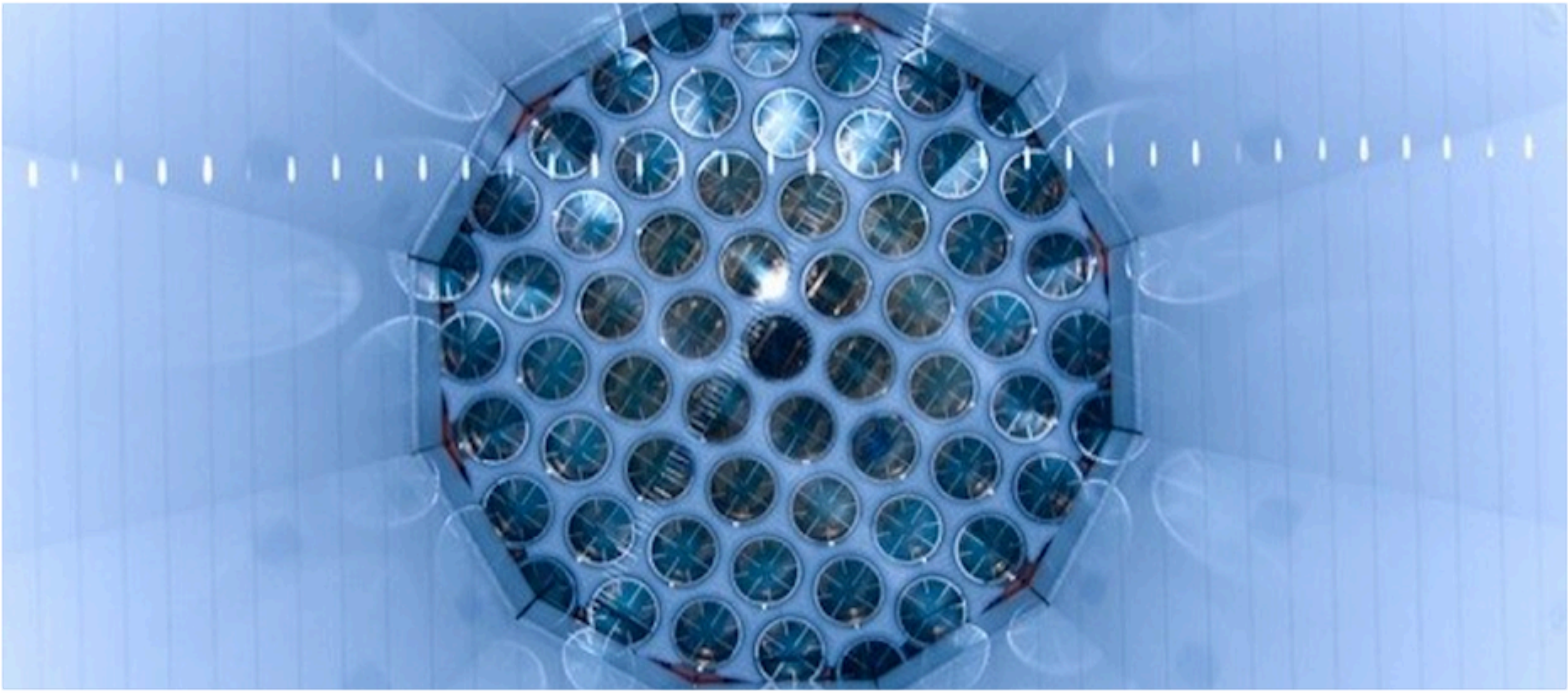


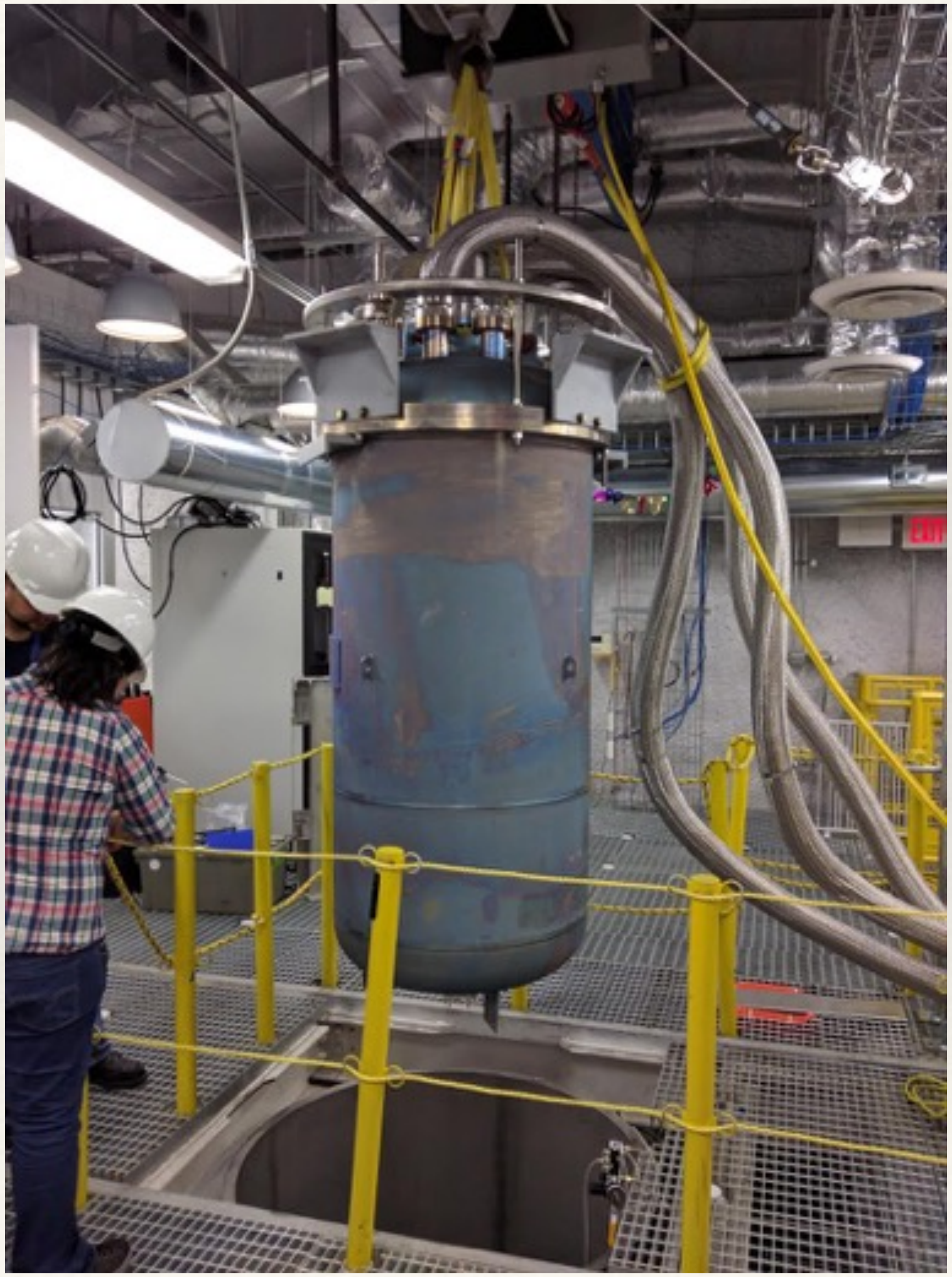
Upward view through the LUX TPC

Searching for dark matter with LUX and LZ

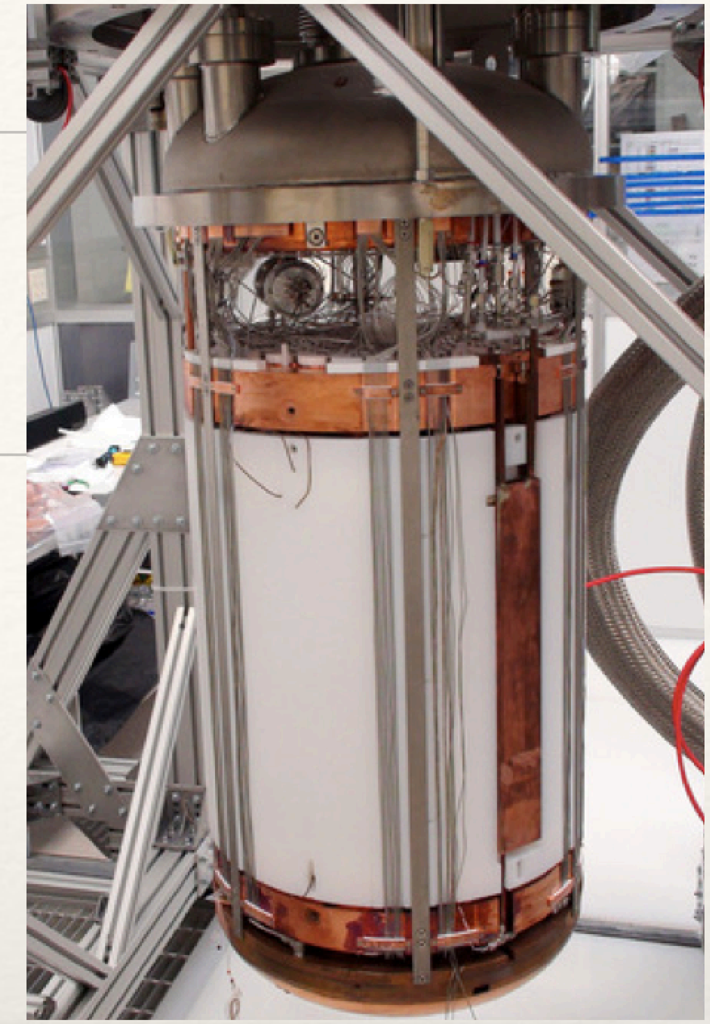
Peter Sorensen on behalf of the LUX Collaboration and the LZ Collaboration

LUX is dead; long live LUX!

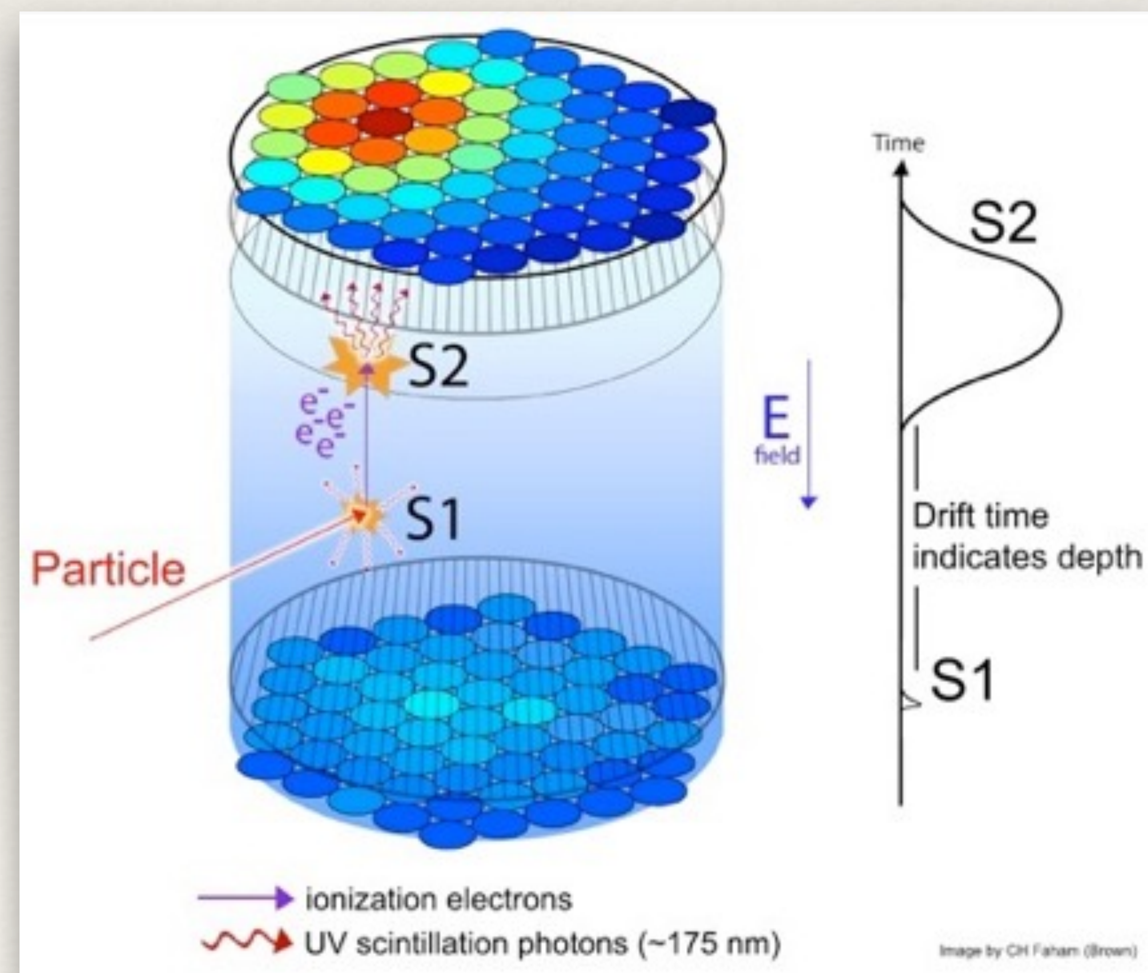
- 6 Oct, 2016: LUX comes up for air after 3+ years in the water shield
- 13 Jan, 2017: WIMP search results from total 95+332 live day exposure published in PRL
- LUX is presently the most sensitive direct detection experiment and a rich physics program is on-going



