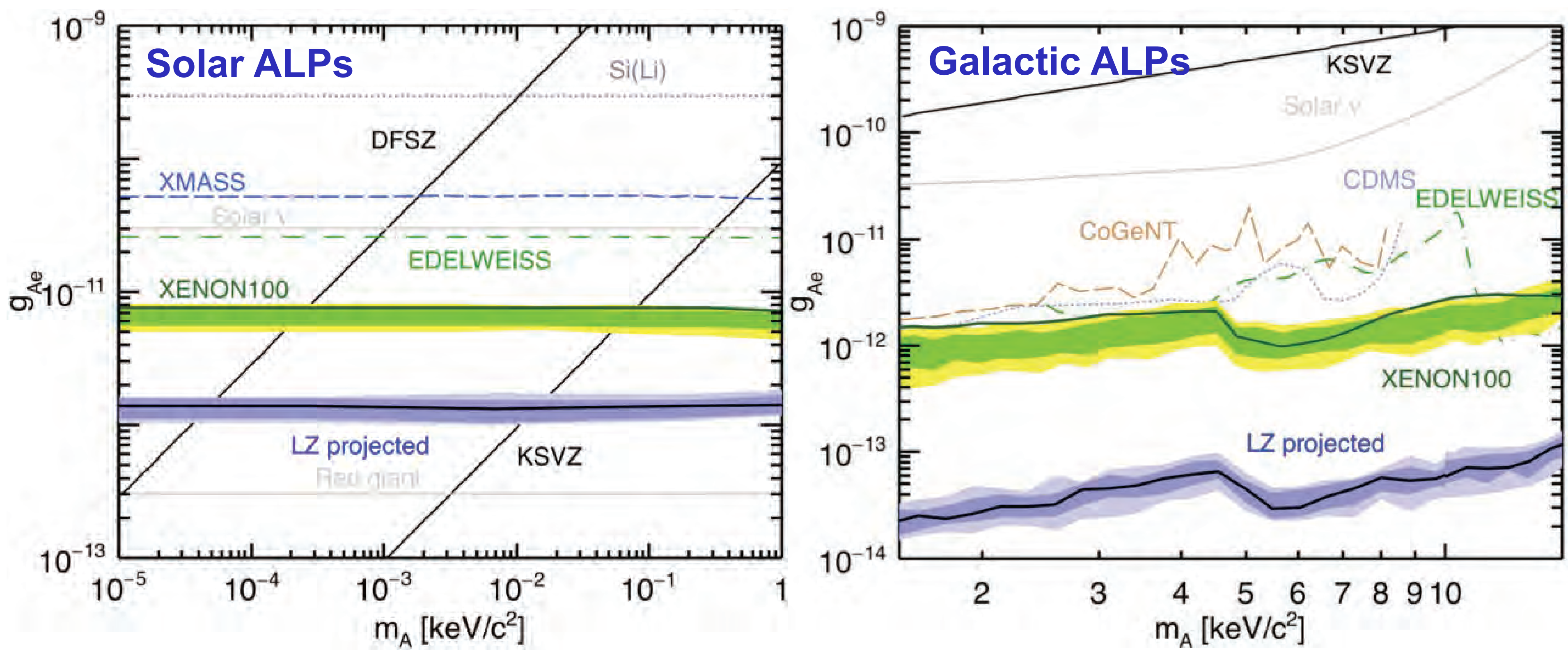
arXiv: 1512.03506

Light Dark Matter Searches with LXe

	S1 + S2	S2 - only
Nuclear Recoils	• Vanilla WIMPs	• Light(er) WIMPs • Asymmetric Dark Matter
Electron Recoils	• ~keV axion-like particles	• subGeV hidden sector models (Rouven's talk)

