The LUX Dark Matter Experiment And an Updated Analysis of Its First Results

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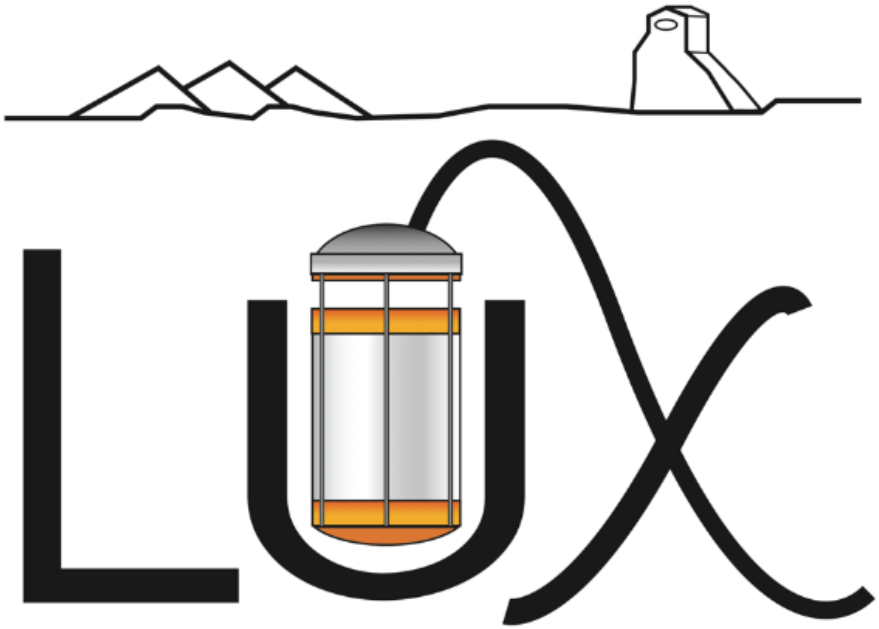
for the LUX Collaboration

The LUX Collaboration



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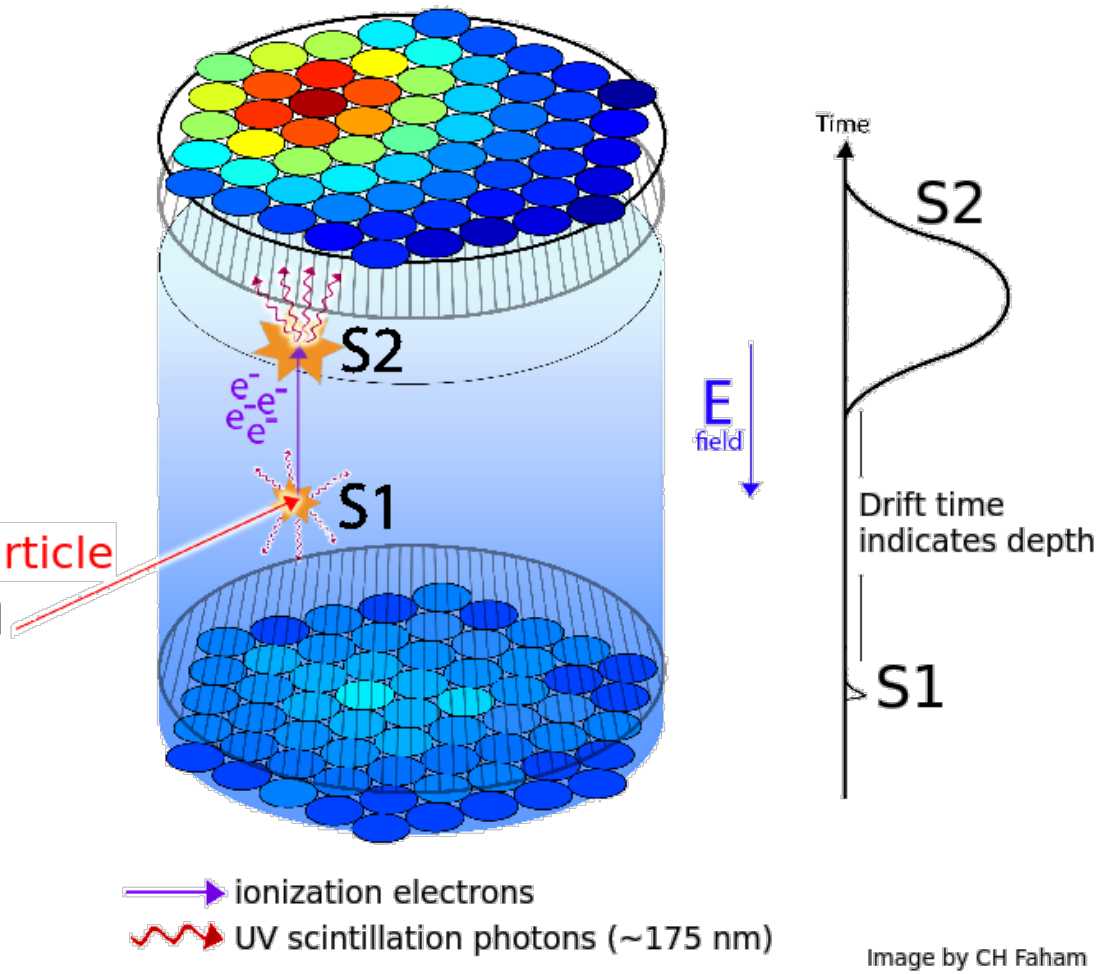
Outline