LUX by the numbers



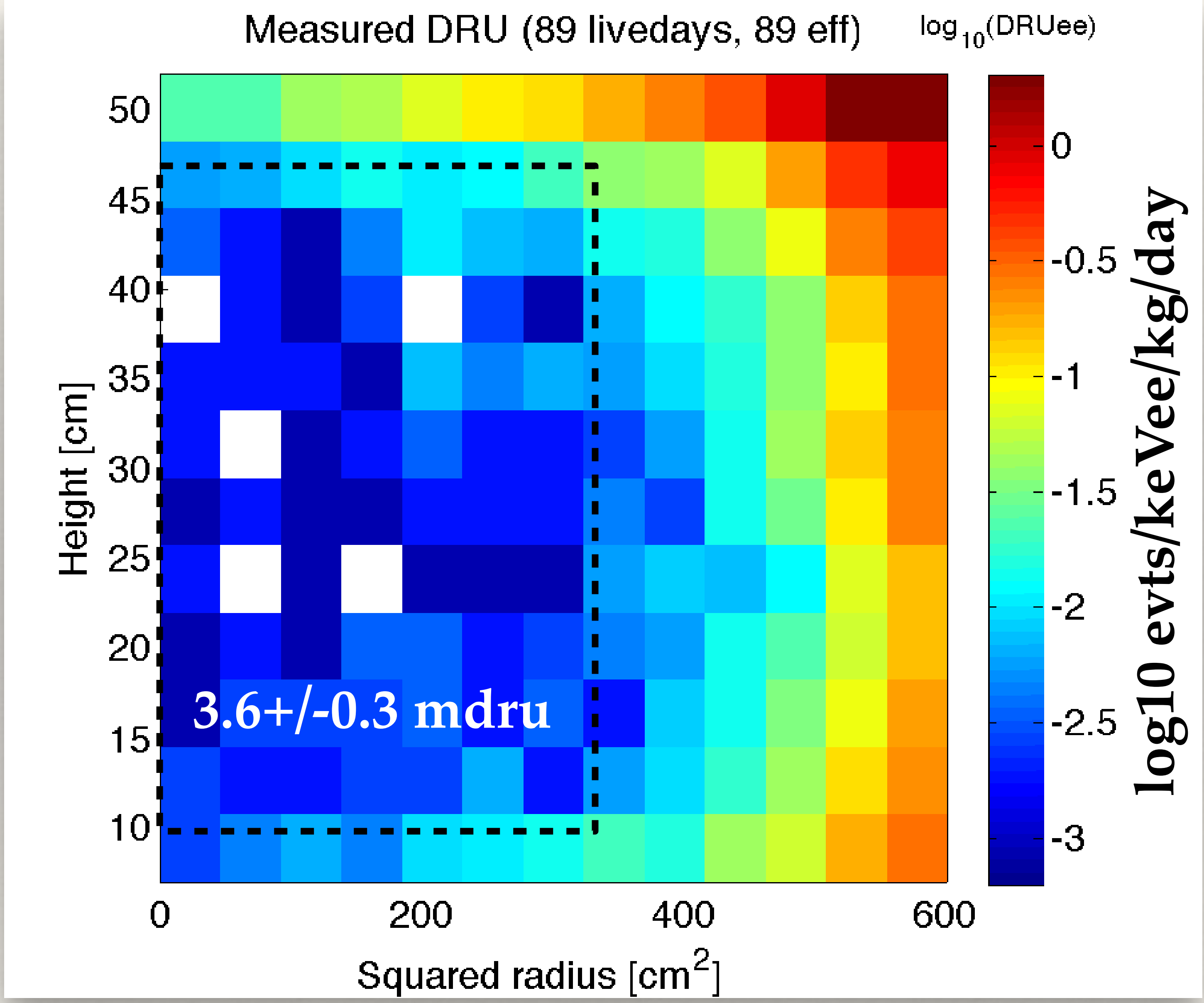
- Central detector:
  - 0.5 m diameter x 0.5 m height dodecagon
  - 370 kg liquid xenon TPC, 250 kg active target mass, ~100 kg fiducial target mass
  - 122 Photomultiplier tubes, Hamamatsu R8778
- 2 ultra low background titanium cryostats
- 1 ultra pure water shield
- pioneering in-situ calibration program including ^{83m}Kr, ^{3}H and DD neutron



Background minimization

- Internal
  - We count and then build with low-background materials (Cu, Ti)
  - Fiducialization takes advantage of xenon's self-shielding
- Intrinsic
  - Dedicated purification system for Kr removal (^{85}Kr beta decay) from Xe via chromatographic separation.
- External
  - 70,000-gallon water tank with active PMT veto system for muon tagging
  - Overburden for reduction of cosmic backgrounds

liquid Xe self-shielding from LUX2013 data

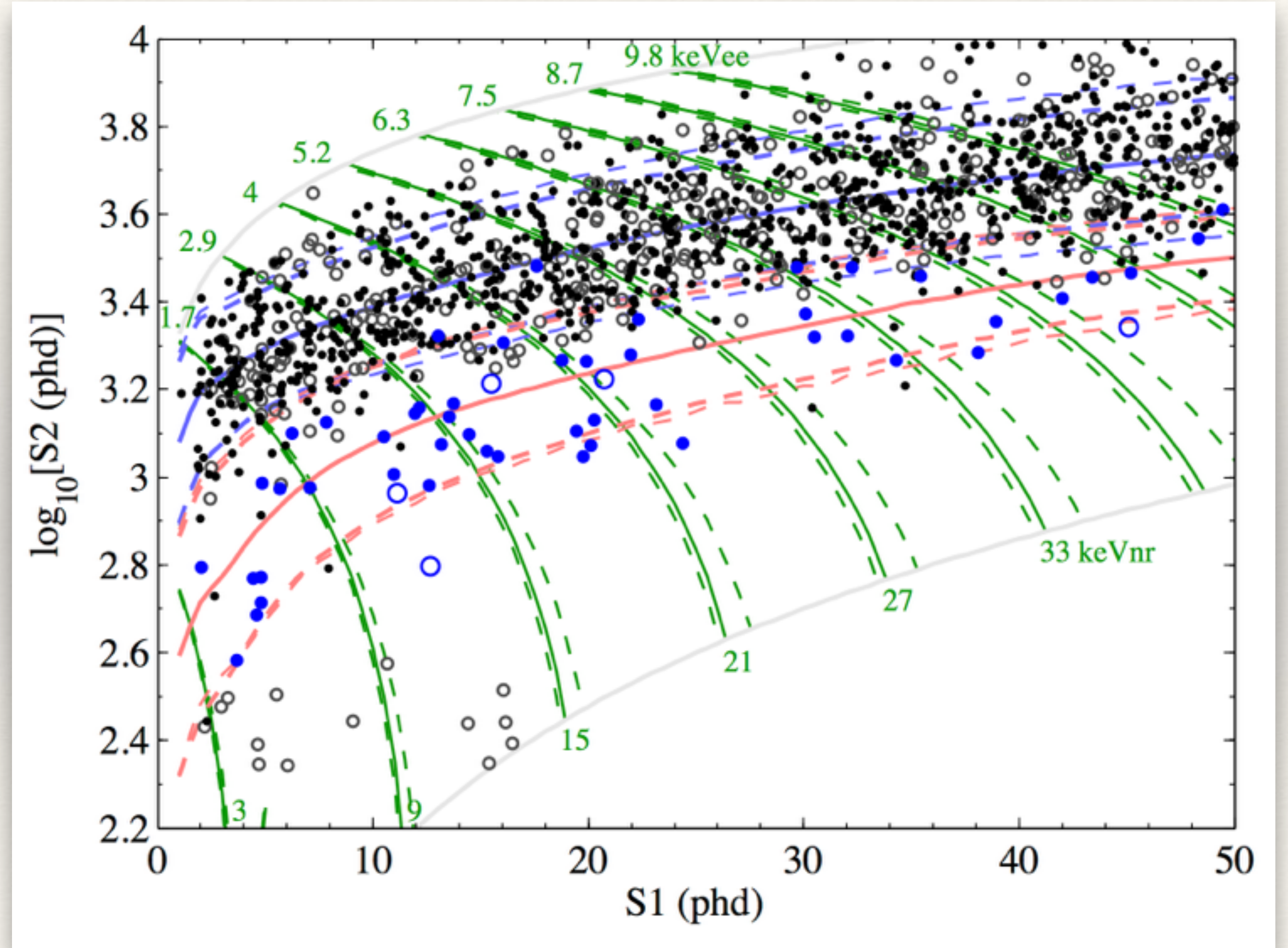


LUX 332 live day exposure (salted)

filled: bulk event
open: outer 1cm of bulk

black: recorded events
blue: sprinkled salt

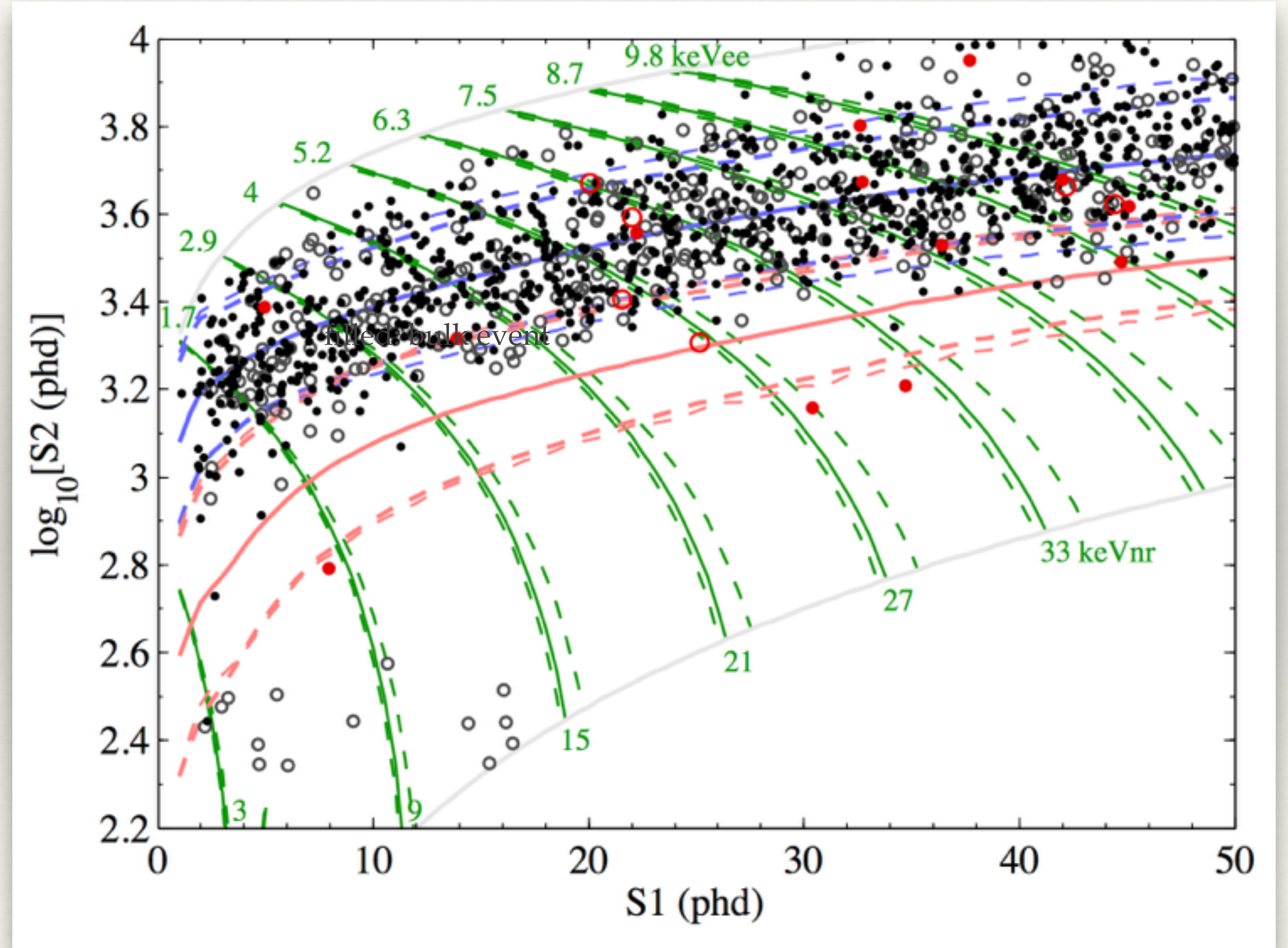
blue bands: background distribution 10% - 90%
red bands: signal distribution 10%-90%
green curves: keV energy