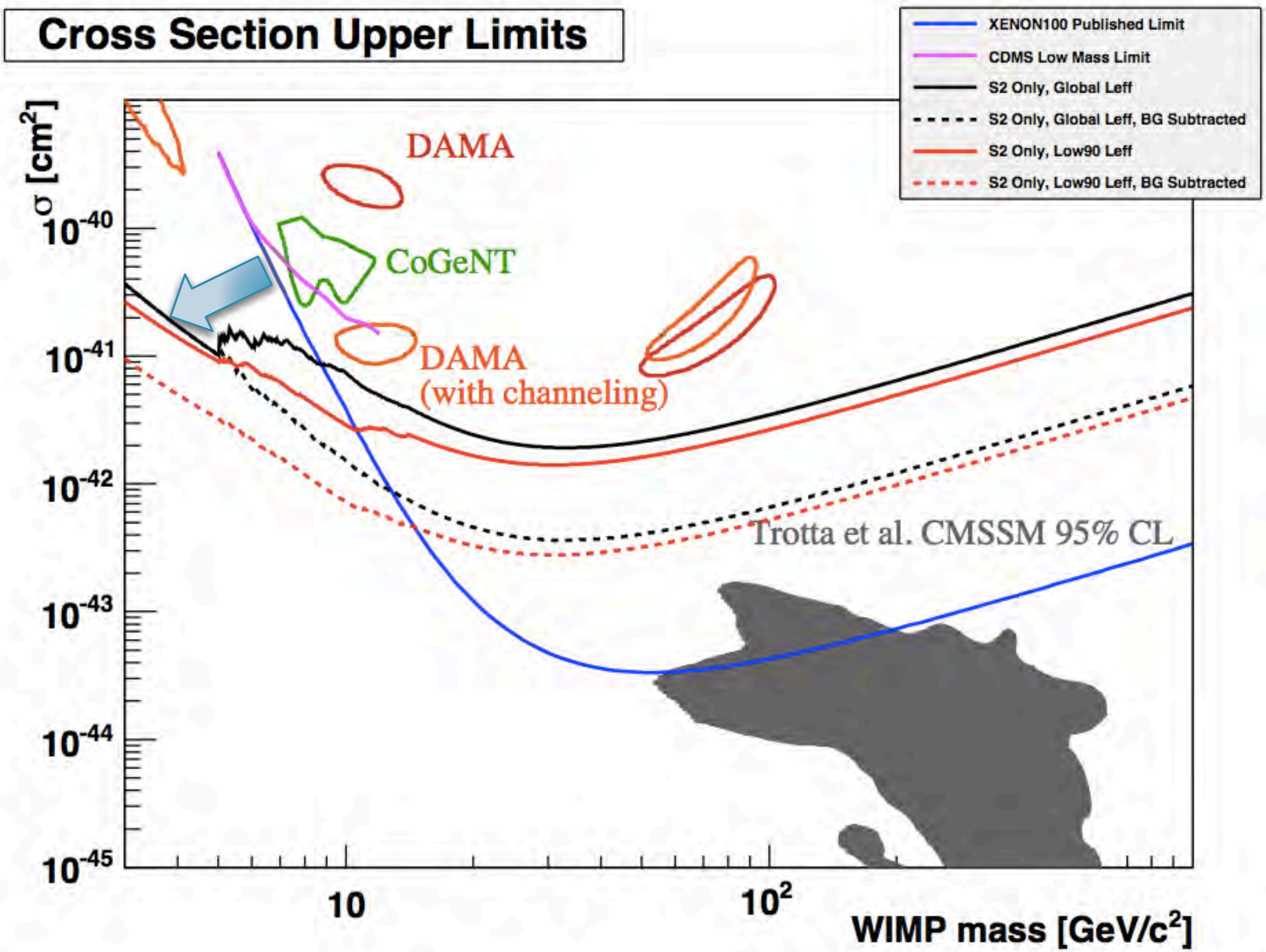
Axion-Like Particles (ALP)

- **Sensitivity to axions and ALPs via the axioelectric effect:**
  - **Nonrelativistic galactic ALPs (DM candidates)**
  - **ALPs emitted by bremss/Compton in the Sun**
- **Technique pioneered in Xenon100 (see arXiv:1404.1455)**



LZ TDR, in preparation

S2-only analysis: Light(er) WIMPs



E. Brown, PhD thesis, unpublished

S2-only analysis: Experimental Challenges

- Xenon10 results were described by Rouven yesterday
- Going to a larger detector doesn't make this any easier
  - No S2-only results from Xenon100 or LUX so far...

- Limited background rejection with S2-only analysis
  - No S1/S2 discrimination, no Z coordinate available
- Electrons can be captured by impurities in drift volume
  - Depth-dependent effect... but we don't know Z coordinate
- Incomplete extraction from liquid phase
  - Uniformity issues? increase extraction field?
- Single electron background, difficult to model/subtract
  - Correlated with larger events (at least to some degree)
  - Electrons trapped under the liquid level? increase field?
  - Imperfections in the grids? can we make better grids?

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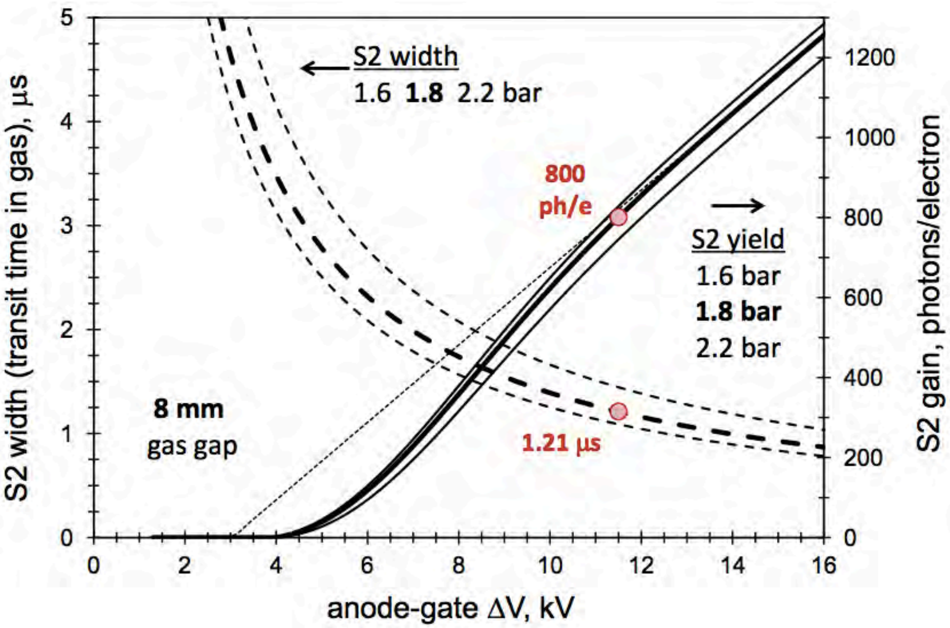
Single Electron Sensitivity in LZ

- **Single electron signal depends on field configuration:**
  - **expected >50 p.e./electron (x2 higher than Xenon10)**
  - **expected 97.6% extraction efficiency for electrons**



