LUX

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LLWI

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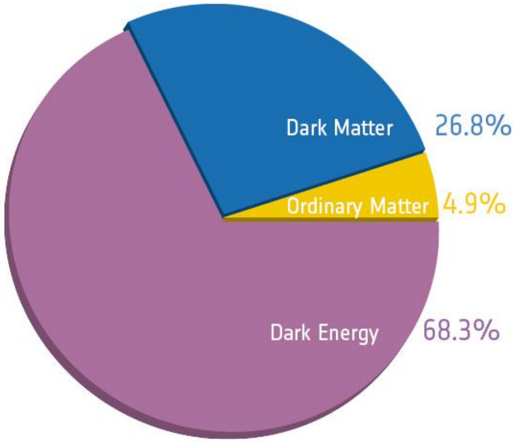
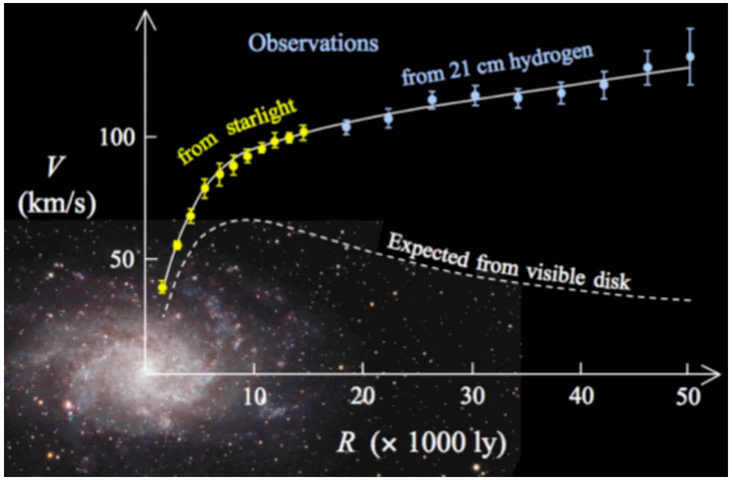
Motivation

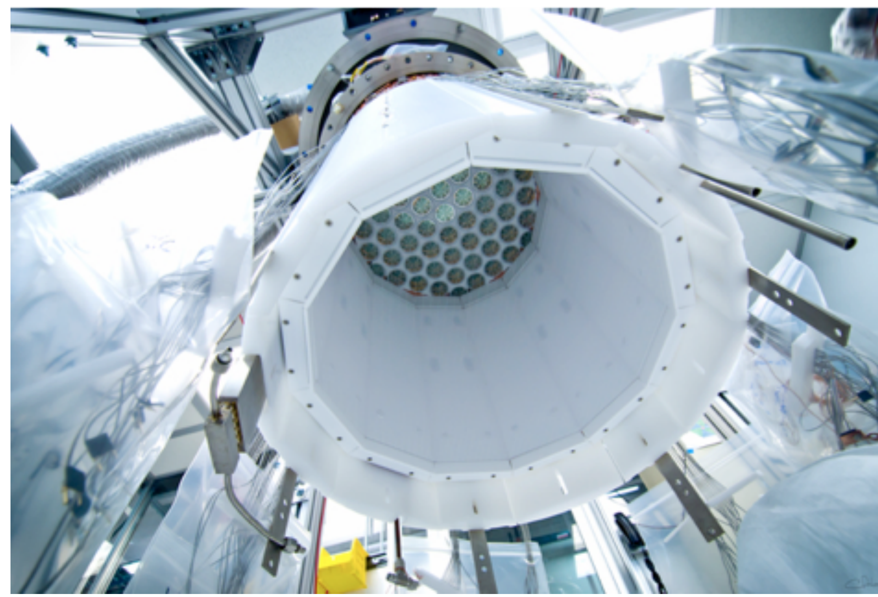
- Much evidence for the gravitational effects of dark matter
  - We believe it may consist of Weakly Interacting Massive Particles (WIMPs)
  - To confirm, we would like to see WIMPS via direct detection





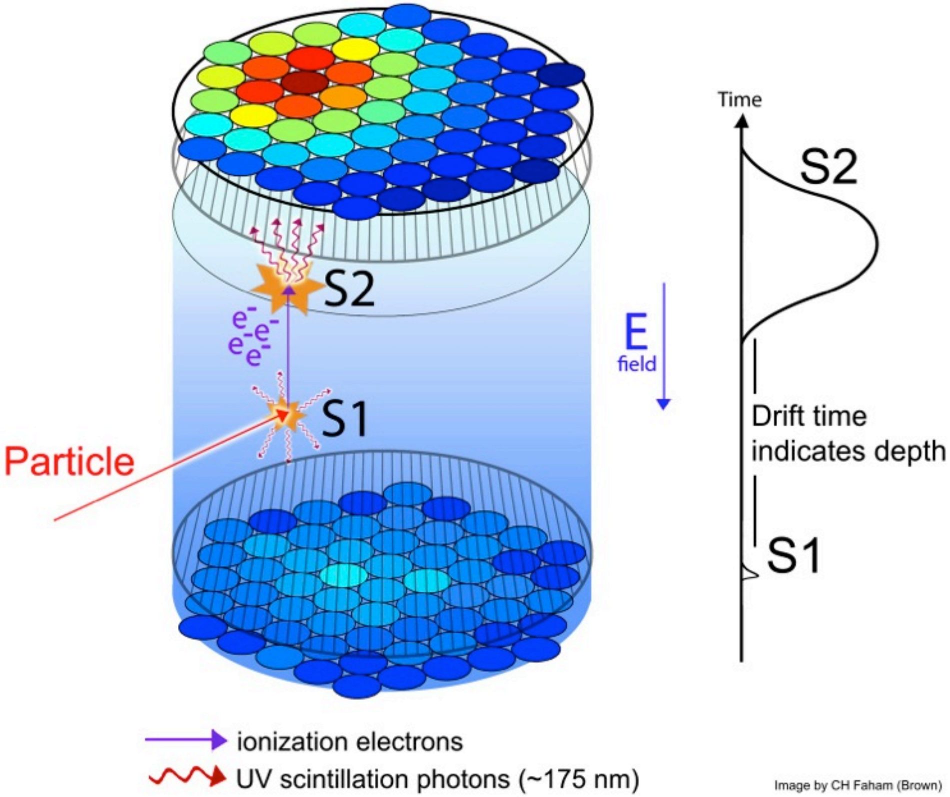
The LUX Detector

- Dual-phase Xe Time Projection Chamber
- Located at Sanford Underground Research Facility (SURF), 4850 ft below the surface (muon shielding)
- 370 kg LXe (250 kg active)
- Outer water tank for gamma&neutron shielding
- 122 PMTs split between top and bottom arrays
- Dimensions:
  - Height: 48 cm
  - Diameter: 47cm
  - Water tank diameter: 7.6m



Events in LUX

- Two scintillation signals for each event.
  - S1: de-excitation of short-lived xenon dimers
  - S2: electrons liberated at the event site extracted into the gas phase and electroluminesce.
- Time difference between S1 and S2 gives depth
- S2 hit pattern gives lateral position information



Event Discrimination

- We plan to detect WIMPs via Nuclear Recoils (NR)
- Most of our background events are Electron Recoils (ER)
- These two types of events produce different amounts of light and charge in the detector
  - Need to study this so we can tell them apart!
  - Characterize charge-to-light ratios (S2 vs S1) and amounts as a function of energy