LUX 332 live day exposure (salt-free!)

salt is now removed

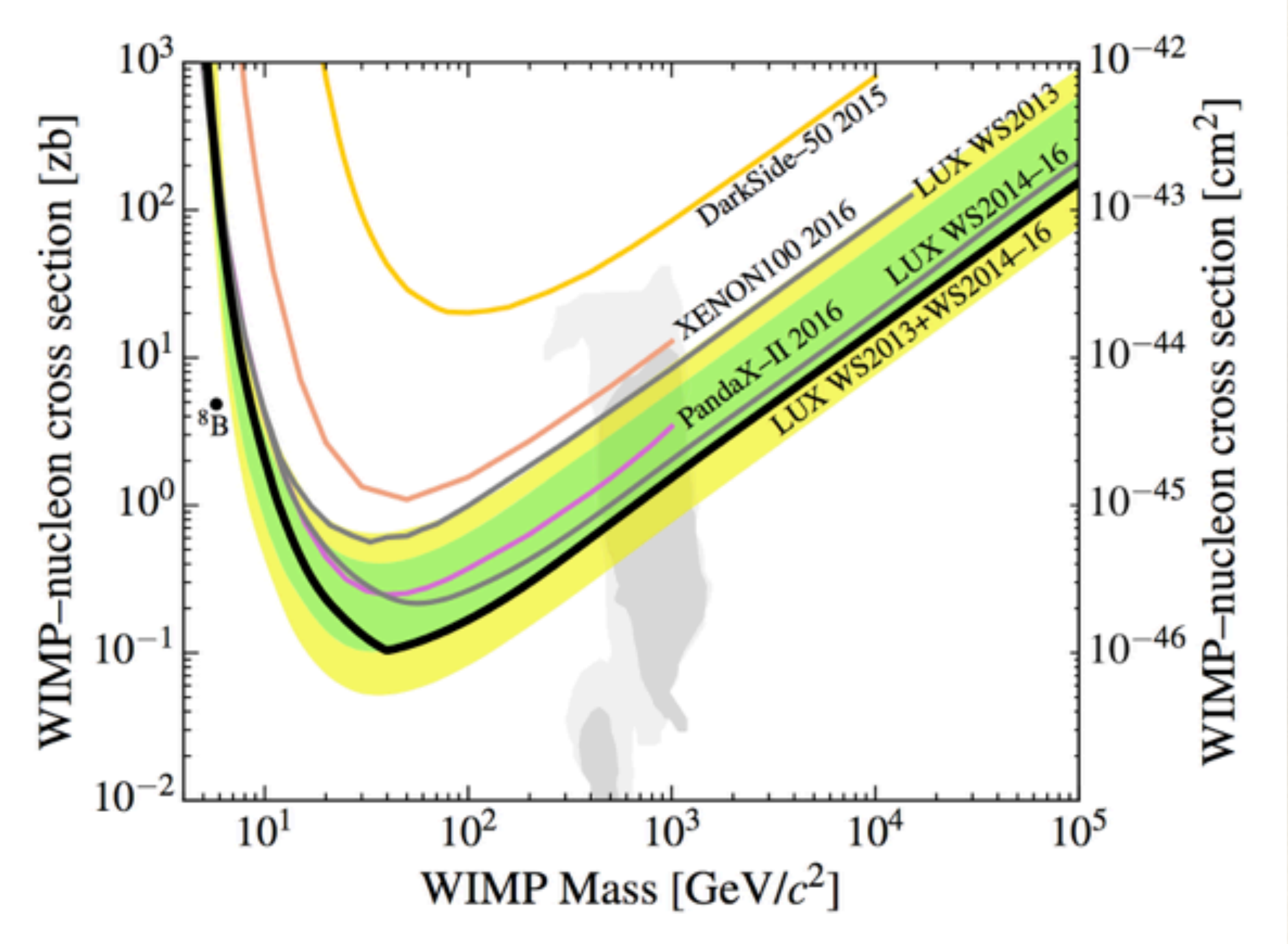
red events removed by post-unsalting cut



LUX 332 + 95 live days results

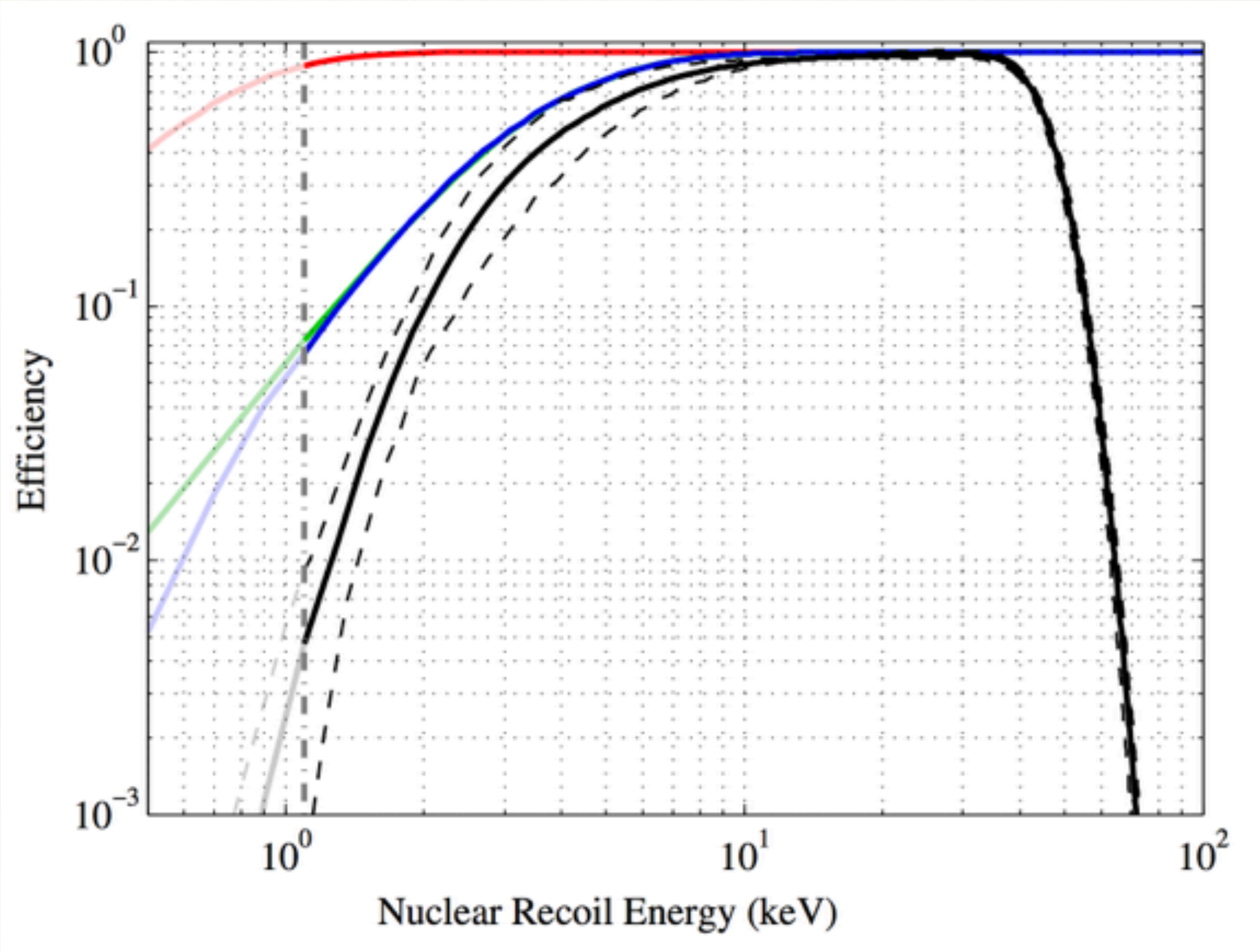
- LUX 2013 results reported on 95 live days
- LUX 2014-2016 results reported on 332 live days
- Total of 33,500 kg-days (~0.1 tonne-year)
- Limits calculated using 5 dimensional unbinned PLR (r, ϕ, dt, S1, S2)
- in between these search campaigns: calibrations and conditioning

Phys. Rev. Lett. 118, 021303



Signal detection efficiency

- S2 efficiency (red)
- S1 efficiency (green)
- combined S1+S2 (blue)
- total after analysis cuts (black)
- range (dashed) is extrema of 16 detectors