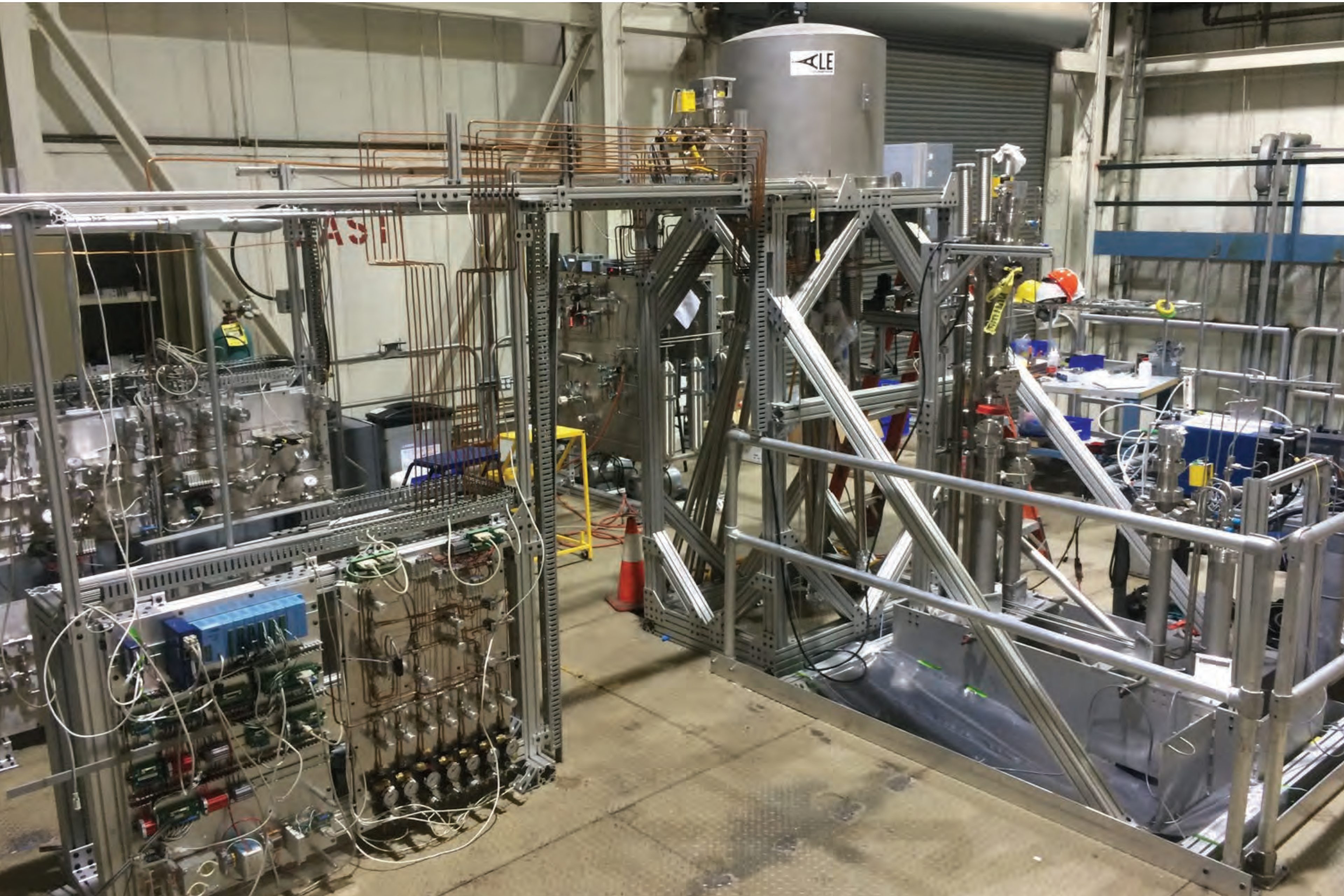
Parameter	value
Gate-Anode separation (and tolerance)	13.0 mm (±0.2 mm)
Gas gap (and tolerance)	8.0 mm (±0.2 mm)
Field in LXe (GXe)	5.2 kV/cm (10.2 kV/cm)
Electron emission probability	97.6 %
S2 photon yield	820 ph/e
S2 width FWHM	1.2 µs
Detailed modeling	
S2 photon yield	910 ph/e
S2 photon *rms*	2.0 %
S2 width FWHM	1.0 µs to 2.0 µs[a]

[a] The larger value is for diffusion-broadened S2 pulses from interactions near the cathode (see Figure 3.6.4).