Signal Production – Signal Events

- Nuclear Recoils
- Lower charge-to-light ratio

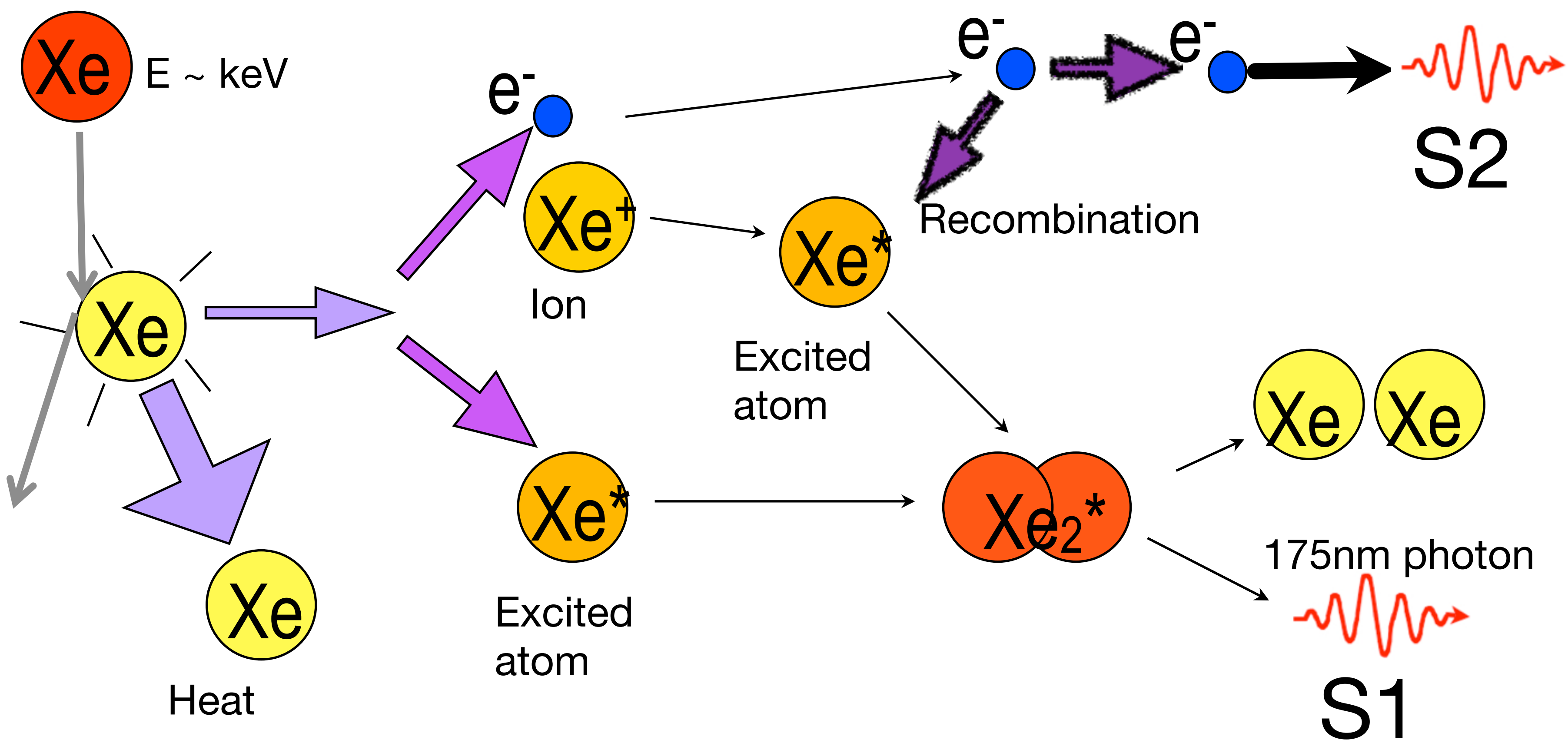


Figure: Gibson/Shutt

Signal Production – Background Events

- Electron Recoils
- Higher charge-to-light ratio

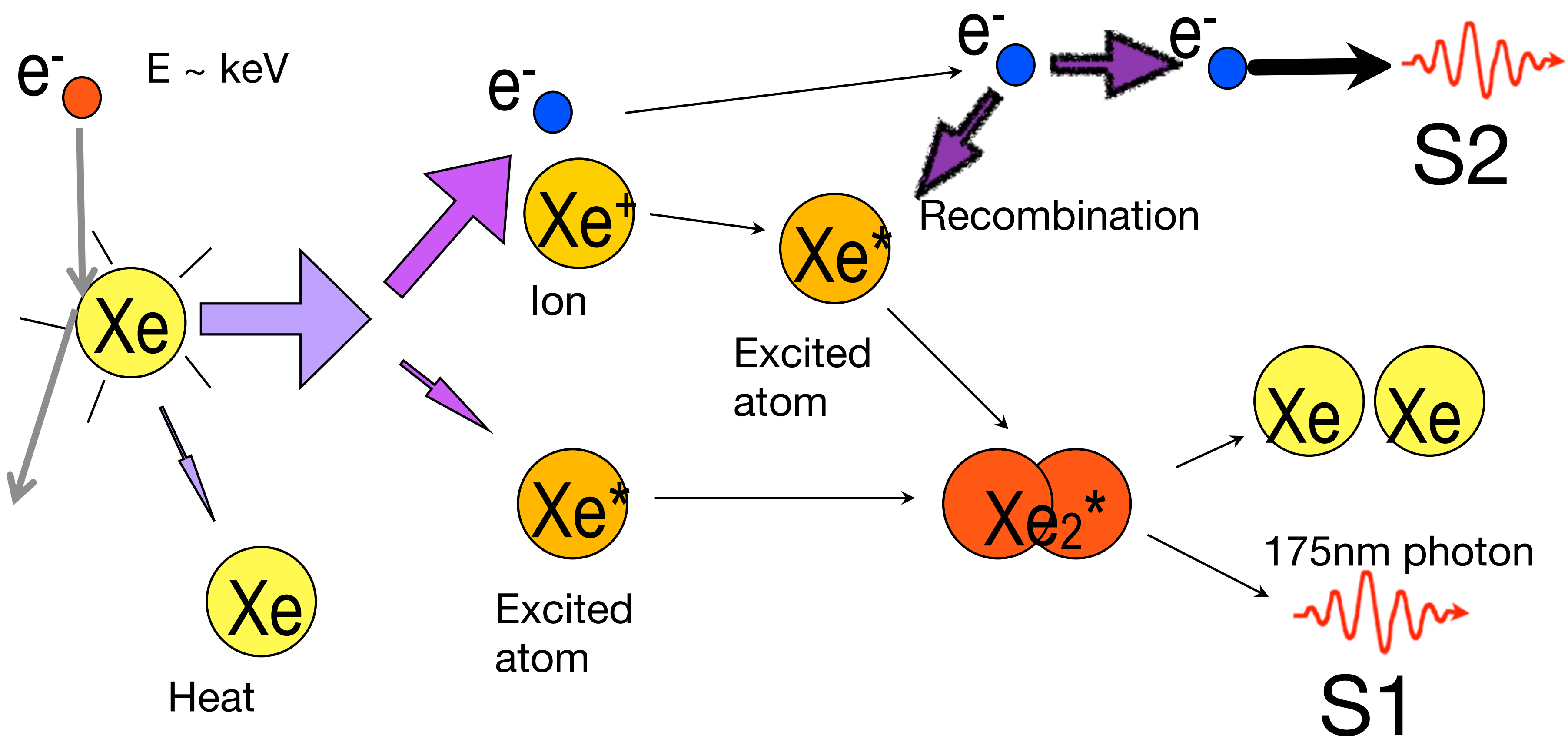
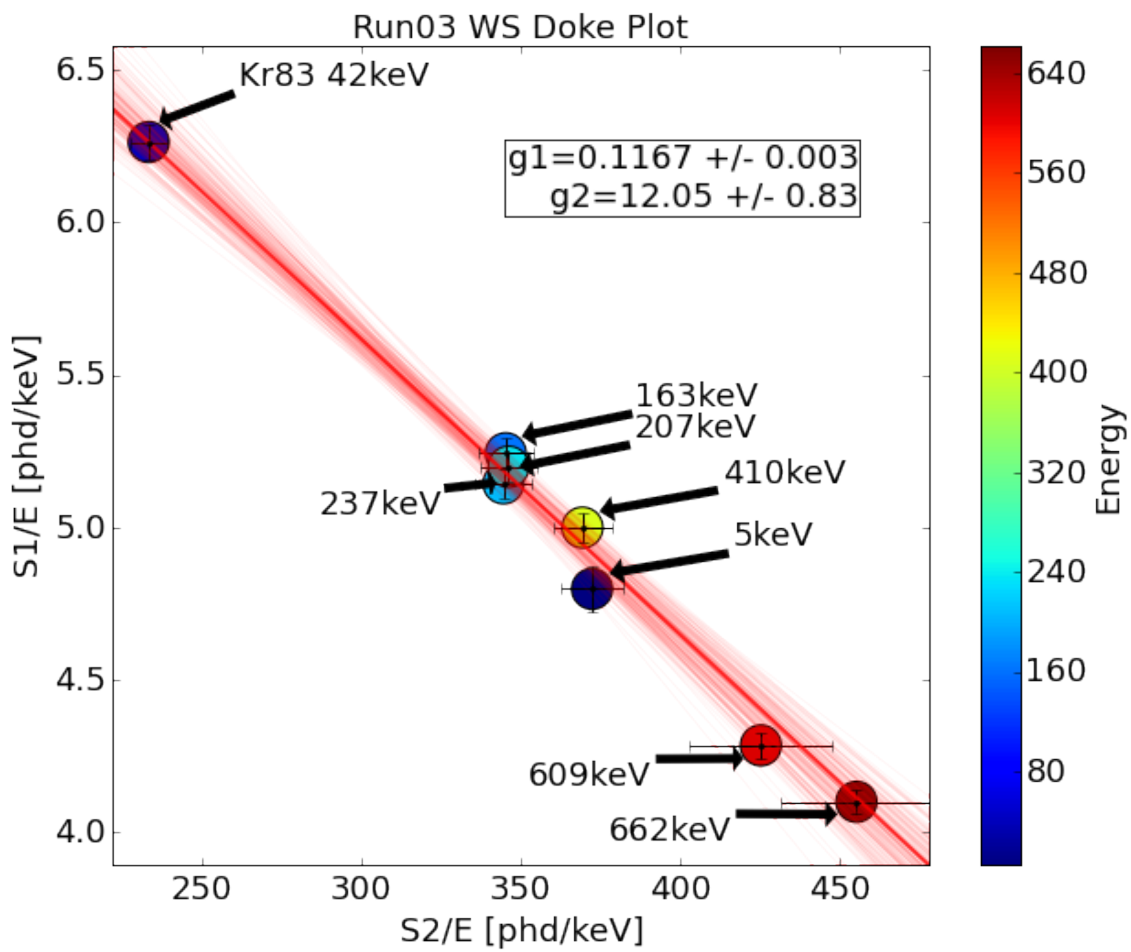