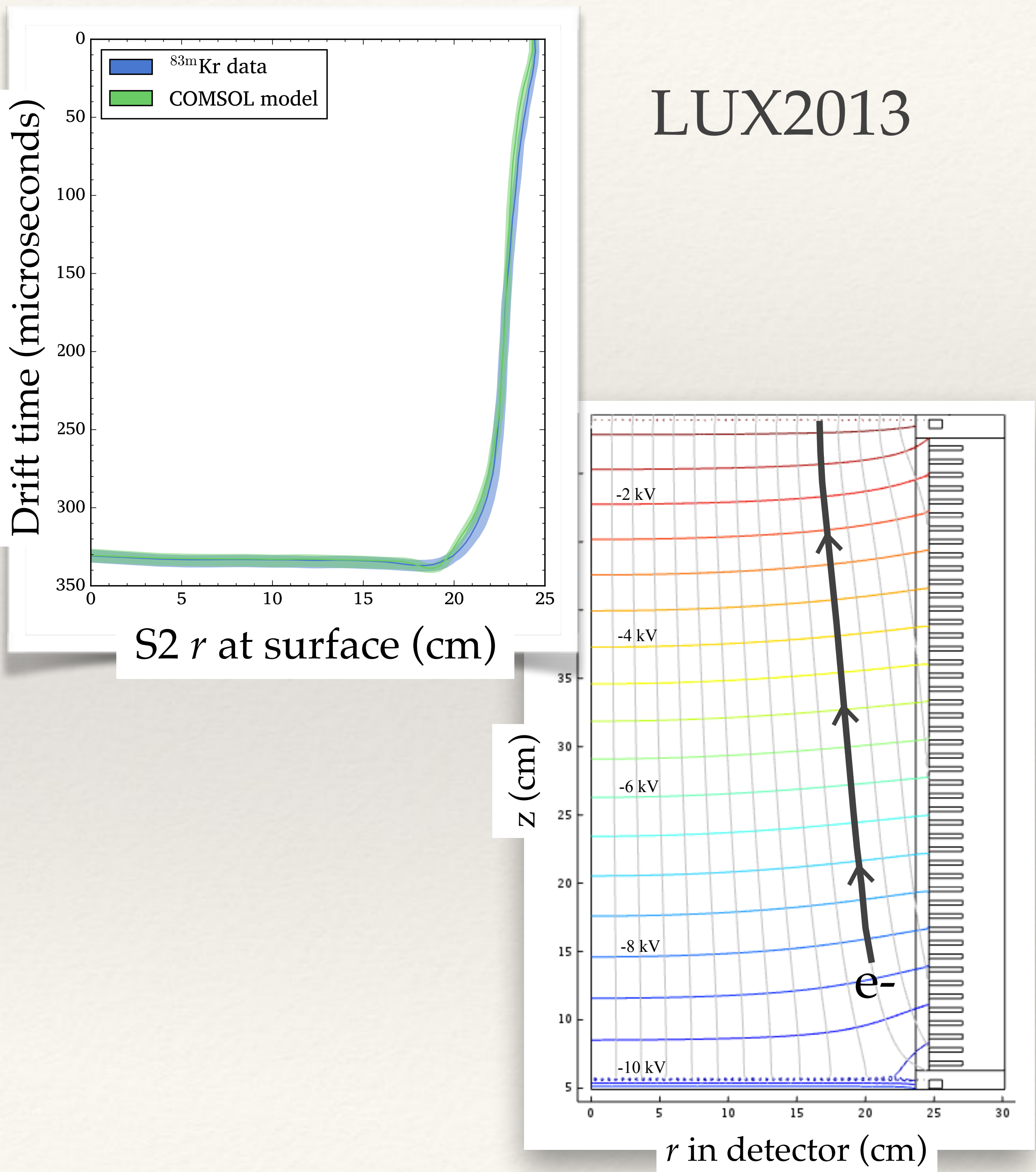


Electrode conditioning

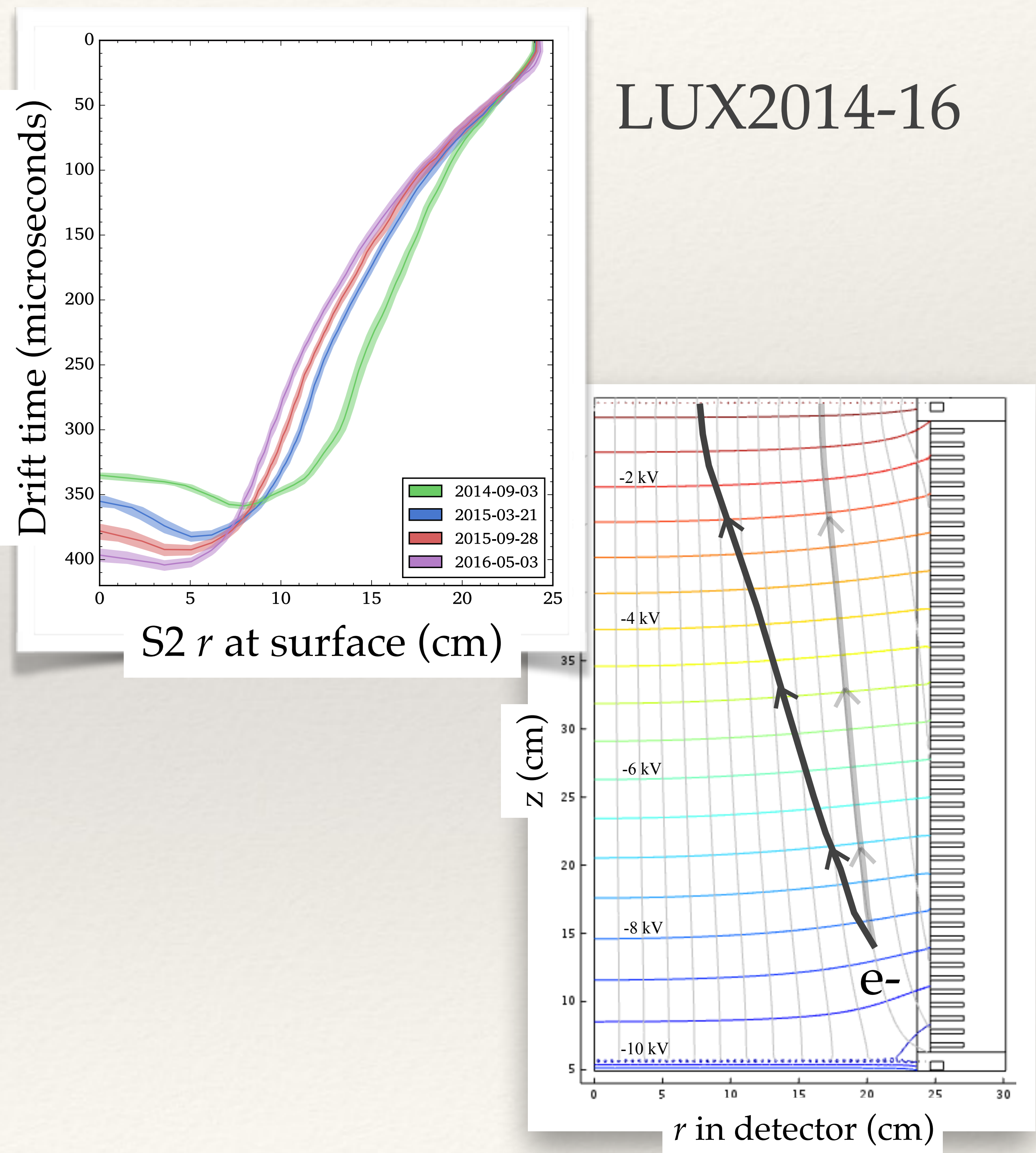
- Standard technique for electron drift detectors
- Consists of maintaining electrode at a voltage just at/above discharge threshold
- Performed after 95 live day result, in cold gas xenon
- Modest success - increased electron emission efficiency from ~50% to about 75%
- Unintended consequence -negative charge build-up on PTFE

Electrode conditioning affect on e- trajectories

LUX2013



LUX2014-16

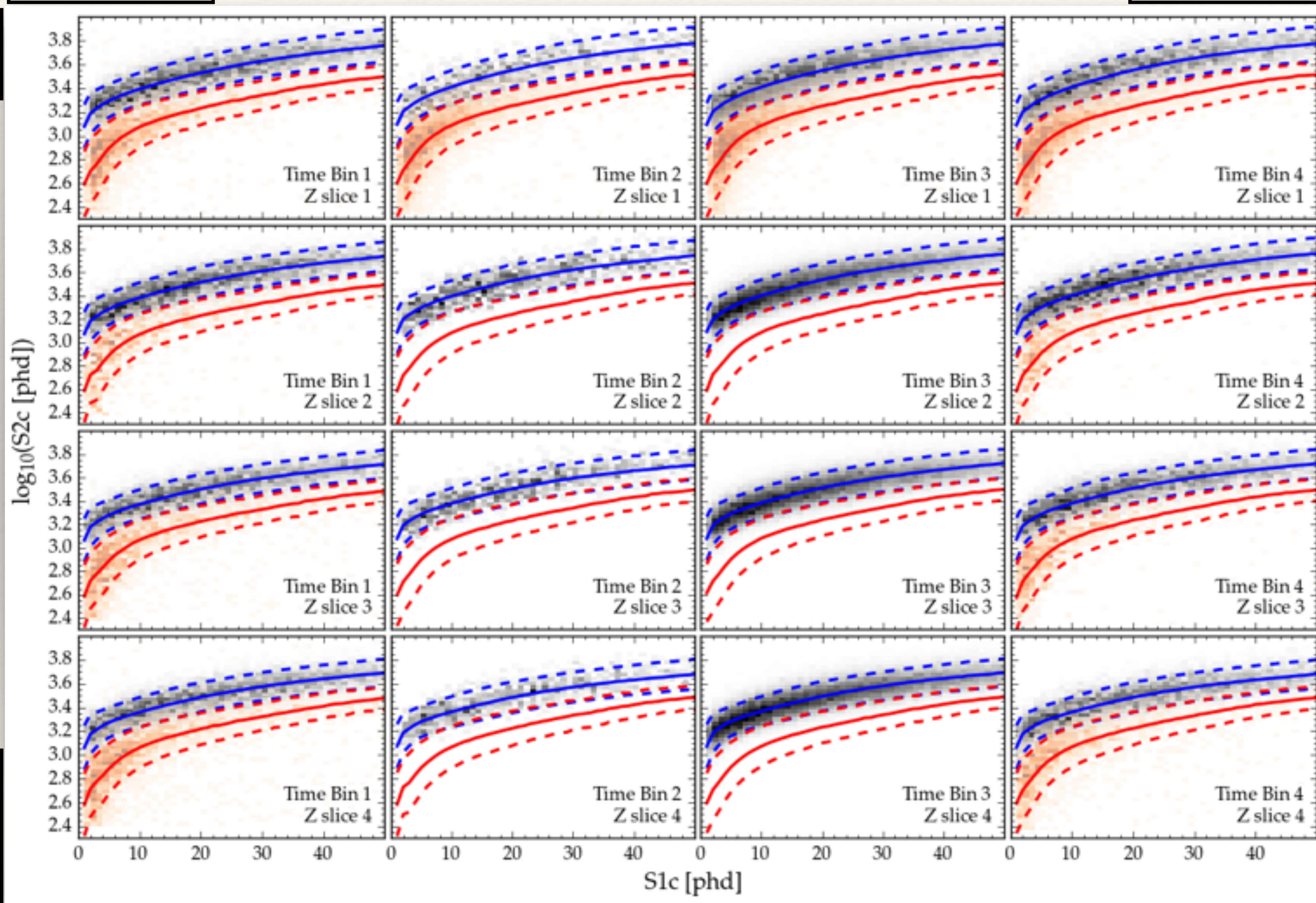


Mitigation: 16 detectors

Sept. 2014 ⟷ May 2016

Top

Bottom



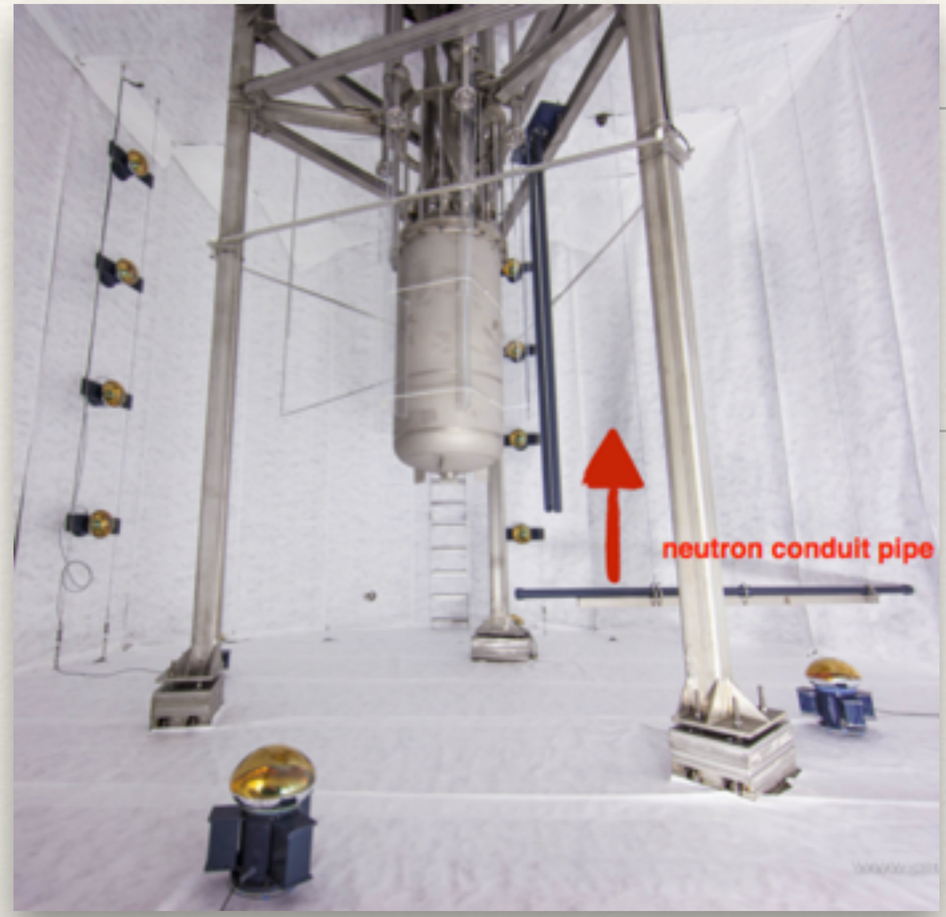
Gray density: CH_3T calibration (ER)