- Time projection chamber principles
- Details of LUX
- Original, published Run 3 analysis
- Run 3 re-analysis
  - Updated algorithms
  - Event Acceptance
  - Calibrations
  - Energy Reconstruction
  - (Not quite) new data
- Concluding remarks

Time Projection Chambers

- LUX is a dual-phase time projection chamber (TPC)
- Particle collision → light (S1) + charge
- Charge is extracted → electroluminescence (S2)
- 3D position reconstruction
  - The S2 is localized in X-Y
  - Time difference between S1 and S2 gives depth



Control of Backgrounds

- Reduce number of background events
  - Xe self-shielding + position → Fiducialization
    - Many events stopped outside/tagged within fiducial volume
  - Low radioactivity compoenents
- Discriminate between signal and background events
  - S2/S1 ratio → low for WIMPs, high for electronic recoils (primary background)
  - Using Profile Likelihood Ratio (PLR) to discriminate using multiple observables

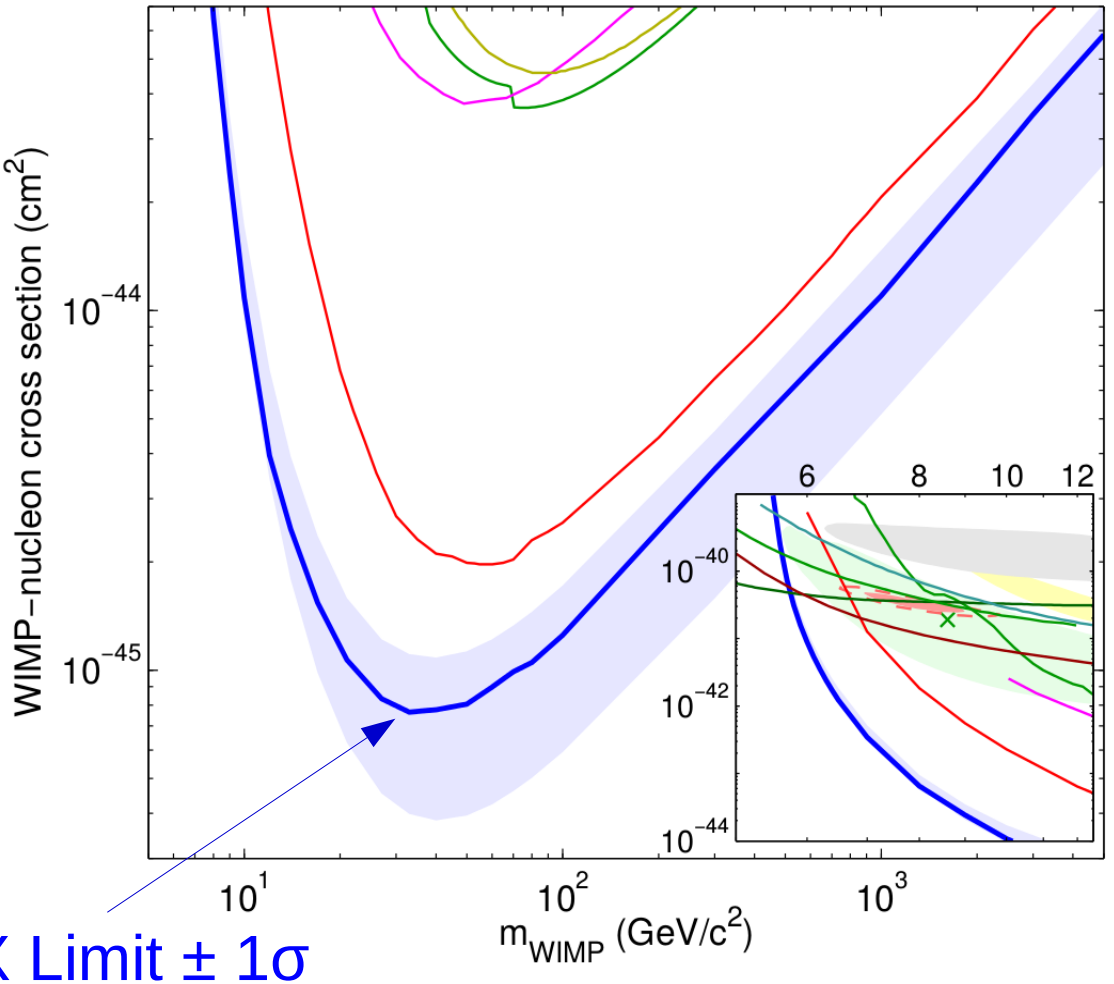
LUX

- Located 4850 (4300 m w.e.) feet below ground in Sanford Underground Research Facility (SURF), Lead, South Dakota
- 370 kg of liquid Xenon
  - 250 kg actively monitored
  - Vessel is placed in a 7.6 m diameter water tank
- Equipped with 122 Photo-multiplier Tubes (PMTs) in two arrays, top and bottom

Original Run 3 Analysis

- 85.3 live days
- 118 kg fiducial volume
- S2 threshold of 200 photoelectrons (phe)
- S1 between 2 and 30 phe
- 160 events observed prior to discrimination with PLR
- NR response conservatively assumed to be 0 below 3 keV
- Obtained best limit of