Figure: Gibson/Shutt

ER energy Calibration

- Measurement of light and charge collection efficiencies
  - Light and charge are anti-correlated (follows from branching on previous slides)
- Consistent over a wide range of energies
- Fundamental input to the analysis

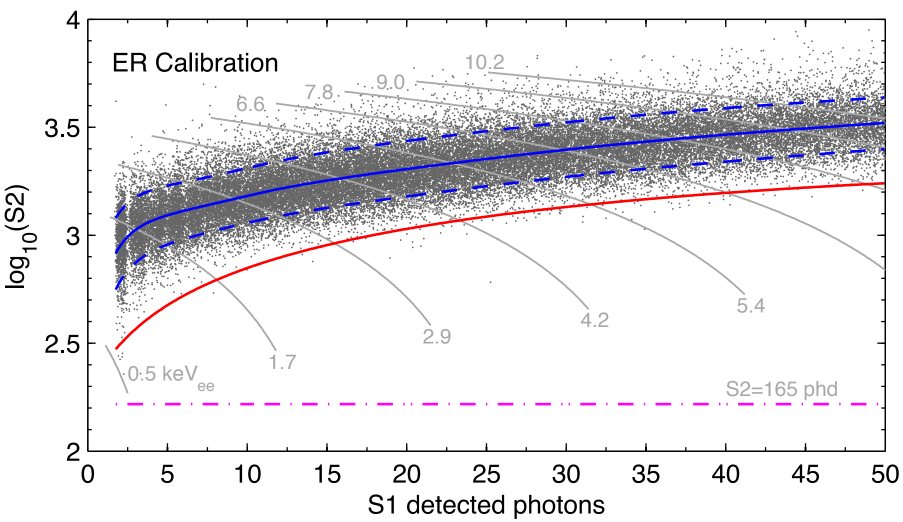
Light And Charge From Radioactive Sources