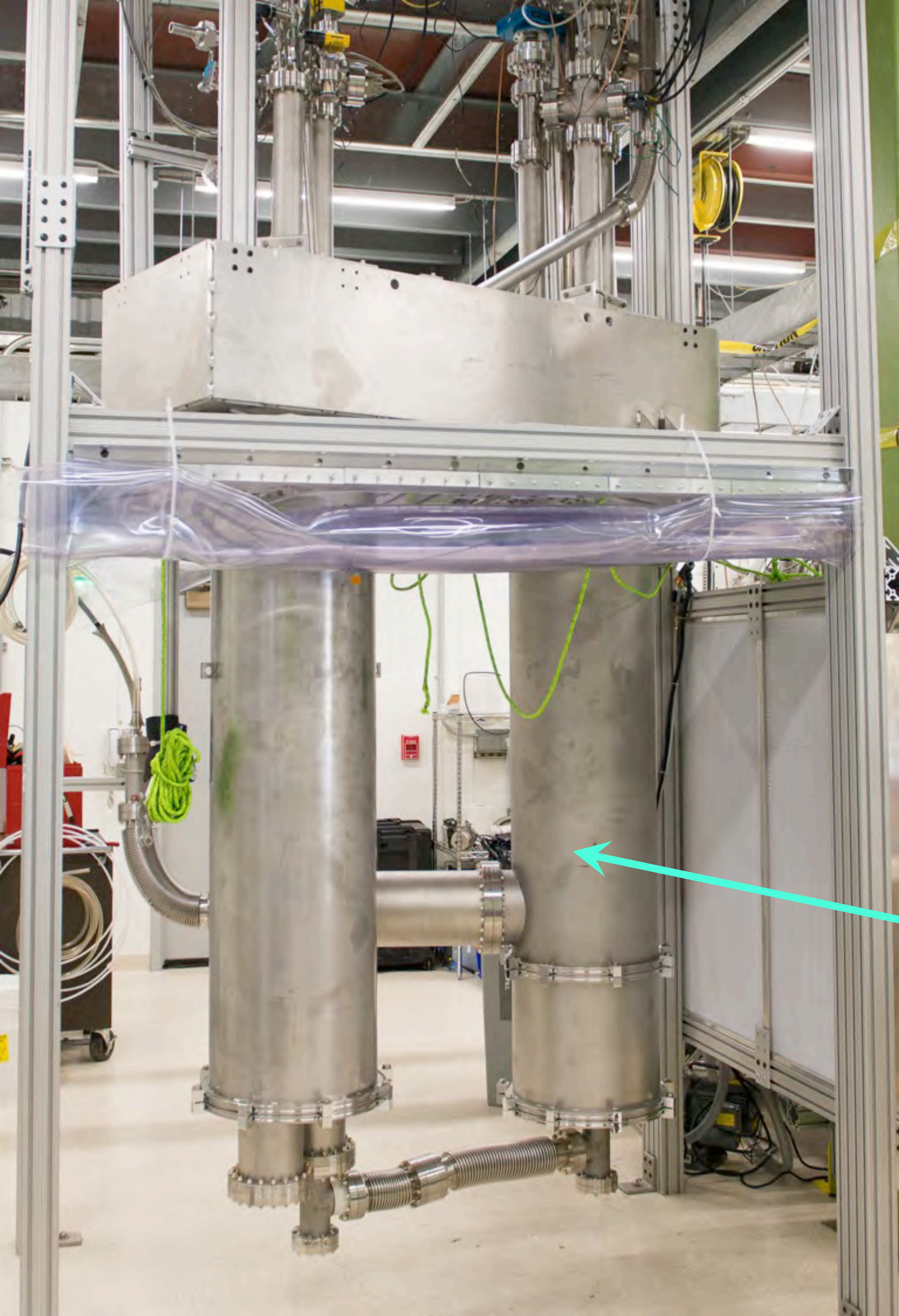
LZ TDR, in preparation

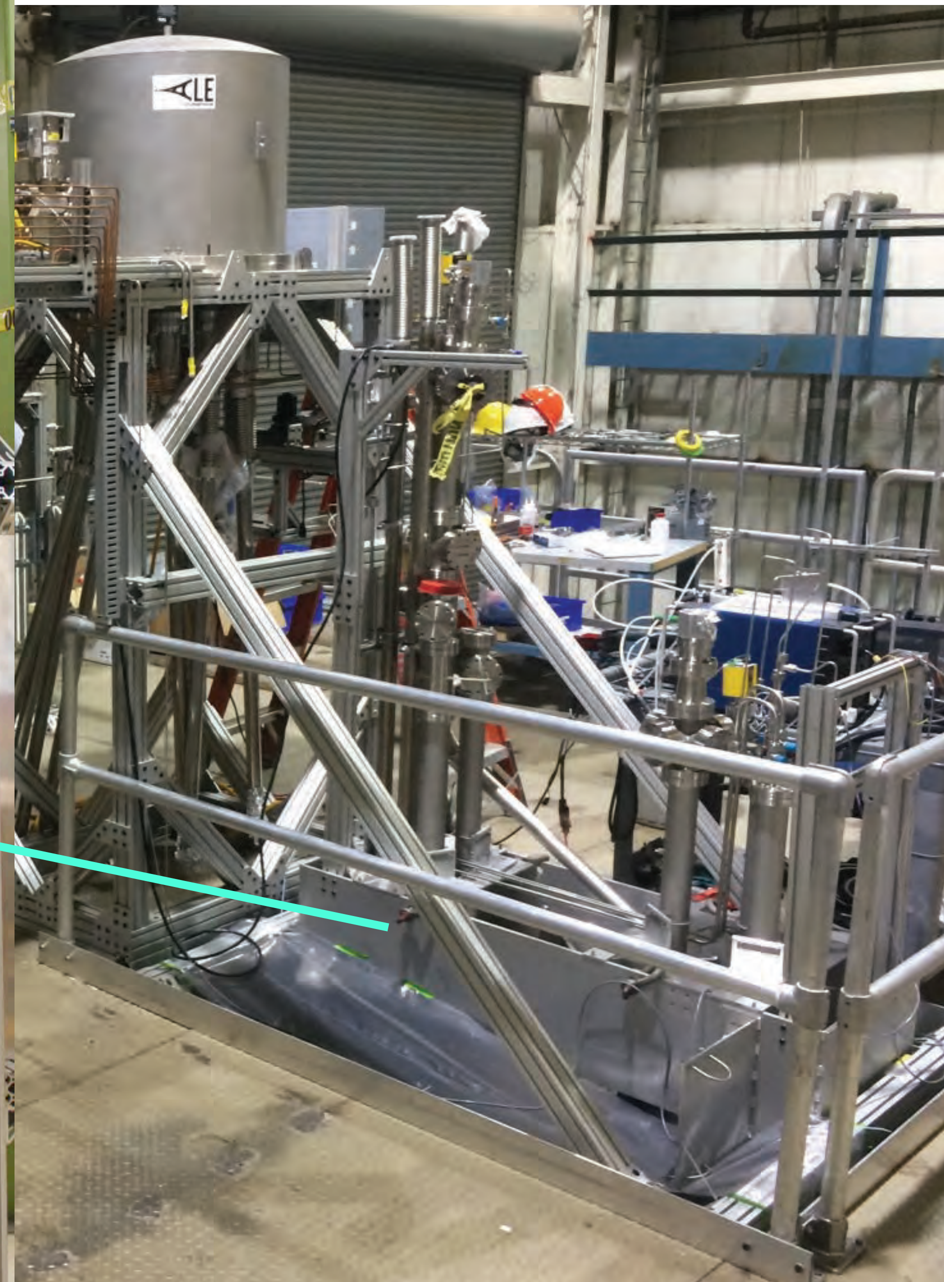
- **Reaching HV specs has proven elusive in all LXe detectors**
  - **very extensive fields/grid R&D/testing in progress at SLAC**