Orange density: DD calibration (NR)

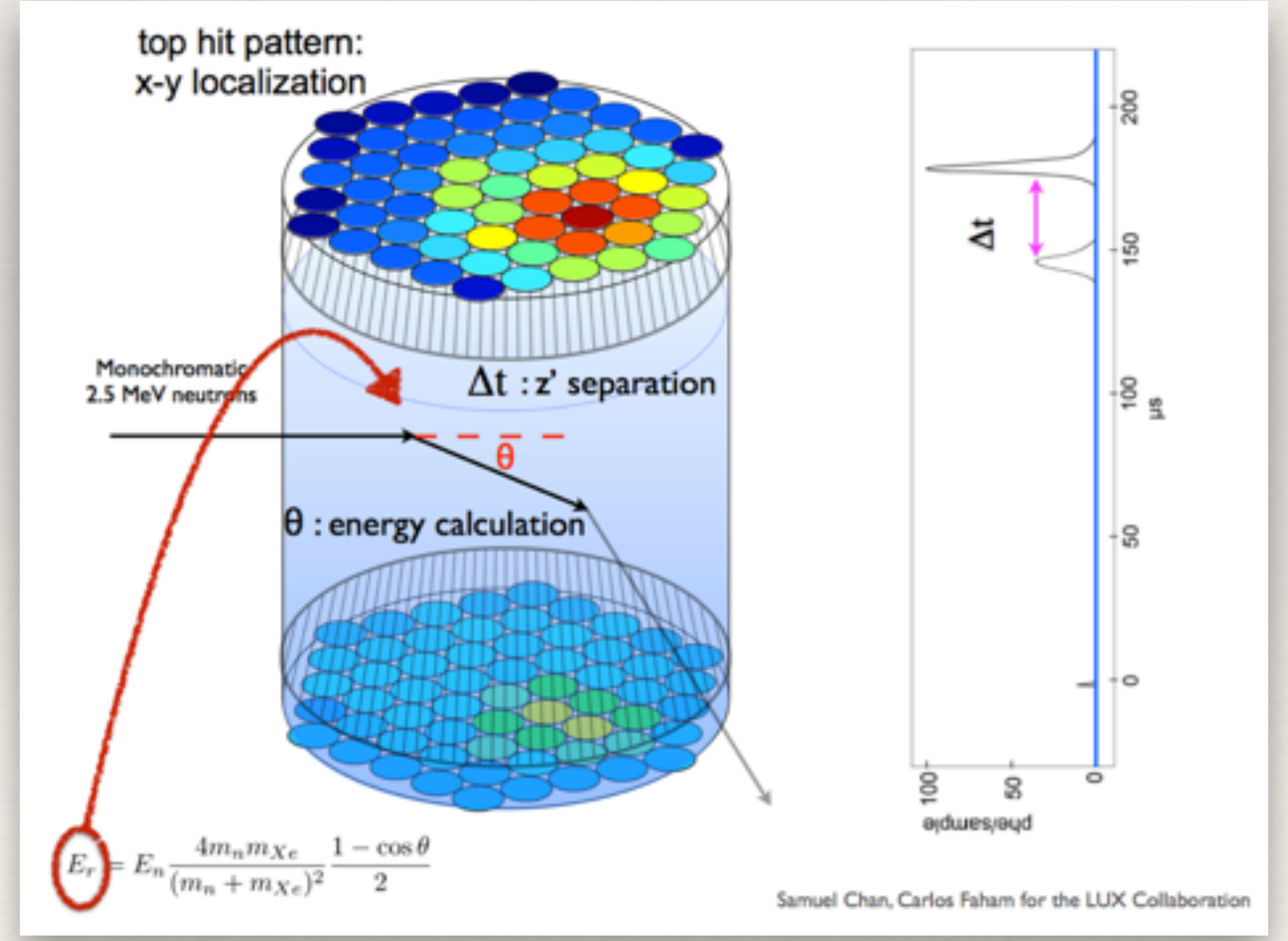
Solid lines: NEST model, ER, NR band mean

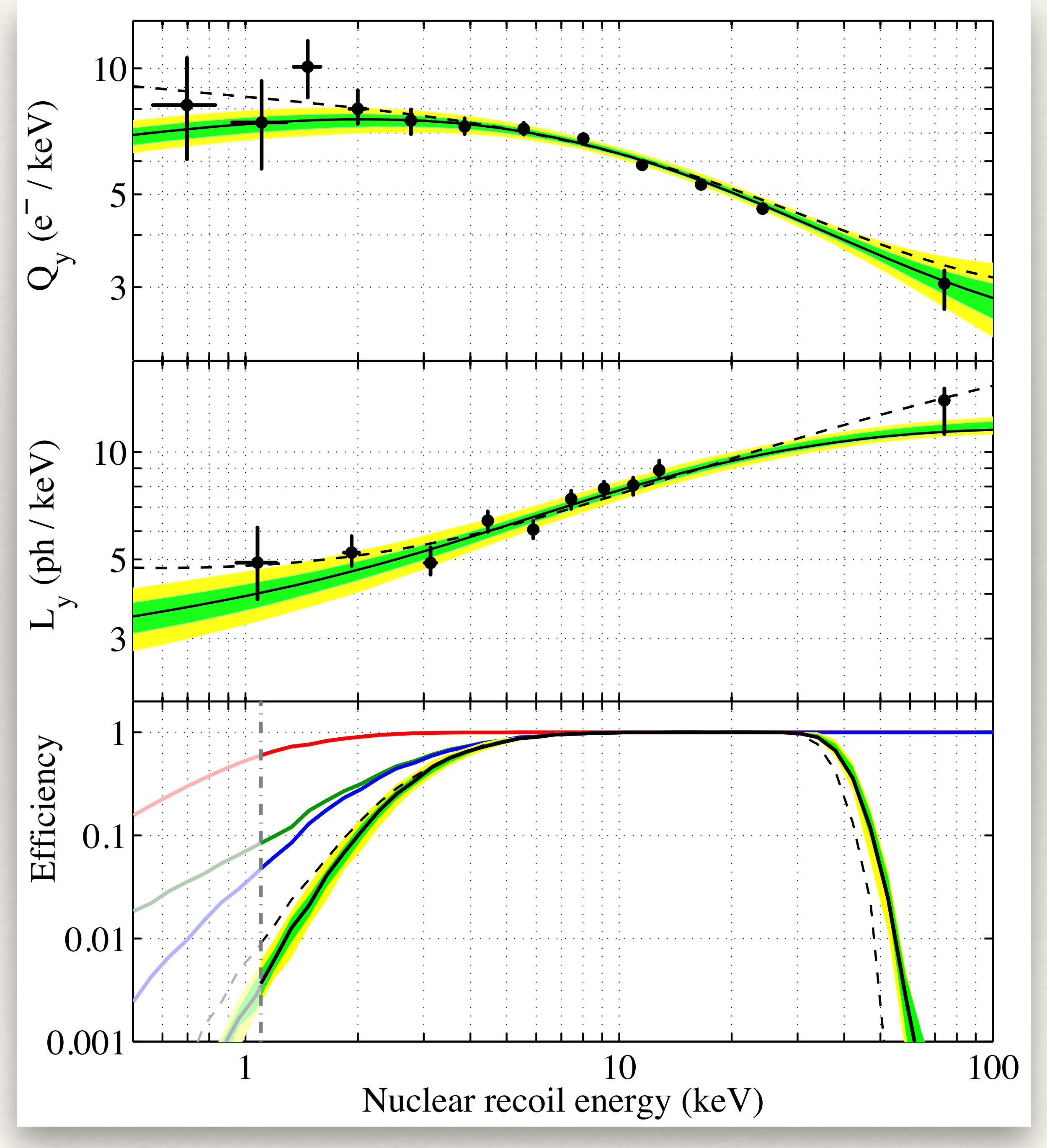
Dashed lines: NEST model, 10-90 percentile.

DD neutron calibration



arXiv:1608.05381





LUX detector physics results

- Too many publications to cover here (and more in the works)
- Partial list below

"Signal yields, energy resolution, and recombination fluctuations in liquid xenon" Phys. Rev. D **95**, 012008 (2017), arXiv:1610.02076

"Low-energy (0.7-74 keV) nuclear recoil calibration of the LUX dark matter experiment using D-D neutron scattering kinematics" (2016), submitted to PRC, arXiv:1608.05381

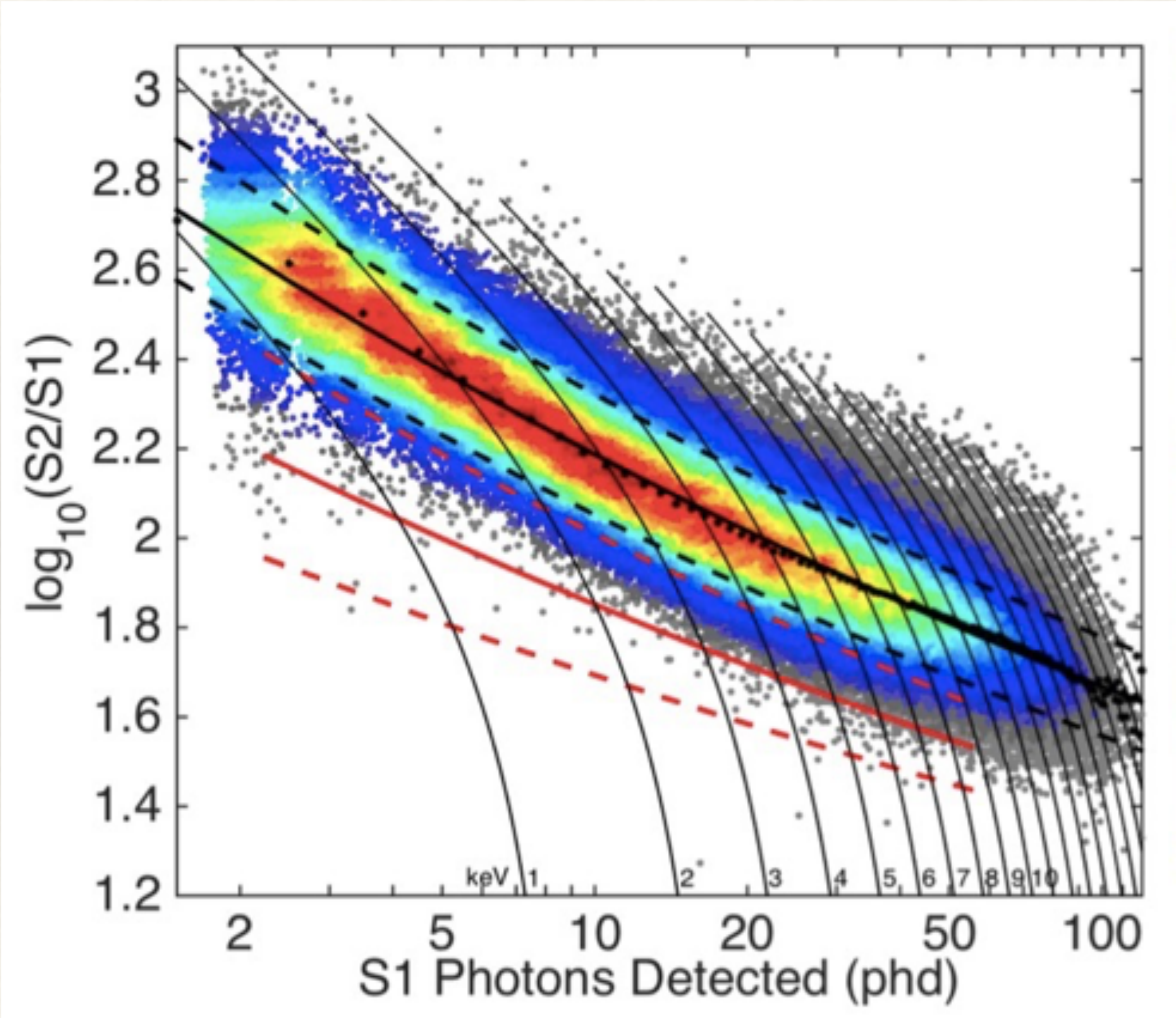
"Chromatographic separation of radioactive noble gases from xenon" (2016), submitted to Astropart. Phys., arXiv:1605.03844