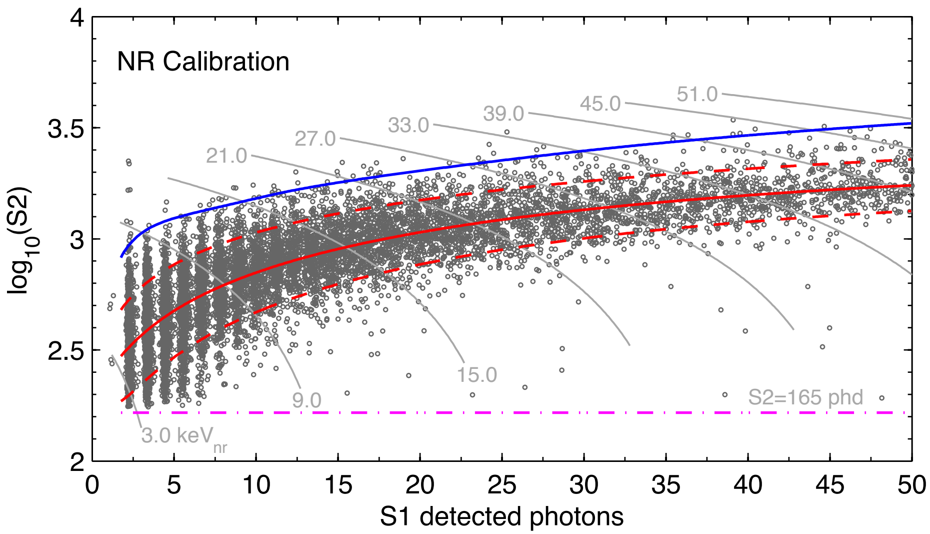


Background and Signal Calibrations

Background Events
- Electron Recoil (ER)
- Higher charge-to-light ratio

Signal Events (WIMP-like)
- Nuclear Recoils (NR)
- Lower charge-to-light ratio

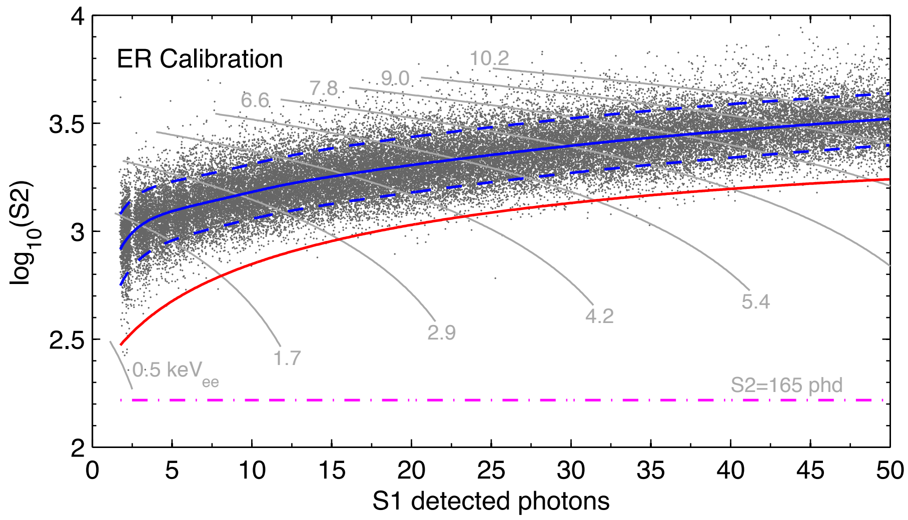


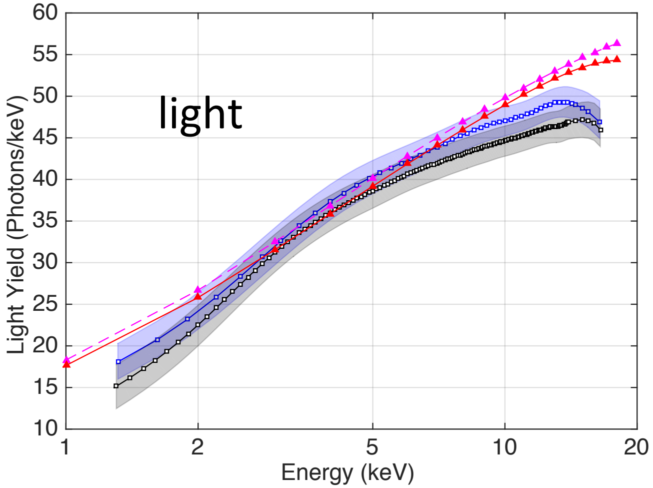


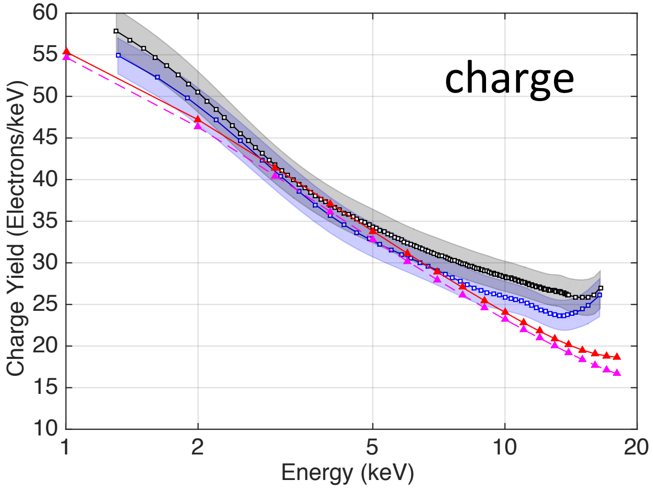
ER background Calibration

Background Events

- Electron Recoil (ER)
- Higher charge-to-light ratio
- Calibrate using high-statistics tritium dataset (165,863 events)
  - Tritium injected into detector at the end of run3
  - Recent paper on tritium calibration, arxiv: 1512.03133



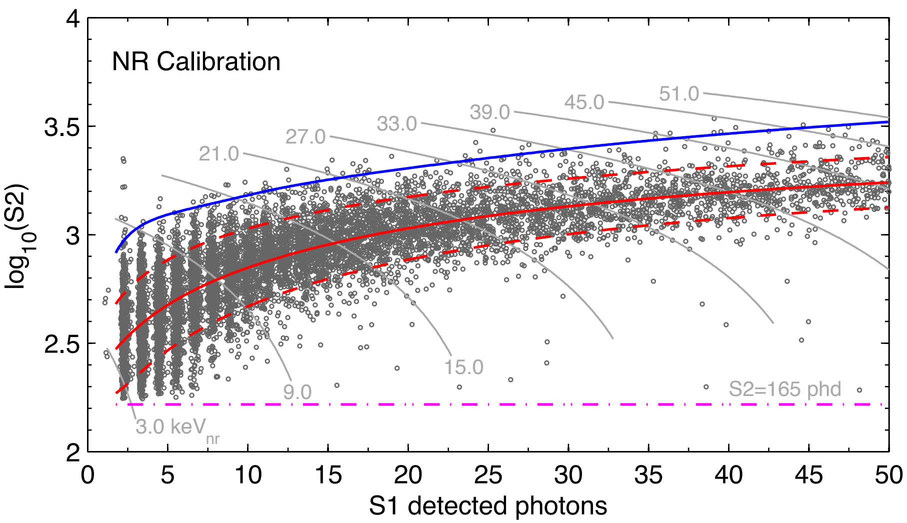


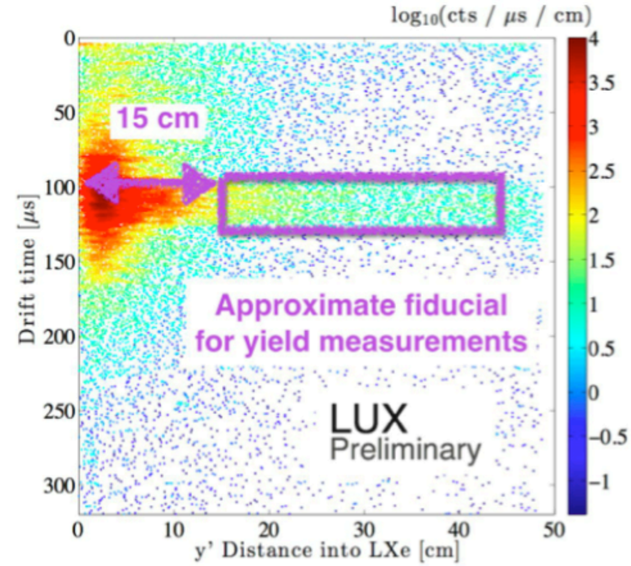


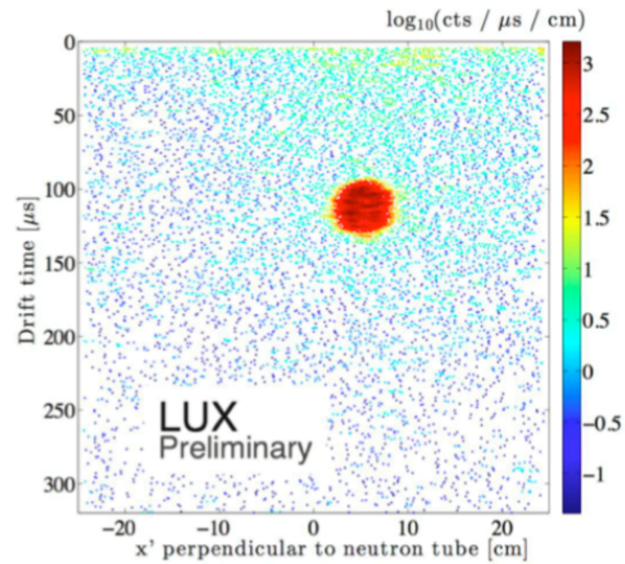
NR Signal Calibration

Signal Events (WIMP-like)

- Nuclear Recoils (NR)
- Lower charge-to-light ratio
- Calibrate using D-D neutrons
  - *In-situ* nuclear recoil (NR) calibration
  - Sensitive to 1.1 keV (Previously 3 keV)
  - New for run3 reanalysis (arxiv:1512.03506v2)
  - Significant improvement for low mass WIMP search