  7.6×10^{-46} cm^2 @ 33 GeV



LUX Limit ± 1σ

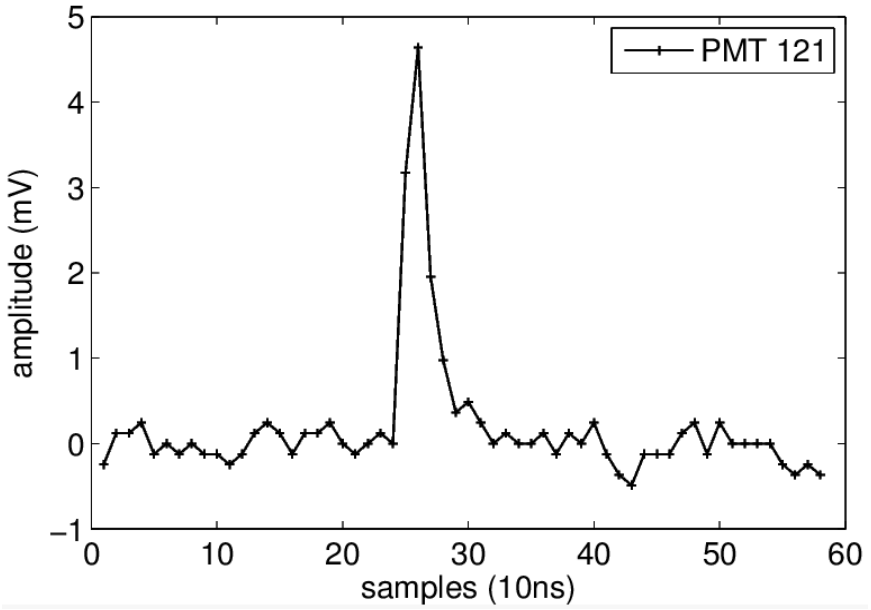
Run 3 Re-analysis

Updated Algorithms

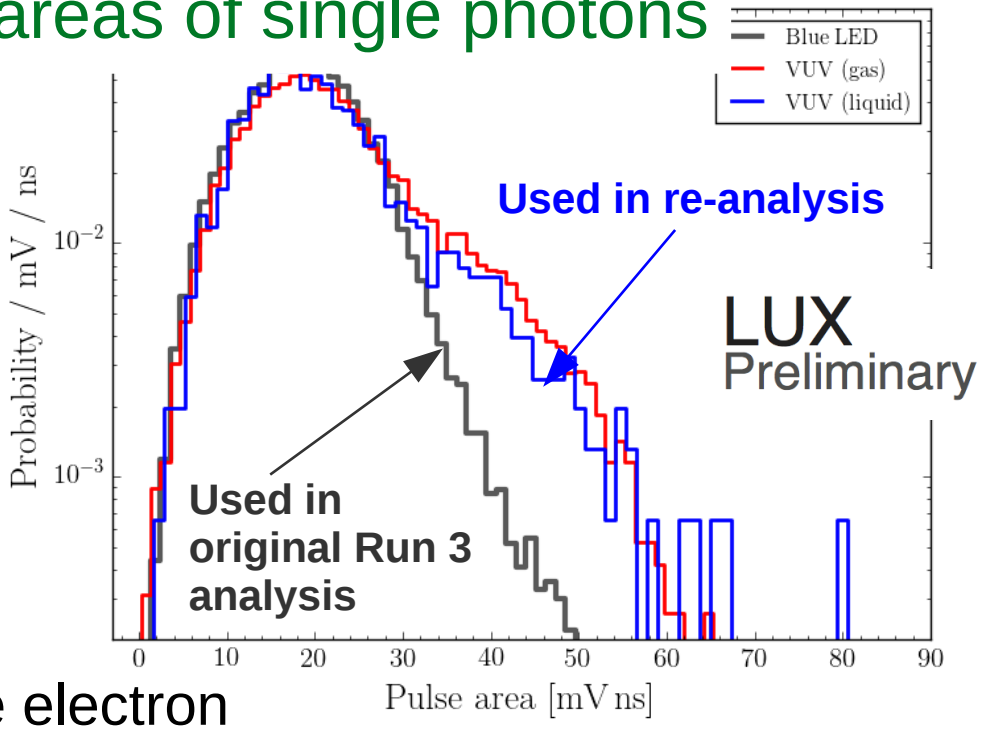
- Accounted for VUV Xe photon energy (see next slide)
- S1 obtained from individual photon counting ("spike count") + pulse area
- S2 based on both PMT arrays