"First spin-dependent WIMP-nucleon cross section limits from the LUX experiment" (2016), Phys. Rev. Lett. 116, 161302, arXiv:1602.03489

"Tritium calibration of the LUX dark matter experiment" (2016), Phys. Rev. D 93, 072009, arXiv:12512:03133

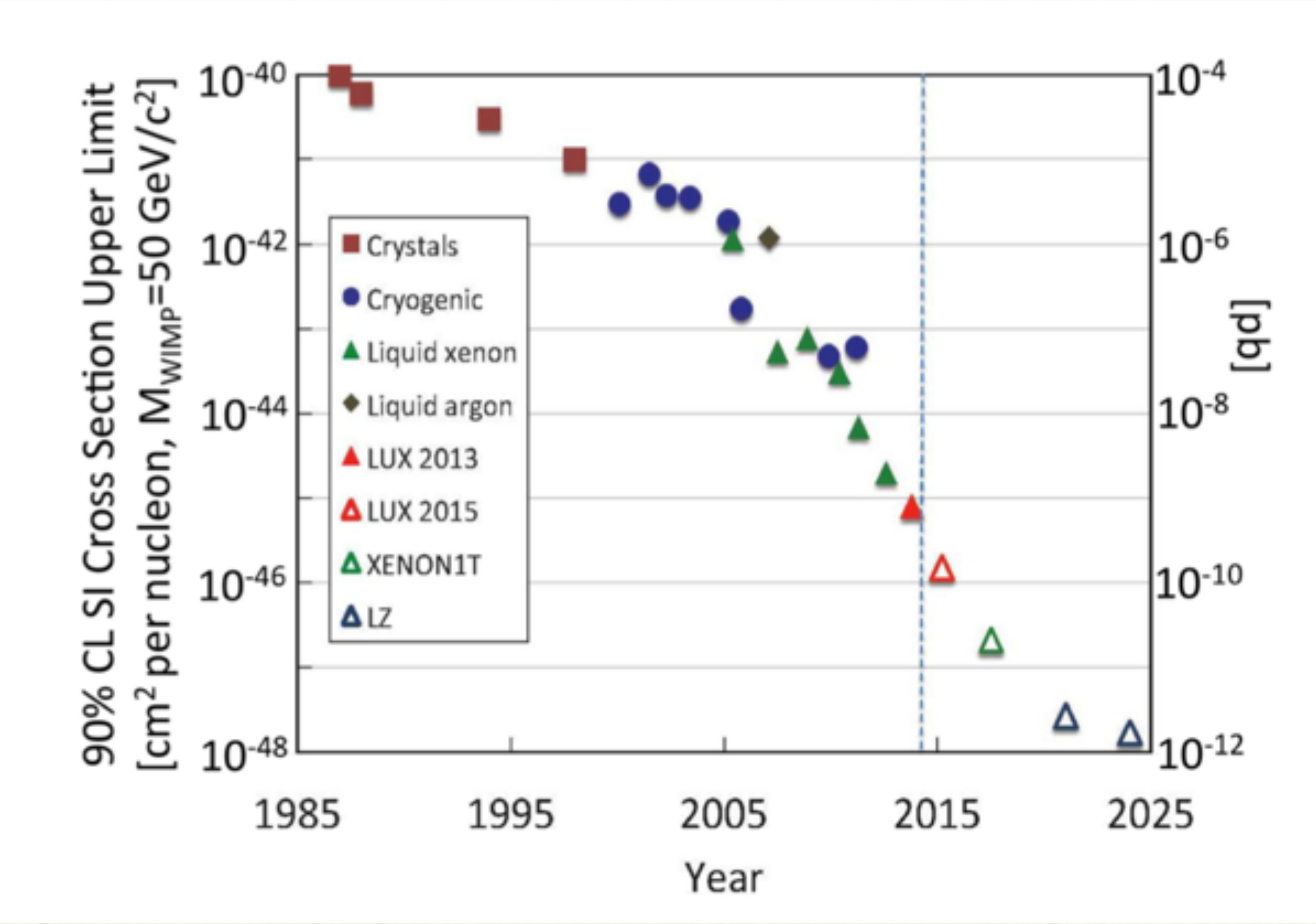
"Radiogenic and muon-induced backgrounds in the LUX dark matter detector" (2014) - Astropart. Phys. 62 33-46 (2015) - arXiv:1403.1299

Tritium beta spectrum in LUX



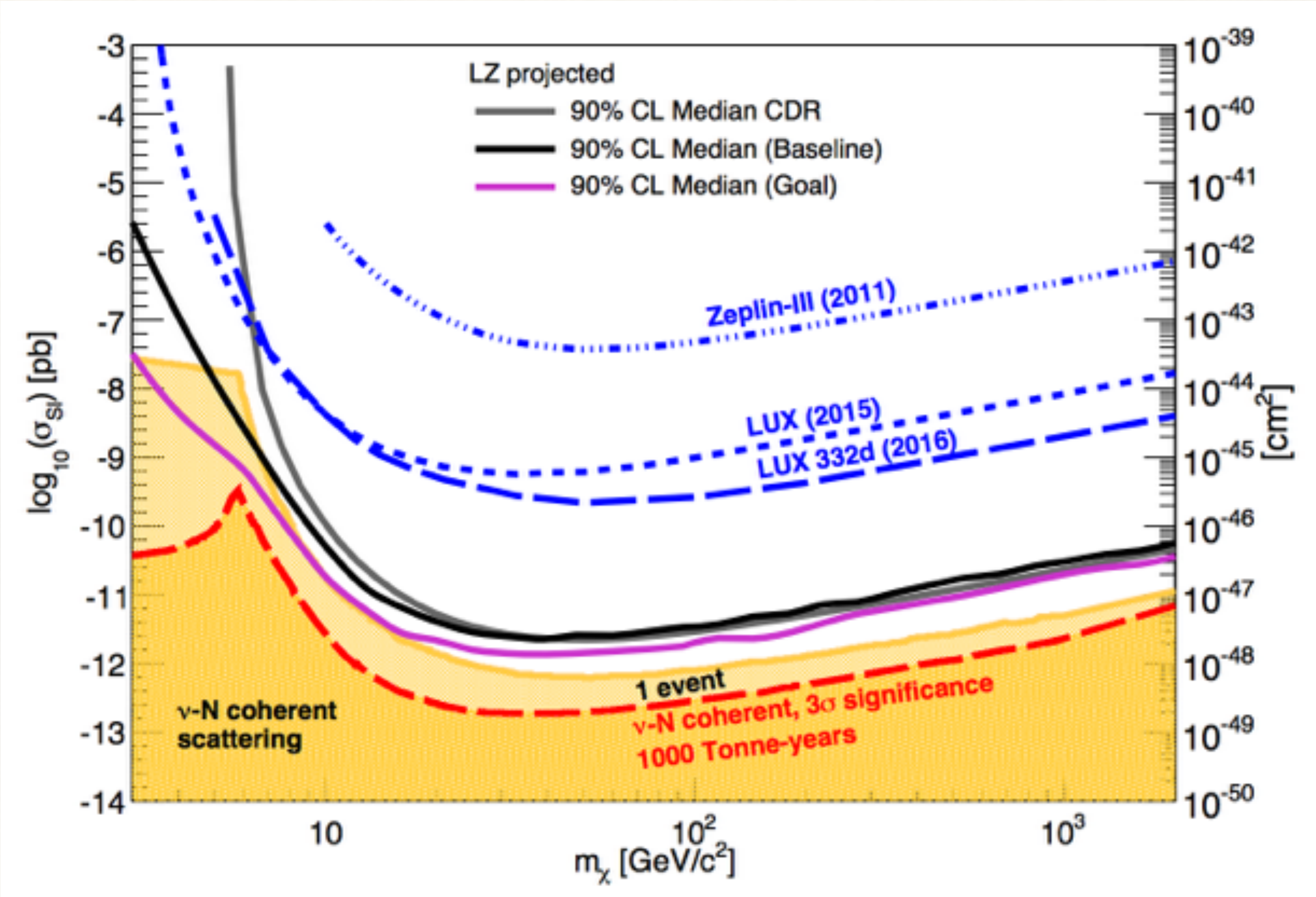
LUX => LZ

- As a benchmark, sensitivity to 50 GeV WIMPs over 4 decades
- LZ design goal approaches 1e-48 cm^2
- Note factor ~x20 in mass results in factor ~x100 in sensitivity
- Due to self shielding Xe and additional background reduction

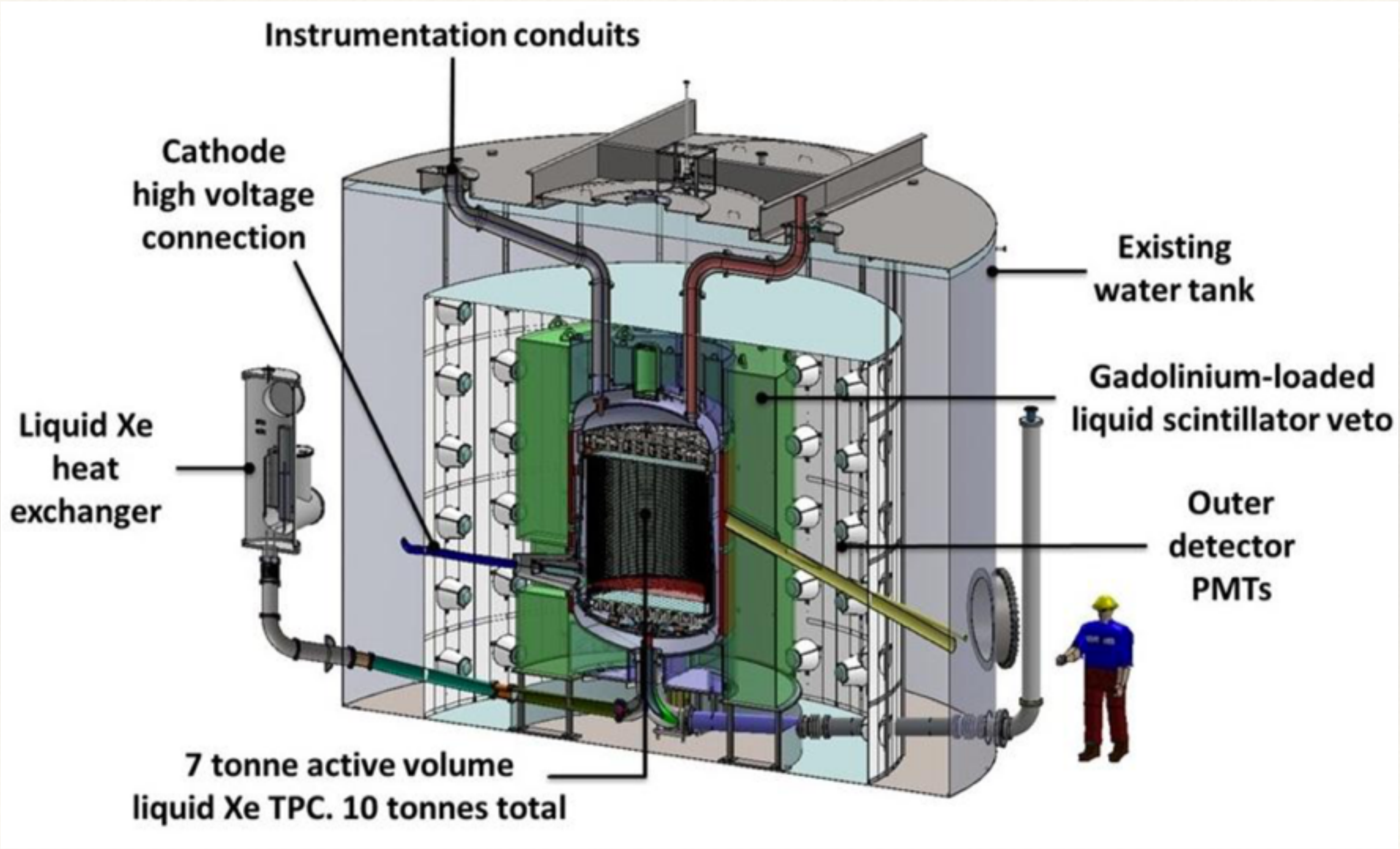


LZ sensitivity

- LZ projected WIMP sensitivity
- This and other plots from the forthcoming LZ Technical Design Report (TDR)
- Expected to appear on arXiv in March