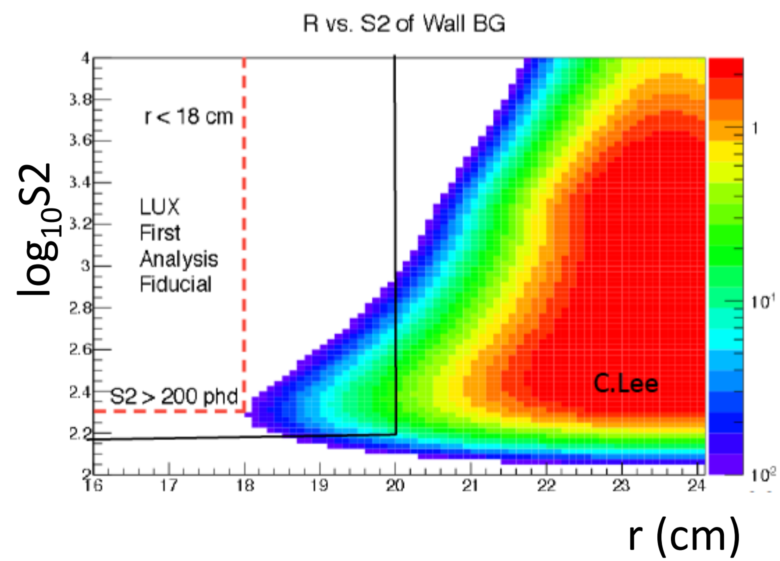






More Updates to analysis

- Background model
  - Enables substantial increase in analysis volume
- Improvements to XY position reconstruction
  - Allows us to make better use of background model

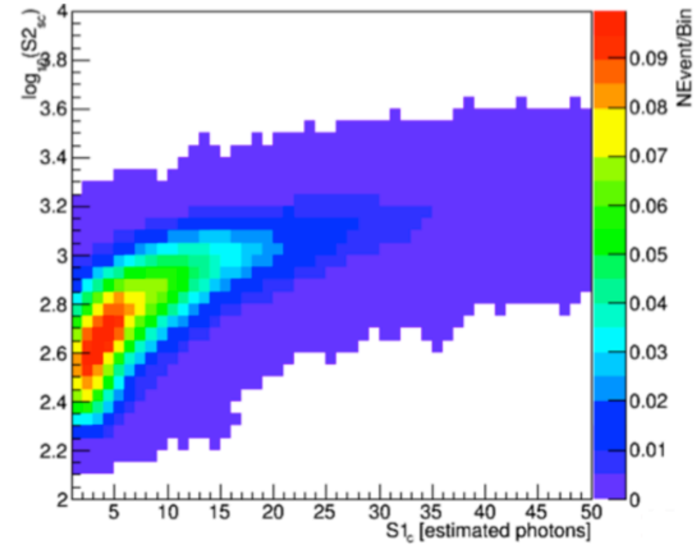


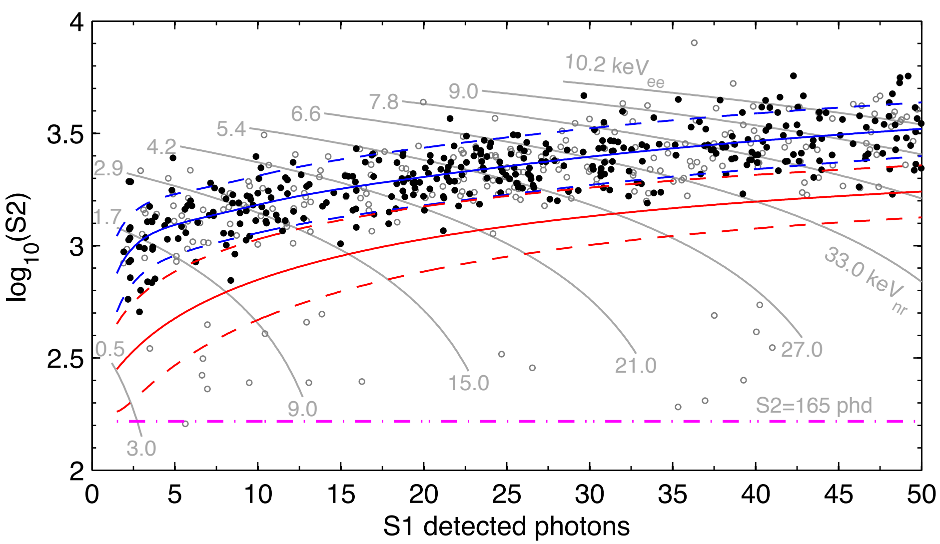
- Further improvements
  - Calibration of PMT waveforms using detected photons (rather than photoelectrons)
  - Fine tuned pulse-finding algorithms
  - Removed systematic biases and noise in pulse area measurements
  - S2 based on both PMT arrays

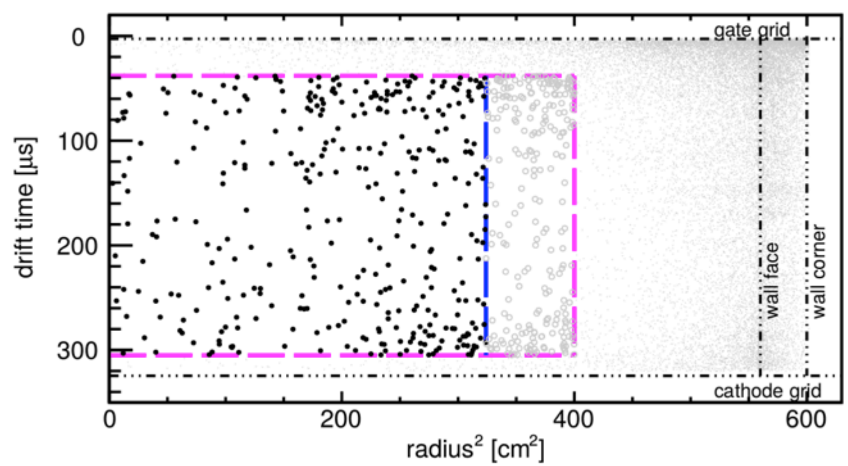
Profile Likelihood Ratio (PLR)

- Compares data to background distribution and signal distributions for different mass models
- Function of S1, S2, radius, and depth
- Fit for systematic parameters (derived from DD data)
- More powerful after calibrations, increased understanding of detector