- Removed systematic biases and noise in pulse area measurements
- Improved background model
- Fine tuned pulse-finding algorithms
- Improved XY position reconstruction

More On VUV Photons

Single Photo-electron



Distribution of pulse areas of single photons



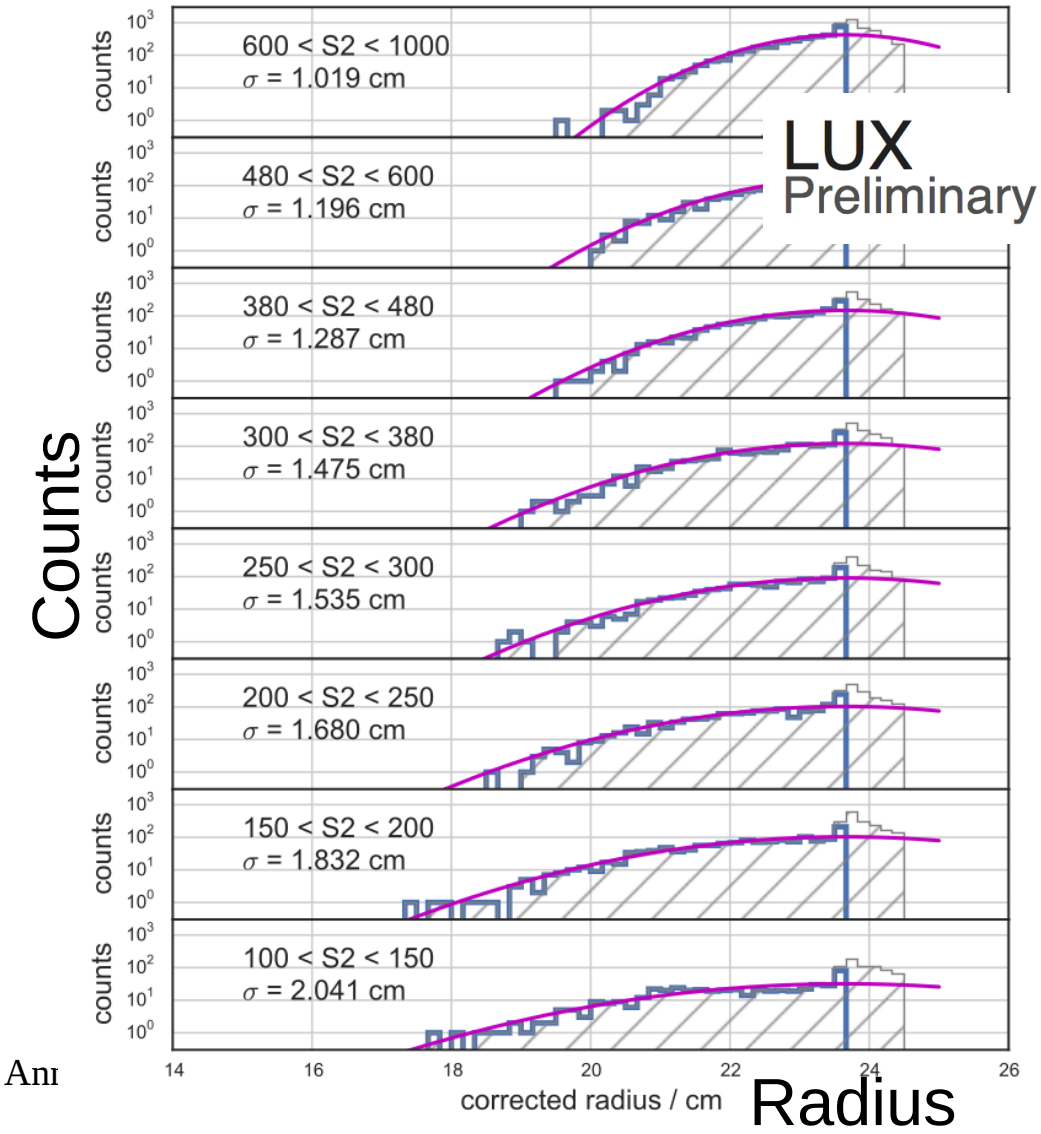
- Photon → PMT photocathode → single electron