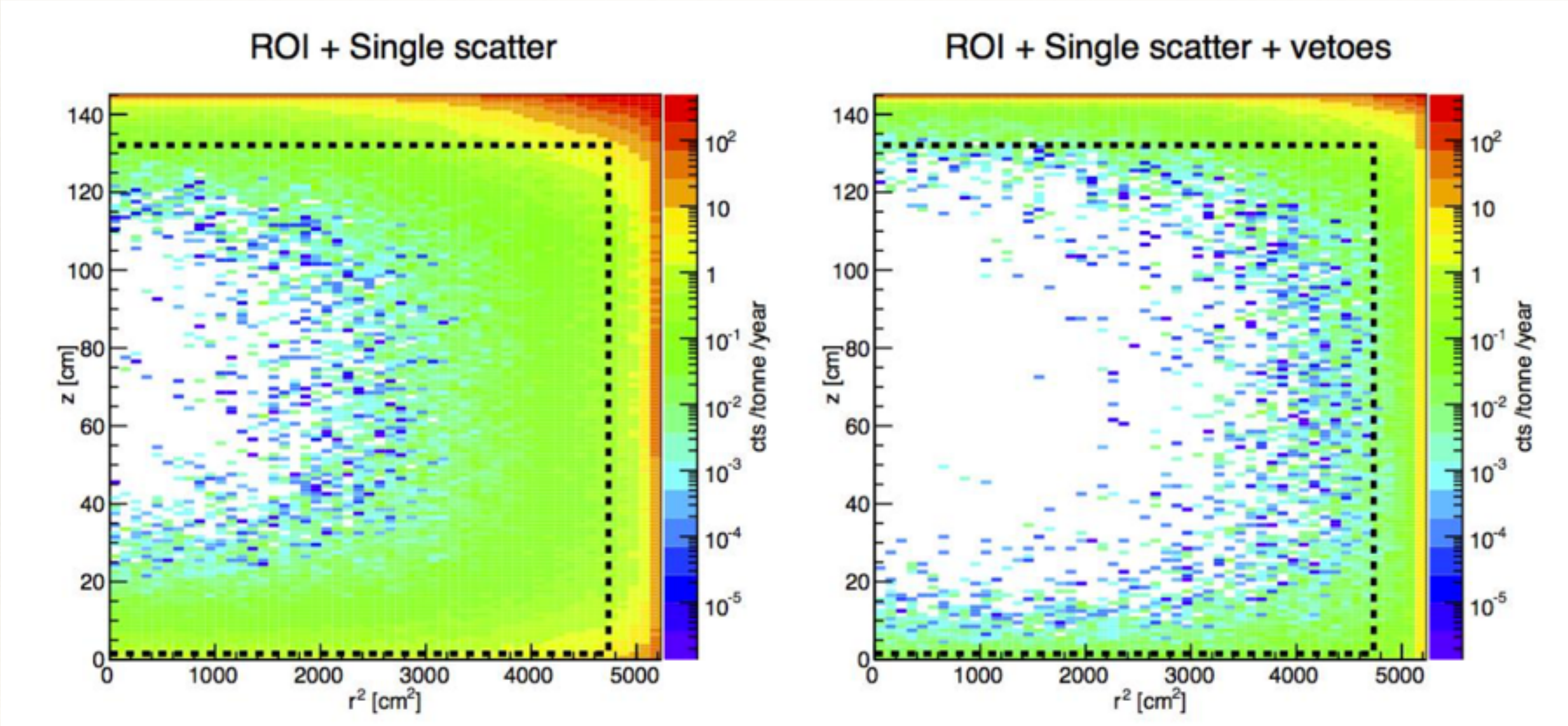


LZ instrument



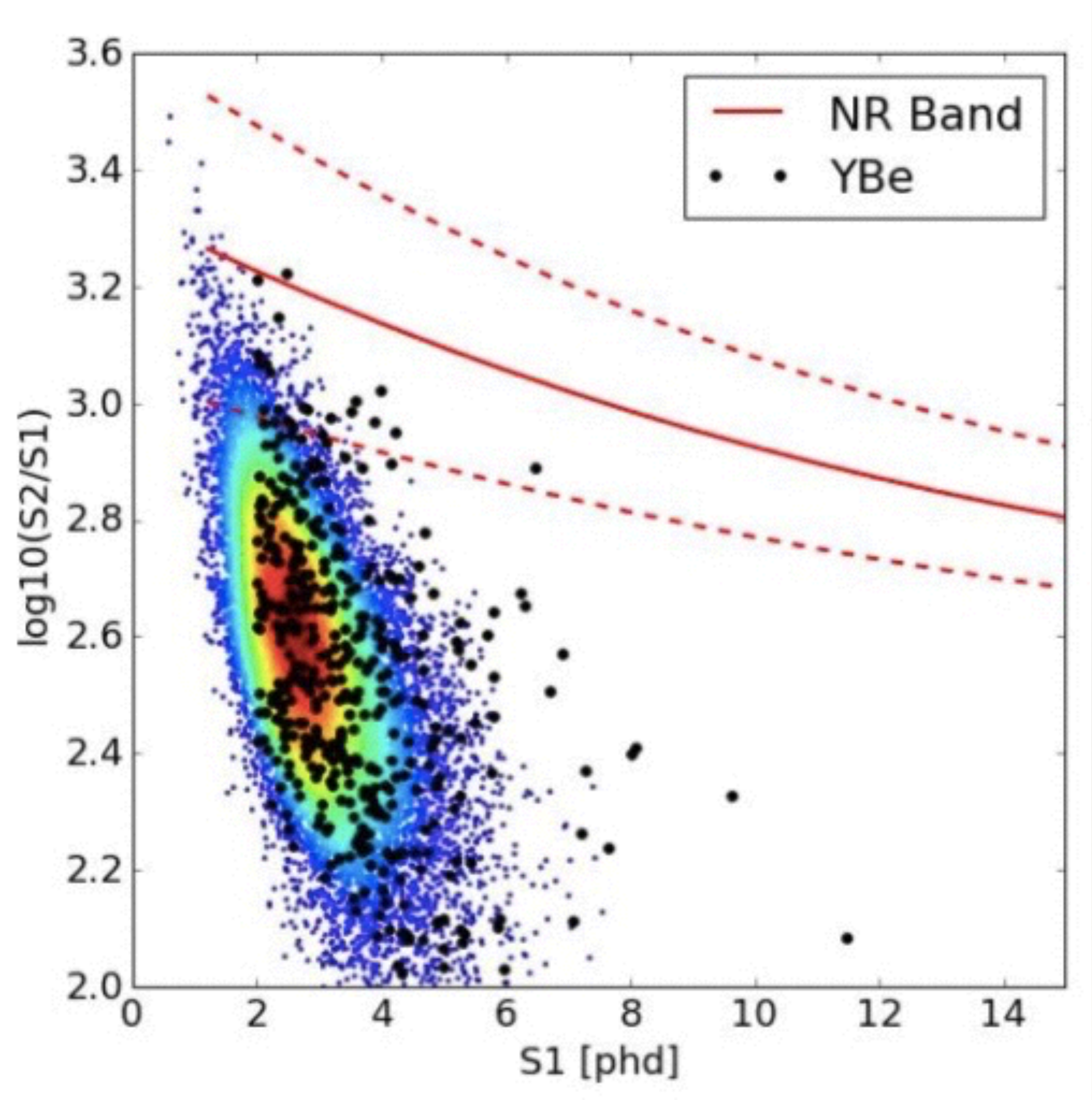
Projected NR-like signal distribution

Total of 6.8 signal-like background events in complete exposure
Rn is dominant component
followed by v-e solar neutrino scattering, and atmospheric v-A scattering



^{8}B neutrino-nucleus scattering

- Background can be profiled due to distinctive shape
- Multiple calibration sources: DD neutron scattering, novel D-reflector neutron scattering, photoneutron scattering



LUX and LZ Collaborations

- LUX:
  - ~20 institutions and ~100 scientists
  - luxdarkmatter.org
- LZ:
  - ~30 institutions and ~200 scientists / engineers
  - lzdarkmatter.org

Summary

- LUX had an extremely productive 4-year run and is still producing new physics results
- The LZ Collaboration is working to ensure a successful follow-on experiment is deployed on or ahead of schedule (presently 2020)