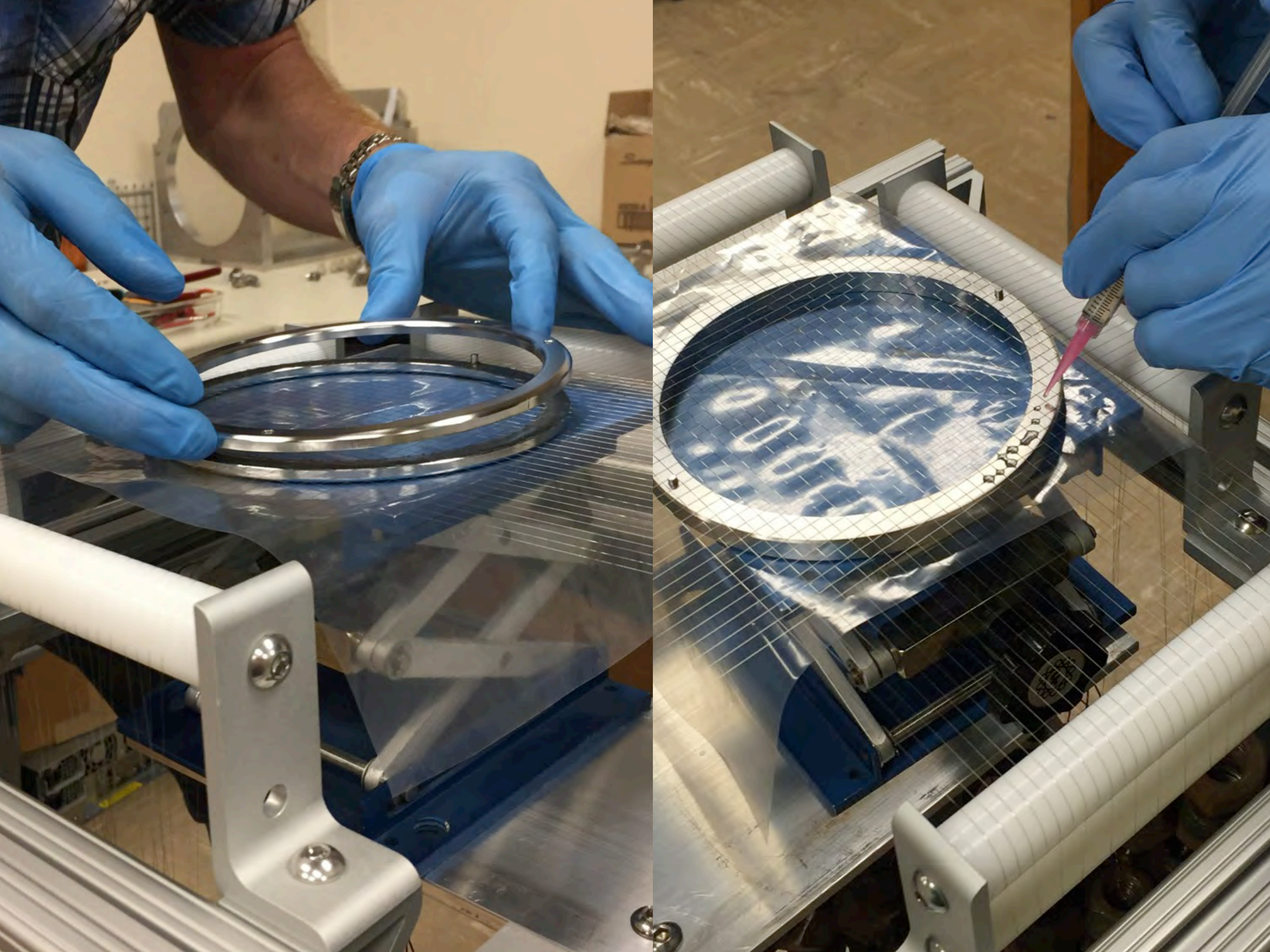
SLAC Noble Liquid Test Platform

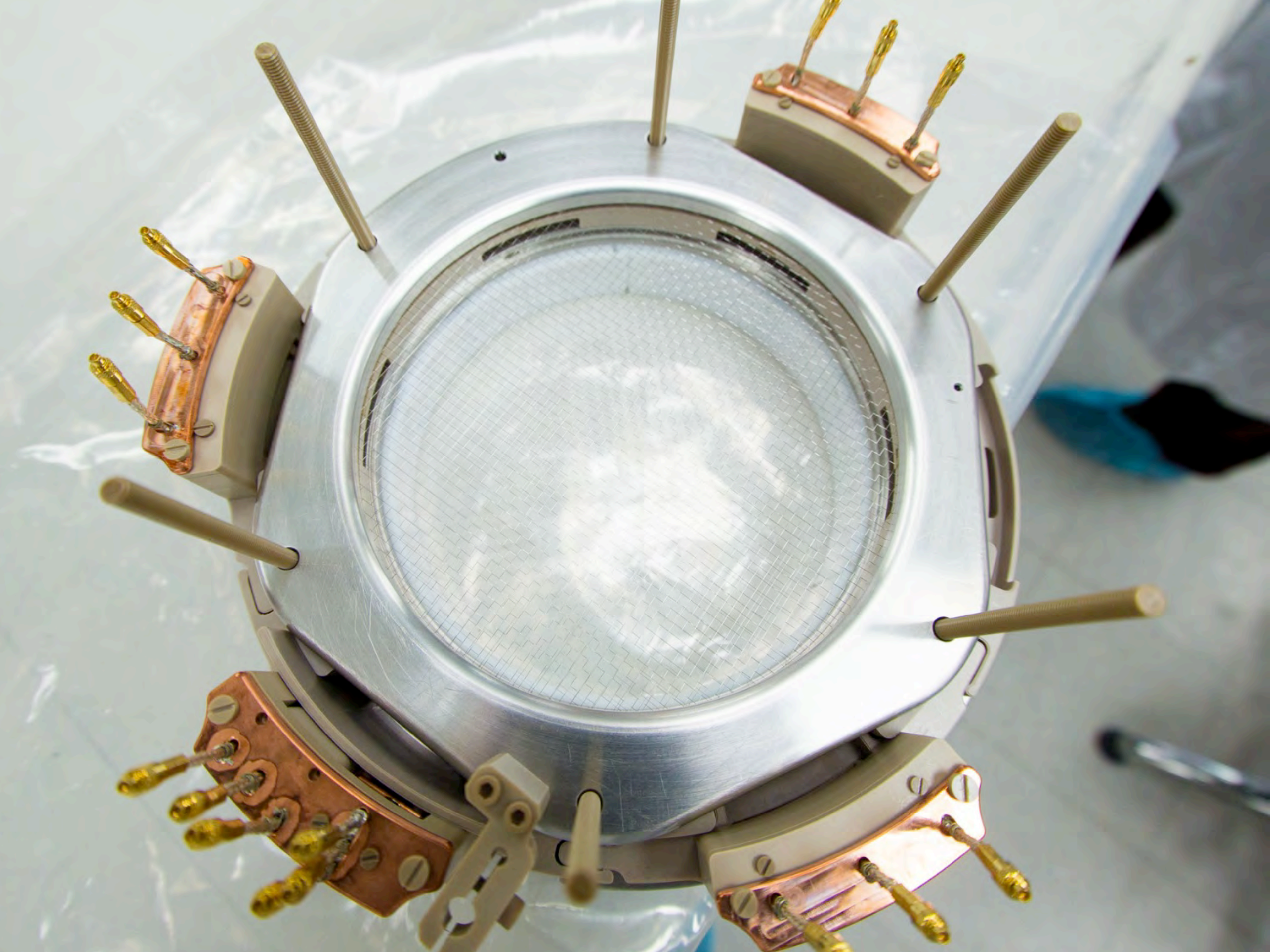


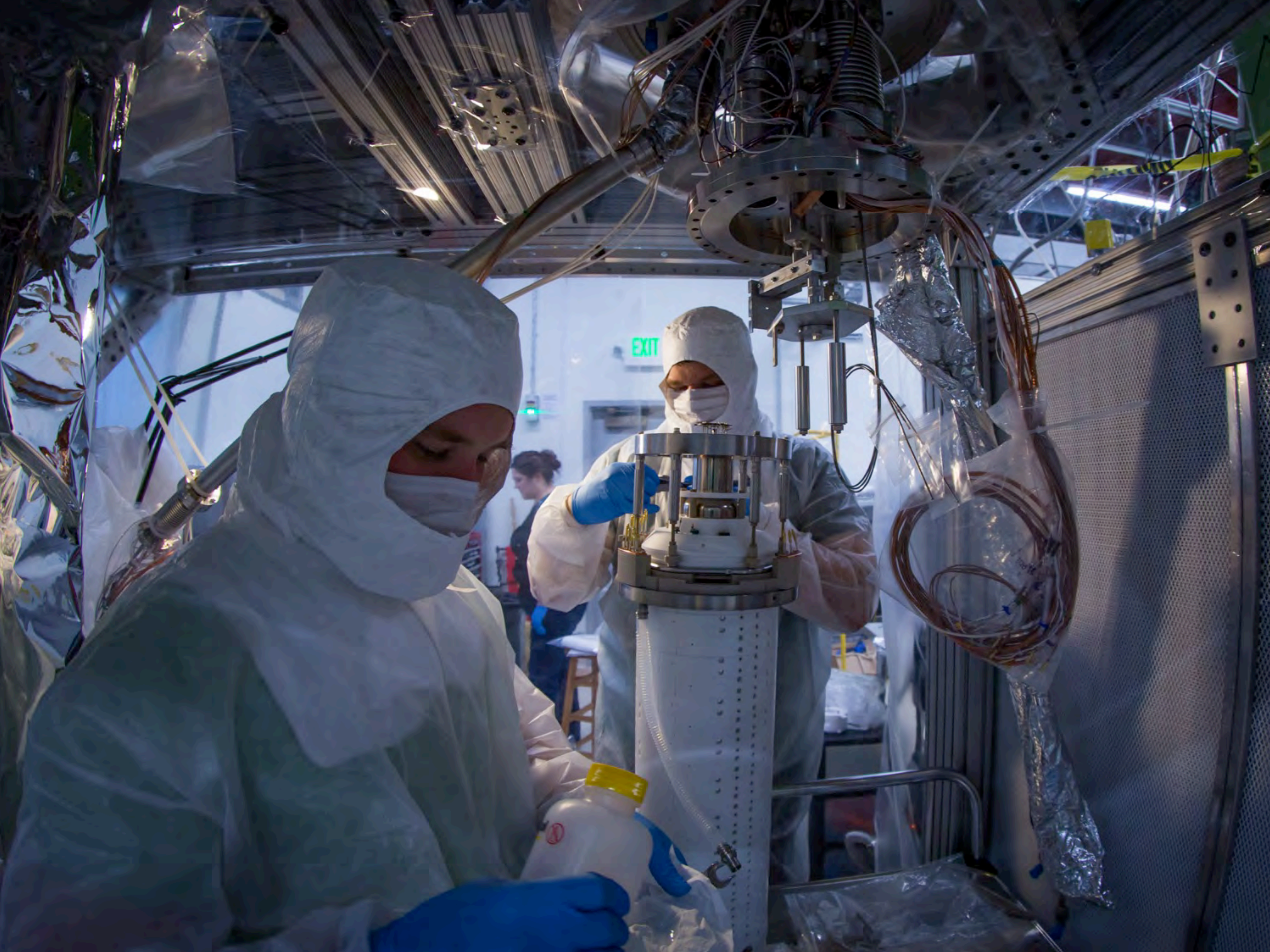
id Test Platform