  Except...
  - Xe scintillation: 175 nm (7.1 eV). Callibration LEDs: 470 nm (2.6 eV)
- Two photo-electrons about 20% of the time in Xe
  - phe (photoelectrons) → phd (detected photons)

Event Acceptance

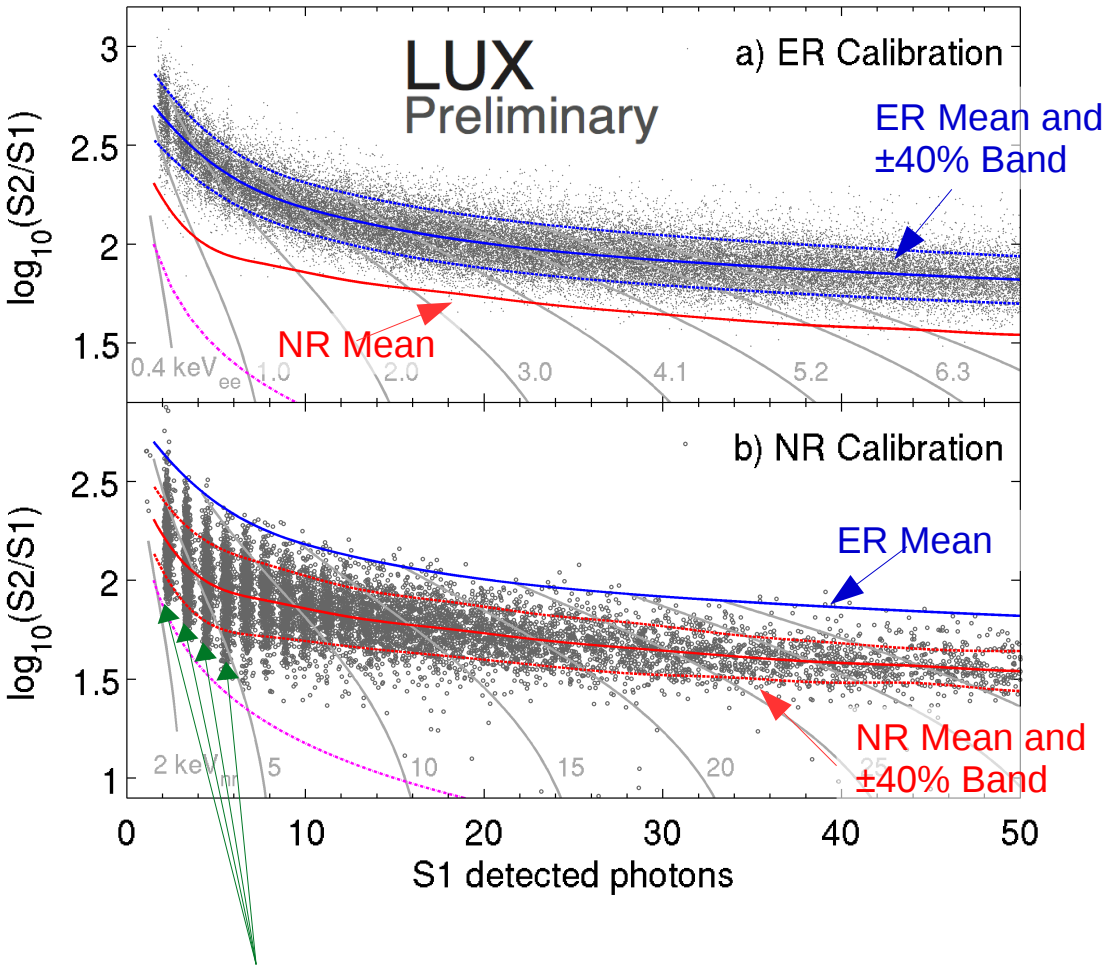
- 95 live days
- Larger fiducial mass (145 kg) thanks to the wall model
- S2 threshold of 165 phd
- Two-photon S1s accepted regardless of area
- 591 Events observed between S1 of 1 and 50 phd prior to the PLR