i.e. Expected signal distribution for a 33 GeV WIMP



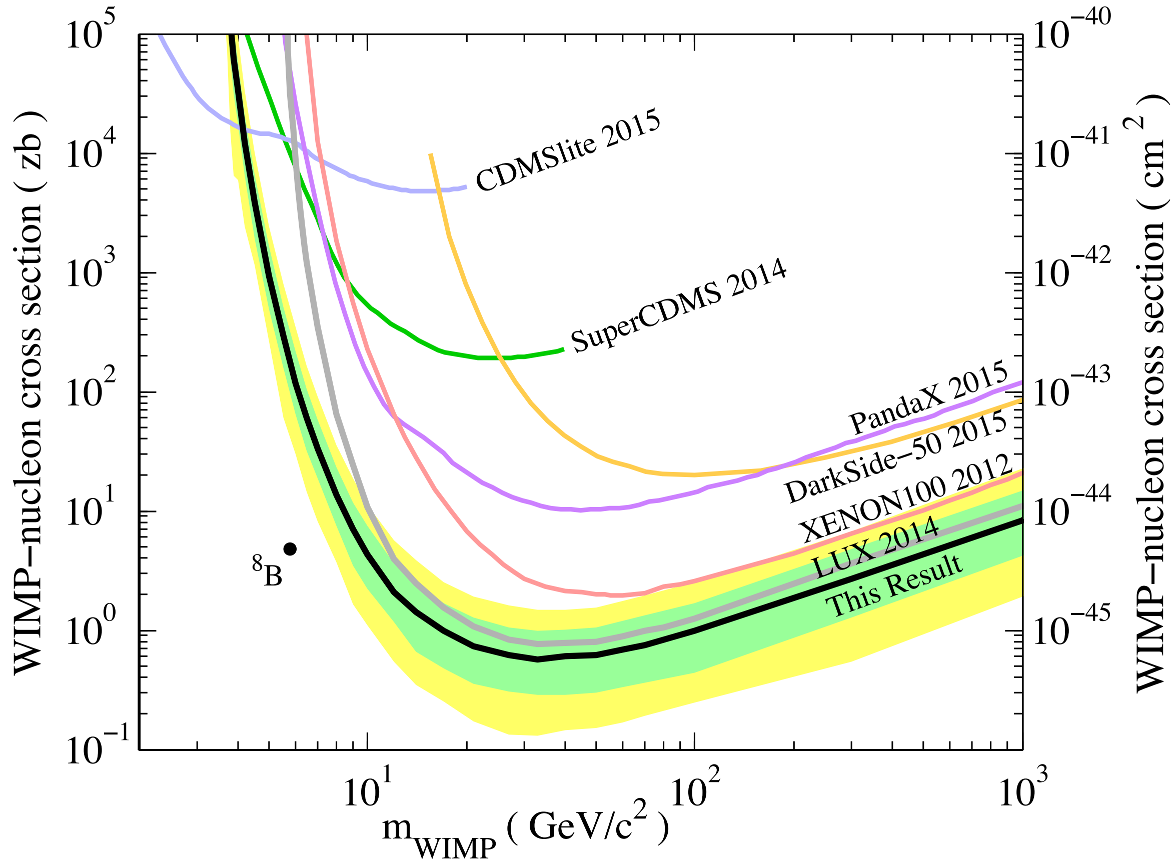




(new for run3 reanalysis arxiv:1512.03506v2)

Limits

- 23% reduction in high-WIMP-mass cross-section limit
- Significant improvement in low-mass reach due to lowering of kinematic thresholds



Green and yellow bands represent 1 and 2 sigma ranges (background only)

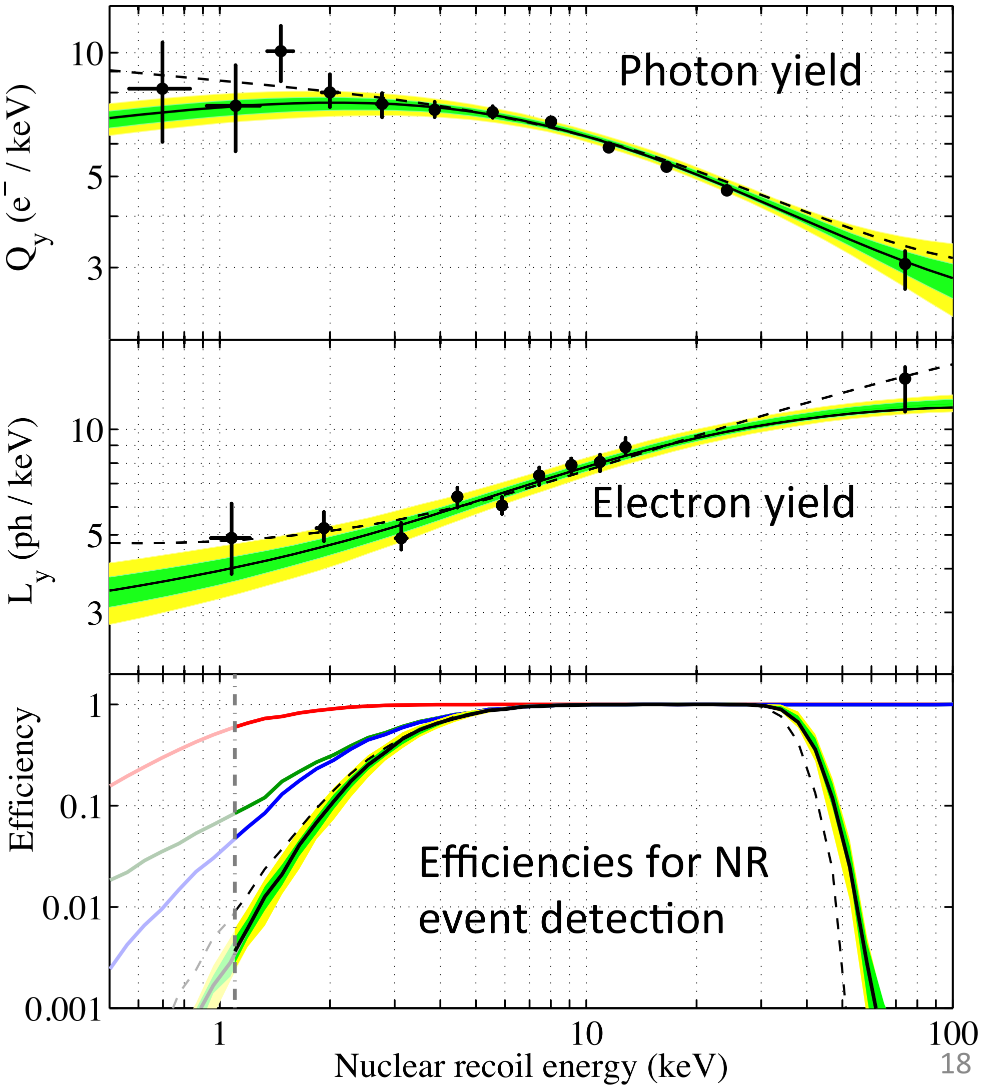
Conclusion

- Improvements to run 3 analysis (95 live days) across many aspects of the analysis
  - Allows reach to lower masses
  - Will benefit run 4 analysis as well as LZ
- More to come! Currently in Run 4 (300 live days)
  - Will run for a few more months at which point LUX will be removed and replaced by LZ
  - Much more data in run 4 so stay tuned!

Backup

D-D neutron calibration

D-D neutron calibration
Nuclear recoils measured *in situ*
Stat errors

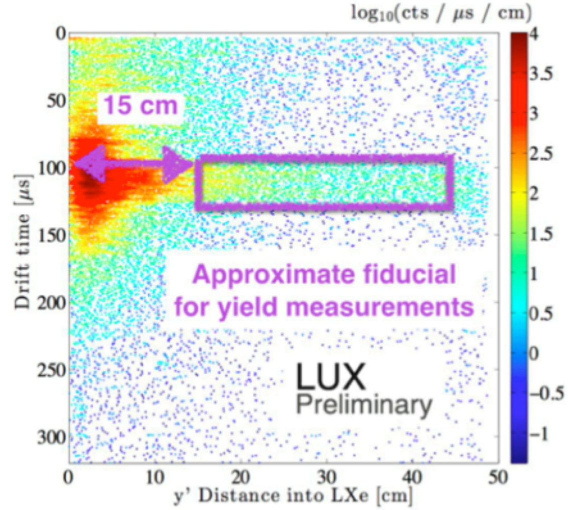


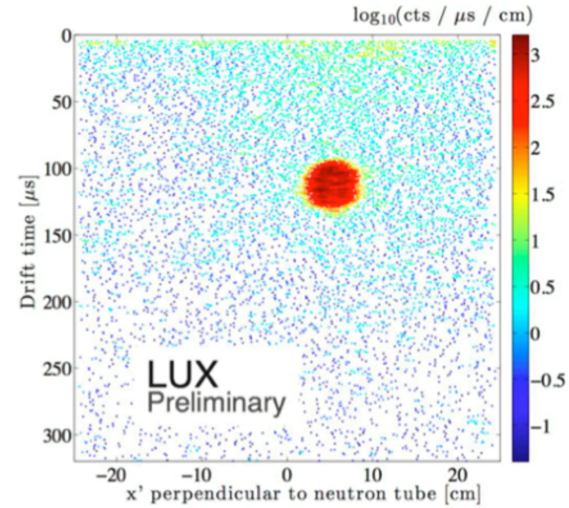
red: detection of an S2 with more than one emitted electron
Green: detection of an S1 with more than one PMT detecting photons
Blue: detection of both an S1 and S2
Black: detection of both an S1 and S2 passing threshold