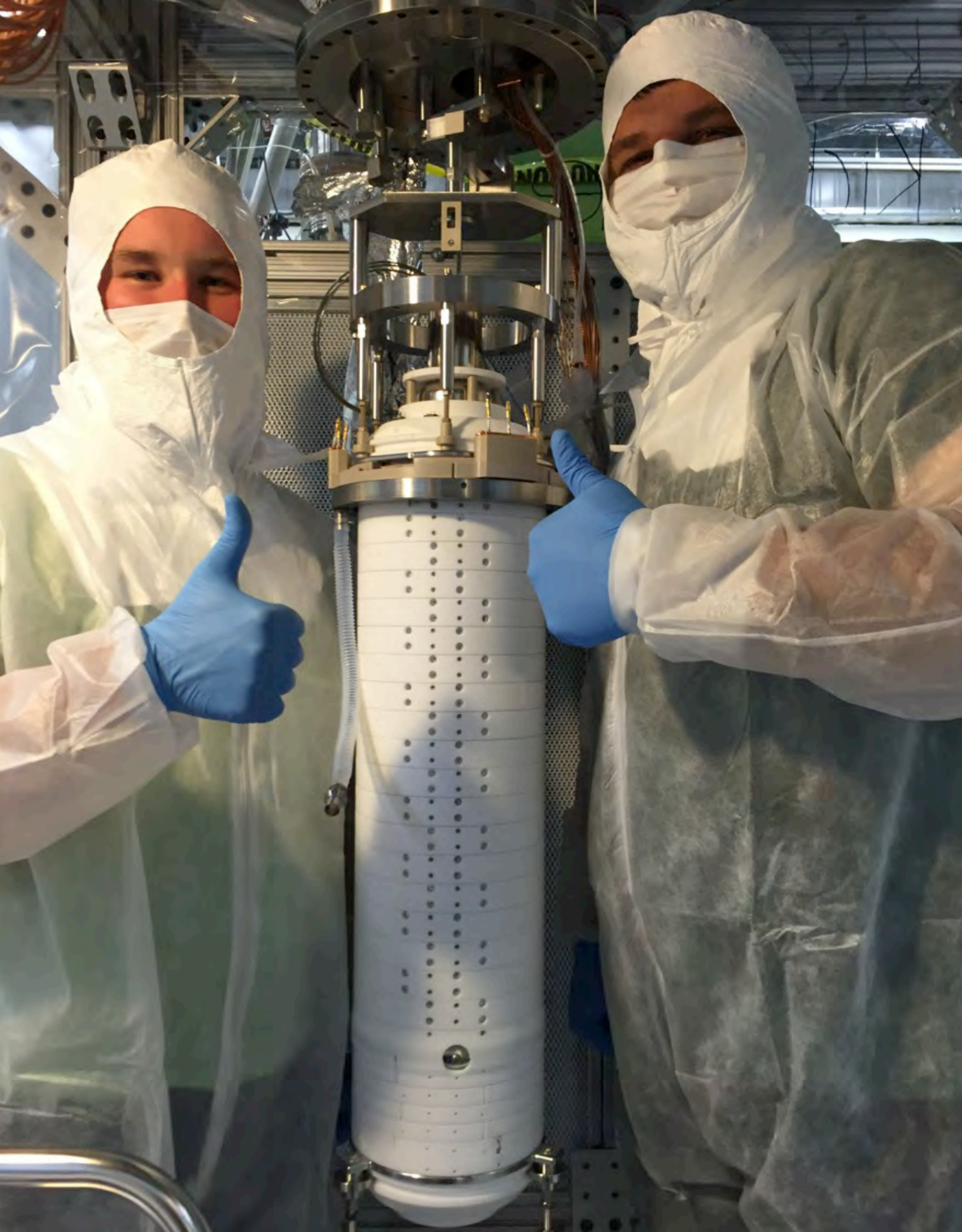


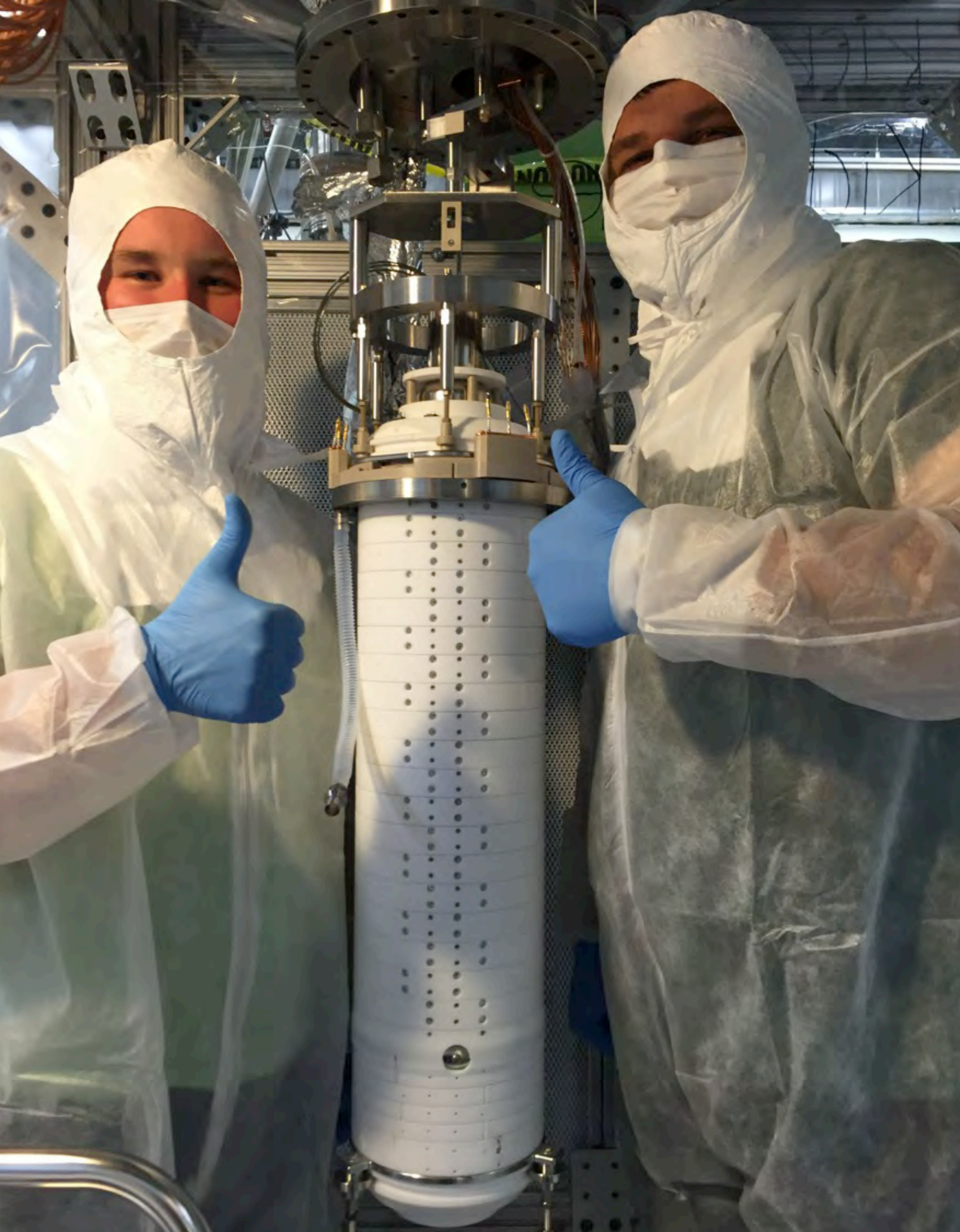







EXIT



Conclusions

- **Low-energy calibrations drastically improved across the field:**
  - **Lower thresholds in LUX**
  - **Sensitivity to lighter DM particles**
- **S2-only analysis is always challenging due to backgrounds**
  - **No S2/S1 or Z-coordinate cut**
- **Single electron sensitivity will be greatly enhanced in LZ**
  - **Single electron background a possible concern (large area)**
  - **Tackling the single electron background very aggressively**
  - **Includes full-scale grid testing**