Penetration of Wall Events Into Fiducial Volume



ER and NR Calibration

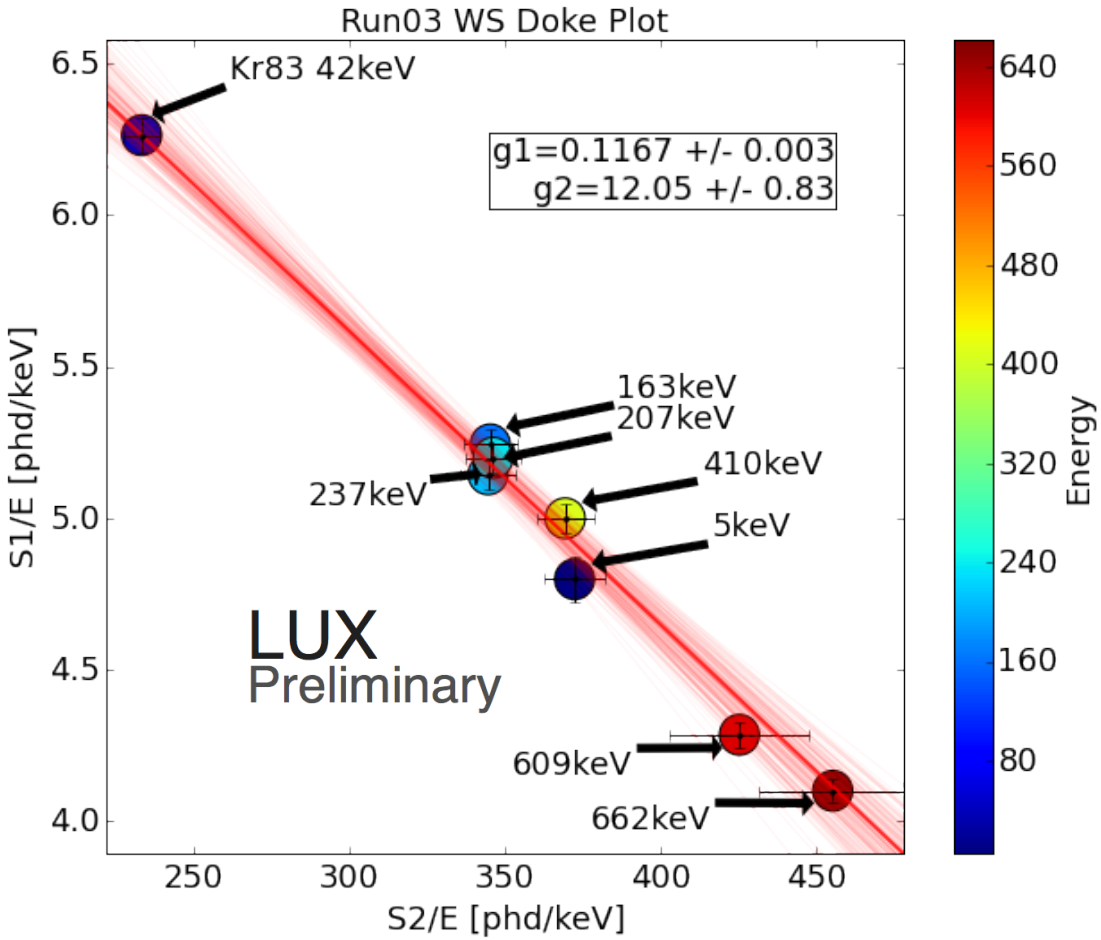
- High stats tritium calibration (165,863 events)
- Deuterium-deuterium (DD) calibration of nuclear recoil light and charge yield
  - Nuclear recoil assumed to be zero below 1.2 keV
- Calibration tunes model inputs, signal and background (NEST)
- PLR tests these models
  - More powerful than cut-and-count