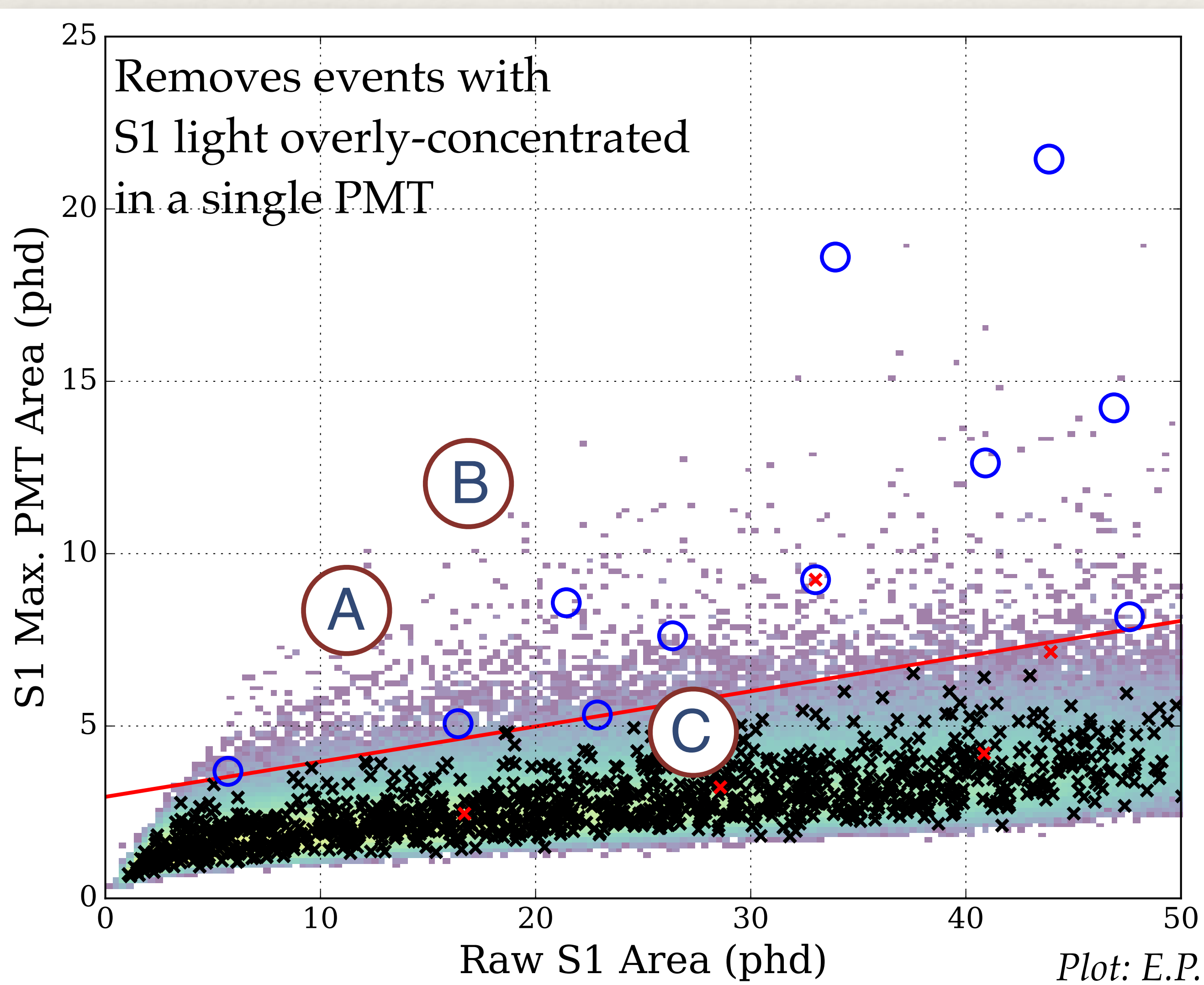
Extra Slides Follow

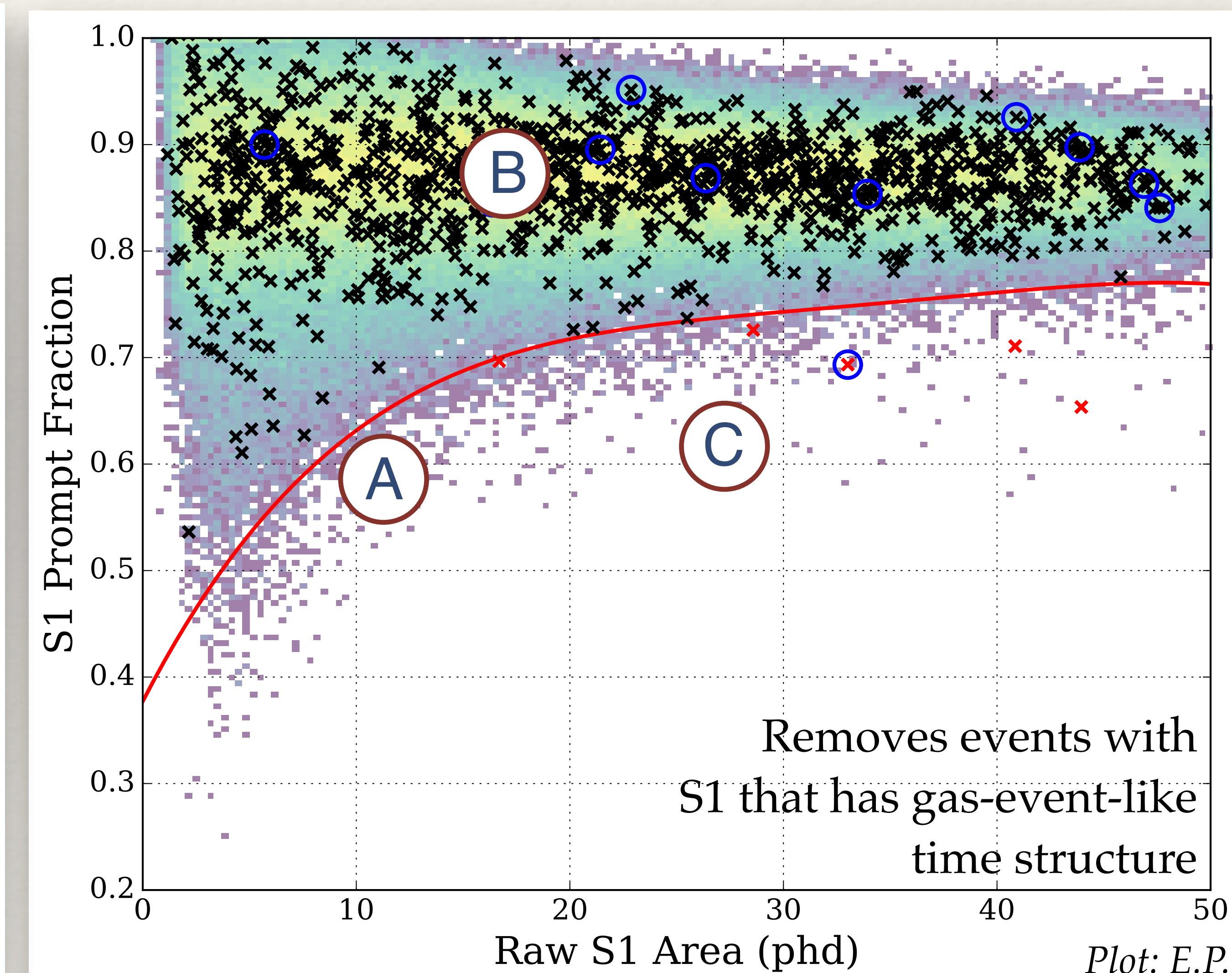
Post-unsalting cuts for new pathologies

- Cuts with high signal acceptance were defined on DD and CH_3T calibration data (shown below)
- Flat signal acceptance of 98.5% with both cuts applied.

Density map: CH_3T calibration data
x : WS2014-16 data passing S1 cuts
○ : WS2014-16 data cut by S1 Max. PMT Area cut
x : WS2014-16 data cut by S1 Prompt Fraction cut

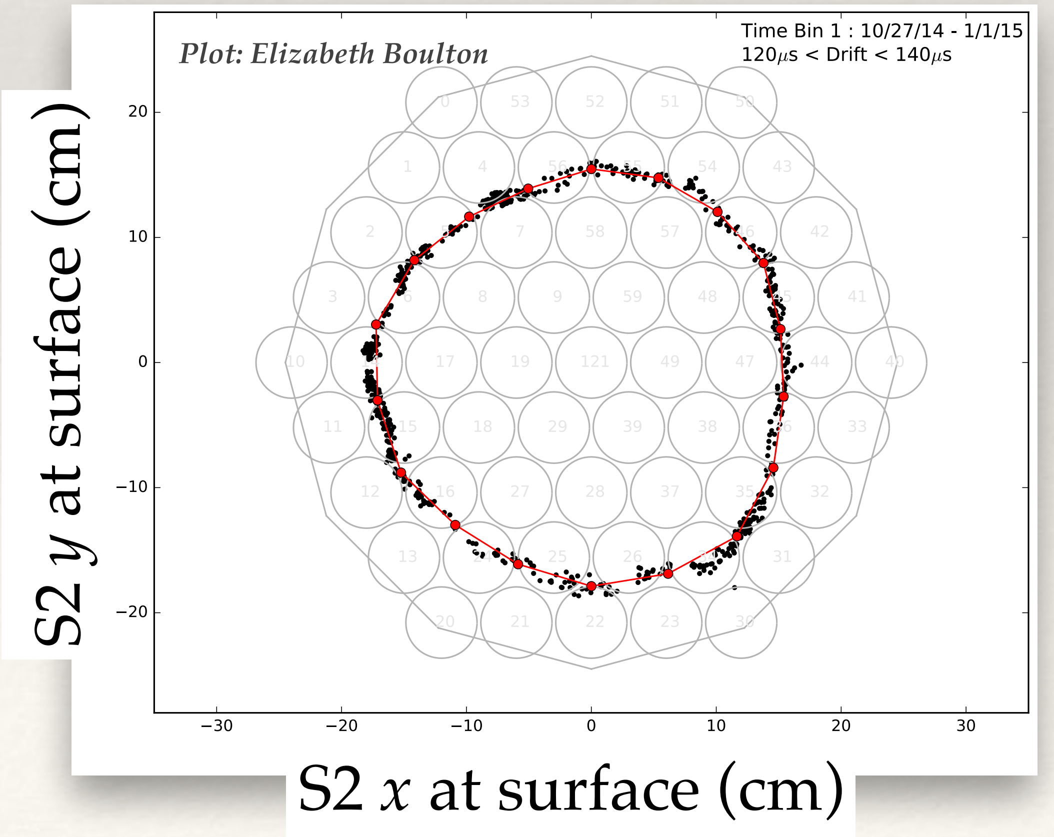
Plot: E.P.

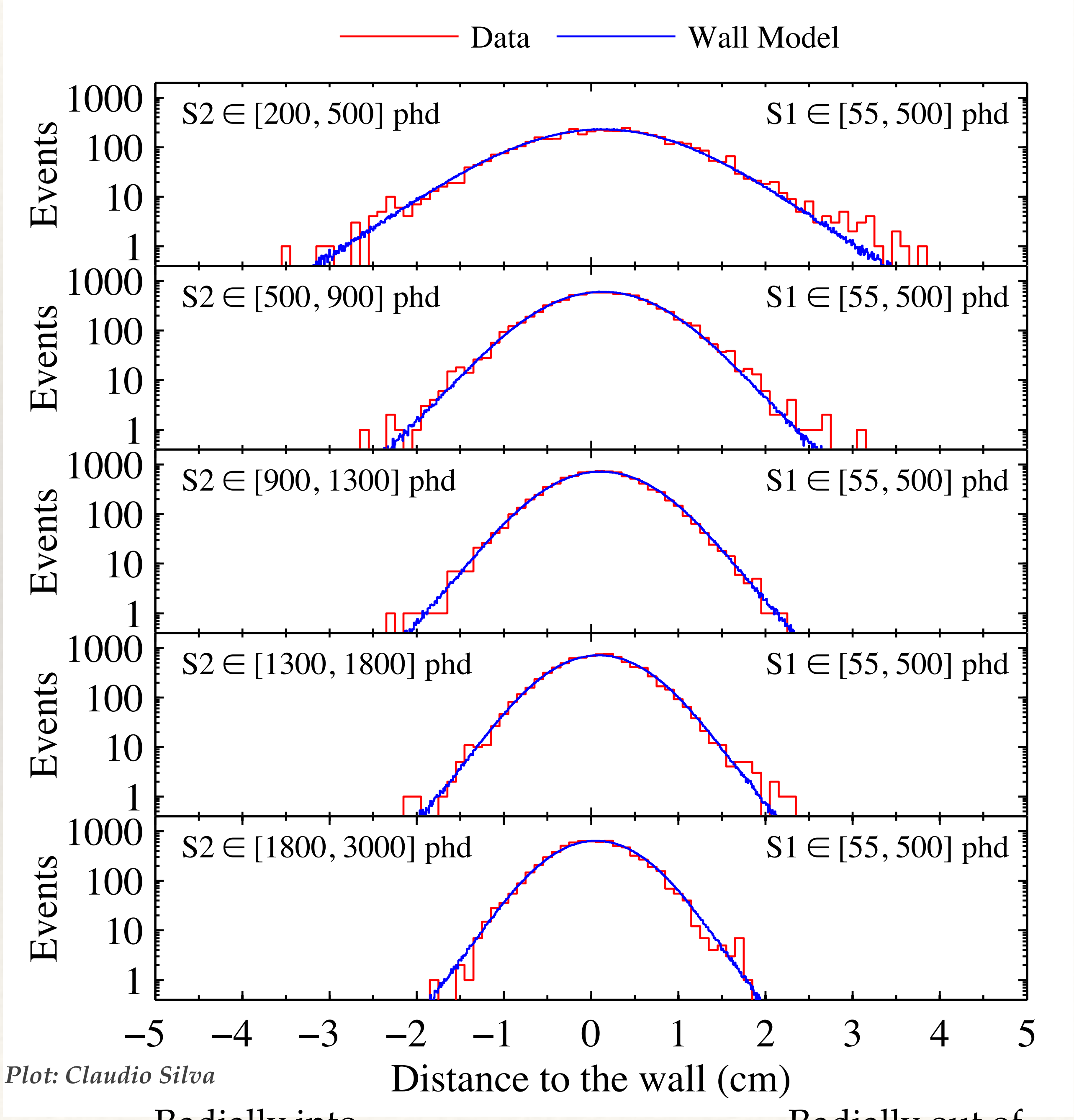




Wall-surface backgrounds

- Understood as radon plate-out on PTFE during exposure to air in construction
- Survives as ^{210}Pb and its daughters (^{210}Bi, ^{210}Po)
- Recoils occur short (~mm) distances from the wall
- Observed wall width due to finite position resolution
- Two-part solution in negotiating this background:
    - a fiducial volume cut 3 cm inwards from the measured wall position
    - a model for the number and position of events originating from the wall-surface backgrounds





Radially into detector ⟷ Radially out of detector