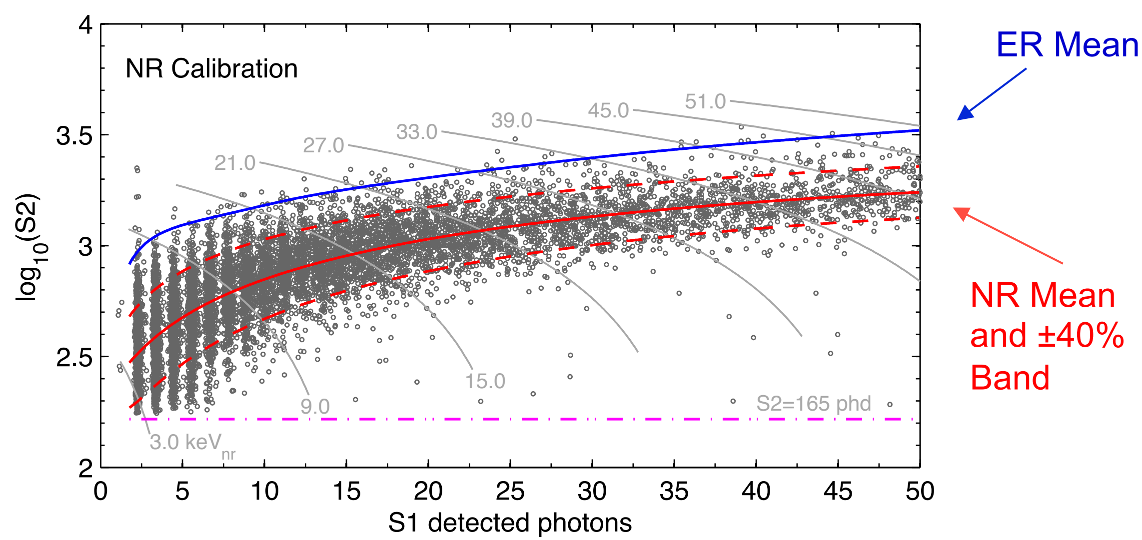
(arxiv:1512.03506v2)

D-D Signal Calibration

- *In-situ* nuclear recoil (NR) calibration
- Yields:
  - Double scatters → electrons/keV
  - + Single Scatters → photons/keV
- Sensitive to 1.1 keV
  - Previously 3 keV
- Significant improvement for low mass WIMP search





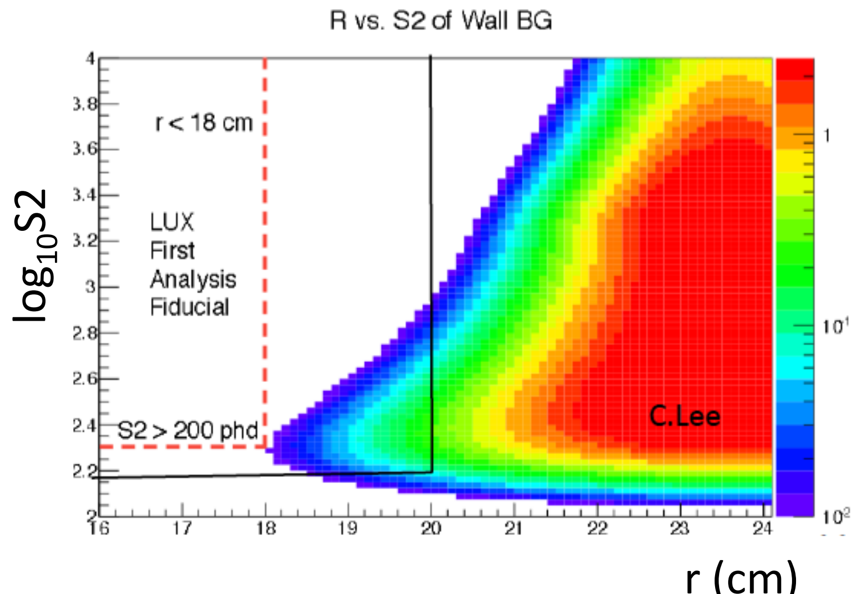


Nuisance parameters

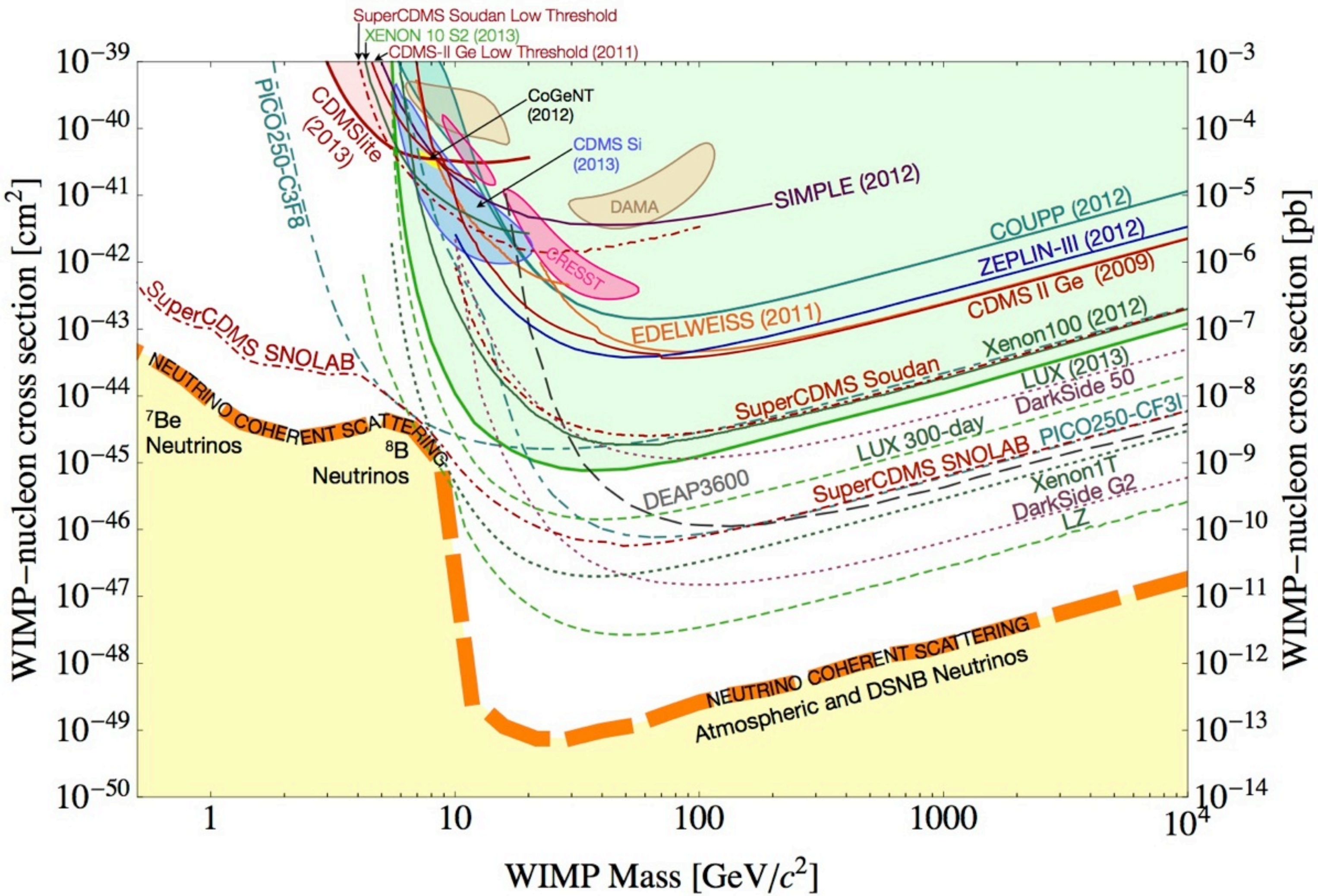
Parameter	Constraint	Fit value
Lindhard k	0.174 ± 0.006	-
S2 gain ratio: $g_{2,\mathrm{DD}}/g_{2,\mathrm{WS}}$	0.94 ± 0.04	-
Low-z-origin γ counts: $\mu_{\gamma,\mathrm{bottom}}$	172 ± 74	165 ± 16
Other γ counts: $\mu_{\gamma,\mathrm{rest}}$	247 ± 106	228 ± 19
β counts: μ_{β}	55 ± 22	84 ± 15
^{127}Xe counts: $\mu_{\mathrm{Xe\text{-}127}}$	91 ± 27	78 ± 12
^{37}Ar counts: $\mu_{\mathrm{Ar\text{-}37}}$	-	12 ± 8
Wall counts: μ_{wall}	24 ± 7	22 ± 4