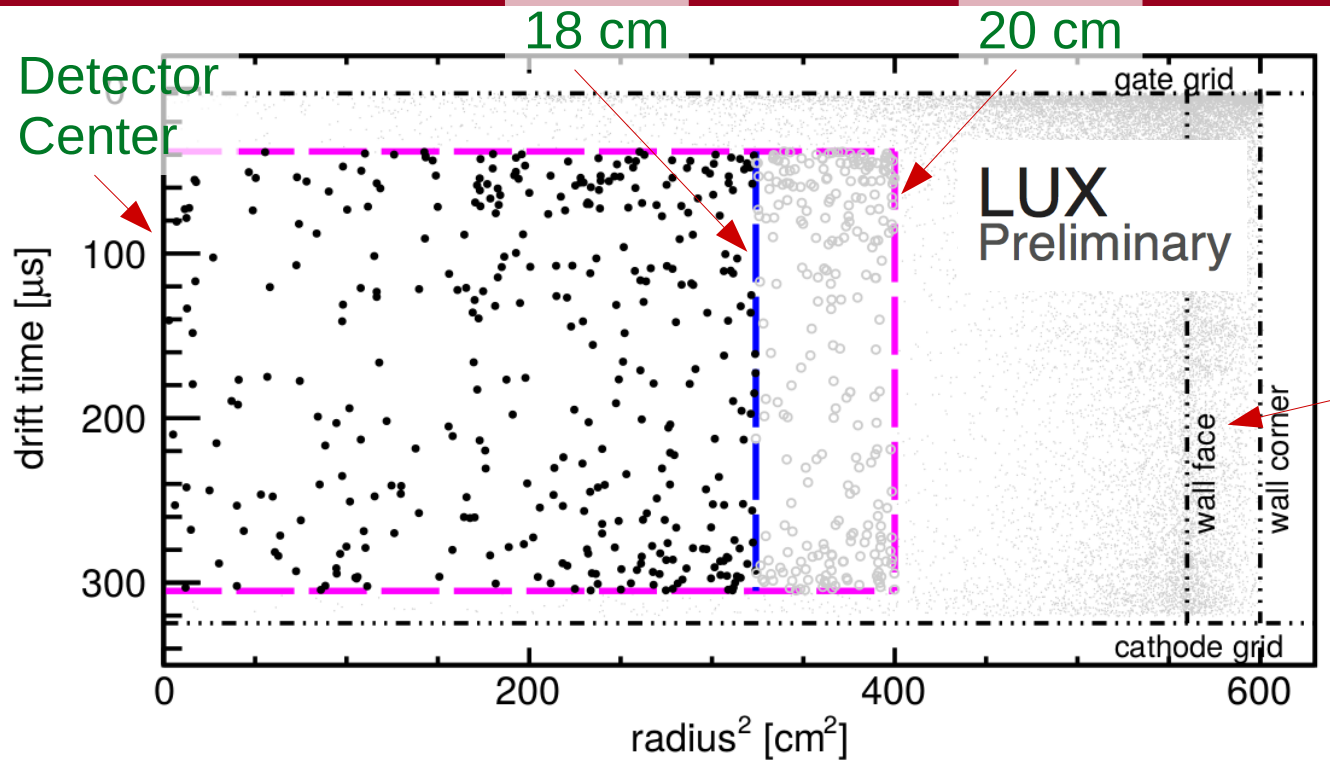
Photon counting creates bands!
Their width comes from corrections

Energy Reconstruction

- "Doke plot": anti-correlation of light and charge
  - The relationship is consistent over a wide range of source energies
  - Indicates good understanding of the detector
- Fit provides:
  - g1 (light collection efficiency)
  - g2 (charge extraction efficiency × single electron area)
  - Both are inputs to PLR



WIMP Search Data After Reanalysis

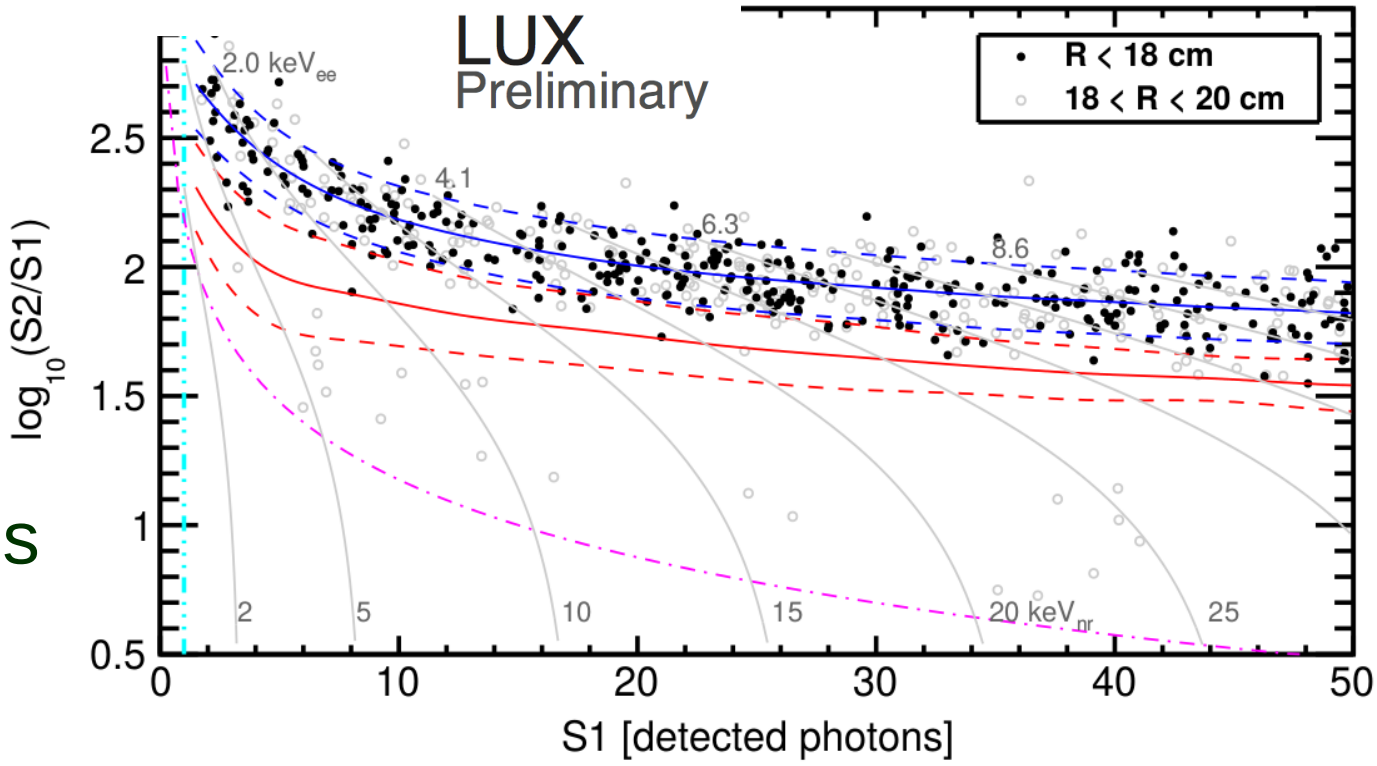


Teflon Wall

- The distribution of WIMP events in radius2 and drift time and in S1-log(s2/s1) space

- While the ER and NR bands are not used in our analysis, it appears that no **obvious** WIMP population is present

PLR-based analysis ongoing!



Conclusions

- The reanalysis of LUX run 3 data improves on the already premier results from 2013
  - The reanalysis implements multiple improvements in all levels, from basic waveform processing to high level calibrations
- New limits (or detection) is coming up in a few weeks
- Run 4 (with approximately 300 live days) is ongoing
  - We already have more data there than Run 3!

Backup

Profile Likelihood Ratio

- PLR compares data observables to modeled signal and background distributions
  - Is the event consistent with signal distribution (at a given mass and cross section)?
  - Is the event consistent with the background distribution?
- LUX PLR is implemented in Root with RooFit and RooStats
  - Function of S1, S2, event radius and depth
  - Multiple background and signal parameters are allowed to vary within their uncertainties
  - If the likelihood of WIMP signal model cross section relative to global maximum likelihood is low (< 0.1), the model is rejected