Background Model

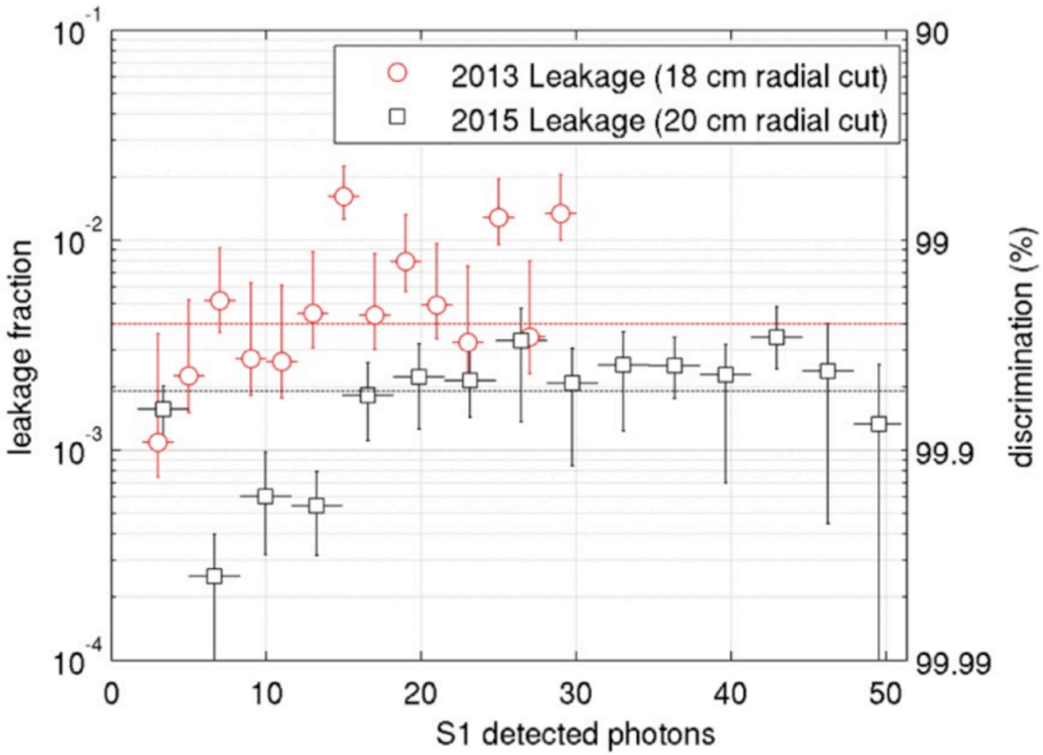
- Internal background
  - Uniform throughout detector volume: Kr-85, Ar-37, Xe-137
- Wall background:
  - Rn222-PB206
  - Including wall model increases analysis radius from 18cm to 20cm



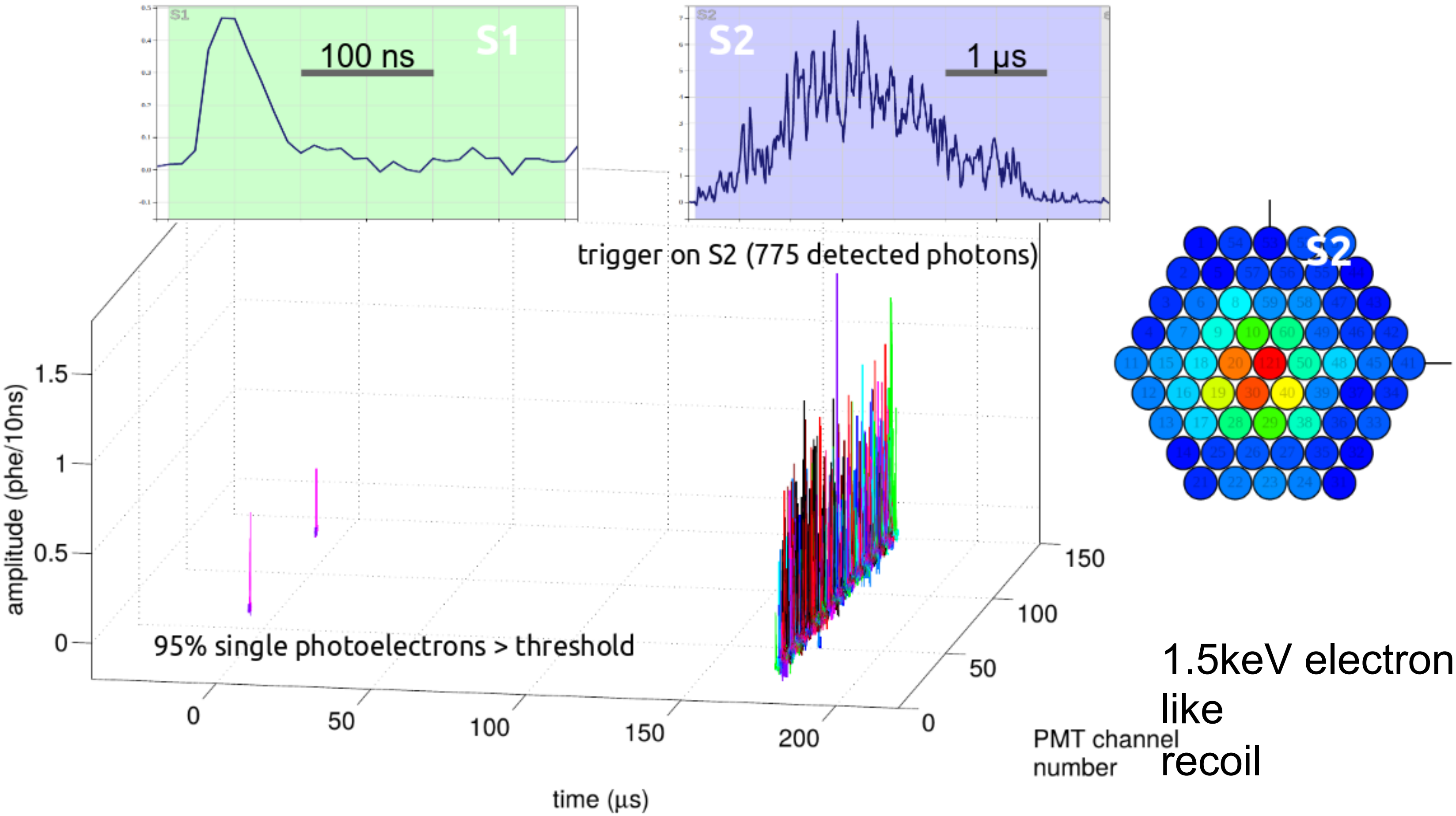
All limits – snowmass (out of date)



ER leakage into NR



Waveform Example



1.5keV electron-like recoil

More updates to analysis: VUV Photons

- Calibration of PMT waveforms using detected photons (rather than photoelectrons)
  - Get 2 photoelectrons ~20% of the time
  - Now use 175nm Xe single photons (rather than 470 nm calibration LEDs)
  - Accounts for double-photoelectron emission at the photocathode